

Common Industry Technical Specification for the Calibration and Verification of Ultra Short Baseline (USBL) Positioning Systems



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Common Industry Technical Specification for the Calibration and Verification of Ultra Short Baseline (USBL) Positioning Systems

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Scope

Operational standardisation and simplification have been identified as major opportunities for the oil and gas industry to reduce inefficiency, complexity, and excess costs. This is especially true with regular lengthy recalibrations of USBL systems when often they can be simply and quickly verified as fit for purpose.

The intended philosophy of this document is such that if a USBL system fails the system verification, a USBL calibration shall be conducted.

This IOGP specification is intended to leverage these opportunities and utilise the collective industry experience of the IOGP community, Suppliers, and other industry stakeholders to develop 'a fit for purpose' shared common industry specification. This specification is intended to be applied globally.

It is assumed the reader is fully familiar with Ultra Short Baseline (USBL) acoustic positioning systems. For the purpose of this document the term USBL is used throughout but is interchangeable with both Super Short or Ultra Short Baseline (SSBL or USBL) terms.

Foreword

This document aims to provide a global common industry technical specification accepted by both Operators (Purchasers) and Contractors (Suppliers) for the calibration and verification of Ultra Short Baseline (USBL) acoustic positioning systems.

It is intended to be included by operators as a specification in tenders and contracts for offshore surveys (e.g., seabed surveys, survey inspection, or construction survey support). This specification is not applicable to USBL systems that are solely used for vessel dynamic positioning purposes.

This document will not duplicate existing material and will, where applicable, reference documents such as:

- IMCA guidance notes:
 - S 017, *Guidance on Vessel USBL Systems for Use in Offshore Survey, Positioning and DP Operations*
 - S 013, *Deep water acoustic positioning*
- IOGP Guidelines:
 - Report 373-19 / IMCA S 015 - *Guidelines for GNSS positioning in the oil & gas industry*
- Kongsberg HiPAP 500 (Rev A), *Calibration Procedure: Survey Applications - HiPAP & Gyro*.
- Sonardyne WP-CAL-SON-2, *White Paper - Calibration and Verification of Sonardyne USBL Systems (including GyroUSBL)*.

The USBL acoustic positioning system is a component of an integrated positioning system and its overall performance relies on accurate, calibrated, and reliable sensors fixed to the vessel frame and interfaced to the USBL system, such as Global Navigation Satellite Systems (GNSS), Heading Reference Systems (HRS), Motion Reference Units (MRU), and Sound Velocity Profilers (SVP). Whilst the correct calibration and verification of the systems are key, this specification will not include detailed specifications on these systems but will reference existing industry guidance and practices.

This document focusses on the technical aspects of USBL calibration and verification requirements. Other factors related to operating a USBL system, out of the scope of this document, are:

- daily operational considerations
- acoustic frequency management
- integration of additional subsea position sensors into the final solution, such as DVL or INS
- handling and storage of batteries
- over-boarding equipment and other safety concerns
- configuration of temporary transducer poles, etc.

Abbreviations

Term	Definition
2Sigma (2σ)	2 x standard deviation error about a mean value
APOS	Acoustic Positioning Operator Station (Kongsberg Maritime)
CASIUS	Calibration of Attitude Sensors in a USBL System (Sonardyne software)
CoG	Centre of Gravity
CRP	Common Reference Point
CTD	Conductivity, Temperature & Depth
DP	Dynamic Positioning
GNSS	Global Navigation Satellite System
ROV	Remotely Operated Vehicle
RTK	Real Time Kinematic
DRMS	Dimensional Root Mean Square
HRS	Heading Reference System
HiPAP	High Precision Acoustic Positioning (Kongsberg Maritime)
IMCA	International Marine Contractors Association
INS	Inertial Navigation System
MRU	Motion Reference Unit
QC	Quality Control
SNR	Signal to Noise Ratio
SSBL	Super Short Baseline (interchangeable with USBL for this specification)
SVP	Sound Velocity Profiler
USBL	Ultra Short Baseline
VRF	Vessel Reference Frame

Definitions

In this document, SHALL denotes a requirement that is mandatory for conformance with the specification and requires that there be no deviation.

In this document, SHOULD denotes a guideline or recommendation where nonconformance with the specification is permissible.

1. Accuracy

In terms of a USBL acoustic positioning system, accuracy refers to the difference between the observed and the true position of a target. This can be expressed as a percentage of the observed slant range (i.e., the distance between the target and the acoustic transducer). It can also be expressed as a combination of angular accuracy in X and Y directions and range detection. These measurement errors can then be related to a linear metric given a set of operational parameters, such as target depth and the horizontal distance between the target and the transducer.

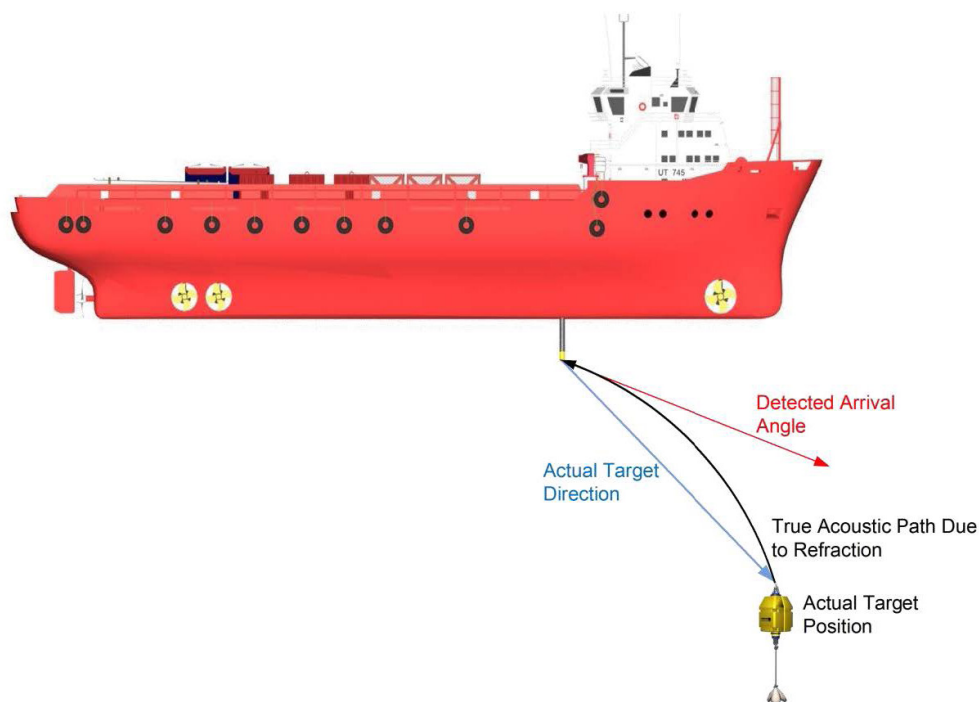


Figure 1: Effects of refraction in positioning a target with a USBL system due to changes in the speed of sound in water [Ref: [7]].

The overall accuracy of a USBL system is affected by how accurately the transducer alignments can be determined. Hence the accuracy to which the transducer alignments are computed depends on the analysis of absolute transponder positions.

This relies on the following factors:

- 1) the cumulative effect of the errors inherent to each component of the USBL system (e.g., USBL, GNSS, MRU, HRS)
- 2) the systematic errors within sensor and software configuration (e.g., application of speed of sound profile, sensor offsets)
- 3) the alignment of the individual components of the USBL system to the vessel coordinate reference system

- 4) accuracy of environmental sensors (e.g., speed of sound sensors) and conditions at the time of calibration (e.g., sea state, thermocline, refraction), see Figure 1
- 5) the calibration geometry determined by the ratio of water depth to vessel stand-off distance

Propagating the factors above into an overall positioning error budget provides an indication of how well the transducer alignments can be resolved. However, the final assessment of the vessel's project readiness should be made in terms of whether the verification result meets project specific accuracy requirements.

The Supplier shall provide the Purchaser with an error budget for the project, detailing the total USBL system accuracy as a linear metric. This error budget shall meet or exceed project accuracy requirements provided by the Purchaser. The error budget shall represent the expectation of achievable accuracy of a single and average subsea position computation within the specified operational parameters. This also defines the difference between the individual sensor and complete system accuracy. Refer to Section 4 of IMCA S017 (Ref: [2]) for examples of USBL error budgets and guidance on how these are developed for various water depths.

To be considered fit for purpose, the USBL acoustic positioning system proposed by the Supplier shall meet the system accuracy required for the application. For example, the acoustic positioning requirements for a dive operation may not be the same as a subsea structure installation operation. The project accuracy requirements shall be defined by the Purchaser within the work scope documentation and detailed by the Supplier within the positioning error budget. Typical system accuracies that a Purchaser may request are demonstrated in Table 1.

Table 1: Three groups of common USBL system accuracy requirements associated with subsea positioning applications.

USBL acoustic positioning accuracy requirements			
Description	Towed tracking accuracy - position requirement	Lower accuracy - position requirement	Standard accuracy - position requirement
Position Uncertainty (1)	Better than 0.3% slant range (2) and increased by +0.1% of slant range for every 10° off-nadir elevation. (3)	Better than 2.75% slant range (2)	Better than 0.3% slant range (2)
Typical applications	Tow fish tracking for hydrographic surveying operations, ROTV tracking for pipeline inspection	Diver positioning, micro-ROV tracking, general subsea navigation	ROV/AUV tracking for As-built surveys, Out-Of-Straightness pipeline survey
NOTES: 1. Accuracy values listed above are quoted at 2DRMS 2. Plus, the absolute positioning accuracy of supporting sensors within the USBL positioning system at 2DRMS, 95% confidence interval (e.g., GNSS, HRS, MRU) 3. For USBL systems that utilise a spherical transducer array, only the lower and standard accuracy position requirement applies to towed applications			

2. Supporting sensor specification

Several factors affect the positioning accuracy of given USBL systems. This section describes the type and specification of sensors that are supplied and interfaced to the USBL calibration software. Each supporting system shall require careful installation, configuration and calibration. The requirements listed below are at the discretion of the Purchaser and dependant on accuracy requirements of the proposed scope of work. The Purchaser's project-specific scope of work shall define supporting sensor requirements, including calibration and certification. The Supplier shall provide the Purchaser with valid test and calibrations certificate for each required system element.

2.1 Sensor offset measurements

Sensor offset measurements shall be determined from the vessel's Common Reference Point (CRP) to the surface positioning antennas, USBL transducer(s), MRUs, etc. Supplier shall produce an offset diagram showing key offsets referenced to a clearly defined and recoverable Vessel Reference Frame (VRF). A repeat survey shall be required if sensors have been physically moved. Where possible, co-locating sensors at the mounted transducer head should be implemented, as it reduces the requirement for offset measurements and maintenance. All offset measurement values shall be verified in the online navigation system, including tagging to the correct antenna and sensor.

2.2 GNSS surface positioning

The Supplier shall install, calibrate, operate, and maintain primary and secondary surface positioning systems in accordance with IOGP Report 373-19 / IMCA S015 (Ref: [5]) guidance. In addition, the Supplier shall demonstrate that any expected correction services are active to ensure that the system is operating at its expected level. The GNSS positions shall be motion compensated within the online navigation package to the relevant Common Reference Point (CRP).

2.3 Motion Reference Unit (MRU)

Where it is not possible to collocate the MRU at the USBL transducer, the sensor should be mounted as close to the vessel Centre of Gravity (CoG) as possible. The MRU shall be directly interfaced to the USBL system. The MRU shall be calibrated into alignment with the Vessel Reference Frame (VRF) through dimensional control observations or through comparison with another currently aligned system.

2.4 Heading Reference Systems (HRS)

The HRS shall be provided via a GNSS or gyrocompass. The HRS shall be calibrated relative to Vessel Reference Frame (VRF) then verified by dimensional control survey methodology. Acceptable methods include:

- by comparison with a known baseline
- another currently aligned system
- astronomical observations

2.5 Synchronisation timing errors

Integration of high-precision survey sensors depends on accurate time referencing. Upon request the Supplier shall make available to the Purchaser a report covering time referencing, clock synchronisation, time stamping, timing accuracy, merging of asynchronous measurements, data output rate, and sensor latency.

2.6 Sound Velocity Profiler (SVP)

The SVP shall be a direct reading sound velocity sensor (i.e., time of flight) or an instrument that measures conductivity, depth and temperature (CTD) separately. The sensor shall have a valid calibration certificate. Reference shall be made to The Hydrographic Society Special Publication 34, *A Comparison between Algorithms for the Computation of the Speed of Sound in Seawater* (Ref: [4]) for guidance on the suitable sound velocity calculation to be applied when using a CTD sensor.

2.7 Transponders

Transponders shall be depth rated for the maximum water depth of the survey area and compatible with the vessel USBL transducer. Refer to IMCA S017 Section 5 (Ref: [2]) on guidance to operational considerations of transponders.

3. Equipment certification

Relevant documentation on USBL systems shall be readily available to the Purchaser. This includes:

- The installation and commissioning report¹
- Current HRS, MRU, and position sensor inputs together with their physical location, configuration and calibration and/or verification status and history
- Depth rating, battery endurance, transducer beam specification and frequency of USBL transponders
- Dimensional control information pertaining to a VRF definition, offsets between sensors, transducer, CoG and any defined CRP¹
- Current diagram showing the integration of the various sensors to the USBL system
- Transducer inspection and/or maintenance reports
- Current system installed software and firmware versions and update log
- Configuration report detailing current offsets, alignments and interfacing parameters of the USBL system as entered in its topside interface
- Copies of recent USBL verifications, full USBL calibrations, coupled with parameters used in the system at the time of the test (offsets, pitch and roll corrections, etc.)²

¹ In many cases, the USBL system installation and commissioning report may provide offsets based on basic survey methods suitable for DP operations. Higher precision dimensional control survey methods may be required for some survey applications.

² In some cases, historical reports, parameters, and test data for the acoustic positioning system may not be available.

4. Minimum specification for USBL calibrations

The USBL acoustic positioning system shall be calibrated to determine the following system offsets³:

- Transducer heading misalignment to Vessel North within the VRF
- Transducer pitch and roll misalignments
- Scale factor

Where sound velocity profiles are applied directly within a USBL system, there shall be no requirement to apply a scale factor adjustment. The purpose of solving for scale factor when processing a USBL calibration is primarily to provide a QC check on the validity of the sound velocity profile used for the calibration. Due to variations in sound velocity, any calculated scale factor should not be considered constant for the system.

Supplier shall maintain current and legacy documentation (in tabular and graphical formats) demonstrating that the current performance of the vessel's USBL system meets the contractual requirements. Supplier shall, on request, provide the Purchaser with suitable procedures to demonstrate compliance with this specification in the planning, execution, and reporting of USBL calibrations and verifications. Supplier shall be able to demonstrate the selection of competent personnel to carry out the calibration or verification operation, QC and approval of the results.

The Supplier shall calibrate the USBL system at a water depth commensurate to achieving the best calibration conditions (e.g., optimal calibration geometry, transducer and transponder beam width, and Signal to Noise Ratio). The optimum water depth for the calibration process is between 200m and 1000m. For operations outside of the specified optimum range, the calibration site shall be agreed between Purchaser and Supplier. A previous system calibration should be considered by the Purchaser on condition that the Supplier can provide suitable evidence to support a successful calibration.

Suitable consideration should be made for the prevailing metocean and known environmental limitations (e.g., seasonal thermoclines, current, tidal range) at the calibration site prior to data collection. Vessel manoeuvrability and USBL data quality are impaired by severe weather conditions affecting the outcome of a system calibration. Typically, a USBL calibration is conducted within the operational weather limits of the project work scope. Operations should be scheduled implementing local knowledge and available environmental data of the area (such as weather forecasts) to achieve the optimum system results.

A system verification (see Section 6 of this specification) shall be conducted upon arrival to worksite. Acceptance is subject to Purchaser review and approval prior to commencing operations.

³ Some calibration software routines also allow for the calculation of the USBL transducer X, Y, and Z offsets with respect to the vessel CRP; however, the Supplier shall determine offsets via a valid dimensional control survey. Where a significant discrepancy occurs between the dimensional control result and any calibration-calculated result, this shall be investigated further.

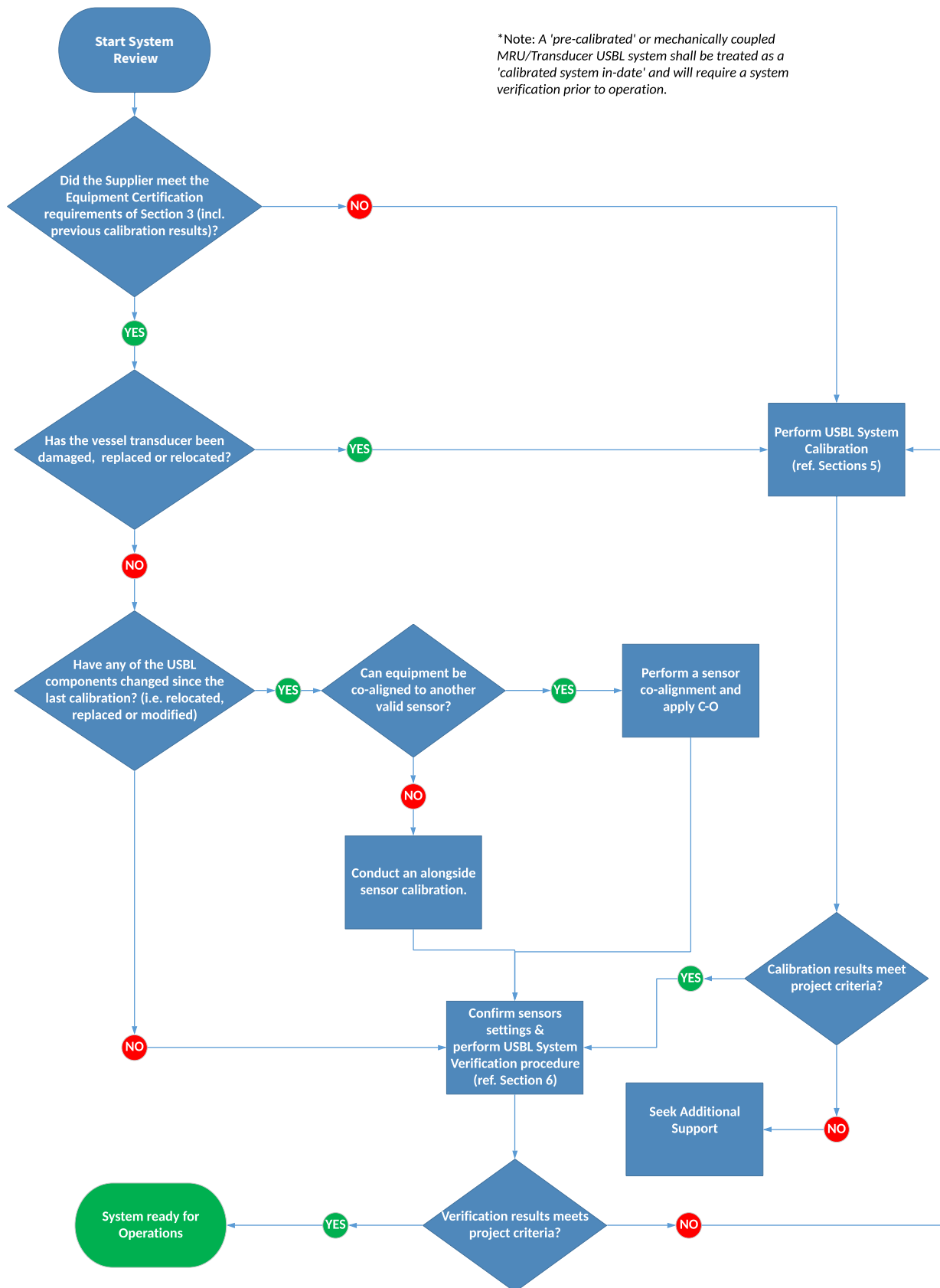


Figure 2: USBL system calibration & verification decision tree

Figure 2 details the considerations and outcomes that inform the Purchaser and Supplier on a system's operational readiness. A full USBL calibration is not required providing a successful project-specific verification test can demonstrate system operational readiness. This includes instances where either supporting sensors or the USBL transducer have been replaced, if the sensor alignment status is fully documented.

If a USBL system fails the system verification, a USBL calibration shall be conducted.

Additionally, the Supplier shall be required to conduct a calibration and verification:

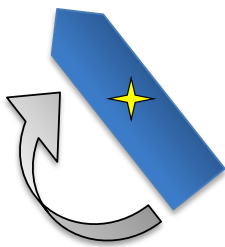
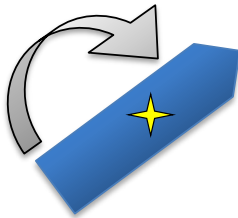
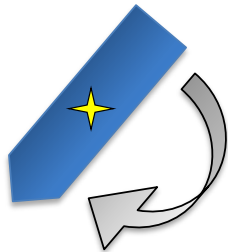
- Following any significant changes or repairs which are deemed to affect the validity of the previous calibration
- Where available documentation on previous system changes or repairs is insufficient
- Where significant discrepancies in position are observed

Significant change to the USBL system includes, but is not limited to, damage to the transducer mounting pole, or changes of HRS, MRU, and GNSS systems where the relationship to the Vessel Reference Frame has not been maintained.

5. System calibration methodology

The Supplier shall provide a USBL calibration procedure that addresses the following requirements:

1	The USBL target transponder shall be safely deployed to the seabed clear of any subsea obstructions, structures, and pipelines. Where possible, the transponder should be installed in a rigid stand or structure bucket, to eliminate movement.
2	Water column sound velocity profiles to seabed and return to sea surface shall be processed and compared to ensure no significant discrepancies. The selected profile processed from transducer depth to seabed shall be entered into the USBL system prior to calibration.
3	A tidal variation strategy should be developed to correct observations or minimise tidal variation during calibration logging periods. This is particularly important in shallow water or areas of large tidal variability.
4	The Supplier shall review the current USBL system's calibration results and transducer alignment corrections prior to conducting a new calibration. There are three acceptable options for the derivation of USBL calibration values. These are: a) Existing calibration values are removed from all systems and new transducer alignment results are only entered directly within the USBL system b) Existing calibration values are removed from all systems and new transducer alignment results are only entered directly within the Supplier's navigation software c) Existing calibration values are retained within the USBL system and residual alignment values are computed and entered into the Supplier's navigation software The strategy shall be agreed between the Purchaser and Supplier.
5	The system transducer shall be positioned above the calibration transponder, or as near as possible.
6	The vessel shall slowly rotate over the transponder, pausing at 90° intervals to record a minimum of 100 valid data points at each interval. The vessel shall maintain a fixed heading at each 90° interval to collect data, minimising the effects of aiding sensor latency (see Figure 3).

	Obs. Interval # 1	Obs. Interval # 2	Obs. Interval # 3	Obs. Interval # 4
				
	After commencing rotation vessel pauses rotation at 90° to observe & log 100 transponder positions	Vessel pauses rotation at 90° to observe & log 100 transponder positions	Vessel pauses rotation at another 90° interval to observe & log 100 transponder positions	Vessel completes rotation at another 90° interval to observe & log 100 transponder positions
	 Direction of vessel rotation  Transponder position on seabed			
	Figure 3: Data collection sequence as a gross error offset check before commencing a full system calibration.			
7	The vessel rotation data shall be processed and analysed to facilitate early identification and removal of any gross offset and/or configuration transducer misalignments.			
8	The vessel shall then re-position at four cardinal points, with a horizontal distance of 30% to 50% of water depth from the target transponder up to a maximum offset of 500m. Operational factors such as Signal-to-Noise Ratio, transducer beam width, direction and power settings are also factors for consideration during selection of offset distance (see Figure 4).			
9	A minimum of 100 valid observations which includes time synchronised: vessel positions, USBL observations and vessel attitude values shall be logged at each cardinal point. The vessel shall maintain a constant heading at each observation station. Figure 4 details the observation stations at a given heading. Supplier shall ensure that the total number of data points recorded is not biased towards any one sector. The orientation of the data collection pattern is determinant on the prevailing weather conditions at that time. The data collection process shall be monitored at each quadrant location to ensure that valid data is being acquired.			

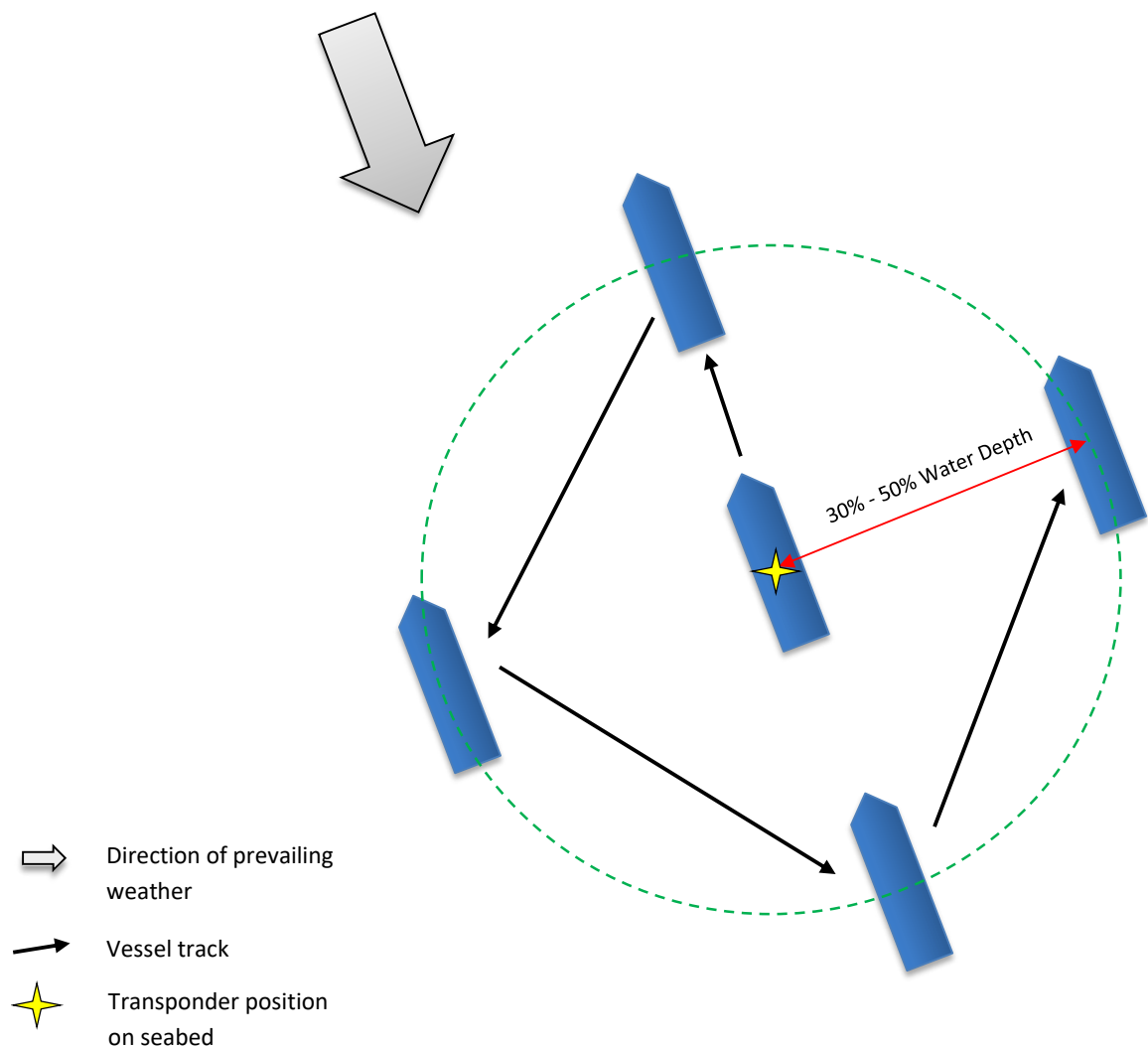


Figure 4: Data collection pattern showing vessel maintaining position and heading into the prevailing weather.

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All position fixes shall be computed and displayed on the online survey system or system software application (e.g., Kongsberg APOS, Sonardyne Ranger) to verify the systematic distribution of position fixes around the transponder.

The average position shall be calculated for each of the four datasets and compared against the overall average in terms of radial distances. The primary numerical assessment shall be to demonstrate that any residual systematic effects are within specification. The maximum difference between the mean of each dataset and the overall average shall be within the positioning accuracy criteria required for the verification to pass. Significant outliers may be removed on agreement between Supplier and Purchaser. Each quadrant dataset shall be evaluated for internal consistency.

11	All collected data shall be processed using either the relevant manufacturer's or the Supplier's software package, as agreed between Purchaser and Supplier. The mean transponder position shall be computed using a least squares solution, including producing the standard deviation of the transponder position.
12	The calibration software routine shall derive estimations of transducer heading, roll, and pitch alignment corrections with respect to Vessel Reference Frame, together with estimations of their uncertainties.
13	If the depth of the transponder can be derived independently (e.g., using suitably calibrated vessel echosounder, or ROV depth during the transponder installation operation), this shall be used as a QC measure on the calibration-derived depth.
14	The new transducer alignment or residual values shall be entered into the relevant system according to the agreed strategy in Section 5, Item 4 above. Compatibility between values in the USBL system and online navigation system shall be verified.
15	The Supplier shall carry out a verification of the USBL system in line with Section 6, upon completion of the calibration. The verification process is completed as evidence that the transducer alignment values have been correctly entered and that the system is operating as required.
16	The Supplier shall provide field calibration results to the Purchaser for review, immediately upon completion of data processing. Within 12 hours of field calibration data acquisition, the Supplier shall provide the Purchaser with a field report of the calibration. The report shall contain: a) location, date and time of calibration b) Supplier and Purchaser representative c) a brief description of method d) calibration results (in tabular and graphical forms) including uncertainty statistics e) references systems used (i.e., primary or secondary) f) water depth of operation g) transducer and transponder settings h) mean sound velocity applied at transducer and cast results used by system i) environmental conditions

When static data collection is impractical, or when non-DP class vessels require USBL operations, data can be acquired dynamically. A set sail pattern as suggested by Figure 5 may be used to collect USBL calibration data. Other suitable calibration options may be agreed between Supplier and Purchaser to determine transducer correction values, depending on vessel manoeuvrability, water depth, and other restrictions.⁴

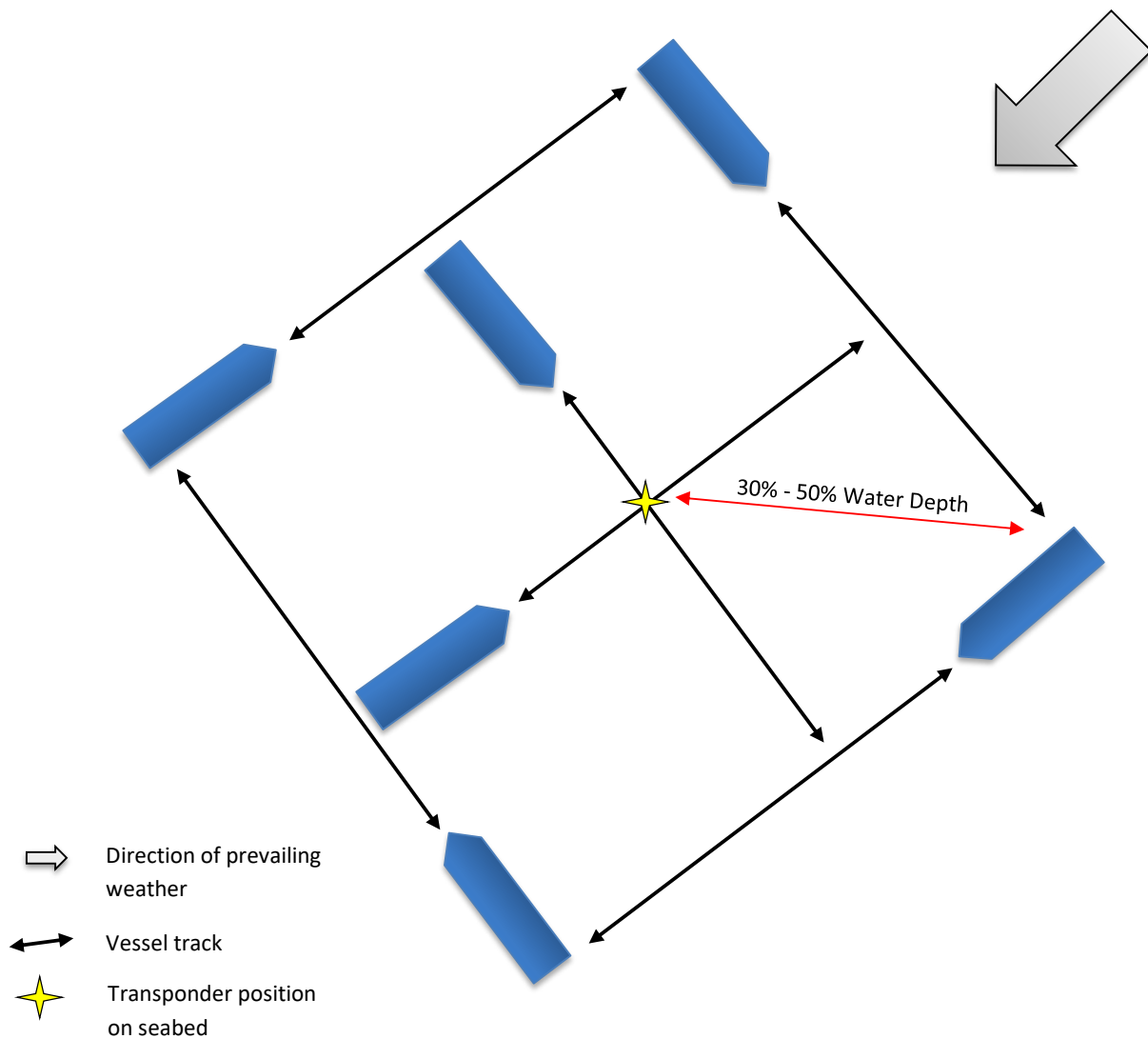


Figure 5: Example square dynamic data collection pattern where run lines are oriented with the prevailing weather. The sail pattern is required to be run in reciprocal directions.

⁴ The dynamic data collection method increases the noise level and cavitation present resulting from increased thruster engine use. For a detailed description of this methodology and for other sail pattern examples please refer to Ref [7], Section 4.7.2.

6. System verification methodology

The objective of a system verification is to prove the accuracy and performance of the integrated USBL system to determine overall positioning quality. This operation shall be conducted immediately after a system calibration (to confirm the correct application of derived transducer alignments) or anytime thereafter (e.g., as an in-field position check at the start of a project, to validate current transducer alignment values).

If the Purchaser is satisfied with the historical trend of previous USBL calibrations, only a system verification is required prior to operations, rather than a full calibration. The vessel's station keeping ability should be considered in the design of the verification exercise. This would typically involve one of the following actions:

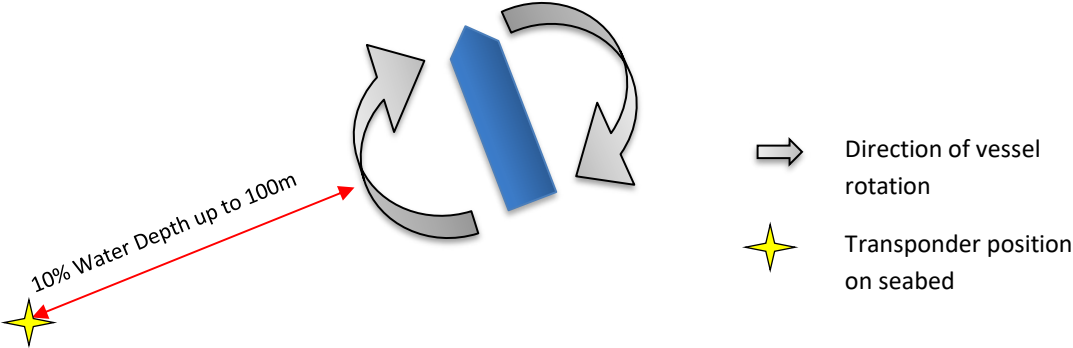
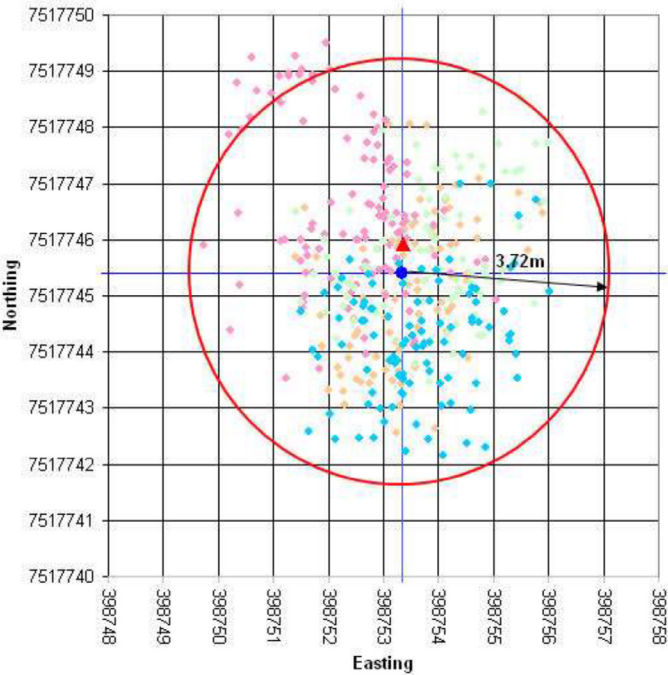
- a) Determine the position of a known point or structure by deploying a transponder onto this point and carrying out a position accumulation, as per points 1- 6 below.
- b) If no known point or structure is available, then deploy a transponder to the seabed and conduct steps 1 – 9 below.

The resulting logged data shall be plotted and examined to ensure that the point distribution of sampled verification data is within the agreed positioning tolerance or error budget for the positioning systems. The Supplier shall perform further checks and calibrations as required to resolve any positioning discrepancies prior to the commencement of work.

If the in-field verification results indicate a failed test (i.e., the maximum distance between the mean of each dataset and the overall average is greater than the project tolerance), the Supplier shall conduct a system calibration on site (ref. Section 5), with agreement of Purchaser, followed by an in-field verification as per steps 1 – 9 below.

The USBL verification operation shall include the following actions, executed according to the vessel's station keeping ability and as agreed between Supplier and Purchaser:

1	A system verification should be undertaken during similar weather and environmental conditions to a system calibration or normal operating conditions. The rate of vessel turn shall be optimised to accommodate the prevailing weather conditions for the best possible data collection.
2	A USBL transponder shall be safely deployed to the seabed as detailed in the previous section. The verification should utilise the transponder already deployed for the calibration if applicable. Depending on the vessel's station keeping ability, a series of tests shall be run to confirm that systematic errors have been minimised such that the overall USBL system is working to specification.
3	For DP vessel operations, setup at a horizontal distance of 10% of water depth up to a maximum offset of 100m away from the seabed transponder (see Figure 6).
4	Position data shall be collected with the vessel stationary on four different headings 90° apart.

5	The four data sets shall be assessed visually in terms of spread, which is an indication of the random noise affecting the system. The spreads shall appear consistent for all four datasets, however variation may be expected according to weather conditions affecting the vessel's relative thrust on each heading. On agreement with the Purchaser, any clear outliers may be removed when assessing the spread.
6	The average position shall be calculated for each of the four datasets and compared against the overall average in terms of radial distances. The primary numerical assessment shall be to demonstrate that any residual systematic effects are within specification. The maximum difference between the mean of each dataset and the overall average shall be within the positioning accuracy criteria required for the verification to pass.
	 The diagram illustrates a vessel verification spin offset. A blue arrow points from a yellow star (transponder position on seabed) to a red arrow (10% Water Depth up to 100m). A grey arrow indicates the direction of vessel rotation. A legend shows a grey arrow for 'Direction of vessel rotation' and a yellow star for 'Transponder position on seabed'. Figure 6: Showing vessel verification spin offset at a distance of 10% water depth up to 100m away from the transponder.
	 The scatter plot shows a normal distribution of reference transponder positions. The x-axis is labeled 'Easting' and ranges from 398748 to 398758. The y-axis is labeled 'Northing' and ranges from 7517740 to 7517750. A red circle represents the 95% confidence interval, with a radius of 3.72m. A blue dot marks the center of the distribution, and a red triangle marks the center of the 95% confidence interval. Figure 7: Results of a 'Good' Spin Verification Test (Ref. [2]) detailing a normal distribution of reference transponder positions with 95% of observations which lie within the given project tolerance of $\pm 3.72\text{m}$.

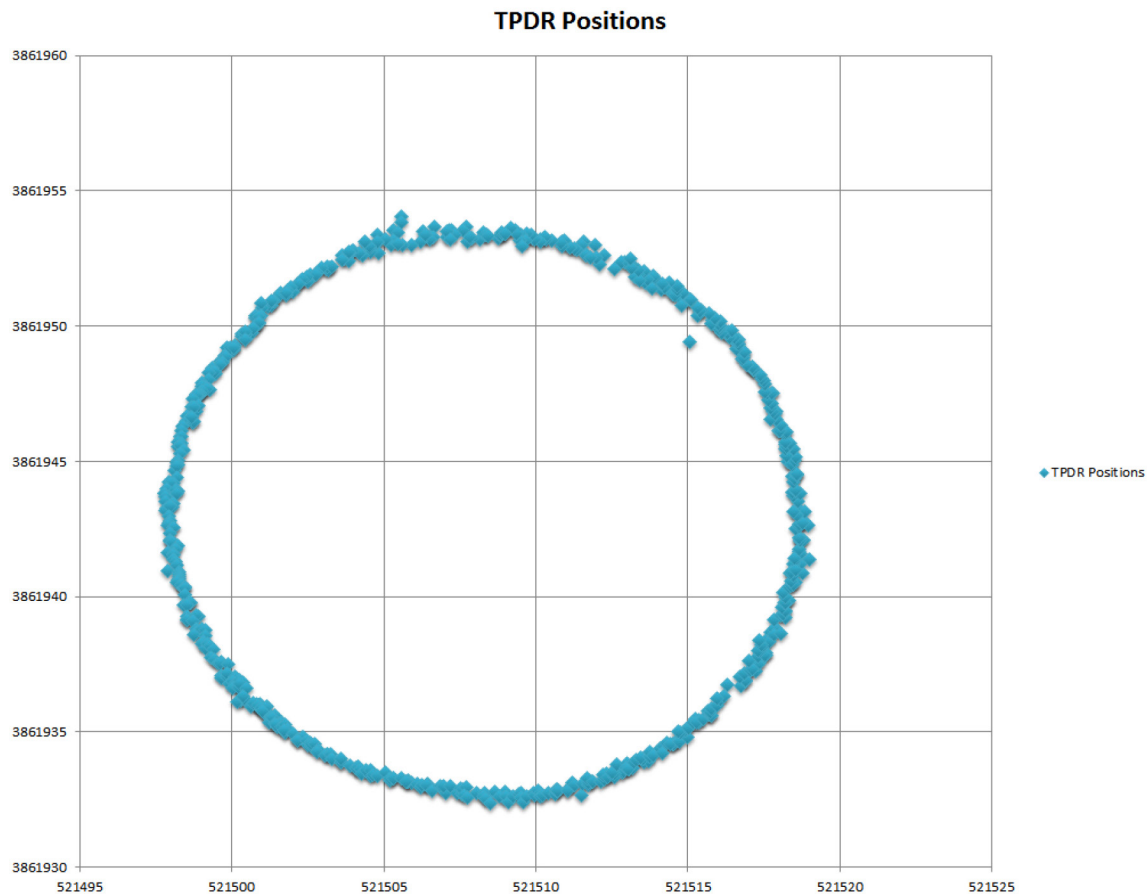


Figure 8: Results of a 'Bad' Spin Verification Test indicating a remaining bias in pitch, roll, heading or offset measurement (Ref. [7])

- | | |
|----------|---|
| 7 | Following the spin test, the vessel shall run a pair of orthogonal transit lines over the transponder at a line length of 50% of water depth or 100m (whichever is greater), at a speed representative of the proposed work scope operating speed, but not greater than 2 knots (see Figure 9). |
| 8 | The vessel shall maintain the same heading during data collection of both transit lines, such that it transits above the transponder and at 90° with respect to the second line, so that roll, pitch and heading bias can easily be assessed. |

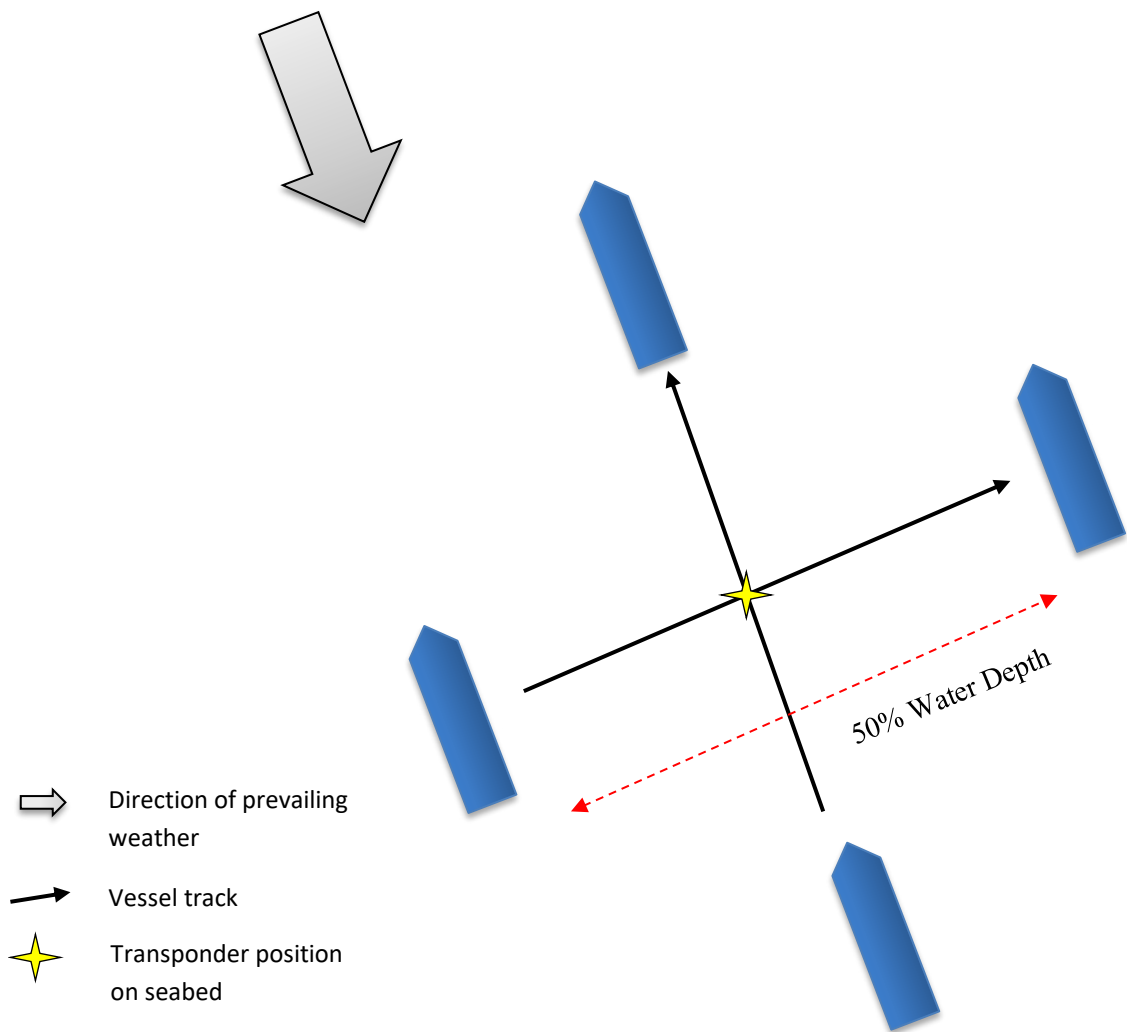


Figure 9: Vessel transit line verification pattern

- 9 The resulting logged data shall be represented in a scatter plot of depth versus distance along track (or time) and examined for both lines. The data points shall be randomly distributed about a trend line of near constant depth to demonstrate that any residual biases are negligible. If the verification results are not within the project specified tolerance, further analysis or recalibration shall be required by the Supplier.

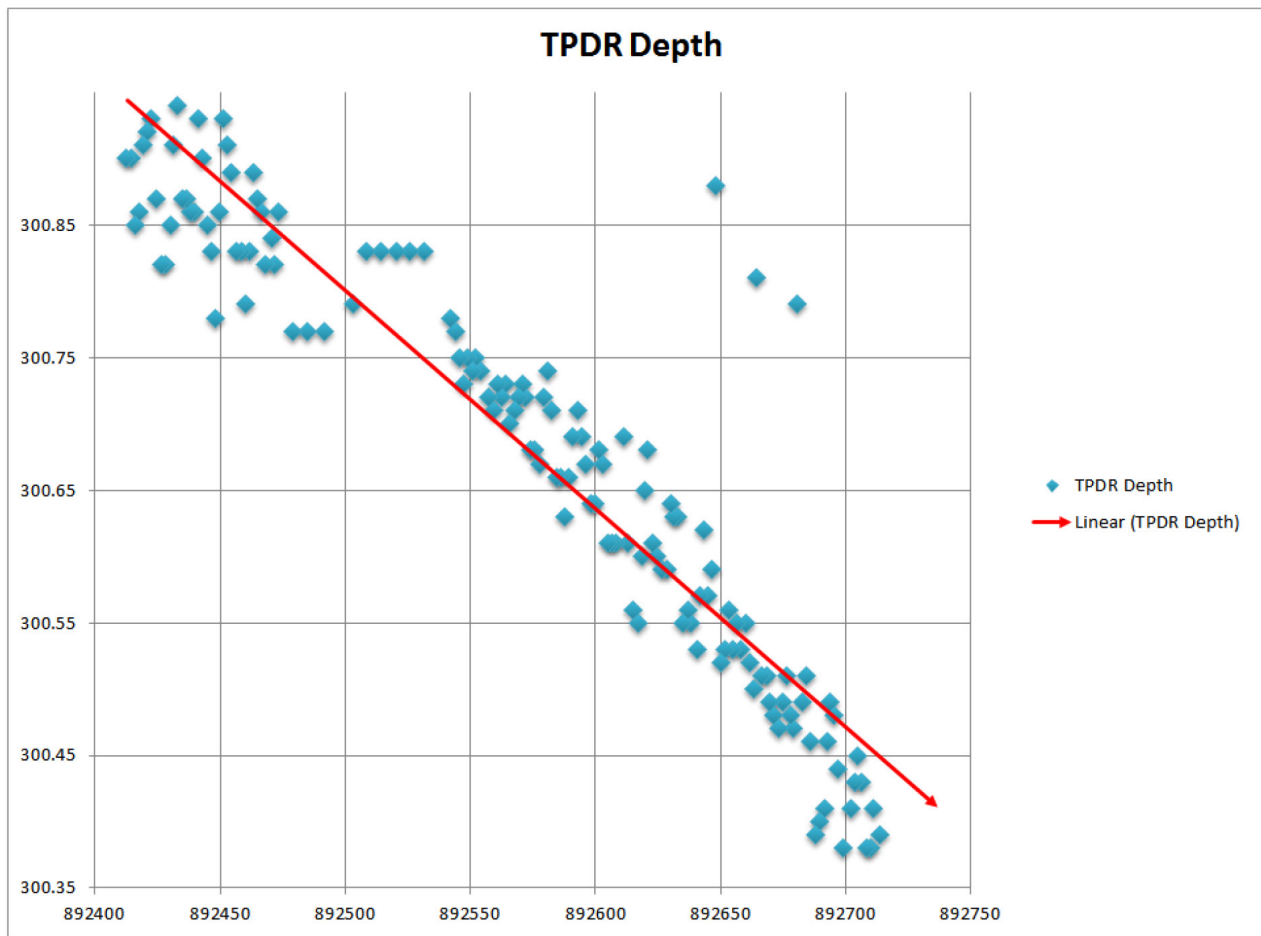


Figure 10: Results of a 'Bad' transit line verification test, showing a linear increase in transponder depth along the transit line, indicating an unknown error in transducer pitch or roll depending on which transit line is being examined (Ref. [7])

For seabed survey applications with a tow fish, it may not be possible to undertake the above verification due to the practicalities of deploying and recovering a transponder on the seabed. In this case, the tow fish should be towed over or along known infrastructure in reciprocal directions. The interpreted results from the tow fish data should be compared against each other and the position of known infrastructure. The average shall be within the positioning accuracy criteria of the project.

References

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<https://www.kongsberg.com/>. Accessed 7 November 2019
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Glossary

Term	Definition
Accuracy	Closeness of agreement between a test result and the accepted reference value.
Acoustic positioning system	A system used to track the position of underwater objects, such as vehicles and divers, by means of acoustic range (and direction measurements depending on the system type).
Bias	An error which is not random in behaviour. A bias may be defined as a systematic effect on the accuracy of a measurement population by a perceived constant or scalar amount.
Calibration	Calibration in measurement technology is the comparison of measurement values delivered by a device under test with those derived by a method of higher order accuracy.
Cardinal Point Heading	Commonly referred as each of the four main points of the compass (north, south, east, and west).
Centre of Gravity (CoG)	Center of Gravity or centre of mass is the point at which the entire weight of a body may be considered as concentrated so that if supported at this point the body would remain in equilibrium in any position. NOTE: On a vessel, the position of the Centre of Gravity moves with vessel loading and ballasting. The stated position of the Centre of Gravity may thus be an average or nominal position.
Common Reference Point (CRP)	Common Reference Point (CRP) of a vessel or vehicle from which offsets to sensors or other points of interest are measured. On a survey vessel typical best practice is to coincide CRP with the nominal Centre of Gravity.
Conductivity, Temperature & Depth (CTD)	Conductivity, Temperature, and Depth meter. Device for making real time measurements of conductivity and temperature against depth over the full water column to derive the speed of sound in water. The resulting Sound Velocity Profile is used to calculate the path an acoustic beam takes through the water column due to refraction.
Dimensional Control Survey	Precision measurement of the positions of sensors and other points of interest referenced to the Vessel Reference Frame. To achieve sufficient accuracy, the technique is normally carried out by land survey techniques.
Distance Root Mean Squared (DRMS)	This is the square root of the average squared distance error.
Dynamic Positioning (DP)	Dynamic Positioning systems allow a vessel to hold station by automatically controlling its thrusters based on input received from positioning and attitude sensors.
Error Budget	A statistical technique used to evaluate the overall, or propagated contributions, of a number of error sources upon a positioning computation.
Global Navigation Satellite System (GNSS)	Global Navigation Satellite System uses satellite signals to provide surface positioning. This commonly refers to such satellite constellations as: GPS, GLONASS, Beidou, Galileo, QZSS.
Heading Reference System (HRS)	A gyrocompass or multiple GNSS antenna-based system which provides the heading of the vessel relative to True North.
International Marine Contractors Association (IMCA)	Trade association for offshore, marine and underwater engineering companies. NOTE: See www.imca-int.com

Term	Definition
International Association of Oil & Gas Producers (IOGP)	The International Association of Oil & Gas Producers encompasses most of the world's leading publicly-traded, private and state-owned oil and gas companies, oil and gas associations and major upstream service companies. NOTE: See www.iogp.org
Metocean data	Generalised term for meteorological and oceanographic data.
Motion Reference Unit	An instrument used for dynamically measuring the pitch, roll and heave of a vessel.
Online Survey System	Computer based system for receiving, recording and performing real-time calculations on live survey sensor and ancillary data for display during vessel operations.
Operational weather limits	The weather state deemed acceptable by the vessel Captain for safe offshore operations.
Outlier	This is an observation that lies an abnormal distance from other values in a random sample from a population.
Pitch	The rotational motion of a ship about its across ship's axis from the horizontal plane, typically positive bow up.
Precision	Measure of the repeatability of a set of measurements.
Purchaser	Any authorized agent of the end client.
Residual scale factor	Refers to the scale factor computed by the USBL calibration routine. Depending on the USBL system this may refer to angle scale or range/depth scale. Angle scale acts as a measure of how well the beam steering angles fit with the calibrated transponder position. Range/depth scale acts as a measurement of how well the depth observations fit with the calibrated depth. Both ultimately represent how effective application of the sound velocity profile has been. The term 'residual' applies on the basis that angle and range measurements are normally already compensated by the sound velocity profile and any further scaling corrections are thus residual in nature.
Roll	The rotational motion of a ship about its along ships axis from the horizontal plane, typically positive port up.
Shall	Denotes a requirement that is mandatory for conformance with the specification and requires that there be no deviation.
Should	Denotes a guideline or recommendation where nonconformance with the specification is permissible.
Slant range (for USBL systems)	In the context of USBL systems, slant range refers to the distance between transducer and transponder.
Signal to Noise Ratio (SNR)	The ratio of the power of the received signal of interest over the background, or other, noise present.
Subsea positioning	This refers to the positioning of any object under the surface of the water using acoustic positioning equipment.
Supplier	Any authorized agent of the organization providing positioning services.
Sound Velocity Profile (SVP)	Sound Velocity Profile is the graphical representation of the calculated or observed speed of sound through the water column. NOTE: SVP also commonly refers to a Sound Velocity Profiler. This is a sensor used to directly observe sound velocity in water.
Tow fish	Vehicle on which survey sensors are mounted that is towed behind a survey vessel.

Term	Definition
Transducer	Any device that converts one form of energy to another. For a USBL system the term is normally applied to devices that produce acoustic pulses from electrical energy.
Transponder	An electronic acoustic device that produces an acoustic response when it receives an acoustic signal from a vessel mounted transducer or another transponder.
Ultra Short Baseline (USBL)	Ultra Short Baseline (USBL) System is a subsea acoustic positioning system used to determine the position of underwater objects, such as vehicles and divers. A transponder or responder is mounted on the object to be positioned and interrogated from a transducer of known position.
Verification	This refers to the verification test of an acoustic system used to prove the system is performing within specification prior to starting operations.
Vertical Datum	Datum describing the relation of gravity-related heights or depths to the Earth.
Vessel Reference Frame (VRF)	A Coordinate Reference System defining the vessel's forward, port/starboard and vertical axes, with origin typically defined as being close to the vessel's centre of gravity (CoG). The VRF is normally defined with reference to vessel General Arrangement (GA) drawings and is the frame within which all sensor offsets and misalignments are measured and applied.
Water column	A water column is a conceptual column of water from the surface of a sea, river, or lake to the bottom sediment.
Water depth	Vertical distance between the sea floor and sea surface with reference to a given vertical datum.

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Registered Office

City Tower
Level 14
40 Basinghall Street
London EC2V 5DE
United Kingdom
T +44 (0)20 3763 9700
reception@iogp.org

Brussels Office

Avenue de Tervuren 188A
B-1150 Brussels
Belgium
T +32 (0)2 790 7762
eu-reception@iogp.org

Houston Office

19219 Katy Freeway
Suite 175
Houston, TX 77094
USA
T +1 (713) 261 0411
reception@iogp.org

| www.iogp.org

This document aims to provide a global common industry technical specification accepted by both Operators (Purchasers) and Contractors (Suppliers) for the calibration and verification of Ultra Short Baseline (USBL) acoustic positioning systems.

It is intended to be included by operators as a specification in tenders and contracts for offshore surveys. This specification is not applicable to USBL systems that are solely used for vessel dynamic positioning purposes.