REPORT OF SURVEY

AIRBORNE LIDAR BATHYMETRIC AND TOPOGRAPHIC SURVEY OF SAMOA 2015

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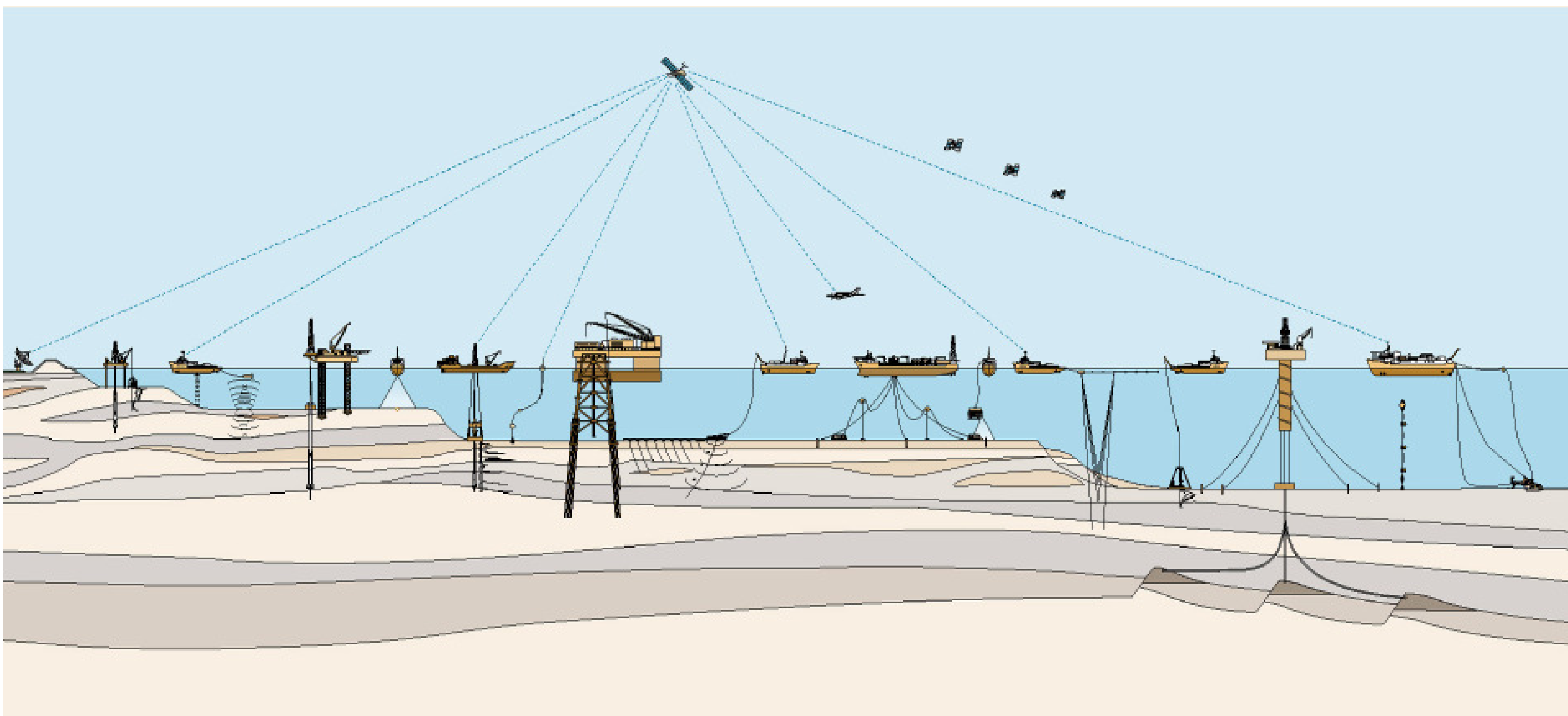

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Survey Period:

6 July to 9 August 2015

Document Number: TLCS00.047.008

Prepared for: Governement of Samoa, Ministry of Natural Resources and Environment, MNRE

Cooperative Research Centre – Spatial Information, CRCSI, Melbourne, Australia

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ABBREVIATIONS

ALB	Airborne LiDAR Bathymetry
ALT	Airborne LiDAR Topography
LIDAR	Light Detection and Ranging
ASCII	American Standard Code for Information Interchange
CD	Chart Datum
CHM	Canopy Height Model
CRCSI	Cooperative Research Centre for Spatial Information
DA	Dynamic Aviation
DEM	Digital Elevation Model
DSM	Digital Surface Model
EGM2008	Earth Gravitational Model 2008
FCM	Foliage Cover Model
FGS	Fugro Geospatial Services
FLC	Fugro LADS Corporation Pty Ltd.
FOA	Foreign Operators Affairs
GCAA	General Civil Aviation Authority
GNSS	Global Navigation Satellite System
GRS80	Geodetic Reference System 1980
LGS	LADS Ground System
LMk3	LADS Mk3
MNRE	Ministry of Natural Resources and Environment
MSL	Mean Sea Level
PPP	Precise Point Positioning
PPK	Post Process Kinematic
TIP	Topographic Integration Point

1. INTRODUCTION

This Report of Survey applies to data collected by Fugro LADS Corporation Pty Ltd (FLC) and Fugro Geospatial Services (FGS) for the Ministry of Natural Resources and Environment (MNRE), requiring an Airborne Laser Bathymetric (ALB) and topographic (ALT) LiDAR survey of the main islands of Samoa, namely Upolu and Savaii. The survey was conducted from 6 July to 9 August 2015. A total of 15 flights were flown for the ALB survey and a total of 46 flights were flown for the ALT survey during the mentioned period.

1.1 Objective

The objective of the Airborne LiDAR survey of Samoa was to obtain bathymetric and topographic data for MNRE to integrate into risk prevention plans when environmental occurrences, such as cyclones or earthquakes, occur.

The Cooperative Research Centre for Spatial Information (CRCSI) also has expertise and significant experience in overseeing previous technical LiDAR (Light Detection And Ranging) projects, including the Pacific Island Coastal Inundation Project which included Samoa. The CRCSI provides assistance and expertise in the technical specifications, coordination and quality control of the LiDAR survey to meet the needs of MNRE.

The total survey area for MNRE was approximately 4000 sq km consisting of;

- 1100 sq km of bathymetry and coastline
- 2900 sq km of topography.

Figures 1 and 2 show the survey areas for the ALB component in Samoa and flight lines flown for each survey area. Figures 3 and 4 show the survey areas for the ALT component over Samoa and flight lines flown for each survey area.

ALB data collection was conducted from a Dynamic Aviation (DA) Beechcraft A90 aircraft, call sign N96Y, fitted with the Fugro LADS Mk 3 and RIEGL VQ-820-G LiDAR systems. All operations were flown out of Faleolo International Airport. Both ALB systems were flown simultaneously to achieve ALB coverage in shallow water and very shallow water, respectively, that meets the accuracy specifications of the project, in table 1 below;

Minimum Standard	IHO Order 1b – ~5m Horizontal accuracy , ~0.5m Vertical accuracy
Required Depth Coverage	5m drying to 30 metres depth, (minimum 85% of 50x50m tiles have> 50 soundings)
Required Data Resolution	5m x 5m

Table 1 – Bathymetry LiDAR Collection Requirements

An ALB field processing office was established at the Insel Fehmarn Hotel, approximately 27km east of Faleolo International Airport. ALB data processing commenced in the field office, with all sorties processed and pre-validated. This allowed for the identification of systematic errors and areas of turbidity and poor coverage. The planning of refly lines was then undertaken to correct these issues, where possible.

Following data collection, all data was relocated to a processing office for validation and checking. This data was then quality controlled, approved and products generated in the Fugro LADS office in Kidman Park, Adelaide.

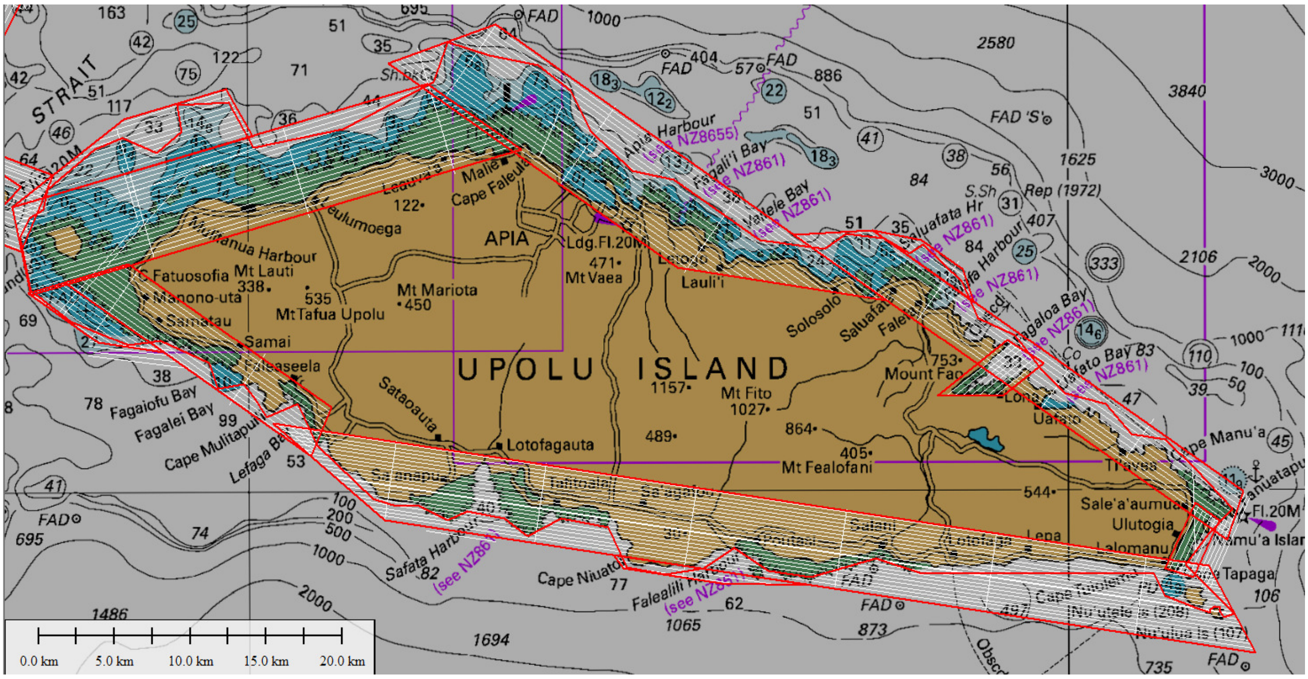

Figure 1 – The MNRE Bathymetric Areas of Interest and Flight Lines Flown over Upolu Island

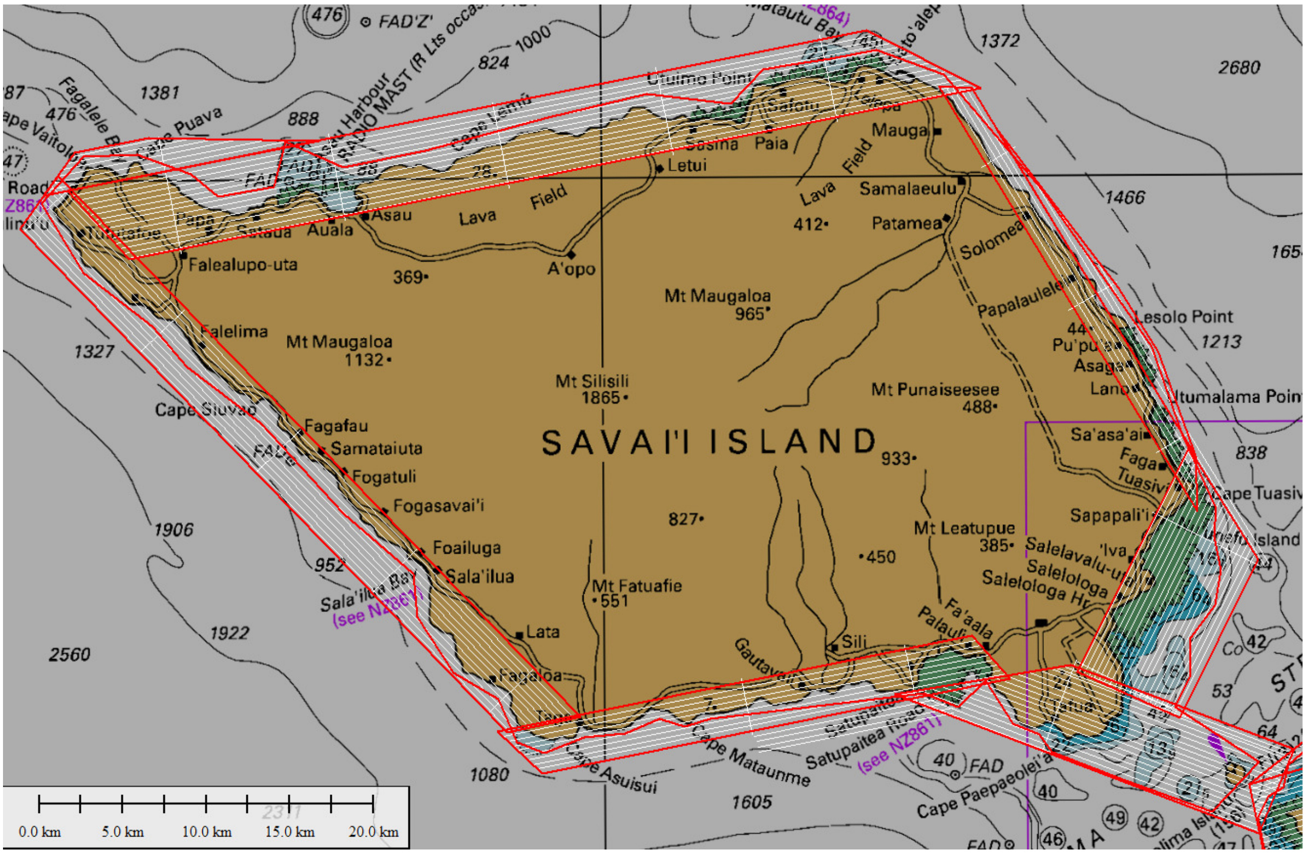

Figure 2 – The MNRE Bathymetric Areas of Interest and Flight Lines Flown over Savai'i Island

ALT data collection was conducted by Fugro Geospatial Services (FGS) from an AusJet Cessna 441 aircraft, call sign VH-LEM, fitted with a RIEGL LMS-Q780 LiDAR system and Phase One medium format camera. All operations were flown out of Faleolo International Airport. The ALT system was flown to meet the accuracy specifications of the project, in table 2 below;

Minimum Standard	ICSM Category 1 Standard – FVA <= +/- 30cm. 95% confidence interval (1.96 x RMSE) FHA <= +/- 80cm. 95% confidence interval (1.73 x RMSE)
Data Resolution	4 pulses per square metre

Table 2 – Topographic LiDAR Collection Requirements

An ALT field processing office was established at the Airport Lodge, approximately 5km southwest of the airport. ALT data processing also commenced in the field office to check for systematic errors and coverage. Refly lines were planned and flown where possible. ALT data was also relocated to a processing office before being quality controlled in the Fugro Geospatial office in Perth. It was then merged with the ALB data in the Fugro LADS office to generate the seamless products.

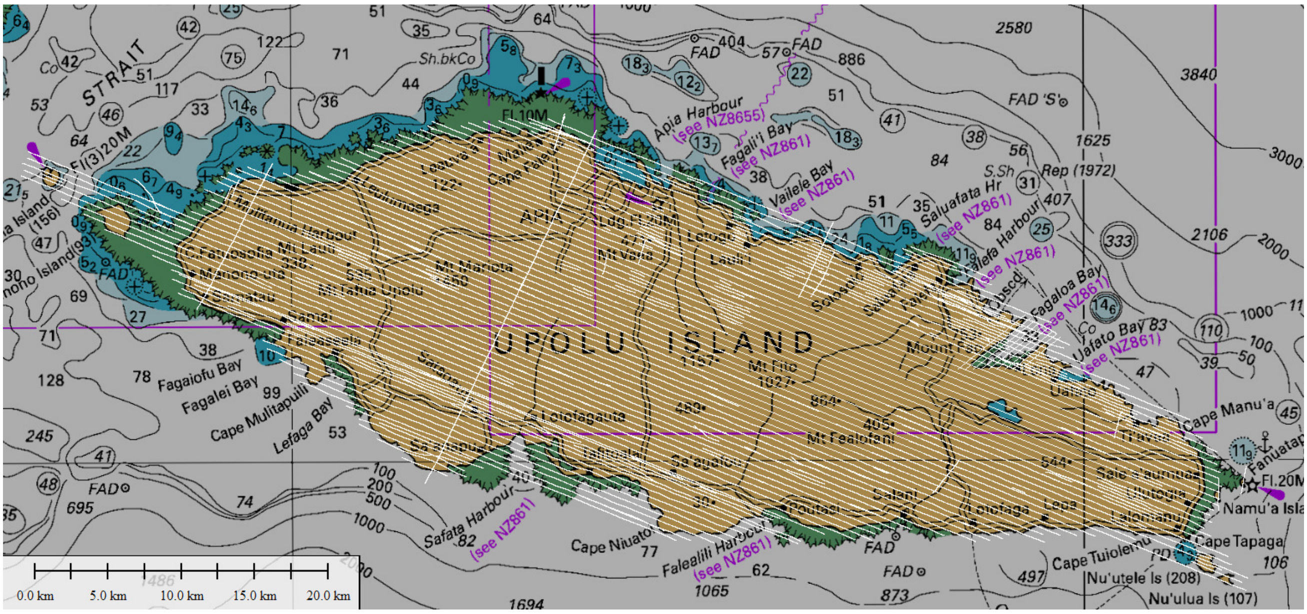

Figure 3 – The MNRE Topographic Areas of Interest and Flight Lines Flown over Upolu Island

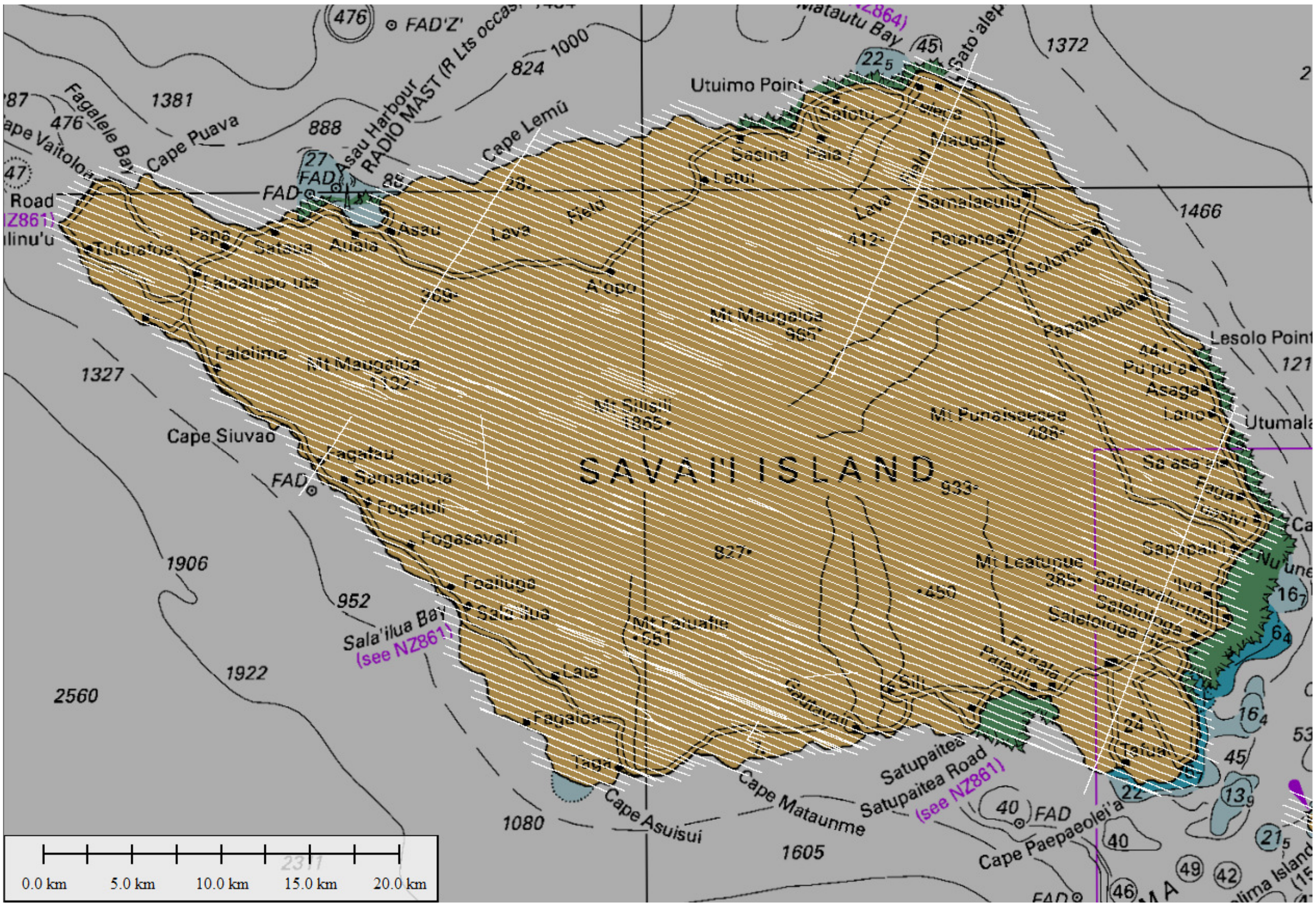

Figure 4 – The MNRE Topographic Areas of Interest and Flight Lines Flown over Savai'i Island

1.2 Survey Area and Strategy

The ALB survey areas were flown in one database for both main islands, which consisted of 19 main sub areas and were flown from Faleolo International Airport. All ALB areas were surveyed to achieve a minimum 5x5 metre laser spot spacing or better, with refly lines flown to achieve a minimum of 85% coverage in each survey area. The contract required data to be collected from 5m drying to 30 metres depth. The overall flight lines flown for each survey area are shown in Figures 1 and 2.

The ALT survey areas were flown in two areas that covered both main islands. Both ALT areas were designed to record a minimum Nominal Post Spacing (NPS) of 4 outbound pulses per square metre and surveyed at 0.5x0.5 metre spot spacing with refly lines flown to achieve 95% coverage in each area, which was a contract requirement. The overall flight lines flown for each survey area are shown in Figures 3 and 4, which include the later acquired NextMap 10 satellite derived data coverage, explained in Section 4.

For acquisition over Samoa a Post Processed solution was calculated using the Applanix POSPac MMS software using Post Processed Kinematic (PPK) methodology. This used the Geoscience Australia Permanent GNSS base station in Apia, SAMO and the Fugro established base station at Faleolo airport over the course of the survey. The final PPK GNSS solution was imported into the processing software for the Fugro LADS Mk 3, RIEGL VQ-820-G and RIEGL LMS-Q780 systems and applied to all measurements.

All ALB and ALT data during data acquisition was referenced to the ITRF08, GRS80 ellipsoid, in UTM coordinates (Zone 2 South) and heights relative to the GRS80 ellipsoid.

Final ALB and ALT data will be supplied to the Samoan Geodetic Reference System 2005 (SGRS2005), which is based on ITRF2000 epoch 2016.0 and heights relative to Mean Sea Level 1993 (MSL). The methodology to transform the ellipsoidal heights to orthometric heights was done on assessment of observed ground control points around Upolu and Savaii. These were surveyed by MNRE surveyors and used to determine the additional correction to apply to the EGM2008 geoid data to reduce the final dataset to MSL. Further information can be found in Section 3.5 and in the Post Survey Spatial Accuracy Report.

No tidal observations, in the end, were deemed necessary for the adequate reduction of the ALB datasets to MSL, and as such weren't observed during the course of the project.

2. SURVEY OPERATIONS

2.1 Field Deployment

The ALB field deployment commenced on 29 June 2015, with the arrival of the aircraft into Samoa from French Polynesia. The FLC Project Manager, survey team and replacement pilots arrived the following day. The deployment finished on 20 July 2015 with the final flight taking place on 18 July 2015 in Samoa. The departure of the remaining field team occurred on 20 July 2015.

An ALB field data processing office was established at the Insel Fehmarn Hotel in Apia during the field deployment period. Four Fugro LADS employees, consisting of three surveyors and one technician, were deployed to Samoa to manage the survey operations.

The ALT field deployment commenced on 3 July 2015 with the arrival of the FGS Project Manager. The aircraft, VH-LEM arrived on 4 July 2015 with a set to work flight taking place on 6 July 2015. The final flight took place on 7 August 2015. The deployment finished on 9 August 2015 with the departure of the aircraft to Australia. The departure of the remaining field team occurred on 10 August 2015.

An ALT field data processing office was initially established at the Insel Fehmarn Hotel in Apia but was then moved to the Airport Lodge on 11 July 2015 so as to have a shorter drive to the airport for the flight crew. Three personnel, consisting of a FGS Project Manager, data processer and system operator, were deployed to Samoa to manage the survey operations.

2.1.1 Operations Description

The Dynamic Aviation, Beechcraft A90 aircraft, call sign N96Y, was fitted and certified with the Fugro LADS Mk 3 Airborne System and RIEGL VQ-820-G system on the 05 June 2015 in Tahiti, French Polynesia. A layback survey was conducted the same day, by Géopolynésie, together with the positioning of three static check marks. A static check of the Airborne System GNSS receivers was carried out on 07 June 2015 at the TASC hangar facilities, Fa'a'ā International Airport.

ALB survey operations in Samoa commenced on 7 July 2015 with the first survey flight. Survey flights were conducted around Samoa from 7 to 18 July 2015. All flights were planned as four hour sorties with fifteen survey flights conducted for the Upolu and Savaii survey areas.

A total of fifteen flights were flown, all effective, achieving a total of 44:55 hours on task.

All of the ALB survey team departed Apia on 20 July 2015.

The AusJet, Cessna 441 aircraft, call sign VH-LEM, was fitted and certified with a RIEGL LMS-Q780 LiDAR system and Phase One medium format camera from the 3 July 2015 in Melbourne, Australia. The lever arms were measured and a calibration flight took place on 3 July 2015 over Geelong, Australia prior to mobilisation of the aircraft to Apia, Samoa.

After arrival in Samoa, another test flight was conducted on 6 July 2015 near Apia city, in Faleula, over an RTK survey control area that was available to validate the LiDAR data. The survey of the Upolu and Savaii islands started after the test flight and continued until the 7 August 2015. All flights were planned as four hour sorties with forty-six survey flights conducted over Upolu and Savaii survey areas.

During this data acquisition period approximately 80% of all the required ALT areas had been acquired. The remaining 20% of the ALT areas required were continually inhabited by low level cloud, particularly over the high level terrain of each island, and the decision was made to finalise the ALT data collection and source alternative Satellite derived data.

A total of thirty-eight fully effective flights were flown, twelve over Savaii and twenty-six for Upolu, achieving a total of 110.18 hours on task with 80.3 hours on line including turns, 12.6 hours ferry to and from the airport and 17 hours lost due to cloud. Out of the eight sorties aborted due to cloud 12.2 hours were lost. A total of 29.2 hours was lost due to poor weather.

All of the ALT survey team departed Apia on 9 August 2015.

2.1.2 Weather and Environmental Conditions

The weather conditions were generally good for ALB survey flights apart from low cloud which impacted the majority of areas, especially the eastern end of Upolu Island. The large sub area on the south east side of Upolu was flown at a lower altitude (1400ft) to mitigate the low cloud base, resulting in a slightly higher density for the Fugro LADS Mk3 data.

Water conditions were very favourable in the majority of areas with good results to 60m depth in most places. The area around Safata Bay, SW of Upolu, was very turbid as a result of discharge from the local river. This impacted the coverage in the area with no real improvement throughout the survey period.

In all, no ALB sorties were aborted due to bad weather although the total time lost due to low cloud was 02:49 hours seeking alternative areas to fly.

Weather conditions for ALT survey flights were continually impacted by low cloud, especially around the high ground on both islands. Survey lines had to be flown in multiple sections to try and achieve the required coverage. Around 80% of the survey areas were successfully flown with cloud preventing the completion of the remaining areas, as mentioned above, with hours lost.

2.1.3 Aircraft System and Defects

The LADS Mk 3 Airborne System and RIEGL VQ-820-G (B2) system were pre-positioned in Papeete, Tahiti on 13 May 2015. Upon arrival of the Dynamic Aviation, Beechcraft A90 aircraft, N96Y, on the 03 June 2015, the airborne systems were subsequently fitted over the next five days. On 08 and 09 June 2015 two trial flights were conducted for the set to work of the aircraft.

One ALB flight was aborted due to the airframe panel near the laser bay door coming loose. The panel was fixed and flying could continue.

One of the pilots had an eye infection needing medical treatment and subsequently one flight had to be cancelled during the survey period. No other major defects were experienced during the deployment period for the LADS Mk 3 Airborne System and RIEGL VQ-820-G system.

During ALT data collection, only one minor issue occurred with the RIEGL LMS-Q780 system. An issue with the operator keyboard in the aircraft occurred but was replaced and subsequently worked fine thereafter. No other defects were experienced during the deployment period.

2.1.4 Weekly Reports

Weekly Reports were compiled that summarised the ALB and ALT data acquisition and processing phases. A digital copy of each report is provided in Annex J.

2.1.5 Personnel

Four FLC personnel were involved in the collection and processing of all field ALB survey data. Two pilots from Dynamic Aviation were also supplied for flight operations.

One FGS employee and two contractors were involved in the collection and processing of all field ALT survey data. Two pilots from AusJet were also supplied for flight operations.

2.2 Subcontractor Support - Géopolynésie

For the ALB survey before Samoa, Géopolynésie provided third party survey support in French Polynesia, which included layback surveys for both ALB systems and the coordination of three static check marks for the static check. See the Post-Survey Spatial Accuracy Report for more details on the survey support and data provided.

3. TECHNICAL DESCRIPTION

3.1 ALB Surveying Systems - Fugro LADS Mk 3 and RIEGL VQ-820-G LiDAR

ALB data was collected using the Fugro LADS Mk 3 Airborne System and RIEGL VQ-820-G Hydrographic Airborne Laser Scanner and processed using the Fugro LADS Mk 3 Ground System and RIEGL RiProcess data processing software respectively.

3.1.1 Data Collection - ALB

The Fugro LADS Mk 3 Airborne System (AS) and RIEGL VQ-820-G were installed in a Beechcraft King Air A90 aircraft. The A90 has a transit speed of 175 knots at altitudes of up to 26000 feet and an endurance of up to four hours. Survey operations were primarily conducted at 1800 feet and 160 knots with a small area conducted in the South East of Upolu at 1400ft to enable collection under low cloud.

The LADS system uses an Nd:YAG laser on a fixed platform with the green returned laser energy captured by the green receiver, and then digitised and logged to a Secure Digital (SD) Card. The height of the aircraft is determined from the green laser, AHRS and GNSS. The system can operate during both day and night. Night operations are enhanced by removing the filter on the receiving optics. Real-time positioning is provided by Fugro Marinestar GNSS PPP or raw GNSS. The POS AV contains an IMU and GNSS logger (roving receiver) that is used in the calculation of post-processed KGNSS positions using the POSPac MMS processing software.

The RIEGL system uses an Nd:YAG laser on a fixed platform with the green returned laser energy captured by the green receiver, and then digitised and logged to a Hard Drive. The height of the aircraft is determined from the green laser. The system can operate during both day and night. RIEGL's RiAcquire software is used for system setup and data logging. Real-time positioning is provided by logging raw GNSS. The POS AV IMU contains an IMU and GNSS logger (roving receiver) that is used in the calculation of post-processed KGNSS positions using the Inertial Explorer processing software.

The following table 3 provides a summary of the aircraft used and operating specifications for each respective system along with digital camera details. See Annex B and C for further information on technical specifications of each respective LiDAR system used.

Aircraft Used and Call Sign	Beechcraft King Air A90 – N96Y (Dynamic Aviation)
Transit speed / height	175 Knots / Up to 26000 ft
Aircraft Endurance	Up to four hours
Survey Operations	Primarily conducted at 1800 ft @ 145 knots. Small area conducted at 1400 ft @ 145 knots
Fugro LADS Mk 3 LiDAR Specifications:	
Laser Rate	1500 Hz
Laser Spot Spacing	Primarily conducted at 5 x 5 metres (P5) Small area conducted at 4 x 4 metres (P4)
Swath Width	360 metres (P5), 273 metres (P4)
Line Spacing	330 metres (P5), 253 metres (P4)
Digital Camera:	Redlake MegaPlus II ES 2020
Image Resolution	>4 pixels/m at an altitude of 1600ft
Capture Rate	1 second / frame (1 Hz)
RIEGL VQ-820-G LiDAR Specifications:	
Laser Rate	284 KHz
MTA Zone	2
Laser Power	Full Power
Field Of View (FOV)	42° FOV - gives 32.1% (170m) Sidelap for LiDAR
Laser Spot Spacing	Nominally 11 points per square metre.
Scan Speed	157 Lines per second
Swath Width	Nominally 530 metres at 1800 ft.

Table 3 – ALB Aircraft and System Settings

3.1.2 Data Processing Overview - ALB

Data processing on both the Fugro LADS Mk 3 Ground System (GS) and RIEGL RiProcess software was commenced in the field and completed in the survey office in Adelaide. The Fugro LADS Mk 3 GS consists of two networked laptops operating on a Linux operating system which can be transported in the aircraft or by survey personnel to the deployment site. Laptops provide the user interface to the Hydrographic Surveyor. The RIEGL RiProcess software operates on a Windows PC and is transported with the GS equipment.

The processing system also contains an optional GNSS logger (base receiver). This allows the subsequent calculation of post-processed Kinematic GNSS positions (L1/L2 carrier phase) from a local GNSS base station if no permanent CORS stations are available or if PPP is not used. The KGNSS positions are calculated off-line using POSPac MMS software, then imported into the GS and RiProcess and applied to soundings for LADS and RIEGL respectively.

Terramodel was used for survey planning and Ground System and Terrascan to review the data. ESRI ArcGIS and Global Mapper were used in the product generation phase.

3.2 ALT Surveying System - RIEGL LMS-Q780 LiDAR / Phase One Camera

3.2.1 Data Collection - ALT

The operating specifications of the RIEGL LMS-Q780 LiDAR and Phase One Camera can be found in the table 4 below and full technical specifications can be found in Annex D.;

Aircraft Used and Call sign	Cessna 441 – VH-LEM (AusJet)
Transit speed / height	Nominally 350 knots @ 35000ft
Survey Height	AGL 650m (2132ft)
Survey Speed	130 – 140 Knots max.
RIEGL LMS-Q780 LiDAR Specifications:	
Laser Rate	350 KHz
MTA Zone	2 (499m – 923m)
Laser Power	50%
eNOHD Single	584m
Line Spacing	423m (includes 10% additional Sidelap, excluding Nav Tolerances)
Field Of View (FOV)	60° FOV - gives 43.6% (327m) Sidelap for LiDAR
	40° FOV - gives 10.0% (50m) Sidelap for LiDAR
Point Ratio (Along / Across)	0.61
Digital Camera:	Phase 1 - iXA-R 180
Image Resolution (GSD)	20cm
Triggering Interval	2.8 sec/frame or 202m (60% forward overlap)
Field Of View (FOV)	54° FOV - gives 36% (247m) Sidelap on Imagery

Table 4 – ALT Aircraft, System Settings

3.2.2 Additional Satellite Topographic Data Sourced

As a consequence of not being able to capture 100% of the required topographic survey areas due to continuous cloud cover, FGS sourced third party satellite data from Intermap Technologies and Airbus, on completion of data collection activities, to fill the remaining gaps in coverage as specified in table 5 below;

Nextmap10:	From Intermap Technologies
Source data	The 10m DEM is a combination of 90m and 30m SRTM v2.1 data, 30m raster Global Dem v2, and 1km GTOPO30 data.
Nominal Accuracy	10 is 5m RMSE, 10m LE95.
Resolution	Resampled 10m grid
Date of Data	1996-2011
Pleiades Imagery:	From Airbus
Resolution	50cm pan sharpen
Nominal Accuracy	8.5m CE90 at nadir
Date of imagery	May-Sept 2014
Band	RGB+PAN

Table 5 – Satellite DEM and Imagery Data Sourced to Fill Topographic Gaps in Coverage

3.2.3 Data Processing Overview - ALT

Data processing on both the Lidar and Imagery data was commenced in the field and completed in the survey office in Perth and China. The Fugro FGS field office was setup with a dedicated high performance mobile workstation which allowed near real time data downloading and field data validation. High performance laptops provided the user interface to the topographic surveyor. Multiple software was used for the field data pre-processing including: Fugro “in house” planning software, RIEGL RiProcess software operating on a Windows PC, Terrasolid, CaptureOne, Applanix Pospac, Global Mapper as the main packages.

Workflow was reviewed to allow the use of the Fugro Data Factory centre to complete the post processing and the generation and QA of the data and Lidar derivates and orthophotos. QA/QC tools were implemented to validate data and derivates against the project specifications particularly to assess raw data integrity, quality and completeness, area coverage and data resolution, spatial accuracy and classification.

Pre-Processing was undertaken in FGS field office including the following tasks:

- Planning and processing test flight data
- Monitoring and validating quality of data as captured
- Establishing GNSS Datum to process Airborne GNSS-IMU data

- QA/QC Base station data for coverage and cycle slip
- QA/QC Lidar Data for coverage and gaps from cloud and terrain issues
- QA/QC imagery data for coverage and imagery quality
- Validating data coverage and reissuing flight plans if required to cover gaps
- Final GNSS-IMU smooth best estimated trajectory files using Applanix Pospac
- Pre-processing airborne data to georeferenced las files in the target horizontal datum and ellipsoidal height run by run using Riegl software package

Post-Processing undertaken in the Fugro Data Factory (China office) including

- Post –processing the Lidar data
- Flight line matching calculating residual angular error and apply these to the data
- Calculating and applying fluctuations
- Applying Geoid undulation
- Validating the spatial accuracy and adjust data to match ground control
- Implementing ground filter algorithms to best filter ground data from above ground data
- Validating filter results and perform level 2 classification for classes 2 and 8
- Re-assess spatial accuracy based on level 2 classified ground data
- Generating Geodetic Validation log file
- Generating Ground surface for orthorectification
- Performing direct image georeferencing using GNSS and IMU
- Orthorectification of the imagery
- Seam line editing
- Orthomosaic
- Review Lidar data classification using orthomosaic
- Integrating satellite data to cover Lidar and phase 1 imagery gaps
- Generating deliverables

3.3 Geodetic Control

All collected data was post-processed relative to the International Terrestrial Reference Frame 2008 (ITRF08@2015.5) datum during the application of the PPK solution. All collected data refers to UTM Zone 2 South, Central Meridian 171° West.

3.3.1 Reference Stations and PPP

Two GNSS base stations, one located in Apia (SAMO) and one located at Faleolo airport (Fugro), were used by FLC and FGS for the post processing of all data in the Upolu and Savaii survey areas. Data was downloaded accordingly after each survey flight. To ensure the latest ITRF2008 coordinates were used for the Fugro base station a 24 hour AUSPOS position was calculated and subsequently used for all sortie post-processing. The latest ITRF2008 SAMO coordinates were obtained from the Geoscience Australia weekly GPS Analysis Report.

For one ALB sortie, positioning data was post-processed using the Precise Point Positioning (PPP) method to provide a PPK GNSS solution which was then applied to all the data. Rapid ephemeris and clock product files were used for the PPP processing.

Three control points were also established on the tarmac at Fa'a'ā International Airport, Tahiti, French Polynesia. These points were used to conduct static position checks of all ALB positioning systems during the initial set to work phase.

Full details of the control reference stations are provided in the Annex E MNRE_Geodetics.

3.4 Position Fixing Systems

3.4.1 Fugro LADS Mk 3, RIEGL VQ-820-G and RIEGL LMS-Q780 LiDAR Positioning Systems

Throughout the survey, the real-time position of the Fugro LADS Mk 3 and RIEGL systems was derived from a Trimble BD982 GNSS receiver. Real-time PPP corrections from the Fugro Marinestar GNSS service were received and applied by the Trimble receiver to the raw LADS GNSS positions. As the LADS Mk 3 is always used for the real-time position of the aircraft, there is no need for the RIEGL VQ-820-G to also receive these corrections. The RIEGL LMS-Q780 on VH-LEM didn't receive real-time corrections. The GNSS/IMU data was post-processed to improve accuracy.

L1/L2 carrier phase PPK GNSS positions from the Trimble BD982 (POS AV) multi-frequency GNSS receivers on each aircraft were calculated using POSPac MMS. These positions were imported into the Ground System and RiProcess and applied to all soundings. Details of the ALB position fixing systems are provided in Annex F MNRE_Position.

3.4.2 LiDAR Horizontal Position Checks - ALB

The ALB positioning systems were subject to a static position check conducted on 07 June 2015, prior to data collection to ensure the positioning systems were operating correctly for the survey.

a. Static Position Check. The derived coordinates of the aircraft LADS GNSS antenna were determined relative to the control on the tarmac at Fa'a'ā International Airport. Data was logged by the Fugro LADS Mk 3 and RIEGL VQ-820-G positioning systems over a two-hour period; this enabled the positions to be verified against the known surveyed points.

   Results of the LADS Mk 3 session were GNSS Only ± 6.739 metres (95% confidence), PPK GNSS PPP ± 0.037 metres (95% confidence) and PPK GNSS base station ± 0.051 metres (95% confidence). These results are consistent with previous surveys and show that the positioning systems were functioning correctly.

Results of the RIEGL VQ-820-G session were GNSS Only ± 8.074 metres (95% confidence), PPK GNSS PPP ± 0.077 metres (95% confidence) and PPK GNSS base station ± 0.067 metres (95% confidence). These results are consistent with previous surveys and show that the positioning systems were functioning correctly.

b. Dynamic Position Check. During each sortie, GNSS data was logged on the aircraft. The LADS real-time GNSS PPP and the post-processed KGNSS PPP positions of the aircraft have been compared. The mean difference was 0.578 metres (95% confidence) and the maximum difference was 2.263 metres.

Details of LiDAR position checks for the ALB system, above are provided in Annex F and also detailed in the Post-Survey Spatial Accuracy Report.

3.4.3 Accuracy of Position

The initial checks on positional accuracy for all three LiDAR systems were presented in the System Verification Report, provided as an annex to the Post-Survey Spatial Accuracy Report.

Full details of the position accuracy are also provided in Annex I.

3.5 Vertical Control

3.5.1 Survey Datum

All soundings for the initial data collection have been reduced directly to the Geodetic Reference System 1980 (GRS80) ellipsoid. Final data was supplied to both the ellipsoid and to the Mean Sea Level (MSL) 1993 local datum.

See Annex G for further information and the Post-Survey Spatial Accuracy Report for final survey reduction of both the ALB and ALT datasets from GRS80 to MSL.

3.5.2 Ellipsoid Data Applied Corrections

The bathymetric and topographic data was processed to the GRS80 ellipsoid as the International Terrestrial Reference Frame (ITRF) is associated with this ellipsoid. The difference between WGS84 and GRS80 of 0.1mm is negligible.

An assessment of the ALB and ALT ellipsoidal datasets was made against the Survey Control points and the following ellipsoidal corrections applied to each respective dataset as per Table 6 below. For further information on the Station Descriptions and comparisons results, see Annex G and the Post-Survey Spatial Accuracy Report:

Dataset	Upolu Island ELL Corrections	Savaii Island ELL Corrections
ALB	+0.14m	+0.18m
ALT	+0.16m	+0.19m

Table 6: ALB and ALT corrections applied to the ellipsoidal datasets for Upolu and Savaii Islands.

3.5.3 Geoid Model Used - EGM2008

A requirement of the survey was to deliver orthometric heights to the Mean Sea Level as determined by the published heights of local survey control marks within the project extents.

To correct the data from ellipsoidal to orthometric heights, the Earth Gravitational Model 2008 (EGM2008) was used with a 1' x 1' grid.

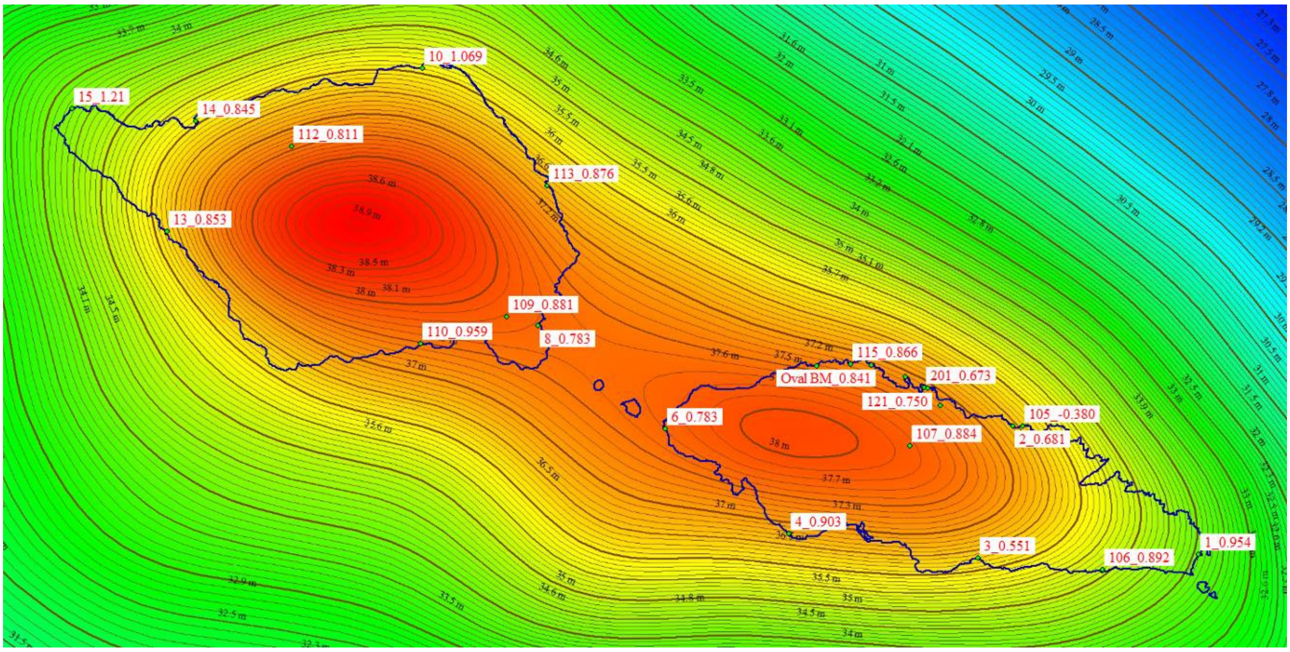

Figure 5: EGM2008 values for Samoan Islands overlaid with Survey Control Points and MSL Correction variation.

3.5.4 Mean Sea Level Reduction

Examination of the ellipsoid to MSL values from levelling indicates a difference of 0.668m between EGM2008 and the observed values based on the primary Upolu MSL benchmark located near Apia. Figure 6 shows the levelling connections from the previous LiDAR survey conducted in 2012/13 and the values which were adopted for that survey.

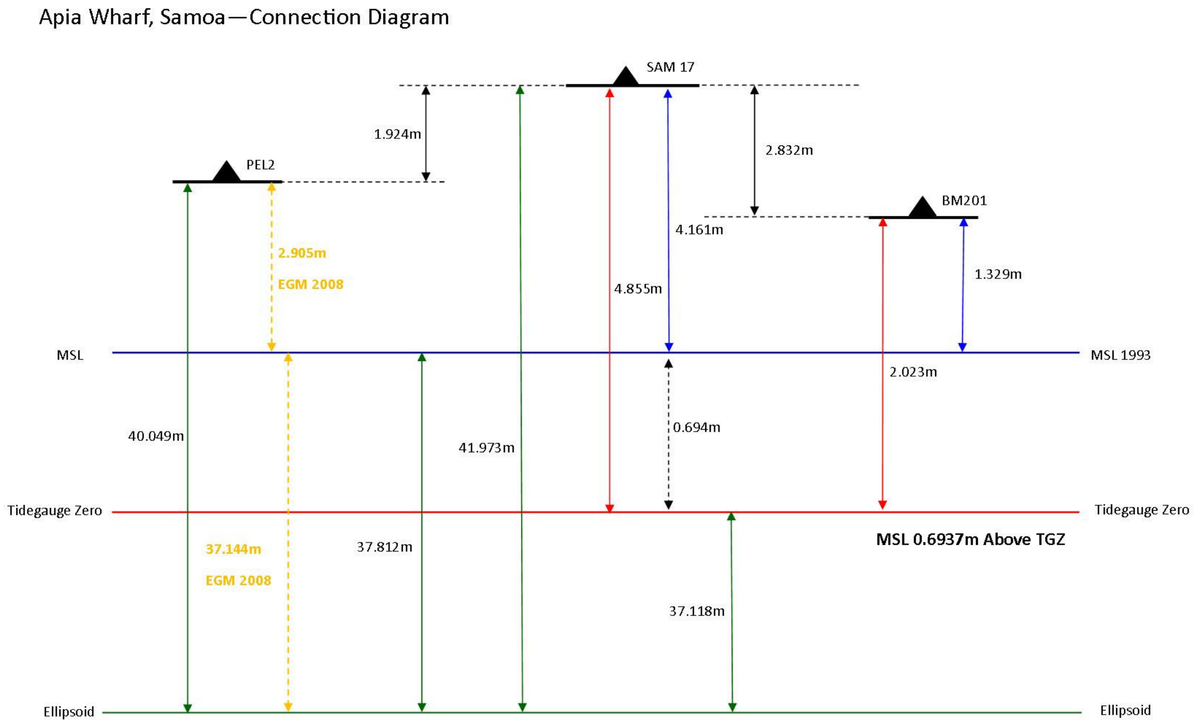

Figure 6: Apia Levelling Connection Diagram based on observations and quoted MSL values (2012 RoS)

From the survey control, mainly established by MNRE surveyors during the LiDAR survey conducted in 2015, alternative correction values were derived based on a wider distribution of points around each of the two Islands, depicted in the figure 5. The reduced EGM08 ALT data was then compared against the selected survey control points to derive the MSL corrections for both Islands. The decision was made to apply the same MSL correction to both the ALT and ALB datasets as depicted in Table 6 below;

Dataset	Upolu Island MSL Corrections	Savaii Island MSL Corrections
ALB	-0.69m	-0.83m
ALT	-0.69m	-0.83m

Table 6: ALB and ALT corrections applied to the EGM2008 reduced datasets for Upolu and Savaii Islands.

3.6 Bathymetry and Topography

The LADS Mk 3 main lines of sounding were conducted using a 5x5 metre laser spot spacing with a swath width of 352 metres, at an aircraft ground speed of 160 knots. Main lines of sounding were flown at 330 metre spacing which provided a planned 100% coverage of the seabed and ensured a 5 metre spot spacing as required by the contract.

The RIEGL VQ-820-G system was flown at the maximum high rate of 284 kHz for the duration of the survey. The swath width was 530m with a sounding density of 11 points per square metre.

The RIEGL LMS-Q780 system was flown at the maximum high rate of 350 kHz for the duration of the survey. The nominal swath width was >720m with an point density of nominally > 4 points per square metre.

3.6.1 Depth Benchmarks

The relative vertical accuracy of the ALB data was verified by comparing ellipsoid depth data against three benchmarks established on the same line. The benchmarks were in depths ranging from approximately 7 to 37 metres.

Twelve benchmark comparisons were conducted using 31595 individual soundings. The average mean depth difference from all benchmark comparisons was 0.01m +/-0.06 with an average standard deviation of ± 0.25m +/-0.01 (1σ). These results are comparable with previous results obtained with the LADS Mk 3 system and show it operated correctly.

The nominated relative benchmark line was flown four times during the survey period.

Full results of the benchmark analysis are provided in Annex H.

3.6.2 Topographic Integration Points (TIP's)

TIP comparisons were conducted to verify the accuracy and precision of the LADS Mk 3, RIEGL VQ-820-G and RIEGL LMS-Q780 systems in the topographic environment. All TIP's consisted of relatively flat areas of open ground (in general a large field or wide road). One TIP was surveyed by Fugro and MNRE surveyors whilst the other four TIP's were independently surveyed by AAM in 2012. Each TIP was flown at least once throughout the duration of the survey.

The Fugro/MNRE TIP comparison results yielded excellent agreement between the LiDAR data and surveyed data with an average Mean Depth Difference of **0.11m ±0.03** and an average Standard Deviation of **0.04m ±0.00**.

The AAM TIP comparison results yielded good agreement between the LiDAR data and the surveyed data with an average Mean Depth Difference of **0.06m ±0.06** and an average Standard Deviation of **0.06m ±0.04**.

Full results of the final reduced data over the Wesley Oval and AAM TIP's are provided in Annex H.

3.6.3 Cross lines

Cross lines were planned across the ALB survey areas at 10km intervals. Comparisons on the final reduced MSL dataset were made with main survey lines for analysis.

The cross line comparison results yielded excellent agreement between the ALB main survey lines and cross lines with an average Mean Depth Difference of **-0.03m ±0.10** and an average Standard Deviation of **0.22m ±0.17**. The results were generated from the intersection of 187 runs and a comparison of 328869 individual depths, derived from a 5m grid. These results are consistent with the correct operation of the ALB systems.

For the ALT survey, cross line comparisons were done during the flight line matching process using class 2 data derived from the initial ground filter. Four cross lines were flown over Savaii and two over Upolu. The results were reported separately for each survey area.

The cross line comparison results for Savaii yielded excellent agreement between the ALT main survey lines and cross lines with an average Mean Difference of **0.00m ±0.05** and an average Standard Deviation of **0.24m ±0.12**. The results were generated from the intersection of 201 runs and a comparison of 2809481 individual points, derived from a 5m grid.

The cross line comparison results for Upolu yielded excellent agreement between the ALT main survey lines and cross lines with an average Mean Difference of **-0.01m ±0.04** and an average Standard Deviation of **0.18m ±0.10**. The results were generated from the intersection of 90 runs and a comparison of 1726528 individual points, derived from a 5m grid.

Results of the final cross line comparisons are provided in Annex H.

3.7 Accuracy of Soundings

3.7.1 Vertical Accuracy Estimates - ALB

A theoretical assessment of the total survey accuracy can be determined by combining the errors due to the ALB systems, the vertical datum (i.e. tides and tidal model or GNSS height datum), swell and water clarity. The depth accuracy of the survey has been assessed theoretically using this method and is presented in Annex I.

The theoretical analysis of the pool of errors indicates that the systems employed and survey practices resulted in IHO Order 1b standards being achieved. This is confirmed by the depth benchmark, TIP's and cross line comparison results.

3.7.2 Vertical Accuracy Estimates - ALT

A theoretical assessment of the total survey accuracy can be determined by combining the errors due to the ALT systems, the vertical datum (i.e GNSS height datum) and the environmental conditions during the survey. The positional accuracy of the survey has been assessed theoretically using this method and is presented in Annex I.

The theoretical analysis of the of errors indicates that the systems employed and survey practices resulted in ICSM Category 1 standards being achieved. This is confirmed by the surveyed ground control points, the TIP's and cross line comparison results.

4. SURVEY RESULTS

4.1 Completeness

The Samoa ALB survey was broken up into two main survey areas. Both survey areas were flown with excellent results, particularly in the shallow regions less than 20 metres. There was only one area of turbidity, due to dirty river discharge located in Safata Bay on Upolu Island, which impacted the coverage obtained.

Caution was used to survey regions when the effects of swell were at a minimum and to maximise opportunities when conditions were calmest over the outer reef edges in all areas. Most survey areas on the outer extremities had a very steep seabed, and despite being surveyed in clean conditions, had the effect of reduced coverage beyond the extinction depth of the LADS Mk 3 System.

Overall, it is considered that the required ALB coverage meets acceptance for both survey areas. The calculation was assessed if 85% of all 50x50m tiles (within 5m drying and 30 metres depth) have greater than 50 soundings in each. A sounding for the purpose of coverage assessment was based on a single populated 5x5m grid. Table 7 below outlines the results for each survey area;

Area	Number of 50x50m Grids (+5m drying to 30m depth)	Number of 50x50m Grids >50 soundings	Area Percentage covered
Upolu	54030	53432	**98.89%**
Savaii	127952	123520	**96.54%**

Table 7: ALB percentage of survey areas covered

The Samoa ALT survey was also broken up into two main survey areas. Both survey areas were flown with good results, apart from the high ground which was obscured by low cloud most of the time impacting the coverage obtained. Each survey area was surveyed when low cloud was at its least to maximise coverage obtained. Flight lines however were regularly obscured by cloud and were flown in sections to acquire data when no or few clouds were present. Satellite data was acquired to fill the gaps left by the LiDAR data after the ALT data collection campaign was completed and areas sourced shown in figures 7 and 8.

Overall, it is considered that the required coverage of 95% has been achieved in the Upolu and Savaii survey areas when combining the ALT and Satellite derived coverage. At the completion of data processing the coverage areas and percentages, including the Satellite coverage shown in Figures 7 and 8, were calculated and provided in Table 8, as follows:

Area	Required SqKm	Achieved SqKm	Area percentage covered
Upolu – Total	1140	1310	115%
(Riegl LMS 820G)		1135	85%
(NextMap 10 Satellite)		175	15%
Savaii – Total	1713	1806	105%
(Riegl LMS 820G)		1578	87%
(NextMap 10 Satellite)		228	13%

Table 8: ALT and Satellite percentage of survey areas covered

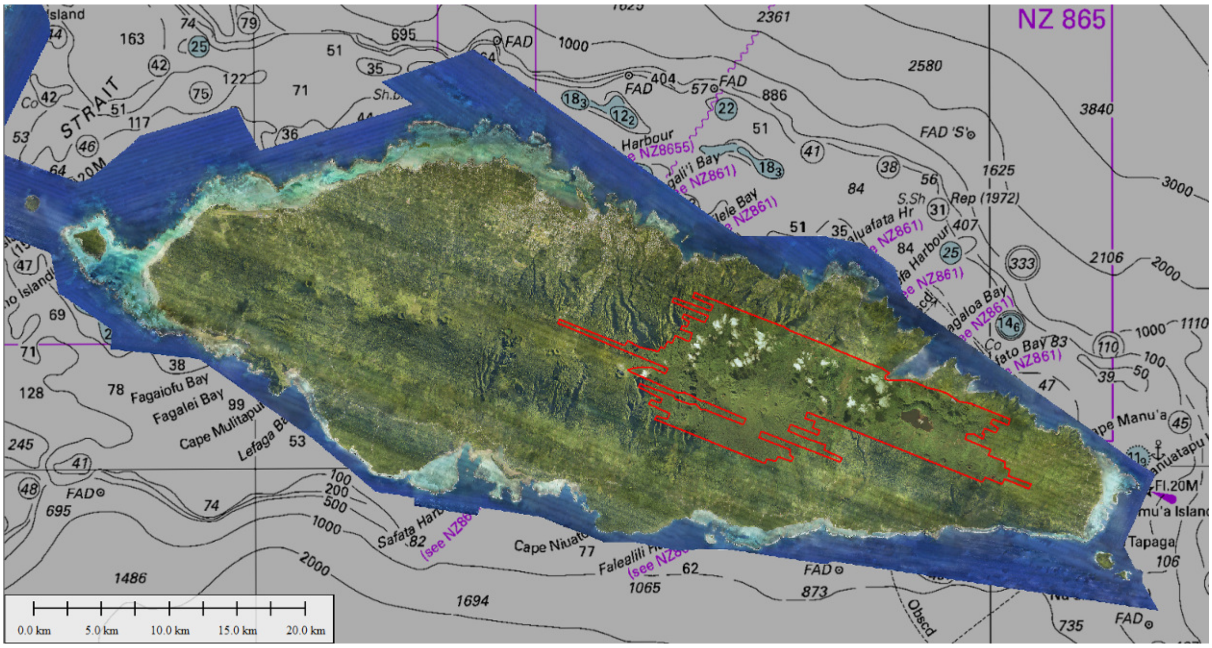

Figure 7 –NextMap10 Satellite Derived DSM and Pleiades Imagery coverage sourced (in Red) for Upolu Survey Area

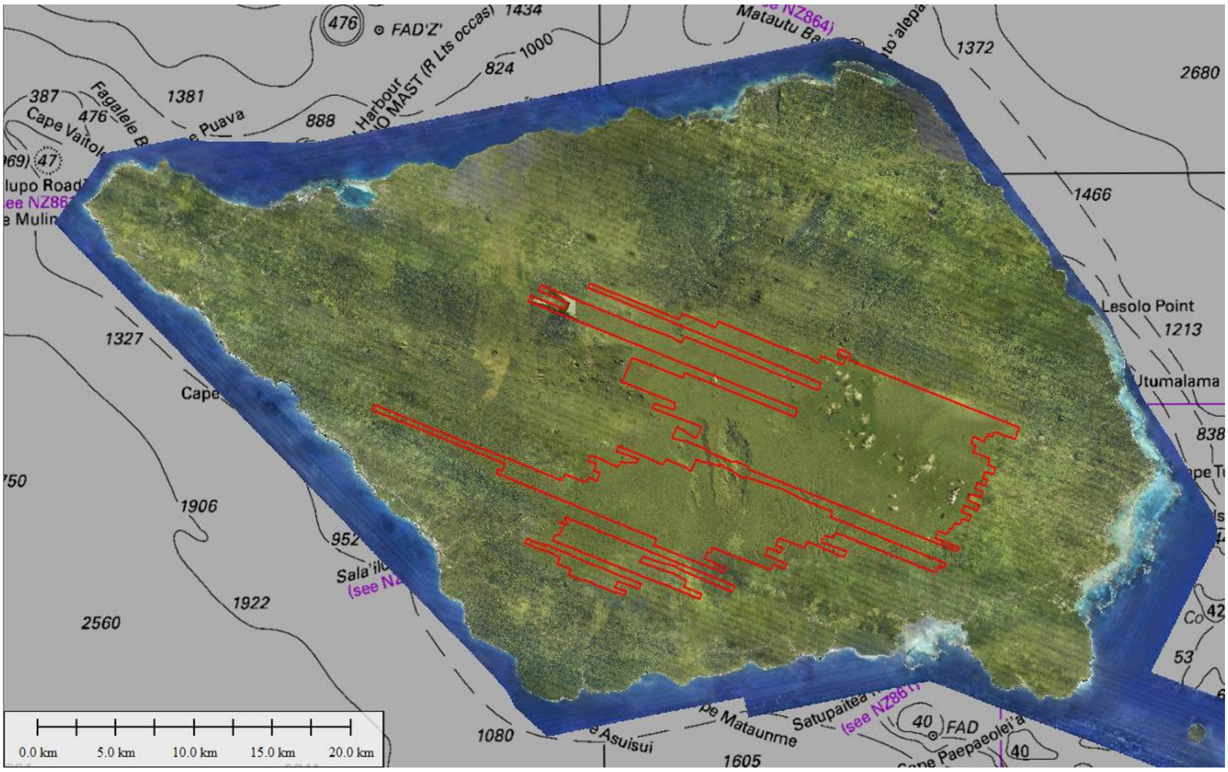

Figure 8 – NextMap10 Satellite Derived DSM and Pleiades Imagery coverage sourced (in Red) for Savaii Survey Area

The merging of the Lidar and satellite data was performed separately for Savaii and Upolu islands. The satellite Nextmap 10 data was merged to the Lidar data keeping the maximum extent of the Lidar data and the minimum extent of the satellite data. Firstly the Nexmap 10 data was checked against the Lidar data in the overlapping areas. Based on the z differences between the 2 datasets a differential dz model was created. This model was then applied to the whole Nextmap 10 dataset. A seamline boundary was created to clip the satellite data before final merging. Additional to the workflow was to merge the Nextmap DTM with the Lidar ground and the Nextmap DSM with the Lidar non ground. This then allowed the generation of the DEM, DSM, CHM, FCM and contours over the whole area of interest.

Nextmap 10 Digital Elevation Model by Intemap Technologies is a fused data model using corrected public data as the input source. The resulting model provides a 10m ground sampling distance. In particular the 10m DEM is a combination of 90m and 30m SRTM v2.1 data, 30m raster Global Dem v2, and 1km GTOPO30 data. The accuracy of Next map 10 is 5m RMSE, 10m LE95.

The final results of the merged ALB, ALT and NextMap10 achieved coverage in each survey area are provided below in Figures 9 and 10 below;

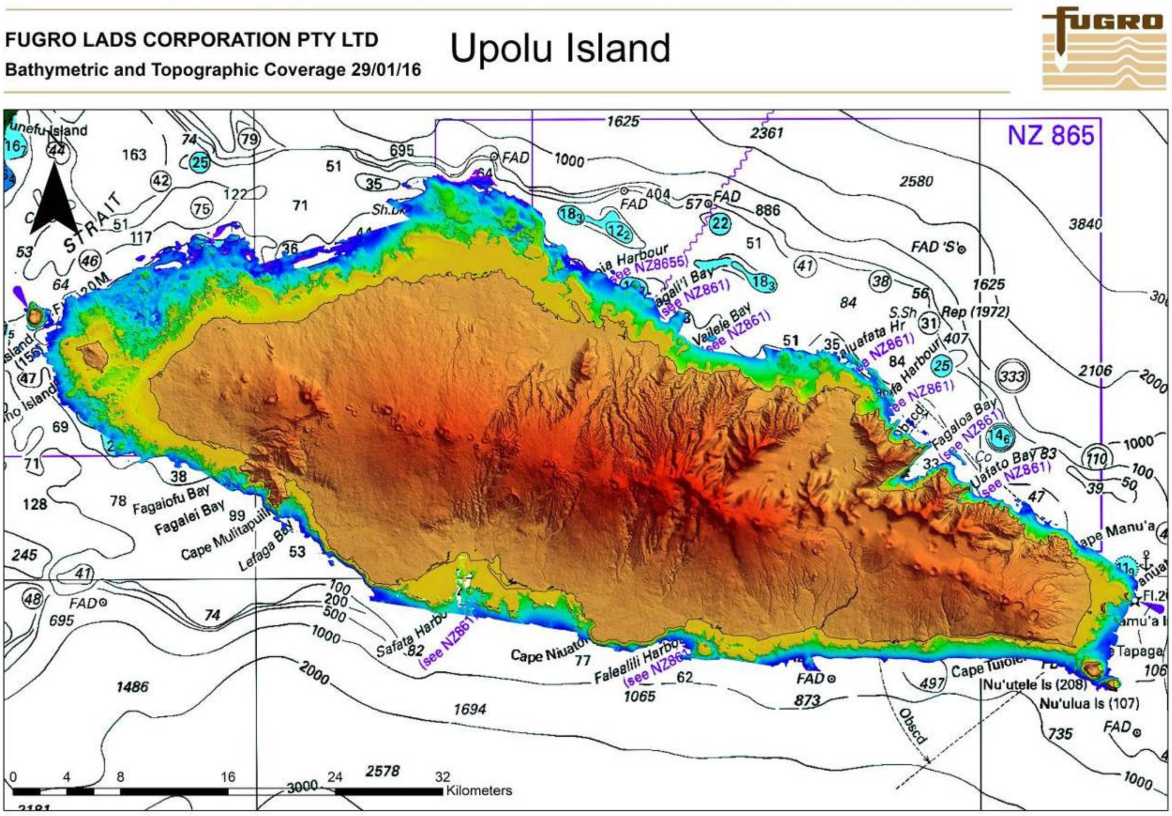

Figure 9 – Final Merged Survey Coverage – Upolu Island

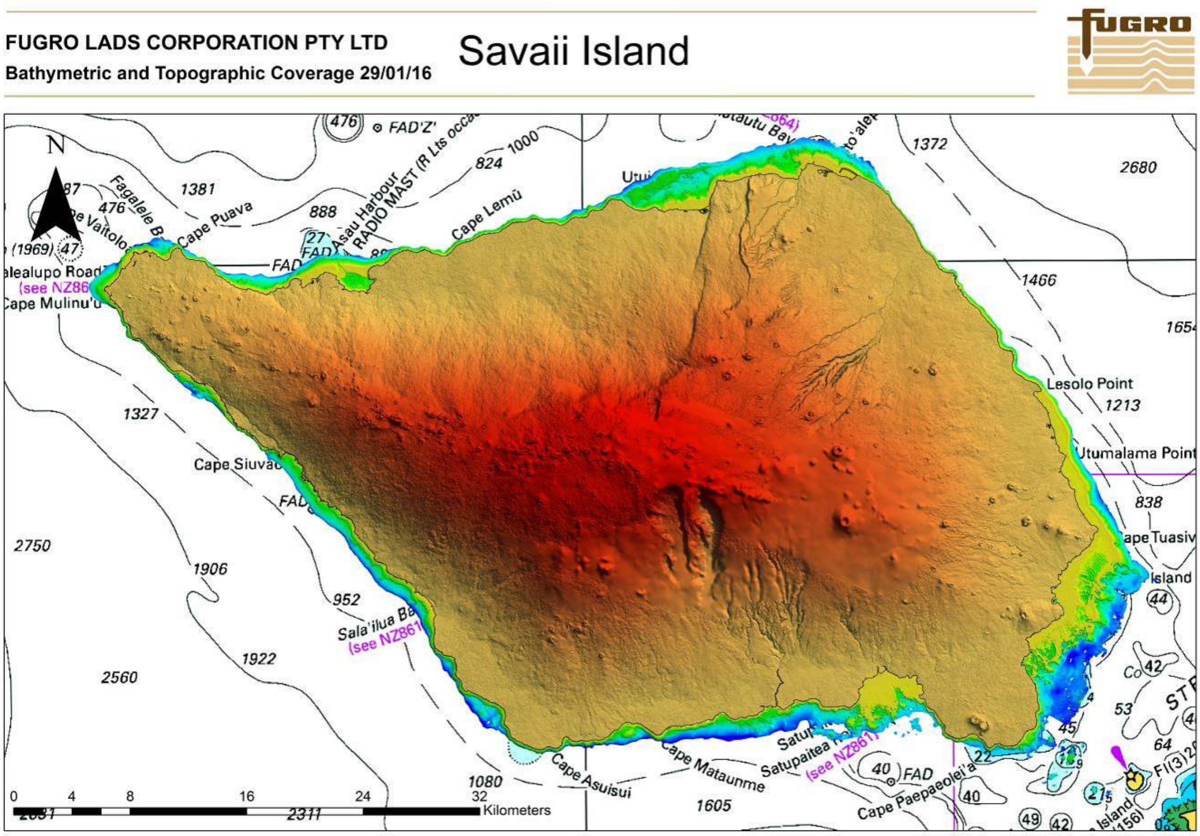

Figure 10 – Final Merged Survey Coverage – Savaii Island

4.2 Aerial Imagery

The Phase1, Redlake and Pleiades Satellite imagery were merged to produce a seamless 3 band RGB orthophoto 8 bit. The 3 datasets were initially pre-processed separately and georeferenced using the GNSS-Imu sbet. The Pleiades imagery was georeferenced using the rational polynomial coefficient model, a mathematical sensor model that incorporates all the physical elements of the imaging system. The orthorectification in 1km tiles was performed of the imagery was performed using the Lidar DEM for the Phase1 imagery, the bathymetric derived Dem for the Redlake imagery and the Nextmap10 Dem for the Pleiades imagery. The orthorectified 1km tiles were then processed in orthovista to obtain a colour balance and seamless 20cm GSD orthophoto.

The final combined results are shown in Figures 11 and 12.

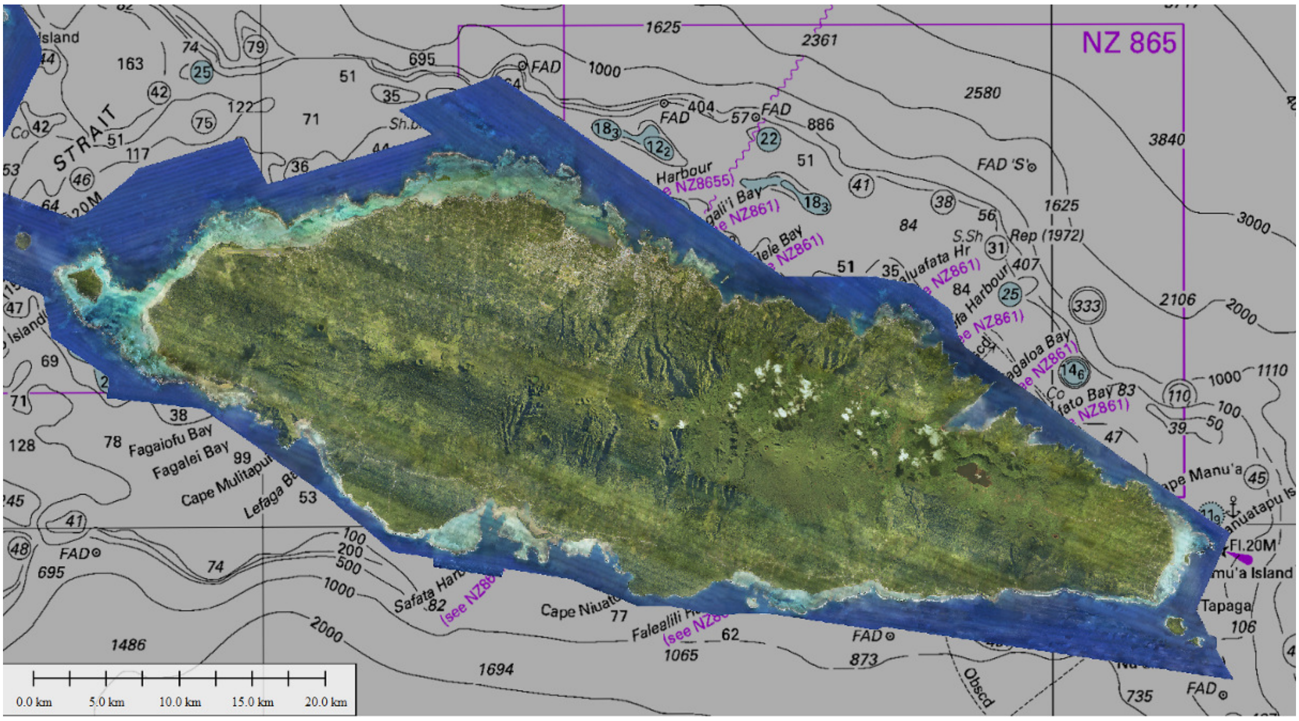

Figure 11 – Final Merged Orthometric Imagery – Upolu Island

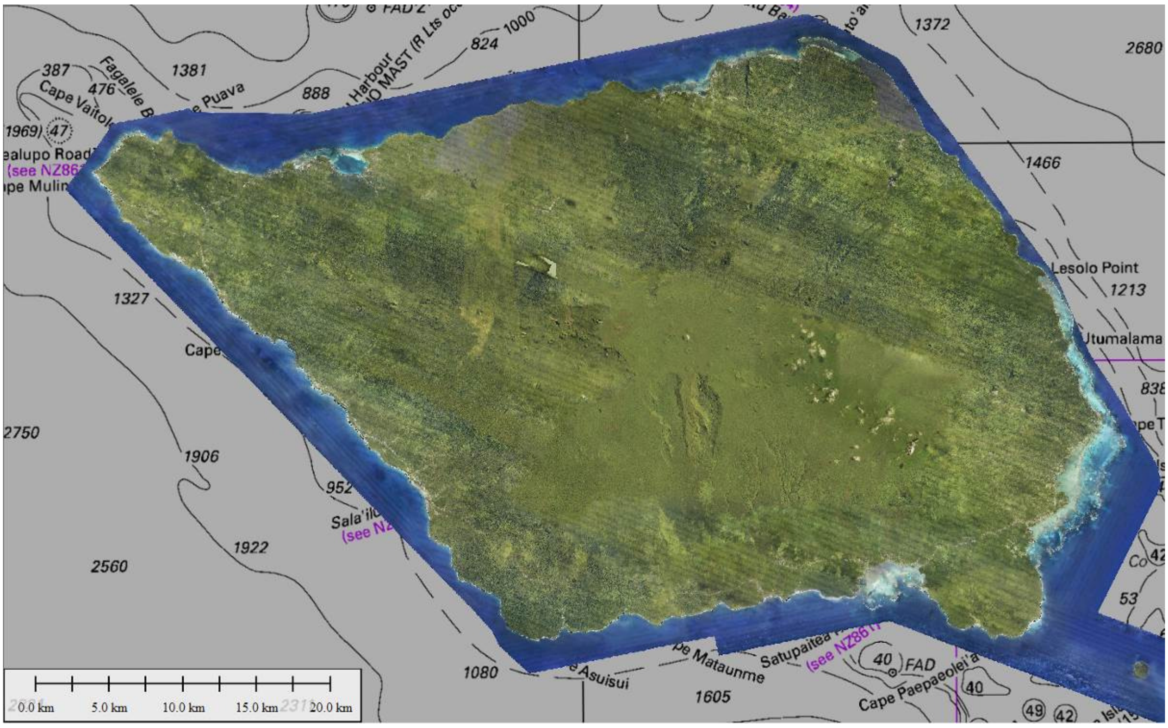

Figure 12 – Final Merged Orthometric Imagery – Savaii Island

4.3 Cultural and Surveyed Features in the ALB Data

4.3.1 Navigational Aids

Numerous marine navigational aids exist and were detected in the survey area. Where detected by the LADS Mk3 or RIEGL VQ-820G systems, they have been rejected by the system and tagged with the appropriate S-57 tag.

4.3.2 Wrecks and Obstructions

One reported wreck was found in Apia Harbour with details in Table 10 below. See Annex L for more details;

Point	Surveyed Latitude	Surveyed Longitude	Easting	Northing	Run Number	Comments
1	13°49'42.5" S	171°49'08.6" W	416886	8471110	20022	Wreck

Table 10: Wrecks and Obstructions detected in the survey areas

4.3.3 Cultural Features

During the processing of the ALB data many cultural features were detected in the dataset and tagged using the standard S-57 tags. Cultural features that were identified were bridges, jetties and pipelines.

Features such as bridges and jetties that were considered not to impede the natural flow of water were rejected, whereas features such as breakwaters that stop the flow of water are retained in the final dataset.

4.3.4 Coastline and Topography

Within the ALB survey data, soundings have been retained up to -5 metres drying depth above the MSL datum (topographic heights). The topographic data has been checked for consistency; topographic data with anomalies such as datum errors has been rejected and removed from the dataset. The ALB topographic data has been merged with the ALT data to create a seamless dataset from the highest point to at least 30m depth below MSL.

4.3.5 Seabed Features

There are a number of seabed features within the survey area where the least depth may not have been found, especially in deeper areas not obtainable by the high density RIEGL laser system. This is due to the nature of the seabed and the survey requirement, which specified 5x5 metre laser spot spacing and 100% coverage. Examinations were not conducted over seabed features at high density laser, and the least depth over shoals may not have been determined for navigation purposes in certain cases. Soundings over features have been assessed by review of their raw laser waveforms, and soundings have been retained where they are considered to be valid. A number of features may be retained in the final data as a result of an assessment of their raw laser waveforms, however as these features have not been examined, the least depth over these features in particular may not have been recorded.

5. DELIVERABLES

A description of all data provided is as follows:

5.1 Interim Data

Coverage Image of the two survey areas was provided on 5 August 2015. Data provided is listed in Annex A.

5.2 Approved Final Digital Data

Final approved data of the two survey areas was delivered on 30 November 2015. Data provided is listed in Annex A.

5.2.1 Bathymetric Data

Final approved, valid processed data for all areas has been supplied with this report as follows;

- Classified LiDAR points in LAS format (Version 1.2), reduced to SGRS2005 and GRS80 ellipsoid.
- LiDAR reflectivity GeoTiff 1km tiles and mosaic in ECW format.
- Digital Elevation Model (DEM) in ESRI binary 5m Grid format.
- Contours in 0.5m interval, ESRI Shapefile format.
- Aerial photography GeoTiff 1km tiles and mosaic in ECW format.
- Coverage tiles in ESRI Shapefile format.

5.2.2 Topographic Data

Final approved, valid processed data for all areas has been supplied with this report as follows;

- Unclassified point cloud in swath in LAS format (Version 1.2), reduced to GRS80 ellipsoid.
- Classified LiDAR points in LAS format (Version 1.2), reduced to SGRS2005 and GRS80 ellipsoid.
- LiDAR intensity tiles Geotiff and mosaic in ECW format.
- Digital Surface Model (DSM) in ESRI binary 1m Grid format.
- Digital Elevation Model (DEM) in ESRI binary 1m Grid format.
- Canopy Height Model (CHM) in ESRI binary 2m Grid format.
- Foliage Cover Model (FCM) in ESRI binary 10m Grid format.
- Contours in 0.5m interval, ESRI Shape format (1 km Tiles).
- Aerial photography Geotiff tiles (1km) and ECW mosaic format.

5.2.3 Additional Data:

The following additional datasets are provided with this report.

- Topo-Bathy difference model in ESRI binary 5m Grid format
- Seamless Digital Elevation Model (DEM) in ESRI binary 5m Grid format
- Seamless contours in 0.5m interval, ESRI Shape format (1 km Tiles)
- Flight Trajectories are supplied in ESRI Shapefile format.
- Survey Marks are supplied in ESRI Shapefile format.
- Survey Mark photos are supplied in JPEG format.
- Metadata statements are supplied in XML format.

5.3 Report Deliveries

The following documentation is also provided:

- A digital copy of the Report of Survey – PDF Format

Annex A. Deliverables

A.1 Interim Deliverables

A.1.1 Interim Data Delivery

Coverage Image of survey areas on 5 August 2015 in PDF format.

File Name	Remarks
Mk3_780_prelimCov_Samoa_05Aug2015_C.pdf	PDF Document

A.2 Approved Final Data Delivery

Final Data delivery on 30 November 2015.

A.2.1 Digital Data Deliverables

A.2.1.1 Bathymetric Data

Final approved, valid processed data for all areas has been supplied as follows;

- Classified LiDAR points in LAS format (Version 1.2), reduced to SGRS2005 and GRS80 ellipsoid.
- LiDAR reflectivity tiles as geotif and mosaic in ECW format.
- Digital Elevation Model tiles and mosaics in Esri Grid format for both bathymetry and seamless datasets.
- Contours in Esri Shape File format for both bathymetry and seamless datasets.
- Aerial photography mosaic in ECW format.
- Bathymetry Coverage tiles for 5m topographic to 30m bathymetric contour in Esri Shape File format.

File Name	Remarks
ProjectNameYYYY-CL-DAT_xxxyyyy_zzz_wwww_hhhh.las *SavaiiLidar2015-C2-ELL_3028504_02S_0001_0001.las* *UpoluLidar2015-C2-MSL_3748468_02S_0001_0001.las*	LiDAR classified point cloud
ProjectNameYYYY-INT-GSD_xxxyyyy_zz_wwww_hhhh.ecw *SavaiiLidar2015-INT-001_3028468_02S_0076_0048.ecw*	Intensity mosaic ECW and tiled geotiff at 1m and 5m resolution

UpoluLidar2015-INT-005_3748443_02S_0085_0040.ecw *SavaiiLidar2015-INT-001_3038504_02S_0001_0001.tif* *UpoluLidar2015-INT-005_3748468_02S_0001_0001.tif*	
Txxxyyyyssppp *b374846801005*	Bathymetry Tiled UTM ESRI GRIDS
Txxxxxxxyyppp *bSavaii15005* *bUpolu15005*	Bathymetry Mosaic UTM ESRI GRIDS
ProjectNameYYYY-SSSS-PPPP_xxxyyyy_zzz_wwww_hhhh.shp *Savaii2015-BAT-CON_3038504_02S_0001_0001.shp* *Upolu2015-BAT-CON_3748468_02S_0001_0001.shp*	Tiled 0.5m interval contour Esri Shape Files
SavaiiCovStats50m.shp *UpoluCovStats50m.shp*	50m cell coverage statistics Shape File
ProjectNameYYYY-SSSS-PPPP-GSD_xxxyyyy_zz_wwww_hhhh.shp	Other UTM Projected Files
ProjectNameYYYY-SSSS-PPPP-GSD_xxxxyyy_wwww_hhhh.shp	Other Geographic Coord Files

A.2.1.2 Topographic Data

Final approved, valid processed data for all areas has been supplied as follows;

- Unclassified point cloud in LAS format (Version 1.2) with ellipsoidal height (WGS84) by swath, 1 file per swath
- Classified LiDAR points (classes 1 to 12 for topographic Lidar with class 2 and 8 at Level 2 classification) in LAS format (Version 1.2), reduced to SGRS2005 and GRS80 ellipsoid in 1km tiles. MKP as a separate files
- LiDAR intensity tiles in Geotiff and mosaic in ECW format.
- Digital Surface Model in ESRI binary 32 bit floating point 1m Grid format, orthometric heights, 1km tiles and overall mosaic for each island.
- Digital Elevation Model in ESRI binary 32 bit floating point 1m Grid format, 1km tiles and overall mosaic for each island
- Canopy Height Model in ESRI binary 32 bit floating point 2m Grid format 1km tiles and overall mosaic for each island.
- Foliage Cover Model in in ESRI binary 32 bit floating point 10m Grid format 1km tiles and overall mosaic for each island.
- Contours 0.5m interval in ESRI Shape format in 1km tiles.

- Aerial photography tiles in geotiff and mosaic in ECW format for the extent of the Lidar and Bathymetric survey. An overall ecw without satellite data is also provided for distribution without restrictions.

File Name	Remarks
SavaiiLidar2015-UNC-ELL-30001_02.las *UpoluLidar2015-UNC-ELL-30339_02.las*	Lidar Unclassified Point cloud ELL in swath
ProjectNameYYYY-CL-DAT_xxxyyyy_zzz_wwww_hhhh.las *SavaiiLidar2015-C2-MSL_3038504_02S_0001_0001.las* *UpoluLidar2015-C2-MSL_3748468_02S_0001_0001.las*	LiDAR classified point cloud – MSL in 1km tiles
SavaiiLidar2015-C2-ELL_3038504_02S_0001_0001.las *UpoluLidar2015-C2-ELL_3748468_02S_0001_0001.las*	LiDAR classified point cloud – ELL in 1km tiles
ProjectNameYYYY-CL—MKP-DAT_xxxyyyy_zzz_wwww_hhhh.las *SavaiiLidar2015-C2-MKP-MSL_3038504_02S_0001_0001.las* *UpoluLidar2015-C2-MKP-MSL_3748468_02S_0001_0001.las*	LiDAR MKP – MSL in 1km tiles
SavaiiLidar2015-C2-MKP-ELL_3038504_02S_0001_0001.las *UpoluLidar2015-C2-MKP-ELL_3748468_02S_0001_0001.las*	LiDAR MKP – ELL in 1km tiles
ProjectNameYYYY-INT-GSD_xxxyyyy_zz_wwww_hhhh.tif *Example for Savaii* *SavaiiLidar2015-INT-1000_3038504_02S_0001_0001.tif* *SavaiiLidar2015-INT-1000_3038504_02S_0001_0001.tfw* *SavaiiLidar2015-INT-1000_3038504_02S_0001_0001.tab* *SavaiiLidar2015-INT-1000_3038504_02S_0001_0001.prj* *SavaiiLidar2015-INT-1000_3038504_02S_0001_0001.ers* *Example for Upolu* *UpoluLidar2015-INT-1000_3748468_02_0001_0001.tif* *UpoluLidar2015-INT-1000_3748468_02_0001_0001.tfw* *UpoluLidar2015-INT-1000_3748468_02_0001_0001.tab* *UpoluLidar2015-INT-1000_3748468_02_0001_0001.prj* *UpoluLidar2015-INT-1000_3748468_02_0001_0001.ers*	Intensity imagery in 1km tiles 1m resolution, Geotiff and associated tfw,tab,prj,ers files
Example for Savaii *SavaiiLidar2015-INT-1000_Overall.ecw* *SavaiiLidar2015-INT-1000_Overall.eww*	Intensity imagery overall file for each island 1m resolution, ECW 5: compression and associated eww,ers,prj,tab files

SavaiiLidar2015-INT-1000_Overall.ers *SavaiiLidar2015-INT-1000_Overall.prj* *SavaiiLidar2015-INT-1000_Overall.tab* *Example for Upolu* *UpoluLidar2015-INT-1000_Overall.ecw* *UpoluLidar2015-INT-1000_Overall.eww* *UpoluLidar2015-INT-1000_Overall.ers* *UpoluLidar2015-INT-1000_Overall.prj* *UpoluLidar2015-INT-1000_Overall.tab*	
txxxyyyyssppp *s303850401001*	DSM Tiled UTM ESRI GRIDS
txxxxxxxyyppp *sSavaii15001* *sUpolu15001*	DSM Mosaic UTM ESRI GRIDS
c335848501002	Canopy model CHM Tiled UTM ESRI GRIDS
cSavaii15002 *cUpolu15002*	Canopy model CHM Mosaic UTM ESRI GRIDS
f335848501010	Foliage Coverage model FCM Tiled UTM ESRI GRIDS
fSavaii15010 *fUpolu15010*	Foliage Coverage model FCM mosaic UTM ESRI GRIDS
SavaiiLidar2015-RGB-200_3038504_02S_0001_0001.tif *SavaiiLidar2015-RGB-200_3038504_02S_0001_0001.tfw* *SavaiiLidar2015-RGB-200_3038504_02S_0001_0001.tab* *SavaiiLidar2015-RGB-200_3038504_02S_0001_0001.prj* *SavaiiLidar2015-RGB-200_3038504_02S_0001_0001.ers*	20cm GSD orthomosaic RGB 8 bit in 1km tiles in geotiff and associated world files
SavaiiLidar2015-RGB-200_Overall.ecw *SavaiiLidar2015-RGB-200_Overall.eww* *SavaiiLidar2015-RGB-200_Overall.ers* *SavaiiLidar2015-RGB-200_Overall.prj* *SavaiiLidar2015-RGB-200_Overall.tab*	20cm GSD orthomosaic RGB 8 bit overall ecw and associated world files
ProjectNameYYYY-SSSS-PPPP-GSD_xxxyyyy_zz_wwww_hhhh.shp	Other UTM Projected Files

ProjectNameYYYY-SSSS-PPPP-GSD_xxxxyyy_wwww_hhhh.shp	Other Geographic Coord Files

A.2.1.3 Additional Data

The following additional datasets are provided;

- Topo-Bathy difference model in Grid format
- Seamless DEM mosaic in Grid format
- Seamless contours mosaic in Shape format
- Flight Trajectories are supplied in Shape format.
- Survey Marks are supplied in Shape format.
- Survey Mark photos are supplied in JPEG format.
- Metadata statements are supplied in XML format.

File Name	Remarks
.xml	Metadata Statements
MarkName_bearing.jpg	Survey Mark Photos
txxxyyyyssppp *m374846801005* *d374846801005*	Tiled UTM ESRI GRIDS where "m" indicates seamless merged data and "d" indicates difference DEM
txxxxxxxyyppp *mSavaii15005* *dSavaii15005* *mUpolu15005* *dSavaii15005*	Mosaic UTM ESRI GRIDS where "m" indicates seamless merged data and "d" indicates difference DEM
ProjectNameYYYY-SSSS-PPPP_xxxyyyy_zzz_wwww_hhhh.shp *Savaii2015-MIX-CON_3038504_02S_0001_0001.shp* *Upolu2015-MIX-CON_3748468_02S_0001_0001.shp*	Tiled Seamless 0.5m interval contour Esri Shape Files
ProjectName-Sensor_YYYY_Trajectories *Samoa-LADS_Mk3_2015_Trajectories.shp* *Upolu-Riegl820_2015_Trajectories.shp*	Flight line trajectory Shape Files
ProjectNameYYYY-SSSS-PPPP-GSD_xxxyyyy_zz_wwww_hhhh.shp	Other UTM Projected Files

ProjectNameYYYY-SSSS-PPPP-GSD_xxxxyyy_wwww_hhhh.shp	Other Geographic Coord Files
ProjectNameYYYY-Tile_Index-Description_wwww_hhhh.shp	Various tile index files

A.2.1.4 Report of Survey

Report of Survey is provided in PDF format.

File Name	Remarks
Samoa_LiDAR_2015_RoS.pdf	Report of Survey

Annex B. Fugro LADS Mk 3 Digital Surveying System

The Fugro LADS Mk 3 hydrographic survey system comprises two main sub-systems: the Airborne System (AS) used for acquiring raw bathymetric data, and the Ground System (GS) which is used to plan operations, calculate depth values from the raw data, provide tools which allow the hydrographic surveyor to validate processed depth values, apply tidal corrections, generate fairsheets and digital survey data and conduct general survey management. Other tools required for quality control activities, in particular contouring and 3-D visualisation software complement these two sub-systems. GNSS logging and data processing hardware and software are also provided.

All sounding data is acquired by the AS which was mounted in a Beech 65-A90-4 (U-21H) owned by Dynamic Aviation and registered N96Y, fixed wing aircraft for the deployment.

The GS software is supported by the UNIX operating system and operates on a laptop personal computer.

Prior to a sortie, planning information is passed from the GS to the AS on USB Flash drive. During the sortie, logged raw sounding, position and airborne system data are logged onto a Secure Disk (SD) card. This is processed on the GS at the completion of each sortie.

The primary Quality Control tools used during this survey were:

- GS Tile Editor
- ArcGIS
- Global Mapper
- MicroStation TerraScan
- LASTools

Data is output from the GS in a format suitable for each particular QC tool.

Real-time GNSS/IMU positioning is accomplished with an Applanix POSAV system and post-processed using POSPac MMS GNSS/Inertial software.

B.1 Equipment

This section provides a description of the Fugro LADS Mk 3 Airborne System (AS) and the Ground System (GS).

B.1.1 Airborne System

A laser, scanner, optical system, photo-multiplier tube and conditioning electronics collect the raw sounding signal. Aircraft position information is obtained from Global Navigation Satellite Systems. Three computers, linked via an FDDI optic fibre network, control and monitor the AS operations. These computers are:

- The System Control Computer (SCC, a ToughBook Linux laptop) for operator interface, logging and overall system coordination.
- The Navigation System and Support (NSS) computer for position monitoring and control.
- The Laser Control and Acquisition (LCA) computer for control of the scanner and laser and digitisation of raw sounding data. The LCA also synchronises overall AS timing.

AS system time is synchronised with GNSS time and all data acquired for logging is appropriately time stamped at the point of acquisition then passed to the SCC to be written to SD card.

Ancillary equipment includes:

- A downward looking video camera to provide images below the aircraft and a forward looking video camera.
- A downward looking Redlake MegaPlus II ES 2020 digital camera to capture digital imagery below the aircraft.
- Systems for temperature control of equipment.
- Aircraft intercom.
- Satellite phone.

The operator interface allows the operator to monitor the quality of sounding, position and other data in order to set appropriate system parameters and control the sequence of sortie operations.

Detailed descriptions of the main AS components and their functions are given under the following headings below. Each of these components were checked by the Fugro LADS Technical Department during trials and acceptance flights conducted during March 2014, in order to achieve the requirements of the Fugro LADS Mk 3 Performance Verification Certificate (provided in Annex L).

- Sounding Equipment
- Positioning Equipment
- Sortie Control
- Ancillary Equipment
- Operator Interface

B.1.2 Sounding Equipment

Soundings in the Fugro LADS Mk 3 system are obtained by the transmission of laser pulses from the aircraft through a scanning system and detecting return signals from land, the sea surface, the water body and the seabed. The transmitting and receiving components are housed on a platform that compensates (within limits) for aircraft pitch and roll. The return signals are electronically amplified and conditioned prior to being digitised and logged.

The primary sounding components of the AS are:

- Laser. A Nd: Yag laser producing infrared energy at a wavelength of 1064nm at 1512 pulses per second of which 1296 pulses are used for sounding purposes.
- Optical Coupler. The optical coupler is used to frequency double the beam to produce green laser pulses of wavelength 532nm. The green pulses are transmitted onto the mirror of the scanner.
- Scanning System. The scanning mirror is oscillated in both the major (across track) and minor (along track) axes. The required scan pattern is generated by controlling software. A selection of possible patterns are listed in B.9, Sounding Patterns section.
- Optical Receiver. The green return signals are detected by the Green Receiver. The green return comprises energy returned from the surface, subsurface and seabed and is used to determine water depth. The green return is transmitted via the scanner into a photomultiplier tube.
- POS AV (Position and Orientation System – Air Vehicles). The POS AV combines a POS Computer System (PCS), Inertial Measurement Unit (IMU) and a Global Navigation Satellite System (GNSS). The PCS combines data from the IMU and GNSS to produce accurate measurements of the laser platform for post processing. The POS AV also reports platform roll to the LCA computer for roll compensation and provides height data.
- LCA computer. This controls the laser and scanner operations and digitises (8 bits at 500MHz) appropriate sections of the electronic green return signal along with platform attitude data and other system parameters. This digital information is passed to the System Control Computer (SCC) where it is logged to a SD Card.
- Waveform Display. This waveform display on the operator laptop presents the operator with sounding waveforms as digitised and is used by the operator to check data quality during acquisition.

B.1.3 Position Equipment

The centre of the scanning mirror is the survey reference point on the aircraft. The GNSS antenna is positioned relative to this point as described in B.7, Laybacks.

The signal from the antenna is fed to the GNSS receiver: a Trimble BD982, multi-frequency GNSS receiver used for real-time aircraft position fixing, track keeping and for computing post-processed KGNSS positions. The data from the Trimble BD982 receiver is independently logged and post-processed as described in Annex C.

The output of the real-time GNSS receiver is fed to the NSS to:

- fix aircraft position and determine ground speed
- calculate aircraft cross track error and automatically maintain track along survey lines
- provide pilot display information
- establish and maintain system UTC time.

The NSS passes the received GNSS and derived information to the SCC computer for logging.

B.2 Sortie Control

A sortie plan is generated on the GS to transfer survey information to the AS. The sortie plan contains spheroidal, grid and magnetic variation parameters and a list of survey objectives including the line number, start/end coordinates and coordinates for navigation checks. During the course of the sortie, the airborne operator amends the sequence of execution to suit local conditions and can amend the scan pattern parameters for the survey lines to suit survey requirements.

The SC computer controls the sequence of survey operations by:

- planning all required flight paths and communicating these to the NSS
- transmitting required parameters for scan patterns, aircraft altitude, etc. to the LCA
- initiating the starting and stopping of system operations, via commands sent to the LCA and NSS at specific waypoints on the run-in and run-out of survey lines.

The operator may abort and restart the sortie operations at any time and the sequence of objectives may be amended at any time. Scan patterns can be amended on all lines except the executing objective. A display of the planned survey line and received GNSS data is situated in the cockpit and used to advise the pilots of required aircraft configurations. The display provides an indication of cross track error with required and actual values for altitude and ground speed.

Aircraft turns are under pilot control assisted by the display. Aircraft altitude and speed are under pilot control, and communication between the operator and pilots is via the aircraft intercom system.

The management of survey operations can be impacted by both low cloud and high ground in the survey area. Fugro LADS Mk 3 is able to operate at different survey heights so that adequate clearances can be maintained while surveying and survey activities can continue below low cloud ceilings. Survey altitudes are available from 1200 to 3000 feet (366 to 915m). Altitudes must be constant for the duration of a survey line but may be varied from line to line by the AS operator during the course of a sortie.

During daytime operations a narrow band green filter is used to filter out other light frequencies from the photomultiplier tube. This filter has a slight attenuating effect on the laser returns, which reduces the maximum depth performance. This filter can be removed once the ambient sunlight levels drop which results in improved performance at night.

Glassy sea conditions may result in very strong green laser surface returns that can saturate the green receiver causing a loss of surface datum. The AS monitors the green surface return performance and advises the operator if green surface saturation occurs.

The laser is designed to be eye safe in accordance with the following standards:

a. ANSI Z136.1-2000 American National Standard for Safe Use of Lasers.

b. IEC 60825-1 (Edition 1.2) International Standard – Safety of Laser Products.

c. AS/NZS 2211.1 Supplement 1:1999 Australian/New Zealand Standard Laser Safety.

The laser power can be reduced by a further factor of four using a built-in attenuator. The operator may activate/deactivate the attenuator at any time.

B.3 Ancillary Equipment

A digital imagery system provides geo-referenced imagery. This system comprises of a Redlake MegaPlus II ES 2020 digital camera, a Matrox 4sight M frame grabber and a Matrox embedded computer running a Windows XP operating system. Images are taken at one-second intervals with a 1600x1200 resolution and a 2-megapixel interline-transfer camera head and controller. At the end of each sortie, the images are copied to the GS using a removable compact flash card.

A video camera is positioned on the platform and directed downward at nadir. It is presented to the operator and recorded throughout the sortie. A forward-looking video camera is also provided to assist the AS operator for the purpose of evaluating the conditions ahead of the aircraft.

B.4 Operator Interface

The operator monitors and controls system operation from the console. The following key information is provided to monitor system performance:

- Sortie Information. The Sortie ID, spheroid and grid in use and available survey objectives are displayed. Sortie objective information includes the scan pattern set for the objective and estimated time to complete the objective.

- Objective Information. The Objective ID, selected scan pattern, required speed and altitude pertaining to the current objective being executed and objective status such as time to completion are presented.

- Waveform Display. This display is on the operator laptop which displays the green sounding return signals as digitised by the LCA. The operator continually assesses this display to determine data quality.

- Depth Profile. A depth profile determined from nadir soundings is available to the operator with an associated confidence factor. As the algorithm is limited by real-time considerations these depths and confidences are indicative only.

- Aircraft Position, Speed, Altitude and Cross Track Error. A number of displays including a copy of the pilot display are available to the operator to determine the aircraft position and performance parameters. Speed and altitude are continually monitored and the pilot informed of deviations from the desired values.

- GNSS status. The operator is provided with the data from the GNSS receiver including number of satellites, satellite altitudes and azimuths, S/N ratio and which satellites are being used.
- Equipment Status. System status and performance parameters are available to the operator including laser power and temperature, dynamic gain values, IMU status and scanner performance.

Items controlled by the operator for sortie execution and data acquisition are:

- sequence of objective execution
- scan pattern for each objective
- operating height for each objective
- depth logging range and topographic height range for each objective
- dynamic gain limits
- green receiver attenuator positions

B.5 Depth and Topographic mode

During normal bathymetric survey mode (Depth Mode) Fugro LADS Mk 3 determines the depth of water with the height datum being determined from the reflected green surface laser signal, GNSS height and IMU height. When over land this green surface signal is not valid and the height datum is obtained from the GNSS and IMU.

This ancillary height datum allows Fugro LADS Mk 3 to measure topographic heights. The topographic height range is dependent on the depth range being used.

B.6 Fugro LADS Mk 3 aircraft and system specifications

Aircraft Type	Beech 65-A90-4 (U-21H) aircraft
Aircraft Modifications	Two laser bay windows for LADS and RIEGL systems
Transit Cruise Speed	160 knots (max 200 knots)
Transit Altitude	To 26000ft
Survey Speed	Dependant on Scan Pattern: Nominal 140 – 210 knots (72-108 metres per second)
Survey Height	1200 to 3000ft (366 to 915m) in 100 ft increments up to 2200ft and 400 ft increments thereafter.
Survey Track-Keeping	+/- 5 metres (manual flying)
Survey Endurance	4.5 hours nominal
Operational Capability	Day/Night operation
Depth Sounding Rate	1512 soundings per second
Swath Width	Dependant on Scan Pattern: Nominal 71 – 600m (independent of aircraft height and water depth)
Scan Pattern	Rectilinear
Sounding Density	Variable: 8x5m, 7x5m, 6x5m, 6x6m, 5x5m, 4.5x4.5m, 4x4m, 3x3m, 2.5x2.5m and 2x2m
Soundings per sq km	Dependant on scan pattern. For 4x4m – 72000/ km^2 (assuming 51m overlap)
Soundings per hour	Up to 5 million
Topographic and Depth Range	-50m (topo) to 80m (depth)
Area Coverage	Dependant on scan pattern. For 4x4m – up to 48.8km^2/hour (14.2sq nm/hr) assuming 51m overlap
Position Fixing	Differential GNSS and post-processed dual frequency KGNSS
Recording Media	SD card, PCMCIA card, compact flash card
Digital Camera	Image Area at 1500ft operating altitude: ~330m x 250m. Image Resolution: >4 pixels/m at an altitude of 1600ft. Digital Image Capture Rate: 1 per second. Digital Image Horizontal Accuracy: +/-5m (95% confidence)

B.7 Laybacks

All laybacks are measured relative to the survey reference position on the aircraft which is the centre of the scanning mirror. The GNSS antenna used for position determination in the AS is positioned on the upper side of the aircraft fuselage aft and to the right (facing forward) of the sounding reference position. The signal from this antenna goes to the GNSS receiver in the POS AV IMU and is then sent to the NSS computer.

Offsets are from the sounding reference point to the antenna with the following axis and sign convention assuming the aircraft is level:

X positive toward the nose of the aircraft

Y positive to the left facing forward

Z positive vertically up

The offsets in the GS are:

X offset: - 0.117m

Y offset: - 0.017m

Z offset: + 1.396m

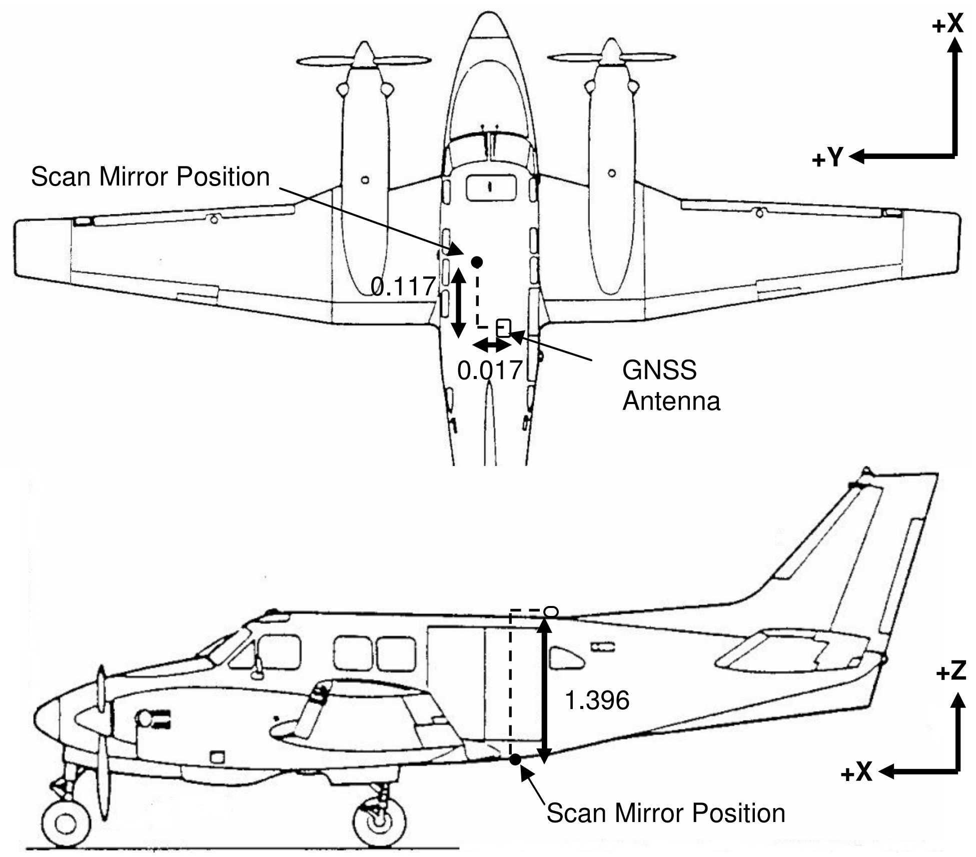

Figure 1 – Laybacks

B.8 Logging parameters

B.8.1 Position fixing

The Airborne System obtains a position fix six times each second.

B.8.2 Navigation update

While executing a survey line under AS control navigation correction is passed to the aircraft autopilot every 0.5 seconds, if fitted.

B.8.3 Post-Processed GNSS

The GNSS airborne and base logging stations log position information from GNSS satellites at 0.2 and 1 second intervals respectively.

B.8.4 Sounding rates

Fugro LADS Mk 3 obtains depth soundings in a rectilinear pattern where the sounding density is variable (see Table 1) but sounding rate is invariant.

For all sounding patterns the soundings are grouped into one second frames made up of 18 scan lines. Each of the 18 scan lines contain 74 laser pulses, of which 72 pulses are used for depth sounding. The outermost laser pulses are not used for depth sounding. This provides an effective sounding rate of 1296 soundings per second.

B.9 Sounding Patterns

Fugro LADS Mk 3 has variable scan pattern functionality as detailed in the following table. The 4x4 and 4ax4a patterns both provide 4x4 metre spot density but have different swath width and survey speeds. Most patterns are available at each of the operational altitudes (1200–3000ft at 100ft increments up to 2200ft and 400ft increments thereafter). A selection of the available sounding patterns is displayed below;

Sounding Density (m)	Swath Width (m)	Line Spacing 200% Coverage (10m Overlap) (m)	Line Spacing 100% Coverage (20m Overlap) (m)	Survey Speed m/sec (kts)
8x5	585	288	565	90 (175)
5x5	360	175	340	90 (175)
4.5x4.5	324	157	304	64 (125)
4x4	288	139	268	72 (140)
4ax4a	227	109	207	90 (175)
3x3	151	71	131	77 (150)
2.5x2.5	125	58	105	72 (140)
2x2	80	35	60	64 (125)

Table 1 – Scan configuration

B.10 Ground System

The Ground System provides the facilities for all LADS survey management tasks from initial mission planning through to production of fairsheets and deliverable digital data.

The primary functions of the GS are:

- Mission planning. This includes the specification of the total survey area, spheroid and grid, survey sub-areas, line spacing, swath widths, survey lines to cover the sub-area, individual survey lines, cross lines, tidal areas and navigation check points.
- Sortie planning. A sortie plan is the specification of a series of survey objectives to be executed by the AS. Survey lines and navigation check objectives are selected by the operator and written to file along with grid and spheroidal information.
- Sortie processing. This function calculates sounding depths and positions from the raw sounding data logged by the AS. Depths and positions are associated with various confidence metrics.
- Data validation, checking and approval. Surveyors validate the calculated soundings on a run by run basis editing soundings as appropriate. The validated data is checked by a more senior surveyor and finally approved by an IHO Category A qualified hydrographic surveyor.
- Data output. Approved data is output to the client in digital form along with hardcopy fair sheets.

In addition, the GS provides facilities for the generation of survey management plots and reports.

B.10.1 Mission Planning

At the commencement of a survey one or more databases are established on the GS. Each database contains spheroid and grid data, tide data and survey objectives.

Sub-areas are defined covering the specific areas to be surveyed. Survey lines are then generated within each sub-area at an operator specified line spacing. Other survey lines can be specified by entering start and end coordinates.

B.10.2 Sortie Planning

Prior to each sortie survey objectives are selected from the appropriate database. The start and end coordinates of the required survey lines are written, together with spheroid and grid data, to a sortie plan on a USB disk. This plan is read by the AS and used to control sortie operations.

B.10.3 Data Processing

Processing parameters suitable for the sortie are set prior to processing. The post-processed KGNSS positions from the local GNSS base station are applied to the data.

Raw sounding data logged by the AS is automatically processed by the GS to produce depth, position and a series of confidence parameters.

Preliminary tides are applied and final verified tides can be reapplied at a later time.

On completion of automatic line processing; operator validation, checking and approval of the sounding data can be conducted.

B.10.4 Data Organisation

Data within the GS database is held on a line by line basis. Within lines, data is grouped into one second frames made up of 18 scans of 72 sounding pulses i.e. 1296 pulses per frame. (The outer two laser pulses are not used for sounding purposes).

B.10.5 Primary and Secondary Soundings

All soundings comprise the primary sounding set. Where data set reduction is required a shoal biased subset of the primary soundings called secondary soundings is created. Secondary soundings form a shoal biased sub-set based on operator selected confidence and secondary selection radius criteria. Only secondary soundings are validated, checked, approved and output. For this survey a secondary sounding reduction radial of one metre has been used which means all soundings have been hydrographically reviewed and all valid soundings have been provided in the final data set.

B.10.6 Automatic Data Processing

Automatic processing is completed in two stages:

1. Sortie Data Processing (SDP). SDP reads the data on the digital file and stores it in the internal GS database for further processing. The data is line based, and consists of raw waveform data, platform data, navigation data, system data, and error and event logs.
2. Sortie Run Processing (SRP). SRP is the second and major processing phase during which sounding depths and positions are calculated on a line by line basis. The process is normally triggered automatically by SDP as each line becomes available, but may be invoked later by the operator if reprocessing of lines with different processing parameters is required.

The major processing steps of SRP are:

- Apply post-processed KGNSS positions to the raw data and digital images from the downward looking camera.
- Process the Raw Waveform to identify surface reflections.
- Process the Raw Waveform to identify and calculate initial depths for the two most likely bottom return pulses.
- Classify each of the identified bottom return pulses by signal noise ratio, agreement with near neighbours and a maximum likelihood estimator.
- Select the most likely bottom return pulse based on the above classification and a shoal weighting function.
- Model the sea surface from the available surface pulses.
- Correct the bottom depths for sea surface datum including tide, slant range, optical propagation and early/late entry. Tidal corrections may be reapplied later if required.
- Calculate position of each sounding on the seabed. This algorithm uses corrected GNSS fixes, aircraft track and speed, antenna offsets, platform attitude (heading, roll and pitch), beam scan angles and sounding depth. Where the GS is unable to determine a depth from the raw data the sounding is classified as “No Bottom Detected” (NBD).

- Calculate primary confidence indices (0-9) for each non-NBD sounding and all frames where:

  C0 = Subsurface Pulse Confidence (signal to noise)

  C1 = Near Neighbour Confidence

  C2 = Pulse Type Confidence

  C3 = Position Confidence

  C4 = Sea Surface Reference Confidence

  C5 = Not Used

  C6 = Coverage Confidence (confidence that the swath covered the planned width)

  CW = Weighted Primary Confidence

- Store each sounding and associated confidence data in the database.

B.10.7 Bottom Object Detection (BOD)

A particular feature in the SRP improves the ability of the Fugro LADS Mk 3 GS to detect small objects on the seabed.

The BOD algorithm proceeds in two phases, each phase can be independently enabled/disabled and tuned via a series of BOD processing parameters set by the operator prior to SRP processing.

Phase one of the algorithm is designed to detect objects 2-3m in height while phase two is only invoked if phase one fails. Phase two is more sensitive and intended to find objects less than 2m in height.

B.10.8 Line Reprocessing and Segmentation

It may be necessary to reprocess the same raw sounding data with different processing parameters. The run identification scheme adopted in Fugro LADS Mk 3 provides a mechanism to manage the reprocessing of survey line data a number of times.

After a line is reprocessed the required segment can then be set to accepted, and the remaining data can be set to anomalous or rejected and is therefore ignored by the system.

B.11 Quality Control

B.11.1 Data Processing

Data processing involves the following stages:

- Automatic Data Processing, described earlier
- Pre-Validation and initial batch and filter cleaning of the data by survey personnel under the supervision of the senior hydrographic surveyor
- Validation of the data
- Checking of the data by a Hydrographic Surveyor / Degree Surveyor
- Visualisation of the data
- Approval of the data

B.11.2 Validation

Validation proceeds through the following steps:

- Examining the Depth Profile for the correct processing of each expected Survey Run.
- Examining a range of position, coverage and system performance confidences to ensure only good data is accepted.
- Resolving anomalous soundings by examining data points in the Survey Run by checking:
  a. the Primary Depth Display
  b. the Waterfall Display
  c. the Waveform Display
  d. the Local Area Display
- Editing operations include selection of the alternate depth, assignment of NBA or deletion of the sounding as appropriate.

Based on assessments made in the above steps the operator segments the line classifying each segment as:

a. Accepted

b. Anomalous, (data not to be used)

c. Rejected, (for refly)

All operator interactions during the validation phase are logged so that complete traceability is maintained.

The imagery, collected by the downward-looking digital camera in real-time, is processed along with the raw data. These images are geo-referenced and can be either manually or automatically displayed alongside of the Raw Data Display, the Waveform Display or the Local Area Display. The images are automatically rotated to fit the current display and are used during all phases of data processing.

These images are displayed in the GS Digital Image Window on the second dual screen monitor. This display is automatically linked to all of the GS displays mentioned previously and the selected sounding is highlighted in the downward-looking image with a yellow circle of 5m diameter.

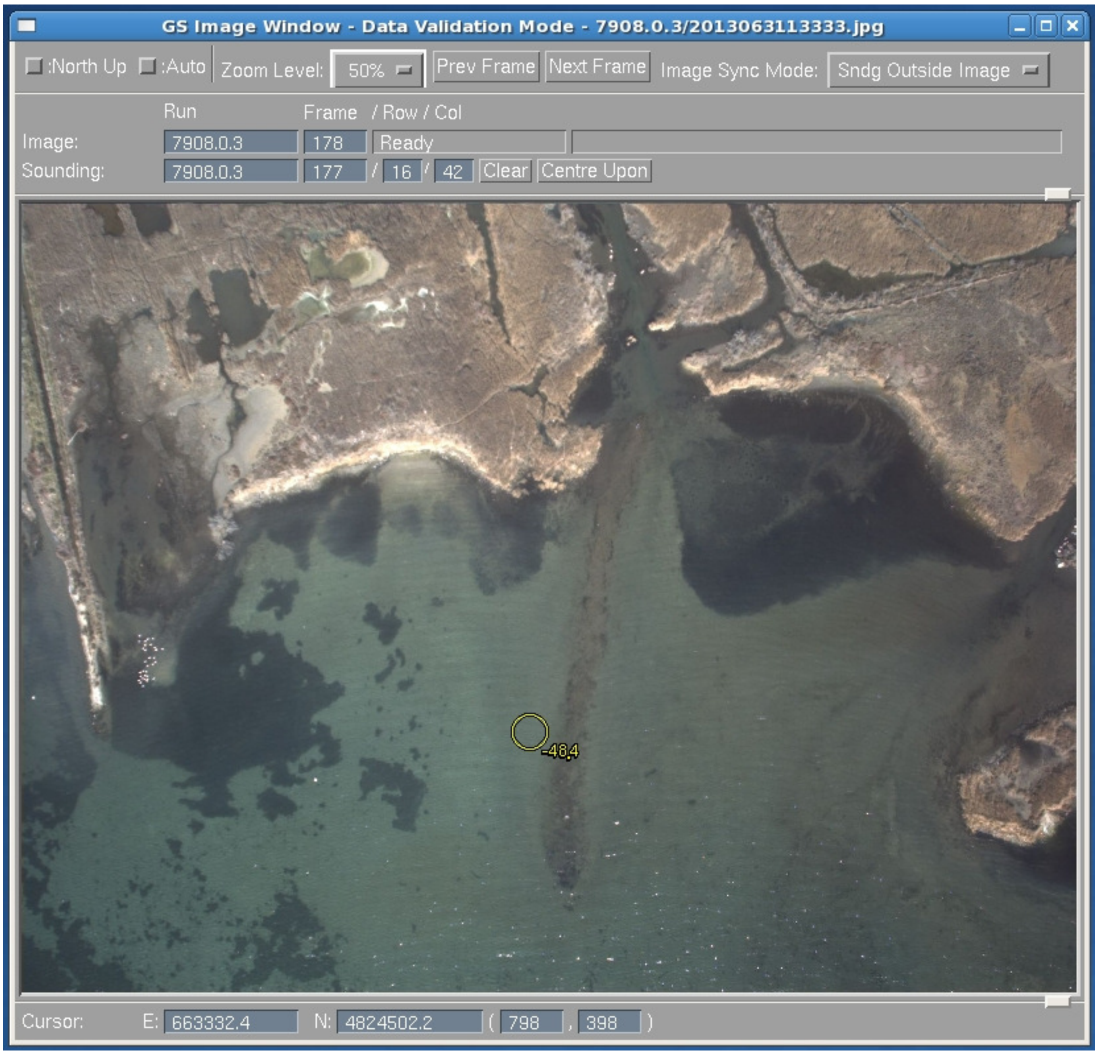

Figure 2

The GS Digital Image Window enables the operator to easily correlate features such as coastline, islands, islets, drying rocks, rocks awash, shallow rocks, kelp, beacons, buoys, boats, jetties, buildings and trees in the image with the data presented in the different GS displays. The quality of imagery and zoom functionality of the window even enables discernment of biological data artefacts, such as bird strikes and fish / whale returns.

B.11.3 Checking

When a line has been validated it is passed to a checker. All edits made by the validator are marked on the line and logged in a validation log. The checker independently assesses the line and checks the validation edits.

B.11.4 Data Visualisation

All validated, checked and approved data can be displayed in the Mission Display within the GS to assess coverage obtained in a survey area and depth differences between lines. The data can also be QC'ed using the GS Tile Editor tool within the Mission Display. This tool displays the data in pre-defined tiles of up to 2x2km, as opposed to single lines, from which edits can be performed. The data can be viewed in slices enabling accepting or rejecting of the data as required. Data lassoing and swapping functions are available to the operator for editing soundings. The Tile Editor includes a slice view, a waveform view, a top view and a grid stats view for checking datum consistency between overlapping data. Anomalies found in the tile editor data are reported back to the checkers for remedial action in the GS.

A number of software packages, other than the GS Tile Editor, are used to produce QC products namely:

- Fledermaus
- CARIS
- LASTools
- ArcGIS
- Global Mapper
- MicroStation TerraScan

B.11.5 Approval

In the final phase, an IHO Category A qualified Hydrographic Surveyor reviews each line and approves the data for delivery. All actions in validation, checking and approval are logged on appropriate forms and the procedures used have been certified as conforming to ISO-9001 Quality Assurance standards.

B.11.6 Audit Trail

All actions in validation, checking and approval are logged on appropriate forms and the procedures used have been certified as conforming to ISO-9001 Quality Assurance standards. In addition, all operator actions are logged by the GS.

B.11.7 Tagging of Soundings in the GS

During data processing on the GS, the operators have the ability to assign S-57 and user-defined tags to gaps and features in the data. This enables accurate delineation and attribution of features using the S-57 feature file.

All actions in validation, checking and approval are logged on appropriate forms and the procedures used have been certified as conforming to ISO-9001 Quality Assurance standards. In addition, all operator actions are logged by the GS.

B.11.8 Database Management and Survey Line Identification

15_4samoa Run Numbers	Density (m)	Remarks
1	5x5	TIP line
50 – 87	5x5	Cross-lines
100 – 106	5x5	Sub Area 1 Main-lines (100% spacing)
200 – 214	5x5	Sub Area 2 Main-lines (100% spacing)
300 – 304	5x5	Sub Area 3 Main-lines (100% spacing)
400 – 403	5x5	Sub Area 4 Main-lines (100% spacing)
500 – 520	5x5	Sub Area 5 Main-lines (100% spacing)
600 – 616	5x5	Sub Area 6 Main-lines (100% spacing)
700 – 709	5x5	Sub Area 7 Main-lines (100% spacing)
800 – 810	5x5	Sub Area 8 Main-lines (100% spacing)
900 – 910	5x5	Sub Area 9 Main-lines (100% spacing)
1000 – 1017	5x5	Sub Area 10 Main-lines (100% spacing)
1100 – 1118	5x5	Sub Area 11 Main-lines (100% spacing)
1200 – 1208	5x5	Sub Area 12 Main-lines (100% spacing)
1300 – 1304	5x5	Sub Area 13 Main-lines (100% spacing)
1400 – 1408	5x5	Sub Area 14 Main-lines (100% spacing)
1500 – 1504	5x5	Sub Area 15 Main-lines (100% spacing)
1600 – 1614	5x5	Sub Area 16 Main-lines (100% spacing)
1700 – 1702	5x5	Sub Area 17 Main-lines (100% spacing)
1800 – 1810	5x5	Sub Area 18 Main-lines (100% spacing)
1900 - 1905	5x5	Sub Area 19 Main-lines (100% spacing)
2000 - 2019	4x4	P4_1400 Main-lines over SA 16 (100% spacing)
2100 - 2126	4x4	P4_1400 Main-lines over SA 5 (100% spacing)
2200 - 2221	4x4	P4_1400 Main-lines over SA 6 (100% spacing)
5000 - 5036	5x5	Coverage-lines

Table 2 - Database line planning and numbering

B.11.9 Line Identifiers

Line identifiers within the Fugro LADS Mk 3 system uniquely define a specific line and are made up of 4 fields separated with a point '.' as follows:

(Items in <> are the generic names for the fields.)

<LineNumber>.<Section>.<Sequence>.<Child>

e.g. 230.1.2.3

Maximum fields are 9999.99.99.9

LineNumber – Range 1..9999
This field uniquely defines the line and is chosen by the operator when defining a line.

Section - Range 0..99
This field denotes the section of the line.

Zero indicates the whole original line. When the line or part of the line is reflown the section number is incremented. Thus:

- 230.0.x.x is the original line
- 230.1.x.x is the first refly
- 230.2.x.x is the second refly.

Sequence - Range 1..99

This field denotes the number of times the logged data for the specific <LineNumber>.<Section> has been processed. Each time a line is processed by the Sortie Run Process (SRP) function the GS allocates a new sequence number for the line. Therefore:

- 230.0.1.x is the first processing of the original line
- 230.0.2.x is the second processing of the original line
- 230.1.1.x is the first processing of the first refly
- 230.1.2.x is the second processing of the first refly.

Child - Range 1..9
This field denotes the segment (or child section) of a <LineNumber> .<Section>.<Sequence>.

Hydrographic surveyors divide lines into ACCEPTED, REJECTED or ANOMALOUS segments during the Line Validation process; these segments are given sequential child numbers. Thus:

230.0.1.1 - is the first child (segment) of the first processing of the original line. This provides the mechanism of ensuring only ACCEPTED data is output for products.

B.11.10 Software Versions

The following software versions (final) were used during survey operations.

System	Version	Remarks
Airborne System	AS 1.7.3	Final Version
Airborne System Real-Time PPP GNSS Receiving System	4.21	Fugro Marinestar GNSS Service using Trimble BD982 within Applanix POSAV Controller
GNSS Airborne Receiver	5.0	Trimble BD982 within Applanix POSAV Controller
GNSS Processing	7.1	Applanix POSPac MMS / POSGNSS
Ground System	A.1.48.2	Final Version
Visualisation and QC	A.1.48.2	GS Tile Editor
	A.1.2.3	Mosaic Build Tool
	10.61	Terramodel
	7.3.3	Fledermaus
	10.1	ArcGIS
	8.11.9.357	MicroStation V8i
	012.006	TerraScan
	15.2	Global Mapper
	150406	LASTools

Table 3 – Software versions

B.11.11 Processing Parameters

Each survey line is processed with a specific set of technical and survey processing parameters, with the set used for each line stored in the GS database. Full details are available in the GS database.

B.12 Data output

B.12.1 Data Formats

The data is delivered in LAS v1.2 format. All files have been written to USB Hard Drives. Specifications for each data format are enclosed within.

B.12.2 File Naming Conventions

All file prefixes are named using the following convention:

<AreaId> : 3 alphanumeric characters field specifying the specific project.

<SoundingDensity > : 1 numeric character specifying the sounding density – one of 2,3,4,5,6.

e.g. 5 indicates 5 x 5 metre spot spacing.

<ClashStatus> : 1 alphanumeric character from C (clashed), U (unclashed).

<%Coverage > : 1 numeric character indicating percentage coverage in flown lines.

e.g. 1 indicates 100%, 2 indicates 200% etc.

<ExportType> : 1 alpha characters indicating purpose of export. Delivered files will have one of I (interim delivery), F (Final delivery), or S (Fairsheet data).

<SheetNumber> : 2-3 alpha numeric characters indicating sheet number.

e.g. 01 indicates Sheet 1

Note: ALL indicates an ALL area export.

<_Version> : 2-3 symbolic/numeric character specifying export version.

e.g. _01 indicates version 1, _2 indicates version 2.

<Extension> : .XYZ for ASCII x,y,z (Eastings, Northings, Depth) files.

For example, the standard prefix for data for the Samoa survey, surveyed at 5x5 metre spot spacing, unclashed, at 100% coverage, interim export of sheet 1, version 1, the file name would be:

SWP5U1I01_01.LAS

Enclosure:

1. Specification for LADS Mk 3 LAS Export Format

Enclosure 1 - Specification for LADS Mk 3 LAS Export Format

FUGRO LADS CORPORATION PTY LTD

LAS EXPORT FORMAT

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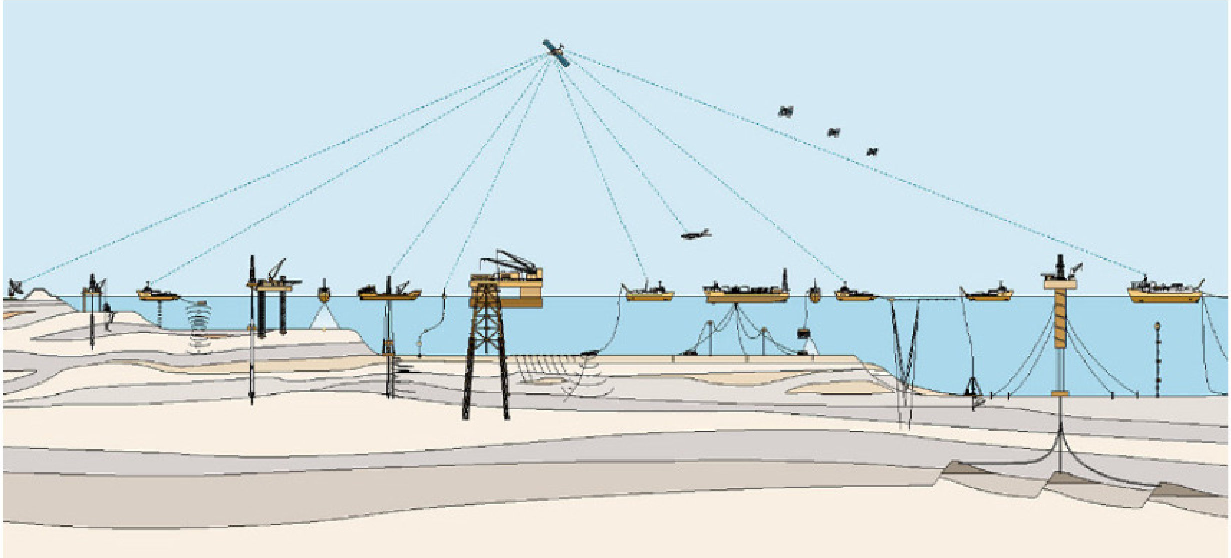

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Page Number	Issue Status	Page Number	Issue Status
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1. Introduction

1.1 Purpose

The purpose of this document is to specify the format of the deliverable files of the LAS Export Format, as produced by the LADS Mk II Ground System, and compatible with LAS Specification Version 1.2 as approved by ASRPS Board on 09/02/2008.

1.2 Scope

This document applies only to the description of the LAS Export Format.

1.3 Definitions, Acronyms and Abbreviations

1.3.1 Definitions

Easting & Northing	The aircraft position is expressed in metres North and East of the false origin on the Universal Transverse Mercator (UTM) Grid. This implies that a change in easting and northing represents a corresponding movement on the earth's surface expressed in metres. Note: Changes in easting and northing are related to changes in latitude and longitude via complex translation equations.
Sounding	A Sounding is the result of a single fire of the laser, and represents the depth at a particular geographic position as measured by the LADS Mk II system.
Run	A single continuous pass of data collection by the LADS aircraft.
Fairsheet	Hardcopy plot of bathymetric survey data.
Julian Day	The numerical day of the year, e.g. January 1 is day 1 and February 28 is day 59.
Secondary/Primary Soundings	Secondary soundings have been accepted by a hydrographer, whereas Primary soundings have been rejected.
No Bottom At (NBA)	These are secondary soundings where the seabed has not been detected by the Ground System, and a NBA depth has been assigned by a Hydrographic Survey Operator. The depth value assigned is the depth which, in the opinion of the HSO has been swept clear by laser, with depths less than this being detected by the system.

1.3.2 Acronyms

AS	Airborne System
CR	Carriage Return character
GPS	Global Positioning System
GS	Ground System
IGLD85	International Great Lake Datum 1985
LAS	Refers to the data file format standard know as the American society for Photogrammetry and Remote Sensing (ASPRS) Lidar Exchange Format (LAS).
LADS	Laser Airborne Depth Sounder
LAT	Lowest Astronomical Tide
LF	Line feed character
NAD83	North American Datum 1983
NAVD88	North American Vertical Datum 1988
NBA	No Bottom At
TMC	Transverse Mercator Coordinate
UTC	Universal Time Co-ordinated
UTM	Universal Transverse Mercator
MLLW	Mean Lower Low Water
WGS84	World Geodetic System 1984

1.3.3

1.4 References

LAS Specification Version 1.2

http://www.asprs.org/society/committees/standards/lidar_exchange_format.html

GeoTIFF Format Specification Version 1
http://www.remotesensing.org/geotiff/spec/geotiffhome.html

2. Format Description

2.1 Overview

The LAS Export Format follows LAS Specification Version 1.2 exporting sounding information in binary little-endian format. Georeferencing information is encoded according to GeoTIFF key tags format as developed for the GeoTIFF standard.

2.2 File Layout

2.2.1 File Contents

Each LAS Export set consists of a directory containing the following files:

1. One or more Sounding data file
2. Parameter/Option file

The Sounding data file contain the data in binary format as per LAS Specification Version 1.2

The Parameters file contains the parameters and options that were used to generate the LAS data. It is written in a free form text format, and includes the following information:

- Area Boundaries
- Export Options
- Sounding Reduction (Clash) Options
- Sounding Attribute Filter Options, used to determine the soundings that were exported
- Spheroid and Grid Information of the original and exported data
- LADS database from which the data was exported
- Time of data export
- Number of soundings exported

2.2.2 File Naming

The generated export files will be stored in export directory of the current database in subdirectory called LS1.
The LAS export file directory has a name consisting of 12 standard ASCII characters as specified by the operator.

A separate directory is created within the LAS export directory to house the tiles for each type of export carried out, consisting one or more of the following

- ellipsoid_with_overlap
- ellipsoid_no_overlap
- tidal_with_overlap
- tidal_no_overlap.

The Sounding data file name includes the following fields separated by "_" (underscore character)

1. Enclosing directory name
2. Datum specification, for example "grs80"
3. Origin of the enclosing tile as "eXXXnYYYY
   where XXX describes Easting in km of the Bottom Left corner
   YYYY describes Northing in km of the Bottom Left corner

The Sounding data files are written with ".las" extension.

The Parameters file has the same name as the name of the export directory with an extension ".PRM"

Exports written to a single file will be housed in the base LAS directory and will be named to match the export name specified by the user.

2.3 Sounding Data File Format

2.3.1 Contents

A number of parameters in Edit Export Option tableau determine the format and data quality. These parameters are set within the GS upon the export of the sounding data, and are described in the following table.

Parameters	Effects
RUN STATUS	selectable between ACCEPTED, ANOMALOUS, REJECTED, NON-REJECTED, ALL_RUNS
POINT DATA FORMAT	selectable between FORMAT_0, FORMAT_1, FORMAT_2, FORMAT_3 as per LAS Version 1.2 Spec
PERFORM CLASH OR BIN	selectable YES NO
PRODUCE PLOT	selectable YES NO
POSITION FORMAT	selectable GRID, GEO (with option BOTH not supported under LAS Spec) specifies the sounding position format
VERTICAL DATUM	selectable MLLW, IGLD85, NAVD88, NAD83, WGS84 specifies the vertical datum

These parameters will be set according to the requirements of the customer or software application to which the data is to be delivered/used.

2.3.2 Format

The LAS output file will contain binary data in a sequence of the following records:

PUBLIC HEADER BLOCK
VARAIBLE LENGTH RECORDS
POINT DATA RECORDS

Point Data may be output in 4 different Point Data Formats as described in LAS Version 1.2 Specification.

2.3.3 Data Mapping

Mapping between LAS Records and LADS derived data is described below.

2.3.3.1 Public Header Block

The following table describes mapping between Public Header Block of LAS format (page 3 of the spec) and LADS Value implemented in LAS export format.

Item	**LADS Value**
File Signature (“LASF”)	LASF
File Source ID	0
Global Encoding	0
Project ID - GUID data 1	0
Project ID - GUID data 2	0
Project ID - GUID data 3	0
Project ID - GUID data 4	00000000
Version Major	1
Version Minor	2
System Identifier	FUGRO LADS MKII
Generating Software	current GS version
File Creation Day of Year	creation JD
File Creation Year	creation Year
Header Size	calculated
Offset to point data	calculated

Item	LADS Value
Number of Variable Length Records	calculated
Point Data Format ID	user defined
Point Data Record Length	defined
Number of point records	calculated
Number of points by return	calculated
X scale factor	0.1 for GRID
Y scale factor	0.000,000,1 for GEO
Z scale factor	0.01
X offset	0.0
Y offset	0.0
Z offset	0.0
Max X	calculated
Min X	calculated
Max Y	calculated
Min Y	calculated
Max Z	70.0
Min Z	-99.99

2.3.3.2 Variable Length Records

Variable Length Records will follow GeoTIFF standard

2.3.3.3 Point Data Records

The following table describes mapping between Point Data Record of LAS format (page 7 of the spec) and LADS Value implemented in LAS export format.

Item	LADS Value
X	calculated
Y	calculated
Z	calculated
Intensity	0-255 (see Note 1)
Return Number	calculated
Number of Returns (given pulse)	calculated
Scan Direction Flag	calculated
Edge of Flight Line	calculated
Classification	0-15 (see Note 2)
Scan Angle Rank	calculated
User Data	0
Point Source ID	0
GPS Time	calculated
Red	0
Green	0
Blue	0

Note 1
Intensity data filed is populated with LADS Relative Reflectivity when required.

Note2
Classification of the data is set as follows:

1. Unclassified data has classification flag set to 0.
2. Classified data is divided in two subsets according to depth, termed 'Bathy' (for detections below the water) and Topo (for detections above the water). The depth value used to define the nominal water level is defined by the user at the time of export, relative to the export depth datum (e.g. LAT, WHS84)..
3. Classification of Bathy subset is set as follows:
   a. Seabed class 13 – all Secondary data in Accepted segments
   b. Non-seabed class 14 – all Primary data in Accepted segments
   c. Bathy Shoals class 15 – Secondary data in Accepted segments clashed at selectable radial range during the export . This is a subset of class 13 with the flag set to 15 after the clash.
4. Classification of Topo subset is set as follows:
   a. Ground class 2 – all Primary and Secondary data in Accepted segments with Multiple Topo return flags set to False
   b. Non Ground class 1– all Primary and Secondary data in Accepted segments with Multiple Topo return flags set to True

Annex C. RIEGL VQ-820-G Surveying System

The RIEGL VQ-820-G hydrographic airborne laser scanner survey system comprises of an airborne system used for acquiring raw bathymetric and topographic data and a ground system which is used to plan operations and store, back-up, manage and post process the collected data. Other tools required for quality control activities, in particular software for merging RIEGL and LADS data, complement the survey system. GNSS/IMU logging and data processing hardware and software are also provided.

The primary Quality Control tools used during this survey were Global Mapper, TerraScan (running in MicroStation) and LASTools. Data is output from the ground system software in a format suitable for each particular QC tool.

Real-time GNSS/IMU positioning is accomplished with an Applanix POS AV IMU and post-processed using Applanix POSPac MMS and Waypoint GrafNav GNSS/IMU software.

C.1 Equipment

This section provides a description of the RIEGL VQ-820-G hydrographic airborne laser scanner survey system.

C.1.1 Airborne System

The airborne system includes the following components:

- 1x VQ-820-G laser unit and scan head
- 1x Applanix POS AV 510 IMU
- 1x L1/L2 GNSS antenna
- 1x laptop / RIEGL data recorder DR680

The laser unit and scan head, which includes the laser transmitter and receiver as well as signal processing electronics, collect the raw sounding signal. Aircraft position information is obtained from Global Navigation Satellite Systems by using an L1/L2 GNSS antenna and POS AV IMU. The system’s laptop software allows the operator to monitor the quality of sounding, position and other data in order to set appropriate system parameters. The raw data is recorded on removable solid-state drives with high input and download data rates.

C.1.2 Sounding Equipment

The main technical specifications of the RIEGL VQ-820-G are provided below:

- Laser Product Classification
  - Laser Class 3B Laser Product according to IEC60825-1:2007
  - Nominal Ocular Hazard Distance (NOHD): 100 m
  - Extended Nominal Ocular Hazard Distance (ENOHD): 600 m
- Range Measurement Performance
  - Accuracy: 25 mm
  - Precision: 25 mm
  - Laser Pulse Repetition Rate: up to 520 kHz
  - Echo Signal Intensity for each target, high-resolution 16 bit intensity information is provided
  - Number of Targets per Pulse: unlimited (digitized waveform processing)
  - Laser Wavelength: green
  - Laser Beam Divergence: 1.0 mrad
  - Laser Beam Footprint: 100 mm @ 100 m, 1000 mm @ 1000 m
  - Full waveform data acquisition (@ 54KHz)
- Scanner Performance
  - Scanning Mechanism: rotating multi-facet mirror
  - Scan Pattern: section of an ellipse
  - Field of View: (selectable) 42° max. 60° (with reduced measurement range)
  - Scan Speed: (selectable) 50 - 200 scans/sec
  - Multiple-time-around (MTA) capability (until zone #3)
- General Technical Data - Scan Head and Laser Unit
  - Power Supply Input Voltage: 18 - 32 V DC
  - Current Consumption: typ. 65 W (Laser 120 W)
  - Main Dimensions 360 x 232 x 279 mm (Laser 323 x 270 x 94mm)
  - Weight approx. 16 kg (Laser 9.5kg)
  - Temperature Range +10℃ up to +40℃ (operation) / -10℃ up to +50℃ (storage)

C.1.3 Positioning Equipment

The IMU measurement point is the survey reference point on the aircraft. The GNSS antenna is positioned relative to this point as described in I.2, System Calibration.

Positioning, movement and attitude of the RIEGL VQ-820-G units system is recorded via an Applanix POS AV 510 IMU connected to an AeroAntenna Technology AERAT1675_180 L1/L2 GNSS antenna.

The main technical specifications of the Applanix POS AV 510 IMU are:

- Logging: Time tag, status, position, attitude, velocity, track and speed, dynamics, performance metrics, raw IMU data and raw GNSS data all at up to 200 Hz
- Media External: Removable 4 GB USB stick. Internal: Embedded 4 GB memory for redundant logging
- Accuracies: 0.05 – 0.3m position, 0.005 m/s velocity, 0.005° roll/pitch, 0.008° heading and 0.10°/hr drift when post-processed
- No export restrictions, not covered by ITAR

The main technical specifications of the AeroAntenna Technology AERAT1675_180 GNSS antenna are:

- Airborne Antenna – Iridium Protected
- GNSS L1 1565 -1607 MHz frequency
- GNSS L2 1217 - 1260 MHz frequency

C.1.4 Operator Interface

The RIEGL VQ-820-G laptop is a Panasonic CF-52Mk 3 Toughbook with a Linux Centos 6 operating system. RIEGL's RiACQUIRE software package is used to remote control the laser unit for configuring system parameters either semi-automatically or manually. RiACQUIRE's tasks include System Integration, Verification Testing and Operational Data Acquisition.

The raw LiDAR data is recorded on one solid state hard drive via the RIEGL DR680 data recorder. The drives are removed from the data recorder at the end of a sortie for post-processing. The DR680 is capable of an input data recording rate of up to 80MB/s for a full 4 hour sortie.

Note:

In normal Fugro LADS airborne LiDAR bathymetric surveys, the RIEGL VQ-820-G is used simultaneously with the LADS Mk 3 system.

For this reason, the laptop was used to:

- Simultaneously control both LADS Mk 3 and RIEGL VQ-820-G systems and
- Perform the navigation over the survey areas.

C.1.5 Ground System

The RIEGL VQ-820-G Ground System provides all the hardware and software necessary to be able to plan, store, back-up, control, post-process and deliver a RIEGL VQ-820-G survey.

It comprises of:

- RIEGL VQ-820-G data processing computer DELL Precision T7500. Intel Xeon CPU X5675 @ 3.07GHz, 24GB RAM, 4.5TB hard disk, with Microsoft Windows 7 64bit operating system installed and fitted with solid state removable raid disk drive and dual video displays.
- HP StorageWorks Ultrium 1840 SAS Tape Drive. Used to backup and restore data to and from LTO Ultrium archive tape.
- Numerous software packages are installed and used for planning, processing and reviewing the RIEGL VQ-820-G data:
    - POSPac MMS and GrafNav are used to post process the aircraft trajectory using either a base station or PPP (Precise Point Positioning) technique.
    - RiPROCESS including SDFCopy / POFImport / SDCImport / RiWORLD and RiMTA is used to post process the RIEGL VQ-820-G LiDAR data
    - TerraScan (application running through Bentley MicroStation) is used to perform the LiDAR point cloud classification and to produce coverage plots
    - LASTools and Global Mapper are used to assess the internal and external overlapping quality of each flight.

RiPROCESS is the main software package used to post-process the raw data into point cloud based data. It is used for fast data access for visualisation, system calibration and scan data adjustment, statistical analysis of matching scan data and as an interface for data exchange with further post-processing tools like TerraScan.

Note:

The LADS Mk 3 Ground System was used to create the project flight plan.

C.2 System Calibration

Before Survey data collection can commence, the RIEGL VQ-820-G system needs to be calibrated for GNSS antenna/IMU lever arms and IMU boresight angles. These are determined by using traditional land survey techniques and a calibration survey flight, which is then iteratively post-processed, respectively.

C.2.1 Lever Arms

All lever arms are measured relative to the survey reference position on the aircraft which, for the RIEGL airborne system, is the IMU's measurement point. The GNSS antenna used for position determination is ideally positioned on the upper side of the aircraft fuselage and as centrally above the IMU reference position as possible.

Two sets of lever arms comprise the RIEGL VQ-820-G system set up parameters as follows:

- The GNSS antenna lever arms (coordinates of the GNSS antenna phase centre in the IMU coordinate system) and

- The IMU lever arms (coordinates of the laser unit reference point in the IMU coordinates system).

C.2.1.1 GNSS Antenna Lever Arms

The GNSS antenna lever arms were determined using traditional land surveying techniques for the Beech 65-A90-4 aircraft N96Y. The X, Y and Z offsets provided in this section are the coordinates of the GNSS antenna phase centre expressed in the IMU coordinates system described in Figure 1.

	GNSS Antenna Lever Arms
X	-0.949m
Y	-0.155m
Z	-0.935m

Table 1 – N96Y GNSS lever arms

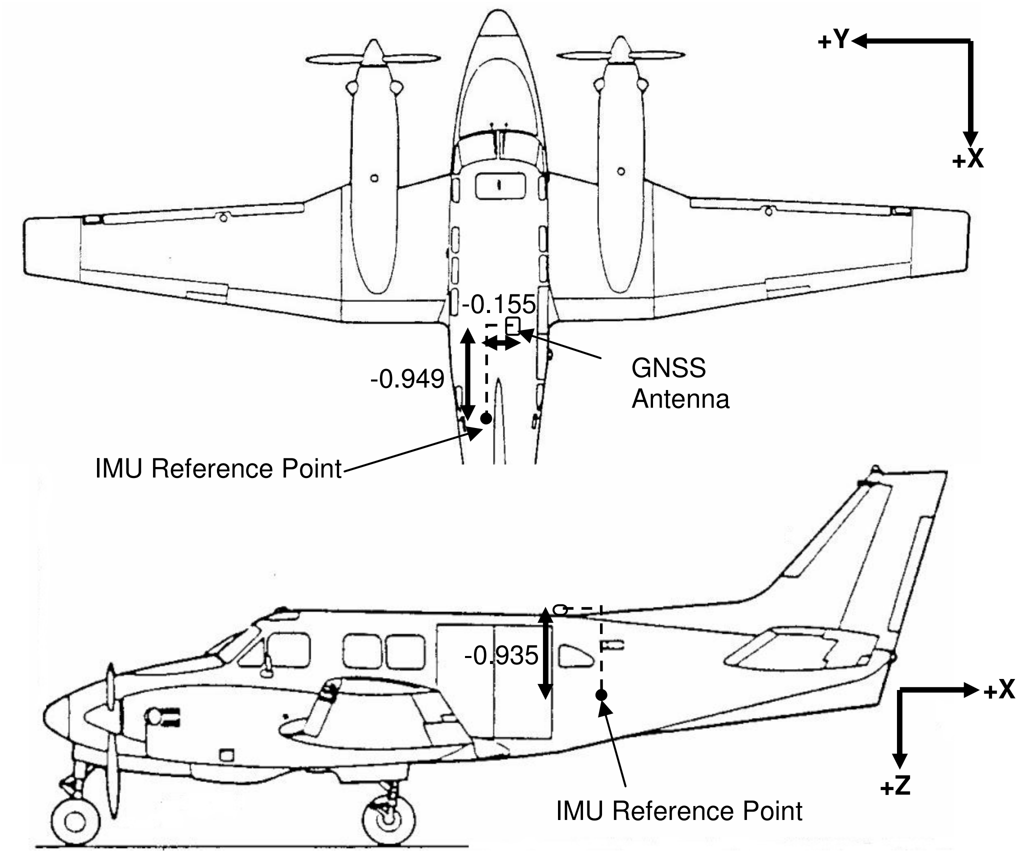


Figure 1 – IMU to GNSS antenna lever arms

Figure 2 shows the GNSS antenna lever arms calculation sheet for N96Y.

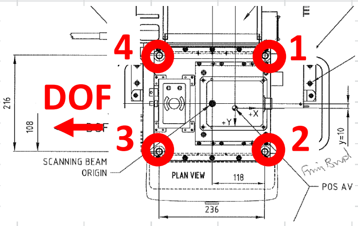
RIEGL APPLANIX IMU To GNSS Antenna Lever Arms Calculation Sheet

INSTRUCTIONS:

1 Check what orientation and from where to where the provided coordinates go from/to
2 Input Coordinates measured in the Yellow cells to **LEFT HAND** convention, X=+DOF, Y=+Right, Z=+Up
3 RL is to be input as height to the centre of the target, ie NO Pogo or height offset.
4 Prism offset is input as centre of target to the base of the target
5 Pogo height is input as centre of target to base of pogo
6 If a different method has been used input 0 for Prism Offset and Pogo Height

Datum Input AIRCRAFT STANDARD Left Hand System

	X	Y	Z		
1	997.891	2006.088	7.231	0.000	Prism Offset
2	998.084	2005.994	7.227	0.000	
3	997.983	2005.785	7.228	0.000	
4	997.789	2005.878	7.233	0.000	
Antenna	997.423	2005.192	7.735	0.000	Pogo Height



RIEGL Calibration Point Numbers

THESE VALUES USED FOR SURVEY IN NED REFERENCE FRAME WITH Z ROTATION 180°

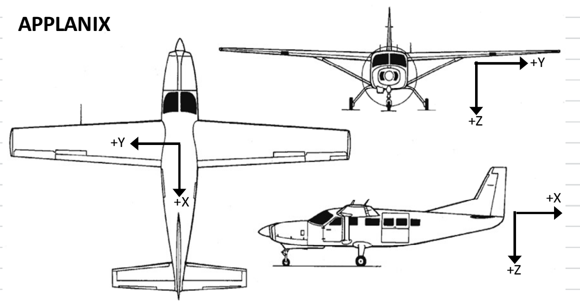
From APPLANIX IMU Origin To L1 Phase Center Lever Arms (m)

APPLANIX	X	Y	Z	
	0.949	0.155	-0.935	
Precision	0.005	0.002	0.002	95% Confidence
	0.011	0.002	0.006	Potential Distance Extrapolation Error

Input these values into AV POSVIEW CONTROLLER

Values used when RIEGL laser is firing BEHIND (reversed 180°)

APPLANIX



From APPLANIX IMU Origin To L1 Phase Center Lever Arms (m)

APPLANIX	X	Y	Z	
	-0.847	0.061	-0.935	
Precision	0.005	0.002	0.002	95% Confidence
	0.011	0.002	0.006	Potential Distance Extrapolation Error

Input these values into AV POSVIEW CONTROLLER

Values used when RIEGL laser is firing FORWARD

APPLANIX

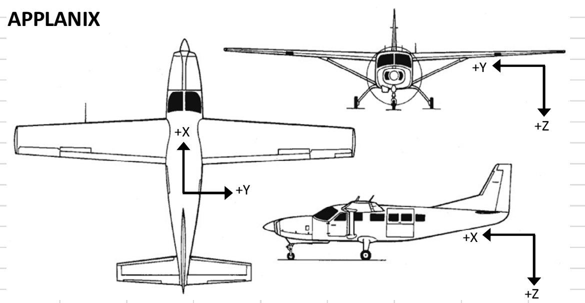


Figure 2: RIEGL GNSS antenna lever arms calculation sheet (RIEGL firing BEHIND)

C.2.1.2 IMU Lever Arms

The IMU lever arms are determined by the RIEGL scanner unit mounting plate dimensions. The X, Y and Z offsets provided in this section are coordinates of the laser unit reference point in the IMU coordinates system described in Figure 1.

	IMU-Laser Lever Arms
X	-0.051m
Y	-0.010m
Z	0.244m

Table 2 – N96Y IMU lever arms

Figure 3 shows the mounting plate dimensions for N96Y.

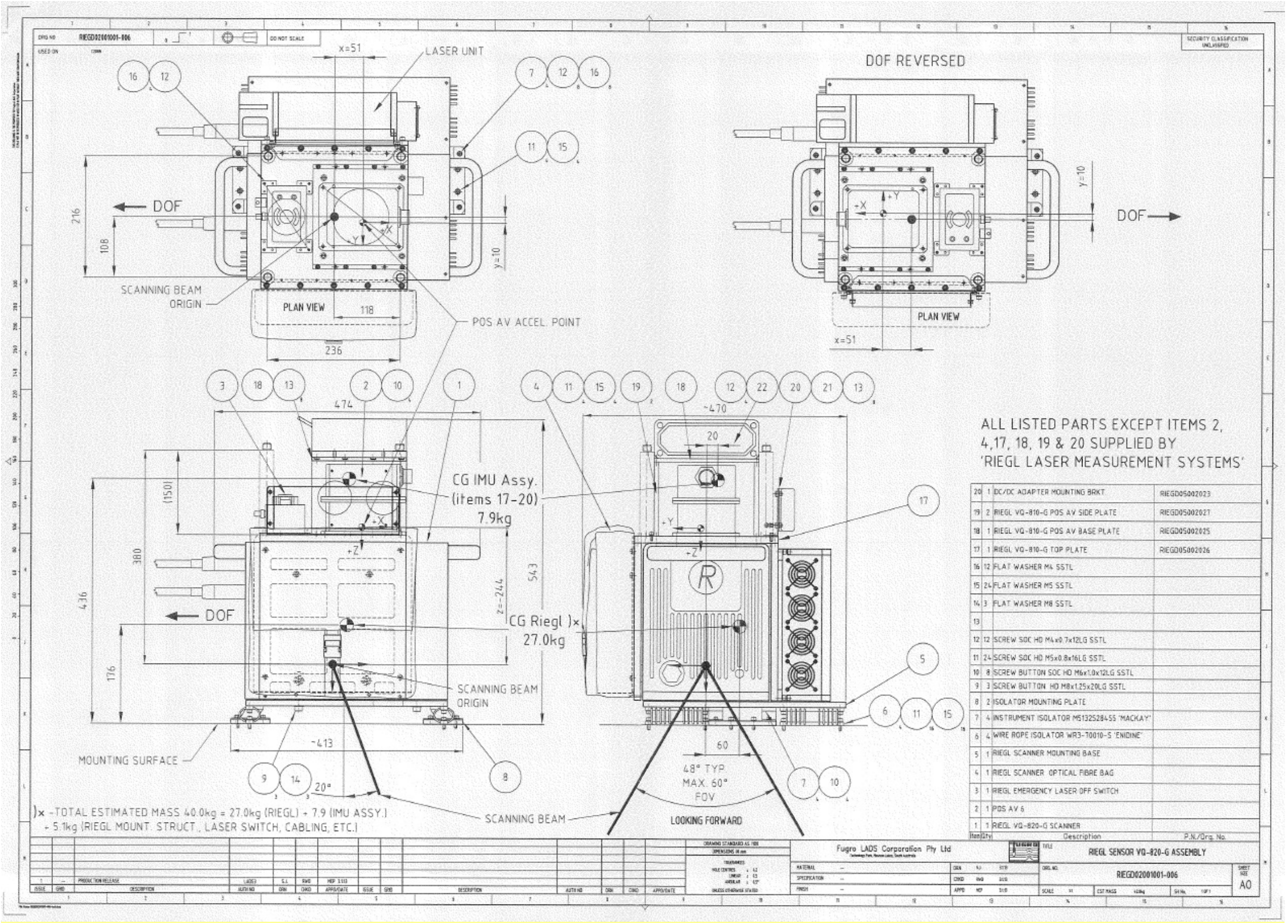


Figure 3: RIEGL VQ-820-G IMU mounting plate dimensions N96Y

C.2.2 Calibration Flights

For the Samoa survey, calibration flights for LADS Mk3 and RIEGL VQ-820-G calibration were flown on 8, 10 and 11 June 2015.

The following sections show the results relative to the calibration flights for the RIEGL VQ-820-G and are listed as:

- Calibration area and flight parameters
- The IMU boresight angles

C.2.3 Calibration Area and Flight Parameters

Figure 4 shows the location of the six calibration flight lines flown on 11 June 2015 over the town of Mahina, Tahiti.

Figure 4: RIEGL VQ-820-G calibration flight plan

The following flight parameters were used during the calibration flights:

	Calibration Flights Parameters
Aircraft ground speed	160 knots
Aircraft altitude (MSL)	2000 feet
Laser program / freq.	284 kHz
Laser power	High
Resulting point density	2.6 pts/m^2
MTA Zone	3 to 4
Laser swath width	610m
Line spacing	150m

Table 3 – Calibration flights survey parameters

C.2.4 IMU Boresight Angles

The IMU boresight angles calculation is based on the analysis of the overlapping areas between separate flight lines. Each flight line point cloud is analysed in order to identify regular surfaces like roof tops. Based on the identified surfaces, pairs of surfaces are identified. These pairs are the same surface surveyed several times in different flight lines. The separations between pairs are then analysed and used to determine the IMU boresight angles.

Table 4 below provides the IMU boresight angles determined for the survey.

	IMU Boresight Angles
Roll	+0.29856°
Pitch	-0.01344°
Yaw	+0.13194°

Table 4 – IMU boresight angles

C.3 Data Collection

The following survey parameters were used for the entire survey:

	Survey Parameters
Aircraft ground speed	160 knots
Aircraft altitude (MSL)	1600 or 3000 feet
Laser program / freq.	284 kHz or 510 kHz
Laser power	High
Resulting point density	3.1, 3.6 or 5.7 pts/m^2
MTA Zone	2 to 4
Laser swath width	450m or 860m
Line spacing	290m

Table 5 – Survey parameters

C.4 Data Processing

C.4.1 Workflow

C.4.1.1 RIEGL Processing Workflow

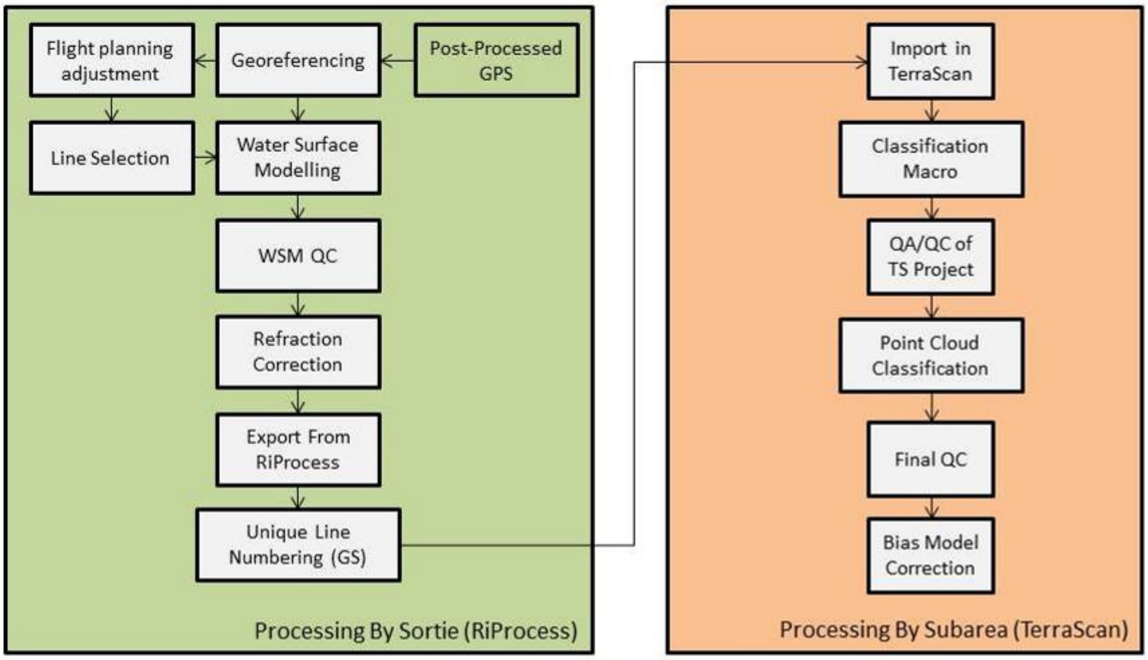


Figure 5: RIEGL VQ-820-G data processing workflow

C.4.2 Trajectory Processing

The trajectory processing of the RIEGL scanning beam origin point for this survey was performed using base station and PPP techniques with Rapid orbit and clock files.

C.4.3 LiDAR Point Cloud Coordinates (Horizontal and Vertical Datum)

The RIEGL point cloud is calculated in the following horizontal and vertical datum's:

- Horizontal: ITRF08 @ Survey epoch / UTM zone 2S
- Vertical: GRS80 Spheroid height in metres

The RIEGL point cloud coordinates are converted into the survey datum's (horizontal and vertical) during the RIEGL/LADS Mk 3 datasets merging task.

Final products have been delivered in the SGRS2005 horizontal datum and MSL vertical datum.

C.4.4 Point Cloud Classification

The following point classes have been used for the Samoa survey:

Class Number	Class Name	Recommended Status	Comments
1	Default	Rejected	Unclassified points
2	Ground	Accepted	Bare ground points
7	Low/High Points	Rejected	High and low points returns
9	Water Surface	Rejected	Water surface points
13	Bathymetry Underwater Seabed	Accepted	Seabed points
14	Bathymetry Non-Seabed	Rejected	Points in the water column that are not seabed
15	Bathymetry Shoals	Accepted	High points subset from seabed points (13)

Table 6 – Survey data point class list

Annex D. RIEGL LMS-Q780 and Phase One Surveying System

D.1 RIEGL LMS-Q780 LiDAR System

Below are the technical specifications of the LMS-Q780 LiDAR system.

Full Waveform Digitizing Airborne Laser Scanner for Wide Area Mapping

RIEGL LMS-Q780

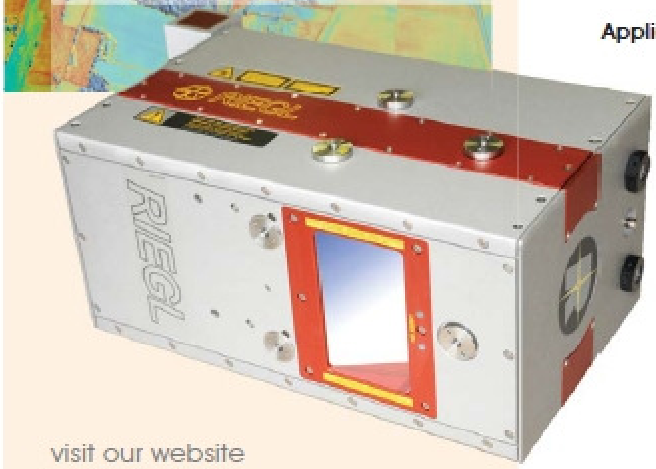
- up to 266 000 measurements/sec on the ground
- operating flight altitude up to 15,500 ft AGL
- multiple time around processing: more than 10 pulses (MTA zone 10) simultaneously in the air
- full waveform analysis for unlimited number of target echoes
- high laser pulse repetition rate up to 400 kHz
- various laser power settings for different fields of application
- high ranging accuracy ≤20 mm
- high scan speed up to 200 lines/sec
- wide scan field of view of 60°
- parallel scan lines
- suited for measuring snowy and icy terrain
- interface for smooth and direct GNSS-time synchronization
- seamless integration and compatibility with other RIEGL ALS-systems and software packages

The new *RIEGL*® LMS-Q780 long-range airborne laser scanner makes use of a powerful laser source, multiple-time-around (MTA) processing, echo digitization and waveform analysis. This combination allows the operation at varying flight altitudes and is therefore ideally suited for aerial survey of complex terrain.

The *RIEGL* LMS-Q780 gives access to detailed target parameters by digitizing the echo signal online during data acquisition, and subsequent off-line waveform analysis. This method is especially valuable when dealing with difficult tasks, such as canopy height investigation or target classification. Multiple-time-around processing allows the utilization of target echo signals which have been detected out of the unambiguity range between two successive laser pulses. In post-processing the correct allocation of ambiguous echo ranges is accomplished by using RiANALYZE in combination with the associated plugin RiMTA.

The operational parameters of the *RIEGL* LMS-Q780 can be configured to cover a wide field of applications. Comprehensive interface features support smooth integration of the instrument into a complete airborne scanning system.

The instrument makes use of the time-of-flight distance measurement principle of infrared nanosecond pulses. Fast opto-mechanical beam scanning provides absolutely linear, unidirectional and parallel scan lines. The instrument is extremely rugged, therefore ideally suited for the installation on aircraft. Also, it is compact and lightweight enough to be installed in small twin- or single-engine planes, helicopters or UAVs. The instrument needs only one power supply and GPS timing signals to provide online monitoring data while logging the precisely time-stamped and digitized echo signal data to the rugged *RIEGL* Data Recorder.



Applications:

Full Laser Power:
- *Wide Area / High Altitude Mapping*
- *Topography & Mining*
- *Glacier & Snowfield Mapping*

Reduced Laser Power:
- *City Modeling*
- *Mapping of Lakesides & River Banks*
- *Agriculture & Forestry*
- *Corridor Mapping*

visit our website
www.riegl.com

RIEGL®
LASER MEASUREMENT SYSTEMS

Airborne Laser Scanning

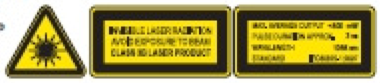
Technical Data *RIEGL* LMS-Q780

Laser Product Classification

Class 3B Laser Product according to IEC60825-1:2007

The following clause applies for instruments delivered into the United States: Complies with 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 50, dated June 24, 2007.

The instrument must be used only in combination with the appropriate laser safety box.



Range Measurement Performance

as a function of laser power setting, PRR, and target reflectivity

Full Laser Power

Laser Power Level	100%			
Laser Pulse Repetition Rate (PRR)	100 kHz	200 kHz	300 kHz	400 kHz
Max. Measuring Range [1) 3)] natural targets $\rho \geq 20$ %	4100 m	3500 m	3000 m	2700 m
natural targets $\rho \geq 60$ %	5800 m	5100 m	4500 m	4100 m
Max. Operating Flight Altitude Above Ground Level (AGL) [2) 3)]	4700 m 15500 ft	4200 m 13700 ft	3700 m 12000 ft	3300 m 11000 ft
NOHD [4)]	200 m	160 m	125 m	105 m
ENOHD [5)]	1500 m	1200 m	960 m	820 m

1) The following conditions are assumed: • target is larger than the footprint of the laser beam • average ambient brightness • visibility 40 km • perpendicular angle of incidence • ambiguity resolved by multiple-time-around processing
2) Reflectivity $\rho \geq 60$ %, max. scan angle 60°, additional roll angle ± 5°
3) In bright sunlight the operational range may be considerably shorter and the operational flight altitude may be considerably lower than under an overcast sky.
4) Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, for single pulse condition
5) Extended Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, for single pulse condition

Reduced Laser Power

Laser Power Level	50%	25%	12%	6%
Laser Pulse Repetition Rate (PRR)	400 kHz	400 kHz	400 kHz	400 kHz
Max. Measuring Range [6) 8)] natural targets $\rho \geq 20$ %	2100 m	1500 m	1120 m	820 m
natural targets $\rho \geq 60$ %	3200 m	2400 m	1800 m	1350 m
Max. Operating Flight Altitude Above Ground Level (AGL) [7) 8)]	2600 m 8600 ft	1950 m 6400 ft	1450 m 4800 ft	1100 m 3600 ft
NOHD [9)]	70 m	68 m	44 m	25 m
ENOHD [10)]	560 m	550 m	360 m	250 m

6) The following conditions are assumed: • target is larger than the footprint of the laser beam • average ambient brightness • visibility 40 km • perpendicular angle of incidence • ambiguity resolved by multiple-time-around processing
7) Reflectivity $\rho \geq 60$ %, max. scan angle 60°, additional roll angle ± 5°
8) In bright sunlight the operational range may be considerably shorter and the operational flight altitude may be considerably lower than under an overcast sky.
9) Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, viewing a single scan line
10) Extended Nominal Ocular Hazard Distance, based upon MPE according to IEC60825-1:2007, viewing a single scan line

Minimum Range [11)]	50 m
Accuracy [12) 13)]	20 mm
Precision [13) 14)]	20 mm
Laser Pulse Repetition Rate	up to 400 kHz
Effective Measurement Rate	up to 266 kHz @ 60° scan angle
Laser Wavelength	near infrared
Laser Beam Divergence [15)]	≤ 0.25 mrad
Number of Targets per Pulse	digitized waveform processing: unlimited [16)] monitoring data output: first pulse

Scanner Performance

Scanning Mechanism	rotating polygon mirror
Scan Pattern	parallel scan lines
Scan Angle Range	± 30° = 60° total
Scan Speed	14 - 200 lines/sec[17)] @ laser power level ≥ 50% 10 - 200 lines/sec[18)] @ laser power level < 50%
Angular Step Width $\Delta\vartheta$ [19)]	$\Delta\vartheta \geq 0.012°$ @ laser power level ≥ 50% $\Delta\vartheta \geq 0.006°$ @ laser power level < 50%
Angle Measurement Resolution	0.001°
Scan Sync	Option for synchronizing scan lines to external timing signal

Intensity Measurement

For each echo signal, high-resolution 16-bit intensity information is provided which can be used for target discrimination and/or identification/classification.

11) Limitation for range measurement capability, does not consider laser safety!
12) Standard deviation one sigma @ 250 m range under RIEGL test conditions.
13) Accuracy is the degree of conformity of a measured quantity to its actual (true) value.
14) Precision, also called reproducibility or repeatability, is the degree to which further measurements show the same result.
15) Measured at the 1/e² points. 0.25 mrad correspond to an increase of 25 cm of beam diameter per 1000 m distance.
16) Practically limited only by the maximum data rate allowed for the RIEGL Data Recorder.
17) Minimum scan speed increasing linearly to 53 lines/sec @ 400 000 Hz PRR @ laser power ≥ 50%
18) Minimum scan speed increasing linearly to 27 lines/sec @ 400 000 Hz PRR @ laser power < 50%
19) Angle between consecutive laser shots, user adjustable

Technical Data to be continued at page 7

2

Echo Signals from Different Targets

The waveform digitization feature of the *RIEGL* LMS-Q780 enables the user to extract most comprehensive information from the echo signals.

Figure 1 illustrates a measurement situation where 3 laser measurements are taken on different types of targets. The red pulses symbolize the laser signals travelling towards the target with the speed of light. When the signal interacts with the diffusely reflecting target surface, a fraction of the transmitted signal is reflected towards the laser instrument, indicated by the blue signals.

In situation 1, the laser pulse hits the canopy first and causes three distinct echo pulses. A fraction of the laser pulse also hits the ground giving rise to another echo pulse. In situation 2, the laser beam is reflected from a flat surface at a small angle of incidence yielding an extended echo pulse width. In situation 3, the pulse is simply reflected by a flat surface at perpendicular incidence resulting in one single echo pulse with a shape identical to the transmitted laser pulse.

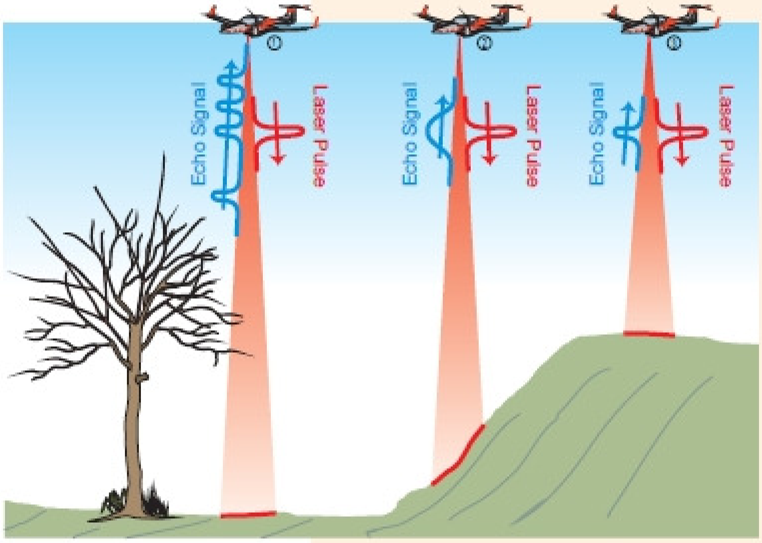


Fig. 1 Echo signals resulting from different types of targets

Echo Digitization *RIEGL* LMS-Q780

The upper line of the acquisition diagram shows the analog signals: the first (red) pulse relates to a fraction of the laser transmitter pulse, and the next 3 (blue) pulses correspond to the reflections by the branches of the tree; the last pulse corresponds to the ground reflection.

This analog echo signal is sampled at constant time intervals (middle line) and is, in the following, analog-to-digital converted, resulting in a digital data stream (bottom line of the acquisition section). This data stream is stored in the *RIEGL* Data Recorder for subsequent off-line post processing, where the echo signals can be perfectly reconstructed and analyzed in detail to precisely derive target distance, pulse shape as an indicator for target type, and other parameters.

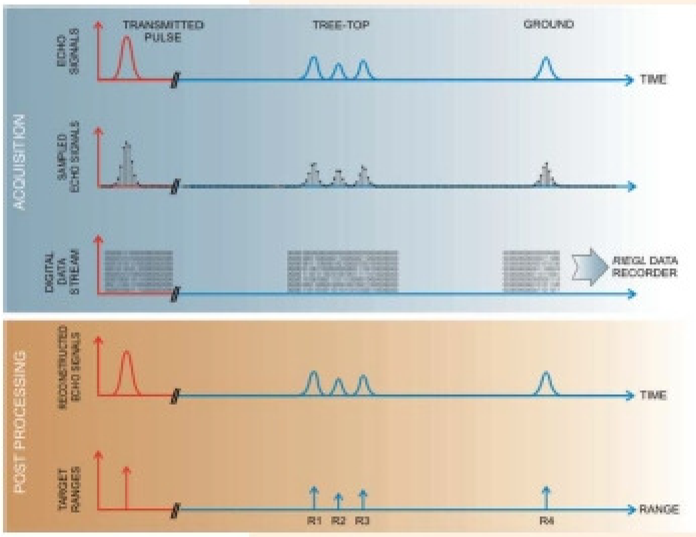


Fig. 2 Data acquisition and post processing

Based upon *RIEGL*'s long-standing expertise and experience in designing, manufacturing and marketing digitizing laser rangefinders for challenging industrial and surveying applications, and due to the careful design of the analog and digital front-end electronics, the LMS-Q780 records the complete information of the echo signal over a wide dynamic range. Thus, in post-processing the signal can be perfectly reconstructed and analyzed in detail to precisely derive target distance, target type, and other parameters.

3

Multiple-Time-Around Data Acquisition and Processing

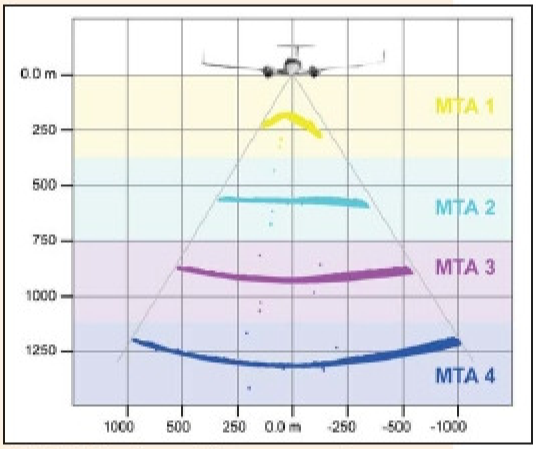


Fig. 3 Profile of scan data processed in MTA zones 1 to 4

In time-of-flight laser ranging a maximum unambiguous measurement range exists which is defined by the measurement repetition rate and the speed of light. When scanning at a pulse repetition rate of, e.g., 400 kHz, measurement ranges above approx. 375 m are ambiguous caused by an effect known as "Multiple-Time-Around" (MTA). In such case target echoes received may not be associated with their preceding laser pulses emitted any longer (MTA-zone 1), but have to be associated with their last but one (MTA-zone 2), or even last but two laser pulses emitted (MTA-zone 3), in order to determine the true measurement range.

Figure 3 gives an impression of ALS data where each single echo of a scan line is associated with each of its last four preceding laser shots emitted. Each single echo is represented by a measurement range calculated in MTA zone 1, 2, 3 and 4 respectively, but only one of the four realizations represents the true point cloud model of the scanned earth surface. The chosen example shows scan data correctly allocated in MTA zone 2, where the earth surface appears more or less flat in contrast to the typical spatial characteristics of incorrectly calculated ambiguous ranges in MTA zones 1, 3 and 4.

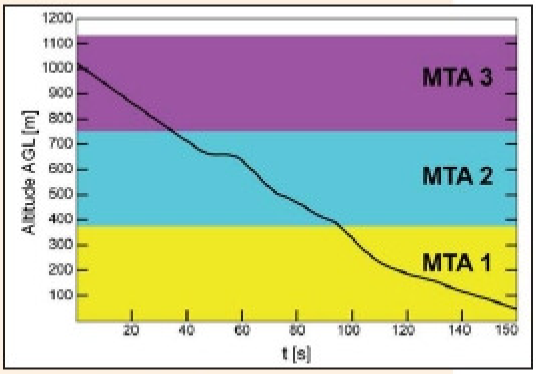
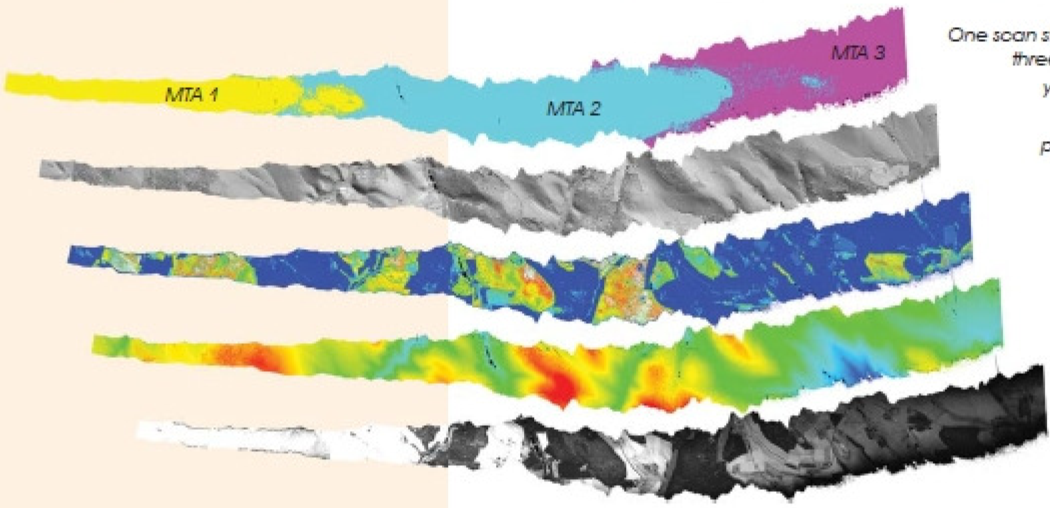


Fig. 4 Flight altitude above ground level descending from 1,000 m to 240 m within 150 seconds

The *RIEGL* LMS-Q780 is capable of acquiring echo signals which arrive after a delay of more than one pulse repetition interval, thus allowing range measurements beyond the maximum unambiguous measurement range. Unique techniques in high-speed signal processing and a novel modulation scheme applied to the train of emitted laser pulses permit range measurements without any perceivable gaps at any distance within the instrument's maximum measurement range. The specific modulation scheme applied to the train of emitted laser pulses avoids a total loss of data at the transitions between MTA-zones and retains range measurement at approximately half the point density.

The correct resolution of ambiguous echo ranges is accomplished using RiANALYZE in combination with the associated plugin RiMTA ALS, which does not require any further user interaction, and maintains fast processing speed for mass data production.

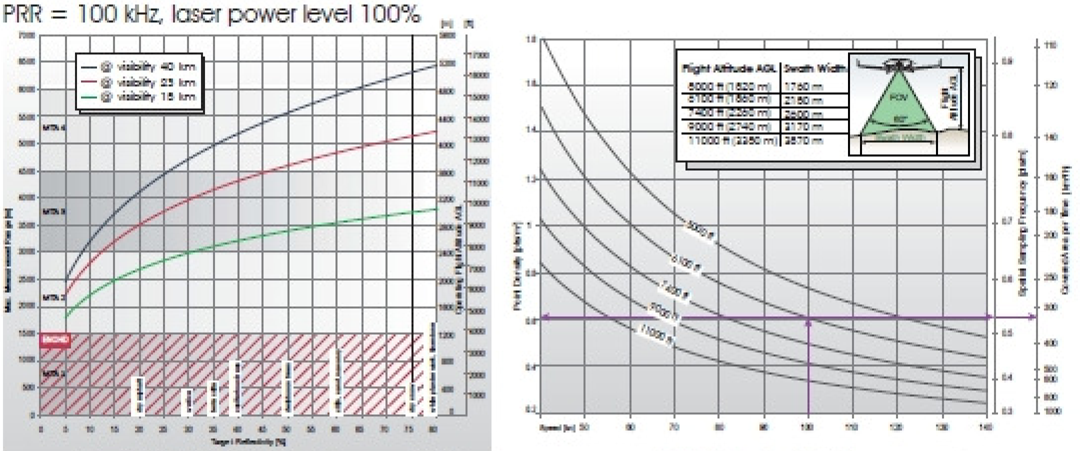


One scan strip transiting three MTA zones: yellow: MTA 1 blue: MTA 2 purple: MTA 3

4

Measurement Range & Point Density *RIEGL* LMS-Q780

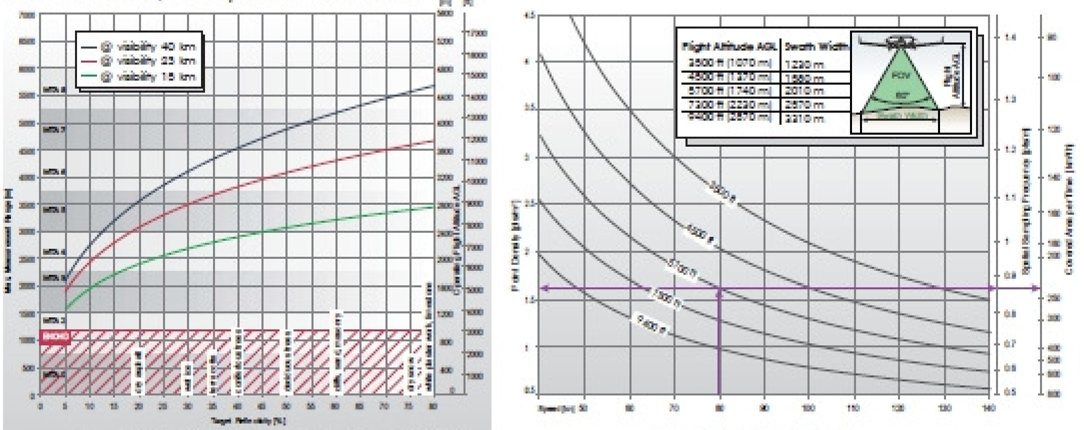
PRR = 100 kHz, laser power level 100%



Example: LMS-Q780 at 100.000 pulses/sec. laser power level 100%
Altitude = 6100ft AGL Speed = 100 kn

Results: Point Density ~ 0.6 pts/m²
Spatial Sampling Frequency ~ 0.53 pts/m
Covered Area per Time ~ 320 km²/h

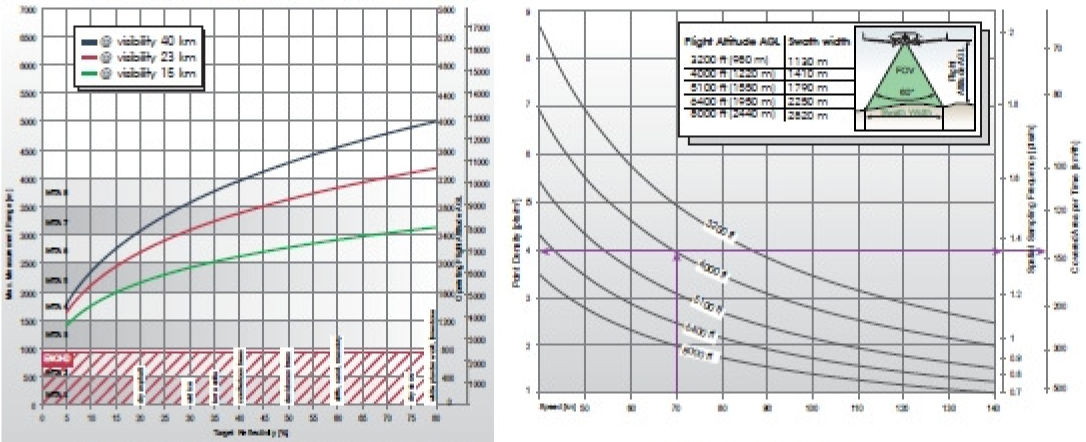
PRR = 200 kHz, laser power level 100%



Example: LMS-Q780 at 200.000 pulses/sec. laser power level 100%
Altitude = 5700ft AGL Speed = 80 kn

Results: Point Density ~ 1.6 pts/m²
Spatial Sampling Frequency ~ 0.87 pts/m
Covered Area per Time ~ 230 km²/h

PRR = 300 kHz, laser power level 100%



Example: LMS-Q780 at 300.000 pulses/sec. laser power level 100%
Altitude = 4000ft AGL Speed = 70 kn

Results: Point Density ~ 4 pts/m²
Spatial Sampling Frequency ~ 1.35 pts/m
Covered Area per Time ~ 140 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL
- ambiguity resolved by multiple-time-around (MTA) processing & flight planning
- target size ≥ laser footprint
- scan angle 60°
- average ambient brightness
- roll angle ±5°

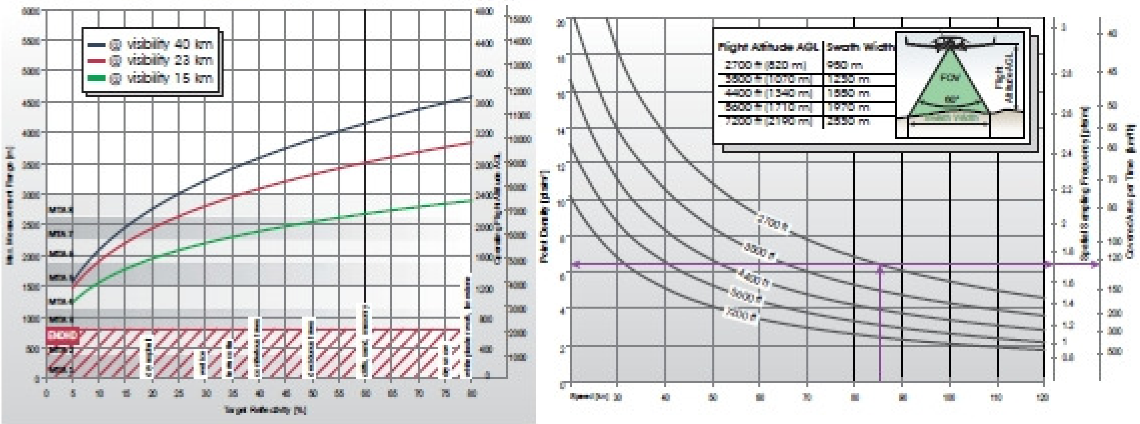
Assumptions for calculation of the Covered Area per Time
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Definition of the Spatial Sampling Frequency
- The Spatial Sampling Frequency is the reciprocal of the 95th percentile of the distribution function of the maximum distances between neighboring scan points. When considering any individual scan point, the probability to find its most distant neighbor within the reciprocal of the Spatial Sampling Frequency is 95%.

5

Measurement Range & Point Density *RIEGL* LMS-Q780

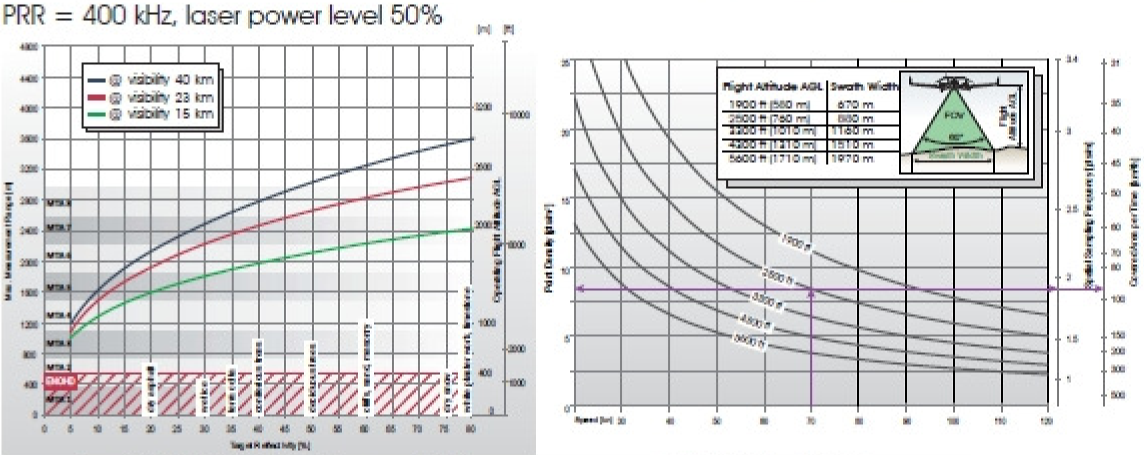
PRR = 400 kHz, laser power level 100%



Example: LMS-Q780 at 400,000 pulses/sec, laser power level 100%
Altitude = 2700ft AGL Speed = 85 kn

Results: Point Density ~ 6.4 pts/m²
Spatial Sampling Frequency ~ 1.7 pts/m
Covered Area per Time ~ 125 km²/h

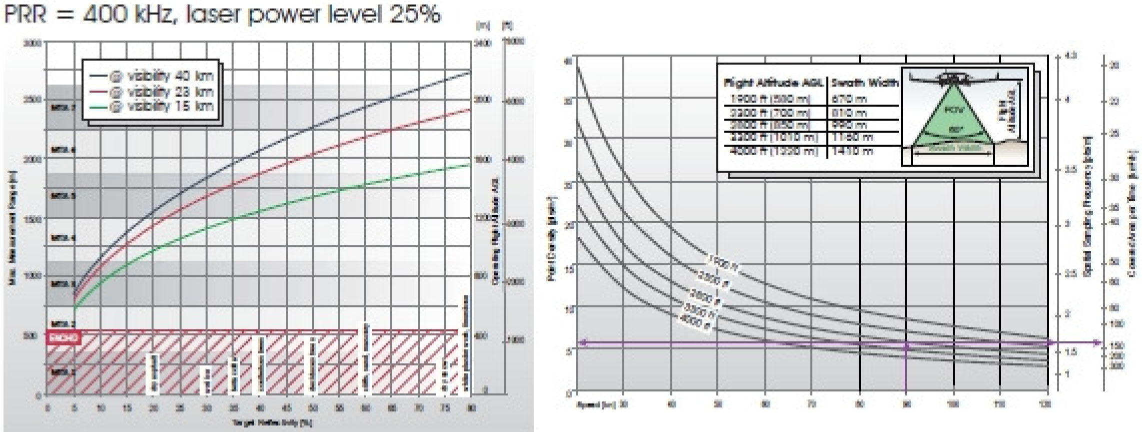
PRR = 400 kHz, laser power level 50%



Example: LMS-Q780 at 400,000 pulses/sec, laser power level 50%
Altitude = 2500ft AGL Speed = 70 kn

Results: Point Density ~ 8.4 pts/m²
Spatial Sampling Frequency ~ 1.9 pts/m
Covered Area per Time ~ 95 km²/h

PRR = 400 kHz, laser power level 25%



Example: LMS-Q780 at 400,000 pulses/sec, laser power level 25%
Altitude = 2800ft AGL Speed = 90 kn

Results: Point Density ~ 5.8 pts/m²
Spatial Sampling Frequency ~ 1.6 pts/m
Covered Area per Time ~ 140 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL
- ambiguity resolved by multiple-time-around (MTA) processing & flight planning
- target size ≥ laser footprint
- scan angle 60°
- average ambient brightness
- roll angle ±5°

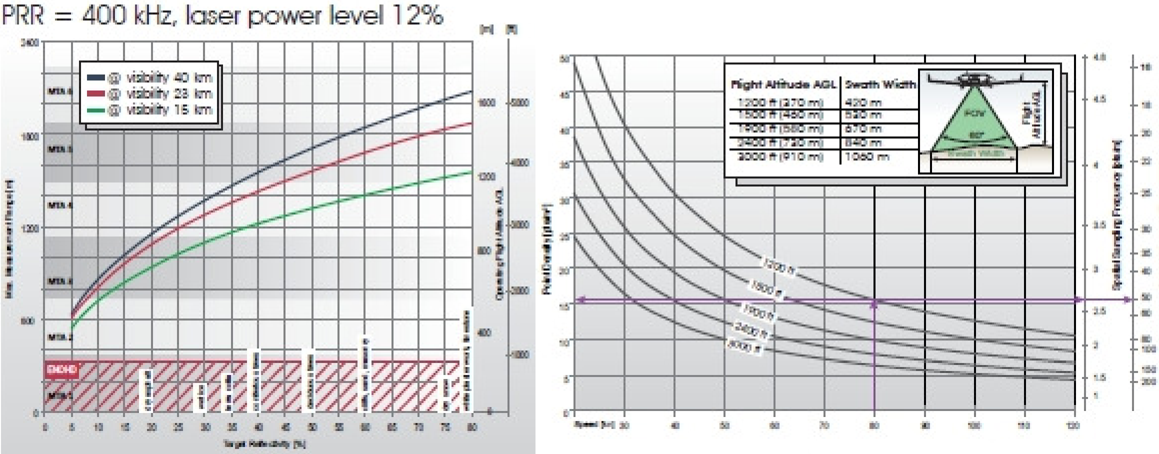
Assumptions for calculation of the Covered Area per Time
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Definition of the Spatial Sampling Frequency
- The Spatial Sampling Frequency is the reciprocal of the 95th percentile of the distribution function of the maximum distances between neighboring scan points. When considering any individual scan point, the probability to find its most distant neighbor within the reciprocal of the Spatial Sampling Frequency is 95%.

6

Measurement Range & Point Density *RIEGL* LMS-Q780

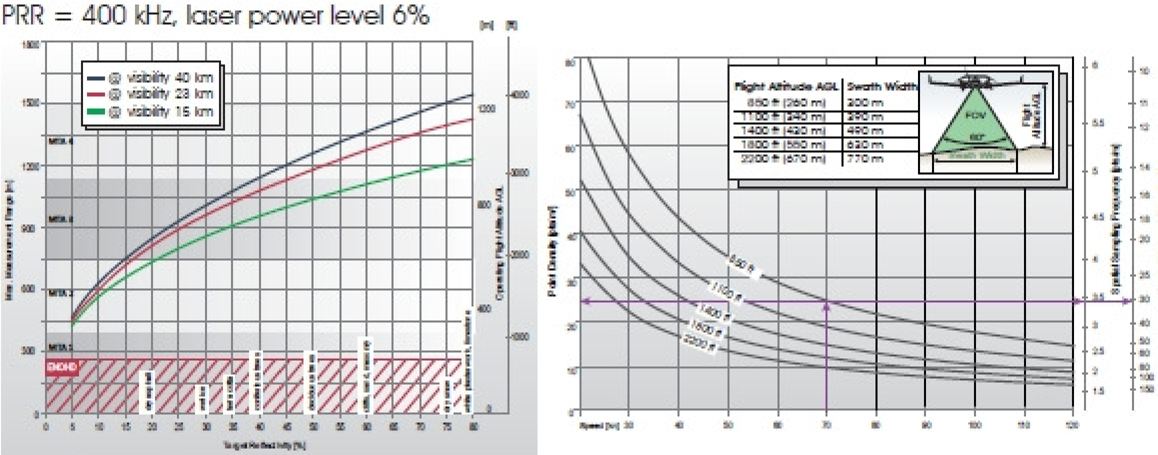
PRR = 400 kHz, laser power level 12%



Example: LMS-Q780 at 400.000 pulses/sec. laser power level 12%
Altitude = 1200ft AGL Speed = 80 kn

Results: Point Density ~ 15.3 pts/m²
Spatial Sampling Frequency ~ 2.6 pts/m
Covered Area per Time ~ 50 km²/h

PRR = 400 kHz, laser power level 6%



Example: LMS-Q780 at 400.000 pulses/sec. laser power level 6%
Altitude = 850ft AGL Speed = 70 kn

Results: Point Density ~ 24.7 pts/m²
Spatial Sampling Frequency ~ 3.4 pts/m
Covered Area per Time ~ 30 km²/h

The following conditions are assumed for the Operating Flight Altitude AGL
- ambiguity resolved by multiple-time-around (MTA) processing & flight planning
- target size ≥ laser footprint
- average ambient brightness
- scan angle 60°
- roll angle ±5°

Assumptions for calculation of the Covered Area per Time
- 20% overlap of neighboring flight strips. This overlap covers a roll angle of ±5° or a reduction of flight altitude AGL of 20%.

Definition of the Spatial Sampling Frequency
- The Spatial Sampling Frequency is the reciprocal of the 95th percentile of the distribution function of the maximum distances between neighboring scan points. When considering any individual scan point, the probability to find its most distant neighbor within the reciprocal of the Spatial Sampling Frequency is 95%.

Technical Data *RIEGL* LMS-Q780 *(continued)*

Data Interfaces

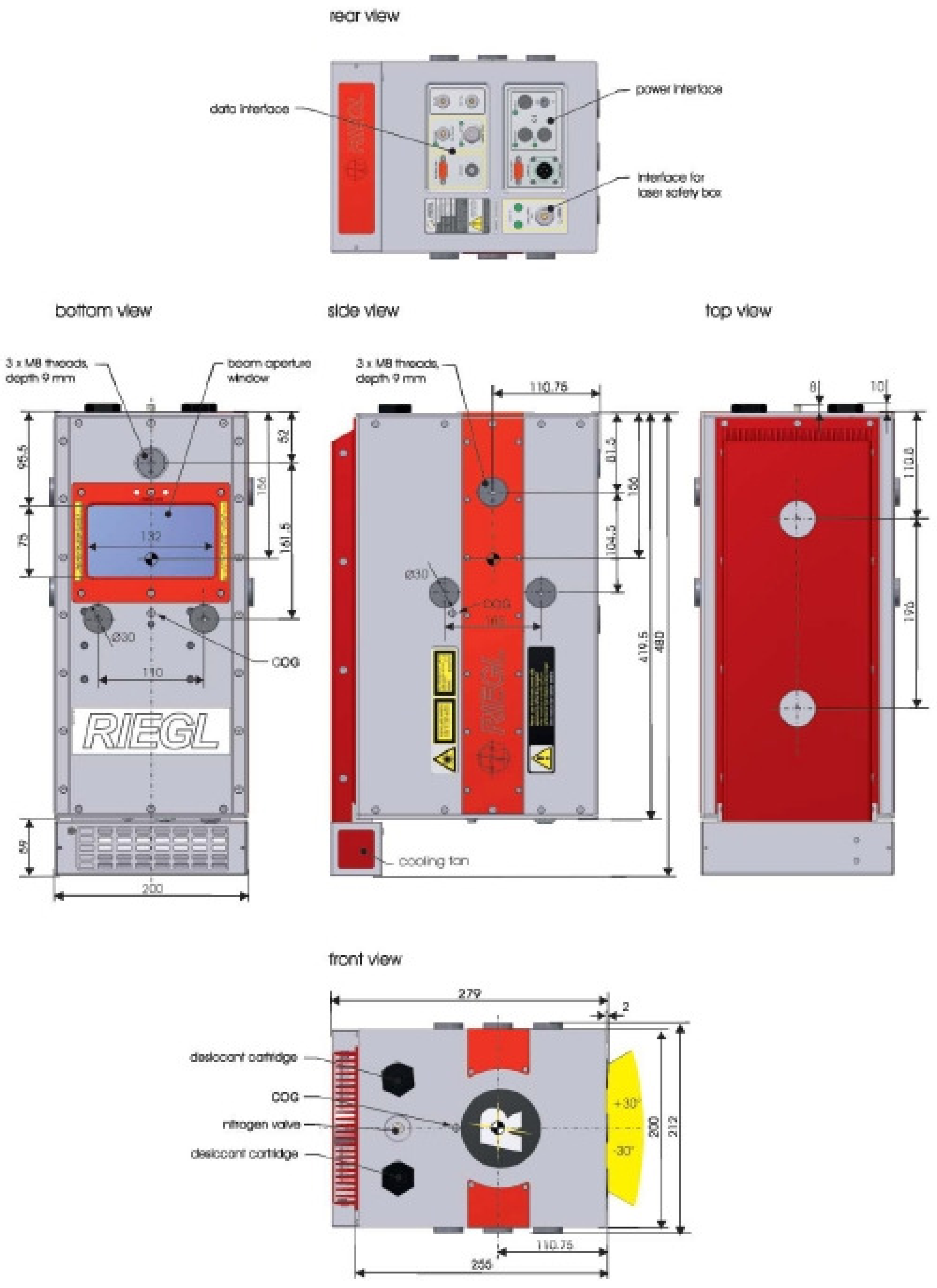
Configuration	TCP/IP Ethernet (10/100 MBit), RS232 (19.2 kBd)
Monitoring Data Output	TCP/IP Ethernet (10/100 MBit)
Digitized Data Output	High speed serial data link to *RIEGL* Data Recorder
Synchronization	Serial RS232 interface, TTL input for 1 pps synchronization pulse, accepts different data formats for GNSS-time information

General Technical Data

Power Supply / Current Consumption	18 - 32 V DC / approx. 7 A @ 24 VDC
Main Dimensions (L x W x H) / Weight	480 x 212 x 279 mm / approx. 20 kg
Protection Class	IP54
Max. Flight Altitude operating / not operating	18500 ft (5600 m) above Mean Sea Level MSL / 18500 ft (5600 m) above MSL
Temperature Range	-5°C up to +40°C (operation) / -10°C up to +50°C (storage)
Mounting of IMU-Sensor	Steel thread inserts on both sides of the laser scanner, rigidly connected to the inner structure of the scanning mechanism

7

Dimensional Drawings *RIEGL* LMS-Q780



all dimensions in mm
origin of scanner's local coordinate system
center of gravity COG

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Data Sheet, *RIEGL* LMS-Q780, 2015-03-24

N.2 Phase One Medium Format Camera

Below are the technical specifications of the iXA-R 180 camera.

Technical Specifications

	iXA-R 180 iXA 180	iXA-R 160 iXA 160	iXA-R 160 Achromatic iXA 160 Achromatic
Camera type	Medium format camera for aerial photography		
Lens mount	- Phase One R dedicated mount — for iXA-R cameras - Phase One SK dedicated mount — for iXA cameras		
Shutter speed	- Focal plane: up to 1/4000 second - Leaf shutter: up to 1/1600 second*		
Shutter control	1/3 f-stop increments		
Interfaces	- USB 3.0 - FireWire 800 - Secured power input (LEMO) - Camera trigger - Mid-exposure pulse - Camera status		
GPS/IMU support	Applanix, NovAtel, IGI, NMEA Devices		
Forward Motion Compensation	TDI controlled		
Data storage	- 1 TB SSD storage (optional iX Controller) - CompactFlash card Type I/II including UDMA 6 and 7		
Syncronization speed in multiple camera configuration	100 microseconds with factory calibrated (FS) lenses		
Resolution	10328 x 7760 (80 MP)	8984 x 6732 (60.5 MP)	8964 x 6716 (60 MP)
Dynamic range	>72 db		
Aspect ratio	4:3		
Pixel size	5.2 micron	6.0 micron	
CCD size effective	53.7 x 40.4 mm	53.9 x 40.4 mm	53.8 x 40.3 mm
Lens factor	1.0		
Light sensitivity (ISO)	35-800	50-800	200-3200
Capture rate			
Full resolution frame	1.5 sec	1.3 sec	1.3 sec
RAW File compression	IIQ large: 80 MB IIQ small: 54 MB	IIQ large: 60 MB IIQ small: 40 MB	

	iXA-R 180 iXA 180	iXA-R 160 iXA 160	iXA-R 160 Achromatic iXA 160 Achromatic
Lens + technology optimizes	- Color cast - Light falloff - Chromatic aberration - Fringing - Sharpness falloff - Lens distortion		
Output format	Phase One Raw, TIF and JPG		
Post processing	- iX Capture - Capture One Pro - Capture One Processing Engine		
IR cut-off filter	Camera system available either with or without IR filter		
Connection to pod	Four M4 bolts		
Tripod sockets	Two 3/8 inch		
Power input	12 – 30 V DC		
Maximum power consumption	20 W		
Dimensions iXA (excluding lens)*	132 x 114 x 128.5 mm / 5.2 x 4.4 x 5 in (W x H x D)		
Dimensions IXA-R (including lens 40)*	128.5 x 114 x 190.5 mm / 5.06 x 4.48 x 7.5 in (W x H x D)		
Dimensions IXA-R (including lens 50)*	128.5 x 114 x 199 mm / 5.06 x 4.48 x 7.83 in (W x H x D)		
Dimensions IXA-R (including lens 70)*	128.5 x 114 x 191 mm / 5.06 x 4.48 x 7.51 in (W x H x D)		
Weight (excluding lens)	1.75 kg / 3.86 lb - for iXA cameras 1.73 kg / 3.81 lb - for iXA-R cameras		
Weight iXA-R (camera and lens)	iXA-R 40 2.5 kg / 5.4 lb iXA-R 50 2.5 kg / 5.6 lb iXA-R 70 2.3 kg / 5.1 lb		
Approvals	FCC (Class A), CE, RoHS		
Operating Conditions			
Temperature	-10° to 40°C (14° to 104°F)		
Humidity	15 to 80% (non-condensing)		

Annex E. Geodetic Records

All collected data was post-processed relative to the International Terrestrial Reference Frame 2008 at epoch 2015.5 (ITRF08) datum during the application of the Kinematic Global Navigation Satellite System (KGNSS) solution. All data was provided in the Samoan Geodetic Reference System 2005 (SGRS2005) (ITRF2000@2016.0). No transformation was performed between ITRF08@2015.5 and ITRF00@2016.0 as there is only a 3cm difference between the datums. All coordinates refer to the Universal Transverse Mercator, Southern Hemisphere projection (UTM South) in Zone 2 unless otherwise stated.

E.1 Geodetic Parameters

The following are the parameters for the Geodetic Datum used for data collection in Samoa. The final data was delivered in SGRS2005.

Geodetic Parameters	
Datum:	International Terrestrial Reference Frame 2008@2015.5
Spheroid:	Geodetic Reference System 1980 (GRS80)
Semi major axis:	a = 6 378 137.000 m
Inverse Flattening:	$^1/_f$ = 298.257 222 101
Local Projection Parameters	
Map Projection:	Universal Transverse Mercator
Grid System:	UTM Zone 2 South
Central Meridian:	171° 00′ 00″ West
Longitude of Origin	000° 00′ 00.00″ East
Latitude of Origin:	000° 00′ 00.00″ South
False Easting:	500 000 m
False Northing:	10 000 000 m
Scale factor on Central Meridian:	0.9996
Units:	metre

Table 1 – Geodetic Datum for Samoa

E.2 GNSS Antenna Lever Arms

Prior to the Samoa survey, a survey in French Polynesia was conducted by Fugro LADS using the same aircraft as for Samoa and so the same lever arms were used for the Samoa survey. The GNSS antenna to reference point for both the LADS and RIEGL systems was surveyed on the aircraft used for the survey. For LADS Mk3, the reference point is the laser source on the scan mirror. For RIEGL 820, it is the IMU reference point. The lever arm to the RIEGL laser source is then applied in the RIEGL processing software. These lever arm values were calculated as shown in Table 7. The values are in the IMU reference frame for LADS Mk3 and in the North, East, Down (NED) reference frame for RIEGL 820. See Enclosure 1 for the Géopolynésie report of the GNSS antenna offset survey and Enclosure 2 for the Lever Arms Calculation Sheet.

Lever Arm	LADS	RIEGL
X	-0.117	0.949
Y	0.017	0.155
Z	-1.396	-0.935

Table 2 – Reference Point to L1 Phase Centre lever arms

E.3 Geodetic Control Stations

E.3.1 Fugro Marinestar GNSS Service

Throughout the survey, the real-time position of the LADS Mk 3 system was derived from a Trimble BD982 GNSS receiver. PPP corrections from the Fugro Marinestar GNSS service were received and applied by the Trimble receiver to the raw GNSS positions. See Annex D for a description of this real-time PPP service.

E.3.2 GNSS Base Stations – Apia and Faleolo Airport

GNSS data was post-processed using the established Geoscience Australia (GA) GNSS base station in Apia and a Fugro established GNSS base station at Faleolo Airport on Upolu Island. The SAMO base station's coordinates were determined by the Geoscience Australia weekly Analysis Report summary for GPS week 1848.

The GA base station in Apia (SAMO) was used for the topographic benchmark check, which compared LADS, RIEGL and topographic LiDAR data from 2012, and for some survey flights. However, small gaps were noticed in some of the data downloaded from the SAMO base station and so it was not used after the first few flights. The Fugro base station was used instead.

A base station was established by Fugro LADS and Fugro Geospatial surveyors at Faleolo airport and was coordinated using AUSPOS. This second base station was setup so as there was a small initial baseline between the aircraft and itself, to improve the KGNSS solution and for minimising the baseline distance between the base station and aircraft when surveying Savai'i Island. The maximum baseline between the base station and the aircraft was 95km.

A PPP solution was used for sortie 3 when unreliable base station data was available. The Rapid precise ephemeris and clock data files were downloaded with an accurate solution achieved.

Refer to Enclosure 3 for station summaries of the base stations and Enclosure 4 for the AUSPOS report.

The ITRF08 coordinates for the GNSS base stations used during the survey were:

BS ID	ITRF08 Latitude	ITRF08 Longitude	Easting	Northing	Ellipsoidal Height
SAMO	13° 50‘ 57.1444“ S	171° 44‘ 18.3351“ W	420 203.07	8 468 827.48	76.7554
Fugro	13° 49‘ 51.10973“ S	172° 00‘ 44.63596“ W	390 585.69	8 470 748.08	46.340

Table 3 – GNSS base station coordinates

E.3.3 Static Position Check Control Marks – Fa’a’ā International Airport, Papeete, Tahiti

Prior to the static session, three marks in a triangle formation were coordinated by Géopolynésie. The aircraft was then positioned so that the LADS laser nadir point (reference point) was close to the centre of this triangle of marks. The laser nadir point on the scanning mirror of the LADS Mk 3 system was plumbed to the ground to measure the distances to the coordinated marks. The height of the reference point above the ground was also measured to determine the height accuracy. The X, Y and Z lever arms, defined by the antenna lever arms survey, were then applied to derive the coordinates of the LADS and RIEGL GNSS antennae. Refer to Enclosure 5 for the Géopolynésie control point coordination calculations. The ITRF08 coordinates of the marks are (UTM Zone 6S):

Point	Easting	Northing	Ellipsoidal Height
1	222 621.580	8 057 200.240	9.469
2	222 631.100	8 057 193.430	9.435
3	222 621.540	8 057 186.900	9.456

Table 4 – Static Position Check Mark Coordinates

E.3.4 Derived Antennae Positions for Static Position Check

The static position check was conducted in a single session on the 7 June 2015.

To derive the antennae positions, the aircraft heading was determined by the POS AV IMU whilst logging the GNSS data. The aircraft heading for the session was found to be 031º.

The values of the ‘Reference Point to L1 Phase Center Lever Arm’ were applied to derive the coordinates of the LADS GNSS antenna. The RIEGL GNSS antenna positon was determined by calculating the distance between the LADS and RIEGL antennae, which is 0.121m, and applying the appropriate hypotenuse distance and angle from the LADS reference point to the RIEGL antenna.

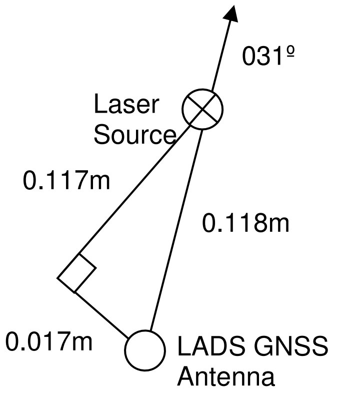
The derived ITRF08 coordinates (UTM Zone 6S) for the LADS laser source position during the static position check was:

Session	Easting	Northing	Ellipsoidal Height
1	222 625.260	8 057 194.269	10.818

Table 5 – LADS Laser source position coordinates

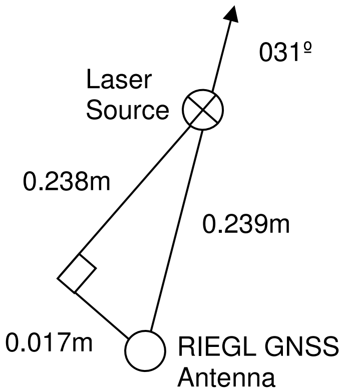
The coordinates for the LADS and RIEGL GNSS antennae positions during the static position check performed on 7 June 2015 were derived from the methodology shown below.

SESSION 1 – 7 June 2015



ΔE = 0.118.sin (031+171.73306)° = -0.046m

ΔN = 0.118.cos (031+171.73306)° = -0.109m



ΔE = 0.239.sin (031+175.93139)° = -0.108m

ΔN = 0.239.cos (031+175.93139)° = -0.213m

The derived ITRF08 coordinates (UTM Zone 6S) for the LADS and RIEGL GNSS antennae positions during the static position check were:

System	Easting	Northing	Ellipsoidal Height
LADS	222 625.215	8 057 194.161	12.214
RIEGL	222 625.152	8 057 194.056	12.214

Table 13 – LADS and RIEGL GNSS antennae coordinates

E.3.5 Ground Control Points – Upolu and Savaii

MNRE Surveyors logged GPS data at selected ground control points and benchmarks around both main islands to help with the caluclation of the geoid model correction required to be applied to reduce the final dataset to the local Mean Sea Level datum. More details are provided in the Post-Survey Spatial Accuracy Report. The field sheets from the ground control points and benchmarks are provided in Enclosure 7.

Enclosures:

1. Géopolynésie GNSS Antenna Offset Survey Report and Calculations – N96Y
2. LADS and RIEGL Antennae Lever Arms Calculation Sheet – N96Y
3. GNSS Station Summaries – SAMO and Fugro Base Station
4. AUSPOS report – Fugro Base Station Coordination – Faleolo Airport
5. Géopolynésie Static Position Check Control Point Calculations – Fa'a'ā Airport
6. Geoscience Australia Weekly Analysis Report Summary GPS Week 1848 – SAMO
7. MNRE Ground Control Points and Benchmarks Field Sheets

Enclosure 1 – Géopolynésie GNSS Antenna Offset Survey Report and Calculations – N96Y

6. CALIBRATION DES INSTRUMENTS AEROPORTES.

La calibrations des instruments à bord de l'aéronef a été effectué afin de positionner les deux antennes GNSS par rapport aux points de référence du laser de chacun des deux systèmes, un LADS et un RIEGL.
D'une seule station on ne pouvait voir les deux systèmes, on a donc visée d'une station le système LADS puis d'une autre station le système RIEGL.
Les coordonnées XYZ des 4 points de calibration de chaque système et du point de calibration de l'antenne GNSS sont données en annexe. Les mesures ont été effectuées avec une station totale LEICA.
Sur le tarmac 3 points ont été positionnés à partir de la station permanente PPT1en mode statique, ces points ont servis à contrôler le GPS de l'aéronef. Voir rapport de calcul est joint en pièce-jointe.

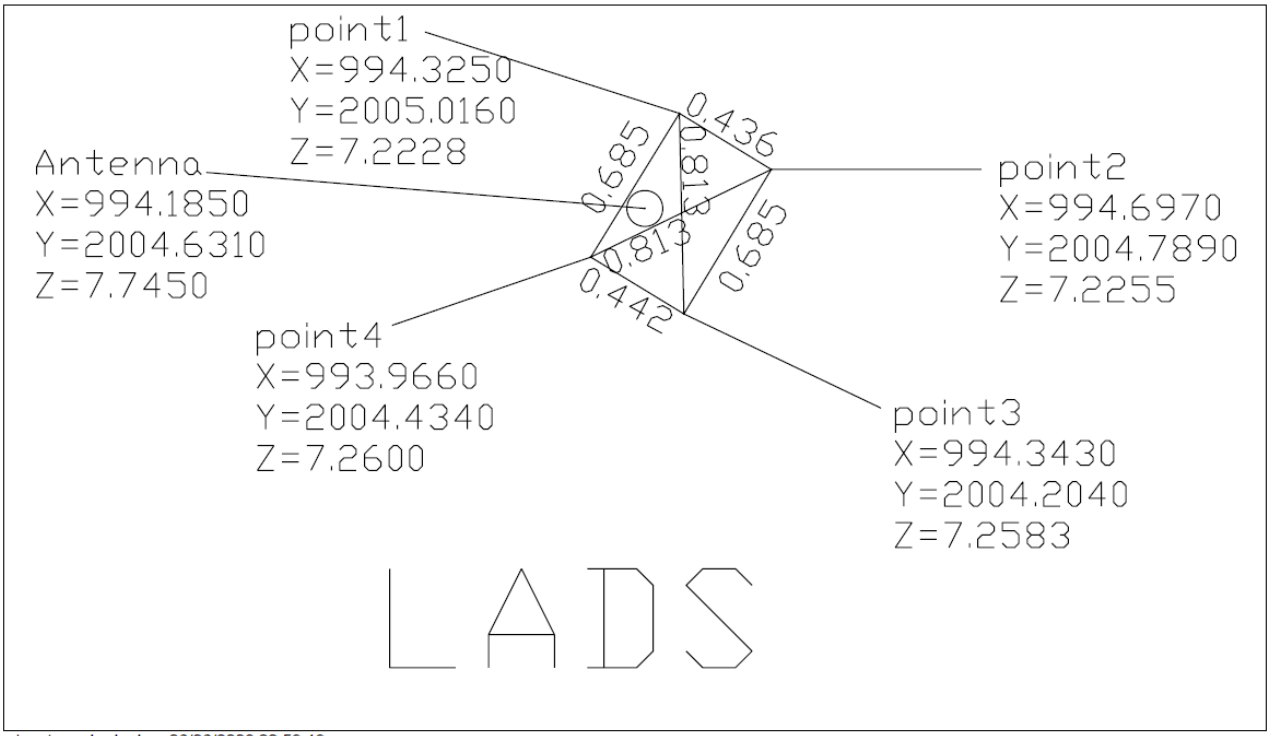
COVADIS CALCULS TOPOMETRIQUES - CALCUL DE POINTS RAYONNES
Système LADS

Nom de la GéoBase traitée : D:\calibfugroavion2\M_1FUGRO.geo
Calculs effectués le : 06/06/2015 à 18:51:11
Tolérances utilisées : Cadastrales 1980 - Canevas : polygonal ordinaire
Projection utilisée : Projection Lambert Zone I
Altération linéaire = 0 mm/km - Correction de niveau zéro = 0 mm/km

Station 2000, reprise 1 (Appareil Standard CV=0.0000 Gr, CO=0.000 m):
X = 1000.000, Y = 2000.000, Z = 5.000, V0 = 0.0000, HI = 1.753

Point	Hp	X	Y	Z	Gi	Dh
1 point1	0.245	994.328	2005.014	7.224	346.0825	7.570
2 point2	0.235	994.697	2004.788	7.226	346.7560	7.145
3 point3	0.235	994.343	2004.205	7.258	340.6910	7.048
4 point4	0.234	993.967	2004.433	7.259	340.3450	7.486
5 GNSS	0.100	994.186	2004.630	7.745	342.8130	7.432
6 Ref	1.300	999.997	2027.853	4.923	399.9930	27.853
7 GNSS	0.100	994.185	2004.632	7.743	342.8230	7.434
8 point4	0.234	993.966	2004.434	7.260	340.3450	7.487
9 point3	0.235	994.343	2004.204	7.257	340.6880	7.048
10 point2	0.235	994.697	2004.789	7.227	346.7615	7.146
11 point1	0.245	994.323	2005.015	7.224	346.0630	7.574
12 Ref	1.300	1000.000	2027.853	4.927	399.9995	27.853
2.14 Ref	1.300	1000.000	2027.853	4.927	399.9995	27.853
2.15 point1	0.245	994.323	2005.017	7.221	346.0760	7.577
2.16 point2	0.235	994.694	2004.788	7.222	346.7350	7.146
2.17 point3	0.235	994.342	2004.204	7.258	340.6805	7.049
2.18 point4	0.234	993.967	2004.435	7.260	340.3575	7.487
2.19 GNSS	0.100	994.185	2004.630	7.748	342.8060	7.433
2.20 Ref	1.300	1000.003	2027.853	4.924	0.0075	27.853
2.21 GNSS	0.100	994.183	2004.631	7.744	342.8000	7.435
2.22 point4	0.234	993.966	2004.433	7.261	340.3420	7.487
2.23 point3	0.235	994.342	2004.204	7.260	340.6835	7.049
2.24 point2	0.235	994.698	2004.791	7.227	346.7755	7.146
2.25 point1	0.245	994.325	2005.018	7.222	346.0890	7.575
2.26 Ref	1.300	999.999	2027.853	4.924	399.9985	27.853

Moyenne Z : point 1 7.2228 – point 2 7.2255 – point 3 7.2583 – point 4 7.2600 – GNSS 7.745



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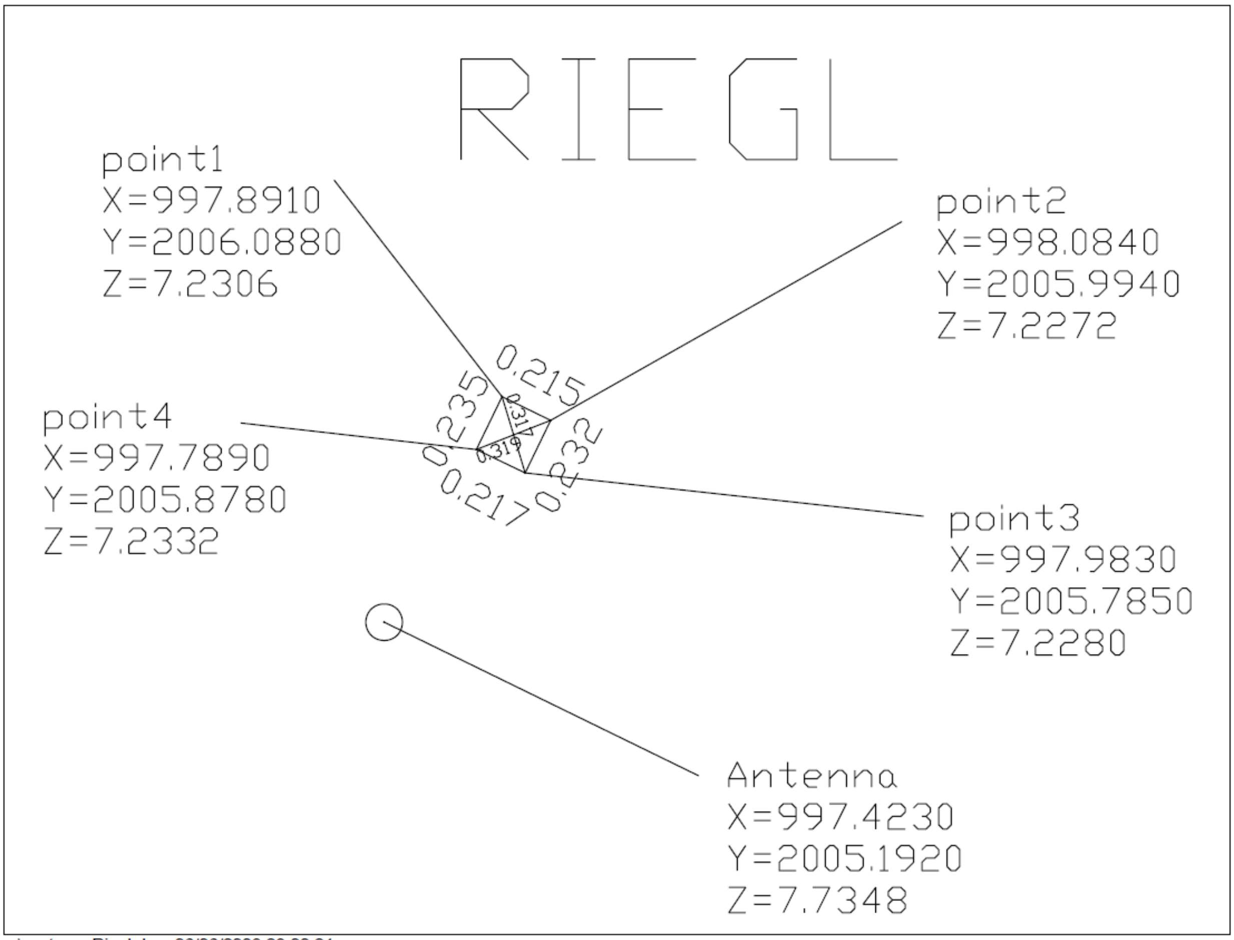
COVADIS CALCULS TOPOMETRIQUES - CALCUL DE POINTS RAYONNES
Système RIEGL

Nom de la GéoBase traitée : D:\calibfugroavion1\M_FUGROCALIB.geo
Calculs effectués le : 06/06/2015 à 18:38:05
Tolérances utilisées : Cadastrales 1980 - Canevas : polygonal ordinaire
Projection utilisée : Projection Lambert Zone I
Altération linéaire = 0 mm/km - Correction de niveau zéro = 0 mm/km

Station 1000, reprise 1 (Appareil Standard CV=0.0000 Gr, CO=0.000 m):
X = 1000.000, Y = 2000.000, Z = 5.000, V0 = 0.0000, HI = 1.764

Point	Hp	X	Y	Z	Gi	Dh
1.1 point1	0.050	997.889	2006.090	7.231	378.7605	6.445
1.2 point2	0.050	998.086	2005.996	7.227	380.3250	6.294
1.3 point3	0.050	997.981	2005.788	7.228	378.6350	6.129
1.4 point4	0.050	997.786	2005.880	7.234	377.0780	6.283
1.5 GNSS	0.234	997.422	2005.194	7.735	370.6715	5.799
1.9 ref	1.300	1000.005	2058.443	4.789	0.0050	58.443
1.10 GNSS	0.234	997.417	2005.191	7.734	370.6045	5.798
1.12 point4	0.050	997.788	2005.877	7.233	377.0875	6.280
1.13 point3	0.050	997.979	2005.784	7.228	378.5985	6.126
1.14 point2	0.050	998.087	2005.993	7.227	380.3280	6.291
1.15 point1	0.050	997.893	2006.088	7.232	378.7850	6.442
1.16 ref	1.300	1000.002	2058.443	4.789	0.0025	58.443
2.0 ref	1.300	1000.002	2058.443	4.789	0.0020	58.443
2.1 point1	0.050	997.894	2006.085	7.232	378.7880	6.439
2.2 point2	0.050	998.084	2005.994	7.229	380.3070	6.293
2.3 point3	0.050	997.984	2005.785	7.228	378.6570	6.126
2.4 point4	0.050	997.791	2005.880	7.233	377.1215	6.282
2.5 GNSS	0.234	997.423	2005.189	7.735	370.6540	5.794
2.6 ref	1.300	999.998	2058.443	4.793	399.9980	58.443
3.0 ref	1.300	999.998	2058.443	4.793	399.9980	58.443
3.1 point1	0.050	997.891	2006.088	7.230	378.7690	6.443
3.2 point2	0.050	998.085	2005.992	7.227	380.3095	6.290
3.3 point3	0.050	997.987	2005.784	7.229	378.6790	6.124
3.4 point4	0.050	997.796	2005.879	7.234	377.1670	6.279
3.5 GNSS	0.234	997.425	2005.195	7.735	370.7045	5.798
3.6 ref	1.300	1000.003	2058.443	4.788	0.0035	58.443
3.7 GNSS	0.234	997.423	2005.193	7.735	370.6690	5.797
3.8 point4	0.050	997.786	2005.876	7.232	377.0635	6.280
3.9 point3	0.050	997.984	2005.785	7.227	378.6515	6.127
3.10 point2	0.050	998.080	2005.997	7.227	380.2760	6.297
3.11 point1	0.050	997.890	2006.088	7.231	378.7635	6.443
3.12 ref	1.300	1000.006	2058.443	4.786	0.0060	58.443

Moyenne Z : point 1 7.2306 – point 2 7.2272 – point 3 7.2280 – point 4 7.2332 – GNSS 7.7348



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Enclosure 2 – LADS and RIEGL Antennae Lever Arms Calculation Sheet – N96Y

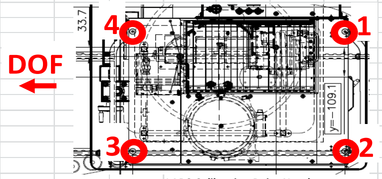
LADS Mk 3 To GNSS Antenna Lever Arms Calculation Sheet

INSTRUCTIONS:

1. Check what orientation and from where to where the provided coordinates go from/to
2. Input Coordinates measured in the Yellow cells to **LEFT HAND** convention, X=+DOF, Y=+Right, Z=+Up
3. RL is to be input as height to the centre of the target, ie NO Pogo or height offset.
4. Prism offset is input as centre of target to the base of the target
5. Pogo height is input as centre of target to base of pogo
6. If a different method has been used input 0 for Prism Offset and Pogo Height

Datum Input AIRCRAFT STANDARD Left Hand System

	X	Y	Z		
1	994.325	2005.016	7.223	0.000	Prism Offset
2	994.697	2004.789	7.226	0.000	
3	994.343	2004.204	7.258	0.000	
4	993.966	2004.434	7.260	0.000	
Antenna	994.185	2004.631	7.745	0.000	Pogo Height



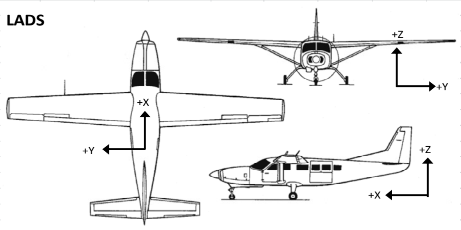
LADS Calibration Point Numbers

From LADS Laser Source To L1 Phase Center Lever Arms (m)

LADS	X	Y	Z	
	-0.117	-0.017	1.396	
Precision	0.004	0.006	0.005	95% Confidence
	0.000	0.000	0.002	Potential Distance Extrapolation Error

Input these values into GROUND SYSTEM

LADS

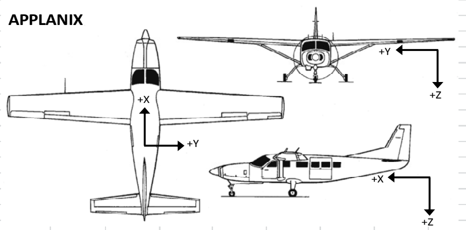


From LADS Laser Source To L1 Phase Center Lever Arms (m)

APPLANIX	X	Y	Z	
	-0.117	0.017	-1.396	
Precision	0.004	0.006	0.005	95% Confidence
	0.000	0.000	0.002	Potential Distance Extrapolation Error

Input these values into AV POSVIEW CONTROLLER

APPLANIX



Datum Input LADS AIRCRAFT STANDARD Right Hand System (LADS USE ONLY)

	X	Y	Z	Pole Lengt	Offset to datum		
1	-0.546	-0.103	0.320	0.600	0.600	0.023	Top of Antenna to L1 Electrical Phase Center Offset
2	-0.546	0.338	0.320	0.600	0.600		
3	0.141	0.338	0.320	0.600	0.600		
4	0.141	-0.103	0.320	0.600	0.600		

NOTES (LADS ONLY):

These coordinates are the platform centric coordinates originating from the laser source point to the calibration point on the platform in aircraft standard right hand system

The Antenna electrical phase center offset has been derived from NGS Calibrated ANTEX file http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=AERAT1675_180_NONE.atx

Rotation around the Z Axis

	dx	dy	dz	XY Dist	Yaw Ang	New Yaw	x'	y'	z'	Slope Dist
1	0.000	0.000	0.000				0.000	0.000	0.000	
2	0.372	-0.227	0.003	0.436	121.3922	269.7243	-0.436	-0.002	0.003	0.436
3	0.018	-0.812	0.035	0.812	178.7301	327.0622	-0.442	0.682	0.035	0.813
4	-0.359	-0.582	0.037	0.684	**-148.3321**	0	0.000	0.684	0.037	0.685
Antenna	-0.140	-0.385	0.522	0.410	-160.0169	-11.6848	-0.083	0.401	0.522	0.664

Rotation around the X Axis

	x'	y'	z'	YZ Dist	Pitch Ang	New Pitch	x''	y''	z''	Slope Dist
1	0.000	0.000	0.000				0.000	0.000	0.000	
2	-0.436	-0.002	0.003	0.003	127.8360	214.722	-0.436	-0.002	0.003	0.436
3	-0.442	0.682	0.035	0.683	2.9813	89.867	-0.442	0.683	-0.002	0.813
4	0.000	0.684	0.037	0.685	**3.1139**	90.000	0.000	0.685	0.000	0.685
Antenna	-0.083	0.401	0.522	0.659	52.4671	139.353	-0.083	0.429	0.500	0.664

Rotation around the Y Axis

	x''	y''	z''	XZ Dist	Roll Ang	New Roll	x'''	y'''	z'''	Slope Dist	Horiz Dist
1	0.000	0.000	0.000				0.000	0.000	0.000		
2	-0.436	-0.002	0.003	0.436	**-89.6306**	270.000	-0.436	-0.002	0.000	0.436	0.436
3	-0.442	0.683	-0.002	0.442	-90.2049	269.426	-0.442	0.683	-0.004	0.813	0.813
4	0.000	0.685	0.000	0.000	180.0000	539.631	0.000	0.685	0.000	0.685	0.685
Antenna	-0.083	0.429	0.500	0.506	-9.4283	350.202	-0.086	0.429	0.499	0.664	0.438

Translation between Ground (Left handed) coordinate system to Right Handed coordinate system

	x'''	y'''	z'''			X''''	Y''''	Z''''
1	0.000	0.000	0.000	1 Swap X and Y	1	0.000	0.000	0.000
2	-0.436	-0.002	0.000	2 Change Sign Y	2	-0.002	0.436	0.000
3	-0.442	0.683	-0.004		3	0.683	0.442	-0.004
4	0.000	0.685	0.000		4	0.685	0.000	0.000
Antenna	-0.086	0.429	0.499		Antenna	0.429	0.086	0.499

Translation to Laser Source Origin

	X	Y	Z				X^	Y^	Z^	
1	-0.546	-0.103	0.320	1 Offset coordinates using point		1	-0.546	-0.103	0.320	
2	-0.546	0.338	0.320	2 take off platform pole offsets		2	-0.547	0.333	0.320	
3	0.141	0.338	0.320	3 Reduce to L1 Phase Centre offs		3	0.137	0.339	0.315	
4	0.141	-0.103	0.320			4	0.139	-0.103	0.320	
				Top to L1 Phase Centi	0.023	Ant	-0.117	-0.017	1.396	0.118

Statistic Generation

	dx	dy	dz		X	Y	Z			
1	0.000	0.000	0.000	average	-0.002	-0.001	-0.001		0.005	Height Error factor
2	-0.002	-0.005	0.000	STDEV	0.001	0.003	0.002		0.004	
3	-0.003	0.001	-0.004	95%Confic	0.004	0.006	0.005		0.001	
4	-0.001	0.000	0.000		0.000	0.000	0.002	Distance Factor		

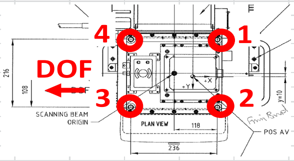
RIEGL APPLANIX IMU To GNSS Antenna Lever Arms Calculation Sheet

INSTRUCTIONS:

1. Check what orientation and from where to where the provided coordinates go from/to
2. Input Coordinates measured in the Yellow cells to **LEFT HAND** convention, X=+DOF, Y=+Right, Z=+Up
3. RL is to be input as height to the centre of the target, ie NO Pogo or height offset.
4. Prism offset is input as centre of target to the base of the target
5. Pogo height is input as centre of target to base of pogo
6. If a different method has been used input 0 for Prism Offset and Pogo Height

Datum Input AIRCRAFT STANDARD Left Hand System

	X	Y	Z		
1	997.891	2006.088	7.231	0.000	Prism Offset
2	998.084	2005.994	7.227	0.000	
3	997.983	2005.785	7.228	0.000	
4	997.789	2005.878	7.233	0.000	
Antenna	997.423	2005.192	7.735	0.000	Pogo Height



RIEGL Calibration Point Numbers

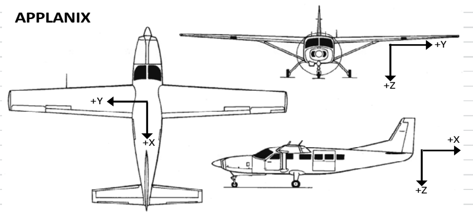
THESE VALUES USED FOR SURVEY IN NED REFERENCE FRAME WITH Z ROTATION 180°

From APPLANIX IMU Origin To L1 Phase Center Lever Arms (m)

APPLANIX	X	Y	Z	
	0.949	0.155	-0.935	
Precision	0.005	0.002	0.002	95% Confidence
	0.011	0.002	0.006	Potential Distance Extrapolation Error

Input these values into AV POSVIEW CONTROLLER
Values used when RIEGL laser is firing BEHIND (reversed 180°)

APPLANIX

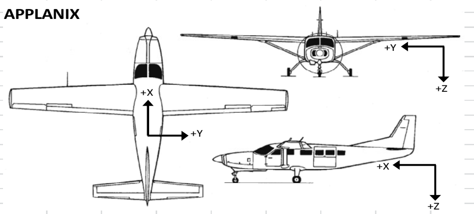


From APPLANIX IMU Origin To L1 Phase Center Lever Arms (m)

APPLANIX	X	Y	Z	
	-0.847	0.061	-0.935	
Precision	0.005	0.002	0.002	95% Confidence
	0.011	0.002	0.006	Potential Distance Extrapolation Error

Input these values into AV POSVIEW CONTROLLER
Values used when RIEGL laser is firing FORWARD

APPLANIX



Datum Input LADS AIRCRAFT STANDARD Right Hand System (LADS USE ONLY)

	X	Y	Z	Pole Lengt	Offset to datum		
1	-0.067	-0.118	-0.014	0.480	0.480	0.023	Top of Antenna to L1 Phase Centre
2	-0.067	0.098	-0.014	0.480	0.480		
3	0.169	0.098	-0.014	0.480	0.480		
4	0.169	-0.118	-0.014	0.480	0.480		

NOTES (LADS ONLY):

These coordinates are the platform centric coordinates originating from the IMU origin point to the calibration point on the platform in aircraft standard right hand system
The Antenna electrical phase center offset has been derived from NGS Calibrated ANTEX file http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=AERAT1675_180_NONE.atx

Datum Input LADS AIRCRAFT STANDARD Right Hand System (APPLANIX reversed 180°) (LADS USE ONLY)

	X	Y	Z	Pole Lengt	Offset to datum		
1	-0.169	0.098	-0.014	0.480	0.480	0.023	Top of Antenna to L1 Phase Centre
2	-0.169	-0.118	-0.014	0.480	0.480		
3	0.067	-0.118	-0.014	0.480	0.480		
4	0.067	0.098	-0.014	0.480	0.480		

NOTES (LADS ONLY):

These coordinates are the platform centric coordinates originating from the IMU origin point to the calibration point on the platform in aircraft standard right hand system
The Antenna electrical phase center offset has been derived from NGS Calibrated ANTEX file http://www.ngs.noaa.gov/ANTCAL/LoadFile?file=AERAT1675_180_NONE.atx

Rotation around the Z Axis

	dx	dy	dz	XY Dist	Yaw Ang	New Yaw	x'	y'	z'	Slope Dist
1	0.000	0.000	0.000				0.000	0.000	0.000	
2	0.193	-0.094	-0.003	0.215	115.9682	270.0617	-0.215	0.000	-0.003	0.215
3	0.092	-0.303	-0.003	0.317	163.1101	317.2036	-0.215	0.232	-0.003	0.317
4	-0.102	-0.210	0.003	0.233	**-154.0935**	0.0000	0.000	0.233	0.003	0.233
Antenna	-0.468	-0.896	0.504	1.011	-152.4210	1.6725	0.030	1.010	0.504	1.130

Rotation around the X Axis

	x'	y'	z'	YZ Dist	Pitch Ang	New Pitch	x''	y''	z''	Slope Dist
1	0.000	0.000	0.000				0.000	0.000	0.000	
2	-0.215	0.000	-0.003	0.003	-86.1082	3.254	-0.215	0.000	-0.003	0.215
3	-0.215	0.232	-0.003	0.232	-0.6411	88.721	-0.215	0.232	-0.005	0.317
4	0.000	0.233	0.003	0.233	**0.6381**	90.000	0.000	0.233	0.000	0.233
Antenna	0.030	1.010	0.504	1.129	26.5190	115.881	0.030	1.016	0.493	1.130

Rotation around the Y Axis

	x''	y''	z''	XZ Dist	Roll Ang	New Roll	x'''	y'''	z'''	Slope Dist	Horiz Dist
1	0.000	0.000	0.000				0.000	0.000	0.000		
2	-0.215	0.000	-0.003	0.215	**-90.9080**	270.000	-0.215	0.000	0.000	0.215	0.215
3	-0.215	0.232	-0.005	0.215	-91.3812	269.527	-0.215	0.232	-0.002	0.317	0.317
4	0.000	0.233	0.000	0.000	180.0000	540.908	0.000	0.233	0.000	0.233	0.233
Antenna	0.030	1.016	0.493	0.494	3.4254	364.333	0.037	1.016	0.492	1.130	1.017

Translation between Ground (Left handed) coordinate system to Right Handed coordinate system

	x'''	y'''	z'''			X''''	Y''''	Z''''
1	0.000	0.000	0.000	1 Swap X and Y	1	0.000	0.000	0.000
2	-0.215	0.000	0.000	2 Change Sign Y	2	0.000	0.215	0.000
3	-0.215	0.232	-0.002		3	0.232	0.215	-0.002
4	0.000	0.233	0.000		4	0.233	0.000	0.000
Antenna	0.037	1.016	0.492		Antenna	1.016	-0.037	0.492

Translation to Laser Source Origin

	X	Y	Z				X^	Y^	Z^	
1	-0.067	-0.118	-0.014	1 Offset coordinates using point		1	-0.067	-0.118	-0.014	
2	-0.067	0.098	-0.014	2 take off platform pole offsets		2	-0.067	0.097	-0.014	
3	0.169	0.098	-0.014	3 Reduce to L1 Phase Centre offs		3	0.165	0.097	-0.016	
4	0.169	-0.118	-0.014			4	0.166	-0.118	-0.014	
				Top to L1 Phase Centr	0.023	Ant	0.949	-0.155	0.935	0.962

Translation to Laser Source Origin

	X	Y	Z				X^	Y^	Z^	
1	-0.169	0.098	-0.014	1 Offset coordinates using point		1	-0.169	0.098	-0.014	
2	-0.169	-0.118	-0.014	2 take off platform pole offsets		2	-0.169	0.313	-0.014	
3	0.067	-0.118	-0.014	3 Reduce to L1 Phase Centre offs		3	0.063	0.313	-0.016	
4	0.067	0.098	-0.014			4	0.064	0.098	-0.014	
				Top to L1 Phase Centr	0.023	Ant	0.847	0.061	0.935	0.849

Statistic Generation

	dx	dy	dz		X	Y	Z			
1	0.000	0.000	0.000	average	-0.002	-0.001	0.000		0.006	Height Error factor
2	0.000	-0.001	0.000	STDEV	0.002	0.001	0.001		0.012	
3	-0.004	-0.001	-0.002	95%Confic	0.005	0.002	0.002		0.003	
4	-0.003	0.000	0.000		0.011	0.002	0.006	Distance Factor		

Enclosure 3 – GNSS Station Summaries – SAMO and Fugro Base Station

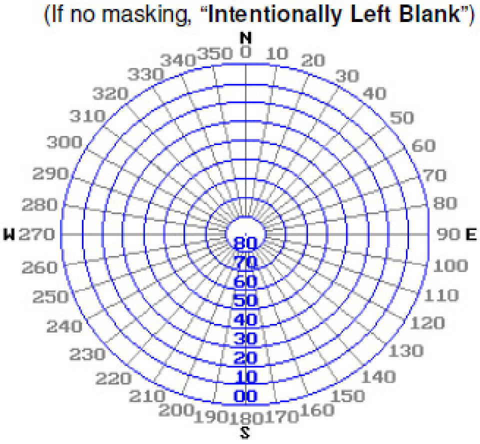
LADS GNSS STATION SUMMARY

Station Name or Number: **Apia Base Station, SAMO**		Date: **4-July-2015**
Location: **Fagalii Airstrip in Apia, Tahiti**		
Country: **Samoa**	State: **Apia**	District: **Fagalii Village**
HORIZONTAL DATUM: ☐ GDA94 ☐ WGS84: ☐ ETRF ☐ NAD83 ☑ ITRF: ☐ Other:	Realisation/Datum: **2008**	Epoch: **2015.5**
VERTICAL DATUM: ☐ AHD ☐ Chart Datum: ☐ Other:	Ellipsoid: ☑ GRS80 ☐ WGS84 ☐ Other:	
GRID SYSTEM PARAMETERS: UTM Zone: **2**	Hemisphere: ☐ North ☑ South	Central Meridian: **171°W**
Latitude: **13° 50‘ 57.1444“ S**	Longitude: **171° 44‘ 18.3351“ W**	Ellipsoidal Height: **76.7554 m**
Easting: **420 203.070 mE**	Northing: **8 468 827.480 mN**	Geoidal Height: **39.5142 m**
Grid Convergence **-0.176765°**	N Value: **37.2412 m** ☐ Observed ☐ AusGeoid09 ☑ EGM08	Probable Life of Mark: **10 years**
Station Establishing Surveyor: **Geoscience Australia**	Establishing Report Reference: **GA Analysis Report GPS Week 1848**	Establishing Survey: **June 2001**

Revisited Date:				
Report Reference:				
Revisiting Surveyor:				

Site Plan

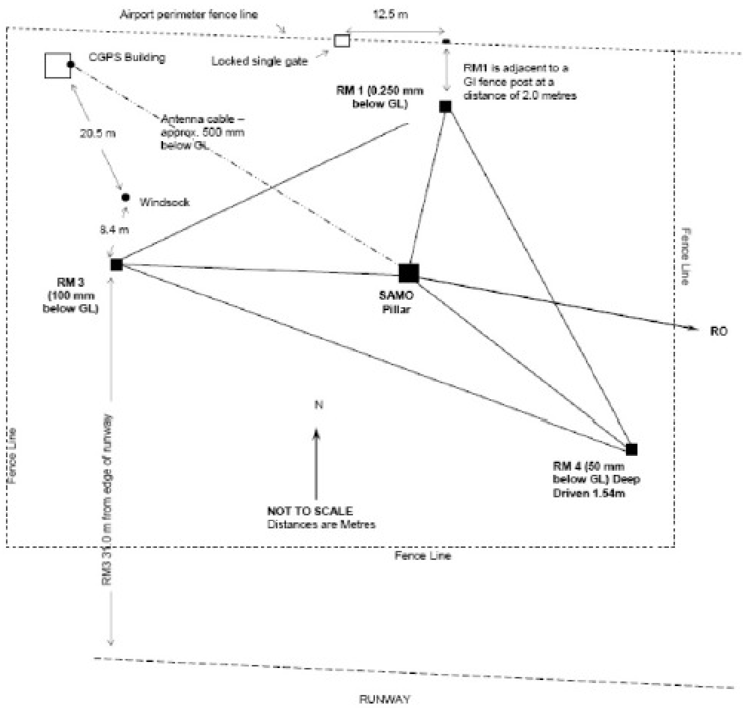
Satellite Obstructions Polar Plot
(If no masking, “**Intentionally Left Blank**”)



Notes:
SAMO base station coordinates obtained from Geoscience Australia weekly Analysis Report summary for GPS week 1848. See report number AUS18487.sum.pdf for more details.

PARTICULARS OF STATION MARK
Location: Near the runway at the Fagalii airstrip.
Access: There is restricted access to the airport airside. Contact Geoscience Australia for access
Description: Monument is a 400mm diameter concrete pillar, 1.5 metres above ground surface. A 250mm diameter stainless steel plate, (antenna mount) is centered into the top of the monument on which the GNSS antenna is screwed into the 5/8" thread.
Construction Diagram:

SAMO Pillar and RM Diagram
FAGALII AIRPORT - SAMOA



STATION PHOTOGRAPHS – Views of Location and Mark

Looking North

Looking East

Looking South

Looking West

Compiled by: **Ben McWilliam**	Date: **5-July-2015**
Checked by: **Luke Chamberlain**	Date: **14-August-2015**

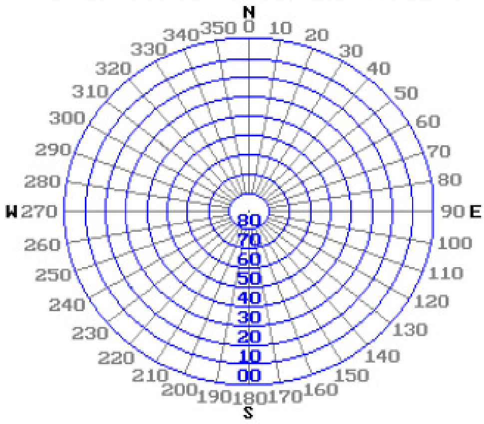
LADS GNSS STATION SUMMARY

Station Name or Number: **Faleolo Airport Base Station**		Date: **6-July-2015**
Location: **Faleolo Airport in Faleolo, Samoa**		
Country: **Samoa**	State: **Faleolo**	District: **Faleolo Airport**
HORIZONTAL DATUM: ☐ GDA94 ☐ WGS84: ☐ ETRF ☐ NAD83 ☑ ITRF: ☐ Other:	Realisation/Datum: **2008**	Epoch: **2015.5**
VERTICAL DATUM: ☐ AHD ☐ Chart Datum: ☑ Other:	Ellipsoid: ☑ GRS80 ☐ WGS84 ☐ Other:	
GRID SYSTEM PARAMETERS: UTM Zone: **2**	Hemisphere: ☐ North ☑ South	Central Meridian: **171°W**
Latitude: **13° 49' 51.10973" S**	Longitude: **172° 00' 44.63596" W**	Ellipsoidal Height: **45.273 m Mark** **46.340 m L1**
Easting: **390 585.690 mE**	Northing: **8 470 748.080 mN**	Geoidal Height: **7.434 m Mark** **8.501 m L1**
Grid Convergence **-0.242045°**	N Value: **37.839 m** ☐ Observed ☐ AusGeoid09 ☑ EGM08	Probable Life of Mark: **1 year**
Station Establishing Surveyor: **Christian Gordini FGS**	Establishing Report Reference: **AUSPOS Report (Job Number 6615)**	Establishing Survey: **Samoa MNRE July 2015**

Revisited Date:				
Report Reference:				
Revisiting Surveyor:				

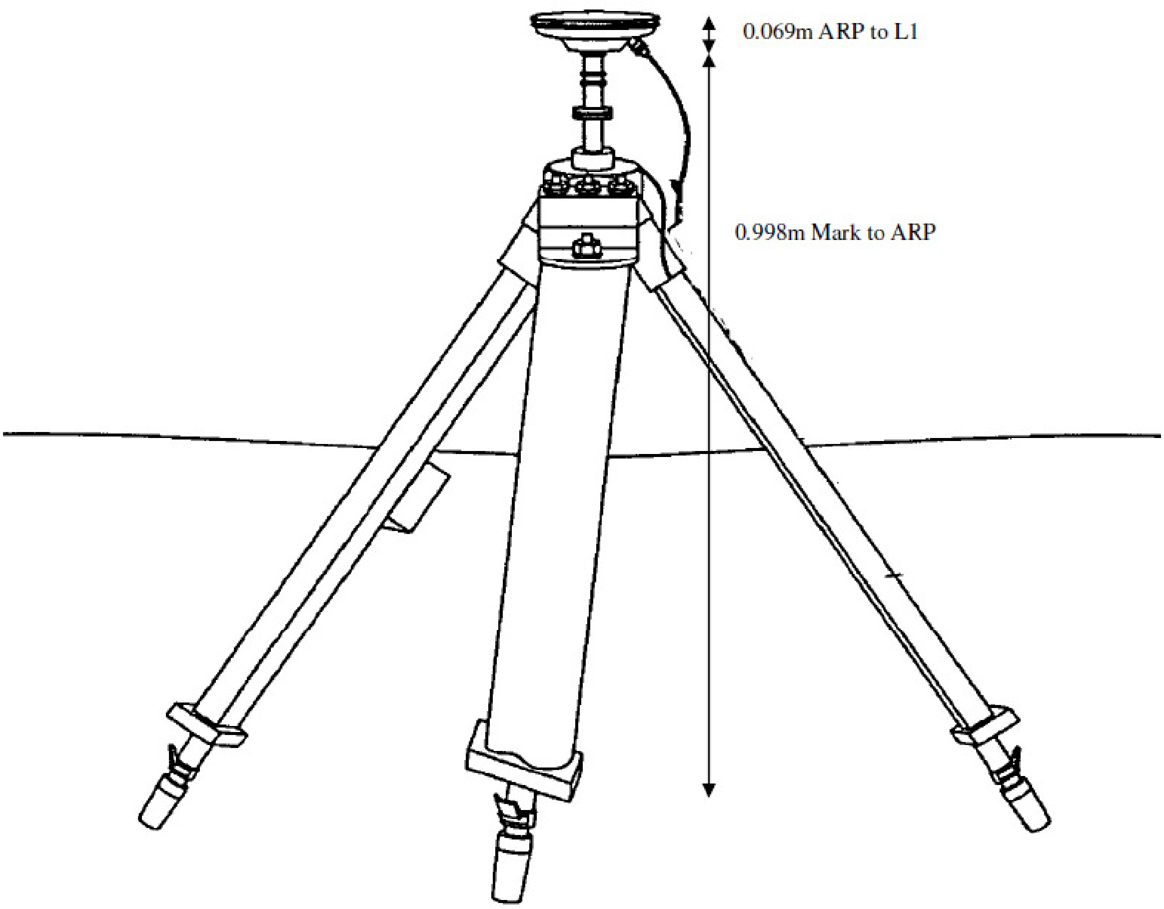
Site Plan

Satellite Obstructions Polar Plot
(If no masking, "**Intentionally Left Blank**")



Notes:

PARTICULARS OF STATION MARK
Location: Behind the Runway sign next to the taxiway at the maintenance hangar at Faleolo Airport.
Access: There is restricted access to the airport airside. Ask permission at gate west of terminal building to drive out to hangar at western end of airport. Can drive up to station mark.
Description: There is no established mark. A point in the ground was marked with a pen, with a tripod established over this mark. The tribrach and 'NOV702GG' GNSS antenna were appropriately screwed on top of the tripod. The DL-V3 receiver and battery were in a pelican case placed next to the tripod and covered with a sun shade for protection from heat and rain.
Construction Diagram:



STATION PHOTOGRAPHS – Views of Location and Mark	

Looking North West

Looking North East

Compiled by: **Ben McWilliam**	Date: **6-July-2015**
Checked by: **Luke Chamberlain**	Date: **14-August-2015**

Enclosure 4 – AUSPOS Report – Fugro Base Station Coordination – Faleolo Airport

AUSPOS GPS Processing Report

July 8, 2015

This document is a report of the GPS data processing undertaken by the AUSPOS Online GPS Processing Service (version: AUSPOS 2.2) . The AUSPOS Online GPS Processing Service uses International GNSS Service (IGS) products (final, rapid, ultra-rapid depending on availability) to compute precise coordinates in ITRF anywhere on Earth and GDA94 within Australia. The Service is designed to process only dual frequency GPS phase data.

An overview of the GPS processing strategy is included in this report.

Please direct any correspondence to geodesy@ga.gov.au

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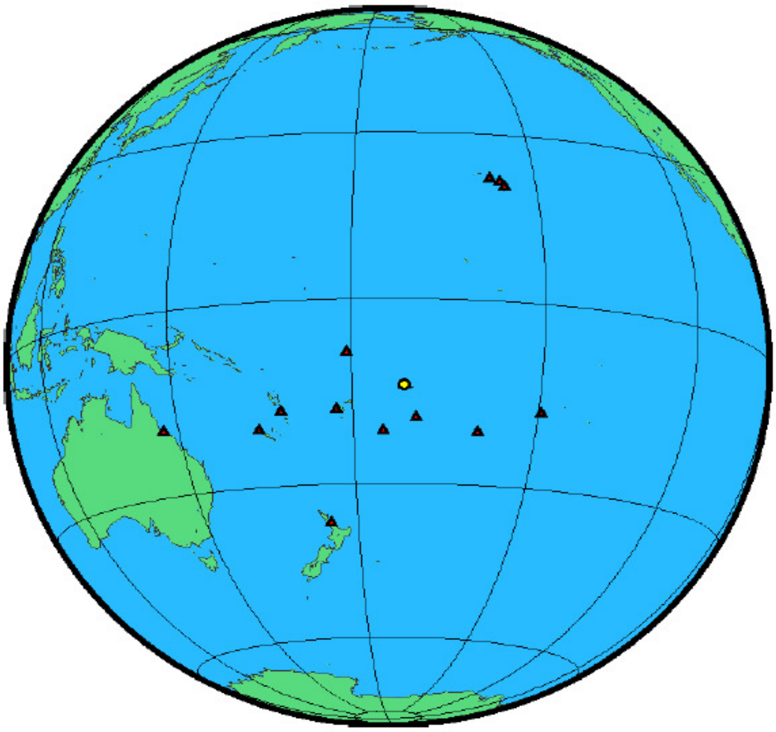
Geoscience Australia
Home Page: http://www.ga.gov.au

1 User Data

All antenna heights refer to the vertical distance from the Ground Mark to the Antenna Reference Point (ARP).

Station (s)	Submitted File	Antenna Type	Antenna Height (m)	Start Time	End Time
0017	00171860_30.zip	NOV702GG_1.02 NONE	0.998	2015/07/05 17:52:00	2015/07/06 00:11:30

2 Processing Summary



Date	User Stations	Reference Stations	Orbit Type
2015/07/05 17:52:00	0017	AUCK CKIS HNLC KOUC LAUT MAUI MKEA NIUM PTVL SAMO TAH1 TONG TOW2 TUVA	IGS rapid

Remark: An IGS Rapid Orbit product has been used in this computation, IGS Rapid orbits are usually of very high quality. However, to ensure you achieve the highest quality coordinates please resubmit approximately 2 weeks after the observation session end to ensure the use of the IGS Final Orbit product.

3 Computed Coordinates, ITRF2008

All computed coordinates are based on the IGS realisation of the ITRF2008 reference frame. All the given ITRF2008 coordinates refer to a mean epoch of the site observation data. All coordinates refer to the Ground Mark.

3.1 Cartesian, ITRF2008

Station	X (m)	Y (m)	Z (m)	ITRF2008 @
0017	-6134338.604	-860771.411	-1514828.874	05/07/2015
AUCK	-5105681.418	461564.005	-3782181.147	05/07/2015
CKIS	-5583182.510	-2054142.974	-2292166.358	05/07/2015
HNLC	-5506798.851	-2240048.868	2302720.753	05/07/2015
KOUC	-5751223.032	1617967.312	-2225743.385	05/07/2015
LAUT	-6075194.622	270923.802	-1917189.192	05/07/2015
MAUI	-5466069.003	-2404327.418	2242127.774	05/07/2015
MKEA	-5464105.328	-2495165.711	2148291.530	05/07/2015
NIUM	-5937160.832	-1054675.433	-2071386.142	05/07/2015
PTVL	-5950573.259	1230677.425	-1932016.956	05/07/2015
SAMO	-6129702.344	-890028.790	-1516806.931	05/07/2015
TAH1	-5246404.371	-3077284.763	-1913838.941	05/07/2015
TONG	-5930303.571	-500148.353	-2286366.258	05/07/2015
TOW2	-5054583.263	3275504.177	-2091538.712	05/07/2015
TUVA	-6307543.782	88455.065	-939277.744	05/07/2015

3.2 Geodetic, GRS80 Ellipsoid, ITRF2008

Geoid-ellipsoidal separations, in this section, are computed using a spherical harmonic synthesis of the global EGM2008 geoid. More information on the EGM2008 geoid can be found at http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/

Station	Latitude (DMS)	Longitude (DMS)	Ellipsoidal Height(m)	Derived Above Geoid Height(m)
0017	-13 49 51.10973	-172 00 44.63596	45.273	7.434
AUCK	-36 36 10.22030	174 50 03.79058	132.677	97.744
CKIS	-21 12 03.68570	-159 48 02.21956	18.399	5.778
HNLC	21 18 11.84943	-157 51 52.38679	21.950	6.205
KOUC	-20 33 31.27926	164 17 14.41890	84.130	23.683
LAUT	-17 36 31.71863	177 26 47.69447	89.653	31.693
MAUI	20 42 23.96809	-156 15 25.30907	3062.076	3044.138
MKEA	19 48 04.88592	-155 27 22.84741	3754.637	3728.346
NIUM	-19 04 35.48850	-169 55 37.45714	89.706	59.087
PTVL	-17 44 57.95697	168 18 54.08231	86.472	22.654
SAMO	-13 50 57.14440	-171 44 18.33515	76.758	39.517
TAH1	-17 34 37.29348	-149 36 22.30003	99.804	92.121
TONG	-21 08 40.96913	-175 10 45.16378	56.294	3.724
TOW2	-19 16 09.38890	147 03 20.48769	88.106	30.171
TUVA	-8 31 31.03688	179 11 47.59505	38.396	3.557

3.3 Positional Uncertainty (95% C.L.) - Geodetic, ITRF2008

Station	Longitude(East) (m)	Latitude(North) (m)	Ellipsoidal Height(Up) (m)
0017	0.008	0.005	0.017
AUCK	0.005	0.004	0.008
CKIS	0.005	0.003	0.007
HNLC	0.005	0.004	0.008
KOUC	0.006	0.003	0.007
LAUT	0.005	0.003	0.008
MAUI	0.005	0.004	0.008
MKEA	0.006	0.004	0.010
NIUM	0.005	0.003	0.007
PTVL	0.006	0.003	0.008
SAMO	0.005	0.003	0.007
TAH1	0.006	0.003	0.008
TONG	0.006	0.004	0.009
TOW2	0.005	0.003	0.008
TUVA	0.005	0.003	0.007

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4 Ambiguity Resolution - Per Baseline

Baseline	Ambiguities Resolved	Baseline Length (km)
KOUC - TOW2	78.0 %	1802.983
SAMO - TONG	63.0 %	885.431
SAMO - TUVA	83.9 %	1150.043
CKIS - TAH1	91.8 %	1141.652
MAUI - MKEA	84.0 %	130.617
KOUC - LAUT	81.8 %	1419.398
CKIS - NIUM	97.4 %	1083.042
AUCK - KOUC	88.1 %	2043.647
NIUM - SAMO	93.5 %	609.704
0017 - SAMO	68.2 %	29.688
HNLC - MAUI	88.3 %	179.772
KOUC - PTVL	75.8 %	525.366
LAUT - TUVA	82.0 %	1021.563
MAUI - TUVA	75.0 %	4128.364
AVERAGE	82.2%	1153.662

Please note for a regional solution, such as used by AUSPOS, an average ambiguity resolution of 50% or better for the network indicates a reliable solution.

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5 Computation Standards

5.1 Computation System

Software	Bernese GNSS Software Version 5.2.
GNSS system(s)	GPS only.

5.2 Data Preprocessing and Measurement Modelling

Data preprocessing	Phase preprocessing is undertaken in a baseline by baseline mode using triple-differences. In most cases, cycle slips are fixed by the simultaneous analysis of different linear combinations of L1 and L2. If a cycle slip cannot be fixed reliably, bad data points are removed or new ambiguities are set up A data screening step on the basis of weighted postfit residuals is also performed, and outliers are removed.
Basic observable	Carrier phase with an elevation angle cutoff of 7° and a sampling rate of 3 minutes. However, data cleaning is performed a sampling rate of 30 seconds. Elevation dependent weighting is applied according to $1/\sin(e)^2$ where e is the satellite elevation.
Modelled observable	Double differences of the ionosphere-free linear combination.
Ground antenna phase centre calibrations	IGS08 absolute phase-centre variation model is applied.
Tropospheric Model	A priori model is the GMF mapped with the DRY-GMF.
Tropospheric Estimation	Zenith delay corrections are estimated relying on the WET-GMF mapping function in intervals of 2 hour. N-S and E-W horizontal delay parameters are solved for every 24 hours.
Tropospheric Mapping Function	GMF
Ionosphere	First-order effect eliminated by forming the ionosphere-free linear combination of L1 and L2. Second and third effect applied.
Tidal displacements	Solid earth tidal displacements are derived from the complete model from the IERS Conventions 2010, but ocean tide loading is not applied.
Atmospheric loading	Applied
Satellite centre of mass correction	IGS08 phase-centre variation model applied
Satellite phase centre calibration	IGS08 phase-centre variation model applied
Satellite trajectories	Best available IGS products.
Earth Orientation	Best available IGS products.

5.3 Estimation Process

Adjustment	Weighted least-squares algorithm.
Station coordinates	Coordinate constraints are applied at the Reference sites with standard deviation of 1mm and 2mm for horizontal and vertical components respectively.
Troposphere	Zenith delay parameters and pairs of horizontal delay gradient parameters are estimated for each station in intervals of 2 hours and 24 hours.
Ionospheric correction	An ionospheric map derived from the contributing reference stations is used to aid ambiguity resolution.
Ambiguity	Ambiguities are resolved in a baseline-by-baseline mode using the Code-Based strategy for 180-6000km baselines, the Phase-Based L5/L3 strategy for 18-200km baselines, the Quasi-Ionosphere-Free (QIF) strategy for 18-2000km baselines and the Direct L1/L2 strategy for 0-20km baselines.

5.4 Reference Frame and Coordinate Uncertainty

Terrestrial reference frame	IGS08 station coordinates and velocities mapped to the mean epoch of observation.
Australian datum	GDA94 coordinates determined via Helmert transformation from ITRF using the Dawson and Woods (2010) parameters.
Derived AHD	For stations within Australia, AUSGeoid09 is used to compute AHD. AUSGeoid09 is the Australia-wide gravimetric quasigeoid model that has been a posteriori fitted to the Australian Height Datum.
Above-geoid heights	Earth Gravitational Model EGM2008 released by the National Geospatial-Intelligence Agency (NGA) EGM Development Team is used to compute above-geoid heights. This gravitational model is complete to spherical harmonic degree and order 2159, and contains additional coefficients extending to degree 2190 and order 2159.
Coordinate uncertainty	Coordinate uncertainty is expressed in terms of the 95% confidence level for both GDA94 and ITRF2008. Uncertainties are scaled using an empirically derived model which is a function of data span, quality and geographical location.

Enclosure 5 – Géopolynésie Static Position Check Control Point Calculations – Fa'a'ā Airport

Rapport sur le traitement des lignes de base

Informations relatives à l'étude		Système de coordonnées	
Nom:	C:\tbc\fugro15\tarnac\TARNAC1.vce	Nom:	UTM
Taille:	147 KB	Datum:	ITRF
Modifié:	07/06/2015 00:06:51	Zone:	6 South
Numéro de référence:		Géoïde:	
Description:		Datum vertical:	

Rapport sur le traitement des lignes de base

Détails des sessions

PPT1 - tarnac1 (16:04:19-16:47:23) (S1)

Observation de ligne de base:	PPT1 --- tarnac1 (B3)
Traité:	07/06/2015 00:05:21
Type de solutions:	Fixe
Fréquence utilisée:	Fréquences multiples
Précision horizontale:	0.006 m
Précision verticale:	0.011 m
RMS:	0.016 m
Rapport:	2.781
PDOP maximum:	1.432
Ephéméride utilisée:	Emission
Modèle d'antenne:	Calibration de Trimble
Heure de démarrage du traitement:	05/06/2015 16:04:19 (Local: UTC-10hr)
Heure d'arrêt du traitement:	05/06/2015 16:47:23 (Local: UTC-10hr)
Durée du traitement:	00:43:04

Composants des vecteurs (Signaler par un repère)

A partir :	PPT1	
Grille	Local	Global

file:///C|/tbc/fugro15/tarnac/tarnacfugro/aa571768.1.html (1 sur 4)07/06/2015 00:26:35

Rapport sur le traitement des lignes de base

Abscisse	226967.267 m	**Latitude**	S17°32'33.26956"	**Latitude**	S17°32'33.26955"
Nord	8058573.098 m	**Longitude**	O149°34'18.69664"	**Longitude**	O149°34'18.69664"
Elévation	35.092 m	**Hauteur**	35.092 m	**Hauteur**	35.092 m

Vers:	tarnac1				
Grille		**Local**		**Global**	
Abscisse	222632.314 m	**Latitude**	S17°33'16.21755"	**Latitude**	S17°33'16.21755"
Nord	8057192.732 m	**Longitude**	O149°36'46.23011"	**Longitude**	O149°36'46.23011"
Elévation	9.103 m	**Hauteur**	9.103 m	**Hauteur**	9.103 m

Vecteur:					
ΔAbscisse	-4334.953 m	**Azimut vers l'avant NS**	253°06'47"	**ΔX**	-1837.574 m
ΔNord	-1380.366 m	**Distance elli.**	4546.981	**Δy**	3966.609 m
ΔElévation	-25.989 m	**ΔHauteur**	-25.989	**ΔZ**	-1251.078 m

Erreurs types

Erreurs vectorielles:					
σ ΔAbscisse	0.002 m	**σ Azimut vers l'avant NS**	0°00'00"	**σ ΔX**	0.004 m
σ ΔNord	0.002 m	**σ Distance elli.**	0.002 m	**σ Δy**	0.004 m
σ ΔElévation	0.006 m	**σ ΔHauteur**	0.006 m	**σ ΔZ**	0.003 m

Matrice de covariance a posteriori (Mètre²)

	X	**y**	**Z**
X	0.0000199725		
y	0.0000110974	0.0000142809	
Z	0.0000055590	0.0000039605	0.0000081740

Occupations

	A partir	**Vers**
ID de point:	PPT1	tarnac1
Fichier de données:	C:\tbc\fugro15\tarnac\TARNAC1 \PPT1156C.15o	C:\tbc\fugro15\tarnac \TARNAC1\55801571.T01

file:///C|/tbc/fugro15/tarnac/tarnacfugro/aa571768.1.html (2 sur 4)07/06/2015 00:26:35

Type de récepteur:	NetR5	R7 GNSS
Numéro de série du récepteur:	4922K62051	4948K15580
Type d'antenne:	Zephyr Geodetic 2 w/Dome	Zephyr Geodetic 2
Numéro de série de l'antenne:	--------	--------
Hauteur de l'antenne (Mesuré):	0.000 m	1.428 m
Méthode de l'antenne:	Base du support d'antenne	Base de l'encoche

Récapitulatif des poursuites

Style de traitement

Masque d'élévation:	10.0 deg
Traitement de démarrage automatique:	Oui
Démarrer le numérotage automatique des ID:	AUTO0001
Vecteurs continus:	Aucun
Générer des résidus:	Oui
Modèle d'antenne:	Automatique
Type d'éphéméride:	Automatique
Fréquence:	Fréquences multiples
Impose flottant:	Aucun

Critères d'acceptation

Composant du vecteur	Drapeau	Echouer
Précision horizontale >	0.050 m + 1.000 ppm	0.100 m + 1.000 ppm
Précision verticale >	0.100 m + 1.000 ppm	0.200 m + 1.000 ppm

Informations relatives à l'étude		Système de coordonnées	
Nom:	C:\tbc\fugro15\tarnac\TARNAC2.vce	Nom:	UTM
Taille:	147 KB	Datum:	ITRF
Modifié:	07/06/2015 00:10:02	Zone:	6 South
Numéro de référence:		Géoïde:	
Description:		Datum vertical:	

Rapport sur le traitement des lignes de base

Détails des sessions

PPT1 - tarnac2 (16:12:29-16:45:28) (S1)

Observation de ligne de base:	PPT1 --- tarnac2 (B1)
Traité:	07/06/2015 00:09:30
Type de solutions:	Fixe
Fréquence utilisée:	Fréquences multiples
Précision horizontale:	0.007 m
Précision verticale:	0.013 m
RMS:	0.026 m
Rapport:	2.169
PDOP maximum:	1.538
Ephéméride utilisée:	Emission
Modèle d'antenne:	Calibration de Trimble
Heure de démarrage du traitement:	05/06/2015 16:12:29 (Local: UTC-10hr)
Heure d'arrêt du traitement:	05/06/2015 16:45:28 (Local: UTC-10hr)
Durée du traitement:	00:32:59

Composants des vecteurs (Signaler par un repère)

A partir :	PPT1	
Grille	**Local**	**Global**

Abscisse	226967.267 m	**Latitude**	S17°32'33.26956"	**Latitude**	S17°32'33.26955"
Nord	8058573.098 m	**Longitude**	O149°34'18.69664"	**Longitude**	O149°34'18.69664"
Elévation	35.092 m	**Hauteur**	35.092 m	**Hauteur**	35.092 m

Vers:	tarnac2				
Grille		**Local**		**Global**	
Abscisse	222622.794 m	**Latitude**	S17°33'15.99184"	**Latitude**	S17°33'15.99184"
Nord	8057199.545 m	**Longitude**	O149°36'46.54955"	**Longitude**	O149°36'46.54955"
Elévation	9.137 m	**Hauteur**	9.137 m	**Hauteur**	9.137 m

Vecteur:					
ΔAbscisse	-4344.473 m	**Azimut vers l'avant NS**	253°13'52"	**ΔX**	-1844.172 m
ΔNord	-1373.554 m	**Distance elli.**	4553.992	**Δy**	3973.660 m
ΔElévation	-25.955 m	**ΔHauteur**	-25.955	**ΔZ**	-1244.472 m

Erreurs types

Erreurs vectorielles:					
σ ΔAbscisse	0.003 m	**σ Azimut vers l'avant NS**	0°00'00"	**σ ΔX**	0.005 m
σ ΔNord	0.003 m	**σ Distance elli.**	0.003 m	**σ Δy**	0.005 m
σ ΔElévation	0.006 m	**σ ΔHauteur**	0.006 m	**σ ΔZ**	0.003 m

Matrice de covariance a posteriori (Mètre^2)

	X	**y**	**Z**
X	0.0000266293		
y	0.0000158000	0.0000203636	
Z	0.0000075343	0.0000058175	0.0000104502

Occupations

	A partir	**Vers**
ID de point:	PPT1	tarnac2
Fichier de données:	C:\tbc\fugro15\tarnac\TARNAC2 \PPT1156C.15o	C:\tbc\fugro15\tarnac \TARNAC2\56451570.t02

Type de récepteur:	NetR5	R8 Model 3
Numéro de série du récepteur:	4922K62051	5153480479
Type d'antenne:	Zephyr Geodetic 2 w/Dome	R8 GNSS/SPS88x Internal
Numéro de série de l'antenne:	--------	--------
Hauteur de l'antenne (Mesuré):	0.000 m	1.500 m
Méthode de l'antenne:	Base du support d'antenne	Base du support d'antenne

Récapitulatif des poursuites

Style de traitement

Masque d'élévation:	10.0 deg
Traitement de démarrage automatique:	Oui
Démarrer le numérotage automatique des ID:	AUTO0001
Vecteurs continus:	Aucun
Générer des résidus:	Oui
Modèle d'antenne:	Automatique
Type d'éphéméride:	Automatique
Fréquence:	Fréquences multiples
Impose flottant:	Aucun

Critères d'acceptation

Composant du vecteur	Drapeau	Echouer
Précision horizontale >	0.050 m + 1.000 ppm	0.100 m + 1.000 ppm
Précision verticale >	0.100 m + 1.000 ppm	0.200 m + 1.000 ppm

Informations relatives à l'étude		Système de coordonnées	
Nom:	C:\tbc\fugro15\tarnac\TARNAC4.vce	Nom:	UTM
Taille:	145 KB	Datum:	ITRF
Modifié:	07/06/2015 00:02:37	Zone:	6 South
Numéro de référence:		Géoïde:	
Description:		Datum vertical:	

Rapport sur le traitement des lignes de base

Détails des sessions

PPT1 - TARNAC3 (15:54:45-16:51:15) (S2)

Observation de ligne de base:	PPT1 --- TARNAC3 (B2)
Traité:	07/06/2015 00:12:10
Type de solutions:	Fixe
Fréquence utilisée:	Fréquences multiples
Précision horizontale:	0.007 m
Précision verticale:	0.011 m
RMS:	0.012 m
Rapport:	2.621
PDOP maximum:	2.580
Ephéméride utilisée:	Emission
Modèle d'antenne:	Calibration de Trimble
Heure de démarrage du traitement:	05/06/2015 15:54:45 (Local: UTC-10hr)
Heure d'arrêt du traitement:	05/06/2015 16:51:15 (Local: UTC-10hr)
Durée du traitement:	00:56:30

Composants des vecteurs (Signaler par un repère)

A partir :	PPT1	
Grille	**Local**	**Global**

Rapport sur le traitement des lignes de base

Abscisse	226967.267 m	**Latitude**	S17°32'33.26956"	**Latitude**	S17°32'33.26955"
Nord	8058573.098 m	**Longitude**	O149°34'18.69664"	**Longitude**	O149°34'18.69664"
Elévation	35.092 m	**Hauteur**	35.092 m	**Hauteur**	35.092 m

Vers:	TARNAC3				
Grille		**Local**		**Global**	
Abscisse	222622.754 m	**Latitude**	S17°33'16.42535"	**Latitude**	S17°33'16.42535"
Nord	8057186.208 m	**Longitude**	O149°36'46.55710"	**Longitude**	O149°36'46.55710"
Elévation	9.124 m	**Hauteur**	9.124 m	**Hauteur**	9.124 m

Vecteur:					
ΔAbscisse	-4344.513 m	**Azimut vers l'avant NS**	253°04'17"	**ΔX**	-1840.806 m
ΔNord	-1386.890 m	**Distance elli.**	4558.065	**Δy**	3975.892 m
ΔElévation	-25.969 m	**ΔHauteur**	-25.969	**ΔZ**	-1257.174 m

Erreurs types

Erreurs vectorielles:					
σ ΔAbscisse	0.003 m	**σ Azimut vers l'avant NS**	0°00'00"	**σ ΔX**	0.005 m
σ ΔNord	0.003 m	**σ Distance elli.**	0.003 m	**σ Δy**	0.004 m
σ ΔElévation	0.006 m	**σ ΔHauteur**	0.006 m	**σ ΔZ**	0.003 m

Matrice de covariance a posteriori (Mètre²)

	X	**y**	**Z**
X	0.0000204766		
y	0.0000122648	0.0000164411	
Z	0.0000051849	0.0000057735	0.0000107788

Occupations

	A partir	**Vers**
ID de point:	PPT1	TARNAC3
Fichier de données:	C:\tbc\fugro15\tarnac\TARNAC4 \PPT1156C.15o	C:\tbc\fugro15\tarnac \TARNAC4\12511570.t01

file:///C|/tbc/fugro15/tarnac/tarnacfugro/ca763dbe.1.html (2 sur 4)07/06/2015 00:15:29

Type de récepteur:	NetR5	5700
Numéro de série du récepteur:	4922K62051	0220381251
Type d'antenne:	Zephyr Geodetic 2 w/Dome	Zephyr Geodetic
Numéro de série de l'antenne:	--------	--------
Hauteur de l'antenne (Mesuré):	0.000 m	1.471 m
Méthode de l'antenne:	Base du support d'antenne	Base de l'encoche

Récapitulatif des poursuites

Style de traitement

Masque d'élévation:	10.0 deg
Traitement de démarrage automatique:	Oui
Démarrer le numérotage automatique des ID:	AUTO0001
Vecteurs continus:	Aucun
Générer des résidus:	Oui
Modèle d'antenne:	Automatique
Type d'éphéméride:	Automatique
Fréquence:	Fréquences multiples
Impose flottant:	Aucun

Critères d'acceptation

Composant du vecteur	Drapeau	Echouer
Précision horizontale >	0.050 m + 1.000 ppm	0.100 m + 1.000 ppm
Précision verticale >	0.100 m + 1.000 ppm	0.200 m + 1.000 ppm

Enclosure 6 – Geoscience Australia Weekly Analysis Report Summary GPS Week 1848 – SAMO

Jul 02, 15 9:33	**AUS18487.SUM**	Page 1/42

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-------------------------------------------------------------------------------
| GEOSCIENCE AUSTRALIA ANALYSIS REPORT                                         |
-------------------------------------------------------------------------------

GPS analysis report            : gpsweek 1848
Agency                         : Geoscience Australia
Contact                        : geodesy@ga.gov.au
Creation Date                  : 01/07/2015    2015 182

Start of GNSS Data             : 07/06/2015    2015 158
End of GNSS Data               : 13/06/2015    2015 164

Report File                    : AUS18487.SUM (this file)
SINEX File                     : AUS18487.SNX

Summary                        :

           GPS analysis report for the Australia, Antarctica, the South
           Pacific and APREF regional GPS networks. This weekly solution
           was created from a combination of the 7 daily solutions.
           The weekly solution was aligned to the IGS08 reference frame,
           which is the IGS realization of ITRF2008, using a minimum
           constraint method to a set of core stations (listed below).

 SAMO 50603M001     7  XXXXXXX     1.03    1.64    7.51

 SAMO 50603M001    -6129702.3420    -890028.7914    -1516806.9306
 SAMO 50603M001  -171 -44 -18.3351   -13 -50 -57.1444     76.7554
```

Enclosure 7 – MNRE Ground Control Points and Benchmarks Field Sheets

Malo o Samoa

Tertiary Control
Field Sheet

Point Number: GCP01

Type/Description:	Known RL:	Status
Village: Satitoa District: Island: Upolu	Surveyor: Date: 2015	CLASS (1st /2nd /3rd Order)

GPS observations (Y/N) Suitable/Stable for a Bench Mark (Y/N)	Horizontal Control (Y/N): Horizontal Coordinates(Y/N):

Locality Sketch – Diagram Update

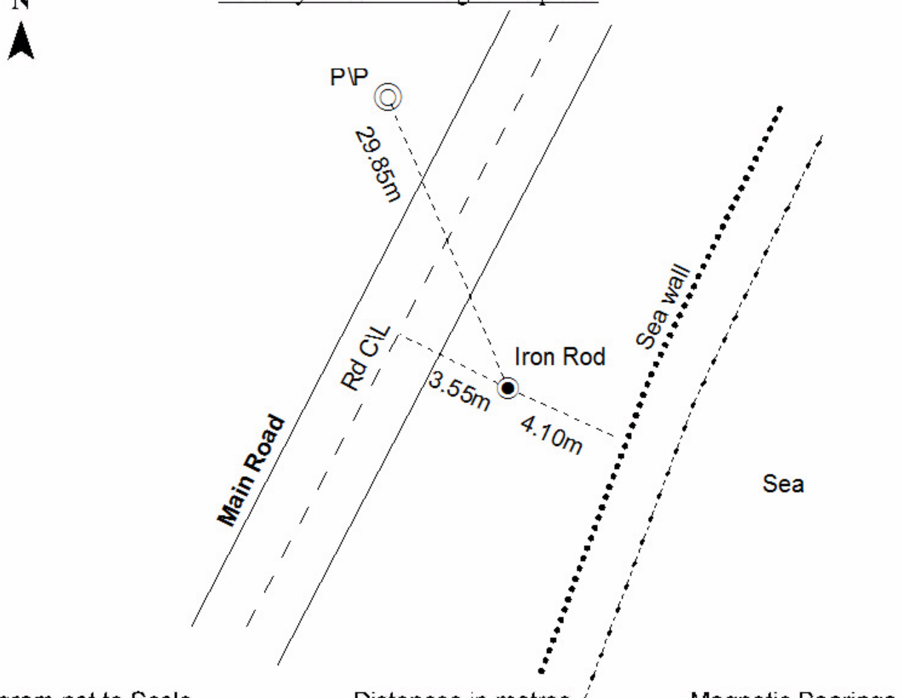


Diagram not to Scale | Distances in metres | Magnetic Bearings

References:

Malo o Samoa

Tertiary Control
Field Sheet

Point Number: GCP02

Type/Description:	Known RL:	Status
Village: Solosolo District: Island: Upolu	Surveyor: Date: 2015	CLASS (1st /2nd /3rd Order)

GPS observations (Y/N) Suitable/Stable for a Bench Mark (Y/N)	Horizontal Control (Y/N): Horizontal Coordinates(Y/N):

Locality Sketch – Diagram Update

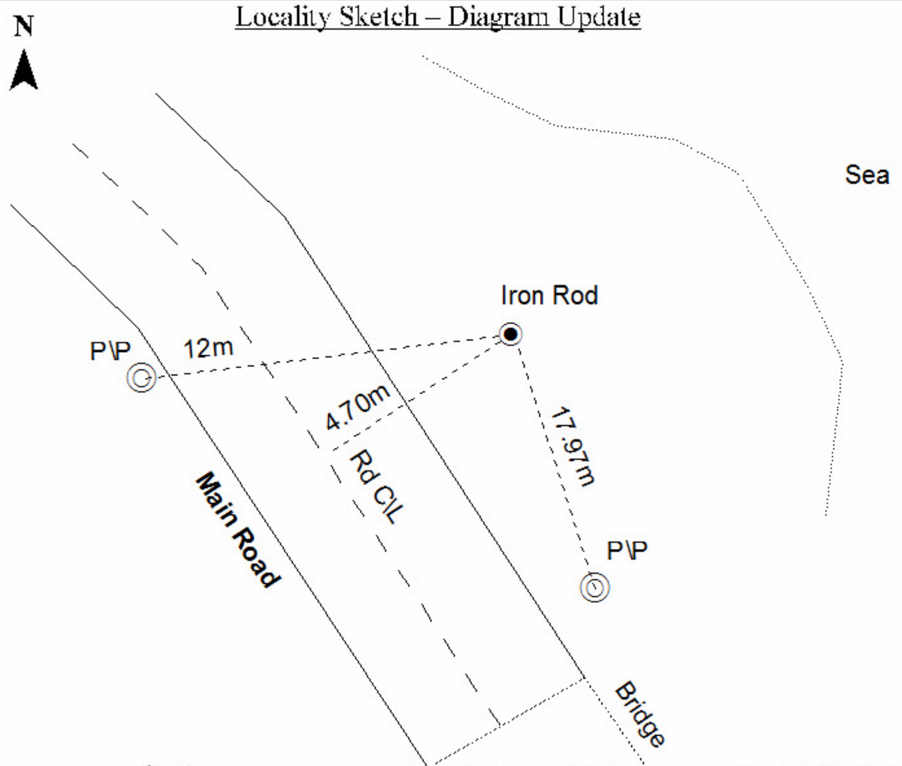


Diagram not to Scale | Distances in metres | Magnetic Bearings

References:

Malo o Samoa

Tertiary Control
Field Sheet

Point Number: GCP03

Type/Description:	Known RL:	Status
Village: Poutasi District: Island: Upolu	Surveyor: Date: 2015	CLASS (1st /2nd /3rd Order)
GPS observations (Y/N) Suitable/Stable for a Bench Mark (Y/N)	Horizontal Control (Y/N): Horizontal Coordinates(Y/N):	

Locality Sketch – Diagram Update

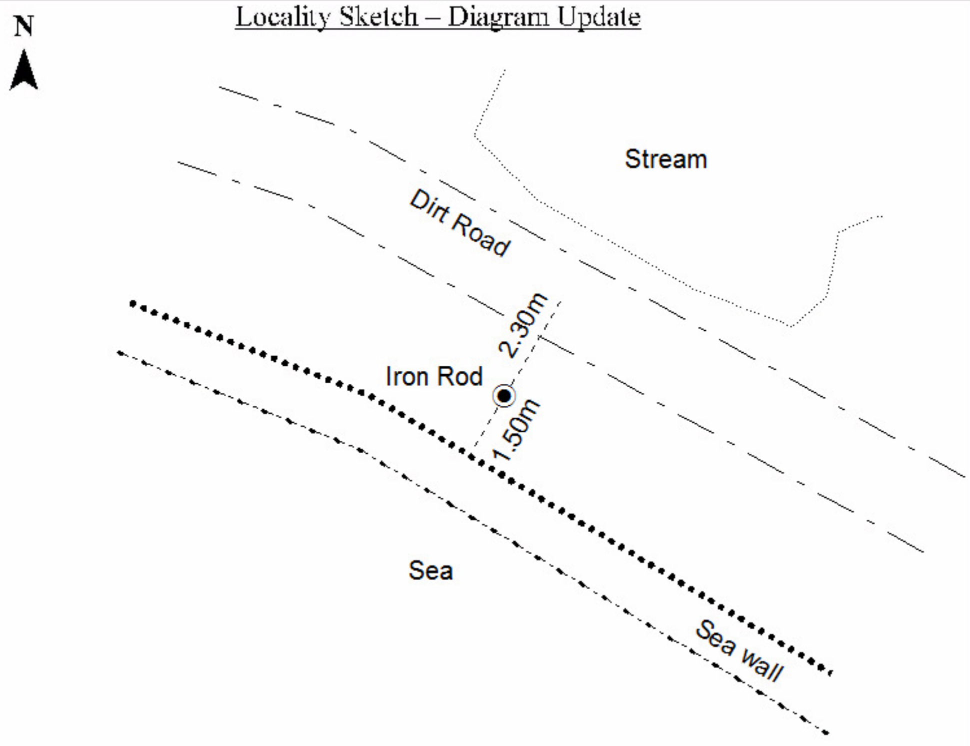


Diagram not to Scale — Distances in metres — Magnetic Bearings

References:

Malo o Samoa

Tertiary Control
Field Sheet

Point Number: GCP04

Type/Description:	Known RL:	Status
Village: Salamumu Tai District: Island: Upolu	Surveyor: Date: 2015	CLASS (1st /2nd /3rd Order)

GPS observations (Y/N) Suitable/Stable for a Bench Mark (Y/N)	Horizontal Control (Y/N): Horizontal Coordinates(Y/N):

Locality Sketch – Diagram Update

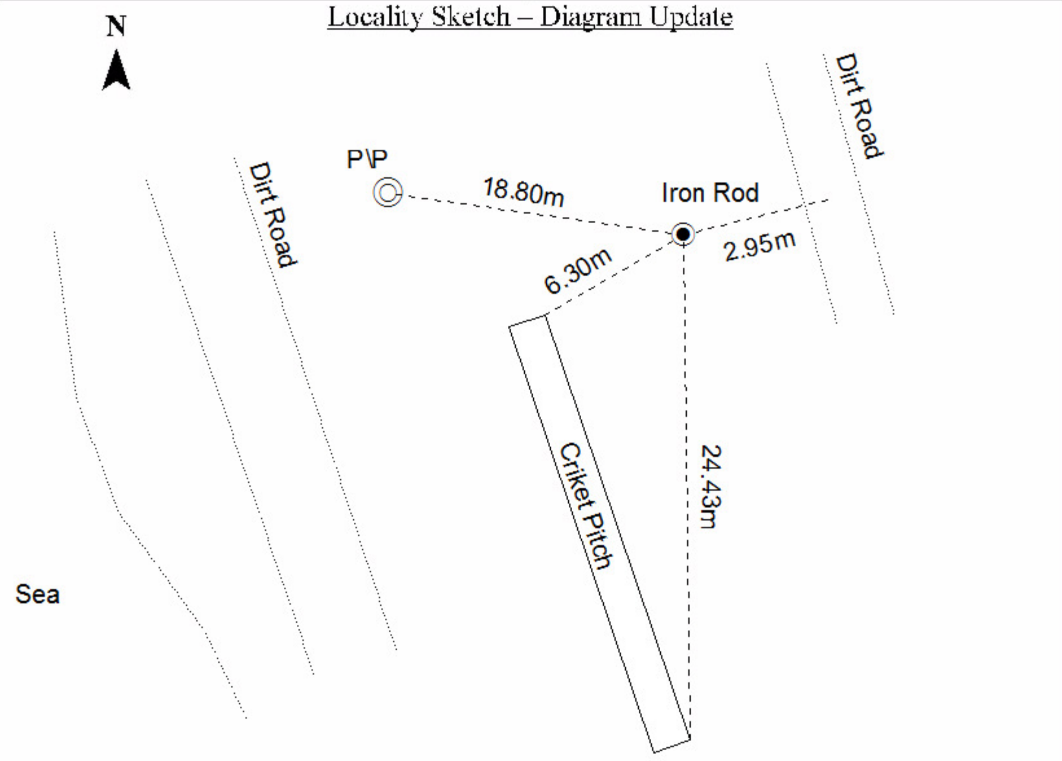


Diagram not to Scale | Distances in metres | Magnetic Bearings

References:

Malo o Samoa

Tertiary Control
Field Sheet

Point Number: GCP06

Type/Description:	Known RL:	Status
Village: Manono Uta District: Island: Upolu	Surveyor: Date: 2015	CLASS (1st /2nd /3rd Order)

GPS observations (Y/N) Suitable/Stable for a Bench Mark (Y/N)	Horizontal Control (Y/N): Horizontal Coordinates(Y/N):

Locality Sketch – Diagram Update

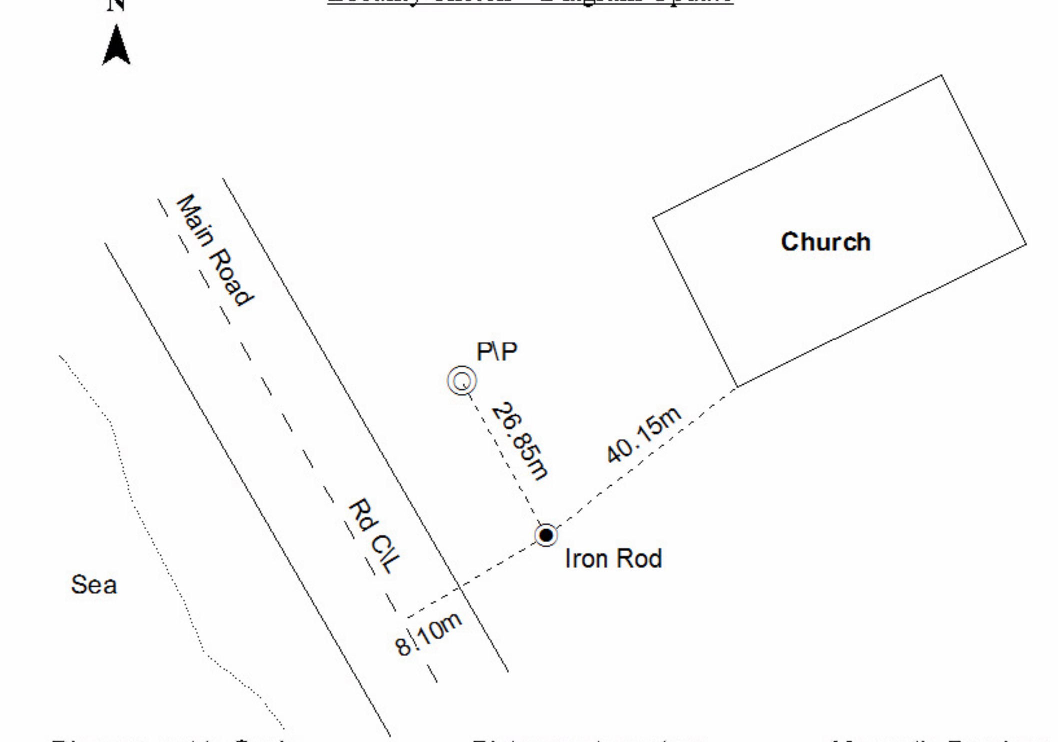


Diagram not to Scale   Distances in metres   Magnetic Bearings

References:

Malo o Samoa

Tertiary Control
Field Sheet

Point Number: GCP08

Type/Description:	Known RL:	Status
Village: Salelologa District: Island: Savaii	Surveyor: Date: 2015	CLASS (1st /2nd /3rd Order)

GPS observations (Y/N) Suitable/Stable for a Bench Mark (Y/N)	Horizontal Control (Y/N): Horizontal Coordinates(Y/N):

Locality Sketch – Diagram Update

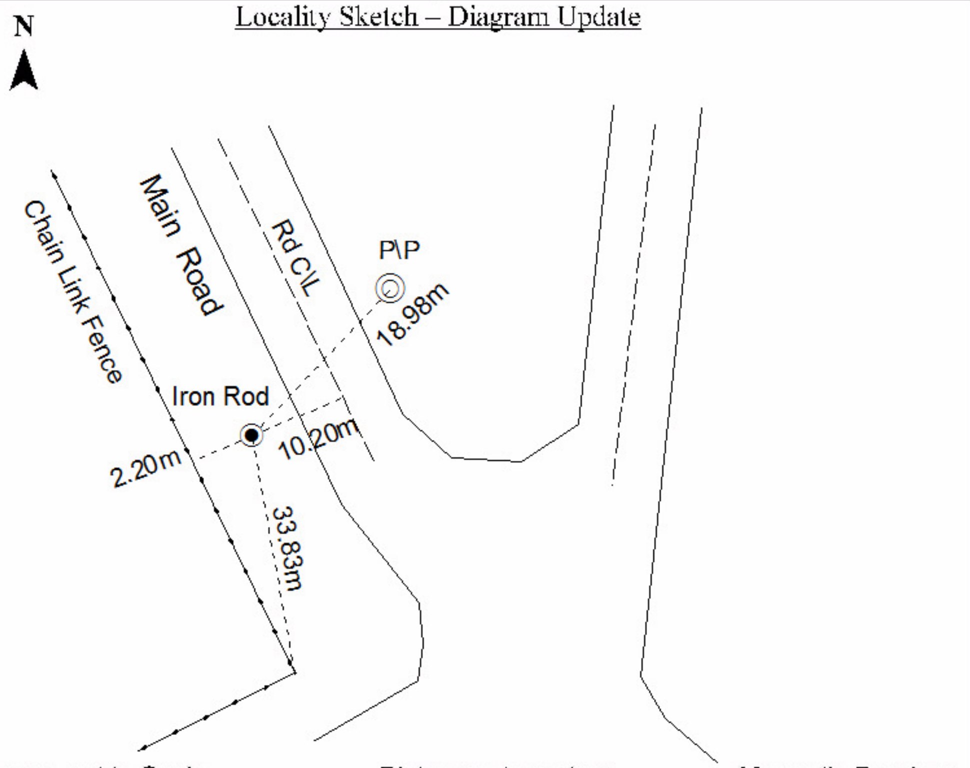


Diagram not to Scale Distances in metres Magnetic Bearings

References:

Malo o Samoa

Tertiary Control
Field Sheet

Point Number: GCP10

Type/Description:	Known RL:	Status
Village: Avao District: Island: Savaii	Surveyor: Date: 2015	CLASS (1st /2nd /3rd Order)

GPS observations (Y/N) Suitable/Stable for a Bench Mark (Y/N)	Horizontal Control (Y/N): Horizontal Coordinates(Y/N):

Locality Sketch – Diagram Update

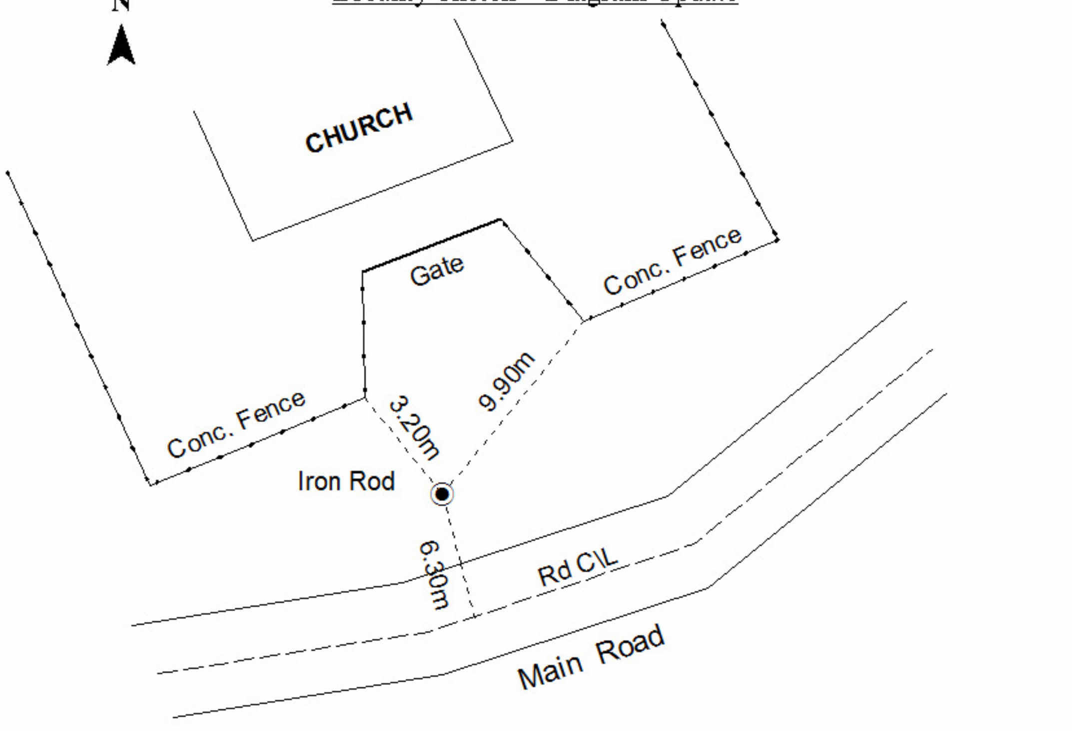


Diagram not to Scale   Distances in metres   Magnetic Bearings

References:

Malo o Samoa

Tertiary Control
Field Sheet

Point Number: GCP13

Type/Description:	Known RL:	Status
Village: Fagafau District: Island: Savaii	Surveyor: Date: 2015	CLASS (1st /2nd /3rd Order)

GPS observations (Y/N) Suitable/Stable for a Bench Mark (Y/N)	Horizontal Control (Y/N): Horizontal Coordinates(Y/N):

Locality Sketch – Diagram Update

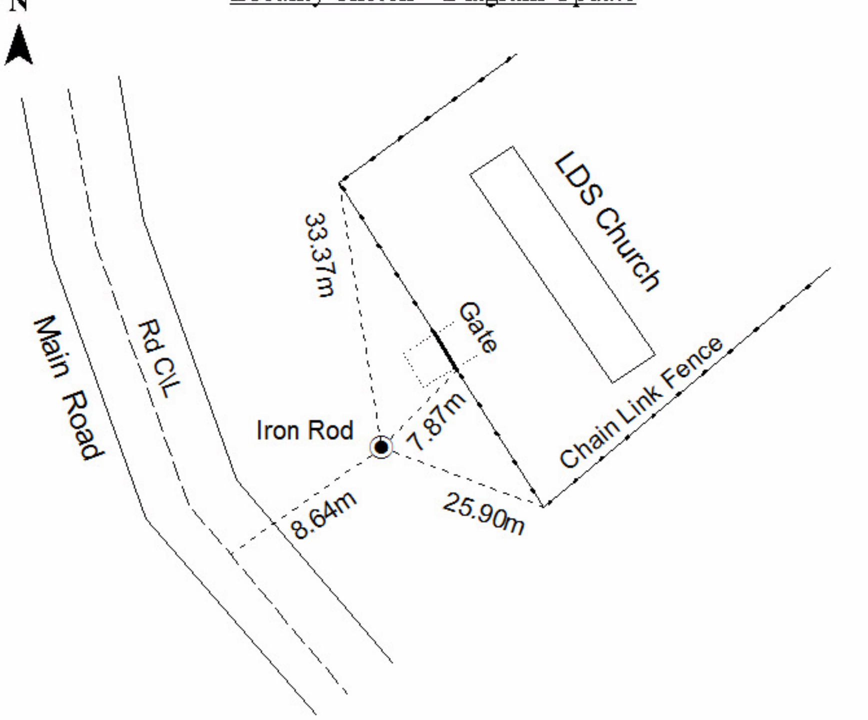


Diagram not to Scale | Distances in metres | Magnetic Bearings

References:

Malo o Samoa

Tertiary Control
Field Sheet

Point Number: GCP15

Type/Description:	Known RL:	Status
Village: Falealupo Tai District: Island: Savaii	Surveyor: Date: 2015	CLASS (1st /2nd /3rd Order)

GPS observations (Y/N) Suitable/Stable for a Bench Mark (Y/N)	Horizontal Control (Y/N): Horizontal Coordinates(Y/N):

Locality Sketch – Diagram Update

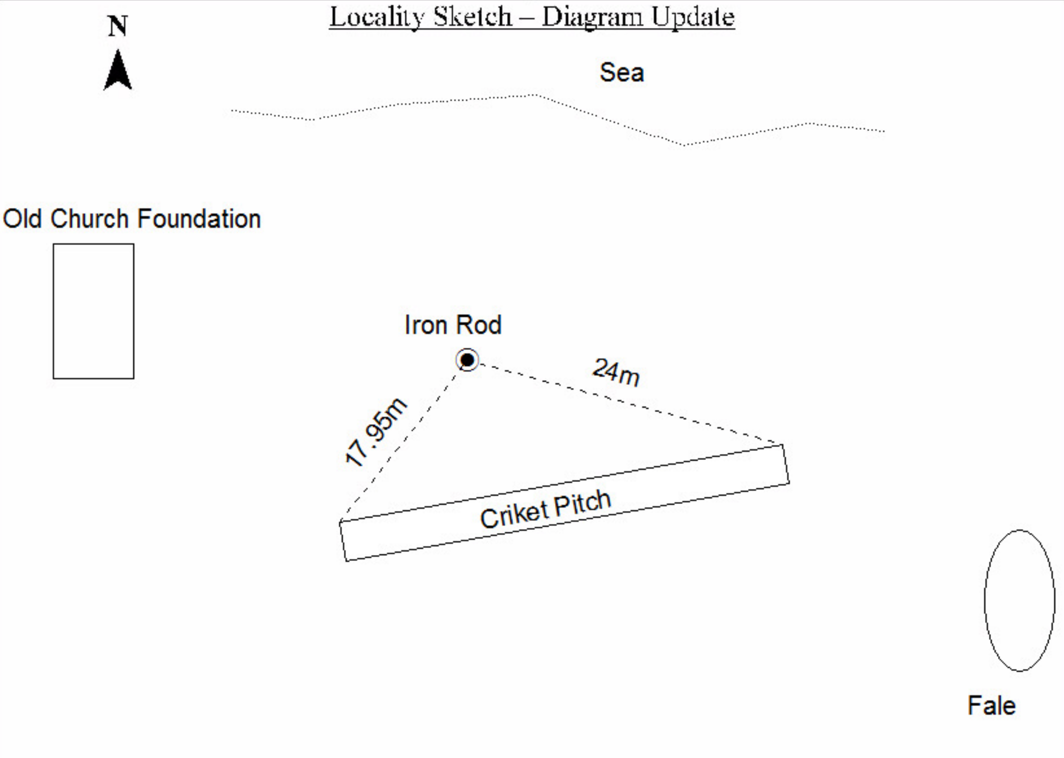


Diagram not to Scale	Distances in metres	Magnetic Bearings

References:

Malo o Samoa

Ministry of Natural Resources and Environment

Vertical Control Project
Field Sheet – Bench Mark Investigation/Identification

Bench Mark Number: 3040

Type/Description: BRASS PLAQUE IN CONCRETE	Known RL:	Status March 2008 FOUND
Village: ZOTOSOA SALEIMOA District: TUAMASAGA Island: UPOLU	Surveyor: LEVEI & UEPA Date: 23/06/08	CLASS (A/B/C/D): B

Suitable for GPS observations (Y/N) Y Suitable/Stable for a Bench Mark (Y/N) Y	Horizontal Control (Y/N): Y Horizontal Coordinates: 8473966.186 N 404078.796 E Order (1st / 2nd / 3rd):

Comments:

Locality Sketch – Diagram Update

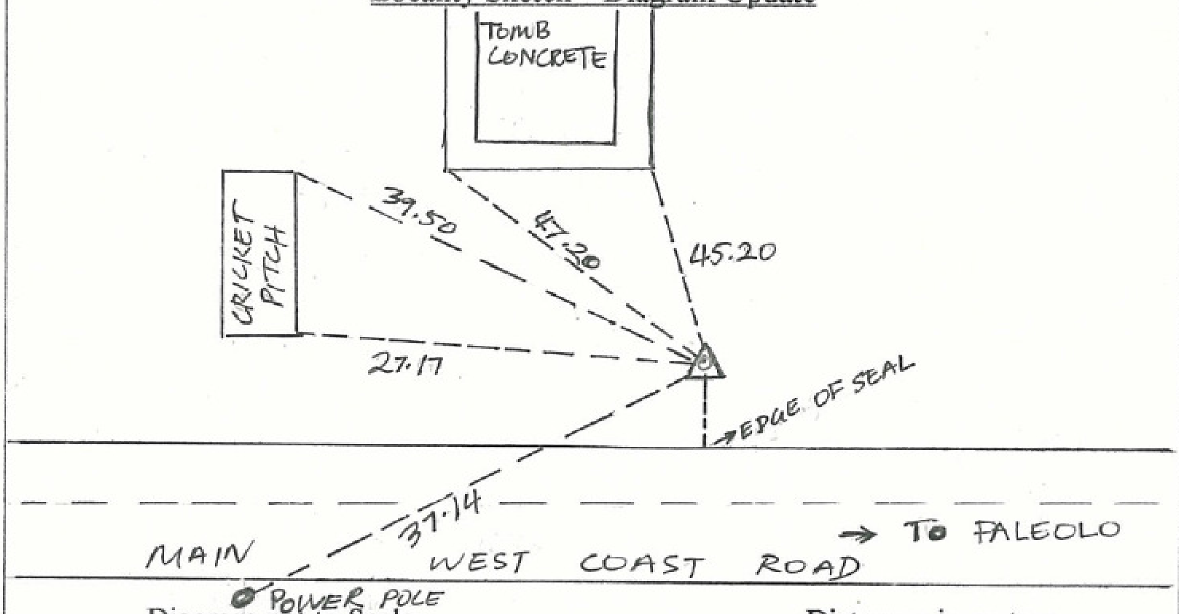


Diagram not to Scale

Distances in metres

References: Samoa Primary Network Survey Mark 103

Malo o Samoa

Ministry of Natural Resources and Environment

Vertical Control Project
Field Sheet – Bench Mark Investigation/Identification

Bench Mark Number: 4015

Type/Description: BOLT IN CONCRETE	Known RL: Ellip Ht : 578.12	Status March 2008 FOUND
Village: LEAOA (BAHAI TEMP.) District: TUAMASAGA Island: UPOLU	Surveyor: LARRY & UEPA Date: 20/05/09	CLASS (A/B/C/D): B
Suitable for GPS observations (Y/N) Y Suitable/Stable for a Bench Mark (Y/N) Y	Horizontal Control (Y/N): Horizontal Coordinates: Order (1st / 2nd / 3rd):	
Comments:		

Locality Sketch – Diagram Update

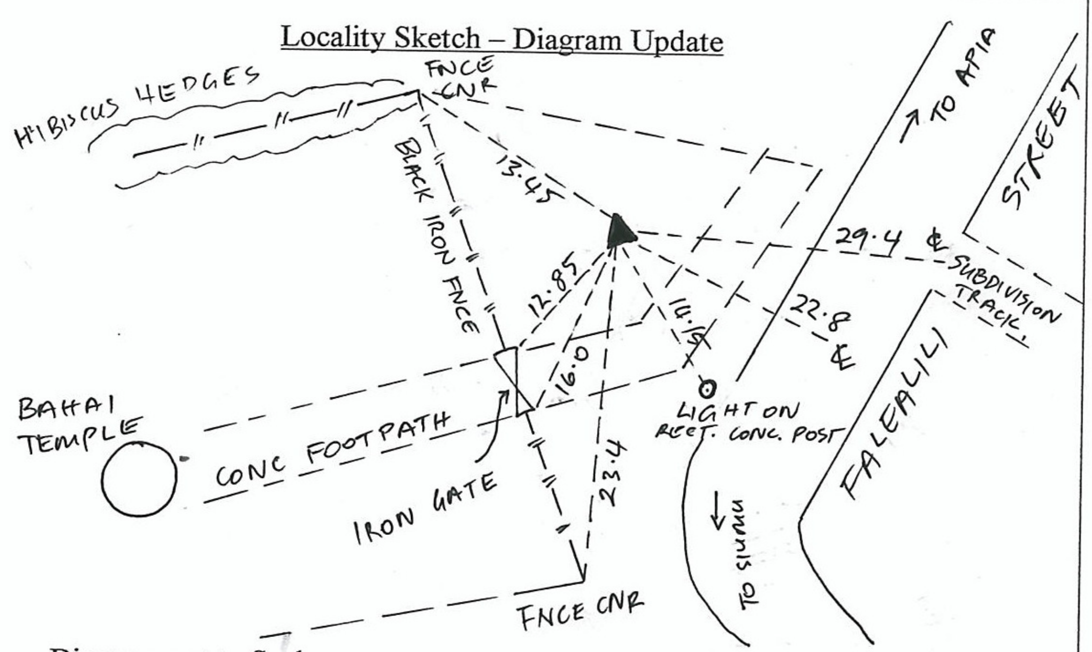


Diagram not to Scale

Distances in metres

References: GPS MARK 107 - SAMOA PRIMARY NETWORK
ALSO BM116A OLD LOCALITY SKETCH. (LEVELLING NETWORK FROM VAILIMA TO SIUMU)

Malo o Samoa

Ministry of Natural Resources and Environment

Vertical Control Project
Field Sheet – Bench Mark Investigation/Identification

Bench Mark Number: 7180 ~~7177~~ 7180

Type/Description: GPS MARK (Bolt in Concrete	Known RL:	Status March 2008 ~~Bot~~ NEW MARK.
Village: PAPA PULELA District: ITU O FAFINE Island: SAVAII	Surveyor: UEPA & LARRY Date: 28/04/09	CLASS (A/B/C/D): B

Suitable for GPS observations (Y/N) Suitable/Stable for a Bench Mark (Y/N)	Horizontal Control (Y/N): Horizontal Coordinates: Order (1^{st} / 2^{nd} / 3^{rd}):

Comments:

Locality Sketch – Diagram Update

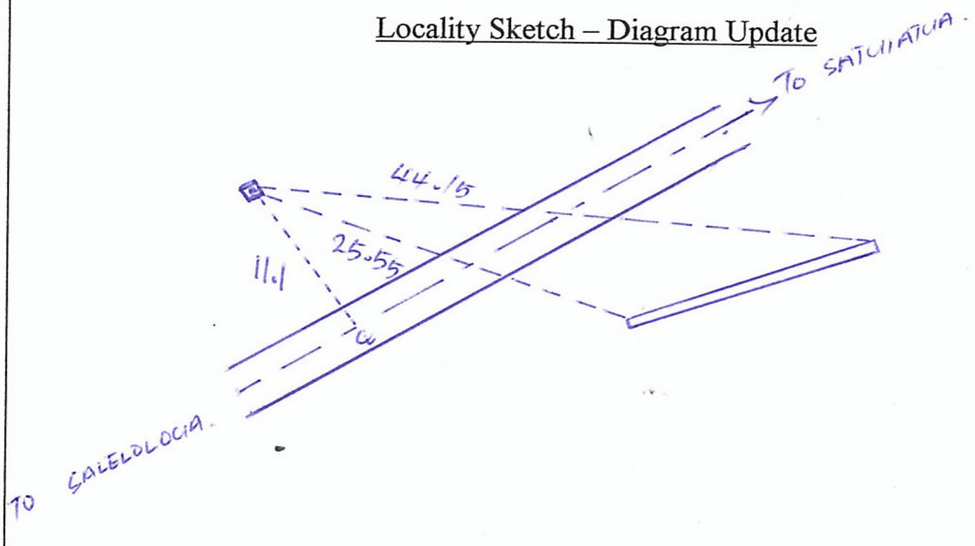


Diagram not to Scale | Distances in metres

References:

Malo o Samoa

Ministry of Natural Resources and Environment

Vertical Control Project
Field Sheet – Bench Mark Investigation/Identification

Bench Mark Number: 7029

Type/Description: BOLT IN CONCRETE	Known RL	Status March 2008 New mark.
Village: PUAPUA District: FAASALELEAGA Island: Savaii	Surveyor: Larry, Ulepa Date. 4/12/08	CLASS (A/B/C/D): B.

Suitable for GPS observations (Y/N) Y Suitable/Stable for a Bench Mark (Y/N) Y	Horizontal Control (Y/N): Horizontal Coordinates: Order (1st / 2nd / 3rd):

Comments:

Locality Sketch – Diagram Update

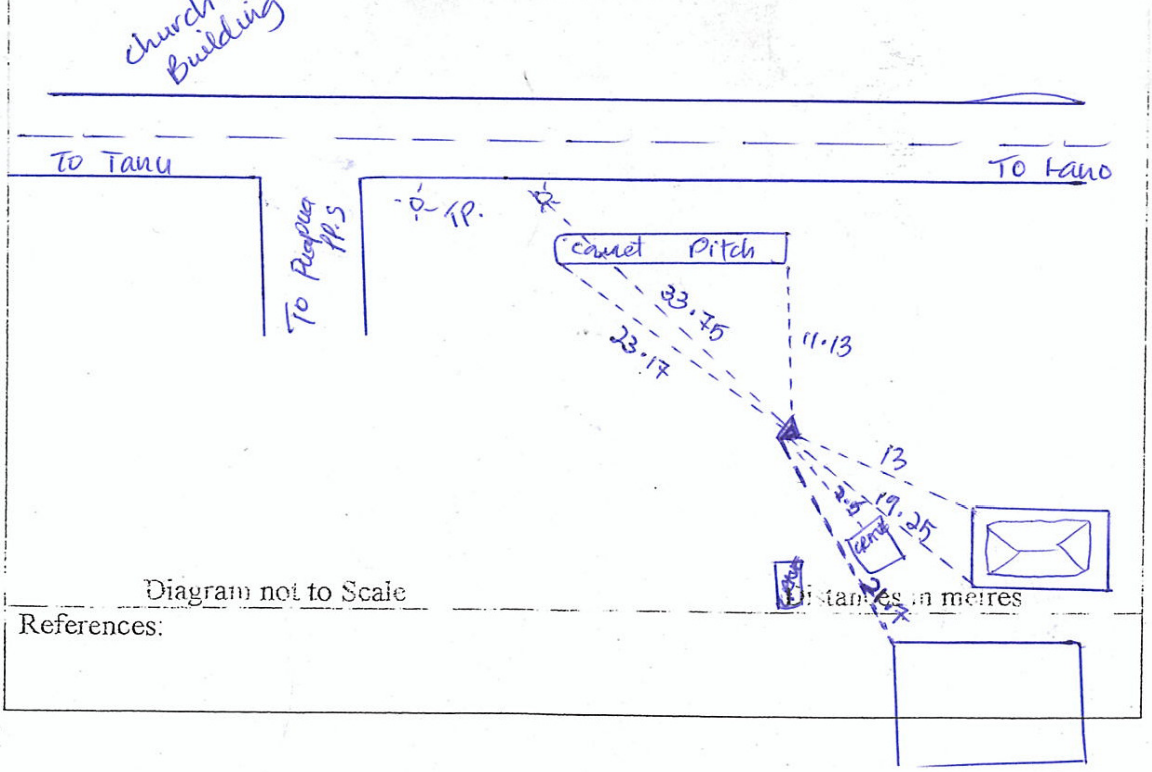


Diagram not to Scale

Distances in metres

References:

Annex F. Position Fixing Systems and Position Fixing System Validation Results

D.1 Position Fixing Systems

Throughout the survey the real-time position of the LADS Mk 3 system was derived from a Trimble BD982 GNSS receiver, with corrections received via Fugro Marinestar with their Marinestar GNSS Precise Point Positioning (PPP) service. This is an integrated DGPS/DGLONASS, decimetre level, phase based, service using satellite 'orbit and clock' data valid worldwide, based upon GPS and GLONASS L1 and L2 frequencies.

The Kinematic GNSS (KGNSS) L1/L2 carrier phase position for LADS and RIEGL was obtained by using the Geoscience Australia base station in Apia, SAMO and the Fugro base station established at Faleolo Airport. This data was combined with the data from the roving Trimble BD982 GNSS receivers on board the aircraft and post-processed in POSPac MMS software after each flight. The Kinematic GNSS solutions were imported into the Ground System (GS) for LADS or RiProcess for RIEGL where it was then applied to all soundings. The dynamic position check function in the GS was used to calculate statistics on the accuracy of the real-time PPP positioning.

D.2 GNSS Static Position Checks

On 7 June 2015, a static position check of the LADS Mk 3 and RIEGL VQ-820-G positioning systems were undertaken using the derived aircraft GNSS antenna position, as determined by the static position check control marks at Fa'a'a Airport, Tahiti. A single observation session of two hours took place using GNSS Only as a connection problem was encountered with the Marinestar correction service. Post-processing of this data using a base station and then also PPP for comparison, provided KGNSS positions for the two aircraft GNSS antennae.

D.2.1 Observations

The observation periods were as follows:

Session	Start Time (UTC)	Stop Time (UTC)	Logging Duration	Average Number of GNSS Satellites
AS – GNSS Only	04:00	06:00	2 hr 00 min	15
POSPac MMS – KGNSS PPP	04:00	06:00	2 hr 00 min	9
POSPac MMS – KGNSS BS	04:00	06:00	2 hr 00 min	14

Table 1 - Static Position Check Observation Sessions

D.2.2 Processing

Kinematic GNSS positions were produced in POSPac MMS using the SAU GNSS base station in Papeete, near the Fa'a'ā airport, for comparing against the PPP positions. A Kinematic GNSS position is produced by solving carrier phase and pseudorange observations in processing algorithms using a double-differencing technique.

The Kinematic GNSS positions were also produced by using PPP processing with Rapid precise ephemeris and clock files and the aircraft files within POSPac MMS software. Corrections are applied for effects such as solid earth tides, satellite phase windup, tropospheric delay, ionospheric delay and satellite antenna offsets.

The GNSS Only POS file data is produced real-time in the POS AV and is logged directly to a USB stick. The files were then processed using POSPac MMS.

D.2.3 Results

The final positions were exported to a commercial spreadsheet/graphical based software package where calculations of means and standard deviations were completed.

Tables 2 and 3 show the comparisons of the different static GNSS solutions for the position of the aircraft GNSS antennae (UTM Zone 6S).

	Easting	**Northing**	**Height**					
Absolute Position	222 625.215	8 057 194.161	12.214					
	Easting ±σE	**Northing ±σN**	**Height ±σH**	**∆ East C-O (m)**	**∆ North C-O (m)**	**∆ Height C-O (m)**	**Abs Acc 2D (95%)**	**Abs Acc 1D (95%)**
Session 1 GNSS Only	222 626.934 +/- 0.585	8 057 189.464 +/- 0.885	13.396 +/- 1.616	-1.719	4.222	-1.182	6.739	5.484
Session 1 KGNSS PPP	222 625.215 +/- 0.000	8 057 194.124 +/- 0.000	12.218 +/- 0.001	0.000	0.037	-0.004	0.037	0.010
Session 1 KGNSS BS	222 625.223 +/- 0.002	8 057 194.116 +/- 0.001	12.172 +/- 0.003	-0.008	0.045	0.042	0.051	0.088

Table 2 - LADS Mk 3 Static Position Check Results

	Easting	Northing	Height					
Absolute Position	222 625.152	8 057 194.056	12.214					
	Easting ±σE	**Northing ±σN**	**Height ±σH**	**Δ East C-O (m)**	**Δ North C-O (m)**	**Δ Height C-O (m)**	**Abs Acc 2D (95%)**	**Abs Acc 1D (95%)**
Session 1 GNSS Only	222 626.618 +/- 0.976	8 057 189.434 +/- 0.885	13.503 +/- 1.756	-1.466	4.622	-1.289	8.074	5.968
Session 1 KGNSS PPP	222 625.189 +/- 0.001	8 057 193.991 +/- 0.000	12.228 +/- 0.001	-0.037	0.065	-0.014	0.077	0.029
Session 1 KGNSS BS	222 625.145 +/- 0.003	8 057 193.997 +/- 0.001	12.168 +/- 0.002	0.007	0.059	0.046	0.067	0.094

Table 3 - RIEGL VQ-820-G Static Position Check Results

Note: Absolute Accuracy 2D (95%) = $2.448 \times (\sigma E^2 + \sigma N^2)^{1/2} + (\Delta \text{East}^2 + \Delta \text{North}^2)^{1/2}$

Note: Absolute Accuracy 1D (95%) = $1.96 \times \sigma H + \Delta \text{Height}$

The calculation of these results was completed in a commercial spreadsheet application; this sheet is enclosed in Enclosures 1 and 2.

The stated theoretical accuracy of each of the positioning systems has been compared against the absolute accuracy achieved during the static position checks in the following tables:

Positioning System	Baseline Distance (km)	Theoretical GNSS Accuracy 2D (m) (95% confidence)	Theoretical GNSS Accuracy 1D (m) (95% confidence)	Absolute GNSS Accuracy 2D (m) (95% confidence)	Absolute GNSS Accuracy 1D (m) (95% confidence)
RT GNSS	N/A	5.0-10.0	10.0-15.0	6.739 / 8.074	5.484 / 5.968
KGNSS PPP	N/A	0.150	0.200	0.037 / 0.077	0.010 / 0.029
KGNSS BS	4.55	0.100	0.150	0.051 / 0.067	0.088 / 0.094

Table 4 - Theoretical and Absolute GNSS Positioning Accuracies Achieved

Note 1: PPP corrections supplied by the Fugro Marinestar GNSS service were used in real-time to control the aircraft navigation during the flight. Accuracies achieved by this service will be better than those achieved in the GNSS Only static position check results.

D.2.4 Conclusion

The absolute accuracy of the logged GNSS Only position solution was consistent with previous results.

The KGNSS PPP position yielded a more accurate result and this positioning solution was subsequently applied to all survey data.

The position check of the three systems shows that there were no gross errors.

D.3 Dynamic Position Check

During each sortie, GNSS data was logged on the aircraft which enabled a KGNSS position solution to be determined. These positions were then compared to the position as determined by the real-time positioning system. For each survey line the mean difference and standard deviation have been calculated. Table 5 shows the mean and standard deviation of the difference in position between the real-time positioning system (AS) and the post-processed KGNSS for each data collection sortie.

Sortie No.	Lines Flown	Max. Difference AS – KGNSS (m)	Mean Difference AS – KGNSS (m)	Overall Mean Standard Deviation (m)
1	17	0.885	0.139	0.051
2	23	1.065	0.182	0.057
3	20	0.548	0.210	0.045
4	22	1.130	0.214	0.033
5	21	1.456	0.199	0.052
6	23	0.815	0.212	0.037
7	23	0.803	0.201	0.046
8	19	0.692	0.195	0.045
9	16	1.198	0.223	0.049
10	18	0.939	0.210	0.051
11	30	0.387	0.169	0.028
12	23	1.579	0.229	0.051
13	21	1.545	0.221	0.048
15	30	1.210	0.189	0.053
16	33	0.492	0.171	0.035
Total	**339**	**Max. Value 1.579**	**Mean Value 0.198**	**Mean Value 0.045**

Table 5 - Dynamic Position Check Results

These results show good agreement between the real-time position and the post-processed KGNSS PPP position. An extract from the GS dynamic GNSS position analysis report for Sortie 8 is provided in Enclosure 4.

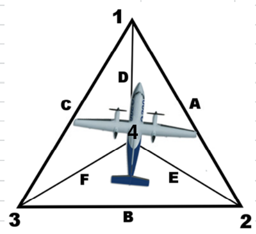
Enclosures:

1. LADS Static Position Check Calculation Sheet
2. RIEGL Static Position Check Calculation Sheet
3. Static Position Check Field Page
4. Example of GS Dynamic Position Analysis Report – Sortie 8

Enclosure 1 – LADS Static Position Check Calculation Sheet

Survey Title: SWP ALB Surveys
Database: 15_2sau_tahiti

Segment	Taped (m)	Check
A	11.700	-0.005
B	11.574	-0.003
C	13.332	-0.008
D	7.010	
E	5.898	
F	8.252	



Aircraft Hdg	031°	Glass Ht	1.13	LS - Glass	LS - Antenna
				0.235	1.396

Point ID	EASTING	NORTHING	ELL HEIGHT	DATUM	SOURCE
1	222621.580	8057200.240	9.469	ITRF08	GeoPolynesie
2	222631.100	8057193.430	9.435	ZONE	
3	222621.540	8057186.900	9.456	UTM 6 S	
4	222625.260	8057194.269	9.453		
Laser Source	222625.260	8057194.269	10.818		
Absolute	222625.215	8057194.161	12.214		

	Easting	Northing	Height					
Absolute Position	222625.215	8057194.161	12.214					
	Easting ±σE	**Northing ±σN**	**Height ±σH**	**Δ East C–O (m)**	**Δ North C–O (m)**	**Δ Height C–O (m)**	**Abs Acc 2D (95% conf)**	**Abs Acc 1D (95% conf)**
Session 1 RT GNSS	222626.934 +/- 0.585	8057189.939 +/- 0.672	13.396 +/- 1.616	-1.719	4.222	-1.182	6.739	5.484
Session 1 KGNSS PPP	222625.215 +/- 0.000	8057194.124 +/- 0.000	12.218 +/- 0.001	0.000	0.037	-0.004	0.037	0.010
Session 1 KGNSS BS	222625.223 +/- 0.002	8057194.116 +/- 0.001	12.172 +/- 0.003	-0.008	0.045	0.042	0.051	0.088

Note: Absolute Accuracy 2D (95% Confidence) = 2.448*(σE2 + σN2)½ + (Δ East2 + Δ North2)½

Note: Absolute Accuracy 1D (95% Confidence) = 1.96*σH + Δ Height

Triangle Solutions

Side	Side Length	Squared	Cos Rule	Acos(rad)	DD	DMS	Angle	Check	
A	11.7	136.890000	-0.6405069733	2.2659545732	129.82963	129:49:47	a		TRI 1
E	5.898	34.786404	0.9220265067	0.3975133132	22.77584	22:46:33	e		
D	7.01	49.140100	0.8878593062	0.4781247671	27.39453	27:23:40	d	180.00000	
B	11.574	133.957476	-0.3192457264	1.8957297846	108.61732	108:37:02	b		TRI 2
F	8.252	68.095504	0.7372054375	0.7418713503	42.50610	42:30:22	f		
E	5.898	34.786404	0.8756619401	0.5039915187	28.87659	28:52:36	e	180.00000	
C	13.332	177.742224	-0.5229927401	2.1211547267	121.53321	121:32:00	c		TRI 3
D	7.01	49.140100	0.8939528284	0.4647071935	26.62576	26:37:33	d		
F	8.252	68.095504	0.8495151584	0.5557307333	31.84103	31:50:28	f	180.00000	
					359.98016	359:58:49		Check	

This section will compute all angles within the three triangles using the Cosine Rule. Things to look for here is that the sum of the angles given doesn't total more or less than 15' of 360 degrees

Join Calculation between Stat-Cal Triangle marks

Line	de	dn	dist	BRG	RawDegBRG	DegBRG	DegBRG
1-2	-9.52	6.810	11.705	-0.94985	-54.42249	305.57751	125.57751
2-3	9.56	6.530	11.577	0.97153	55.66480	55.66480	235.66480
3-1	-0.04	-13.340	13.340	0.00300	0.17180	0.17180	180.17180

Bearing Quadrant Calculations

Column	Row	Quadrant	Min	Max	AntiClockwise	Clockwise
2	1	4	270	360	305.57751	125.57751
1	1	1	0	90	55.66480	235.66480
2	2	3	180	270	180.17180	0.17180

Quadrant	Min	Max
1	0	90
2	90	180
3	180	270
4	270	360

This section will calculate the joins between the three ground calibration points from the given coordinates. It will then ensure the triangle bearings are given in a clockwise direction by calculating the quadrant the bearing should be in, and adjusting accordingly.

Laser Source Coordinate Calculation

From Pt	NewRawBRG	NewBRG	dist	de	dn	New E	New N	
1	148.33078	148.33078	7.01	3.680	-5.966	222625.260	8057194.274	
1	148.35335	148.35335	7.01	3.678	-5.968	222625.258	8057194.272	
2	278.18298	278.18298	5.898	-5.838	0.839	222625.262	8057194.269	
2	278.17090	278.17090	5.898	-5.838	0.838	222625.262	8057194.268	
3	26.78821	26.78821	8.252	3.719	7.366	222625.259	8057194.266	
3	26.79756	26.79756	8.252	3.720	7.366	222625.260	8057194.266	
						222625.260	8057194.269	Average
						+/- 0.001	+/- 0.003	Std Deviation

From the calculated triangle angles, the calculated bearings from the calibration marks and the distances measured to the plumbed laser source, two coordinates are calculated for each calibration point.
An average is calculated and used.
Watch out for a high standard deviation (>0.005) as this could mean erroneous data, or an error in the calculation sheet.

GPS Antenna Coordinate Calculation

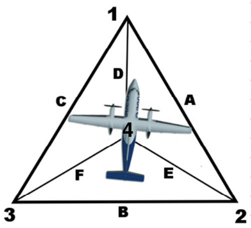
Hypotenuse	Angle from heading	DD	NewBrgRaw	NewBRG	DMS	de	dn	GPS EAST	GPS NORTH
0.118	171:43:59								
0.118	171:43:59	171.73306	202.73306	202.7330556	202:43:59	-0.046	-0.109	**222625.215**	**8057194.161**

Finally the GPS Absolute position is calculated from the given angle and hypotenuse length. The angle refers to a clockwise angle from the Aircraft Heading

Enclosure 2 – RIEGL Static Position Check Calculation Sheet

Survey Title:	SWP ALB Surveys
Database:	15_2sau_tahiti

Segment	Taped (m)	Check
A	11.700	-0.005
B	11.574	-0.003
C	13.332	-0.008
D	7.010	
E	5.898	
F	8.252	



Aircraft Hdg	031°	Glass Ht	1.13	LS - Glass	LS - Antenna
				0.235	1.396

Point ID	EASTING	NORTHING	ELL HEIGHT	DATUM	SOURCE
1	222621.580	8057200.240	9.469	ITRF08	GeoPolynesie
2	222631.100	8057193.430	9.435	ZONE	
3	222621.540	8057186.900	9.456	UTM 6 S	
4	222625.260	8057194.269	9.453		
Laser Source	222625.260	8057194.269	10.818		
Absolute	222625.152	8057194.056	12.214		

	Easting	Northing	Height					
Absolute Position	222625.152	8057194.056	12.214					
	Easting ±σE	**Northing ±σN**	**Height ±σH**	**Δ East C–O (m)**	**Δ North C–O (m)**	**Δ Height C–O (m)**	**Abs Acc 2D (95% conf)**	**Abs Acc 1D (95% conf)**
Session 1 RT GNSS	222626.618 +/- 0.976	8057189.434 +/- 0.885	13.503 +/- 1.756	-1.466	4.622	-1.289	8.074	5.968
Session 1 KGNSS PPP	222625.189 +/- 0.001	8057193.991 +/- 0.000	12.228 +/- 0.001	-0.037	0.065	-0.014	0.077	0.029
Session 1 KGNSS BS	222625.145 +/- 0.003	8057193.997 +/- 0.001	12.168 +/- 0.002	0.007	0.059	0.046	0.067	0.094

Note: Absolute Accuracy 2D (95% Confidence) = 2.448*(σE2 + σN2)½ + (Δ East2 + Δ North2)½

Note: Absolute Accuracy 1D (95% Confidence) = 1.96*σH + Δ Height

Triangle Solutions

Side	Side Length	Squared	Cos Rule	Acos(rad)	DD	DMS	Angle	Check	
A	11.7	136.890000	-0.6405069733	2.2659545732	129.82963	129:49:47	a		TRI 1
E	5.898	34.786404	0.9220265067	0.3975133132	22.77584	22:46:33	e		
D	7.01	49.140100	0.8878593062	0.4781247671	27.39453	27:23:40	d	180.00000	
B	11.574	133.957476	-0.3192457264	1.8957297846	108.61732	108:37:02	b		TRI 2
F	8.252	68.095504	0.7372054375	0.7418713503	42.50610	42:30:22	f		
E	5.898	34.786404	0.8756619401	0.5039915187	28.87659	28:52:36	e	180.00000	
C	13.332	177.742224	-0.5229927401	2.1211547267	121.53321	121:32:00	c		TRI 3
D	7.01	49.140100	0.8939528284	0.4647071935	26.62576	26:37:33	d		
F	8.252	68.095504	0.8495151584	0.5557307333	31.84103	31:50:28	f	180.00000	
					359.98016	359:58:49		Check	

This section will compute all angles within the three triangles using the Cosine Rule. Things to look for here is that the sum of the angles given doesn't total more or less than 15' of 360 degrees

Join Calculation between Stat-Cal Triangle marks

Line	de	dn	dist	BRG	RawDegBRG	DegBRG	DegBRG
1-2	-9.52	6.810	11.705	-0.94985	-54.42249	305.57751	125.57751
2-3	9.56	6.530	11.577	0.97153	55.66480	55.66480	235.66480
3-1	-0.04	-13.340	13.340	0.00300	0.17180	0.17180	180.17180

Bearing Quadrant Calculations

Column	Row	Quadrant	Min	Max	AntiClockwise	Clockwise	Quadrant	Min	Max
							1	0	90
2	1	4	270	360	305.57751	125.57751	2	90	180
1	1	1	0	90	55.66480	235.66480	3	180	270
2	2	3	180	270	180.17180	0.17180	4	270	360

This section will calculate the joins between the three ground calibration points from the given coordinates. It will then ensure the triangle bearings are given in a clockwise direction by calculating the quadrant the bearing should be in, and adjusting accordingly.

Laser Source Coordinate Calculation

From Pt	NewRawBRG	NewBRG	dist	de	dn	New E	New N	
1	148.33078	148.33078	7.01	3.680	-5.966	222625.260	8057194.274	
1	148.35335	148.35335	7.01	3.678	-5.968	222625.258	8057194.272	
2	278.18298	278.18298	5.898	-5.838	0.839	222625.262	8057194.269	
2	278.17090	278.17090	5.898	-5.838	0.838	222625.262	8057194.268	
3	26.78821	26.78821	8.252	3.719	7.366	222625.259	8057194.266	
3	26.79756	26.79756	8.252	3.720	7.366	222625.260	8057194.266	
						222625.260	8057194.269	Average
						+/- 0.001	+/- 0.003	Std Deviation

From the calculated triangle angles, the calculated bearings from the calibration marks and the distances measured to the plumbed laser source, two coordinates are calculated for each calibration point.
An average is calculated and used.
Watch out for a high standard deviation (>0.005) as this could mean erroneous data, or an error in the calculation sheet.

GPS Antenna Coordinate Calculation

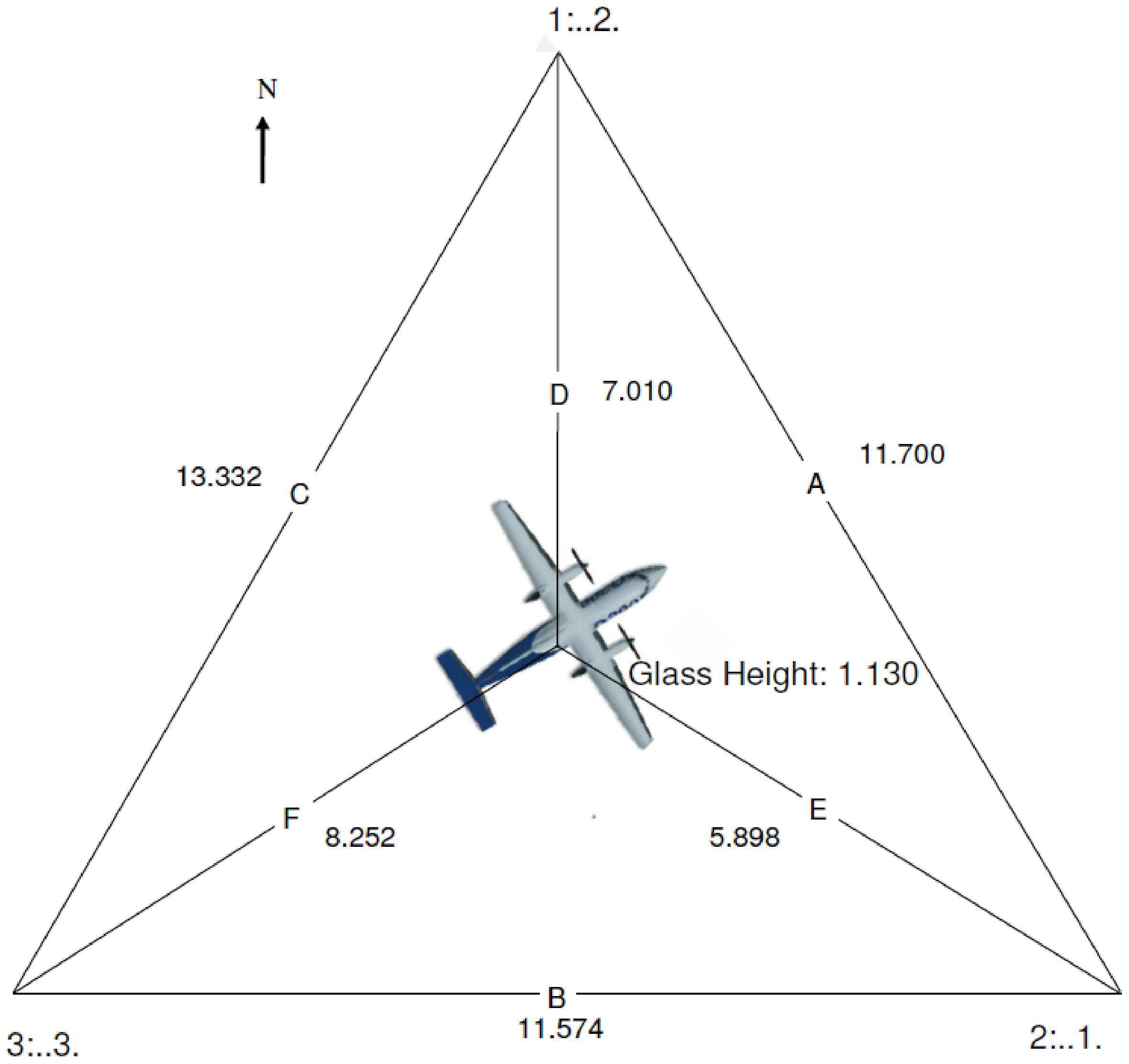
Hypotenuse	Angle from heading	DD	NewBrgRaw	NewBRG	DMS	de	dn	GPS EAST	GPS NORTH
0.239	175:55:53								
0.239	175:55:53	175.93139	206.93139	206.9313889	206:55:53	-0.108	-0.213	**222625.152**	**8057194.056**

Finally the GPS Absolute position is calculated from the given angle and hypotenuse length. The angle refers to a clockwise angle from the Aircraft Heading

Enclosure 3 – Static Position Check Field Page

Static Position Check Field Page

Database: 15_2sau_tahiti	Date: 7-June-2015
Location: Fa'a'a Airport, Tahiti	Surveyor: BCM



- Record ALL Distances including Glass Height
- Record Contract Surveyor's Point Names
- Draw a North Arrow
- Use opposite side of page for Marks Recovery Diagram

Enclosure 4 – Example of GS Dynamic Position Analysis Report – Sortie 8

GS VERSION A.1.48.2

POSITION ANALYSIS REPORT FOR SORTIE 8 FLOWN ON 191 2015 (10/07/15)

MISSION TITLE: ALB Survey of Samoa

RUN COUNT: 19

Statistics for Run 1009.0.2

GPS Start Time 00:13:28 End Time 00:19:19

DGPS_HRMS Min= 0.000m Max= 0.000m

KGPS_HRMS Min= 0.035m Max= 0.038m

AS_EHE Min= 0.207m Max= 0.210m

AS_PDOP Min= 1.25m Max= 1.31m

POST_PROCESSED_PDOP Min= 1.00m Max= 1.10m

AS_SVS Min=16 Max=18

POST_PROCESSED_SVS Min=11 Max=12

AS_LATENCY_OF_CORRECTIONS Min= 7s Max= 25s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 704 DGPS = 0)

Latitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

Longitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

RMS Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

Airborne System - KGPS (Sample Size: AS = 704 KGPS = 704)

Latitude Min= -0.318m Max= 0.257m Mean= -0.040m Stdev= 0.055m

Longitude Min= -0.309m Max= -0.065m Mean= -0.196m Stdev= 0.043m

RMS Min= 0.079m Max= 0.353m Mean= 0.208m Stdev= 0.040m

DGPS - KGPS (Sample Size: DGPS = 0 KGPS = 704)

Latitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

Longitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

RMS Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

DGPS - AS Height (Sample Size: AS = 704 DGPS = 0)

WGS84 Ht Min= 0.000m Max= 0.000m Mean= 0.000m

KGPS - AS Height (Sample Size: AS = 704 KGPS = 704)

WGS84 Ht Min= 0.939m Max= 1.247m Mean= 1.105m

Airborne System GPS Mode : diff

Airborne System Racal Basestation :

Statistics for Run 1008.0.1

GPS Start Time 00:23:06 End Time 00:29:21

DGPS_HRMS Min= 0.000m Max= 0.000m

KGPS_HRMS Min= 0.035m Max= 0.035m

AS_EHE Min= 0.209m Max= 0.211m

AS_PDOP Min= 1.28m Max= 1.31m

POST_PROCESSED_PDOP Min= 1.20m Max= 1.30m

AS_SVS Min=16 Max=17

POST_PROCESSED_SVS Min=12 Max=12

AS_LATENCY_OF_CORRECTIONS Min= 7s Max= 22s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 752 DGPS = 0)

Latitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

Longitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

RMS Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

Airborne System - KGPS (Sample Size: AS = 752 KGPS = 752)

Latitude Min= -0.185m Max= 0.292m Mean= 0.105m Stdev= 0.054m

Longitude Min= -0.118m Max= 0.136m Mean= 0.042m Stdev= 0.044m

RMS Min= 0.004m Max= 0.309m Mean= 0.126m Stdev= 0.042m

DGPS - KGPS (Sample Size: DGPS = 0 KGPS = 752)

Latitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

Longitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

RMS Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

DGPS - AS Height (Sample Size: AS = 752 DGPS = 0)

WGS84 Ht Min= 0.000m Max= 0.000m Mean= 0.000m

KGPS - AS Height (Sample Size: AS = 752 KGPS = 752)

WGS84 Ht Min= 1.030m Max= 1.183m Mean= 1.098m

Airborne System GPS Mode : diff

Airborne System Racal Basestation :

Statistics for Run 1007.0.1

GPS Start Time 00:32:49 End Time 00:38:51

DGPS_HRMS Min= 0.000m Max= 0.000m

KGPS_HRMS Min= 0.034m Max= 0.035m

AS_EHE Min= 0.209m Max= 0.210m

AS_PDOP Min= 1.23m Max= 1.31m

POST_PROCESSED_PDOP Min= 1.30m Max= 1.40m

AS_SVS Min=18 Max=18

POST_PROCESSED_SVS Min=12 Max=12

AS_LATENCY_OF_CORRECTIONS Min= 7s Max= 22s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 726 DGPS = 0)

Latitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

Longitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

RMS Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

Airborne System - KGPS (Sample Size: AS = 726 KGPS = 726)

Latitude Min= -0.252m Max= 0.077m Mean= -0.059m Stdev= 0.043m

Longitude Min= -0.357m Max= -0.126m Mean= -0.234m Stdev= 0.029m

RMS Min= 0.169m Max= 0.358m Mean= 0.245m Stdev= 0.028m

DGPS - KGPS (Sample Size: DGPS = 0 KGPS = 726)

Latitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

Longitude Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

RMS Min= 0.000m Max= 0.000m Mean= 0.000m Stdev= 0.000m

DGPS - AS Height (Sample Size: AS = 726 DGPS = 0)

WGS84 Ht Min= 0.000m Max= 0.000m Mean= 0.000m

KGPS - AS Height (Sample Size: AS = 726 KGPS = 726)

WGS84 Ht Min= 1.125m Max= 1.460m Mean= 1.270m

Airborne System GPS Mode : diff

Annex G. Vertical Datum and Ellipsoidal Reduction

G.1 Vertical Datum

All soundings are relative to the Mean Sea Level (MSL) 1993 datum as established by the National Tidal Centre Australia.

G.2 Vertical Datum Corrections Workflow

The vertical datum correction workflow to correct both the ALB and ALT data to Mean Sea Level (MSL) involved comparing each dataset to the static GPS observation survey control points, performed by MNRE surveyors in 2015. An ellipsoidal correction was then determined and applied for each dataset to tie the data to the local control. From there, the ALB and ALT data was essentially treated the same with the geoid model applied and then a common MSL correction for each island applied, to reduce all the data to the local MSL datum. Figure 5 shows the workflow followed.

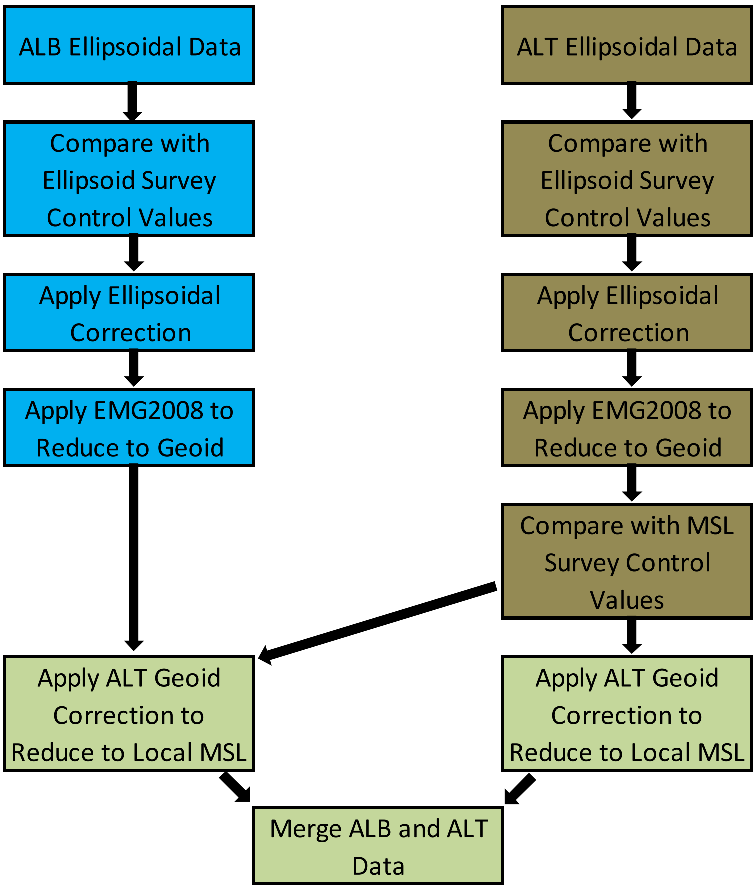


Figure G1: Vertical Datum Corrections Workflow

G.3 Ellipsoidal Data

The bathymetric and topographic data was processed to the GRS80 ellipsoid as the International Terrestrial Reference Frame (ITRF) is associated with this ellipsoid. The difference between WGS84 and GRS80 of 0.1mm is negligible.

An assessment of the ALB and ALT ellipsoidal datasets was made against the Survey Control points with the following results in Table 6 below. For further information on the Station Descriptions and comparisons results, see the Post-Survey Spatial Accuracy Report:

Dataset	Upolu Island	Savaii Island
ALB	-0.14m +/- 0.07m	-0.18m +/- 0.09m
ALT	-0.16m +/- 0.10m	-0.19m +/- 0.12m

Table G1: Mean Differences of the ALB, ALT comparisons against the ellipsoidal control points for Upolu and Savaii Islands.

G.4 Geoid Model Used - EGM2008

A requirement of the survey was to deliver orthometric heights to the Mean Sea Level as determined by the published heights of local survey control marks within the project extents.

To correct the data from ellipsoidal to orthometric heights, the Earth Gravitational Model 2008 (EGM2008) was used with a 1’ x 1’ grid.

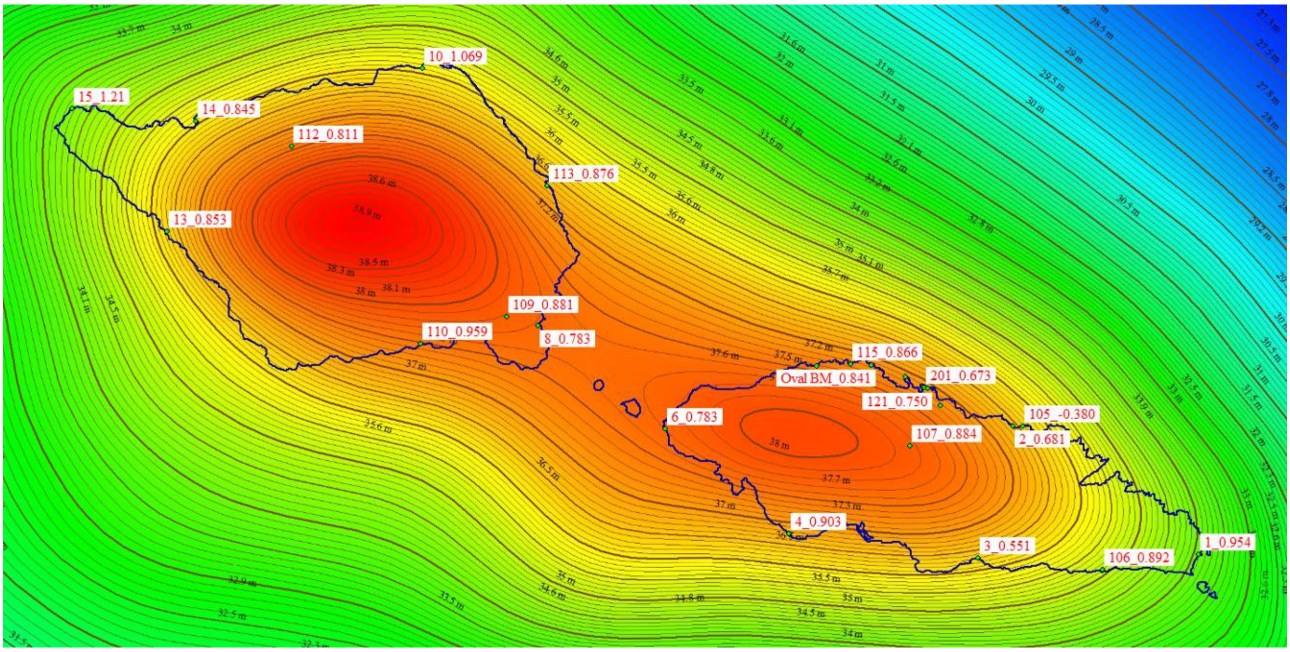


Figure G2: EGM2008 values for Samoan Islands overlaid with Survey Control Points and MSL Correction variation

G.5 Mean Sea Level Derivation

G.5.1 Upolu Island – MSL Historical Definition

The vertical datum for Upolu Island is MSL derived from tidal observations at Mulinuu between 1951 and 1969. In February 1993, a new tide gauge was installed on the main wharf in Apia as part of the South Pacific Sea Level and Climate Monitoring Project. This has since been used, along with associated benchmark BM1006 (BM201 fixed 1.3292m above MSL), as the vertical datum for Upolu Island for measuring MSL. This MSL datum has not changed since 1993 and so has been used for the data collected over Upolu. No correction to MSL in 2015 has been calculated.

G.5.2 Savai'i Island – MSL Historical Definition

The vertical datum for Savai'i Island is also MSL derived from three months of sea level observations taken by the New Zealand Navy in 1976. The primary benchmark for Savai'i Island is BM7500 at Asua wharf which is 2.478m above the observed MSL. This MSL datum has not changed since 1976 and so has been used for the data collected over Savai'i. No correction to MSL in 2015 has been calculated.

G.5.3 Upolu and Savaii – MSL Correction to EGM2008

Examination of the ellipsoid to MSL values from levelling indicates a difference of 0.668m between EGM2008 and the observed values based on currently existing information. Figure 2 shows the levelling connections from the previous LiDAR survey conducted in 2012/13.

Apia Wharf, Samoa—Connection Diagram

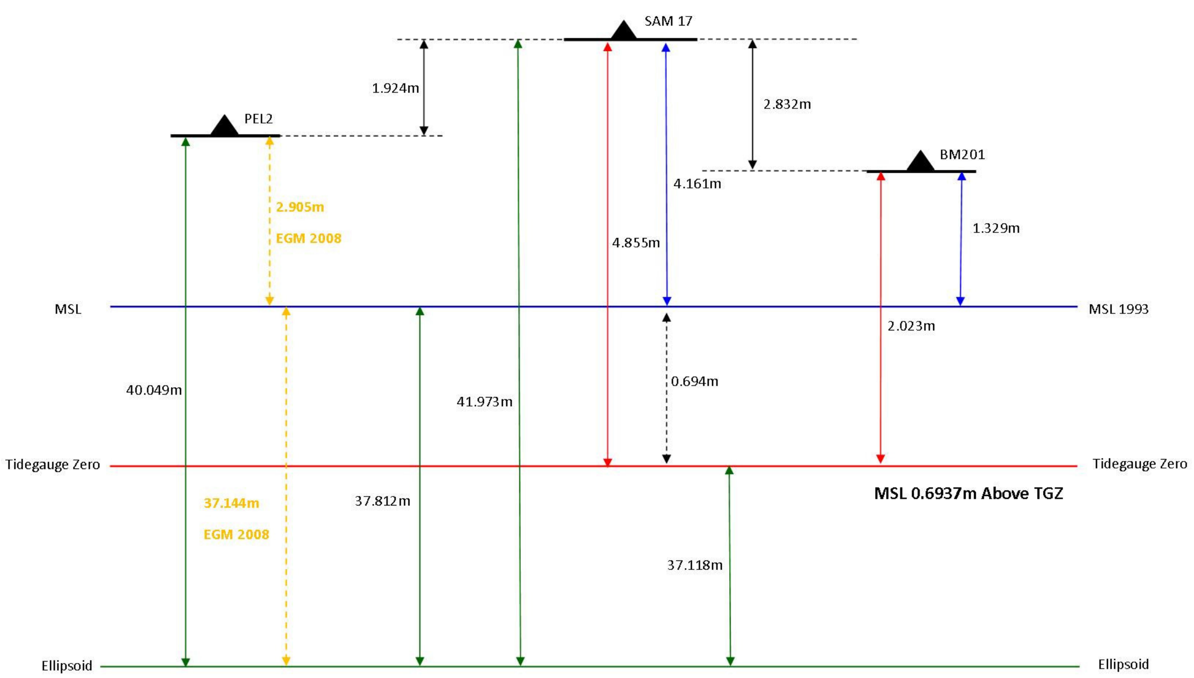


Figure G3: Apia Levelling Connection Diagram based on observations and quoted MSL values (2012 RoS)

From the survey control, mainly established by MNRE surveyors during the LiDAR survey conducted in 2015, alternative correction values were derived based on a wider distribution of points around each of the two Islands, depicted in the figure 6. The reduced EGM08 ALT data was then compared against the selected survey control points to derive the MSL corrections for both Islands, depicted in Table 7 below;

ALT Ellipsoidal Correction and Observed MSL Correction

Upolu

Stn No	Easting	Northing	Ell Height	Lidar Height	Corr	Corrected Lidar Ell (+0.16)	Reduced Lidar Geoid	Obs MSL	MSL Corr
1	453826.53	8449489.4	36.37	36.21	0.16	36.37	2.38	1.493	-0.89
2	429631.27	8466139.95	41.53	41.24	0.29	41.4	4.78	4.256	-0.52
3	425045.18	8448988.17	38.48	38.38	0.10	38.54	2.13	1.618	-0.51
4	400451.66	8452196.57	42.06	41.93	0.13	42.09	5.13	4.397	-0.73
6	384329.11	8465808.16	39.91	39.71	0.20	39.87	2.12	1.416	-0.70
107	416153.62	8463579.01	578.12	577.88	0.24	578.04	540.20	539.397	-0.80
201	418048	8471151	39.14	39.17	-0.03	39.33	2.00	1.329	-0.67
				Mean	**0.16**			**Mean**	-0.69
				Stdev	**0.10**			**Stdev**	0.14

Savaii

Stn No	Easting	Northing	Ell Height	Lidar Height	Corr	Corrected Lidar Ell (+0.19)	Reduced Lidar Geoid	Obs MSL	MSL Corr
8	367664.09	8479315.17	43.33	43.27	0.06	43.46	5.67	4.858	-0.81
10	352577.77	8512836.16	42.58	42.28	0.30	42.47	6.52	5.618	-0.90
13	319279.25	8491477.41	99.94	99.78	0.16	99.97	63.63	62.829	-0.80
14	323013.37	8505892.59	39.25	39.1	0.15	39.29	3.16	2.478	-0.68
109	363645.42	8480421.29	67.67	67.39	0.28	67.58	29.77	29.006	-0.76
110	352344.56	8476970.68	45.27	45.26	0.01	45.45	7.96	6.826	-1.13
112	335557.52	8502669.92	257.67	257.44	0.23	257.63	220.22	219.439	-0.78
113	368910.13	8497476.26	39.48	39.15	0.33	39.34	2.61	1.883	-0.73
				Mean	**0.19**			**Mean**	-0.83
				Stdev	**0.12**			**Stdev**	0.14

Table G2: ALT Survey Control Points Adopted for Analysis and Ellipsoidal / MSL Corrections Derived for Upolu and Savaii Islands (highlighted in green)

Therefore for the following corrections were applied to **both the ALT and ALB** Ellipsoidal datasets:

- Upolu Survey Area – that **0.69m was subtracted** to the EGM2008 values to reduce all ellipsoidal data to MSL
- Savai'i Survey Area – that **0.83m was subtracted** to the EGM2008 values to reduce all ellipsoidal data to MSL.

Annex H. Benchmark and Cross Line Comparison Results

H.1 General

Benchmarks and cross lines are used as the primary means of checking the quality of LiDAR data. A depth benchmark is typically a flat area of seabed which is re-surveyed on each sortie to check for correct system operation and correct application of tides or ellipsoidal heights in that area; the depth benchmark results can also be used in the assessment of the precision of the survey.

Cross lines are compared against main survey lines, and are used to check correct system operation and the tidal model throughout the survey area.

Topographic Integration Points (TIP's) were flown over and used as topographic benchmarks. These sites were flat areas of dry land on which analysis of the accuracy and precision of the LADS Mk 3 and RIEGL VQ-820-G topographic capabilities could be made.

This data is used solely as a system performance check; the results achieved are not used by the system to perform any sort of system calibration. The results are incorporated into the final accuracy and precision calculations for the survey.

H.2 Depth Benchmarks

Three benchmark areas were selected along cross line 73.0.2 so as comparisons could be made with the other 73.0 lines flown of which four were flown during the survey.

The dimensions of each benchmark area are around 360 metres x 180 metres (2 frames of data). The centre coordinates for the benchmark areas are (ITRF08, UTM 2S):

BM ID	Location	Easting	Northing	Average Ellipsoidal Height	Remarks
BM1	Upolu Offshore	406 544	8 480 287	20.8m	73.0.1, 73.0.4 - 73.0.6
BM2	Upolu Offshore	405 426	8 478 702	0.9m	73.0.1, 73.0.4 - 73.0.6
BM3	Upolu Inshore	404 812	8 477 831	30.3m	73.0.1, 73.0.4 - 73.0.6

Table 1 – Centre coordinates for benchmark areas

H.2.1 Benchmark Comparison Function

The LADS data is compared against the gridded benchmark surface in the Ground System and statistics are generated which include the number of points compared, the mean depth difference (MDD) and the standard deviation (SD) between the data sets. The comparison compares the secondary data against the benchmark surface, if the data over the benchmark area is not suitable, either due to turbidity, roll locks, etc, then it is set to rejected and no comparison is made.

H.2.2 Benchmark Lines

The total number of benchmarks compared during the survey was 12. The ellipsoid (GRS80) in use for the comparison of benchmarks was the same as that used for application to main line soundings.

H.2.3 Benchmark Results

The averages of the mean depth differences and standard deviations for each of the benchmarks are as follows:

BM ID	Nominal Depth	Number of Comparisons	Average MDD	Average SD
1	20.8m	11274	0.04 +/- 0.03	0.16 +/- 0.01
2	0.9m	9037	-0.11 +/- 0.09	0.14 +/- 0.01
3	30.3m	11284	0.10 +/- 0.05	0.46 +/- 0.01
	Total	**31595**	**0.01 +/- 0.06**	**0.25 +/- 0.01**

Table 2 – Benchmark Results

H.2.4 Conclusion

Twelve benchmark comparisons were conducted using 31595 individual soundings. The average mean depth difference from all benchmark comparisons was -0.01m +/-0.06 with an average standard deviation of ± 0.25m +/-0.01 (1σ). These results are comparable with previous results obtained with the LADS Mk 3 system and show it operated correctly.

Details on individual benchmark comparisons are in Enclosure 1.

H.3 2012 Bathymetry Data Comparisons

A comparison of the ALB data with the LiDAR bathymetry data flown in 2012 was conducted as an absolute accuracy check on the system. Initially three areas at different depths were chosen from the 2012 data which intersected cross line 74.0.1 and the main survey lines. A shallow water benchmark area near the airport on line 1008.0.1 was also selected so as comparisons with LADS Mk3 / RIEGL and the 2012 data could be done. The results are shown in the tables below.

Benchmark 9m

Run ID	Pattern	Sortie	No. of Comparisons	Mean Depth Difference	Standard Deviation	Remarks
74.0.1.1	P5_1800	8	2517	0.05	0.19	
1110.0.1	P5_1800	1	2596	0.05	0.21	
1110.0.2	P5_1800	13	2582	0.09	0.21	
			Mean	**0.06**	**0.20**	
			StDev	**0.02**	**0.01**	

Table 3 – LADS Mk 3 and 2012 LiDAR depth benchmark comparisons

Benchmark 23m

Run ID	Pattern	Sortie	No. of Comparisons	Mean Depth Difference	Standard Deviation	Remarks
74.0.1	P5_1800	8	1126	-0.27	0.31	Sloping seabed on large shoal
1108.0.3	P5_1800	1	1157	-0.23	0.36	Sloping seabed on large shoal
1108.1.1	P5_1800	15	1157	-0.20	0.34	Sloping seabed on large shoal
			Mean	**-0.23**	**0.34**	
			StDev	**0.04**	**0.03**	

Table 4 – LADS Mk 3 and 2012 LiDAR depth benchmark comparisons

Benchmark 17m

Run ID	Pattern	Sortie	No. of Comparisons	Mean Depth Difference	Standard Deviation	Remarks
74.0.1	P5_1800	8	2148	-0.15	0.15	Sloping seabed
1106.0.1	P5_1800	1	2244	-0.28	0.17	Sloping seabed
			Mean	**-0.22**	**0.16**	
			StDev	**0.09**	**0.01**	

Table 5 – LADS Mk 3 and 2012 LiDAR depth benchmark comparisons

Benchmark 5m

System	Run ID	Sortie	No. of Comparisons	Mean Depth Difference	Standard Deviation	Remarks
LADS Mk 3	1008.0.1	8	4731	0.13	0.13	
RIEGL VQ-820-G	1008.0.1	8	71639	-0.25	0.15	
			Mean	**-0.06**	**0.14**	
			StDev	**0.27**	**0.01**	

Table 6 – LADS Mk 3, RIEGL VQ-820-G and 2012 LiDAR depth benchmark comparisons

An overall average Mean Depth Difference of -0.11m ±0.11 and Standard Deviation of 0.21m ±0.02 confirms the LADS and RIEGL bathymetry data matches well with the data acquired in 2012 albeit with a sloping seabed in places.

On completion of the final ALB dataset an overall comparisons was conducted on both the 2012 LiDAR areas as outlined in section H.6 below.

H.4 Cross Line Comparisons

Thirty-two cross lines and six cross line were flown across the ALB and ALT survey areas respectively. Comparisons were made with the main survey lines for analysis. Details are tabled below for both LADS and RIEGL LMS-Q780 systems.

H.4.1 Mean Differences and Standard Deviation

The averages of the Mean Depth Differences and Standard Deviation for each merged LADS Mk3 and RIEGL VQ-820-G cross line from the ALB survey are in the table below:

Survey Area	Cross Run	No. of Comparisons	Mean Depth Difference	Standard Deviation
Savaii	20165	2507	-0.06	0.35
Savaii	20166	12108	-0.13	0.40
Savaii	20167	6946	-0.15	0.21
Savaii	20168	2736	0.09	0.27
Savaii	20249	11076	0.08	0.13
Savaii	20250	3115	0.04	0.47
Savaii	20251	7678	0.16	0.28
Savaii	20252	8542	-0.01	0.31
Savaii	20279	3806	-0.01	0.34
Savaii	20280	15388	-0.01	0.11
Savaii	20281	24371	0.03	0.10
Savaii	20283	10038	-0.03	0.41
Savaii	20303	10304	-0.11	0.30
Savaii	20304	13754	-0.16	0.23
Savaii	20305	10319	-0.07	0.44
Savaii	20306	3454	-0.13	0.44
Savaii	20307	10159	-0.06	0.20
Savaii	20308	10591	-0.01	-0.31
Upolu	20109	26711	0.04	0.23
Upolu	20110	23752	0.01	0.07
Upolu	20170	23930	0.09	0.07
Upolu	20171	21084	0.05	0.13
Upolu	20172	20286	0.00	0.20
Upolu	20291	2855	-0.27	0.29
Upolu	20311	18316	-0.16	0.10
Upolu	20312	25043	-0.09	0.06
	Total Mean	**328869**	**-0.03**	**0.22**
	StDev		**0.10**	**0.17**

Table 7 – ALB cross line comparison results

The averages of the Mean Differences and Standard Deviation for each RIEGL LMS-Q780 cross line from the ALT survey are in the tables below:

Site	Cross Run	Target Run	Run Line Intersection	No. of comparison	Mean Difference	Standard Deviation
Savaii	30444	30178	1	23077	-0.03	0.36
Savaii	30444	30179	1	24819	-0.01	0.38
Savaii	30444	30207	3	1097	-0.05	0.29
Savaii	30444	30208	3	3621	-0.14	0.33
Savaii	30444	30209	3	10320	-0.14	0.38
Savaii	30444	30210	3	14404	-0.06	0.25
Savaii	30444	30211	3	18023	0.00	0.19
Savaii	30444	30212	3	22347	0.02	0.12
Savaii	30444	30234	1	22901	0.00	0.35
Savaii	30444	30235	1	22602	-0.02	0.41
Savaii	30444	30236	1	20193	-0.02	0.41
Savaii	30444	30237	1	18543	-0.03	0.49
Savaii	30444	30238	1	16280	0.00	0.52
Savaii	30444	30239	1	8522	-0.03	0.56
Savaii	30444	30240	1	1335	-0.10	0.56
Savaii	30444	30281	3	23925	-0.01	0.10
Savaii	30444	30282	2	23845	0.01	0.12
Savaii	30444	30284	3	23828	0.00	0.13
Savaii	30444	30285	2	24133	-0.02	0.14
Savaii	30444	30286	2	23513	-0.02	0.13
Savaii	30444	30287	1	23762	-0.01	0.12
Savaii	30444	30288	1	24007	-0.01	0.13
Savaii	30444	30289	1	24825	0.00	0.15
Savaii	30444	30290	1	24438	-0.02	0.16
Savaii	30444	30291	1	23619	-0.02	0.18
Savaii	30444	30292	1	23166	-0.02	0.19
Savaii	30444	30293	1	24837	-0.01	0.17
Savaii	30444	30294	1	25503	0.00	0.16
Savaii	30444	30306	1	25599	-0.01	0.23
Savaii	30444	30307	1	24454	-0.01	0.30
Savaii	30444	30308	1	24821	0.01	0.30
Savaii	30444	30309	1	24518	0.00	0.28
Savaii	30444	30310	1	22877	-0.02	0.32
Savaii	30444	30311	1	23656	-0.02	0.32
Savaii	30461	30391	1	10001	-0.03	0.23
Savaii	30461	30441	1	8497	0.06	0.19
Savaii	30461	30443	1	19752	0.01	0.19
Savaii	30598	30019	1	23262	0.00	0.18

Savaii	30598	30177	1	15754	0.05	0.41
Savaii	30598	30206	2	2988	0.10	0.25
Savaii	30598	30207	3	10019	0.11	0.25
Savaii	30598	30208	3	14964	0.10	0.21
Savaii	30598	30209	3	17263	0.03	0.13
Savaii	30598	30210	3	19672	0.00	0.14
Savaii	30598	30211	3	22248	-0.02	0.10
Savaii	30598	30212	3	23374	0.02	0.10
Savaii	30598	30214	1	15695	-0.18	0.48
Savaii	30598	30215	1	20293	0.02	0.25
Savaii	30598	30216	1	20279	0.00	0.24
Savaii	30598	30217	1	21987	0.01	0.18
Savaii	30598	30218	1	23069	0.03	0.17
Savaii	30598	30220	1	23826	0.01	0.11
Savaii	30598	30221	1	23390	0.00	0.12
Savaii	30598	30250	1	23978	-0.01	0.13
Savaii	30598	30251	1	22062	-0.02	0.23
Savaii	30598	30281	3	23167	0.02	0.10
Savaii	30598	30282	2	22970	0.00	0.12
Savaii	30598	30283	1	22030	-0.01	0.15
Savaii	30598	30348	1	22461	0.01	0.12
Savaii	30598	30349	1	24651	0.01	0.10
Savaii	30598	30350	2	23510	0.01	0.09
Savaii	30598	30351	2	24710	0.01	0.10
Savaii	30598	30353	1	23599	0.00	0.11
Savaii	30598	30354	1	23384	0.00	0.11
Savaii	30598	30357	1	23396	0.01	0.07
Savaii	30598	30358	1	24048	0.00	0.08
Savaii	30598	30359	1	23053	0.01	0.09
Savaii	30598	30360	1	23600	0.01	0.10
Savaii	30598	30361	1	23892	0.01	0.14
Savaii	30598	30362	1	22799	0.01	0.12
Savaii	30598	30363	1	24156	0.01	0.11
Savaii	30598	30364	1	23411	0.01	0.10
Savaii	30598	30365	1	24650	0.00	0.11
Savaii	30598	30366	1	23790	0.01	0.11
Savaii	30598	30367	1	23136	0.01	0.11
Savaii	30598	30368	1	22034	0.00	0.15
Savaii	30598	30369	1	21929	0.01	0.16
Savaii	30598	30370	1	21466	-0.02	0.15
Savaii	30598	30371	1	21246	-0.01	0.16
Savaii	30598	30372	1	21672	0.00	0.18
Savaii	30598	30373	1	20944	0.01	0.21

Savaii	30598	30374	1	19915	0.01	0.21
Savaii	30598	30375	1	21980	0.00	0.17
Savaii	30598	30390	1	23671	0.01	0.22
Savaii	30598	30394	1	21670	0.00	0.30
Savaii	30598	30395	1	19874	0.04	0.32
Savaii	30598	30404	1	23917	0.01	0.22
Savaii	30598	30405	1	23222	-0.01	0.21
Savaii	30598	30406	1	22118	-0.02	0.24
Savaii	30598	30407	1	20885	-0.02	0.28
Savaii	30598	30408	1	20263	0.00	0.32
Savaii	30598	30409	1	18383	-0.04	0.33
Savaii	30598	30410	1	18224	-0.03	0.33
Savaii	30603	30020	1	12212	0.19	0.41
Savaii	30603	30021	1	9401	0.11	0.19
Savaii	30603	30022	1	16552	0.02	0.22
Savaii	30603	30023	1	21457	-0.01	0.17
Savaii	30603	30024	1	19772	0.03	0.18
Savaii	30603	30025	1	20660	0.01	0.18
Savaii	30603	30026	1	20415	0.02	0.20
Savaii	30603	30027	1	19825	0.04	0.22
Savaii	30603	30028	1	20070	0.06	0.23
Savaii	30603	30029	1	19815	0.04	0.23
Savaii	30603	30030	1	21253	0.06	0.21
Savaii	30603	30031	1	22882	0.02	0.19
Savaii	30603	30032	1	22286	0.03	0.20
Savaii	30603	30033	1	22102	0.06	0.23
Savaii	30603	30034	1	21320	0.07	0.24
Savaii	30603	30035	1	21454	0.10	0.29
Savaii	30603	30036	1	20593	0.09	0.30
Savaii	30603	30037	1	21865	0.08	0.28
Savaii	30603	30038	1	20627	0.08	0.26
Savaii	30603	30039	1	22385	0.05	0.23
Savaii	30603	30196	1	21824	-0.04	0.34
Savaii	30603	30198	1	19042	-0.02	0.33
Savaii	30603	30199	1	20758	-0.05	0.35
Savaii	30603	30200	1	19894	-0.05	0.36
Savaii	30603	30201	1	21294	-0.03	0.27
Savaii	30603	30202	1	19168	-0.05	0.35
Savaii	30603	30203	1	17084	-0.06	0.46
Savaii	30603	30206	2	16318	-0.06	0.33
Savaii	30603	30207	3	18781	-0.03	0.29
Savaii	30603	30208	3	16791	-0.04	0.34
Savaii	30603	30209	3	15411	-0.07	0.41

Savaii	30603	30210	3	15982	-0.09	0.41
Savaii	30603	30211	3	16062	-0.01	0.36
Savaii	30603	30212	3	14880	-0.11	0.38
Savaii	30603	30266	1	21757	0.07	0.26
Savaii	30603	30268	1	23483	0.04	0.25
Savaii	30603	30281	3	18175	0.02	0.31
Savaii	30603	30282	2	17288	0.04	0.37
Savaii	30603	30284	3	16781	0.03	0.40
Savaii	30603	30285	2	16610	0.12	0.36
Savaii	30603	30286	2	17737	0.09	0.33
Savaii	30603	30313	1	17143	-0.05	0.36
Savaii	30603	30314	1	16084	-0.06	0.37
Savaii	30603	30323	1	21244	0.00	0.24
Savaii	30603	30350	2	18620	0.05	0.32
Savaii	30603	30351	2	8914	-0.05	0.37
Savaii	30603	30352	1	7427	-0.06	0.46
Savaii	30603	30355	1	8167	-0.01	0.51
Savaii	30603	30356	1	6207	0.04	0.52
Savaii		**Total Mean**	**201**	**2809481**	**0.00**	**0.24**
		stDev			**0.05**	**0.12**

Table 8: RIEGL LMS-Q780 cross line comparison results - Savaii

Site	Cross Run	Target Run	Run Line Intersection	No. of comparison	Mean Difference	Standard Deviation
Upolu	30515	30001	1	5533	-0.02	0.08
Upolu	30515	30004	1	6430	-0.02	0.08
Upolu	30515	30005	1	8533	0.06	0.06
Upolu	30515	30006	1	14617	0.00	0.08
Upolu	30515	30007	1	20236	-0.03	0.06
Upolu	30515	30008	1	22995	-0.01	0.06
Upolu	30515	30071	2	14200	0.01	0.23
Upolu	30515	30109	1	20002	-0.01	0.26
Upolu	30515	30110	1	21378	-0.02	0.19
Upolu	30515	30111	1	23526	-0.02	0.17
Upolu	30515	30112	1	23741	-0.01	0.13
Upolu	30515	30113	1	24124	0.00	0.11
Upolu	30515	30114	1	23065	-0.01	0.12
Upolu	30515	30115	1	23400	0.01	0.11
Upolu	30515	30116	2	2466	0.00	0.25
Upolu	30515	30123	1	23928	-0.01	0.09
Upolu	30515	30124	1	22461	-0.02	0.07
Upolu	30515	30125	1	23501	-0.02	0.06

Upolu	30515	30126	1	22978	-0.02	0.06
Upolu	30515	30127	1	22889	0.00	0.06
Upolu	30515	30128	1	22551	0.01	0.06
Upolu	30515	30129	1	22851	-0.02	0.05
Upolu	30515	30130	1	22003	-0.02	0.06
Upolu	30515	30131	1	23268	-0.01	0.06
Upolu	30515	30132	1	22663	-0.01	0.07
Upolu	30515	30133	1	23547	0.01	0.06
Upolu	30515	30136	1	7021	-0.01	0.06
Upolu	30515	30138	1	3968	-0.01	0.07
Upolu	30515	30274	2	20819	-0.03	0.15
Upolu	30515	30299	1	18034	-0.01	0.26
Upolu	30515	30330	1	23608	0.01	0.07
Upolu	30515	30342	1	13814	-0.01	0.05
Upolu	30515	30344	1	20138	0.01	0.21
Upolu	30515	30345	1	22418	0.01	0.17
Upolu	30515	30346	1	20584	-0.01	0.19
Upolu	30515	30552	1	3088	0.00	0.25
Upolu	30515	30574	2	6210	0.01	0.26
Upolu	30515	30645	1	16215	0.00	0.22
Upolu	30515	30648	2	21994	-0.02	0.15
Upolu	30515	30649	2	18549	0.01	0.21
Upolu	30644	30009	1	18896	-0.04	0.17
Upolu	30644	30010	1	19711	-0.05	0.17
Upolu	30644	30011	1	18294	-0.05	0.14
Upolu	30644	30012	1	21684	0.01	0.19
Upolu	30644	30013	1	23365	0.00	0.19
Upolu	30644	30014	1	22121	-0.02	0.20
Upolu	30644	30015	1	21766	0.03	0.18
Upolu	30644	30016	1	16168	-0.07	0.31
Upolu	30644	30040	1	21941	0.00	0.22
Upolu	30644	30057	1	23026	0.00	0.17
Upolu	30644	30059	1	21819	-0.01	0.17
Upolu	30644	30060	1	21714	-0.01	0.18
Upolu	30644	30061	1	20921	-0.04	0.18
Upolu	30644	30062	1	20531	-0.05	0.16
Upolu	30644	30063	1	21629	-0.03	0.16
Upolu	30644	30069	1	18478	0.03	0.39
Upolu	30644	30071	2	20869	0.00	0.26
Upolu	30644	30074	1	21905	0.00	0.16
Upolu	30644	30084	1	18812	0.04	0.39
Upolu	30644	30085	1	17043	0.02	0.39
Upolu	30644	30086	1	19886	0.06	0.42

Upolu	30644	30087	1	20610	0.03	0.40
Upolu	30644	30088	1	20885	0.04	0.32
Upolu	30644	30089	1	20582	0.02	0.23
Upolu	30644	30090	1	21122	0.03	0.23
Upolu	30644	30093	1	20168	0.02	0.22
Upolu	30644	30094	1	21019	0.02	0.19
Upolu	30644	30116	2	20652	0.03	0.24
Upolu	30644	30117	1	22351	0.02	0.27
Upolu	30644	30118	1	18436	0.03	0.37
Upolu	30644	30119	1	21782	-0.06	0.43
Upolu	30644	30120	1	18295	-0.03	0.42
Upolu	30644	30160	1	20240	-0.07	0.16
Upolu	30644	30164	1	22603	-0.05	0.18
Upolu	30644	30169	1	21406	-0.04	0.15
Upolu	30644	30171	1	22879	-0.05	0.19
Upolu	30644	30172	1	22440	-0.08	0.22
Upolu	30644	30204	1	22766	-0.04	0.15
Upolu	30644	30205	1	20963	-0.01	0.17
Upolu	30644	30274	2	11537	-0.04	0.15
Upolu	30644	30344	1	23254	0.00	0.22
Upolu	30644	30345	1	24855	0.00	0.19
Upolu	30644	30380	1	15401	-0.02	0.20
Upolu	30644	30574	2	8909	0.00	0.26
Upolu	30644	30632	1	20051	0.00	0.22
Upolu	30644	30642	1	21048	-0.02	0.13
Upolu	30644	30643	1	10583	-0.02	0.16
Upolu	30644	30645	1	23042	-0.02	0.23
Upolu	30644	30648	2	21220	-0.02	0.16
Upolu	30644	30649	2	19037	-0.01	0.21
Upolu		**Total Mean**	**90**	**1726528**	**-0.01**	**0.18**
		stDev			**0.04**	**0.10**

Table 9: RIEGL LMS-Q780 cross line comparison results - Upolu

H.4.2 Cross line Comparison Results - ALB

For the ALB results, the mean of the average mean depth differences of -0.03m +/-0.10 and the mean of the average standard deviation of 0.17m +/-0.22 (1σ) was generated from the intersection of 187 runs and the comparison of 328869 individual depths.

The final number of accepted comparisons was affected by the rejection of unacceptable values from this statistical analysis as a result of three main poor quality indications:

- Insufficient comparisons - intersections with less than 500 comparisons were rejected.
- Poor C0 confidence value - comparisons with a Subsurface Confidence less than 6 were rejected.

- All comparisons containing topographic data were rejected as this data contains artefacts such as trees and manmade structures which influence the results.

The cross line comparisons are generally good and indicate that the LADS Mk 3 system operated correctly.

H.4.3 Cross line Comparison Results – ALT

For the ALT results, the cross lines were used during the flightline matching process using class 2 data derived from the initial ground filter. Four cross lines were flown over Savaii and two over Upolu

The cross line comparison results for Savaii yielded excellent agreement between the RIEGL main survey lines and cross lines with an average Mean Difference of 0.00m ±0.05 and an average Standard Deviation of 0.24m ±0.12. The results were generated from the intersection of 201 runs and a comparison of 2809481 individual points, derived from a 5m grid.

The cross line comparison results for Upolu yielded excellent agreement between the RIEGL main survey lines and cross lines with an average Mean Difference of -0.01m ±0.04 and an average Standard Deviation of 0.18m ±0.10. The results were generated from the intersection of 90 runs and a comparison of 1726528 individual points, derived from a 5m grid.

H.5 Topographic Integration Point (TIP) Comparisons

TIP comparisons were conducted to verify the accuracy and precision of all LiDAR Systems in the topographic environment. The TIP's were an oval at Wesley College near Apia and also four TIP's that were surveyed during the 2012 survey. The Wesley oval TIP was surveyed by Fugro LADS and MNRE surveyors whilst the 2012 TIP's were surveyed by AAM with the reference data supplied relative to the ellipsoid. The Wesley oval was overflown four times whilst the AAM TIP's were overflown once during main line surveying operations. The final processed and respective ALB and ALT LiDAR datasets were then compared.

The centre coordinates for the TIP's are (ITRF08, UTM 2S):

TIP ID	Location	Easting	Northing	Average Ellipsoid Height	Remarks
N/A	Wesley Oval	411 126	8 474 153	43.7m	Overflown with ALB / ALT
1	Central Apia	418 181	8 471 249	39.7m	Overflown with ALB / ALT
2	West Apia	414 971	8 470 326	45.1m	Overflown with ALT Only
3	East Apia	419 262	8 468 931	66.5m	Overflown with ALT Only
4	Faleolo Airport	392 078	8 470 641	42.6m	Overflown with ALB / ALT

Table 10 – TIP Locations

H.5.1 Wesley Oval TIP Results

The ellipsoidal topographic benchmark comparison results calculated by ALB and ALT can be seen in Table 7.

System	No. of Comparisons	Mean Difference	Standard Deviation	Remarks
ALB	740	0.13	0.04	Final ELL Reduced Dataset
ALT	828	0.09	0.04	Final ELL Reduced Dataset
	Mean	**0.11**	**0.04**	
	StDev	**0.03**	**0.00**	

Table 11: ALB and ALT Wesley Oval topographic benchmark results

The topographic benchmark comparison results yielded excellent agreement between the LiDAR data and surveyed benchmark data with an average Mean Difference of 0.11m ±0.03 and an average Standard Deviation of 0.04m ±0.00. This shows that both the Riegl VQ-820_G and RIEGL LMS-Q780 systems meet the respective topographic vertical accuracy requirements..

H.5.2 2012 TIP Results

The topographic vertical accuracy was also checked by comparing the data to the 2012 TIP data surveyed at 4 locations. Only TIP1 and TIP4 were flown over for the ALB survey. TIPs 2 and 3 were flown over as part of the ALT survey. The respective merged LADS and RIEGL VQ-820-G data and RIEGL LMS-Q780 results are in the table below after the ellipsoidal corrections were applied.

System	TIP	No. of Comparisons	Mean Depth Difference	Standard Deviation	Remarks
LADS Mk 3 / RIEGL VQ-820-G	1	201	0.07	0.03	Tarmac / Grass
LADS Mk 3 / RIEGL VQ-820-G	4	80	0.14	0.11	Tarmac / Grass
RIEGL LMS-Q780	1	199	-0.05	0.03	Tarmac / Grass
RIEGL LMS-Q780	2	164	0.03	0.04	Tarmac / Grass
RIEGL LMS-Q780	3	115	0.06	0.03	Tarmac / Grass
RIEGL LMS-Q780	4	73	0.09	0.11	Tarmac / Grass
		Mean	**0.06**	**0.06**	
		StDev	**0.06**	**0.04**	

Table 12: LADS and RIEGL against 2012 TIP results

The TIP comparison results yielded good agreement between the LiDAR data and the surveyed TIP data with an average Mean Difference of 0.06m ±0.06 and an average Standard Deviation of 0.06m ±0.04.

H.6 2015 & 2012 Bathymetric Data Comparisons

The ALB survey conducted in 2015 was compared against the ALB survey areas conducted over the international airport and Apia, collected in 2012. The results of the difference between the final MSL reduced datasets are reported in the table below:

Survey Area	No. of Comparisons	Mean Difference	Standard Deviation
Airport	1005708	-0.10	0.84
Apia	1446819	-0.04	0.86
Total /Mean	**1226264**	**-0.07**	**0.85**
StDev		**0.04**	**0.01**

Table 13: Airborne LiDAR Bathymetry 2015 & 2012 Data Result Comparisons

The LADS Mk3 and RIEGL VQ-820-G comparison data results yielded good agreement between the two LiDAR datasets with an average Mean Difference of -0.07m ±0.04 and an average Standard Deviation of 0.85m ±0.01. The higher standard deviation most likely reflects the wider spot spacing of the LADS Mk3 system and areas of sloping seabed.

H.7 2015 & 2012 Topographic Data Comparisons

The ALT survey conducted in 2015 was compared against the ALB survey areas conducted over the international airport and Apia, collected in 2012. The results of the difference between the final MSL reduced datasets are reported in the table below:

Survey Area	No. of Comparisons	Mean Difference	Standard Deviation
Airport	8779376	-0.03	0.26
Apia	37378860	-0.01	0.38
Total /Mean	**46158236**	**-0.02**	**0.32**
StDev		**0.01**	**0.08**

Table 14: Airborne LiDAR Topographic 2015 & 2012 Data Results Comparisons

The RIEGL LMS-Q780 comparison data results yielded good agreement between the two LiDAR datasets with an average Mean Difference of -0.02m ±0.01 and an average Standard Deviation of 0.32m ±0.08.

H.8 2015 Topographic LiDAR & Satellite Data Comparisons

The results of the difference between the RIEGL LMS-Q780 data, collected in 2015, and the Nextmap10 Satellite Data DTM in the overlapping area are reported in the table below:

Survey Area	No. of Comparisons	Mean Difference	Standard Deviation
Upolu	14720	0.01	9.24
Savaii	31203	-0.01	4.64
Total /Mean	**45923**	**0.00**	**6.94**
StDev		**0.01**	**3.25**

Table 15: RIEGL LMS-Q780 2015 & Nextmap10 Data Results

The RIEGL LMS-Q780 comparison data results show a small Mean Difference of 0.00m ±0.01 but a high standard deviation of 6.94m ±3.25. This is due to the resolution of the satellite data being 15 metres as compared to the very high resolution LiDAR data and the hilly terrain over which the data was collected.

H.9 Ground Control Point (GCP) Comparisons

GCP comparisons were conducted to verify the height accuracy of both the ALB / ALT systems and to assist in the reduction to the local MSL datum. The GCP's were pre-selected points mainly around the coasts of both main islands and were surveyed by MNRE surveyors during and after survey operations. The reference data was supplied relative to the ellipsoid and MSL. Each control point was flown over at least once during main line surveying operations. The LiDAR data was then processed and validated prior to comparisons being conducted. The final results for both systems are included in the Post-Survey Spatial Accuracy Report.

Enclosures:

1. Benchmark Comparisons - 2015

Enclosure 1 – Benchmark Comparisons - 2015

Benchmark 17m

Run ID	Pattern	Sortie	No. of Comparisons	Mean Depth Difference	Standard Deviation	Remarks
73.0.1	P5_1800	2	2777	0.01	0.15	Some BODs in Benchmark
73.0.4	P5_1800	6	2804	0.01	0.15	Some BODs in Benchmark
73.0.5	P5_1800	8	2722	0.07	0.15	Some BODs in Benchmark
73.0.6	P5_1800	16	2971	0.06	0.17	Some BODs in Benchmark
			Mean	**0.04**	**0.16**	
			StDev	**0.03**	**0.01**	

Benchmark 37m

Run ID	Pattern	Sortie	No. of Comparisons	Mean Depth Difference	Standard Deviation	Remarks
73.0.1	P5_1800	2	2784	-0.17	0.12	
73.0.4	P5_1800	6	2872	-0.2	0.14	
73.0.5	P5_1800	8	2664	0.06	0.12	
73.0.6	P5_1800	16	2860	-0.06	0.14	
			Mean	**-0.11**	**0.14**	
			StDev	**0.09**	**0.01**	

Benchmark 7m

Run ID	Pattern	Sortie	No. of Comparisons	Mean Depth Difference	Standard Deviation	Remarks
73.0.1	P5_1800	2	2821	0.04	0.44	Feature rich seabed
73.0.4	P5_1800	6	2946	0.11	0.46	Feature rich seabed
73.0.5	P5_1800	8	2688	0.17	0.46	Feature rich seabed
73.0.6	P5_1800	16	2931	0.08	0.46	Feature rich seabed
			Mean	**0.10**	**0.46**	
			StDev	**0.05**	**0.01**	

Annex I. Horizontal and vertical Accuracy

I.1 Horizontal Accuracy of Soundings - ALB

I.1.1 Theoretical Accuracy Trimble BD982

The theoretical accuracy of the positioning system, when using a base station, is related to the distance between the roving GNSS receiver and a base station or network of base stations. The relationship between baseline distance and theoretical accuracy has not been determined specifically for the Trimble BD982 receiver however empirical data tests have been performed in the past on similar receivers.

The theoretical accuracy of the positioning system, when using precise point positioning (PPP), is related to which precise orbit and clock data is used in the processing solution. Three precise products are normally generated by Analysis Centres for use with post-processing, namely Ultra-Rapid, Rapid and Final products. The Final products are the most accurate but have a lag time of at least 12 days. The Rapid products, which were partly used for this survey, have a lag time of at least 8 hours.

I.1.2 Fugro Marinestar GNSS Real-Time PPP solution

Trimble have detailed the horizontal standard deviation of positions obtained by the BD982 GNSS receiver with Fugro Marinestar GNSS PPP corrections and have determined the expected error to be 0.25m + 0.5ppm (1σ). This standard deviation defines the theoretical repeatability of position fixes.

Accuracy figures for the modelled Fugro Marinestar GNSS PPP corrections are quoted at 0.10m (95%) horizontal and 0.15m (95%) vertical. Given that the modelled solution is calculated for the real-time position based on observations from all the satellites in the constellation, the achieved accuracies for the real-time system during operations should be similar to the observed absolute accuracy obtained during the static position check conducted under similar conditions.

The accuracy of the real-time PPP position was found to be 0.286m (2D 95% confidence) as determined by all the sorties flown in Samoa. This is consistent with previous results and is sufficient for the real-time positioning of the aircraft. In any event, more accurate post-processed KGNSS base station positions were applied to soundings during post-processing.

I.1.3 Post-Processed Applanix POSPAC MMS Dual Frequency KGNSS Solution

The theoretical accuracy of the post-processed POSPac MMS positional data has been determined from the POSPac MMS Software's User Manual and through consultation with Trimble and NovAtel. For a PDOP of less than 3, minimum 6 satellites and a baseline of 30km the following POSPac MMS data processing accuracy has been quoted:

L1/L2 Carrier Phase, fixed ambiguities, forward / backward processing = 0.10 metres + 1ppm

Therefore the expected accuracy of the post-processed solution = 0.13 metres

I.1.4 Practical Accuracy

The actual performance of the positioning solutions was checked by:

a. Static position check

b. Dynamic position monitoring.

I.1.4.1 Static Position Check

Static position checks were conducted for the following GNSS positions:

a. Real-Time GNSS Only: GPS and GLONASS Solution

b. KGNSS PPP: Forward and backward processed L1/L2 carrier phase, float ambiguities (off-line)

c. KGNSS BS: Forward and backward processed L1/L2 carrier phase, fixed ambiguities (off-line)

I.1.4.2 Dynamic Position Monitoring

During the survey, GNSS data was logged on the aircraft which enabled post-processing using a base station and PPP Rapid clock and orbit files to produce KGNSS result files (off-line). These result files were then compared to the position as determined by the real-time PPP on the AS. For each survey line, the mean difference and standard deviation have been calculated.

I.1.5 Accuracy of Position (LADS Mk3)

The total expected error of the LADS Mk 3 system is a combination of the following errors:

a. GNSS errors (EGNSS), as previously stated, have a theoretical maximum of ± 0.13 metres (95% confidence - KGNSS).

b. Errors in assigning frame centre reference positions from GNSS fixes (Eframe ref) have been assessed as ± 0.66 metres (95% confidence).

c. Platform and laser positioning errors (Eplat, this includes such errors as optical alignment, IMU angles, IMU mount, Optical Coupler mount, Scanner mount, Laser output, Laser mount, Major, Minor and Delta scan mirrors, timing and aircraft height). The resultant error in position has been assessed as ± 1.3 metres (95% confidence).

d. Sea surface errors (Esurface) due to swell. These are variable and dependant on the angle of incidence of the laser beam at the air/sea boundary, the depth of water and sea state.

They have been assessed and are tabled below.

Depth (m)	Sea State 1	Sea State 2	Sea State 3	Sea State 4
5	0	0.03	0.31	0.55
10	0.01	0.06	0.62	1.10
15	0.01	0.09	0.93	1.65
20	0.02	0.12	1.24	2.20
30	0.04	0.18	**1.86**	3.30
40	0.05	0.24	2.48	4.40

Table 1 – Sea surface errors due to sea state

Total Expected Error = $((EGNSS)^2 + (Eframe\ Ref)^2 + (Eplat)^2 + (Esurface)^2)^{½}$

In the following scenario, in a depth of 30 metres, with sea state 3, the total error is expected to be:

Total Expected Error = $((0.13)^2 + (0.66)^2 + (1.3)^2 + (1.86)^2)^{½}$

= **2.37** metres at the 95% confidence level

Analysing the positional data obtained from both the static and dynamic position checks it has been concluded that during the survey IHO Order-1b precision for position was achieved.

I.1.6 Accuracy of Position (Riegl 820G)

The total expected error of the Riegl 820G system is a combination of the following errors:

a. GNSS errors (EGNSS), as previously stated, have a theoretical maximum of ± 0.13 metres (95% confidence - KGNSS).

b. Errors in assigning frame centre reference positions from GNSS fixes (Eframe ref) have been assessed as ± 0.66 metres (95% confidence).

c. Platform and laser positioning errors (Eplat, this includes such errors as optical alignment, IMU angles, IMU mount, Optical Coupler mount, Scanner mount, Laser output, Laser mount, Major, Minor and Delta scan mirrors, timing and aircraft height). The resultant error in position has been assessed as ± 0.48 metres (95% confidence).

d. Sea surface errors (Esurface) due to swell. These are variable and dependant on the angle of incidence of the laser beam at the air/sea boundary, the depth of water and sea state.

They have been assessed and are tabled below.

Depth (m)	Sea State 1	Sea State 2	Sea State 3	Sea State 4
5	0	0.03	0.31	0.55
10	0.01	0.06	**0.62**	1.10
15	0.01	0.09	0.93	1.65
20	0.02	0.12	1.24	2.20
30	0.04	0.18	1.86	3.30
40	0.05	0.24	2.48	4.40

Table 2 – Sea surface errors due to sea state

Total Expected Error = $((EGNSS)^2 + (Eframe\ Ref)^2 + (Eplat)^2 + (Esurface)^2)^{½}$

In the following scenario, in a realistic depth of 10 metres, with sea state 3, the total error is expected to be:

Total Expected Error = $((0.13)^2 + (0.66)^2 + (0.48)^2 + (0.62)^2)^{½}$

= **1.03** metres at the 95% confidence level

Analysing the positional data obtained from both the static and dynamic position checks it has been concluded that during the survey IHO Order-1b precision for position was achieved.

I.1.7 GNSS Positional Accuracy - Summary

I.1.7.1 Static Position Check (LADS Mk3)

Fa'a'a International Airport

Absolute accuracy of real-time GNSS Only = 6.739 metres

Absolute accuracy of post-processed KGNSS PPP = 0.037 metres

Absolute accuracy of post-processed KGNSS BS (4.6km baseline) = **0.051** metres

I.1.7.2 Static Position Check (Riegl 820G)

Fa'a'a International Airport (French Polynesia)

Absolute accuracy of real-time GNSS Only = 8.074 metres

Absolute accuracy of post-processed KGNSS PPP = 0.077 metres

Absolute accuracy of post-processed KGNSS BS (4.6km baseline) = **0.067** metres

I.1.7.3 Dynamic Position Check

Survey Areas

Mean value of range distances over all lines of survey between real-time PPP and POSPac MMS KGNSS BS/PPP = 0.198 metres

Maximum value of range distances over all lines of survey between real-time PPP and POSPac MMS KGNSS BS/PPP = 1.579 metres

I.1.8 ALB System Positional Accuracy Summary

I.1.8.1 Theoretical Accuracy (LADS Mk3)

Maximum (depth = 30m, sea state 3) = **2.37** metres

Target:

- IHO Order-1b Horizontal Accuracy at 30m (95% confidence) = 5 metres + 5% of the depth = 6.50 metres

Survey Horizontal Accuracy (95% confidence) = better than 2.4 metres

I.1.8.2 Theoretical Accuracy (Riegl 820G)

Maximum (depth = 10m, sea state 3) = **0.8** metres

Target:

- IHO Order-1b Horizontal Accuracy at 10m (95% confidence) = 5 metres + 5% of the depth = 5.50 metres

Survey Horizontal Accuracy (95% confidence) = better than 1.0 metres

I.2 Vertical Accuracy of Soundings - ALB

I.2.1 Fugro LADS Mk 3 System Accuracy

A standard deviation of 0.15 metres (68% confidence) is the historical average for the LMk3 system obtained from benchmark data collected during previous surveys and during trials. This value has been adopted as the LADS Mk 3 system accuracy for this survey.

I.2.2 Riegl VQ-820-G System Accuracy

A standard deviation of 0.025 metres (68% confidence) is the quoted range accuracy from RIEGL SYSTEMS. This value has been adopted as the Riegl 820G system accuracy for this survey.

I.2.3 Vertical Datum

I.2.3.1 Tides and Tide Models

No tides were applied for this survey. Ellipsoidal height data from the post-processed KGNSS base station or PPP data were used as the primary vertical datum.

I.2.3.2 GNSS Ellipsoidal Heights

Ellipsoidal height (GRS80) data from the post-processed KGNSS base station or PPP solution were used as the primary datum for data processing and consistency for the survey. Good KGNSS base station or PPP solutions were obtained on all lines flown throughout the survey. An allowance of 0.10 metres (68% confidence) has been allowed for ellipsoidal height errors in the post-processed solution.

I.2.4 Swell

Swell had little affect on survey operations in the survey areas. Survey operations were conducted in conditions where swell was less than 2 metres and in a sea state of 1-3, though generally conditions were about a sea state 1. An allowance of 0.10 metres (68% confidence) has been allowed for any residual affects of swell and sea state.

I.2.5 Water Clarity

Water clarity was very good for most of the survey areas. Where possible, data affected by poor water clarity has been removed. An allowance of 0.10 metres (68% confidence) for the affects of degraded water clarity has been included in the accuracy model due to the general clear nature of the survey areas in Samoa.

I.2.6 Theoretical Accuracy of Soundings

An assessment of the total survey accuracy can be determined by combining the errors due to each respective LiDAR system, the vertical datum (i.e. ellipsoidal heights), swell and water clarity. These are combined using a Gaussian model as follows:

σ^2 Survey = σ^2 LiDAR System + σ^2 Water Clarity + σ^2 Residual Swell + σ^2 Vertical Datum

and 95% confidence limit = 1.96σ (for a single dimensional distribution)

I.2.6.1 Accuracy of Soundings (LADS Mk3) – Ellipsoidal Height Datum (GRS80)

Average Depth	LADS Mk 3 total 1σ	Water Clarity 1σ	Residual Swell 1σ	Ellipsoidal Height Datum 1 σ	Survey Accuracy (68% conf.)	Survey Accuracy (95% conf.)	Contract Requirement	IHO Order-1b
30m	0.15m	0.07m	0.07m	0.10m	0.21m	0.41m	±0.55m	±0.63m

Table 3 – Theoretical Survey Accuracy – Ellipsoidal Height Datum (GRS80)

The minimum requirements for IHO Order-1b depth accuracy, is defined as:

$\pm(a^2 + (b \times d)^2)^{½}$, where:

a = 0.5m (the value of uncertainty that does not vary with depth)

b = 0.013 (the coefficient of the portion of uncertainty that varies with depth)

d = 30m (depth)

As shown in Table 2, the achieved accuracy of soundings for the LADS Mk3 is expected not to exceed 0.41 metres (95% confidence) down to depths of 30 metres. This is within IHO Order-1b minimum requirements for depth accuracy, and is consistent with the benchmark results achieved for this project (refer to Annex H for results).

I.2.6.2 Accuracy of Soundings (Riegl VQ-820-G) – Ellipsoidal Height Datum (GRS80)

Average Depth	Riegl 820G total 1σ	Water Clarity 1σ	Residual Swell 1σ	Ellipsoidal Height Datum 1 σ	Survey Accuracy (68% conf.)	Survey Accuracy (95% conf.)	Contract Requirement	IHO Order-1b
10m	0.025m	0.05m	0.03m	0.10m	0.12m	0.23m	±0.55m	±0.52m

Table 3 – Theoretical Survey Accuracy – Ellipsoidal Height Datum (GRS80)

The minimum requirements for IHO Order-1b depth accuracy, is defined as:

$\pm(a^2 + (b \times d)^2)^{½}$, where:

a = 0.5m (the value of uncertainty that does not vary with depth)

b = 0.013 (the coefficient of the portion of uncertainty that varies with depth)

d = 5m (depth)

As shown in Table 3, the achieved accuracy of soundings for the Riegl–VQ-820G is expected not to exceed 0.23 metres (95% confidence) down to depths of 10 metres. This is within IHO Order-1b minimum requirements for depth accuracy, and is consistent with the benchmark results achieved for this project (refer to Annex H for results).

I.3 Accuracy of Pulses - ALT

The nominal accuracy of the Riegl LMS-Q780 is 20mm range accuracy at 250m range with a divergence of 0.25mrad as per Riegl specification and test certificate - 999263. The GNSS accuracy is the same as for the Riegl VQ-820-G quoted in sections above.

Annex J. Summary of Survey Activities

J.1 ALB Activities

	SURVEY FLIGHTS EXECUTED			FLIGHT TIMES						TIME ON TASK / LINES FLOWN SAMOA					TRANSIT
DATE	DAILY FLIGHT NUMBER	GS FLIGHT NUMBER	ZONE(S) FLOWN	ENGINE START	WHEELS OFF	WHEELS ON	ENGINE STOP	TOTAL ENGINE TIME	TOTAL FLIGHT TIME	ON TASK	OFF TASK	TIME LOST	TOTAL TOT	LINES FLOWN	SURVEY TRANSIT TIME
07-Jul-15	1	1	11	6:35	6:54	10:06	10:11	3:36	3:12	6:57	10:00	0:27	2:36	17	0:09
08-Jul-15	2	2	11,13	6:41	7:03	10:31	10:36	3:55	3:28	7:12	10:27	0:55	2:20	23	0:13
	3	3	2, 3, 4, 15	13:45	13:59	17:38	17:41	3:56	3:39	14:08	17:25	0:17	3:00	20	0:22
09-Jul-15	4	4	8, 9, 18	6:48	7:07	10:57	11:00	4:12	3:50	7:16	10:45	0:00	3:29	22	0:21
	5	5	1, 2, 8	12:41	12:58	16:42	16:45	4:04	3:44	13:09	16:33	0:26	2:58	21	0:20
10-Jul-15	6	6	10,17,18	6:43	6:59	10:39	10:43	4:00	3:40	7:06	10:33	0:34	2:53	23	0:13
11-Jul-15	7	7	10, 14	6:47	7:03	10:25	10:29	3:42	3:22	7:11	10:19	0:44	2:24	23	0:14
	8	8	10, 3, 2	12:51	13:06	15:57	16:02	3:11	2:51	13:13	15:46	0:11	2:22	19	0:18
12-Jul-15	9	9	16	7:38	7:54	12:25	12:28	4:50	4:31	8:00	12:17	0:12	4:05	16	0:14
	10	10	16	13:52	14:10	17:09	17:12	3:20	2:59	14:19	17:03	0:15	2:29	18	0:15
13-Jul-15	11	11	5, 7, 19	6:41	6:56	10:54	10:57	4:16	3:58	7:10	10:48	0:07	3:31	30	0:20
	12	12	2,6	12:46	13:01	17:08	17:11	4:25	4:07	13:11	16:59	0:26	3:22	23	0:19
14-Jul-15	13	13	11, 12, Spags	6:34	6:50	10:39	10:42	4:08	3:49	7:05	10:32	0:28	2:59	21	0:22
16-Jul-15	14	15	6,12	12:51	13:04	17:02	17:05	4:14	3:58	7:00	10:31	0:20	3:11	30	0:27
18-Jul-15	15	16	12	6:53	7:12	11:08	11:11	4:18	3:56	7:20	10:55	0:19	3:16	33	0:21
Total								***60:07***	***55:04***			***5:41***	***44:55***	***339***	***4:28***

J.2 ALT Activities

LEM Aircraft hours

Day	Date	hours	number of sessions	session lost	Description
Friday	3-Jul	2.28	0	0	Calibration
Friday	3-Jul	2.22	0	0	mob Essendon _ new castle
Saturday	4-Jul	3.07	0	0	mob Newcastle -Norfolk island
Saturday	4-Jul	5.10	0	0	mob Norfolk-Apia
Sunday	5-Jul	0.00	0	0	preparation for flying
Monday	6-Jul	5.15	1	0	survey
Tuesday	7-Jul	5.58	2	0	survey
Wednesday	8-Jul	3.98	1	0	Survey
Thursday	9-Jul	2.93	0	7	attempts 7 sessions no surveyed lines
Friday	10-Jul	3.57	1	1	2 sessions 1 session lost
Saturday	11-Jul	3.52	1	0	survey multiple attempts
Sunday	12-Jul	5.17	1	0	survey
Monday	13-Jul	6.37	2	0	survey
Tuesday	14-Jul	0.00	0	0	Cloudy / Pilot rest day
Wednesday	15-Jul	2.30	1	0	survey
Thursday	16-Jul	6.65	2	0	survey
Friday	17-Jul	4.42	1	0	survey
Saturday	18-Jul	6.60	2	0	Survey
Sunday	19-Jul	4.75	1	0	Survey
Monday	20-Jul	6.72	2	0	Survey
Tuesday	21-Jul	0.00	0	0	Cloudy / Pilot rest day

Wednesday	22-Jul	8.32	2	0	Survey
Thursday	23-Jul	2.38	2	0	Survey
Friday	24-Jul	3.42	1	0	Survey
Saturday	25-Jul	6.02	2	0	Survey
Sunday	26-Jul	4.27	1	0	Survey
Monday	27-Jul	0.00	0	0	Cloudy
Tuesday	28-Jul	1.53	0	0	Survey
Wednesday	29-Jul	5.28	2	0	Survey
Thursday	30-Jul	3.13	1	0	Survey
Friday	31-Jul	0	0	0	Cloudy/ pilot rest day over 100 hours in a month limit
Saturday	1-Aug	1.27	1	0	Survey
Sunday	2-Aug	3.60	2	0	Survey
Monday	3-Aug	0.00	0	0	cloudy/rain
Tuesday	4-Aug	5.88	2	0	Survey
Wednesday	5-Aug	3.77	2	0	Survey
Thursday	6-Aug	1.42	0	0	Survey
Friday	7-Aug	5.13	2	0	Survey
Saturday	8-Aug	0.00	0	0	preparation for demob
Sunday	9-Aug	8.00	0	0	demob Apia - Norfolk
Monday	10-Aug	7.00	0	0	demob Norfolk-Newcastle-Essendon
total		150.78	38.00	8.00	

Survey lines summary

Date	Site	Start Survey	End Survey	Line ID	Time on Task
06/07/15	Upolu	08:07:10	08:08:12	30001	00:01:02
06/07/15	Upolu	08:12:52	08:13:29	30002	00:00:37
06/07/15	Upolu	08:18:39	08:19:17	30003	00:00:38
06/07/15	Upolu	08:24:48	08:25:47	30004	00:00:59
06/07/15	Upolu	09:21:13	09:31:26	30005	00:10:13
06/07/15	Upolu	09:34:49	09:44:37	30006	00:09:48
06/07/15	Upolu	09:51:44	10:03:30	30007	00:11:46
06/07/15	Upolu	10:07:31	10:18:02	30008	00:10:31
06/07/15	Upolu	10:31:34	10:43:32	30009	00:11:58
06/07/15	Upolu	10:48:15	10:59:33	30010	00:11:18
06/07/15	Upolu	11:02:55	11:14:30	30011	00:11:35
06/07/15	Upolu	11:18:07	11:24:31	30012	00:06:24
06/07/15	Upolu	11:28:28	11:30:57	30013	00:02:29
06/07/15	Upolu	11:34:25	11:36:28	30014	00:02:03
06/07/15	Upolu	11:40:13	11:42:01	30015	00:01:48
06/07/15	Upolu	11:45:28	11:46:21	30016	00:00:53
06/07/15	Upolu	11:58:16	11:59:51	30017	00:01:35
06/07/15	Upolu	12:03:04	12:04:46	30018	00:01:42
07/07/15	Savaii	07:49:07	07:50:14	30019	00:01:07
07/07/15	Savaii	07:58:32	07:59:06	30020	00:00:34
07/07/15	Savaii	08:03:19	08:05:30	30021	00:02:11
07/07/15	Savaii	08:12:19	08:14:19	30022	00:02:00

07/07/15	Savaii	08:19:21	08:22:07	30023	00:02:46
07/07/15	Savaii	08:31:53	08:34:15	30024	00:02:22
07/07/15	Savaii	08:39:07	08:42:42	30025	00:03:35
07/07/15	Savaii	08:45:54	08:49:04	30026	00:03:10
07/07/15	Savaii	08:51:48	08:55:46	30027	00:03:58
07/07/15	Savaii	08:58:13	09:02:14	30028	00:04:01
07/07/15	Savaii	09:06:17	09:11:55	30029	00:05:38
07/07/15	Savaii	09:23:07	09:27:49	30030	00:04:42
07/07/15	Savaii	09:32:17	09:38:49	30031	00:06:32
07/07/15	Savaii	09:42:13	09:47:11	30032	00:04:58
07/07/15	Savaii	09:51:44	09:58:12	30033	00:06:28
07/07/15	Savaii	10:03:14	10:08:32	30034	00:05:18
07/07/15	Savaii	10:14:03	10:21:07	30035	00:07:04
07/07/15	Savaii	12:56:04	13:02:08	30036	00:06:04
07/07/15	Savaii	13:06:46	13:14:05	30037	00:07:19
07/07/15	Savaii	13:19:03	13:26:42	30038	00:07:39
07/07/15	Savaii	13:30:28	13:39:34	30039	00:09:06
08/07/15	Savaii	07:56:06	07:57:08	30041	00:01:02
08/07/15	Savaii	08:01:33	08:03:08	30042	00:01:35
08/07/15	Savaii	08:12:33	08:14:08	30043	00:01:35
08/07/15	Savaii	08:19:16	08:21:20	30044	00:02:04
08/07/15	Savaii	08:26:35	08:29:23	30045	00:02:48
08/07/15	Savaii	08:34:33	08:37:37	30046	00:03:04
08/07/15	Savaii	08:44:10	08:47:26	30047	00:03:16

08/07/15	Savaii	08:51:54	08:55:49	30048	00:03:55
08/07/15	Savaii	09:00:51	09:04:14	30049	00:03:23
08/07/15	Savaii	09:09:10	09:13:31	30050	00:04:21
08/07/15	Savaii	09:25:53	09:30:24	30051	00:04:31
08/07/15	Savaii	09:36:00	09:41:29	30052	00:05:29
08/07/15	Savaii	09:47:14	09:52:02	30053	00:04:48
08/07/15	Savaii	09:57:41	10:03:05	30054	00:05:24
08/07/15	Savaii	10:07:37	10:12:52	30055	00:05:15
08/07/15	Savaii	10:27:43	10:37:28	30056	00:09:45
08/07/15	Upolu	07:32:43	07:40:21	30040	00:07:38
10/07/15	Savaii	09:10:26	09:16:15	30064	00:05:49
10/07/15	Savaii	09:20:52	09:27:03	30065	00:06:11
10/07/15	Savaii	09:32:39	09:39:29	30066	00:06:50
10/07/15	Savaii	09:49:38	09:57:02	30067	00:07:24
10/07/15	Savaii	10:01:55	10:09:25	30068	00:07:30
10/07/15	Upolu	07:29:09	07:37:25	30057	00:08:16
10/07/15	Upolu	07:42:17	07:44:30	30058	00:02:13
10/07/15	Upolu	07:51:22	08:00:11	30059	00:08:49
10/07/15	Upolu	08:05:20	08:15:13	30060	00:09:53
10/07/15	Upolu	08:19:29	08:29:09	30061	00:09:40
10/07/15	Upolu	08:33:52	08:43:49	30062	00:09:57
10/07/15	Upolu	08:49:30	09:01:36	30063	00:12:06
11/07/15	Savaii	08:58:34	09:03:09	30072	00:04:35
11/07/15	Savaii	09:12:31	09:18:59	30073	00:06:28

11/07/15	Upolu	08:13:35	08:28:43	30069	00:15:08
11/07/15	Upolu	08:35:26	08:39:17	30070	00:03:51
11/07/15	Upolu	08:41:08	08:51:17	30071	00:10:09
11/07/15	Upolu	09:26:05	09:39:50	30074	00:13:45
11/07/15	Upolu	09:52:26	09:55:03	30075	00:02:37
11/07/15	Upolu	09:57:31	10:00:57	30076	00:03:26
11/07/15	Upolu	10:08:54	10:10:34	30077	00:01:40
11/07/15	Upolu	10:15:46	10:18:28	30078	00:02:42
11/07/15	Upolu	10:20:16	10:23:23	30079	00:03:07
11/07/15	Upolu	10:26:48	10:29:30	30080	00:02:42
11/07/15	Upolu	10:31:26	10:34:56	30081	00:03:30
11/07/15	Upolu	10:47:03	10:48:56	30082	00:01:53
12/07/15	Upolu	07:41:04	07:56:37	30084	00:15:33
12/07/15	Upolu	08:04:32	08:18:42	30085	00:14:10
12/07/15	Upolu	08:21:29	08:34:50	30086	00:13:21
12/07/15	Upolu	08:38:16	08:50:52	30087	00:12:36
12/07/15	Upolu	08:52:31	09:05:51	30088	00:13:20
12/07/15	Upolu	09:10:20	09:23:48	30089	00:13:28
12/07/15	Upolu	09:28:48	09:36:22	30090	00:07:34
12/07/15	Upolu	09:38:22	09:39:37	30091	00:01:15
12/07/15	Upolu	09:43:50	09:45:22	30092	00:01:32
12/07/15	Upolu	09:48:41	09:55:06	30093	00:06:25
12/07/15	Upolu	09:59:42	10:06:04	30094	00:06:22
12/07/15	Upolu	10:17:50	10:19:50	30095	00:02:00

12/07/15	Upolu	10:23:04	10:27:31	30096	00:04:27
12/07/15	Upolu	10:29:18	10:33:58	30097	00:04:40
12/07/15	Upolu	10:36:37	10:36:40	30098	00:00:03
12/07/15	Upolu	10:36:48	10:41:12	30099	00:04:24
12/07/15	Upolu	10:44:25	10:48:35	30100	00:04:10
12/07/15	Upolu	10:52:56	10:57:21	30101	00:04:25
12/07/15	Upolu	10:59:48	11:04:45	30102	00:04:57
12/07/15	Upolu	11:09:45	11:13:09	30103	00:03:24
12/07/15	Upolu	11:16:37	11:19:41	30104	00:03:04
12/07/15	Upolu	11:22:21	11:25:04	30105	00:02:43
12/07/15	Upolu	11:26:55	11:29:41	30106	00:02:46
12/07/15	Upolu	11:32:13	11:34:14	30107	00:02:01
13/07/15	Upolu	07:27:55	07:35:14	30109	00:07:19
13/07/15	Upolu	07:39:56	07:47:13	30110	00:07:17
13/07/15	Upolu	07:50:33	07:57:39	30111	00:07:06
13/07/15	Upolu	08:00:51	08:07:53	30112	00:07:02
13/07/15	Upolu	08:10:57	08:18:30	30113	00:07:33
13/07/15	Upolu	08:21:12	08:28:14	30114	00:07:02
13/07/15	Upolu	08:31:37	08:39:18	30115	00:07:41
13/07/15	Upolu	08:41:51	08:47:10	30116	00:05:19
13/07/15	Upolu	08:48:56	08:55:33	30117	00:06:37
13/07/15	Upolu	08:57:26	09:03:36	30118	00:06:10
13/07/15	Upolu	09:05:56	09:13:24	30119	00:07:28
13/07/15	Upolu	09:17:17	09:24:11	30120	00:06:54

13/07/15	Upolu	09:27:17	09:28:18	30121	00:01:01
13/07/15	Upolu	09:45:15	09:47:59	30122	00:02:44
13/07/15	Upolu	09:51:57	09:59:09	30123	00:07:12
13/07/15	Upolu	10:02:28	10:09:37	30124	00:07:09
13/07/15	Upolu	10:12:17	10:18:24	30125	00:06:07
13/07/15	Upolu	10:21:02	10:27:09	30126	00:06:07
13/07/15	Upolu	10:31:12	10:35:42	30127	00:04:30
13/07/15	Upolu	10:38:07	10:42:05	30128	00:03:58
13/07/15	Upolu	10:45:49	10:53:16	30129	00:07:27
13/07/15	Upolu	10:55:17	11:02:02	30130	00:06:45
13/07/15	Upolu	11:06:11	11:11:18	30131	00:05:07
13/07/15	Upolu	11:14:08	11:18:58	30132	00:04:50
13/07/15	Upolu	11:22:33	11:28:51	30133	00:06:18
13/07/15	Upolu	11:31:16	11:32:08	30134	00:00:52
13/07/15	Upolu	11:32:53	11:33:14	30135	00:00:21
13/07/15	Upolu	11:34:17	11:34:49	30136	00:00:32
13/07/15	Upolu	11:37:53	11:38:27	30137	00:00:34
13/07/15	Upolu	16:10:51	16:10:55	30138	00:00:04
13/07/15	Upolu	16:12:15	16:12:42	30139	00:00:27
13/07/15	Upolu	16:14:32	16:14:57	30140	00:00:25
13/07/15	Upolu	16:15:40	16:15:59	30141	00:00:19
13/07/15	Upolu	16:16:18	16:17:00	30142	00:00:42
13/07/15	Upolu	16:20:15	16:20:39	30143	00:00:24
13/07/15	Upolu	16:20:59	16:21:37	30144	00:00:38

13/07/15	Upolu	16:25:56	16:26:32	30145	00:00:36
13/07/15	Upolu	16:30:56	16:32:32	30146	00:01:36
13/07/15	Upolu	16:35:02	16:36:08	30147	00:01:06
13/07/15	Upolu	16:38:31	16:39:52	30148	00:01:21
13/07/15	Upolu	16:44:31	16:46:06	30149	00:01:35
13/07/15	Upolu	16:48:56	16:49:25	30150	00:00:29
13/07/15	Upolu	16:50:01	16:50:28	30151	00:00:27
13/07/15	Upolu	16:52:25	16:52:42	30152	00:00:17
15/07/15	Upolu	15:30:20	15:32:34	30156	00:02:14
15/07/15	Upolu	15:37:49	15:39:16	30157	00:01:27
15/07/15	Upolu	15:50:05	15:53:02	30158	00:02:57
15/07/15	Upolu	15:53:26	15:54:05	30159	00:00:39
15/07/15	Upolu	15:54:26	15:58:26	30160	00:04:00
15/07/15	Upolu	15:59:15	16:00:05	30161	00:00:50
15/07/15	Upolu	16:04:50	16:05:20	30162	00:00:30
15/07/15	Upolu	16:05:55	16:06:30	30163	00:00:35
15/07/15	Upolu	16:07:13	16:09:52	30164	00:02:39
15/07/15	Upolu	16:10:25	16:10:50	30165	00:00:25
15/07/15	Upolu	16:11:18	16:13:06	30166	00:01:48
15/07/15	Upolu	16:18:00	16:18:17	30167	00:00:17
15/07/15	Upolu	16:18:34	16:19:27	30168	00:00:53
15/07/15	Upolu	16:21:27	16:23:14	30169	00:01:47
15/07/15	Upolu	16:24:56	16:25:21	30170	00:00:25
15/07/15	Upolu	16:30:51	16:32:40	30171	00:01:49

15/07/15	Upolu	16:35:56	16:37:00	30172	00:01:04
15/07/15	Upolu	16:41:00	16:41:40	30173	00:00:40
16/07/15	Savaii	08:03:52	08:16:40	30177	00:12:48
16/07/15	Savaii	08:24:22	08:33:29	30178	00:09:07
16/07/15	Savaii	08:36:21	08:46:05	30179	00:09:44
16/07/15	Savaii	08:48:51	08:53:09	30180	00:04:18
16/07/15	Savaii	08:56:37	09:00:40	30181	00:04:03
16/07/15	Savaii	09:02:05	09:06:17	30182	00:04:12
16/07/15	Savaii	09:07:59	09:12:13	30183	00:04:14
16/07/15	Savaii	09:14:13	09:16:40	30184	00:02:27
16/07/15	Savaii	09:20:52	09:24:05	30185	00:03:13
16/07/15	Savaii	09:25:07	09:27:46	30186	00:02:39
16/07/15	Savaii	09:30:47	09:33:47	30187	00:03:00
16/07/15	Savaii	09:35:46	09:38:41	30188	00:02:55
16/07/15	Savaii	09:42:07	09:45:56	30189	00:03:49
16/07/15	Savaii	09:49:09	09:53:41	30190	00:04:32
16/07/15	Savaii	09:58:34	10:02:02	30191	00:03:28
16/07/15	Savaii	10:06:46	10:09:33	30192	00:02:47
16/07/15	Savaii	10:16:57	10:17:27	30193	00:00:30
16/07/15	Savaii	10:19:02	10:23:36	30194	00:04:34
16/07/15	Savaii	10:25:37	10:28:14	30195	00:02:37
16/07/15	Savaii	10:38:10	10:46:17	30196	00:08:07
16/07/15	Savaii	15:47:02	15:55:34	30198	00:08:32
16/07/15	Savaii	15:58:34	16:07:31	30199	00:08:57

16/07/15	Savaii	16:10:34	16:19:26	30200	00:08:52
16/07/15	Savaii	16:22:22	16:31:54	30201	00:09:32
16/07/15	Savaii	16:34:27	16:43:50	30202	00:09:23
16/07/15	Savaii	16:47:20	16:57:57	30203	00:10:37
16/07/15	Upolu	07:31:49	07:31:56	30174	00:00:07
16/07/15	Upolu	07:33:47	07:37:34	30175	00:03:47
16/07/15	Upolu	07:49:00	07:53:13	30176	00:04:13
17/07/15	Savaii	08:09:21	08:19:13	30206	00:09:52
17/07/15	Savaii	08:23:04	08:34:43	30207	00:11:39
17/07/15	Savaii	08:38:33	08:49:00	30208	00:10:27
17/07/15	Savaii	08:52:17	09:04:04	30209	00:11:47
17/07/15	Savaii	09:07:50	09:18:48	30210	00:10:58
17/07/15	Savaii	09:23:35	09:34:52	30211	00:11:17
17/07/15	Savaii	09:39:10	09:50:39	30212	00:11:29
17/07/15	Savaii	10:00:03	10:04:04	30213	00:04:01
17/07/15	Savaii	10:13:32	10:19:45	30214	00:06:13
17/07/15	Savaii	10:23:14	10:29:37	30215	00:06:23
17/07/15	Savaii	10:32:30	10:38:45	30216	00:06:15
17/07/15	Savaii	10:41:20	10:48:15	30217	00:06:55
17/07/15	Savaii	10:51:14	10:56:18	30218	00:05:04
17/07/15	Upolu	07:34:54	07:47:28	30204	00:12:34
17/07/15	Upolu	07:53:31	08:00:53	30205	00:07:22
18/07/15	Savaii	07:53:42	07:55:55	30220	00:02:13
18/07/15	Savaii	08:03:16	08:05:43	30221	00:02:27

18/07/15	Savaii	08:09:42	08:10:28	30222	00:00:46
18/07/15	Savaii	08:10:54	08:11:47	30223	00:00:53
18/07/15	Savaii	08:12:24	08:13:18	30224	00:00:54
18/07/15	Savaii	08:13:35	08:14:16	30225	00:00:41
18/07/15	Savaii	08:14:41	08:14:57	30226	00:00:16
18/07/15	Savaii	08:18:21	08:18:44	30227	00:00:23
18/07/15	Savaii	08:19:25	08:20:21	30228	00:00:56
18/07/15	Savaii	08:20:42	08:20:59	30229	00:00:17
18/07/15	Savaii	08:21:11	08:23:08	30230	00:01:57
18/07/15	Savaii	08:25:34	08:28:17	30231	00:02:43
18/07/15	Savaii	08:28:56	08:29:02	30232	00:00:06
18/07/15	Savaii	08:30:14	08:30:27	30233	00:00:13
18/07/15	Savaii	08:38:20	08:43:02	30234	00:04:42
18/07/15	Savaii	08:46:11	08:51:15	30235	00:05:04
18/07/15	Savaii	08:54:55	09:01:58	30236	00:07:03
18/07/15	Savaii	09:05:16	09:12:15	30237	00:06:59
18/07/15	Savaii	09:17:57	09:25:09	30238	00:07:12
18/07/15	Savaii	09:27:53	09:34:27	30239	00:06:34
18/07/15	Savaii	09:40:53	09:47:27	30240	00:06:34
18/07/15	Savaii	09:50:27	09:57:41	30241	00:07:14
18/07/15	Savaii	10:00:25	10:08:00	30242	00:07:35
18/07/15	Savaii	10:13:13	10:21:14	30243	00:08:01
18/07/15	Savaii	10:25:21	10:31:52	30244	00:06:31
18/07/15	Savaii	10:35:23	10:42:32	30245	00:07:09

18/07/15	Savaii	10:46:38	10:54:02	30246	00:07:24
18/07/15	Savaii	10:57:52	11:06:33	30247	00:08:41
18/07/15	Savaii	11:10:28	11:15:13	30248	00:04:45
18/07/15	Savaii	15:21:02	15:21:05	30249	00:00:03
18/07/15	Savaii	15:21:12	15:25:06	30250	00:03:54
18/07/15	Savaii	15:28:37	15:33:26	30251	00:04:49
18/07/15	Savaii	16:11:22	16:11:51	30263	00:00:29
18/07/15	Savaii	16:14:23	16:14:51	30264	00:00:28
18/07/15	Savaii	16:19:35	16:20:20	30266	00:00:45
18/07/15	Savaii	16:24:38	16:24:49	30267	00:00:11
18/07/15	Savaii	16:25:16	16:26:01	30268	00:00:45
18/07/15	Savaii	16:27:35	16:28:02	30269	00:00:27
18/07/15	Savaii	16:28:41	16:29:05	30270	00:00:24
18/07/15	Savaii	16:29:22	16:29:43	30271	00:00:21
18/07/15	Savaii	16:35:42	16:36:12	30272	00:00:30
19/07/15	Savaii	09:05:57	09:18:10	30281	00:12:13
19/07/15	Savaii	09:20:30	09:33:10	30282	00:12:40
19/07/15	Savaii	09:35:45	09:38:34	30283	00:02:49
19/07/15	Savaii	09:40:40	09:48:40	30284	00:08:00
19/07/15	Savaii	09:51:14	09:58:24	30285	00:07:10
19/07/15	Savaii	10:00:52	10:08:39	30286	00:07:47
19/07/15	Savaii	10:12:31	10:18:53	30287	00:06:22
19/07/15	Savaii	10:22:14	10:28:10	30288	00:05:56
19/07/15	Savaii	10:31:34	10:37:05	30289	00:05:31

19/07/15	Savaii	10:39:45	10:45:29	30290	00:05:44
19/07/15	Savaii	10:48:35	10:54:10	30291	00:05:35
19/07/15	Savaii	10:56:58	11:03:16	30292	00:06:18
19/07/15	Savaii	11:06:21	11:11:38	30293	00:05:17
19/07/15	Savaii	11:15:52	11:20:03	30294	00:04:11
19/07/15	Savaii	11:28:23	11:28:44	30295	00:00:21
19/07/15	Savaii	11:29:01	11:30:40	30296	00:01:39
19/07/15	Savaii	11:34:49	11:37:16	30297	00:02:27
19/07/15	Savaii	11:40:59	11:42:51	30298	00:01:52
19/07/15	Upolu	07:41:55	07:41:58	30273	00:00:03
19/07/15	Upolu	07:43:37	07:50:14	30274	00:06:37
19/07/15	Upolu	07:54:10	08:01:02	30275	00:06:52
19/07/15	Upolu	08:03:46	08:10:16	30276	00:06:30
19/07/15	Upolu	08:13:42	08:20:41	30277	00:06:59
19/07/15	Upolu	08:27:10	08:34:32	30278	00:07:22
19/07/15	Upolu	08:37:28	08:43:38	30279	00:06:10
19/07/15	Upolu	08:46:17	08:52:05	30280	00:05:48
20/07/15	Savaii	08:20:22	08:20:58	30304	00:00:36
20/07/15	Savaii	08:24:52	08:25:15	30305	00:00:23
20/07/15	Savaii	08:31:37	08:40:44	30306	00:09:07
20/07/15	Savaii	08:45:37	08:51:50	30307	00:06:13
20/07/15	Savaii	08:57:13	09:01:41	30308	00:04:28
20/07/15	Savaii	09:04:21	09:09:25	30309	00:05:04
20/07/15	Savaii	09:13:00	09:17:43	30310	00:04:43

20/07/15	Savaii	09:21:52	09:28:05	30311	00:06:13
20/07/15	Savaii	09:30:34	09:32:58	30312	00:02:24
20/07/15	Savaii	09:36:00	09:37:16	30313	00:01:16
20/07/15	Savaii	09:41:20	09:42:56	30314	00:01:36
20/07/15	Savaii	09:46:16	09:46:36	30315	00:00:20
20/07/15	Savaii	09:48:21	09:48:41	30316	00:00:20
20/07/15	Savaii	09:53:16	10:02:17	30317	00:09:01
20/07/15	Savaii	10:05:40	10:13:56	30318	00:08:16
20/07/15	Savaii	10:17:22	10:25:35	30319	00:08:13
20/07/15	Savaii	10:30:01	10:37:35	30320	00:07:34
20/07/15	Savaii	10:41:06	10:48:20	30321	00:07:14
20/07/15	Savaii	10:54:53	10:59:38	30322	00:04:45
20/07/15	Savaii	11:09:04	11:16:47	30323	00:07:43
20/07/15	Upolu	07:27:29	07:35:02	30299	00:07:33
20/07/15	Upolu	07:47:27	07:48:01	30300	00:00:34
20/07/15	Upolu	07:53:18	07:53:54	30301	00:00:36
20/07/15	Upolu	08:00:58	08:03:25	30302	00:02:27
20/07/15	Upolu	08:04:55	08:05:43	30303	00:00:48
20/07/15	Upolu	15:49:22	15:49:37	30325	00:00:15
20/07/15	Upolu	15:51:10	15:51:24	30326	00:00:14
20/07/15	Upolu	15:53:09	15:54:06	30327	00:00:57
20/07/15	Upolu	15:57:25	15:57:39	30328	00:00:14
20/07/15	Upolu	15:58:10	15:58:18	30329	00:00:08
20/07/15	Upolu	15:59:04	15:59:41	30330	00:00:37

20/07/15	Upolu	16:00:43	16:00:57	30331	00:00:14
20/07/15	Upolu	16:05:04	16:05:19	30332	00:00:15
20/07/15	Upolu	16:06:13	16:06:24	30333	00:00:11
20/07/15	Upolu	16:07:59	16:08:22	30334	00:00:23
20/07/15	Upolu	16:08:56	16:09:11	30335	00:00:15
20/07/15	Upolu	16:17:25	16:22:01	30336	00:04:36
20/07/15	Upolu	16:22:28	16:24:53	30337	00:02:25
20/07/15	Upolu	16:27:39	16:34:52	30338	00:07:13
20/07/15	Upolu	16:37:37	16:42:55	30339	00:05:18
20/07/15	Upolu	16:48:09	16:51:40	30340	00:03:31
20/07/15	Upolu	16:52:16	16:56:39	30341	00:04:23
20/07/15	Upolu	16:59:57	17:00:11	30342	00:00:14
20/07/15	Upolu	17:01:24	17:01:35	30343	00:00:11
22/07/15	Savaii	08:08:04	08:10:28	30347	00:02:24
22/07/15	Savaii	08:14:40	08:21:27	30348	00:06:47
22/07/15	Savaii	08:23:27	08:29:38	30349	00:06:11
22/07/15	Savaii	08:33:03	08:41:06	30350	00:08:03
22/07/15	Savaii	08:43:39	08:52:07	30351	00:08:28
22/07/15	Savaii	08:57:51	09:01:03	30352	00:03:12
22/07/15	Savaii	09:01:16	09:06:52	30353	00:05:36
22/07/15	Savaii	09:11:55	09:14:22	30354	00:02:27
22/07/15	Savaii	09:17:07	09:20:14	30355	00:03:07
22/07/15	Savaii	09:24:33	09:27:36	30356	00:03:03
22/07/15	Savaii	09:30:47	09:33:17	30357	00:02:30

22/07/15	Savaii	09:36:22	09:38:54	30358	00:02:32
22/07/15	Savaii	09:41:13	09:44:04	30359	00:02:51
22/07/15	Savaii	09:47:29	09:50:23	30360	00:02:54
22/07/15	Savaii	09:53:31	09:56:19	30361	00:02:48
22/07/15	Savaii	10:00:26	10:02:59	30362	00:02:33
22/07/15	Savaii	10:05:39	10:07:54	30363	00:02:15
22/07/15	Savaii	10:11:39	10:14:14	30364	00:02:35
22/07/15	Savaii	10:17:08	10:19:27	30365	00:02:19
22/07/15	Savaii	10:24:13	10:27:06	30366	00:02:53
22/07/15	Savaii	10:30:00	10:32:36	30367	00:02:36
22/07/15	Savaii	10:36:47	10:39:46	30368	00:02:59
22/07/15	Savaii	10:42:49	10:45:20	30369	00:02:31
22/07/15	Savaii	10:48:27	10:51:08	30370	00:02:41
22/07/15	Savaii	10:54:18	10:56:43	30371	00:02:25
22/07/15	Savaii	11:00:08	11:02:33	30372	00:02:25
22/07/15	Savaii	11:05:16	11:07:48	30373	00:02:32
22/07/15	Savaii	11:11:17	11:13:53	30374	00:02:36
22/07/15	Savaii	11:16:22	11:19:03	30375	00:02:41
22/07/15	Savaii	15:12:05	15:15:19	30382	00:03:14
22/07/15	Savaii	15:17:14	15:20:21	30383	00:03:07
22/07/15	Savaii	15:22:37	15:26:54	30384	00:04:17
22/07/15	Savaii	15:29:27	15:31:55	30385	00:02:28
22/07/15	Savaii	15:34:37	15:37:52	30386	00:03:15
22/07/15	Savaii	15:39:52	15:44:03	30387	00:04:11

22/07/15	Savaii	15:46:41	15:51:31	30388	00:04:50
22/07/15	Savaii	15:54:23	15:57:57	30389	00:03:34
22/07/15	Savaii	16:02:41	16:07:41	30390	00:05:00
22/07/15	Savaii	16:11:13	16:17:14	30391	00:06:01
22/07/15	Savaii	16:20:22	16:27:09	30392	00:06:47
22/07/15	Savaii	16:32:34	16:35:51	30393	00:03:17
22/07/15	Savaii	16:40:49	16:43:23	30394	00:02:34
22/07/15	Savaii	16:45:55	16:49:07	30395	00:03:12
22/07/15	Upolu	07:35:52	07:39:02	30344	00:03:10
22/07/15	Upolu	07:46:16	07:48:51	30345	00:02:35
22/07/15	Upolu	07:52:15	07:56:43	30346	00:04:28
22/07/15	Upolu	14:01:20	14:09:05	30376	00:07:45
22/07/15	Upolu	14:12:00	14:19:18	30377	00:07:18
22/07/15	Upolu	14:30:35	14:38:10	30378	00:07:35
22/07/15	Upolu	14:42:37	14:44:48	30379	00:02:11
22/07/15	Upolu	14:45:57	14:49:29	30380	00:03:32
22/07/15	Upolu	14:54:57	14:57:29	30381	00:02:32
23/07/15	Savaii	09:29:33	09:29:50	30396	00:00:17
23/07/15	Savaii	09:31:15	09:31:27	30397	00:00:12
23/07/15	Upolu	15:49:48	15:51:35	30398	00:01:47
24/07/15	Savaii	15:06:32	15:11:55	30404	00:05:23
24/07/15	Savaii	15:15:21	15:21:55	30405	00:06:34
24/07/15	Savaii	15:23:56	15:29:22	30406	00:05:26
24/07/15	Savaii	15:33:03	15:38:48	30407	00:05:45

24/07/15	Savaii	15:41:39	15:45:57	30408	00:04:18
24/07/15	Savaii	15:49:07	15:54:27	30409	00:05:20
24/07/15	Savaii	15:57:01	16:01:30	30410	00:04:29
24/07/15	Savaii	16:12:10	16:14:06	30411	00:01:56
24/07/15	Savaii	16:16:12	16:16:44	30412	00:00:32
24/07/15	Savaii	16:22:03	16:22:31	30413	00:00:28
24/07/15	Savaii	16:22:41	16:23:12	30414	00:00:31
24/07/15	Savaii	16:23:30	16:23:47	30415	00:00:17
24/07/15	Savaii	16:25:04	16:25:49	30416	00:00:45
24/07/15	Savaii	16:26:56	16:27:21	30417	00:00:25
24/07/15	Savaii	16:30:08	16:30:38	30418	00:00:30
24/07/15	Savaii	16:30:49	16:31:19	30419	00:00:30
24/07/15	Savaii	16:33:47	16:34:08	30420	00:00:21
24/07/15	Savaii	16:37:22	16:37:40	30421	00:00:18
24/07/15	Savaii	16:40:47	16:41:09	30422	00:00:22
24/07/15	Savaii	16:43:51	16:44:52	30423	00:01:01
24/07/15	Savaii	16:47:08	16:47:43	30424	00:00:35
24/07/15	Upolu	14:22:19	14:22:25	30399	00:00:06
24/07/15	Upolu	14:24:30	14:25:22	30400	00:00:52
24/07/15	Upolu	14:44:15	14:44:52	30401	00:00:37
24/07/15	Upolu	14:48:29	14:48:43	30402	00:00:14
24/07/15	Upolu	14:49:25	14:49:59	30403	00:00:34
25/07/15	Savaii	08:38:23	08:38:35	30426	00:00:12
25/07/15	Savaii	08:41:07	08:41:41	30427	00:00:34

25/07/15	Savaii	08:42:08	08:42:25	30428	00:00:17
25/07/15	Savaii	08:43:16	08:43:52	30429	00:00:36
25/07/15	Savaii	08:49:13	08:49:23	30430	00:00:10
25/07/15	Savaii	08:50:03	08:50:13	30431	00:00:10
25/07/15	Savaii	08:51:45	08:52:08	30432	00:00:23
25/07/15	Savaii	08:54:43	08:55:04	30433	00:00:21
25/07/15	Savaii	08:58:29	08:59:28	30434	00:00:59
25/07/15	Savaii	09:03:17	09:05:25	30435	00:02:08
25/07/15	Savaii	09:07:27	09:08:56	30436	00:01:29
25/07/15	Savaii	09:10:53	09:11:52	30437	00:00:59
25/07/15	Savaii	09:14:55	09:15:10	30438	00:00:15
25/07/15	Savaii	09:19:04	09:20:03	30439	00:00:59
25/07/15	Savaii	09:24:12	09:28:41	30440	00:04:29
25/07/15	Savaii	09:32:10	09:37:10	30441	00:05:00
25/07/15	Savaii	15:24:00	15:24:30	30442	00:00:30
25/07/15	Savaii	15:30:45	15:32:15	30443	00:01:30
25/07/15	Savaii	15:33:48	15:36:52	30444	00:03:04
25/07/15	Upolu	08:05:53	08:08:42	30425	00:02:49
26/07/15	Upolu	09:53:13	09:54:15	30445	00:01:02
26/07/15	Upolu	09:54:53	09:56:00	30446	00:01:07
26/07/15	Upolu	09:58:36	09:59:16	30447	00:00:40
26/07/15	Upolu	10:00:09	10:00:25	30448	00:00:16
26/07/15	Upolu	10:03:29	10:04:02	30449	00:00:33
26/07/15	Upolu	10:04:41	10:04:56	30450	00:00:15

26/07/15	Upolu	10:16:11	10:16:25	30451	00:00:14
26/07/15	Upolu	10:17:26	10:17:37	30452	00:00:11
26/07/15	Upolu	10:21:44	10:22:38	30453	00:00:54
26/07/15	Upolu	10:26:45	10:26:59	30454	00:00:14
26/07/15	Upolu	10:27:53	10:28:17	30455	00:00:24
26/07/15	Upolu	10:29:31	10:29:39	30456	00:00:08
29/07/15	Savaii	10:23:26	10:24:09	30457	00:00:43
29/07/15	Savaii	10:32:41	10:33:21	30458	00:00:40
29/07/15	Savaii	10:36:41	10:37:18	30459	00:00:37
29/07/15	Savaii	10:38:54	10:39:05	30460	00:00:11
29/07/15	Savaii	10:43:44	10:46:46	30461	00:03:02
29/07/15	Savaii	10:49:25	10:49:41	30462	00:00:16
29/07/15	Savaii	10:52:28	10:53:03	30463	00:00:35
29/07/15	Savaii	11:01:55	11:02:29	30464	00:00:34
29/07/15	Savaii	11:04:29	11:04:48	30465	00:00:19
29/07/15	Savaii	11:07:21	11:07:42	30466	00:00:21
29/07/15	Savaii	11:09:08	11:09:42	30467	00:00:34
29/07/15	Savaii	11:14:16	11:14:23	30468	00:00:07
29/07/15	Upolu	11:17:07	11:17:33	30469	00:00:26
29/07/15	Upolu	11:22:43	11:25:44	30470	00:03:01
29/07/15	Upolu	11:27:12	11:27:31	30471	00:00:19
29/07/15	Upolu	11:30:15	11:30:36	30472	00:00:21
29/07/15	Upolu	11:32:54	11:34:21	30473	00:01:27
29/07/15	Upolu	11:36:50	11:37:10	30474	00:00:20

29/07/15	Upolu	11:39:33	11:39:54	30475	00:00:21
29/07/15	Upolu	11:44:01	11:44:32	30476	00:00:31
29/07/15	Upolu	11:46:38	11:47:02	30477	00:00:24
29/07/15	Upolu	11:47:50	11:48:46	30478	00:00:56
29/07/15	Upolu	11:49:24	11:50:36	30479	00:01:12
29/07/15	Upolu	11:51:05	11:51:56	30480	00:00:51
29/07/15	Upolu	11:52:10	11:52:36	30481	00:00:26
29/07/15	Upolu	11:54:33	11:54:45	30482	00:00:12
29/07/15	Upolu	11:55:02	11:55:46	30483	00:00:44
29/07/15	Upolu	11:56:47	11:57:10	30484	00:00:23
29/07/15	Upolu	11:57:51	11:58:11	30485	00:00:20
29/07/15	Upolu	11:59:04	11:59:20	30486	00:00:16
29/07/15	Upolu	12:00:38	12:00:52	30487	00:00:14
29/07/15	Upolu	12:01:43	12:01:53	30488	00:00:10
29/07/15	Upolu	15:02:44	15:02:45	30489	00:00:01
29/07/15	Upolu	15:04:32	15:04:58	30490	00:00:26
29/07/15	Upolu	15:07:42	15:08:49	30491	00:01:07
29/07/15	Upolu	15:10:24	15:10:41	30492	00:00:17
29/07/15	Upolu	15:11:58	15:12:34	30493	00:00:36
29/07/15	Upolu	15:13:10	15:13:32	30494	00:00:22
29/07/15	Upolu	15:13:49	15:14:02	30495	00:00:13
29/07/15	Upolu	15:14:23	15:18:06	30496	00:03:43
29/07/15	Upolu	15:21:54	15:25:49	30497	00:03:55
29/07/15	Upolu	15:28:40	15:32:30	30498	00:03:50

29/07/15	Upolu	15:34:47	15:38:19	30499	00:03:32
29/07/15	Upolu	15:41:01	15:44:48	30500	00:03:47
29/07/15	Upolu	15:49:27	15:51:47	30501	00:02:20
29/07/15	Upolu	15:55:08	15:57:11	30502	00:02:03
29/07/15	Upolu	15:59:30	16:01:02	30503	00:01:32
29/07/15	Upolu	16:03:15	16:05:22	30504	00:02:07
29/07/15	Upolu	16:07:48	16:09:54	30505	00:02:06
29/07/15	Upolu	16:12:25	16:15:18	30506	00:02:53
29/07/15	Upolu	16:17:23	16:20:14	30507	00:02:51
29/07/15	Upolu	16:23:14	16:25:59	30508	00:02:45
29/07/15	Upolu	16:28:36	16:31:08	30509	00:02:32
29/07/15	Upolu	16:33:58	16:36:24	30510	00:02:26
29/07/15	Upolu	16:38:54	16:41:15	30511	00:02:21
29/07/15	Upolu	16:44:44	16:45:16	30512	00:00:32
29/07/15	Upolu	16:46:54	16:47:20	30513	00:00:26
29/07/15	Upolu	16:48:23	16:48:50	30514	00:00:27
29/07/15	Upolu	16:52:10	16:55:40	30515	00:03:30
30/07/15	Savaii	08:47:25	08:47:38	30517	00:00:13
30/07/15	Savaii	08:53:47	08:54:35	30519	00:00:48
30/07/15	Savaii	08:57:53	08:58:22	30520	00:00:29
30/07/15	Savaii	09:00:18	09:01:01	30521	00:00:43
30/07/15	Savaii	09:04:00	09:04:50	30522	00:00:50
30/07/15	Savaii	09:06:14	09:06:44	30523	00:00:30
30/07/15	Savaii	09:10:08	09:11:14	30524	00:01:06

30/07/15	Savaii	09:14:44	09:15:09	30525	00:00:25
30/07/15	Savaii	09:15:37	09:15:49	30526	00:00:12
30/07/15	Savaii	09:17:21	09:18:16	30527	00:00:55
30/07/15	Savaii	09:20:34	09:21:52	30528	00:01:18
30/07/15	Savaii	09:22:30	09:22:46	30529	00:00:16
30/07/15	Savaii	09:24:33	09:25:32	30530	00:00:59
30/07/15	Savaii	09:28:17	09:29:01	30531	00:00:44
30/07/15	Savaii	09:30:31	09:30:36	30532	00:00:05
30/07/15	Savaii	09:30:51	09:31:20	30533	00:00:29
30/07/15	Savaii	09:33:57	09:34:57	30534	00:01:00
30/07/15	Savaii	09:37:39	09:38:16	30535	00:00:37
30/07/15	Savaii	09:42:54	09:43:47	30536	00:00:53
30/07/15	Savaii	09:46:30	09:47:02	30537	00:00:32
30/07/15	Savaii	09:47:49	09:48:27	30538	00:00:38
30/07/15	Savaii	09:48:43	09:49:08	30539	00:00:25
30/07/15	Savaii	09:51:35	09:52:13	30540	00:00:38
30/07/15	Savaii	09:53:40	09:53:49	30541	00:00:09
30/07/15	Savaii	09:54:44	09:54:58	30542	00:00:14
30/07/15	Savaii	09:55:39	09:55:51	30543	00:00:12
30/07/15	Savaii	09:58:36	09:58:58	30544	00:00:22
30/07/15	Savaii	10:01:25	10:02:44	30545	00:01:19
30/07/15	Savaii	10:05:34	10:06:43	30546	00:01:09
30/07/15	Savaii	10:10:03	10:10:44	30547	00:00:41
30/07/15	Savaii	10:11:03	10:11:07	30548	00:00:04

30/07/15	Savaii	10:19:19	10:19:34	30549	00:00:15
30/07/15	Upolu	08:19:30	08:19:55	30516	00:00:25
01/08/15	Upolu	15:10:47	15:11:05	30551	00:00:18
01/08/15	Upolu	15:14:31	15:14:44	30552	00:00:13
01/08/15	Upolu	15:16:01	15:16:18	30553	00:00:17
01/08/15	Upolu	15:19:50	15:20:17	30554	00:00:27
01/08/15	Upolu	15:22:22	15:22:46	30555	00:00:24
01/08/15	Upolu	15:25:45	15:26:02	30556	00:00:17
01/08/15	Upolu	15:28:40	15:29:18	30557	00:00:38
02/08/15	Upolu	09:31:28	09:32:02	30558	00:00:34
02/08/15	Upolu	09:36:01	09:36:27	30559	00:00:26
02/08/15	Upolu	09:44:10	09:44:41	30560	00:00:31
02/08/15	Upolu	09:45:57	09:46:18	30561	00:00:21
02/08/15	Upolu	09:47:48	09:48:19	30562	00:00:31
02/08/15	Upolu	09:48:46	09:49:16	30563	00:00:30
02/08/15	Upolu	09:54:21	09:54:35	30564	00:00:14
02/08/15	Upolu	09:56:49	09:57:15	30565	00:00:26
02/08/15	Upolu	10:00:23	10:01:26	30566	00:01:03
02/08/15	Upolu	10:03:56	10:04:11	30567	00:00:15
02/08/15	Upolu	15:30:13	15:31:03	30568	00:00:50
02/08/15	Upolu	15:31:52	15:32:25	30569	00:00:33
02/08/15	Upolu	15:33:42	15:34:09	30570	00:00:27
02/08/15	Upolu	15:36:26	15:37:38	30571	00:01:12
02/08/15	Upolu	15:39:57	15:40:24	30572	00:00:27

02/08/15	Upolu	15:42:47	15:43:09	30573	00:00:22
02/08/15	Upolu	15:44:51	15:45:13	30574	00:00:22
02/08/15	Upolu	15:46:08	15:46:31	30575	00:00:23
02/08/15	Upolu	15:47:58	15:48:21	30576	00:00:23
02/08/15	Upolu	15:50:20	15:50:47	30577	00:00:27
02/08/15	Upolu	15:51:01	15:51:23	30578	00:00:22
02/08/15	Upolu	15:51:59	15:52:20	30579	00:00:21
02/08/15	Upolu	15:55:46	15:56:07	30580	00:00:21
02/08/15	Upolu	15:57:33	15:58:00	30581	00:00:27
02/08/15	Upolu	16:00:04	16:00:35	30582	00:00:31
02/08/15	Upolu	16:03:33	16:03:44	30583	00:00:11
02/08/15	Upolu	16:04:20	16:05:08	30584	00:00:48
02/08/15	Upolu	16:07:18	16:07:53	30585	00:00:35
02/08/15	Upolu	16:10:17	16:10:29	30586	00:00:12
02/08/15	Upolu	16:13:57	16:14:12	30587	00:00:15
02/08/15	Upolu	16:17:47	16:19:19	30588	00:01:32
04/08/15	Savaii	08:57:44	09:01:31	30590	00:03:47
04/08/15	Savaii	09:05:35	09:08:39	30591	00:03:04
04/08/15	Savaii	09:10:52	09:14:04	30592	00:03:12
04/08/15	Savaii	09:18:34	09:20:07	30593	00:01:33
04/08/15	Savaii	09:21:23	09:24:29	30594	00:03:06
04/08/15	Savaii	09:27:20	09:28:37	30595	00:01:17
04/08/15	Savaii	09:32:19	09:34:08	30596	00:01:49
04/08/15	Savaii	09:35:28	09:36:00	30597	00:00:32

04/08/15	Savaii	09:42:31	09:48:25	30598	00:05:54
04/08/15	Savaii	09:52:15	09:54:20	30599	00:02:05
04/08/15	Savaii	09:57:02	09:58:07	30600	00:01:05
04/08/15	Savaii	09:58:27	09:58:36	30601	00:00:09
04/08/15	Savaii	10:01:00	10:01:34	30602	00:00:34
04/08/15	Savaii	10:09:08	10:15:15	30603	00:06:07
04/08/15	Upolu	10:33:05	10:35:27	30604	00:02:22
04/08/15	Upolu	10:38:42	10:42:10	30605	00:03:28
04/08/15	Upolu	10:45:13	10:45:51	30606	00:00:38
04/08/15	Upolu	10:47:07	10:47:57	30607	00:00:50
04/08/15	Upolu	10:50:44	10:51:13	30608	00:00:29
04/08/15	Upolu	10:52:26	10:52:51	30609	00:00:25
04/08/15	Upolu	10:56:55	10:57:41	30610	00:00:46
04/08/15	Upolu	10:58:30	10:58:43	30611	00:00:13
04/08/15	Upolu	10:59:23	11:00:10	30612	00:00:47
04/08/15	Upolu	11:02:28	11:04:07	30613	00:01:39
04/08/15	Upolu	11:04:47	11:05:09	30614	00:00:22
04/08/15	Upolu	11:07:28	11:08:41	30615	00:01:13
04/08/15	Upolu	11:09:18	11:09:53	30616	00:00:35
04/08/15	Upolu	11:13:25	11:15:43	30617	00:02:18
04/08/15	Upolu	11:16:01	11:16:12	30618	00:00:11
04/08/15	Upolu	11:18:49	11:20:00	30619	00:01:11
04/08/15	Upolu	11:20:30	11:21:11	30620	00:00:41
04/08/15	Upolu	11:23:21	11:24:08	30621	00:00:47

04/08/15	Upolu	11:24:39	11:24:48	30622	00:00:09
04/08/15	Upolu	11:27:39	11:28:46	30623	00:01:07
04/08/15	Upolu	11:29:05	11:29:35	30624	00:00:30
04/08/15	Upolu	11:31:44	11:32:00	30625	00:00:16
04/08/15	Upolu	11:33:25	11:33:59	30626	00:00:34
04/08/15	Upolu	11:35:58	11:36:25	30627	00:00:27
04/08/15	Upolu	11:38:41	11:39:47	30628	00:01:06
04/08/15	Upolu	11:41:57	11:42:32	30629	00:00:35
04/08/15	Upolu	11:46:04	11:46:29	30630	00:00:25
04/08/15	Upolu	14:29:13	14:30:41	30631	00:01:28
04/08/15	Upolu	14:33:02	14:34:06	30632	00:01:04
04/08/15	Upolu	14:34:36	14:34:53	30633	00:00:17
04/08/15	Upolu	14:36:00	14:36:14	30634	00:00:14
04/08/15	Upolu	14:37:09	14:37:32	30635	00:00:23
04/08/15	Upolu	14:39:39	14:39:54	30636	00:00:15
04/08/15	Upolu	14:42:10	14:42:30	30637	00:00:20
04/08/15	Upolu	14:42:56	14:43:26	30638	00:00:30
04/08/15	Upolu	14:44:56	14:45:10	30639	00:00:14
04/08/15	Upolu	14:45:32	14:46:01	30640	00:00:29
04/08/15	Upolu	14:50:16	14:51:03	30641	00:00:47
04/08/15	Upolu	14:51:28	14:52:17	30642	00:00:49
04/08/15	Upolu	14:55:40	14:56:14	30643	00:00:34
04/08/15	Upolu	15:01:49	15:06:14	30644	00:04:25
04/08/15	Upolu	15:10:47	15:11:16	30645	00:00:29

04/08/15	Upolu	15:11:40	15:12:06	30646	00:00:26
04/08/15	Upolu	15:13:47	15:14:04	30647	00:00:17
04/08/15	Upolu	15:16:59	15:21:06	30648	00:04:07
04/08/15	Upolu	15:23:10	15:26:26	30649	00:03:16
04/08/15	Upolu	15:33:03	15:33:15	30650	00:00:12
04/08/15	Upolu	15:40:03	15:40:38	30651	00:00:35
04/08/15	Upolu	15:42:37	15:43:38	30652	00:01:01
04/08/15	Upolu	15:45:38	15:46:02	30653	00:00:24
05/08/15	Savaii	09:12:00	09:11:42	30654	00:00:18
05/08/15	Savaii	09:13:12	09:13:03	30655	00:00:09
05/08/15	Savaii	16:20:14	16:20:03	30684	00:00:11
05/08/15	Upolu	14:33:15	14:33:32	30656	00:00:17
05/08/15	Upolu	14:40:23	14:41:28	30657	00:01:05
05/08/15	Upolu	14:44:01	14:45:00	30658	00:00:59
05/08/15	Upolu	14:46:55	14:47:10	30659	00:00:15
05/08/15	Upolu	14:50:40	14:51:33	30660	00:00:53
05/08/15	Upolu	14:54:41	14:55:11	30661	00:00:30
05/08/15	Upolu	14:56:20	14:56:38	30662	00:00:18
05/08/15	Upolu	14:57:08	14:57:34	30663	00:00:26
05/08/15	Upolu	15:00:16	15:00:55	30664	00:00:39
05/08/15	Upolu	15:09:19	15:10:07	30665	00:00:48
05/08/15	Upolu	15:10:31	15:10:49	30666	00:00:18
05/08/15	Upolu	15:15:03	15:15:26	30667	00:00:23
05/08/15	Upolu	15:17:00	15:17:25	30668	00:00:25

05/08/15	Upolu	15:20:08	15:20:21	30669	00:00:13
05/08/15	Upolu	15:22:12	15:22:54	30670	00:00:42
05/08/15	Upolu	15:26:26	15:26:59	30671	00:00:33
05/08/15	Upolu	15:27:23	15:27:31	30672	00:00:08
05/08/15	Upolu	15:30:23	15:30:51	30673	00:00:28
05/08/15	Upolu	15:34:37	15:35:46	30674	00:01:09
05/08/15	Upolu	15:38:20	15:39:01	30675	00:00:41
05/08/15	Upolu	15:39:47	15:41:00	30676	00:01:13
05/08/15	Upolu	15:43:07	15:43:18	30677	00:00:11
05/08/15	Upolu	15:45:49	15:46:14	30678	00:00:25
05/08/15	Upolu	15:48:34	15:49:22	30679	00:00:48
05/08/15	Upolu	15:54:27	15:54:35	30680	00:00:08
05/08/15	Upolu	15:54:47	15:54:56	30681	00:00:09
05/08/15	Upolu	15:55:30	15:55:48	30682	00:00:18
05/08/15	Upolu	15:58:46	15:59:25	30683	00:00:39
07/08/15	Savaii	16:14:18	16:14:48	30691	00:00:30
07/08/15	Savaii	16:17:19	16:18:34	30692	00:01:15
07/08/15	Savaii	16:20:58	16:21:22	30693	00:00:24
07/08/15	Savaii	16:24:32	16:25:00	30694	00:00:28
07/08/15	Savaii	16:27:54	16:28:54	30695	00:01:00
07/08/15	Savaii	16:29:42	16:30:00	30696	00:00:18
07/08/15	Savaii	16:31:13	16:32:46	30697	00:01:33
07/08/15	Savaii	16:34:45	16:36:19	30698	00:01:34
07/08/15	Savaii	16:38:14	16:39:27	30699	00:01:13

07/08/15	Savaii	16:42:10	16:44:22	30700	00:02:12
07/08/15	Savaii	16:46:51	16:48:45	30701	00:01:54
07/08/15	Savaii	16:51:21	16:53:27	30702	00:02:06
07/08/15	Savaii	16:55:58	16:57:03	30703	00:01:05
07/08/15	Savaii	16:59:20	17:01:43	30704	00:02:23
07/08/15	Savaii	17:04:33	17:05:52	30705	00:01:19
07/08/15	Savaii	17:08:11	17:10:42	30706	00:02:31
07/08/15	Upolu	13:52:14	13:52:57	30685	00:00:43
07/08/15	Upolu	13:54:13	13:55:25	30686	00:01:12
07/08/15	Upolu	14:00:04	14:00:41	30687	00:00:37
07/08/15	Upolu	14:02:51	14:04:11	30688	00:01:20
07/08/15	Upolu	14:05:05	14:05:32	30689	00:00:27
07/08/15	Upolu	14:06:49	14:06:57	30690	00:00:08
					33:12:18

Annex K. Weekly Reports

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 5 July 2015

Created By	**Luke Chamberlain**	**Sent to:**	**Bismark Crawley**
Weekly Report	**001**	**Next Report Due**	**12th July 2015**

Project Contacts

Project role	Name	Contact Details
FLC Project Manager	**Luke Chamberlain**	**l.chamberlain@fugro.com / (+685) 763 6552**
FGS Project Manager	**Cristian Gordini**	**c.gordini@fugro.com / (+61) 422 274 088**

The Status of the Project:

	ALB	ALT
Planning Phase.	Completed 80%	Completed 90%
Acquisition Phase	Currently at 0%	Currently at 0%
Processing Phase:	Currently at 0%	Currently at 0%
Delivery Phase:	Currently at 0%	Currently at 0%

Changes to the status in the last week:

	ALB	ALT
Planning Phase.	Project Plan submitted to MNRE. Compiling survey, verification and processing plans for both FLC / FGS	Submitted Survey Plan, verification plan and processing plan to FLC for compiling.
Acquisition Phase		
Processing Phase:		
Delivery Phase:		

The past 7 days: Problems & Events

Date	ALB – Describe the event or problem	ALT – Describe the event or problem
Mon 29/6	All survey personnel in transit to Samoa	Organized itinerary for CG and SS to Samoa
Tue 30/6	All survey personnel arrived late afternoon in Samoa	Submitted Survey Plan and Verification Plan
Wed 1/7	Meeting held with MNRE, contract signing immanent after legal department reviewed. Survey assistance offered to conduct benchmark topo survey in next few days. Meeting arranged for tomorrow to discuss further with MNRE survey department. Airport passes obtained for all non-pilot personnel. ATC advised of ALB operating areas. Discussion had with Insel Hotel Reservation Manager, trying to accommodate us from 7 to 14 July but no rooms yet	Meeting with AC and LC and RG discussing timing of arrival in Samoa, VISA, Accommodation, weather, Survey plan

1448: Samoa ALT/ALB project — Weekly Acquisition Report: 5 July 2013

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 5 July 2015

Thurs 2/7	Meeting held with MNRE surveyors. Equipment and personnel from MNRE available to assist in conducting benchmark survey tomorrow morning. Riegl Verification report being finalised for FP / Samoa. MNRE Contract Immanent before first flight Saturday	Organising field processing gear, laptop and case with tray for downloading Riegl data. Installing relevant software, departing to Samoa
Fri 3/7	Conducted Topographic Benchmark survey with assistance from MNRE staff and equipment. Contract finalisation in hands of cabinet hearing next Monday, 06 July.	Travelling to Samoa. SS arrived in the afternoon and CG arrived at night Arrival of VH-LEM delayed to late afternoon, Saturday (4 July)
Sat 4/7	Afternoon flight cancelled due to Mk3 scanner not operating correctly. Testing being conducted with Adelaide support, ongoing. Verification report being finalised for FLC, waiting on remaining Riegl comparisons. Assistance given to FGS personnel on logistical issues today	Organized rental car and driving permit, Meeting with local surveyors SS, LC and CG to discuss availability of surveyor to perform ground control. Set up processing station and testing. Organized custom clearance with Manager for Polynesian Airlines Pilots from AusJet and LEM arrived at night.
Sun 5/7	Both intended flights cancelled for today while troubleshooting continues on LADS Mk3 scanner.	CG and pilots CC and AM went to Airport to organize LEM, clean the cover glass, refuel the aircraft and meet with ATC. Organized gear for starting survey on Monday. SS finalized flight plan. Clarification required for capture at 40 degree FOV and 70% forward overlap for imagery. LC sent email to Nathan Quadros. Navigator BF arrived at night. Meeting between CG, SS and CC and BF briefing for tomorrow operations. Submitted flight plans to ATC and plan A and plan B for the week.

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 5 July 2015

The next 7 days:

Planned Date	ALB – Describe the event or foreseen problem	ALT – Describe the event or foreseen problem
Mon 6/7	Rectify LADS Mk3 scanner issue Compile verification results Meet with MNRE surveyors	Starting early in the morning with test flight and runs from north to south on Upolu island Organising hotel for Wednesday Thursday and Friday Verification of test data Meeting with MNRE surveyors to discuss vertical datum and ground control Calculate transformation parameters ITRF08 to Samoa horizontal Datum Briefing for the week with CG, SS, CC, AM, BF
Tue 7/7	Standby Flights for Upolu and Savaii Islands (North Coast) Moving hotel for majority staff	Survey Upolu island Process and validate data Moving hotel
Wed 8/7	Survey Flights Upolu and Savaii Island (North Coasts)	Continuing capture on Upolu island Processing data
Thu 9/7	Survey Flights Upolu and Savaii Island (North Coasts)	Continuing capture on Upolu island Processing data
Fri 10/7	Survey Flights Upolu and Savaii Island (South Coasts)	Continuing capture on Upolu island Processing data CG returning to Australia
Sat 11/7	Survey Flights Upolu and Savaii Island (South Coasts)	TBA
Sun 12/7	Survey Flights Upolu and Savaii Island (South Coasts) All FLC personnel return to Insel Hotel	TBA

1448: Samoa ALT / ALB project Weekly Field Report for Week Ending: 12 July 2015

Created By	Luke Chamberlain	Sent to:	Bismark Crawley
Weekly Report	002	Next Report Due	19th July 2015

Project Contacts

Project role	Name	Contact Details
FLC Project Manager	**Luke Chamberlain**	**l.chamberlain@fugro.com / (+685) 763 6552**
FGS Project Manager	**Cristian Gordini**	**c.gordini@fugro.com / (+61) 422 274 088**

The Status of the Project:

	ALB	ALT
Planning Phase.	Completed 95%	Completed 90%
Acquisition Phase	Currently at 80%	Currently at 29%
Processing Phase:	Currently at 0%	Currently at 0%
Delivery Phase:	Currently at 0%	Currently at 0%

Changes to the status in the last week:

	ALB	ALT
Planning Phase.	Survey Plan submitted to MNRE. Compiling processing plans for both FLC / FGS. MNRE contract in final stages of officially signing with cabinet verbal approval Friday.	Survey control being laid. To organize local support for weather monitoring to facilitate aircraft movement to target cloud free lines.
Acquisition Phase	Acquisition phase commenced on Tuesday 7 July after some initial issues with LADS Mk3 scanner resolved. Since that time 10 flights have been conducted for the ALB. Cloud has impacted the majority of areas especially in the eastern end of Upolu Island. Four of the survey areas have been planned to fly at a lower altitude to mitigate against the cloud base as an option if required. Expectation is another 4 more flights will complete the ALB phase but heavily dependent on accessibility to areas with cloud and high terrain. Water conditions are very favourable in majority of areas with good results to 60m depth in areas. Area around Fagaiofu Bay, SW of Upolu, very dirty though with discharge from local river impacting area and coverage.	Acquisition phase started on Monday 6th July. Cloud coverage lower than 1700feet has been a constant over the past week. The crew has managed to acquire mainly in the morning before 11am. Currently the percentage of Line km completed is about 29%. Crew has moved to airport lodge this will save almost 2 h drive per day allowing pilots and operator to rest more at night.
Processing Phase:	Field processing and coverage review is ongoing.	Field processing is happening in near real time. Some issues related to internet connection have been resolved.
Delivery Phase:		Preparing working instruction for production team.

1448: Samoa ALT / ALB project Weekly Field Report for Week Ending: 12 July 2015

The past 7 days: Problems & Events

Date	ALB – Describe the event or problem	ALT – Describe the event or problem
Mon 6/7	Planned double flights cancelled due to scanner issue with LADS Mk3. Resolved though in afternoon. Verification plan sent to MNRE. Plan for further survey control support dispatched to MNRE survey department. Meeting tomorrow to discuss.	1 session in the morning 14 runs in Upolu island. Cloud in the afternoon no flight.
Tue 7/7	Flight 1 conducted in am. Second flight cancelled due to pilot unwell. Meeting held with MNRE in morning, support gained to conduct the ALT ground control around Upolu and Savaii Islands over coming two to three weeks.	2 sessions in Savai'I island one in the morning 21 runs in and one in the afternoon 4 runs.
Wed 8/7	Flights 2 and 3 conducted today. Cloud impacting areas though but favourable water conditions. Data coverage review and BM comparisons in progress	1 session in the morning in Upolu Island 14 runs. Clouds in the afternoon no flight
Thurs 9/7	Flights 4 and 5 conducted today. Cloud still an issue.	No survey due to cloud
Fri 10/7	Flight 6 conducted in morning, second flight cancelled due to pilot seeking treatment for eye infection.	1 session in the morning. Issue with weather in the afternoon
Sat 11/7	Flights 7 and 8 conducted today. Cloud impacting areas but resolved to flying lower.	1 session. Cristian Gordini out with Surveyor to locate Lidar ground control points.
Sun 12/7	Flights 9 and 10 conducted today.	1 good Session in the morning in Upolu Island. Due to cloud no flight in the afternoon

The next 7 days:

Planned Date	ALB – Describe the event or foreseen problem	ALT – Describe the event or foreseen problem
Mon 13/7	Planned double flight in am and pm. Coverage review and reflies identified	Continuing capture
Tue 14/7	Planned double flight in am and pm for reflies.	Pilot Rest Day. Cristian Gordini returning to Australia. Stan Shumeyko FPC.
Wed 15/7	Coverage assessment	Continuing capture
Thu 16/7	Possible Demob for ALB team if coverage achieved	Continuing capture
Fri 17/7	Transit N96Y back to Tahiti	Continuing capture
Sat 18/7		Continuing capture
Sun 19/7		Continuing capture

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 19 July 2015

Created By	**Luke Chamberlain**	**Sent to:**	**Bismark Crawley**
Weekly Report	**003**	**Next Report Due**	**26th July 2015**

Project Contacts

Project role	Name	Contact Details
FLC Project Manager	**Luke Chamberlain**	**l.chamberlain@fugro.com / (+685) 763 6552**
FGS Project Manager	**Cristian Gordini**	**c.gordini@fugro.com / (+61) 422 274 088**

The Status of the Project:

	ALB	ALT
Planning Phase.	Completed 95%	Completed 95%
Acquisition Phase	Currently at 100%	Currently at 60%
Processing Phase:	Currently at 0%	Currently at 0%
Delivery Phase:	Currently at 0%	Currently at 0%

Changes to the status in the last week:

	ALB	ALT
Planning Phase.	MNRE contract dispatched to Adelaide for signing. Some control work ongoing with MNRE assistance.	Survey control being completed at Upolu Island. Surveyors planning to get control at Savai'i island next week.
Acquisition Phase	Over the last 7 days 5 flights were flown to complete the ALB acquisition. Cloud was the biggest impact over the week but a decision to fly lines at a lower altitude for some areas was made in order to complete areas while water conditions remained favourable. Safata Harbour, along the southern coast of Uplolu Island, remained turbid during the whole survey period with no improvement. N96Y departed Samoa on Sunday morning with all remaining personnel departing Monday 20 July.	Acquisition phase continued with some good days. Cloud cover however is limiting the survey and planned lines need to be flown in multiple sessions. This has slowed down the acquisition and with current rate the aim to complete the capture early in August. Currently approximately 60% of like km have been completed of the planned lines.
Processing Phase:	Field processing and coverage review conducted in order to identify gaps and coverage to the 30m contour. Processing phase will now be coordinated in Adelaide	Field processing is happening in near real time. Some issues related to internet connection have been resolved. Some issues related to internet connection were resolved unlocking Digicel devise and using blue-sky Sim cards.
Delivery Phase:		Processing plan has been discussed with FLADS and needs to be finalized.

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 19 July 2015

The past 7 days: Problems & Events

Date	ALB – Describe the event or problem	ALT – Describe the event or problem
Mon 13/7	Flight 11 and 12 conducted.	2 sessions were completed at Upolu island.
Tue 14/7	Flight 13 conducted. Afternoon flight cancelled due to low cloud and rain. N96Y maintenance conducted.	Pilot Rest day. Raining and overcast all day.
Wed 15/7	No flights conducted due to weather. All remaining reflies identified for remaining flights.	1 session in the morning in Upolu Island. Clouds in the afternoon no flight
Thurs 16/7	Flight 14 conducted in afternoon.	2 sessions covering both Upolu and Savai'l islands.
Fri 17/7	No flights conducted due to weather. Pilot rest day.	1 session covering both Upolu and Savai'l islands.
Sat 18/7	Remaining Flight 15 conducted during clear weather conditions. N96Y packed in afternoon ready for departure	2 sessions covering both Upolu and Savai'l islands.
Sun 19/7	N96Y departed Samoa early morning for French Polynesia for demob. Field office packed.	1 session covering both Upolu and Savai'l islands.

The next 7 days:

Planned Date	ALB – Describe the event or foreseen problem	ALT – Describe the event or foreseen problem
Mon 20/7	All remaining FLC personnel depart Samoa.	Continuing capture
Tue 21/7		Pilot Rest day – LEM 100 hourly
Wed 22/7		LEM 100 hourly
Thu 23/7		Continuing capture
Fri 24/7		Continuing capture
Sat 25/7		Continuing capture
Sun 26/7		Continuing capture

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 26 July 2015

Created By	**Luke Chamberlain**	**Sent to:**	**Bismark Crawley**
Weekly Report	**004**	**Next Report Due**	**2nd August 2015**

Project Contacts

Project role	Name	Contact Details
FLC Project Manager	**Luke Chamberlain**	**l.chamberlain@fugro.com / (+685) 763 6552**
FGS Project Manager	**Cristian Gordini**	**c.gordini@fugro.com / (+61) 422 274 088**
A/FLC PM	**Alex Cowdery**	**a.cowdery@fugro.com (+61) 458 458 459**

The Status of the Project:

	ALB	ALT
Planning Phase.	Completed 95%	Completed 90%
Acquisition Phase	Currently at 100%	Currently at 78%
Processing Phase:	Currently at 5%	Currently at 0%
Delivery Phase:	Currently at 0%	Currently at 0%

Changes to the status in the last week:

	ALB	ALT
Planning Phase.	MNRE contract dispatched to Adelaide for signing. Some control work ongoing with MNRE assistance.	Surveyors processing surveying data for control over Upolu island. Control at Savai'i island to be done
Acquisition Phase	All personnel demobilized Monday 20 July.	Acquisition phase continued with little good window. Cloud cover continues to be an issues and planned lines need still to be flown in multiple sessions. This is causing considerable delays. Currently approximately 78% of line km of the planned lines has been completed. 71 lines are partially flown 7 lines to be completely flown, 105 line completely flown. Some minor issues with the navigator keyboard in the aircraft occurred. The keyboard has been replaced and is working fine.
Processing Phase:	Processing phase initiated in Adelaide	Field processing is happening in near real time. Some issues related to hard drive space. New hard drives were sent from Australia and should arrive this Monday 27/7.
Delivery Phase:	Currently on schedule.	Processing plan has been discussed with FLADS and needs to be finalized.

1448: Samoa ALT/ALB project Weekly Acquisition Report: 19 July 2015

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 26 July 2015

The past 7 days: Problems &/Or Events

Date	ALB – Describe the event or problem	ALT – Describe the event or problem
Mon 20/7	Demobilize personnel to Adelaide. No issues.	Good day with 2 full sessions covering both Upolu and Savai'l islands multiple partial lines flown.
Tue 21/7	Initiation of data processing workflows. PM staff on Leave. No Issues.	Pilot Rest day. Raining and overcast all day.
Wed 22/7	Continued data processing workflows. PM staff on Leave. No Issues.	Good day with 2 full sessions covering both Upolu and Savai'l islands multiple partial lines flown.
Thurs 23/7	Continued data processing workflows. PM staff on Leave. No Issues.	2 sessions covering both Upolu and Savai'l islands multiple partial lines flown.
Fri 24/7	Continued data processing workflows. PM staff on Leave. No Issues.	1 session covering both Upolu and Savai'l islands multiple partial lines flown.
Sat 25/7		2 sessions covering both Upolu and Savai'l islands multiple partial lines flown.
Sun 26/7		1 session covering Upolu Island. 3 partial lines done.

The next 7 days:

Planned Date	ALB – Describe the event or foreseen problem	ALT – Describe the event or foreseen problem
Mon 13/7		Continuing capture
Tue 14/7		Continuing capture
Wed 15/7		LEM 100 hourly / Crew moving hotel room due full booked over the nights of 29th and 30th.
Thu 16/7		Continuing capture
Fri 17/7		Continuing capture
Sat 18/7		Continuing capture
Sun 19/7		Continuing capture

1448: Samoa ALT/ALB project Weekly Acquisition Report: 19 July 2015

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 2 Aug 2015

Created By	Luke Chamberlain	Sent to:	Bismark Crawley
Weekly Report	005	Next Report Due	09 August 2015

Project Contacts

Project role	Name	Contact Details
FLC Project Manager	**Luke Chamberlain**	**l.chamberlain@fugro.com / (+685) 763 6552**
FGS Project Manager	**Cristian Gordini**	**c.gordini@fugro.com / (+61) 422 274 088**

The Status of the Project:

	ALB	ALT
Planning Phase.	Currently 95%	Currently 95%
Acquisition Phase	Completed at 100%	Currently at 80%
Processing Phase:	Mk3 currently at 10%. Riegl currently at 0%	Currently at 0%
Delivery Phase:	Currently at 0%	Currently at 0%

Changes to the status in the last week:

	ALB	ALT
Planning Phase.	Contract signed and dispatched to MNRE 27 July. Waiting on some ground control data from MNRE Surveyors	MNRE Surveyors processing surveying data for control over Upolu island. Control at Savai'i island to be done. Fugro waiting for data and coordinates.
Acquisition Phase	ALB completed.	Acquisition phase seriously affected by weather issues. Cloud cover continues to be an issues and only patch work was possible over the last 7 days. This is causing considerable delays. Currently approximately 80% of line km of the planned lines has been completed. 71 lines are partially flown 7 lines to be completely flown, 105 lines completely flown. Aircraft has done the 100 hourly service. Pilot reached 100 hours of fly this month and needed to take an extra rest day, this was however coincident with complete cloud coverage.
Processing Phase:	Processing phase of LADS Mk3 and Riegl datasets initiated in Adelaide.	New hard drives have been received from field crew.
Delivery Phase:	Requires discussion with MNRE on schedule with potential delays with ALT data collection.	Processing plan has been discussed with FLADS and needs to be finalized.

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 2 Aug 2015

The past 7 days: Problems & Events

Date	ALB – Describe the event or problem	ALT – Describe the event or problem
Mon 27/7	Mk2 data and Riegl 820 processing in progress. PM on leave.	No flight due to weather
Tue 28/7	Mk2 data and Riegl 820 processing in progress. PM on leave.	Aircraft 100 hourly maintenance / 1 session in the afternoon
Wed 29/7	Mk2 data and Riegl 820 processing in progress. PM on leave.	2 sessions covering both Upolu and Savai'I islands multiple partial lines flown.
Thurs 30/7	Mk2 data and Riegl 820 processing in progress. PM on leave.	1 session covering both Upolu and Savai'I islands multiple partial lines flown.
Fri 31/7	Mk2 data and Riegl 820 processing in progress. PM on leave.	Pilot rest day
Sat 1/8		1 session multiple partial lines flown.
Sun 2/8		1 session multiple partial lines flown

The next 7 days:

Planned Date	ALB – Describe the event or foreseen problem	ALT – Describe the event or foreseen problem
Mon 3/8	Continuation of data processing. PM returns from leave.	Continuing capture
Tue 4/8	Continuation of data processing.	Continuing capture
Wed 5/8	Continuation of data processing.	Navigator changeover/Continuing capture
Thu 6/8	Continuation of data processing.	Continuing capture
Fri 7/8	Continuation of data processing.	Pilot rest day
Sat 9/8		Continuing capture
Sun 10/8		Continuing capture

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 9 Aug 2015

Created By	**Luke Chamberlain**	**Sent to:**	**Bismark Crawley**
Weekly Report	**006**	**Next Report Due**	**23 August 2015**

Project Contacts

Project role	Name	Contact Details
FLC Project Manager	**Luke Chamberlain**	**l.chamberlain@fugro.com / (+61) 418 807 713**
FGS Project Manager	**Cristian Gordini**	**c.gordini@fugro.com / (+61) 422 274 088**

The Status of the Project:

	ALB	ALT
Planning Phase.	Completed 100%	Completed 100%
Acquisition Phase	Completed 100%	Currently at 80%
Processing Phase:	Mk3 currently at 15%. Riegl currently at 0%	Currently at 0%
Delivery Phase:	Currently at 0%	Currently at 0%

Changes to the status in the last week:

	ALB	ALT
Planning Phase.	MNRE surveyors completed ground control work on both Savaii and Upolu Islands. Waiting on data.	Surveyors processing surveying data for control over Upolu island. Control at Savai'i island to be done. Fugro waiting for data and coordinates.
Acquisition Phase	ALB completed.	Acquisition phase seriously affected by weather issues. Cloud cover continues to be an issues and only patch work was possible over the last 7 days. This is causing considerable delays. Currently approximately 81% of line km of the planned lines has been completed. 71 lines are partially flown 7 lines to be completely flown, 105 lines completely flown. Discussed demobilization option and filling gaps with Satellite data.
Processing Phase:	Processing phase of LADS Mk3 and Riegl datasets initiated in Adelaide. Also compiling the "Post Survey Accuracy Report"	All data is being pre-processed and will be sent to the Production centre for post processing once aircraft arrives in Melbourne.
Delivery Phase:	Requires discussion with MNRE on schedule with potential delays with ALT data collection.	Processing plan has been discussed with FLADS and needs to be finalized.

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 9 Aug 2015

The past 7 days: Problems & Events

Date	ALB – Describe the event or problem	ALT – Describe the event or problem
Mon 3/8	Mk3 data and Riegl 820 processing in progress. PM returned from leave.	Raining, low cloud
Tue 4/8	Mk3 data and Riegl 820 processing in progress.	One session attempting survey. Low cloud in the area. Minor gaps from 40 degree FOV coverage filled
Wed 5/8	Mk3 data and Riegl 820 processing in progress.	One session attempting survey. Low cloud in the area. Minor gaps from 40 degree FOV coverage filled
Thurs 6/8	Mk3 data and Riegl 820 processing in progress.	Low cloud, sensor issues.
Fri 7/8	Mk3 data and Riegl 820 processing in progress.	One session attempting survey. Low cloud in the area. Minor gaps from 40 degree FOV coverage filled
Sat 8/8		Preparation for Demob
Sun 9/8		Demob Apia-Norfolk

The next 7 days:

Planned Date	ALB – Describe the event or foreseen problem	ALT – Describe the event or foreseen problem
Mon 10/8	Continuation of data processing.	Demob Norfolk island – Essendon
Tue 11/8	Continuation of data processing.	Shipping data to production centre
Wed 12/8	Continuation of data processing.	Organizing Satellite order
Thu 13/8	Continuation of data processing.	Processing plan
Fri 14/8	Continuation of data processing.	Processing plan
Sat 14/8		
Sun 15/8		

1448: Samoa ALT / ALB project
Weekly Field Report for Week Ending: 16 Aug 2015

Created By	**Luke Chamberlain**	**Sent to:**	**Bismark Crawley**
Weekly Report	**007**	**Next Report Due**	**30th August 2015**

Project Contacts

Project role	Name	Contact Details
FLC Project Manager	**Luke Chamberlain**	**l.chamberlain@fugro.com / (+685) 763 6552**
FGS Project Manager	**Cristian Gordini**	**c.gordini@fugro.com / (+61) 422 274 088**

The Status of the Project:

	ALB	ALT
Planning Phase.	Completed 100%	Completed 100%
Acquisition Phase	Completed 100%	Currently at 80%
Processing Phase:	Mk3 currently at 23%. Riegl currently at 5%	Currently at 0%
Delivery Phase:	Currently at 0%	Currently at 0%

Changes to the status in the last week:

	ALB	ALT
Planning Phase.		MNRE Surveyors have provided ground control over Upolu Islands only at this stage. Savaii control to be completed by end of August. Fugro to review the coordinates and the MSL values.
Acquisition Phase	ALB completed.	Field crew demobilized on Sunday 10th
Processing Phase:	Processing phase of LADS Mk3 and Riegl datasets initiated in Adelaide. Also compiling the "Post Survey Accuracy Report"	Data has arrived in Perth office and is being organized for the next phase of post processing.
Delivery Phase:	Requires discussion with MNRE on schedule with potential delays with ALT data collection.	Processing plan will be reviewed to include satellite data merging.

The past 7 days: Problems & Events

Date	ALB – Describe the event or problem	ALT – Describe the event or problem
Mon 11/8	Mk3 data and Riegl 820 processing in progress.	Demobilization to Australia
Tue 12/8	Mk3 data and Riegl 820 processing in progress.	Sent disk with data to Perth / Implementing best Satellite option to fill gaps
Wed 13/8	Mk3 data and Riegl 820 processing in progress.	Implementing best Satellite option to fill gaps
Thurs 14/8	Mk3 data and Riegl 820 processing in progress.	Low cloud, sensor issues.
Fri 15/8	Mk3 data and Riegl 820 processing in progress.	Received data and organizing for Production stage 2
Sat 16/8		Copying data for production
Sun 17/8		Copying data for production

1448: Samoa ALT / ALB project Weekly Field Report for Week Ending: 16 Aug 2015

The next 7 days:

Planned Date	ALB – Describe the event or foreseen problem	ALT – Describe the event or foreseen problem
Mon 17/8	Continuation of data processing.	Satellite / Radar Plan
Tue 18/8	Continuation of data processing.	Processing plan / transferring data to production
Wed 19/8	Continuation of data processing.	transferring data to production
Thu 20/8	Continuation of data processing.	transferring data to production
Fri 21/8	Continuation of data processing.	transferring data to production
Sat 22/8		
Sun 23/8		

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 25 Sep 2015

Created By	**Luke Chamberlain**	**Sent to:**	**Luke Chamberlain**
Status Report	**001**	**Next Report Due**	**9th October 2015**

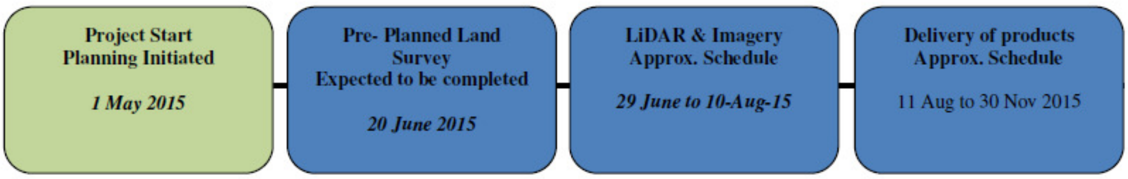
Project Contacts

Project role	Name	Contact Details
FLC PM	**Luke Chamberlain**	L.Chamberlain@fugro.com
FGS PM	**Cristian Gordini**	C.Gordini@fugro.com

1. Project Management

- ALB and ALT data undergoing processing currently.
- Satellite Data Ordered to supplement ALT coverage gaps.
- MNRE Survey Control completed for Upolu. Awaiting results for Savaii Island with expected completion 02 October 2015. **Require this ASAP to define MSL corrections.**
- Invoices for mobilisation and ALB Data Collection submitted to MNRE and **overdue for payment (Due 23 Sep).**

2. Project Timing



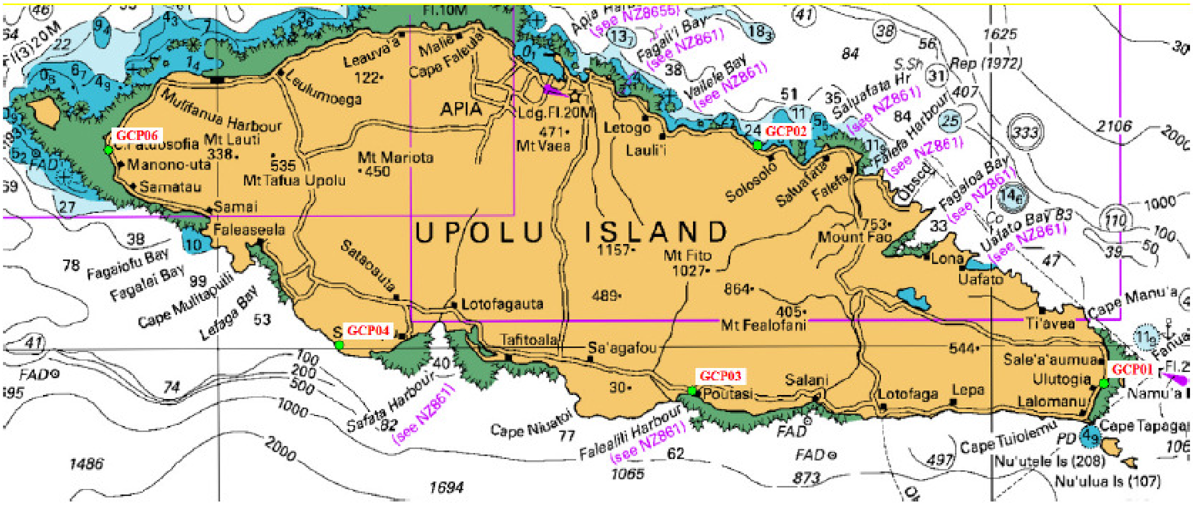
3. Health and Safety

- Data Acquisition was conducted within the safe work guidelines of Fugro and MNRE.
- No incidents to report.

4. Survey Control Work

- FLC / FGS received position details for 5 x Control for Upolu this past week. **Awaiting formal Station description and photo's of each one (GCP01 – 04 and 06).** See figure below.
- MNRE expect to complete control work for Savaii end of next week, 02 Oct 2015.
- FLC / FGS compiling Post Survey Spatial Accuracy Report – 50% completed. Waiting on FGS input and completion of Samoa Survey Control to define MSL corrections.

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 25 Sep 2015



5. ALB Processing

a. RIEGL 820 Data Processing

- Riegl 820 – Classification commenced this week. Target completion 06 Nov

# of sorties	Flown	Line Selection		WSM		QC & Refraction	
SAM_SWP1	Fugro	Fugro		Fugro		Fugro	
	15	15	100%	15	100%	15	100%
# of tiles	Created	Classified		Final QC			
(0.5x0.5Km)	Fugro	Fugro		Fugro			
	7844	25	0%	0	0%		

b. LADS data processing

- LADS Mk3 Validation / QC 100% complete

# of lines	Flown	Prevaled					
FP_SWP1	Fugro	Fugro					
	344	344	100%				
# of tiles	Total	PreValed		Validated		Final QC/Check	
FP_SWP1	Fugro	Fugro		Fugro		Fugro	
	2139	2139	100%	2139	100%	2139	100%

c. Mk3 / 820 Merging and QC

- Not commenced. Target completion 13 Nov

# of subareas	Surveyed	Processed		Merged		Delivered	
FP_SWP1	FUGRO	Fugro		FUGRO		FUGRO	
	23	0	0%	0	0%	0	0%

1448: Samoa ALT/ALB project Fortnightly Project Report: 25 September 2015

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 25 Sep 2015

6. ALT Processing

a. Riegl 780 Data Processing

- Geodetic Validation nearly complete. Classification commencing next week. Target completion 06 Nov.

Flights	Riprocess Stage	Convert To LAS	Trj Created	ReTile	QC completed	GV Work
Done	38	38	38	38	38	19
Processing	0	0	0	0	0	19
Not started	0	0	0	0	0	0
% completed	100%	100%	100%	100%	100%	50%

# of tiles	Created	Classified		Final QC	
(1x1Km)	Fugro	Fugro		Fugro	
	0	0	-	0	-

b. Satellite Airbus World DEM

- Order in progress with Airbus. Expected delivery ~09 October

c. Aerial Imagery (Phase 1 Sensor)

Flights	IIQ->TIF	Create Overview	EO	Project Creation	APM	Ortho Frames	Ortho tiles
Done	38	38	38	38	0	0	0
Processing	0	0	0	0	0	0	0
Not started	0	0	0	0	38	38	38
% complete	100%	100%	100%	100%	0%	0%	0%

d. Satellite Imagery (Pleiades Mono)

- Fugro MAPS commenced processing of RGB imagery, waiting on World DEM data.

7. Quality Issues and Rectifications

- In correspondence with Nathan Quadros on timing of QC. Tentative date scheduled for ~16 Oct for initial introduction to QC s/w.

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 09 Oct 2015

Created By	**Luke Chamberlain**	**Sent to:**	**Luke Chamberlain**
Status Report	**002**	**Next Report Due**	**23 October 2015**

<u>Project Contacts</u>

Project role	Name	Contact Details
FLC PM	**Luke Chamberlain**	**L.Chamberlain@fugro.com**
FGS PM	**Cristian Gordini**	**C.Gordini@fugro.com**

1. Project Management

- ALB and ALT data undergoing processing currently.
- Satellite Data Ordered to supplement ALT coverage gaps. **Issue identified with availability of World DEM data in time to meet deadlines. See comments below in section 6b.**
- MNRE Survey Control completed for Upolu. Awaiting results for Savaii Island with expected completion 12 October 2015. **Require this ASAP to define MSL corrections.**
- Invoices for mobilisation and ALB Data Collection paid to FLC.

2. Project Timing

Project Start Planning Initiated	Pre- Planned Land Survey Expected to be completed	LIDAR & Imagery Approx. Schedule	Delivery of products Approx. Schedule
1 May 2015	*20 June 2015*	*29 June to 10-Aug-15*	11 Aug to 30 Nov 2015

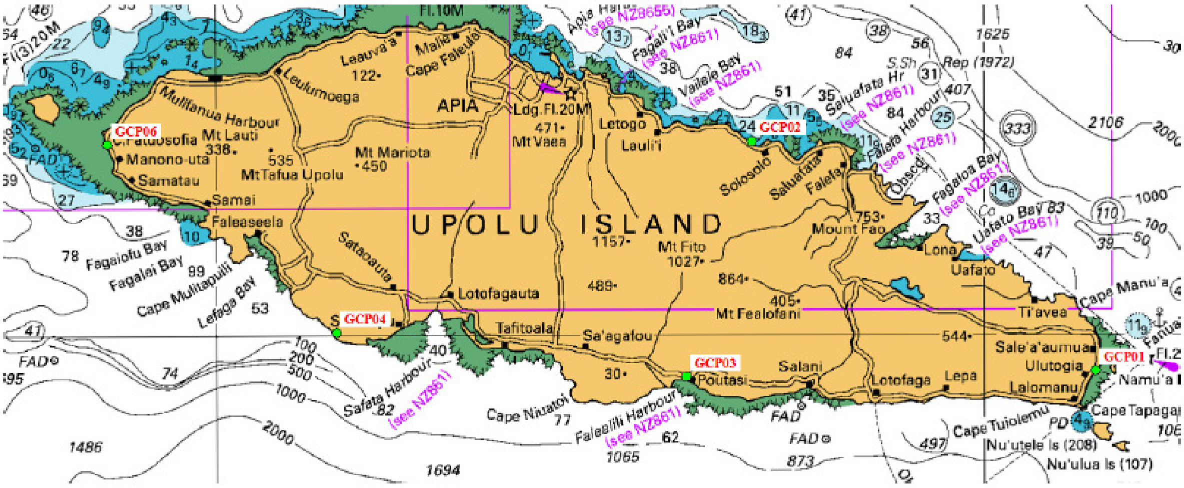
3. Health and Safety

- No incidents to report.

4. Survey Control Work

- FLC / FGS received position details for 5 x Control for Upolu this past week. **Awaiting formal Station description and photo's of each one (GCP01 – 04 and 06).** See figure below.
- MNRE expect to complete control work for Savaii by 12 Oct 2015. Acknowledge that data required to complete processing.
- FLC / FGS compiling Post Survey Spatial Accuracy Report – 80% completed. **Waiting on completion of Samoa Survey Control to define MSL corrections.**

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 09 Oct 2015



5. ALB Processing

a. RIEGL 820 Data Processing

- Riegl 820 – Classification commenced this week. Target completion 06 Nov.

# of sorties	Flown	Line Selection		WSM		QC & Refraction	
SAM_SWP1	Fugro	Fugro		Fugro		Fugro	
	15	15	100%	15	100%	15	100%
# of tiles	Created	Classified		Final QC			
(0.5x0.5Km)	Fugro	Fugro		Fugro			
	7844	964	12%	480	6%		

b. LADS data processing

- LADS Mk3 Validation / QC 100% complete

# of lines	Flown	Prevaled					
FP_SWP1	Fugro	Fugro					
	344	344	100%				
# of tiles	Total	PreValed		Validated		Final QC/Check	
FP_SWP1	Fugro	Fugro		Fugro		Fugro	
	2139	2139	100%	2139	100%	2139	100%

c. Mk3 / 820 Merging and QC

- Not commenced. Target completion 13 Nov

# of subareas	Surveyed	Processed		Merged		Delivered	
FP_SWP1	FUGRO	Fugro		FUGRO		FUGRO	
	23	0	0%	0	0%	0	0%

d. Products

- Not commenced.

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 09 Oct 2015

6. ALT Processing

a. Riegl 780 Data Processing

- Geodetic Validation completed. Classification commenced. Target completion 06 Nov.

Flights	Riprocess Stage	Convert To LAS	Trj Created	ReTile	QC completed	GV Work
Done	38	38	38	38	38	19
Processing	0	0	0	0	0	19
Not started	0	0	0	0	0	0
% completed	100%	100%	100%	100%	100%	50%

# of tiles	Created	Classified		Final QC	
(1x1Km)	Fugro	Fugro		Fugro	
	3313	33	1%	0	0%

b. Satellite Airbus World DEM

- **Fugro MAPS informed FGS that "Airbus World DEM" data won't be processed in time by end of October. FGS looking into alternatives to meet deadline and advise by end of this week. Some sample data from NextMap10 DSM was made available to FGS over the weekend and is now being evaluated against the Lidar data. The second alternative is the DSM derived from ALOS PALSAR imagery 10 m resolution.**

c. Aerial Imagery (Phase 1 Sensor)

Flights	IIQ->TIF	Create Overview	EO	Project Creation	APM	Ortho Frames	Ortho tiles
Done	38	38	38	38	38	38	38
Processing	0	0	0	0	0	0	0
Not started	0	0	0	0	0	0	0
% complete	100%	100%	100%	100%	100%	8%	8%

d. Satellite Imagery (Pleiades Mono)

- Fugro MAPS commenced processing of RGB imagery but now waiting on "World DEM data" to complete.

e. Products

- Clarification feedback queries submitted to MNRE 09 Oct on Intensity Image, DSM, DEM, MKP, CHM, FCM. MNRE QC representative replied on behalf of MNRE for clarification on items.

7. Quality Issues and Rectifications

- In correspondence with Nathan Quadros on timing of QC. Tentative date scheduled for ~16 Oct for initial introduction to QC s/w.

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 23 Oct 2015

Created By	Luke Chamberlain	Sent to:	Luke Chamberlain
Status Report	003	Next Report Due	06 November 2015

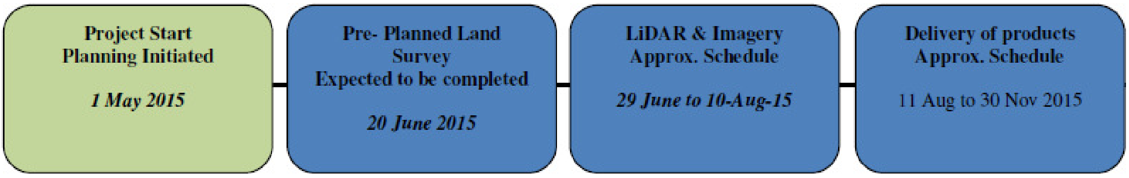
Project Contacts

Project role	Name	Contact Details
FLC PM	**Luke Chamberlain**	L.Chamberlain@fugro.com
FGS PM	**Cristian Gordini**	C.Gordini@fugro.com

1. Project Management

- ALB and ALT data undergoing processing currently.
- Satellite Data Ordered to supplement ALT coverage gaps. Informed by Airbus that **World DEM data now not available in time to meet deadlines.**
  - **Alternative DEM's sourced from NextMap10 (for RGB image processing) and SkyGeo (ALOS-1) for merging into final combined DEM. See comments below in section 6b.**
- MNRE Survey Control received for both Upolu and Savaii.

2. Project Timing



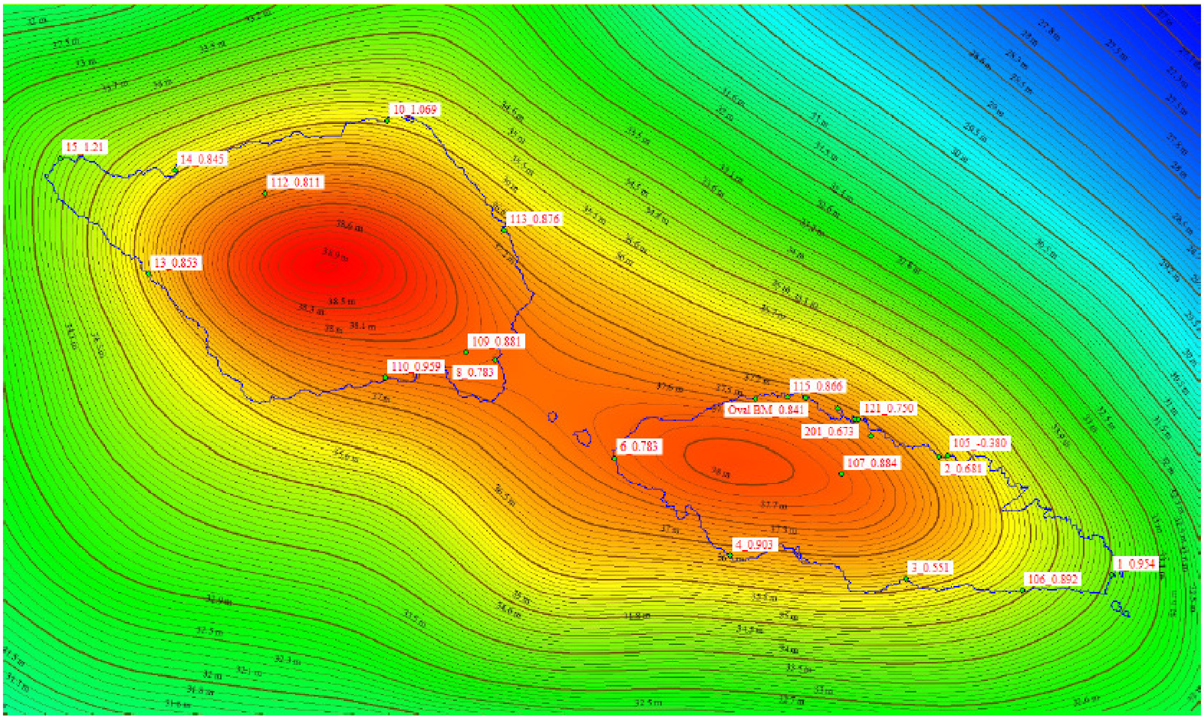
3. Health and Safety

- No incidents to report.

4. Survey Control Work

- FLC / FGS received position details for:
  - 5 x new Survey Control points for Upolu (1, 2, 3, 4, and 6)
  - 4 x new Survey Control points for Savaii (8, 10, 13 and 15)
  - See figure below showing distribution of new and existing survey control along with MSL / EGM08 variation. **Proposed MSL corrections for Upolu = 0.718m and Savaii = 0.887m respectively but will confirm once all comparisons made against LiDAR data.**
  - **Awaiting formal Station description and photo's of each one from MNRE Surveyors.**
- FLC / FGS compiling Post Survey Spatial Accuracy Report
  - 98% completed. Dispatch by Thu 29 Oct for review.

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 23 Oct 2015



5. ALB Processing

a. RIEGL 820 Data Processing

- Riegl 820 – Classification commenced. Target completion 06 Nov.

# of sorties	Flown	Line Selection		WSM		QC & Refraction	
SAM_SWP1	Fugro	Fugro		Fugro		Fugro	
	15	15	100%	15	100%	15	100%
# of tiles	Created	Classified		Final QC			
(0.5x0.5Km)	Fugro	Fugro		Fugro			
	7844	3952	50%	3500	45%		

b. LADS data processing

- LADS Mk3 Validation / QC 100% complete

# of lines	Flown	Prevaled					
FP_SWP1	Fugro	Fugro					
	344	344	100%				
# of tiles	Total	PreValed		Validated		Final QC/Check	
FP_SWP1	Fugro	Fugro		Fugro		Fugro	
	2139	2139	100%	2139	100%	2139	100%

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 23 Oct 2015

c. **Mk3 / 820 Merging and QC**

- Not commenced. Target completion 13 Nov

# of subareas	Surveyed	Processed		Merged		Delivered	
FP_SWP1	FUGRO	Fugro		FUGRO		FUGRO	
	23	0	0%	0	0%	0	0%

d. **Products**

- Not commenced.

6. ALT Processing

a. **Riegl 780 Data Processing**

- Geodetic Validation completed. Classification commenced. Target completion 06 Nov.

Flights	Riprocess Stage	Convert To LAS	Trj Created	ReTile	QC completed	GV Work
Done	38	38	38	38	38	19
Processing	0	0	0	0	0	19
Not started	0	0	0	0	0	0
% completed	100%	100%	100%	100%	100%	100%

# of tiles	Created	Classified / QC	
(1x1Km)	Fugro	Fugro	
	3313	1017	31%

b. Satellite Derived DEM

- Fugro MAPS informed FGS that "Airbus World DEM" data won't be processed in time by end of October.
- Alternatives sourced:
    - **NextMap10 DSM** was made available to FGS and is being used to process the Airbus Pleiades Mono imagery. **Addendum received from InterMap to expand EULA license agreements to cover broader usage within MNRE.**
    - ALOS-1 PALSAR imagery 10 m resolution has been ordered and will be incorporated in the final topographic DEM model. Expected to receive this data mid-November now. **Addendum received from SkyGeo to expand EULA license agreements to cover broader usage within MNRE.**

c. **Aerial Imagery (Phase 1 Sensor)**

Flights	IIQ->TIF	Create Overview	EO	Project Creation	APM	Ortho Frames	Ortho Tiles (3313)
Done	38	38	38	38	38	38	1405
Processing	0	0	0	0	0	0	0
Not started	0	0	0	0	0	0	0
% complete	100%	100%	100%	100%	100%	100%	42%

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 23 Oct 2015

d. Satellite Imagery (Airbus Pleiades Mono)

- Fugro MAPS continuing the processing of **Pleiades Mono** Imagery with NextMap10 DSM.
  - Target completion 02 Nov.
  - Fugro pursuing broader License terms for use of imagery, ongoing.
  - Merging with Phase 1 / Redlake Imagery, target completion 15 Nov.

e. Products

- Various ongoing clarification feedback queries submitted to MNRE QC representative.

7. Quality Issues and Rectifications

- In correspondence with Nathan Quadros on timing of QC. Tentative date re-scheduled for ~13 Nov for introduction to QC s/w.

1448: Samoa ALT/ALB project   Fortnightly Project Report: 23 October 2015

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 06 Nov 2015

Created By	**Luke Chamberlain**	**Sent to:**	**Luke Chamberlain**
Status Report	**004**	**Next Report Due**	**20 November 2015**

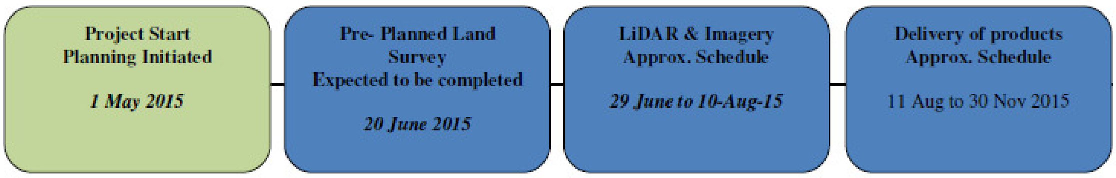
Project Contacts

Project role	Name	Contact Details
FLC PM	**Luke Chamberlain**	**L.Chamberlain@fugro.com**
FGS PM	**Cristian Gordini**	**C.Gordini@fugro.com**

1. Project Management

- ALB and ALT data undergoing processing currently and in adjustment / merging stages
- Satellite Data Status:
  - Pleiades Imagery finalised mid Nov.
  - Alternative DEM's sourced from NextMap10 (for RGB image processing) and SkyGeo (ALOS-1) for merging into final combined DEM. See comments below in section 6b.
- MNRE Survey Control received for both Upolu and Savaii. **Waiting on pictures and Station Summaries from MNRE surveyors for inclusion into report.**
- **FLC currently drafting ALT data collection invoice to be forwarded to MNRE for review / payment**.

2. Project Timing



3. Health and Safety

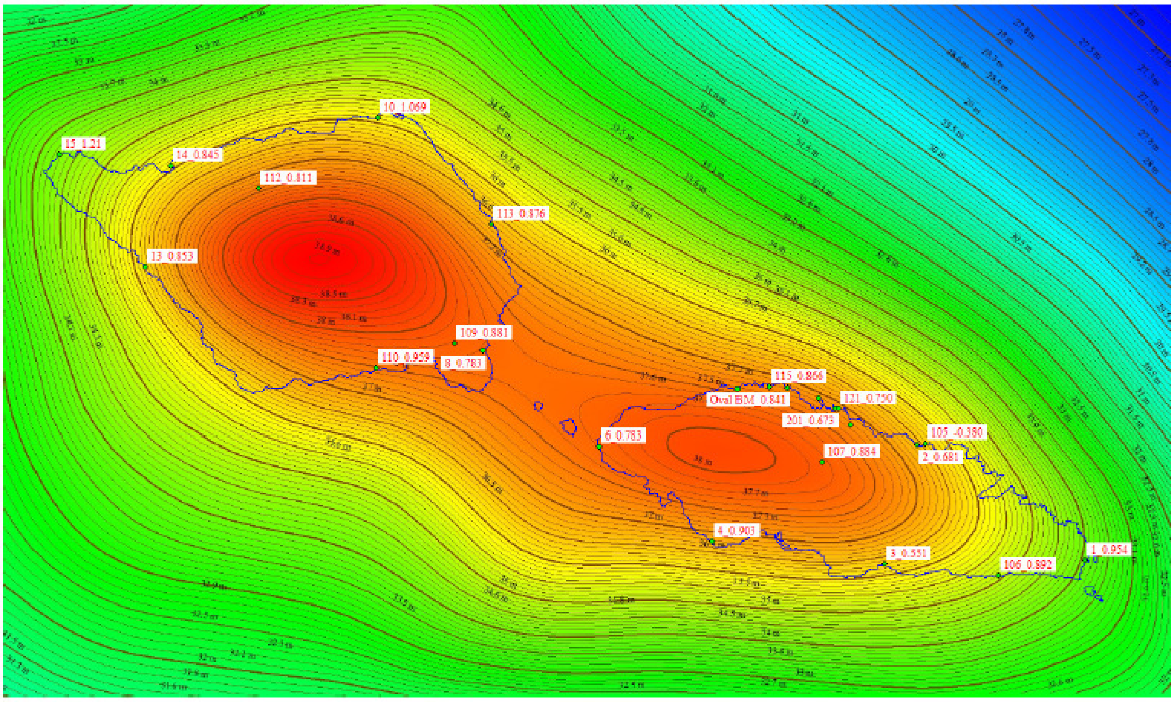
- No incidents to report.

4. Survey Control Work

- FLC / FGS received all survey position details for:
  - 5 x new Survey Control points for Upolu (1, 2, 3, 4, and 6)
  - 4 x new Survey Control points for Savaii (8, 10, 13 and 15)
  - See figure below showing distribution of new and existing survey control along with MSL / EGM08 variation.
  - **Proposed MSL corrections for Upolu = 0.718m and Savaii = 0.887m respectively but will confirm once all comparisons made against adjusted LiDAR data.**
  - **Awaiting formal Station description and photo's of each one from MNRE Surveyors.**

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 06 Nov 2015

- FLC / FGS compiling Post Survey Spatial Accuracy Report
  - 98% completed. Delayed to incorporate the survey control comparisons on final adjusted datasets and subsequent recommendations to shift to MSL, aiming for completion 18 Nov.



1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 06 Nov 2015

5. ALB Processing

a. RIEGL 820 Data Processing

- Riegl 820 – Classification 100% completed.

# of sorties	Flown	Line Selection		WSM		QC & Refraction	
SAM_SWP1	Fugro	Fugro		Fugro		Fugro	
	15	15	100%	15	100%	15	100%
# of tiles	Created	Classified		Final QC			
(0.5x0.5Km)	Fugro	Fugro		Fugro			
	7844	7844	100%	7844	100%		

b. LADS data processing

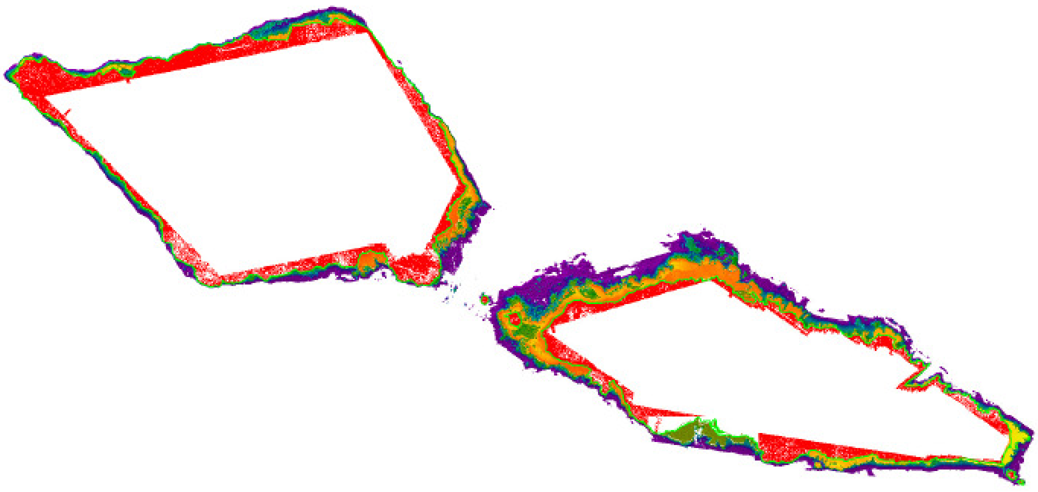
- LADS Mk3 Validation / QC 100% complete

# of lines	Flown	Prevaled					
FP_SWP1	Fugro	Fugro					
	344	344	100%				
# of tiles	Total	PreValed		Validated		Final QC/Check	
FP_SWP1	Fugro	Fugro		Fugro		Fugro	
	2139	2139	100%	2139	100%	2139	100%

c. Mk3 / 820 Merging and QC

- **In progress**. Target completion 13 Nov. Preliminary image of ALB coverage below.

# of subareas	Surveyed	Processed		Merged		Delivered	
FP_SWP1	FUGRO	Fugro		FUGRO		FUGRO	
	23	0	0%	0	0%	0	0%



1448: Samoa ALT/ALB project Fortnightly Project Report: 06 November 2015

d. Products

- Final products will be compiled once data shifted to MSL

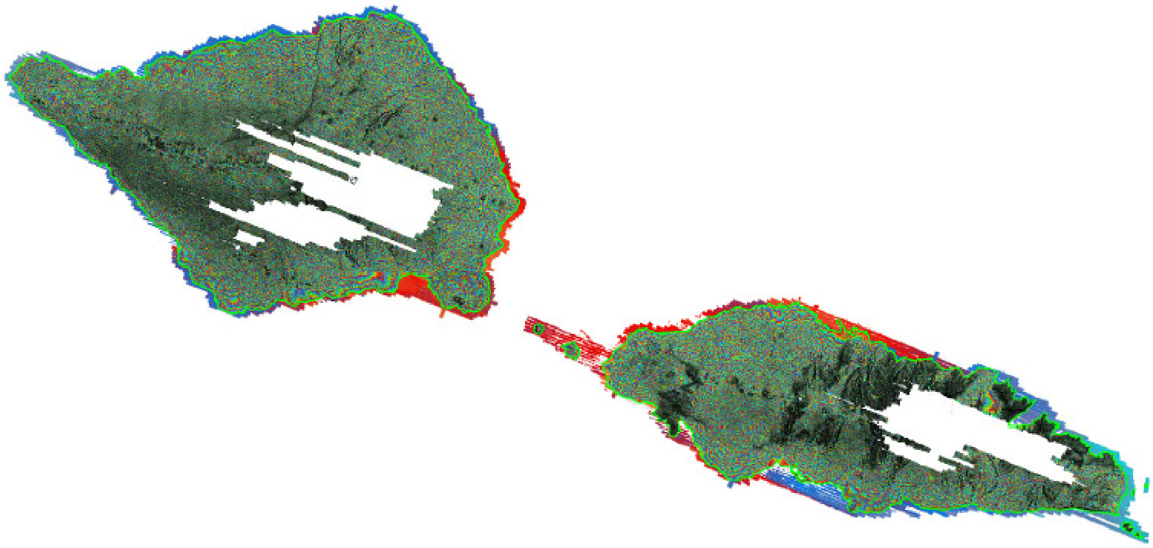
6. ALT Processing

a. Riegl 780 Data Processing

- ALT Classification completed and awaiting small area in Fagaloa Bay to be provided from ALB data set to cover gap in bay. Target completion 20 Nov.

Flights	Riprocess Stage	Convert To LAS	Trj Created	ReTile	QC completed	GV Work
Done	38	38	38	38	38	19
Processing	0	0	0	0	0	19
Not started	0	0	0	0	0	0
% completed	100%	100%	100%	100%	100%	100%

# of tiles	Created	Classified / QC	
(1x1Km)	Fugro	Fugro	
	3313	3313	100%



b. Satellite Derived DEM

- **NextMap10 DSM** was made available to FGS and is being used to process the Airbus Pleiades Mono imagery.
    - **May have to be used for final product depending on quality of ALOS-1 data**.
    - Addendum received from InterMap to expand EULA license agreements to cover broader usage within MNRE.

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 06 Nov 2015

- ALOS-1 PALSAR imagery 10 m resolution
  - **Has been received by FGS but end quality not as good as NextMap10, being investigated if it can be improved.**
  - **Either the ALOS-1 or NextMap10 DEM will be matched into the ALT data once received**
  - Addendum received from SkyGeo to expand EULA license agreements to cover broader usage within MNRE.

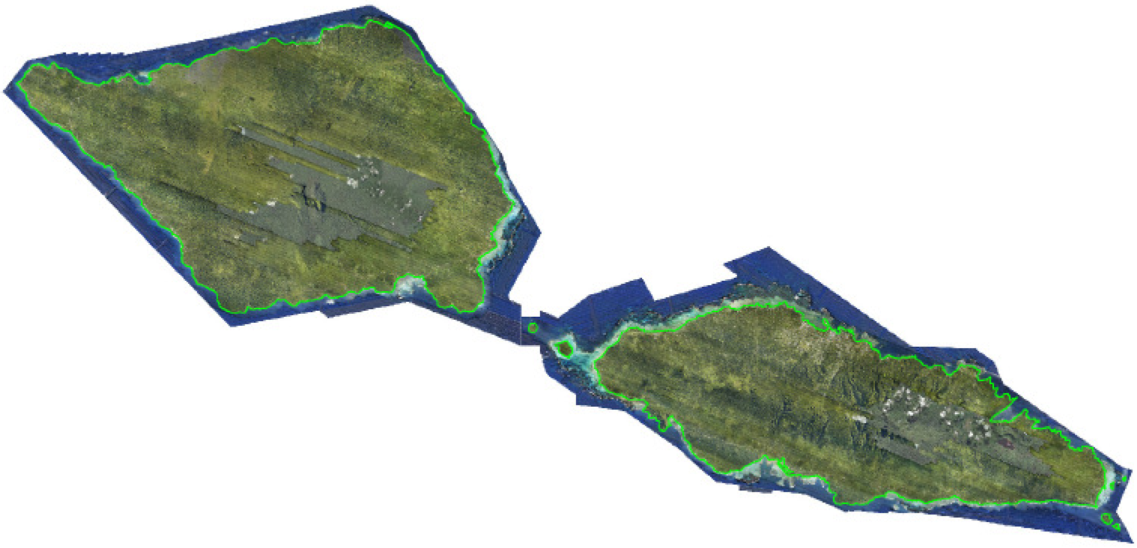
c. RGB Imagery

- **(Phase 1 Sensor and Redlake) Processing**

Flights	IIQ->TIF	Create Overview	EO	Project Creation	APM	Ortho Frames	Ortho Tiles (3931)
Done	38	38	38	38	38	38	3650
Processing	0	0	0	0	0	0	0
Not started	0	0	0	0	0	0	0
% complete	100%	100%	100%	100%	100%	100%	92%

- **Satellite Imagery (Airbus Pleiades Mono)**
  - Fugro MAPS continuing the processing of **Pleiades Mono** Imagery with NextMap10 DSM.
    a. Prelim product supplied but final data delayed to 13 Nov for some additional improvement in quality.
    b. Airbus not willing to relax license terms beyond MNRE's / Samoan Govt use, otherwise will have to pursue additional license for wider distribution.
    c. Merging with Phase 1 / Redlake Imagery, target completion 19 Nov.
    d. Preliminary imagery below with all three image sources from Phase One, Redlake and Pleiades sensors.

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 06 Nov 2015



d. Products

- Final products will be compiled once data shifted to MSL

7. Quality Issues and Rectifications

- To ensure seamless dataset, proposing to:
  - assess both the bathymetric and topographic data against the Ellipsoidal survey control
  - make minor adjustments to both ALT / ALB ellipsoidal datasets to match
  - apply the EGM08 geoid and applicable MSL correction (based on survey control again)
- In correspondence with Nathan Quadros on timing of QC. Tentative date re-scheduled for mid - Nov for introduction to QC s/w.

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 04 Dec 2015

Created By	**Luke Chamberlain**	**Sent to:**	**Luke Chamberlain**
Status Report	**005**	**Next Report Due**	**18 December 2015**

Project Contacts

Project role	Name	Contact Details
FLC PM	**Luke Chamberlain**	L.Chamberlain@fugro.com
FGS PM	**Cristian Gordini**	C.Gordini@fugro.com

1. Project Management

- ALB and ALT data undergoing final adjustment / merging stages
- Satellite Data Status:
    - Pleiades Imagery completed and merged final mosaics created.
    - NextMap10 DEM being merged into ALT into final combined ALT data. See comments below in section 6b.
- MNRE Survey Control Station Summaries received from MNRE surveyors for inclusion into report.
- FLC submitted ALT data collection invoice to MNRE for review / payment.
- Contract extension request submitted to MNRE to **31 Jan 2016** to cover CRCsi QC process also with no penalties.

2. Project Timing

Project Start Planning Initiated ***1 May 2015***	**Pre- Planned Land Survey Expected to be completed** ***20 June 2015***	**LiDAR & Imagery Approx. Schedule** ***29 June to 10-Aug-15***	**Delivery of products Approx. Schedule** 11 Aug to 15 Dec 2015

3. Health and Safety

- No incidents to report.

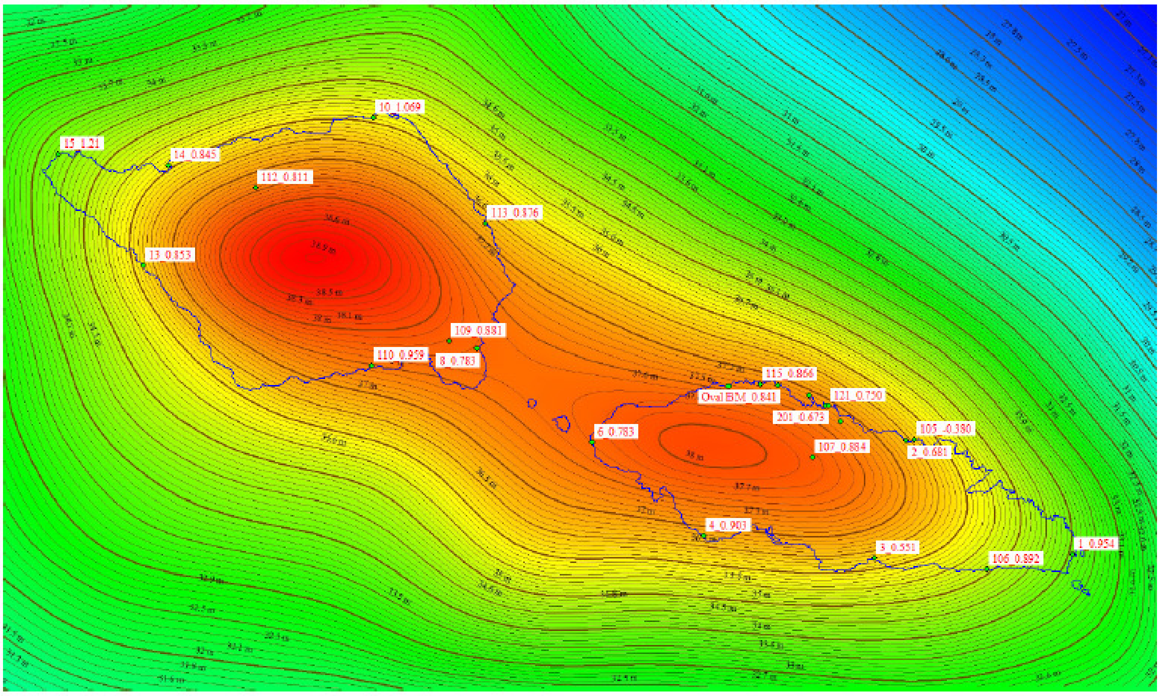
4. Survey Control Work

- FLC / FGS finalising flight line adjustments and checks against Survey Control points:
    - ALT ellipsoidal comparisons with Survey Control are:
        - Upolu = -0.16m +/- 0.10m
        - Savaii = -0.19m +/- 0.12m
    - ALB ellipsoidal comparisons with Survey Control are:
        - Upolu = -0.14m +/- 0.07m
        - Savaii = -0.18m +/- 0.09m
    - Proposing to shift all respective Ellipsoid datasets by these amounts so mean average = 0

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 04 Dec 2015

- Proposed MSL corrections for Upolu = 0.718m and Savaii = 0.887m respectively but will confirm once all comparisons made against adjusted LiDAR data.
- **Station descriptions received but waiting on photo's still from MNRE Surveyors.**

- FLC / FGS compiling Post Survey Spatial Accuracy Report
  - 98% completed. Dispatched draft report to CRCSi / MNRE for comment 04 Dec.



1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 04 Dec 2015

5. ALB Processing

a. RIEGL 820 Data Processing

- Riegl 820 – Classification 100% completed.

# of sorties	Flown	Line Selection		WSM		QC & Refraction	
SAM_SWP1	Fugro	Fugro		Fugro		Fugro	
	15	15	100%	15	100%	15	100%
# of tiles	Created	Classified		Final QC			
(0.5x0.5Km)	Fugro	Fugro		Fugro			
	7844	7844	100%	7844	100%		

b. LADS data processing

- LADS Mk3 Validation / QC 100% complete

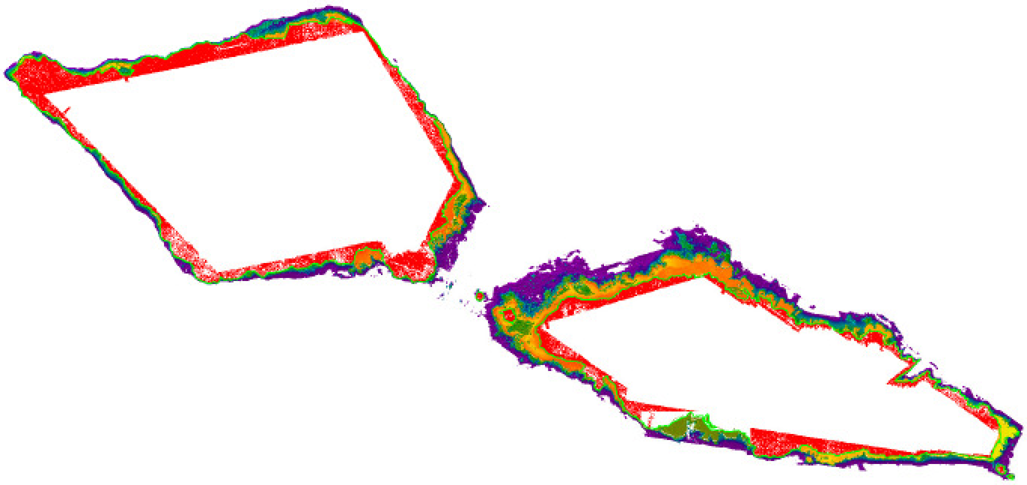
# of lines	Flown	Prevaled					
FP_SWP1	Fugro	Fugro					
	344	344	100%				
# of tiles	Total	PreValed		Validated		Final QC/Check	
FP_SWP1	Fugro	Fugro		Fugro		Fugro	
	2139	2139	100%	2139	100%	2139	100%

c. Mk3 / 820 Merging and QC

- **In progress**. Target completion 13 Nov. Preliminary image of ALB coverage below.

# of subareas	Surveyed	Processed		Merged		Delivered	
FP_SWP1	FUGRO	Fugro		FUGRO		FUGRO	
	23	23	100%	20	**87%**	0	0%

1448: Samoa ALT / ALB project
Project Report for Fortnightly Ending: 04 Dec 2015



d. Products

- Final products will be compiled once data shifted to MSL. Target completion 15 Dec.

6. ALT Processing

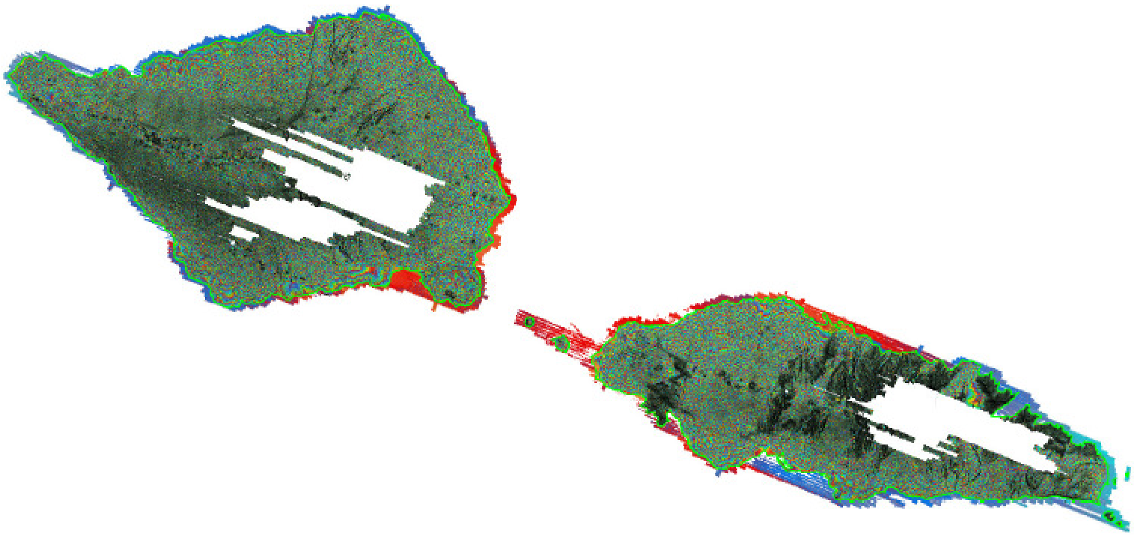
a. Riegl 780 Data Processing

- ALT Classification completed.
  - NextMap10 merging 50% completed.
  - Waiting small area in Fagaloa Bay to be provided from ALB data set to cover gap in bay. FLC experienced delays due to processing issue now resolved. Target completion 11 Dec.

Flights	Riprocess Stage	Convert To LAS	Trj Created	ReTile	QC completed	GV Work
Done	38	38	38	38	38	19
Processing	0	0	0	0	0	19
Not started	0	0	0	0	0	0
% completed	100%	100%	100%	100%	100%	100%

# of tiles	Created	Classified / QC	
(1x1Km)	Fugro	Fugro	
	3313	3313	100%

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 04 Dec 2015



b. Satellite Derived DEM

- **NextMap10 DSM**
  - Was used to process the Airbus Pleiades Mono imagery
  - **Also used for final DEM product and currently 50% merged with ALT data.**
  - Addendum received from InterMap to expand EULA license agreements to cover broader usage within MNRE.

- ALOS-1 PALSAR imagery 10 m resolution
  - Has been received by FGS but end quality not as good. NextMap10 DSM being used

c. RGB Imagery

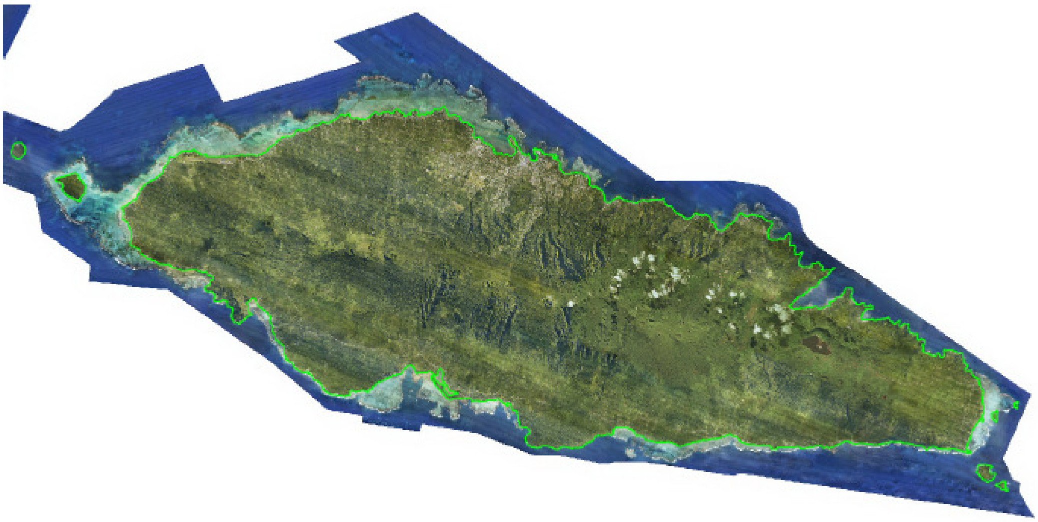
- **(Phase 1 Sensor and Redlake) Processing**

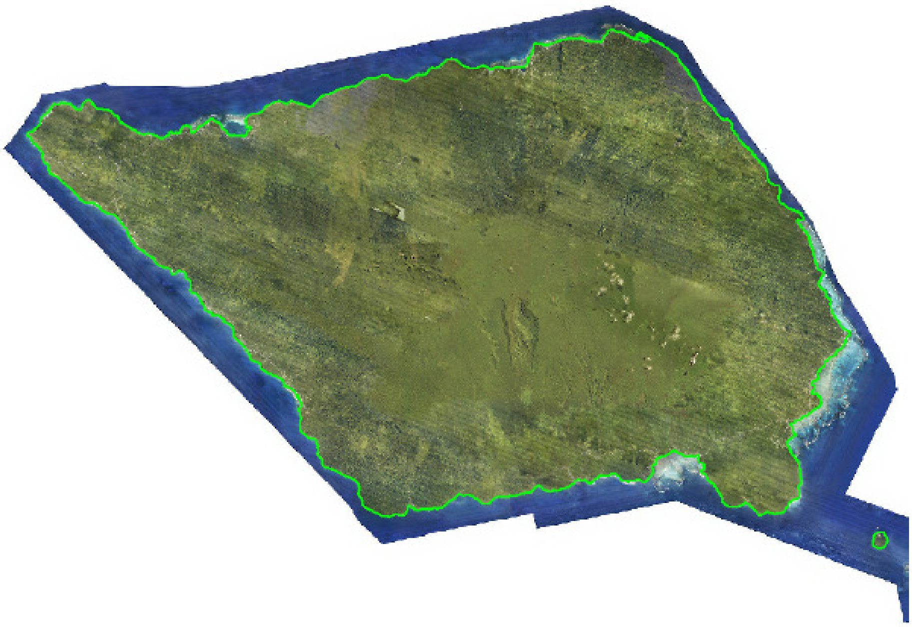
Flights	IIQ->TIF	Create Overview	EO	Project Creation	APM	Ortho Frames	Ortho Tiles (3931)
Done	38	38	38	38	38	38	3650
Processing	0	0	0	0	0	0	0
Not started	0	0	0	0	0	0	0
% complete	100%	100%	100%	100%	100%	100%	100%

- **Satellite Imagery (Airbus Pleiades Mono)**
  - Fugro MAPS continuing the processing of **Pleiades Mono** Imagery with NextMap10 DSM.
    a. Prelim product supplied but final data delayed to 13 Nov for some additional improvement in quality.

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 04 Dec 2015

b. **Airbus not willing to relax license terms beyond MNRE's / Samoan Govt use, MNRE will have to pursue additional license for wider distribution if required in future.**
c. Merging with Phase 1 / Redlake Imagery, 100% completed 19 Nov.
d. Final imagery below with all three image sources from Phase One, Redlake and Pleiades sensors.





1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 04 Dec 2015

d. **Products**
- Final products will be compiled once data shifted to MSL, target 15 Dec.

7. Quality Issues and Rectifications

- To ensure seamless dataset, proposing to:
  - assess both the bathymetric and topographic data against the Ellipsoidal survey control
  - make minor adjustments to both ALT / ALB ellipsoidal datasets to match
  - apply the EGM08 geoid and applicable MSL correction (based on survey control again)
- **Post Survey Spatial Accuracy report (Draft) submitted to CRCSi / MNRE , 04 Dec 2015 for comment.**
- **In correspondence with Nathan Quadros on timing of QC. Re-scheduled for 18 Dec to handover data for QC.**

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 18 Dec 2015

Created By	**Luke Chamberlain**	**Sent to:**	**Luke Chamberlain**
Status Report	**006**	**Next Report Due**	**04 January 2015**

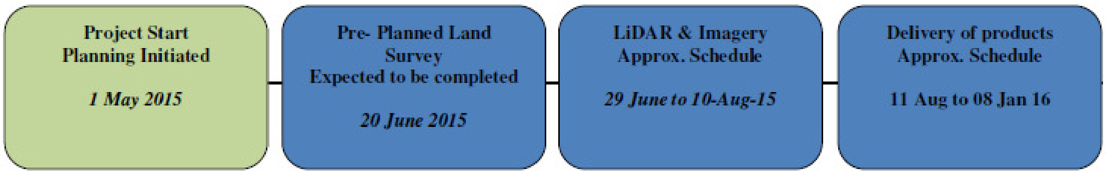
Project Contacts

Project role	Name	Contact Details
FLC PM	**Luke Chamberlain**	L.Chamberlain@fugro.com
FGS PM	**Cristian Gordini**	C.Gordini@fugro.com

1. Project Management

- ALT data
  - LAS file reduction 100% complete and supplied to FLC for “seamless” product generation.
  - 85% complete on topographic product generation.
- ALB data
  - Delayed one week due to error in final stages of merging, 87% complete currently.
- Data delivery now delayed to **08 January 2016** to CRCSI for QC.
- FLC submitted ALT data collection invoice to MNRE for payment, overdue as of **08 Dec 2015**. (Now subject to contract revision to be signed with new contract extension)
- Contract extension request submitted to MNRE to **31 Mar 2016** to cover CRCsi QC process also with no penalties.

2. Project Timing



3. Health and Safety

- No incidents to report.

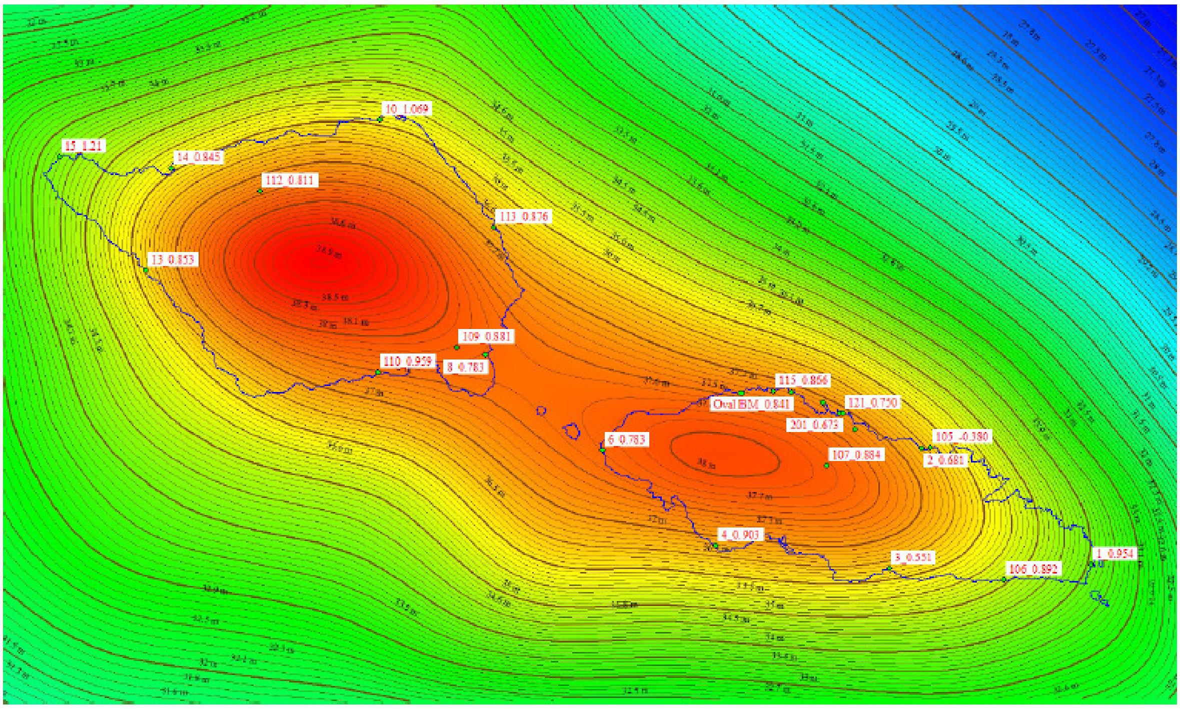
4. Survey Control Work

- FLC / FGS finalising flight line adjustments and checks against Survey Control points:
  - ALT ellipsoidal comparisons with Survey Control are:
    - Upolu = -0.16m +/- 0.10m
    - Savaii = -0.19m +/- 0.12m
  - ALB ellipsoidal comparisons with Survey Control are:
    - Upolu = -0.14m +/- 0.07m
    - Savaii = -0.18m +/- 0.09m

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 18 Dec 2015

- Proposing to shift all respective Ellipsoid datasets by these amounts so mean average = 0
- **Revised proposed MSL corrections to use for entire project, which will be based on the ALT agreement now for Upolu = 0.689m and Savaii = 0.824m respectively.**
- **Station descriptions received but waiting on photo's still from MNRE Surveyors.**

- Post Survey Spatial Accuracy Report
  - Draft submitted for comment 04 Dec. CRCSI feedback received 11 Dec for action.
  - **Crosstie results 100% completed for ALT data and now incorporated into report.**
  - Will submit final report once ALB data 100% reduced, 24 Dec 2015.



1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 18 Dec 2015

5. ALB Processing

a. RIEGL 820 Data Processing

- Riegl 820 – Classification 100% completed.

# of sorties	Flown	Line Selection		WSM		QC & Refraction	
SAM_SWP1	Fugro	Fugro		Fugro		Fugro	
	15	15	100%	15	100%	15	100%
# of tiles	Created	Classified		Final QC			
(0.5x0.5Km)	Fugro	Fugro		Fugro			
	7844	7844	100%	7844	100%		

b. LADS data processing

- LADS Mk3 Validation / QC 100% complete

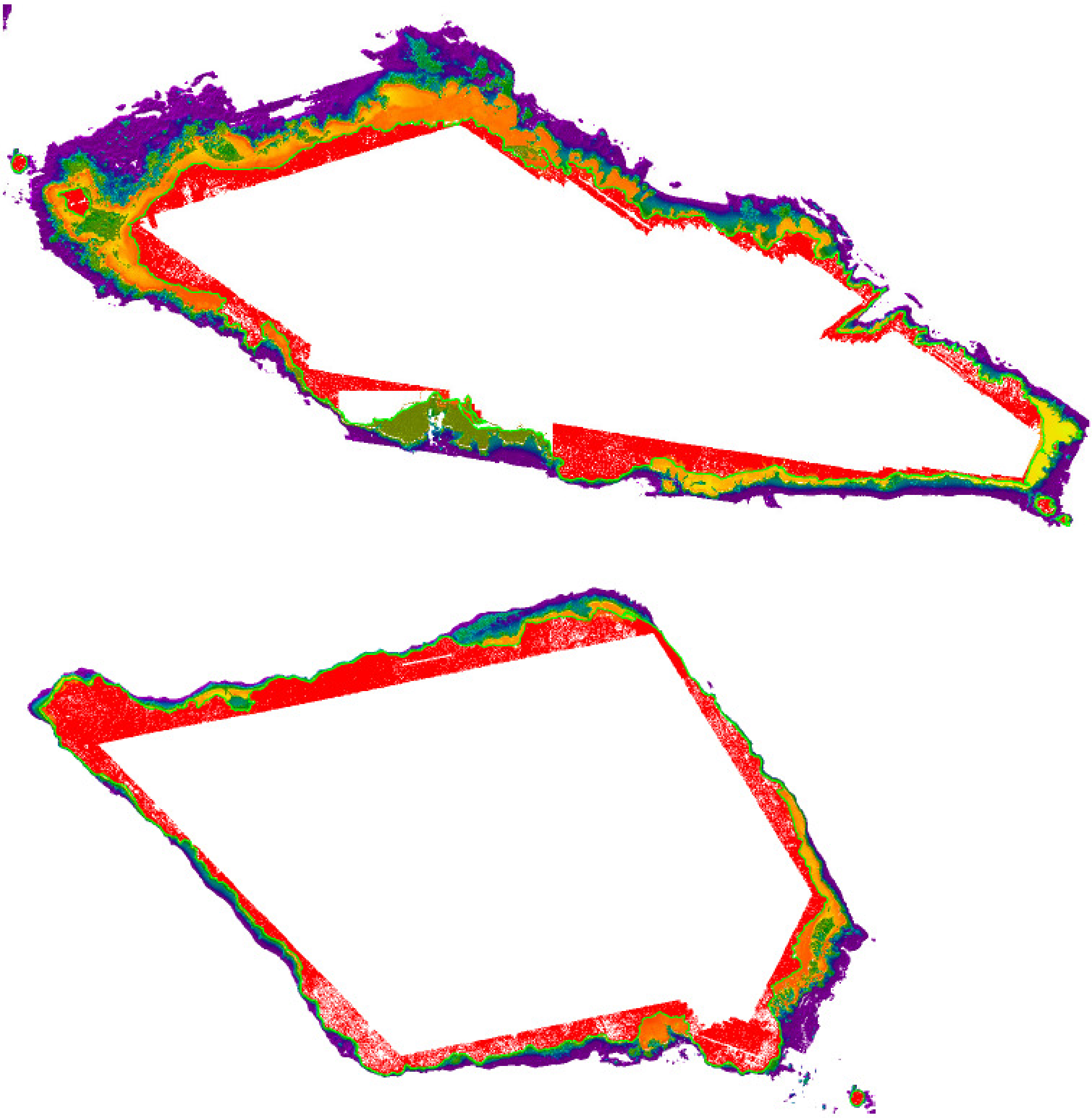
# of lines	Flown	Prevaled					
FP_SWP1	Fugro	Fugro					
	344	344	100%				
# of tiles	Total	PreValed		Validated		Final QC/Check	
FP_SWP1	Fugro	Fugro		Fugro		Fugro	
	2139	2139	100%	2139	100%	2139	100%

c. Mk3 / 820 Merging and QC

- **In progress**. Target completion 13 Nov. Preliminary image of ALB coverage below.

# of subareas	Surveyed	Processed		Merged		Delivered	
FP_SWP1	FUGRO	Fugro		FUGRO		FUGRO	
	23	23	100%	20	**87%**	0	0%

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 18 Dec 2015



d. Bathymetric and Seamless Products

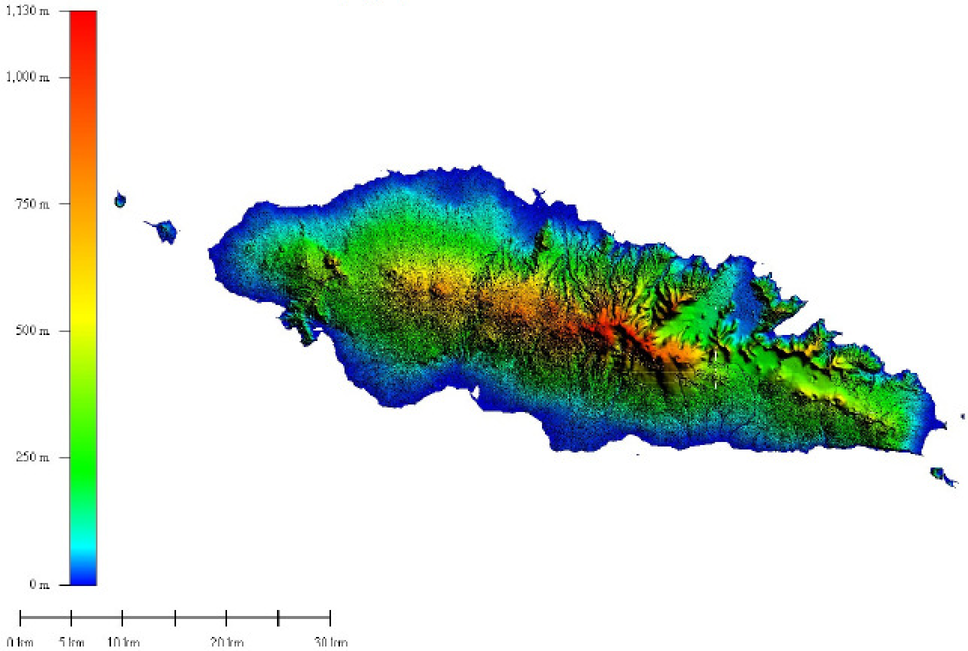
- Final products will be compiled once data shifted to MSL. Target completion now 08 January (given Christmas shutdown from 24 Dec to 04 Jan).

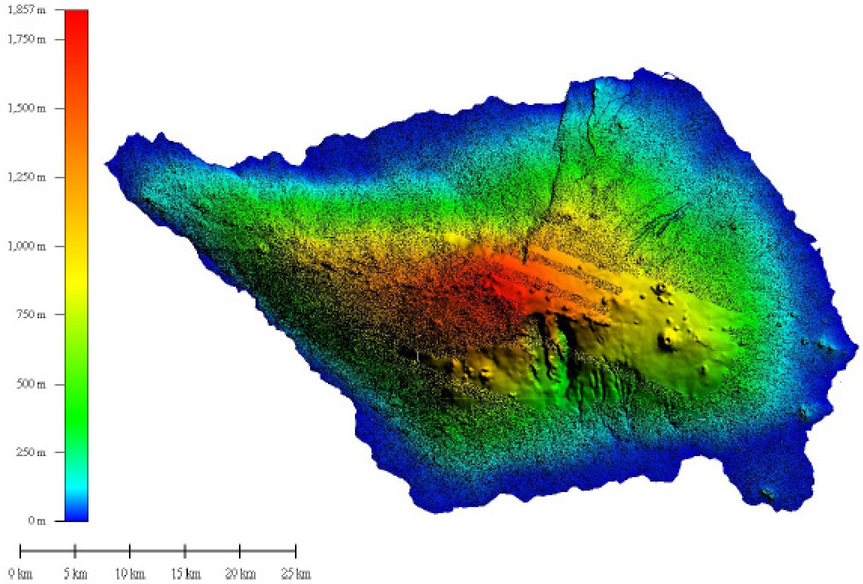
1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 18 Dec 2015

6. ALT Processing

a. Riegl 780 Data Processing

- ALT Classification and merging 100% completed.
  - Fagaloa Bay data from ALB data set also 100% completed and incorporated into topographic dataset.





1448: Samoa ALT/ALB project Fortnightly Project Report: 18 December 2015

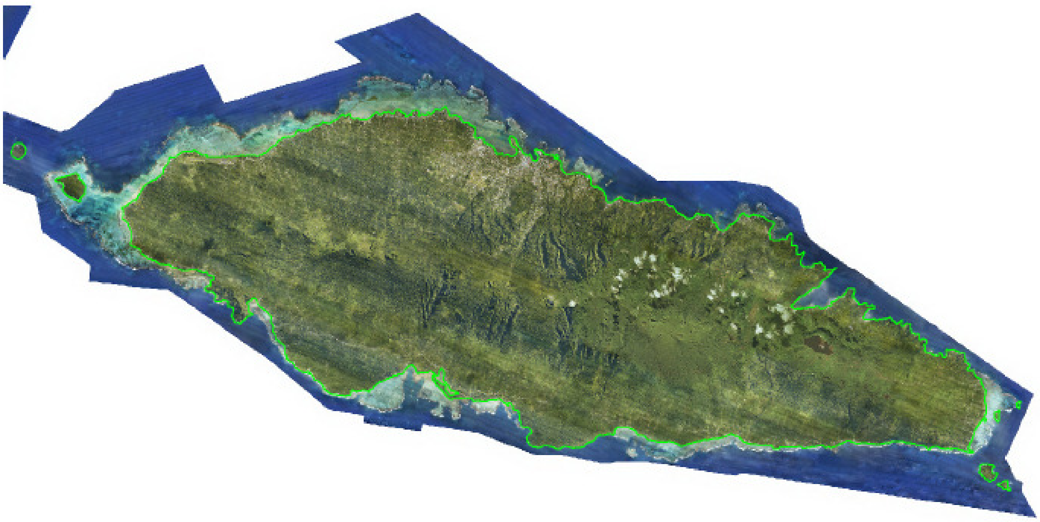
1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 18 Dec 2015

b. Satellite Derived DEM

- **NextMap10 DSM**
  - **100% merged with ALT data and used to generate the final ALT data products.**

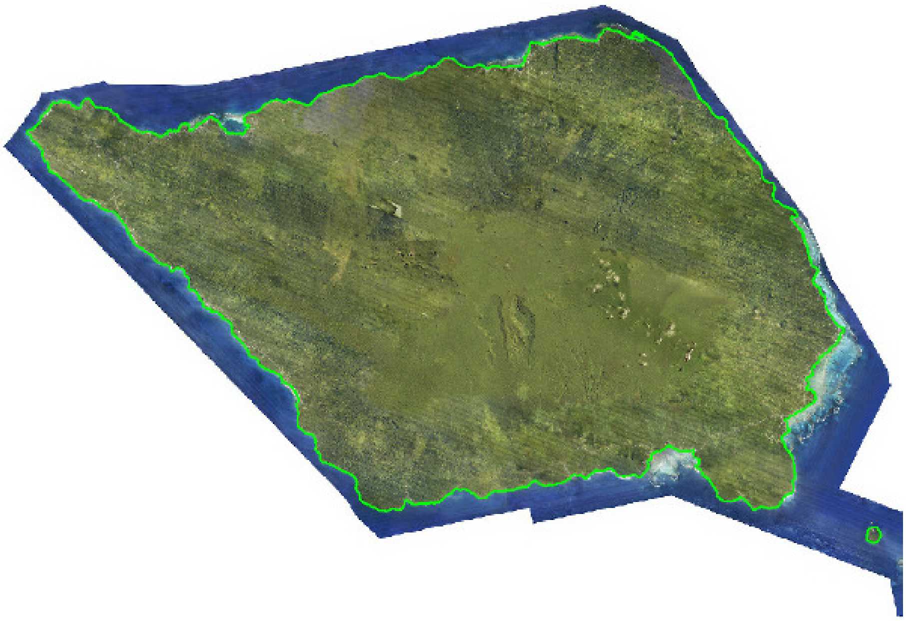
c. RGB Imagery

- Final imagery below with all three image sources from Phase One, Redlake and Pleiades sensors 100% completed. One combined topographic / bathymetric dataset produced for each survey area.
- Airbus not willing to relax license terms beyond MNRE's / Samoan Govt use, MNRE will have to pursue additional license for wider distribution if required in future.
- **Suggestion from CRCSI to provide an additional mosaic with Pleiades Imagery clipped out for distribution outside of Samoan Govt if required**.



Final combined Phase 1, Redlake and Pleiades Imagery for - Upolu Is, Samoa

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 18 Dec 2015



Final combined Phase 1, Redlake and Pleiades Imagery for – Savaii Is, Samoa

d. Topographic Products

- Final products currently being compiled, target completion for topographic components Tues, 22 Dec.

7. Quality Issues and Rectifications

- To ensure seamless dataset, proposing to:
  - assess both the bathymetric and topographic data against the Ellipsoidal survey control
  - make minor adjustments to both ALT / ALB ellipsoidal datasets to match
  - apply the EGM08 geoid and applicable MSL correction (based on survey control again)
- **Post Survey Spatial Accuracy report feedback received from CRCSi, 11 Dec 2015. Some minor actions completed and will submit final versions once ALB merging process completed.**
- **In correspondence with Nathan Quadros on timing of QC. Re-scheduled for 08 Jan to handover data for QC.**

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 01 Jan 2016

Created By	**Luke Chamberlain**	**Sent to:**	**Luke Chamberlain**
Status Report	**007**	**Next Report Due**	**15 January 2015**

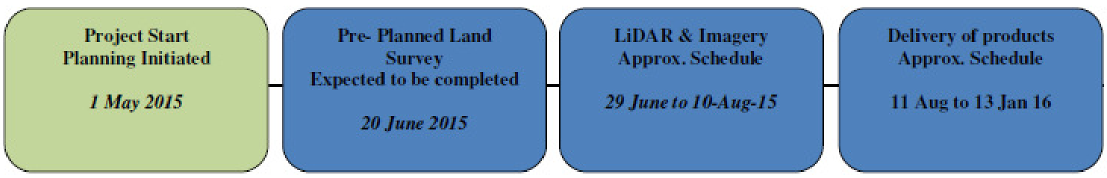
Project Contacts

Project role	Name	Contact Details
FLC PM	**Luke Chamberlain**	**L.Chamberlain@fugro.com**
FGS PM	**Cristian Gordini**	**C.Gordini@fugro.com**

1. Project Management

- ALT data
  - LAS file reduction 100% complete and supplied to FLC for "seamless" product generation.
  - 100% complete on topographic product generation and currently having final QC (Savaii 100% complete, Upolu 50% complete).
- ALB data
  - Savaii ALB merging 100% complete and reduced to MSL.
  - Upolu ALB merging 80% complete with final reduction to MSL remaining to do.
- Data delivery discussed with CRCSI for QC and arranged to
  - deliver **Savaii Survey Area** by Friday 08 Jan
  - and **Upolu Survey Area** by Thursday 14 Jan.
- FLC submitted ALT data collection invoice to MNRE for payment, overdue as of **08 Dec 2015**. (Now subject to contract revision to be signed with new contract extension - Ongoing)
- Contract extension request submitted to MNRE to **31 Mar 2016** to cover CRCsi QC process also with no penalties.

2. Project Timing



3. Health and Safety

- No incidents to report.

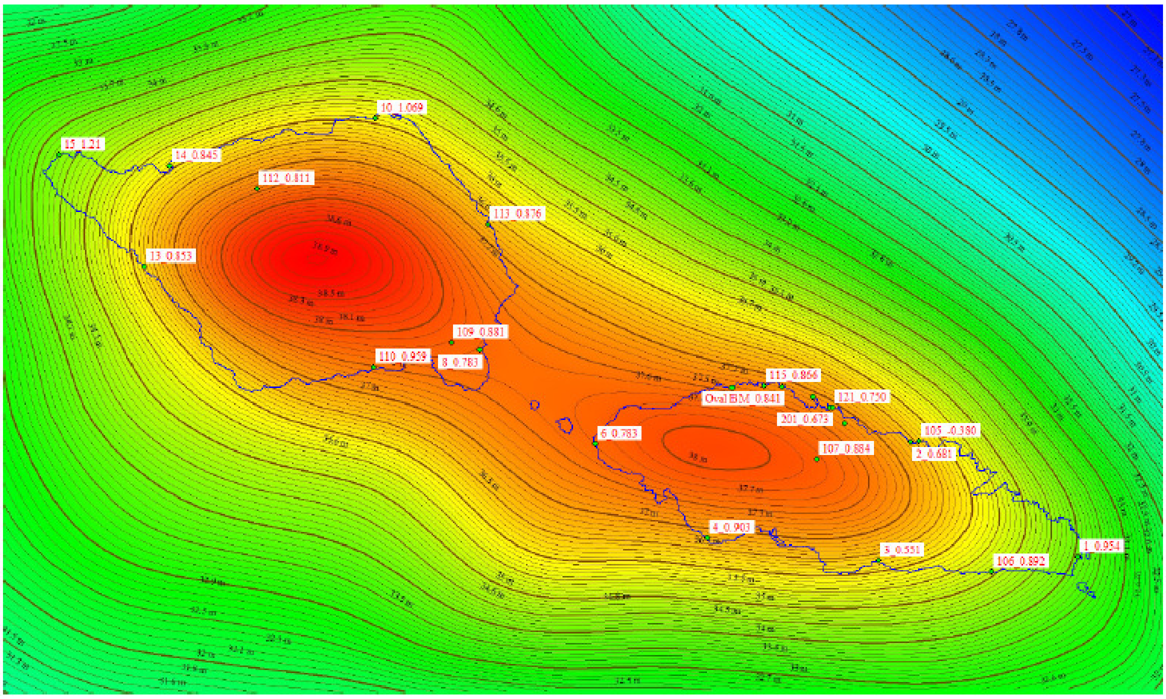
4. Survey Control Work

- FLC / FGS finalising flight line adjustments and checks against Survey Control points:
  - ALT ellipsoidal comparisons with Survey Control are:
    - Upolu = -0.16m +/- 0.10m

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 01 Jan 2016

- Savaii = -0.19m +/- 0.12m
- ALB ellipsoidal comparisons with Survey Control are:
  - Upolu = -0.14m +/- 0.07m
  - Savaii = -0.18m +/- 0.08m
- Proposing to shift all respective Ellipsoid datasets by these amounts so mean average = 0
- Revised proposed MSL corrections to use for entire project, which will be based on the ALT agreement now for Upolu = 0.689m and Savaii = 0.824m respectively.
- Received most Station descriptions and photo's from MNRE Surveyors. One station description for BM7500 requested to incorporate into report.

- Post Survey Spatial Accuracy Report
  - All outstanding survey control comparisons completed and actions addressed from CRCSi feedback.
  - Will submit final Post Survey Accuracy report **08 Jan 2016**.



1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 01 Jan 2016

5. ALB Processing

a. RIEGL 820 Data Processing

- Riegl 820 – Classification 100% completed.

# of sorties	Flown	Line Selection		WSM		QC & Refraction	
SAM_SWP1	Fugro	Fugro		Fugro		Fugro	
	15	15	100%	15	100%	15	100%
# of tiles	Created	Classified		Final QC			
(0.5x0.5Km)	Fugro	Fugro		Fugro			
	7844	7844	100%	7844	100%		

b. LADS data processing

- LADS Mk3 Validation / QC 100% complete

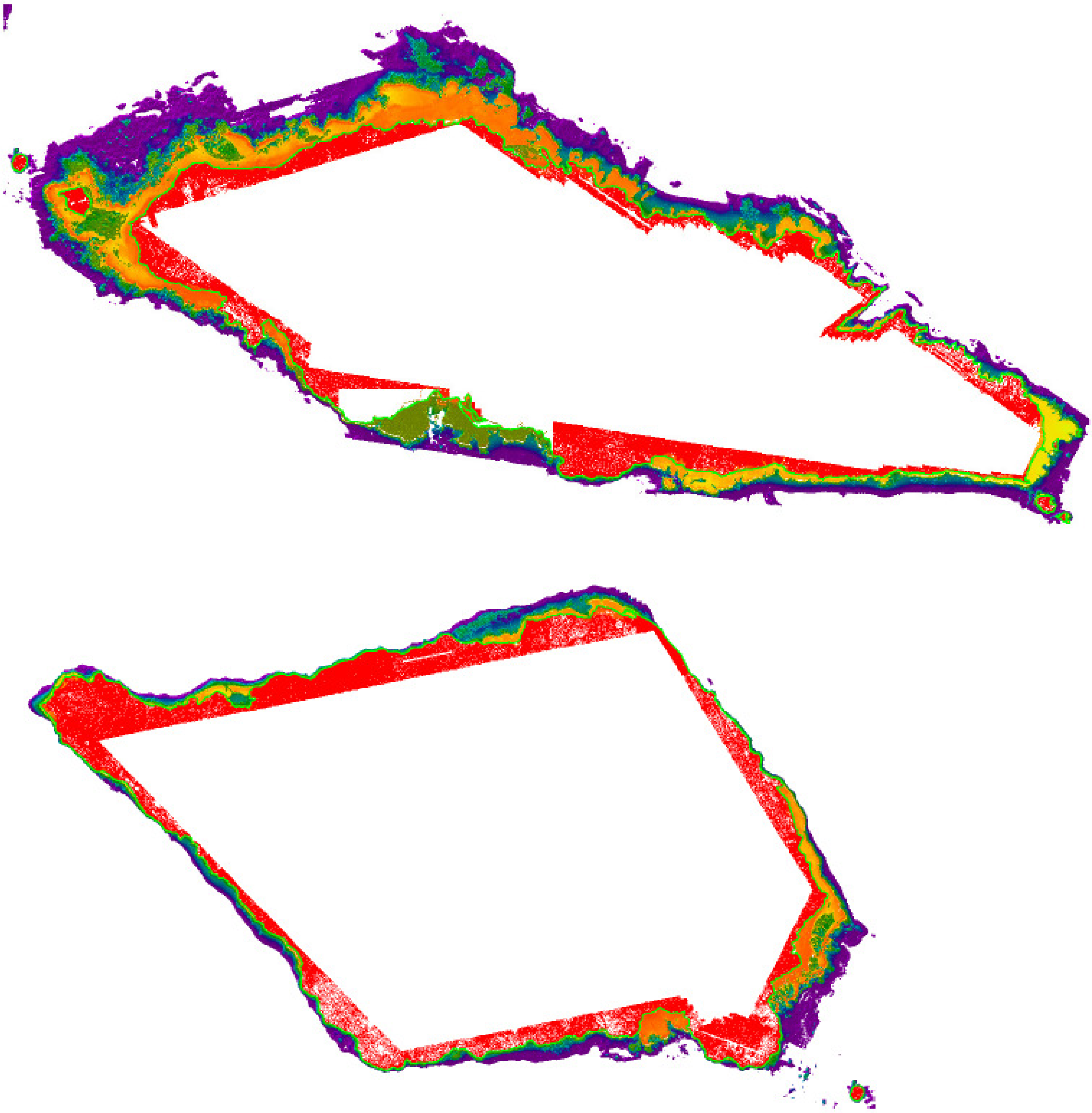
# of lines	Flown	Prevaled					
FP_SWP1	Fugro	Fugro					
	344	344	100%				
# of tiles	Total	PreValed		Validated		Final QC/Check	
FP_SWP1	Fugro	Fugro		Fugro		Fugro	
	2139	2139	100%	2139	100%	2139	100%

c. Mk3 / 820 Merging and QC

- **In progress**. Target completion 13 Nov. Preliminary image of ALB coverage below.

# of subareas	Surveyed	Processed		Merged		Delivered	
FP_SWP1	FUGRO	Fugro		FUGRO		FUGRO	
	23	23	100%	20	**100%**	0	0%

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 01 Jan 2016



d. Bathymetric and Seamless Products

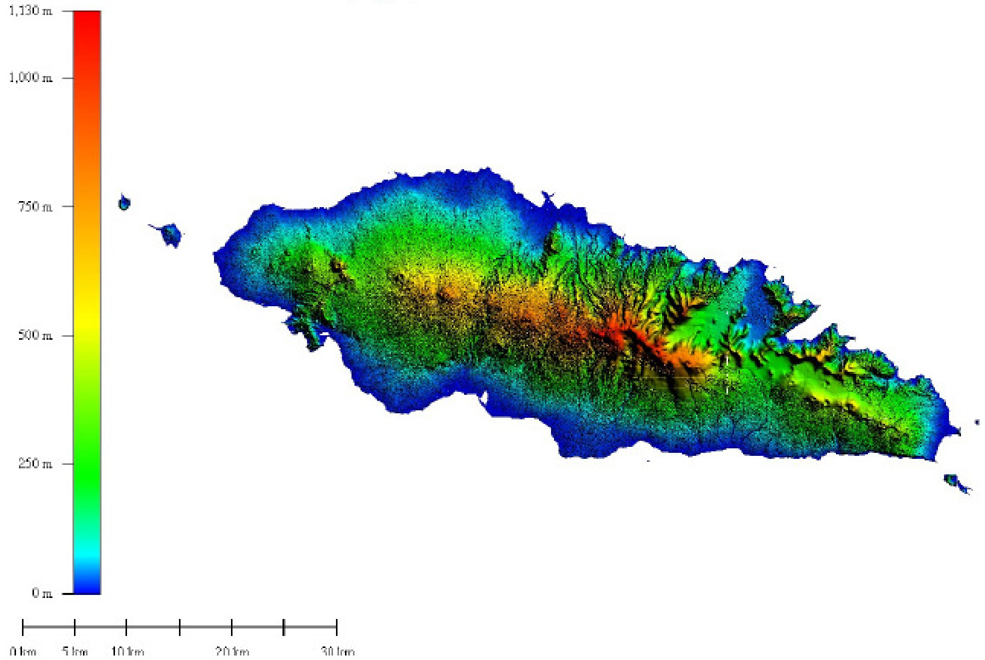
- Final products for Savaii commenced. **Target completion now 08 January**.
- Final products for Upolu in progress once final reduction to MSL complete. **Target completion 13 January**.

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 01 Jan 2016

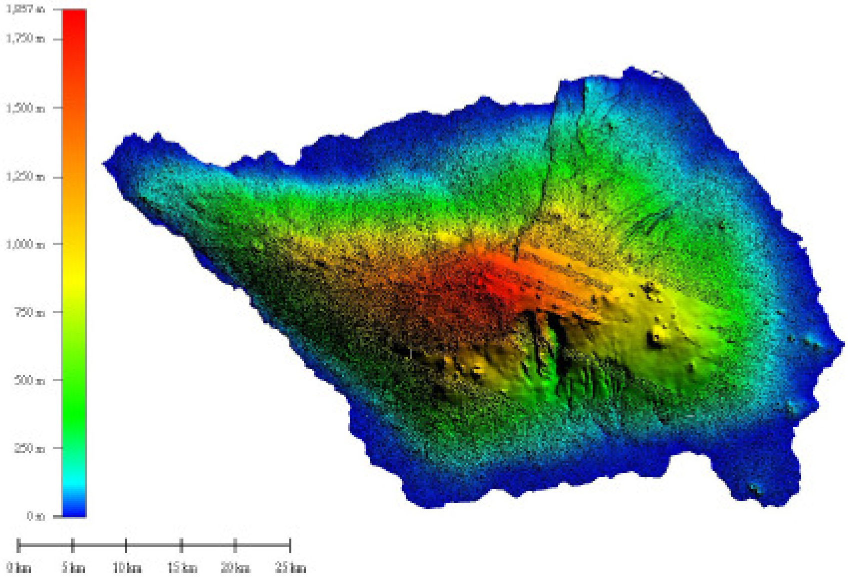
6. ALT Processing

a. Riegl 780 Data Processing

- ALT Classification and merging 100% completed.
    - Fagaloa Bay data from ALB data set also 100% completed and incorporated into topographic dataset.



1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 01 Jan 2016



b. Satellite Derived DEM

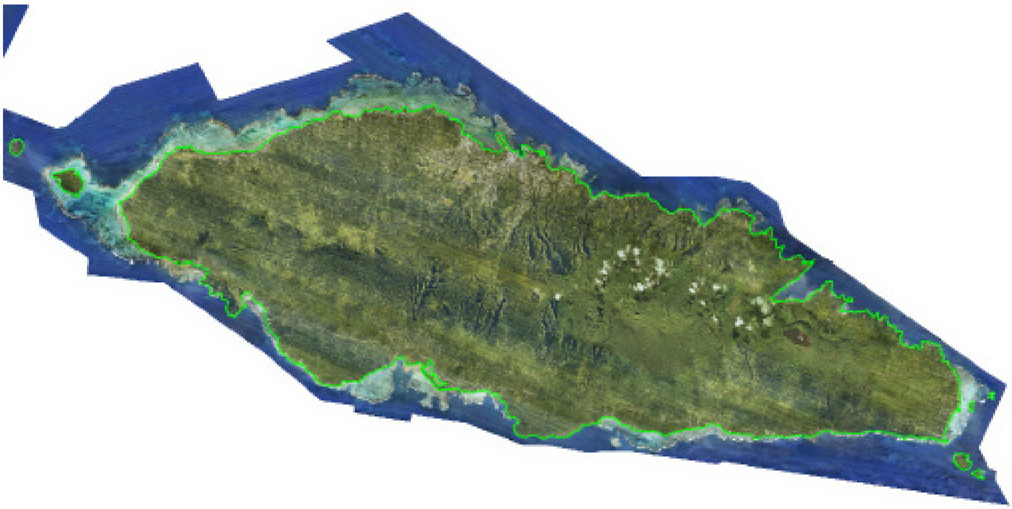
- **NextMap10 DSM**
  - **100% merged with ALT data and used to generate the final ALT data products.**

c. RGB Imagery

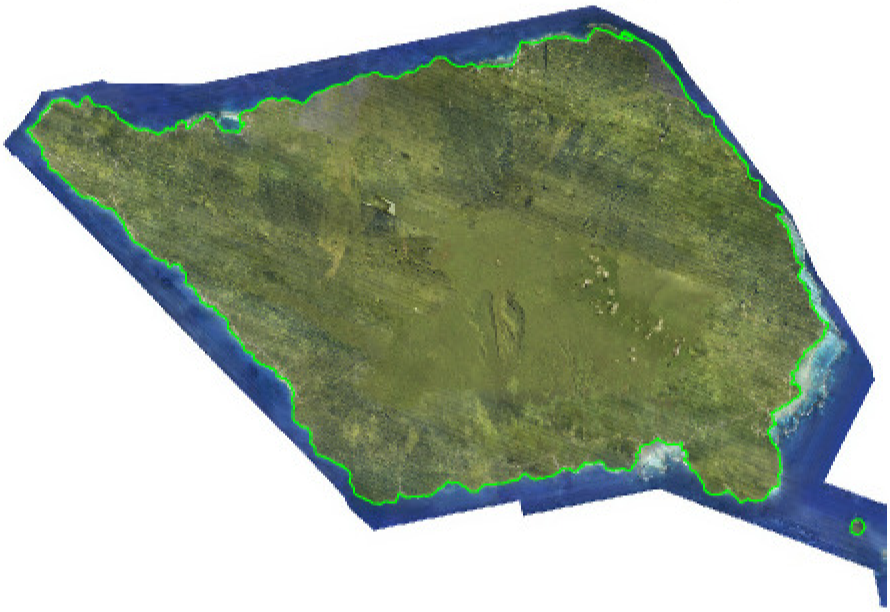
- Final imagery below with all three image sources from Phase One, Redlake and Pleiades sensors 100% completed. One combined topographic / bathymetric dataset produced for each survey area.
- Airbus not willing to relax license terms beyond MNRE's / Samoan Govt use, MNRE will have to pursue additional license for wider distribution if required in future.
- Suggestion from CRCSI to provide an additional mosaic with Pleiades Imagery clipped out for distribution outside of Samoan Govt if required. **Also 100% completed and will form part of the deliverables.**

1448: Samoa ALT/ALB project Fortnightly Project Report: 01 January 2015

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 01 Jan 2016



Final combined Phase 1, Redlake and Pleiades Imagery for - Upolu Is, Samoa



Final combined Phase 1, Redlake and Pleiades Imagery for – Savaii Is, Samoa

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 01 Jan 2016

d. Topographic Products

- Final products currently being compiled, target completion for topographic components Tues, 22 Dec.

7. Quality Issues and Rectifications

- To ensure seamless dataset, proposing to:
  - assess both the bathymetric and topographic data against the Ellipsoidal survey control
  - make minor adjustments to both ALT / ALB ellipsoidal datasets to match
  - apply the EGM08 geoid and applicable MSL correction (based on survey control again)
- Post Survey Spatial Accuracy report will be submitted 08 January.
- **In correspondence with Nathan Quadros on timing of QC. Re-aligned deliverables for Savaii survey area first by Friday 08 Jan and Upolu following week by Thursday 13 Jan.**

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 15 Jan 2016

Created By	**Luke Chamberlain**	**Sent to:**	**Luke Chamberlain**
Status Report	**008**	**Next Report Due**	**29 January 2015**

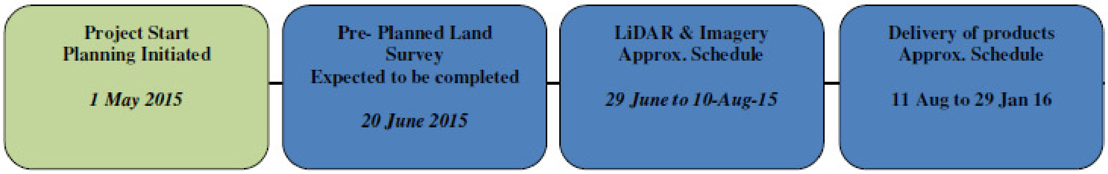
Project Contacts

Project role	Name	Contact Details
FLC PM	**Luke Chamberlain**	L.Chamberlain@fugro.com
FGS PM	**Cristian Gordini**	C.Gordini@fugro.com

1. Project Management

- ALT data
  - LAS file reduction 100% complete and supplied to FLC for "seamless" product generation.
  - All Upolu and Savaii Topographic Data supplied to CRCSI for QC review.
- ALB data
  - LAS file reduction 100% complete
  - In final stages of bathy and seamless product generation.
- Data delivery to CRCSI for QC
  - Topographic Data
    - delivered **Savaii Survey Area,** Monday 11 Jan
    - delivered **Upolu Survey Area,** Friday 15 Jan
    - **Ongoing feedback being received on amendments / changes to ALT products from CRCSI**
  - Bathymetric / Seamless Data
    - Experiencing delays due to intensive processing requirements of seamless products (contours inparticular).
    - Aim to deliver both Savaii and Upolu (without contours) by **Friday 22 Jan**.
    - Deliver remaining products (contours) and reports by **Friday 29 Jan.**
- FLC submitted ALT data collection invoice to MNRE for payment, overdue as of **08 Dec 2015**. Will be incorporated into final payment now.
- Contract extension request submitted to MNRE to **31 Mar 2016** to cover CRCsi QC process also with no penalties.

2. Project Timing



3. Health and Safety

- No incidents to report.

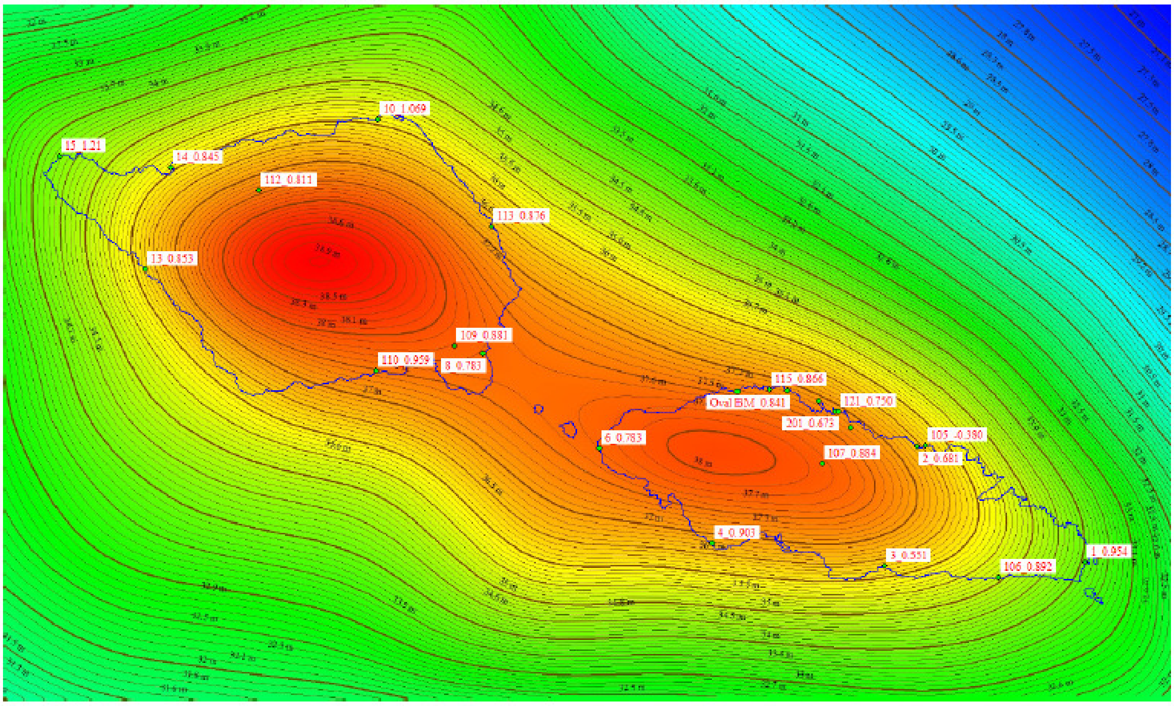
1448: Samoa ALT/ALB project Fortnightly Project Report: 15 January 2015

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 15 Jan 2016

4. Survey Control Work

- FLC / FGS pursued following flight line adjustments and checks against Survey Control points:
  - ALT ellipsoidal comparisons with Survey Control are:
    - Upolu = -0.16m +/- 0.10m
    - Savaii = -0.19m +/- 0.12m
  - ALB ellipsoidal comparisons with Survey Control are:
    - Upolu = -0.14m +/- 0.07m
    - Savaii = -0.18m +/- 0.08m
  - Revised proposed MSL corrections to use for entire project, which will be based on the ALT agreement now for Upolu = 0.689m and Savaii = 0.824m respectively.
  - Final reduced Mean MSL Diff for
    - **ALT data was Upolu = 0.00m and Savaii = 0.00m**
    - **ALB data was Upolu = -0.09m and Savaii = -0.06m**

- Post Survey Spatial Accuracy Report
  - Submitted final version to MNRE / CRCSI, **11 Jan 2016**.



1448: Samoa ALT/ALB project Fortnightly Project Report: 15 January 2015

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 15 Jan 2016

5. ALB Processing

a. RIEGL 820 Data Processing

- Riegl 820 – Classification 100% completed.

# of sorties	Flown	Line Selection		WSM		QC & Refraction	
SAM_SWP1	Fugro	Fugro		Fugro		Fugro	
	15	15	100%	15	100%	15	100%
# of tiles	Created	Classified		Final QC			
(0.5x0.5Km)	Fugro	Fugro		Fugro			
	7844	7844	100%	7844	100%		

b. LADS data processing

- LADS Mk3 Validation / QC 100% complete

# of lines	Flown	Prevaled					
FP_SWP1	Fugro	Fugro					
	344	344	100%				
# of tiles	Total	PreValed		Validated		Final QC/Check	
FP_SWP1	Fugro	Fugro		Fugro		Fugro	
	2139	2139	100%	2139	100%	2139	100%

c. Mk3 / 820 Merging and QC

- 100% completed.

# of subareas	Surveyed	Processed		Merged		Delivered	
FP_SWP1	FUGRO	Fugro		FUGRO		FUGRO	
	23	23	100%	20	**100%**	0	0%

d. Bathymetric and Seamless Products

- Final products for Upolu and Savaii commenced, but experiencing processing issues with respect to seamless products and time required to compile.
  - Aim to supply all data (except contours) by **Friday 22 January**.
  - Supply all remaining products by **Friday 29 January**

6. ALT Processing

a. Riegl 780 Data Processing

- ALT Classification and merging 100% completed.
  - Fagaloa Bay data from ALB data set also 100% completed and incorporated into topographic dataset.

b. Satellite Derived DEM

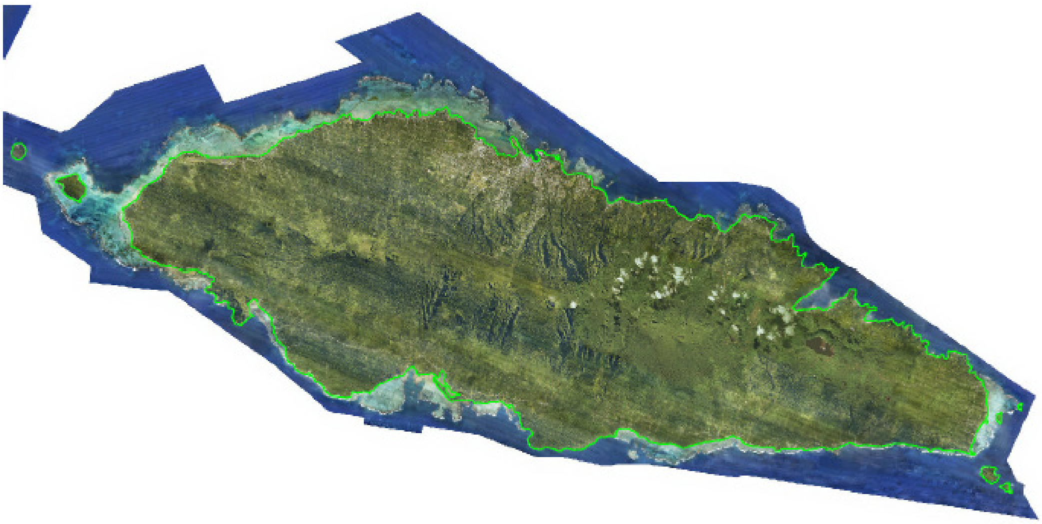
- **NextMap10 DSM**

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 15 Jan 2016

- **100% merged with ALT data and used to generate the final ALT data products.**

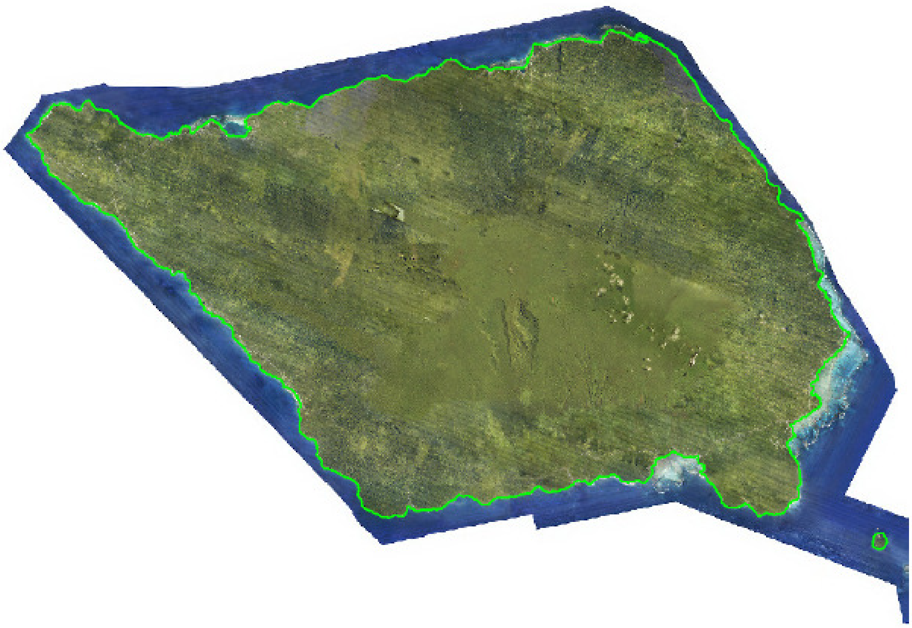
c. RGB Imagery

- Final imagery below with all three image sources from Phase One, Redlake and Pleiades sensors 100% completed. One combined topographic / bathymetric dataset produced for each survey area.
- Airbus not willing to relax license terms beyond MNRE's / Samoan Govt use, MNRE will have to pursue additional license for wider distribution if required in future.
- Suggestion from CRCSI to provide an additional mosaic with Pleiades Imagery clipped out for distribution outside of Samoan Govt if required. **Also 100% completed and will form part of the deliverables.**



Final combined Phase 1, Redlake and Pleiades Imagery for - Upolu Is, Samoa

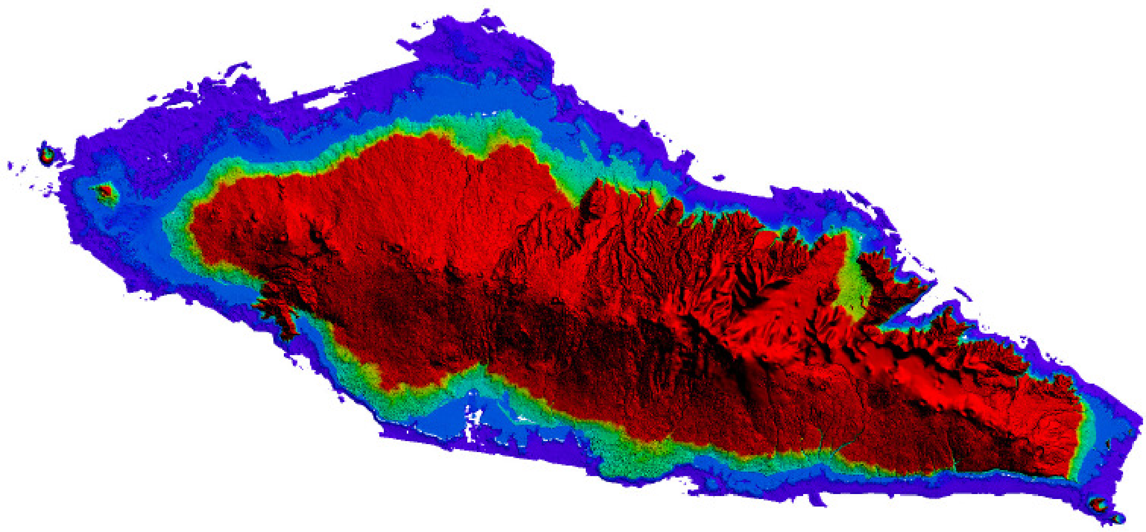
1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 15 Jan 2016



Final combined Phase 1, Redlake and Pleiades Imagery for – Savaii Is, Samoa

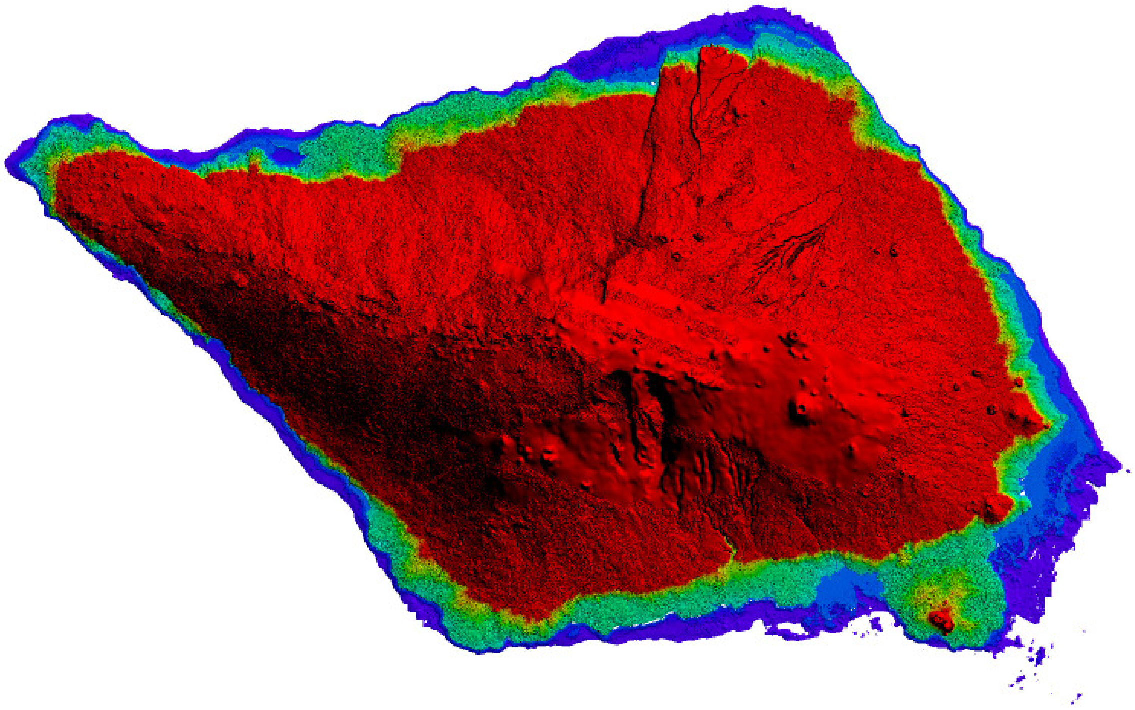
7. Products

- Topographic Products - 100% completed.
- Bathymetric and Seamless Products – 80% complete.



Final combined ALB and ALT coverage for - Upolu Is, Samoa

1448: Samoa ALT / ALB project
Project Report for Fortnight Ending: 15 Jan 2016



Final combined ALB and ALT coverage for - Savaii Is, Samoa

8. Quality Issues and Rectifications

- All topographic data and products submitted to CRCSI for review with ongoing feedback received.
- **All bathymetric data and seamless products (except for contours) aiming for delivery on Friday 22 January.**
- **All remaining products (contours) and Report of Survey for delivery on Friday 29 January.**

Annex L. Seabed Features and Wrecks

An inspection of data relative to Chart images has been made and features not fully represented on the chart are listed below. This does not represent a full chart comparison, rather a summary of notable seabed features that may need to be represented on the chart for navigation purposes.

L.1 Seabed Features Detected

Point	Least Depth	Surveyed Latitude	Surveyed Longitude	Easting	Northing	Run Number	Comments
1	Drying 2.46m	13°49’42.5” S	171°49’08.6” W	416886	8471110	20022	Wreck
2							
3							
4							
5							

L.2 Supporting Images

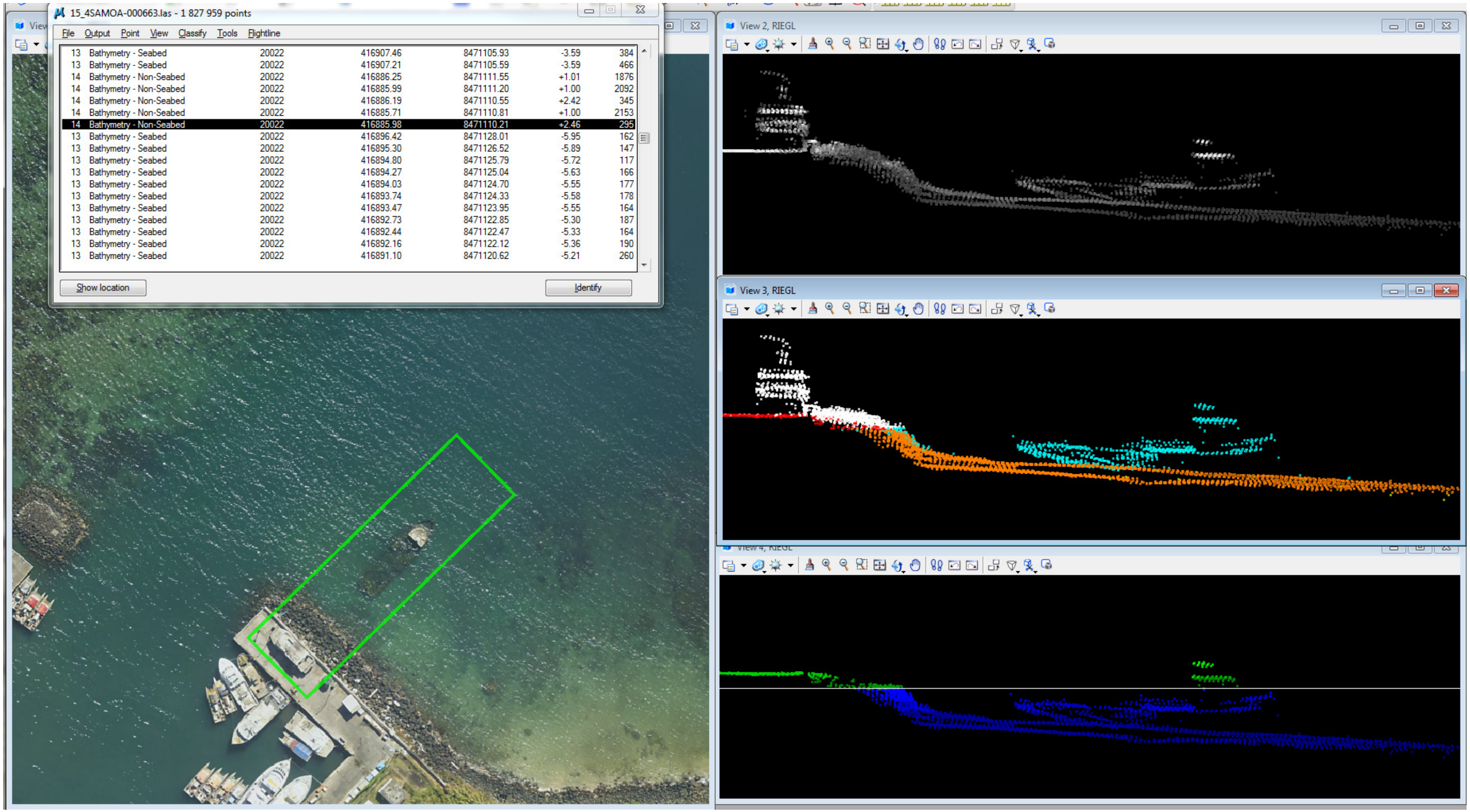


Figure 1 – Wreck Apia Harbour

Annex M. Fugro LADS Mk 3 Performance Verification Certificate

Fugro LADS Corporation

LADS Mk 3 Performance Verification Certificate

The LADS Mk 3 B2 System was flown for system performance verification over Gulf St Vincent, South Australia, Sorties 17, 19 & 26 conducted during March 2014.

A surveyed benchmark run with submerged targets and benchmark areas was used to verify vertical and horizontal accuracy.

The system performance was verified as meeting the requirements of IHO Order 1 depth and horizontal accuracy.

Reference: LADS3R00001005-006 and Riegl CAL-1402-S2220710

Approving Authority: ______________ 09th April 2014

Mark Penley, Technical Manager

Certified System™ Quality ISO 9001 SAI GLOBAL

TL/ENG/041

Issue 7.0

Annex N. Service Warranty

FUGRO LADS CORPORATION PTY LIMITED

SERVICE WARRANTY

1. This report and the hydrographic interpretation and assessment carried out in connection with the report (together the “Services”) were complied and carried out by Fugro LADS Corporation Pty Limited (“Fugro LADS”) for the Ministry of Natural Resources and Environment (MNRE) (the “Client”) in accordance with the terms of the contract. The Services were performed by Fugro LADS with the skill and care ordinarily exercised by a reasonable hydrographic survey contractor, at the time the Services were performed. Further, and in particular, the Services were performed by Fugro LADS taking into account the limits of the scope of works required by the Client, the time scale involved and the resources, including financial and manpower resources, agreed between Fugro LADS and the Client.

2. Other than that expressly contained in the contract and in paragraph 1 above, Fugro LADS provides no other representation or warranty whether express or implied, in relation to the Services.

3. The Services were performed by Fugro LADS exclusively for the purposes of the Client. Fugro LADS is not aware of any interest of or reliance by any party other than the Client in or on the Services. Unless stated in the contract or report for the Services or expressly provided in writing, Fugro LADS does not authorise, consent or condone any party other than the Client relying upon the services. Should this report or any part of this report, or otherwise details of the Services or any part of the services be made known to any such party and such party relies thereon that party does so wholly at its own and sole risk and Fugro LADS disclaims any liability to such parties. Any such party would be well advised to seek independent advice from a competent hydrographic survey contractor/consult and and/or lawyer.

4. It is Fugro LADS’s understanding that this report is to be used for the purpose described in Section 1 – “Introduction and Scope of Work” of the report. That purpose was a significant factor in determining the scope and level of the Services. Should the purpose for which the report is used, or the Client’s proposed use of the data change, this report may no longer be valid and any further use of or reliance upon the report or data in those circumstances by the Client without Fugro LADS’s review and advice shall be at the Client’s sole and own risk. Should Fugro LADS be requested to review the report after the date hereof, Fugro LADS shall be entitled to additional payment at the then existing rates or such other terms as agreed between Fugro LADS and the Client.

5. The passage of time may result in man-made and/or natural changes in site conditions and changes in regulatory or other legal provisions, technology or economic conditions which could render the report inaccurate or unreliable. The information and conclusions contained in this report should not be relied upon if any such changes have taken place and in any event after a period not greater than two years (or typically six months in the case of seabed features information) from the date of this report or as stated in the report without the written advice of Fugro LADS. In the absence of such written advice from Fugro LADS, reliance on the report after the specified time period, Fugro LADS shall be entitled to additional payment at the then existing rate or such other terms as may be agreed upon between Fugro LADS and the Client.

6. The observations and conclusions described in this report are based solely upon the Services which were provided pursuant to the agreement between the Client and Fugro LADS. Fugro LADS has not performed any observations, investigations, studies or testing not specifically set out or required by the contract between the Client and Fugro LADS. Fugro LADS is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the Services.

7. Where the Services have involved the use of any information provided by third parties or the Client and upon which Fugro LADS was reasonably entitled to rely then the Services clearly are limited by the accuracy of such information. Unless otherwise stated, Fugro LADS was not authorised and did not attempt to verify independently the accuracy or completeness of information, documentation or materials received from the Client or third parties, including laboratories and information services, during the performance of the services. Fugro LADS is not liable for any inaccurate information or conclusions, the discovery of which inaccuracies required the doing of any act including the gathering of any information which was not reasonably available to Fugro LADS and including the doing of any independent investigation of the information provided to Fugro LADS save as otherwise provided in terms of the contract between the Client and Fugro LADS.