

Section 4: Navigation

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1 Navigation and Positioning System Description

1.1 System Configuration

1.1.1 Navigation Hardware and Software

System	Hardware (Type and Serial No.)	Software version
CONCEPT	Spectra Integrated Navigation Sys.	9.8.03
FGPS	SeisPos navigation processing sys	10.80/11.00
External Header	General Header	Syntron v2
Acoustic System	None	
TS-meter	SD204	Minisoft 200W
Echo sounders	Simrad EA-500 12Khz Furuno FCN-271	
Gravity sensor	N/A	
Current Meter	None	

1.2 Survey Positioning Method Used

The survey was carried out using Multiwave's standard mode of operation for single streamer and single source surveys. Positioning of the vessel was by differential DGPS, with delivery of differential correction data in RTCM-104 format.

Source and front-end streamer positions were computed by gyro compass orientated layback from the reference point to tow-point, and first compass from the tow-point to the centre of source and centre of the near group. The offset from the centre of source to centre of the near group was verified by use of water breaks. Streamer tail end positioning was accomplished by compass streamer modelling and an active GPS tail buoy.

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1.3 Surface Positioning

1.3.1 Vessel Navigation

Summary

System 1: Trimble 4000SSi Receiver
RTCM Delivery System: Fugro Starfix via the Optus SPOT satellite link
Computation Software: Fugro MRGPS version 2.4.09

System 2: Trimble 4000SSi receiver
RTCM Delivery System: Fugro Starfix via the Inmarsat AP-SAT SPOT satellite link.
Computation Software: Fugro MRGPS version 2.4.09

Fugro MRDGPS interfaced to the Spectra System provided primary vessel positioning.

The two sources of corrections were transmitted to and received onboard the vessel by independent means thereby providing a high degree of redundancy to ensure continuous vessel positioning.

Although Selective Availability was turned off in May 2000 differential corrections are still required in conjunction with GPS positioning to provide a high quality continuous vessel position.

Reference Stations Used (Primary System) Source: Spot Optus

Name	ID	Latitude	Longitude	Distance	Comments
Melbourne	385	037°48'29.014" S	144°57'48.027" E	325 km	Selected constantly
Bathurst	336	033°25'46.902" S	149°34'01.960" E	930km	Selected constantly
Brisbane	275	027°28'38.507" S	153°01'37.338" E	1640km	Selected constantly
Dunedin	026	045° 52'10.214" S	170°30'39.315" E	2550km	Selected constantly
Broome	185	017°57'36.389" S	116°04'32.992" E	2900km	Selected constantly

Reference Stations Used (Secondary System) Source: Inmarsat POR and Spot ApSat

Name	ID	Latitude	Longitude	Distance	Comments
Melbourne	385	037°48'29.014" S	144°57'48.027" E	325 km	Selected constantly
Bathurst	336	033°25'46.902" S	149°34'01.960" E	930 km	Selected constantly
Kalgoorlie	315	030°45'06.959" S	121°28'49.881" E	2000 km	Selected constantly
Townsville	195	019°15'52.647" S	146°48'44.108" E	2200 km	Selected constantly
Darwin	125	012°22'25.628" S	130°52'17.261" E	3100 km	Selected constantly

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1.3.2 Float Navigation

Source surface navigation was provided by the MRDGPS software and interfaced to Spectra. The in-sea units incorporated a GPS receiver and interfacing for direct data transmission of the raw satellite position by conventional UHF telemetry radio.

Raw GPS position from the floats was compared against the GPS position of the vessel and a range and bearing calculated. These range / bearing values were input into Spectra with a resultant relative position better than 3 metres.

1.4 Streamer and Source Positioning

1.4.1 Streamer Compasses

2100m Configuration

10 series 5011 Digibird combined magnetic compass and streamer depth controllers were attached to the streamer.

Compass Sampling Rate	=	2 seconds
Averaging constant	=	14 seconds

Magnetic Declination entered into Spectra for the GS02 prospect was: 13.44° at Position: 038°07'00.000"S 149°02'00.000"E

The computation was performed using GeoMag V2.2.0.0 for 2002-09-01 and verified by Ship's Charts.

Compass performance was monitored on a line-to-line basis throughout the acquisition phase of the survey.

1.4.2 Gyro Compass

The gyrocompass used during the survey was:

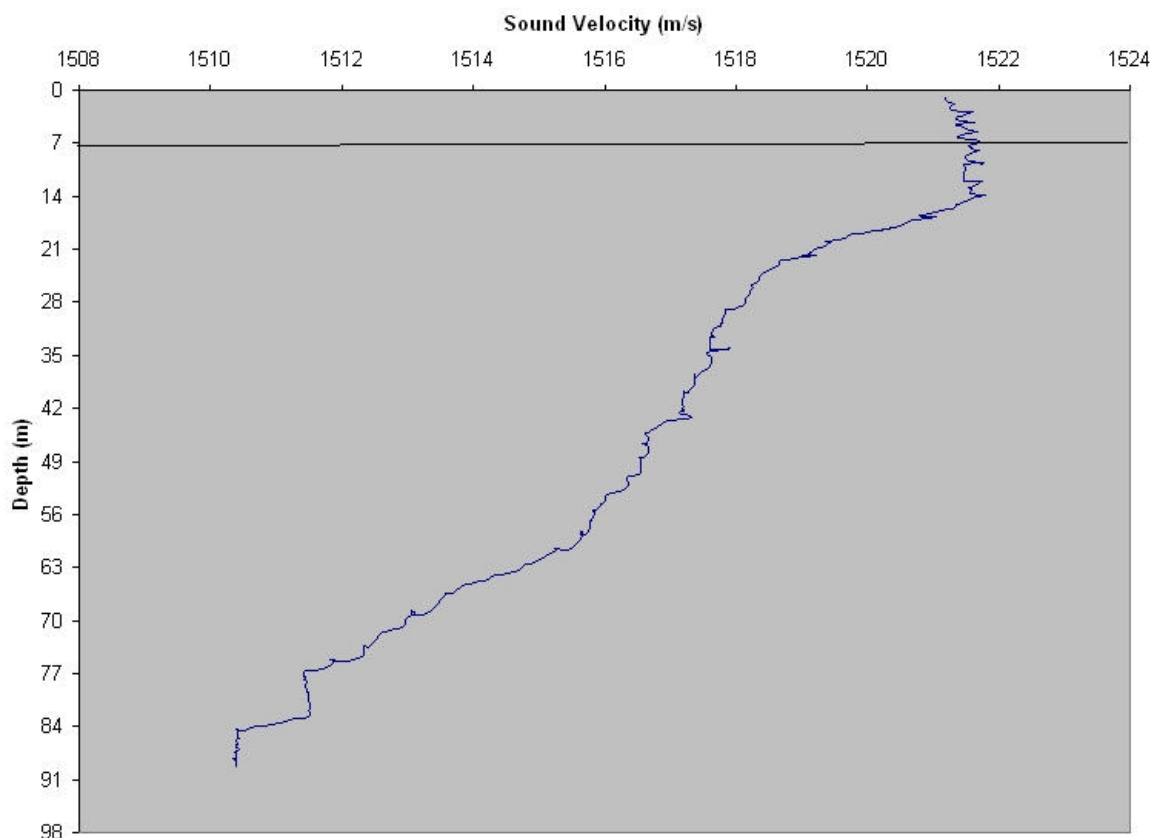
Primary Gyro 1:	Anschutz Kiel Type:110-310 Serial No: 3974
Secondary Gyro 2:	Anschutz Kiel Type:110-310 Serial No: 5185

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1.4.3 Velocity of Sound in Water

On the start up of prospect GBS02, the 01st of January 2003, a T/S dip was performed. We are using the same data for the GS02 survey, d/t the short period in time separating the two surveys.

The mean value of this T/S dip was 1516 m/s and was entered into Spectra. The result is illustrated in the graph below:



1.4.4 Echo Sounders

Primary echo sounder: Simrad Model EA500 12KHz
Secondary echo sounder: Furuno Model FCN-271

The echo sounders speed of sound was set to 1516.0 m/s. A draught correction of ZERO was entered in both echo sounders. The water depth exceeded the range of the Secondary echosounder and consequently no data was recorded with this sensor throughout the survey.

All depths recorded were based on the position of the Fathometer's transducer on the vessel's Hull. Depths are NOT draught corrected and all depths should have 5.65m added to the depth to give the true water depth from the surface.

2 Navigation Systems Verification and Monitoring

2.1 Echo Sounder Verification

The primary echo sounder, Simrad EA-500 12khz, was installed and tested by qualified technicians January 15 2002 while in port Singapore.

A lead-line verification was carried out on the Secondary Furuno FCN-271 echo sounder while alongside East Arm Wharf in Darwin, December 2001. Two tests were carried out at one-hour intervals:

Test 1 : 18.5m / 18.0m Echo sounder reading of 12.1m

Test 2 : 18.2m / 18.0m Echo sounder reading of 12.1m

Average lead-line distance = 18.17m

All depths recorded are based on the position of the Fathometer's transducer on the vessel's Hull. Depths are NOT draught corrected and all depths should have 5.65m added to the depth to give the true water depth from the surface.

2.2 Gyro Monitoring

C&B Survey Group was appointed to carry out the Gyro calibration work on M/V Polar Duke at Cairns dock in Australia. The datum point for GPS observations was PSM no.52097 and verified with measurements to PSM no.45129. The true bearing between the 2 points was calculated from the measured co-ordinates. Two independent RTK measurements were taken at each of the 2 control points and compared to ensure the accuracy of the derived bearing. A Leica TC1010 Total Station was then used to take simultaneous readings to the centres of the stern and bow of the vessel and the UTC time of each observation recorded. Gyro readings onboard were recorded and later compared between the surveyed azimuths and hence a difference was derived. This difference was then applied to both gyros in Spectra as a correction. The Gyro Calibration was performed in a southwesterly direction. The results are shown below:

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Gyro calibration results for the 05th of November 2002.

The results were as follows:

Gyro 1 Primary

Ship Heading @ 192°: -0.90 Degree C-O

Applied Ships gyro Correction: (minus) -0.90 Degrees

Gyro 2 Secondary

Ship Heading @ 192°: -1.80 Degree C-O

Applied Ships gyro Correction: (minus) -1.80 Degrees

2.3 GPS Monitoring

DGPS verification was carried out after the gyro calibration. The primary and secondary GPS antennas were checked before and after a 20 minute logging session using the Differential GPS systems onboard the vessel. The mean of the 2 RTK measured positions for each antenna was compared to the mean of the Differential GPS position logged over the 20-minute period to verify the GPS systems.

The results are shown below:

<u>GPS1</u>	<i>Latitude</i>	<i>Longitude</i>
<i>Differential GPS Position</i>	-16.927426	145.780393
<i>RTK Surveyed Position</i>	-16.927410	145.780393
<i>Difference</i>	0.000016 (~1.7m)	0.00m

<u>GPS2</u>	<i>Latitude</i>	<i>Longitude</i>
<i>Differential GPS Position</i>	-16.927427	145.780392
<i>RTK Surveyed Position</i>	-16.9274135	145.7804085
<i>Difference</i>	0.0000135 (~1.5m)	0.0000165 (~1.8m)

2.4 rGPS Monitoring

While alongside in Cairns, an integrity check of the rGPS pods was carried out. A coordinated point was established on the quayside, which was surveyed by taking the mean of 3 independent RTK measurements. Each pod was then positioned upon this point with range/bearing data to each pod being recorded for 10 min sessions. dGPS data was simultaneously recorded during each session. The range/bearing was computed between the vessel's dGPS position and the coordinated point, and then compared with the observed range/bearing to each rGPS pod. The C-O difference for each pod is shown below:

<u>Pods in use</u>	<i>C-O Difference (Range/Bearing)</i>
<i>Pod 689</i>	<i>0.49m / 1.11°</i>
<i>Pod 869</i>	<i>0.98m / 0.49°</i>
<i>Pod 870</i>	<i>0.12m / 0.68°</i>

<u>Spare</u>	<i>C-O Difference (Range/Bearing)</i>
<i>Pod 1065</i>	<i>1.10m / 1.12°</i>
<i>Pod 864</i>	<i>1.99m / 3.18°</i>

3 Navigation Processing

Navigation post-processing was carried out on-board through to UKOOA P1/90 final data format.

3.1 The *SeisPos* System

Created and Supported by Fast Geophysical Positioning Solutions (FGPS) in Swanley, Kent, UK.

SeisPos is a Windows NT/2000/98/95 software program, which enables processing of raw navigation data for marine seismic streamer surveys from UKOOA P2 raw data format to UKOOA P1/90 final data format. **SeisPos** supports simultaneous multiple projects and background processing. Data formats supported are UKOOA P2/91 and P2/94. The following Modules are used:

Input: reads the data stored in UKOOA P2 format and compiles a log of warnings. Implicitly alerts the user of format integrity problems. Stores all data in a proprietary format relational database.

Precondition: applies user defined gating, filtering and interpolation/extrapolation parameters to all data and presents interactive time series plots enabling quality appraisal and manual editing and rejection. All raw data is *read only*.

Adjust Network: performs a fully integrated weighted least squares adjustment of the positioning network. This includes LS estimates of streamer rotation and stretch and revised compass offsets and bearings for the interpolation of receiver group positions based on the concatenation of circular arcs between all nodes (compass or other) along the streamers.

The adjustment computation outputs final node coordinates and corrected compass positions and bearings along with QC data using a staged process enabling the survey line to be processed in as many sections as may be required according to data quality.

Output: interpolates receiver group positions and outputs selected records to file in UKOOA P1/90 format.

QC: allows analysis and manipulation (comparisons, rate of change etc.) of time series plots of all data and adjustment statistics (coordinates, error ellipse semi-major axes, processed observations, SD's, residuals, rotation, stretch, unit variance, redundancy, number of iterations. Shot time and distance interval).

Database: allows analysis, editing and textual output of all header and data tables stored in the database at all stages of the process.

3.2 Quality Control – *P1Tools*

P1Tools is a quality appraisal and utilities package for the QC of final data stored in UKOOA P1/90 format. The package operates on the Windows platforms. The modules incorporated are:

QC Nodes: enables time series analysis of shot to shot user specified node movement along orthogonal and radial axes. Outputs summary statistics to .csv file.

QC Offsets: enables time series analysis of shot to shot user specified node offsets along orthogonal and radial axes. Also provides integrity check for the type and number of nodes, the source firing sequence and the shot point range. Outputs summary statistics to .csv file.

Compare: enables time series analysis of position differences for user specified nodes between two P1/90 data sets along orthogonal and radial axes. Outputs summary statistics to .csv file.

Extract: outputs user selected data to ascii file for further analysis and third party software use.

Replay: two-dimensional replay of the vessel, source, receiver groups and tailbuoy.

4 Observations

4.1 Navigation Summary

All systems performed well throughout the survey period except for ramp in Position Dilution of Precision (PDOP) during which there was a reduced number of satellites in view.

Gyro #2 was out of service d/t an error occurring on job GBS02. This did not affect the quality on the GS02 survey since we had a fully operational gyro #1 defined as master in Spectra. Gyro #1 worked perfectly.

4.1.1 DGPS

V1G1 Primary dGPS System using SCF corrections from stations Melbourne SF (385), Bathurst (336), Brisbane (275), Dunedin (026) and Broome SF (185) performed well throughout the whole survey.

V1G2 Secondary dGPS System using corrections from Melbourne (385), Bathurst (336), Kalgoorlie (315), Townsville (195) and Darwin (125) performed well throughout the whole survey.

Both systems had periods of high PDOP from 1430 to 1830 hours local time due to the occurrence of poor satellite geometry and low number of satellites in view. In these periods both systems were switched to height aiding based on the local geoidal height in the survey area. The geoidal height was based on both observations of the height during Auto 3D positioning and calculations from NIMA EGM96 Calculator. Both methods indicated the same geoidal height. This was also approved by the onboard client representative.

4.1.2 rGPS

We lost the TB signal between sequence 004 and 005 on this prospect. The combination of active compasses and low feather let us continue production to completion of the prospect without retrieval of the streamer. The onboard client approved further production without the active tail buoy position.

The rGPS source positioning performed well for the duration of the survey.

5 Conclusions

In total there were 25 sequences shot, with all navigation systems working well throughout the survey except from gyro #2 and the loss of TB signal after sequence 005.

The Transverse Mercator utilised for this survey centred around 147° E with the Survey Datum being GDA-94 in the GRS-80 spheroid. Final p190's were provided in the GDA-94 datum.

6 Navigation System

The navigation system is made up of two GPS (Global positioning system) units with differential corrections and an integrated navigation package (Spectra). The GPS are Trimble 4000SSi units. Differential corrections are supplied by Spot satellite for the primary system whereas the secondary system consists of corrections from Inmarsat. The navigation package allows a great deal of flexibility and reliability.

6.1 Spectra Integrated Navigation System

6.1.1 General

Spectra, a real-time navigation system, sends and receives information via two acquisition systems referred to as Runts which contain interfaces to communicate with the vessel's navigation system. Using triggers (both internal and external), Spectra can synchronize systems with events generated inside and outside of Spectra. Hence data can be conveyed for successful acquisition.

6.1.2 File and Menu Structure

Spectra logs a p294 raw data file and a processed p190 data file, along with quality control and audit files, to a directory that is user selected via a system boot file which, when manually started, instructs Spectra which configuration files to use in the boot process. These configuration files are contained in a user created directory.

6.1.3 Displays

Spectra enables operator-configurable displays that are adjustable in size and content. The display system enables the operator to monitor all attached devices, data quality in real-time as well as multiple video displays of lines being tracked and online statistics. Spectra offers a real-time steering display, which is utilized by the bridge and is a direct representation of the current location.

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6.1.4 Survey Line Tracking

Survey pre-plots were supplied using GDA-94 co-ordinates.
The projection used:

Transverse Mercator
Origin Longitude 147°E
Origin Easting: 500000.000
Origin Latitude 000°
Origin Northing: 10000000
Scale factor: 0.9996

Semi-major Axis: 6378137.000
Inverse Flattening: 298.257222100
(No datum shifts were incurred from WGS-84 to GDA-94).

Spectra used a cocktail of the positions from both navigation systems to derive a weighted real-time position, which can be compared to a predictive position, for the next successive position for the shot point.

6.1.5 Data Logging

Spectra was configured to generate a data logging event mark based on a distance of 25 metre spacing. Spectra is configurable to record either all possible records or selected position records. Data is stored in a directory in standard comma delimited ASCII format, allowing files to be easily read by any popular spreadsheet or text editor. Primary media for data storage is hard disk whilst the secondary system consists of a Mammoth Exabyte tape drive.

6.1.6 System Timing

Timing is achieved via independent, stand-alone GPS receivers that are directly interfaced to each of the Runts. Each separate GPS receiver also offers a stand-alone (non-differential) position input in circumstances where either primary or secondary position systems are unavailable. During this survey, a differentially corrected position was available all the time.

6.1.7 Streamer Modelling

Spectra is able to perform streamer modelling in real time and calculate the associated P190 format for direct logging to disk or output via serial port. The streamer is shown on the graphics window in real time.

6.1.8 Compass Device

The current streamer modelling capability requires the interface to the Digicourse 293A bird surface unit. The configuration of the interface is a typical serial port configuration. Communication can be bi-directional enabling Spectra to query the Digicourse unit as well as receive data from it.

7 Offset Diagram

