AIRBORNE TOPOGRAPHIC LiDAR REPORT

OAHU, HAWAII

Contract No. G10PC00026
Requisition No. 0040075464
Task Order No. G13PD00211

January 31, 2013

Completed by Photo Science, Inc.

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1. SUMMARY/SCOPE

1.1. SUMMARY
This report contains a summary of the Oahu LiDAR acquisition task order, issued by the USGS National Geospatial Technical Operations Center (NGTOC), under their Geospatial Products and Services Contract (GPSC). A separate but related task order was issued by the NOAA Coastal Services Center (Contract Number EA133C-11-CQ-0009; Requisition Number NCNP0000-13-00518; Task Order Number 20) to leverage the same resources committed to the USGS LiDAR project for the acquisition of LiDAR data in the northern 2/3 portion of Oahu. The combined task orders yielded one study area covering the entire island of Oahu. The intent of this document is to only provide specific validation information for the LiDAR data acquisition/collection work completed for the USGS project.

1.2. SCOPE
The scope of the Oahu LiDAR task order included the acquisition of aerial topographic LiDAR using state of the art technology, along with necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems, for the island of Oahu. The aerial data collection was designed with the following specifications listed in Table 1 below.

<table>
<thead>
<tr>
<th>LiDAR</th>
<th>Flight Altitude (AGL)</th>
<th>Field of View</th>
<th>Side Overlap</th>
<th>RMSEz</th>
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</thead>
<tbody>
<tr>
<td>Average Point Density</td>
<td>1.15 pts / m^2</td>
<td>4,000 ft</td>
<td>36.0 degrees</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15 cm or better</td>
</tr>
</tbody>
</table>

1.3. LOCATION/COVERAGE
The Oahu LiDAR project boundary consists of two areas of interest, one encompassing the northern ~2/3 of the Island of Oahu (NOAA task order) and the southern ~1/3 of the island (USGS task order). The project area totals approximately 619 square miles as shown in Figure 1 on the following page.
Figure 1. Oahu LiDAR Project Boundary
1.4. DURATION
The aircraft and flight crew arrived in Honolulu, HI in late May 2013, with sensor installation and testing occurring shortly thereafter. The first attempt to collect LiDAR data occurred on June 01, 2013 along the western coast of the island. Acquisition occurred during the months of June and July whenever weather permitted. Acquisition continued into the second week of August with the final acquisition flight occurring on August 09, 2013. The LiDAR sensor was removed from the aircraft on August 10, 2013. In summary, nineteen sorties were required to collect the LiDAR data for the project, over a period of approximately 9 weeks.

1.5. ISSUES
The primary issue of concern with this task order was the overall weather conditions during the time Photo Science was on-site in Oahu. This particular season (June/July/August) was specifically selected for the aerial acquisition, based on close review of historic weather patterns that indicated June/July/August to be the driest time of year. However, persistent cloud cover and rain plagued flight operations the entire time Photo Science was on-site for the LiDAR acquisition work. With rain nearly every day, sustaining saturated and high humidity conditions, the island exhibited a cycle of daily self-generating cloud cover once the sun came up (warming conditions) each day, particularly in the higher elevations. Active trade winds, tropical storms, and diurnal variations of cloud cover produced quick changing weather conditions that meant that the flight crew had to rely on daily visual assessments of the weather/cloud cover to determine if acquisition could occur each day.

In addition to weather concerns, Photo Science was faced with consistent challenges in flight coordination. Photo Science worked closely with both civilian and military Air Traffic Control in order to coordinate flights and gain access to as much of the island as possible. These challenges required acquisition to often take place during late-night or early morning hours, with flights nearly always in the air by 7:00 AM.

Due to these challenges, Photo Science was forced to abandon the originally planned flightlines. A modified flight plan was created to capture the coastal areas, which were of a higher priority than the mountainous interior areas. This coastal flight plan was modified further on multiple occasions to take advantage of good flying conditions in certain portions of the island. This strategy allowed for Photo Science to acquire roughly 72% of the island. Persistent cloud cover on the eastern mountain ridge prevented any acquisition from occurring in this area. The only other area that could not be acquired was the higher elevations of the restricted Schofield Barracks.

2. PLANNING / EQUIPMENT

The entire target area was comprised of 160 planned flight lines and approximately 4028 flight line kilometers. Please refer to Figure 2 on the following pages.
Figure 2. Oahu Originally Planned Flight Lines
Detailed project flight planning calculations were performed for the Oahu project using Optech ALTM Nav planning software. Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity. Please note that certain values in the table below are listed as “Variable” due to the various flight plans used, as described in Section 1.5 of this document. A brief summary of the aerial acquisition parameters for the project are shown in the LiDAR System Specification Table 2 below:

### Table 2. LiDAR System Specifications

<table>
<thead>
<tr>
<th>LiDAR System Specifications</th>
<th></th>
</tr>
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<tbody>
<tr>
<td><strong>Terrain and Aircraft</strong></td>
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<td>Flying Height AGL</td>
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<td>Recommended Ground Speed (GS)</td>
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<td><strong>Coverage</strong></td>
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<tr>
<td>Line Spacing</td>
<td>Variable</td>
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<tr>
<td><strong>Point Spacing and Density</strong></td>
<td></td>
</tr>
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<td>Maximum Point Spacing Across Track</td>
<td>0.923 m</td>
</tr>
<tr>
<td>Maximum Point Spacing Along Track</td>
<td>0.939 m</td>
</tr>
<tr>
<td>Average Point Density</td>
<td>1.15 pts / m²</td>
</tr>
</tbody>
</table>

### 2.1. EQUIPMENT: AIRCRAFT

All flights for the Oahu project were accomplished through the use of a customized twin-engine Piper PA-31 Navajo (Tail # N3949W). This aircraft provided an ideal, stable aerial base for LiDAR acquisition. This aerial platform has relatively fast cruise speeds which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds which proved ideal for collection of high-density, consistent data posting using a state-of-the-art Optech LiDAR system.
Figure 3. Operations Aircraft

Figure 4. In-Flight Operations
2.2. **LiDAR Sensor**

Photo Science utilized an Optech LiDAR sensor, serial number 240 during the project. This system is capable of collecting data at a maximum frequency of 167kHz, which affords elevation data collection of up to 167,000 points per second. The system utilizes a Multi-Pulse in the Air option (MPIA). This sensor is also equipped with the ability to measure up to 5 returns per outgoing pulse from the laser and these come in the form of 1st, 2nd, 3rd, 4th, and last returns. The intensity of the first four returns is also captured during aerial acquisition. During mission collection of the Oahu project the LiDAR operator monitored point density and swath to ensure data integrity and desired coverage were obtained.

![Figure 5. Optech Gemini LiDAR System](image)

2.3. **Base Station Information**

A GPS base station was utilized during all phases of flight. Base station PSI HJR at Kalaeloa Airport (formerly NAS Barbers Point) was occupied during airborne operations of the project. The base station location was verified using NGS OPUS service and subsequent surveys. Data sheets, graphical depiction of base station locations and log sheets used during station occupation are available in Appendix A.
Figure 6. Trimble R7 GNSS receiver with a Zephyr Geodetic 2 Antenna

Figure 7. PSI HJR Base Station Location
2.4. **Time Period**

Project specific flights were conducted over (18) days. Nineteen sorties, or aircraft lifts were completed. Accomplished sorties are listed below:

- 130601a-240
- 130605a-240
- 130606a-240
- 130612a-240
- 130619a-240
- 130620a-240
- 130704a-240
- 130705a-240
- 130717a-240
- 130718a-240
- 130727a-240
- 130730a-240
- 130806a-240
- 130806b-240
- 130807a-240
- 130808a-240
- 130809a-240
- 130802a-240
- 130802a-240

3. **Processing Summary**

Applanix + POSPac Mobile Mapping Suite software was used for post-processing of airborne GPS and inertial data (IMU), which is critical to the positioning and orientation of the LiDAR sensor during all flights. POSPac combines aircraft raw trajectory data with stationary GPS base station data yielding a “Smoothed Best Estimate Trajectory (SBET) necessary for additional post processing software to develop the resulting geo-referenced point cloud from the LiDAR missions.

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Applanix POSPac processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: Max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory. All relevant graphs produced in the POSPac processing environment for each sortie during the Photo Science Oahu project mobilization are available in Appendix B.

The generated point cloud is the mathematical three dimensional composite of all returns from all laser pulses as determined from the aerial mission. Laser point data are imported into TerraScan and a manual calibration is performed to assess the system offsets for pitch, roll, heading and scale. 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. Point clouds were created using Optech DASHMap Post Processor software. GeoCue distributive processing software was used in the creation of some files needed in downstream processing, as well as in the tiling of the dataset into more manageable file sizes. TerraScan and TerraModeler software packages were then used for the automated data classification, manual cleanup, and bare earth generation. Project specific macros were developed to classify the ground and remove side overlap between parallel flight lines.

All data will manually be reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper will be used as a final check of the bare earth dataset. GeoCue will then be used to create the deliverable industry-standard LAS files for both the All Point Cloud Data and the Bare Earth. In-house software will then used to perform final statistical analysis of the classes in the LAS files. All graphic statistical analysis will be provided within the Final Report.

Due to the differing needs of each agency, the vertical datums used were different between the USGS and the NOAA deliverables for this project. Orthometric heights were used for the USGS deliverables while ellipsoid heights were used for the NOAA deliverables. Photo Science processed and adjusted the data in ellipsoid heights using the ellipsoid heights of control points collected by Photo Science and Sam O. Hirota, Inc. The completed dataset (using ellipsoid heights) was provided to Dewberry...
for the QA/QC process. Upon approval by Dewberry, the dataset will be converted to orthometric heights, adjusted to control using orthometric heights and all required deliverables will then be provided to USGS.

Metadata was generated for the project on a deliverable level.

3.1. **Flight Logs**

Flight logs were completed by LIDAR sensor technicians for each mission during acquisition. These logs depict a variety of information, including:

- Job / Project #
- Flight Date / Lift Number
- FOV (Field of View)
- Scan Rate (HZ)
- Pulse Rate Frequency (Hz)
- Ground Speed
- Altitude
- Base Station
- PDOP avoidance times
- Flight Line #
- Flight Line Start and Stop Times
- Flight Line Altitude (AMSL)
- Heading
- Speed
- Returns
- Crab

Notes: (Visibility, winds, ride, weather, temperature, dew point, pressure, etc). Project specific flight logs for each sortie are available in Appendix C.

3.2. **LAS Classification Scheme**

The classification classes are determined by the USGS Version 1.0 specifications and are an industry standard for the classification of LIDAR point clouds. All data starts the process as Class 1 (Unclassified), and then through automated classification routines, the classifications are determined using TerraScan macro processing.

The classes used in the dataset are as follows and have the following descriptions:

- Class 1 – Processed, but Unclassified – These points would be the catch all for points that do not fit any of the other deliverable classes. This would cover things like vegetation, buildings, cars, bridges, etc.
- Class 2 – Bare earth ground – This is the bare earth surface
- Class 7 – Noise – Low or high points, manually identified above or below the surface that could be noise points in point cloud.
- Class 9 – In-land Water – Points found inside of inland lake/ponds
- Class 10 – Ignored Ground – Points found to be close to breakline features. Points are typically moved to this class from Class 2. This class is ignored during the DEM creation.
- Class 17 – Overlap Default (Unclassified) – Points found in the overlap between flight lines. These points are created through automated processing methods and not cleaned up during processing.
• Class 18 – Overlap Bare-earth ground – Points found in the overlap between flight lines. These points are created through automated processing, matching the specifications determined during the automated process, that are close to the Class 2 dataset (when analyzed using height from ground analysis)
• Class 25 – Overlap Water – Points found in the overlap between flight lines that are located inside hydro features. These points are created through automated processing methods and not cleaned up during processing.

3.3. **Classified LAS Processing**
The bare earth surface is then manually reviewed to ensure correct classification on the Class 2 (Ground) points. After the bare-earth surface is finalized; it is then used to generate all hydro-breaklines through heads-up digitization.

All ground (ASPRS Class 2) LiDAR data inside of the Lake Pond and Double Line Drain hydro flattening breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 1 meter was also used around each hydro flattened feature to classify these ground (ASPRS Class 2) points to Ignored ground (ASPRS Class 10). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (ASPRS Class 2) points were reclassified to the correct classification after the automated classification was completed.

All overlap data was processed through automated functionality provided by TerraScan to classify the overlapping flight line data to approved classes by USGS. The overlap data was classified to Class 17 (Overlap Default) and Class 18 (Overlap Ground). These classes were created through automated processes only and were not verified for classification accuracy. Due to software limitations within TerraScan, these classes were used to trip the withheld bit within various software packages. These processes were reviewed and accepted by USGS through numerous conference calls and pilot study areas.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper is used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files for both the All Point Cloud Data and the Bare Earth. Photo Science proprietary software was used to perform final statistical analysis of the classes in the LAS files, on a per tile level to verify final classification metrics and full LAS header information.

3.4. **Hydro Flattening Breakline Process**
Class 2 LiDAR was used to create a bare earth surface model. The surface model was then used to heads-up digitize 2D breaklines of Inland Streams and Rivers with a 30 meter nominal width, Inland Ponds and Lakes of 8,000 sq. meters or greater surface area as well as Coastal Shorelines and Coastal Islands.

Elevation values were assigned to all Inland Ponds and Lakes, Inland Pond and Lake Islands, Inland Stream and River Islands and Coastal Shorelines and Coastal Islands using TerraModeler functionality.

Elevation values were assigned to all Inland streams and rivers using Photo Science proprietary software.

All ground (ASPRS Class 2) LiDAR data inside of the collected inland breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 1 meter was also used around each hydro flattened feature. These points were moved from ground (ASPRS Class 2) to Ignored Ground (ASPRS Class 10).

The breakline files were then translated to ESRI Shapefile format using ESRI conversion tools.
3.5.  **Hydro Flattening Raster DEM Process**

Class 2 LiDAR in conjunction with the hydro breaklines were used to create a 1.0 meter Raster DEM. Using automated scripting routines within ArcMap, an ERDAS Imagine IMG file was created for each tile. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

4. **Deliverables**

- Raw point cloud swath LAS in version 1.2 format
- Classified point cloud in LAS version 1.2 format
- Hydro flattened raster DEM in ERDAS .IMG format
- Hydro flattened breaklines in shape file format
- Ground control points in ESRI geodatabase format
- As-flown flightlines in ESRI geodatabase format
- Tile index in shape file format
- Project and deliverable level metadata in XML format
- Accuracy Assessment in XLS format
- Project and acquisition reports in PDF format
5. **PROJECT COVERAGE VERIFICATION**

The Oahu project area coverage verification was performed by comparing coverage of processed .LAS files captured during project collection to generate project shape files depicting boundaries of specified project areas. Please refer to Figure 8.

*Figure 8. Oahu Flightline Swath LAS Coverage*
6. **GROUND CONTROL AND CHECK POINT COLLECTION**

The Photo Science, Inc. and local surveying team (Sam O. Hirota, Inc.) completed a GPS survey of variously selected ground control points for LiDAR accuracy validation. Figure 9 shows control point locations across the project area. Table 3 depicts the Final Control Reports for Oahu as computed in TerraScan as a quality assurance check. Please see Dewberry's independent qualitative and quantitative quality assessment using independent control points established by NOAA survey crews to validate FVA, SVA and CVA. Josh Novac, GISP is Dewberry's contact for the assessment, his contact information follows:

Josh Novac, GISP  
Associate Project Manager  
Remote Sensing Services  
1095 South Monaco Parkway  
Denver, CO 80224  
813.421.8632 direct  
303.825.2322 fax

*Figure 9. Oahu Control Point Locations*
## Table 3. Oahu Final Control Report (units = meters)

<table>
<thead>
<tr>
<th>Number</th>
<th>Easting</th>
<th>Northing</th>
<th>Known Z</th>
<th>Laser Z</th>
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**Average dz** +0.003 m  
**Minimum dz** -0.226 m  
**Maximum dz** +0.174 m  
**Average Magnitude** 0.063 m  
**Root Mean Square** 0.082 m  
**Std Deviation** 0.083 m
7. **Selected Images**

![Aerial View of Diamond Head](image)

Diamond Head
Honolulu

Makapu’u Point Lighthouse
APPENDIX A
BASE STATION LOCATION / DATA SHEETS
Station Occupation Report
For Airborne GPS

Project: Oahu LIDAR

Location: Kalaeloa Airport
Completed by: Berry

Project Number: 7505-018
Date: June 1, 2013

Receiver: Trimble 2
Receiver Type: RTK II
Antenna Type: Zephyr Broadband
Station ID: 481 4TR
Start – H.I. (m): 1.0665 1.0667 1.0666
End – H.I. (m): 1.0666
H.I. (ft): 3.46
Start Time: 6:16 AM
End Time: 8:54 AM
Time Zone: HST
Operator: Berry

Comments: (1306010-240) V01PEP by 1306050-240

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Station Occupation Report
For Airborne GPS

Project:       Oahu LiDar

Location:      Kahului Airport

Completed by:  Berry

Receiver:      Trimble 2

Receiver Type: RTK ENRG

Antenna Type:  Zephyr ZR-126

Station ID:    PSI-HJR

Start – H.I. (m): 1.680 1.678 1.679

End – H.I. (m):  1.679

H.I. (ft):      5.51

Start Time:    6:18 AM

End Time:      9:30 AM

Time Zone:     HST

Operator:      Berry

Comments:      130612a-240

Project Number: 7505-07-3

Date: June 12, 2013
Station Occupation Report
For Airborne GPS

Project: Oahu LiDAR

Location: Kaua’i Airport

Completed by: Barry

Receiver: Trimble 2
Receiver Type: M40S
Antenna Type: Zephyr 6000B.2
Station ID: PS 416R

Start -- H.I. (m): 1.67, 1.69, 1.65
End -- H.I. (m): 1.69

H.I. (ft):

Start Time: 6:00 AM
End Time: 9:15 AM

Time Zone: HST

Operator: Barry

Comments: 130° 6' 19" - 240°
Station Occupation Report
For Airborne GPS

Project: ahn LIDAR

Location: Kakabelon Airport (PHTR)

Completed by: Barry

Receiver: Trucole "2"
Receiver Type: 204155
Antenna Type: Raytheon SA4830-2
Station ID: 181 34020
Start -- H.I. (m): 1.739 1.740 1.741
End -- H.I. (m): 1.740
H.I. (ft): 5.705
Start Time: 2:30 AM
End Time: 6:50 AM
Time Zone: HST (-10 UTC)
Operator: Barry

Comments

180000 ft - 1778

Copyright (c) 1996 Photo Science, Inc.
Station Occupation Report
For Airborne GPS

Project: DanuLIDAR

Location: Kalaeloa Airport
Completed by: Barry

Project Number: J525-061
Date: June 5, 2013

Receiver: Trimble 72
Receiver Type: P4 GPS
Antenna Type: Zenith Stealth 2
Station ID: PSI 4JR
Start - H.I. (m): 1,628 / 1,628 / 1,630
End - H.I. (m): 1,629

H.I. (ft): 5,347
Start Time: 5:35 AM
End Time: 3:22 AM
Time Zone: HST
Operator: Barry

Comments

Bob 6/24a - 240
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**Comments:**

- BVN06a - 04a

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Copyright (c) 1996 Photo Science, Inc.
Station Occupation Report
For Airborne GPS

Project: China LiDAR

Location: Kalaeloa Airfield

Completed by: Barry

Receiver: Trimble "S"

Receiver Type: R9100

Antenna Type: Leica Geodetic Zephyr

Station ID: PBHTK

Start -- H.I. (m): 1.678 1.681 1.679

End -- H.I. (m): 1.680

H.I. (ft): 5.505

Start Time: 10:13 AM

End Time: 10:02 AM

Time Zone: HST

Operator: Barry

Comments: B0608a-240

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Station Occupation Report
For Airborne GPS

Project: Oahu

Location: HJR
Completed by: NC

Receiver: T2
Receiver Type: GNSS 5700
Antenna Type: Zephyr 620
Station ID: 091 HJR

Start – H.I. (m): 1.666
End – H.I. (m): 1.666
H.I. (ft): 735

Start Time: 1139
End Time: 1159
Time Zone: HST
Operator: MC

Comments

130117a-240
Station Occupation Report
For Airborne GPS

Project: Oahu
Location: HSR
Completed by: MC

Project Number: 7525-061
Date: 7/18/13

Receiver: TA
Receiver Type: 5700
Antenna Type: 24hr, 6x6
Station ID: PSI HSR
Start - H.I. (m): 1.735
End - H.I. (m): 1.735
H.I. (ft): 602
Start Time: 015
End Time: HST
Time Zone: HST
Operator: MC

Comments
130718a-240
Station Occupation Report
For Airborne GPS

Project: Oahu LiDAR

Location: Kalaolua Airport
Completed by: Berry

Project Number: 7525-061
Date: July 27, 2013

Receiver: Trimble
Receiver Type: 3200
Antenna Type: Zeffour Exradar
Station ID: PSI HJE

Start – H.I. (m): 1,681, 1,682, 1,682
End – H.I. (m): 1,682
H.I. (ft): 5,565
Start Time: 8:16AM
End Time: 10:56PM
Time Zone: HST
Operator: Berry

Comments 1307276-246
Station Occupation Report
For Airborne GPS

Project: Oahu L.I.D.A.

Location: Kahului Airport
Completed by: Vacant

Receiver: Trimble
Receiver Type: S700
Antenna Type: Zephyr Epipolar
Station ID: 181 4TR
Start – H.I. (m): 1.768 1.770 1.769
End – H.I. (m): 1.769
H.I. (ft): 5.80
Start Time: 3:43 PM
End Time: 5:30 PM
Time Zone: HST
Operator: Vacant

Comments: 130730a - 240
Station Occupation Report
For Airborne GPS

Project: Oahu
Location: HJR
Completed by: MC

Project Number: 7535.061
Date: July 4, 2013

Receiver: T2
Receiver Type: GNSS 5700
Antenna Type: Zephyr 6.0
Station ID: 054-H39

Start – H.I. (m): 1.57
End – H.I. (m): 1.57
H.I. (ft):
Start Time: 045
End Time: 1015
Time Zone: HST
Operator: MC

Comments: 130704-240
Station Occupation Report
For Airborne GPS

Project: Oahu

Location: HJR
Completed by: MC

Project Number: 3505-001
Date: 7/5/13

Receiver: TA
Receiver Type: ALPS 5700
Antenna Type: Zephyr 600
Station ID: PSI 'HJR

Start – H.I. (m): 1.477
End – H.I. (m): 1.477
H.I. (ft): 555
Start Time: 10:25
End Time: 4:51
Time Zone: MST
Operator: MC

Comments: 130705a-240
Station Occupation Report
For Airborne GPS

Project: Danville LiDAR

Location: Kabelna Airport

Completed by: Barry

Project Number: 7525-061

Date: August 2, 2003

Receiver: Trimble

Receiver Type: 5200

Antenna Type: 2meter Phasecenter

Station ID: PSI 45R

Start -- H.I. (m): 1612 1612 1610
End -- H.I. (m): 1611

H.I. (ft): 5408.3

Start Time: 11:25 AM
End Time: 2:50 PM

Time Zone: HST

Operator: Barry

Comments

130802 a-240
Station Occupation Report
For Airborne GPS

Project: Oahu LiDAR

Location: Kalaeloa Airport

Completed by: Berry

Receiver: Trimble
Receiver Type: 5700
Antenna Type: Zephyr/Prodmus
Station ID: PS1 HSR

Start -- H.I. (m): 1.651 1.651 1.650
End -- H.I. (m): 1.651
H.I. (ft): 5.42

Start Time: 8:20 AM
End Time: 10:20 AM
Time Zone: HST
Operator: Berry

Comments

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Station Occupation Report
For Airborne GPS

Project:  Cabu LiOAR

Location:  Kahuku Airport

Completed by:  Berry

Receiver:  Trimble

Receiver Type:  5700

Antenna Type:  Zephyr Aeronetic

Station ID:  PSI HSR

Start -- H.I. (m):  1.675 1.675 1.675

End -- H.I. (m):  1.675

H.I. (ft):  5,543

Start Time:  8:19 PM

End Time:  8:45 PM

Time Zone:  HST

Operator:  Berry

Comments

13D806b-240

Project Number:  7825-061

Date:  August 06, 2013

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Station Occupation Report
For Airborne GPS

Project: Oahu LiDAR

Location: Kauai Airport

Completed by: Berry

Receiver: Trimble 5700
Receiver Type: Zephyr Brodane
Antenna Type: PSI HTR
Station ID:
Start -- H.I. (m): 1.634 1.634 1.673
End -- H.I. (m): 1.634
H.I. (ft): 5.36
Start Time: 4:35 PM
End Time: 7:30 PM
Time Zone: HST
Operator: Berry

Comments

30807a-240
Station Occupation Report
For Airborne GPS

Project: PAULIN

Location: Kabelco Airport
Completed by: Berry

Project Number: 7525-0161
Date: August 8, 2013

Receiver: Trimble
Receiver Type: 5700
Antenna Type: Zebraxa Predator
Station ID: PS1 HTR

Start -- H.I. (m): 1,694 1,695 1,693
End -- H.I. (m): 1,694
H.I. (ft): 5555
Start Time: 6:04 AM
End Time: 11:30 AM
Time Zone: HST
Operator: Berry

Comments

130808-240
Station Occupation Report
For Airborne GPS

Project: Oahu LiDAR

Location: Kaelua Airport

Completed by: Barry

Receiver: Trimble
Receiver Type: 5700
Antenna Type: Zephyr Geodetic
Station ID: P31-HJR
Start -- H.I. (m): 1,607, 1,607, 1,606
End -- H.I. (m): 1,607
H.I. (ft): 5,217
Start Time: 6:11 AM
End Time: ~10:40 AM
Time Zone: HST
Operator: Barry

Comments

/30809a-240
From: opus [opus@ngs.noaa.gov]
Sent: Thursday, June 06, 2013 12:00 AM
To: Jeremy Berry
Subject: OPUS solution : 76021560.DAT OP1370490063085

FILE: 76021560.DAT OP1370490063085

2005 NOTE: The IGS precise and IGS rapid orbits were not available
2005 at processing time. The IGS ultra-rapid orbit was/will be used to
2005 process the data.
2005

NGS OPUS SOLUTION REPORT

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: jberry@photoscience.com          DATE: June 06, 2013
RINEX FILE: 7602156p.13o               TIME: 04:00:47 UTC

SOFTWARE: page5  1209.04 master13.pl 082112   START: 2013/06/05  15:35:00
EPHEMERIS: igu17433.eph [ultra-rapid]     STOP: 2013/06/05  18:22:00
NAV FILE: brdc1560.13n                    OBS USED:  6464 /  6657   :  97%
ANT NAME: TRM57971.00     NONE             # FIXED AMB:    30 /    37   :  81%
ARP HEIGHT: 1.575                             OVERALL RMS: 0.019(m)

REF FRAME: NAD_83(PA11)(EPOCH:2010.0000)    IGS08 (EPOCH:2013.4266)

          X:  -5514650.754(m)   0.076(m)        -5514651.670(m)   0.076(m)
          Y:  -2219938.988(m)   0.017(m)        -2219936.321(m)   0.017(m)
          Z:   2303406.813(m)   0.036(m)         2303407.973(m)   0.036(m)
          LAT:   21 18 35.76183      0.011(m)    21 18 35.79870      0.011(m)
          E LON:  201 55 38.62753      0.020(m)   201 55 38.52982      0.020(m)
          W LON:  158  4 21.37247      0.020(m)   158  4 21.47018      0.020(m)
          EL HGT:    24.372(m)   0.085(m)            24.658(m)   0.085(m)
ORTHOG HGT:    9.337(m)   0.144(m) [ H = h-N (N = GEOID12A HGT)]

UTM COORDINATES    STATE PLANE COORDINATES
UTM (Zone 04)     SPC (5103 HI 3)
Northing (Y) [meters]  2356732.404            15864.137
Easting (X) [meters]   596185.961              492467.156
Convergence [degrees]  0.33705373           -0.02638504
Point Scale           0.99971432             0.99999070
Combined Factor       0.99971049             0.99998687

US NATIONAL GRID DESIGNATOR: 4QEJ9618556732(NAD 83)

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**NEAREST NGS PUBLISHED CONTROL POINT**

TU1662 BARBERS PT NAS BASE CONT TR BN N211837.272 W1580414.874 192.9

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.
APPENDIX B
AIRBORNE GPS/IMU PROCESSING REPORT
Lift GNSS Reports

There are five lifts, each with separate graph reports generated from processing software. The lifts are as follows:

130601a-240
130605a-240
130606a-240
130608a-240
130612a-240
130619a-240
130620a-240
130704a-240
130705a-240
130717a-240
130718a-240
130727a-240
130730a-240
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**Processing mode**

- **Forward**
- **Reverse**

Processing mode: 0 = Fixed NL, 1 = Fixed WL, 2 = Fixed, 3 = DGPS, 4 = C/A, 5 = GPS Nav, 6 = DR
130727a-240
130730a-240
130808a-240
APPENDIX C
FLIGHT LOGS
**LIDAR MISSION RECORD SHEET - Optech**

<table>
<thead>
<tr>
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<th>Alt. (AMSL)</th>
<th>Heading</th>
<th>Speed</th>
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**NOTES**

- Voided By 130605a - 240
**LIDAR MISSION RECORD SHEET - Optech**

**Project Name:** Osir LIDAR  
**Project Number:**  
**Navigation File:**  

**Project's Scanning Requirements:**  
- FOV (half-degrees):  
- Scan Rate (Hz):  
- Pulse Rate Frequency (Hz):  
- Ground Speed (kts): 140  
- Altitude AGL (ft): 4000  
- MPA or SPIA?:  

**GPS Base Location(s):**  
**PDOP Avoidance:**  
**Static or Flyover?**  
**if flyovers, times:**  

**Data Information:**  
- LIDAR Unit: Optech Gemini sn240  
- HD #:  
- POS File Name:  
- from → to: 000 → 013  

**Date Flown:** June 25, 2012  
**Takeoff Time:**  
**Landing Time:**  
**Airport:** HJR  

**Weather:**  
- Begin Temp: 21  
- Begin Dewpoint: 17  
- Begin Pressure: 1004  
- End Temp:  
- End Dewpoint:  
- End Pressure:  

**Last Calibration Mission:**  

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**MISSION PAGE 1 OF 1**
# Lidar Mission Record Sheet - Optech

## Project Information
- **Project Name:** Optech Lipar
- **Project Number:** 7525-061 / 7505-078
- **Navigation File:** Data entered for WIR

## Project's Scanning Requirements
- **FOV (half-degrees):** 20
- **Scan Rate (Hz):** 327
- **Pulse Rate Frequency (Hz):** 820

## Data Information
- **LIDAR Unit:** Optech Gemini sn240
- **HD #:** 330 41
- **POS File Name:** Prod002z-240
- **Time:** 000 - 015

## Weather
- **Temperature:** 20°C
- **Dewpoint:** 17°C
- **Pressure:** 3000 hPa
- **End Temperature:** 27°C
- **End Dewpoint:** 16°C
- **End Pressure:** 3040 hPa

## Flight Log

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<tr>
<th>Flight Line #</th>
<th>Start</th>
<th>Stop</th>
<th>Alt. (AMSL)</th>
<th>Heading</th>
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<td>180</td>
<td>100</td>
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<td>100</td>
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<td>100</td>
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<td>100</td>
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<tr>
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**Last Calibration Mission:**

*Test 2600*
LIDAR MISSION RECORD SHEET - Optech

Project Name: FLW 7300
Project Number: 2013/LPS-075
Navigation File: 2013/LPS-075

Project's Scanning Requirements:
- FOV (half-degrees): 20
- Ground Speed (kts): 220
- Scan Rate (Hz): 4.95
- Altitude AGL (ft): 2000
- Pulse Rate Frequency (Hz): 70
- MPIA or SPIA?: N/A

GPS Base Location(s): R
PDOP Avoidance: 0.000
Static or Flyover?: Flyover

13000530-240

Flight Line # | Start | Stop | Alt. (AMSL) | Heading | Speed | Returns | Crab
--- | --- | --- | --- | --- | --- | --- | ---
10 | 1900 | 1900 | 2600 | NW | 120 | 0-100% | 2
20 | 1910 | 1910 | 2500 | NW | 120 | 0-100% | 3
29 | 1950 | 1950 | 2500 | SE | 180 | 0-100% | 2
38 | 1800 | 1800 | 2600 | NW | 120 | 0-100% | 3
47 | 1610 | 1610 | 2500 | NW | 120 | 0-100% | 3
56 | 1400 | 1400 | 2600 | NW | 120 | 0-100% | 3
65 | 1210 | 1210 | 2500 | NW | 120 | 0-100% | 3
74 | 1020 | 1020 | 2500 | NW | 120 | 0-100% | 3
83 | 0810 | 0810 | 2500 | NW | 120 | 0-100% | 3
92 | 0620 | 0620 | 2500 | NW | 120 | 0-100% | 3
101 | 0430 | 0430 | 2500 | NW | 120 | 0-100% | 3
110 | 0240 | 0240 | 2500 | NW | 120 | 0-100% | 3
119 | 0050 | 0050 | 2500 | NW | 120 | 0-100% | 3
128 | 1900 | 1900 | 2500 | NW | 120 | 0-100% | 3
137 | 1710 | 1710 | 2500 | NW | 120 | 0-100% | 3
146 | 1520 | 1520 | 2500 | NW | 120 | 0-100% | 3
155 | 1330 | 1330 | 2500 | NW | 120 | 0-100% | 3
164 | 1140 | 1140 | 2500 | NW | 120 | 0-100% | 3
173 | 0950 | 0950 | 2500 | NW | 120 | 0-100% | 3
182 | 0760 | 0760 | 2500 | NW | 120 | 0-100% | 3
191 | 0570 | 0570 | 2500 | NW | 120 | 0-100% | 3
200 | 0380 | 0380 | 2500 | NW | 120 | 0-100% | 3

The lift now mostly void after 4000' or so. Flows...
## LIDAR MISSION RECORD SHEET - Optech

### Project Scanning Requirements
- **FOV (half-degrees):** 20
- **Scan Rate (Hz):** 2000
- **Pulse Rate Frequency (Hz):** 1478

### Data Information
- **LIDAR Unit:** Optech Gemini sn240
- **HD #:** 3301
- **POS File Name:** 2016120

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### Notes
- Weather: (Add comments here)

---

**Last Calibration Mission:**

**NOTES (weather, visibility, winds, ride, etc.):**

- Rainy
- Cloudy
- Low visibility

---

**MISSION PAGE 1 OF__**
### LIDAR MISSION RECORD SHEET - Optech

**Project Name:** [Redacted]

**Project Number:** [Redacted]

**Navigation File:** [Redacted]

### Project's Scanning Requirements
- **FOV (half-degrees):** [Redacted]
- **Scan Rate (Hz):** [Redacted]
- **Pulse Rate Frequency (Hz):** [Redacted]
- **Ground Speed (kts):** [Redacted]
- **Altitude AGL (ft):** [Redacted]
- **MPIA or SPA?:** [Redacted]

### Data Information
- **LIDAR Unit:** Optech Gemini sn240
- **HD #:** [Redacted]
- **POS File Name:** [Redacted]
- **from:** [Redacted]
- **to:** [Redacted]

### Flights

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**NOTES (weather, visibility, winds, ride, etc.):**

- 4:30 - 5:00 PM: "End of flight plans."
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**NOTES (weather, visibility, winds, etc.):**

- Fine weather.
- Visibility: 10 miles.
- Winds: Light NW.

**Additional Notes:**

- All flights were successful.
- No issues encountered.

**Mission Page:**

- LIDAR Mission Record Sheet - Optech
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<th>LTREF</th>
<th>HREF</th>
<th>HHR</th>
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**Mission Details**

- **Date:** 130720-240
- **Location:** [Image]
- **Mission Name:** [Image]
- **Duration:** [Image]
- **Elevation:** [Image]

**Additional Notes**

- **Weather:** [Image]
- **Location:** [Image]
- **Time:** [Image]

**Scientific Data**

- **SN240/N22948W**
- **GPS Date:** 7525-018
- **GPS Time:** 7-27-13
- **SN240/N22948W**
- **GPS Date:** 7525-018
- **GPS Time:** 7-27-13

**Project Details**

- **Lidar Mission Record Sheet - Optic**
- **Project Number:** [Image]
- **Team:** [Image]
**LIDAR MISSION RECORD SHEET - Optech**

**Project Name:** Oahu LIDAR  
**Project Number:** 7525-06/7525-07B  
**Navigation File:** Koloa HAA-010

**Project's Scanning Requirements**
- FOV (half-degrees): 70
- Ground Speed (kts): 140
- Scan Rate (Hz): 70
- Altitude AGL (ft): 4000
- Pulse Rate Frequency (Hz): 57
- MPA or SPIA?: MPA

**Data Information**
- **LIDAR Unit:** Optech Gemini sn240  
- **HD #:** 592-1  
- **POS File Name:** 130802a_240  
- **From:** → 000 →

**GPS Base Location(s):** PS1 HRS

**Weather**
- **Begin Temp:** 59  
- **Begin Dewpoint:** 18  
- **Begin Pressure:** 30.2  
- **End Temp:** 30  
- **End Dewpoint:** 17  
- **End Pressure:** 30.2

**Last Calibration Mission: 130802a - 240**

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**NOTES (weather, visibility, winds, ride, etc.):**
- Cloud
- Wind
- Cloud near Koko
- Cloud near Koko
- Clouds over e end
- Possible cloud

**PHOTO SCIENCE**

523 Wellington Way • Lexington KY • 40503 • 859.277.8700 • www.photoscience.com
LIDAR MISSION RECORD SHEET - Optech

**Project Name**: Onbly 1.DAR
**Project Number**: 7525-0aal
**Navigation File**: Makana H200_40

---

**Project's Scanning Requirements**

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**Weather**

- Begin Temp
- Begin Dewpoint
- Begin Pressure
- End Temp
- End Dewpoint
- End Pressure

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**Last Calibration Mission**

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**Flight Log**

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**NOTES (weather, visibility, winds, ride, etc.)**

- Cloud
**LIDAR MISSION RECORD SHEET - Optech**

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**Project's Scanning Requirements**

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**GPS Base Location(s)** | P7I HJR |

**PDOP Avoidance** | 5 |

**Static or Flyover?** | 5 |

**Weather**

| Begin Temp |  |
| Begin Dewpoint | HJR |
| Begin Pressure |  |
| End Temp |  |
| End Dewpoint |  |
| End Pressure |  |

**Last Calibration Mission:**

130800b - 240

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**NOTES** (weather, visibility, winds, ride, etc.)

Switch to 501, only 1
LIDAR MISSION RECORD SHEET - Optech

Project Name: [Project Name]
Project Number: 7605-0178 7625-0501
Navigation File: [Navigation File]

Pilot: [Pilot]
Tech: [Tech]
Aircraft: N3949US

Date Flown: August 5, 2013
Takeoff Time: 0635 / 0735m
Landing Time: 0644 / 7440m
Airport: HJR

Weather
Begin Temp
Begin Dewpoint
End Temp
End Dewpoint
Begin Pressure
End Pressure

GPS Base Location(s): [GPS Base Location(s)]
PDOP Avoidance
Static or Flyover?
→ if flyovers, times:

Data Information
LIDAR Unit: Optech Gemini sn240
HD #: S9301
POS File Name: TD800b
from → to: 000 →

NOTES (weather, visibility, winds, ride, etc.)

Strip 001, 010
Strip 021
Strip 031
Strip 041
Strip 051
Strip 061
Strip 071
Strip 081
Strip 091
Strip 101
Strip 111
Strip 121
Strip 131
Strip 141
Strip 151
Strip 161
Strip 171
Strip 181
Strip 191
Strip 201

Vap
Zamponi to add length to line 9
# LIDAR MISSION RECORD SHEET - Optech

**Project Name:**

**Project Number:**

**Navigation File:**

**Project's Scanning Requirements**
- FOV (half-degrees): 20
- Scan Rate (Hz): 47
- Pulse Rate Frequency (Hz): 20
- Ground Speed (kts): 146
- Altitude AGL (ft): 2500
- MPA or SPIA?

**Data Information**
- LIDAR Unit: Optech Gemini sn240
- HD #: 93901
- POS File Name: 130807a
- from → to: 000 → 130807a-240

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**NOTES (weather, visibility, winds, ride, etc.):**

- E50
- Preview Boundary: 04/25/13 - 130807a-240
- Strip 4

**Last Calibration Mission:**

**Weather**
- Begin Temp
- Begin Dewpoint
- Begin Pressure
- End Temp
- End Dewpoint
- End Pressure

**PDOP Avoidance**
- 36.46

**Date Flown:**
- August 07-2013

**Takeoff Time:**
- 05:52

**Landing Time:**
- 05:30

**Airport:**
- OAHU

**Pilot:**
- Garrett

**Tech:**
- XXX

**Aircraft:**
- N3949W


**Mission Page 1 of 1**
# LIDAR MISSION RECORD SHEET - Optech

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### Project's Scanning Requirements

- **FOV (half-degrees):** 20
- **Scan Rate (Hz):** 297
- **Pulse Rate Frequency (Hz):** 70
- **Ground Speed (kts):** 140
- **Altitude AGL (ft):** 4000
- **MPIA or SPIA:** MPA

### Data Information

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### Weather

- **Begin Temp:** HJR
- **Begin Dewpoint:** HJR
- **Begin Pressure:** HJR
- **End Temp:** HJR
- **End Dewpoint:** HJR
- **End Pressure:** HJR

### GPS Base Location(s)

- PSI HJR

### PDOP Avoidance

- 0

### Static or Flyover?

- Flyover

### Last Calibration Mission

- Brand new

### NOTES (weather, visibility, winds, ride, etc.)

- Cloud
- Switch to southeastern 
- New plan

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NOTES (weather, visibility, winds, ride, etc.)
### LIDAR MISSION RECORD SHEET - Optech

**Project Name:** Optech LIDAR

**Project Number:** 7505-078 7525-061

**Navigation File:** Ridgewood, PA

#### Project's Scanning Requirements

- **FOV (half-degrees):** 20
- **Ground Speed (kts):** 140
- **Scan Rate (Hz):** 37
- **Altitude AGL (ft):** 4000
- **Pulse Rate Frequency (Hz):** 70
- **MPIA or SPIA:**

#### GPS Base Location(s)

- PSLHPR

#### PDOP Avoidance

- Blocking

#### Static or Flyover?

- Flyovers, times:

#### Last Calibration Mission:

#### Fit Line # | Start | Stop | Alt (AMSL) | Heading | Speed | Returns | Crab
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**NOTES** (weather, visibility, winds, ride, etc.): Marine July 19th, oh, pickup for clouds.

---

**Weather**

- Begin Temp
- Begin Dewpoint
- Begin Pressure
- End Temp
- End Dewpoint
- End Pressure

**Weather**

- Ground Temperature:
- Airport Temperature: HJR

---

**Data Information**

- **LIDAR Unit:** Optech Gemini SN240
- **HD #:** SN405 SP01
- **POS File Name:** 130809
- **from:** to 000→
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Last Calibration Mission: [Mission Notes]