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Final Technical Report
August 1980

BATHYMETRIC DATA REDUCTION SYSTEM

Synectics Corporation

Donald T. Alvarez
Joan R. Terenzette
David A. Kolassa

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
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This report describes the development of the bathymetric data reduction system. It addresses mathematical areas (projection transformations and their inverses, fathogram processing and geographic sectioning) data accuracy considerations. (Registration and data manipulation), software accomplishments (digitizing, batch processing and data base) and software/hardware configuration. This report contains appendices detailing terms used, loadlines and file and record formats.

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TECHNICAL REPORT SUMMARY
FINAL REPORT
BATHYMETRIC DATA REDUCTION SYSTEM (BDRS)

1. TECHNICAL PROBLEM

The Scientific Data Department (SD) of the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC) is responsible for the acquisition, evaluation, maintenance and exploitation of data related to the disciplines of bathymetry and hydrography. As the accelerated exploitation of the world's oceans continues due to increased demands for accurate sea floor topography in support of both national defense and natural resource exploitation, DMAHTC's role was becoming more difficult due primarily to:

- ✓ An increase in the amount of data arriving at DMAHTC for inclusion into its library system;
- ✓ A dramatic increase in the number of requests for data by users, both old and new; and
- ✓ The ever-increasing demands for more accurate data being provided in a more timely manner.

Recognizing the situation, DMAHTC/SD embarked on the phased development of a system that would, as a minimum, be capable of: converting analog sources into digital data; storing the data in a bathymetric data base; evaluating and manipulating the stored data; and outputting the data in a form acceptable to DMAHTC customers. This system, known today as the Bathymetric Data Reduction Subsystem (BDRS), was to be part of a DMAHTC-wide system capable of supporting its goals and objectives digitally.

2. GENERAL METHODOLOGY

Methods used during the course of the 36-month project included in-depth analysis of: production/operational environments; existing DMAHTC hardware systems; and hardware/software technologies. The independent digitization, batch and data base subsystems were developed independently according to specific user requirements. Interactive software dialogues and procedures were based on user inputs. System test and evaluation was performed at DMAHTC, Washington, D.C.

3. TECHNICAL RESULTS

The BDRS system concluded that: the concept was valid; efficient conversion, storage and maintenance of digital bathymetry exists; operational procedures were key to the integration of the three subsystems; and the selected hardware was responsive in meeting the goals and objectives of the development effort. The major technical result was the accurate and timely conversion, storage and retrieval of digital bathymetry/hydrography in support of DMAHTC operational goals and objectives.

4. IMPLICATIONS FOR FURTHER RESEARCH

Three major areas should be addressed as future considerations: Hardware technology; Digital Data Base exploitation; and Interfaces to existing, planned, and future DMAHTC systems. Regarding hardware technology, input devices and automated techniques, capable of cost-effectively converting source material to a usable digital format, are continually being developed and tested in the laboratories. The inclusion of such devices and/or techniques into the existing BDRS framework would greatly enhance the system's ability to support the growing production demands being placed on DMAHTC. Additionally, computer/peripheral, communications and plotter/recorder hardware should be continually monitored. The area of digital data exploitation should be seriously considered for further research. Expansion of existing data base capabilities in support of additional on-line data base users and the development of, and experimentation with additional data manipulation and exploitation techniques capable of providing new and varied products to DMAHTC customers, should be rigorously pursued. Interfaces to/from DMAHTC systems should be carefully designed and reviewed to insure data interchangeability/compatibility between systems supporting the same goals and objectives.

5. SPECIAL COMMENTS

The BDRS is one of the first major multi-technology systems implemented in the production environment for the purpose of supporting bathymetric/hydrographic production requirements.

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EVALUATION

The Bathymetric Data Reduction System resulting from this development effort is installed and operating within the Scientific Data Department of the Defense Mapping Agency Hydrographic Topographic Center (DMAHTC). This is the first system of its kind capable of the evaluation of fathograms, digityzing of Bathymetric source data, processing the data into a uniform geographic reference frame and the inclusion of the digital data into the digital Bathymetric Data Library. The system provides for the efficient provision of digital data to the variety of nautical chart products produced by DMAHTC and will prove of great value in the cost effective, accurate production of DOD required products. This effort is within Technical Plan thrust R2D.

Joseph J Palermo
JOSEPH J. PALERMO
Project Engineer

SECTION 1. INTRODUCTION

1.1 PURPOSE

The purpose of this document is to first present an account of the critical subsystem and technical problems encountered during the design, development, and implementation of the BDRS. Secondly, to provide an evaluation of the solutions developed by Synectics Corporation to these problems.

1.2 ORGANIZATION

This document is divided into five areas. Section 2 is dedicated to a discussion of problems whose solutions are mathematical in nature. A discussion of the software accomplishments pertaining to the BDRS is given in Section 3. Section 4 deals primarily with problems of accuracy that occur in data input and manipulation. Section 5 identifies and discusses the hardware and software configurations utilized to meet the functional objectives of the BDRS. The last section will deal with conclusions and recommendations relative to the current and possibly future BDRS. Additionally, three appendices are provided with: Appendix A containing a "BDRS Glossary of Terms"; Appendix B detailing the load lines for all BDRS functional software; and Appendix C identifying and discussing, in detail, all BDRS file and record formats.

SECTION 2. MATHEMATICAL APPLICATIONS

2.1 PURPOSE

The purpose of this section is to provide a detailed account of the mathematical algorithms and their applications within the BDRS problem environment. The four contexts in which algorithms have been developed are registration, coordinate transformations, geographic sectioning and fathogram processing.

2.2 REGISTRATION

2.2.1 Problem To Be Solved

The problem to be solved by n point registration is twofold. First, a function must be constructed whose domain is comprised of physical X-Y locations on a digitizing table and whose range is comprised of X-Y coordinates in an earth rectangular frame, given that n values (3 to 8) of the function are known. The construction of this function is referred to as day '1' n-point registration. Second, a function must be constructed which maps table X-Y locations to table X-Y locations given that n (from 3 to 8) values of the function are known. This construction is entitled day 'n' n point registration.

Day '1' registration, from an empirical point of view, results in the geodetic significance of points on a map which has been placed on the digitizing table. Day 'n' registration results in mapping back to day 1 the points on the map as it lies on the table translated or rotated relative to the day 1 registration of the map. Since both algorithms are identical from a mathematical point of view, it suffices to give a presentation of day 1 registration.

2.2.2 Method of Solution

The idea of the n-point registration is to convert X-Y table values to a form which can be converted to lat/long values on the earth's surface. A pure table X-Y value is physically meaningless.

The problem is a typical statistical one of finding a function given that you know some of the ordered pairs that the function must satisfy. In registration you know:

(a) the table X-Y values of the registration points

(b) the map scale mil values of the lat/long values of the registration points (the map scale mil values are found by taking the output from the map projection itself and converting to units of mils)

To be more precise, let X^1, X^2,...X^n be the map scale mil X values of the registration points, let Y^1, Y^2,...Y^n be the map scale mil Y values of the registration points, let X_1, X_2,...X_n be the known table X values, let Y_1,...Y_n be the table Y values. You know for each ordered pair of X-Y table points X_i,Y_i the map scale mil equivalent X^i,Y^i. This constitutes the known relations which must be approximated by the function being sought. What properties should the function have beside fitting the known data? Simplicity requires that the function be linear. Geometrical considerations suggest finding two function f,g such that

(a) $f(X_i,Y_i) \simeq X^i$

(b) $g(X_i,Y_i) \simeq Y^i$

Given the assumption of linearity we get

(a) $f(X_i,Y_i) = AX_i+BY_i+C \simeq X^i$

(b) $g(X_i,Y_i) = DX_i+EY_i+F \simeq Y^i$

Now we must impose some conditions which allow us both to solve for A,B,C,D,E and F unambiguously and which lend geodetic meaning to the physical table X-Y values. That is, given an arbitrary table X-Y pair, the functions f and g must map the pair into an approximately correct map scale mil ordered pair.

The classical approach to a statistical problem in a linear model is the least squares best fit algorithm. The idea is to minimize the sum of the squares of the differences between known data values and the values predicted statistically. In registration we have known map scale mil values. We want the functions f and g to yield predicted map scale mil values such that we minimize the sums of the squares of the differences between the predicted map scale mil values (i.e., $f(X_i,Y_i)$, $g(X_i,Y_i)$) and the known map scale mil values (i.e., X^i,Y^i).

More explicitly, given that

(a) $X^i = AX_i+BY_i+C$

(b) $Y^i = DX_i+EY_i+F$

minimize

$$(c)\ \sum_{i=1}^{n} [X^{i} - (AX_{i}+BY_{i}+C)]^{2}$$

$$(d)\ \sum_{i-1}^{n} [Y^{i} - (DX_{i}+EY_{i}+F)]^{2}$$

by picking the correct values of A,B,C,D,E, and F

$$\text{Let } H(X^{i},X_{i},Y_{i}) = \sum_{i=1}^{n} [X^{i}-(AX_{i}+BY_{i}+C)]^{2}$$

$$\text{and } G(Y^{i},X_{i},Y_{i}) = \sum_{i=1}^{n} [Y^{i}-(AX_{i}+BY_{i}+C)]^{2}$$

the requirement of minimizing these expressions is logically equivalent to the following six equations:

$$(1)\quad \frac{\partial H}{\partial A} = \phi$$

$$(2)\quad \frac{\partial H}{\partial B} = \phi$$

$$(3)\quad \frac{\partial H}{\partial C} = \phi$$

$$(4)\quad \frac{\partial G}{\partial D} = \phi$$

$$(5)\quad \frac{\partial G}{\partial E} = \phi$$

$$(6)\quad \frac{\partial G}{\partial F} = \phi$$

Taking the derivatives and simplifying we get the following six equations:

$$(1)\quad A\sum_{i=1}^{n} (X_{i})^{2} + B\sum_{i=1}^{n} X_{i}Y_{i} + C\sum_{i=1}^{n} X_{i} = \sum_{i=1}^{n} X^{i}X_{i}$$

$$(2)\quad A\sum_{i=1}^{n} X_{i}Y_{i} + B\sum_{i=1}^{n} (Y_{i})^{2} + C\sum_{i=1}^{n} Y_{i} = \sum_{i=1}^{n} X^{i}Y_{i}$$

$$(3)\quad A\sum_{i=1}^{n} X_{i} + B\sum_{i=1}^{n} Y_{i} + n = \sum_{i=1}^{n} X^{i}$$

$$(4)\quad D\sum_{i=1}^{n} (X_{i})^{2} + E\sum_{i=1}^{n} X_{i}Y_{i} + F\sum_{i=1}^{n} X_{i} = \sum_{i=1}^{n} Y^{i}X_{i}$$

(5) $$D\sum_{i=1}^{n} X_iY_i + E\sum_{i=1}^{n} (Y_i)^2 + F\sum_{i=1}^{n} Y_i = \sum_{i=1}^{n} Y^iY_i$$

(6) $$D\sum_{i=1}^{n} X_i + E\sum_{i=1}^{n} Y_i + n = \sum_{i=1}^{n} Y^i$$

Note that all expressions are known in the above equations except for A,B,C,D,E, and F. To solve for these, treat equations 1,2, and 3 as 3 equations in 3 unknowns A,B, and C; and treat equations 4,5, and 6 as 3 equations in 3 unknowns D,E, and F. Then we can write equations 1-3 and 4-6 as:

$$XY = Z$$

$$XW = V$$

where

$$X = \begin{pmatrix} \sum_{i=1}^{n} (X_i)^2 & \sum_{i=1}^{n} X_iY_i & \sum_{i=1}^{n} X_i \\ \sum_{i=1}^{n} X_iY_i & \sum_{i=1}^{n} (Y_i)^2 & \sum_{i=1}^{n} Y_i \\ \sum_{i=1}^{n} X_i & \sum_{i=1}^{n} Y_i & N \end{pmatrix}$$

$$Y = \begin{pmatrix} A \\ B \\ C \end{pmatrix} \qquad W = \begin{pmatrix} D \\ E \\ F \end{pmatrix}$$

$$Z = \begin{pmatrix} \sum_{i=1}^{n} X^iX_i \\ \sum_{i=1}^{n} X^iY_i \\ \sum_{i=1}^{n} X^i \end{pmatrix} \qquad V = \begin{pmatrix} \sum_{i=1}^{n} Y^iX_i \\ \sum_{i=1}^{n} Y^iY_i \\ \sum_{i=1}^{n} Y^i \end{pmatrix}$$

Note that X is a symmetric matrix

To solve for $Y = \begin{pmatrix} A \\ B \\ C \end{pmatrix}$, $W = \begin{pmatrix} D \\ E \\ F \end{pmatrix}$ find the inverse of X; X^{-1} to get

$$(1) \begin{pmatrix} A \\ B \\ C \end{pmatrix} = X^{-1}Z$$

$$(2) \begin{pmatrix} D \\ E \\ F \end{pmatrix} = X^{-1}V$$

The matrix X^{-1} exists if its determinant is non-zero which seems to work always. If it does not work, new registration points must be chosen.

The software for this approach requires solving for the elements of X,Z,W, finding X^{-1}, and multiplying $X^{-1}Z$ and $X^{-1}V$. Having found these values we have for an arbitrary table XY pair X_i,Y_i that

$$(1) \quad X^i = AX_i+BY_i+C$$

$$(2) \quad Y^i = DX_i+EY_i+F$$

Upon conversion of X^i,Y^i to meters we multiply by the map scale to get U^i,V^i; the earth scale meter equivalents of X^i,Y^i. This pair U^i,V^i is the input into the inverse map projection. The output is the pair θ,ψ called the latitude and longitude of the table point X_i,Y_i.

2.2.3 Source and History of Approach

The adopted approach to registration was developed 'in-house' at Synectics Corporation. In particular, the idea of solving for the X and Y dimensions independently resulted in minimizing errors which could result from redigitizing single control points when a registration is unacceptable.

2.2.4 Empirical Results and Evaluation

Since the mathematical model of registration is both statistical and linear, there are empirical situations in which problems can arise. In the ideal situation, the source map is not distorted badly by shrinkage or expansion. We have noted that such distortion is rarely compensated for within the linear model. A distorted map can be registered within the residual tolerance level. This should not be taken as evidence that the statistical fit has adequately compensated for the distortion. The model is linear; therefore, the scaling which occurs is uniform along an axis. Thus, the actual map shrinkage is spread uniformly over the map. This could make the functions constructed in registration both meet the residual test and fail to provide an adequate mapping. Thus, the chart must be known to be in good condition or poor empirical data from the table might be allowed to infiltrate the data base.

It is crucial to pick registration points intelligently. If 8 registration points are picked representative of the map as a whole, that is, in no obvious geometrical pattern, and the document is in good physical condition, then the results of registration can be trusted. All mathematical computations are performed in over-kill double precision.

2.2.5 Future Topics of Interest

Since the mathematical model of registration is linear, the idea obviously arises of utilizing a model in which non-linear terms contribute to statistical prediction. The linear model is quite satisfactory given a chart in good condition and an intelligent choice of registration points. Thus the employment of a non-linear model would be motivated if an attempt were made to register charts in less than optimal condition.

The linear model could also be supplemented with a normally distributed error term whose expectation value is zero and whose standard deviation reflects user input in accuracy in entering a control point. However, it seems arbitrary to assign such a standard deviation for an arbitrary user. Thus, this term does not appear in the functions constructed by registration.

2.3 COORDINATE TRANSFORMATIONS

2.3.1 Problem to be Solved

The problem to be solved by the coordinate transformations is to convert between earth rectangular and geodetic coordinates utilizing the Mercator, Miller, Lambert, Polyconic and Transverse Mercator projections. The conversion from geodetic to earth rectangular coordinates is effected by the map projection itself. Inverses had to be constructed as well to convert earth rectangular to geodetic coordinates.

2.3.2 Method of Solution

The projection types utilized are conformal projections. As Thomas has shown in "Conformal Projections in Geodesy and Cartography", Coast and Geodetic Survey Special Publication 251, all conformal mappings of the spheroid upon a plane are expressed by the analytic function

$$X+iy = f(\lambda \underline{+} ir) \quad \text{where}$$

$$r = \ln \left[\tan \left(\frac{\pi}{4} + \frac{\phi}{2}\right) . \left(\frac{1-\xi \sin\phi}{1+\xi \sin\phi}\right)^{\xi/2} \right]$$

and ϕ equals the latitude of the point, λ the longitude and ξ the eccentricity. The form of the Mercator and Transverse Mercator mapping is then determined by which line or lines in the projection are to be held true to scale and by the necessary geometric form of map elements corresponding to meridians and parallels. Once the form of f is determined, the real and imaginary parts of $X+iy = f(\lambda \underline{+} ir)$ are equated which must in turn satisfy the well known Cauchy Riemann equations:

$$(1) \quad \frac{\partial x}{\partial \lambda} = \frac{\partial y}{\partial r}$$

$$(2) \quad \frac{\partial x}{\partial r} = - \frac{\partial y}{\partial \lambda}$$

to finally obtain x as a function of λ and r and y as a function of λ and r. The mapping equation is thus derived.

2.3.2.1 Mercator Mapping Equation

The Mercator projection is the simplest and most basic of the conformal map projections. The form of f is linear and the initial conditions quite simple. As Thomas indicates, the initial condition is that the scale of the projection must be true at the equator. Thus, for a latitude of $\phi=0$, $r=\ln(1) = \phi$, and $Y=0$; and $x=a\lambda$, the product of the equatorial radius and the longitude λ. Thus since $x+iy=f(\lambda+ir)$ we have $a\lambda+i.\phi=f(\lambda+i.\phi)=f(\lambda)=a(\lambda+ir).=x+iy$. Equating real and imaginary parts of $x+iy=a.(\lambda+ir)$ we have:

(1) $x=a\lambda$

(2) $$y=ar= a.\ln\left[\tan\left(\frac{\pi}{4} + \frac{|\phi|}{2}\right) \quad \left(\frac{1-\xi\sin\phi}{1+\xi\sin\phi}\right)^{\xi/2}\right]$$

$$= a.\ln\left[\frac{(\sin\phi+1)}{\cos\phi} \quad . \quad \left(\frac{1-\xi\sin\phi}{1+\xi\sin\phi}\right)^{\xi/2}\right]$$

The scale or magnification of a point at latitude ϕ given a conformal projection is the Jacobian of x and y with respect to r and λ divided by $N\cos\phi$ where $N= \frac{a}{1-\xi^2\sin^2\phi}$; the distance from the point along that line from the minor axis of the spheroid perpendicular to the line tangent to the point. In this case the scale become $\frac{a}{N} . \sec\phi$.

2.3.2.2 Inverse Mercator Mapping Equation

Given the Mercator mapping function Y = f(x) which maps a latitude to an earth scale meter value, find a method to calculate the latitude given the earth scale meter value.

The Mercator mapping equation in question takes the form:

$$Y = (A/_{SCALAC}) \ . \ \ln\left[\tan\left(\frac{\pi}{4} + \frac{|P|}{2}\right) \ . \ \left(\frac{1-ZECC.SIN\ (P)}{1+ZECC.SIN\ (P)}\right)^{ZECC/2}\right]$$

Where Y = the earth scale meter value and P = the latitude value. Given this form for f(x), an expression 6(x) must be derived such that the form p = 6(P) is obtained. Given an initial approximation P_o to P, Wegstein iteration is used to improve the desired latitude value.

To derive the form P - 6(p) we proceed as follows. Since SCALAC is a constant we eliminate it to get

$$Y_1 = A.\ln\left[\tan\left(\frac{\pi}{4} + \frac{|P|}{2}\right) \ . \ \left(\frac{1-ZECC.SIN(P)}{1+ZECC.SIN(P)}\right)^{ZECC/2}\right]$$

$$Y_1 = A.\ln\left[\tan\left(\frac{\pi}{4} + \frac{|P|}{2}\right)\right] + Y(P)$$

where $Y(P) = A.\ln\left[\left(\frac{1-ZECC.SIN(P)}{1+ZECC.SIN(P)}\right)^{ZECC/2}\right]$

But $Y(P) = A.ZECC.1/2 \ln\left(\frac{1-ZECC.SIN(P)}{1+ZECC.SIN(P)}\right)$

So if we let B = ZECC.SIN(P) and use the series expansion $1/2 \ln \frac{1+B}{1-B} =$

$B+1/3B^3 + 1/5B^5 + \ldots$ with AE2 = A.ZECC, AE4 = $\mathrm{A.ZECC.ZECC}/_{3!}$

AE6 = $\mathrm{A.ZECC.ZECC.ZECC}/_{5!}$ we get

$$Y(P) = \mathrm{SIN}(P).(AE2 + \mathrm{SIN}^2(P).(AE4 + \mathrm{SIN}^2\, P).AE6)$$

Therefore:

$$Y_1 = A.\ln\left(\tan\frac{\pi}{4} + \frac{|P|}{2}\right) - Y(P)$$

$$\rightarrow \frac{Y_1 - Y(P)}{A} = \ln\left(\tan\frac{\pi}{4} + \frac{|P|}{2}\right)$$

$$\rightarrow \mathrm{EXP}\left\{\left[\frac{Y_1 - Y(P)}{A}\right]\right\} = \tan\left(\frac{\pi}{4} + \frac{|P|}{2}\right)$$

$$\rightarrow P = 2 .\left(\arctan\left(\exp\left\{\left[\frac{Y_1 - Y(P)}{A}\right]\right\}\right) - \frac{\pi}{4}\right)$$

Thus we have derived the correct form P = 6(P) for use by the iteration scheme.

The initial approximation P_0 to P is obtained by considering ZECC = 0; that is, a spherical earth model is employed. Proceeding as before we have:

$$Y_1 = A.\ln\left(\tan\left(\frac{\pi}{4} + \frac{|P|}{2}\right)\right)$$

$$P_0 = 2. \left(\arctan\left(\exp(Y_1/_A)\right) - \frac{\pi}{4}\right)$$

Thus P_0 is calculated exactly.

Having obtained P_0 and P = 6(P) Wegstein iteration is used as follows:

(1) Initialization

$\bar{P}_0 = P_0$

$P_1 = G(\bar{P}_0)$

$$\bar{P}_1 = G(P_1) + \frac{G(P_1) - P_1}{\dfrac{P_1 - P_o}{G(P_1) - P_1} - 1}$$

(2) At Iteration n + 1

$$Pn+1 = G(\bar{P}n)$$

$$\bar{P}n+1 = G(Pn+1) + \frac{G(Pn+1) - Pn+1}{\dfrac{Pn+1 - Pn}{G(Pn+1) - Pn+1} -1}$$

(3) Convergence at tolerance E

$$\frac{\bar{P}n+1 - \bar{P}n}{\bar{P}n+1} < \varepsilon$$

This will occur unless G^1 (P) equals 1 at P. If convergence does not occur, the initial approximation P_o is output as the latitude.

2.3.2.3 Transverse Mercator Mapping Equation

As Thomas points out, the initial condition of the Transverse Mercator projection is that the scale is true along the central meridian of the map. Thus, for a point at longitude zero and latitude ϕ we have x=0. Given that $x+iY=f(\lambda+ir)$ we have $iy=f(ir)=i$. $\int_0^{\phi} Rd\phi=iS\phi=$ the distance along the meridian from the equator at longitude λ to the point at latitude ϕ with R= the radius of curvature $=(1-\xi^2)\ .a.(1-\xi^2\sin^2\phi)^{-3/2}$. But $r = \int_0^{\phi} \frac{R}{N} \sec\phi d\phi$ by the condition on r for all conformal projections. Thus $dr=\frac{R}{N}\sec\phi d\phi$ and $Rd\phi=N\cos\phi dr$. Therefore $S\phi= \int_0^{\phi} N\cos\phi dr=f(r)$ since λ is zero. Thus we have $x+iy=S\phi=f(r)$. Now we want to subject x and y to the Cauchy Riemann equations so that equations for x and y in terms of λ and r are needed. Thomas proceeds to expand $x+iy=f(\lambda+ir)$ about the point z=ir in a Taylor Series. Then real and imaginary components are equated yielding the desired forms for x and y in terms of λ and r. Once all terms are computed and the Cauchy Riemann equations applied, Thomas reaches his desired mapping equations.

The scale K for the projection at a point λ,ϕ is

$$K= \left[\left(\frac{\partial x}{\partial\lambda}\right)^2 + \left(\frac{\partial y}{\partial\lambda}\right)^2\right]^{1/2} \quad N\cos\phi$$

$$= \frac{1}{N\cos\phi} \quad \frac{\lambda x}{\partial\lambda} \quad . \ (1 + \tan^2 r)^{1/2}$$

2.3.2.4 Inverse Transverse Mercator Equations

The following algorithm, taken from Rapp and Sprinsky, Page 30 is employed.

$$\Delta\lambda = \sec\phi\left[\frac{X}{N} - \frac{1}{6}\left(\frac{X}{N}\right)^3 (1 + 2t_1^2 + \eta_1^2) + \frac{1}{120}\left(\frac{X}{N}\right)^5 (5 + 28t_1^2 + 24t_1^4 + 6\eta_1^2 + 8t_1^2\eta_1^2)\right]$$

$$\phi = \phi' \ \frac{t_1}{2} (1 + \eta_1^2)\left(\frac{X}{N}\right)^2 + \frac{t_1}{24} (1 + \eta_1^2) \ (5 + 3t_1^2 + \eta_1^2 - 4\eta_1^4$$

$$+ 9\eta_1^2 t_1^2)\left(\frac{X}{N}\right)^4 - \frac{t_1}{720} \ (61 + 90t_1^2 + 45t_1^4 + 107n_1^2$$

$$- 162e'^2 \sin^2\phi' + 45e'^2 t_1^2 \sin \phi')\left(\frac{X}{J}\right)^6$$

where: $t_1 = \tan\phi'$

$\eta_1^2 = e'^2 \cos^2\phi'$

e'^2 = second eccentricity squared

ϕ' = foot point latitude

X = UTM Easting

$N = a'/(1 - e^2 \sin^2\phi)\frac{1}{2}$

$a' = .9996.a$

a = semi-major axis of the ellipsoid

$\Delta\lambda$ = longitude difference from central meridian of point.

ϕ = latitude of point

e^2 = eccentricity squared

Having computed $\Delta\lambda$, and ϕ, the longitude itself must be computed as follows:

$$\lambda = -(\Delta\lambda - (6(30 - n) - 3)\ \rho\ )$$

where: λ = longitude

ρ = .01745327252

n = zone number

The first negative converts longitude positive eastward to positive westward.

A first approximation to foot point latitude is computed from:

$$\phi' = S(1 + S^2 \quad (AA + S^2 \quad (BB + S^2 \quad (CC + S^2 DD))))$$

where:

$AA = -3e^2/6$

$BB = (12e^2 \ + 45e^4)/120$

$CC = -(48e^2 \ + 1023e^4 \ +1170e^6)/5040$

$DD = (192e^2 \ + 18384e^4 \ +75099e^6 \ +6048e^8)/362880$

$S = Y/(.9996a(1-e^2))$

Y = UTM Northing

Improved approximations of ϕ' are obtained by Newton iteration, that is:

$$\phi'(i + 1) = \phi'\ (1) - \frac{F}{F'}$$

where: $F = S - S\ 2$

and:

$$S\ 2 = A\phi' - (B/2) \sin (2\phi') + (C/4) \sin (4\phi') - (D/6) \sin (6\phi')$$

$$A = 1 + \frac{3}{4}e^{2} + \frac{45}{64}e^{2} + \frac{175}{256}e^{6}$$

$$B = \frac{3}{4}e^{2} + \frac{15}{16}e^{4} + \frac{525}{512}e^{6}$$

$$C = \frac{15}{64}e^{4} + \frac{105}{256}e^{6}$$

$$D = \frac{35}{512}e^{6}$$

and:

$$F' = (1 - e^{2} \sin^{2}\phi')\frac{1}{2}$$

2.3.2.5 Additional Projection Transformations

During the final phase of the BDRS, three projection transformation algorithms were added. Those added were Miller, Lambert, and Polyconic. A detailed explanation of each algorithm can be found in the program documentation.

2.3.3 Source and History of Approach

The Thomas derived projections have been rigorously tested and approved in many cartographic projects. The inverse to the Mercator Mapping was developed at Synectics Corporation. The inverse to the Transverse Mercator mapping has been obtained from Rapp and Sprinsky.

2.3.4 Empirical Results and Evaluation

The transformations from earth rectangular to geographic coordinates, when combined with the transformations derived in registration, are accurate to within a second of arc within the well-known bounds of application of the map projections themselves. They are accurate enough to satisfy any requirements which stays within this limitation. The inverse Transverse Mercator mapping is confined to one zone at a time. The inverse Mercator mapping equation handles arbitrary earth rectangular values.

2.4 GEOGRAPHIC SECTIONING ALGORITHMS

2.4.1 Problem to be Solved

The sectioning algorithms provide the capabilities to perform circle, path, and polygon searches within areas generated on the surface of the earth. The earth is imagined to be a sphere of unit radius.

2.4.2 Method of Solution

To perform a given search, the routine must be called twice; the first call generates the appropriate parameters to describe the region in question, and the second call accesses points and calculates whether they fall inside the test region.

2.4.2.1 Circle Search

✓ First Call

On first call the input lat-long values of the center and radial point are converted to spherical coordinates on a unit sphere.

✓ Second Call

First the input test point is converted to spherical coordinates on a unit sphere. Then the great circle distances from the center point to the radial point and from the center point to the test point are calculated. If the latter distance is less than the former, the test point is within the region defined by the center and radial points.

The distances are calculated as follows:

Let R and S be vectors eminating from the origin of the sphere to the 2 points in question. The dot product of R and S is the cosine of the angle between the two vectors. The angle is the great circle distance in question. Formally we have

$$R \cdot S = X_1 X_2 + Y_1 Y_2 + Z_1 Z_2$$

but

$$X_1 = \sin\theta_1 \cdot \cos\phi_1$$

$$Y_1 = \sin\theta_1 \cdot \sin\phi_1$$

$$Z_1 = \cos\theta_1$$

$$X_2 = \sin\theta_2 \cos\phi_2$$

$$Y_2 = \sin\theta_2 \cos\phi_2$$

$$Z_2 = \cos\theta_2$$

where θ is latitude and ϕ is longitude. Thus $R \cdot S = \sin\theta_1 \sin\theta_2 (\cos(\phi_1 - \phi_2)) + \cos\theta_1 \cos\theta_2$, letting W = distance sought we have

$$W - \text{ARCCOS} \left[\sin\theta_1 \sin\theta_2 (\cos(\phi_1 - \phi_2)) + \cos\theta_1 \cos\theta_2 \right]$$

Q.E.D.

2.4.2.2 Polygon Search

✓ First Call

On first call, the input lat-long values of the polygonal vertices are converted to Cartesian X-Y-Z coordinates on the surface of a unit sphere centered at the origin of the coordinate system.

✓ Second Call

On second call the input lat-long values of the test points are converted to Cartesian X-Y-Z coordinates on the surface of a unit sphere centered at the origin of the coordinate system.

To calculate whether a given test point lies within the polygonal test region, the following insight is utilized. Suppose the n vertices of the polygon have coordinates $<X_1, Y_1, Z_1>$, $<X_2, Y_2, Z_2>$, ... $<X_n, Y_n, Z_n>$ and the test point has coordinates $<X_t, Y_t, Z_t>$. Consider the planes defined by the triangles whose vertices are $\left\{<X_1, Y_1, Z_1>, <X_2, Y_2, Z_2>, <X_3, R_3, Z_3>\right\}$, $\left\{<X_1, Y_1, Z_1>, <X_3, Y_3, Z_3>, <X_4, Y_4, Z_4>\right\}$, ... $\left\{<X_1, Y_1, Z_1>, <X_{n-1}, Y_{n-1}, Z_{n-1}>, <X_n, Y_n, Z_n>\right\}$ and the line defined as that line connecting the origin to the coordinates $<X_t, Y_t, Z_t>$. Let W_1, W_2, ... W_{n-2} be the points of intersection between the line and each of the planes. Let $\theta_1, \theta_2, \theta_3$ be for a given triangle and a given plane, the angles described from the point of intersection W_k to the triangular vertices $\left\{<X_1, Y_1, Z_1>, <X_{k-1}, Y_{k-1}, Z_{k-1}>, <X_k, Y_k, Z_k>\right\}$. If $\theta_1 + \theta_2 + \theta_3 \simeq 2\pi$ then the point of intersection lies within the triangular region. If this occurs for at least one triangle, the point is obviously in the polygonal region.

The following is a formal derivation for a test point and a given triangle. First the equation of the plane of the triangle is calculated, then the point of intersection is calculated, then the origin of the coordinate system is translated to this point of intersection, and finally the angles are calculated and summed.

✓ Calculate equation of plane of triangle

The general equation of a plane is given by the formula $A \cdot X+B \cdot Y+C \cdot Z+D=0$. To determine the planar equation given 3 points $<X_1,Y_1,Z_1>$, $<X_2,Y_2,Z_2>$, $<X_3,Y_3,Z_3>$ we have

$$A = Y_1(Z_2-Z_3) - Z_1(Y_2-Y_3) + (Y_2Z_3 - Z_2Y_3)$$

$$B = -\left[X_1(Z_2-Z_3) - Z_1(X_2-X_3) + (X_2Z_3 - Z_2X_3)\right]$$

$$C = X_1(Y_2-Y_3) - Y_1(X_2-X_3) + (X_2Y_3-Y_2X_3)$$

$$D = -\left[X_1(Y_2Z_3-Z_2Y_3) - Y_1(X_2Z_3-Z_2X_3) + Z_1(X_2Y_3-Y_2X_3)\right]$$

Given that the three points are triangular vertices, the above coefficients determine the plane of the triangle.

✓ Point of Intersection

Suppose that RP(I), I=1,2,3 is the XYZ coordinate of the test point. Then the equation of the line in space through the origin and the test point is

$$\frac{X}{RP(1)} = \frac{Y}{RP(2)} = \frac{Z}{RP(3)}$$

Suppose $RP(1) \neq 0$. Then we proceed as follows:

$$Y = \frac{RP(2) \cdot X}{RP(1)} \qquad Z = \frac{RP(3) \cdot X}{RP(1)}$$

$$\rightarrow \quad A \cdot X+B \cdot \left[\frac{RP(2) \cdot X}{RP(1)}\right] + C \cdot \left[\frac{RP(3) \cdot X}{RP(1)}\right] + D = 0$$

$$\rightarrow \quad X \cdot \left[A + \frac{B \cdot RP(2)}{RP(1)} + C \cdot \frac{RP(3)}{RP(1)}\right] = -D$$

→ $$X = \frac{-D}{A+\frac{B\cdot RP(2)}{RP(1)} + C\cdot \frac{RP(3)}{RP(1)}}$$

Let $E = \frac{B\cdot RP(2)}{RP(1)}$

$F = \frac{C\cdot RP(3)}{RP(1)}$

$H = A+E+F$

then we have

$$X = \frac{-D}{H}$$

Let RPI(I), I=1,2,3 be the coordinate of the point of intersection. Then we have

$$RPI(1) = X + \frac{-D}{H}$$

$$RPI(2) = \frac{RP(2)\cdot RPI(1)}{RP(1)}$$

$$RPI(3) = \frac{RP(3)\cdot RPI(1)}{RP(1)}$$

✓ Translate origin to point of intersection

Suppose $<X_j,Y_j,Z_j>$ is an arbitrary point in X-Y-Z space. Then SJI(I), I=1,2,3 is defined as follows:

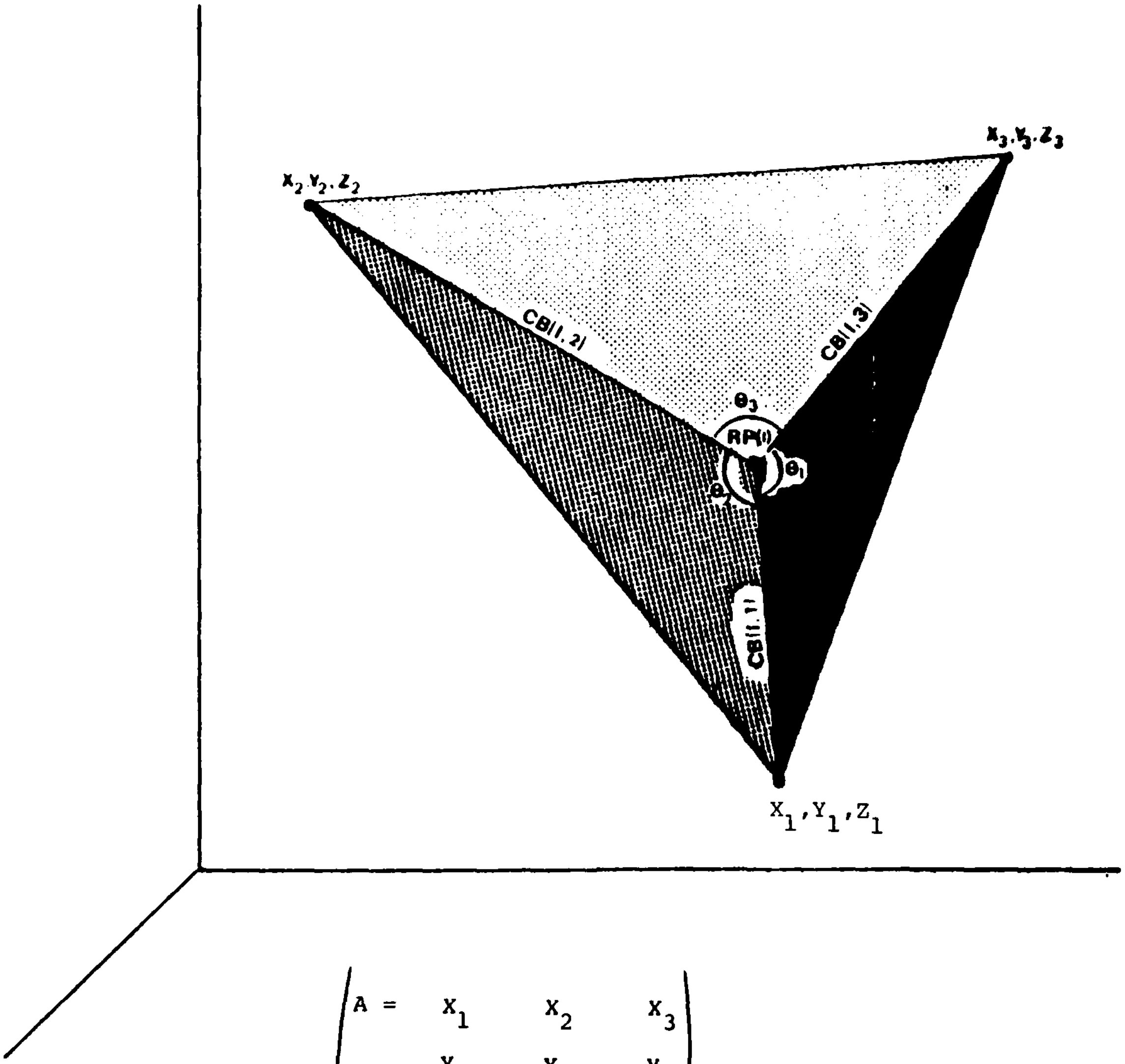
$SJI(1) = X_j-RPI(1)$

$SJI(2) = Y_j-RPI(2)$

$SJI(3) = Z_j-RPI(3)$

Then SJI(I) is the translated point.

- Get the Angles



$$\left(A = \begin{matrix} X_1 & X_2 & X_3 \\ Y_1 & Y_2 & Y_3 \\ Z_1 & Z_2 & Z_3 \end{matrix} \right)$$

CB = A - RPI

Note the CB is the array A translated to a new origin at RPI. Thus each column of CB is a coordinate. To find $\theta_1, \theta_2, \theta_3$, proceed as follows. Take the following vector dot products

(1) <CB(I,1), CB(I,2)>

(2) <CB(I,1), CB(I,3)>

(3) <CB(I,2), CB(I,3)>

according to the formula

$$\vec{A}\cdot\vec{B} = \sqrt{A_x^2 + A_y^2 + A_z^2} \cdot \sqrt{B_x^2 + B_y^2 + B_z^2} \cdot \cos\theta$$

where $A = A_{x}\cdot\hat{i} + A_{y}\cdot\hat{j} + A_{z}\cdot\hat{k}$

$B = B_{x}\cdot\hat{i} + B_{y}\cdot\hat{j} + B_{z}\cdot\hat{k}$

Given that the following assignments are made

(1) $\text{RMAG1} = (\text{CB}(1,1)^2 + \text{CB}(2,1)^2 + \text{CB}(3,1)^2)^{1/2}$

(2) $\text{RMAG2} = (\text{CB}(1,2)^2 + \text{CB}(2,2)^2 + \text{CB}(3,2)^2)^{1/2}$

(3) $\text{RMAG3} = (\text{CB}(1,2)^2 + \text{CB}(2,3)^2 + \text{CB}(3,3)^2)^{1/2}$

we have

(1) $\overrightarrow{\text{CB}}(I,1) \cdot \overrightarrow{\text{CB}}(I,2) = \text{RMAG1} \cdot \text{RMAG2} \cdot \cos\theta_2 = \text{DOT1}$

(2) $\overrightarrow{\text{CB}}(I,1) \cdot \overrightarrow{\text{CB}}(I,3) = \text{RMAG1} \cdot \text{RMAG3} \cdot \cos\theta_1 = \text{DOT2}$

(3) $\overrightarrow{\text{CB}}(I,2) \cdot \overrightarrow{\text{CB}}(I,3) = \text{RMAG2} \cdot \text{RMAG3} \cdot \cos\theta_3 = \text{DOT3}$

Therefore

(1) $I\theta_2 = \text{DOT1}/(\text{RMAG1}\cdot\text{RMAG2})$

(2) $I\theta_1 = \text{DOT2}/(\text{RMAG1}\cdot\text{RMAG3})$

(3) $I\theta_3 = \text{DOT3}/(\text{RMAG2}\cdot\text{RMAG3})$

Therefore

(1) θ_2 - ARCCOS($I\theta_2$)

(2) θ_1 - ARCCOS($I\theta_1$)

(3) θ_3 - ARCCOS($I\theta_3$)

2.4.2.3 Path Search

✓ First Call

First the 3 points input which define the path are converted to XYZ coordinates on the surface of a unit sphere yielding $<X_1,Y_1,Z_1>$, $<X_2,Y_2,Z_2>$, $<X_3,Y_3,Z_3>$. The vertices of the quadrangle defined by the path are found as follows. Let $\Delta X=X_3-X_2$, $\Delta Y=Y_3-Y_2$ and $\Delta Z=Z_3-Z_2$. The four vertices are:

(1) $<X_3,Y_3,Z_3>$

(2) $<X_2-\Delta X, Y_2-\Delta Y, Z_2-\Delta Z>$

(3) $<X_1-\Delta X, Y_1-\Delta Y, Z_1-\Delta Z>$

(4) $<X_1+\Delta X, Y_1+\Delta Y, Z_1+\Delta Z>$

This follows by the obvious symmetry of the sphere.

✓ Second Call

This is just a 4 sided polygon search.

2.4.3 Source and History of Approach

The sectioning algorithms were completely developed in-house at Synectics Corporation.

2.4.4 Empirical Results and Evaluation

The sectioning algorithms have been tested thoroughly and are accurate in typical application environments. The only source of approximation consists in assuming that the earth is circular. Thus geodetic paths on the ellipsoid are considered to be great circle paths on the surface of the earth. For large earth test areas, this could result in some inaccuracy in polygon searches. The extent of the inaccuracy has not been rigorously analyzed.

2.5 FATHOGRAM PROCESSING

2.5.1 Problem to be Solved

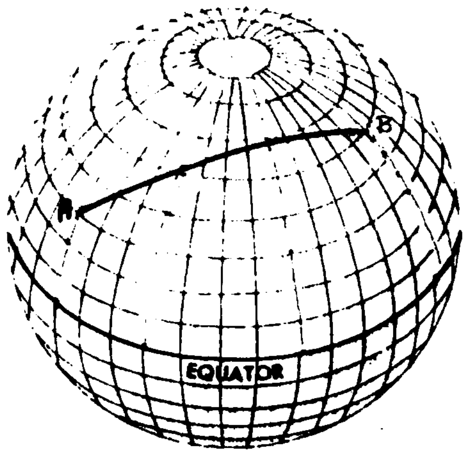
The major problem to be solved in fathogram processing is how to mathematically solve for a latitude, longitude position along the ship's track at a regular interval. To obtain a solution to this problem the following questions must be answered. Should calculations take into consideration the curved surface of the earth or deal only with a plane as if the ship's track was plotted on a chart? What navigational data (geographic positions, courses, speeds) should be assumed to be the most accurate? If adjustments to the navigational data is necessary, how should they be made?

2.5.2 Method of Solution

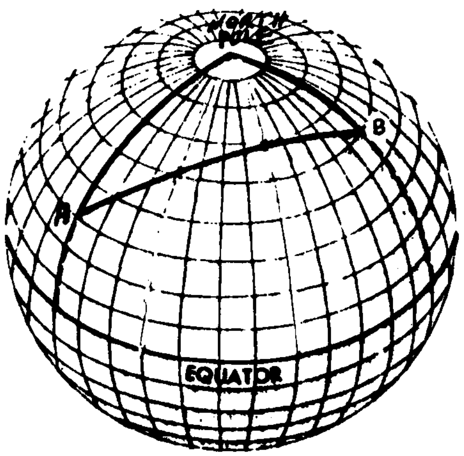
To deal with the ship's track as if it were on a flat surface such as a chart seems questionable since the ship does, in reality, travel over a curved surface. Therefore, the approach utilized to solve this problem considers the track as it actually occurs along the curved surface of the earth. All of the mathematical computations deal not with a plane, but with a curved surface. Basically this involves the use of Great Circle Sailing Computation which is nothing more than using oblique spherical triangles to calculate each segment of the ship's track.

Figure 2-1 illustrates a general overview of how spherical geometry is employed. A ship's track along the surface of the earth is made into a spherical triangle using the North Pole, the point of departure (A), and the point of arrival (B) as vertices. The sides of this triangle are comprised of the distance in degrees of arc traveled between points A and B, the arc from point A to the North Pole, and the arc from point B to the North Pole. The two arcs from the given points to the Pole are equivalent to the colatitude of the points. A closer view of this triangle is shown in Figure 2-2.

By knowing certain sides and angles of this spherical triangle, all other unknown sides and angles can be solved for. The main algorithms

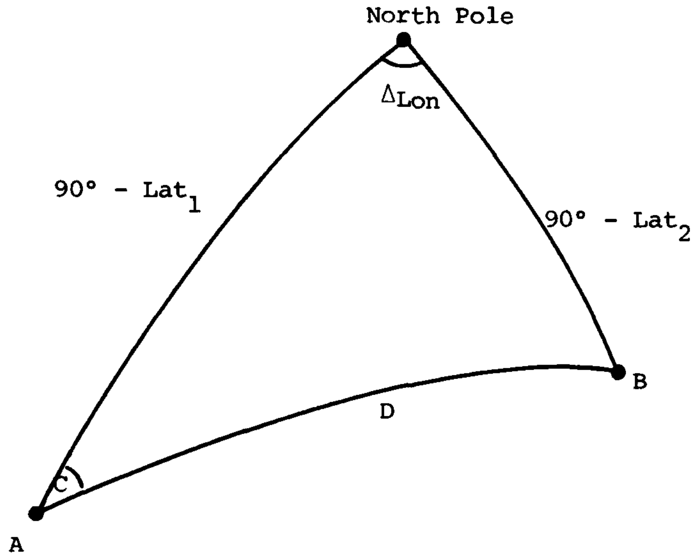


Ship's Track Along the
Surface of the Earth.



Spherical Triangle Used
for Calculating Ship's
Geographic Position

Figure 2-1. Spherical Geometry Overview



Point of Departure in Northern Hemisphere

A = point of departure (Lat_1, Lon_1)

B = point of arrival (Lat_2, Lon_2)

90° - Lat_1 = Colatitude of point A -
One side of spherical triangle
(Measured in degrees of arc)

90° - Lat_2 = Colatitude of point B -
One side of spherical triangle
(measured in degrees of arc)

D = distance traveled on the surface of the earth between A and B (measured in degrees of arc)

ΔLon = the difference in longitude between point A and B.

C = the initial course of the ship.

Figure 2-2. North Pole Triangulation Illustration used for great circle sailing computation, which are actually an application of spherical triangle geometry, follow:

(1) $\text{hav } C = \sec L_1 \cos D \; [\text{hav } CoL_2 - \text{hav } (D^{\sim}CoL_1)]$ where hav represents the haversine function $(\frac{1-\cos}{2})$, C is the initial course, L_1 is the latitude of the point of departure, L_2 is the latitude of the point of arrival, D is the distance between these two points, CoL_2 is $90°-L_2$ if L_1 and L_2 are both in the same hemisphere and $90°+L_2$ if they are in different hemispheres, $D^{\sim} CoL_1$ is the absolute difference between D and CoL_1, and CoL_1 is $90° - L_1$.

(2) $\text{hav } D = \text{hav } DL_0 \quad \cos L_1 \cos L_2 + \text{hav}\ell$ where DL_0 is the difference in longitude and ℓ is the difference in latitude of the two points.

In instances where the initial course and distance between points are known, the values of the latitude and longitude of point B may be computed by rearranging the above equations. To solve for the latitude:

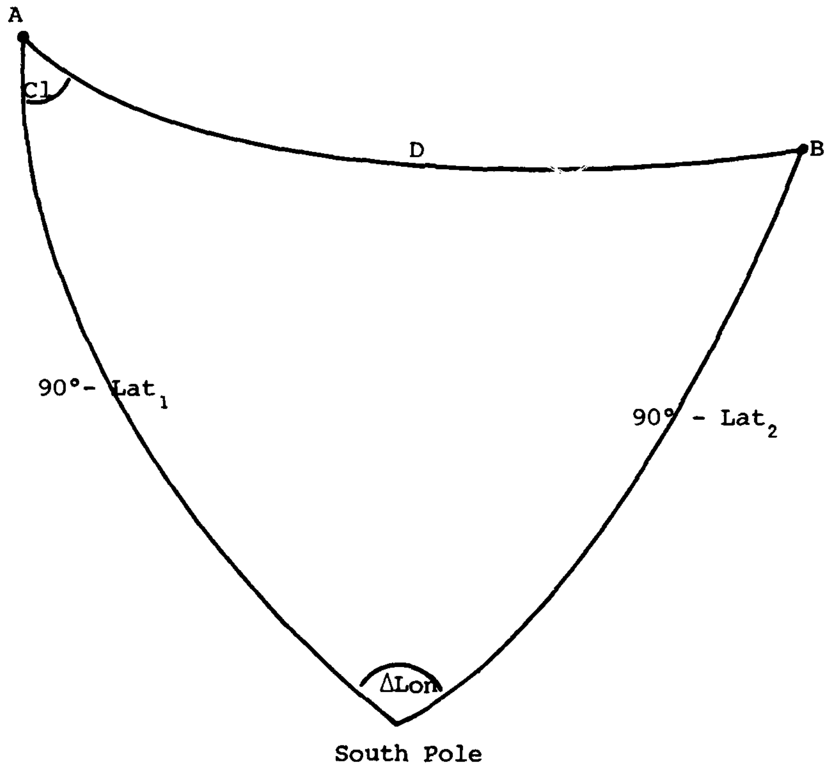
$$(3) \qquad \cos CoL_2 = \frac{\sec L_1 \csc D \cos (D^{\sim}CoL_1) - 1 + \cos C}{\sec L_1 \csc D}$$

To solve for the longitude:

$$(4) \qquad \cos DL_0 = \frac{\cos L_1 \cos L_2 - \cos\ell + \cos D}{\cos L_1 \cos L_2}$$

So far only sailing in the Northern Hemisphere has been taken into consideration. Although calculations are identical in the Southern Hemisphere, the spherical triangle itself is slightly different using the South Pole as one of its vertices. Figure 2-3 depicts this situation. In this case, all of the angles and sides are defined the same except for angle C1 which is equal to the supplement of the initial course angle (180° - C). All of the computations deal with the latitudes as if they were positive quantities. If latitudes in the Southern Hemisphere are solved for, a negative sign is added once the actual calculation is complete. For cases where the point of departure and the point of arrival are in different hemispheres, the Pole used to form the triangle always depends on the location of the point of departure. The triangle diagrams for these cases are illustrated in Figure 2-4. At the present moment, geographic position calculations can only be made right up to where the actual crossing of the equator occurs. The ability to cross the equator is not currently a capability of the process but this limitation can be eliminated.

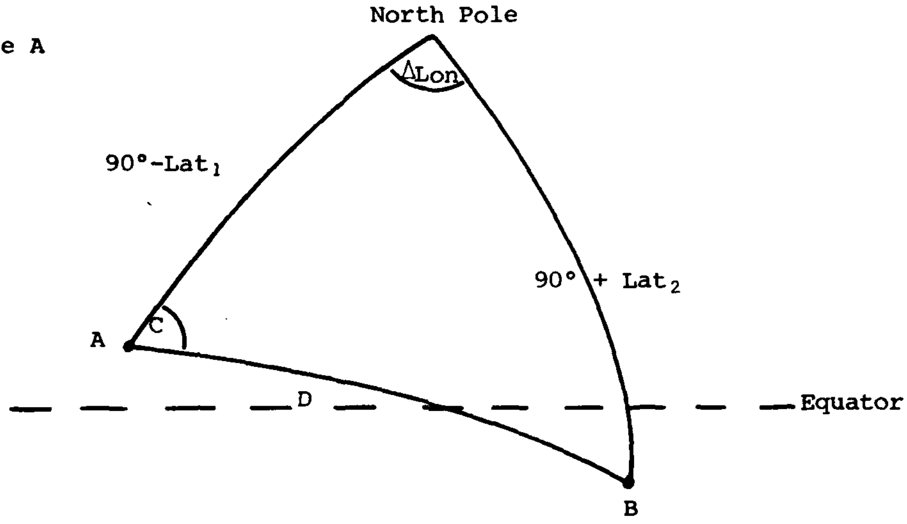
Up until now, a general overview of spherical triangles and their application to calculating latitude, longitude points along the earth's surface has been presented. A more detailed look is now needed into the



Point of Departure in Southern Hemisphere

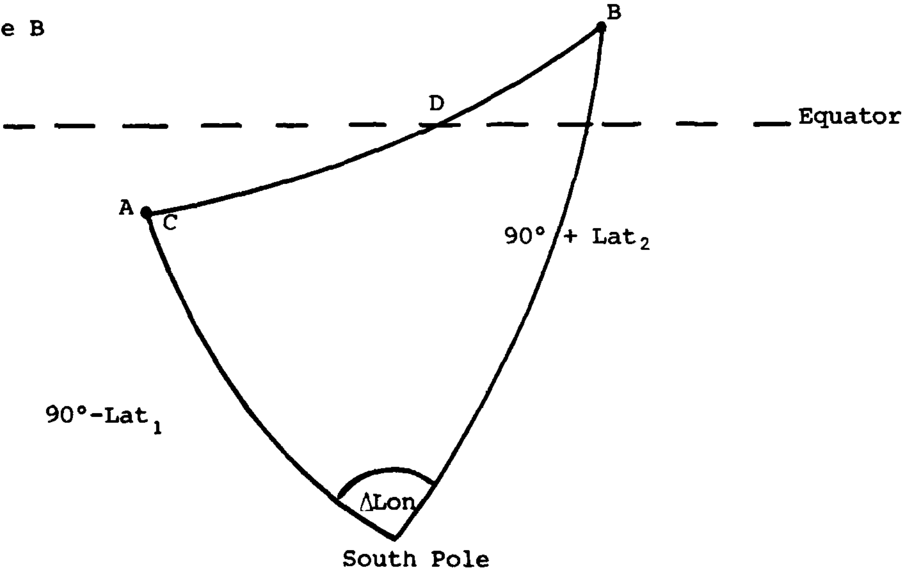
Figure 2-3. South Pole Triangulation Techniques

Figure A



Point of Departure in Northern Hemisphere and
Point of Arrival in Southern Hemisphere.

Figure B



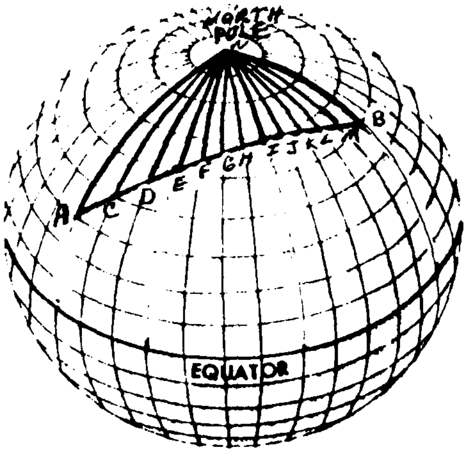
Point of Departure in Southern Hemisphere and
Point of Arrival in Northern Hemisphere.

Figure 2-4. North & South Poles Triangulation Illustration actual application for fathogram processing. Figure 2-1 illustrates just one spherical triangle across a large portion of the earth. It is actually one great circle sailing route. However, since most ships involved in this process are not necessarily following one great circle route, not just one big spherical triangle is solved. Instead, many very small triangles are used (Reference Figure 2-5). Every time the navigational log gives geographic positions or speed changes or course changes, these are considered to be critical points along the ship's track. The spherical triangles solved are those containing critical points as vertices.

For example, take the simplest case where two geographic positions along the ship's track are given and no speed or course change occurs between these points. This first point becomes the point of departure and the second point becomes the point of arrival for this segment of the ship's track. Since the latitude and longitude for both of them is known, the use of equation (2) makes it possible to solve for the distance between these points. Once this is accomplished, the calculated distance is now used in equation (1) to solve for the initial course angle. This shall be referred to as the adjusted course of the ship between the two points. With this information it becomes possible to calculate the latitude and longitude at any delta time interval along this track segment. The process involves first computing the distance traveled in a given delta time interval. For reference purposes, this computed distance will be referred to as the delta distance interval. Next, a very small spherical triangle is constructed using the delta distance interval as one side, the known point of departure as A, and a geographic point located a delta distance interval from A as point B. Now algorithms (3) and (4) can be used in succession to solve for the latitude and longitude of point B. This process of dividing the large spherical triangle representing a track segment into smaller ones to solve for latitude, longitude points along the segment, is repeated until the point of arrival (at the end of the segment) is reached.

Before any more discussion of the calculation of geographic points can continue, another topic must be introduced. As stated in Section 2.5.1, a judgment as to what navigational data can be considered the most accurate must be made. For this fathogram process, any given geographic positions are considered to be the most correct data. Therefore, whenever possible, calculations are based on given geographic fixes. Since it seems arbitrary to choose the integrity of given courses over given speeds or vice versa, both speeds and courses are adjusted and always take second priority to geographic positions. Thus, tracks are broken down into segments with given geographic points at each end. These segments constitute the major spherical triangles.

Following along these lines of thought, it becomes necessary to break down the calculations of geographic positions into three major cases.



Instead of using just one large spherical triangle, many smaller ones are used. For example, triangles ANC, CND, DNE, ENF, FNG, GNH, HNI, INJ, JNK, KNL, LNM, MNB are solved independently. AC, CD, DE, EF, FG, GH, HI, IJ, JK, KL, LM, MB represent track segments which comprise the entire ship's track line.

Figure 2-5. Ship's Track Line

The first case is one in which no speed or course change occurs between two given latitude, longitude points. The solution of this case has already been thoroughly discussed. The second case involves the situation where only speed changes occur between two given geographic positions. Therefore, the geographic positions of the speed changes are unknown. The solution for this case requires that the latitude, longitude for each critical point (point where the speed change occurs) be calculated. To accomplish this task, the total distance between points A and B is calculated using algorithm (2). Next, the given speeds and times between critical points are used along with the computed total distance of the track segment to proportionately divide the segment into parts. This, in essence, adjusts the speeds between the critical points.

The following example demonstrates how this speed adjustment is made. Assume that between points A and B the speed changes three times. The points where the speed changes will be designated as P1, P2, P3. Let S1, S2, S3, and S4 equal the speed between points A and P1, P1 and P2, P2 and P3, P3 and B respectively. In the same manner, let T1, T2, T3, T4 equal the time interval between points A and P1, P1 and P2, P2 and P3, P3 and B. Using these given speeds and times, calculate the distance between A and B with the following relationship:

$$DC = \Delta T1(S1) + \Delta T2(S2) + \Delta T3(S3) + \Delta T4(S4).$$

Next, compute the actual total distance (TD) of the segment using algorithm (2). In almost every case DC and TD will differ indicating the given speeds are inaccurate and need adjusting. The next step is to compute the following ratios:

$$FP1 = \Delta T1(S1)/DC$$

$$FP2 = \Delta T2(S2)/DC$$

$$FP3 = \Delta T3(S3)/DC$$

$$FP4 = \Delta T4(S4)/DC$$

Using these fractional parts of the total computed distance, the adjusted distances traveled between critical points can be calculated:

$$D1 = FP1\ (TD)$$

$$D2 = FP2\ (TD)$$

$$D3 = FP3\ (TD)$$

$$D4 = FP4\ (TD)$$

Once these distances between critical points are computed, the location of these points is actually designated on the track segment. Each part of the segment is then treated as a separate spherical triangle. Reference Figure 2-6. For example, points A, P1, and the Pole form the first triangle taken into consideration. Using algorithms (3) and (4), the latitude and longitude of point P1 is computed. Then P1, P2, and the Pole form the next triangle and the geographic position of P2 can be calculated. This process continues until all critical points are computed.

These critical points are now treated as if they were given geographic positions with no speed or course changes between them. The process stated previously for calculating the latitude, longitude points at the given delta time interval is employed for each of these separate spherical triangles. It should be noted that in these calculations no speed change is considered more accurate than any other since that would be an arbitrary decision. Therefore, they are all equally taken into account.

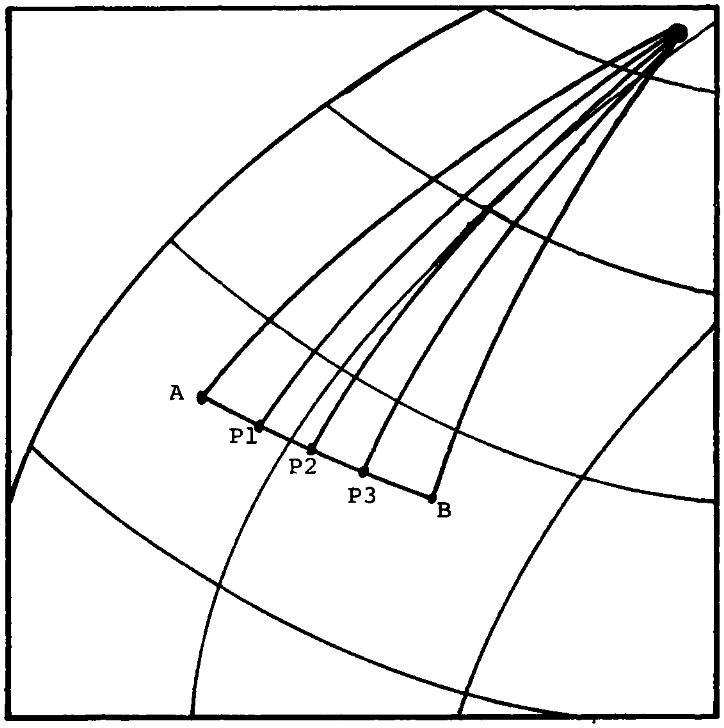
The third and final situation that must be dealt with is when course changes occur between two given geographic positions. The geographic positions of the course changes are unknown. In this case the solution involves many steps and can best be described by use of an example. In Figure 2-7-A, points A and B are the two known points between which the course changes two times. The locations of these course changes (critical points), P1 and P2, are unknown. The first step in this process is to compute the locations of P1', P2', and B', using the given speeds, courses, and times. These are designated in Figure 2-7-B. As can be seen in this figure, the location of the calculated B (labeled B') and the given B is not the same. In most instances, this will happen since input data is often inaccurate. Remembering that given geographic points are always considered the correct locations, an adjustment must be made to the given courses and given speeds so that the end point, B', will be located correctly at B. Since no one given course change can be considered more correct than any other, each is equally taken into account and the following method is employed to make the necessary adjustments. The difference in latitude (ΔLAT) and the difference in longitude (ΔLONG) is calculated between points B and B' (reference Figure 2-7-C). If these delta differences are within a given epsilon, say ten seconds of arc, then no further adjustments are necessary and P1' and P2' are used as the critical points (P1 and P2). On the other hand, if they are not within the given epsilon, an adjustment to the location of the critical points results. This is done by equally dividing and proportionately adding the delta latitude and longitude differences to each calculated critical point producing P1'' and P2'' (reference Figure 2-7-D). In this particular example,

$$\text{Lat of P1''} = (\text{Lat of P1'}) + (\Delta\text{LAT}/3)$$

$$\text{Lat of P2''} = (\text{Lat of P2'}) + 2(\Delta\text{LAT}/3)$$

$$\text{Lat of B''} = (\text{Lat of B'}) + 3(\Delta\text{LAT}/3) = (\text{Lat of B'}) + \Delta\text{LAT}$$

The longitude is calculated in a like manner.



Example of a Speed Change Segment of Track

A, B - Known geographic points on the ship's track.

P1, P2, P3 - Points where a speed change occurs.

Figure 2-6. Example of a Speed Change Segment of Track

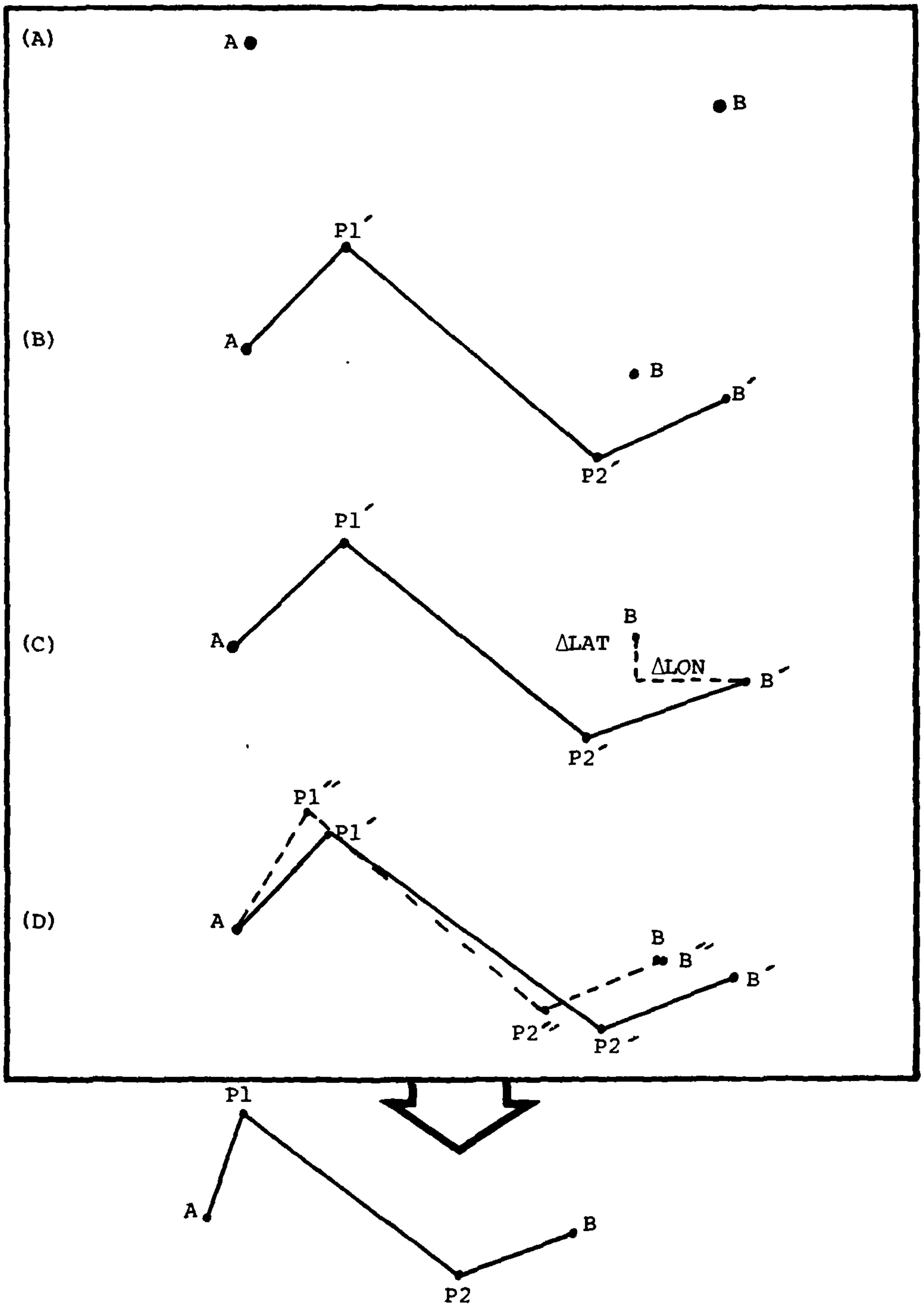


Figure 2-7. Adjusted Track of Ship

The above mentioned adjustment process is an iterative method which comes to a completion when the calculated end point falls within the epsilon tolerance. Once the geographic positions of the critical point are computed, they are considered to be known latitude, longitude points. As shown in Figure 2-8, individual spherical triangles are formed using these critical points as vertices. The previously described method to solve between two known geographic points with no speed or course changes between them is employed.

It is possible to have a situation where both course and speed changes occur between two known geographic positions. When this happens, it is handled as if it were a case of course changes between two known points. Since this method automatically adjusts speeds when the courses are adjusted, it easily lends itself to a course and speed change situation.

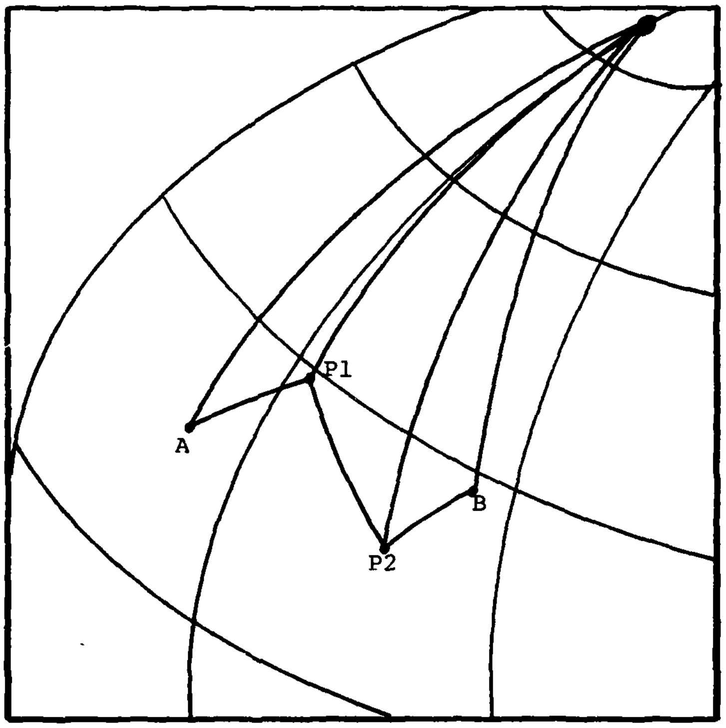
2.5.3 Source and History of Approach

The great circle sailing computation algorithms were extracted from American Practical Navigator originally by Nathaniel Bowditch, published by the U.S. Navy Hydrographic Office, 1958, page 232. This entire approach to fathogram processing, however, was completely developed in-house at Synectics Corporation. In particular, the idea of working completely in a geographic reference frame and computing all geographic positions, not as if they were located on a flat surface chart but, as they actually occur on a curved earth surface.

2.5.4 Empirical Results and Evaluations

The calculated geographic positions appear to be quite accurate. Two factors contribute to this accuracy. One, all computations take into account the curvature of the earth's surface. This is accomplished by employing oblique spherical triangles which deal with distances in degrees of arc on the earth's surface, not X,Y values on a plane. Two, by calculating points along the earth's surface and not on a X,Y plane, all results are in geographics. Therefore, processing through more algorithms to produce geographic points from X,Y coordinates is not necessary.

Of course, it should be stressed that the results are only as accurate as the navigational data used as input.



Example of a Course Change Segment of Track

A, B - Known geographic positions on the ship's track.

P1, P2 - Points where a course change occurs.

Figure 2-8. Example of a Course Change Segment of Track

SECTION 3. SOFTWARE ACCOMPLISHMENTS

3.1 PURPOSE

The purpose of this section is to discuss some of the more interesting developments which have occurred during the creation of the BDRS software. The discussions included are not intended to exhaust all facets of the system. The focus of each separate discussion will be from the key novel capabilities provided by the software in satisfying the requirements of the three BDRS subsystems; digitization and voice entry, batch, and data base.

3.2 DIGITIZATION AND VOICE ENTRY SUBSYSTEM

3.2.1 Data Entry

The key accomplishment of this BDRS subsystem is that of providing the capability to digitize sounding, discrete point and trace data from nautical charts. This data is then stored in a compact and conveniently accessible form. Sounding values may be entered manually with a keyboard or vocally using the Threshold 500 Voice Recognition device. When using the voice station the sounding given will be displayed on the cursor display. If the sounding was entered vocally, it will also appear on the Threshold 500 Voice Recognition display.

To physically record a sounding or discrete point the user has three options to choose from. The data may be entered manually using the keyboard, or the pushbuttons on the cursor. Using the voice box is the third option available. As the data is entered a visual display is provided at the Tektronix 4010 display unit. The display cursor flashes the sounding value on its display indicating the data has been entered. This eliminates the need for a user to continually look at the Tektronix 4010 display unit.

The sounding data may also be edited by the user in a very simple way using either the special key board or the 'voice box'. Thus, a complete capability is provided to create and edit sounding data which makes maximum use of system resources to ease the task of the user in data entry and edit.

3.2.2 Fathograms

An important capability of this BDRS subsystem is that of digitizing fathograms; that is, graphs of depth/time coordinates supplemented with such parameters as geographic fixes, loxodrome bearings, and ship velocities. Once a digitized fathogram file has been created, a file of geographic-depth positions can be constructed and entered into a data base. Thus, the analog information of the fathogram is integratable into the general BDRS data base framework.

3.2.3 Registration

The algorithm of registration has been thoroughly discussed in Section 2.2 of this document. It should however be emphasized here that the development and implementation of this algorithm within this subsystem provides the subsystem user a very efficient and easily employed method of registering charts so that information in a feature digitized from that chart is easily accessed and accurately edited. In the Lineal Input System (LIS) no such method was employed, and the errors inherent in both the LIS day '1' and day 'n' registration procedures have been eliminated. Within the conceptual structure of the registration scheme developed by Synectics Corporation, it could become an easy matter to edit table files even when they are created by the batch program which converts arbitrary geographic files to table files. Thus, at some later date, an arbitrary geographic file constructed from information in the data base could be converted to table form, edited, and reconverted to geographic coordinates.

3.2.4 Review Mode

The capability exists to display the data of a table file on a Tektronix 4010 display given a user selected window. Each feature, whether consisting of trace data, discrete points, or soundings, is searched and data which falls within the window is displayed. This provides the user with all he needs to discover where he desires to make edit changes.

3.3 BATCH PROCESSES SUBSYSTEM

3.3.1 Fathogram Processing

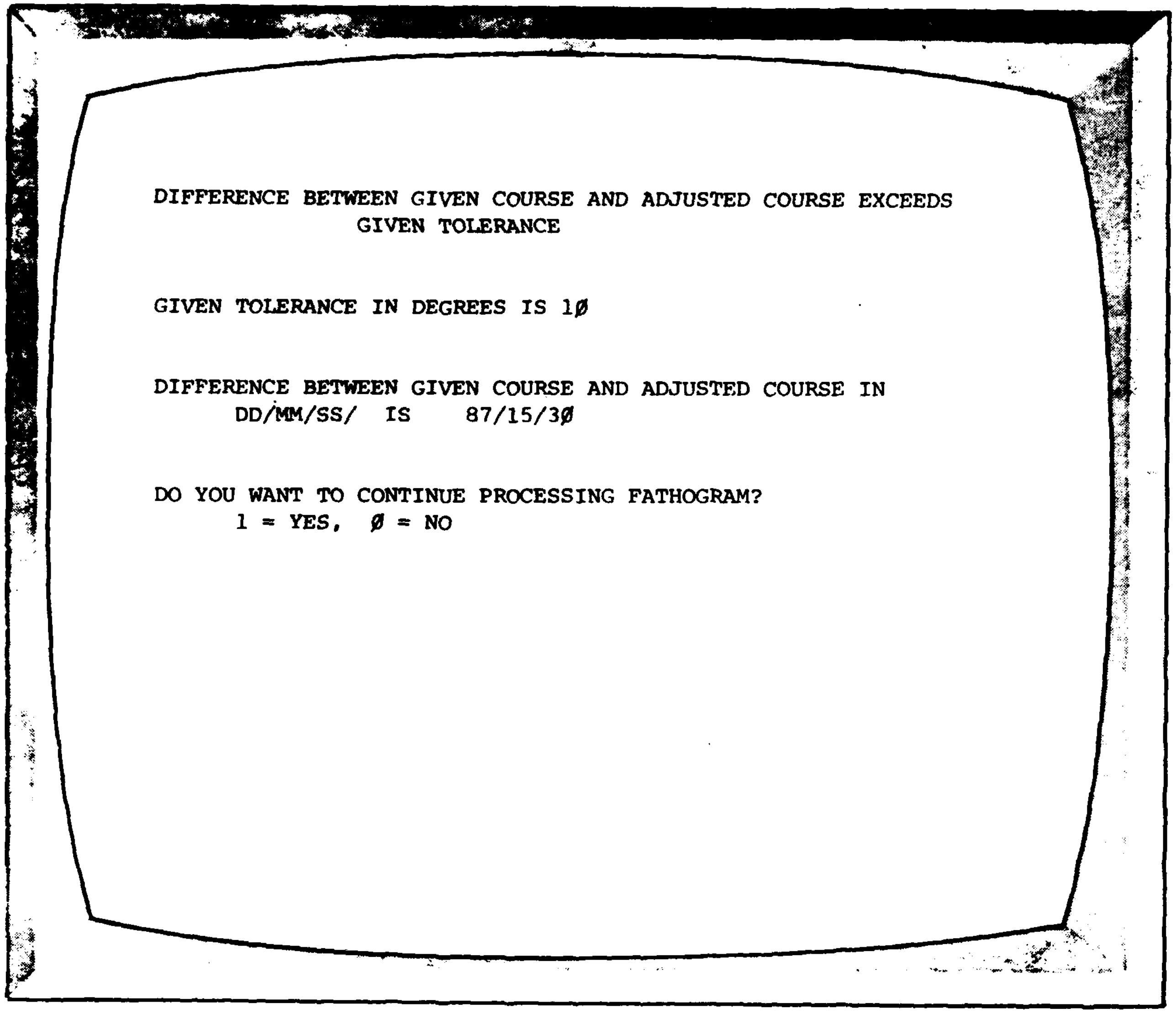
The unique feature of this process is that a geographic file of position/depth points is created as output. Up until this time any other fathogram process has output points in X,Y, depth format and, in order to get a geographic position, the X,Y points had to be processed through a projection transformation. As can be readily seen, this old method had two drawbacks. One, two processes were needed to obtain geographic output, and, two, since X,Y points were computed, it assumed the earth to be a plane and not a curved surface. Calculations were based on the ship's track being drawn on a chart. In contrast, BDRS fathogram processing bases all track calculations on a curved surface which much better represents the true surface of the earth. Also, this single fathogram process deals completely in the geographic realm.

Another capability of fathogram processing is that it can be used as a tool to quickly evaluate the data being processed. This capability is greatly needed since the accuracy of the fathogram data is often questionable as stated in Section 4.2.1.2. During the fathogram processing itself, a report to the CRT screen signals any course or speed adjustment that is greater than user defined bounds. If desired, the process can be aborted immediately and the data evaluated as poor. Also, at the end of the run a report to the line printer indicates the largest course and speed adjustment made. If the adjusted courses and speeds are much different from the given courses and speeds, this is a good indication that the data is poor. Figure 3-1 depicts an example CRT display of the above mentioned operation.

Data can also be evaluated once the fathogram process is complete by visual inspection of the ship's track line which can be easily displayed on the CRT screen using the routine "TESTPLOT." If the track line suddenly changes direction and there is no indication of such a course change in the ship's navigational log, then the accuracy of the given data is highly questionable. An example of this track line output is displayed in Figure 3-2. The ship's navigational log stated all of the courses ranged between 115° and 120°, yet the track line definitely changes course drastically. An inspection of the log data resulted in proof that obvious course changes were completely left out of the log data. This causes the accuracy of the data to become suspect. If, however, the track line and adjusted courses and speeds are very close to the given data, then the data is probably reliable.

3.3.2 Plot Functions

The plot software has several features worthy of especial notice. The development of this software is such that, in principle, any other type of plotter can be added to the BDRS hardware configuration simply by accessing an intermediate plot file. Second, the Xynetics interface routines are written in simple Fortran and are in principle, usable by other computer systems. Finally, the development of further plot functions is readily



```
DIFFERENCE BETWEEN GIVEN COURSE AND ADJUSTED COURSE EXCEEDS
             GIVEN TOLERANCE


GIVEN TOLERANCE IN DEGREES IS 10


DIFFERENCE BETWEEN GIVEN COURSE AND ADJUSTED COURSE IN
      DD/MM/SS/  IS    87/15/30


DO YOU WANT TO CONTINUE PROCESSING FATHOGRAM?
      1 = YES,  0 = NO
```

Figure 3-1. Adjusted Course Display

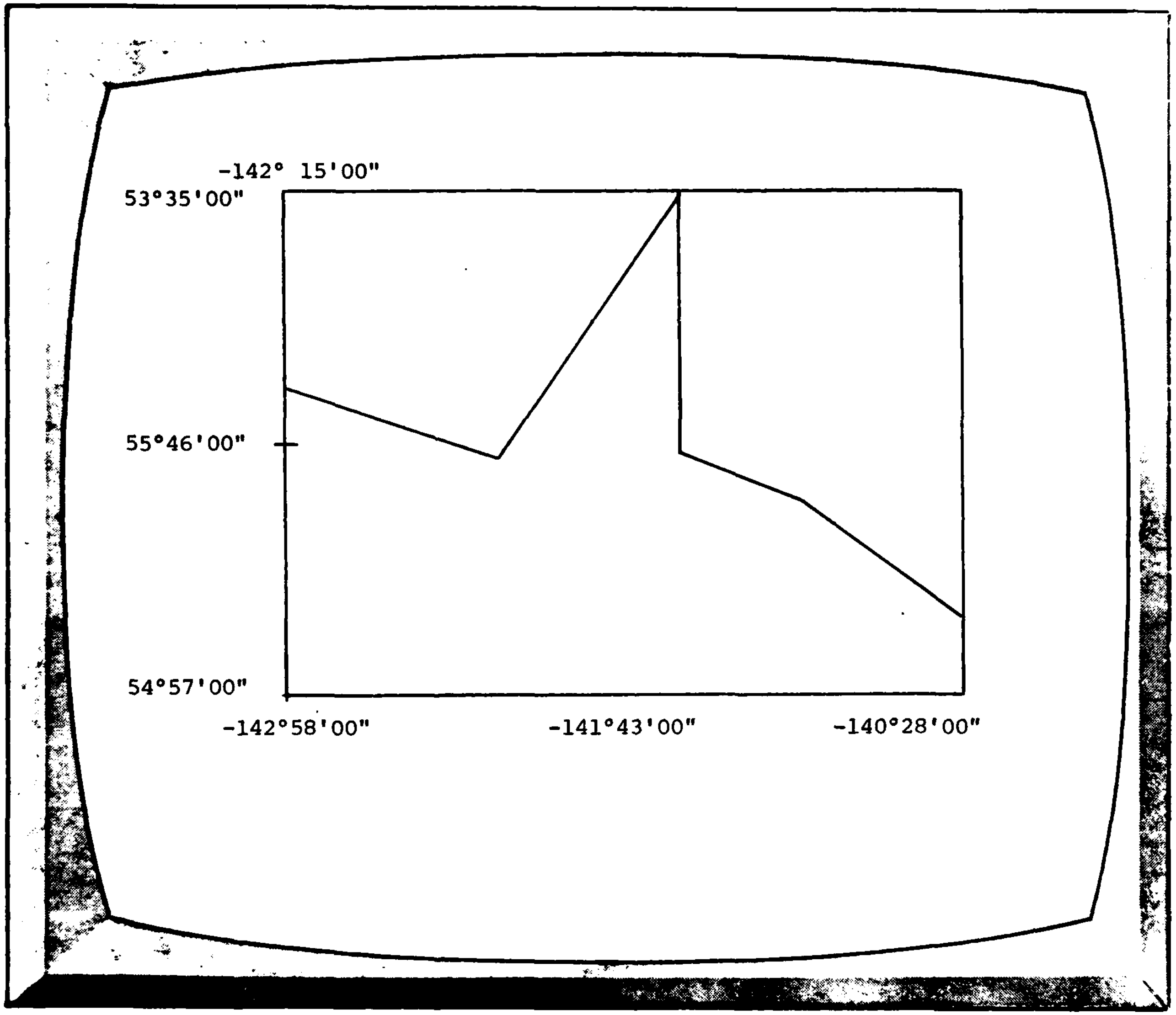


Figure 3-2. Track Line Output From Fathogram Processing

integratable into the current software due to the simple calling sequence of any plot function. For example, functions existing on other computer systems interfacing with a Calcomp plotter may be integrated into the BDRS system to produce the same type of output.

3.3.3 Depth Adjustment

Two useful features are provided by this capability. One, it offers a means by which incoming depth data can be evaluated before being entered into the data base. Two, if necessary, it adjusts the depths according to user defined criteria and outputs the results in a standard formatted BDRS geographic file. Since this new adjusted file is stored on disk, its creation has no affect on the data base data. If desired, it can be loaded into the data base or discarded completely.

To fully understand how these features are implemented, a short explanation of the depth adjustment process is necessary. This process is executed in several phases. The first phase is to convert the data to be adjusted to a geographic reference frame and to acquire the geographic bounds of this data. This is accomplished by performing a BDRS table to geographic conversion. The next phase is to section the BDRS Geographic Data Base utilizing the geographic bounds from above. These two files are then used as input to the Depth Adjustment function. Next, a grid system containing delta latitude, longitude grid matrix buckets is created over the geographic area in question. Each grid matrix bucket represents a random record stored on disk and, in most instances, covers a four minute latitude value by a four minute longitude value. A limiting factor of 32767 random records per file exists. Therefore, if the four minute bucket size produces more than 32767 grid buckets for the given geographic area, the bucket size is increased by one minute until there are less than 32767 buckets (random records) per area. In Figure 3-3 a geographic area containing 25° of longitude and 5° of latitude is represented using this grid system. It consists of 375 x 75, or 28125 grid buckets each four minutes by four minutes in size.

Once the grid system is created, the sounding data within the geosectioned file is processed to average depths within each grid bucket. This is accomplished by calculating and storing in each random record (grid bucket) the sum of the soundings and total number of soundings located in each bucket. The next phase of this program is to input process the geographic data needing adjustment. The grid bucket address of each sounding is computed and then the sounding value itself is compared to the grid bucket averaged sounding. If the input sounding does not meet user input criteria, the sounding value is adjusted. A variety of adjustment options are available and more can easily be implemented if such additional

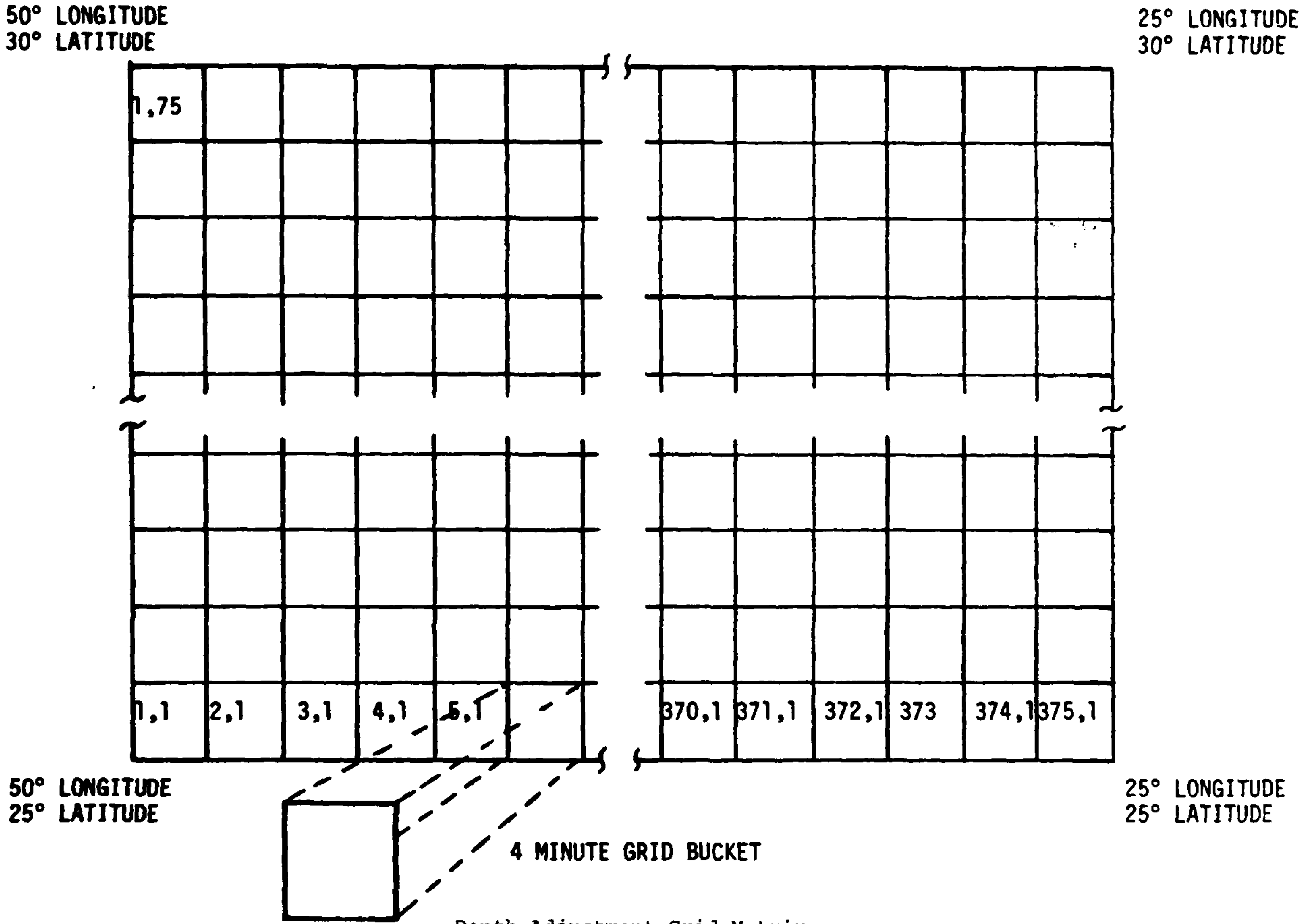


Figure 3-3. Depth Adjustment Grid Matrix

options seem warranted. As the data points are adjusted, they are output processed in their original geographic position. No geographic position adjustment is made due to the fact that the adjustments are arbitrary. That is, no judgment to the validity of each geographic position can scientifically be calculated.

This process can easily be implemented as an evaluation tool since a final printed report indicates the percentage of soundings that were adjusted. Obviously, if a large percentage were adjusted, then the data may be evaluated as poor compared to that stored in the data base. If the comparison percentage range is made extremely small, then all but very accurate data will be adjusted. An even closer analysis of the data can be made by using as input a sectioned file that has been geo-sectioned using a high evaluation code. In this case, only extremely accurate data base soundings will be used for comparison purposes. Thus, the accuracy of incoming data can be quickly ascertained with use of the depth adjustment process.

3.4 DATA BASE SUBSYSTEM

The highlight of the BDRS data base subsystem is its ability to support the access and retrieval of a user defined random geographic area. Such a capability, which has far reaching potential for exploitation, envolves the extensive utilization of mapping and sectioning algorithms which are in affect the nucleus of the entire data base process. In the sub-sections that follow, an attempt will be made to provide the reader with a better understanding of what the Synectics' developed algorithms do and how they support the overall data base process. Part 1 of the discussion will concentrate on the flow of data in-to and out-of the BDRS data base, highlighting those periods of the process which envolve the use of the mapping and sectioning algorithms. Parts 2 and 3 will attempt to detail the individual processes of mapping and sectioning.

3.4.1 Data Flow

The flow of data through the BDRS data base, as depicted in Figure 3-4, may be segmented into the six (6) major processes or operations: 1) Source Evaluation; 2) Input of Document/Source Description Information; 3) Digitization (Analog to X,Y conversion); 4) Conversion and Input Processing; 5) Document/Source Review and Modifications; and 6) Geographic Sectioning/Product Generation. Each process corresponds to the numbered process flow illustrated in Figure 3-4 and envolves the following:

1) Source Evaluation - This off-line process envolves the review of selected analog source for the purpose of accummulating that

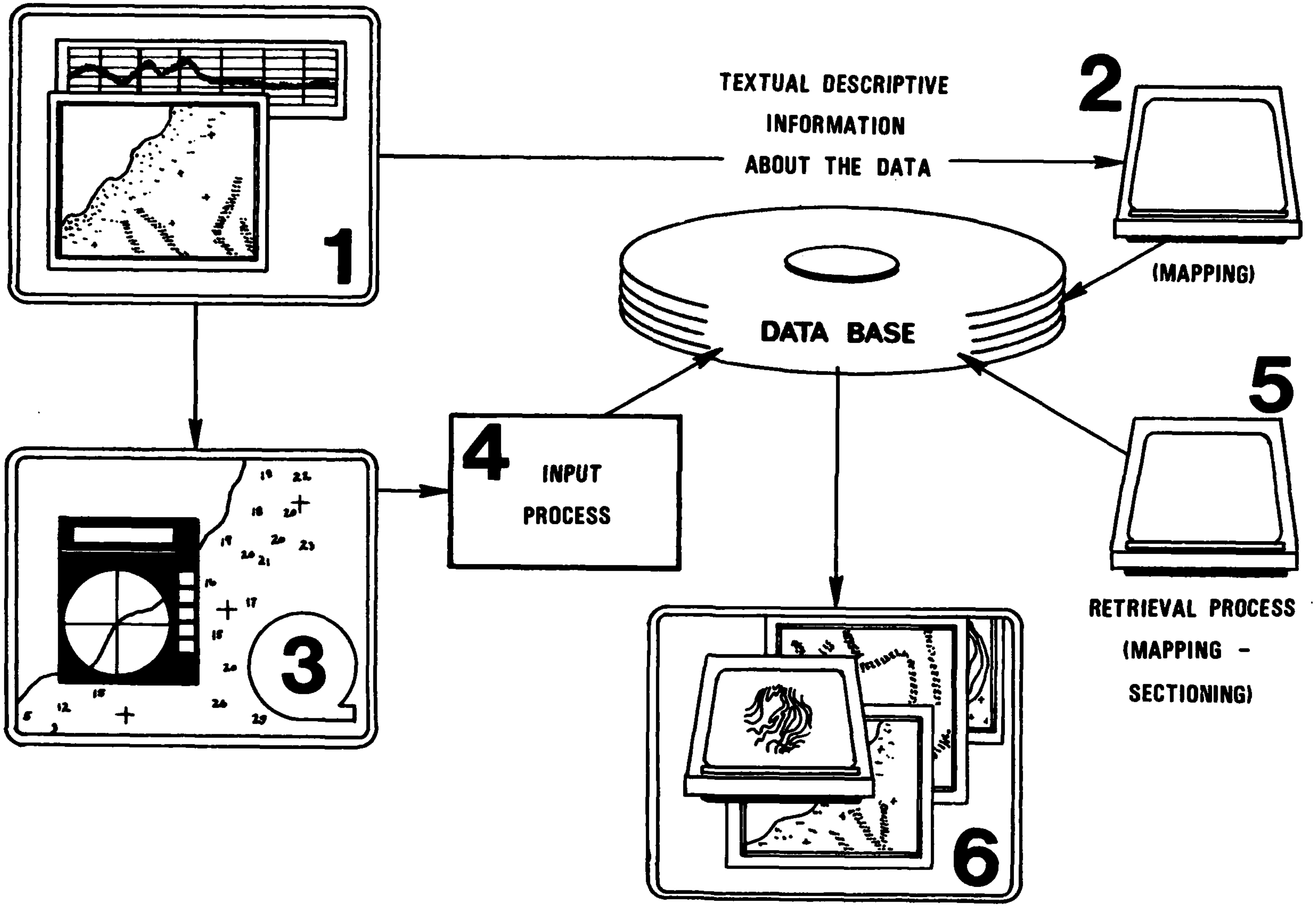
information required to adequately describe the document. If the selected source is to be input into the data base, such information is required by the on-line data base INPUT process. Without it, entry into the data base will be denied. Required information includes such items as: Source ID, Platform Name, Sheet Number, Document Bounding Rectangle, Navigational Aids, etc. Reference Appendix C of this document for a detailed description of the document and source description records.

2) Input of Document/Source Information - Once the select source (document) has been evaluated and the appropriate information assembled, it can be input to the data base via the ON-LINE data base process (Step 2, Figure 3-4). This process, which involves the use of the mapping algorithm, interactively constructs and stores in the data base a document description record and one or more source description records for the selected document. Additionally, using the documents bounding geographic rectangle which was input as part of the document description record, the geographic reference to the document is constructed via a call to the mapping algorithm. This "MAPPING" process envolves the use of a 450 x 225 grid which equates to the entire surface of the earth. The document being mapped, is logically positioned on the grid relative to its geographic location and the corresponding grid-cell numbers are noted. Each cell of the grid has a pseudo data record associated with it within the geographic sub-index of the data structure. The purpose of this record is to accumulate those document numbers that were identified by mapping as residing within the cell. Hence, the final step of the mapping process is to add to each record the document number of the newly mapped source. Once this entire process has been completed, the data base is now ready to receive the digital data associated with the document. Figure 3-5 offers a graphic illustration of the "Mapping" process.

3) Digitization -

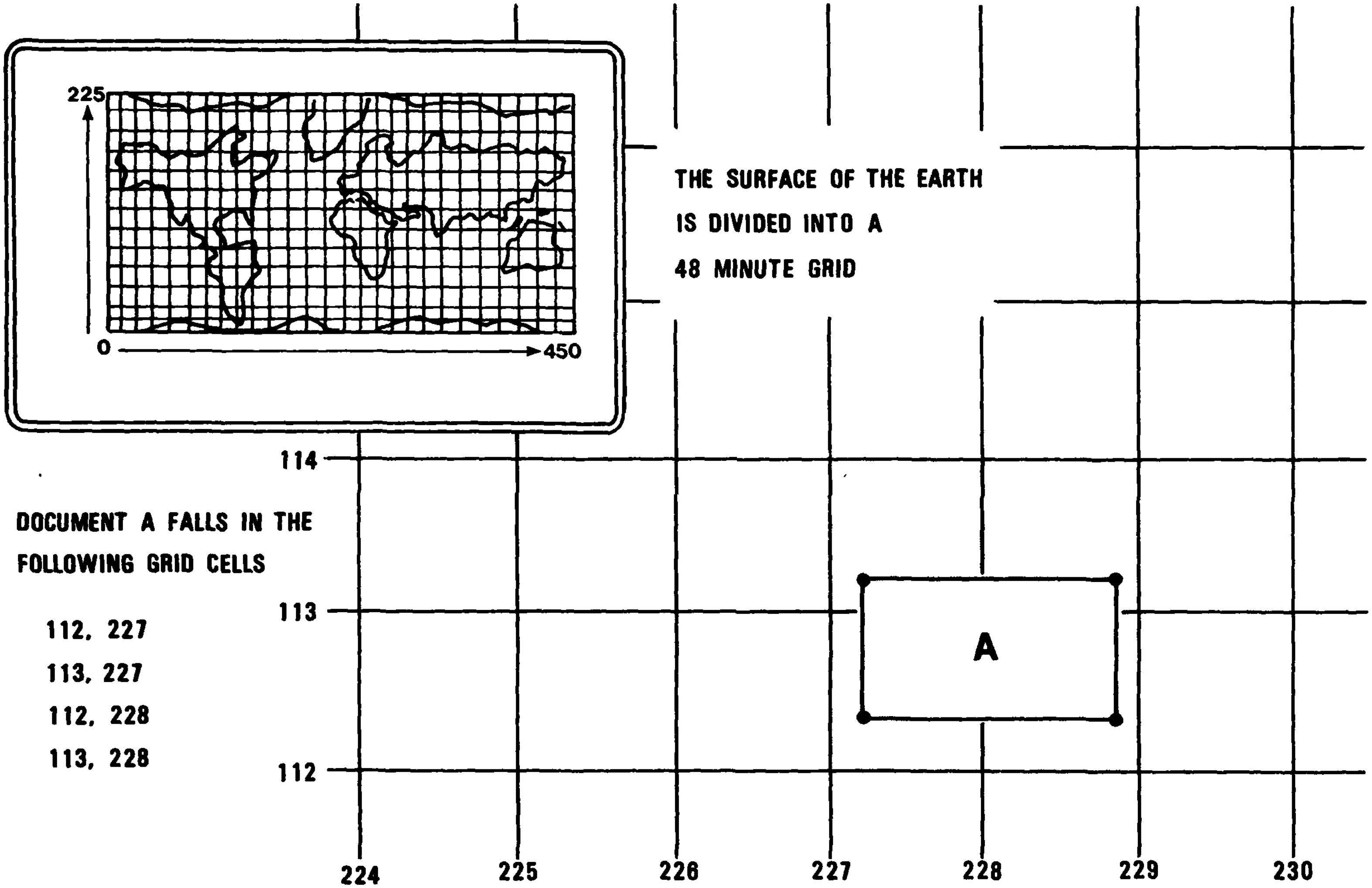
and

4) Conversion and Input Processing - The digitization/X,Y to geographic conversion processes are depicted as steps 3 & 4, Figure 3-4. This process involves the conversion of selected analog source material to a form capable of being loaded into the BDRS data base (BDRS formatted Standard Geographic format). Once the digitization/editing operation has been completed, the file is input to the batch table-to-geographic conversion process. The resultant file is then loaded into the data base via the batch Input-Process function. If this process is to be completed successfully, step 2 must have already been completed without error. Note that neither the Mapping nor the Sectioning algorithms are used during these processes.



DATA FLOW THROUGH THE BDRS

Figure 3-4



EXAMPLE OF THE MAPPING GRID SCHEME

Figure 3-5

5) Document/Source Review and Modification -

and

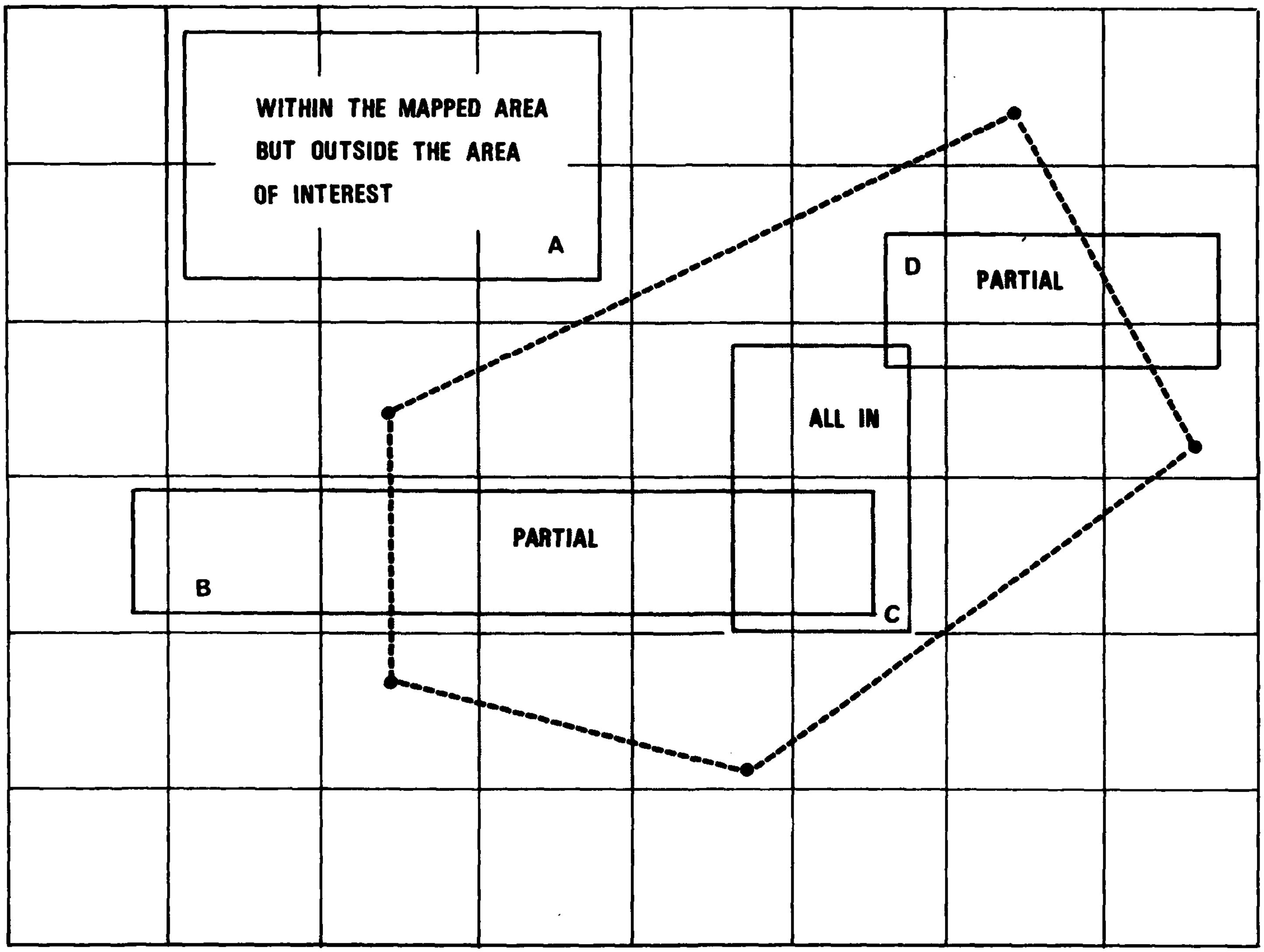
6) Geographic Sectioning/Product Generation - Two access methods are available to the user for purposes of data retrieval and review. The first, and most straightforward method, is retrieval by document number. This capability allows the user to access the data in its virgin form. It is in no way tied to geographics and for that reason, does not require the support of the Mapping or Sectioning algorithms. The second, and most powerful method of access is by random geographics. This process, which may be executed in varying forms from either the master console, 6052 CRT, or 4014 Graphic CRT, is accomplished using the following sequence of programmed operations:

✓ The user is asked to define his/her geographic area of interest. This can be in the form of a circle, path, or 3 to 8 sided polygon.

✓ The mapping routine is then called to perform the mapping operation. This process is nearly identical to the one discussed in step 2, with the only exception being that instead of passing the bounding rectangle of a new document, we are passing a user defined area of interest. The end result of the process is that mapping identifies those grid cells which are in or around the user defined geo area. Figure 3-6 graphically depicts some typical mapping examples.

✓ A pseudo data record, which resides within the data structure for each geo-cell, is then read from those cells identified by mapping as having fallen within the user area. The document numbers stored in each record are accumulated in an internal buffer until all cell records have been processed. The end result of such a cycle is the creation of an internal array containing the document numbers of those charts stored in the data base which fall within (or around) the user area of interest.

✓ Now that the candidate documents have been identified, the process which involves the use of "Sectioning" may begin. Each candidate document number is used to retrieve their respective document description records. Once this is done, sectioning compares the bounding rectangle of the document to that of the user defined geographic area. At this point, a determination is made by sectioning as to whether or not the document resides within the select area. If it does, the digital data for that document is directed to the



POSSIBLE SITUATIONS

Figure 3-6

appropriate destination and the cycle of processing candidate documents continues. If it does not, the document is discarded and the process goes on. The end result of this process, depending on the request type, could be in the form of a graphic display on the 4014 CRT or a disk resident BDRS formatted Geographic file.

3.4.2 Mapping

The need to provide the BDRS data base user with a random geographic access capability was the motivating factor behind the development of the "Mapping" algorithm. This algorithm provides the mechanism through which digital holdings may be associated with geographic locations without physically shredding the input processed file.

The mapping algorithm views the earth as a flat surface and divides it into a grid. Each cell of the grid represents 48 minutes of longitude by 48 minutes of latitude. This divides the earth into 225 grid cells of latitude and 450 cells of longitude. Each grid line is numbered consecutively in each direction, beginning in the lower left corner of the grid (Figure 3-7). This number is then used throughout the mapping process to identify a specific area of the earth.

The 48 minute grid was chosen because it was found to be the best suited for the type of charts and other sources of data the BDRS would use. It should be noted that the size of the chart does not affect the mapping process in any way. What is affected is the amount of processing that must be done. A chart that is four degrees of longitude by four degrees of latitude would cover a minimum of twenty-five grid cells using a 48 minute grid. A ten minute grid using the same chart would include a minimum of 576 cells. Since each grid cell requires processing, the smaller the grid size the greater the processing time. However, if charts covered an area of one minute of latitude and longitude it would be worthwhile to change to a smaller grid. Enlarging the grid would reduce the number of cells that would be processed. However, a larger grid scheme would allow more documents to fall in any single cell, thus increasing the number of documents that would have to be processed. Considering the problems that could be created by the size of the grid, the 48 minute scheme proved an effective size for the BDRS.

As stated earlier, mapping is used to retrieve as well as input into the data base. The process begins with the geographic coordinates that define a circle, path, or polygon. The coordinates are converted to seconds of arc and mapped onto the grid. The grid can now be seen to represent an X,Y grid with the rows representing the Y value and columns representing the X value. This concept is illustrated in Figure 3-7. The method for determining which cells are used is dependent on the type of search being performed.

In a circle search the radius is first computed and used to give the minimum and maximum latitude and longitude values of the area. It is now possible to look at each column of grid cells defined by the min/max values. Beginning with the left side an array stores the minimum and maximum cell numbers and all those that fall in between. This produces a square area covering the circle as illustred in Figure 3-8.

Polygon searches are handled in a different manner in order to find the smallest number of cells for the area. This is accomplished by calculating the slope of the line between two points forming a side of the polygon. Using the slope it is possible to determine algebraically through which grid cells the line will pass for each side of the polygon. Starting at the left hand side of the polygon each column of cells is examined to find the minimum and maximum cells for that column. These cell numbers are stored in an array with those additional cells that fall in between. The process is repeated for each column the polygon passes through.

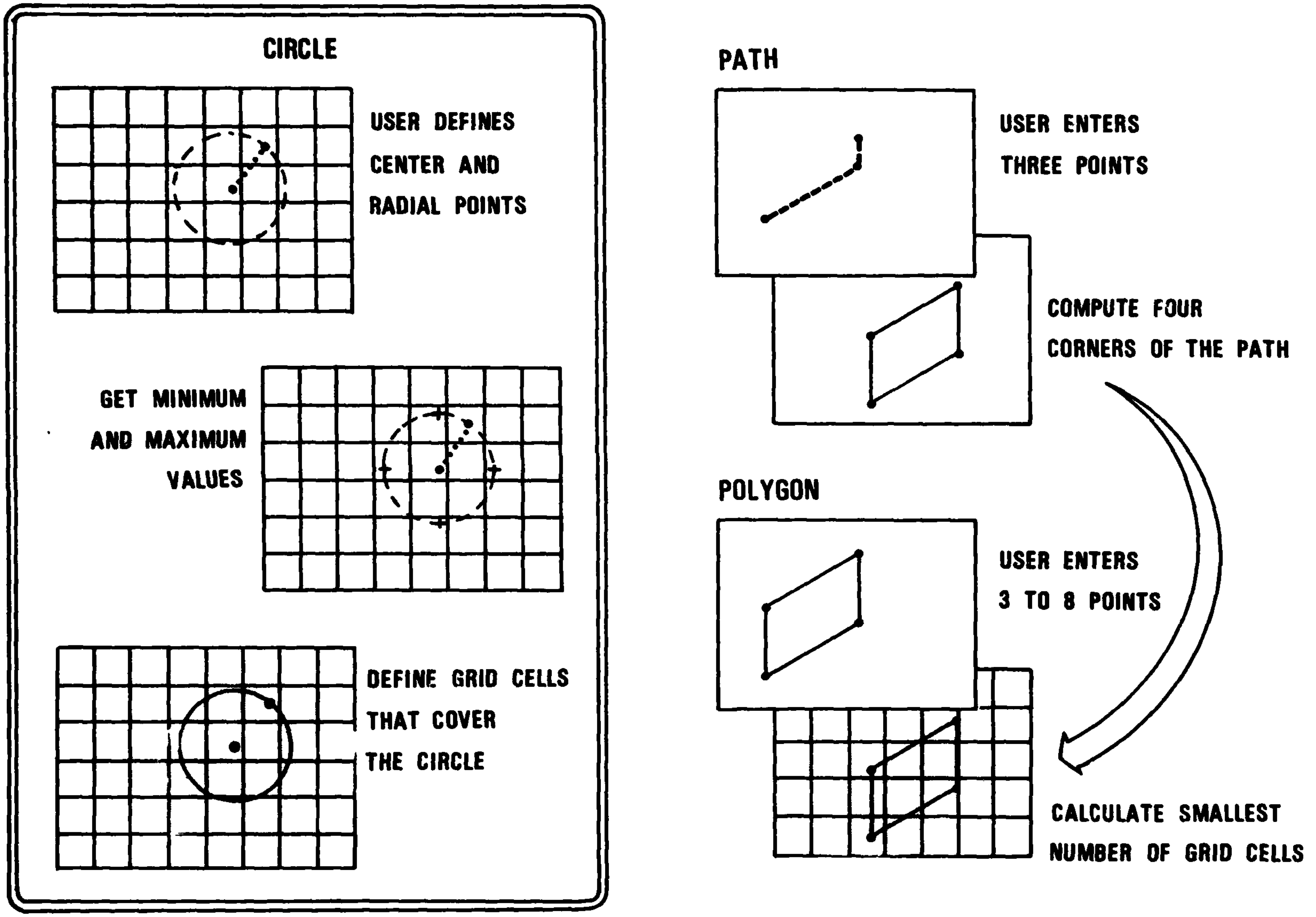
Path searches use the same process as the polygon except for a preliminary step. The path is given by three points, two end points and one side point. Four corners are determined from the three points. The path now represents a four sided polygon and follows the polygon processing just discussed.

Mapping at this point has built an array of grid numbers that cover the area of interest. The array can then be used as a sub-index for inputting into the data base or building an array of document numbers. Figure 3-9 gives an overall picture of the mapping function.

The problem that mapping creates is when a search area crosses the international date line. This case is illustrated in Figure 3-10. When this situation arises, the minimum and maximum bounds of the area will be computed and result in a reverse image of the intended area. This was corrected by testing for the condition and adjusting the values.

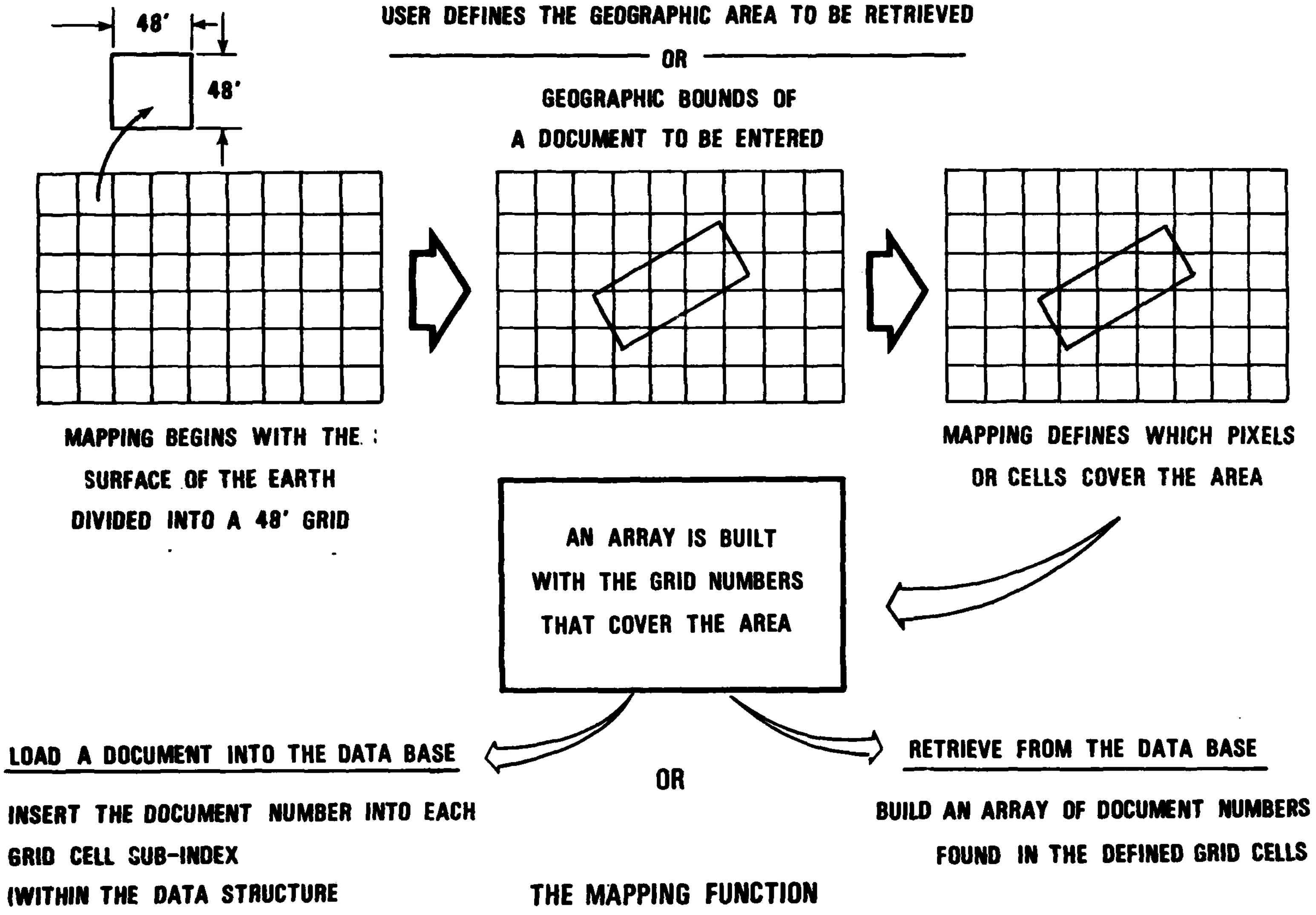
3.4.3 Sectioning

Mapping has provided the means of identifying those documents that fall in or around an area. However, some of these documents will not necessarily



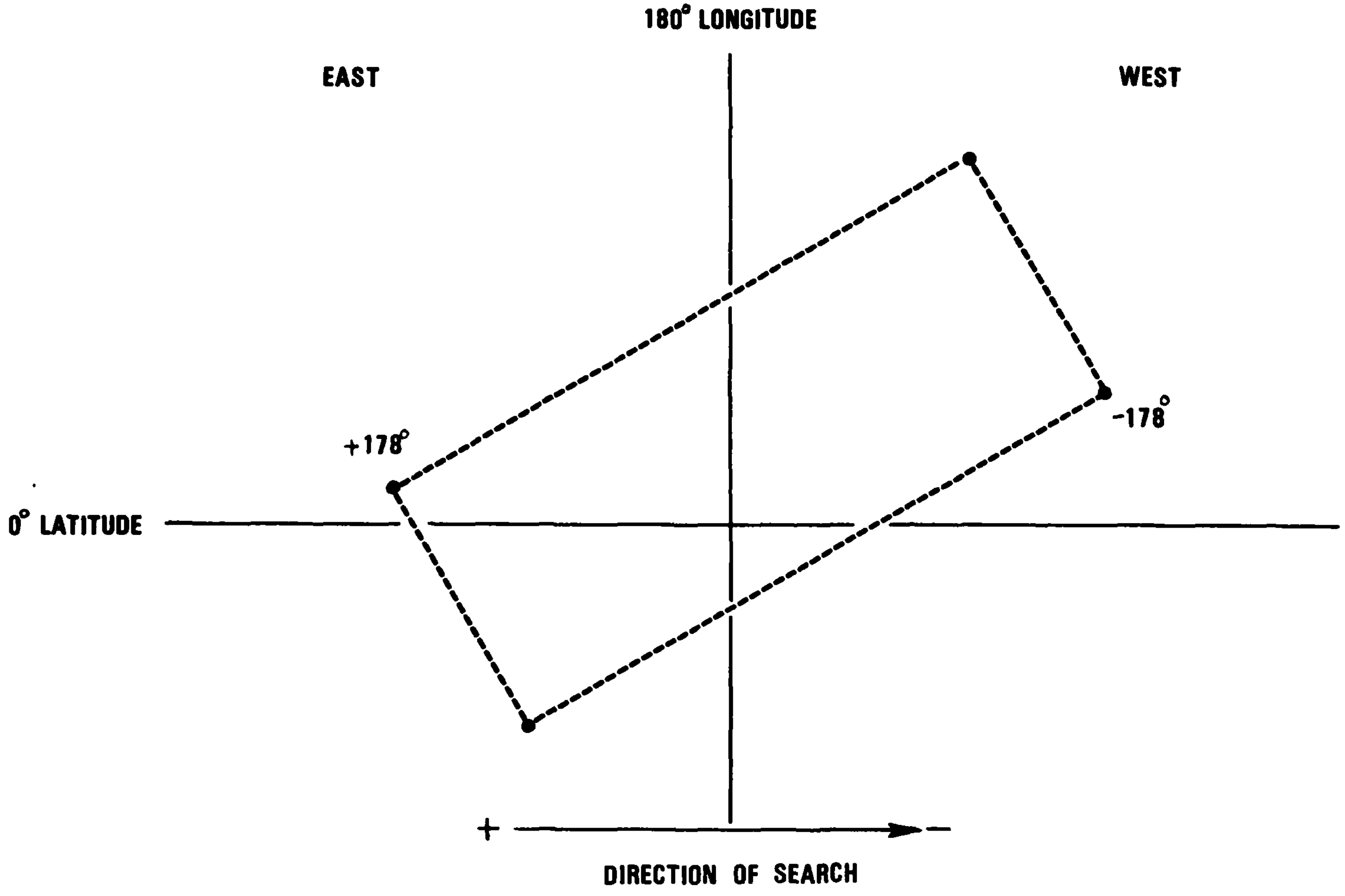
MAPPING A CIRCLE PATH OR POLYGON

Figure 3-8



THE MAPPING FUNCTION

Figure 3-9



INTERNATIONAL DATELINE PROBLEM

Figure 3-10

fall entirely inside the area. Figure 3-6 shows how mapping will include documents that fall outside the area and partially inside the area. Sectioning therefore takes documents one at a time and determines one of three conditions; all in, all out, or partial. The mathematical procedures used in sectioning have previously been described in detail in Section 2 of this document. Therefore, the following discussion will deal with the concept and problems present in the sectioning algorithm.

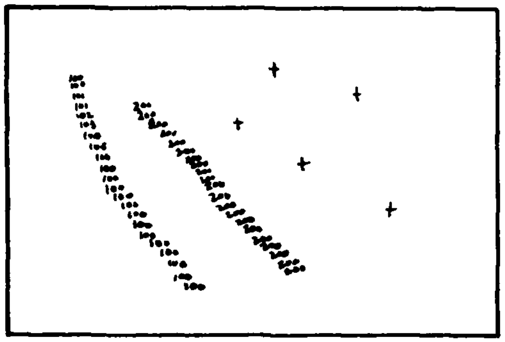
A bounding rectangle describes a polygon around the data. For example, a document bounding rectangles are given when the user inputs the geographic bounds of the document. This confines the data to a specific area on the surface of the earth. In addition to the document, there exists feature bounding rectangles. A feature is essentially a string of data that has been digitized contiguously. As the feature is being digitized, each point is compared to find a minimum, maximum latitude and longitude. These values are what determine the bounding rectangle of the feature, as shown in Figure 3-11. When sectioning is called it takes the points that form the bounding rectangle and calculates the status as being all in, all out, or partial. Therefore, the test points used by sectioning are the points defining the bounds of a document, or the min/max values of a feature.

When the sectioning algorithm is called it determines which condition exists for the data being tested. If a document falls all in the area, there is no need for further testing. All the data for that document will be written to a disk file. If a document is found to be out of the area, then it is disregarded. However, if a document is found to be partially in, further processing is needed to determine what part of the document falls inside.

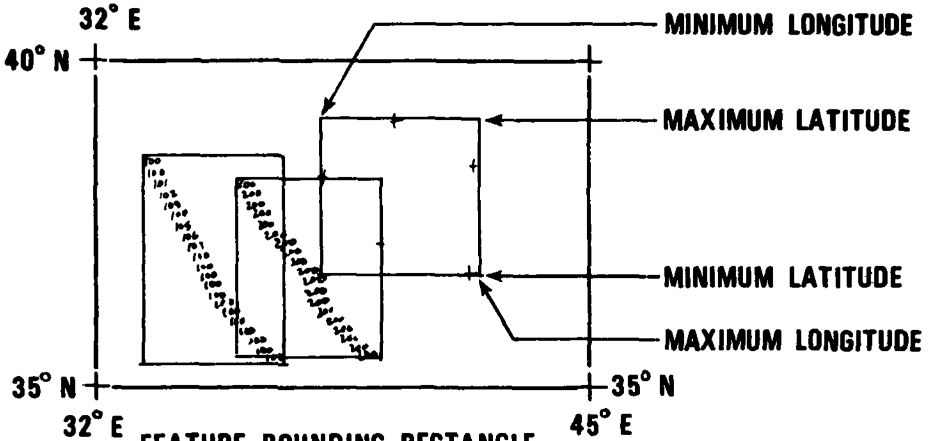
To do this sectioning moves down a level in the data structure, testing each feature of the document. If a feature is in, it is written to the disk file, if it is out it is bypassed. A feature that rests partially in causes sectioning to move down another level in the data structure. At this level each point in the feature is tested to see if it is in or out and writes the appropriate data to disk.

This process continues for all the documents that reside in the area of interest, with the end result a new BDRS geographic file.

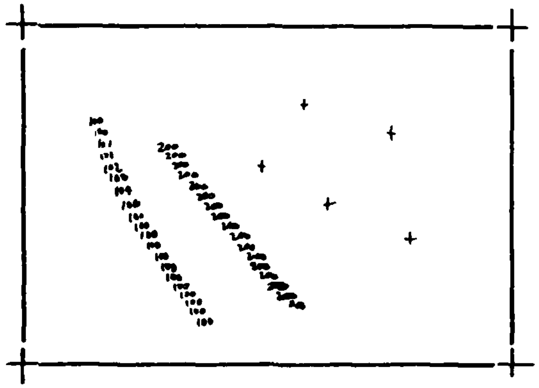
During the retrieval process, certain conditions will arise that must be checked for. These special cases will now be discussed along with the derived solution for each.



DOCUMENT CONTAINING SOUNDINGS AND DISCRETE POINTS



FEATURE BOUNDING RECTANGLE



DOCUMENT BOUNDING RECTANGLE

A DOCUMENT BOUNDING RECTANGLE IS GIVEN BY THE BOUNDS OF THE DOCUMENT INPUT BY THE USER

A FEATURE BOUNDING RECTANGLE IS GIVEN BY THE MINIMUM AND MAXIMUM LATITUDE AND LONGITUDE VALUES OF THE FEATURE

EXAMPLES OF BOUNDING RECTANGLES

Figure 3-11

Using the test points sectioning calculates where each point falls relative to the search area. Figure 3-12 illustrates a document that has one test point within the search area. If at least one point falls inside the area the document is at least partially in. However, as shown in Figure 3-13, conditions will exist where all the test points fall outside the search area and the bounding rectangle is partially inside.

To solve for this condition, the line formed by two test points is tested to see if it crosses any of the lines of the polygon. If there is at least one intersection of lines then the bounding rectangle is partially in.

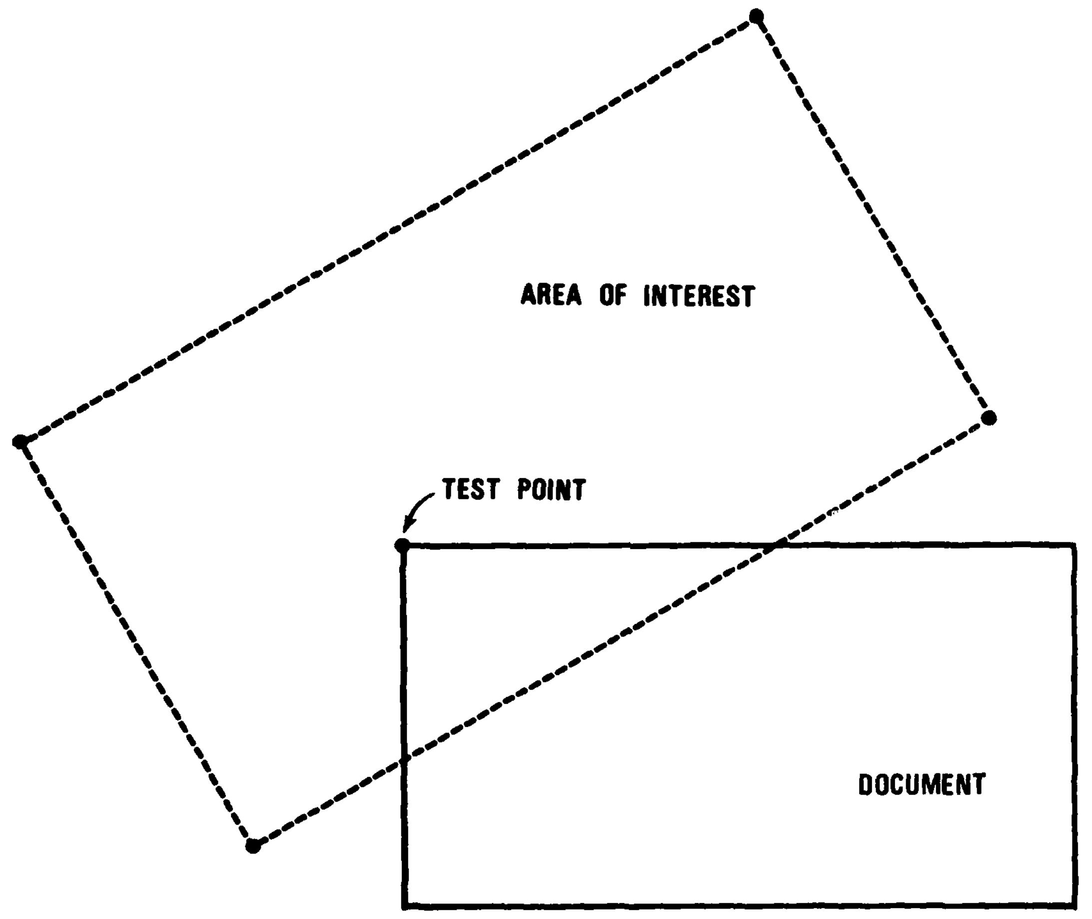
Even if the bounding rectangle fails the check just discussed it could still be partially in as depicted in Figure 3-14. In this case the bounding rectangle totally encompasses the search area. The first test by sectioning will find no test points within the area, and the second test will find no lines crossing. This problem is as common to the path and polygon searches as it is to the circle.

In polygon searches, the solution is to reverse the points. What is done is to check if any of the points of the polygon search area fall inside the bounding rectangle. As illustrated in Figure 3-14, the polygon search area falls inside the bounding rectangle, which proves the bounding rectangle is partially in.

The solution to the circle (Figure 3-14) is to use the center point as a test point. If the center of the circle is within the bounding rectangle then the feature or document is partially in.

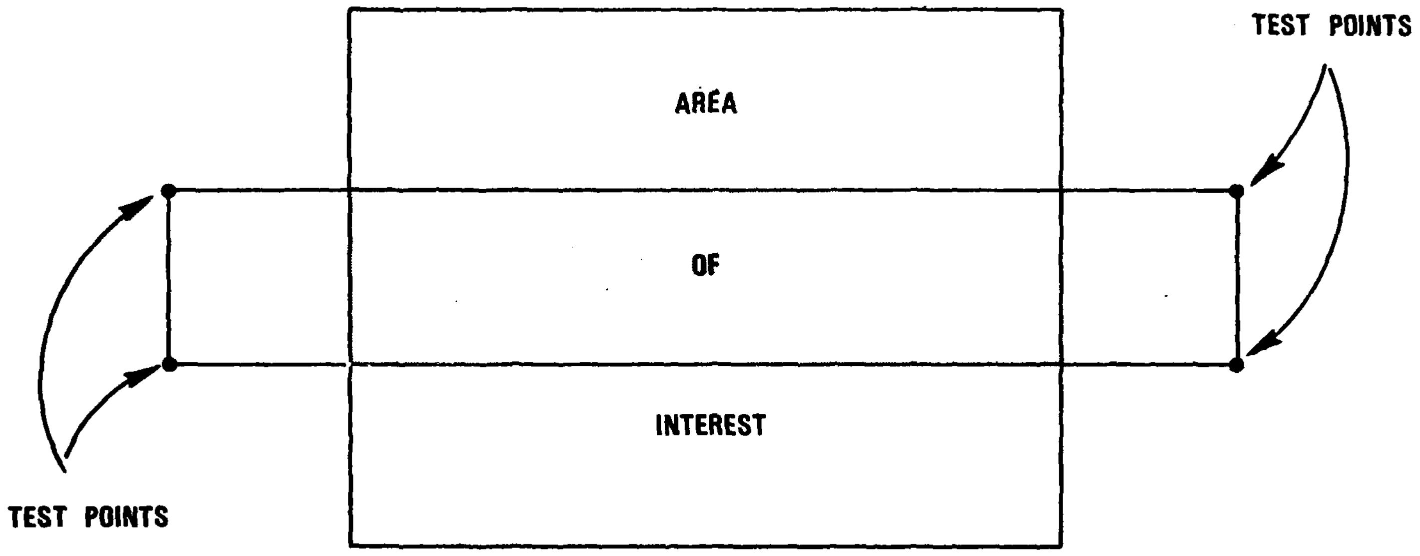
Additional problems can exist when using the circle searches. With this type of search the distance between the center of the circle and a test point is calculated. If the distance is less than or equal to the radius of the circle, the point is in. It is possible for the distance to the test points to be greater than the radius and the bounding rectangle still falls within the search area (Example A, Figure 3-15).

The solution is to determine the equation of the line between two test points and calculate the distance from the center point to the line. If the distance is less than the radial distance the area could be partially in. However, this solution creates another problem as shown in Example B of Figure 3-15. The problem arises when the distance from center point to the line is computed. We create imaginary lines which appear to be within the circle but really do not exist. The solution is to begin comparing the center point to the actual end points of the line being tested. If the center point does not fall between two end points the status is all out.



EXAMPLE OF A SINGLE TEST POINT
WITHIN AN AREA OF INTEREST

Figure 3-12



EXAMPLE OF A BOUNDING RECTANGLE

WITH TEST POINTS OUTSIDE THE AREA OF INTEREST

Figure 3-13

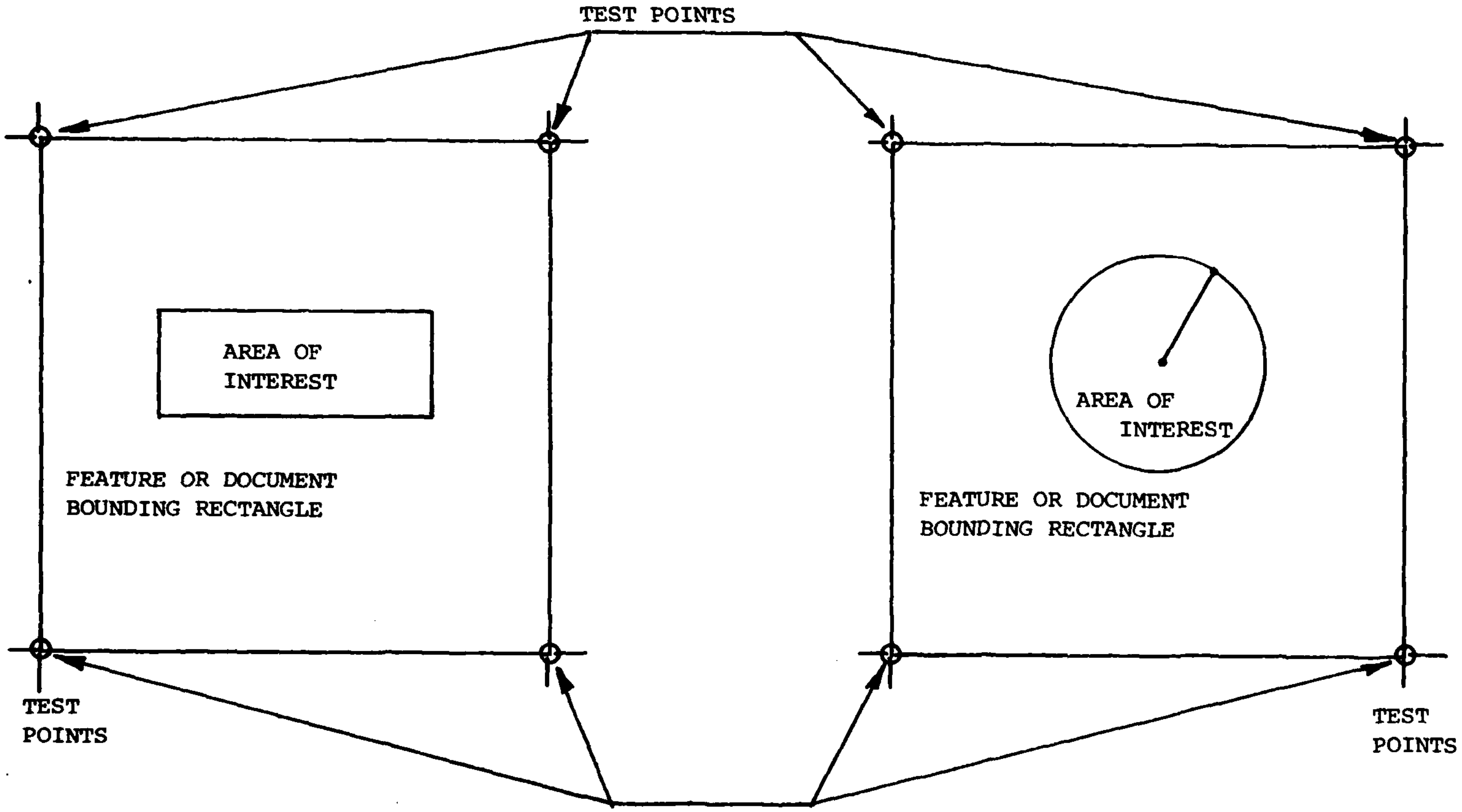


Figure 3-14. Problem of Bounding Rectangles Larger Than Area of Interest

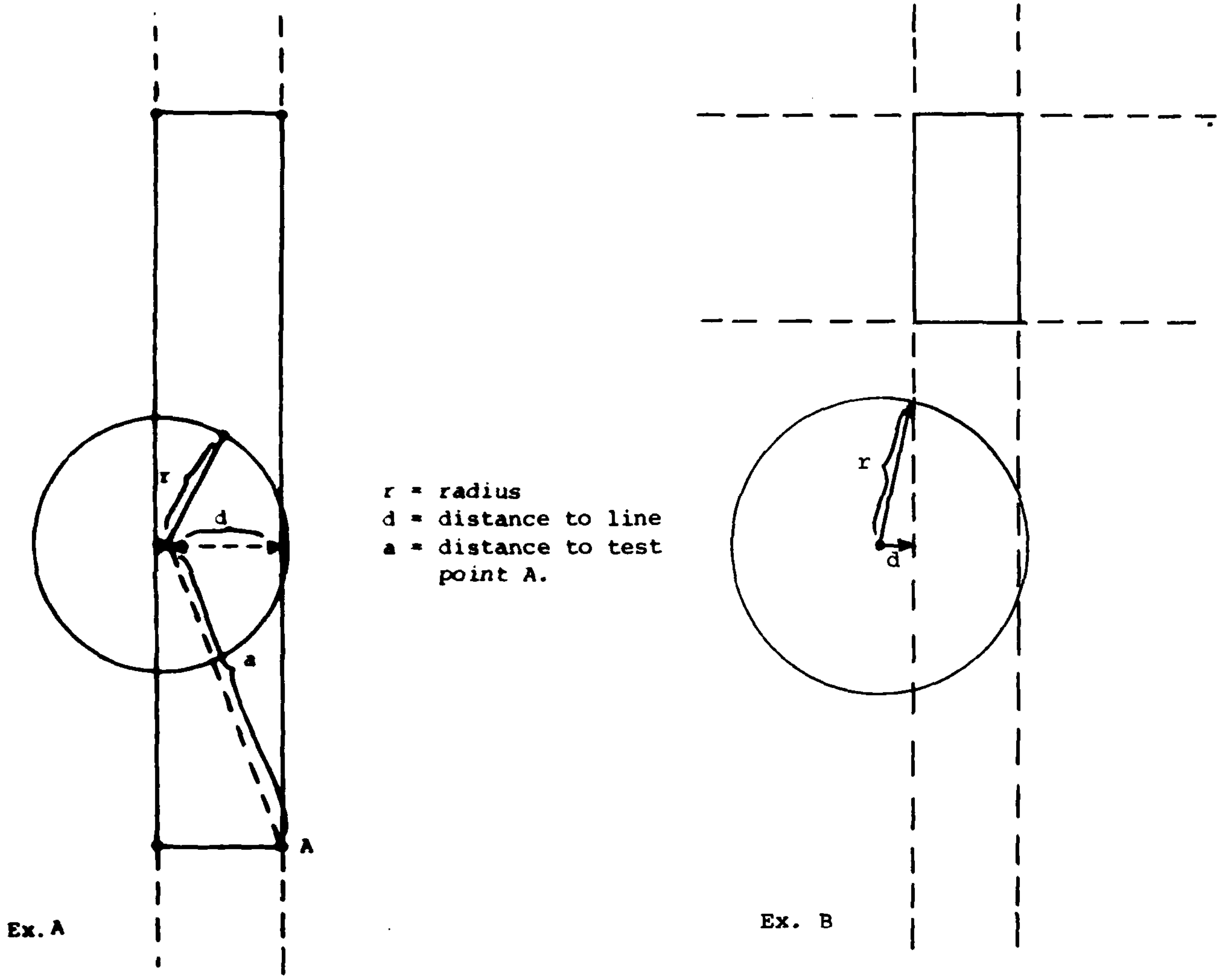


Figure 3-15. Circle Search Problems

As described in Section 2 of this document, sectioning converts geographic values to cartesian X,Y,Z coordinates on the surface of a unit sphere which gives the coordinates in terms of spherical angles. The use of spherical angles creates a problem when a search area crosses zero longitude. The spherical angle of longitude values is 0 for 0° longitude and increases in an easterly direction until a complete revolution around the earth is made. Therefore, zero longitude represents the minimum and maximum spherical angle that could exist for any longitude value. When sectioning computes the minimum and maximum values of a search area that crosses 0° longitude, it will, in effect, produce a reversed image (Figure 3-16). For example, if an area between 2°W and 2°E was sectioned, the spherical angles produced would be 6.25 and .035 respectively. When comparing these angles, the algebraic minimum value is that of the 2°E longitude. This results in a sectioned area between 2°E and 2°W instead of the desired area between 2°W and 2°E. In addition to this, any document that is in the eastern hemisphere with one side at zero longitude would be viewed as a reverse image. This problem is easily corrected by comparing the geographic values to check for this condition. If the conditions exist appropriate adjustments are made allowing sectioning to continue.

The solutions to the problems associated with sectioning provide a full capability to perform geographic retrievals. The only restrictions that are placed upon the user are mathematical in nature. These are - the points must be entered in a clockwise direction (beginning on the left hand side if a polygon search), and cannot form internal angles greater than 180°. However, no geographic restrictions exist. The search area can be as large as the total surface of the earth or as small as desired. Invalid conditions are checked for and rejected such as the input points being the same or when they form a straight line. This enables users to successfully and accurately retrieve any geographic area using circle, path, or polygon searches.

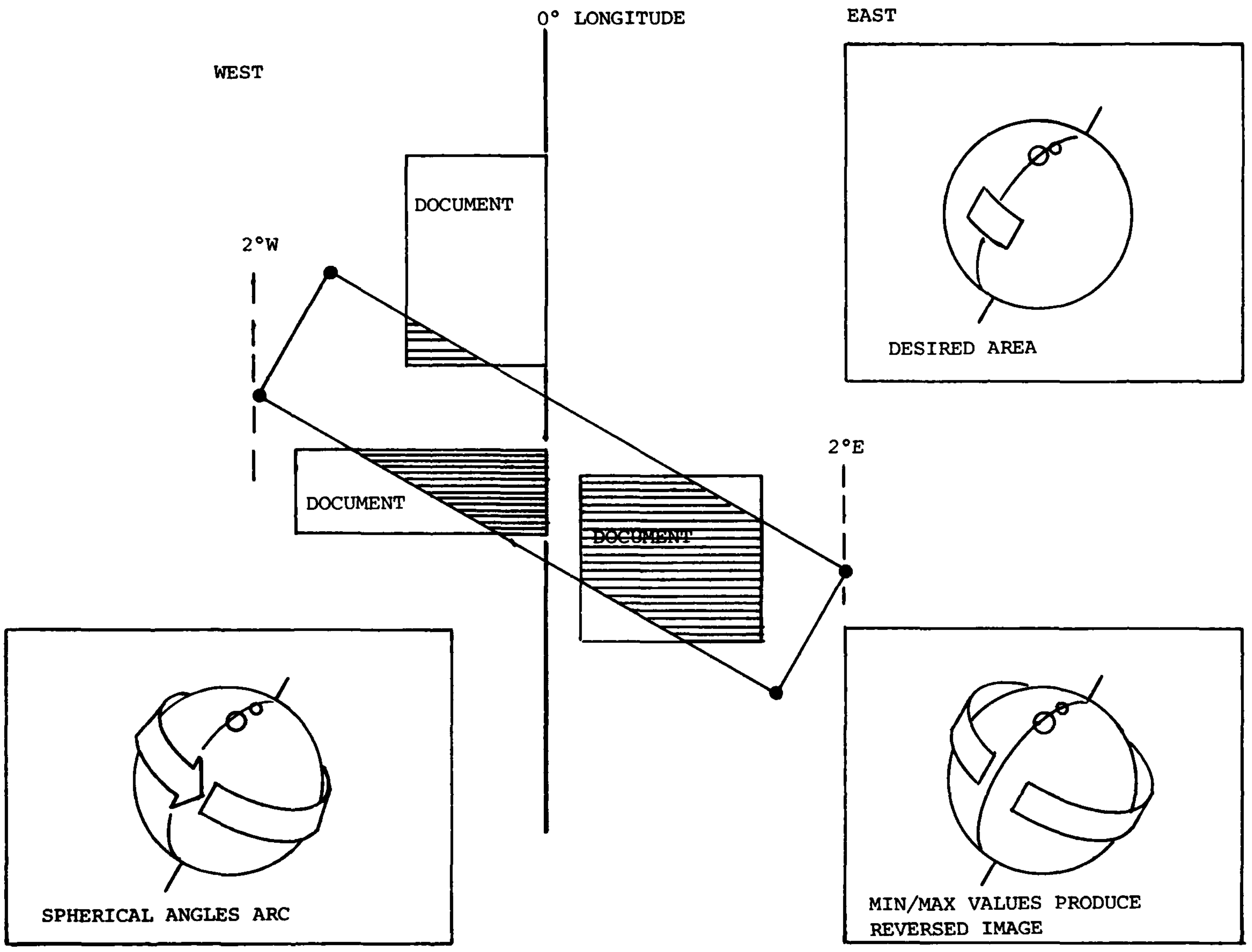


Figure 3-16. Crossing 0° Longitude

SECTION 4. THE PROBLEMS OF ACCURACY

4.1 PURPOSE

The purpose of this section is to analyze the critical contexts within which considerations of accuracy are relevant. In each such context, the intent is to identify both where considerations of accuracy have been analyzed and where further analysis is required.

4.2 DATA

4.2.1 Accuracy of Source Analog Data

4.2.1.1 Charts

The accuracy of data portrayed on man-made navigational charts and maps is clearly suspect in many instances. Charts become distorted because of shrinkage and expansion, and the distortion is clearly a highly complex non-linear phenomena from a mathematical point of view. The algorithm of registration does little, if anything, constructive to compensate for this distortion as registration is represented within the classical linear model of maximum likelihood which assumes uniform stretching or shrinking in an arbitrary direction.

When such charts are digitized and converted to geographic coordinates, information becomes available to the data base which seriously threatens its integrity. Thus, the ability to edit the data base becomes of paramount importance. A serious look should be taken at providing such a capability, if the BDRS system is to be used as a true data base system rather than a librarian as it was originally designed to be.

The accuracy of data portrayed on charts produced mechanically by plotters on such systems as the Lineal Input System, presents another problem as the material out of which the charts are made is much more resistant to distortion. These problems will be discussed momentarily in Section 4.3 of this document.

4.2.1.2 Fathograms

The accuracy of fathogram data is of a highly questionable nature. The navigational data listed in the ship's log, especially the speeds and courses, have been proven inaccurate in many instances. In fact, in some cases if the given course was actually followed, the end position of the ship would be in a completely different direction than where its end position was reported. Therefore, course and speed adjustments are often necessary when the actual fathogram processing occurs.

Besides errors in the log navigational data, the echogram itself may contain inaccurate data. Many times the paper speed of the fathogram seems to change without any notification being given. It is possible that either the evaluator who checks this data fails to correctly scale and mark the times, or the person in charge on the ship forgets to mark the time and later guesses its position on the fathogram. In any case, the times must be properly marked on the echogram and the digitizer must in some way be notified of paper speed changes. Otherwise, this inaccurate input data will produce unreliable results.

4.2.1.3 Data Entry of Analog Source Materials

Data is entered by the user within the digitization subsystem of BDRS. When graphical feature data is entered with a cursor, the data is accepted as is by the system; that is, there is no error term employed by the software to smooth out the errors which occur in data entry itself. In a linear model, the typical assumption of statisticians is that such error can be modeled by a probability distribution with a zero expectation and a variance characteristic of the particular user. Whether the inclusion of such an error term would be fruitful within BDRS itself has not been analyzed empirically.

A natural question to ask is how to check whether the data entered by the user is representative of the data supplied on the chart. The proof plot provides the check required. If the proof plot is a perfect overlay of the original source chart as it is taped on the table when digitized, then each digitized point is within an epsilon of its correct position. That is, depending upon the resolution of the data when digitized (from 1 mil to 10 mils), and accuracy of the plotting device. It may appear (to the human eye) that two chart points overlap each other, but in reality may actually be a few mils apart.

The accuracy of the sounding data entered by the user can be checked by the user as he enters the sounding value. This value is displayed on the Tektronix 4010 display. If the user is employing the Threshold 500 Voice unit, his entry is further displayed on the Threshold display unit.

4.2.2 Accuracy of Processed Data

4.2.2.1 Registration

The algorithm of registration is thoroughly discussed in Section 2.2.2 of this document. In this section several corollaries pertaining to the problem of accuracy will be deduced from the mathematical properties of the algorithm.

It was noted in Section 2.2.4 of this document that registration points should be picked judiciously; that it is representative of the chart as a whole and not in any obvious geometrical pattern. The reason for this latter condition finds its justification in the mathematical fact that an earth scale meter rectangle of arbitrary vertices can result from a digitized rectangle with acceptable residuals. For example, in registering a UTM chart, if the vertices of a rectangle are used for control points and the user enters the wrong northings and eastings for the points, then if his incorrect entries also constitute the vertices of a rectangle, the registration algorithm will produce a mapping which has acceptable residuals. Other obvious geometric shapes have this same characteristic.

A second property of the algorithm, which is actually quite unfortunate, is that a seriously distorted chart may be registered with acceptable residuals. Thus, it is the users responsibility to ensure that he is not allowing poor data into the BDRS system. There is a check which can be employed for this case. It is discussed in Section 4.2.2.2 of this document.

A final corollary of this algorithm is that the proper registration of a good source chart generates an extremely accurate mapping from the coordinate frame of the table to the earth rectangular frame in day 1 registration. The simplicity of the algorithm conjoined with the partitioning of symmetric matrices to find inverses results in a very accurate mapping.

4.2.2.2 Coordinate Transformations

When geographic coordinates are mapped to the earth scale meter frame and then back to the geographic frame, the resultant geographic coordinates are within a second of arc of the original geographic coordinates. The case of iterating this procedure to check for an accumulation of harmful error has not been checked rigorously.

Since the coordinate transformations and the registration transformation are so accurate, the following sequence constitutes an excellent test of whether the source analog chart is distorted badly.

- ✓ Register the chart and build a table file;
- ✓ Convert table file to geographic file;
- ✓ Convert geographic file to table file; and
- ✓ Plot table file.

If the plot overlays cleanly with the source data, then the chart is in good condition. Otherwise, the accuracy of the chart is seriously suspect.

4.2.2.3 Fathogram Processing

As stated in Section 4.2.1.2, the accuracy of the log navigational data is in many instances questionable. Therefore, much track adjusting occurs with regards to courses and speeds. The mathematical algorithms used for these calculations are discussed thoroughly in Section 2.5. It should be stressed here, however, that the accuracy of the fathogram processing output is directly related to the accuracy of the input. Consequently, even though very precise mathematical algorithms are employed, the output will be precisely calculated, but incorrect, if the input is inaccurate. For good results good data is imperative. If the differences between given courses and speeds and adjusted courses and speeds are large, then the input data should be thoroughly questioned. In turn, the output file should probably be disregarded.

Also, if paper speed changes are not noted on the fathogram and, therefore, not taken into account during the processing, the geographic values will not be correct even though correct depth values are calculated. Thus, if a change in paper speed occurs, a new file must be produced with the same document number and a new sheet number. This will result in the computation of a new time scale and correct correlation of depth values to the latitude, longitude points. As can be seen, the user must somehow be aware of paper speed changes. Only accurate, well marked fathograms and accurate corresponding navigational data will assure reliable results.

4.3 PROBLEM OF VALIDATION

In order to evaluate the accuracy of the map projections, charts must be utilized which represent data to the degree of accuracy being tested. The Hydrographic/Topographic Center has provided such a chart for the Mercator projection test. Charts of such high caliber were also provided for each mapping demanded.

To evaluate the accuracy of the polygon search algorithm, a high precision Gnomic projection chart is required. The great circle vertices of the polygon will map to straight lines on such a chart. Thus, one may construct with precision arbitrary earth polygonal regions on the chart and test arbitrary points for inclusion within the defined chart polygonal region.

If the accuracy of the map projections is precisely known, the accuracy of the functions constructed in registration can be tested by simply comparing their output with the known output of geographic points either identical to or different from the registration points.

The overall problem of all of these validation procedures is that they demand charts which are 'known' to be accurate within the degree of precision for which a test is to be made. If the charts are machine produced from the Lineal Input System (LIS), then the projections must conform to those employed in LIS itself. Whether this is desirable or not has not been rigorously analyzed within the BDRS research.

SECTION 5. SYSTEM CONFIGURATION

5.1 PURPOSE

The basic objective of this section is to review the overall BDRS system configuration in terms of both its hardware and software architectures. Additionally, special attention will be paid to key technical areas such as data base structure, file and record formats, etc.

5.2 HARDWARE CONFIGURATION

Figure 5-1 depicts BDRS hardware configuration, consisting of the following:

- ✓ Data General ECLIPSE C300 Processor - 128K core memory
- ✓ Data General Magnetic Tape Units, 9 Track (2)
- ✓ Data General 6012 CRT
- ✓ Centronics Line Printer
- ✓ Data General, 92MB Disk Drive, dual portable
- ✓ Data Automation Digitizing Tables (2)
- ✓ Tektronix Graphic Terminal, 4010, (2)
- ✓ Data General 6052 CRT
- ✓ Tektronix 4014 Graphic Terminal

Station One (Figure 5-2)

- ✓ 42" X 60" active Area Data Automation (X/Y Digitizer Table)
- ✓ Standard Cursor (five push buttons)
- ✓ Tektronix 4010 CRT
- ✓ 16 Key Keyboard

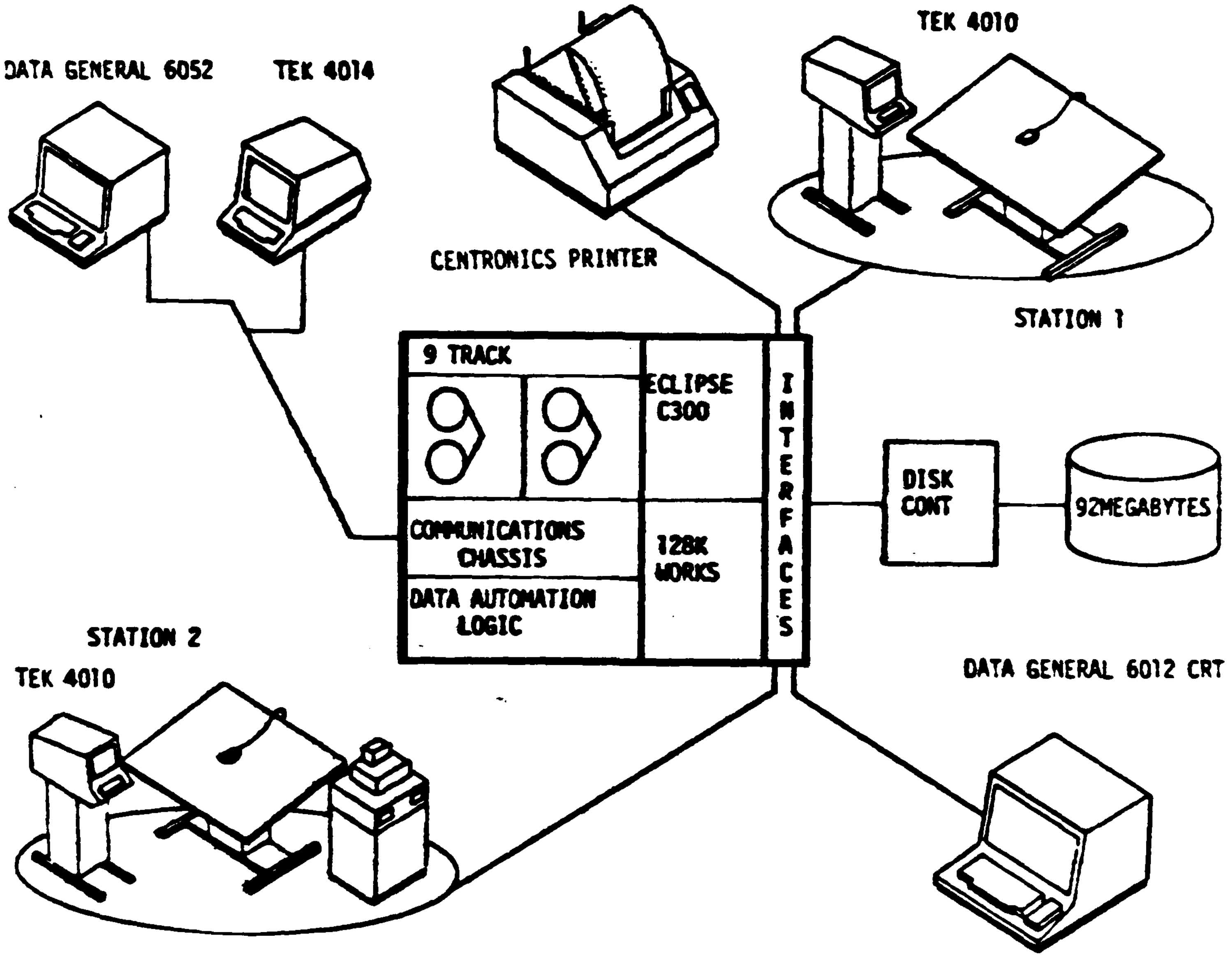


Figure 5-1. BDRS Hardware Configuration

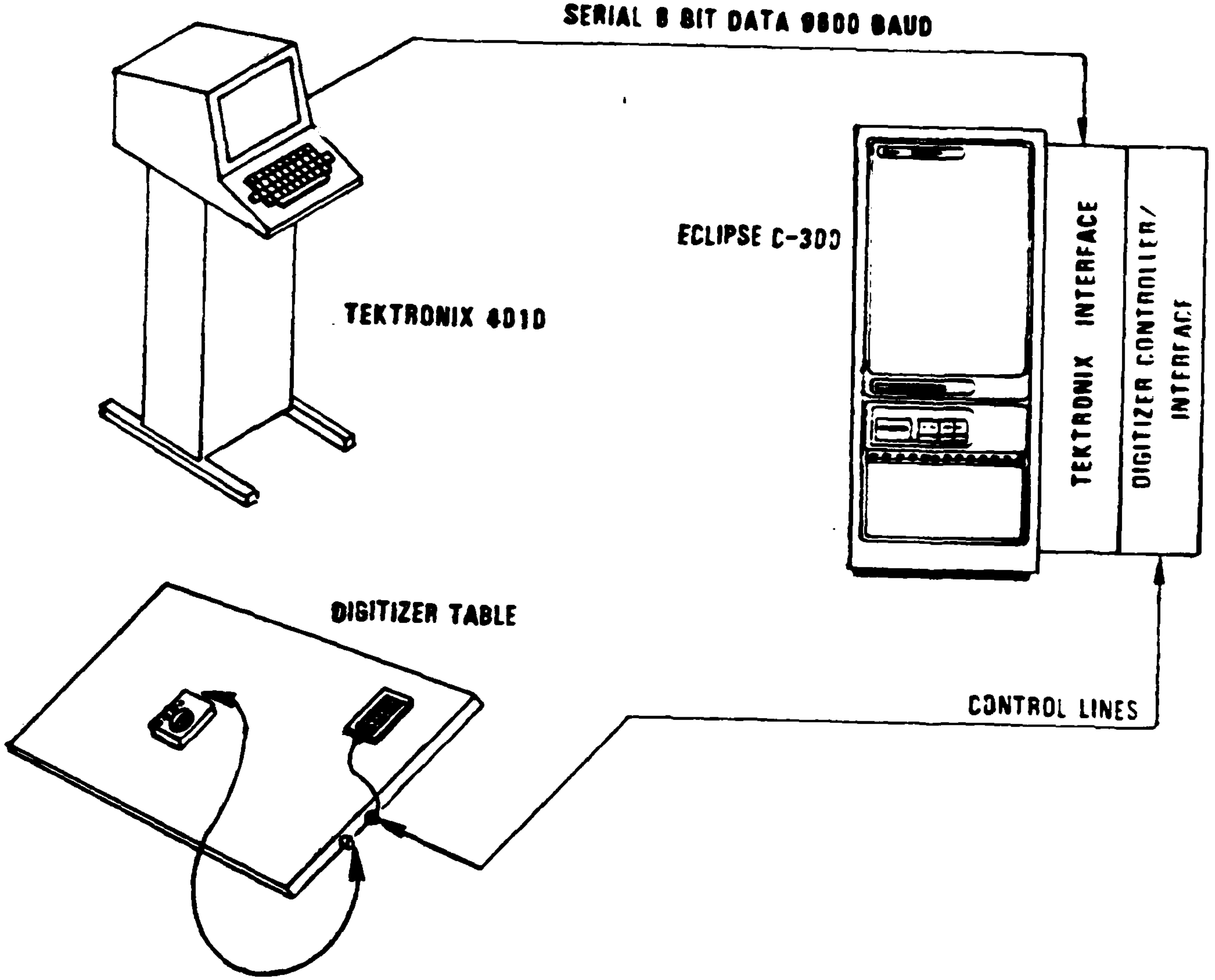


Figure 5-2. Station 1

Station Two (Figure 5-3)

- ✓ 42" X 60" active area Data Automation (X/Y Digitizer Table)
- ✓ Special Cursor (LED display/five push buttons)
- ✓ Tektronix 4010 CRT
- ✓ Threshold Technology, Inc., - Model 500 voice data entry terminal
- ✓ 16 Key Keyboard

5.3 BDRS SOFTWARE CONFIGURATION

5.3.1 Software Description

The software developed for the BDRS provides the capability for supporting the acquisition, maintenance and exploitation of bathymetric/hydrographic data pertinent to the goals and objectives of the Scientific Data Department (SD) of DMAHTC. The design concept employed, allows for the integration of the BDRS to existing and/or planned systems within the DMAHTC structure for the purpose of contributing to the overall operational/production requirements of DMA at the Hydrographic/Topographic Center.

DMAHTC's Bathymetric Data Library (BDL) operational requirements defined a need to convert data from its graphic analog form (i.e., charts, smooth sheets, fathograms, etc.) to a digitial one, capable of being exploited for the purpose of supporting the BDL operational objective. Additionally, a capability which would allow for the storage and retrieval of the digital data in a geographic format, was identified as being necessary if the BDL is to become and remain responsive to its role of supporting chart/product generation.

To accomplish these goals, the BDRS was configured with the software falling into three functionally oriented subsystems; Digitization, Batch, and Data Base.

5.3.1.1 Key Areas

To achieve the functional objectives of the BDRS, two different operating systems were required. The first operating system: "BDRSSYS1",

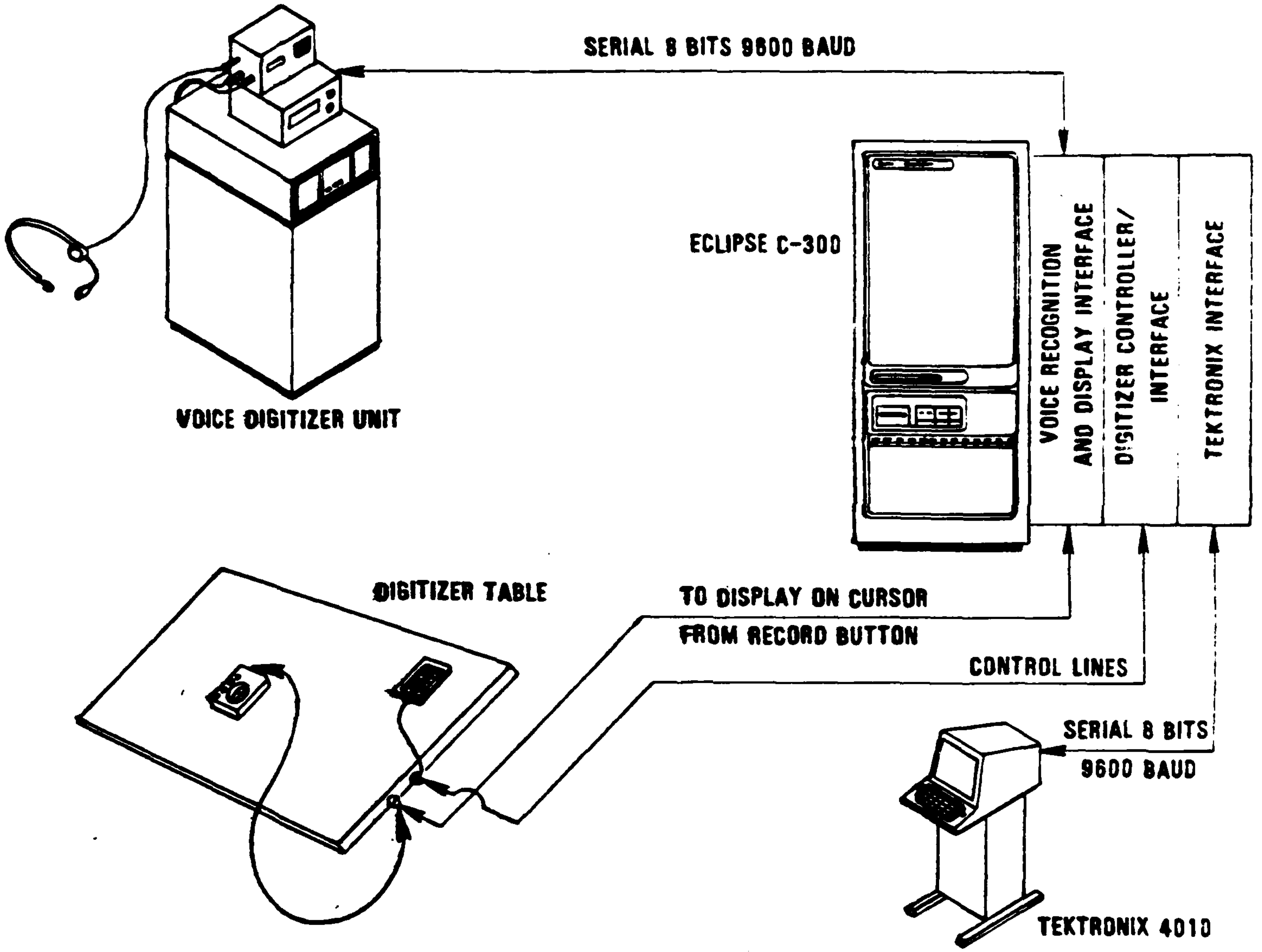


Figure 5-3. Station 2

was developed to support the running of both digitizing tables in the foreground and any other function in the background.

The second operating system, "BDRSSYS2", was developed to allow the voice digitizing process to be executed in either ground of the system. This leaves one ground available for other BDRS functions to be executed.

In addition to developing tailored operating systems, foreground/background processing, multi-tasking and overlays were utilized in developing the BDRS.

5.3.1.1.1 Foreground/Background Processing

The BDRS operates in a foreground/background mode. This permits unrelated tasks to be executed sharing the basic system resources. The process makes it appear that the tasks are being executed simultaneously. Figure 5-4 depicts the combinations of processes that could be run on the BDRS using the dual ground processing approach.

5.3.1.1.2 Multi-Tasking

The following is a detailed discussion concerning the Multi-Tasking convention of Data General's RDOS/FORTRAN. It has been used extensively by both the BDRS Digitization and ON-Line Data Base processes and for that reason should be closely reviewed.

✓ Multi-Tasking

A task is a logically complete unit of program execution that requires system resources such as memory and CPU control. A program, the current executable contents of a user address space, contains the code paths or sequences of instructions that tasks execute.

Single-tasking operation is relatively simple, involving a single flow of control through a program, no matter how complex the branching structure of that program may be (Figure 5-5). Multitasking consists of multiple, concurrent flows through a program, where the various flows (tasks) compete for CPU control (Figure 5-6).

In multitasking, a single program deals easily and efficiently with two or more tasks at one time. Although there is only one CPU, and in reality, only one instruction executes at a time, it appears as though several instructions from different tasks are executing simultaneously. This is because tasks take turns executing. For example, when one suspends execution (because of I/O or some other reason), another task takes over control. All of this happens automatically within the operating system and is invisible to the user. Thus, you

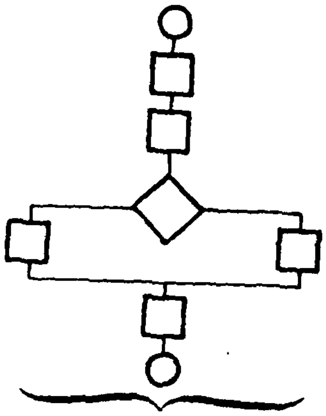
	FOREGROUND	BACKGROUND
*	2 TABLE DIGITIZATION***	BDRS BACKGROUND
*	2 TABLE DIGITIZATION***	ON-LINE DATA BASE
*	2 TABLE DIGITIZATION***	BATCH DATA BASE
*	2 TABLE DIGITIZATION***	CLI
**	ON-LINE DATA BASE	BATCH
**	BATCH	BATCH DATA BASE
**	CLI	ON-LINE DATA BASE
**	1 TABLE DIGITIZATION***	BATCH
**	ON-LINE DATA BASE	1 TABLE DIGITIZATION***
**	DATA BASE BATCH	ON-LINE DATA BASE
**	ON-LINE DATA BASE	DATA BASE MASTER MODE
**	CLI	1 TABLE DIGITIZATION***

* NOTE: MUST BE RUN USING 1 TTY SYSTEM (BD$\overset{s}{\text{R}}$SYS1)

** NOTE: MUST BE RUN USING 2 TTY SYSTEM (BD$\overset{s}{\text{R}}$SYS2)

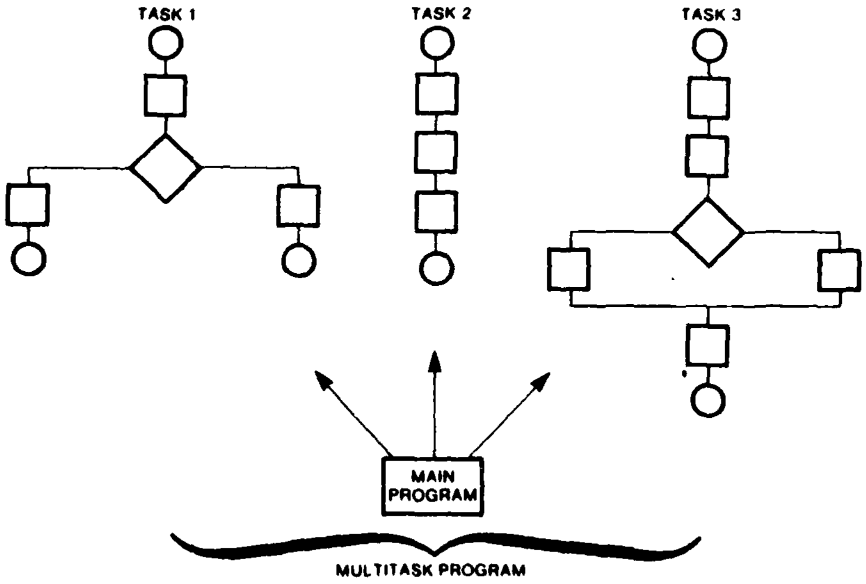
*** NOTE: WHEN RUNNING THE 2 TABLE DIGITIZATION PROCESS, IT MUST BE EXECUTED IN THE FOREGROUND. FOR THE 1 TABLE PROCESS, IT MAY BE RUN IN EITHER GROUND, BUT YOU MUST USE THE TABLE 2/ VOICE SOFTWARE.

Figure 5-4. Examples of the BDRS Systems Utilization of Foreground Background Processing



In a decision box, ◇ , control might take either path, based on the state of some variable.

Figure 5-5. Single-Task Program



Tasks 1, 2, 3, are executing concurrently

In a decision box, ◇ , control might take either path, based on the state of some variable

Figure 5-6. Multitask Program

have no need to keep track of the various tasks and to appropriately switch control among them. Multitasking takes care of this for you and at the same time handles the environment more efficiently. While one or more tasks await completion of their I/O operations, other tasks use the time thus made available to do their computations. As many as 255 tasks may be active at the same time.

With multitasking, you may exercise a fine control over the tasks which the system selects for execution and the time at which it selects them. When you define a task and specify the instructions it will execute, you also assign the task a priority relative to other tasks. However, you may change task priorities during program execution. This allows you to control which tasks receive CPU control and when. A task scheduler allocates CPU control to the highest priority task that is ready either to perform or to continue to perform its function.

Although each task in a multitask environment may execute independently, a certain amount of interaction between the tasks is often required. DGC's multitasking allows you to communicate between tasks conveniently, providing for synchronization. For example, a task may suspend its own execution at a certain point, awaiting a signal from another task.

In certain situations, it is appropriate for two or more tasks to execute exactly the same sequence(s) of instructions yet still remain independent of one another and use their own sets of data. In such cases, it is more efficient for all of the tasks to share a single set of instructions than to duplicate the code several times. This sharing is possible provided that the code does not modify itself, and that FORTRAN sets aside a separate data space for each task.

To provide this separate space for each task, FORTRAN allocates a part of the runtime stack for variables which the task uses. Thus, it separates the unmodified, shared code from the modified data areas. We call the shared code re-entrant code since various tasks are entering and using the code at the same time.

The actual sequence of events in the use of re-entrant code is as follows. Each time you initiate a task in a multitasking program, FORTRAN assigns the task a task control block and a piece of the runtime stack. The task control block keeps track of which instructions the task is executing and the data space allocated to the task. Two or more tasks execute a single subroutine (re-entrant code) at one time, although the tasks are not executing the same statement at a given instant. Figure 5-7 illustrates the status of the program at one point in time. It is not a dynamic picture of these operations.

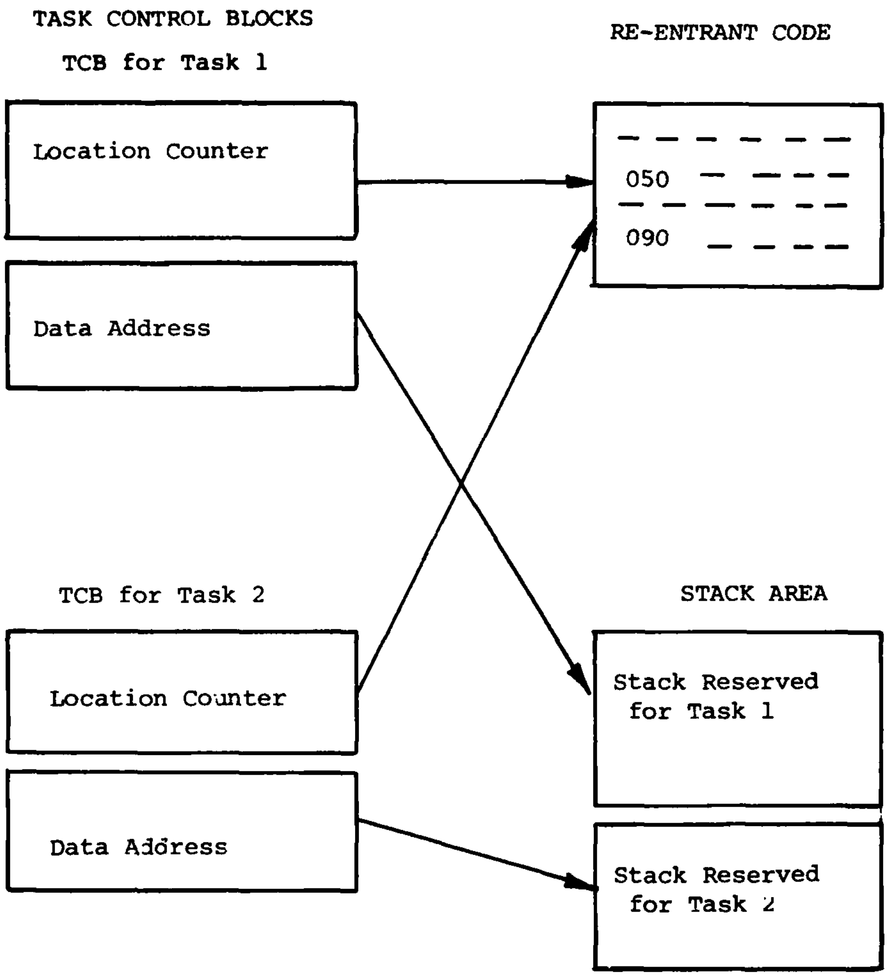


Figure 5-7. Task Control Block and Use of Re-entrant Code

5.3.1.1.3 Overlays

In many cases, an applications program is too large to reside in main memory at one time. If you have written your program in modules (for example, using subroutines or functions), you may use the overlaying technique to overcome this size difficulty. An overlay is a reserved area in main memory which various program parts or modules can share.

The program parts (subroutines, functions, etc.) reside in secondary storage (on disk) until needed by the program. Whenever the program requires a given subroutine, you must load it from the secondary storage area into the overlay area and execute it. (Some Data General operating systems load subroutines automatically when you call them.) While a given subroutine is in the overlay area, the other subroutines not in use remain in secondary storage (on disk).

The size of the overlay area you reserve in main memory should be large enough to accommodate the largest subroutine or function that you intend to call. You may have more than one overlay area for a single program, and within each overlay area, you may have as many as 256 overlays. Therefore, you may have a much larger program than main memory can ordinarily accommodate, provided that you write it in modules.

Let us assume that you are using FORTRAN on an RDOS system and you load the main program with subprograms 1 and 4 to reside in main memory and subprograms 2 and 3 to be used as overlays. Figure 5-8 indicates the positions of the various program parts at a given moment after loading and before executing the program.

This technique of overlaying, is used extensively throughout the entire BDRS system. Care should be taken to fully understand this technique and how it was utilized within the BDRS software architecture, so that future activity relative to the maintenance of existing software packages will be relatively straight-forward in nature.

5.3.2 Digitizing Software

Sources of input into the BDRS are in graphic analog form. These sources include fathograms, charts, random and survey track data, foreign source data, smooth sheets and others. The digitizing process is designed to produce digital data from these sources using state-of-the-art hardware and software technology.

The digitizing software is structured modularly. Each module represents an overlay which performs a separate function in the digitizing

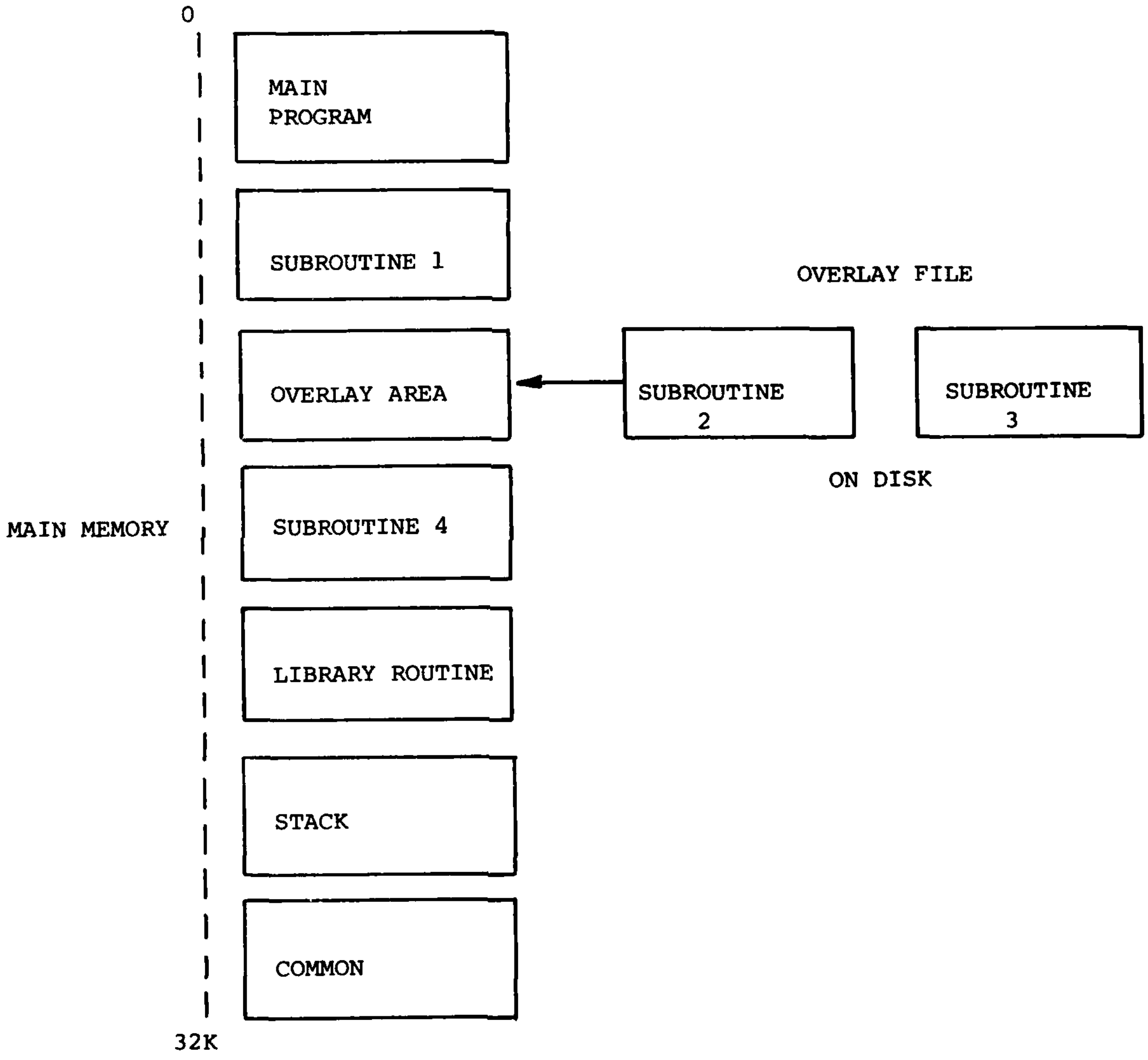


Figure 5-8. Overlays

process. This architecture is shown in Figure 5-9. The Master Mode module is the main element in the overall software. Each of the five digitizing functions are accessed using the cursor push buttons when in Master Mode. This type of approach allows for additional functions to be added at a later time without major modifications to existing software.

The output of the digitization process is a collection of table files which represent the analog data in a digital form. Throughout the process the user has a number of different options available for entering data. The options include the "voice box", the cursor, and the keyboard. Visual feedback during the process allows maximum control to create, and edit new and existing files. The relationship of input to output in the digitizing process is given in Figure 5-10.

5.3.3 Batch Software

The Batch processes provide the interfacing of the digitizing subsystem to the data base. Batch functions were designed with the simpliest of architectures. Each function is a stand-alone operation using no overlays. To reduce the complexity of each function, unique operations were divided into subroutines. Figure 5-11 shows the separate functions and the input/output of each.

5.3.4 Data Base Software

The data base software supports the capability to store, retrieve, and maintain geographical bathymetric data. It also provides interactive access as well as conventional batch access. In order to build such a capability, the Data Base Subsystem was divided into three unique processes; On-Line, Batch, and Master Mode. The architecture used to implement these processes varies depending on the mode of operation.

5.3.4.1 On-Line Data Base

The architecture employed in designing this capability makes use of the multi-tasking and overlaying techniques described earlier. The multi-tasking was used to support two terminals concurrently. The 6052 CRT is used to create and edit document and source description records. Additional functions allow a user to geographically locate a point and change the depth or location or both. The second terminal is the Tektronix 4014 graphic CRT which supports on-line sectioning of the

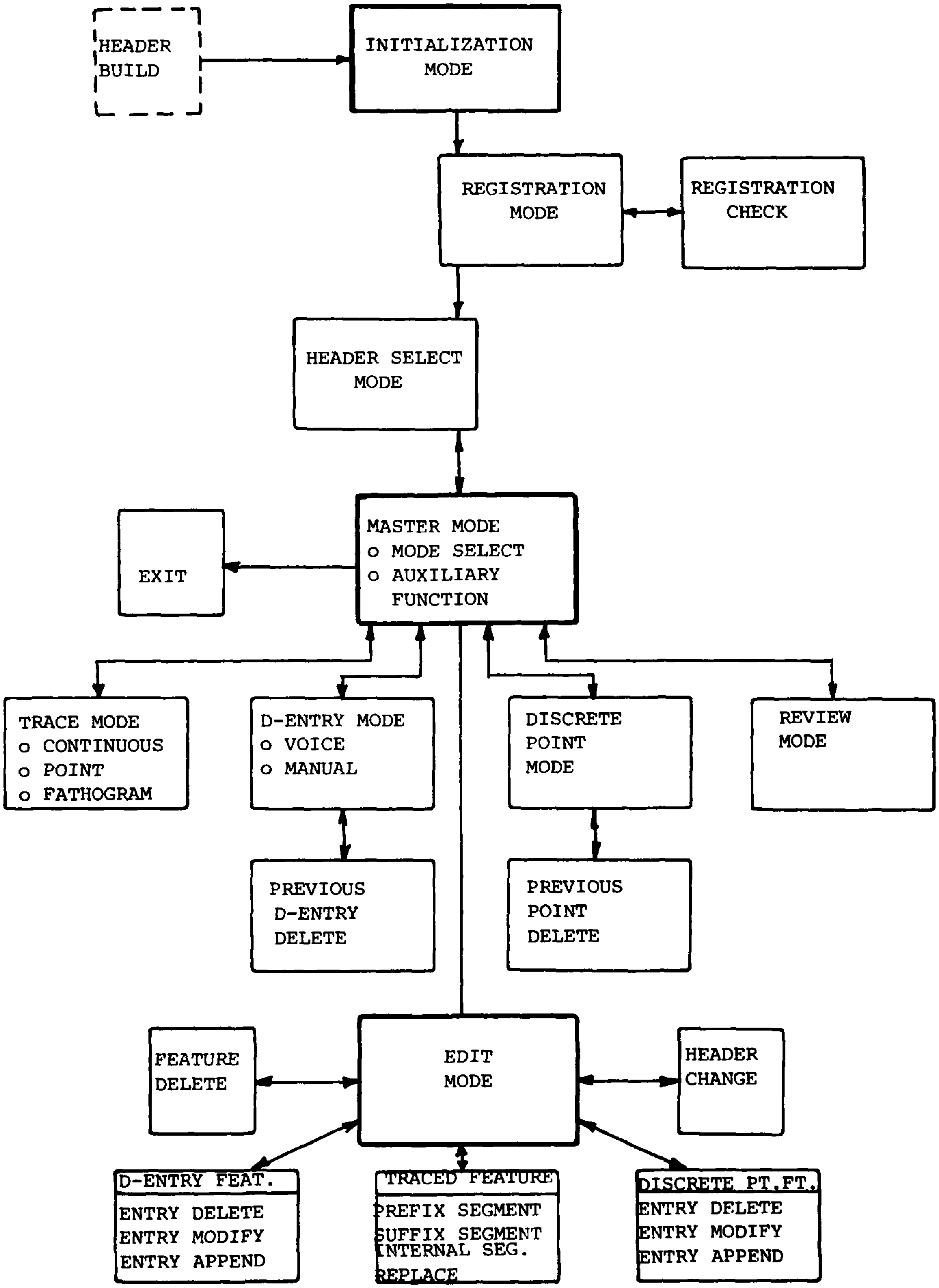


Figure 5-9. Digitization Functional Architecture

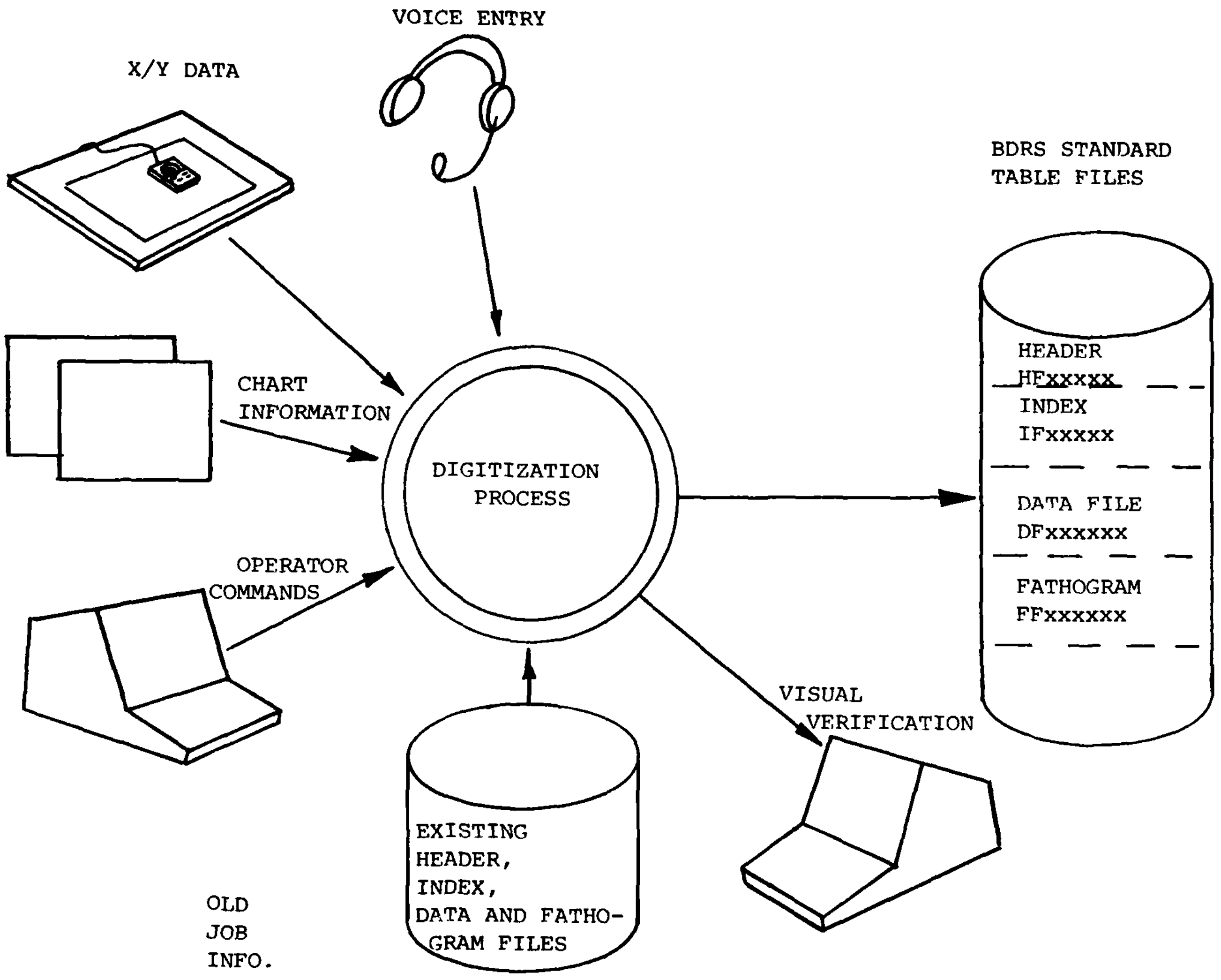


Figure 5-10. Digitization Input and Output

INPUT	FUNCTION	OUTPUT
BDRS STANDARD TABLE FILE	PROOF PLOT	INTERMEDIATE PLOT FILE
INTERMEDIATE PLOT FILE	PLOT DRIVER	MAG TAPE FILE
BDRS TABLE FILE	PHILLIPS TRACK LINE	INTERMEDIATE PLOT FILE
BDRS FATHOGRAM TABLE FILE	ECHOGRAM PLOT	INTERMEDIATE PLOT FILE
BDRS TABLE FILE THAT HAS BEEN CREATED BY A BDRS GEO TO TABLE CONVERSION	GEBCO TRACK LINE PLOT	INTERMEDIATE PLOT FILE
BDRS STANDARD TABLE FILE CONTAINING SOUNDINGS	MODIFIED GEBCO	BDRS STANDARD TABLE FILE WITH MODIFIED SOUNDINGS
BDRS STANDARD FATHOGRAM TABLE FILE AND SHIP's LOG FILE	FATHOGRAM PROCESSING	BDRS STANDARD GEOGRAPHIC FILE
BDRS GEOGRAPHIC FILE CONTAINING SOUNDING VALUES TO BE ADJUSTED AND A BDRS GEO-SECTIONED FILE FROM THE DATA BASE	DEPTH ADJUSTMENT	BDRS GEOGRAPHIC FILE CONTAINING ADJUSTED SOUNDING VALUES

Figure 5-11. Batch Input/Output

INPUT	FUNCTION	OUTPUT
BDRS STANDARD GEOGRAPHIC FILE	DATUM SHIFT	BDRS STANDARD GEOGRAPHIC FILE
BDRS STANDARD TABLE FILES	OUTPUT BDRS TABLE DATA TO MAGNETIC TAPE	MAGNETIC TAPE FILE
MAGNETIC TAPE FILE	INPUT BDRS TABLE DATA FROM MAGNETIC TAPE	BDRS TABLE DATA ON DISK FROM 9-TRACK MAG TAPE
BDRS STANDARD TABLE FILE	TABLE TO GEOGRAPHIC CONVERSION	BDRS STANDARD GEOGRAPHIC FILE
BDRS STANDARD GEOGRAPHIC FILE	GEOGRAPHIC TO TABLE CONVERSION	BDRS STANDARD TABLE FILE
SOURCE DESCRIPTION DATA INDEX AND UNIVAC 1108 FORMATTED GEOGRAPHIC SOUNDING DATA ON MAGNETIC TAPE	UNIVAC 1108 TO BDRS CONVERSION	BDRS GEOGRAPHIC FILE ON DISK
LIS GEOGRAPHIC DATA FILE ON MAGNETIC TAPE	LIS TO BDRS CONVERSION	BDRS GEOGRAPHIC FILE ON DISK

Figure 5-11. Batch Input/Output (Continued)

AD-A091 942 SYNECTICS CORP ROME N Y F/G 8/10
BATHYMETRIC DATA REDUCTION SYSTEM.(U)
AUG 80 D T ALVAREZ, J R TERENZETTE F30602-76-C-0412
UNCLASSIFIED CJ-0756-A RADC-TR-80-273 NL

2 of 3
AD A
09194

data base. Each overlay represents either a group of utility subroutines or a specific function of the on-line processes.

5.3.4.2 Batch Data Base

The architecture behind the batch software is not as complex as the on-line software. This mode of operation uses a single task with four overlays. Each overlay performs a separate function of either input, output, or logical deletion of data in the data base.

5.3.4.3 Data Base Master Mode

Master Mode software allows the user to control the operational environment of the data base. Physical deletion of a file as well as user access is controlled under this mode of operation. The architecture is comprised of a single task using six overlays. Each function defined by its separate overlay is loaded from disk when called by the Executive routine.

5.3.5 Files and Record Formats

All three subsystems of the BDRS produce, and process files. The digitizing process produces four unique table files; header, index, data, and fathogram (when a fathogram is digitized). Batch processes produces table and geographic files. The Data Base creates and uses geographic files. The location of these files in relation to each subsystem is depicted in Figure 5-12.

In addition to files, there exists document and source description records which are essential to the data base. The document and source description record is used to describe each document that is loaded into the data base. For every document there can only be one document description record. The source description record gives more information about the file that has been digitized. There can be more than one source description record for a document.

The structure, contents, and further discussion of the files and records can be found in Appendix C of this document.

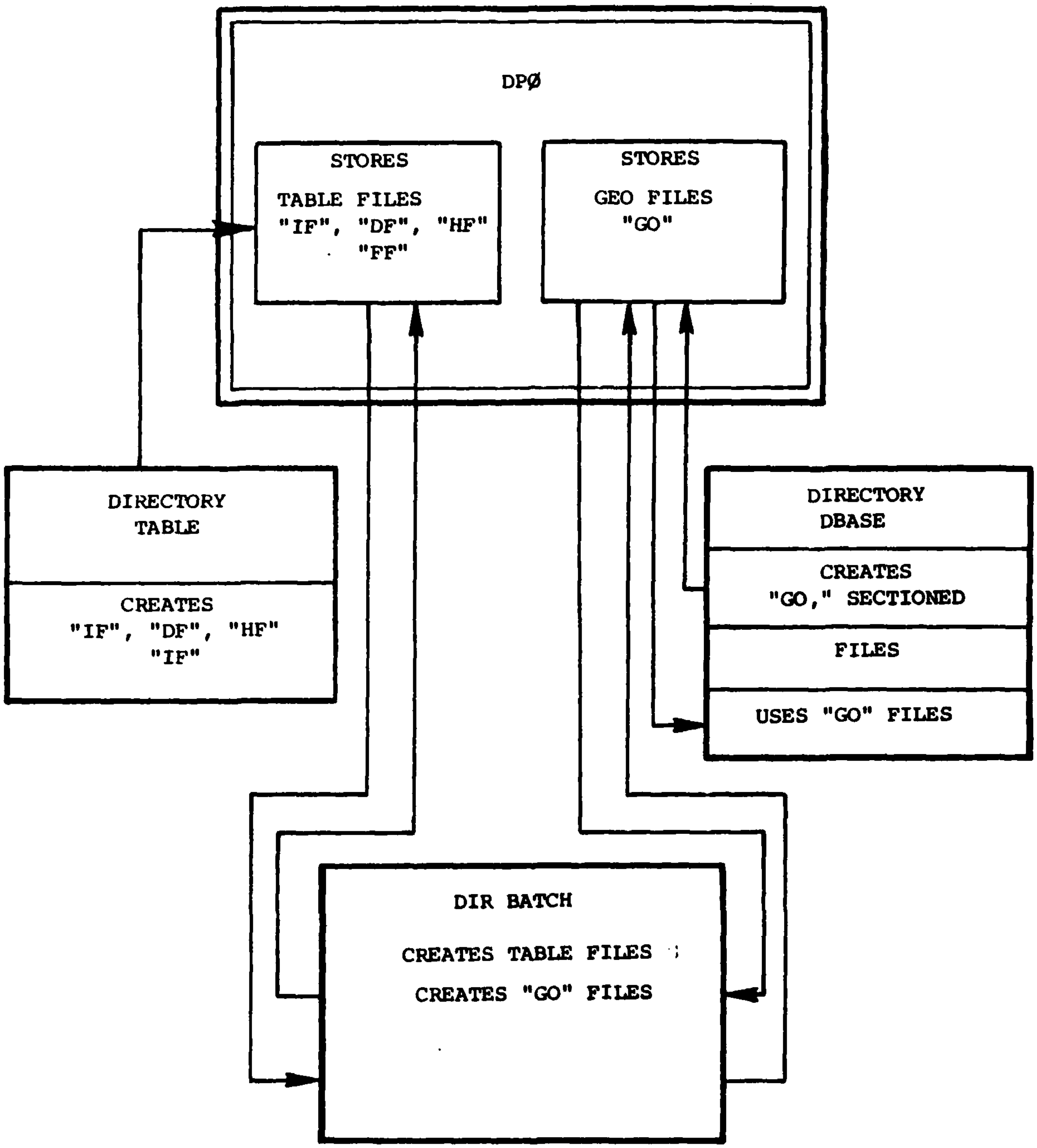


Figure 5-12. File Map

5.3.6 Data Base Structure

The structure of the BDRS data base, as illustrated in Figure 5-13, consists of two distinct INFOS files, the Index file and the Data Base file. As illustrated, the Index file contains five levels of indexes, each of which performs the following function:

✓ Index Level 0

The purpose of this index is to provide the data base user the capability to access the BDRS data base file via one of three distinct entry paths, GEOgraphics, USER ID, or DOCument number. In actuality this is, to use INFOS terminology, a "dummy index level" used as an alternative to the method of establishing three separate Index files to achieve the same end result. Without the use of such a "Dummy" index level, the overhead associated with maintaining three separate index files in core could become overbearing and would definitely lead to the degradation of system response times.

✓ Index Level 1

Index Level 1 consists of three separate INFOS "tree structures", each of which is accessed via the Level 0 dummy index. The Geographic tree structure, as shown in Figure 5-13, represent the scheme for geographically segmenting the earths surface. Each low level segment, or cell, represents a fixed geographic area and points to: 1) a record in the data base file containing qualitative/quantitative information about that cell, and 2) Index Level 2 tree structure containing a document entry for each document containing coverage for that area. The document number tree structure of Index Level 1 contains a document number entry for each document currently stored in the data base file. Each low level entry in the tree structure points to 1) a record in the data base file describing the document, and 2) a tree structure in Index Level 2 of all Source description records associated with a particular document.

✓ Index Level 2

Index Level 2 also has three tree structures associated with it. For the GEO tree structures of Index Level 1, a tree structure is maintained in Index Level 2 of all document numbers with coverage in each of the basic GEO cells. The document number stored in this index tree structure will be used by the BDRS data base software to access the actual data stored in the data base file. Access will be gained via the document number index as shown in Figure 5-13. The Index Level 2 tree structure associated with the document number index of Level 1 is used to carry those Source ID numbers, each of which

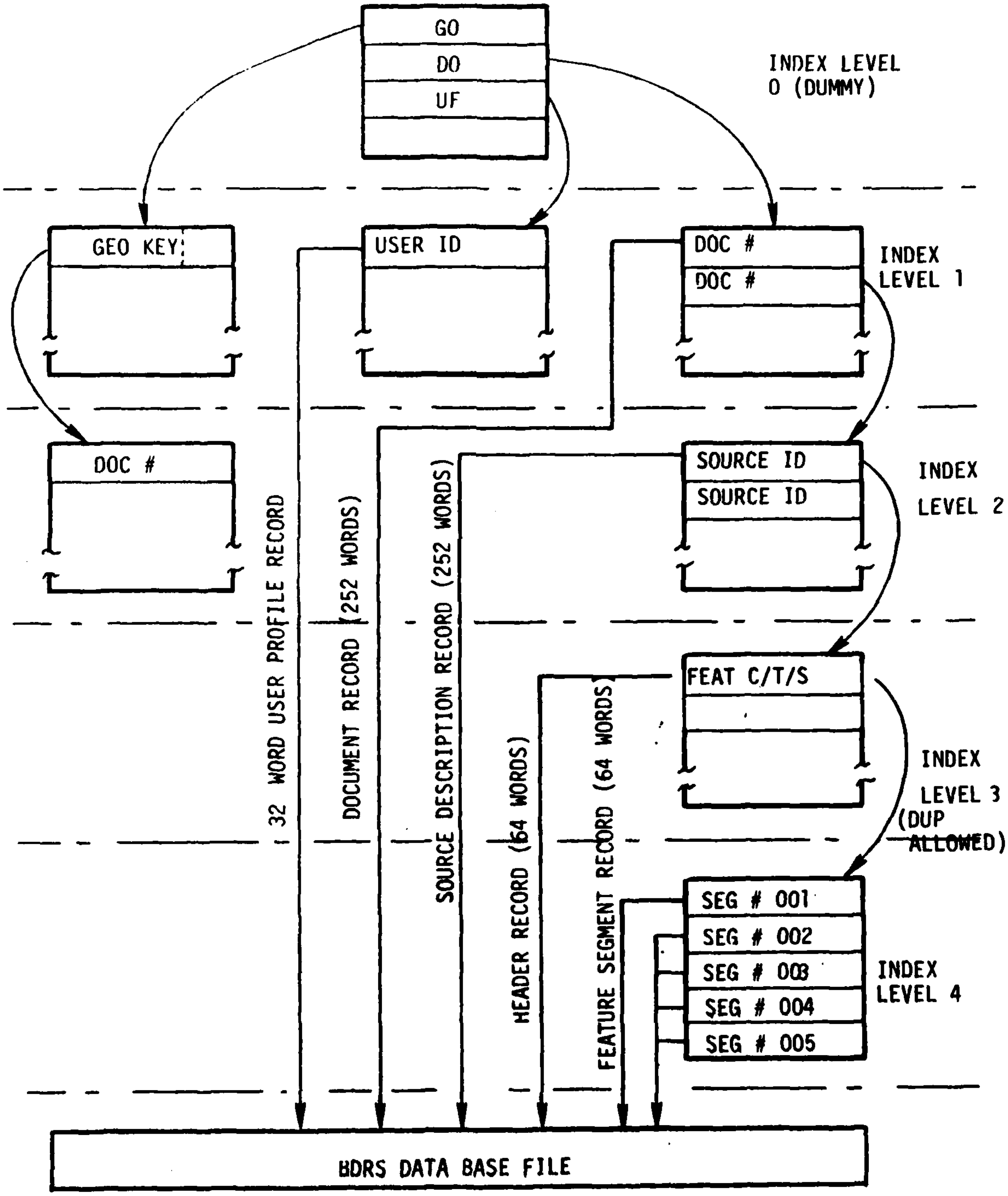


Figure 5-13. BDRS Data Base Structure

represents a unique source description record, associated with each unique document. Each low level entry in this tree structure points to 1) the actual source description record in the data base file, and 2) a feature classification tree structure, for each source, located within Index Level 3 of the document number index.

✓ Index Level 3

This index level has but one tree structure associated with it, and that structure called feature classification, falls within the Document index path to the data base file. Its purpose is to provide a further breakdown of bathymetric data into class and types. As mentioned earlier, each document has one or more source descriptor records associated with it and each source may, or may not, have one or more types of features associated with it. So as a result, Index Level 3 is used to "breakout" features by class and type, all of which are directly related to a source entry in Index level 2. Each entry in the Index level 3 tree structure simply points to an Index level 4 tree structure which contains an entry for every feature stored in the BDRS data base.

✓ Index Level 4

This Index level represents the "ground floor" of the Index file. It is at this level that an entry must exist for each record stored in the data base file. Each feature or string of lat, long, and depth values is represented by a unique segment number stored in a Level 4 tree structure with respect to its entry in the feature classification Index level 3.

SECTION 6. CONCLUSIONS AND RECOMMENDATIONS

6.1 GENERAL

Synectics Corporation is pleased to have been given the opportunity to work closely with Rome Air Development Center (RADC) and the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC) over the past 36 months in the phased development and implementation of the Bathymetric Data Reduction System (BDRS). We are of the opinion that efforts such as this demonstrate the feasibility and effectiveness of the "team-concept" in system design, development, and implementation: that is, the production centers working closely with the research laboratories and private industry in the specification and development of state-of-the-art based automated systems and techniques, in support of DMA's growing production requirements.

Throughout the 36 month development period, the goal of establishing a cost-effective system, capable of demonstrating its functionality and applicability in the operational/production environment at DMAHTC was rigorously pursued. Additionally, care was taken to include in the software/system concept, the "hooks and handles" deemed necessary to support future growth and system adaptability/expandability. The strict adherance to this approach by Synectics, RADC, and DMAHTC, resulted in the development of a system which with time and attention could play a much greater role than was originally intended in support of DMAHTC's "soon-to-be-digital" operation.

In the subsections that follow, the topics of hardware, software, and file maintenance will be discussed relative to their respective limitations, whether they be known or anticipated. Additionally, recommendations will be offered that will, if adopted, vastly enhance the existing BDRS capability by either eliminating known system limitations or by providing new means by which the system users may further exploit the BDRS resident digital bathymetry. Prior to continuing, Synectics would like to clarify its meaning of the term "limitations". Its use is in no way meant to infer that the current BDRS system is not responsive to those system requirements identified in the SOW. Those limitations that will be discussed relate primarily to the current hardware configuration and its inability to support an expanded BDRS production capability. Such hardware limitations surfaced early-on in the effort (Synectics Technical Proposal) and were agreed upon as being 'givens' if a cost-effective, functionally oriented system development was to be achieved.

6.2 HARDWARE

The current BDRS hardware configuration, as shown in Figure 6-1, adequately supported the cost-effective development of the Digitization, Batch, and Data Base processes of the BDRS. However, if maximum benefits are to be realized from the functional processes of the BDRS once the system has been transitioned into a production support role, hardware upgrading will be required. This process will not require the "moth-balling" of existing hardware components. Figure 6-2 graphically depicts a candidate configuration which would combine existing hardware components, with newly acquired ones, to form an extremely powerful BDRS configuration. Such a configuration would support extensive growth relative to digital data base exploitation. The rationale used in defining an "advanced" configuration was based primarily on the following:

- ✓ Inability of certain hardware components of the current configuration to support system growth;
- ✓ The need to separate the incompatible processes of digitization and data base. Any attempt to combine a high priority real-time data collection process, such as digitization, with a highly interactive I/O bound data base application, will inevitably result in the inefficient use of system resources and user response time degradation; and
- ✓ The need to support, in a timely and efficient manner, an anticipated increase in user demands on the BDRS data base.

In the paragraphs that follow, specific hardware components of the current configuration will be discussed with regard to: 1) the impact each has on the growth of the current system, 2) what role each component will play in the advanced configuration, and 3) what additional components of similar nature will be required to assure maximum system expandability/flexibility.

- ✓ Disk Storage

  Disk storage capacity of the current BDRS system is 92 megabytes. This is more than adequate to support the processes of digitization and batch, but falls far short of supporting what is anticipated as being a large, ever growing bathymetric data base. Additionally, under the current configuration, the 92 MB disk is supporting all system activities, resulting in the phenomena known as "disk-thrashing". That is, the uncontrollable movement of the read/write heads in support of totally unrelated activities. Such thrashing results in extremely poor utilization of system resources and ultimately

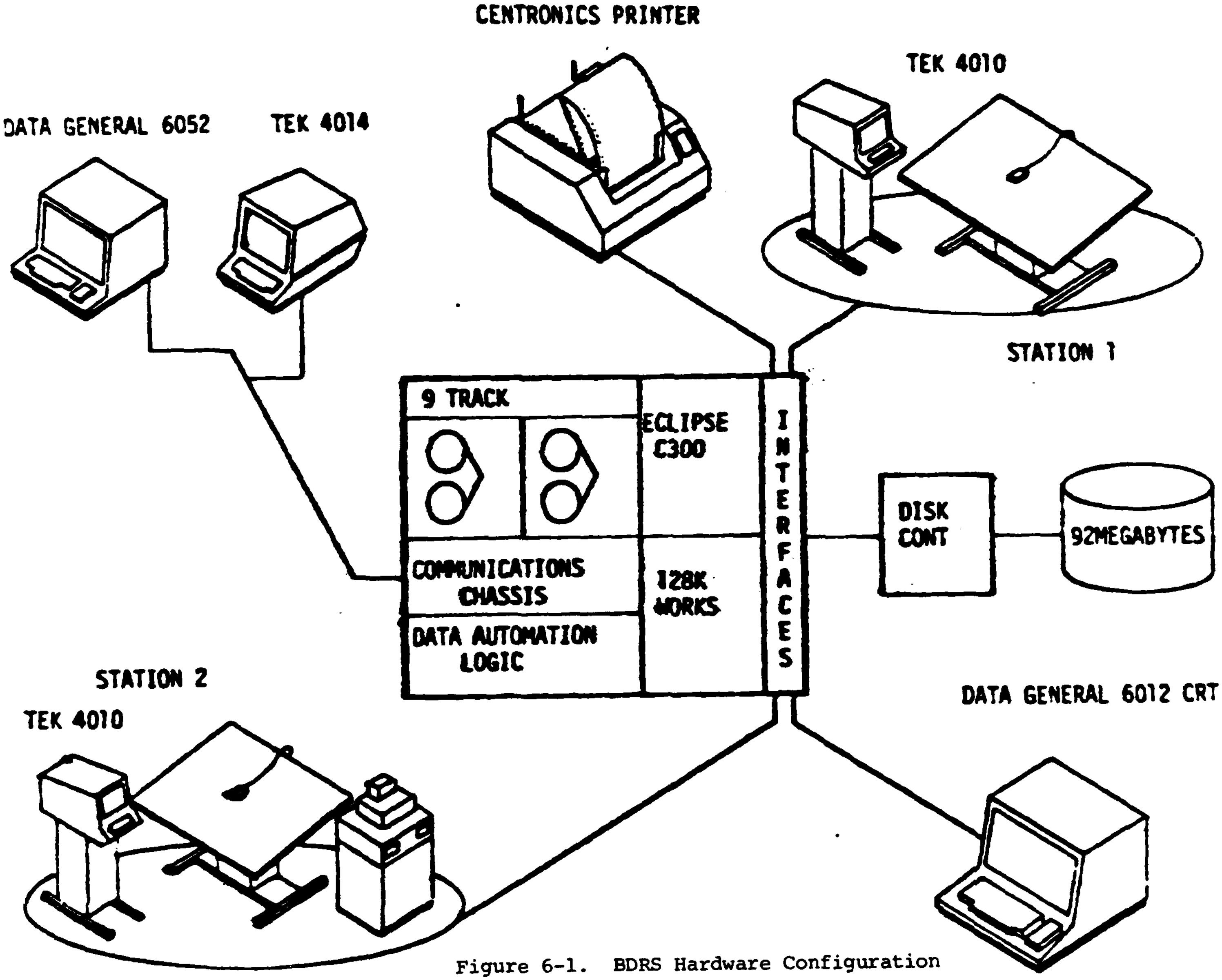


Figure 6-1. BDRS Hardware Configuration

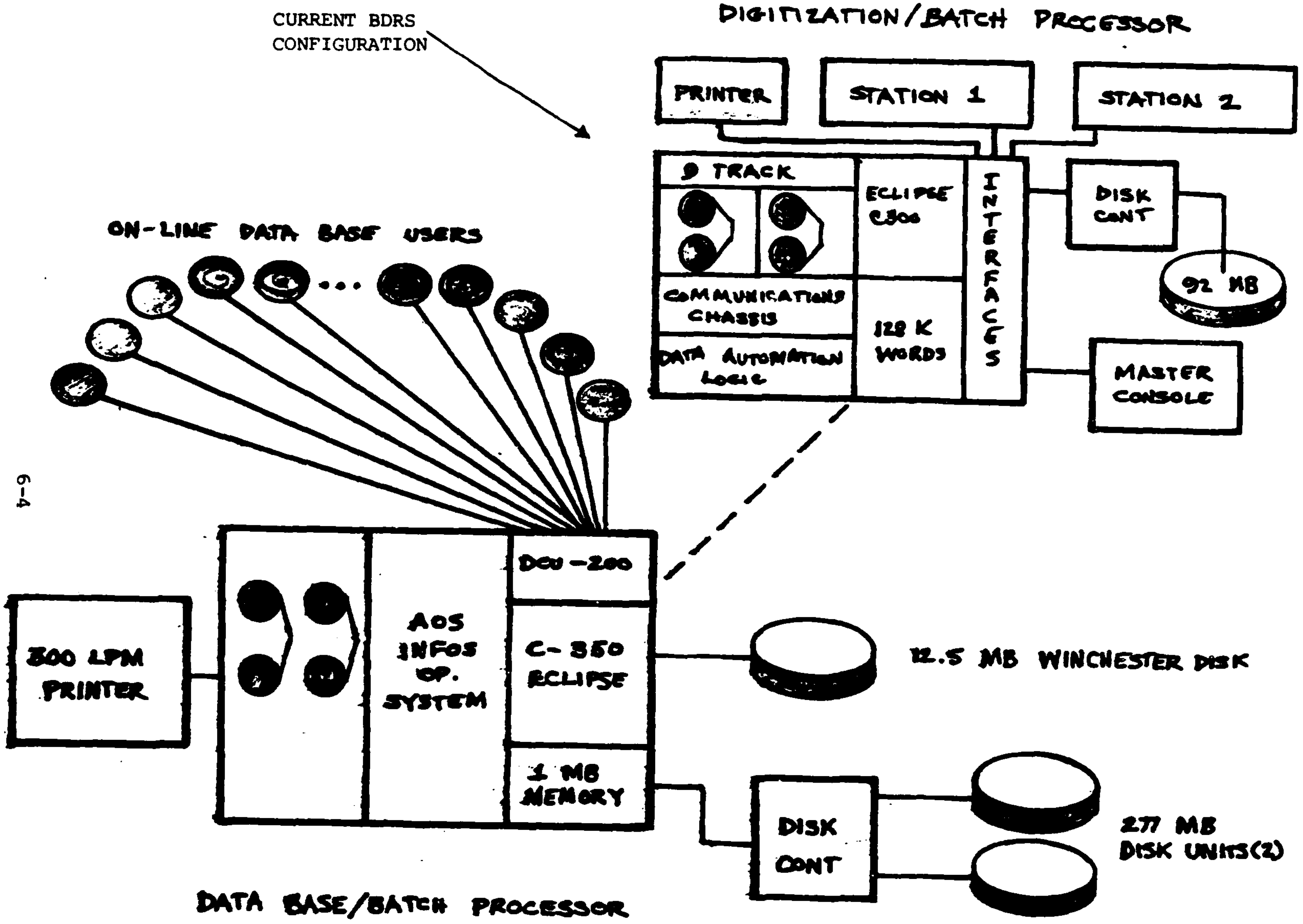


Figure 6-2. Enhanced BDRS Configuration

limits the ability of the system to be responsive in a timely and efficient manner to user processes.

A means of alleviating such restraints would be to, as illustrated in Figure 6-2, dedicate the 92 MB disk to the digitization and batch processes and, on a separate data base configuration, install dual 277 MB disks to provide dedicated storage to the BDRS data base. Additionally, a small, fast fixed-head disk could be used as a system disk, supporting only operating system and application software storage. The data base storage facility may be expanded to support four (4) 277 MB disks per controller, with a two controller, 8-pack configuration being maximum.

✓ Line Printer

The current BDRS Centronics Line Printer, which runs at a maximum rate of 100 LPM, would be inadequate in its support of a large, report-oriented data base system. At minimum, a 300 LPM printer should be dedicated to the data base process, with the current printer being relegated to the digitization/batch subsystem.

✓ Voice Input

Recent breakthroughs in hardware technology, relative to Voice Input, have lead to the development of a faster Voice Input device, capable of handling a much larger vocabulary. The current voice configuration is more than capable of supporting its intended role and could be field-upgraded with the new hardware for the purpose of further enhancing its applicability to DMAHTC as a viable data entry tool.

✓ Memory

Currently, there is an inadequate amount of memory (256 KB) to support more than two on-line data base users at a given time. Additional factors also contribute to this problem, primarily operating system limitations, and will be discussed later in the section. The availability of free or uncommitted memory, plays a major role in whether or not INFOS can be responsive, in a timely manner, to requests for data resident within the data base structure. The more free memory that can be made available to INFOS, the better your data base related response times will be. The reason for this is that INFOS makes an attempt to maintain in memory as much of the most frequently used data and index information as it can. If large amounts of free memory are available, INFOS will be required to perform far fewer disk accessed in attempting to satisfy a user request for data. Fewer disk accesses translates into quicker response times for the users.

The advanced configuration addresses this problem by specifying one million bytes of memory, or 4X the current configuration. This will, in conjunction with a more advanced operating system, benefit DMAHTC in two ways: 1) INFOS will have the free memory it needs to operate efficiently, and 2) there will be memory available to support the development of new applications or the addition of more on-line data base users.

✓ Hard-Copy Device

Currently, no "QUIK-LOOK" capability exists by which the user may obtain a hardcopy version of what he is currently viewing on the Graphic CRT. The inclusion of such a capability would eliminate the need to take the data through the complete "Proof Plot" process whenever a simple hardcopy is required. Such a device is available from Tektronix as a standard off-the-shelf item.

✓ Spare Parts

The issue of excessive "down-time" due to hardware failure is a critical one which must be addressed and dealt with by supervisory DMAHTC personnel. Currently, all hardware components of the BDRS are covered under maintenance contract with Synectics Corporation; who in turn has issued sub-contracts to the appropriate vendors for on-call maintenance of their components. Such a maintenance contract, whether it be with Synectics or directly with the hardware firms, should be considered "mandatory", if excessive down-times are to be avoided and the BDRS is to remain a viable responsive production support tool.

In addition, DMAHTC could maintain a selection of spare parts which have, over time, proven to be more susceptible to failure due to repeated use. Candidates for such a selection could be Data Automation's 5-button cursors and 16 key keyboards. With such spare parts on hand, failures would have no impact on what could be an emergency production schedule.

✓ Communications Controller

Data General Corporation's DCU-200 Communication Controller is capable of supporting a maximum of 256 remote synchronous/ asychronous communication lines. It is fully supported by DG's AOS operating system and communications handling software (CAM). Its basic function is to relieve the main processor of the burden of handling each and every interrupt created by a key strike at the remote terminal devices. It will, unless otherwise advised, accommodate data in its own internal buffers until the desired number of characters have been assembled. Once this is done, it will interrupt the main CPU and pass the data on. The benefits of such a capability are obvious when you consider the potential for user accesses.

6.3 SOFTWARE

The current BDRS system is comprised of two basic categories of software, operating system, and applications. The operating system (RDOS) was provided by Data General Corporation with the hardware, while the applications software was developed by Synectics Corporation during the 36 month development period. In the subsections that follow, sub-sets of each category which are felt to be limitations of the system, will be discussed relative to their respective roles in the current BDRS. Additionally, improvements to such sub-sets will be recommended that will, if implemented, greatly enhance the overall BDRS system.

6.3.1 Operating System (RDOS)

The present BDRS runs under the control of Data General's RDOS (MRDOS) Operating System. The RDOS architecture is based on a foreground/background approach to multi-processing which strictly limits the size of each process to the 32K word partition size. Such a limitation contributes to the current systems inability to support more than two (2) ON-line data base users from within a single ground (32K partition). Complex multi-tasking programming techniques must be used if a single ground is to be used to run more than one process. This technique was used successfully for both the digitization and on-line data base processes. Additionally, multi-tasking mandates the use of the RDOS overlay facility. This is done at the expense of user response times caused by added disk accesses or "thrashing", so as to minimize the per-task consumption of memory within the particular ground or 32K partition. The smaller each task, the more tasks that can be run concurrently from within a single ground. However, it becomes extremely difficult to continuously fragment complex code so that additional users may be supported from within a single ground. At some point, a practical maximum is reached, and Synectics is of the opinion that such a maximum, relative to the ON-line data base process, has been met at two (2). If an expanded BDRS ON-line data base capability is to be developed in the future, Synectics recommends a hardware configuration similar to the one illustrated in Figure 6-2, supported by an AOS type operating system.

AOS is a Data General developed operating system capable of supporting true multi-processing. It supports up to 2 MB of memory, which is 8X that of the current BDRS. Such expandability is critical to the viability and responsive growth of a data base capability such as the one currently implemented. AOS also eliminates the need to, using advanced programming techniques, "program-around" the limitations of the operating system relative to multi-processing. Under AOS control, multi-user processes are supported as a standard feature of the operating system.

6.3.2 Applications Software

Inasmuch as the BDRS has demonstrated its ability to support, in a functional sense, DMAHTC's bathymetric data reduction process, attention should be focused on ways of enhancing and refining its capabilities. Throughout the BDRS development period, it became increasingly obvious to all, that a number of application areas offered far greater potential for further exploitation/development than had been originally envisioned. It also became evident that other applications would require refinements if they were to be totally effective in supporting DMAHTC production objectives.

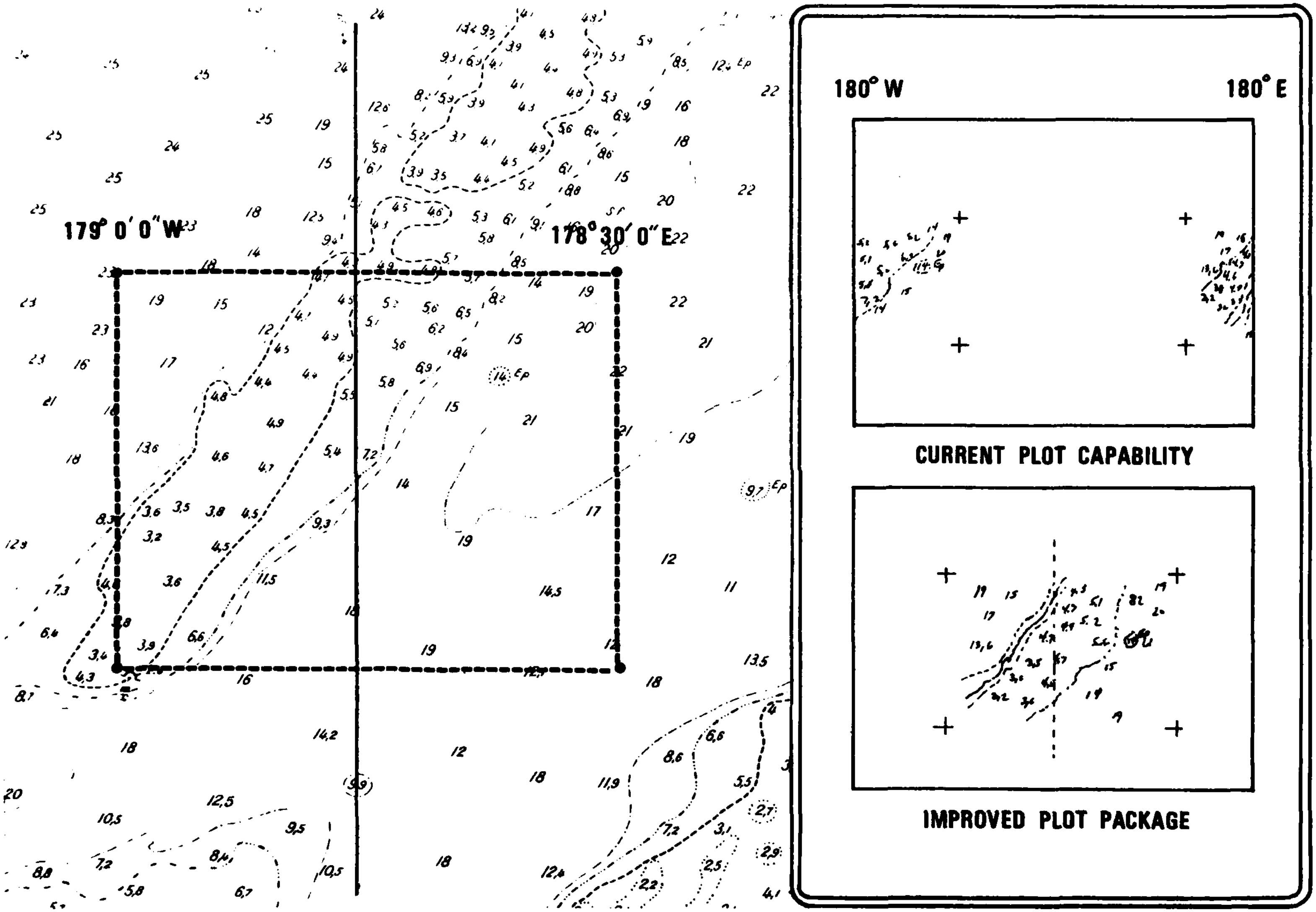
In the paragraphs that follow, a number of such applications will be identified and discussed with regard to their current and recommended capabilities.

✓ Plotting Capabilities

The current plot packages are able to plot data represented in BDRS X, Y table format. This limits its ability to plot geo-sectioned data crossing 180° of longitude. As illustrated in Figure 6-3, a geo-sectioned file crossing the international date line will not be plotted as a continuous chart. Instead, the data will be plotted at opposite ends, exactly as it would be found on an X,Y table.

During implementation this condition was never brought up as a capability. However, the plot packages could be upgraded to plot such cases representing data as it would be viewed on the surface of the earth. To do this it would be necessary to check for the condition in the conversion from geographics to table coordinates, and make appropriate adjustments. This enhancement would reduce the size and present a more meaningful plot of the data.

In addition, the current plot routines, except GEBCO TRACK LINE, do not label the geographic bounds of the plot. Plotting the



INTERNATIONAL DATELINE PLOTS

Figure 6-3

geographic bounds and intervals would be a useful enhancement providing the user with a quick method of geographically referencing the data.

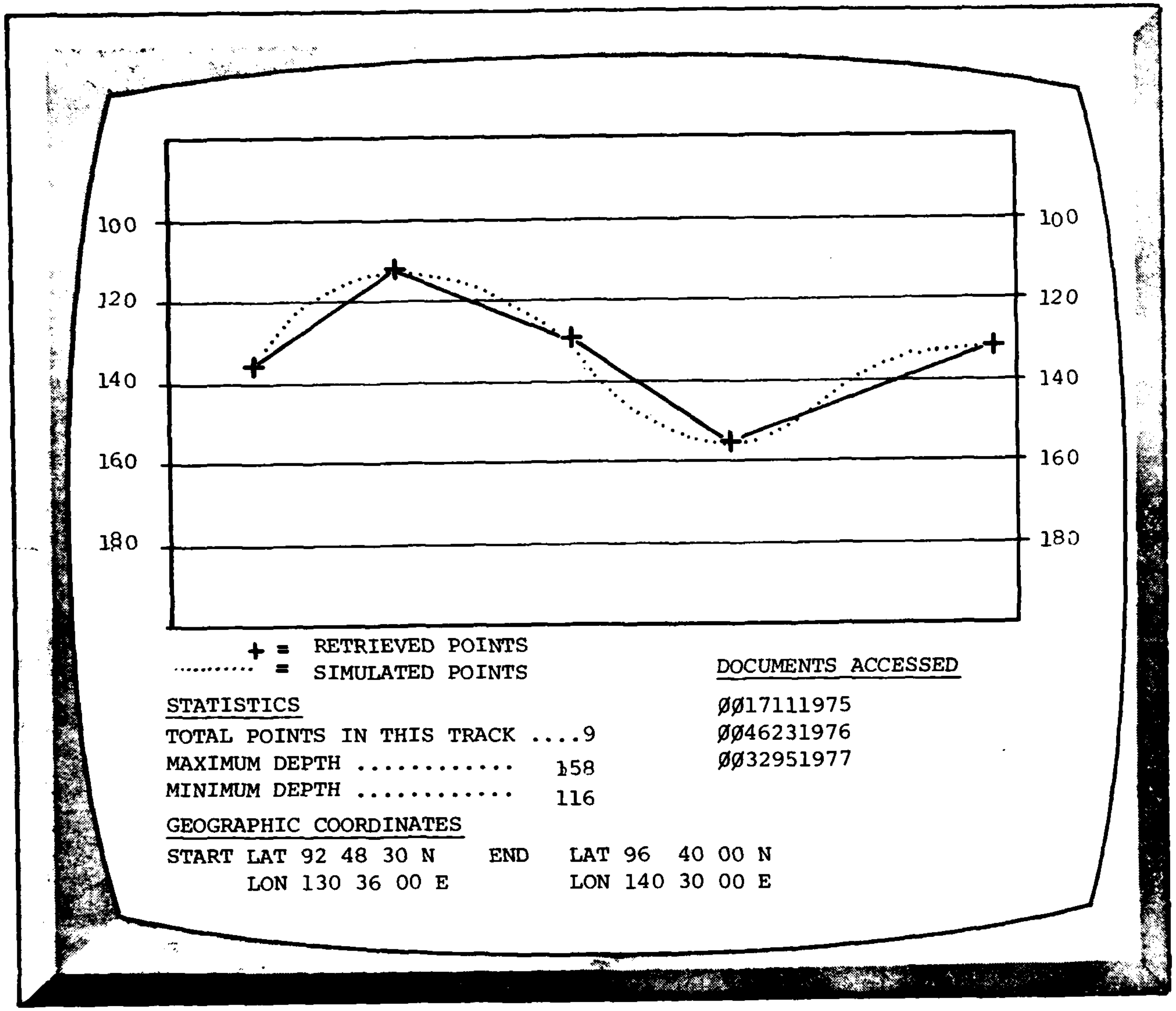
✓ Geographic Retrievals

On-line retrievals provide expedient accessing of geographic data within the data base. However, due to core restrictions relative to internal buffer sizes, this process is limited by the size of the geographic area that can be retrieved and displayed. The maximum area allowed is one that will cover no more than 150 mapping grid cells. This corresponds to an area that is eight degrees of latitude by twelve degrees of longitude. If an area larger than this is retrieved only that data covering the above mentioned area will be displayed. This restriction, however, does not exist for the batch geographic sectioning routines which has far more core available to it for buffering. This condition should be upgraded to allow the retrievals to cover any geographic area.

Additional improvements should be made to further exploit the data base. Currently the BDRS is only capable of displaying the data as described by the plot packages and the graphics CRT. This allows the data to be viewed as one dimension. Some additional capabilities that could be added using BDRS geographic data are cross sectional displays of the data base, bottom contour plots and simulation of a three dimensional model of the ocean floor.

A cross sectional retrieval and display, in theory, would allow the user to enter two geographic points and produce a single track of data. This track could then be displayed as a cross section of the ocean floor. Once the points are plotted, a curve fitting algorithm could be used to simulate additional depths. Figure 6-4 illustrates a sample cross sectional display. This capability would, in effect, simulate a fathogram from the data base.

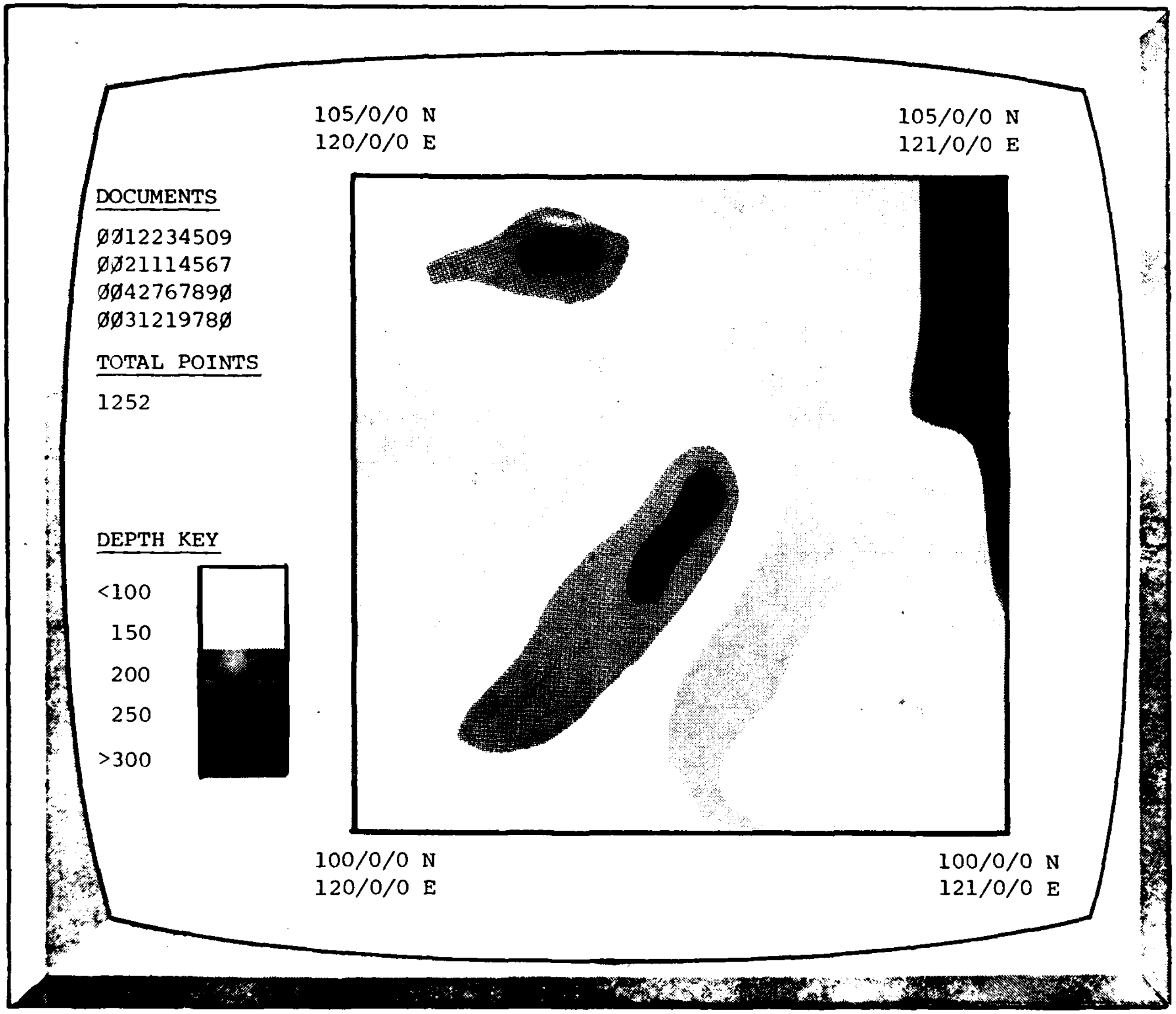
Bottom contour charts could also be produced using the current BDRS geographic formats. Averaging techniques could be employed to produce a display as shown in Figure 6-5. Depths within a user defined range would be grouped together to form a bottom contour and displayed as such. This could be implemented on the Tektronix Graphic CRT using various shading patterns to represent the different depth values. Although shading patterns represent one way of representing bottom contours, another option would be to upgrade the system using a color graphics CRT. Such a capability could be made to allow the user to define what colors would represent particular depth values. Additional options could control the depth ranges to make the bottom contouring



```
  + =  RETRIEVED POINTS
 ..... =  SIMULATED POINTS                    DOCUMENTS ACCESSED
STATISTICS                                    0017111975
TOTAL POINTS IN THIS TRACK ....9              0046231976
MAXIMUM DEPTH ............    158             0032951977
MINIMUM DEPTH ............    116
GEOGRAPHIC COORDINATES
START LAT 92 48 30 N    END   LAT 96  40 00 N
      LON 130 36 00 E         LON 140 30 00 E
```

CROSS SECTIONAL DISPLAY

Figure 6-4



BOTTOM CONTOUR DISPLAY

Figure 6-5

as fine as desired. For example, a rough contour would include depths of 100 to 200 feet. The user may wish to break this down into contours of 100 to 150, and 150 to 200 feet. This would enable high and low points to be flagged within the area.

BDRS geographic files could also be used to simulate a model of the ocean floor (Figure 6-6). The location of a depth would be calculated in relation to a grid, and a depth value would be stored for a particular grid cell. The depths stored for the grid would then be used to calculate additional depths filling in the remaining grid cells. The depths from the grid would then be converted to X,Y locations on a CRT display, creating a model of the ocean floor. Further development could provide capabilities to rotate, and scale the model, as well as offering isometric, dimetric and perspective views of the area.

✓ Fathogram Processing

Although Fathogram Processing is presently an efficient capability, a few limitations exist that could, without too much effort, be eliminated.

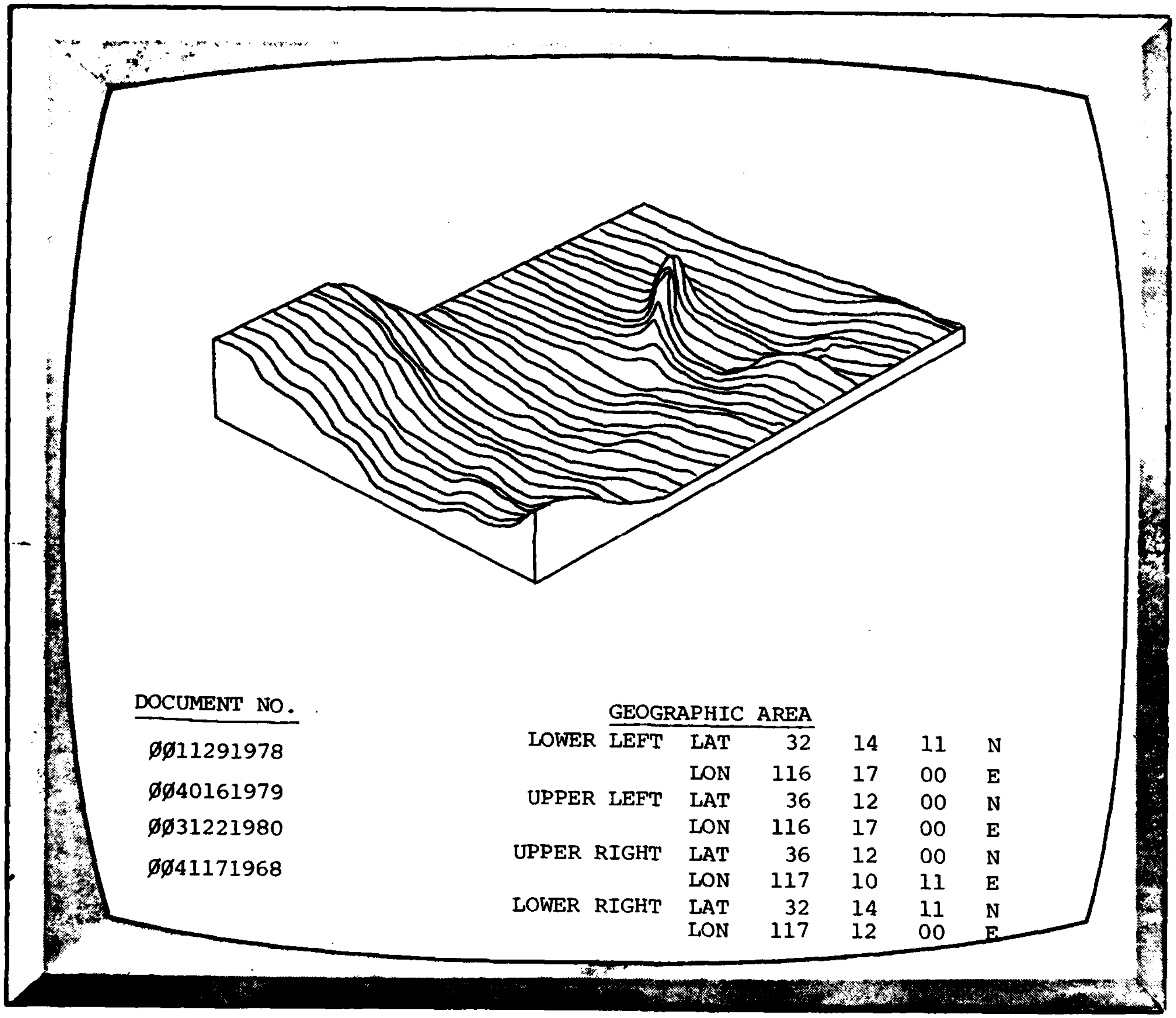
At the moment, every time the paper speed changes, a new file with the same document number but a different sheet number must be created. This has no effect on the actual fathogram processing. It does, however, hamper the digitizing process since it becomes necessary to stop digitizing, close the current file, and create a new one. If this doesn't have to be repeated often, no drawback really exists. But, if the paper speed changes are frequent, this method becomes cumbersome.

A suggested solution to this problem is to incorporate paper speed change data into fathogram file change records during the digitization process. This would eliminate the need to create new files and thus make fathogram digitization a smoother process.

The other limitation that presently exists is the incapability to calculate geographic positions when the ship's track crosses the equator. It is now necessary to produce two files. One, containing track segments above the equator, and the other containing track below. A simple addition can be made, however, to obtain this capability.

✓ Geographic to Table Conversion

The geographic to table conversion, as it presently exists, produces an extremely accurate and useful table file. However,



DOCUMENT NO.

0011291978

0040161979

0031221980

0041171968

GEOGRAPHIC AREA

LOWER LEFT	LAT	32	14	11	N
	LON	116	17	00	E
UPPER LEFT	LAT	36	12	00	N
	LON	116	17	00	E
UPPER RIGHT	LAT	36	12	00	N
	LON	117	10	11	E
LOWER RIGHT	LAT	32	14	11	N
	LON	117	12	00	E

PROFILE DISPLAY

Figure 6-6

it is limited in one respect. It cannot be immediately edited. Only original table files, not table files produced from a geographic file conversion, can be edited. Adding this one capability would greatly enhance the geographic to table conversion. In principle, this is possible to implement by employing a day 'n' registration on the resultant table file.

This can be seen as follows. When the file is converted, the registration points of the file are also converted. The resultant file has been day 1 registered in the sense that a perfect fit is obtained with least square best fit coefficients of ϕ. This means that any table point in the file need only be scaled to earth scale meters followed by a translation from the chart earth scale meter lower left hand corner to a true origin to obtain the true earth scale meter value of the table point. The plotted chart, when placed on the table, is registered as a day 'n' registration of the perfect fit file. Therefore, given that a set of registration points are in the geographic file, an arbitrary geographic file can be brought to table, edited, and reconverted to geographic form.

The mathematical simulation of this is as follows. Suppose (ϕ,λ) are the latitude and longitude of an arbitrary coordinate in the geographic file. Let X_L,Y_L be the map scale meter value of the lower left hand corner of the chart. Let X_λ, Y_ϕ be the map scale meter value of the coordinate (ϕ,λ). The table X,Y of the point is

(1) $X = [(X_\lambda - X_L) + 3 \text{ inches}]$. conversion to mils

(2) $Y = [(Y_\phi - Y_L) + 3 \text{ inches}]$. conversion to mils

Let X_n,Y_n be the map point X,Y (ϕ,λ) when the map is placed on the table which is produced by a plot of the table file. Then registration will map X_nY_n to X,Y and X_λ,Y_ϕ need only be calculated from equations 1 and 2 to give the map scale meter values of (ϕ,λ). When scaled to earth scale meters by multiplying by the map scale, the earth scale meter value is obtained for (ϕ,λ).

6.4 FILE MAINTENANCE

An efficient, accurate, and meaningful method of maintaining files is of utmost importance if the full capability of BDRS is to be realized. In a very short time a large number of files can be created and, unless they are properly maintained, total confusion will occur. An organized system must be designed to keep track of the files' contents, creators, dates of creation, etc. Also, a magnetic tape backup of all files should be produced on a regular basis. Although it is up to the user to develop a file maintenance system inherent to his/her own needs, some suggestions on how this necessary task can be accomplished follow.

Much information about the file can be stated in the filename (Job ID) created when a file is digitized. For example, the eight character filename can be used to designate when the file was created, by whom, and what it contains. Four characters can be used to store the date the file was digitized (two for the month, two for the year). Two other characters can be the user's initials or special ID. The last two characters can represent a code indicating certain characteristics of, or source of the file's contents. An example filename would appear as "0180PB24", where 01 represents the month, 80 represents the year, PB is the user's initials, and 24 is a file content or source code. A written log should also be maintained daily in which any new "Job ID" and its description is recorded.

The importance of making sure that all files are saved on backup tape must be stressed. A good rule to follow is to save each day's work to tape. Also, on the first of every month a backup tape of the last month's work could be produced. If the above mentioned filenaming convention is used, dumping the month's files to tape would be an easy process. For example, one simple command to dump to tape all files with 0180 in them would save all table files including the data, header, index, and fathogram files created during the entire month of January 1980. Possibly, after saving the month's table files to tape, they could then be deleted leaving plenty of room on the disk for new files to be created.

Another important aspect of file maintenance is to keep track of what happens to a table file once it is created. The line printer summary sheets of each BDRS run should be kept together in an orderly manner for each "Job ID". This way, no matter what BDRS function the file is processed through, a complete record of its history is available on the summary print outs.

The above suggestions are just a few ways in which file maintenance can be accomplished. The user can devise his/her own system if desired. However, the importance of a standard file maintenance system from the inception of BDRS is imperative for success.

APPENDIX A
GLOSSARY

GLOSSARY

AUXILIARY FUNCTIONS -- These functions allow the user to enter or change digitizing parameters. To display these functions, the user must be digitizing and be in "Master Mode." Keying in an "A(CR)" at the console will display the auxiliary functions.

BACKGROUND TERMINAL FOR BDRS -- The main console from which all BDRS functions are initiated.

BASE ELEVATION -- The starting elevation when digitizing a bottom contour. The user will be asked to enter the value if "Bottom Contour" was selected during header selection. User may alter this elevation in Master Mode by hitting "I(CR)" or "D(CR)" which will increment or decrement the elevation respectively by the contour interval. The elevation can also be changed using Auxiliary Functions.

BASE LATITUDE -- The latitude where the chart or map is most accurate.

BOTTOM LATITUDE -- The bottom (lowest) latitude of the area being digitized.

CENTRAL MERIDIAN -- The center or mid longitude value of the area being digitized.

CHART LEFT LONGITUDE -- The left longitude of the map or chart being used.

CHART/MAP SCALE -- The ratio between the linear dimensions of a map or chart and the actual dimensions represented.

CLASS MASK -- The first two numbers of the feature class codes. It is used during the digitizing function.

COMMENT BLOCK -- A 64-word block used to store ASCII characters input by the user in the Master Mode Auxiliary Functions. These characters can be made up of any remarks the user wishes to input.

CONTOUR INTERVAL -- Used when digitizing bottom contours. The user is asked to input this value if "Bottom Contour" was chosen during header selection. The current elevation can be incremented or decremented by this value. The user can change this value by entering "Auxiliary Functions".

CORRECTED DEPTH -- An echo sounding depth value that has been adjusted according to the salinity, density, and temperature of the water.

COURSE TOLERANCE -- During fathogram processing, the maximum acceptable difference in degrees between the given course and the computed adjusted course.

DATA BLOCK -- A 64-word block used to store feature data. In table data files these blocks consist of X, Y or X,Y, depth points. In geographic file data blocks, the data is stored in lat, lon or lat, lon, depth values.

DATA FILE -- (DF "jobid") -- A table file comprised of feature data sets. These sets consist of a feature header block and its corresponding data blocks. Each block is 64 words long. In the data blocks, data is stored in X, Y coordinates and X, Y, depth coordinates. It is located in DP0.

DATUM SHIFT CONSTANTS - X, Y, and Z offsets of the ellipsoid center for a particular geographic area.

DIRECTORY -- A path within a total disk organization leading to a specified set of programs. BDRS consists of a master directory, DP0, and three other directories - DBASE, BATCH, and TABLE.

DISCRETE POINTS -- A single digitized point with no sounding value.

EASTING -- Used when registering a UTM chart for digitization. The value can be found on the chart.

ELLIPSOID (SPHEROID) CODE -- A number indicating to which ellipsoid model the geographic data is referenced.

FATHOGRAM FILE (FF "jobid") -- A file created when a fathogram is digitized. It contains information about the depth scale and time scale of the fathogram.

FEATURE -- A group of related digital data.

FEATURE INDEX BLOCK -- A 64-word block containing pointer, window, and mask information about some feature.

FOREGROUND TERMINAL FOR BDRS -- The secondary console for use of BDRS functions. This terminal can only be used by initiation from the background.

GEOGRAPHIC BOUNDS -- The user specified geographic area beginning with the lower left lat/lon and preceding in a clockwise direction.

GEOGRAPHIC FILE (GO "jobid") -- A file in which data is stored in lat/lon values. The BDRS standard geographic file is comprised of records that are 64 words long. Records number one through four contain parameter block one and two, registration block, and comment block. The subsequent records are comprised of feature sets. Each set contains a geographic header followed by its corresponding data blocks. It is located in DP0.

GEO-SECTIONED FILE -- A file that has been created by retrieving data from the data base within a specified geographic area.

HEADER (FEATURE HEADER) -- A 64 word block found at the beginning of a feature data set containing parameters describing the specific feature.

HEADER FILE (HF "jobid") -- A table file created when digitization occurs. It consists of headers chosen by the operator from the Bathymetric Master Library of headers on disk for inclusion into the job's working header set during Header Select Mode. It is located in DP0.

INDEX FILE (IF "jobid") -- A multipurpose table file containing the following 64 word blocks: parameter one and two, registration, comment, and feature index. It is located in DP0.

INPUT FILENAME -- In any BDRS function, the name of an existing file on which some operation will be performed. (one to eight characters).

INTERMEDIATE PLOT FILE -- A disk resident plot file containing the correctly formatted data needed by the "PLOTDR" function to produce a Xynectic or Calcomp compatible magnetic tape plot file. All intermediate plot files are stored in directory Batch and are named "PLOTXX." The "XX" represents the 2 character extension input by the user at the time the intermediate plot file is created.

JOB I.D. -- A one to eight character name identifying a table file. This name can be made up of characters, numbers, or both.

LEFT LONGITUDE -- The left most longitude of the area being digitized.

LOGICAL DELETION -- An option within the Data Base Batch function. This allows a user to mark a specific document or a specific sheet of the document for deletion. Once the document is marked, it can be physically deleted using Master Mode in Data Base. If marked for a total or a partial deletion, the document cannot be retrieved geographically or by the document number.

LOGICAL RETRIEVAL-- An option in the Data Base Batch function. This option allows a user to retrieve data geographically according to specified parameters. Data may be retrieved by the shipname, the evaluation code or by the date.

MAP PROJECTION -- A representation or method of representing all or part of the surface of a sphere or spheroid, such as the earth, upon a plane surface.

MATHEWS TABLE AREA -- An area of the world numbered 1-52. For each specific area, Mathews Table contains sounding correction values based on salinity, water density, and temperature.

NORTHING -- A value found on a UTM chart that is used during the registration process.

OCTAL DUMP -- The contents of the records in a file given in octal numbers.

OPERATOR ID -- The user's assigned ID or his/her name. It indicates the person exercising the Data Base Batch fucntions.

OUTPUT FILENAME -- The name of the file to be created by some BDRS function. (one to eight characters).

PARAMETER BLOCKS -- 64-word blocks used to record and store the status and control information for a job.

PLATFORM NAME -- A one to twenty-seven character shipname.

PLOT FILE EXTENSION -- A 2 character addition to an intermediate plot filename. When an intermediate plot file is created, its filename is "PLOTXX", where "XX" is the plot file extension.

QUADRANT CODE -- A number from 1-4 indicating a specific quadrant of the earth's surface. (1 = NE, 2 = NW, 3 = SW, 4 = SE).

RECORDING RESOLUTION -- In trace data, the distance in mils to the next point that will be recorded.

REGISTRATION -- Corresponding a latitude and longitude value with table X and Y coordinates. Registration takes a minimum of two points and a maximum of eight.

REGISTRATION BLOCK -- A 64 word block containing the X, Y registration points and their corresponding lat, lon values.

REQUESTOR ID -- The assigned ID of the individual desiring specific use of the data base. This ID has to be valid and located in the data base or the request will be rejected.

RESIDUALS -- The distance between the original registration points and the new re-registered points in mils.

RIGHT LONGITUDE -- The right longitude of the area being digitized.

SEARCH TOLERANCE -- Used to locate a feature during Edit Mode. When using trace data edit, the search tolerance is used in joining candidate features to edit segments.

SHEET NUMBER -- A four character code used to identify a specific sheet of a document.

SHIP'S LOG FILE -- A specially formatted file containing ship's navigational log data (time, course, speed, latitude, longitude) used for fathogram processing. It is located in directory Batch. A ship's log file must be created for every fathogram that is processed.

SOUNDING COMPARISON PERCENTAGE RANGE -- In BDRS Depth Adjustment function, the plus/minus percentage range used to compare a sounding to the average sounding for that particular geographic area stored in the data base.

SOURCE DESCRIPTION RECORD -- A 252 word BDRS record identified by the source ID. This record contains specific information concerning the data associated with it. It contains such things as the document number, shipname, the date, and other specific information on the data.

SOURCE ID -- A twenty character code that identifies the source description record. This code must be exactly twenty characters.

SPEED TOLERANCE -- During fathogram processing, the maximum acceptable difference in knots between the given speed and the computed adjusted speed.

STANDARD PARALLEL -- A parallel on a map projection along which the scale is as stated.

TABLE FILE -- A file in which data is stored in X, Y coordinates. The BDRS standard table file consists of four distinct disk resident files, each unique to the job name: header file, index file, data file, and fathogram file (when a fathogram is digitized). It is located in DP0.

TO DATE -- The date associated with the data and stored in the source description records. Data can be retrieved from the data base using this date.

TOP LATITUDE -- The top Northernmost latitude of the area being digitized.

TRACE DATA -- A series of digitized points that form a continuous line.

UNCORRECTED DEPTH -- An echo sounding depth value that has not been adjusted according to the salinity, density, and temperature of the water.

UTM ZONE NUMBER -- A number from 1 to 60 representing a specific Universal Transverse Mercator Zone. Beginning at the 180th meridian, 6° columns are numbered 1 through 60 eastward.

ZULU TIME -- Greenwich mean time. (the zone time at the Greenwich (0°) meridian).

APPENDIX B
BDRS FUNCTIONAL SOFTWARE LOADLINES

VBDRS LOAD LINE

```
FILENAME:  D.LD                              PURPOSE:  TO RUN 2 TABLES IN THE FOREGROUND
DIRECTOR:  TABLE
TO LOAD: @ D.LD @ (CR)                       SYSTEM:  BDRSSYS1
TO EXECUTE:  EXFG DIGITIZE

RLDR 3/K 20/C DIGITIZE S2EXEC[RAMR1 PARS1 RPRS1 PACK1 MCTR MILLER POLPRO LAMBERT, RAMR2 COEF2
MAKEX MAKEY SOLVX SOLVY OLDX OFFX NEWX ONX OLDY OFFY NEWY ONY REGCHK
ERROR RPRS2 PACK2 RNTRUN,
VINIZ VOLD VDOCSR DCOD1, VNEW PARSE DCOD2, TT500 VTIO VINIT
DCOD3, VHDRSL DCOD4, VHDRM JOBCL DCOD8, VPTMOD VPTBND, VDEPTH VUPBND DSPLD,
FENTRY VFPARM VFCHANGE VRPRS2 VFPS1 VFPACK2,
VTRACE PLTVT, VREVIEW PLTVR DSPLR DATAIN CHANGE VRCHARSZ,
VCGDSY VCGSRT VCGRM VOFETDEL,
VEDPY1 VSCHFT V1SRTVEC VTOLCHK VILNGVEC VIPLUS VIRCDSP VIDRTDSP VIPLTVE
V1SNDSPL V1DSPLE VDSPHDR,
VDPEDIT V2SNDSPL V2DSPLE V2PLTVE VSFLREC VTTI5 V2FETDEL VSPEND
V2EWFIB VCHARSZ BDOT V2EDTTYP,
VDRTEDT V3DRTDSP V3PLTVE V3PLUS VCROSS VDFLRED VAPPND V3FETDEL
V3EWFIB VSQUARE V3EDTTYP,
VTRC1 VTRCSTR V4SRTVEC V4LNGVEC V4PLTVE V4PLUS V4CANFL V4ESGFL,
VTRC2 V5CANFL V5ESGFL VSEGCHK VBLDTAB V5PLTVE V5EWFIB V5PLUS V5FETDEL]
S1EXEC[KRAM1 KPRS1 KRPR1 KPCK1 MCTR1 KMILLER KPOLPRO KLAMBERT, KRAM2 KCOF2
KMAKX KMAKY KSLVX KSLVY KOLDX KOFFX KNEWX KONX KOLDY KOFFY KNEWY
KONY KRGCK KERROR KRPR2 KPCK2 KRNTRN,
INIZ OLDJ KDOCSR KCOD5, NEWJ PARS DCOD6, HDRSL DCOD7,
HDRM ZJOBC DCOD9, PTMOD KPTBND, DDEPTH KUPBND DSPXD, TRACE PLTXT,
KENTRY KFPARM KFCHANGE KRPRS2 KFPS1 KFPACK2,
REVIEW PLTXR DSPXR DATXIN CHANXE KRCHARSZ ,
KCGDSY KCGSRT KCGRM KOFETDEL,
KEDPY1 KSCHFT K1SRTVEC KTOLCHK K1LNGVEC K1PLUS KTRCDSP K1DRTDSP K1PLTVE
KISNDSPL K1DSPLE KDSPHDR,
KDPEDIT K2SNDSP1 K2DSPLE K2PLTVE kSFLREC KK16 K2FETDEL KSPEND
K2EWFIB KCHARSZ KDOT K2EDTTYP,
KDRTEDT K3DRTDSP K3PLTVE K3PLUS KCROSS KDFLREC KAPPND K#FETDEL
K3EWFIB KSQUARE K3EDTTYP,
KTRC1 KTRCSTR K4SRTVEC K4LNGVEC K4PLTVE K4PLUS K4CANFL K4ESGFL,
KTRC2 K5CANFL K5ESGFL KSEGCHK KBLDTAB K5PLTVE K5EWFIB K5PLUS K5FETDEL]
VFIB ZFLOAT NCONV CRT2 TAB2 VADJM VDRVR
KFIB KCONV KFLOAT CRT1 TAB1 KADJM LONGTRACE F5TASK LB @MFLIB@
```

BDRS LOAD LINE

FILENAME: K.LD

DIRECTORY: TABLE

TO LOAD: @K.LD @(CR)

TO EXECUTE: EXFG BDRS (CR)

PURPOSE: TO RUN 1 TABLE IN THE FOREGROUND USING TABLE 1.

SYSTEM: BDRSSYS2

```
RLDR 2/K 20/C BDRS DEXEC[KRAM1 KPRS1 KRPR1 KPCK1 MCTR1 KMILLER KPOLPRO KLAMBERT,
KRAM2 KCOF2 KMAKX KMAKY KSLVX KSLVY KOLDX KOFFX KNEWX KONX KOLDY KOFFY KNEWY
KONY KRGCK KERROR KRPR2 KPCK2 KRNTRN,
INIZ OLDJ KDOCSR DCOD5, NEWJ PARS DCOD6, HDRSL DCOD7,
HDRM ZJOBC DCOD9,
PTMOD KPTBND, DDEPTH KUPBND DSPXD, TRACE PLTXT,
KENTRY KFPARM KFCHANGE KRPRS2 KFPS1 KFPACK2,
REVIEW PLTXR DSPXR DATXIN CHANXE KRCHARSZ
,KCGDSY KCGSRT KCGRM KOFETDEL,
KEDPY1 KSCHFT K1SRTVEC KTOLCHK K1LNGVEC K1PLUS KTRCDSP K1DRTDSP K1PLTVE
K1SNDSPL K1DSPLE KDSPHDR,
KDPEDIT K2SNDSPL K2DSPLE K2PLTVE KSFLREC KK16 K2FETDEL DSPEND
K2EWFIB KCHARSZ KDOT K2EDTTYP,
KDRTEDT K3DRTDSP K3PLTVE K3PLUS KCROSS KDFLREC KAPPND K3FETDEL
K3EWFIB KSQUARF K3EDTTYP,
KTRC1 KTRCSTR K4SRTVEC K4LNGVEC K4PLTVE K4PLUS K4CANFL K4ESGFL,
KTRC2 K5CANFL K5ESGFL KSETCHK KBLDTAB K5PLTVE K5EWFIB K5PLUS K5FETDEL]
PDUMP KFIB KCONV KFLOAT CRT1 TAB1 KADJM LONGTRACE F5TASK LB @MFLIB@
```

BDRS BATCH "PROOF PLOT"

FILENAME: PRFPLT
LOCATION: batch
PURPOSE: TO PREPARE A FILE FOR INPUT TO PLOTDR
INPUT REQUIRED: BDRS STANDARD TABLE FILE (DISK)
OUTPUT: INTERMEDIATE PLOT FILE (DISK)
TO EXECUTE: PRFPLT (CR)

LOAD LINE FILENAME: PRFPLT.LD
LOCATION: BATCH
TO EXECUTE LOAD: @ PRFPLT.LD @ (CR)
LOAD LINE CONTENTS: RLDR PRFPLT DRUNPK DPUNPK SDUNPK BLDPLT ANGL NCONV @MFLIB@

BDRS BATCH "PLOT DRIVER"

FILENAME: PLOTDR

LOCATION: BATCH

PURPOSE: TO GENERATE A TAPE CAPABILE OF BEING RUN ON EITHER THE XYNETICS OR CALCOMP PLOTTERS.

INPUT REQUIRED: INTERMEDIATE PLOT FILE CREATED BY PRFPLT, PHILLIPS, ECHPLT, OR GEBTPK

OUTPUT: MAG TAPE FILE

TO EXECUTE: PLOTDR (CR)

LOAD LINE FILENAME: PLOTDR.LD

LOCATION: BATCH

TO EXECUTE LOAD: @PLOTDR.LD @(CR)

LOAD LINE CONTENT:

```
RLDR/V/L PLOTDR [PLOTS PLOT SYMBOL NUMBER NEWPEN
WHERE BUFF WRTAP
REST WD2B, CCPLOTS CCPLOT CCSYMBOL CCNUMBER CCNEWPEN
CCWHERE CCBUFF
CCSYMTB ] LONGTRACE @MFLIB@
```

BDRS BATCH "PHILLIPS" TRACK PLOT

FILENAME: PHILLIPS

LOCATION: BATCH

PURPOSE: TO FORMAT AN INTERMEDIATE PLOT FILE ACCORDING TO "PHILLIPS TRACK" REQUIREMENTS SO THAT IT MAY BE USED AS INPUT TO PLOTDR.

INPUT REQUIRED: BDRS TABLE FILE

OUTPUT: INTERMEDIATE PLOT FILE TO BE INPUT TO PLOTDR.

TO EXECUTE: PHILLIPS (CR)

LOAD LINE FILENAME: PHILLIPS.LD

LOCATION: BATCH

TO EXECUTE LOAD: @PHILLIPS.LD@(CR)

LOAD LINE CONTENT: RLDR PHILLIPS TRKDEP HEADG BLDPLT NCONV @MFLIB@

*To be further developed and tested when DMAHTC develops the specific requirements

BDRS BATCH "ECHOGRAM" PLOT

FILENAME: ECHPLT

LOCATION: BATCH

PURPOSE: TO PREPARE A FATHOGRAM FILE FOR PLOTTING.

INPUT REQUIRED: BDRS FATHOGRAM TABLE FILE.

OUTPUT: INTERMEDIATE PLOT FILE.

TO EXECUTE: ECHPLT (CR).

LOAD LINE FILENAME: ECHPLT.LD

LOCATION: BATCH

TO EXECUTE LOAD: @ECHPLT.LD@

LOAD LINE CONTENT: RLDR ECHPLT BLDPLT DRUNPK NCONY LONGTRACE @MFLIB@

BDRS BATCH "GEBCO TRACK LINE PLOT"

FILENAME: GEBTRK

LOCATION: BATCH

PURPOSE: TO PREPARE AN INTERMEDIATE PLOT FILE ACCORDING TO "GEBCO TRACK LINE" REQUIREMENTS SO THAT IT MAY BE USED AS INPUT TO PLOTDR.

INPUT REQUIRED: BDRS TABLE FILE THAT HAS BEEN CREATED BY A BDRS GEO TO TABLE CONVERSION.

OUTPUT: INTERMEDIATE PLOT FILE TO BE INPUT TO PLOTDR.

TO EXECUTE: GEBTRK (CR)

LOAD LINE FILENAME: GEBTRK.LD

LOCATION: BATCH

TO EXECUTE LOAD: @GEBTRK.LD @(CR)

LOAD LINE CONTENT: RLDR GEBTRK PLTKMK PLTDL PLTDOCN GETINPUT GTPRS1 PLOTDEG GTPACK1 ABORTGT GTREPORT GTUNPACK GFLOAT GDFREAD GTGETXY GTMILLER GTMINM BLDPLT NCONY CONV01 LONGTRACE @MFLIB@

BDRS BATCH "MODIFIED GEBCO"

FILENAME: MODGEB

LOCATION: BATCH

PURPOSE: TO CORRECT/UNCORRECT AND/OR CHANGE THE UNITS OF MEASURE FOR SOUNDING DEPTHS CONTAINED IN A BDRS TABLE FILE.

INPUT REQUIRED: BDRS STANDARD TABLE FILE CONTAINING SOUNDING VALUES.

OUTPUT: BDRS STANDARD TABLE FILE (WITH MODIFIED SOUNDINGS).

TO EXECUTE: MODGEB (CR)

LOAD LINE FILENAME: MODGEB.LD

LOCATION: BATCH

TO EXECUTE LOAD: @MODGEB.LD @(CR)

LOAD LINE CONTENTS: RLDR MODGEB CRINF CORR LONGTRACE @UFLIB@

BDRS BATCH "FATHOGRAM PROCESSING"

FILENAME: FATHOGRAM

LOCATION: BATCH

PURPOSE: TO PREPARE A GEOGRAPHIC FILE CONTAINING LAT/LONG AND DEPTH POINTS AT ANY DELTA TIME INTERVAL ALONG A SHIP'S TRACK USING THE SHIP'S NAVIGATIONAL LOG AND CORRESPONDING FATHOGRAM.

INPUT REQUIRED: BDRS STANDARD FATHOGRAM TABLE FILE AND A SHIP'S LOG FILE.

OUTPUT: BDRS STANDARD GEOGRAPHIC FILE.

TO EXECUTE: FATHOGRAM (CR).

LOAD LINE FILENAME: FATHOGRAM.LD

LOCATION: BATCH

TO EXECUTE LOAD: @FATHOGRAM.LD @ (CR)

LOAD LINE CONTENTS: RLDR FATHOGRAM LATLON COURSE SPEED GNAME FFREAD DFREAD GETDEPTH STORE DFWRT CRFHR WPRCB REPORTFATH ABORTFATH FLOGDATA FATHSTOP FPARS1 FFLOAT CONV01 LONGTRACE @MFLIBJR@

BDRS BATCH "DEPTH ADJUSTMENT"

FILENAME: DEPADJ

LOCATION: BATCH

PURPOSE: TO COMPARE AND ADJUST SOUNDING VALUES IN A BDRS GEOGRAPHIC FILE TO THE AVERAGE SOUNDING VALUE FOR THAT LOCATION STORED IN THE BDRS DATA BASE.

INPUT REQUIRED: BDRS GEOGRAPHIC FILE CONTAINING SOUNDING VALUES TO BE ADJUSTED AND A BDRS GEO-SECTIONED FILE FROM THE DATA BASE.

OUTPUT: BDRS GEOGRAPHIC FILE CONTAINING ADJUSTED SOUNDING VALUES.

TO EXECUTE: DEPADJ (CR)

LOAD LINE FILENAME: DEPADJ.LD

LOCATION: BATCH

TO EXECUTE LOAD: @ DEPADJ.LD @(CR)

LOAD LINE CONTENTS: RLDR DEPADJ CRBUCKETS FINDBUCKET PHEADADJ INDEP DPABORT ADJSD STDUNIT DPREPT DPREAD DPWRT ADJPACK ADJDAT CONV01 LONGTRACE @MFLIPJR@

BDRS BATCH "DATUM SHIFT"

FILENAME: DATSHIFT

LOCATION: BATCH

PURPOSE: TO CONVERT LAT/LONG POINTS OF A BDRS GEOGRAPHIC FILE FROM ONE SPECIFIC ELLIPSOID MODEL TO ANOTHER.

INPUT REQUIRED: BDRS STANDARD GEOGRAPHIC FILE.

OUTPUT: BDRS STANDARD GEOGRAPHIC FILE.

TO EXECUTE: DATSHIFT (CR).

LOAD LINE FILENAME: DATSHIFT.LD

LOCATION: BATCH

TO EXECUTE LOAD: @ DATSHIFT.LD @ (CR)

LOAD LINE CONTENTS: RLDR DATSHIFT PDUMP DSPACK DSDAT SHIFT PHEAD INDAT DSREAD DSREPT DSABORT DSABRT2 DSWRT CONV01 LONGTRACE @MFLIBJR@

BDRS BATCH "OUTPUT PROCESS BDRS TABLE DATA TO MAGNETIC TAPE"

FILENAME: TABMAGTP
LOCATION: BATCH
PURPOSE: TO OUTPUT BDRS TABLE DATA TO 9-TRACK MAGNETIC TAPE.
INPUT REQUIRED: BDRS STANDARD TABLE FILES.
OUTPUT: MAGNETIC TAPE FILE.
TO EXECUTE: TABMAGTP (CR)

LOAD LINE FILENAME: TABMAGTP.LD
LOCATION: BATCH
TO EXECUTE LOAD: @ TABMAGTP.LD @ (CR)
LOAD LINE CONTENTS: RLDR TABMAGTP ANAMEMT ABORTMT WRTP RECREDMT CONV01
REPORTMT LONGTRACE @MFLIB@

BDRS BATCH "INPUT PROCESS BDRS TABLE DATA FROM MAGNETIC TAPE"

FILENAME: MAGTPTAB

LOCATION: BATCH

PURPOSE: TO INPUT BDRS TABLE DATA TO DISK FROM 9-TRACK MAGNETIC TAPE.

INPUT REQUIRED: MAGNETIC TAPE FILE (PRODUCED FROM A BDRS OUTPUT PROCESS TABLE DATA TO MAGNETIC TAPE).

OUTPUT: BDRS STANDARD TABLE FILE (DISK).

TO EXECUTE: MAGTPTAB (CR)

LOAD LINE FILENAME: MAGTPTAB.LD

LOCATION: BATCH

TO EXECUTE LOAD: @ MAGTPTAB.LD @ (CR).

LOAD LINE CONTENTS: RLDR MAGTPTAB TWRD RDTP OPTPMOUNT GCTS CHF REPORTTAB CONV01 LONGTRACE PDUMP @MFLIBJR@

FILENAME: TABGEO
LOCATION: BATCH
PURPOSE: TO CONVERT A BDRS TABLE FILE TO A BDRS GEOGRAPHIC FILE.
INPUT REQUIRED: BDRS STANDARD TABLE FILE.
OUTPUT: BDRS STANDARD GEOGRAPHIC FILE.
TO EXECUTE: TABGEO (CR).

LOAD LINE FILENAME: TABGEO.LD
LOCATION: BATCH
TO EXECUTE LOAD: @ TABGEO.LD @ (CR).
LOAD LINE CONTENTS: RLDR TABGEO ANAME Z3FLOAT WRT RECRED CLEAR INVUTM INVMERCATOR
INVLAMBERT PDUMP INVPOLYCON INVMILLER
PRM1 IPRM2 HDR ERN PACK FEAUD REPORT2 CONV01 ABORT2 LONGTRACE @MFLIB@

BDRS BATCH "TABLE TO GEOGRAPHIC CONVERSION"

FILENAME: GEOTAB
LOCATION: BATCH
PURPOSE: TO CONVERT BDRS GEOGRAPHIC DATA TO BDRS TABLE DATA.
INPUT REQUIRED: BDRS STANDARD GEOGRAPHIC FILE.
OUTPUT: BDRS STANDARD TABLE FILE.
TO EXECUTE: GEOTAB (CR).

LOAD LINE FILENAME: GEOTAB.LD
LOCATION: BATCH
TO EXECUTE LOAD: @ GEOTAB.LD @ (CR).
LOAD LINE CONTENTS: RLDR GEOTAB ZOUT MINM HEAD AINPUT REDREC PB1 PB2 WRTOUT MCTR UTM
MILLER LAMBERT POLPRO
INCA INCB INCC INCD ABSA ABSB TINCA TINCB TABSA REPORT1 ABORT1 PB1DONE
ZFLOAT CONV01 Z3FLOAT HGETXY LONGTRACE @MFLIB@

BDRS BATCH "GEOGRAPHIC TO TABLE CONVERSION"

BDRS BATCH "UNIVAC 1108 TO BDRS CONVERSION"

FILENAME: STRSOR
LOCATION: BATCH
PURPOSE: TO READ SOURCE DESCRIPTION DATA INDEX RECORDS FROM TAPE AND CREATE A BDRS DISK RESIDENT SOURCE FILE.
INPUT REQUIRED: SOURCE DESCRIPTION DATA INDEX RECORDS ON MAGNETIC TAPE.
OUTPUT: DISK RESIDENT SOURCE FILE.
TO EXECUTE: STRSOR (CR).

LOAD LINE FILENAME: STRSOR.LD
LOCATION: BATCH
TO EXECUTE LOAD: @ STRSOR.LD @ (CR)
LOAD LINE CONTENTS:

```
RLDR STRSOR GET6 REDSDI PHYREC SORSID PDUM FINDOC
RDWTID LONGTRACE @MFLIB@
```

FILENAME: CAMAIN
LOCATION: BATCH
PURPOSE: TO CONVERT UNIVAC 1108 FORMATTED GEOGRAPHIC SOUNDING DATA ON TAPE TO A BDRS GEOGRAPHIC FILE ON DISK.
INPUT REQUIRED: UNIVAC 1108 FORMATTED GEOGRAPHIC SOUNDING DATA ON MAGNETIC TAPE.
OUTPUT: BDRS GEOGRAPHIC FILE (DISK).
TO EXECUTE: CAMAIN (CR).

LOAD LINE FILENAME: CAMAIN.LD
LOCATION: BATCH
TO EXECUTE LOAD: @ CAMAIN.LD @ (CR)
LOAD LINE CONTENTS:

```
RLDR CAMAIN GP2GP UBKDATA CONV36 STORGO PARM1 FGOHDR
UWRTBK CORSID RDWTID REDUN ENDREP LONGTRACE @MFLIB@
```

BDRS BATCH "LIS TO BDRS CONVERSION"

FILENAME: MAINGEO

LOCATION: BATCH

PURPOSE: TO CONVERT A STANDARD LIS GEOGRAPHIC DATA FILE ON TAPE TO A DISK RESIDENT BDRS STANDARD FORMATTED GEOGRAPHIC FILE.

INPUT REQUIRED: MAGNETIC TAPE CONTAINING A STANDARD LIS GEOGRAPHIC DATA FILE.

OUTPUT: BDRS STANDARD GEOGRAPHIC FILE (DISK).

TO EXECUTE: MAINGEO (CR).

LOAD LINE FILENAME: MAINGEO.LD

LOCATION: BATCH

TO EXECUTE LOAD: @ MAINGEO.LD @ (CR)

LOAD LINE CONTENTS: RLDR MAINGEO TYPEIN REDLIS WRTBLK REC0 REC20 REC40 REC41 DMS FLTFLT DIDF ABORT REPORT LINVUTM CONV01 @UFLIB@

ON-LINE DATA BASE "LOAD-LINE"

FILENAME: ONLINELD
DIRECTORY: DBASE
TO LOAD: @ ONLINELD @ (CR)
TO EXECUTE: EXFG ONLINEDB (CR)
OR
ONLINEDB (CR)

PURPOSE: TO RUN THE ON-LINE DB PROCESS.
SYSTEM: BDRSSYS1 FOR BACKGROUND
OR
BDRSSYS2 FOR EITHER GROUND

THE LOAD LINE:

```
RLDR 3/K 20/C ONLINEDB 01EXEC 01OPT 01DDO 01CLEAR [01PKT 01KER 01RER 01KRW
01OPEN 01CLOSE 01UPD 01RRK 01KDL 01DLI 01RHK 01DSI 01KEW 01PACK1 01RPRS1,
01SEC, 01MAP, 01BSR 01DSR] [01LON, 01LOF, OLINP, 01REV, 01DEL] TKEXEC TKCLOSE
GPLT14 TK14 RPRS1 PACK1 TKPKT TKKER TKRRK TKRER [TKOPEN GETAREA VFPS1,
TKMAP MAPAREA, TKSEC SECDOC SECSOURCE TKPLOT RECPLOT MINM GETXY MILLER
GPTDEG] PDUMP F5INFOS.LB @MFLIB@
```

- * COMMENTS REGARDING THE FORMAT/PUNCTUATION OF THIS LOAD LINE ARE IDENTICAL TO THOSE SHOWN FOR THE DIGITIZATION LOAD LINE.
- * F5INFOS.LB IS THE INFOS SYSTEM LIBRARY AND MUST BE PRESENT IF INFOS IS TO BE USED.

BATCH LOAD LINE

FILENAME: BEXECLD
DIRECTORY: DBASE
TO LOAD: @ BEXECLD @ (CR)
TO EXECUTE: BEXEC (CR)

PURPOSE: TO PROVIDE BATCH ACCESS TO THE DATA BASE FOR THE PURPOSE OF INPUT PROCESSING, OUTPUT PROCESSING, AND DELETING BDRS GEOGRAPHIC INFORMATION TO/FROM THE DATA BASE.

THE LOAD LINE: RLDR 2/K BEXEC [DBBDL, DBBIN STDUNIT DBDSI, DBBOG DBSEC DBMAP DBPACK DBPBWT DBGSR DBLR DLRS DLRE DLRD, DBBOD DBDWT DBDSR DCONV] DBUPD DBRER DBKER DBKRW DBRRK DBOPEN DBCLOSE DBPKT PDUM LONGTRACE F5INFOS.LB @MFLIB@

MASTER MODE LOAD LINE

FILENAME: BMASTM.LD
DIRECTORY: DBASE
TO LOAD: @ MASTM.LD @ (CR)
TO EXECUTE: MASTM (CR)

PURPOSE: TO SUPPORT THE SYSTEM SUPERVISOR IN MAINTAINING CONTROL OF THE CONTENTS OF, AND ACCESS TO, THE DATA BASE.

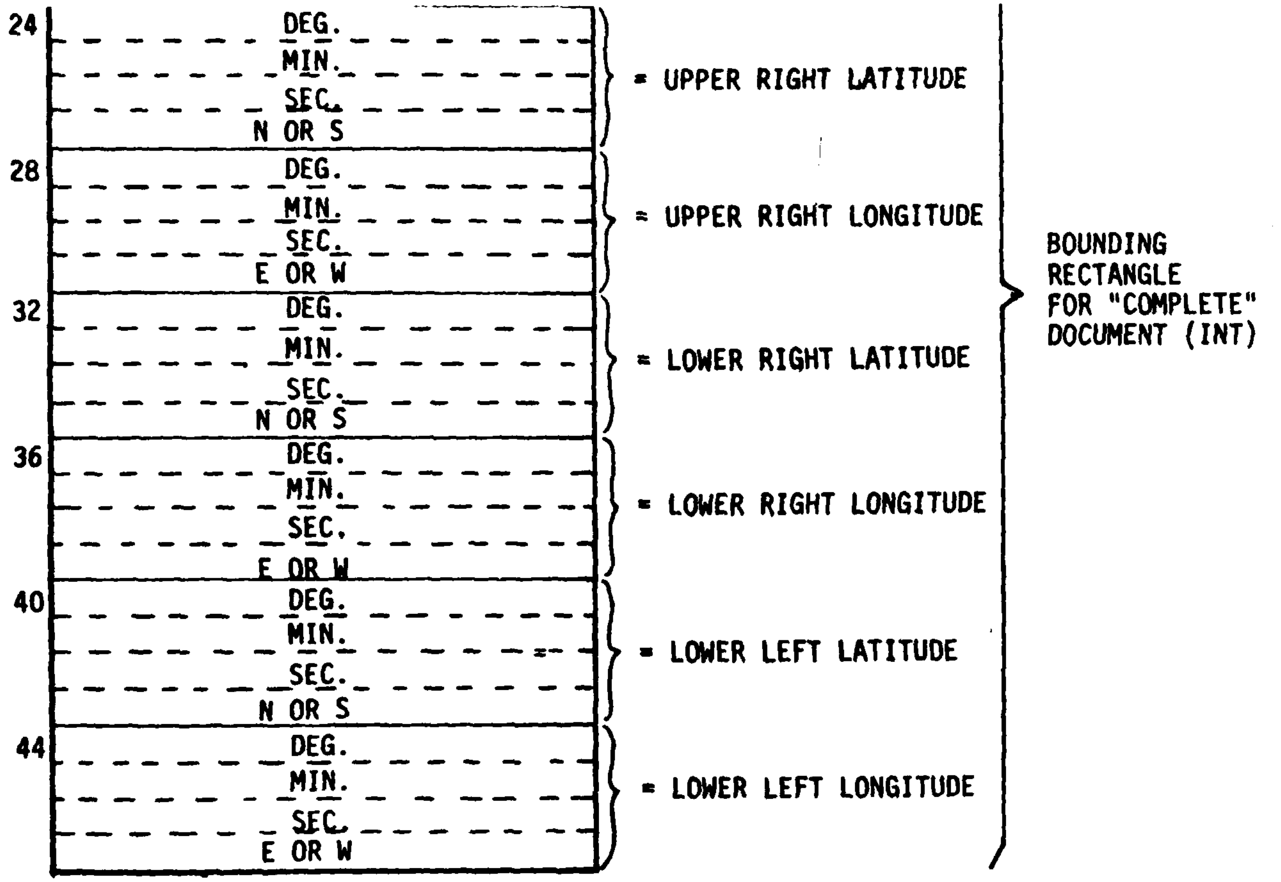
THE LOAD LINE: RLDR MASTM DBOPEN DBCLOSE DBKER DBRER DBKKL DBUPD DBRHK DBRRK DBDL.I DBMAP DBPKT DBKEW [MMDMPUF, MMADDUF, MMDELUF, MMMODUF, MMDPDOC, MMRVDOC] F5INFOS.LB @UFLIB@

* COMMENTS REGARDING THE FORMAT/PUNCTUATION OF THIS LOAD LINE ARE IDENTICAL TO THOSE SHOWN FOR DIGITIZATION.

APPENDIX C
BDRS FILES AND RECORD FORMATS

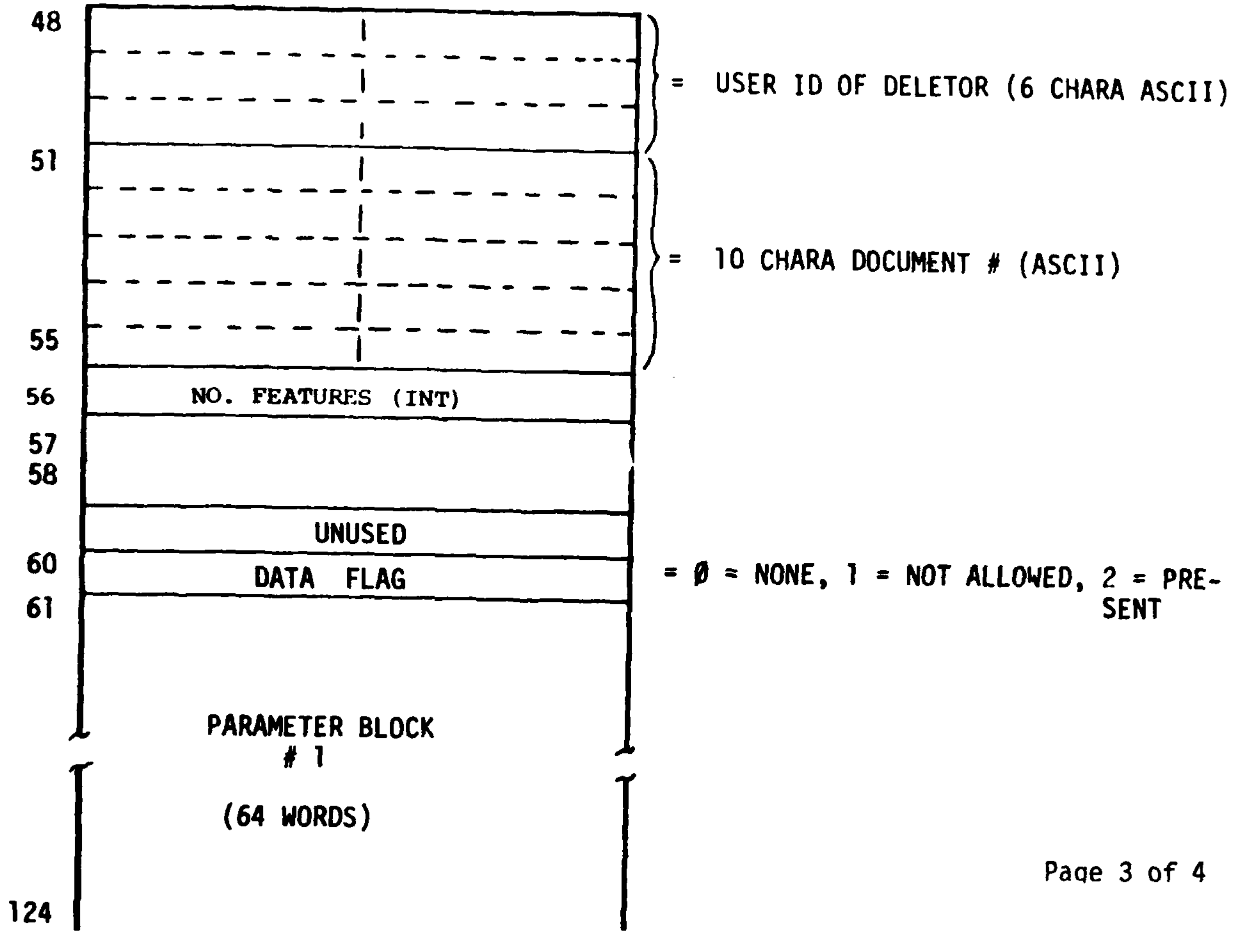
BDRS DATA BASE DOCUMENT DESCRIPTION RECORD (252 WORDS)

1	D R	= RECORD FLAG (ASCII)
2	LOGICAL DELETE FLAG	= 0 = OK, 1 = ALL DELETED, 2 = PARTIAL
3	MO	= DATE OF LOGICAL DELETION (INTEGER)
4	DA	
5	YR	
6	NO. OF SOURCE RECORDS	= NO. SOURCE CURRENTLY STORED (INT)
7		
8	NO. OF SHEETS CURRENTLY STORED	= NO. CURRENTLY STORED (INT)
9	MO	= DATE DOC. RECORD WAS INPUT (INTEGER)
10	DA	
11	YR	
12	|	= 6 CHAR. USER-ID OF OPERATOR WHO INPUT THE DATA (ASCII)
	|	
	|	
15	CLASSIFIED DATA FLAG	= 0 = NO., 1 = YES
16	DEG.	= UPPER LEFT LATITUDE
	MIN.	
	SEC.	
	N OR S	
20	DEG.	= UPPER LEFT LONGITUDE
	MIN.	
	SEC.	
	E OR W	

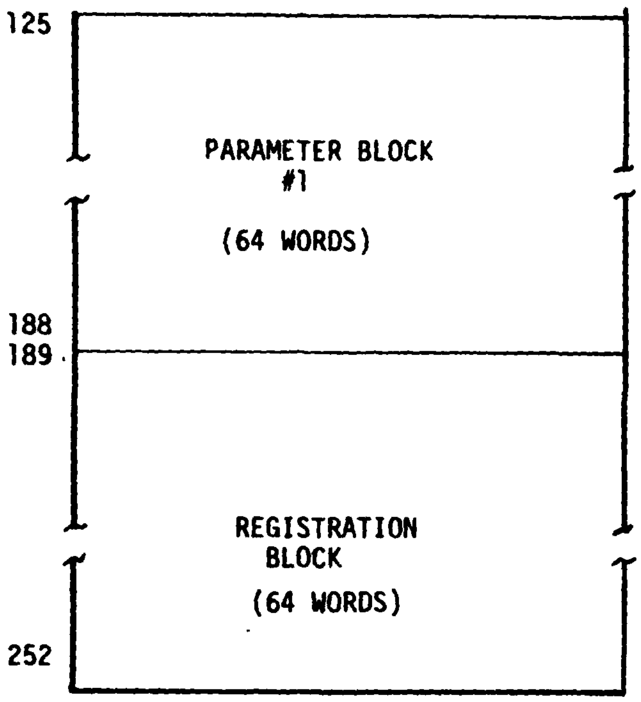


BDRS DATA BASE DOCUMENT DESCRIPTION RECORD (252 WORDS)

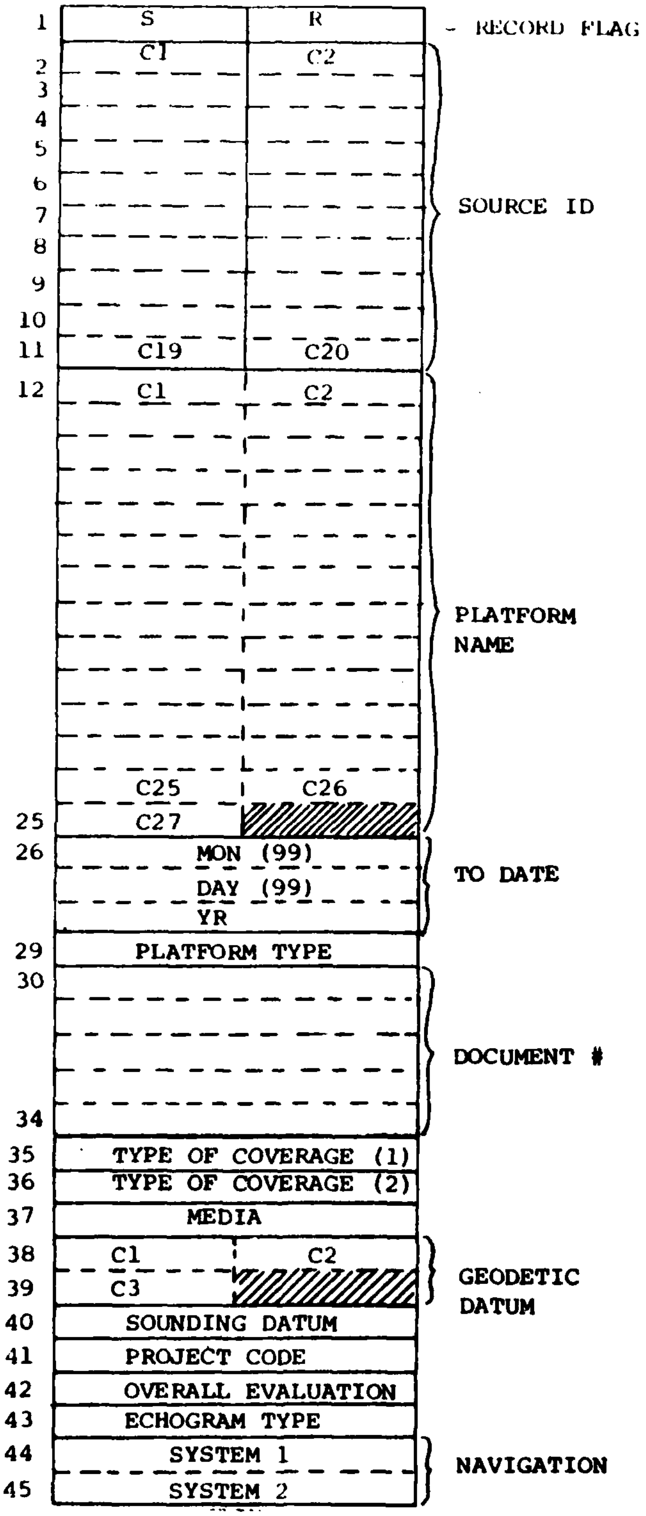
Page 2 of 4


48
51
55
56
57
58
60
61
124
= USER ID OF DELETOR (6 CHARA ASCII)
= 10 CHARA DOCUMENT # (ASCII)
NO. FEATURES (INT)
UNUSED
DATA FLAG
= 0 = NONE, 1 = NOT ALLOWED, 2 = PRESENT
PARAMETER BLOCK
1
(64 WORDS)

Page 3 of 4


125
PARAMETER BLOCK #1
(64 WORDS)
188
189
REGISTRATION BLOCK
(64 WORDS)
252

Page 4 of 4



DB SOURCE DESC. RECORD - 252 WORDS

46	CLASSIFICATION	SECURITY
47	DECLASSIFICATION	
48	GDS/EXEMPT	
49	OLD DOWNGRADING GRP	
50	CONTROL/RELEASE	
51	DATE (MO)	
52	OF (DA)	
53	ORIGIN (YR)	
54		
64	NO.OF SOUNDINGS (INT)	
66		REMARKS CHARACTERS
100		
241	CLASSIFIED DATA 0=NO 1=YES	
242	DATA/NO DATA 0=NO 1=YES	
243	C1 C2 C3 C4	SHEET #
245	# OF FEATURES	
246	LOGICAL DELETE FLAG	0=NO 1=YES
247	MO	DATE OF DELETION
248	DA	
249	YR	
250		USER-ID OF DELETOR
251		
252		

DB SOURCE DESC. RECORD - 252 WORDS

BDRS GEOGRAPHIC FILE FORMAT

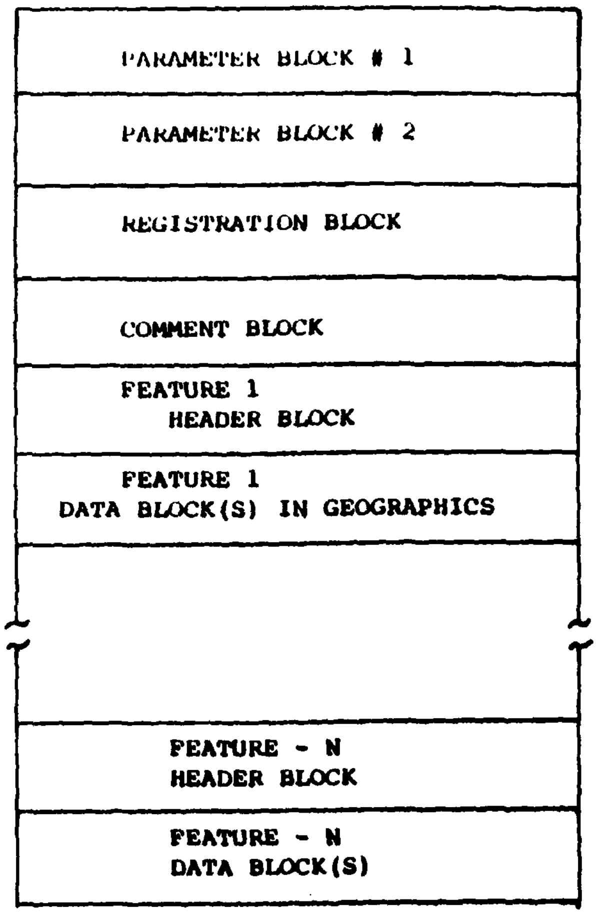
The BDRS Standard Geographic File Format is depicted in Figure No. A-1. It is comprised of 64 word records of which record number one thru record number four contain parameter block one, parameter block two, registration block and comment block. The subsequent records are comprised of feature sets. Each set contains a BDRS geographic header followed by geographic data record(s). The following word position, field, description and record layout define each element within the above mentioned records.

PARAMETER BLOCK #1

WORD	FIELD	DESCRIPTION
1	GO	Geo. File Flag (ASCII "GO")
2	DOCNUM	Doc. # (10 ASCII) -
7 bits 0-7	FATHO	1 if Fathogram, 0 otherwise
7 bits 8-15	UOM	Units of Measure
		1 Meters.Meters
		2 Feet.Feet
		3 Fathoms.Feet
		4 Fathoms.Fathoms
8 bits 0-7	REGTYP	0 if Fathogram
		1 if Correlation
8 bits 8-5	RESOL	Recording Resolution
9	UNUSED	
10	Base Elevation/Depth	Base Contour
11	Interval	Contour Interval
12-21	SX	Source ID (ASCII)
	S1-S2	Country Code
	S3	Data Type ID
	S4-S14	Platform ID
	S15-S20	Date
22	UNUSED	
23	MON	Month of Conversion (ASCII)

WORD	FIELD	DESCRIPTION
24	DAY	Day of Conversion (ASCII)
25	YEAR	Year of Conversion (ASCII)
26-29		System Converted from (ASCII)
30-31		Sheet Number (4 ASCII Character)
32-33	NSD	Total # of Soundings for File*
34-35	NPT	Total # of Discrete Points for File*
36-40	ASCII Filename	Filename
41-46	UNUSED	
47-58		Least Squares Coefficients (Deformation Coefficients) -
47-48	AA*	
49-50	BB*	
51-52	CC*	
53-54	DD*	
55-56	EE*	
57-58	FF*	
59-64	UNUSED	

*NOTE - Single Precision Floating Point



BDRS STANDARD GEOGRAPHIC FILE FORMAT

WORD	0	15	WORD	0	15
1	G	O	33	OF SOUNDING IN FILE	
2	DOCUMENT # ASCII		34	TOTAL # OF DISCRETE	
3			35	POINTS FOR FILE	
4			36	FILE NAME 10	
5			37	ASCII CHARACTER	
6			38		
7	FATHO	UOM	39		
8	REGTYP	RESOL	40		
9	UNUSED		41	UNUSED	
10	BASE EVAL/DEPTH		42		
11	INTERVAL		43		
12	SOURCE ID		44		
13	20 ASCII CHARACTERS		45		
14			46		
15			47		
16			48	LEAST SQUARES	
17			49	COEFFICIENTS	
18			50	(SIX FLOATING POINT	
19			51	WORDS	
20			52		
21			53		
22	UNUSED		54		
23	MONTH		55		
24	DAY		56		
25	YEAR		57		
26	SYSTEM CONVERTED		58		
27	FROM		59	UNUSED	
28			60		
29			61		
30	SHEET NUMBER		62		
31			63		
32	TOTAL #		64		

PARAMETER BLOCK # 2

WORD	FIELD	DESCRIPTION
1-4	A	Major Axis of Earth Model Ellipsoid**
5-8	B	Minor Axis**
9-12	E	First Eccentricity**
13-16	EP	Second Eccentricity**
17-20	CM	Chart Central Meridian**
21-24	BL	Base Latitude**
25-28	UP	Upper Standard Parallel**
29-32	LP	Lower Standard Parallel**
33-36	CHL	Chart Left Longitude**
37-40	RMS	Map Scale**
41-44	TLAT	Top Latitude**
45-48	BLAT	Bottom Latitude**
49-52	TLON	Left Longitude**
53-56	RLON	Right Longitude**
57	IQUAD	Quadrant
		1 - NE
		2 - NW
		3 - SW
		4 - SE
58	IPROJ	Projection Type
		1 - UTM Grid
		2 - Mercator
		3 - Lambert
		4 - Polyconic
		5 - Miller
59	IZN	UTM Zone Number
60	ISC	Speroid Code
		1 - CLARK 1866
		2 - CLARK 1880
		3 - CLARK 1858

**NOTE - Double Precision Floating Point

WORD	FIELD	DESCRIPTION
		4 - BESSEL
		5 - HOUGH
		6 - WGS 72
		7 - WGS 80
		8 - INTERNATIONAL
		9 - KRASSOUSKY
		10 - EVEREST
		11 - AUSTRALIAN
		12 - FISCHER
		13 - AIRY
61-64	UNUSED	

WORD	0 15	WORD	0 15
1	A	33	CHL
2		34	
3		35	
4		36	
5	B	37	RMS
6		38	
7		39	
8		40	
9	E	41	TLAT
10		42	
11		43	
12		44	
13	EP	45	BLAT
14		46	
15		47	
16		48	
17	CM	49	TLON
18		50	
19		51	
20		52	
21	BL	53	RLON
22		54	
23		55	
24		56	
25	UP	57	IQUAD
26		58	IPROJ
27		59	IZN
28		60	ISC
29	LP	61	UNUSED
30		62	
31		63	
32		64	

REGISTRATION BLOCK

WORD	FIELD	DESCRIPTION
1	NRP	Number of registrates points use for registration max of ten
2-4	UNUSED	
5	RX1	X(1) Value used in Registration
		Y(1) " " " "
		X(2) " " " "
		Y(2) " " " "
.		
.		
.		
23	RX10	X(10) Value used in Registration
24	RY10	Y(10) " " " "
25-26	LAT1*	LAT(1) Latitude used in Registration- units .01" of arc
27-28	LONG1*	LONG(1) Longitude used in Registration units .01" of arc
.		
.		
.		
61-62	LAT10*	LAT(10) Latitude used in Registration units .01" of arc
63-64	LONG10*	LONG(10) Longitude used in Registratio units .01" of arc

WORD	0 15	WORD	0 15
1	NUMBER OF REG. PTS.	33	
2	UNUSED	34	
3	"	35	
4	"	36	
5	RX1	37	
6	RY1	38	
7	RX2	39	
8	RY2	40	
9	RX3	41	
10	RY3	42	
11	RX4	43	
12	RY4	44	
13	.	45	
14	.	46	
15	.	47	
16	.	48	
17	.	49	
18	.	50	
19	.	51	
20	.	52	
21	.	53	
22	.	54	
23	RX10	55	
24	RY10	56	
25	LATITUDE # 1	57	
26		58	
27	LONGITUDE # 1	59	
28		60	
29	LATITUDE # 2	61	LATITUDE # 10
30		62	
31	LONGITUDE # 2	63	LONGITUDE # 10
32		64	

COMMENT BLOCK

WORD	FIELD	DESCRIPTION
1		Comment block contains user generated comments. Note: A zero byte denotes a carriage return, the second zero byte denotes end of comment for recor
.		
.		
.		
.		
.		
.		
.		
.		
.		
64		

WORD	0 15	WORD	0 15
1	ASCII COMMENTS	33	
2		34	
3		35	
4		36	
5		37	
6		38	
7		39	
8		40	
9		41	
10		42	
11		43	
12		44	
13		45	
14		46	
15		47	
16		48	
17		49	
18		50	
19		51	
20		52	
21		53	
22		54	
23		55	
24		56	
25		57	
26		58	
27		59	
28		60	
29		61	
30		62	
31		63	
32		64	

FEATURE HEADER RECORD

WORD	FIELD	DESCRIPTION
1	HDRFLG(-1)	Header Block Flag
2 bits 0-7	CC	Binary Class Code
bits 8-15	TT	Binary Type Code
3 bits 0-7	SS	Binary Subtype Code
3 bits 8-15 to 8	DX	Descriptor Codes in ASCII
9	NDB	Number of Data Blocks in feature
10-11	LATMIN	Geographic Minimum of Feature Latitude*
12-13	LONMIN	Minimum of Longitude*
14-15	LATMX	Maximum of Latitude*
16-17	LONMX	Maximum of Longitude*
18-19	FSTLAT	First Latitude of Feature*
20-21	FSTLON	First Longitude of Feature*
22-23	LSTLAT	Last Latitude of Features*
24-25	LSTLON	Last Longitude of Feature*
26	NDB	Number of Discrete Points Within Feature Data Blocks
27	NSD	Number of Soundings in Ensuing Data Blocks
28-37	SX	SOURCE ID (ASCII)
	S1-S2	Country Code ID
	S3	Datatype ID
	S4-S14	Platform ID
	S15-20	DATE
38	Base/ele/depth	Base Contour
39	Interval	Contour Interval
40	DS	Depth Scale
41	TS	Time Scale

WORD	FIELD	DESCRIPTION
42	RESOL.	Resolution in Mils
43-47	DN	Document Number (ASCII)
48-49	DHN	Sheet Number (ASCII)
50-51	MIND	Minimum Depth*
52-53	MAXD	Maximum Depth*
54 Bits 0-7	UNCOR	**Uncorrected**/corrected soundings (0-Uncorrected, 1-corrected)
54 Bits 8-15	UOM	Unit of Measure
		1 - Meters.Meters
		2 - Feet.Feet
		3 - Fathoms.Feet
		4 - Fathoms.Fathoms
55-64	Free Text	

*NOTE - Single Precision Floating Point

WORD	0	15
1	HDRFL (-1)	
2	CC	TT
3	SS	D1
4	D2	D3
5	D4	D5
6	D6	D7
7	D8	D9
8	D10	UNUSED
9	NDB	
10	LATMIN	
11		
12	LONMIN	
13		
14	LATMX	
15		
16	LONMX	
17		
18	FSTLAT	
19		
20	FSTLON	
21		
22	LSTLAT	
23		
24	LSTLON	
25		
26	NDP	
27	NSD	
28	SOURCE ID	
29	(20 ASCII CHAR)	
30		
31		
32		

WORD	0	15
33		
34		
35		
36		
37		
38	BASE ELEVATION/DEPTH	
39	INTERVAL	
40	DS DEPTH SCALE	
41	TS TIME SCALE	
42	RESOL (RESOLUTION)	
43	DN (DOCUMENT)	
44	NUMBER 10 ASCII	
45	CHAR	
46		
47		
48	SHEET NUMBER 4 ASCII	
49	CHAR	
50	MINIMUM DEPTH	
51		
52	MAXIMUM DEPTH	
53		
54	UNCOR	UOM
55	FREE TEXT AREA	
56	(20 ASCII CHAR)	
57		
58		
59		
60		
61		
62		
63		
64		

GEOGRAPHIC DATA RECORD

The BDRS standard geographic data block is constructed as follows. A minus two in the first word indicates the beginning of a geographic data block. The second word contains the specific block number, e.g., a counter. The third word is a data type/number of points in data field code.

Bits 0-1 are the data type code
  0-0 increment
  0-1 absolute
  1-0 incremental, bits 0-7 latitude, 8-15 longitude

Bits 2-15 give the number of points in the data type field that follows.

A value other than zero (0) in word 27 of the header block indicates that the data block contains depth values. The data will be constructed similar to one of the configurations in Figure No. 7. If a zero (0) is contained in word 27 of the header block, no depth values are contained in the data block. It will be constructed similar to one of the data blocks in Figure No. 8. A change of data type is indicated by encountering a new two bit data type code, followed by the number of points in the new data type field.

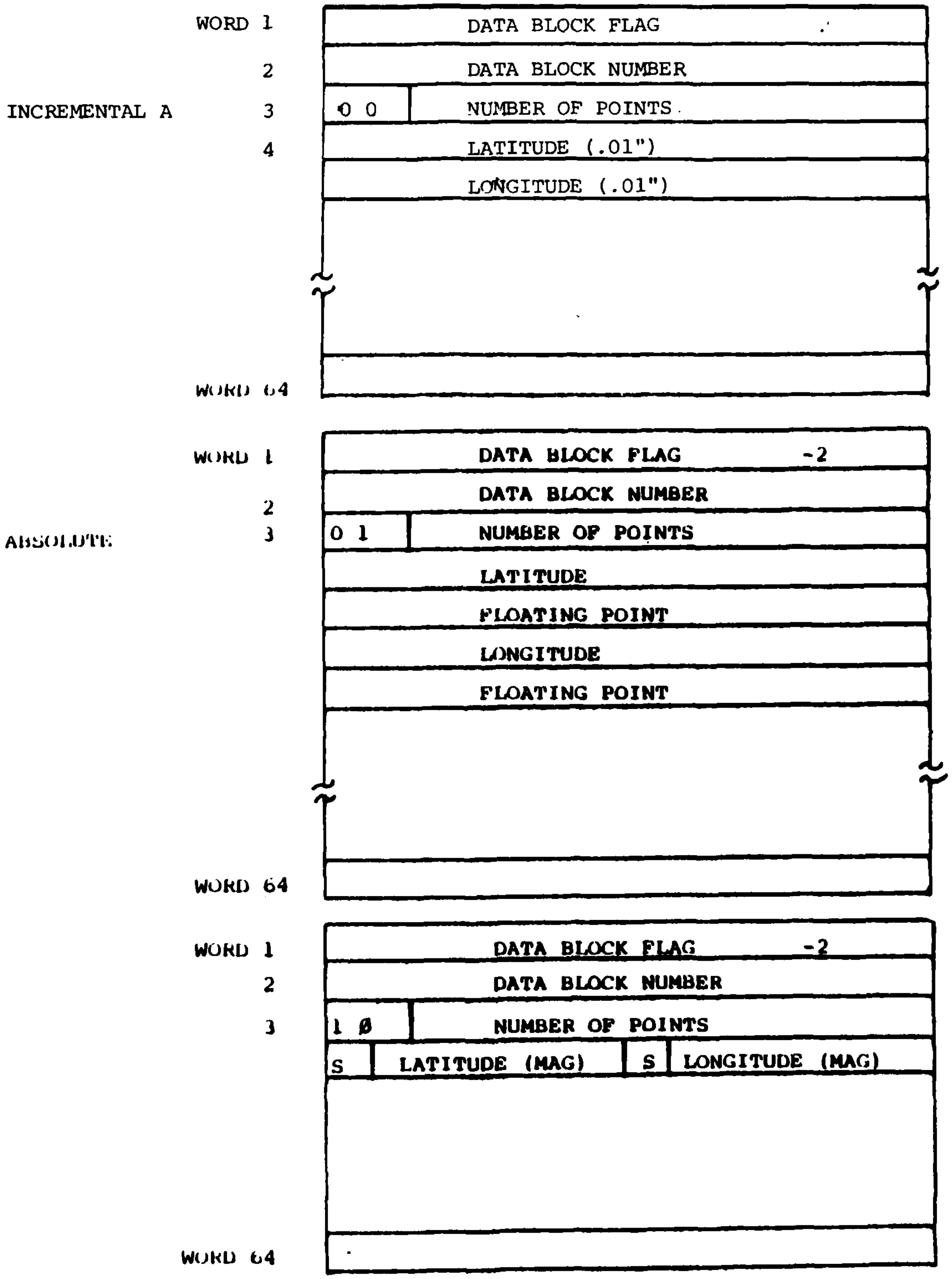
The 00 incremental value consists of two 16-bit Data General integer words, one word for latitude and one word for longitude. The 01 absolute values consist of four 16 bit Data General words (two floating point values), two words for latitude and two words for longitude. Note: Each Data General floating point value consists of two 16 bit Data General words (Reference Programmer's Reference Manual ECLIPSE COMPUTER 015-0000-24-00). The 10 incremental values consist of one integer word containing a latitude and longitude (2 bytes). Each byte is a signed magnitude of a value in the range: $1 \le \text{MAGNITUDE} \le 127$ (with a least count of .91"). The first bit of each byte is the sign bit and the remaining seven bits contain a value between zero and one hundred and twenty seven. Figure No. 9 depicts an example of a data block with soundings.

<table>
<tr><td></td><td>WORD 1</td><td colspan="4">DATA BLOCK FLAG</td></tr>
<tr><td></td><td>2</td><td colspan="4">DATA BLOCK NUMBER</td></tr>
<tr><td>INCREMENTAL A</td><td>3</td><td>0 0</td><td colspan="3">NUMBER OF POINTS</td></tr>
<tr><td></td><td>4</td><td colspan="4">LATITUDE (.01")</td></tr>
<tr><td></td><td>5</td><td colspan="4">LONGITUDE (.01")</td></tr>
<tr><td></td><td>6</td><td colspan="4">DEPTH</td></tr>
<tr><td></td><td>7</td><td colspan="4">FLOATING POINT</td></tr>
<tr><td></td><td></td><td colspan="4"></td></tr>
<tr><td></td><td>WORD 64</td><td colspan="4"></td></tr>
</table>

<table>
<tr><td></td><td>WORD 1</td><td colspan="4">DATA BLOCK FLAG -2</td></tr>
<tr><td></td><td>2</td><td colspan="4">DATA BLOCK NUMBER</td></tr>
<tr><td>ABSOLUTE</td><td>3</td><td>0 1</td><td colspan="3">NUMBER OF POINTS</td></tr>
<tr><td></td><td>4</td><td colspan="4">LATITUDE</td></tr>
<tr><td></td><td>5</td><td colspan="4">FLOATING POINT</td></tr>
<tr><td></td><td>6</td><td colspan="4">LONGITUDE</td></tr>
<tr><td></td><td>7</td><td colspan="4">FLOATING POINT</td></tr>
<tr><td></td><td>8</td><td colspan="4">DEPTH</td></tr>
<tr><td></td><td>9</td><td colspan="4">FLOATING POINT</td></tr>
<tr><td></td><td></td><td colspan="4"></td></tr>
<tr><td></td><td>WORD 64</td><td colspan="4"></td></tr>
</table>

<table>
<tr><td>WORD 1</td><td colspan="4">DATA BLOCK FLAG -2</td></tr>
<tr><td>2</td><td colspan="4">DATA BLOCK NUMBER</td></tr>
<tr><td>3</td><td>1 0</td><td colspan="3">NUMBER OF POINTS</td></tr>
<tr><td>4</td><td>S</td><td>LATITUDE (MAG)</td><td>S</td><td>LONGITUDE (MAG)</td></tr>
<tr><td>5</td><td colspan="4">DEPTH</td></tr>
<tr><td>6</td><td colspan="4">FLOATING POINT</td></tr>
<tr><td></td><td colspan="4"></td></tr>
<tr><td>WORD 64</td><td colspan="4"></td></tr>
</table>

BDRS GEOGRAPHIC DATA BLOCKS WITH SOUNDINGS



BDRS DATA BLOCKS WITHOUT SOUNDINGS

WORD	0	15	WORD	0	15
1		-2	33	LAT	LONG
2		1	34	DEPTH FLOATING	
3	01	1	35	POINT	
4	LATITUDE FLOATING		36		
5	POINT (.01)		37		
6	LONGITUDE FLOATING		38		
7	POINT (.01)		39		
8	DEPTH		40		
9	FLOATING POINT		41		
10	00	3	42		
11	LATITUDE		43		
12	LONGITUDE		44		
13	DEPTH FLOATING		45		
14	POINT		46		
15	LATITUDE		47		
16	LONGITUDE		48		
17	DEPTH FLOATING		49		
18	POINT		50		
19	LATITUDE		51		
20	LONGITUDE		52		
21	DEPTH FLOATING		53		
22	POINT		54		
23	10	4	55		
24	LAT	LONG	56		
25	DEPTH FLOATING		57		
26	POINT		58		
27	LAT	LONG	59		
28	DEPTH FLOATING		60		
29	POINT		61		
30	LAT	LONG	62		
31	DEPTH FLOATING		63		
32	POINT		64		

BDRS DIGITIZING TABLE AND FILES FORMAT

The BDRS Standard Table Files consist of four distinct disk resident files, each unique to the job name: Header File, Index File, Data File, and Fathogram File (when fathogram is digitized). Each file and the record content will be discussed in the proceeding paragraphs.

Header File

The Header File (Filename HF job I.D.) depicted in Figure No. A-10 consists of headers chosen by the operator from the Bathymetric Master Library of headers on disk for inclusion into the job's working header set during Header Select Mode. (The Bathymetric Master Library file's names for Station #1 and Station #2 are "BDRS.HF" and "VBDRS.HF" respectively). In addition, each time a new permanent header is created in Master Mode, it is appended to the Header File. Each header entry is stored as a string of ASCII characters expanded out to 62 characters with blanks to make the Header Entry 31 integer wods long (Figure No. A-11).

The following is an example of header:

13010200000000000000000000 ABOVE MEAN HIGH WATER

where the twenty six digit code represents an LIS compatible header code, and the remaining characters are the textual header description. The Header File is organized into "pages" of 15 headers each to facilitate their display on the CRT terminal. A Header Entry Format is as follows:

WORD	FIELD	DESCRIPTION
1	CC	LIS-compatible Class Code (2 ASCII characters)
2	TT	LIS-compatible Type Code (2 ASCII characters)
3	SS	LIS-compatible Subtype Code (2 ASCII characters)
4-13	DX	LIS-compatible Descriptor Codes (20 ASCII characters)
14-31	CX	Free Text Field (36 ASCII characters)

Index File

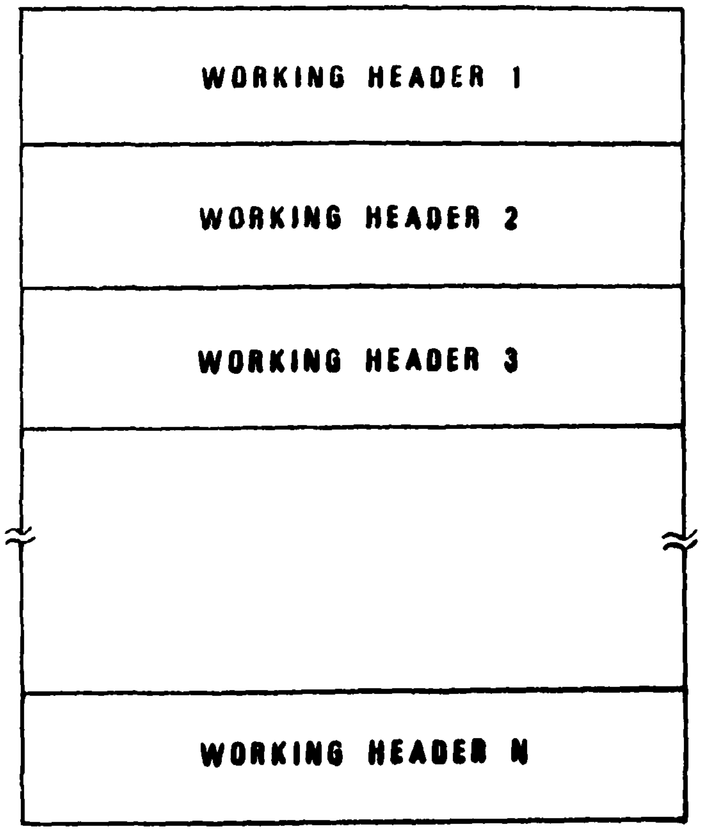
The Index File, (filename IF job I.D.) depicted in Figure No. A-12 is a multipurpose file. It contains parameters, registration, commentary, and index blocks

64 words in length. The parameter blocks are used to record the status and control information for a job. The comment block is used to store ASCII characters input by the user in the Master Mode auxiliary functions. These characters can be made up of any remarks the user wishes to input. The index block contains pointer, window and mask information about some feature.

Parameter Block #1

Parameter block number one is depicted in Figure No. A-13 and its description is as follows:

WORD	FIELD	DESCRIPTION
1-6	INAME	ASCII "IF" followed by eight ASCII character job I.D.
7	IFUOM	Bits 0-7 Fathogram indicator, if bit 0-7 equal one fathogram file Bits 8-15 Units of Measure 1 - Meters.Meters 2 - Feet.Feet 3 - Fathoms.Feet 4 - Fathoms.Fathoms
8	DKRES	Digitizing table recording resolution in mi
9	LASTHB	Last header block pointer (random pointer into file DF job I.D.)
10	LASTBL	Last data block pointer (random record pointer into file DF job I.D.)
11	ICHDR	Current header block pointer (random record pointer into file DF job I.D.)
12	ELBASE	Base elevation/depth
13	CONINT	Base elevation/depth interval
14	UNUSED	
15	TPTS	Total number of discrete points in file (DF job I.D.)

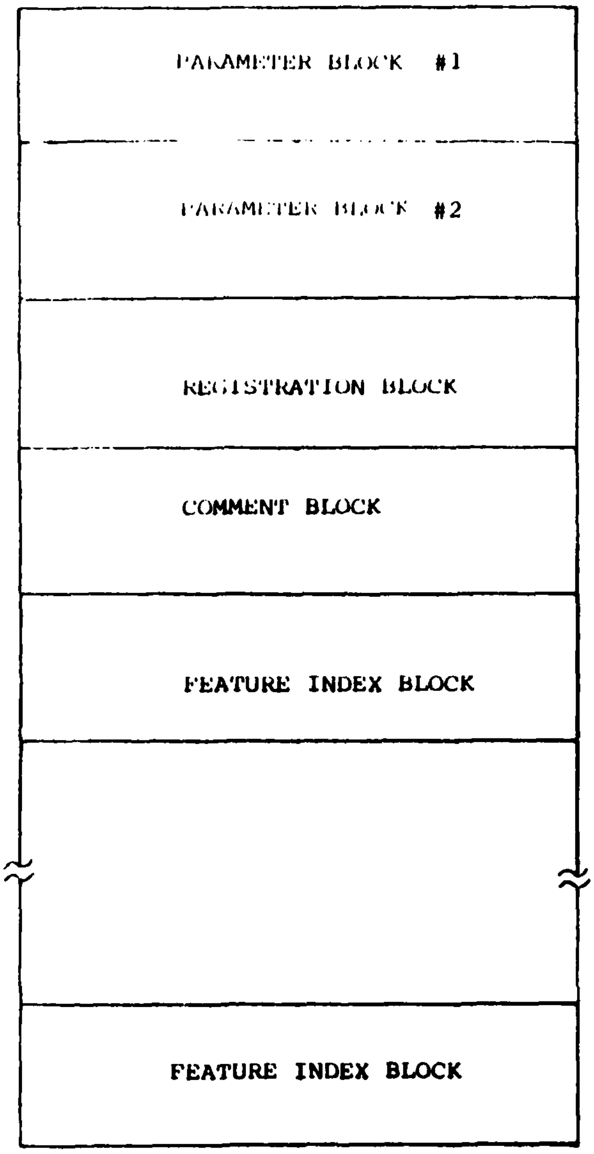


WORKING HEADER FILE

0 8 16

1	C	C
2	T	T
3	S	S
4	D1	D2
5	D3	D4
6	D5	D6
7	D7	D8
8	D9	D10
9	D11	D12
10	D13	D14
11	D15	D16
12	D17	D18
13	D19	D20
14	C1	C2
15	C3	C4
16	C5	C6
17	C7	C8
18	C9	C10
19	C11	C12
20	C13	C14
21	C15	C16
22	C17	C18
23	C19	C20
24	C21	C22
25	C23	C24
26	C25	C26
27	C27	C28
28	C29	C30
29	C31	C32
30	C33	C34
31	C35	C36

WORKING HEADER BLOCK FORMAT



BDRS FEATURE INDEX FILE

WORD	FIELD	DESCRIPTION
16	TSDS	Total number of soundings in file (DF job I.D.)
17	TFTS	Total number of features in file (DF job I.D.)
18	UNUSED	
19	UNUSED	
20	LHLINE	Pointer to the current page of header to indicate the present header selected (HF job I.D.)
21-30	ISID	Source I.D. (20 ASCII characters)
31	FIBP	Block index pointer (random record pointer into file IF Job I.D.)
32	FIWP	Next unused word pointer into block FIBP
33	IDSC	Display Scale
34	STRMOD	
35	NEW	New job flag (NEW = 1)
36	CORECT	Uncorrected/corrected depth values (0=uncorrected, 1=corrected)
37	FTHBLP	Random pointer to last fathogram parameter block written to file FF job I.D.
38-39	AA	Least square coefficients used to correct
40-41	BB	input X,Y values back to day one
42-43	CC	registration form.
44-45	DD	
46-47	FF	
48-49	GG	
50-55	UNUSED	
56-60	DOCNO	Document number (10 ASCII characters)
61-62	SHEET	Sheet number (4 ASCII numeric characters)
63-64	UNUSED	

WORD	0	15	WORD	0	15
1	1	P	33	DISPLAY SCALE	
2	C1	C2	34	STRMOD	
3	C3	C4	35	NEW JOB FLAG (=1 NEW)	
4	C5	C6	36	UN/CORRECTED SOUNDINGS	
5	C7	C8	37	FATHO BLK PTR	
6	C9	-	38	AA	
7	FATHO	UOM	39		
8	RESOL		40	BB	
9	LAST HDR BLK		41		
10	LAST DATA BLK		42	CC	
11	CURRENT HDR PTR		43		
12	BASE ELEV/DEPTH		44	DD	
13	INTERVAL		45		
14	UNUSED		46	EE	
15	TOTAL NUM DISCRETE PTS		47		
16	TOTAL NUM SOUNDINGS		48	FF	
17	TOTAL NUM FEATURES		49		
18	NOT USED		50		
19	NOT USED		51		
20	LAST HEADER LINE		52		
21	SOURCE ID		53		
22			54		
23			55		
24			56	DOCUMENT NUMB	
25			57		
26			58		
27			59		
28			60		
29			61	SHEET NUM	
30			62		
31	BLK INDEX PTR		63	NOT USED	
32	WORD INDEX PTR		64		

PARAMETER BLOCK #2

WORD	FIELD	DESCRIPTION
1-4	A	Major Axis of Earth Model Ellipsoid*
5-8	B	Minor Axis**
9-12	E	First Eccentricity**
13-16	EP	Second Eccentricity**
17-20	CM	Chart Central Meridian**
21-24	BL	Base Latitude**
25-28	UP	Upper Standard Parallel**
29-32	LP	Lower Standard Parallel*
33-36	CHL	Chart Left Longitude**
37-40	RMS	Map Scale**
41-44	TLAT	Top Latitude**
45-48	BLAT	Bottom Latitude**
49-52	TLON	Left Longitude**
53-56	RLON	Right Longitude**
57	IQUAD	Quadrant
		1 = NE
		2 = NW
		3 = SW
		4 = SE
58	IPROJ	Projection Type
		1 = UTM Grid
		2 = Mercator
		3 = Lambert
		4 = Polyconic
		5 = Miller
59	IZN	UTM Zone Number
60	ISC	1 - CLARK 1866
		2 - CLARK 1858
		3 - CLARK 1858
		4 - BESSEL
		5 - HOUGH
		6 - WGS 72

WORD	FIELD	DESCRIPTION
		7 - WGS 80
		8 - INTERNATIONAL
		9 - KRASSOUSKY
		10 - EVEREST
		11 - AUSTRALIAN
		12 - FISCHER
		13 - AIRY
61-64	UNUSED	

WORD	0 15	WORD	0 15
1	A	33	CHL
2		34	
3		35	
4		36	
5	B	37	RMS
6		38	
7		39	
8		40	
9	E	41	TLAT
10		42	
11		43	
12		44	
13	EP	45	BLAT
14		46	
15		47	
16		48	
17	CM	49	TLON
18		50	
19		51	
20		52	
21	BL	53	RLON
22		54	
23		55	
24		56	
25	UP	57	IQUAD
26		58	IPROJ
27		59	IZN
28		60	ISC
29	LP	61	UNUSED
30		62	
31		63	
32		64	

REGISTRATION BLOCK

WORD	FIELD	DESCRIPTION
1	NRP	Number of registrates points used for registration (max of ten)
2-4	UNUSED	
5	RX1	X(1) Value used in Registration
6	RY1	Y(1) Value used in Registration
7	RX2	X(2) Value used in Registration
8	RY2	Y(2) Value used in Registration
.		
.		
.		
23	RX10	X(10) Value used in Registration
24	RY10	Y(10) Value used in Registration
25-26	LAT1*	LAT(1) Latitude used in Registration-units .01" of arc
27-28	LONG1*	LONG(1) Longitude used in Registration-units .01" of arc
.		
.		
.		
61-62	LAT10*	LAT(10) Latitude used in Registration-units .01" of arc
63-64	LONG10*	LONG(10) Longitude used in Registration-units .01" of arc

*Data General Single Precision Floating Point.

WORD	0 15	WORD	0 15
1	NUMBER OF REG. PTS	33	
2	UNUSED	34	
3	"	35	
4	"	36	
5	RX1	37	
6	RY1	38	
7	RX2	39	
8	RY2	40	
9	RX3	41	
10	RY3	42	
11	RX4	43	
12	RY4	44	
13	.	45	
14	.	46	
15	.	47	
16	.	48	
17	.	49	
18	.	50	
19	.	51	
20	.	52	
21	.	53	
22	.	54	
23	RX10	55	
24	RY10	56	
25	LATITUDE # 1	57	
26		58	
27	LONGITUDE # 1	59	
28		60	
29	LATITUDE # 2	61	LATITUDE # 10
30		62	
31	LONGITUDE # 2	63	LONGITUDE # 10
32		64	

COMMENT BLOCK

WORD	FIELD	DESCRIPTION
1		Comment block contains user generated comments. Note: A zero byte denotes a carriage return, the second zero byte denotes end of comment for record.
.		
.		
.		
.		
.		
.		
.		
.		
.		
64		

WORD	0 15	WORD	0 15
1	ASCII COMMENTS	33	
2		34	
3		35	
4		36	
5		37	
6		38	
7		39	
8		40	
9		41	
10		42	
11		43	
12		44	
13		45	
14		46	
15		47	
16		48	
17		49	
18		50	
19		51	
20		52	
21		53	
22		54	
23		55	
24		56	
25		57	
26		58	
27		59	
28		60	
29		61	
30		62	
31		63	
32		64	

FEATURE INDEX BLOCK

The Feature Index Block format is shown in Figure No. A-17. Each index record contains a total of 8 indices per 64 word block. (Figure No. A-18). The elements within the index are as follows:

WORD	FIELD	DESCRIPTION
1	FEATURE POINTER	The pointer to the block where the header for the feature begins.
2	MINX	The smallest X-value in which the feature is contained.
3	MINY	The smallest Y-value in which the feature is contained.
m	MAX X	The largest X-value in which the feature is contained.
5	MAX Y	The largest Y-value in which the feature is contained.
6	CC	LIS-compatible Type code (2 ASCII characters)
7	TT	LIS-compatible Type code (2 ASCII characters)
8	SS	LIS-compatible Subtype code (2 ASCII characters)

NOTE: Word 31 of parameter block number one is the random index pointer to the feature index block in use. Word 32 of parameter block number one is the word pointer of the next unused 8 word set for storing the next feature's index.

0 15

1	FEATURE POINTER
2	MIN X
3	MIN Y
4	MAX X
5	MAX Y
6	CC
7	TT
8	SS

FEATURE INDEX FORMAT

WORD	0 15	WORD	0 15
1	FEATURE POINTER	33	FEATURE POINTER
2	MINX	34	MINX
3	MINY	35	MINY
4	MAXX	36	MAXX
5	MAXY	37	MAXY
6	CC	38	CC
7	TT	39	TT
8	SS	40	SS
9	FEATURE POINTER	41	
10	MINX	42	
11	MINY	43	
12	MAXX	44	
13	MAXY	45	
14	CC	46	
15	TT	47	
16	SS	48	
17	FEATURE POINTER	49	
18	MINX	50	
19	MINY	51	
20	MAXX	52	
21	MAXY	53	
22	CC	54	
23	TT	55	
24	SS	56	
25	FEATURE POINTER	57	
26	MINX	58	
27	MINY	59	
28	MAXX	60	
29	MAXY	61	
30	CC	62	
31	TT	63	
32	SS	64	

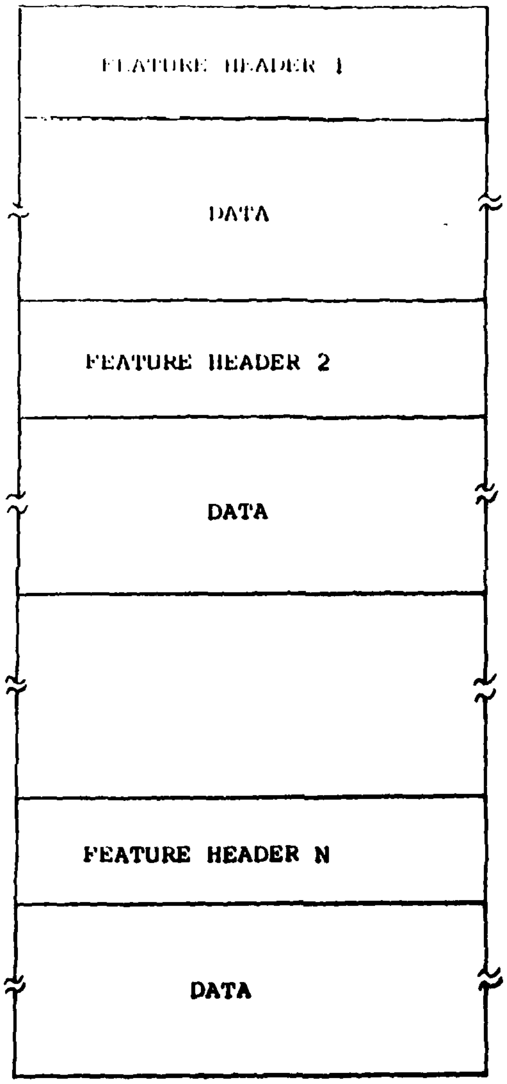
BDRS Table Coordinate Data File

The BDRS Table Coordinate Data File is depicted in Figure No. A-19 (file name DF job I.D.). It is comprised of feature data sets. Each set contains a feature header block followed by N data blocks. Each block is 64 words long.

Feature Header Block

The Feature Header Block (64 word record) contains feature parameter characteristics as shown in Figure No. A-20. These parameters are as follows:

WORD	FIELD	DESCRIPTION
1	HID	Header identification. This value is always -1.
2	CC	LIS-compatible Class Code in binary.
2	TT	LIS-compatible Type code in binary
3	SS	LIS-compatible Subtype code in binary
3-8	Dx	LIS-compatible code in binary
8	FATHO	Fathogram flag code as follows: 1 = Start selection of fathogram 2 = Continuation of long fathogram where the Y-range (depth) has not changed. 3 = Continuation of long fathogram where the Y-range (depth) has changed.
9	DEPTH/ELEV	The depth or elevation value for the contours data which follows.
10	INTERVAL	Contour interval.
11	SKIP COUNT	Used to denote the number of data blocks to skip if this feature is deleted. It is always 0 otherwise.



BDRS TABLE COORDINATE DATA FILE

WORD	FIELD	DESCRIPTION
12	MINX	The feature window bounding rectangle.
13	MINY	
14	MAXX	
15	MAXY	
16	FIRST X	The first coordinate point of the feature
17	FIRST Y	
18	LAST X	The last coordinate point of the feature
19	LAST Y	
20	MIN D	Minimum depth value for sounding
21	MAX D	Maximum depth value for sounding
22	NDPTS	Number of discrete points within the data blocks, otherwise 0.
23	NSOUND	Number of soundings within the data blocks, otherwise 0.
24-33	Sx	Source identification for this feature (20 ASCII char)
34	BLOCK INDEX PTR	Points to the block within the index file which has the index for this feature (For future use)
35	WORD INDEX PTR	Points to the word within the above block (For future use)
36	DEPTH ORIGIN	Initial depth on fathogram D-Axis
37	DEPTH SCALE	Increments on fathogram D-Axis
38	TIME SCALE	Increment on Fathogram T-Axis
39	RESOLUTION	Recording resolutions for this feature.
40-57	Cx	Free text field (96 ASCII characters). This is derived from the chosen header in Master Mode.
58-62	DOCNO	Document number (10 ASCII Characters)
63-64	SHEET	Sheet number (4 ASCII characters)

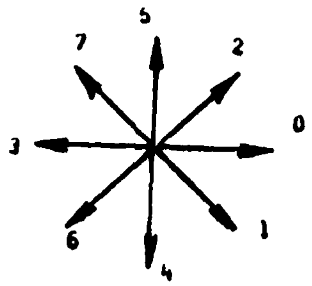
WORD	0	15	WORD	0	15
1	HID (-1)		33	S19	S20
2	CC	TT	34	BLOCK INDEX PTR	
3	SS	D1	35	WORD INDEX PTR	
4	D2	D3	36	DEPTH ORIGIN	
5	D4	D5	37	DEPTH SCALE	
6	D6	D7	38	TIME SCALE	
7	D8	D9	39	RESOLUTION	
8	D10	FATHO	40	FT1	FT2
9	DEPTH/ELEV		41	FT3	FT4
10	INTERNAL		42	FT5	FT6
11	SKIP COUNT		43	FT7	FT8
12	MIN X		44	FT9	FT10
13	MIN Y		45	FT11	FT12
14	MAX X		46	FT13	FT14
15	MAX Y		47	FT15	FT16
16	FIRST X		48	FT17	FT18
17	FIRST Y		49	FT19	FT20
18	LAST X		50	FT21	FT22
19	LAST Y		51	FT23	FT24
20	MIN D		52	FT25	FT26
21	MAX D		53	FT27	FT28
22	NDPTS		54	FT29	FT30
23	NSOUND		55	FT31	FT32
24	S1	S2	56	FT33	FT34
25	S3	S4	57	FT35	FT36
26	S5	S6	58	DC1	DC2
27	S7	S8	59	DC3	DC4
28	S9	S10	60	DC5	DC6
29	S11	S12	61	DC7	DC8
30	S13	S14	62	DC9	DC10
31	S15	S16	63	ST1	ST2
32	S17	S18	64	ST3	ST4

Data Block

The Data Block is used to store the digitized feature data. Several data-word types are used as shown in Figure No. A-21.

NULL VECTOR - used to denote "no data" within the word.

SHORT VECTOR - A 3-bit value used when the distance from the current data point to the previous point is equal to the resolution increment. Each vector is assigned a value from 0-7 depending on the new points direction relative to the previous point; i.e.,

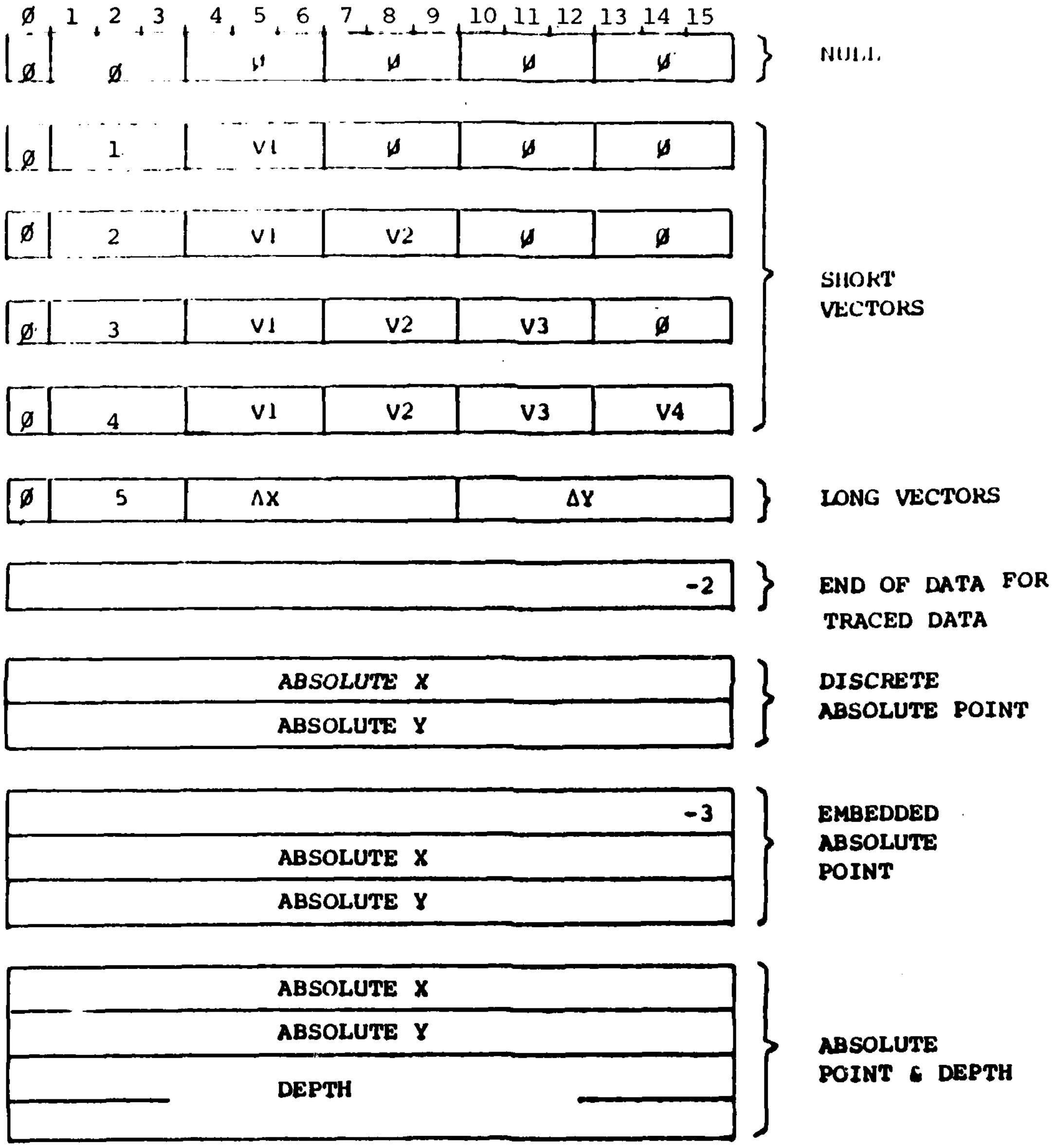


Short vectors are identified by 0 in the high bit of the word, and a short vector count (1 to 4) in the word, contained in the next three bits.

LONG VECTOR - Data word type used when the change between the current and previous points digitized is greater than 1 resolution element and less than 32 mils on either axis. Long vectors are identifiable by 0 in the high order bit of the data word, and 5 in the next three bits.

END OF DATA - A word containing a -2, to indicate that the trace feature string has terminated.

DISCRETE ABSOLUTE POINT - used in discrete point mode. Each word contains an unsigned 16 bit integer word for X and Y.



DATA BLOCK FORMATS

AD-A091 942 SYNECTICS CORP ROME N Y F/G 8/10
BATHYMETRIC DATA REDUCTION SYSTEM.(U)
AUG 80 D T ALVAREZ, J R TERENZETTE F30602-76-C-0412
UNCLASSIFIED CJ-0756-A RADC-TR-80-273 NL

3 of 3
AD A
[illegible]

END
DATE
FILMED
1-81
DTIC

EMBEDDED ABSOLUTE POINT - used in trace mode when the change betwe current and previous point is 32 mils or greater. Ea X,Y point is tagged with a -3 in the first word.

ABSOLUTE POINT & DEPTH - used in D-entry mode to denote a sounding The first two words are the X,Y coordinate (unsigned 16-bit integers) and the third word represents the de value as a 32-bit floating point number.

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