



Airborne Lidar Commissioning Report
Optech ALTM Galaxy T2000
S/N 5060503

Prepared for:

Servicios Politécnicos Aéreos, S.A (SPASA)
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1 SYSTEM CONFIRMATION AND ACCEPTANCE

Teledyne Optech Incorporated, by virtue of the signature on the title page of this report, hereby certifies that the Optech **Galaxy T2000** bearing the sensor serial number **5060503** has been delivered, calibrated and proven to be in good operating order and condition, and that it performs in accordance with the system specifications contained within the Sales Agreement.

The Buyer, by virtue of the signature on the title page, hereby acknowledges that the system has been demonstrated to be calibrated and to meet system accuracy specifications.

1.1 Summary statement

The system with the following model and sensor head serial numbers:

Model	ALTM Galaxy T2000
S/N	5060503

has been tested according to the test program outlined by Teledyne Optech Incorporated herein. The system was tested onsite the following period:

Start Date	[June 2023]
End Date	[June 2023]

The results of these tests as well as additional data are presented in this report. The purpose of this document is to provide relevant calibration information that demonstrates system functionality, to present the results of the test completed for the system, and to confirm that this system meets the accuracy specifications identified in the applicable sales agreement. The system is purchased by:

[SPASA]

The issuance of this report by Teledyne Optech Incorporated shall represent the certificate of conformance for the system.

2 SYSTEM SPECIFICATIONS

The following table lists the specifications and requirements of this system.

Table 1: System specifications

PARAMETER	SPECIFICATION
Sensor Performance	
Performance envelope ^{1, 2, 3, 4}	150-6000 m AGL, nominal
Absolute horizontal accuracy ^{2, 3}	1/10,000 × altitude; 1 σ
Absolute elevation accuracy ^{2, 3}	< 0.03-0.25 m RMSE from 150-6500 m AGL
Laser Configuration	
Topographic laser	1064-nm near-infrared
Laser classification	Class IV (US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1)
Pulse repetition frequency (effective)	Programmable, 50-2000 kHz
Beam divergence	0.16 mrad (1/e) or 0.23 mrad (1/e ²)
Laser range precision ⁵	< 0.008 m, 1 σ
Minimum target separation distance	< 0.7 m (discrete)
Range capture	Up to 8 range measurements, including last
Intensity capture	Up to 8 intensity measurements, including last (12-bit)
Sensor Configuration	
Position and orientation system	POS AV™ AP60 (OEM); 220-channel dual frequency GNSS receiver; GNSS airborne antenna with Iridium filters; high-accuracy AIMU (Type 57); non-ITAR
Scan angle (FOV)	10-60°
Swath width	10-115% of altitude AGL
Scan frequency	Maximum 160 Hz (320 scan lines/sec)
Flight management system	Optech FMS (Airborne Mission Manager and Nav) with operator console
SwathTRAK™	Dynamic FOV for fixed-width data swaths in variable terrain
PulseTRAK™	Multipulse tracking algorithm with no density loss across PIA transition zones
Roll compensation	±5° minimum
Data storage	Removable SSD (primary); internal SSD (spare)
Power requirements	28 V; 400 W
Dimensions and weight	Sensor: 0.34 × 0.34 × 0.25 m, 27 kg — PDU: 0.42 × 0.33 × 0.10 m, 6.5 kg
Operating temperature	0 to +35°C
Optional Peripherals	
External data storage	Ruggedized, removable 2.5" SSD
Image capture	Compatible with all Optech CS-Series and most 3rd party digital metric cameras (integration kits available)
Full waveform capture	12-bit Optech IWR-3 Intelligent Waveform Recorder with removable SSD
Gyro-stabilization	SOMAG GSM4000 integration kit
Multi-sensor mounts and pods	Machined aluminum sensor mounts; single or dual Galaxy configurations + cameras Carbon-fiber sensor mounts supporting nadir and fore/aft oblique cameras Heli-pod mount options for Bell 206/407 (FAA-approved)

1. Target reflectivity ≥20%; 99% detection probability

2. Dependent on selected operational parameters; assumes nominal FOV of up to 40° in standard atmospheric conditions (i.e. 23-km visibility) and use of Optech LMS Professional software suite

3. Angle of incidence ≤20°

4. Target size ≥ laser footprint

5. Under Teledyne Optech test conditions, 1 sigma

Notes

To meet its stated accuracy, the airborne lidar must receive GPS data of sufficient quality. GPS data quality will be viable only when all of the following conditions are met:

- At least 6 satellites are in lock (tracked by receiver) throughout the survey
- Elevation of satellites is above 15°
- Geometry of the satellites is good (i.e., PDOP <4)
- Processed via PP-RTX

If one or more of these conditions is not met, or if any source of electromagnetic interference causes the GPS receivers to repeatedly lose lock, the specified accuracy of the airborne lidar cannot be guaranteed.

3 RESULTS AND CONCLUSIONS

This section provides the test and procedure results from the test flights. The pass or fail criteria for each section are based on the airborne lidar Galaxy system specification.

Surveying parameters: PRF 1200 kHz; Scan Frequency 85Hz; Full Scan Swath 58deg; AGL around 1000m

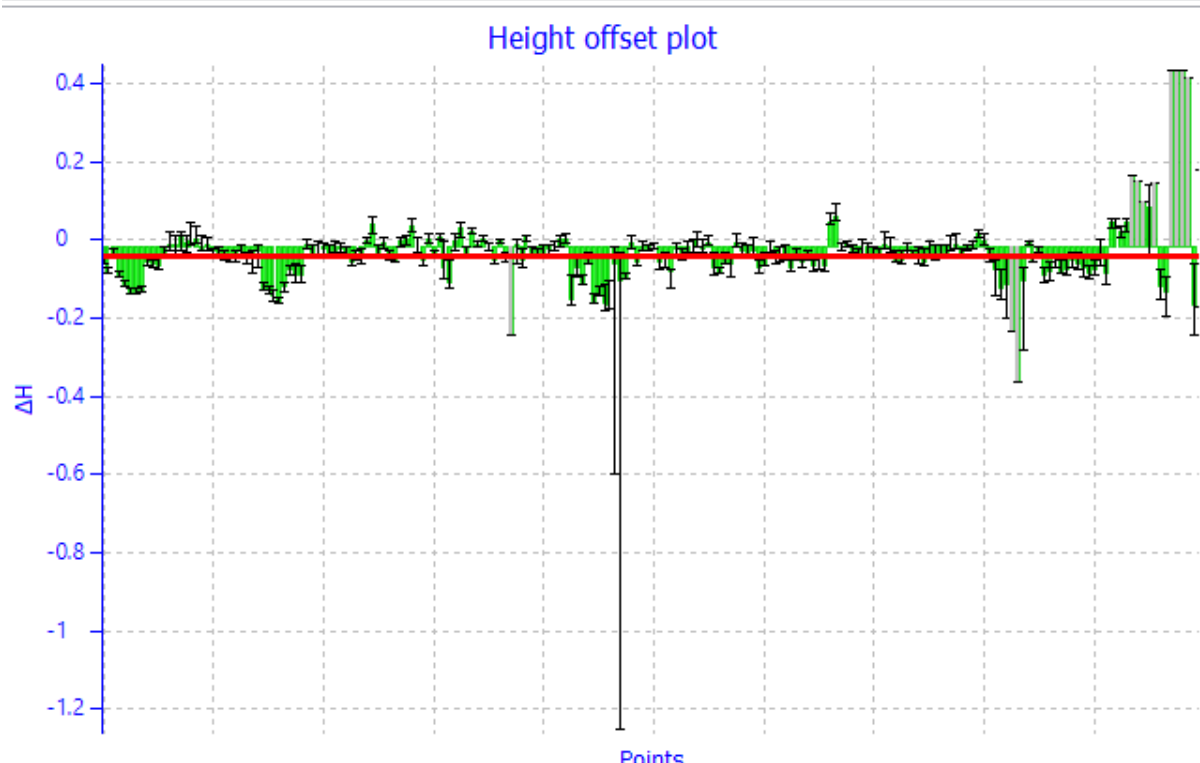
3.1 Vertical accuracy over calibration control field

Data was collected over Hormigos in Spain against 189 survey control points to analyze the scanner swath against a trusted control field. The following table shows the results of the vertical accuracy between strips and compared to the calibration control field.

Results indicate that the system with sensor S/N 5060503 demonstrates a swath vertical accuracy equal to or better than the system specification, using a 58° field of view.

Table 2: Absolute accuracy over calibration control field

Number of selected control points	189
Average height difference	-0.027
Standard deviation	0.045



3.2 Optech LMS accuracy verification

3.2.1 Relative horizontal accuracy: Roof line analysis

The roof line analysis compares roof lines in the overlapping areas of flight lines. For a pair of roof lines, it computes the shortest vector between the lines at the center point of one of the lines. The roof line table compares the position and orientation of line features between flight lines. Based on the specification and the flying height of 1000 meters, the ALTM must meet a horizontal accuracy of $1000 \text{ m} / 10000 = 0.10 \text{ m}$.

The sensor with S/N 5060503 exceeds this horizontal specification with an RMS value of the horizontal distance between roof lines of 0.046 m.

Table 3: Relative horizontal roof line analysis from the Optech LMS area

Flight 20191010	Mean	RMS	Minimum	Maximum
Delta East	0.000	0.024	-0.111	0.599
Delta North	0.000	0.040	-0.500	0.714
Delta Height	-0001	0.018	-0.256	0.126
Horizontal Separation	-0.000	0.046	-0.639	0.718
Diff. Azimuth	0.02122	0.60883	-7.25478	6.41966
Diff. Slope	0.01298	0.21208	-0.63703	2.22383

3.2.2 Relative vertical accuracy: Selected tie planes

The results of this section are used to assess the laser point accuracy after applying calibration corrections. Part of the calibration process is to find common artificial and natural planes between flightlines. This relative accuracy demonstrates how well the points of different flight lines agree in their comparison to the common tie planes.

Table 4: Selected tie planes from the boresight strips

Flight	Line	No. points	Mean-d	RMS-d
20230606	L0001	841762	0.000	0.002
20230606	L0002	811880	0.000	0.001
20230606	L0003	532624	0.000	0.001
20230606	L0004	640148	0.000	0.001
20230606	L0005	542612	0.000	0.001
20230606	L0006	517462	-0.000	0.001
20230606	L0007	563560	-0.000	0.002
20230606	L0008	553346	-0.000	0.001

Legend

Column 1 – Flight	Julian date of the flight.
Column 2 – Line	Flight line number designated by Optech LMS.
Column 3 – No. points	Total number of points on the common tie planes for the given flight line.
Column 4 – Mean-d	Average point-to-plane distance for the points on the tie-planes for the given flight line.
Column 5 – RMS-d	Root-mean-square value for the point-to-plane distances for the points on the tie-planes for the given flight line.

4 POS AV LEVER ARMS AND COMMUNICATION PARAMETERS

4.1 Sensor head constants

The following measurements have been calculated in the lab at Teledyne Optech and will remain constant. This is for creating an SBET centered on the IMU center of navigation.

Table 5: Reference to IMU Mounting Angles

User Frame to IMU Misalignment	Value in POS AV
X	0.000°
Y	0.000°
Z	180.000°

Table 6: Reference to IMU Lever Arm

User Frame to IMU Lever Arm	Value in POS AV
X	0
Y	0
Z	0

4.2 GPS eccentricity values

The following measurements are valid only for the aircraft client used during calibration, when using the Trimble aircraft antenna.

Table 3: Aircraft to Reference Mounting Angle

Aircraft to Reference Mounting Angle	Value in POS AV
X	0.000 deg
Y	0.000 deg
Z	0.000 deg

Table 4: Reference to GPS antenna lever arms

Reference to GPS antenna	Value in POS AV
X	Custom
Y	Custom
Z	Custom

Applanix-derived lever arms, Aircraft specific

5 REPORT GENERATION SOFTWARE

The following software was used to generate this report.

Table 5: Software used to generate the report

Software	Version
Optech AAM Planner	customer
Optech FMS Nav	customer
Optech LMS Pro	4.6.1.30889
Optech Decode	6.4.0.0
POSPac MMS	8.8

6 CALIBRATION FILES

6.1 LCP file

The calibrated LCP file in LMS 4.6 format.



5060503_1200PRF_8
5SF_58FOV_1000AG

6.2 Range intensity correction table

The range intensity correction table in LMS 4.6 format.



5060503_RIC_.TBL

6.3 RES file

The calibrated RES file in LMS 4.4 format.



5060503_RES_IPCO
NON.RES