## AIRBORNE LIDAR TASK ORDER REPORT

# LITTLE BIGHORN BATTLEFIELD MONUMENT
# 0.35M NPS LIDAR
# UNITED STATES GEOLOGICAL SURVEY (USGS)


## CONTRACT NUMBER: G10PC00057

## TASK ORDER NUMBER: G14PD00514

**Woolpert Project Number: 74471**
**October 2014**

# PROJECT REPORT

## LITTLE BIGHORN BATTLEFIELD NATIONAL MONUMENT 0.35M NPS LIDAR

## WOOLPERT PROJECT #74471

For:

**United States Geological Survey (USGS)**
1400 Independence Road
Rolla, Missouri 65401

By:

**Woolpert**
4454 Idea Center Boulevard
Dayton, OH 45430-1500
Tel 937.461.5660

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# SECTION 1: OVERVIEW

## PROJECT NAME: LITTLE BIGHORN BATTLEFIELD NATIONAL MONUMENT 0.35M NPS LIDAR

## WOOLPERT PROJECT #74471

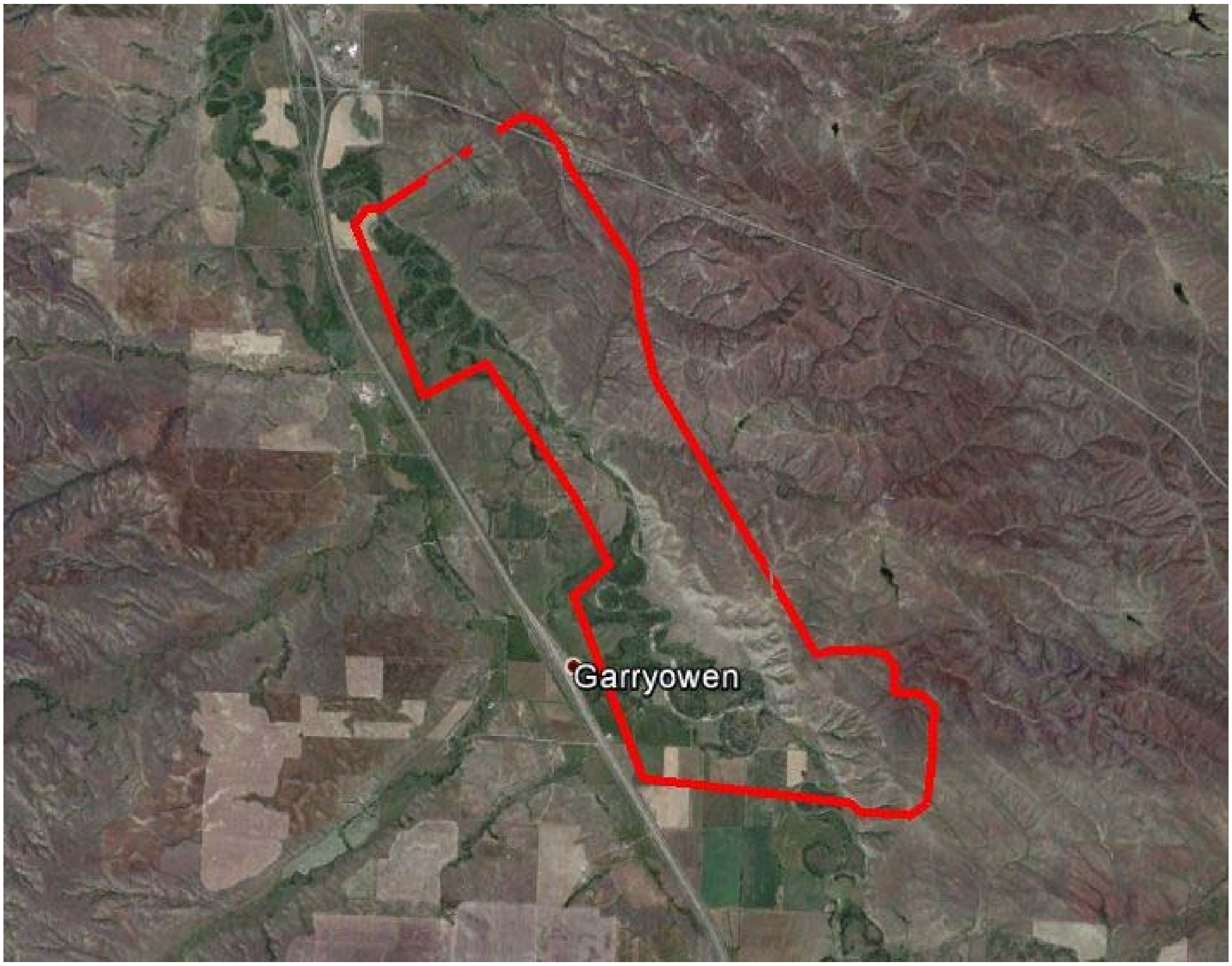
This report contains a comprehensive outline of the Little Bighorn Battlefield National Monument 0.35M NPS LiDAR Processing task order for the United States Geological Survey (USGS). This task is issued under Contract Number G10PC00057, as task order number G14PD00514. The project area covers approximately 5.5 square miles in Montana. The LiDAR was collected and processed to meet a maximum Nominal Post Spacing (NPS) of 0.35 meters. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

The data was collected using a Leica ALS70 500 kHz Multiple Pulses in Air (MPiA) LiDAR sensor installed in a Leica gyro-stabilized PAV30 mount. The ALS70 sensor collects up to four returns per pulse, as well as intensity data, for the first three returns. If a fourth return was captured, the system does not record an associated intensity value. The aerial LiDAR was collected at the following sensor specifications:

| | |
|---|---|
| Post Spacing (Minimum): | 1.1 ft / 0.35m |
| AGL (Above Ground Level) average flying height: | 4,500 ft / 1,372 m |
| MSL (Mean Sea Level) average flying height: | 7,560 ft/ 2,304 m |
| Average Ground Speed: | 135 knots / 155 mph |
| Field of View (full): | 15 degrees |
| Pulse Rate: | 376 kHz |
| Scan Rate: | 69.4 Hz |
| Side Lap (Average): | 25% |

The LiDAR data was processed and projected in UTM, Zone 13N, North American Datum of 1983 (2011) in units of meters. The vertical datum used for the task order was referenced to NAVD 1988, GEOID12A, in units of meters.

**Figure 1.1 LiDAR Task Order AOI**



# SECTION 2: ACQUISITION

The existing LiDAR data was acquired with a Leica ALS70 500 kHz Multiple Pulses in Air (MPiA) LiDAR sensor system, on board a Cessna Titan 404. The ALS70 LiDAR system, developed by Leica Geosystems of Heerbrugg, Switzerland, includes the simultaneous first, intermediate and last pulse data capture module, the extended altitude range module, and the target signal intensity capture module. The system software is operated on an OC50 Operation Controller aboard the aircraft.

**Table 2.1: ALS70 LiDAR System Specifications**

The ALS70 500 kHz Multiple Pulses in Air (MPiA) LiDAR System has the following specifications:

| | |
|---|---|
| Specification | |
| Operating Altitude | 200 – 3,500 meters |
| Scan Angle | 0 to 75° (variable) |
| Swath Width | 0 to 1.5 X altitude (variable) |
| Scan Frequency | 0 – 200 Hz (variable based on scan angle) |
| Maximum Pulse Rate | 500 kHz (Effective) |
| | |
| Range Resolution | Better than 1 cm |
| Elevation Accuracy | 7 - 16 cm single shot (one standard deviation) |
| Horizontal Accuracy | 5 – 38 cm (one standard deviation) |
| | |
| Number of Returns per Pulse | 7 (infinite) |
| Number of Intensities | 3 (first, second, third) |
| Intensity Digitization | 8 bit intensity + 8 bit AGC (Automatic Gain Control) level |
| | |
| MPiA (Multiple Pulses in Air) | 8 bits @ 1nsec interval @ 50kHz |
| | |
| Laser Beam Divergence | 0.22 mrad @ $1/e^2$ (~0.15 mrad @ 1/e) |
| Laser Classification | Class IV laser product (FDA CFR 21) |
| Eye Safe Range | 400m single shot depending on laser repetition rate |
| | |
| Roll Stabilization | Automatic adaptive, range = 75 degrees minus current FOV |
| Power Requirements | 28 VDC @ 25A |
| Operating Temperature | 0-40°C |
| Humidity | 0-95% non-condensing |
| Supported GNSS Receivers | Ashtech Z12, Trimble 7400, Novatel Millenium |

Prior to mobilizing to the project site, Woolpert flight crews coordinated with the necessary Air Traffic Control personnel to ensure airspace access.

Woolpert survey crews were onsite, operating a Global Navigation Satellite System (GNSS) Base Station for the airborne GPS support.

The LiDAR data was collected in one (1) mission.

An initial quality control process was performed immediately on the LiDAR data to review the data coverage, airborne GPS data, and trajectory solution. Any gaps found in the LiDAR data were relayed to the flight crew, and the area was re-flown.

**Figure 2.1: LiDAR Flight Layout**

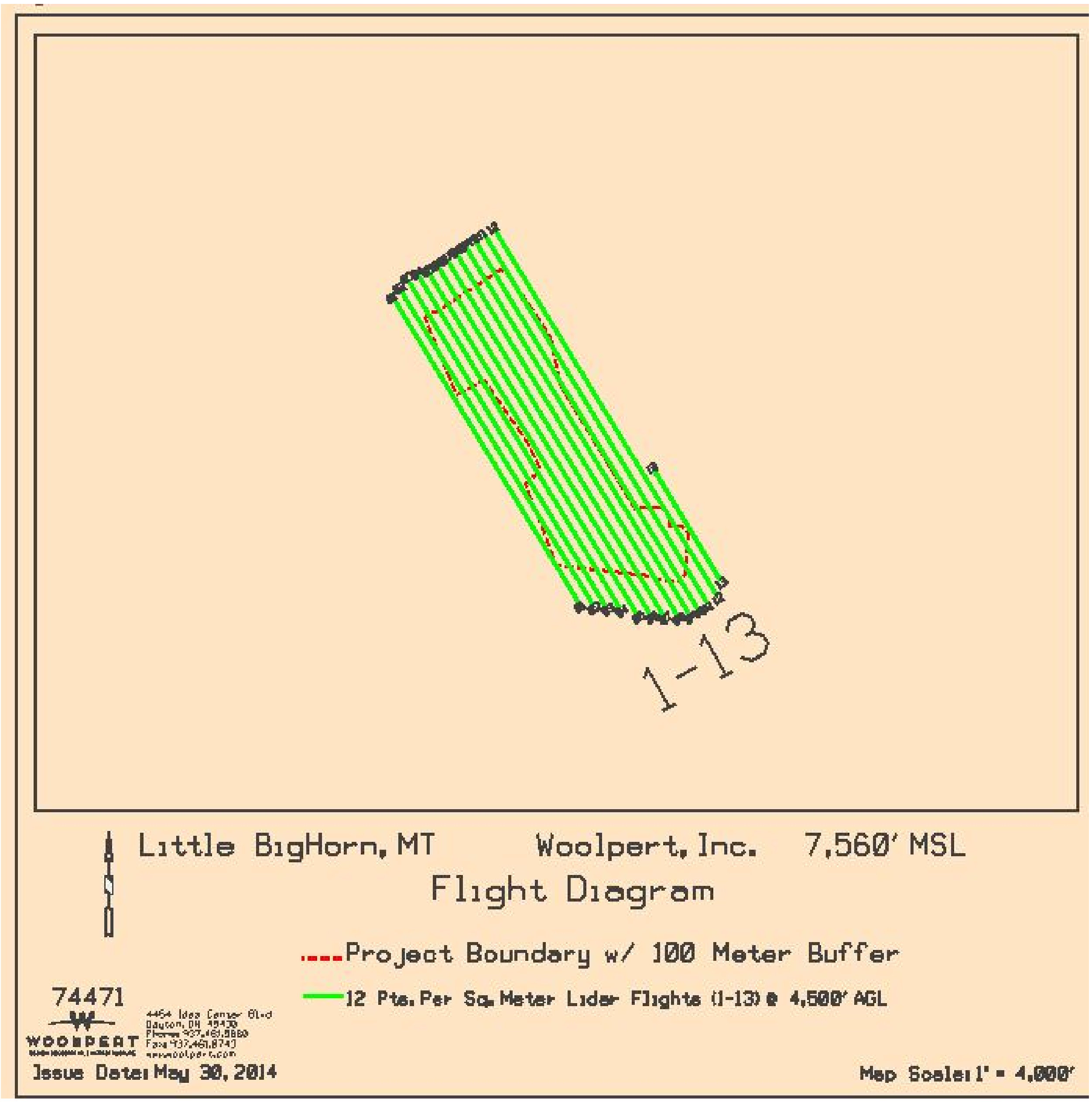


**Table 2.2: Airborne LiDAR Acquisition Flight Summary**

| Airborne LiDAR Acquisition Flight Summary | | | |
|---|---|---|---|
| Date of Mission | Lines Flown | Mission Time (UTC)<br><br>Wheels Up/<br><br>Wheels Down | Mission Time (Local = EDT)<br><br>Wheels Up/<br><br>Wheels Down |
| June 12, 2014 – Sensor 7108 | 1-13 | 14:52 – 20:19 | 08:52PM – 02:19pm |

# SECTION 3: LIDAR DATA PROCESSING

## APPLICATIONS AND WORK FLOW OVERVIEW

1. Resolved kinematic corrections for three subsystems: inertial measurement unit (IMU), sensor orientation information and airborne GPS data. Developed a blending post-processed aircraft position with attitude data using Kalman filtering technology or the smoothed best estimate trajectory (SBET).
   **Software:** POSPac Software v. 5.3, IPAS Pro v.1.35.

2. Calculated laser point position by associating the SBET position to each laser point return time, scan angle, intensity, etc. Created raw laser point cloud data for the entire survey in LAS format. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift.
   **Software:** ALS Post Processing Software v.2.75 build #25, Proprietary Software, TerraMatch v. 14.01.

3. Imported processed LAS point cloud data into the task order tiles. Resulting data were classified as ground and non-ground points with additional filters created to meet the task order classification specifications. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Based on the statistical analysis, the LiDAR data was then adjusted to reduce the vertical bias when compared to the survey ground control.
   **Software:** TerraScan v.14.011.

4. The LAS files were evaluated through a series of manual QA/QC steps to eliminate remaining artifacts from the ground class.
   **Software:** TerraScan v.14.011.

## GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)-INERTIAL MEASUREMENT UNIT (IMU) TRAJECTORY PROCESSING

### EQUIPMENT

Flight navigation during the LiDAR data acquisition mission is performed using IGI CCNS (Computer Controlled Navigation System). The pilots are skilled at maintaining their planned trajectory, while holding the aircraft steady and level. If atmospheric conditions are such that the trajectory, ground speed, roll, pitch and/or heading cannot be properly maintained, the mission is aborted until suitable conditions occur.

The aircraft are all configured with a NovAtel Millennium 12-channel, L1/L2 dual frequency Global Navigation Satellite System (GNSS) receivers collecting at 2 Hz.

All Woolpert aerial sensors are equipped with a Litton LN200 series Inertial Measurement Unit (IMU) operating at 200 Hz.

A base-station unit was mobilized for the acquisition mission, and was operated by a member of the Woolpert acquisition team. Each base-station setup consisted of one Trimble 4000 – 5000 series dual frequency receiver, one Trimble Compact L1/L2 dual frequency antenna, one 2-meter fixed-height tripod, and essential battery power and cabling. Ground planes were used on the base-station antennas. Data was collected at 1 or 2 Hz.

Woolpert's acquisition team was on site, operating a GNSS base station.

The GNSS base station operated during the LiDAR acquisition missions is listed below:

**Table 3.1: GNSS Base Station**

| Station | Latitude | Longitude | Ellipsoid Height (L1 Phase center) |
|---|---|---|---|
| Name | (DMS) | (DMS) | (Meters) |
| CP01 | 45°31'18.31794" | -107°22'39.05983" | 1022.047 |

## DATA PROCESSING

All airborne GNSS and IMU data was post-processed and quality controlled using Applanix MMS software. GNSS data was processed at a 1 and 2 Hz data capture rate and the IMU data was processed at 200 Hz.

## TRAJECTORY QUALITY

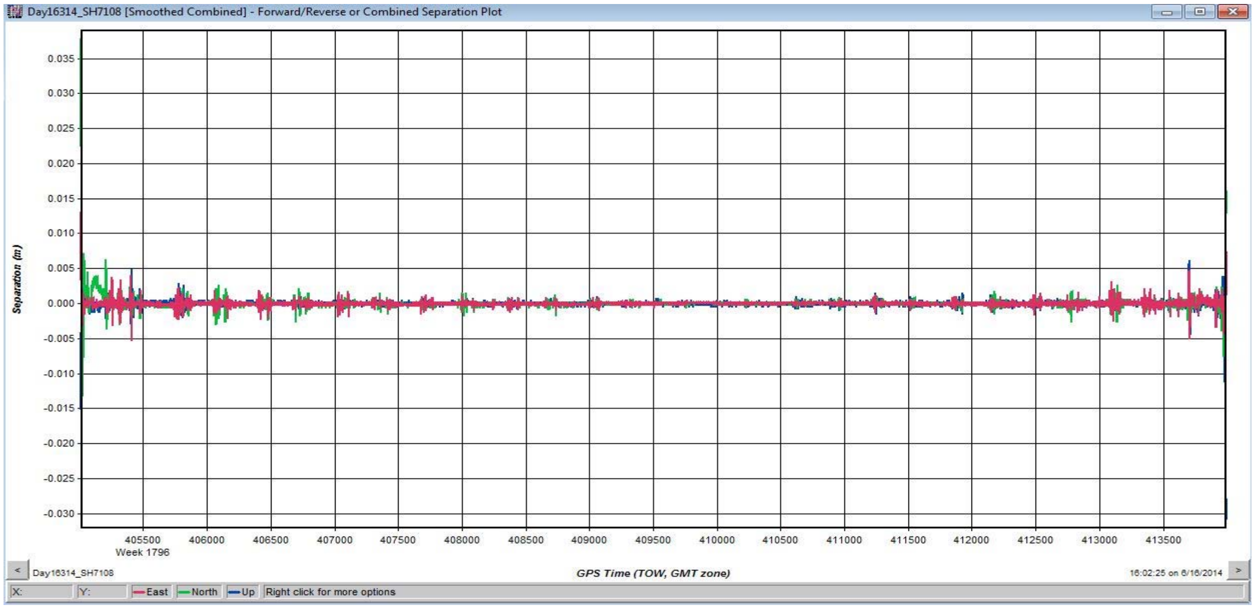
The GNSS Trajectory, along with high quality IMU data are key factors in determining the overall positional accuracy of the final sensor data. Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the Combined Separation, the Estimated Positional Accuracy, and the Positional Dilution of Precision (PDOP).

### Combined Separation

The Combined Separation is a measure of the difference between the forward run and the backward run solution of the trajectory. The Kalman filter is processed in both directions to remove the combined directional anomalies. In general, when these two solutions match closely, an optimally accurate reliable solution is achieved.

Woolpert's goal is to maintain a Combined Separation Difference of less than ten (10) centimeters. In most cases we achieve results below this threshold.

**Figure 3.1: Combined Separation, Day16314 SH7108**

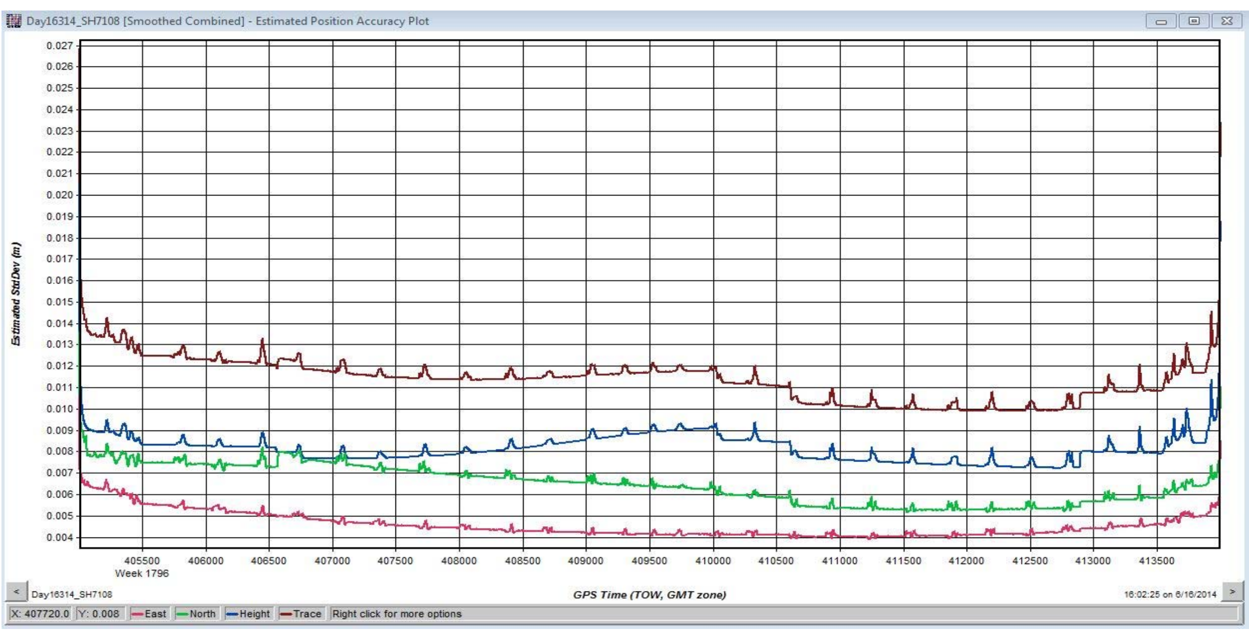



## Estimated Positional Accuracy

The Estimated Positional Accuracy plots the standard deviations of the east, north, and vertical directions along a time scale of the trajectory. It illustrates loss of satellite lock issues, as well as issues arising from long baselines, noise, and/or other atmospheric interference.

Woolpert's goal is to maintain an Estimated Positional Accuracy of less than ten (10) centimeters, often achieving results well below this threshold.

**Figure 3.2: Estimated Positional Accuracy, Day16314 SH7108**

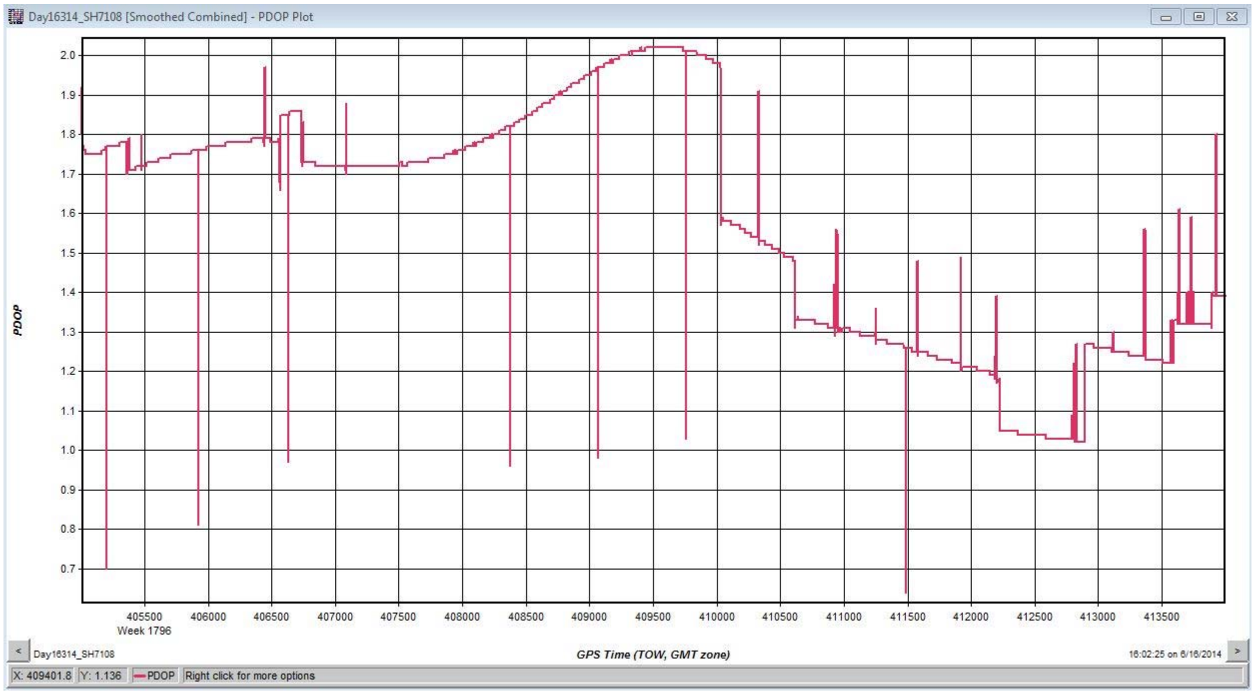


### PDOP

The PDOP measures the precision of the GPS solution in regards to the geometry of the satellites acquired and used for the solution.

Woolpert's goal is to maintain an average PDOP value below 3.0. Brief periods of PDOP over 3.0 are acceptable due to the calibration and control process if other metrics are within specification.

**Figure 3.3: PDOP, Day16314 SH7108**




# LIDAR DATA PROCESSING

When the sensor calibration, data acquisition, and GPS processing phases were complete, the formal data reduction processes by Woolpert LiDAR specialists included:

- Processed individual flight lines to derive a raw "Point Cloud" LAS file. Matched overlapping flight lines, generated statistics for evaluation comparisons, and made the necessary adjustments to remove any residual systematic error.

- Calibrated LAS files were imported into the task order tiles and initially filtered to create a ground and non-ground class. Then additional classes were filtered as necessary to meet client specified classes.

- Once all project data was imported and classified, survey ground control data was imported and calculated for an accuracy assessment. As a QC measure, Woolpert has developed a routine to generate accuracy statistical reports by comparisons against the TIN and the DEM using surveyed ground control of higher accuracy. The LiDAR is adjusted accordingly to meet or exceed the vertical accuracy requirements.

- The LiDAR tiles were reviewed using a series of proprietary QA/QC procedures to ensure it fulfills the task order requirements. A portion of this requires a manual step to ensure anomalies have been removed from the ground class.

- The LiDAR LAS files are classified into the Default (Class 1), Ground (Class 2), Noise (Class 7), Water (Class 9), Ignored Ground (Class 10), Overlap default (Class 17), and Overlap Ground (Class 18) classifications.

- FGDC Compliant metadata was developed for the task order in .xml format for the final data products.

- The horizontal datum used for the task order was referenced to UTM13N American Datum of 1983 (2011). The vertical datum used for the task order was referenced to NAVD 1988, meters, GEOID12A. Coordinate positions were specified in units of meters.

# SECTION 4: HYDROLOGIC FLATTENING

## HYDROLOGIC FLATTENING OF LIDAR DEM DATA

Little Bighorn Battlefield National Monument 0.35m NPS LiDAR Processing task order required the compilation of breaklines defining water bodies and rivers. The breaklines were used to perform the hydrologic flattening of water bodies, and gradient hydrologic flattening of double line streams and rivers. Lakes, reservoirs and ponds, at a minimum size of 2-acres or greater, were compiled as closed polygons. The closed water bodies were collected at a constant elevation. Rivers and streams, at a nominal minimum width of 30.5 meters (100 feet), were compiled in the direction of flow with both sides of the stream maintaining an equal gradient elevation. The Little Bighorn River was collected however, even though its nominal width is under 100 feet.

## LIDAR DATA REVIEW AND PROCESSING

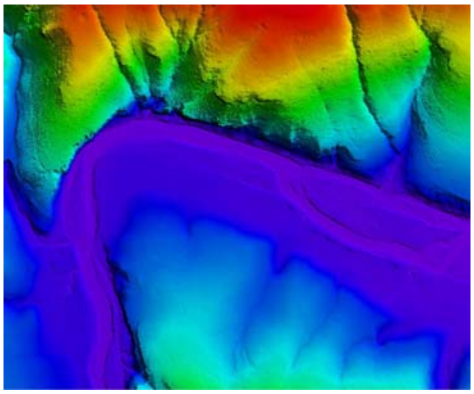
Woolpert utilized the following steps to hydrologically flatten the water bodies and for gradient hydrologic flattening of the double line streams within the existing LiDAR data.

1. Woolpert used the newly acquired LiDAR data to manually draw the hydrologic features in a 2D environment using the LiDAR intensity and bare earth surface. Open Source imagery was used as reference when necessary.

2. Woolpert utilizes an integrated software approach to combine the LiDAR data and 2D breaklines. This process “drapes” the 2D breaklines onto the 3D LiDAR surface model to assign an elevation. A monotonic process is performed to ensure the streams are consistently flowing in a gradient manner. A secondary step within the program verifies an equally matching elevation of both stream edges. The breaklines that characterize the closed water bodies are draped onto the 3D LiDAR surface and assigned a constant elevation at or just below ground elevation.

3. The lakes, reservoirs and ponds, at a minimum size of 2-acres or greater, were compiled as closed polygons. **Figure 4.1** illustrates a good example of 2-acre lakes and 30.5 meters (100 feet) nominal streams identified and defined with hydrologic breaklines. The breaklines defining rivers and streams, at a nominal minimum width of 30.5 meters (100 feet), were draped with both sides of the stream maintaining an equal gradient elevation.

**Figure 4.1**



4. All ground points were reclassified from inside the hydrologic feature polygons to water, class nine (9).

5. All ground points were reclassified from within a buffer along the hydrologic feature breaklines to buffered ground, class ten (10).

6. The LiDAR ground points and hydrologic feature breaklines were used to generate a new digital elevation model (DEM).

**Figure 4.2**

**Figure 4.3**

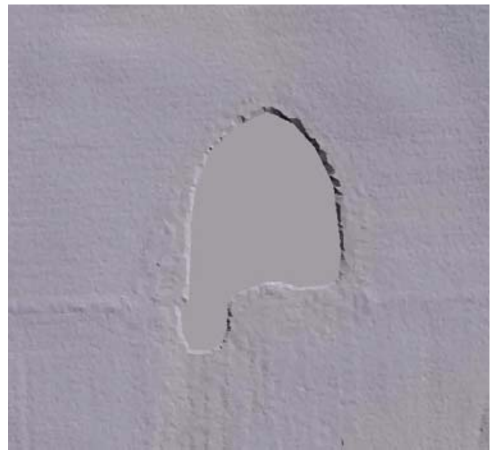


**Figure 4.2** reflects a DEM generated from original LiDAR bare earth point data prior to the hydrologic flattening process. Note the "tinning" across the lake surface.

**Figure 4.3** reflects a DEM generated from LiDAR with breaklines compiled to define the hydrologic features. This figure illustrates the results of adding the breaklines to hydrologically flatten the DEM data. Note the smooth appearance of the lake surface in the DEM.

Terrascan was used to add the hydrologic breakline vertices and export the lattice models. The hydrologically flattened DEM data was provided to USGS in ERDAS .IMG format at a 1-meter cell size.

The hydrologic breaklines compiled as part of the flattening process were provided to the USGS as an ESRI shapefile. The breaklines defining the water bodies greater than 2-acres were provided as a PolygonZ file. The breaklines compiled for the gradient flattening of all rivers and streams at a nominal minimum width of 30.5 meters (100 feet) were provided as a PolylineZ file.

# DATA QA/QC

Initial QA/QC for this task order was performed in Global Mapper v15, by reviewing the grids and hydrologic breakline features. Additionally, ESRI software and proprietary methods were used to review the overall connectivity of the hydrologic breaklines.

Edits and corrections were addressed individually by tile. If a water body breakline needed to be adjusted to improve the flattening of the DEM data, the area was cross referenced by tile number, corrected accordingly, a new DEM file was regenerated and reviewed.

# SECTION 5: FINAL ACCURACY ASSESSMENT

## FINAL VERTICAL ACCURACY ASSESSMENT

The vertical accuracy statistics were calculated by comparison of the LiDAR bare earth points to the ground surveyed quality check points.

**Table 5.1: Overall Vertical Accuracy Statistics**

| | | |
|---|---|---|
| Average error | -.010 | meters |
| Minimum error | -.081 | meters |
| Maximum error | 0.056 | meters |
| Root mean square | 0.033 | meters |
| Standard deviation | 0.032 | meters |

**Table 5.2: Swath Quality Check Point Analysis, FVA, UTM 13N (2011), NAD83, NAVD88 GEOID12A, Little Bighorn Battlefield National Monument**

| Point ID | Easting (UTM meters) | Northing (UTM meters) | TIN Elevation (meters) | Dz (meters) |
|---|---|---|---|---|
| 2001 | 309510.8 | 5048715.877 | 935.41 | -0.047 |
| 2002B | 310172.6 | 5049062.422 | 981.27 | 0.006 |
| 2002C | 309510.8 | 5048715.876 | 935.41 | -0.045 |
| 2003 | 311056.6 | 5049540.352 | 978.74 | 0.024 |
| 2004 | 310876 | 5048847.512 | 1002.38 | 0.035 |
| 2005 | 310366.9 | 5048613.363 | 958.81 | 0.017 |
| 2006 | 310784.4 | 5046912.405 | 940.74 | -0.005 |
| 2007 | 310985.7 | 5046482.584 | 941.4 | -0.015 |
| 2008 | 311827.7 | 5043660.701 | 950.59 | -0.045 |
| 2009 | 312605.6 | 5043569.298 | 951.58 | 0.021 |
| 2010 | 312959.3 | 5043503.545 | 951.37 | -0.032 |
| 2011 | 314405 | 5043339.653 | 1038.7 | -0.022 |
| 2012 | 314403.3 | 5043566.298 | 1029.98 | -0.007 |
| 2012A | 314403.3 | 5043566.296 | 1029.98 | -0.011 |

| Point ID | Easting (UTM meters) | Northing (UTM meters) | TIN Elevation (meters) | Dz (meters) |
|---|---|---|---|---|
| 2012B | 314405 | 5043339.651 | 1038.7 | -0.013 |
| 2013 | 314316.3 | 5043716.815 | 1034.95 | 0.026 |
| 2014 | 313396.6 | 5044598.295 | 1028.53 | -0.005 |
| 2015 | 313144.9 | 5045115.407 | 1043.27 | 0.056 |
| 2016 | 312289.4 | 5045593.579 | 987.47 | -0.081 |
| 2017 | 312252.4 | 5046273.336 | 973.58 | -0.003 |
| 2018 | 311589.9 | 5046821.86 | 950.36 | -0.004 |
| 2019 | 310937.7 | 5047919.115 | 984.25 | -0.015 |
| 2020 | 310344.4 | 5049137.033 | 990.9 | -0.067 |
| 2021 | 310475.1 | 5049710.574 | 974.82 | -0.027 |
| 2022 | 311996.9 | 5045441.213 | 948.97 | 0.012 |

## VERTICAL ACCURACY CONCLUSIONS

LAS Swath Fundamental Vertical Accuracy (FVA) Tested 0.064 meters fundamental vertical accuracy at 95 percent confidence level, derived according to NSSDA, in open terrain in open using (RMSEz) x 1.9600, tested against the TIN.

Bare-Earth DEM Fundamental Vertical Accuracy (FVA) Tested 0.068 meters fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 Tested against the DEM.

**Table 5.3: Quality Check Point Analysis, Tall Weeds and Crops, UTM 13N (2011), NAD83, NAVD88 GEOID12A, Little Bighorn Battlefield National Monument**

| Point ID | Easting (UTM meters) | Northing (UTM meters) | DEM Elevation (meters) | Absolute Dz (meters) |
|---|---|---|---|---|
| 4001 | 309522.672 | 5048707.733 | 934.51 | 0 |
| 4002 | 310143.786 | 5049032.161 | 978.19 | 0.026 |
| 4002A | 310143.795 | 5049032.298 | 978.19 | 0.029 |
| 4003 | 311037.789 | 5049554.566 | 978.02 | 0.122 |
| 4004 | 310835.721 | 5048839.844 | 999.29 | 0.027 |
| 4005 | 310358.447 | 5048618.124 | 957.5 | 0.504 |
| 4006 | 310890.925 | 5046850.58 | 938.72 | 0.031 |
| 4007 | 310944.86 | 5046574.711 | 939.57 | 0.065 |
| 4008 | 311828.031 | 5043624.73 | 950.48 | 0.027 |
| 4009 | 312569.745 | 5043547.41 | 951.34 | 0.031 |
| 4010 | 312946.824 | 5043490.022 | 951.26 | 0.169 |
| 4011 | 314407.331 | 5043312.331 | 1034.69 | 0.137 |
| 4012 | 314377.504 | 5043568.457 | 1031.11 | 0.069 |
| 4013 | 314341.912 | 5043742.635 | 1034.38 | 0.09 |
| 4014 | 313417.117 | 5044604.765 | 1025.77 | 0.083 |
| 4015 | 313218.43 | 5045052.88 | 1032.29 | 0.013 |
| 4016 | 312318.895 | 5045611.63 | 985.57 | 0.08 |
| 4017 | 312275.172 | 5046308.829 | 967.4 | 0.013 |
| 4018 | 311571.205 | 5046774.392 | 948.17 | 0.049 |
| 4019 | 310891.24 | 5047915.684 | 984.15 | 0.034 |
| 4020 | 310381.957 | 5049115.682 | 989.33 | 0.04 |
| 4021 | 310517.501 | 5049691.794 | 973.53 | 0.038 |
| 4022 | 311978.626 | 5045462.489 | 949.32 | 0.099 |

## ACCURACY CONCLUSIONS

Tall Weeds and Crops Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.165 meters supplemental vertical accuracy at the 95th percentile, tested against the DEM. Tall Weeds and Crops Errors larger than 95th percentile include:

- Point 4005, Easting 310358.447, Northing 5048618.124 Z-Error 0.504 meters
- Point 4010, Easting 312946.824, Northing 5043490.022 Z-Error 0.169 meters

## CONSOLIDATED VERTICAL ACCURACY ASSESSMENT

## ACCURACY CONCLUSIONS

Consolidated Vertical Accuracy (CVA) Tested 0.131 meters consolidated vertical accuracy at the 95th percentile level, tested against the DEM. Consolidated errors larger than 95th percentile include:

- Point 4005, Easting 310358.447, Northing 5048618.124 Z-Error 0.504 meters

- Point 4010, Easting 312946.824, Northing 5043490.022 Z-Error 0.169 meters

- Point 4011, Easting 314407.331, Northing 5043312.331 Z-Error 0.137 meters

| Approved By: | | | |
|---|---|---|---|
| Title | Name | Signature | Date |
| Associate<br>LiDAR Specialist<br>Certified Photogrammetrist #1281 | Qian Xiao |  | October 2014 |

# SECTION 6: FLIGHT LOG

## FLIGHT LOG

Flight log for the project is shown on the following page.

# Woolpert

| Leica LIDAR | MM/DD/YYYY | Day of Year | Project # | Phase # | Project Name |
|---|---|---|---|---|---|
| | 6/12/2014 | 163 | 74471 | GS | Little Bighorn Battlefield National Monument |

| Operator | Aircraft | Hobbs Start | Local Start Time | Zulu Start Time | Base |
|---|---|---|---|---|---|
| Other | N404CP | 4817.1 | 8:52:00 | 14:52:00 | |
| **Pilot** | **Sensor Type** | **Hobbs End** | **Local End Time** | **Zulu End Time** | **PDI** |
| GEBHART | ALS-7108 | 4822.3 | 2:19:00 | 20:19:00 | |

| Wind Dir/Speed | Visibility | Ceiling | Cloud Cover % | Temp | Dew Point | Pressure | Haze/Fire/Cloud | Departing | KRAP |
|---|---|---|---|---|---|---|---|---|---|
| 020/2 | | | | | | | | Arriving | KRAP |

| Scan Angle (FOV) | Scan Frequency (Hz) | Pulse Rate (kHz) | Laser Power % | Fixed Gain | | Mode | | Threshold Values | |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 69.4 | 376 | 96 | Gain - Course/Up | | Single | | A | |
| | | | | Gain - Fine/Down | | Multi | | B | |

| Air Speed | | AGL | | MSL | | Waveform Used | | | | Waveform Mode | Pre-Trigger Dist. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 135 | Kts | 4500 | Ft | 7560 | Ft | Yes | | No | | @ NS | Ft |

| Line # | Dir. | Line Start Time | Line End Time | Time On Line | SV's | HDOP | PDOP | Line Notes/Comments | |
|---|---|---|---|---|---|---|---|---|---|
| Test | n/a | | | n/a | n/a | n/a | n/a | GPS Began Logging At: | |
| | | ↓ Times entered are Zulu / GMT ↓ | | | | | | Verify S-Turns Before Mission Yes Y No | |
| 1 | SE | 17:50:00 | 17:52:00 | | 22 | | 1.1 | | |
| 2 | NW | 17:54:00 | 17:56:00 | | 22 | | 1.1 | | |
| 3 | SE | 17:59:00 | 18:02:00 | | 21 | | 1.1 | | |
| 4 | NW | 18:05:00 | 18:07:00 | | 21 | | 1.2 | | |
| 5 | SE | 18:10:00 | 18:12:00 | | 21 | | 1.2 | | |
| 6 | NW | 18:15:00 | 18:17:00 | | 21 | | 1.2 | | |
| 7 | SE | 18:21:00 | 18:23:00 | | 21 | | 1.2 | | |
| 8 | NW | 18:26:00 | 18:28:00 | | 21 | | 1.1 | | |
| 9 | SE | 18:31:00 | 18:34:00 | | 21 | | 1.1 | | |
| 10 | NW | 18:36:00 | 18:38:00 | | 21 | | 1.1 | | |
| 11 | SE | 18:41:00 | 18:44:00 | | 21 | | 1 | | |
| 12 | NW | 18:46:00 | 18:48:00 | | 20 | | 1.2 | | |
| 13 | SE | 18:51:00 | 18:52:00 | | 21 | | 1 | | |
| ↑ Times entered are Zulu / GMT ↑ | | | | Page | | 1 | | Verify S-Turns After Mission Yes S No | |

Additional Comments:

Drive #

FLI4.9-02 10/16/12 R 07

# SECTION 7: FINAL DELIVERABLES

## FINAL DELIVERABLES

The final LiDAR deliverables are listed below.

- LAS v1.2 classified point cloud
- LAS v1.2 raw unclassified point cloud flight line strips no greater than 2GB. Long swaths greater than 2GB will be split into segments)
- Hydrologically flattened Polygon z and Polyline z shapefiles
- Hydrologically flattened bare earth 1-meter DEM in ERDAS .IMG format
- 1-meter Digital Surface Models in ERDAS .IMG format
- 8-bit gray scale intensity images
- Tile Layout and data extent provided as ESRI shapefile
- Control points provided as ESRI shapefile
- FGDC compliant metadata per product in XML format
- LiDAR processing report in pdf format
- Survey report in pdf format

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