

Table of Contents

1	NAVIGATION AND POSITIONING SYSTEM DESCRIPTION	2
1.1	SYSTEM CONFIGURATION	2
1.1.1	<i>Navigation Hardware and Software</i>	2
1.1.2	<i>System Timing</i>	2
1.2	SURVEY POSITIONING METHOD USED	2
1.3	SURFACE POSITIONING	3
1.3.1	<i>Vessel Navigation</i>	3
1.3.2	<i>Float Navigation</i>	3
1.4	STREAMER AND SOURCE POSITIONING	4
1.4.1	<i>Streamer Compasses</i>	4
1.4.2	<i>Gyro Compass</i>	4
1.5	AUXILLIARY NAVIGATION SENSORS	4
1.5.1	<i>Echo Sounder</i>	4
2	NAVIGATION SYSTEMS VERIFICATION AND MONITORING.....	5
2.1	ECHO SOUNDER VERIFICATION	5
2.2	GYRO MONITORING.....	5
2.3	GPS MONITORING.....	5
2.4	RGPS HEALTH CHECKS	5
3	NAVIGATION PROCESSING.....	6
3.1	THE FGPS SEISPOS SYSTEM.....	6
3.2	FIRST LINE TEST DATA	6
3.3	INITIAL QC	6
3.4	POST-PROCESSING FLOW	6
3.5	FINAL QC	6
3.6	WATER DEPTH PROCESSING.....	7
4	OBSERVATIONS	8
4.1	NAVIGATION SUMMARY	8
4.1.1	<i>DGPS Systems</i>	8
4.1.2	<i>Echo Sounder</i>	8
4.1.3	<i>Gyro</i>	8
4.1.4	<i>RGPS</i>	8
4.2	PROCESSING AND QC SUMMARY.....	8
APPENDIX 1	NAVIGATION SYSTEMS & DIAGRAMS.....	9
	DGPS REFERENCE STATIONS.....	9
	TOWING ARRANGEMENT SEQUENCE 1-13	10
	TOWING ARRANGEMENT SEQUENCE 14-46	11
	OFFSET DIAGRAM SEQUENCE 1-13.....	12
	OFFSET DIAGRAM SEQUENCE 14-46.....	13
APPENDIX 2	PROCESSING LOG - BY SEQUENCE NUMBER	14
APPENDIX 3	CALIBRATIONS AND TESTS.....	16

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	RTN μ (30/207P & 30/208P)	Spectra 9.8.06
	Linux Workstations	Red Hat 7.3
External Header	N/A	Gcs90v2
Acoustic System	N/A	
TS-meter	Saiv AS STD/CTD model SD204	
Echo sounder	SIMRAD EA600	

1.1.2 System Timing

Spectra issued closures to the source firing system and recording system 50 milliseconds before the predicted time of peak pressure. Spectra received the time break back from the GunLink source controller and all Spectra system positions are output for this time.

An addition trigger was issued from spectra 450 milliseconds after time zero. This was sent to the recording system as a timing verification. The trigger was 5 milliseconds in duration.

1.2 Survey Positioning Method Used

This survey was carried out using Multiwave's standard mode of operation for single streamer/single source surveys.

Positioning of the vessel was by Single frequency differential GPS with delivery of differential correction data in RTCM 104 format and recorded in the P2/94 files.

The sources were positioned relative to the vessel using a network consisting of rGPS units mounted on sub-arrays 1, 2 & 3 (strings 1,2 and 3 were in use only).

The centre near group of the streamer was positioned by a combination of compass heading units and nominal offsets from the vessel.

The centre last group of the streamer was positioned using a network consisting of one rGPS system unit mounted on the tail buoy, a nominal offset to the tail buoy and streamer mounted compass heading units.

The streamer shape was modelled by 22 Digicourse series 5011 combined streamer depth control and magnetic compass units on the streamer.

Least squares condition equations for the streamer assuming circular arcs between compasses and relating the tracking nodes, compasses, tension corrected distances between compasses, rotation bias and scale were used to compute scale, rotation and individual compass corrections. The streamer shape was then computed by the circular arc method.

1.3 Surface Positioning

1.3.1 Vessel Navigation

Summary

System 1: Fugro Multifix 4 Version 1.06
Differential correction delivery Starfix Spotbeam and Inmarsat B.

System 2: Fugro Multifix 4 Version 1.06
Differential correction delivery Starfix Spotbeam and Inmarsat B.

Differential Correction Systems: Thales Skyfix via Spot Beam (109E-Sat) satellite and Inmarsat (POR).

All systems had the same accuracy and were set to have the same weight in the solution.

Fugro Multifix is a multiple reference station DGPS system tailored for the specific needs of seismic surveying. State-of-the art algorithms combine reference station data and pseudo range measurements into the best position estimates.

By employing a correlation model for weighting the multiple range corrections in a least squares estimation process, the optimum pseudo-range corrections are obtained. W-testing and F-testing techniques detect and reject correction outliers.

Quality control is based upon UKOOA's recommended DGPS quality indicators - the precision and reliability of the fix are displayed as an Error Ellipse and Marginally Detectable Errors (MDE).

The differential corrections were transmitted to, and received on-board the vessel by two independent means and provided a high degree of redundancy to ensure continuous vessel positioning.

➤ **Further information is given in Appendix 1.**

Although Selective Availability was turned off in May 2000 differential corrections are still required to provide a high quality continuous vessel position. Less frequent updates are required however.

1.3.2 Float Navigation

Float (both tail buoy and source) surface navigation was provided by Seatex Seatrack relative GPS. The in-sea units incorporated a GPS receiver and interfacing for direct data transmission of the raw satellite pseudo-range data via UHF link to the vessel.

On board the vessel, the raw pseudo-range data from the float unit was matched with simultaneously received data at the vessel's GPS receiver to compute a vector describing the location of the float unit relative to the vessel from which the float position was derived. Relative positioning CEP was better than 2 m.

1.4 Streamer and Source Positioning

1.4.1 Streamer Compasses

22 series 5011 Digicourse combined magnetic compass and streamer depth controllers were attached to the streamer. All compasses were used for positioning and shaping the streamers.

Compass Sampling Rate	= 2 second
Averaging constant	= 14 seconds

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

1.4.2 Gyro Compass

The gyrocompasses used during the survey were:

Gyro 1	- Simrad HS50 GPS
Gyro 2	- Tokyo Keiki MK.ES

The gyro correction values as computed during the mobilisation calibration were as follows:

Gyro 1	- plus 1.48 degrees
Gyro 2	- plus 0.08 degrees

1.5 Auxilliary Navigation Sensors

1.5.1 Echo Sounder

The echo sounder speed of sound was set to 1500 m/s. A draught correction of zero was entered in the echo sounder. Depth data was recorded throughout the survey using a dual transducer/dual frequency (12 kHz, 200 kHz) Simrad EA600 Echo sounder.

2 Navigation Systems Verification and Monitoring

2.1 Echo Sounder Verification

A verification was performed, alongside in Portland on 15th of November 2005. This was done using a lead-line, and also TS-Dip readings.

- The Echo sounder verification results are given in Appendix 3

➤

2.2 Gyro Monitoring

Dockside verification was performed in two opposite directions in Loyang Shipyard, Singapore on 16th July 2004.

- The gyro verification results are in Appendix 3

➤

2.3 GPS Monitoring

Health checks onshore were carried out to verify that the installation was satisfactorily operational (data reception, transmission, processing and Logging were verified) and that operational settings were correct. Each system used, including duplicates was verified.

- The onshore Health Check results are in Appendix 3

➤

2.4 RGPS Health Checks

Health checks were carried out during the Mobilization in Singapore, to verify installation and operational settings were satisfactory.

- The onshore Health Check results are in Appendix 3

3 Navigation Processing

3.1 The FGPS Seispos System

SeisPos is an off-line navigation QC and post-processing system for 2D and 3D streamer surveys supplied by Fast Geophysical Processing Services. It runs under various Windows operating systems and has a graphical front end. A relational database management system is used for data storage. SeisPos is capable of automatic filtering and gating of the observations in addition to manual editing, before new adjustments are calculated. There is a comprehensive set of QC tools available such as graphical plots of any node or observation parameters and combinations of these, comparison of online and processed P1/90.

3.2 First Line Test data

A water-break analysis was performed during the first line to confirm the nominal offsets for the front end of the streamer. An offset shot was also performed after any streamer re-deployment.

3.3 Initial QC

Initial QC consisted of on-line monitoring of the systems and of producing an end of line QC report utilising the Spectra QCN (Quality Control Node). The report was generated as a Postscript document which is included as part of the final data shipment. If any discrepancies were found, they would be further investigated and any problems were noted in the navigation logs.

The report included comparisons between the systems, plots of network reliability, SMA (Semi Major Axis), MDE (Mean Detectable Error) and TS-plots of compasses, depths and source separation.

3.4 Post-processing Flow

The lines were post processed using Multiwave's standard 2D processing flow consisting of the following stages:

- Import P2/94 to database and check for header changes.
- Check for missing shots and perform shot edits.
- Update a-priori SD's and magnetic declination if required.
- Pre-process data applying standard gating and filtering, hand-edit any remaining observation spikes.
- Compass calibration and bias check.
- Network adjustment
- Processing QC report generation.
- Export final P1/90
- QC of final P1/90
- Comparison of online and final P1/90

3.5 Final QC

Final QC was performed during the post processing and consisted of checking the various reports and plots generated by SeisPos, checking consistency of logs and P1/90 QC and comparison. Any discrepancy was noted in the processing log.

3.6 Water Depth Processing

The recorded water depth data was corrected for vessel draught, and a speed of sound correction was also applied to the processed water depth.

Corrections for draft and water velocity were carried out in post-processing.

4 Observations

4.1 Navigation Summary

During the Survey the towing configuration was changed. This was due to equipment damage caused on the streamer due to it being too close to the gun arrays. This happened after sequence 013.

All systems performed very well throughout the survey, however during acquisition the below systems required further detail.

4.1.1 DGPS Systems

All DGPS systems performed well during this survey. Reference station data via the Spot antenna was available and recorded after sequence 1.

4.1.2 Echo Sounder

The 12 kHz transducer worked well throughout the survey, although was slightly intermittent in areas of rapid slope change. The 200 KHz transducer was only usable in depths up to 300m. Both transducers were logged in the P2. Only the 12 KHz was used in the final P190.

4.1.3 Gyro

The primary and secondary gyro performed well during the survey, with no problems.

4.1.4 RGPS

During the survey all pods except that on gun string sub array 2 performed well. Gun Pod 2 was unusable up to sequence 13. The pod was changed out after this sequence and performed well for the remainder of the survey.

4.2 Processing and QC Summary

The data quality during this survey was generally good except for occasional noisy rGPS data on the gun strings, and occasional noisy echo-sounder data.

The client's specifications for the survey were met and there are no significant problems to report.

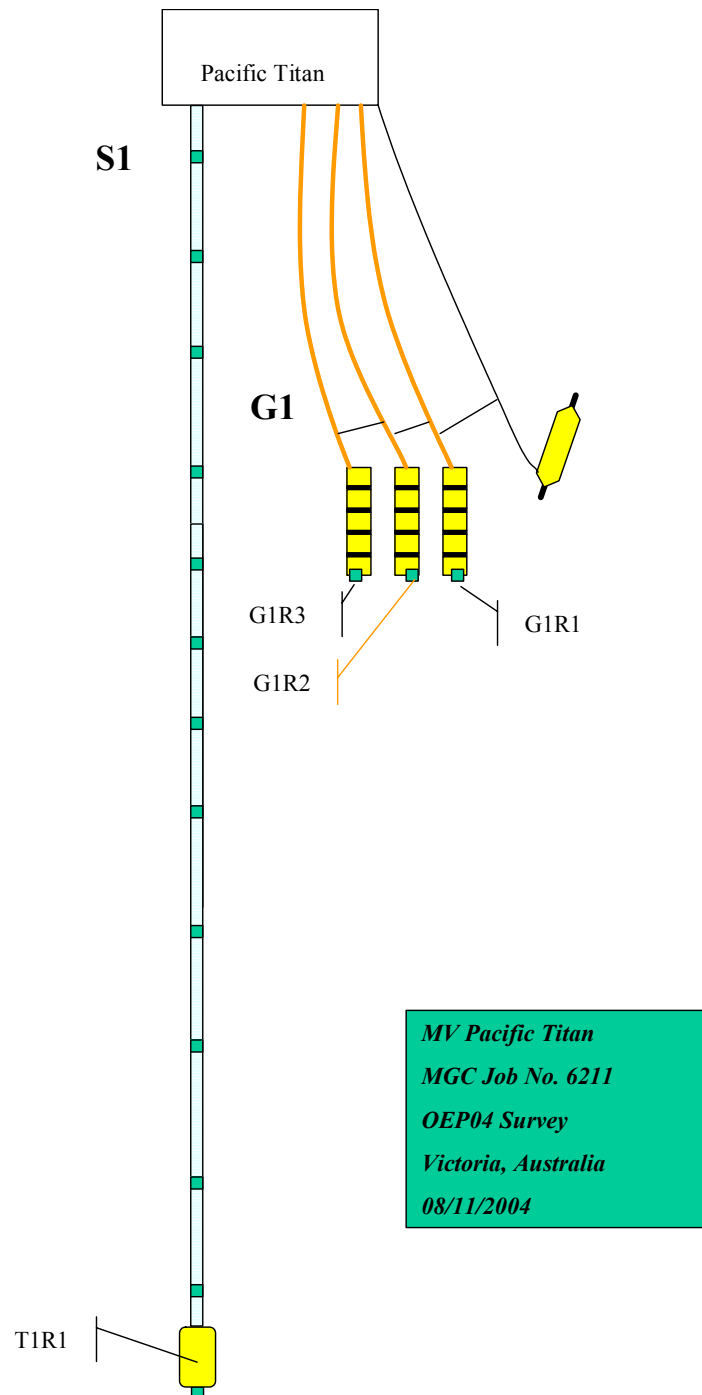
Appendix 1 Navigation Systems & Diagrams

DGPS Reference Stations

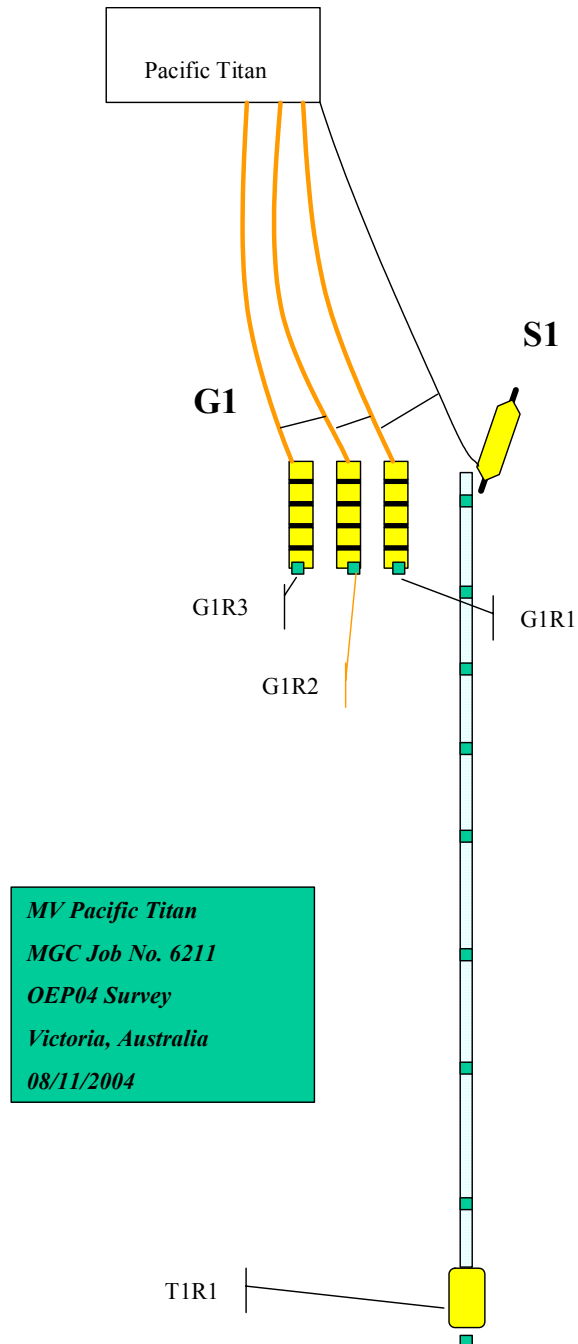
V1G1		WGS84		
Ref. St. Name	No.	Latitude	Longitude	Height (m)
Adelaide	355	032° 07' 03.054"S	133° 41' 22.838" E	07.26
Melbourne	385	037° 48' 29.010"S	144° 57' 48.028" E	82.05
Sydney	336	033° 25' 46.884"S	149° 34' 01.967" E	756.65

V1G2		WGS84		
Ref. St. Name	No.	Latitude	Longitude	Height (m)
Adelaide	355	032° 07' 03.054"S	133° 41' 22.838" E	07.26
Melbourne	385	037° 48' 29.010"S	144° 57' 48.028" E	82.05
Sydney	336	033° 25' 46.884"S	149° 34' 01.967" E	756.65

Towing Arrangement Sequence 1-13



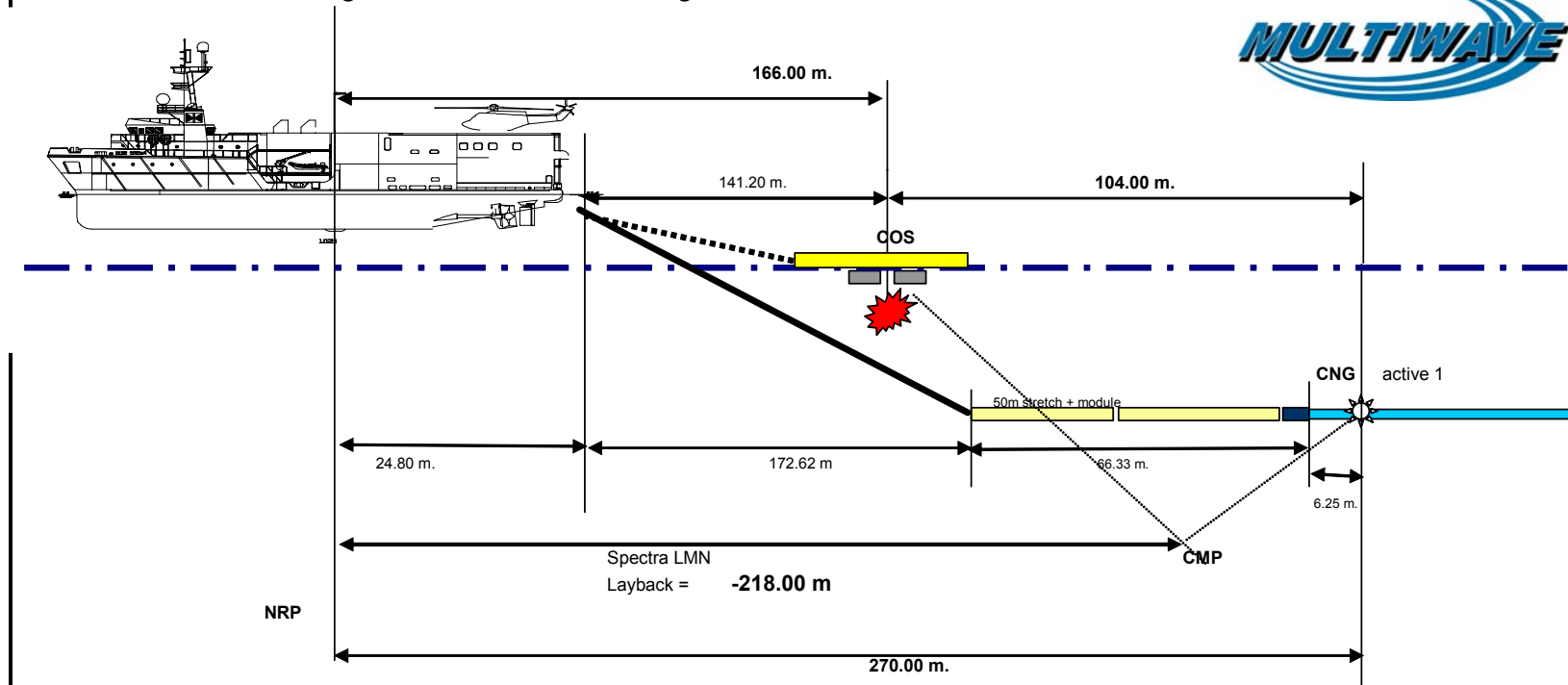
Towing Arrangement Sequence 14-46



Section 4: Navigation

Offset Diagram Sequence 1-13

M/V Pacific Titan Towing Dimensions/Offset Diagram



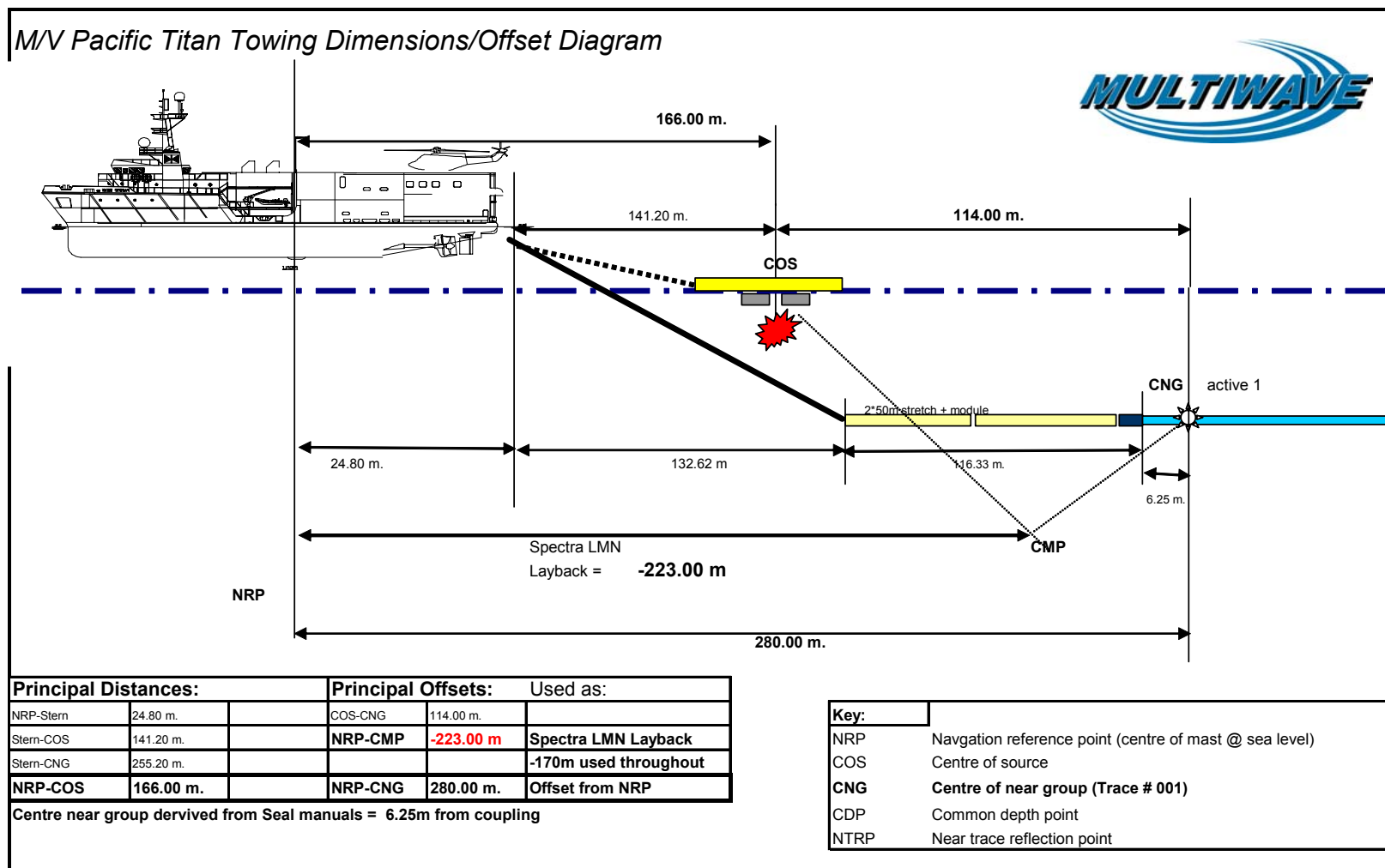
Principal Distances:			Principal Offsets:		Used as:
NRP-Stern	24.80 m.		COS-CNG	104.00 m.	
Stern-COS	141.20 m.		NRP-CMP	-218.00 m	Spectra LMN Layback
Stern-CNG	245.20 m.				-170m used throughout
NRP-COS	166.00 m.		NRP-CNG	270.00 m.	Offset from NRP

Centre near group derived from Seal manuals = 6.25m from coupling

Key:	
NRP	Navigation reference point (centre of mast @ sea level)
COS	Centre of source
CNG	Centre of near group (Trace # 001)
CDP	Common depth point
NTRP	Near trace reflection point

Section 4: Navigation

Offset Diagram Sequence 14-46



Appendix 2 Processing Log - by Sequence Number

Prospect: **SANTOS 2D 2004**
Area: **Otway Basin**
Date: **November 08th – 26th 2004**
Prefix : **OEP04**

Line Name	Sequence	Database	FGSP	LGSP	Missed Shots/Interpolated	P190 output	QC report	Comments
26-01-001	001	6211_fr001	1001	2221		Y	Y	
59-01-002	002	6211_fr001	1001	2101		Y	Y	No Echo data sp 1336-1510
51-01-003	003	6211_fr001	1001	2784		Y	Y	sp 1398-1424 no TB, gun2 rgps, Gun 1 RGPS u/s 1240-1422
57-01-004	004	6211_fr001	1001	2571		Y	Y	
47-01-005	005	6211_fr005	1001	1501		Y	Y	
45-01-006	006	6211_fr005	1001	1590		Y	Y	
53-01-007	007	6211_fr005	1060	1606		Y	Y	
53-02-008	008	6211_fr005	1487					DNP
55-01-009	009	6211_fr005	1001	2749		Y	Y	
49-01-010	000	6211_fr005	1001	2134		Y	Y	Streamer at 8m
53-03-011	011	6211_fr005	1487	1657				DNP d/t Whale
43-01-012	012	6211_fr005	1540	2134		Y	Y	Streamer at 8m
53-04-013	013	6211_fr005	1487					DNP d/t tangle
02-01-014	014	6211_fr014	1001	3130		Y	Y	offset change to 280m, streamer at 8m
06-01-015	015	6211_fr014	1001	2482		Y	Y	strmr at 8m
10-01-016	016	6211_fr014	1001	2073		Y	Y	strmr at 8m
08-01-017	017	6211_fr014	1001	2394		Y	Y	strmr at 8m
41-01-018	018	6211_fr018	1001	1833		Y	Y	strmr at 8m
31-01-019	019	6211_fr018	1001	2158		Y	Y	strmr at 8m
39-01-020	020	6211_fr018	1001	2435		Y	Y	strmr at 8m

Section 4: Navigation

Line Name	Sequence	Database	FGSP	LGSP	Missed Shots/Interpolated	P190 output	QC report	Comments
53-05-021	021	6211_fr018	1487	2174		Y	Y	strmr at 8m
04-01-022	022	6211_fr018	1001	2200		Y	Y	strmr at 8m
29-01-023	023	6211_fr018	1001	1679		Y	Y	strmr at 9m
37-01-024	024	6211_fr018	1001	1740		Y	Y	strmr at 9m
43-02-025	025	6211_fr018	1001	1659		Y	Y	strmr at 8m
33-01-026	026	6211_fr018	1001	2546		Y	Y	strmr at 8m
21-01-027	027	6211_fr018	1001	2769		Y	Y	strmr at 9m
15-01-028	028	6211_fr018	1001	1055				DNP d/t cable noise
15-02-029	029	6211_fr018	1001	1034				DNP d/t streamer problem
15-03-030	030	6211_fr018	1001	2748		Y	Y	strmr at 9m
19-01-031	031	6211_fr018	1001	2650		Y	Y	strmr at 9m
27-01-032	032	6211_fr018	1001	2664		Y	Y	strmr at 9m
35-01-033	033	6211_fr018	1001	2180		Y	Y	strmr at 8m
25-01-034	034	6211_fr018	1001	1991		Y	Y	strmr at 7m
17-01-035	035	6211_fr018	1001	2353		Y	Y	strmr at 7m
23-01-036	036	6211_fr018	1001	2351		Y	Y	strmr at 7m
07-01-037	037	6211_fr018	1001	2306		Y	Y	strmr at 7m
13-01-038	038	6211_fr018	1001	1491		Y	Y	strmr at 7m
03-01-039	039	6211_fr018	1001					DNP d/t Nav Operator Error
13-02-040	040	6211_fr018	1372	1998		Y	Y	strmr at 7m
05-01-041	041	6211_fr018	1001	2290		Y	Y	strmr at 7m
11-01-042	042	6211_fr018	1001	2294	2192	Y	Y	strmr at 7m
03-02-043	043	6211_fr018	1001	1657		Y	Y	strmr at 7m
09-01-044	044	6211_fr018	1001	1524		Y	Y	strmr at 7m
01-01-045	045	6211_fr018	1001	1551		Y	Y	strmr at 7m
03-03-046	046	6211_fr018	1538	2049		Y	Y	strmr at 7m

Appendix 3 Calibrations and Tests

Introduction

Swift Survey Pte Ltd was appointed by Multiwave Geophysical Company, to carry out the following survey work on MV Pacific Titan at Singapore Offshore Supply Base, Loyang.

- Gyro calibration in North-North-West (NNW) and South-South-East (SSE) direction. There are two gyros onboard. One is called the NMEA Gyro (Gyro 1) and the other is the Ship's Gyro.
- GPS verification. There are two positioning systems onboard. They are: S1_GPS1 and S1_GPS2.

Summary of Results

<u>System</u>	<u>Computed</u>	<u>Observed</u>	<u>C-O</u>
NMEA Gyro in NNW direction	339.013 deg.	337.480 deg.	+1.533 deg
Ship Gyro in NNW direction	339.013 deg.	339.033 deg.	-0.021 deg
NMEA Gyro in SSE direction	159.816 deg.	157.920 deg.	+1.896 deg
Ship Gyro in NNW direction	159.816 deg.	159.640 deg.	+0.176 deg

	<u>Computed - Observed</u>	
	<u>Easting</u>	<u>Northing</u>
S1_GPS1 in NNW direction	-0.299m	+0.595m
S1_GPS2 in NNW direction	-0.280m	+0.678m
S1_GPS1 in SSE direction	-0.001m	-0.793m
S1_GPS2 in SSE direction	-0.073m	-0.801m

	<u>Computed - Observed</u>	
	<u>Bearing</u>	<u>Distance</u>
Tail Buoy (Serial No. 1322)	+0.443 deg	+1.271m
Tail Buoy (Serial No. 1251)	+0.821 deg	-0.339m
Tail Buoy (Serial No. 1249)	-0.776 deg	-0.055m
Tail Buoy (Serial No. 1183)	+1.310 deg	-0.471m

Method of Calibration

Gyro Calibration

A built-line (i.e. centre-line of the vessel) was first established onboard MV Pacific Titan. In this case the built-line is the foremast at the bow of the vessel and the stern light mast of the vessel.

One reflector was sited at the stern mast and another reflector was installed at the foremast of the vessel.

Three points on Loyang Jetty, stations GPS 83, GPS 81 and GR19 were used during the gyro calibration. The True bearing from GPS81 to GPS80 was established by sun-shots. This bearing was transferred to station GPS81 and GPS83.

For gyro calibration in NNW direction, a Total Station was set up at station GR 19 and a reference station set up at station GPS83. True bearings and horizontal distances were observed to the reflectors at the stern and bow of the vessel.

For gyro calibration in SSE direction, a Total Station was set up at station GPS 83 and a reference station set up at station GR 19. True bearings and horizontal distances were observed to the reflectors at the stern and bow of the vessel.

During each observation, readings from the ship's gyro were simultaneously logged. A total of 30 sets of reading were logged with the vessel in the NNW and SSE directions.

The gyro calibrations were carried out on 16th July 2004.

GPS Verification

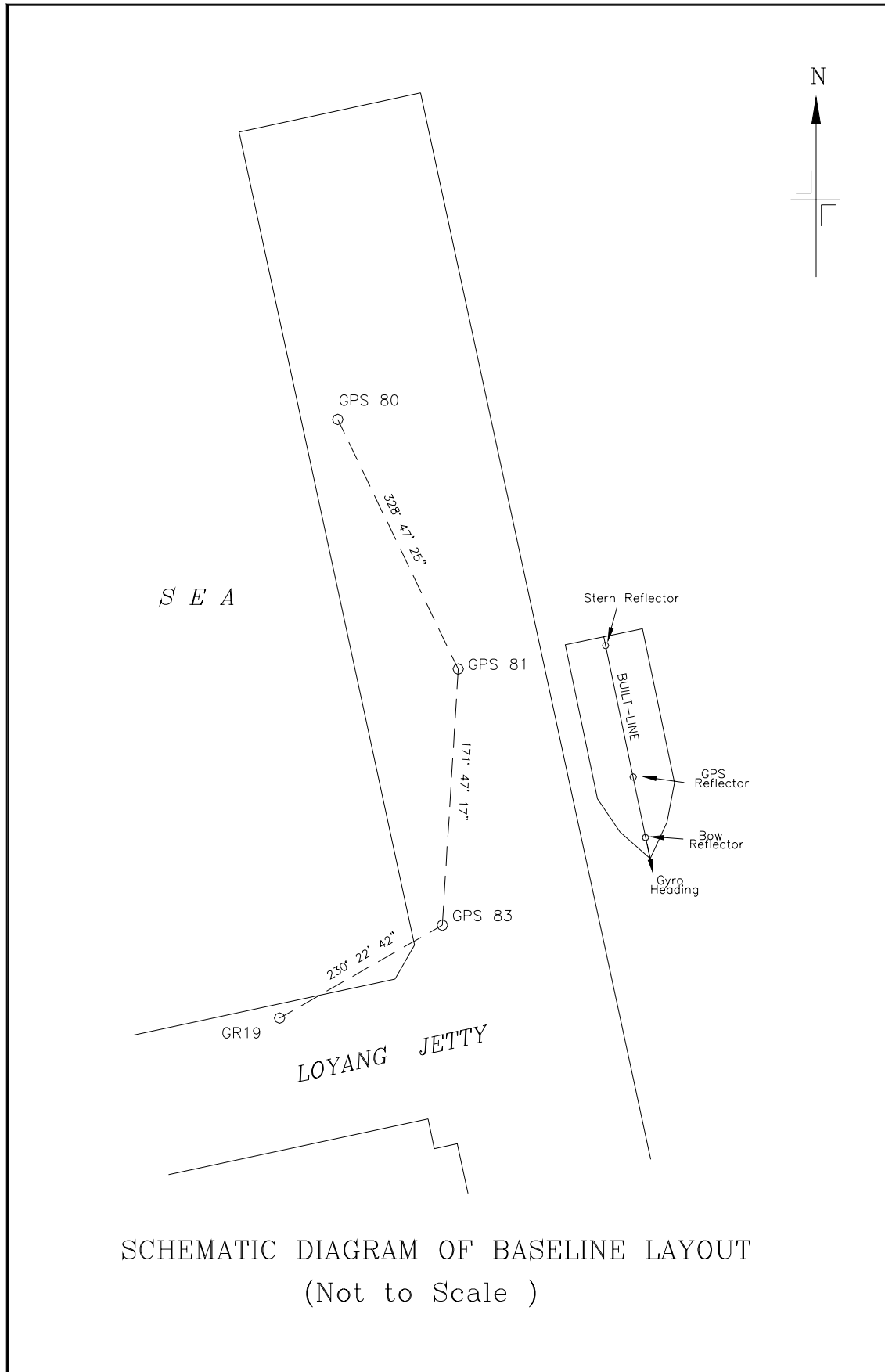
GPS verification was carried out on 16th July 2004.

A single reflector was attached to the GPS antenna. For GPS verification in the NNW and SSE directions, a Total Station was set up at station GPS 83 and a reflector on tripod was set up at station GR 19.

Using station GR 19 as a reference bearing, the Total Station observed 30 sets of bearings and horizontal distances to the reflector at the GPS antenna. Readings were taken at 30 seconds interval. Simultaneously, the vessel also recorded the GPS positions.

The coordinates of the GPS antennae were computed and these were compared to the ship's printout to derive the difference in their Eastings and Northings.

Section 4: Navigation



Section 4: Navigation

RGPS Verification

The last RGPS verification was held at the Island of Peblokan on the 7th of September 2004. The following were the results for all Pods:

RGPS HEALTH CHECK

Location Pablokan

07-Sep-04

Survey Position: **Testpoint @ Pablokan North Jetty**

Bessel 1841 - Batavia	
TM Origin 108°E	
scale 0.9996	
Easting	321707.710
Northing	9394433.980

WGS84	005.4768828S
	106.3920667E
Convergence	0.15358398

Verification Summary:

<i>Pod</i>	<i>Mean Easting</i>	<i>Mean Northing</i>	<i>C-O (E)</i>	<i>C-O (N)</i>	<i>SD (E)</i>	<i>SD (N)</i>
322	321708.82	9394436.47	1.11	2.49	0.65	0.49
948	321708.66	9394436.05	0.95	2.07	0.42	0.32
320	321708.79	9394434.24	1.08	0.26	0.42	0.39
335	321708.09	9394435.47	0.38	1.49	0.46	0.43
183	321706.87	9394436.23	-0.84	2.25	0.46	0.37
252	321708.26	9394436.24	0.55	2.26	0.47	0.23
182	321707.67	9394436.95	-0.04	2.97	0.35	0.37
249	321708.18	9394436.59	-0.04	2.61	0.86	0.73
225	321709.30	9394435.35	1.59	1.37	0.43	0.54
340	321707.84	9394433.61	0.13	-0.37	0.42	0.58

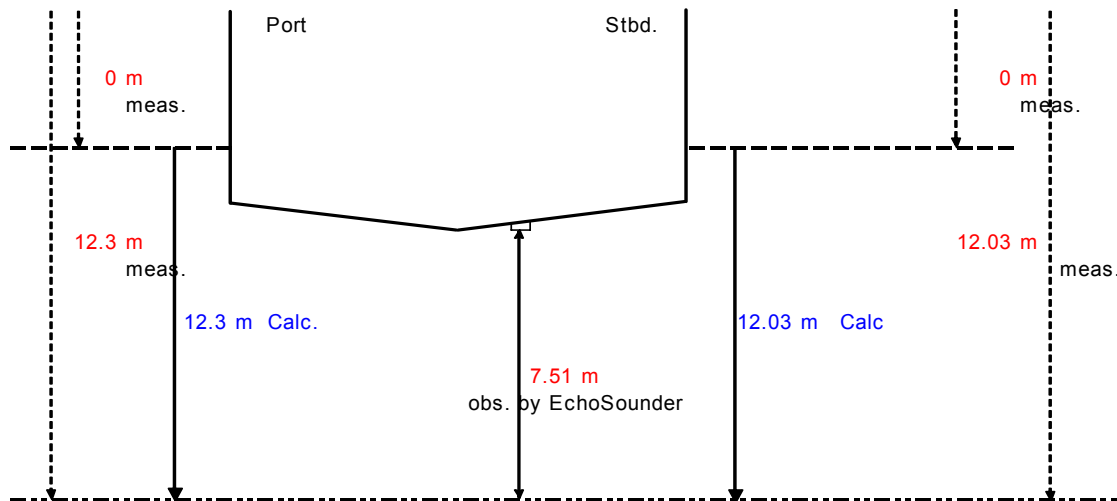
Section 4: Navigation

Echo Sounder Verification

ECHOSOUNDER CALIBRATION - m/v. PACIFIC TITAN

Alongside:- **PORTLAND**
Date: **15 Nov 04**
Time: **02:30** GMT
Taken in Port after Bad Weather
Job: **6211**
Client: **SANTOS**

Measurements taken:-	metres		
Port Freeboard		EchouSounder Reading	7.51
Port Lead-Line	12.3	Time	02:30
Stbd Freeboard		Stbd Draught marks:	4.75
Stbd Lead-Line	12.03	Port Draught marks:	4.85



Draft Marks:
Port : 4.85 m
Stbd : 4.75 m
Theoretical Draft = 4.8 m

Electronic Depth + Theoret.Draft 12.31 m

True Measured Water depth = 12.165 m

Difference = 0.145

TEXT = Measured
TEXT = Calculated
TEXT = Observed

TEXT = Results