LADS Survey - A Case Study on Australia's Northwest Shelf

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Laser Airborne Depth Sounder (LADS) systems provide an accurate, rapid and cost effective method of surveying coastal areas. These systems have been used by governments and commercial organisations over the last decade to conduct surveys for nautical charting, coastal zone management, territorial sea baseline determination, offshore exploration and defence applications. In the field of offshore exploration commercial LADS surveys have been used to provide high definition bathymetric data to support 3D seismic data collection in poorly surveyed shallow areas. This paper describes the conduct of a LADS Mk II survey for the oil and gas industry on Australia's Northwest Shelf and the quality control procedures undertaken.

System Details - LADS Mk II

The LADS Mk II system consists of an Airborne System for data collection and a Ground System for data processing. The Airborne System is fitted inside a Dash 8-200 series aircraft which has a transit speed of 250 knots at altitudes of up to 25,000 feet (7,620 metres) and an endurance of up to eight hours. Note that for aviation operations altitudes are reported in feet. The aircraft is certified by the Civil Aviation Safety Authority Australia, to Regular Passenger Transport standards and is fitted with the Traffic Alert and Collision Avoidance System. Survey operations are conducted from heights between 1,200 feet (366 metres) and 1,800 feet (549 metres) at ground speeds between 140 and 175 knots. The aircraft is fitted with a Nd: YAG laser on a stabilised platform, which operates at 900 Hertz to provide 5x5 metre laser spot spacing in the main line sounding mode of operation across a swath width of 240 metres. The electro-mechanical scanner also provides higher density modes of operation with laser spot spacings of 4x4, 3x3 and 2x2 metres with reduced swath widths. Green laser pulses are scanned beneath the aircraft in a rectilinear pattern. The pulses are reflected from the land, sea surface, within the water column and from the seabed (Figure 1). The green returned laser energy from the sea surface and the sea floor is captured by the green receiver and then digitised and logged to Digital Linear Tape. An infra-red laser is directed vertically beneath the aircraft. The height of the aircraft is determined by the received infra-red laser pulses and this is supplemented by an AHRS inertial height reference and DGPS height.

The LADS Mk II system can operate by day and night. Real-time positioning is provided by Wide-Area Differential GPS (WADGPS) and raw GPS. The Airborne System also contains GPS signal logging for use in determining post-processed DGPS and KGPS positions.

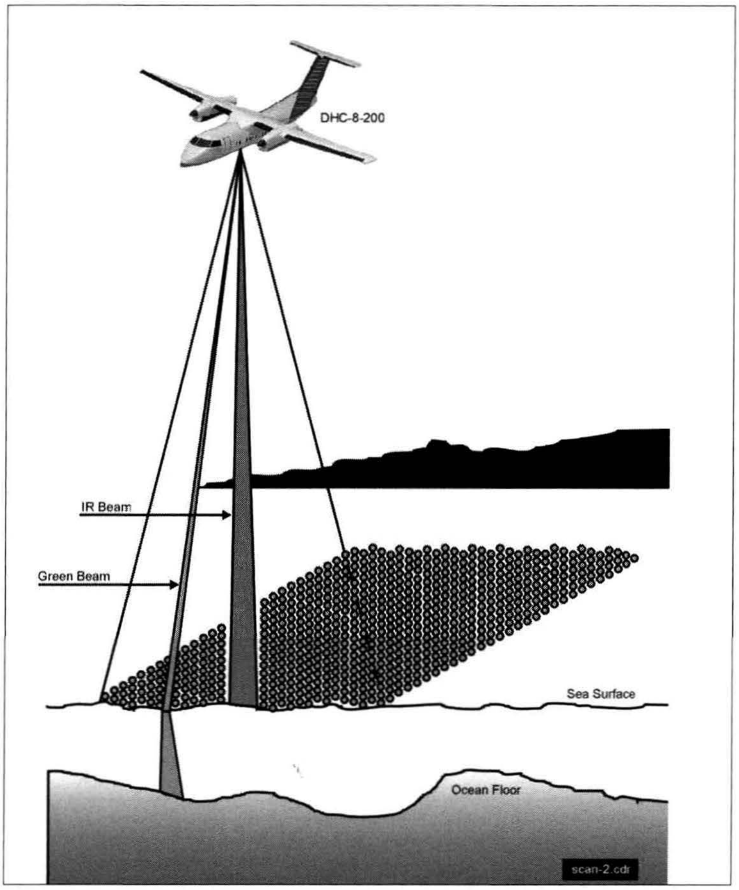

Figure 1: The laser scan

Data collected by the Airborne System is processed on the Ground System which consists of a portable Digital Alpha 4100 computer which can be transported in the aircraft to the deployment site. A number of terminals are connected to provide a user interface for the hydrographic surveyor. In addition, a smaller processing system, the Porta-GS, is also available. The Ground System also contains GPS signal logging equipment (base receiver). This allows the subsequent calculation of either a DGPS or Coarse Acquisition (C/A) code + carrier phase smoothed position from a base station which is established at the operating site. The output files from the Ashtech PNAV process can be imported into the Ground System to allow post-processed positions to be applied to soundings.

Performance Specifications - LADS Mk II

Maximum depth	70 metres	
Maximum topographic height	50 metres	
Sounding rate	900 soundings / second	(3.24 million soundings / hour)
Sounding patterns	5x5 metres	240 metre swath at 175 knots
	4x4 metres	200 metre swath at 140 knots
	3x3 metres	100 metre swath at 150 knots
	2x2 metres	50 metre swath at 140 knots
Aircraft operating heights	1,200 – 1,800 feet	366 - 550 metres
Aircraft endurance	8 hours (+ 1 hour in reserve)	
Aircraft range	2,000 nautical miles	

Survey Requirement - Seismic Vessel Exploration

This LADS Mk II survey collected bathymetric data in a remote and shallow area to facilitate seismic vessel operations. TGS Nopec licensed the processed LADS bathymetry data to assist in the planning and execution of the 2001 Flinders 3D Marine Seismic Survey. The data was considered necessary to:

a. Maximise the coverage achievable with towed seismic streamers
b. Allow such coverage to be achieved with maximum safety and efficiency
c. Provide high-quality bathymetry for follow-on exploration activity

The seismic vessel navigation was constrained by the draft of the vessel and the depth of the towed equipment. The considerable length of the tow also restricted vessel manoeuvrability. Towed equipment draws up to 10 metres depth and extends up to two miles astern of the seismic vessel (Figure 2).

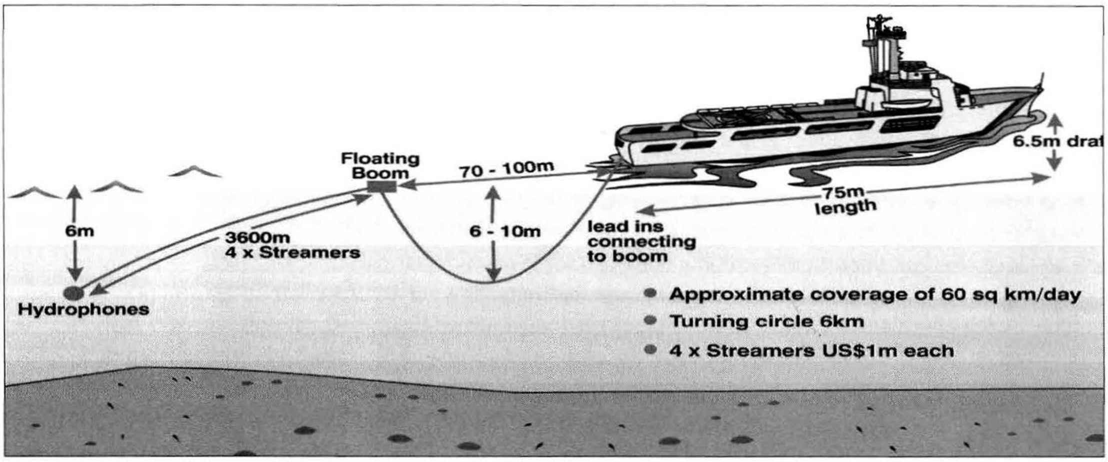

Figure 2: Seismic vessel on task

Survey Area - Northwest Shelf

The survey area is situated on the remote Northwest Shelf of Australia. The area extends south of Barrow Island and Mary Anne Passage in the north east, to Peak Island and Observation Island in the south west (Figure 3). This is an area of 3,305 square kilometres, all of which is less than 20 metres deep. The survey area joins a 1998 LADS Mk II survey area of 1,239 sq km east of Barrow Island. In total this forms a continuous area of 4,544 sq km (1,322 sq nm), which has been surveyed by LADS Mk II primarily to facilitate seismic data collection, seismic data processing and oil field development activities.

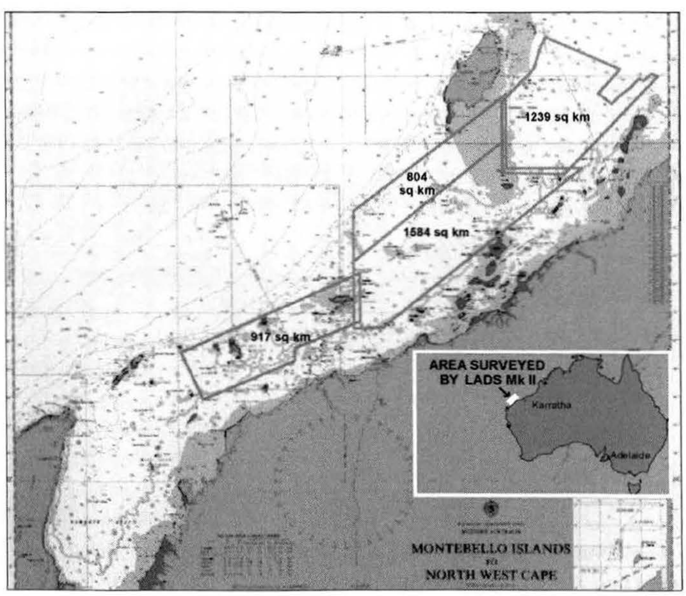

Figure 3: LADS Mk II survey area - 4,544 square kilometres

Field Operations - Karratha

On 18 October 2000 the LADS Mk II aircraft deployed to the remote town of Karratha, which is located near the Port of Dampier. Field operations were conducted for a period of 7.5 weeks, during which time 26 survey sorties were flown, an average of one sortie of 7.5 hours duration for every two days deployed. Survey sorties were conducted during the evening and night; sortie take-off time was at 1500 and the aircraft returned at approximately 2230. This routine enabled the highest quality data to be collected, as it avoided the noon period when high sun elevations increase noise levels on the received laser waveforms. Following take-off the aircraft proceeded to the survey area which is located between 80 and 150 nautical miles west of Karratha. On each sortie checks for position, depth and target detection were conducted prior to commencing sounding. Main lines were then sounded at 5x5 metre laser spot spacing. Main lines of sounding were up to 67 kilometres long (36 nautical miles); a flying time of 12 minutes was required to complete each line which was followed by an aircraft turning time between lines of 4.5 minutes. The most productive sortie was sortie 9 in the Barrow database which was flown on 25 October, 2000. A total of 22 main lines of 36 nautical miles length were flown, which resulted in 305.7 square kilometres (88.96 sq nm) being surveyed on a single flight. In addition to the main lines of sounding, eight cross-tie lines were flown at right angles to the main lines. Refly lines were also flown to improve coverage in some areas. Very shallow areas and shoals significant to seismic operations were later examined at 3x3 metre laser spot spacing in order to confirm the least depth in these areas.

Parts of the survey area were affected by high turbidity. This was most significant during the period of spring tides, when strong tidal streams caused seabed sediment to be suspended in the water. To minimise the effect of dirty water these periods were largely avoided; up to six sorties were planned during the week centred on neap tides and only one sortie was then planned during the following spring tide period. This plan was most effective in avoiding high turbidity. The survey area was also affected by isolated patches of Trichodesmium (blue green algae) on the sea surface, which attenuated the laser pulses. These areas had to be reflown on subsequent sorties to complete the coverage in these areas.

Data Processing - Field and Depot

In excess of 150 million soundings were collected in the survey area. In order to manage this large amount of data, the survey was subdivided into three separate areas and each area was managed as a separate database. This arrangement avoided a number of potential data management problems. For example, data processing, data review, application of tides, data export and database saves were all simpler and quicker due to this database partitioning. Another data management strategy utilised to reduce costs was to conduct the majority of data processing at the survey depot in Adelaide. A small processing system was set up at the field operating site to allow the Airborne System tapes to be copied following each flight. The copied tape was then despatched to the survey depot in Adelaide and would arrive the next day for processing. This enabled the number of surveyors in the field to be reduced to only two. Once the data was received at the survey depot it was automatically processed and then each survey line was interactively validated by a hydrographic surveyor. As some sorties were quite large, this validation process took one to two days. Following this, the data was checked and approved at the survey depot. Interim data was also exported from the Ground System in ASCII format, burnt onto CD and passed to the customer. This allowed the seismic survey planning to be refined during the course of the laser hydrographic survey. The timely provision of interim data also resulted in extending the boundaries of the survey areas in a number of areas to meet emerging new requirements.

Tide Modelling

The reduction of soundings for tide required careful management due to significant changes in mean sea level which occur across this large survey area. For example, mean sea level varies from 1.0 metre above Lowest Astronomical Tide (LAT) at Serrurier Island, to 2.4 metres above LAT at the Barrow Island Tanker

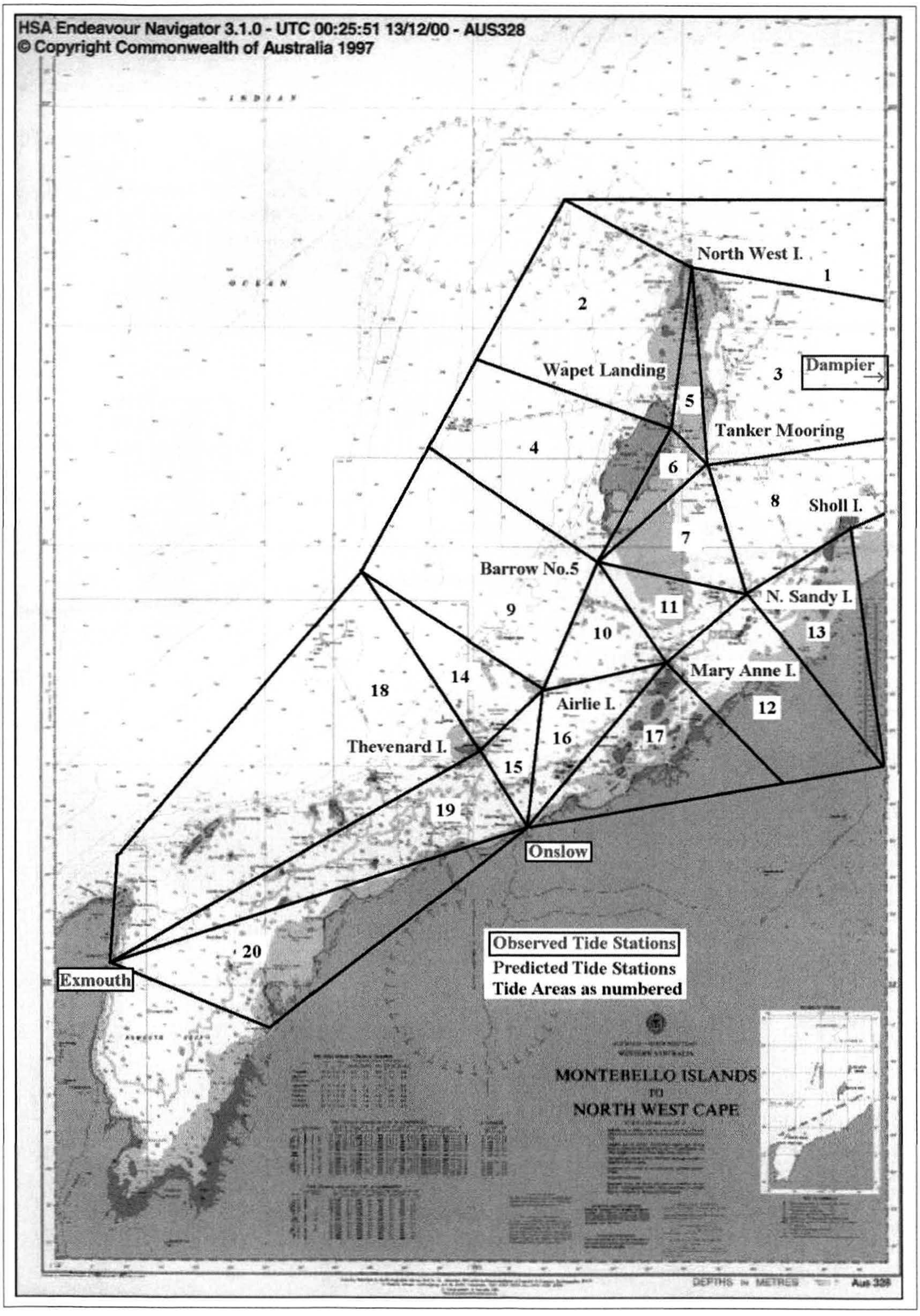

Figure 4: Tidal model showing tide areas and tide stations

Mooring. To accommodate these variations a tidal model was created which covered the survey area consisting of twenty Tide Areas and using three observed and 11 predicted Tide Stations.

Observed tides were provided by the Western Australian Department of Transport - Tides and Waves Section for Dampier, Onslow and Exmouth. Predicted tidal heights were calculated from tidal constituents and adjusted by the Calculated - Observed height (C-O) from the nearest observed Tide Station. Within each Tide Area soundings were automatically reduced by a tide height interpolated on the plane through the triangle formed by the Tide Stations. Linear interpolation was used for all Tide Areas which contained only two Tide Stations. The suitability of the tide model was checked in the analysis of the intersections between the main lines of sounding and cross-tie lines, which is discussed later.

Positioning - Systems and Checks

Real-time positions were determined during the survey using an Ashtech GG24 GPS receiver with WADGPS (Racal Skyfix/LandStar) corrections. The real-time differential corrections were received via the Optus Satellite and the corrections were provided from the reference station in Dampier. A local DGPS reference station was established to provide redundancy of position. The local base station was sited on a coordinated site on the roof of the Avis building in Karratha. The DGPS positions were determined off line using data logged at the base station and on the aircraft. This data was processed through Ashtech PNAV software to calculate both a DGPS and Coarse Acquisition code + carrier phase smoothed position solution. The Coarse Acquisition code + carrier phase smoothed position solution results were then imported into the Ground System to check the WADGPS real-time position.
A number of quality checks were conducted during the survey. Prior to commencing sounding, a static position check was conducted with the LADS Mk II aircraft on the tarmac at Karratha airport. During each sortie the positioning systems were also checked against a known lighthouse and a known pinnacle on the seabed; in addition, the real-time WADGPS and post-processed DGPS positions were compared. These quality checks are discussed below.

Static Position Check

On 19 October 2000 a static position check was conducted of all positioning systems at the airport in Karratha. The aircraft was positioned over previously surveyed marks on the tarmac; the position of the laser was then plumbed to the tarmac and measured relative to these marks in order to deduce the position of the GPS antenna. Three position logging sessions were conducted. Table 1 shows the comparison of different GPS static solutions for the position of the aircraft GPS antenna. A reference station power failure interrupted Session 1 and this was therefore repeated as Session 3.

Positioning System	Easting (m)	Northing (m)
Absolute Position of GPS Antenna	476 052.56	7 709 892.74

SESSION 1	Power	Failure			
SESSION 2 1 hr 53 min (9 satellites)	Easting (m) (95% confidence)	Northing (m) (95% confidence)	Δ East Calculated - Observed	Δ North Calculated - Observed	Absolute Accuracy (m) (95% confidence)
AS WADGPS Broome (650 km away)	476 049.12 +/- 1.57	7 709 891.59 +/- 1.35	3.44	1.15	5.70
PNAV DGPS	476 052.61 +/- 0.20	7 709 892.82 +/- 0.21	-0.05	-0.08	0.38
PNAV Code + Carrier	476 052.59 +/- 0.03	7 709 892.66 +/- 0.03	-0.03	0.08	0.13

SESSION 3 1 hr 49 min (8 satellites)	Easting (m) (95% confidence)	Northing (m) (95% confidence)	Δ East Calculated - Observed (m)	Δ North Calculated - Observed (m)	Absolute Accuracy (m) (95% confidence)
AS WADGPS Dampier (9 km away)	476 052.50 +/- 1.02	7 709 892.55 +/- 0.79	0.06	0.19	1.49
PNAV DGPS	476 052.54 +/- 0.22	7 709 892.82 +/- 0.14	0.02	-0.08	0.34
PNAV Code + Carrier	476 052.48 +/- 0.05	7 709 892.69 +/- 0.02	0.08	0.05	0.15

Table 1: Comparison of different GPS static solutions for the position of the aircraft GPS antenna

The results of the static position check show a significant difference in the accuracy of the real-time WADGPS positions over a 9 km baseline length (Karratha) and 650 km baseline (Broome). During survey operations the Dampier WADGPS reference station was used for real-time positioning and operations up to 250 kilometres from the base station were undertaken. A scatter plot of the results of the Dampier WADGPS static calibration is provided (Figure 5).

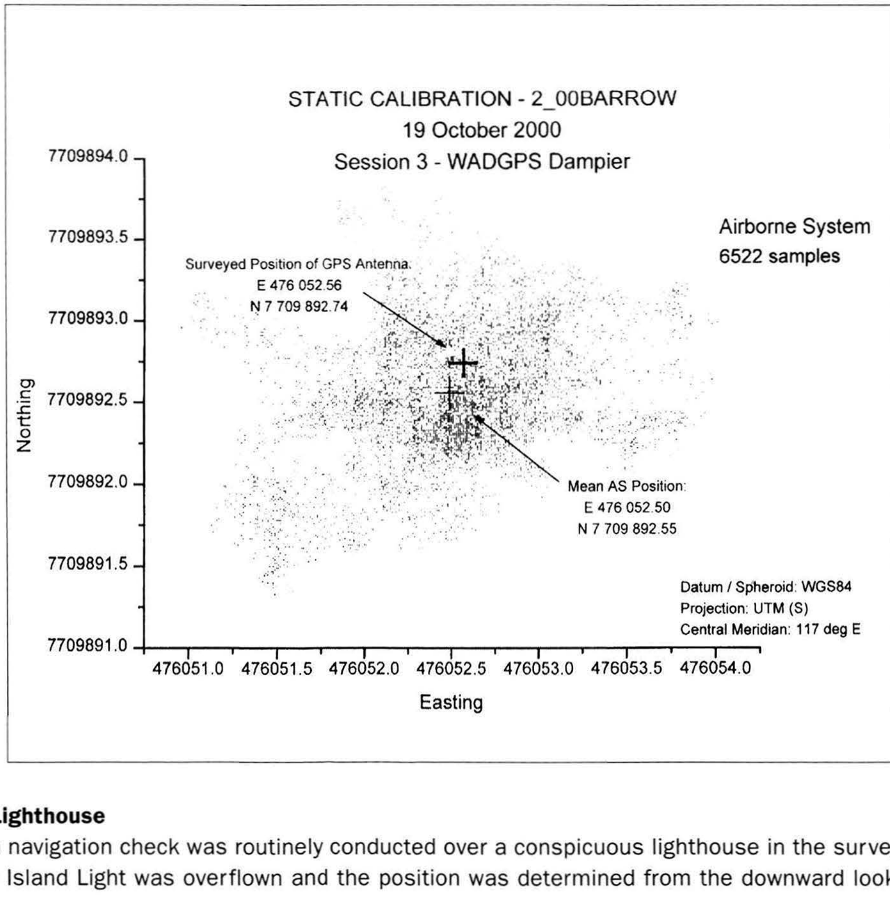

Figure 5: Scatter plot of WADGPS (Dampier)

Position Check - Lighthouse

On survey flights a navigation check was routinely conducted over a conspicuous lighthouse in the survey area. North Sandy Island Light was overflown and the position was determined from the downward looking video record.

Initial corrections (both port/starboard and forward/aft) for the platform position in relation to the coordinated mark were manually extracted from the downward looking video tape by the hydrographic surveyor after each sortie. These initial corrections were entered into the Ground System which were combined with the platform pitch and roll, aircraft position, aircraft heading and time over the mark to compute the actual offsets in eastings and northings in metres. These results are shown in Table 2.

			Δ East (m)		Δ North (m)	
Nav Check Name	No. of Sorties flown	No. of Passes	Mean	Standard Deviation	Mean	Standard Deviation
North Sandy Island Light	22	22	-0.2	3.6	2.2	3.5

Table 2: Position check over lighthouse results

The precision of this check is limited by the difficulty in accurately determining the centre of the target and the video pixel size, however it provides a gross error check on position. The results are consistent with correct system operation.

Position Confidence Check - Shoal

During the LADS Mk II survey in 1998 in the adjacent area, a shoal with a well defined 4.6 metre pinnacle was detected. During the course of this survey, this feature was resurveyed on each sortie to provide a confidence check. For the 26 survey lines flown the 95 per cent CEP of the position of the feature had a radius of 2.8 metres.

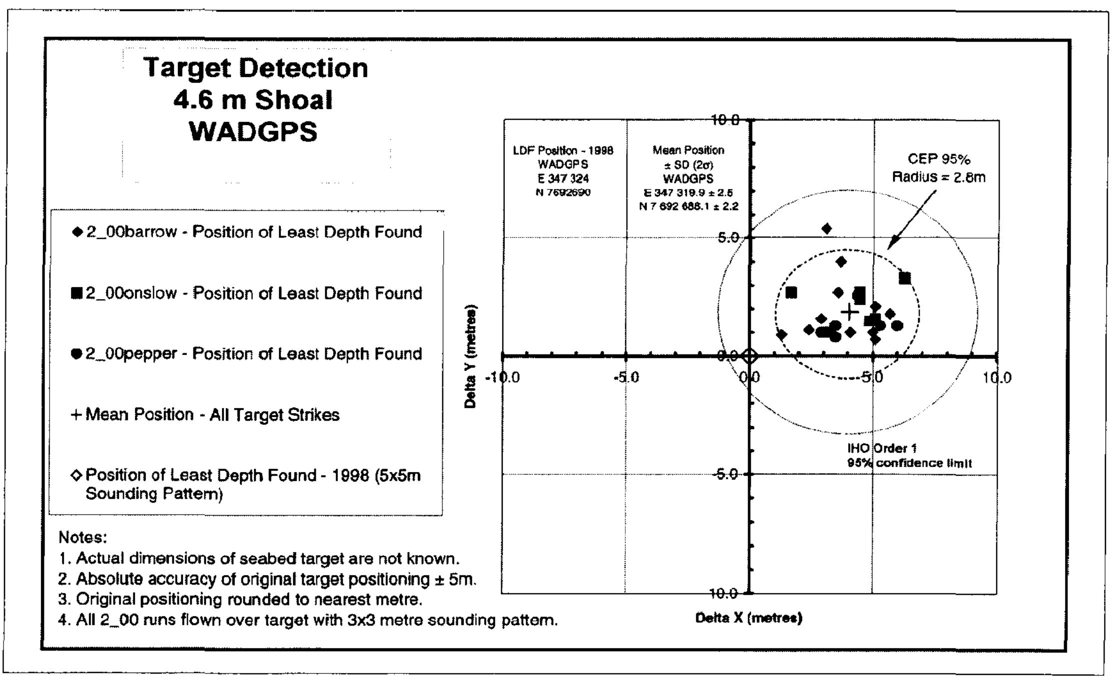

Figure 6: Detection of a well defined shoal in the survey area

Position Check - Dynamic Comparison

Following each sortie the real-time WADGPS aircraft position (Dampier base station) was checked against the post-processed code + carrier phase DGPS (Karratha base station) at intervals of one second. The mean and standard deviation of the vector differences between the two position systems are shown in Figure 7.

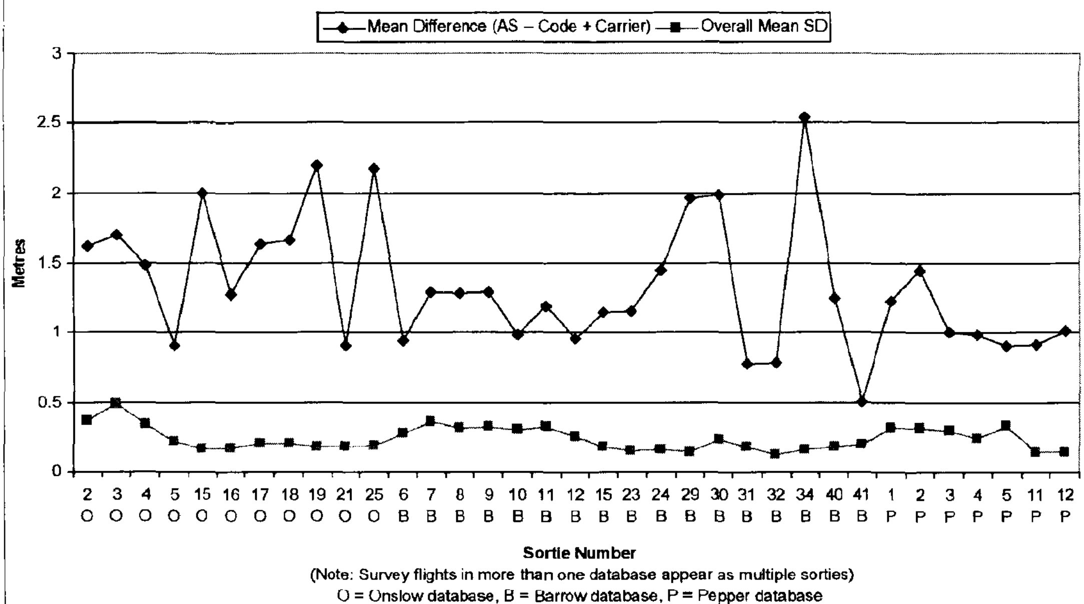

Figure 7: Display of raw laser waveforms on LADS Mk II ground system. 3 x 3 metre laser spot spacing. 2 metre cube target visible on central sounding (11.3 metres)

These results show an average difference of 1.33 metres and 0.241 metres standard deviation.

Measurement of Depths

Main Line Sounding

The main line sounding mode of operation was used in the survey area. This provides 5x5 metre laser spot spacing across a 240 metre swath at a speed of 175 knots; main lines of sounding were flown at 200 metre spacing which provided a 40 metre overlap with each adjacent line. The main lines of sounding were also created with a width of 200 metres; this attribute is used to calculate a Coverage Confidence for each line. The Coverage Confidence is used to detect gaps in the data between the lines of survey and is calculated using the distance off track, width of the swath and navigation position error. A few gaps were detected at the start of lines and these were subsequently reflown. Main lines of sounding were orientated parallel to the coastline.

Examinations of Seabed Features

Following main line sounding, shallow areas and isolated shoals were examined at 3x3 metre high-density laser sounding. This mode of sounding provides a 100 metre swath at an aircraft speed of 150 knots; lines were flown at 80 metre spacing which provides a 20 metre overlap with the adjacent line. Examination lines were generally short (up to 5.7 nautical miles) and as many as 40 such lines were flown on a single sortie. The orientation of the examinations were along the main axis of each shoal.

Depth Checks

Depth Comparisons

During the 1998 LADS Mk II survey in the adjacent area, a number of sites were surveyed to check ongoing relative system performance. A total of five areas were identified and surveyed in flat areas of approximately 300 metres by 300 metres; depths ranged from 13 to 20 metres. A survey line was flown over these areas on each sortie of this survey with depths compared to the data obtained in the 1998 survey. This approach was taken since it was not practical to undertake a ship acoustic survey to generate well-defined and independent benchmark areas. The results are shown in Table 3 where MDD represents the mean depth difference of the new survey data compared to the 1998 data.

Ground System Site ID	Site Name	Nominal Depth (metres)	MDD (metres)	SD (metres)
1	Barrow 2	20	0.41	0.17
2	**Barrow 3**	18	0.14	0.16
3	Barrow 4	16	0.07	0.14
4	Barrow 5	13	0.20	0.14
5	Barrow 6	14	0.43	0.14

Table 3: Benchmark comparisons

As a consequence of the relative nature of these data, it is not possible to formulate valid depth accuracy predictions for this particular survey. It is noted that there is a larger MDD on sites Barrow 2 and Barrow 6 which were at either end of the survey line. This difference is thought to be due to the improved tidal model which was implemented for the 2000 survey.

Depth Checks - Cross-tie Comparisons

Eight cross-tie lines were sounded across the three databases. These lines have been compared against the main lines of sounding. The results of the cross-tie comparisons are shown in Table 4.

Run Number	Number of Depth Comparisons	Number of Intersecting Runs	MDD (metres)	Mean SD (metres)
52.0.1 (P)	130 426	64	-0.04	0.16
52.0.1 (B)	151 200	69	-0.17	0.18
53.0.1 (P)	141 766	64	0.02	0.20
53.0.2 (B)	227 560	103	-0.02	0.22
54.0.1 (P)	88 866	42	0.13	0.20
54.0.2 (B)	220 674	96	0.09	0.24
55.0.1 (O)	135 328	67	0.15	0.22
56.0.1 (O)	144 303	79	0.15	0.18
	1 240 123	584		

Table 4: Cross-tie comparisons

These results are generated from the intersection of 584 main lines of sounding with the cross-tie runs and the comparison of over 1.24 million individual depths. They show very good consistency over the entire survey area. Again no absolute accuracy assessment can be derived from cross-tie analysis, however, the comparisons do indicate excellent repeatability over the entire survey run.

Depth Checks - Target Detection

The detection of small targets on the seabed requires high-density and high-quality data and a processing system capable of identifying these features. At the sea surface, the footprint of the laser beam is approximately 2.5 metres and the laser beam diverges as it passes through the water column. In very shallow water, 2x2 metre or 3x3 metre laser spot spacing is required to provide the highest probability of small feature detection. In addition, in order to detect small features, seabed returns with high signal-to-noise ratios are required which occurs in clear water. The LADS Mk II Ground System has a special Bottom Object Detection (BOD) algorithm which detects raw laser waveforms from small objects close to the seabed; an example of this is presented in Figure 8.

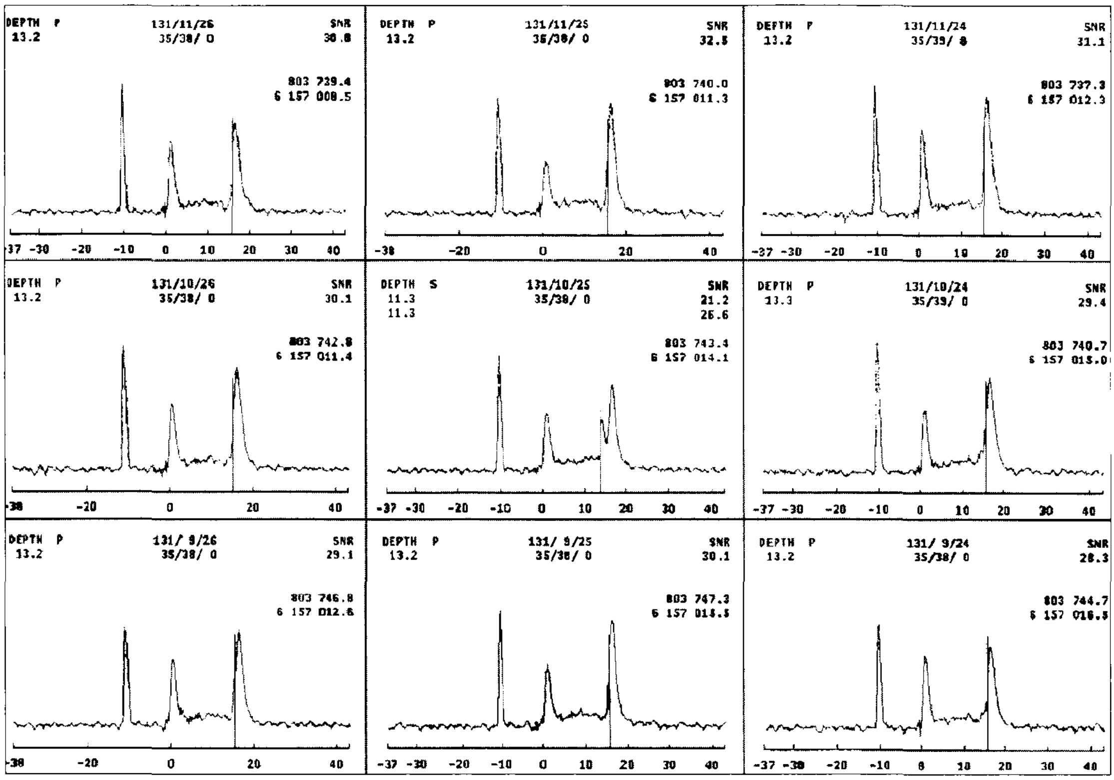

Figure 8: Display of Raw Laser Waveforms on LADS Mk II Ground System. 3x3 metre laser spot spacing. 2 metre cube target visible on central sounding (11.3 metres)

Target Detection Tests

In order to gather data on the target detection capability of the LADS Mk II system a series of tests are being conducted. A number of 2 metre cubes have been laid in depths ranging from 10 to 20 metres in the Gulf of St. Vincent, South Australia. In addition, a number of other targets including 2x2 x 1, 1.4 x 1.4 and 1 x 1 metre have been deployed.

These trials have shown target detection to be affected by the following:

a. Water clarity
b. Sounding density
c. Target size
d. Depth of water
e. Reflectivity

A controlled trial was conducted in 1999 when 18 passes were flown over these targets. Six passes were flown at 3x3 metre laser spot spacing, and the targets were detected on each occasion. 12 passes were flown at 5x5 metre laser spot spacing and the targets were detected on eight occasions. During this trial the surveyed height of the targets above the seabed was measured but not recorded in the trials results. These tests are ongoing, however, they do show that high density laser spot spacing is required to achieve a high probability of detecting a 2 metre cube target in 10 to 20 metres of water.

Target Detection – Measures Taken

To provide a high probability of IHO Order-1 target detection the following steps were taken during survey operations on the Northwest Shelf:

a. Turbid water was avoided. Survey operations were conducted concurrently in three separate databases. Potentially turbid areas were sounded during neap tides and highly turbid areas were reflown later in the survey under improved conditions

b. Examinations at 3x3 metre laser spot spacing were conducted over shoal areas, sandwave areas and over individual isolated and detached shoals

c. The data was processed on the Ground System using the BOD algorithm which identifies returns from small objects on the seabed. Raw laser waveforms are available for review on the LADS Mk II Ground System

For this survey on the Northwest Shelf a 2 metre target was obviously not available to check target detection performance in the field. A daily confidence check was conducted on the pinnacle that was used for the position checks. This feature was surveyed at 3x3 metre laser spot spacing on each sortie. The mean depth measured over the 26 sorties was 4.5 ± 0.3 metres (95% confidence).

IHO Order-1 - Horizontal Accuracy

The IHO Order-1 required position accuracy is 5 metres + 5% of depth. All parameters are to be accounted for and a statistical method is to be used to combine the errors at the 95% confidence level.
For the LADS Mk II survey, the total expected error in position is considered to be a combination of the following errors:

a. GPS errors (Egps) The manufacturer has stated the expected error to be 1.01 metres + 1.4 ppm. In addition, ionospheric delays typically cause a bias of 0.20 to 0.25 metres per 100 kilometres. Over a baseline distance of 250 kilometres, the upper bound of accuracy is assessed as:
Egps = 1.01 + 1.4ppm + 2.5ppm
= ±1.99 metres (95 per cent confidence)

b. Errors in assigning the aircraft reference positions from GPS fixes. This value has been determined from the least squares calculation of the aircraft position from the GPS fixes. The standard deviation of the frame reference position (Eframe Ref) was ± 0.66 metres (95 per cent confidence)

c. Platform and laser positioning errors (Eplat, this includes such errors as gimbal angles, optical alignment, AHRS angles, AHRS mount, Optical Coupler mount, Scanner mount, Laser output, Laser mount, Major, Minor and Delta scan mirrors, timing and aircraft height). The resultant error in position has been modelled and determined to be ± 2.14 metres (95 per cent confidence)

d. Position errors of detecting objects due to the size of the laser spots (Espot). There is an uncertainty of the position of an object detected by the system due to the size of the laser spot. The diameter of the laser spot is 2.5 metres on the surface of the sea and it diverges as it passes through the water column. The effective width of the spot is also limited by the receiver field of view. In a depth of 15 to 20 metres, the effective laser spot size is considered to be approximately 5 metres in diameter. Therefore the uncertainty of position within that beam (Espot) is assessed as ± 2.5 metres (95 per cent confidence)

e. Sea surface errors (Esurface) due to waves. These are variable and dependant on the angle of incidence of the laser beam at the air/sea boundary, the depth of water and sea state. They have been modelled and are displayed in Table 5

Depth	Sea State 1	Sea State 2	Sea State 3	Sea State 4
5 metres	0.00 m	0.03 m	0.31 m	0.55 m
10 metres	0.01 m	0.06 m	0.62 m	1.10 m
15 metres	0.01 m	0.09 m	0.93 m	1.65 m
20 metres	0.02 m	0.12 m	1.24 m	2.20 m

Table 5: Sea surface errors (Esurface)

Total Expected Error = $((Egps)^2 + (Eframe\ Ref)^2 + (Eplat)^2 + (Espot)^2 + (Esurface)^2)^{1/2}$

Taking the worst case scenario, at the most westerly point of the survey area from the Dampier Racal reference station in a depth of 20 metres with a sea state of 4, the total error is expected to be:

= 4.5 metres at the 95 per cent confidence level.

During the majority of sorties undertaken in the survey area the observed sea state was assessed as being between 2 and 4.

IHO Order-1 – Depth Accuracy

Unfortunately it is not possible to calculate LADS depth accuracy in this case study due to the absence of an independent benchmark data set which would have provided an estimate of MDD. The depth comparisons and cross-tie comparisons show very good repeatibility however.

IHO Order-1 - Bottom Search and System Detection Capability

The IHO Order-1 100 per cent bottom search requirement states that a full bottom search is required in selected areas where the bottom characteristics and risk of obstructions are potentially dangerous to vessels. For these areas searched it must be ensured that cubic features greater than 2 metres can be discerned by the sounding equipment. For the LADS Mk II survey shallow banks, sandwave areas and all isolated and detached shoals were examined at 3x3 metre laser spot spacing in order to detect such features. This approach is consistent with the tests being conducted in Adelaide, South Australia.

Conclusion

The conduct of a LADS Mk II survey requires careful planning and execution if it is to achieve the requirements of IHO Order-1. A DGPS reference station was established close to the survey area to provide redundancy of position. Position checks were conducted on known marks on the tarmac, during flight,

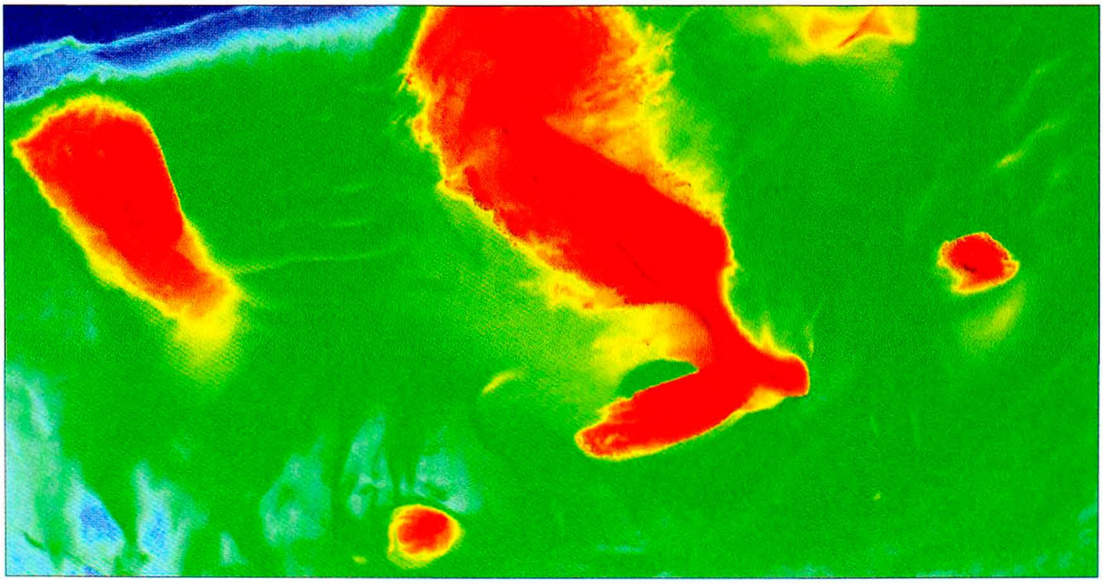

Figure 9: LADS Mk II data around Serrurier Island

over a conspicuous lighthouse and over a submerged pinnacle. In addition, position accuracy was assessed theoretically.

A complex tidal model was used to relate the survey to the low water datum over this very large area. Depth checks were conducted using existing benchmarks and from cross-tie comparisons. These measurements were then used in a theoretical calculation of depth accuracy.
Target detection requirements were addressed by reflying selected areas at 3x3 metre laser spot spacing during periods of low turbidity.
Following this LADS survey a marine seismic survey was successfully conducted throughout this area. At the time of writing (February 2002) LADS Mk II was again in Karratha surveying additional areas on the Northwest Shelf of Australia.

Biography

Commander Mark Sinclair RAN (Rtd.) is Survey Manager at Tenix LADS Corporation, responsible for the design and execution of LADS Mk II survey projects around the world. He has been in charge of LADS Mk II laser surveys in Australia and New Zealand, Scandinavia (Norway and Finland) and the USA (Florida, Washington, Alaska and Midway Island). He has a broad marine background and joined LADS in January 1997 after serving 20 years in the Royal Australian Navy. He joined the RAN in 1977 and completed a Bachelor of Science degree in physical oceanography at the University of New South Wales. He served as an Officer of the Watch on an icebreaker, patrol boat, tanker and destroyer and as Navigating Officer of a minesweeper, destroyer, oceanographic ship and hydrographic ship. In 1988, he commanded the interim survey ship HMAS Brunei and, in 1989, commanded the survey ship HMAS Paluma. Two years later, he completed a Graduate Diploma in land data management at Royal Melbourne Institute of Technology. Over the next five years, he served as Officer-in-Charge of the RAN Hydrographic School, followed by OIC of the RAN LADS system.

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