Ministry Of Agriculture Natural Resources and Environment

Water Development Department Cyprus

PURCHASE SERVICES FOR THE IMPLEMENTATION OF ARTICLE 6 OF THE EUROPEAN DIRECTIVE 2007/60 EC (Article 7 of the harmonization LAW 70 (I) / 2010) TO PROVIDE FOR THE EVALUATION AND MANAGEMENT OF FLOOD RISK MANAGEMENT

LIDAR AND DIGITAL AERIAL PHOTOGRAPHY SURVEY REPORT

Final

PRISMA CONSULTING ENGINEERS S.A. – T.C. GEOMATIC Ltd –

OFEK AERIAL PHOTOGRAPHY (1987) Ltd

Nicosia, September 2013

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PART A – GENERAL APPROACH TO THE PROJECT

1. Background

The Water Development Department (WDD) of the Ministry of Agriculture, Natural Resources and Environment, Cyprus identified 19 areas of significant risk of flooding as by the article (Article 5) of Directive 2007/60/EC and the relevant article (Article 6) of Law 70 (I) / 2010 and signed a contract with a Joint Venture of companies (hereunder the "JV") for:

Develop detailed hydrological models that identify the flood hydrographs to be used in hydraulic modeling for the production of hazard maps. These models will form the basis for future revisions to the flood hazard, as well as other hydrologic models and flood studies in specific areas.

Obtaining a highly accurate topography of the riverbed and the riparian zone of the relevant sections of rivers using technology LIDAR, including aerial photographs, and where required additional, site topography, etc., which were used to create the geometry of hydraulic models in the elaboration of hazard maps, as well as future plans for flood risk management.

Producing an information file of road crossings (bridges, culverts, etc.) and other structures that affect the flow and the bed are the parts of the rivers in these regions (which will serve to create the geometry of hydraulic models and future plans for flood risk management)

Develop detailed hydraulic models that calculate the depths and flow velocities to be used in the creation of hazard maps for specific locations. The future models also form the basis for revisions to the flood hazard and measures used in the design of plans for flood risk management. Also, these models will form the basis for other hydraulic flood models and studies in specific areas.

Develop, at the river basin, flood hazard maps and flood risk maps.

Establish infrastructure to the Contracting Authority for management and review of hydrologic and hydraulic modeling and flood hazard maps and flood risk.

OFEK Aerial Photography is company that specializes in executing of Aerial surveys using various techniques of Aerial Photography, LIDAR and Remote Sensing and developing or integration of computerized solutions for visualization and Data Processing. OFEK is the selected sub-contractor for caring the services of aerial photography and LIDAR , in the framework of an agreement between WDD and the Joint Venture (JV) of PRIZMA CONSULTING ENGINEERS S.A,TC GEOMATIC LTD from Cyprus ,Ofek Aerial Photography from Israel and.

In this report we specify all the activities and means that have been applied for the implementation of the aerial survey stage of the contract, to meet the technical requirements and deliverables as presented in our offer for the project.

1.1. Our understanding of the Aims of Services

We understand that the requested products are needed to obtain a highly accurate topography of the riverbed and the riparian zone of the relevant sections of rivers, which were used to create the geometry of hydraulic models in the elaboration of hazard maps, as well as future plans for flood risk management. This data will also support preliminary studies, feasibility studies and master plans in urban areas cadastre projects or detailed design of infrastructures in urban areas and selected interurban areas.

For that purpose LIDAR data and Aerial photographs are required meeting the following specifications:

A. 0.5 points/m² density as raw cloud of points (ALS format) and as A grid file in X, Y, Z derived from the processed LiDAR file and geo referenced to the local Datum. The elevation accuracy of each sign shall be ± 15 cm or better.

B. The cloud of points should represent the surface coverage (digital surface) soil in ASCII format with the positions X, Y, Z without the deduction of points that correspond to vegetation, buildings and other human constructions.

C. Digital Terrain model of bare ground (Bare Earth Digital Terrain Model), which depicts the bare soil surface in the form of TIN (Triangular Irregular Network) which will result from the triangulation of the cloud points of the surface coverage in conjunction with the fracture lines.

D. Digital model of surface coverage (Digital Surface Model) in the form of regular grid (Raster DEM)-dimensional cell 2 by 2 meters, in the form of GeoTIFF.

E. All lines rupture (break lines) in the form of ESRI shape file or ESRI feature class used to create elevation models.

F. Digital model of bare soil in the form of regular grid (Raster DEM)-dimensional cell 2 by 2 meters, in the form of GeoTIFF.

G. 1 meter interval Contour lines of bare soil model in the form of ESRI shape file or ESRI feature class.

H. The aerial photographs taken during the flights.

I. Diagram of the final shooting aerial photography using icons (thumbnails).

J. All raw data of additional topographical renderings that had to be made for the purpose of filling the gaps in the data LIDAR.

K. All control points and reference format ESRI shape file Feature class, which is used in calibration, testing, processing and validation of the LIDAR points of the products obtained from them.

L. All raw data files, Metadata files, index maps and reports which will enable further use of the acquired data by the client.

2. Project Management and Control

2.1. General

Our management considers this program as a very important opportunity and assign its leading personnel under the personal to it, supervision of Chief Executive Officer.

The program was led and controlled by a specially established project management consisting of a fully dedicated project management team.

The project management team was responsible for all aspects of the project, including, but not limited to, quality control, time table control, sub-contractors control (performance, time table, and quality) and will assure timely and continuous contact with the customer.

2.2. Project Management and Key Personnel

The project management team was activated and monitored all inside and subcontractors activities related to the project. The project manager Mr. Ran Kor was the only one authorized to introduce any changes needed for the smooth development of the project.

The project team included the following staff:

Staff Name	Position in the project	Contact data
Mr. Asaf Dado	Project Coordinator	asafd@ofek-air.com
Mr. Ran Kor	Project manager, GIS and photogrammetry Expert	ran@ofek-air.com
Mr. Shachar Kaufman	Project Technical manager, LiDAR Expert	Shachark@ofek-air.com
Mr. Roy Lannes	Pilot, Aviation Coordinator	
Mr. Amos Hayoun	Pilot, Chief Pilot	amos@ofek-air.com
Mr. Yariv Casif	Program QA manager geodetic engineer,Ofek Chief surveyor and C.T.O	yarivc@Ofek-air.com

Mr. Daniel Brody	Air Crew, Senior Navigator	

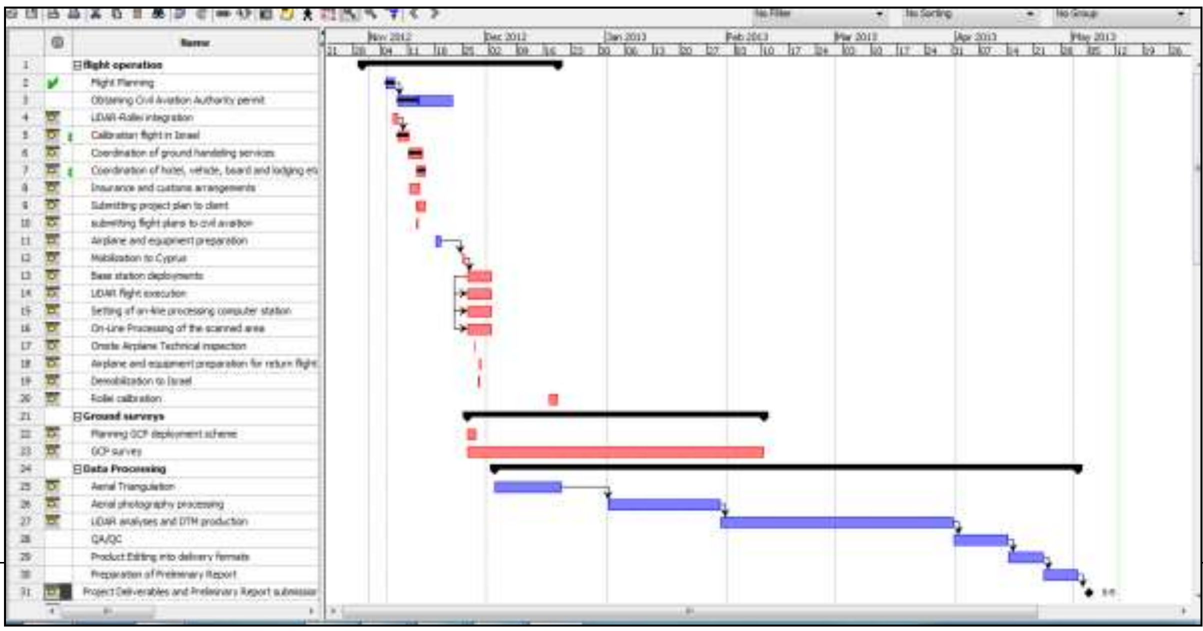
The staff also included operators of LIDAR processing workstations, photogrammetry operator and other supporting staff. All of the project team members were highly trained professionals with substantial experience in their field of duty.

2.3. General concept of Quality Assurance (QA)

Our organization QA procedures responds to ISO 9002.The QA manager created a detailed program for quality assurance based upon the relevant quality standards defined in the contracts. For every task specific acceptance standards were determined and applied.

2.4. Activities Diary

Item	Description of Activity	Date
1	Submission of flight plans	13 Nov. 2012
2	Flight plans approval	18 Nov. 2012
3	A/c and Aircrew mobilization	24 Nov. 2012
4	Survey flights	25 -29 Nov-.2012
5	Ground surveys of GCP's	26 Nov- 10 Feb.2012
6	Data processing	3 Dec-29 April 2012
7	Delivery Preliminary report and products	May 13, 2013



2.5. Production steps

Descriptions of main technological stages of LIDAR survey. The Airborne LIDAR and Aerial photography survey included the following main stages:

A. Establishment of Geodetic support.

B. Airborne data acquisition.

C. On-site preliminary processing for quality assessment.

D. Ground control points

E. Office processing of survey products.

F. Verification and data quality control.

G. delivery

While working on the mapping and modeling the most critical factors which were taken into account were the following:

Providing appropriate spatial resolution of 0.5 LIDAR points per square meter and absolute geodetic accuracy of 0.15 m RMSEz or better for Z coordinate for all survey data.

Providing reliable geodetic accuracy of GCPs to insure the target accuracy level of Z deviation < 15 cm.

Processed data should be in the form which facilitates its usage for making maps, structural analysis and other kinds of geomorphologic processing.

The aerial photos should enable topographical interpretation of the most important objects and support correct vegetation removal and true ground detection during LIDAR data processing.

PART B – THE ON SITE AIRBORN SURVEY

3. The methodology for performance of Aerial Photography

3.1. General

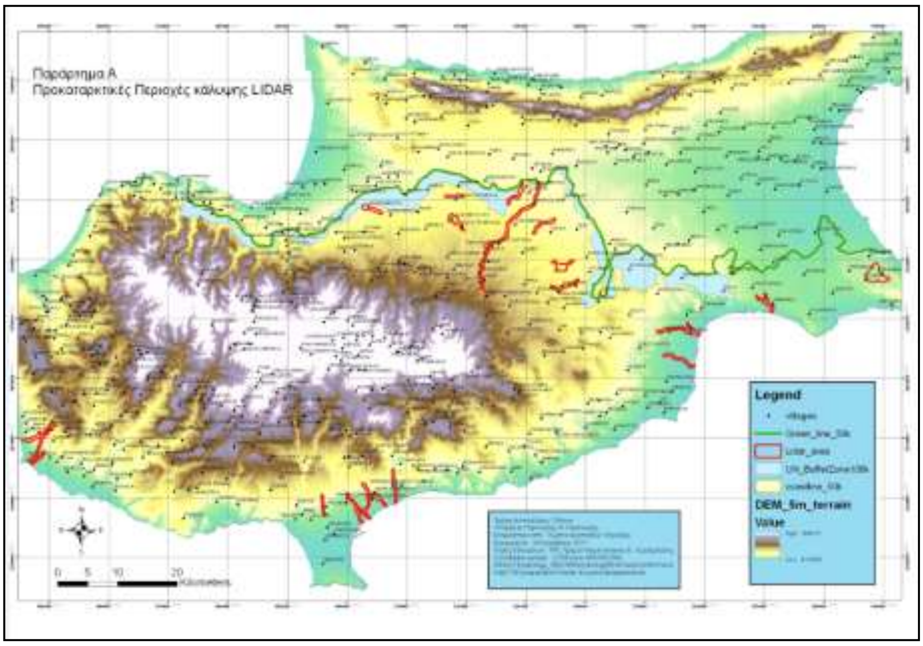
Aerial survey works were carried out by means of airborne LIDAR, digital aerial photography camera, IMU and other airborne accessories which support the task. Ofek mobilized to the site Piper Navaho P-34, Fixed wing aircraft which was equipped with all necessary hardware and software to ensure high quality navigation during survey missions and geodetic support. All the equipment that was used is certified by manufacturers and in working order (see Appendix B).

Ground survey methods were also employed to support aerial survey data.

3.2. Areas Coverage Plan

Coverage planning was based on the requested scale for each area, regardless of the Above Ground Level (AGL). During a flight mission a different altitude was set for each area in order to keep with the required scale.

3.3. Areas and Scales



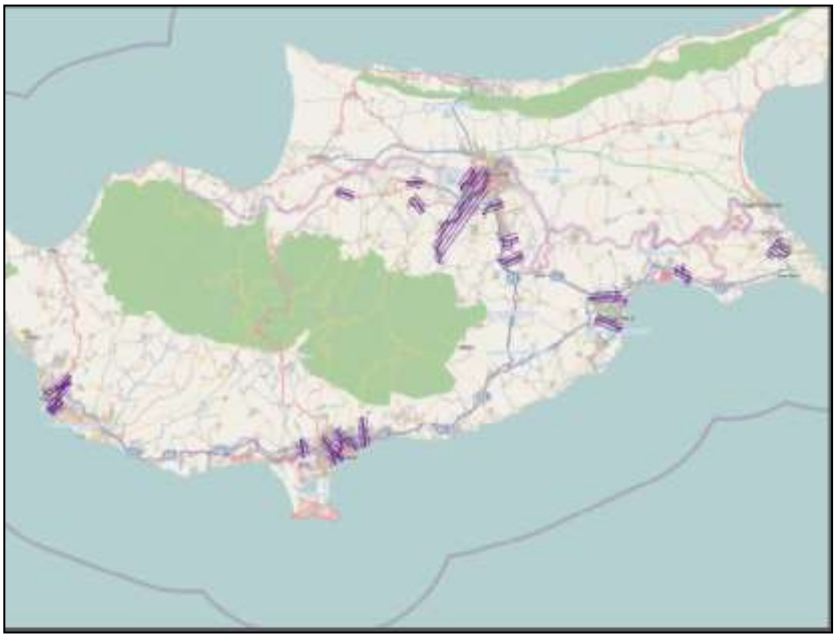


Image: distribution of flight lines

Imagery specifications:

Forward overlap between exposures: 60%-65%. LIDAR data collected continuously along the strip including at least extra 1 km in the edges.

Side lap between " strips”: 25% - 35%

The RGB strip width (digital images) - 814m

The LiDAR data strip width- 680m

The required LIDAR density was 0.5 points/m² (required). In order to confirm the quality of the output Ofek performed the survey in better density of at least 1 points/m²

The photographs are vertical with tilts not exceeding 20 and crab of not more than 50

Cloud cover of more than 1% was not permitted and any cloud at the principal point was avoided.

Color image balancing and enhancement was done. The corrected images were saved as a separate file and the original clearly marked and maintained.

All (AOI) was covered by overlapping imagery + two extra models at the edges of each strip.

Although the required resolution of the digital images was 50cm the actual resolution of the images acquired was no less than 20 cm.

All image files shall were clearly labeled with a consistent string depicting Strip Number, Image Number, Date and Time (See Appendix A- Photo index).

3.4. Pre-flight coverage planning and quality control

The ALTM-NAV and AeroTopol flight planning modules were used to plan the LIDAR and photogrammetric coverage. These programs take into account the required scale, end-lap, side-lap and terrain levels in order to plan the flight lines and the exposures positions.

An interim report was produced, pointing out planning mistakes, gaps, overlap problems or special terrain conditions that can result in failure of meeting the project demands. The above mentioned Systems also provided a Flight Management System (FMS) file containing:

An exposure plan, for real-time, in-flight-performance quality control

GPS controlled exposure.

Those systems did the calculation of the exposure number based on the digitization of all the polygons of the target area and planning the coverage. By that we could achieve true estimation of photogrammetric models for each area and for the entire project and confirm seamless coverage as demonstrated in the image below.

Image: Flight planning example from ALTM – NAV

3.5. The Photography System

3.5.1. The mission concept

As mentioned above, aerial photography was carried out during LIDAR survey mission as an accompanying source of geospatial and topographical data. The main reasons for applying of digital aerial photography along with LIDAR survey are as following:

Availability of aerial picture that can significantly facilitate office interpretation of the data, collected during LIDAR survey mission.

Use of digital photos to create digital orthophoto maps and outlining the contours of objects on such maps. The orthophoto was made a demo for internal use only. As this product was not part of the required deliverables, and did not want through basic production quality assessments checks, we did not submit it to the client even as an unofficial product. As an alternative, we submitted the images in a geo-referenced format.

Stereoscopic analysis of images to ensure a better interpretation and stereo photogrammetric analysis of stereographs with the measurement of horizontal and vertical dimensions of objects especially of break lines.

Ofek's aerial photography airborne systems are uniquely and precisely developed to accompany the entire mapping workflow process. The system, as per the performed order of actions, includes the following components:

Flight planning and management unit

Calibrated digital aerial photography unit, GPS and IMU oriented, stabilized by special high-speed gyroscopic mount.

Automatic photography reception unit that organizing the photos in image catalogue

Adaptable output for Aerial triangulation and orthophoto maps production.

Orientated data and Stereoscopic models output for production of line maps through digital photogrammetry.

Computerized Output and reports adaptable for Geographic Information System (GIS)

The processes outcomes can be imported to each one of the main digital stereo-plotters for production of line maps (vectors) such as: topographic maps, infrastructures maps, etc.

3.6. LIDAR System

Ofek uses Optec Airborne Laser Terrain Mapper (ALTM) 3100 for LIDAR survey works. ALTM 3100 includes semiconductor laser for making range-finder (distance) measurements with pulse repetition rate up to 100 kHz.

The laser is an emitter of rays with frequencies in the near infrared range of spectrum. With each scan, measurements are taken of the slant range to the point of reflection and of the beam angle in the LIDAR's coordinate system.

3.6.1. Operation concept

The 3D Laser Scanner is a computerized survey instrument based on a laser range-finder, just like a total-station. The scanner is placed opposite the object and emits a laser pulse directed to the object by internal perpendicular mirrors. The pulse reaches object's surface and reflected from it. The scanner captures the reflected pulse and calculates the range to the hitting point. Using the angular information from the mirrors ("vertical" and "horizontal" angles) and the distance, the scanner calculates the exact 3D position (X, Y, Z) of the hitting point in any desired coordinate system. Then, the mirrors slightly change their position and the next pulse is emitted. This procedure is repeated 70 times in a second until the entire scene has been captured and the visible area of the object is completely scanned. Thus, a Cloud of Point (COP) of the object's surface is produced. In addition to the COP spatial data (XYZ), the scanner produces an Intensity Map in which reflected energy, from each specific point, is represented by a correlated color (color-energy correlation). Such intensity map provides very impressive and 3D Laser Scanner easy-to-use visualization of the object and enables producing of its CAD modeling and mapping.

Up to five reflections can be registered for each scan line. This capability renders laser images more informative as responses from several objects of the scene can be received simultaneously with each single scan. First reflections was received from foliage, wires and towers of power transmission lines, edges of buildings while last reflections will usually come from the ground or other hard surfaces like roofs. Such a possibility is regarded to be extremely important while making DTM for hydrographical need under dense tree canopy.

In most cases the required survey parameters can be achieved in a single pass of a survey aircraft along the survey pass thus reducing the duration of aerial work. As laser scanning is carried out using equipment which is capable of registering both the FIRST, LAST and intermediate reflections, scan densities correspond to LAST pulses reflected from the ground and ground objects (first of all, water surface, buildings and structures). Due to such a feature, an actual scan density happens to be 30-40% higher than the theoretic number, due to FIRS and intermediate pulses reflections that basically hit treetops, power lines towers and wires and other above ground objects.

Positioning and Geodetic Data Conversion

The path of the aircraft was registered by an airborne GPS (GLONASS) receiver. Position data obtained together with measured slant distances and scan angles. This synchronization provides accurate geodetic coordinates in WGS-84 of objects which reflect the laser beams. By post process of the aerial data and ground records of reference stations near the surveyed area the data was converted to the local national coordinate system.

3.6.2. LIDAR Coverage specifications

For all the area	
Flight altitude	750-780 m AGL
Aircraft speed	Maximum 140 knt.

Scan Angle	20°
Av. density of points	1.0 points /m² (a point each 1 m²)
overlap	25%
Data recording	First, second, third and last pulse, Intensity for each echo
Height accuracy target	0.15 m
Position accuracy	0.4 m

3.7. Camera

The medium format digital camera that was used for the project is Trimble Rollei AIC Pro with phase one digital back 39mp size. The camera triggering was synchronized to the LIDAR by ALTM-Nav and AeroTopoL airborne Modules to ensure coverage of the same area. The camera and lenses were newly calibrated immediately upon termination of the survey and before processing the data, in order to insure high quality and precision of the aerial photography products (see Appendix B calibration report). The post calibration of the camera is a normal procedure as it present the current calibration values of the camera.

3.7.1. Exposure and image movement compensation

Forward Motion Compensation (FMC) and stabilization unit is built in part of the photography system. A shutter speed and lens aperture profile were chosen to suit the prevailing illumination conditions .In turbulent conditions, shutter speeds was no longer than 1/250 of a second to reduce the image movement caused by aircraft rotations.

3.7.2. LIDAR and Camera mounting

The camera and LIDAR sensor were installed on a designated mount, which attenuates the effects of aircraft vibration .The stabilizer was also equipped with IMU and two GPS units for Automatic orientation of the device according to the flight plan course.

3.8. Aircraft

The aerial mission was flown using Piper Navajo PA-34 aircraft tail number 4X-CBD. The Aircraft was equipped with APPLANIX IMU which connected to the ALTM-Nav Flight Management System (FMS) and additional GPS system that is attached to the camera and backed up the camera's integral D-GPS ; this allowed highly accurate execution and process of the flight lines.

Image: 4X-CBD

3.9. Airborne GPS and Navigational support of the survey

A navigation system used for providing navigational support for the aerial survey. This system is controlled by the ALTM-NAV flight management software which is a standard part of ALTM 3100 set. A dedicated LCD is installed in the pilots' cockpit, which displays all navigational data such as the selected course and lateral course deviation. The use of the navigation system considerably improves the quality of aerial work and greatly reduces the number of survey areas that would otherwise need re-surveying. The Navigational support also includes permanent geodetic control which allows correct interpretation of aerial survey data (laser scanning, digital aerial photography, etc.) in the required coordinate system. All the data checked at the end of each survey day by visual and automated analysis to detect any gaps or fragments with an inappropriate data quality. Such fragments were surveyed once more.

The aerial navigation was carried out by two airborne GPS units (an aerial unit attached to the A/C Autopilot and second System attached to the camera), the navigation is supervised in real-time by the navigator's using navigator's display.

4. Geodetic support during the airborne survey

The Geodetic support is an integral part of the survey and was carried out in the following stages:

Observing the existing local (national) permanent GPS station and selection of those which are suitable to be used as a basis for airborne LIDAR purposes. The following stations were selected :

Base Station	X	Y	Z
EVRYCHOU	N35°02'18.72638"	E32°53'59.82235"	473.82
LARNAKA	N34°55'50.57801"	E33°37'55.21926"	47.126
LEFKOSIA	N35°09'39.83624"	E33°21'46.44464"	192.67
LEMESOS	N34°40'03.26939"	E33°01'30.49093"	50.209
PARALIM	N35°02'04.15780"	E33°58'56.37341"	102.31
POLIS	N35°01'58.85428"	E32°25'39.05170"	68.768
PAFOS	N34°46'25.96186"	E32°25'40.39818"	114.37

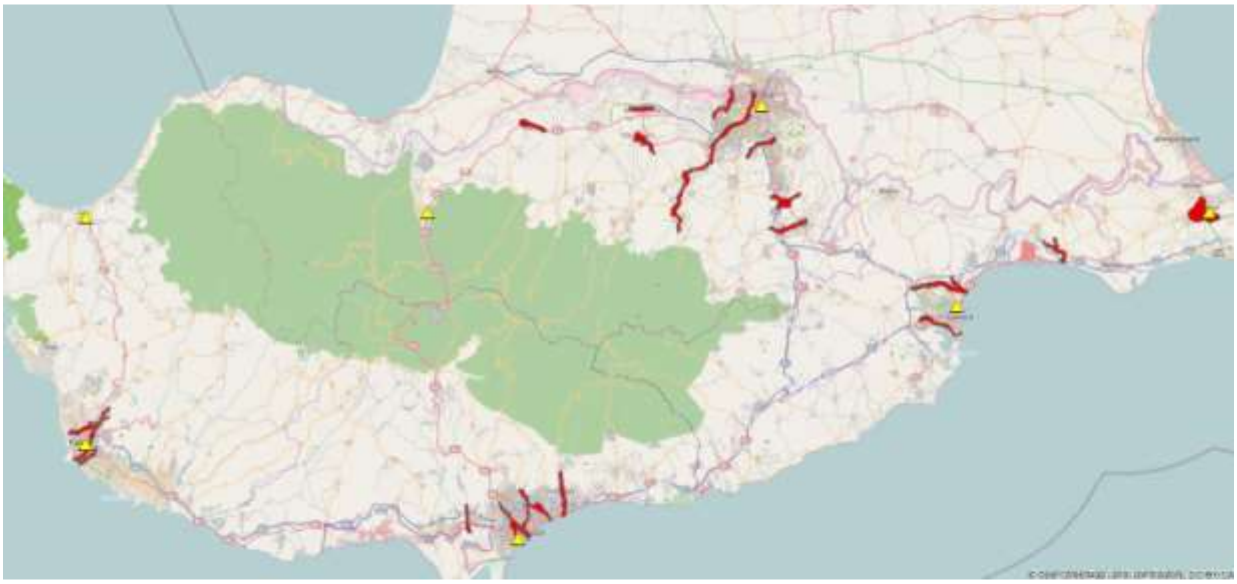


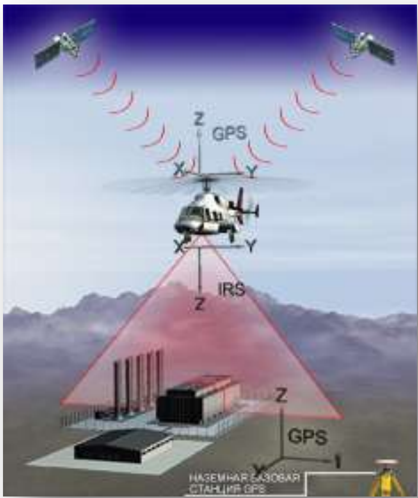
Image: distribution of base stations during flight

Determination of which DGPS base station can serve for real time use during survey missions of each sub area.

The Airborne GPS system has three points of interface with the photographing system:

A. Defining exposure time with the highest accuracy possible
B. The ground and air borne GPS stations recorded their positions simultaneously with a rate of 1 second Frequency.
C. Applanix IMU report of the plane's movement was calculated relative to the camera location during exposure for the purpose of calculating the LIDAR and Photo and projection centers.

The interaction between the different geodetic support aids is demonstrated in the figure below:

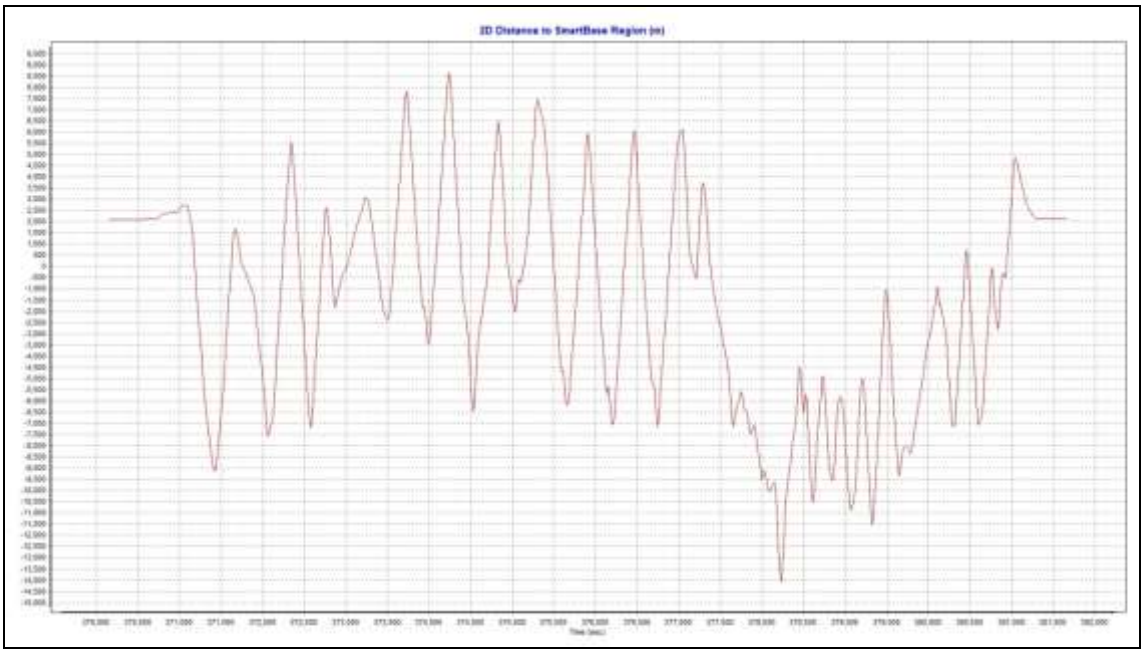


The surveyors confirmed that the ground stations are recording at least one and a half hour before flight, in a range of less than 25 km from the target area (See Appendix D- IMU& GPS Report). The Airborne GPS was also started record before flight. The record continued until the aerial mission ended. The altitude of the GCPs was calculated and integrated in all the mapping products.

In order to confirm that all the above mentioned, data IMU report is plotted demonstrating the following:

A. Distance from base station
B. Number of Satellite recorded during each moment of flight

Image (below): Example of distance from base station report (See appendix D)



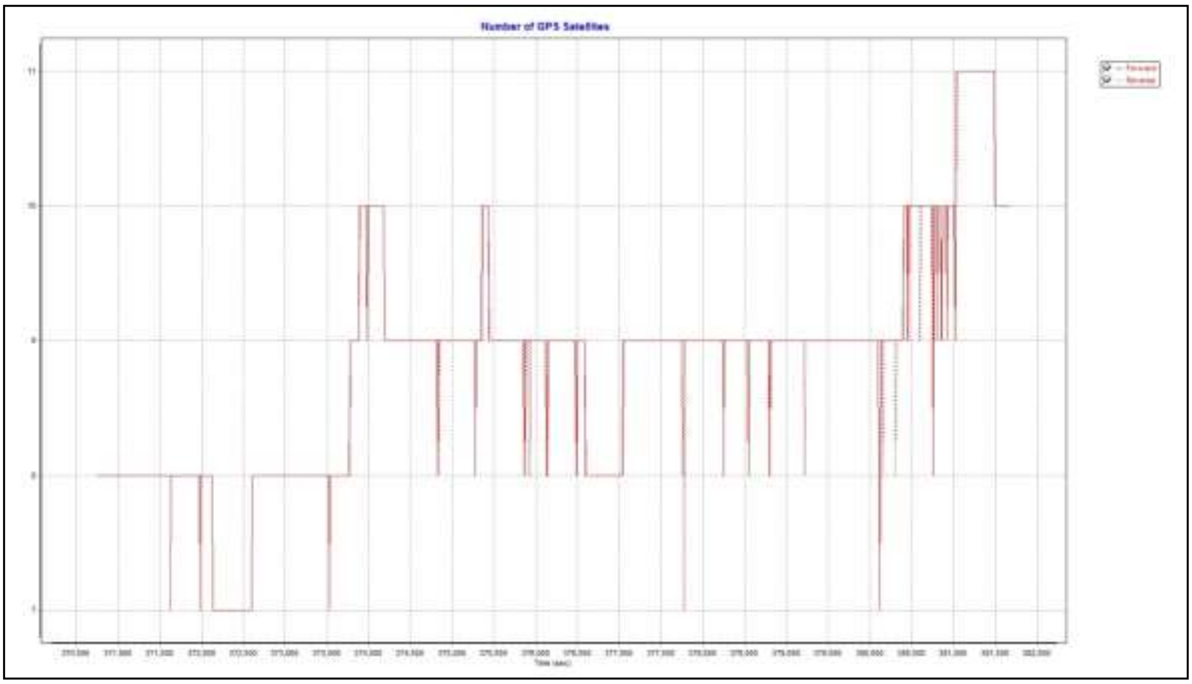


Image (above): Example of Satellite observation report (See appendix D)

4.1. <u>Flight Operation, documentation & Coordination</u>

4.1.1. Air Crew

Our crew included pilot, Navigator/Airborne systems operator , Ground technician/ data editor.

Staff Position	Staff Name	Experience
Pilot	Amos Hayoun	8
Co pilot	Roy Lannes	16
Airborne systems Operator	Daniel Brody	6
Ground technician	Shachar Kaufman	9

4.1.2. Flight Coordination

Ground handling and operating services

The project coordinator hired local services of Abelair Aviation Ltd., a local aviation company for coordinating flights and for supplying Ground services. The flight services included:

A. Flight plans.
B. Notes for airmen - NOTAMS.
C. Meteorology services.
D. Special photography flight clearances (military zones, restricted and congested traffic lines).
E. Ground services including:
    a. Refueling
    b. Maintenance
    c. Parking
    d. Customs
    e. Entry permits and maneuverability in the airfield

The local aviation company Abelair with the support of the contracting party obtained The Civil Aviation and Military authorizations needed for flying in Cyprus and in the project area. Flight plans were submitted on a daily basis in order to allow aerial photography any day that weather conditions permit.

4.1.3. Considerations for decision to fly on operational days

Sun Angles- The photography was made only with a sun angle of between 20º and 50 º (usually between 30º and 50º).

Visibility- Photography was only performed in conditions of clear visibility with no significant disruption to the tone reproduction in the photo. Relevant details were not lost as a result of atmospheric haze or dust. Photographs are free of clouds, density, shadow or smoke.

4.1.4. Security Control

The images were transferred to the Cyprus security authorities for inspection and removal of restricted areas.

4.2. Photography Flights Quality Control

All of the flight products were checked and approved by the technical manager and the Quality Control manager According to the following standards:

Tasks	Activity	Criterions of Acceptance
Aerial Photography		
	Photography Planning	Approved by the client
	Cloud Coverage	Without clouds or shades
	All the areas covered by a stereo model	Total Coverage
	2 extra model at each side of flight line	Verified
	Position of flight lines	Verified
	Flight Directions	According to plan
	Sun Angle	< 30º
	Hours of solar reflection, Hot spot	none
	Photographs resolution	< 0.20m GSD
	Forward Overlap between photos	60%(+/- 5%)

	Frame Deviation, side lap between strips	30%(+/- 5%)
	Photographic Scale	Verified
	Crab (Drift) for used photos	< 5º
	Tilt for used photos	< 2º
	Photographic Quality Control report	Verified
	LIDAR	Aerial Photography
	Av. density of points	>0.5 pnt/m
	Overlap between LiDAR data strips	>25%
	Data records (COP) covers all the AOIs	100%

4.3. <u>Flight Reports</u>

A. The content of Index Plots
B. An index plot was prepared in a computerized format to show the relative positions of all the photographs. The index contains the following information:
C. Base-map
D. Area name and delineation
E. Dates of photography
F. Grid of geographical coordinates
G. Run (strip) numbers at both edges of each strip and where changes occur within a strip
H. Photo numbers

4.3.1. Photo numbering and print annotation

Numbering of the exposures was done automatically by camera real-time projection. The AeroTopol software is designed for collection of flight metadata during the flight what help to organized the considerably big number of photos which been collected during the flight. A file "

Cyprus_projection_centers_cgrs.shp " was delivered in SHP format containing the following attributes :

- Run Number
- Photo Number
- XYZ coordinates
- Area Name

Flight Report for each day (air crew report) –

- Appendix A specify the full report of each flight, which contains the following information:
- Run number and flight direction.
- Year(s), month(s) and day(s) of photography
- Aircraft type and identification
- Names of pilot(s), navigator and photographer
- Start and end time for each run in local time.
- Photo numbers of all offered photography.
- Computed altitude above mean sea level (true altitude)
- Nominal scale of photography
- Weather conditions - cloud type, degree of haze and turbulence etc.

4.4. Photo Control Points

The photo control points are an important element for achieving the required accuracy. The photo control points were retrieved from the following:

A. Projection centers that were calculated from the airborne and ground GPS station records.
B. GPS ground control points that were measured by ground D-GPS stations.
C. Thousands of Aero-Triangulation Tie points
D. Check points

5. Ground Control Points (GCP)

5.1. Methodology

Described herein is the methodology of the GCP acquisition:

A. Part of the control points were marked and measured in the field according to pre-planning schedule before flight.
B. Other points were measured on stable elements that can be clearly identified in the photos after the flight.
C. GPS control points were marked on the ground and measured on the block corners. Additional points were marked and measured inside the block.
D. Locations for the ground DGPS control stations, which were used during the flight, were determined in advance. In this project, the national permanent base stations were used as presented in the image below.
E. The ground stations confirmed to record data at least one and a half hour before flight, in a range of less than 25 km from the target area.
F. The Airborne GPS started record before flight .The record continued until the aerial mission ended.

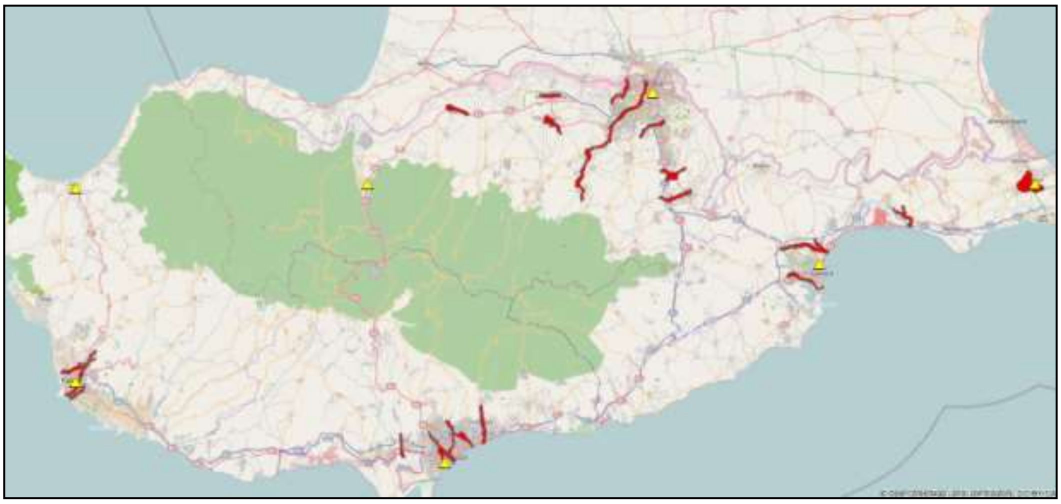


Image: The location of base stations referring to the covered areas.

Base Station	x	y	Z
EVRYCHOU	N35°02'18.72638"	E32°53'59.82235"	473.82
LARNAKA	N34°55'50.57801"	E33°37'55.21926"	47.126
LEFKOSIA	N35°09'39.83624"	E33°21'46.44464"	192.67
LEMESOS	N34°40'03.26939"	E33°01'30.49093"	50.209
PARALIM	N35°02'04.15780"	E33°58'56.37341"	102.31
POLIS	N35°01'58.85428"	E32°25'39.05170"	68.768
PAFOS	N34°46'25.96186"	E32°25'40.39818"	114.37

5.1.1. Adjustment to the national network

The Network ,which was used for the flight is UTM-WGS 84 zone 36.The transformation to the local network CGRS 1993 LTM was done in post process according to the local mapping authorities parameters.

The local surveyors purchased national triangulation points and benchmarks that were used as reference points to tie the project to the national network.

The following data was collected from the national mapping authorities (DLS):

- Transformation parameters:
  - Spheroid parameters (a, 1/f)
  - Datum transformation from WGS 84 to the National datum
  - (Dx, Dy, Dz , Rx, Ry, Rz, D scale)
- Projection method:
  - The Projection method that was used is Traverse Mercator
  - Central Meridian (origin Longitude)
  - Scale factor
  - Southernmost parallel (origin Latitude)
  - False east false north and their factors

Coordinates in WGS 84 and in the local system of the base stations were used for checking the transformation formula.

Coordinates in the local system of several ground points (minimum 3 X, Y points and 4 benchmarks Z) which were allocated and measured by our surveyors in site in order to a reference to the project adjusted network. The points were established in maximum 15km from project area center.

5.1.2. Procedures for establishment of Geodetic Net

The following concept was determined in advance and approved by the project manager:

A. The Number of control points that were used in each area is at least 20.

B. The amount and location of checkpoints that were used for each area and measured by GPS. The selected locations for check points were usually flat sites, which are big enough to contain few LIDAR points.

C. A total amount of 489 points that were measured, in each area at least 20 Points. (see appendix G –Control Points Index). Part of these control points were used as check point (see Appendix F – Accuracy report)

D. The points are covering the total area of each AOI polygon.

Image : Sample for distribution of GCP's in Paphos Area

All the points were measured by DGPS observation in RTK mode.

5.1.3. Check points

Some of the photo control points (ground DGPS, AT points) were used as reference points for quality control purpose only. These points served as check points.

The methodology for using check points:

A. Check Points were distributed homogeneously over the photogrammetric block. Their further use in surveys to follow is taken into account.

B. At least 6 Check Points were defined for each photogrammetric block,

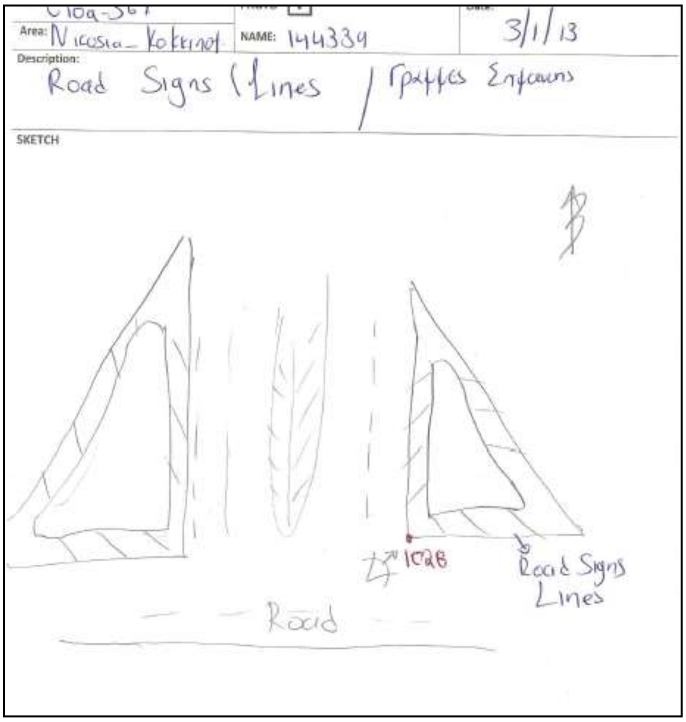
C. The coordinates of Check Points were defined by GPS measurement on an equal accuracy as the other Control points.

5.1.4. *Final deliveries of GPS Measurements Products*

The final list of GPS control and check points. (See Appendix G)

Directory which contains GCP descriptions (see "Reports and Metadata \ Control points\sketch+jpg "dir.) and GCP's index "control point_ by_ area.shp"

The Control and Check Points were documented in the field as follows:



PART C- THE PROCESS OF OUTPUT DATA

6. LIDAR Data processing

Aerial LIDAR survey data is processed using special software packages for the comprehensive laser data analysis and, in particular, for the creation Digital terrain models and of vector models of on-ground objects. There are two major modes of data processing:

Basic data processing- implemented through a set of algorithms used to derive primary laser data. It includes calibration, express analysis, pilot stage quality control and some other procedures.

Thematic data processing- oriented to address general geodetic and cartographic tasks. In case of flood hazard mapping thematic data processing is aimed to work out the set of data files liable to the next stages of geospatial processing.

6.1. Basic Data Processing Capabilities that were applied

A. Simultaneous representation of laser scans data (laser points) in plane and profile.

B. Separation and color-coded presentation of data relating to various passes of the flight. Color coding (deletion from the screen) of laser points relating to individual passes.

C. Direct access to any pass of the flight in the flight pass window.

D. Overlaying of the digital map with the flight data in the flight pass window.

E. Image zoom function available in flight path, plane and profile view windows (images can be visualized at any selected scale); Image rotation function available in plane and profile view windows (plane and frontal rotation).

F. Data visualization by way of a parallel projection with the deletion of invisible points.

G. Color-coding of laser points according to their geodetic altitude. Color-coding parameters can be set up automatically or manually.

H. Indication of geodetic coordinates (North, East, Altitude) of any laser point and current cursor position.

I. Creation of spatial corridors to select data for plane and profile views (Select Corridor).

J. Plane and profile measurements.

K. Visualization of geo-referenced digital aerial photos with respect to the scale and location of laser data.

L. Plane measurements using aerial photos.

M. Selection of a system to represent current coordinates.

N. Algorithm allowing the identification of true ground surface points and automated layer-by-layer differentiation of data relating to various objects. Visualization of individual layers with the parameter setup function.

O. Representation of ground surface points as a group of lines of equal altitudes.

P. Easy export of data and aerial photos into CAD and GIS systems.

6.2. Methodology

Usage of LIDAR data for terrain analyses requires the fulfillment of morphological selection of original LIDAR points. It is implemented by means of TERRASOLID software. At the first stage LIDAR point separation by "ground – not ground" criteria is implemented. Then all cloud of LIDAR points are divided into groups according their semantic essences. It is done by means of a number of sophisticated algorithms of geomorphologic treatment.

Classes of points which were distinguished:

- Ground (true terrain features) – DTM;
- Vegetation;
- Buildings and structures;
- Watery objects – basins, rivers, lakes and so on.
- Power lines: towers, wires.
- Fences.

(Vegetation through Fences: DSM)

For this project the DSM classification to the abovementioned categories was done only roughly and for internal QA procedures, and therefore the DSM was supplied to the client only as one DSM layer.

Break lines were generated from LIDAR COP integrated with photogrammetry interpretation of the 3D stereoscopic models of the digital images.

The following elements were decoded:

- The center river bed (stream centerlines).
- Open ducts (channels) of rainwater.
- Bottom and tops riverside.
- Roads that cut across or along the river.
- Recharge and other mounds within or alongside the riverbed
- Excavation and earthworks of roads (road embankments).
- Other structures within or near the bed that might affect the flow.

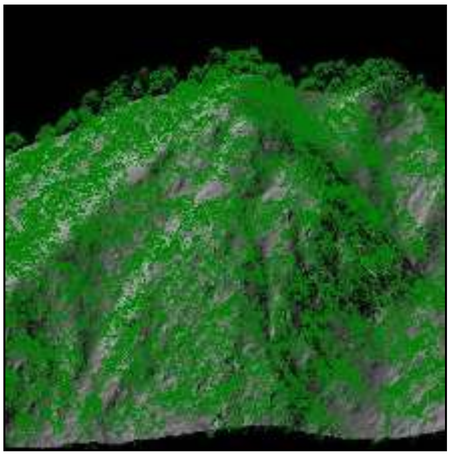
6.2.1. Point classification algorithms and methodology

The LIDAR point's classification procedure is a core of any geospatial technology based on usage of LIDAR data for topographical and hydrographical needs as well as in all GIS applications.

Laser point's classification is regarded as the first and the most important stage of the office processing. The major part of such a work is usually done automatically by means of specialized software such as TERRASOLID. Nevertheless it is important to have highly skilled team of photogrammetric specialists and operators to fulfill the full laser point classification completely and properly. The operator's role in that process is ensuring final quality control and partially implementation a manual classification for complicated and fine man-made objects like bridges, complex shape building and artificial channels and so on.

The whole point cloud is divided into two main categories: "ground" and "non-ground". The principal results of such classification are depicted at the figure below.

Image: Point cloud classification for "ground" and "non-ground"



Such classification actually forms three point classes - "ground", "non-ground" and "undefined". The last category consists of the points that cannot be unambiguously referred to the first or second classes. Such points usually lie at the border layer near to true ground and usually correspond to low vegetation like grass or bushes.

The rough stage of ground – non-ground separation is carried out in nearly automatic mode and in most cases does not require human to be involved at the further stages of processing. The percentage of not-classified points varies according to the nature of the surveyed area. In country side areas without complicated terrain and great number of man-made objects the percentage of not-classified points usually does not exceed 1-2%. In urban areas the percentage is usually no larger than 3-5%. For such parts, manual labor is needed in order to perform the necessary fine selection.

During the point classification, we select LIDAR points reflected from the ground points to be used as a framework (seeding points) to form TIN (Triangular Irregular Net) which plays a major role for building Digital Terrain Models (topographical or hydrographical) at the next steps of processing. The apt examples are described in the figures below.

TIN model of the true ground (made by LIDAR points classified as “ground”) is shown with a gray color, while all other on-ground object like building walls and roofs, vegetation, polls, power lines, flying birds, are shown with red and yellow.

TIN models of true ground are used as a main object of geospatial analysis for wide variety of applications. In particular such TIN is used as a main tool in flood prediction.

In the mathematical principles of true ground detection some heuristic ways are in use. The special software exploits the apriority knowledge regarding mathematical characteristic of true ground surface. If terrain is not excessively complicated and LIDAR point density is set properly, such a prerequisite is sufficient to detect the true ground surface fully automatically. If not, additional man labor is required.

6.3. LIDAR Process Deliverables

The following deliveries were made:

- Laser files with intensity values
- DTM – xyz FORMAT
- DSM – xyz format
- All control points and reference areas that were used in the project
- All aerial photography
- Reports:
  - Flight reports
  - Sensor report
  - Accuracy reports
  - GPS base stations reports

6.4. LIDAR Products accuracy

The required accuracy of all LIDAR deliveries were equal or better than RMSEz = 15 cm. This target accuracy was achieved as evident from the check points report of each block. (see appendix F- QA report of accuracy).

The Accuracy check report is based on comparison of known Z values of the GPS measurements with the check points of each area. An example for area C1 is presented below:

Area C1

Number	Easting	Northing	Known Z	Laser Z	Dz

323	223526.776	382964.284	292.365	292.500	+0.135
305	224878.728	384160.720	269.961	270.040	+0.079
325	223183.668	381588.119	308.101	308.170	+0.069
300	230422.004	389865.952	183.052	183.120	+0.068
324	224040.440	382842.690	294.944	295.000	+0.056
287	227230.740	387273.917	221.715	221.760	+0.045
299	231411.939	391843.914	165.771	165.810	+0.039
304	226996.116	386175.545	237.549	237.580	+0.031
302	228287.906	388343.633	207.118	207.130	+0.012
328	222230.082	378942.990	344.291	344.300	+0.009
284	229027.922	389376.864	195.895	195.900	+0.005
344	223318.772	383931.792	291.346	291.350	+0.004
333	224949.909	384208.257	268.290	268.290	+0.000
296	223992.935	382893.990	294.282	294.280	-0.002
313	228616.447	389022.430	199.656	199.650	-0.006
292	226005.240	384498.404	256.960	256.950	-0.010
280	231352.558	390889.537	172.431	172.420	-0.011
336	222502.133	380762.805	324.451	324.440	-0.011
316	232052.327	392657.192	157.044	157.030	-0.014
301	229590.046	389570.804	189.855	189.840	-0.015
306	224202.128	384008.873	274.825	274.800	-0.025
303	227385.723	387478.891	220.429	220.400	-0.029

309	226981.341	385139.458	249.454	249.380	-0.074
329	221883.879	378999.826	348.165	348.050	-0.115

Average dz	+0.010
Minimum dz	-0.115
Maximum dz	+0.135
Average magnitude	0.036
Root mean square	0.051
Std deviation	0.051

6.5. DTM processing

6.5.1. Input Data:

- Aerial Photography- the aerial photographs that were used to produce the DTM are those digital images that were specified in clause above.
- LiDAR Data- the products of LIDAR Clouds Of Points process after the separation of DTM and DSM.
- GPS ground control point

6.5.2. Aerial Triangulation

Aerial triangulation was done using ground control points. The ground control points and check points were measured in every photo in which they appear. The accuracy of measurement of ground control points depends on the pixel structure of the photos. Points can be identified by an operator to within between 1/3 and 1/5 of a pixel. Therefore suitable standard deviation settings for planimetry (XY) and height (Z) are calculated as follows:

- SDxy = 1/3 pixel * image scale e.g. pixel size = 20micron, image scale 1:10 000 SDxy = 1/3 * 0.02mm * 10 000 = 70mm = 0.07m
- SDz = SDxy * 1.5 or: SDz = SDxy * h/b
- Where h/b is the base to height ratio. For the example above where pixel size is 20 micron, SDz = 0.07*1.5 = 0.105m

Tie points and pass points were generated in the software using feature based matching, least squares matching and manual measurement. After the measurements are made a bundle block adjustment is performed using the measured control points and tie and pass points. The unknowns are the exterior orientation parameters X,Y,Z, omega, phi and kappa for each photo.

A measure of the level of accuracy achieved in the block is called sigma naught. The bundle block adjustment is computed in several iterations. Typical results of sigma naught should be between 1/5 and 1/3 of a pixel (< 3.4 micron).

Post processing of the block is then carried out in order to check the interior orientation. Self-calibration is carried out in order to check that the camera calibration parameters obtained during exterior orientation processing are stable.

Visual inspection is carried on in this stage to confirm that the same tie points are recognized in at least 4-6 photos. This density of good tie points should cover all the AOI as presented in the sample of block c19 below:

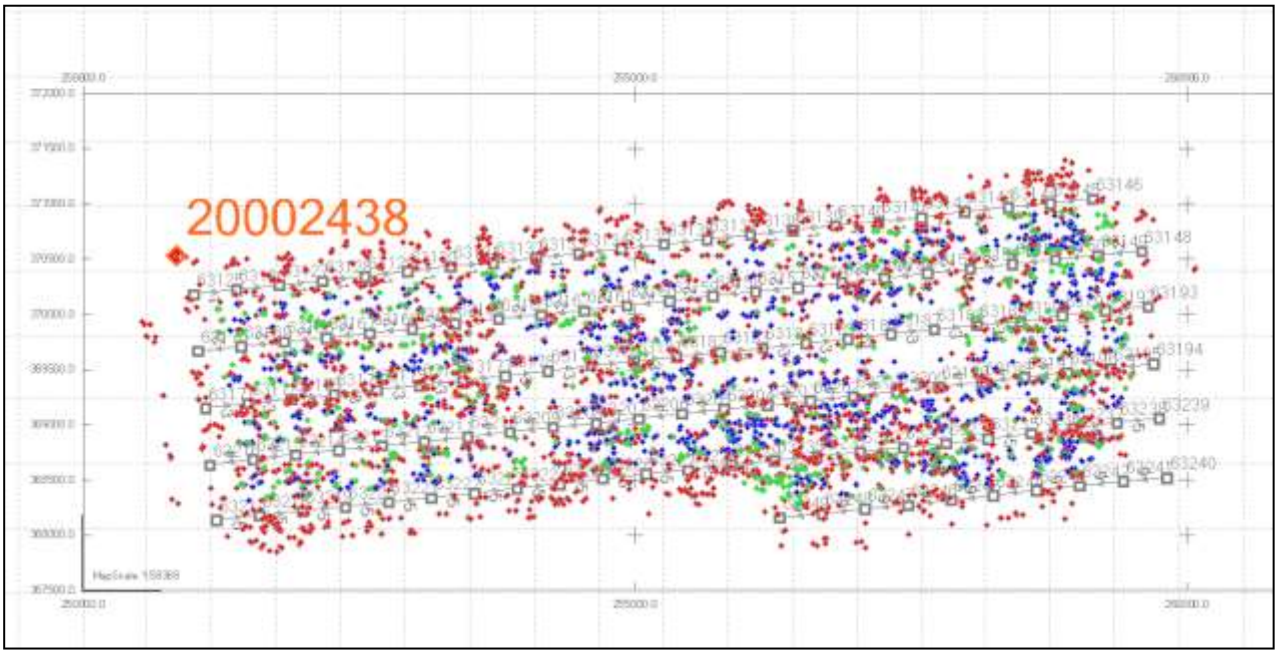


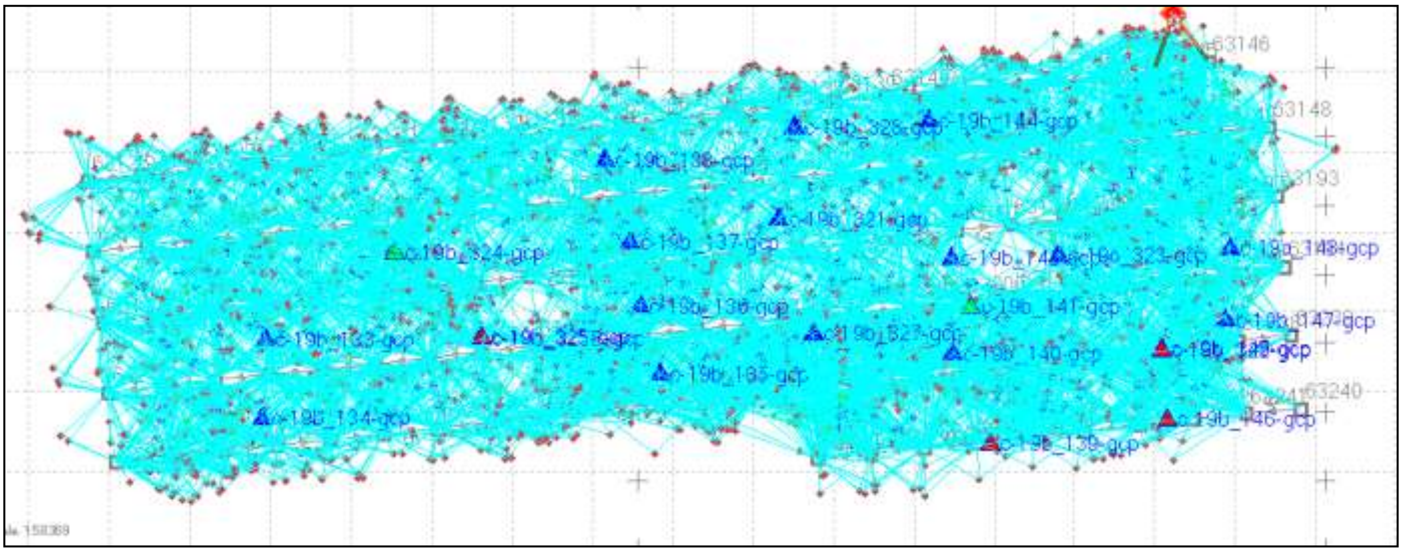
Figure 13: Sample of tie points distribution in block c19

Red *– Recognized in 4 images*

Green *- Recognized in 5 images*

Blue *- Recognized in 6 images*

Visual inspection is carried on in this stage to confirm that tie points have correct relative distance between their positions (blue) all over the block:



6.6. <u>DTM Display</u>

Once all checks have been performed and expected accuracies have been achieved the resulting exterior orientations are used in subsequent processes.

The DTM was displayed in the following formats: Mesh, profiles, dots, contours, TIN, quality indicators. In each different display the operator can select the best view to check the quality of the DTM.

6.7. <u>Interactive Terrain Editing</u>

A. Editing of the DTM is done following the automatic batch process, in order to achieve the highest accuracy. The editing including point-by-point edit, Lake Edit, smoothing, geomorphic Edit, cloud fill, tree canopy removal, hedge and building removal.

B. The operator performs all this activity manually over 3D view of stereo images while viewing the LIDAR processed point as reference.

C. The data collection includes elevation points along the lines of slope changes, significant points such as peaks and valleys, and the profiles at regular intervals (discontinued and brake lines).

D. It was essential to assure the careful placement of sampling to present the surface in areas of rapid variation of the ground slopes. The density of points in the collection shall be chosen as a function of the type of terrain.

6.8. Quality Assurance

To assure the high level of DTM Quality the following procedure was performed:

A. Batch process of seam lines feathering procedure was done by the operator, to remove buildings and tree canopy.

B. Where 3D vector data are available with height values, such as e.g. roads, rivers, lakes, etc., these were introduced to get a better correlation.

C. All correlation results were checked on the stereo workstation to remove gross errors and ensure a good fit to the ground. Forest areas were corrected to the ground level depending on the stereo availability of ground level. The operator will generate statistical reports comparing DTM with control points.

D. The DTM is delivered as a TIN model and as contours. Contours were derived at 1-meter intervals.

E. The data were delivered in AutoCAD *.DWG format or DWG format as specified by the clients.

7. Re-editing of the LiDAR delivery following to WDD comments

Following to the product delivery made in May 13, 2013, the publication of the new Geoid model for Cyprus by the Department of Land and Surveys, and the further communication made between the WDD and the JV representative, Ofek set to adjust the LiDAR deliveries to the new model. The adjustment process included the following steps:

A. Ofek received the new geoid height model for Cyprus from the DLS.

B. The model is a grid of points with a 500 meters by 500 meters separation.

C. In order to set the full height model, The height values between the 500 meters grid were interpolated. See below a detailed explanation of the interpolation process.

D. The height model was adjusted according to the new model where each point was re calculated by adding the difference between the height models.

E. As a measure of quality control, The recalculated height models accuracy was checked by comparison to ground control points (that were re-measured in the field in the MSL height)

F. Once the quality control was approved, the deliveries production process was re done in the new MSL height.

G. for each area the full list of deliverables was reproduced, among them: DTM+DSM in tiff and xyz format, break lines in SHP format, contours lines in SHP format and TIN model in LANDXML format.

The interpolation process used by Ofek during the LiDAR processing is as follows:

A. Laser point positions are usually first computed in WGS84 geocentric coordinate system. Positions are defined as longitude, latitude and ellipsoidal height values.

B. These values need to be transformed into a local coordinate system which is normally planar and often uses a geoid based height model.

C. The coordinate conversion task can be divided into two separate steps:

D. XY conversion (from longitude, latitude into easting, northing)

E. Z adjustment (elevation difference between WGS84 ellipsoid and local height model) - this is the process we used.

F. The elevation adjustment cannot be defined as one mathematical formula as the geoid has no mathematical shape. Therefore, the elevation adjustment needs to be defined by using local points for which the elevation difference is known. In this project we used the model that was received from the DLS (the model covered the entire LIDAR project area) containing points in a 500mX500m grid.

G. Additional information received from the DLS contained 489 ground control points. Those points were measured by GPS RTK and use the same mathematical formula for conversion. Therefore it is meaningless to add then them in the 500 meter grid as a base for conversion.

H. The actual adjustment of the laser points data between the two height models was made using the tools of the TerraScan software.

I. The TerraScan operates in the following manner:

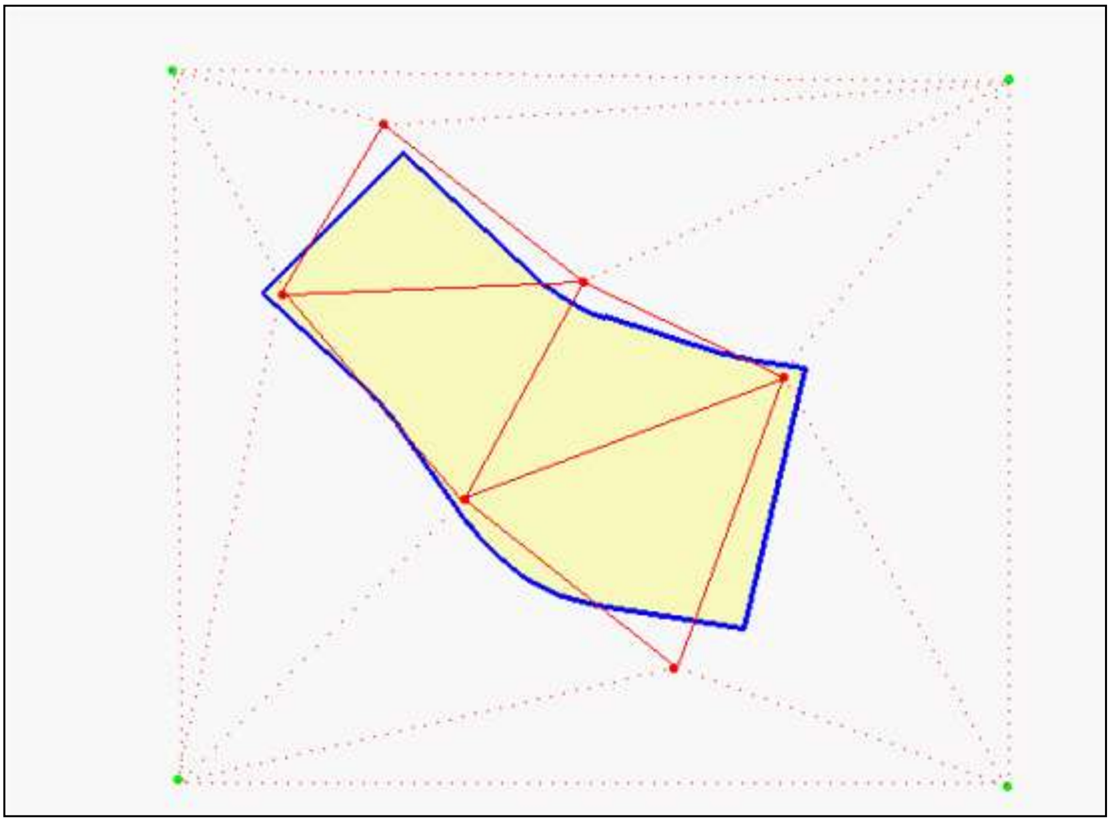
   a. Insertion of points from file - text file containing space delimited x y dz points (the 500 meter grid).

   b. The input points are modeled as a triangulated surface to enable aerial interpolation of adjustment values.

   c. Elevation adjustments are derived by linear interpolation along linear element’s segments.

d. The process will result in aerial interpolation of adjustment values.

e. The input data format is illustrated below:



In the above illustration:

yellow area is the area covered by laser data

the six red points are known x y dz –points

8. Quality Assessment and Quality Control

Ofek Organization responds to Quality Assurance (Q.A.) ISO 9002 standards. The following table describing the checks and criterions of acceptance for each process stage and products:

Tasks	Activity	Criterions of Acceptance
Aerial Photography		
	Photography Planning	Approved by the client
	Cloud Coverage	< 1º
	All the areas covered by a stereo model, kappa, phi and omega	Total Coverage 2 extra model at each side of flight line
	Position of flight lines	V
	Flight Directions	According to flight plan
	Sun Angle	< 30º
	Hours of solar reflection, Hot spot	None
	Overlap between photos	60% (+/- 2%)
	Frame Deviation, side lap between strips	30% (+/- 2%)
	Photographic Scale	
	Crab (Drift)	< 5º
	Tilt	< 2º
	Metadata exist for every photo	V
	Photographic Quality Control	Done
	GSD (ground sample distance)	<= 20 cm.
	Sensor resolution (micron)	6.8
	Linear elements (clearness and sharpness)	V

	Newton Rings	None
	Histogram of color balance for White Values Black Values	 < 255 > 0
	Visual Check in comparison to the original raw files (sharpness, colors)	V
	LIDAR Av. density of points	1.0 points /m² (a point each 1 m²)
	LiDAR COP strips Overlap	25%
	LIDAR Data recording	First, second, third and last pulse, Intensity for each echo
Projection Centers for Aerial photography		
	Planning Stage	
	Vector between reference and Rover	< 25 km.
	(SRI) Sample of the interval rhythm	1 Sec.
	Data Storage of the GPS card	>= 32MB
	Satellites Ephemeris Prediction for flight dates	> 8
	Reference Station adjusted to the National Net	RMS < 1 cm

	Operation Stage	
	No. of satellites	> 5
	PDOP (Reference and Rover)	< 2.5
	Airborne Data DGPS	Event mark register for each exposure (M file)
	Airborne and ground Data	Existence of 3 files (B,E,S) for

		each day of photography
	Ground DGPS base station records	Data is covering all flight time
	Post Processing Stage	
	Elimination of noise	None
	Consistency of coverage	All area should be covered
	Precision of airborne vectors according to the calculation software report	< 0.4m
	Precision of 90% of the projection centers	< 0.5 m
Ground Control Points		
	Standard horizontal Deviation	< 0.03 meters
	Standard Deviation of altitude	< 0.05 meters
	Consistency of coverage by local Geoid's model	< 90% of the area
Aero Triangulation		
	Exterior Orientation: (RMSE) standard horizontal deviation (sigma naught)	< 3.4 micron (1/2 pixel)
	Standard horizontal Deviation of terrain points	< 0.10 m
	Standard altitude Deviation of terrain points	< 0.125 m
	No' of tie points per model	> 9
	Final RMSE of all control points (ground, Tie, Pass)- X,Y	<15 micron at photo scale
	Final RMSE of all control points (ground, Tie, Pass)- Z	<25 micron at photo scale
	Overlap between AT Block (if applicable)	2 flight lines
DTM Measurements		
	Regular Interval	2 X 2m
	Standard Deviation of platitude interpolation	< = 0.25 meters

	If ground visible, single error	< = 0.15 meters
	Completeness, contours, boundaries	100% + 20 m' each side
	Contour lines vertical interval	1.0 m'
	distance between contour labels	<= 250 m'
	Height accuracy target	0.25 m
	Position accuracy	0.4 m
Restitution (of break lines and terrain elements)		
	Standard Deviation on accuracy, well determined points	< 0.15 m
	Logical Consistency, checked reviewed captured data	100%
	Completeness, checked comparing captured data plotted with contact print	100%
Edition		
	Editing	
	Layers not recognized	None
	Correlation Feature / layer code	100 %
	Correlation of symbols and text for their codes	100 %
	Closed Polygons	Not Applicable
	Output format	V
	Coordinate frame (numbers, position, layers)	V
	Topology (overshoot / undershoot)	V
	Altimetry Data	V
	Regular points greed covering the area	V
	3D break lines	V

	Couture lines according to vertical interval	V
	Elimination of noises in contour lines (size in map scale)	< 0.2 mm
	Cartography	
	Legend– all the symbols existing, same type of fonts and colors	V
	Headings – according to the required index	V
	Index Map name of the map or sheet	V
	North Arrow, Logotypes and other cartographic symbols	V
	Reference dates and name of the performers	Relative
	Hard Copies Impressions (plots)	
	The distances deviations between 90% of well defined characteristics in the impression (plot) from the distance measured in field or on the copies in Compact Disc.	Not applicable
	Deviation distance between 100% of well defined characteristics or features in the plot from a measured distance in field or in soft copy (CD).	Not applicable
	Text fonts, colors, line thickness	Not applicable
Delivery		
	Data and documentation for data capture were reviewed with respect to the acceptable quality levels specified in the TOR documents and in this technical proposal.	100%

9. Summary of Deliverables

This section summarizes the project deliverables formats to be supplied to the customer:

Item	Description	Delivered directory or File name	Storage device
1	0.5-1 points/m² density as raw cloud of points (ALS format) and as A grid file in X, Y, Z derived from the processed LIDAR file and geo referenced to the local Datum. The elevation accuracy of each sign shall be ± 15 cm or better.	LiDAR\Raw-LiDAR-Data (dir.)	HHG
2	Digital Terrain model of bare ground (Bare Earth Digital Terrain Model), which depicts the bare soil surface in the form of TIN (Triangular Irregular Network) which will result from the triangulation of the cloud points of the surface coverage in conjunction with the fracture lines.	LiDAR\Tin With Break Line (dir.)	
3	Digital model of surface coverage (Digital Surface Model) in the form of regular grid (Raster DEM)-dimensional cell 2 by 2 meters, in the form of GeoTIFF.	LiDAR\DSM Raster (dir.)	
4	Digital model of bare soil in the form of regular grid (Raster DEM)-dimensional cell 2 by 2 meters, in the form of GeoTIFF.	LiDAR\DTM Raster (dir.)	
5	All lines rupture (break lines) in the form of ESRI shape file or ESRI feature class used to create elevation models.	LiDAR\break lines (dir.)	
6	1 m Contour lines of bare soil model in the form of ESRI shape file or ESRI feature class.	LiDAR\Contour lines (dir.)	
7	The aerial photographs taken during the flights.	Aerial photographs\Images (dir.)	
8	Diagram of the final shooting aerial photography using icons (thumbnails).	Aerial photographs\Diagram	

9	All raw data of additional topographical renderings that had to be made for the purpose of filling the gaps in the data LIDAR.	Not Applicable	
10	All raw data files, Metadata files, index maps and reports.	Reports and Metadata	
11	All control points and its reference format ESRI shape file Feature class is used in calibration, testing, processing and validation of the LIDAR points of the products obtained from them.	Control points	

APPENDICES

Flight reports and photo index – Appendix A

Airborne Equipment Calibration reports – Appendix B

Base station Report – Appendix C

IMU & GPS report – Appendix D

Aero Triangulation Report for each area – Appendix E

QA Report of Accuracy for each area – Appendix F

Ground Control points Index - Appendix G

The appendices will be submitted to the WDD separately in digital form (CD).

		Name
1		⊟ **flight operation**
2	✔	Flight Planning
3		Obtaining Civil Aviation Authority permit
4		LiDAR-Rollei integration
5		Calibration flight in Israel
6		Coordination of ground handeling services
7		Coordination of hotel, vehicle, board and lodging etc
8		Insurance and customs arrangements
9		Submitting project plan to client
10		submitting flight plans to civil avaition
11		Airplane and equipment preparation
12		Mobilization to Cyprus
13		Base station deployments
14		LiDAR flight execution
15		Setting of on-line processing computer station
16		On-Line Processing of the scanned area
17		Onsite Airplane Technical inspection
18		Airplane and equipment preparation for return flight
19		Demobilization to Israel
20		Rollei calibration
21		⊟ **Ground surveys**
22		Planning GCP deployment scheme
23		GCP survey
24		⊟ **Data Processing**
25		Aerial Triangulation
26		Aerial photography processing
27		LiDAR analyses and DTM production
28		QA/QC
29		Product Editing into delivery formats
30		Preparation of Preliminary Report
31		Project Deliverables and Preliminary Report submission