Federal Emergency Management Agency

# Bristol County, Massachusetts

# Narragansett HUC 8 LiDAR FY2010

# Technical Support Data Notebook

## Terrain Project Narrative

## Elevation Data Acquisition

## CID 25005C

**CASE NO. 11-01-0718S**
**CONTRACT NO. HSFEHQ-09-D-0370**
**TASK ORDER NO. HSFEHQ-10-J-0005**

**Date June 17, 2011**

**Prepared By:**

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## 1. Introduction

Beginning in Fiscal Year 2010, FEMA initiated a five-year program for Risk Mapping, Assessment, and Planning (Risk MAP). The vision for Risk MAP is to deliver quality data that increases public awareness and leads to action that reduces risk to life and property. In order to realize the Risk MAP vision FEMA is acquiring high resolution terrain elevation and land cover elevation data to increase production efficiencies for NFIP regulatory products and support risk assessment data development. FEMA has made a commitment through Risk MAP to work closely with NDEP (National Digital Elevation Program) partners to obtain and support the collection of terrain data throughout the United States.

Terrain data, collected under the Risk MAP program, will be required to meet minimum specifications outlined in the *Draft Procedure Memorandum No. 61—Standards for LiDAR and Other High Quality Digital Topography dated August 1st, 2010*[1]. FEMA also requires all deliverables for topographic data collection be submitted in accordance with *Appendix M: Data Capture Standards March 2009*[2]. All relevant project materials have been reviewed to insure that these requirements are met.

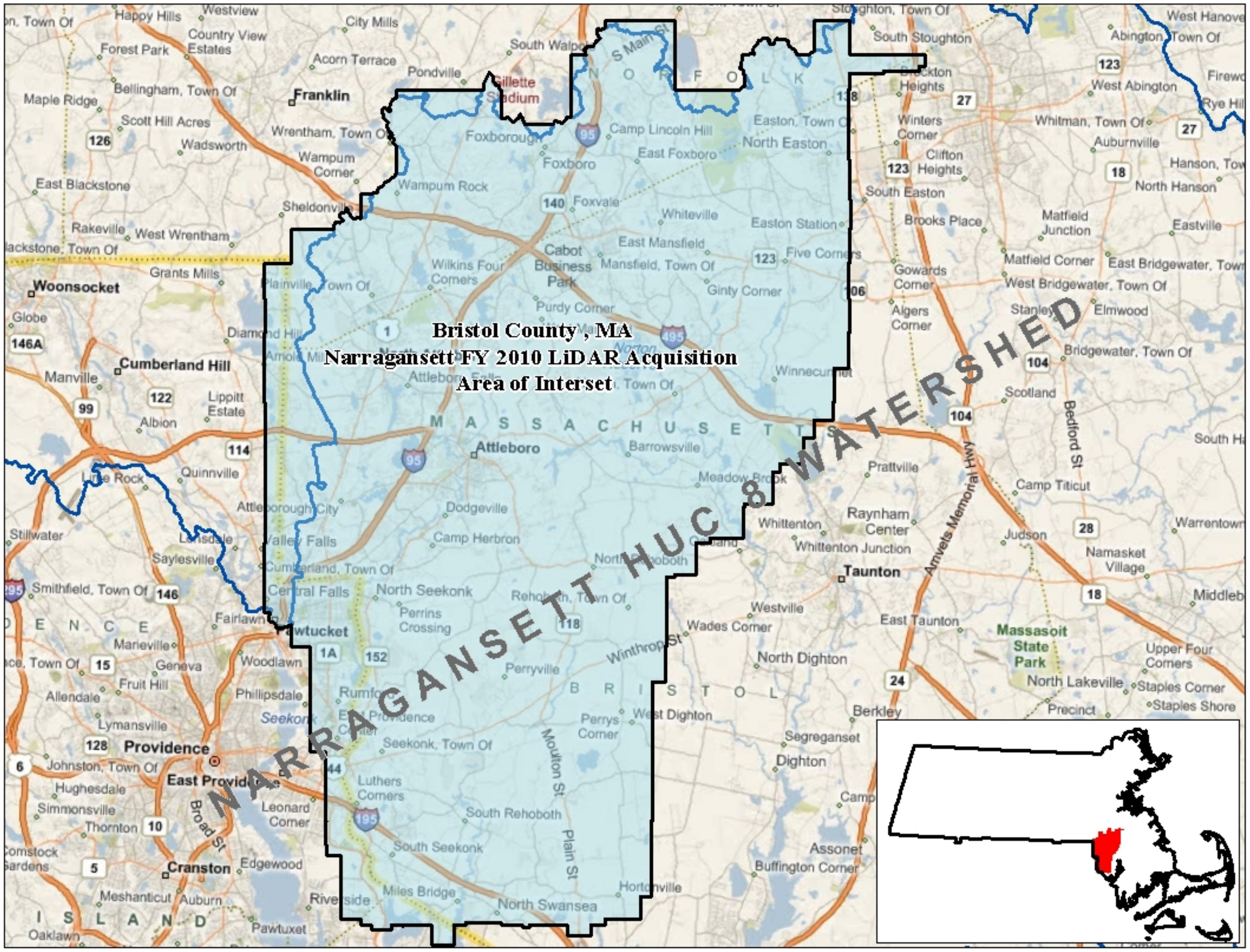
The objectives for elevation data acquisition within the Narragansett watershed are as follows:

1. LAS point cloud files collected for 217 square miles
2. LAS point cloud files captured using the "Highest" vertical accuracy requirements
3. LAS point cloud files collected at equivalent of a 2-foot contour accuracy
4. LAS point cloud files collected using a nominal pulse spacing of 1-meter
5. LAS classified as Bare Earth processed for 217 square miles.

**Table 1. Vertical Accuracy Requirements**

| Contour Accuracy | Specification Level | $RMSE_z$ | FVA | CVA |
|---|---|---|---|---|
| 2ft | Highest | 18.5 cm | 24.5 cm | 36.3 cm |

**Figure 1. General Project Location**



The block acquired for this project covers portions of Norfolk, Plymouth and Bristol Counties in Massachusetts. The following communities are either partially or completely included within this Area of Interest:

Bristol County:

- City of Attleboro
- Town of Dighton
- Town of Easton
- Town of Mansfield
- Town of North Attleborough
- Town of Norton
- Town of Rehoboth
- Town of Seekonk
- Town of Swansea
- City of Taunton

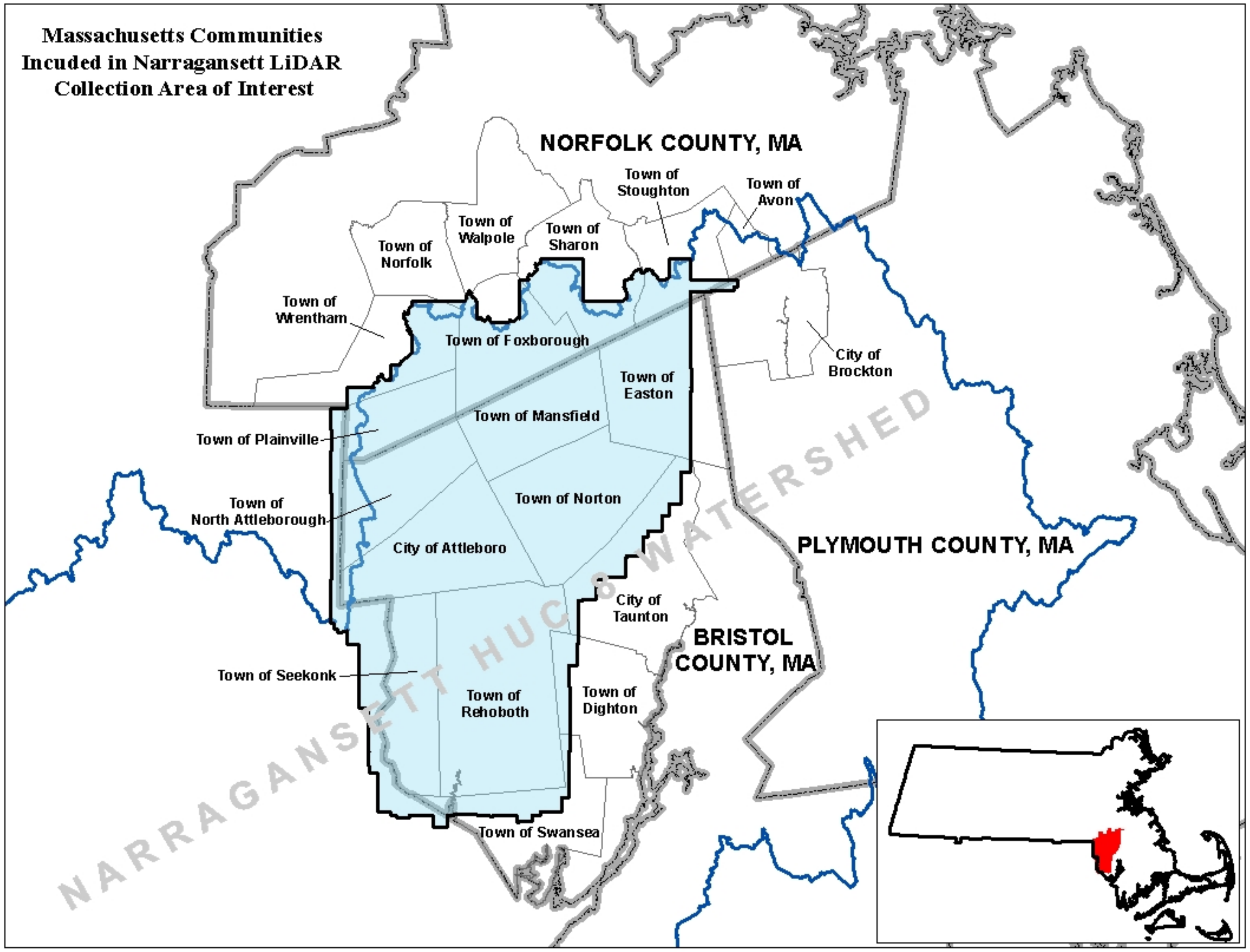
Norfolk County:

- Town of Avon
- Town of Foxborough
- Town of Norfolk
- Town of Plainville
- Town of Sharon
- Town of Stoughton
- Town of Walpole
- Town of Wrentham

Plymouth County:

- City of Brockton

**Figure 2. Massachusetts Communities Located Within Narragansett Area of Interest**



**2. Scope of Work**

Statement of Priorities
PTS Elevation Data Acquisition
STARR – Contract # HSFEHQ-09-D-0370

The contractor shall acquire elevation data to support flood hazard data updates based on the minimum requirements shown of the attached ordering sheet. Elevation data shall comply with the draft FEMA Procedure Memorandum: Standards for LiDAR and Other High Quality Elevation Data.

The contractor shall respond with pricing for the minimum elevation collections and bare earth processing specified the attached ordering sheet. The contractor's proposal shall identify any breakline creation or other post-processing that is required to use the elevation data for the flood hazard data updates based on the risk, terrain type, anticipated engineering methods and other relevant factors. The proposal must explain the reasons this additional processing is needed.

The contractor will also be responsible for performing QA of the elevation data as specified in the Standards for LiDAR and Other High Quality Elevation Data procedure memo.

The contractor shall also propose collection and processing alternatives that group the collections into larger, more cost effective collection blocks or other collection and processing alternatives that may be more advantageous for the government as an alternative option.

Scope Details:

LiDAR data acquisition (point cloud) for 217 square miles within the Narragansett Watershed. All data captured to the "Highest" vertical accuracy requirement. The acquisition specification is the equivalent of a 2-foot contour accuracy and will be collected with a nominal pulse spacing of 1-meter. Post processing is required for all 217 square miles covering entire collection area.

**3. Issues**

A. Special Problem Reports

None

B. Project Modifications

None

## 4. Information for the Next Mapping Partner

The Narragansett LiDAR collection AOI consists of one large functional area that covers 217 square miles. This area only covers a portion of the Narragansett Watershed.. This project included both LiDAR point cloud development and Bare Earth post processing. Point Cloud LiDAR data for this project is partially classified LAS 1.2 binary file format. The Bare Earth LiDAR for this project has been classified using ASPRS LiDAR classifications. Bare Earth classified as class 2 is considered to be Bare Earth and points classified as class 8 are Model Key. All data for this project has been collected using the following spatial reference information:

Projection: Universal Transverse Mercator
UTM Zone: 19
Linear units: Meter
Horizontal Datum: North American Datum 1983
Vertical Datum: North American Vertical Datum of 1988
Vertical units: Meters

LAS point files are named according to the UTM Coordinates at the southwest corner of the tile, following the zz_0xxxyyy convention, where z is the UTM zone number, x and y are the UTM coordinates.

**Table 2. LAS file information**

| Product | # Tiles | Total File Size | Point Count | Avg. Point Spacing |
|---|---|---|---|---|
| Point Cloud Narragansett | 342 | 53.1GB | 1933168824 | 0.6 |
| Bare Earth Narragansett | 342 | 50.4GB | 1933168824 | 0.6 |

Details about the storage of this dataset can be found within Appendix G of this document.

Ground control and quality control checkpoints were collected by CompassData, Inc. Photo Science, Inc. performed LiDAR acquisition flights, automated processing and Bare Earth manual edits.. Independent QC of the point cloud and bare earth surface was performed by CompassData, Inc. Quality Assurance testing was conducted by Greenhorne & O'Mara, Inc. All firms were under contract to STARR, A Joint Venture which held the FEMA Professional Technical Services contract and task order for this work. All contact information for the project team can be found in Appendix A of this document.

A. Ground Control Survey

Ground Control is collected throughout the AOI for use in the processing of LiDAR data to ensure data accurately represents the ground surface. QA/QC checkpoints, also collected throughout the AOI, are used for independent quality checks of the processed LiDAR data.

GPS based surveys were utilized to support both processing and testing of LiDAR data within FEMA designated Areas of Interest (AOIs). Geographically distinct ground points were surveyed using GPS technology throughout the AOIs to provide support for three distinct tasks:

Task1 was to provide Vertical Ground Control to support the aerial acquisition and subsequent bare earth model processing. To accomplish this, survey-grade Trimble R-8 GPS receivers were used to collect a series of control points located on open areas, free of excessive or significant slope, and at least 5 meters away from any significant terrain break. Most if not all control points were collected at street/road intersections on bare level pavement.

Task 2 was to collect Fundamental Vertical Accuracy (FVA) checkpoints to evaluate the initial quality of the collected point cloud and to ensure that the collected data was satisfactory for further processing to meet FEMA specifications. The FVA points were collected in identical fashion to the Vertical Ground Control Points, but segregated from the point pool to ensure independent quality testing without prior knowledge of FVA locations by the aerial vendors.

Task 3 was to collect Consolidated Vertical Accuracy CVA) checkpoints to allow vertical testing of the bare-earth processed LiDAR data in different classes of land cover, including: open (pavement, open dirt, short grass), High Grass and Crops, Brush and Low Trees, Forest, and Urban. CVA points were collected in similar fashion as Control and FVA points with emphasis on establishing point locations within the predominant land cover classes within each AOI or Functional AOI Group.

In order to successfully collect the Forest land cover class, it was necessary to establish a Backsight and Initial Point with the R8 receiver, and then employ a Nikon Total Station to observe a retroreflective prism stationed under tree canopy. This was necessary due to the reduced GPS performance and degradation of signal under tree canopy. The R-8 receivers were equipped with cellular modems to receive real-time correction signals from the Keystone Precision Virtual Reference Station (VRS) network encompassing the Region 1 AOIs.

Use of the VRS network allowed rapid collection times (~3 minutes/point) at 2.54 cm (1 inch) initial accuracy. All points collected were below the 8cm specification for testing 24cm, highest category LiDAR data. To ensure valid in-field collections, an NGS monument with suitable vertical reporting was measured using the same equipment and procedures used for Control, FVA and CVA points on a daily basis. The measurement was compared to the NGS published values to ensure that the GPS collection schema was producing valid data and as a physical proof point of quality of collection. Those monument measurements are summarized in the Accuracy report included in the data delivered to FEMA.

In order to meet FEMA budgetary requirements, AOIs were consolidated into Functional Groups: if AOIs were contiguous, they were treated as one large AOI to allow collection of 20 FVA points and 15 additional CVA points across the group of AOIs. 20 FVA points are necessary to allow testing to CE95 – 1 point out of 20 may fail vertical testing and still allow the entire dataset to meet 95% accuracy requirements. In similar fashion, 20 CVA points are necessary to test to CE95 as discussed above.

15 CVA points were collected per AOI or per Functional Group with the intention at the outset that 5 of the collected FVAs would perform double – duty as Open-class CVA points, to total 20 CVAs per AOI or Functional Group. The Functional Groups are as follows:

- Narragansett/Charles/Blackstone (northeast)
- Nashua, Blackstone (north and west)
- Quinnipiac
- Quincy/Suffolk (while included as part of the FEMA Charles AOI, was physically separated from the Charles AOI polygon and treated as an independent functional area)

The following software packages and utilities were used to control the GPS receiver in the field during data collection, and then ingest and export the collected GPS data for all points:

- Trimble Survey Controller
- Trimble Pathfinder Office

The following software utilities were used to translate the collected Latitude/Longitude Decimal Degree HAE GPS data for all points into Latitude/Longitude Degrees/Minutes/Seconds for checking the collected monument data against the published NGS Datasheet Lat/Long DMS values and into UTM NAD83 Northings/Eastings:

- U.S. Army Corps of Engineers CorpsCon
- National Geodetic Survey Geoid09NAVD88

MSL values were determined using the most recent NGS-approved geoid model to generate geoid separation values for each Lat/Long coordinate pair. In this fashion, Orthometric heights were determined for each Control, FVA and CVA point by subtracting the generated Geoid Separation value from the Ellipsoidal Height (HAE) for publication and use as MSL NAVD88(09).

**Figure 3. Narragansett Area of Interest Ground Control Survey**

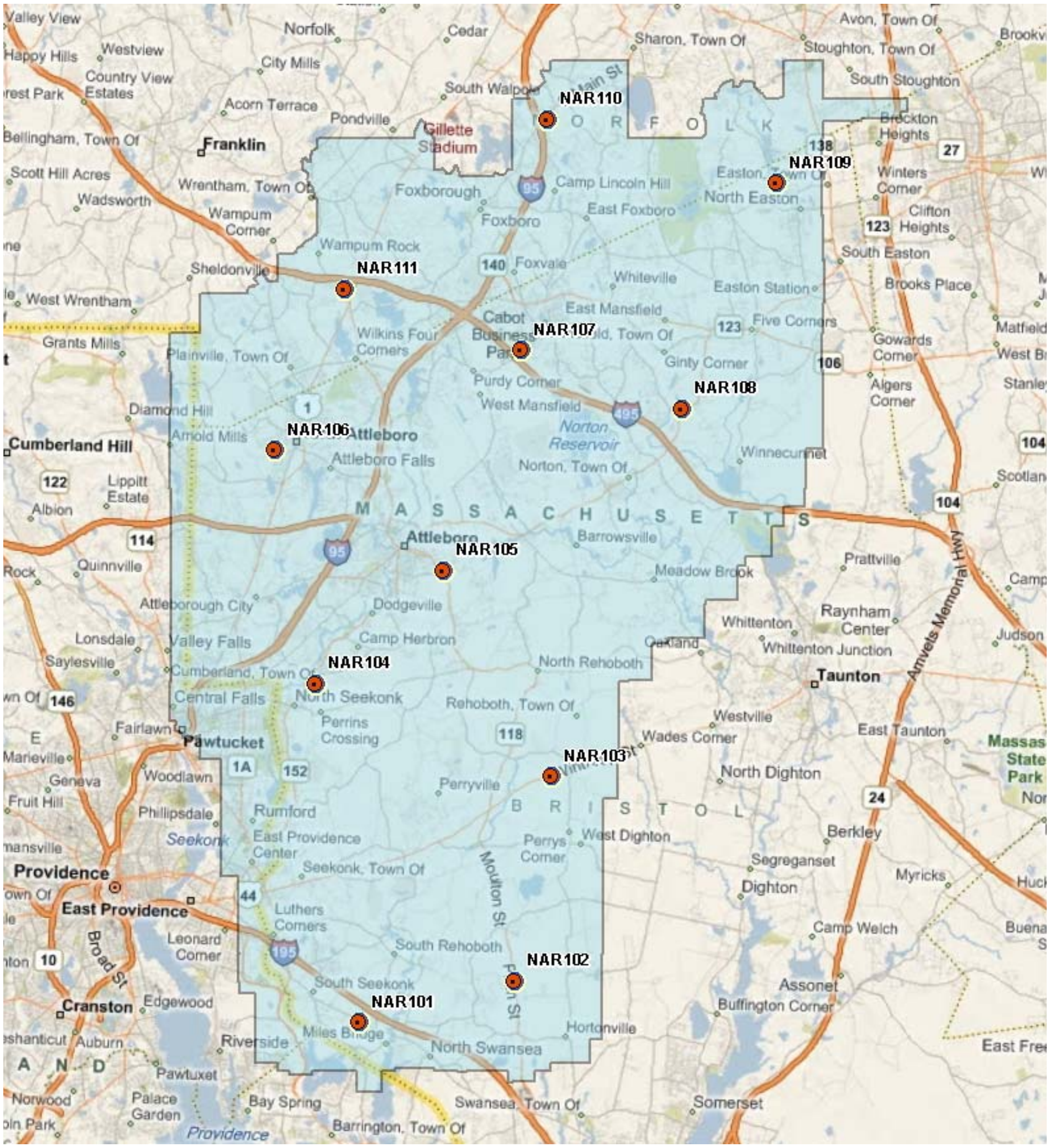
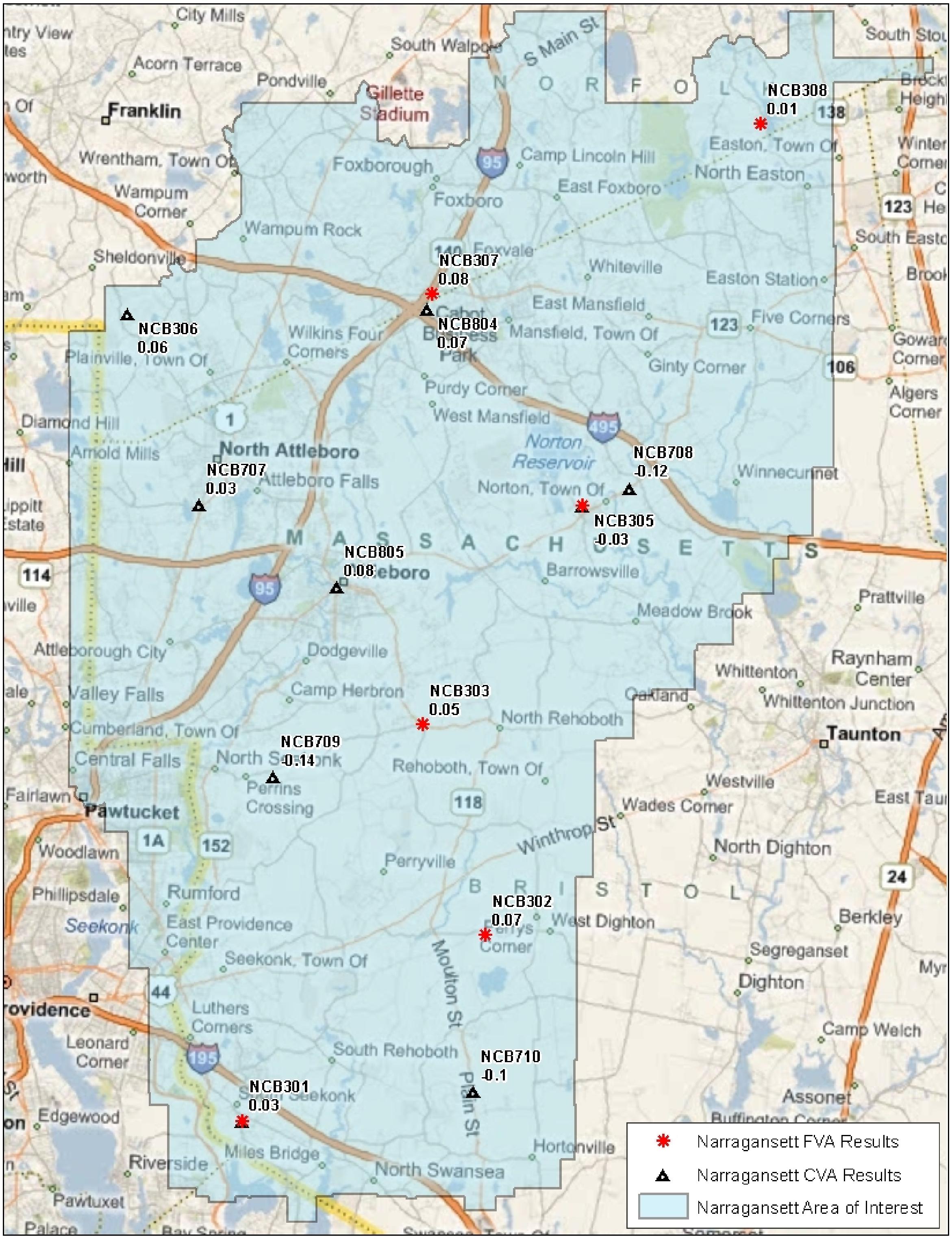


**Figure 4. Narragansett FVA CVA Results**



B. Data Acquisition

LiDAR acquisition products include Pre- and Post- flight reports which contain information on the flight lines, equipment parameters, and other pertinent acquisition details. The LiDAR product is considered to be point cloud data and consists of 1500mx1500m tiles of LAS points which are partially classified such that the bare earth points can be calibrated to the ground surface and tested via the independent QC to ensure the ground surface is accurately represented.

Applanix software was used in the post processing of the airborne GPS and inertial data that is critical to the positioning and orientation of the sensor during all flights. POSPac MMS provides the smoothed best estimate of trajectory (SBET) that is necessary for Optech's post processor to develop the point cloud from the LiDAR missions. The point cloud is the mathematical three dimensional collections of all returns from all laser pulses as determined from the aerial mission.

Optech's DASHMap software and Leica's ALS Post Processor software were used to create the Raw LIDAR Flight Line strips. At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above ground features are removed from the data set. The GeoCue and TerraScan software packages are then used for the automated data classification. Project specific macros are created to classify the ground and to remove the side overlap between parallel flight lines.

LAS Class 2 (Ground) is used to check the surveyed control points against the Triangulated LIDAR surface. Any bias is then removed using macro functionality within TerraScan.Unclassified Point Cloud tiles are then created using TerraScan macro functionality. These tiles are populated within GeoCue to ensure correct LAS versioning and LAS Header information. LAS Class 2 is used to check the independent QC points against the Triangulated LiDAR surface. If RMSE is not within guidelines TerraScan software is utilitzed to remove any bias, and the check is performed again.

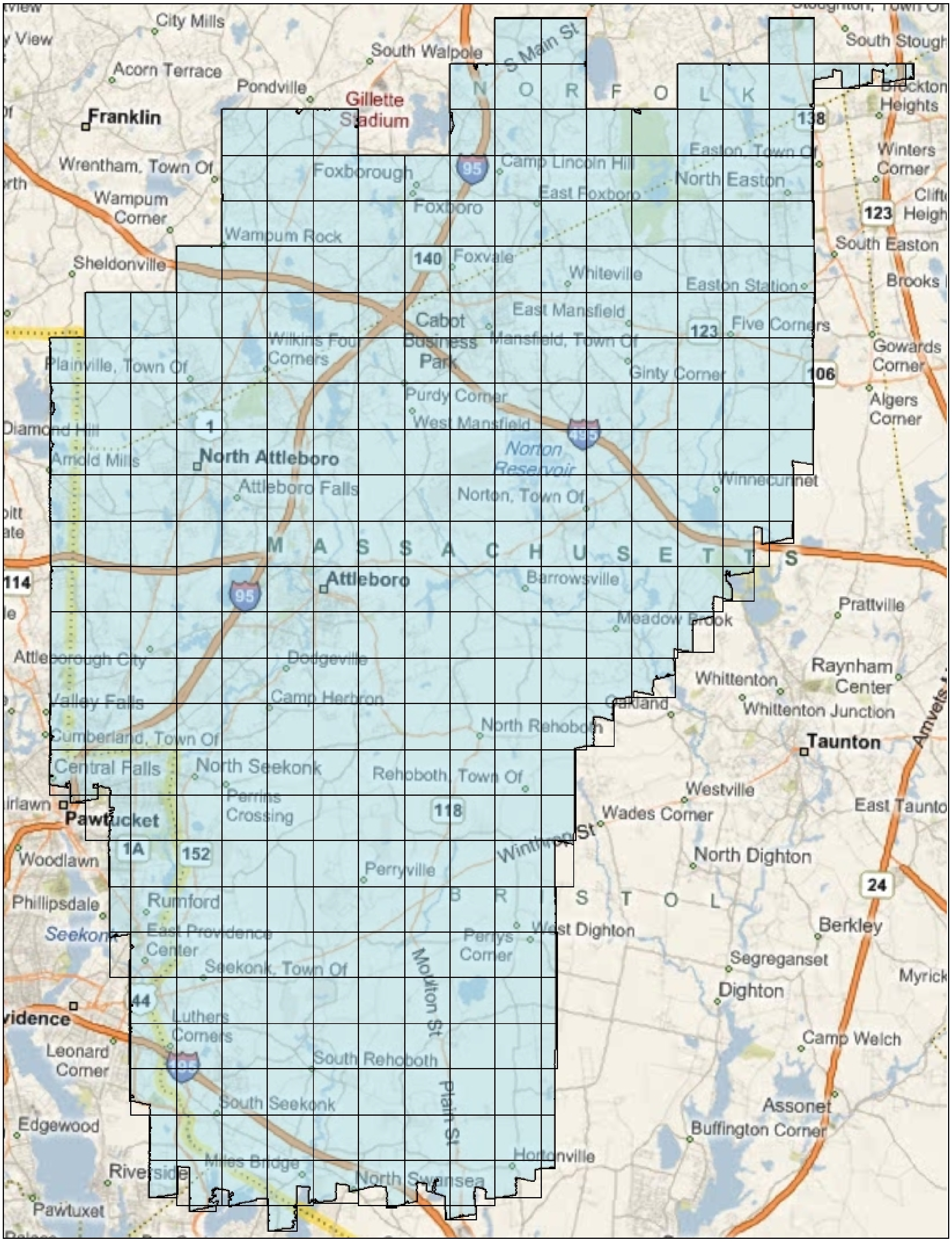
C. Post Processing

Point Cloud data is manually reviewed and any remaining artifacts are removed using functionality provided within the TerraScan and TerraModeler software packages. Additional project specific macros are created and run within GeoCue/TerraScan to ensure correct LAS classification prior to project delivery.

All points were placed in one of the following categories: 1 Unclassified, 2 Ground, 7 Noise, and 12 Overlap Points. Model Key points were then generated from the Ground points and placed in Category 8.

Final Classified LAS tiles are created within GeoCue to confirm correct LAS versioning and header information. In-house software is then used to check LAS header information and final LAS classification prior to delivery. LAS Class 2 is used to check the independent QC points against the Triangulated LiDAR surface.

**Figure 5. Narragansett Area of Interest Point Cloud and Post Processing Area**



## D. Quality Control

Fundamental Vertical Accuracy (FVA) checkpoints are 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 and/or buildings. Checkpoints are located on flat or uniformly sloping terrain and at least five (5) meters away from an break line where there is a change in slope. Checkpoints are located randomly across the acquisition area. At least 20 FVA points were collected for each test.

Consolidated Vertical Accuracy (CVA) checkpoints are collected randomly across different land use types using the ASPRS NSSDA land cover types. The points are located in flat areas with no substantial elevation breaks within a five meter radius. The CVA assessment incorporates a representative sample of the FVA assessment points into the dataset to save on the total number of points collected. CVA points were not collected for any land class comprising less that 10% of the total project area; this may have resulted in less than 4 land classes being collected in a particular area. At least 15 CVA points were collected and 5 FVA points used, for a total of at least 20 points for the CVA testing.

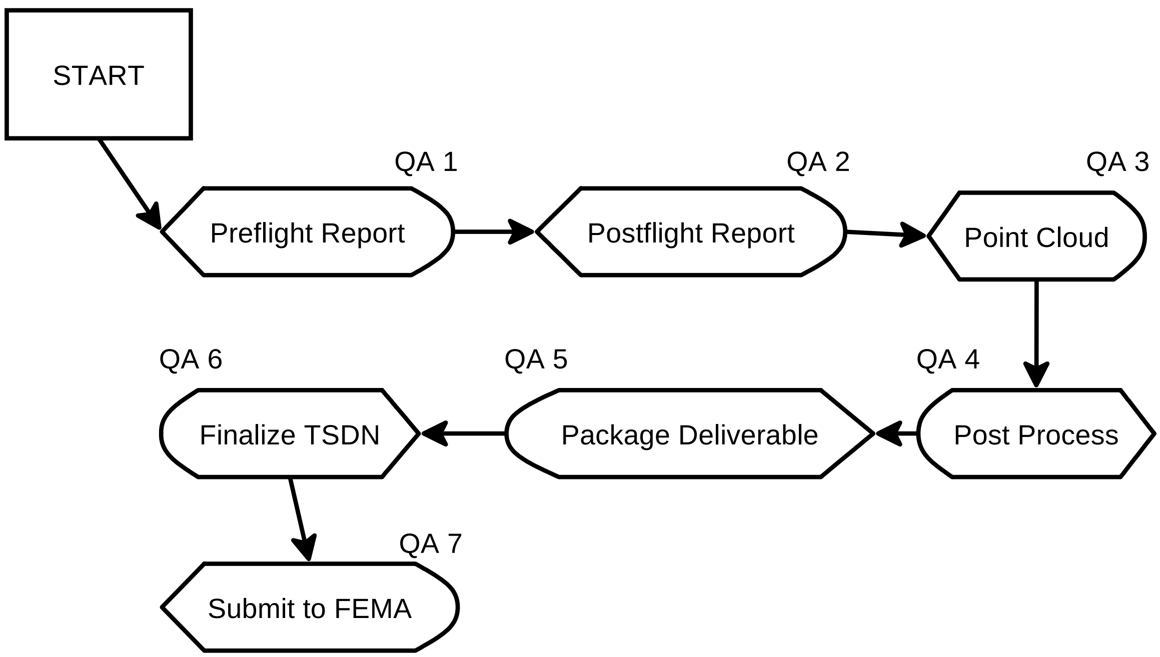
All checkpoints were collected by CompassData to ensure the 'independence' of the quality control check. All points were collected at three times the accuracy of the surface being checked. Thus to check a 24.5cm surface the points were collected accurate to 8cm.

Tests were conducted when processing by the LiDAR vendor was complete and points were called for. CompassData provided the point coordinates in an excel spreadsheet to the LiDAR vendor. The LiDAR vendor found the corresponding elevation from a surface created from the LiDAR points, filled in the spreadsheet and returned it to CompassData. CompassData compared the elevation of the LiDAR data with that of the accuracy check point, calculated the difference and reported their findings both in terms of $RMSE_z$ and at the 95% confidence level (computed as $RMSE_z$ x 1.9600). LiDAR datasets passing the quality control checks were delivered to STARR for quality assurance approval.

E. Quality Assurance

Quality assurance for all elevation data collected for this project has been completed using *FEMA Draft PM61*$_1$, *FEMA Appendix M*$_2$, *USGS LiDAR Guidelines and Base Specifications v13*$_3$, and *FEMA Appendix A*$_4$ as guidance. Products generated during this project are checked for conformance to the aforementioned guidance and specifications before submittal to FEMA.

**Figure 6. Quality Assurance Workflow**




QA1: Preflight Planning and Reporting

Project preflight operations planning were delivered as a report. This report was reviewed for completeness based on: *Table 4.1 and checklists provided in section 4.2.1in PM61*$_1$. The report was reviewed and is compliant with FEMA guidance and specifications. This report is included within Appendix C of this document. Appendix G contains information about the location of report data on the MIP.

QA2: Post flight Report

Post flight reporting for this project has been reviewed for both content and completeness based upon: *Table 4.2 and checklists provided in section 4.2.1in PM61*[1]. The report is included with Appendix E of this document. The report is complete and all content meets the guidance and specifications.

QA3: Raw Point Cloud Review

Fully calibrated raw point cloud data has been reviewed at both a macro and micro level using *Table 4.3 and checklists provided in section 4.2.1in PM61*[1], and USGS *LiDAR Guidelines and Base Specifications v13*[3]. 5% of the total number of project tiles was reviewed for compliance with USGS and FEMA specifications. All tiles reviewed for this project passed both the macro and micro reviews. Quality assurance results for the point cloud are contained within Appendix F of this document.

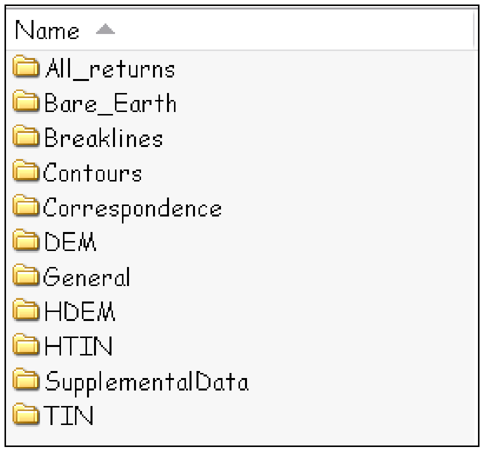
QA4: Bare Earth Review

Post-processed data has been reviewed at both a macro and micro level using *Table 4.4 and checklists provided in section 4.2.1in PM61*[1], and USGS *LiDAR Guidelines and Base Specifications v13*[3]. 10% of the total number of project tiles was reviewed for compliance with USGS and FEMA specifications. All tiles reviewed for this project passed both the macro and micro reviews. Quality assurance results for the bare earth are contained within Appendix F of this document.

QA5: Create Delivery Package

All deliverables have been organized in accordance with *Appendix M: Data Capture Standards March 2009 Section M.4.2.8*[2].

**Figure 7. Terrain Deliverable Directory Structure**




QA6: Finalization of Deliverables and TSDN

All data to be submitted for delivery has been reviewed for completeness based on the map activity statement, scope of work, and FEMA deliverable requirements. Quality assurance checklists are included in Appendix F of this document.

QA7: FEMA submission

All data for the elevation data acquisition task was delivered to FEMA on April 15, 2011. A transmittal of this submission is included in Appendix G of this document.

## 5. References

1. Draft Procedure Memorandum 61 included in Appendix H
2. FEMA Appendix M section M.4 included in Appendix H
3. USGS LiDAR Guidelines and Base Specifications v13 included in Appendix H
4. Appendix A: Guidance for Aerial Mapping and Surveying [includes guidance on Light Detection and Ranging Systems (LIDAR)] http://www.fema.gov/library/viewRecord.do?id=2206

# Appendix A: Contact Information

STARR Contacts:

Project Management and Quality Assurance

| | |
|---|---|
| Company | Greenhorne & O'Mara, Inc. |
| Name | Diane Rogers |
| Email | drogers@g-and-o.com |
| Phone | 301-982-2800 |
| Mailing Address | 5565 Centerview Drive, Suite 107<br>Raleigh, NC 27606 |

LiDAR Ground Control and QC survey

| | |
|---|---|
| Company | Compass Data, Inc. |
| Name | Hayden Howard |
| Email | haydenh@compassdatainc.com |
| Phone | 303-627-4058 |
| Mailing Address | 12353 East Easter Avenue, Suite 200<br>Centennial, CO 80112 |

LiDAR data acquisition and Post Processing

| | |
|---|---|
| Company | Photo Science, Inc |
| Name | Paul Bishop |
| Email | bishop@photoscience.com |
| Phone | 859-277-8700 |
| Mailing Address | 2670 Wilhite Drive<br>Lexington, KY 40503 |

# Appendix B: FEMA Compliance Forms and Metadata

| | |
|---|---|
| Project Name: | **Region 1: Narragansett, Massachusetts – Elevation Data Acquisition** |
| Statement of Work No.: | FEMA TASK ORDER NUMBER: HSFEHQ-10-J-0005<br>WORK ORDER NUMBER: CP HQ 10 001 |
| Interagency Agreement No.: | STARR PROJECT NUMBER: 400000058<br>STARR PARTNER TRACKING NUMBER: CP HQ 10 001 |
| CTP Agreement No.: | N/A |
| Statement/Agreement Date: | 10/ 10/10 |
| Certification Date: | 5/16/11 |

| | Tasks/Activities Covered by This Certification (Check All That Apply) |
|---|---|
| ☐ | Base Map |
| ☐ | Topographic Data Development |
| X | Survey: Including Ground Control Points (GCPs), Fundamental Vertical Accuracy Testing (FVA), and Consolidated Vertical Accuracy Testing (CVA). |
| ☐ | Hydrologic Analysis |
| ☐ | Hydraulic Analysis |
| ☐ | Alluvial Fan Analysis |
| ☐ | Coastal Analysis |
| ☐ | Floodplain Mapping |
| | This is to certify that the work summarized above was completed in accordance with the statement/agreement cited above and all amendments thereto, together with all such modifications, either written or oral, as the Regional Project Officer and/or Assistance Officer or their representative have directed, as such modifications affect the statement/agreement, and that all such work has been accomplished in accordance with the provisions contained in *Guidelines and Specifications for Flood Hazard Mapping Partners* cited in the contract document, and in accordance with sound and accepted engineering practices within the contract provisions for respective phases of the work. This is also to certify that data files submitted for the work summarized above are complete and final. Any revisions made to the already submitted data are included in the final submittal. |

| | | |
|---|---|---|
| Name: | Philipp H. Hummel, PLS | COLORADO LICENSED PROFESSIONAL LAND SURVEYOR<br>PHILIPP H. HUMMEL<br>38155<br>April 16, 2011 |
| Title: | Professional Land Surveyor, Geodesist | |
| Firm Represented: | Compass Data, Inc. | |
| Registration No.: | 38155 | |
| Signature: | Philipp Hummel | For and on behalf of Compass Data, Inc.<br>Job. No.: 1508 |

This form must be signed by a representative of the firm or agency contracted to perform the work, who must be a registered or certified professional in the area of work performed, in compliance with Federal and State regulations.

| | |
|---|---|
| Project Name: | Narragansett, LiDAR Acquisition |
| Statement of Work No.: | HSFEHQ-10-J-0005 |
| Interagency Agreement No.: | N/A |
| CTP Agreement No.: | N/A |
| Statement/Agreement Date: | N/A |
| Certification Date: | May 13, 2011 |

| | **Tasks/Activities Covered by This Certification (Check All That Apply)** |
|---|---|
| ☐ | Base Map |
| ☒ | Topographic Data Development |
| ☐ | Survey |
| ☐ | Hydrologic Analysis |
| ☐ | Hydraulic Analysis |
| ☐ | Alluvial Fan Analysis |
| ☐ | Coastal Analysis |
| ☐ | Floodplain Mapping |
| | This is to certify that the work summarized above was completed in accordance with the statement/agreement cited above and all amendments thereto, together with all such modifications, either written or oral, as the Regional Project Officer and/or Assistance Officer or their representative have directed, as such modifications affect the statement/agreement, and that all such work has been accomplished in accordance with the provisions contained in *Guidelines and Specifications for Flood Hazard Mapping Partners* cited in the contract document, and in accordance with sound and accepted engineering practices within the contract provisions for respective phases of the work. This is also to certify that data files submitted for the work summarized above are complete and final. Any revisions made to the already submitted data are included in the final submittal. |

| | |
|---|---|
| Name: | Mark E. Meade, PE, PLS, CP |
| Title: | Senior Vice President |
| Firm/Agency Represented: | Photo Science |
| Registration No.: | R1050 |
| Signature: | |

American Society for Photogrammetry and Remote Sensing
MARK E. MEADE
CERTIFIED
PHOTOGRAMMETRIST
(ASPRS) No. 1050
Exp. 03/21/12

| | |
|---|---|
| | This form must be signed by a representative of the firm or agency contracted to perform the work, who must be a registered or certified professional in the area of work performed, in compliance with Federal and State regulations. |

## Ground Control Metadata

Identification_Information:
 Citation:
  Citation_Information:
   Originator: Federal Emergency Management Agency
   Publication_Date: 20110131
   Title: TERRAIN, Naragansett, Massachusetts
   Geospatial_Data_Presentation_Form: FEMA-DCS-Terrain
   Publication_Information:
    Publication_Place: Washington, DC
    Publisher: Federal Emergency Management Agency
   Online_Linkage: http://hazards.fema.gov
   Larger_Work_Citation:
    Citation_Information:
     Originator: Federal Emergency Management Agency
     Publication_Date: 20110131
    Title: FEMA CASE 11-01-0718S
 Description:
  Abstract: The Narragansett AOI consists of one area which is part of a larger functional area. See the Ground Control process step for further information on functional areas. Ground Control is collected throughout the AOI for use in the processing of LiDAR data to ensure data accurately represents the ground surface. QA/QC checkpoints, (FVA and CVA - see Ground Control process step for further information) also collected throughout the AOI, are used for independent quality checks of the processed LiDAR data.
  Purpose: Provide high resolution terrain elevation and land cover elevation data. Terrain data is used to represent the topography of a watershed and/or floodplain environment and to extract useful information for hydraulic and hydrologic models.

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  Time_Period_Information:
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 Status:
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   Theme_Keyword: elevation
  Theme:

Theme_Keyword_Thesaurus: FEMA NFIP Topic Category
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Theme_Keyword: Topography
Theme_Keyword: Digital Terrain Model
Theme_Keyword: Elevation Data
Theme_Keyword: LIDAR
Theme:
Theme_Keyword_Thesaurus: None
Theme_Keyword: Ground Control
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Place_Keyword: COUNTY BRISTOL
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Place_Keyword: COUNTY BRISTOL
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Place_Keyword: COUNTY BRISTOL
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Place_Keyword: COUNTY BRISTOL
Place_Keyword: COUNTY-FIPS 005
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Place_Keyword: FEMA-CID 250054
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Place_Keyword: FEMA-CID 255216
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Place_Keyword: FEMA-CID 250066
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Place_Keyword: FEMA-CID 255224

Access_Constraints: None
Use_Constraints: Acknowledgement of FEMA would be appreciated in products derived from these data. This digital data is produced for the purposes of updating/creating a DFIRM database.
Data_Set_Credit: Ground control and quality control checkpoints were collected by CompassData, Inc. Quality Assurance testing was conducted by Greenhorne & O'Mara, Inc. All firms were under contract to STARR, A Joint Venture which held the FEMA contract and task order for this work.

Data_Quality_Information:
Logical_Consistency_Report: Survey data have been confirmed to be in proper units, coordinate systems and format.
Completeness_Report: Survey data have been checked for completeness, points have been collected in correct vegetation units, and distributed throughout the AOI.

Positional_Accuracy:
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: Deliverables were tested by for both vertical and horizontal accuracy. The vertical unit of the data file is in meters with 2-decimal point precision.
Quantitative_Vertical_Positional_Accuracy_Assessment:
Vertical_Positional_Accuracy_Value:
Vertical_Positional_Accuracy_Explanation: RMSE in meters.

Lineage:

Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Ground_Control Narragansett
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110131
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other1
Source_Contribution: Control points for tying LiDAR data to the ground surface.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: FVA_CVA Narragansett
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110131
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other2
Source_Contribution: Quality Assurance points to confirm LiDAR data meets vertical accuracy requirements.

Process_Step:
Process_Description: GPS based surveys were utilized to support both processing and testing of LiDAR data within FEMA designated Areas of Interest (AOIs). Geographically distinct ground points were surveyed using GPS technology throughout the AOIs to provide support for three distinct tasks.
Task 1 was to provide Vertical Ground Control to support the aerial acquisition and subsequent bare earth model processing. To accomplish this, survey-grade Trimble R-8 GPS receivers were used to collect a series of control points located on open areas, free of excessive or significant slope, and at least 5 meters away from any significant terrain break. Most if not all control points were collected at street/road intersections on bare level pavement.
Task 2 was to collect Fundamental Vertical Accuracy (FVA) checkpoints to evaluate the initial quality of the collected point cloud and to ensure that the collected data was satisfactory for further processing to meet FEMA specifications. The FVA points were collected in identical fashion to the Vertical Ground Control Points, but segregated from the point pool to ensure independent quality testing without prior knowledge of FVA locations by the aerial vendor.
Task 3 was to collect Consolidated Vertical Accuracy CVA) checkpoints to allow vertical testing of the bare-earth processed LiDAR data in different classes of land cover, including: Open (pavement, open dirt, short grass), High Grass and Crops, Brush and Low Trees, Forest, Urban. CVA points were collected in similar fashion as Control and FVA points with emphasis on establishing point locations within the

predominant land cover classes within each AOI or Functional AOI Group. In order to successfully collect the Forest land cover class, it was necessary to establish a Backsight and Initial Point with the R8 receiver, and then employ a Nikon Total Station to observe a retroreflective prism stationed under tree canopy. This was necessary due to the reduced GPS performance and degradation of signal under tree canopy.

The R-8 receivers were equipped with cellular modems to receive real-time correction signals from the Keystone Precision Virtual Reference Station (VRS) network encompassing the Region 1 AOIs. Use of the VRS network allowed rapid collection times (~3 minutes/point) at 2.54 cm (1 inch) initial accuracy.

All points collected were below the 8cm specification for testing 24cm, Highest category LiDAR data. To ensure valid in-field collections, an NGS monument with suitable vertical reporting was measured using the same equipment and procedures used for Control, FVA and CVA points on a daily basis. The measurement was compared to the NGS published values to ensure that the GPS collection schema was producing valid data and as a physical proof point of quality of collection. Those monument measurements are summarized in the Accuracy report included in the data delivered to FEMA.

In order to meet FEMA budgetary requirements, AOIs were consolidated into Functional Groups: if AOIs were contiguous, they were treated as one large AOI to allow collection of 20 FVA points and 15 additional CVA points across the group of AOIs. 20 FVA points are necessary to allow testing to CE95 – 1 point out of 20 may fail vertical testing and still allow the entire dataset to meet 95% accuracy requirements.

In similar fashion, 20 CVA points are necessary to test to CE95 as discussed above. 15 CVA points were collected per AOI or per Functional Group with the intention at the outset that 5 of the collected FVAs would perform double –duty as Open-class CVA points, to total 20 CVAs per AOI or Functional Group.

The Functional Groups are as follows: Narragansett/Charles/Blackstone(northeast), Nashua, Blackstone(north and west), Quinnipiac, Quincy/Suffolk (while included as part of the FEMA Charles AOI, was physically separated from the Charles AOI polygon and treated as an independent functional area).

The following software packages and utilities were used to control the GPS receiver in the field during data collection, and then ingest and export the collected GPS data for all points: Trimble Survey Controller, Trimble Pathfinder Office.

The following software utilities were used to translate the collected Latitude/Longitude Decimal Degree HAE GPS data for all points into Latitude/Longitude Degrees/Minutes/Seconds for checking the collected monument data against the published NGS Datasheet Lat/Long DMS values and into UTM NAD83 Northings/Eastings: U.S. Army Corps of Engineers CorpsCon, National Geodetic Survey Geoid09NAVD88.

MSL values were determined using the most recent NGS-approved geoid model to generate geoid separation values for each Lat/Long coordinate pair. In this fashion, Orthometric heights were determined for each Control, FVA and CVA point by subtracting the generated Geoid Separation value from the Ellipsoidal Height (HAE) for publication and use as MSL NAVD88(09).

Process_Date: 2011

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 19
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -69.000000

Latitude_of_Projection_Origin: 0.000000
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000010
Ordinate_Resolution: 0.000010
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.00
Denominator_of_Flattening_Ratio: 298.257222
Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Datum_Name: North American Vertical Datum of 1988
Altitude_Resolution: 0.01
Altitude_Distance_Units: meters
Altitude_Encoding_Method: Attribute Values

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142850\SupplementalData\GroundControl Narragansett
Entity_Type_Definition: Ground Control Survey for LiDAR collection
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142850\SupplementalData\FVA_CVA Narragansett
Entity_Type_Definition: Survey for Horizontal and Vertical LiDAR QC
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Overview_Description:
Entity_and_Attribute_Overview: The Terrain data package is made up of several data themes containing primarily spatial information. These data supplement the Elevation datasets by providing additional information to aid flood risk evaluation and flood hazard area delineations.
Entity_and_Attribute_Detail_Citation: Appendix M of FEMA Guidelines and Specifications for FEMA Flood Hazard Mapping Partners contains a detailed description of the data themes and references to other relevant information.

Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:

Contact_Organization: Federal Emergency Management Agency Engineering Library
Contact_Address:
Address_Type: mailing address
Address: Marie Sparrow, Zimmerman Associates, Inc.
Address: 847 South Pickett Street
City: Alexandria
State_or_Province: Virginia
Postal_Code: 22304
Country: USA
Contact_Voice_Telephone: 1-877-336-2627
Contact_Electronic_Mail_Address: miphelp@mapmodteam.com

Distribution_Liability: No warranty expressed or implied is made by FEMA regarding the utility of the data on any other system nor shall the act of distribution constitute any such warranty.
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Format_Name: FEMA-DCS-Terrain
Digital_Transfer_Option:
Online_Option:
Computer_Contact_Information:
Network_Address:
Network_Resource_Name: http://hazards.fema.gov
Fees: Contact Distributor

Metadata_Reference_Information:
Metadata_Date: 20110131
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: FEMA Representative
Contact_Organization: Federal Emergency Management Agency
Contact_Address:
Address_Type: mailing address
Address: 500 C Street, S.W.
City: Washington
State_or_Province: District of Columbia
Postal_Code: 20472
Country: USA
Contact_Voice_Telephone: 1-877-336-2627
Contact_Electronic_Mail_Address: miphelp@mapmodteam.com
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Extensions:
Online_Linkage: http://hazards.fema.gov
Online_Linkage: http://www.epsg.org
Profile_Name: FEMA NFIP Metadata Content and Format Standard

## Acquisition Metadata

Identification_Information:
Citation:
Citation_Information:
Originator: Federal Emergency Management Agency
Publication_Date: 20110330
Title: TERRAIN, Naragansett, Massachusetts
Geospatial_Data_Presentation_Form: FEMA-DCS-Terrain
Publication_Information:
Publication_Place: Washington, DC
Publisher: Federal Emergency Management Agency
Online_Linkage: http://hazards.fema.gov
Larger_Work_Citation:
Citation_Information:
Originator: Federal Emergency Management Agency
Publication_Date: 20110330
Title: FEMA CASE 11-01-0718S
Description:
Abstract: The Narragansett AOI consists of one area which is part of a larger functional area. See the Ground Control process step for further information on functional areas. Ground Control is collected throughout the AOI for use in the processing of LiDAR data to ensure data accurately represents the ground surface. QA/QC checkpoints, (FVA and CVA - see Ground Control process step for further information) also collected throughout the AOI, are used for independent quality checks of the processed LiDAR data.
LiDAR acquisition products include Pre- and Post- flight reports which contain information on the flightlines, equipment parameters, and other pertinant acquisition details. The LiDAR product is considered to be point cloud data and consists of 1500mx1500m tiles of LAS points which are partially classified such that the bare earth points can be calibrated to the ground surface and tested via the independent QC to ensure the ground surface is accurately represented.
Purpose: Provide high resolution terrain elevation and land cover elevation data. Terrain data is used to represent the topography of a watershed and/or floodplain environment and to extract useful information for hydraulic and hydrologic models.
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110330
Currentness_Reference: ground condition
Status:
Progress: Complete
Maintenance_and_Update_Frequency: Unknown
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -71.43433
East_Bounding_Coordinate: -71.055549
North_Bounding_Coordinate: 42.22065
South_Bounding_Coordinate: 41.734156
Keywords:

Theme:
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  Theme_Keyword: elevation
Theme:
  Theme_Keyword_Thesaurus: FEMA NFIP Topic Category
  Theme_Keyword: Land Surface
  Theme_Keyword: Topography
  Theme_Keyword: Digital Terrain Model
  Theme_Keyword: Elevation Data
  Theme_Keyword: LIDAR
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Place_Keyword: FEMA-CID 250060
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Place_Keyword: FEMA-CID 250061
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Place_Keyword: COMMUNITY REHOBOTH, TOWN OF
Place_Keyword: FEMA-CID 250062
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Place_Keyword: STATE MA
Place_Keyword: COUNTY BRISTOL
Place_Keyword: COUNTY-FIPS 005
Place_Keyword: COMMUNITY SEEKONK, TOWN OF
Place_Keyword: FEMA-CID 250063
Place:

Place_Keyword_Thesaurus: None
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Place_Keyword: COUNTY BRISTOL
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Place_Keyword: FEMA-CID 255220
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Place_Keyword_Thesaurus: None
Place_Keyword: REGION I
Place_Keyword: STATE MA
Place_Keyword: COUNTY BRISTOL
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Place_Keyword: COMMUNITY SWANSEA, TOWN OF
Place_Keyword: FEMA-CID 255221
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Place_Keyword_Thesaurus: None
Place_Keyword: REGION I
Place_Keyword: STATE MA
Place_Keyword: COUNTY BRISTOL
Place_Keyword: COUNTY-FIPS 005
Place_Keyword: COMMUNITY TAUNTON, CITY OF
Place_Keyword: FEMA-CID 250066
Place:
Place_Keyword_Thesaurus: None
Place_Keyword: REGION I
Place_Keyword: STATE MA
Place_Keyword: COUNTY BRISTOL
Place_Keyword: COUNTY-FIPS 005
Place_Keyword: COMMUNITY WESTPORT, TOWN OF
Place_Keyword: FEMA-CID 255224

Access_Constraints: None
Use_Constraints: Acknowledgement of FEMA would be appreciated in products derived from these data. This digital data is produced for the purposes of updating/creating a DFIRM database.
Data_Set_Credit: Ground control and quality control checkpoints were collected by CompassData, Inc. LiDAR was acquired and processed by Photo Science, Inc. Quality Control testing was performed by CompassData, Inc. Quality Assurance testing was conducted by Greenhorne & O'Mara, Inc. All firms were under contract to STARR, a Joint Venture which held the FEMA contract and task order for this work.

Data_Quality_Information:
Logical_Consistency_Report: Survey data have been confirmed to be in proper units, coordinate systems and format. The terrain data have been confirmed as complete LAS format data files. Header files are in proper LAS format with content as specified by FEMA Procedural Memo No. 61.
Completeness_Report: Survey data have been checked for completeness, points have been collected in correct vegetation units, and distributed throughout the AOI. The terrain data have been checked for

completeness against AOI polygons. No gaps as defined by FEMA Procedural Memo No. 61 are known to exist within the dataset.

Positional_Accuracy:
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: Deliverables were tested by for both vertical and horizontal accuracy. The vertical unit of the data file is in meters with 2-decimal point precision.
Quantitative_Vertical_Positional_Accuracy_Assessment:
Vertical_Positional_Accuracy_Value: 0.166
Vertical_Positional_Accuracy_Explanation: Fundamental Vertical Accuracy (FVA) equal to the 95th percentile confidence level (RMSE[z] x 1.9600) calculated in open terrain. Reported in meters.

Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Ground_Control Narragansett
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110131
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other1
Source_Contribution: Control points for tying LiDAR data to the ground surface.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: FVA_CVA Narragansett
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110131
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other2
Source_Contribution: Quality Assurance points to confirm LiDAR data meets vertical accuracy requirements.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Narragansett_Collection_Area

Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110330
Source_Currentness_Reference: publication date
Source_Citation_Abbreviation: Other3
Source_Contribution: Shapefile of Naragansett LiDAR acquisition area.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: All_Returns
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110330
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other4
Source_Contribution: Point Cloud (All Returns) LAS point files named according to Naragansett LiDAR Tile Index.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Narragansett_PreFlightReport
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110330
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other5
Source_Contribution: Document contains the operations plans for the LiDAR acquisition.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Narragansett_PostFlightReport
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110330

Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other6
Source_Contribution: Document contains the acquisition and calibration report for the LiDAR acquisition
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Narr_Tile_Index
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110330
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other7
Source_Contribution: Shapefile of tile index used to populate and reference the LAS tiled data.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Region 1 Charles Narragansett partial Blackstone Testing Results FVA CVA
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110330
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other8
Source_Contribution: Document contains QC test results for both FVA and CVA blind check point tests against open area and bare earth surfaces generated from All Returns and Bare Earth (respectively) LAS points.
Process_Step:
Process_Description: GPS based surveys were utilized to support both processing and testing of LiDAR data within FEMA designated Areas of Interest (AOIs). Geographically distinct ground points were surveyed using GPS technology throughout the AOIs to provide support for three distinct tasks.
Task 1 was to provide Vertical Ground Control to support the aerial acquisition and subsequent bare earth model processing. To accomplish this, survey-grade Trimble R-8 GPS receivers were used to collect a series of control points located on open areas, free of excessive or significant slope, and at least 5 meters away from any significant terrain break. Most if not all control points were collected at street/road intersections on bare level pavement.
Task 2 was to collect Fundamental Vertical Accuracy (FVA) checkpoints to evaluate the initial quality of the collected point cloud and to ensure that the collected data was satisfactory for further processing to meet FEMA specifications. The FVA points were collected in identical fashion to the Vertical Ground Control Points, but segregated from the point pool to ensure independent quality testing without prior knowledge of FVA locations by the aerial vendor.

Task 3 was to collect Consolidated Vertical Accuracy CVA) checkpoints to allow vertical testing of the bare-earth processed LiDAR data in different classes of land cover, including:  Open (pavement, open dirt, short grass), High Grass and Crops, Brush and Low Trees, Forest, Urban.  CVA points were collected in similar fashion as Control and FVA points with emphasis on establishing point locations within the predominant land cover classes within each AOI or Functional AOI Group.  In order to successfully collect the Forest land cover class, it was necessary to establish a Backsight and Initial Point with the R8 receiver, and then employ a Nikon Total Station to observe a retroreflective prism stationed under tree canopy. This was necessary due to the reduced GPS performance and degradation of signal under tree canopy.

The R-8 receivers were equipped with cellular modems to receive real-time correction signals from the Keystone Precision Virtual Reference Station (VRS) network encompassing the Region 1 AOIs.  Use of the VRS network allowed rapid collection times (~3 minutes/point) at 2.54 cm (1 inch) initial accuracy.

All points collected were below the 8cm specification for testing 24cm, Highest category LiDAR data.  To ensure valid in-field collections, an NGS monument with suitable vertical reporting was measured using the same equipment and procedures used for Control, FVA and CVA points on a daily basis.  The measurement was compared to the NGS published values to ensure that the GPS collection schema was producing valid data and as a physical proof point of quality of collection.  Those monument measurements are summarized in the Accuracy report included in the data delivered to FEMA.

In order to meet FEMA budgetary requirements, AOIs were consolidated into Functional Groups:  if AOIs were contiguous, they were treated as one large AOI to allow collection of 20 FVA points and 15 additional CVA points across the group of AOIs.  20 FVA points are necessary to allow testing to CE95  – 1 point out of 20 may fail vertical testing and still allow the entire dataset to meet 95% accuracy requirements.

In similar fashion, 20 CVA points are necessary to test to CE95 as discussed above.  15 CVA points were collected per AOI or per Functional Group with the intention at the outset that 5 of the collected FVAs would perform double –duty as Open-class CVA points, to total 20 CVAs per AOI or Functional Group.

The Functional Groups are as follows: Narragansett/Charles/Blackstone(northeast), Nashua, Blackstone(north and west), Quinnipiac, Quincy/Suffolk (while included as part of the FEMA Charles AOI, was physically separated from the Charles AOI polygon and treated as an independent functional area).

The following software packages and utilities were used to control the GPS receiver in the field during data collection, and then ingest and export the collected GPS data for all points:  Trimble Survey Controller, Trimble Pathfinder Office.

The following software utilities were used to translate the collected Latitude/Longitude Decimal Degree HAE GPS data for all points into Latitude/Longitude Degrees/Minutes/Seconds for checking the collected monument data against the published NGS Datasheet Lat/Long DMS values and into UTM NAD83 Northings/Eastings:  U.S. Army Corps of Engineers CorpsCon, National Geodetic Survey Geoid09NAVD88.

MSL values were determined using the most recent NGS-approved geoid model to generate geoid separation values for each Lat/Long coordinate pair.  In this fashion, Orthometric heights were determined for each Control, FVA and CVA point by subtracting the generated Geoid Separation value from the Ellipsoidal Height (HAE) for publication and use as MSL NAVD88(09).

Process_Date: 2011

Process_Step:

Process_Description: Using an Optech Gemini LiDAR system, 44 flight lines of highest density (Nominal Pulse Spacing of 1.0m) were collected over the Narragansett area which encompasses 217 square miles. A total of 6 missions were flown on December 8, 2010, and December 10, 2010.  one airborne global positioning system (GPS) base station was used to support the LiDAR data acquisition: Mansfield, LW5147.  Additional information can be found in the Post-Flight Aerial Acquisition Report.

Process_Date: 2011

Process_Step:
  Process_Description: Applanix software was used in the post processing of the airborne GPS and inertial data that is critical to the positioning and orientation of the sensor during all flights.  POSPac MMS provides the smoothed best estimate of trajectory (SBET) that is necessary for Optech's post processor to develop the point cloud from the LiDAR missions.  The point cloud is the mathematical three dimensional collection of all returns from all laser pulses as determined from the aerial mission. Optech's DASHMap software and Leica's ALS Post Processor software were used to create the Raw LIDAR Flight Line strips.  At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above ground features are removed from the data set. The GeoCue and TerraScan software packages are then used for the automated data classification. Project specific macros are created to classify the ground and to remove the side overlap between parallel flight lines.
LAS Class 2 (Ground) is used to check the surveyed control points against the Triangulated LIDAR surface.  Any bias is then removed using macro functionality within TerraScan.
Unclassified Point Cloud tiles are then created using TerraScan macro functionality.  These tiles are populated within GeoCue to ensure correct LAS versioning and LAS Header information.
LAS Class 2 is used to check the independent QC points against the Triangulated LiDAR surface.  If RMSE is not within guidelines TerraScan software is utilitzed to remove any bias, and the check is performed again.
  Process_Date:  2011

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 19
Transverse_Mercator:
  Scale_Factor_at_Central_Meridian: 0.999600
  Longitude_of_Central_Meridian: -69.000000
  Latitude_of_Projection_Origin: 0.000000
  False_Easting: 500000.000000
  False_Northing: 0.000000
    Planar_Coordinate_Information:
      Planar_Coordinate_Encoding_Method: coordinate pair
      Coordinate_Representation:
        Abscissa_Resolution: 0.000010
        Ordinate_Resolution: 0.000010
      Planar_Distance_Units: meters
Geodetic_Model:
  Horizontal_Datum_Name: North American Datum 1983
  Ellipsoid_Name:  Geodetic Reference System 80
  Semi-major_Axis: 6378137.00
  Denominator_of_Flattening_Ratio: 298.257222
    Vertical_Coordinate_System_Definition:
      Altitude_System_Definition:
      Altitude_Datum_Name: North American Vertical Datum of 1988

Altitude_Resolution: 0.01
Altitude_Distance_Units:  meters
Altitude_Encoding_Method:  Attribute Values

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142850\SupplementalData\GroundControl Narragansett
Entity_Type_Definition: Ground Control Survey for LiDAR collection
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142850\SupplementalData\FVA_CVA Narragansett
Entity_Type_Definition: Survey for Horizontal and Vertical LiDAR QC
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142851\SupplementalData\Narragansett_Collection_Area
Entity_Type_Definition: Area Spatial File
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142851\All_Returns
Entity_Type_Definition: LAS 1.2 files
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142851\SupplementalData\Narragansett_PreFlight Report
Entity_Type_Definition: Digital Document
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142851\SupplementalData\Narragansett_PostFlight Report
Entity_Type_Definition: Digitial Document
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:

Entity_Type:
Entity_Type_Label: Terrain\2142851\SupplementalData\Narr_Tile_Index
Entity_Type_Definition: Area Spatial File
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142852\SupplementalData\Region 1 Charles Narragansett partial Blackstone Testing Results FVA CVA
Entity_Type_Definition: Digital Document
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Overview_Description:
Entity_and_Attribute_Overview: The Terrain data package is made up of several data themes containing primarily spatial information. These data supplement the Elevation datasets by providing additional information to aid flood risk evaluation and flood hazard area delineations.
Entity_and_Attribute_Detail_Citation: Appendix M of FEMA Guidelines and Specifications for FEMA Flood Hazard Mapping Partners contains a detailed description of the data themes and references to other relevant information.

Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Federal Emergency Management Agency Engineering Library
Contact_Address:
Address_Type: mailing address
Address: Marie Sparrow, Zimmerman Associates, Inc.
Address: 847 South Pickett Street
City: Alexandria
State_or_Province: Virginia
Postal_Code: 22304
Country: USA
Contact_Voice_Telephone: 1-877-336-2627
Contact_Electronic_Mail_Address: miphelp@mapmodteam.com

Distribution_Liability: No warranty expressed or implied is made by FEMA regarding the utility of the data on any other system nor shall the act of distribution constitute any such warranty.
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Format_Name: FEMA-DCS-Terrain
Digital_Transfer_Option:
Online_Option:
Computer_Contact_Information:
Network_Address:

Network_Resource_Name: http://hazards.fema.gov
Fees: Contact Distributor

Metadata_Reference_Information:
Metadata_Date: 20110330
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: FEMA Representative
Contact_Organization: Federal Emergency Management Agency
Contact_Address:
Address_Type: mailing address
Address: 500 C Street, S.W.
City: Washington
State_or_Province: District of Columbia
Postal_Code: 20472
Country: USA
Contact_Voice_Telephone: 1-877-336-2627
Contact_Electronic_Mail_Address: miphelp@mapmodteam.com
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Extensions:
Online_Linkage: http://hazards.fema.gov
Online_Linkage: http://www.epsg.org
Profile_Name: FEMA NFIP Metadata Content and Format Standard

## Processing Metadata

Identification_Information:
  Citation:
    Citation_Information:
      Originator: Federal Emergency Management Agency
      Publication_Date: 20110330
      Title: TERRAIN, Naragansett, Massachusetts
      Geospatial_Data_Presentation_Form: FEMA-DCS-Terrain
      Publication_Information:
        Publication_Place: Washington, DC
        Publisher: Federal Emergency Management Agency
      Online_Linkage: http://hazards.fema.gov
      Larger_Work_Citation:
        Citation_Information:
          Originator: Federal Emergency Management Agency
          Publication_Date: 20110330
        Title: FEMA CASE 11-01-0718S
  Description:
    Abstract: The Narragansett AOI consists of one area which is part of a larger functional area. See the Ground Control process step for further information on functional areas. Ground Control is collected throughout the AOI for use in the processing of LiDAR data to ensure data accurately represents the ground surface. QA/QC checkpoints, (FVA and CVA - see Ground Control process step for further information) also collected throughout the AOI, are used for independent quality checks of the processed LiDAR data.
LiDAR acquisition products include Pre- and Post- flight reports which contain information on the flightlines, equipment parameters, and other pertinant acquisition details. The LiDAR product is considered to be point cloud data and consists of 1500mx1500m tiles of LAS points which are partially classified such that the bare earth points can be calibrated to the ground surface and tested via the independent QC to ensure the ground surface is accurately represented.
The Bare Earth deliverables consists of tiles of fully classified LAS points. A full narrative accompanies this deliverable, as well as the independent QC report.
    Purpose: Provide high resolution terrain elevation and land cover elevation data. Terrain data is used to represent the topography of a watershed and/or floodplain environment and to extract useful information for hydraulic and hydrologic models.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date: 20110330
    Currentness_Reference: ground condition
  Status:
    Progress: Complete
    Maintenance_and_Update_Frequency: Unknown
  Spatial_Domain:
    Bounding_Coordinates:
      West_Bounding_Coordinate: -71.43433
      East_Bounding_Coordinate: -71.055549
      North_Bounding_Coordinate: 42.22065

South_Bounding_Coordinate: 41.734156
Keywords:
Theme:
Theme_Keyword_Thesaurus: ISO 19115 Topic Category
Theme_Keyword: elevation
Theme:
Theme_Keyword_Thesaurus: FEMA NFIP Topic Category
Theme_Keyword: Land Surface
Theme_Keyword: Topography
Theme_Keyword: Digital Terrain Model
Theme_Keyword: Elevation Data
Theme_Keyword: LIDAR
Theme:
Theme_Keyword_Thesaurus: None
Theme_Keyword: Ground Control
Theme_Keyword: Point Cloud
Theme_Keyword: LAS Point Files
Theme_Keyword: Bare Earth
Place:
Place_Keyword_Thesaurus: None
Place_Keyword: REGION I
Place_Keyword: STATE MA
Place_Keyword: COUNTY BRISTOL
Place_Keyword: COUNTY-FIPS 005
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Place_Keyword: FEMA-CID 250048
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Place_Keyword: COUNTY BRISTOL
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Place_Keyword: COMMUNITY ATTLEBORO, CITY OF
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Place_Keyword: FEMA-CID 250054
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Place_Keyword: COUNTY-FIPS 005
Place_Keyword: COMMUNITY RAYNHAM, TOWN OF
Place_Keyword: FEMA-CID 250061
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Place_Keyword: STATE MA
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Place_Keyword: COMMUNITY REHOBOTH, TOWN OF
Place_Keyword: FEMA-CID 250062
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Place_Keyword_Thesaurus: None
Place_Keyword: REGION I
Place_Keyword: STATE MA
Place_Keyword: COUNTY BRISTOL
Place_Keyword: COUNTY-FIPS 005

Place_Keyword: COMMUNITY SEEKONK, TOWN OF
Place_Keyword: FEMA-CID 250063
Place:
Place_Keyword_Thesaurus: None
Place_Keyword: REGION I
Place_Keyword: STATE MA
Place_Keyword: COUNTY BRISTOL
Place_Keyword: COUNTY-FIPS 005
Place_Keyword: COMMUNITY SOMERSET, TOWN OF
Place_Keyword: FEMA-CID 255220
Place:
Place_Keyword_Thesaurus: None
Place_Keyword: REGION I
Place_Keyword: STATE MA
Place_Keyword: COUNTY BRISTOL
Place_Keyword: COUNTY-FIPS 005
Place_Keyword: COMMUNITY SWANSEA, TOWN OF
Place_Keyword: FEMA-CID 255221
Place:
Place_Keyword_Thesaurus: None
Place_Keyword: REGION I
Place_Keyword: STATE MA
Place_Keyword: COUNTY BRISTOL
Place_Keyword: COUNTY-FIPS 005
Place_Keyword: COMMUNITY TAUNTON, CITY OF
Place_Keyword: FEMA-CID 250066
Place:
Place_Keyword_Thesaurus: None
Place_Keyword: REGION I
Place_Keyword: STATE MA
Place_Keyword: COUNTY BRISTOL
Place_Keyword: COUNTY-FIPS 005
Place_Keyword: COMMUNITY WESTPORT, TOWN OF
Place_Keyword: FEMA-CID 255224

Access_Constraints: None
Use_Constraints: Acknowledgement of FEMA would be appreciated in products derived from these data. This digital data is produced for the purposes of updating/creating a DFIRM database.
Data_Set_Credit: Ground control and quality control checkpoints were collected by CompassData, Inc. LiDAR was acquired and processed by Photo Science, Inc. Quality Control testing was performed by CompassData, Inc. Quality Assurance testing was conducted by Greenhorne & O'Mara, Inc. All firms were under contract to STARR, A Joint Venture which held the FEMA contract and task order for this work.

Data_Quality_Information:
Logical_Consistency_Report: Survey data have been confirmed to be in proper units, coordinate systems and format. The terrain data have been confirmed as complete LAS format data files. Header files are in proper LAS format with content as specified by FEMA Procedural Memo No. 61.

Completeness_Report: Survey data have been checked for completeness, points have been collected in correct vegetation units, and distributed throughout the AOI. The terrain data have been checked for completeness against AOI polygons. No gaps as defined by FEMA Procedural Memo No. 61 are known to exist within the dataset.

Positional_Accuracy:
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: Deliverables were tested by for both vertical and horizontal accuracy. The vertical unit of the data file is in meters with 2-decimal point precision.
Quantitative_Vertical_Positional_Accuracy_Assessment:
Vertical_Positional_Accuracy_Value: 0.186
Vertical_Positional_Accuracy_Explanation: Consolidated Vertical Accuracy (CVA) equal to the 95th percentile confidence level (RMSE[z] x 1.9600) calculated against the bare earth surface in all ground cover classes. Reported in meters.

Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Ground_Control Narragansett
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110131
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other1
Source_Contribution: Control points for tying LiDAR data to the ground surface.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: FVA_CVA Narragansett
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110131
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other2
Source_Contribution: Quality Assurance points to confirm LiDAR data meets vertical accuracy requirements.
Source_Information:
Source_Citation:
Citation_Information:

Originator: STARR
Publication_Date: 2011
Title: Narragansett_Collection_Area
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110330
Source_Currentness_Reference: publication date
Source_Citation_Abbreviation: Other3
Source_Contribution: Shapefile of Naragansett LiDAR acquisition area.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: All_Returns
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110124
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other4
Source_Contribution: Point Cloud (All Returns) LAS point files named according to Narr_Tile_Index.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Narragansett_PreFlightReport
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110124
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other5
Source_Contribution: Document contains the operations plans for the LiDAR acquisition.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Narragansett_PostFlightReport
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:

Single_Date/Time:
Calendar_Date: 20110124
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other6
Source_Contribution: Document contains the acquisition and calibration report for the LiDAR acquisition
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Narr_Tile_Index
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110124
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other7
Source_Contribution: Shapefile of tile index used to populate and reference the LAS tiled data.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Region 5 Charles Narragansett partial Blackstone Testing Results FVA CVA
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110124
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other8
Source_Contribution: Document contains QC test results for both FVA and CVA blind check point tests against open area and bare earth surfaces generated from All Returns and Bare Earth (respectively) LAS points.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: R1_Narragansett_Terrain_TSDN
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110124
Source_Currentness_Reference: ground condition

Source_Citation_Abbreviation: Other9
Source_Contribution: Contains complete narrative on the acquisition and processing of the LiDAR dataset, includes area diagrams, reports and metadata.
Source_Information:
Source_Citation:
Citation_Information:
Originator: STARR
Publication_Date: 2011
Title: Bare_Earth
Type_of_Source_Media: DIGITAL
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20110124
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Other10
Source_Contribution: Bare Earth LAS point files named according to the Narr_Tile_Index.

Process_Step:
Process_Description: GPS based surveys were utilized to support both processing and testing of LiDAR data within FEMA designated Areas of Interest (AOIs). Geographically distinct ground points were surveyed using GPS technology throughout the AOIs to provide support for three distinct tasks.
Task 1 was to provide Vertical Ground Control to support the aerial acquisition and subsequent bare earth model processing. To accomplish this, survey-grade Trimble R-8 GPS receivers were used to collect a series of control points located on open areas, free of excessive or significant slope, and at least 5 meters away from any significant terrain break. Most if not all control points were collected at street/road intersections on bare level pavement.
Task 2 was to collect Fundamental Vertical Accuracy (FVA) checkpoints to evaluate the initial quality of the collected point cloud and to ensure that the collected data was satisfactory for further processing to meet FEMA specifications. The FVA points were collected in identical fashion to the Vertical Ground Control Points, but segregated from the point pool to ensure independent quality testing without prior knowledge of FVA locations by the aerial vendor.
Task 3 was to collect Consolidated Vertical Accuracy CVA) checkpoints to allow vertical testing of the bare-earth processed LiDAR data in different classes of land cover, including: Open (pavement, open dirt, short grass), High Grass and Crops, Brush and Low Trees, Forest, Urban. CVA points were collected in similar fashion as Control and FVA points with emphasis on establishing point locations within the predominant land cover classes within each AOI or Functional AOI Group. In order to successfully collect the Forest land cover class, it was necessary to establish a Backsight and Initial Point with the R8 receiver, and then employ a Nikon Total Station to observe a retroreflective prism stationed under tree canopy. This was necessary due to the reduced GPS performance and degradation of signal under tree canopy.
The R-8 receivers were equipped with cellular modems to receive real-time correction signals from the Keystone Precision Virtual Reference Station (VRS) network encompassing the Region 1 AOIs. Use of the VRS network allowed rapid collection times (~3 minutes/point) at 2.54 cm (1 inch) initial accuracy.
All points collected were below the 8cm specification for testing 24cm, Highest category LiDAR data. To ensure valid in-field collections, an NGS monument with suitable vertical reporting was measured using the same equipment and procedures used for Control, FVA and CVA points on a daily basis. The measurement was compared to the NGS published values to ensure that the GPS collection schema was

producing valid data and as a physical proof point of quality of collection.  Those monument measurements are summarized in the Accuracy report included in the data delivered to FEMA.
In order to meet FEMA budgetary requirements, AOIs were consolidated into Functional Groups:  if AOIs were contiguous, they were treated as one large AOI to allow collection of 20 FVA points and 15 additional CVA points across the group of AOIs.  20 FVA points are necessary to allow testing to CE95  – 1 point out of 20 may fail vertical testing and still allow the entire dataset to meet 95% accuracy requirements.
In similar fashion, 20 CVA points are necessary to test to CE95 as discussed above.  15 CVA points were collected per AOI or per Functional Group with the intention at the outset that 5 of the collected FVAs would perform double –duty as Open-class CVA points, to total 20 CVAs per AOI or Functional Group.
The Functional Groups are as follows: Narragansett/Charles/Blackstone(northeast), Nashua, Blackstone(north and west), Quinnipiac, Quincy/Suffolk (while included as part of the FEMA Charles AOI, was physically separated from the Charles AOI polygon and treated as an independent functional area).
The following software packages and utilities were used to control the GPS receiver in the field during data collection, and then ingest and export the collected GPS data for all points:  Trimble Survey Controller, Trimble Pathfinder Office.
The following software utilities were used to translate the collected Latitude/Longitude Decimal Degree HAE GPS data for all points into Latitude/Longitude Degrees/Minutes/Seconds for checking the collected monument data against the published NGS Datasheet Lat/Long DMS values and into UTM NAD83 Northings/Eastings:  U.S. Army Corps of Engineers CorpsCon, National Geodetic Survey Geoid09NAVD88.
MSL values were determined using the most recent NGS-approved geoid model to generate geoid separation values for each Lat/Long coordinate pair.  In this fashion, Orthometric heights were determined for each Control, FVA and CVA point by subtracting the generated Geoid Separation value from the Ellipsoidal Height (HAE) for publication and use as MSL NAVD88(09).
  Process_Date: 2011
Process_Step:
  Process_Description: Using an Optech Gemini LiDAR system, 44 flight lines of highest density (Nominal Pulse Spacing of 1.0m) were collected over the Narragansett area which encompasses 217 square miles. A total of 6 missions were flown on December 8, 2010, and December 10, 2010.  one airborne global positioning system (GPS) base station was used to support the LiDAR data acquisition: Mansfield, LW5147.  Additional information can be found in the Post-Flight Aerial Acquisition Report.
  Process_Date: 2011
Process_Step:
  Process_Description: Applanix software was used in the post processing of the airborne GPS and inertial data that is critical to the positioning and orientation of the sensor during all flights.  POSPac MMS provides the smoothed best estimate of trajectory (SBET) that is necessary for Optech's post processor to develop the point cloud from the LiDAR missions.  The point cloud is the mathematical three dimensional collection of all returns from all laser pulses as determined from the aerial mission.
Optech's DASHMap software and Leica's ALS Post Processor software were used to create the Raw LIDAR Flight Line strips.  At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above ground features are removed from the data set. The GeoCue and TerraScan software packages are then used for the automated data classification. Project specific macros are created to classify the ground and to remove the side overlap between parallel flight lines.
LAS Class 2 (Ground) is used to check the surveyed control points against the Triangulated LIDAR surface.  Any bias is then removed using macro functionality within TerraScan.
Unclassified Point Cloud tiles are then created using TerraScan macro functionality.  These tiles are populated within GeoCue to ensure correct LAS versioning and LAS Header information.

LAS Class 2 is used to check the independent QC points against the Triangulated LiDAR surface.  If RMSE is not within guidelines TerraScan software is utilitzed to remove any bias, and the check is performed again.
Process_Date:  2011
Process_Step:
Process_Description:
Point Cloud data is manually reviewed and any remaining artifacts are removed using functionality provided within the TerraScan and TerraModeler software packages.
Additional project specific macros are created and run within GeoCue/TerraScan to ensure correct LAS classification prior to project delivery.
Final Classified LAS tiles are created within GeoCue to confirm correct LAS versioning and header information.
In-house software is then used to check LAS header information and final LAS classification prior to delivery.
LAS Class 2 is used to check the independent QC points against the Triangulated LiDAR surface.
Process_Date: 2011

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 19
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -69.000000
Latitude_of_Projection_Origin: 0.000000
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000010
Ordinate_Resolution: 0.000010
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum 1983
Ellipsoid_Name:  Geodetic Reference System 80
Semi-major_Axis: 6378137.00
Denominator_of_Flattening_Ratio: 298.257222
Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Datum_Name: North American Vertical Datum of 1988
Altitude_Resolution: 0.01
Altitude_Distance_Units:  meters
Altitude_Encoding_Method:  Attribute Values

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142850\SupplementalData\GroundControl Narragansett
Entity_Type_Definition: Ground Control Survey for LiDAR collection
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142850\SupplementalData\FVA_CVA Narragansett
Entity_Type_Definition: Survey for Horizontal and Vertical LiDAR QC
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142851\SupplementalData\Narragansett_Collection_Area
Entity_Type_Definition: Area Spatial File
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\214851\All_Returns
Entity_Type_Definition: LAS 1.2 files
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142851\SupplementalData\Narragansett_PreFlightReport
Entity_Type_Definition: Digital Document
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142851\SupplementalData\Narragansett_PostFlightReport
Entity_Type_Definition: Digitial Document
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142851\SupplementalData\Narr_Tile_Index
Entity_Type_Definition: Area Spatial File

Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142852\SupplementalData\Region 1 Charles Narragansett partial Blackstone Testing Results FVA CVA
Entity_Type_Definition: Digital Document
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142852\SupplementalData\R1_Narragansett_Terrain_TSDN
Entity_Type_Definition: Digital Document
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Detailed_Description:
Entity_Type:
Entity_Type_Label: Terrain\2142852\Bare_Earth
Entity_Type_Definition: LAS 1.2 files
Entity_Type_Definition_Source: FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: Data Capture Standards and Data Capture Guidelines (available at http://www.fema.gov/fhm/dl_cgs.shtm)
Overview_Description:
Entity_and_Attribute_Overview: The Terrain data package is made up of several data themes containing primarily spatial information. These data supplement the Elevation datasets by providing additional information to aid flood risk evaluation and flood hazard area delineations.
Entity_and_Attribute_Detail_Citation: Appendix M of FEMA Guidelines and Specifications for FEMA Flood Hazard Mapping Partners contains a detailed description of the data themes and references to other relevant information.

Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Federal Emergency Management Agency Engineering Library
Contact_Address:
Address_Type: mailing address
Address: Marie Sparrow, Zimmerman Associates, Inc.
Address: 847 South Pickett Street
City: Alexandria
State_or_Province: Virginia
Postal_Code: 22304
Country: USA
Contact_Voice_Telephone: 1-877-336-2627
Contact_Electronic_Mail_Address: miphelp@mapmodteam.com

Distribution_Liability:  No warranty expressed or implied is made by FEMA regarding the utility of the data on any other system nor shall the act of distribution constitute any such warranty.
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Format_Name: FEMA-DCS-Terrain
Digital_Transfer_Option:
Online_Option:
Computer_Contact_Information:
Network_Address:
Network_Resource_Name: http://hazards.fema.gov
Fees: Contact Distributor

Metadata_Reference_Information:
Metadata_Date: 20110330
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: FEMA Representative
Contact_Organization: Federal Emergency Management Agency
Contact_Address:
Address_Type: mailing address
Address: 500 C Street, S.W.
City: Washington
State_or_Province: District of Columbia
Postal_Code: 20472
Country: USA
Contact_Voice_Telephone: 1-877-336-2627
Contact_Electronic_Mail_Address: miphelp@mapmodteam.com
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Extensions:
Online_Linkage: http://hazards.fema.gov
Online_Linkage: http://www.epsg.org
Profile_Name: FEMA NFIP Metadata Content and Format Standard

# Appendix C: Pre Flight Planning Report

# Narragansett

# Pre-Flight Operations Plan

November 2010

## Planned GPS Stations

Photo Science has completed preliminary flight planning for Narragansett project area. Narragansett is scheduled to be acquired this fall when the leaves are off and delivered to FEMA in late spring of 2011. The Narragansett area is 217 square miles and initial planning details are depicted in Figure 1 on the following page. This Figure details that STARR expects to collect **42 flight lines covering 557 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 (217 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

Eleven (11) 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.

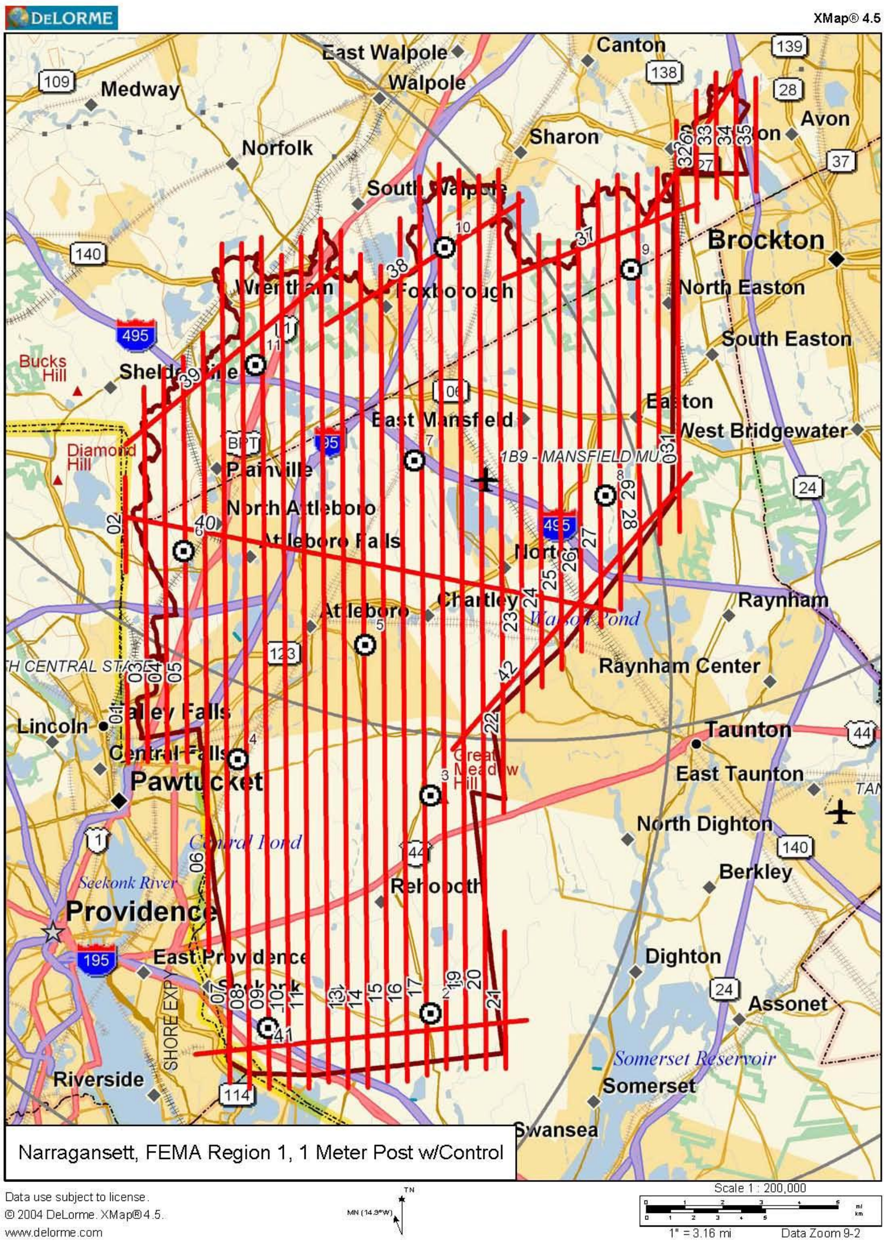



**Figure 1-Narragansett Flight Lines, Ground Control, and Airport Locations**

## Planned Airport Locations

Photo Science will be utilizing one airport for Narragansett for mobilization and demobilization. As indicated in Figure 1 the airport will be Mansfield Municipal, Mansfield, MA . 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 |

Acquisition (217 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)

## 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.

# Appendix D: Ground Control Survey and Vertical Testing Quality Control

CompassData

# FEMA Region 1 – MA, NH, CT
# Ground Control Project Report for Photo Science Inc.

## November 22, 2010

## Project Information

| | |
|---|---|
| **CDI Project Number:** | **FSG1508** |
| **Geographic Location:** | **New England; MA, NH, CT** |
| **Number of GCPs Requested:** | **86** |
| **Number of GCPs Collected:** | **86** |

## Project Specifications

| | |
|---|---|
| **Precision (Horizontal/Vertical):** | **CDI Precision-1 ≤ 8cm H/V** |
| **Coordinate System:** | **UTM** |
| **Datum:** | **NAD83** |
| **Zone:** | **18 & 19** |
| **Altitude Reference:** | **HAE (WGS84) and NAVD88 (09)** |
| **Units:** | **Meters** |

## RTK GPS

All Ground Control Points for this project were collected within the boundaries of the Keystone Precision Instruments New England Virtual Reference Station System, which provides continuous real-time broadcast correction signals within a network of 170 base stations encompassing New England and the northern Mid-Atlantic region.

All Control Points were observed for 180 epochs to determine a coordinate location ≤ 8cm in both Horizontal and Vertical to support subsequent LiDAR post-processing and bare earth deliverables generation.

All data collected were well within the confines of the Keystone VRS system with multiple base locations providing position and correction data for each point collected.

## Summary

The purpose of this project was to locate and survey photo-identifiable ground control points (GCPs) in multiple areas of interest as defined by FEMA-supplied shape and kml files. The GCP coordinates are to be used to control the vertical aspect of all newly-flown LiDAR data during post-processing and subsequent deliverables creation. CompassData visited the project area, found suitable GCPs, and determined accurate coordinates for each GCP according to the customer's specifications.

## Equipment

CompassData used a Trimble R8 to perform the Control survey. This device is accurate to within 1 cm on a position-by-position basis per Trimble specifications. Operating within the VRS network provided accurate coordinate values at or around 5 cm H/V within 3-5 minutes observation times. CompassData has consistently demonstrated this level of accuracy on many GCP collection jobs across North and South America and Africa. Specifications for the Trimble R8 are available upon request.

## Survey Methodology

CompassData has met the required precision for this project by using a high-quality GPS receiver with differential corrections provided by a VRS network surrounding the project area. The GPS antenna sat atop a bubble-leveled, fixed-height range pole that was placed over the center of the desired GCP. At least 180 positions (captured at a rate of one per second) were geometrically averaged to calculate a single coordinate for each GCP. All required field documentation was filled out and the points were identified on web-based imagery and diagrammed on the CompassData-supplied sketch sheets. Digital pictures of each GCP location were collected in the field.

## Quality Control Procedures

CompassData collects GCPs with an unobstructed view of the sky to ensure proper GPS operation. CompassData works to avoid potential sources of multipath error such as trees, buildings, and fences that may adversely affect the GPS accuracy.

Additional quality control comes from the fact that at least 180 GPS positions are collected for each GCP.  While operating within a VRS, valid solutions are reached within seconds; however, we continue to collect additional data to ensure meeting collection specifications.  To ensure project integrity, a GCP will be reobserved or moved to a more suitable location if it does not meet project specifications.

In addition to the aforementioned procedures, CompassData "surveys" existing geodetic control monuments to see if our coordinates match the published coordinates to the required accuracy.  These monuments are usually established by the National Geodetic Survey (NGS) in the United States.  If it is found that our coordinates are outside the acceptable accuracy, the reason for the difference will be found or the GCPs will be reobserved under different GPS constellation constraints.   There are certain geodetic considerations that must be taken into account that affect whether a GPS-derived coordinate will line up with a survey monument, especially when these monuments reference local coordinate systems or the systems of another country.  Sometimes the published coordinates for a monument are not accurate, although this is very infrequent.

CompassData visited multiple survey monuments during the course of this project. The results of those monument measurements are summarized in the Accuracy Report.

## Deliverables

Deliverables for this project include:

- Coordinates (in spreadsheet format)
- Image Chips
- Sketch Sheets
- Digital Pictures
- QA/QC Data

## Project Notes

All collected points were retrieved from the Trimble Survey Controller in Decimal Degrees, NAD83, HAE Meters.

CorpsCon was used to generate files in the following format:

Degrees Minutes Decimal Seconds, NAD83 HAE (QC purposes)
UTM Meters, NAD83 HAE

Geoid09 was then used to generate the geoid separation at every Lat/Long location. NAVD88(09) orthometric heights were then generated in spreadsheet form using the formula HAE - Geoid = Orthometric Height. Those values were then included into the final delivery coordinate CSV files and have been tested against NGS monuments collected during the course of this survey and are showing millimeter-level agreement.

The Horizontal and Vertical accuracies reported in the Final Coordinates file were obtained from the Survey Report generated by Trimble Survey Controller. The report contains all points collected during each daily survey deployment, including CVAs, FVAs and Ground Control. Copies of these reports can be provided upon request once the CVA and FVA data has been redacted.

## Contact Information

Hayden Howard Phone: (303) 627-4058 E-mail: haydenh@compassdatainc.com

| NARRAGANSETT, MASSACHUSETTS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| **GCP** | **Date** | **Vert_Prec** | **Horz_Prec** | **Latitude** | **Longitude** | **Easting** | **Northing** | **HAE** | **GEOID09_Seperation** | **NAVD88** |
| NAR101 | 10/17/2010 | 0.0073 | 0.0043 | 41.77963 | -71.2967937 | 309124.282 | 4627858.758 | -25.293574 | -29.473 | 4.17943 |
| NAR102 | 10/17/2010 | 0.0061 | 0.0043 | 41.79535 | -71.2249845 | 315137.563 | 4629447.784 | 1.11983745 | -29.33 | 30.4498 |
| NAR103 | 10/17/2010 | 0.0061 | 0.0043 | 41.8669 | -71.210567 | 316540.020 | 4637360.832 | 8.30246389 | -29.126 | 37.4285 |
| NAR104 | 10/17/2010 | 0.0085 | 0.004 | 41.89691 | -71.321241 | 307444.558 | 4640935.406 | -0.2008636 | -29.172 | 28.9711 |
| NAR105 | 10/17/2010 | 0.011 | 0.0073 | 41.93744 | -71.2633722 | 312364.097 | 4645307.560 | 12.2115317 | -28.994 | 41.2055 |
| NAR106 | 10/17/2010 | 0.0088 | 0.0058 | 41.97752 | -71.3430288 | 305881.822 | 4649935.227 | 52.7231908 | -29.011 | 81.7342 |
| NAR107 | 10/17/2010 | 0.01 | 0.0073 | 42.01474 | -71.2295975 | 315387.709 | 4653817.278 | 17.6674627 | -28.783 | 46.4505 |
| NAR108 | 10/17/2010 | 0.0094 | 0.0055 | 41.99573 | -71.1541396 | 321582.876 | 4651547.084 | 1.0921006 | -28.745 | 29.8371 |
| NAR109 | 10/17/2010 | 0.011 | 0.0067 | 42.07491 | -71.1128172 | 325222.773 | 4660253.857 | 24.5916182 | -28.508 | 53.0996 |
| NAR110 | 10/17/2010 | 0.011 | 0.0067 | 42.09515 | -71.2201254 | 316403.925 | 4662726.093 | 49.4429266 | -28.595 | 78.0379 |
| NAR111 | 10/17/2010 | 0.0076 | 0.0049 | 42.03424 | -71.3124292 | 308587.341 | 4656165.114 | 42.2276865 | -28.858 | 71.0857 |
| | | | | | | | | | | |
| **Survey Control** | | | | | | | | | | |
| NGS_AJ4042 | 10/17/2010 | 0.01 | 0.0067 | 42.10734 | -71.0588689 | 329772.470 | 4663745.593 | 46.4823982 | -28.349 | 74.8314 |
| NGS_AJ4047 | 10/17/2010 | 0.0079 | 0.0052 | 42.03918 | -71.3054652 | 309178.594 | 4656697.394 | 32.5307598 | -28.838 | 61.3688 |
| | | | | | | | | | | |
| **Metadata** | | | | | | | | | | |
| *UTM 19 North, NAD83, NAVD88* | | | | | | | | | | |
| *All units in meters where applicable.* | | | | | | | | | | |
| *HAE - GEOID09 = NAVD88* | | | | | | | | | | |

NAR101_C


NAR 101
6
© 2010 Google
Imagery Date: May 1, 2010
19 T 308997.97 m E 4627824.77 m N elev 4 m
Google

NAR102_C

NAR103_C


NAR 103
© 2010 Google
©2010 Google
Imagery Date: May 1, 2010
19 T 316405.34 m E 4637393.33 m N elev 38 m
Eye alt 1.04 km

NAR104_C

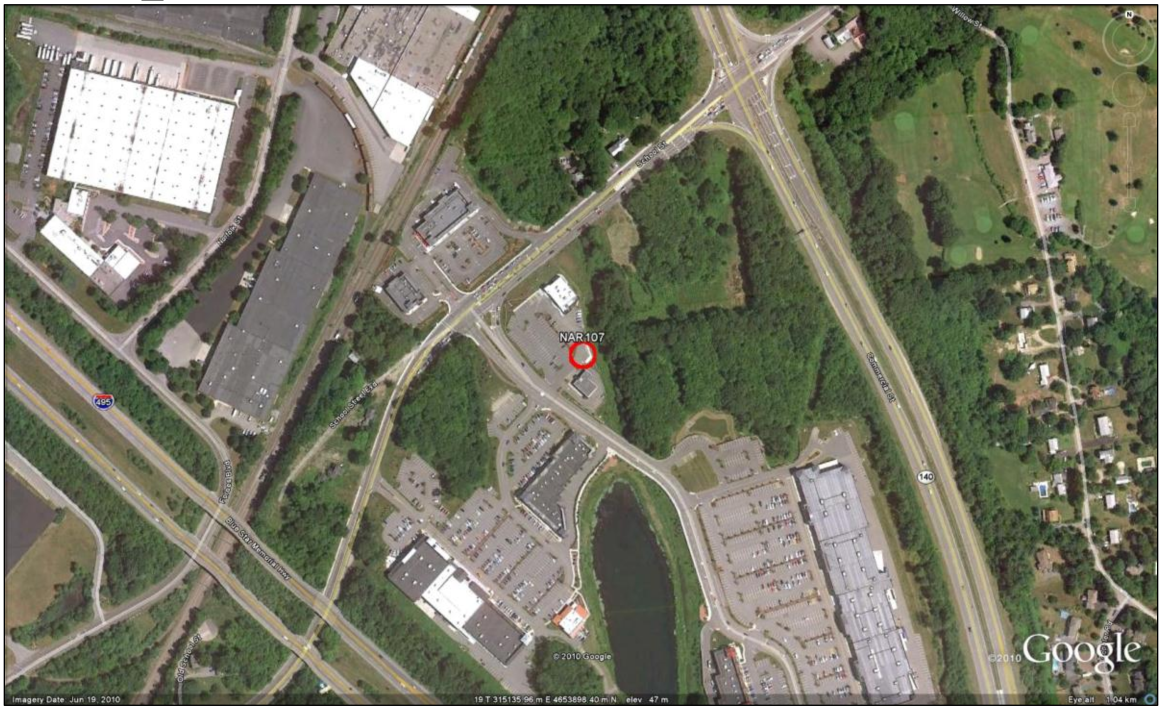

NAR 104
152
© 2010 Google
©2010 Google
Imagery Date: May 1, 2010
19 T 307506.91 m E 4640977.91 m N elev 29 m
Eye alt 880 m

NAR105_C


NAR105
118
© 2010 Google
©2010 Google
Imagery Date: May 1, 2010
19 T 311955.76 m E 4645494.92 m N elev 41 m
Eye alt 1.04 km

NAR106_C

NAR107_C


NAR107
495
140
© 2010 Google
©2010 Google
Imagery Date: Jun 19, 2010
19 T 315135.96 m E 4653898.40 m N elev 47 m
Eye alt 1.04 km

NAR108_C


NAR108
123
© 2010 Google
©2010 Google
Imagery Date: Jun 19, 2010
19 T 321530.12 m E 4651508.94 m N elev 28 m
Eye alt 1.03 km

NAR109_C

NAR110_C


NAR 110
©2010 Google
Imagery Date: Jun 19, 2010
© 2010 Google
Google

NAR111_C

**CompassData**

*GCP Station Diagram for LiDAR*

| | |
|---|---|
| **Project Name:** Narragansett | **GCP Number:** NAR101 |
| **CDI Project Number: 1508** | **Date:** 10/17/2010 |


**GPS Antenna Height: 2m**

**Comments:**

Point taken in parking lot east of the miniature golf course.
Bristol County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

CompassData

*GCP Station Diagram for LiDAR*

| | |
|---|---|
| **Project Name:** Narragansett | **GCP Number:** NAR102 |
| **CDI Project Number: 1508** | **Date:** 10/17/2010 |


LiDAR

LiDAR

**GPS Antenna Height: 2m**

**Comments:**

Point taken in dirt field located S, SW and W of several baseball fields and NE of Martin St.
Bristol County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

CompassData

*GCP Station Diagram for LiDAR*

LiDAR

| Project Name: Narragansett | GCP Number: NAR103 |
|---|---|
| CDI Project Number: 1508 | Date: 10/17/2010 |


**GPS Antenna Height: 2m**

**Comments:**

Point taken in parking lot between two buildings
Bristol County, Massachusetts

| Disk (Roll) / Frame Number: | Sketch 1 of 1 |
|---|---|
| Collected By: Bryan Frazier | Checked By: |

LiDAR

CompassData

*GCP Station Diagram for LiDAR*

LiDAR

| | |
|---|---|
| **Project Name:** Narragansett | **GCP Number:** NAR104 |
| **CDI Project Number: 1508** | **Date:** 10/17/2010 |


**GPS Antenna Height: 2m**

**Comments:**

Point taken in SE part of the parking lot. SW of the basketball courts.
Bristol County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

LiDAR

# CompassData

*GCP Station Diagram for LiDAR*

| | |
|---|---|
| **Project Name:** Narragansett | **GCP Number:** NAR105 |
| **CDI Project Number: 1508** | **Date:** 10/17/2010 |


**GPS Antenna Height: 2m**

**Comments:**

Point taken on outer edge of baseball diamond where dirt meets the grass in Finberg Field.
Bristol County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

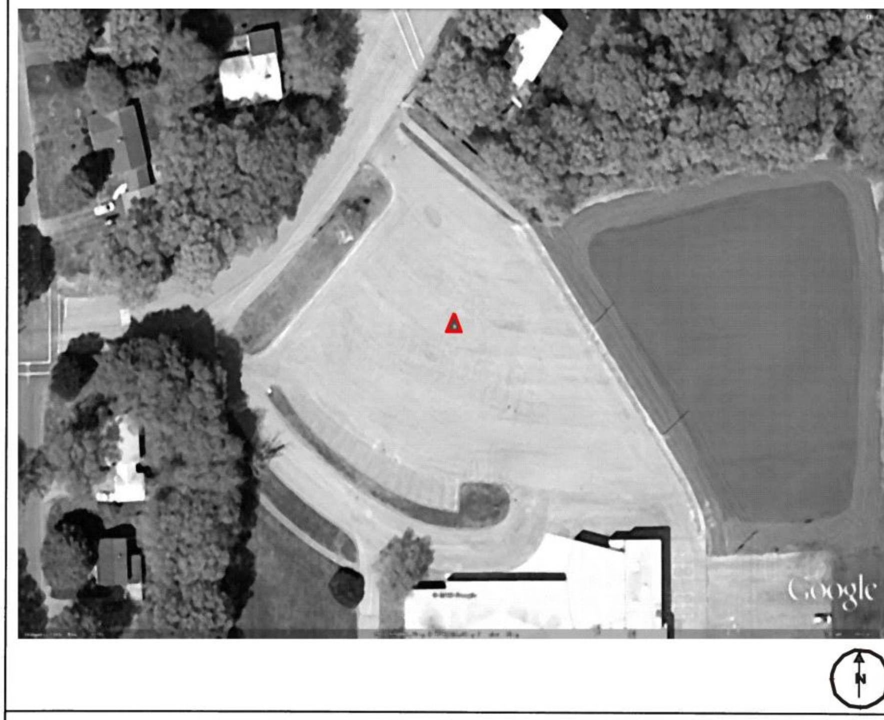
LiDAR

LiDAR

CompassData

*GCP Station Diagram for LiDAR*

| Project Name: Narragansett | GCP Number: NAR106 |
|---|---|
| CDI Project Number: 1508 | Date: 10/17/2010 |




**GPS Antenna Height: 2m**

**Comments:**

Point taken in the parking lot of the YMCA.
Bristol County, Massachusetts

| Disk (Roll) / Frame Number: | Sketch 1 of 1 |
|---|---|
| Collected By: Bryan Frazier | Checked By: |

LiDAR

LiDAR

# CompassData

## *GCP Station Diagram for LiDAR*

LiDAR

| | |
|---|---|
| **Project Name:** Narragansett | **GCP Number:** NAR107 |
| **CDI Project Number: 1508** | **Date:** 10/17/2010 |


N

| |
|---|
| **GPS Antenna Height: 2m** |
| **Comments:**<br>Point taken in the parking lot of the YMCA.<br>Bristol County, Massachusetts |

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

LiDAR

CompassData

*GCP Station Diagram for LiDAR*

| | |
|---|---|
| **Project Name:** Narragansett | **GCP Number:** NAR108 |
| **CDI Project Number: 1508** | **Date:** 10/17/2010 |


LiDAR LiDAR

**GPS Antenna Height: 2m**

**Comments:**

Point taken in the parking lot west of buildings.
Bristol County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

# CompassData

*GCP Station Diagram for LiDAR*

| Project Name: Narragansett | GCP Number: NAR109 |
|---|---|
| CDI Project Number: 1508 | Date: 10/17/2010 |


N

**GPS Antenna Height: 2m**

**Comments:**

Point taken in the SE part of the cemetary located on Canton St.
Bristol County, Massachusetts

| Disk (Roll) / Frame Number: | Sketch 1 of 1 |
|---|---|
| Collected By: Bryan Frazier | Checked By: |

LiDAR

LiDAR

**CompassData**

*GCP Station Diagram for LiDAR*

LiDAR

| | |
|---|---|
| **Project Name:** Narragansett | **GCP Number:** NAR110 |
| **CDI Project Number: 1508** | **Date:** 10/17/2010 |


N

**GPS Antenna Height: 2m**

**Comments:**

Point taken in the Northern part of the parking lot located on S. Main St.
Bristol County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

LiDAR

CompassData

*GCP Station Diagram for LiDAR*

LiDAR

| | |
|---|---|
| **Project Name:** Narragansett | **GCP Number:** NAR111 |
| **CDI Project Number: 1508** | **Date:** 10/17/2010 |


**GPS Antenna Height: 2m**

**Comments:**

Point taken in the Western part of the parking lot located on
Old Taunton St.
Bristol County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

LiDAR

NAR101_E

NAR101_N

NAR101_S

NAR101_W

NAR102_E

NAR102_N

NAR102_S

NAR102_W

NAR103_E

NAR103_N

NAR103_SW

NAR103_W

NAR104_E

NAR104_N

NAR104_S

NAR104_W

NAR105_E

NAR105_N

NAR105_S

NAR105_W

NAR106_E

NAR106_N

NAR106_S

NAR106_W

NAR107_E

NAR107_N

NAR107_S

NAR107_W

NAR108_E

NAR108_N

NAR108_S

NAR108_W

NAR109_E

NAR109_N

NAR109_S

NAR109_W

NAR110_E

NAR110_N

NAR110_S

NAR110_W

NAR111_NE

NAR111_NW

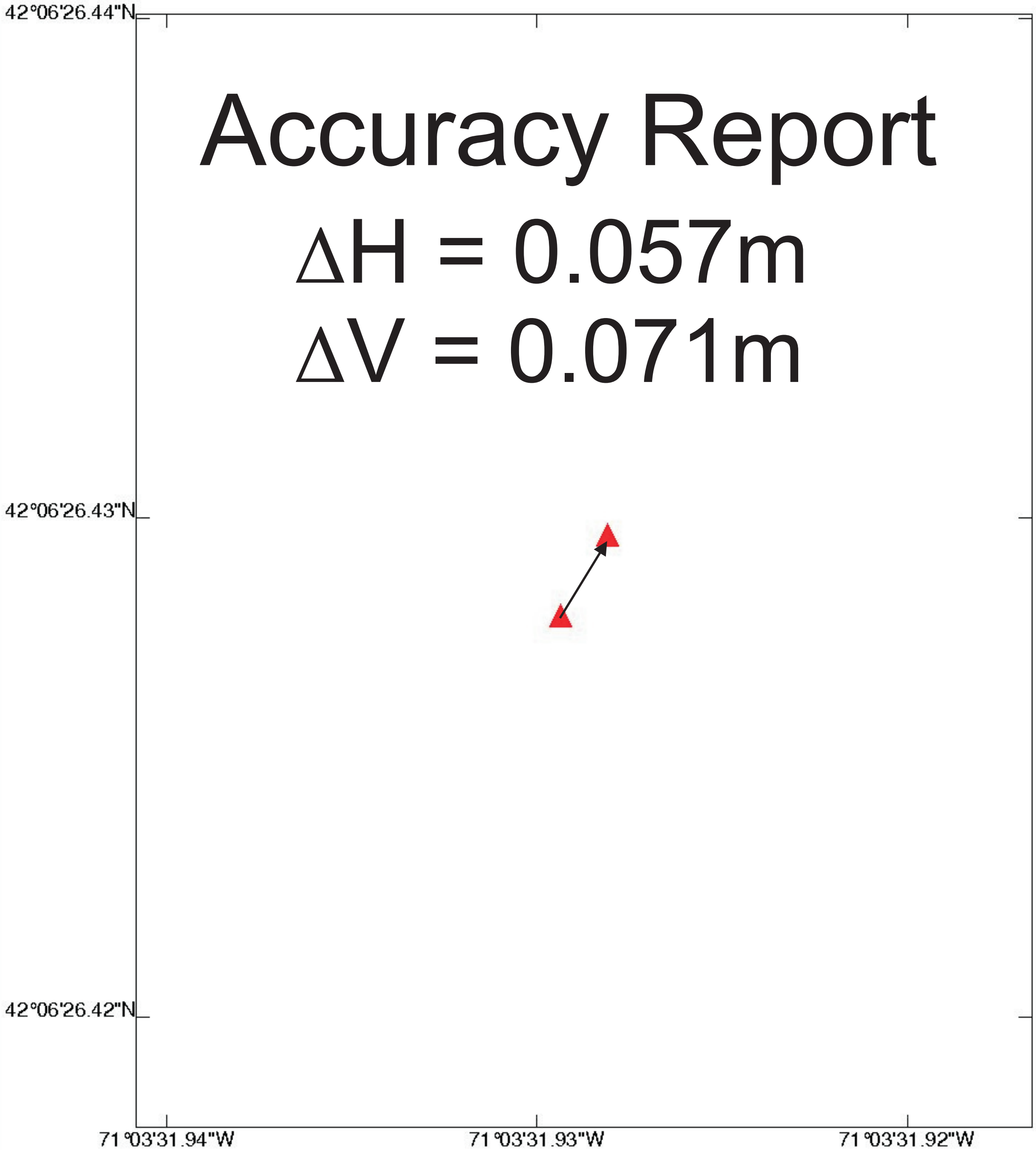
NAR111_SE

NAR111_SW

CompassData

# Accuracy Report

## ΔH = 0.057m
## ΔV = 0.071m




NGS_AJ4042 10_17_2010

Lat/Long
WGS 1984

N

Scale 1:4.00
0 0.150
Meters

10/28/2010

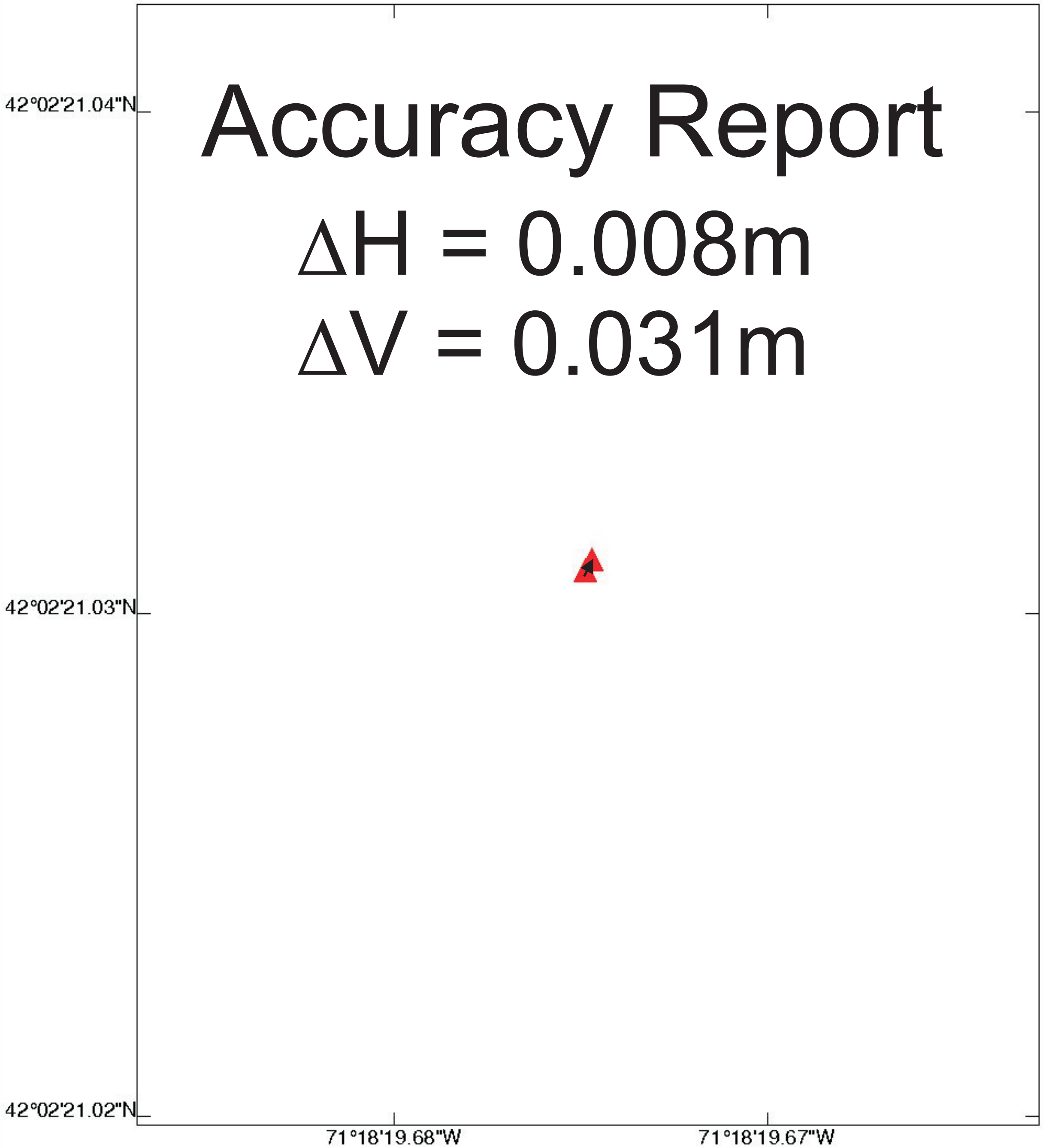
GPS Pathfinder® Office
Trimble

CompassData

# Accuracy Report

$\Delta H = 0.008m$

$\Delta V = 0.031m$




NGS_AJ4047 10_17_2010

Lat/Long
WGS 1984

N

Scale 1:4.00

0 0.150

Meters

10/28/2010

GPS Pathfinder® Office

Trimble

CompassData

# FEMA Region 1 – MA, NH, CT
# FVA and CVA Project Report for FEMA
# Inc. Narragansett, Charles, Concord, lac stone, Nashua & Quinnipiac

## Project Information

**CDI Project Number:** FSG1508
**Geographic Location:** New England; MA, NH, CT
**Number of FVA/CVAs Requested:** 210
**Number of GCPs Collected:** 210

## Project Specifications

**Precision (Horizontal/Vertical):** CDI Precision-1 ≤ 8cm H/V
**Coordinate System:** UTM
**Datum:** NAD83
**Zone:** 18 & 19
**Altitude Reference:** HAE (WGS84) and NAVD88 (09)
**Units:** Meters

## RTK GPS

All FVA and CVA Quality Assurance Points for this project were collected within the boundaries of the Keystone Precision Instruments New England Virtual Reference Station System, which provides continuous real-time broadcast correction signals within a network of 170 base stations encompassing New England and the northern Mid-Atlantic region.

All QA Points were observed for 180 epochs to determine a coordinate location ≤ 8cm in both Horizontal and Vertical to support subsequent LiDAR post-processing and bare earth deliverables generation.
All data collected were well within the confines of the Keystone VRS system with multiple base locations providing position and correction data for each point collected.

## Summary

The purpose of this project was to locate and survey photo-identifiable QA test points (FVA/CVAs) in multiple areas of interest as defined by FEMA-supplied shape and kml files. The QA coordinates are to be used to test the vertical aspect of all newly-flown LiDAR data during post-processing and subsequent deliverables creation. CompassData visited the project area, found suitable FVA and CVA locations, and determined accurate coordinates for each point according to the customer's specifications.

## Equipment

CompassData used a Trimble R8 to perform the Control survey. This device is accurate to within 1 cm on a position-by-position basis per Trimble specifications. Operating within the VRS network provided accurate coordinate values at or around 5 cm H/V within 3-5 minutes observation times. CompassData has consistently demonstrated this level of accuracy on many GCP collection jobs across North and South America and Africa. Specifications for the Trimble R8 are available upon request.

## Survey Methodology

CompassData has met the required precision for this project by using a high-quality GPS receiver with differential corrections provided by a VRS network surrounding the project area. The GPS antenna sat atop a bubble-leveled, fixed-height range pole that was placed over the center of the desired QA point. At least 180 positions (captured at a rate of one per second) were geometrically averaged to calculate a single coordinate for each FVA/CVA point. All required field documentation was filled out and the points were identified on web-based imagery and diagrammed on the CompassData-supplied sketch sheets (FVA points only). Digital pictures of each GCP location were collected in the field.

## Quality Control Procedures

CompassData collects QA points with an unobstructed view of the sky to ensure proper GPS operation. CompassData works to avoid potential sources of multipath error such as trees, buildings, and fences that may adversely affect the GPS accuracy.

Additional quality control comes from the fact that at least 180 GPS positions are collected for each point. While operating within a VRS, valid solutions are reached within seconds; however, we continue to collect additional data to ensure meeting collection specifications. To ensure project integrity, an FVA or CVA will be reobserved or moved to a more suitable location if it does not meet project specifications.

In addition to the aforementioned procedures, CompassData "surveys" existing geodetic control monuments to see if our coordinates match the published coordinates to the required accuracy. These monuments are usually established by the National Geodetic Survey (NGS) in the United States. If it is found that our coordinates are outside the acceptable accuracy, the reason for the difference will be found or the GCPs will be reobserved under different GPS constellation constraints. There are certain geodetic considerations that must be taken into account that affect whether a GPS-derived coordinate will line up with a survey monument, especially when these monuments reference local coordinate systems or the systems of another country. Sometimes the published coordinates for a monument are not accurate, although this is very infrequent.

CompassData visited multiple survey monuments during the course of this project. The results of those monument measurements are summarized in the Accuracy Report.

## Deliverables

Deliverables for this project include:

- Coordinates (in spreadsheet format)
- Image Chips
- Sketch Sheets (FVA points only)
- Digital Pictures
- QA/QC Data

## Project Notes

All collected points were retrieved from the Trimble Survey Controller in Decimal Degrees, NAD83, HAE Meters.

CorpsCon was used to generate files in the following format:

Degrees Minutes Decimal Seconds, NAD83 HAE (QC purposes)
UTM Meters, NAD83 HAE

Geoid09 was then used to generate the geoid separation at every Lat/Long location. NAVD88(09) orthometric heights were then generated in spreadsheet form using the formula HAE - Geoid = Orthometric Height. Those values were then included into the final delivery coordinate CSV files and have been tested against NGS monuments collected during the course of this survey and are showing millimeter-level agreement.

The Horizontal and Vertical accuracies reported in the Final Coordinates file were obtained from the Survey Report generated by Trimble Survey Controller. The report contains all points collected during each daily survey deployment, including CVAs, FVAs and NGS Monuments.

## Contact Information

Hayden Howard Phone: (303) 627-4058 E-mail: haydenh@compassdatainc.com

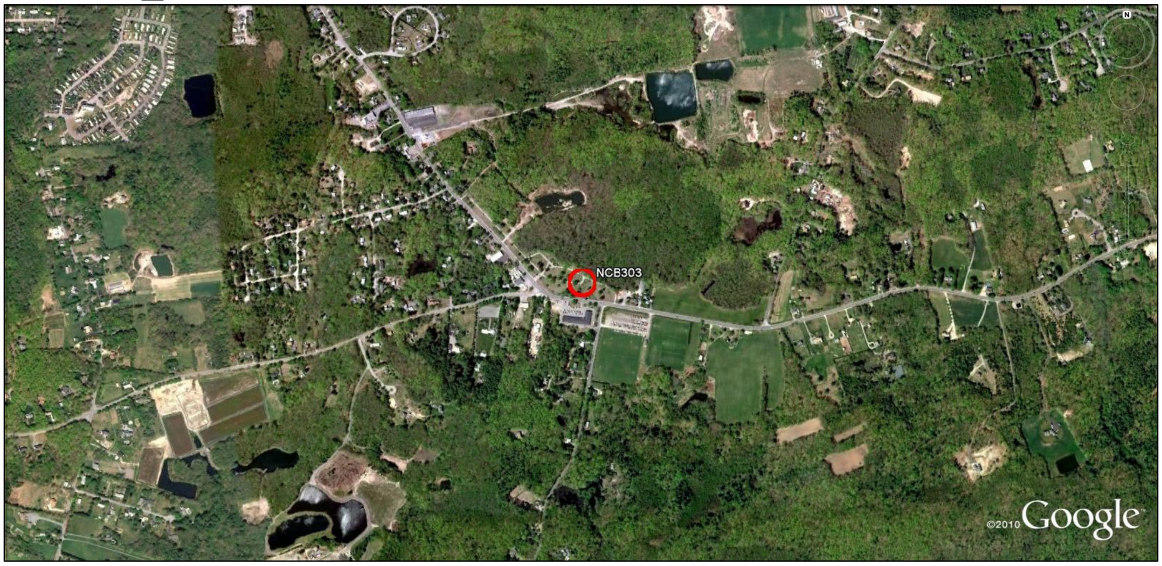
December 29, 2010

| NARRAGANSETT, MASSACHUSETTS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| **CVAs/FVAs** | **Date** | **Vert_Prec** | **Horz_Prec** | **Latitude** | **Longitude** | **Easting** | **Northing** | **HAE** | **GEOID09_** | **NAVD88** |
| NCB301 | 10/17/2010 | 0.0088 | 0.0043 | 41.78496824 | -71.31612809 | 307533.374 | 4628494.838 | -19.4557 | -29.485 | 10.02927 |
| NCB302 | 10/17/2010 | 0.0058 | 0.0043 | 41.84186471 | -71.22206853 | 315513.463 | 4634605.935 | 5.708915 | -29.206 | 34.91492 |
| NCB303 | 10/17/2010 | 0.0073 | 0.0049 | 41.90379683 | -71.24860791 | 313490.146 | 4641539.998 | 15.29916 | -29.065 | 44.36416 |
| NCB305 | 10/17/2010 | 0.0085 | 0.0067 | 41.96978824 | -71.18779139 | 318721.9 | 4648736.941 | 2.482906 | -28.838 | 31.32091 |
| NCB307 | 10/17/2010 | 0.0091 | 0.0064 | 42.03130204 | -71.24977641 | 313765.162 | 4655700.389 | 36.74493 | -28.774 | 65.51893 |
| NCB308 | 10/17/2010 | 0.0104 | 0.0061 | 42.08429426 | -71.12082521 | 324586.148 | 4661311.798 | 41.79883 | -28.495 | 70.29383 |
| NCB707 | 12/3/2010 | | | 41.96706444 | -71.3395303 | 306139.995 | 4648766.875 | 60.485 | -29.028 | 89.513 |
| NCB707_BK | 12/3/2010 | 0.0021 | 0.0015 | 41.96732591 | -71.33903318 | 306181.983 | 4648794.783 | 30.946 | -29.027 | 59.973 |
| NCB707_TP | 12/3/2010 | 0.0024 | 0.0015 | 41.96718943 | -71.33928807 | 306160.447 | 4648780.205 | 31.494 | -29.028 | 60.522 |
| NCB708 | 12/3/2010 | | | 41.97529852 | -71.16895553 | 320298.206 | 4649309.082 | 24.906 | -28.808 | 53.714 |
| NCB708_BK | 12/3/2010 | 0.0027 | 0.0021 | 41.97546413 | -71.16917801 | 320280.238 | 4649327.938 | -2.226 | -28.807 | 26.581 |
| NCB708_TP | 12/3/2010 | 0.0024 | 0.0021 | 41.97529201 | -71.16953396 | 320250.261 | 4649309.574 | -2.792 | -28.808 | 26.016 |
| NCB709 | 12/3/2010 | | | 41.88738619 | -71.30763521 | 308544.841 | 4639847.906 | 34.154 | -29.18 | 63.334 |
| NCB709_BK | 12/3/2010 | 0.0018 | 0.0012 | 41.88782107 | -71.30815676 | 308502.867 | 4639897.358 | 3.909 | -29.18 | 33.089 |
| NCB709_TP | 12/3/2010 | 0.0021 | 0.0015 | 41.88772468 | -71.30785261 | 308527.814 | 4639885.976 | 4.047 | -29.18 | 33.227 |
| NCB710 | 12/3/2010 | | | 41.79563246 | -71.22471219 | 315161.002 | 4629478.234 | 30.52 | -29.329 | 59.849 |
| NCB710_BK | 12/3/2010 | 0.0018 | 0.0015 | 41.79524572 | -71.22500797 | 315135.313 | 4629435.928 | 1.026 | -29.33 | 30.356 |
| NCB710_TP | 12/3/2010 | 0.0018 | 0.0012 | 41.79558868 | -71.22503459 | 315134.087 | 4629474.066 | 1.532 | -29.329 | 30.861 |
| NCB804 | 12/3/2010 | 0.0024 | 0.0021 | 42.02699888 | -71.25117182 | 4655225.613 | 313637.08 | 30.982 | -28.785 | 59.767 |
| NCB805 | 12/3/2010 | 0.0024 | 0.0015 | 41.94393227 | -71.28411217 | 4646074.36 | 310663.866 | 9.836 | -29.004 | 38.84 |
| | | | | | | | | | | |
| **Survey Control** | | | | | | | | | | |
| NGS_AJ4042 | 10/17/2010 | 0.01 | 0.0067 | 42.10734157 | -71.05886892 | 329772.470 | 4663745.593 | 46.4824 | -28.349 | 74.8314 |
| NGS_AJ4047 | 10/17/2010 | 0.0079 | 0.0052 | 42.0391753 | -71.3054652 | 309178.594 | 4656697.394 | 32.53076 | -28.838 | 61.36876 |
| | | | | | | | | | | |
| **Metadata** | | | | | | | | | | |
| *UTM 19 North, NAD83, NAVD88* | | | | | | | | | | |
| *All units in meters where applicable.* | | | | | | | | | | |
| *HAE - GEOID09 = NAVD88* | | | | | | | | | | |

NCB301_C

NCB302_C

NCB303_C



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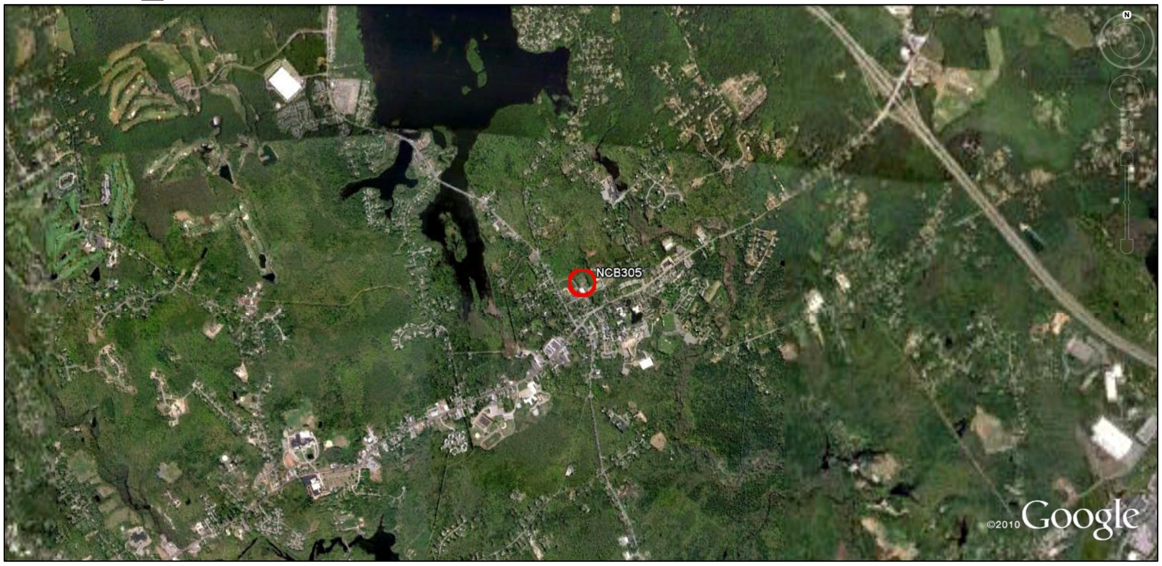

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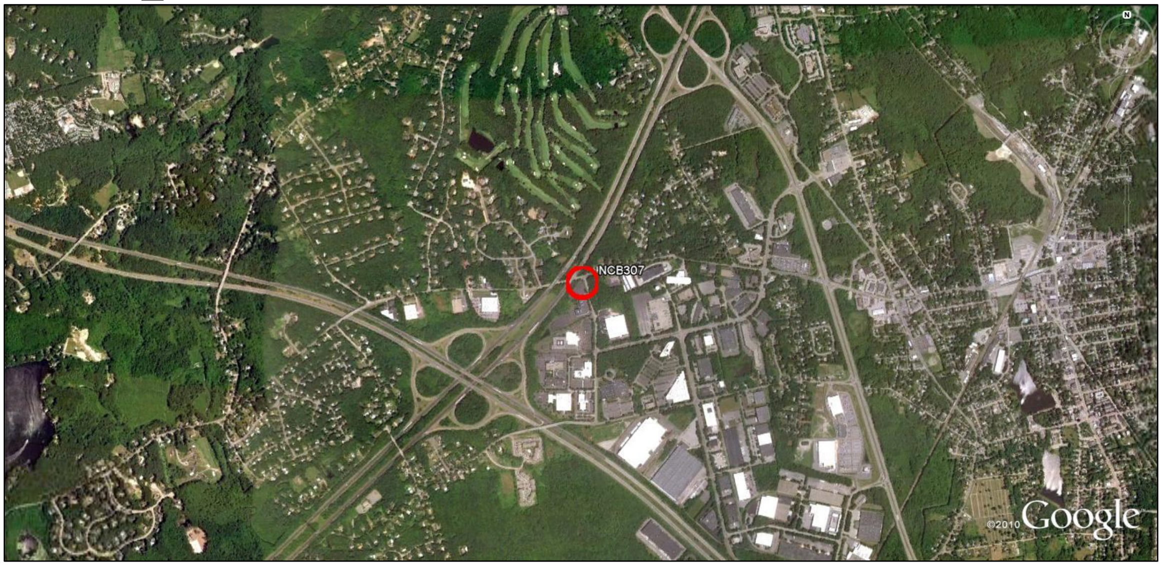
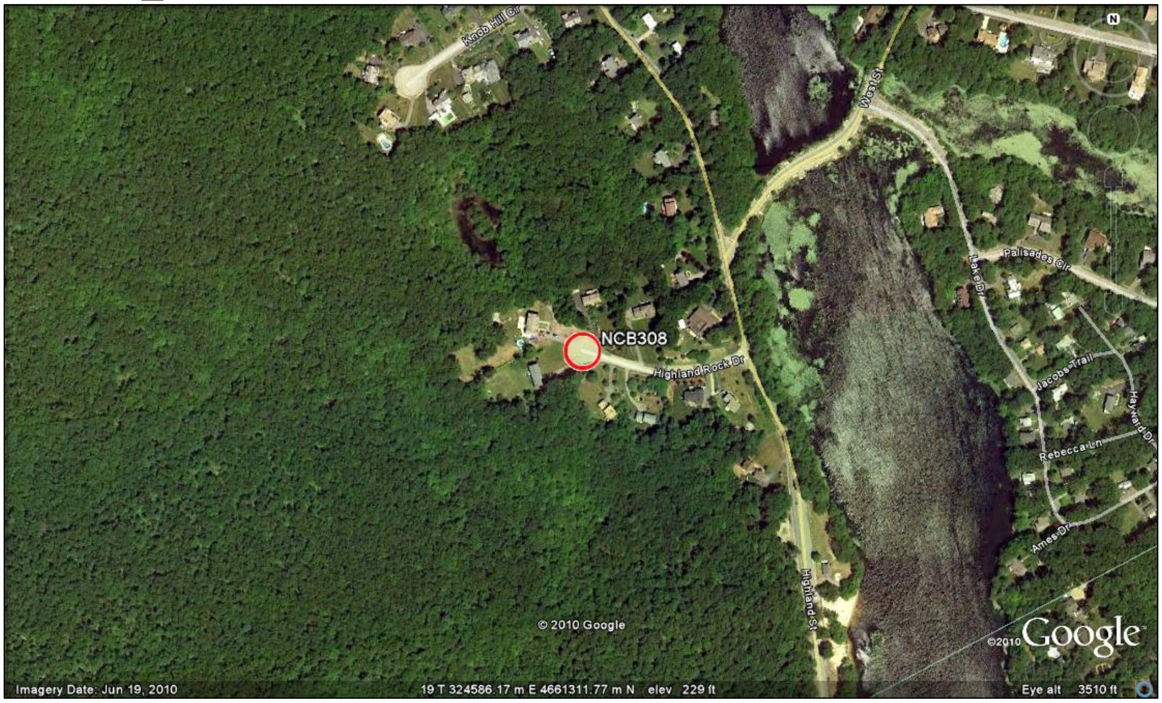
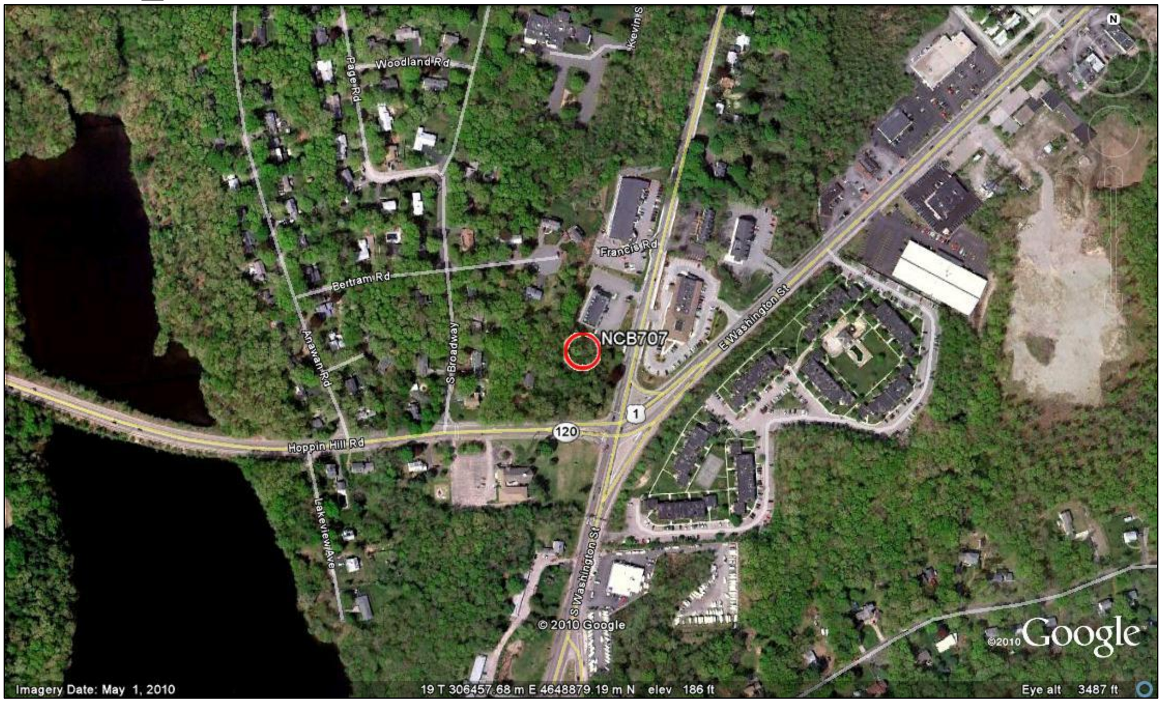


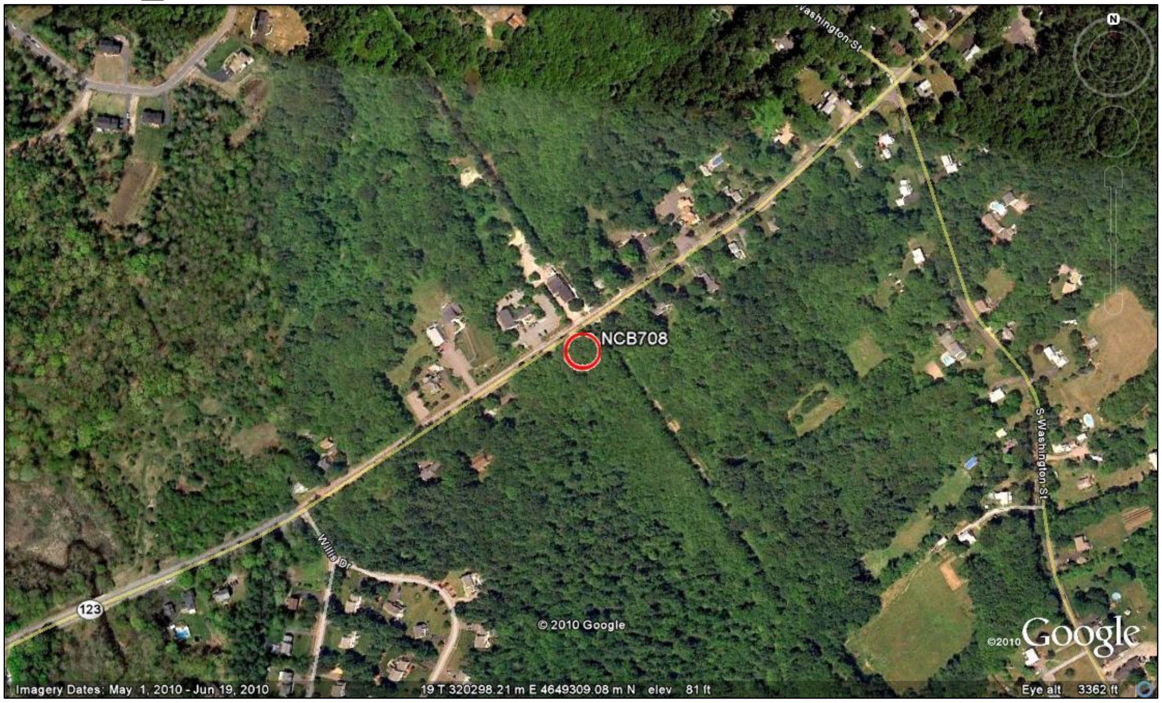
NCB308_C


NCB308
Highland Rock Dr
Knob Hill Cir
West St
Lake Dr
Palisades Cir
Jacobs Trail
Hayward Dr
Rebecca Ln
Ames Dr
Highland St
© 2010 Google
©2010 Google
Imagery Date: Jun 19, 2010
19 T 324586.17 m E 4661311.77 m N elev 229 ft
Eye alt 3510 ft

NCB707_C


Woodland Rd
Page Rd
Francis Rd
Bertram Rd
NCB707
E Washington St
Arawan Rd
S Broadway
1
120
Hoppin Hill Rd
Lakeview Ave
S Washington St
© 2010 Google
©2010 Google
Imagery Date: May 1, 2010
19 T 306457.68 m E 4648879.19 m N elev 186 ft
Eye alt 3487 ft

NCB708_C

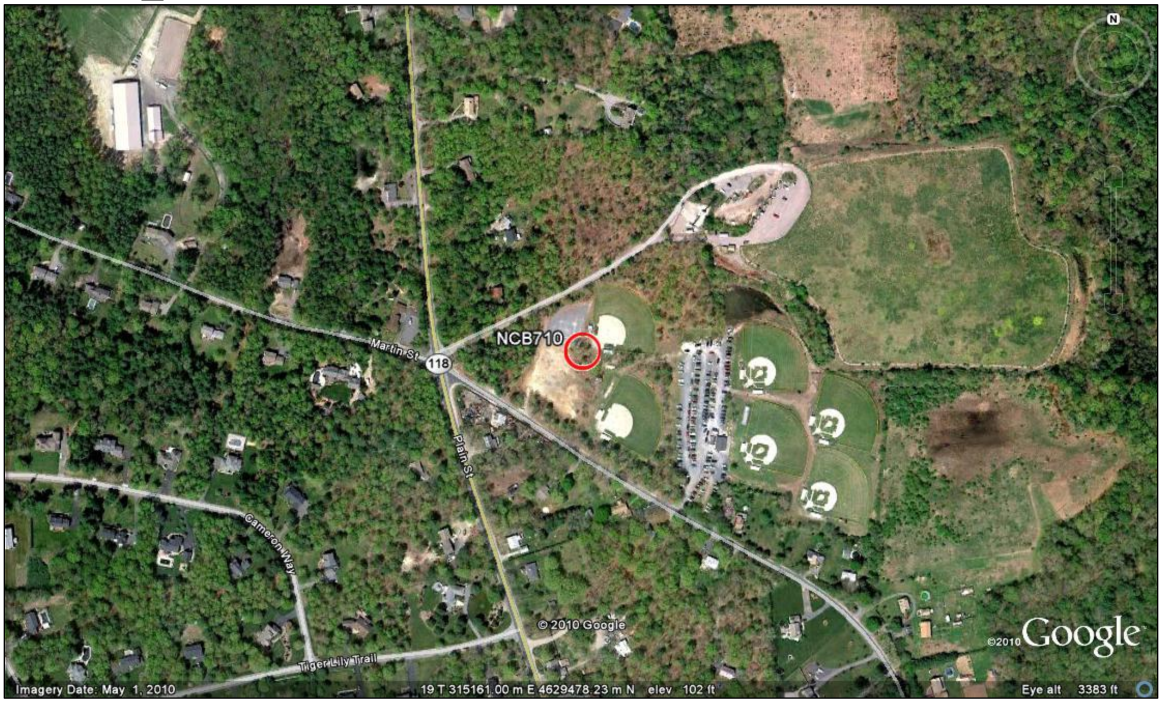


Washington St
NCB708
S Washington St
Willis Dr
123
© 2010 Google
©2010 Google
Imagery Dates: May 1, 2010 - Jun 19, 2010
19 T 320298.21 m E 4649309.08 m N elev 81 ft
Eye alt 3362 ft

NCB709_C


Woodland Ave
NCB709
Rock Ave
Cross St
2 Rod Way
Ramblin Brook Rd
© 2010 Google
©2010 Google
Imagery Date: May 1, 2010
19 T 308544.84 m E 4639847.91 m N elev 114 ft
Eye alt 3395 ft

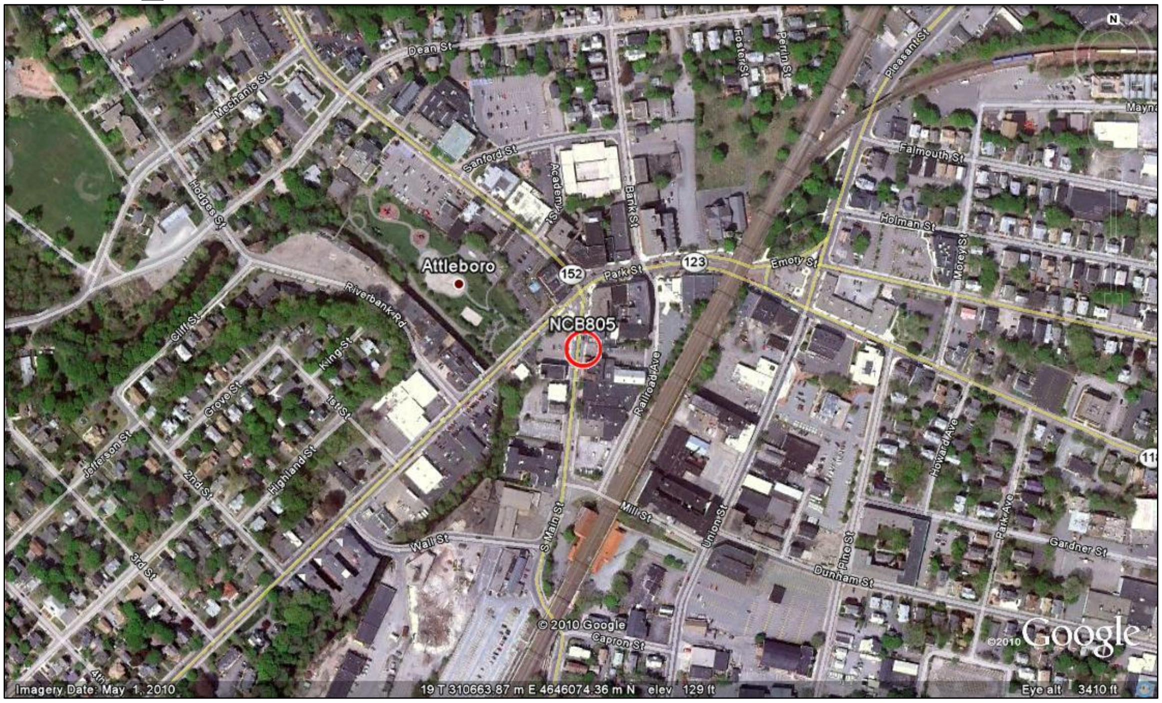
NCB710_C


NCB710
Martin St
118
Plain St
Cameron Way
Tiger Lily Trail
© 2010 Google
Imagery Date: May 1, 2010
19 T 315161.00 m E 4629478.23 m N elev 102 ft
Eye alt 3383 ft
©2010 Google

NCB804_C

NCB804
Cabot Blvd
Hampshire St
95
Blue Star Memorial Hwy
West St
© 2010 Google
Google
Imagery Date: Jun 19, 2010
19 T 313637.08 m E 4655225.61 m N elev 199 ft
Eye alt 3480 ft

NCB805_C

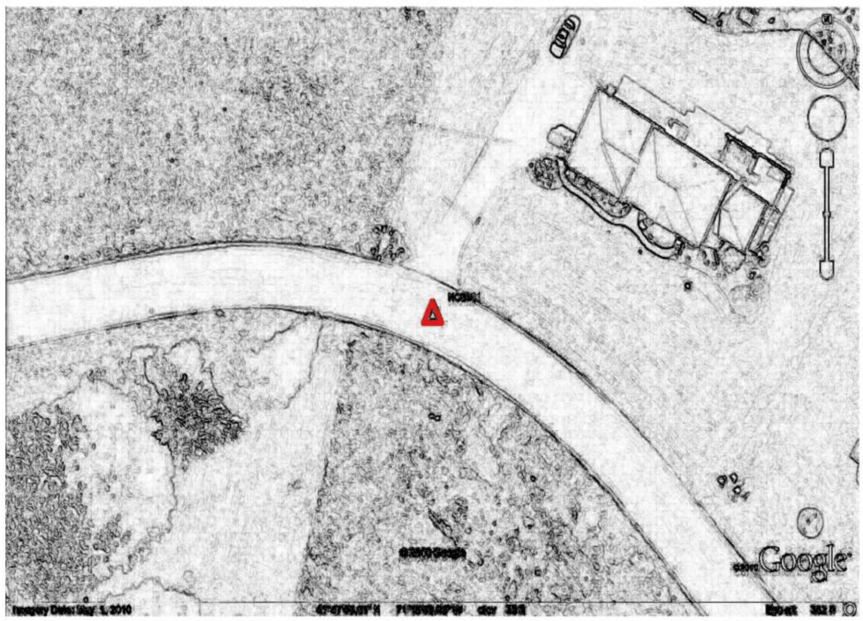


Dean St
Mechanic St
Sanford St
Academy St
Bank St
Foster St
Perrin St
Pleasant St
Falmouth St
Holman St
Morey St
Hodges St
Attleboro
152
Park St
123
Emory St
Riverbank Rd
NCB805
Cliff St
King St
Grove St
1st St
Jefferson St
2nd St
Highland St
Railroad Ave
Howard Ave
Union St
Mill St
S Main St
Wall St
3rd St
Pine St
Park Ave
Gardner St
Dunham St
Capron St
© 2010 Google
Imagery Date: May 1, 2010
19 T 310663.87 m E 4646074.36 m N elev 129 ft
Eye alt 3410 ft
Google

CompassData

*GCP Station Diagram for LiDAR*

| **Project Name:** Narragansettt | **GCP Number:** NCB301 |
|---|---|
| **CDI Project Number:** 1508 | **Date:** 10/17/2010 |




**GPS Antenna Height: 2m**

**Comments:**

Point collected in front of residence on Woo Dr approximately .06 miles east of Warren Ave.
Bristol County, Massachusetts

| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
|---|---|
| **Collected By:** Bryan Frazier | **Checked By:** |

LiDAR

LiDAR

# CompassData

*GCP Station Diagram for LiDAR*

| | |
|---|---|
| **Project Name:** Narragansettt | **GCP Number:** NCB302 |
| **CDI Project Number:** 1508 | **Date:** 10/17/2010 |


**GPS Antenna Height: 2m**

**Comments:**

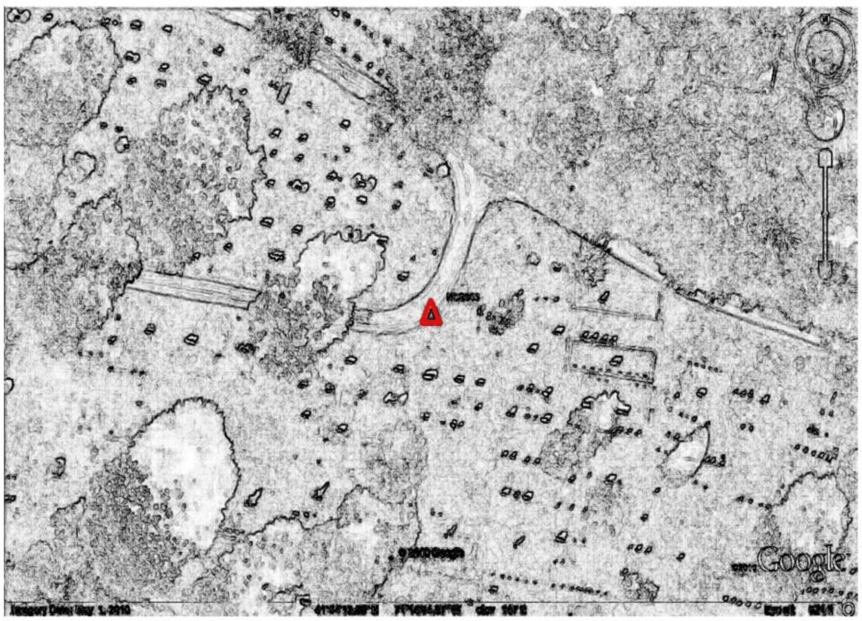
Point collected at intersection of Francis Farm Rd and Taylor Dr.
Bristol County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

CompassData

*GCP Station Diagram for LiDAR*

| | |
|---|---|
| **Project Name:** Narragansettt | **GCP Number:** NCB303 |
| **CDI Project Number:** 1508 | **Date:** 10/17/2010 |




**GPS Antenna Height: 2m**

**Comments:**

Point collected in Oak Knoll Cemetery at the northeast corner of Park St and Tremont St intersection
Bristol County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

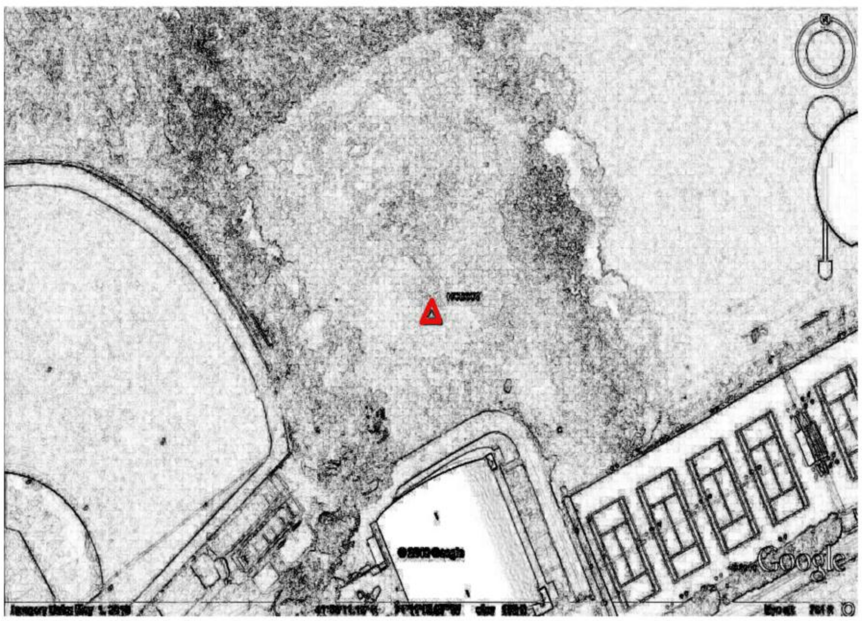
LiDAR

LiDAR

CompassData

*GCP Station Diagram for LiDAR*

| | |
|---|---|
| **Project Name:** Narragansettt | **GCP Number:** NCB305 |
| **CDI Project Number:** 1508 | **Date:** 10/17/2010 |




LiDAR

**GPS Antenna Height: 2m**

**Comments:**

Point collected in field north of building between ballfields just north of Clark Recreation Dr/College Green Rd.
Bristol County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

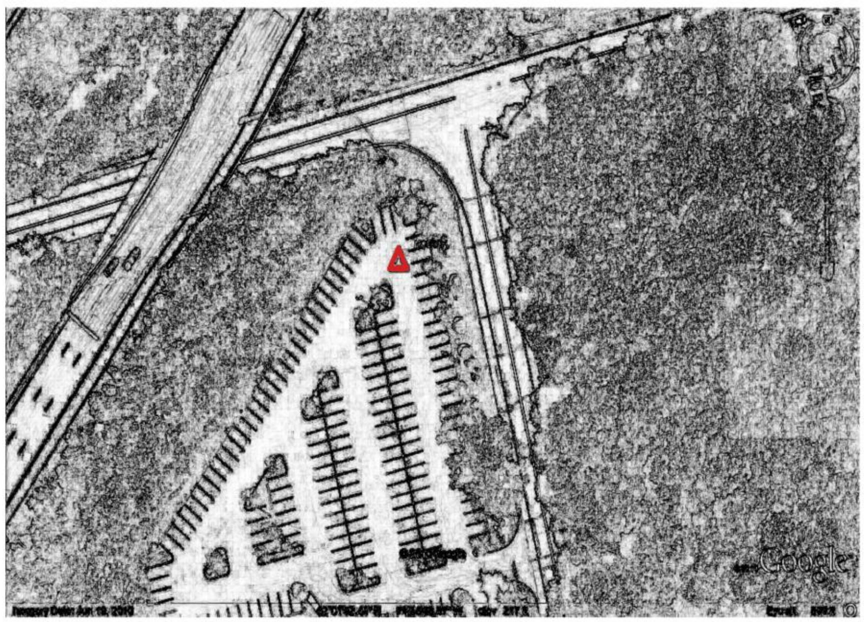
**CompassData**

*GCP Station Diagram for LiDAR*

LiDAR

LiDAR

| | |
|---|---|
| **Project Name:** Narragansettt | **GCP Number:** NCB307 |
| **CDI Project Number:** 1508 | **Date:** 10/17/2010 |




**GPS Antenna Height: 2m**

**Comments:**

Point collected in the northeast corner of Wells Fargo Financial parking lot
located at the southwest corner of Green St and Hampshire St
Norfolk County, Massachusetts

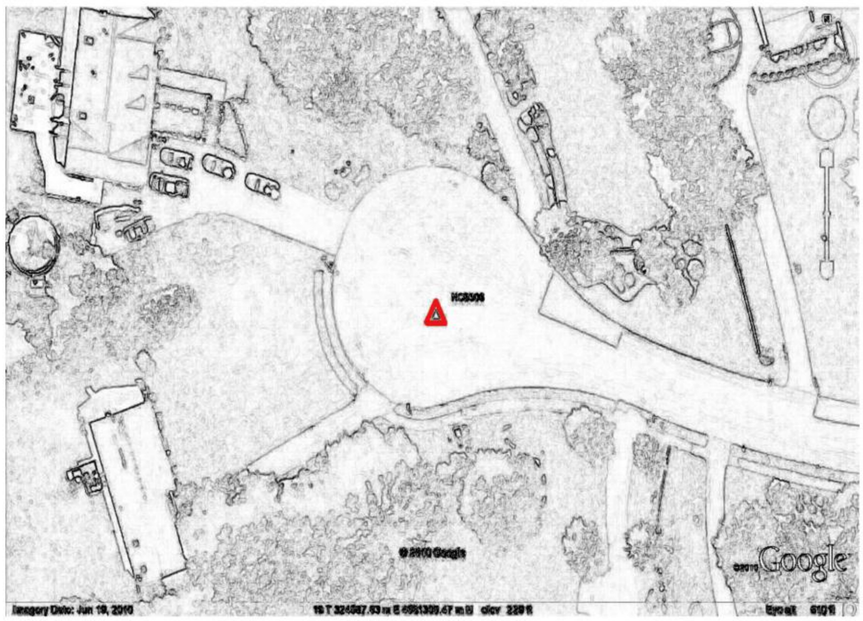
| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

CompassData

*GCP Station Diagram for LiDAR*

LiDAR

| | |
|---|---|
| **Project Name:** Narragansettt | **GCP Number:** NCB308 |
| **CDI Project Number:** 1508 | **Date:** 10/17/2010 |




**GPS Antenna Height: 2m**

**Comments:**

Point collected in cul-de-sac at the end of Highland Rock Dr.
Norfolk County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

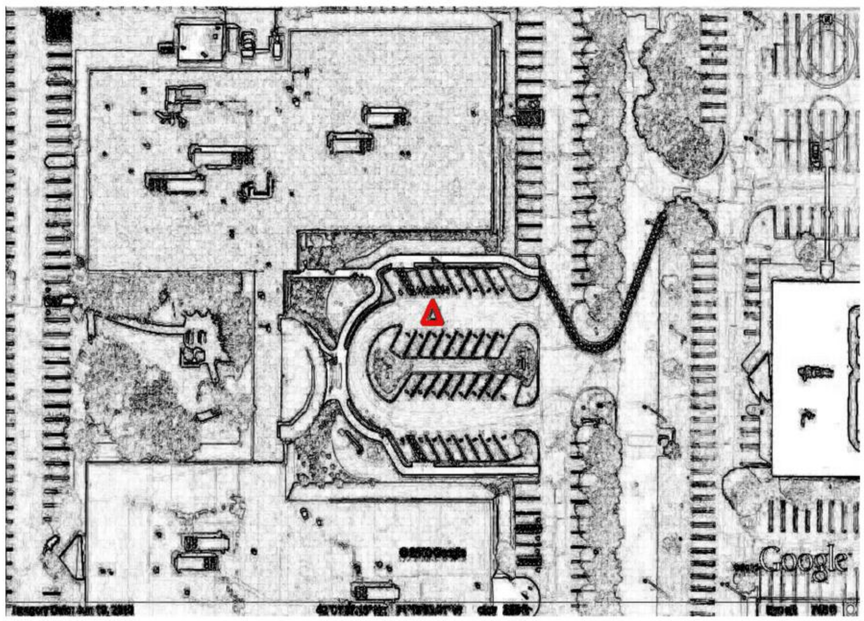
LiDAR

CompassData

*GCP Station Diagram for LiDAR*

LiDAR

| Project Name: Narragansettt | GCP Number: NCB804 |
| --- | --- |
| CDI Project Number: 1508 | Date: 12/03/2010 |




**GPS Antenna Height: 2m**

**Comments:**

Point collected in front of American Express building located at 9 Hampshire Street, Mansfield MA
Norfolk County, Massachusetts

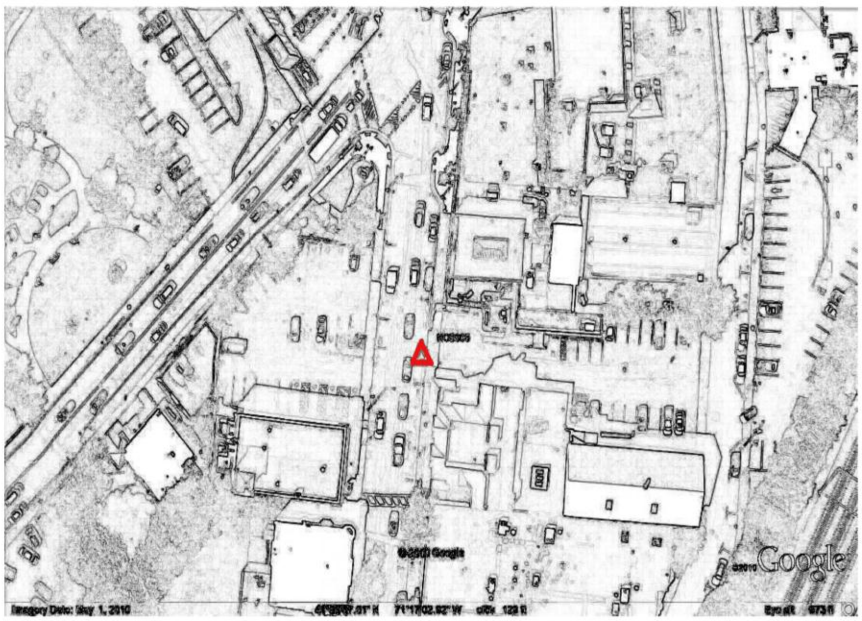
| Disk (Roll) / Frame Number: | Sketch 1 of 1 |
| --- | --- |
| Collected By: Bryan Frazier | Checked By: |

LiDAR

CompassData

*GCP Station Diagram for LiDAR*

| | |
|---|---|
| **Project Name:** Narragansettt | **GCP Number:** NCB805 |
| **CDI Project Number:** 1508 | **Date:** 12/03/2010 |




**GPS Antenna Height: 2m**

**Comments:**

Point collected in an urban setting on S Main St just south of the intersection of County St and S Main St
Bristol County, Massachusetts

| | |
|---|---|
| **Disk (Roll) / Frame Number:** | **Sketch** 1 **of** 1 |
| **Collected By:** Bryan Frazier | **Checked By:** |

NCB301_E

NCB301_N

NCB301_S

NCB301_W

NCB302_E

NCB302_N

NCB302_S

NCB302_W

NCB303_E

NCB303_N

NCB303_S

NCB303_W

NCB305_E

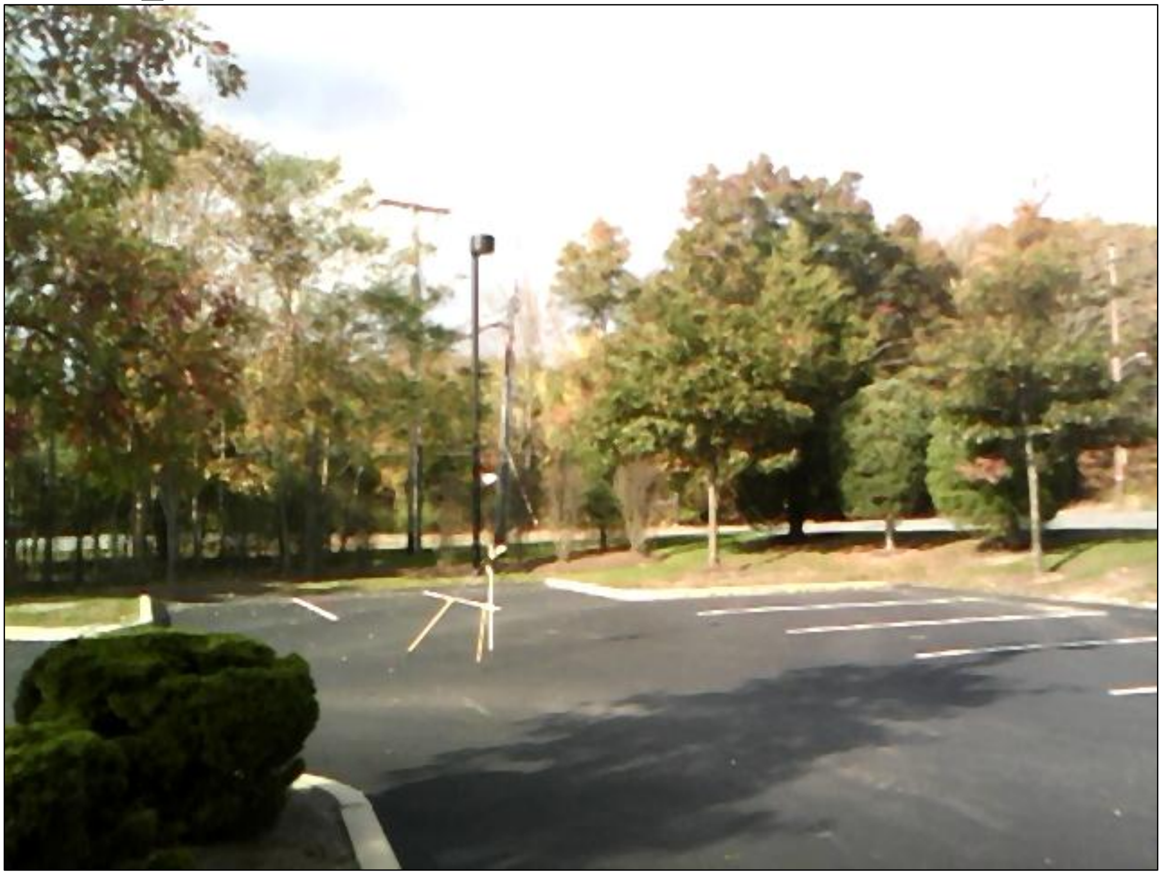
NCB305_N

NCB305_S

NCB305_W

NCB307_E

NCB307_N



NCB307_S

NCB307_W

NCB308_E

NCB308_N

NCB308_S

NCB308_W

NCB707

NCB708

NCB709

NCB710

NCB804_E

NCB804_N

NCB804_S

NCB804_W

NCB805_E

NCB805_N

NCB805_S

NCB805_W

| CHARLES/NARRAGANSETT/BLACKSTONE, MASSACHUSETTS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FVA-Points | Date | Vert_Prec | Horz_Prec | Latitude | Longitude | Northing (GPS) | Easting (GPS) | MSL (GPS) | MSL (LiDAR) | Δ Z | Δ $Z^2$ |
| NCB301 | 10/17/2010 | 0.01 | 0.00 | 41.78496824 | -71.31612809 | 4628494.838 | 307533.374 | 10.029 | 10.00 | **0.03** | 0.0009 |
| NCB302 | 10/17/2010 | 0.01 | 0.00 | 41.84186471 | -71.22206853 | 4634605.935 | 315513.463 | 34.915 | 34.84 | **0.07** | 0.0056 |
| NCB303 | 10/17/2010 | 0.01 | 0.00 | 41.90379683 | -71.24860791 | 4641539.998 | 313490.146 | 44.364 | 44.31 | **0.05** | 0.0029 |
| NCB304 | 10/17/2010 | 0.01 | 0.01 | 41.94280306 | -71.37045848 | 303502.475 | 4646143.418 | 36.592 | 36.58 | **0.01** | 0.0001 |
| NCB305 | 10/17/2010 | 0.01 | 0.01 | 41.96978824 | -71.18779139 | 4648736.941 | 318721.900 | 31.321 | 31.36 | **-0.04** | 0.0015 |
| NCB306 | 10/17/2010 | 0.01 | 0.00 | 42.02329697 | -71.37028870 | 303764.026 | 4655080.966 | 104.193 | 104.13 | **0.06** | 0.0039 |
| NCB307 | 10/17/2010 | 0.01 | 0.01 | 42.03130204 | -71.24977641 | 4655700.389 | 313765.162 | 65.519 | 65.44 | **0.08** | 0.0062 |
| NCB308 | 10/17/2010 | 0.01 | 0.01 | 42.08429426 | -71.12082521 | 4661311.798 | 324586.148 | 70.294 | 70.28 | **0.01** | 0.0002 |
| NCB309 | 10/15/2010 | 0.01 | 0.00 | 42.05207431 | -71.48272370 | 294547.718 | 4658540.495 | 92.074 | 92.13 | **-0.06** | 0.0031 |
| NCB310 | 10/17/2010 | 0.01 | 0.01 | 42.11784653 | -71.33078729 | 4665489.855 | 307320.864 | 75.617 | 75.54 | **0.08** | 0.0059 |
| NCB311 | 10/15/2010 | 0.01 | 0.01 | 42.13692204 | -71.10350297 | 4667120.100 | 326162.869 | 71.197 | 71.12 | **0.08** | 0.0059 |
| NCB312 | 10/15/2010 | 0.01 | 0.00 | 42.11868159 | -71.56626220 | 287856.380 | 4666140.866 | 152.275 | 152.33 | **-0.06** | 0.0031 |
| NCB313 | 10/17/2010 | 0.01 | 0.00 | 42.15137656 | -71.40417059 | 4669381.293 | 301359.001 | 62.492 | 62.54 | **-0.05** | 0.0023 |
| NCB314 | 10/16/2010 | 0.01 | 0.01 | 42.15445876 | -71.20470537 | 4669278.445 | 317849.221 | 40.964 | 40.91 | **0.05** | 0.0030 |
| NCB315 | 10/15/2010 | 0.02 | 0.02 | 42.18015524 | -71.5995968 | 4675576.809 | 298445.293 | 97.177 | 97.31 | **-0.13** | 0.0177 |
| NCB316 | 10/15/2010 | 0.02 | 0.02 | 42.121683 | -71.471289 | 4666242.506 | 295717.649 | 69.524 | 69.35 | **0.17** | 0.0303 |
| NCB317 | 10/17/2010 | 0.02 | 0.01 | 42.19412426 | -71.28963491 | 4673867.749 | 310950.283 | 69.647 | 69.53 | **0.12** | 0.0137 |
| NCB318 | 10/17/2010 | 0.01 | 0.01 | 42.26184851 | -71.31358273 | 4681441.377 | 309177.060 | 56.169 | 56.31 | **-0.14** | 0.0198 |
| NCB319 | 10/17/2010 | 0.01 | 0.01 | 42.3403519 | -71.30523056 | 4690139.969 | 310102.157 | 62.979 | 63.09 | **-0.11** | 0.0123 |
| NCB320 | 10/16/2010 | 0.01 | 0.01 | 42.42419552 | -71.3136755 | 4699469.255 | 309660.020 | 66.862 | 66.93 | **-0.07** | 0.0047 |
| | | | | | | | | | | | |
| **Metadata** | | | | | | **Z Mean** | **0.07** | | **RMSE:** | **0.085** | |
| *UTM 19 North, NAD83, NAVD88* | | | | | | **Z Min:** | **-0.14** | | *** 1.9600** | **0.166** | |
| *All units in meters where applicable.* | | | | | | **Z Max:** | **0.17** | | | | |
| *HAE - GEOID09 = NAVD88* | | | | | | | | | | | |

| CHARLES/NARRAGANSETT/BLACKSTONE, MASSACHUSETTS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CVA Testing @ 36.3cm Req'd Accuracy | | | | | | | | | | |
| | | | | | | | | | | |
| **CVAs** | **Typ** | **Date** | **Latitude** | **Longitude** | **Northing (GPS)** | **Easting (GPS)** | **MSL (GPS)** | **MSL (LiDAR)** | **Δ Z** | **Δ $Z^2$** |
| NCB301 | O | 10/17/2010 | 41.7849682 | -71.3161281 | 4628494.838 | 307533.374 | 10.029 | 10.00 | **0.03** | 0.00086 |
| NCB305 | O | 10/17/2010 | 41.9697882 | -71.1877914 | 4648736.941 | 318721.900 | 31.321 | 31.35 | **-0.03** | 0.00085 |
| NCB306 | O | 10/17/2010 | 42.0232970 | -71.3702887 | 4655080.966 | 303764.026 | 104.193 | 104.13 | **0.06** | 0.00395 |
| NCB312 | O | 10/15/2010 | 42.1186816 | -71.5662622 | 4666140.866 | 287856.380 | 152.275 | 152.35 | **-0.08** | 0.00568 |
| NCB319 | O | 10/17/2010 | 42.3403519 | -71.3052306 | 4690139.969 | 310102.157 | 62.979 | 63.10 | **-0.12** | 0.01466 |
| NCB701 | F | 11/21/2010 | 42.4401810 | 71.2986303 | 4701210.743 | 310945.898 | 83.864 | 84.05 | **-0.19** | 0.03460 |
| NCB702 | F | 11/21/2010 | 42.3996846 | 71.2997642 | 4696716.338 | 310730.807 | 41.222 | 41.41 | **-0.19** | 0.03534 |
| NCB703 | F | 11/21/2010 | 42.2969861 | 71.3477593 | 4685420.328 | 306465.675 | 66.446 | 66.49 | **-0.04** | 0.00194 |
| NCB704 | F | 11/21/2010 | 42.1728595 | 71.6016680 | 4672245.549 | 285112.761 | 87.663 | 87.72 | **-0.06** | 0.00325 |
| NCB705 | F | 11/21/2010 | 42.1578859 | 71.3862152 | 4670062.450 | 302862.852 | 42.068 | 42.05 | **0.02** | 0.00032 |
| NCB706 | F | 11/21/2010 | 42.1015156 | 71.1535517 | 4663291.743 | 321927.411 | 93.695 | 93.75 | **-0.06** | 0.00303 |
| NCB707 | F | 11/21/2010 | 41.9670644 | 71.3395303 | 4648766.875 | 306139.995 | 60.485 | 60.45 | **0.03** | 0.00122 |
| NCB708 | F | 11/21/2010 | 41.9752985 | 71.1689555 | 4649309.082 | 320298.206 | 24.906 | 25.03 | **-0.12** | 0.01538 |
| NCB709 | F | 11/21/2010 | 41.8873862 | 71.3076352 | 4639847.906 | 308544.841 | 34.154 | 34.29 | **-0.14** | 0.01850 |
| NCB710 | F | 11/21/2010 | 41.7956325 | 71.2247122 | 4629478.233 | 315161.002 | 30.520 | 30.62 | **-0.10** | 0.01000 |
| NCB801 | U | 11/21/2010 | 42.3049093 | 71.3261950 | 4686251.323 | 308267.450 | 38.909 | 38.90 | **0.01** | 0.00008 |
| NCB802 | U | 11/21/2010 | 42.1534120 | 71.4913255 | 4669813.904 | 294164.121 | 83.204 | 83.32 | **-0.12** | 0.01346 |
| NCB803 | U | 11/21/2010 | 42.1325780 | 71.1254288 | 4666682.629 | 324338.796 | 56.482 | 56.53 | **-0.05** | 0.00230 |
| NCB804 | U | 11/21/2010 | 42.0269989 | 71.2511718 | 4655225.613 | 313637.080 | 59.767 | 59.70 | **0.07** | 0.00449 |
| NCB805 | U | 11/21/2010 | 41.9439323 | 71.2841122 | 4646074.360 | 310663.867 | 38.840 | 38.76 | **0.08** | 0.00640 |
| | | | | | | | | | | |
| | | | | | | **Z Mean** | **-0.11** | **RMSE:** | | **0.094** |
| | | | | | | **Z Min:** | **-0.19** | *** 1.9600** | | **0.184** |
| | | | | | | **Z Max:** | **0.08** | **95-Percentile** | | **0.186** |
| | | | | | | | | | | |
| | | | | | | | | | | |
| **Metadata** | | | | | | | | | | |
| *UTM 19 North, NAD83, NAVD88* | | | | | | | | | | |
| *All units in meters where applicable.* | | | | | | | | | | |
| *HAE - GEOID09 = NAVD88* | | | | | | | | | | |

CompassData

# Region 1: Test results for Charles, Narragansett and adjoining Blackstone areas, MA


## Summary

In FEMA-Region 1 the areas of Charles, Narragansett and partially Blackstone encompasses in total about 560 square miles. A LiDAR data acquisition was ordered for a 2' equivalent contour accuracy, which equals the highest specification level. The area was flown and post-processed by Photo Science. CompassData performed the quality control of the collected and processed LiDAR data with a fundamental vertical accuracy (FVA) and a consolidated vertical accuracy (CVA) assessment, respectively. The planning, data collection, data processing, and data testing were successfully accomplished by the STARR members.


## Index



## Final Test Results

**The vertical accuracy requirements based on flood risk and terrain slope are met with 16.6 cm and 18.6 cm for both FVA and CVA testing. The mandatory requirements for the highest specification for vertical accuracy, 95% confidence level are for FVA < 24.5 cm and CVA < 36.3 cm.**

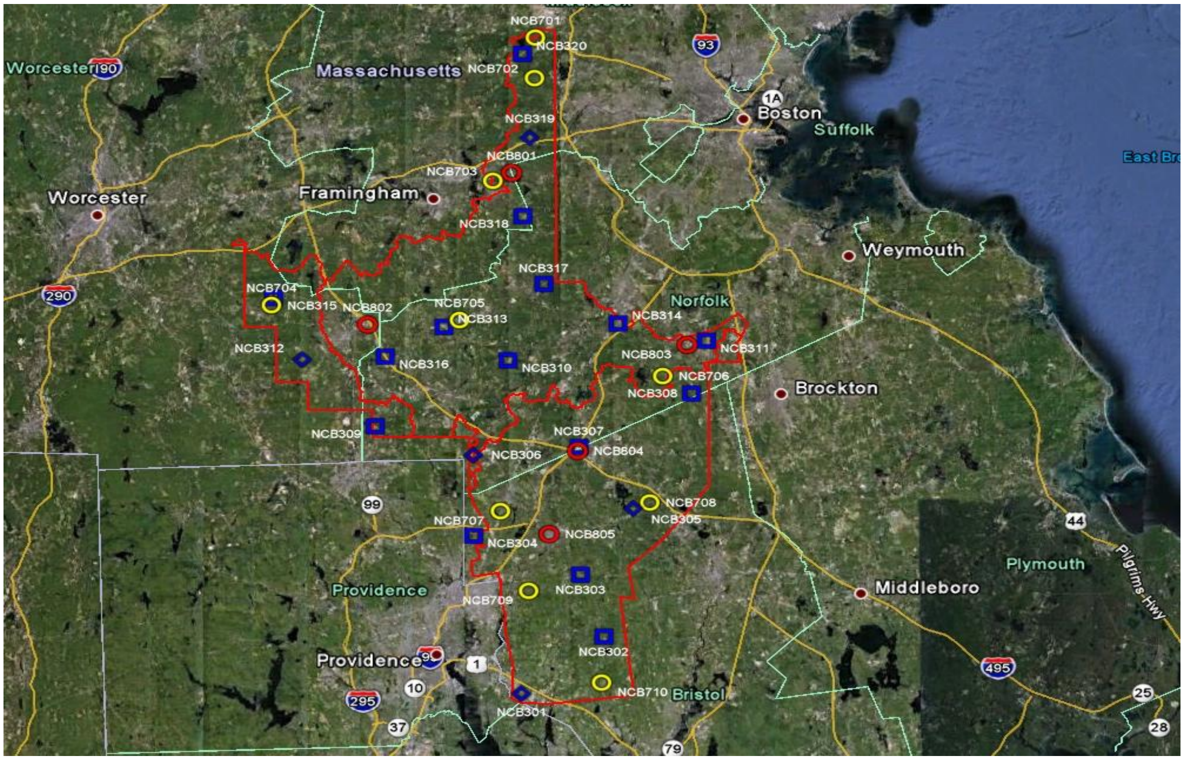
### FVA Test

Tested 16.6 cm fundamental vertical accuracy at 95% confidence level in open terrain using $RMSE_{(z)}$ x 1.9600. The Root Mean Square Error for the elevation differences between GPS control points and LiDAR points is 8.5 cm calculated with 20 FVA points.

## CVA Test

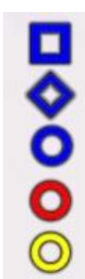
Tested 18.6 cm consolidated vertical accuracy at 95th percentile in: open terrain, forest terrain, and urban terrain. The Root Mean Square Error for the elevation differences between GPS control points and LiDAR points is 9.4 cm calculated with 20 supplemental vertical accuracy points (SVA).

## Distribution of Testing Points




**Region 1, Blackstone, MA**

<u>Legend:</u>



FVA points in open terrain on hard surface

FVA points in open terrain used as well in CVA test

SVA points in open terrain

SVA points in urban terrain

SVA points in forest terrain

According to the area to be tested the 20 FVA points are evenly distributed. Additional 20 SVA points are distributed in respect to the available major land classes.

## FVA Test Details

| FVA-Points | Date | Northing (GPS) | Easting (GPS) | MSL (GPS) | MSL (LiDAR) | Δ Z |
|---|---|---|---|---|---|---|
| NCB301 | 10/17/2010 | 4628494.838 | 307533.374 | 10.029 | 10.00 | **0.03** |
| NCB302 | 10/17/2010 | 4634605.935 | 315513.463 | 34.915 | 34.84 | **0.07** |
| NCB303 | 10/17/2010 | 4641539.998 | 313490.146 | 44.364 | 44.31 | **0.05** |
| NCB304 | 10/17/2010 | 303502.475 | 4646143.418 | 36.592 | 36.58 | **0.01** |
| NCB305 | 10/17/2010 | 4648736.941 | 318721.900 | 31.321 | 31.36 | **-0.04** |
| NCB306 | 10/17/2010 | 303764.026 | 4655080.966 | 104.193 | 104.13 | **0.06** |
| NCB307 | 10/17/2010 | 4655700.389 | 313765.162 | 65.519 | 65.44 | **0.08** |
| NCB308 | 10/17/2010 | 4661311.798 | 324586.148 | 70.294 | 70.28 | **0.01** |
| NCB309 | 10/15/2010 | 294547.718 | 4658540.495 | 92.074 | 92.13 | **-0.06** |
| NCB310 | 10/17/2010 | 4665489.855 | 307320.864 | 75.617 | 75.54 | **0.08** |
| NCB311 | 10/15/2010 | 4667120.100 | 326162.869 | 71.197 | 71.12 | **0.08** |
| NCB312 | 10/15/2010 | 287856.380 | 4666140.866 | 152.275 | 152.33 | **-0.06** |
| NCB313 | 10/17/2010 | 4669381.293 | 301359.001 | 62.492 | 62.54 | **-0.05** |
| NCB314 | 10/16/2010 | 4669278.445 | 317849.221 | 40.964 | 40.91 | **0.05** |
| NCB315 | 10/15/2010 | 4675576.809 | 298445.293 | 97.177 | 97.31 | **-0.13** |
| NCB316 | 10/15/2010 | 4666242.506 | 295717.649 | 69.524 | 69.35 | **0.17** |
| NCB317 | 10/17/2010 | 4673867.749 | 310950.283 | 69.647 | 69.53 | **0.12** |
| NCB318 | 10/17/2010 | 4681441.377 | 309177.060 | 56.169 | 56.31 | **-0.14** |
| NCB319 | 10/17/2010 | 4690139.969 | 310102.157 | 62.979 | 63.09 | **-0.11** |
| NCB320 | 10/16/2010 | 4699469.255 | 309660.020 | 66.862 | 66.93 | **-0.07** |

| | | | |
|---|---|---|---|
| **Z Mean** | **0.07** | **RMSE:** | **0.085** |
| **Z Min:** | **-0.14** | *** 1.9600** | **0.166** |
| **Z Max:** | **0.17** | | |

*UTM Zone 19 North, NAD83, NAVD88*
*MSL = NAVD88/Geoid09*
*All units in meters*

<u>Note:</u>

All 20 of the FVA points (open terrain) passed. 100% of the points are within the 24.5 cm confidence level. The FVA test is passed.

CompassData

## CVA Test Details

| CVAs | Typ | Date | Northing (GPS) | Easting (GPS) | MSL (GPS) | MSL (LiDAR) | Δ Z |
|---|---|---|---|---|---|---|---|
| NCB301 | O | 10/17/2010 | 4628494.838 | 307533.374 | 10.029 | 10.00 | **0.03** |
| NCB305 | O | 10/17/2010 | 4648736.941 | 318721.900 | 31.321 | 31.35 | **-0.03** |
| NCB306 | O | 10/17/2010 | 4655080.966 | 303764.026 | 104.193 | 104.13 | **0.06** |
| NCB312 | O | 10/15/2010 | 4666140.866 | 287856.380 | 152.275 | 152.35 | **-0.08** |
| NCB319 | O | 10/17/2010 | 4690139.969 | 310102.157 | 62.979 | 63.10 | **-0.12** |
| NCB701 | F | 11/21/2010 | 4701210.743 | 310945.898 | 83.864 | 84.05 | **-0.19** |
| NCB702 | F | 11/21/2010 | 4696716.338 | 310730.807 | 41.222 | 41.41 | **-0.19** |
| NCB703 | F | 11/21/2010 | 4685420.328 | 306465.675 | 66.446 | 66.49 | **-0.04** |
| NCB704 | F | 11/21/2010 | 4672245.549 | 285112.761 | 87.663 | 87.72 | **-0.06** |
| NCB705 | F | 11/21/2010 | 4670062.450 | 302862.852 | 42.068 | 42.05 | **0.02** |
| NCB706 | F | 11/21/2010 | 4663291.743 | 321927.411 | 93.695 | 93.75 | **-0.06** |
| NCB707 | F | 11/21/2010 | 4648766.875 | 306139.995 | 60.485 | 60.45 | **0.03** |
| NCB708 | F | 11/21/2010 | 4649309.082 | 320298.206 | 24.906 | 25.03 | **-0.12** |
| NCB709 | F | 11/21/2010 | 4639847.906 | 308544.841 | 34.154 | 34.29 | **-0.14** |
| NCB710 | F | 11/21/2010 | 4629478.233 | 315161.002 | 30.520 | 30.62 | **-0.10** |
| NCB801 | U | 11/21/2010 | 4686251.323 | 308267.450 | 38.909 | 38.90 | **0.01** |
| NCB802 | U | 11/21/2010 | 4669813.904 | 294164.121 | 83.204 | 83.32 | **-0.12** |
| NCB803 | U | 11/21/2010 | 4666682.629 | 324338.796 | 56.482 | 56.53 | **-0.05** |
| NCB804 | U | 11/21/2010 | 4655225.613 | 313637.080 | 59.767 | 59.70 | **0.07** |
| NCB805 | U | 11/21/2010 | 4646074.360 | 310663.867 | 38.840 | 38.76 | **0.08** |

| | | | |
|---|---|---|---|
| **Z Mean** | **-0.11** | **RMSE:** | **0.094** |
| **Z Min:** | **-0.19** | *** 1.9600** | **0.184** |
| **Z Max:** | **0.08** | **95-Percentile** | **0.186** |

*Land Class Types: O = Open, F = Forest, U = Urban*

*UTM Zone 19 North, NAD83, NAVD88*
*MSL = NAVD88/Geoid09*
*All units in meters*

Note:

All 20 of the SVA points (open, forest, and urban terrain) passed. 100% of the points are within the 36.3 cm confidence level. The CVA test is passed.

# Appendix E: Post Flight Reports

2670 Wilhite Drive
Lexington, Kentucky 40503
Phone 859-277-8700 + Fax 859-277-8901
www.photoscience.com

March 29, 2011

Post Flight Report
PSI Project 7556-005
Narragansett, MA LiDAR

FEMA Task Order Number: HSFEHQ-10-J0005
Client: STARR (Project Number: 40000058)
Project Name: Narragansett
Attached Reference file: *7556-005_Narragansett_MA_Background.ZIP*

General Specifications: 1-meter nominal spacing LiDAR Acquisition and processing with a 24.5 cm vertical accuracy at 95% confidence.

Acquisition Dates: LiDAR data for the Narragansett data was acquired on the dates of 12/08/2010, 12/10/2010, over 6 lifts by two different Aircraft.

Equipment Used: The data was collected with a Optech Gemini, Serial Numbers 246 and 247, Base GPS Receiver used was a Trimble 5700 collecting data at half second intervals. The aircraft used were Cessna 206 models, tail numbers N2448G and N7266Z. The pilots were Mark Young and Nick Greenwell and the Operators were Jeremy Berry and Nathan Galieti. The Base Station was set on the monument “Mansfield, LW5147” at the Mansfield Airport 1B9 set by the crews.

Project: The project consisted of 44 flight lines of 390.66 miles. The project was flown at an altitude of 5,000 feet above ground and at a planned average speed of 116 knots with a field of view of 36 degrees. The scan rates used was 30.1 Hz with a Laser Pulse Rate of 71.429 Hz with Multi-Pulse enabled. The full swath width was 989.18 meters with a planned sidelap of 30%. The point spacing was .912 meter with a NADIR point density of 1.2 points per square meter and an average point density of 2.93 points per square meter. The planned vertical accuracy was 0.13 meters. The area consisted of 217 square miles.

GPS Base Station / Monument: The Base Station was set on the monument “Mansfield, LW5147” at the Mansfield Airport 1B9 set by the crews. Information on this monument is included in the attached .ZIP file under “Base Station Data”.

Control: 13 control points were collected as part of the project and used to calibrate the project data, remove any bias and verify accuracy. This data is compared to the collected model and results indicated below. This control data in included in the attached .ZIP file under “Control”.

Flight Files: The planned flight files are included as reference in the attached .ZIP file under "Flight Files".

Flight Logs: Flight Logs used by the crew are included in the attached .ZIP file under "Flight Logs" and include the following type information:

- job #/name
- block or AOI
- date (s) flown
- aircraft tail #
- lines - #
- lines - direction
- lines – altitude
- lines – speed
- conditions
- comments
- pilot name
- operator name
- AGC switch
- GPS base station used

Processing Summary: Data is included in the attached .ZIP file under "Processing Summary" which includes GPS / IMU processing summary data including at a minimum:

- Processing Logs
- Message Logs
- Extract Logs
- Laser configuration files for each lift
- Max Horizontal GPS Variance (cm)
- Max Vertical GPS Variance (cm)
- Notes on GPS quality (High, Good, etc.)
- GPS separation plot
- GPS altitude plot
- PDOP plot
- Plot of GPS distance from base station/s

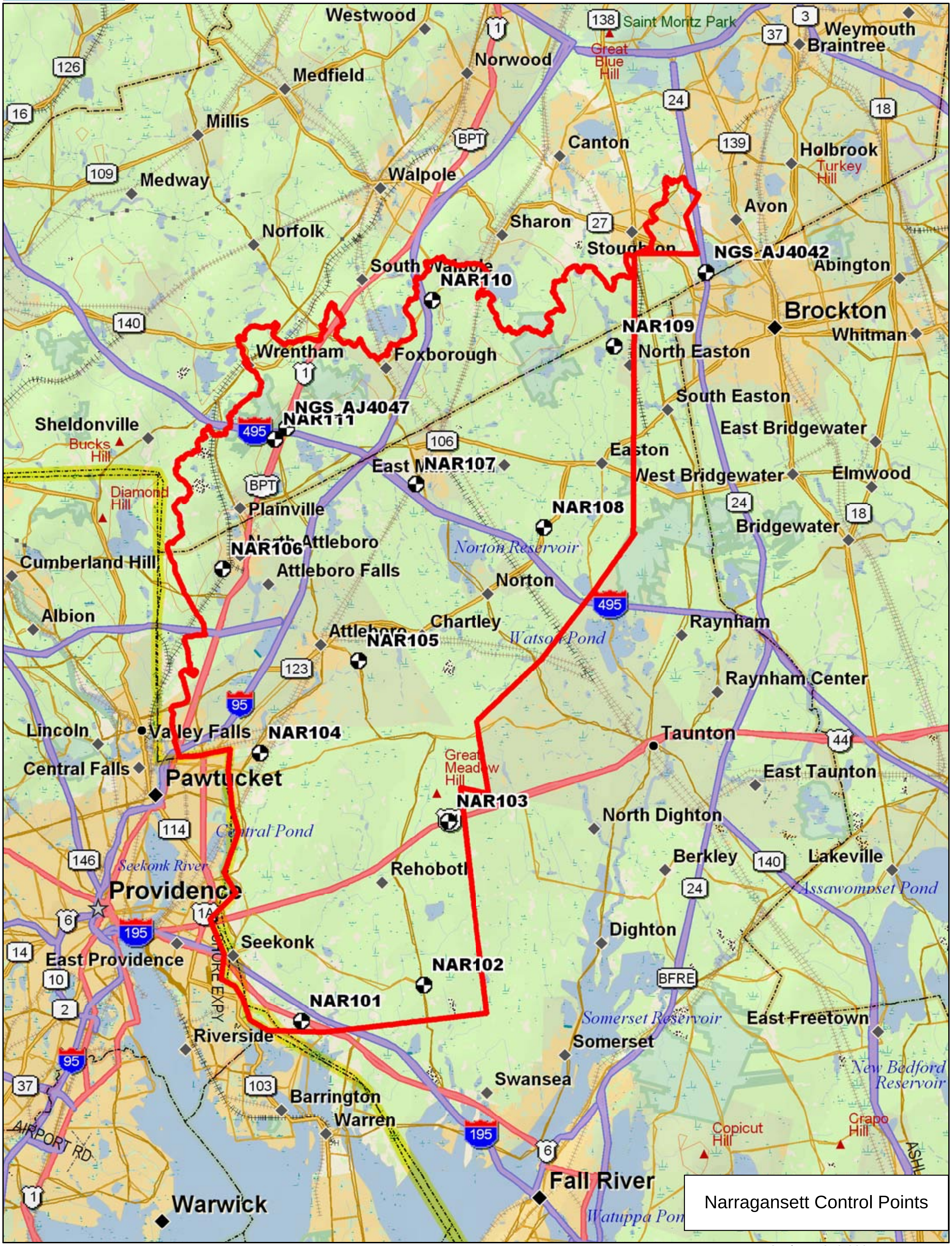
Project Coverage: within the attached .ZIP file in the "Project Coverage" directory is the overall boundary Shape File and the as flown trajectory Shape Files which include the project calibration flight lines (cross flights).

Accuracy: The LiDAR data was tested against the Control check points indicated above and the results are included in the "Accuracy Results" directory in the attached .ZIP file.

The LiDAR data as collected tested at 0.095 (meters) fundamental vertical accuracy at 95% confidence level. Within the accuracies indicated in the specifications, as provided.

Sincerely,

Forrest Godby
Senior Project Manager / Flight Operations Manager

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www.delorme.com

TN
MN (14.9°W)

Scale 1 : 250,000
1" = 3.95 mi Data Zoom 9-2

```
309124.28,4627858.76,NAR101
315137.56,4629447.78,NAR102
316540.02,4637360.83,NAR103
307444.56,4640935.41,NAR104
312364.10,4645307.56,NAR105
305881.82,4649935.23,NAR106
315387.71,4653817.28,NAR107
321582.88,4651547.08,NAR108
325222.77,4660253.86,NAR109
316403.93,4662726.09,NAR110
308587.34,4656165.11,NAR111
329772.47,4663745.59,NGS_AJ4042
309178.59,4656697.39,NGS_AJ4047
```

| Statistical Analysis | |
|---|---|
| Average Dz | 0.08 |
| Minimum Dz | -0.029 |
| Maximum Dz | 0.15 |
| RMSE | 0.095 |
| Standard Deviation | 0.054 |

| Coordinate System |
|---|
| Horizontal Projection |
| NAD83 - UTM Zone 19N, Meters |
| Vertical Datum |
| NAVD88 - Geoid09, Meters |

| Point | Easting | Northing | Known Z | LIDAR Z | Dz |
|---|---|---|---|---|---|
| NAR101 | 309124.28 | 4627858.76 | 4.18 | 4.29 | 0.11 |
| NAR102 | 315137.56 | 4629447.78 | 30.45 | 30.51 | 0.06 |
| NAR103 | 316540.02 | 4637360.83 | 37.43 | 37.56 | 0.13 |
| NAR104 | 307444.56 | 4640935.41 | 28.97 | 29.04 | 0.07 |
| NAR105 | 312364.10 | 4645307.56 | 41.21 | 41.31 | 0.10 |
| NAR106 | 305881.82 | 4649935.23 | 81.73 | 81.81 | 0.08 |
| NAR107 | 315387.71 | 4653817.28 | 46.45 | 46.60 | 0.15 |
| NAR108 | 321582.88 | 4651547.08 | 29.84 | 29.91 | 0.07 |
| NAR109 | 325222.77 | 4660253.86 | 53.10 | 53.21 | 0.11 |
| NAR110 | 316403.93 | 4662726.09 | 78.04 | 78.16 | 0.12 |
| NAR111 | 308587.34 | 4656165.11 | 71.09 | 71.17 | 0.08 |
| NGS_AJ4042 | 329772.47 | 4663745.59 | 74.83 | 74.81 | -0.02 |
| NGS_AJ4047 | 309178.59 | 4656697.39 | 61.37 | 61.34 | -0.03 |

# Base Monument for NARR_1B9

```
DATABASE =  ,PROGRAM = datasheet, VERSION = 7.85
1         National Geodetic Survey,   Retrieval Date = NOVEMBER 28, 2010
 LW5147 ***********************************************************************
 LW5147  PACS         -  This is a Primary Airport Control Station.
 LW5147  DESIGNATION -  MANSFIELD
 LW5147  PID          -  LW5147
 LW5147  STATE/COUNTY-  MA/BRISTOL
 LW5147  USGS QUAD   -
 LW5147
 LW5147                         *CURRENT SURVEY CONTROL
 LW5147  ___________________________________________________________________
 LW5147* NAD 83(2007)-  41 59 51.83741(N)    071 11 32.63915(W)     ADJUSTED
 LW5147* NAVD 88      -        35.61   (meters)     116.8    (feet)  GPS OBS
 LW5147  ___________________________________________________________________
 LW5147  EPOCH DATE   -        2002.00
 LW5147  X            -   1,530,446.961 (meters)                    COMP
 LW5147  Y            -  -4,493,704.408 (meters)                    COMP
 LW5147  Z            -   4,245,421.236 (meters)                    COMP
 LW5147  LAPLACE CORR-           2.37  (seconds)                    DEFLEC09
 LW5147  ELLIP HEIGHT-           6.817 (meters)          (02/10/07) ADJUSTED
 LW5147  GEOID HEIGHT-         -28.78  (meters)                     GEOID09
 LW5147
 LW5147  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
 LW5147  Type    PID    Designation                     North   East  Ellip
 LW5147  -------------------------------------------------------------------
 LW5147  NETWORK LW5147 MANSFIELD                        0.29   0.24   0.69
 LW5147  -------------------------------------------------------------------
 LW5147
 LW5147.This mark is at Mansfield Airport (1B9)
 LW5147
 LW5147.The horizontal coordinates were established by GPS observations
 LW5147.and adjusted by the National Geodetic Survey in February 2007.
 LW5147
 LW5147.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
 LW5147.See National Readjustment for more information.
 LW5147.The horizontal coordinates are valid at the epoch date displayed above.
 LW5147.The epoch date for horizontal control is a decimal equivalence
 LW5147.of Year/Month/Day.
 LW5147
 LW5147.The orthometric height was determined by GPS observations and a
 LW5147.high-resolution geoid model.
 LW5147
 LW5147.GPS derived orthometric heights for airport stations designated as
 LW5147.PACS or SACS are published to 2 decimal places.  This maintains
 LW5147.centimeter relative accuracy between the PACS and SACS.  It does
 LW5147.not indicate centimeter accuracy relative to other marks which are
 LW5147.part of the NAVD 88 network.
 LW5147
 LW5147.Photographs are available for this station.
 LW5147
 LW5147.The X, Y, and Z were computed from the position and the ellipsoidal ht.
 LW5147
 LW5147.The Laplace correction was computed from DEFLEC09 derived deflections.
 LW5147
```

```
LW5147.The ellipsoidal height was determined by GPS observations
LW5147.and is referenced to NAD 83.
LW5147
LW5147.The geoid height was determined by GEOID09.
LW5147
LW5147;                    North         East     Units Scale Factor Converg.
LW5147;SPC MA M     -   860,863.397   225,485.019   MT  0.99997079   +0 12 23.8
LW5147;SPC MA M     - 2,824,349.33    739,778.77   sFT  0.99997079   +0 12 23.8
LW5147;UTM  19      - 4,651,849.573   318,419.504   MT  1.00000573   -1 28 02.4
LW5147
LW5147!             -  Elev Factor  x  Scale Factor =   Combined Factor
LW5147!SPC MA M     -   0.99999893  x   0.99997079  =   0.99996972
LW5147!UTM  19      -   0.99999893  x   1.00000573  =   1.00000466
LW5147
LW5147:                Primary Azimuth Mark                         Grid Az
LW5147:SPC MA M     -  MANSFIELD AZ MK                              311 03 51.3
LW5147:UTM  19      -  MANSFIELD AZ MK                              312 44 17.5
LW5147
LW5147|---------------------------------------------------------------------|
LW5147| PID    Reference Object                     Distance      Geod. Az  |
LW5147|                                                           dddmmss.s |
LW5147| LW5356 419 A                               235.366 METERS 14336     |
LW5147| MY5414 MANSFIELD AZ MK                     APPROX. 0.7 KM 3111615.1 |
LW5147|---------------------------------------------------------------------|
LW5147
LW5147                         SUPERSEDED SURVEY CONTROL
LW5147
LW5147  NAD 83(1996)-  41 59 51.83745(N)    071 11 32.63956(W) AD(        ) A
LW5147  ELLIP H (06/22/01)    6.810  (m)                       GP(        ) 4 1
LW5147  NAD 83(1996)-  41 59 51.83738(N)    071 11 32.63964(W) AD(        ) 1
LW5147  ELLIP H (05/22/00)    6.809  (m)                       GP(        ) 4 1
LW5147  NAD 83(1996)-  41 59 51.83703(N)    071 11 32.63959(W) AD(        ) 1
LW5147  ELLIP H (06/29/98)    6.797  (m)                       GP(        ) 4 1
LW5147  NAD 83(1992)-  41 59 51.83556(N)    071 11 32.63872(W) AD(        ) 1
LW5147  ELLIP H (10/08/95)    6.770  (m)                       GP(        ) 4 2
LW5147  NAD 83(1986)-  41 59 51.83432(N)    071 11 32.63531(W) AD(        ) 1
LW5147  NGVD 29 (07/20/87)   35.9    (m)          118.     (f) GPS OBS
LW5147
LW5147.Superseded values are not recommended for survey control.
LW5147.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
LW5147.See file dsdata.txt to determine how the superseded data were derived.
LW5147
LW5147_U.S. NATIONAL GRID SPATIAL ADDRESS: 19TCG1841951849(NAD 83)
LW5147_MARKER: DH = HORIZONTAL CONTROL DISK
LW5147_SETTING: 66 = SET IN ROCK OUTCROP
LW5147_SP_SET: ROCK OUTCROP
LW5147_STAMPING: MANSFIELD 1985
LW5147_MARK LOGO: NGS
LW5147_MAGNETIC: N = NO MAGNETIC MATERIAL
LW5147_STABILITY: A = MOST RELIABLE AND EXPECTED TO HOLD
LW5147+STABILITY: POSITION/ELEVATION WELL
LW5147_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
LW5147+SATELLITE: SATELLITE OBSERVATIONS - March 17, 2010
LW5147
LW5147  HISTORY     - Date     Condition        Report By
LW5147  HISTORY     - 1985     MONUMENTED       NGS
LW5147  HISTORY     - 1985     GOOD             NGS
```

```
LW5147  HISTORY     - 19861121 GOOD             MAGS
LW5147  HISTORY     - 19880520 GOOD             NGS
LW5147  HISTORY     - 19990930 GOOD             WOOLPT
LW5147  HISTORY     - 20000608 GOOD             NGS
LW5147  HISTORY     - 20100317 GOOD             INDIV
LW5147
LW5147                          STATION DESCRIPTION
LW5147
LW5147'DESCRIBED BY NATIONAL GEODETIC SURVEY 1985 (REP)
LW5147'THE STATION IS LOCATED ABOUT 4.0 KM (2.5 MI)
LW5147'SOUTH-SOUTHEAST OF MANSFIELD, 0.4 KM (0.25 MI) EAST OF INTERSTATE
LW5147'HIGHWAY 495, AT THE MANSFIELD MUNICIPAL AIRPORT AND NEAR THE END OF
LW5147'THE NORTHWEST-SOUTHEAST RUNWAY.
LW5147'OWNERSHIP--MANSFIELD MUNICIPAL AIRPORT, DAVID AND ROY POWELL,
LW5147'AIRPORT MANAGERS, MANSFIELD MA 02048, PHONE 617-339-3624
LW5147'
LW5147'TO REACH THE STATION FROM THE POST OFFICE IN MANSFIELD, GO SOUTH ON
LW5147'MAIN STREET, FOR 2.O KM (1.25 MI) TO A CROSSROAD, WILLOW STREET ON
LW5147'THE RIGHT, FRUIT STREET ON THE LEFT, TURN LEFT AND GO EAST AND
LW5147'SOUTHEAST ON FRUIT STREET FOR 1.3 KM (0.8 MI) TO A DRIVEWAY LEADING
LW5147'TO THE AIRPORT ON THE RIGHT. TURN RIGHT AND GO SOUTH ON THE DRIVEWAY
LW5147'FOR 1.0 KM (0.05 MI) TO A GATE AT THE TERMINAL BUILDING.  PASS
LW5147'THROUGH THE GATE AND GO SOUTHEAST FOR 0.3 KM (0.2 MI) TO THE WIND
LW5147'SOCK AND THE AZIMUTH MARK.  CONTINUE SOUTHEAST FOR 0.7 KM (0.45 MI)
LW5147'TO THE STATION AS DESCRIBED.
LW5147'
LW5147'THE STATION IS A STANDARD NGS DISK
LW5147'STAMPED---MANSFIELD 1985 --,
LW5147'SET INTO A DRILL HOLE IN ROCK OUTCROP. LOCATED
LW5147'86.3 METERS (283.0 FT) WEST-NORTHWEST FROM THE EXTREME SOUTHEAST
LW5147'CORNER OF THE RUNWAY
LW5147'34.7 METERS (114.0 FT) WEST-NORTHWEST FROM THE SOUTH BLUE LIGHT OF
LW5147'FOUR BLUE LIGHTS.
LW5147'18.3 METERS (60.0 FT) SOUTHEAST FROM THE SOUTHERLY EDGE OF THE
LW5147'RUNWAY AND
LW5147'10.1 METERS (33.0 FT) NORTHEAST FROM A CARSONITE WITNESS POST SET ON
LW5147'EDGE OF A DRAINAGE DITCH.
LW5147'
LW5147'AZIMUTH MARK NO. 1 IS A STANDARD NGS DISK
LW5147'STAMPED---MANSFIELD 1985---,
LW5147'SET INTO THE TOP OF A ROUND CONCRETE MONUMENT
LW5147'30 CM IN DIAMETER FLUSH WITH GROUND.  LOCATED
LW5147'25.9 METERS (85.0 FT) SOUTHEAST FROM THE WIND SOCK AND
LW5147'16.6 METERS (54.0 FT) EAST-NORTHEAST FROM THE EAST EDGE OF THE
LW5147'TAXIWAY.
LW5147'TO REACH THE AZIMUTH FROM THE STATION,
LW5147'GO NORTHWEST FOR 0.7 KM (0.45 MI) TO THE WIND SOCK AND THE
LW5147'AZIMUTH MARK AS DESCRIBED.
LW5147'THE UNDERGROUND MARK IS A STANDARD NGS DISK
LW5147'STAMPED---MANSFIELD 1985---,
LW5147'SET INTO AN IRREGULAR MASS OF CONCRETE 1.1 METERS BELOW THE SURFACE.
LW5147'
LW5147'AN EDM TIE WAS MADE TO MANSFIELD AZ MK
LW5147'
LW5147'DESCRIBED BY R. T. WOODRUFF
LW5147
LW5147                          STATION RECOVERY (1985)
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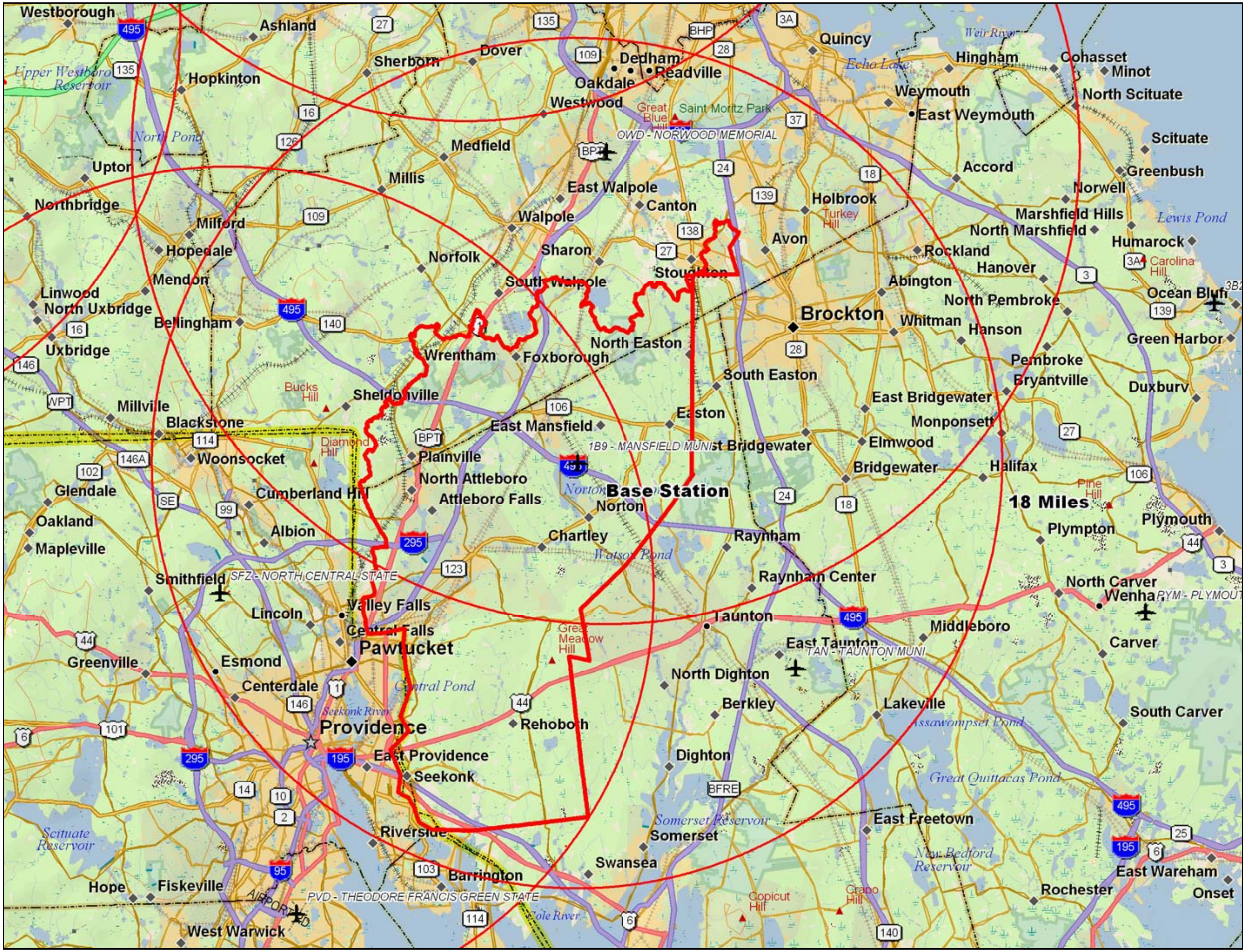
```
LW5147
LW5147'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1985
LW5147'RECOVERED IN GOOD CONDITION.
LW5147
LW5147                          STATION RECOVERY (1986)
LW5147
LW5147'RECOVERY NOTE BY MASSACHUSETTS GEODETIC SURVEY 1986
LW5147'RECOVERED IN GOOD CONDITION.
LW5147
LW5147                          STATION RECOVERY (1988)
LW5147
LW5147'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1988
LW5147'THE STATION WAS RECOVERED IN GOOD CONDITION AS DESCRIBED IN THE 1985
LW5147'AIRPORT SURVEY PROJECT.  A NEW DESCRIPTION FOLLOWS.
LW5147'THE STATION IS LOCATED ABPIT 2.9 KM (1.80 MI) SOUTHEAST FROM THE
LW5147'CENTER OF MANSFIELD, 0.5 KM (0.30 MI) NORTH OF INTERSTATE HIGHWAY 495,
LW5147'AT THE MANSFIELD MUNICIPAL AIRPORT, NEAR THE SOUTH CORNER OF THE
LW5147'SINGLE RUNWAY.
LW5147'OWNERSHIP--CITY OF MANSFIELD, C/O PRESIDENT RAYMOND G. POWELL, FRUIT
LW5147'STREET, MANSFILED MA 02048.  PHONE 617 339-3624.
LW5147'TO REACH THE STATION FROM THE POST OFFICE IN MANSFIELD, GO SOUTH FOR
LW5147'1.9 KM (1.20 MI) ON SOUTH MAIN STREET TO A PAVED CROSS ROAD, FRUIT
LW5147'STREET ON THE LEFT AND WILLOW STREET ON THE RIGHT.  THIS POINT MAY
LW5147'ALSO BE REACHED BY GOING NORTH FOR 1.2 KM (0.75 MI) ON SOUTH MAIN
LW5147'STREET FROM THE OVERPASS BRIDGE OVER INTERSTATE HIGHWAY 495 AT EXIT
LW5147'11.  TURN LEFT AND GO SOUTHEAST FOR 1.1 KM (0.70 MI) ON FRUIT STREET
LW5147'TO A PAVED DRIVE ON THE RIGHT, LEADING TO THE WEST END OF THE HANGARS.
LW5147'TURN RIGHT AND GO SOUTHWEST THEN SOUTHEAST FOR 0.4 KM (0.25 MI) ON
LW5147'THE PAVED DRIVE BETWEEN THE HANGARS, ACROSS THE PARKING RAMP THEN
LW5147'SOUTHWEST ON THE TAXIWAY TO THE SOUTHEAST END OF THE RUNWAY.  CROSS
LW5147'THE RUNWAY THEN GO NORTHWEST FOR 86 M (282.2 FT) TO THE STATION ON THE
LW5147'SOUTHWEST SIDE OF THE RUNWAY.
LW5147'THE STATION IS A STANDARD NGS DISK SET INTO A DRILL HOLE IN THE TOP OF
LW5147'A 0.6 BY 0.8 METER EXPOSURE OF OUTCROP FLUSH WITH THE GROUND.  LOCATED
LW5147'86.3 M (283.1 FT) WEST-NORTHWEST FROM THE SOUTH CORNER OF THE ASPHALT
LW5147'RUNWAY, 34.8 M (114.2 FT) WEST-NORTHWEST FROM THE SOUTHWEST ONE OF
LW5147'FOUR LANDING LIGHTS AT THE DISPLACED THRESHOLD, 29.7 M (97.4 FT)
LW5147'SOUTHWEST FROM THE CENTER OF THE RUNWAY, 18.1 M (59.4 FT) SOUTHWEST
LW5147'FROM THE SOUTHWEST EDGE OF THE ASPHALT RUNWAY, AND 10.0 M (32.8 FT)
LW5147'NORTHEAST FROM A FIBERGLASS WITNESS POST ON THE NORTHEAST EDGE OF A
LW5147'DRAINAGE DITCH.
LW5147'DESCRIBED BY C.L. SMITH, TYPED BY R.L. ZURFLUH.
LW5147
LW5147                          STATION RECOVERY (1999)
LW5147
LW5147'RECOVERY NOTE BY WOOLPERT CONSULTANTS 1999 (ARL)
LW5147'RECOVERED AS DESCRIBED.  THIS STATION IS DESIGNATED AS THE PRIMARY
LW5147'AIRPORT CONTROL STATION.
LW5147
LW5147                          STATION RECOVERY (2000)
LW5147
LW5147'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 2000 (CSM)
LW5147'THE STATION IS LOCATED ON THE SOUTHEAST SIDE OF MANSFIELD, AT THE
LW5147'MANSFIELD MUNICIPAL AIRPORT ON THE SOUTHWEST SIDE OF RUNWAY 36,
LW5147'IN THE GRASS FIELD ABOUT 35.05 M (114.99 FT) NORTHWEST OF THE
LW5147'DISPLACED THRESHOLD BAR FOR RUNWAY 36.  OWNERSHIP--CITY OF
LW5147'MANSFIELD. NOTE--CONTACT MR. DAVID DINNEN, (AIRPORT MANAGER) ONE
```

```
LW5147'DAY IN ADVANCE BEFORE OCCUPYING THE STATION, PHONE 508-339-3624.
LW5147'TO REACH THE STATION FROM THE INTERSECTION OF NORTH-SOUTH MAIN
LW5147'STREET AND EAST-WEST STREETS AT THE CITY PARK IN THE CENTER OF
LW5147'MANSFIELD, GO SOUTH ON SOUTH MAIN STREET FOR 1.61 KM (1.00 MI) TO
LW5147'THE JUNCTION OF FRUIT STREET ON THE LEFT, TURN LEFT, EASTERLY ON
LW5147'FRUIT STREET FOR 0.72 KM (0.45 MI) TO THE JUNCTION OF HALL STREET ON
LW5147'THE LEFT (AT A STOP SIGN), TURN LEFT, SOUTHEASTERLY AND CONTINUE
LW5147'AHEAD ON FRUIT STREET FOR 0.56 KM (0.35 MI) TO THE AIRPORT ENTRANCE
LW5147'DRIVE ON THE RIGHT, TURN RIGHT, SOUTHWEST ON THE DRIVE AND BEAR
LW5147'RIGHT ACROSS THE PARKING LOT TO THE SECURITY GATE, PASS THROUGH
LW5147'THE GATE AND BEAR LEFT BETWEEN THE HANGARS AND ONTO THE APRON,
LW5147'GO SOUTHEAST ACROSS THE APRON PASSING THE AIRPORT OFFICE
LW5147'BUILDING TO THE SOUTHEAST SIDE OF THE APRON TO A TAXIWAY, TURN
LW5147'LEFT, SOUTHEAST ON THE TAXIWAY AND BEAR RIGHT, NORTHWEST FOR
LW5147'ABOUT 0.05 KM (0.05 MI) TO THE JUNCTION OF THE PARALLEL TAXIWAY AND
LW5147'WIND SOCK ON THE LEFT, TURN LEFT, SOUTHEAST ON THE TAXIWAY FOR
LW5147'0.72 KM (0.45 MI) TO THE END OF RUNWAY 36, TURN RIGHT, SOUTHWEST
LW5147'CROSSING THE END OF RUNWAY 36 AND ONTO THE GRASS, TURN RIGHT,
LW5147'NORTHWEST FOR ABOUT 76.2 M (250.0 FT) TO THE DISPLACED THRESHOLD
LW5147'AND THRESHOLD LIGHTS ON THE RIGHT, CONTINUE AHEAD, NORTHWEST
LW5147'FOR ABOUT 30.48 M (100.00 FT) TO THE STATION IN A SMALL AREA OF
LW5147'EXPOSED ROCK OUTCROP FLUSH WITH THE GROUND.  THE STATION IS AN
LW5147'NGS HORIZONTAL DISK SET IN A DRILL HOLE IN ROCK OUTCROP.  LOCATED
LW5147'18.14 M (59.51 FT) SOUTHWEST OF THE SOUTHWEST EDGE OF RUNWAY 36,
LW5147'34.81 M (114.21 FT) WEST-NORTHWEST OF THE SOUTHWEST ONE OF FOUR
LW5147'THRESHOLD LIGHTS, AND 10.06 M (33.01 FT) NORTHEAST OF AN NGS
LW5147'FIBERGLASS WITNESS POST SET ALONG THE TREE LINE.
LW5147'
LW5147
LW5147                          STATION RECOVERY (2010)
LW5147
LW5147'RECOVERY NOTE BY INDIVIDUAL CONTRIBUTORS 2010 (KK)
LW5147'RECOVERED IN GOOD CONDITION.
```

Hemlock Ln
Hall St
Stillbrook Ln
Tracy Cir
Heather Ln
Fruit St
Short St
Longwood Cir
Jefferson Rd
Emerson Cir
Access Rd
Shea Cir
MANSFIELD AZ MK
Nathan Rd
Harding Ln
Essex St
S Main St
MANSFIELD
Blue Star Memorial Hwy
495
Reservoir St
Columbine Rd
Thornton Rd
Barberry Rd
Azalea Rd
Hickory Rd
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2011 Europa Technologies
© 2011 Google
©2008
Google
42°00'06.74" N 71°11'49.64" W
elev 113 ft
Jun 19, 2010
Eye alt 6623 ft




Data use subject to license.



www.delorme.com

TN

MN (14.9°W)

Scale 1 : 350,000

0 2 4 6 8 10 mi

0 3 6 9 12 15 km

1" = 5.52 mi

Data Zoom 9-0

STATE(s): MASSACHUSETTS

Project Numbers 7556-005 A003

AREA ID: ~~FE~~ NARR_1B9

STARR-FEMA

AREA NAME: NARRAGANSETT - FEMA

FILE TYPES/NAMES: ☒ OPTECH: NARR_1B9_OP ☒ LEICA: 1B9_NARRA_MA

Lines: 44 FL Miles: 945 Square Miles: ____ Flight Altitudes: 5,000 Tide Coord: Yes See Notes NO

AIRPORT ID: 1B9 Name: MANSFIELD MUNICIPAL

Services: FULL ☒ Self ☒ None ☐ See Notes RUNWAY Length: 3500 Ft

Contact Name(s): David Dinneen / Mzuzger

Phone(s): (___) ___-____ (___) ___-____ e-mail: ____

Hotels: ALL MAJOR

Rentals: ENTERPRISE

EXIST BASE Station: LW5147 Name: MANSFIELD

TYPE: PACS ☒ SACS ☐ Other ☐ Data Sheet Attached ☒

SET BASE STATION Name: ____ Date Set: ____

What was Set: Re-Bar ☐ or: ____ CAP: ____

Who Set: ____ Where Set: ____ Attach Data Sheet

Logs ☐ by: ____ Sectional ☐ by: ____ Lo En-route ☐ by: ____ Database ☐ by: ____ OPTECH ☒ by: FB LEICA ☒ by: FB

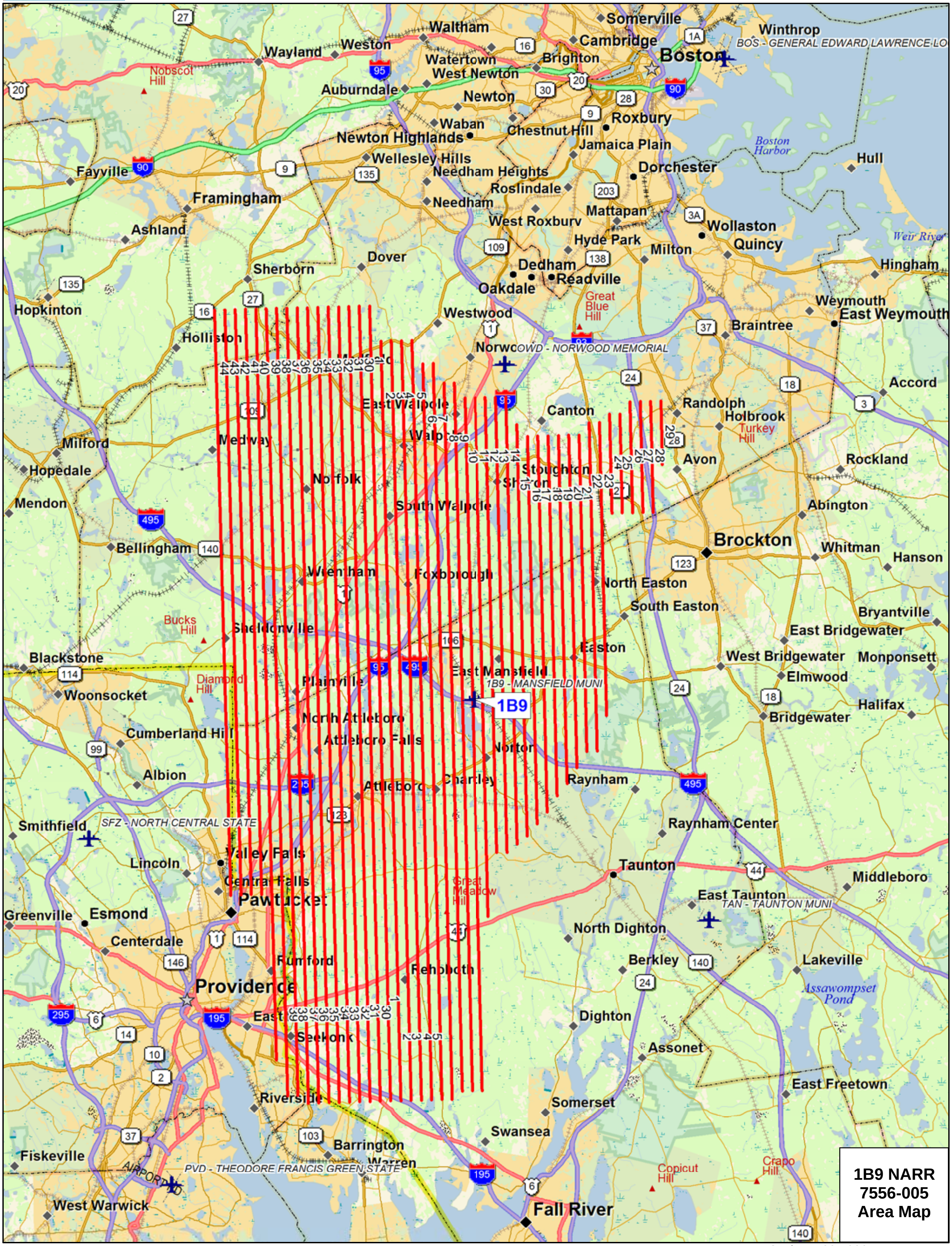
Accuracy: Vert; 24.5 Horiz; ____cm Post Spacing: 1.0m Points Sq Meter: ____

NOTES:

HIGH PRIORITY

42 0 0 71 11 48

14.3 SQ

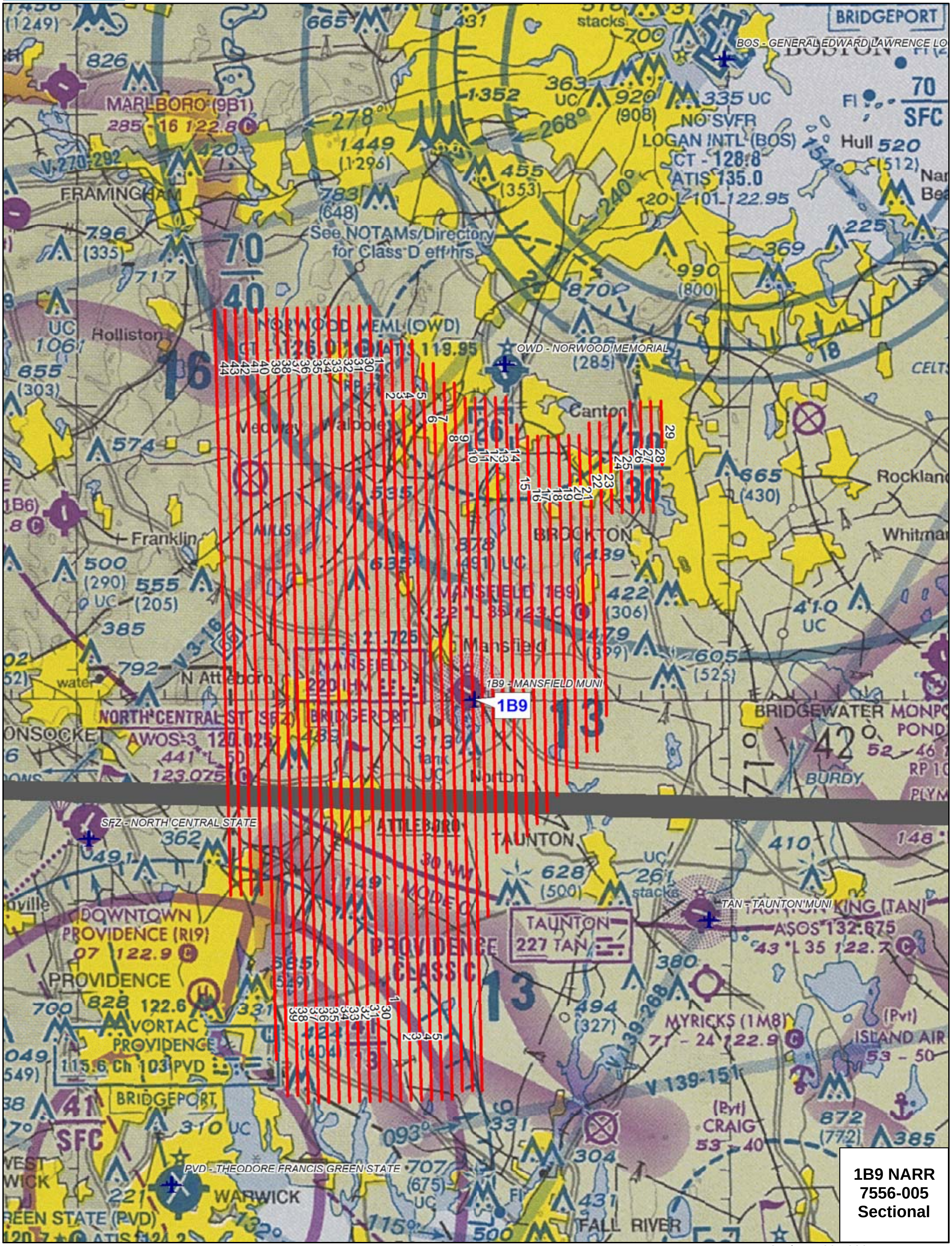





TN
MN (14.9°W)

Scale 1 : 325,000
1" = 5.13 mi
Data Zoom 9-2

XMap® 4.5

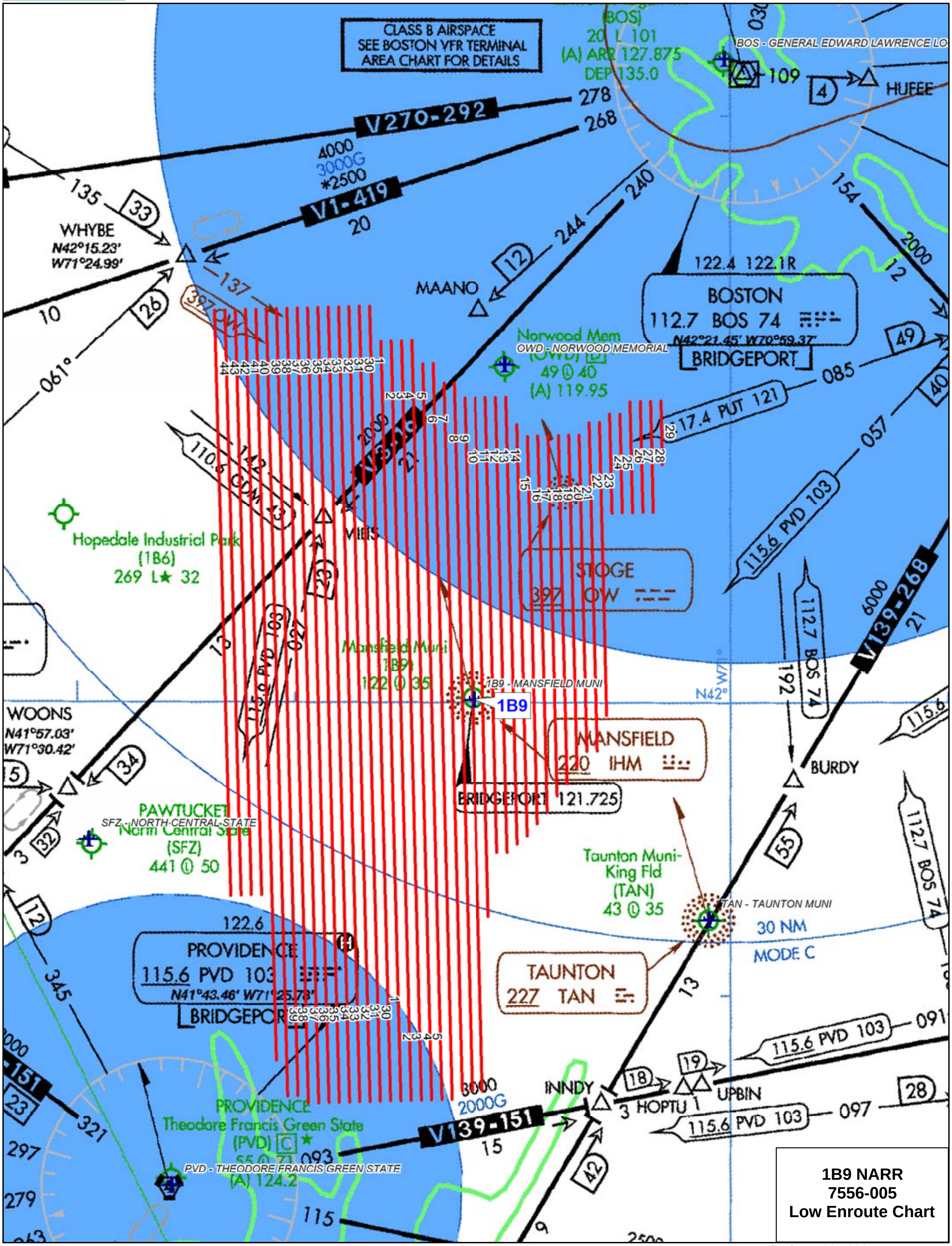



**1B9 NARR**
**7556-005**
**Sectional**

Scale 1 : 325,000

1" = 5.13 mi    Data Zoom 9-2

TN
MN (14.9°W)




Scale 1 : 325,000

1" = 5.13 mi

Data Zoom 9-2

TN

MN (14.9°W)

Mass Area: 1B9 NARR Project No 7556-005

*Contact: Photo Science; F Godby at 859 277-8700 or Cell: 859 421-5258*

# Flight Logs

| FLIGHT LINE | FL MILES | ALTITUDE | BASE STATION | FLIGHT FILES | DATE FLOWN | S/N | FIELD QC | Comments |
|---|---|---|---|---|---|---|---|---|
| 1 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 2 | 29.8 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 3 | 29.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 4 | 29.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 5 | 29.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 6 | 28.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 7 | 28.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 8 | 27.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 9 | 27.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 10 | 27.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 11 | 20.3 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 12 | 17.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 13 | 17.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |

*Flight Logs should be FAXED to 859-277-8901 immediately after each days flights with lines and other details noted*

*Operator:* ______________ *AIRCRAFT Tail Number:* ______________

*Pilot:* ______________ *Sensor Serial Number:* ______________ **Date:** ______________

| FLIGHT LINE | FL MILES | ALTITUDE | BASE STATION | FLIGHT FILES | DATE FLOWN | S/N | FIELD QC | Comments |
|---|---|---|---|---|---|---|---|---|
| 14 | 17.5 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 15 | 16.1 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 16 | 15.2 | 5170 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 17 | 14.8 | 5170 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 18 | 14.1 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 19 | 13.6 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 20 | 13.0 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 21 | 12.4 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 22 | 12.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 23 | 11.5 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 24 | 3.9 | 5240 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 25 | 3.9 | 5240 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 26 | 4.3 | 5230 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 27 | 4.3 | 5230 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |

*Flight Logs should be FAXED to 859-277-8901 immediately after each days flights with lines and other details noted*

*Operator:* ____________________ *AIRCRAFT Tail Number:* ____________________

*Pilot:* ____________________ *Sensor Serial Number:* ____________________ **Date:** ____________________

| FLIGHT LINE | FL MILES | ALTITUDE | BASE STATION | FLIGHT FILES | DATE FLOWN | S/N | FIELD QC | Comments |
|---|---|---|---|---|---|---|---|---|
| 28 | 4.3 | 5220 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 29 | 2.5 | 5210 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 30 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 31 | 31.2 | 5170 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 32 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 33 | 31.2 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 34 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 35 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 36 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 37 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 38 | 30.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 39 | 30.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 40 | 29.5 | 5170 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 41 | 22.9 | 5210 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |

*Flight Logs should be FAXED to 859-277-8901 immediately after each days flights with lines and other details noted*

*Operator:* ____________________ *AIRCRAFT Tail Number:* ____________________

*Pilot:* ____________________ *Sensor Serial Number:* ____________________ **Date:** ____________________

| FLIGHT LINE | FL MILES | ALTITUDE | BASE STATION | FLIGHT FILES | DATE FLOWN | S/N | FIELD QC | Comments |
|---|---|---|---|---|---|---|---|---|
| 42 | 22.9 | 5220 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 43 | 22.9 | 5210 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 44 | 22.9 | 5210 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |

*Flight Logs should be FAXED to 859-277-8901 immediately after each days flights with lines and other details noted*

Operator: ____________________ AIRCRAFT Tail Number: ____________________

Pilot: ____________________ Sensor Serial Number: ____________________ **Date:** ____________________

1Bq

PHOTO SCIENCE
Geospatial Solutions

# Station Occupation Report For Airborne GPS

**Project:** Narr - 1B9

**Location:** 1B9 **Project Number:** 7556-005

**Completed by:** Nathan Celieti **Date:** 12/8/10

**Receiver:** 2 S/N 1073

**Receiver Type:** Trimble 5700

**Antenna Type:** Zephyr Geodetic

**Station ID:** Narr-1B9

**Start -- H.I. (m):** 1.511 (m)

**End -- H.I. (m):** 1.511 (m)

**H.I. (ft):** 4.96 (ft)

**Start Time:** 9:28 AM EST

**End Time:** 3:29 PM EST

**Time Zone:** EST

**Operator:** Nathan Celieti

**Comments** Station used for N24486 & ~~A~~ 667
101208a+b-246
101208a+b-247

# LIDAR MISSION RECORD SHEET – Optech

PHOTO SCIENCE
Geospatial Solutions

2670 Wilhite Drive - Lexington KY - 40503 - 859.277.8700 - www.photoscience.com

| | |
|---|---|
| Project Name | FEMA MASS |
| Project Number | 7556-005 |
| ALTM-NAV-pln File | NARR_IB9_OP.pln |

| | |
|---|---|
| Pilot | Young |
| Operator | Berry |
| Aircraft | N7266Z |

| | | | | | |
|---|---|---|---|---|---|
| Date Flown: | December 8, 2010 | | | | |
| Takeoff Time (Z): | 1445Z | Local: | 945 EST | Airport | 1B9 |
| Landing Time (Z) | 1740Z | Local: | 1240 EST | Airport | 1B9 |

**Project's Scanning Requirements**

| | | | |
|---|---|---|---|
| FOV (half-degrees): | ± 18.0 ° | Altitude AGL (ft): | |
| Scan Rate: | 30.1 Hz | MPiA (circled) or SPiA | |
| Pulse Rate: | 71 kHz | Fixed or Auto (circled) | |
| Ground Speed: | 116 kts | A.R.F.: Samples | 1000 |
| | | Range | 300 |

**Data Information**

| | |
|---|---|
| LIDAR Unit | Optech Gemini sn246 |
| HD # | 246 HD1 |
| POS File Name | 101208a |
| from, to | 000 → 025 |

| | Ground | Airport |
|---|---|---|
| Begin Temp | -2°c | SFZ |
| Begin Dewpoint | -13°c | |
| Begin Pressure | 2973 | |
| End Temp | +1°c | SFZ |
| End Dewpoint | -13°c | |
| End Pressure | 2972 | |

| | | | |
|---|---|---|---|
| GPS Base Location(s) | Mansfield | | |
| PDOP Avoidance | Good all day | | |
| Static or Flyover? | Static | --> if flyovers, times: | - |

101208a-246

| Flight Line Name/# | Start Time | End Time | Alt. (AMSL) | Heading | Speed | Returns | Crab | NOTES (weather, visibility, winds, ride, etc.) |
|---|---|---|---|---|---|---|---|---|
| 4 | 1507 | 1521 | 5160' | S | 116 | 100% | 14 | Clouds above plan, turbulence |
| 3 | 1524 | 1538 | 5150' | N | 116 | 100% | -11 | |
| 2 | 1542 | 1556 | 4690' | S | 116 | 100% | 15 | |
| 1 | 1559 | 1614 | 4600' | N | 116 | 100% | -13 | |
| 30 | 1618 | 1632 | 4600' | S | 116 | 100% | 15 | |
| 31 | 1635 | 1649 | 4606' | N | 116 | 100% | -9 | |
| 32 | 1652 | 1707 | 4600' | S | 116 | 100% | 14 | Refly last 3miles |
| 33 | 1710 | 1724 | 4600' | N | 116 | 100% | -11 | Refly last 3miles |
| Improv | 1728 | 1730 | 4600' | E | 116 | 100% | -9 | |

Sheet 1 of __

300 ft

# LIDAR MISSION RECORD SHEET – Optech

PHOTO SCIENCE
Geospatial Solutions

2670 Wilhite Drive - Lexington KY - 40503 - 859.277.8700 - www.photoscience.com

| | |
|---|---|
| Project Name | Fema-Mass |
| Project Number | 7556-005 |
| ALTM-NAV-pln File | NARR 1B8-00.ph |

| Pilot | Young |
|---|---|
| Operator | Berry |
| Aircraft | N7266Z |

| Date Flown: | December 8, 2010 | | |
|---|---|---|---|
| Takeoff Time (Z): 1820Z | Local: 120PM EST | Airport 1B9 | |
| Landing Time (Z) 2200Z | Local: 500PM EST | Airport 1B9 | |

| Project's Scanning Requirements | | | |
|---|---|---|---|
| FOV (half-degrees): | ± 18 ° | Altitude AGL (ft): | 5000' |
| Scan Rate: | 30.1 Hz | MPiA or SPiA | |
| Pulse Rate: | 71 kHz | Fixed or Auto | |
| Ground Speed: | 116 kts | A.R.F.: Samples - Range - | |

| Data Information | |
|---|---|
| LIDAR Unit | Optech Gemini sn246 |
| HD # | 246HD1 |
| POS File Name | 101208b |
| from, to | 000 → 080 |

| | Ground | Airport |
|---|---|---|
| Begin Temp | -1°c | SFZ |
| Begin Dewpoint | -15°c | |
| Begin Pressure | 29.73 | |
| End Temp | -3°c | SFZ |
| End Dewpoint | -16°c | |
| End Pressure | 29.81 | |

340
15

| | | |
|---|---|---|
| GPS Base Location(s) | Mansfield | |
| PDOP Avoidance | Good all day | |
| Static or Flyover? | Static | --> if flyovers, times: - |

101208b-246

| Flight Line Name/# | Start Time | End Time | Alt. (AMSL) | Heading | Speed | Returns | Crab | NOTES (weather, visibility, winds, ride, etc.) |
|---|---|---|---|---|---|---|---|---|
| 34 | 1833 | 1848 | 4800' | S | 116 | 100% | 9 | Clouds above turbulence Refly S. end Smiles ✓ |
| 33 | 1852 | 1854 | 4750 | N | 116 | 100% | -11 | Patch |
| 32 | 1859 | 1902 | 4800' | S | 116 | 100% | 7 | Patch |
| 35 | 1905 | 1920 | 4750' | N | 116 | 100% | -10 | Refly N 1/5th ✓ |
| 36 | 1923 | 1937 | 4800' | S | 116 | 100% | 6 | Refly N 1/3rd ✓ |
| 37 | 1940 | 1955 | 4750' | N | 116 | 100% | -9 | Refly N 1/3rd ✓ |
| 38 | 1959 | 2013 | 4750' | S | 116 | 100% | 8 | Refly N 1/3rd ✓ |
| 39 | 2016 | 2031 | 4800' | N | 116 | 100% | -7 | Refly N half ✓ |
| 40 | 2034 | 2047 | 4800' | S | 116 | 100% | 8 | Refly N 1/3rd ✓ |
| 41 | 2051 | 2103 | 4800 | N | 116 | 100% | -9 | Refly N half ✓ |
| 42 | 2107 | 2117 | 4800 | S | 116 | 100% | 6 | Refly N 1/3rd |
| 43 | 2120 | 2131 | 4800 | N | 116 | 100% | -12 | Refly N 1/2 |
| 44 | 2134 | 2145 | 4800' | S | 116 | 100% | 8 | All good |
| Improv ov | 2148 | 2151 | 4850 | E | 116 | 100% | -8 | |

flight #1

# LIDAR MISSION RECORD SHEET – Optech

PHOTO SCIENCE Geospatial Solutions

2670 Wilhite Drive - Lexington KY - 40503 - 859.277.8700 - www.photoscience.com

| | |
|---|---|
| Project Name | Narr_IB9 |
| Project Number | 7556-005 |
| ALTM-NAV .pln File | NARR_IB9_OP.pln |

| Pilot | Greenwell |
|---|---|
| Operator | Galieti |
| Aircraft | N2448G |

| Date Flown: 12/8/10 | | |
|---|---|---|
| Takeoff Time (Z): 1438 | Local: 938 | Airport IB9 |
| Landing Time (Z): 1825 | Local: 1:25 | Airport IB9 |

**Project's Scanning Requirements**

| | | |
|---|---|---|
| FOV (half-degrees): | ± 18 ° | Altitude AGL (ft): 5000 |
| Scan Rate: | 30 Hz | MPiA or SPiA |
| Pulse Rate: | 70 kHz | Fixed or Auto |
| Ground Speed: | 116 kts | A.R.F.: Samples / Range |

**Data Information**

| | |
|---|---|
| LiDAR Unit | Optech Gemini sn247 |
| HD # | 2 |
| POS File Name | 101208a |
| from, to | D → |

| | Ground | Airport |
|---|---|---|
| Begin Temp | -4 | KBED |
| Begin Dewpoint | -12 | |
| Begin Pressure | 29.64 | |
| End Temp | | — |
| End Dewpoint | | |
| End Pressure | | |

Occasl CLDS @ ALT very light in area not on line

* CLDS @ prj altitude

101208a-247

| | | |
|---|---|---|
| GPS Base Location(s) | Narr_IB9 @ (IB9) | |
| PDOP Avoidance | none till 1920Z | |
| Static or Flyover? | static | --> if flyovers, times: |

| Flight Line Name/# | Start Time | End Time | Alt. (AMSL) | Heading | Speed | Returns | Crab | NOTES (weather, visibility, winds, ride, etc.) |
|---|---|---|---|---|---|---|---|---|
| 29 | 1507 | 1509 | 5218 | 178 | 116 | 100 | 13 | |
| 28 | 1513 | 1516 | 5282 | 358 | 114 | 100 | 9 | |
| 27 | 1520 | 1523 | 5215 | 178 | 123 | 100 | 13 | all clear reg TB occ. light cld @ alt |
| 26 | 1528 | 1531 | 5182 | 358 | 119 | 100 | 8 | around line. |
| 25 | 1535 | 1537 | 5232 | 178 | 116 | 100 | 13 | |
| 24 | 1542 | 1544 | 5153 | 358 | 111 | 99 | 7 | possible high drops @ N end |
| 23 | 1549 | 1554 | 5259 | 178 | 122 | 100 | 11 | 2-3 mi from S end light TB |
| 22 | 1559 | 1605 | 5128 | 358 | 110 | 100 | 9 | |
| 21 | 1610 | 1616 | 5183 | 178 | 118 | 100 | 12 | |
| descent due to clds → 20 | 1620 | 1627 | 5167 | 358 | 109 | 100 | 10 | CLDS @ AH around line CLR @ line |
| 19 | 1632 | 1638 | 4892* | 178 | 113 | 100 | 14 | OCL LGT TB @ S End |
| 18 | 1643 | 1650 | 4744* | 358 | 117 | 100 | 9 | OCL LGT TB @ S End ~5.6 mi |
| 17 | 1654 | 1702 | 4815* | 178 | 113 | 100 | 16 | OCL LGT TB & LGT wing rocking |
| 16 | 1706 | 1714 | 4857* | 358 | 116 | 100 | 9 | LGT TB through line |
| 15 | 1719 | 1727 | 4822* | 178 | 106 | 100 | 12 | LGT wing rocking through line |
| 14 | 1731 | 1740 | 4825* | 358 | 109 | 100 | 9 | LGT wing rocking through line |
| 5mi from with check overlap 13 | 1744 | 1752 | 4814* | 178 | 108 | 100 | 14 | |
| 12 | 1757 | 1806 | 4814* | 358 | 116 | 100 | 9 | |
| cross line | 1811 | 1814 | 4760* | 090 | 131 | 100 | 5 | |
| | | | | | | | | |

flight #2

# LIDAR MISSION RECORD SHEET – Optech

PHOTO SCIENCE Geospatial Solutions

2670 Wilhite Drive - Lexington KY - 40503 - 859.277.8700 - www.photoscience.com

| | |
|---|---|
| Project Name | Narr_1B9 |
| Project Number | 7556-005 |
| ALTM-NAV .pln File | NARR_1B9_OP.pln |

| | |
|---|---|
| Pilot | Greenwell |
| Operator | Gedieli |
| Aircraft | N2448G |

| | | | | | |
|---|---|---|---|---|---|
| Date Flown: | 12/8/16 | | | | |
| Takeoff Time (Z): | 1914 | Local: | 2:14 | Airport | 1B9 |
| Landing Time (Z): | 2200 | Local: | 5:00 | Airport | 1B9 |

| Project's Scanning Requirements | | | |
|---|---|---|---|
| FOV (half-degrees): | ± 18 ° | Altitude AGL (ft): | 5000 |
| Scan Rate: | 30 Hz | MPiA or SPiA | |
| Pulse Rate: | 70 kHz | Fixed or Auto | |
| Ground Speed: | 116 kts | A.R.F. : Samples / Range | |

| Data Information | |
|---|---|
| LiDAR Unit | Optech Gemini sn247 |
| HD # | 1 |
| POS File Name | 1012086 |
| from, to | 0 → |

| | Ground | Airport |
|---|---|---|
| Begin Temp | / | — |
| Begin Dewpoint | / | |
| Begin Pressure | 29.74 | |
| End Temp | / | — |
| End Dewpoint | / | |
| End Pressure | 29.74 | |

| | | |
|---|---|---|
| GPS Base Location(s) | 1B9 A (PAC) | |
| PDOP Avoidance | none till 1920 local | |
| Static or Flyover? | static | --> if flyovers, times: |

1012086-247

| Flight Line Name/# | Start Time | End Time | Alt. (AMSL) | Heading | Speed | Returns | Crab | NOTES (weather, visibility, winds, ride, etc.) |
|---|---|---|---|---|---|---|---|---|
| 11 | 1927 | 1936 | 5193 | 178 | 110 | ~100 | 8 | |
| 10 | 1943 | 1956 | 5100 | 358 | 113 | ~100 | 7 | |
| 9 | 2001 | 2014 | 5160 | 178 | 119 | ~100 | 10 | halfway down line lost nav data. |
| 8 | 2019 | 2032 | 5128 | 358 | 120 | ~100 | 8 | N end of line starting to look HZ |
| 7 | 2037 | 2050 | 5179 | 178 | 119 | ~100 | 10 | sun setting looking HZ, little fog @ 5 from N |
| 6 | 2055 | 2109 | 5174 | 358 | 126 | ~100 | 8 | |
| 5 | 2113 | 2127 | 5155 | 178 | 110 | ~100 | 12 | |
| cross line | 2134 | 2135 | 5000 | 090 | 132 | ~100 | 6 | |

Sheet 1 of 1

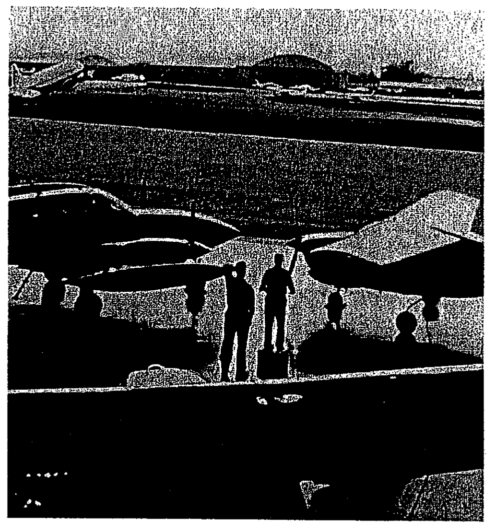
**PHOTO SCIENCE**
*Geospatial Solutions*

# Station Occupation Report For Airborne GPS

**Project:** Fema-Mass

**Location:** K1B9 (mansfield municipal) **Project Number:** 7556-005

**Completed by:** Berry **Date:** 12-10-2010



**Receiver:** Trimble "4"

**Receiver Type:** 5700

**Antenna Type:** Zephyr

**Station ID:** Mansfield

**Start -- H.I. (m):** 1.578

**End -- H.I. (m):** 1.578

**H.I. (ft):** 5.18

**Start Time:** 7:52 Am EST

**End Time:** 10:49Am EST

**Time Zone:** Est

**Operator:** Berry

**Comments** 101210a-246
101210a-247

# LIDAR MISSION RECORD SHEET – Optech

PHOTO SCIENCE Geospatial Solutions
2670 Wilhite Drive - Lexington KY - 40503 - 859.277.8700 - www.photoscience.com

| | |
|---|---|
| Project Name | Fema-mass |
| Project Number | 7556-005 |
| ALTM-NAV pln File | NARR-1B9-OP.ph |

| Pilot | Young |
|---|---|
| Operator | Berry |
| Aircraft | N7266Z |

| | | | | | |
|---|---|---|---|---|---|
| Date Flown: | December 10, 2010 | | | | |
| Takeoff Time (Z): | 1305Z | Local: | 805 AM EST | Airport | 1B9 |
| Landing Time (Z) | 1506Z | Local: | 1006 PM EST | Airport | 1B9 |

| Project's Scanning Requirements | | | |
|---|---|---|---|
| FOV (half-degrees): | ± 18.0 ° | Altitude AGL (ft): | 5000' |
| Scan Rate: | 36.10 Hz | MPiA or SPiA | |
| Pulse Rate: | 71 kHz | Fixed or Auto | |
| Ground Speed: | 116 kts | A.R.F.: | Samples 1000 Range 300 |

| Data Information | |
|---|---|
| LiDAR Unit | Optech Gemini ~~sn~~246 |
| HD # | 246 HD2 |
| POS File Name | 101210a |
| from, to | 000 → 017 |

| | Ground | Airport |
|---|---|---|
| Begin Temp | -11°C | SFZ |
| Begin Dewpoint | -15°C | |
| Begin Pressure | 30.39 | |
| End Temp | -9°C | SFZ |
| End Dewpoint | -14°C | |
| End Pressure | 30.38 | |

Chm

| | | |
|---|---|---|
| GPS Base Location(s) | Mansfield | |
| PDOP Avoidance | Good all day | |
| Static or Flyover? | Static | --> if flyovers, times: – |

101210a-246

| Flight Line Name/# | Start Time | End Time | Alt. (AMSL) | Heading | Speed | Returns | Crab | NOTES (weather, visibility, winds, ride, etc.) |
|---|---|---|---|---|---|---|---|---|
| 34 | 1313 | 1319 | 5200 | S | 116 | 100% | 5 | Clear Smooth @ altitude |
| 35 | 1328 | 1335 | 5200' | N | 116 | 100% | -4 | All Insare patches for this area |
| 36 | 1338 | 1344 | 5200' | S | 116 | 100% | 3 | " |
| 37 | 1347 | 1354 | 5200' | N | 116 | 100% | -6 | " plane 7 miles |
| 38 | 1358 | 1404 | 5200' | S | 116 | 100% | 3 | " |
| 39 | 1408 | 1415 | 5200 | N | 116 | 100% | -5 | " |
| 40 | 1419 | 1425 | 5200' | S | 116 | 100% | 5 | " |
| 41 | 1429 | 1435 | 5200' | N | 116 | 100% | -4 | " |
| 42 | 1438 | 1444 | 5200' | S | 116 | 100% | 4 | " |
| 43 | 1447 | 1453 | 5200 | N | 116 | 100% | -5 | " |
| Improv | 1455 | 1458 | 5200 | E | 116 | 100% | -2 | " |

# LIDAR MISSION RECORD SHEET – Optech

PHOTO SCIENCE Geospatial Solutions

2670 Wilhite Drive - Lexington KY - 40503 - 859.277.8700 - www.photoscience.com

| | |
|---|---|
| Project Name | 1B9 NARR |
| Project Number | 7556_005 |
| ALTM-NAV pln File | NARR_1B9_OP.pln |

| | |
|---|---|
| Pilot | Greenwell |
| Operator | Galicki |
| Aircraft | N2448G |

| | | |
|---|---|---|
| Date Flown: 12/10/10 #1 | | |
| Takeoff Time (Z): 1210 | Local: 7:10 | Airport BED |
| Landing Time (Z): 1530 | Local: 10:30 | Airport 1B9 |

| Project's Scanning Requirements | | | |
|---|---|---|---|
| FOV (half-degrees): | ± 18 ° | Altitude AGL (ft): | 5000 |
| Scan Rate: | 30 Hz | MPiA or SPiA | |
| Pulse Rate: | 70 kHz | Fixed or Auto | |
| Ground Speed: | 116 kts | A.R.F.: Samples / Range | |

| Data Information | |
|---|---|
| LiDAR Unit | Optech Gemini sn247 |
| HD # | 2 |
| POS File Name | 101210a |
| from, to | 0 → 20 |

| | Ground | Airport |
|---|---|---|
| Begin Temp | -14 C | KBED |
| Begin Dewpoint | -16 C | |
| Begin Pressure | 30.43Hg | |
| End Temp | ~~-4~~ C -7 | KBED. |
| End Dewpoint | -14 ~~-7~~ C | |
| End Pressure | ~~30.43Hg~~ 30.48 | |

| | |
|---|---|
| GPS Base Location(s) | 1B9 (NARR_1B9) (PAC) |
| PDOP Avoidance | none during day |
| Static or Flyover? | Static --> if flyovers, times: |

101210a-247

| Flight Line Name/# | Start Time | End Time | Alt. (AMSL) | Heading | Speed | Returns | Crab | NOTES (weather, visibility, winds, ride, etc.) |
|---|---|---|---|---|---|---|---|---|
| 11 | 1319 | 1327 | 4931 | 178 | 113 | 100 | 4 | |
| 10 | 1331 | 1340 | 5090 | 358 | 120 | 100 | 4 | |
| 9 | 1345 | 1353 | 5160 | 178 | 119 | 100 | 5 | |
| 8 | 1359 | 1407 | 5150 | 358 | 120 | 100 | 3 | |
| 7 | 1413 | 1426 | 5180 | 178 | 116 | 100 | 4 | 4-5 mi from N plane flew under |
| 6 | 1432 | 1445 | 5125 | 358 | 117 | 100 | 4 | ~~poss.~~ plane 3 mi from N end |
| 5 | 1450 | 1504 | 5150 | 178 | 120 | 100 | 5 | |
| crossline | 1511 | 1513 | 5090 | 090 | 122 | 100 | 1 | |
| | | | | | | | | |
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| | | | | | | | | |

# Mass Area: 1B9 NARR    Project No 7556-005

Contact: Photo Science; F Godby at 859 277-8700 or Cell: 859 421-5258

**Flight Logs**

| FLIGHT LINE | FL MILES | ALTITUDE | BASE STATION | FLIGHT FILES | DATE FLOWN | S/N | FIELD QC | Comments |
|---|---|---|---|---|---|---|---|---|
| 1 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12-8-10 | 246 | JB | Some Clusters |
| 2 | 29.8 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | of Atmospheric |
| 3 | 29.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | returns |
| 4 | 29.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 5 | 29.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | 247 | NG | |
| 6 | 28.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 7 | 28.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 8 | 27.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 9 | 27.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 10 | 27.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 11 | 20.3 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 12 | 17.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 13 | 17.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |

Flight Logs should be FAXED to 859-277-8901 immediately after each days flights with lines and other details noted

**Operator:** Barry

**Pilot:** [illegible]

**AIRCRAFT Tail Number:** 726[illegible]

**Sensor Serial Number:** 246

**Date:** 12-8-10

| FLIGHT LINE | FL MILES | ALTITUDE | BASE STATION | FLIGHT FILES | DATE FLOWN | S/N | FIELD QC | Comments |
|---|---|---|---|---|---|---|---|---|
| 14 | 17.5 | 5160 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | 12-8-10 | 247 | NG | |
| 15 | 16.1 | 5160 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 16 | 15.2 | 5170 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 17 | 14.8 | 5170 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 18 | 14.1 | 5160 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 19 | 13.6 | 5150 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 20 | 13.0 | 5150 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 21 | 12.4 | 5160 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 22 | 12.9 | 5150 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 23 | 11.5 | 5160 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 24 | 3.9 | 5240 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 25 | 3.9 | 5240 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 26 | 4.3 | 5230 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 27 | 4.3 | 5230 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |

*Flight Logs should be FAXED to 859-277-8901 immediately after each days flights with lines and other details noted*

**Operator:** Berry
**Pilot:** [illegible]
**AIRCRAFT Tail Number:** N2226
**Sensor Serial Number:** 246
**Date:** 12-8-10

| FLIGHT LINE | FL MILES | ALTITUDE | BASE STATION | FLIGHT FILES | DATE FLOWN | S/N | FIELD QC | Comments |
|---|---|---|---|---|---|---|---|---|
| 28 | 4.3 | 5220 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | 12-8-10 | 247 | NG | |
| 29 | 2.5 | 5210 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 30 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | 12-8-10 | 246 | JB | |
| 31 | 31.2 | 5170 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 32 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 33 | 31.2 | 5150 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | Reflight Needed Reflight 10-12 |
| 34 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 35 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 36 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 37 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 38 | 30.9 | 5150 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 39 | 30.9 | 5150 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 40 | 29.5 | 5170 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 41 | 22.9 | 5210 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |

*Flight Logs should be FAXED to 859-277-8901 immediately after each days flights with lines and other details noted*

**Operator:** Berry

**Pilot:** Young

**AIRCRAFT Tail Number:** N726GT

**Sensor Serial Number:** 246



**Date:** 12-8-2010

| FLIGHT LINE | FL MILES | ALTITUDE | BASE STATION | FLIGHT FILES | DATE FLOWN | S/N | FIELD QC | Comments |
|---|---|---|---|---|---|---|---|---|
| 42 | 22.9 | 5220 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | Refight Needed Reflight 10-12 |
| 43 | 22.9 | 5210 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |
| 44 | 22.9 | 5210 | 1B9_NAR | NARR_1B9_O 1B9_NARRA_ | | | | |

*Flight Logs should be FAXED to 859-277-8901 immediately after each days flights with lines and other details noted*

**Operator:** Berry

**Pilot:** Yeoman

**AIRCRAFT Tail Number:** 726G7

**Sensor Serial Number:** 246

**Date:** 12-8-10

# Mass Area: 1B9 NARR Project No 7556-005 Flight Logs

Contact: Photo Science; F Godby at 859 277-8700 or Cell: 859 421-5258

| FLIGHT LINE | FL MILES | ALTITUDE | BASE STATION | FLIGHT FILES | DATE FLOWN | S/N | FIELD QC | Comments |
|---|---|---|---|---|---|---|---|---|
| 1 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 2 | 29.8 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 3 | 29.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 4 | 29.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 5 | 29.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247b | | |
| 6 | 28.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247b | | |
| 7 | 28.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247b | | |
| 8 | 27.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247b | | |
| 9 | 27.8 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247b | | |
| 10 | 27.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247b | | |
| 11 | 20.3 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247b | | |
| 12 | 17.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247a | | |
| 13 | 17.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247a | | |

*Flight Logs should be FAXED to 859-277-8901 immediately after each days flights with lines and other details noted*

**Operator:** Galieti **AIRCRAFT Tail Number:** N24486

**Pilot:** Greenwell **Sensor Serial Number:** 247 **Date:** 12/8/10

| FLIGHT LINE | FL MILES | ALTITUDE | BASE STATION | FLIGHT FILES | DATE FLOWN | S/N | FIELD QC | Comments |
|---|---|---|---|---|---|---|---|---|
| 14 | 17.5 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247a | | |
| 15 | 16.1 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 16 | 15.2 | 5170 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 17 | 14.8 | 5170 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 18 | 14.1 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 19 | 13.6 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 20 | 13.0 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 21 | 12.4 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 22 | 12.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 23 | 11.5 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 24 | 3.9 | 5240 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 25 | 3.9 | 5240 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 26 | 4.3 | 5230 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | | | |
| 27 | 4.3 | 5230 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | ✓ | | |

*Flight Logs should be FAXED to 859-277-8901 immediately after each days flights with lines and other details noted*

**Operator:** Galieti **AIRCRAFT Tail Number:** N2448G

**Pilot:** Greenwell **Sensor Serial Number:** 247 **Date:** 12/8/10

| FLIGHT LINE | FL MILES | ALTITUDE | BASE STATION | FLIGHT FILES | DATE FLOWN | S/N | FIELD QC | Comments |
|---|---|---|---|---|---|---|---|---|
| 28 | 4.3 | 5220 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247a | | |
| 29 | 2.5 | 5210 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | 12/8/10 | 247a | | |
| 30 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 31 | 31.2 | 5170 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 32 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 33 | 31.2 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 34 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 35 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 36 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 37 | 31.2 | 5160 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 38 | 30.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 39 | 30.9 | 5150 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 40 | 29.5 | 5170 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |
| 41 | 22.9 | 5210 | 1B9_NAR | NARR_1B9_O<br>1B9_NARRA_ | | | | |

*Flight Logs should be FAXED to 859-277-8901 immediately after each days flights with lines and other details noted*

**Operator:** Galieti

**Pilot:** Greenwell

**AIRCRAFT Tail Number:** N2 448G

**Sensor Serial Number:** 247

**Date:** 12/8/10

```
Plan Type : Fixed Survey

******************Survey Totals*********************************
Total Passes      : 44
Total Length      : 1522.498 km
Total Flight Time : 11:35:33
Total Laser Time  : 07:02:55
Total Swath Area  : 1054.223 km^2
Total AOI Area    : 1428.98 km^2


Number of Sub-Areas : 1

******************Area 1*********************************

Area Flight Profile
-----------------------------
Total Length  : 1522.498 km
Flight Time   : 11:35:33
Laser Time    : 07:02:55
Swath Area    : 346.962 km^2
AOI Area      : 1428.98 km^2
Altitude      : 5000 ft AGL
Speed         : 116.6 kts
Flight Lines  : 44
Pass Heading  : 178.49
Pass Spacing  : 227.89 m
Overlap       : 30% = 761.29 m
Turn Time     : 5 min

Area LIDAR Settings
-----------------------------
Desired Res     : 0.912 m
Density         : 1.2 ppm^2
Cross Track Res : 0.835 m
Down Track Res  : 0.997 m
Scan Frequency  : 30.1 Hz
Scan Angle      :  18 deg
Scan Cutoff     :  0.02 deg
Scan Offset     : 0 deg
System PRF      : 71.429 kHz
Swath Width     : 989.18 m
DEM Estimates
-----------------------------
DEM Min Z       : -1
DEM Max Z       : 483

Cost Estimates
-----------------------------
Area Cost       : $0
Time Cost       : $0
```

```
           Flight Log
------------------------------
Project Number: 7556-005
S/N           : 247
Operator      : Galieti
Pilot(s)      : Greenwell
Aircraft      : N2448G
Airport       : KBED & 1B9
Mission       : 1
Wheels Up     : 1300 Z
Flight Length :
HOBBS Start   :
HOBBS End     :

           Weather
------------------------------
Date          : December 10, 2010
Julian Day    : 344
Temperature   : -14 C
Visibility    : clear
Clouds        : High OVC
Precipitation : none
Wind Dir      :
Wind Speed    :
Pressure      : 30.43 HG
           Statistics
------------------------------
Laser Time    : 01:14:32

=======================================
13:01:35.751 GMT : 00:00:02 (212) GPS 1PPS Lost
13:01:35.751 GMT : 00:00:03 (166) Divergence Error
13:01:35.751 GMT : 00:00:03 (107) Rx Shutter Closed
13:01:35.751 GMT : 00:00:03 (109) Tx Shutter Closed
13:01:35.751 GMT : 00:00:04 (164) Beam Wide
13:01:35.751 GMT : 00:00:12 (204) POSAV Connected
13:01:35.751 GMT : 00:00:13 (207) POSAV Rate Not 50 Hz
13:01:35.751 GMT : 00:00:13 (211) POSAV new status
13:01:35.751 GMT : 00:00:14 (213) GPS 1PPS Ok
13:01:35.751 GMT : 00:00:23 (120) Laser PS Comm Ok
13:01:35.751 GMT : 00:00:23 (112) Laser Emission Off
13:01:35.751 GMT : 00:00:45 (208) POSAV Rate Is 50 Hz
13:01:35.751 GMT : 00:00:45 (211) POSAV new status
13:01:35.751 GMT : 00:00:46 (215) Nav Data Ok
13:01:35.751 GMT : 00:00:47 (211) POSAV new status
13:01:35.751 GMT : 00:01:33 (211) POSAV new status
13:01:35.751 GMT : 00:01:45 (211) POSAV new status
13:01:35.751 GMT : 12:23:55 (211) POSAV new status
12:58:37.175 GMT : 12:58:35 (153) Eyesafety Disabled
12:58:37.275 GMT : 12:58:35 (162) Roll Comp On
12:58:37.875 GMT : 12:58:36 (164) Beam Wide
12:58:37.875 GMT : 12:58:36 (144) MultiPulse Mode Varies
12:58:41.475 GMT : 12:58:40 (165) Beam Narrow
```

```
12:59:34.076 GMT : 12:59:32 (157) Safe Unaided Profile
12:59:34.076 GMT : 12:59:32 (157) Safe Unaided Profile
13:05:13.78 GMT : 13:05:12 (157) Safe Unaided Profile
13:05:13.98 GMT : 13:05:12 (157) Safe Unaided Profile
13:05:19.48 GMT : 13:05:17 (106) Rx Shutter Open
13:05:19.48 GMT : 13:05:17 (108) Tx Shutter Open
13:19:45.49 GMT : 13:19:44 (113) Laser Emission On
13:27:52.396 GMT : 13:27:50 (112) Laser Emission Off
13:31:56.099 GMT : 13:31:55 (113) Laser Emission On
13:40:11.905 GMT : 13:40:09 (112) Laser Emission Off
13:45:23.408 GMT : 13:45:22 (113) Laser Emission On
13:53:50.615 GMT : 13:53:49 (112) Laser Emission Off
13:59:24.419 GMT : 13:59:23 (113) Laser Emission On
14:07:56.425 GMT : 14:07:55 (112) Laser Emission Off
14:13:34.23 GMT : 14:13:33 (113) Laser Emission On
14:26:46.44 GMT : 14:26:45 (112) Laser Emission Off
14:32:07.544 GMT : 14:32:06 (113) Laser Emission On
14:45:16.755 GMT : 14:45:15 (112) Laser Emission Off
14:50:39.959 GMT : 14:50:39 (113) Laser Emission On
15:04:08.37 GMT : 15:04:07 (112) Laser Emission Off
15:11:56.777 GMT : 15:11:55 (113) Laser Emission On
15:13:46.778 GMT : 15:13:45 (112) Laser Emission Off
15:15:22.28 GMT : 15:15:21 (157) Safe Unaided Profile
15:15:27.18 GMT : 15:15:25 (107) Rx Shutter Closed
15:15:27.28 GMT : 15:15:25 (109) Tx Shutter Closed

            Flight Log
------------------------------
Project Number: 7556-005
S/N           : 247
Operator      : Galieti
Pilot(s)      : Greenwell
Aircraft      : N2448G
Airport       : KBED & 1B9
Mission       : 1
Wheels Up     : 1300 Z
Flight Length :
HOBBS Start   :
HOBBS End     :

            Weather
------------------------------
Date          : December 10, 2010
Julian Day    : 344
Temperature   : -14 C
Visibility    : clear
Clouds        : High OVC
Precipitation : none
Wind Dir      :
Wind Speed    :
Pressure      : 30.43 HG
            Statistics
------------------------------
Laser Time    : 01:14:32
```

========================================

## Flight Log

------------------------------

Project Number: 7556-005
S/N : 247
Operator : Galieti
Pilot(s) : Greenwell
Aircraft : N2448G
Airport : KBED & 1B9
Mission : 1
Wheels Up : 1300 Z
Flight Length :
HOBBS Start :
HOBBS End :

## Weather

------------------------------

Date : December 10, 2010
Julian Day : 344
Temperature : -14 C
Visibility : clear
Clouds : High OVC
Precipitation : none
Wind Dir :
Wind Speed :
Pressure : 30.43 HG

## Statistics

------------------------------

Laser Time : 01:14:32

| START | STOP | LINE# | ALT | PRF | FREQ | ANGLE | MP | DIV | RC | HDG | Plan File |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13:19:46.19 | 13:27:52.696 | 11 | 1521 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.54 |
| 13:31:57.199 | 13:40:11.705 | 10 | 1585 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.54 |
| 13:45:24.008 | 13:53:51.515 | 9 | 1577 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.53 |
| 13:59:25.419 | 14:07:57.725 | 8 | 1570 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.53 |
| 14:13:35.23 | 14:26:48.44 | 7 | 1583 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.52 |
| 14:32:08.144 | 14:45:17.555 | 6 | 1572 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.51 |
| 14:50:40.759 | 15:04:10.07 | 5 | 1580 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.51 |
| 15:11:57.677 | 15:13:48.178 | 5 | 1585 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.51 |

```
           Flight Log
------------------------------
Project Number: 7556-005
S/N           : 246
Operator      : BERRY
Pilot(s)      : YOUNG
Aircraft      : N7266Z
Airport       : K1B9
Mission       : 101210A
Wheels Up     : 1305Z
Flight Length :
HOBBS Start   :
HOBBS End     :

           Weather
------------------------------
Date          : December 10, 2010
Julian Day    : 344
Temperature   : -11C
Visibility    : >10
Clouds        : 11000FT
Precipitation : NO
Wind Dir      : CLM
Wind Speed    : CLM
Pressure      : 30.39
           Statistics
------------------------------
Laser Time    : 01:03:09

=======================================
08:33:06.953 GMT : 00:00:02 (212) GPS 1PPS Lost
08:33:06.953 GMT : 00:00:03 (166) Divergence Error
08:33:06.953 GMT : 00:00:03 (107) Rx Shutter Closed
08:33:06.953 GMT : 00:00:03 (109) Tx Shutter Closed
08:33:06.953 GMT : 00:00:04 (164) Beam Wide
08:33:06.953 GMT : 00:00:09 (120) Laser PS Comm Ok
08:33:06.953 GMT : 00:00:09 (112) Laser Emission Off
08:33:06.953 GMT : 00:00:11 (213) GPS 1PPS Ok
08:33:06.953 GMT : 00:00:12 (204) POSAV Connected
08:33:06.953 GMT : 00:00:12 (207) POSAV Rate Not 50 Hz
08:33:06.953 GMT : 00:00:13 (211) POSAV new status
08:33:06.953 GMT : 00:00:25 (208) POSAV Rate Is 50 Hz
08:33:06.953 GMT : 00:00:26 (211) POSAV new status
08:33:06.953 GMT : 00:00:26 (215) Nav Data Ok
08:33:06.953 GMT : 00:00:27 (211) POSAV new status
08:33:06.953 GMT : 00:01:56 (211) POSAV new status
13:00:14.809 GMT : 00:04:39 (211) POSAV new status
13:04:33.813 GMT : 13:04:32 (211) POSAV new status
13:05:20.114 GMT : 13:05:19 (153) Eyesafety Disabled
13:05:20.314 GMT : 13:05:19 (162) Roll Comp On
13:05:20.714 GMT : 13:05:20 (164) Beam Wide
13:05:20.914 GMT : 13:05:20 (144) MultiPulse Mode Varies
13:05:25.514 GMT : 13:05:25 (165) Beam Narrow
13:05:37.214 GMT : 13:05:36 (106) Rx Shutter Open
```

```
13:05:37.314 GMT : 13:05:36 (108) Tx Shutter Open
13:13:21.622 GMT : 13:13:20 (113) Laser Emission On
13:19:12.827 GMT : 13:19:11 (112) Laser Emission Off
13:28:28.036 GMT : 13:28:27 (113) Laser Emission On
13:35:28.343 GMT : 13:35:27 (112) Laser Emission Off
13:38:17.346 GMT : 13:38:16 (113) Laser Emission On
13:44:23.952 GMT : 13:44:23 (112) Laser Emission Off
13:47:43.055 GMT : 13:47:42 (113) Laser Emission On
13:54:02.362 GMT : 13:54:00 (112) Laser Emission Off
13:58:11.267 GMT : 13:58:10 (113) Laser Emission On
14:04:21.874 GMT : 14:04:21 (112) Laser Emission Off
14:08:43.979 GMT : 14:08:43 (113) Laser Emission On
14:15:57.888 GMT : 14:15:56 (112) Laser Emission Off
14:19:41.093 GMT : 14:19:40 (113) Laser Emission On
14:25:34.4 GMT : 14:25:33 (112) Laser Emission Off
14:29:08.604 GMT : 14:29:08 (113) Laser Emission On
14:35:14.512 GMT : 14:35:13 (112) Laser Emission Off
14:38:53.217 GMT : 14:38:52 (113) Laser Emission On
14:44:13.523 GMT : 14:44:11 (112) Laser Emission Off
14:47:29.428 GMT : 14:47:28 (113) Laser Emission On
14:53:02.735 GMT : 14:53:02 (112) Laser Emission Off
14:55:54.238 GMT : 14:55:53 (113) Laser Emission On
14:58:05.541 GMT : 14:58:04 (112) Laser Emission Off
14:58:20.342 GMT : 14:58:19 (107) Rx Shutter Closed
14:58:20.442 GMT : 14:58:19 (109) Tx Shutter Closed

           Flight Log
------------------------------
Project Number: 7556-005
S/N           : 246
Operator      : BERRY
Pilot(s)      : YOUNG
Aircraft      : N7266Z
Airport       : K1B9
Mission       : 101210A
Wheels Up     : 1305Z
Flight Length :
HOBBS Start   :
HOBBS End     :

           Weather
------------------------------
Date          : December 10, 2010
Julian Day    : 344
Temperature   : -11C
Visibility    : >10
Clouds        : 11000FT
Precipitation : NO
Wind Dir      : CLM
Wind Speed    : CLM
Pressure      : 30.39
           Statistics
------------------------------
Laser Time    : 01:03:09
```

========================================

Flight Log

------------------------------

Project Number: 7556-005
S/N : 246
Operator : BERRY
Pilot(s) : YOUNG
Aircraft : N7266Z
Airport : K1B9
Mission : 101210A
Wheels Up : 1305Z
Flight Length :
HOBBS Start :
HOBBS End :

Weather

------------------------------

Date : December 10, 2010
Julian Day : 344
Temperature : -11C
Visibility : >10
Clouds : 11000FT
Precipitation : NO
Wind Dir : CLM
Wind Speed : CLM
Pressure : 30.39

Statistics

------------------------------

Laser Time : 01:03:09

| START | STOP | LINE# | ALT | PRF | FREQ | ANGLE | MP | DIV | RC | HDG | Plan File |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13:13:21.422 | 13:19:14.227 | 35 | 1576 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.46 |
| 13:28:28.536 | 13:35:29.543 | 36 | 1577 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.45 |
| 13:38:17.446 | 13:44:24.752 | 37 | 1574 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.45 |
| 13:47:43.555 | 13:54:03.762 | 37 | 1569 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.45 |
| 13:58:11.967 | 14:04:22.774 | 39 | 1571 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.43 |
| 14:08:44.679 | 14:15:58.388 | 40 | 1570 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.43 |
| 14:19:41.593 | 14:25:34.6 | 41 | 1576 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.42 |
| 14:29:09.604 | 14:35:15.712 | 42 | 1587 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.41 |

```
 14:38:54.017  14:44:13.223    43   1592   70    30.10   18.00   ON  NAR
ON       0.00        358.41
 14:47:29.528  14:53:03.435    43   1587   70    30.10   18.00   ON  NAR
ON       0.00        358.41
 14:55:54.939  14:58:06.241    43   1583   70    30.10   18.00   ON  NAR
ON       0.00        358.41

           Flight Log
------------------------------
Project Number: 0
S/N           : 0
Operator      : ???
Pilot(s)      : ???
Aircraft      : ???
Airport       : ???
Mission       : ???
Wheels Up     : ???
Flight Length :
HOBBS Start   :
HOBBS End     :
           Weather
------------------------------
Date          : December 08, 2010
Julian Day    : 342
Temperature   : ???
Visibility    : ???
Clouds        : ???
Precipitation : ???
Wind Dir      : ???
Wind Speed    : ???
Pressure      : ???
           Statistics
------------------------------
Laser Time    : 0

=======================================

           Flight Log
------------------------------
Project Number: 0
S/N           : 0
Operator      : ???
Pilot(s)      : ???
Aircraft      : ???
Airport       : ???
Mission       : ???
Wheels Up     : ???
Flight Length :
HOBBS Start   :
HOBBS End     :
           Weather
------------------------------
Date          : December 08, 2010
Julian Day    : 342
```

```
Temperature   : ???
Visibility    : ???
Clouds        : ???
Precipitation : ???
Wind Dir      : ???
Wind Speed    : ???
Pressure      : ???
           Statistics
------------------------------
Laser Time    : 0

=======================================

           Flight Log
------------------------------
Project Number: 0
S/N           : 0
Operator      : ???
Pilot(s)      : ???
Aircraft      : ???
Airport       : ???
Mission       : ???
Wheels Up     : ???
Flight Length :
HOBBS Start   :
HOBBS End     :
           Weather
------------------------------
Date          : December 08, 2010
Julian Day    : 342
Temperature   : ???
Visibility    : ???
Clouds        : ???
Precipitation : ???
Wind Dir      : ???
Wind Speed    : ???
Pressure      : ???
           Statistics
------------------------------
Laser Time    : 0



        START          STOP LINE#    ALT  PRF     FREQ   ANGLE   MP  DIV
RC        HDG    Plan File
=======================================

           Flight Log
------------------------------
Project Number: 0
S/N           : 0
Operator      : ???
Pilot(s)      : ???
Aircraft      : ???
```

```
Airport       : ???
Mission       : ???
Wheels Up     : ???
Flight Length :
HOBBS Start   :
HOBBS End     :

           Weather
------------------------------
Date          : December 08, 2010
Julian Day    : 342
Temperature   : ???
Visibility    : ???
Clouds        : ???
Precipitation : ???
Wind Dir      : ???
Wind Speed    : ???
Pressure      : ???
           Statistics
------------------------------
Laser Time    : 01:56:27

=======================================
10:25:56.168 GMT : 14:59:40 (106) Rx Shutter Open
10:25:56.168 GMT : 14:59:41 (108) Tx Shutter Open
10:25:56.168 GMT : 15:00:29 (109) Tx Shutter Closed
10:25:56.168 GMT : 15:00:30 (107) Rx Shutter Closed
10:25:56.168 GMT : 15:00:49 (108) Tx Shutter Open
10:25:56.168 GMT : 15:00:52 (106) Rx Shutter Open
10:25:56.168 GMT : 15:00:53 (107) Rx Shutter Closed
10:25:56.168 GMT : 15:00:57 (106) Rx Shutter Open
15:02:52.437 GMT : 15:02:51 (107) Rx Shutter Closed
15:02:52.637 GMT : 15:02:51 (109) Tx Shutter Closed
15:03:00.337 GMT : 15:02:59 (106) Rx Shutter Open
15:03:00.337 GMT : 15:02:59 (108) Tx Shutter Open
15:07:15.34 GMT : 15:07:14 (113) Laser Emission On
15:21:11.153 GMT : 15:21:10 (112) Laser Emission Off
15:24:24.756 GMT : 15:24:24 (113) Laser Emission On
15:38:51.47 GMT : 15:38:50 (112) Laser Emission Off
15:42:26.974 GMT : 15:42:26 (113) Laser Emission On
15:56:21.288 GMT : 15:56:20 (112) Laser Emission Off
15:59:30.992 GMT : 15:59:30 (113) Laser Emission On
16:14:25.108 GMT : 16:14:24 (112) Laser Emission Off
16:18:22.113 GMT : 16:18:21 (113) Laser Emission On
16:32:42.529 GMT : 16:32:41 (112) Laser Emission Off
16:35:10.432 GMT : 16:35:09 (113) Laser Emission On
16:49:53.45 GMT : 16:49:51 (112) Laser Emission Off
16:52:53.454 GMT : 16:52:52 (113) Laser Emission On
17:07:18.672 GMT : 17:07:17 (112) Laser Emission Off
17:10:06.575 GMT : 17:10:06 (113) Laser Emission On
17:24:50.994 GMT : 17:24:49 (112) Laser Emission Off
17:28:31.998 GMT : 17:28:31 (113) Laser Emission On
17:30:07 GMT : 17:30:06 (112) Laser Emission Off
17:31:34.402 GMT : 17:31:33 (107) Rx Shutter Closed
```

```
17:31:34.402 GMT : 17:31:33 (109) Tx Shutter Closed

           Flight Log
------------------------------
Project Number: 0
S/N           : 0
Operator      : ???
Pilot(s)      : ???
Aircraft      : ???
Airport       : ???
Mission       : ???
Wheels Up     : ???
Flight Length :
HOBBS Start   :
HOBBS End     :

           Weather
------------------------------
Date          : December 08, 2010
Julian Day    : 342
Temperature   : ???
Visibility    : ???
Clouds        : ???
Precipitation : ???
Wind Dir      : ???
Wind Speed    : ???
Pressure      : ???
           Statistics
------------------------------
Laser Time    : 01:56:27

=======================================

           Flight Log
------------------------------
Project Number: 0
S/N           : 0
Operator      : ???
Pilot(s)      : ???
Aircraft      : ???
Airport       : ???
Mission       : ???
Wheels Up     : ???
Flight Length :
HOBBS Start   :
HOBBS End     :

           Weather
------------------------------
Date          : December 08, 2010
Julian Day    : 342
Temperature   : ???
Visibility    : ???
Clouds        : ???
```

Precipitation : ???
Wind Dir : ???
Wind Speed : ???
Pressure : ???

Statistics

------------------------------

Laser Time : 01:56:27

| START | STOP | LINE# | ALT | PRF | FREQ | ANGLE | MP | DIV | RC | HDG | Plan File |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15:07:16.24 | 15:21:12.453 | 4 | 1571 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.5 |
| 15:24:25.656 | 15:38:51.57 | 2 | 1450 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.49 |
| 15:42:27.574 | 15:56:17.888 | 1 | 1414 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.49 |
| 15:59:31.492 | 16:14:25.708 | 1 | 1381 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.49 |
| 16:18:22.613 | 16:32:42.829 | 30 | 1391 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.48 |
| 16:35:10.532 | 16:49:54.65 | 32 | 1393 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.47 |
| 16:52:54.254 | 17:07:18.972 | 33 | 1398 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.47 |
| 17:10:07.175 | 17:24:51.694 | 33 | 1387 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.47 |
| 17:28:32.798 | 17:30:07.7 | 33 | 1397 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.47 |

Flight Log

------------------------------

Project Number: 7556-005
S/N : 246
Operator : BERRY
Pilot(s) : YOUNG
Aircraft : N7266Z
Airport : 1B9
Mission : 101208B
Wheels Up : 120 PM EST
Flight Length : -
HOBBS Start : -
HOBBS End : -

Weather

------------------------------

Date : December 08, 2010
Julian Day : 342
Temperature : -1C
Visibility : CLOUDS AT 5700'
Clouds : CLOUDS AT 5700'
Precipitation : NEGATIVE GHOST RIDER

```
Wind Dir      : 340
Wind Speed    : BLOWING AT 15 KTS
Pressure      : 2973
           Statistics
------------------------------
Laser Time    : 02:33:39

=======================================
13:40:23.615 GMT : 00:00:02 (212) GPS 1PPS Lost
13:40:23.615 GMT : 00:00:03 (166) Divergence Error
13:40:23.615 GMT : 00:00:03 (107) Rx Shutter Closed
13:40:23.615 GMT : 00:00:03 (109) Tx Shutter Closed
13:40:23.615 GMT : 00:00:04 (164) Beam Wide
13:40:23.615 GMT : 00:00:05 (213) GPS 1PPS Ok
13:40:23.615 GMT : 00:00:09 (120) Laser PS Comm Ok
13:40:23.615 GMT : 00:00:09 (112) Laser Emission Off
13:40:23.615 GMT : 00:00:12 (204) POSAV Connected
13:40:23.615 GMT : 00:00:13 (207) POSAV Rate Not 50 Hz
13:40:23.615 GMT : 00:00:14 (211) POSAV new status
13:40:23.615 GMT : 00:00:22 (215) Nav Data Ok
13:40:23.615 GMT : 00:00:23 (208) POSAV Rate Is 50 Hz
13:40:23.615 GMT : 00:00:24 (211) POSAV new status
13:40:23.615 GMT : 00:00:25 (211) POSAV new status
13:40:23.615 GMT : 00:01:52 (211) POSAV new status
13:40:23.615 GMT : 00:03:00 (211) POSAV new status
18:09:05.496 GMT : 18:09:04 (211) POSAV new status
18:13:51.001 GMT : 18:13:49 (153) Eyesafety Disabled
18:13:51.201 GMT : 18:13:49 (162) Roll Comp On
18:13:51.901 GMT : 18:13:50 (164) Beam Wide
18:13:52.001 GMT : 18:13:50 (144) MultiPulse Mode Varies
18:13:53.101 GMT : 18:13:52 (165) Beam Narrow
18:26:09.516 GMT : 18:26:08 (106) Rx Shutter Open
18:26:09.516 GMT : 18:26:08 (108) Tx Shutter Open
18:33:52.326 GMT : 18:33:51 (113) Laser Emission On
18:48:38.444 GMT : 18:48:36 (112) Laser Emission Off
18:52:29.049 GMT : 18:52:27 (113) Laser Emission On
18:55:00.252 GMT : 18:54:58 (112) Laser Emission Off
18:59:40.958 GMT : 18:59:39 (113) Laser Emission On
19:02:38.362 GMT : 19:02:37 (112) Laser Emission Off
19:05:31.865 GMT : 19:05:30 (113) Laser Emission On
19:20:15.884 GMT : 19:20:14 (112) Laser Emission Off
19:23:18.788 GMT : 19:23:17 (113) Laser Emission On
19:37:58.706 GMT : 19:37:57 (112) Laser Emission Off
19:40:40.609 GMT : 19:40:39 (113) Laser Emission On
19:55:37.328 GMT : 19:55:35 (112) Laser Emission Off
19:59:01.332 GMT : 19:59:00 (113) Laser Emission On
20:13:22.85 GMT : 20:13:21 (112) Laser Emission Off
20:17:01.055 GMT : 20:16:59 (113) Laser Emission On
20:31:25.073 GMT : 20:31:23 (112) Laser Emission Off
20:34:10.876 GMT : 20:34:09 (113) Laser Emission On
20:47:50.694 GMT : 20:47:49 (112) Laser Emission Off
20:51:50.499 GMT : 20:51:49 (113) Laser Emission On
21:04:01.114 GMT : 21:03:59 (112) Laser Emission Off
21:07:08.618 GMT : 21:07:07 (113) Laser Emission On
```

```
21:17:58.632 GMT : 21:17:57 (112) Laser Emission Off
21:20:44.735 GMT : 21:20:43 (113) Laser Emission On
21:31:44.749 GMT : 21:31:43 (112) Laser Emission Off
21:34:24.252 GMT : 21:34:22 (113) Laser Emission On
21:45:15.866 GMT : 21:45:14 (112) Laser Emission Off
21:48:57.47 GMT : 21:48:56 (113) Laser Emission On
21:51:28.673 GMT : 21:51:26 (112) Laser Emission Off
21:51:44.374 GMT : 21:51:42 (107) Rx Shutter Closed
21:51:44.374 GMT : 21:51:42 (109) Tx Shutter Closed

           Flight Log
------------------------------
Project Number: 7556-005
S/N           : 246
Operator      : BERRY
Pilot(s)      : YOUNG
Aircraft      : N7266Z
Airport       : 1B9
Mission       : 101208B
Wheels Up     : 120 PM EST
Flight Length : -
HOBBS Start   : -
HOBBS End     : -

           Weather
------------------------------
Date          : December 08, 2010
Julian Day    : 342
Temperature   : -1C
Visibility    : CLOUDS AT 5700'
Clouds        : CLOUDS AT 5700'
Precipitation : NEGATIVE GHOST RIDER
Wind Dir      : 340
Wind Speed    : BLOWING AT 15 KTS
Pressure      : 2973
           Statistics
------------------------------
Laser Time    : 02:33:39

=======================================

           Flight Log
------------------------------
Project Number: 7556-005
S/N           : 246
Operator      : BERRY
Pilot(s)      : YOUNG
Aircraft      : N7266Z
Airport       : 1B9
Mission       : 101208B
Wheels Up     : 120 PM EST
Flight Length : -
HOBBS Start   : -
HOBBS End     : -
```

## Weather

------------------------------

Date           : December 08, 2010
Julian Day     : 342
Temperature    : -1C
Visibility     : CLOUDS AT 5700'
Clouds         : CLOUDS AT 5700'
Precipitation  : NEGATIVE GHOST RIDER
Wind Dir       : 340
Wind Speed     : BLOWING AT 15 KTS
Pressure       : 2973

## Statistics

------------------------------

Laser Time     : 02:33:39

| START | STOP | LINE# | ALT | PRF | FREQ | ANGLE | MP | DIV | RC | HDG | Plan File |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18:33:53.226 | 18:48:38.244 | 34 | 1426 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.46 |
| 18:52:29.049 | 18:55:01.052 | 33 | 1435 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.47 |
| 18:59:41.958 | 19:02:39.262 | 35 | 1447 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.46 |
| 19:05:32.466 | 19:20:16.684 | 36 | 1454 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.45 |
| 19:23:19.488 | 19:37:59.206 | 36 | 1446 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.45 |
| 19:40:41.309 | 19:55:37.028 | 38 | 1445 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.44 |
| 19:59:02.332 | 20:13:24.65 | 38 | 1456 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.44 |
| 20:17:01.855 | 20:31:26.173 | 40 | 1445 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.43 |
| 20:34:11.476 | 20:47:51.494 | 41 | 1464 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.42 |
| 20:51:51.099 | 21:04:02.614 | 42 | 1459 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.41 |
| 21:07:09.218 | 21:17:59.132 | 43 | 1460 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.41 |
| 21:20:45.335 | 21:31:46.749 | 44 | 1454 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.4 |
| 21:34:25.052 | 21:45:16.866 | 44 | 1475 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.4 |
| 21:48:58.17 | 21:51:29.173 | 44 | 1479 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.4 |

## Flight Log

------------------------------

Project Number: 0
S/N            : 0

```
Operator      : ???
Pilot(s)      : ???
Aircraft      : ???
Airport       : ???
Mission       : ???
Wheels Up     : ???
Flight Length :
HOBBS Start   :
HOBBS End     :
           Weather
------------------------------
Date          : December 08, 2010
Julian Day    : 342
Temperature   : ???
Visibility    : ???
Clouds        : ???
Precipitation : ???
Wind Dir      : ???
Wind Speed    : ???
Pressure      : ???
           Statistics
------------------------------
Laser Time    : 0

========================================
15:12:35.543 GMT : 00:00:02 (212) GPS 1PPS Lost
15:12:35.543 GMT : 00:00:03 (166) Divergence Error
15:12:35.543 GMT : 00:00:03 (107) Rx Shutter Closed
15:12:35.543 GMT : 00:00:03 (109) Tx Shutter Closed
15:12:35.543 GMT : 00:00:04 (164) Beam Wide
15:12:35.543 GMT : 00:00:08 (213) GPS 1PPS Ok
15:12:35.543 GMT : 00:00:12 (204) POSAV Connected
15:12:35.543 GMT : 00:00:13 (207) POSAV Rate Not 50 Hz
15:12:35.543 GMT : 00:00:13 (211) POSAV new status
15:12:35.543 GMT : 00:00:18 (120) Laser PS Comm Ok
15:12:35.543 GMT : 00:00:18 (112) Laser Emission Off
15:12:35.543 GMT : 00:00:20 (208) POSAV Rate Is 50 Hz
15:12:35.543 GMT : 00:00:20 (211) POSAV new status
15:12:35.543 GMT : 00:00:22 (211) POSAV new status
15:12:35.543 GMT : 00:00:22 (215) Nav Data Ok
15:12:35.543 GMT : 00:01:57 (211) POSAV new status
14:44:05.275 GMT : 00:03:20 (307) Format Disk

           Flight Log
------------------------------
Project Number: 0
S/N           : 0
Operator      : ???
Pilot(s)      : ???
Aircraft      : ???
Airport       : ???
Mission       : ???
Wheels Up     : ???
Flight Length :
```

```
HOBBS Start   :
HOBBS End     :
           Weather
-----------------------------
Date          : December 08, 2010
Julian Day    : 342
Temperature   : ???
Visibility    : ???
Clouds        : ???
Precipitation : ???
Wind Dir      : ???
Wind Speed    : ???
Pressure      : ???
           Statistics
-----------------------------
Laser Time    : 0

======================================

           Flight Log
-----------------------------
Project Number: 0
S/N           : 0
Operator      : ???
Pilot(s)      : ???
Aircraft      : ???
Airport       : ???
Mission       : ???
Wheels Up     : ???
Flight Length :
HOBBS Start   :
HOBBS End     :
           Weather
-----------------------------
Date          : December 08, 2010
Julian Day    : 342
Temperature   : ???
Visibility    : ???
Clouds        : ???
Precipitation : ???
Wind Dir      : ???
Wind Speed    : ???
Pressure      : ???
           Statistics
-----------------------------
Laser Time    : 0



        START          STOP LINE#    ALT  PRF     FREQ   ANGLE   MP  DIV
RC        HDG    Plan File
======================================

           Flight Log
```

```
------------------------------
Project Number: NARR_1B9
S/N            : 247
Operator       : Galieti
Pilot(s)       : Greenwell
Aircraft       : N2448G
Airport        : 1B9 Mansfield, MA
Mission        : 1
Wheels Up      :
Flight Length  :
HOBBS Start    :
HOBBS End      :

           Weather
------------------------------
Date           : December 08, 2010
Julian Day     : 342
Temperature    : -4 C @KBED
Visibility     : clear
Clouds         : none
Precipitation  : nill
Wind Dir       :
Wind Speed     :
Pressure       : 29.64 HG @KBED
           Statistics
------------------------------
Laser Time     : 01:42:05

=======================================
15:18:13.952 GMT : 00:04:38 (157) Safe Unaided Profile
15:18:13.952 GMT : 00:04:38 (162) Roll Comp On
15:18:13.952 GMT : 00:04:38 (157) Safe Unaided Profile
15:18:13.952 GMT : 00:04:39 (164) Beam Wide
14:45:27.775 GMT : 00:04:42 (165) Beam Narrow
14:45:29.875 GMT : 00:04:44 (211) POSAV new status
14:46:45.876 GMT : 14:46:44 (157) Safe Unaided Profile
14:47:01.876 GMT : 14:47:00 (157) Safe Unaided Profile
14:47:01.876 GMT : 14:47:01 (157) Safe Unaided Profile
14:47:13.376 GMT : 14:47:11 (152) Invalid Beam
14:47:13.576 GMT : 14:47:11 (152) Invalid Beam
14:47:28.076 GMT : 14:47:26 (157) Safe Unaided Profile
14:47:28.276 GMT : 14:47:26 (157) Safe Unaided Profile
14:48:44.577 GMT : 14:48:43 (157) Safe Unaided Profile
14:48:44.677 GMT : 14:48:43 (157) Safe Unaided Profile
14:48:45.277 GMT : 14:48:44 (144) MultiPulse Mode Varies
14:51:43.278 GMT : 14:51:42 (211) POSAV new status
15:00:24.783 GMT : 15:00:23 (157) Safe Unaided Profile
15:00:29.183 GMT : 15:00:27 (106) Rx Shutter Open
15:00:29.383 GMT : 15:00:27 (108) Tx Shutter Open
15:07:31.987 GMT : 15:07:30 (113) Laser Emission On
15:09:26.188 GMT : 15:09:24 (112) Laser Emission Off
15:13:52.591 GMT : 15:13:51 (113) Laser Emission On
15:16:21.093 GMT : 15:16:19 (112) Laser Emission Off
15:20:54.095 GMT : 15:20:53 (113) Laser Emission On
```

```
15:23:10.697 GMT : 15:23:09 (112) Laser Emission Off
15:28:35.6 GMT : 15:28:34 (113) Laser Emission On
15:31:02.102 GMT : 15:31:00 (112) Laser Emission Off
15:35:22.005 GMT : 15:35:20 (113) Laser Emission On
15:37:30.206 GMT : 15:37:29 (112) Laser Emission Off
15:42:37.11 GMT : 15:42:35 (113) Laser Emission On
15:44:53.911 GMT : 15:44:52 (112) Laser Emission Off
15:49:28.814 GMT : 15:49:27 (113) Laser Emission On
15:55:00.818 GMT : 15:54:59 (112) Laser Emission Off
15:59:09.921 GMT : 15:59:08 (113) Laser Emission On
16:05:35.525 GMT : 16:05:34 (112) Laser Emission Off
16:10:21.828 GMT : 16:10:20 (113) Laser Emission On
16:16:26.333 GMT : 16:16:24 (112) Laser Emission Off
16:20:57.836 GMT : 16:20:56 (113) Laser Emission On
16:27:35.74 GMT : 16:27:33 (112) Laser Emission Off
16:32:11.844 GMT : 16:32:10 (113) Laser Emission On
16:38:54.148 GMT : 16:38:52 (112) Laser Emission Off
16:43:19.252 GMT : 16:43:18 (113) Laser Emission On
16:50:22.757 GMT : 16:50:21 (112) Laser Emission Off
16:54:59.86 GMT : 16:54:58 (113) Laser Emission On
17:02:09.565 GMT : 17:02:08 (112) Laser Emission Off
17:06:49.968 GMT : 17:06:48 (113) Laser Emission On
17:14:38.674 GMT : 17:14:37 (112) Laser Emission Off
17:19:02.977 GMT : 17:19:02 (113) Laser Emission On
17:27:06.983 GMT : 17:27:05 (112) Laser Emission Off
17:31:45.587 GMT : 17:31:44 (113) Laser Emission On
17:40:01.293 GMT : 17:40:00 (112) Laser Emission Off
17:44:38.496 GMT : 17:44:37 (113) Laser Emission On
17:52:48.802 GMT : 17:52:46 (112) Laser Emission Off
17:57:42.006 GMT : 17:57:40 (113) Laser Emission On
18:06:25.612 GMT : 18:06:24 (112) Laser Emission Off
18:11:03.916 GMT : 18:11:02 (113) Laser Emission On
18:14:04.918 GMT : 18:14:03 (112) Laser Emission Off
18:19:06.122 GMT : 18:19:05 (157) Safe Unaided Profile
18:19:28.822 GMT : 18:19:27 (157) Safe Unaided Profile
18:19:33.122 GMT : 18:19:31 (107) Rx Shutter Closed
18:19:33.222 GMT : 18:19:31 (109) Tx Shutter Closed
```

```
           Flight Log
------------------------------
Project Number: NARR_1B9
S/N           : 247
Operator      : Galieti
Pilot(s)      : Greenwell
Aircraft      : N2448G
Airport       : 1B9 Mansfield, MA
Mission       : 1
Wheels Up     :
Flight Length :
HOBBS Start   :
HOBBS End     :
```

```
           Weather
------------------------------
```

```
Date           : December 08, 2010
Julian Day     : 342
Temperature    : -4 C @KBED
Visibility     : clear
Clouds         : none
Precipitation : nill
Wind Dir       :
Wind Speed     :
Pressure       : 29.64 HG @KBED
           Statistics
------------------------------
Laser Time     : 01:42:05

=======================================

           Flight Log
------------------------------
Project Number: NARR_1B9
S/N            : 247
Operator       : Galieti
Pilot(s)       : Greenwell
Aircraft       : N2448G
Airport        : 1B9 Mansfield, MA
Mission        : 1
Wheels Up      :
Flight Length :
HOBBS Start    :
HOBBS End      :

           Weather
------------------------------
Date           : December 08, 2010
Julian Day     : 342
Temperature    : -4 C @KBED
Visibility     : clear
Clouds         : none
Precipitation : nill
Wind Dir       :
Wind Speed     :
Pressure       : 29.64 HG @KBED
           Statistics
------------------------------
Laser Time     : 01:42:05


        START           STOP LINE#    ALT  PRF     FREQ   ANGLE   MP  DIV
RC        HDG    Plan File
=======================================
 15:07:31.787  15:09:26.488    29   1599   70    30.10   18.00   ON  NAR
ON       0.00       178.63
 15:07:31.787  15:09:26.488    29   1599   70    30.10   18.00   ON  NAR
ON       0.00       178.63
```

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15:13:53.391 | 15:16:22.293 | 28 | 1582 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.62 |
| 15:13:53.391 | 15:16:22.293 | 28 | 1583 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.62 |
| 15:20:55.095 | 15:23:12.597 | 27 | 1586 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.62 |
| 15:20:55.095 | 15:23:12.597 | 26 | 1586 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.61 |
| 15:28:36.2 | 15:31:03.002 | 26 | 1579 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.61 |
| 15:35:21.805 | 15:37:32.006 | 24 | 1597 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.6 |
| 15:42:38.31 | 15:44:52.111 | 24 | 1568 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.6 |
| 15:42:38.31 | 15:44:56.211 | 24 | 1569 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.6 |
| 15:49:29.014 | 15:55:01.618 | 23 | 1611 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.6 |
| 15:59:09.621 | 16:05:36.125 | 22 | 1570 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.59 |
| 15:59:09.621 | 16:05:36.125 | 21 | 1571 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.59 |
| 16:10:22.728 | 16:16:25.833 | 21 | 1576 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.59 |
| 16:20:57.736 | 16:27:37.74 | 20 | 1536 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.58 |
| 16:32:12.844 | 16:38:53.848 | 19 | 1463 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.58 |
| 16:43:20.452 | 16:50:24.157 | 18 | 1450 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.57 |
| 16:43:20.452 | 16:50:24.157 | 17 | 1450 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.57 |
| 16:55:00.76 | 17:02:11.065 | 17 | 1482 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.57 |
| 16:55:00.76 | 17:02:11.065 | 17 | 1483 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.57 |
| 17:06:49.968 | 17:14:39.674 | 16 | 1468 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.56 |
| 17:19:04.177 | 17:27:03.583 | 15 | 1477 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.56 |
| 17:31:46.287 | 17:40:01.993 | 14 | 1468 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.55 |
| 17:31:46.287 | 17:40:01.993 | 14 | 1466 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.55 |
| 17:44:39.096 | 17:52:50.302 | 13 | 1456 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.55 |
| 17:57:42.206 | 18:06:27.812 | 12 | 1472 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.54 |
| 18:11:04.416 | 18:14:06.318 | 12 | 1440 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.54 |
| 18:11:04.416 | 18:14:06.318 | 12 | 1438 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.54 |

```
------------------------------
Project Number: NARR_1B9
S/N            : 247
Operator       : Galieti
Pilot(s)       : Greenwell
Aircraft       : N2448G
Airport        : 1B9
Mission        : 2
Wheels Up      : 1914 Z
Flight Length :
HOBBS Start    :
HOBBS End      :

           Weather
------------------------------
Date           : December 08, 2010
Julian Day     : 342
Temperature    :
Visibility     : +10 SM
Clouds         : SCT 060
Precipitation : nill
Wind Dir       :
Wind Speed     :
Pressure       : 29.74 HG
           Statistics
------------------------------
Laser Time     : 01:30:36

=======================================
19:46:19.541 GMT : 19:14:34 (157) Safe Unaided Profile
19:14:58.319 GMT : 19:14:56 (157) Safe Unaided Profile
19:14:58.519 GMT : 19:14:56 (157) Safe Unaided Profile
19:16:11.22 GMT : 19:16:10 (157) Safe Unaided Profile
19:16:16.92 GMT : 19:16:15 (157) Safe Unaided Profile
19:16:20.02 GMT : 19:16:18 (106) Rx Shutter Open
19:16:20.22 GMT : 19:16:18 (108) Tx Shutter Open
19:27:11.628 GMT : 19:27:10 (113) Laser Emission On
19:36:44.835 GMT : 19:36:43 (112) Laser Emission Off
19:43:55.741 GMT : 19:43:54 (113) Laser Emission On
19:56:47.05 GMT : 19:56:45 (112) Laser Emission Off
20:01:23.853 GMT : 20:01:22 (113) Laser Emission On
20:07:17.158 GMT : 20:07:15 (214) Nav Data Lost
20:07:21.158 GMT : 20:07:19 (215) Nav Data Ok
20:14:47.963 GMT : 20:14:45 (112) Laser Emission Off
20:19:23.167 GMT : 20:19:21 (113) Laser Emission On
20:32:15.376 GMT : 20:32:14 (112) Laser Emission Off
20:37:20.98 GMT : 20:37:19 (113) Laser Emission On
20:50:36.19 GMT : 20:50:34 (112) Laser Emission Off
20:55:38.393 GMT : 20:55:36 (113) Laser Emission On
21:09:12.503 GMT : 21:09:10 (112) Laser Emission Off
21:13:28.506 GMT : 21:13:27 (113) Laser Emission On
21:27:34.217 GMT : 21:27:33 (112) Laser Emission Off
21:34:02.521 GMT : 21:34:01 (113) Laser Emission On
21:35:29.722 GMT : 21:35:28 (112) Laser Emission Off
```

```
21:37:34.224 GMT : 21:37:33 (157) Safe Unaided Profile
21:37:35.024 GMT : 21:37:33 (157) Safe Unaided Profile
21:37:38.624 GMT : 21:37:37 (107) Rx Shutter Closed
21:37:38.824 GMT : 21:37:37 (109) Tx Shutter Closed

           Flight Log
------------------------------
Project Number: NARR_1B9
S/N           : 247
Operator      : Galieti
Pilot(s)      : Greenwell
Aircraft      : N2448G
Airport       : 1B9
Mission       : 2
Wheels Up     : 1914 Z
Flight Length :
HOBBS Start   :
HOBBS End     :

           Weather
------------------------------
Date          : December 08, 2010
Julian Day    : 342
Temperature   :
Visibility    : +10 SM
Clouds        : SCT 060
Precipitation : nill
Wind Dir      :
Wind Speed    :
Pressure      : 29.74 HG
           Statistics
------------------------------
Laser Time    : 01:30:36

=======================================

           Flight Log
------------------------------
Project Number: NARR_1B9
S/N           : 247
Operator      : Galieti
Pilot(s)      : Greenwell
Aircraft      : N2448G
Airport       : 1B9
Mission       : 2
Wheels Up     : 1914 Z
Flight Length :
HOBBS Start   :
HOBBS End     :

           Weather
------------------------------
Date          : December 08, 2010
Julian Day    : 342
```

Temperature   :
Visibility    : +10 SM
Clouds        : SCT 060
Precipitation : nill
Wind Dir      :
Wind Speed    :
Pressure      : 29.74 HG

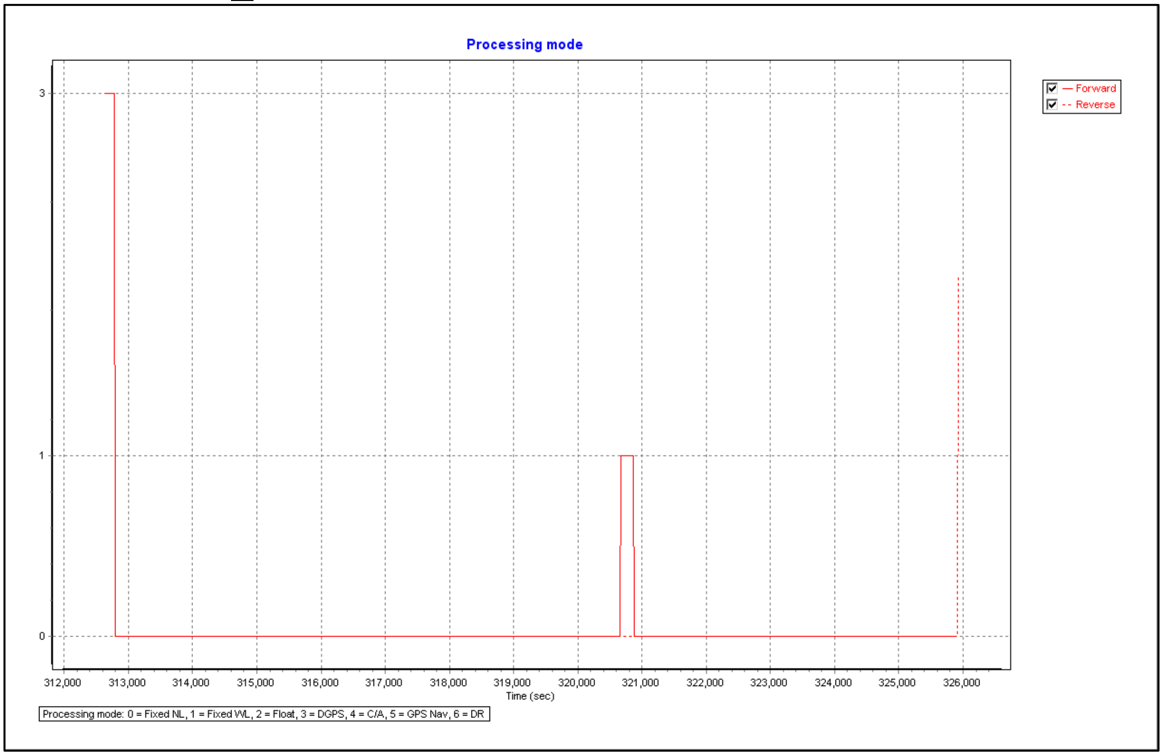
Statistics

------------------------------

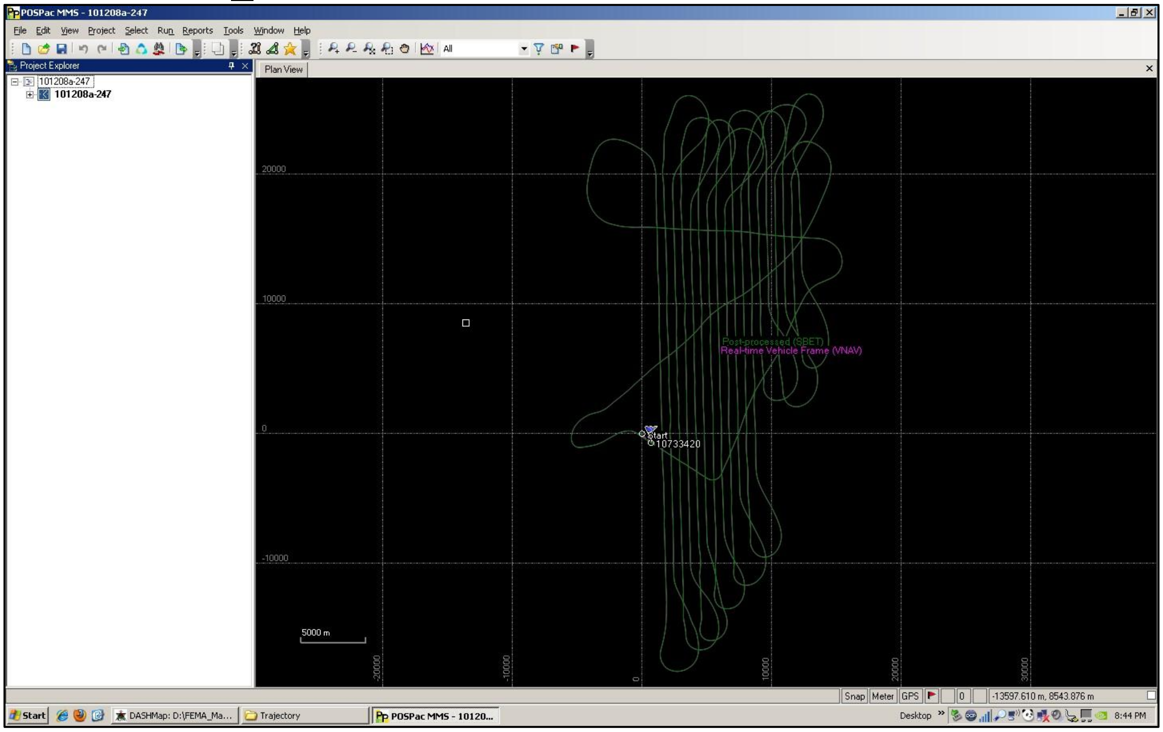
Laser Time    : 01:30:36

| START | STOP | LINE# | ALT | PRF | FREQ | ANGLE | MP | DIV | RC | HDG | Plan File |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 19:27:12.228 | 19:36:46.135 | 11 | 1565 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.54 |
| 19:43:56.641 | 19:56:48.35 | 10 | 1560 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.54 |
| 19:43:56.641 | 19:56:48.35 | 10 | 1560 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.54 |
| 20:01:24.553 | 20:14:48.163 | 9 | 1584 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.53 |
| 20:01:24.553 | 20:14:48.163 | 9 | 1585 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.53 |
| 20:19:23.067 | 20:32:16.376 | 8 | 1559 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.53 |
| 20:37:20.98 | 20:50:35.99 | 7 | 1580 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.52 |
| 20:55:39.293 | 21:09:11.903 | 6 | 1560 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 358.51 |
| 21:13:29.406 | 21:27:36.517 | 5 | 1575 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.51 |
| 21:34:03.621 | 21:35:30.322 | 5 | 1519 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.51 |
| 21:34:03.621 | 21:35:30.322 | 5 | 1516 | 70 | 30.10 | 18.00 | ON | NAR | ON | 0.00 | 178.51 |

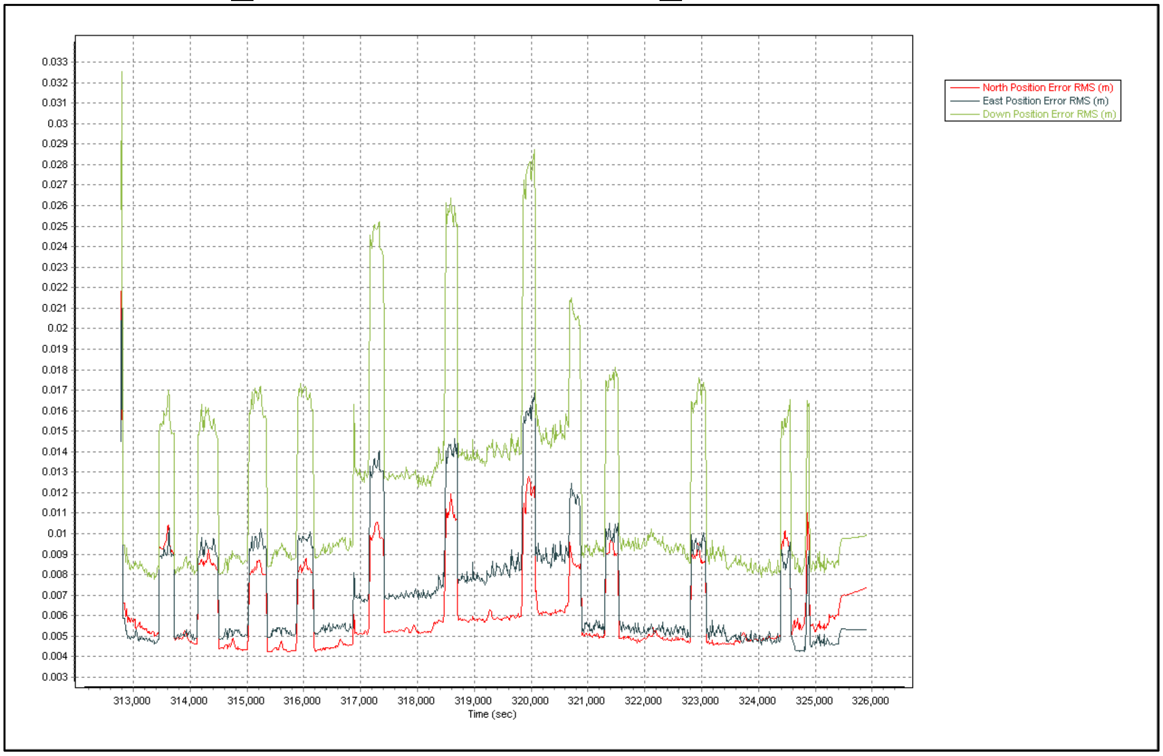
101208A-247_PROCESSMODE



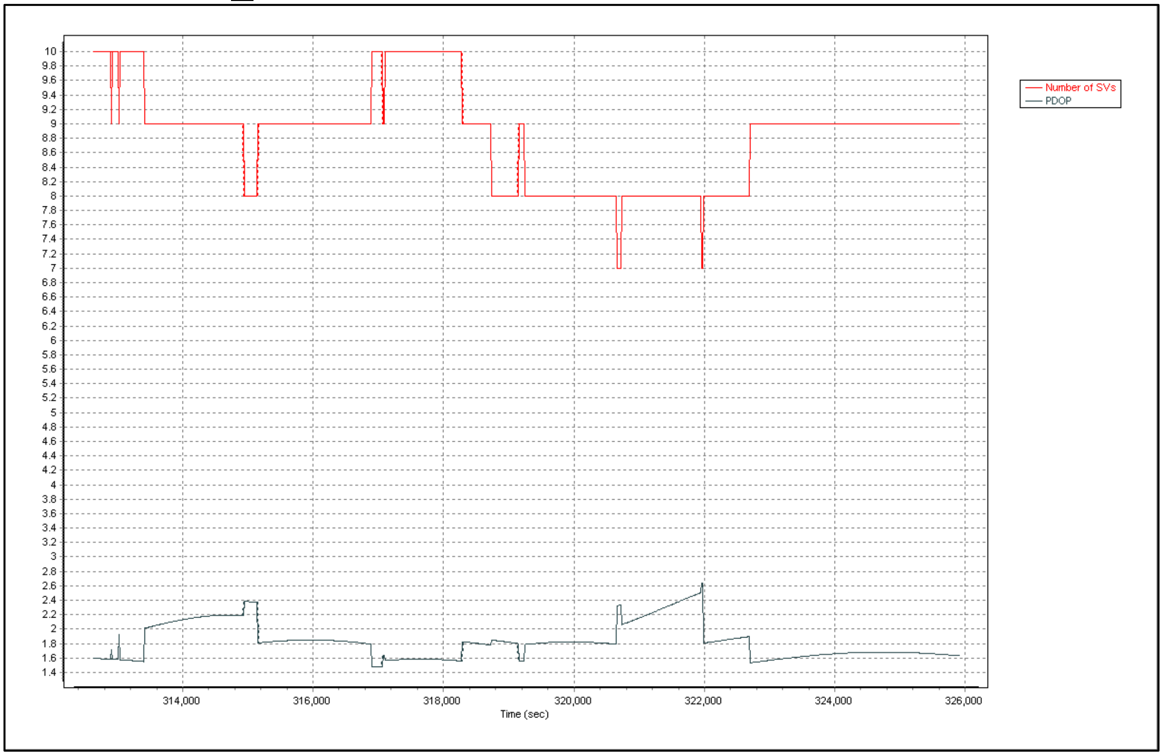
# 101208A-247_SCREENSHOT



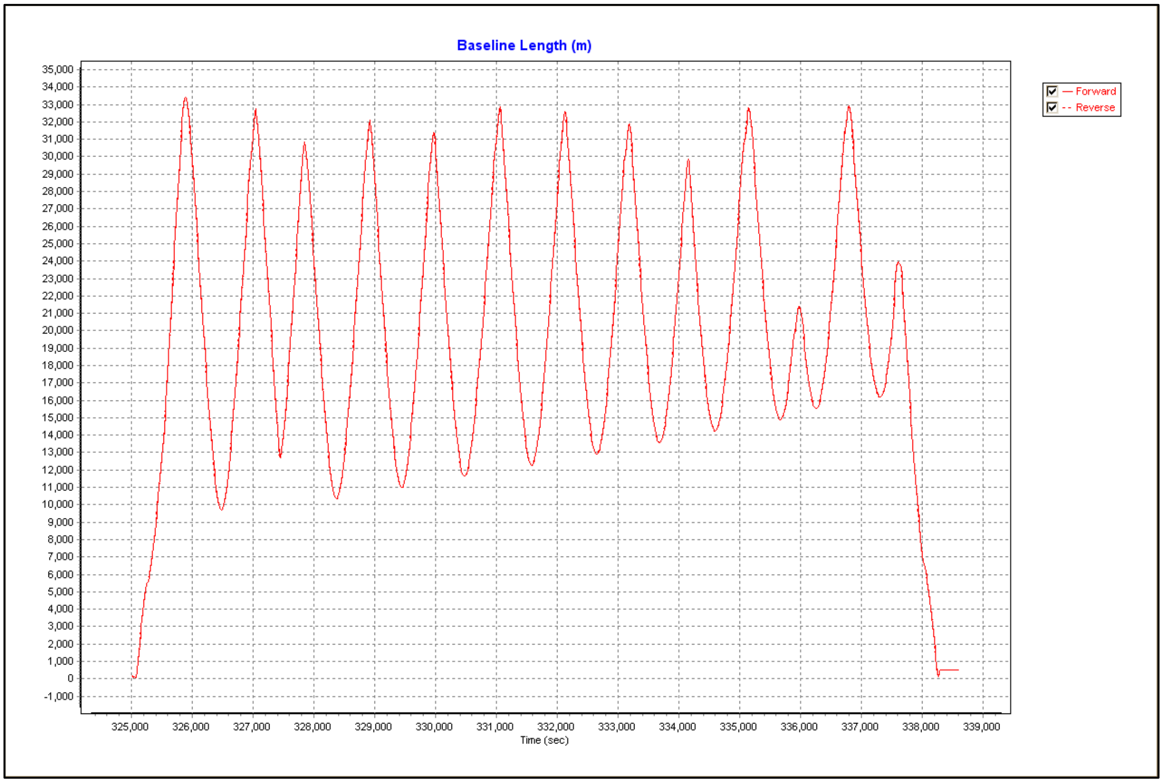
101208A-247_SMOOTHPERFMETRIC_NED



# 101208A-247_SVS&PDOP



# 101208B-246-BASELINELENGTH



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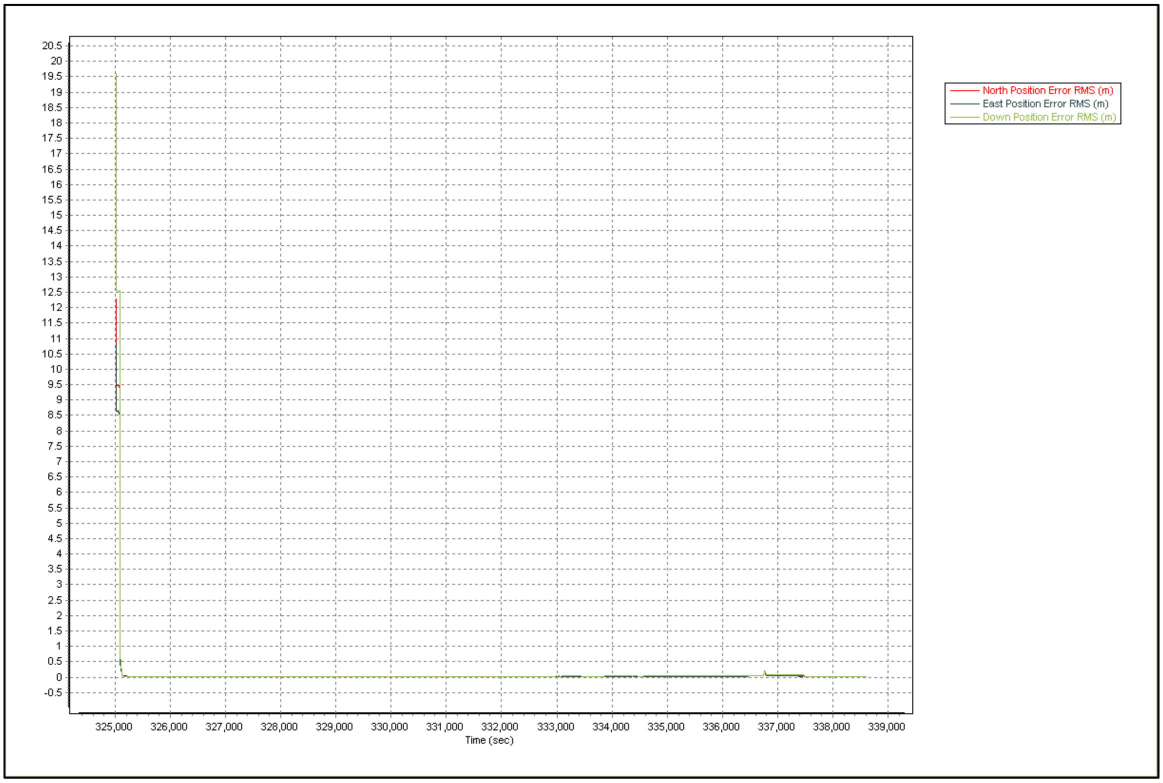

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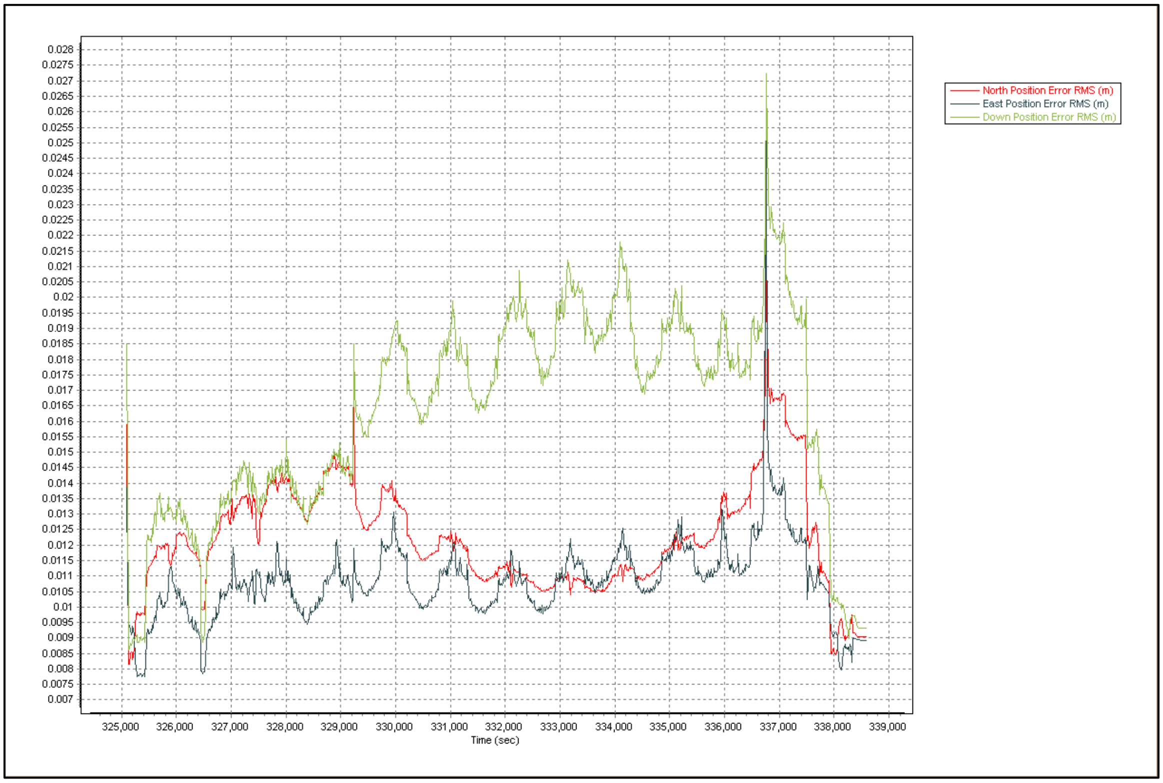
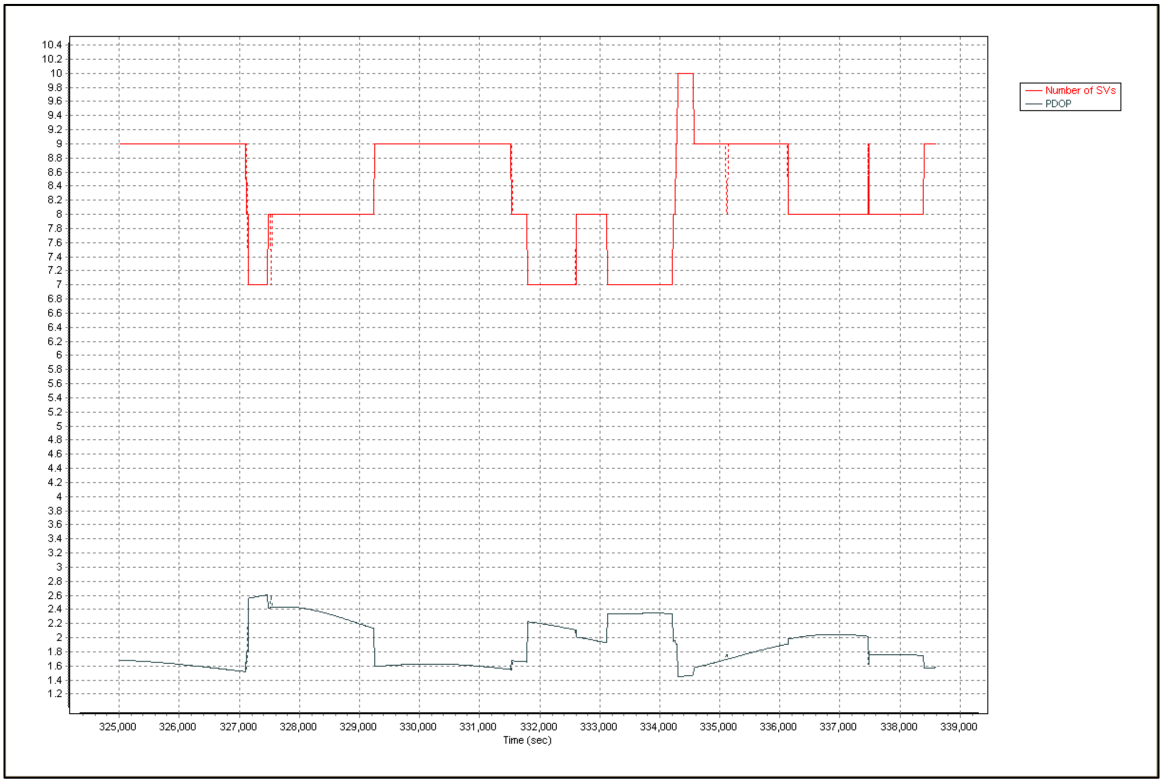


101208B-246-PDOP&SVS



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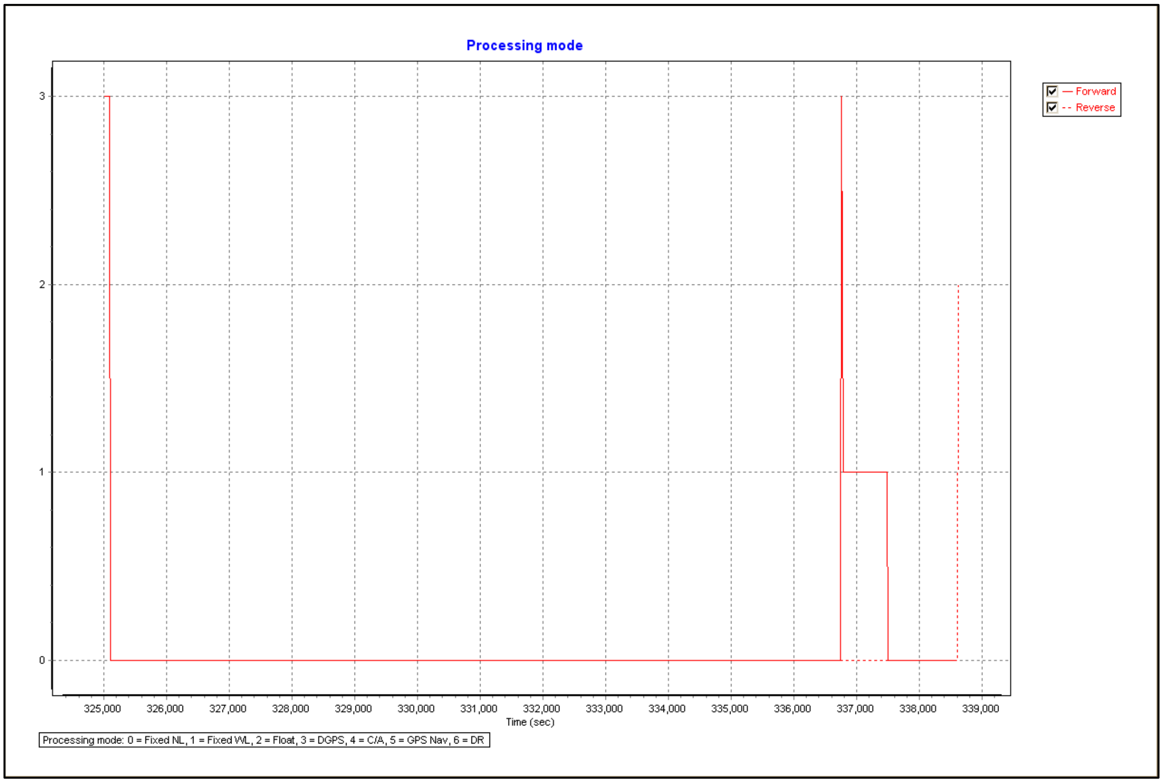

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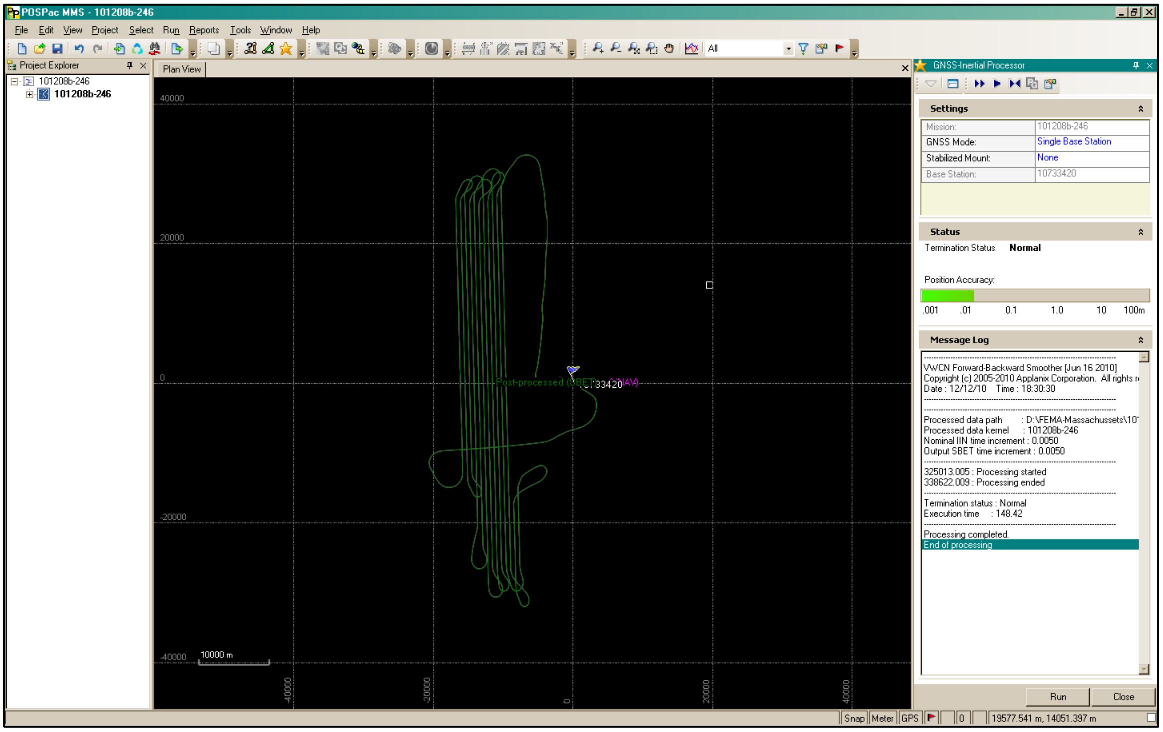

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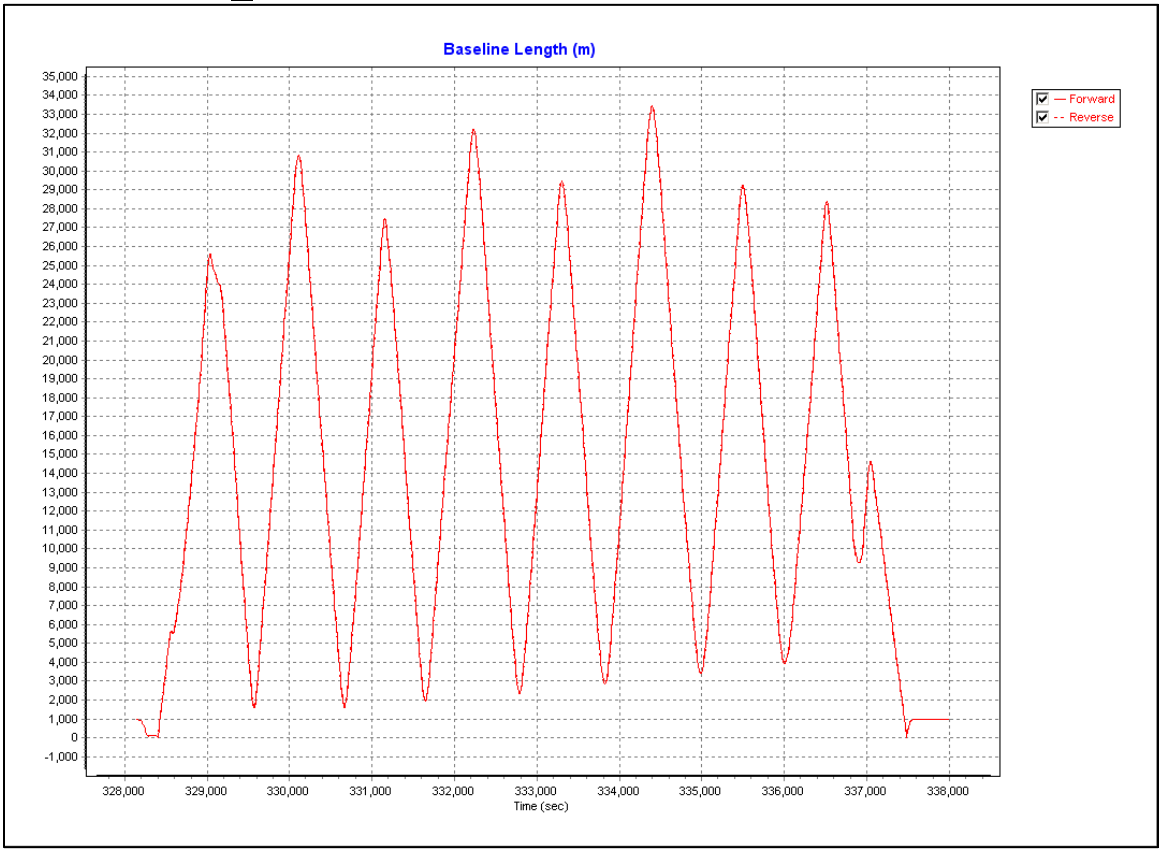

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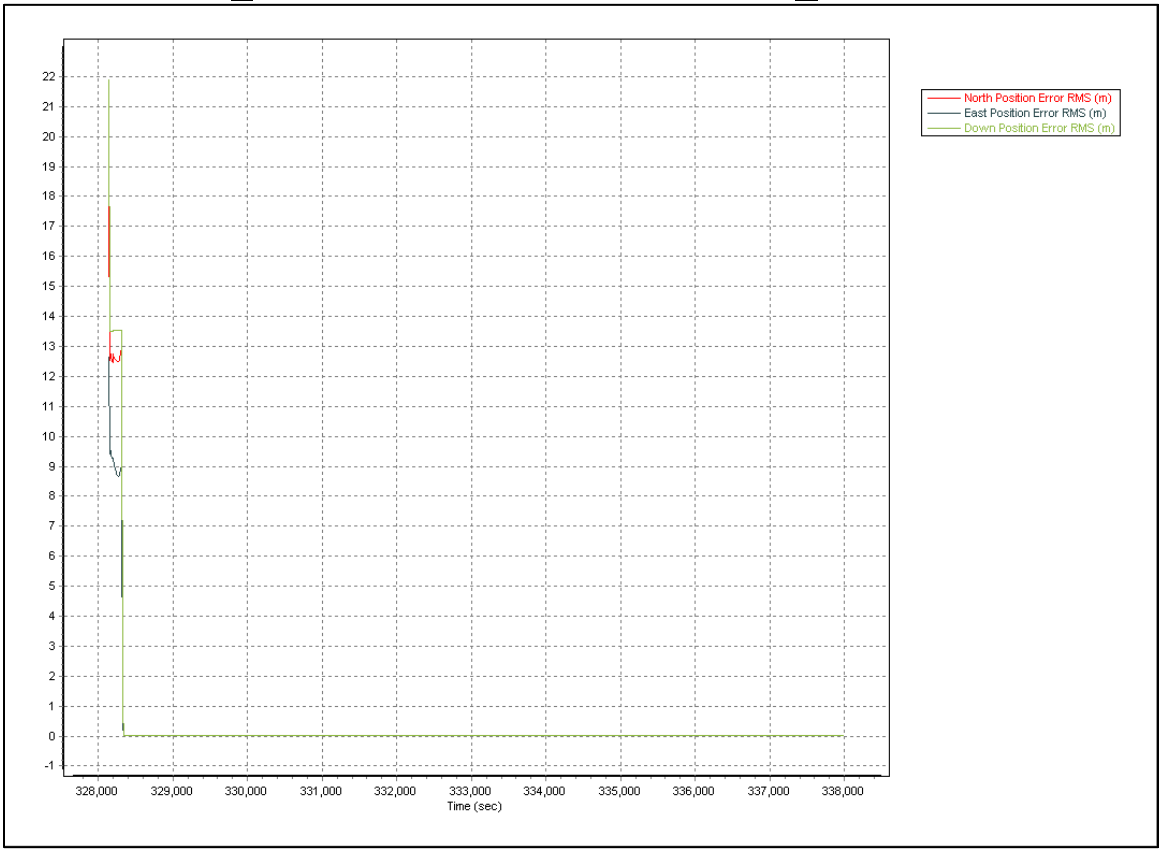

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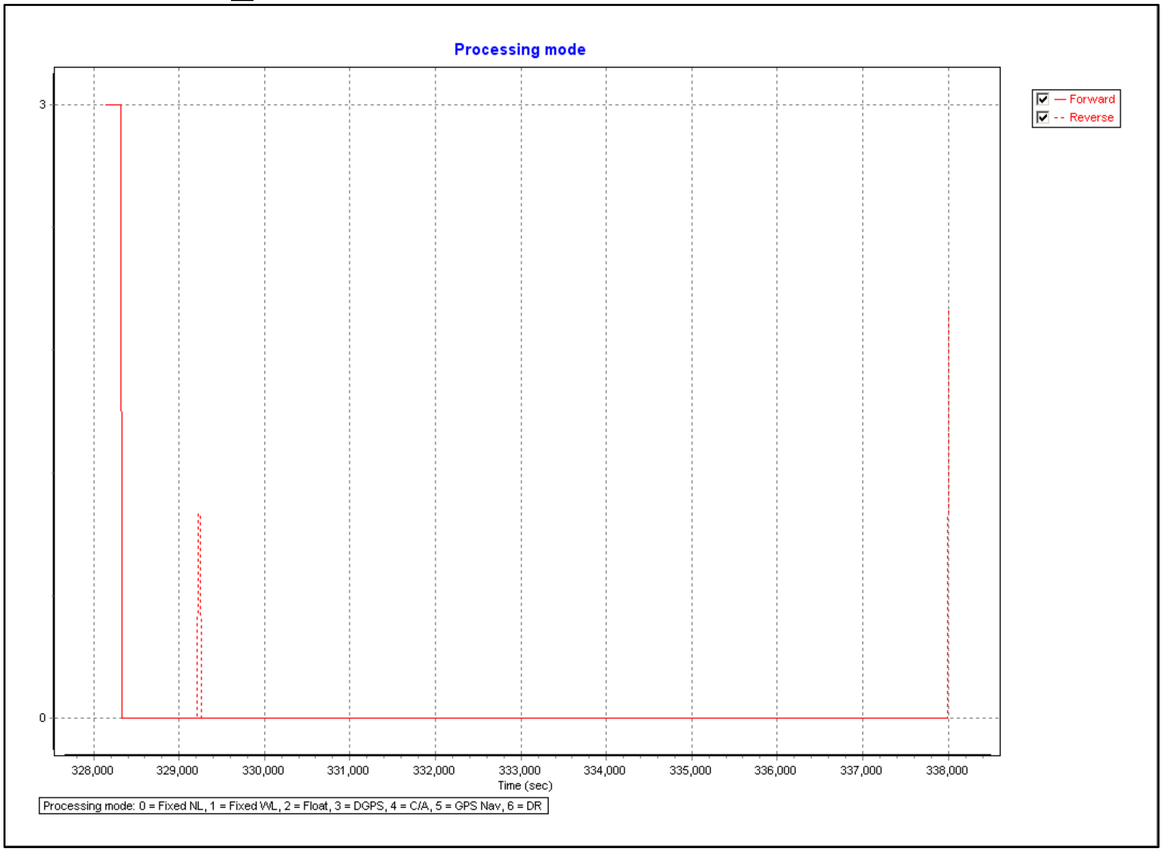
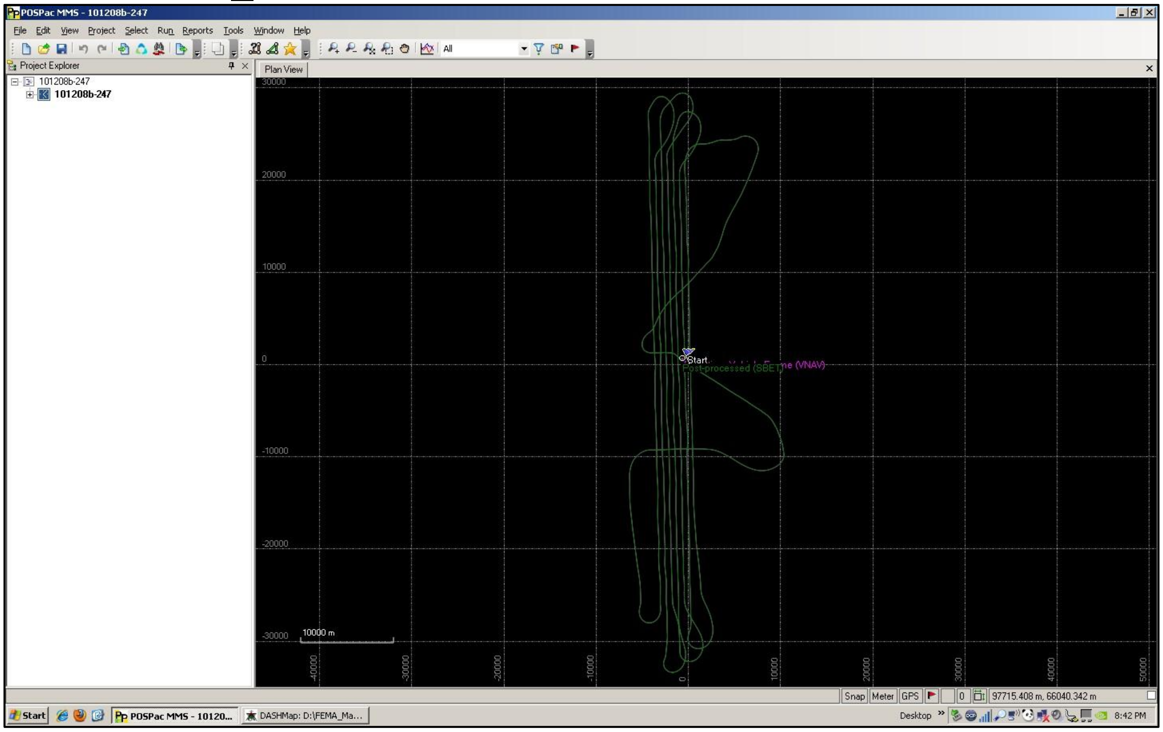


101208B-247_SCREENSHOT



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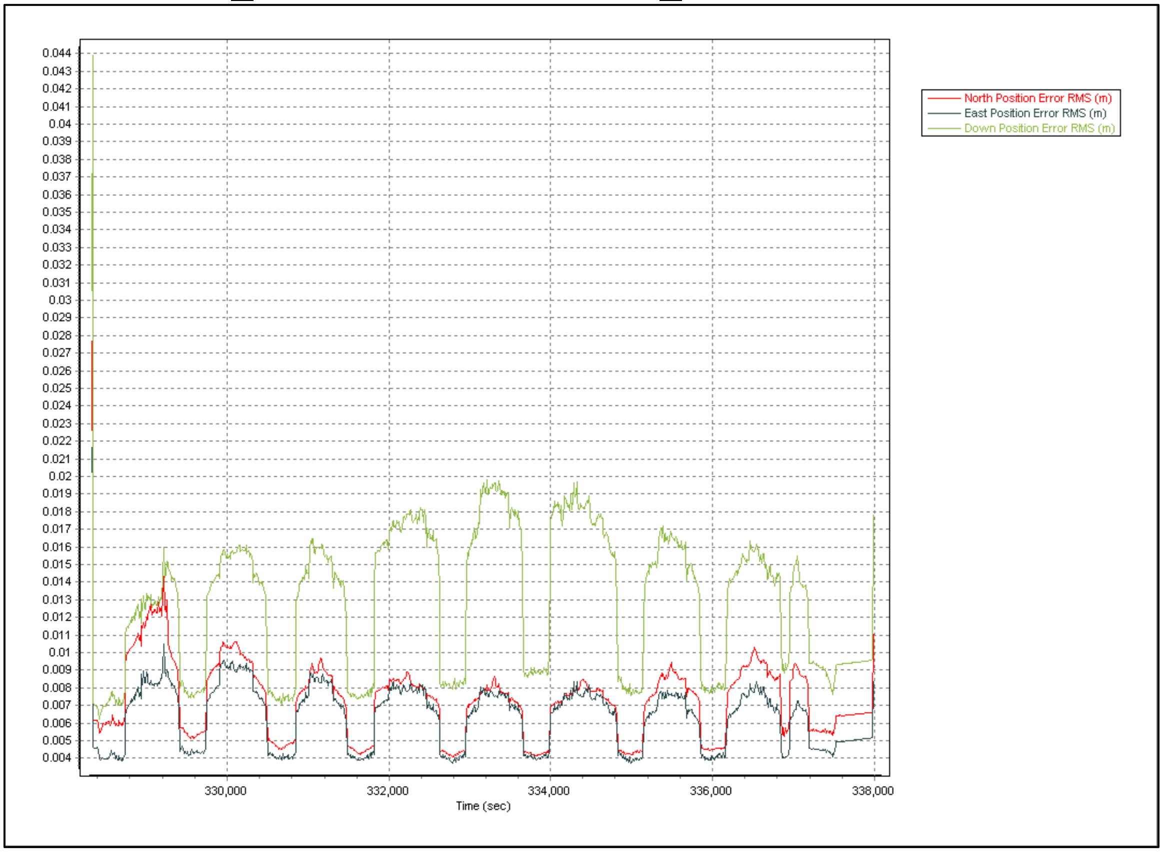
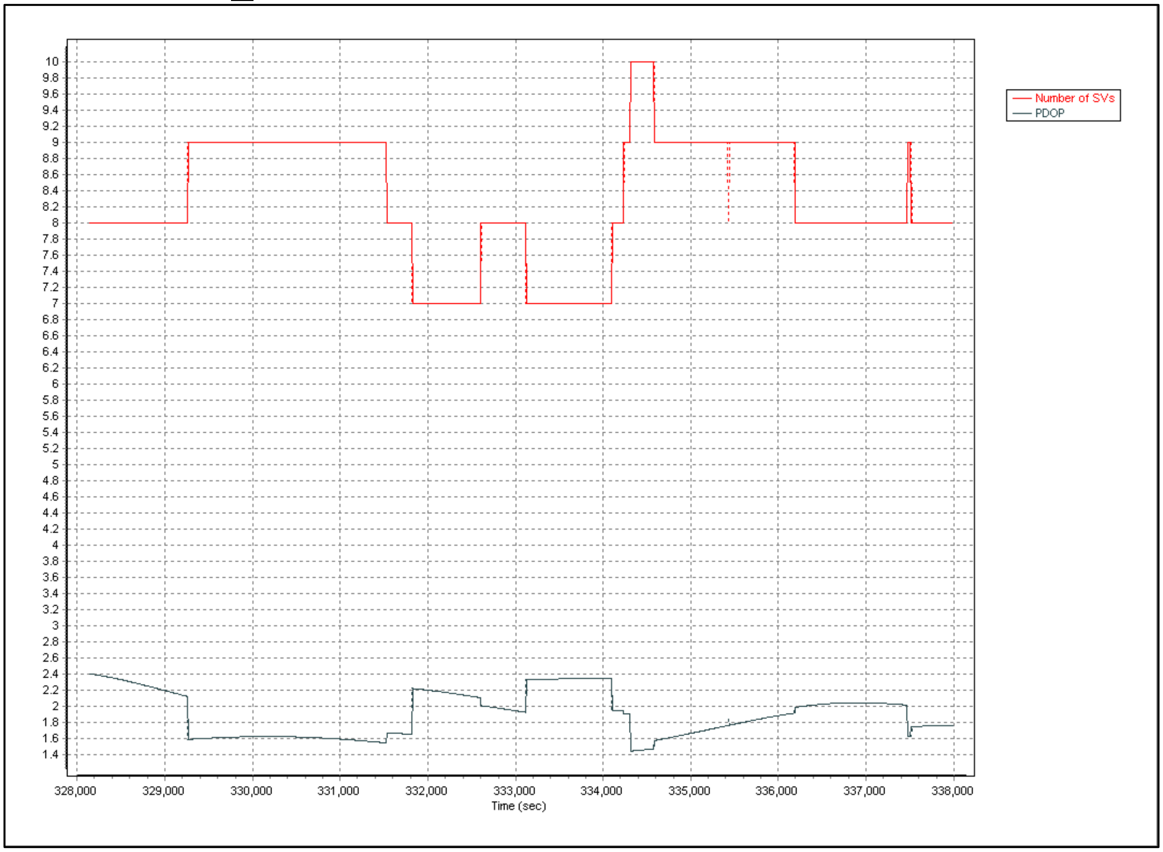


101208B-247_SVS&PDOP



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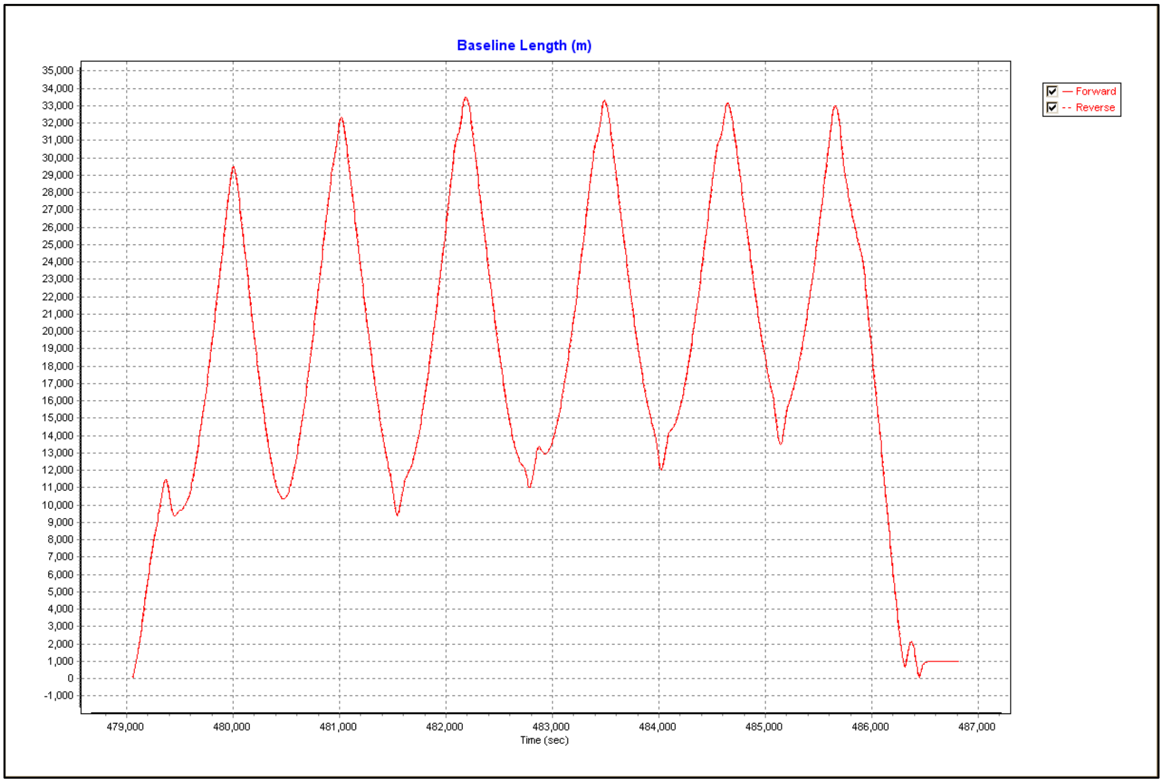

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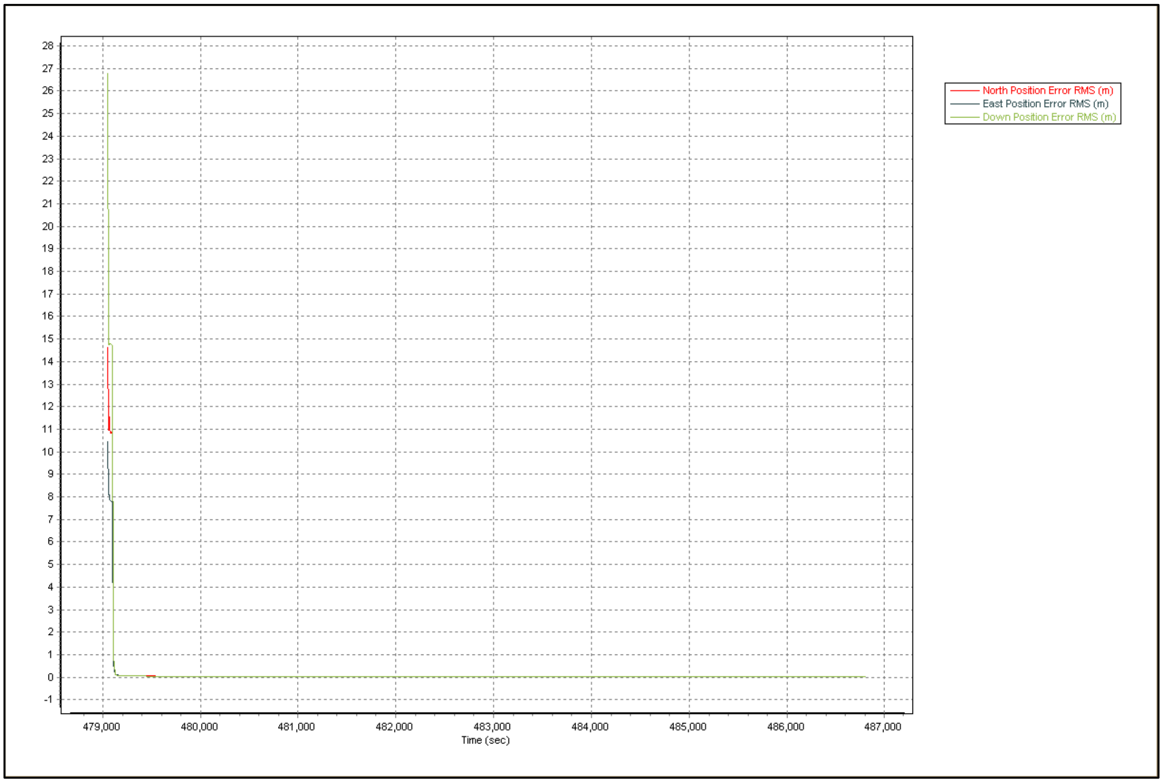

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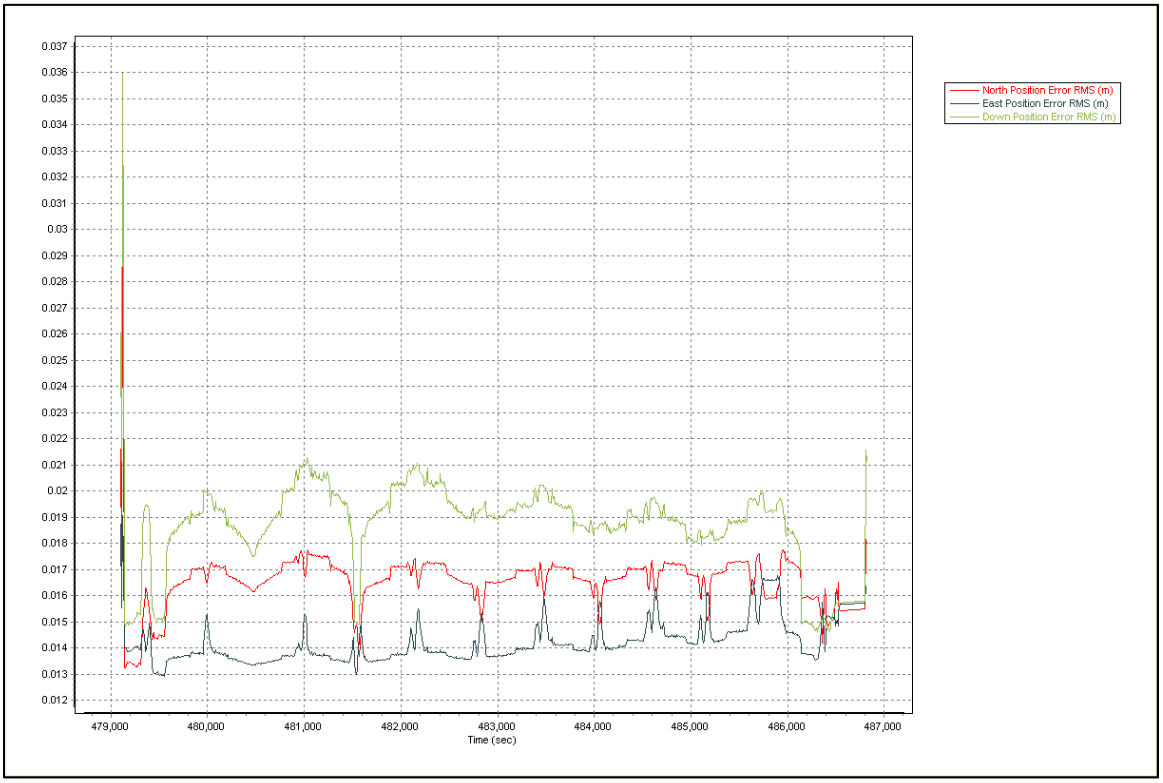
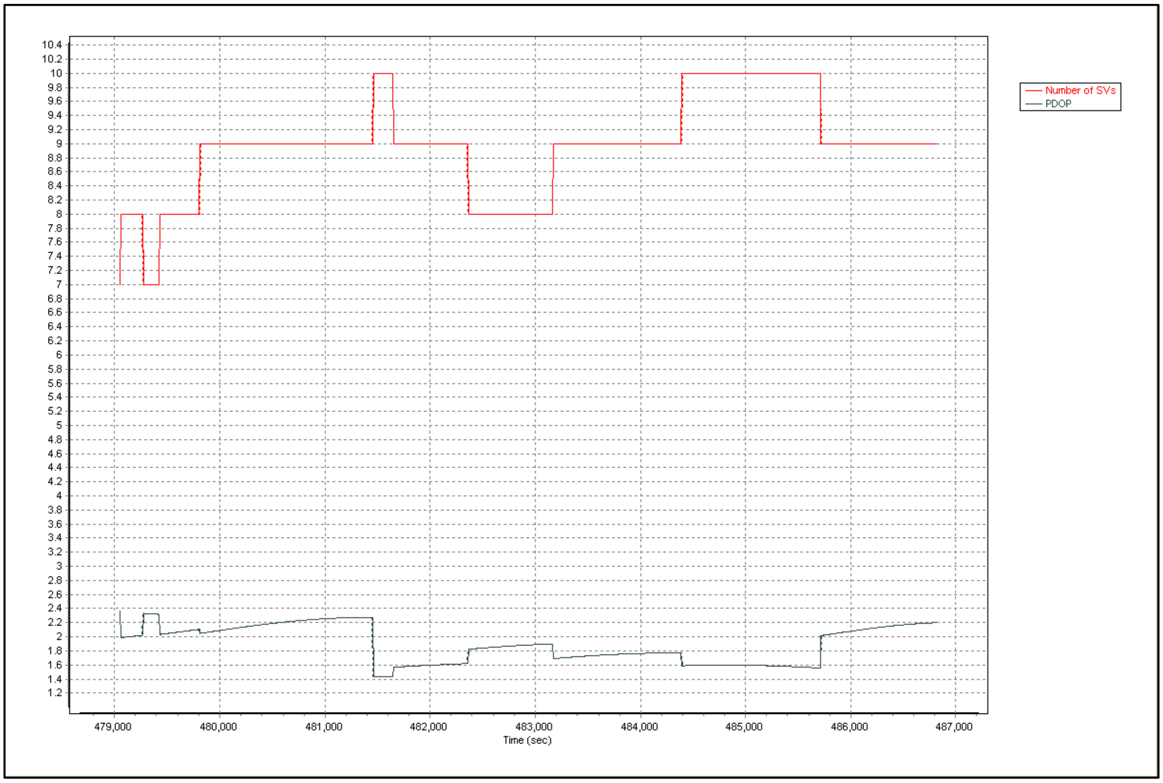


101210A-246-PDOP&SVS



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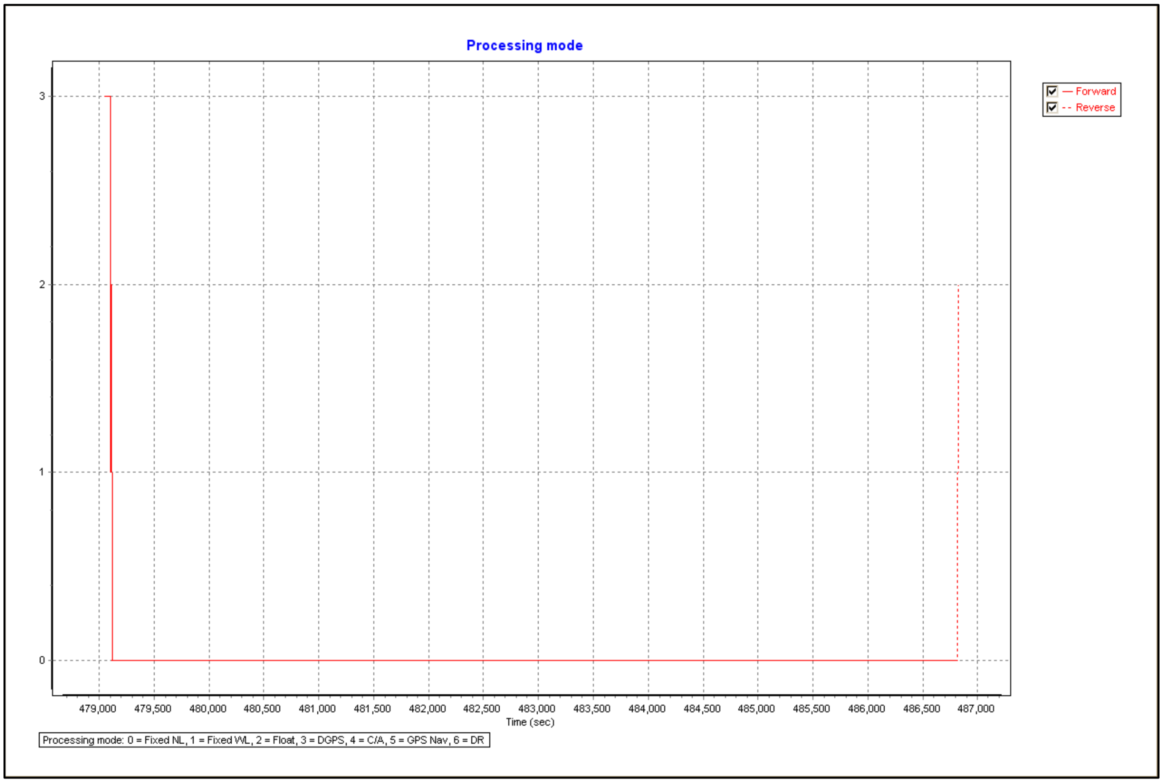
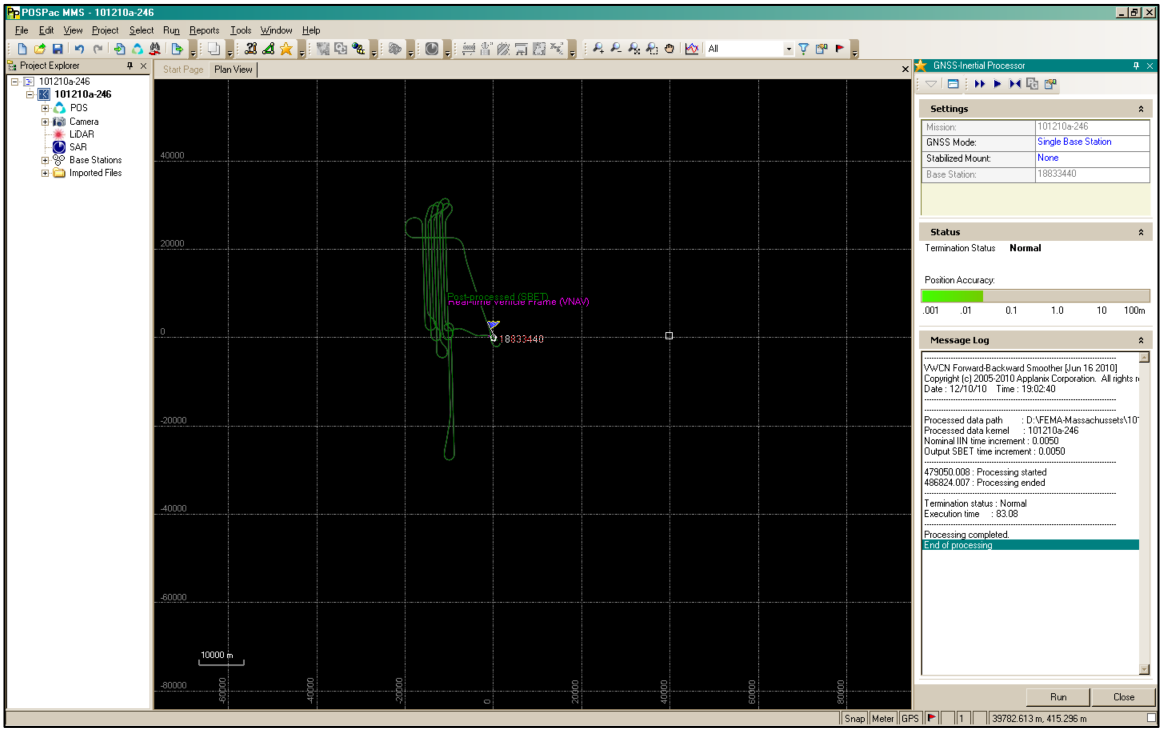


# 101210A-246-TRAJECTORY



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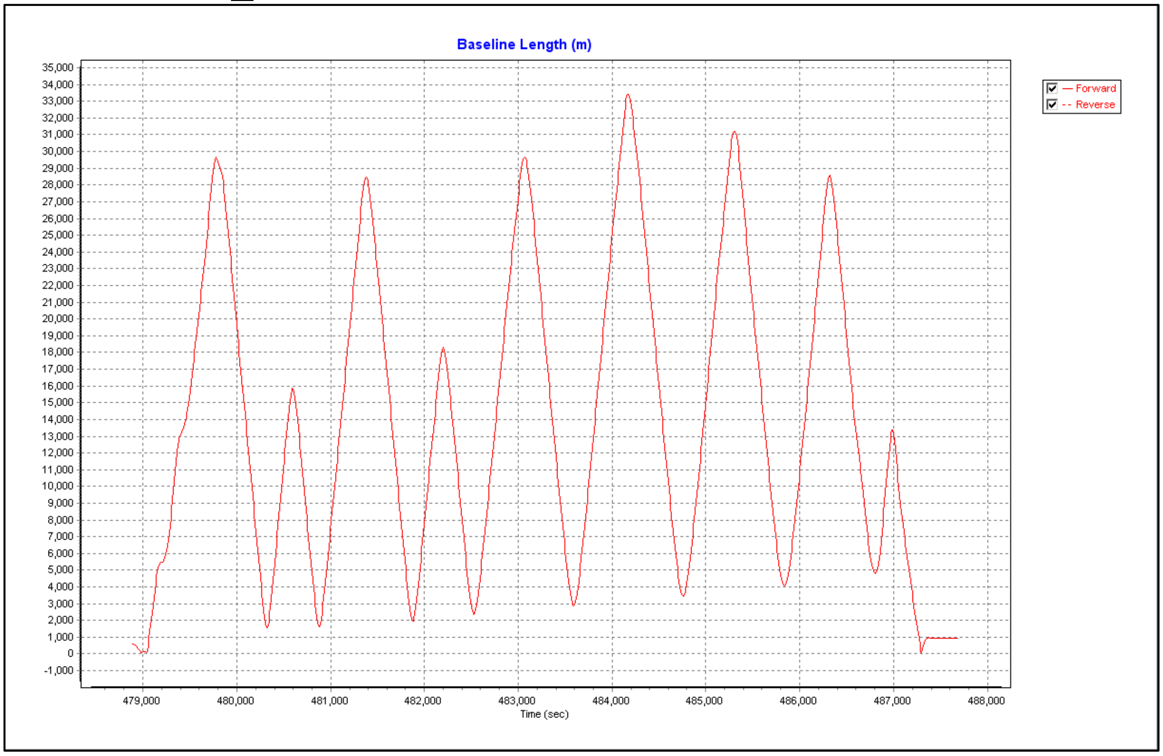

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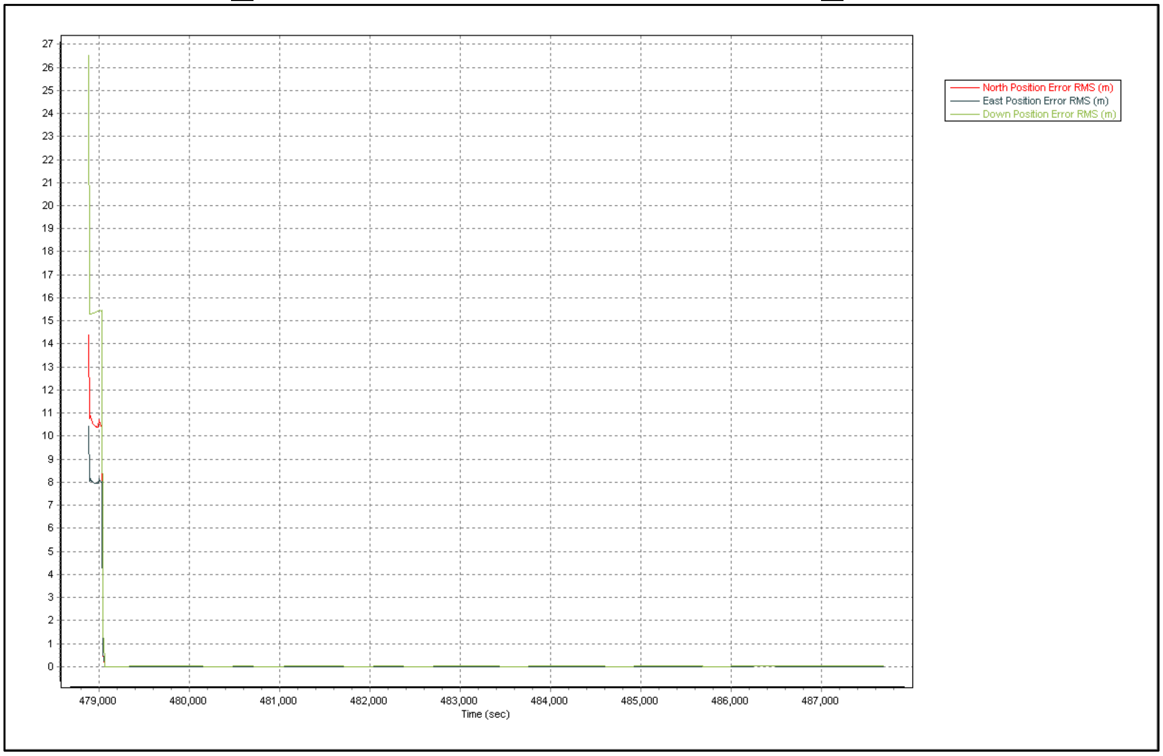

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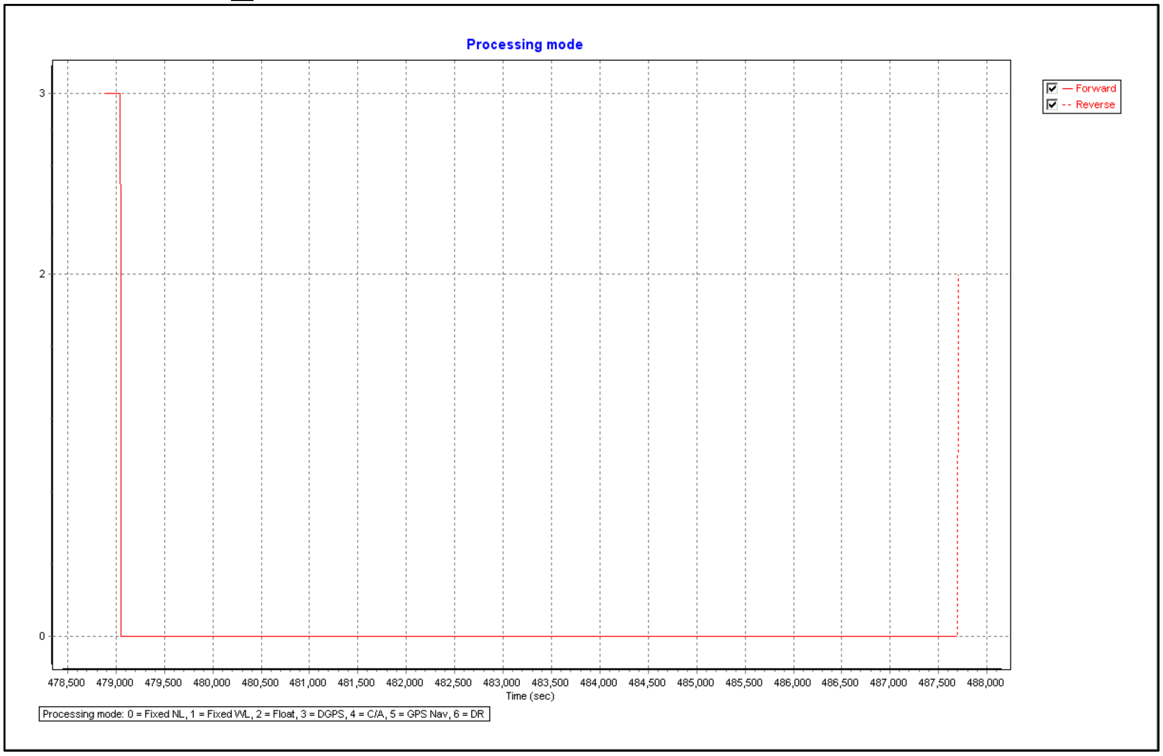
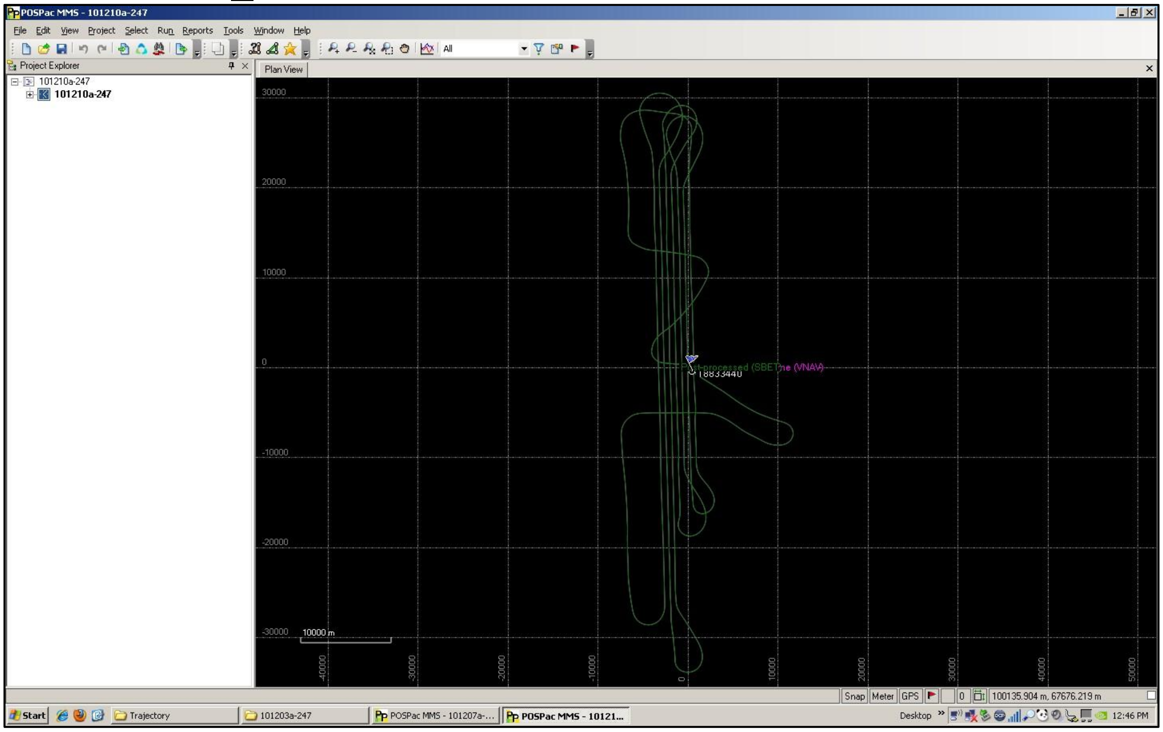


# 101210A-247_SCREENSHOT



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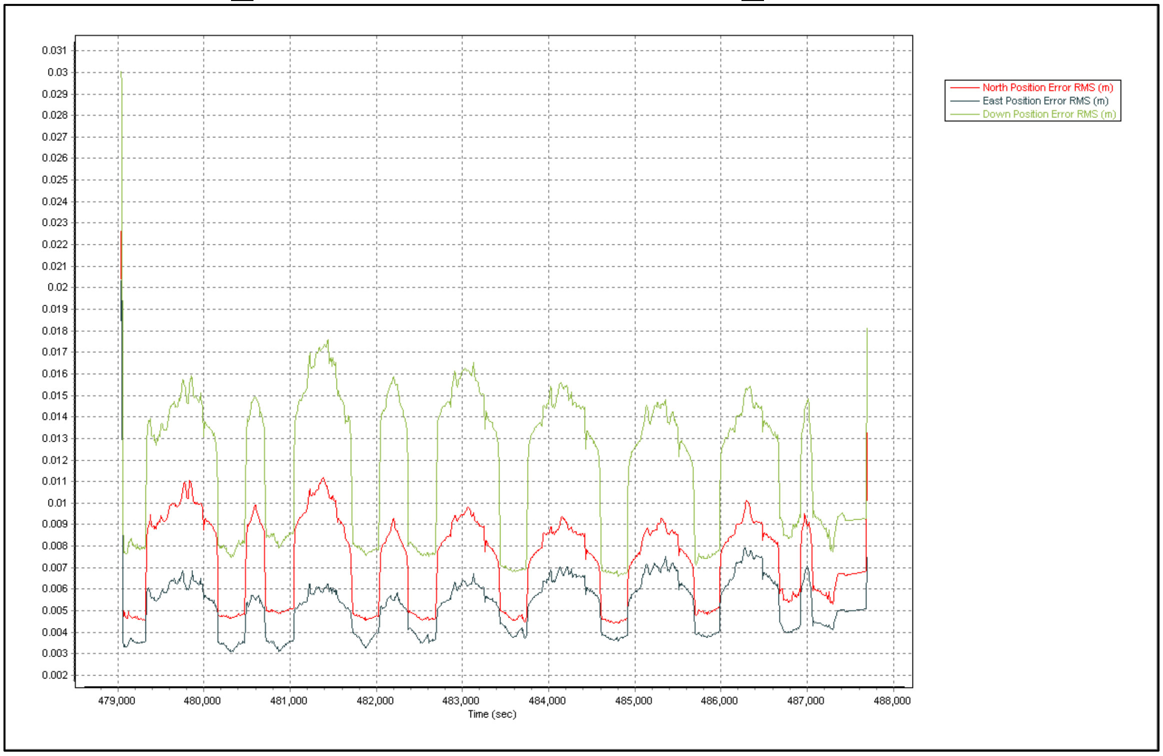
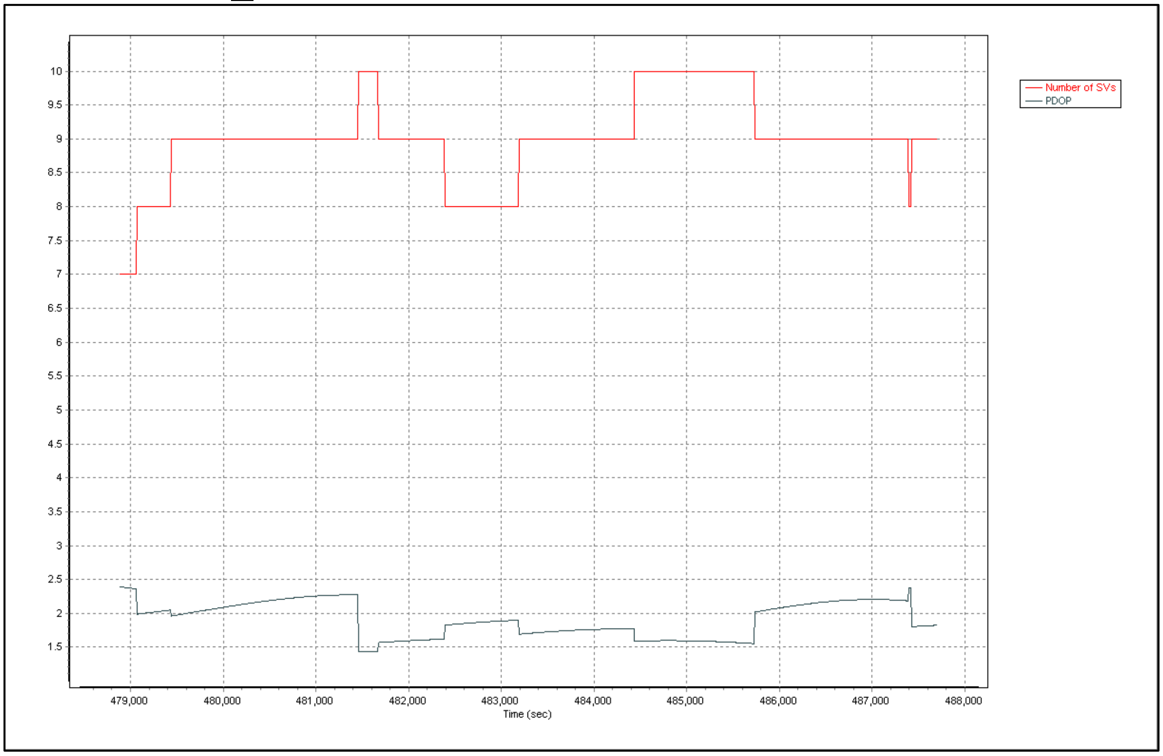
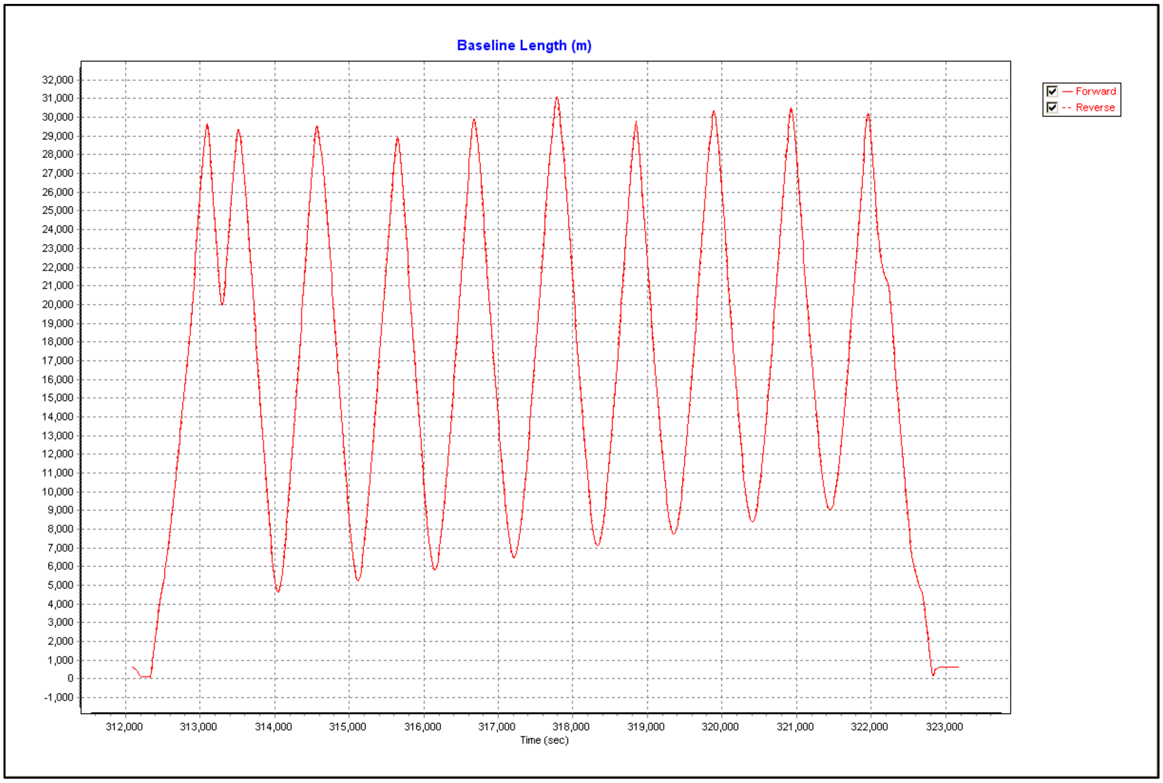


101210A-247_SVS&PDOP



# 101208A-246-BASELINELENGTH



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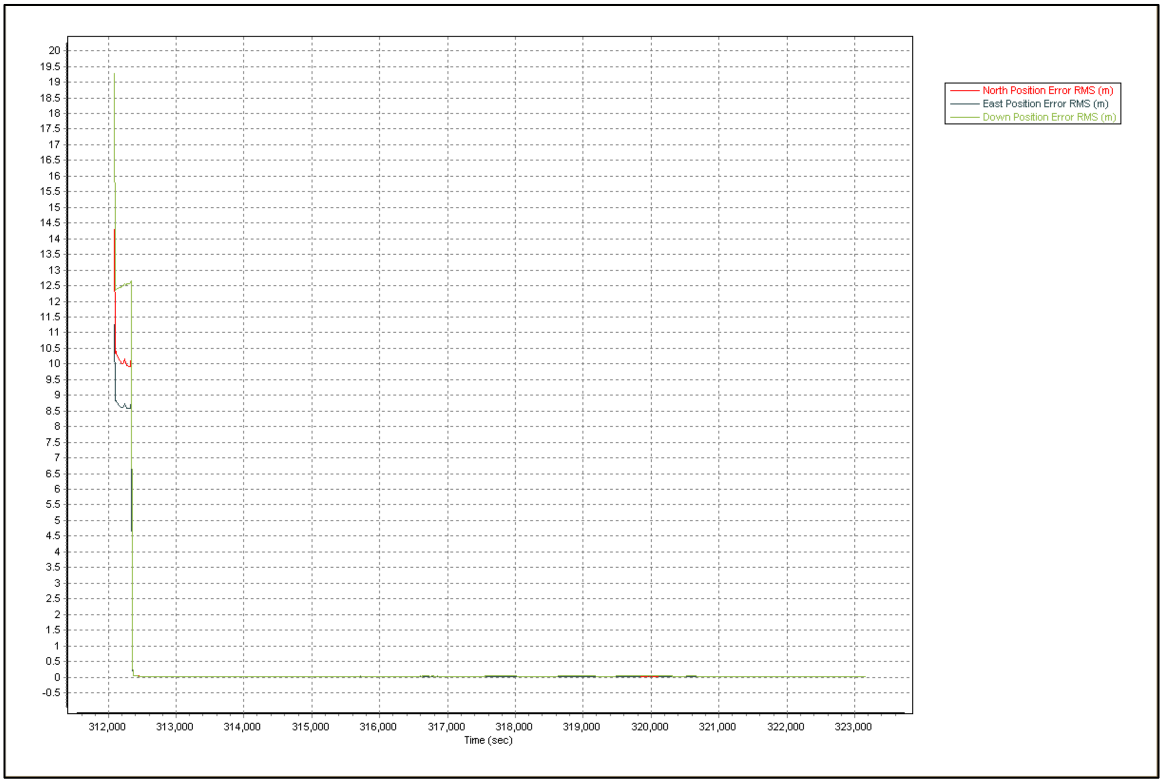
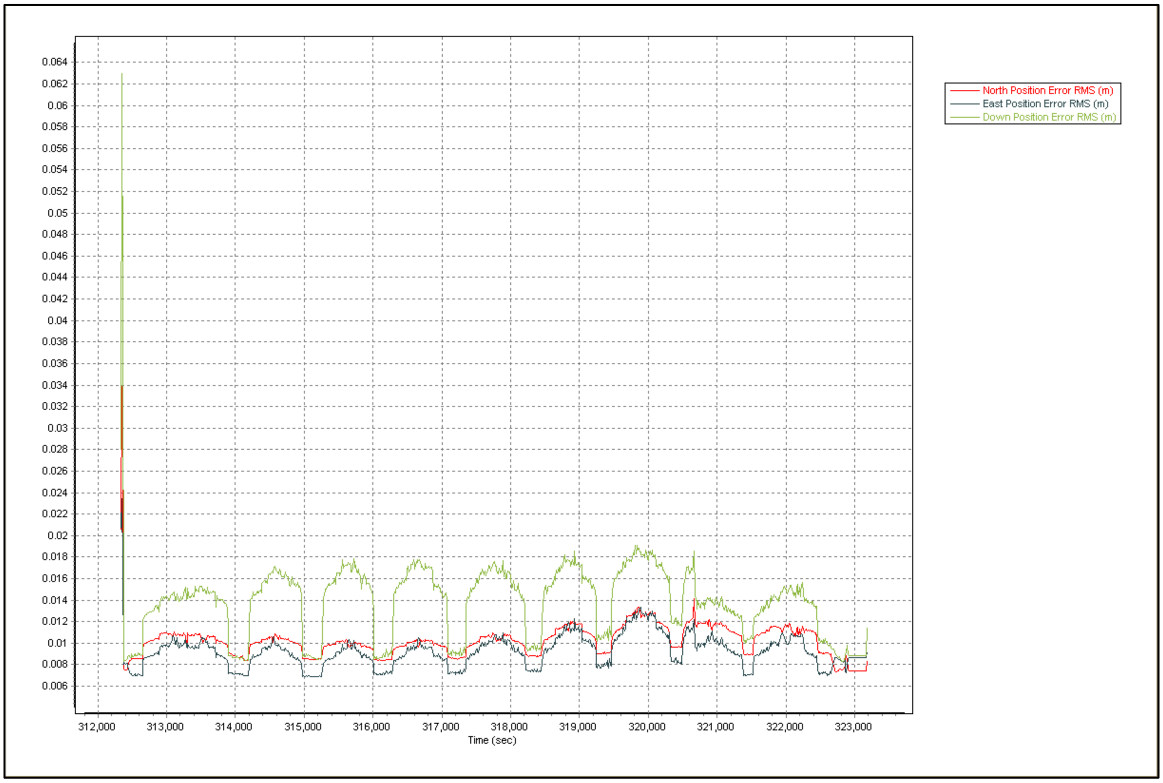
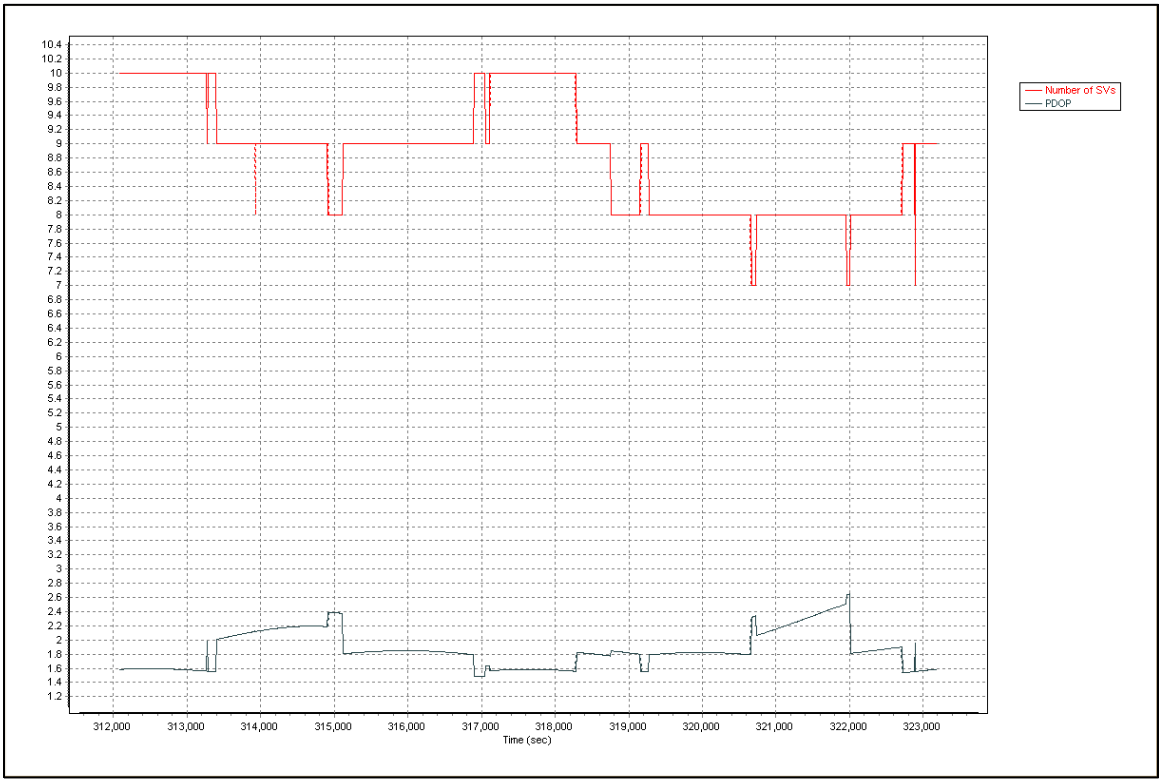


# 101208A-246-NEDPOSITIONERROR-SMOOTHED



# 101208A-246-PDOP&SVS



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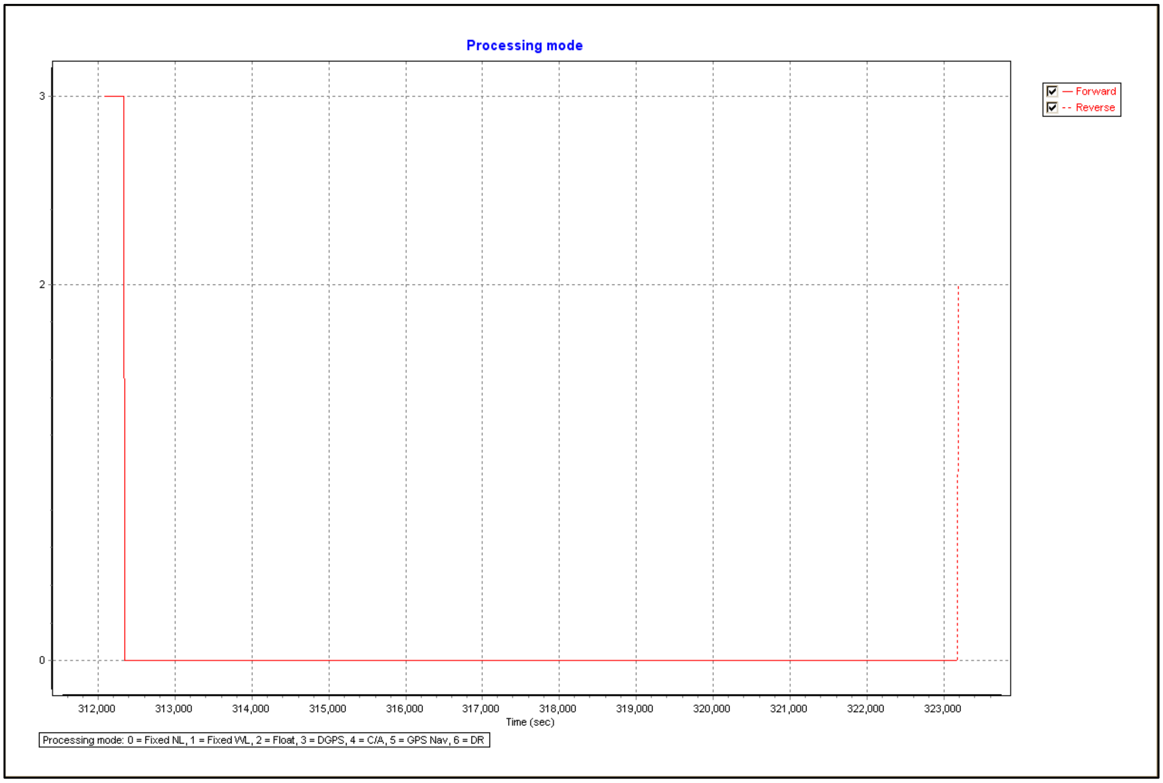

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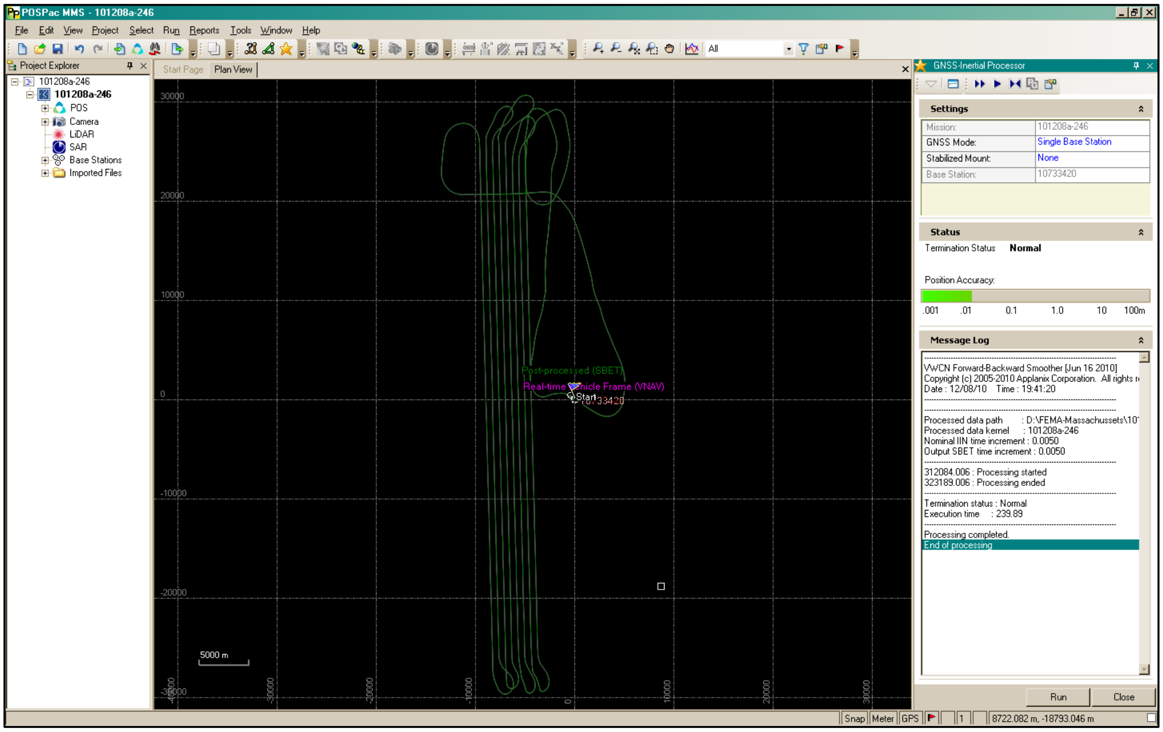

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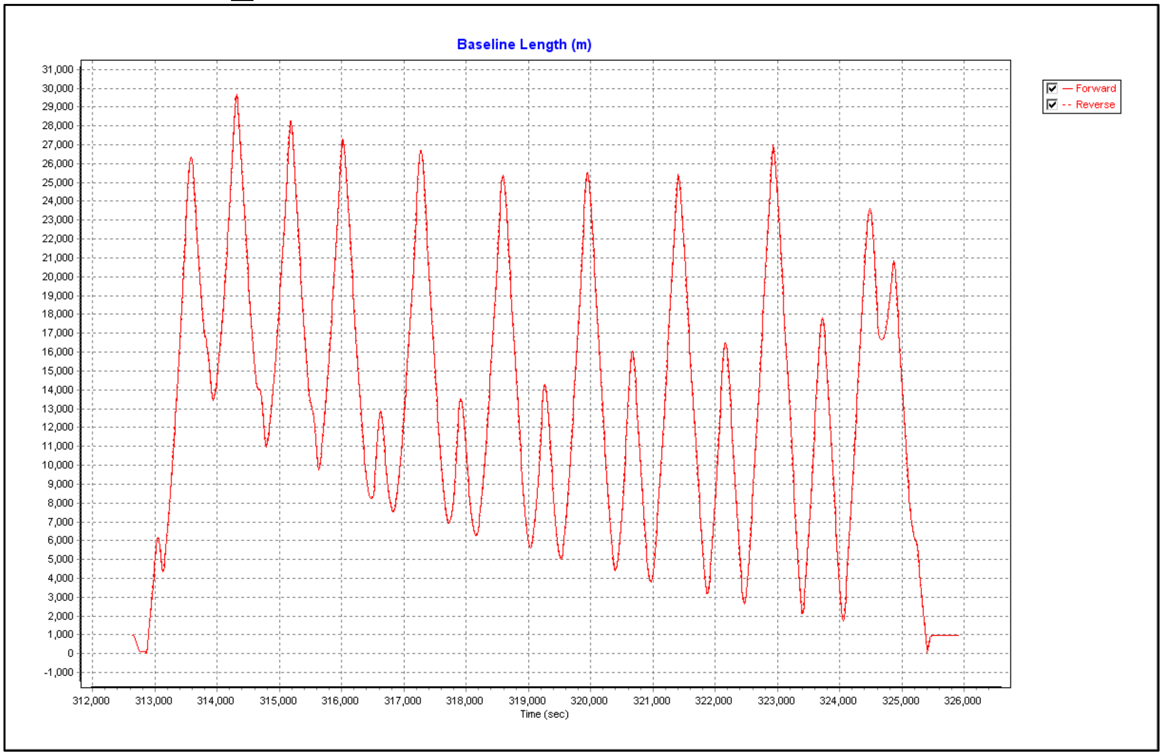

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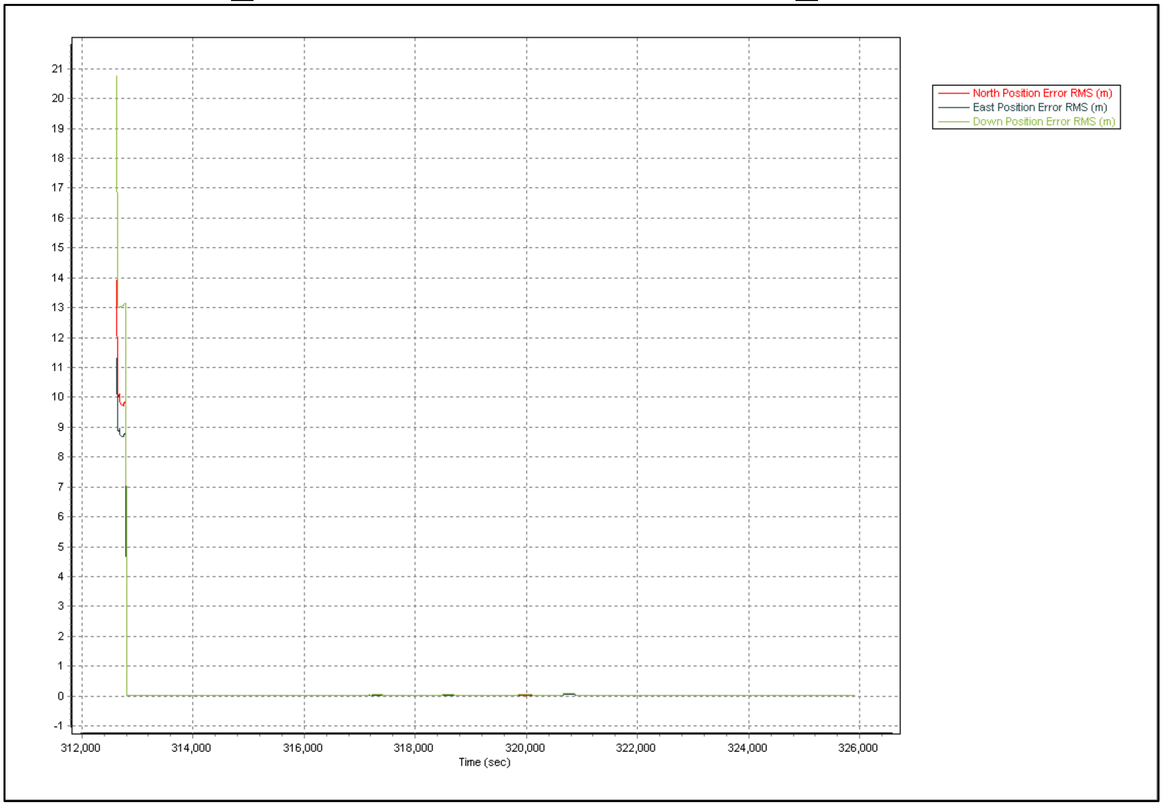


# Appendix F: Quality Assurance

| | | | | | | |
|---|---|---|---|---|---|---|
| Project Name: | Narragansett | | | | | |
| Project Description: | LiDAR .las | | | | | |
| State: | MA, RI | | | | | |
| HUC-8: | 1090004 | | | | | |
| Provider Name: | Photo Science | | | | | |
| Collection Area: | Narragansett HUC 8 | | | | | |
| Specification Level: | | | | | | |
| Contour Accuracy: | | | | | | |
| NPS: | 0.64 | | | | | |
| | | | | | | |
| Date Delivered: | 3/9/2011 | Point Cloud | 3/17/2011 | Bare Earth | | |
| Date QC: | 3/14/2001 | Point Cloud | 3/29/2011 | Bare Earth | | |
| | | | | | | |
| Media: | Hard Drive | | | | | |
| Contents of Media: | .las | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| Reviewed By: | Dan Hoff | | | | | |

| Post-Flight-Report | | |
|---|---|---|
| | Included | Comments |
| **GPS Base Station INFO** | | |
| GPS base station - names | P | |
| GPS base station - lat/longs | P | |
| GPS base station - heights | P | |
| GPS base station - Maximum PDOP | F | |
| GPS base station - map | P | |
| GPS base station - spatial data | F | |
| **GPS/IMU** | | |
| GPS quality - Max horizontal variance (cm). | F | |
| GPS quality - Max vertical variance (cm). | F | |
| GPS quality - Notes on GPS quality | P | |
| GPS quality - GPS separation plot | F | |
| GPS quality - GPS altitude plot | F | |
| GPS quality - PDOP plot | P | |
| GPS quality - Plot of GPS distance from base stations | P | |
| **Coverage** | | |
| Coverage - Verification of AOI coverage | P | |
| Coverage - Spatial data | P | |
| **Flights** | | |
| Flights - Calibration lines | P | |
| Flights - As-flown trajectories | P | |
| Flights - Spatial data | P | |
| **Control** | | |
| Control - Ground control and base station layout | P | |
| Control - Spatial data | F | |
| **Data verification/QC** | | |
| Data verification process documented | P | |

| Flight logs | Included | Comments |
|---|---|---|
| Incorporated as appendix | N | |
| Job # / name | Y | |
| Lift # | Y | |
| Block or AOI designator | Y | |
| Date | Y | |
| Aircraft tail number, type | Y | |
| Pilot name | Y | |
| Operator name | Y | |
| Airport of operations | Y | |
| GPS base station names | Y | |
| **Flight lines** | | |
| Flight line | Y | |
| Line # | Y | |
| Direction | Y | |
| Start/stop | Y | |
| Altitude | Y | |
| Scan angle/rate | Y | |
| Speed | Y | |
| Conditions | Y | |
| Comments | Y | |
| **Settings** | | |
| AGC switch setting | N/A | |
| Laser pulse rate | Y | |
| Mirror rate | Y | |
| Field of view | Y | |
| Comments | Y | |

| | | | |
|---|---|---|---|
| Point File Information QC | | | |
| | Point Cloud | | Bare Earth |
| LAS Version: | 1.2 | | 1.2 |
| Total Number of Tiles: | 359 | | 340 |
| Number of tiles to be reviewed: | **25** | | 24 |
| | | | |
| **All LAS** | | | |
| Coverage Area SqMi | 289.5 | 217 in scope, 289.5 includes overlapping tiles and voids at edge of collection | |
| Voids or Gaps | Pass | Only over water | Pass |
| Average Point Spacing | 0.64 | | 0.63 |
| QC tiles with NPS > Spec Level | Pass | only at edge of collection | Pass |
| | | | |
| **5% LAS Review** | | | |
| Tile selection | Done | PC_Review feature class in .gdb | Done |
| LASinfo | Pass | | |
| LAS2DEM | Pass | 100% review | Pass |

| | | |
|---|---|---|
| **Macro Review** | | |
| | | |
| **LAS Point Cloud Files** | Pass/Fail | Comments |
| Projection | P | |
| Datum | P | |
| Units | P | |
| Area covered 100m buffer | P | |
| Data Voids | P | |
| Correct Header | P | |
| Correct NPS | P | |
| **Returns Contain** | | |
| GPS time stamp | P | |
| GPS second in microsec | P | |
| Easting | P | |
| Northing | P | |
| Elevation | P | |
| Intensity | P | |
| Return # | P | |
| Classification | P | |
| Classification is correct | P | Point Cloud |
| Cloud file structure conforms to layout | P | |
| Cloud file naming conforms to project | P | |
| Tiles checked for gaps and voids | P | |
| | | |
| **Micro Review** | | |
| Total Number of Tiles: | 359 | |
| Number of tiles to be reviewed: | **25** | |
| | | |
| | Pass/Fail | |
| Excessive Noise | P | more noise than I have seen in other datasets, far more points as well |
| Elevation Steps | P | |
| LP360 Scan and profile | P | |

| Macro Review | | |
|---|---|---|
| | | |
| **LAS Bare Earth** | **Pass/Fail** | **Comments** |
| Projection | P | |
| Datum | P | |
| Units | P | |
| Area covered 100m buffer | | few northern most tips of HUC are not designated as Narrigansett-- these are included in Charles |
| Data Voids | P | |
| Correct Header | P | |
| Correct NPS | P | |
| **Returns Contain** | | |
| GPS time stamp | P | |
| GPS second in microsec | P | |
| Easting | P | |
| Northing | P | |
| Elevation | P | |
| Intensity | P | |
| Return # | P | |
| Classification | P | |
| Classification is correct | P | |
| Cloud file structure conforms to layout | P | |
| Cloud file naming conforms to project | P | |
| Tiles checked for gaps and voids | P | |
| | | |
| **Micro Review** | | |
| Total Number of Tiles: | 340 | |
| Number of tiles to be reviewed: | 24 | |
| | | |
| Excessive Noise | P | |
| Elevation Steps | P | |
| 2% Artifacts | P | |
| LP360 Scan and profile | P | |

# Appendix G: Deliverables

STARR

| | |
|---|---|
| **Date:** | **Contract #** |
| July 15, 2011 | HSFEHQ-090D-0370 |
| | **Task Order #** |
| | HSFEHQ -10-J-0005 |

**Subject:**

**STARR Elevation Data (LiDAR)**

**Transmittal:**

**To:** **Marie Sparrow**
**FEMA Engineering Library**
**%Zimmerman Associates, Inc**
**847 South Pickett Street**
**Alexandria, VA 22304**

**From:** **James Huffines**
**Greenhorne & O'Mara, Inc**
**5565 Centerview Drive**
**Ste 107**
**Raleigh, NC 27606**

**Transmitted:**

- ☐ For Your Use
- ☐ For Your Approval/Signature
- ☐ For Your Information
- ☐ For Your Review
- ☐ As Requested
- ☒ For Storage

**The following:**

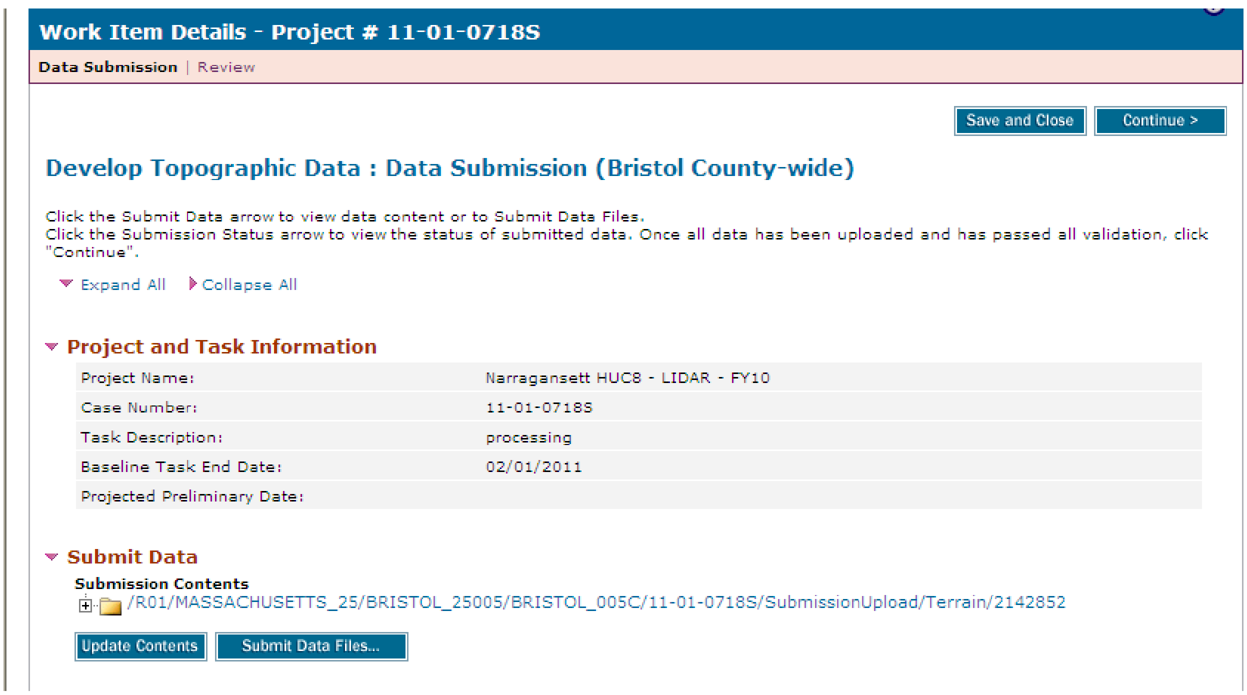
| COPIES | DATE | DESCRIPTION |
|---|---|---|
| 1 | 7/15/11 | Narragansett HUC8, MA terrain data - see readme.txt included on hard drive for directory structure. |
| | | Includes: Ground Control data, QC Checkpoint (FVA/CVA) data, PreFlight Report, PostFlight Report, Tile Index shapefile, Collection Area shapefile, Point Cloud (All Returns) LAS files, Bare Earth (Fully Classified) LAS files, QC Testing Results, QA Review spreadsheet, Compliance Certificates for Survey and LiDAR, Metadata for Survey, Point Cloud Data, and Bare Earth Data, and TSDN |
| | | |

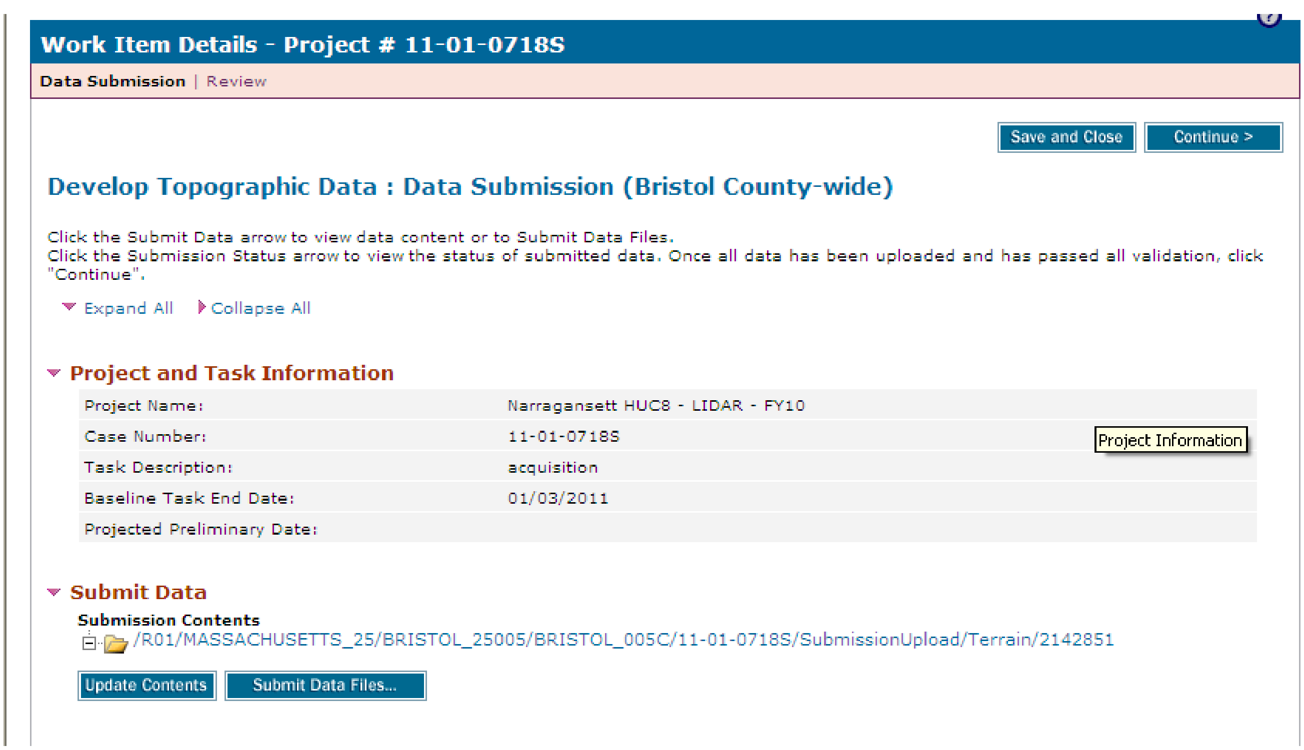
**Remarks:**

If you have any questions or require additional information please feel free to contact me at 919-532-2332.
Please sign this transmittal upon receipt and mail to address shown above or fax to 919-851-8393.

Printed Name and Date: ______________________

Signature: ______________________________


Work Item Details - Project # 11-01-0718S
Data Submission | Review
Save and Close
Continue >
Develop Topographic Data : Data Submission (Bristol County-wide)
Click the Submit Data arrow to view data content or to Submit Data Files.
Click the Submission Status arrow to view the status of submitted data. Once all data has been uploaded and has passed all validation, click "Continue".
Expand All
Collapse All
Project and Task Information
Project Name: Narragansett HUC8 - LIDAR - FY10
Case Number: 11-01-0718S
Task Description: processing
Baseline Task End Date: 02/01/2011
Projected Preliminary Date:
Submit Data
Submission Contents
/R01/MASSACHUSETTS_25/BRISTOL_25005/BRISTOL_005C/11-01-0718S/SubmissionUpload/Terrain/2142852
Update Contents
Submit Data Files...


Work Item Details - Project # 11-01-0718S
Data Submission | Review
Save and Close
Continue >
Develop Topographic Data : Data Submission (Bristol County-wide)
Click the Submit Data arrow to view data content or to Submit Data Files.
Click the Submission Status arrow to view the status of submitted data. Once all data has been uploaded and has passed all validation, click "Continue".
Expand All
Collapse All
Project and Task Information
Project Name: Narragansett HUC8 - LIDAR - FY10
Case Number: 11-01-0718S
Project Information
Task Description: acquisition
Baseline Task End Date: 01/03/2011
Projected Preliminary Date:
Submit Data
Submission Contents
/R01/MASSACHUSETTS_25/BRISTOL_25005/BRISTOL_005C/11-01-0718S/SubmissionUpload/Terrain/2142851
Update Contents
Submit Data Files...

## Work Item Details - Project # 11-01-0718S

**Data Submission** | Review

Save and Close | Continue >

### Develop Topographic Data : Data Submission (Bristol County-wide)

Click the Submit Data arrow to view data content or to Submit Data Files.
Click the Submission Status arrow to view the status of submitted data. Once all data has been uploaded and has passed all validation, click "Continue".

Expand All | Collapse All

#### Project and Task Information

| | |
|---|---|
| Project Name: | Narragansett HUC8 - LIDAR - FY10 |
| Case Number: | 11-01-0718S |
| Task Description: | ground control |
| Baseline Task End Date: | 11/30/2010 |
| Projected Preliminary Date: | |

#### Submit Data

**Submission Contents**

/R01/MASSACHUSETTS_25/BRISTOL_25005/BRISTOL_005C/11-01-0718S/SubmissionUpload/Terrain/2142850

Update Contents | Submit Data Files...

# Appendix H: Guidance Documents

U.S. Department of Homeland Security
500 C Street, SW
Washington, DC 20472

FEMA

**DATE**

**MEMORANDUM FOR:** Mitigation Division Directors Regions I-X, CTPs, Mapping Partners

**FROM:** Doug Bellomo, Director
Risk Analysis Division

**SUBJECT:** Procedure Memorandum No. XX—Standards for Lidar and Other High Quality Digital Topography

**EFFECTIVE DATES:** August 1, 2010



**Background**: Beginning in Fiscal Year (FY) 2010, Federal Emergency Management Agency (FEMA) initiated a five-year program for Risk Mapping, Assessment, and Planning (Risk MAP). FEMA's vision for the Risk MAP program is to deliver quality data that increases public awareness and leads to mitigation actions that reduce risk to life and property. To achieve this vision, FEMA will transform its traditional flood identification and mapping efforts into a more integrated process of accurately identifying, assessing, communicating, planning for, and mitigating flood risks.

Under Risk MAP, FEMA seeks to:

- Deliver new data and products that expand risk awareness and promote mitigation planning that leads to risk reduction actions.
- Increase production efficiencies for Flood Insurance Rate Maps (FIRMs) and Flood Insurance Studies (FISs).

**Issue:** To implement FEMA's Risk MAP vision and provide the high quality topographic data necessary to meet Risk MAP's goals, FEMA Regions and Mapping Partners need upgraded guidance concerning the accuracy, and processing of high quality topographic data including Light Detection and Ranging (lidar) data. To that end, this Procedure Memorandum will supersede Appendix A: Guidance for Aerial Mapping and Surveying of the *Guidelines and Specifications for Flood Hazard Mapping Partners* (Guidelines) in key areas (defined in the Procedure Memorandum Attachments), and must be implemented beginning with all topographic data collected by FEMA beginning in FY 2010.

**Actions Taken:** When procuring topographic data under the Risk MAP Program the Mapping Partner assigned to obtain topographic data or perform independent QA of topographic data must meet the specifications detailed in this Procedure Memorandum's attachments. The attachments align FEMA's high quality topographic specifications, found in Appendix A of the Guidelines, with the United States Geological Survey (USGS) *Lidar Guidelines and Base Specifications* v13 so that data procured and used by the Federal government is consistent across agencies and is updated to industry standards. Further, adherence to these specifications will support the Risk MAP Program by closing gaps in existing flood hazard data; supporting risk assessments; and better communicating risks to community officials and the public.

Existing elevation data, not acquired by FEMA, but planned for use on a new flood hazard analysis must comply with the accuracy, density and the final product metadata requirements detailed in the attachments and, but is not required to comply with the other specifications included and referenced below.

Consistent with FEMA's overall approach to flood hazard identification, this Procedure Memorandum aligns FEMA topographic data specifications to level of risk, and accounts for different slopes in the terrain that can affect the accuracy of base flood elevations and the delineation of mapped floodplains. These specifications represent the minimum requirements. Where funding partners are involved or where the engineering requirements dictate, projects may use higher specification levels or include additional processing. Quality assurance requirements for high quality topographic data are also provided.

**Attachments:**
Attachment 1 – Definitions
Attachment 2 – Alignment of FEMA Appendix A to USGS *Lidar Guidelines and Base Specification* v13
Attachment 3 – Topographic Breakline and Hydro-Enforcement Specifications
Attachment 4 – Topographic Data Quality Review Process

**Distribution List:**

**Attachment 1 – Definitions**

**Digital Elevation Data –** Includes all of the following terms: mass points, point clouds, breaklines, contours, TINs, DEMs, DTMs or DSMs.

- **Breakline –** A linear feature demarking a change in the smoothness or continuity of a surface such as abrupt elevation changes or a stream line. The two most common forms of breaklines are as follows:
  - A **soft breakline** ensures that known elevations, or z-values, along a linear feature are maintained (e.g., elevations along a pipeline, road centerline or drainage ditch), and ensures the boundary of natural and man-made features on the Earth's surface are appropriately represented in the digital terrain data by use of linear features and polygon edges They are generally synonymous with 3-D breaklines because they are depicted with series of x/y/z coordinates.
  - A **hard breakline** defines interruptions in surface smoothness, e.g., to define streams, shorelines, dams, ridges, building footprints, and other locations with abrupt surface changes. Although some hard breaklines are three dimensional (3-D) breaklines, they are often depicted as two dimensional (2-D) breaklines because features such as shorelines and building footprints are normally depicted with a series of horizontal coordinates only which are often digitized from digital orthophotographs that include no elevation data.
- **Contours –** Lines of equal elevation on a surface. An imaginary line on the ground, all points of which are at the same elevation above or below a specified vertical datum.
- **Digital Elevation Model (DEM) –** An elevation model created for use in computer software where bare-earth elevation values have regularly spaced intervals in latitude and longitude (x and y). The $\Delta x$ and $\Delta y$ values are normally measured in feet or meters to even units; however, the National Elevation Dataset (NED) defines the spacing interval in terms of arc-seconds of latitude and longitude, e.g., 1/3rd arc-second.
- **Digital Surface Model (DSM) –** An elevation model created for use in computer software that is similar to DEMs or DTMs except that DSMs depict the elevations of the top surfaces of buildings, trees, towers, and other features elevated above the bare earth.
- **Digital Terrain Model (DTM) –** An elevation model created for use in computer software of bare-earth mass points and breaklines. DTMs are technically superior to a gridded DEM for many applications because distinctive terrain features are more clearly defined and precisely located, and contours generated from DTMs more closely approximate the real shape of the terrain.
- **Mass Points –** Irregularly spaced points, each with latitude and longitude location coordinates and elevation values typically used to form a TIN.
- **Metadata –** Project descriptive information about the elevation dataset.
- **Point Cloud –** Often referred to as the "raw point cloud", this is the first data product of a lidar instrument. In its crudest form, a lidar raw point cloud is a collection of range measurements and sensor orientation parameters. After initial processing, the range and orientation of each laser value is converted to a position in a three dimensional frame of reference and this spatially coherent cloud of points is the base for further processing and analysis. The raw point cloud typically includes first, last, and intermediate returns for each laser pulse. In addition to spatial information, lidar intensity returns provide texture or color information. The combination of three dimensional spatial information and spectral information contained

in the lidar dataset allows great flexibility for data manipulation and extraction. As used in this procedure memorandum, two additional lidar data processing terms are defined as follows:

  - **Lidar Preliminary Processing –** The initial processing and analysis of laser data (GPS/IMU/laser ranges) to fully "calibrated point clouds" in some specified tile format. All lidar data will be set to ASPRS LAS Class 1 (unclassified) and must include testing for Fundamental Vertical Accuracy (FVA). The tile format can change later, if necessary.
  - **Lidar Post-Processing –** The final processing and classification of lidar data to the required ASPRS LAS classes, per project specifications. This must include testing for Consolidated Vertical Accuracy (CVA). At this point, the datasets are referred to as the "classified point cloud."
- **Triangulated Irregular Network (TIN) –** A set of adjacent, non-overlapping triangles computed from irregularly-spaced points with lattitude, longitude, and elevation values. The TIN data structure is based on irregularly-spaced point, line, and polygon data interpreted as mass points and breaklines and stores the topological relationship between triangles and their adjacent neighbors. The TIN model may be preferable to a DEM when it is critical to preserve the precise location of narrow or small features, such as levees, ditch or stream centerlines, isolated peaks or pits in the data model.
- **Z-Values –** The elevations of the 3-D surface above the vertical datum at designated x/y locations.

**Geospatial Accuracy Standard –** A common accuracy testing and reporting methodology that facilitates sharing and interoperability of geospatial data. Published in 1998, the National Standard for Spatial Data Accuracy (NSSDA) is the Federal Geographic Data Committee (FGDC) standard relevant to digital elevation data when assuming that errors follow a normal error distribution. However, after it was learned that lidar datasets do not necessarily follow a normal distribution in vegetated terrain, the National Digital Elevation Program (NDEP) published its "Guidelines for Digital Elevation Data" and the American Society for Photogrammetry and Remote Sensing (ASPRS) published the "ASPRS Guidelines: Vertical Accuracy Reporting for Lidar Data," both of which were published in 2004 and use newer terms defined below as Fundamental Vertical Accuracy (FVA), Supplemental Vertical Accuracy (SVA) and Consolidated Vertical Accuracy (CVA). All of these standards, designed for digital elevation data, replace the National Map Accuracy Standard (NMAS) that is applicable only to graphic maps defined by map scale and contour interval.



**Accuracy –** The closeness of an estimated value (e.g., measured or computed) to a standard or accepted (true) value of a particular quantity. Note: With the exception of GPS Continuously Operating Reference Stations (CORS), assumed to be known with zero errors relative to established datums, the true locations of 3-D spatial coordinates or other points are not known, but only estimated. Therefore, the accuracy of other coordinate information is unknown and can only be estimated. Other accuracy definitions are as follows.

- **Absolute Accuracy –** A measure that accounts for all systematic and random errors in a data set. Absolute accuracy is stated with respect to a defied datum or reference system.
- **Accuracy**$_r$ **–** The NSSDA reporting standard in the horizontal component that equals the radius of a circle of uncertainty, such that the true or theoretical horizontal location of the

point falls within that circle 95-percent of the time. $Accuracy_r = 1.7308 \times RMSE_r$. Horizontal accuracy is defined as the positional accuracy of a dataset with respect to a horizontal datum.

- **$Accuracy_z$ —** The NSSDA reporting standard in the vertical component that equals the linear uncertainty value, such that the true or theoretical vertical location of the point falls within that linear uncertainty value 95-percent of the time. $Accuracy_z = 1.9600 \times RMSE_z$. Vertical accuracy is defined as the positional accuracy of a dataset with respect to a vertical datum.
- **Consolidated Vertical Accuracy (CVA) –** The result of a test of the accuracy of vertical checkpoints (z-values) consolidated for two or more of the major land cover categories, representing both open terrain and other land cover categories. Computed by using the 95$^{th}$ percentile, CVA is always accompanied by Fundamental Vertical Accuracy (FVA).
- **Fundamental Vertical Accuracy (FVA) –** The value by which vertical accuracy can be equitably assessed and compared among datasets. The FVA is determined with vertical checkpoints located only in open terrain, where there is a very high probability that the sensor will have detected the ground surface. FVA is calculated at the 95% confidence level in open terrain only, using $RMSE_z \times 1.9600$,
- **Local Accuracy –** A value that represents the uncertainty in the coordinates of a control point relative to the coordinates of other directly-connected, adjacent control points at the 95-percent confidence level. The reported local accuracy is an approximate average of the individual local accuracy values between this control point and other observed control points used to establish the coordinates of the control point.
- **Network Accuracy –** A value that represents the uncertainty in the coordinates of a control point with respect to the geodetic datum at the 95-percent confidence level. For National Spatial Reference System (NSRS) network accuracy classification in the U.S., the datum is considered to be best expressed by the geodetic values at the CORS supported by the National Geodetic Survey (NGS). By this definition, the local and network accuracy values at CORS sites are considered to be infinitesimal, i.e., to approach zero.
- **Percentile –** Any of the values in a dataset of errors dividing the distribution of the individual errors in the dataset into one hundred groups of equal frequency. Any of those groups can specify a specific percentile, e.g., the 95$^{th}$ percentile as defined below.
- **Precision –** A statistical measure of the tendency of a set of random numbers to cluster about a number determined by the dataset. *Precision* relates to the quality of the method by which the measurements were made and is distinguished from *accuracy* which relates to the quality of the result. The term "precision" not only applies to the fidelity with which required operations are performed, but, by custom, has been applied to methods and instruments employed in obtaining results of a high order of precision. Precision is exemplified by the number of decimal places to which a computation is carried and a result stated.
- **Positional Accuracy** – The accuracy of the position of features, including horizontal and/or vertical positions.
- **Relative Accuracy** – A measure that accounts for random errors in a data set. Relative accuracy may also be referred to as point-to-point accuracy. The general measure of relative accuracy is an evaluation of the random errors (systematic errors and blunders removed) in determining the positional orientation (e.g., distance, azimuth) of one point or feature with respect to another.
- **Root Mean Square Error (RMSE) –** The square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent

source of higher accuracy for identical points. The vertical RMSE ($RMSE_z$), for example, is calculated as the square root of $\sum(Z_n - Z'_n)^2/N$, where:

- $Z_n$ is the set of N z-values (elevations) being evaluated, normally interpolated (for TINs and DEMs) from dataset elevations of points surrounding the x/y coordinates of checkpoints
- $Z'_n$ is the corresponding set of checkpoint elevations for the points being evaluated
- N is the number of checkpoints
- n is the identification number of each of the checkpoints from 1 through N.

- **Supplemental Vertical Accuracy (SVA) –** The result of a test of the accuracy of z-values over areas with ground cover categories or combination of categories other than open terrain. Computed by using the 95$^{th}$ percentile, SVA is always accompanied by Fundamental Vertical Accuracy (FVA). SVA values are computed individually for different land cover categories. Each land cover type representing 10% of more of the total project area is typically tested and reported as an SVA. SVA specifications are normally target values that may be exceeded so long as overall CVA requirements are satisfied.
- **95% Confidence Level** – Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value. The reported accuracy value reflects all uncertainties, including those introduced by geodetic control coordinates, compilation, and final computation of ground coordinate values in the product. Where errors follow a normal error distribution, $Accuracy_z$ defines vertical accuracy at the 95% confidence level (computed as $RMSE_z$ x 1.9600), and $Accuracy_r$ defines horizontal (radial) accuracy at the 95% confidence level (computed as $RMSE_r$ x 1.7308).
- **95$^{th}$ Percentile –** Accuracy reported at the 95$^{th}$ percentile indicates that 95% of the errors will be of equal or lesser value and 5% of the errors will be of larger value. This term is used when errors may not follow a normal error distribution, e.g., in forested areas where the classification of bare-earth elevations may have a positive bias. Vertical accuracy at the 95% confidence level and 95$^{th}$ percentile may be compared to evaluate the degree to which actual errors approach a normal error distribution.



**Resolution –** In the context of elevation data, resolution is synonymous with the horizontal density of elevation data points for which two similar terms are used:

- **Nominal Pulse Spacing (NPS)** – The estimated average spacing of irregularly-spaced lidar points in both the along-track and cross-track directions resulting from: the laser pulse repetition frequency (e.g., 100,000 pulses of laser energy emitted in one second from a 100 kHz sensor); scan rate (sometimes viewed as the number of zigzags per second for this common scanning pattern); field-of-view; and flight airspeed. Lidar system developers currently provide "design NPS" as part of the design pulse density, although the American Society for Photogrammetry and Remote Sensing (ASPRS) is currently developing standard procedures to compute the "empirical NPS" which should be approximately the same as the "design NPS" when accepting statistically insignificant loss of returns and disregarding void areas, from water for example. The NPS assessment is made against single swath first return data located within the geometrically usable center portion (typically ~90%) of each swath. Average along-track and cross-track pulse spacing should be comparable. When point density is increased by relying on overlap or double-coverage it should be documented in metadata and not by changing the project's reported NPS. The NPS should be equal to or less than the Digital Elevation Model (DEM) post spacing when gridded DEMs are required as part of project specifications. This same definition for NPS could similarly apply to irregularly-spaced mass points from photogrammetry or Interferometric Synthetic Aperture Radar (IFSAR) data. NPS pertains to lidar only and is not intended to pertain to photogrammetry or IFSAR.

- **DEM Post Spacing –** Sometimes confused with Nominal Pulse Spacing, the DEM Post Spacing is defined as the constant sampling interval in x- and y-directions of a DEM lattice or grid. This is also called the horizontal resolution of a gridded DEM or the DEM grid spacing. It is standard industry practice to have:
  - 1-meter DEM post spacing for elevation data with 1-foot equivalent contour accuracy;
  - 2-meter DEM post spacing for elevation data with 2-foot equivalent contour accuracy;
  - 5-meter DEM post spacing for elevation data with 5-foot equivalent contour accuracy.

**Attachment 2 – Alignment of FEMA Appendix A to USGS Lidar Specification v13**

FEMA is aligning Appendix A of the *Guidelines and Specifications for Flood Hazard Mapping Partners* (Guidelines) to the USGS *Lidar Guidelines and Base Specification* v13 to modernize the FEMA specifications to current industry practice, leverage the expertise of the USGS Geography discipline, maintain Federal standards across agencies, and support the use of elevation products acquired as part of Risk MAP by other agencies for other purposes thus maximizing the Government's investment.

Overall, new elevation data purchased by FEMA must comply with the USGS *Lidar Guidelines and Base Specification* v13, except where specifically noted in this Procedure Memorandum.

Because FEMA's needs for elevation are specific to floodplain mapping, FEMA has some unique requirements that differ from the USGS specifications. To supplement the existing USGS specifications, FEMA-specific items such as cross section surveys, bridges, and other features in Appendix A of the Guidelines remain valid except where superseded by more current information provided in this attachment. Table 1 summarizes the sections in Appendix A that are fully superseded, partially superseded or not superseded by this Procedure Memorandum.

**Table 2.1 Currency of Major Sections within FEMA's Appendix A: Guidance for Aerial Mapping and Surveying**

| Section | Name | Status |
|---|---|---|
| A.1 | Introduction | Is not superseded and remains valid. |
| A.2 | Industry Geospatial Standards | Remains valid but is appended by additional standards which use newer standards from the National Digital Elevation Program (NDEP) and American Society for Photogrammetry and Remote Sensing (ASPRS) to test elevation data for Fundamental Vertical Accuracy (FVA), Supplemental Vertical Accuracy (SVA), and Consolidated Vertical Accuracy (CVA). |
| A.3 | Accuracy Guidelines | Partly superseded, especially Table 2, below, that specifies variable vertical accuracy standards and nominal pulse spacing (NPS), depending on the risk level and terrain slope within the floodplain being mapped. |
| A.4 | Data Requirements | Major portions are superseded. Subsection A.4.2.3 pertaining to breaklines, subsection A.4.3 pertaining to elevation data vertical accuracy, and subsection A.4.5 pertaining to mapping area, are superseded. Subsection A.4.11 pertaining to other digital topographic data requirements, including Table A-3, Digital Topographic Data Requirements Checklist, is now superseded by other FEMA procurement guidelines. Subsection A.4.9 on data formats is partially superseded by the addition of lidar LAS formatted datasets. Subsections pertaining to cross sections (A.4.6) and hydraulic structures (A.4.7) remain valid. |
| A.5 | Ground Control | Is not superseded and remains valid. |
| A.6 | Ground Surveys | Is not superseded and remains valid. |

| Section | Name | Status |
|---|---|---|
| A.7 | Photogrammetric Surveys | Remains valid but is appended by additional standards which require low confidence areas to be delineated for photogrammetry as well as lidar and interferometric synthetic aperture radar (IFSAR). The vast majority of section A.7 remains valid and unchanged. |
| A.8 | Airborne LiDAR | Superseded with references the USGS *Lidar Guidelines and Base Specification* v13; and by NDEP and ASPRS guidelines for accuracy testing and reporting of lidar data. |

## 2.1Elevation Specifications Based on Risk Levels

FEMA maintains a national dataset that estimates flood risk. The basic data is calculated at the Census Block Group level, and is also aggregated to the sub-watershed, watershed and county levels. These data assign a risk value and a risk rank to each area. The areas are grouped into 10 classes with an equal number of members based on risk rank. These 10 classes are called risk deciles.

The table below provides the minimum elevation standards for new engineering analyses produced by FEMA. The highest and high specifications are suitable for either basic or enhanced engineering analyses. The medium and low specifications are suitable for basic engineering analyses. Where more than 20% of the project area covered by the new elevation will have enhanced engineering analyses, the next higher elevation specification level may be appropriate. When the scope of the enhanced engineering analyses is not sufficient to justify increasing the overall project specification level, the bulk elevation data collection may be enhanced by field survey in areas of enhanced engineering analyses if necessary.



**Table 2.2. Vertical Accuracy Requirements based on Flood Risk and Terrain Slope within the Floodplain being mapped**

| Level of Flood Risk | Typical Slopes | Specification Level | Vertical Accuracy, 95% Confidence Level FVA/CVA | Lidar Nominal Pulse Spacing (NPS) |
|---|---|---|---|---|
| High (Deciles 1,2,3) | Flattest | Highest | 24.5 cm/36.3 cm | ≤1 meter |
| High (Deciles 1,2,3) | Rolling or Hilly | High | 49.0 cm/72.6 cm | ≤2 meters |
| High (Deciles 2,3,4,5) | Hilly | Medium | 98.0 cm/145 cm | ≤3.5 meters |
| Medium (Deciles 3,4,5,6,7) | Flattest | High | 49.0 cm/72.6 cm | ≤2 meters |
| Medium (Deciles 3,4,5,6,7) | Rolling | Medium | 98.0 cm/145 cm | ≤3.5 meters |

| | | | | |
|---|---|---|---|---|
| Medium (Deciles 4,5,6,7) | Hilly | Low | 147 cm/218 cm | ≤5 meters |
| Low (Deciles 7,8,9,10) | All | Low | 147 cm/218 cm | ≤5 meters |

Whereas contour lines are for visual interpretation and are unnecessary for FEMA's automated H&H analyses, the term "equivalent contour accuracy" is used to show the accuracy of contour lines that could be produced from a DEM if needed for manual analysis; this is also for the benefit of those who do not understand NSSDA terminology that defines vertical accuracy at the 95% confidence level. Table 3 explains "equivalent contour accuracy" for various standard contour intervals, referenced also in terms of vertical root mean square error ($RMSE_z$), National Standard for Spatial Data Accuracy (NSSDA) $Accuracy_z$, SVA and CVA.

**Table 2.3. Accuracy Terms that Equal "Equivalent Contour Accuracy"**

| Equivalent Contour Accuracy | FEMA Specification Level | $RMSE_z$ | NSSDA $Accuracy_z$ 95% confidence level | SVA (target) | CVA (mandatory) |
|---|---|---|---|---|---|
| 1 ft | | 0.30 ft or 9.25 cm | 0.60 ft or18.2 cm | 0.60 ft or18.2 cm | 0.60 ft or18.2 cm |
| 2 ft | Highest | 0.61 ft or 18.5 cm | 1.19 ft or 36.3 cm | 1.19 ft or 36.3 cm | 1.19 ft or 36.3 cm |
| 4 ft | High | 1.22 ft or 37.1 cm | 2.38 ft or 72.6 cm | 2.38 ft or 72.6 cm | 2.38 ft or 72.6 cm |
| 5 ft | | 1.52 ft or 46.3 cm | 2.98 ft or 90.8 cm | 2.98 ft or 90.8 cm | 2.98 ft or 90.8 cm |
| 8 ft | Medium | 2.43 ft or 73.9 cm | 4.77 ft or 1.45 m | 4.77 ft or 1.45 m | 4.77 ft or 1.45 m |
| 10 ft | | 3.04 ft or 92.7 cm | 5.96 ft or1.82 m | 5.96 ft or1.82 m | 5.96 ft or1.82 m |
| 12 ft | Low | 3.65 ft or 1.11m | 7.15 ft or 2.18 m | 7.15 ft or 2.18 m | 7.15 ft or 2.18 m |

FEMA's requirements for elevation data are specific to flood risk analysis. As a result, FEMA's requirements diverge from the USGS specification which is intended to serve a different purpose. Two of the key differences with the FEMA specifications are the requirements for vertical accuracy and nominal pulse spacing. The FEMA requirements in these areas are only similar to the USGS requirements in the highest specification level, but otherwise differ for the lower accuracy levels.

All data collected must go through lidar preliminary processing and the unclassified point cloud must be tested as specified in the USGS specification. Where the Mapping Activity Statement (MAS) requires bare earth post-processing of the floodplain area of interest (AOI), the elevation data must be tested and comply with both the FVA and CVA requirements. Where no bare earth post-processing is specified, only the FVA requirements apply for lidar preliminary processing.

Many other organizations require higher-accuracy lidar data for diverse applications and combine their resources to solve multiple needs with lidar. FEMA prefers to acquire elevation data through partnerships so that the resulting data will meet a broader variety of end user needs and be more consistent with the overall USGS specification. These partnership elevation collection activities will frequently utilize specifications that exceed the minimums described above in Table 2. Before committing funds to a new elevation mapping project, FEMA Regional staff should first determine whether funds could be spent more effectively by cooperating with other agencies to more cost-effectively acquire elevation data. FEMA is a member of the National Digital Elevation Program (NDEP) which was formed, in part, to avoid duplication of effort among state and federal government agencies acquiring digital elevation data. USGS maintains state geospatial liaisons that are a good source of information regarding the status of existing and/or planned mapping activities in their states.

## 2.2 Light Detection and Ranging (lidar)

Lidar is capable of delivering 1- foot equivalent contour accuracy with sub-meter NPS used to produce DEMs with 1-meter DEM gridded post spacing. Therefore, lidar could satisfy FEMA's requirements for elevation data in high risk, moderate risk, and low risk areas. Lidar is often the best technology for mapping the elevations of the bare earth terrain in dense vegetation.

If this technology is selected for high risk areas, lidar will be collected in accordance with the USGS *Lidar Guidelines and Base Specification*, v13, for the National Geospatial Program except as noted. FEMA does not require the data to be hydro-flattened, as specified in v13. Also, FEMA does not require all data to be processed to the bare earth terrain, but instead limits the area to be processed to areas in the vicinity of floodplains that will require hydraulic modeling. See FEMA's Procurement Guidelines for specifics on this topic.

The following USGS specifications are most relevant to FEMA and are consistent with FEMA requirements:

- Fundamental Vertical Accuracy (FVA) pertains only to open, non-vegetated terrain. The FVA is specified at a higher level of accuracy than other land cover categories. The FVA is a mandatory specification that must be satisfied in order to be usable by FEMA for flood risk mapping within the specified level of flood risk.
- Supplemental Vertical Accuracy (SVA) pertains to other major land cover categories representative of the floodplain being mapped. SVA values are target values, where one SVA category can test higher and another lower than the target SVA value so long as the overall CVA is satisfied for the consolidated equivalent contour accuracy.
- Consolidated Vertical Accuracy (CVA) pertains to all land cover categories combined. Compliance with the CVA specification is mandatory in order for an elevation dataset to qualify for satisfaction of a specified equivalent contour accuracy.
- For the highest specification level equivalent to 2 foot contour accuracy, the relative accuracy should be ≤ 7 cm $RMSE_z$ within individual swaths; ≤ 10 cm $RMSE_z$ within swath overlap (between adjacent swaths). These relative accuracy specifications double to 14 and 20 cm, respectively, for risk areas that utilize the high elevation specification with 4 foot equivalent contour accuracy. This specification is not applicable to lower risk areas.
- Consistent with USGS *Lidar Guidelines and Base Specification*, v13, a regular grid, with cell size equal to the design NPS*2 will be laid over the first return data within the geometrically usable center portion of each swath. At least 90% of the cells in the grid shall contain at least one lidar point.
- All data collected will be delivered consistent with the USGS Raw Point Cloud deliverable requirements.

- Where lidar post-processing is performed, the deliverables must also include the classified point cloud deliverable. The data will be delivered in full compliance with LAS classes 1 (processed, but unclassified), 2 (bare-earth ground), 7 (noise), 9 (water), 10 (ignored), and 11 (withheld). All points not identified as “withheld” are to be classified. “Overlap” classification (Class 12) shall not be used.
- The horizontal datum shall be referenced to the latest adjustment of the North American Datum of 1983 (NAD83 [NSRS2007]).
- The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD88) whenever available. Areas outside of the continental U.S. where NAVD88 is not available should be referenced to a reproducible local datum that can be used to support floodplain management.
- The most recent approved Geoid model from the National Geodetic Survey (NGS) shall be used to perform conversions from ellipsoidal heights to orthometric heights.
- The standard coordinate reference system and units shall be Universal Transverse Mercator (UTM), meters. Considerations for other standard coordinate systems such as State Plane can be made for projects which are contributed to by mapping partners.
- The single non-overlapped tiling scheme shall be established and agreed upon by the data producer and FEMA prior to collection, consistent with the USGS *Lidar Guidelines and Base Specifications,* v13.
- Specifications for breaklines and hydro-enforcement are addressed in Attachment B.
- Specifications for lidar accuracy testing by land cover categories within the floodplain being mapped are addressed in Attachment C.

Lidar dataset deliverables shall include the following:

1. Metadata should comply with the requirements in the USGS *Lidar Guidelines and Base Specification*, v13. In addition, the finished elevation product for hydraulic modeling should be documented by a FGDC-compliant metadata file that complies with the FEMA Elevation Metadata Profile. Project documentation must also include a Pre-flight Operations Plan and Post-flight Aerial Survey and Calibration Report as described in Attachment 4.
2. Raw point cloud data shall comply with the requirements in the USGS Lidar Guidelines and Base Specification, v13.
3. Classified point cloud data shall comply with requirements in the USGS Lidar Guidelines and Base Specification, v13.
4. Optional breaklines, when produced, shall be delivered in compliance with guidance in Attachment 3
5. Optional digital bare earth elevation data product(s) (e.g., DEM, DTM, contours) in file formats specified in the Statement of Work.

## 2.3 Photogrammetry

Photogrammetry is also capable of delivering 1-foot equivalent contour accuracy and a DEM with 1-meter post spacing. Therefore, photogrammetry could also satisfy FEMA’s requirements for elevation data in high risk, moderate risk, and low risk areas. Except for the new requirement to delineate areas of low confidence, existing guidance published in section A.7, Photogrammetric Surveys, in Appendix A of FEMA's Guidelines, remain current for new aerial image acquisition with either film or digital cameras.

The USGS annually contracts for leaf-off orthoimagery of selected areas under the National Geospatial Program, typically producing digital orthophotographs with pixel resolution of 30 cm (~1 foot) or 15 cm (~6 inches), as do many states and local governments; and the USDA contracts for leaf-on orthoimagery of major areas of the U.S. annually under the National Agricultural Imagery Program (NAIP) with pixel resolution of 1 meter. Although intended for production of digital orthophotos, those same images could be reused for production of digital elevation data because the aerotriangulation (AT) solution for production of orthophotos can be reused for establishing stereo models from which DEMs can be produced by photogrammetric auto-correlation and/or manual compilation. Elevation accuracies typically achievable by reuse of digital imagery and AT metrics are as follows:

- Typically acquired at an elevation of approximately 4,800 feet above mean terrain, imagery and AT solutions used to produce digital orthophotos with 6-inch pixel resolution should be acceptable for elevation data with 2.5-foot equivalent contour accuracy
- Typically acquired at an elevation of approximately 9,600 feet above mean terrain, imagery and AT solutions used to produce digital orthophotos with 1-foot pixel resolution should be acceptable for elevation data with 5-foot equivalent contour accuracy
- Typically acquired at an elevation of approximately 30,000 feet above mean terrain, imagery and AT solutions used to produce digital orthophotos with 1-meter pixel resolution should be acceptable for elevation data with 15-foot equivalent contour accuracy.

Photogrammetric dataset deliverables shall include the following:

1. Metadata shall include:
    - Collection Report detailing mission planning and flight logs, flying heights, camera parameters, forward overlap and sidelap.
    - Survey Report detailing the collection of control and reference points used for calibration and QA/QC.
    - Aerial triangulation (AT) report detailing compliance with relevant accuracy statistics.
    - Processing Report detailing photogrammetric processed used to manually compile elevation data or to semi-automatically compile elevation data with automated image correlation or other techniques.
    - QA/QC reports.
    - Geo-referenced extents of each delivered dataset.
2. Digital bare earth elevation data product (DEM, DTM, mass points, breaklines, contours) specified in the Statement of Work.
3. Optional breaklines, when produced, shall be delivered in compliance with guidance in Attachment 3



## 2.4 Ground Surveys

All ground surveys must be performed in accordance with procedures in Section A.5, Ground Control, and Section A.6, Ground Surveys, in Appendix A of FEMA's Guidelines. Cross-section surveys and hydraulic structure surveys shall also be performed in accordance with sections A.4.6 and A.4.7, respectively, of Appendix A.

## 2.5 Low Confidence Areas

Regardless of technology used, FEMA requires that low confidence areas be delineated by the data provider to indicate areas where the vertical data may not meet the data accuracy requirements due to heavy vegetation even though the specified nominal pulse spacing was met or exceeded in those areas. The metadata must explain steps taken to minimize the areas delineated as low confidence areas. Accuracy test points are normally retained within such areas and are not discarded. The data provider must take reasonable steps to minimize areas delineated as low confidence areas, taking into consideration the density of the vegetation in the floodplain being mapped and other factors.
These low confidence areas must be delivered as polygons in accordance with a database schema. The database schema for polygons defining low confidence areas is as follows.

**Feature Dataset:** TOPOGRAPHIC **Feature Class:** CONFIDENCE
**Feature Type:** Polygon
**Contains M Values:** No **Contains Z Values:** No
**Annotation Subclass:** None
**XY Resolution:** Accept Default Setting **Z Resolution:** Accept Default Setting
**XY Tolerance:** 0.003 **Z Tolerance:** N/A

### 2.5.1 Description

This polygon feature class will depict areas where the ground is obscured by dense vegetation, meaning that the resultant bare-earth digital terrain model (DTM) may not meet the required accuracy specifications in these obscured areas. Low confidence areas can pertain to lidar, photogrammetry or IFSAR.

### 2.5.2 Table Definition

| Field Name | Data Type | Allow Null Values | Default Value | Domain | Precision | Scale | Length | Responsibility |
|---|---|---|---|---|---|---|---|---|
| OBJECTID | Object ID | | | | | | | Assigned by Software |
| SHAPE | Geometry | | | | | | | Assigned by Software |
| DATESTAMP_DT | Date | Yes | | | 0 | 0 | 8 | Assigned by Contractor |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by Contractor |
| SHAPE_AREA | Double | Yes | | | 0 | 0 | | Calculated by |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Contractor |
| TYPE | Long Integer | No | 1 | Obscure | 0 | 0 | | Assigned by Contractor |

## 2.5.3 Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Low Confidence Area | "Low confidence areas" are defined by the data provider to indicate areas where the vertical data may not meet the data accuracy requirements due to heavy vegetation even though the nominal pulse spacing was met or exceeded in those areas. | Capture as closed polygon. Compiler does not need t z-values of vertices; feature class will be 2-D only. |

### Attachment 3 – Topographic Breakline and Hydro-Enforcement Specifications

FEMA has no minimum breakline requirements; breaklines are optional and depend upon the procedures used to perform hydrologic and hydraulic modeling. The FEMA Project Manager should specify the breaklines requirements if desired based on the planned approach for hydraulic analysis or the mapping partner may propose breakline requirements based on the anticipated hydraulic modeling approach.

When optional breaklines are produced, the following breakline topology rules must be followed for the applicable feature classes. The topology must be validated by each contractor prior to delivery to FEMA.

| **Name: BREAKLINES_Topology** | | | Cluster Tolerance: 0.003<br>Maximum Generated Error Count: Undefined<br>State: Analyzed without errors | |
|---|---|---|---|---|
| **Feature Class** | **Weight** | **XY Rank** | **Z Rank** | **Event Notification** |
| COASTALSHORELINE | 5 | 1 | 1 | No |
| HYDROGRAPHICFEATURE | 5 | 1 | 1 | No |
| PONDS_AND_LAKES | 5 | 1 | 1 | No |
| HYDRAULICSTRUCTURE | 5 | 1 | 1 | No |
| ISLAND | 5 | 1 | 1 | No |

***Topology Rules***

| Name | Rule Type | Trigger Event | Orgin (FeatureClass::Subtype) | Destination (FeatureClass::Subtype) |
|---|---|---|---|---|
| Must not intersect | The rule is a line-no intersection rule | No | HYDRAULICSTRUCTURE::All | HYDRAULICSTRUCTURE::All |
| Must not intersect | The rule is a line-no intersection rule | No | HYDROGRAPHICFEATURE::All | HYDROGRAPHICFEATURE::All |
| Must not intersect | The rule is a line-no intersection rule | No | COASTALSHORELINE::All | COASTALSHORELINE::All |
| Must not intersect | The rule is a line-no intersection rule | No | PONDS_AND_LAKES::All | PONDS_AND_LAKES::All |
| Must not intersect | The rule is a line-no intersection rule | No | ISLAND::All | ISLAND::All |
| Must not overlap | The rule is a line-no overlap line rule | No | HYDROGRAPHICFEATURE::All | COASTALSHORELINE::All |
| Must not self-intersect | The rule is a line-no self intersect rule | No | HYDRAULICSTRUCTURE::All | HYDRAULICSTRUCTURE::All |
| Must not self-intersect | The rule is a line-no self intersect rule | No | HYDROGRAPHICFEATURE::All | HYDROGRAPHICFEATURE::All |
| Must not self-intersect | The rule is a line-no self intersect rule | No | COASTALSHORELINE::All | COASTALSHORELINE::All |

| Name | Rule Type | Trigger Event | Orgin (FeatureClass::Subtype) | Destination (FeatureClass::Subtype) |
|---|---|---|---|---|
| Must not self-intersect | The rule is a line-no self intersect rule | No | PONDS_AND_LAKES::All | PONDS_AND_LAKES::All |
| Must not self-intersect | The rule is a line-no self intersect rule | No | ISLAND::All | ISLAND::All |

**Attachment 4 – Topographic Data Quality Review and Reporting Process**

To complement the topographic data specifications in this procedure memorandum, this attachment describes data quality review processes and reporting obligations to be performed on new topographic data procured by FEMA as part of a flood hazard study or Risk MAP project. The mapping partner responsible for producing the elevation data is responsible for the quality of the product. In addition, FEMA may assign another mapping partner to perform Independent QA/QC of Topographic Data

Existing topographic data leveraged by FEMA should be certified to meet or tested for the vertical accuracy requirements specified in this procedure memo. In addition, the quality reviews described here are best practices that may be applied to existing topographic data. However, some of the documentation needed to perform some of these reviews may not be readily available for existing data..

## 4.1 Quality Reviews and Reporting Performed by Data Provider

The mapping partner responsible for producing new elevation data must submit copies of QA reports as specified in USGS Lidar Guidelines and Base Specification version 13. Unless the responsibility for checkpoint surveys and vertical accuracy testing is specifically assigned to a different mapping partner performing Independent QA/QC, the mapping partner responsible for producing the elevation data must test the unclassified point cloud data for Fundamental Vertical Accuracy (FVA) and, when lidar post-processing is performed must also test the bare earth product for Supplemental Vertical Accuracy (SVA) and Consolidated Vertical Accuracy (CVA).

### 4.1.1 Ground Survey of Quality Review Checkpoints

Quality review checkpoint surveys shall be performed in accordance with procedures in Section A.6.4, Checkpoint Surveys and A.6.5 Survey Records, in Appendix A of FEMA's Guidelines.

Checkpoints surveyed for accuracy reporting shall not be used by the data provider in the calibration or adjustment of the topographic data.

### 4.1.2 Assessment of Initial Vertical Accuracy

Assessment of the fully calibrated, raw point cloud initial vertical accuracy is required to ensure data has successfully completed preliminary processing. The absolute and relative accuracy of the data, relative to known control, shall be verified <u>prior</u> to classification and subsequent product development , by calculating FVA, measured in open, non-vegetated terrain. The spatial distribution of checkpoints for FVA testing should be based on the entire project collection area, distributed to avoid clustering, and support vertical accuracy reporting that is representative of the whole project.

If the project area exceeds 2,000 square miles it must be divided into smaller blocks of 2,000 square miles or less and tested as individual areas. In addition, the division of large project areas should apply the following rules if applicable:

- Divide areas by vendor used

- Divide areas by sensor type (manufacturer)

- Divide areas by flight dates if significant temporal difference is present

- Other logical project divisions based factors that might have a systematic relationships to data quality.

Reporting of positional accuracy shall be in accordance with ASPRS/NDEP standards as well as the USGS *Lidar Guidelines and Base Specification*, v13, Section II.13 and shall use the following statement:

Tested ____ (meters) fundamental vertical accuracy at 95% confidence level

Reporting on the assessment of the point cloud initial vertical accuracy shall include the following at a minimum:

- ***A description of the process used to test the points***
- A graphic depicting the spatial distribution of the ground survey checkpoints
- Descriptive statistics and RMSEz in FVA calculations

**4.1.3 Assessment of Bare Earth Vertical Accuracy**

When bare earth post-processing is included in the project, assessment of the vertical accuracy for the delivered bare earth elevation product is required to ensure data has successfully completed post processing. Reporting of positional accuracy shall be in accordance with ASPRS/NDEP standards for FVA and CVA. Testing should be performed on the bare earth deliverable as specified in the mapping activity statement, along with the following guidance:

- If an assessment of initial vertical accuracy (FVA) was conducted prior to the processing of the data (section 4.1.2), the FVA checkpoints can again be used in the CVA computations if located within the area to be processed

- The SVA for up to three significant land cover categories, in terms of percentage of the project area covered, shall be tested in addition to the open/bare ground areas already tested for FVA Land cover categories making up 10% or more of the project area should be included in the SVA testing

- For smaller projects less than 1,000 square miles, fewer check points for SVA testing is acceptable. The number of checkpoints shall be reduced to control the QA cost to about 10% of the acquisition and processing cost. The checkpoints should be distributed evenly across the SVA land cover types.

- Processing areas greater than 2,000 square miles must be divided into smaller blocks of 2,000 square miles or less and tested as individual areas. In addition, the division of large processing areas should apply the following rules if applicable:

- Divide areas by vendor used
- Divide areas by sensor type (manufacturer)
- Divide areas by flight dates if significant temporal difference is present
- Other logical project divisions based factors that might have a systematic relationships to data quality.

1.

- Each block of 2,000 square miles or less shall be tested for FVA, SVA, and CVA

Checkpoints used for testing SVA of the bare earth elevation product must be located in the areas where bare earth post-processing was performed, distributed to avoid clustering, and support vertical accuracy reporting that is representative of the post processed areas. The SVA results will then be combined with the FVA results to compute CVA for the entire project area.

Reporting on the assessment of the vertical accuracy of the post-processed, delivered elevation data shall include the following at a minimum:

- ***A description of the process used to test the points***
- A graphic depicting the spatial distribution of the ground survey checkpoints
- An analysis of checkpoints that have errors exceeding the 95$^{th}$ percentile in SVA and CVA calculations
- Descriptive statistics and RMSEz in FVA calculations



### 4.1.4 Aerial Data Acquisition and Calibration

The mapping partner responsible for producing new elevation data must also submit a pre-flight Operations Plan and a post-flight Aerial Acquisition and Calibration Report will be provided to FEMA and/or their representatives by the data acquisition provider and uploaded to the MIP by the data provider.  This information will aid future quality review efforts.  The required reporting includes the following, outlined in Tables 4.1 and 4.2.

**Table 4.1.  Pre-flight Operations Plan**

| Item | Contents | Format |
|---|---|---|
| Flight Operations | • Planned flight lines | MS Word or |

| | | |
|---|---|---|
| Plan | • Planned GPS stations<br>• Planned control<br>• Planned airport locations<br>• Calibration plans<br>• Quality procedures for flight crew (project-related for pilot and operator)<br>• Planned scanset (sensor settings and altitude)<br>• Type of aircraft<br>• Procedure for tracking, executing, and checking reflights<br>• Considerations for terrain, cover, and weather in project | PDF |



**Table 4.2. Post-flight Aerial Acquisition and Calibration Report**

| Item | Contents | Format |
|---|---|---|
| GPS Base station info | • Base station name<br>• Latitude/Longitude (ddd-mm-ss.sss)<br>• Base height (Ellipsoidal meters)<br>• Maximum Position Dilution of Precision PDOP<br>• Map of locations | Excel, TXT, MS Word, or PDF for data; ESRI shape file for map of locations (data and info may be in attribute table) |
| GPS/IMU processing summary | • Max Horizontal GPS Variance (cm)<br>• Max Vertical GPS Variance (cm)<br>• Notes on GPS quality (High, Good, etc.)<br>• GPS separation plot<br>• GPS altitude plot<br>• PDOP plot<br>• Plot of GPS distance from base station/s | MS Word or PDF with screenshots |
| Coverage | • Verification of project coverage | ESRI shape files reflecting the actual coverage area and not the applicable tiles. |
| Flights | • As-flown trajectories<br>• Calibration lines | ESRI shape files |

| Item | Contents | Format |
|---|---|---|
| Flight logs | • Incorporated as appendix<br>Should include:<br>• Job # / name<br>• Lift #<br>• Block or AOI designator<br>• Date<br>• Aircraft tail number, type<br>• Flight line, line #, direction, start/stop, altitude, scan angle/rate, speed, conditions, comments<br>• Pilot name<br>• Operator name<br>• AGC switch setting<br>• Laser pulse rate<br>• Mirror rate<br>• Field of view<br>• Airport of operations<br>• GPS base station names or numbers<br>Comments | |
| Control | • Ground control and base station layouts | ESRI shape files |
| Data verification/QC | • Description of data verification/QC process<br>• Results of verification and QC steps | MS Word, Excel or PDF |

## 4.2 Quality Reviews and Reporting Performed by Independent QA/QC

When a mapping partner is assigned to perform *Independent QA of Topographic Data* macro and micro reviews of the submitted reports and data shall be performed. Macro reviews are automated processes or are checks required to establish overall data quality and shall be applied to the entire project area. Micro reviews are typically manual in nature and shall be used to check no less than 3 project tiles or 5% of the total number of project tiles, whichever is the greater amount.

Tables 4.3 and 4.4 outline macro and micro reviews to be conducted on the raw point cloud and for data that is post-processed. Some reviews are duplicated between the raw point cloud and post-processing phases due to the potential for errors to be introduced into the data during post-processing.



**Table 4.3. Review of fully calibrated raw point cloud**

| Macro Reviews | |
|---|---|
| **Product** | **Reviewed for** |
| Pre-flight Operations Plan | • Compliance with section 4.1.4 and checklists in 4.2.1<br>• Compliance with the specifications outlined in the Mapping Activity Statement |
| Post-flight Aerial Acquisition and Calibration Report | • Compliance with section 4.1.4 and checklists in 4.2.1<br>• Compliance with the specifications outlined in the Mapping Activity Statement |

| Macro Reviews | |
|---|---|
| **Product** | **Reviewed for** |
| LAS Point Cloud Files | • Project area coverage – buffered by a minimum of 100 meters<br>• Data voids<br>• Inclusion of GPS time stamp<br>• Correct projection, datum and units<br>• Multiple Discrete Returns (at least 3 returns per pulse)<br>• Correct header information<br>• Other LAS attributes required by Mapping Activity Statement such as intensity values<br>• Correct nominal pulse spacing as required by specific risk and/or level of study and buy-up options. |
| Metadata | • Compliance with the FEMA Terrain Metadata Profile |
| **Micro Reviews** | |
| **Product** | **Reviewed for** |
| LAS Point Cloud Files | • Excessive noise<br>• Elevation steps<br>• Other anomalies present in the point cloud |



**Table 4.4. Review of post-processed data**

| Macro Reviews | |
|---|---|
| **Product** | **Reviewed for** |
| LAS Point Cloud Files | • Compliance with checklists in section 4.2.1<br>• Project area coverage – buffered by a minimum of 100 meters<br>• Data voids<br>• Inclusion of GPS time stamp<br>• Correct projection, datum and units<br>• Multiple Discrete Returns (at least 3 returns per pulse)<br>• Correct header information<br>• Other LAS attributes required by Mapping Activity Statement such as intensity values<br>• Correct nominal pulse spacing as required by specific risk and/or level of study and buy-up options.<br>• Easting, northing and elevation reported to nearest 0.01m or 0.01 ft<br>• Correct file-naming convention |
| Metadata | • Compliance with the FEMA Terrain Metadata Profile |

| Macro Reviews | |
|---|---|
| **Product** | **Reviewed for** |
| **Micro Reviews** | |
| **Product** | **Reviewed for** |
| LAS Point Cloud Files | • Excessive noise<br>• Elevation steps<br>• Other anomalies present in the point cloud<br>• Correct classification and cleanliness: no more than 2% of the project area classified to bare ground shall contain artifacts such as buildings, trees, overpasses or other above-ground features in the ground point classification (Class 2). In addition, no more than 2% of the project area shall contain incorrect classifications of points. (USGS *Lidar Guidelines and Base Specification*, v13, Section IV.14.<br>• |
| Optional - Breaklines | • Correct topology<br>• Horizontal placement<br>• Completeness<br>• Continuity<br>*See Attachment 3 for breakline topology rules to be checked against* |

If the mapping partner responsible *Independent QA of Topographic Data* is tasked to perform assessment of vertical accuracy of the elevation data as described above in sections 4.1.2 and 4.1.3:

- Assessment of FVA only for pre-processed data to be stored and FVA, SVA, and CVA for post-processed data
- Review of data provider vertical accuracy assessment reports

### 4.2.1 Recommended Checklists

The following checklists are recommended for use during Independent QA/QC review to facilitate the process.



***Pre-flight review checklist***

| Checklist | Pass / Fail | Comments |
|---|---|---|
| Planned lines – sufficient coverage, spacing, and length | | |
| Planned GPS stations | | |
| Planned ground control – sufficient to control and boresight | | |
| Calibration plans | | |
| Vendor quality procedures | | |
| Lidar sensor scan set – planned for proper scan angle, sidelap, design pulse. | | |
| Aircraft utilizes ABGPS | | |

| | | |
|---|---|---|
| Sensor supports project design pulse density | | |
| Type of aircraft – supports project design parameters | | |
| Reflight procedure – tracking, documenting, processing | | |
| Project design supports accuracy requirements of project | | |
| Project design accounts for land cover and terrain types | | |

***Post-flight review checklists***

| Checklist for QA of Flight Logs | | |
|---|---|---|
| Checklist | Included Yes/No | Comments |
| Flight logs – job #/name | | |
| Flight logs – block or AOI | | |
| Flight logs – date | | |
| Flight logs – aircraft tail # | | |
| Flight logs – lines - # | | |
| Flight logs – lines - direction | | |
| Flight logs – lines – start/stop | | |
| Flight logs – lines – altitude | | |
| Flight logs – lines – scan angle | | |
| Flight logs – lines – speed | | |
| Flight logs – conditions | | |
| Flight logs – comments | | |
| Flight logs - pilot name | | |
| Flight logs - operator name | | |
| Flight logs - AGC switch | | |
| Flight logs – GPS base stations | | |



| Checklist for Aerial Acquisition Report | | |
|---|---|---|
| Checklist | Included? Yes/No | Comments |
| GPS base station – names | | |
| GPS base station – lat/longs | | |
| GPS base station – heights | | |
| GPS base station – map | | |
| GPS quality – separation plot | | |
| GPS quality – PDOP plot | | |

| | | |
|---|---|---|
| GPS quality - horizontal Acc. | | |
| GPS quality - vertical Acc. | | |
| Sensor calibration process | | |
| Verification of AOI coverage | | |
| As-flown trajectories | | |
| Ground control layout | | |
| Data verification process documented | | |

***Final terrain product review checklists***

| Checklist for QA of Terrain Products | | |
|---|---|---|
| **Checklist** | **Pass/Fail** | **Comments** |
| Vertical datum correct | | |
| Horizontal datum correct | | |
| Projection correct | | |
| Vertical units correct | | |
| Horizontal units correct | | |
| Each return contains – GPS week, GPS second, easting, northing, elevation, intensity, return # and classification | | |
| No duplicate entries | | |
| GPS second reported to nearest microsecond | | |
| Easting, northing, and elevation reported to nearest 0.01 m or 0.01 ft | | |
| Classifications correct – 1. Unclassified; 2. Bare-earth ground; 7. Noise; 9. Water; 10. Ignored ground; 11. Withheld | | |
| Cloud file structure conforms to project tile layout | | |
| Naming conforms project requirements | | |
| Deliverable tiles checked for significant gaps not covered by aerial acquisition checks and/or caused by data post-processing/filtering | | |

# M.4 Terrain Submittal Standards

## M.4.1 Overview

This section describes the format and type of terrain data required to be submitted to FEMA for FISs. All data must be submitted in digital format. The Mapping Partner performing "Develop Topographic Data" is required to submit the data in this section.

The Mapping Partner should refer to Appendix A of these Guidelines for guidance on terrain data production. This section is not intended to detail the specifications and procedures for coastal hydrographic surveys. The reader is referred to the following additional sources for details on coastal surveys:

- National Oceanic and Atmospheric Administration (NOAA) NOS Hydrographic Survey Specifications and Deliverables (April 2007);
- NOAA Office of Coast Survey Hydrographic Surveys Division Field Procedures Manual (March 2007); and
- U.S. Army Corps of Engineers (USACE) National Coastal Mapping Program Joint LiDAR Bathymetry Technical Center for Expertise.
- Appendix D of the *Guidelines and Specifications for Flood Hazard Mapping Partners* (February 2007).

The submitting Mapping Partner must retain copies of all Project-related data for a period of 3 years. The submitting Mapping Partner will need these data for responding to the following:

- Questions from FEMA or the receiving Mapping Partner during the review of the final draft materials;
- Comments and appeals submitted to FEMA during the 90-day appeal period following the issuance of preliminary maps; and
- Other concerns and issues that may develop during the processing of the new or revised FIS report and FIRM.

## M.4.2 Requirements

### M.4.2.1 Data Files

The minimum data required for the terrain data submission are the source terrain and topographic maps from the terrain data used in the study. These data can be contained in a single file or in tiled files. When tiled files are submitted, they must be accompanied by a tiling index file. If any processing has been performed, the original and final files must be submitted as well. For instance, if terrain data were blended from three different sources to create the final terrain data, the original of the three sources and the final terrain file that results from the blending process must be submitted. This information is required to be a georeferenced, digital submittal. The following information must be submitted when it is used to perform a study:

- LiDAR data (bare earth and all returns);
- Tiling index for data files;
- Breaklines and Mass Points;
- Contours;
- Bathymetry;
- Digital Elevation Models (DEMs);
- Hydro-corrected DEMs;
- Triangulated Irregular Networks (TINs);
- Hydro-corrected TINs;
- USGS topographic data;
- All other terrain data; and
- LiDAR data generated as part of the project must be submitted as two separate files: one for bare earth only, and one for all returns if bare earth processing was performed as part of this project. For existing LiDAR data not processed as part of the project, the bare earth data must be submitted, and the submittal of the all returns data (if available) is optional.

A project narrative describing the SOW, direction from FEMA, issues, information for next Mapping Partner, etc. (see DCS User Guide for additional details).

### M.4.2.2 General Correspondence

A file that compiles general correspondence must be submitted by the Mapping Partner assigned to "Develop Topographic Data." General correspondence is the written correspondence generated or received by the Mapping Partner to fulfill the requirements of developing topographic data. Correspondence includes any documentation generated during this task such as letters; transmittals; memoranda; general status reports and queries; SPRs; technical issues that need to be documented; and direction given by FEMA.. Contractual documents, such as a signed SOW or MAS, are not to be submitted as a part of this appendix.

### M.4.2.3 Certification of Work

FEMA-funded (including CTP-funded projects if they are a part of FEMA's flood mapping program) terrain data development must be certified using the Certification of Compliance Form provided in Figure M-11 in section M.10. Submittal of this certification at "Develop Topographic Data" workflow step is required if this is the only task performed by the Mapping Partner. Mapping Partners that are contracted to perform multiple mapping tasks can submit one certification form to certify all the work performed. A PDF file of this form with the original signature, data, and seal affixed to the form must be submitted digitally in the general directory identified in section M.4.2.8. This form must be signed by a registered or certified professional from the firm contracted to perform the work, or by the responsible official of a government agency. A digital version of this form is available at www.fema.gov.

### M.4.2.4 Acceptable File Formats

Terrain data used to perform the study must be submitted in a georeferenced, digital format as listed below. These data can be contained in a single file or in a tiled set of files. Any tiled data must have an accompanying index spatial file.

- Contours, Masspoints, and breaklines – Personal geodatabase, DXF, or shapefile
- DEMs – ESRI grid, GeoTIFF, or ASCII grid
- LiDAR – LAS file, ASCII x, y, z file
- Terrain – ESRI ArcGIS
- Word – project narrative
- PDF – correspondence and certification

PDF files must be created using the source file (e.g., Word file), if the source file is created by the Mapping Partner, rather than raster scans of hard copy text documents. PDF files created must allow copying of text and pasting to another document. In addition, ESRI shapefiles must include .PRJ files.

### M.4.2.5 Metadata

A metadata file in XML format that complies with the NFIP Terrain Metadata Profiles (provided in Section M.14) must be included with the submittal. The profiles follow the FGDC Content Standard for metadata and define additional domains and business rules for some elements that are mandatory for FEMA, based on the specific submittal type. For each spatial data source in the metadata file, the Mapping Partner must assign a Source Citation Abbreviation.

If metadata is available from an agency or organization that provided data for use in the study, it should be included in the metadata submittal in addition to the NFIP Terrain Metadata Profiles. Reference the data providers' original metadata record in the Lineage section of the NFIP metadata profile. If there is a Web-accessible metadata record for the original data set, the URL to the metadata may be provided in the optional Source Citation - Online Linkage element. Otherwise, the Source Contribution [free text] element may include information on how to access the metadata record for the data sets obtained.

### M.4.2.6 Transfer Media

Mapping Partners must submit files via the internet by uploading to the MIP (http://www.hazards.fema.gov) or by mailing the files to FEMA on one or more of the following electronic media:

- CD-ROM;
- DVD; or
- External Hard Drive (for very large data submissions with a return label for shipment back to the partner).

In special situations or as technology changes, other media may be acceptable if coordinated with FEMA.

When data is mailed to FEMA, all submitted digital media must be labeled with at least the following information:

- Mapping Partner's name;
- Community name and State for which the FIS was prepared;
- Terrain Data;
- Date of submission (formatted mm/dd/yyyy); and
- Disk [*sequential number*] of [*number of disks*]. The media must be numbered sequentially, starting at Disk 1. [Number of disks] represents the total number of disks in the submission.

### M.4.2.7 Transfer Methodology

Terrain artifacts can be uploaded to the MIP by following the guidelines for Data Submission and Validation located on the MIP (https://hazards.fema.gov) under "User Guidance" in the "Guides & Documentation" tab of "MIP User Care".

### M.4.2.8 Directory Structure and Folder Naming Conventions

The files presented in section M.4.2 Requirements must be submitted to the MIP or mailed to FEMA within the following directory structure. Data files must be organized under an applicable 8-digit Hydrologic Unit Code (HUC-8). The following folders can be created either on a local work space (i.e., a personal computer) or within the work space for the community on the MIP. If the following folders are generated locally, these newly created folders and their contents must be uploaded to the MIP. Terrain files are arranged into appropriate directories based on data type.

- \HUC-8\General
  - Project narrative
  - Certification
- \HUC-8\Correspondence
  - Letters; transmittals; memoranda; general status reports and queries; SPRs; technical issues; direction by FEMA; and internal communications, routing slips, and notes.
- \HUC-8\All_Returns
  - LIDAR data – All Returns
  - LIDAR Tile Index spatial file (if used)
- \HUC-8\Bare_Earth
  - LIDAR data – Bare Earth Points
  - LIDAR Tile Index spatial file (if used)
- \HUC-8\Breaklines
  - 3D breakline spatial files
  - 3D breakline Tile Index spatial file (if used)

  - 2D breakline spatial files
  - 2D breakline Tile Index spatial file (if used)
  - Mass Points
- \HUC-8\Contours
  - Contour spatial files
  - Contour Tile Index spatial file (if used)
  - Bathymetric files
  - Bathymetric Tile Index spatial file (if used)
- \HUC-8\DEM
  - Uncorrected DEM files
  - Tile Index spatial file (if used)
- \HUC-8\HDEM
  - Hydrologically correct DEM files
  - Tile Index spatial file (if used)
- \HUC-8\TIN
  - Uncorrected TIN files
  - Terrain (ESRI ArcGIS format)
  - Tile index spatial file (if used)
- \HUC-8\HTIN
  - Hydrologically corrected TIN files
  - Terrain (ESRI ArcGIS format)
  - Tile Index spatial file (if used)
- \HUC-8\Supplemental Data
  - As-built drawings
  - GIS representation of structures

# U.S. Geological Survey
# National Geospatial Program
# Lidar Guidelines and Base Specification

## Version 13 – ILMF 2010

The U.S. Geological Survey National Geospatial Program (NGP) has cooperated in the collection of numerous lidar datasets across the nation for a wide array of applications. These collections have used a variety of specifications and required a diverse set of products, resulting in many incompatible datasets and making cross-project analysis extremely difficult. The need for a single base specification, defining minimum collection parameters and a consistent set of deliverables, is apparent.

Beginning in late 2009, an increase in the rate of lidar data collection due to American Reinvestment and Recovery Act (ARRA) funding for The National Map makes it imperative that a single data specification be implemented to ensure consistency and improve data utility. Although the development of this specification was prompted by the ARRA stimulus funding, the specification is intended to remain durable beyond ARRA funded NGP projects.

The primary intent of this specification is to create consistency across all NGP funded lidar collections, in particular those undertaken in support of the National Elevation Dataset (NED). Unlike most other "lidar specs" which focus on the derived bare-earth DEM product, this specification places unprecedented emphasis on the handling of the source lidar point cloud data. This is to assure that the complete source dataset collected remains intact and viable to support the wide variety of non-DEM science and mapping applications that benefit from lidar technology. In the absence of other comprehensive specifications or standards, it is hoped that this specification will, to the highest degree practical, be adopted by other USGS programs and disciplines, and by other Federal agencies.

Adherence to these minimum specifications ensures that bare-earth Digital Elevation Models (DEMs) derived from lidar data is suitable for ingestion into the NED (National Elevation Dataset) at the 1/9 arc-second resolution, and can be resampled for use in the 1/3 and 1 arc-second NED resolutions. It also ensures that the point cloud source data are handled in a consistent manner by all data providers and delivered to the USGS in clearly defined formats. This allows straight-forward ingest into CLICK (Center for Lidar Information, Coordination, and Knowledge) and simplifies subsequent use of the source data by the broader scientific community, particularly with regard to cross-collection analysis.

It must be stressed that this is a **base specification,** defining minimum parameters. It is expected that local conditions in any given project area, specialized applications for the data, or the preferences of cooperators, may mandate more stringent requirements. The

USGS encourages the collection of more detailed, accurate, or value-added data. A list of common upgrades to the minimum requirements defined here is provided in Appendix 1.

In addition, it is recognized that the USGS NGP also employs lidar technology for specialized scientific research and other projects whose requirements are incompatible with the provisions of this Specification. In such cases, and with properly documented justification supporting the need for the variance, waivers of any part or all of this Specification may be granted.

It is conceivable that in some cases, based on specific topography, land cover, intended application, or other factors, the USGS-NGP may require specifications more rigorous than those defined in this document. It is expected that this would be highly uncommon.

Lidar is still a relatively new technology; adolescent but not fully matured.. Advancements and improvements in instrumentation, software, processes, applications, and understanding are constantly being made. It would not be possible to develop a set of guidelines and specifications that address all of these advances. The current document is based on our understanding of and experience with the industry and technology at the present time. Furthermore, we acknowledge that there is a lack of commonly accepted "best practices" for numerous processes and technical assessments (i.e., measurement of NPS, point clustering, classification accuracy, etc.). The USGS encourages the development of such best practices through the appropriate industry and professional governance organizations, and we eagerly await the opportunity to include them in future revisions to this and other similar documents.

It is not the intention of the USGS to stifle the development of the lidar industry, nor to discourage innovation within the technology. Technical alternatives to any part of this document may be submitted with any proposal and will be given due professional consideration.

# I. COLLECTION

1. Multiple Discrete Return, capable of at least 3 returns per pulse

   *Note: Full waveform collection is both acceptable and welcomed; however, waveform data is regarded as supplemental information. The requirement for deriving and delivering multiple discrete returns remains in force in all cases.*

2. Intensity values for each return.

3. Nominal **Pulse** Spacing (NPS) of 1-2 meters, dependent on the local terrain and landcover conditions. Assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath. Average along-track and cross-track point spacings should be comparable.

4. Collections designed to achieve the NPS through swath overlap or multiple passes are generally discouraged. Such collections may be permitted with prior approval.

5. Data Voids [areas => $(4*NPS)^2$, measured using $1^{st}$-returns only] within a single swath are not acceptable, except:

   - where caused by water bodies
   - where caused by areas of low near infra-red (NIR) reflectivity such as asphalt or composition roofing.
   - where appropriately filled-in by another swath

6. The spatial distribution of geometrically usable points is expected to be uniform and free from clustering. In order to ensure uniform densities throughout the data set:

   - A regular grid, with cell size equal to the design NPS*2 will be laid over the data.
   - At least 90% of the cells in the grid shall contain at least 1 lidar point.
   - Assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.
   - Acceptable data voids identified previously in this specification are excluded.

   *Note: This requirement may be relaxed in areas of significant relief where it is impractical to maintain a consistent NPS.*

7. Scan Angle: Total FOV should not exceed $40^{o}$ (+/-$20^{o}$ from nadir) USGS quality assurance on collections performed using scan angles wider than $34^{o}$ will be particularly rigorous in the edge-of-swath areas. Horizontal and vertical accuracy shall remain within the requirements as specified below.

   *Note: This requirement is primarily applicable to oscillating mirror lidar systems. Other instrument technologies may be exempt from this requirement.*

8. Vertical Accuracy of the lidar data will be assessed and reported in accordance with the guidelines developed by the NDEP and subsequently adopted by the ASPRS. The complete guidelines may be found in Section 1.5 of the Guidelines document. See:

   http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf

   Vertical accuracy requirements using the NDEP/ASPRS methodology are:

   FVA <= 24.5cm ACCz, 95% (12.5cm RMSEz)
   CVA <= 36.3cm, 95th Percentile
   SVA <= 36.3cm, 95th Percentile

   - Accuracy for the lidar point cloud data is to be reported independently from accuracies of derivative products (i.e., DEMs). Point cloud data accuracy is to be tested against a TIN constructed from bare-earth lidar points.
   - Each landcover type representing 10% or more of the total project area must be tested and reported as an SVA.
   - For SVAs, the value is provided as a target. It is understood that in areas of dense vegetation, swamps, or extremely difficult terrain, this value may be exceeded. Overall CVA requirements must be met in spite of "busts" in individual SVAs.

   *Note: These requirements may be relaxed in cases:*

   - *where there exists a demonstrable and substantial increase in cost to obtain this accuracy.*
   - *where an alternate specification is needed to conform to previously contracted phases of a single larger overall collection effort, i.e., multi-year statewide collections, etc.*
   - *where the USGS agrees that it is reasonable and in the best interest of all stakeholders to use an alternate specification.*

9. Relative accuracy <=7cm $RMSE_Z$ within individual swaths; <=10cm RMSEz within swath overlap (between adjacent swaths).
10. Flightline overlap 10% or greater, as required to ensure there are no data gaps between the usable portions of the swaths. Collections in high relief terrain are expected to require greater overlap. Any data with gaps between the geometrically usable portions of the swaths will be rejected.
11. Collection Area: Defined Project Area, buffered by a minimum of 100 meters.
12. Collection Conditions:
    - Atmospheric: Cloud and fog-free between the aircraft and ground
    - Ground:
      - Snow free. Very light, undrifted snow may be acceptable in special cases, with prior approval.

- No unusual flooding or inundation, except in cases where the goal of the collection is to map the inundation.

- Vegetation: Leaf-off is preferred, however:
  - As numerous factors will affect vegetative condition at the time of any collection, the USGS NGP only requires that penetration to the ground must be adequate to produce an accurate and reliable bare-earth surface suitable for incorporation into the 1/9 (3-meter) NED.
  - Collections for specific scientific research projects may be exempted from this requirement, with prior approval.

## II. DATA PROCESSING and HANDLING

1. All processing should be carried out with the understanding that all point deliverables are required to be in fully compliant LAS format, v1.2 or v1.3. Data producers are encouraged to review the LAS specification in detail.

2. If full waveform data is collected, delivery of the waveform packets is required. LAS v1.3 deliverables with waveform data are to use external "auxiliary" files with the extension ".wdp" for the storage of waveform packet data. See the LAS v1.3 Specification for additional information.

3. GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each pulse. Adjusted GPS Time is defined to be Standard (or satellite) GPS time minus $1*10^9$. See the LAS Specification for more detail.

4. Horizontal datum shall be referenced to the North American Datum of 1983/HARN adjustment. Vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88). The most recent NGS-approved Geoid model shall be used to perform conversions from ellipsoidal heights to orthometric heights.

5. The USGS preferred Coordinate Reference System for the Conterminous United States (CONUS) is: UTM, NAD83, Meters. Each discrete project is to be processed using the predominant UTM zone for the overall collection area.

   State Plane Coordinate Reference Systems that have been accepted by the European Petroleum Survey Group (EPSG) and that are recognized by ESRI GIS software may be used by prior agreement with the USGS.

   Alternative projected coordinate systems for collections in Alaska, Hawaii, and other areas Outside the Conterminous United States (OCONUS) must be approved by the USGS prior to collection.

6. All references to the Unit of Measure "Feet" or "Foot" must specify either "International" or "U.S. Survey"

7. Long swaths (those which result in a LAS file larger than 2GB) should be split into segments no greater than 2GB each. Each segment will thenceforth be

regarded as a unique swath and shall be assigned a unique File Source ID. Other swath segmentation approaches may be acceptable, with prior approval. Renaming schemes for split swaths are at the discretion of the data producer. The Processing Report shall include detailed information on swath segmentation sufficient to allow reconstruction of the original swaths if needed.

8. Each swath shall be assigned a unique File Source ID. The Point Source ID field for each point within each LAS swath file shall be set equal to the File Source ID prior to any processing of the data. See the LAS Specification.

9. Point Families (multiple return "children" of a single "parent" pulse) shall be maintained intact through all processing prior to tiling. Multiple returns from a given pulse shall be stored in sequential (collected) order.

10. All collected swaths are to be delivered as part of the "Raw Data Deliverable". This includes calibration swaths and cross-ties. All collected points are to be delivered. No points are to be deleted from the swath LAS files. <u>This in no way requires or implies that calibration swath data are to be included in product generation</u>. Excepted from this are extraneous data outside of the buffered project area (aircraft turns, transit between the collection area and airport, transit between fill-in areas, etc.). These points may be permanently removed.

11. Outliers, blunders, noise points, geometrically unreliable points near the extreme edge of the swath, and other points deemed unusable are to be identified using the "Withheld" flag, as defined in the LAS specification.

    - This applies primarily to points which are identified during pre-processing or through automated post-processing routines.
    - If processing software is not capable of populating the "Withheld" bit, these points may be identified using Class=11.
    - "Noise points" subsequently identified during manual Classification and Quality Assurance/Quality Control (QA/QC) may be assigned the standard LAS classification value for "Noise" (Class=7), regardless of whether the noise is "low" or "high" relative to the ground surface.

12. The ASPRS/LAS "Overlap" classification (Class=12) shall not be used. ALL points not identified as "Withheld" are to be classified.

    - If overlap points are required to be differentiated by the data producer or cooperating partner, they must be identified using a method that does not interfere with their classification, such as:
        - Overlap points are tagged using Bit:0 of the User Data byte, as defined in the LAS specification. (SET=Overlap).
        - Overlap points are classified using the Standard Class values + 16.
        - Other techniques as agreed upon in advance
    - The technique utilized must be clearly described in the project metadata files.

*Note: A standard bit setting for identification of overlap points has been planned for a future version of LAS.*

13. Positional Accuracy Validation: The absolute and relative accuracy of the data, both horizontal and vertical, and relative to known control, shall be verified prior to classification and subsequent product development. This validation is obviously limited to the Fundamental Vertical Accuracy, measured in clear, open areas. A detailed report of this validation is a required deliverable.

14. Classification Accuracy: It is expected that due diligence in the classification process will produce data that meets the following test:

    Within any 1km x 1km area, no more than 2% of non-withheld points will possess a demonstrably erroneous classification value.

    This includes points in Classes 0 and 1 that should correctly be included in a different Class as required by the contract.

    *Note: This requirement may be relaxed to accommodate collections in areas where the USGS agrees classification to be particularly difficult.*

15. Classification Consistency: Point classification is to be consistent across the entire project. Noticeable variations in the character, texture, or quality of the classification between tiles, swaths, lifts, or other non-natural divisions will be cause for rejection of the entire deliverable.

16. Tiles:

    *Note: This section assumes a projected coordinate reference system.*

    - A single non-overlapped tiling scheme will be established and agreed upon by the data producer and the USGS prior to collection. This scheme will be used for **all** tiled deliverables.
    - Tile size must be an integer multiple of the cell size of raster deliverables.
    - Tiles must be sized using the same units as the coordinate system of the data.
    - Tiled deliverables shall conform to the tiling scheme, without added overlap.
    - Tiled deliverables shall edge-match seamlessly and without gaps in both the horizontal and vertical.

## III. HYDRO-FLATTENING REQUIREMENTS

*Note: Please refer to Appendix 2 for reference information on hydro-flattening.*

Hydro-flattening pertains only to the creation of derived DEMs. No manipulation of or changes to originally computed lidar point elevations are to be made. Breaklines may be used to help classify the point data.

1. Inland Ponds and Lakes:
   - ~2-acre or greater surface area (~350' diameter for a round pond) at the time of collection.
   - Flat and level water bodies (single elevation for every bank vertex defining a given water body).
   - The entire water surface edge must be at or below the immediately surrounding terrain.
   - Long impoundments such as reservoirs, inlets, and fjords, whose water surface elevations drop when moving downstream, should be treated as rivers.
2. Inland Streams and Rivers:
   - 100' **nominal** width: This should not unnecessarily break a stream or river into multiple segments. At times it may squeeze slightly below 100' for short segments. Data producers should use their best professional judgment.
   - Flat and level bank-to-bank (perpendicular to the apparent flow centerline); gradient to follow the immediately surrounding terrain.
   - The entire water surface edge must be at or below the immediately surrounding terrain.
   - Streams channels should break at road crossings (culvert locations). These road fills should not be removed from DEM. However, streams and rivers should **not** break at elevated bridges. Bridges should be removed from DEM. When the identification of a feature as a bridge or culvert cannot be made reliably, the feature should be regarded as a culvert.
3. Non-Tidal Boundary Waters:
   - Represented only as an edge or edges within the project area; collection does not include the opposing shore.
   - The entire water surface edge must be at or below the immediately surrounding terrain.
   - The elevation along the edge or edges should behave consistently throughout the project. May be a single elevation (i.e., lake) or gradient (i.e., river), as appropriate.

4. Tidal Waters:

   - Water bodies such as oceans, seas, gulfs, bays, inlets, salt marshes, very large lakes, etc. Includes any water body that is affected by tidal variations.

   - Tidal variations over the course of a collection or between different collections, will result in discontinuities along shorelines. This is considered normal and these "anomalies" should be retained. The final DEM should represent as much ground as the collected data permits.

   - Variations in water surface elevation resulting in tidal variations during a collection should NOT be removed or adjusted, as this would require either the removal of valid, measured ground points or the introduction of unmeasured ground into the DEM. The USGS NGP priority is on the ground surface, and accepts there may be occasional, unavoidable irregularities in water surface.

   - Scientific research projects in coastal areas often have very specific requirements with regard to how tidal land-water boundaries are to be handled. For such projects, the requirements of the research will take precedence.

Cooperating partners may require collection and integration of single-line streams within their lidar projects. While the USGS does not require these breaklines be collected or integrated, it does require that if used and incorporated into the DEMs, the following guidelines are met:

1. All vertices along single-line stream breaklines are at or below the immediately surrounding terrain.
2. Single-line stream breaklines are not to be used to introduce cuts into the DEM at road crossings (culverts), dams, or other such features. This is hydro-enforcement and as discussed in Section VI, creates a non-traditional DEM that is not suitable for integration into the NED.
3. All breaklines used to modify the surface are to be delivered to the USGS with the DEMs.

The USGS does not require any particular process or methodology be used for breakline collection, extraction, or integration. However, the following general guidelines must be adhered to:

1. Bare-earth lidar points that are in close proximity breaklines should be excluded from the DEM generation process. This is analogous to the removal of masspoints for the same reason in a traditional photogrammetrically compiled DTM.

   The proximity threshold for reclassification as "Ignored Ground" is at the discretion of the data producer, but in general should be approximately equal to the NPS.

2. These points are to be retained in the delivered lidar point dataset and shall be reclassified as "Ignored Ground" (class value = 10) so that they may be subsequently identified.

3. Delivered data must be sufficient for the USGS to effectively recreate the delivered DEMs using the lidar points and breaklines without significant further editing.

## IV. DELIVERABLES

The USGS shall have unrestricted rights to all delivered data and reports, which will be placed in the public domain. This specification places no restrictions on the data provider's rights to resell data or derivative products as they see fit.

### 1. Metadata

*Note: "Metadata" refers to all descriptive information about the project. This includes textual reports, graphics, supporting shapefiles, and FGDC-compliant metadata files.*

- Collection Report detailing mission planning and flight logs.
- Survey Report detailing the collection of control and reference points used for calibration and QA/QC.
- Processing Report detailing calibration, classification, and product generation procedures including methodology used for breakline collection and hydro-flattening *(see Sections III and Appendix 1 for more information on hydro-flattening)*.
- QA/QC Reports (detailing the analysis, accuracy assessment and validation of:
  - The point data (absolute, within swath, and between swath)
  - The bare-earth surface (absolute)
  - Other optional deliverables as appropriate
- Control and Calibration points: All control and reference points used to calibrate, control, process, and validate the lidar point data or any derivative products are to be delivered.
- Geo-referenced, digital spatial representation of the precise extents of each delivered dataset. This should reflect the extents of the actual lidar source or derived product data, exclusive of Triangular Irregular Network (TIN) artifacts or raster NODATA areas. A union of tile boundaries or minimum bounding rectangle is not acceptable. ESRI Polygon shapefile or geodatabase is preferred.
- Product metadata (FGDC compliant, XML format metadata). One file for each:

- Project
- Lift
- Tiled deliverable product group (classified point data, bare-earth DEMs, breaklines, etc.). Metadata files for individual tiles are not required.

- FGDC compliant metadata must pass the USGS metadata parser (“mp”) with no errors or warnings.

**2. Raw Point Cloud**

- All returns, all collected points, fully calibrated and adjusted to ground, by swath.
- Fully compliant LAS v1.2 or v1.3, Point Record Format 1, 3, 4, or 5
- LAS v1.3 deliverables with waveform data are to use external “auxiliary” files with the extension “.wdp” for the storage of waveform packet data. See the LAS v1.3 Specification for additional information.
- Georeference information included in all LAS file headers
- GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each pulse.
- Intensity values (native radiometric resolution)
- 1 file per swath, 1 swath per file, file size not to exceed 2GB, as described in Section II, Paragraph 7.

**3. Classified Point Cloud**

*Note: Delivery of a classified point cloud is a standard requirement for USGS NGP lidar projects. Specific scientific research projects may be exempted from this requirement.*

- Fully compliant LAS v1.2 or v1.3, Point Record Format 1, 3, 4, or 5
- LAS v1.3 deliverables with waveform data are to use external “auxiliary” files with the extension “.wdp” for the storage of waveform packet data. See the LAS v1.3 Specification for additional information.
- Georeference information included in LAS header
- GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each pulse.
- Intensity values (native radiometric resolution)
- Tiled delivery, without overlap (tiling scheme TBD)

- Classification Scheme (minimum):

| Code | Description |
|---|---|
| 1 | Processed, but unclassified |
| 2 | Bare-earth ground |
| 7 | Noise (low or high, manually identified, if needed) |
| 9 | Water |
| 10 | Ignored Ground (Breakline Proximity) |
| 11 | Withheld (if the "Withheld" bit is not implemented in processing software) |

*Note: Class 7, Noise, is included as an adjunct to the "Withheld" bit. All "noise points" are to be identified using one of these to methods.*

*Note: Class 10, Ignored Ground, is for points previously classified as bare-earth but whose proximity to a subsequently added breakline requires that it be excluded during Digital Elevation Model (DEM) generation.*

4. **Bare Earth Surface (Raster DEM)**

*Note: Delivery of a bare-earth DEM is a standard requirement for USGS NGP lidar projects. Specific scientific research projects may be exempted from this requirement.*

- Cell Size no greater than 3 meters or 10 feet, and no less than the design Nominal Pulse Spacing (NPS).
- Delivery in an industry-standard, GIS-compatible, 32-bit floating point raster format (ERDAS .IMG preferred)
- Georeference information shall be included in each raster file
- Tiled delivery, without overlap
- DEM tiles will show no edge artifacts or mismatch. A quilted appearance in the overall project DEM surface, whether caused by differences in processing quality or character between tiles, swaths, lifts, or other non-natural divisions, will be cause for rejection of the entire DEM deliverable.
- Void areas (i.e., areas outside the project boundary but within the tiling scheme) shall be coded using a unique "NODATA" value. This value shall be identified in the appropriate location within the file header.
- Vertical Accuracy of the bare earth surface will be assessed and reported in accordance with the guidelines developed by the NDEP and subsequently adopted by the ASPRS. The complete guidelines may be found in Section 1.5 of the Guidelines document. See:

  http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf

Vertical accuracy requirements using the NDEP/ASPRS methodology are:

FVA <= 24.5cm ACCz, 95%   (12.5cm RMSEz)
CVA <= 36.3cm, 95th Percentile
SVA <= 36.3cm, 95th Percentile

All QA/QC analysis materials and results are to be delivered to the USGS.

- Depressions (sinks), natural or man-made, are **not** to be filled (as in hydro-conditioning and hydro-enforcement).

- Water Bodies (ponds and lakes), wide streams and rivers (“double-line”), and other non-tidal water bodies as defined in Section III are to be hydro-flattened within the DEM. Hydro-flattening shall be applied to all water impoundments, natural or man-made, that are larger than ~2 acre in area (equivalent to a round pond ~350’ in diameter), to all streams that are nominally wider than 100’, and to all non-tidal boundary waters bordering the project area regardless of size. The methodology used for hydro-flattening is at the discretion of the data producer.

  *Note: Please refer to the Sections III and VI for detailed discussions of hydro-flattening.*

5. **Breaklines**

*Note: Delivery of the breaklines used in hydro-flattening is a standard requirement for USGS NGP lidar projects. Specific scientific research projects may be exempted from this requirement. If hydro-flattening is achieved through other means, this section may not apply.*

- All breaklines developed for use in hydro-flattening shall be delivered as an ESRI feature class (PolylineZ or PolygonZ format, as appropriate to the type of feature represented and the methodology used by the data producer). Shapefile or geodatabase is preferred.

- Each feature class or shapefile will include properly formatted and accurate georeference information in the standard location. All shapefiles must include the companion .prj file.

- Breaklines must use the same coordinate reference system (horizontal and vertical) and units as the lidar point delivery.

- Breakline delivery may be as a continuous layer or in tiles, at the discretion of the data producer. Tiled deliveries must edge-match seamlessly in both the horizontal and vertical.

## APPENDIX 1
## COMMON DATA UPGRADES

1. Independent 3rd-Party QA/QC by another AE Contractor (encouraged)
2. Higher Nominal Pulse Spacing (point density)
3. Increased Vertical Accuracy
4. Full Waveform collection and delivery
5. Additional Environmental Constraints
    - Tidal coordination, flood stages, crop/plant growth cycles, etc.
    - Shorelines corrected for tidal variations within a collection
6. Top-of Canopy (First-Return) Raster Surface (tiled). Raster representing the highest return within each cell is preferred.
7. Intensity Images (8-bit gray scale, tiled)
8. Detailed Classification (additional classes):

| Code | Description |
|---|---|
| 3 | Low vegetation |
| 4 | Medium vegetation (use for single vegetation class) |
| 5 | High vegetation |
| 6 | Buildings, bridges, other man-made structures |
| n | additional Class(es) as agreed upon in advance |

9. Hydro-Enforced and/or Hydro-Conditioned DEMs
10. Breaklines (PolylineZ and PolygonZ) for single-line hydrographic features (narrow streams not collected as double-line, culverts, etc.), including appropriate integration into delivered DEMs
11. Breaklines (PolylineZ and PolygonZ) for other features (TBD), including appropriate integration into delivered DEMs
12. Extracted Buildings (PolygonZ): Footprints with maximum elevation and/or height above ground as an attribute.
13. Other products as defined by requirements and agreed upon in advance of funding commitment.

## APPENDIX 2

## HYDRO-FLATTENING REFERENCE

The subject of modifications to lidar-based DEMs is somewhat new, and although authoritative references are available, there remains significant variation in the understanding of the topic across the industry. The following material was developed to provide a definitive reference on the subject only as it relates to the creation of DEMs intended to be integrated into the USGS NED. The information presented here is not meant to supplant other reference materials and it should not be considered authoritative beyond its intended scope.

The term "**hydro-flattening**" is also new, coined for this document and to convey our specific needs. It is not, at this time, a known or accepted term across the industry. It is our hope that its use and acceptance will expand beyond the USGS with the assistance of other industry leaders.

Hydro-flattening of DEMs is predominantly accomplished through the use of breaklines, and this method is considered standard. Although other techniques may exist to achieve similar results, this section assumes the use of breaklines. The USGS does not require the use of any specific technique.

The Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition (Maune *et al.*, 2007) provides the following definitions related to the adjustment of DEM surfaces for hydrologic analyses:

1. **Hydrologically-Conditioned (Hydro-Conditioned)** – Processing of a DEM or TIN so that the flow of water is continuous across the entire terrain surface, including the removal of all spurious sinks or pits. The only sinks that are retained are the real ones on the landscape. Whereas "hydrologically-enforced" is relevant to drainage features that are generally mapped, "hydrologically-conditioned" is relevant to the entire land surface and is done so that water flow is continuous across the surface, whether that flow is in a stream channel or not. The purpose for continuous flow is so that relationships/links among basins/catchments can be known for large areas. This term is specifically used when describing EDNA (see Chapter 4), the dataset of NED derivatives made specifically for hydrologic modeling purposes.

2. **Hydrologically-Enforced (Hydro-Enforced)** – Processing of mapped water bodies so that lakes and reservoirs are level and so that streams flow downhill. For example, a DEM, TIN or topographic contour dataset with elevations removed from the tops of selected drainage structures (bridges and culverts) so as to depict the terrain under those structures. Hydro-enforcement enables hydrologic and hydraulic models to depict water flowing under these structures, rather than appearing in the computer model to be dammed by them because of road deck elevations higher than the water levels. Hydro-enforced TINs also utilize breaklines along shorelines and stream centerlines, for example, where these breaklines form the edges of TIN triangles along the alignment of drainage features. Shore breaklines for streams would be 3-D breaklines

> with elevations that decrease as the stream flows downstream; however, shore breaklines for lakes or reservoirs would have the same elevation for the entire shoreline if the water surface is known or assumed to be level throughout. See figures 1.21 through 1.24. See also the definition for "hydrologically-conditioned" which has a slightly different meaning.

While these are important and useful modifications, they both result in surfaces that differ significantly from a traditional DEM. A "hydro-conditioned" surface has had its sinks filled and may have had its water bodies flattened. This is necessary for correct flow modeling within and across large drainage basins. "Hydro-enforcement" extends this conditioning by requiring water bodies be leveled and streams flattened with the appropriate downhill gradient, and also by cutting through road crossings over streams (culvert locations) to allow a continuous flow path for water within the drainage. Both treatments result in a surface on which water behaves as it physically does in the real world, and both are invaluable for specific types of hydraulic and hydrologic (H&H) modeling activities. Neither of these treatments is typical of a traditional DEM surface.

A traditional DEM such as the NED, on the other hand, attempts to represent the ground surface more the way a bird, or person in an airplane, sees it. On this surface, natural depressions exist, and road fills create apparent sinks because the road fill and surface is depicted without regard to the culvert beneath. Bridges, it should be noted, are removed in most all types of DEMs because they are man-made, above-ground structures that have been added to the landscape.

*Note: DEMs developed solely for orthophoto production may include bridges, as their presence can prevent the "smearing" of structures and reduce the amount of post-production correction of the final orthophoto. These are "special use DEMs" and are not relevant to this discussion.*

For years, raster Digital Elevation Models (DEMs), have been created from a Digital Surface Model (DSM) of masspoints and breaklines, which in turn were created through photogrammetric compilation from stereo imagery. Photogrammetric DSMs inherently contain breaklines defining the edges of water bodies, coastlines, single-line streams, and double-line streams and rivers, as well as numerous other surface features.

Lidar technology, however, does not inherently collect the breaklines necessary to produce traditional DEMs. Breaklines have to be developed separately through a variety of techniques, and either used with the lidar points in the generation of the DEM, or applied as a correction to DEMs generated without breaklines.

In order to maintain the consistent character of the NED as a traditional DEM, the USGS NGP requires that all DEMs delivered have their inland water bodies flattened. This does not imply that a complete network of topologically correct hydrologic breaklines be developed for every dataset; only those breaklines necessary to ensure that the conditions defined in Section III exist in the final DEM.

**APPENDIX 3**

**SAMPLE METADATA TEMPLATE**

[to be added]

## APPENDIX 4

## REFERENCES


Maune, D.F., 2007. Definitions, in *Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition* (D.F. Maune, editor), American Society for Photogrammetry and Remote Sensing, Bethesda, MD pp. 550-551

National Digital Elevation Program, 2004. *Guidelines for Digital Elevation Data—Version 1*, 93 p., available online at: http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf (last date accessed: 29 September 2009)

FEMA, 2003. *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A: Guidance for Aerial Mapping and Surveying*, 59 p., available online at: http://www.fema.gov/library/viewRecord.do?id=2206 (last date accessed 29 September 2009)


USGS NED Website: www.ned.usgs.gov

USGS CLICK Website: www. lidar.cr.usgs.gov

MP-Metadata Parser: http://geology.usgs.gov/tools/metadata