Sonardyne
SOUND IN DEPTH

WP-CAL-SON-2

White Paper - Calibration and Verification of Sonardyne USBL Systems (including GyroUSBL)

Issue B Rev 0

Issue Date: 20 November 2015

Sonardyne International Limited
Blackbushe Business Park
Yateley, Hampshire
GU46 6GD United Kingdom

T. +44 (0) 1252 872288
F. +44 (0) 1252 876100
E. support@sonardyne.com
W. www.sonardyne.com

Contacting the Sonardyne Support Team

24-hour Emergency Telephone Helpline: +44 (0) 1252 877600

The Sonardyne 24-hour helpline is answered at the UK Headquarters during normal office hours (08:00 to 17:00). Outside these hours, your call is automatically transferred to an agency, which logs the details of your emergency and alerts the appropriate Sonardyne personnel.

Our aim is to make sure emergency requests are dealt with immediately during office hours, and are responded to within 30 minutes at all other times.

Please note the helpline is for emergency use only.

If you require non-emergency product support, please contact your nearest Sonardyne office. Alternatively, contact the Sonardyne Head Office:

Sonardyne International Ltd
Blackbushe Business Park
Yateley
Hampshire
GU46 6GD
United Kingdom

Telephone: +44 (0) 1252 872288

Fax: +44 (0) 1252 876100

Email: support@sonardyne.com

Note

Email and telephone support is available during normal UK office hours (08:00 to 17:00).

Contents

Figures

Tables

Amendment History

The amendment history records all amendments and additions made to this manual.

Issue	Revision	Date	Comments	Section	Page
A	1		Initial Issue	All	All
B	0		General update	All	All

1 About this White Paper

1.1 Purpose

This white paper describes the theory of Ultra Short Baseline (USBL) positioning and the factors that can affect the performance of the USBL system. It discusses the significance of the external sensors that interface to the USBL system, and how any errors in such sensors can affect the position solution. It also highlights the potential errors arising from the installation of the system, and how this can be mitigated through a calibration.

As there are some cases where a USBL calibration may not be possible or essential, this paper also covers techniques used to determine approximate values for the transceiver corrections and also techniques to assess the current performance of a calibrated or uncalibrated USBL system.

Note

This document is not to be used as a procedure in its own right.

1.1 Related Publications

Table 1–1 Related Publications

Publication	Title
White Paper	*Introduction to Metrology*
White Paper	*Acoustic Metrology Guidance Using Sonardyne Systems*
White Paper	*Overview of LBL Box-in*
White Paper	*Overview of Errors in Hydro-Acoustic Positioning Systems*
White Paper	*Inverted Rig Move*
White Paper	*iUSBL*
White Paper	*Introduction to LBL*
White Paper	*Least Squares*
White Paper	*Pipeline Operations*
White Paper	*Riser Tower Monitoring*
White Paper	*Structure Placement*
OM-7942	*Operating Manual for CASIUS System*
UM-8250	*Marksman L/USBL and Ranger 2 Pro USBL User Manual*
GN-DAT-SON	*Guidance Note – Using DAT Tool*

2 Reference Material

2.1 Training Courses

For details on available Sonardyne training courses, please refer to our website at http://www.sonardyne.com/Support/Training/index.html

Should you require advanced or refresher courses including Project Planning courses, please contract survey.support@sonardyne.com and request details of what can be provided.

2.2 Datasheets & White Papers

Sonardyne's other white papers are available upon request at

http://www.sonardyne.com/Support/White_Papers/index.html

3 Introduction

Ultra-Short BaseLine (USBL), sometimes called Super Short BaseLine (SSBL), is an underwater positioning system that uses a vessel mounted transceiver to detect the range and bearing to a target using acoustic signals. This range and bearing technique is based on two principles. The first is that an accurate range can be determined by knowing precisely the time taken for an acoustic signal to travel between the target and the transceiver and the speed at which the signal travelled (sound speed).

The second is that the bearing and elevation can be determined by knowing the discreet difference in phase between the received signals at the multiple transducers present in the transceiver. This allows the USBL system to calculate the angle of the arriving signal.

A Sonardyne USBL transceiver is a multi-element transducer comprising of a single dedicated transmission element and a number of dedicated receive elements. The USBL system is also comprised of several other components, which includes attitude sensors for the accurate determination of vessel pitch, roll and heading (e.g. VRU and heading sensor), and accurate surface positioning systems, which would typically be a GNSS receiver. The USBL system also features the vessel mounted hardware and software, from which the USBL is controlled, along with the associated cabling and all important deployment pole upon which the transceiver is mounted.

Figure 3-1 A through-hull deployment machine and over the side deployment pole

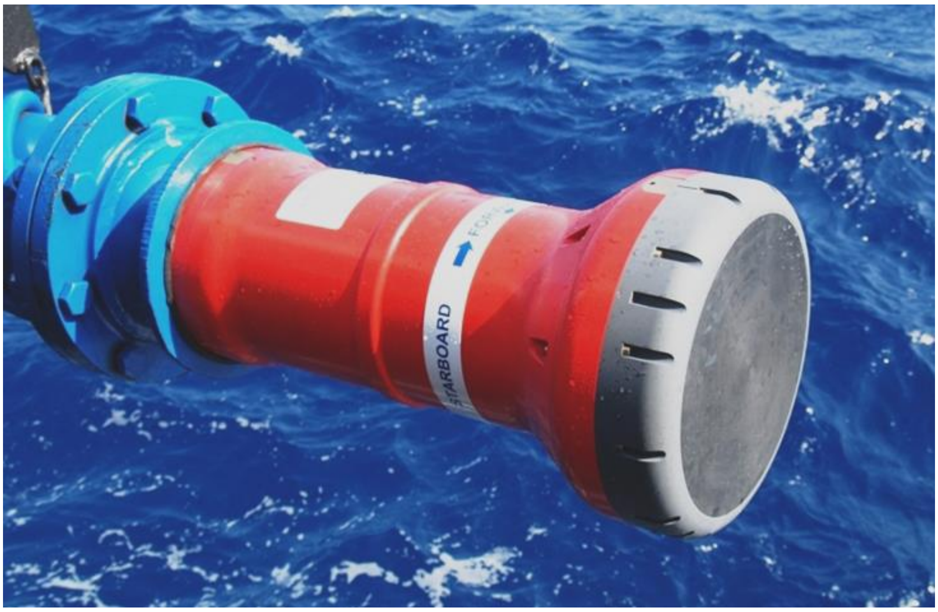
USBL can be used in water depths from less than 10 metres up to several thousands of metres, without the requirement to alter any of the components. As most USBL systems operate in and around the MF frequency spectrum (~19-34 KHz), they provide the potential to achieve good ranges to targets, whilst also maintaining a reasonable degree of range resolution, which can be improved when utilising Sonardyne Wideband® or Wideband 2 technology.

Ranger 2 is a survey grade USBL acoustic positioning system designed for shallow and deep water, long range tracking of underwater targets and position referencing for dynamically positioned (DP) vessels. The system calculates the position of a subsea target, for example an ROV, by measuring the range and bearing from a vessel-mounted transceiver to an acoustic transponder fitted to the target. Multiple subsea targets over a wide area and range of water depths can be simultaneously and precisely positioned.

Using a heading, pitch and roll sensor, the system can compute the position of a target with respect to the vessel. With the addition of a GNSS this position can be converted to real-world co-ordinates.

Many of the latest generation of USBL transceivers, like the Sonardyne GyroUSBL range, include an in-built high quality motion sensor to reduce errors due to latency, hull flex and deployment pole flex. As a result the need to undertake calibration may be reduced.

Figure 3-2 Sonardyne HPT 7000 GyroUSBL fitted to temporary over the side pole



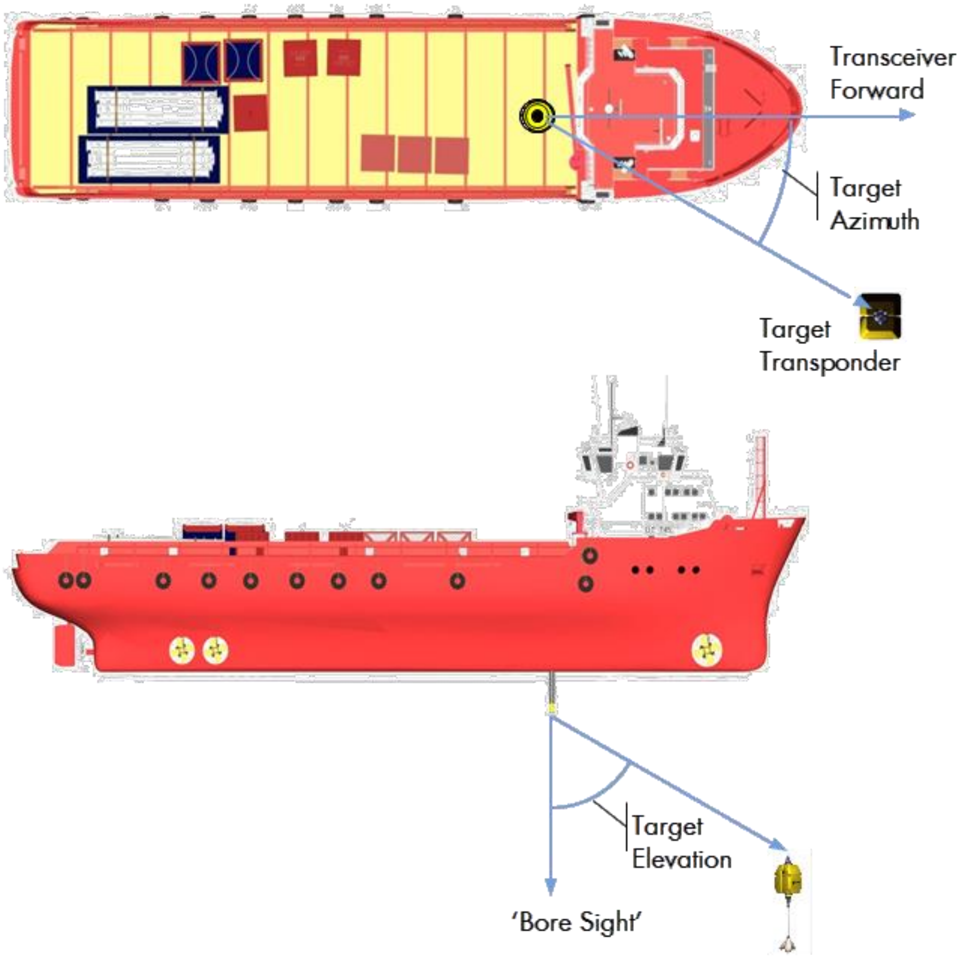
To be able to understand the potential performance of a USBL system, many factors must be taken into account. The quality of the installation, aiding sensors, calibration, the positioning of the USBL transceiver with respect to noise sources as well as the type of USBL transceiver being used will all play an important role in determining the absolute performance of the system.

4 USBL Calibration

4.1 Why Calibrate?

USBL relies on the ability to determine a range and a bearing to a subsea target. This bearing can be represented as an azimuth and elevation relative to the face of the transceiver:

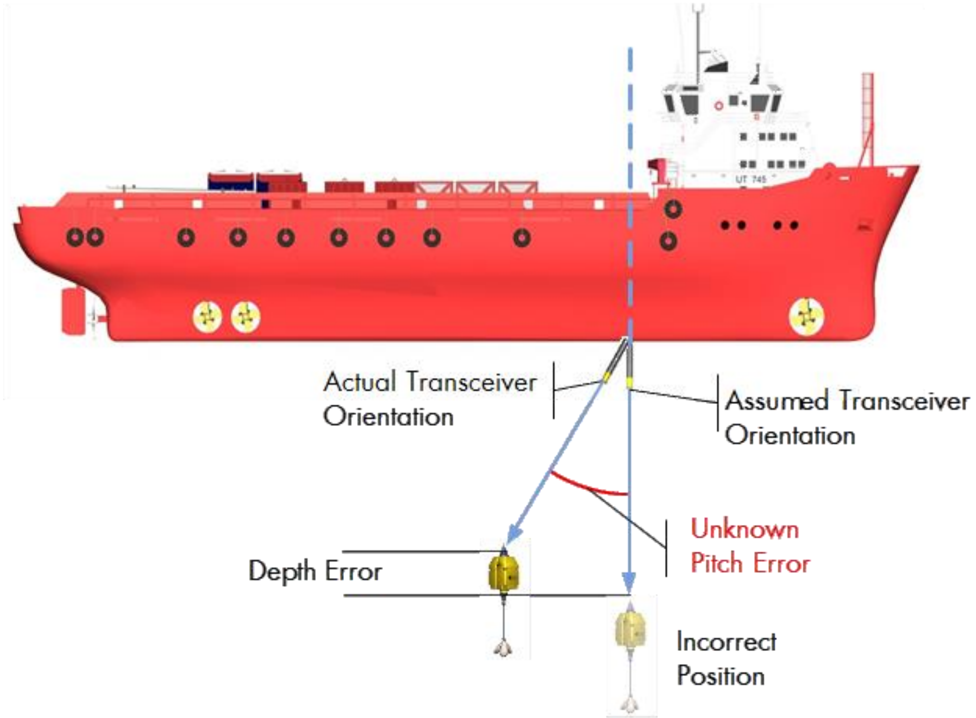
Figure 4-1 Azimuth and elevation to a target from a USBL transceiver



This means that following a successful interrogation of a target and providing sound speed is accurately known, the USBL system can compute the location of the target relative to the face of the transceiver. The problem lies in determining the location of the target relative to a reference system on the vessel itself. To achieve this, the exact orientation of the transceiver face in pitch, roll and heading must be known relative to the vessel reference system, as must any offsets in x, y and z relative to the common reference point (CRP) such as the GNSS antenna. This problem can be solved by carrying out a USBL calibration.

To further understand why a USBL system needs calibrating, it is useful to identify how the USBL transceiver's orientation can affect a targets resultant position. For example, if a USBL transceiver is mounted with a pitch offset relative to the vessel reference frame, as opposed to absolutely vertical, and the target transponder is precisely in line with the transceiver, the following effect will occur:

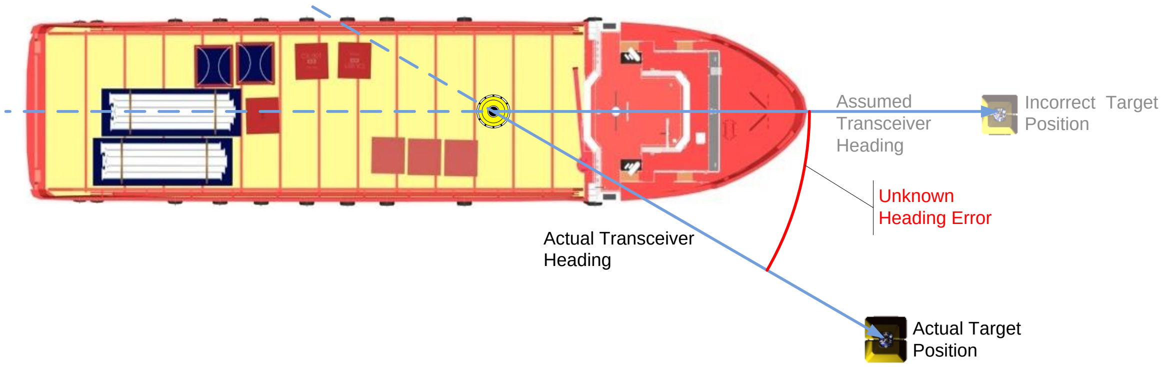
Figure 4-2 Effect of a transceiver pitch error on target position



In the example shown in *Figure 4-2*, a targets signal is detected at 0° (vertical) to the face of the transceiver, and as the system does not know the pitch error, then it assumes this means the target is 0° from the vessel. This results in an incorrect target position and depth. The same principle can also be applied to any error in the roll axis of the transceiver.

The effect on a target position caused by any heading (yaw) error in the orientation of the transceiver (misalignment) follows the same principle, but does not affect depth. In this case it affects the apparent easting and northing of the target. The effect can be illustrated as follows:

Figure 4-3 Effect of a transceiver heading error on target position



If any errors are present in the transceivers orientation, these will cause errors in the targets position as described. As the angular misalignments are translated into positional errors the positional error will increase in magnitude directly proportional to the distance from the target. This means any error in the pitch or roll of the transceiver will become increasingly apparent in deeper water, whereas any error in the heading of the transceiver will become more significant at larger horizontal offsets to the target. The effects of angular error can be estimated based on the following graph:

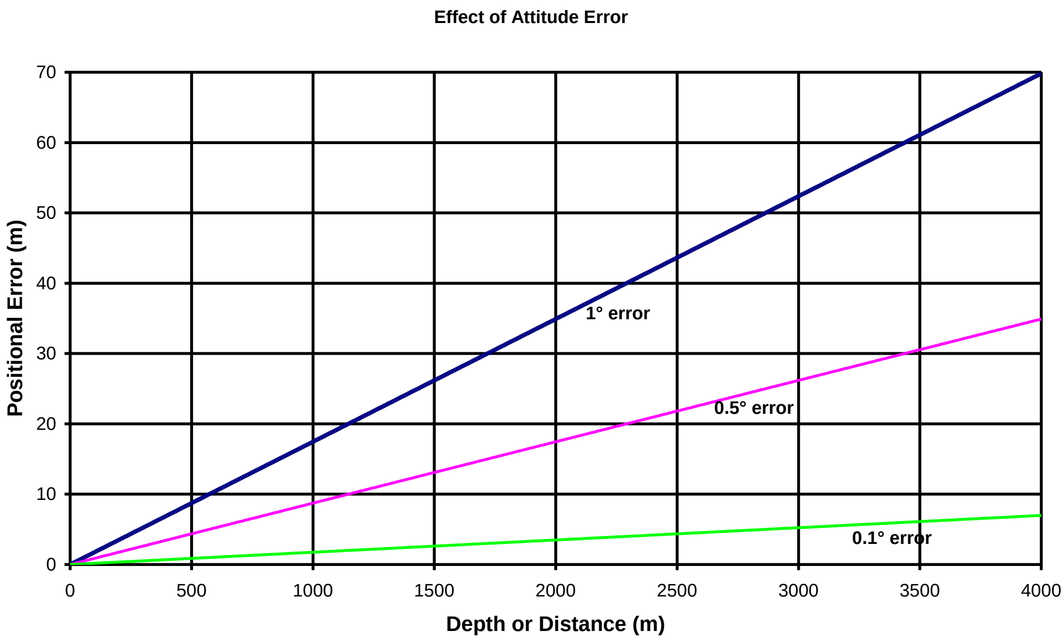


Figure 4-4 Effects of angular error on position

Figure 4-4 shows that a 1° error in the transceiver heading would translate to a 35 m positional error at a distance of 2 km (1.75% of range), for example during Towfish tracking. Whereas a 0.5° error in transceiver pitch or roll would lead to 17.5 m positional error at a depth of 2,000 m (0.88% of range), for example in ROV positioning.

It should also be noted that a 1° error at 100 m depth or layback equates to a position error of only 1.75 m (1.75% of range).

Note

The actual errors are more complex due to the potential interaction between pitch, roll and heading, but for the purpose of this paper these are not addressed.

There are several methods that can be used to calculate the misalignment errors in a USBL system. These range from a basic static alignment process (where the misalignments are manually calculated) to a full calibration, such as Sonardyne's CASIUS Tool software. Many third party software packages are also available. In order to be able to support a problematic calibration, Sonardyne CASIUS calibration data must be supplied. We cannot assist with calibrations performed in third party packages.

As well as determining any pitch, roll or heading error in the orientation of a transceiver, a CASIUS calibration will also be able to calculate any errors in the offsets of the transceiver to the vessels GNSS antenna in use. Unlike the orientation errors, these errors will lead to a systematic error in the targets position of a fixed amount, regardless of distance or depth.

A CASIUS calibration can also correct for any uncertainties regarding the speed of sound propagation through the water column at the time of calibration, which is essential when determining the true distance to the target.

4.2 Importance of Sound Speed

The speed of propagation of acoustic signals through the water is significant for the two key reasons shown in *Sections 4.2.1* and *4.2.2.*

4.2.1 Time of Flight

Acoustic positioning systems do not directly measure distance; they measure the time of flight of the acoustic signals. This is known as the two way travel time. The speed of sound is used to determine the accurate distance to the target based upon the time between transmission and reception of the acoustic signal (time of flight or travel time). Therefore any error in the sound velocity entered into the USBL system will translate into an incorrect calculation of range.

4.2.2 Refraction

Changes in the speed of sound throughout the water column lead to a phenomenon known as refraction. This is where an acoustic signal has its direction of travel altered when passing between layers of differing density and elasticity, and therefore sound speed, causing the signal to bend. Refraction of sound in seawater can be compared to light refracting through a prism. Sound waves can also be considered lazy as they are drawn to the regions of lower speeds within the water column.

As discussed in *Section 3* the USBL system relies on the ability of the transceiver to accurately detect the targets position relative to the transceiver face through accurate determination of the angle of the arriving signal. Refraction due to the variation of the speed of sound through the water column will alter the signal path, and the arriving angle may not represent the actual direction to the target. The amount of refraction will increase at higher elevations. When the vessel is directly over the transponder very little refraction will be experienced.

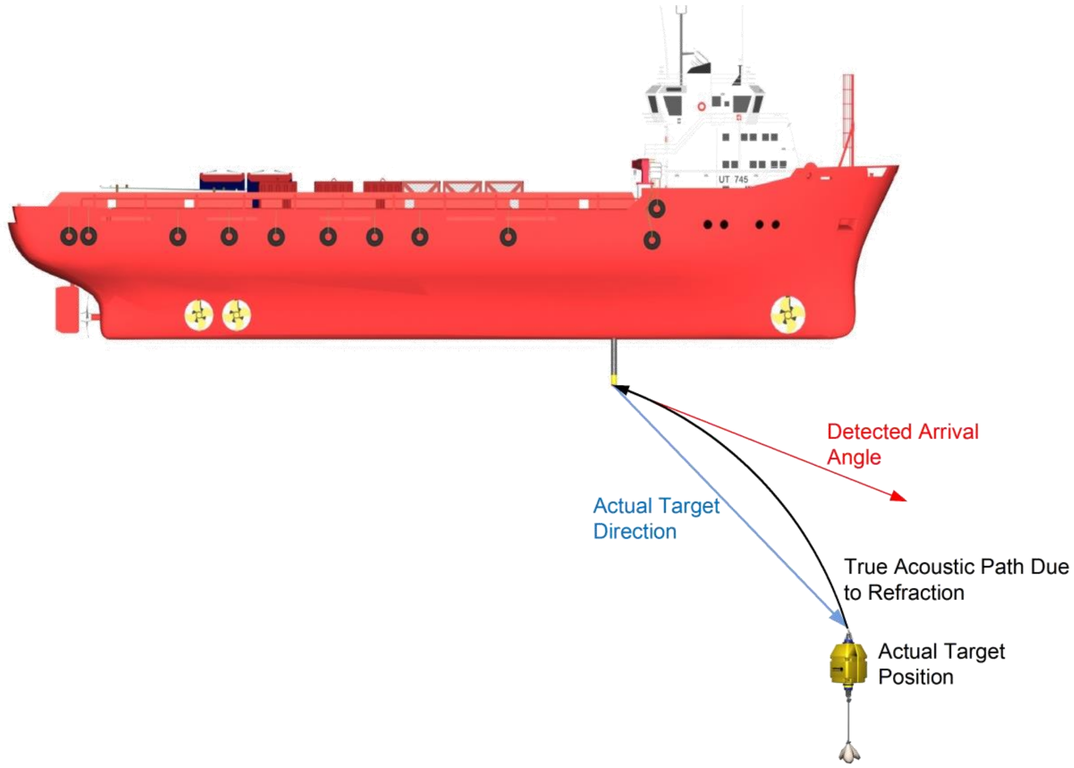


Figure 4-5 Exaggerated effects of refraction

4.3 Sensor Calibration

It is also very important to be aware of the mounting of any VRU and heading sensor instrumentation. This is because even if the transceiver is mounted with 0° error in pitch, roll and heading with respect to the motion reference unit, there will still be an error in position if a heading sensor or VRU is not aligned into the same reference frame as that with which the x, y, z offset were measured. This error should ideally be accounted for by a heading sensor calibration or VRU calibration, but a Sonardyne USBL calibration can account for these unknown errors.

This means that it is very important to mount vessel attitude sensors correctly, or have some knowledge of their mounting. It is common place in the offshore industry for a heading sensor to be calibrated during a mobilisation phase, but all too often, little or no attention is afforded to the calibration of a VRU into vessel frame.

Often a temporary survey spread will include survey grade motion units which should be securely mounted, ideally as close to the USBL transceiver as possible. This is to reduce the potential for uncompensated USBL motion. Conversely, a motion unit installed in the bowls of a vessel may be more difficult to install than a unit installed on the vessel bridge. This could reduce the quality of a USBL calibration.

By calibrating the sensors, it allows the operator to then isolate any transceiver errors through a USBL calibration. If these sensors are not calibrated, when a USBL calibration is performed, the resulting pitch, roll and heading corrections will be composed of the transceiver errors plus the sensor mounting errors. This means that if any sensors are moved or replaced, then a full USBL calibration would usually be required.

If, however, all the sensors are calibrated, and their mounting corrections known, and applied in any software or hardware settings, then a USBL calibration should provide the pitch, roll and heading corrections that are purely relative to the transceiver. Therefore if any sensors are changed or subsequently altered, all that is needed is to calibrate the new sensor or sensor position, as opposed to a USBL calibration. Then a verification check should be performed (see *Section 4*).

Note

VRU calibration should be performed in accordance with manufacturer's recommendations, and is usually performed prior to USBL commissioning.

4.4 Static Transceiver Calibration

There are practical ways to provide potential estimates of USBL system errors, without the need to perform a full USBL calibration. This may be done in cases where a full USBL calibration is not permitted, or where it is deemed unnecessary. Generally these methods will produce less accurate results than a CASIUS calibration.

4.4.1 Internal Transceiver to Ship Calibration

Some Sonardyne USBL transceivers are fitted with low grade pitch and roll sensors, but they are not dynamically compensated, so are of little operational use on a dynamic vessel at sea. These can be compared with high-quality vessel mounted sensors to determine approximate values for the transceivers pitch and roll relative to the vessel motion sensor. It is recommended that this only be done in low dynamic environments (alongside or in very calm weather).

These values can then be used within Sonardyne software as corrections for the transceivers alignment, to improve system performance either in place of USBL calibration values, or to improve a full USBL calibration by allowing better vessel positioning with respect to the transponder.

GyroUSBL transceivers, fitted with survey grade motion sensors, can be accurately aligned to the vessel reference frame by comparison to a vessel mounted motion reference unit using a software tool in Ranger 2. The GyroUSBL may already have valid CASIUS calibration derived corrections that can be entered into and used by Ranger 2.

Note

A comparison between the transceiver motion sensors and the vessel VRU are only recommended if the VRU is correctly aligned with the ships plane of reference, or the mounting angles of the VRU are reasonably well known.

4.4.2 Transceiver Heading Alignment Check

There are several ways to determine if there is any transceiver misalignment resulting in a potential heading error. The most common method is to place a transponder at a known bearing relative to the USBL transceiver – this would typically be directly fore or aft of the transceiver to give a target bearing of 0° or 180°. The transponder is then positioned within the Sonardyne navigation software and the observed bearing is compared to the actual bearing (in this case 0° or 180°), with the difference being the alignment error between the heading sensor and the transceiver.

Again, if the heading sensor is incorrectly aligned or uncalibrated (i.e. corrections are not known), the resulting value will not represent the true transceiver heading error relative to the ships centre line. In cases where the heading sensor is correctly aligned, or any corrections are known, placing the transponder further away can increase the confidence in the results. This is sometimes achieved by placing the transponder along a quay side, as opposed to from the vessel. Quay's can provide difficult acoustic environments due to hard reflections from walls and also their typically shallow nature. This means that good tracking over a very long baseline is not usually possible, reducing the likely accuracy of this method.

GyroUSBL transceivers can be aligned to vessel frame by comparison to a vessel mounted motion reference unit using a software tool in Ranger 2. The GyroUSBL may already have valid CASIUS calibration derived corrections that can be entered and used by Ranger 2.

4.4.3 Barge Calibration

When utilizing a USBL system on board a static barge and the potential for undertaking a full USBL calibration is not always possible, the above methods can be utilized to align the USBL transceiver into vessel frame.

Greater care should also be taken when installing the VRU and when determining the VRU mounting angles so more accurate transceiver pitch and roll errors can be determined from a transceiver to VRU correction.

A GyroUSBL may be pre-calibrated or have the required precision without a calibration, depending on the project requirements and the certainty of any x, y, z offsets measurement to the aiding sensors, such as GNSS. This means that the GyroUSBL can be quickly and easily aligned to a vessel reference sensor if these are well known.

4.5 Calibration of Attitude Sensors In the USBL System (CASIUS)

CASIUS requires that data is gathered from all around the beacon, at reciprocal headings and from over the top of the beacon at reciprocal headings. All of this allows for the determination of the transceiver offsets, mean speed of sound, and USBL heading, pitch and roll errors along with an accurate transponder position. Sonardyne does not restrict how the data is gathered, but does recommend certain practices. These include:

- Data should be gathered with the transceiver directly over the target, to maximise the determination of pitch and roll errors.
- Data should be gathered with the vessel at a distance of 1/3 x water depth (to a minimum offset of 50 m and a maximum of 500 m) from the target at a full range of azimuths from the transponder (i.e. all around) to aid in the determination of heading errors.
- Data should be gathered at reciprocal headings to maximise the available information to determine the transceiver offsets.

Along with the above guidelines, careful consideration needs to be made to how the data is collected. In general and in order to provide a realistic assessment of the system performance, it is recommended that the data is collected in a method that reflects how the vessel will be used operationally i.e. stationary or dynamic.

With both stationary and dynamic calibrations, it is recommended that the calibration is performed in water depths that reflect the upper limit of the operational environment. For example, if the vessel is to operate using USBL in water depths ranging between 200 m–1,000 m, then the calibration should be performed in 1,000 m. This is critical, because as described in *Section 4.1*, angular errors will cause a positional error that increases with target distance. In the case of a small angular error, these will be easier to identify when calibrating in deeper water, and may not be critical in shallow water.

The absolute maximum depth for a CASIUS calibration is dictated by the system's ability to maintain a good SNR; this will vary for each system type and each installation. For more detailed information on the expected performance of a particular system, contact Sonardyne support.

To ensure that data can be gathered with the transceiver directly over the target, and at equal distances, a 'transceiver to ship calibration' routine (as named in Ranger 2) should be carried out and, if fitted, depth sensor readings should be taken from the transponder. These can be used in a comparison of the final results.

Up-to-date, accurate surface and mean sound speed values must also be used. It is usually preferable to use fixed mean and surface sound speed values over using a sound speed profile for the CASIUS data collection.

When selecting a beacon reply signal the user should ideally choose the highest available frequency. This will improve timing resolution at the transceiver and aid in the correct computation of the azimuth and elevation of the incoming signal. Channel selection should also account for variation in vessel noise across the frequency band to ensure an adequate SNR is available for good, reliable detection.

Where SNR is low, first increase the transponder source level. If SNR is still poor, using a lower frequency channel may help by reducing transmission loss due to absorption. This can help by up to 10 dB in the MF band. This gain may be offset by increased vessel noise at the lower end of the frequency band. A noise plot tool in the navigation software is available with all 5G & 6G transceivers to aid in the selection of the most appropriate address/frequency. Using a more powerful or directional transponder will also help to increase SNR at the transceiver, as long as the vessel remains within the optimal operating cone of the transponder.

For best results, the USBL system should be fully configured as a stand-alone system. All known offsets should be entered into the Sonardyne navigation software. Prior to commencing the CASIUS data collection, the performance of all aiding sensors should be verified and the user should confirm that aiding sensor telegrams are of a sufficient frequency and resolution. For Ranger 2 / Marksman, the attitude and heading sensors should be configured to output at a minimum of 10 Hz and to 2 decimal places.

Sonardyne can only offer support when calibration is carried out using CASIUS, and so it is recommended that if another package is used to calibrate the USBL system, then CASIUS data should also be collected at the same time.

Once the data collection is completed, it can be processed using Sonardyne's CASIUS software. This will result in the calculation of the resulting pitch, roll and heading corrections (these should be entered into the Sonardyne USBL software, using the same sign convention). It will also calculate an adjustment to the transceiver offsets. There is potential for any unresolved errors to be pushed into the calculated transceiver offsets but if the pole offset has been accurately measured by land survey techniques then these should not be updated based on USBL calibration results.

CASIUS will also give a computed sound speed value and a box-in position of the subsea transponder which can be used as a QC of the calibration. An example of a CASIUS calibration report can be seen in Appendix A.

If Ranger 2/Marksman has multiple aiding sensors configured into the system, data will be collected for all available sensors. Each sensor can then be selected in turn and processed separately to calculate corrections for each option. This can also be used as a QC check. If the aiding sensors are properly installed and calibrated into the vessel reference frame prior to the data collection, there should be little or no difference between them. Any significant difference might indicate a problem with one of the sensors.

4.6 When to Calibrate

In most applications a USBL system will require a CASIUS calibration when first installed. Deciding the length of validity of a CASIUS calibration thereafter depends on several factors. First and foremost it helps to have some knowledge of the actual installation. If for example the USBL transceiver is permanently mounted on a rigid through-hull deployment pole that was fitted in a shipyard, then it is fair to say that it will not be likely to move an observable amount relative to the vessel. However if the transceiver has been fitted on a temporary pole on a vessel of opportunity, then less confidence is likely to exist in the repeatability of the system over time and in different conditions.

One of the benefits of a CASIUS Calibration over a verification check (verification checks are discussed in depth in the next section) is that it will also compute the offsets to the aiding sensors in angle and/or in x, y, z. A vessel that has been dimensionally controlled using land survey techniques and maintains a rigid change control policy to ensure no unknown system changes have occurred, may be able to extend the validity of a CASIUS calibration by performing regular system verification checks to confirm the final positioning accuracy of the system.

In most cases, a verification check should be first undertaken to quantify the performance of the system. If the verification shows the system accuracy to be within the specified project tolerance then a calibration may not be required.

Consideration must also be given to what the system is to be used for in order to ascertain what the accuracy requirements are, as these will also dictate if and how you perform a calibration. If for example a system is to be used to track a target in shallow water, the effects from a pitch or roll error may be negligible. The opposite is true as you move into deeper water or longer lay-backs.

For information on assessing current performance of a USBL system please refer to *Sections 5.3* and *5.4.*

A CASIUS calibration will usually remain valid unless:-

4.6.1 Changes Made to Deployment Pole

If the pole used to deploy the USBL below the vessel keel has been removed and refitted or is suspected of being damaged or bent, thereby changing the relationship between the USBL transceiver and the vessel reference frame, a calibration should be undertaken. Use of a GyroUSBL will reduce the possible error (errors due to a change in the x, y, z offsets will remain). For lower accuracy work, a verification check can be performed to ensure the system meets the required specification.

4.6.2 Operations Change to Significantly Deeper Water

A calibration should be performed at the intended working depth or deeper up to a maximum dictated by the maintenance of a good acoustic signal to noise ratio. If the calibration is performed at a shallower depth than the working depth, the error value will be scaled accordingly as the depth increases. Calibrating at the working depth will also give a true representation of the system performance.

Calibrating in water depths approaching the range limits of the USBL system or beacon being used may reduce the quality of the calibration. A reduction in the signal to noise ratio can reduce the system precision. It is necessary to balance good signal to noise against making the angular errors observable. In cases where signal to noise is affecting the calibration, it may be better to perform the calibration at a shallower depth than the intended worksite but it should be noted that the CASIUS results will not reflect the system performance at the final working depth - this can be ascertained by performing a verification check once at the worksite.

4.6.3 An Aiding Sensor is Changed

If a VRU or heading sensor is replaced, the USBL should ideally be recalibrated to ensure any difference in readings due to slight changes in mounting between the new and old sensor are accounted for and to ensure the sensor's output is sufficient to give the required precision.

If multiple vessel aiding sensors are available to Ranger 2, an alignment tool in the software can be used to align the new aiding sensor with the existing sensors. Assuming the sensor is properly installed and of the same quality, a CASIUS calibration may not be required and a verification check can suffice.

4.6.4 USBL Transceivers Removed and Refitted

If the USBL transceiver is removed for any reason, a calibration should be performed to ensure the alignment of the USBL transceiver to the vessel motion sensor aiding inputs. In shallower water scenarios, where angular error effects are minimal, and when using GyroUSBLs that are mechanically coupled to their motion reference unit, it may be sufficient to perform a verification check to confirm if the old installation corrections are still valid, depending on the project specification.

4.7 Suggested CASIUS Data Collection Methods

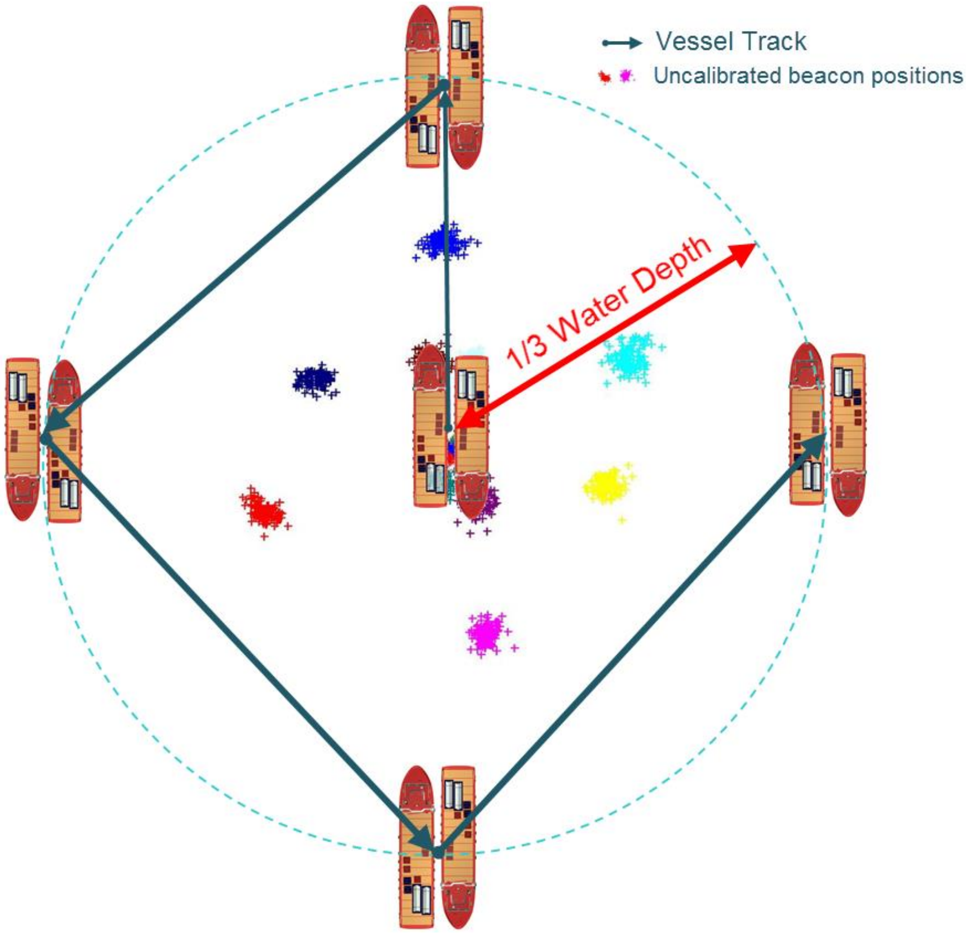
4.7.1 For DP Vessels – Stationary

Stationary data collection is when the vessel remains at fixed locations. The benefit of this method is that the number of observations that are made can be easily controlled, vessel thruster noise is generally lower and time can be given to allow aiding sensor reading to settle. The basic requirements for data collection are:

- Simultaneously record USBL target data, vessel position and vessel attitude data. Usually 200 fixes at each location.
- Collect data at a set of cardinal points that are a horizontal distance of 1/3 x water depth to a minimum of 50 m and a maximum offset of 500 m from the target.
- Collect data from directly over the target.
- The vessel should remain on a fixed heading at each cardinal point, minimising any effects of aiding sensor latency.
- Collect data on the reciprocal heading (180° subtracted from the original heading) and this heading should be the same throughout.
- Vessel noise is minimised by selecting an appropriate heading to the weather.

A typical vessel track is shown in *Figure 4-6*. The collected datasets are then processed together.

Figure 4-6 Stationary data collection pattern (Cardinal points)



Data can be collect in any order and the heading/orientation of the cardinal points should be selected to minimise vessel noise with regards to weather. Data collection at the centre cardinal can be collected using a slow spin (when using modern inertial type aiding sensors that do not suffer lag) or on four headings, 90° apart and used as a gross error check of the offsets. This could be data collect during a verification test. It is only necessary to collect data on two headings.

4.7.2 For Non DP – Run Lines

Run line data collection is when the data is gathered as the vessel is manoeuvring around the target, while following the guidelines discussed. This method provides an obvious benefit when operating from a vessel with no DP system, making stationary data collection impractical. As mentioned, it is recommended to gather the data in a way that best reflects how the vessel will be used operationally. This means even if the vessel is fitted with a DP system, then a dynamic calibration may be recommended if the system was to be used while dynamic, e.g. Towfish tracking, pipeline surveys etc.

Run line calibrations are critical when considering the stability of the deployment pole that will be used during dynamic tracking scenarios. This is because the pole may suffer from stress induced movement while the vessel is dynamic, and a stationary calibration may not accommodate for this. However, unlike stationary data collection, it is more difficult to control the number of data points that are gathered, as this will be determined by the speed of the vessel. Operators should also be aware of the potential for higher levels of noise and cavitation present due to increased thruster and engine use.

Figure 4-7 Dynamic data collection pattern (run lines)

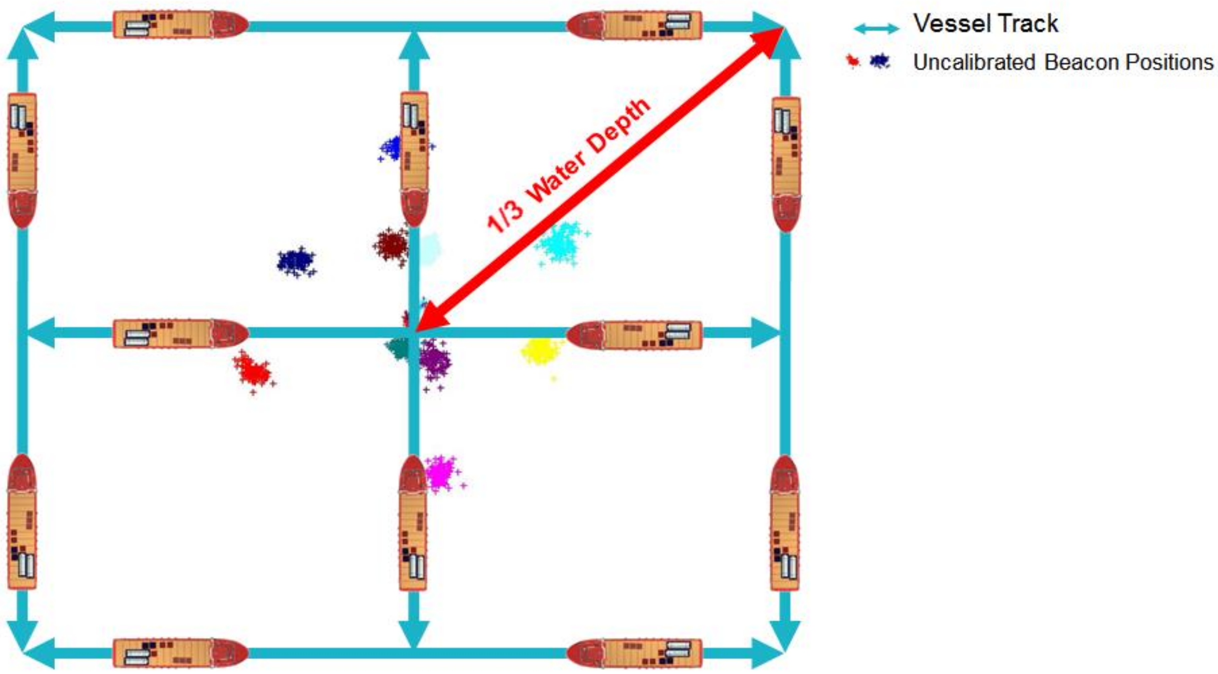


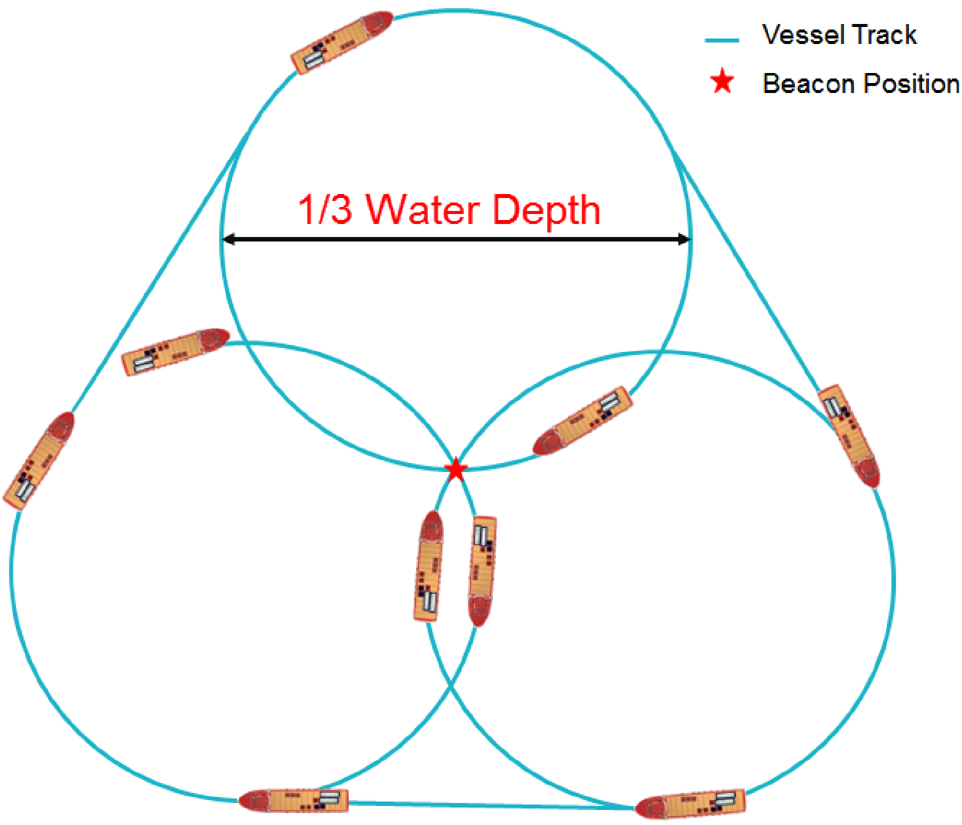
Figure 4-7 illustrates a suggested sail pattern that can be used to collect data. It shows the pattern broken up into a number of straight run lines. This is recommended as it minimises any effects of heading sensor latency and the potential effects of centripetal acceleration that may affect some VRU's that are not mounted at the centre of rotation during vessel turns. These effects are usually only seen with older generation heading sensors and VRUs, as newer inertial based technologies such the Ring Laser Gyro (RLG) will remain stable at higher rates of rotation.

- Vessel heading should be equal to the course made good and data must be gathered on reciprocal headings.
- The data collection pattern can be orientated in any direction to suit the prevailing weather conditions.
- Collect data on lines that are a horizontal distance of 1/3 x water depth to a minimum of 50 m and a maximum offset of 500 m from the target.
- Square pattern (*Figure 4-7*) is only a recommendation. Provided the recommended guidelines are followed, then other patterns may be appropriate. Consideration should be given to heading sensor and VRU stability.
- Vessel speed should reflect the operational use of the system, but should not exceed the tolerances of the deployment pole. Consideration should also be given to ensuring enough data points are collected, while maintaining a suitable steerage speed.

4.7.3 Small Vessel, Shallow Water – Clover Leaf

For small inshore vessels in shallow water (<50 m) fitted with modern survey grade aiding sensors but without DP, it may be difficult to collect calibration data due to the limited time available to collect good USBL positions as the vessel passes the beacon. In this case it may be more convenient to collect data using alternative sail patterns such as the clover leaf.

Figure 4-8 Dynamic data collection pattern for shallow water

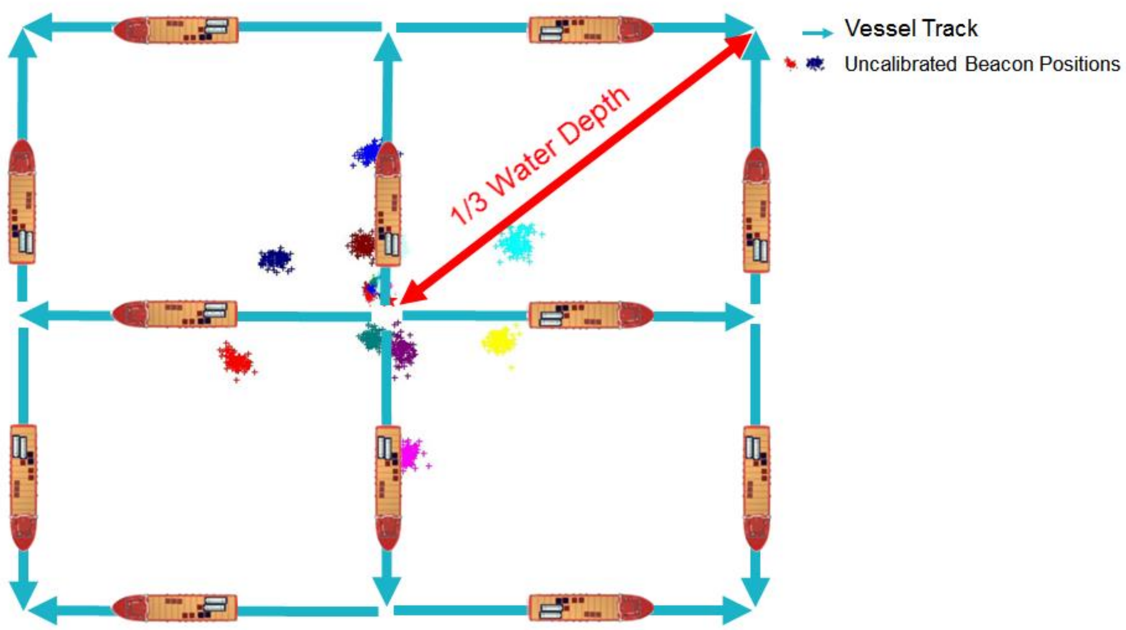


4.7.4 30° Tilted Head – Static or Dynamic

Some transceivers may be fitted with a tilt adaptor to improve performance from a certain direction, usually rearwards, so as to improve tracking at higher elevations. This makes calibration using traditional sail patterns difficult. In the case of a rear facing transceiver, it will not be possible to collect data forward of the transceiver, preventing the collection of reciprocal data.

When calibrating a tilted transceiver it is only necessary to collect data on a single heading at each run line or cardinal point. Run lines should start at the beacon and then persist to 86% of water depth (for a 30° tilt); this should ensure that data is gathered within the optimal cone of reception for the USBL transceiver.

Figure 4-9 Dynamic data collection pattern for a 30° Tilted Transceiver



5 Verification

5.1 What is Verification?

For the purpose of USBL, a verification check is the process of quantifying the quality of a USBL system position and the performance of its aiding sensors and the installation offsets, either before a USBL calibration (perhaps at the start of a project to determine if one is needed), or after a USBL calibration, to confirm the correct application of derived corrections. There is no standard procedure that is in use, and in many cases no checks are performed. As a minimum, the system should be utilised to confirm the quality of the position in an operational setting, which is not necessarily done through a calibration itself.

Note

A verification check can be performed in order to verify that a previous calibration is valid. This can take place immediately following a calibration, or at any time after, and can be used to identify whether a subsequent calibration is necessary. On some occasions, a verification check maybe sufficient, rather than completing a full calibration.

There are several different methods that can be used to verify a system's performance depending on the type of work that is to be carried out and what is available at the time the verification check is to be performed. These are detailed in the following sections.

5.2 Why Verify?

Due to the cost of vessel time to perform a CASIUS calibration it may be valid to perform a check of the final system performance using methods other than a full calibration.

An operator should consider a verification check is performed:-

- Prior to a CASIUS calibration to see if a project tolerance can be met with the existing corrections.
- Post CASIUS calibration to confirm the success of the calibration and check offsets have been entered correctly into the system.
- To extend the validity of calibration on a dimensionally controlled, change managed vessel where no system changes have been recorded.
- At the end of a project to ensure the system is still performing as expected.
- When changes are made to the deployment pole or it is suspected to be damaged.
- When the operational scenario has significantly changed, ie water depth or layback.
- When there are suspected performance issues with the system.
- When installing a GyroUSBL or other USBL transceiver with internal motion compensation, to confirm corrections and offsets are correct.
- After USBL transceiver or an aiding sensor is changed.
- Any time the system performance needs to be quantified.

5.3 Verification Method

Prior to performing a system verification, it is essential that an up-to-date sound speed profile or surface and mean values are obtained, and correctly applied within the software. This is because the effects of refraction (see *Section 4.2.2*) can be misinterpreted as an error in the corrections, or offsets applied within the system.

The methods discussed in *Section 4.4* can be utilised while the vessel is in port, and may provide the operator with an indication of a system's performance prior to setting to work. However it should be noted that the port environment only provides shallow water, and therefore a true determination of the effects of any residual errors cannot be made. More rigorous methods are available to determine system performance while at sea, in an operational environment.

5.3.1 Transceiver Pitch/Roll Spin Check

The most common method of identifying the presence of any residual pitch and/or roll errors in the attitude of the USBL transceiver is to perform what is known as a spin check. The technique involves manoeuvring the vessel through a 360° rotation while directly over the top of the transponder. Position data can be collected continuously or at 90° intervals during the spin. This can only be successfully achieved if the vessel has a DP system.

The spin should be performed with the USBL transceiver directly above the transponder, and using the USBL transceiver as the centre of rotation. This minimises the effects of a transceiver heading misalignment and/or refraction. It is also crucial to ensure that the offsets between the USBL and GNSS antenna are accurately defined. Operators should ensure that the vessel spin is of a suitable rate of turn to accommodate the prevailing weather conditions and to ensure sufficient data is gathered without creating excessive vessel noise.

During the spin, the vessel's position and heading should be logged alongside the transponders position. If no residual pitch and/or roll errors are present, and the offsets are accurately defined, the transponder position should remain static throughout the spin, only displaying a spread of positions due to random error. If the transponder position appears to move, usually in a circular shape (sometimes referred to as a 'doughnut'), then this may be attributed to a pitch, roll and or offset error. To ensure that this error is not due to incorrect offsets the system can be tested in a different water depth. With an offset error, the doughnut will not change directly proportional to depth as with angular errors, e.g. a larger diameter 'doughnut' in deeper water, smaller diameter 'doughnut' in shallower water will be due to an angular error.

Whilst this test identifies the potential presence of any residual errors, it does not identify whether it is in pitch or roll, or both that contribute. A pitch error in the USBL transceiver can be detected during a Transceiver Alignment Sail-Away Check. As you sail a line over the top of a transponder, its depth will continually increase or decrease (depending on positive or negative pitch) as you sail towards or away from it.

5.3.2 Transceiver Alignment Sail-Away Check

A simple method to check the alignment of the transceiver while at sea is to sail a straight line over the top of a transponder that is placed on the seabed at a known location. You can then determine an approximate heading error using trigonometry. This is done by measuring the distance of the vessel from the known transponder location and the distance travelled by the transponder (perpendicular to the vessel sail line) from its known location (the across track error) and then using the following equation:

$$\tan\theta = \frac{\text{across track error}}{\text{distance}}$$

With the distance being the vessels distance from the transponders known location and θ being the calculated heading error. This method would not normally be used in place of a CASIUS calibration, unless a full CASIUS calibration was not possible.

5.3.3 Verification against a Known Point

Often at a worksite there will be existing published coordinates for existing assets (such as a wellhead), boxed-in transponders or transponder frames that can be used to confirm the final accuracy of the USBL system simply by taking a fix. This can be quickly performed by tracking a transponder at the known location and comparing the results to the published coordinates. The vessel should be positioned slightly offset to the target to highlight pitch, roll and heading at once.

This has the benefit of directly showing the performance of the system and all of the aiding sensors. Caution should be used when testing against a known point as a system verification check as the quality of the known position is rarely published. Often a wellhead will be derived from the surface position of the vessel that drilled the well and will not be as accurate as the USBL positioning system being tested.

Should the USBL position not match the published coordinates to the required tolerance, a spin test, directly over the known point, should be undertaken to ascertain the quality of the known point as this should highlight any systematic bias in the USBL in all cases except where pole flex due to water current causes a position bias on a particular bearing (in the direction of the water current).

This type of verification check should ideally be performed over a long enough period to check the precision and accuracy of the system and its aiding sensors. The more critical the application, the longer the test should be run.

5.4 Interpretation of Results

5.4.1 Transceiver Pitch/Roll Check

During a spin test, the vessel should sit with the USBL transceiver positioned directly over the beacon. It is usually standard practice to monitor the navigation screen in the third party software, and on the Sonardyne USBL software as the vessel rotates through 360°. This allows the operator to observe the actual motion of the transponder position as the vessel performs the spin and can identify if any issue is present in real-time. The operator can also confirm that offsets have not been duplicated in the two systems. All relevant data is automatically logged (time, vessel position and heading, transponder position) and this can then be plotted in a spreadsheet or using the DAT program supplied with Ranger 2/Marksman, to identify potential residual pitch and/or roll errors.

Figure 5-1 Scatter plot showing transponder position during vessel spin test

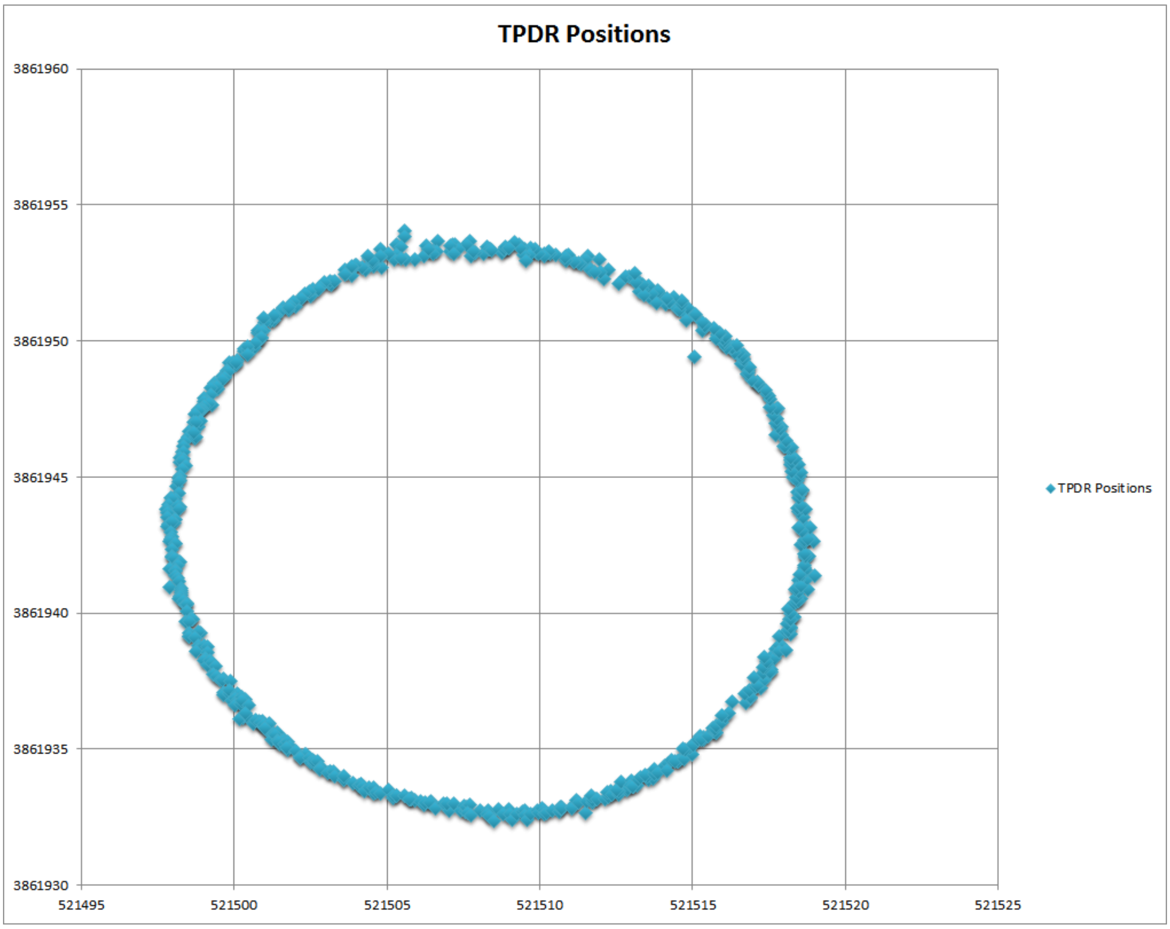


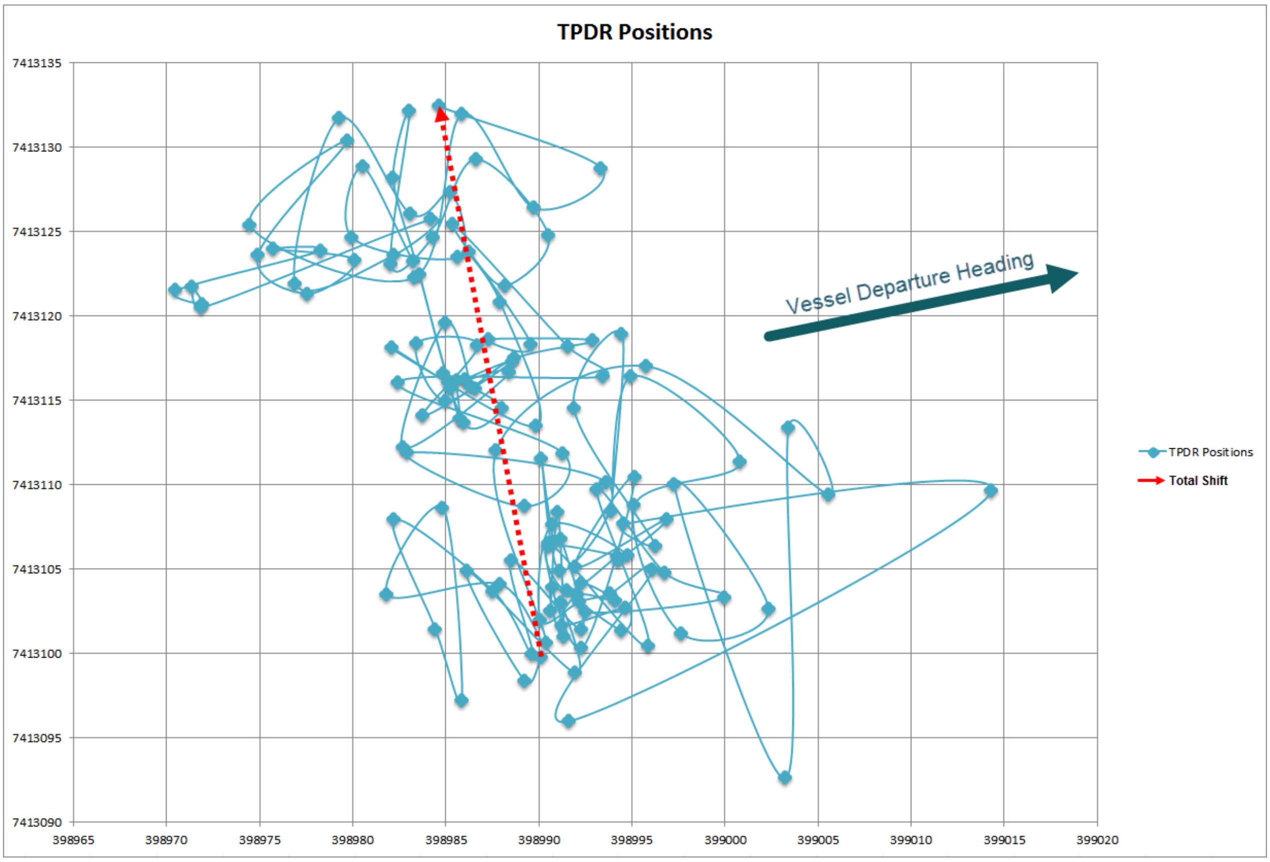
Figure 5-1 shows a doughnut where the transponder positions are biased with respect to the vessel heading. In a calibrated system with no pitch or roll alignment error and well known offsets, you would expect the transponder to remain static as the vessel rotates, producing a plot with an even scatter of positions with respect to heading.

5.4.2 Transceiver Heading/Pitch check

In order to confirm the alignment of the transceiver with respect to the vessel reference frame, a line can be sailed directly over the beacon. As the effect angular errors will have on a position will vary with distance, any heading misalignment will increase as the vessel moves towards or away from a transponder. The same will be true of pitch errors with respect to transponder depth. Sound velocity error can also give a change in depth; this will produce a “Smile” effect in depth as vessel sails towards, over, then away from transponder.

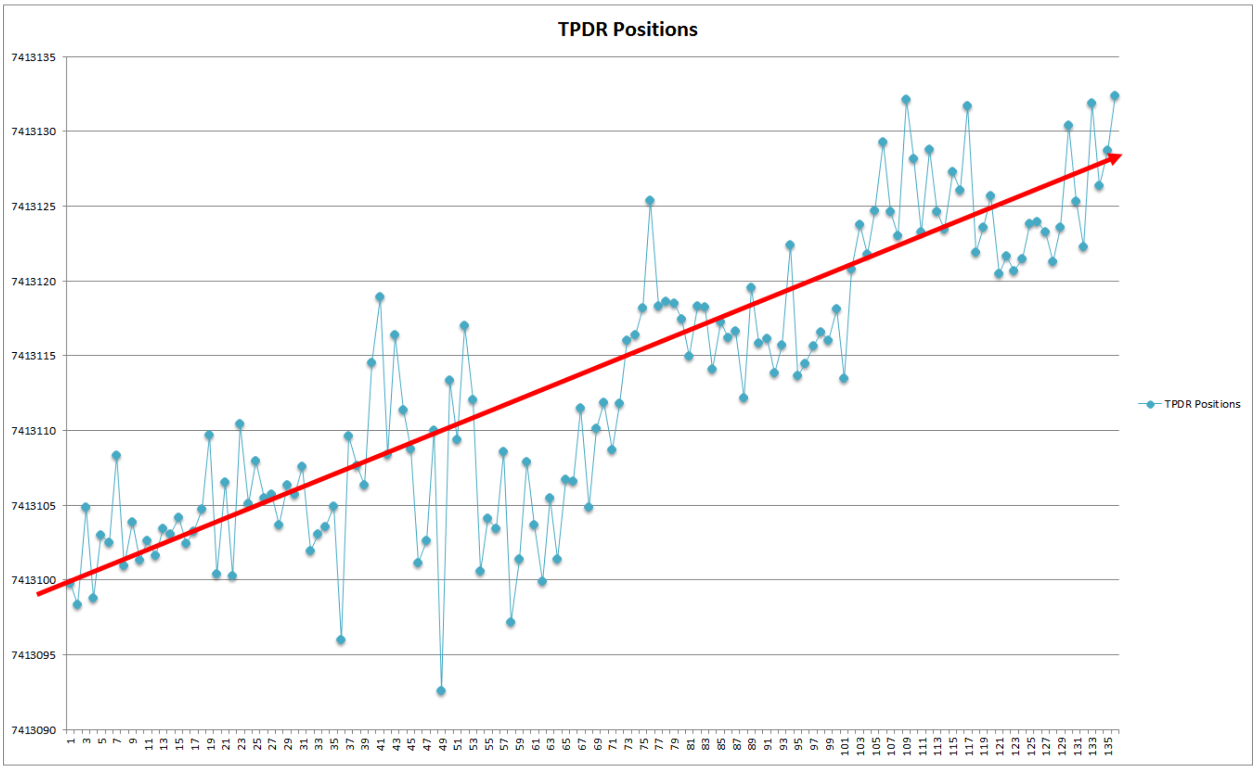
On completion of sailing a run line for the purpose of performing a transceiver alignment check, as discussed in *Section 5.4.2*, the approximate residual heading error can be estimated using trigonometry. The data however can also be represented visually, to identify the effect on position caused by the transceiver misalignment at varying distances. This can be done by plotting a scatter plot in Excel or DAT tool of the Vessel distance vs. the transponder delta position (movement from its known location):

Figure 5-2 Scatter plot showing transponder departure versus vessel distance



In *Figure 5-2,* the beacon can be seen to have a generally Northern trend as the vessel moves away from the transponder. The effect can be more clearly seen in real time on the navigation screen or by plotting the Northing position data against time or fix number as shown in *Figure 5-3*. In systems with no residual alignment errors, the beacon position would not change with distance. The spread of data may increase with distance.

Figure 5-3 Scatter plot showing transponder position northing versus fix number



If the calculated transponder depth is also logged while sailing a run line (for the alignment check), then the data can be further analysed to isolate the presence of any pitch errors by plotting the Transponder Depth vs. Vessel Distance:

Figure 5-4 Scatter plot showing transponder depth moving with distance

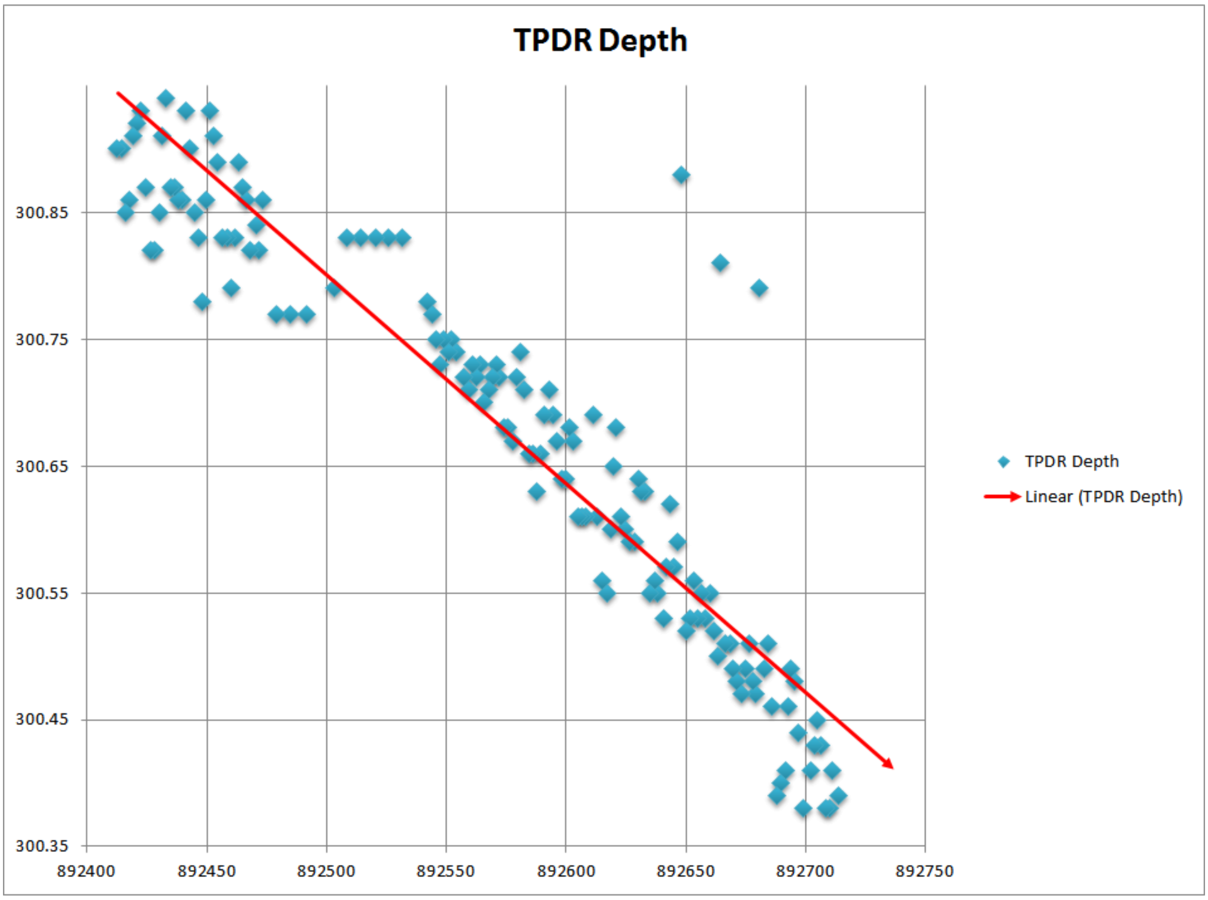


Figure 5-4 clearly shows the depth of the transponder increasing as the vessel sails away, indicating a negative tilt error may remain.

On verifying the correct application of CASIUS derived corrections, and identifying if any residual attitude errors remain, it is then down to the operator to determine if these errors are manageable and still conform to the project specification, or if further analysis or recalibration is required.

Note

For a more detailed discussion on how errors can affect USBL system, refer to "White Paper – Errors in Hydro-Acoustic Positioning Systems.pdf" (WP-ERR-SON).

6 Feedback

Have you noticed an error in our documentation?

Do you have suggestions to improve our documentation?

Please let us know by completing this form and sending it to:

Survey Customer Support Group
Sonardyne International Limited
Blackbushe Business Park
Yateley, Hampshire
GU46 6GD
United Kingdom

Or alternatively, contact the Survey Customer Support Group by phone on:

+44 (0) 1252 872288

Or by email at:

survey.support@sonardyne.com

Technical Document Feedback Form

Name :	
Company:	
Email / Contact Address:	
Document Name:	
Document Version:	
Page Number(s):	

Description of Problem / Suggestion / Correction:

……
……
……
……
……
……
……
……
……
……
……
……
……
……
……
……
……
……
……
……
……
……
……
……
……

Appendix A – CASIUS Calibration Report

A.1 Stationary CASIUS Calibration in 2,168 m

CASIUS Calibration Report

Sonardyne
SOUND IN DEPTH

Vessel: Device No: 191 Date/Time: 13 August

Settings:

Initial Estimates for BoxIn	
Transceiver depth offset	8.550m
Transceiver depth	8.550m
Antenna starboard offset	0.000m
Antenna forward offset	0.000m
Antenna height offset	0.000m

Error Estimates for BoxIn	
DGPS lags USBL	0.00s
Range measurement	0.2m
Range gate	1.0m
DGPS position	2.0m
Beacon position	30.0m
Beacon depth	5.0m
Sound velocity	15.0m/s
Transceiver depth	0.5m
Transceiver offset	1.0m

Transceiver & Beacon	
Transceiver Index	11
Beacon Name	1104
Turn Around Time	125.0ms

Depth Aiding	
Boresight Angle Limit	22.0°
Depth Difference Limit	1.0m

Transceiver Attitude Calculation Inputs	
Angle Gate	2.0°
Known Heading Correction	n/a

Values Used During Data Collection	
Transceiver Pitch Correction	-0.12°
Transceiver Roll Correction	0.12°
Transceiver Heading Correction	-8.83°
Sound Velocity	1496.3m/s

Results:

Beacon BoxIn	Beacon Eastings	Beacon Northings	Beacon Depth	Sound Velocity	Transceiver Starboard Offset	Transceiver Forward Offset
Before	206.10m	2654.40m	2168.80m	1496.29m/s	1.39m	4.46m
Calculated	207.45m	2651.27m	2167.69m	1496.00m/s	1.66m	4.55m
Calculated Accuracy	0.03m	0.03m	0.16m	0.07m/s	0.02m	0.02m

Transceiver Attitude	Pitch Correction	Roll Correction	Heading Correction
Before	-0.12°	0.12°	-8.83°
Calculated	-0.12°	0.15°	-5.67°
Calculated Accuracy	0.00°	0.00°	0.02°

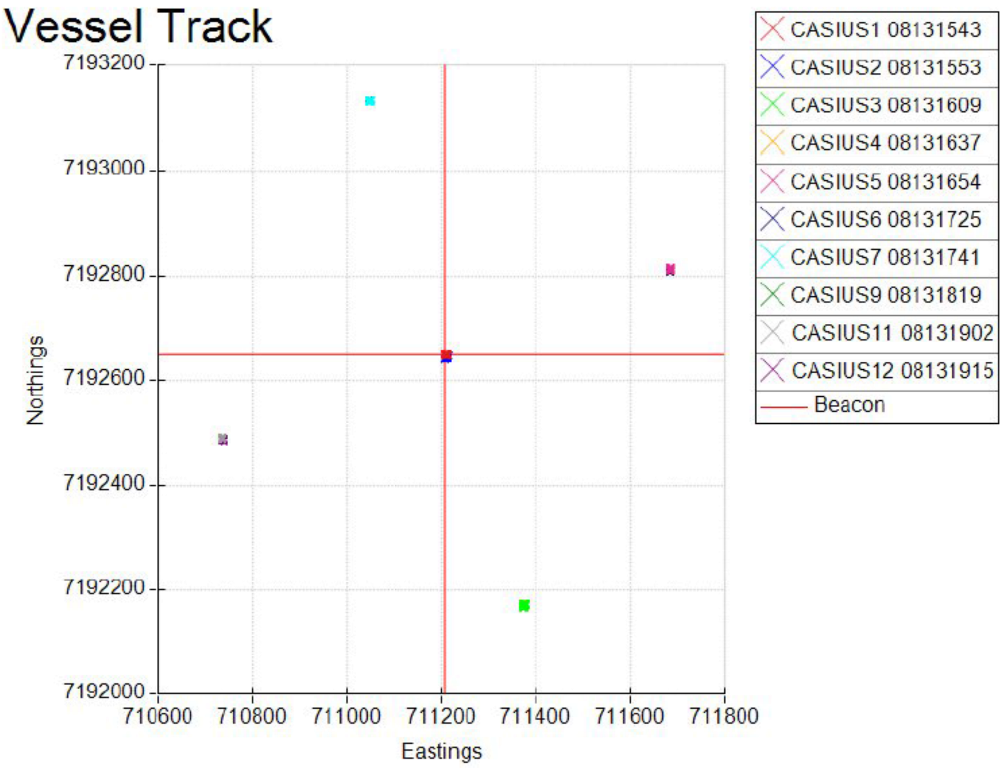
Statistics:

	Before CASIUS (distance)	After CASIUS (distance)	Before CASIUS (% depth)	After CASIUS (% depth)
39.4% Beacon Positions (1 sigma)	25.3m	5.6m	1.17	0.26
50.0% Beacon Positions (CEP)	27.2m	6.8m	1.26	0.31
63.2% Beacon Positions (1 Drms)	29.2m	8.5m	1.35	0.39
86.5% Beacon Positions (2 sigma)	34.4m	14.5m	1.59	0.67
98.2% Beacon Positions (2 Drms)	44.9m	24.9m	2.07	1.15

General:

	Beacon BoxIn	Transceiver Attitude
Number of Iterations	2	3
Number of Fixes Used	1965	1964
Number Depth Aided		0
Average weighted residuals	0.002	0.449

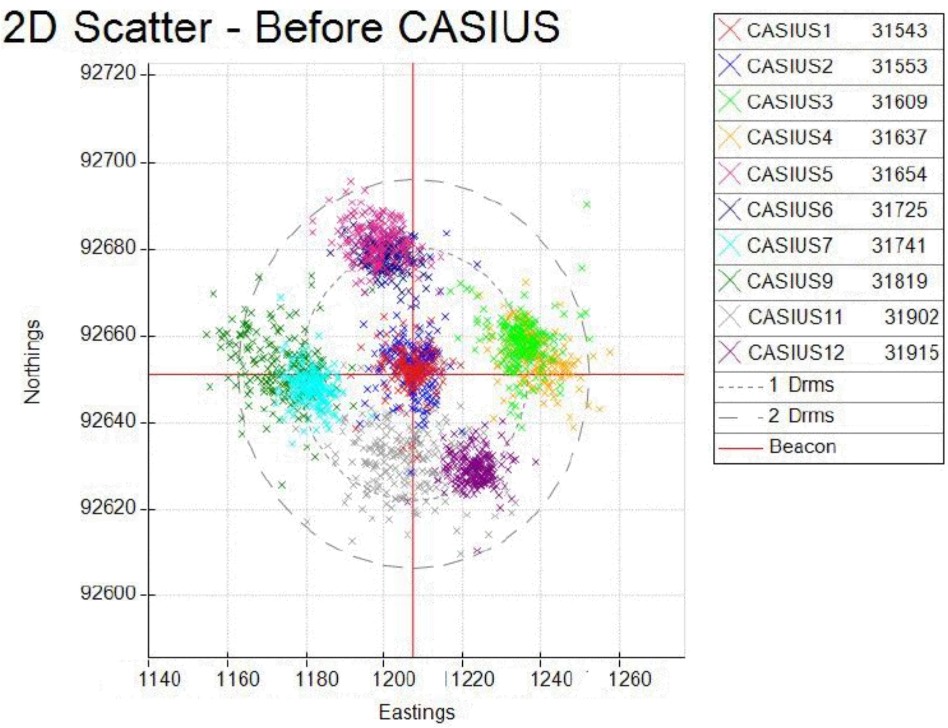
13 August 1 of 4 Version 5.0.1.8

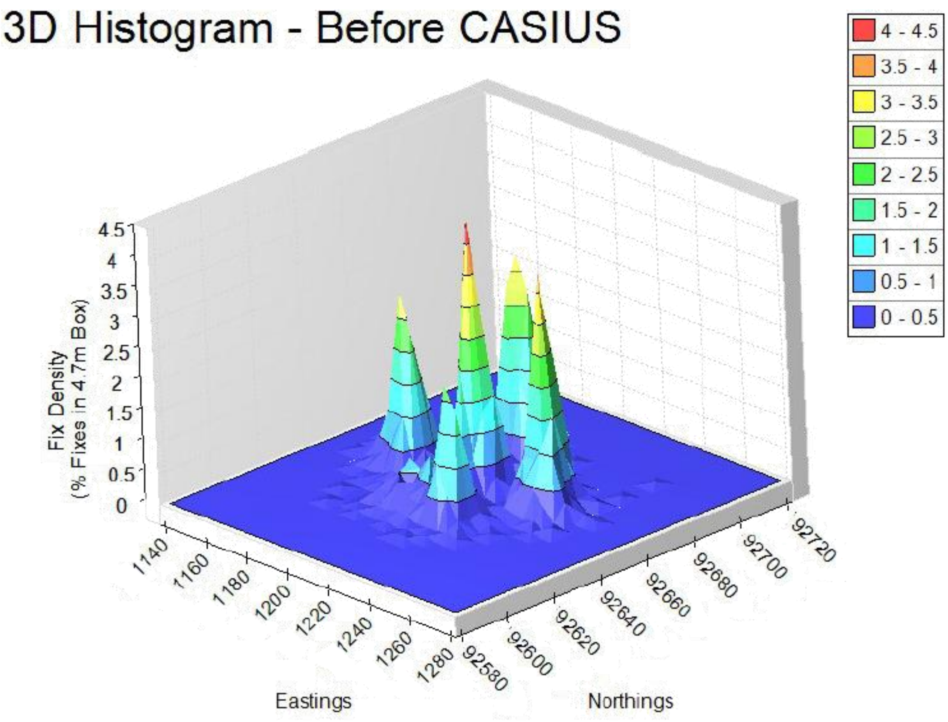


Data used:

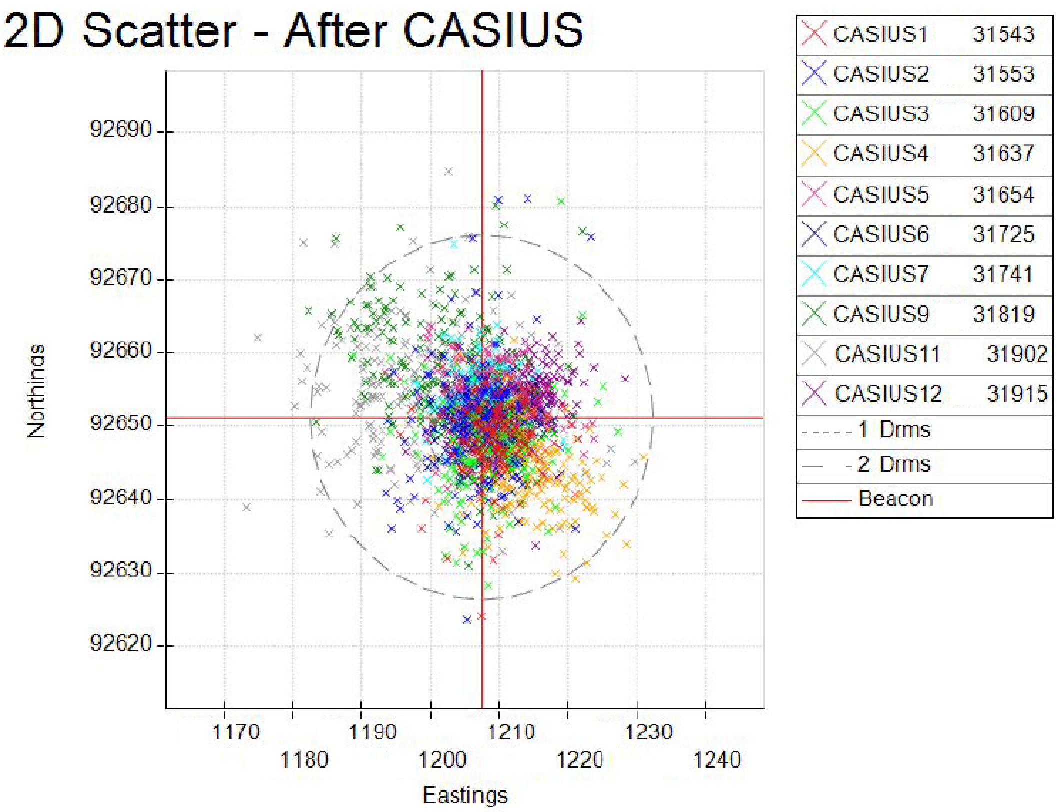
Name	Filename	Start	End	#Acoustic	#Position
CASIUS1 081315				181	545
CASIUS2 081315				204	614
CASIUS3 081316				202	607
CASIUS4 081316				206	620
CASIUS5 081316				203	611
CASIUS6 081317				217	653
CASIUS7 081317				205	617
CASIUS9 081318				208	626
CASIUS11 081319				210	638
CASIUS12 081319				206	617

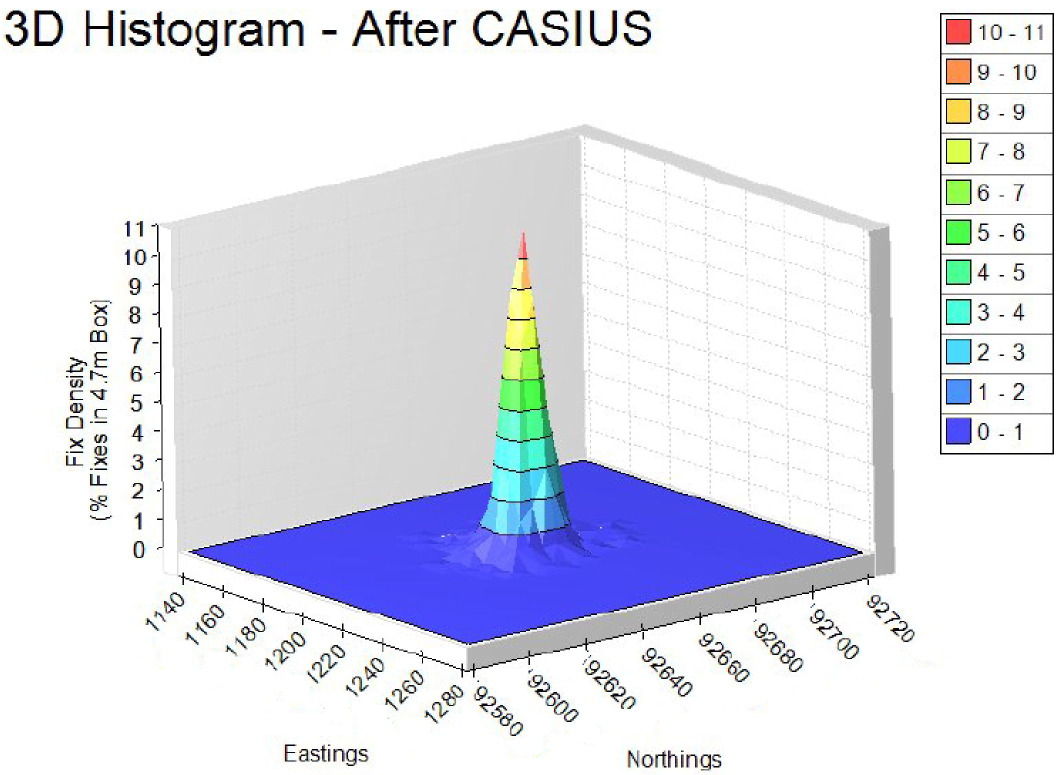
13 August 2 of 4 Version 5.0.1.8





13 August 3 of 4 Version 5.0.1.8





13 August

4 of 4

Version 5.0.1.8

A.2 CASIUS Results Explained

A.2.1 Initial Estimates for Box-In

Measured offset from the USBL and GNSS system to the vessels central reference point (CRP). The CRP should be at the waterline of the vessel to ensure that measured depths match the computed depths and sound velocity profiles. These values can be changed during processing should they have been entered wrongly at the time of collection.

In this example, no offsets were entered from the GNSS to the CRP so as not to duplicate the offset, as the GNSS had been pre-configured to output a position relative to the CRP. This method can produce position errors if the GNSS is not properly configured to compute the lever arm.

A.2.2 Error Estimates for Box-In

These are the values used by the least squares algorithm to weight data based on the confidence levels expected of each measurement type. These values may change depending on the sensors used. In general it is not necessary to change these values to improve the result of the CASIUS calibration and the true error distribution is rarely known. Using slightly pessimistic values to those given on a datasheet will allow for any slight systematic errors.

Depth values should also allow for vessel heave and tide. Ballast level changes from CRP can be accounted in ‘transceiver depth’, this value, along with the ‘transceiver offsets’, should also allow for change in offsets due to rotations from attitude and heading corrections.

GNSS Lag – Depending on how the data has been collected this factor could be important. It is recommended that the latency of the GNSS UTC clock behind the USBL processor clock is determined as closely as possible and the value entered. This latency becomes more critical as the vessel motion increases and needs to be known to 100ms for a vessel moving at 3 knots to keep the resulting rotational correction errors below 1/10th of a degree. If the data is collected while stationary, where this latency is less critical, or if the latency is unknown, enter ‘0’ in this box. CASIUS will assume there are equivalent latencies between validity and internal logging of the acoustic & GNSS.

This example shows the GNSS has been configured with zero offsets as the GNSS was outputting a telegram correct to the CRP. Depending on how the GNSS was configured, this could be an additional source of error or latency.

Over confidence in any of the measurements could distort the calibration and any changes should be made with caution in a methodical manner.

A.2.3 Depth Aiding

The USBL’s ability to measure the angle off boresight is not as good as measuring azimuth or range. When the range and depth are accurately known it can be beneficial to use depth aiding.

The depth aiding works on the principle that the depth of the transceiver is known from start-up data, the depth of the transponder is known from the ‘Box In’ calculation and the acoustic range is known. This means the 2-D range of the beacon from the transceiver can be calculated as the square root of the differences of the range squared and the depth squared.

The X & Y components of the 2D range can then be apportioned in the same ratio as in the original acoustic observation. Depth aiding will only occur for fixes when the calculated angle off boresight is greater than the Boresight Angle Limit in the Start Up page AND the Depth Difference Limit is exceeded.

Boresight Angle Limit - The user is asked for the boresight angle above which Pythagorean depth aiding will be done, it is normal to set this to between 10 and 20°. If none is required then enter 90 degrees.

Depth Difference Limit - In most cases this should kept within 0.5% of the water depth. If the difference between the USBL depth and the beacon depth calculated from the "box in" is greater than the depth difference limit, then the fix is a candidate for depth fixing. If this difference is more than 100 times the Depth Difference Limit, then the fix is ignored in the transceiver attitude correction calculation.

A.2.4 Values Used During Data Collection

This shows the sound speed value and any calibration offsets that were entered in the system during the CASIUS data collection.

A.2.5 Results

For each of the variables, a before and after valued is displayed as well as a confidence level (calculated accuracy) for the result. For a system with a permanent installation, where no changes have occurred to the aiding sensors, it is reasonable to expect that little change should exist in the before and calculated values.

For a new installation, a larger difference may be seen depending on how well known the offsets are prior to the calibration.

The second data box shows, in red, the calculated Pitch, Roll and Heading Correction that should be entered into the navigation software.

A.2.6 Statistics

This should give the user an idea of the overall performance of the system based on the quality of the data and the error values that were used during CASIUS processing. The figure generally quoted is 1DRMS, representing 63.2% of the position data.

A.2.7 General

This shows the amount of position data used during CASIUS processing.

'Number Depth Aided' shows the number of ranges outside of the boresight angle limit set in the Depth Aiding data box. The depth aiding works on the principle that the depth of the Transceiver is known from start-up data, the depth of the Beacon is known from the 'Box In' calculation and the acoustic range is known.

This means the 2-D range of the beacon from the Transceiver can be calculated as the square root of the differences of the Range squared and the Depth squared. The X & Y components of the 2D range can then be apportioned in the same ratio as in the original acoustic observation. Ideally the maximum amount of depth aided ranges would be around 20% of the total number of fixes.

A.2.8 Vessel Track

The vessel track plot shows the raw GNSS antenna positions that have been used, along with the acoustic position fixes, to compute the CASIUS solution. These boxes can be zoomed when viewed in the CASIUS software. Position dropouts can be seen as fixes at position 0,0. Tracks with a higher spread of data could indicate that corrections to the GNSS were not being received at the time.

A.2.9 2D Scatter – Before CASIUS

This scatter plot shows the uncalibrated position fixes for each dataset by colour. Ideally, in an uncalibrated system, if a static data collection method was used, this should show tight grouping for each dataset and for a dynamic calibration it will usually show the positions in thin stripes. This indicates the system is suitably aided for the conditions and is working with good precision. Datasets with a high spread should be reviewed to assess the cause, this could indicate that a thruster is washing over the transceiver or simply that the wind picked up during that dataset, causing an increase in vessel noise. A dataset not typical of the rest of the datasets may be discarded and recollected.

This example shows that the data collected from directly over the beacon is already centred about the CASIUS derived box-in position shown by the red cross hairs. This indicates pitch and roll are already close to their ideal calibration value. Other outer cardinal points have rotated, indicating a heading misalignment.

A.2.10 3D Histogram – Before CASIUS

The uncalibrated positions are now shown as a 3D density heap with taller peaks showing areas with more position fixes. Depending on the magnitude of the misalignment and the data collection method used, this may not clearly show the position clusters. This is normal.

A.2.11 2D Scatter – After CASIUS

As for the ‘2D Scatter – Before CASIUS’ but now shows the processed calibrated positions. If the calibration has been successful, the datasets should all have converged into a single tight group centred on the CASIUS derived boxed-in position shown by the red cross hairs. Common causes for the data not to converge tightly are poor sound speed estimates and deployment pole or reference beacon movement.

A.2.12 3D Histogram – After CASIUS

As for the ‘3D Histogram – Before CASIUS’ but should now show the datasets have converged into a heap. A tighter, sharper peak indicates a lower spread of data and a better calibration result. When viewed in the CASIUS software, the 3D heap can be rotated and viewed from different angles. The peak should be observed from all viewpoints to ensure no secondary peaks exist. Secondary peaks could indicate a problem with the calibration such a deployment pole or reference beacon movement.

Definitions

Term	Definition
6G®	Sonardyne's sixth generation technology hardware platform.
Absolute	Refers to a position in its true real world location (co-ordinates)
Accuracy	Degree to which the measurement conforms to the true value
Acoustic Signal	Information carried by sound pressure waves through water. The Sonardyne acoustic signal has a finite length.
Acoustic Transceiver	An instrument that emits and receives acoustic signals, and extracts information from them. Transceivers can measure the time it takes a signal to travel from its transducer to a transponder and return. Some can encode and send data in a message and extract digital data from a message (Acoustic Telemetry). Used on a surface vessel or to mark a point on the seabed, or fixed to a mobile for tracking or positioning.
Acoustic Transducer	A device that converts electrical signals into acoustic signals and vice versa.
Acoustic Transponder	An instrument that emits an acoustic signal when it detects an interrogating acoustic signal.
AHRS	Attitude and Heading Reference System. An inertial sensor that provides outputs of heading, pitch and roll.
Bore-sight	The axis about which the transducer maximum power gain is being directed.
CASIUS	Calibration of Attitude Sensors in a USBL System. CASIUS is the Sonardyne recommended USBL calibration tool for the determination of accurate transceiver offsets (X, Y and Z) in relation to the GPS antenna and the transceiver Pitch, Roll and Heading errors. It also determines accurate 'through water' sound velocity calculation.
COMPATT	COMPuting and Telemetry Transponder (see Acoustic Intelligent Transponder).
CRP	Common Reference Point. The origin of the vessel frame is called the vessel's Common Reference Point (CRP). The position of the vessel's CRP is arbitrary and can be at any convenient location on the vessel.
Data Fusion Engine (DFE)	Acts as the system controller, generates the display signals for the monitor, processes the data from the transceiver for the display to the operator and output to a DP system talks to various "attitude" sensors and other navigation systems.
Differential Global Positioning System (DGPS)	A 24 hour, world-wide radio navigation system. GPS receivers track and decode the data from satellites and calculate the position and speed of a vehicle.
Dynamic Positioning Reference (DP Reference)	Several position inputs e.g. GPS receivers, taut wire sensors, LBL, SBL, or USBL acoustic positioning sensors, wind speed indicators etc.
Dynamic Positioning System (DPS)	Automatically maintains a vessel with a constant heading, and in a fixed position without an anchor and provides more flexibility in operation.
Digital Signal Processing (DSP)	The representation of signals by a sequence of numbers or symbols and the processing of these signals. D.S.P includes subfields like: audio and speech signal processing, sonar and radar signal processing, sensor array processing.
Firmware	The firmware installed on the transponder. Firmware upgrades can be installed via 6G Terminal.

Term	Definition
Geodetic Co-ordinates	The position of any point on or near the earth surface is defined by an angle of latitude and an angle of longitude. For a point on earth P: Latitude is defined as the angle between the normal plane at P and the plane of the earth's equator. Longitude is defined as the angles between the meridians plane through P and the defined zero meridian plane or "Greenwich" plane. [Ref. Geodesy, fourth edition, Bomford, Oxford, sections 2.03 and 4.10(d)].
GNSS	Global Navigation Satellite System.
Global Positioning System (GPS)	A multi-user, 24-hour, worldwide radio navigation system using the NAVSTAR constellation of satellites. GPS receivers are capable of tracking and decoding data from the satellites and using it to compute the position and velocity of a vehicle.
Gyro Compass	A gyro compass is similar to a gyroscope. It is a compass that finds true north by using an (electrically powered) fast-spinning wheel and friction forces in order to exploit the rotation of the earth. Gyro compasses are widely used on ships. They have two main advantages over magnetic compasses: They find true north, i.e., the direction of earth's rotational fields, e.g. those created by ferrous metal in a ship's hull.
Heading, Roll and Pitch (HRP)	Is a compensated vessel frame. This is a frame sharing the same origin as the vessel frame but with the z axis vertical and the y axis parallel with a meridian passing through the origin (points true north).
Inclinometer	An analogue device which measures the angle of the transponder.
Inertial Navigation System (INS)	A navigation aid that uses a computer, motion sensors and rotation sensors to continuously calculate the position, orientation and velocity of moving object without the need for external references.
Long BaseLine Positioning System (LBL)	A system where two or more transponders are on the seabed. The positions of the transponders are established by a calibration process in a seabed frame. The distances from a transducer to each transponder are measured using a transceiver. The position of the transducer can be computed in the seabed frame. The name comes from the "baselines" joining each transponder.
MF	Medium Frequency (19–34 kHz).
ROV	A remotely operated vehicle controlled and powered by a cable connection so it can travel between the sea surface and seabed.
Signal to Noise Ratio (SNR)	This is the ratio of the signal power to noise power in unit bandwidth generally quoted in dB. Effective operation requires that the strength of a transmitted signal is sufficient to be detected above the noise level at the receiver.
Sound Speed	If seawater is at a constant temperature, salinity and pressure, the speed at which sound travels in seawater is constant. Sound speed can be derived from values of conductivity, temperature and depth, or it can be measured directly using time-of-flight instruments.
Sound Speed Profile	At different depths the temperature, salinity and pressure vary, so the local sound speed varies. Depth cannot be measured directly. So pressure measurements are taken, and the depth calculated, using knowledge of density and local gravity. Derivation of density requires knowledge of temperature and salinity. Salinity cannot be measured directly but conductivity can be measured. A method of measuring the sound speed profile is from a profile of pressure, temperature and conductivity and a formula to compute depth and sound speed.

Term	Definition
SPRINT	Subsea Precision Reference Inertial Navigation Technology. An Acoustically aided inertial navigation system for subsea vehicles. The system extends the operating limits of USBL and improves the operational efficiency of LBL by using sparse arrays.
Sonardyne	Sonardyne International Limited and its affiliates.
Sonardyne Wideband® 2	6G® transponders and transceivers use Sonardyne Wideband® 2 ultra-wide bandwidth signals giving a faster and robust transmission of data, more precise ranging and mitigation from multipath in shallow water and amongst steel structures in deep-water.
TCVR	Transceiver. A transceiver is controlled via a serial cable.
TPDR	Transponder. A transponder is controlled via an acoustic communications link.
True North	The direction of the shortest line that can be drawn, across the surface of the earth, from the observer and the north pole. (The north pole is where the north end of the spin axis of the earth meets the surface).
Ultra-Short BaseLine Positioning System (USBL)	A system similar to an SBL system except the system uses three or more elements in a single transducer array. The measurements it makes are the differences in "time-phase" of the signals from each element. The co-ordinate frame is fixed to the transducer array which must be oriented in the vessel frame to the equivalent to the SBL.
UTC	Universal Time Co-ordinate. The primary time standard by which the world regulates clocks and time. Closely related successor to Greenwich Mean Time (GMT).
Universal Transverse Mercator (UTM)	A projection system that is used to transform geodetic co-ordinates into an orthogonal two dimensional system, suitable for representation on a plane such as a chart. The co-ordinates are called easting and northing which are equivalent to x and y respectively. The UTM system is a worldwide system. Each projection covers 6 degrees of longitude with the central meridian at 3, 9 degrees etc. east of Greenwich and from 84 degrees north to 80 degrees south. The scale factor on a central meridian is 0.9996 (with some exceptions). The projection is orthomorphic this means at a point the scale in all directions is the same, there is no local distortion. NOTE: Scale factors change with distance from the central meridian. For points away from the central meridian grid north and true north diverge. The difference is called the CONVERGENCE which is positive when grid north is east of true north. The point where the central meridian meets the spheroid equator is given a false easting of 500,000 m. Many countries mapping systems are based on the same system but use a particular reference spheroid.
Vertical Reference Unit (VRU)	Measures the instantaneous roll and pitch of a vessel. The origin of the VRU is usually at the centre of the internal inclinometer at a location inside the VRU defined by the VRU manufacturer.

Sonardyne
SOUND IN DEPTH

Global Headquarters, UK
Blackbushe Business Park
Yateley,
Hampshire
GU46 6GD
United Kingdom
T. +44 (0) 1252 872288
F. +44 (0) 1252 876100
sales@sonardyne.com

Rio das Ostras, Brasil
Av. Zen lotes 05 e 06,
Quadra D,
Zen, Rio das Ostras – RJ,
CEP 28890-000, Brasil
T. +55 22 2123 4950
F. +55 22 2123 4951
brasil.sales@sonardyne.com

Singapore, Asia
34 Loyang Crescent,
Block B,
Singapore,
508993
T.+65 6542 1911
F. +65 6542 6937
asia.sales@sonardyne.com

Houston, USA
8280 Willow Place Drive North,
Suite 130,
Houston,
Texas
77070, USA
T. +1 281 890 2120
F. +1 281 890 7047
usa.sales@sonardyne.com

Aberdeen, UK
Units 12–14,
The Technology Centre,
Claymore Drive,
Bridge of Don, Aberdeen
AB23 8GD, UK
T. +44 (0) 1224 707875
F. +44 (0) 1224 707876
sales@sonardyne.com

24/7 Emergency Helpline
T. +44 (0) 01252 877600

Email Support
support@sonardyne.com

Website
www.sonardyne.com

Twitter
@sonardyne