AMERICAN SAMOA LIDAR DATA ACQUISITION AND PROCESSING

POST-FLIGHT AERIAL ACQUISITION AND CALIBRATION REPORT

Contract No. EA133C-11-CQ-0009
Requisition No. NCNP0000-12-02073
Task Order No. 14

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Completed by Photo Science, Inc.

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1. Summary / Scope

1.1. Summary

This report contains a summary of the American Samoa LiDAR acquisition task order, issued by the NOAA Coastal Service's Center, and which included a number of other government agency partners: American Samoa Department of Commerce (ASDOC), the U.S. Geological Survey (USGS), the U.S. Fish & Wildlife Service (USFWS), the USDA Natural Resources Conservation Service (NRSC), and the National Park Service (NPS). A separate but related task order was issued by the USGS National Geospatial Technical Operations Center (NGTOC), under their Geospatial Products and Services Contract (GPSC), to leverage the same resources committed to the NOAA LiDAR project, and acquire high-resolution digital aerial imagery for the same study area and during the same general time frame. The intent of this document is to only provide specific validation information for the LiDAR data acquisition/collection work completed for the NOAA project.

1.2. Scope

The scope of the American Samoa 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 primary islands of American Samoa and Rose Atoll. The aerial data collection was designed with the following specifications listed in Table 1 below.

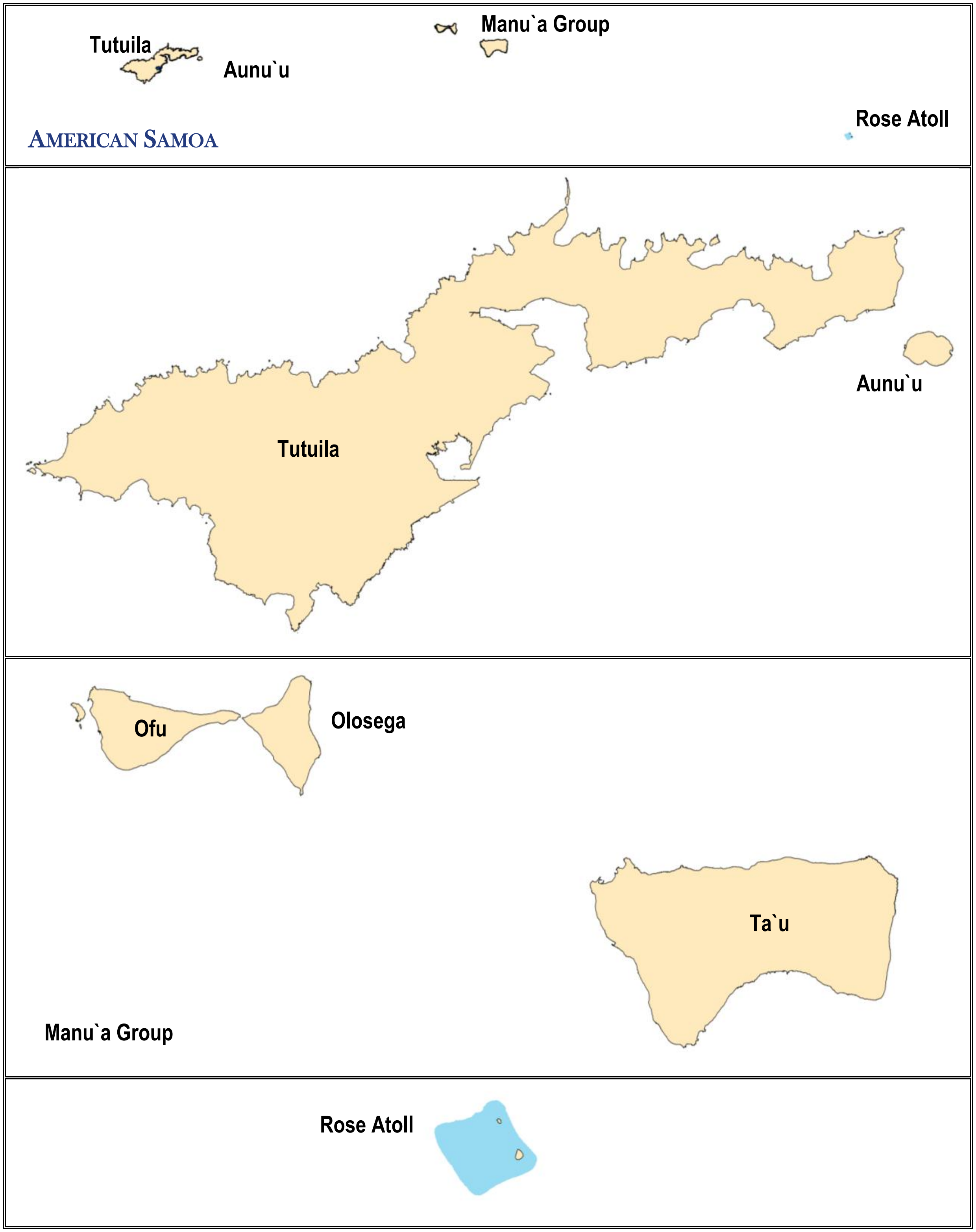
Table 1. Planned LiDAR Specifications

LiDAR				
Average Point Density	**Flight Altitude (AGL)**	**Field of View**	**Side Overlap**	**RMSEz**
1.43 pts / m^2	4,000 ft	36.0 degrees	50%	15 cm or better

1.3. Location / Coverage

The American Samoa LiDAR project boundary consists of the five main islands of American Samoa (Tutuila, Aunu`u, Ofu, Olosega, Ta`u), as well as Rose Atoll. The project area totals approximately 89 square miles as shown in Figure 1 on the following page.

Figure 1. American Samoa LiDAR Project Boundary



1.4. DURATION

The aircraft and flight crew arrived in Pago Pago, American Samoa, on June 15, 2012, with sensor installation and testing occurring by June 18, 2012. The first attempt to collect LiDAR data occurred on June 20, 2012 under less than optimal weather conditions. A sensor problem was discovered and quickly fixed. On June 25, 2012, LiDAR data was collected for approximately 95% of the island of Tutuila and 100% of Aunu`u. On June 28, 2012, LiDAR data was collected for 100% of the islands of Ofu and Olosega. And on July 5, 2012, LiDAR data was collected for 100% of Rose Atoll and the low-lying areas of the island of Ta`u. Although the crew stood-by as long as possible, for clearing weather to collect the remaining areas on Ta`u and small slivers on Tutuila, no further data was collected due to persistent low-hanging cloud cover. The LiDAR sensor was removed from the aircraft on July 19, 2012, when the imaging sensor was installed (USGS portion of the project). In summary, seven sorties were required to collect the LiDAR data for the project, over a period of approximately one month.

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 American Samoa. This particular season (June/July) 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. Additionally, this particular year (2012) was predicted to be drier than previous years. Nonetheless, 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 islands exhibited a cycle of daily self-generating cloud cover once the sun came up (warming conditions) each day, particularly in the higher elevations. Unusual trade wind activities and less than reliable local weather predictions also 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. Dense, tropical vegetation dominates the island group, with limited open areas except along road corridors, some shoreline areas, and populated areas/local villages. Combined with the weather conditions, vegetation conditions also added to the complexity and challenges of this project.

2. PLANNING / EQUIPMENT

The entire target area was comprised of 82 planned flight lines and approximately 794 flight line kilometers. Please refer to Figures 2-5 on the following pages.

Figure 2. Ofu and Olosega Planned Flight Lines

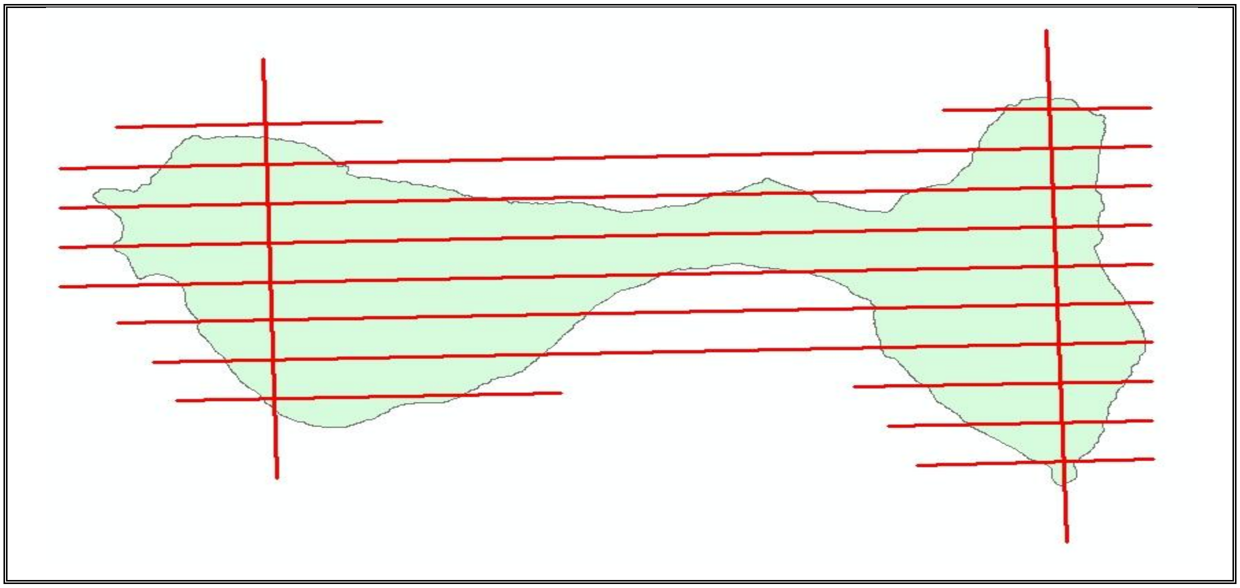


Figure 3. Ta`u Planned Flight Lines

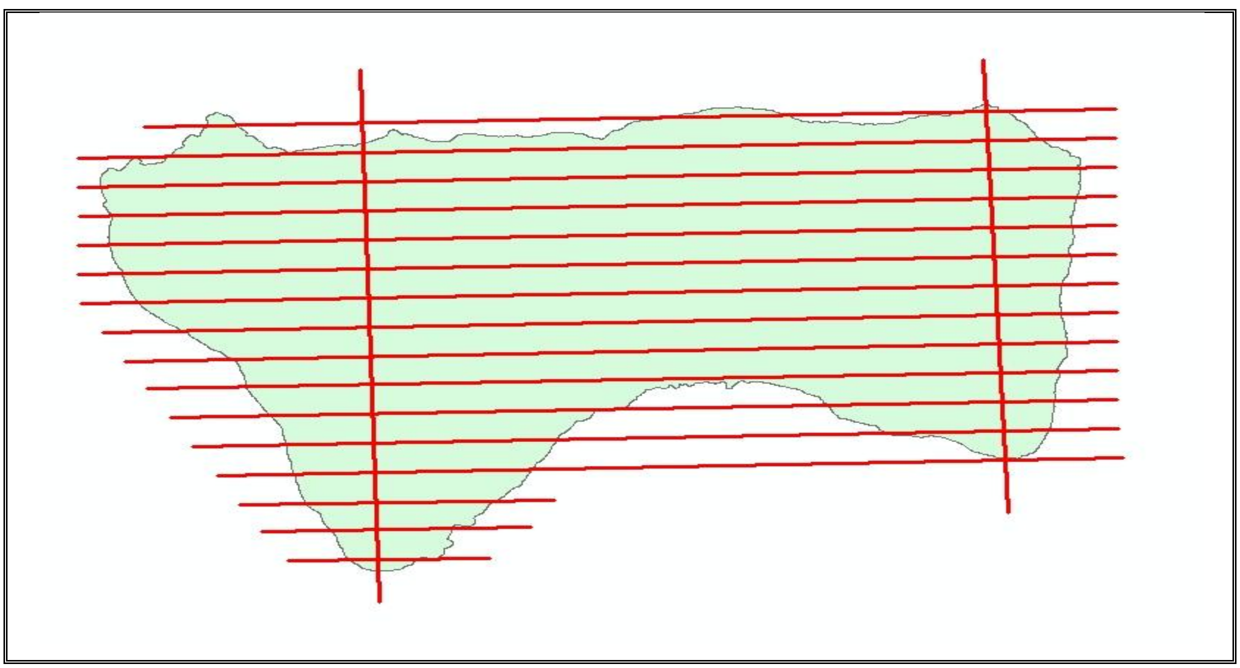


Figure 4. Rose Atoll Planned Flight Lines

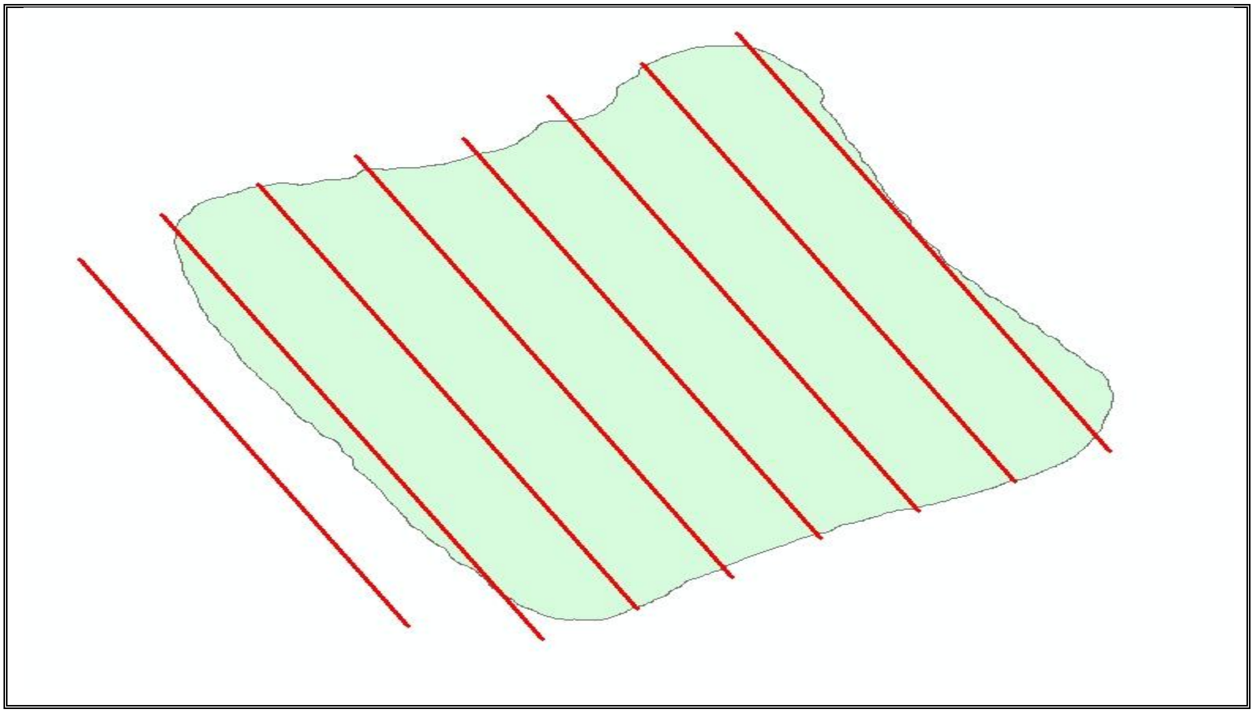
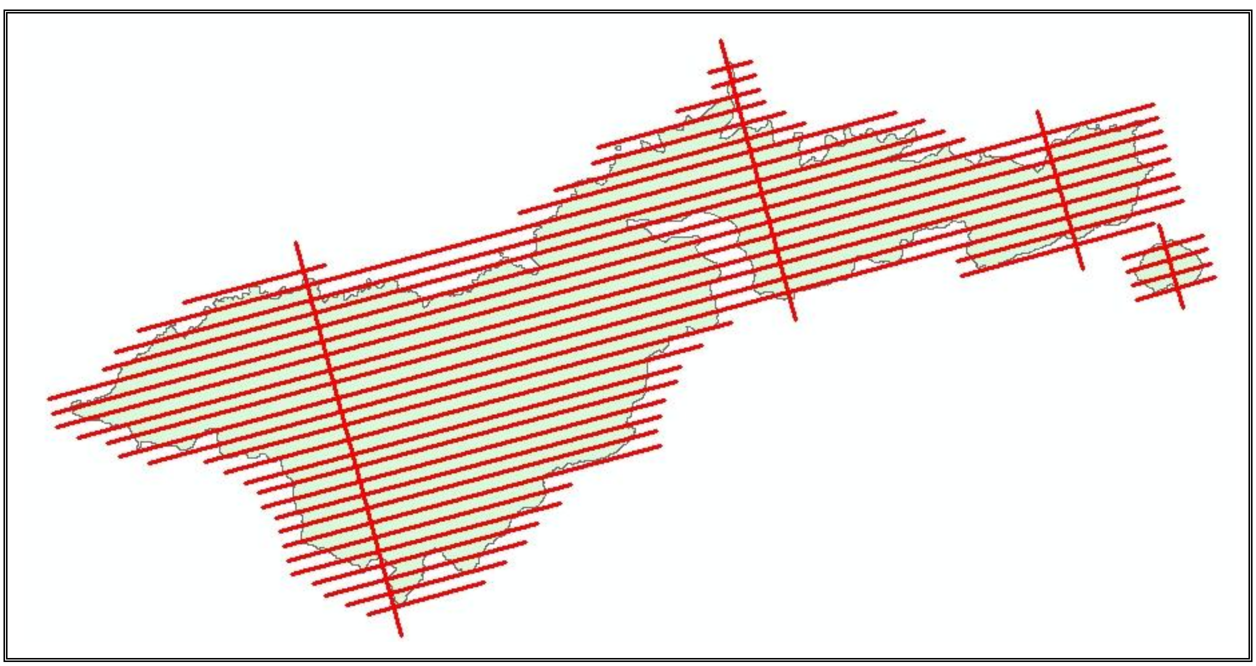


Figure 5. Tutuila and Aunu`u Planned Flight Lines



Detailed project flight planning calculations were performed for the American Samoa 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. 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

LiDAR System Specifications	
Terrain and Aircraft	**Flying Height AGL:** 1219 m; 4,000 feet
	Recommended Ground Speed (GS): 120 kts
Scanner	**Field of View (FOV):** 36.0; degrees
	Scan Rate Setting used (SR): 37 Hz
Laser	**Laser Pulse Rate used:** 70,000 Hz
	Multi Pulse in Air Mode: Enabled
Coverage	**Full Swath Width:** 791 m
	Line Spacing (No DTM): 395 m
Point Spacing and Density	**Maximum Point Spacing Across Track:** 0.838 m
	Maximum Point Spacing Along Track: 0.834 m
	Average Point Density: 1.43 pts / m^2

2.1. EQUIPMENT: AIRCRAFT

All flights for the American Samoa project were accomplished through the use of a customized twin-engine Beechcraft King Air 90 (Tail # N87E).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 6. Operations Aircraft

Figure 7. In-Flight Operations

2.2. LiDAR Sensor

Photo Science utilized an Optech LiDAR sensor, serial number 246 during the project. This system is capable of collecting data at a maximum frequency of 500 kHz, which affords elevation data collection of up to 500,000 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 American Samoa project the LiDAR operator monitored point density and swath to ensure data integrity and desired coverages were obtained.

Figure 8. Optech Gemini LiDAR System

2.3. Base Station Information

GPS base stations were utilized during all phases of flight. Base stations “Satellite Triang Station 022” (PID AA3709) and “TAU A” (PID AA4463) were occupied during airborne operations of the project. Both base station locations were 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 9. Trimble GNSS 5700 Receiver (A)

Figure 10. Trimble GNSS 5700 Receiver (B)

2.4. TIME PERIOD

Project specific flights were conducted over (3) days. Seven sorties, or aircraft lifts were completed. Accomplished sorties are listed below:

- 120625a-246
- 120625b-246
- 120625c-246
- 120627a-246
- 120705a-246
- 120705b-246
- 120705c-246

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 American Samoa 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. QT Modeler 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.

3.1. FLIGHT LOGS

Flight logs were completed by LIDAR sensor technicians for each mission during acquisition. These logs depict various 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, dewpoint, pressure, etc). Project specific flight logs for each sortie are available in Appendix C.

4. PROJECT COVERAGE VERIFICATION

The American Samoa project area coverage verification was performed by comparing coverage of processed .LAS files capured during project collection to generated project shape files depicting boundaries of specified project areas. Please note the Ta`u project area does not approach 100% .LAS coverage. Please refer to Figures 11-14 on the following pages.

Figure 11. Ofu and Olosega LAS File Coverage

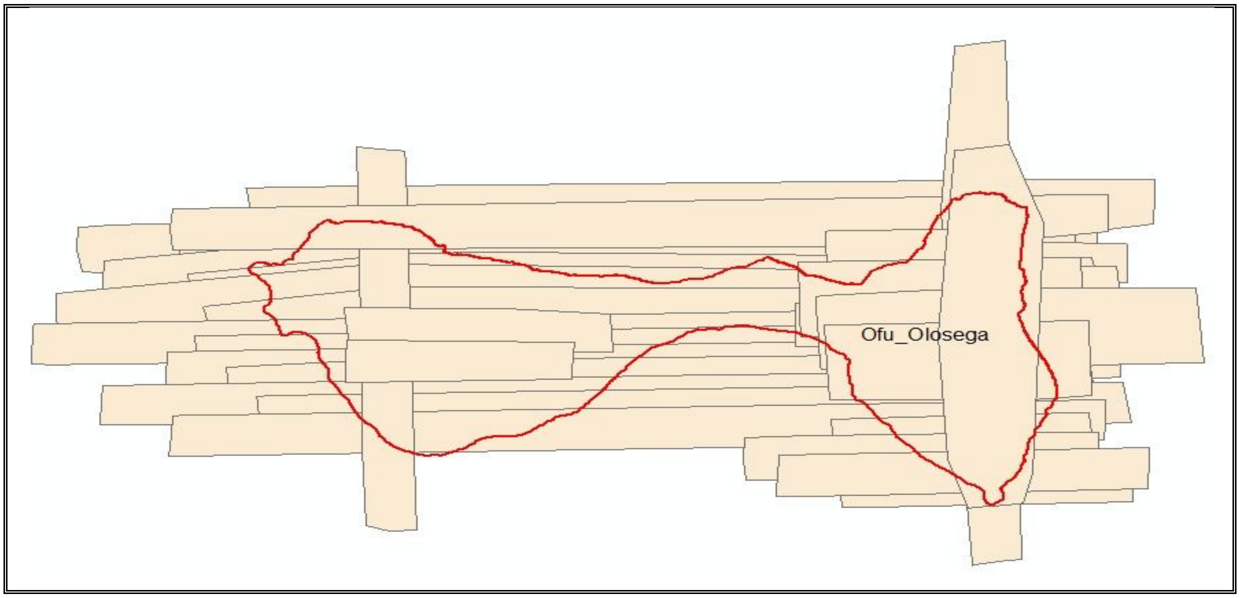


Figure 12. Tutuila and Aunu`u LAS File Coverage

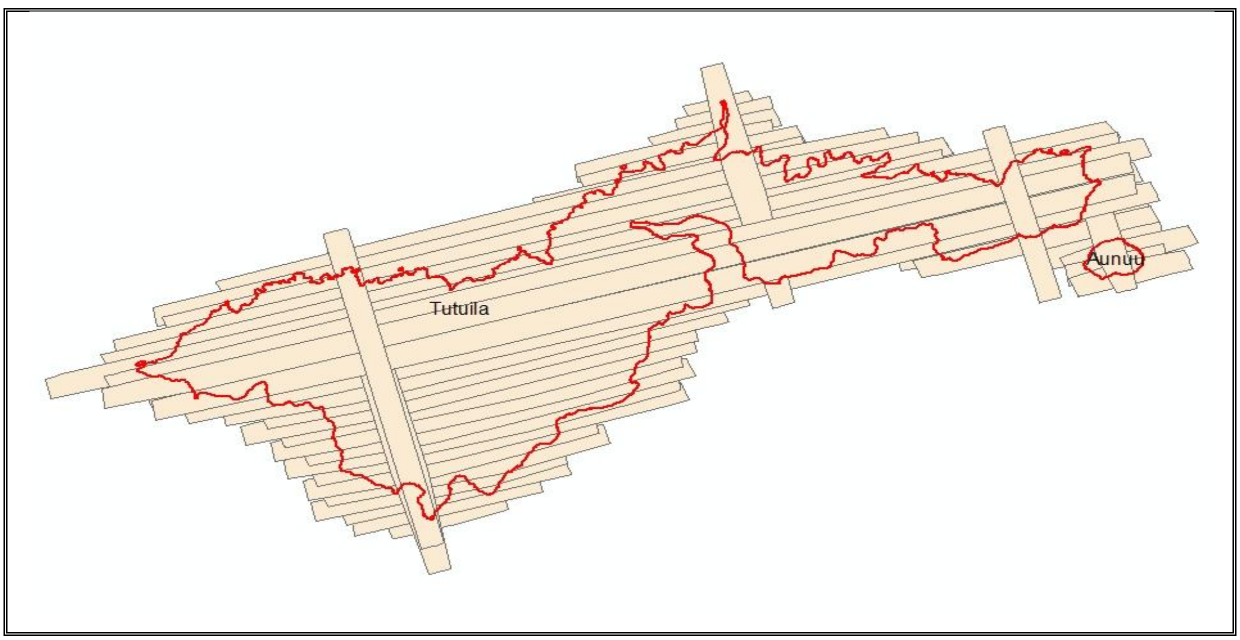


Figure 13. Rose Atoll LAS File Coverage

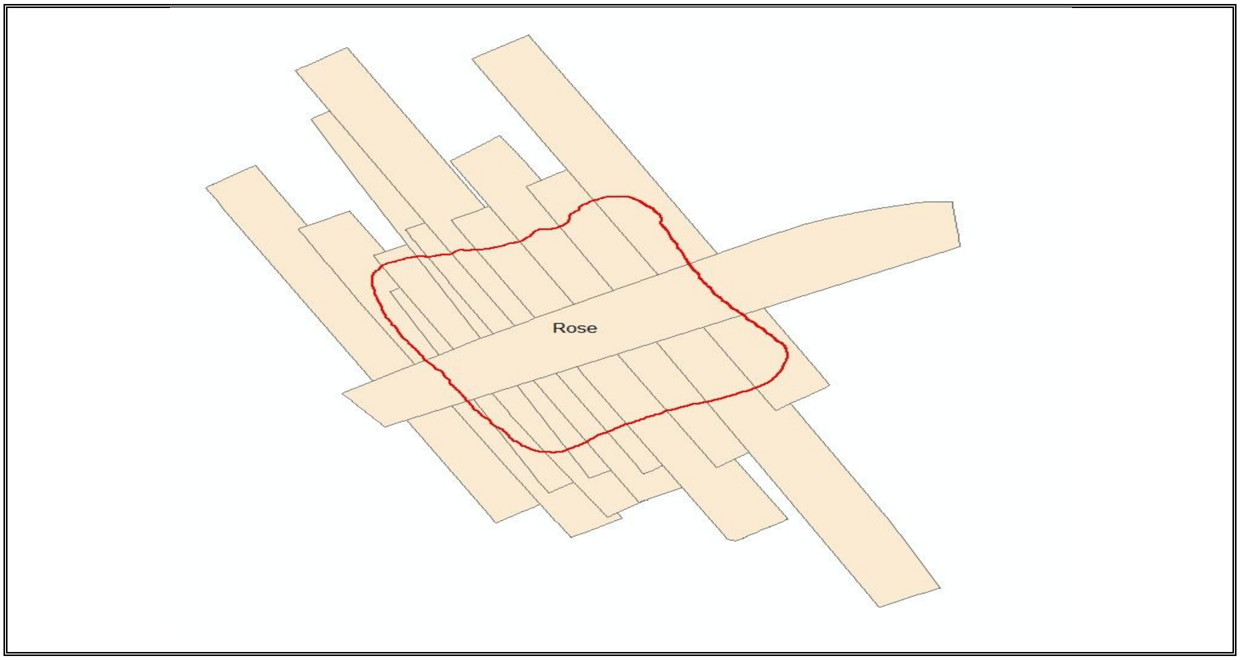
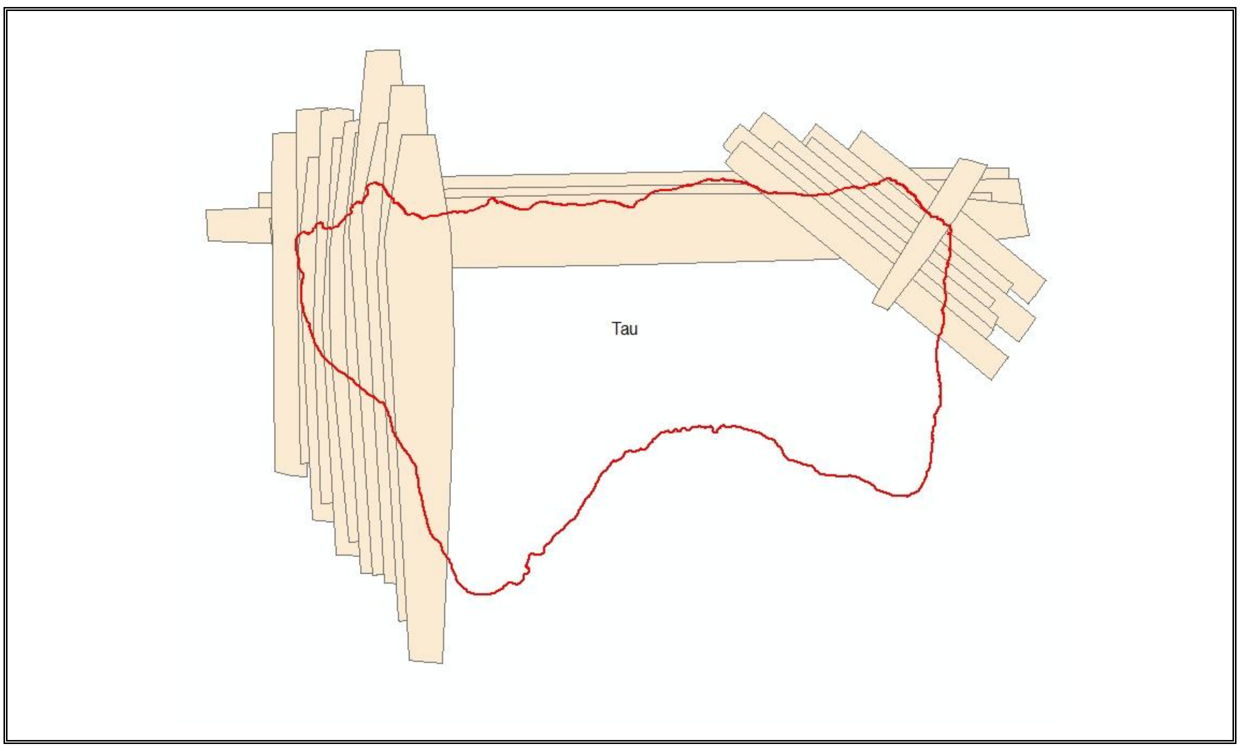


Figure 14. Ta`u LAS File Coverage



5. GROUND CONTROL AND CHECK POINT COLLECTION

The Photo Science and local surveying team (POB Mapping Services) completed a GPS survey of variously selected ground control points for LiDAR accuracy validation. Figure 15 shows control point locations across project areas Tutuila and Aunu`u. Figure 16 shows point locations across project area Ofu, Olosega, and Ta`u areas. Tables 3-5 depict the Final Control Reports for Ofu, Olosega, Ta`u, and Tutuila as computed in TerraScan as a quality assurance check. Note that additional ground control points, collected for a different client's project (airport imagery), were used as additional blind check points for validating the LiDAR data. These points proved to be good additions to the overall validation process.

The Manu`a Islands Ground Control Points Survey Report from POB Mapping Services is available in Appendix D.

Figure 15. Tutuila and Aunu`u Control Point Locations

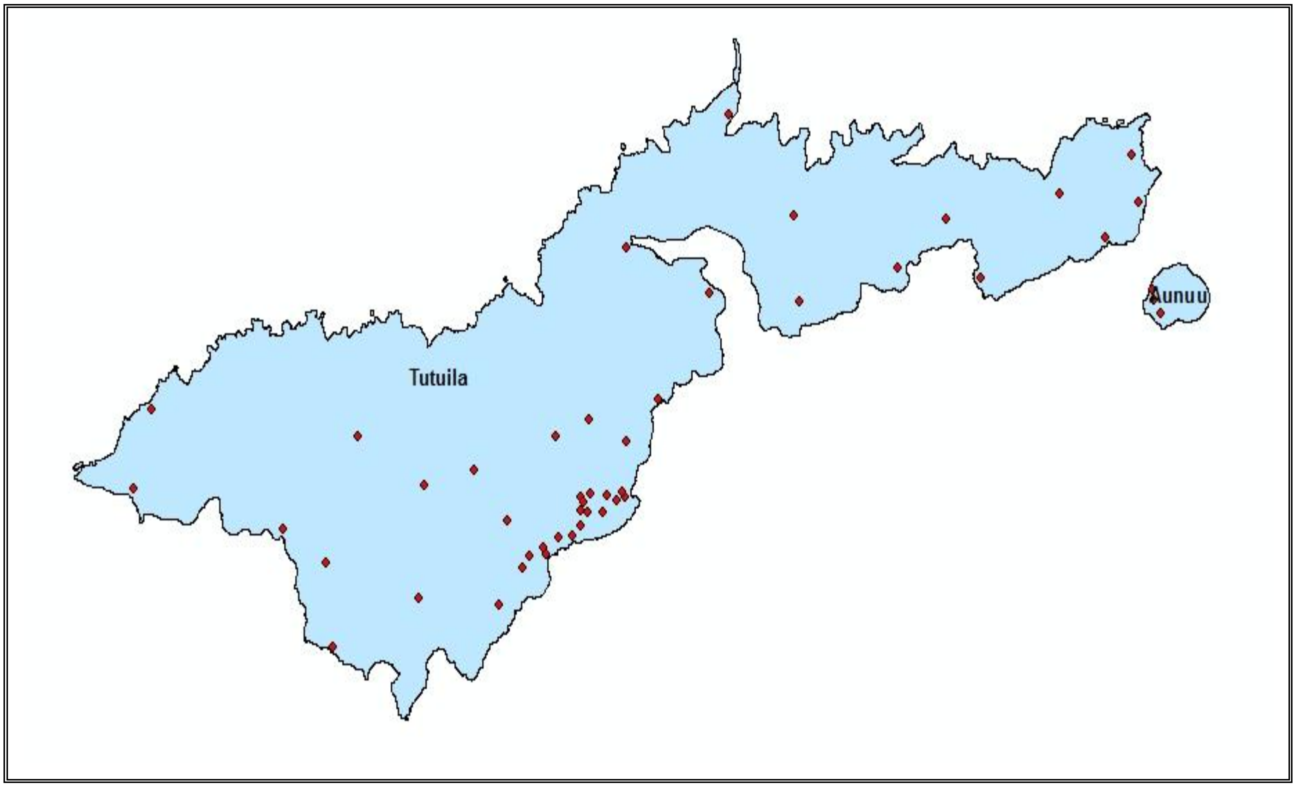


Figure 16. Ofu, Olosega and Ta`u Ground Control Point Locations

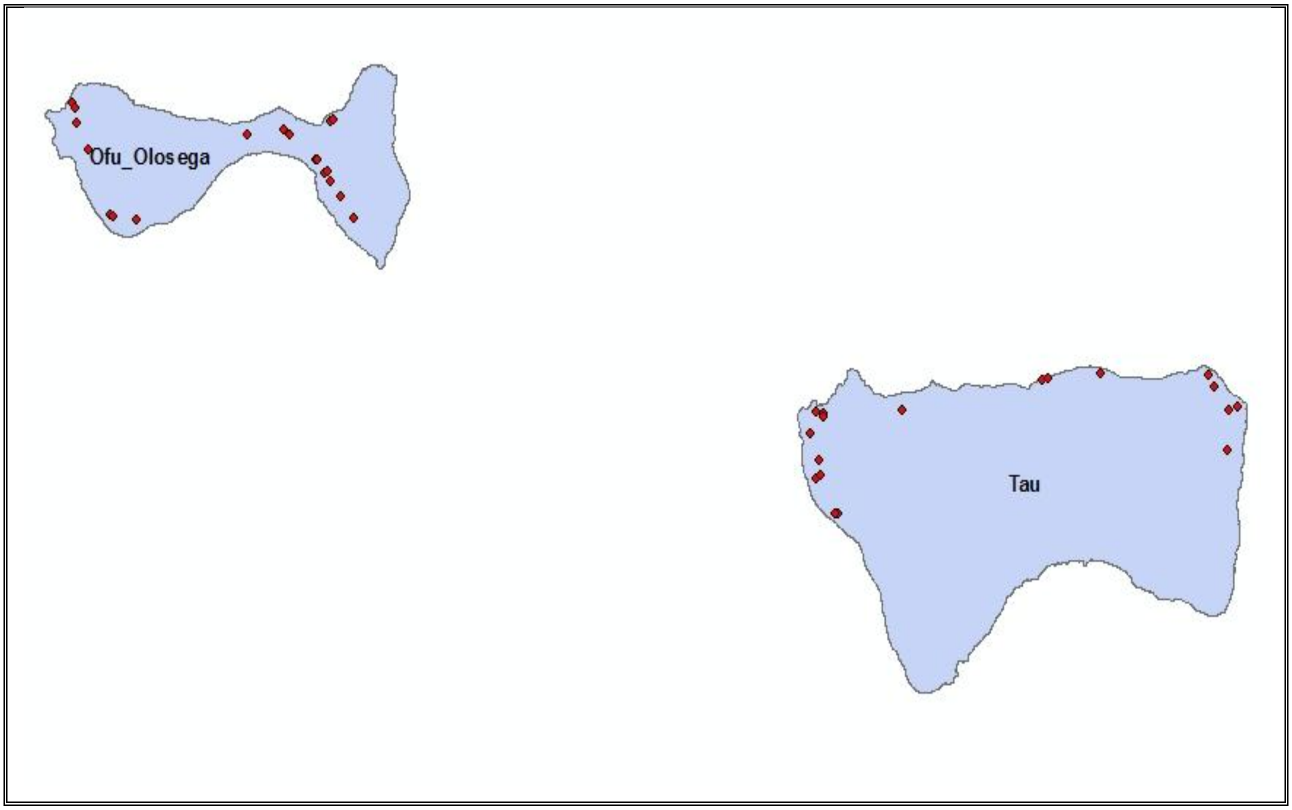


Table 3. Ofu and Olosega Final Control Report (units = meters)
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Ofu and Olosega Final Control Report					
Number	**Easting**	**Northing**	**Known Z**	**Laser Z**	**Dz**
GCP1	642275.179	8433900.093	3.877	3.960	+0.083
GCP2	642353.439	8433776.673	1.170	1.240	+0.070
GCP3	642385.200	8433474.950	2.576	2.630	+0.054
GCP4	642651.521	8432881.448	2.710	2.800	+0.090
GCP5	643209.019	8431519.777	3.502	3.420	-0.082
GCP6	643276.018	8431474.361	3.045	2.950	-0.095
GCP7	643827.397	8431434.633	3.539	3.420	-0.119
GCP8	646523.186	8433202.210	28.148	28.180	+0.032
GCP9	647400.630	8433338.372	2.771	2.840	+0.069
GCP10	647543.804	8433214.787	4.276	4.310	+0.034
GCP11	648181.479	8432702.069	4.801	4.690	-0.111
GCP12	648213.990	8432677.482	4.447	4.450	+0.003
GCP13	648364.040	8432400.896	3.859	3.790	-0.069
GCP14	648433.522	8432431.209	2.356	2.270	-0.086
GCP15	648524.231	8432211.786	2.490	2.450	-0.040
GCP16	648753.262	8431922.112	3.691	3.610	-0.081
GCP17	649093.655	8431456.140	5.846	removed	*
GCP18	648521.401	8433514.773	3.164	3.220	+0.056
GCP19	648535.539	8433510.603	4.481	4.540	+0.059
GCP20	648580.272	8433529.134	4.453	4.520	+0.067
GCP21	660453.206	8427312.384	3.362	outside	*
GCP22	660430.662	8427274.268	3.447	outside	*
GCP23	660249.903	8427359.970	1.512	outside	*
GCP24	660104.220	8426895.964	4.398	outside	*
GCP25	660256.733	8425940.971	5.300	outside	*
GCP26	660778.738	8425224.140	3.655	outside	*
GCP27	660713.806	8425212.114	2.402	outside	*
GCP28	660359.453	8426019.102	34.723	outside	*
GCP29	660327.288	8426334.353	47.305	outside	*
GCP30	662350.174	8427405.520	130.259	outside	*
GCP31	665727.747	8428049.670	11.235	outside	*
GCP32	665865.863	8428078.155	9.683	outside	*
GCP33	667126.464	8428176.197	4.599	outside	*
GCP34	669867.592	8427891.121	32.016	outside	*
GCP35	670240.998	8427383.631	25.710	outside	*
GCP36	670187.978	8426566.906	48.247	outside	*
GCP37	670451.778	8427467.762	31.833	outside	*
GCP38	670439.979	8427455.871	31.852	outside	*
GCP39	669758.358	8428136.391	31.739	outside	*
GCP40	669749.874	8428127.682	31.824	outside	*

Average dz	**-0.003 m**
Minimum dz	**-0.119 m**
Maximum dz	**+0.090 m**
Average Magnitude	**0.068 m**
Root Mean Square	**0.074 m**
Std Deviation	**0.076 m**

Table 4. Ta`u Final Control Report (units = meters)
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Ta`u Final Control Report					
Number	**Easting**	**Northing**	**Known Z**	**Laser Z**	**Dz**
GCP1	642275.179	8433900.093	3.877	outside	*
GCP2	642353.439	8433776.673	1.170	outside	*
GCP3	642385.200	8433474.950	2.576	outside	*
GCP4	642651.521	8432881.448	2.710	outside	*
GCP5	643209.019	8431519.777	3.502	outside	*
GCP6	643276.018	8431474.361	3.045	outside	*
GCP7	643827.397	8431434.633	3.539	outside	*
GCP8	646523.186	8433202.210	28.148	outside	*
GCP9	647400.630	8433338.372	2.771	outside	*
GCP10	647543.804	8433214.787	4.276	outside	*
GCP11	648181.479	8432702.069	4.801	outside	*
GCP12	648213.990	8432677.482	4.447	outside	*
GCP13	648364.040	8432400.896	3.859	outside	*
GCP14	648433.522	8432431.209	2.356	outside	*
GCP15	648524.231	8432211.786	2.490	outside	*
GCP16	648753.262	8431922.112	3.691	outside	*
GCP17	649093.655	8431456.140	5.846	outside	*
GCP18	648521.401	8433514.773	3.164	outside	*
GCP19	648535.539	8433510.603	4.481	outside	*
GCP20	648580.272	8433529.134	4.453	outside	*
GCP21	660453.206	8427312.384	3.362	3.400	+0.038
GCP22	660430.662	8427274.268	3.447	3.490	+0.043
GCP23	660249.903	8427359.970	1.512	1.500	-0.012
GCP24	660104.220	8426895.964	4.398	4.400	+0.002
GCP25	660256.733	8425940.971	5.300	5.330	+0.030
GCP26	660778.738	8425224.140	3.655	3.720	+0.065
GCP27	660713.806	8425212.114	2.402	2.450	+0.048
GCP28	660359.453	8426019.102	34.723	34.650	-0.073
GCP29	660327.288	8426334.353	47.305	47.220	-0.085
GCP30	662350.174	8427405.520	130.259	130.130	-0.129
GCP31	665727.747	8428049.670	11.235	11.270	+0.035
GCP32	665865.863	8428078.155	9.683	9.730	+0.047
GCP33	667126.464	8428176.197	4.599	4.560	-0.039
GCP34	669867.592	8427891.121	32.016	32.000	-0.016
GCP35	670240.998	8427383.631	25.710	25.790	+0.080
GCP36	670187.978	8426566.906	48.247	48.290	+0.043
GCP37	670451.778	8427467.762	31.833	31.760	-0.073
GCP38	670439.979	8427455.871	31.852	31.840	-0.012
GCP39	669758.358	8428136.391	31.739	31.840	+0.101
GCP40	669749.874	8428127.682	31.824	31.640	-0.184

Average dz	**-0.005 m**
Minimum dz	**-0.184 m**
Maximum dz	**+0.101 m**
Average Magnitude	**0.058 m**
Root Mean Square	**0.072 m**
Std Deviation	**0.073 m**

Table 5. Tutuila and Aunu`n Final Control Report (units = meters)
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Tutuila Final Control Report					
Number	**Easting**	**Northing**	**Known Z**	**Laser Z**	**Dz**
PI01	523739.430	8414544.913	32.320	32.350	+0.030
PI02	518220.328	8416314.713	3.713	3.690	-0.023
PI03	523910.050	8412557.202	4.787	4.890	+0.103
PI04	526521.752	8416355.979	154.661	154.640	-0.021
PI05	527967.141	8416727.465	44.044	44.080	+0.036
PI06	528926.508	8415546.013	20.955	21.020	+0.065
PI07	531255.270	8417925.382	6.132	6.050	-0.082
PI08	532328.896	8417391.923	2.553	2.580	+0.027
PI09	533244.258	8418410.246	3.931	3.930	-0.001
PI10	532317.939	8421964.693	1.706	1.640	-0.066
PI11	537278.167	8420685.077	5.684	5.690	+0.006
PI12	540101.028	8421501.103	2.554	2.560	+0.006
PI13	541482.724	8422629.686	3.087	3.060	-0.027
PI14	535271.225	8425119.565	2.754	2.630	-0.124
PI15	537144.521	8422742.051	254.190	254.270	+0.080
PI16	546063.486	8422206.243	2.589	2.480	-0.109
TP01	518736.459	8418151.413	47.412	47.400	-0.012
TP02	522475.915	8415347.909	4.076	4.050	-0.026
TP03	526379.000	8413729.945	91.294	91.420	+0.126
TP04	528688.126	8413563.344	18.617	18.670	+0.053
TP05	524647.998	8417506.472	401.317	401.370	+0.053
TP06	530292.817	8417525.558	8.946	8.940	-0.006
TP07	534713.952	8420899.732	2.904	2.960	+0.056
TP08	542510.426	8421248.330	32.694	32.560	-0.134
GCP1	529353.765	8414442.130	15.268	15.380	+0.112
GCP2	529536.041	8414713.429	8.455	8.490	+0.035
GCP3	529951.712	8414920.666	7.687	7.770	+0.083
GCP4	530019.281	8414740.934	7.670	7.760	+0.090
GCP5	530777.128	8415172.423	3.790	3.860	+0.070
GCP6	530383.710	8415145.295	6.640	6.690	+0.050
GCP7	531020.418	8415428.547	2.475	2.520	+0.045
GCP8	531669.897	8415729.882	1.981	2.030	+0.049
GCP9	532035.451	8416009.295	2.103	2.150	+0.047
GCP10	532291.760	8416078.798	1.991	2.020	+0.029
GCP11	532222.408	8416199.787	1.397	1.450	+0.053
GCP12	531782.984	8416125.547	1.705	1.790	+0.085
GCP13	531306.817	8416179.314	1.475	1.540	+0.065
GCP14	531026.672	8416110.408	2.430	2.520	+0.090
GCP15	531002.680	8415769.486	2.225	2.280	+0.055
GCP16	531091.253	8415973.749	2.199	2.250	+0.051
GCP17	531209.845	8415743.028	2.188	2.290	+0.102
AOA_GCP	544736.479	8423234.257	1.903	2.000	+0.097
TULA_GCP	546817.187	8424139.220	4.240	4.250	+0.010
ALAO_GCP	547029.906	8423056.279	3.598	3.710	+0.112
AUNUU_GCP1	547640.752	8420406.253	1.618	1.640	+0.022
AUNUU_GCP2	547454.881	8420726.647	1.721	1.750	+0.029
AUNUU_GCP3	547430.304	8420972.249	2.338	2.270	-0.068

Average dz	+0.028 m
Minimum dz	-0.134 m
Maximum dz	+0.126 m
Average Magnitude	0.058 m
Root Mean Square	0.068 m
Std Deviation	0.063 m

6. Selected Images


Pago Harbor, Island of Tutuila

View of Matafao Mountain, Island of Tutuila

Rose Atoll

Fiti`uta Airport, Island of Ta`u