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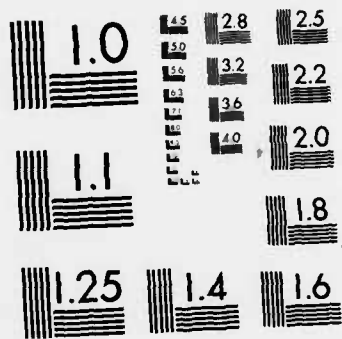
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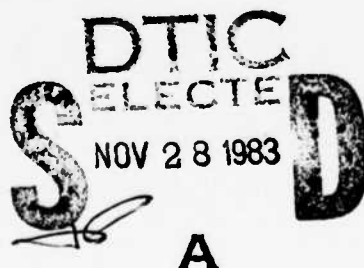
Advanced edit system

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JANUARY 1983

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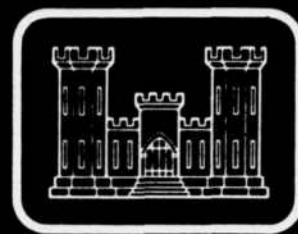


Prepared for

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ENGINEER TOPOGRAPHIC LABORATORIES
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An advanced edit system with high resolution interactive graphic workstations and support software for editing digital cartographic and mapping data was developed for ETL to be used by Defense Mapping Agency Aerospace Center. (DMAAC). The hardware consists of PDP-11/70 computer with two Intergraph Corp. dual screen workstations; one has vector storage tubes; the other workstation has a raster color display with 1024 by 1024 pixels.		

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Conversion software programs were developed to convert AGDS Scan Data, CRT Printhead data, Gerber plot data, DLMS Culture and Terrain data, and RAPS data (various cartographic data base and plotter data instructions) into the Intergraph design file data format for display and editing. Additional programs convert the design file data back to the various data bases or plotter instructions.

Numerous interactive graphic manipulation commands are provided as a starting point for developing special commands to move, delete, add, or copy features in a design file.

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PREFACE

This report describes work performed under contract DAAK70-79-C-0180 for the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia 22060 by Soncraft, Inc., Chicago, Illinois 60619. The Contracting Officer's Technical Representative was Mr. John H. Garlow.



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1. INTRODUCTION

This document constitutes the final technical report by Soncraft, Inc. of the work completed under Contract DAAK70-79-C-0180 for the development of an Advanced Edit System (AES) to allow interactive editing of digital cartographic data and the regeneration of various formatted digital cartographic data tapes from the edited data.

1.1 Reference Documents

The documents as listed in Table I were supplied by the Government for use during the course of this contract.

Table I - Reference Documents

- o AGDS Scan-Graphic Data File Specification
- o Gerber - Plotter Instruction Format
- o Symbol Vector Generator Data Tape and Font Tape Input Format
Image Graphics, Inc. 10 January 1978
- o Raster Scanner Plotter Data Format
- o DMA Product Specification for Digital Landmass System (DLMS)
Data Base, July 1977
- o Broomall Industries Editing Station Output Format for DMAAC,
Scan Graphics System, September 1978
- o AES - Programmer's and Operator's Manual
Soncraft, Inc. January 1982

1.2 CPU Hardware Requirements

The minicomputer and its peripherals are commercial components and are listed in Table II. The computer is a PDP-11/70 equipped with 256K bytes of RAM, a cache memory, and a 64 bit floating point processor (FPP). The online storage units are two 300 megabyte disk drives, each having a removable disk pack for storing the online data base and

an average transfer rate of 1.209 million bits per second. The inter-connection is shown in Figure 2 and the general appearance of the equipment is illustrated in Figures 3 and 4.

Table II - AES Hardware Components

Item	MFR	Model
Computer Subsystem		
1. Cabinet 0, PDP-11/70 CPU with 11/70 CPU, and Floating point processor	DEC	11/79-UK
2. Cabinet 1, with SDLC, and 256 K Byte Memory	DEC	11/70-VK
3. Disk Controller	Micro-Computer System	MSC 1100
4. Magnetic Tape Drive (Qty 2) 800/1600 BPI	Cipher Data	F920640-98-12000
5. Disk Drive, 300 MBYTE (Qty 2)	AMPEX	DM9300
6. Alpha Numeric Terminal	Zenith Data	WH-19
7. Line Printer	Data Products	244523-001-2260
8. DECwriter II	DEC	LA-36
Vector Workstation		
1. 19/19 Display + Menu + Keyboard + Cursor	Intergraph	FSDSP012A
2. High Precision Backlite Digitizing Table	Altek	ACT46-3
Raster or Imagery Workstation		
1. Color Display Terminal	Ramtek	9400
2. Color Display Controller	Intergraph	FDSP01201
3. Table and Keyboard & Cursor	Intergraph	FDSP02001

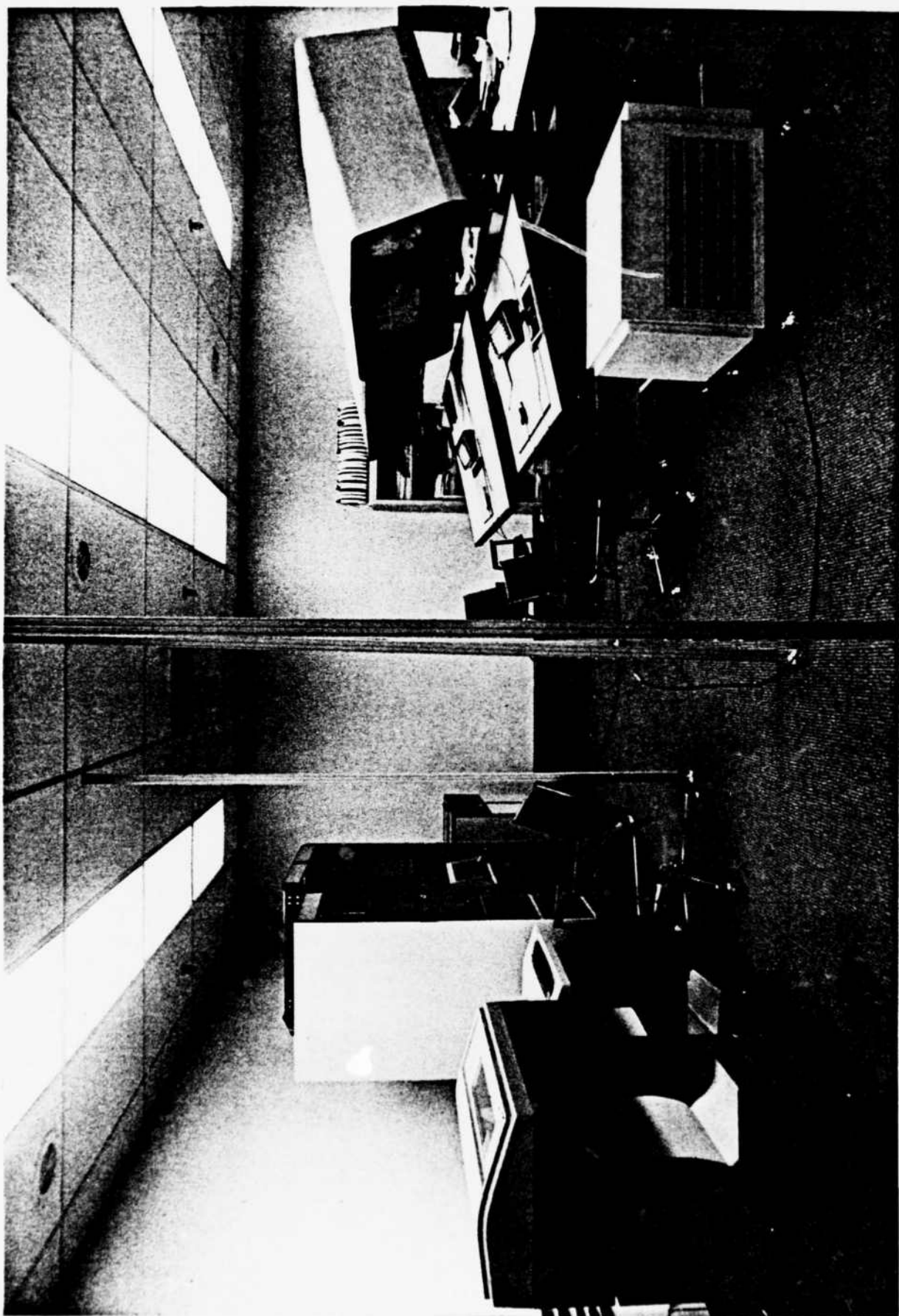
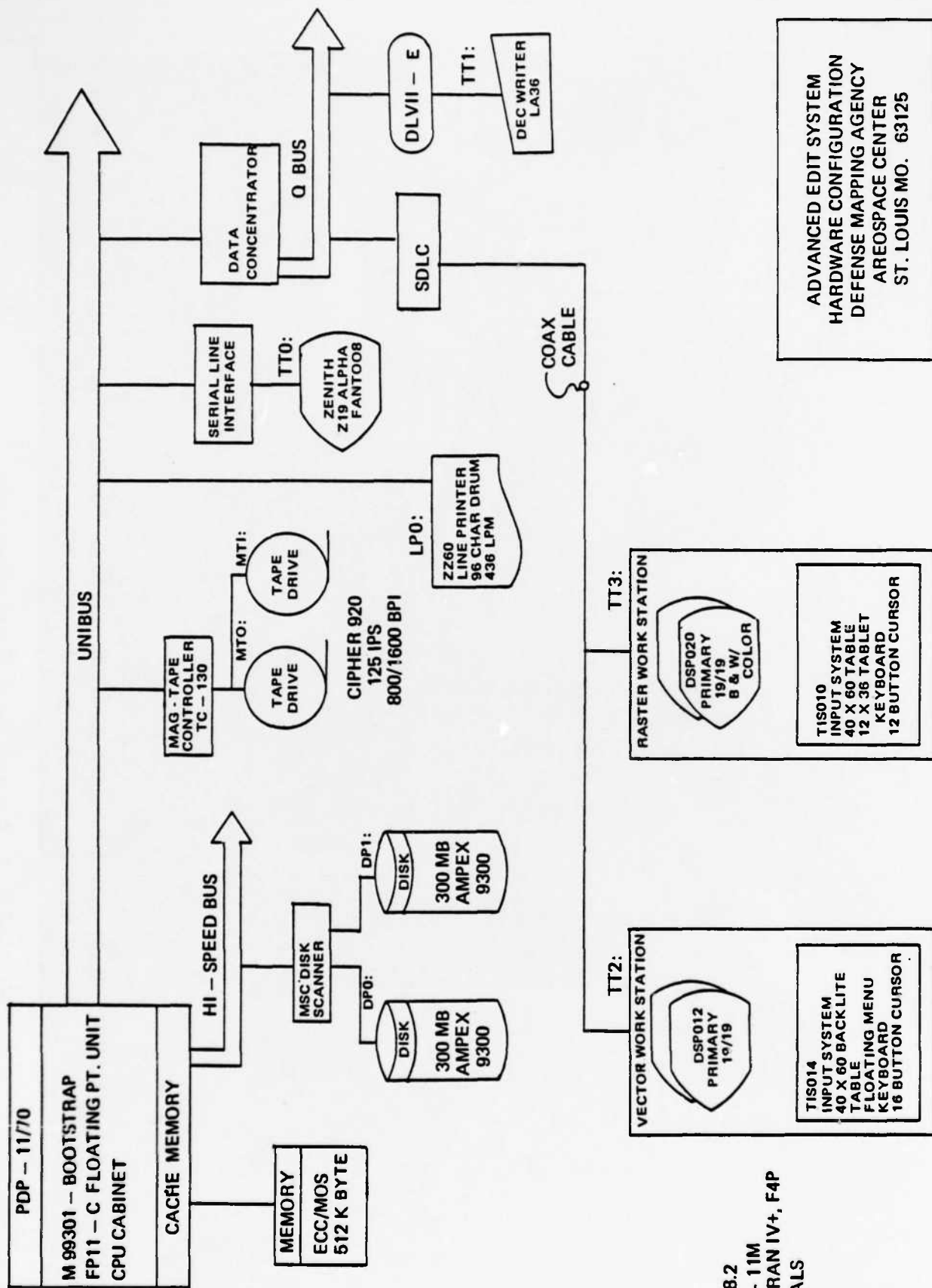


FIGURE 1 Advanced Edit System



SOFTWARE

1. SL 001 - IGDS 8.2
2. SL 008 - RSX - 11M
3. SL 009 - FORTRAN IV+, F4P
4. SL 0016 - EBSALS

FIGURE 2 AES HARDWARE CONFIGURATION

1.3 Disk Data Scanner

The Disk Data Scanner (DDS) from Intergraph Corporation is a direct memory access device capable of searching millions of words of disk memory, at maximum disk rotational speeds, to locate any desired set of display vectors or elements without burdening the central processing unit with reading and comparing each element with desired values.

The DDS allows the system to maintain satisfactory response time during highly interactive graphic display operations in multiple workstation configurations. Data may be retrieved 10 to 30 times faster with a DDS than under CPU control only.

1.4 Graphic Work Station

The graphic workstation as illustrated in Figure 3 is the main terminal for viewing and editing graphic information. Each workstation consists of two CRT screens, a digitizing table, a floating cursor, a menu for selecting editing commands, and an alphanumeric keyboard for entering text and additional controlling information.

1.4.1 Vector Display Station

The Vector display system includes the control electronics for a cluster, two vector storage display screens, the screen mounting and elevator assembly, and the alphanumeric keyboard. The control electronics consists of a DEC LSI-11 microprocessor with 64K bytes of memory that communicates with the terminal concentrator at .5 megahertz using Synchronous Data Link Communication protocol at distances up to 6000 feet. Slower cluster devices are buffered by the LSI-11 until they are ready to receive their data. Certain editing functions are totally supported locally by the LSI-11

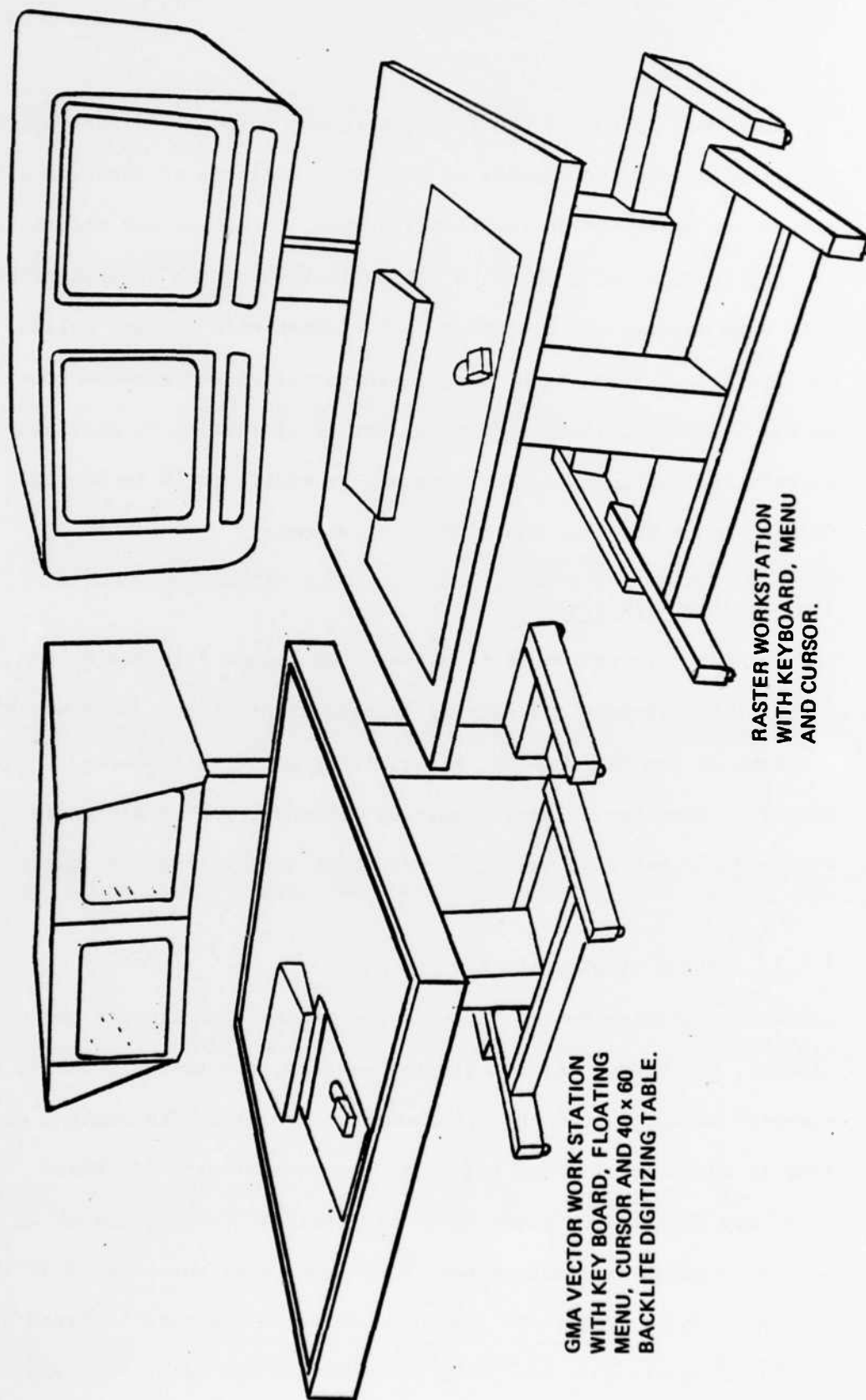


FIGURE 3 GRAPHIC WORKSTATIONS

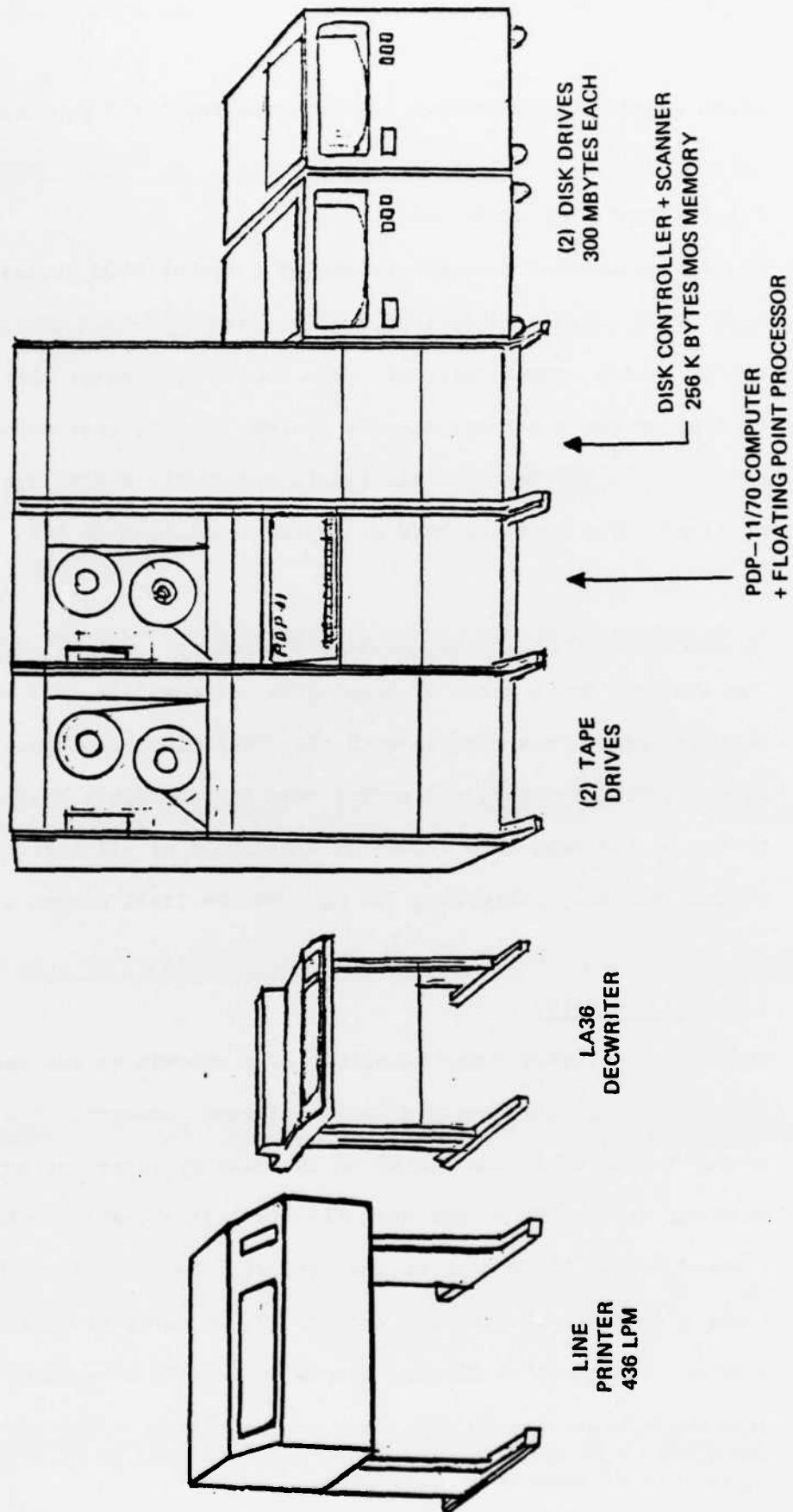


FIGURE 4 AES EQUIPMENT CABINETS

which significantly reduces the required PDP-11/70 processing time.

1.4.2 Raster Display System

The Raster Display System consists of a Ramtek 9400 series display controller, a 19-inch monochrome monitor, and a 19-inch color monitor. The raster system communicates with the central processor through an LSI-11 controller and a primary display system. The microprocessor display generator in the Ramtek control unit controls the displays on both monitors. The monitors have a display resolution of 1024 by 1024.

2. INTERACTIVE GRAPHIC DATA SYSTEM FEATURES

The AES provides a means of displaying all the data in a nearly 1:1 relative scale relationship with the final plotter outputs, including line weights, spacing, and positions. It provides a realistic presentation of the data that allows an evaluation of all interactive changes without actually replotting the data on the final output plotters.

2.1 Zoom Operation

The graphic display routines allow for a zoom-in on any section of a display through the use of a series of menu commands. The area to be zoomed-in can be in the center of the display screen or any other selected area. The screen normally displays a complete picture of the plotted data. Since most of the data will be plotted at 1000 units per inch, a complete chart would require 30,000 units of measure along its X-axis. The graphics display system is capable of zooming-in on any area until there are 50 units across the screen. This gives a zoom-in capability of about 60:1 enlargement.

The same display can be zoomed-out until there are over four billion units of resolution along the X-axis. With this capability it is possible to display adjacent manuscripts on the same screen to depict the matching features between the two manuscripts.

The color graphic workstation, in addition to having the normal software zoom-in and zoom-out capabilities as described above, has an additional hardware zooming capability that allows a section of the screen to be enlarged by a factor of eight. The display then can be panned across the screen under control of the floating cursor located on the menu pad.

2.2 Level of Elements in a Design File

All features of a graphic data file are placed as elements in a design file on disk. An element can consist of a line segment, a line string, or a shape such as a rectangular box, a circle, an ellipse, or an arc. Each element has a common header associated with it to enable rapid retrieval and display. Some of the information in the common block for each element is the element type, the element level, the range, the element weight, the graphic group, and the line code. The range consists of high and low values for the X, Y, and Z values for the element. Within the design, an element can be placed on one of 63 different levels. The Data Disk Scanner software is capable of selecting only those elements that are to be displayed. For example, let level one contain all contour lines, level two contain drainage, level three contain roads, and level four contain miscellaneous features. Any combination of these levels, or all levels could be selected and displayed simultaneously on the workstation screen.

2.3 Line Weights

Many of the data formats that are read into the AES do not have specified line weights. These elements are displayed with the lowest line weight available on the system (three). In other cases, a specific line weight is included in the input data tape format, such as the CRT printhead and Gerber plot tapes. The line weights for these input data tapes are stored according to the line weight number that is contained on the input tape. In the case of the CRT printhead, the lowest line weight used is three one-thousandths which is thinner than can be displayed on the monitor. Therefore, these lines will be given a line weight of three, which is the thinnest line that can be displayed. In the case of the Gerber plot tapes, the line weights are designated as aperture numbers. The aperture numbers can vary depending on the aperture bar that is used on the Gerber plotter. Again, the line weight and the aperture number may not actually correspond to the final line weight that is to be plotted.

2.4 Line Codes

Each line, line string, or shape can be drawn with a specific line code. There are five line codes, numbered from zero to four, available on either workstation. The line codes on the vector station are drawn in a monochrome color as a solid line, dash lines, dot lines, or variations to give the five combinations. On the color raster terminal, the line codes are displayed as five different colors, with green representing line code zero. Features are generally placed in the design files with a line code of zero to represent a solid line.

The AES allows for temporary assignment of a line code to elements that are on different levels of the design file. Through menu commands, a color can be selected for a line code to be used in displaying elements that are on a specific level of the design file. This line code assignment is only temporary and enables the operator to distinguish those elements associated with a specific level. There are other commands that can be selected to designate that only elements on a selected level will be manipulated. For example, if roads are to be moved, the level which contains the roads is selected for manipulation and the roads can be moved without changing contour lines, drainage, or other features that might be adjacent to or on top of the road features.

2.5 Menu Summary

The command menu is one of the key elements in making the AES a truly interactive system. It enables the user to exercise the total graphic capabilities of the system. The command menu, as initially delivered with the system, is shown in figure 5. The menu can be modified to meet specific requirements that may arise after the system has been used for a period of time.

2.5.1 Elements

- o Many geometric elements can be interactively constructed using a variety of available construction techniques to create a design.

For example:

- Lines at any angle.
- Circles and circular arcs.
- Ellipses and elliptical arcs.

- Circular and parabolic fillets.
- Rectangles (defined by end points of a diagonal).
- Orthogonal and nonorthogonal polygons.
- Interior boundaries in an enclosed area.
- Irregular curves (cubic spline curve-fitting).
- Spiral arcs.
- o Each element may be displayed in any of 32 line weights (thickness).
- o Any element can be displayed with a maximum of five line codes.
- o Lines can be represented as centerline or as rectangles having user-definable line width.
- o Elements can be created on any of 63 drawing levels.
- o Elements can be created by digitizing, by drawing on the display screens, or by keying-in the precise location.

2.5.2 Element Manipulation

- o Design elements can be manipulated in the following ways:
 - Copy to any level or position.
 - Copy parallel (offset from the original by a constant spacing).
 - Move to any level or position.
 - Modify (change the geometric definition).
 - Scale (enlarge or shrink relative to other elements).
 - Delete all or a part.
 - Rotate through any angle.
 - Mirror about any axis.
 - Two separate curves can be smoothly joined.
- o The level on which an element resides can be determined at any time.

2.5.3 Geometric Line Constructs

- o A line of any length from a point to a selected line at any angle.
- o A line of any length from a point on a selected line at any angle.
- o A radial line from a given point to a specified arc or circle.
- o A line tangent or perpendicular to a circle, circular arc, parabola, parabolic arc, spiral arc, line string, or curve from any designated point on or off the element.
- o A straight line can be extended by a graphically defined or keyed-in distance.
- o Two lines can be extended until they intersect.

2.5.4 Point Constructs

- o The user can command a reusable snap point to be located in precise relationship to existing elements. He may then easily relocate the cursor at such a point whenever necessary. These commands involve the use of a point cell (a special type of regular cell). As such, the point cell will respond to the same manipulation commands as a regular cell. A point may be designated:
 - At a keyed-in distance along any linear element.
 - At a precise intersection point of two lines, circles, or circular arcs.

2.5.5 Element Groupings

- o Elements can be grouped together to form cells (symbols).
- o Cells can be combined to form nested cells.
- o Cells can be manipulated like elements (i.e. rotated, scaled, mirrored, etc.).
- o Cells are named and stored in a cell library and can be recalled for use at any time.

- o A cell has an origin point so that it can be precisely placed anywhere on the drawing.
- o Cells or elements can be identified as a group having any number of user-assignable attributes (associated elements). These groups can be selectively displayed.
- o Cells, elements, or cells and elements can be grouped (graphics groups) and can be jointly manipulated using element manipulation commands.
- o A fence placed around cells or elements permits the fenced contents to be manipulated as one element.
- o A series of lines, arcs, and curves may be designated as a single element.

2.5.6 Screens And Screen Manipulation

- o There are two display screens to aid in design.
- o A number of commands are available which affect the viewed area and the origin:
 - The entire design area can be viewed at once.
 - Any desired area of the entire design can be chosen to be displayed on either screen.
 - Any point on the display can be designated as the center point of the next updated display.
 - A zoom in or out can be performed on either screen.
 - Any point in the design can be specified as being the origin of an updated display.
 - No matter how small an area is currently being viewed, the entire design can be displayed with one command.
- o The overview mode allows for determining the current location when working in a very large design or in a design with many repetitive elements.
- o The tutorial displays can be utilized and still maintain a view of the design.
- o Previous designs can be recalled and displayed on one screen while viewing the working design on the other.

- o One screen can be frozen to provide a temporary history view of the design while the operator changes the design on the other screen.
- o A key-in command allows a previous design to be retrieved for future work.
- o Time can be saved by delaying automatic screen updates.
- o The display parameters for the two screens can be interchanged.
- o A "working window" can be chosen to reduce the volume of data that must be continually accessed by the graphics system. This results in even faster system response.
- o Different combinations of drawing levels can be displayed on each screen.

2.5.7 Selective Display Modes

IGDS (Interactive Graphic Display System) enables the user to selectively eliminate a number of classes of elements from the display of the drawing under construction. This reduces the time required to erase and redraw an image on the screen.

- o The AES has the option to display or not to display any or all of the following: line weights, area or element patterns, text nodes, enter data fields, point cells, lines with width, level symbology, dimensions, and construction lines.
- o Whether displayed or not, the selective display characteristics are entered in the design file if they have been defined by the user.
- o Another time saver is the fast display mode for fonts, text, cells, and curves. Each of these modes produces a simplified representation of certain elements on the screen.

2.5.8 Locks

Locks automatically allow more precise alignment of elements with less effort. The system locks can be selectively activated.

- o Point lock makes the first input point of an element exactly the same as the last input point of the immediately preceding element.

- o Snap lock makes an input point exactly the same as a chosen endpoint of any previously placed element (or point as defined by a point cell).
- o Text node lock activates the attaching of input text strings to predefined text nodes.
- o Graphic group lock enables elements to be grouped together so that they can be manipulated as one element.
- o Axis lock is a software T-square.
- o Unit lock causes a user-defined roundoff factor to be applied to all points selected with the cursor.
- o Grid lock causes cursor-selected input points to be locked to the nearest user-defined grid position.
- o Angle lock and scale lock cause the user-defined or system default roundoff factors to be applied to angle or scale definitions.
- o Level lock allows the user to manipulate elements on any displayed level, or to restrict manipulations to elements on a single level.

2.5.9 Working Units And Measurement Commands

- o Any working units (English or metrics) that are convenient can be specified. Over four billion addressable points along each axis ensure accuracy, regardless of the size of the total drawing.
- o An optional user-defined grid can be displayed for reference data inputs.
- o The following measurement capabilities are supported:
 - Locate X, Y-coordinates of a point.
 - Measure the delta-X and delta-Y distance between two points.
 - Measure any angle defined by cursor input points.
 - Measure the radius of a circle or circular arc.
 - Measure the distance between two points along an element.

- Measure the angle between two lines, whether or not they intersect on the display screen.
 - Measure the perpendicular distance between a point and a line or arc.
 - Measure the area and perimeter of a closed figure.
- o The roundoff factor can be specified that will be applied to the unit roundoff lock.
 - o The number of working units per grid interval can be specified.
 - o Angles can be read out in conventional, azimuth, or bearing format.
 - o The number of decimal places appearing in readout data from measurement commands can be specified.

2.5.10 Levels, Symbology, and Patterning

- o A drawing can contain up to 63 distinct levels of graphic and text information.
- o One or any combination of levels can be displayed at any time. Elements are placed on only one level at a time, but they can easily be moved or copied from level to level.
- o All elements on any given level can be automatically displayed as solid, dotted, short-dash, long-dash, or dash-dot.
- o In addition to the system-supplied line patterns, a user-defined pattern can be applied to any element.
- o User-defined patterns can be applied to areas at any scale, angle, or spacing.
- o The symbology of any element or all elements within a designated area can be changed at any time.

2.5.11 Automatic Dimensioning

- o Extension lines and dimension lines with arrowheads are placed automatically.
- o System-calculated dimensions can be automatically entered on the drawing or they can be reviewed and edited before placement.

- o Dimensional text can be automatically placed to the left, center, or right of extension lines, or can be placed anywhere manually.
- o A line can be automatically labeled with its length and angular inclination text appearing parallel to the line.
- o Both string and stack dimension modes are supported with dimension lines and arrowheads placed either internally or externally to the witness lines.
- o All dimension data associated with a given measurement can be deleted as a group or selectively deleted for editing purposes.
- o Optional display of dimensional data and construction elements avoids having to work on a cluttered drawing.
- o User-defined line terminators, such as arrowheads, can be used in dimensioning unusual situations.
- o Linear, angular, arc length, and radial dimensioning modes are provided.

2.5.12 Text

- o The user can define up to 255 text fonts (styles).
- o Any combination of fonts can be used in a single drawing.
- o Existing text fonts can be updated at any time.
- o Text can be placed with any height, aspect ratio, spacing, and line orientation.
- o The user can specify the text attributes: font, line length, line spacing, height, and width.
- o Text height and width and line width can be specified graphically with the cursor or can be input from the keyboard.
- o Text can be placed manually at any location and along any linear element in a drawing.
- o The system will automatically scale and place a text string between two points specified by the user.
- o Text can be placed above or below a designated line.

- o The font of existing text strings can be interactively changed at any time.
- o Many justification modes are available for text nodes.
- o Text strings can be edited, regardless of font.

2.5.13 Design File Manipulation

- o Automatic file compaction can be performed at any time for efficient storage.
- o Design Files can be stored on magnetic tape and retrieved for later manipulation.
- o A copy of a Design File can be obtained with a single command for alternate design activities.
- o All elements within a user-specified area on the display can be copied or moved to another Design File.
- o The contents of a user-specified design can be merged into the currently active design.

2.5.14 Operator Feedback

Feedback assures the user that the system is repnding to requests.

- o A dynamically changing message field at the top of each screen tells the user what command he has selected, displays prompts regarding expected data inputs, displays error messages, and gives the status of system parameters.
- o A selectively displayable header informs the user about displayed levels, the area of the design viewed, and working units.
- o An optional audible response to each operator action provides positive confirmation.
- o For some manipulation commands the user must be assured that the correct element was chosen (deletions, for example). The vector workstation does this by flashing the chosen element.
- o An audible alarm notifies the user of major errors (e.g., Design File overflow, I/O errors, etc.).

2.5.15 User Commands

- o User Commands are created by the user and permit the execution of several basic menu commands as one command.
- o User Commands are selected from the menu in the same manner as standard IGDS commands.
- o User Commands can call disk-resident FORTRAN programs.

3. ADVANCED EDIT SYSTEM DATA INPUT AND OUTPUT

The data to be presented graphically on the display screens consists of various tape formats which are used to control a number of different plotters, of DLMS data, or of Digital Product Data Formats. A specific set of programs were written by Soncraft, Inc. for each input format that converted the data directly into the required Intergraph format.

These programs are listed in Table III and diagramed in Figure 6.

A set of standard Intergraph subroutines were used for placing features or elements into the design file. The Intergraph subroutines handled all the routine bookkeeping required to make the data comply with various header formats for both the main control header and the individual elements.

TABLE III - SOFTWARE ROUTINES DEVELOPED BY SONICRAFT, INC.

<u>NAME</u>	<u>FUNCTION</u>
RAPI	RAPS Data Input
GERI	Standard Gerber Data Input
CPHI	CRT Print Head Data Input
TAGI	AGDS TAG Edit Data Input
SENI	AGDS Vectorized Data Input
DLTI	CDB Standard Terrain Data Input
DLCI	CDB Standard Planimetry Input
RAPO	RAPS Data Output
GERO*	Standard Gerber Data Output
CPHO	CRT Printhead Data Output
DLTO	CDB Standard Terrain Data Output
DLCO	CDB Standard Planimetry Data Output
GLSS	Graphic Line Symbolization System
GERSRT	Gerber Sort

* Not a contract item. Routine may not be completely debugged.

AES PROGRAM USAGE

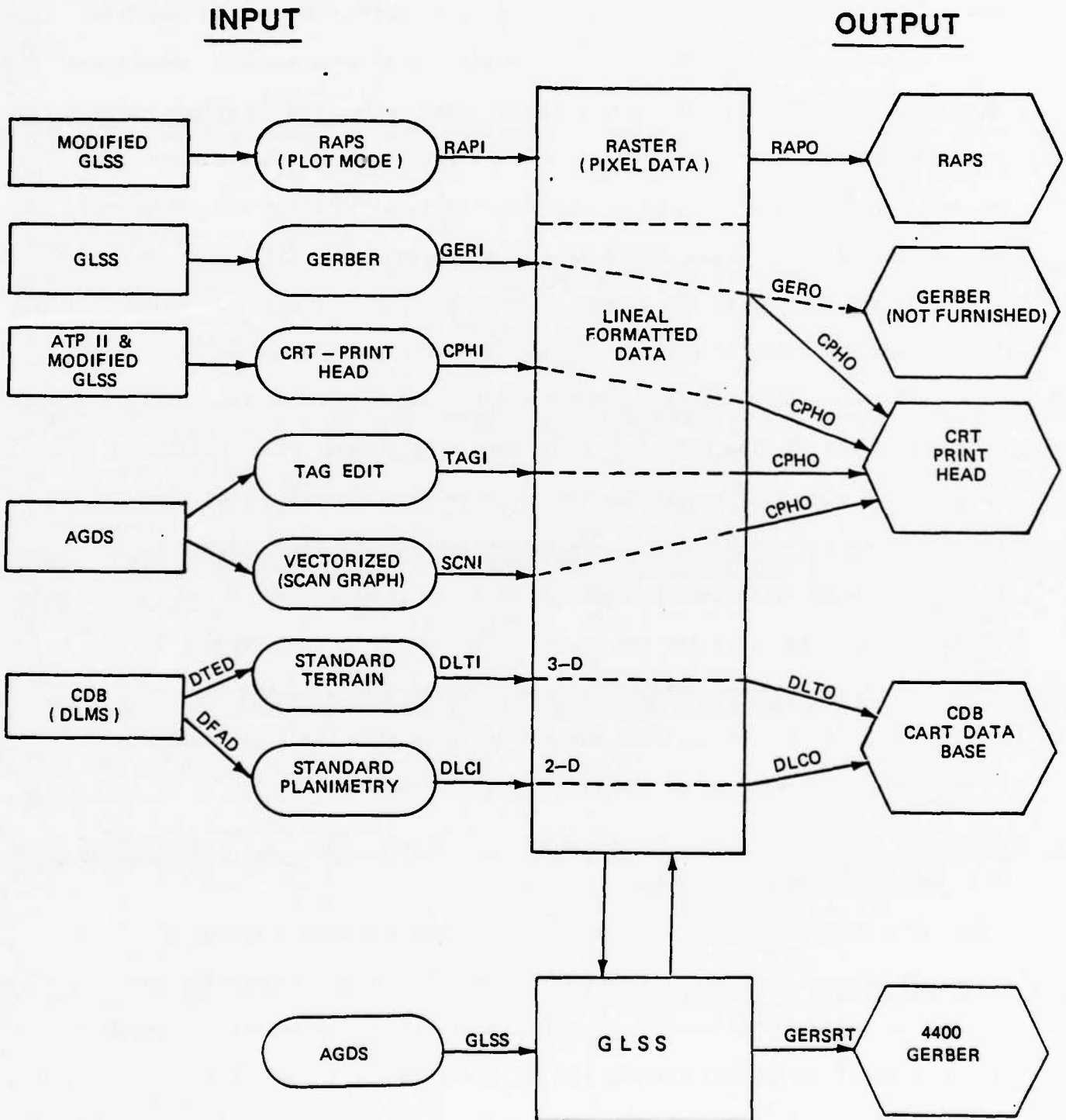


FIGURE 6 AES PROGRAM USAGE

3.1 AES Internal Data Format

The internal data format of the AES requires the first 18 words of each element to be the same, even though all the information may not be required for a specific element. This enables the high speed data scanner, associated with the disk controller, to scan a design file quickly and to select only those elements that are to be displayed at a workstation. This element header block contains the type of element, the level on which the element resides in the design file, the number of words in the total element, the X, Y, and Z-range of the element, the graphic group number, an index to an attribute link, properties indicators, and display symbology. The display symbology stores style and weight information but is capable of storing only 32 line weights. Since some of the input data contains more than 32 line weights, it was necessary to find another method of storing input data with more than 32 line weights. The line weights for a data file were split into two groups, with one group stored on one level of the design file and the second group stored on a different level. Although the required information is stored in a design file, the presentation to the operator may not be in exactly the line width relationship that will be on the final plotted drawing.

3.2 Comparison of Design Files

There is a requirement for verifying or comparing two data files to ensure that they contain the same data features. Either workstation can be used to perform this verification; however, the color graphic terminal can show small variations between the files very quickly. A color terminal can display one file in green and a second file in red or

blue. Where the line features are identical, the red and green mix to give a third color, orange. Any line segments that do not compare will be shown as separate red and green lines, one color for each design file.

If the two design files are not in the same area of the graphic display file, the elements of one of the files can be moved by placing a fence around the complete design file and moving the elements on top of the other file location. If the files are at two different scales, are skewed, or have a variable scale associated with them, they can still be made to overlay one another by using a special program called Elastic Transformation Program. This Elastic Body Small Angle Least Squares (EBSALS) program provides the capability to elastically merge two or more AES design files. Special "monument" cells are placed in each file to provide the basis for performing the elastic transformation. Intergraph Manual 77-0302A is the user's manual for this program that gives a detailed explanation of its operation.

3.3 CRT Printhead Conversion

The data for the CRT printhead is recorded on tape in variable length blocks with a maximum record length of 4096 bytes. There is no special header information associated with this data format.

3.3.1 CRT Printhead Input Data Format

The input format contains control information that enables sections of a tape to be plotted or skipped under operator control. Controls

for using these records are associated with the plotter itself and not with the Advanced Edit System. The first three words of a block contain the image number, page number, and record number. The next three words are associated with setting the CRT printhead position for plotting a two-inch window of information. The seventh word will set the line weight and wobble or dither requirement. Following this is the X and Y-point information for defining the feature.

There can also be character control information that would set the character point size and font number before going into the ASCII mode for recording the actual text. Text can be placed at any angle from zero to 360 degrees.

3.3.2 Storage of Features

The X and Y points for a feature are stored in the design file either as line segments of two points or as line strings with many points. Line strings containing more than 97 points are broken into separate line strings. This is a limitation of the AES system that no more than 97 points can be associated with any one line string. However, these line strings have a common group number assigned, or they can be placed as complex shapes so that the line string can be manipulated or changed as though it were one feature or element.

The various functions of the CRT printhead input data are handled according to Table IV.

Table IV - Range of AES and CRT Printhead Characteristics

<u>Function</u>	<u>CRT Printhead Range</u>	<u>AES Range</u>
Line Weight	0-1024	0-31
Spot Wobble	Yes, No	Line Code=0,1
Beam Intensity	0-1024	Not handled
Font Number	0-4095	1-256
Font Size	4-9 & 10-72 point	1-4 billion
Character Angle	0-360	0-360
ASCII Text	1-254	1-254

As shown in Table IV, only 32 different line weights can be handled without using a second level or overlay in the design file. Also, the beam intensity is not handled in the design files because it is not required on the CRT printhead. Only 256 of the 4000 font numbers are handled at one time. A different group of font control files can be substituted when necessary for different manuscripts. The font sizes 4-72 are stored as sizes 4 to 72. The binary sizes are multiplied by 100 and stored in the design file.

3.3.3 Editing CRT Printhead Features

All of the features in the design file can be edited using the standard Intergraph menu commands which allow deletion, addition, and modification of the elements. Modifications such as moving a cross tie on a railroad symbol or deleting a section of a contour line and reconstructing it again can be made. Features can be added or extended at any desired location.

3.3.4 CRT Printhead Output Data Format

The output format for the CRT printhead plot tape contains the same header information as associated with the input tape. Block sizes are variable in length and contain the image page and record numbers

along with the CRT position location. This allows each record number or page to be individually plotted under control of the operator. There was an initial problem with the CRT printhead output in that the commands were being placed in a three inch plot window instead of a two inch window. This problem was corrected after being informed that, although the documentation states that a three inch window can be used, the actual window being plotted on the CRT system was a two inch window.

Another problem occurred in plotting the CRT printhead output when the origin of the file was taken as location (0,0). Upon review of the CRT printhead documentation, it was determined that an offset of 547 units must be applied to every X and Y point to move the plot window from the border. An additional 500 units had to be added to accommodate the two inch window instead of the three inch window. The 500 unit offset represents one-half inch since the plotting is done at 1000 increments per inch.

In addition to the normal line strings and segments plotting, the CRT printhead output program can handle closed shapes, arcs, circles, or ellipses. The additional capabilities were added to accommodate features such as circles or shapes that can be placed in a design file by the other conversion programs.

3.4 Gerber Plot

The Gerber plotter is a flat bed plotter equipped with a standard Gerber light head. The light head has an aperture wheel containing 24 different

openings. The apertures are changed by assigning different aperture numbers to specify the desired opening. The aperture settings, numbered one to 24, are stored as line weights within the design file.

3.4.1 Gerber Input Data Format

The Gerber tape data are stored in character format in fixed record lengths of 756 bytes. There are various 'G' function codes to describe whether a linear interpolation, circular interpolation, aperture selection, flash option, or character string, to be sent to the Gerber system control console, is to be handled next. There are drafting functions or 'D' codes which lower or raise the pen, turn the photohead light on or off, select an aperture, or cause the printing of messages for the control console. In addition, there are three 'M' stop codes which cause the system to stop momentarily to allow the operator to change the aperture wheel or film, to give the operator specific messages, or to end the job. The actual positional information is recorded as X, Y, I, or J character data followed by the absolute values for the location to which the plotter is to move. The conversion program GERI reads this character information and stores the required data in an IGDS design file.

3.4.2 Storage of Gerber Features

The information from the Gerber input tape is stored in a design file with the aperture settings stored as line weights, and the X and Y locations are stored as line segments or line strings. The circular interpolation data are stored as circles or arcs in the design file. Text strings are not handled by the Gerber program, since they would normally be converted

into line segments or circular patterns for plotting. Messages to the operator are displayed on the terminal.

3.4.3 Editing of Gerber Features

The graphic features in this design file can be edited using the standard menu commands that are available. They enable features to be deleted, added, or moved as required.

3.4.4 Gerber Data Output Format

A design file containing Gerber data can be converted for plotting using the CRT Printhead program - CPHO. A program can be written to convert each element or feature of the design file data into the required Gerber plot format. As each element is read from the design file, its aperture setting would be compared with the previous element to determine if it was the same. If different, a new aperture setting would be output to the Gerber tape before transmitting the actual X and Y locations that represent the feature or element.

3.5 Scan Graphic Data (AGDS)

The Scan Graphic Data comes from the output of a Vectorizing Station. The data are read and stored in a design file for graphical display. Since the design file data are output in the CRT Printhead format, the AGDS tag number is not saved. This tag number could be stored on level 63, as is done for the DLMS Planimetry data, so that the operator could determine what type of feature is being displayed. A simple decoding of the tag number could also be applied to place certain groups of features on specific levels for the graphics operator.

3.5.1 Scan Graphic Input Format

The Scan Graphic Data are stored in blocks of 256 words; the input format consists of five different record types to represent the feature information. Type one is line data which are placed in a design file as line strings. Type two is text strings data that are placed in a design file as text at the angle specified. Type three is point data that are placed in the design file as lines of zero length. Type four is fiduciary data points that are placed in the design file as circles of unit diameter. The first block of information on the input tape is the file header data that gives location of area, accuracy, date generated, classification, etc. This 1790 word record is skipped upon reading the input tape since it is not needed to place data into design file.

3.5.2 Editing of Scan Graphic Features

Features in this design file can be manipulated using the standard menu commands which are available. The information can be added, deleted, and modified as necessary to produce the desired graphical representation.

3.5.3 Scan Graphic Data Output Format

The output information from this file is converted, through the use of program CPHO, into the necessary commands for operating the CRT printhead plotter. The CRT Printhead output routine is capable of handling line strings, line segments, and circles necessary to represent all the features produced by the input data.

3.6 Tag Edit Data (AGDS)

This input data comes from a Broomall graphic display system. Formats

are described in the document "Broomall Industries Editing Station Output Format for DMAAC Scan-Graphics System September 1978". Feature data are extracted from the input tape and stored in the design file. The design file can be displayed and edited to represent the final graphic information desired. The design file is then converted to CRT Printhead plot format on magnetic tape for plotting.

3.6.1 Tag Edit Data Input Format

The input tape format has six different types of blocked information. The volume, file header, and end of file labels have 80-byte blocks. The fiducial head has a 576-byte block. The manuscript head and all feature records are in 4608 byte blocks. The header label is an 80 byte block and is stored on level 63 of the design file.

3.6.2 Storage of Tag Edit Features

The XY points for each feature are converted into line strings and stored in a design file. If the line string is longer than 97 points, a graphic group number is associated with the separate segments of the feature so that they will be operated upon as a single group during editing of the graphic information. The feature code and Z elevation are not presently saved within the design file because they are not needed to generate the CRT Printhead output. The feature code and Z elevation data can be added to the design file if a specific need arises for including this information.

3.6.3 Editing of Features

The Tag Edit features can be modified as needed to provide the required

graphic representation of the various features. All editing of this design file can be accomplished using the standard Intergraph menu commands.

3.6.4 Tag Edit Data Output Format

The output from the Tag Edit design file is converted to CRT Printhead format for plotting. The feature line strings are plotted in sections for an entire 2 inch window area at one time. Those elements that cross the window area border are clipped so that only elements within the window are plotted at one time. The window area is moved to an adjacent area and elements in the new window are plotted. This procedure is repeated until the whole design file has been plotted. No additional data such as header information or feature code numbers are plotted.

3.7 Raster Plotter System (RAPS)

The raster scanner data comes from a system that is capable of scanning drawings that are 48" x 72". Resolution along the scan lines may be 1000, 500, or 250 pixels per linear inch. Resolution along the axis of the raster drum plotter corresponds to that along the scan lines: 1000, 500, or 250 scan lines per inch. The usable width along the axis of the drum plotter is 48 inches. Usable length along the drum plotter scan lines is 72 inches.

3.7.1 Raps Input Data Format

The input data for the raster scan are either in run length coding (RLC) or full binary data (BIN). In the RLC mode, only the transitions of "off" to "on" and "on" to "off" are recorded, except that a maximum

of 127 pixels may be skipped even if no transitions occur. Full binary format has a bit set "on" or "off" for each pixel along the scan line. The first two words of each data block give the Y-address and number of words in a block. The last word of each data block is a checksum. There are no other data blocks on the tape except an end of plot or end of tape record.

3.7.2 Storage of Features

The raster data are stored in a pixel format in the design file. This requires a two-step conversion to convert the raster data to pixel format. The first step reads the input tape and selects a section which will be a 1000 x 1000 square for final storage in the design file. These data are placed in a temporary file. The data are further converted during step two by a program called TRANS2 and placed in a special image file to be displayed on the raster terminal. The actual conversion time is fairly long since there are two separate steps that are required. Also, the data being taken from the input file may not be near the beginning of the tape and may, therefore, require reading the input tape until the desired section of the input file is reached.

An improved method of handling this raster data would be to have the information read in as line segments and stored in a design file. Some quick calculations have shown that it may be possible to store one-fourth to one-third of a RAPS raster tape in one design file instead of the present one-thousandth. By using line strings instead of pixels, it is possible to display the raster file on the vector terminal as well as on the raster terminal. Therefore, raster data could be edited on either

workstation.

3.7.3 Editing of Features

The raster data being stored as pixel information can be modified by using the special pixel commands that are available on the raster terminal. These commands enable modification of individual pixels or all pixels within a fence defined by the operator. The fence is the standard IGDS fence selected from the menu. The value of individual pixels can be determined and modified if necessary. Since raster data are either an on or an off condition, only two pixel values are presently used in this image file.

A regular design file can be overlayed on top of the pixel data contained in the image file. Vector information can then be entered into this design file. The vector information can be in a form that would be suitable for output by one of the plot routines that are presently available.

3.7.4 RAPS Data Output Format

The output from the raster image file is another raster tape which will contain the input data file merged with the changes that have been made to the pixel image file. Some of the input files are on two tapes, called even and odd. To regenerate these two tapes, the operator is required to run the program twice, once for each tape.

The raster output data are generated in a one-step operation, rather than two steps as used during the input process. The input tape is

mounted on one drive and the blank output reel is mounted on the second drive. The conversion program then reads the input tape and merges it with the raster image file.

3.8 DLMS Planimetry (DFAD - Digital Feature Analysis Data)

The DLMS Planimetry or culture data contains information on three basic types of features - point, linear, and areal. Associated with each feature is the feature identification code, surface material, height, etc. The latitude and longitude locations required to place the feature on the manuscript follow each feature header. All the information contained on the input tape is placed in the design file in a form that can be retrieved and an output tape can be generated that duplicates the information originally on the input tape.

3.8.1 DFAD Input Data Format

Details of the DFAD format are described in DMA Products Specification for Digital Landmass Systems (DLMS) Data Base Manual. The DLMS planimetry input data tape header record provides the latitude and longitude of the southwest corner of the manuscript. The header record information is placed on one level within the design file so it can be retrieved and rebuilt for the output tape header record.

The feature records have fixed length blocks with a checksum. Each feature has a header indicating the feature number, type (point, linear, or areal), feature identification code, surface material code, height, and other information, depending upon the feature type. Following each feature header are a variable number of latitude and longitude points

giving the displacement of the feature from the southwest corner of the manuscript. The magnetic tape contains many blocks of feature data in order to depict the complete manuscript. The last block of information is marked with an end of file. Another manuscript can be placed on the tape following the end of file, if desired.

3.8.2 Storage of DFAD Features

The Planimetry data are stored on three levels of the design file. The header information is placed on one level with a rectangular block depicting the extent of the manuscript. The feature header data are placed on a separate level of the design file. This information is stored as text, allowing it to be modified to change the feature identification code, the surface material code, or other characteristics of the feature. The latitude and longitude data are stored at one-tenth second increments in the design file. Routines CVLLM and CVMLL will convert the latitude and longitude data to meters and vice versa. These subroutines could be modified to store the data as a Lambert Conformal Projection or other projections that might be desired. A prompt could be added in the input program to indicate the type of projection that should be stored within a design file. The subroutine CVLLM would then make the required calculation for each data point.

The graphic feature data are stored on one level for all features. A modification to the routine could allow the various types of features to be stored on different levels of the design for identification or location purposes.

The planimetry or DFAD data are stored as four basic types of data. Point features are stored either as rectangles or circles, depending upon the length of the feature. Linear features are stored as line strings. Areal features are also stored as line strings, with the last point being the same location as the first point. As it is placed in the design file, each feature is assigned a group number which corresponds to the feature analysis code on the input tape. Line strings with a common group number can be manipulated or changed as though they are one unit.

3.8.3 Editing of DFAD Features

The DFAD design file graphics features can be edited using the standard menu commands that enable features to be deleted, added, or moved as may be required to achieve the desired results. If a feature is deleted, the associated text for the feature should also be removed from the design file. If a feature is added, the associated text for the feature must also be added to the proper level of the design file.

3.8.4 DFAD Output Format

A separate program converts the design file into the required Univac formatted magnetic tape. More than one manuscript can be placed on a single magnetic tape. The program has an option to merge a design file with an existing input tape and to write a complete output tape in which the manuscripts are selected from either input tape or design file data.

3.9 DLMS Terrain (DTED - Digital Terrain Elevation Data)

The Digital Terrain Elevation Data (DTED) provides information on the elevation points within a manuscript. The elevation data are read and stored in a three dimensional design file to enable the data to be displayed in an isometric view. Because of the large number of data points contained on the input tape, the program has been written to allow sections of the input tape to be selected for placement into a design file. The operator is prompted for the desired area of the manuscript to be placed in a design file for displaying and editing. The output program DLCO merges the input file with the design file to produce a new DTED tape containing the changes.

3.9.1 DTED Input Format

The beginning of the DTED tape contains volume, header record, and user label records of each manuscript that is not stored in the design file because the input tape is required to be merged with the design file to produce an output tape.

The elevation points for one longitudinal line are stored in one tape record. The conversion program reads these data and stores only those points lying within the area selected for display in the design file.

3.9.2 Storage of DTED Features

The elevation points are stored in a design file as three-dimensional line strings, to represent profile lines at one longitudinal location. The total number of points is divided into groups of 97 points for storage, since line strings are limited to 97 points. The line strings, for one

profile line, are given a group number to allow easy selection and manipulation.

3.9.3 Editing of Features

The elevation points in this design file can be edited using the standard 3-D menu commands that are available. By proper manipulation, elevation points on selected individual profile lines can be modified to be higher or lower than originally depicted. Special user commands can be written to perform large scale changes on an area of the file as the need arises. The user commands might be to separate two overlapping features or to provide a specific minimum spacing. Another command might delete DFAD elements and associated text in one operation. User commands are easily written to perform editing functions that would involve many menu selections and calculations.

3.9.4 DTED Output Format

The DLTO program prompts the operator to read the original input tape and merge it with the design file to produce a new output tape with the corrected elevation information. This program also prompts the operator to change the header information associated with the DTED data. The tape label creation date and other information contained in the header label can be changed. The program determines the XY range of the profile lines and then merges the lines with the input tape. It is not required to know the original XY range selected when the input tape was read. The program determines the range of the design file elements and merges them with the input tape.

4. SUGGESTED CHANGES AND IMPROVEMENTS

The various AES Programs place all elements mainly on one level of a design file. The elements are then moved, under control of the graphic operator, to other levels as desired. The programs can be modified to prompt the operator for the levels on which to place the elements from one input tape. Contours could be placed on one level with drainage on a second level and roads on a third, etc. This method would not increase the conversion time but it would reduce the time necessary to overlay four or five manuscripts to check for interference. The manuscripts could quickly be displayed on the color workstation with the various features being different colors.

The AES has only CRT Printhead, DFAD, DTED, and RAPS output. The system could be expanded to include both the old and new Gerber plotters plus Calcomp, Xynetics, and Zeta plotters. A standard method of storing elements for the various features and type formats would simplify training additional operators on the techniques needed to modify and manipulate the manuscript.

4.1 RAPS Input and Storage Format

The RAPS data are displayed on a color raster workstation in a pixel 1024 x 1024 format. This displayed area represents one (1) square inch of the final manuscript. If the final manuscript is 30 X 70 inches then 2,100 square inches would have to be individually displayed to see the total manuscript. The present system takes approximately 5 minutes to display the 1000 X 1000 square area as pixel information. This time can be reduced by using a different method of storing RAPS data in a design

file.

The pixel information is run length code that could easily be converted into line segments and stored in a design file. Since most of the information in a RAPS file is open space, the total number of line segments for the manuscripts would be a reasonable number. A sample file was generated using this method and it was possible to store approximately one fourth of the manuscript in one design file of 32,000 blocks. The time to display this file was 1.5 minutes. Using this procedure, it would be possible to display a complete RAPS tape in less than 5 minutes. This is a considerable improvement over the 5 minutes presently needed to display a 1000 X 1000 square area.

Since the data are stored as line segments, the design file could be displayed on either a GMA vector display or a raster workstation. The pixel image file can be displayed only on the Ramtek workstation.

An output conversion program to merge the line segment design file with the input tape would be required. The program could be difficult to write since elements in a design file can be deleted, moved, or added. If the elements in the design file are in sequential order, the output program performs a simple merge. Any elements out of sequence would have to be placed in order or handled on a special basis.

4.2 DLMS DFAD Data Improvements

The DLMS feature header information is stored as a text string in the design file for each feature. The last number in this text string indicates the number of XY points used to place a feature in the design file. If

a design file is modified, this number has to be changed to agree with the total number of points for the feature. Current AES software requires this number be changed to correspond to the revised total number of XY points. The program could be modified to automatically determine the number of points for a feature and provide a message to indicate that the number of points has been changed.

When an element is modified, it is placed at the end of a design file. The elements as they are originally placed in the design file are grouped together to correspond to one feature. Modified elements for one feature are no longer grouped. The complete design file, therefore, would have to be read to find all elements that are associated with that one feature. The program will build a table of elements and their locations within a design file. It would then output the elements from the table and mark them as used to prevent duplicating the XY points. The points may have to be reordered or sorted so that they connect the line strings in the proper manner. The line strings are originally placed in a counterclockwise direction, but the modified line string can be placed in a clockwise direction. The program would detect this and reorder the points in the counterclockwise direction. The DFAD data does not include ellipses or arcs to graphically represent a feature, except point features which can be a circle.

4.3 CRT Printhead Output

The CRT Printhead output program scans the design file to determine the maximum range of all elements. This information is used for determining the movements of the CRT printhead for outputting the elements. The CRT

printhead is moved to the lowest location and the complete design file is scanned to look for elements that would be placed in the first window. A tape block is written even if no element is located in the window. More efficient plotting could be realized if the program were modified to eliminate the placing of blank or empty block information on the tape which results in unnecessary plotter head movements.

4.4 GERBER Input Improvements

The current GERBER Input is in EBCDIC character format. The new plotters are being designed to read ASCII tape format. The GERBER Input Program could be modified to automatically determine the type of input tape format and convert the plotting instructions into design element format. This simple change would enable either type of GERBER format to be read without going through a separate conversion program.

5. CONCLUSIONS AND RECOMMENDATIONS

This program has been very helpful in integrating the AES to the specific needs of the DMA for the purpose of editing manuscripts. It is possible to convert three or four overlay manuscripts into design files and display them in less than one hour. If the manuscripts do not contain registration points, they can be moved or manipulated to place them as desired. Those input tapes that contain registration marks can be displayed, in an overlay manner, and registered for viewing. Sections of manuscripts that need to be analyzed in detail can be enlarged so that a small area can fill the screen. The features can then be edited and a corrected output tape can be generated.

Some of the commands needed to edit a file require a complex sequence of operations. Special user commands can be written to sequence through a set of operations to make specific changes to a design file. These edit functions must be identified and documented so that the proper user commands can be written. Many manually performed editing functions must be learned over a period of time in order to produce a usable manuscript. Some effort should be made to identify features and their reasons for being modified so that specific AES user commands can be written.

The AES provides a quick means of displaying and editing digital data prior to final printing. The system software is continually being upgraded by the manufacturer to add features and capabilities.

It may be desirable to add a Data Management Retrieval System (DMRS) capability to this system. A DMRS would allow additional attributes to be tied to each feature as it is placed in a design file so that it can be cross-referenced against other features having similar characteristics. However, the addition of a DMRS capability would provide another level of complexity that would have to be learned before the system could be fully utilized.

APPENDIX - ABBREVIATIONS

AES	Advanced Edit System
AGDS	Advanced Graphic Data System
BPI	Bits Per Inch
CDB	Cartographic Data Base
CPU	Central Processing Unit
DEC	Digital Equipment Corporation
DFAD	Digital Feature Analysis Data
DLMS	Digital Landmass System
DMA	Defense Mapping Agency
DMRS	Data Management Retrieval System
DTED	Digital Terrain Elevation Data
EBSALS	Elastic Body Small Angle Least Square
ETL	Engineer Topographic Laboratories
GLSS	Graphics Line Symbolization System
IGDS	Interactive Graphic Display System
IPS	Inches per Second
LPM	Lines Per Minute
SDLC	Synchronous Data Link Control

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