SCOPE OF WORK
FOR THE
CENTRAL AND EASTERN MASSACHUSETTS 2013 LIDAR PROJECT
BY THE
U. S. GEOLOGICAL SURVEY
AND
PARTICIPATNG MUNICIPALITIES IN MASSACHUSETTS
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PURPOSE

This is a cooperative project between the U. S. Geological Survey (USGS) and participating municipalities in Massachusetts to produce high-resolution elevation products in cooperation with other federal, state and local partners. The LiDAR will be collected in fall 2013 during leaf off conditions and will be detailed enough to support local, regional, state, and national purposes.

This project, known as the Central and Eastern Massachusetts 2013 LiDAR Project, will be managed by the USGS National Geospatial Technical Operations Center's (NGTOC) Commercial Partnership Team, via the USGS Geospatial Products and Services Contract (GPSC2). Quality Assurance will be conducted by USGS NGTOC personnel.

The data gathered and all deliverables from this project will be made available without license restrictions, greatly benefitting all levels of government, including U.S. Department of Interior science programs and USGS geospatial program goals for *The National Map*, and for the National Spatial Data Infrastructure (NSDI).

This project supports the various missions of the Massachusetts partners who require highly accurate elevation information to meet government operational needs. The partnership significantly reduces federal, state and local spending by achieving an economy of scale, sharing procurement and contract mobilization costs, reducing contract management costs, including quality assurance, and minimizing impacts on related administrative resources.

BACKGROUND

OMB Circular A-16 "Coordination of Geographic Information and Related Spatial Data Activities" provides for improvements in coordination and use of spatial data. Spatial data refers to information about places or geography, and has traditionally been shown on maps. This Circular describes the effective and economical use and management of spatial data assets in the digital environment for the benefit of the government and the nation.

The National Map is a collaborative effort to improve and deliver topographic information for the nation. It provides public access to high-quality, geospatial data and information from multiple partners to help support decision-making by resource managers and the public. *The National Map* is the product of a consortium of Federal, State, and local partners who work together to acquire, process and provide geospatial data to enhance America's ability to access, integrate, and apply geospatial data at global, national, and local scales.

This project is for LiDAR surveys to be collected over several areas in central to eastern Massachusetts. The data is to be acquired and processed under the requirements identified in a Task Order to be issued by the USGS. The total area of the Massachusett's Sandy LiDAR area of interest is approximately 2,000 square miles. This data will assist in the evaluation of storm damage and erosion of the local environment as part of USGS Hurricane Sandy response. This project will require hydro-flattening.

The Central and Eastern Massachusetts 2013 LiDAR Project deliverables will include LiDAR, a classified point cloud, intensity imagers and DEMs covering the participating communities, coastal areas of New Hampshire, Massachusetts and Rhode Island and other areas in Massachusetts that resolve certain issues or completes county coverage (see Attachment A). The USGS will manage the commercial production contract, and USGS will conduct quality assurance.

SCOPE OF WORK

This scope of work (SOW) is for planning, acquisition, processing, and derivative products of LiDAR data to be collected at a nominal pulse spacing (NPS) of 0.7 meters, including overlap. LiDAR data, and derivative products produced in compliance with this SOW are based on the "U.S. Geological Survey National Geospatial Program LiDAR Base Specification Version 1.0", which is incorporated by reference into this SOW. This specification may be viewed at *http://pubs.usgs.gov/tm/11b4/.* These LiDAR specifications are required baseline specifications. In addition to the Specification Requirements, this SOW shall meet NEEA QL2. For any item which is not specifically addressed, the referenced Specification Version 1 will be the required specification authority.

NEEA QL2

Source	Accuracy	Point density Spacing	Nominal Pulse Spacing	Nominal post Spacing	RMSE in Open Terrain	Equivalent Contour Accuracy
LiDAR	Medium to high	2 pts/sq. m	0.7 m	1 m	9.25 cm	1ft.

DATA ACQUISITION (COLLECTION)

The contractor shall be responsible for acquisition of lidar data of sufficient density and quality to meet the requirements specified in **the referenced Version 1.0 specification.**

Collection area: The collection area shall be defined as the Defined Project Area, buffered by no less than 100-meters. The Project Area is defined in **"Attachment A – Project Description and Diagram"**.

Nominal Pulse Spacing: Nominal Pulse Spacing (NPS) shall be no greater than 0.7 meters and includes overlap. Assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

Signal Returns The laser system shall be configured to collect multiple echoes per pulse, with a minimum of a first return and a last return and at least one additional intermediate return. All returns captured during acquisition shall be delivered. Return number shall be recorded.

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

Signal Strength: The signal strength (intensity) of each return pulse shall be recorded.

Clustering: 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:

1. A regular grid, with cell size equal to the design 2*NPS will be laid over the data.

2. At least 90% of the cells in the grid shall contain at least 1 lidar point.

3. Clustering will be tested against the 1st return only data

4. Acceptable data voids identified elsewhere in this specification are excluded.

Control: LIDAR shall be acquired using the following control specifications.

1. **Supplemental Ground Control**: Differentially corrected GPS Ground Control used to supplement the Airborne GPS positional accuracy.
2. **Ground Control Quality Check points**: The Contractor shall collect additional Ground Control Check Points in each project area which shall be delivered in ESRI Arc Shape format and will be used by the Government for validation.
    a. A minimum of twenty (20) check points shall be collected uniformly dispersed over the project area in **each** of the land cover classifications in which there is **more than 10% coverage** to verify fundamental, supplemental, and consolidated vertical accuracies. **In addition – Points shall be collected for those areas which are classified as Urban, even if there is less than 10% coverage.**
    b. Fundamental vertical accuracy checkpoints should be 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.
    c. Checkpoints should be located on flat or uniformly sloping terrain and will be at least five (5) meters away from any breakline where there is a change in slope.
    d. The checkpoint accuracy shall satisfy a Local Network accuracy of 5-centimeteres at the 95% confidence level.
    e. Check points shall not be incorporated into the contractor's vertical solution.
    f. Most common land cover categories are (**but not limited to**):
        i. Bare Earth/Open Terrain
        ii. Urban
        iii. Tall Weeds/Crops (do not use Low Veg)
        iv. Brush lands and Trees (do not use Med Veg)
        v. Forested and Fully Grown (do not use High Veg)

Vertical Accuracy Requirements: Lidar collected under this SOW shall meet or exceed these vertical accuracies. Assessment procedures shall comply with NDEP guidelines. See C.1.b.(i)(a) below for complete vertical accuracy reporting requirements.

1. $RMSE_Z$ = 9.25 cm
2. FVA = 18.13 cm 95% Confidence Level (Required Accuracy)
3. CVA = 26.9 cm 95th Percentile (Required Accuracy)
4. SVA = 26.9 cm 95th Percentile (Target Accuracy)

Positional Accuracy Validation: The absolute and relative accuracy of the data, both horizontal and vertical, relative to known control, shall be verified prior to classification and subsequent product development. A detailed report of this validation is a required deliverable

Relative Accuracy Requirements: Relative accuracy shall be <= 7**-cm** $RMSE_Z$ within individual swaths and <=**10-cm** $RMSE_Z$ or within swath overlap (between adjacent swaths)

Acquisition Window: Acquisition window shall be at a period of annual minimal water level in the fall-winter 2013 leaf off window running through April 15, 2014.

Swath Length: Long swaths (those which result in a LAS file larger than 2GB) shall be split into segments. Each segment shall thenceforth be regarded as a unique swath. Other swath segmentation criteria may be acceptable, with prior approval.

Full Swath data shall be delivered Edge data from each swath shall not be trimmed from the delivered data.

Overlap: Flight line overlap of 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.

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

1. where caused by water bodies

2. where caused by areas of low near infra-red (NIR) reflectivity such as asphalt or composition roofing; or

3. where appropriately filled-in by another swath

Data Acquisition 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 National Geospatial Program (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.

Time of Day: Time of day is not of concern.

DATA PROCESSING AND HANDLING

The contractor shall be responsible for post processing of lidar data of sufficient density and quality to meet the requirements specified in the ***National Geospatial Program Lidar Base Specification Version 1.0***. 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. Specifications of the LAS data sets will be verified.

ACCURACY REPORTING

1. **Data Accuracy:** Data collected under this SOW shall meet the National Standard for Spatial Database Accuracy (NSSDA) accuracy standards. The NSSDA standards specify that vertical accuracy be reported at the 95 percent confidence level for data tested by an independent source of higher accuracy. For example the metadata statement shall read, "Tested __ (meters, feet) vertical accuracy at 95 percent confidence level."

2. **Accuracy of the Lidar Point Cloud Data:** The Fundamental Vertical Accuracy (FVA) of the Lidar Point Cloud data shall be calculated against TINs derived from the final calibrated and controlled swath data. The required accuracy (ACC_Z) is: 18.13 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 9.25 cm in the "open terrain" land cover category. This is a required accuracy.

3. **Accuracy of the Derived DEM:** The accuracy (ACC_Z) of the derived DEM shall be calculated and reported in three (3) ways:

    a. **Fundamental Vertical Accuracy (FVA):** The required FVA is: 18.13 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 9.25 cm in the "open terrain" land cover category. This is a required accuracy.

b. **Supplemental Vertical Accuracy (SVA): SVAs** shall be reported for each of the land cover classes identified above. The target SVA is: 26.9 cm at a 95th percentile level, derived according to ASPRS Guidelines, Vertical Accuracy Reporting for LiDAR Data, i.e., based on the 95th percentile error for each required land cover class. These are target accuracies.
c. **Consolidated Vertical Accuracy (CVA):** The required CVA is: 26.9 cm at a 95th percentile level, derived according to ASPRS Guidelines, Vertical Accuracy Reporting for LiDAR Data, i.e., based on the 95th percentile error in <u>all</u> land cover categories combined. This is a required accuracy.

Hydro Flattening Requirements:

Inland Ponds and Lakes:

For inland ponds and lakes approximately 2-acre or greater surface area (~350' diameter for a round pond):

1. Flat and level water bodies (single elevation for every bank vertex defining a given water body).
2. The entire water surface edge must be at or just below the immediately surrounding terrain.
3. Long impoundments such as reservoirs, inlets, and fjords, whose water surface elevations drop when moving downstream, should be treated as rivers.

Inland Streams and Rivers:
For inland streams and rivers of 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.)

1. Flat and level bank-to-bank (perpendicular to the apparent flow centerline); gradient to follow the immediately surrounding terrain.
2. The entire water surface edge must be at or just below the immediately surrounding terrain.
3. Streams should break at road crossings (culvert locations). These road fills should not be removed from DEM. However, streams and rivers should **not** break at 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.

Non-Tidal Boundary Waters:

1. Represented only as an edge or edges within the project area; collection does not include the opposing shore.
2. The entire water surface edge must be at or below the immediately surrounding terrain.
3. 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.

Tidal Waters:
This includes water bodies such as oceans, seas, gulfs, bays, inlets, salt marshes, very large lakes, etc. that is affected by tidal variations.

1. Tidal variations over the course of a collection, and 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.
2. Variations in water surface elevation resulting in tidal variations during a collection should NOT be removed or adjusted, as this requires either the removal of ground points or the introduction of unmeasured ground into the DEM. The USGS NGP priority is on the ground surface, and accepts the unavoidable irregularities in water surface.
3. 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.

DELIVERABLE PRODUCTS

The following deliverable products shall be produced from the lidar acquisition described above.

Raw Point Cloud Data:

1. Fully compliant LAS v1.2 or v1.3, Point Record Format 1, 3, 4, or 5

2. 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. Georeference information included in all LAS file headers

4. GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each return.

5. Intensity values

6. Full swaths, all collected points to be delivered.

7. 1 file per swath, 1 swath per file, file size not to exceed 2GB, as described in Section II, Paragraph 5.

Classified Point Cloud:

1. Fully compliant LAS v1.2 or v1.3, Point Record Format 1, 3, 4, or 5, including "File Source ID."

2. 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. Georeference information included in LAS header

4. GPS times are to be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each return.

5. Intensity values

6. Tiled delivery, without overlap

7. Classification Scheme (minimum):

    Code 1 – Processed, but unclassified
    Code 2 – Bare-earth ground
    Code 7 – Noise (low or high, manually identified, if needed
    Code 9 – Water
    Code 10 – Ignored Ground (Breakline Proximity)

Note: Class 7, Noise, is included as a convenience for the data producer. It is not required that all "noise" be assigned to Class 7.

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.

Bare Earth Surface (Raster DEM):

1. Cell Size shall be one (1.0) meter, and no less than the design Nominal Pulse Spacing (NPS).

2. Delivery in an industry-standard, GIS-compatible, 32-bit floating point raster format (ERDAS .IMG preferred)

3. Georeference information shall be included in raster file

4. Tiled delivery, without overlap

5. DEM tiles will show no edge artifacts or mismatch

6. 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.

7. Vertical Accuracy ($RMSE_Z$) of the bare earth surface is to be assessed using the methods described in the FEMA "Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A", Section A.8.5 paragraph 1, Section A.8.6.1, and Section A.8.6.2 (substituting the contracted vertical accuracy requirements ($RMSE_Z$) for those listed in

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

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

9. 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.

Control: All control shall be delivered to the Government.

LiDAR Intensity Image in grayscale 8-bit GeoTiff format using the same tile structure as the other Lidar deliverables**.**

Breaklines: Hydro Enforced/Flattened breaklines shall be delivered in mutually agreeable format, preferably ESRI Arc Shape format.

Metadata: The following requirements for Metadata shall be met:

1. Collection Report detailing mission planning and flight logs.
    a. Survey Report detailing the collection of control and reference points used for calibration and QA/QC.
    b. Processing Report detailing calibration, classification, and product generation procedures including methodology used for breakline collection and hydro-flattening.
    c. QA/QC Reports (detailing the analysis, accuracy assessment and validation of:
        i. The point data (absolute, within swath, and between swath)
        ii. The bare-earth surface (absolute)
        iii. Other optional deliverables as appropriate
2. 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.
3. 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 is preferred.
4. Product metadata (FGDC compliant, XML format metadata). One file for each:
    a. Project
    b. Lift *(note: this one per lift – not one per project)*
    c. Tiled deliverable product group (classified point data, bare-earth DEMs, breaklines, etc.). Metadata files for individual tiles are not required.

Project Report: The contractor shall deliver a production report which details:

1. A record of field work procedures.
2. Data derivation and adjustments.
3. Quality control procedures and results.
4. Any problems encountered and solutions used in resolving such problems.
5. Statistical report summarizing the results of the airborne GPS adjustment and the overall accuracy of the adjusted IMU data.
6. Production report shall be Microsoft Word, Adobe PDF format or other compatible digital format.

Acquisition Reports: Contractor shall provide regular progress updates to the technical point of contact throughout the data acquisition process.

1. Update frequency shall be based upon the collection period, but no less that once a week.
2. Reports shall be delivered as shapefiles which represent the geographic extent of the acquired data.
3. Updates shall commence at acquisition onset and shall continue until acquisition is complete.

Project Pilot: Contractor shall deliver a Project Pilot Delivery consisting of the FVA reporting of the UNCLASSIFIED point cloud data, a minimum of five (5) square miles of classified LAS data in each of the primary land cover categories (SVA categories), and corresponding Hydro Flattened Bare Earth DEM's.

TILING SCHEME AND DATA FORMAT

1. **Tile Coverage:** Tiles which lie completely within the project area shall be complete to the tile edges. Tiles which lie partially outside the project boundary shall be complete to the project boundary with enough overlap beyond the project boundary to ensure that no parts of the project are omitted.

2. **Tile Size:**
   Tiles shall be 1500 meters x 1500 meters

   Tiled deliverables shall conform to the tiling scheme, without added overlap.

   Tiling scheme will be used for all tiled deliverables.

   Tiled deliverables shall edge-match seamlessly in both the horizontal and vertical.

3. **Tile Naming:**
   Tiles shall be named according to the US National Grid conventions.

4. **Spatial Reference System**:

   The Spatial Reference System shall be: UTM, NAD83, Meters; NAVD88, Meters, Zone 18.