DEEPWATER USBL POSITIONING TRIAL
FOR
PHOENIX INTERNATIONAL, INC.

REVISION 0

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Contents

1.0 Introduction

This document summarizes the results of a deepwater USBL trial performed on behalf of Phoenix International Inc.

The equipment under test was a Sonardyne ‘Fusion’ USBL system equipped with a Type 8023 transceiver. The transponder used was a 4000m rated 7806 Mk4 directional ‘Compatt’. All equipment was supplied from Sonardyne, Inc. in Houston.

Sonardyne personnel on the trial were Dave Ross, Sonardyne’s Technical Manager based in Houston and Ralph Gall, Product Support Engineer also based in Houston.

The trial vessel was the USNS ‘Apache’, a vessel in the U.S. Navy’s Military Sealift Command. Mobilization commenced on Sunday 19th October in Key West, Florida.

Two other vendors provided systems and personnel for the trial, however this report is only concerned with the performance of the Sonardyne system. Sonardyne’s system was tested on 22nd October. Access to other vendor’s test results was not permitted.

To ensure a fair comparison, each vendor used the same set of vessel sensors. In this case a TSS MAHRS unit provided vessel heading and a TSS DMS2-05 provided pitch and roll data.

2.0 Trials Procedure

The trial involved executing the following set of tracking tasks in a water depth of approximately 3000m.

- Deploy transponder with floatation and track it to the seabed.
- Perform a calibration to determine the transceiver mounting offsets.
- Steam away from the transponder to establish a maximum slant range.
- Reposition over the transponder and assess the effect of vessel thrusters.
- Change to a lower reply frequency and move off location and reassess max range.
- Acoustically release the transponder and track to the surface.

Sonardyne's trial commenced at 07.30am on 22nd October 2003.

Prior to the trial, no sound velocity data from the site was available. A Phoenix owned velocity probe was deployed on site but the timed release on the unit failed to operate and the probe was lost. In the absence of velocity data, a best estimate was obtained by comparison between depth measurements from the transponder and ranges to the transponder when directly above. This estimate was further refined from the output of the calibration.

3.0 Results

3.1 Tracking During Deployment

The 7806 'Compatt' transponder was deployed with 3000m rated floatation and an anchor weight of approx 190lbs. The transponder was successfully tracked from a depth of approx 400m until it reached the seabed at 2825m. Tracking from a much shallower depth would normally have occurred however communication checks to the transponder prevented tracking prior to it reaching this depth.

The track of the transponder to the seabed is shown in Fig 1.

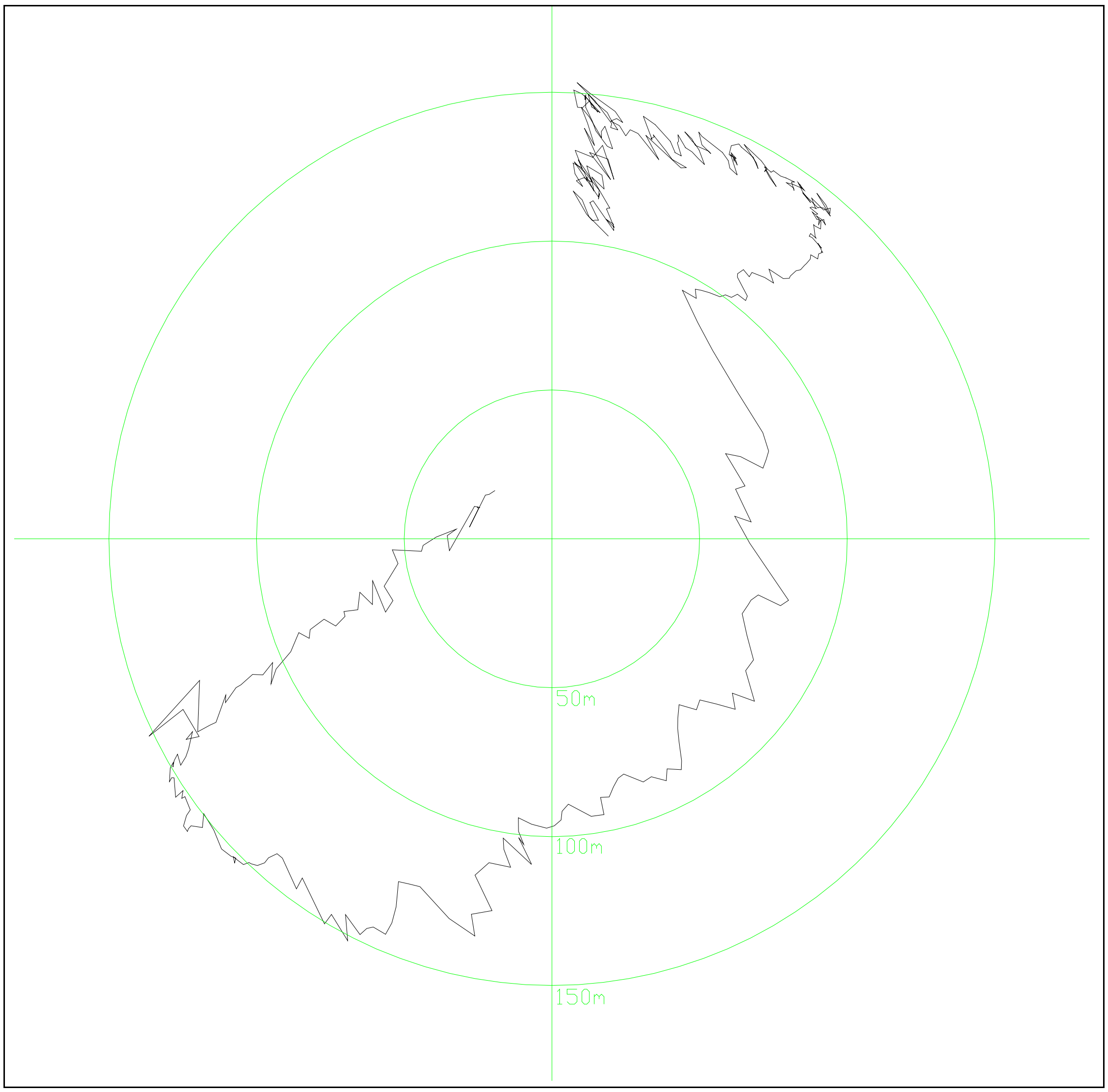

Fig 1. Track of Transponder to Seabed From Surface.

The initial depth estimate based on the observed range to the transponder was 2853m. This depth was not supported by data from the depth sensor fitted to the transponder that indicated a depth of 2816m. Even allowing for the tolerance in the depth sensor (+/- 8m) there was clearly an adjustment of sound velocity required. This was achieved during processing of the calibration data that established the best fit depth as 2825m and a mean speed of sound through the water column of 1516.2 m/s.

3.2 Calibration

The calibration routine recommended by Sonardyne is designed to very accurately determine the angular offsets between the transceiver head as mounted on the deployment pole and the attitude sensors tracking the vessel motion. These corrections allow absolute accuracies of +/- 0.3% of slant range to be achieved.

During the calibration procedure, tracking data is collected from the system as the vessel steams a regular pattern over and around the transponder location. The data collected is processed using Sonardyne’s CASIUS (Calibration of the Attitude Sensors In the USBL System) software. In addition to the mounting offsets, other outputs from CASIUS include accurate transponder position and sound velocity.

Difficulty was encountered during the calibration phase of the trial due to the lack of rigidity in the deployment pole and the effect on the pole of the surface currents that constantly exceeded 2 kts. The pole was an over-the-side design manufactured from a lightweight alloy that exhibited reasonably significant flexing whilst on deck in the stowed position. Once deployed, bracing fore and aft limited pole motion along the pitch axis but, as the tracking results show, motion across the vessel in the roll axis was very significant.

Vessel motion was accurately monitored during the trial using a TSS DMS2-05 VRU but it was clear that the benefit of using such an accurate motion sensor was limited due to the motion of the deployment pole.

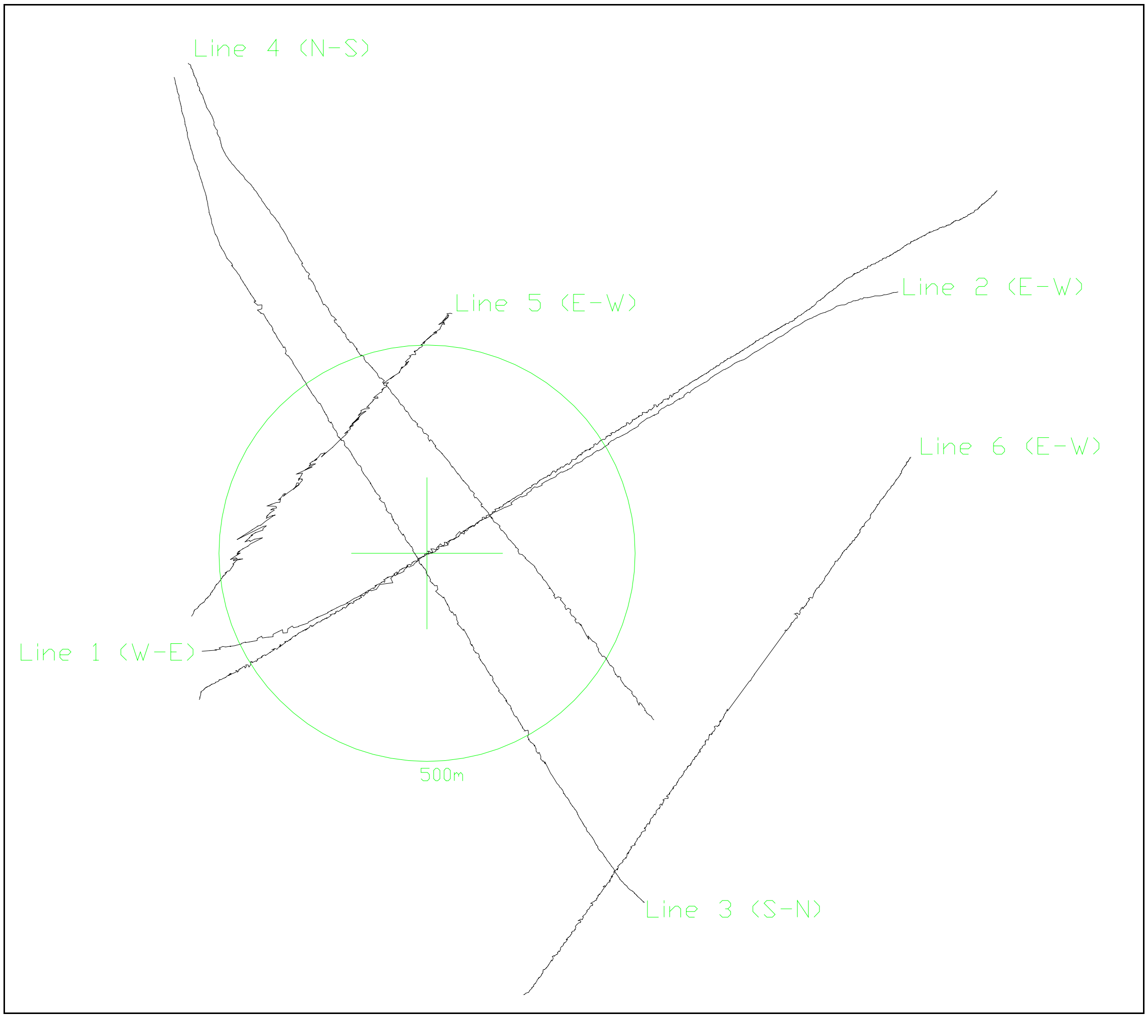

Fig 2. Vessel Track During Data Collection for Calibration.

Tracking of the transponder during the calibration phase was excellent during line 1 - with the current - and line 2 - into the current (See Fig 2.). Tracking during runs across the current (lines 3 & 4) was entirely unsatisfactory due to the motion of the pole. This motion was, at times, of such magnitude as to cause concern over whether the pole may break off. More data was collected during lines 5 and 6 but no data running across the current was of use in the calibration process.

In the end, data was collected from a total of 4 runs all along courses approximately parallel to the direction of the current. This data was processed using Sonardyne's CASIUS program and a co-ordinate for the transponder was produced. This co-ordinate turned out to be reasonably accurate despite the problems experienced during data collection.

The data set ultimately proved unsuitable to accurately determine the pitch, roll and alignment offsets as would normally be expected. This meant that position biases normally removed from the system by the CASIUS processing remained in the system during the latter tracking phases of the trial. This would have an effect on absolute accuracy of the tracking but did not impact the range testing performed subsequently.

3.3 Maximum Slant Range Test (24.472 KHz, Channel 9).

The first range test was performed with the transponder configured to reply on a channel approximately in the middle of the Medium Frequency (MF) band. The reply frequency used was Sonardyne Channel 9, 24.472Khz. Data was logged on the Fusion system to provide the track of the vessel from GPS as well as the position of the transponder obtained from the USBL system.

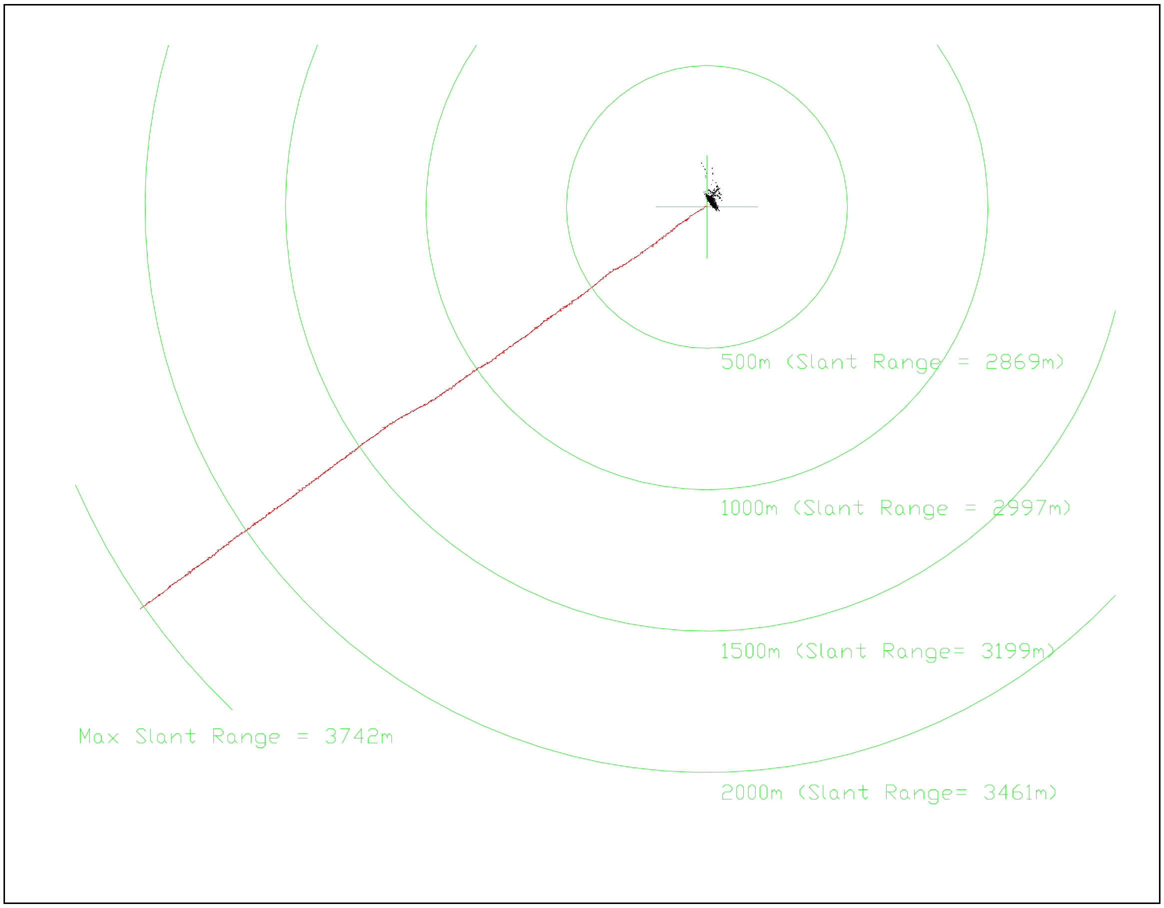

Fig 3. Vessel Track (Red) and Transponder Scatter Plot (Black) During 24.472KHz Range Test (North to Top of the Page).

On this test, a maximum slant range of 3742m was achieved.

The 7806 transponder is designed for use in deep water with a high source level of 202dB and an approximate –3dB beam-width of +/- 45º. Additionally, the all-digital type 8023 transceiver is optimized for tracking directly beneath it in a beam approximately +/- 50º. Given the sub-optimal geometry of the trial, the slant range achieved was about as expected.

The scatter plot of the transponder positions is shown close up in Fig 4.

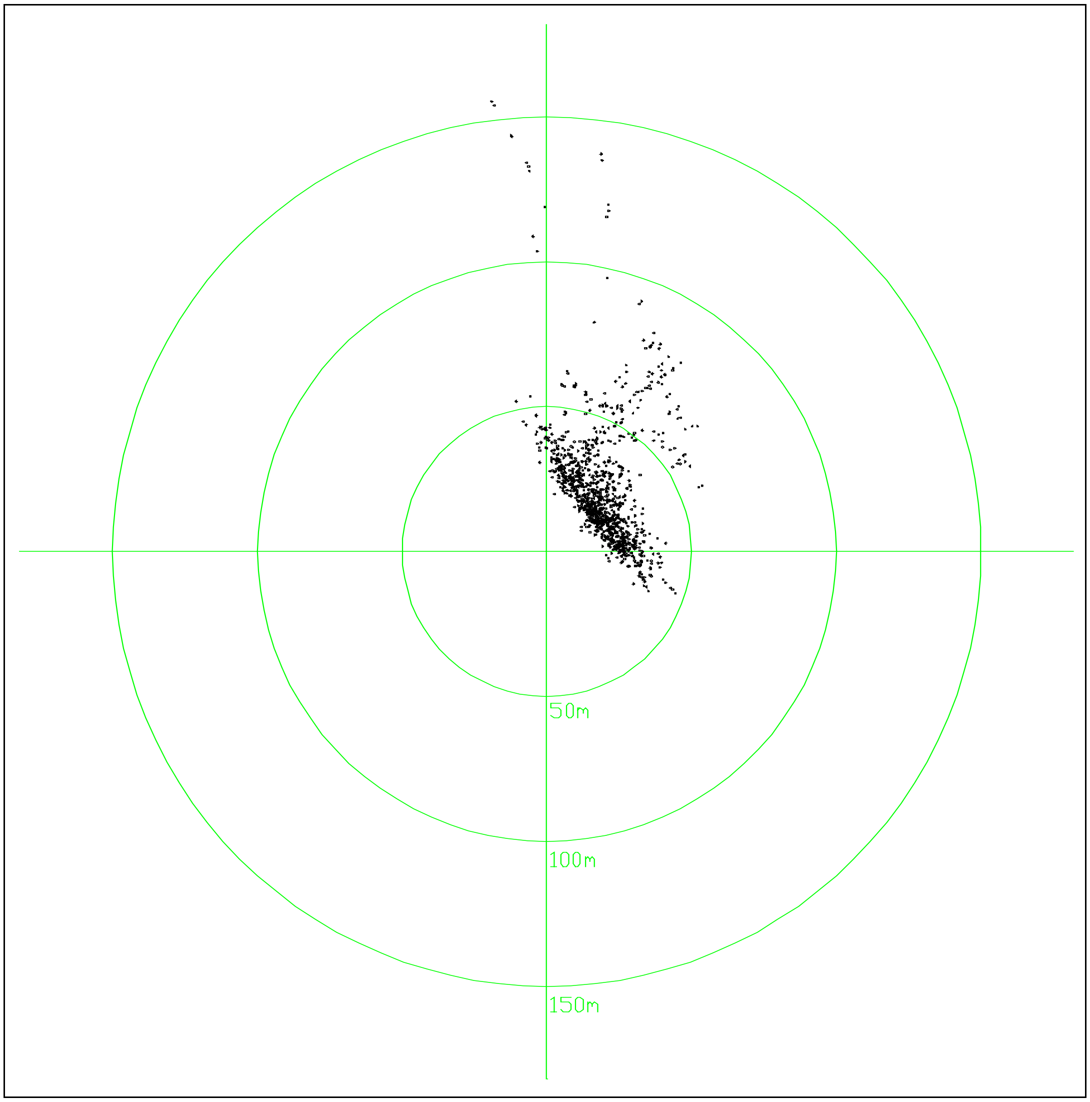

Fig 4. Transponder Scatter Plot During 24.472KHz Range Test.
(North to Top of the Page).

From the plot it is clear to see that the repeatability of the system in the pitch axis was excellent but the pole motion in the roll axis of the vessel resulted in smearing of the plotted positions across the course of the vessel (approx 216º).

Furthermore, the uncorrected bias in transceiver mounting along the vessel pitch axis (due to the poor CASIUS calibration result) resulted in a small shift of the mean position from the CASIUS co-ordinate in a direction astern of the vessel track. (The CASIUS position obtained for the transponder is at the center of the range rings in Fig 4).

3.4 Effect of Thrusters on Tracking

Following the first range test, the vessel returned to a position nearer to the transponder so that the effect of running vessel thrusters could be gauged. Tracking commenced from a horizontal range of just over 750m using the same Ch9 reply frequency as used on the first range test. The vessel then drifted across the area while turning it's heading using a tunnel thruster on the bow.

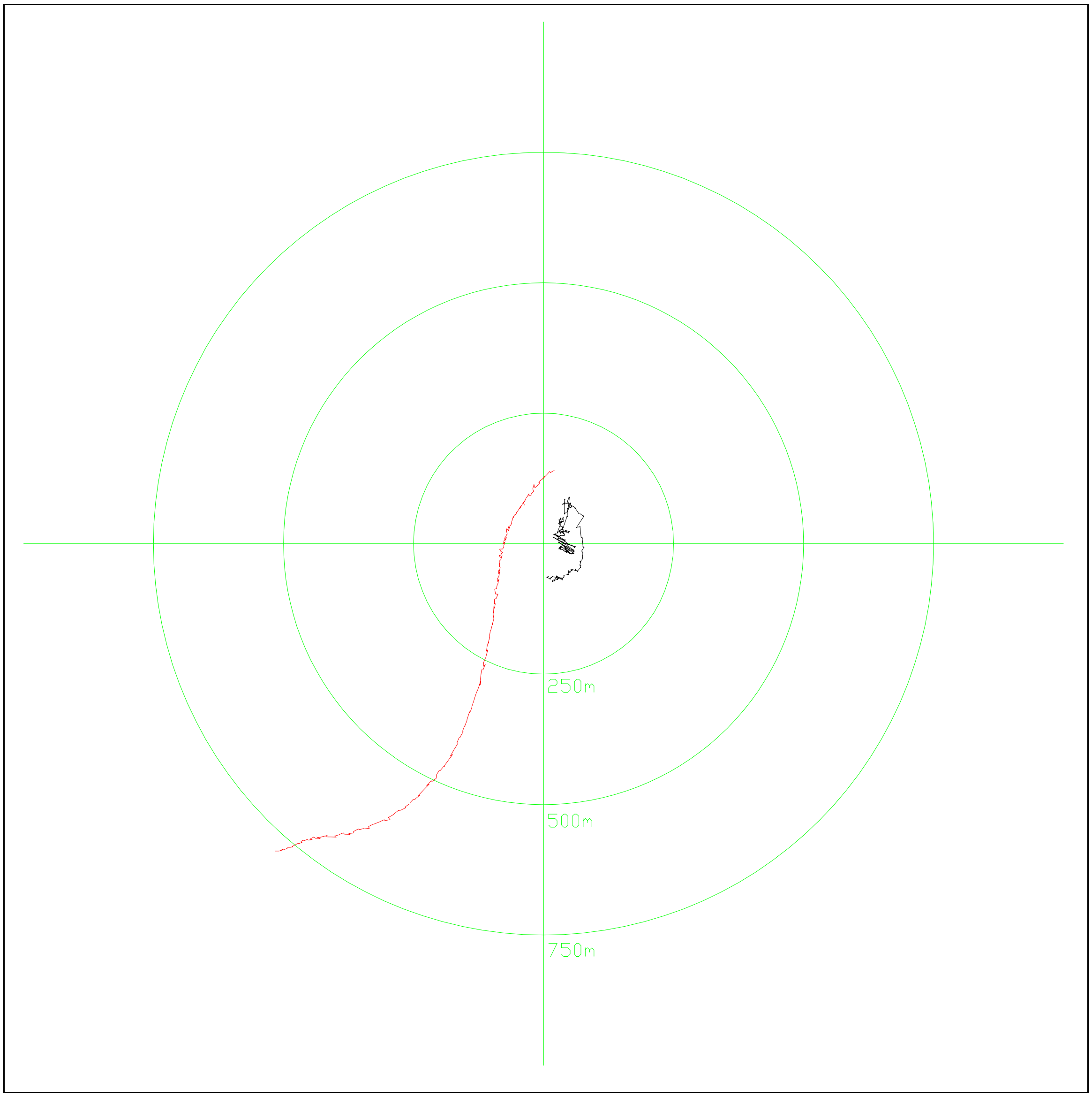

Fig 5. Vessel Track (in red) and Transponder Scatter Plot (in black) During Thruster Tests.

The scatter plot obtained is more clearly shown in Fig 6.

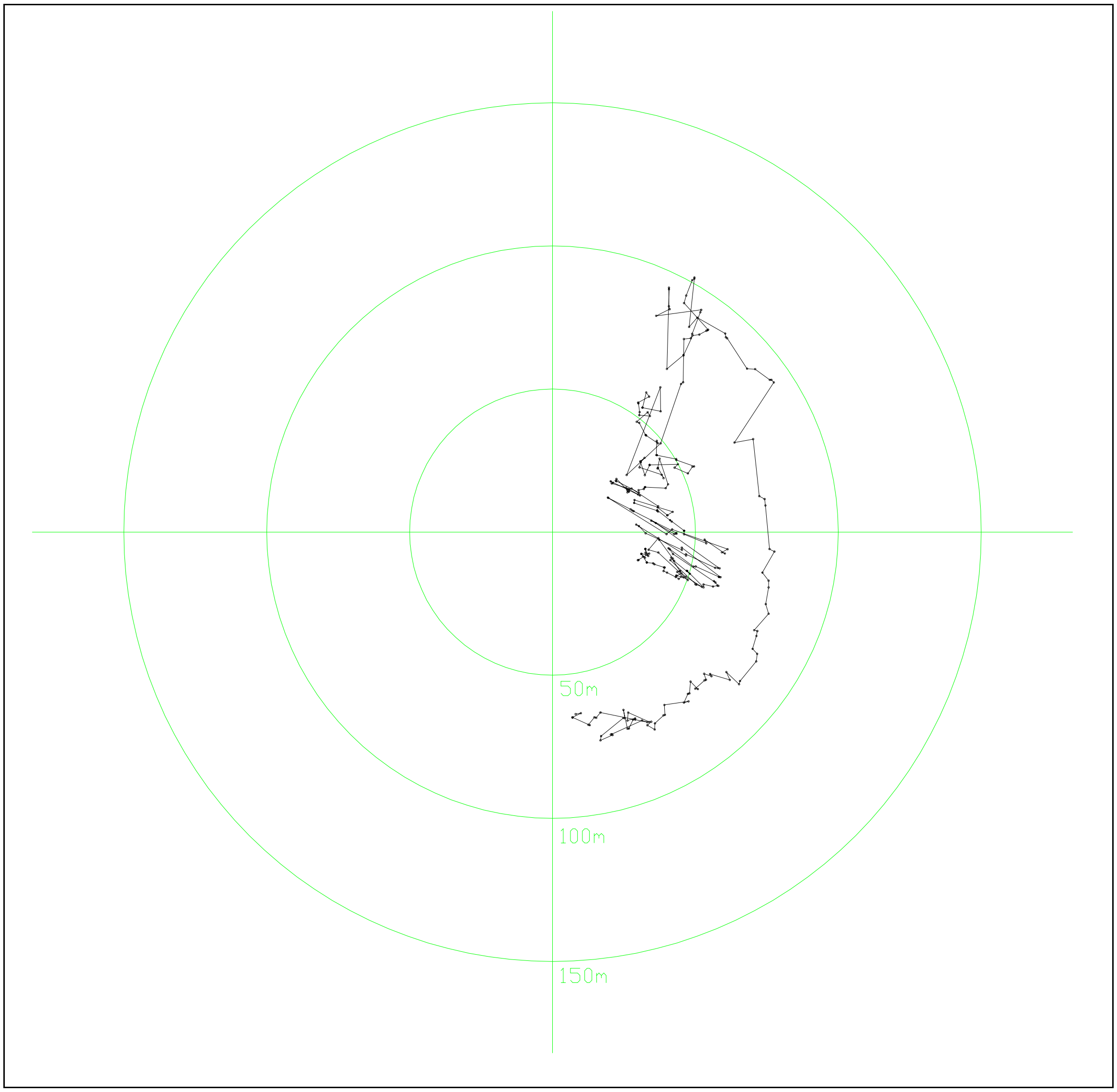

Fig 6. Transponder Scatter Plot During Thruster Tests.

The running of the thruster had no discernable effect on the ability of the system to track the target.

The clockwise track of the transponder shown in Fig 6 is due to the vessel turning to starboard during the test with an uncorrected bias in the mounting of the transceiver in the vessel's pitch axis.

Noise measurements were made during the test using the in-built spectrum analyzer feature in the Fusion system. Whilst this showed an increase in ambient in-channel noise of approximately 5dB (to 85dB Peak) when the thruster was running this was not enough of an increase to affect the tracking of the transponder.

3.5 Maximum Slant Range Test (19.230 KHz, Channel 1).

Upon completion of the thruster tests, the vessel moved off with the current on an approximate heading of 026º. This time the Compatt was acoustically reconfigured to reply on 19.230 KHz, Ch1. The vessel track and transponder scatter plot is shown in Fig 7.

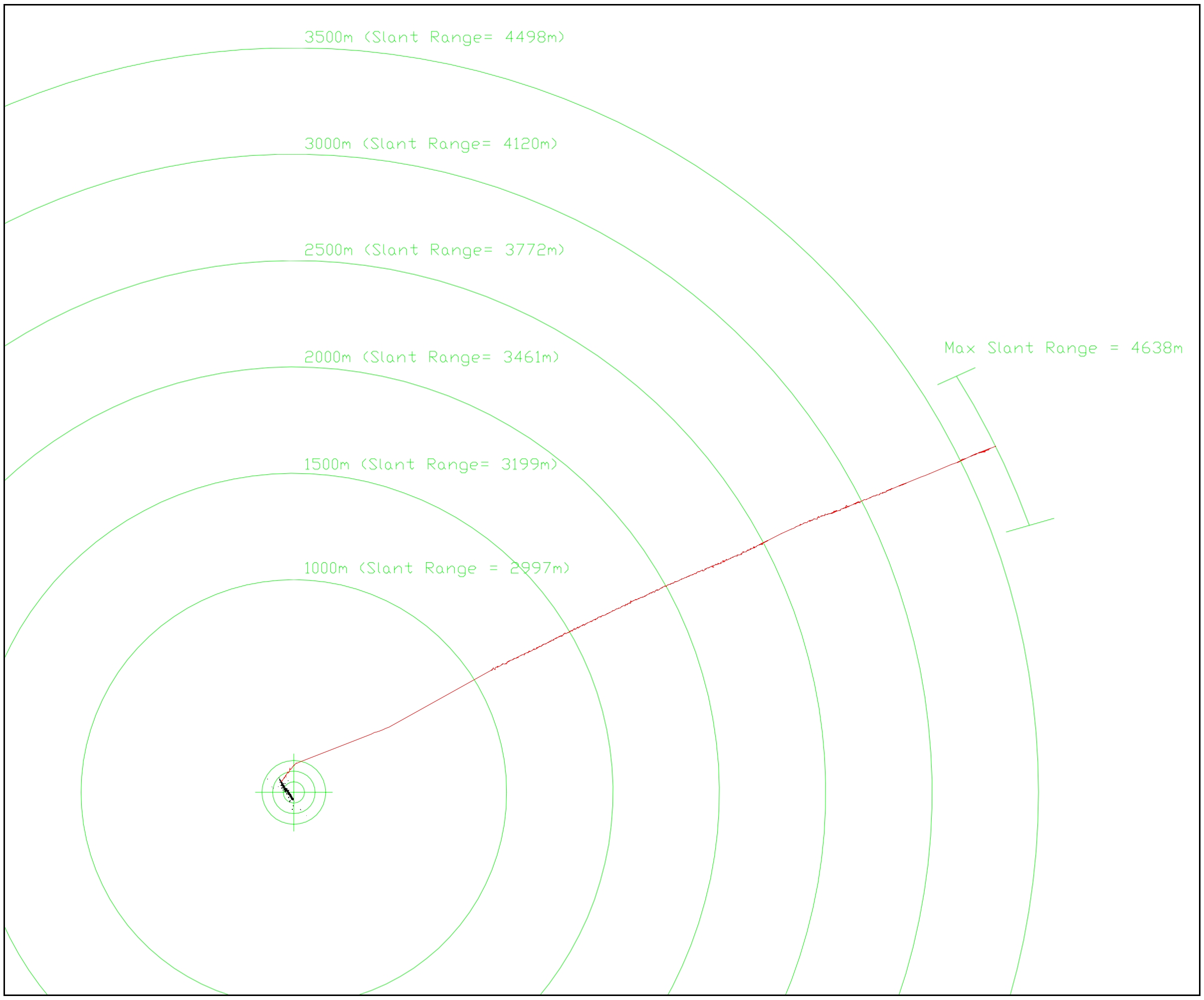

Fig 7. Vessel Track (Red) and Transponder Scatter Plot (Black) During 19.230 KHz Range Test (North to Top of the Page).

Again, despite the directional nature of both the transceiver and transponder and the sub-optimal geometry, tracking at a maximum slant range of 4638m was achieved. This increased slant range (from 3742m up to 4683m) is the result of reduced transmission losses from absorption at lower frequency.

The scatter plot of transponder positions is more clearly shown in Fig 8.

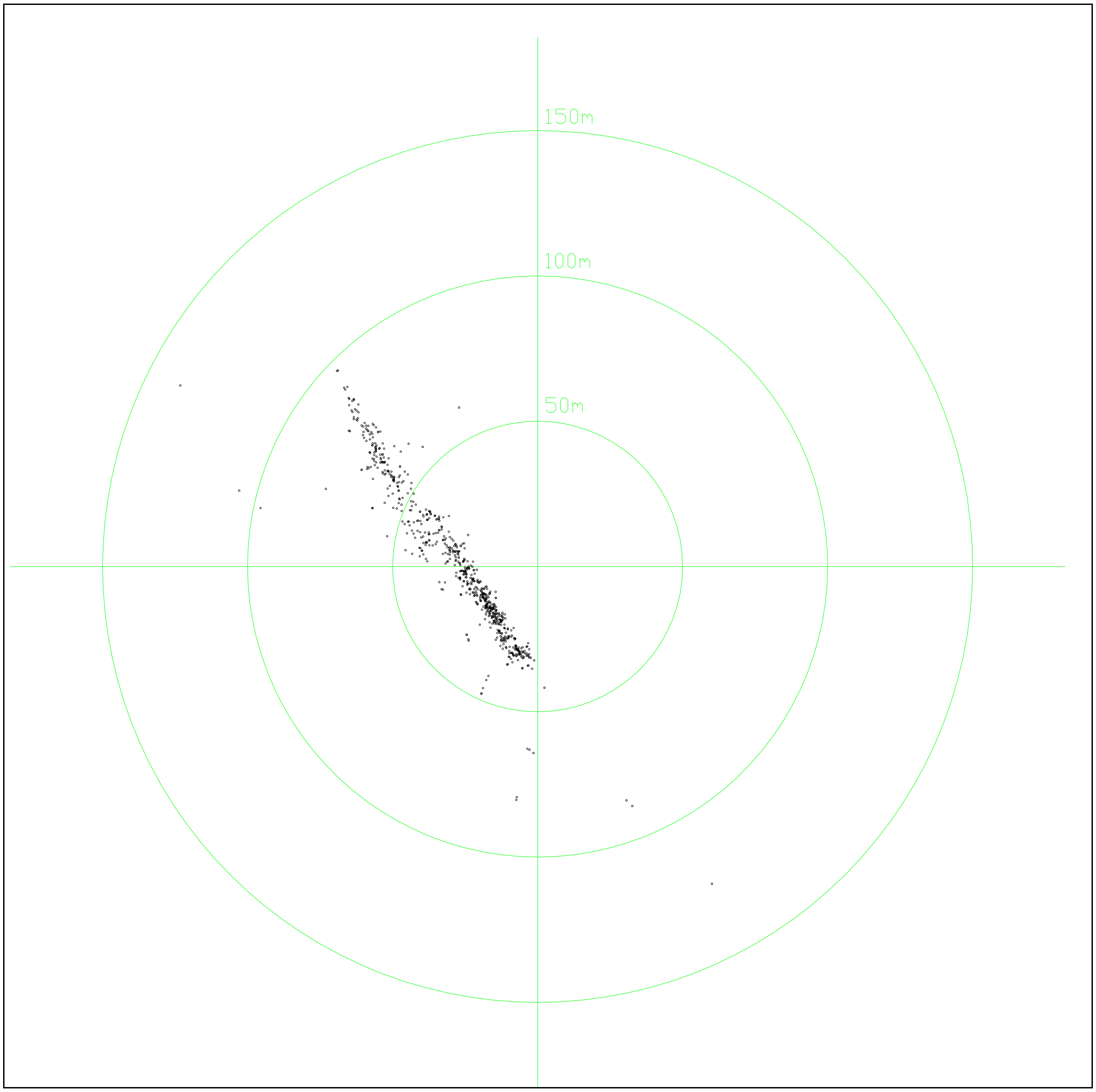

Fig 8. Transponder Scatter Plot During 19.230KHz Range Test.
(North to Top of the Page).

Whilst a slight degradation in the repeatability of the transponder position may have been expected at a lower frequency, the most noticeable affect on the scatter plot was once again the motion of the pole in the roll axis. The smearing seen in Fig 8 clearly demonstrates that the largest source of error in the system is due to the uncompensated motion in the pole. The magnitude of the smearing is increased in comparison to that in Fig 4 however this is to be expected due to the longer slant range achieved during this phase of the trial (+24% increase in range) and the correspondingly greater effect of pole instability.

Once again the mean position of the transponder is shifted away from the mean transponder position calculated from CASIUS. The direction of the shift is once again directly astern of the vessel's course and is entirely consistent with an uncorrected mounting error in the pitch axis as previously determined from Fig 4. (The CASIUS position is in the center of the range rings in Fig 8).

4.0 Conclusions

Despite some difficulty in properly calibrating the system due to pole instability the tracking ranges achieved were about what was expected for the system as configured. The directional transducers on the transceiver and transponder meant that achieving a target 6000 m slant range by moving away from the transponder location was always in doubt. On the other hand, noise measurements taken on the vessel indicated that the target range would be easily achieved in a straight up and down configuration

Based on a peak in-channel noise level of 80dB, a repeatability and maximum range prediction was performed for the 24.472 KHz reply frequency and this is shown in Appendix C. The maximum achievable range using the same equipment as used on the trial, in the presence of the noise levels as measured onboard and in a straight up and down configuration is in excess of 7500m.

Further predictions based on the increased noise level of 85dB experienced during the thruster trials were processed using both the 24.472 KHz and 19.230 KHz reply frequencies. The results are also included in Appendix C but both show maximum ranges in excess of 7500m despite the increased noise due to thruster activity.

To maximize the accuracy and repeatability of tracking using the Sonardyne system it is suggested that thought be given to ways of stabilizing the transceiver mounting in the roll axis of the vessel. While the increased absolute accuracy may not be required for Phoenix's application, the vibration experienced during the trial could conceivably damage not only a transceiver but also the pole itself.

Appendix A – CASIUS Report

Apache | **CASIUS calibration report** | Casius Version 4.5b | Excel 9.0 | LUSBL version 6

Comments: Casius on USNS Apache Oct 22 2003

data file: Phoenix Box-in Calibration @ 2: Path: C:\Sonardyne\Trip Reports\Apache\Casius\
report file: Phoenix Casius Report.xlr
log start: 22 Oct 2003 14:12 log end: 22 Oct 2003 17:34 duration: 3:22

INPUTS:	Tp East	Tp North	Tp Depth	Sound vel	Tcvr Stbd Offset	Tcvr Fwd Offset	Pitch Corr	Roll corr	Head corr
Used by USBL	-----	-----	-----	1,510.0	-----	-----	0.00	0.00	0.00
Initial Estimates	164,291.9	2,637,959.2	2,835.0	1,510.0	6.10	2.95	-----	-----	-----
Estimate accuracy	30.0	30.0	10.0	50.0	1.0	1.0	-----	-----	-----

Distance units are metres

Range gate	1.0	angle gate	2.0	% slant range				
Range accy	0.2			Ant Stbd Offset	0.0	Tcvr Index	15	
Tcvr Depth Offset	9.41			Ant Fwd Offset	0.0	Beacon Name	201:201	
Tcvr depth	4.50	accuracy	0.5	Ant Height Offset	0.00	Turn Around Time	125	ms
Depth aid angle limit	22.0	depth limit	1.0			DGPS lags USBL by	0	seconds
DGPS protocol	NMEA 0183 GGA							

OUTPUTS:

	Tp East	Tp North	Tp Depth	Sound vel	Tcvr Stbd Offset	Tcvr Fwd Offset	Pitch Corr	Roll corr	Head corr
Calculated	164,235.2	2,637,923.8	2,824.6	1,516.2	5.85	2.85	**-1.53**	**-2.86**	**-1.41**
Calc accuracy	0.51	0.46	1.45	0.50	0.18	0.17	0.02	0.02	0.15

		Before CASIUS	After CASIUS
39.4% Tpdr posns.	(1 sigma)	147.3	27.9
50.0% Tpdr posns.	(CEP)	154.4	36.0
63.2% Tpdr posns.	(1 Drms)	165.7	49.6
86.5% Tpdr posns.	(2 sigma)	194.7	116.0
98.2% Tpdr posns.	(2 Drms)	242.2	137.0

	Box In	Tcvr Attitude
No. of iterations	3	3
No. Depth aided		0
No. of fixes used	688	678
Average weighted residuals	0.03	10.89

N.B. The Pitch, Roll & Heading corrections are to be entered as the USBL tcvr/ship grid corrections.

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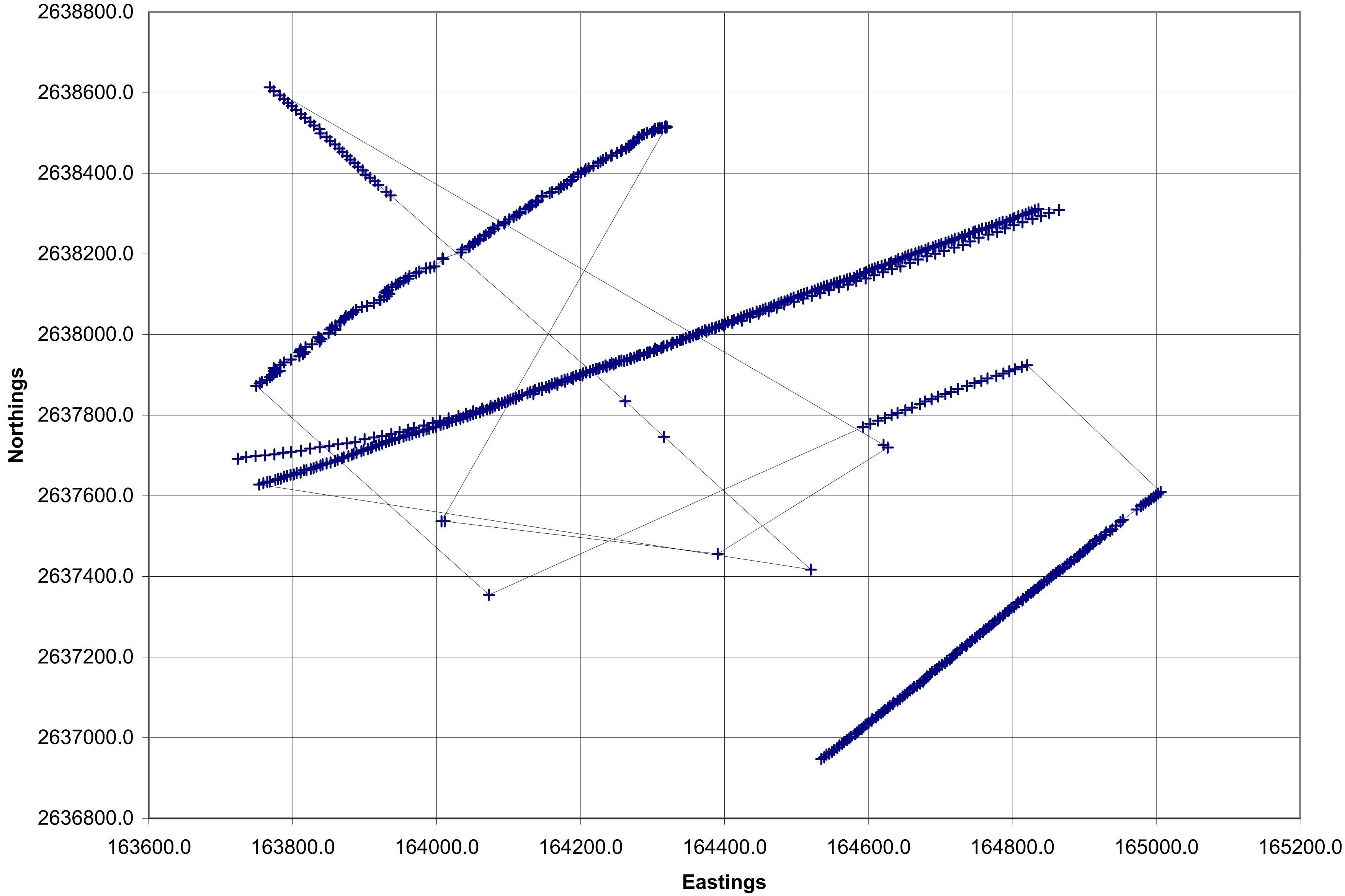
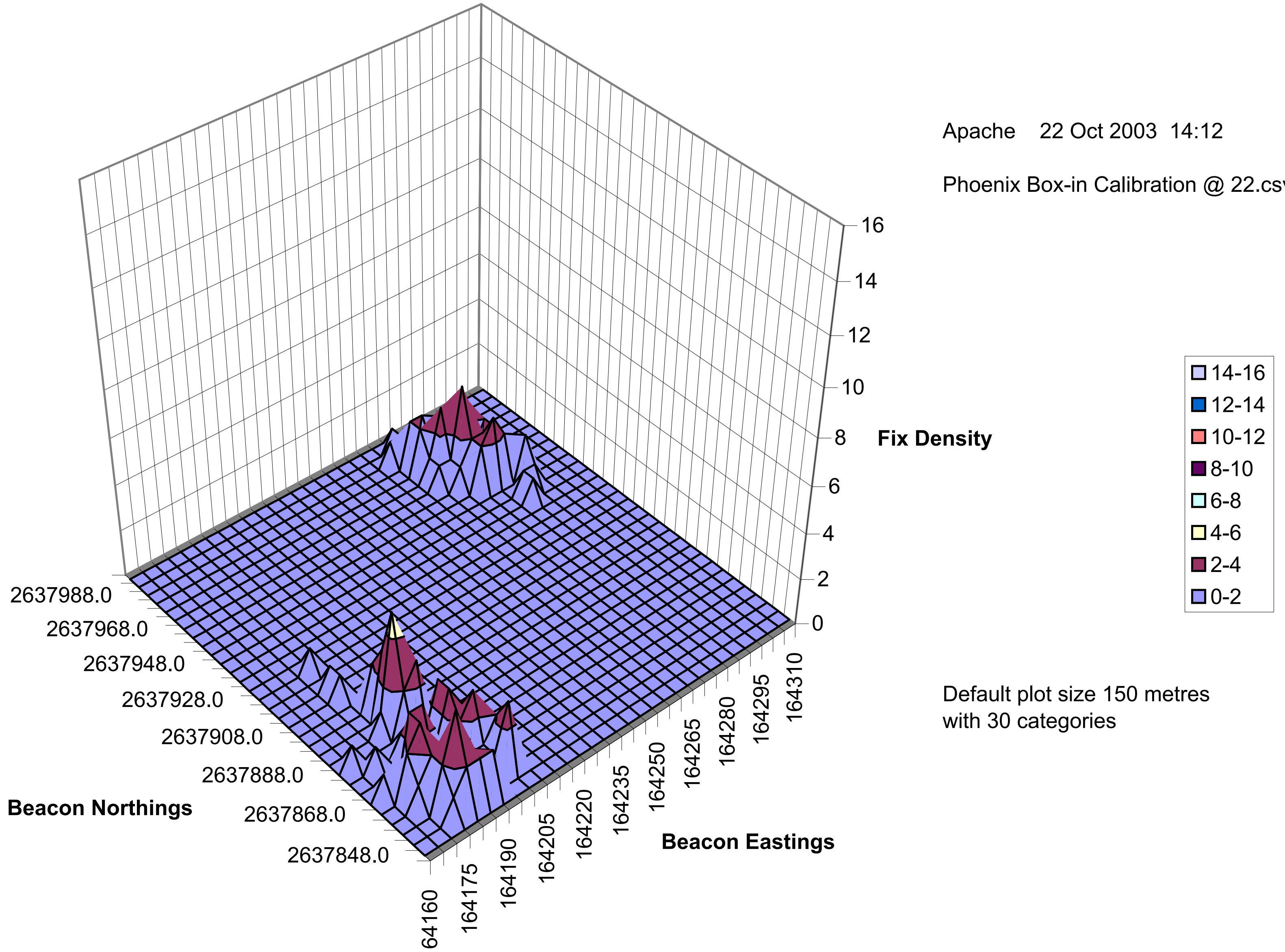
Casius on USNS Apache Oct 22 2003

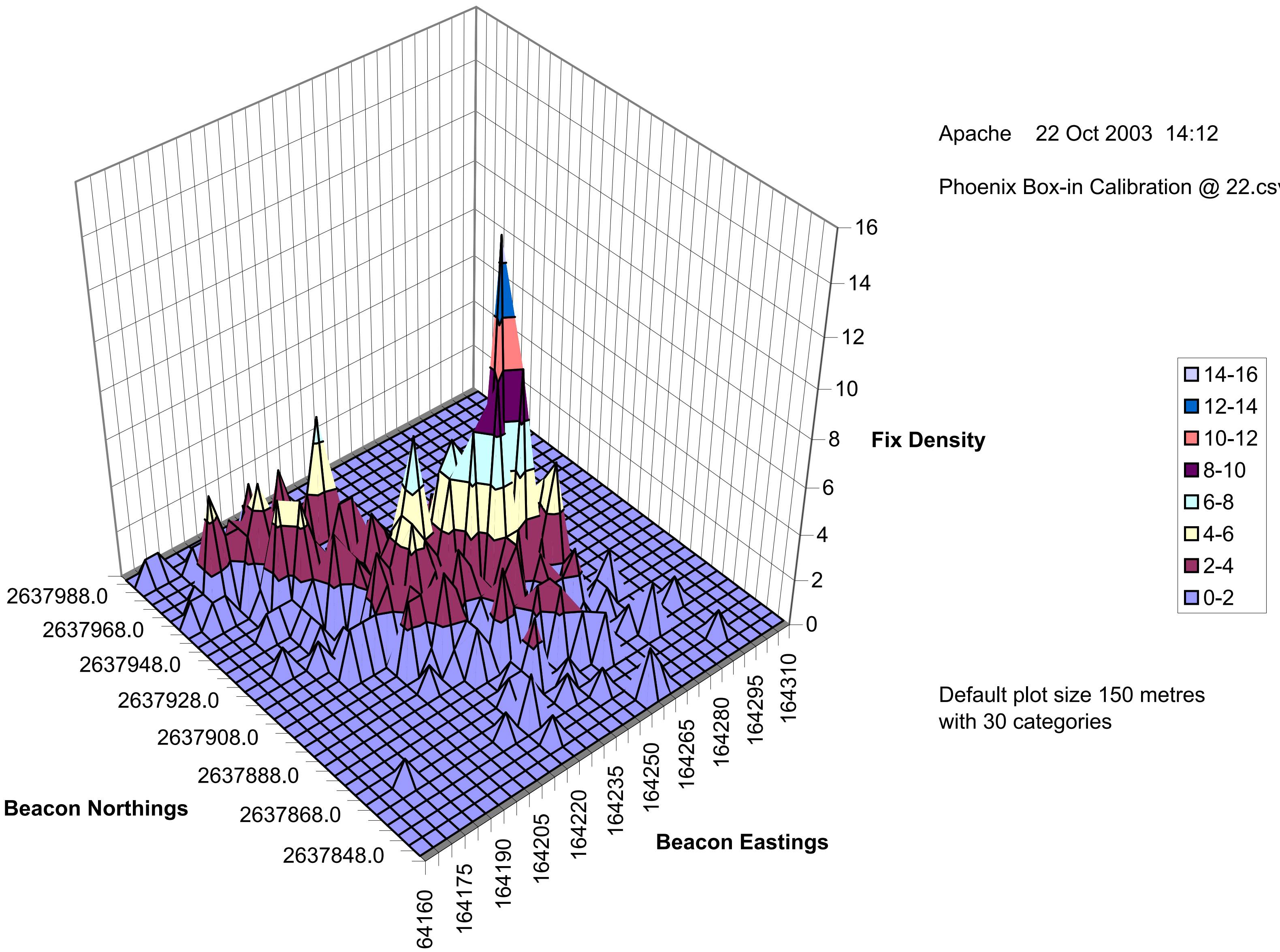


Casius on USNS Apache Oct 22 2003



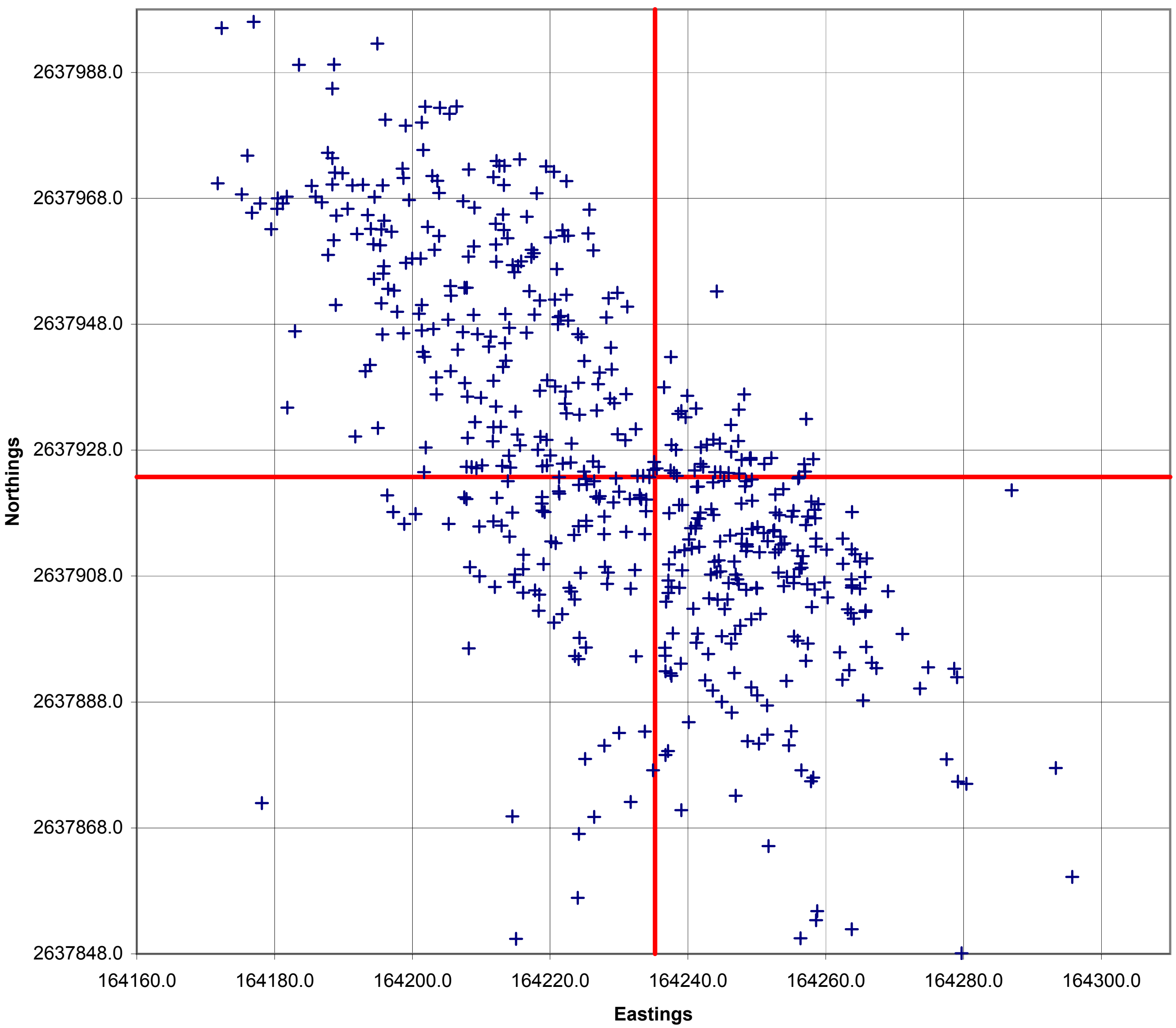
 3D Scatter Before CASIUS

Casius on USNS Apache Oct 22 2003



Default plot size 150 metres
with 30 categories

Casius on USNS Apache Oct 22 2003



Apache

2D Scatter After CASIUS

22 Oct 2003 14:12

Phoenix Box-in Calibration @ 22.csv

Default plot size 150 metres

Appendix B - Relevant Log Files

For convenience, relevant extracts from the MS Access compatible files generated by Fusion USBL during tracking have been reformatted into MS Excel. These files were the source of the plots included in this report.

All times are reported in GMT. To convert to relevant local times for the trial, subtract 4 hours.

The relevant files are :

'PositionLog Deployment.xls'

This contains tracking data for the transponder during the descent to the seabed. This data was logged prior to the geodetic parameters being adjusted to match the Phoenix Winfrog system. As a result the coordinates are block shifted compared to other log files.

'PositionLog Ch9 Range Test.xls'

This contains tracking data for the USNS Apache and the transponder during the 24.472 KHz range tests.

'PositionLog Thruster and Ch1 Range Test.xls'

This contains tracking data for the USNS Apache and the transponder during the Thruster tests and the 19.230 KHz range tests.

Appendix C – Range and Repeatability Predictions

LBL & USBL, RANGE & REPEATABILITY PREDICTION FOR BIG HEAD

Version 2.5 9 Jan 00

Measured noise in channel	80.0	dB//uPa
Channel freq. (19-32 kHz)	24.472	kHz
Source level of beacon	202	dB//uPa.m
Safety margin (allow for fade)	0	dB
Detection threshold	12	dB
Pitch standard deviation	0.10	degs
Roll standard deviation	0.10	degs
Gyro standard deviation	0.50	degs
USBL face depth	5	m
& water temp	10	°C
Beacon water temp	4	°C

SINGLE POINT EXAMPLE

Beacon Depth	6000	m	Off Axis Angle	5	
Beacon Range	500	m	Off Axis Loss	0.13	dB
Beacon Slant Range	6021	m	Noise Rejection	38.2	dB
			Absorption	2.97	dB/Km
			Absorption	17.9	dB
USBL SD	**0.22%**	**Slant Range**	Spreading Loss	75.6	dB
USBL SD	**13.1**	**m**	SNR in Channel	28.40	dB
Drms incl. attitude	**20.2**	**m**	SNR in MF Band	11.40	dB
Beacons in LBL Array	5		**Max Depth**	**7531**	**m**
Beacon at Array Centre?	n		**@ 5 deg. Max Horiz. Range**	**628**	**m**
			Maximum Slant Range	**7557**	**m**
LBL SD	**0.46**	**m**			

LBL & USBL, RANGE & REPEATABILITY PREDICTION FOR BIG HEAD

Version 2.5 9 Jan 00

Measured noise in channel	85.0	dB//uPa
Channel freq. (19-32 kHz)	24.472	kHz
Source level of beacon	202	dB//uPa.m
Safety margin (allow for fade)	0	dB
Detection threshold	12	dB
Pitch standard deviation	0.10	degs
Roll standard deviation	0.10	degs
Gyro standard deviation	0.50	degs
USBL face depth	5	m
& water temp	10	°C
Beacon water temp	4	°C

SINGLE POINT EXAMPLE

Beacon Depth	6000	m	Off Axis Angle	9	
Beacon Range	1000	m	Off Axis Loss	0.52	dB
Beacon Slant Range	6083	m	Noise Rejection	37.8	dB
			Absorption	2.97	dB/Km
			Absorption	18.1	dB
USBL SD	**0.42%**	**Slant Range**	Spreading Loss	75.7	dB
USBL SD	**25.3**	**m**	SNR in Channel	22.74	dB
Drms incl. attitude	**30.6**	**m**	SNR in MF Band	5.74	dB
Beacons in LBL Array	5		**Max Depth**	**7455**	**m**
Beacon at Array Centre?	n		**@ 9 deg. Max Horiz. Range**	**1242**	**m**
			Maximum Slant Range	**7557**	**m**
LBL SD	**0.45**	**m**			

LBL & USBL, RANGE & REPEATABILITY PREDICTION FOR BIG HEAD

Version 2.5 9 Jan 00

Measured noise in channel	85.0	dB//uPa
Channel freq. (19-32 kHz)	19.23	kHz
Source level of beacon	202	dB//uPa.m
Safety margin (allow for fade)	0	dB
Detection threshold	12	dB
Pitch standard deviation	0.10	degs
Roll standard deviation	0.10	degs
Gyro standard deviation	0.50	degs
USBL face depth	5	m
& water temp	10	°C
Beacon water temp	4	°C

SINGLE POINT EXAMPLE

Beacon Depth	6000	m	Off Axis Angle	9	
Beacon Range	1000	m	Off Axis Loss	0.33	dB
Beacon Slant Range	6083	m	Noise Rejection	24.0	dB
			Absorption	1.92	dB/Km
			Absorption	11.7	dB
USBL SD	**0.25%**	**Slant Range**	Spreading Loss	75.7	dB
USBL SD	**15.1**	**m**	SNR in Channel	29.31	dB
Drms incl. attitude	**22.9**	**m**	SNR in MF Band	12.31	dB
Beacons in LBL Array	5		**Max Depth**	**10149**	**m**
Beacon at Array Centre?	n		**@ 9 deg. Max Horiz. Range**	**1692**	**m**
			Maximum Slant Range	**10289**	**m**
LBL SD	**0.27**	**m**			