ELECTRON BEAM RECORDERS FOR AUTOMATED CARTOGRAPHY

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I. Introduction and Historical Background

Electron Beam Recorders have been developed for the Defense Mapping Agency to produce aerospace, topographic and hydrographic charts and other high resolution imagery and cartographic products.

A computer controlled electron beam recorder (EBR) delivered to the Aerospace Center, St. Louis, Mo. in May, 1978 by Image Graphics, Inc., under a subcontract with the Synectics Corporation is the principal cartographic output device of the Charting, Publishing and Air Facilities subsystems of the Automated Air Information Production System (AAIPS).

Two other cartographic electron beam recording systems which will be delivered to the Hydrographic/Topographic Center, Washington, D.C. and the U.S. Army Engineering Laboratories, Ft. Belvoir, Va. early next year will be used to produce a variety of master recordings in either lineal or raster data formats for the production of maps, charts, text and high resolution continuous tone imagery.

II. System Description

A typical computer controlled electron beam recorder (EBR) system developed for automated cartography is shown in Figure 1. The Cartographic EBR is a complete stand-alone electronic recording system which can produce high quality imagery, graphics and text on film

from raster or lineal digital data on magnetic tape. The system is capable of generating graphic arts quality alphanumerics and symbols from a digital font library stored on-line and plotting lines, arcs and contours of variable widths at high speeds. Line widths, character styles, sizes, angles and positions can be rapidly changed upon command. High resolution imagery or graphics can also be recorded in raster format as black and white or continuous tone gray levels using either binary or run length encoded data.

Input data is rapidly composed and recorded directly on film. The latent images generated in the EBR are processed into visible images using conventional film processing techniques. These master recordings and color separations are then used to prepare press-ready printing plates for conventional multicolor printing presses or to prepare high resolution black and white or color composite photographs.

Functional Sections

There are five functional sections of a Cartographic EBR System as shown in Figure 2.

The Input Section consists of a 7 or 9 track magnetic tape system which accepts industry standard ½" magnetic tape with data densities of 800 or 1600 bpi and operates at 45, 75 or 125 ips, and a keyboard console. Input data stored on magnetic tape as data files call out the commands needed to generate each of the cartographic products or high resolution imagery.

For names or symbol placement, the input commands call out the type of character style or special symbol which are stored on-line as digital representations on a magnetic disk and transfers the characters or symbols into computer memory. The input tape also provides recording parameters such as size, angle and position for controling the Symbol/Vector Generator.

For plotting lines, arcs and contours of variable widths, the input data files supply command codes to the minicomputer and Symbol/Vector Generator for computing position of the electron beam and variations in angle and line width.

For high resolution imagery or raster data, the input

data files are supplied as an 8 Bit code to the minicomputer for controlling the Raster Scan Translator. The raster data may be binary or run length encoded for recording either black and white or grey level data.

The keyboard console is used as an auxillary input/output (I/O) communications line with the minicomputer.

The Control Section consists of a Digital Equipment Corporation PDP11/34 or PDP11/45 basic binary minicomputer processor with a 16 bit word and 64K words of memory. The minicomputer transfers operating data and plotting instructions to the Data Translator Section to generate and position characters, symbols, vectors or rasters.

In addition, the Control Section contains magnetic disk storage for storing the operating software package and other utility software programs which control lineal or raster recording; and a digital font library for characters and symbols.

The Data Translator Section consists of two major subsystems; (a) a Symbol/Vector Generator (SVG) for lineal and character/symbol data and (b) a Raster Scan Translator (RST) for raster plot and image data.

The SVG and RST convert digital data from the computer controller into analog signals which drive the EBR. The SVG includes all of the Circuitry for:
(a) Character and symbol generation with variable size and orientation control.
(b) Vector generation in incremental and stroke vector modes with variable line width control.
(c) Automatic intensity control.
(d) X - Y random positioning.
(e) Other controls and interfaces for the EBR.

All scaling of character and symbol sizes and positioning of characters with the proper orientation and exposure level; all line work and map features with the proper line width, orientation and exposure level; and all random positioning, is accomplished with the SVG.

The RST includes all of the circuitry for:
(a) Recording a variety of raster formats from 500 to 32,000 elements per line in one axis and 500

to 32,000 lines in the other axis.
(b) Automatic intensity control.
(c) Other controls and interfaces for the EBR.

The Software programs provided with the Cartographic EBR are:
Operating System - for PDP11/34 or PDP11/45 minicomputer controllers is Digital Equipment Corporations standard RSX11M multitasking system.

Vector/Symbol Plot (VSP) - is the principle plot program which controls all plotting; and all names and text composition and placement from input data tapes.

Font Library Update (FLU) - is the software package which is used to create digital font libraries on magnetic disks from properly formatted input font tapes. FLU can be used to add, delete, display or list symbol data and to perform minor editing on font data words.

Raster Scan (RS) - this is a software package which controls the raster plot data supplied to the Raster Scan Translator.

Conversion Programs (CV) - are real-time conversion programs developed for converting existing data bases in Gerber or Calcomp plot formats into Symbol/Vector Generator formats for controlling plotting.

Font Preparation - Digital Fonts may be prepared with a stand-alone system from original artwork of symbols or characters which are scanned and digitized with a scanning optical beam. The digitized symbols and characters are processed and edited and then formatted into a digital font input tape for the Cartographic EBR. FLU is used to develop and maintain the Font Library. Two sizes of each font are stored on magnetic disk. All other sizes and orientation are produced with the Symbol/Vector Generator hardware.

A Graphics Display Terminal has been provided to allow viewing of the data being plotted by the EBR during the recording process. The display is a Tektronix 619 storage display which is interfaced directly to the SVG and the RST.

The Recording Section uses an Electron Beam Recorder (EBR) which is an instrument that converts electrical

signals representative of map features, alphanumeric characters, graphic plots or variable density pictures into latent images on electron sensitive film. The latent image is formed by exposing the film with a precisely controlled, finely focused electron beam. An EBR may be regarded as analogous to a cathode ray tube (CRT) recorder where the lens and the phosphor faceplate have been removed and the recording medium placed in the vacuum.

An EBR, consists of a high resolution electron gun, an electromagnetic system for focusing, deflecting and controlling the electron beam, a film transport mechanism for handling various film media, a fully automatic vacuum system which maintains suitable vacuum in various parts of the recorder and a number of highly regulated power supplies, electronic circuits and monitors. Operation control functions of the EBR have been kept to a minimum and are readily accessible to provide the operator with convenient control and ease of operation. Modular construction provides ease of maintenance, trouble-shooting and repair.

Recording Media - various recording media may be used in Electron Beam Recorders; (a) high resolution fine grain silver halide electron sensitive film which is processed by conventional wet chemistry after exposure to electrons (b) dry silver which forms visible images by heat after exposure to electrons and requires no processing whatsoever; (d) electrostatic films and papers which are processed with toner solutions; and (e) electron resists which can be developed by conventional means.

A typical recording film selected for the Cartographic EBR is Kodak Direct Electron Recording Film, Type SO-219 which has a very fine grain emulsion and can be enlarged over 30X without graininess.

III. Performance Characteristics

Table I lists some of the performance characteristics of a typical Cartographic EBR System.

IV. Cartographic EBR Output

Figures 3- 8 are typical examples of output and applications of Cartographic EBR Systems. Figure 3 is a

TABLE I - TYPICAL CARTOGRAPHIC EBR SYSTEM PERFORMANCE CHARACTERISTICS

Film Sizes	140, 127, 105, 70 and 35 mm
Film Transports	Single frame pull down (pin registration or registration punches available)
Maximum Image Size	8¾" X 5"
Minimum Line Width	6 μm
Maximum Vector Length	1024 elements (250 mil-inches)
Line Widths	6 to 261 μm with 8 bit (256 levels) control, in 1 μm increments
Character Sizes	8-250 mil-inches
Character Rotation	1^{o} Increments
Addressable Positions	32,768 X 19,859 address matrix over a 8¾" X 5" format area
Congruity of Sequential Images	± .003%
Geometric Fidelity	± .01% (with software correction) ± .05% (without software correction)
Maximum Optical Density	2.35+
Density Range	64 Levels for graphics 256 Levels for imagery
Background Density	0.1 density units
Video Bandwidth	DC - 10 MHz
Lineal Data Recording	
Random Points	40,000 points/sec
Adjacent Points (IVP)	125,000 points/sec
Stroke Vectors (1024 points)	1,000,000 points/sec
Character/Symbol Recording	20-2000 Characters/sec depending upon style, size and quality
Raster Data Recording	
Elements/Scan	500 - 32,000 computer selectable
Lines/Raster	500 - 32,000 computer selectable
Scan Rates	50 - 2000 lines/sec continuously variable

composite photograph prepared to show samples of the Automated Air Information System cartographic products produced by the AAIPS Cartographic EBR System.

Figure 4 is a standard Instrument Approach Chart which is presently recorded at full scale (8¼" x 5") with the AAIPS Cartographic EBR. A contact negative is made from the EBR positive, from which press ready printing plates are made.

Figure 5 is a master recording with Instrument Approach Charts recorded at 4:1 reduction. This recording can be subsequently enlarged to produce a 16 up film flat which can be used to produce a press-ready printing plate containing 16 full size pages (8¼" x 5").

Figure 6,a,b, c are three color separations recorded at 1/6 scale with the AAIPS Cartographic EBR. The color separations are enlarged to full size (20"x45") film flats from which printing plates are produced for a color press. The final product is a color Enroute Chart.

Figure 7 is an example of high resolution raster imagery. This aerial photograph has been recorded at different sizes and different density levels to enhance the input image data using the gamma enhancement circuits in the Cartographic EBR.

Figure 8 is another example of high resolution raster imagery. This satellite image was made from LANDSAT computer compatible input tapes. The data was recorded at different sizes and density levels to enhance the input data.

The Cartographic EBR output clearly illustrates the systems capability of recording both lineal and raster data. The system offers the cartographer the ability to intermix both lineal and raster data bases on the final cartographic product.

V. Acknowledgements

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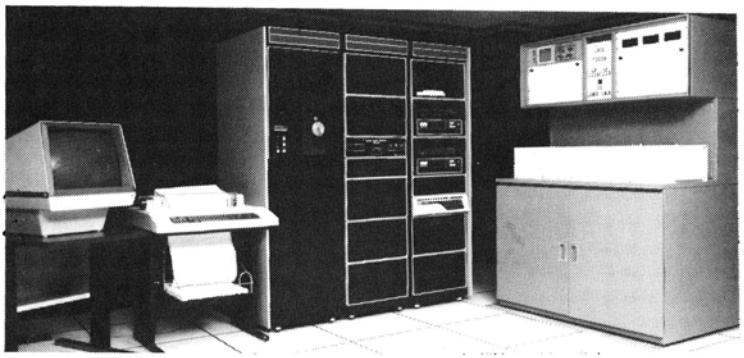

Figure 1 Cartographic EBR System

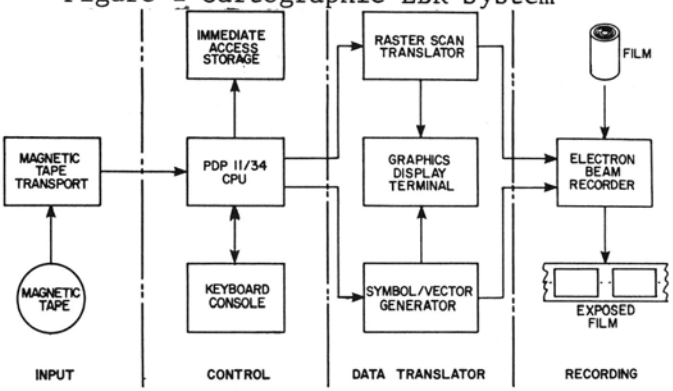

Figure 2 Functional Sections

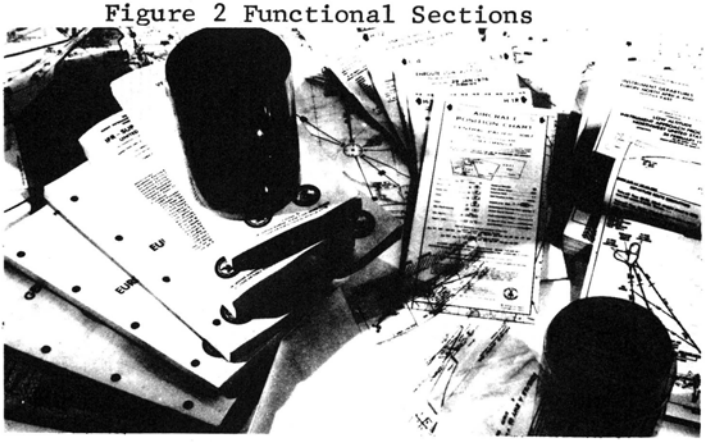

Figure 3 AAIPS Cartographic Products

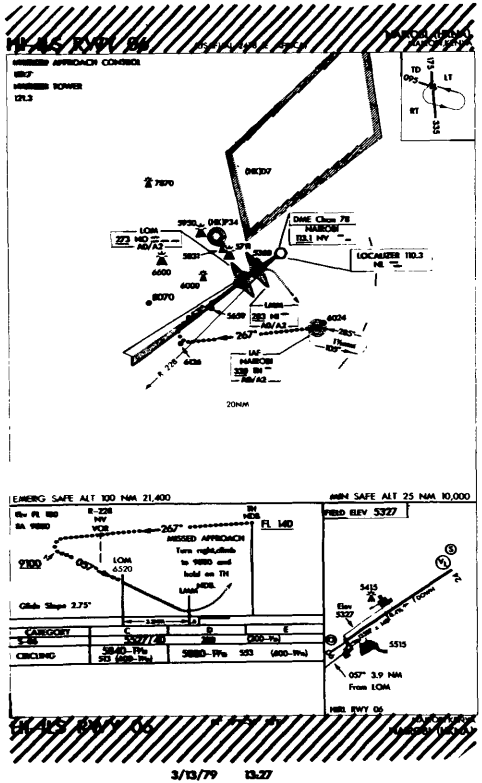

Figure 4 AAIPS Instrument Approach Chart Recorded at Full 5"x8" Scale

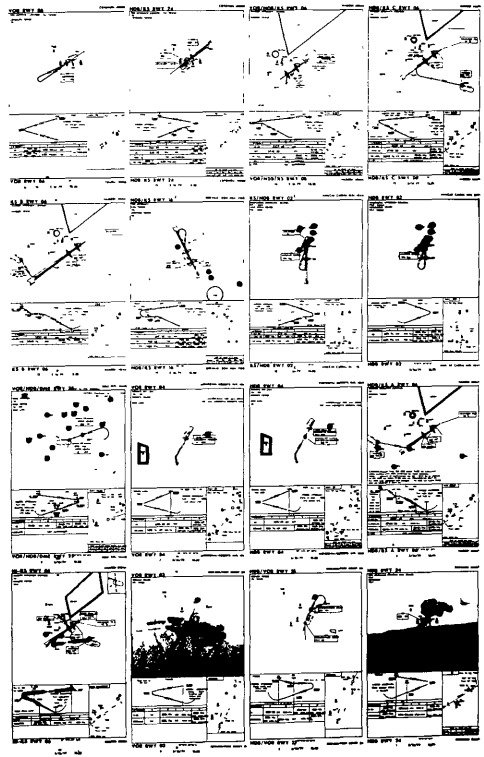

Figure 5 16 AAIPS Approach Charts Recorded at ¼ Scale

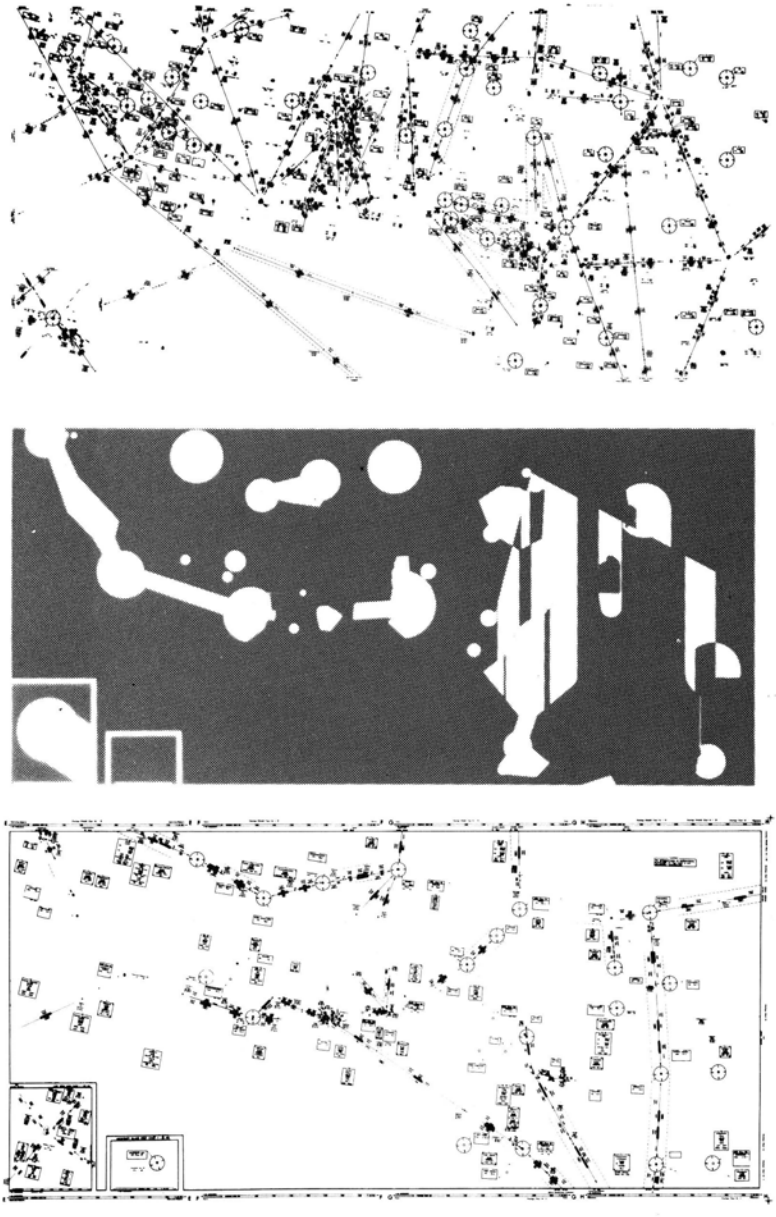

Figure 6a, b and c Enroute Chart Separations (1/6 scale)

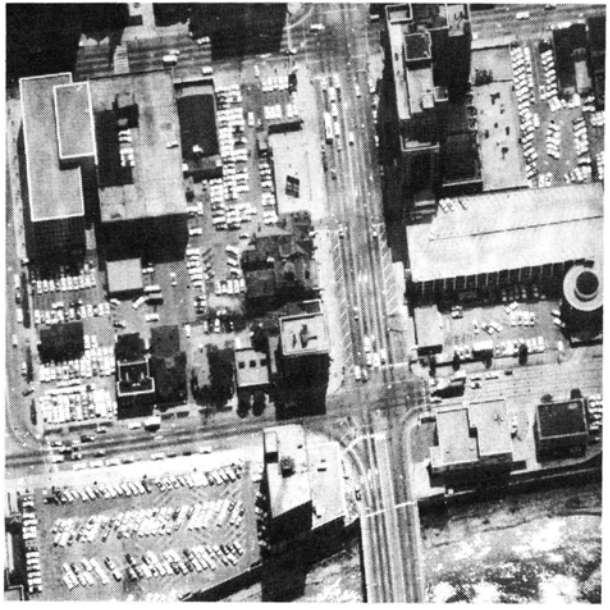

Figure 7 - High Resolution Aerial Photograph Recorded in Raster Format

Figure 8 - LANDSAT Image Recorded in Raster Format