



ALTM Factory Acceptance Protocol
Optech ALTM Titan MW
Serial Number – 5120349

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1 ALTM SYSTEM COMPONENTS

Component	Device	Type	Serial Number
POS system	PCS		
	Inertial measurement unit	FMU-301(IMU-46)	14/00486
Sensor head	Sensor head	Optech	5120349
Control rack	Control rack	Optech	5130350
Camera system	Camera head	CS 10000	13-017-CM1-017
	Camera controller	CS 10000	5840060
Optech IWD-2		12 bits	13DIG039
1 set of Interconnect cables			
6 Lidar hard drives		SSD (SATA II)	
2 camera hard drives			
2 waveform recorder hard drives		SSD	

2 SOFTWARE

Component	Type	Version Number
FMS Planner		v 4.9.1
FMS Nav		V 4.9.1
Optech LMS	Professional 64-bit	v 2.4.2
AquaDX	64-bit	v 1.7.6
PosPac MMS	Service Pack 1	v 7.1.5535.25591
Digitizer Data Retrieval	12 bits	V6.2.0.0

3 FACTORY LABORATORY CONFORMANCE

Laser Divergence (1/e ²) (mrad)								
532 nm			1064 nm			1550 nm		
Spec	Meas	Pass/Fail	Spec	Meas	Pass/Fail	Spec	Meas	Pass/Fail
0.7 mrad 1/e	0.64	Pass	0.28 mrad 1/e	0.28	Pass	0.28 mrad 1/e	.23	Pass
Comment: To Improve the spot size for terrain mapping, Optech has reduced the spec on the 1064 and 1550 nm beams from 0.5 mrad 1/e ² to 0.4 mrad 1/e ² (0.28 mrad 1/e).								


3.1 IMU performance

IMU Type	Estimated Error	Range (±)	Variation	Pass / Fail
IMU-7, 8, 29, 31, 46	Accelerometer Bias	4000 micro-g	600 micro-g	Pass
	Accelerometer Scale Error	2500 ppm	500 ppm	Pass
	Gyro Bias	8 deg/hr	4 deg/hr	Pass
	Gyro Scale Error	800 ppm	400 ppm	Pass

4 CALIBRATION PROCESS


4.1 Factory intensity correction tables

Item	Pass / Fail
Intensity Data Collection Measurements	Complete
Intensity Tables	Complete

File	 5120349_Titan3.tbl
Purpose	To correct for the effect of varying range based on return signal strength
Note	Range biases are measured in meters

4.2 Factory range correction matrix

Item	Pass / Fail
Range Data Collection Measurements	TBD (see note below)
4x11 Matrix Generation for 3 channels	Complete

File	 5120349_Titan3.res
Purpose	To correct for the effect of varying range based on pulse repetition frequency (PRF) and electronic timing
Note	Range biases are measured in meters. Range offsets are subject to change based on calibration check after delivery.

4.3 Factory range offsets in meters

Offset	50 kHz	75 kHz	100 kHz	125 kHz	150 kHz	175 kHz	200 kHz
Channel 1	-13.319	-13.336	-13.358	-13.329	-13.317	-13.326	-13.319
Channel 2	-21.542	-21.525	-21.516	-21.512	-21.510	-21.530	-21.512
Channel 3	-21.514	-21.515	-21.516	-21.520	-21.519	-21.520	-21.523

Offset	225 kHz	250 kHz	275 kHz	300 kHz
Channel 1	-13.312	-13.311	-13.311	-13.314
Channel 2	-21.516	-21.514	-21.519	-21.513
Channel 3	-21.520	-21.520	-21.520	-21.520

4.4 Factory flight and data processing

Item	Pass / Fail
Airborne test flight (data quality & calibration check)	Complete

File	RES file
------	----------

Purpose	To correct for systematic effects of this system
Note	It is recommended that a complete calibration be performed after system delivery to verify and establish a final set of parameters

4.5 Sensor head constants

Reference Point to FMU	Value	Units
X	-0.2737	m
Y	0.0475	m
Z	0.2107	m

Reference Point to Scanner	Value	Units
X	-0.3497	m
Y	-0.072	m
Z	0.4596	m

Reference Point to Camera	Value	Units
X	-0.278	m
Y	0.08	m
Z	0.4997	m

FMU to GSM Pivot Point	Value	Units
X	-0.0763	m
Y	-0.0475	m
Z	-0.0042	m

FMU to Scanner	Value	Units
X	-0.076	m
Y	-0.1195	m
Z	0.2489	m

FMU to Camera	Value	Units
X	-0.0043	m
Y	0.0325	m
Z	0.289	m

Scanner to GSM Pivot Point	Value	Units
X	0.0003	m
Y	-0.072	m
Z	0.2531	m

GSM Pivot Point to Fixed Mirror	Value	Units
X	-0.01795	m
Y	0.04817	m
Z	0.27119	m


5 CALIBRATION SUMMARY

5.1 RES file for post-processing

Parameter (unit)	Value
Offset - Polynomial Coefficient a0 (deg)	-0.000068
Scale - Polynomial Coefficient a1 (deg)	0.999833
Polynomial Coefficient a2	-0.000012072
Polynomial Coefficient a3	-0.000028873
Polynomial Coefficient a4	-0.00000026804
Polynomial Coefficient a5	0.000000039215
Time Lag, positive (seconds)	0.0000184

Parameter (unit)	Value
Time Lag, negative (seconds)	0.0000184
Droop a0	0.9
Droop a1	1.2
Droop b0	-1.0
Droop b1	-1.0

5.2 LCP File for post-processing

Parameter (unit)	Value
Scan-offset (deg)	0.0
Scan-scale	0.9938608830329895
Channel 1 imu_ex (deg)	0.09959397101385246
Channel 1 imu_ey (deg)	0.10679356449870958
Channel 1 imu_ez (deg)	-0.06388574779092271
Channel 2 imu_ex (deg)	-0.04568281234800475
Channel 2 imu_ey (deg)	0.09725821271988032
Channel 2 imu_ez (deg)	-0.06308370911677993
Channel 3 imu_ex (deg)	-0.4456308681706038
Channel 3 imu_ey (deg)	0.10854402080763705
Channel 3 imu_ez (deg)	-0.07699891956348515
Channel 1, 2 & 3 pos_dx (m) - no GSM	0.0061599998734891415
Channel 1, 2 & 3 pos_dy (m) - no GSM	-0.07199999690055847
Channel 1, 2,& 3 pos_dz (m) - no GSM	0.4356200098991394
<p>Comment: Values reported by LMS after boresight block adjustment</p> <div style="text-align: center;">  5120349_Titan3_non-GSM.lcp </div>	

6 DATA ACCURACY

Item	Result
Angle shot to shot performance (100khz)	0.00310
Summary calibration check	Pass
Range Capture (4 returns and intensity)	Pass
Minimum target separation	Pass
Roll compensation	Pass
Real time display	Pass

6.1 Point Density and Area coverage

AGL (m)	Per Channel PRF (kHz)	Scan Freq. (Hz)	Scan Half Angle (deg)	FMS planner Nominal point density (m ²)	Planned X – Y points spacing at 140knots	Channel	Flight data point density (m ²)
1819 (Based on 20% target reflectivity)	50	21	25	0.40	X : 1.4557 Y : 1.7148	1	3.83
						2	3.86
						3	3.87
1565	250	25	30	1.91	X : 0.3642 Y : 1.4404	1	1.73
						2	1.71
						3	1.75
904	100	25	30	1.32	X : 0.525 Y : 1.4404	1	1.29
						2	1.21
						3	1.25
409	200	53	15	10.22	X : 0.1440 Y : 0.6795	1	9.77
						2	9.81
						3	9.76

7 VERTICAL ABSOLUTE ACCURACY STATISTICS

Flight day	Flight altitude (m AGL)	Per Channel Laser PRF (kHz)	Scan freq. (Hz)	FOV (\pm°)	Channel #	Mean diff. from GCPs (m)	Std dev. (m)	RMS (m)
17015 B	987	100	25	30	1	-0.0338	0.0155	0.0372
					2	0.0038	0.0201	0.0205
					3	-0.0148	0.0176	0.023
	994	100	25	30	1	-0.0128	0.0174	0.0216
					2	0.0041	0.0205	0.0209
					3	-0.0142	0.0147	0.0204
993	100	25	30	1	-0.0022	0.0136	0.0138	
				2	0.0204	0.0198	0.0284	
				3	0.0027	0.0151	0.0154	
845	75	43	18	1	-0.016	0.0148	0.0218	
				2	0.0304	0.0187	0.0357	
				3	-0.002	0.0151	0.0152	
740	125	65	12	1	-0.0061	0.0203	0.0212	
				2	0.0005	0.0225	0.0225	
				3	-0.0054	0.0184	0.0192	
583	250	52	15	1	0.0069	0.0103	0.0124	
				2	0.0226	0.0128	0.0260	
				3	0.0131	0.0094	0.0161	
17015 A	1565	250	25	30	1	0.0269	0.0213	0.0344
					2	0.0097	0.0225	0.0245
					3	-0.0317	0.0259	0.0409
	1819	50	21	25	1	-0.0431	0.0158	0.0459
					2	-0.0317	0.0259	0.0409
					3	0.0158	0.0190	0.0247
	2088	100	25	30	1	-0.0115	0.0168	0.0204
					2	0.0009	0.0271	0.0271
3					0.0158	0.0190	0.0247	
1244	200	32	25	1	-0.006	0.0355	0.0360	
				2	0.0109	0.0573	0.0583	
				3	-0.0101	0.0710	0.0717	
891	100	25	30	1	-0.0157	0.0161	0.0225	
				2	0.0058	0.0198	0.0206	
				3	-0.0042	0.0175	0.0180	
899	100	25	30	1	-0.0056	0.0160	0.0169	
				2	0.0059	0.0168	0.0178	
				3	-0.0105	0.0152	0.0184	
904	100	25	30	1	-0.0065	0.0162	0.0175	
				2	0.0253	0.0172	0.0306	
				3	0.0103	0.0157	0.0187	
902	75	43	18	1	-0.0255	0.0152	0.0297	
				2	0.0197	0.0188	0.0273	

Flight day	Flight altitude (m AGL)	Per Channel Laser PRF (kHz)	Scan freq. (Hz)	FOV (±°)	Channel #	Mean diff. from GCPs (m)	Std dev. (m)	RMS (m)					
	737	125	65	12	3	-0.0091	0.0144	0.0170					
					1	-0.0085	0.0180	0.0199					
					2	-0.0064	0.0233	0.0241					
	568	250	52	15	15	3	-0.0061	0.0190	0.0200				
						1	-0.0166	0.0172	0.0204				
						2	0.0010	0.0140	0.0141				
						3	-0.0048	0.0108	0.0118				

8 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 897 meters, the Titan should meet a horizontal accuracy of $897\text{m} / 7500 = 0.1196\text{ m}$.

The sensor with S/N 5120349 exceeds the horizontal specification with an RMS value of the horizontal distance between roof lines of 0.118m.

Table 1: Roof line analysis from Optech LMS for 17015 B

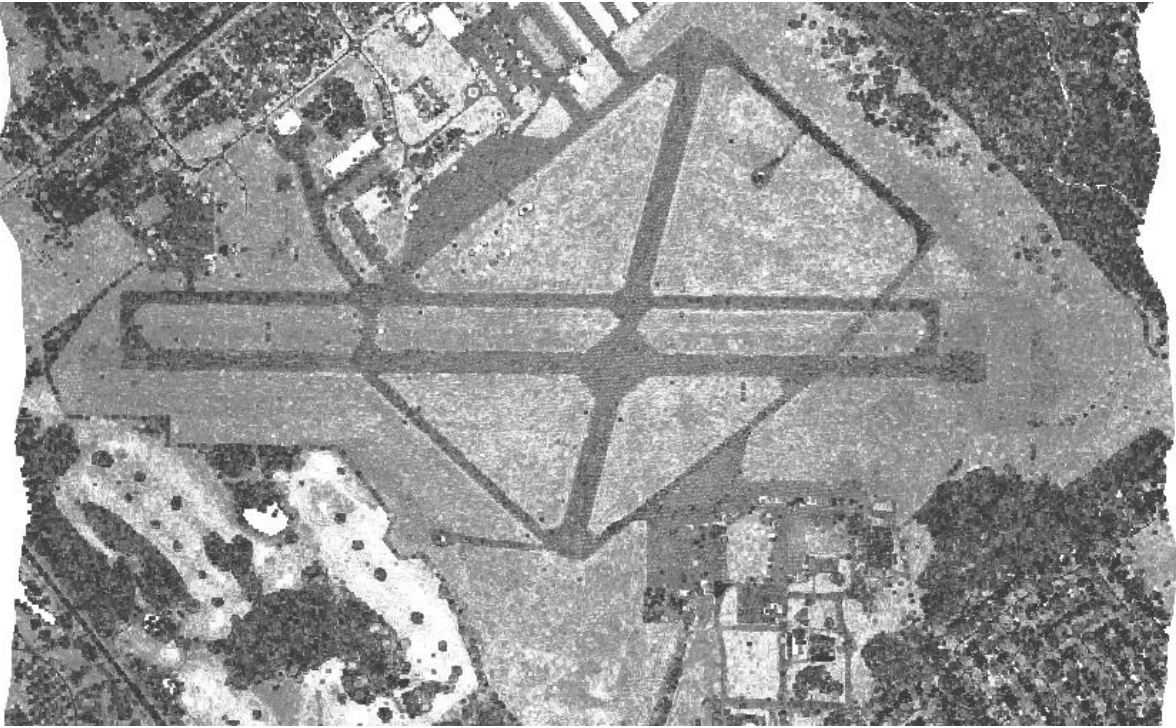
150127 Flight	Mean	RMS	Minimum	Maximum
Delta East (m)	-0.006	0.079	-0.383	0.804
Delta North (m)	0.004	0.088	-0.816	0.367
Delta Height (m)	-0.000	0.031	-0.284	0.103
Horizontal Distance	0.008	0.118	-0.854	0.402
Difference of Azimuth (deg)	-0.00334	0.22589	-0.99827	.95138
Difference of Slope (deg)	0.00740	0.08224	-0.54881	.62222

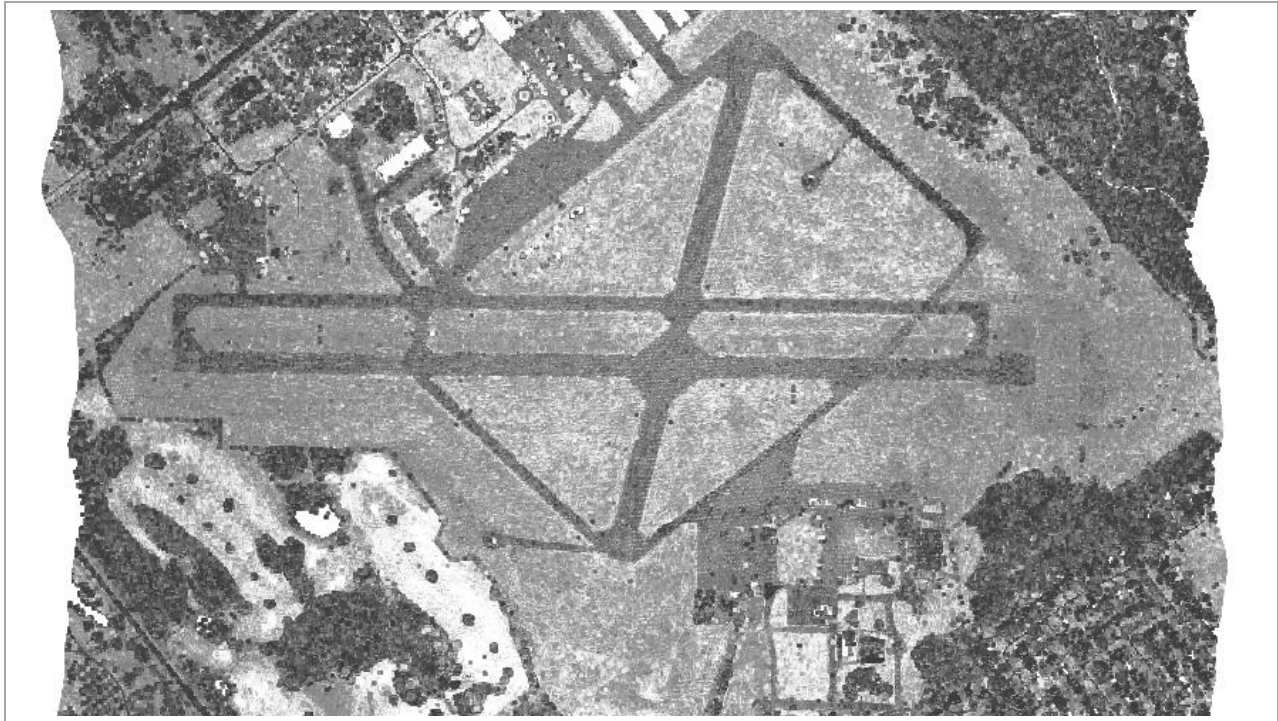
9 MAXIMUM ALTITUDE PERFORMANCE

AGL (m)	Chan.	Chan. PRF (kHz)	Scan Freq. (Hz)	Scan Half Angle (deg)	Oshawa runway control average nadir intensity
2088	1	100	25	30	9.6
	2	100	25	30	2.4

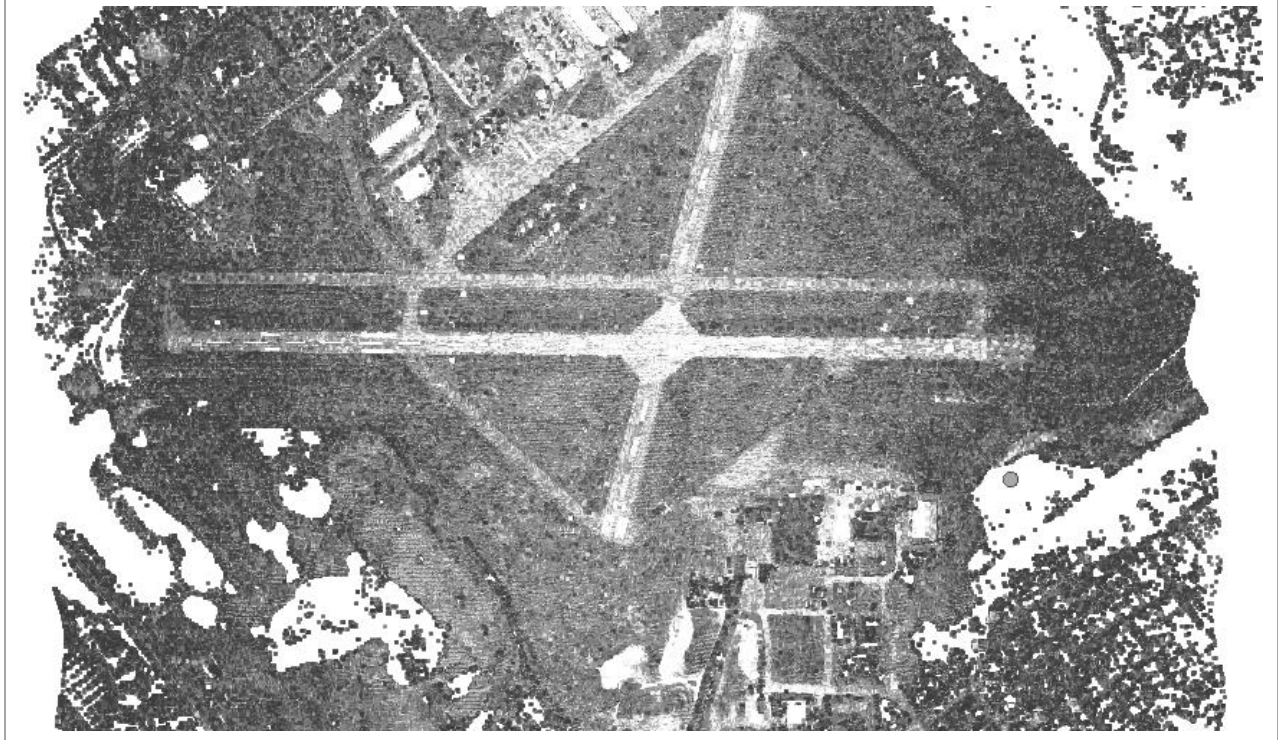
	3	100	25	30	6.4
1565	1	250	25	30	11.9
	2	250	25	30	6.0
	3	250	25	30	11.5

10 ALTITUDE DEPENDENT RANGING CAPABILITIES

AGL (m)	Chan.	Chan. PRF (kHz)	Scan Freq. (Hz)	Scan Half Angle (deg)
1565	1	250	25	30
				
1565	2	250	25	30



1565	3	250	25	30
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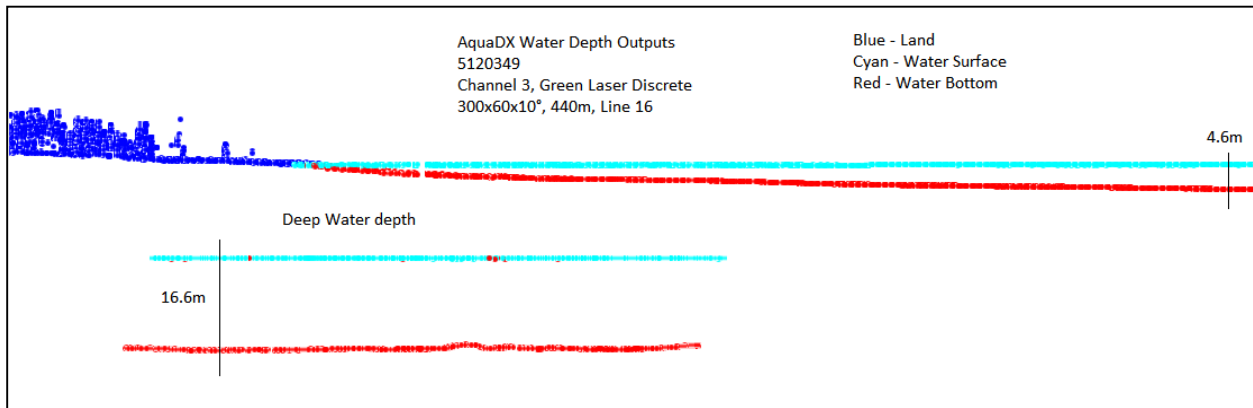


11 WATER DEPTH PERFORMANCE

AGL (m)	Chan.	Chan. PRF (kHz)	Scan Freq. (Hz)	Scan Half Angle (deg)	Area
440	3	100	60	10	Lake Huron

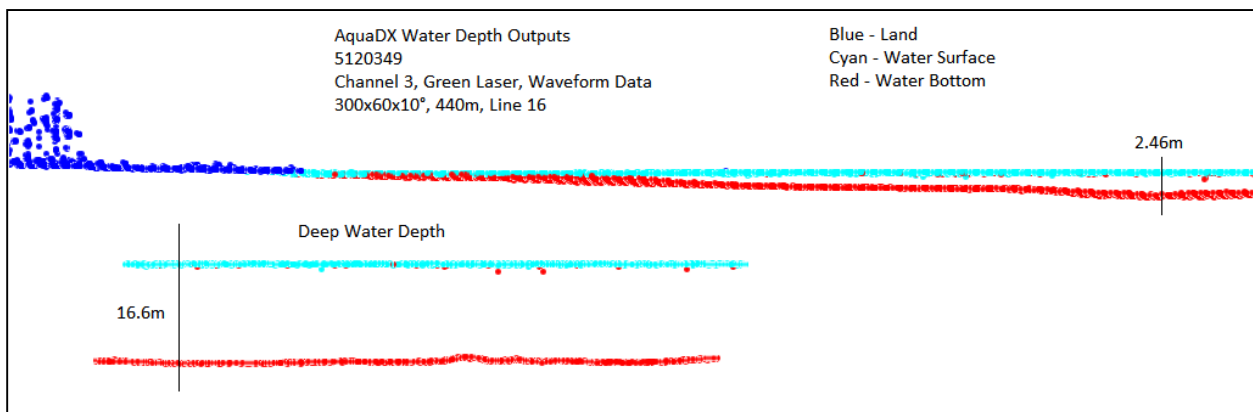
11.1 Discrete Returns, Green Laser, Channel 3

The discrete data collected with the green laser of Channel 3 was processed through Optech AquaDX to obtain classified water data and accurate water depth measurements



11.2 Waveform Returns from IWD, Green Laser, Channel 3

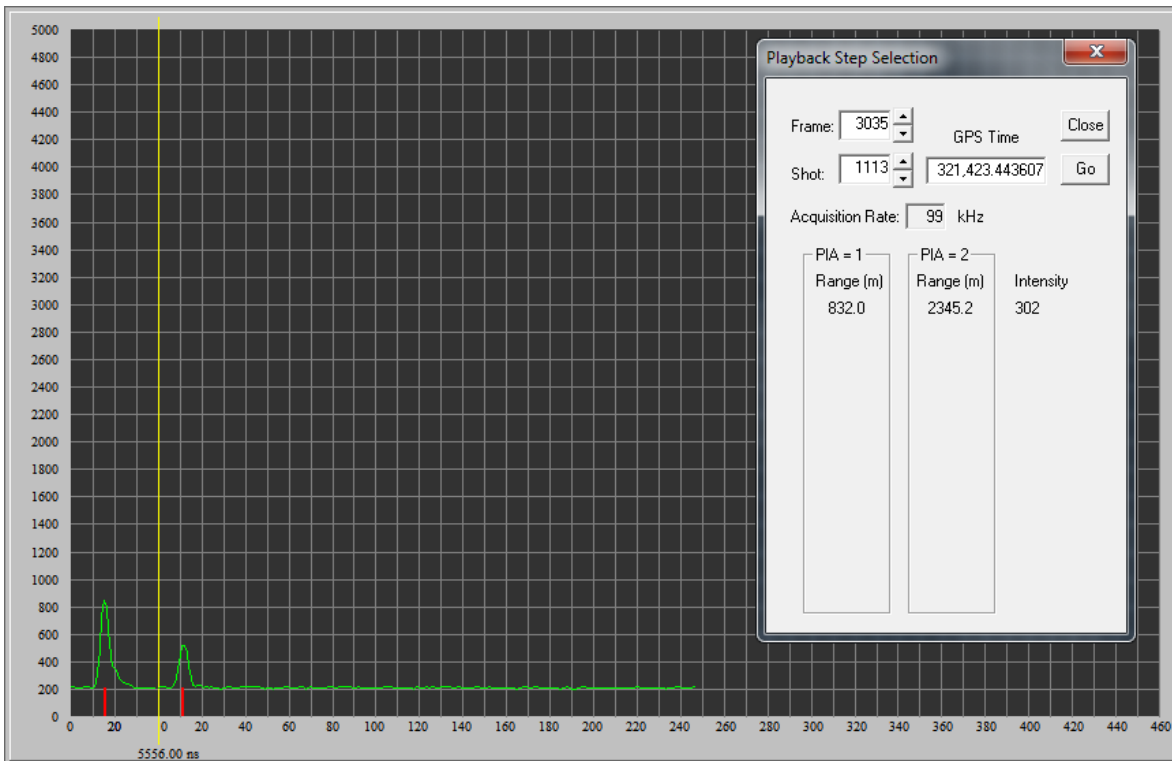
The waveform digitizer for the Optech Titan MW 5120349 is paired to the Channel 3 green laser. The waveform data collected was processed through AquaDX to obtain classified water data and accurate water depth measurements.



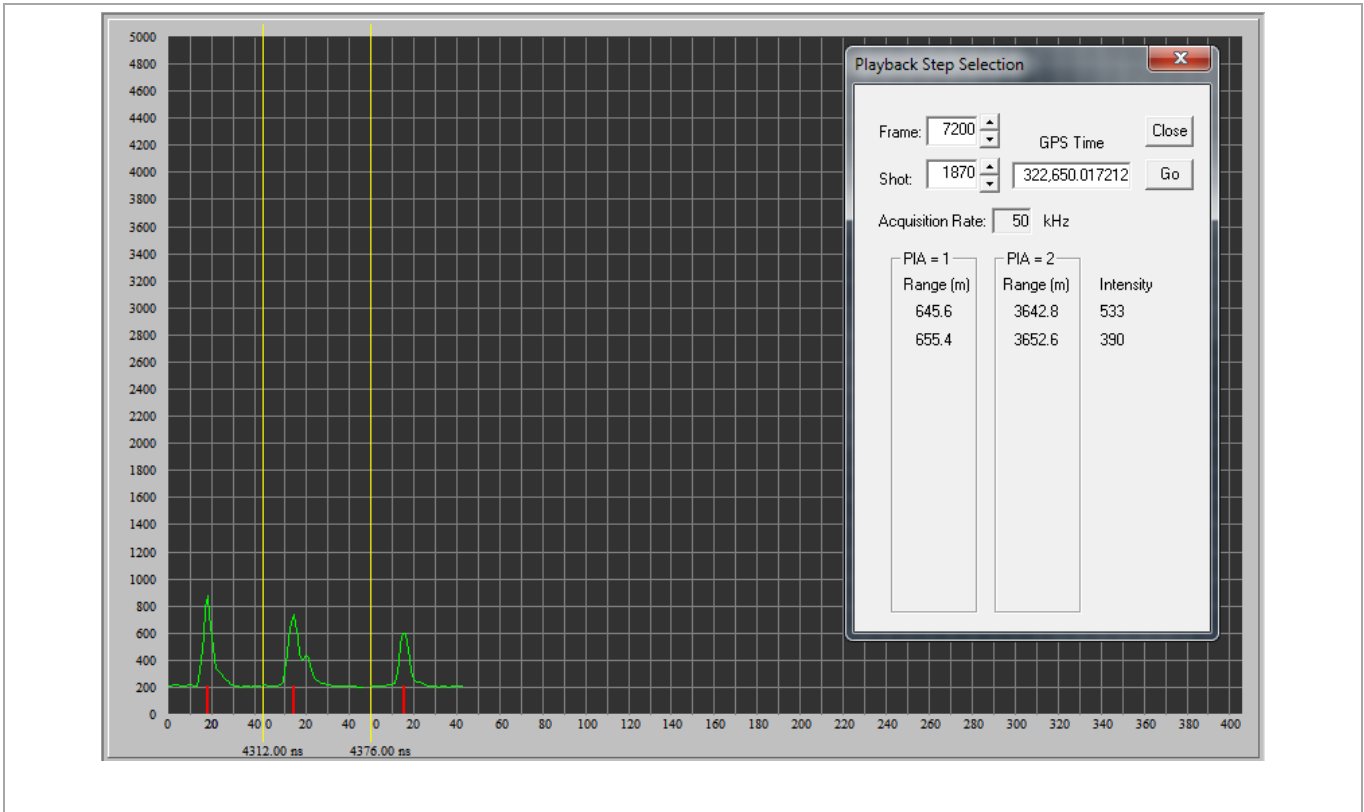
12 IWD PERFORMANCE

12.1 Waveform Returns

AGL (m)	Chan.	Chan. PRF (kHz)	Scan Freq. (Hz)	Scan Half Angle (deg)	Decimation or Truncating Mode	Segment Mode	Return Threshold
450	3	225	52	15	Decimating	Single	50
800	3	100	52	15	Truncating	Single	75



600	3	50	30	25	Truncating	Multiple	50
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12.2 IWD sample interval

Item	Pass
IWD sample interval (1ns)	Checked