



AIRBORNE LASER TERRAIN MAPPER

(ALTM)

Performance Report

ALTM Gemini
Serial Number:
07sen201/07con201

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SUMMARY

System 07SEN201 – 07CON201 was flown on four different occasions for functionality and calibration. Data collection altitudes ranged from 1065m to 2900m AGL. All tests indicate that the system is operating within specification. Please note that this system was delivered in March and it had been agreed that the customer would operate the system for a period of time in which it would be ascertained as to whether or not it was meeting their expectations. The values in this report are representative of the test flights that occurred from Jan – March, in Toronto, and in June at the customer’s location. The data collected in June was collected by the customer and processed by Optech..

1 INTRODUCTION

The purpose of this ALTM System Acceptance Report is to confirm that Optech ALTM Gemini 07SEN201 – 07CON201 meets all specifications and customer requirements at the time of delivery. It demonstrates that elevation and horizontal accuracy performance is within specification; also that other system outputs including first, second, third and last pulse capture and intensity measurements are performing as they should.

2 SYSTEM SPECIFICATIONS

This certifies that Optech ALTM Gemini, bearing SN# 07SEN201 – 07CON201 complies with the specifications set forth in Table 1 below.

Table 1 ALTM Gemini system specifications

Specifications			
Serial numbers	Sensor Head 07SEN201 Control Rack 07CON201		
Operating altitude	150 – 4000 m nominal		
General Enhanced Accuracy Specifications	Laser Repetition Rate	Horizontal Accuracy (m 1 δ)	Vertical Accuracy (m 1 δ) AGL
	33 kHz 50 kHz	1/5500 x altitude	< 5 cm up to 500 m < 10 cm up to 1 km < 15 cm up to 2 km < 20 cm up to 3 km < 25 cm up to 4 km
	70 kHz	1/5500 x altitude	< 5 cm up to 500 m < 10 cm up to 1 km < 15 cm up to 2 km
	100 kHz	1/5500 x altitude	< 10 cm up to 500 m < 15 cm up to 1 km < 20 cm up to 2 km
	125 kHz	1/5500 x altitude	< 10 cm up to 500 m < 15 cm up to 1 km
	143 kHz	1/5500 x altitude	< 15 cm up to 500 m < 20 cm up to 1 km
	167 kHz	1/5500 x altitude	< 35 cm @ 750 m
Range capture	Up to 4 range measurements for each pulse including last		
Intensity capture	12 bit dynamic range for each measurement		
Scan frequency	Variable; maximum 70 Hz		
Scan angle	Variable from 0 to $\pm 25^\circ$, in increments of $\pm 1^\circ$		
Scanner Product	Scan Angle x Scan Frequency ≤ 1000		
Roll compensation	5 Hz update rate (Scan angle + Roll Comp. Angle = FOV, i.e. $\pm 25^\circ$ allows $\pm 5^\circ$ compensation)		
Swath width	Variable; 0 to 0.93 x altitude m		
Position Orientation System	Applanix – Optech custom POS including internal 12 channel dual frequency 10 Hz GPS receiver		
Laser repetition rate	33 kHz (maximum AGL 4.0 km) 50 kHz (maximum AGL 3.0 km) 70 kHz (maximum AGL 2.5 km) 100 kHz (maximum AGL 2.0 km) 125 kHz (maximum AGL 1.6 km) 142 kHz (maximum AGL 1.4 km) 166 kHz (maximum AGL 1.2 km)		
Data storage hard drive	Ruggedized removable hard drive, (10hr continuous log time @ 100 KHz)		
Beam divergence	Dual 0.3 mrad (1/e) and 0.8 mrad (1/e) *; 0.16 mrad optional		
Eye safe range	<i>See eye safety table</i>		
Laser classification	Class IV (FDA CFR 21)		
Power requirements	28 V (continuous), 45 A (maximum)		
Operating temperature	Control rack: 10 to 35° C Sensor head: -10 to 35° C (assuming the use of thermal jacket)		
Storage Temperature	Control Rack: - 10 ° to 50° C Sensor Head: 0 ° to 50° C		
Humidity	0 – 95% non-condensing		

Control Rack Measurements	653mm x 591mm x 485mm, 55kg
Sensor Head Measurements	298mm x 249mm x 437mm, 23kg

*** Operational altitude calculated depending on eye safe table.**

Notes:

* To meet its stated accuracy, the ALTM 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 the receiver) throughout the survey
- Elevation of the satellites is above 15°
- Geometry of the satellites is good (i.e. PDOP < 4)
- Aircraft stays within 30 km of the GPS base station.

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

** Eye safe limits depend on beam divergence, scanner settings and viewing conditions. The system provides four user programmable settings: 80 m – wide divergence, unaided viewing; 400 m – wide aided and narrow divergence unaided viewing; 600 m – narrow profiling unaided and 1500 m – narrow divergence, aided viewing.

Default Eye Safety Settings for Serial # 07SEN201

0 – eye safety off

100 m – unaided, wide divergence

450 m – unaided, narrow divergence

600 m – unaided, profiling, narrow divergence / aided, wide divergence

2400 m – aided, narrow divergence (10 shot)

Row	Default Range	Scan Product	Product Flag	Divergence	Message
0	0	NA	NA	NA	(153) Eye safety Disabled
1	100	NA	NA	Narrow	(152) Invalid Beam
2	100	600	< product	Wide	(151) Scan too slow
3	100	600	> product	Wide	(155) Safe unaided wide
4	450	300	< product	Narrow	(151) Scan too slow
5	450	300	> product	Narrow	(156) Safe unaided narrow
6	450	NA	NA	Wide	(155) Safe unaided wide
7	600	NA	NA	Narrow	(157) Safe unaided profile
8	600	600	< product	Wide	(155) Safe unaided wide
9	600	600	> product	Wide	(160) Safe Aided Wide
10	2400	NA	NA	Wide	(160) Safe Aided Wide
11	2400	300	< product	Narrow	(151) Scan too slow
12	2400	300	> product	Narrow	(159) Safe aided

Allowed overlap of 3 pulse as per eye safe range spreadsheet for determining scan product.

3 INITIAL AND FINAL CALIBRATION PARAMETERS

3.1 Final Calibration Parameters

Based on the results presented below, the final system calibration parameters for ALTM Gemini, 07SEN201 – 07CON201 are listed in Appendix D. The final field calibration values were used to process all calibration flights used in generating the final statistics listed in Tables 4 and 5.

This report outlines the results obtained from calibration flights performed at Optech Inc. & Aerometric. Flights performed at Aerometric calibration site. The results of these flights have been used for the calibration of the system. Flights that were out of Optech calibration parameters were processed but may no have been used in the final derivation of the calibration numbers.

Table 2 *Lab and Field Calibration Numbers.*

Parameter	Initial Lab Calibration Values	Final Optech Calibration Values
ALTM ID	07SEN201 – 07CON201	07SEN201 – 07CON201
ALTM Type	Gemini	Gemini
TIM – First Pulse Offset		
33 kHz Pulse Offset (m)	-2.640610	-2.827610
50 kHz Pulse Offset (m)	-2.589149	-2.761149
70 kHz Pulse Offset (m)	-2.729149	-2.752149
100 kHz Pulse Offset (m)	-2.566523	-2.733523
125 kHz Pulse Offset (m)	-2.473697	-2.704697
142 kHz Pulse Offset (m)	-2.566465	-2.696465
166 kHz Pulse Offset (m)	-2.563554	-2.785554
TIM – Second Pulse Offset		
33 kHz Pulse Offset (m)	-2.784902	-2.924902
50 kHz Pulse Offset (m)	-2.733442	-2.828442
70 kHz Pulse Offset (m)	-2.865250	-2.830250
100 kHz Pulse Offset (m)	-2.710816	-2.840816
125 kHz Pulse Offset (m)	-2.617989	-2.812989
142 kHz Pulse Offset (m)	-2.710758	-2.790758
166 kHz Pulse Offset (m)	-2.707846	-2.867856
TIM – Third Pulse Offset		
33 kHz Pulse Offset (m)	-2.808945	-2.953945
50 kHz Pulse Offset (m)	-2.757484	-2.882484
70 kHz Pulse Offset (m)	-2.889293	-2.869293
100 kHz Pulse Offset (m)	-2.734858	-2.874858
125 kHz Pulse Offset (m)	-2.642031	-2.842031
142 kHz Pulse Offset (m)	-2.734800	-2.844800
166 kHz Pulse Offset (m)	-2.731889	-2.931889
TIM – Last Pulse Offset		

33 kHz Pulse Offset (m)	-5.131057	-5.296057
50 kHz Pulse Offset (m)	-5.079596	-5.228596
70 kHz Pulse Offset (m)	-5.211404	-5.219404
100 kHz Pulse Offset (m)	-5.056970	-5.209970
125 kHz Pulse Offset (m)	-4.964143	-5.173143
142 kHz Pulse Offset (m)	-5.056912	-5.166912
166 kHz Pulse Offset (m)	-5.054001	-5.246001
Cross-flight Scanner		
Offset (degrees)	0.0008	0.0008
Scale (no units)	1.0199	1.02135
Lag (msec)	0.000012	0.000012
IMU Corrections (Narrow Beam Divergence)		
Pitch	0.000	-0.0072
Roll	0.000	-0.0250
Heading	0.000	-0.020

Table 3 *Daily calibration numbers*

5156, 07SEN201/07CON201			
Julian day	08108	08208	Average
GPS Quality	Level 1	Level 1	
Pitch	-0.0093	-0.005	- 0.0072
Roll	- 0.0236	- 0.0263	- 0.0250
Scale	1.02139	1.02130	1.02135
Lag Correction	0.000012	0.000012	0.000012

3.2 Horizontal Accuracy Analysis

The horizontal accuracy of the system was confirmed statistically through a series of two independent flights over Optech's calibration building in Newmarket, Ontario (Table 4).

Profiles were used to establish the X component of the accuracy while edge scans were used to establish the Y component. Results indicate that system 07SEN201 - 07CON201 has a demonstrated horizontal accuracy better than $\pm 1/5500 \times \text{AGL m}$ using the 0.30 mrad divergence option and therefore surpasses the minimum XY specification (Table 5).

Table 4 *Horizontal analysis using final calibration numbers.*

Flight	Flight Altitude (m AGL)	Attribute	Calibration Number	Laser Freq. (kHz)	Pulse	Mean Difference (m)	Standard Deviation (m)	RMS (m)	Sample Size (# of Points)	Accuracy (m 1 δ)	Specification (m 1 δ)
08108	1100m	Pitch	-0.0072	70	middle	-0.024	0.159	0.161	7	± 0.158	± 0.200
	1100m	Roll	-0.0250	70	middle	-0.116	0.082	0.139	526	± 0.145	± 0.200
08208	1105m	Pitch	-0.0072	70	middle	-0.011	0.173	0.173	8	± 0.174	± 0.201
	1105m	Roll	-0.0250	70	middle	-0.087	0.075	0.117	780	± 0.187	± 0.201

3.3 Absolute Vertical Accuracy Analysis

The vertical accuracy of the system was confirmed using a hard, flat surface with unobstructed ground control points (Figure 1). Two testing sites were used to validate vertical accuracy - 2047 points surveyed on the Oshawa Airport runway.

Data over the runways were collected from altitudes of about 1065m to 1075m, agl. Laser points within a 1.00 m radius of ground control points were differenced to quantify the vertical accuracy of the system. Last pulse returns were used in the analysis. Results indicate that system 07SEN201 - 07CON201 demonstrates vertical accuracy equal to or better than the elevation specification using 33, 50, 70, & 100 PRF (Table 5).

Table 6 illustrates flights conducted by customer which include Multipulse vertical statistics. This has been included at the request of the customer. It is noted that several strips of the customer's data contains results that were based on operations whereby the system was subject to blind zones and altitudes outside of the system capabilities. These have been highlighted.

Table 5 Vertical analysis using final calibration values.

Flight	Flight Altitude (m AGL)	Laser Freq. (kHz)	Pulse	Mean Difference (m)	Stdev. (m)	RMS (m)	Sample Size (# of Points)	FOV (+/- Deg)	Accuracy (m 1 σ)
08108	1075m	33kHz	Last	-0.078	0.081	0.113	258	25	± 0.090
08108	1075m	33kHz	Last	-0.005	0.078	0.078	178	25	± 0.032
08108	1075m	50kHz	Last	-0.098	0.059	0.114	375	25	± 0.100
08108	1075m	50kHz	Last	-0.066	0.060	0.089	329	25	± 0.069
08108	1070m	70kHz	Last	-0.059	0.066	0.088	563	25	± 0.065
08108	1070m	70kHz	Last	-0.088	0.073	0.114	441	25	± 0.093
08108	1065m	100kHz	Last	-0.074	0.073	0.104	725	25	± 0.096
08108	1065m	100kHz	Last	-0.080	0.071	0.107	548	25	± 0.098
08208	1070m	70kHz	Last	-0.011	0.062	0.063	432	25	± 0.033
08208	1070m	70kHz	Last	-0.064	0.052	0.083	557	25	± 0.074
08208	1065m	100kHz	Last	-0.030	0.065	0.071	555	25	± 0.050
08208	1065m	100kHz	Last	-0.061	0.062	0.087	744	25	± 0.084
08208	1065m	100kHz	Last	-0.057	0.054	0.079	548	25	± 0.075
08208	1065m	100kHz	Last	-0.073	0.056	0.095	719	25	± 0.091

Table 6 Vertical Analysis using optimized calibration values

Flight	Flight Altitude (m AGL)	Roll Value	Laser Freq. (kHz)	Pulse	Mean Difference (m)	Stdev. (m)	RMS (m)	Sample Size (# of Points)	FOV (+/- Deg)	Accuracy (m 1 σ)
17308	2081m	-0.003	33kHz	Last	0.030	0.023	0.038	39	15	± 0.040
17308	3625m	0.003	33kHz	Last	-0.017	0.047	0.050	26	25	± 0.047
17308	3625m	0.003	33kHz	Last	-0.015	0.121	0.122	33	25	± 0.050
17308	2081m	-0.003	50kHz	Last	-0.019	0.034	0.039	64	15	± 0.032
17308	2675m	0.003	50kHz	Last	-0.055	0.067	0.087	69	25	± 0.057
17308	2119m	-0.0075	70kHz	Last	-0.116	0.090	0.147	113	20	± 0.147
17308	1810m	-0.0075	70kHz	Last	-0.047	0.133	0.141	80	25	± 0.081
17308	1175m	-0.0075	100kHz	Last	-0.015	0.100	0.101	114	25	± 0.081
17308	1175m	-0.0075	100kHz	Last	0.001	0.117	0.117	129	25	± 0.121
17308	2074m	-0.0075	100kHz	Last	-0.165	0.060	0.175	139	15	± 0.193
17308	1567m	-0.0075	125kHz	Last	-0.011	0.083	0.084	167	20	± 0.080
17308	1360m	-0.0075	142kHz	Last	-0.047	0.139	0.147	174	20	± 0.145

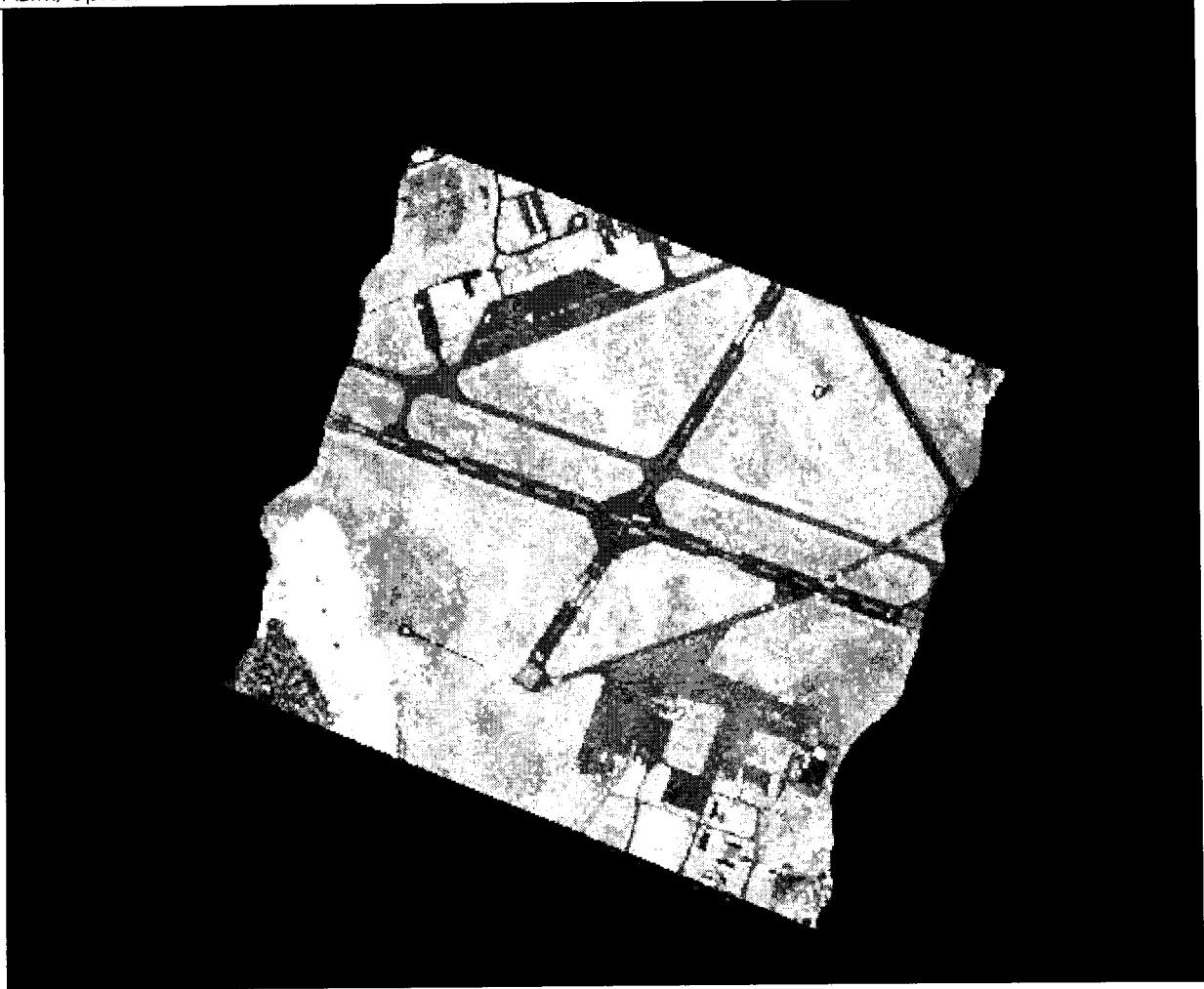


Figure 1 Intensity image of Oshawa Airport, Oshawa, Canada. Data collected at ~1100 m agl.

The intensity image was inspected to ensure that “banding” of the image due to the recording of different intensities from forward and backward scans was within specification. This test ensures that the alignment of the lidar receiver is optimized.

Table 6 Intensity Banding with flying height & scanner parameters.

Flight	Aircraft Height (agl)	PRF (kHz)	% (n-m)/n
08108	1000m	100kHz MP	2.66%
08208	1000m	100kHz MP	6.75%
08208	1000m	70kHz MP	4.67%

3.4 Altitude Dependent Ranging Capabilities

Tests performed over the runway revealed some average dropout rates that were above expected values, whereby dropouts are a function of the lack of a return signal for the outgoing pulse (Table 8). Results below are from flights 08108 and 08208 over the runway control area. Expected average dropout rates are <10 %, assuming there are no water bodies in the sample area and little atmospheric interference.

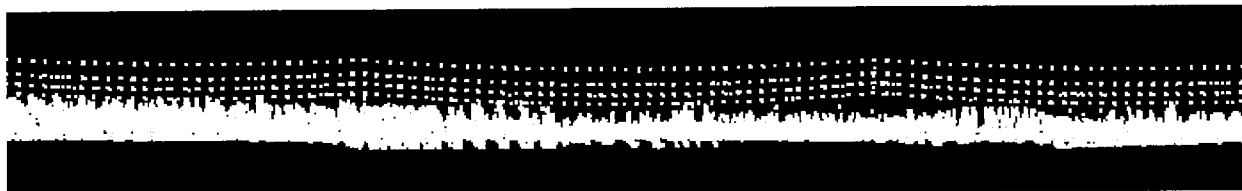
Table 7 *ALTM dropout rates given varying altitudes.*

Julian Day	Aircraft Height (agl)	PRF (kHz)	Dropouts (%)
08108	1000m	33kHz	0.21%
08108	1000m	50kHz	0.19%
08108	1000m	70kHz	0.10%
08108	1000m	100kHz	0.05%
08208	1000m	70kHz	0.06%
08208	1000m	100kHz	0.21%

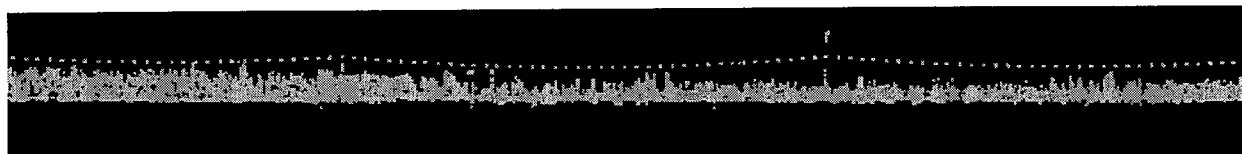
3.5 First / Last Pulse Feature Discrimination

The ALTM Gemini simultaneously records the first and last returns of a given pulse. To test this feature data was collected over a power wire corridor on Julian Day 14307. The processed data confirmed that the system is capable of collecting ground and wire hits from a single outgoing pulse. These tests indicate that this feature is functioning correctly.

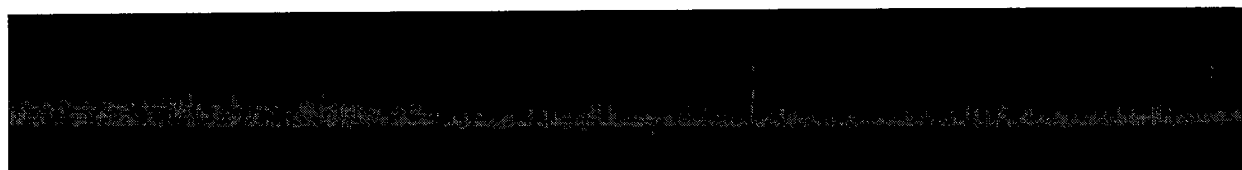
First



Second



Third



Last



4 APPENDIX A:

4.1 GPS Eccentricity Values

The following measurements are valid only for aircraft C-GAWS when using the Novatel aircraft antenna. Note: The “User to GPS Antenna” offsets were calculated by summing the internal “User to Reference Point” measurements (determined at Optech) with the surveyed relative position of the GPS airborne antenna to the sensor head (i.e. “Reference Point to GPS Antenna”).

Reference Point to GPS Antenna	
X	0.811 m
Y	-0.446 m
Z	-1.446 m

User (Scanner Mirror) to GPS Antenna (POS/AV)	
X	0.862 m
Y	-0.416 m
Z	-0.953 m

4.2 Sensor Head Constants

The following measurements were calculated in the lab at Optech and will remain constant.

User Frame to IMU Misalignment (POS/AV)	
X	0.006
Y	-0.015
Z	-0.025

User to IMU Lever Arm (POS/AV)	
X	-0.090 m
Y	-0.008 m
Z	-0.096 m

User to Reference Point	
X	-0.051 m
Y	-0.030 m
Z	-0.488 m

5 APPENDIX B:

5.1 IP Addresses

Details on installation can be found in the accompanying documentation (NG_POS.doc).

IP Addresses	
POS version	4.0 (TCP)
Laptop IP address	192.9.202.99
Laptop Subnet Mask	255.255.255.0
POS IP Address	192.9.202.40

6 APPENDIX C:

6.1 Base Station GPS Antenna

Monument Description:		
Date (M/D/Y): June 15, 2008	GPS Receiver Type: Novatel Antenna Type: Novatel	Epoch Interval: 1Hz Elevation Mask: 0 degrees Observation Type: Static
Observation Coordinate:		
Station1: Buttonville	N 43 51 28.59620 W -79 22 10.29498 H 165.913	
Station2: Optech	N 43 46 45.23396 W -79 29 14.51642 H 173.967	

7 APPENDIX D:

7.1 Calibration File

Narrow Beam Divergence

[CALIBRATION]

```

AltmSerialNo= 07SEN201
ImuType= LN200A1
ImuRate= 200
ScannerScale=1.021350
ScannerOffset=0.000800
IMURoll=-0.02500
IMUPitch=-0.007200
IMUHeading=-0.020000
UserTolmuEx=0.006000
UserTolmuEy=-0.015000
UserTolmuEz=-0.025000
UserTolmuDx=-0.090000
UserTolmuDy=-0.008000
UserTolmuDz=-0.096000
UserToRefDx=-0.051000
UserToRefDy=-0.030000
UserToRefDz=-0.488000
TimeLag=0.000012
IntensityGainFor3070=20.000000
UseLeftDroopCorrection=25.000000
UseRightDroopCorrection=10.000000
Temperature=15.000000
Pressure=1013.250000

```

[INTENSITY]

```

IntensityTable33Khz=R:\ALTM\5156\AVG_hardware_cfg_June2008\33k Intensity Table.txt
IntensityTable50Khz=R:\ALTM\5156\AVG_hardware_cfg_June2008\50k Intensity Table.txt
IntensityTable70Khz=R:\ALTM\5156\AVG_hardware_cfg_June2008\70k Intensity Table.txt
IntensityTable100Khz=R:\ALTM\5156\AVG_hardware_cfg_June2008\100k Intensity Table.txt
IntensityTable125Khz=R:\ALTM\5156\AVG_hardware_cfg_June2008\125k Intensity Table.txt
IntensityTable142Khz=R:\ALTM\5156\AVG_hardware_cfg_June2008\142k Intensity Table.txt
IntensityTable166Khz=R:\ALTM\5156\AVG_hardware_cfg_June2008\166k Intensity Table.txt

```

[RangeOffset33KHz]

```

LastPulseRange=-5.296057
FirstPulseRange=-2.827610
SecondPulseRange=-2.924902
ThirdPulseRange=-2.953945

```

[RangeOffset50KHz]

```

LastPulseRange=-5.228596
FirstPulseRange=-2.761149
SecondPulseRange=-2.828442
ThirdPulseRange=-2.882484

```

[RangeOffset70KHz]

```

LastPulseRange=-5.219404
FirstPulseRange=-2.752149
SecondPulseRange=-2.830250
ThirdPulseRange=-2.869293

```

[RangeOffset100KHz]

```

LastPulseRange=-5.209970
FirstPulseRange=-2.733523
SecondPulseRange=-2.840816
ThirdPulseRange=-2.874858

```

[RangeOffset125KHz]

```

LastPulseRange=-5.173143
FirstPulseRange=-2.704697
SecondPulseRange=-2.812989
ThirdPulseRange=-2.842031

```

[RangeOffset142KHz]

```

LastPulseRange=-5.166912
FirstPulseRange=-2.696465
SecondPulseRange=-2.790758
ThirdPulseRange=-2.844800

```

[RangeOffset166KHz]

```

LastPulseRange=-5.246001
FirstPulseRange=-2.785554
SecondPulseRange=-2.867856
ThirdPulseRange=-2.931889

```


7.2 Intensity table

33kHz	50kHz	70kHz	100kHz	840 859 0.12
1 1 -0.32	0 0 -0.40	0 0 -0.50	0 0 -0.59	860 879 0.11
2 2 -0.27	1 1 -0.32	1 1 -0.31	1 1 -0.52	880 999 0.12
3 3 -0.23	2 2 -0.25	2 2 -0.27	2 2 -0.42	1000 1059 0.13
4 4 -0.19	3 4 -0.20	3 3 -0.25	3 3 -0.32	1060 1079 0.12
5 6 -0.15	5 5 -0.18	4 4 -0.24	4 4 -0.26	1080 1139 0.13
7 9 -0.12	6 7 -0.20	5 5 -0.22	5 5 -0.23	1140 1379 0.14
10 13 -0.09	8 8 -0.18	6 6 -0.16	6 7 -0.20	1380 1399 0.13
14 19 -0.07	9 9 -0.16	7 8 -0.15	8 10 -0.13	1400 1419 0.14
20 30 -0.05	10 10 -0.10	9 14 -0.12	11 11 -0.12	1420 1439 0.13
31 46 -0.03	11 11 -0.07	15 17 -0.08	12 13 -0.09	1440 1479 0.14
47 71 -0.02	12 14 -0.06	18 22 -0.07	14 14 -0.08	1480 1539 0.13
72 110 -0.01	15 15 -0.07	23 28 -0.06	15 15 -0.07	1540 1579 0.14
111 139 0	16 23 -0.06	29 39 -0.05	16 18 -0.06	1580 1599 0.13
140 140 0.02	24 32 -0.05	40 57 -0.04	19 20 -0.05	1600 1619 0.14
141 159 0	33 49 -0.04	58 76 -0.03	21 22 -0.04	1620 1639 0.13
160 160 0.02	50 62 -0.03	77 119 -0.02	23 24 -0.03	1640 1659 0.14
161 161 0	63 63 -0.02	120 121 -0.01	25 29 -0.02	1660 1679 0.13
162 179 0.01	64 64 -0.03	122 137 0	30 30 -0.01	1680 1739 0.14
180 180 0.02	65 65 -0.02	138 141 0.01	31 34 -0.01	1740 1759 0.13
181 199 0.01	66 67 -0.03	142 142 0	35 36 -0.01	1760 1779 0.14
200 200 0.03	68 91 -0.02	143 148 0.01	37 42 -0.01	1780 1839 0.13
201 211 0.01	92 92 -0.01	149 149 0	43 44 -0.01	1840 1859 0.14
212 219 0.02	93 93 -0.02	150 156 0.01	45 49 -0.01	1860 1899 0.13
220 259 0.03	94 95 -0.01	157 157 0	50 50 -0.01	1900 1919 0.14
260 499 0.04	96 96 -0.02	158 170 0.01	51 52 -0.01	1920 1939 0.13
500 759 0.05	97 99 -0.01	171 171 0.02	53 58 -0.01	1940 1959 0.14
760 1079 0.06	100 100 -0.02	172 173 0.01	59 60 -0.01	1960 2219 0.13
1080 1099 0.07	101 102 -0.01	174 174 0.02	61 67 -0.01	2220 2239 0.14
1100 1139 0.06	103 103 -0.02	175 176 0.01	68 79 -0.01	2240 2379 0.13
1140 1739 0.07	104 127 -0.01	177 179 0.02	80 89 -0.01	2380 2399 0.14
1740 2479 0.08	128 128 0	180 181 0.01	90 97 -0.01	2400 2419 0.13
2480 2879 0.09	129 135 -0.01	182 183 0.02	98 102 -0.01	2420 2439 0.14
2880 2919 0.1	136 139 0	184 185 0.01	103 110 0	2440 2479 0.13
2920 2939 0.09	140 140 0.01	186 207 0.02	111 112 -0.01	2480 2619 0.14
2940 3319 0.1	141 141 -0.01	208 219 0.01	113 120 0	2620 2639 0.15
3320 3339 0.11	142 144 0	220 299 0.02	121 121 -0.01	2640 2659 0.14
3340 3359 0.1	145 145 -0.01	300 379 0.03	122 139 0	2660 2859 0.15
3360 3939 0.11	146 159 0	380 399 0.04	140 140 -0.01	2860 3059 0.16
3940 4579 0.12	160 160 0.01	400 479 0.03	141 159 0	3060 3259 0.17
4580 5099 0.13	161 179 0	480 619 0.04	160 160 -0.02	3260 3539 0.18
5100 5100 0.14	180 180 0.01	620 699 0.05	161 164 0	3540 3819 0.19
	181 183 0	700 979 0.06	165 168 0.01	3820 3839 0.2
	184 185 0.01	980 1139 0.07	169 175 0.02	3840 3859 0.19
	186 189 0	1140 1179 0.06	176 179 0.03	3860 4019 0.2
	190 199 0.01	1180 2119 0.07	180 180 -0.02	4020 4039 0.21
	200 200 0.02	2120 2579 0.08	181 181 0.04	4040 4219 0.2
	201 211 0.01	2580 2979 0.09	182 183 0.03	4220 4439 0.21
	212 219 0	2980 3319 0.1	184 198 0.04	4440 5100 0.22
	220 279 0.02	3320 3779 0.11	199 199 0.03	
	280 499 0.03	3780 4379 0.12	200 200 -0.02	
	500 699 0.04	4380 5100 0.13	201 201 0.02	
	700 959 0.05		202 202 0.03	
	960 1799 0.06		203 203 -0.01	
	1800 2599 0.07		204 219 0.04	
	2600 2959 0.08		220 239 -0.01	
	2960 3359 0.09		240 319 0.01	
	3360 3699 0.1		320 339 0.02	
	3700 4199 0.11		340 359 0.04	
	4200 4219 0.12		360 379 0.06	
	4220 4239 0.11		380 459 0.07	
	4240 4959 0.12		460 519 0.08	
	4960 5100 0.13		520 579 0.09	
			580 599 0.1	
			600 619 0.09	
			620 639 0.1	
			640 839 0.11	

	3260 3279 0.11		
	3280 3339 0.12		
125kHz	3340 3359 0.11	142kHz	166kHz
0 0 -0.60	3360 3519 0.12	0 0 -0.57	0 0 -0.75
1 1 -0.54	3520 3559 0.13	1 1 -0.46	1 1 -0.68
2 2 -0.43	3560 3579 0.12	2 2 -0.37	2 2 -0.55
3 3 -0.35	3580 3619 0.13	3 3 -0.3	3 3 -0.45
4 4 -0.30	3620 3639 0.14	4 4 -0.26	4 4 -0.36
5 5 -0.25	3640 3679 0.13	5 5 -0.23	5 5 -0.30
6 6 -0.23	3680 3739 0.14	6 6 -0.2	6 6 -0.26
7 7 -0.22	3740 3759 0.15	7 7 -0.19	7 7 -0.24
8 8 -0.21	3760 3779 0.14	8 8 -0.17	8 8 -0.22
9 10 -0.2	3780 3879 0.15	9 9 -0.16	9 9 -0.21
11 11 -0.19	3880 4239 0.16	10 11 -0.15	10 10 -0.2
12 12 -0.18	4240 5100 0.17	12 12 -0.14	11 11 -0.19
13 13 -0.17		13 14 -0.13	12 15 -0.18
14 14 -0.16		15 17 -0.12	16 16 -0.17
15 15 -0.15		18 20 -0.11	17 17 -0.16
16 17 -0.14		21 21 -0.1	18 18 -0.15
18 18 -0.13		22 24 -0.09	19 19 -0.14
19 19 -0.12		25 41 -0.08	20 20 -0.13
20 21 -0.11		42 45 -0.07	21 22 -0.12
22 22 -0.1		46 47 -0.06	23 26 -0.11
23 26 -0.11		48 51 -0.05	27 31 -0.1
27 37 -0.1		52 63 -0.04	32 38 -0.09
38 41 -0.09		64 84 -0.03	39 45 -0.08
42 45 -0.08		85 97 -0.02	46 53 -0.07
46 61 -0.07		98 113 -0.01	54 61 -0.06
62 75 -0.06		114 129 0	62 71 -0.05
76 77 -0.07		130 130 0.01	72 81 -0.04
78 79 -0.06		131 131 0	82 91 -0.03
80 82 -0.07		132 139 0.01	92 105 -0.02
83 84 -0.06		140 140 -0.02	106 119 -0.01
85 85 -0.05		141 151 0.01	120 120 0
86 90 -0.06		152 159 0.02	121 121 -0.01
91 94 -0.05		160 160 -0.04	122 137 0
95 97 -0.04		161 166 0.02	138 139 0.01
98 101 -0.03		167 167 0.03	140 140 -0.02
102 105 -0.02		168 168 0.02	141 150 0.01
106 109 -0.01		169 179 0.03	151 159 0.02
110 139 0		180 180 -0.04	160 160 -0.07
140 140 -0.03		181 191 0.03	161 172 0.02
141 159 0		192 195 0.04	173 179 0.03
160 160 -0.07		196 199 0.03	180 180 -0.07
161 179 0		200 200 -0.04	181 199 0.03
180 180 -0.07		201 202 0.02	200 200 -0.07
181 183 0		203 203 0.03	201 203 0.02
184 184 -0.01		204 219 0.01	204 219 0
185 199 0		220 239 -0.04	220 259 -0.07
200 200 -0.07		240 319 -0.03	260 299 -0.06
201 202 -0.01		320 359 -0.02	300 319 -0.05
203 203 -0.02		360 379 -0.03	320 339 -0.04
204 219 -0.04		380 419 -0.02	340 379 -0.03
220 259 -0.07		420 439 -0.01	380 479 -0.02
260 319 -0.06		440 459 0	480 559 -0.01
320 379 -0.05		460 499 0.01	560 639 0
380 419 -0.04		500 619 0.02	640 759 0.01
420 439 -0.02		620 819 0.03	760 819 0.02
440 499 -0.01		820 939 0.04	820 939 0.03
500 659 0		940 1079 0.05	940 1059 0.04
660 799 0.01		1080 1379 0.06	1060 1179 0.05
800 819 0.02		1380 1599 0.07	1180 1339 0.06
820 839 0.01		1600 1859 0.08	1340 1499 0.07
840 959 0.02		1860 2099 0.09	1500 1699 0.08
960 1239 0.03		2100 2339 0.1	1700 2039 0.09
1240 1299 0.04		2340 2579 0.11	2040 2339 0.1
1300 1339 0.05		2580 2779 0.12	2340 2619 0.11
1340 1759 0.06		2780 2959 0.13	2620 2739 0.12
1760 2099 0.05		2960 3099 0.14	2740 2839 0.13
2100 2359 0.06		3100 3219 0.15	2840 2939 0.14
2360 2479 0.07		3220 3359 0.16	2940 3059 0.15
2480 2559 0.08		3360 3559 0.17	3060 3179 0.16
2560 2659 0.09		3560 3799 0.18	3180 3499 0.17
2660 2679 0.1		3800 4079 0.19	3500 3819 0.18
2680 2699 0.09		4080 4099 0.2	3820 4679 0.19
2700 2939 0.1		4100 4139 0.19	4680 4979 0.2
2940 2959 0.11		4140 5099 0.2	4980 5019 0.21
2960 2979 0.1		5100 5100 0.19	5020 5039 0.2
2980 3159 0.11			5040 5100 0.21
3160 3179 0.12			
3180 3239 0.11			
3240 3259 0.12			