LARGE FORMAT LASER SCANNER/PLOTTER SYSTEM

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I. Introduction and Historical Background

Two Large Format Laser Scanner/Plotter Systems were developed for the Defense Mapping Agency's Aerospace Center, St. Louis, Mo. and Topographic Center, Washington, D.C. under the sponsorship of the Rome Air Development Center, Griffiss Air Force Base, Rome, N.Y.

The original systems were designed and assembled by CBS Laboratories, Stamford, Ct. and EPSCO Laboratories, Wilton, Ct. in 1976. Image Graphics, Inc. completed the integration, installation and testing, and introduced significant hardware and software improvements to the systems.

The Laser Scanner/Plotter is a stand alone system capable of scanning and digitizing charts or documents in the form of opaque hard copy or photographic film and plotting positive or negative output on film up to 52" x 72" (132 cm x 183 cm) in less than 30 minutes, with a basic laser spot size of .001" (.025 mm). It is currently the only available device which can both scan and plot this size format in such a short time at high resolution. In addition, the system has gray scale capability; can generate mirror images, and can accommodate variable thickness scan or plot materials.

II. System Description

Figure 1 is a photograph of the system installed at the Aeorspace Center in St. Louis, Mo. The system is composed of two main subsystems. First is the opto-mechanical section which consists of the drum-carriage assembly, all optical and laser components, and an environmental chamber. Second is the electronics control section comprised of tape drives, a dedicated mini-computer, and all electronic hardware for controls, data processing and interfacing.

The Laser Scanner/Plotter is a raster type system and utilizes a rotating drum (53" long x 25" diameter) mechanism to provide scanning in the vertical direction. Film is held on the drum by means of a vacuum system, clamps, and pressure sensitive tape. The left end of the drum contains a high resolution magnetic tachometer which encodes the drum position. Horizontal scan is provided by a lens carriage moving on a lead screw along the length of the drum. Mounted on the carriage are the laser beam focusing and deflecting optics and intensity control circuits. A stepper motor and lead screw encoder accurately position the carriage. The complete optical system is shown in schematic form in Figure 2. The light source is a Lexel Argon Ion Laser, Model 75.2 supplied with a temperature compensated wavelength selector. It has a maximum usable power output of 25 mw at 476.5 nanometers. The narrow divergence beam outputted by the laser passes through a solenoid operated shutter and is folded by two front surface mirrors into a path in line with the optical carriage motion. Stability is maintained by a feedback circuit controlling the laser power output which holds the beam intensity constant

During each drum revolution, 6 lines or channels are scanned or recorded using an acousto-optical beam deflector. This method allows the drum speed to be 1/6 that required for a single channel system to finish scanning a full size film sheet in less than 30 minutes.

The A/O modulator, an Isomet Model 1206, is driven by an IGI driver module which contains six high frequency channel outputs. The frequencies cover a range of 100-130 MHz in 6 MHz steps. A three bit spot position code received from the control logic, is demultiplexed and used to switch the output from one of the six channels

into an RF balanced modulator. Each frequency may also be amplitude modulated for gray scale control. The output of the RF balanced modulator is fed to a power amplifier which drives the A/O modulator.

Laser beam modulation is achieved by placing an optical stop in the path of the undiffracted beam, and then switching on and off the acoustical excitation.

The diffracted portion of the laser beam is folded by a final mirror and focused on the scanning surface with an objective lens. The beam diameter entering the objective is approximately .9 mm, thereby producing the diffraction limited spot associated with a f/36 lens.

Spot deflection is achieved by changing the acoustical excitation frequency in steps of approximately 6 MHz from a center frequency of 110 MHz. This relatively small change in frequency alters the diffraction angle, which results in a .025 mm change in spot location.

Although the plotting density range is from 0.025 to 2; or an exposure range of less than 100:1, the static extinction ratio of the A/O modulator/deflector will be at least 1000:1 with a dynamic capability at least several hundred. This insures that the minimum fog level requirements will not be exceeded during operation.

The Raster Scanner/Plotter System uses a combination of an f/1 lens, and two mirrors to collect the light reflected from the drum surface and direct it as a collimated bundle on the photocathode of a photomultiplier tube. The first two elements of the collection optics have holes bored through them to permit the scanning beam to pass through without distortion. A 2.0 neutral density filter is placed in the optical path directly in front of the photomultiplier tube to prevent excessive light from striking the tube face and damaging the photocathode.

A self contained environmental control unit is located at the right end of the drum carriage assembly. The unit intakes room air, and ducts conditioned air to the film chamber to control the internal plotter environment $70^{\circ} \pm 1^{\circ}F$ and $50\% \pm 1\%$ RH. A return duct is located at the lower section of the equipment.

Status signals are located on the main control panel to indicate out of limit conditions for either temperature or humidity. A recorder is also provided to monitor and record the two parameters.

A simplified block diagram of the Scanner/Plotter System is shown in Figure 3. Output of the system is either digital data on magnetic tape or imagery on film. Data which has been scanned is digitized and recorded on magnetic tape. Data which has been previously digitized is supplied on magnetic tape as an input to the system and recorded on film.

Two magnetic tape drives, (Kennedy Model 9300), are located in the upper portion of Bays 1 and 2 of the raster plotter control electronics rack. The dual density formatter and the interface logic hardware are located in the computer rack. Each tape drive has its own Western Peripheral TC-130 formatter and direct memory access interface to the CPU. The magnetic tape transports have the following characteristics:

1. Tape speed 125 inches/second, and
2. Recording density of 800 NRZI/1600 PE bytes per inch, selectable.

Two transports are required in order to keep up with the high data rate associated with the system thruput.

The minicomputer controller consists of a Digital Equipment Corporation PDP 11/40 minicomputer with 32K core memory, a 30 CPS Decwriter, a TU-60 dual cassette drive for program storage, and a VT-55 Display Terminal.

The necessary data transfer rate from and to the computer is accomplished by double buffering the input tape data, and by executing core/plotter transfers simultaneously with tape reading.

The Scanner/Plotter is interfaced to the minicomputer controller through six DR11-B Direct Memory Access (DMA) units.

Each DMA channel provides the following data transfer capability:

1. High speed direct memory access to and from the PDP 11/40 core memory via 16 parallel input, and 16 parallel output data lines.
2. Programmed single word data transfer over the 16 parallel input and 16 parallel output lines.

3. Three software controlled function data lines and three software read status lines, all used for control commands.

The operation of the Scanner/Plotter System is automatically controlled using the PDP 11/40 software and special purpose logic. Data parameters such as starting point, window area, etc., are entered into the computer by means of a Decwriter or VT55 unit. The system is automatically started and data recording or scanning is initiated. During operation error checks are continually made. If any are found, operation ceases and appropriate indications are given to the operator. Otherwise scanning or recording continues until the desired window area is completed.

A raster is scanned into the Scanner/Plotter data format in the following manner:
In one revolution of the drum, the electro-optical system scans or plots six continuous lines on the periphery of the drum. At the end of the revolution, the carriage drive increments the optical carriage a distance equal to the six lines. The electro-optical system then scans or plots another six lines on the drum periphery. This continues until the desired format area has been covered.

The six continuous lines are generated in the electro-optical system by the use of an acousto-optical (A-O) modulator/deflector. At a given X coordinate, (angular position of drum rotation), the beam deflector time sequentially positions the laser beam along the Y axis (parallel to the drum axis) at a separation of a position resolution element (0.025 mm). The deflector repeats the motion along the Y axis. The action of the deflector is not that of sweeping the beam along the Y axis (and therefore smearing the beam), but is a random access type of motion, locating the beam to specific positions.

Synthesis of 0.050 mm or 0.100 mm resolution elements is accomplished by means of hard-wired high speed logic. The process involves the averaging of adjacent spot density levels.

III. System Output and Capabilities

Figure 4 is a typical example of the type of images

which have been digitized and recorded on the Scanner/Plotter System. It illustrates a medium to high density image scanned and plotted in the 1 element (0.025 mm) resolution mode. High quality results can be obtained when scanning and recording in either 1, 2 or 4 element resolution modes.

Figures 5 and 6 contain the basic operating characteristics of the scan and plot modes respectively. It should also be noted that the system can scan or plot up to 16 gray shades, generate mirror images, and operate with either run-length or binary code formats.

In addition, other features presently being installed include a real-time display for both scan and plot, and the capacity to operate with a single tape drive.

IV. Applications

The Scanner/Plotter can be used for a number of automated cartography applications:

A. Preparation of raster digital data base by digitizing large format maps;
B. Input-output device for other systems;
C. Proof plotter;
D. Lineal to raster conversion by recording linear data on electron beam recorder, digitizing with a high performance raster scanner and plotting on Scanner/Plotter;
E. Image processing and enhancement of gray scale images by scanning and recording (during the same run) selective gray scale combinations; and
F. Generation of color separation plates by use of high power laser.

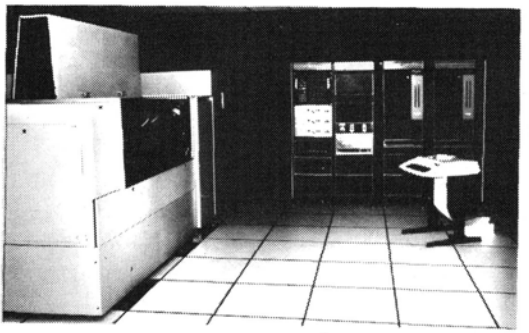

Figure 1 Laser Scanner/Plotter System

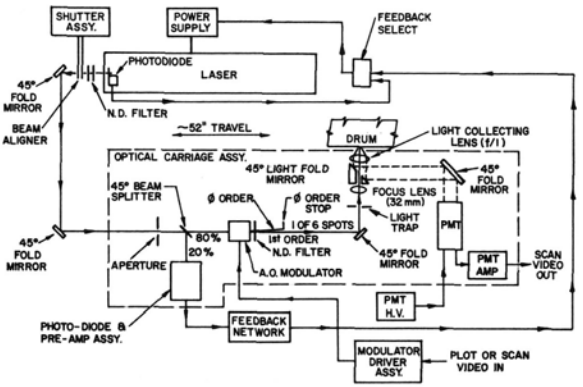

Figure 2 Optical Schematic

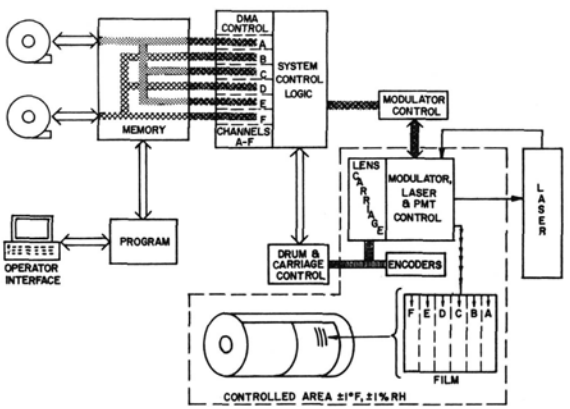

Figure 3 Block Diagram

Figure 4 Digitized/Recorded Image

SCANNER CHARACTERISTICS

CARTOGRAPHIC INPUT PRODUCTS	POSITIVE OR NEGATIVE OPAQUE, SEMI OPAQUE, TRANSPARANCIES
MAXIMUM SIZE OF INPUT	132 cm X 183 cm (52" x 72")
MAXIMUM SCAN FORMAT	127 cm x 178 cm (50" x 70")
THICKNESS OF SCAN MATERIAL	004" to 010" IN STEPS OF 0005"
SCAN TIMES 127 cm x 178 cm (50" x 70") 61 cm x 76 cm (24" x 30")	 30 MINUTES OR LESS 15 MINUTES OR LESS
RESOLUTIONS	40, 20, & 10 lp/mm
MINIMUM SPOT SIZE	025 mm (001")
POSITIONAL ACCURACY	± 050 mm (± 002")
POSITIONAL REPEATABILITY	± 025 mm (± 001")
OUTPUT	9 TRACK MAGNETIC TAPE, 800/1600 bpi IN RASTER FORMAT

Figure 5

PLOTTER CHARACTERISTICS

INPUT	9 TRACK MAGNETIC TAPES, 800/1600 bpi, 125 ips, RASTER FORMAT RUN LENGTH OR BINARY
OUTPUT	EXPOSED FILM, BLACK & WHITE, NEGATIVE OR POSITIVE
FILM TYPE	KODAK MP 2562 x MP 4562
MAXIMUM FILM SIZE	132 cm x 183 cm (52" x 72")
MAXIMUM PLOT FORMAT	127 cm x 178 cm (50" x 70")
THICKNESS OF FILM	004" to 010" IN STEPS OF 0005"
RECORD TIME 127 cm x 178 cm (50"x70") 61 cm x 76 cm (24" x 30")	 30 MINUTES OR LESS 15 MINUTES OR LESS
VARIABLE LINE WIDTHS	10 mm TO 80 mm (004" to 032") in 025 mm (001") INCREMENTS
MINIMUM SPOT SIZE	025 mm (001")
POSITIONAL ACCURACY	± 050 mm (± 002")
POSITIONAL REPEATABILITY	± 025 mm (± 001")

Figure 6