NOAA FORM 76-35A

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-O167-KR-03

Registry No. H11209

LOCALITY

State Alaska

General Locality Chatham and Sumner Straits

Sublocality Spanish Islands and Decision Passage

2003

HYDROGRAPHER	**CHIEF OF PARTY**
MARK SINCLAIR	DARREN STEPHENSON

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NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION **HYDROGRAPHIC TITLE SHEET**	REGISTRY NO. **H11209**
INSTRUCTIONS – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office	FIELD NUMBER. **N/A**
State: Alaska	
General Locality: Chatham and Sumner Straits	
Sublocality: Spanish Islands and Decision Passage	
Scale: 1:10,000	**Date of Survey:** May 15 to June 27, 2003
Instructions dated: March 18, 2003	**Project No:** OPR-O167-KR-03
Vessel: Tenix LADS Aircraft, VH - LCL	
Hydrographer: M.J. Sinclair	**Chief of Party:** D.J. Stephenson
Surveyed by: G.K. Stringfellow, H.E. Parker, M.S. Hawkins	
Soundings taken by echo sounder, hand lead, pole: Laser Airborne Depth Sounder	
Graphic record scaled by: N/A	
Graphic records checked by: N/A	
Protracted by: N/A	**Automated plot by:** HP Design Jet 800ps
Verification by:	
Soundings in: Fathoms at MLLW	
REMARKS: Contract No. DG133C-03-CQ-0011 **Contractor:** Tenix LADS Incorporated, 2548 Beach Blvd, Biloxi, MS, 39531 **Subcontractor:** John Oswald and Associates, 12001 Audubon Dr., Anchorage, AK, 99516 **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.	
All times are recorded in UTC	
Projection is UTM Zone 8	

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A. EQUIPMENT

The LADS Mk II hydrographic survey system comprises two main sub-systems: the Airborne System (AS) used for acquiring raw bathymetric data, and the Ground System (GS) which is used to plan operations, calculate depth values from the raw data, provide tools which allow the hydrographic surveyor to validate processed depth values, apply tidal corrections, generate smooth sheets and digital survey data and conduct general survey management. These two sub-systems are complemented by other tools required for quality control activities, in particular contouring and 3-D visualization software. The general data flow between the sub-systems and tools is illustrated in Figure 1.

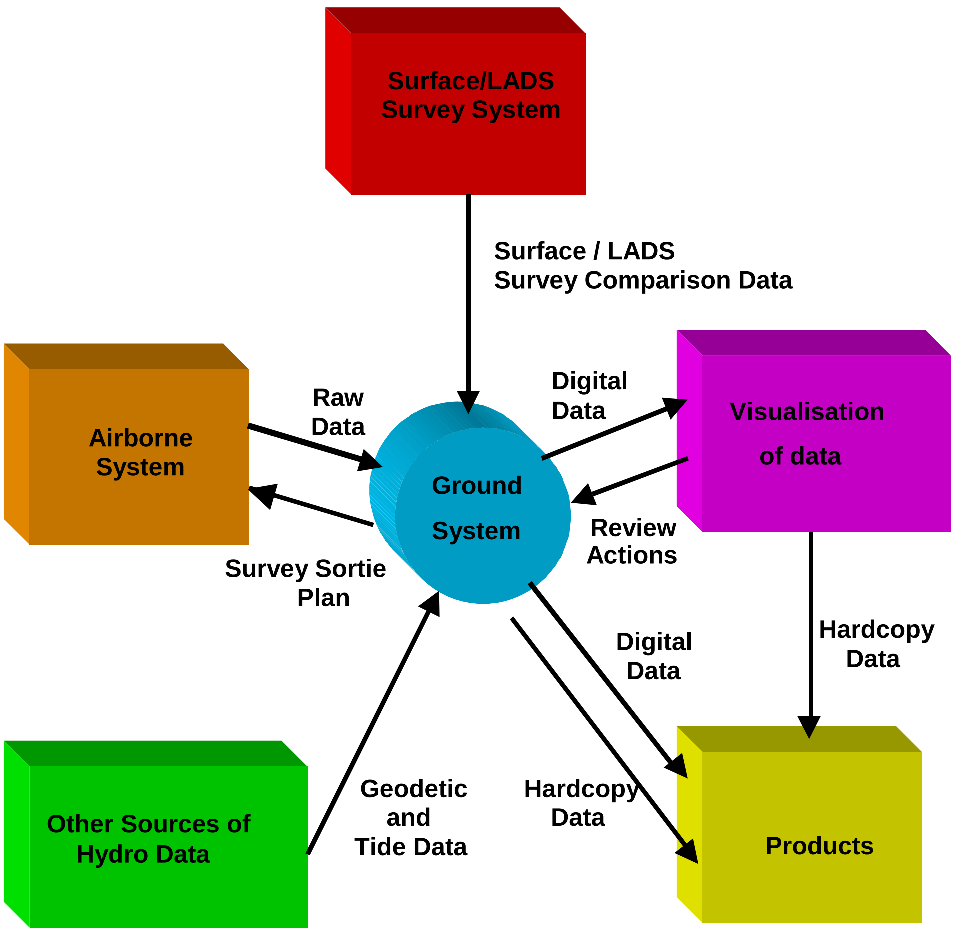


Figure 1 – General data flow within LADS Mk II

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 controlled via servo systems using information from an Attitude and Heading Reference System (AHRS) mounted on the platform. Aircraft position information is obtained from the Global Positioning System. 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:

- The System Control Computer (SCC) for operator interface, logging and overall system coordination,
- The Navigation System and Support (NSS) computer for position monitoring and control, and
- 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.

Ancillary equipment includes:

- A downward video camera and VCR to provide images below the aircraft and a forward looking video camera.
- Systems for temperature control of equipment.
- VHF transceiver and aircraft intercom.

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 equipment and their function are given under the following headings:

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

A.1.1 Sounding Equipment

Soundings in the LADS Mk II system are obtained by the transmission of laser pulses from the aircraft through a scanning system and 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. A 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, subsurface and seabed and is used to determine water depth. The green return is transmitted via the scanner into a photomultiplier tube. The electronic output of the two return signals are electronically mixed prior to digitization.
- Attitude and Heading Reference System (AHRS). The AHRS is a laser gyro inertial navigation system providing platform attitude information to the platform servo system that in turn maintains platform stability. 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 System Control Computer (SCC) where it is logged to digital linear tape.
- Waveform Display. This CRT display presents the operator with sounding waveforms as digitized and is used by the operator to check data quality during acquisition.

A.1.2 Position 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 Laybacks.

The signal from the 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 to record GPS data for calculating KGPS 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 computer for logging.

Two GPS receivers are used on the aircraft. An Ashtech GG24 single frequency GPS receiver is used to provide positioning of the aircraft and an Ashtech Z12 dual frequency GPS receiver is used to compute post-processed positions. The data from this receiver is independently logged and post-processed.

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 and grid parameters and a list of survey objectives including the line number, start/end coordinates and coordinates for navigation checks. During the course of the sortie the airborne operator amends the sequence of execution to suit local conditions and can amend the scan pattern parameters for the survey lines to suit survey requirements.

The SC computer controls the sequence of survey operations by:

- Planning all required flight paths and communicating these to the NSS.
- Transmitting required parameters for scan patterns 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 at any time and the sequence of objectives may be amended 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 position 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 operations can be impacted by both low cloud and high ground in the survey area. LADS Mk II is able to operate at different survey heights so that adequate clearances can be maintained while surveying and survey activities can continue below low cloud ceilings. Survey altitudes at 200ft increments are available from 1200 to 2200 feet

(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. The images as recorded are used as supplemental information during sounding validation.

A forward looking video camera is also provided to assist the Airborne Systems Operator evaluate conditions ahead of the aircraft.

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 is displayed each of the mixed red/green sounding return signals as digitized by the LCA (the traces are overlayed). 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 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, S/N ratio 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.

A.1.6 Depth and Topographic Mode

During normal bathymetric survey mode (Depth Mode) LADS Mk II 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 Mk II to obtain topographic heights up to 50 meters above mean sea level.

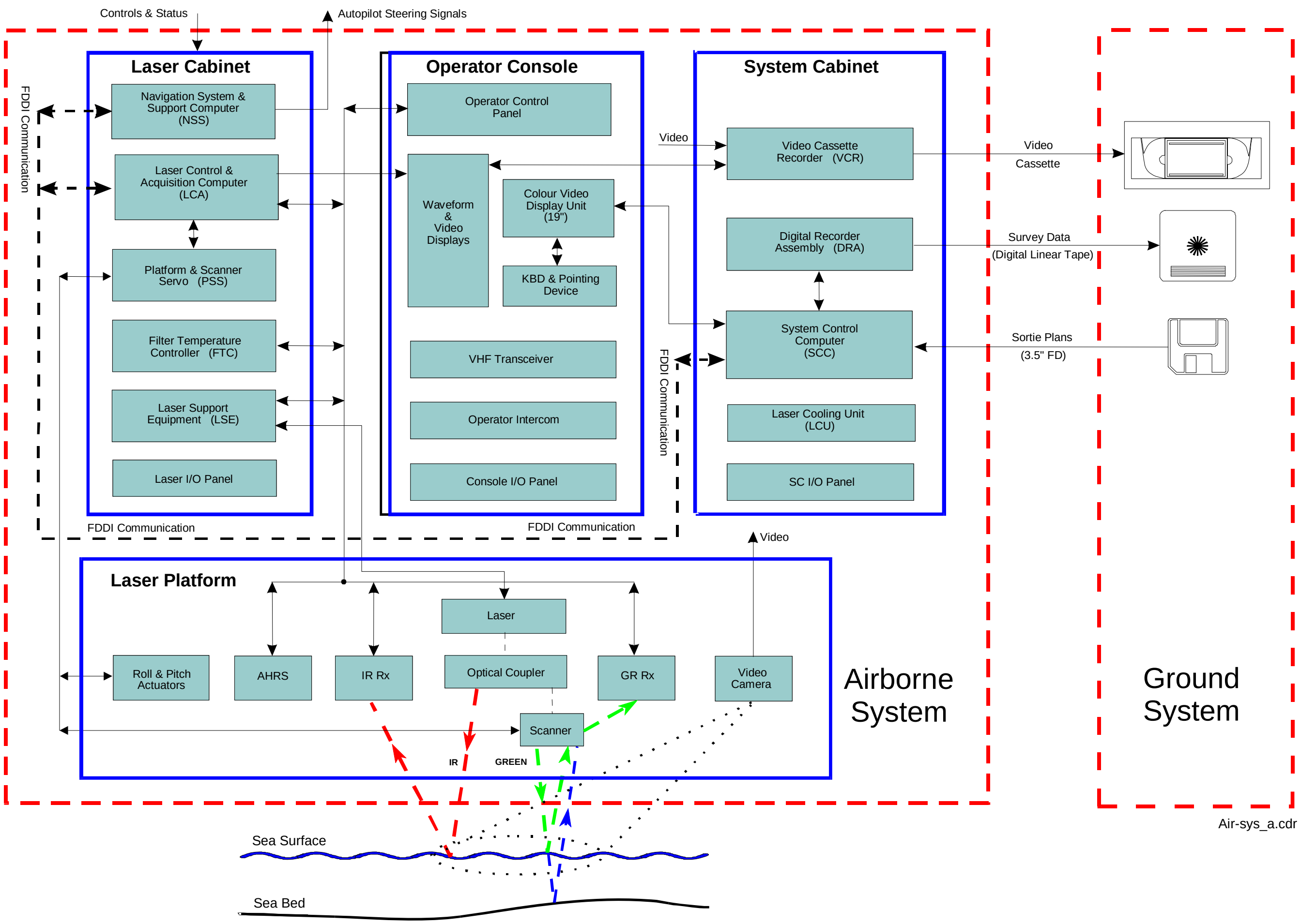


Figure 2- Airborne System Functional Block Diagram

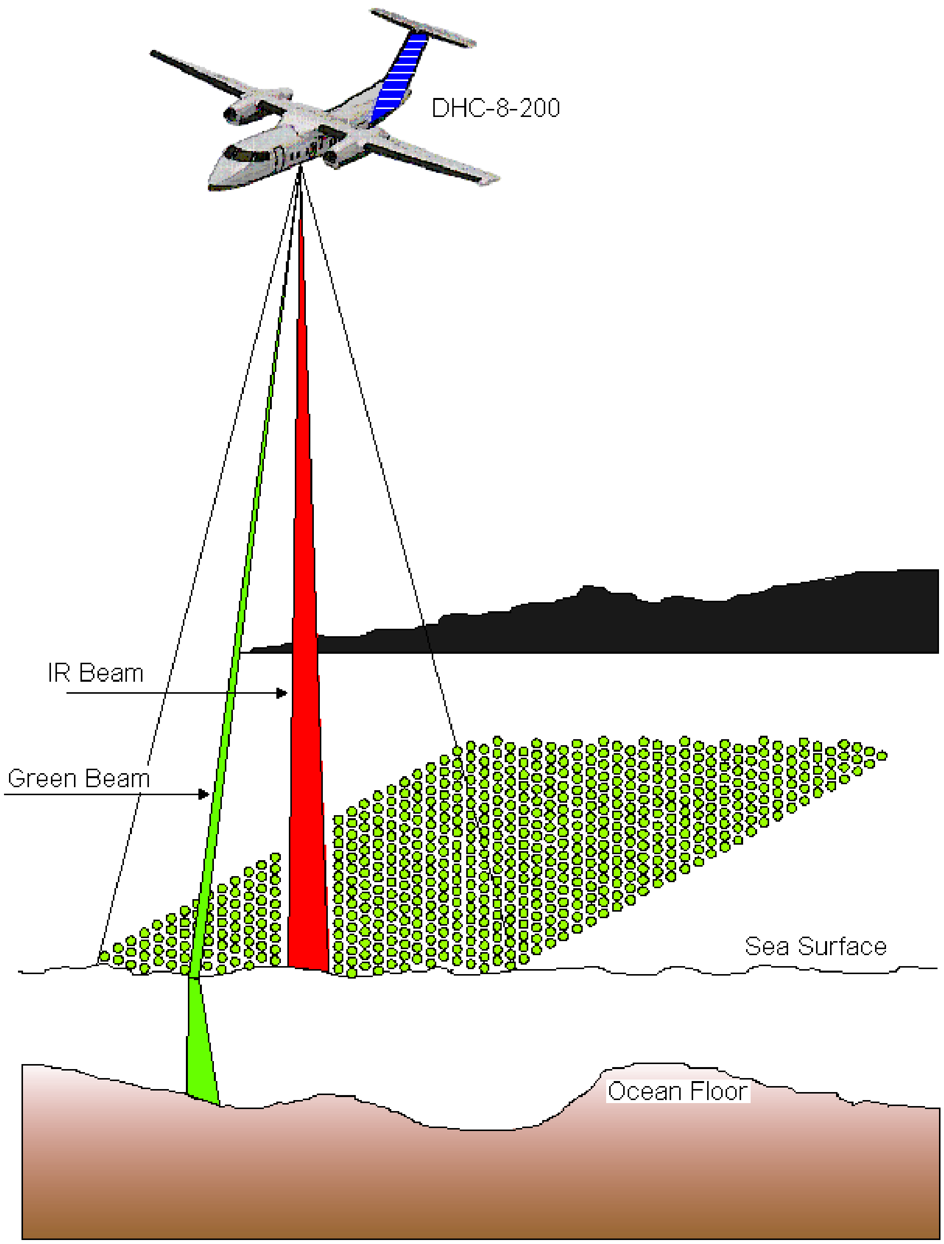


Figure 3 - The Laser Scan

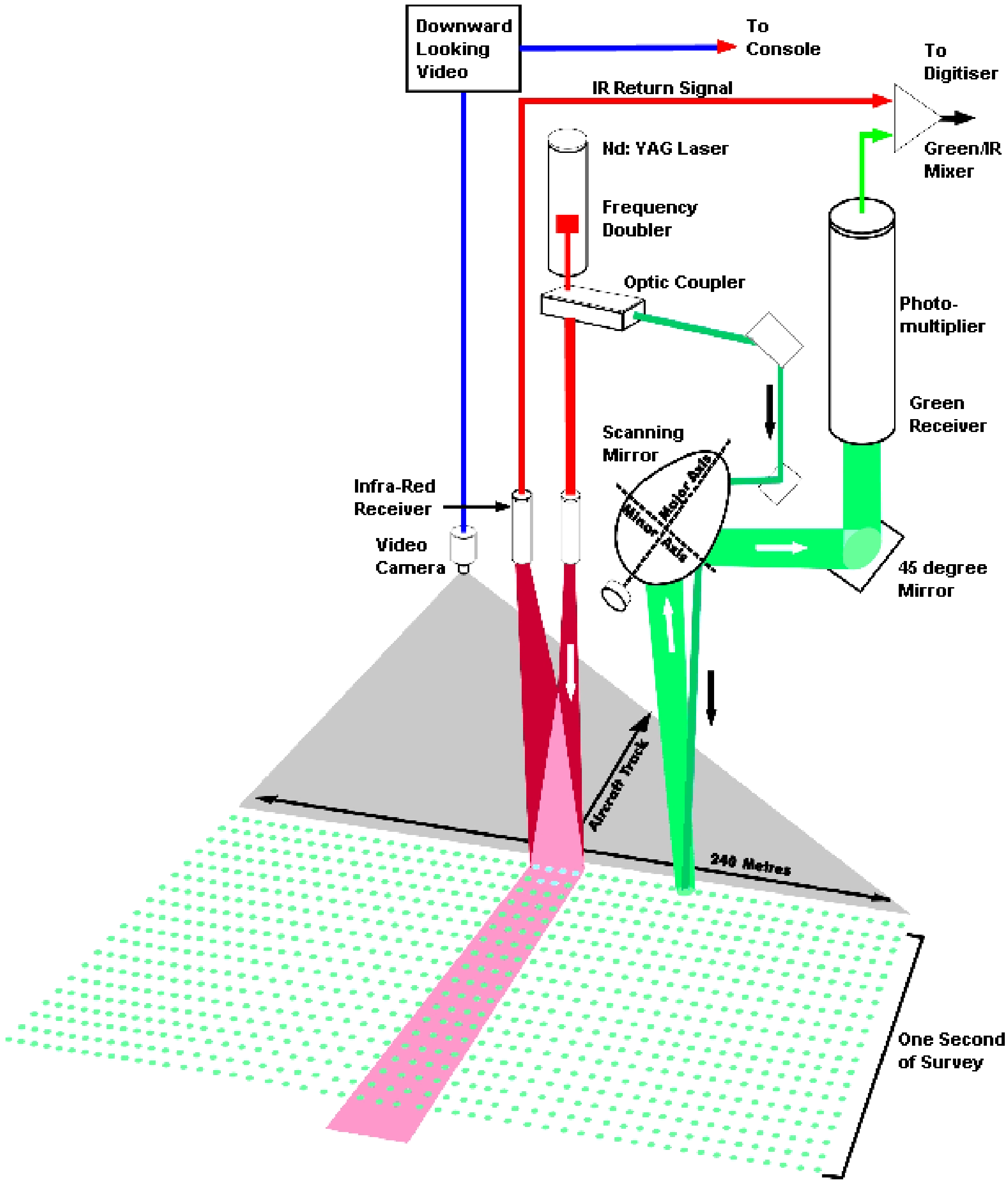


Figure 4 – The Airborne System Scanner, Laser and receivers

A.1.7 LADS Mk II Aircraft and System Specifications

Aircraft Type	DeHavilland Dash 8-200, twin turbo prop, high wing
Aircraft Modifications	Long range tanks, pressurized laser bay window and autopilot interface
Transit Cruise Speed	250 knots (maximum 275 knots)
Transit Altitude	To 25 000 feet
Survey Speed	Dependant on Scan Pattern: Nominal 140 – 210 knots (72-108 meters per second)
Survey Height	1200 feet to 2200 feet (366 meters to 671 meters) in 200 feet increments
Survey Track-Keeping	+/- 5 m (manual or via autopilot coupling)
Survey Endurance	8 hours nominal
Operational Capability	Day/Night Operation
Depth Sounding Rate	900 soundings per second
Swath Width	Dependant on Scan Pattern: Nominal 50 – 288 meters (independent of aircraft height and water depth)
Scan Pattern	Rectilinear
Sounding Density	Variable: 6x6m, 5x5m, 4x4m, 3x3m and 2x2m
Soundings per sq km	Dependant on scan pattern. For 4x4m – 75 000/ km^2 (assuming 32m overlap)
Soundings per hour	Up to 3 million
Topographic and Depth Range	-50 meters (topo) to 70 meters (depth)
Area Coverage	Dependant on scan pattern. For 4x4m – up to 41.5km^2/hour (12.1 sq nm/hr) assuming 32m overlap
Position Fixing	Real-time GPS and post-processed Kinematic GPS (L1/L2 Dual Frequency)
Recording Media	Digital Linear Tape (DLT) and VHS/PAL Video Tape

A.1.8 Logging Parameters

A.1.8.1 Position Fixing

The Airborne System 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 Mk II 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 Mk II has variable scan pattern functionality as detailed in the following table. The 4x4 and 4ax4a patterns both provide 4x4 meter spot density but have different swath width and survey speeds. All patterns are available at each of the operational altitudes (1200 – 2200ft at 100ft 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	80	160	72 (140)
4ax4a	150	60	120	90 (175)
3x3	100	40	80	77 (150)
2x2	50	20	40	72 (140)

Table 1 – Scan Configuration

A.2 GROUND SYSTEM – OVERVIEW

Conversion of raw sounding data from the Airborne System to final data is accomplished on a Ground System. There are four Ground Systems available for operations, as follows:

a. Ground System Gandalf, consisting of a Compaq Alpha ES40 Series 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 and a HP 800ps Design Jet Plotter.

b. Ground System Frodo, consisting of a Compaq Alpha Series 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 and a HP 800ps Design Jet Plotter.

c. Ground System Hobbes, comprising a four CPU Compaq (DEC) Alpha Series 4100 multi-processor server with 256MB RAM, up to 750GB disk space, DLT drives and magazines, DAT drive, and networked to a series of X-term or personal computer operator consoles, HP 750c DesignJet plotter, printers and QC workstations.

d. Portable Ground System Hobbit, consisting of a Digital Alpha Workstation 500AU single processor server with 256MB RAM, up to 140GB disk space, DLT drives, DAT drives and networked to a series of X-term or personal computer operator consoles, HP 750c DesignJet plotter, printers and QC workstations.

The hydrographic software is a Tenix LADS Corporation 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 smooth sheets and deliverable digital data.

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, 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.
- 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 more senior surveyor and finally approved by the Field Party Leader.
- Data output. Approved data is output to the client in digital form along with hardcopy smooth sheets.

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

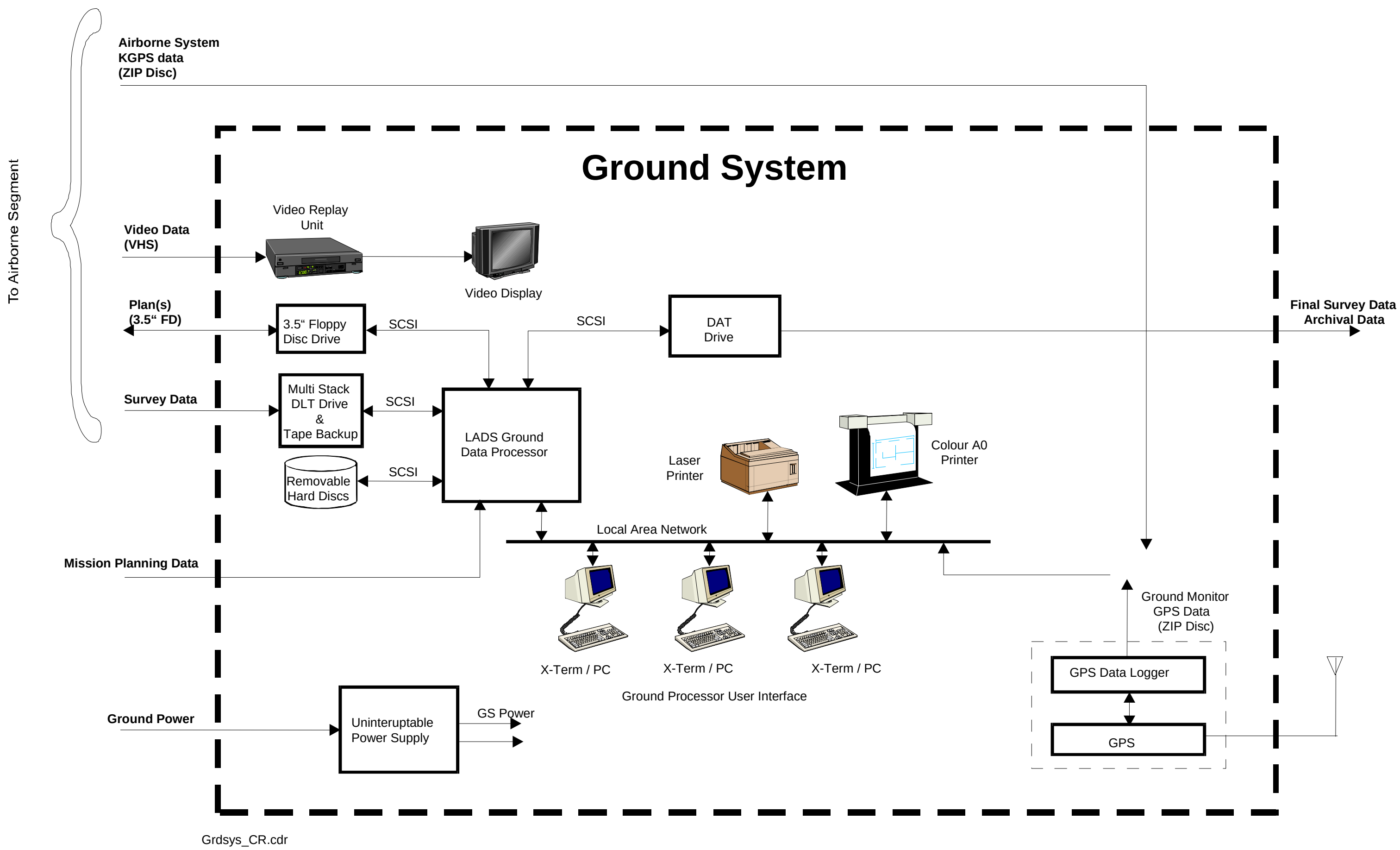


Figure 5 – Block Diagram of the LADS Mk II Ground System

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 with each sub-area at an 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 Data Processing

Processing parameters suitable for the sortie are set prior to processing. The KGPS positions from the local reference station are applied to the data.

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 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 lines data is grouped into one second frames made up of 18 scans of 48 sounding pulses i.e. 864 pulses per frame. (The outer two laser pulses are not used for sounding purposes.)

A.2.5 Primary and Secondary Soundings

All 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 sub-set 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 one meter has been used which means all soundings have been hydrographically reviewed and all valid soundings have been provided in the final data set.

A.2.6 Automatic Data Processing

Automatic processing is completed in two stages:

i. 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.

ii. 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 positions and height to the raw data.
- Process the raw waveform to identify surface reflections.
- Process the raw waveform to identify and calculate initial depths for the two most likely bottom return pulses.
- Classify each of the identified bottom return pulses by signal noise ratio, agreement with near neighbors and a maximum likelihood estimator.
- Select the most likely bottom return pulse based on the above classification and a shoal weighting function.
- Model the sea surface from the available surface pulses.
- Correct the bottom 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 corrected GPS 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 (signal to noise)

  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 sub-set (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 Mk II 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 processing.

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.

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 Mk II provides a mechanism to manage the reprocessing of survey line data a number of 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 therefore ignored by the system.

A.3 GROUND SYSTEM – USER INTERFACE

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

A.3.1 Composite Depth Profile Display

The Composite Depth Profile is used for overall assessment of the depths along the line and the general quality of the data. The operator may pan and zoom along/into 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 new displays are initialized at the coordinates of the cross hairs.

Figure 6 – Composite Depth Profile Display

Three profiles, with distance along track on the X axis and depth on the Y, 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.

A.3.2 Primary Depth Display

The Primary Depth Display shows the depths of all soundings across and along one second of the swath. 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 and secondary yellow with NBD soundings 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 eg. waveform display or sounding audit display are required.

The position, time, frame, row, column and confidences are displayed for the sounding under the cursor.

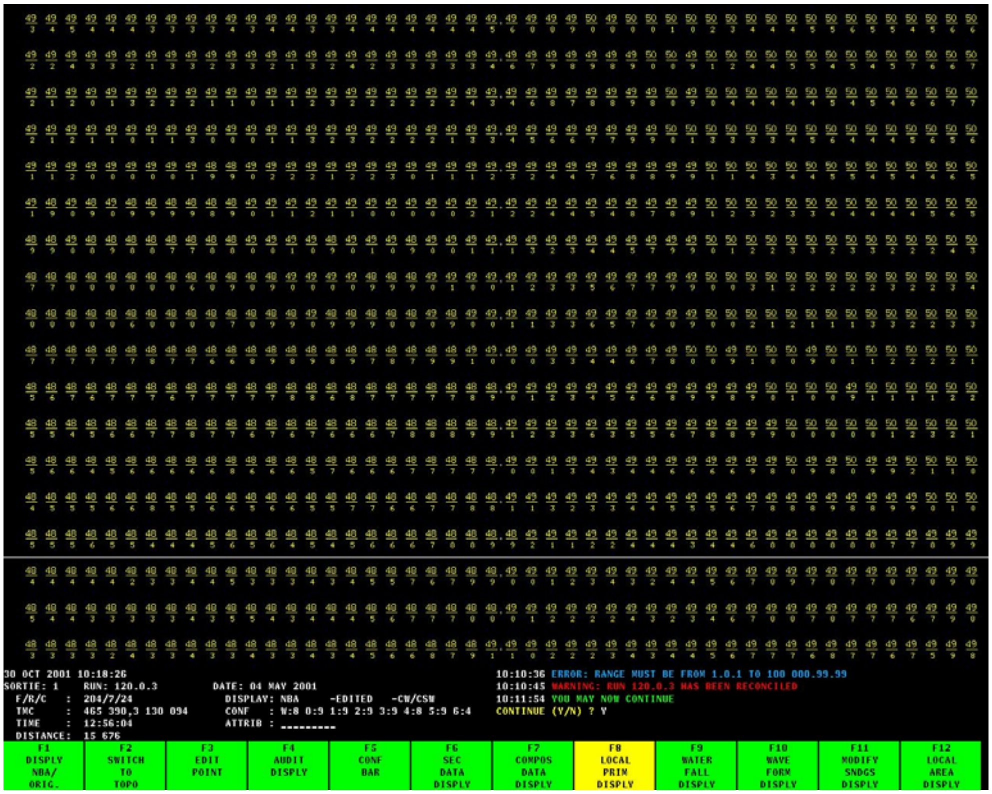


Figure 7-Primary Data Display

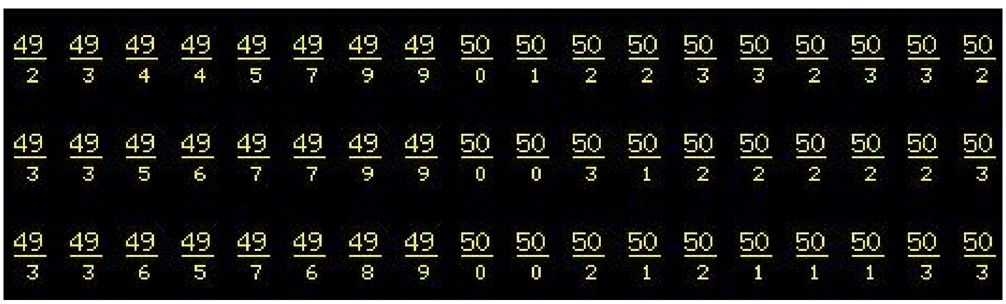


Figure 8 – Enlarged depiction of soundings in Figure 7

A.3.3 Sounding Waveform Display

The Sounding Waveform Display shows a matrix of nine sounding waveforms centered on the current or nominated sounding. The display is invoked from the primary or waterfall displays and can then be scrolled along or across the swath. This display allows an operator to assess the actual quality of the data and to resolve or clarify specific sounding values eg. 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, and signal/noise ratio are presented. A more detailed discussion of the interpretation of waveforms is given in the Laser Waveforms – Nature and Interpretation section.

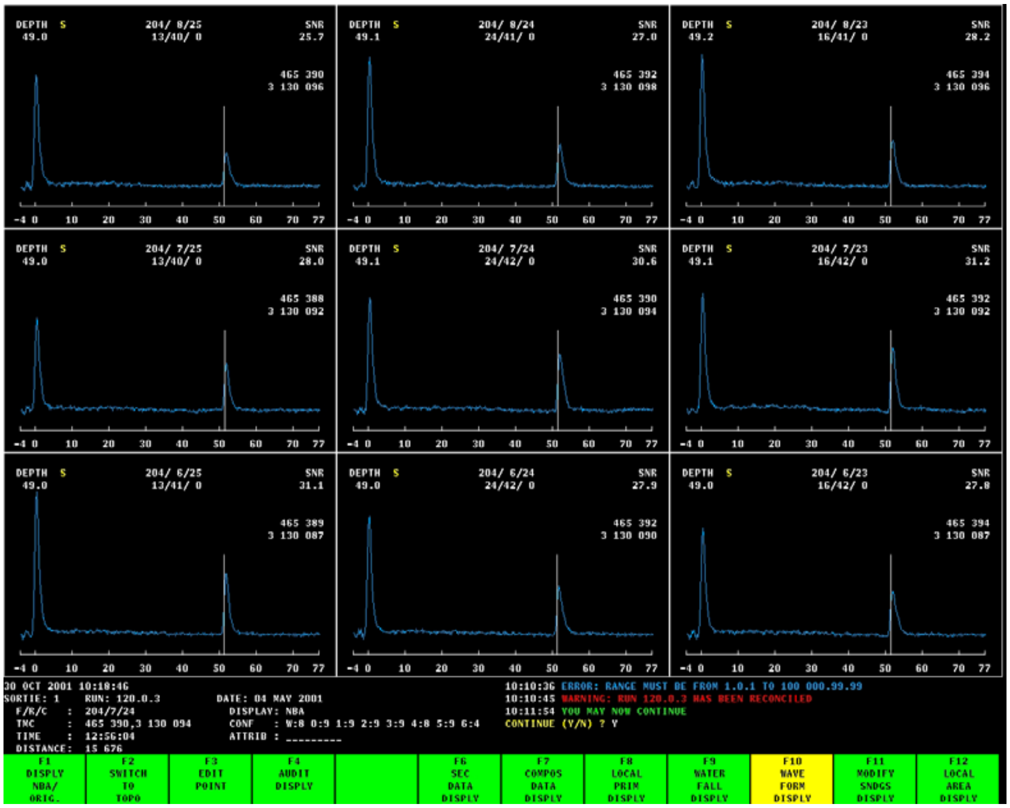


Figure 9 – Sounding Waveform Display for a group of soundings

A.3.4 Depth Waterfall Display

The Depth 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 or anomalous or noisy data.

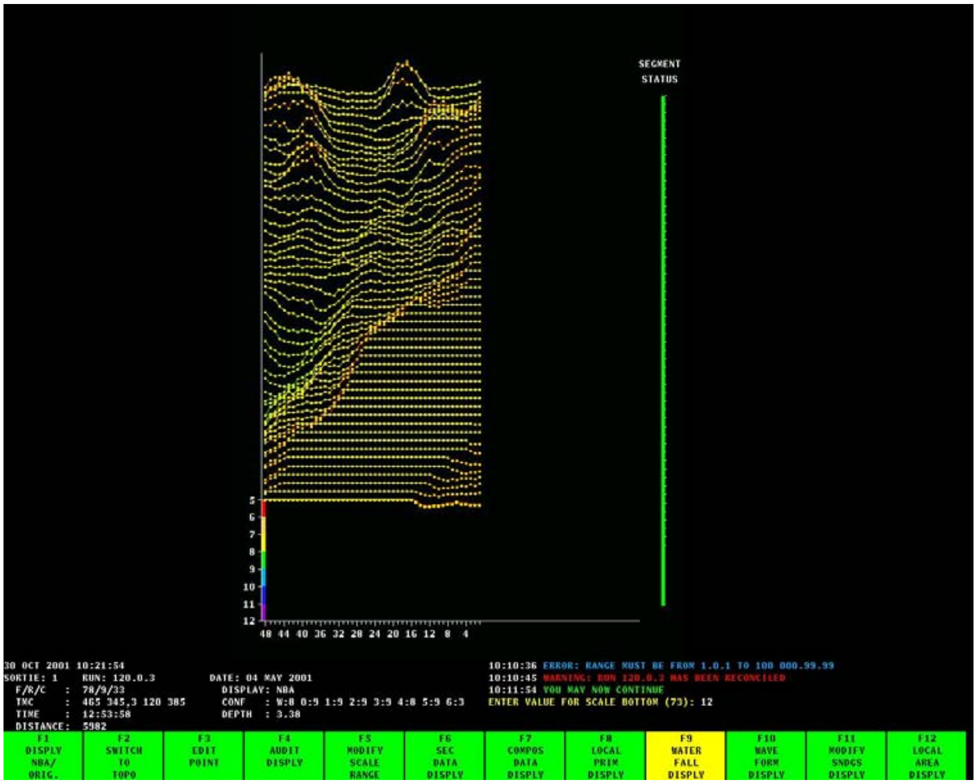


Figure 10 – Depth Waterfall Display

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 TIN contouring.

When a line is selected for validation, the operator is presented with a list of all lines in the database that overlap the selected line. The operator nominates overlapping lines appropriate for the current validation. 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.

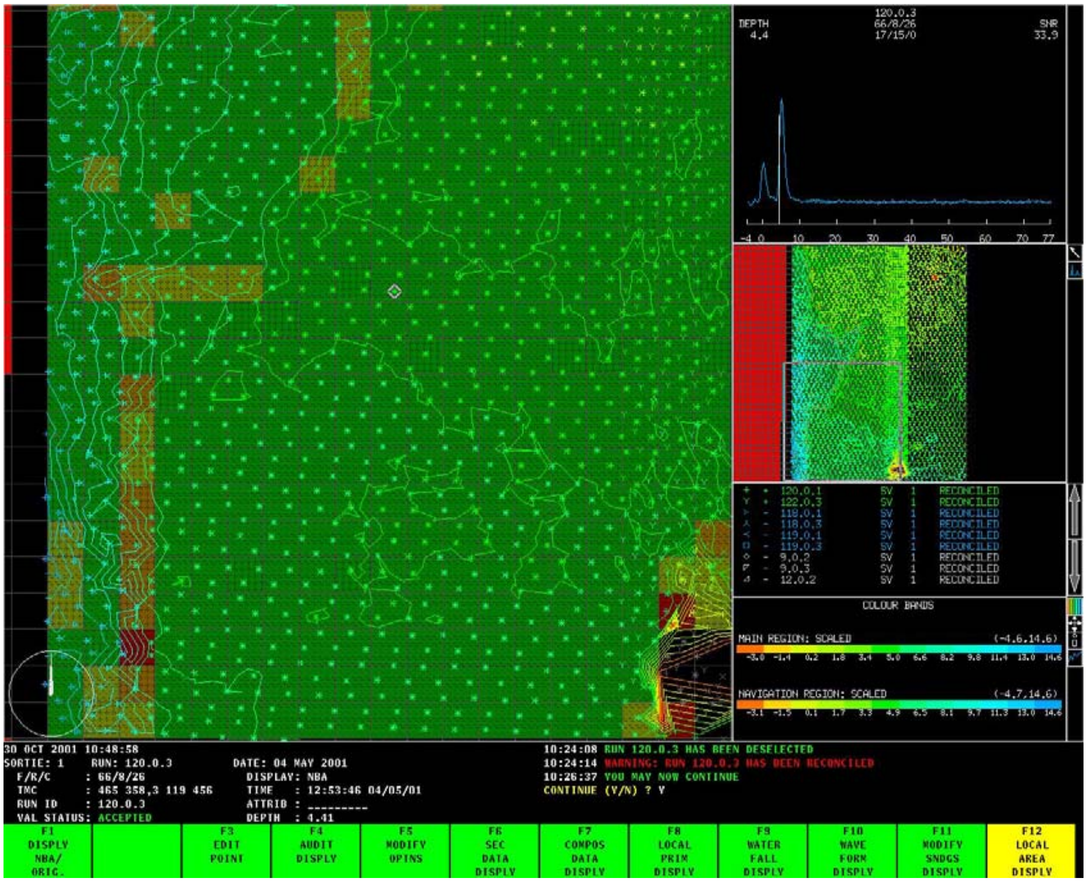


Figure 11 – Local Area Display – Small Scale

The display is divided into five sub-windows:

- The navigation window, second on the right, provides a top level view of the area currently selected.
- 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 white rectangle within the navigation window shows the position and extent of the area displayed in the working window.
- The waveform window, top right, shows the waveform for the currently selected sounding, highlighted by a white triangle, from the working window.
- The runs window, third on the right, lists the nominated overlapping runs along with the symbol used to represent soundings from that line. A subset of the runs may be selected for display and analysis and these are highlighted.
- The color band window shows the operator set color band ranges for the navigation and working windows.

The lower region of the screen displays summary information similar to that on the Composite and Primary Displays i.e. eastings, northings, time etc.

TIN contours of the displayed soundings are typically shown in both the navigation and working windows.

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, cells that pass are color filled and failed cells are displayed as black. The color of a cell indicates the degree of variation in the depths of soundings within the cell. Green represents small variation with an increasing red component as the depth variation increases (Figure 12).

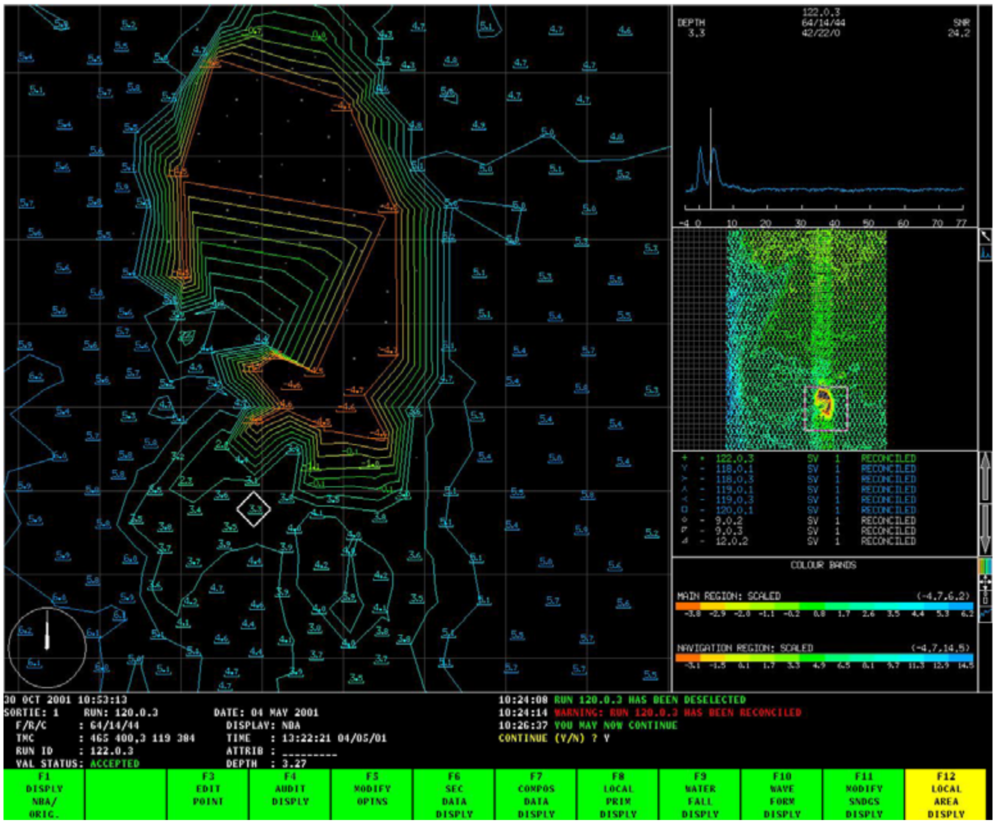


Figure 12 – Local Area Display – Medium Scale

In both the navigation and working window the soundings are displayed at their geographical positions. Soundings are shown as symbols (a separate symbol per line) in the navigation window and at small (zoomed out) scales in the working window (Figure 11). As the operator zooms in on the working window symbols in the working window are replaced by depth values (Figure 12) and at the largest scales the waveform for each sounding is displayed adjacent to the sounding value (Figure 13). 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.

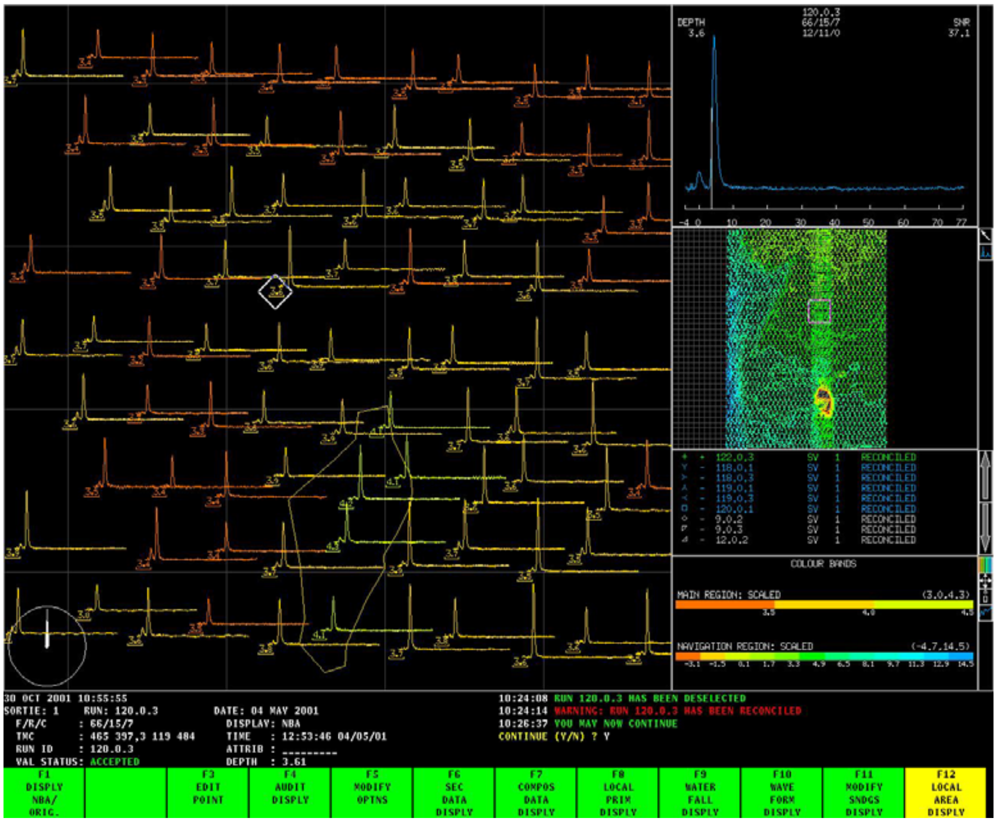


Figure 13 – Local Area Display – Large Scale

A.3.6 Audit Display

The Audit Display is used to check additional data associated with a 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.

A.4 SOFTWARE VERSIONS

System	Version	Remarks
Tenix LADS Airborne System	AS 7.0.23	Dated January 29, 2003
GPS Base Station Receiver	-	Ashtech Z12
GPS Airborne Receiver	-	Ashtech Z12
GPS Logging	5.6.0	Ashtech PNAV Datalogger Software.
GPS Processing	2.5.5	Ashtech PNAV (Precise Differential GPS Navigation Trajectory Software)
Tenix LADS Ground System	E5.10.0 E5.11.0 E5.11.2 E5.11.14 E5.12.1 E5.12.2 E5.14.0 E5.14.2 E5.14.6	

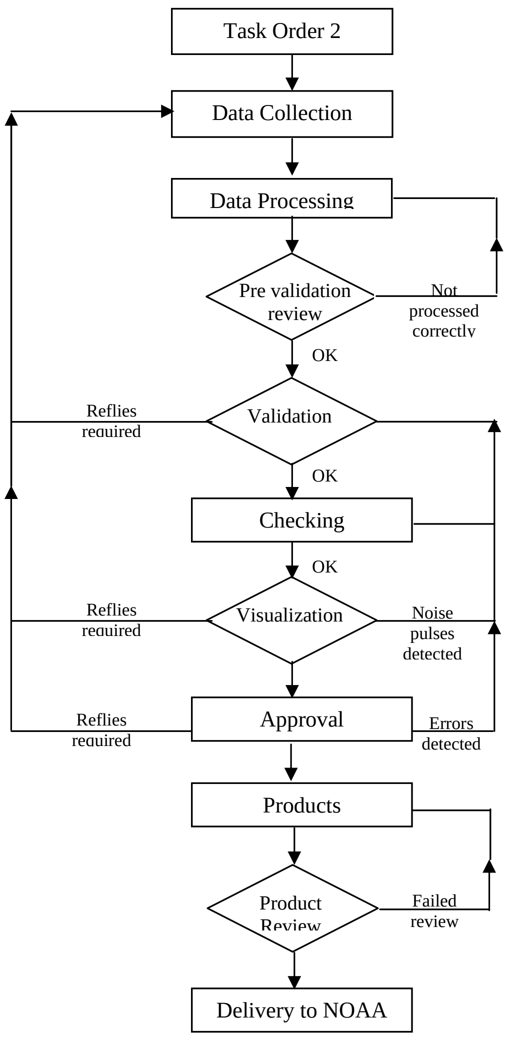
Table 2 - Software versions

B. QUALITY CONTROL

B.1 DATA PROCESSING

Data processing involves the following stages:

- Automatic Data Processing, described earlier.
- Pre-Validation and initial batch and filter cleaning of the data by a senior hydrographic surveyor.
- Validation of the data by a hydrographic surveyor.
- Checking of the data.
- Visualization of the data.
- Approval of the data.



B.2 VALIDATION

Validation proceeds through the following steps:

Examining the Depth Profile for the correct processing of each expected Survey Run.

Examining the Position Confidence (C3) profile to verify that adequate position accuracy is maintained during the Survey Run. Note: Other profiles of supporting data such as EHE, number of satellites, and latency may also be examined as run profiles.

Examining the Coverage Confidence (C6) profile to verify that no coverage gaps exist in the Survey Run.

Resolving anomalous soundings by examining data points in the Survey Run by checking:

a. the Primary Depth Display
b. the Waterfall Display
c. the Waveform Display
d. the Local Area Display

Editing operations include selection of the alternate depth, assignment of NBA or deletion of the sounding as appropriate.

Based on assessments made in the above steps the operator segments the line classifying each segment as:

a. Accepted
b. Anomalous (data not to be used) or
c. Rejected (for refly)

All operator interactions during the validation phase are logged so that complete traceability is maintained.

B.3 CHECKING

When a line has been validated it is passed to a checker. All edits made by the validator are marked on the line and logged in a validation log. The checker independently assesses the line and checks the validation edits.

B.4 DATA VISUALIZATION

All validated and approved 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 TIN models 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 back to the checkers for remedial action in the GS.

A number of software packages are used to produce these QC products namely:

- CARIS HIPS/SIPS
- Terramodel package by Spectra Precision Software Inc.
- Olex
- Generic Mapping Tools (GMT)
- Visualization Tool Kit (VTK) supplied by Kitware, Inc.

The GMT package is described in Wessel, P. and W.H.F. Smith, New, improved version of Generic Mapping Tools released, EOS Trans. Amer. Geophys U., Vol . 79 (47), pp. 579, 1998 and provided by The School of Ocean and Earth Science and Technology, University of Hawaii, and Laboratory for Satellite Altimetry, National Ocean and Atmospheric Administration, http://www.soest.hawaii.edu/gmt.

In turn the GMT package utilizes the NetCDF software library produced by:
University Corporation for Atmospheric Research/UNIDATA
Boulder Colorado, http://unidata.ucar.edu.

Terramodel is supplied by Trimble Navigation Limited
749 North Mary Ave
Sunnyvale, California 94088-3642
www.trimble.com

VTK is supplied by Kitware, Inc.
469 Clifton Corporate Parkway
Clifton Park, NY 12065
U.S.A
www.kitware.com

VTK is described in The Visualization Toolkit – An Object-Oriented Approach to 3D Graphics, Will Schroeder, Ken Martin, Bill Lorensen - Prentice Hall PTR 1998

B.5 APPROVAL

In the final phase the Survey Team Leader reviews each line prior to approval.

B.6 AUDIT TRAIL

All 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. In addition, all operator actions are logged by the GS.

Laser Waveforms - Nature and Interpretation

The Sounding Waveform Display (Figure 14) 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 bar showing depth of the seabed ③ and alternative seabed ④ if it exists.
- Depth of the seabed ⑤ and alternative seabed ⑥.
- Signal noise ratio of the seabed ⑦ and alternative seabed ⑧.
- Reference position of sounding in frame/row/column ⑨.
- Real time green receiver gain values for sounding measurement ⑩.
- Grid coordinates of sounding on the survey spheroid and grid ⊛.

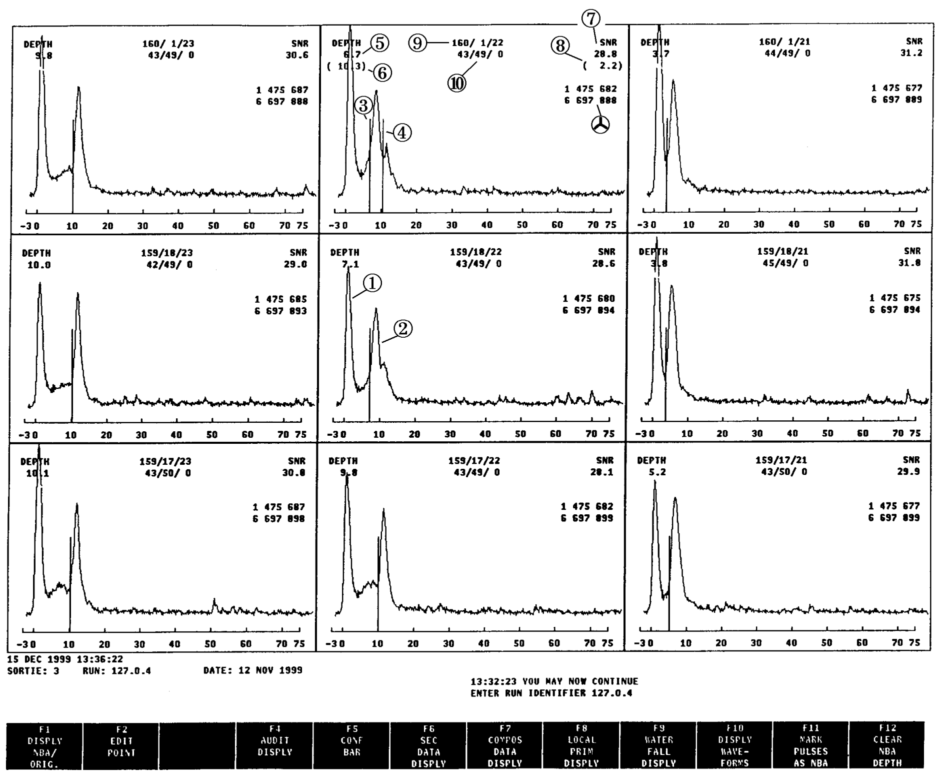


Figure 14 - Annotated Sounding Waveform Display

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 infra-red, GPS and inertial (AHRS) heights and filtered green surface returns. The SRP then selects up to two possible seabed returns for each waveform based on signal to noise 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 two seabed returns were found the most likely is selected based on S/N versus depth criteria. The selected return is indicated on the waveform display by a white depth bar the other in blue. 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. Detection of an object on the seabed will depend on both the density of the scan pattern, gain of the system, 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 and ability of the algorithms in the automatic processing system to detect the pulse from the object. The amount of laser light reflected by the target is in turn influenced by the size of the target, the depth of water (which effects 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 controls the maximum depths that can be measured by the system.

B.7 DATABASE MANAGEMENT AND SURVEY LINE IDENTIFICATION

Sub-Area	Run Numbers	Sounding Density	Line Spacing (meters)	Line Type	Remarks
South of Kruzof Island	610	4x4	N/A	Benchmark	
Spanish Islands South	10	4x4	N/A	Crossline	
Spanish Islands South	11	4x4	N/A	Crossline	
SA1	108 – 135	4x4	80	Survey	Main lines in Kuiu Island
SA2	201 – 238	4x4	80	Survey	Main lines in Spanish Islands
SA3	300 – 313	4x4	80	Survey	Main lines in E/W Spanish Islands
SA4	400- 423	4x4	80	Survey	Main lines NE Coronation Island
SA7	700 – 714	4x4	80	Survey	Main lines New Cape Decision
SA8	801 – 819 (Odds)	4x4	80	Survey	Main lines New Spanish Islands

Table 3: Line Planning and Numbering

B.7.1 Line Identifiers

Line identifiers within the LADS Mk II system uniquely define a specific line and are made up of 4 fields separated with a point '.' as follows:

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

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

eg. 101.1.2.3

Maximum fields are
100000.99.99.9

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 and

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 Sortie Run Process (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 and
101.1.2.x is the second processing of the first refly.

Child – Range 1..9
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. When the line is reconciled 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.

The reconciliation process writes the surveyor nominated ACCEPTED, REJECTED or ANOMALOUS flag to each line segment. This provides the mechanism of ensuring only ACCEPTED data is output for products.

B.7.2 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 for the line. Full details are recorded in the Survey Data Management Folder held by TLI.

B.8 DATA OUTPUT AND DELIVERABLES

Digital data deliverables and graphics (smooth sheet, coverage plot and sun illuminated images) are output and prepared in accordance with:

- NOS HYDROGRAPHIC SURVEYS. SPECIFICATIONS and DELIVERABLES. March 2003.
- STATEMENT OF WORK. LIDAR SURVEY SERVICES. OPR-O167-KR-03 of March 18, 2003.
- Certain deviations from the above documents were agreed to in a meeting between Tenix LADS Inc. and PHB held at PHB on 7 May 2003. Specifically:
- Delivered digital data to be compatible with the latest versions of Caris and MicroStation
- A three meter clash to be used in lieu of a five meter bin and
- 2D MicroStation seed files to be supplied not 3D

A three meter clash is where the shoalest sounding within a three meter radius will be selected and is a way for the shoal biased data to be represented.

All conversion factors, rounding conventions, sounding alignment on the smooth sheet and datums are as per the above documents.

A specific function was designed and implemented in the GS to accommodate NOAA specific outputs. This function outputs the digital data files required for NOAA delivery and all ancillary files required for the generation of the graphics. All unit conversions and rounding are centralized in one software package so that packages such as Caris, Terramodel and MicroStation do not modify any data output from the GS and are only used for contouring, graphic generation and drafting tasks.

In summary the NOAA output function:

1. Performs a clash at a specified radial, typically 3 meters on all edited and fully corrected data. This resultant data set is output as the Edited Data Set along with flags indicating which soundings are selected from the clash in step 2. A further three ancillary (internal) outputs are generated from this set:
    - The data set is output to Terramodel along with a separate output of NBA soundings for Coverage Plot generation.

- The data set is output to Terramodel for Sun Illuminated Image generation.
- The soundings are converted to smooth sheet depth units and input to Terramodel for smooth sheet contour generation.

2. Performs a second clash at the specified plot scale radial. The resultant data set is output as the preliminary smooth sheet data. In addition two ancillary outputs are generated, one in smooth sheet depth units the other in smooth sheet drying units with soundings to the appropriate datum and rounded as per the NOAA specification. These later two outputs are input to a MicroStation routine for plotting on the smooth sheet and tagging of the soundings.

Finally the Full Resolution Caris compatible output is generated.

Digital data sets delivered are:

- Caris compatible full resolution data set.
- Edited data set.
- Preliminary smooth sheet data i.e. set of all soundings plotted on the smooth sheet.

The depths in these three data sets are in meters.

The NOAA output function of the GS outputs soundings for presentation on the smooth sheet. Soundings are selected with a plot scale reduction radius, in this case 54m.

The soundings are imported into MicroStation V8 via a proprietary utility that:

a. Places soundings on the correct layer at the sounding position (see below),
b. Creates a MicroStation tag for each sounding,
c. Formats the sounding (see below).

Soundings are rounded and placed on layers and formatted as follows (as per the NOAA specification):

- Soundings below MLLW are relative to MLLW, rounded about 0.75 and placed on layer “Soundings”, text is vertical no arithmetic sign.
- Soundings above MLLW but up to 2.3 feet above MHW are relative to MLLW, rounded about 0.3 and placed on layer “Soundings”, text is vertical with minus sign.
- Soundings above 2.3 feet above MHW are relative to MHW, rounded about 0.3 and placed on layer “Drying Features”, text is slanted and in parenthesis.

Contours including the MHW line, were generated in Terramodel where they were manually edited in order to cartographically represent the soundings on the smooth sheet. These contours were imported into MicroStation Layer “Contours”.

The final smooth sheet was saved using the MicroStation ARCHIVE function as a V7.dgn file.

MicroStation Version 8 files have been found to be incompatible with MicroStation 95 which is used by NOAA. This has been investigated and found to be the result of differences in how B-splines are handled in the two packages. A software routine has been created to re-parameterize the B-splines created in MicroStation Version 8 to make them compatible with MicroStation 95. This routine has been run over the smooth sheet .dgn file supplied to NOAA.

The coverage plot is generated in Terramodel based on a 5 meter grid and then imported into MicroStation for final drafting, exporting as a GEOTIFF image and plot file generation.

The Sun Illuminated Images are generated in Terramodel then imported into MicroStation for final drafting, exporting as a GEOTIFF images and plot file generation.

Detailed specifications for the Caris compatible output, ASCII Edited Data Set and ASCII Preliminary smooth sheet Data are contained in Appendices I and II.

A list of files delivered is contained in Separates G.

B.8.1 File Naming Conventions

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

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

Ext	Data Type	File format
edt	Edited dataset – 3 meter subset of all accepted data.	ASCII. Lat, Long, Depth (meters), Tide, Date/Time, Clash Flag.
cls	Preliminary smooth sheet Data – Subset of edited data at plot scale.	ASCII. Lat, Long, Depth (meters).
add	Added Soundings – Soundings added to smooth sheet.	ASCII. Lat, Long, Depth (meters)
txt	File containing GS export parameters	TXT.
caf	LADS MK II Caris Output Data	Caris compatible format.
cbf	LADS MK II Waveform Data	Caris compatible format.

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

<SmoothsheetNumber>_<VersionNumber>.<Plot Type>.<Extension>
where <Extension> is derived from the data type as per the following table:

Ext	Data Type	File format
pzip	MicroStation Archived Files	MicroStation Version 7 archive format
plt	MicroStation Plot Files	HPGL-2 format

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 an Attitude and Heading Reference System (AHRS) that minimizes the motion effect (roll and pitch) of the aircraft and all residuals from the local horizontal are logged by the Airborne System for correctional processing by the Ground System.

Sounding depths and positions are determined in the Ground System from the raw waveform, aircraft height and platform attitude parameters as logged by the Airborne System.

The Ground System 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, benchmark lines and analysis of overlaps, redundancy from the 200% 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 positioned on the upper side of the aircraft fuselage forward and to the left (facing forward) of the sounding reference position. 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 antenna with the following axis and sign convention assuming the aircraft is level:

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

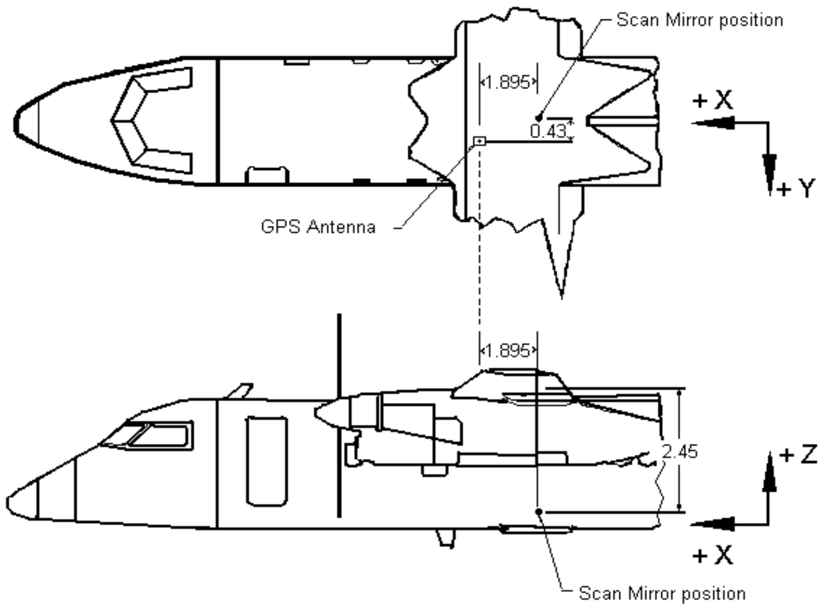


Figure 15 - Laybacks

D. APPROVAL SHEET

LETTER OF APPROVAL - OPR-O167-KR-03

This report and the accompanying smooth sheets 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 smooth sheets have been closely reviewed and are considered complete and adequate as per the Statement of Work.

____

Mark Sinclair
Hydrographer
Tenix LADS Incorporated

Date____________________________

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

Page Number	Issue Status	Page Number	Issue Status
Title Page	1.00		
ii	1.00		
iii	1.00		
iv	1.00		
1	1.00		
2	1.00		
3	1.00		
4	1.00		
5	1.00		
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15	1.00		
16	1.00		
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18	1.00		
19	1.00		
20	1.00		
21	1.00		

CONTENTS

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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).

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1.2 Scope

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

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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

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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

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1.3.1.3 Abbreviations

Nil

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1.4 References

Glossary of LADS Terminology	0006A00005

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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.

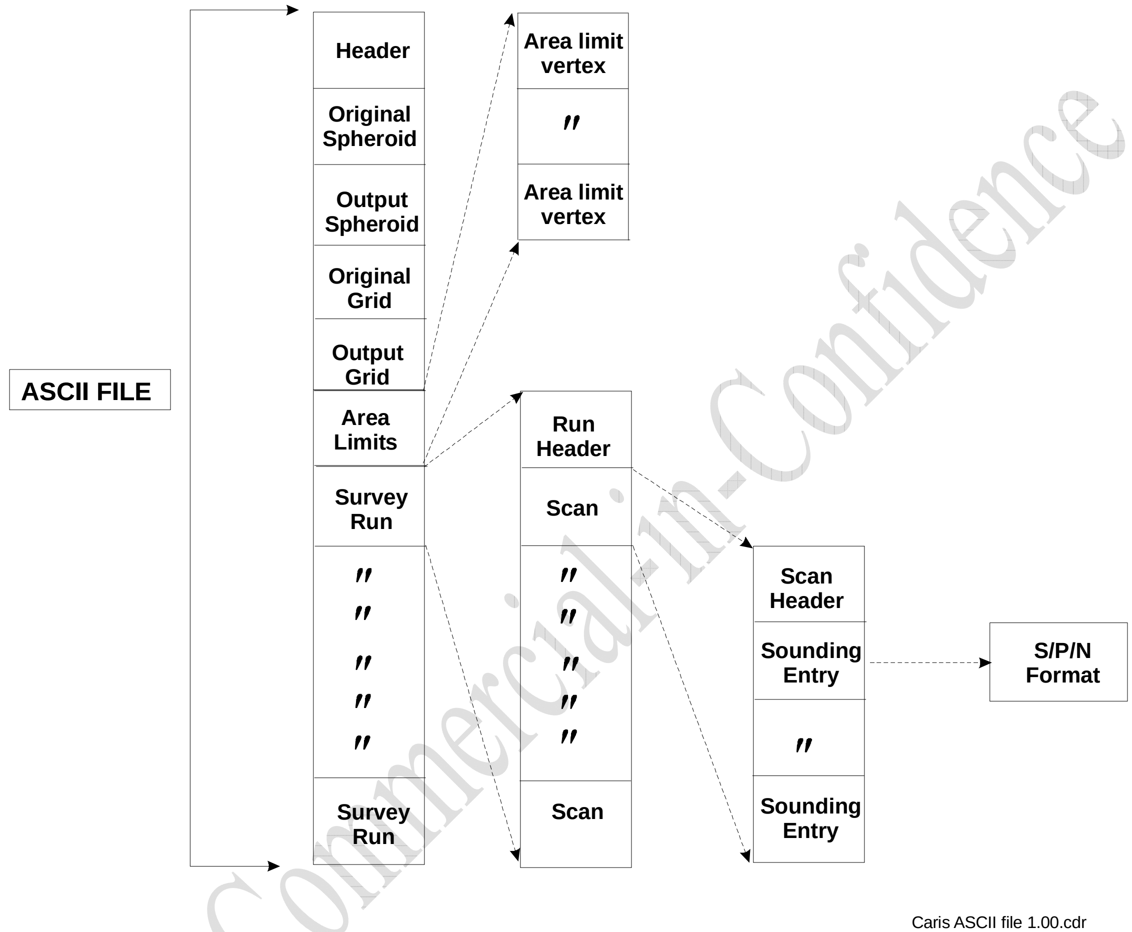

Figure 2-1 Structure of the ASCII file from the Output CARIS Data Function

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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

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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

Name	Format	Range	Comments
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

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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

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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

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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

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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, ($1/18^{th}$) 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

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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	D(8)	-5_000_000 ..	0 when no contender exists.

Name	Format	Range	Comments
Position Easting - output spheroid		5_000_000	
Contender Depth Position Northing - output spheroid	D(9)	-10_000_000 .. 20_000_000	0 when no contender exists.
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

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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 0 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 - LADS MK II GROUND SYSTEM OUTPUT FORMAT SPECIFICATION FOR NOAA DELIVERABLES

This is a controlled document.

Copy No:

Issue No: 1.00

LADS Mark II

Ground System
Output Format Specification
for NOAA Deliverables

Document Number: LADS2A05.001.012

Authorised by: ______________________

Date: 17/09/2003

Tenix LADS Corporation

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

Page Number	Issue Status	Page Number	Issue Status
Title Page	1.00		
ii	1.00		
iii	1.00		
iv	1.00		
1	1.00		
2	1.00		
3	1.00		
4	1.00		
5	1.00		
6	1.00		

CONTENTS

1. Introduction

1.1 Purpose

The purpose of this document is to specify the formats of the deliverable files produced by the **Output NOAA Data Function** of the Laser Airborne Depth Sounder (LADS) Mk II Ground System (GS). It excludes descriptions of the files to be delivered that are generated by the **Output CARIS Data Function** as they are described by the document LADS2A05.001.008, LADS Mk II GS Output Format Specification for CARIS.

1.2 Scope

The document applies to the results generated by the **Output NOAA 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.
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

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1.3.1.2 Acronyms

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

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1.3.1.3 Abbreviations

Nil

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1.4 References

Glossary of LADS Terminology	0006A00005

2. GS Output Format

2.1 Overview

When the **Output NOAA Data Function** is run two data files are generated per export area :

1. Edited data. This data comprises data clashed at an operator selected thinning radial based on the survey density. (This is typically 1 metre less than the survey density.)

2. Smoot Sheet Plot Scale Clashed data. This is a clashed subset of that produce in 1 above and represents the data that appears on the smooth sheet for the area. The clash radial is based on the plot scale.

Each file name has the following structure:

- a 1-12 character prefix (prompted for in the GS),
- followed by an underscore and the letter V, and then
- a version number from 1 to 999 which starts at 1 and is updated sequentially as exports are re-performed with the same name.

The maximum length of the filenames including the extension is 21 characters.

For example, if the operator enters a filename of SHEET_1, and it is the first time they have exported the data under the name of SHEET_1, the two output files will be called:

“SHEET_1_V1.CLS”, and

“SHEET_1_V1.EDT”.

The structure of each field of these files is described in the following sections.

2.2 Output Format

2.2.1 Edited Data

The information associated with the **Edited Data** output is listed below. It is a space delimited ASCII file with one sounding per CR/LF terminated line.

Name	Format	Range	Comments
Latitude	F(12,8)	-90.0 .. 90.0	Expressed in degrees.
Longitude	F(13,8)	-180.0 .. 180.0	Expressed in degrees.
Depth	F(5,2)	-15.00 .. 99.99	metres corrected for tide to MLLW datum
Tidal Correction	F(5,2)	-9.99 .. 18.00	in metes to nearest centimetre
Julian Day	D(3)	1 .. 366	Julian day of survey
Year	D(4)	1000 .. 9999	year of survey
Time	X	00:00:00 .. 23:59:59	HH:MM:SS – UTC to nearest second
Plot Scale Clash Flag	X	Y or N	if Y then this sounding is “clashed in”. i.e. it is included in the Smooth Sheet Plot Data and will appear on the smooth sheet. if N then this sounding is “clashed out”. i.e. it is NOT included in the Smooth Sheet Plot Data and will NOT appear on the smooth sheet.

Table 1 Output Information for Edited Data

The format of the information associated with the **Edited Data** output is as shown below.

Format
F(12,8) ∧F(13,8)∧ F(5,2) ∧ F(5,2) ∧ D(3)∧ D(4) ∧ X∧ X←

Table 2 Format of Edited Data records.

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2.2.2 Smooth Sheet Plot Scale Clashed Data

The information associated with the **Smooth Sheet Plot Scale Clashed Data** output is listed below. It is a space delimited ASCII file with one sounding per CR/LF terminated line.

Name	Format	Range	Comments
Latitude	F(12,8)	-90.0 .. 90.0	Expressed in degrees.
Longitude	F(13,8)	-180.0 .. 180.0	Expressed in degrees.
Depth	F(5,2)	-15.00 .. 99.99	metres corrected for tide to MLLW datum

Table 3 Output Information for Smooth Sheet Plot Scale Clashed Data

The format of the information associated with the **Smooth Sheet Plot Data** output is as shown below.

Format
F(12,8) ∧F(13,8)∧ F(5,2) ←

Table 4 Format of Smooth Sheet Plot Scale Clashed Data records.

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	Space
←	Line terminator	<CR><LF>

Table 5 ASCII Format Legend

APPENDIX III – LISTING OF DIGITAL AND HARDCOPY MEDIA

The following digital products are provided:

Report Files

Reference	Remarks
Descriptive Report	Microsoft Word 2000
Descriptive Report Appendix I – VI	Microsoft Word 2000
Data Acquisition and Processing Report	Microsoft Word 2000
Data Acquisition and Processing Report Appendix I – II	Microsoft Word 2000
Horizontal and Vertical Control Report	Microsoft Word 2000
Separates Report	Microsoft Word 2000

Digital Data Sheet H111209

Reference	Remarks
H11209_V1.edt	3 meter clash of all accepted data
H11209_V1.cls	Subset of edited data at plot scale
H11209_V1.add	Soundings added to smooth sheet
H11209_V1.caf	LADS Mk II Caris Output
H11209_V1.cbf	LADS Mk II Waveform Data
LADSMKII	Caris vessel file
H11209_V1.pzip	MicroStation Version 7
H11209_V1_Image180	MicroStation Version 7
H11209_V1_ Image270	MicroStation Version 7
H11209_V1_ ImageCov	MicroStation Version 7
H11209_V1_Smooth	MicroStation Version 7
H11209_V1.plt	MicroStation Plot Files
H11209_V1_ Image180	MicroStation Plot Files
H11209_V1_ Image270	MicroStation Plot Files
H11209_V1_ ImageCov	MicroStation Plot Files
H11209_V1_Smooth	MicroStation Plot Files

Hardcopy Sheet A

H11209_V1	1 x smooth sheet
H11209_V1	1 x Coverage Plot
H11209_V1	2 x Sun Illuminated Images

Other Digital Data

Chart Comparison	Microsoft Excel 2000
Additional Boatwork inside Lidar Area	Microsoft Excel 2000
Preliminary Tides	Microsoft Excel 2000
Verified Tides	Microsoft Excel 2000
Tide Station Reports	Microsoft Word 2000
Tide Application Reports	Microsoft Excel 2000