International Hydrographic Review, Monaco, LXV(2), July 1988

SWATH MAPPING DATA MANAGEMENT WITHIN THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

by Lt. Daniel R. HERLIHY, NOAA (*), Stephen P. MATULA (*), and Capt. Christian ANDREASEN, NOAA (*)

Abstract

In 1983, the United States proclaimed the establishment of a maritime Exclusive Economic Zone (EEZ) extending beyond the territorial sea to a distance of 200 nautical miles from its coastline. The proclamation reserved for the U.S. the sovereign right to explore for, exploit, conserve, and manage all natural resources within this new 3.4 million square nautical mile territory, an area roughly 1.2 times the total U.S. land mass. In order to help determine the characteristics and resources of the U.S. EEZ, a detailed program was developed to systematically map the entire area using multi-beam swath sounding systems. The program is under the direction of the National Oceanic and Atmospheric Administration (NOAA), United States Department of Commerce. Field operations commenced in early 1984 as two NOAA ships, equipped with advanced bathymetric swath mapping and precision navigation capabilities, began surveying off the coast of central California. Two additional ships have been added since and, to date, 36,000 square nautical miles of bathymetric mapping have been completed, a product of 95,000 lineal nautical miles of swath sounding. With such an enormous amount of data produced by swath mapping systems, the necessity for a comprehensive data management program was recognized early in the project. This paper describes the two-level data management system that has evolved, the lower level utilized aboard NOAA ships that acquire and initially process swath data, and the upper level employed by the Ocean Mapping Section, which is responsible for receiving, verifying, final processing and archiving all bathymetric swath data.

(*) NOAA/National Ocean Service, Office of Charting and Geodetic Services, 6001 Executive Blvd., Rockville, Maryland 20852, USA.

I. INTRODUCTION

In 1984, the United States initiated a program to systematically map its newly proclaimed 200 nautical mile Exclusive Economic Zone (EEZ) using sophisticated swath sonar and precision navigation systems. Based on its historical role in bathymetric mapping, the Office of Charting and Geodetic Services (C&GS), National Ocean Service, National Oceanic and Atmospheric Administration (NOAA) was assigned overall responsibility for the program. Within C&GS, the Ocean Mapping Section, hereby referred to as the Project Office, is tasked with daily management.

Encompassing a 3.4 million square nautical mile expanse of ocean, the U.S. EEZ mapping project represents the largest bathymetric survey ever attempted. To date, 36,000 square nautical miles of bathymetry have been completed, a product of 95,000 lineal nautical miles of swath sounding. From the beginning, data management has been a priority consideration. The number of data products and quantities of data produced by swath mapping systems is significantly larger than with traditional single-sounding lines of hydrography. This fact, combined with the formidable size of the area to be surveyed, clearly indicates that comprehensive data management is critical to the overall success of the project.

Data management of NOAA bathymetric swath surveys has by necessity evolved into a two-level system, shipboard data management and project office data management. Shipboard data management is designed to acquire, process, and transfer data from different ships in similar formats, for incorporation into a common database. Project Office data management applies to receiving and verifying individual surveys, creating a composite database, and producing a set of useful data products.

II. SHIPBOARD DATA MANAGEMENT

Four NOAA ships (*Discoverer, Surveyor, Mt. Mitchell,* and *Davidson*) are currently assigned to the EEZ bathymetric mapping project, with a fifth *(Whiting)* scheduled to begin operations in the fall of 1988. Although ship capabilities (size, personnel, equipment, etc.) vary considerably, standard operational guidelines and procedures have been implemented to assure uniform data products. Due to the large quantities of information produced by swath mapping systems, proper shipboard data management is essential throughout the four stages of bathymetric surveying: project planning, data acquisition, data processing, and data disposition (Fig. 1).

PROJECT PLANNING

NOAA bathymetric swath surveying is accomplished by projects; the detail-

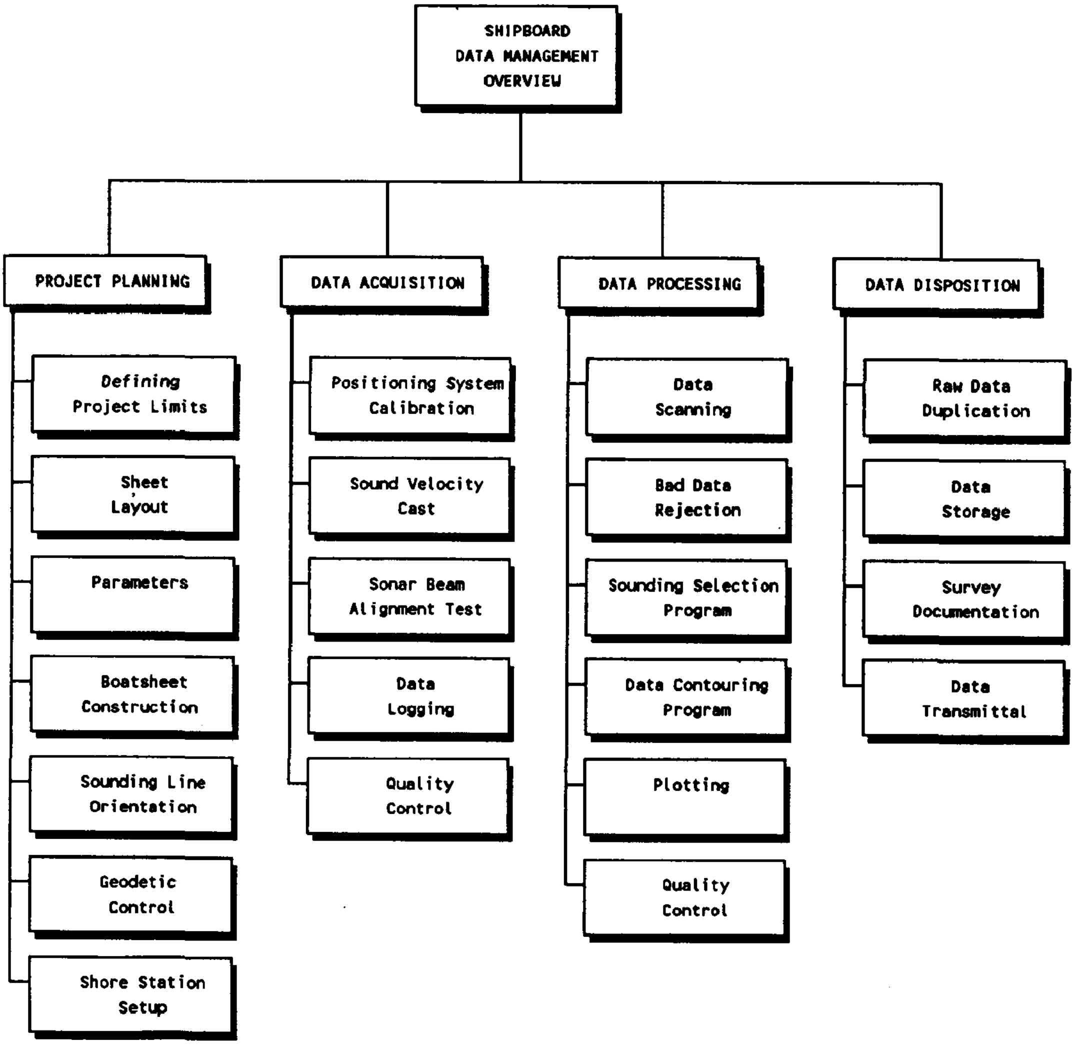

FIG. 1. — Shipboard Data Management Program.

ing of a specific ship to survey a designated area over an established time frame. Survey ships normally are scheduled for two to three projects per field season, ranging in length from two to four months each. Individual projects are divided into a series of legs, times when the ship is actually underway surveying, typically between eleven and twenty-five days duration. Due to the precise nature of NOAA bathymetric mapping, considerable planning is required by each ship before field operations begin.

Defining Project Limits

Large-scale reconnaissance surveys of the U.S. EEZ have been conducted by the United States Geological Survey since 1984, using the British GLORIA (Geological Long-Range Inclined Asdic) side-scan sonar system. Based on these surveys, areas of significant geologic interest have been designated as 'priority regions' to be mapped first by NOAA. These priority regions are divided into geographic units called 'Map Areas', for use in defining project limits and monitoring survey progress. A map area is a specific section of the EEZ, 1 degree of longitude by 1/2 degree of latitude, except in Alaska where it is 1 and 1/2 degrees of longitude by 1/2 degree of latitude, due to the convergence of the meridians in this region. A number of map areas are defined and prioritized as survey objectives at the beginning of each project.

Sheet Layout

Since map areas cover large sections of ocean and would be difficult to survey as single units, they are divided into a series of survey sheets. Individual survey sheets are assigned an official archive registry number and all data associated with a sheet is handled as a separate data set. The most common map area division is three sheets, each 20 minutes of longitude by 30 minutes of latitude, at a standard survey scale of 1:50,000. In special cases, bathymetric swath surveys have been conducted at a smaller scale of 1:20,000 over site specific bottom features. Survey sheets are laid out within designated map areas in the order of anticipated completion.

Parameters

Once the project layout has been completed, individual survey sheets are geographically defined by a set of parameters. Parameters determine sheet size, scale, and location, and establish an X-Y coordinate system over the geographic grid for ease of positioning. Parameter data files are created and utilized throughout data acquisition and processing.

Boatsheet Construction

Field survey sheets, known as 'boatsheets', are constructed by computer, using the parameter files. Boatsheets are utilized during data acquisition to create real-time track and swath plots. These plots are the primary tool used to navigate the ship and assure overlapping swath coverage between adjoining sounding lines.

Sounding Line Orientation

Bathymetric sounding lines are run parallel to the depth contours, whenever possible, to maintain uniform swath widths and ease in obtaining complete bottom coverage. Through the use of prior surveys and existing bathymetric maps, a detailed sounding line orientation plan is developed based on existing knowledge of the prevailing contours.

Geodetic Control

Shore control stations for electronic navigation are either recovered from the existing geodetic control network or new marks are established. Geodetic marks are required for both primary navigation stations and calibration system stations. Control stations are chosen for their proximity to the coastline, unobstructed line of sight to the survey area, and ease of shore station construction.

Shore Station Setup

Primary navigation and calibration electronic systems are placed over the recovered/established geodetic marks. These systems are activated just prior to the ship arriving in the survey area and are maintained by shore parties throughout the project.

DATA ACQUISITION

Bathymetric data collected for the EEZ mapping project are acquired using multi-beam swath survey systems. Two different swath systems are utilized aboard NOAA ships: General Instruments' Sea Beam for deep-water (greater than 600 meters) surveys aboard *Surveyor* (installed 1979), *Discoverer* (1986), and *Mt. Mitchell* (1987), and the NOAA Bathymetric Swath Survey System (BSSS), a modified General Instruments Bo'sun survey system, for shallow-water (100-600 meters) surveys aboard *Davidson* (1978). In addition, an intermediate depth (100-1000 meters) swath mapping system, General Instruments' Hydrochart II or equivalent, is scheduled to be installed aboard *Whiting* in summer 1988.

Sea Beam covers a swath width roughly equal to 70% of water depth. BSSS is theoretically capable of covering a swath up to 2.5 times the water depth, although inaccuracies associated with the outer three beams on each side of the ship limit the usable swath to approximately 1.5 times the water depth. Besides this difference in swath coverage, Sea Beam differs from BSSS in the following: it has a lower data acquisition rate from the sonar due to the deeper waters, it requires less processing because of a digital processor within the sonar and the motion of the ship is accounted for in the sonar processor. NOAA requires the sounding accuracy for both systems to meet International Hydrographic Organization (IHO) standards of better than 1 percent of depth.

Two precision long-range radio navigation systems are currently used to position NOAA swath surveys: Cubic Precision's ARGO (Automatic Ranging Grid Overlay) and Hastings Teledyne's Raydist. Both ARGO and Raydist are medium frequency (1.6 — 4.0 MHz) phase comparison systems which measure ranges in terms of whole and partial lanes. The whole lane count is ambiguous and must be carefully monitored to avoid lane 'jumping'. It is anticipated that all bathymetric mapping will be positioned using the Global Positioning System (GPS) as soon as it becomes fully operational in the early 1990's. Positioning accuracy for swath surveys is required to be better than 50-meter circular error of position which, at a scale of 1:50,000, exceeds IHO standards of 1.5 mm at the scale of the survey.

Positioning System Calibration

Calibrating the primary positioning system is the first step in the data acquisition process. ARGO and Raydist systems are currently calibrated using either Motorola's Mini-Ranger microwave shore-based system or GPS. When using Mini-Ranger, a position is calculated using lines of position from two shore stations and then compared to a position obtained in the same manner from different stations. The inverse distance between the two calculated positions must be less than ten meters to be acceptable. Correctors are obtained by comparing the averaged calibration position to a position simultaneously determined from the primary positioning system. This procedure is repeated until at least three acceptable calibrations are accomplished, with the correctors averaged to determine values used during data acquisition. For GPS calibration, the position obtained is compared directly to the ARGO position.

Sound Velocity Cast

Corrections to echo soundings, based on differences of the speed of sound in water, are also required before data acquisition can commence. NOAA ships obtain sound velocity data in one of two ways: via an electronic conductivity, temperature, and depth (CTD) cast or by the analysis of discrete water samples collected from a Nansen cast. Sound velocity casts are required at least once per survey leg. A sound velocity file is constructed from the data and appropriate correctors are applied to individual soundings in both types of swath systems. In addition, Sea Beam uses sound velocity data to correct for ray bending during data acquisition, while BSSS applies ray bending corrections during post-processing.

XBT observations are taken routinely by NOAA survey ships every 12-24 hours to identify variations in the ocean thermal structure. Software is currently being developed which will use XBT data to determine when the thermal structure of a survey area changes enough to warrant an updated sound velocity cast.

Sonar Beam Alignment Test

A sonar beam alignment test, developed by NOAA, is required to be run at the beginning and end of all EEZ mapping projects. The test is used to verify overall system performance and/or isolate specific beam pointing errors for subsequent correction. Test procedures measure the errors associated with the fore and aft steering of the acoustic projector beam (pitch error), the athwartship alignment of the received beams (roll bias error), and the heading of the gyrocompass relative to the heading from the primary positioning system (swath alignment error). Specifications dictate that each error be resolved to less than 0.25 degree.

Data Logging

At the center of the Sea Beam and BSSS data acquisition are the Digital Equipment Corporation PDP-11 based computer system and the SURVEY data logging program. Input consists of processed depths (Sea Beam) or unprocessed sonar slant ranges (BSSS), positioning system rates, gyrocompass heading, and heave/pitch/roll corrections. Input information is relayed to the SURVEY program at specified time intervals through a master interface known as the CAMAC (Computer Automated Measurement and Control) Crate. SURVEY output consists of a raw data magtape, floppy disk survey summary file, real-time track and swath plot and bridge steering needle. A real-time contour plot, orientated relative to ship's head only, is also produced directly from sonar output (Fig. 2).

All swath data are collected, segregated and processed by survey summary files. Separate and unique survey summary files are created automatically by the SURVEY program each time it is activated, based on the Julian day and the first three digits of the time. Survey summary files can be as short as a few minutes or as long as several hours. Usually, the fewer the number of survey summary files, the shorter the overall processing time for a survey sheet.

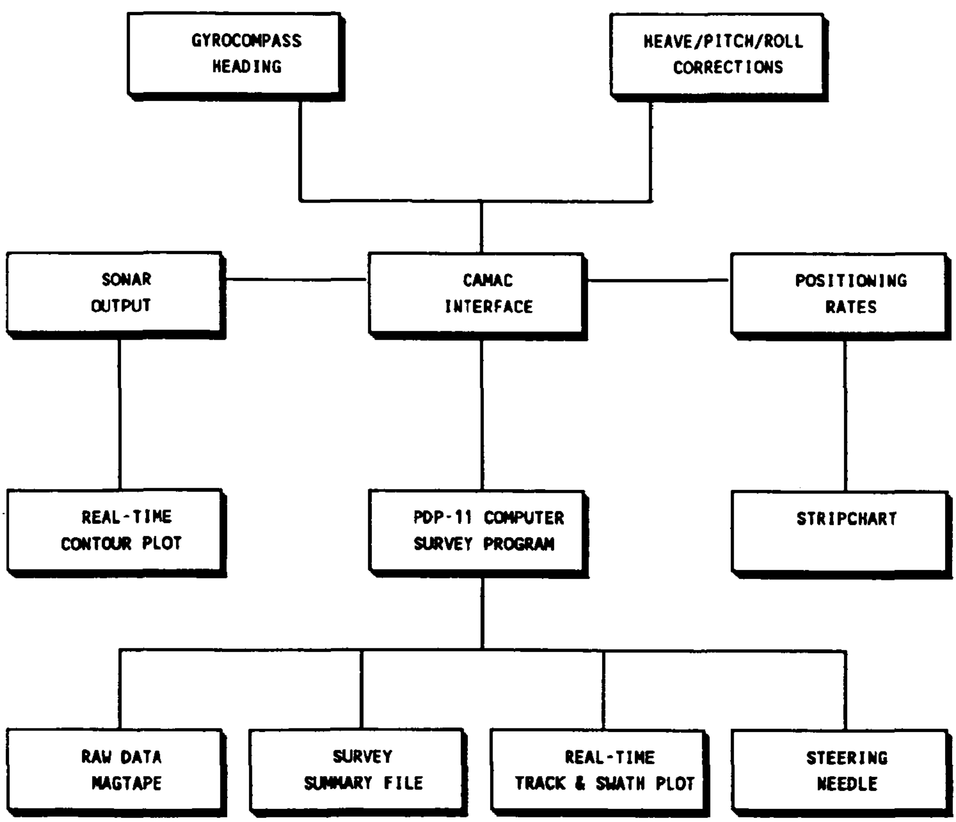

FIG. 2. — Shipboard Data Acquisition System.

Quality Control

Real-time sonar and positioning quality control checks are an integral part of NOAA swath mapping procedures. Sea Beam and BSSS on-line contour plotters are run continuously during data acquisition and examined on a regular basis for the presence of artifacts or sonar degradation. Problems that arise are attended to immediately and, if necessary, data acquisition is halted until the situation is remedied. Bad data are flagged and later rejected during processing. Gaps caused by the rejection of bad data are re-run to assure complete bottom coverage.

Stripchart recorders are connected to ARGO and Raydist receivers to graphically keep track of lanes. An accounting is kept of each lane from opening to closing system calibrations. In addition, an independent whole lane check is obtained as often as possible (at least once per day) on all Sea Beam ships using GPS. Discrepancies that arise in lane counts, which cannot be resolved by either check method, require data acquisition to be discontinued and a complete system re-calibration to be done.

DATA PROCESSING

NOAA Sea Beam and BSSS have separate PDP-11 data acquisition and processing computer systems. Processing programs generally fall into two categories: programs to verify data content and quality and programs to create final data products. A sounding selection program is employed by both swath systems to reduce large quantities of raw data and create conventional point sounding plots. Sea Beam also runs a data conversion program that reformats raw data sets used to produce contour plots (Fig. 3). Data processing for both routines begins with scanning for and eliminating bad data.

Data Scanning

During the first stage of data processing, real-time contour plots and navigation stripcharts are visually scanned for bad data flags applied during data acquisition, as well as for any additional areas of questionable data that may have been missed. A log sheet is kept listing the exact starting and stopping times of all areas of bad data.

Bad Data Rejection

Once all hardcopy data has been scanned, sections of bad data are windowed around during processing or marked for 'no-plot' later. By using the windowing technique, original raw data is never deleted, only ignored and thus can be recovered later if necessary.

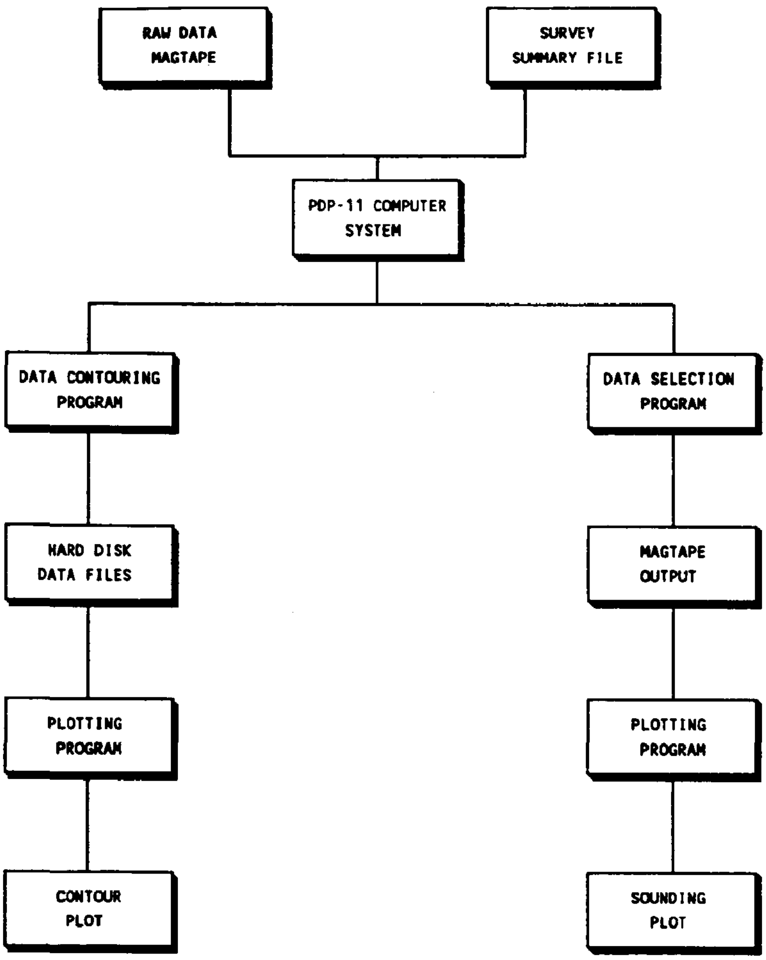

FIG. 3. — Shipboard Data Processing System.

Sounding Selection Program

Sea Beam and BSSS utilize a similar sounding selection program to sieve through large quantities of raw data. The program reads raw data tapes and survey summary files, divides the survey sheet into a series of plottable unit areas (PUA) and, after performing a statistical analysis of all data points falling within the PUA, selects a single reduced minimum and maximum sounding for output to magnetic tape. For Sea Beam, the PUA dimension is internally fixed at approximately 250 meters squared. Due to its shallower depth range, the BSSS PUA is variable and depends on such factors as survey scale and ship's speed. Separate processing runs are done for all survey summary file data sets associated with an individual survey sheet, the data being combined on a single output tape. This output tape is used to plot a conventional point sounding plot.

Data Contouring Program

A data contouring program for machine contouring of field sheets is available only on NOAA's Sea Beam systems and is not available for BSSS processing. This will be changed with the next generation systems. The program reads raw data tapes and survey summary files, integrates positioning and sonar information, and converts the data into a format that can be read by a plotting program. Output is in the form of data files stored on hard disk.

Plotting

Sounding selection output tapes are read by a sounding plot program, which plots individual depths on a standard geographic grid. Minimum soundings only, maximum soundings only, or both minimum and maximum soundings can be plotted. Due to the high density of data points available at the standard 1:50,000 EEZ survey scale, minimum soundings only are chosen. Also, these are the soundings of primary interest for nautical charting purposes.

A plotting program reads hard disk files created by the data contouring program and plots single swath contours by sounding line. A contour interval of 10 or 20 meters is normally used. Separate plotting runs are required to combine individual data files into a complete contour map.

Quality Control

Final sounding and contour plots are used extensively during post-processing to verify data quality. Sounding lines known as 'crosslines', which run at right angles to the general orientation of mainscheme lines, are plotted separately as overlays. Detailed comparisons are made between crossline and mainscheme soundings/contours to check for offsets that may be caused by sonar or positioning errors. This same technique is used between individual sheets that junction. EEZ survey sheets are required to junction with neighboring sheets by at least one full swath width for comparison purposes. In addition, all junctions resulting from overlapping swaths are checked for discrepancies. If problems arise during these comparisons, raw data listings are printed and reviewed for the areas in question and, if necessary, the data are rejected and the lines re-run.

DATA DISPOSITION

Swath surveys completed during one leg of a project are required to be transferred off the ship by the end of the following leg. This ensures timely shipboard processing and eliminates the problem of data backlogs. Before a survey is considered complete, the following post-processing tasks are required:-

Raw Data Duplication

All original raw digital data necessary to re-create a survey are duplicated before the survey is transferred off the ship. This is done to ensure a backup in case data are lost or damaged during transfer or problems arise with the original data during the verification process.

Data Storage

Duplicated raw data magtapes and floppy disk files are stored aboard ship until the survey has been verified, duplicated again, and the original data sent to archive. Once this has been accomplished, the ship is notified to destroy all stored data associated with a particular survey.

Survey Documentation

A series of reports, including a descriptive report, geodetic control report and corrections to echo soundings report are written and submitted with each survey to document how the survey was conducted and to describe any special circumstances that may have occurred during the survey. The reports are used extensively during the verification process and are archived with the raw data sets.

Data Transmittal

All data associated with a bathymetric swath survey, including original raw data tapes and survey summary files, processed output tapes, real-time contour plots, navigation stripcharts, real-time track and swath plot, positioning system calibration information, final sounding and contour plots, raw data listings and all required reports are transferred to the Ocean Mapping Section in Rockville, Maryland, for final processing, survey verification and data archiving.

III. PROJECT OFFICE DATA MANAGEMENT

The Project Office currently maintains data from 118 surveys conducted through the end of the 1987 field season. The management program that has developed is designed to preserve data integrity during the receipt of data submissions, final processing, survey verification and data archival (Fig. 4).

DATA RECEIPT

Swath survey data is received in the Project Office almost continuously throughout the regular field season (March to December). All data submissions

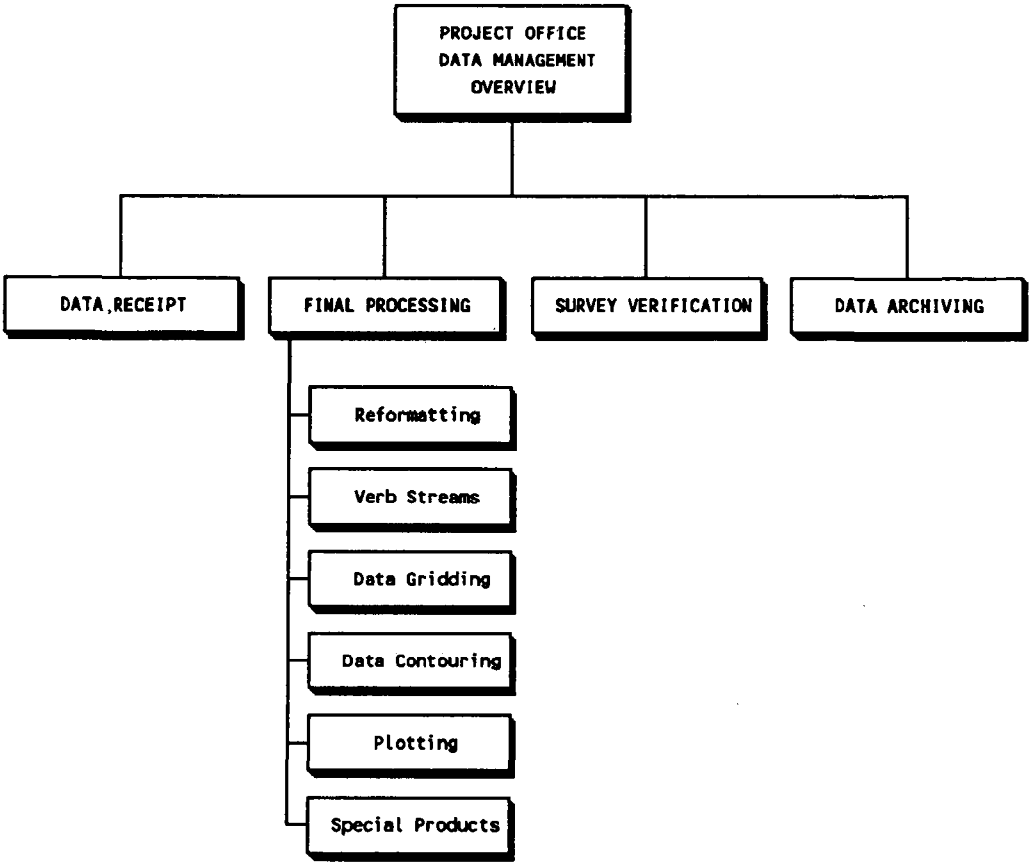

FIG. 4. — Project Office Data Management Program.

are accompanied by an official 'Letter of Data Transmittal', a complete list of individual data items. After a survey arrives, the data are checked against the transmittal for any discrepancies and the transmittal is checked for any omissions of specific data that are required for each survey.

Once the data has been logged into the Project Office, it is stored in 'ready' tape and file cabinets set aside for surveys awaiting final processing. Each survey is assigned to a verifier, who is responsible for conducting final processing and examining all aspects of the survey for completeness and accuracy.

FINAL PROCESSING

Due to the capacity limitations of current NOAA shipboard PDP-11 computers, final data processing is performed by the Project Office on its Control Data Corporation Cyber 170-815 mainframe computer. The primary input to final processing is the sounding selection output tape produced aboard ship.

Final processing continues the procedure of statistically reducing the large quantity of data points in the original raw data set to a workable number. The sounding selection program takes the original soundings for a given area (Fig. 5a), and, through use of the plottable unit area principle, selects approximately two percent of the total soundings (Fig. 5b). Final processing further reduces the data set by gridding the selected soundings (Fig. 5c). Finally, contour vectors are created from the gridded data set and a contour plot is produced (Fig. 5d).

Reformatting

Selected sounding tapes produced by shipboard PDP-11 computers are not directly compatible with the Project Office Cyber computer. Therefore, the first step in final processing involves reformatting the data word structures to run on the Cyber. A reformatted selected sounding file, containing all the data associated with a single survey sheet, is created on hard disk.

Verb Streams

During the reformatting process, statistical information is collected about the data and used to create attribute parameters known as 'verb streams'. The verb stream command files are used to direct operations of a commercial contouring package, Radian Corporation's Contour Plotting System 1 (CPS-1), which grids and contours the data.

Data Gridding

The CPS-1 contouring software first converts all geographic positions contained on the selected sounding tape into Cartesian coordinates in the Universal Transverse Mercator (UTM) projection. Based on these coordinates, a mesh of equally-spaced fixed grid positions at 250-meter intervals is created. Each grid value is selected using a weighted linear least squares algorithm. The actual depth value at each grid point is an interpolated representation of the ocean bottom. The resultant Cartesian coordinate and gridded data files remain on hard disk.

Data Contouring

Once all the gridded values have been determined, CPS-1 subdivides the areas between points and forms contouring vectors. The vectors are converted to specific pen or raster screen commands, depending on the desired display media, and stored as a hard disk data file. Later, this file, along with all the other data files created in the process, are transferred and stored on one magnetic tape. In addition, a second copy of the reformatted selected sounding file is copied and stored on a separate tape as backup. For nautical charting purposes, a Mercator grid

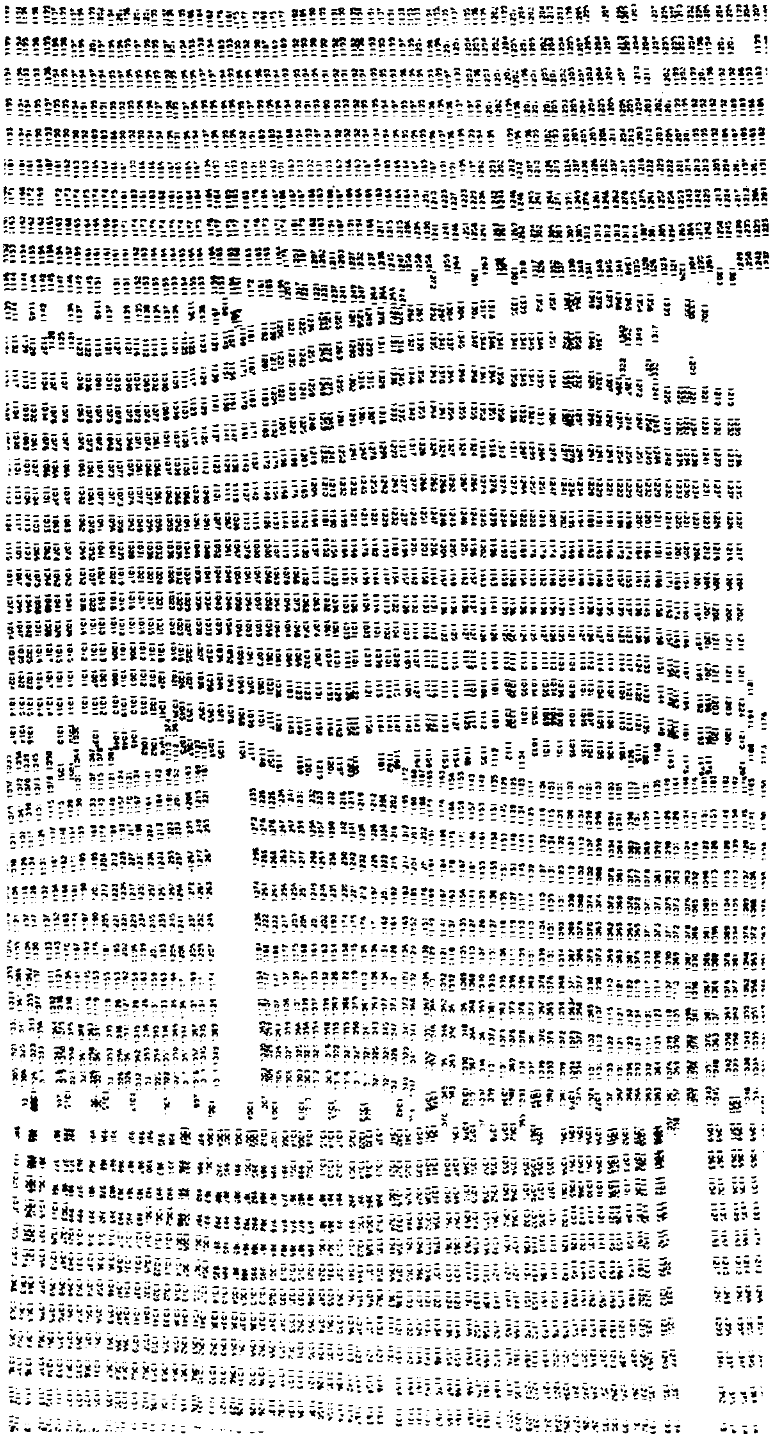

FIG. 5a. — Original raw data set.

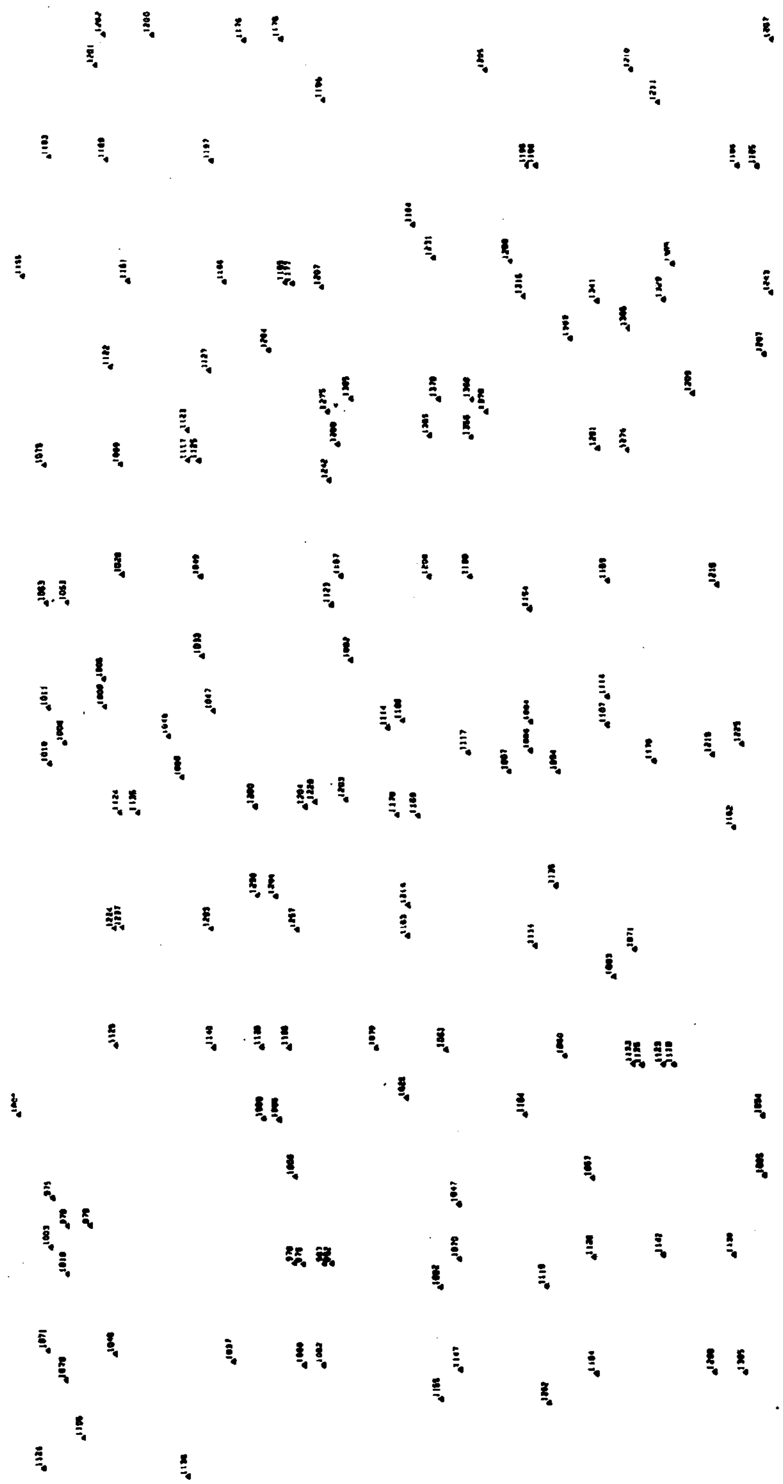

FIG. 5b. — Selected soundings chosen from the original raw data.

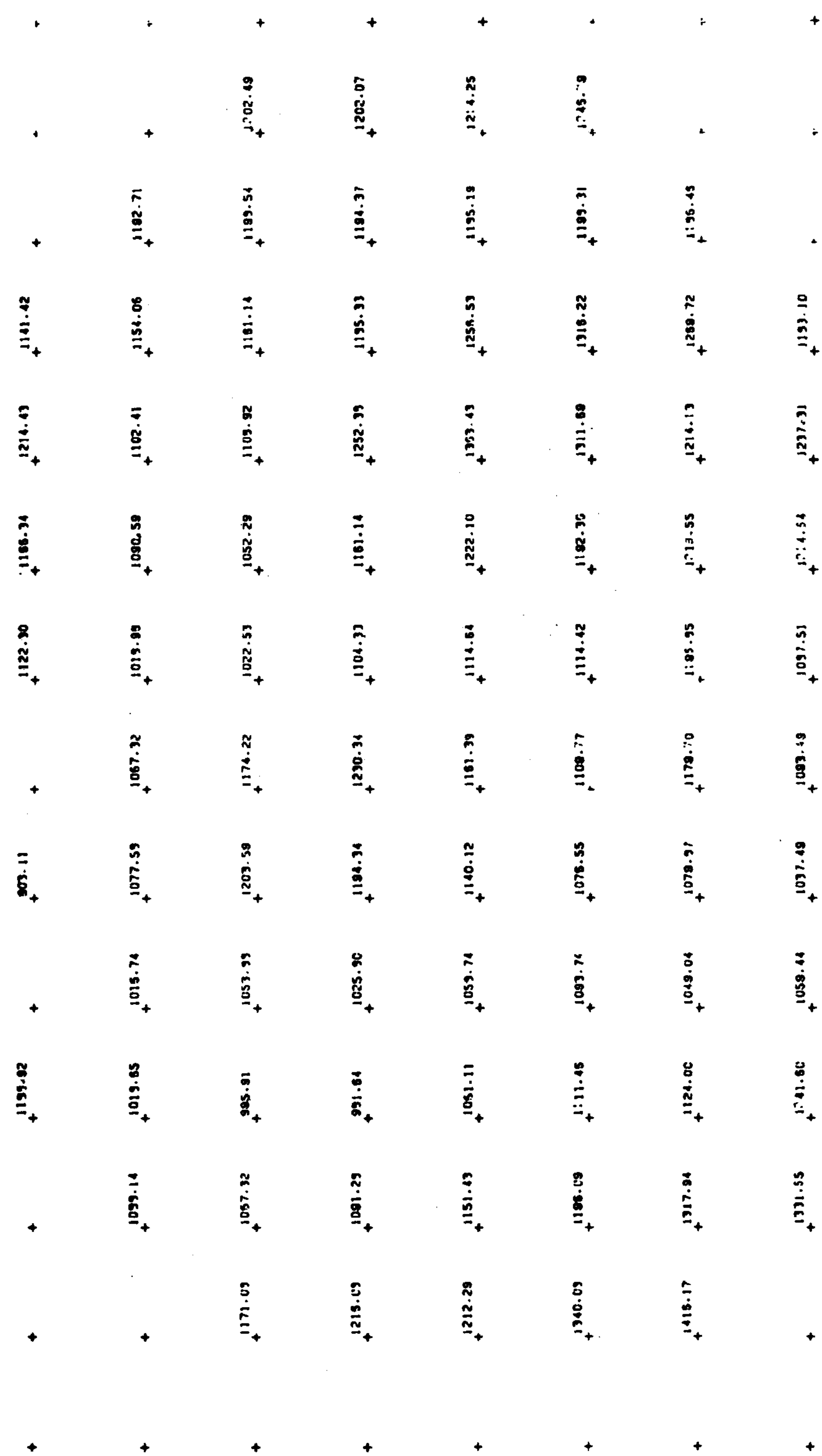

FIG. 5c. — Gridded data set derived from the selected soundings.

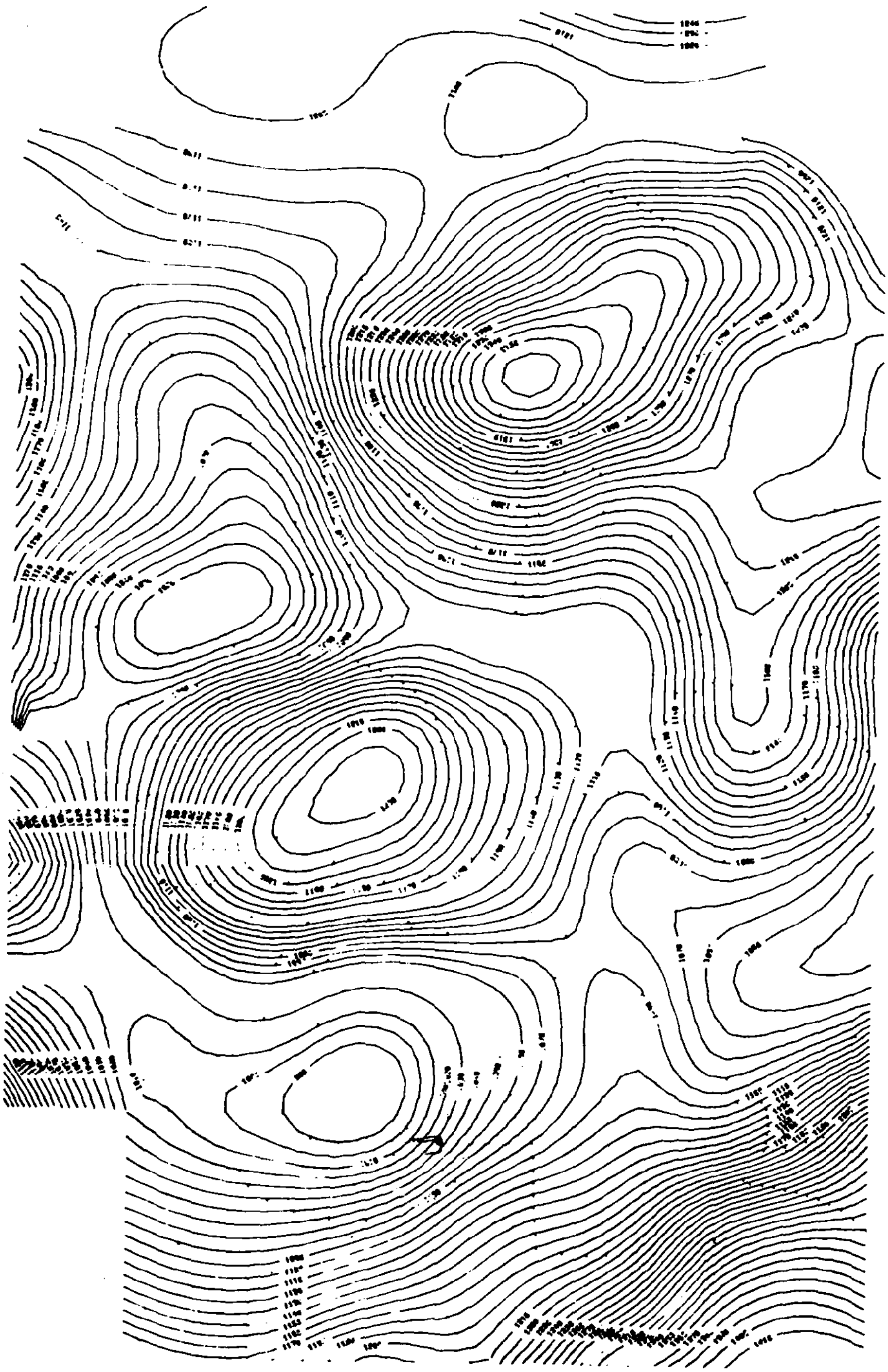

FIG. 5d. — Contour plot created from the gridded data.

of minimum depths is created from which machine contours are generated for application to the charts. A database file record is maintained for each survey sheet to track such information as when the survey was processed, data file names and sizes and geographic boundaries.

Plotting

Gridded data contour plots at scales of 1:50,000 and 1:100,000 are constructed from the contour vector file. The plots are reviewed for any problems caused by artifacts in the data. Artifacts are removed by identifying and marking bad data points for no-plot. Final contour plots are then created from the edited data set. Individual CPS-1 contour vector files are later combined by Map Area and plotted as 1:100,000 scale base maps.

Special Products

In addition to the standard CPS-1 contour plots and base maps produced during final processing, two specialized products are being developed by the Project Office to better display swath data. The first are color-fill contour plots, which have the area between major contours fully shaded with alternating colors, and the second are three dimensional mesh plots. Both types of plots greatly increase visual data display and are useful tools for interpreting seafloor morphology. Eventually, digital GLORIA imagery and the digital bathymetry will be combined into a textured three-dimensional plot for geologic interpretation.

SURVEY VERIFICATION

Formal survey verification enables the Project Office to maintain close quality control over shipboard data collection. A standardized verification process has been developed and is applied to each survey before the data is approved for inclusion in the EEZ database.

During verification, individual data sets are examined first and then the survey is evaluated as a whole. All survey components are reviewed for accuracy, completeness and proper application. Special attention is given to positioning calibrations and application of correctors, sound velocity corrections, horizontal control computations and plot comparisons (crosslines and junctions).

Final CPS-1 contour plots are examined and compared to raw data contour plots produced aboard ship. Discrepancies are resolved by reviewing the raw data records and eliminating bad data points that may have been missed during initial shipboard processing.

The verification process concludes with the submission of a report which documents the overall survey quality, any deficiencies encountered in the data and a summary of what new findings occurred as a result of the survey. A copy of the verification report remains with the data for reference and a copy is forwarded back to the ship as a tool for improving future performance.

DATA ARCHIVING

As the final step in its data management program, the Project Office copies and concatenates all raw data tapes and survey summary files and transfers the originals to an official archives facility for permanent storage. The copies are retained in the Project Office for future use and as a safeguard in the event the archived data is ever damaged or destroyed.

Following survey verification, most hardcopy data is destroyed because of the logistics involved in storing such large quantities of data. Retained is a copy of the ship's descriptive report, a copy of the verification report, sound velocity information, and for Sea Beam surveys, the real-time contour plots.

IV. FUTURE CONSIDERATIONS

SEA BEAM COMPUTER SYSTEM UPGRADE

NOAA Sea Beam data acquisition and processing systems will soon be upgraded with Digital Equipment Corporation MicroVAX II computers. This conversion is necessary to speed up and streamline present shipboard acquisition and processing procedures. The first upgrade will be implemented aboard *Mt. Mitchell* in the summer 1988.

The new system will consist of two identical MicroVAX II computers, communicating via an Ethernet connection. Data logging can occur on one or both of the computers, although only one has primary data connections and can query navigation information. The other computer has secondary, receive-only connections, but can run identical data logging programs for backup or new program testing. Raw data is logged on hard disk and electronically transferred to the processing computer via the Ethernet. Processing also occurs on hard disk, eliminating the need for magnetic tapes, except as a final storage media for raw and processed data files.

The current track and swath plot, which uses brackets to depict swath coverage, will be replaced by a geographically oriented real-time track and contour plot. The new plot will allow operators to more accurately monitor sonar and positioning data by observing actual contour overlap between adjoining sounding lines. As with the current system, a final smooth contour plot will be a product of the processing scheme.

The Project Office has also recently acquired a MicroVAX II computer system and is in the process of converting its final processing programs from the Cyber to the MicroVAX. Having compatible computer systems will facilitate an easier exchange of software and data between the ships and the Project Office.

BSSS REPLACEMENT

After the next generation swath system has been installed and tested aboard

Whiting in the summer 1988, a second system will be procured to replace the BSSS aboard *Davidson*. Replacement is necessary due to the age of the BSSS and the fact that it is essentially a one-of-a-kind system, which makes repair and procurement of replacement parts difficult. The new system will also increase *Davidson's* depth limit from 600 to 1000 meters, enabling more efficient junctions with Sea Beam surveys.

OPTICAL DISK STORAGE

One of the primary data management problems associated with swath mapping systems is how to maintain and access the large quantities of data currently stored on magnetic tape. As a proposed solution, the Project Office has acquired an optical storage device for its MicroVAX computer system and is currently evaluating the practicality of transferring all past and future data files to optical platters. The optical system is designed to write once and read many times (WORM) and has a one gigabyte on-line capability, with a second gigabyte available by turning the platter over. With this amount of storage capacity, a single optical platter could hold all the data associated with several dozen surveys. If data can be transferred easily and safely, optical systems will be recommended for shipboard data storage and transfer.

CONVERSION TO GPS

As stated earlier, NOAA plans to convert all swath mapping positioning control to GPS as soon as the system becomes fully operational in the early 1990's. The ability to utilize GPS as primary control will eliminate the burden and logistics of establishing and maintaining shore-based positioning systems.