U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

Data Acquisition and Processing Report

Type of Survey Hydrographic Lidar

Project No. OPR-H328-KRL-08

Time frame July – August 2008

LOCALITY

State Florida

General Locality Approaches to Miami

2008

HYDROGRAPHER	**CHIEF OF PARTY**
MARK SINCLAIR	SCOTT RAMSAY

LIBRARY & ARCHIVES

DATE

NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTRY No.
HYDROGRAPHIC TITLE SHEET	**H11868 – H11871, H12008**

State Florida

General Locality Approaches to Miami

Scale 1:10,000 **Date of Survey** July 13 to August 26, 2008

Instructions dated March 25, 2008 **Project No.** OPR-H328-KRL-08

Vessel Tenix LADS Aircraft, call sign VH-LCL

Hydrographer M.J. Sinclair **Chief of Party** S.R. Ramsay

Surveyed by J.G. Guilford, W.T. Newsham, K.J. Oberhofer, B.A. Weidman, J.K. Young, D.J. Stubbing, C.N. Waite, V.X. Sicari, R.B. Touchstone.

Soundings by Laser Airborne Depth Sounder

Graphic record scaled by B.A. Weidman

Graphic record checked by S.R. Ramsay, J.G. Guilford **Automated Plot** N/A

Verification by

Soundings in Meters at MLLW

REMARKS

Requisition / Purchase Req. # NCNJ3000-8-37170

Contractor Tenix LADS, Incorporated, 925 Tommy Munro Dr., Suite J, Biloxi, MS 39532

Sub-Contractor John Oswald and Associates, 12001 Audubon Dr., Anchorage, AK 99516

Times All times are recorded in UTC.

Datum and Projection NAD83, UTM (N) Zone 17

Purpose The purpose of this survey is to provide NOAA with modern, accurate hydrographic survey data with which to update the nautical charts of the assigned area.

Acronyms A complete list of all acronyms used throughout this report is provided at Appendix I of the Separates Report.

TABLE OF CONTENTS

A. EQUIPMENT

The LADS MkII hydrographic survey system comprises two main subsystems. The Airborne System (AS) is used to acquire raw bathymetric data, real-time Global Positioning System (GPS) data, downward-looking video and digital imagery. The Ground System (GS) is used to plan operations, calculate depth values from the raw data, apply post-processed kinematic GPS (KGPS) positioning, apply tidal corrections, provide tools to allow the collected data to be evaluated and export digital data for the compilation of final survey deliverables. These two subsystems are complemented by other tools required for quality control activities; in particular, contouring, 3-D visualization and georeferenced imagery review. Third party software is also used for product compilation, image creation and survey management, namely CARIS and Terramodel. The general data flow between the subsystems and tools is illustrated in Figure 1.

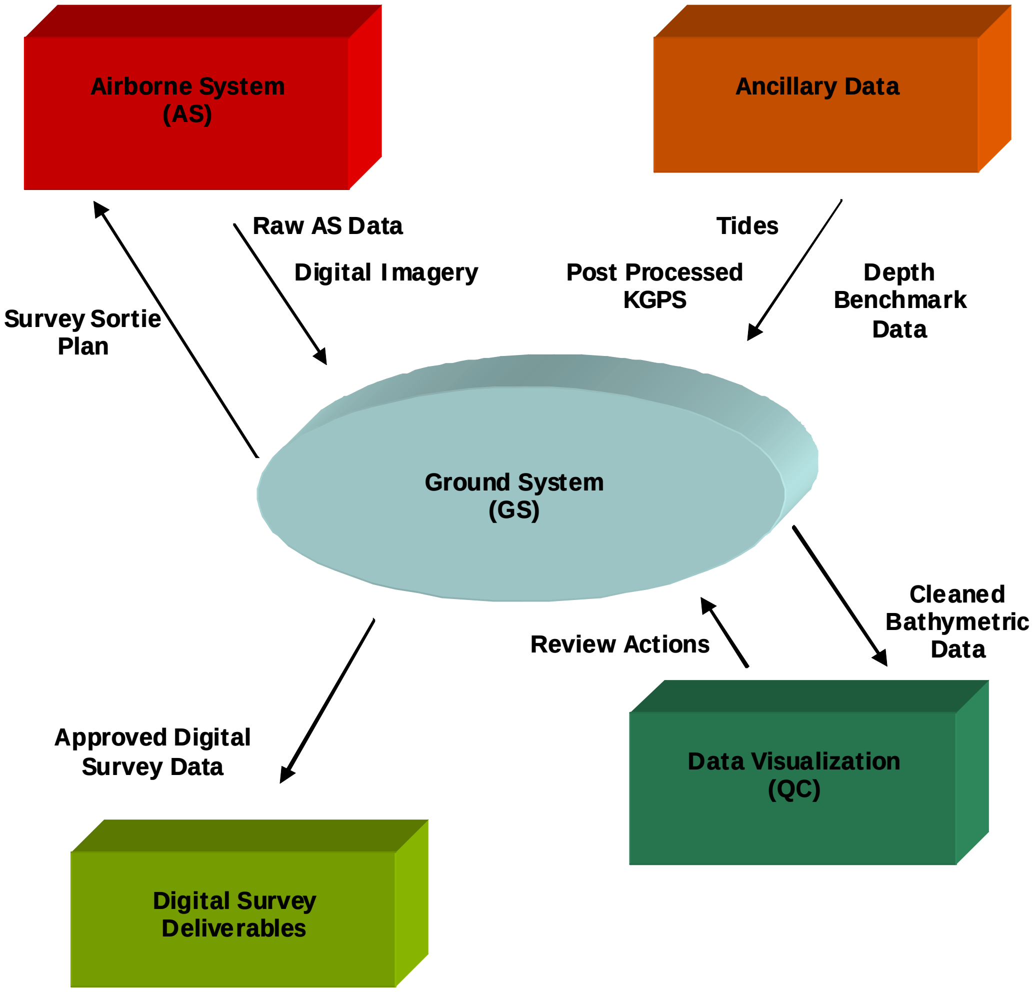


Figure 1 – General data flow within LADS MkII

A.1 AIRBORNE SYSTEM

A laser, scanner, optical system, photo-multiplier tube and conditioning electronics collect the raw sounding signal. These items are mounted on a stabilized platform that is controlled via servo systems, using information from an Attitude and Heading Reference System (AHRS) mounted on the platform. Aircraft position information is obtained using GPS. Figure 2 illustrates the major components of the AS.

Three computers, linked via an FDDI optic fiber network, control and monitor the AS operations. These computers are:

a. The System Control Computer (SCC) for operator interface, logging and overall system coordination.

b. The Navigation System and Support (NSS) computer for position monitoring and control.

c. The Laser Control and Acquisition (LCA) computer for control of the scanner and laser and digitization of raw sounding data. The LCA also synchronizes overall AS timing.

AS system time is synchronized with GPS time, and all data acquired for logging is appropriately time-stamped at the point of acquisition, then passed to the SCC to be written to Digital Linear Tape (DLT).

Ancillary equipment includes:

- A video camera and VCR to display and record the view below the aircraft and a forward-looking video camera for real-time operator awareness.
- A Redlake MegaPlus II ES 2020 digital camera used to capture georeferenced imagery below the aircraft.
- Systems for temperature control of equipment.
- VHF transceiver and aircraft intercom.
- Satellite phone.

The operator interface allows the operator to monitor the quality of sounding, position and other data in order to set appropriate system parameters and control the sequence of sortie operations.

Detailed descriptions of the main AS components and their functions are given under the headings below. Each of these components was checked by the LADS Technical Department on trials flights conducted during March 2007, in order to achieve the requirements of the LADS MkII Performance Verification Certificate (provided at Appendix III).

- Sounding Equipment
- Positioning Equipment
- Sortie Control
- Ancillary Equipment
- Operator Interface

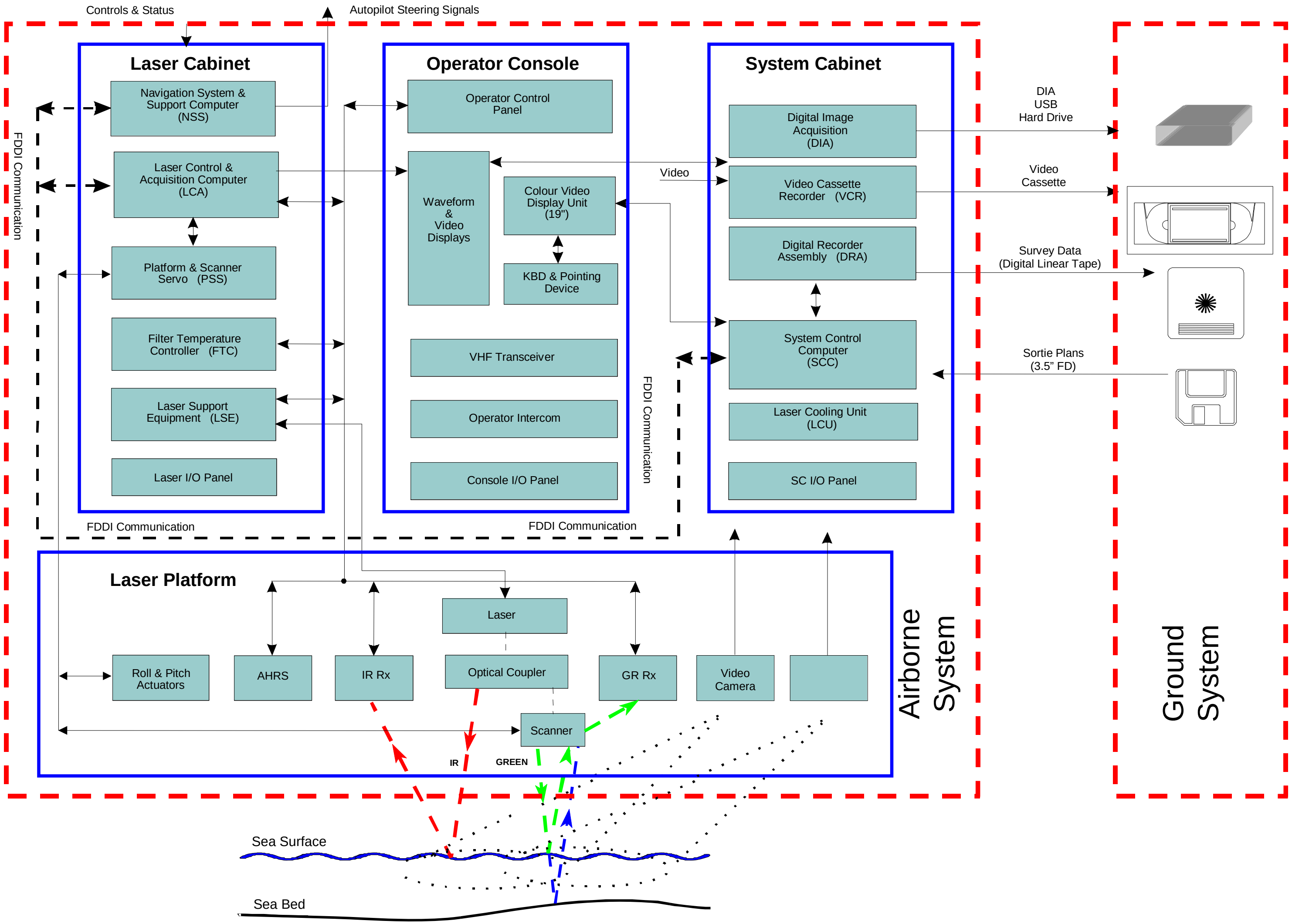


Figure 2 – AS Functional Block Diagram

A.1.1 Sounding Equipment

Soundings in the LADS MkII system are obtained by the transmission of laser pulses via a scanning system aboard the aircraft and by detecting return signals from land, the sea surface, the water body and the seabed. The transmitting and receiving components are housed on a stabilized platform that compensates for aircraft pitch and roll. The return signals are electronically amplified and conditioned prior to being digitized and logged.

The primary sounding components of the AS are:

- Laser. An Nd: YAG laser producing IR energy at a wavelength of 1064nm at 990 pulses per second, of which 900 pulses are used for sounding purposes.
- Optical Coupler. The optical coupler is used to split the IR beam. Part of the IR beam is transmitted vertically to nadir on the sea surface. The other part of the split beam is frequency-doubled to produce green laser pulses of wavelength 532nm. The green pulses are transmitted onto the mirror of the scanner.
- Scanning System. The scanning mirror is oscillated in both the major (across track) and minor (along track) axes. The required scan pattern is generated by controlling software. All possible patterns are listed in the Sounding Patterns section.
- Optical Receivers. The IR and green return signals are detected by two separate receivers. The IR return from the surface of the sea is used to establish a height datum. The IR receiver is a solid-state detector producing an electronic signal from the IR return. The green return comprises energy returned from the surface, water column and seabed, and is used to determine water depth (refer to Figure 3 and Figure 4). The green return is transmitted via the scanner into a photomultiplier tube. The electronic outputs of the two return signals are electronically mixed prior to digitization.
- AHRS. The AHRS is a laser gyro inertial navigation system providing platform attitude information to the platform servo system, that in turn maintains platform stabilization. The AHRS also reports platform attitude to the LCA computer and provides height data.
- LCA computer. This controls the laser and scanner operations and digitizes (8 bits at 500MHz) appropriate sections of the composite electronic red / green return signal along with platform attitude data and other system parameters. This digital information is passed to the SCC where it is logged to DLT.
- Waveform Display. This Cathode Ray Tube (CRT) display presents the operator with real-time sounding waveforms and is used by the operator to check data quality during acquisition.

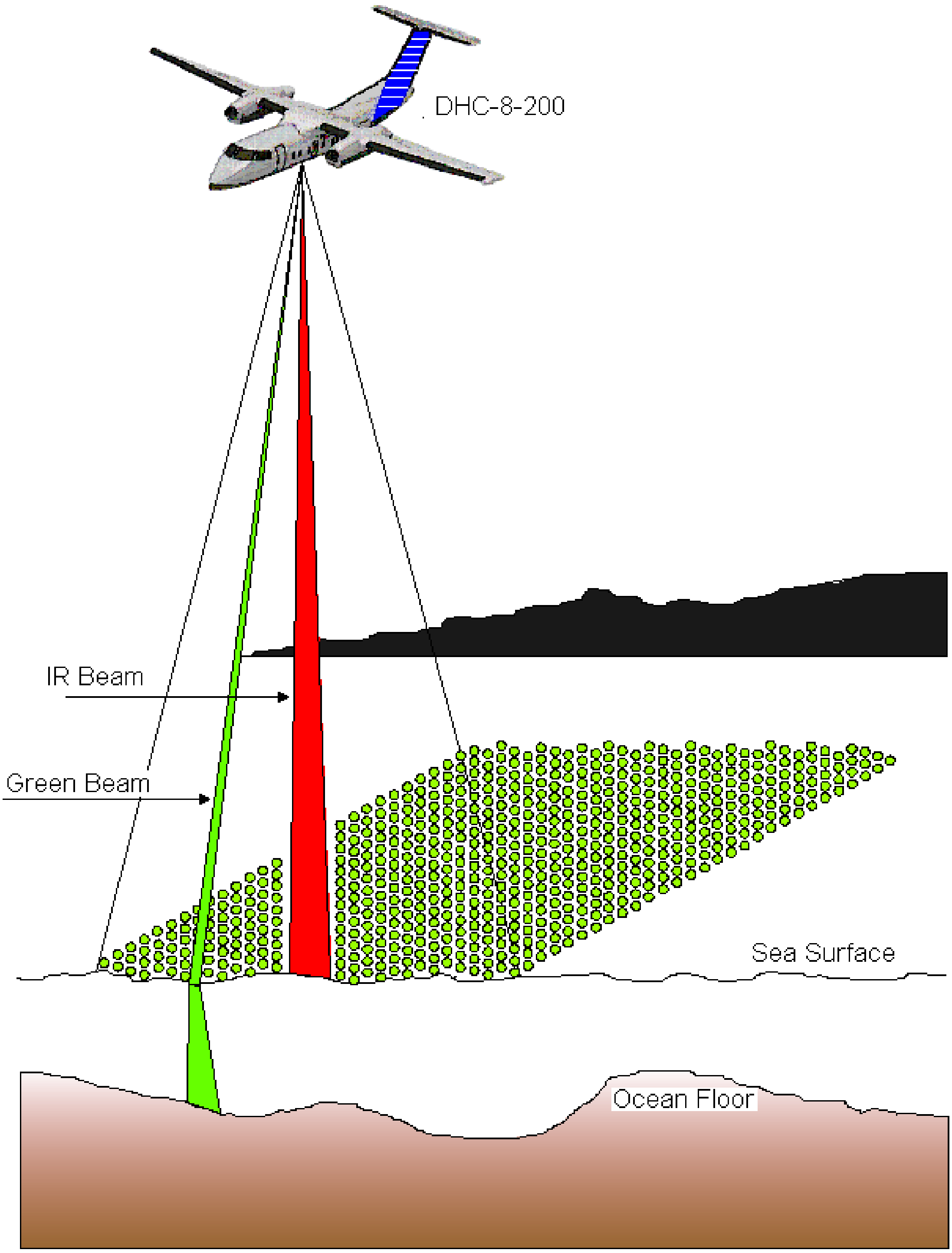


Figure 3 – The Laser Scan

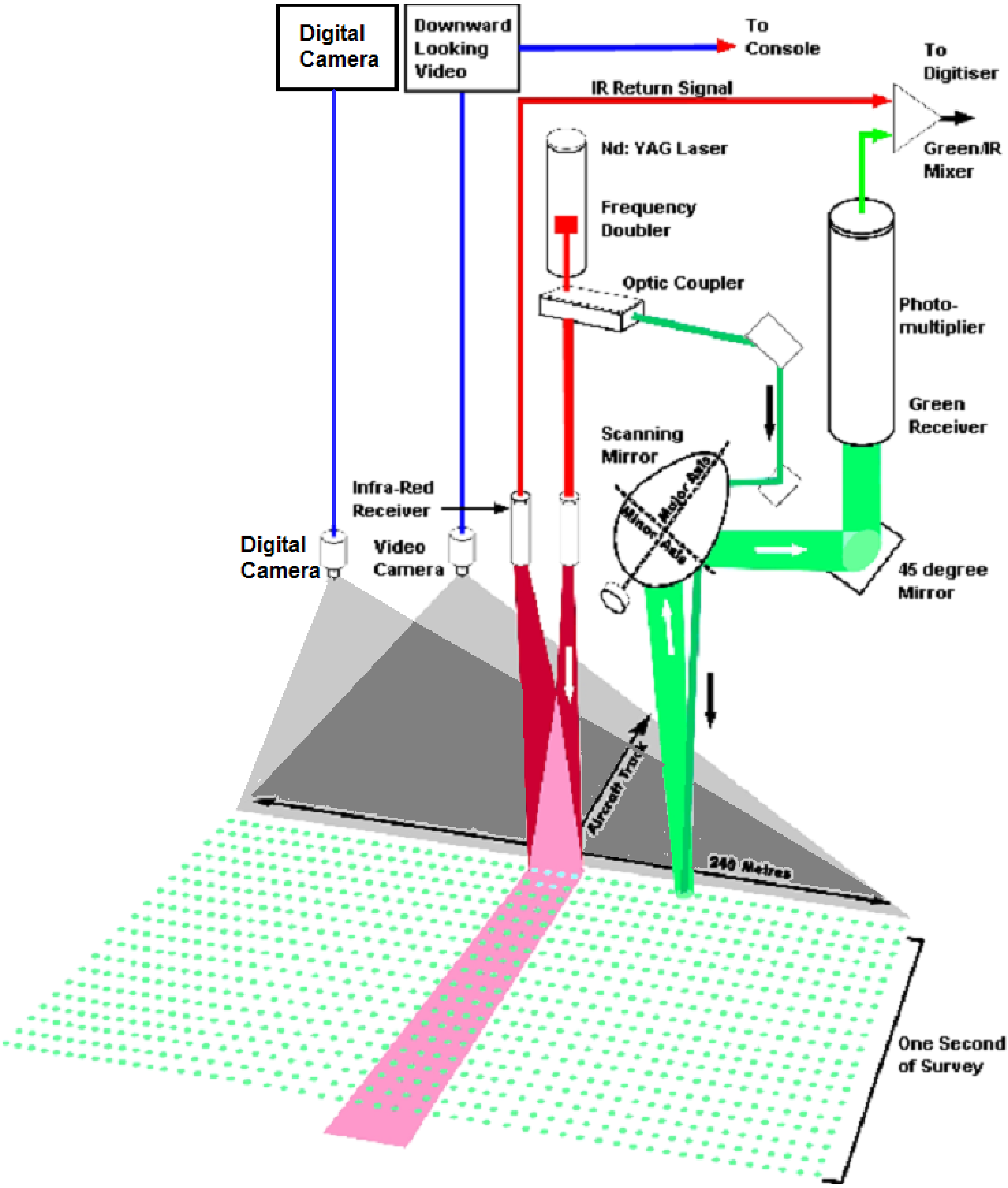


Figure 4 – The AS Scanner, Laser and Receivers

A.1.2 Positioning Equipment

The center of the scanning mirror is the survey reference point on the aircraft. The GPS antenna is positioned relative to this point, as described in Section C.

The signal from the GPS antenna is split and fed to two independent GPS receivers. One is used for real-time aircraft position fixing and track keeping, and the second is used to record GPS data for calculating post-processed KGPS positions. An Ashtech GG24 single-frequency GPS receiver is used to provide real-time positioning of the aircraft. An Ashtech Z12 dual-frequency GPS receiver is used to independently log and compute post-processed positions.

The output of the real-time GPS receiver is fed to the NSS to:

- Fix aircraft position and determine ground speed.
- Calculate aircraft cross-track error and automatically maintain track along survey lines.
- Provide pilot display information.
- Establish and maintain system UTC time.

The NSS passes the received GPS and derived information to the SCC for logging.

A.1.3 Sortie Control

A sortie plan is generated on a floppy disk on the GS to transfer survey information to the AS. The sortie plan contains spheroidal, grid and magnetic variation parameters and a list of survey objectives including the line number, start and end coordinates, and coordinates for navigation position checks. During the course of the sortie, the airborne operator amends the sequence of survey objectives and aircraft altitude to suit environmental conditions and amends the scan pattern parameters for the survey lines to suit survey specifications.

The SCC controls the sequence of survey operations by:

- Planning all required flight paths and communicating these to the NSS.
- Transmitting required parameters for scan patterns, aircraft altitude, etc. to the LCA.
- Initiating the starting and stopping of system operations, via commands sent to the LCA and NSS at specific waypoints on the run-in and run-out of survey lines.

The operator may abort and restart the sortie operations and re-order the sequence of objectives at any time. Scan patterns can be amended on all lines except the executing objective. A display of the planned survey line and received GPS data is situated in the cockpit and used to advise the pilots of required aircraft configurations. The display provides an indication of cross-track error with required and actual values for altitude and ground speed.

Aircraft positioning during survey acquisition is under automatic control of the NSS, via the aircraft autopilot. Aircraft turns are under pilot control assisted by the display. Aircraft altitude and speed are under pilot control, and communication between the operator and pilots is via the aircraft intercom system.

The management of survey objectives execution can be impacted by both low cloud coverage and high ground in the survey area. LADS MkII is able to operate at different survey heights, irrespective of scan pattern, so that adequate aircraft clearances can be maintained above high terrain or below low cloud ceilings as required. Survey altitudes at 200ft increments are available from 1,200 to 2,200ft (366 to 671m). Altitudes must be constant for the duration of a survey line but may be varied from line to line by the AS operator during the course of a sortie.

During daytime operations a narrow-band green filter is used to filter out other light frequencies from the photomultiplier tube. This filter has a slight attenuating effect on the laser returns, which reduces the maximum depth performance. This filter can be removed once the ambient sunlight levels drop, which results in improved performance at night.

Glassy sea conditions may result in very strong IR surface returns that can saturate the IR receiver, causing a loss of surface datum. The AS monitors the IR surface return performance and advises the operator if IR saturation occurs. The operator can activate an IR attenuator that provides correct IR surface return amplitudes to be fed to the IR receiver. Should sea surface conditions change, which may result in lower IR return amplitudes, the AS informs the operator to deactivate the IR attenuator.

The laser is designed to be eye safe in accordance with the following standards:

a. ANSI Z136.1-2000, American National Standard for Safe Use of Lasers

b. IEC 60825-1 (Edition 1.2) International Standard – Safety of Laser Products

c. AS/NZS 2211.1 Supplement 1:1999 Australian / New Zealand Standard Laser Safety

The laser power can be reduced by a further factor of four using a built-in green attenuator. The operator may activate / deactivate the green attenuator at any time.

A.1.4 Ancillary Equipment

A video camera is positioned on the stabilized platform and directed downward at nadir. A calibrated graticule is superimposed on the camera image to provide the operator with a scan width and distance reference. The image, graticule and other relevant system information, including position and time, are presented to the operator and recorded throughout a sortie.

A forward-looking video camera is also provided to assist the AS operator for the purpose of evaluating conditions ahead of the aircraft.

A Digital Imagery system provides georeferenced imagery. This system comprises a Redlake MegaPlus II ES 2020 digital camera, a Matrox 4Sight M frame grabber and a Matrox embedded computer running Windows EP embedded operating systems. Images are taken at one-second intervals with a 1600x1200 resolution and a 2-megapixel interline-transfer camera head and controller. At the end of each sortie, the images are copied to the LADS GS with the use of a removable hard drive.

A.1.5 Operator Interface

The operator monitors and controls system operation from the console. The following key information is provided to monitor system performance:

- Sortie Information. The Sortie ID, spheroid and grid in use and available survey objectives are displayed. Sortie objective information includes the scan pattern set for the objective and estimated time to complete the objective.
- Objective Information. The Objective ID, selected scan pattern, required speed and altitude pertaining to the current objective being executed and objective status, such as time to completion, are presented.
- Waveform Display. This display is a CRT on which displayed is each of the mixed red / green sounding return signals as digitized by the LCA (the traces are overlaid). The operator continually assesses this display to determine data quality.
- Depth Profile. A depth profile determined from nadir soundings is available to the operator with an associated confidence factor. As the algorithm is limited by real-time considerations, these depths and confidences are only indicative.
- Aircraft Position, Speed, Altitude and Cross-Track Error. A number of displays including a copy of the pilot display are available to the operator to determine the aircraft position and performance parameters. Speed and altitude are continually monitored and the pilot is informed of deviations from the desired values.
- GPS Status. The operator is provided with the data from the GPS receiver including number of satellites, satellite altitudes and azimuths, signal to noise ratio (SNR) and which satellites are being used.
- Equipment Status. System status and performance parameters are available to the operator including laser power and temperature, dynamic gain values, AHRS status and scanner performance.

Items controlled by the operator for sortie execution and data acquisition are:

- Sequence of objective execution
- Scan pattern for each objective
- Operating height for each objective
- Depth logging range and topographic height range for each objective
- Dynamic gain limits
- IR and green receiver attenuator positions
- Seabed reflectivity and seabed gradient controls

A.1.6 Depth and Topographic Mode

During normal bathymetric survey mode (Depth Mode), LADS MkII determines the depth of water with the height datum being determined from the reflected IR laser signal, GPS height and AHRS height. When over land this IR signal is not valid and the height datum is obtained from the GPS and AHRS.

This ancillary height datum allows LADS MkII to measure topographic heights. The topographic height range is dependent on the depth range in use. In addition, the topographic range may be reduced due to returns from thick foliage such as trees and mangroves, which may prevent laser returns from being received from ground level.

A.1.7 LADS MkII Aircraft and System Specifications

Aircraft Type	De Havilland Dash 8-200, twin turbo prop, high wing
Aircraft Modifications	Long range tanks, pressurized laser bay window and autopilot interface
Transit Cruise Speed	250kts (maximum 275kts)
Transit Altitude	To 25,000ft
Survey Speed	Dependent on Scan Pattern: Nominal 140-210kts (72-108m per second)
Survey Height	1,200 to 2,200ft (366 to 671m) in 200ft increments
Survey Track-Keeping	+/- 5m (manual or via autopilot coupling)
Survey Endurance	8 hours nominal
Operational Capability	Day / Night Operation
Depth Sounding Rate	900 soundings per second
Swath Width	Dependent on Scan Pattern: 50-288m (independent of aircraft height and water depth)
Scan Pattern	Rectilinear
Sounding Density	Variable: 6x6m, 5x5m, 4x4m, 3x3m, 2.5x2.5m and 2x2m
Soundings per sq km	Dependent on scan pattern. For 4x4m – 75 000/km^2 (assuming 32m overlap)
Soundings per hour	Up to 3 million
Topographic and Depth Range	-50m (topo) to 70m (depth)
Area Coverage	Dependent on scan pattern. For 4x4m – up to 41.5km^2/hr (12.1 sq nm/hr) assuming 32m overlap
Position Fixing	Autonomous GPS and post-processed L1 + L2 dual-frequency KGPS
Recording Media	DLT, VHS Video Tape, USB Hard Drive
Digital Camera	Image Area at 1500ft operating altitude: ~330m x 250m. Image Resolution: >4 pixels/m at an altitude of 1600ft. Digital Image Capture Rate: 1 per second. Digital Image Horizontal Accuracy: +/-5m (95% confidence).

A.1.8 Logging Parameters

A.1.8.1 Position Fixing

The AS obtains a position fix every 0.5 seconds.

A.1.8.2 Navigation Update

While executing a survey line under AS control navigation, correction is passed to the aircraft autopilot every 0.5 seconds.

A.1.8.3 Post-Processed GPS

The GPS airborne and base logging stations log position information from GPS satellites at 0.5-second intervals.

A.1.8.4 Sounding Rates

LADS MkII obtains depth soundings in a rectilinear pattern where the sounding density is variable (see Table 1) but sounding rate is invariant.

For all sounding patterns, the soundings are grouped into one-second frames made up of 18 scan lines. Each of the 18 scan lines contains 50 laser pulses, of which 48 pulses are used for depth sounding. The outermost laser pulses are not used for depth sounding. This provides an effective sounding rate of 864 soundings per second.

A.1.9 Sounding Patterns

LADS MkII has variable scan pattern functionality as detailed in the following table. The 4x4 and 4ax4a patterns both provide 4x4m spot density but have different swath width and survey speeds. All patterns are available at each of the operational altitudes (1,200 – 2,200ft in 200ft increments).

Sounding Density (m)	Swath Width (m)	Line Spacing 200% Coverage (m)	Line Spacing 100% Coverage (m)	Survey Speed m/sec (kts)
6x6	288	125	250	108 (210)
5x5	240	100	200	90 (175)
4x4	192	85	170	72 (140)
4ax4a	150	60	120	90 (175)
3x3	100	40	80	77 (150)
2.5x2.5	75	30	60 / 70	72 (140)
2x2	50	20	40	72 (140)

Table 1 – Scan Configuration

A.2 GROUND SYSTEM – OVERVIEW

Conversion of raw sounding data from the AS to final depth data is accomplished on a GS (refer to Figure 5). There are four GS's available for operations, as follows:

a. GS Bilbo, comprising a single CPU Compaq (DEC) Alpha Series 4100 Server with 256MB ram, up to 750GB disk space, DLT and Digital Audio Tape (DAT) drives.

b. GS Frodo, consisting of a Compaq Alpha ES40 3-processor Server with 1 GB EEC RAM, 764 GB disk space, DLT drives and magazines, DAT drive, CD-ROM drive and is networked to up to 12 Compaq 1.5 GHz PCs.

c. GS Gandalf, consisting of a Compaq Alpha ES40 3-processor Server with 1 GB EEC RAM, 764 GB disk space, Super DLT (SDLT), DLT, and DAT drives, a CD-ROM drive and is networked to a series of 8 HP Small Form Factor PCs with Windows and Linux (dual boot) that serve as processing terminals for GAP, Fledermaus, CARIS, etc. Gandalf is also networked to an HP 750c DesignJet plotter, printers and QC workstations.

d. GS Katrina, consisting of a Compaq Alpha ES40 3-processor Server with 1 GB EEC RAM, 764 GB disk space, SDLT and DLT drives and magazines, DAT drive, CD-ROM drive and is networked to an HP 800ps DesignJet plotter, printers, and QC workstations.

The GS hydrographic software is a Tenix LADS, Inc. proprietary package written in ADA to operate in a UNIX True-64 (DEC) environment.

The GS provides the facilities for all LADS survey management tasks from initial mission planning through to production of final digital deliverables.

The primary functions are:

- Mission planning. This includes the specification of the total survey area, spheroid and grid, survey sub-areas, line spacing, swath widths, survey lines to cover the sub-area, individual survey lines, depth benchmark areas and lines, crosslines, tidal areas and navigation check points.
- Sortie planning. A sortie plan is the specification of a series of survey objectives to be executed by the AS. Survey lines and navigation check objectives are selected by the operator and written to floppy disk along with grid and spheroidal information.
- Sortie processing. This function calculates sounding depths and positions from the raw sounding data logged by the AS. Depths and positions are associated with various confidence metrics.
- Quality Control. Utilities within the GS for data integrity checks include the Positioning Analysis Software (PAS) for generating static and dynamic GPS check reports and data, navigation position checks, depth benchmark comparisons and crossline comparisons.
- Data validation, checking and approval. Surveyors validate the calculated soundings on a run-by-run basis editing soundings as appropriate. The validated data is checked by a senior surveyor and finally approved by the Field Party Leader.

- Data output. Approved data is output to the client in S-57 digital format.

In addition, the GS provides facilities for the generation of survey management plots and reports.

Ground System

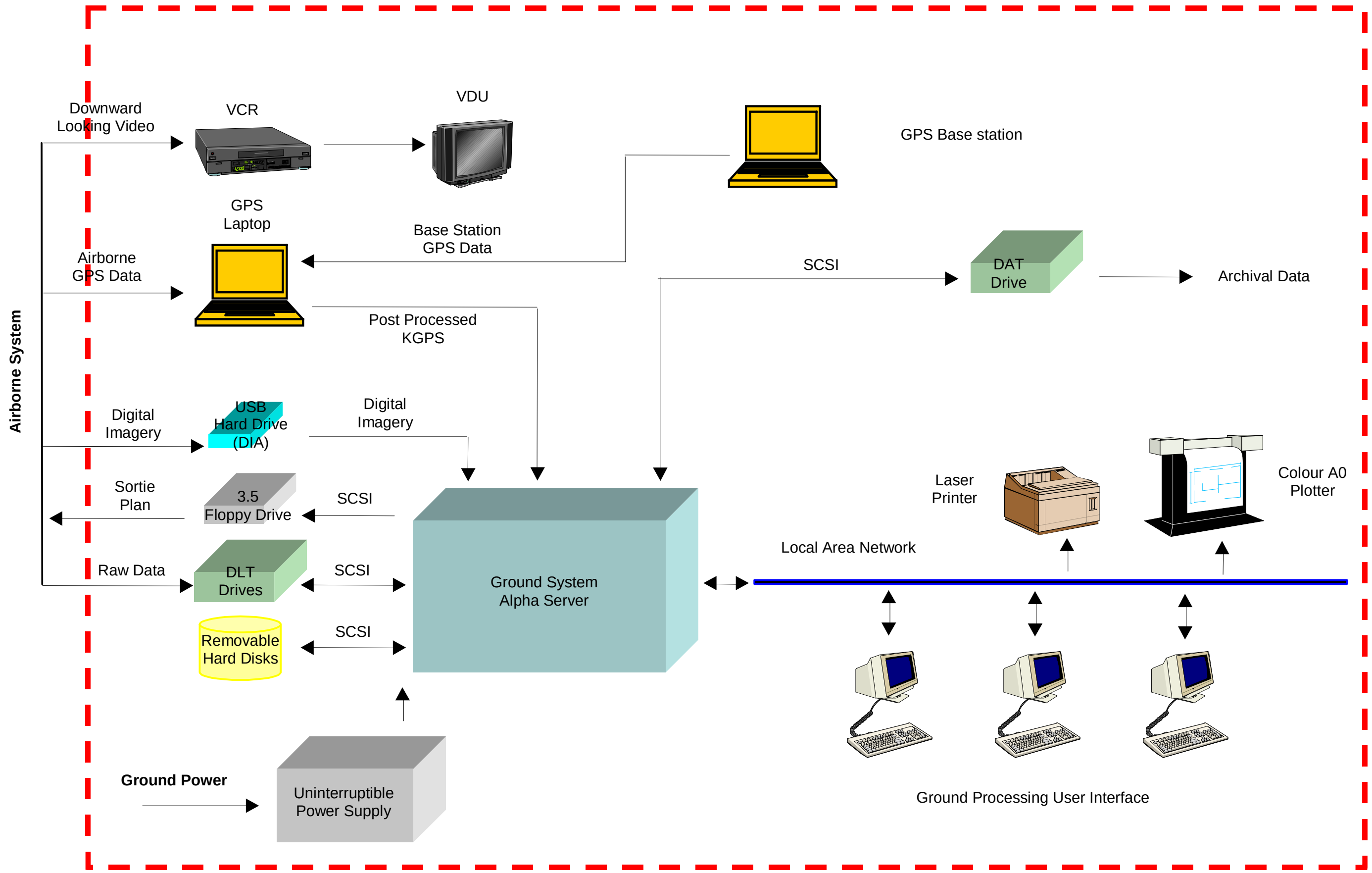


Figure 5 – Block Diagram of the LADS MkII GS

A.2.1 Mission Planning

At the commencement of a survey, one or more databases are established on the GS. Each database contains spheroid and grid data, tide data and survey objectives.

Sub-areas are defined covering the specific areas to be surveyed. Survey lines are then generated within each sub-area at operator specified line spacing. Other survey lines can be specified by entering start and end coordinates.

A.2.2 Sortie Planning

Prior to each sortie, survey objectives are selected from the appropriate database. The start and end coordinates of the required survey lines are written, together with spheroid and grid data, to a sortie plan on a floppy disk. This plan is read by the AS and used to control sortie operations.

A.2.3 Sortie Processing

Processing parameters are set prior to sortie processing. The post-processed KGPS positions from the local reference station are applied first. Preliminary tides are applied and final verified tides can be reapplied at a later time.

Raw sounding data logged by the AS is automatically processed by the GS to produce depth, position and a series of confidence parameters.

On completion of automatic line processing, operator quality control checks, validation, checking and approval of the sounding data can be conducted.

A.2.4 Data Organization

Data within the GS database is held on a line-by-line basis. Within the survey lines the data is grouped into one-second frames made up of 18 scans of 48 sounding pulses (864 pulses per frame).

A.2.5 Primary and Secondary Soundings

All processed soundings comprise the primary sounding set. Where data set reduction is required, a shoal-biased subset of the primary soundings called secondary soundings is created. Secondary soundings form a shoal-biased subset based on operator selected confidence and secondary selection radius criteria. Only secondary soundings are validated, checked, approved and output. For this survey a secondary sounding reduction radial of 1m has been used, which means all soundings have been hydrographically reviewed and all valid soundings have been provided in the final data set. All incorrect secondary soundings were set to Primary during the course of data validation, checking and approval and were excluded from the final dataset.

A.2.6 Automatic Data Processing

Automatic processing is completed in two stages:

1. Sortie Tape Processing (STP).

   STP reads the data on the tape and stores it in the internal GS database for further processing. The data is line-based and consists of raw waveform data, navigation data, platform data, system data, and error and event logs. This process also includes producing a backup of the raw data tape on DAT or DLT.

2. Sortie Run Processing (SRP).

   SRP is the second and major processing phase during which sounding depths and positions are calculated on a line-by-line basis. The process is normally triggered automatically by STP as each line becomes available, but may be invoked later by the operator if reprocessing of lines with different processing parameters is required.

The major processing steps of SRP are:

- Apply post-processed KGPS position data to the raw data and digital images from the downward-looking camera.
- Process the raw waveform to identify surface reflections.
- Process the raw waveform to identify and calculate initial depths. Up to five possible seabed returns can be established per waveform.
- Classify each of the identified seabed return pulses by SNR, agreement with near neighbors and a maximum likelihood estimator.
- Select the most likely seabed return pulse based on the above classification and a shoal weighting function.
- Model the sea surface from the available surface pulses.
- Correct the calculated depths for sea surface datum including tide, slant range, optical propagation and early / late entry. Tidal corrections may be reapplied later if required.
- Calculate position of each sounding on the seabed. This algorithm uses KGPS fixes, aircraft track and speed, antenna offsets, platform attitude (heading, roll and pitch), beam scan angles and sounding depth. Where the GS is unable to determine a depth from the raw data, the sounding is classified as “No Bottom Detected” (NBD).
- Calculate primary confidence indices (0-9) for each non-NBD sounding and all frames where:

  C0 = Subsurface Pulse Confidence (based on SNR)

  C1 = Near Neighbor Confidence

  C2 = Pulse Type Confidence

  C3 = Position Confidence

  C4 = Sea Surface Reference Confidence

C5 = Not Used

C6 = Coverage Confidence (confidence that the swath covered the planned width)

CW = Weighted Primary Confidence

- Store each sounding and associated confidence data in the database.
- Determine the secondary sounding subset (it may be appropriate to have all soundings classified as Secondary) and for each secondary sounding, calculate and store secondary confidences.

CS1 = Secondary Neighbor Confidence (near neighbor agreement)

CS2 = Useable Points Confidence

CS3 = Secondary Area Confidence

CSW = Weighted Secondary Confidence

A.2.7 Bottom Object Detection (BOD)

A particular feature in the SRP improves the ability of the LADS MkII GS to detect small objects on the seabed.

The BOD algorithm proceeds in two phases. Each phase can be independently enabled / disabled and tuned via a series of BOD processing parameters set by the operator prior to SRP.

Phase one of the algorithm is designed to detect objects 2-3m in height, while phase two is only invoked if phase one fails. Phase two is more sensitive and intended to find objects less than 2m in height. The BOD depth contender is described further under Section B.9.

A.2.8 Line Reprocessing and Segmentation

It may be necessary to reprocess the same raw sounding data with different processing parameters. The run identification scheme adopted in LADS MkII provides a mechanism to manage the reprocessing of survey line data multiple times.

After a line is reprocessed, the required segment can then be set to Accepted, and the remaining data can be set to Anomalous or Rejected, and is subsequently excluded from final data output.

A.3 GROUND SYSTEM – USER INTERFACE

The following displays and their associated operations are the primary tools used for data validation, checking and approval.

A.3.1 Composite Data Display

The Composite Data Display is used for overall assessment of the depths along the line and the general quality of the data. The operator may pan along and zoom into specific areas of the line. The position in Eastings and Northings of the nadir at that point, the distance along track, time of acquisition and frame number of the point under the cross hairs is displayed as the operator pans along the line.

The operator can position cross hairs at the point of interest on this display before invoking more detailed displays. The other displays are initialized at the position of the cross hairs.

Figure 6 – Composite Data Display

Three profiles, with distance along track on the X axis and depth on the Y axis, are superimposed on this display:

- For each scan the average of all soundings across a scan is graphed as a green line. If the number of NBD soundings in the scan exceeds a specified number (set as a processing parameter), the green line is drawn across the bottom of the display.
- The shoalest secondary sounding in each scan can be displayed as a yellow dot.
- The deepest secondary sounding in each scan can be displayed as a yellow dot.

These profiles enable the operator to rapidly assess where there is a high NBD count and assess where there are areas of noise.

Below the depth profiles, two operator selectable profiles are displayed. Each of these can be one of:

- Any of the primary or secondary confidences.
- Parameters related to the integrity of the height datum.
- Tidal correction and tidal area boundaries.

The Composite Data Display is also used to segment the data into the following line subsets:

- Accepted – data is to be cleaned and exported in the final dataset.
- Anomalous – data is rejected and will not be exported, but adequate coverage exists from overlapping sub-areas.
- Rejected – data is rejected and the survey line must be reflown to obtain adequate coverage.

A.3.2 Local Primary Display

The Local Primary Display shows the depths of all soundings across the 18 scans conducted during one second of data acquisition. Soundings are arranged logically (not by position) as a row per scan of 48 soundings across the row. A white bar between rows indicates a frame boundary. Primary soundings are green, secondary soundings are yellow and NBD soundings are marked as “NB”.

The length of the bar between the integer and decimal values of the depth of each sounding is proportional to the primary (CW) or secondary weighted confidence (CSW) as appropriate.

The operator may scroll forward or backward along the line and position the cursor over soundings for which detailed displays, such as the Waveform Display or Sounding Audit Display, are required.

The survey line identifier, position, time, frame, row, column and confidences are displayed for the sounding at the bottom of the Local Primary Display.

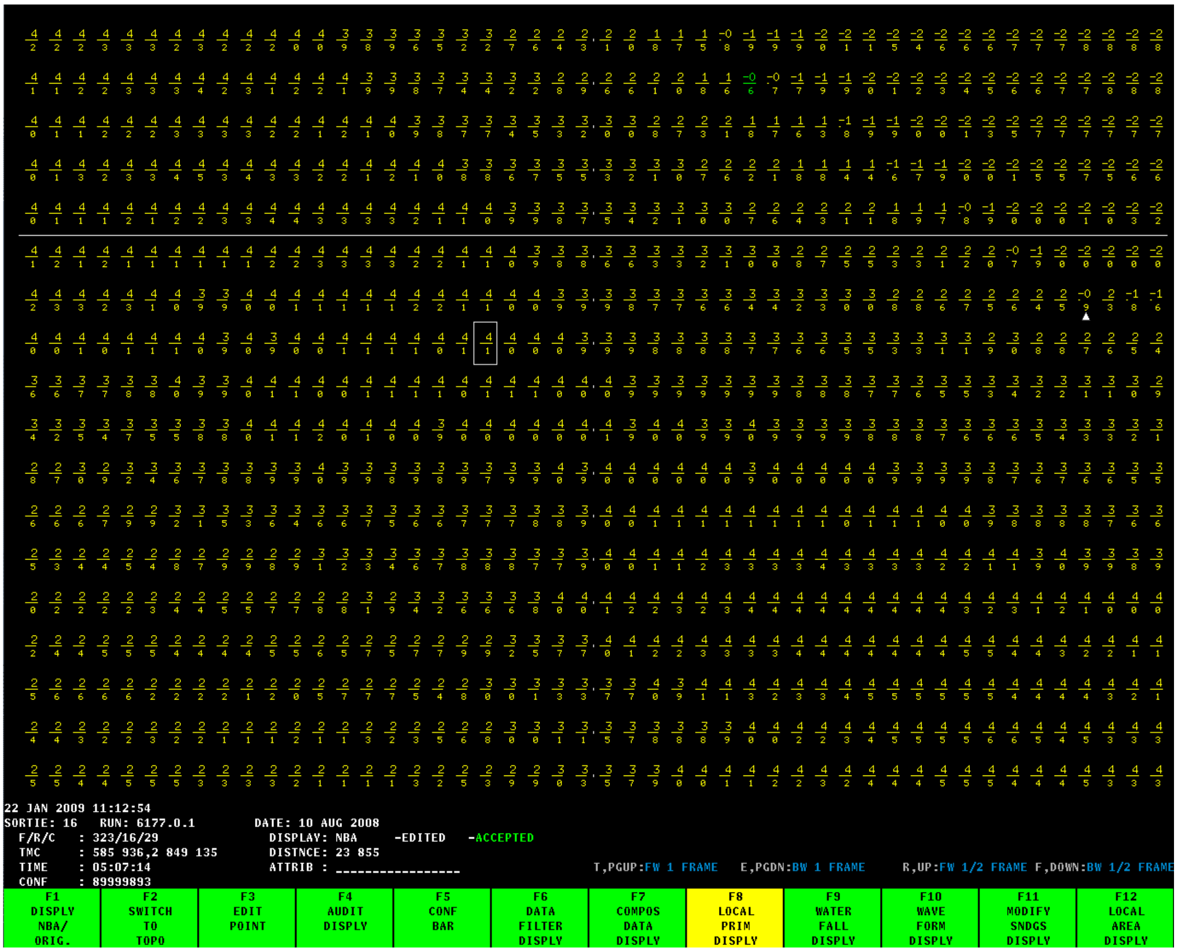


Figure 7 – Local Primary Display

A.3.3 Waveform Display

The Waveform Display shows a matrix of nine sounding waveforms, centered on the nominated sounding. The display is invoked from the Composite Data, Local Primary, Waterfall and Local Area Displays. This display allows an operator to assess the quality of the laser waveform and to resolve or clarify specific sounding values, such as incorrect selection from multiple bottom returns or a false sounding value due to noise in the signal.

Within each waveform window the frame, row, column, gain settings, position, depth, alternate contender depth and SNR are presented. A more detailed discussion of the interpretation of waveforms is given in Section B.9.

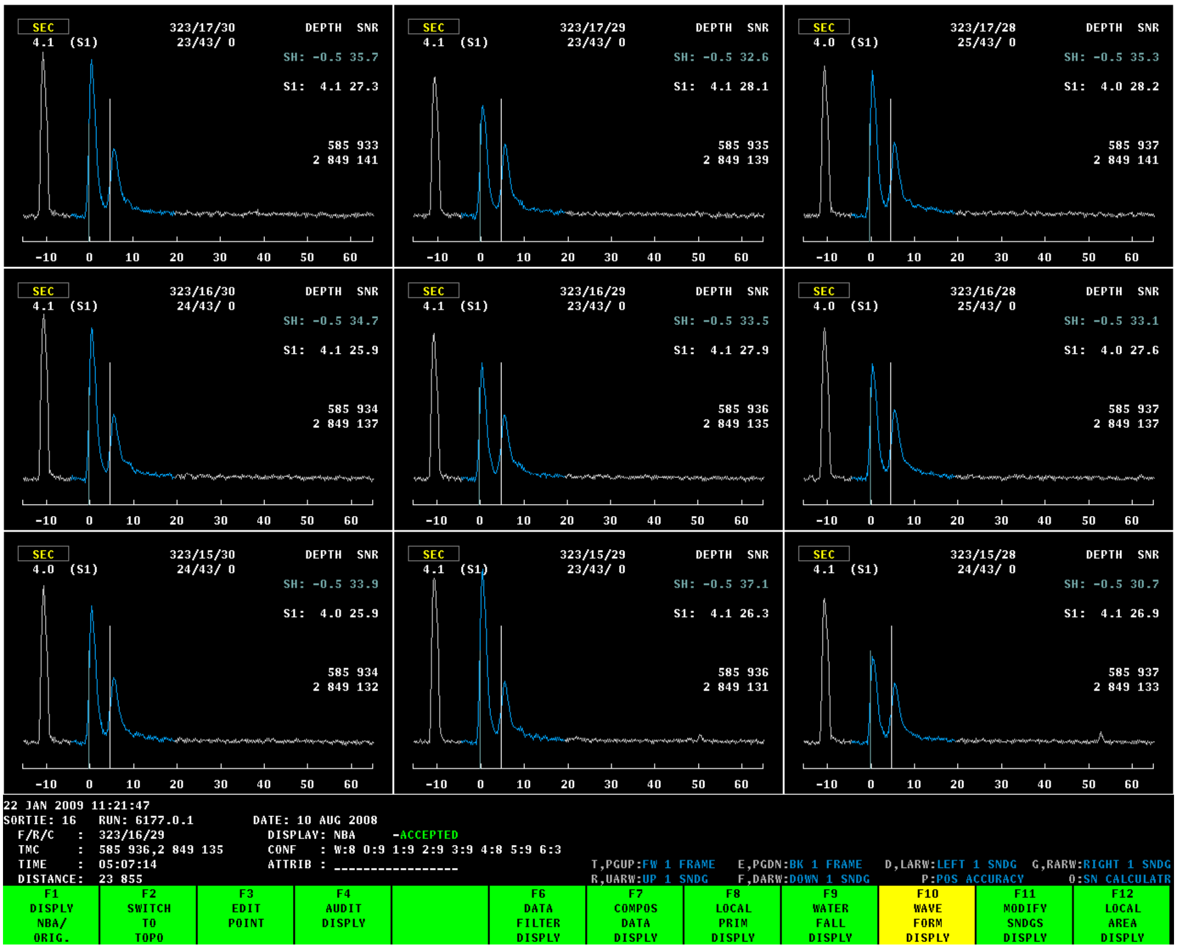


Figure 8 – Waveform Display

A.3.4 Waterfall Display

The Waterfall Display is a pseudo 3-D display constructed from multiple color-coded profiles of the depths across each swath for three frames along a line. Secondary soundings are displayed as yellow dots. The operator may scroll forward or back along a line and select an individual sounding for which to invoke the Waveform Display.

The display allows an operator to gain a general assessment of the shape and nature of the bottom and is particularly good for identifying seafloor objects and spurious noise outliers.

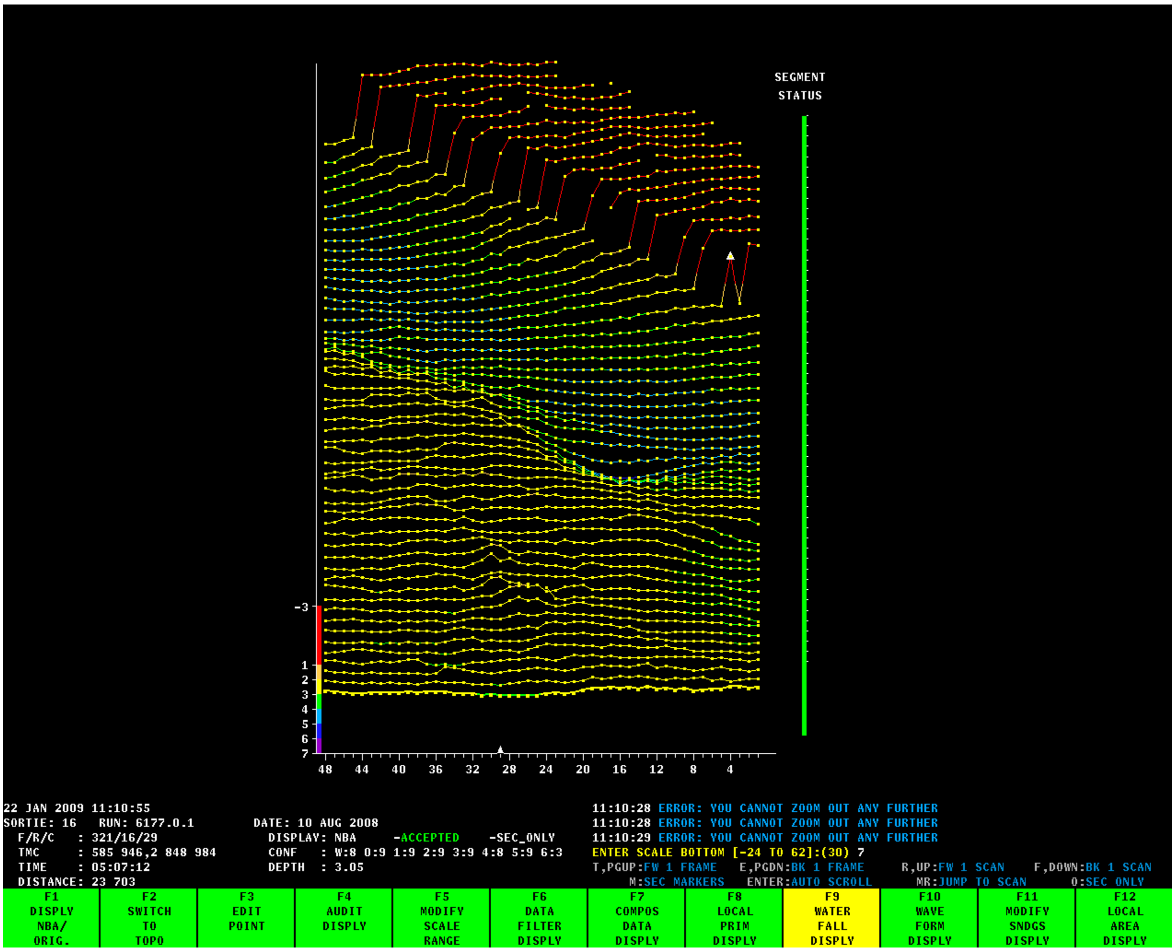


Figure 9 – Waterfall Display

A.3.5 Local Area Display

The primary purpose of the Local Area Display is to check consistency of data across overlapping runs. Facilities provided include coverage and depth variation checks (based on grid cells of nominated size) and tinned contouring.

When this display is invoked, the soundings from the currently selected line and nominated overlapping lines, centered on the current cursor position (as set in the Composite or Primary Displays), are shown. Soundings are presented in their true geographic positions and color-banded by depth.

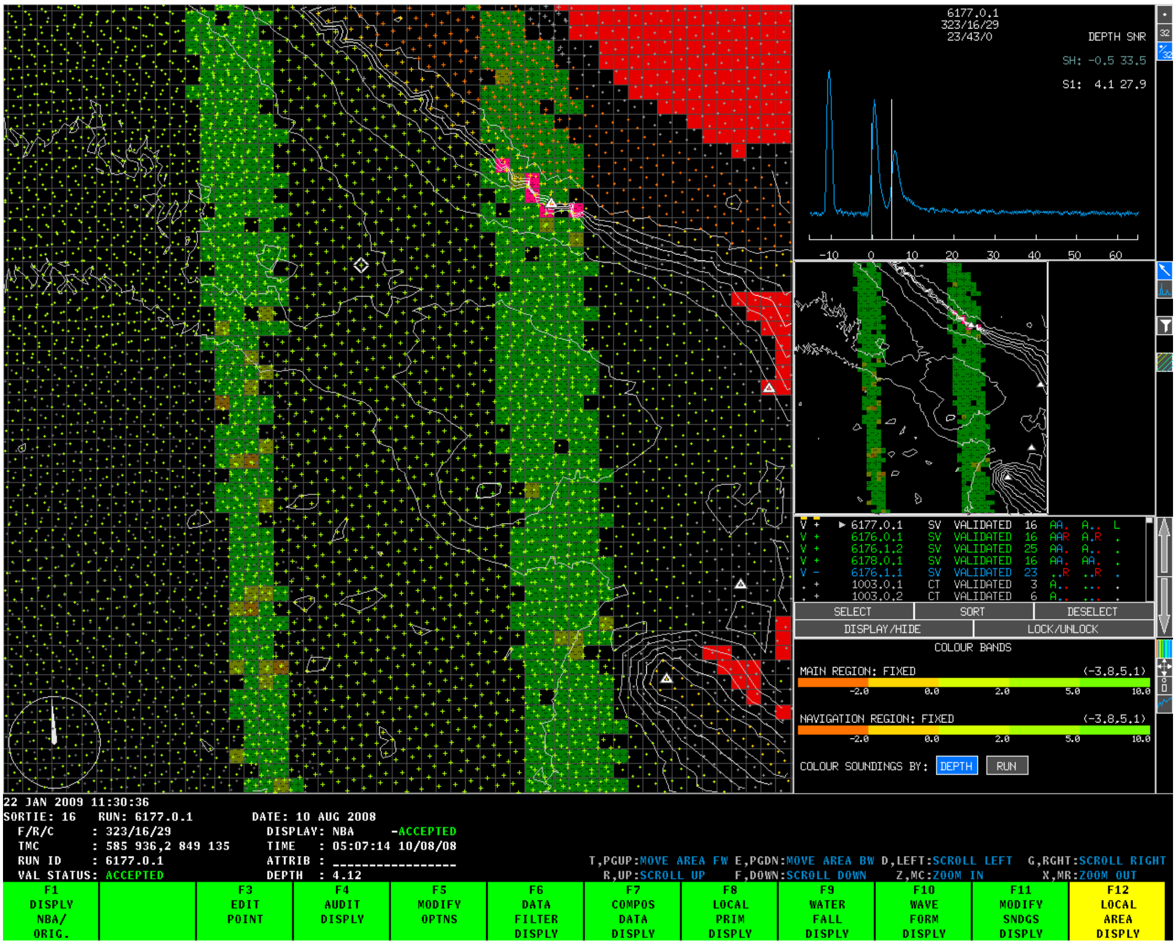


Figure 10 – Local Area Display – Small Scale

The display is divided into five sub-windows, as shown in Figure 11:

a. The working window, on the left, provides a detailed scalable view of a sub-region. The operator may pan, zoom and select soundings in this window. A rectangle within the navigation window shows the position and extent of the area displayed in the working window.

b. The waveform window, positioned in the top right of the display, shows the waveform for the currently selected sounding, highlighted by a white triangle in the working window.

c. The navigation window, positioned middle right in the display, provides a top-level view of the area currently selected.

d. The runs window, directly below the navigation window, lists the overlapping runs along with the status of the line, e.g. Accepted, Anomalous or Rejected.

e. The color band window shows the color band depth ranges for displayed soundings in the navigation and working windows. The soundings can be colored by depth or by line.

The lower region of the screen displays summary information similar to that on the Composite and Primary Displays.

TIN contours of the displayed soundings can be shown in both the navigation and working windows and contour intervals can be amended as required.

For the purposes of coverage and depth variation checks, the operator selects a cell size appropriate to the sounding density. For each cell the system checks coverage criteria. When there is no sounding coverage from any survey line, the cell is colored bright red. When there is coverage from a survey line the cell is displayed black. When there is sounding coverage from both the primary and overlapping lines the cell is color filled green, olive, light brown, dark brown, orange, red, purple or pink. The color of a cell indicates the degree of variation in the depths of soundings within the cell. Green represents a mean depth variation from the primary survey line sounding of less than 0.0m, olive less than 0.2m, light brown less than 0.4m and so on.

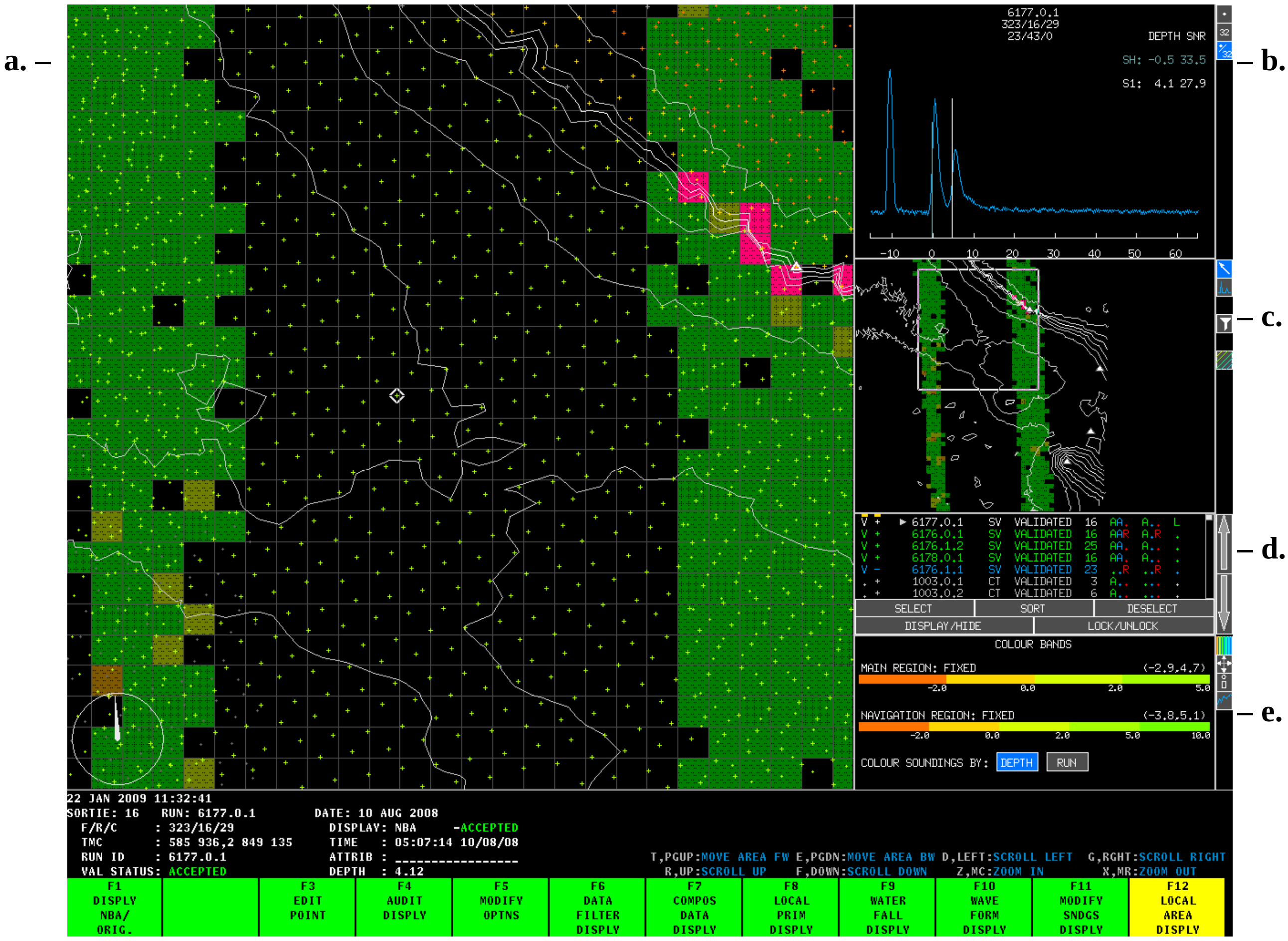


Figure 11 – Local Area Display – Medium Scale

In both the navigation and working window, the soundings are displayed at their geographical positions. As the operator zooms in on the working window, symbols in the working window are replaced by depth values (refer to Figure 12). The sub-region displayed in the working window is represented by a white square in the navigation window.

On selecting a sounding in the working window, the sounding is highlighted with an enclosing diamond and its waveform is shown in the waveform window.

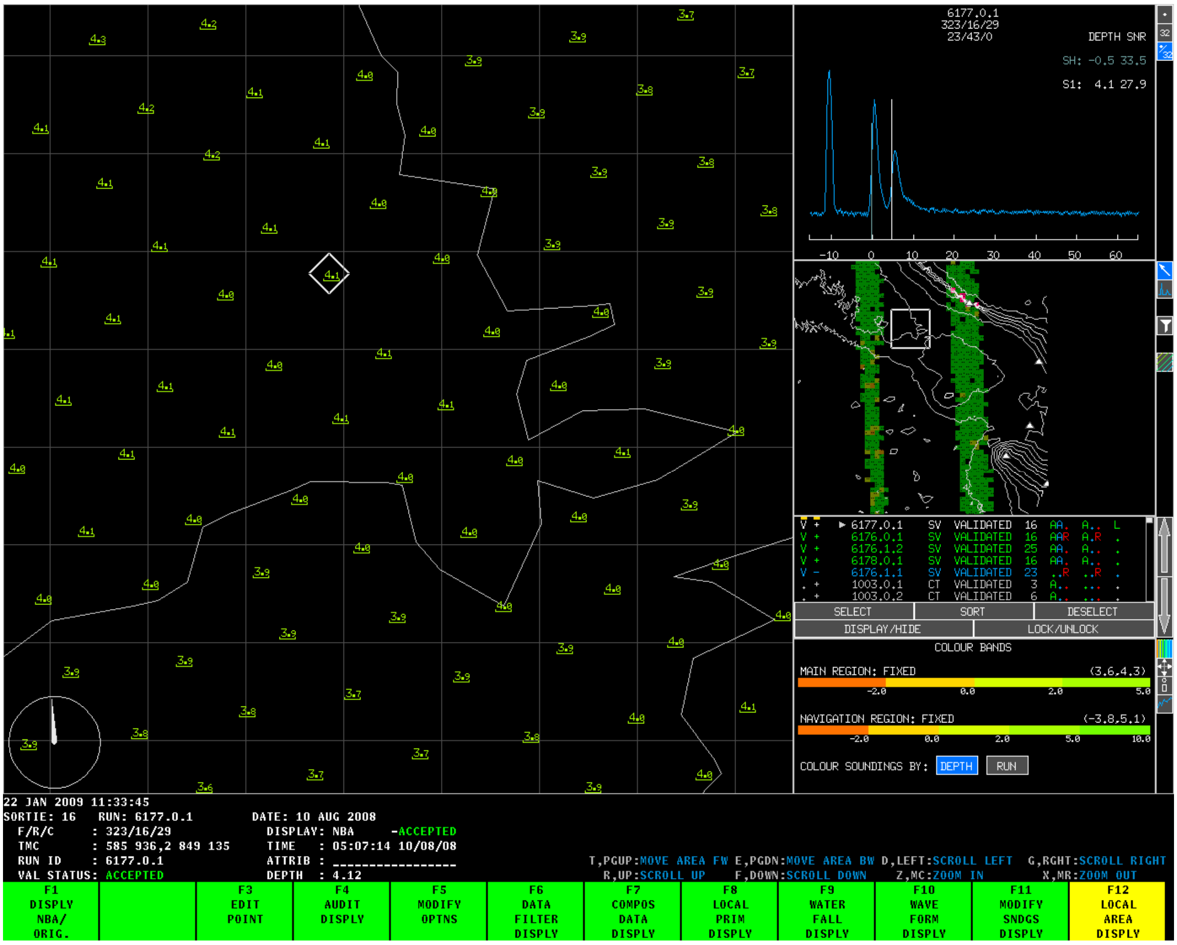


Figure 12 – Local Area Display – Large Scale

A.3.6 GS Digital Image Window

The imagery collected by the downward-looking digital camera in real-time is processed along with the raw data. These images are georeferenced and can be either manually or automatically displayed alongside of the Raw Data Display, the Waveform Display or the Local Area Display. The images are automatically rotated to fit the current display.

These images are displayed in the GS Digital Image Window on the second dual-screen monitor. This display is automatically linked to all of the GS displays mentioned previously and the selected sounding is highlighted in the downward-looking image with a circle of 5m diameter.

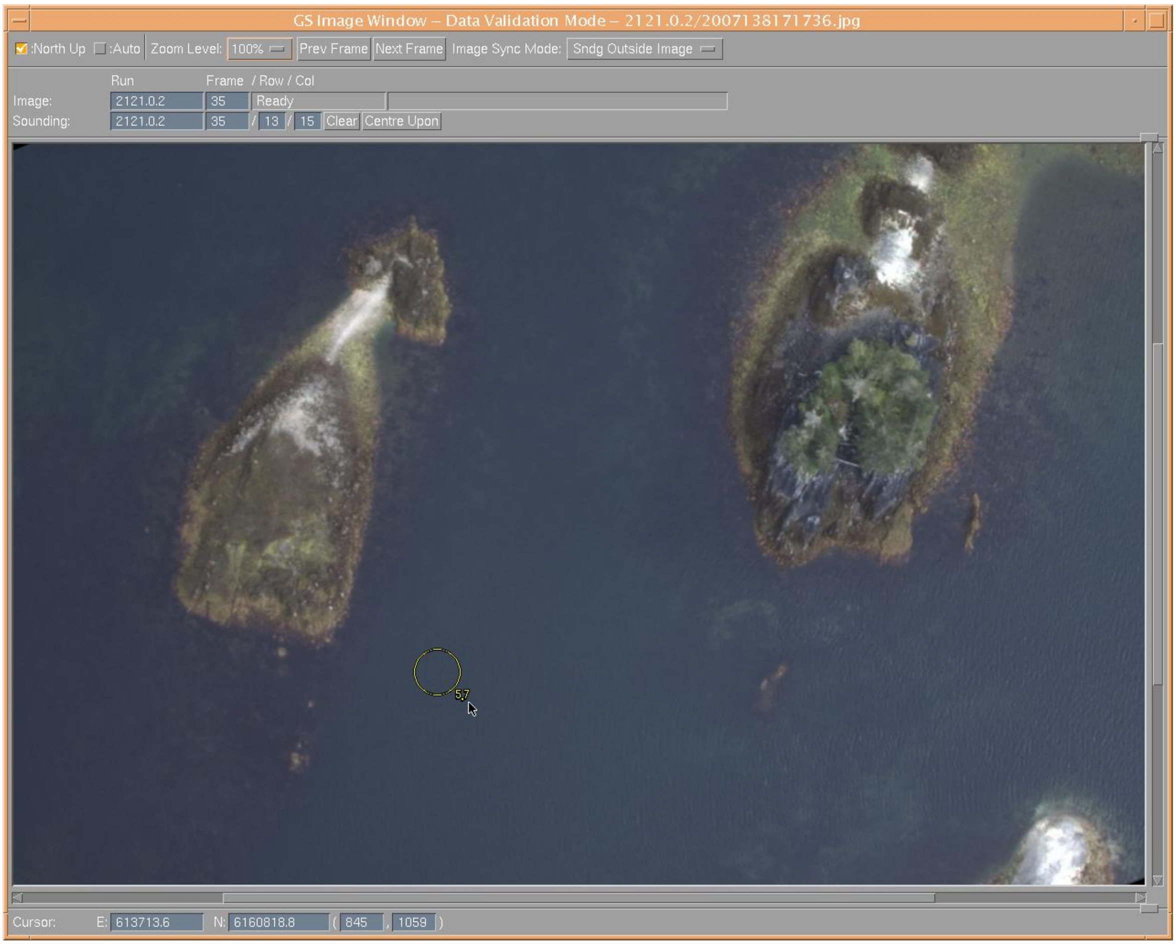


Figure 13 – GS Digital Image Window – Daylight image from Alaska 2008

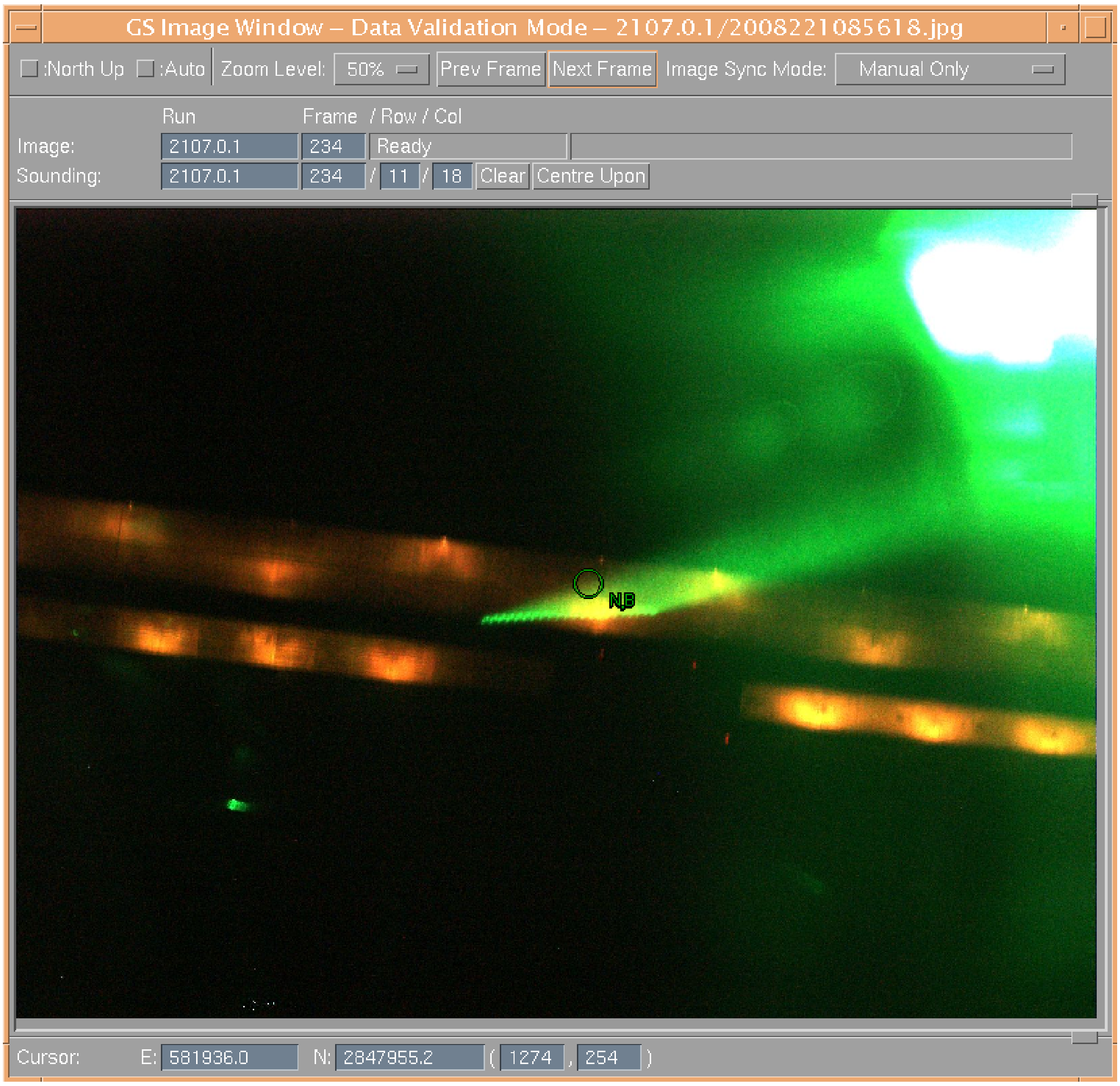


Figure 14 – GS Digital Image Window – Night image from Approaches to Miami 2008 (Rickenbacker Causeway)

For daylight survey operations the GS Digital Image Window enables the operator to easily correlate features such as coastline, islands, islets, drying rocks, rocks awash, shallow rocks, kelp, beacons, buoys, boats, jetties, buildings and trees in the image with the data presented in the different GS displays. The quality of imagery and zoom functionality of the window even enables discernment of biological data artifacts, such as bird strikes and whale returns. Sea lions sunning themselves on drying rocks have also been noted in the imagery.

For night time survey operations digital imagery has limited usefulness. Only areas that are artificially illuminated can be discerned in the imagery and correlated with bathymetric data (refer to Figure 14).

A.3.7 Audit Display

The Audit Display is used to view additional data associated with a single sounding. The display enables an operator to check details such as the aircraft height and heading, platform angles, mirror scan angles and tidal reduction of the sounding (refer to Figure 15).

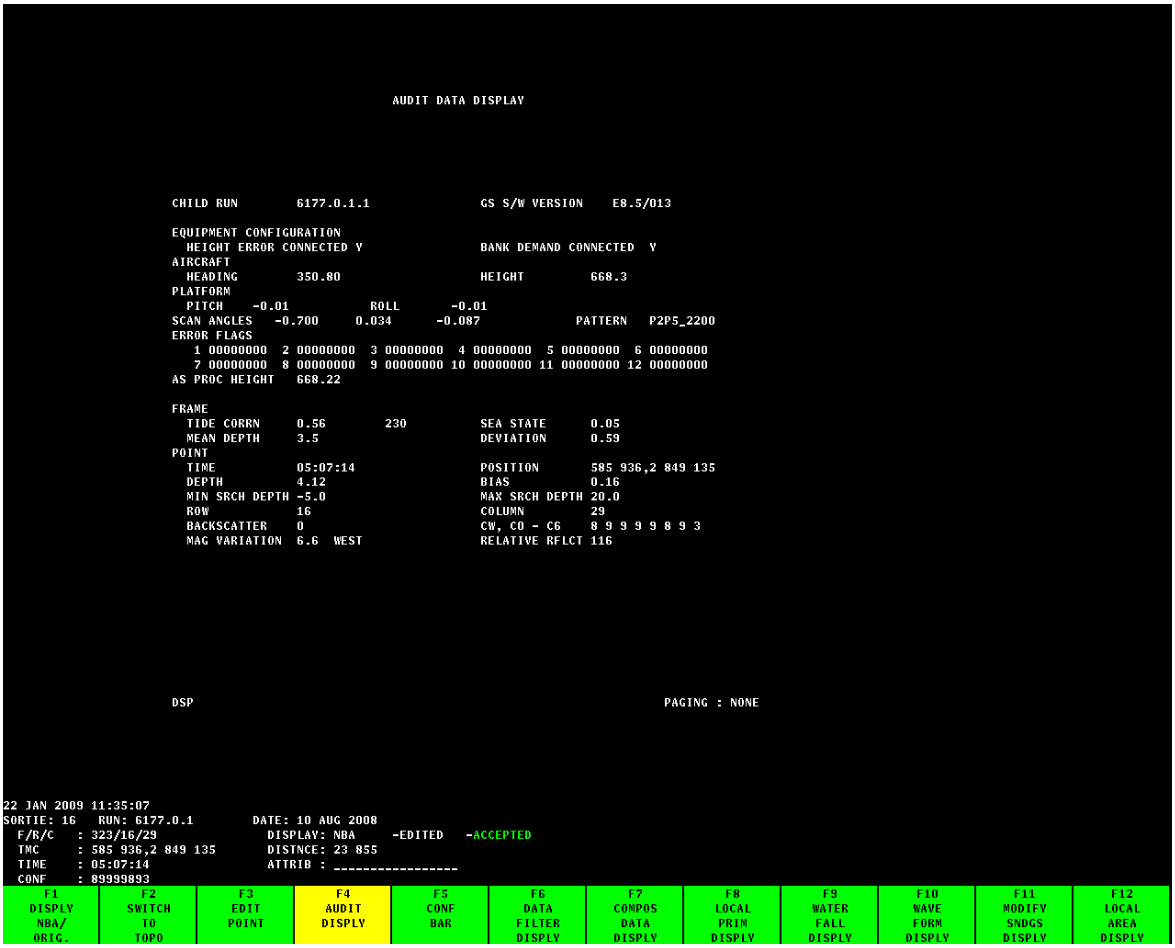


Figure 15 – Audit Display

A.3.8 Data Filter Display

The Data Filter Display is used to edit numerous points at one time. The display contains two separate windows (refer to Figure 16). The first is representative of the shoalest and deepest soundings per scan, similar to the Composite Data Display. The second window displays numerous filter tabs, each of which is used to set the parameters for the required block edit.

The Data Filter Display essentially enables the operator to reapply the sortie processing parameters to specific survey lines, or areas of lines, with amended values to reduce the single point editing required to validate, check and approve the data. The filters can highlight specific types of soundings and tags, and rapidly set soundings to NB, Primary or Secondary within different depth ranges and SNR's.

Figure 16 – Data Filter Display

A.4 SOFTWARE VERSIONS

System	Version	Remarks
Tenix LADS AS	AS 9.0.4	Airborne System Software Version
GPS Logging AS	5.6.0	Ashtech PNAV Data Logger Software
GPS Logging BS	3.22	GrafNav GPS Data Logger Software
GPS Processing	8.10	GrafNav (Precise Differential GPS Navigation Trajectory Software)
Tenix LADS GS	E8.5.10 to E8.7.00	Ground System Software Version
CARIS BASE Editor	2.1.0.0	
CARIS HIPS and SIPS	6.1.1.2	
GMT	3.3.1	Component of the LADS ‘QC Tools’
VTK	3.1	Component of the LADS ‘QC Tools’
MBT	–	LADS MkII Mosaic Build Tool
ER Mapper	7.1	Image Compression Software

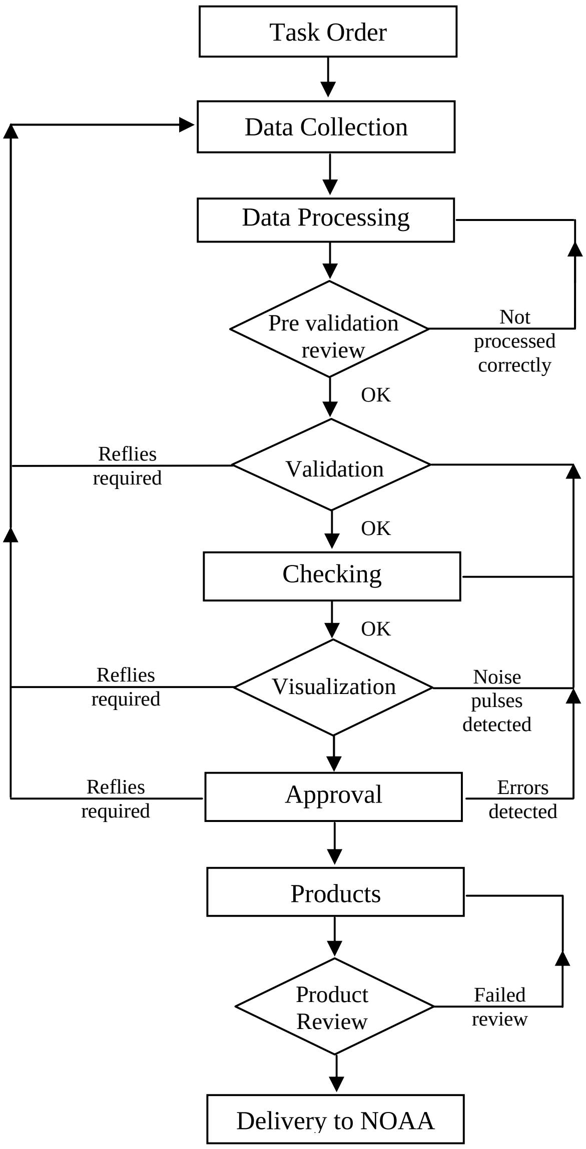
Table 2 – Software versions

B. QUALITY CONTROL

B.1 DATA PROCESSING

Data processing involves the following stages:

- Automatic data processing as described in Section A.2.6
- Survey line acceptance and segmentation by Deputy Project Manager / Project Manager
- Pre-validation of the data by senior surveyors
- Validation of the data by hydrographic surveyors
- Checking of the data by the Deputy Project Manager
- Visualization of the data by a senior surveyor
- Approval of the data by Project Manager



Refer to Section A.3 for the specific GS User Interface displays used to conduct data pre-validation, validation, checking and approval.

B.2 PRE-VALIDATION

Pre-validation is the first interactive step of data processing.

Pre-validation is conducted to confirm that the automatic data processing has been performed correctly and to give guidance for the validation process. The survey data that sufficiently passes quality checks is segmented to Accepted status for validation by hydrographic surveyors. When the required coverage is not obtained, the line is nominated to be reflown. The majority of reflies are created during the in-field pre-validation phase. Some data cleaning is also undertaken during the pre-validation stage, with obvious noise, turbidity and datum shifts removed. The majority of pre-validation will be conducted using filters provided in the Data Filter Display (refer to Section A.3.8).

B.3 VALIDATION

Validation proceeds through the following steps:

1. Examining the depth profile on the Composite Data Display for the correct processing and segmentation of each survey line.
2. Examining the position confidence (C3) profile to verify that adequate positioning accuracy is maintained during the survey line. Additional positioning quality confidences, such as PDOP, number of satellites and correction latency, are examined in profile along the survey line.
3. Examining the coverage confidence (C6) profile to verify that no coverage gaps exist due to the aircraft flying off the predetermined track.
4. Examining the Kalman filter tilt and bias for the line to determine areas that datum shifts have occurred due to excessive aircraft roll, poor sea surface datum or prolonged periods flying over topography.
5. Resolving erroneous soundings after examining outlying data points along the survey line using:

a. The Primary Depth Display

b. The Waterfall Display

c. The Waveform Display

d. The Local Area Display

Validation data editing operations are generally applicable to single depth soundings, but data filters may be applied when pre-validation has missed significant areas of erroneous soundings. The typical single point edits required include the selection of an alternate depth contender, inserting a waveform depth contender where an automatic one does not exist and deletion of the sounding, as appropriate. Tagging of soundings is also an integral part of data validation and is discussed in Section B.8.

B.4 CHECKING

Once a line has been validated it goes through an independent checking phase by the Deputy Project Manager. All soundings edited by the validator are highlighted on the line and the checker ensures the correct edit has been made during validation. Checking also involves identification of residual unedited erroneous soundings missed during data validation and review of the tagged data points.

B.5 DATA VISUALIZATION

All checked data is exported from the GS in a defined ASCII format for spatial presentation and checking. The position, depth, run and other relevant information are extracted from the line-based data for use in the generation of Triangulated Irregular Networks (TINS) and gridded data sets. Both of these are used to produce contour plots, sun-illuminated color-banded images and coverage check plots. Anomalies found in these plots are reported to the Project Manager for remedial action in the GS.

A number of software packages are used to produce these products and create query files to be imported into the GS for sounding interrogation.

B.6 APPROVAL

In the final phase the Project Manager reviews each line from start to finish to ensure that all data edits and tags were made correctly during pre-validation, validation and checking and that no erroneous soundings remain in the final dataset. Each survey line is reviewed primarily in the Local Area Display (refer to Section A.3.5).

B.7 AUDIT TRAIL

The significant filter and single point edit actions in validation, checking and approval are logged on appropriate forms, and the procedures used have been certified as conforming to ISO-9001 Quality Assurance standards. All operator actions are logged by the GS for complete traceability.

B.8 TAGGING OF SOUNDINGS

During data processing on the GS, the operators have the ability to assign S-57 and user-defined tags to gaps and features in the data. This enables accurate delineation and attribution of unsurveyed polygons and features requiring further investigation in the S-57 feature file.

B.8.1 Lidar Gap Tagging

The following user-defined tags were used to delineate gaps in the lidar seabed coverage, typically at a 50m interval:

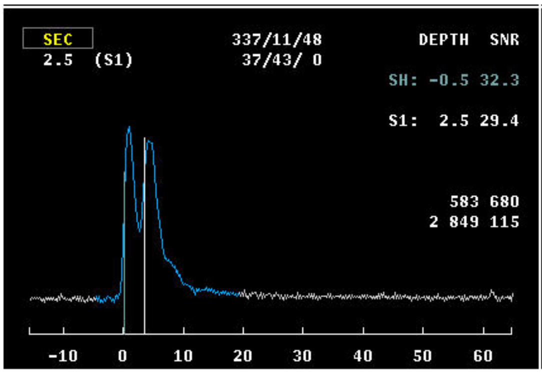
GB	Bathymetry data gap due to ships / boats.
GM	Bathymetry / topography data gap due to mangroves.
SEZ	Bathymetry / topography data gap due to the secondary exclusion zone (SEZ).
GLS	Bathymetry data gap due to glassy seas.
GTR	Topography data gap due to the laser return of trees.
GT	Bathymetry gap due to localized turbidity.

A data gap due to boats occurs when a vessel is over flown during data collection. Additional lines are planned to cover these gaps, but due to vessels being anchored at the same position throughout the survey period, some gaps may not be filled.

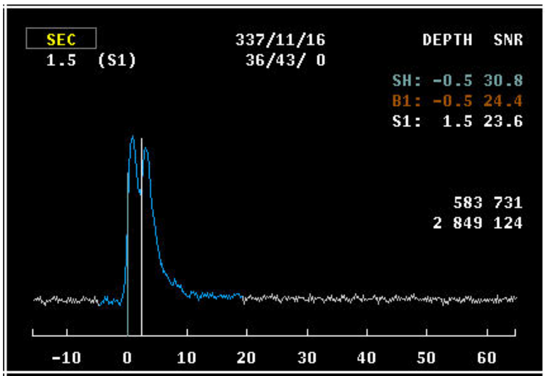
A data gap due to mangroves occurs when a seabed or drying return is not possible due to the presence of foliage. Where this occurs the operator will tag the most seaward foliage detection to delineate the areas of mangroves.

A data gap due to the SEZ occurs in very shallow water, where the waveform return from the seabed is mixed with the waveform return from the sea surface. SEZ gaps are common along most coastlines at the land / sea interface. Neither the seabed nor a drying return can be determined, so a gap exists in this very shallow area. The laser waveform returns displayed below demonstrate the limitations of lidar in very shallow water. These waveforms are selected from a single laser scan in a shallow area of Biscayne Bay.

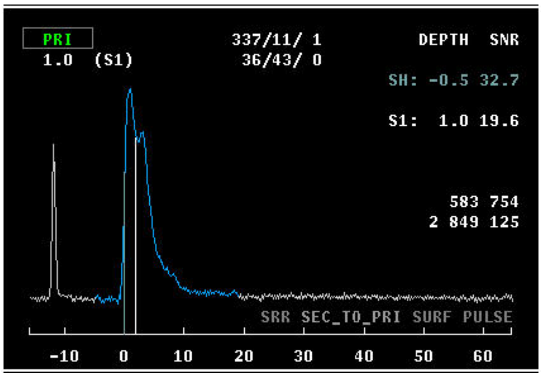
At between 2.5 and 1.5m water depth there is clear separation of the sea surface and seabed return. In this case, at ~1.0m depth the returns have merged and an inaccurate depth has been detected and subsequently removed by the operator. In less than 1.0m depth the shallow water algorithm is unable to extract a depth altogether, and this sounding is automatically rejected by the secondary exclusion zone.



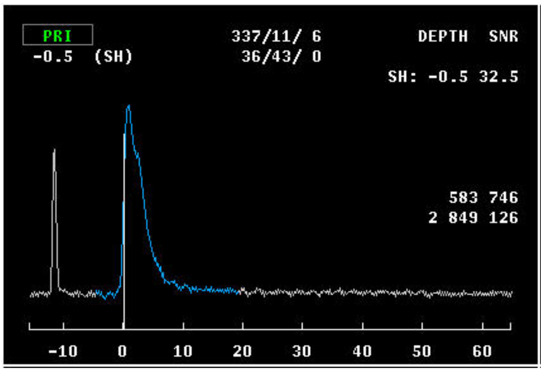
2.5m depth



1.5m depth



~1.0m depth (inaccurate and removed)



No Bottom Detected, within the SEZ

Figure 17 – Shallow Water Laser Waveforms and the SEZ

A data gap due to glassy seas occurs in extremely calm conditions, where the sea surface laser returns at nadir become saturated. This sea surface saturation drives the automated green receiver gains down, resulting in very attenuated seabed returns, or no discernable seabed return at all. Glassy sea gaps are most common adjacent to coastlines, typically in shallow water.

A data gap due to trees occurs where trees grow along the Mean High Water (MHW) line and a bare earth lidar return is not possible due to the presence of foliage. Where this occurs, the operator will tag the most seaward foliage return.

A data gap due to turbidity occurs where the presence of poor water clarity leads to inaccurate seabed depth detection and subsequent sounding deletion, or no return from the seabed at all.

B.8.2 Lidar Feature for Examination Tagging

During the validation, checking and approval of lidar data using the GS, seabed features that are considered ‘suspicious’, or least depth has not been adequately surveyed, are tagged for further examination by surface vessels. These features are potentially returns from matter within the water column, such as marine life, fishing nets, suspended sediment, etc.

The tags associated with features requiring further investigation have been compiled in CARIS .hob files.

B.9 LASER WAVEFORMS - NATURE AND INTERPRETATION

The annotated Sounding Waveform Display (refer to Figure 18) contains the following data:

- Graphic of raw laser waveforms showing return from the water surface (1) and seabed (2) for a matrix of 9 adjacent soundings
- Depth contender showing selected seabed return (3) and alternate subsurface return contenders (4) if they exist
- The Frame, Row and Column of the active sounding (5)
- The real-time green receiver gain values for sounding measurement (6)
- Type of sounding, currently there are up to 5 subsurfaces that can be selected by the GS, a shallow return, two subsurface returns and BOD returns for both subsurfaces (7)
- Depth values for the possible subsurfaces (8) and the SNR for the respective depth values (9)
- The selected depth and the type of return (10)
- The status of the sounding, either Secondary, Primary or NBD (11)
- Grid coordinates of sounding on the survey spheroid and grid (12)

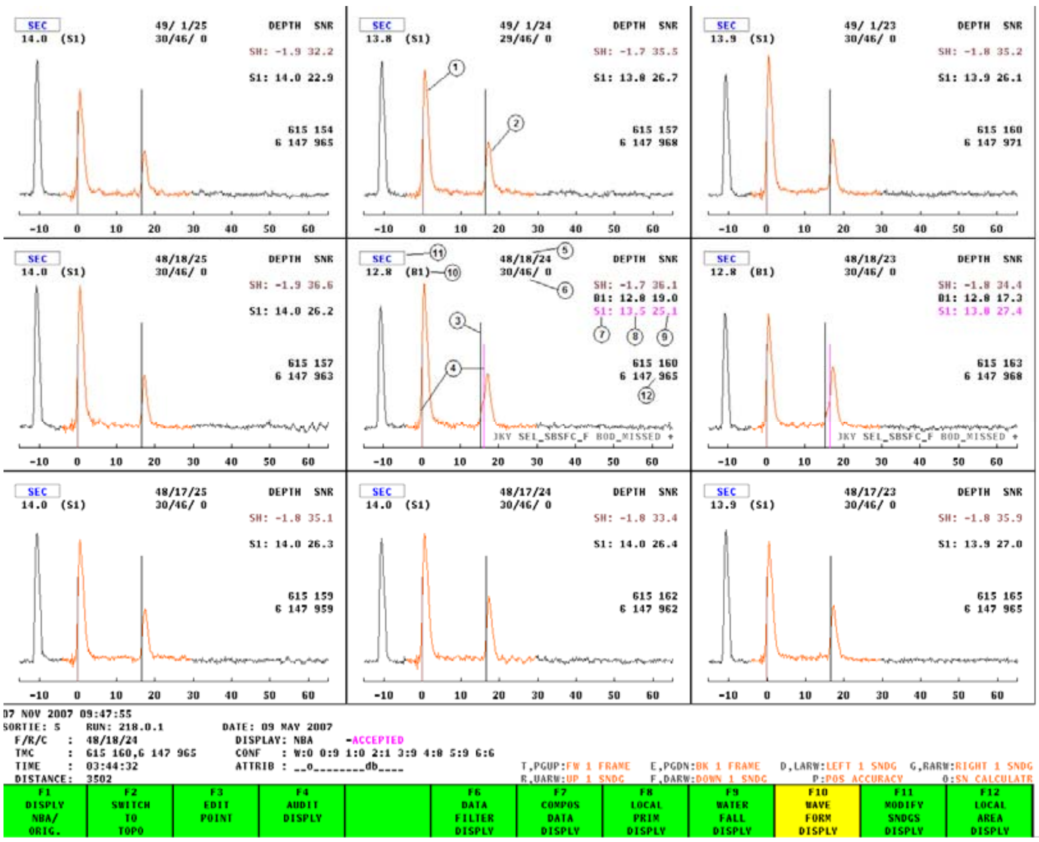


Figure 18 – Annotated Sounding Waveform Display

The raw laser waveform represents the level of energy detected by the green receiver as a function of depth. A surface model, or datum, is then calculated from the infrared, GPS and inertial AHRS heights and filtered green surface returns. The SRP selects up to five possible seabed returns for each waveform based on SNR criteria. If no possible seabed returns are found, the sounding is classified as NBD.

Depths, measured from the surface datum to the 50% point on the leading edge of a seabed return, are calculated for each possible seabed return. These depths are then corrected for the optical path of light through the water and the height of tide.

Where more than one seabed return is found, the most likely is selected based on SNR versus depth criteria. The selected return is indicated on the Waveform Display by a white depth contender bar and the alternate depth contender bars are colored green. During validation the operator will check these selections and edit as appropriate.

Objects on the seabed will appear on the raw laser waveform before the seabed return. Detection of an object on the seabed will depend on both the density of the scan pattern, gain of the green receiver, backscatter from the water column and the ratio between the level of laser energy reflected from the target and that from the illuminated area of the seabed. The latter is in turn influenced by the size of the target, the depth of water (which affects the area of seabed illuminated) and the reflectance of the target compared with the surrounding seabed.

Backscatter from the water column is received as noise on the raw laser waveform and ultimately limits the maximum gain that can be applied, which influences the maximum depths that can be measured by the system.

B.10 DATABASE MANAGEMENT

B.10.1 Survey Line Identification

The table below lists all of the survey lines flown during the survey and the specific reason for them being conducted:

Sub-Area	Lines	Sounding Density (m)	Line type	Remarks
Depth Benchmark Runs	1 – 19	2.5x2.5	BM Lines	For depth accuracy checks
5	168 – 189	2.5x2.5	Main Survey Lines	100% coverage (70m line spacing)
6	241 – 248 256 – 261	2.5x2.5	Main Survey Lines	100% coverage (70m line spacing)
7	314 – 344	2.5x2.5	Main Survey Lines	100% coverage (70m line spacing)
8	409 – 410 418 – 420	2.5x2.5	Main Survey Lines	100% coverage (70m line spacing)
9	500 – 502	2.5x2.5	Main Survey Lines	100% coverage (70m line spacing)
-	1003 – 1004	2.5x2.5	Additional Coverage Lines	For additional coverage and crossline comparison checks
-	1100 – 1116	2.5x2.5	Additional Coverage Lines	For additional coverage
-	1170 / 1175 / 1177	2.5x2.5	Additional Coverage Lines	For additional coverage
-	1322 – 1343	2.5x2.5	Additional Coverage Lines	For additional coverage
-	1600 – 1614	2.5x2.5	Additional Coverage Lines	For additional coverage in channels
11	2100 – 2107	2.5x2.5	Main Survey Lines	100% coverage (60m line spacing)
12	3200 – 3305	2.5x2.5	Main Survey Lines	100% coverage (60m line spacing)
13	4317 – 4325 4353 – 4373	2.5x2.5	Main Survey Lines	100% coverage (60m line spacing)
14	4417 – 4421	2.5x2.5	Main Survey Lines	100% coverage (60m line spacing)
16	4434 – 4449	2.5x2.5	Main Survey Lines	100% coverage (60m line spacing)
15	4504 – 4511	2.5x2.5	Main Survey Lines	100% coverage (60m line spacing)

Sub-Area	Lines	Sounding Density (m)	Line type	Remarks
18	5000 – 5043	2.5x2.5	Main Survey Lines	100% coverage (60m line spacing)
19	6108 – 6179	2.5x2.5	Main Survey Lines	100% coverage (60m line spacing)
-	7006 – 7008	2.5x2.5	Main Survey Lines	For additional coverage
-	7100 – 7109	2.5x2.5	Main Survey Lines	For additional coverage
-	7200	2.5x2.5	Main Survey Lines	For additional coverage
-	7301 – 7307	2.5x2.5	Main Survey Lines	For additional coverage
-	7400	2.5x2.5	Main Survey Lines	For additional coverage
-	7501 – 7504	2.5x2.5	Main Survey Lines	For additional coverage
-	7600 – 7603	2.5x2.5	Additional Coverage Lines	For additional coverage
-	7606 – 7607	2.5x2.5	Additional Coverage Lines	For additional coverage

B.10.2 Line Identifier Convention

Line identifiers within the LADS MkII system uniquely define a specific line and are made up of 4 fields separated with a decimal ‘.’ as follows:

(Items in <> are the generic names for the fields.)

<LineNumber>.<Section>.<Sequence>.<Child>

e.g. 101.1.2.3

Maximum fields are
100000.99.99.99

LineNumber – Range 1...100000
This field uniquely defines the line and is chosen by the operator when defining a line.

Section – Range 0...99
This field denotes the section of the line.

Zero indicates the whole original line. When the line or part of the line is reflown, the section number is incremented. Thus:

- 101.0.x.x is the original line
- 101.1.x.x is the first refly
- 101.2.x.x is the second refly

Sequence – Range 1...99
This field denotes the number of times the logged data for the specific <LineNumber> .<Section> has been processed. Each time a line is processed by the SRP function, the GS allocates a new sequence number for the line. Thus:

- 101.0.1.x is the first processing of the original line
- 101.0.2.x is the second processing of the original line
- 101.1.1.x is the first processing of the first refly
- 101.1.2.x is the second processing of the first refly

Child – Range 1...99
This field denotes the segment (or child section) of a <LineNumber> .<Section>.<Sequence>.

Hydrographic surveyors divide lines into Accepted, Rejected or Anomalous segments during the Line Validation process. These segments are given sequential child numbers. Thus:

- 101.0.1.1 – is the first child (segment) of the first processing of the original line
- 101.1.2.3 – is the third child (segment) of the second processing of the first refly

B.10.3 Processing Parameters

Each survey line is processed with a specific set of processing parameters, with the set used for the line recorded on the Survey Line History Sheet. Full details are recorded in the survey data management folders held by TLI.

B.11 ERROR MINIMIZATION AND MODELS

B.11.1 Water Clarity

The greatest contributor to depth performance, seabed coverage and data quality with a lidar system is water clarity. In order to minimize the errors and data gaps attributed to poor water clarity, ongoing analysis of the water column conditions was imperative.

This was conducted during survey operations by monitoring raw laser waveforms using the CRT waveform display component of the AS in real-time. It was generally observed that water clarity conditions were optimal for lidar survey during the flooding tide. At low tide water clarity was typically poor in the north of the survey area, particularly in the vicinity of

Miami main Channel. In a number of localized areas water clarity did not improve, regardless of tidal state.

One land based water clarity reconnaissance was conducted following Tropical Storm 'Fay'. Secchi disk observations were taken from bridges and jetties on Virginia Key and Key Biscayne to determine the impact of this storm on water clarity within the survey area. As a result of the turbidity observed during this reconnaissance, a programmed sortie was postponed 24 hours to allow for water clarity conditions to improve.

B.11.2 Total Propagated Error

For this survey area, global horizontal and vertical uncertainties have been assigned based on the defined horizontal and vertical error budget, as stated in the Horizontal and Vertical Control Report. The assigned horizontal uncertainty is 1.96m and the assigned vertical uncertainty is 0.39m.

However, when the calculated BASE Surface grid node standard deviation is greater than the assigned vertical uncertainty, the standard deviation is used as the uncertainty value. This has occurred in areas of high relief, which is common throughout the survey area. In some sloping areas the standard deviation may exceed IHO Order-1 limits. This could be attributed to a 3m grid resolution being used for BASE Surfaces.

B.12 DATA OUTPUT AND DELIVERABLES

Digital data deliverables and graphics BASE Surface and S-57 feature file are output and prepared in accordance with:

- NOS HYDROGRAPHIC SURVEYS. SPECIFICATIIONS AND DELIVERABLES. April 2008.
- STATEMENT OF WORK. LIDAR SURVEY SERVICES. OPR-H328-KRL-08 of March 25, 2008.

All data is exported in meters as per the above documents.

B.12.1 Lidar Sheet Deliverables

Digital datasets delivered are:

- Full resolution dataset
- BASE Surface created in CARIS
- S-57 feature files created in CARIS

Full resolution dataset:
A full resolution dataset is created during export from the GS. The export is in a CARIS compatible format (*.CAF) and includes accepted data. Data is imported into CARIS HIPS in order to create a dataset in HDCS format. Data is delivered in the HDCS format. Data is stored to centimeter precision and is in meters. Soundings are not rounded.

BASE Surface:
The BASE Surface is created using the Uncertainty BASE Surface option in CARIS HIPS using a resolution of 3m.

S-57 feature file:
The S-57 feature file contains features such as rocks, islets, MHW line (both natural and man made coastline), MLLW line, delineation of coverage gaps and cultural features, and has replaced the traditional smooth sheet. All features have been generated and attributed using CARIS BASE Editor software.

MHW and MLLW lines have been interpolated and edited where necessary using CARIS. The BASE Surface has been used as the source for the interpolation of linework.

The MHW line was also quality controlled against publicly available imagery to check for correct interpolation of the data, particularly in areas of where cultural features were present.

Rocks were identified using the measured data and BASE Surface and then flagged in CARIS HIPS. The features were created as S-57 objects and attributed using CARIS BASE Editor.

All S-57 objects created in BASE Editor were exported to an S-57 feature file (*.000) as the final step.

B.12.2 File Naming

File names for all items output by the GS are constructed as follows:

<RegistryNumber> . <Extension>
where <Extension> is derived from the data type as per the following table:

Ext	Data Type	File format
.txt	File containing GS export parameters	TXT
.caf	LADS MkII CARIS Output Data	CARIS compatible format
.cbf	LADS MkII Waveform Data	CARIS compatible format

File names for all items output by CARIS are constructed as follows:

<RegistryNumber> . <Extension>
where <Extension> is derived from the data type as per the following table:

Ext	Data Type	File format
.000	S-57 feature file	.000 Ed 3.1
.hns	CARIS HYDROGRAPHIC NAVIGATION SURFACE	CARIS BASE Surface Format
.xml	CARIS BASE Surface parameters file	XML (Extended Markup Language)

B.12.3 Summary of Digital Deliverables

A directory listing of each digital deliverable is provided at Appendix II.

C. CORRECTIONS TO SOUNDINGS

The optics and electronics for laser transmission and reflected waveform collection for all soundings is done by equipment mounted on a stabilized platform within the aircraft. This platform is stabilized by a servo system, with information provided from the AHRS. This minimizes the motion effect (roll and pitch) of the aircraft. All attitude residuals from the local horizontal are logged by the AS for correctional processing by the GS.

Sounding depths and positions are determined in the GS from the raw laser waveform, aircraft height, platform attitude parameters and GPS, as logged by the AS.

The GS automatically corrects soundings for aircraft height and heading, offsets between sensors, latency, mirror and platform angles, sea surface model errors, refraction of the laser beam at the sea surface, the effects of scattering of the beam in the water column and reduction for tide.

Correct operation of the system is verified by static and dynamic position checks, depth benchmark comparisons, analysis of overlaps from the 100% coverage of the seabed and crossline comparison results.

All laybacks are measured relative to the survey reference position on the aircraft, which is the center of the scanning mirror. The GPS antenna used for position determinations in the AS is located on the upper side of the aircraft fuselage, forward and to the left of the sounding reference position (refer to Figure 19). The signal from this antenna is passed to a splitter, one signal going to the GPS receiver in the Navigation Systems computer of the AS and the other passes to the GPS airborne logger.

Offsets are from the sounding reference point to the GPS antenna with the following axis and sign convention:

- X positive, toward the nose of the aircraft
- Y positive, to the left, facing forward
- Z positive, vertically up

The offsets are:

- X offset: + 1.895m
- Y offset: + 0.43m
- Z offset: + 2.45m

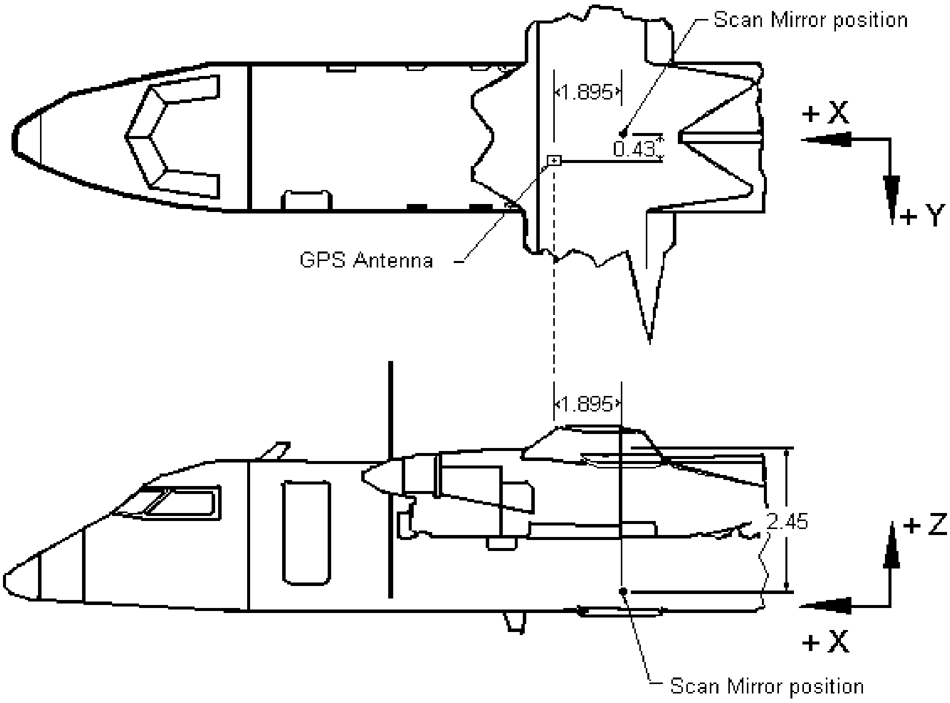


Figure 19 – Laybacks

D. APPROVAL SHEET

LETTER OF APPROVAL – OPR-H328-KRL-08

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the accomplishment of this survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and the accompanying digital data have been closely reviewed and are considered complete and adequate as per the Statement of Work.

Report	Submission Date
Data Acquisition and Processing Report	April 27, 2009

Mark Sinclair
Hydrographer
Tenix LADS, Inc.

Date: April 27, 2009

APPENDIX I – LADS MK II GROUND SYSTEM OUTPUT FORMAT SPECIFICATION FOR CARIS

This is a controlled document.

Copy No:
Issue No: 1.00

LADS Mark II

Ground System
Output Format Specification
for CARIS

Document Number: LADS2A05.001.008

Authorised by: ______________________

Date: 06/05/2003

Tenix LADS Corporation

Tenix

Amendment Status

As necessary, authorised amendments will be issued to holders of this document. Amendments will take the form of replacement or additional pages.
The amendment status appears at the top right side of each page. For instance, Issue 1.00, where 1 is the Issue and 00 is the Amendment. The next amendment change would appear as 1.01.
Upon receipt, amendment pages are to be inserted in this document and superseded pages removed. For each amendment incorporated, the amendment number, date of incorporation and the signature of the amending officer must be entered in the table below.

Amendment Number	Date Incorporated	Entered By

List of Effective Pages

CONTENTS

1. Introduction

1.1 Purpose

The purpose of this document is to specify the format produced by the **Output CARIS Data Function** of the Laser Airborne Depth Sounder (LADS) Mk II Ground System (GS).

1.2 Scope

The document applies to the results generated by the **Output CARIS Data Function** of the LADS Mk II Ground System.

1.3 Definitions, Acronyms and Abbreviations

1.3.1.1 Definitions

Mission	A mission is defined as a continuous period of operation of the LADS Mk II System, with the objective of conducting a survey of an area of ocean defined by the customer. Individual survey flights are called sorties.
Easting & Northing	The aircraft position is expressed in metres North and East of the false origin on the Universal Transverse Mercator (UTM) Grid. This implies that a change in easting and northing represents a corresponding movement on the earth's surface expressed in metres. Note: The changes in eastings and northings are related to changes in latitude and longitude via complex translation equations.
Julian Day	The numerical day of the year i.e. January 1 is day 1 and February 28 is day 59.
Soundings	Soundings consist of depth information that results from laser events and, position information corresponding to GPS data. The waveform as seen on the displays is a composite of the Green and IR returns. The soundings, numbered 1 to 48 for each scan, are always numbered from the starboard side.
Survey Run	This is the part of the survey objective where depth soundings are taken.
Fairchart	Hardcopy plot of bathymetric survey data. The soundings appearing on the fairchart are the sub-set of soundings that have the field "Fairchart Selected" set to "Y".
No Bottom At (NBA)	These are secondary soundings where the seabed has not been detected by the Ground System, and a NBA depth has been assigned by a Hydrographic Survey Operator. The depth value assigned is the depth

which, in the opinion of the Hydrographic Survey Operator has been swept clear by laser, with depths less than this being detected by the system

1.3.1.2 Acronyms

AS	Airborne System
GS	Ground System
GPS	Global Positioning System
LADS	Laser Airborne Depth Sounder
UTC	Universal Time Coordinated
NBA	No Bottom At
UTM	Universal Transverse Mercator
NBD	No Bottom Detected

1.3.1.3 Abbreviations

Nil

1.4 References

Glossary of LADS Terminology	0006A00005

2. GS Output Format

2.1 Overview

When the **Output CARIS Data Function** is run the results take the form of two files per run:

1 An ASCII file with CAF(CARIS ASCII Format) extension,
2 A Binary file with CBF (CARIS Binary Format) extension.

Each file name has the following structure:

- a 1-12 character prefix (prompted for in the GS),
- followed by an underscore, and then
- 7-14 digits that describe in the following order; the run number (1-4 digits), an underscore, run segment (1-2 digits), an underscore, run sequence (1-2 digits), an underscore and run child (1-2 digits).

The maximum length of the filenames including the extension is 30 characters.

For example, if the operator enters a filename of OTWAY, then for run 1020.0.1.2, the two output files will be called:

“OTWAY_1020_0_1_2.CAF”, and

“OTWAY_1020_0_1_2.CBF”.

A GS tableau option allows for the CAF files to be kept together in a single file or spread over one file per run. In the case of the single file the filename will be of the form “OTWAY.CAF”. Binary files will always be separate.

The structure of an ASCII file is shown in Figure 2-1 below, with the components being described in the following sections.

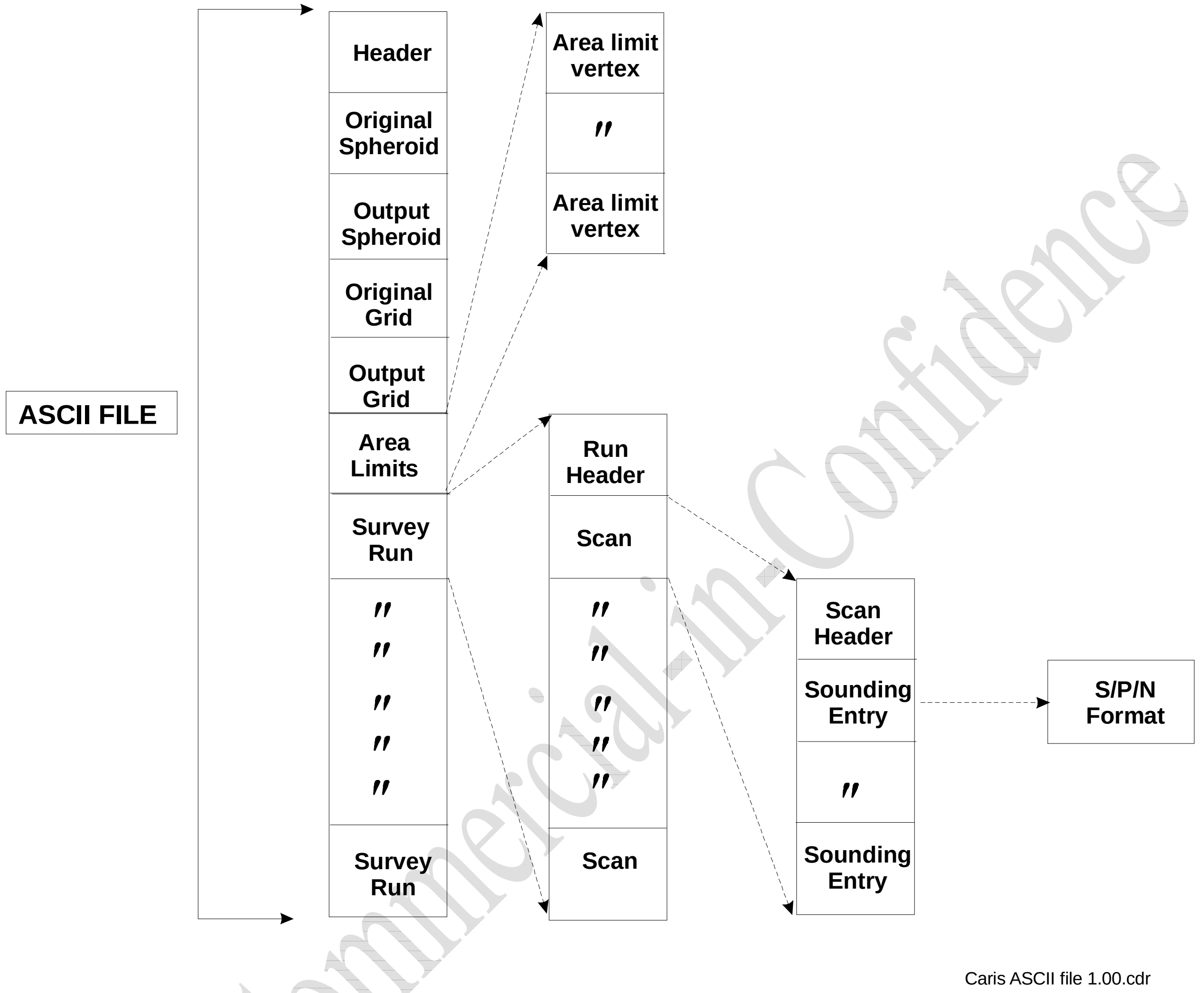


Figure 2-1 Structure of the ASCII file from the Output CARIS Data Function

2.2 Output Information

2.2.1 Header

The information associated with the **Header** output is listed below.

Name	Format	Range	Comments
Header identifier	X(3)	HCA	Header of CARIS ASCII format
Specification Issue	F(5,2)		Issue number of the specification
Mission title	X(40)		
Mission ident number	D(3)	1.. 999	
Time of data output	D(7)		Julian date, formatted as dddyyyy
Data scope	X(1)	S,P,A	S – All secondary soundings, P – All Primary soundings. A – All Primary soundings, including soundings where the sea bed was not found (NBD)
NBA included	X(1)	Y, N	This flag indicates that soundings marked as “No Bottom At” have been included.
Clash Range Radial	D(3)	0 .. 550	Represents the minimum distance in metres between soundings. Soundings contained in the fairchart are identified with the “fairchart selected” flag in the sounding data. If no reduction processing was performed this value will be 0, and the “fairchart selected” flag will be set true for all soundings.
Position transform applied	X(1)	Y, N	This flag indicates that positions used in this data have been transformed to a spheroid or grid different to that used to collect the data. The values for the original and output spheroid/grid are detailed below.

Table 1 Header Output Information

The format of the information associated with the **Header** output is as shown below:

Format
X(3) ∧F(5,2) ∧X(40) ∧D(3) ∧D(7) ∧X(1) ∧X(1) ∧D(3) ∧X(1)←

Table 2 Format of Header Information

2.2.2 Original/Output Spheroid

The information associated with the **Original/Output Spheroid** output is listed below.

Name	Format	Range	Comments
Spheroid entry identifier 1	X(2)	C1,D1	C – Original, D – Output.
Spheroid ident text	X(40)		
Spheroid entry identifier 2	X(2)	C2,D2	C – Original, D – Output.
Major semi axis	F(10,2)	6_300_000.0 .. 6_500_000.0	
Minor semi axis	F(10,2)	6_300_000.0 .. 6_500_000.0	
Flattening	F(9,6)	250.0 .. 350.0	
Eccentricity	F(14,12)	0.006 .. 0.0075	
Spheroid entry identifier 3	X(2)	C3,D3	C – Original, D – Output.
GPS X offset	F(8,2)	-1000.0 .. 1000.0	The following "GPS" prefixed fields represent the transformation parameters required to move from the WGS84 spheroid to this spheroid.
GPS Y offset	F(8,2)	-1000.0 .. 1000.0	
GPS Z offset	F(8,2)	-1000.0 .. 1000.0	
GPS X rotation	F(10,5)	-206.0 .. 206.0	Uses the Coordinate Axis Rotation sign convention. (ie. rotations effect the axis). A positive rotation is defined as clockwise when viewed from the origin along the axis. (eg for a given position, a positive rotation about the Z axis will result in the transformed position having a longitude with a smaller value)
GPS Y rotation	F(10,5)	-206.0 .. 206.0	see above
GPS Z rotation	F(10,5)	-206.0 .. 206.0	see above
GPS Scale factor	F(8,5)	-1.0 .. 1.0	

Table 3 Output Information for Original/Output Spheroid

The format of the information associated with the **Original/Output Spheroid** output is as shown below:

Format
X(2) ∧X(40) ←
X(2) ∧F(10,2) ∧F(10,2) ∧F(9,6) ∧F(14,12) ←
X(2)∧F(8,2) ∧F(8,2) ∧F(8,2) ∧ F(10,5) ∧ F(10,5) ∧ F(10,5) ∧F(8,5) ←

Table 4 Format of Original/Output Spheroid Information

2.2.3 Original/Output Grid

The information associated with the **Original/Output Grid** output is listed below.

Name	Format	Range	Comments
Grid Entry Identifier	X(2)	F1,G1	F – Original, G – output
Grid ident text	X(20)		
Latitude of true origin	D(3)	-90 .. 90	
Central meridian longitude	D(4)	-180 .. 180	
Zone identifier	X(2)	1 .. 60, SP	1 .. 60 – UTM Zone identifier. SP – identifies a non-standard (special) zone.
False origin easting	D(8)	-5_000_000 .. 5_000_000	
False origin northing	D(9)	-10_000_000 .. 20_000_000	
Central scale factor	F(7,4)	0.5 .. 1.5	

Table 5 Output Information for Original/Output Grid

The format of the information associated with the **Original/Output Grid** output is as shown below:

Format
X(2) ∧X(20) ∧D(3) ∧D(4) ∧X(2) ∧D(8) ∧D(9) ∧F(7,4) ←

Table 6 Format of Original/Output Grid Information

2.2.4 Area Limits

The information associated with the **Area Limits** output is listed below.
There can be up to 10 vertices defining and area, with these vertices being numbered from 0-9. Lines are only output for vertices that have been defined. i.e. for a rectangle only 4 vertices are output.
The polygon points are ordered in a clockwise fashion, and the polygon is not closed geometrically. The coordinates are relative to the output spheroid and grid systems.

Name	**Format**	**Range**	**Comments**
Area limits identifier 1	X(2)	L0	Entry identifier for polygon point 1
Lat	F(12,8)	-90.0 .. 90.0	
Long	F(13,8)	-180.0 .. 180.0	
Easting	D(8)	-5_000_000 .. 5_000_000	
Northing	D(9)	-10_000_000 .. 20_000_000	
…			
Area limits identifier **n**	X(2)	L[**n-**1]	Entry identifier for polygon point **n**
Lat	F(12,8)	-90.0 .. 90.0	
Long	F(13,8)	-180.0 .. 180.0	
Easting	D(8)	-5_000_000 .. 5_000_000	
Northing	D(9)	-10_000_000 .. 20_000_000	
Where **n** = 1 .. 10			

Table 7 Output Information for Area Limits

The format of the information associated with the **Area Limits** output is as shown below:

Format
X(2) ∧F(12,8) ∧F(13,8) ∧D(8) ∧ D(9) ←

Table 8 Format of Area Limits Output

2.2.5 Run Header

The information associated with the **Run Header** output is listed below.

Name	Format	Range	Comment
Run header identifier	X(2)	R1	
Run identifier	X(14)		The run identifier has a format as follows: Run.section.sequence.child (eg. 100.0.1.1) Where Run = run number Section = section number of main run. Used when a section of the run is reflown. Sequence = identifies the nth flown occurrence of the same run Child = portion of run accepted manually by hydrographic selection
Date flown	D(7)		Julian Date, formatted as dddyyyy
Planned Track	D(3)	0 .. 360	The planned track of the run in degrees, expressed as a grid bearing
Status	X(9)	ACCEPTED, ANOMALOUS or REJECTED	The run status of the child run.

Table 9 Output Information for Run Header

The format of the information associated with the **Run Header** output is as shown below.

Format
X(2) ∧X(14) ∧D(7)∧D(3)∧X(9)←

Table 10 Format of Run Header Output

2.2.6 Scan Header

The information associated with the **Scan Header** output is listed below.

Name	Format	Range	Comment
Scan header identifier	X(2)	W1	
Scan Reference Position lat - output spheroid	F(12,8)	-90.0 .. 90.0	Corresponds to position of sounding at column 24 in the Output Spheroid. Expressed in degrees.
Scan Reference Position long - output spheroid	F(13,8)	-180.0 .. 180.0	Corresponds to position of sounding at column 24 in the Output Spheroid. Expressed in degrees.
Time - year	D(4)	0 .. 9999	
Time – Julian Day	D(3)	1 .. 366	
Time – Hour	D(2)	0 .. 23	
Time – Minute	D(2)	0 .. 59	
Time – Second	D(2)	0 .. 59	
Scan Row Number	D(2)	1 .. 18	The Scan Number can be considered as a time component, (1/18th) of a second
Tide Correction	F(6,2)	-20.00 .. 20.00	Represents the tide adjustment made to the observed depth to give the sounding Depth relative to the LAT datum.

Table 11 Output Information for Scan Header

The format of the information associated with the **Scan Header** output is as shown below.

Format
X(2) ∧F(12,8) ∧F(13,8) ∧D(4) ∧D(3) ∧D(2) ∧D(2) ∧D(2) ∧D(2) ∧F(6,2) ←

Table 12 Format of Scan Header Output

2.2.7 Sounding Entry (S, P, N)

The information associated with the **Sounding Entry** output is listed below.

Name	Format	Range	Comments
Sounding identifier	X(1)	S,P,N,X	S - secondary sounding, P - primary sounding, N - NBA sounding, X – NBD sounding.
Selected Depth Position lat - output spheroid	F(12,8)	-90.0 .. 90.0	Expressed in degrees.
Selected Depth Position long - output spheroid	F(13,8)	-180.0 .. 180.0	Expressed in degrees.
Selected Depth Position Easting - output spheroid	D(8)	-5_000_000 .. 5_000_000	
Selected Depth Position Northing - output spheroid	D(9)	-10_000_000 .. 20_000_000	
Contender Depth Position lat - output spheroid	F(12,8)	-90.0 .. 90.0	Expressed in degrees. 0.0 when no contender exists.
Contender Depth Position long - output spheroid	F(13,8)	-180.0 .. 180.0	Expressed in degrees. 0.0 when no contender exists.
Contender Depth Position Easting - output spheroid	D(8)	-5_000_000 .. 5_000_000	0 when no contender exists.
Contender Depth Position Northing	D(9)	-10_000_000 .. 20_000_000	0 when no contender exists.

Name	Format	Range	Comments
- output spheroid			
Frame	D(4)	1..1749	Frame number
Row	D(2)	1..18	Scan number
Column	D(2)	1..48	Sounding number
Selected Depth	F(6,2)	-99.99 .. 99.99	Selected Depth to tide datum (includes tide correction) in metres 99.99 when no depth was detected
Contender Depth	F(6,2)	-99.99 .. 99.99	Contender Depth to tide datum (includes tide correction) in metres 99.99 when no depth was detected
Flag	D(1)	0..255	Validation flag from LADS Ground System (see Table 15 – Validation Flag bit values)
Comment	X(10)		Operator comment
Spare	X(10)		Spare field for future expansion

Table 13 Output Information for Sounding Entry

The format of the information associated with the **Sounding Entry** output is as shown below.

Format
X(1) ∧F(12,8) ∧F(13,8) ∧D(8) ∧D(9) ∧ F(12,8) ∧F(13,8) ∧D(8) ∧D(9) ∧D(4) ∧D(2) ∧D(2) ∧F(6,2) ∧F(6,2) ∧D(1) ∧X(10) ∧X(10)←

Table 14 Format of Sounding Entry Output

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
spare	Clashed	Converted NBD	Manual Secondary	Swapped Contenders	Significant Contender	Excessive Gradient	Depth Edited

Table 15 – Validation Flag bit values

2.3 ASCII Format Legend

The legend for the symbols used in the format tables is listed below.

Symbol	Description	Comments
X	Text	
D(max_size)	Integer	Max_size represents the maximum number of characters allowed for the integer, including a leading minus sign if appropriate.
F(max_size,aft_digits)	Float	Max_size represents the maximum number of characters allowed for the float, including a leading minus sign if appropriate. Aft_digits represents the number of digits after the decimal point. Eg “ -10.000” would be represented as F(7,3)
^	Field separator	May be comma, space, tab.
←	Line terminator	(may be <CR><LF>, <LF>, <CR>)

Table 16 ASCII Format Legend

2.4 Binary Waveform Format

Raw waveform data is provided in a binary file in the following format.

2.4.1 Header

The information associated with the **Binary File Header** is listed below.

Name	Format	Minimum value	Maximum Value	Comments
Header identifier	ASCII(3)	HCB		Header identifier for Caris Binary file
Specification Issue major issue number	uchar	0	255	1
Specification Issue minor issue number	uchar	0	255	0
Mission Title	ASCII(40)	0	255	A string of 40 ASCII characters as per 2.2.1 Header. String is space padded.
Run Identifier	ushort	1	9 999	LADS run number range 1..9 999
Run Segment	uchar	0	99	LADS run segment number range 0..99
Run Sequence	uchar	0	99	LADS run sequence number range 0..99
Run Child	uchar	0	99	LADS run child number range 0..99

Table 17 Binary File Header

2.4.2 Scan Header

The information associated with the **Binary Scan Header** is listed below.

Name	**Format**	**Minimum value**	**Maximum Value**	**Comments**
Scan header identifier	ASCII(2)	W1		
Time - year	ushort	0	9999	
Time – Julian Day	ushort	1	366	
Time – Hour	uchar	0	23	
Time – Minute	uchar	0	59	
Time – Second	uchar	0	59	

Table 18 Binary Scan Header

2.4.3 Waveform

The information associated with the **Waveform** is listed below.

Name	Format	Minimum value	Maximum Value	Comments
Waveform identifier	ASCII(2)	WF		Waveform identifier
Frame	ushort	1	1 749	LADS frame number range 1..1 749
Row	uchar	1	18	LADS scan number range 1..18
Column	uchar	1	48	LADS sounding number range 1..48
Selected Depth Index	uchar	0	255	Index into the waveform indicating position of the selected depth
Contend Depth Index	uchar	0	255	Index into the waveform indicating position of the contending depth. 0 indicates no contender
Waveform Sample 1	uchar	0	255	1st sample of the digital waveform
Waveform Sample 2	uchar	0	255	2nd sample of the digital waveform
. . .				
Waveform Sample 120	uchar	0	255	120th sample of the digital waveform

Table 19 Binary Waveform

2.5 Binary Format Legend

The legend for additional symbols used in the format tables is shown below.

Symbol	Description	Minimum value	Maximum Value	Binary Size (bytes)
ASCII	ASCII character	0	255	1
ushort	Unsigned 16 bit Integer	0	65 535	2
uchar	Unsigned 8 bit Integer	0	255	1

Table 20– Binary Format Legend

APPENDIX II – LISTING OF DIGITAL DATA ON THE USB HARD DRIVE

OPR-H328-KRL-08

<USB Drive Letter>:\OPR-H328-KRL-08\Report_Files\

Reference	**Remarks**
Cover	Adobe Acrobat PDF and MS Word 2003
DA&P_Report	Adobe Acrobat PDF and MS Word 2003
DA&P_Report_Appendix_<I-III>	Adobe Acrobat PDF and MS Word 2003
H&V_Control_Report	Adobe Acrobat PDF and MS Word 2003
H&V_Control_Report_Appendix_<I-IV>	Adobe Acrobat PDF and MS Word 2003
Separates_Report	Adobe Acrobat PDF and MS Word 2003
Separates_Report_Appendix_I	Adobe Acrobat PDF and MS Word 2003
Spine	Adobe Acrobat PDF and MS Word 2003

<USB Drive Letter>:\OPR-H328-KRL-08\Tidal_Data\

Reference	**Remarks**
8723214_VIRGINIA_KEY_verified_MLLW_ smoothed	.txt file containing verified tides for Virginia Key supplied by JOA
Sortie_<sortie number>\Sortie_<sortie number>	.xls file containing; a. preliminary tides b. final tides for the tide application for each sortie
Tide_application_reports\TIDE_APPLICATION _REPORT_sortie_<*sortie number*>	.txt file of the Sortie Tide Application Report output from the GS
Tide_monitor_data\Sortie_<*sortie number*>\TIDE_MONITOR_DATA_REPORT_ sortie<*sortie number*>_ts<*tide station number*>	.txt file of the TIDE_MONITOR_ DATA_REPORT output from the GS

H11868

<USB Drive Letter>:\OPR-H328-KRL-08\H11868\Report_Files

Reference	**Remarks**
H11868_Descriptive_Report_Cover	Adobe Acrobat PDF and MS Word 2003
H11868_Descriptive_Report	Adobe Acrobat PDF and MS Word 2003
H11868_Descriptive_Report_Appendix_<I–V>	Adobe Acrobat PDF and MS Word 2003
H11868_Descriptive_Report_Spine	Adobe Acrobat PDF and MS Word 2003

<USB Drive Letter>:\ OPR-H328-KRL-08\ H11868\BASE_Surface\

Reference	**Remarks**
H11868_3m_FINAL.hns	CARIS BASE Surface file
H11868_3m_FINAL.xml	XML parameters file

<USB Drive Letter>:\ OPR-H328-KRL-08\ H11868\Chart_Comparisons\

Reference	**Remarks**
H11868_ChartComp.xls	Microsoft Excel 2003
H11868_Chartcomp.hob	CARIS.hob file
Screendumps\08_4fl_gs_tags_chartcompD… <chart_comparison_number>_<la/wf>.jpg	Screen captures for each chart comparison

<USB Drive Letter>:\ OPR-H328-KRL-08\H11868\Data\

Reference	**Remarks**
Vessel\H11868.hvf	CARIS vessel file
H11868_V1.caf	LADS MKII CARIS output
H11868_V1_<LineNumber>_<Section>_... …<Sequence>_<Child>.cbf	LADS MKII Waveform data
Params.txt	.txt file

H11868 (cont.)

<USB Drive Letter>:\ OPR-H328-KRL-08\H11868\HDCS_Data\

Reference	Remarks
H11868\ H11868\<Year-Julian Day>\ <LineNumber>	CARIS HDCS data. Project\Vessel\Day\Line format

<USB Drive Letter>:\ OPR-H328-KRL-08\ H11868\Lidar_Coverage\

Reference	Remarks
H11868_Shoal.tif	Geotif file
H11868_Uncertainty.tif	Geotif file

<USB Drive Letter>:\ OPR-H328-KRL-08\H11868\S57_Feature_File\

Reference	Remarks
US511868.000	S-57 feature file

H11869

<USB Drive Letter>:\OPR-H328-KRL-08\H11869\Report_Files

Reference	Remarks
H11869_Descriptive_Report_Cover	Adobe Acrobat PDF and MS Word 2003
H11869_Descriptive_Report	Adobe Acrobat PDF and MS Word 2003
H11869_Descriptive_Report_Appendix_<I–V>	Adobe Acrobat PDF and MS Word 2003
H11869_Descriptive_Report_Spine	Adobe Acrobat PDF and MS Word 2003

<USB Drive Letter>:\ OPR-H328-KRL-08\ H11869\BASE_Surface\

Reference	Remarks
H11869_3m_FINAL.hns	CARIS BASE Surface file
H11869_3m_FINAL.xml	XML parameters file

<USB Drive Letter>:\ OPR-H328-KRL-08\ H11869\Chart_Comparisons\

Reference	Remarks
H11869_ChartComp.xls	Microsoft Excel 2003
H11869_Chartcomp.hob	CARIS.hob file
Screendumps\08_4fl_gs_tags_chartcompD… <chart_comparison_number>_<la/wf>.jpg	Screen captures for each chart comparison

<USB Drive Letter>:\ OPR-H328-KRL-08\H11869\Data\

Reference	Remarks
Vessel\H11869.hvf	CARIS vessel file
H11869_V1.caf	LADS MKII CARIS output
H11869_V1_<LineNumber>_<Section>_... …<Sequence>_<Child>.cbf	LADS MKII Waveform data
Params.txt	.txt file

H11869 (cont.)

<USB Drive Letter>:\ OPR-H328-KRL-08\H11869\HDCS_Data\

Reference	**Remarks**
H11869\ H11869\<Year-Julian Day>\ <LineNumber>	CARIS HDCS data. Project\Vessel\Day\Line format

<USB Drive Letter>:\ OPR-H328-KRL-08\ H11869\Lidar_Coverage\

Reference	**Remarks**
H11869_Shoal.tif	Geotif file
H11869_Uncertainty.tif	Geotif file

<USB Drive Letter>:\ OPR-H328-KRL-08\H11869\S57_Feature_File\

Reference	**Remarks**
US511869.000	S-57 feature file

NB: The list of reports and survey data deliverables in this Appendix will be amended as each survey, H11870 to H12008, is delivered and will be supplied as a separate Word document.

APPENDIX III – LADS MKII PERFORMANCE VERIFICATION CERTIFICATE

Tenix

TenixLADSCorporation

LADS Mk II Performance Verification Certificate

Quality System

Quality Endorsed Company ISO9001 Lic20782

The LADS Mk II System was flown for system performance verification over Gulf St Vincent, South Australia, Sorties 3 to 10, during March 2007.

A well-surveyed benchmark run was used to verify depth and position, with the latter by using submerged targets at known positions in the benchmark area. The system performance was verified as meeting the requirements of IHO Order 1 depth and horizontal accuracy.

Approving Authority: M. Penley 2 / 8 / 07

Mark Penly, Technical Manager