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THREE-DIMENSIONAL PERSPECTIVE SOFTWARE FOR REPRESENTATION OF DIGITAL IMAGERY DATA

REPORT NO. 195

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NATIONAL SPACE TECHNOLOGY LABORATORIES

THREE-DIMENSIONAL PERSPECTIVE SOFTWARE

FOR REPRESENTATION OF DIGITAL IMAGERY DATA

by

Bobby G. Junkin

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THREE-DIMENSIONAL PERSPECTIVE SOFTWARE
FOR REPRESENTATION OF DIGITAL IMAGERY DATA

By Bobby G. Junkin*

SUMMARY

A generalized three-dimensional perspective software capability has been developed at the NASA/NSTL Earth Resources Laboratory within the framework of a low-cost computer-oriented geographically based information system using the Earth Resources Laboratory Applications Software (ELAS) operating subsystem. This perspective software capability was developed primarily to support data display requirements at the NASA/NSTL Earth Resources Laboratory. It provides a means of displaying three-dimensional feature space object data in two-dimensional picture plane coordinates and makes it possible to overlay different types of information on perspective drawings to better understand the relationship of physical features. An example topographic data base is constructed and is used as the basic input to the plotting module. Examples are shown which illustrate oblique viewing angles that convey spatial concepts and relationships represented by the topographic data planes.

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THREE-DIMENSIONAL PERSPECTIVE SOFTWARE
FOR REPRESENTATION OF DIGITAL IMAGERY DATA

INTRODUCTION

The NASA/NSTL Earth Resources Laboratory (ERL) has developed several computer software programs and procedures (references 1-4) within the framework of a computer-oriented information system (references 5-6) for the processing and analysis of data from disparate, geographically oriented base maps and from remote sensor aircraft and satellite systems. These different types of information are compiled into data bases which contain information on land use, elevation, slope, soil series, rainfall, population density, etc. The capability to manipulate, store, analyze, display, and disseminate the large volumes of data in these data bases has evolved through research efforts at the ERL (References 5 and 6).

Examples of several practical modular systems, with emphasis on low cost, are given in reference 5. These systems, an example of which is shown in figure 1, consist of an image display system, a graphic digitizer, a small digital computer, and an output recording device. All hardware components used in these low-cost data processing systems are off-the-shelf. The software consists of a Landsat multispectral scanner data reformatting program, a series of supervised and unsupervised spectral-pattern-recognition programs, a program to reference the image

data to a map base, a data storage and retrieval program, and various applications programs.

The software support concept has evolved into an operating subsystem referred to as the Earth Resources Laboratory Applications Software (ELAS) (reference 7). This software system accepts as input a variety of data types including topographic data tapes from the National Cartographic Information Center (NCIC) (reference 8). Users of these data require oblique viewing angles to convey spatial concepts and relationships represented by the topographic data planes. For example, the relationship of Landsat classification components to elevation may be visualized by perspective color mapping of the classification data plane on the topographic elevation data plane. Other graphic information such as aspect or slope can be placed on the perspective plot to relate the data elements to the terrain profile. This report addresses the procedures involved in the development of a generalized three-dimensional perspective software capability to support the above display requirements and presents typical results using a topographic data base.

THREE-DIMENSIONAL GRAPHICS WITH PERSPECTIVE

General Overview

There are several steps required to determine the two-dimensional perspective picture plane coordinates for the display of three-dimensional feature space object data (Reference 9). First, the coordinates of the feature space object are translated to the vantage point coordinate system. Then the vantage point coordinates are rotated through two angles to align with the vantage point line of sight passing through the origin of the reference coordinate system. Finally, the perspective transformation is applied to obtain the two-dimensional picture plane coordinates for the actual display on two-dimensional display devices (i.e., X-Y plotters on CRT screens). An integral part of this display is the removal of hidden lines on the other side of the object from the vantage point.

Coordinate Systems

There are three rectangular coordinate systems involved in the derivation of two-dimensional picture plane coordinates. These are the reference coordinate system (X,Y,Z), the vantage point coordinate system (X',Y',Z'), and the picture plane coordinate system (X'',Y'',Z''). A brief description of each follows.

1. (X,Y,Z) Reference System. This is a right-handed fixed
    system of axes. The coordinates of the vertices of all
    objects as well as the vantage point (X_0, Y_0, Z_0) are given
    in this system.

2. (X',Y',Z') Vantage Point System. The vantage point
    (X_0, Y_0, Z_0) specified in the reference system is taken as
    the origin of the vantage point coordinate system, in
    which coordinates are denoted as (X',Y',Z'). This is a
    left-handed coordinate system wherein the Z' axis goes
    from (X_0, Y_0, Z_0) through the origin of the (X,Y,Z) reference
    system. The X' axis is parallel to the XY plane of the
    (X,Y,Z) reference system.

3. (X",Y") Picture Plane System. This is a two-dimensional
    coordinate system which represents the plane of the actual
    perspective drawing. This plane goes through the origin
    (X,Y,Z) of the reference system and is chosen perpendicular
    to the Z' axis. The X" axis is chosen to lie in the XY
    plane. These coordinate systems are depicted in Figure 2.

Coordinate Transformations

We first consider the translation from the reference
coordinates to the vantage point coordinates. From Figure 3
we see that:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} X_0 - X \\ Z - Z_0 \\ Y_0 - Y \end{bmatrix}$$

(1)

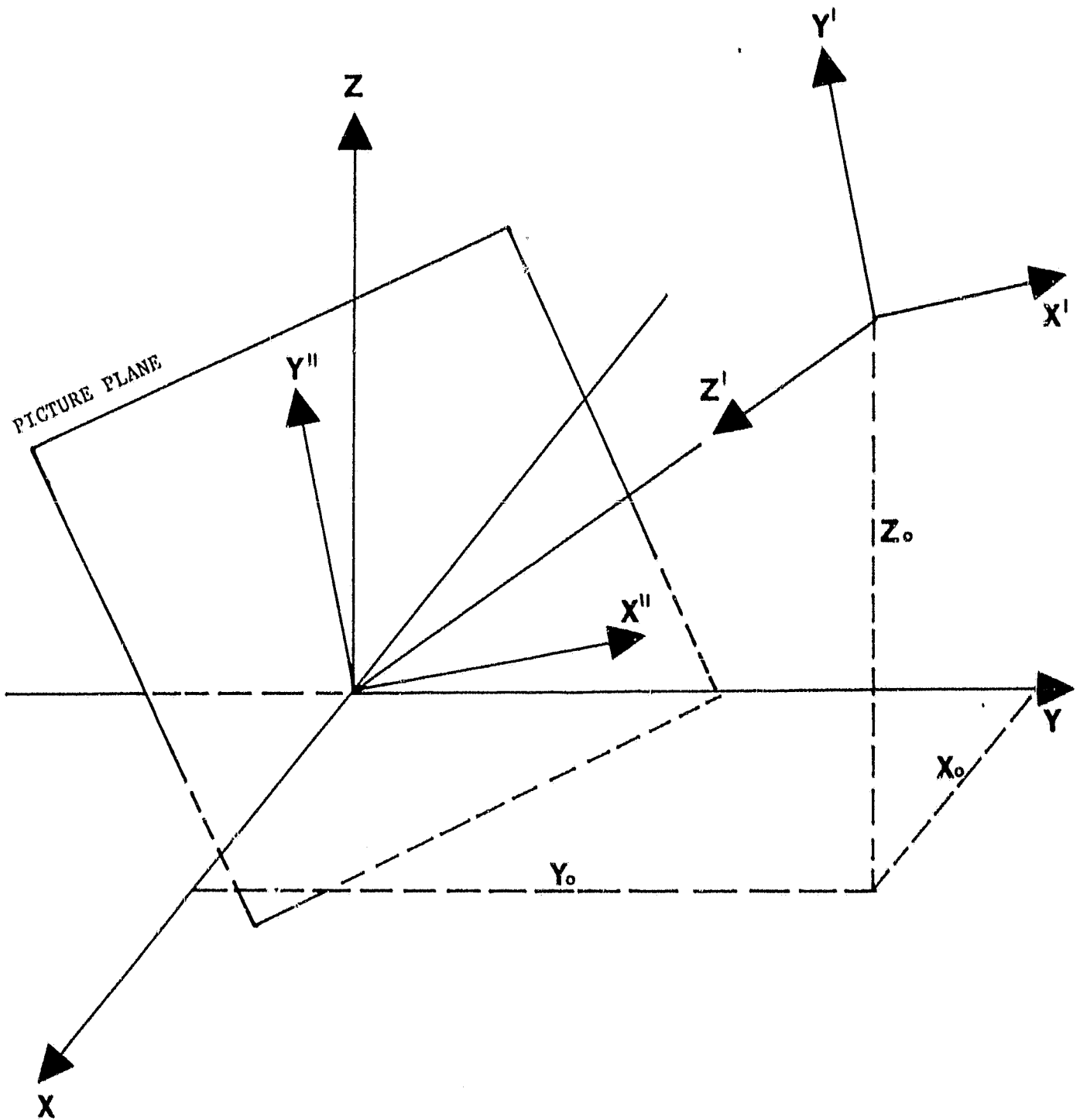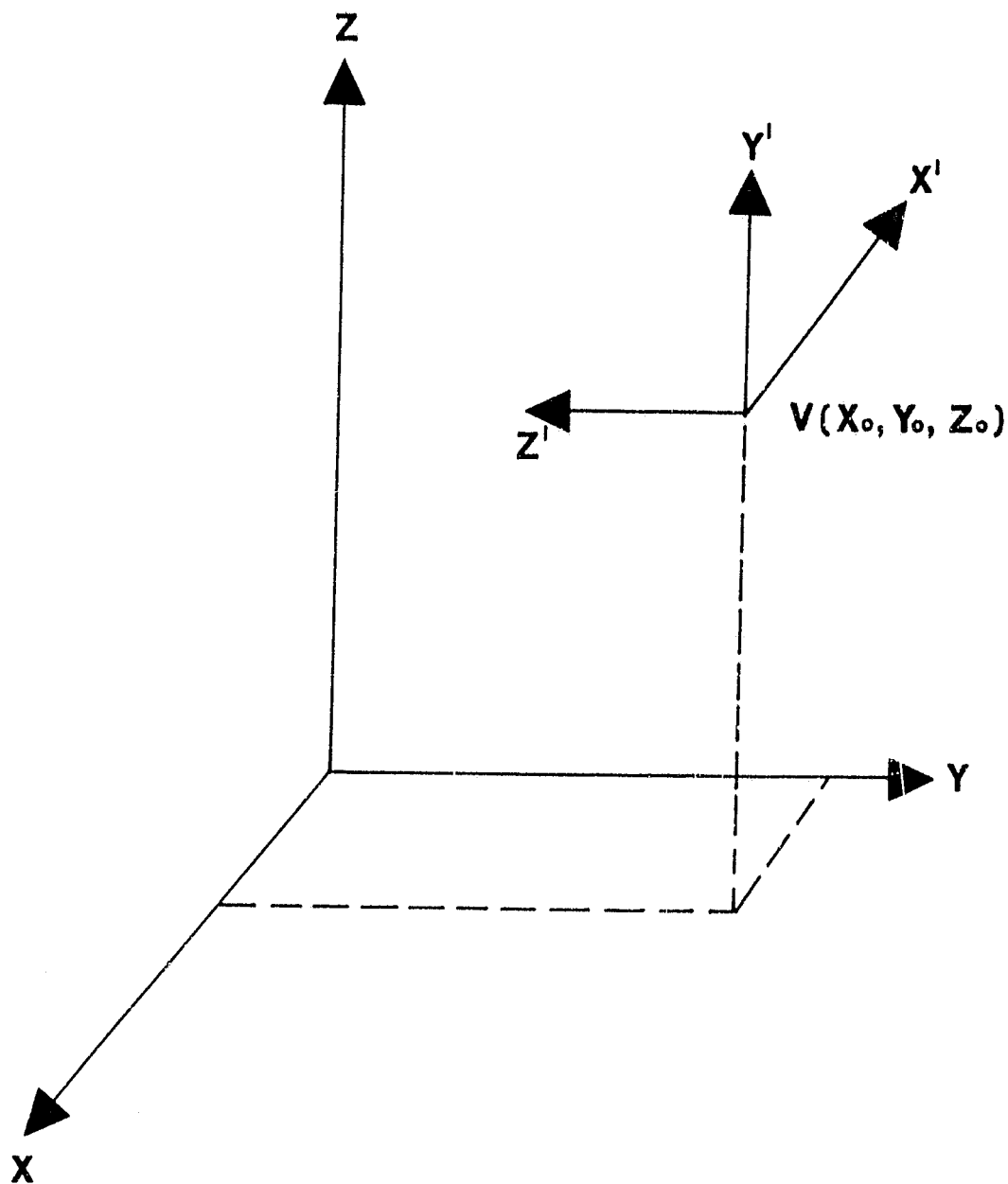Figure 2. REFERENCE, VANTAGE POINT AND PICTURE PLANE COORDINATE SYSTEMS

Figure 3. INITIAL POSITION OF REFERENCE AND VANTAGE POINT
        COORDINATE SYSTEMS

These equations can be expressed more conveniently in matrix form as:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} X - X_o \\ Y - Y_o \\ Z - Z_o \end{bmatrix} \tag{2}$$

or:

$$\bar{X}' = \bar{R}_T \bar{X} \tag{3}$$

Two rotations are now required so that the vantage point coordinate system is oriented whereby the Z' axis goes through the origin of the reference coordinate system. This is accomplished with a rotation about the Y' axis by the angle α, followed by a rotation about the X' axis by the angle β. The rotations about the X' and Y' axes are shown in Figures 4 and 5, respectively. The final rotation in Figure 5 results in the Z' axis passing through the origin of the reference coordinate system. A rotation about the Y' axis through the angle α results in the following transformation matrix:

$$\bar{R}_Y = \begin{bmatrix} \cos\alpha & 0 & -\sin\alpha \\ 0 & 1 & 0 \\ \sin\alpha & 0 & \cos\alpha \end{bmatrix} \tag{4}$$

After this rotation the Z' axis points at (0,0,Z).
The second rotation operates on the result of the first

8
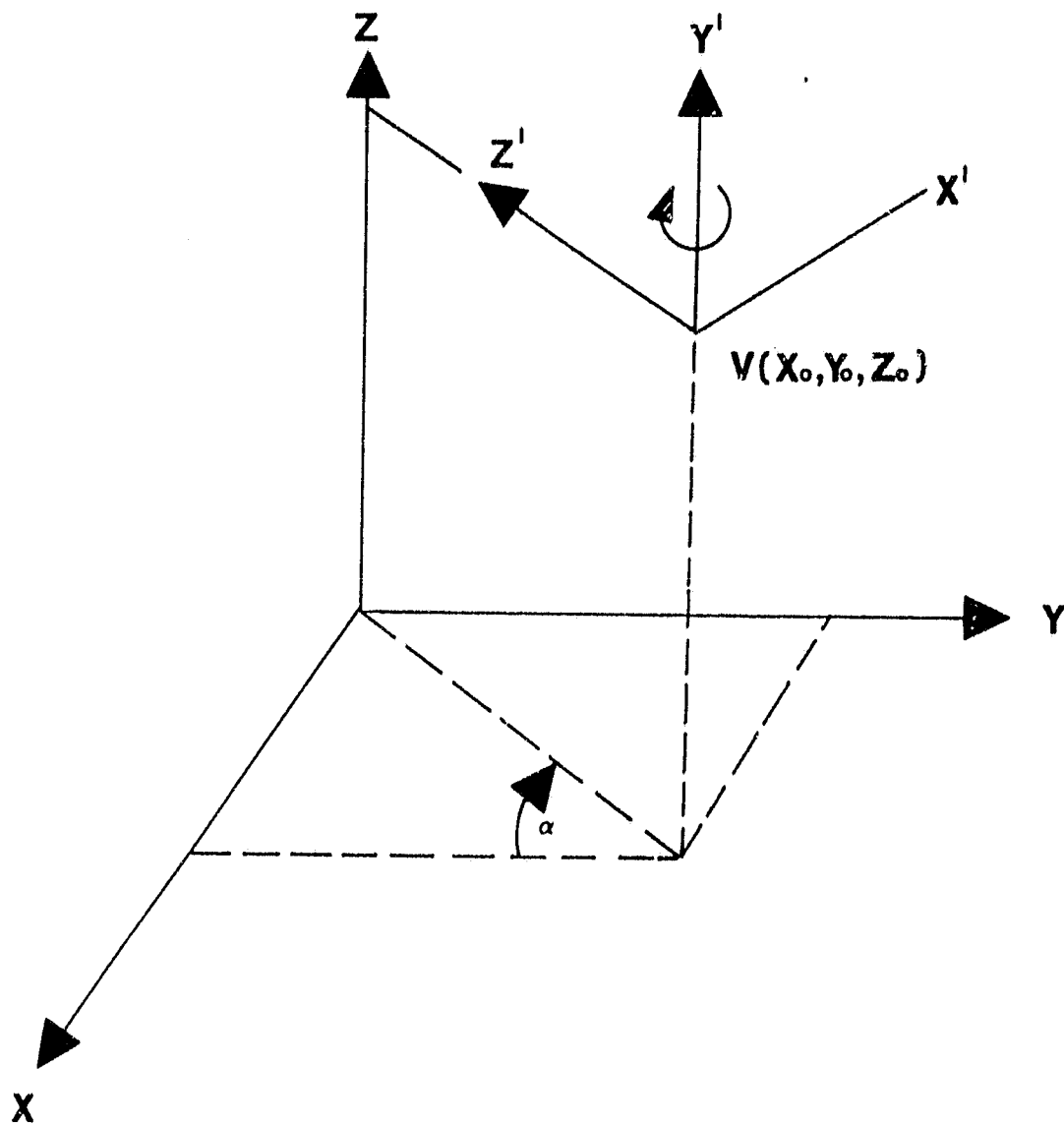
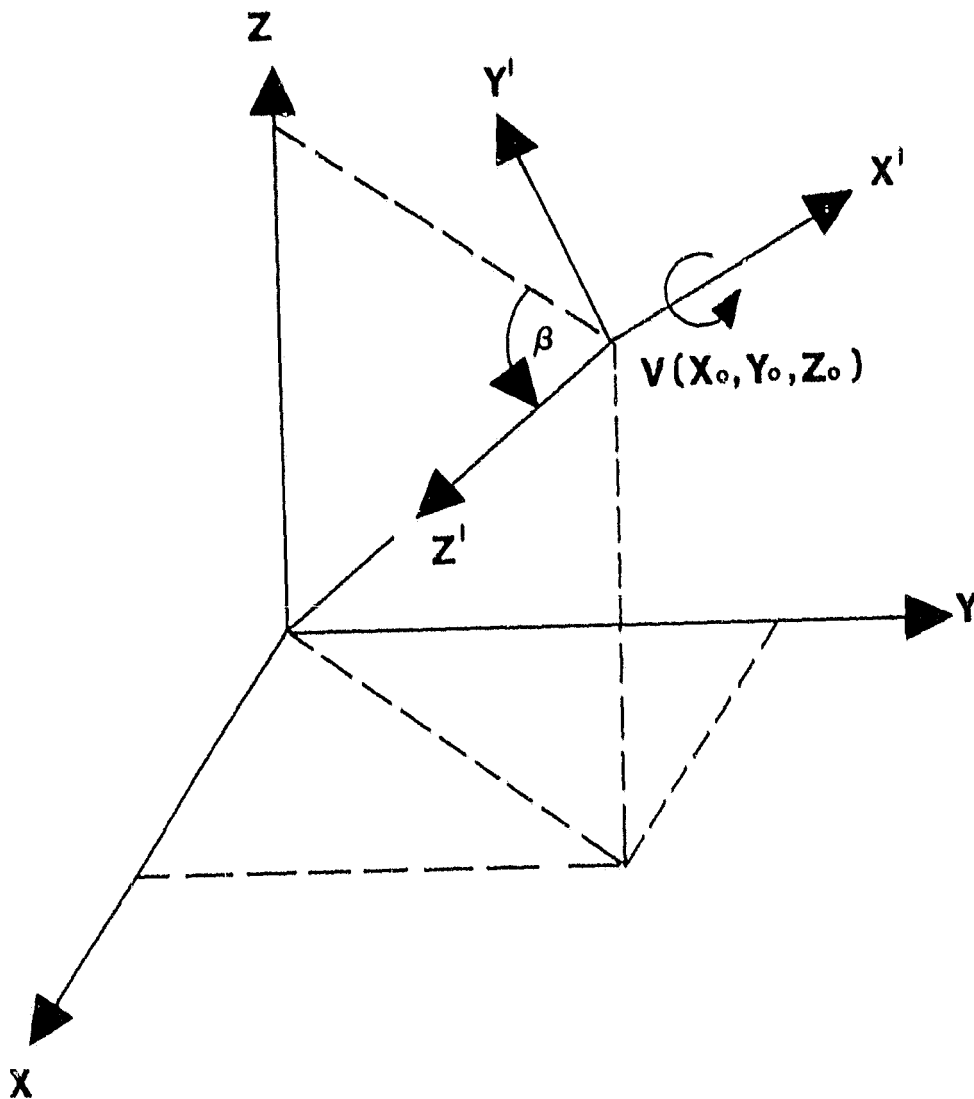Figure 4. ROTATION THROUGH ANGLE α ABOUT Y' AXIS

Figure 5. ROTATION THROUGH ANGLE β ABOUT X' AXIS

rotation and results in the Z' axis going through $(0,0,0)$. This transformation matrix is:

$$\bar{R}_X = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\beta & \sin\beta \\ 0 & -\sin\beta & \cos\beta \end{bmatrix} \tag{5}$$

Thus, the total transformation can be written as:

$$\bar{X}' = \bar{R}_X \bar{R}_Y \bar{R}_T \bar{X} \tag{6}$$

Expanding the above equation yields:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} -(X-X_O)\cos\alpha + (Y-Y_O)\sin\alpha \\ -(X-X_O)\sin\beta\sin\alpha - (Y-Y_O)\sin\beta\cos\alpha + (Z-Z_O)\cos\beta \\ -(X-X_O)\cos\beta\sin\alpha - (Y-Y_O)\cos\beta\cos\alpha - (Z-Z_O)\sin\beta \end{bmatrix} \tag{7}$$

From basic trigonometry, the following relations are obtained from figure 4:

$$\left. \begin{aligned} \sin\alpha &= X_O/d \\ \cos\alpha &= Y_O/d \end{aligned} \right\} \tag{8}$$

and from figure 5:

$$\left. \begin{aligned} \sin\beta &= Z_O/D \\ \cos\beta &= d/D \end{aligned} \right\} \tag{9}$$

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$$d = \sqrt{X_o^2 + Y_o^2}$$

$$D = \sqrt{X_o^2 + Y_o^2 + Z_o^2}$$

(10)

Projective Transformation

Once the Z' axis is oriented to pass through the origin of the reference system, the 3-D coordinates (X',Y',Z') must be projected onto the X"Y"-picture plane to generate the actual 2-D coordinates. This projection is shown in figure 6. Noting similar triangles in this figure, the point V"(X",Y") in the picture plane is related to the point V'(X',Y',Z') in the vantage point system by the following equations:

$$X'' = DX'/Z'$$

$$Y'' = DY'/Z'$$

(11)

Scaling

The final step before displaying the (X",Y") perspective data on a CRT screen or other display device is to scale the data to fit within display limits. Basically, this involves scanning the (X",Y") data to find maximum and minimum X" and Y" values for use in computing linear transformation of the form
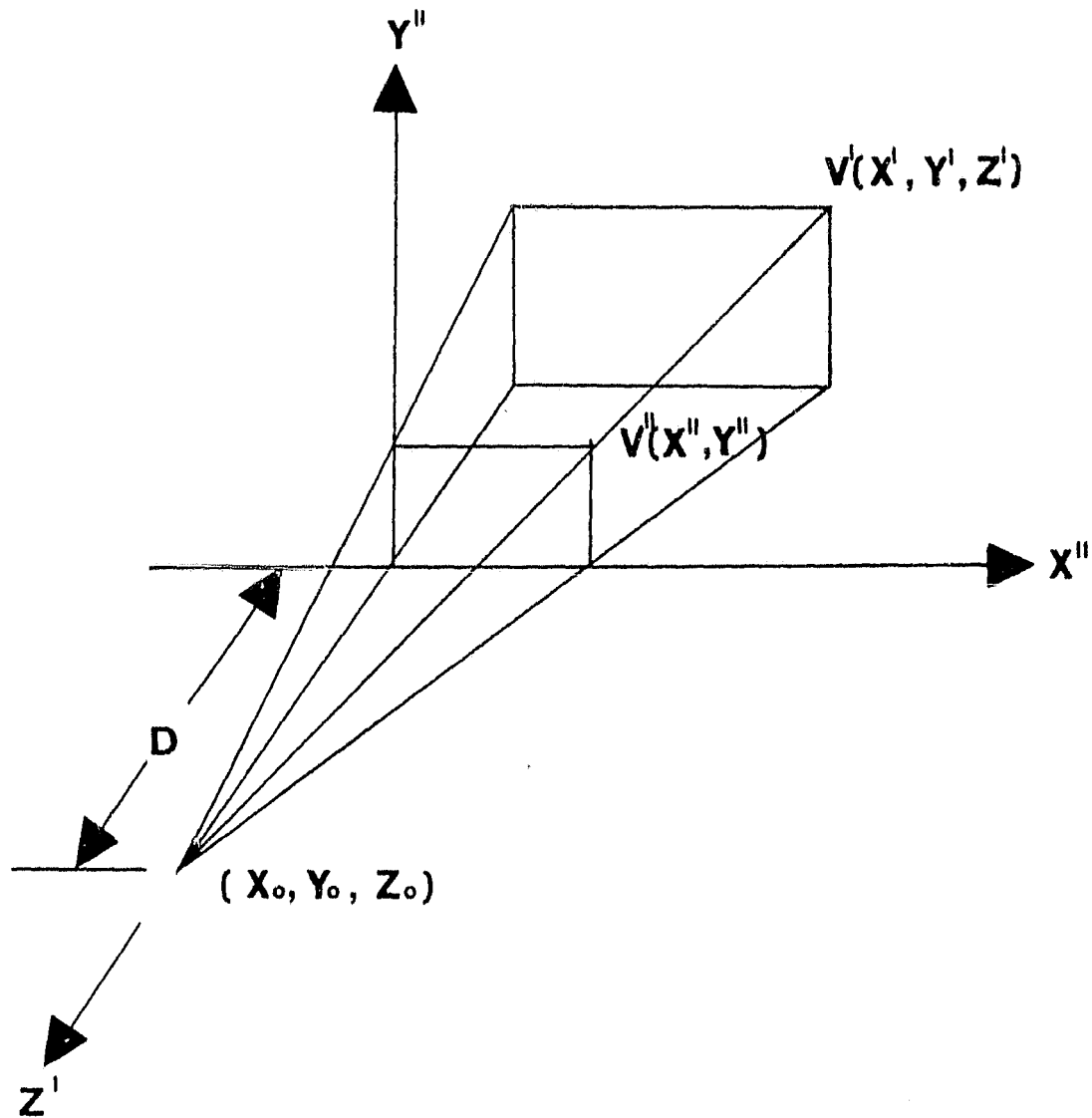
Figure 6.   GEOMETRY FOR PERSPECTIVE PROJECTION

$\hat{Y} = A_0 Y'' + A_1$. For elevation data obtained from contour profiles we want A_0 and A_1 to be such that Y''_{min} is 0 and Y''_{max} is some value Z_{max}. Thus, we have:

$$A_0 Y''_{min} + A_1 = 0$$
$$A_0 Y''_{max} + A_1 = Z_{max} \tag{12}$$

Solving for A_0 and A_1:

$$A_0 = Z_{max}/(Y''_{max} - Y''_{min})$$
$$A_1 = -A_0 Y''_{min} \tag{13}$$

The elevation data values are then computed from:

$$\hat{Y} = \left[Z_{max}/(Y''_{max} - Y''_{min}) \right] \left(Y'' - Y''_{min} \right) \tag{14}$$

Hidden Line Procedure

There are several algorithms in the literature for eliminating hidden lines from the perspective representation of data in three-space (references 10-14). The two-dimensional representation of a three-dimensional surface consists of line segments of a succession of curves. The basic approach used herein is to eliminate all of those line segments which are behind other surfaces and which would not be visible in a plot of the data in two dimensions. A lower boundary (or

horizon array) for all lines is set up below which no line
is drawn. Visibility arrays are set up and then the line
segment points of the curve closest to the observer are
tested. If the point is visible then it is inserted in the
visibility array and becomes a point in the horizon array.
If it is not visible then the next point of the line segment
is tested and the process repeated until all points along
the curve have been tested. The visibility array now contains
the points for plotting the first curve in the foreground.
This logic is then applied to the line segment points of the
next curve furthest from the observer. At each step the
horizon array is also tested and updated.

INITIAL APPROACH

Background

Most large-scale computer facilities have some form of software capability for the graphic display of three-dimensional feature space data in two-dimensional form. Initial investigations at the NASA/ERL revealed that there was no 3-D software capability available from local vendors for implementation on the NASA/ERL computer system. Subsequent efforts led to the development and implementation of a basic 3-D program for a specific function.

Program Implementation

The complete program as developed on the NASA/ERL computer system for a specific function is shown in figure 7. Buffer arrays are defined as shown in this figure. The DATAPLOT software routines PLOTS, PLOT and DPINIT are used to create the plot file for plotting on the STATOS plotting system. An offset origin on the STATOS is defined and boundary vectors and loop counters are initialized. The logical parameters A, B, and S(I,J) are used in the "hidden-line" logic whereby a visibility check is performed on each point along a curve to determine if it is hidden by other parts of the surface. The domain of the function $Z = F(X,Y)$ is also defined as shown in this figure.

Results

One example of a surface that can be represented in a perspective display plot is defined by the following
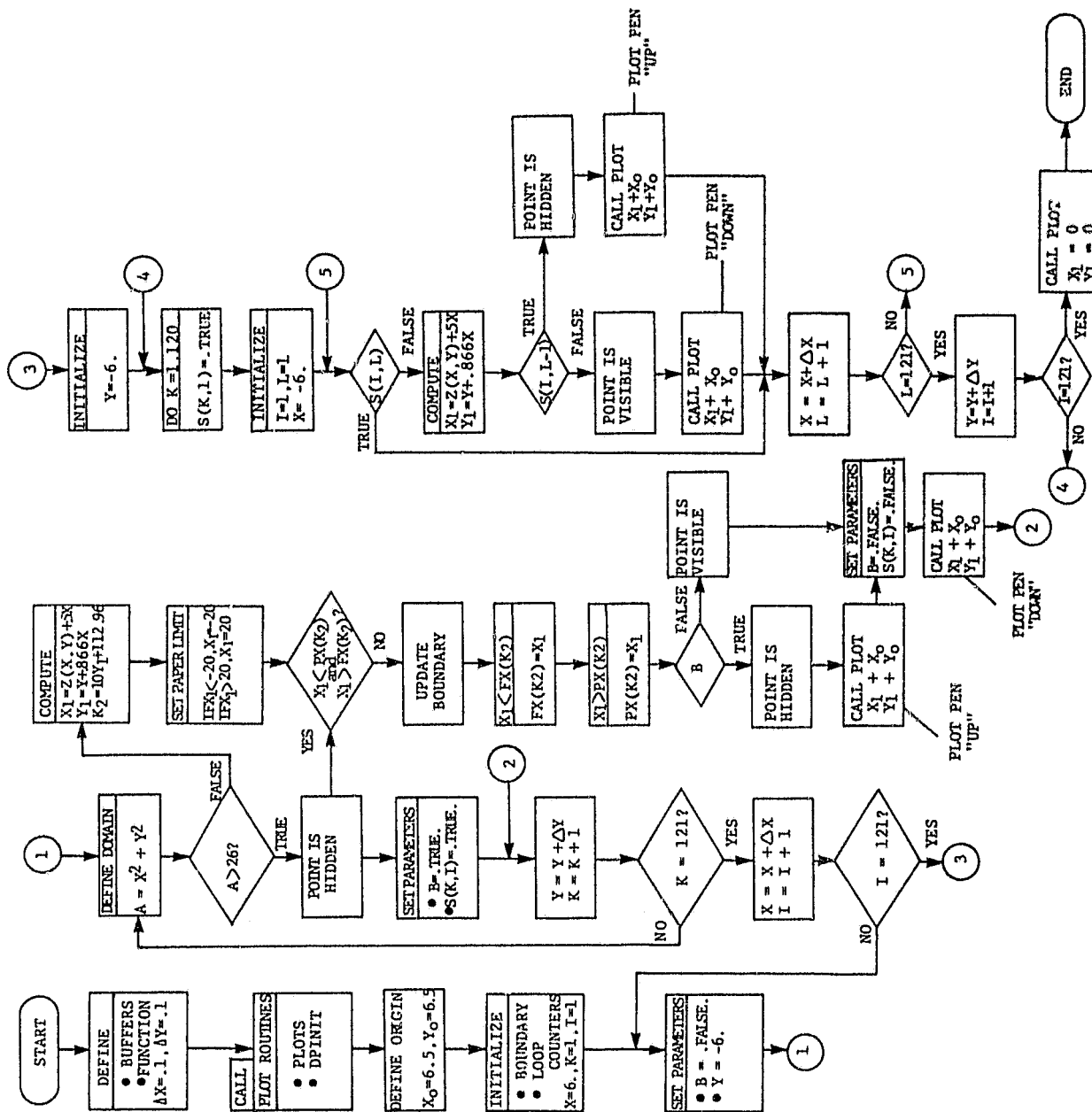
Figure 7. FLOW CHART FOR THREE-DIMENSIONAL PERSPECTIVE SOFTWARE USING A SPECIFIC FUNCTION

START

DEFINE
• BUFFERS
• FUNCTION
$\Delta X = .1, \Delta Y = .1$

CALL
PLOT ROUTINES
• PLOTS
• DPINIT

DEFINE ORIGIN
$X_o = 6.5, Y_o = 6.5$

INITIALIZE
• BOUNDARY
• LOOP
  COUNTERS
$X = 6., K = 1, I = 1$

SET PARAMETERS
• B = .FALSE.
• Y = -6.

DEFINE DOMAIN
$A = X^2 + Y^2$

$A > 26?$

POINT IS HIDDEN

SET PARAMETERS
• B = .TRUE.
• S(K,I) = .TRUE.

$Y = Y + \Delta Y$
$K = K + 1$

$K = 121?$

$X = X + \Delta X$
$I = I + 1$

$I = 121?$

COMPUTE
$X_1 = Z(X,Y) + 5X$
$Y_1 = Y + .866X$
$K_2 = 10Y_1 + 112.96$

SET PAPER LIMIT
$IFX_1 < -20, X_1 = -20$
$IFX_2 > 20, X_1 = 20$

$X_1 < FX(K_2)$ and $X_1 > FX(K_2)?$

UPDATE BOUNDARY

$X_1 < FX(K_2)$
$FX(K_2) = X_1$

$X_1 > PX(K_2)$
$PX(K_2) = X_1$

B

POINT IS VISIBLE

POINT IS HIDDEN

CALL PLOT
$X_1 + X_o$
$Y_1 + Y_o$
PLOT PEN "UP"

SET PARAMETERS
B = .FALSE.
S(K,I) = .FALSE.

CALL PLOT
$X_1 + X_o$
$Y_1 + Y_o$
PLOT PEN "DOWN"

INITIALIZE
$Y = -6.$

DO K = 1,120
$S(K,I) = .TRUE.$

INITIALIZE
$I = 1, L = 1$
$X = -6.$

$S(I,L)$

COMPUTE
$X_1 = Z(X,Y) + 5X$
$Y_1 = Y + .866X$

$S(I,L-1)$

POINT IS HIDDEN

POINT IS VISIBLE

CALL PLOT
$X_1 + X_o$
$Y_1 + Y_o$
PLOT PEN "UP"

CALL PLOT
$X_1 + X_o$
$Y_1 + Y_o$
PLOT PEN "DOWN"

$X = X + \Delta X$
$L = L + 1$

$L = 121?$

$Y = Y + \Delta Y$
$I = I + 1$

$I = 121?$

CALL PLOT
$X_1 = 0$
$Y_1 = 0$

END

single-valued continuous exponential function:

$$Z = EXP \quad -.225(2X-Y)^2 - 3.239(Y-.5X)^2 \tag{15}$$

An example of a perspective function that can be used to generate (X',Y') data for 2-D display plotting is given by:

$$\left. \begin{aligned} X'' &= Z' + X' \cos\alpha \\ Y'' &= Y' + X' \sin\alpha \end{aligned} \right\} \tag{16}$$

An example plot using these functions is shown in figure 8. This plot was created using a function domain of $-6 \le (X',Y') \le 6$. This example serves to illustrate one approach for the display of three-dimensional data in two-dimensional perspective. An obvious shortcoming to this approach is the function definition requirement. A much more flexible and efficient approach is described in the next section.
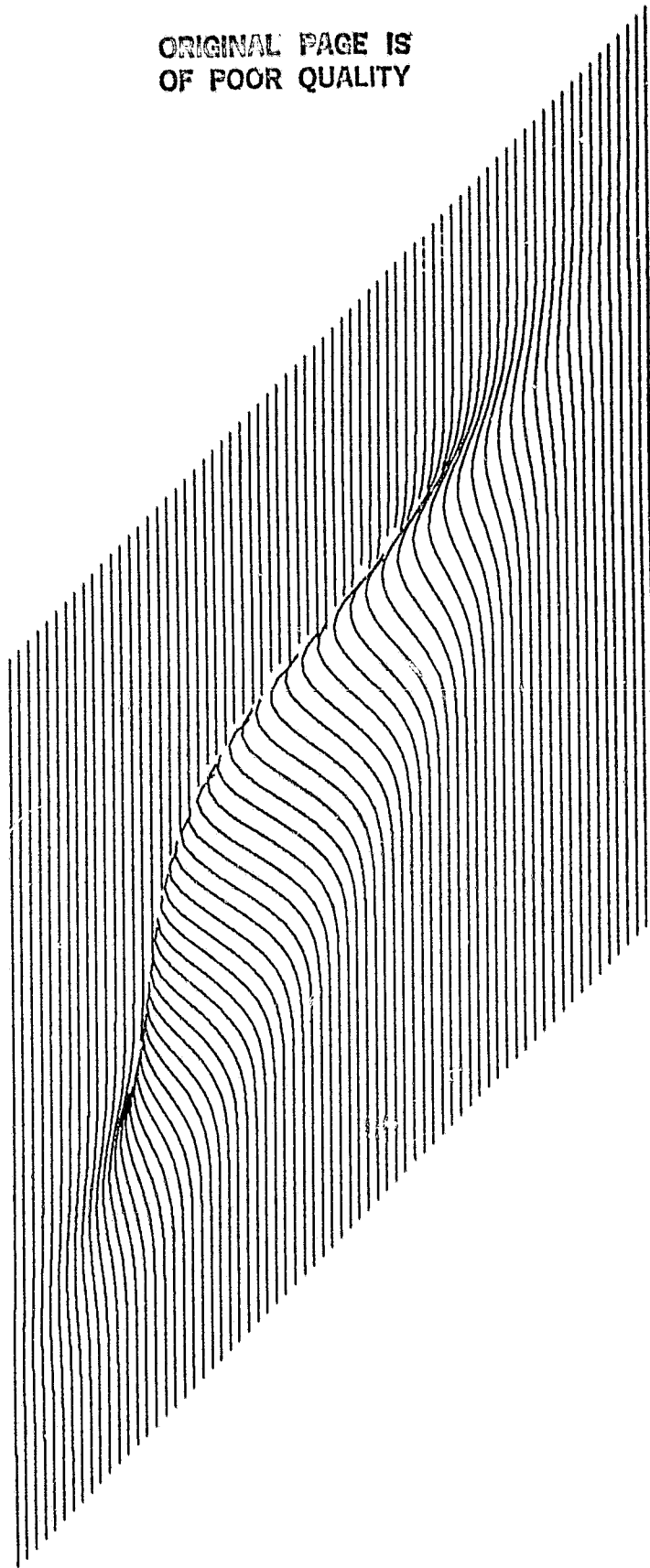
Figure 8. EXAMPLE OF THREE-DIMENSIONAL PLOT FOR A SPECIFIC FUNCTION

THREE-DIMENSIONAL SOFTWARE DEVELOPMENT

Discussion

The development of three-dimensional perspective software capability to support the display requirements addressed earlier in this report has been accomplished under the ELAS operating subsystem. A functional diagram of this geographically based information system is shown in figure 9. The generalized three-dimensional program as developed for running on the NASA/ERL computer system is summarized in the flow chart shown in figure 10. Various functional programs such as CFSUB, RDWR, RIO, ILBYTE, and ISBYTE were used in this development.

Description of Program

The application module name for this program is referred to as PDDD. This application module determines the two-dimensional perspective picture coordinates for the display of three-dimensional data, such as the NCIC elevation data that has been processed through the topographic application modules (reference 15). This program provides for the overlay of other types of data onto this perspective. The program can be executed either in the demand (interactive) or batch mode of operation. The data are processed beginning with the surface profile closest to the observer. Each profile is read and scaled according to a previously determined scale factor. Overlay data are then extracted from the appropriate input. The (X'', Y'') picture plane data and the overlay data
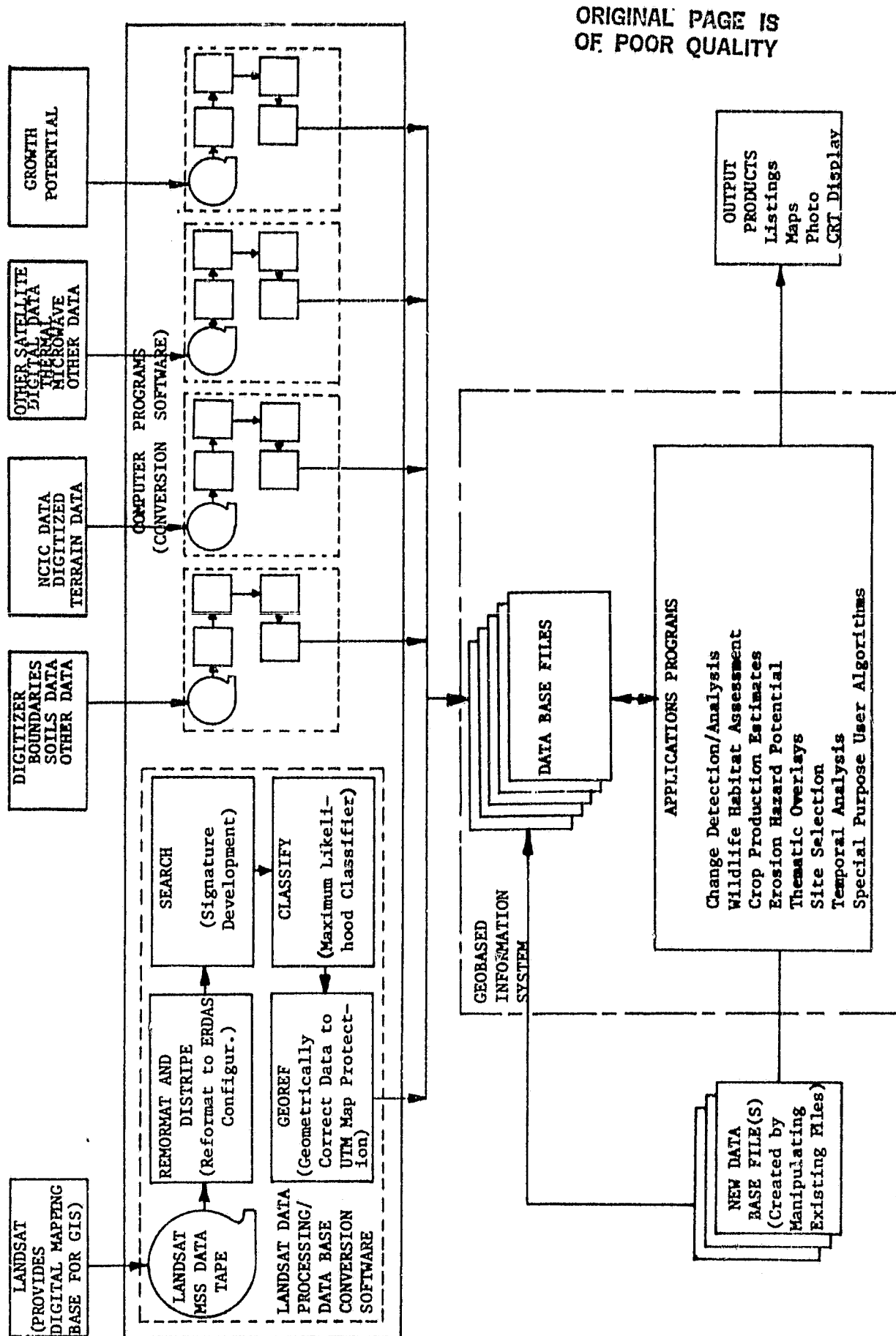
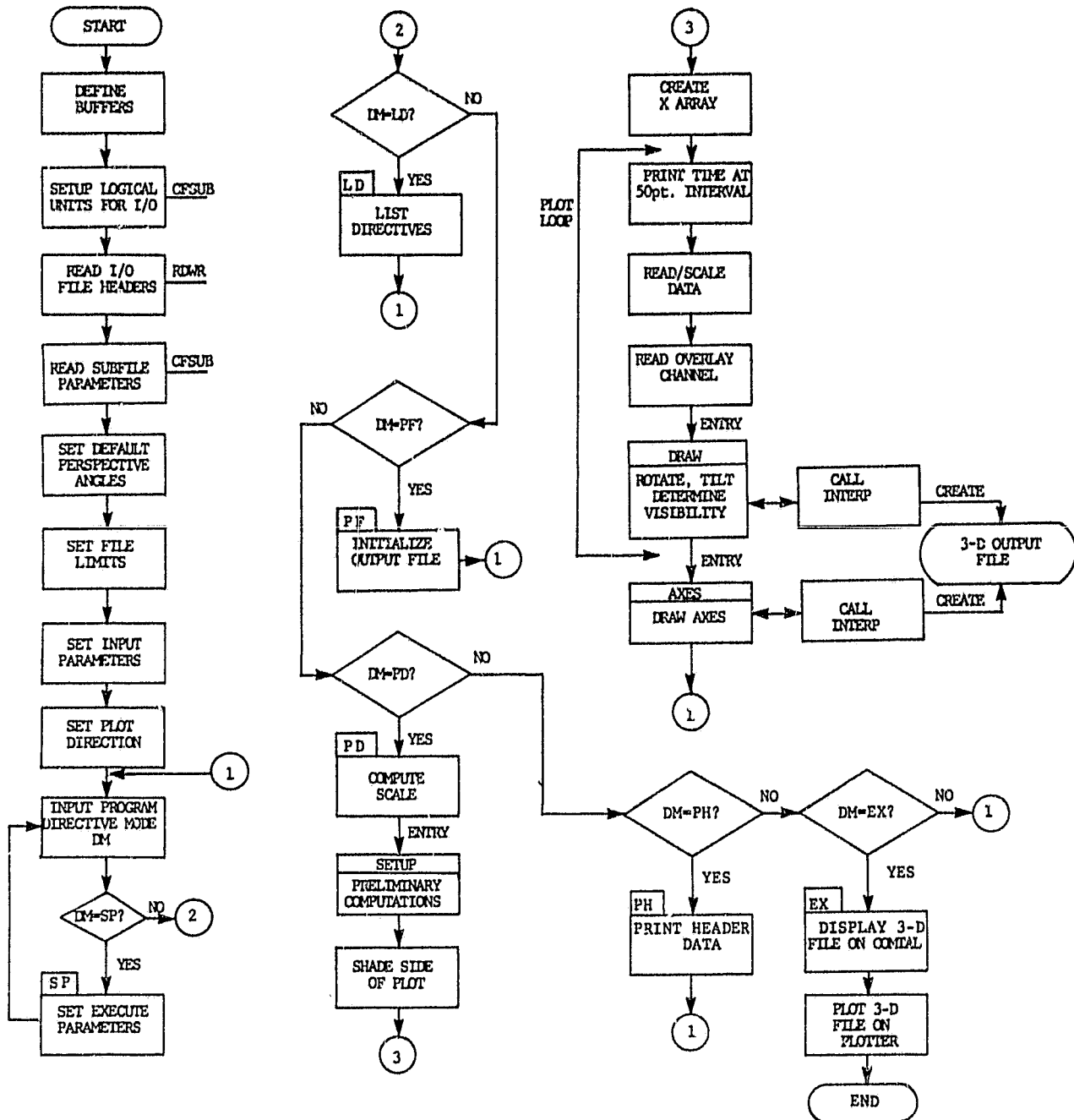Figure 9. GEORAPHICALLY BASED INFORMATION SYSTEM

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Figure 10.   FLOW CHART FOR GENERALIZED THREE-DIMENSIONAL PERSPECTIVE SOFTWARE

are then passed to the subroutine HIDLIN (figure 11) to determine if any portion of the line is visible. Visible segments of the line are then passed to the subroutine INTERP (figure 12) which writes the data to a disk file for subsequent plotting on an X-Y type plotter or viewing on an image display device.

Directives and Operating Instructions

The input for PDDD is a standard ELAS data file referred to as ID1. The output is another ELAS data file known as ODF. Two channels of data from ID1 are specified as input channels; these two channels may or may not be distinct depending on what type of output the user wants. For example, suppose the user has a two-channel input file where channel 1 contains NCIC elevation data as output from TOP6. Then each value in channel 1 represents a range of elevations. Suppose channel 2 contains the Landsat classification values that correspond to the elevation values for each pixel in channel 1. If the user specifies the input channels as 1 and 2, the program would output the classification value contained in channel 2 at the 3-D perspective coordinate (line, element and elevation value) determined by the corresponding data of channel 1. If the user specifies the input channels as 1 and 1, the program would output the elevation value in channel 1 at the 3-D perspective coordinate determined by the same data (line, element, and elevation value) in channel 1.
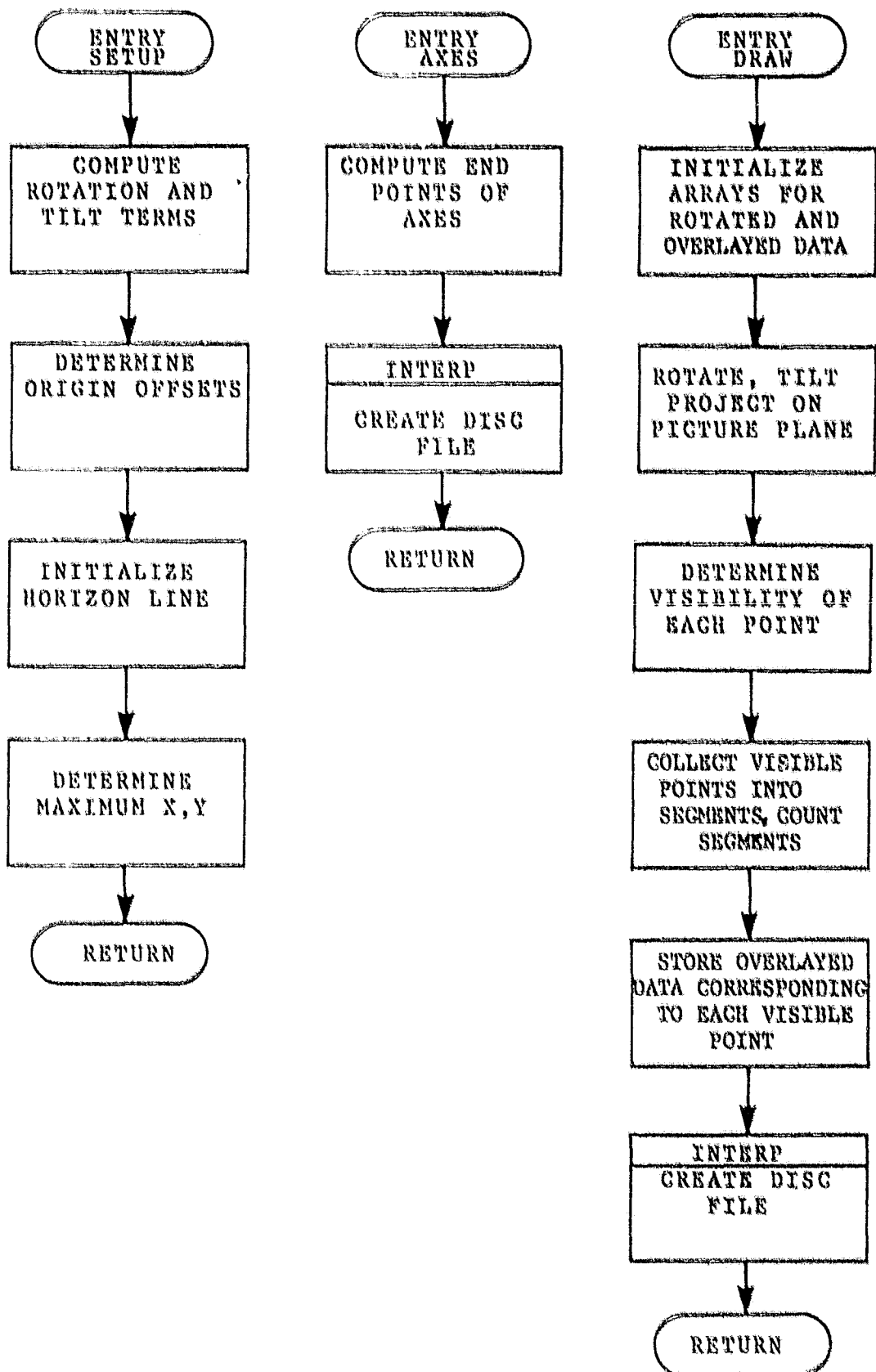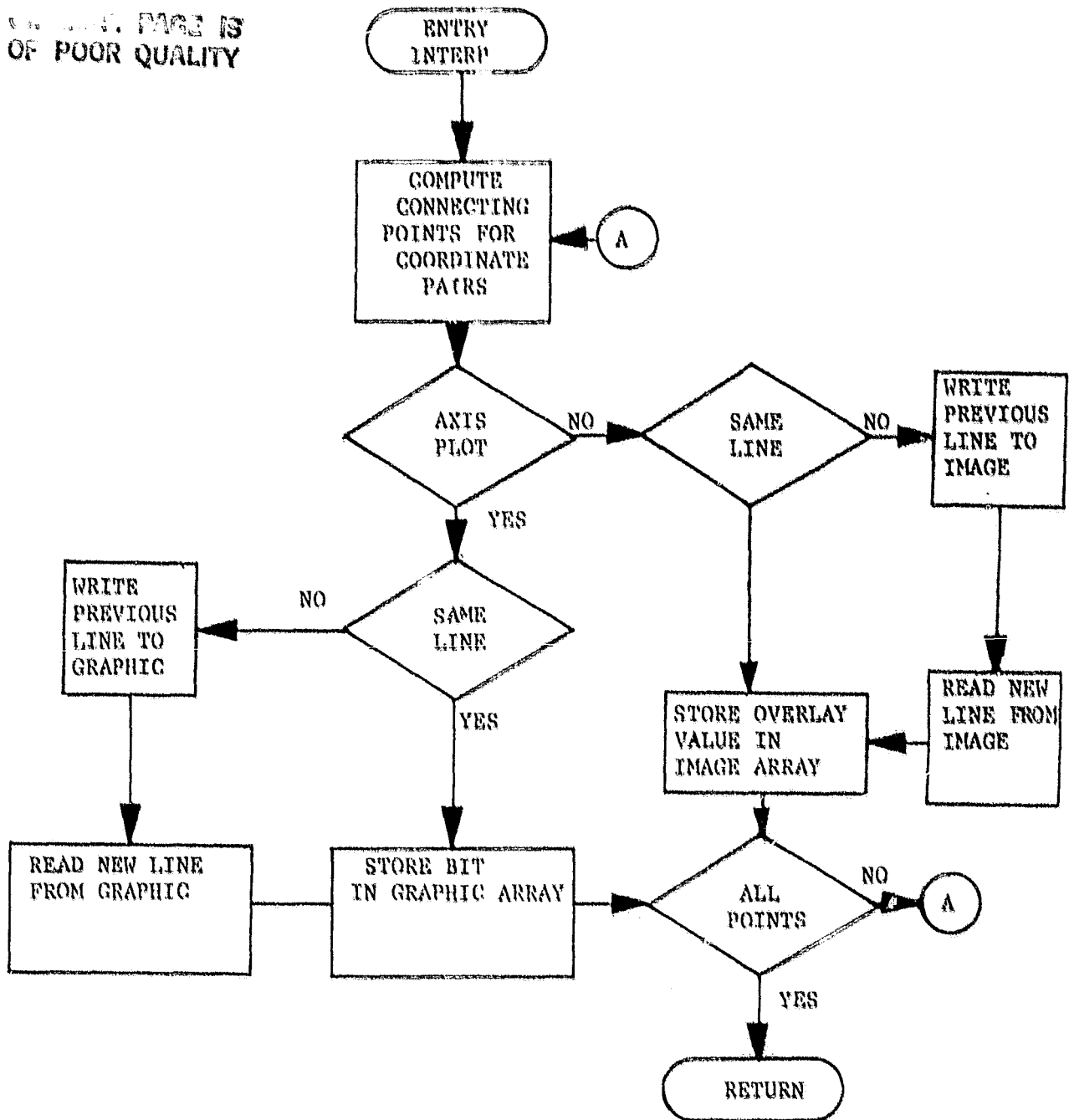
Figure 11. FLOW CHART FOR SUBROUTINE HIDLIN

Figure 12. FLOW CHART FOR SUBROUTINE INTERP

The following directives control the operation of the
program:

LD   -   List directives.

SP   -   Set parameters.

PH   -   Print header information (input and output).

PF   -   Prepare file. Write zeroes in output channel.

PD   -   Plot data. (PD, R, T where R = rotation angle
         in degrees and T = tilt angle in degrees.)

The following parameters, with typical values in parentheses,
are required input:

IL   -   Initial line (1).

LL   -   Last line ($\leq$ IL + 1024).

IE   -   Initial element (1).

LE   -   Last element ($\leq$ IE + 1024).

NCH   -   Number of input channels (2).

CH   -   Channel numbers for input (1,2).

INCL   -   Input line increment (1).

INCE   -   Input element increment (1).

XOF   -   X offset to plot origin (10).

YOF   -   Y offset to plot origin (10).

NCO   -   Number of output channels (1).

CHO   -   Channel number for output (1).

SDIS   -   Maximum scaled data value (50).

X   -   Number of rasters per element on X-axis (2).

Y   -   Number of rasters per element on Y-axis (4).

TOPOGRAPHIC DATA BASE CONSTRUCTION FOR 3-D INPUT

Digitized topographic elevation data are obtained from the National Cartographic Information Center (NCIC) in the planar format. These data are digitized from 1:250,000-scale maps and are available from NCIC on 800- or 1600-BPI tapes.

These data serve as input to a series of three topographic application modules for the construction of a topographic data base and subsequent input to the three-dimensional plotting module PDDD. The first module consists of six overlays--TOP0, TOP1, TOP2, TOP3, TOP4, and TOP5; a second module (TOP6) computes slope, aspect, and slope length on the output of TOP5; a third module (T6CH) computes the average north-south slope and the average east-west slope in addition to the four variables computed in TOP6. Basically, these modules reformat the NCIC data from tape into the ELAS data file format, rotate the data 90 degrees to a north-south orientation, compute mapping coefficients that relate transposed plate coordinates to UTM coordinates (eastings and northings), resample the 16-bit data to a UTM grid file, and use this file to compute slope, aspect, slope length, and average slopes. These modules are summarized in figure 13. A technical writeup of these procedures with a topographic data base example is contained in reference 15.

INPUT SETUP

TAPE-TO-DISC
NCIC CELL SIZE – 63.5 METERS

ROTATION – E/W to N/S

MAPPING EQUATIONS
$$x = A_1 + A_2 X_E + A_3 Y_N$$
$$y = B_1 + B_2 X_E + B_3 Y_N$$

RESAMPLING, PART 1
  INPUT PARAMETERS

RESAMPLING, PART 2
  RESAMPLE TO DESIRED CELL SIZE

TOPOGRAPHIC PARAMETERS
  – ELEVATION
  – SLOPE
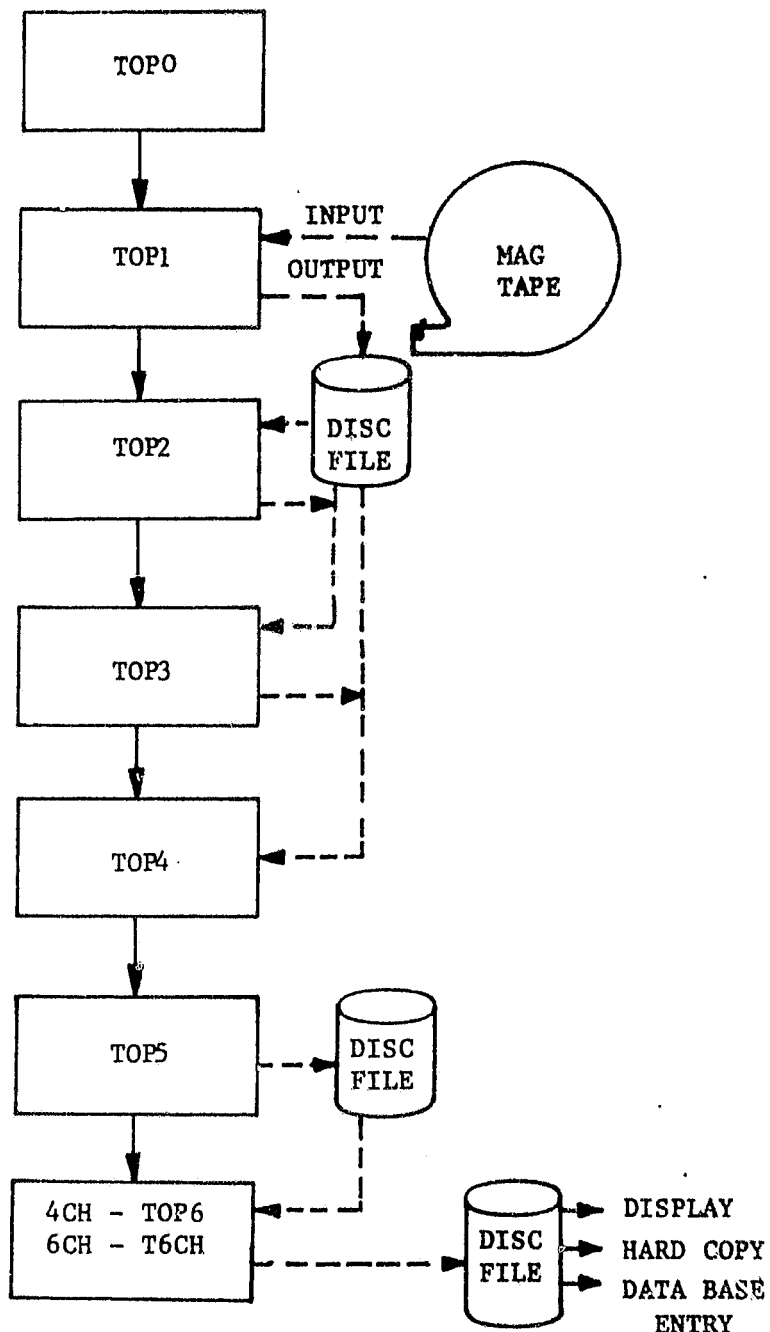 – ASPECT
  – SLOPE LENGTH
  – E/W SLOPE
  – N/S SLOPE

TOPO

TOP1   INPUT   MAG
        OUTPUT   TAPE

TOP2   DISC FILE

TOP3

TOP4

TOP5   DISC FILE

4CH – TOP6   DISC   DISPLAY
6CH – T6CH   FILE   HARD COPY
                      DATA BASE
                      ENTRY

Figure 13. NASA/ERL TOPOGRAPHIC DATA PROCESSING AND ANALYSIS SOFTWARE OVERVIEW

RESULTS USING OLYMPIC NATIONAL PARK TOPOGRAPHIC DATA BASE

The TOPO application modules were used to construct a multi-channel topographic data base file containing elevation, slope, aspect and slope length parameters for the Olympic National Park in the State of Washington at a cell size of 50 meters x 50 meters. Another channel in this data base contains the results of classifying a Landsat MSS data set for this area and subsequently improved by using elevation data. The park encompasses some one million acres and includes the Olympic Mountains. Elevations in the Olympic Park range from sea level to approximately 8,000 feet with variations in vegetation responding to severe changes in terrain and rainfall patterns within the park.

A vegetation-type land cover classification derived from the Landsat MSS data and improved using NCIC elevation data is shown in figure 14. Further details on the derivation of these results are given by Cibula in reference 16. The color codes for the 21 classes are shown in figure 15. The relationship of the classification components to the elevation components may be visualized from figure 16 which contains the perspective color mapping of the classification data plane on the topographic elevation data plane. This perspective plot was obtained using a viewing rotation angle of -10 degrees and a tilt angle away from the viewer of 45 degrees. A backside view of a section of the elevation and classification data planes for this same area is shown in figure 17.
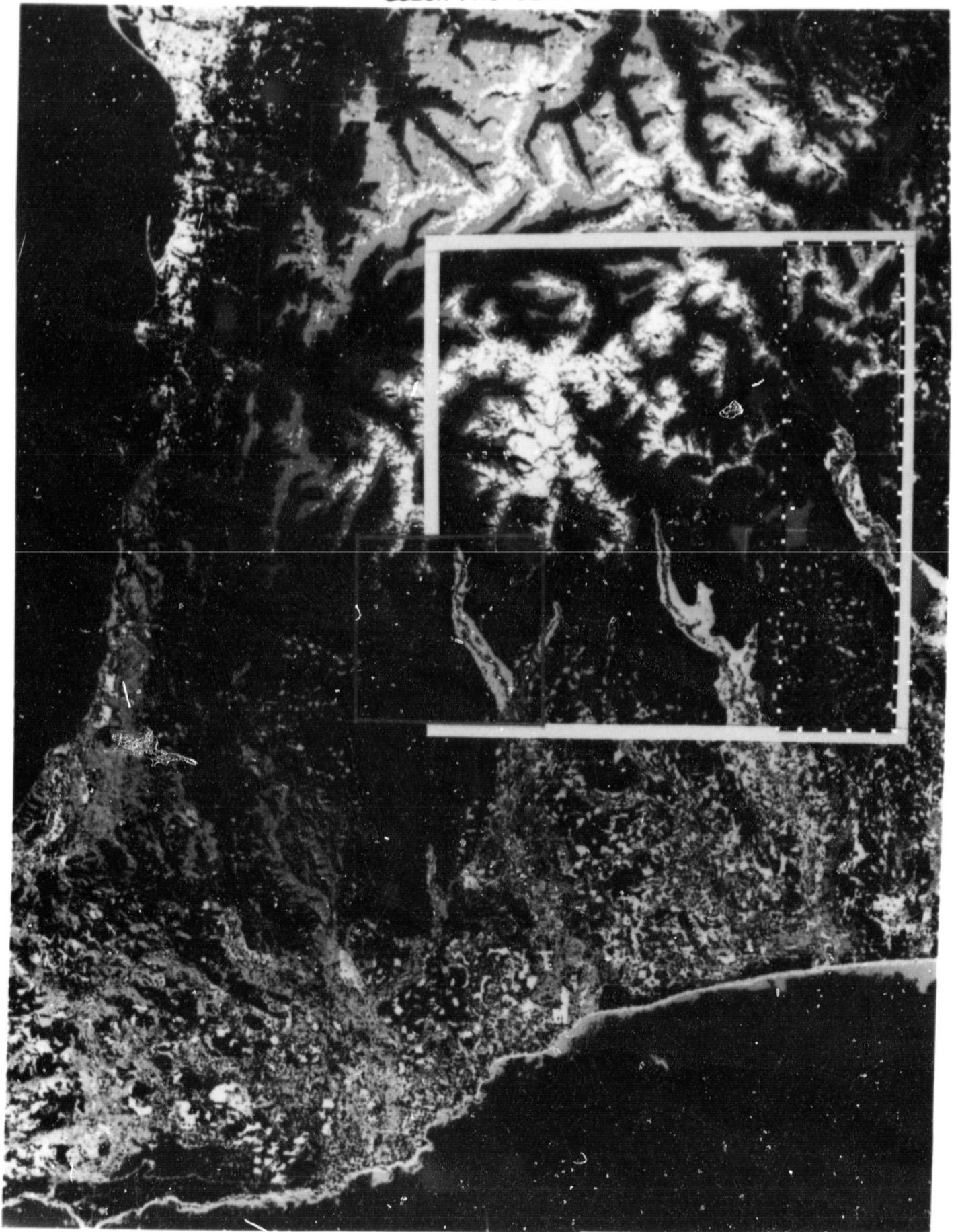
Figure 14.- Vegetation type land cover classification derived from Landsat MSS data.

Figure 15. COLOR CODES FOR OLYMPIC NATIONAL PARK VEGETATION CLASSIFICATION DERIVED FROM LANDSAT MSS DATA

| CLASSIFICATION	COLOR CODE	DESCRIPTION
1		WATER
2		HARDWOODS OR HARDWOOD/CONIFEROUS MIX
3		LOWLAND HARDWOOD OR HARDWOOD/CONIFEROUS MIX; MAY INCLUDE BRUSH OR SLASH
4		AGRICULTURAL FIELDS WITHOUT VEGETATION OR WITH VERY LITTLE (24); CLEAR CUT AREAS; SLASH; CLEAR CUTS WITH EARLY REGENERATION (c.a. 20-30% VEGETATION COVER OR LESS), CONCRETE, OTHER INERTS (INCLUDES SOME URBAN)
5		PASTURE & OTHER GRASSLANDS
6		BEACH, RIVER GRAVELS, WET SAND, DRIFTWOOD, MODERATELY DARK COLORED INERT MATERIALS
7		SHADOWS
8		SNOW, ICE OR GLACIERS
9		SCRUB; HIGH ELEVATION HARDWOOD; VINE MAPLE & SITKA ALDER
10		ALPINE MEADOWS (CLASS 44 WITH SPARSE VEGETATION)
11		SUB-ALPINE FOREST; SILVER FIR, MOUNTAIN HEMLOCK, SUB ALPINE FIR
12		WESTERN HEMLOCK, DOUGLAS FIR, SILVER FIR
13		WESTERN HEMLOCK, DOUGLAS FIR
14		LOWLAND WESTERN HEMLOCK, & SITKA SPRUCE
15		COASTAL HEMLOCK, CEDAR; SOME REGENERATION OF THESE SPECIES IS INCLUDED (41)
16		BARE ROCK, IN MOUNTAINS
17		HIGH ELEVATION BURN AREAS WITH PARTIAL REGENERATION
18		
19		HARDWOODS (RED ALDER) OR HARDWOOD/CONIFER MIX OF VARYING DEGREES
20		
21		

31

Figure 17.- A backside perspective view.

Figure 18 shows a section of this same area with no rotation and 60 degrees tilt. The displays in figures 16, 17, and 18 can be located in figure 14 by the indicated boundary markings. These results are but a few examples of how three-dimensional perspective graphics can be used to convey spatial concepts and relationships represented by topographic data planes.

Figure 18.- Perspective relationship of classification to elevation for no rotation and a tilt of 60 degrees.

35

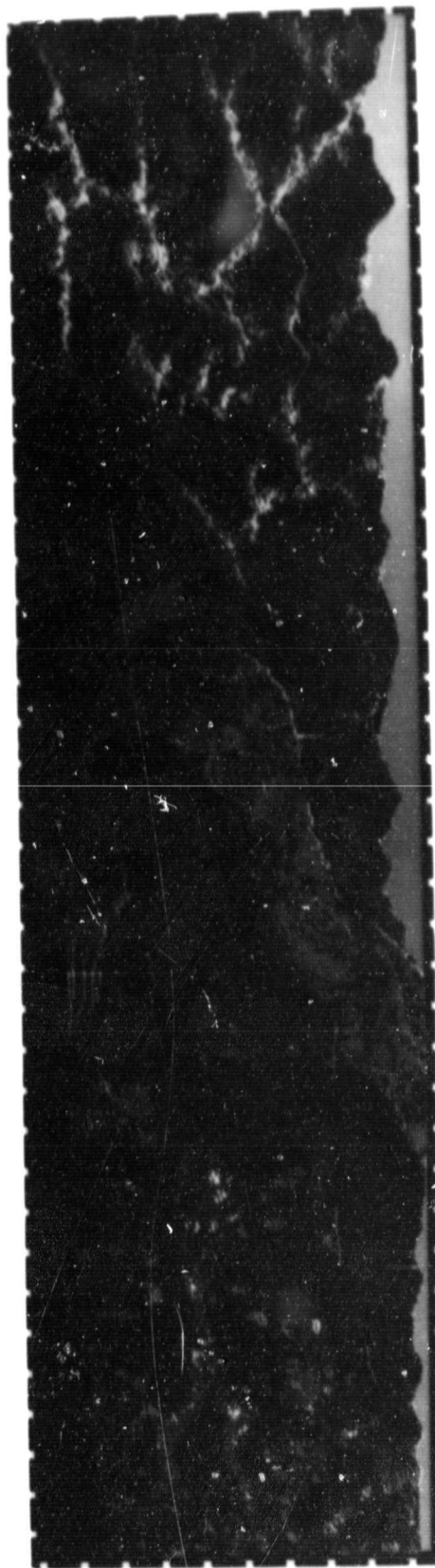# CONCLUDING REMARKS

A generalized three-dimensional perspective software capability has been developed at the NASA/ERL within the framework of the Earth Resources Laboratory Applications Software (ELAS) operating subsystem. This perspective software capability provides a means of displaying three-dimensional feature space object data in two-dimensional perspective picture plane coordinates and makes it possible to superimpose disparate or spatial information on perspective drawings to better understand relationships of physical features.

Digitized topographic elevation data obtained from the National Cartographic Information Center are used as input to a series of topographic application modules for the construction of a topographic data base. These data base parameters are subsequently input to the three-dimensional plotting module and serve to illustrate one type of data base input. The relationship of a Landsat classification to elevation is illustrated by the perspective color mapping of the classification data plane on the topographic elevation data plane. The example displays illustrate oblique viewing angles that convey spatial concepts and relationships represented by the topographic data planes.

REFERENCES

1.* Junkin, Bobby G.: A Method for the Processing and Analysis of Digital Terrain Elevation Data. ERL Interim Report No. 177, 1979.

2. Junkin, Bobby G.: A Procedure for Extraction of Disparate Data from Maps into Computerized Data Bases. NASA Reference Publication 1048, October 1979.

3. Pearson, Ronnie W.: MAXL4X--A Large Area Classifier. Proceedings of the Symposium on Machine Processing of Remotely Sensed Data, Purdue University, 1977.

4. Graham, Marcellus H.: Digital Overlaying of the Universal Transverse Mercator Grid with Landsat-Data-Derived Products. NASA TM-58200, 1977.

5. Whitley, Sidney L.: A Procedure for Automated Land Use Mapping Using Remotely Sensed Multispectral Scanner Data. NASA TR R-434, 1975.

6. Whitley, Sidney L.: Low-Cost Data Analysis Systems for Processing Multispectral Scanner Data. NASA TR R-467, 1976.

7.* "ELAS," Earth Resources Laboratory Applications Software. ERL Interim Report No. 183, March 1980.

8. "Digital Terrain Tapes," U.S. Department of the Interior, Geological Survey, National Cartographic Information Center, User Guide, Second Edition.

9. Newman, W.M., and R. F. Sproull: Principles of Interactive Computer Graphics, New York, McGraw-Hill Book Company, 1973.

10. Wright, T.: "A Two-Space Solution to the Hidden Line Problem for Plotting Functions of Two Variables," IEEE Transactions on Computers, Vol. C-22, No. 1, pp. 28-33, January 1973.

11. Williamson, H.: "Hidden-Line Plotting Program," Communications of the ACM, Vol. 15, No. 2, pp. 100-103, February 1972.

12. Gottlieb, M.: "Hidden-Line Subroutines for Three-Dimensional Plotting," Byte Publications, Inc., pp. 49-58, May 1978.

13. Loutrel, P.: "A Solution to the Hidden-Line Problem for Computer Drawn Polyhedra," IEEE Transactions on Computers, Vol. C-19, pp.205-213, March 1970.

14. Potmesic, M.: An implementation of the Loutrell Hidden-Line Algorithm. Rensselaer Polytechnic Institute. Technical Report CRL-49, September 1976.

15. Junkin, B.G, M.H. Graham and W. G. Cibula: Application of a Digital Geo-Based Information System to Land Resource Management. Proposed NASA Technical Memoranda, In Preparation.

16.* Cibula, W. G.: Computer Implemented Land Cover Classification Using Landsat MSS Digital Data: A Cooperative Research Project Between the National Park Service and NASA-III. Vegetation and Other Land Cover Analysis of Olympic National Park. NASA/ERL Report No. 193, October 1980.

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