

# Panay River Flood Plain:

DREAM LiDAR Data Acquistion and Processing Report









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## **Abbreviations**

ALTM	Airborne Laser Terrain Mapper
DAC	Data Acquisition Component

DEM Digital Elevation Model
DSM Digital Surface Model
DTM Digital Terrain Model

DVC Data Validation Component

FOV Field of View

FTP File Transfer Protocol
GPS Global Positioning System

GNSS Global Navigation Satellite System

POS Position Orientation System
PRF Pulse Repetition Frequency

NAMRIA National Mapping and Resource Information Authority



### 1.1 About the DREAM Program

The UP Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) conducts a research program entitled "Nationwide Disaster Risk and Exposure Assessment for Mitigation (DREAM) Program" funded by the Department of Science and Technology (DOST) Grants-in-Aid Program. The DREAM Program aims to produce detailed, up-to-date, national elevation dataset for 3D flood and hazard mapping to address disaster risk reduction and mitigation in the country.

The DREAM Program consists of four components that operationalize the various stages of implementation. The Data Acquisition Component (DAC) conducts aerial surveys to collect Light Detecting and Ranging (LiDAR) data and aerial images in major river basins and priority areas. The Data Validation Component (DVC) implements ground surveys to validate acquired LiDAR data, along with bathymetric measurements to gather river discharge data. The Data Processing Component (DPC) processes and compiles all data generated by the DAC and DVC. Finally, the Flood Modeling Component (FMC) utilizes compiled data for flood modeling and simulation.

Overall, the target output is a national elevation dataset suitable for 1:5000 scale mapping, with 50 centimeter horizontal and vertical accuracies. These accuracies are achieved through the use of state-of-the-art airborne Light Detection and Ranging (LiDAR) technology and appended with Synthetic-aperture radar (SAR) in some areas. It collects point cloud data at a rate of 100,000 to 500,000 points per second, and is capable of collecting elevation data at a rate of 300 to 400 square kilometers per day, per sensor.

### 1.2 Objectives and Target Outputs

The program aims to achieve the following objectives:

- a) To acquire a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management;
- b) To operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country;
- c) To develop the capacity to process, produce and analyze various proven and potential thematic map layers from the 3D data useful for government agencies;
- d) To transfer product development technologies to government agencies with geospatial information requirements, and;
- e) To generate the following outputs:
  - 1) flood hazard map
  - 2) digital surface model
  - 3) digital terrain model and
  - 4) orthophotograph



### Introduction

## 1.3 General Methodological Framework

The methodology employed to accomplish the project's expected outputs are subdivided into four (4) major components, as shown in Figure 1. Each component is described in detail in the following sections.

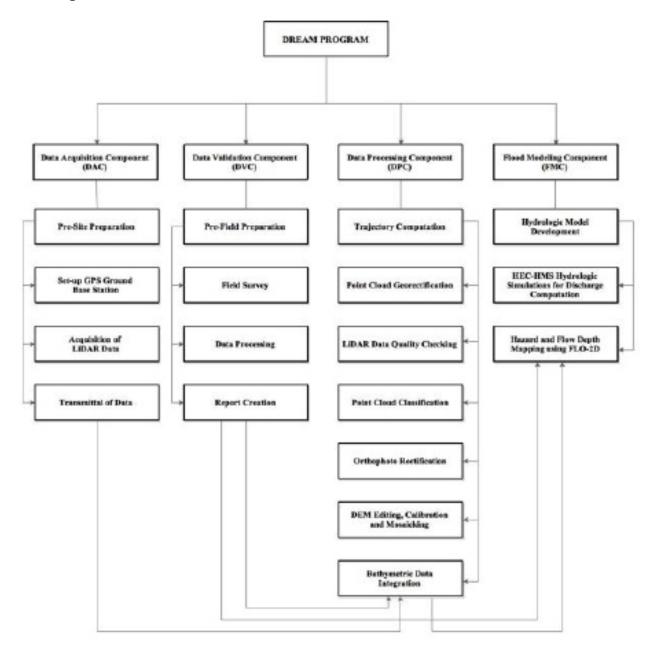


Figure 1. The General Methodological Framework of the Program





## **Study Area**

The Panay River Basin located in the north eastern part island of Panay in Western Visayas. The Panay River Basin is considered as the 12th largest river basin in the Philippines. It covers an estimated basin area of 1,843 square kilometers. The location of Panay River Basin is as shown in Figure 2.

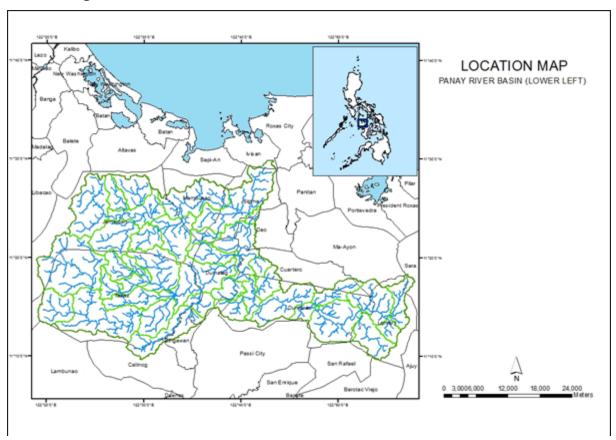


Figure 2. The Panay River Basin Location Map

This area includes the whole province of Capiz and a part of Iloilo and Aklan. The upper part of the Panay River Basin consists of the Upper Panay River mainstream basin and three major tributary basins, the Badbaran, Mambusao, and Maayon river basins. It traverses through the Roxas City and the towns of Capiz and Pontevedra and drains the northern portion of the island.

The land and soil characteristics are important parameters used in assigning the roughness coefficient for different areas within the river basin. The roughness coefficient, also called Manning's coefficient, represents the variable flow of water in different land covers (i.e. rougher, restricted flow within vegetated areas, smoother flow within channels and fluvial environments).

The shape files of the soil and land cover were taken from the Bureau of Soils, which is under the Department of Environment and Natural Resources Management, and National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Panay River Basin are shown in Figures 3 and 4, respectively.

## **Study Area**

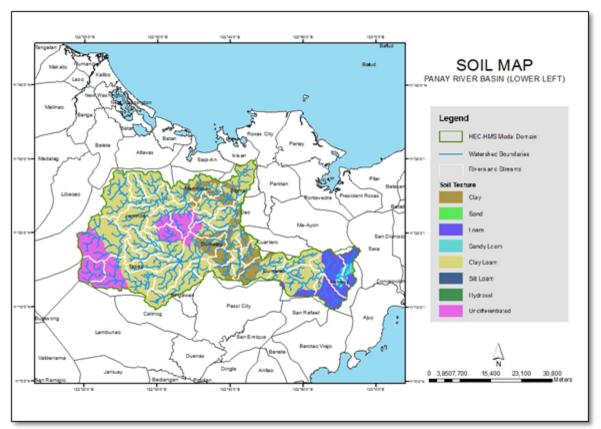


Figure 3. Panay River Basin Soil Map

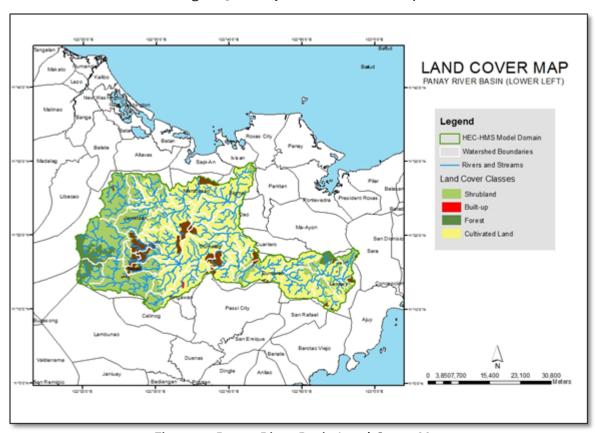


Figure 4. Panay River Basin Land Cover Map





### 3.1 Acquisition Methodology

The methodology employed to accomplish the project's expected outputs are subdivided into four (4) major components, as shown in Figure 5. Each component is described in detail in the following sections.

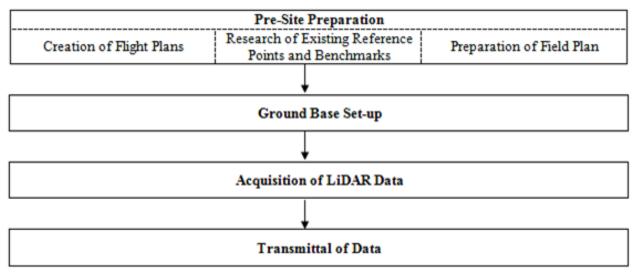


Figure 5. Flowchart of Project Methodology

#### 3.1.1 Pre-site Preparations

#### 3.1.1.1 Creation of Flight Plans

Flight planning is the process of configuring the parameters of the aircraft and LiDAR technology (i.e., altitude, angular field of view (FOV)), speed of the aircraft, scans frequency and pulse repetition frequency) to achieve a target of two points per square meter point density for the floodplain. This ensures that areas of the floodplain that are most susceptible to floods will be covered. LiDAR parameters and their computations are shown in Table 1.

The parameters set in the LiDAR sensor to optimize the area coverage following the objectives of the project and to ensure the aircraft's safe return to the airport (base of operations) are shown in Table 1. Each flight acquisition is designed for four operational hours. The maximum flying hours for Cessna 206H is five hours.

Table 1. Relevant LiDAR parameters

Parameter		Formula	Description	
SW (Swath Width)		SW = 2 * H * tan (θ/2)	H – altitude Θ – angular FOV	
Pointing Space	ΔXacross	ΔXacross = (Θ * H) / (Ncos2(Θ/2))	ΔXacross – point spacing across the flight line H – altitude Θ – angular FOV N – number of points in one scanning line	
	ΔXalong	ΔXalong = v / fsc	ΔXalong- point spacing along the flight line v – forward speed (m/s) fsc – scanning rate or scan frequency	
Point density, dmin		dmin = 1 / ( ΔXacross * ΔXalong)	ΔXacross, ΔXalong point spacings	
Flight line separa- tion, e		e = SW * ( 1 – overlapping fac- tor)	SW – swath width	
# of flight lines, n		n = w / [(1 – overlap) * SW]	w-width of the map that will be produce in meters. The direction of flights will be perpendicular to the width.	

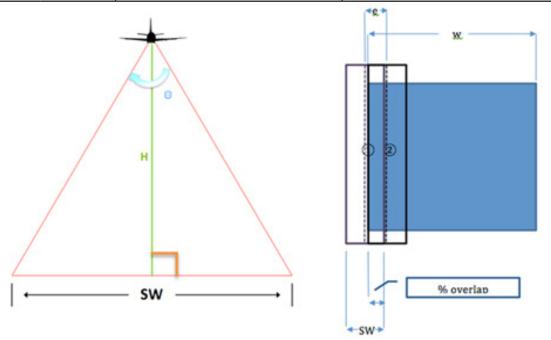


Figure 6. Concept of LiDAR data acquisition parameters

The relationship among altitude, swath, and FOV is show in Figure 6. Given the altitude of the survey (H) and the angular FOV, the survey coverage for each pass (swath) can be calculated by doubling the product of altitude and tangent of half the field of view.

# 3.1.1.2 Collection of Existing Reference Points and Benchmarks

Collection of pertinent technical data, available information, and coordination with the National Mapping and Resource Information Authority (NAMRIA) is conducted prior to the surveys. Reference data collected includes locations and descriptions of horizontal and vertical control (elevation benchmarks) points within or near the project area. These control points are used as base stations for the aerial survey operations. Base stations are observed simultaneously with the acquisition flights.

#### 3.1.1.3 Preparation of Field Plan

In preparation for the field reconnaissance and actual LiDAR data acquisition, a field plan is prepared by the implementation team. The field plan serves as a guide for the actual fieldwork and included personnel, logistical, financial, and technical details. Three major factors are included in field plan preparation: priority areas for the major river basin system; budget; and accommodation and vehicle rental.

LiDAR data are acquired for the floodplain area of the river system as per order of priority based on history of flooding, loss of lives, and damages of property. The order of priority in which LiDAR data surveys are conducted by the team for the floodplain areas of the 18 major river systems and 3 additional systems is shown in Table 2.

Table 2. List of Target River Systems in the Philippines

	Target River System	Location	Area of the River Sys- tem (km²)	Area of the Flood Plain (km²)	Area of the Watershed (km²)
1	Cagayan de Oro	Mindanao	1,364	25	1,338.51
1.1	Iponan	Mindanao	438	33	404.65
2	Mandulog	Mindanao	714	7	707.41
2.1	Iligan	Mindanao	153	7	146.38
2.2	Agus	Mindanao	1,918	16	1,901.60
3	Pampanga	Luzon	11,160	4458	6702
4	Agno	Luzon	6,220	1725	4495
5	Bicol	Luzon	3,173	585	2,587.79
6	Panay	Visayas	2,442	619	1823
7	Jalaur	Visayas	2,105	713	1,392
8	Ilog Hilbangan	Visayas	2,146	179	1967
9	Magasawang Tubig	Luzon	1,960	483	1,477.08
10	Agusan	Mindanao	11,814	262	11,551.62
11	Tagoloan	Mindanao	1,753	30	1,722.90
12	Davao	Mindanao	1,609	54	1555
13	Tagum	Mindanao	2,504	595	1,909.23
14	Buayan	Mindanao	1,589	201	1,388.21
15	Mindanao	Mindanao	20,963	405	20,557.53
16	Lucena	Luzon	238	49	189.31
17	Panay	Luzon	1,029	90	938.61
18	Boracay	Visayas	43.34	43.34	N/A
19	Cagayan	Luzon	28,221	10386	17,835.14

#### 3.1.2 Ground Base Set-up

A reconnaissance is conducted one day before the actual LiDAR survey for purposes of recovering control point monuments on the ground and site visits of the survey area set in the flight plan for the floodplain. Coordination meetings with the Airport Manager, regional DOST office, local government units and other concerned line government agencies are also held.

Ground base stations are established within 30-kilometer radius of the corresponding survey area in the flight plan. This enables the system to establish its position in three-dimensional (3D) space so that the acquired topographic data will have an accurate 3D position since the survey required simultaneous observation with a base station on the ground using terrestrial Global Navigation Satellite System (GNSS) receivers.

#### 3.1.3 Acquisition of Digital Elevation Data (LiDAR Survey)

Acquisition of LiDAR data is done by following the flight plans. The survey uses a LiDAR instrument mounted on the aircraft with its sensor positioned through a specially modified peep hole on the belly of the aircraft. The pilots are guided by the flight guidance software which uses the data out of the flight planning program with a mini-display at the pilot's cockpit showing the aircraft's real-time position relative to the current survey flight line. The reference points established by NAMRIA are also monitored and used to calibrate the data.

As the system collected LiDAR data, ranges and intensities are recorded on hard drives dedicated to the system while the images are stored on the camera hard drive. Position Orientation System (POS) data is recorded on the POS computer inside the control rack. It can only be accessed and downloaded via file transfer protocol (ftp) to the laptop computer. GPS observations were downloaded each day for efficient data management.

### 3.1.4 Transmittal of Acquired LiDAR Data

All data surrendered are monitored, inspected and re-checked by securing a data transfer checklist signed by the downloader (Data Acquisition Component) and the receiver (Data Processing Component). The data transfer checklist shall include the following: date of survey, mission name, flight number, disk size of the necessary data (LAS, LOGS, POS, Images, Mission Log File, Range, Digitizer and the Base Station), and the data directory within the server. Figure 7 shows the arrangement of folders inside the data server.

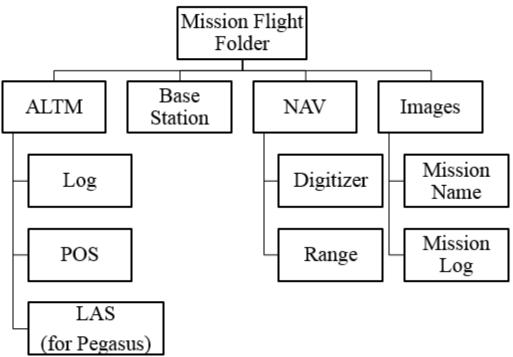
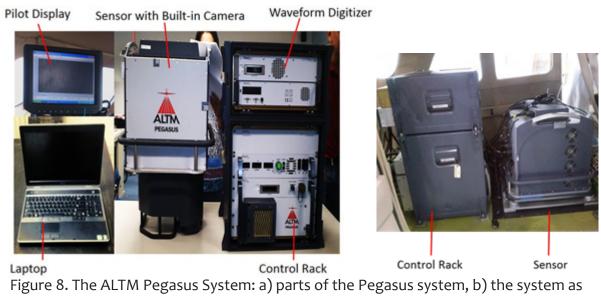


Figure 7. LiDAR Data Management for transmittal

#### 3.1.5 Equipment (ALTM Pegasus)

The ALTM Pegasus (Optech, Inc) is a laser based system suitable for topographic survey (Figure 8). It has a dual output laser system for maximum density capability. The LiDAR system is equipped with an Inertial Measurement Unit (IMU) and GPS for geo-referencing of the acquired data (Annex A contains the technical specification of the system).

The camera of the Pegasus sensor is tightly integrated with the system. It has a footprint of 8,900 pixels across by 6,700 pixels along the flight line (Annex B contains the technical specification of the D-8900 aerial digital camera).



installed in Cessna T206H

## 3.2 Processing Methodology

The schematic diagram of the workflow implemented by the Data Processing Component (DPC) is shown in Figure 9. The raw data collected by the Data Acquisition Component (DAC) is transferred to DPC. Pre-processing of this data starts with the computation of trajectory and georectification of point cloud, in which the coordinates of the LiDAR point cloud data are adjusted and checked for gaps and shifts, using POSPac, LMS, LAStools and Quick Terrain (QT) Modeler software.

The unclassified LiDAR data then undergoes point cloud classification, which allows cleaning of noise data that are not necessary for further processing, using TerraScan software. The classified point cloud data in ASCII format is used to generate a data elevation model (DEM), which is edited and calibrated with the use of validation and bathymetric survey data collected from the field by the Data Validation and Bathymetry Component (DVBC). The final DEM is then used by the Flood Modeling Component (FMC) to generate the flood models for different flooding scenarios.

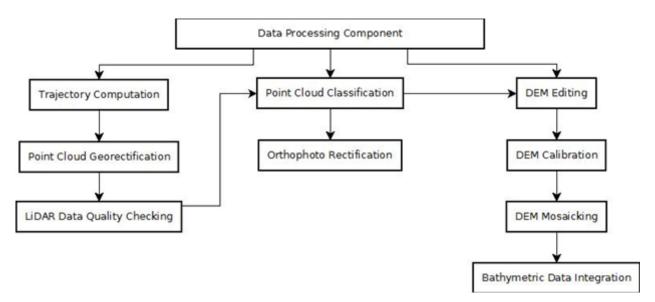


Figure 9. Schematic diagram of the data processing

#### 3.2.1 Data Transfer

The Panay mission, named 1P2GES162A, was flown with the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) by Pegasus system on June 10, 2013. The Data Acquisition Component (DAC) transferred 20.3 Gigabytes of Range data, 115 Megabytes of POS data, 188 Megabytes of GPS base station data, and no raw image data to the data server on June 18, 2013.

#### 3.2.2 Trajectory Computation

The trajectory of the aircraft is computed using the software POSPac MMS v6.2. It combines the POS data from the integrated GPS/INS system installed on the aircraft, and the Rinex data from the GPS base station located within 25 kilometers of the area. It then computes the Smoothed Best Estimated Trajectory (SBET) file, which contains the best estimated trajectory of the aircraft, and the Smoothed Root Mean Square Estimation error file (SMRMSG), which contains the corresponding standard deviations of the position parameters of the aircraft at every point on the computed trajectory.

The key parameters checked to evaluate the performance of the trajectory are the Solution Status parameters and the Smoothed Performance Metrics parameters. The Solution Status parameters characterize the GPS satellite geometry and baseline length at the time of acquisition, and the processing mode used by POSPac. The acceptable values for each Solution Status parameter are shown in Table 3.

The Smoothed Performance Metrics parameters describe the root mean square error (RMSE) for the north, east and down (vertical) position of the aircraft for each point in the computed trajectory. A RMSE value of less than 4 centimeters for the north and east position is acceptable, while a value of less than 8 centimeters is acceptable for the down position.

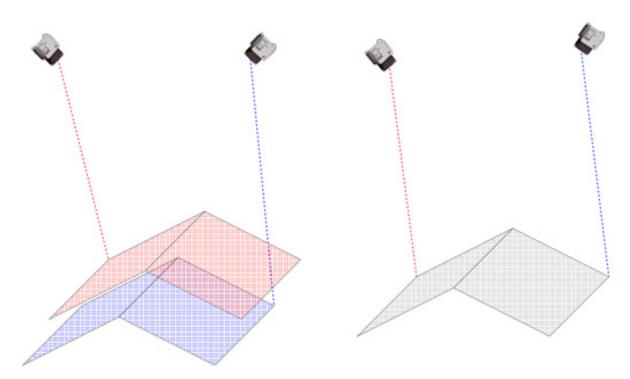
Parameter	Optimal Value	
Number of satellites	More than 6 satellites	
Position Dilution of Precision	Less than 3	
Baseline Length	Less than 30 km	
Processing mode	Less than or equal to 1, however short burt- sts of values greater than 1 are acceptable	

Table 3. Smoothed Solution Status parameters in POSPac MMS v6.2.

#### 3.2.3 LiDAR Point Cloud Rectification

The trajectory file (SBET) and its corresponding accuracy file (SMRMSG) generated in PO-SPac are merged with the Range file to compute the coordinates of each individual point. The coordinates of points within the overlap region of contiguous strips vary due to small deviations in the trajectory computation for each strip. These strip misalignments are corrected by matching points from overlapping laser strips. This is done by the LiDAR Mapping Suite (LMS) software developed by Optech.

LMS is a LiDAR software package used for automated LiDAR rectification. It has the capability to extract planar features per flight line and to form correspondence among the identical planes available in the overlapping areas (illustrated in Figure 10). In order to produce geometrically correct point cloud, the redundancy in the overlapping areas of flight lines is used to determine the necessary corrections for the observations.



**Figure 10.** Misalignment of a single roof plane from two adjacent flight lines, before rectification (left). Least squares adjusted roof plane, after rectification (right).

The orientation parameters are corrected in LMS by using least squares adjustment to obtain the best-fit parameters and improve the accuracy of the LiDAR data. The primary indicators of the LiDAR rectification accuracy are the standard deviations of the corrections of the orientation parameters. These values are seen on the Boresight corrections, GPS position corrections, and IMU attitude corrections, all of which are located on the LMS processing summary report. Optimum accuracy is obtained if the Boresight and IMU attitude correction standard deviations are less than 0.001°, and if the GPS position standard deviations are below 0.01 meter.

#### 3.2.4 LiDAR Data Quality Checking

After the orientation parameters are corrected and the point cloud coordinates are computed, the entire point cloud data undergoes quality checking, to see if: (a) there are remaining horizontal and vertical misalignments between contiguous strips, and; (b) to check if the density of the point cloud data reach the target density for the site. The LAStools software is used to compute for the elevation difference in the overlaps between strips and the point cloud density. It is a software package developed by Rapidlasso GmbH for filtering, tiling, classifying, rasterizing, triangulating and quality checking Terabytes of LiDAR data, using robust algorithms, efficient I/O tools and memory management. LAStools can quickly create raster representing the computed quantities, which provide guiding images in determining areas where further quality checks are necessary. The target requirements for floodplain acquisition, computed by LAStools, are shown in Table 4.

Table 4. Parameters investigated during quality checks.

Criteria	Requirement	
Minimum per cent overlap	25%	
Average point cloud density per square meter	2.0	
Elevation difference between strips (on flat areas)	0.20 meters	

LAStools can provide guides where elevation differences probably exceed the 20 cm limit. An example of LAStools output raster visualizing points in the flight line overlaps with a vertical difference of  $\pm$ 0 cm (displayed as dense red/blue areas) is shown in Figure 11.

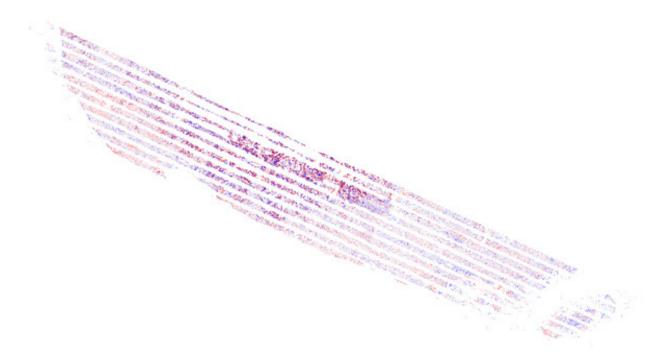


Figure 11. Elevation difference between flight lines generated from LAStools

To investigate the occurrences of elevation differences in finer detail, the profiling tool of Quick Terrain Modeler software is used. Quick Terrain Modeler (QT Modeler) is a 3D point cloud and terrain visualization software package developed by Applied Imagery, Inc. The profiling capability of QT Modeler is illustrated in Figure 12.

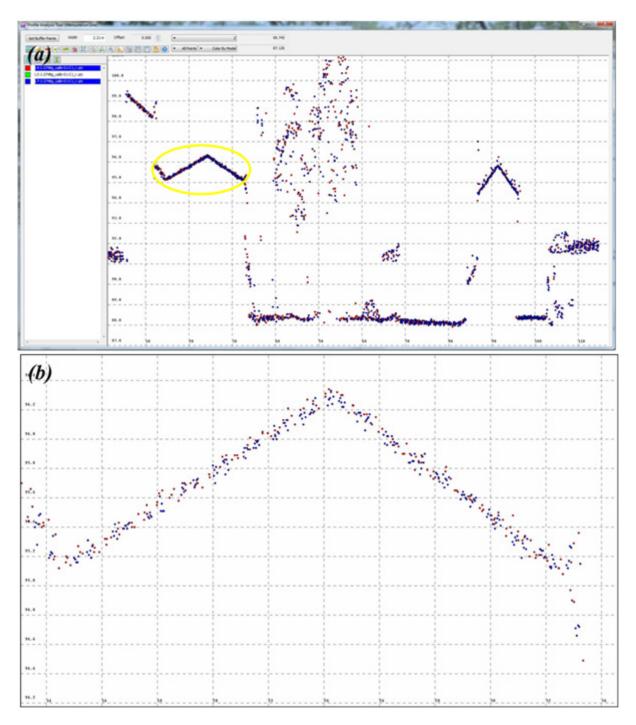


Figure 12. Profile over roof planes (a) and a zoomed-in profile on the area encircled in yellow (b)

The profile (e.g., over a roof plane) shows the overlapping points from different flight lines which serve as a good indicator that the correction applied by LMS for individual flight lines is good enough to attain the desired horizontal and vertical accuracy requirements. Flight lines that do not pass quality checking are subject for reprocessing in LMS until desired accuracies are obtained.

#### 3.2.5 LiDAR Point Cloud Classification and Rasterization

Point cloud classification commences after the point cloud data has been rectified. TerraScan is a TerraSolid LiDAR software suite used for the classification of point clouds. It can read airborne and vehicle-based laser data in raw laser format, LAS, TerraScan binary or other AS-CII-survey formats. Its classification and filtering routines are optimized by dividing the whole data into smaller geographical datasets called blocks, to automate the workflow and increase efficiency. In this study, the blocks were set to 1 km by 1 km with a 50 m buffer zone to prevent edge effects.

The process includes the classification of all points into Ground, Low Vegetation, Medium Vegetation, High Vegetation and Buildings. The classifier tool in TerraScan first filters air points and low points by finding points that are 5 standard deviations away from the median elevation of a search radius, which is 5 meters by default. It then divides the region into 6om by 6om search areas (the maximum area where at least one laser point hits the ground) and assigns the lowest points in these areas as the initial ground points from which a triangulated ground model is derived. The classifier then iterates through all the points and adds the points to the ground model by testing if it is (a) within the maximum iteration angle of 4° by default from a triangle plane, and (b) if it is within the maximum iteration distance (1.2 m by default) from a triangle plane. The ground plane is continuously updated from these iterations. The ground classification technique is illustrated in Figure 13. It is apparent that the smaller the iteration angle, the less eager the classifier is to follow changes in the point cloud (small undulations in terrain or hits on low vegetation). An angle close to 4° is used in flat terrain areas while an angle of 10° is used in mountainous or hilly terrains.

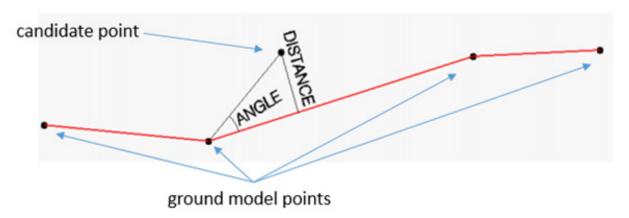


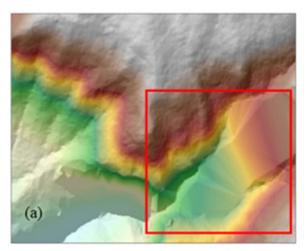
Figure 13. Ground classification technique employed in Terrascan

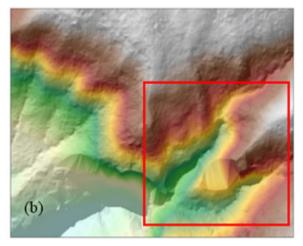
The parameters for ground classification routines used in floodplain and watershed areas are listed in Table 5.

Table 5. Ground classification parameters used in Terrascan for floodplain and watershed areas

Classification maximums	Floodplain (default)	Watershed (adjusted)
Iteration angle (degrees)	4	8
Iteration distance (meters)	1.20	1.50

The comparison between the produced DTM using the default parameters versus the adjusted is shown in Figure 14. The default parameters may fail to capture the sudden change in the terrain, resulting to less points being classified as ground that makes the DTM interpolated (Figure 14a). The adjusted parameters work better in these spatial conditions as shown in Figure 14b. Statistically, the number of ground points and model key points correctly classified can increase by as much as fifty percent (50%) when using the adjusted parameters.





**Figure 14.** Resulting DTM of ground classification using the default parameters (a) and adjusted parameters (b)

The classification to Low, Medium and High vegetation is a straightforward testing of how high a point is from the ground model. The range of elevation values and its corresponding classification is shown in Table 6.

Table 6. Classification of Vegetation according to the elevation of points

Elevation of points	Classification	
(meters)		
0.05 to 0.15	Low Vegetation	
0.15 to 2.50	Medium Vegetation	
2.50 to 50.0	High Vegetation	

The classification to Buildings routine tests points above two meters (2.0 m) if they only have one echo, and if they form a planar surface of at least 40 square meters with points adjacent to them. Minimum size and Z tolerance are the parameters used in the classify buildings routine as shown in Figure 15.

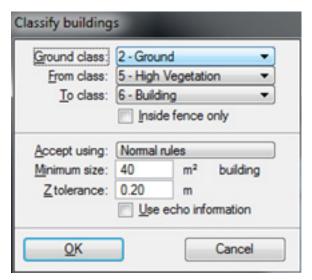


Figure 15. Default TerraScan building classification parameters

Minimum size is set to the smallest building footprint size of 40 m2 while the Z tolerance of 20cm is the approximate elevation accuracy of the laser points.

The point cloud data are examined for possible occurrences of air points which are to be deleted manually in the TerraScan window. Air points are defined as groups of points which are significantly higher or lower from the ground points. The different examples of air points are shown in Figure 16.

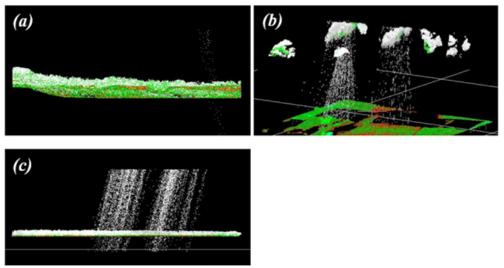


Figure 16. Different examples of air points manually deleted in the TerraScan window

The noise data can be as negligible as shown in Figure 16a or can be as severe as the one shown in Figure 16c. A combination of cloud points and shower of short ranges is displayed in Figure 16b. Shower of short ranges are caused by signal interference from the radio transmission of the tower and the aircraft. During every transmission on a specific frequency (around 120MHz), the signal is getting distorted due to the interference causing showers of short ranges in the output LAS.

Classified LiDAR point clouds that are free of air points, noise and unwanted data are processed in TerraScan to produce Digital Terrain Model (DTM) and the corresponding first and last return Digital Surface Models (DSM). These ground models are produced in the American Standard Code for Information Interchange format (ASCII) format. DTMs are produced by rasterizing all points classified to ground and model key points in a 1 m by 1 m grid. The last return DSMs are produced by rasterizing all last returns from all classifications (Ground, Model Key Points, Low, Medium, High Vegetation, Buildings and Default) in a 1 m by 1 m grid. The first return DSMs on the other hand are produced by rasterizing all first returns from all classifications. Power lines are usually included in this model. All of these ground models are used in the mosaicking, manual editing and hydro correction of the topographic dataset, in preparation for the floodplain hydraulic modelling.

#### 3.2.6 DEM Editing and Hydro-correction

Even though the parameters of the classification routines are optimized, various digital elevation models (DTM, first and last return DSM) that are automatically produced may still display minor errors that still need manual correction to make the DEMs suitable for fine-scale flood modelling. This is true especially for features that are under heavy canopy. Natural embankments on the side of the river might be flattened or misrepresented because no point pierced the canopy on that area. The same difficulty might also occur on smaller streams that are under canopy. The DTM produced might have discontinuities on these channels that might affect the flood modelling negatively. Manual inspection and correction is still a very important part of quality checking the LiDAR DEMs produced.

To correctly portray the dynamics of the flow of water on the floodplain, the river geometry must also be taken into consideration. The LiDAR data must be made consistent to the topographic surveys done for the area, and the bathymetric data must be "burned", or integrated, into the DEM to make the dataset suitable for hydraulic analyses. However, no cross-sectional survey was performed for this area.





### **Results and Discussion**

## 4.1 LiDAR Acquisition in Panay Floodplain

#### 4.1.1 Flight Plans

Plans were made to acquire LiDAR data within the Panay floodplain. Each flight mission had an average of 15 flight lines and ran for at most 4 hours including take-off, landing and turning time. The parameter used in the LiDAR system for acquisition is found in Table 7.

Table 7. Parameters used in LiDAR System during Flight Acquisition.

Fixed Variables	Values			
Flying Height (AGL - Above Ground Level) (m)	750m	1000 m	1200 m	
Overlap	30 %	30%	30 %	
Max. field of View	50	50	50	
Speed of Plane (kts)	130	130	130	
Turn around minutes	5	5	5	
Swath (m)	661.58 m	882 m	1058.53 m	

The parameters that set in the LiDAR sensor to optimize the area coverage following the objectives of the project and to ensure the aircraft's safe return to the airport (base of operations) are shown in Table 7. Each flight acquisition is designed for four operational hours. The maximum flying hours for Cessna 206H is five hours.

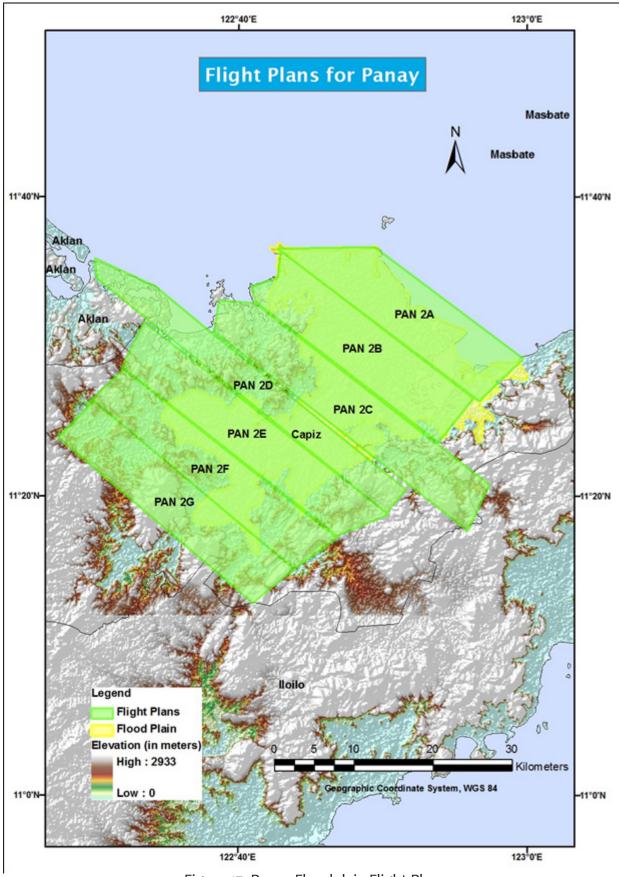


Figure 17. Panay Floodplain Flight Plans



#### 4.1.2 Ground Base Station

The project team used the CPZ-14 and CPZ-20 GCP located in Brgy. Lanot, Roxas City, Capiz, Philippines. The certification for the base station is found in Annex D. The ground control point (GCP) was used as reference point during flight operations using TRIMBLE SPS R8, a dual frequency GPS receiver.

Table 8. Details of CPZ-14 used as base station for the LiDAR Acquisition

Station Name	CPZ	-14
Order of Accuracy	2n	d
Relative Error (horizontal positioning)	1:500	000
Coordinates Philippins Bal	Latitude	11°33'24.51899''
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Longitude	122°47'34.41876''
erence of 1992 Datum (FRS 92)	Ellipsoidal Height	4.91900 m
Grid Coordinates, Philippine Transverse	Easting	1277923.165 m
Mercator Zone 5 (PTM Zone 5 PRS 92)	Northing	477410.249 m
Coordinates Would Coordet	Latitude	11°33'19.98412''
Geographic Coordinates, World Geodet- ic System 1984 Datum (WGS 84)	Longitude	122°47'39.56494''
ic system 1904 Datum (Wd3 04)	Ellipsoidal Height	60.96000 m
Grid Coordinates, Universal Transverse	Easting	1277475.87
Mercator Zone 51 North (UTM 51N WGS 1984)	Northing	477418.16

**Table 9.** Details of CPZ-20 used as base station for the LiDAR Acquisition

Station Name	CPZ	-20
Order of Accuracy	2n	d
Relative Error (horizontal positioning)	1:500	000
Coordinates Philippins Bot	Latitude	11°23'45.02906''
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Longitude	122°41'2.93748''
erence of 1992 Datum (FR3 92)	Ellipsoidal Height	15.18900 m
Grid Coordinates, Philippine Transverse	Easting	1260129 <b>.</b> 553 m
Mercator Zone 5 (PTM Zone 5 PRS 92)	Northing	465529.46 m
Coordinates Would Coordat	Latitude	11°23'45.52508''
Geographic Coordinates, World Geodet- ic System 1984 Datum (WGS 84)	Longitude	122°41'8.09853''
ic system 1904 Datum (Wd3 04)	Ellipsoidal Height	71.35900 m
Grid Coordinates, Universal Transverse	Easting	1259688.49
Mercator Zone 51 North (UTM 51N WGS 1984)	Northing	465541.53





Figure 18. CPZ-14, located in Panay, Capiz (a) and CPZ-20, located in Dao, Capiz (b)

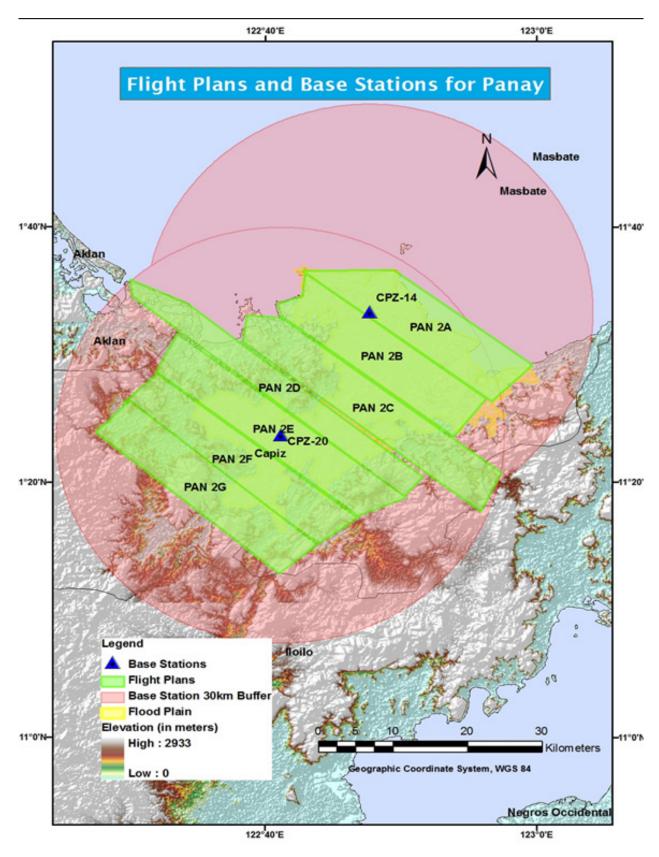


Figure 19. Panay Flight Plans and Base Stations.

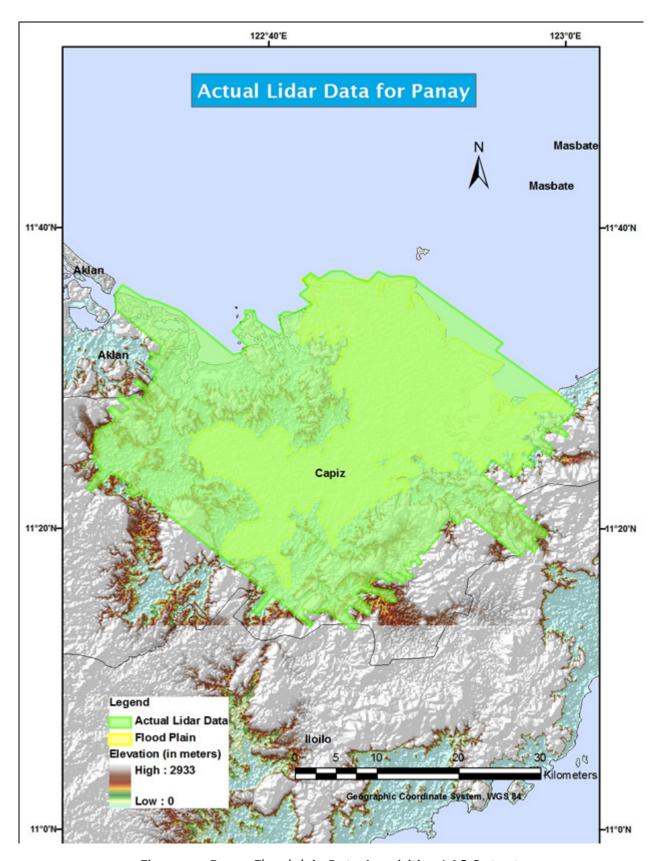


Figure 20. Panay Floodplain Data Acquisition LAS Output.



Table 10. Flight Missions for LiDAR Data Acquisition in Panay floodplain.

	Igne Missions			Area Sur-	Area		Flying	Hours
Date Sur- veyed	Name	Flight Plan Area (km²)	Surveyed Area (km²)	veyed within the River System (km²)	Surveyed Outside the River Systems (km²)	No. of Images (Frames)	Hours	Min- utes
May 19, 2013	1P2B139A							
May 20, 2013	1P2C140A							
May 21, 2013	1P2A140B							
Jun 3, 2013	1P2D141A							
Jun 4, 2013	1P2E141B							
Jun 6, 2013	1P2CS155A	1688.2	1614.6	1275.6	339	0	37	25
Jun 8, 2013	1P2A156A							
Jun 9, 2013	1P2ABS158B							
Jun 10, 2013	1P2ABS160A							
Jun 11, 2013	1P2F161A							
Jun 12, 2013	1P2GES162A							

Fourteen (14) missions were conducted to complete the LiDAR Data Acquisition in Panay floodplain, for a total of thirty-seven hours and twenty-five minutes (37 hr. 25mins.) of flying time for RP-C9022. All fourteen (14) missions were acquired using the Pegasus LiDAR System. The total area to be surveyed according to the flight plan and the total area of actual coverage per mission is shown in Table 10.

Panay floodplain with 618.62 square kilometers was completely surveyed from May 19 to June 12, 2013 by Mark Gregory Ano, Jasmine Alviar and Christopher Joaquin as shown in Table 11.

Table 11. Area of Coverage (in sq km) of the LiDAR Data Acquisition in Panay floodplain.

Location	Date Sur- veyed	Operator	Mission Name	Flood- plain Surveyed Area (km²)	Total Flood- plain Area (km²)	Wa- ter-shed Surveyed Area (km²)	Total Wa- ter-shed Area (km²)
	May 19, 2013	J. Alviar	1P2B139A	205		24.2	
	May 20, 2012	M. Ano	1P2C140A	67.1		81.8	
	May 20, 2013	C. Joaquin	1P2A140B	11.5		0.00	
	May 21, 2013	C. Joaquin	1P2D141A	53.5		79.9	
	May 21, 2013	J. Alviar	1P2E141B	76.8		48.5	
	Jun 3, 2013	M. Ano	1P2CS155A	31.7		50.8	
	Jun 4, 2013	J. Alviar	1P2A156A	86.2	6.06	10.4	
Panay	Jun 6, 2013	C. Joaquin	1P2ABS158B	25.8	618.62	16.0	1823.13
	Jun 8, 2013	C. Joaquin	1P2ABS160A	87.1		9.70	
	Jun 9, 2013	M. Ano	1P2F161A	40.1		194	
	lum 40, 2042	C. Joaquin	1P2GES162A	31.7		133	
	Jun 10, 2013	J. Alviar	1P2ABCS162B	36.9		13.0	
	Jun 11, 2013	M. Ano	1P2S163B	68.0		96.9	
	Jun 12, 2013	J. Alviar	1P2S164A	57.9		30.6	

### 4.2 LiDAR Data Processing

#### 4.2.1 Trajectory Computation

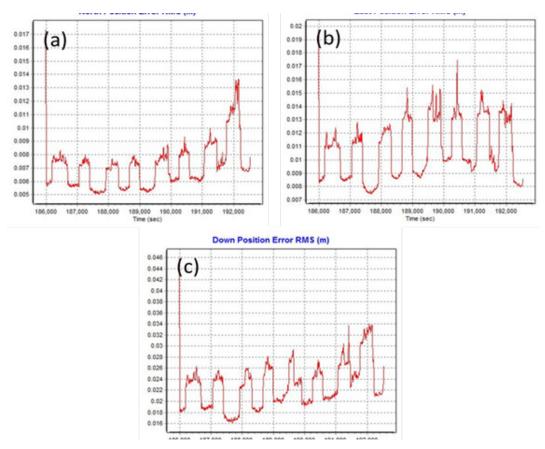


Figure 21. Smoothed Performance Metric Parameters of Panay flight

The Smoothed Performance Metric parameters of the Panay flight are shown in Figure 20. The x-axis is the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week. The y-axis is the RMSE value for a particular aircraft position with respect to GPS survey time. The North (Figure 20a) and east (Figure 20b) position RMSE values fall within the prescribed accuracy of 4 centimeter, and all Down (Figure 20c) position RMSE values fall within the prescribed accuracy of 8 centimeter.

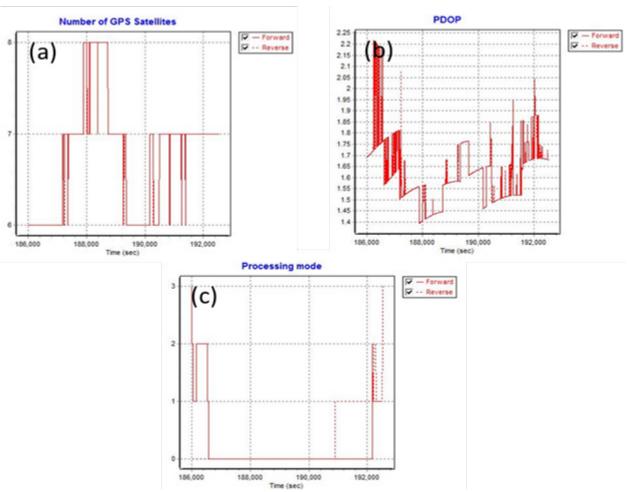


Figure 22. Solution Status Parameters of Panay Flight.

The Solution Status parameters of the computed trajectory for Panay flight, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used are shown in Figure 21. The number of GPS satellites (Figure 21a) graph indicates that the number of satellites during the acquisition was between 7 and 9. The PDOP (Figure 21b) value does not exceed the value of 3, indicating optimal GPS geometry. The processing mode (Figure 21c) varies from 0 to 3, the value 0 corresponds to a Fixed, Narrow-Lane mode, which indicates an optimum solution for trajectory computation by POSPac MMS v6.2; the value 1 corresponds a Wide-Lane mode; and the value 2 corresponds a Float mode. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions as indicated in the methodology.

#### 4.2.2 LiDAR Point Cloud Computation

The LAS data output contains 9 flight lines, with each flight line containing two channels, a feature of the Pegasus system. The result of the boresight correction standard deviation values for both channel 1 and channel 2 are better than the prescribed 0.001°. The position of the LiDAR system is also accurately computed since all GPS position standard deviations are less than 0.0018 meter. The attitude of the LiDAR system passed accuracy testing since the standard deviation of the corrected roll and pitch values of the IMU attitudes are less than 0.001°.

#### 4.2.3 LiDAR Data Quality Checking

The LAS boundary of the LiDAR data on top of the SRTM elevation data is shown in Figure 22. The map shows gaps in the LiDAR coverage that are attributed to cloud cover present during the survey.

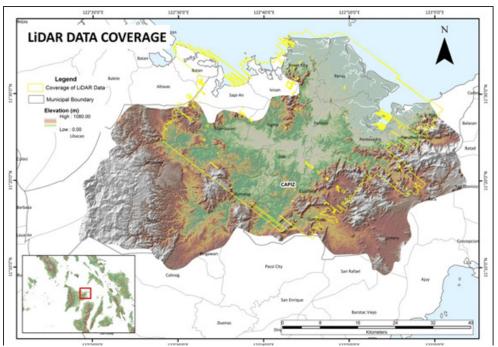


Figure 23. Coverage of LiDAR data for the Panay mission

The overlap data for the merged LiDAR data showing the number of channels that pass through a particular location is shown in Figure 24. Since the Pegasus system employs two channels, an average value of 2 (blue) for areas where there are only two overlapping flight lines, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines, are expected. The average data overlap for Panay is 48.25%.

The density map for the merged LiDAR data, with the red areas showing the portions of the data that satisfy the 2 points per square meter requirement, is shown in Figure 24. It was determined that 93.4% of the total area satisfied the point density requirement.

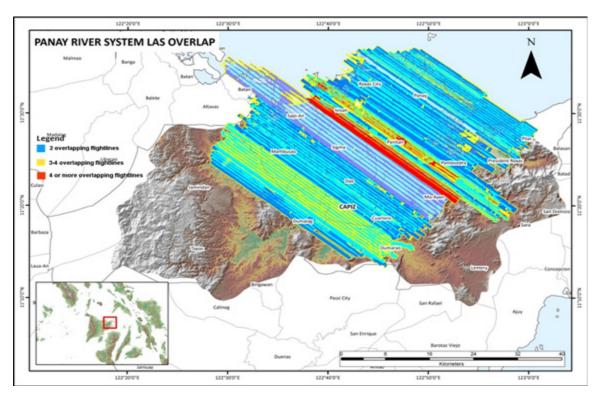


Figure 24. Image of data overlap for the Panay mission

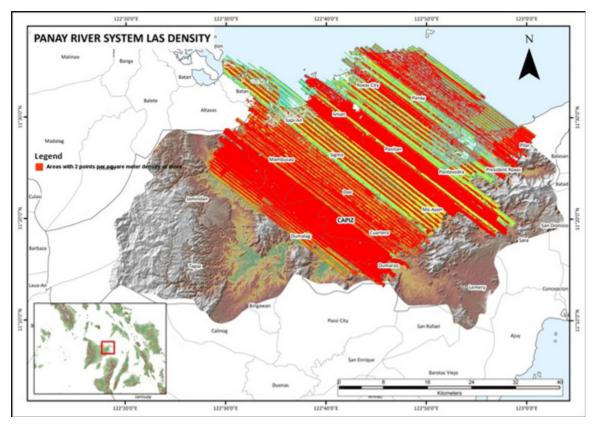


Figure 25. Density map of merged LiDAR data for the Panay mission

The elevation difference between overlaps of adjacent flight lines is shown in Figure 26. The default color range is from blue to red, where bright blue areas correspond to a -0.20 meter difference, and bright red areas correspond to a +0.20 meter difference. Areas with bright red or bright blue need to be investigated further using QT Modeler.

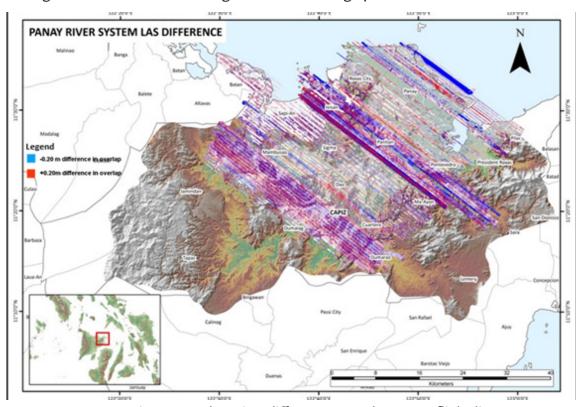
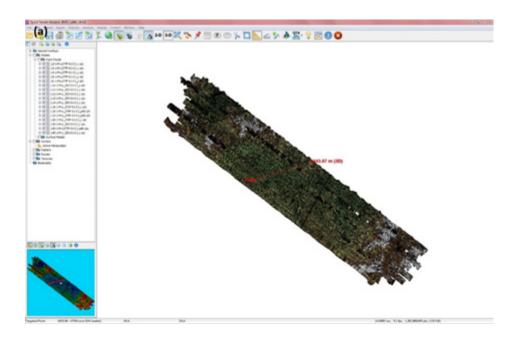


Figure 26. Elevation difference map between flight lines

A screen capture of the LAS data loaded in QT Modeler is shown in Figure 27a. A line graph showing the elevations of the points from all of the flight strips traversed by the profile in red line is shown in Figure 27b. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. No reprocessing was necessary for this LiDAR dataset.



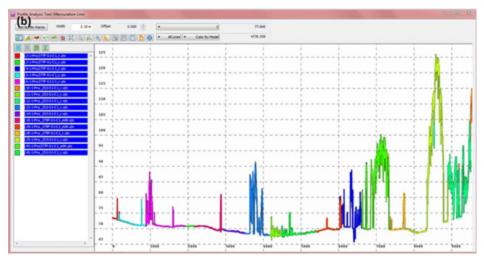
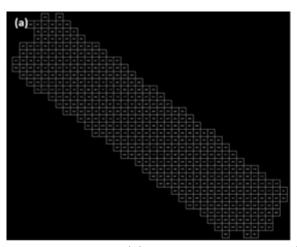


Figure 27. Quality checking with the profile tool of QT Modeler

#### 4.2.4 LiDAR Point Cloud Classification and Rasterization

The block system that TerraScan employed for the LiDAR data is shown in Figure 28a generated a total of 2,399 1 kilometer by 1 kilometer blocks. The final classification of the point cloud for a mission in the Panay floodplain is shown in Figure 28b. The number of points classified to the pertinent categories along with other information for the mission is shown in Table 12.



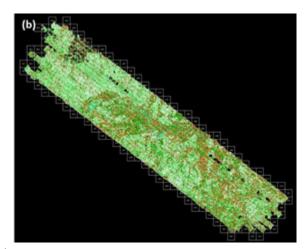
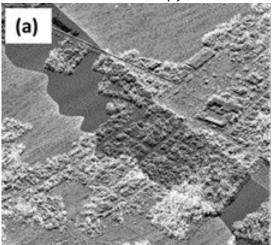


Figure 28. (a) Panay floodplain and (b) Panay classification results in TerraScan

Table 12. Panay classification results in TerraScan

Pertinent Class	Count
Ground	1,180,264,200
Low Vegetation	1,111,867,478
Medium Vegetation	1,464,776,122
High Vegetation	1,349,677,348
Building	59,559,267
Number of 1km x 1km blocks	2,399
Maximum Height	718.08 m
Minimum Height	46.35 m

An isometric view of an area before (a) and after (b) running the classification routines for the mission is shown in Figure 29. The ground points are in brown, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.



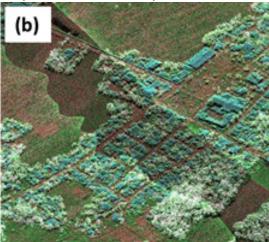


Figure 29. Point cloud (a) before and (b) after classification

#### 4.2.5 DEM Editing and Hydro-correction

Portions of DTMs before and after manual editing are shown in Figure 30. It shows that the embankment might have been drastically cut by the classification routine in Figure 30a and clearly needed to be retrieved to complete the surface as in Figure 30b to allow to hydrologically correct flow of water. A small stream suffers from discontinuity of flow due to an existing bridge in Figure 30c. The bridge is removed also in order to hydrologically correct the flow of water through the river in Figure 30d.

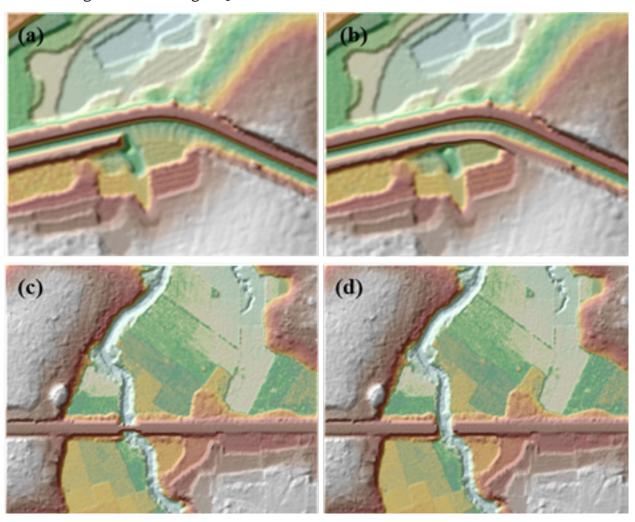


Figure 30. Images of DTMs before and after manual editing

The extent of the validation survey done by the Data Validation Component (DVC) in Panay to collect points with which the LiDAR dataset is validated is shown in Figure 31. A total of 3989 control points were collected. The good correlation between the airborne LiDAR elevation values and the ground survey elevation values, which reflects the quality of the LiDAR DTM is shown in Figure 32. The computed RMSE between the LiDAR DTM and the surveyed elevation values is 9.663 centimeters with a standard deviation of 9.659 centimeters. The LE 90 value represents the linear vertical distance that 90% of the sampled DEM points and their respective DVC validation point counterparts should be found from each other. Other statistical information can be found in Table 13. The final DTM and extent of the bathymetric survey done along the river is shown in Figure 33.

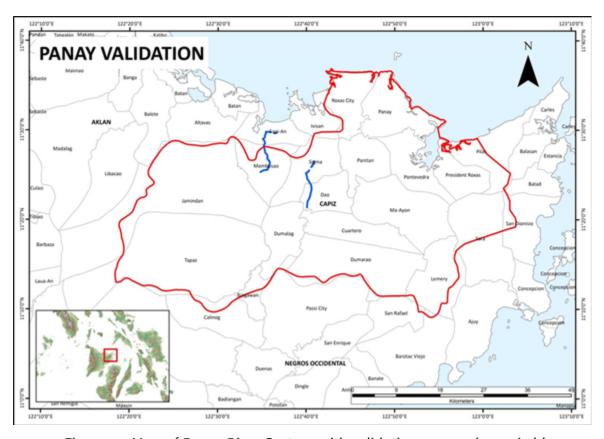


Figure 31. Map of Panay River System with validation survey shown in blue

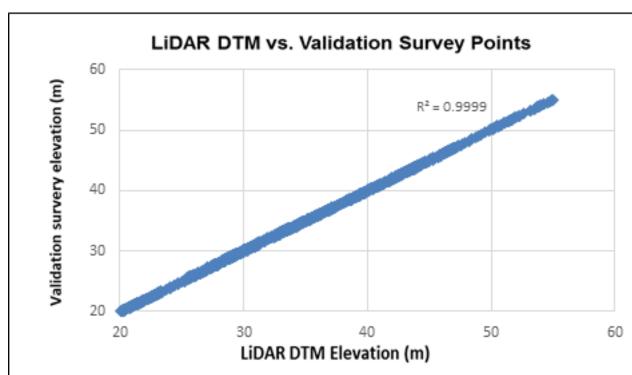


Figure 32. One-one Correlation plot between topographic and LiDAR data

Table 13. Statistical values for calibration of flights.

Statistical Information	Values (cm)
Min	-18.972
Max	19.581
RMSE	9.663
Stdev	9.659
LE90	13.671

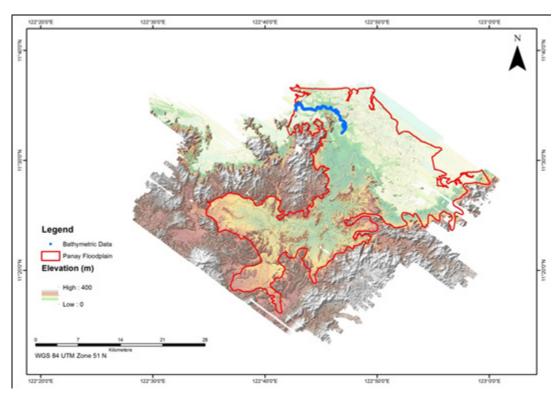


Figure 33. Final DTM of Panay with validation survey shown in blue

The floodplain extent for Panay is also presented, showing the completeness of the LiDAR dataset and DSM produced, is shown in Figure 34. Samples of 1 kilometer by 1 kilometer of DSM and DTM are shown in Figure 35 and Figure 36, respectively.

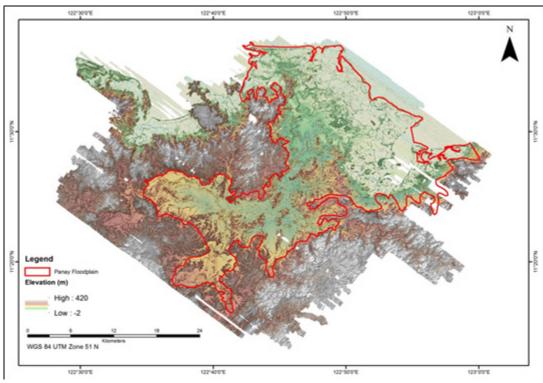


Figure 34. Final DSM in Panay



Figure 35. Sample 1x1 square kilometer DSM

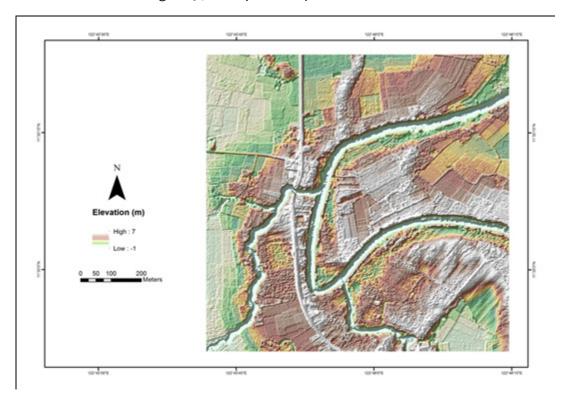


Figure 36. Sample 1x1 square kilometer DTM







# ANNEX A. OPTECH TECHNICAL SPECIFICATION OF THE PEGASUS SENSOR

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 °
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37° (FOV dependent)
Vertical target separation distance	<0.7 m
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digi- tizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
Dimensions and weight	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	o-95% non-condensing

# ANNEX B. OPTECH TECHNICAL SPECIFICATION OF THE D-8900 AERIAL DIGITAL CAMERA

Parameter	Specification
	Camera Head
Sensor type	60 Mpix full frame CCD, RGB
Sensor format (H x V)	8, 984 x 6, 732 pixels
Pixel size	6μm x 6 μm
Frame rate	1 frame/2 sec.
FMC	Electro-mechanical, driven by piezo technology (patented)
Shutter	Electro-mechanical iris mechanism 1/125 to 1/500++ sec. f-stops: 5.6, 8, 11, 16
Lenses	50 mm/70 mm/120 mm/210 mm
Filter	Color and near-infrared removable filters
Dimensions (H x W x D)	200 x 150 x 120 mm (70 mm lens)
Weight	~4.5 kg (70 mm lens)
	Controller Unit
Computer	Mini-ITX RoHS-compliant small-form-factor embedded computers with AMD TurionTM 64 X2 CPU 4 GB RAM, 4 GB flash disk local storage IEEE 1394 Firewire interface
Removable storage unit	~500 GB solid state drives, 8,000 images
Power consumption	~8 A, 168 W
Dimensions	2U full rack; 88 x 448 x 493 mm
Weight	~15 kg
	Image Pre-Processing Software
Capture One	Radiometric control and format conversion, TIFF or JPEG
Image output	8,984 x 6,732 pixels 8 or 16 bits per channel (180 MB or 360 MB per image)

## **Annex C**

## **ANNEX C. THE SURVEY TEAM**

Data Acquisition Component Sub-team	Designation	Name	Agency /Affiliation
Data Acquisition Component Leader	Data Component Project Leader –I	ENGR. CZAR JAKIRI S.vSARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP TCAGP
LiDAR Operation	Senior Science Research Specialist	MARK GREGORY ANO	UP TCAGP
LiDAR Operation	Research Associate	JASMINE ALVIAR	UP TCAGP
Ground Survey	Research Associate	ENGR. GEROME HIPOLITO	UP TCAGP
LiDAR Operation / Data Download and Transfer	Research Associate	CHRISTOPHER JOA- QUIN	UP TCAGP
LiDAR Operation	Airborne Security	SSG. ERWIN DELOS SANTOS	Philippine Air Force (PAF)
LiDAR Operation	Pilot	CAPT. JAMAAL CLE- MENTE	ASIAN AEROSPACE CORP (AAC)

#### ANNEX D. NAMRIA CERTIFICATION

### **QZN-14**



Republic of the Philippines Department of Environment and Natural Resources NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

April 26, 2013

#### CERTIFICATION

To whom it may concern:

Island: VISAYAS

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: CAPIZ

Station Name: CPZ-14

Order: 2nd

Municipality: PANAY

PRS92 Coordinates

Latitude: 11° 33' 24.51899" Longitude: 122º 47' 34,41876"

Ellipsoidal Hgt: 4.91900 m.

Barangay: POBLACION ILAWOD

WGS84 Coordinates

Latitude: 11° 33' 19.98412"

Longitude: 122° 47' 39.56494"

Ellipsoidal Hgt: 60.96000 m.

PTM Coordinates

Northing: 1277923.165 m.

Easting: 477410.249 m.

Zone:

4

Northing: 1,277,475.87

**UTM Coordinates** Easting: 477,418.16

Zone:

Location Description

From Roxas City, travel E to the Mun. of Panay. Then proceed directly to the town plaza, where the station is located. Station is located at Panay Park, about 30 m. from the chuch and about 30 m. from the nat'l. road. Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground, with inscriptions "CPZ-14 2007 NAMRIA".

Requesting Party: UP-TCAGP

Pupose: OR Number: Reference 3943584 B

T.N.:

2013-0364

RUEL DM. BELEN, MNSA Director, Mapping and Geodesy Department





Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41 Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98

ww.namria.gov.ph

#### **QZ-20**



Republic of the Philippines Department of Environment and Natural Resources NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

June 13, 2013

#### CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: CAPIZ

Station Name: CPZ-20

Order: 2nd

Barangay: POBLACION ILAWOD

Island: VISAYAS

Municipality: DAO

PRS92 Coordinates

Longitude: 122° 41' 2.93748"

Ellipsoidal Hgt: 15.18900 m.

WGS84 Coordinates

Latitude: 11° 23' 40.52508"

Latitude: 11° 23' 45.02906"

Longitude: 122° 41' 8.09853"

Ellipsoidal Hgt: 71.35900 m.

PTM Coordinates

Northing: 1260129.553 m.

Easting:

465529.46 m.

Zone:

Northing: 1,259,688.49

**UTM Coordinates** 

465,541.53 Easting:

Zone:

51

Location Description

From Roxas City, travel S to the Mun. of Dao. Then proceed directly to the town plaza. Station is located on the W side of the basketball court fronting the stage and the mun. hall. Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground, with inscriptions "CPZ-20 2007 NAMRIA".

Requesting Party: UP-TCAGP

Pupose: OR Number: Reference

T.N.:

FREE ISSUE 2013-0569

RUEL DM. BELEN, MNSA

Director, Mapping and Geodesy Department





NAMRIA OFFICES:

Main: Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41 Branch: 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98 www.namria.gov.ph



# ANNEX F. DATA TRANSFER SHEET FOR PANAY FLOOD-PLAIN

Data Transfer Sheet for 1P2CS155A, 1P2A156A, 1P2ABS158B, 1P2ABS160A, 1P2F161A, 1P2GES162A, and 1P2ABCS162B Missions

		LOCATION	Z:VAirborne Raw/257P	Z:Vairborne_ Raw\259P	Z:Vairborne Raw/211P	Z:Wirborne_ Raw/212G	7-14 irhomo	Raw/214G	Z:\Airborne_ Raw\216G	Z:\Airborne_ Raw\217P	Z:\Airbome_ Raw\219P	Z:\Airbome_ Raw\225P		
	FLIGHT	PLAN	26.8KB	32.1KB		35.1KB 35.2KB	39.4KB	32.8KB	32.1KB	9	33.2KB + 36.1KB	40.1KB		
	OPERATOR	(DPC LOGS)	626KB	635BYTES	1.27KB + 633KB	366 BYTES	39.	325 KB	50 BYTES + + 583KB 32	1.00KB + 406KB	33 540 BYTES + + 581KB 36	829 BYTES + 528KB		
	BASE	STATION(S)	5.08MB	5.76MB	19.1MB	19.1MB		8.43MB	3.94MB	4.53MB	6.00MB	6.00MB		+
_		LOG FILE RANGE DIGITIZER STATION(S) (DPC LOGS)	12.4GB N/A	29.6GB NVA	11.2GB N/A	6.72GB N/A		4.49GB N/A	14.0GB N/A	37.4GB N/A	20.3GB N/A	8.63GB N/A		PRIETO S
Jun 18, 2013	MISSION	LOG FILE		N/A	N/A	N/A		N/A	N/A	NA	N/A	N/A	^	Name/Signature John PRINTO Position 55R3
Jun 18, 2013	RAW	IMAGES	7.28GB	NA	N/A	N/A		N/A	N/A	N/A	N/A	NA	Received by	Name/Signa Position
AIA		POS	701KB 115MB	208MB	243MB	91.5MB		95.8MB	863KB 170MB	220MB	188MB			
-		LOGS POS	701KB	1.52M B	1.30M B	485KB		570KB	863KB	1.60M B	1.16M B	654KB		-1
	RAW	LAS	121MB	171MB	50.7MB	53.9MB		33.1MB	110MB	361MB	194MB	68.2MB		100
		SENSOR	PEGASUS 121MB	PEGASUS 171MB	PEGASUS 50.7MB	PEGASUS 53.9MB 485KB 91.5MB N/A		PEGASUS 33.1MB 570KB 95.8MB N/A	PEGASUS 110MB	PEGASUS 361MB	PEGASUS 194MB	PEGASUS 68.2MB 654KB 106MB		- John
		MISSION NAME	Jun 3, 2013 257P 1P2CS155A	1P2A156A	Jun 6, 2013 261P 1BRY158A	Jun 6, 2013 263P 1P2ABS158B		Jun 7, 2013 265P 1P2F159A	Jun 8, 2013 267P 1P2(AB)S160A	Jun 9, 2013 269P 1P2F161A	Jun 10, 2013 271P 1P2GES162A	Jun 10, 2013 273P 1P2ABCS162B	Received from	Name/Signature C
	FLIG	NO.	3 257P	3 259P	3 261P	3 263P		3 265P	3 267P	3 269P	3 271P	3 273P		
		DATE	Jun 3, 2013	Jun 4, 2013 259P 1P2A156A	Jun 6, 2013	Jun 6, 2013		Jun 7, 2013	Jun 8, 2013	Jun 9, 2013	un 10, 2013	un 10, 2013		

## Data Transfer Sheet for 1P2S163B and 1P2S164A

					DAT	A TRAN	DATA TRANSFER SHEET Aug 27, 2013	E				
DATE	FLIGHT NO.	MISSION NAME	RAW	L06s	POS	RAW	MISSION LOG FILE	RANGE	DIGITIZER	BASE	OPERATOR COMMENTS	FLIGHT
Aug 23, 2013 449P	3449P	1MND1CD234A	57.9/65.1 MB	57.9/65.1 1.15/1.05 MB MB	267MB	N/A	N/A	26.2GB	NA			
Aug 23, 2013 451P	3451P	1MND1B234B	76.5MB	524KB	88.9MB	N/A	N/A	7.65GB	NA		410B	бэкв
Aug 24, 2013 453P	453P	1MND1EBS235A	73.1/104 MB	73.1/104 544/549K MB B	172MB	N/A	N/A	18.7GB			451B	21.3/25.4 KR
Jun 11, 2013 275P	275P	1P6JS163A	115MB	757KB	150MB	NA	N/A	11.7GB			341B	17 2KB
. Jun 11, 2013277P	277P	1P2S1638	258MB	1.3MB	200MB	N/A	N/A	25.8GB			9558	57 2KB
· Jun 12, 2013 279P	279P	1P2S164A	129MB	882KB	160MB	N/A	N/A	13.7GB			869B	
Jul 20, 2013 335P	335P	1TGMAS199A	260MB	1.38MB	211MB	N/A	N/A	26.3GB	N/A		1.62KB	36.9KB
		Received from	(			Received by	ý					
		Name/Signature Position PA	J. S. C.	13		Name/Sign Position	Name/Signature Benjamin Magalton Position SIRS	By Mary	agadian			
		Date 091113	3			Date	08 127 /13					

# Data Transfer Sheet for 1P2B139A, 1P2A140A, 1P2A140B and 1P2A141A

DATE         FLIGHT NO.         MISSION           NAME         NAME           May 19, 2013         245         1P2B139A											
	NO	SENSOR	RAW LAS	SOOT	POS	RAW	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)	SERVER
		PEGASUS	98.5 MB	1.50 MB	172 MB	29.78 KB	233 KB	20.1 GB	N/A	6.85 MB	WFREENAS/ge ostorage/Airbor ne Raw/245P
May 20, 2013 247 1P2A140A		PEGASUS 77.4 MB	77.4 MB	1.34 MB	180 MB	23.7 GB	190 KB	14.6 GB	N/A	11.3 MB	WFREENASige ostorage/Airbor ne Raw/247P
May 20, 2013 249 1P2A140B		PEGASUS	36.3 MB	555 KB	96.9 MB	15.5 GB	97 KB	6.69 GB	N/A	11.3 MB	WFREENAS\ge ostorage\Airbor ne Raw\249P
May 21, 2013 251 1P2A141A		PEGASUS 100 MB		1.40 MB 193 MB		33.9 GB	259 KB	20.0 GB	N/A	10.7 MB	WFREENASige ostorage/Airbor ne Raw/251P
Receiv	Received from					Received by					
Name Position Signature	Aubren nre ork	Aubrey J. Matria SCHS Red Austral	. Bu			Name Benjama Magalton Position 25R3 Signature fighteryold	solamin Mas 55Rs p./myelu	gallon			

## **ANNEX F. FLIGHT LOGS**

# 1. Flight log for 1P2B139A Mission

Flight Log No.: ~73				]	
Flight Log	18 Total Flight Time:			Udar Operator  Myrico Signature over Printed Name	DREAM 6
S Aircraft Type: Cesnna 1206H   6 Aircraft Identification: AP-C @ 22	17 tanding:			200	-
4 Type: VFR	16 Take off:			Placin Company  () Clement  Sylature over Planed II	
1 HOAR Operator: J. Alviga. 2 ALIM Model: Regards 3 Mission Hame: 1728/344 4 Type: VER 5 Arcraft Type: Cesnin. 7 Filot: J. Cleaning 8 Co-Filot: They Rodge 12 Almost of Annual Chamber Chamber of Mission Chamber Cham	Roxas (15 Total Engine Time:	lo .		Acceptation Fight Contined by  Asceptation Space Sharper PAR Signature and Printed Hame (FAR Prepresentative)	
Alvia ZALIMModel: R.	14 Engine Off:	Mission completus	tions:		
THIDAR Operator: J. All. Thiot: J. Crossoft 8	13 Engine On: 06 40 H	79 Remarks:	21 Problems and Solutions:	Acquisition Pigyr popeoved by NAL 1/2 Was Signature from Printed Name (End User Representative)	

Elight log for 15 Take off:

15 Take off:

15 Take off:

15 Take off:

16 Take off:

18 Total Flight Time:

16 Take off:

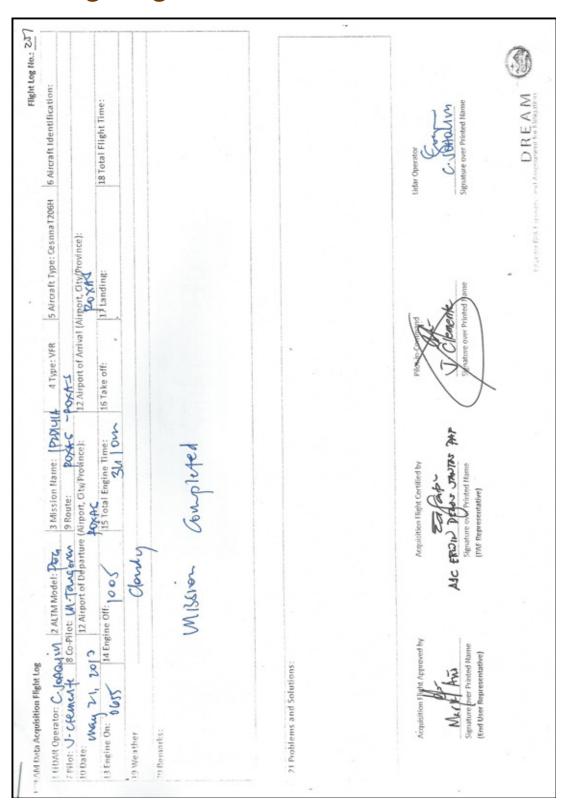
18 Total Flight Time:

19 Total Flight 4 Type: VFR 5 Aircraft Type: CesnnaT206H 6 Aircraft Identification: R ? - C962 Flight Log No.: 297 DREAM C 11 Dat Operator: Mark And 2 ALTM Model: Parant 3 Mission Hame: 1924 4 4 Type: VFR 5 Aircraft Type: Cesnn 7 Filot: J. Chemen H. 8 Co-Filot: M. Temperator 9 Route: Respect of Province): 12 Airport of Departure (Airport, Gty/Province): 2 May 208 12 Airport of Departure (Airport, Gty/Province): 15 Take off: 17 Landing: has acquired but abouted unción ALC EROND DATE SANTER PAR 15 Total Engine Time: Acquisition Flight Certified by clore y 21 Problems and Solutions: TEAM Data Acquisition Flight Log 014-60 19 Weather

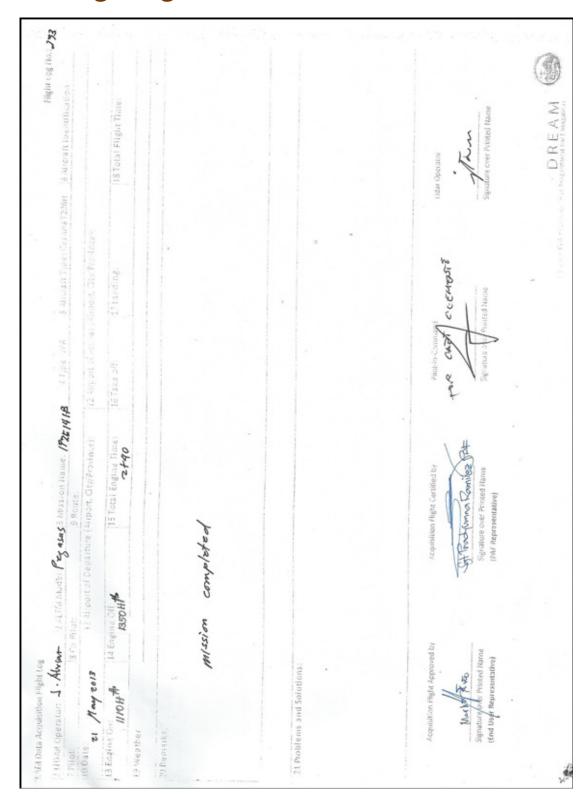
Flight log for 1P2A140B Mission Flight Log No.: 249 3 Mission Hame: P2A 1405 4 Type: VFR 5 Aircraft Type: Cesnna 7206H 6 Aircraft Identification: 18 Total Flight Time: 12 Airport of Arrival (Airport, City/Province): 17 Landing: data acquired but aborted mission date to air traffic and pracip-text 16 Take off: 10 Date: WAY 20, 29 > 12 Airport of Departure (Airport, City/Province): 12A

13 Engine On: | 135 | 14 Engine Off: 1515 JAC ERD IN DELOS STANTES PAPE SERVICE POPE Acquisition Flight Certified by LIDAR Operator: C.JOGAIN 2 ALTM Model: 21 Problems and Solutions: 17/M Data Acquisition Flight Log 19 Weather 29 Penjarks:

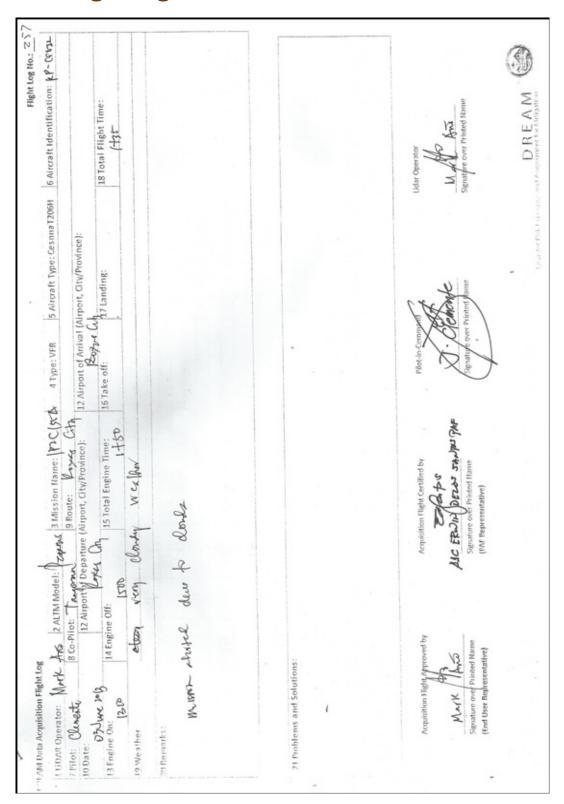
## 4. Flight log for 1P2D141A Mission



# 5. Flight log for 1P2E141B Mission



## 6. Flight log for 1P2CS155A Mission



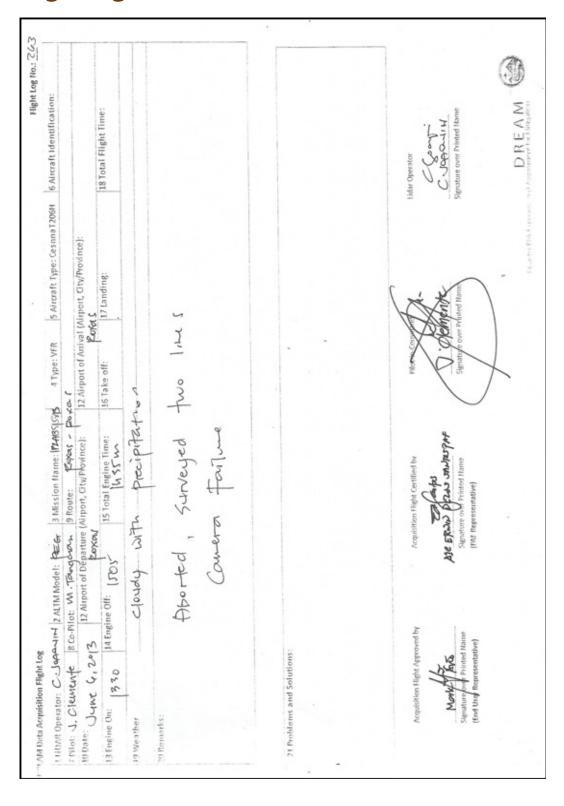
# 7. Flight log for 1P2A156A Mission

18 The state of th	6 Take off:  17 Landing:  18 Landing:  19 Pilot-In-Command:  19 Command:  10 Comman	LUDAR Operator: J. Alvige	2 ALTM Model: Pregasus	3 Mission Name: 1P2A15CA	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022	RP-C90
Pilot-in Command  Take off: 17 Landing  Wanatuk over Phinted hame	Pilot-in Command  Pilot-in Command  Vignatus cover Printed hame	lot: J. Clemente 8 Co.P	Hot: M. Tolmsonom	9 Route: Roxas	I will be to be desired of	(Almost City/Drovince).		
Pilot-in command  Pilot-in command  Signatuse over Printed hame	Pilot-in Command  Pilot-in Command  Vignatus over Printed hame	Jate: 4 Jume 2013	12 Airport of Departure (	Amport, cryprovince).	To various or various	(Coxas		
doubly  (complete hospitals)  Le failure (no captures)  Teported to Optich  Teported by Acceptures)  All From Piers Suparre over Mined Hane  Signature over Mined Hane  (PM Representative)	denotes  Corrupted to Captures)  Tapourted to Optich  Tapourted by Acc Fruit Medition High Continue by  Acc Fruit Mane Signature over Mined Hame  Signature over Mined Hame  (FM Representative)	ngine On: 0355	gine Off:	15 Total Engine Time: 3 +₹5	16 Take off:	17 Landing:	18 Total Flight Time:	
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Acquisition Flight Certified by  AC FRAND MASS SAWAS FAR  Signature over Printed Hame  (FAI Representative)	Acquisition Flight Certified by  AC EPAN MAN ARE Signature over Minted Hame  (PM Representative)							
LATE (NO captures)  AC FROM Misser Signature over Minted Name (PAI Representative)	Ac Fru Mitted thy  Signature over Minted thane (FAT Representative)	Problems and Solutions:		,				
Ato Epolis Miss Short Representative)  Signature over Printed Name (PAI Representative)	Ac Epun Mass Share Reference Printed Rame (PAI Representative)	camera fail	ure (no captures	(8				
Acquisition Flight Certified by  MC EPUN Pitters Supplies FRE Signature over Printed Hame (PMF Representative)	AC ERUN Pitted Barne (PMF Representative)							
(PAF Representative)	(PAF Representative)	Acquisition Flight Approved by		tion Flight Certified by	Pilot-in-Comm	The state of the s	Miviar Allviar	
DREAM (S	DREAM CO	Signature over Printed Name (End User Representative)	(PAF Rey	presentative)	41			
							DREAM	

# 8. Flight log for 1P2ABS158B Mission

							(3)
No. of the control of	18 Total Flight Time:				o ppm output	Lidar Operator  A Via - Signature over Printed Name	
A Type: VFR   S Arctan Type: Les mis 12001   O Arctan Continue Con	17 Landing:				explained with lugues pom output	Cover Printed Library	
Soracoy 12 Airport of Arri	16 Take off:					Pilot-in	
1 HDAR Operator: J. Alviar 2 ALTM Model: Process 3 Mission Hanne: [Exyl884 4 Tippe: VPR 7 Filor: J. Clement & Co-Pilot: M. Tangona 9 Route: Roys - Borney 10 Date: 1. 2 Althout of Departure (Alport, Civ/Prownce): 12 Althout of Antiva	15 Total Engine Time:	4		4 ppm haguirment)	t gheb	Acquisition flight Certified by  The France Search Control Hame (FAT Representative)	
2-ALTM Model: Presest 3-Pilot: M. Tangen 12 Airport of Departu	14 Engine Off:	partly derivery	n complete		na failuse -		
10 Date: 1. Clement & Co-filot:	H0280	19 Weather	no 155/111	(at has)	21 Problems and Solutions: Camera Assur	Acquisition Flight Approved by  Werth Are Signature over Pinted Name (End User Representative)	

## 9. Flight log for 1P2ABS160A Mission



# 10. Flight log for 1P2F161A Mission

figure of the following the following the fine time:  15 Take off:  15 Take off:  15 Take off:  15 Take off:  17 Tanding:  18 Total Flight Time:  2 + 15  2 + 15  2 + 15  2 + 15  2 + 15  2 + 15  2 + 15  2 + 15  3 + 10  4	16 Take off: 17 (anding: 18 Total Flight Tin
Figure Off: 12 Total Engine Time: 15 Take off: 12 Panding: 18 Total Flight Time: 24 15  And Ethy dendy, retay with dy 24 15  The dendy, retay with dy 24 15  The marcy hadren high Certified by Filed incompany of Filed incompany of Filed incompany	gine Tine: 16 Take off: 17 fanding: 18 Total Flight Time: 3+35
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Acquisition Flight Certified by  ALC FRAIN DEAN SANDON PAR  Signature over Printed Name  (19th Prepresentation)	letech
Flor-les-Command  T. C.	to dute images
	Flor-les-Command  T. C.

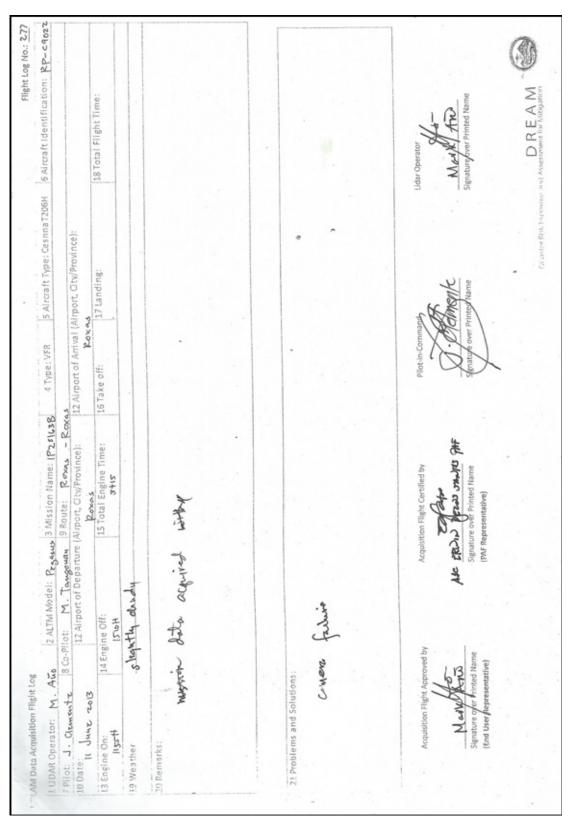
# 11. Flight log for 1P2GES162A Mission

12 Airport of Date:  12 Airport of Departure (Airport, Gty/Province): 13 Airport of Arrival (Airport, Cty/Province): 14 Engine Off: 15 Airport of Arrival (Airport, Cty/Province): 15 Take off: 17 Landing: 19 Weather 19 Meants: 5 Arreyed Sowre lines  Lat aborted wission due to cloud cover	(Airport, Cty/Province):    17 Landing:   1040  C-V-Cr	18 Total Flight Time:
The state of state		18 Total Flight Time:
Heavy Chad Cover  Surveyed Sourc lines  but aborted mission		18 Total Flight Time:
Samo	re to cloud court	
Samo	re to cloud court	
	THE RESERVE AND ADDRESS OF THE PARTY OF THE	
21 Problems and Solutions:		
Acquisition Flight Approved by  Mac Printed Wanne Signature deed Printed Name (End User Representative)	PHONE COMPANY CONTRACTOR CONTRACTOR SINGLE CONTRACTOR HARDE	Signature over Printed Name
	an name albert pigli ander Kil	DREAM C

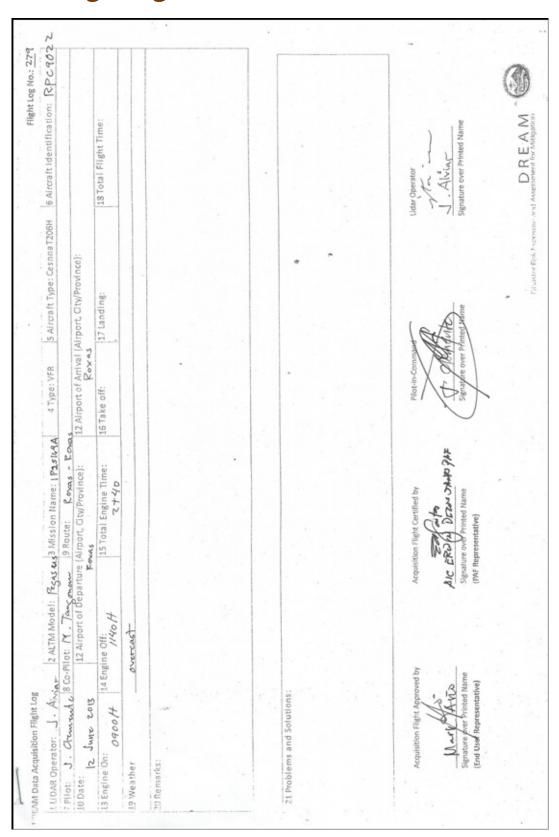
# 12. Flight log for 1P2ABCS162B Mission

Acquisition Flight Approved by Acquisition Flight Certified by Pilot-in-Command  Asc ERDIN Tipes She Signature over Printed Name Signature over Printed Name (Find User Representative)  (End User Representative)
Acquisition flight Certified by  ALC EROLD Repose State of Parties of Parties (PAF Representative)  (PAF Representative)
Asc ERALD Nebes sawings paper Signature over Pladed Hame (PAE Repersentative)
Asc ERDID Tepes Saw Trs pare Signature over Princed Hame (PAF Representative)
Acquisition Flight Certified by  Pilot-in-Command  ALC ERDIN Reposessitative of the Manne (PAF Representative)  Signature over Printed Hanne (PAF Representative)
As the Representative over Printed Hame  [FA Representative]
Action And Stelling Then Certified by Pilot-in-Command Act (RD), Reposentative)  Signature on Criminal Name (PAF Representative)
Jaclius — nee from age along  Magnistican Hight Certified by  ALC ERDIN THEORY THE  Signature over Printed Hame  (PMF Representative)
Section Acquisition High Certified by Pilot-in-Command Ac ERDIN Repos Section Party September (PA February PAT) Repos Section Plane (PAF Representative)
Sections — new towaste of No.  Acquisition Hight Certified by  ALC ERDIN TERMS THE Separation over Printed Hame  (FAF Representative)
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a factor. The terring of the Photin Command red by Ase ERDLD Webland Hame (PAR February)
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a factors — new sons of Ala Ala Marie Marie over Pipeles Barre over Pi
a failers— nee tonage of the safe of the s
a failur — ne ton age alta Photin Command  Neys also To The State  Ase ERDIN Meas states for Supplied Hame  Supplied Hame  (PM Representative)
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# 13. Flight log for 1P2S163B Mission



## 14. Flight log for 1P2S164A Mission



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