Final Survey Report

Task Order Name: AZ_GrandCanyonNP_2019_B19

Task Order Number: 140G0219F0272

Grand Canyon National Park

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Section 1. Executive Summary

1.1 Introduction

In support of the National Park Service Task Order 140G0219F0272 LiDAR Project, a geodetic control survey was performed for the collection of quality assurance and quality control (QA/QC) verification points. The importance of this survey was twofold; to ensure a homogenous project meeting defined project accuracy, and to "tie" the mapping to existing Continually Operating Reference Stations (CORS) & National Geodetic Survey (NGS) framework used for aerial acquisition. This allows for repeatable measurements for current and future surveying and mapping needs.

The survey encompassed multiple areas of interest (AOI) across Grand Canyon National Park totaling 729.61 square miles of LiDAR. The survey was performed during the period of October 17th, 2019 through October 24th, 2021 with a total of one hundred and thirteen (113) measured points. These QA/QC points were subdivided into 3 main categories: non-vegetated checkpoints, vegetated checkpoints, and Lidar calibration points.

Due to the rugged terrain and isolated pockets of cellular data coverage, Atlantic employed two methodologies' dynamically during the project. Real Time Network – Real Time Kinematic (RTN-RTK) was used when cellular data was available utilizing the Leica Smartnet RTN stations as this provides an instantaneous answer without any additional post processing. When cellular coverage was not available, static Global Navigation Satellite Survey System (GNSS) observations were conducted. These static sessions were initially postprocessed with the NGS Online Processing User Service (OPUS) using CORS. Then processed as a static network using Grafnet 8.60.6717 for final coordinate generation.

Also due to the rugged terrain, inaccessibility, vast distances between points to be collected and the sensitive nature of the landscape, many points were collected by mobilizing into the Canyon via helicopter. A 2012 American Eurocopter AS-350 AStar (Tail Number: N835PA) operated by Papillon Airways was deployed to access the Western side of the Canyon along the Hualapai Indian Reservation and a 2013 American Eurocopter AS-350 AStar (Tail Number: N841PA) operated by The National Park Service was also used to collect the remainder of the points throughout The Grand Canyon National Park.

The final required accuracy of the LiDAR Calibration Points (LCPs), QA/QC checkpoints were defined by the specified LiDAR for this project, the Lidar vertical accuracy is to meet a Root Mean Square Error ($RMSE_Z$) of 10 cm. Typically, QA/QC surveys should be at least three times as accurate as the final products being tested, therefore a $RMSE_{XY}$ of 10.0 cm or less & $RMSE_Z$ of 3.3 cm or less is required. Based on the analysis of the RTN-RTK checkpoints and OPUS network accuracy values, this geodetic control data meets this projects requirement for calibrating and testing the horizontal and vertical accuracies of the acquired products.

Section 2. Survey Standards and Equipment

2.1 Applicable Standards

The accuracy standards for the QA/QC survey is to be approximately three times as accurate as the Lidar which required a vertical $RMSE_Z$ of 10 cm in non-vegetated areas. Although not specifically tested, the Lidar horizontal accuracy is defined to comply with the “compiled to meet” statement of having a $RMSE_R$ of 60cm or less. Therefore, the accuracy for the QA/QC survey was defined to have a horizontal $RMSE_R$ of <2cm and a $RMSE_Z$ of <3cm to meet and exceed project requirements.

2.2 Datum and Coordinate Systems

Horizontal: Universal Transverse Mercator (UTM) Zone 12 North, NAD83 (2011) meters.
Vertical: North American Vertical Datum 88 (NAVD88) Geoid12B meters.

2.3 Survey Equipment

The following survey equipment was utilized to collect the survey coordinates:

- Topcon GNSS HiperV GPS System S/N: 1132-10004 (Dual Frequency)
- Trimble GNSS R8 – Model 2 GPS System S/N: 4638122371 (Dual Frequency)
- Trimble GNSS R8 – Model 2 GPS System S/N: 4639122449 (Dual Frequency)
- Trimble GNSS R10 GPS System S/N: 5739470190 (Dual Frequency)
- Trimble T10 Tablet Data Collector S/N: 01TT5B6X3745107
- Trimble GNSS R10 GPS System S/N: 5739470192 (Dual Frequency)
- Trimble T10 Tablet Data Collector S/N: 01TT5B6X3745090
- Trimble GNSS R12 GPS System S/N: 6043F00741 (Dual Frequency)
- Trimble TDC 600 Data Collector S/N: 6051X0051
- Trimble GNSS R12 GPS System S/N: 6043F00709 (Dual Frequency)
- Trimble TDC 600 Data Collector S/N: 6051X00285

Section 3. Survey and Methodology

3.1 Real Time Network Survey – Real Time Kinematic

RTN-RTK use is a standard throughout the Geo-Spatial industry and was chosen to be the most efficient way to execute this survey when cell phone coverage was available. The Leica Smartnet RTN is a system of established GNSS receivers that transmits real-time corrections which are sent to the GNSS rover receiver via cellular connections. The internal accuracy for the fixed ambiguity solutions pertaining to the RTN-RTK network results in a repeatable accuracy of <2cm horizontally and <3cm vertically at the 95% confidence level. All QA/QC points were surveyed utilizing a 2-meter rod leveled over each point coupled with Trimble’s R8, R10 or R12 GNSS receiver using the Leica Smartnet RTN. The GNSS receivers are configured to log data at 1 Hz with an update rate of 10Hz, and at a 10° degrees’ mask with a collection rate of 180 seconds or better. During collection, the field technician monitored standard field criteria to optimize each observation. These field criteria include but is not limited to number of SV's, PDOP, RMS, and status of ambiguity i.e. "fixed" or "float". RTN-RTK Root Mean Square values and digital field notes can be found in a separate appendix document.

In instances where cell phone coverage was not available, RTN-RTK was not an option and static GNSS observations were performed. Similar to RTN-RTK acquisition, a GNSS receiver was positioned with a fixed height tripod over the point and data was collected for a minimum of 30-45 minutes. These observations were compiled, processed and constrained in a GNSS static network. A GNSS static network objective is to "tie" a series of survey control either preexisting or newly set through simultaneous measurements of three-dimensional GNSS baseline vectors each treated as a separate distance observation and adjusted as part of a trilateration network typically forming a closed polygon. All static observation processing results and constrained network accuracies were derived from Grafnet 8.60.2105. with respect to GNSS receiver antenna type and antenna height reading.

3.2 QA/QC Survey Points

To initially control the Lidar during the calibration phase of production, calibration survey points were required. The LCPs were strategically positioned throughout the project area of interest. These LCPs are located on hard to semi-hard surfaces with flat or moderate slope to allow for a good sampling of ground surface types where the Lidar reflectivity would yield a good range.

To test the vertical accuracy of the Lidar point cloud, Lidar checkpoints were surveyed and used in an independent verification process, post calibration. These check points were collected in two different categories: Non-vegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA). Checkpoints serve to analyze or "ground truth" the accuracy of the LIDAR return with respect to surface types found within the project area of interest.

Figures 1 and 2 display the survey collection of thirty-three (33) LiDAR Calibration Points, forty-five (45) NVA, and thirty-five (35) VVA checkpoints. Final point coordinates summary, photographs of the LCPs and Checkpoints, observation digital Field notes, and static session forms can be found in the separate appendix document.

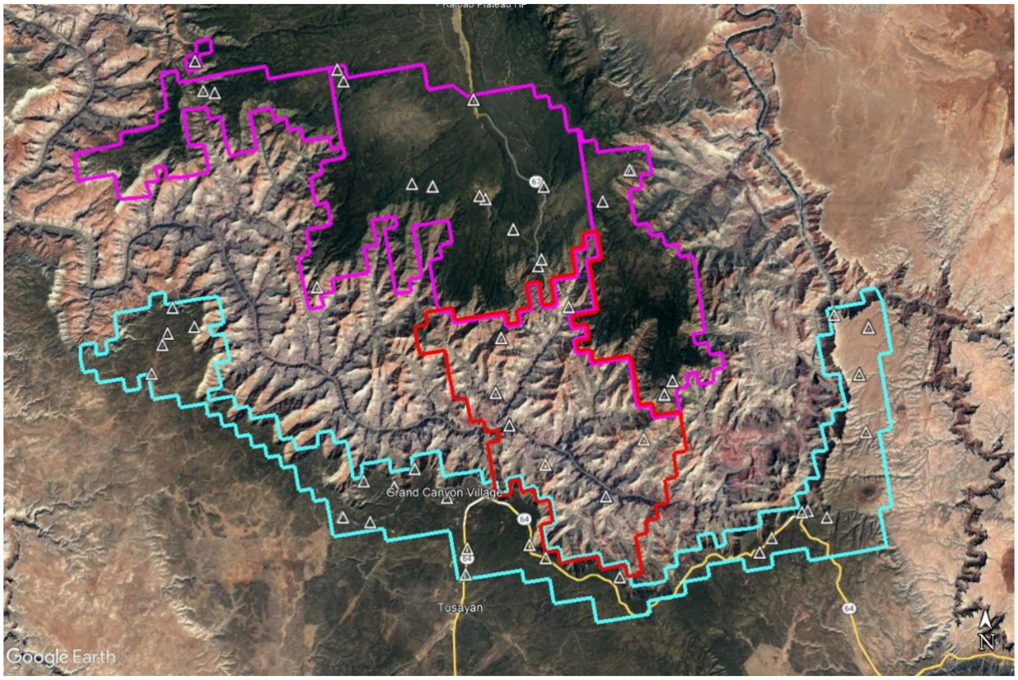

Figure 1: Project Survey Map (Base)

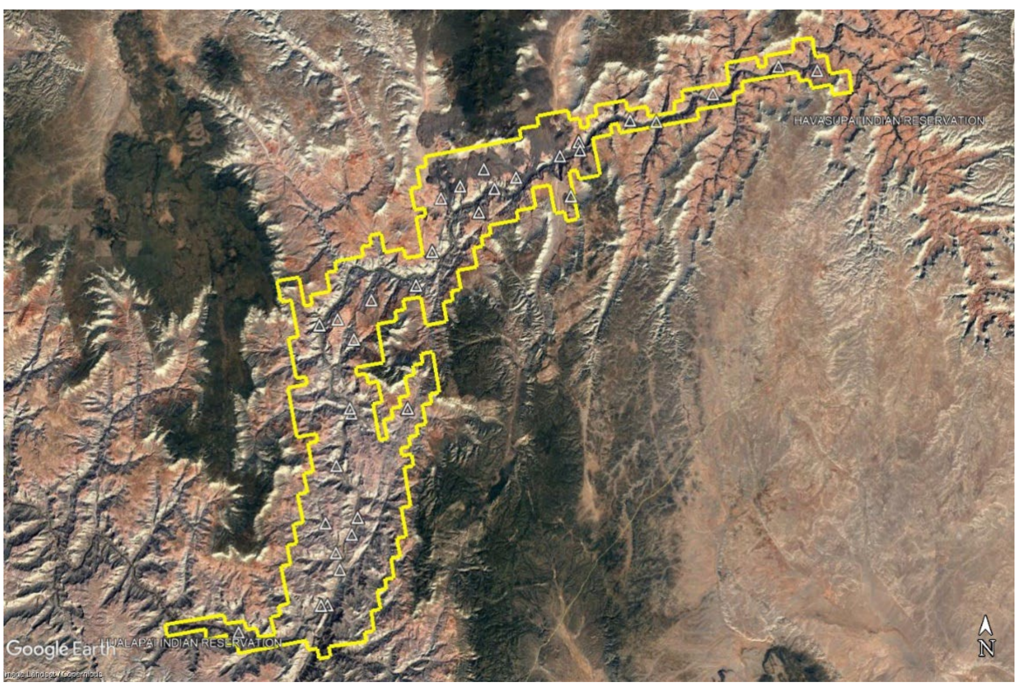

Figure 2: Project Survey Map (Option)

Section 4. Accuracy

4.1 Summary of Target Accuracies

The accuracy of this survey can be defined in multiple ways due to the methods for how the set verification monuments, Lidar calibration points, and checkpoints were derived. The accuracy of this survey was based on the analysis of the RTN-RTK final verification point checks at a 95% confidence level which statistically was <2cm horizontally and <3cm vertically. This was confirmed by the daily check measurements on the verification points. The static measurements also met the same accuracy based on the statistical data provided by the Grafnet & OPUS reports. The data easily exceeds the requirements for testing the vertical accuracy of the Lidar data.

Section 5. Custody Transfer Assurance

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