LONDON ARRAY WINDFARM

EXPORT CABLE ROUTE POST-CONSTRUCTION SURVEY

(AUGUST/SEPTEMBER 2013)

MOBILISATION AND OPERATIONS REPORT

FINAL - REV1

MARCH 2014

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CONTENTS

FIGURES

TABLES

1. INTRODUCTION

This document outlines the Operations of the Wessex Explorer and the procedures that were performed during mobilisation and verification of the hydrographic survey equipment (Figure 1), in preparation for DONG London array Export cable post construction survey.

MV Wessex Explorer is permanently mobilised with a suite of hydrographic survey equipment. The vessel is owned by Hayes Marine and regularly operated by EGS International Ltd (EGSi), Bordon, Hampshire, UK. All of the survey equipment is regularly calibrated & verified, references to which are made within this report where appropriate.

FIGURE 1: MV WESSEX EXPLORER

1.1. SURVEY OPERATIONS

The London Array survey operations were conducted using the 'Wessex explorer' on a 12 hour basis between 31stth August and 8th September2013. Initial vessel mobilisation took place whilst was alongside Gosport Marina. The full mobilisation was completed alongside in Ramsgate Marina.

A summary and breakdown of survey operations are presented in Table 1 and Table 2, respectively.

Date	Activity
27/08/2013	Project Kick Off Meeting, DONG, Ramsgate
28/08/2013	Mobilisation
29/08/2013	Mobilisation, Site Induction, London Array
30/08/2013	Mobilisation
31/09/2013	Commence survey operations in the Swale
01/09/2013	Continue survey operations in the Swale/Kentish flats
02/09/2013	Continue survey operations at Kentish flats towards Princes channel.
03/09/2013	Continue survey operations at Kentish flats Rock Dump
04/09/2013	Continue survey operations at Princess Channel extending to Foulgers Gat and Substation 1
05/07/2013	Continue survey at Substation 2
06/07/2013	Waiting on Weather at Ramsgate Marina
07/07/2013	Survey remaining area at Princes channel
08/07/2013	Demobilise vessel

TABLE 1: SUMMARY OF SURVEY OPERATIONS

Activity	Total (hh:mm)
Mob/Demob	54:30
Operational	57:25
Transit (EGS)	34:55
Transit (Client)	00:00
Transit (Weather)	00:00
Weather (Port)	12:00
Weather (Site)	00:00
Standby (Port)	147:55
Standby (Client)	05:15
Downtime	00:00
Sum Totals	312:00

TABLE 2: BREAKDOWN OF SURVEY OPERATIONS

1.1.1. HSE

Prior to the start of survey operations, a full HSE meeting was undertaken at the EGSi Offices in Bordon, UK on 25thth August 2013. During these meetings, the Hazard Identification and Risk Assessment (HIRA) document prepared for the London Array survey was presented to the survey personnel by the EGSi Health and Safety Manager. Before sailing, all survey personnel and vessel crew were given vessel safety inductions by the vessel master. A kick-off meeting was held on 27th August in the DONG Ramsgate office in the presence of key personnel involved in the project. A London Array induction was carried out on 29th August and a site familiarisation briefing given by the Marine Coordinator.

A vessel Audit was conducted with the vessel signed off for operations on the 30th August.

A man overboard drill was performed 30th August 2013 and further talks took place whilst alongside.

Prior to deployment of any equipment, a toolbox talk was held with the survey personnel and vessel crew involved in the operations. During the talks, the procedures for equipment deployment were outlined and any hazards involved in the operations were discussed. Full PPE was worn at all times by all personnel working on the vessel's back deck. Personal locator beacons (PLB) were also attached to the lifejackets.

No HSE Incidents occurred during the survey operations on London Array Export cable survey 2013.

Table 3 below presents a summary of the project man hour allocation:

Total Man Hours	499:00
Total Man Hours - Exposure *Operational/transit	277:00
Total Hours - Local	499:00
Total Hours - Processing	90:00

TABLE 3: PROJECT MAN HOUR ALLOCATION

2. SURVEY EQUIPMENT CALIBRATION AND VERIFICATION

The remainder of this document details the calibration and verification procedures for the following items of equipment:

- Primary horizontal/vertical positioning system - V5 Applanix POS MV 320E
- Secondary vertical positioning system - Leica 1200 GPS
- Secondary horizontal positioning system - C&C Technologies C-Nav 2050 DGPS
- Attitude system - V5 Applanix POS MV 320E
- Primary Sound Velocity Profiler - Valeport SoundBar 2
- Secondary Sound Velocity Profiler - Valeport Monitor SVP
- Multibeam Echo Sounder - Kongsberg EM3002D

The specific tasks undertaken can be summarised as:

- Sensor Offsets
  - Reference Frame Survey (RFS)
  - Offset/mounting angle entry in online survey systems
- Navigation system
  - Hardware installation
  - Alignment to vessel reference frame (RFS)
  - Heading calibration
  - Static verification
  - Dynamic verification
- SVP Comparison
  - Comparison between primary & secondary profilers
- MBES verification
  - Alignment to vessel reference frame (RFS)
  - Roll patch test
  - Pitch patch test
  - Heading patch test
  - Repeatability Test

The majority of the vessel calibration and verification procedures were conducted prior-to arrival in Ramsgate. Initial vessel mobilisation took place whilst the vessel was on a hard stand in Gosport shipyard (Hampshire, England). Calibration procedures and sea trials were conducted in the Solent between the 17th and 19th June 2013. Additional verification procedures were conducted in Ramsgate Marina on 30th August 2013 prior to the LAL survey. Further validations included navigation check, dynamic navigation comparison, heading verification, QINSy MBES calibration, lead line Check, SVP comparison.

3. SENSOR OFFSETS

3.1. REFERENCE FRAME SURVEY

MV Wessex Explorer is permanently mobilised with a suite of hydrographic equipment including a V5 Applanix POS MV 320E, hull-mounted Kongsberg EM3002D Multibeam Echo Sounder (MBES) and a C&C Technologies C-Nav 2050 DGPS. A Leica 1200 GPS was also installed to acquire precise vertical measurements, allowing near-real-time computation and normalisation of the tide element prior-to post-processing of the V5 Applanix POS MV 320E data with POSPac MMS 6.2.

On 15th May 2013, *Geo-Spatial Survey Solutions* conducted a Reference Frame Survey (RFS) of MV Wessex Explorer whilst the vessel was on a hard stand in Gosport shipyard (Hampshire, England). The full RFS survey report is included within this document, as Appendix A. Land survey and photogrammetric techniques were used to establish sensor offset locations & orientations relative to the vessel reference frame (established by the RFS).

The horizontal and vertical origin of coordinates, the common reference point (CRP) (x = 0.0000m; y = 0.0000m; z = 0.0000m), was defined as the centre of the indicator on the top of the V5 Applanix Type40 IMU (Figure 3), in close proximity to the vessel's centre line. The V5 Applanix Type40 IMU was installed away from the MBES transducers in order to provide line-of-sight for the RFS, thereby maximising RFS precision and accuracy.

Sensor offsets and rotations within this report are presented with respect to the Tate/Bryant coordinate and rotation convention (Figure 2).

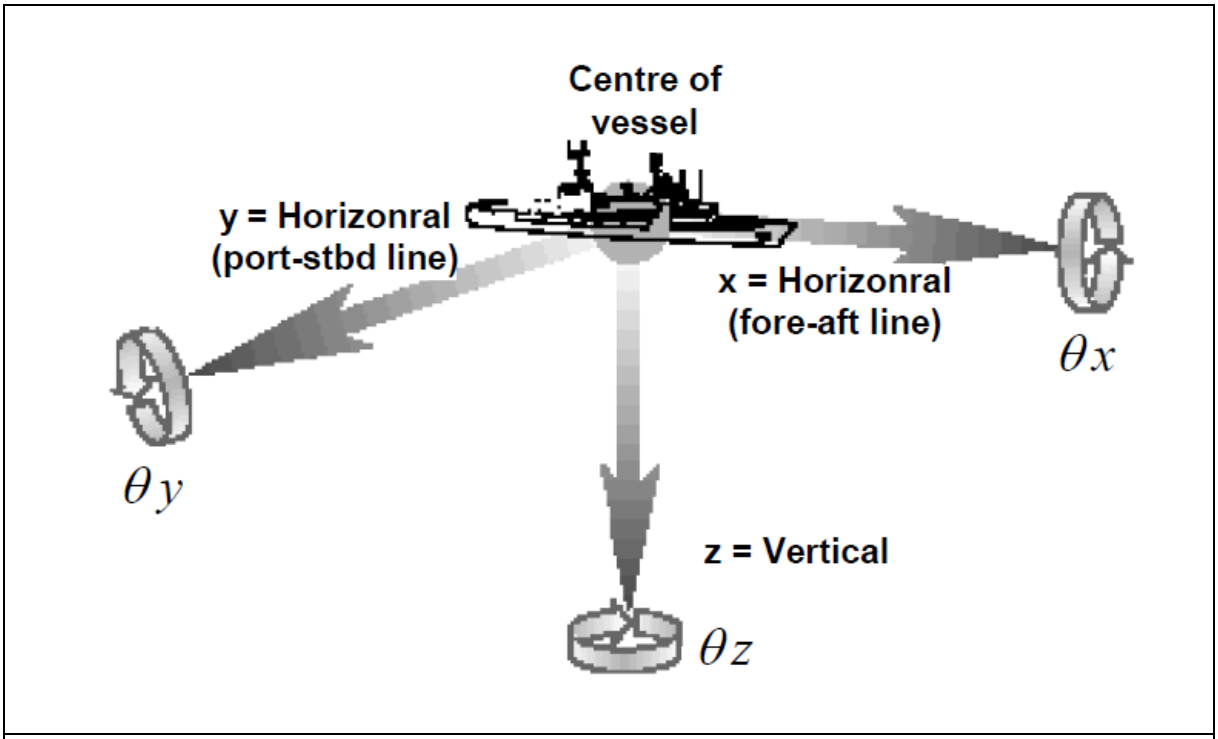


FIGURE 2: TATE/BRYANT COORDINATE AND ROTATION CONVENTION

Instrument offsets relative to the CRP (Figure 3), as provided by *Geo-Spatial Survey Solutions*, are summarised below (Table 4). All coordinates were obtained using multiple Total Station setups and are accurate to within ±0.5mm.

Node	X (m; +ve fwd.)	Y (m; +ve stbd.)	Z (m; +ve down)
CRP – POS MV Type40 IMU	0.0000	0.0000	0.0000
EM3002D port transducer	+0.5773	-1.2135	+2.8208
EM3002D starboard transducer	+0.5632	-0.3452	+2.8200
POS MV port antenna hole	-3.1002	-2.0272	-2.2447
POS MV starboard antenna hole	-3.1040	+0.5089	-2.2615
C-Nav 2050 DGPS centre of shoulder	-2.8438	-0.7655	-2.5723
Leica 1200 GPS antenna (Phase L1)	-0.0402	-0.7788	-5.6568
Leica 1200 GPS antenna (Phase L2)	-0.0402	-0.7788	-5.6458

TABLE 4: MV WESSEX EXPLORER INSTRUMENT OFFSETS

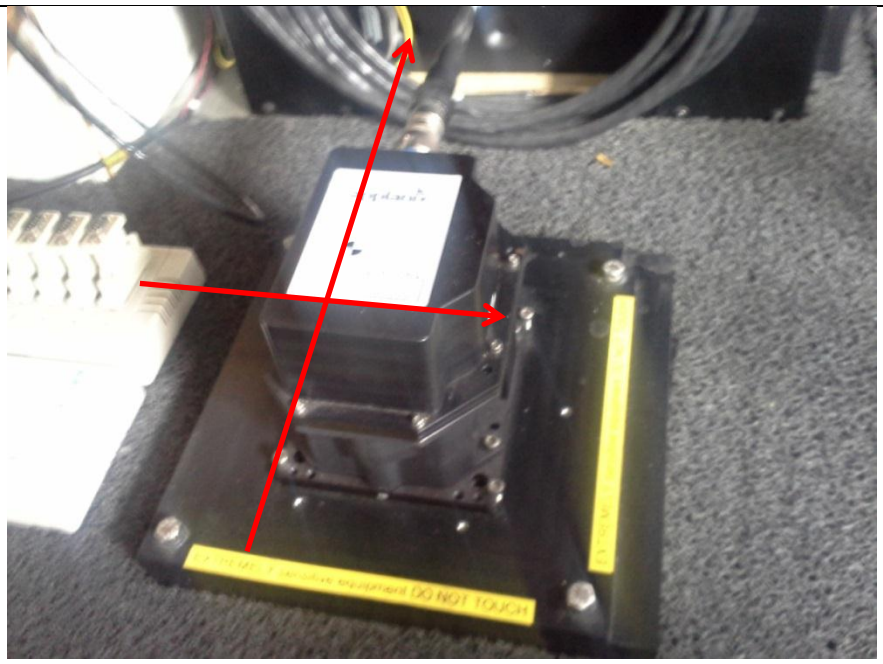


FIGURE 3: MV WESSEX EXPLORER CRP

V5 APPLANIX TYPE40 IMU MOUNTED POINTING ASTERN

Instrument locations are displayed in the vessel offset diagram (Figure 4).

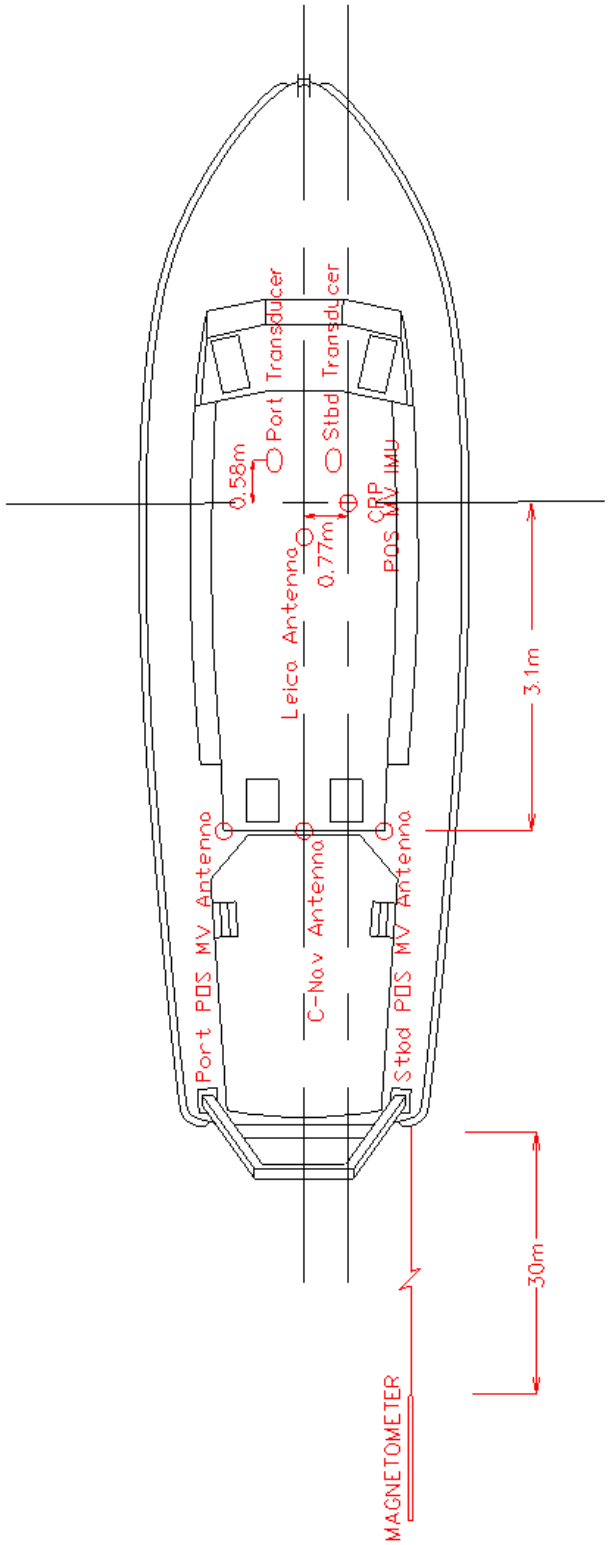


FIGURE 4: MV WESSEX EXPLORER VESSEL OFFSET DIAGRAM

3.2. V5 APPLANIX POS MV 320

This section describes the normalisation of the attitude & positioning system to the vessel reference frame. The V5 Applanix POS MV 320E was mobilised onboard MV Wessex Explorer as a replacement for the Kongsberg Seatex Seapath 330+ that was previously installed.

3.2.1. MOUNTING ANGLES

The V5 Applanix POS MV 320E uses state-of-the-art inertial and GPS technology to provide accurate heading, attitude, heave, position and velocity data. This tightly-coupled system uses inertially-aided real-time kinematic technology to provide a high level of positioning accuracy even under the most demanding environmental conditions.

The V5 Applanix POS MV 320E has been configured to perform all lever-arm and attitude computations at the output node location. In this case the output node to the MBES system was selected as the CRP which is located at the top of the V5 Applanix Type40 IMU (Figure 3).

For practical reasons, the V5 Applanix Type40 IMU was installed pointing astern (Figure 3); this mounting angle was accounted for in the controller software, POSView 7.41 (Table 5 and Table 6).

Mounting Angle (RFS)	X (˚)	Y (˚)	Z (˚)
IMU Frame to Vessel Reference Frame	-0.28988	-0.45120	+0.29649

TABLE 5: V5 APPLANIX POS MV TYPE40 IMU RELATIVE TO THE VESSEL REFERENCE FRAME AS STATED IN THE RFS.

Mounting Angle (POSView 7.41)	X (˚)	Y (˚)	Z (˚)
IMU Frame to VesselReference Frame	-0.28988	-0.45120	-179.70350

TABLE 6: V5 APPLANIX POS MV TYPE40 IMU RELATIVE TO THE VESSEL REFERENCE FRAME AS ENTERED IN POSVIEW 7.41

3.2.2. OFFSETS

The V5 Applanix POS MV 320E antennas were not installed at the time of the RFS. The vertical mounting offset of the Port and Starboard antennas (11.5 and 15.0mm, respectively) was measured by tape measure and the phase offset accounted for in the final antenna installation parameters (Table 7).

Node	X (m; +ve fwd.)	Y (m; +ve stbd.)	Z (m; +ve down)
POS MV port antenna (Phase)	-3.1002	-2.0272	-2.3222
POS MV starboard antenna (Phase)	-3.1040	+0.5089	-2.3425
Centre of Rotation	-2.8570	-0.7700	0.2190

TABLE 7: V5 APPLANIX POS MV 320E ANTENNA INSTALLATION OFFSETS

3.3. KONGSBERG EM3002D

3.3.1. MOUNTING ANGLES

This section describes the normalisation of the MBES reference frame to the vessel reference frame. Initially, the mounting angles of the MBES heads, as-surveyed during the RFS, were input into Kongsberg SIS 3.9.2 (Table 8). These angles were then verified and improved-upon during the patch tests & Repeatability Test as described in section 5. During the preliminary calibration procedure, yaw values were left as zero (Table 9).

Mounting Angle (RFS)	Yaw (˚)	Pitch (˚)	Roll (˚)
Port EM3002D transducer	+3.82030	+3.23738	+40.26582
Starboard EM3002D transducer	-2.52132	+2.13911	-40.30598

TABLE 8: MOUNTING ANGLES RELATIVE TO THE VESSEL REFERENCE FRAME AS STATED IN THE RFS

Mounting Angle (Kongsberg SIS 3.9.2)	Yaw (˚)	Pitch (˚)	Roll (˚)
Port EM3002D transducer	0.0000	+3.23738	+40.26582
Starboard EM3002D transducer	0.0000	+2.13911	-40.30598

TABLE 9: MOUNTING ANGLES RELATIVE TO THE VESSEL REFERENCE FRAME AS ENTERED IN KONGSBERG SIS 3.9.2

3.3.2. OFFSETS

Within the MBES acquisition software, Kongsberg SIS 3.9.2, the CRP was selected as the datum point for which position and attitude are valid. The vessel-reference-frame-normalized output of the V5 Applanix POS MV 320E is also valid at this point. The only outstanding procedure is, therefore, to refer the physical offsets of the MBES transducer acoustic centres (Table 10; Figure 5) to the vessel reference frame as detailed in the RFS.

Node	X (m; +ve fwd.)	Y (m; +ve stbd.)	Z (m; +ve down)
CRP	+0.0000	+0.0000	+0.0000
Port EM3002D transducer	+0.5773	-1.2135	+2.8208
Starboard EM3002D transducer	+0.5632	-0.3452	+2.8200
Waterline			+1.3200

TABLE 10: SENSOR OFFSETS RELATIVE TO CRP AS ENTERED IN KONGSBERG SIS 3.9.2

In addition to the transducer offsets, it is necessary to give the system a waterline value so that Kongsberg SIS 3.9.2 can correctly place the SVP relative to the MBES transducers. This is particularly important when surveying in areas with distinct pycnoclines.

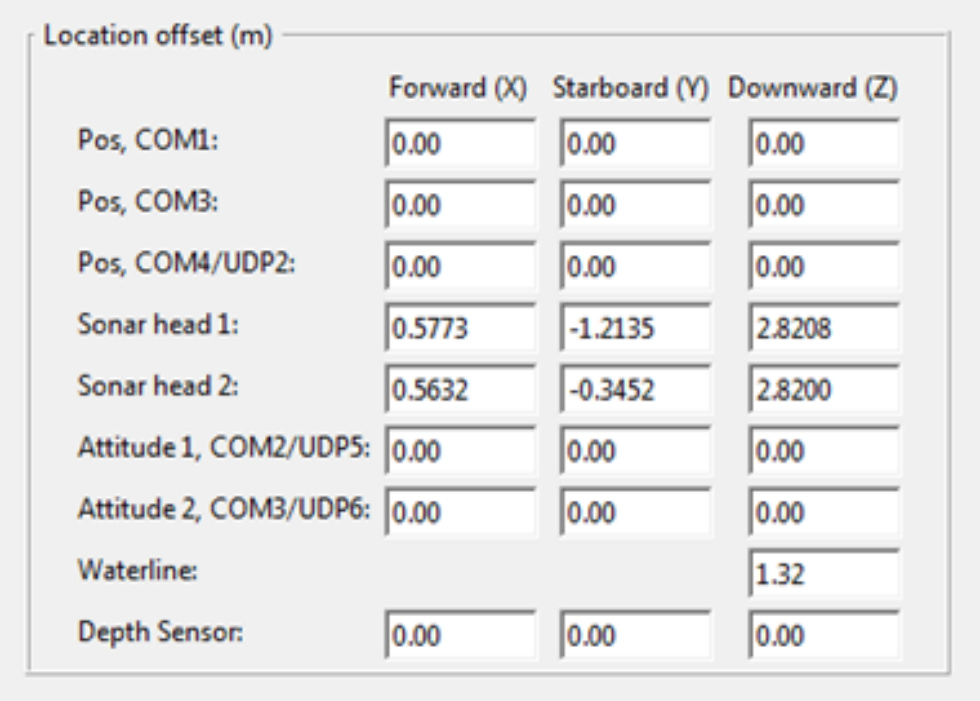


FIGURE 5: KONGSBERG SIS LOCATION OFFSETS

4. NAVIGATION SYSTEM – V5 APPLANIX POS MV 320E

4.1. RTCM 3 CORRECTIONS

The V5 Applanix POS MV 320E provided the primary positioning system receiving RTCM 3 RTK corrections throughout survey operations.

4.2. HEADING CALIBRATION (GAMS)

The GPS Azimuth Measurement System (GAMS) calibration was performed on 17th June 2013 in accordance with manufacturer guidelines. During the GAMS calibration only the offsets of the primary (port) antenna were input into POSView 7.41. The vessel was manoeuvred through a series of tight turns / figure-of-eights until the heading accuracy reduced below the desired accuracy threshold. The vessel was then maintained on a constant heading whilst the automated calibration protocol cycled through to completion.

Once the GAMS solution was complete, the GAMS-computed baseline was compared to the results of the RFS. The GAMS- and RFS-calculated baselines agreed to within 4 decimal places (2.5361m). The GAMS calibration was, therefore, accepted and saved to the configuration file.

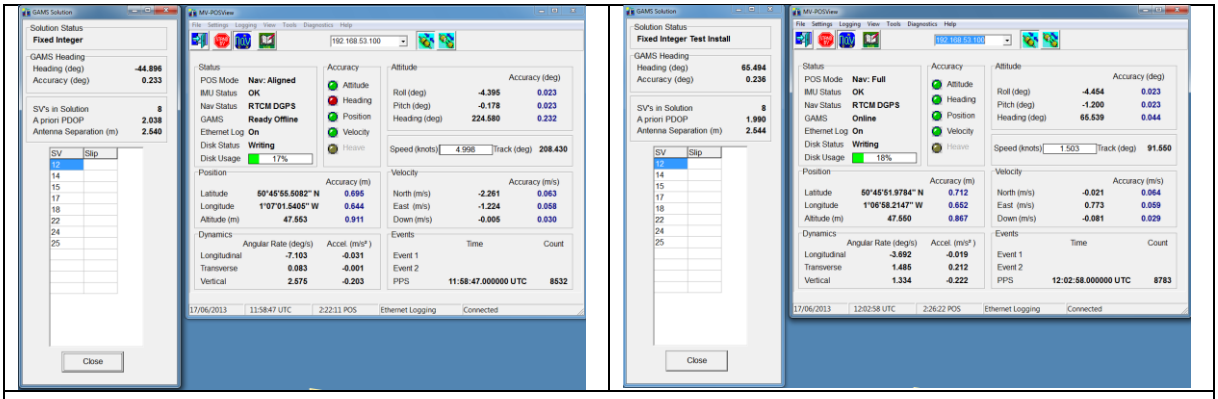


FIGURE 6: GAMS CALIBRATION; BEFORE & AFTER

4.3. ALONGSIDE RTK HEADING VERIFICATION

After the completion of survey operations, an alongside RTK heading verification was conducted in Ramsgate Marina on 30th August 2013. The Leica 1200 (with SmartNet) was placed on the bow and stern of MV Wessex Explorer, and positions of the centre line logged for 1 minute at each location.

The POS MV true heading was also recorded during this procedure. The average positions of the bow and stern recorded by the Leica 1200 (with SmartNet) were entered into QPS QINSy 8.0 Line Manager and a computed baseline heading was generated. This Baseline heading was then compared against the logged V5 Applanix POS MV 320E data.

RTK Baseline Heading True (°)	POS MV Heading True (°)	C-O (°)
173.05	172.54	0.51

TABLE 11: SUMMARY OF HEADING SYSTEM VERIFICATION

A C-O value of 0.51° was calculated but not entered into the software due to the accuracy of the V5 Applanix POS MV 320E and the precision of the RFS.

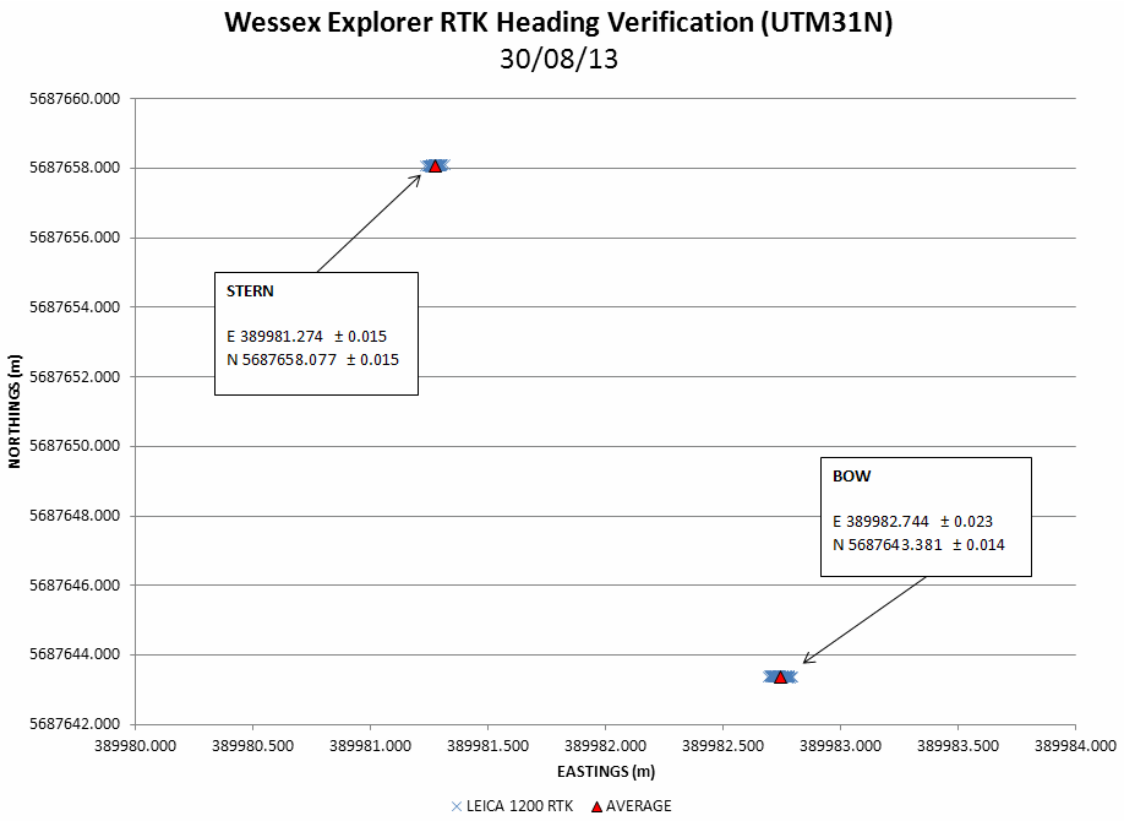


FIGURE 7: RTK HEADING VERIFICATION

E1	N1	Lat1	Lon1	E2	N2	Lat2	Lon2	MP1	MP2	Radius	Length (Grid)	Azimuth° (True)
389981.275	5687658.077	51;19;46.41506 N	1;25;15.04622 E	389982.745	5687643.381	51;19;45.94054 N	1;25;15.13849 E	0.00	14.77	0.00	14.77	173.05

FIGURE 8: AVERAGE BOW AND STERN POSITIONS ENTERED INTO QINSY LINE MANAGER TO OBTAIN COMPUTED BASELINE (AZIMUTH°)

4.4. STATIC VERIFICATION 1

The Leica 1200 (with SmarNet) was used as an independent positional check of the permanently mobilized survey equipment on board MV Wessex Explorer.

On the 28/06/13 the Leica 1200 (with SmarNet) was placed over the Beachy Head Ordnance Survey Passive Station (station number C1TV5995; Appendix B) and data were logged at 1Hz for 30 minutes. Data were acquired in OSGB36/ODN coordinates in order to perform a direct comparison with the established coordinates of the control point.

FIGURE 9: BEACHY HEAD PASSIVE STATION (C1TV5995) STATIC VERIFICATION

The Leica observations were subsequently plotted (Figure 10 and Figure 11) and average values compared with the position of Beachy Head Passive Station, established by the Ordnance Survey (Table 12).

Position (OSGB36)	Beachy Head Passive Station (m)	Leica 1200 (with SmartNet) Observations Average (m)	C-O (m)
Easting (m)	559038.370	559038.416 ± 0.005	-0.046
Northing (m)	95789.998	95789.993 ± 0.005	0.005
Orthometric Height (m)	162.978	162.968 ± 0.010	0.010

TABLE 12: POSITIONING VERIFICATION C-O RESULTS

The average difference between the OS surveyed position of Beachy Head Passive Station and the logged data was -0.046m in the Easting, 0.005m in the Northing and 0.010m in the vertical. The Leica 1200 (with SmarNet) was then used to survey Sovereign Harbour cill, as described in section 5.5.

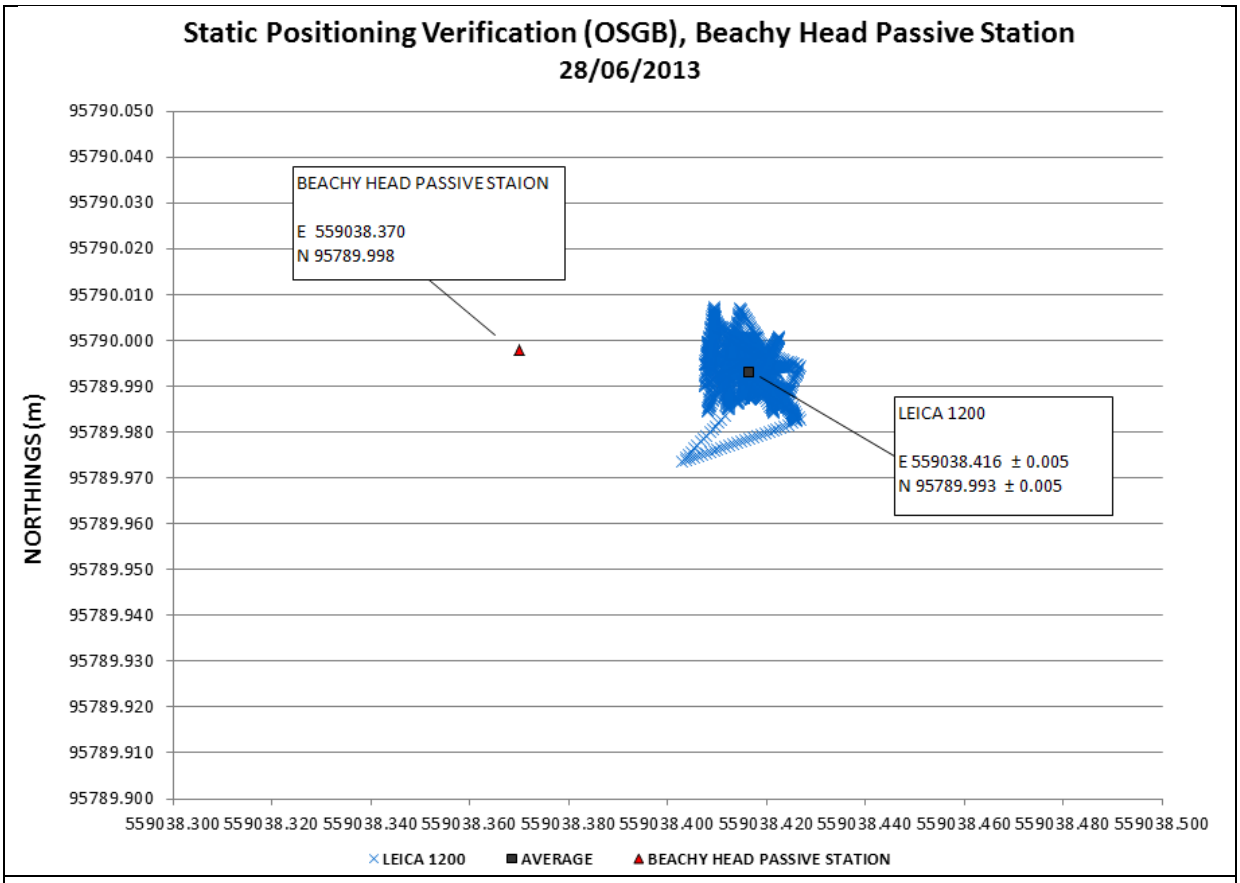


FIGURE 10: STATIC POSITIONING VERIFICATION (HORIZONTAL), BEACHY HEAD PASSIVE STATION

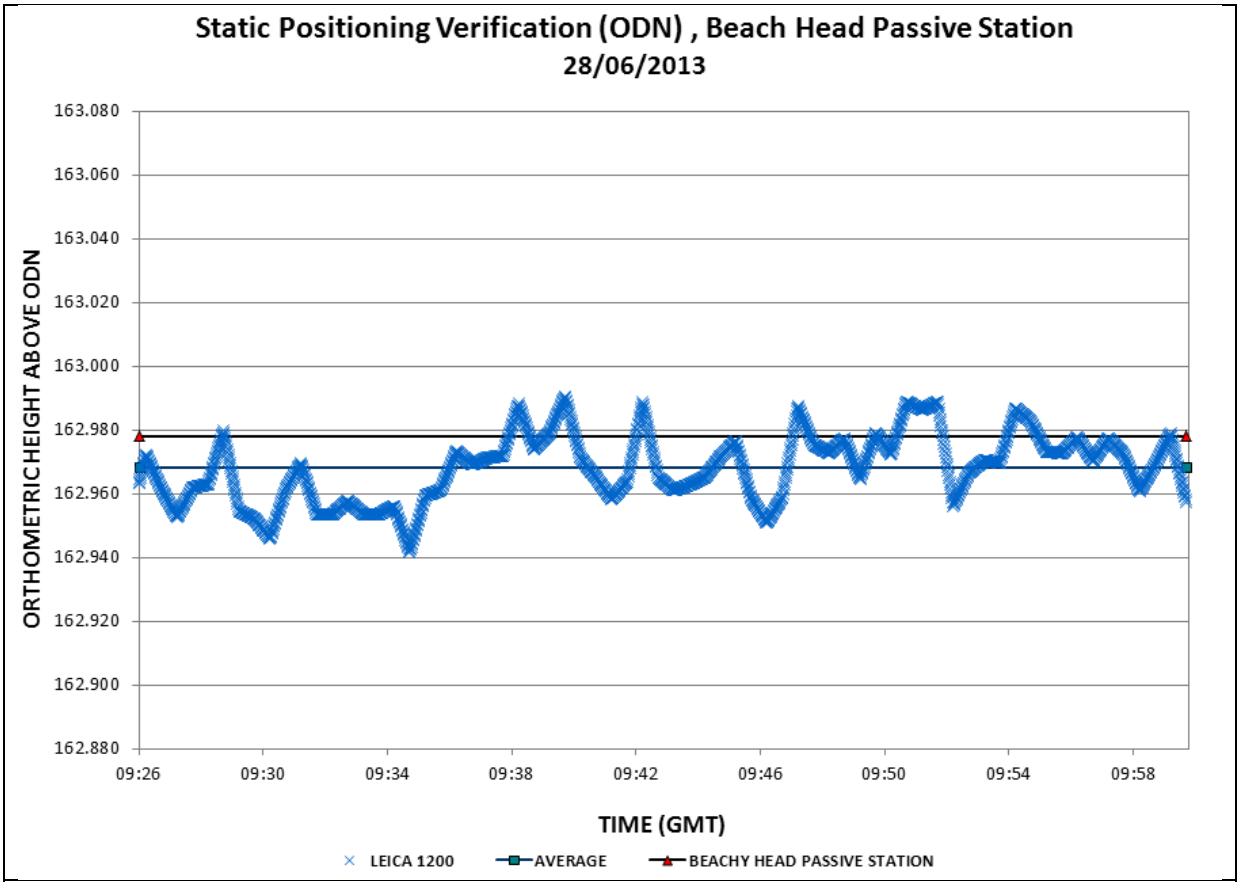


FIGURE 11: STATIC POSITIONING VERIFICATION (VERTICAL), BEACHY HEAD PASSIVE STATION

4.5. STATIC VERIFICATION 2

The Leica 1200 (with SmartNet) was used as an independent positional check of the permanently mobilised survey equipment on board the Wessex Explorer whilst alongside in Ramsgate Marina.

On the 27th September the Leica 1200 antenna was placed over Royal ST Georges C1TR3557 an Ordnance Survey passive station (*Appendix B*), Sandwich Kent. Data were logged in QINSy for 20mins at 1.0Hz.

The results were plotted in UTM Zone 31 North and an overall mean calculated. The average of the observations was then compared with the position of the passive station, established by Ordnance Survey

FIGURE 12: ROYAL ST GEORGES STATIC NAVIGATION CHECK LOCATION

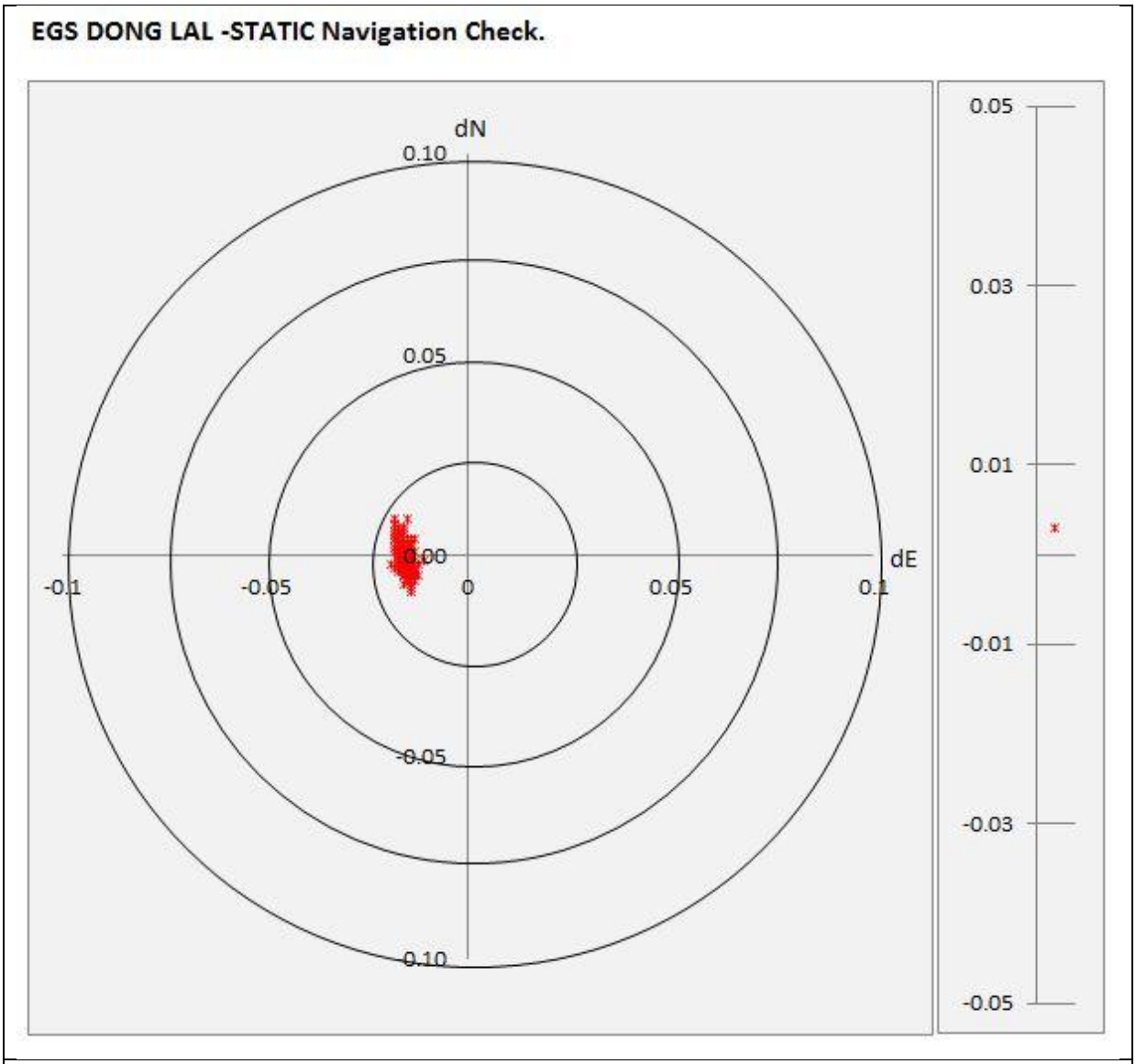


FIGURE 13: STATIC NAVIGATION RESULTS C1TR3557

	Royal St Georges UTM31	Observations - Average UTM31	C-O (m)
Easting (m)	386154.630	386154.61	0.0170
Northing (m)	5681149.560	5681149.56	-0.004
Ellipsoidal Height (m)	47.098	47.09	-0.008

TABLE 13: POSITIONING VERIFICATION C-O RESULTS

4.6. DYNAMIC VERIFICATION

An RTK positioning verification was performed after the end of survey operations in Ramsgate Marina on 30th August 2013.

The V5 Applanix POS MV 320E was interfaced with RTCM 3 RTK corrections from Margate Tower. A comparison of the CRP position output by the Leica 1200 (with SmartNet) and

the V5 Applanix POS MV 320E RTK was used as a dynamic verification of the vessel positioning system.

The observed difference in the horizontal and vertical positions of the CRP output by both systems calculated in QINSy (Figure 14) acts as a 'health check' confirming that the correct lever arms, offsets and heading misalignments are entered. The results of this verification are summarised in Table 14, below.

	dE	dN	dH
Leica 1200 (with SmartNet) vs. V5 Applanix POS MV 320E RTK	-0.02	0.03	-0.03

TABLE 14: DYNAMIC POSITIONING VERIFICATION RESULTS

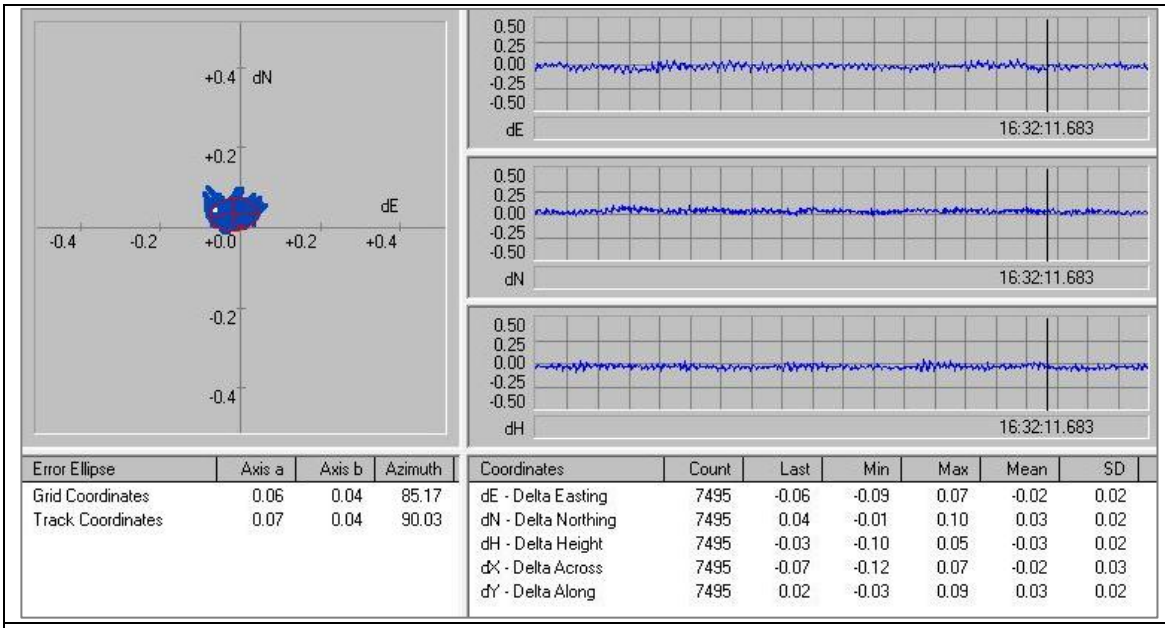


FIGURE 14: COMPARISON BETWEEN OBSERVED POSITIONS OF VESSEL CRP USING LEICA 1200 SMARTNET AND POS MV RTK SYSTEMS

5. MULTIBEAM CALIBRATION – KONGSBERG EM3002D

5.1. INTRODUCTION

MV Wessex Explorer is permanently mobilised with a full suite of state-of-the-art survey equipment. The relative horizontal and vertical position of the survey systems was established by the RFS to within 0.5mm and can be considered as being fixed. Section 0 describes the normalisation of the V5 Applanix POS MV 320E reference frame to the vessel reference frame. Section 3.3 describes the normalisation of the Kongsberg EM3002D MBES reference frame to the vessel reference frame.

When a MBES, attitude and positioning system are installed, there will always be some residual misalignment between sensors. Therefore, the only outstanding element is to demonstrate that the angular offsets of the Kongsberg EM3002D and V5 Applanix POS MV 320E reference frames are, indeed, aligned. This is achieved via patch tests and Repeatability Test. Calibration procedures were repeated until any outstanding misalignments were reduced to zero.

Deviations in the roll alignment will translate to depth measurement errors in the outer beams, increasing with beam angle. Deviations in pitch will result in along-track position errors, whilst deviations in heading will, similarly, result an along- and across-track displacement seabed targets.

If the data collection system is not synchronised to GPS time, it is also necessary to determine the latency of the positioning system. Whilst it is possible to investigate roll, pitch and heave errors in real-time, It is not possible to make real-time latency adjustments unless RTK positioning is available as it is difficult to isolate latency errors from positional errors. For the purpose of the annual calibration procedure, the appropriate calibration lines were run without making any real-time changes. The V5 Applanix POS MV 320E data were post-processed and a Smoothed Best Estimate Trajectory (SBET) produced in POSPac MMS 6.2. The SBET was applied in CARIS HIPS and SIPS 8.1 and any residual angular offsets investigated.

5.2. ANNUAL CALIBRATION

The annual Kongsberg EM3002D MBES patch test & Repeatability Test were performed on 18/06/13 and 19/06/13, respectively (Figure 15). Roll and Pitch patch tests were conducted over the wreck of the SS Algerian (Figure 16). The heading patch test and final Repeatability Test were conducted over un-unclassified wreck (UKHO: 19606), due-East of East Bramble Cardinal.

Fresh SVP casts were performed prior-to each set of calibration lines. After MBES acquisition, the V5 Applanix POS MV 320E positioning data were post-processed in POSPac MMS 6.2 and a Smoothed Best Estimate Trajectory (SBET) created. The SBET was merged with the calibration data in CARIS HIPS & SIPS 8.1 and the lines were investigated for residual angular offsets prior to the final Repeatability Test conducted on 19/06/13.

The weather conditions were settled and sea state was calm. The system performed to top specifications during all tests, as expected.

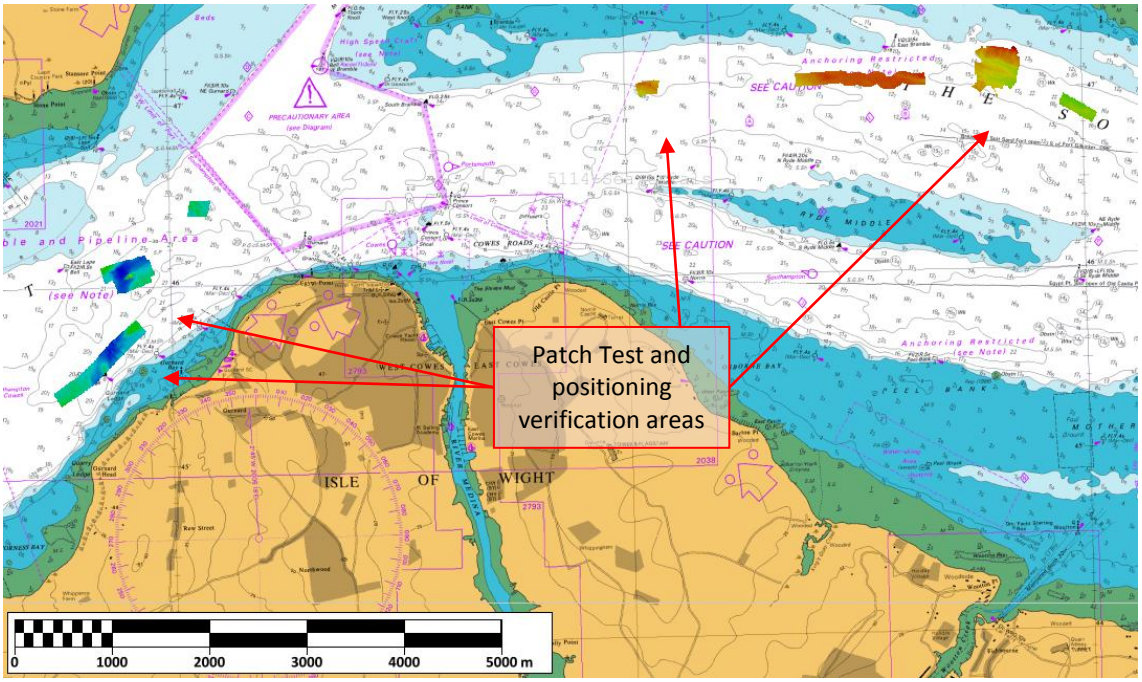


FIGURE 15: THE SOLENT, 19TH JUNE 2013 - MBES PATCH TEST AND POSITIONING VERIFICATION AREAS

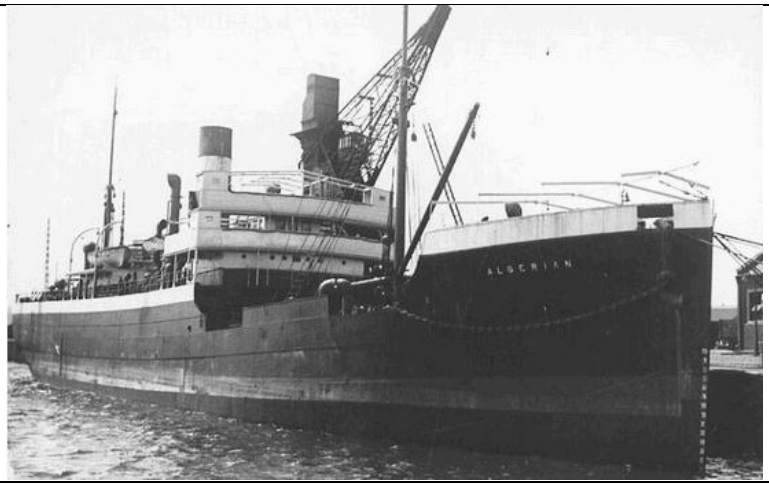


FIGURE 16: SS ALGERIAN

5.2.1. ROLL CALIBRATION

To verify any residual roll offset, three lines were run adjacent to each other with approximately 70% overlap (Figure 16). These lines were run in alternate directions at the same nominal speed over a relatively flat seabed in relatively deep water. Any resulting roll errors were compensated during post-processing and new angles determined.

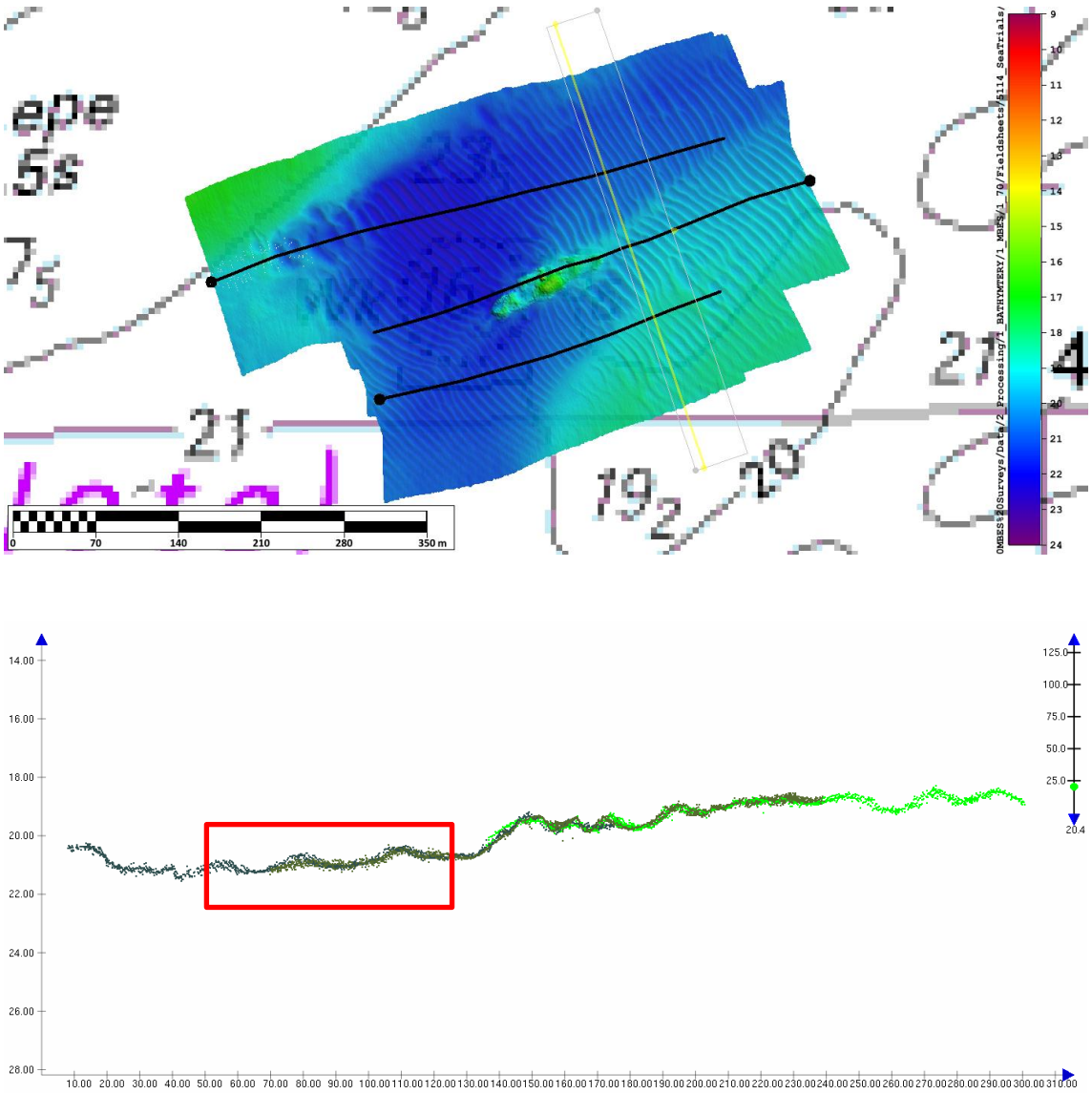


FIGURE 17: ROLL CALIBRATION

ACROSS-TRACK SECTION SHOWING THE CORRECT VERTICAL ALIGNMENT OF THE OUTER BEAMS OVER THE NADIR BEAMS OF THREE VERIFICATION LINES. THE STARBOARD HEAD OVERLAP IS HIGHLIGHTED BY A RED BOX.

Figure 17 shows that there is no residual error in the roll alignment of the MBES heads relative to the vessel reference frame. A minor adjustment was made to the roll of the starboard head as highlighted in Figure 17 and detailed in Table 15.

Roll Mounting Angle (°)	RFS	Patch Test	Changes Applied
Port EM3002D transducer	+40.26582	+40.26582	nil
Starboard EM3002D transducer	-40.30598	-40.23098	0.07500

TABLE 15: ROLL CALIBRATION RESULTS

5.2.2. PITCH CALIBRATION

To verify any residual pitch offset, two lines were run in opposite directions with roughly 100% overlap over a seabed target (SS Algerian) at the same nominal speed. Any resulting pitch errors were compensated during post-processing and new angles determined.

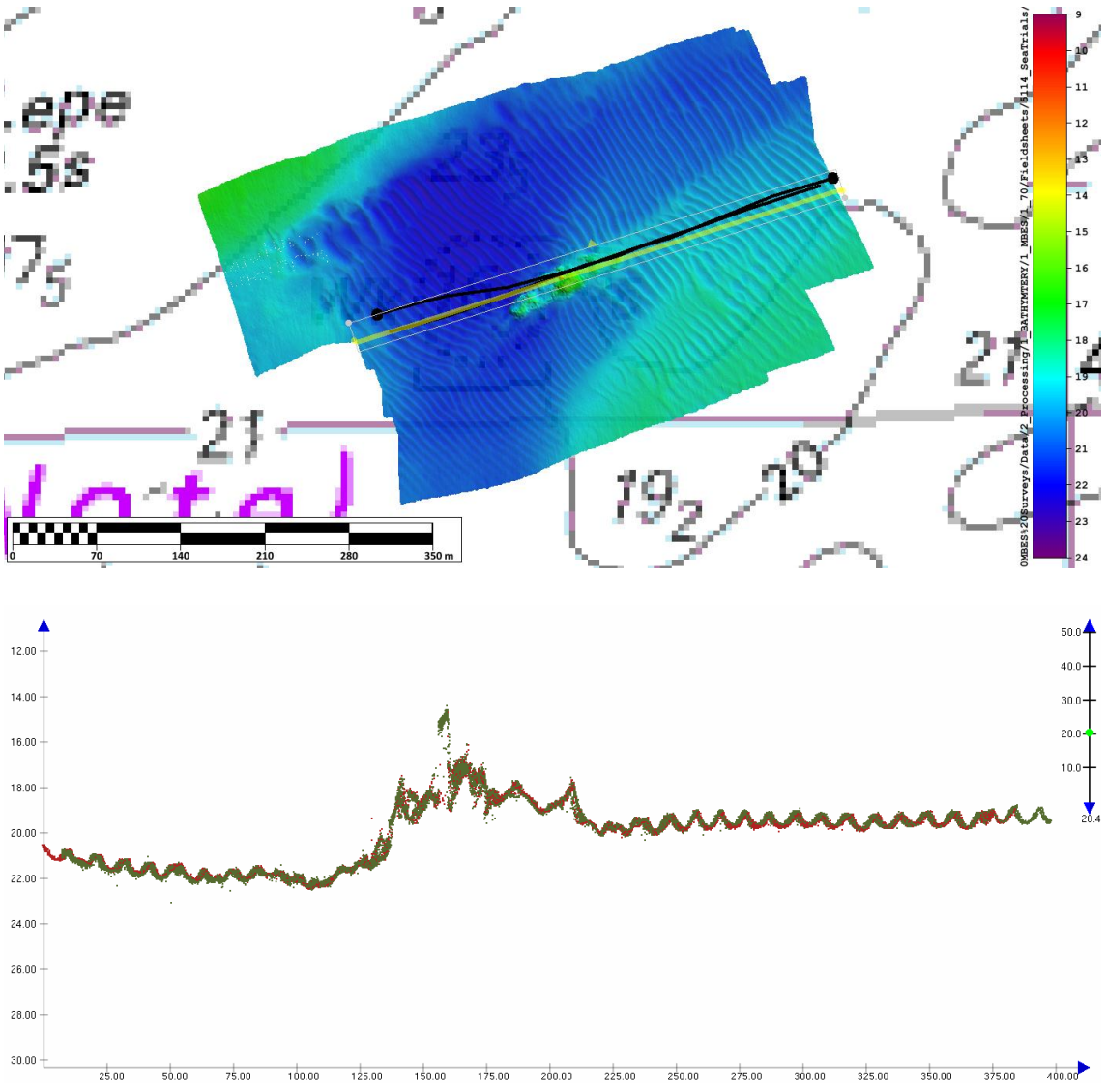


FIGURE 18: PITCH CALIBRATION

ALONG-TRACK SECTION SHOWING THE CORRECT HORIZONTAL POSITIONING OF THE SEABED FEATURES

Figure 18 shows that there is no residual error in the pitch alignment of the MBES heads relative to the vessel reference frame, as detailed in Table 15.

Pitch Mounting Angle (°)	RFS	Patch Test	Changes Applied
Port EM3002D transducer	+3.23738	+3.23738	nil
Starboard EM3002D transducer	+2.13911	+2.13911	nil

TABLE 16: PITCH CALIBRATION RESULTS

5.2.3. LATENCY CALIBRATION

During the pitch patch test (5.2.2) two lines were run with approximately 100% overlap, in the same nominal direction at survey speed (~4.0 knots) and full speed (~8.0 knots).

Once the SBET was merged with the MBES data in CARIS HIPS & SIPS 8.1, it was possible to investigate latency due to the accuracy of post-processed positioning (1-2cm). No latency errors were observed in the patch test data.

5.2.4. HEADING CALIBRATION

To verify the residual heading offset, two lines were run in the same direction with approximately 20% overlap over a seabed target in the outer beams, at the same nominal speed. A third line was run in the same direction with the seabed target located at the nadir.

Initially zero-values were input into the acquisition software, Kongsberg SIS 3.9.2. During post-processing heading offsets were adjusted as detailed in Table 17. A further verification of the new heading values was conducted during the Repeatability Test, conducted on 19/06/13 (Figure 19).

Heading Mounting Angle (°)	RFS	Patch Test	Changes Applied
Port EM3002D transducer	+3.82030	+1.30000	-2.52030
Starboard EM3002D transducer	-2.52132	+1.30000	+3.82132

TABLE 17: HEADING CALIBRATION RESULTS

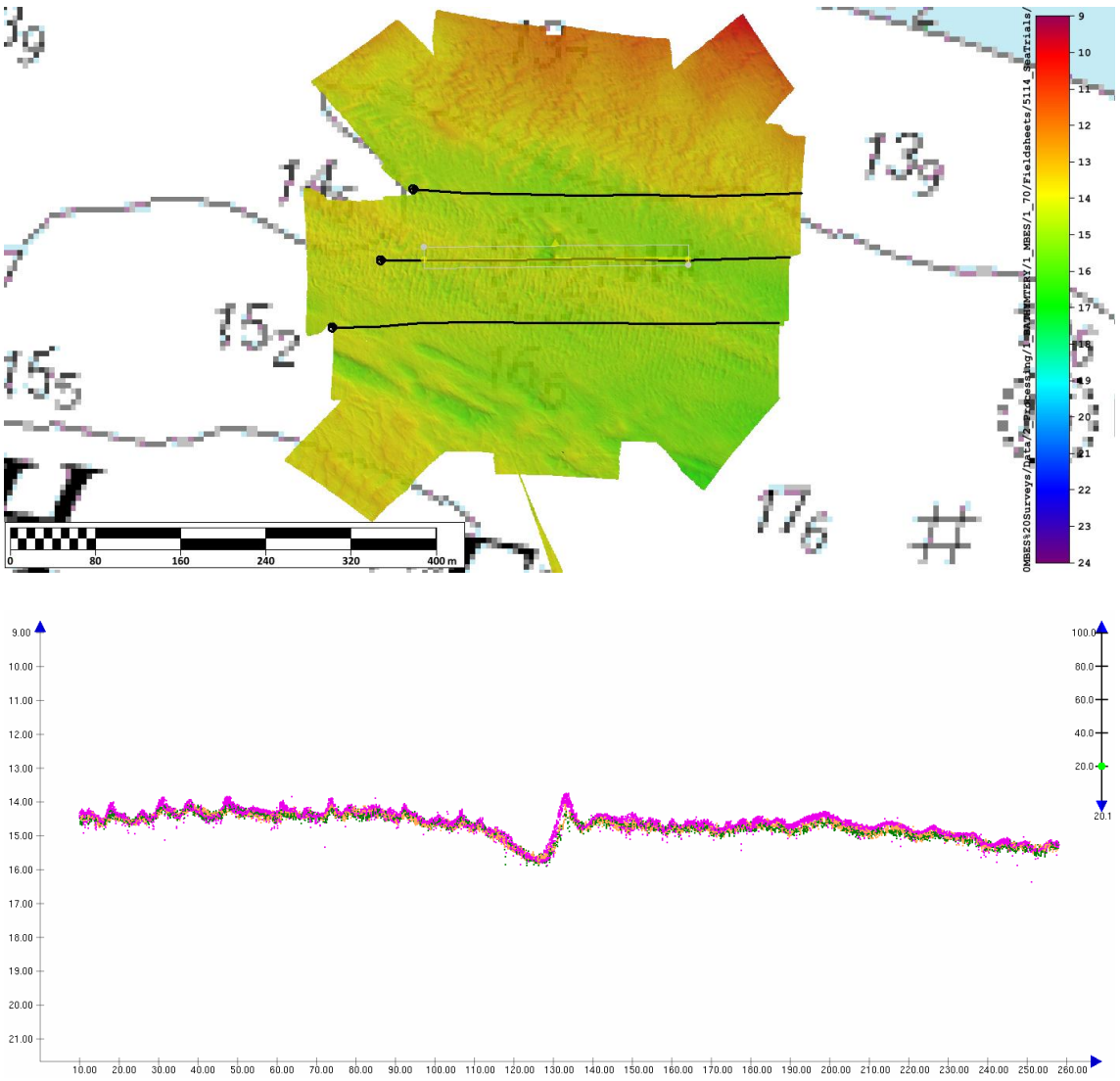


FIGURE 19: HEADING CALIBRATION

ALONG-TRACK SECTION SHOWING THE CORRECT HORIZONTAL POSITIONING OF THE SEABED TARGET

5.2.5. Calibration Results Summary

The residual angular offsets, as determined in the Solent on the 19/06/13 are summarized below (Table 18; Figure 20).

MBES	Roll Offset (˚)	Pitch Offset (˚)	Heading Offset (˚)
Sonar Head 1	+40.26582	+3.23738	1.30000
Sonar Head 2	-40.23098	+2.13911	1.3000
Attitude 1 (COM2)	nil	nil	nil
Stand-alone Heading	nil	nil	nil

Table 18: Calibration Results Summary

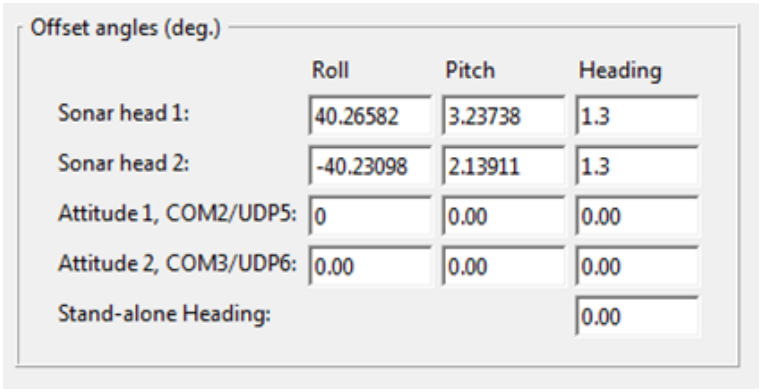


Figure 20: Kongsberg SIS 3.9.2 Offset Angles

5.2.6. Known Seabed Target

EGSi regularly conducts patch tests, repeatability tests and positioning verifications over a known seabed target. The results of the 2013 verification are detailed in Table 19, below and demonstrate that positioning is in agreement with previous surveys.

Position (UTM30N)	EGSi 2008 (m)	EGSi 2012 (m)	EGSi 2013 (m)	2008-2013 (m)
Easting (m)	626500.91	626500.70	626500.85	+0.06
Northing (m)	5625871.20	5625871.25	5625871.30	-0.20

Table 19: Known Target Verification Results

5.3. REPEATABILITY TEST

In order to verify the correct functioning of survey equipment mobilised onboard MV Wessex Explorer a repeatability test was conducted.

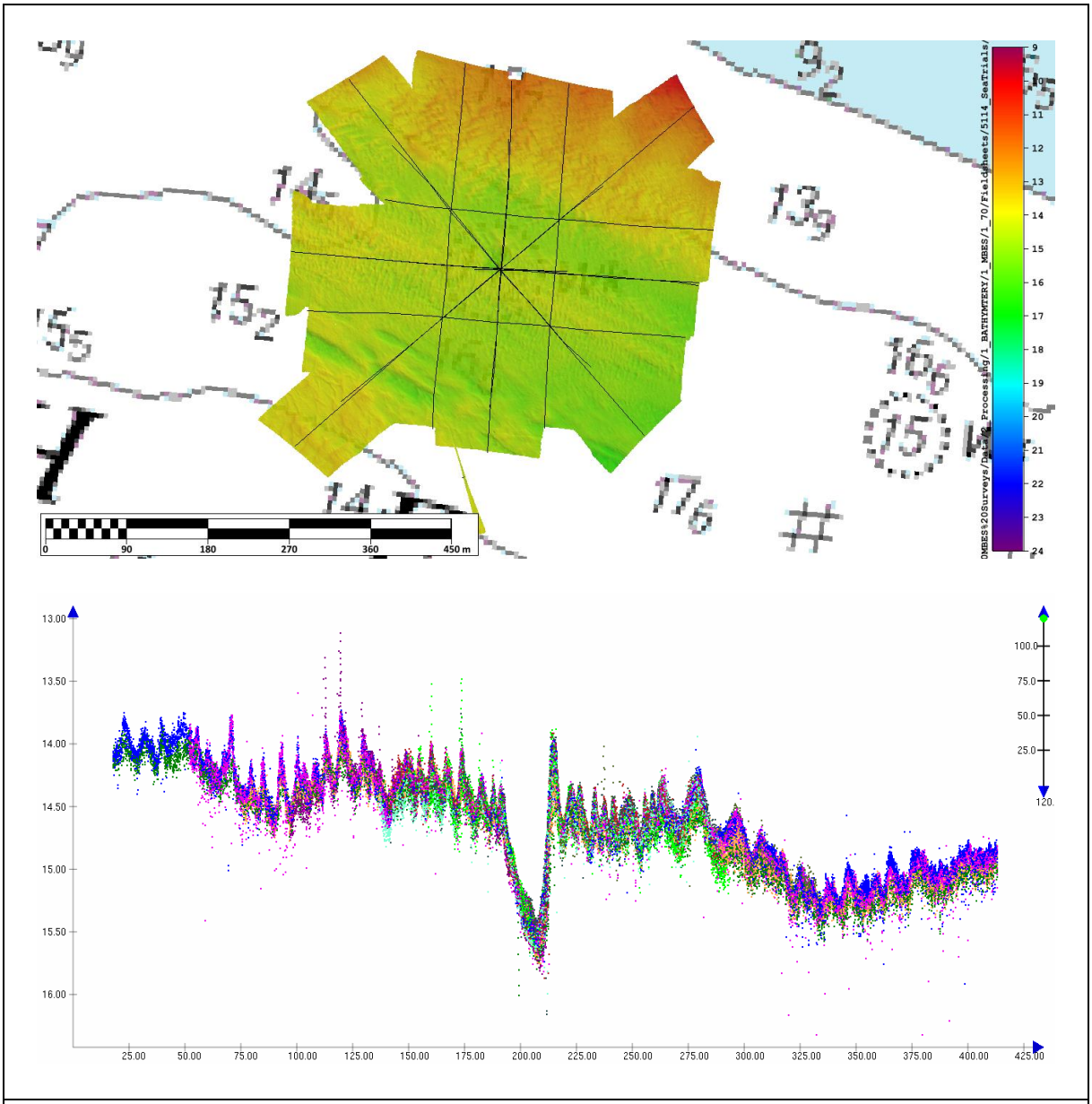


FIGURE 21: REPEATABILITY TEST

Total Observed Vertical (TVU) and Horizontal (THU) Uncertainties were calculated and the system was found to be performing well within the requirements of IHO Special Order. Detailed results of the repeatability test are given in section 0.

5.4. SOUND VELOCITY PROFILER COMPARISON

The vertical density structure of the water column must be known in order to correctly calculate acoustic ray paths. Fresh Sound Velocity Profiles (SVPs) must be taken when a significant change in the speed of sound through the water column is observed.

The two sensors used for acquiring sound data were:

- Valeport SoundBar 2 SN 23862 (Primary)
- Valeport Monitor SVP SN 23389 (Secondary)

A shallow-water SVP comparison was conducted in Ramsgate Harbour on 4thSeptember 2013. The two instruments agreed within 0.20 ±0.09 m/s of each other (Figure 22).
The Valeport SoundBar2 was selected as the primary SVP as it is an extremely easy and quick instrument to deploy, with SVP data going straight into the MBES acquisition computer and no major data processing required. Accuracy is, in fact, improved due to the facility with which SVPs can be acquired with negligible impact on survey operations.
All sensors were factory calibrated by Valeport. Calibration certificates can be found in Appendix C.

In addition to the two SVPs, a Sound Velocity Sensor (SVS) is hull-mounted next-to the MBES transducers. The calibration certificate for the SVS has expired, but it is not used for data acquisition. The SVS is used for visualization purposes and as a real-time indication of the evolving sound velocity at the transducer heads.

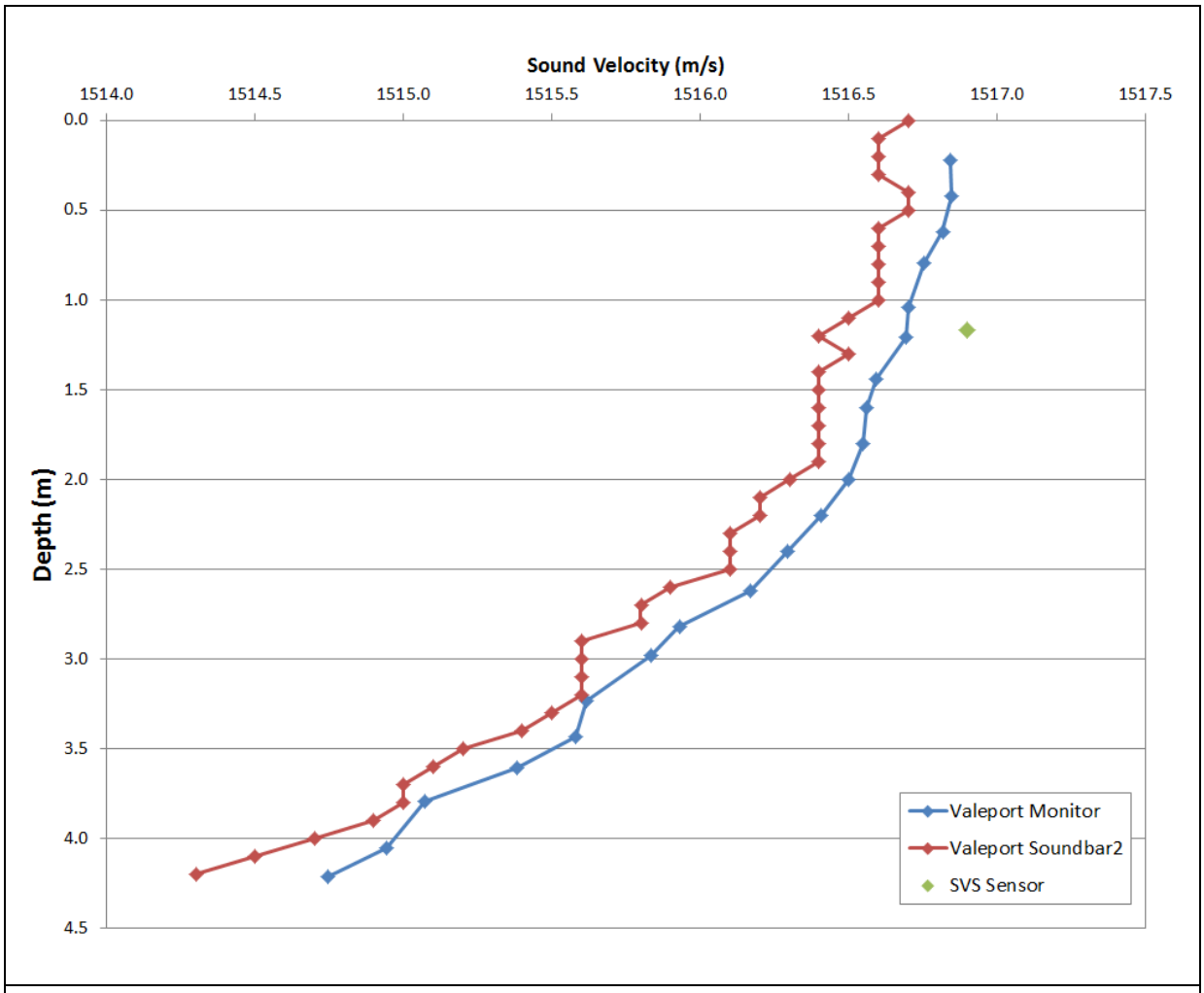


FIGURE 22: SVP COMPARISON BETWEEN VALEPORT MONITOR AND VALEPORT SOUNDBAR 2

5.5. LOCAL VERIFICATION – KENTISH FLATS

QINSy MBES Calibration

As the MBES data was also logged in QINSY a further calibration was conducted on the LAL cable route over a series of sand waves in the Kentish flats area. Reciprocal lines were run over flat areas for roll and a series of lines over the sandwaves determined Pitch and yaw. The results can be seen below.

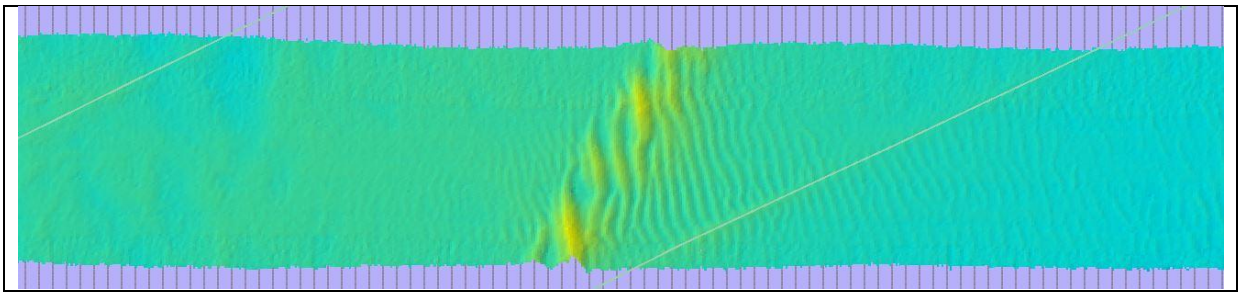


FIGURE 23: 5 OVERLAPPING MBES LINES SHOWING GOOD CORRELATION BETWEEN ADJACENT SWATHS

CALIBRATION RESULTS

Calibrated Transducer	:	EM3002 PORT - Transducer 1
Roll	:	40.50°
Roll Correction	:	0.23°
Roll Calib. Quality	:	Manually calibrated
Pitch	:	2.94°
Pitch Correction	:	-0.30°
Pitch Calib. Quality	:	Manually calibrated
Heading	:	1.10°
Heading Correction	:	-0.20°
Heading Calib. Quality	:	Manually calibrated

FIGURE 24: PORT TRANSDUCER CALIBRATION RESULTS (QINSY)

CALIBRATION RESULTS

Calibrated Transducer	:	EM3002 STBD - Transducer 2
Roll	:	-40.38°
Roll Correction	:	-0.15°
Roll Calib. Quality	:	Manually calibrated
Pitch	:	2.26°
Pitch Correction	:	0.13°
Pitch Calib. Quality	:	Manually calibrated
Heading	:	1.10°
Heading Correction	:	-0.20°
Heading Calib. Quality	:	0.0005 m²

FIGURE 25 STARBOARD TRANSDUCER CALIBRATION RESULTS (QINSY)

6. TOTAL PROPAGATED UNCERTAINTY – TPU

The Total Propagated Uncertainty associated to a given sounding can be calculated either by inputting the standard deviations of each sensor (as specified by the manufacturer) and the standard deviations associated to the RFS into the vessel-specific error model (Theoretical TPU). Alternatively, the Observed TPU can be computed from acquired data.

If the parameters entered in the error model are correct and the survey equipment is correctly installed and calibrated, the two TPUs should match closely in normal survey conditions.

6.1.1. THEORETICAL TPU

6.1.1.1. ANCILLARY SYSTEM MANUFACTURER SPECIFICATIONS

All sensors RMS standard deviations at 1 sigma (68% confidence level) are listed in Table 20 as-specified by the manufacturer.

Sensor	Component	Uncertainty
V5 Applanix POS MV 320E (real-time with RTCM corrections)	Position Heading Roll & Pitch Heave	0.5 – 2.0m (1σ) 0.02° (1σ 2.0m baseline) 0.02° (1σ) 0.05m / 5% (greatest)
Leica 1200 GPS (post-processed)	Horizontal Vertical	0.0010m + 1ppm (kinematic) 0.0020m + 1ppm (kinematic)
C&C C-Nav 2050 (real-time DGPS)	Horizontal Vertical	<0.10m <0.15m
Valeport SoundBar2	Speed of sound in water	±0.02 m/s
Reference Frame Survey	Horizontal & Vertical	0.0005m
Calibration Values	Angular Offsets	0.005°

TABLE 20: THEORETICAL SENSOR STANDARD DEVIATIONS

6.1.1.2. ERROR BUDGET

Standard deviations as entered in the vessel-specific error model are listed in Table 21. Error budget results for 15m water depth are presented as charts in Figure 26, Figure 27 and Figure 28.

Sensor	Uncertainty (RMS Standard Deviation)
RFS precision (m)	0.0005
Positioning error (m)	0.02
Motion Gyro (°)	0.02
Heave % Amp.	5

Sensor	Uncertainty (RMS Standard Deviation)
Heave (m)	0.05
Roll (˚)	0.02
Pitch (˚)	0.02
Position Nav (m)	0.02
MRU Alignment precision (˚)	0.005
Speed of Sound (m/s)	0.1
Latency (µs)	1
Vertical Reduction (Draft + Tide) (m)	0.03

TABLE 21: STANDARD DEVIATIONS AS ENTERED IN THE ERROR BUDGET

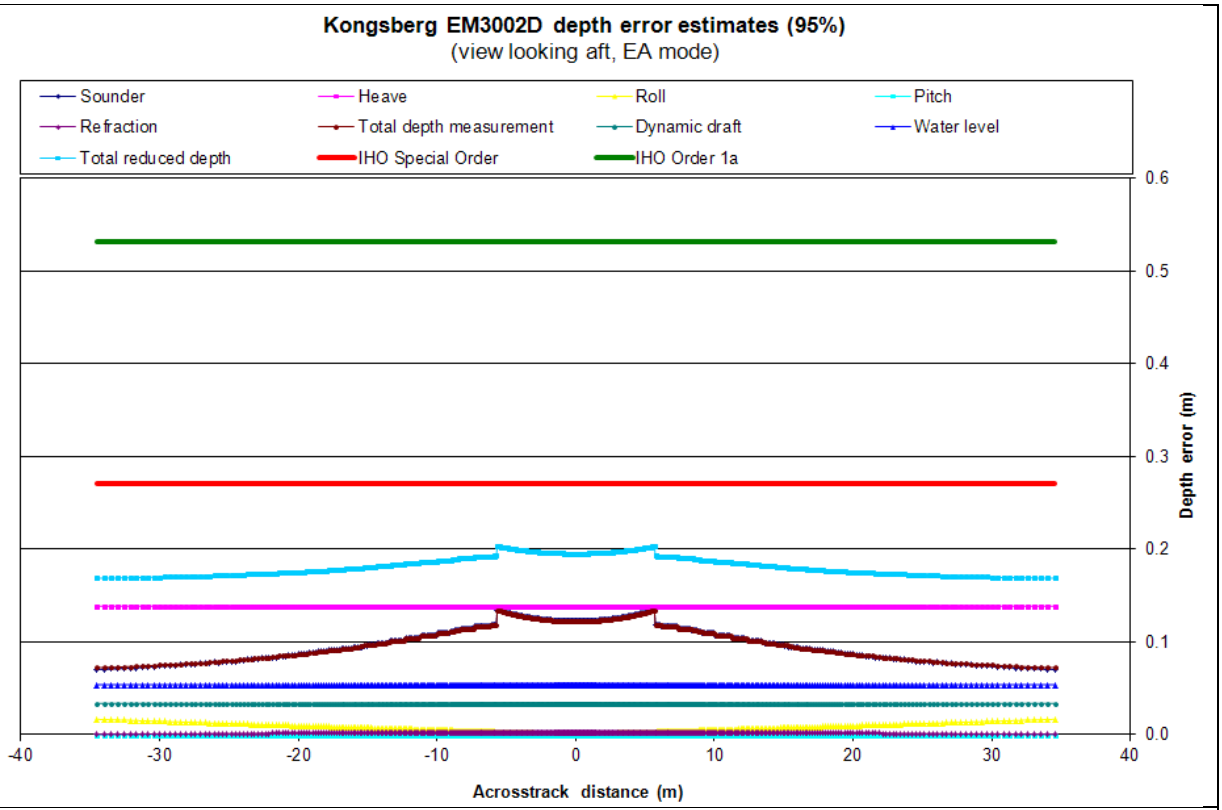


FIGURE 26: ERROR BUDGET – DEPTH ERROR ESTIMATES

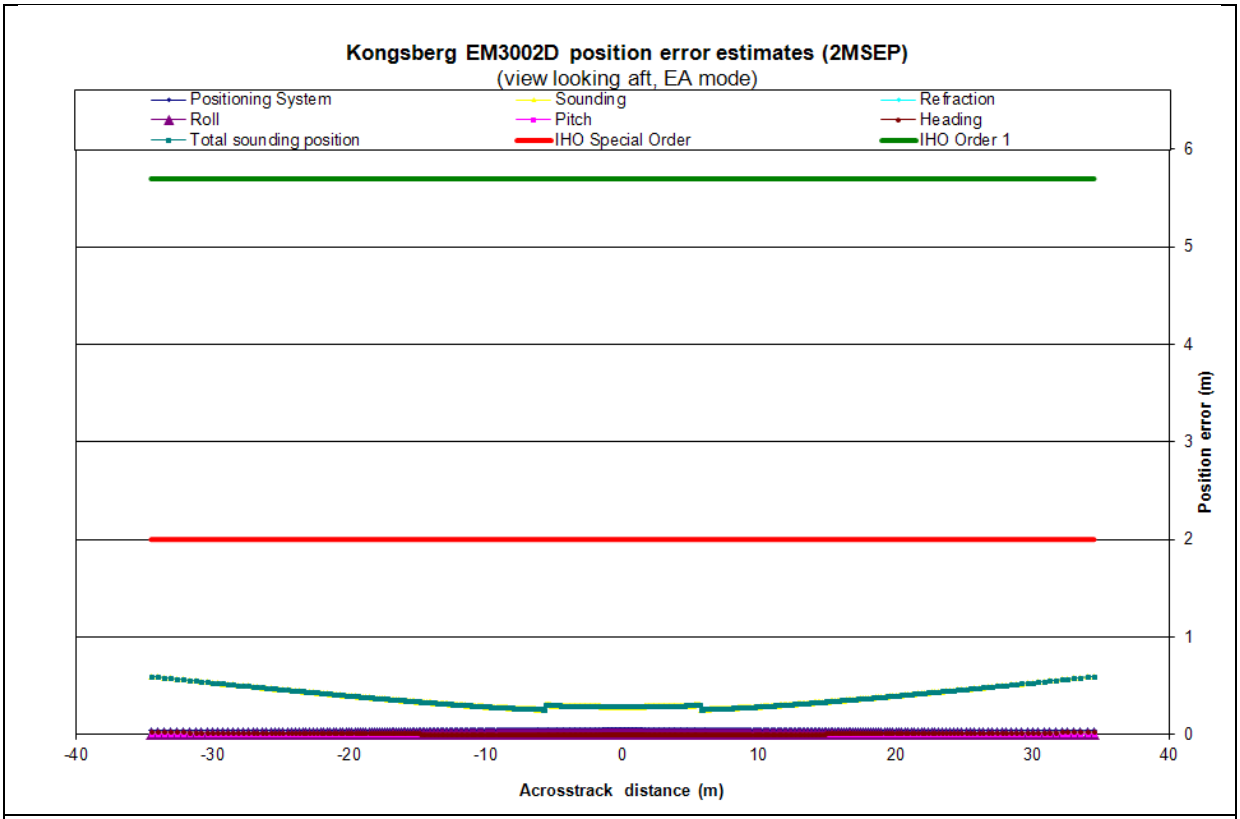


FIGURE 27: ERROR BUDGET – POSITION ERROR ESTIMATES

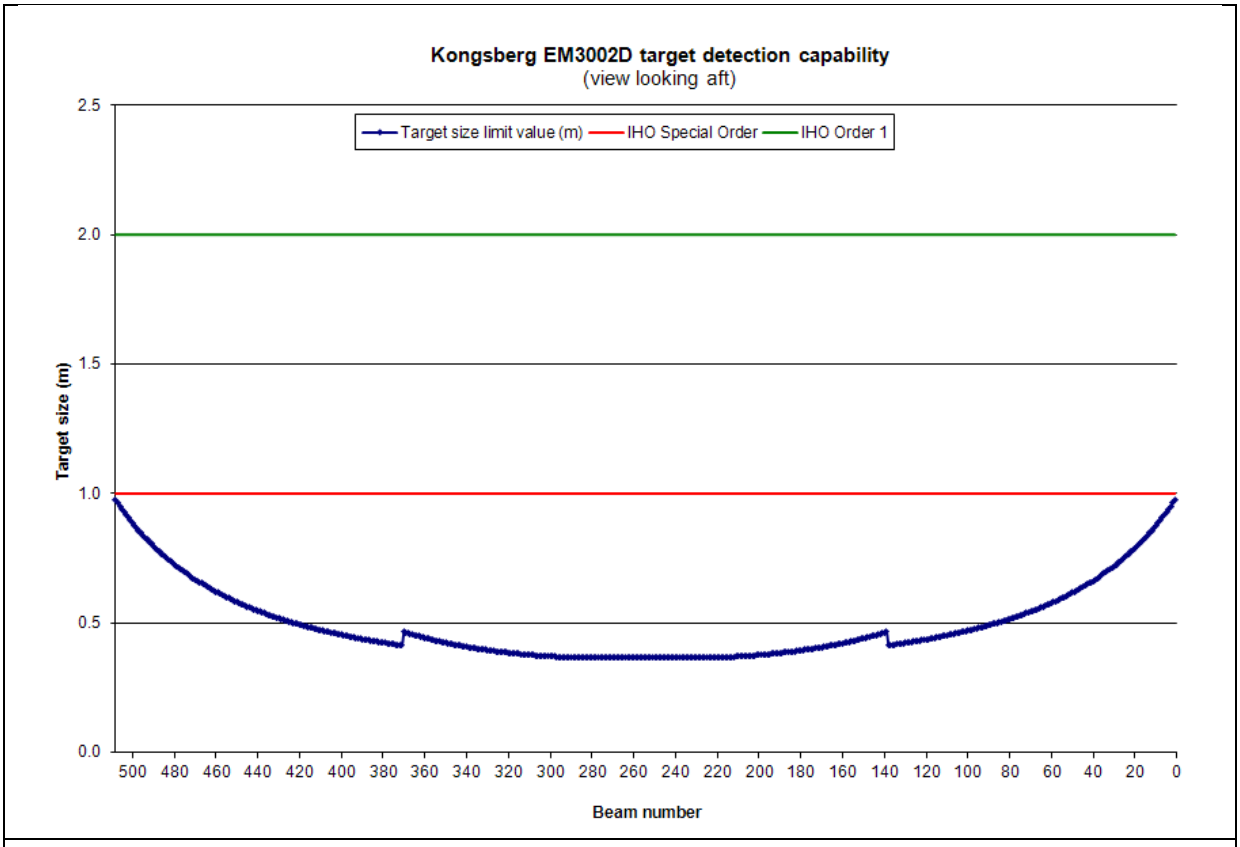


FIGURE 28: ERROR BUDGET – TARGET DETECTION CAPABILITY

The error budget for MV Wessex Explorer demonstrates that the system is theoretically capable of exceeding IHO Special Order based on the input parameters listed in Table 21.

6.1.2. OBSERVED TPU

6.1.2.1. TOTAL OBSERVED HORIZONTAL UNCERTAINTY

To determine the observed Total Horizontal Uncertainty (THU) associated to the soundings, a sample section was chosen within the Repeatability Test area, over a relatively small and isolated target on the seabed. No soundings were rejected. The soundings were queried and Eastings and Northings exported as txt file. Average values and standard deviations of the population were computed and results are summarised in Table 22. It should be noted that as only 13 lines were run over the target, it was not possible to isolate a large population for the purposes of this calculation.

Coordinates	**Average** (m)	**Observed THU** (Standard Deviation; m)	**Population** (Number of Soundings)	**Special order** (m)
Eastings	5627448.00	0.28	252	2
Northings	626010.02	0.26	252	2

TABLE 22: OBSERVED THU STATISTICS SUMMARY

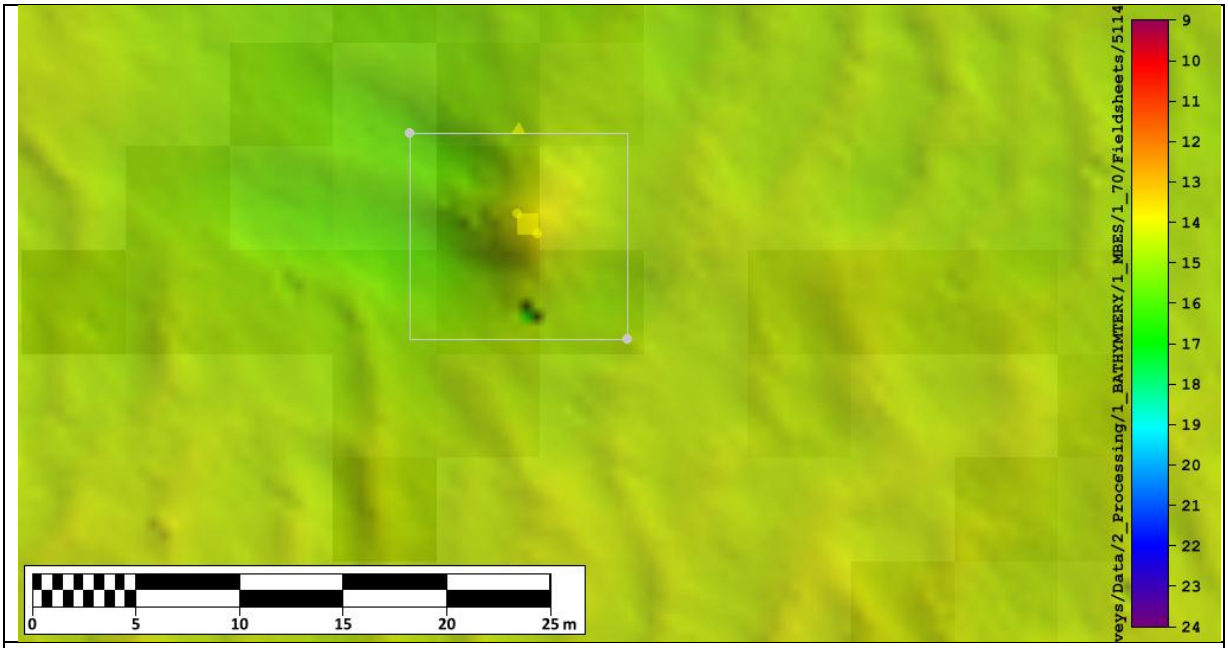


FIGURE 29: TVU SUBSET LOCATION

6.1.2.2. TOTAL OBSERVED VERTICAL UNCERTAINTY

To determine the observed Total Horizontal Uncertainty (THU) associated to the soundings, a sample section was chosen from the LAL Export cable route. Overlapping swaths provided information from which the Total vertical uncertainty could be processed. This data is displayed at 95% confidence levels (2 Sigma).

From Figure 30 it can be determined that this sub section of data is within the custom limit set by DONG of 0.2m at 2 Sigma.

Plots for the entire cable route were generated confirming that the entire cable route was within the custom limit.

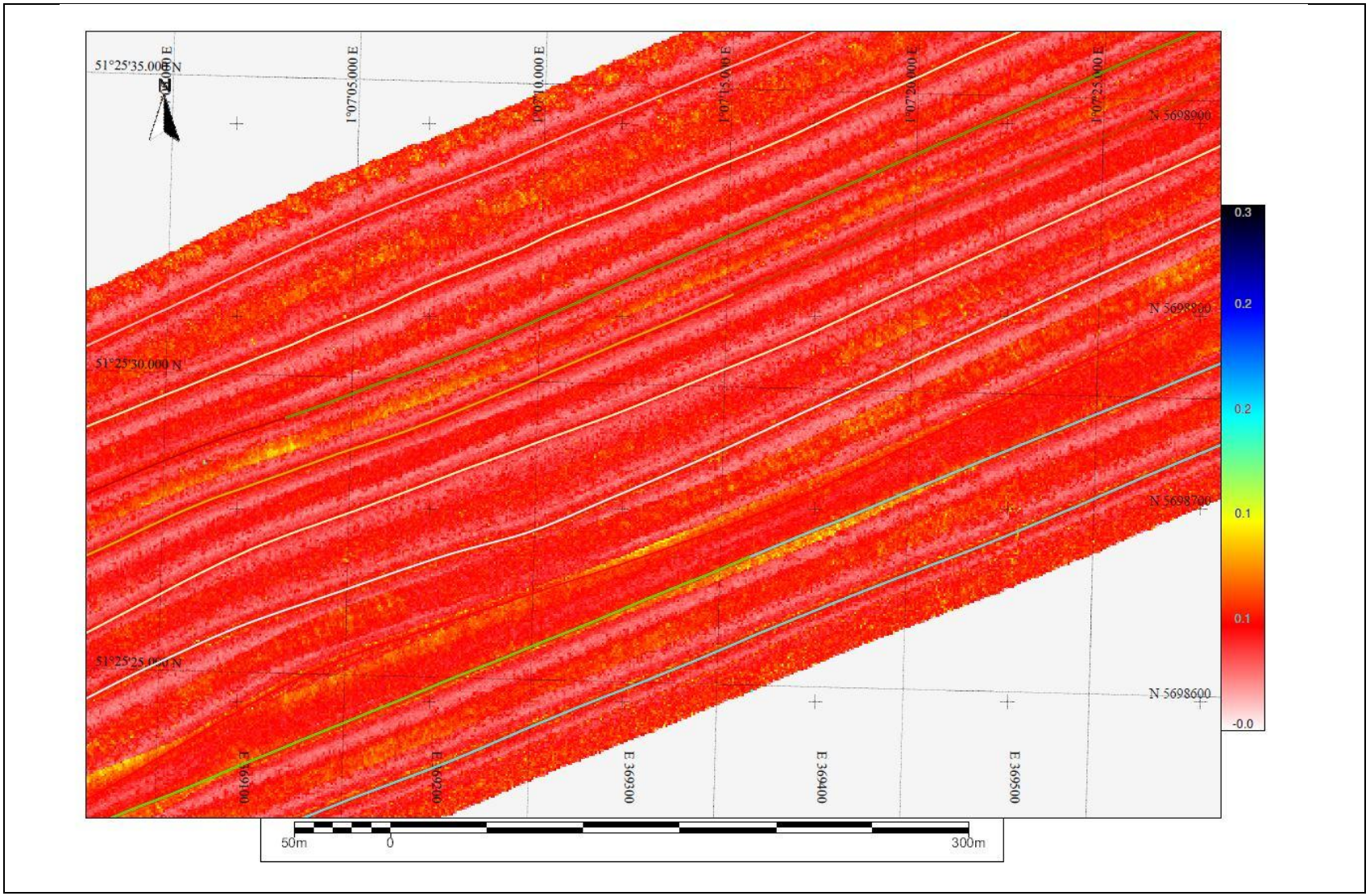


FIGURE 30: SECTION OF EXPORT CABLE ROUTE DISPLAYED AT 95% CONFIDENCE

7. CONCLUSIONS

Vessel mobilisation, calibration and verification were carried out safely and following manufacturer-specified procedures. Data acquired during the mobilisation and repeatability test exceeded IHO special order and indeed the custom order as set out by DONG.

APPENDIX A – REFERENCE FRAME SURVEY

Geo-Spatial
Survey Excellence

Reference Frame Survey - Wessex Explorer

Surveyed at Endeavour Quay, Gosport - 15/05/2013

Client

EGS International Ltd

Document reference

EGS/3637

A	For use	EGS/3637	12/06/13			
0	For use	EGS/3637		17/05/13		
Rev No	Reason For Issue	Doc Number	Rev Date	Written	Verified	Approved

Geo-Spatial
Energy Solutions

Contents

Page 1

Geo-Spatial

1 Introduction

Geo-Spatial Survey Solutions Ltd was awarded the contract by the EGS International Ltd to perform a reference frame survey of Wessex Explorer.
The work was performed during the period 15-05-13 to 17-05-13 at Endeavour Quay, Gosport , Hampshire.

1.1 General

This report details the results and describes the work performed.

1.2 Health Safety Environment

The work conditions on site were acceptable and deemed to be safe.
No dangerous situation, near accident or accident occurred during our site visit.

2 Scope of Work

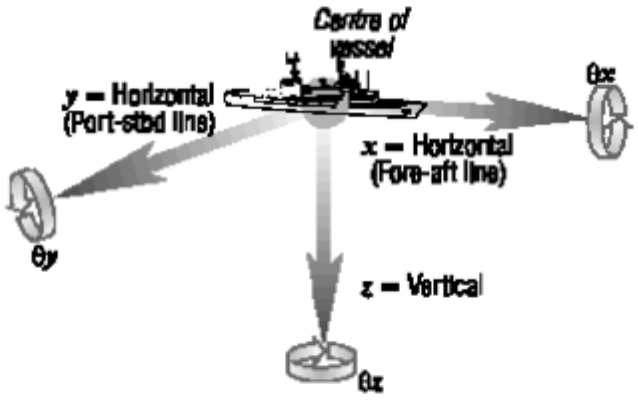
To survey and produce 3D co-ordinate positions, yaw, pitch and roll angles of the following equipment.

IMU	Base plate
POS MV	Antenna - Port
POS MV	Antenna - Starboard
EM 3002	Transducer - Port
EM 3002	Transducer - Starboard
Single beam	Transducer
C-Nav	Antenna support
Leica	Antenna
Various	Antenna supports
Witness marks	

3 Coordinate Reference System

The ships reference frame was determined from the centreline of the keel and fixed points defined on the boat, the origin of these co-ordinates was translated to the Coordinate Reference Point which is the centre of the IMU base plate and is set to the co-ordinate value of X = 0, Y = 0, Z = 0.
The phase centre is given for the height of each antenna which is 66mm above the mechanical reference plane of the antenna for Pos MV and C-Nav, and offset values of L1 = 85mm and L2 = 74mm was used for both phase centres of the Leica antenna.

The co-ordinate orientation is as per the Applanix diagram shown below.



Page 2

Geo-Spatial

4 Results

The following summarize the results of the survey, co-ordinates are in mm and angles in decimal degrees.

4.1 Position and installation angles for IMU, Transducers

Name	Yaw	Pitch	Roll	X(+Fwd)	Y(+Stbd)	Z(+Down)
IMU V5 type 40	+0.29649	-0.45120	-0.28988	0.0	0.0	0.0
IMU base plate	+0.29649	-0.45120	-0.28988	0.0	0.0	146.5
EM3002 port	+3.8203	+3.23738	+40.26582	+577.3	-1213.5	+2820.8
EM3002 starboard	-2.52132	+2.13911	-40.30598	+563.2	-345.2	+2820.0
Single beam transducer	n/a	+3.18331	+0.70279	+1168.8	-589.4	+2806.7

Definitions:
Pitch: Positive is Bow up
Roll: Positive is Starboard down
Yaw: Positive is clockwise

4.2 Location of Antennas and reference points

Name	X(+Fwd)	Y(+Stbd)	Z(+Down)
POS MV Port top centre of hole	-3100.2	-2027.2	-2244.7
Antenna port 1 top of thread	-2840.2	-1566.3	-2524.0
Antenna port 2 top of thread	-2841.1	-1164.1	-2537.5
Antenna port 3 top of thread	-2840.1	-966.0	-2541.2
C NAV centre of shoulder	-2843.8	-765.5	-2572.3
Antenna starboard 4 top of thread	-2840.3	-563.6	-2545.1
Antenna starboard 5 top of thread	-2842.1	-365.4	-2544.1
Antenna starboard 6 top of thread	-2841.1	+38.3	-2539.5
POS MV starboard top centre of hole	-3104.0	+508.9	-2261.5
Antenna Leica AX 1203 under side	-40.2	-778.8	-5278.8
Antenna Leica AX 1203 (Phase L1)	-40.2	-778.8	-5656.8
Antenna Leica AX 1203 (Phase L2)	-40.2	-778.8	-5645.8
Centre line reference inside cabin	-2856.6	-770.3	+218.7
Starboard aft bollard – witness mark	-7298.6	+427.8	+447.1
Starboard aft bolt –witness mark	-8076.8	+283.9	+417.2

Geo-Spatial
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Centre aft bolt – witness mark	-8043.5	-773.7	+384.2
Port aft bolt – witness mark	-8080.1	-1847.6	+419.7
Port aft bollard – witness mark	-7300.3	-1977.9	+452.7
Starboard centre bollard – witness mark	-1038.4	+1209.3	+499.1
Starboard centre bolt – witness mark	+811.5	+1276.4	+398.1
Port centre bollard – witness mark	-1066.0	-2741.1	+496.0
Port centre bolt – witness mark	+788.0	-2824.6	+398.0

5 Comments

Accuracy for the lever arm figures

All Total Station 3D co-ordinates are within +/- 0.5mm for each ordinate, these values were obtained by observations from multiple station set ups and the mean obtained showing on average a standard deviation of 0.32mm. The standard deviation on the photogrammetric points on the extended base line of the IMU was 0.024mm and is used in the calculation below.

Accuracy statement for the misalignment angles

The base line length on which the angle is computed is defined by the length of the extended base line applied to the IMU mounting plate and in this case it was 0.977m.

coord sd (m)	sqroot(cood sd)2 (m)	Baseline length (m)	Angular error (deg)	Max Lever arm (m)	Max discrepancy (m)
0.000024	0.000034	0.977	0.00200	5.510	0.00019

Survey Temperature
The air temperature during the survey in Gosport was approx. + 15 deg. Celsius.

6 Work Procedure

Generally, all positions were obtained by measuring bearings and distances from the instrument (Total station) to a retro reflective target placed on the point to be measured. Several locations with the Total station were necessary to sight all points to be measured.
From each set up, several common points were measured along with points of interest which can be either components to survey or coded targets for Tritop photogrammetry sessions. All points of relevance were measured at least twice and all set ups were calculated into a common coordinate reference system for the vessel.

7 Personnel

The survey work was performed by the following personnel:
Senior Surveyor Roger Davies
Senior Surveyor Peter Carr

8 Equipment

The following equipment was used:

Hardware

- Leica TCR1103 Total Station, serial no . 620663
Calibration certificate expiry date 06.03.2014.
- Tritop photogrammetric CMM
Self calibrating at each time of use.

Software

- SC4W 3D coordinate calculation software, version no 1.195.0.110
- Rhinoceros CAD modelling Version 5.0 SR1

9 References

Applanix POS MV V5 Installation and Operation Guide, appendix E – Drawings.

Geo-Spatial
Energy Solutions

Appendix 1

Total Station Calibration Certificate

Tritop Self Calibration Output

Photographs Identifying Components

Geo-Spatial
Survey Excellence

Calibration Certificate

Certificate No: MPS22142 **Re-Calibration Due:** 06/03/2014

Customer Name: Geo-Spatial

Make/Model: Leica TCRA1103 Total Station

Plant No: CSJ0009348 **Serial No:** 620663

We certify that this instrument has been calibrated in accordance with ISO 10012-1 2003 using a Collimation system s/n 091026 which has been calibrated to National and International standards by a NAMAS registered laboratory registration No. 0026

For and on behalf of M & P Survey Equipment Ltd

Signed .....

Position TECHNICIAN **Issue Date:** 06/03/2013

M & P Survey Equipment Ltd is accredited in the field of Calibration:

Geo-Spatial

EDM Based on: TDRA1100plus / V2012.06 / 06.03.2013 / 65246

Date: 06/03/2013 10:30:33
Technician: chris
Notes: Outgoing test

Instrument No.: 620633
Customer: Geo-Special
Test Result: ---

Measurement 1: 12.4905 [m]
Single Dist: 12.4908 / 12.4908 / 12.4908 / 12.4906 / 12.4905 /
Dist Mean: 12.49068 [m] Sigma: 0.12 [mm] Diff.: 0.39 [mm] PPM: 15.1
Measurement 2: 12.5281 [m]
Single Dist: 12.5286 / 12.5286 / 12.5284 / 12.5285 / 12.5283 /
Dist Mean: 12.52571 [m] Sigma: 0.16 [mm] Diff.: 0.61 [mm] PPM: 15.1
Measurement 3: 12.4905 [m]
Single Dist: 12.4910 / 12.4909 / 12.4909 / 12.4906 / 12.4910 /
Dist Mean: 12.49113 [m] Sigma: 0.04 [mm] Diff.: 0.63 [mm] PPM: 15.1

Measurement R
Single Dist: 12.4872 / 12.4871 / 12.4872 / 12.4874 / 12.4875 /
Dist Mean: 12.4873 [m] Sigma: 0.14 [mm]

Measurement SR
Single Dist: 12.4878 / 12.4877 / 12.4878 / 12.4878 / 12.4878 /
Dist Mean: 12.4878 [m] Sigma: 0.03 [mm]

Statistic:
AddConst IR (old/new): -40.00 / -40.50 [mm]
AddConst SR (old/new): -40.00 / -41.00 [mm]
Temperature: 25.4 Pressure: 988
Sigma: 0.16

PAGE 1


```
TRITOP Documentation
========================

Length-Unit = [mm]
 Angle-Unit = [deg]

================================
| Project WE2.tri              |
================================

  Alignment   :
  Inspector   : Roger Davies
  Part-Nr.    : IMU
  Date        : 15/05/2013
  Location    : Endeavour Quay Gosport
  Company     : EGS International Ltd
  Department  :
  Project     : Wessex Explorer
  System      :
  Charge-Nr.  :
  Version     :
  Part        :
  Comment 1   :
  Comment 2   :
  Comment 3   :

  Project-Status                 : Bundled
  Thickness-Correction           : Thickness of points is corrected
  Average Image Point Deviation  : 0.07411 pixels
  Average Object Point Deviation : 0.01705 mm
  Temperature                    : 15.00 °C

Cameras
-------
      name: Canon EOS 1 Ds Mark II
     lense:     24.0
pixel size:      7.2 µm
```

Geo-Spatial
Survey Solutions

Images

image	id	x	y	z	dx	dy	dz	omega	phi	kappa	domega	dphi	dkappa
image_001.JPG	1	-371.82	1249.53	1400.29	+0.04	+0.05	+0.04	-35.54	-38.39	-126.85	0.00	0.00	0.00
image_002.JPG	2	-319.14	1263.15	1430.38	+0.04	+0.05	+0.04	-35.59	-31.07	140.72	0.00	0.00	0.00
image_003.JPG	3	-303.42	1186.91	1411.17	+0.04	+0.04	+0.04	-33.57	-29.14	48.69	0.00	0.00	0.00
image_004.JPG	4	-357.91	1245.43	1425.22	+0.05	+0.05	+0.04	-39.14	-32.79	-38.10	0.00	0.00	0.00
image_005.JPG	5	-309.56	1122.60	1319.55	+0.04	+0.04	+0.04	-34.15	-26.86	-159.05	0.00	0.00	0.00
image_006.JPG	6	173.48	1158.14	1351.61	+0.03	+0.04	+0.04	-35.77	-14.63	-167.50	0.00	0.00	0.00
image_007.JPG	7	712.87	1159.70	1348.36	+0.03	+0.04	+0.03	-40.16	12.60	168.58	0.00	0.00	0.00
image_008.JPG	8	1014.45	1008.51	1323.36	+0.05	+0.04	+0.05	-35.45	29.99	106.26	0.00	0.00	0.00
image_009.JPG	9	1090.78	1045.30	1267.91	+0.03	+0.03	+0.03	-36.36	20.10	172.18	0.00	0.00	0.00
image_010.JPG	10	104.69	1284.68	1429.31	+0.03	+0.05	+0.04	-38.91	-40.05	-132.08	0.00	0.00	0.00
image_011.JPG	11	396.01	1318.80	1451.48	+0.04	+0.06	+0.05	-26.49	-52.79	-109.44	0.00	0.00	0.00
image_012.JPG	12	701.48	1568.94	1509.25	+0.04	+0.05	+0.05	-29.20	-55.46	-172.52	0.00	0.00	0.00
image_013.JPG	13	1002.63	1401.52	1516.35	+0.03	+0.05	+0.04	-26.12	-46.17	175.56	0.00	0.00	0.00
image_014.JPG	14	1178.59	1449.47	1691.49	+0.04	+0.05	+0.06	-29.38	-36.87	-99.96	0.00	0.00	0.00
image_015.JPG	15	438.24	928.58	1468.30	+0.03	+0.06	+0.05	-8.55	-62.24	-94.57	0.00	0.00	0.00
image_016.JPG	16	411.10	1048.16	1440.04	+0.03	+0.04	+0.04	-40.34	-37.04	-158.61	0.00	0.00	0.00
image_017.JPG	17	726.93	1021.98	1398.21	+0.03	+0.03	+0.03	-43.47	4.75	168.65	0.00	0.00	0.00
image_018.JPG	18	-349.01	870.01	1310.93	+0.04	+0.04	+0.04	-22.86	-42.59	-115.27	0.00	0.00	0.00
image_019.JPG	19	51.19	891.91	1353.18	+0.03	+0.04	+0.03	-31.84	-15.32	-36.91	0.00	0.00	0.00
image_020.JPG	20	-469.64	377.66	673.16	+0.03	+0.03	+0.02	-13.29	-47.22	-91.81	0.00	0.00	0.00
image_021.JPG	21	-377.57	126.62	595.86	+0.02	+0.03	+0.03	-7.32	-49.88	-89.32	0.00	0.00	0.00
image_022.JPG	22	-36.92	360.44	712.34	+0.04	+0.04	+0.03	-16.86	-6.39	-173.51	0.00	0.00	0.00
image_023.JPG	23	420.69	286.41	724.04	+0.03	+0.05	+0.02	2.83	2.12	-178.94	0.00	0.00	0.00
image_024.JPG	24	576.87	251.15	727.51	+0.03	+0.06	+0.03	6.12	28.62	173.58	0.00	0.00	0.00
image_025.JPG	25	0.00	0.00	0.00	+0.00	+0.00	+0.00	0.00	0.00	0.00	0.00	0.00	0.00
image_026.JPG	26	111.15	363.98	723.11	+0.03	+0.05	+0.03	-3.45	-25.41	-177.67	0.00	0.00	0.00
image_027.JPG	27	-107.95	771.23	1007.10	+0.03	+0.03	+0.03	-24.83	-28.10	-134.68	0.00	0.00	0.00
image_028.JPG	28	-206.58	1083.48	1409.43	+0.04	+0.04	+0.04	-30.56	-41.91	-96.68	0.00	0.00	0.00
image_029.JPG	29	-190.04	1080.84	1384.33	+0.04	+0.05	+0.04	-20.95	-61.85	-91.86	0.00	0.00	0.00
image_030.JPG	30	-48.13	650.19	1407.76	+0.04	+0.07	+0.06	4.24	-61.61	-84.03	0.00	0.00	0.00
image_031.JPG	31	34.55	658.57	1746.43	+0.03	+0.04	+0.05	-1.29	-45.30	-88.66	0.00	0.00	0.00
image_032.JPG	32	180.21	1079.25	1732.41	+0.03	+0.05	+0.04	-23.22	-42.72	-94.34	0.00	0.00	0.00
image_033.JPG	33	819.13	885.86	1737.39	+0.03	+0.06	+0.05	-2.52	-51.89	-88.41	0.00	0.00	0.00
image_034.JPG	34	1137.23	1366.67	1700.56	+0.04	+0.06	+0.05	-28.09	-43.70	-104.97	0.00	0.00	0.00
image_035.JPG	35	1158.01	801.91	1746.92	+0.03	+0.07	+0.04	1.84	-51.36	-84.87	0.00	0.00	0.00
image_036.JPG	36	1198.24	350.37	1680.80	+0.09	+0.10	+0.06	28.39	-49.81	-62.78	0.00	0.00	0.00
image_037.JPG	37	892.78	1305.78	1439.04	+0.03	+0.05	+0.04	-28.18	-45.66	-124.57	0.00	0.00	0.00

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image_038.JPG	38	772.36	1259.21	1398.34	+0.06	+0.06	+0.05	-39.99	-22.88	-148.98	0.00	0.00	0.00
image_039.JPG	39	640.65	1247.92	1393.58	+0.03	+0.04	+0.04	-44.84	-2.07	-178.01	0.00	0.00	0.00
image_040.JPG	40	-465.72	1055.84	1606.37	+0.06	+0.06	+0.06	-25.99	-18.74	-129.55	0.00	0.00	0.00
image_041.JPG	41	-104.00	971.12	1246.66	+0.03	+0.04	+0.04	-32.42	-26.80	-136.00	0.00	0.00	0.00
image_042.JPG	42	618.09	585.58	771.04	+0.03	+0.03	+0.04	-26.81	26.54	144.62	0.00	0.00	0.00
image_043.JPG	43	64.74	524.62	736.24	+0.02	+0.03	+0.02	-26.13	-30.19	-120.89	0.00	0.00	0.00
image_044.JPG	44	180.39	335.44	447.91	+0.03	+0.03	+0.05	0.17	-75.60	-91.08	0.00	0.00	0.00
image_045.JPG	45	8.58	1503.07	434.16	+0.03	+0.04	+0.04	-54.20	-77.19	-99.37	0.00	0.00	0.00
image_046.JPG	46	638.69	1389.02	377.69	+0.04	+0.04	+0.07	-44.06	-87.74	-88.22	0.00	0.00	0.00
image_047.JPG	47	549.17	830.31	563.60	+0.03	+0.04	+0.04	2.69	-87.52	-90.26	0.00	0.00	0.00
image_048.JPG	48	552.90	1061.96	1028.60	+0.03	+0.04	+0.03	-15.02	-73.58	-95.48	0.00	0.00	0.00
image_049.JPG	49	-182.17	1326.90	1409.25	+0.04	+0.05	+0.04	-36.55	-48.35	-125.79	0.00	0.00	0.00
image_050.JPG	50	-257.85	1274.18	1356.53	+0.04	+0.05	+0.05	-38.28	-23.76	-161.69	0.00	0.00	0.00

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```
TRITOP Scalebars
------------------------
   name: 1000 U/AB
   type: Uncoded scale bar
 status: Blocked scale bar

  coded 1:          0    coded 2:          1
uncoded 1:         -1  uncoded 2:         -1

Nominal length: 1069.9400
Temperature corrected length: 1069.9325
Deviation between scalebars:  +0.0000
Weight:   1.0000

-----------------------------------------------
   name: 1000 V/CD
   type: Uncoded scale bar
 status: Used scale bar

  coded 1:          2    coded 2:          3
uncoded 1:       1129  uncoded 2:       1155

Nominal length: 1069.9800
Temperature corrected length: 1069.9725
Deviation between scalebars:  +0.0000
Weight:   1.0000

-----------------------------------------------
```

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TRITOP Points

id	x	y	z	dev	dev x	dev y	dev z
2	+1655.020	+388.481	+976.020	0.0197	0.0134	0.0113	0.0090
3	+1658.312	+1333.791	+915.127	0.0126	0.0095	0.0048	0.0068
90	+1602.606	+501.147	+764.356	0.0186	0.0136	0.0097	0.0081
91	+2633.007	+1043.449	+1050.705	0.0415	0.0377	0.0111	0.0134
92	+1628.078	+1370.103	+835.345	0.0119	0.0081	0.0046	0.0075
93	+1633.860	+1335.019	+553.238	0.0198	0.0148	0.0068	0.0114
95	+2649.626	+942.726	+631.712	0.0426	0.0364	0.0119	0.0186
96	+204.442	-248.306	+148.337	0.0181	0.0060	0.0128	0.0114
97	+528.634	+23.789	+30.734	0.0100	0.0039	0.0054	0.0075
98	+621.912	+291.299	+904.017	0.0154	0.0075	0.0109	0.0079
99	+566.996	+290.031	+903.668	0.0121	0.0058	0.0086	0.0063
100	+512.014	+288.757	+903.367	0.0108	0.0050	0.0077	0.0057
101	+457.107	+287.483	+902.632	0.0115	0.0051	0.0083	0.0061
102	+402.176	+286.256	+902.110	0.0149	0.0062	0.0109	0.0080
103	+620.657	+346.234	+902.570	0.0160	0.0081	0.0109	0.0083
104	+565.726	+345.013	+902.015	0.0142	0.0070	0.0098	0.0075
105	+510.810	+343.749	+901.566	0.0130	0.0064	0.0090	0.0069
106	+455.792	+342.475	+901.042	0.0115	0.0053	0.0081	0.0062
107	+400.870	+341.218	+900.676	0.0120	0.0053	0.0086	0.0066
360	-122.445	+1.331	-0.062	0.0252	0.0075	0.0146	0.0192
361	-62.142	+0.956	+0.060	0.0212	0.0071	0.0119	0.0160
362	+0.021	-0.007	-0.008	0.0143	0.0048	0.0080	0.0108
363	+61.419	+0.221	+0.033	0.0120	0.0040	0.0065	0.0093
364	+121.552	-0.002	-0.010	0.0101	0.0034	0.0055	0.0078
365	+0.306	+122.771	-0.009	0.0131	0.0042	0.0068	0.0104
366	-0.090	+62.677	+0.011	0.0150	0.0051	0.0078	0.0117
367	-0.794	-61.464	+0.138	0.0151	0.0050	0.0087	0.0113
368	-1.163	-121.031	+0.205	0.0222	0.0056	0.0141	0.0162
370	+1517.090	+504.455	+434.413	0.0153	0.0103	0.0073	0.0086
371	+1478.459	+458.618	+434.747	0.0154	0.0102	0.0076	0.0087
372	+1438.050	+410.463	+434.432	0.0137	0.0085	0.0072	0.0080
373	+1398.586	+363.540	+435.736	0.0133	0.0081	0.0073	0.0076
374	+1360.609	+318.159	+436.310	0.0147	0.0089	0.0083	0.0083
375	+1437.670	+413.658	+556.882	0.0146	0.0089	0.0081	0.0082
376	+1438.063	+412.311	+496.621	0.0147	0.0092	0.0078	0.0084

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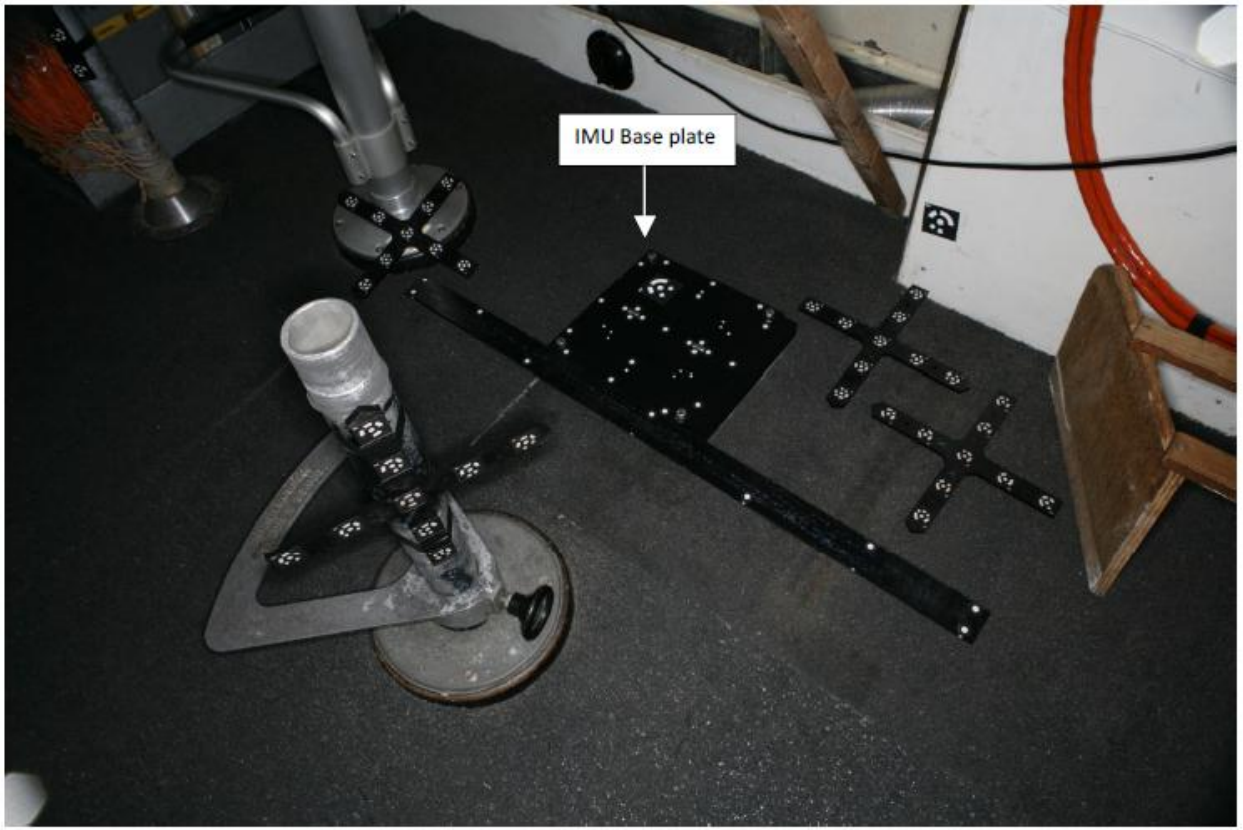
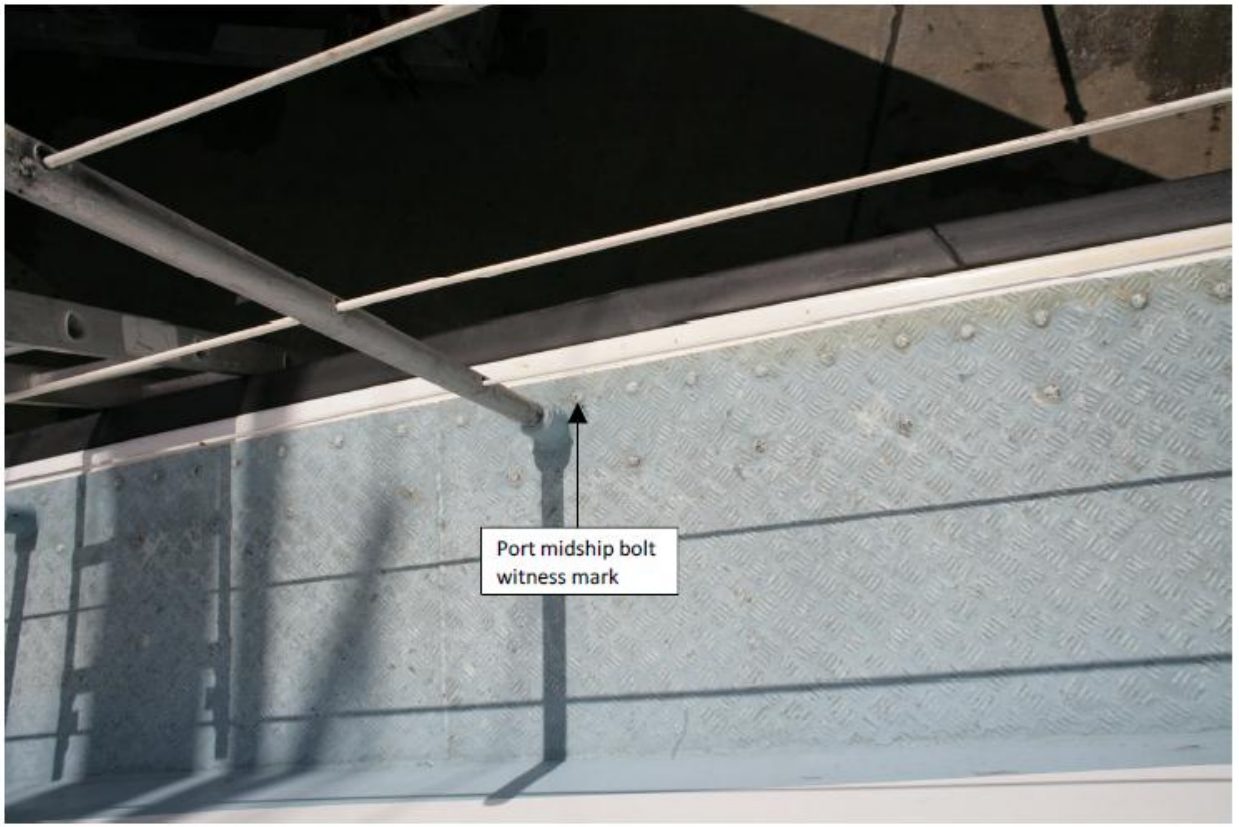
1064	+194.479	+262.995	+21.338	0.0255	0.0082	0.0145	0.0193
1100	+734.090	+235.536	+25.713	0.0145	0.0072	0.0069	0.0105
1073	+27.534	+258.841	+19.294	0.0363	0.0113	0.0217	0.0268
1049	+382.569	+226.544	+27.577	0.0080	0.0033	0.0039	0.0062
1078	-120.183	+255.155	+16.955	0.0463	0.0102	0.0248	0.0377
1045	+386.123	+267.516	+21.810	0.0184	0.0061	0.0102	0.0141
1129	+1672.145	+326.827	+977.078	0.0222	0.0155	0.0124	0.0098
1140	-118.543	+214.720	+22.403	0.0210	0.0079	0.0107	0.0162
1048	+467.268	+169.610	+27.385	0.0074	0.0031	0.0037	0.0056
1215	+27.660	+218.391	+24.731	0.0162	0.0060	0.0078	0.0128
1011	+559.263	-30.050	+31.979	0.0099	0.0043	0.0056	0.0069
1012	+591.863	-3.123	+31.218	0.0152	0.0059	0.0080	0.0115
1046	+472.560	+212.545	+26.320	0.0102	0.0044	0.0050	0.0076
1014	+856.281	+278.853	+19.690	0.0416	0.0171	0.0243	0.0291
1015	+861.259	+271.142	+23.954	0.0125	0.0065	0.0061	0.0088
1016	+598.355	+264.632	+25.753	0.0169	0.0071	0.0080	0.0130
1017	+561.948	+214.696	+25.935	0.0106	0.0049	0.0052	0.0078
1207	+194.978	+254.435	+25.983	0.0199	0.0077	0.0094	0.0157
1050	+371.605	+210.270	+26.751	0.0079	0.0032	0.0038	0.0061
1020	+586.747	+179.648	+26.691	0.0103	0.0045	0.0051	0.0078
1079	-120.292	+247.055	+21.518	0.0324	0.0106	0.0172	0.0253
1022	+528.221	+101.525	+28.814	0.0103	0.0043	0.0051	0.0078
1023	+529.479	+80.385	+29.355	0.0082	0.0034	0.0041	0.0062
1024	+546.443	+91.785	+29.010	0.0083	0.0033	0.0042	0.0064
1025	+588.526	+100.967	+28.622	0.0105	0.0044	0.0052	0.0080
1026	+385.440	+86.837	+29.706	0.0082	0.0032	0.0043	0.0063
1027	+402.958	+98.504	+29.347	0.0106	0.0041	0.0055	0.0081
1028	+404.710	+77.634	+29.894	0.0101	0.0040	0.0052	0.0077
1029	+419.941	+88.992	+29.539	0.0101	0.0039	0.0053	0.0077
1051	+340.341	+172.583	+27.782	0.0074	0.0029	0.0037	0.0057
1031	+466.684	+88.657	+29.374	0.0078	0.0031	0.0040	0.0059
1088	+866.367	+238.729	+25.045	0.0133	0.0069	0.0062	0.0095
1033	+511.289	+91.220	+29.137	0.0090	0.0036	0.0046	0.0068
1034	+375.639	-35.684	+32.801	0.0143	0.0053	0.0085	0.0102
1035	+467.273	+3.402	+31.494	0.0110	0.0043	0.0060	0.0082
1036	+465.352	-33.194	+32.423	0.0141	0.0057	0.0083	0.0099
1055	+343.108	+83.813	+29.945	0.0093	0.0036	0.0051	0.0070
1038	+345.345	-6.315	+32.167	0.0113	0.0041	0.0063	0.0085



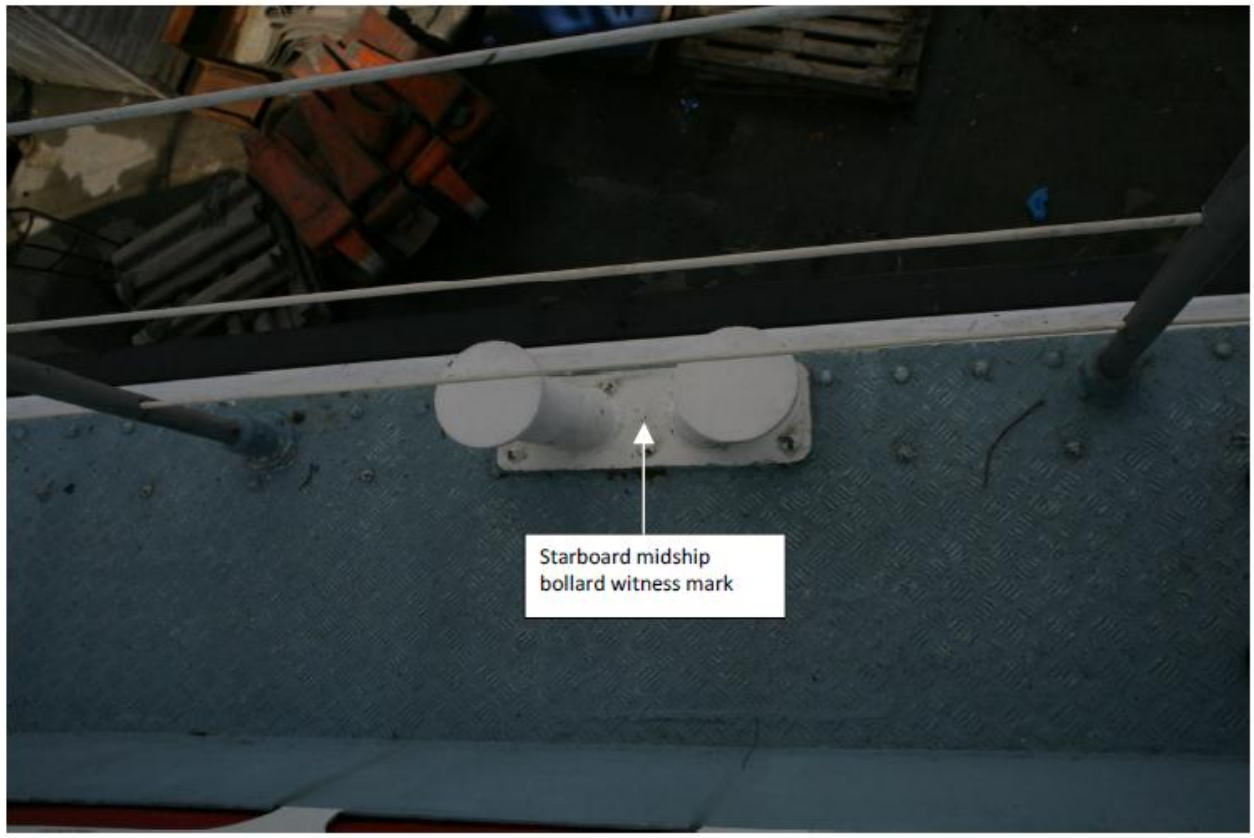
IMU Base Plate



Port Midship Bolt Witness Mark

Port Midship Bollard Witness Mark

Starboard Midship Bolt Witness Mark



Starboard Midship Bollard Witness Mark

Port Aft Witness Marks

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Centre Aft Bolt Witness Mark

Starboard Aft Witness Marks

Interior Witness Mark

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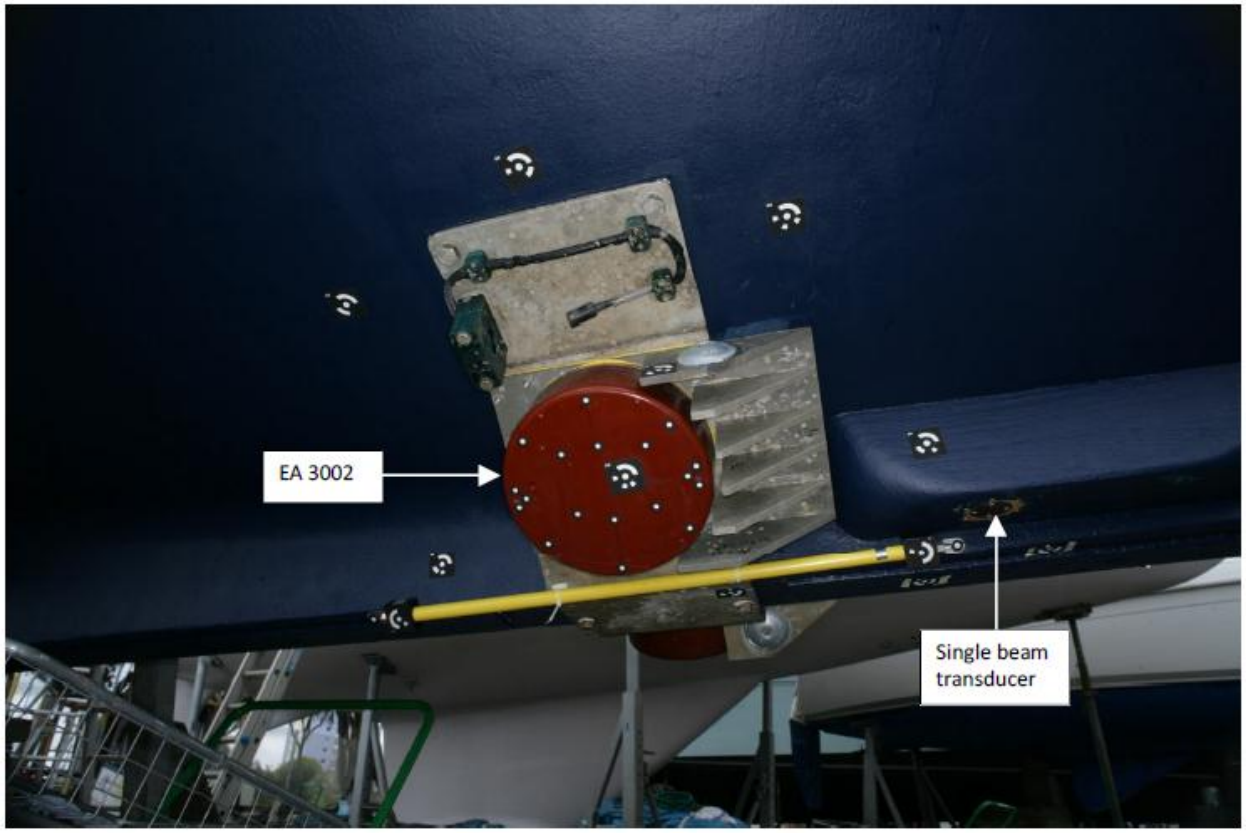

Starboard EA 3002 and Single Beam Transducer

Port EA 3002

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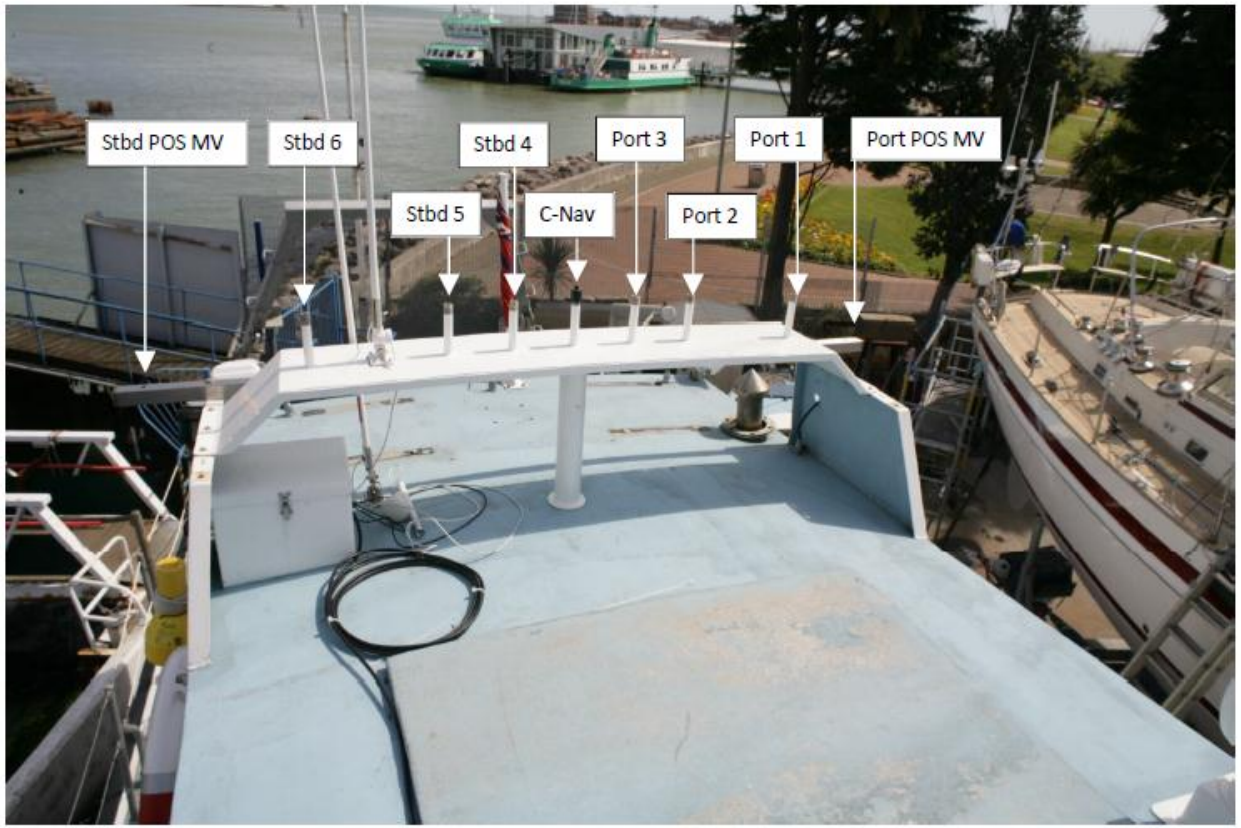

Antennae Mounting Points Viewed Aft

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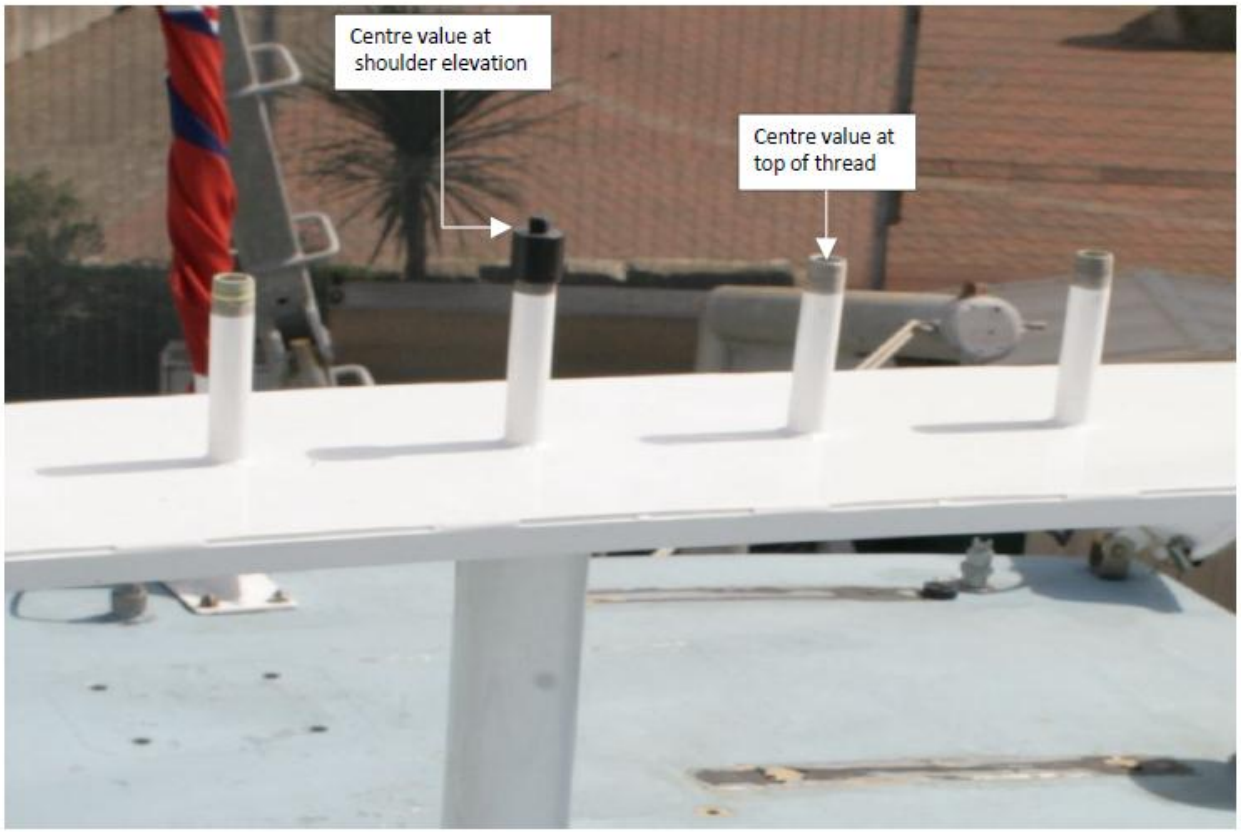


Antennae Measurement Locations

APPENDIX B – BEACHY HEAD/ ROYAL ST GEORGES GPS STATION DESCRIPTION

Passive station: Beachy Head - C1TV5995

Overview

Type of mark:
Pillar
Flush bracket:
S1834
Grid reference:
TV590957
Access to mark:
foot
Keys required:
No

Last visted by OS:
28/01/2002
On Landranger sheet:
199
On Explorer sheet:
123
Permission required:
No

Date of observation:
12/08/1999
Coordinates last checked:
28/01/2002
Planned next check:
28/01/2007

Coordinates of this station

ETRS89 Cartesian

X:
4044564.420
Y:
17832.930
Z:
4915447.920

ETRS89 Geodetic

Latitude:
N 50 ° 44' 23.791385"
Longitude:
E 0 ° 15' 9.438356"
Ellipsoid height:
207.574

National Grid (converted by OSTN02/OSGM02)

Eastings:
559038.370
Northings:
95789.988
Height:
162.978

Passive station: Royal St Georges - C1TR3557

TWEET SHARE SHARE

Overview

Type of mark:
Rivet
Flush bracket:
Not Available
Grid reference:
TR350577
Access to mark:
2WD Vehicle
Keys required:
No

Last visted by OS:
07/09/2000
On Landranger sheet:
169
On Explorer sheet:
150
Permission required:
No

Date of observation:
25/04/1997
Coordinates last checked:
07/09/2000
Planned next check:
07/09/2005

Coordinates of this station

ETRS89 Cartesian

X:
3997505.730
Y:
95464.420
Z:
4952450.910

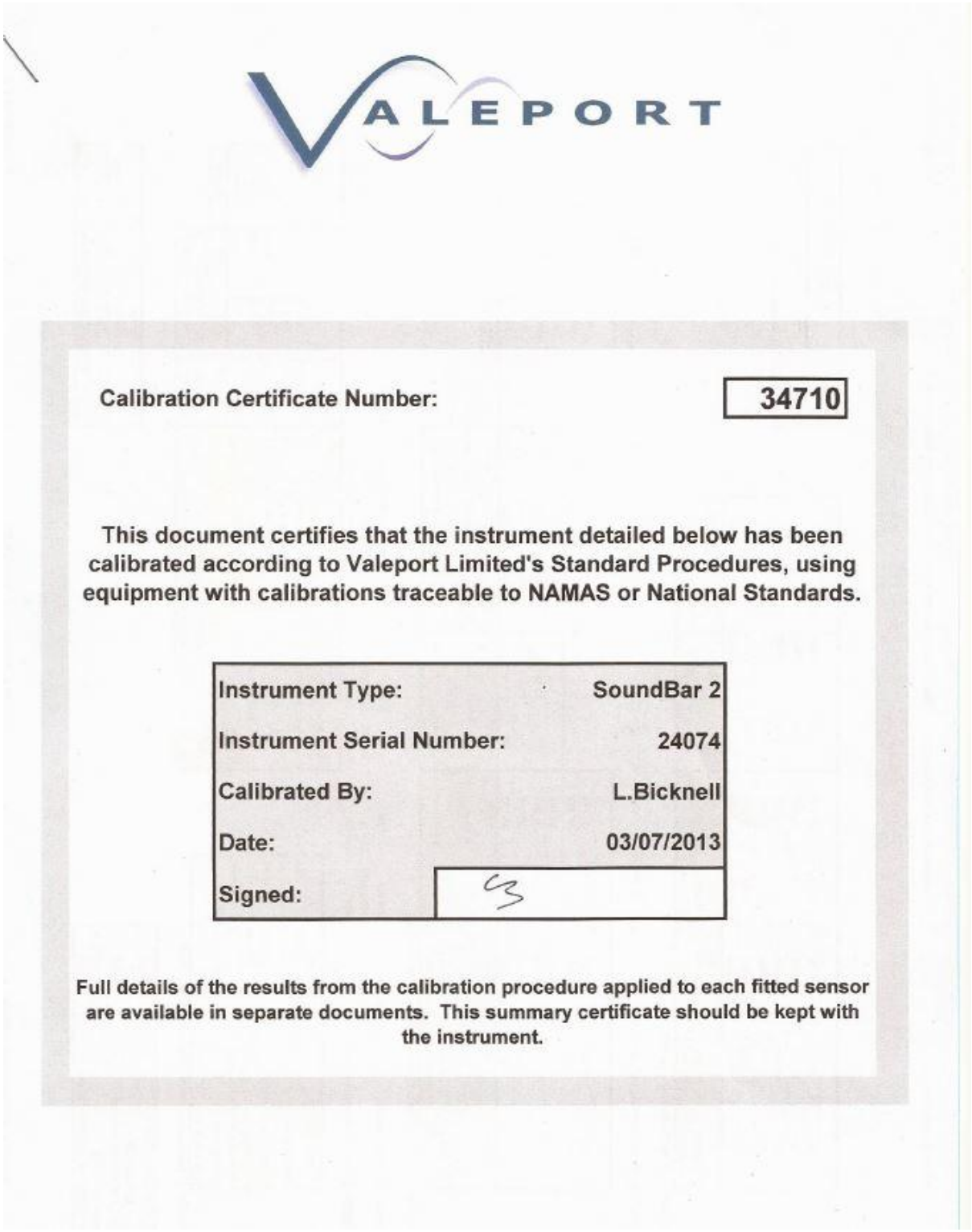
ETRS89 Geodetic

Latitude:
N 51 ° 16' 13.099739"
Longitude:
E 1 ° 22' 4.873019"
Ellipsoid height:
47.098

National Grid (converted by OSTN02/OSGM02)

Eastings:
635028.972
Northings:
157738.099
Height:

APPENDIX C – SVP CALIBRATION CERTIFICATES



VALEPORT

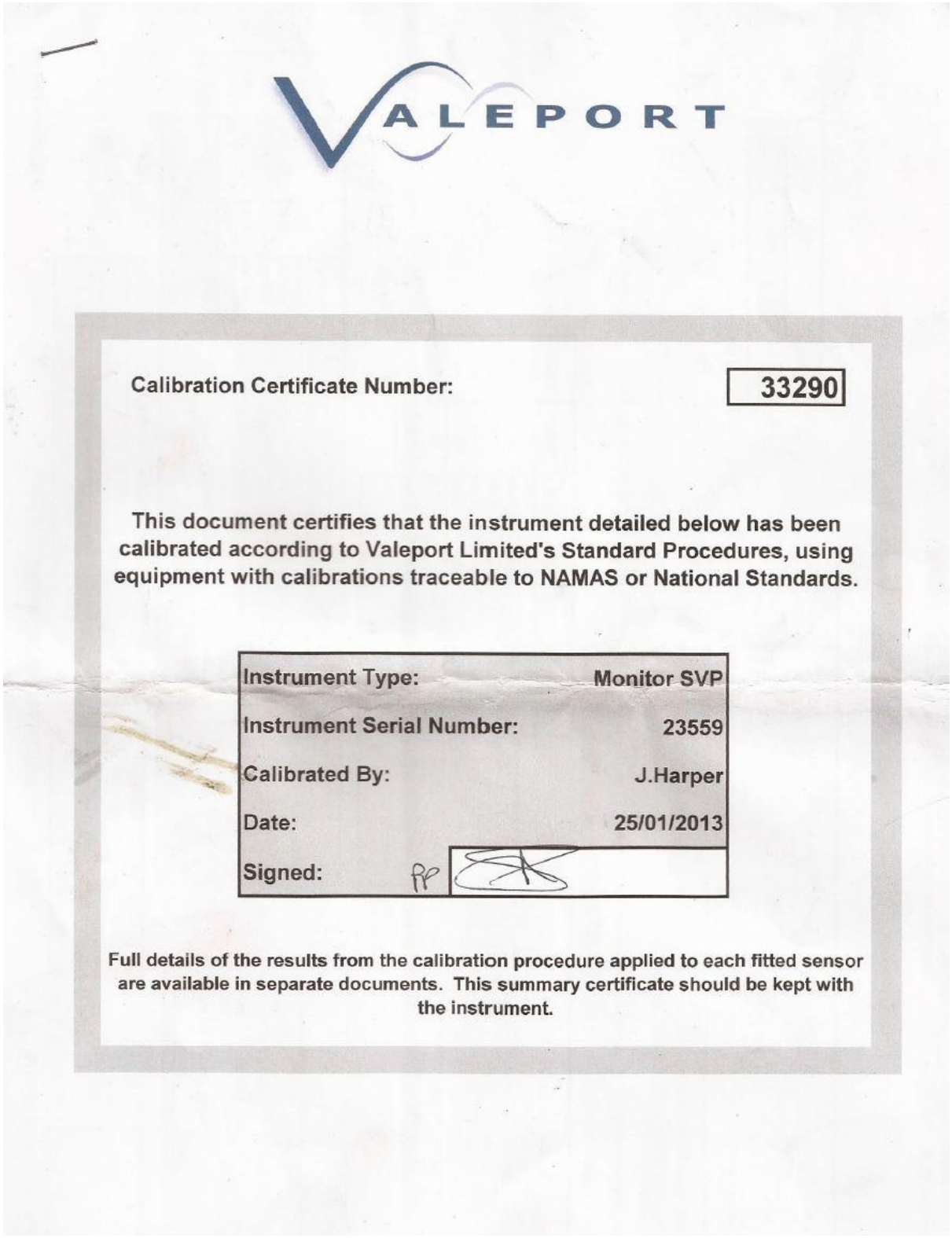
Calibration Certificate Number: 34710

This document certifies that the instrument detailed below has been calibrated according to Valeport Limited's Standard Procedures, using equipment with calibrations traceable to NAMAS or National Standards.

Instrument Type:	SoundBar 2
Instrument Serial Number:	24074
Calibrated By:	L.Bicknell
Date:	03/07/2013
Signed:	

Full details of the results from the calibration procedure applied to each fitted sensor are available in separate documents. This summary certificate should be kept with the instrument.

*Calibration certificate valid for 24 months



VALEPORT

Calibration Certificate Number: 33290

This document certifies that the instrument detailed below has been calibrated according to Valeport Limited's Standard Procedures, using equipment with calibrations traceable to NAMAS or National Standards.

Instrument Type:	Monitor SVP
Instrument Serial Number:	23559
Calibrated By:	J.Harper
Date:	25/01/2013
Signed:	

Full details of the results from the calibration procedure applied to each fitted sensor are available in separate documents. This summary certificate should be kept with the instrument.

*Calibration certificate valid for 24 months