Multibeam Survey Suite Components

1 Auxiliary Sensors and Components

A multibeam survey system is comprised of more components than just the Sonic 2024 Multibeam Echosounder. These components are the auxiliary sensors, which are required to provide the necessary information for a multibeam survey. This does not mean that these sensors are a minor part of the survey system; each auxiliary sensor is required for any multibeam survey operation. The required sensor data:

- Position: Differential Global Positioning System Receiver
- Heading: Gyrocompass
- Attitude: Motion Sensor
- Refraction correction: Sound Velocity Probe

Each of the individual sensors requires their own setup and operation procedures. The details, discussed here, concerning the installation and calibration of the auxiliary sensors, is supplemental to any and all manufacturer's documentation.

1.1 Differential Global Positioning System

The Global Positioning System (GPS) is well known to all surveyors. There was a period of time when the GPS position was intentionally made less accurate; this was Selective Availability (SA). When SA was enacted, the GPS position became too inaccurate for survey use. It was during this period that the concept of differential corrections was established. Differential corrections were derived from users monitoring the GPS position at a known survey point and computing the corrections required to adjust the various pseudo ranges to make the GPS position agree with the known survey position. If a vessel was operating within the local area and observing the same satellite constellation; the derived pseudo range corrections could be applied on board to make for a more accurate and consistent position. The corrections are normally transmitted over a radio link and applied within the GPS receiver.

1.1.1 Installation

The first and foremost consideration when installing the DGPS system is the location of the respective antennae. Both the GPS antenna and the differential antenna (if they are two separate antennae) need to be mounted on the vessel in such a way so as to have a totally unobstructed view of the sky.

When installing the GPS antenna, the surveyor should be aware of the position of the stacks and masts; in particular are davits or cranes that may be currently in a stored position, but will be in use during survey operations. If mounting the antenna on a vessel that has helicopter landing facilities, coordinate the placement of the antenna with the personnel in charge of helicopter operations.

When the location for the antennae has been determined the next step is determining how the coaxial cable, connecting the antenna and the receiver, is to be run. The cables should be run in such a manner so as to be protected from possible damage. Cables should not be run through hatches or windows, if it can be avoided; if such runs are necessary then a block or other such obstruction should be placed so that the hatch or window will not close on the cable. If the cables are to be suspended between two points, a rope or other line should be strung to carry the weight of the cables. Cables should never be kinked; all cables have a minimum bending radius, if it is known adhere to it, if it is not known use common sense. Do not run cables in a manner that they will become safety hazards on the vessel, causing personnel to trip or be caught on them. Avoid running cables along voltage carrying lines.

It is important to mark the cables at both ends to denote what they are and to where they go.

The connection to the antenna may be required to be completely water proofed (depending on the manufacturer's recommendations) using electrical tape, with a secondary covering of self-amalgamated tape. Ensure that there are no air gaps in the tape; they will become a channel for water. If a cable is to be run upwards from the antenna, form a drip loop by leaving slack in the cable that will hang below the antenna connector. This will allow any water that flows down the cable to collect and drip from the slack loop instead of running into the connector.

The cables, connectors and antennae should be inspected regularly for signs of damage, corrosion or abuse. Any abrasions on the cable should be securely taped; if possible, a waterproof coating should also be applied.

1.1.2 GPS Calibration

Prior to commencing survey operations, the accuracy of the Differential GPS position and transformation to local datum should be determined. There are two main methods to determine the accuracy of the DGPS position and data transformation. For both methods, a local land survey benchmark is required.

1.1.2.1 Position Accuracy Determination Method 1

The GPS antenna is physically placed over the survey benchmark. The surveyor will ensure that the antenna has a clear view. This is particularly important if the benchmark being used is in a dock area. The surveyor will also ensure that, if a separate antenna is used to receive differential corrections, that it is not blocked.

The GPS position data should be logged, in the data collection software, for not less than 15 minutes. The collected data can then be averaged, standard deviations determined, and compared to the published position of the survey benchmark.

The two main causes of error, in this area, are:

- Wrong geodetic transformations being applied to the WGS-84 position derived from GPS.
- Erroneous coordinates for the Differential reference station.

1.1.2.2 Position Accuracy Determination Method 2

This method is most easily accomplished during the gyrocompass calibration. The antenna remains mounted on the vessel. The surveyor will set up on the known survey benchmarks; using standard land survey techniques, the exact absolute position of the antenna can be determined. During the period that the surveyor is 'shooting in' the GPS antenna, the GPS position will be logged on board, the averaging and statistical analysis will be as above.

The surveyor will need to take numerous shots to also obtain an average, due to the possible movement of the vessel while alongside.

1.2 Gyrocompass

Utmost care is required for the installation of the gyrocompass. The gyrocompass is a sensor that can not be situated randomly. The purpose of the gyrocompass is to measure the vessel's heading. In order to do this the gyrocompass should be placed on the centre line running from the bow stem to the midpoint of the stern. If it is not possible to place the gyrocompass on the centreline of the vessel, it can be mounted on a parallel to the centre line.

All survey grade gyrocompasses will be plainly marked for alignment on the centre line. This marking may be an etched line fore and aft on the mounting plate, or possibly metal pins on the front and the back of the housing that point down. If no marking exists, then measuring the fore and aft faces and finding the centre may be sufficient.

No matter how well the gyrocompass is placed, there exists a possible error between the true vessel's heading and the gyrocompass derived heading. Any new installation of a gyrocompass should include a gyrocompass calibration. There are various methods to perform a gyrocompass calibration; the best method employed will be determined by the location of the vessel, the time allotted for the calibration and the resources at hand.

1.2.1 Gyrocompass Calibration Methods

After the installation of gyrocompass (henceforth termed gyro) on a vessel, that gyro should be calibrated to ensure that the heading it determines is the true heading of the vessel.

If the error is large, the gyro can be physically rotated to align itself with the true vessel heading. Small errors can be corrected, either by internal adjustment to the gyro, or in the software that receives the gyro reading.

1.2.1.1 Standard Land Survey Technique

One of the most accurate methods to determine the gyro error involves the use of standard recognised land survey techniques. The time and equipment involved requires that a substantial period be allotted for such a calibration.

- If possible the vessel will be berthed alongside a quay or dock that has a survey benchmark located in close proximity.
- If a survey benchmark is not located close to the berth, then the surveyor will have to run a transit from the nearest, suitable, local survey bench mark to establish a point on the quay that has a well defined position. From this point another point should be established along the quay to form a baseline.
- When the vessel comes alongside, all lines should be made as taut as possible. The gyro should be allowed 2 hours to settle down after the vessel has come alongside.
- The stern of the vessel should be measured, with a metal tape, to determine the centre point of the stern. A survey reflector will be placed at this position. Another survey reflector will be placed exactly at the bow. It will be verified that the reflectors are accurately placed on the centre line of the vessel by either measurements or survey techniques.
- The surveyor will set up on one benchmark; a round of readings will be taken from the benchmark to the fore and aft reflectors. Simultaneous to this, the survey

personnel will record the gyro heading as it is read by the survey computer. Any variation between the digital output and the physical gyro reading should be remedied prior to the commencement of readings. It is recommended that the personnel on the vessel and the surveyors on the quay be in constant communication to assist in coordinating the measurements.

- One round of readings will be considered to be not less than 30 sets, a set being one reading each from the bow and stern reflectors.
- Upon completion of the round from benchmark one, the surveyor will move to benchmark two and repeat the process.
- Upon the completion of all rounds from the two benchmarks the vessel will turn about. With the vessel, now heading on the reciprocal heading, the gyro will be allowed at least 1 hour to settle down.
- When the gyro has been given sufficient time to settle down a further series of range and bearing measurements will be made in exactly the same manner as before.

When all readings are completed, the surveyor will calculate the azimuth between the two survey reflectors for each set of readings. The azimuth readings will be compared with the headings taken on board the vessel from the gyro, itself. If there has been little or no movement of the vessel, an average can be taken of the azimuths and for the gyro readings and compared. By calculating the standard deviation of the readings, the surveyor can determine the degree of movement during the recording process. If the deviation is greater than the stated accuracy of the gyro, the comparison readings should be based on simultaneous time.

If physical adjustments are required, they should be made and the calibration process repeated. If the adjustment is determined to be minor and can be accounted for in the survey software, the correction value should be entered and then verified using the calibration process. This check of the calibration value can be an abbreviated version of the calibration process detailed above.

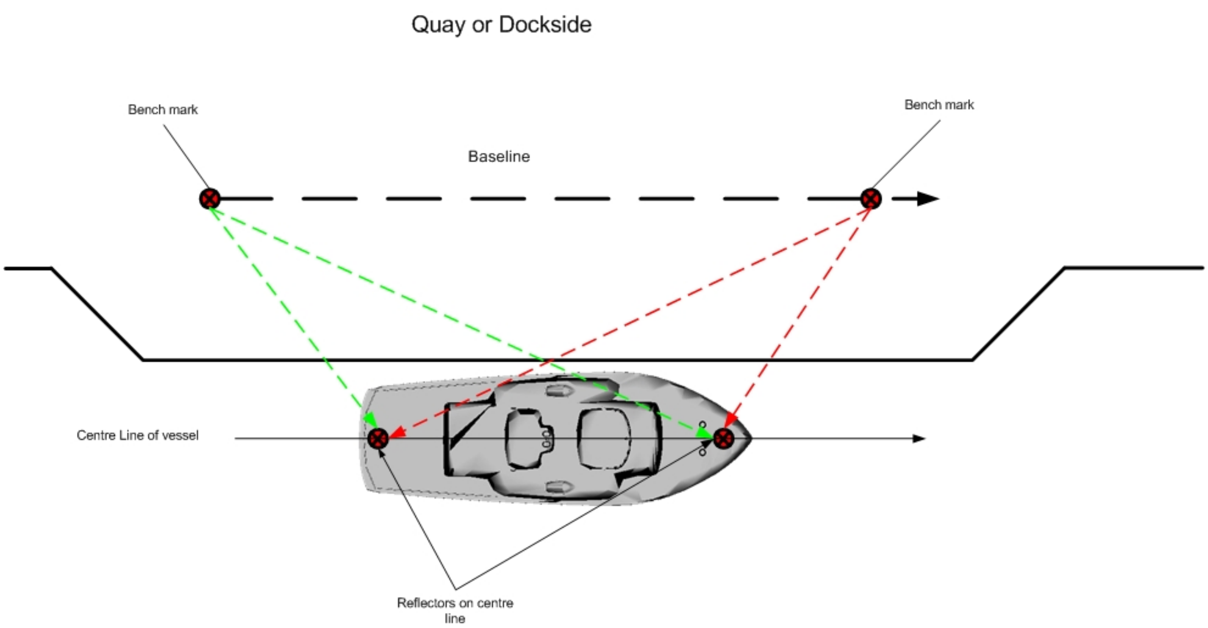

Figure 1: Gyrocompass Calibration method 1

- Quayside Benchmarks have known geodetic positions.
- Measure Range and Bearing to reflectors on vessel centre line
- Using Range and Bearing to reflectors, determine geodetic position for reflectors
- Calculate bearing from stern reflector to bow reflector will give the true heading of the vessel
- True heading of vessel is then compared to gyrocompass reading taken at the same time as the Range and Bearing measurements
- Benchmarks do not have to be on the quay, but should be in a position to give accurate Range and Bearing to the reflectors

1.2.1.2 Tape and Offset Method of Gyro Calibration

This method relies on measuring the offset distance from a baseline on the quay, with a known azimuth, to a baseline that is established on the vessel. There are greater areas for error when using this method, particularly in establishing a baseline with known azimuth.

A baseline is established on the quay as close as possible to the vessel's side. It is very important that the azimuth of this baseline be as accurately determined as possible. The baseline should be of a length that will exceed the baseline that is established on the vessel.

A baseline is established on the vessel that is parallel to the centre line of the vessel. It should not be assumed that the side of the vessel is parallel to the centre line. This baseline should be on the deck that faces the dock. The baseline on the vessel should be as long as possible, the longer the better.

With the vessel secured alongside the quay, the vessel baseline will be compared to the quayside baseline. Two points will be established on the quayside baseline that corresponds exactly to the fore and aft positions on the vessel baseline. That is: the points that are established on the quayside baseline should be normal to the points on the vessel baseline.

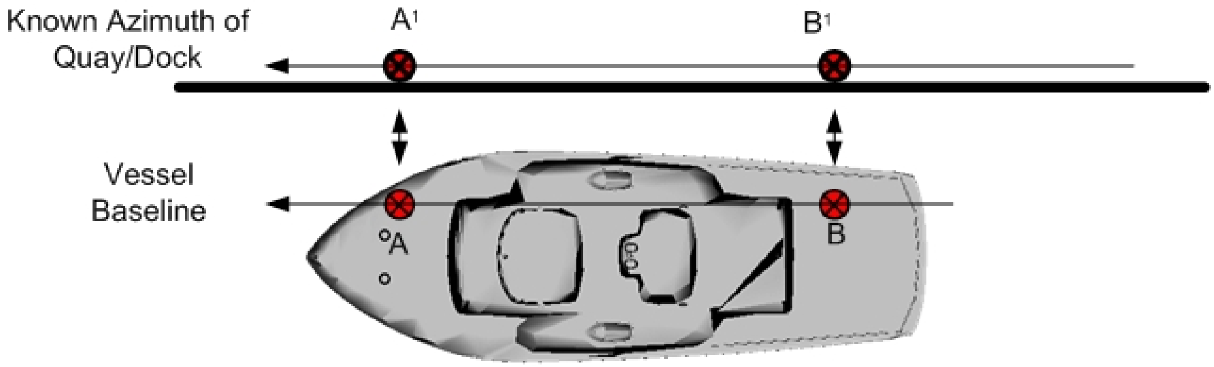

Figure 2: Gyro Calibration Method 2

The example, below, will illustrate the math involved.

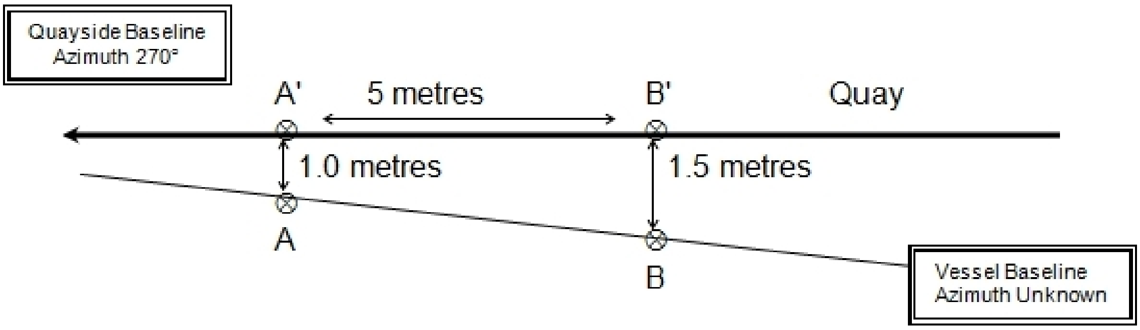

Figure 3: Gyro Calibration Method 2 example

A to A'	1.0 metres	**B to B'**	1.5 metres
Side a	5.0 metres	**Side b**	1.5 – 1.0 = **0.5 metres**
Angle b'	Arctan 0.5/5.0 = 5.7°		
Ship Azimuth = 270° + 5.7° = **275.7°**			

Table 1: Gyro Calibration Method 2 computation

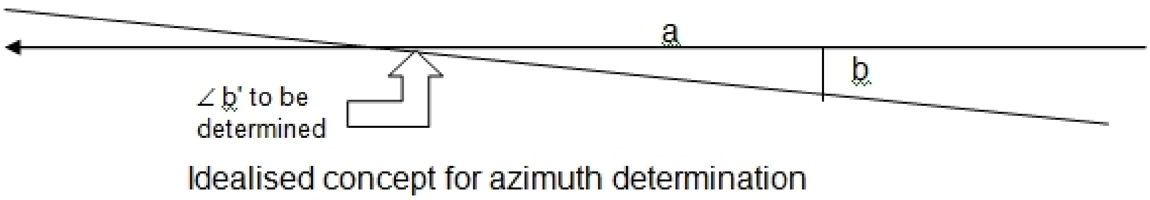

Figure 4: Idealised concept of Gyro Calibration Method 2

In this example the vessel heading for this set of readings is 275.7°; this would be compared to the gyro reading recorded at the same time the offsets were measured.

In the above example, if the bow was further out from the quay than the stern, the angle b' would be subtracted from the azimuth of the quay, i.e. 270° - 5.7° = 264.3°.

1.3 The Motion Sensor

The motion sensor is used to determine the attitude of the vessel in terms of pitch, roll and heave. Pitch is the movement of the bow going up and down. Roll is the movement of the port and starboard side going up and down. Heave is the vessel going up and down.

The sonar head is physically attached to the vessel; as the vessel moves, so does the sonar head. The motion sensor reports the movements of the vessel to the data collection software; the data collection software, using the offsets to the motion sensor and to the sonar head, computes the movement at the sonar head to correct the multibeam data for pitch, roll and heave.

One important aspect of the motion sensor is the sign convention used by the motion sensor as compared to the sign convention used in the collecting software. The surveyor must be aware of the convention that is used and what adjustments are necessary, if any, to ensure that the convention is consistent with the data collection computer.

There exist two major areas of thought as to where the motion sensor should be situated. One group believes that the motion sensor should go as close to the multibeam as possible, even if the multibeam is mounted on an over-the-side pole. The second group believes the motion sensor should be placed as close to the centre of rotation for the vessel as possible.

Placing the motion sensor on the hydrophone pole would seem to solve for all movement of the pole itself, but in fact the motion sensor, mounted in this fashion, can provide false attitude measurements. This is particularly true when there is significant roll; the motion sensor on the pole can interpret a portion of this roll as heave, which is not true. By placing the motion sensor as close to the centre of rotation (also called the centre of gravity) as possible, only the real heave of the vessel will be measured. All software will solve for the motion of the sonar head, based on the offsets that have been entered into the setup files for the vessel configuration; this is called a lever arm adjustment. The other consideration is that the motion data is usually applied to the GPS antenna. The GPS antenna is usually mounted high on the vessel, so any pitch or roll will induce a large amount of movement in the GPS antenna thus providing a false position due to the antenna movement. If the motion sensor is mounted on the hydrophone pole it is reporting an exaggerated motion because it is far from the centre of motion of the vessel; this exaggerated motion then would be applied to the GPS antenna position and the vessel position computation would be in error.

The other consideration is that the alignment of the motion sensor must be on or parallel to the centre line of the vessel; it is essential to prevent 'bleed-over' of pitch and roll. If the motion sensor is not aligned with the centre line, when the vessel rolls some of the roll will be seen as pitch as the motion sensor's accelerometers and gyros are not aligned with the axes of the vessel it is mounted on. It is more difficult to obtain this precise alignment if the motion sensor is placed on the pole.

Mount the motion sensor as close to the centre of rotation (or centre of gravity as possible) and perfectly aligned to the centre line of the vessel.

The motion sensor should be mounted on as level a platform as possible. After mounting the motion sensor, the actual 'mounting angles' should be measured. Some motion sensors contain internal programs that can measure the mounting angles. Some data collection software packages also include the capability to measure mounting angles. The mounting angles are the measured degrees of the actual physical mounting of the motion sensor. This is to compensate for sloping or warped decks. Many decks have some slope to them and this should be accounted for to ensure that the pitch and roll values that the motion sensor derives is for vessel movement and not for its physical mounting on the deck. The mounting angles should be measured prior to any multibeam calibration and not changed after the calibration.

Prior to measuring the mounting angles, the vessel should be put in good trim by the engineer. On a small vessel it is important that the angles be measured without undue influence from people standing around. A false measurement can be induced by two people sitting on the gunwale having a conversation while the measuring process is being completed. It is usually a good idea to have all personnel leave a small vessel during the measuring process.

If the motion sensor mounting angles have been entered in the motion sensor or the data collection software they can only be changed prior to the multibeam calibration (patch test); they are not to be changed after the patch test.

It is important to keep the motion sensor in mind when surveying. A motion sensor takes time to 'settle down' after a turn or a speed change and most of the settling down will depend on the heave bandwidth that is entered into the motion sensor. Some motion sensors can take in position, speed and heading data to assist them in the settling process. Depending on the degree of the turn or the amount of the speed change a practical period of 2 minutes should be allowed for the motion sensor to settle. It is prudent to plan the survey such to allow for this time via the 'run in' to the start of data collection; thus allowing the motion sensor time to settle and the heave normalise. If this is not done, many times motion artefacts or erroneous depths will be seen at the beginning of line and the processed data will not be correct.

Monitor the motion sensor (all data collection software provides a time series window to monitor individual data) to ensure that it is operating properly.

1.4 Sound Velocity Probes

There are two basic types of sound velocity probes. One type measures the parameters of sound velocity in water; those being **C**onductivity (Salinity), **T**emperature, and **D**epth (Pressure), these are normally referred to as CTD probes. The other type of probe contains a small transducer and has a reflecting plate, at a known distance from the transducer that reflects the sound, the time is measured for this transmission and the sound velocity determined by that measurement; these are called Time of Flight probes. There is third type, known as the Expendable Bathythermograph (**XBT**) which is launched and as it passes through the water column sends back temperature readings (through two very thin wires); it is not recovered, it is expendable.

The CTD and Time of Flight probes store the data internally. The data is downloaded to a computer after the probe is recovered.

1.4.1 CTD Probes

The CTD probe type of sound velocity probe has instruments to measure the conductivity of the water, water temperature, and a pressure sensor to measure depth. The CTD probe is a good choice if any of this information is also required; to obtain a velocity a formula must be used.

There are various formulae available that are based on the parameters that are recorded by the CTD. The UNESCO algorithm is considered a universal standard and was put forth by C-T. Chen and F.J. Millero in 1977. The Chen-Millero (and Li) equation is complex as is Del Grosso's (1974) and have been termed Refined. Simple formula, such as Mackenzie's (1981), also yields good results.

When using a CTD, it is very important that the probe be allowed to sit, fully submerged, in the water for a few minutes prior to deploying it; this is to allow the probe to reach equilibrium with the water temperature   It is also important that the tube, through which the water flows pass the sensors, is checked for obstructions or marine growth.

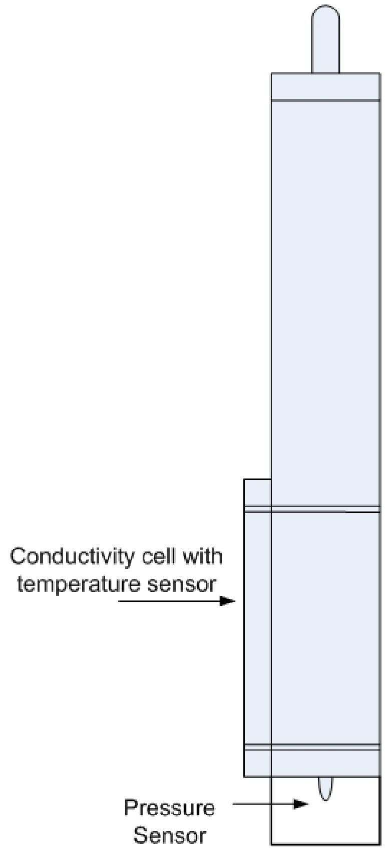

Figure 5: CTD Probe

1.4.2 Time of Flight Probe

The Time of Flight probe incorporates a transducer that transmits an acoustic pulse that reflects back from a plate that it is at a very precise distance from the transducer. The two-way travel time is measured, divided by 2, and the sound velocity determined. The Time of Flight probe is usually considered more accurate for multibeam survey work.

The sound velocity probe that is mounted close to the Sonic 2024 sonar head is a time of flight probe.

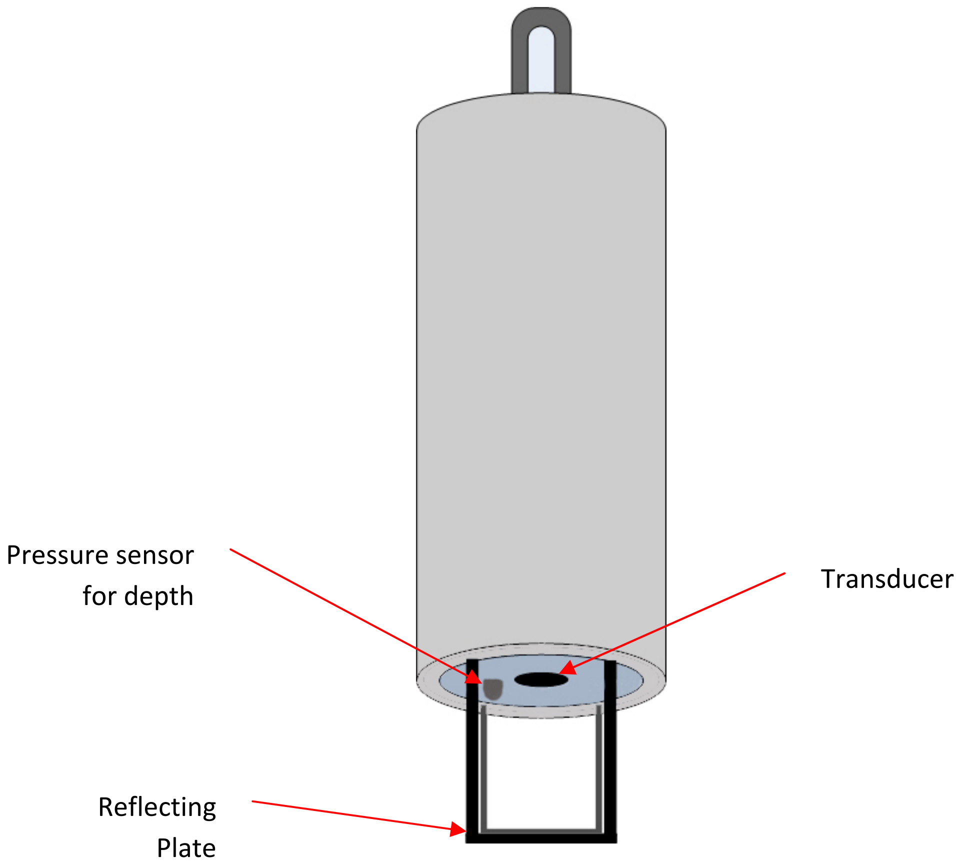

Figure 6: Time of Flight SV probe

1.4.3 XBT Probes

The XBT is a probe which free falls through the water column at a more or less constant speed (the probe is designed to fall at a known rate so that the depth can be inferred) and measures the temperature as it passes through the water column. Inside the probe is the thermograph, which is attached to a spool of very fine wire. Two very small wires transmit the temperature data from the probe back to a computer. The XBT is not recovered. XBT probes can be launched whilst underway and are used extensively by Navy and Defence forces for rapid determination of the sound velocity without stopping the vessel.

1.5 The sound velocity cast

There are no set rules for when to take a measurement of the water column sound velocity. Common sense is a good guideline. The conditions, detailed below, have a major influence as to when to take a sound velocity cast.

1.5.1 Time of Day

Throughout the day the upper level sound velocity characteristic will change mainly due to solar heating or cooling due to cloud cover or precipitation. Another main element of the time of day changes is tides.

When working in tidally influenced areas, the sound velocity can change drastically due to a salt wedge that moves in and out with the tide. The surveyor must be aware of the relationship of the time of the tide to the salt wedge.

1.5.2 Fresh water influx

Any river, stream or runoff will drastically change the sound velocity through the introduction of freshwater and also through a temperature difference.

1.5.3 Water Depth

The sound velocity cast should always be made in the deepest part of the survey area. The sound velocity profile cannot be extrapolated to deeper depths as there are too many possible variables.

1.5.4 Distance

If the survey area is large, then it is quite possible that there will be differences across the range of the survey area even in open water.

1.5.5 Deploying and recovering the Sound Velocity Probe

The guide lines for deploying and recovering the sound velocity probe are based on common sense, but are sometimes ignored during the actual operation. The guidelines, below, are for a hand cast in shallow water. The softline, used for the cast, should be marked to provide an indication of the amount of line out.

1.5.5.1 Shallow water sound velocity cast / deployment by hand

1. Plan where the cast is to be made
    a. In a small area, deploy in the deepest part of the survey area
    b. Always do a cast prior to starting the survey
2. Liaise with the captain or office of the watch with the plan position and time of deployment and time required for the cast
3. Prepare the probe for casting (some probes may need to be programmed prior to each launch)
4. Secure the probe to the downline with a bowline knot or shackle
5. **Secure the bitter end of the downline to the vessel**
6. Request permission, from the bridge or helm, to deploy and await their OK to launch
    a. Bridge or helm to ensure that the vessel is out of traffic
    b. Bridge or helm to assess wind and sea conditions and advise as to which side of vessel the deployment should be made
7. Put the probe in the water until it is totally covered and let it remain there for a period of time to acclimate to the sea temperature. This is very important with a CTD type of probe, but of less concern for a time-of-flight probe
8. Verify the water depth
9. Lower the probe at a constant rate; only the downcast should be used
10. Try not to allow the probe to touch the bottom
11. Recover the probe rapidly
12. As soon as the probe is on deck, notify the bridge or helm that they are free to manoeuvre, but remain in the area
13. Rinse the probe with fresh water and dry thoroughly
14. Download the cast and verify that it looks good
15. Load the cast into the data collection software

1.5.5.2 *Deep Water Cast / Deployment by mechanical means*

A cast in deeper water requires more preparation and planning. A deep water cast can be considered to be any cast that is deployed via an 'A' Frame, winch, or other mechanical means. Even a shallow water cast can fall under this definition when mechanical means are used.

One of the main concerns, in a deep water cast, is that the probe will not go straight down due to the current flow or vessel drift due to wind and/or currents. This being the case, weights must be used to ensure the cable (and probe) go as straight down as possible.

Unless the sound velocity probe is designed to have additional weight attached to it, no weights should be attached to the sound velocity probe. The weights, which enable deployment as straight as possible, are attached to the end of the cable. The probe should be attached to the cable approximately 3 – 5 metres above the weights; if the weights hit the bottom this should provide enough scope for the probe to land clear of the weights.

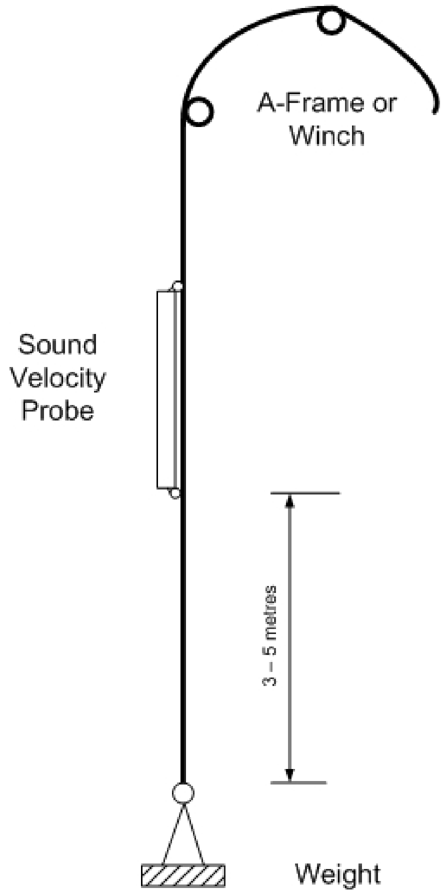

Figure 7: Deploying a sound velocity probe via a winch or A - Frame

The other major consideration when deploying a probe in deeper water is that the vessel must be stationary longer and will drift. If there is a large variation in depths, the depth when the probe went in, may not be the same depth when the probe reaches the bottom. It is essential that enough cable be deployed to ensure a full profile to the sea floor.