Output Devices Panel

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MBA Information Systems

Edward Snow
RETICON

Patrick Grosso
Image Graphics, Inc.

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i/o Metrics

Carr: According to Ray Boyle, good interaction makes good engineers, and this morning we are going to make you good engineers because I want you to interact with our panel members. We are blessed with a variety of technical talent here; you are looking at presidents and vice presidents of corporations, representing five technologies. These gentlemen have come on their own time, spending their own money, from all over the United States. As Ray said, we are going to let them talk to you for a few minutes, and then we would like you to ask them questions on an informal basis.

The first speaker today is John Constantine from Constantine Engineering Labs. John is the president; he has several sons that are running different parts of his organization in California--from California to New Jersey to Pennsylvania. Paul, one of his sons, is installing some equipment today, and he said, "Dad, you go talk and I will install hardware." John, I turn the floor over to you for a talk about precision cathode-ray tubes.

Constantine: I appreciate the opportunity to come and discuss what pertains to our model--the latest in the science of electron beam control. I would like to tell Dr. Boyle that I was converted about 25 years ago regarding the precision requirements in cathode-ray-tube (CRT) technology. Basically, we were manufacturers of deflection yokes that are required to deflect the electron beam on the face of the CRT. The precision had to be commensurate with the output on the face. Since we are going to discuss output devices, it is a little bit difficult to determine just which is the output device in these automatic loops. Rather than trying to label any one component, we will just jump 25 years when CRT's had spot sizes of 5 mil for the flying-spot scanners to today where we discuss 0.5-mil or 12-μm spot sizes on the face of the tube. That implies that all the components behind the face, including the computer that has to drive the amplifiers to position the spot, must have a precision commensurate with the 0.5-mil spot compared to the 4- or 7-in total deflection. That works out to a pretty small percentage of precision.

The uses today, where we have built equipment, are for such applications as the quick-look monitor for the ERTS system, which takes the data from the ERTS satellite and converts it to a 70-mm photograph negative which is then enlarged to 8.5 by 11 in. In this ERTS system, we are discussing 0.6 mil on the face of the CRT (that's on a 3- by 3-in raster which implies 5,000 lines) with a reduction of .75 to the film plane; you are looking at a lot of detail. We have a photo of an ERTS picture of northern California which shows Lake Tahoe from 600 m. That represents a 4,600-line capability on the face of the tube. Once it goes through the lens and onto the particular RAFR film, you get down to possibly the resolution capability of 1,200 lines, which is quite a loss through the lens and film system. The Goddard system, which is going to be used for some application requiring a film recorder, is able to record on that film a 4,000-line raster and actually resolve them on the film. In a period of a couple of years we have made quite an improvement in the output devices capability from the face of the CRT to the film. We are starting off with a 0.55-mil spot and winding up with 4,000 lines on the film. As Dr. Boyle said, the problem is getting rid of the noise.

ERTS requires gray-level capability on the output of the CRT and onto the film. The digitization there is much more difficult than straight black/white digitization. In that area we have recently delivered a large-format scanner capable of scanning a 14-in-square master letter; that is digitized, stored, and then played back onto a printer. These letters are actually used for generating the masters on the phototypesetting equipment. Originally these are 12-in-square letters that have been made by hand, and the object is to digitize them, store them on disks and tapes, and then play them back on a precision printer. We have the capability of digitizing the letter that is 12-in square, storing that data, then playing it back on the printer which can produce up to 256 characters on a plate that is about 6-in square. This is another area where the CRT, optics, film, and computer are all tied in. The output is actually the glass plate that goes into the phototypesetter. Another area is the reverse--digitizing for X-ray scanning and enhancement. The other end is going down to the microscopic area where the CRT raster is focused onto a small section that you wish to examine, such as cells or chromosomes. That information can be stored and operated on similar to any other type of digitization. All of these things have to be done with precision that is commensurate with the percentage, resolution, and gray levels that you are looking for on the final output.

Boyle: One of the most interesting aspects is the use of the precision CRT as the photo light for x-y recorders, which you have been involved with. Also I think it is one of the most exciting developments, to get to the flexibility of any sort of symbol plotted on the x-y tables.

Constantine: The system used at Ft. Belvoir was capable of using a 2-mil spot with wobbling to produce circles. In that manner they were able to use it for filling in letters and plotting and transferring the letters on the map section. We won't consider that particular high-resolution application.

Carr: For those of you who will be visiting the Engineer Topographic Laboratories on Wednesday and Thursday, this hardware will be shown. It is a subrow system of positions on the Gerber plotter, and we will be driving the hardware with minicomputers talking to each other. This is a chance to see it in operation. As John indicated, there are two problems: one is getting resolution and one is getting too much resolution. If you make the spot too small, then you have to do something to generate wide lines. This gets into something that you never really see on the surface until you dig a little deeper. If you put a 2-um line down and you try to generate lines which are 25, 100, or 200 μm, you've got to move that spot around to do what we call "dittering" or "diddling." You have to control that spot to generate all of the lines and all of the symbols that you need to work without the map machine.

With all the work that has been done between SELCO Labs, CBS Laboratories, and another electronics house that we don't have a representative from--Adage--as well as amplifiers and data handling hardware built by us, I strongly recommend that you see this system in operation. As far as I know, it represents the state of the art of CRT's applied to a plotting operation.

For the past several years there have been quite a few developments going on in drum raster plotters--large, rotating, mechanical drums on which you can either wrap film to output or you can wrap documents to scan. One company that has been doing considerable work in this area is MBA Information Systems, which currently has two projects going on large drum recording devices. Tom Healey will be talking about some of the work at MBA. Tom is basically a businessist who has gotten into auto-mechanical hardware in the past few years. His background has lead him to be manager of MBA's Electro-Optical Systems Group. I'll leave it to Tom to tell us the details.

Healey: I will address raster drum scanning and recording devices, primarily raster scanning technology touched on previously by Constantine.

(Figure 1) Talking about raster map production devices (Ray Boyle indicates that the smaller users would go to services bureaus), the raster plotting devices are a fairly large investment. Therefore, you will probably only find major use within the large-volume production facilities. Large volume is defined as the ability to generate a full set of 4-color separations for a 42- by 60-in map within a half a day, or specifically 2 full-color maps in one 8-hr day or approximately 1,000 full maps per year on 2 shifts. The raster finishing or raster scanning plotter has a cartographic resolution, accuracy, and registration. The specific device that Howard Carr referred to has 800-line/in resolution and 0.5-mil accuracy. Registration is 0.5 mil and repeatability is 0.5 mil, all referenced to the recording surface--7-mil Estar lithographic film. This film is very flexible and must be handled very, very carefully, as you well know, in order to make it meet these requirements. These are some of the parameters that make raster scanning very attractive.

Area fill can be accomplished by software instruction within raster scanning and plotting. The problem inherent with the vector-type devices does not exist, that is the fact that one has to scribe, scribe, scribe, and scribe some more to effect an area fill. In

CHART PRODUCTION FEATURES OF RASTER TECHNOLOGY

HIGH SPEED LARGE FORMAT PLOTS (FULL SET OF COLOR SEPARATION IN 4 HOURS)
4000 COLOR SEPARATION/YEAR

FIXED THRUPUT (PLOT TIME FIXED AND INDEPENDENT OF COMPLEXITY OF DATA)

LARGE AREA FILL IN ONE STEP (DOES NOT EFFECT PLOT TIME)

ELECTRONIC HALF TONE GENERATION

CARTOGRAPHIC QUALITY

RESOLUTION	8001 pl
ACCURACY	$\pm$ .001
REPEATABILITY	$\pm$ .0005"
REGISTRATION	$\pm$ .0005"

Figure 1

raster this is done in one step in software; software-generated halftones are being generated now.

Another thing we've done with raster scanning plotters is to use a laser to record directly on offset plates as well as lithographic film. The hardware (fig. 2) for this device is simply a disk-operating system with minicomputer control that works offline in this particular system. This system is under contract with the National Oceanographic and Atmospheric Agency, National Ocean Survey (NOS). The original data, that is the digital data, that we were talking about before is taken from their 360/195 and put onto magnetic tape for input to this system.

The raster drum plotter features (fig. 3) are 800 lines/in resolution, 3-mil spot size, 42- by 60-in recording on 44- by 66-in film, offline production, and the option to upgrade to a scanner plotter. Film is loaded on the clamps. All the energy from the laser and the laser light is behind the drum to comply with OSHA safety rulings. The drum has a 90-in circumference and can take 70-in or 76-in film.

There are several significant factors of a raster scan system (fig. 4). The drum plotter can be upgraded to a scanner. The scan spot size is 3 mil, and the input graphic size could again be 44 by 64 in. The scan window is 42 by 60 in, and the scan time would be 1 hr per film record. The old original graphics (specific production negatives) could be scanned and then merged on an interactive display with data from updated information.

The scanning resolution on the device in figure 5 is 800 lines/in. It is possible to change scale from a half to a factor of 2. The system has tolerance scaling that is anamorphic, and there is the ability now to add a hardware multiply-and-divide to do interim scaling from one data base to another within that range. As the computers and some of the other devices become a little bit more powerful, we will be able to scale even more. The scanner/plotter inputs would be digital data, either coming directly from a digital data base on film or on magnetic tape or the analog data from previous records. The outputs, again, can be either digital data or analog data.

We are presently building a scanner/plotter for the Rome Air Development Center (fig. 6). It will take JOG-size input and output and scan them in either color or black and white. It will discriminate 32 colors and 16 gray levels with spot sizes that run from about 0.5 to 4 mil.

Another feature of a laser raster scanning plotter (fig. 7) is the ability to scan and plot color. Color scanning is accomplished by one laser, which is an argon-ion laser that is poisoned with krypton, giving you red, green, and blue. These can be compensated to effectively give you a white light beam, so that if you have an original that is in color or color-coded, you can actually do color pulls with laser scanning.

<u>Peucker (Simon Fraser Univ.)</u>: If you had a 40- by 60-in plot with 800 lines/in, I calculate that you produce about 2 billion spots/hr or about 3000 spots/sec.

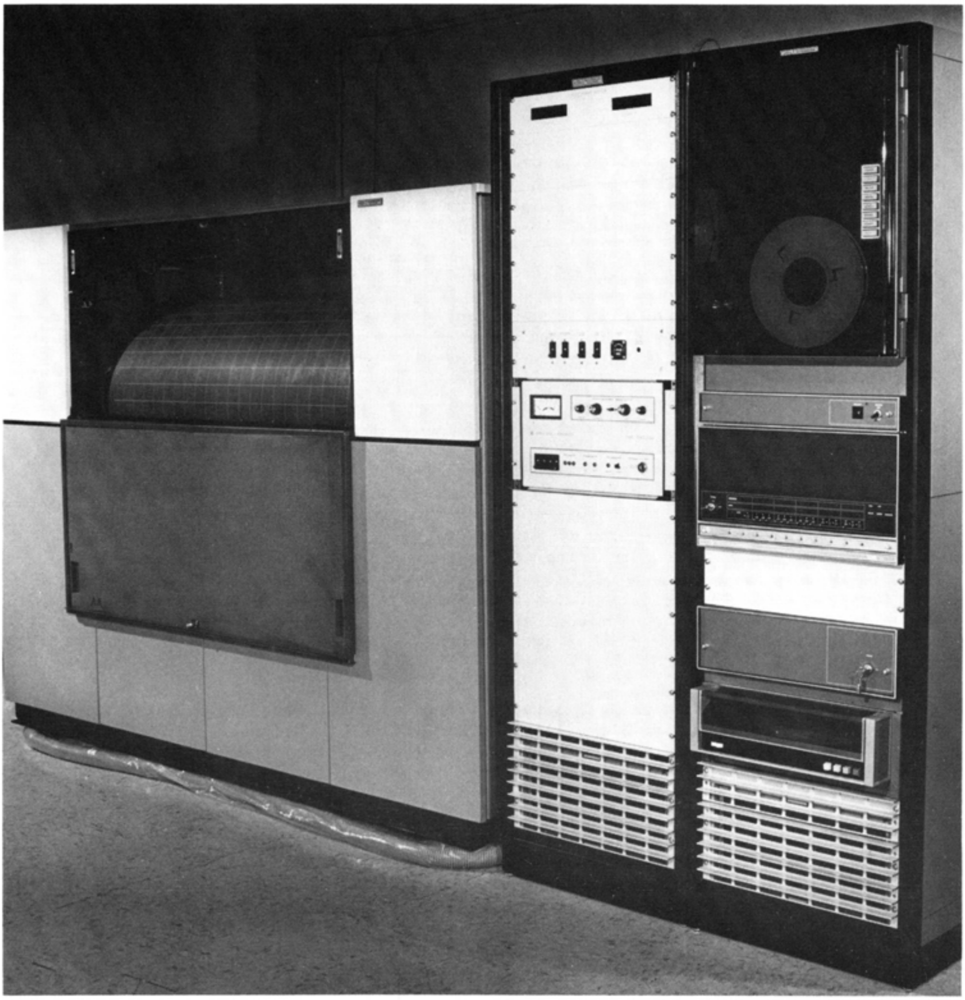


Figure 2

Raster Drum Plotter Features

- 800 Line resolution with 0.003" spot size
- 42" X 60" recording on 44" X 66" film
- Off - Line production system
- Real Time Disk - controlled computer system
- Upgrade to scanner plotter

Figure 3

SIGNIFICANT RASTER SCAN SYSTEM FACTORS

COMPACTED RASTER TAPE DATA BASE, ALL - DIGITAL MAP PRODUCTION

COLOR FEATURE SEPARATION CAPABILITY

CARTOGRAPHIC REGISTRATION & FULL RESOLUTION

FLEXIBILITY TO SCAN ARCHIVAL FLAT DOCUMENTS AND PLOT SEPARATION NEGATIVES/ POSITIVES

ON LINE SOFTCOPY MERGE/EDIT/VERIFY

SCALE CHANGE LINEAR AND ANAMORPHIC FACTOR OF 2 and 1/2 + TOLERANCE SCALING

Figure 4

Figure 5

Scanner

- Accept color coded archival records
- Discriminate 32 colors and 16 gray levels
- Spot sizes of 0.0005, 0.0007, 0.001, 0.0013, 0.002, 0.004 inches
- Input graphic size: JOG size chart (24" X 32")
- Pin registration
- Absolute position determination

Figure 6

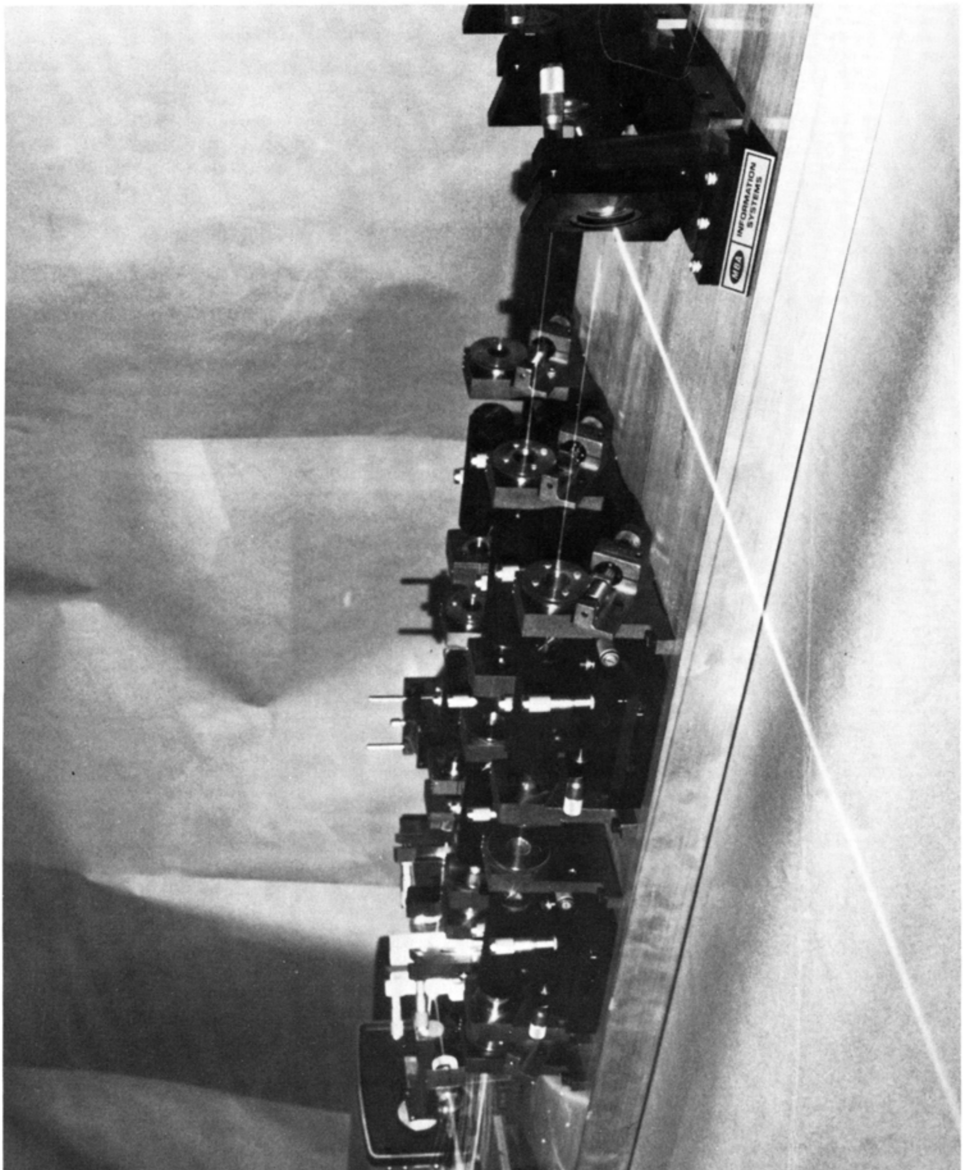


Figure 7

Healey: I think you will find that the data rates are higher; considering dead time and all the things that you are putting in there, the data rate is about 0.5 MHz.

Peucker: If I have to do that point by point without scan conversion, I could get away with the minicomputer. If I have to do scan conversion for a 40- by 60-in scan, simply to keep the data in core, I think it needs quite a beating.

Healey: It is a very large amount of data. No, you don't do that, Tom. The data is handled quite differently. Let's take a look at an individual color separation. You will find that the percentage of black area to clear area is very very low, or in the case of a large area fill the inverse may be true. If the inverse is true, we can invert this in a negative way so that we can decide which data field we are going to compress. The information is generated by the computer (360/195) as a compressed binary-image on magnetic tape, so we are only storing actual data points on tape. For example, in the final checkout for the plotter, we are going to plot every point. That is about 10 reels of 2400-in/reel magnetic tape--no way will this be done in the production operation. Data will be stored in greatly compressed binary-image form, from about 25,000 in of data to a little less that 1 roll of magnetic tape, which is approximately a 10:1 data compression.

What we do when we are going to fill the whole plot is just, for one line, do a delta-mode compression as far as our controls are concerned. For instance at position X1333 we turn on, and then we go all the way to where it is going to turn off, say X46001, and turn it off. So we are not storing all that data, all the dots between X1333 and X46001, as far as the magnetic tape is concerned.

Chrisman (Harvard Univ.): I am following on Peucker's question. You are compressing each raster line in terms of where it starts and where it stops, is that right?

Healey: That is one of the techniques that we use. There are several compression techniques that are used in this system--that is the simplest.

Chrisman: What are the others?

Healey: We also use the redundant area compression, which means that we take care of more than just one line at a time.

Chrisman: Wouldn't you get a bigger compression by doing line recognition and ignoring entirely the raster nature of your physical device? In looking at the linear nature of the actual feature that you are trying to represent, Peucker and I are trying to ask you whether you can have such a small data base if you have an actual linear feature system that you could generate whatever raster that you needed without having to worry about the physical nature of your output device.

Healey: Yes, that kind of software, I know, is in the works, but it is not here operationally today to handle that particular size format, as far as I know. We are following this very carefully. We know that a number of people are working in the area as we are. We are talking about a system that is going to go operational and start producing charts next month.

Chrisman: My problem is the feeling that if we get systems which are nailed to the floor by the bulk of data implied in a system like that, we will never be able to get out of it. A billion is a big number. I am scared; I am a little guy, you know. I use one little device. I grew up with a CalComp plotter, you know. When you start conceiving billions, I get scared.

Healey: That is one of the reasons that I prefaced my remarks with the fact that I honestly don't think the little guy (small user) is going to wind up with a large production plotter like this. The little guy doesn't have to turn out that many maps every day.

Chrisman: But I would like to have access to the data that is being developed that way. I think everybody should have access to this data, no matter whether they are small or large. I would rather have the data bases not be dependent on the device.

Healey: The data that we are getting originally is coming from a digital data base--the base that NOS has. What we are trying to do is not to go back into the big data base every time. We have small segments that we are going to update. We will take those small segments with the new data and merge them with data that we have stored on the last piece of film that was exposed on the plate. Then we will scan everything else. There is just one section in this hopper here, or similar to that, that has changed; that data would come in through any one of a number of the new systems, as far as we are concerned.

Carr: That is a good question. It raises a point that I think a lot of people overlooked when they got into raster scanning and raster plotting hardware, and that is the software to support it. Recently, in some of our work at ETL, we have tried to apply a new type of computation to raster data. We have worked with the Goodyear Aerospace Group to evaluate their unit, STARRAN, which uses associative ray techniques. We do have two representatives from Goodyear who have been working in this area. We found that we could take software programs that were requiring about 3 hr of computer time and reduce that to about 7 sec using STARRAN techniques. We are talking about handling an awful lot of data in this 7 sec. I would like you to talk to the people here from Goodyear; they may be able to answer some of your questions about handling large amounts of data in a very quick manner.

The next gentleman that I would like to present is Edward Snow from RETICON. RETICON has been involved in manufacturing microchip arrays for image scanning--self-scanning type of technology.

Snow: I feel a little bit out of place here, today. First of all, I am not sure that the device that I am going to talk about might not be more appropriate in the session on input rather than output devices. I am going to talk about a component--a semiconductor component--rather than a complete system. The component is a silicon-photodiode ray--a self-scan photodiode ray or solid-state image sensor that goes under a variety of names. These devices are integrated circuits which, in presently available types, contain up to 1024 photodiodes (individual photo sensors) together with multiplex chips, multiplex switches, and scanning circuitry, all on a single chip of silicon less than 1 inch in dimension. These devices are presently being used in facsimile systems in optical character recognition (OCR) as well as in size, position, industrial inspection applications; they certainly have applications, I am sure, in cartography. I am not an expert in cartography, however, so I am going to describe the device and leave the applications more or less up to you.

(Slide) (Editor's note: Slides not available for publication.) This is the type of device we are talking about. This particular one has 1000 photodiodes in a line down the center of the silicon chip. These are on 1-mil centers. The total package is about 1.5 by 4 in. In addition to the photodiodes there are multiplex switches and shift-register scanning circuitry built on to the integrated circuit chip.

(Slide) Here we have represented schematically the 1- by 1-mil photodiode, a capacitor, a multiplex switch which is an MOS transistor, and a scanning ciruit. In operation, the photodiode senses light and converts it to electrical charges which are stored on this capacitor. As we scan through the shift register, these charges are read out in sequence through the switches and onto an output line. We get a sequence of charged pulses, each one proportional to light intensity of the corresponding cell.

(Slide) Here are a few of these devices, showing that with the same basic design these devices can be made in any length, from small ones (this one is 256 elements) available down to 64 elements up to 1024 elements, which are commonly used for OCR applications. The large ones can be used for full-page width facsimile. We can scan a full page of information in approximately 1 sec with a device like this.

In the background is shown some of the topology of the silicon chip. You see the line of photo sensors (each one being a little area like this), the storage capacitor on which charges are integrated, and a multiplex switch through which it is read out. One of the switch register circuits is shown on this side. These devices here are line scanners or linear arrays. There are also matrix arrays available.

(Slide) Here we show a schematic of these devices. They are essentially the same thing, except we have two switches--one for x and one for y addressing--so that they can be raster scanned.

(Slide) Here is a photograph of the matrix array of one of these devices.

(Slide) Here we see a 2-dimensional array having 50 by 50 photocells with 2 shift-registers for scanning, one on each edge of the chip. The shift registers are in the background. There are 2 switches that you can't make out unless you know what you are looking for on each cell. This device is on 0.4-mil centers in each dimension.

(Slide) This shows the kind of output one gets from these devices. This is simply scanning as an image sensor across a black-to-white transition on a piece of paper. The paper is imaged onto the array;

there is a black/white edge right here. We see a low output from the diodes here and a fairly abruptly changing output to the high level right here. In fact, one can make a black/white transition in a single diode space if the optics are good enough. This corresponds to 1 mil in the common variety devices. These are the recharge pulses coming out of the device as each of those charge pulses is sampled in sequence. If we go through an integrating sample and hold circuit, then we get an output array form like this. The devices are capable of dynamic ranges up to about 1000:1 or even better in some applications.

(Slide) This shows some of the progress in the state of the art. In devices of a few years ago, we were able to make about 32 diodes in a row. Here is a picture of a horse that was taken with this device. The device is scanned in this dimension electronically, and there is a mechanical scan in the other dimension which you can't quite make out in the picture. If we go to 64 elements, you can see that maybe it is a mule. Finally, by the time we get up to 512 elements, we are making very good duplication of the original. The dynamic range in this picture is limited by the CRT that the picture is displayed on, not the image sensor. These devices are now available up to 1024 elements, and shortly they will be available up to 2000 elements.

(Slide) In this last slide, I show some of the same pictures. This is just displayed on a line plotter. We have actually threshholded the output instead of using the analog form to display black/white information, again going from a poor-resolution, 32-element device up to a 512-element device.

I would like to summarize by mentioning some of the advantages of this type of device. The obvious attributes are the small size, weight, and low-voltage. Another is the almost perfect geometric accuracy as compared to CRT devices or vidicon cameras as a pickup device. This device has the diodes on essentially perfectly defined center-to-center spacings. Since it is scanned electronically rather than by electron beam, one knows the exact position of each point of information. The devices are read out by a digital clock which controls the scan rate. These clock rates can be set arbitrarily up to about 10 MHz, diode-to-diode sample rate. Since it is a clock system, it makes it very compatible with computer-processing data.

As far as the state of the art is concerned, linear arrays can be used for full-page scanning, that is, for digitizing information with a full-page scan. We have up to 1000-element devices, and 2000-element devices will be along shortly. Matrix arrays of 50 by 50 elements are available, and 100 by 100 or 200 by 200 will be available before too long. This technology is very, very flexible as far as the nature of the scan. I mentioned line scan devices and 2-dimensional raster scan devices. Devices that scan in a circle have been built also. The geometrical format of this type of device is almost completely arbitrary. I think that we used the 50- by 50-element chip that RETICON built for producing images on a TV set, and we have that on display. We are seeing technology come along to the point where images are being produced from small chips no bigger than the tip of your finger.

At this time, I would like to introduce Pat Grosso from Image Graphics, Inc., who is going to talk about electron beam technology. Pat was involved in the ERTS program from the very beginning--reducing some of these digital data being transmitted back to picture form. He has worked as a manager of CBS Laboratories and was involved in the NASA installation in the Goddard Space Flight Center, as well as one in South America. He has published several papers and is currently the new president of Image Graphics, Inc.

Grosso: Electron beam recorders (EBR) have been selected as the hard-copy output devices for a variety of high-resolution applications--for imagery, graphics, and data. This includes the NASA Earth Resources Technology Satellite (ERTS) program that we have heard so much about in the U.S., Canada, and Brazil. There is an extensive display of ERTS images in the lobby, and you will be getting samples of some of the output products.

Today, I would like to talk about the use of EBR's as hard-copy output devices not only for imagery, but also point-by-point plotting for automated cartography. The high resolution and computer-control capability of electron beam recording enabled the geometric and radiometric errors caused by the satellite and the sensors to be corrected to within mapping accuracies, online during recording. Colvocoresses from USGS has written numerous papers on the subject; in fact a recent paper is being handed out in the lobby. This recording ability, cost-effectively, increases the image throughput of the overall ERTS system by decreasing the extensive computer processing time, which is normally required to provide a suitable data base for other types of raster and optical-mechanical recording systems where the beam cannot be programed.

EBR's have recently been adapted for automated cartographic applications. EBR systems are now capable of generating map separations on film from computer-processed data bases. The film is subsequently enlarged to make printing plates for conventional printing presses, from which full-scale color composite maps are produced.

Figure 1 shows such a system developed by CBS Laboratories under contract to the Automated Cartography Branch at Ft. Belvoir, directed by Howard Carr. Map and character data bases are stored on computer-generated, digital magnetic tapes. The tapes are read and the data transferred to the core memory of a PDP-11 minicomputer. For point-by-point plotting, such as a contour sheet, the minicomputer computes the positional and vector information from the raw digital data and transfers these signals into a vector generator. The vector generator converts the digital signals to analog signals which accurately position a 3-μm-diameter electron beam over a 32-k by 32-k address matrix. During plotting, the line width can be varied automatically by software instructions and hardware control.

In addition to being able to plot point-by-point in a very accurate fashion, the EBR system also can produce graphic-arts-quality characters, such as are used on a names data sheet. Digital representations of characters or symbols are read into the 1.2-million work disk which is used as a character library. Over 40 fonts of 100 characters can be stored on each disk. The disk controller is capable of controlling 3 disks, so the system is capable of calling up 16,000

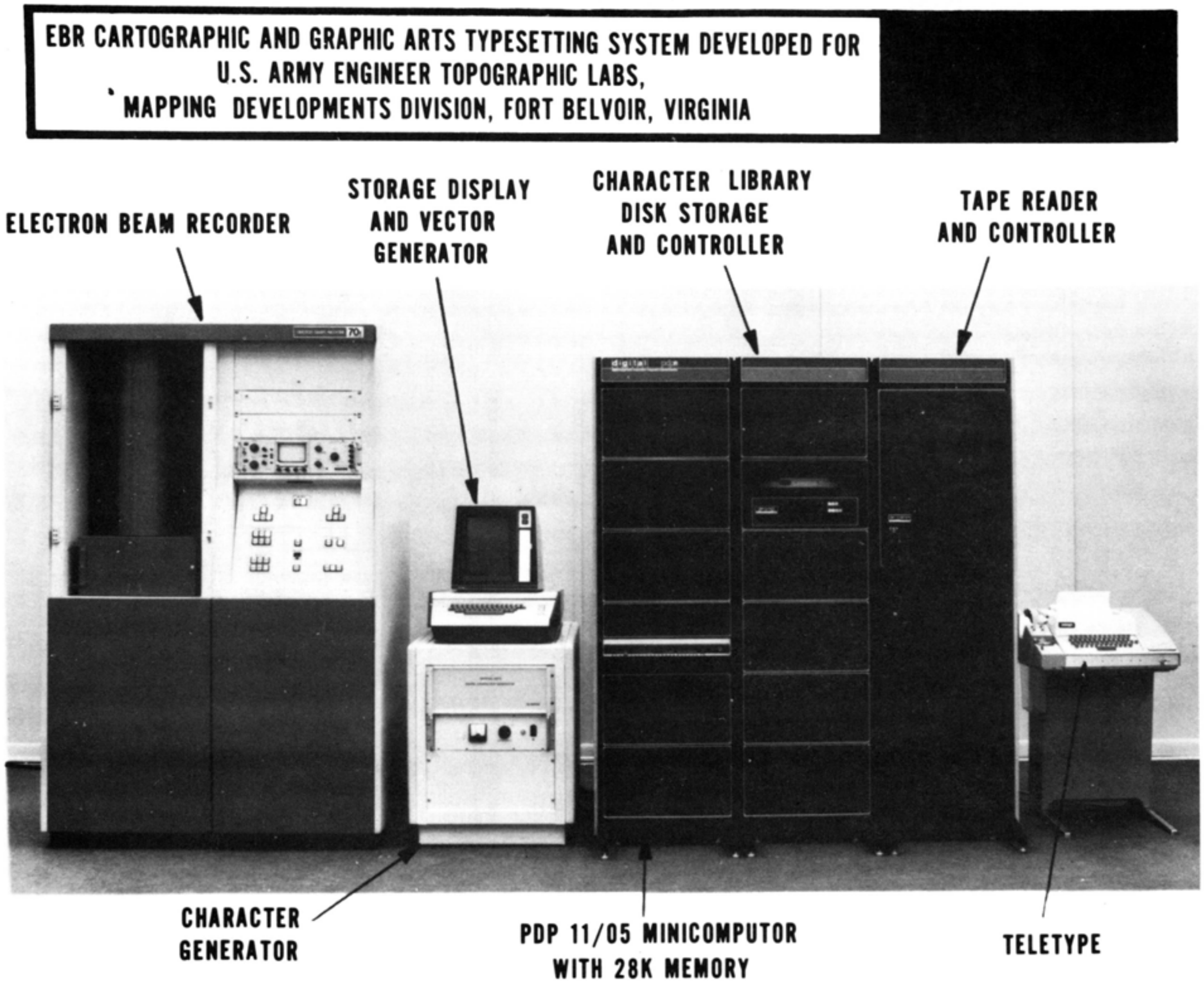

EBR CARTOGRAPHIC AND GRAPHIC ARTS TYPESETTING SYSTEM DEVELOPED FOR
U.S. ARMY ENGINEER TOPOGRAPHIC LABS,
MAPPING DEVELOPMENTS DIVISION, FORT BELVOIR, VIRGINIA
ELECTRON BEAM RECORDER
STORAGE DISPLAY AND VECTOR GENERATOR
CHARACTER LIBRARY DISK STORAGE AND CONTROLLER
TAPE READER AND CONTROLLER
CHARACTER GENERATOR
PDP 11/05 MINICOMPUTOR WITH 28K MEMORY
TELETYPE

Figure 1

characters in a random fashion at any one time. Characters are generated using a sub-raster from the digital character generator.

The EBR records directly on film in vacuum and thereby eliminates all problems associated with cathode ray tubes with regard to resolution and brightness losses caused by lens and phosphor coatings. A very small spot size can be produced for very high-resolution applications. Using electron sensitive film, which is a very fine-grain silver halide emulsion like a spectrographic plate, you obtain extremely good definition of characters or map line work that you record. The film is wet-processed in the conventional manner, and images can be either positive or negative, depending upon the processing or the type of film that is used. Recently, electron-sensitive films which require no processing whatsoever have also been made available on an experimental basis by Eastman Kodak. These should be of importance for proofing and certain cartographic applications.

Figure 2 is an enlarged section of a typical contour sheet plotted with a 3-μm beam. This recording was actually made from two map-separate data bases. Even under very high magnification, one cannot distinguish the joins between the two separates. Copies of the original recordings and some of the prints are on a display here.

Figure 3 shows some enlargements of characters that were generated with this system. The characters are graphic arts quality and were recorded at 48X reduction. Even under very high magnification, you can see the graphic arts quality is still retained. Sample recordings of graphic-arts-quality characters on 70-mm and 5-in formats are available for viewing.

The EBR high-resolution beam and the fine-grain emulsion of the electro-sensitive film enable enlargements of over 10 times to full map scales. Some of these full-scale maps are also on display. These film chips can be readily utilized in production of maps and other cartographic products.

Figure 4 is a flow chart that indicates how one might use the film chips in map production. Map separates (70-mm) generated from digital data bases through the EBR cartographic system are used as color separates; these can be enlarged to produce negatives from which printing plates can be made. The printing plates are then run through a conventional multicolor press to generate 20- by 30-in to 40- by 60-in maps. The micromap film chips can also be used directly to expose full-size diazo printing plates with a UV platemaker. The printing plates made directly from micromaps are used to print 20- by 30-in color composite maps using a conventional color press.

Figure 5 shows the use of the EBR system for recording at full scale. This capability would be useful for preparing and revising aviation flight charts. Here the different separations for airport patterns, approach procedures, and names data would be recorded at full scale on 5- by 8-in film and either contact printed individually or combined on enlarged composite printing plates with as many as 32 "pages-up." The printing plates would be then run through a conventional press. The flight charts are printed, cut, and collated; the final product would be a complete flight information handbook. This particular

SECTIONAL ENLARGEMENT OF
A TYPICAL CONTOUR SHEET MADE FROM TWO MICROMAP SEPARATIONS

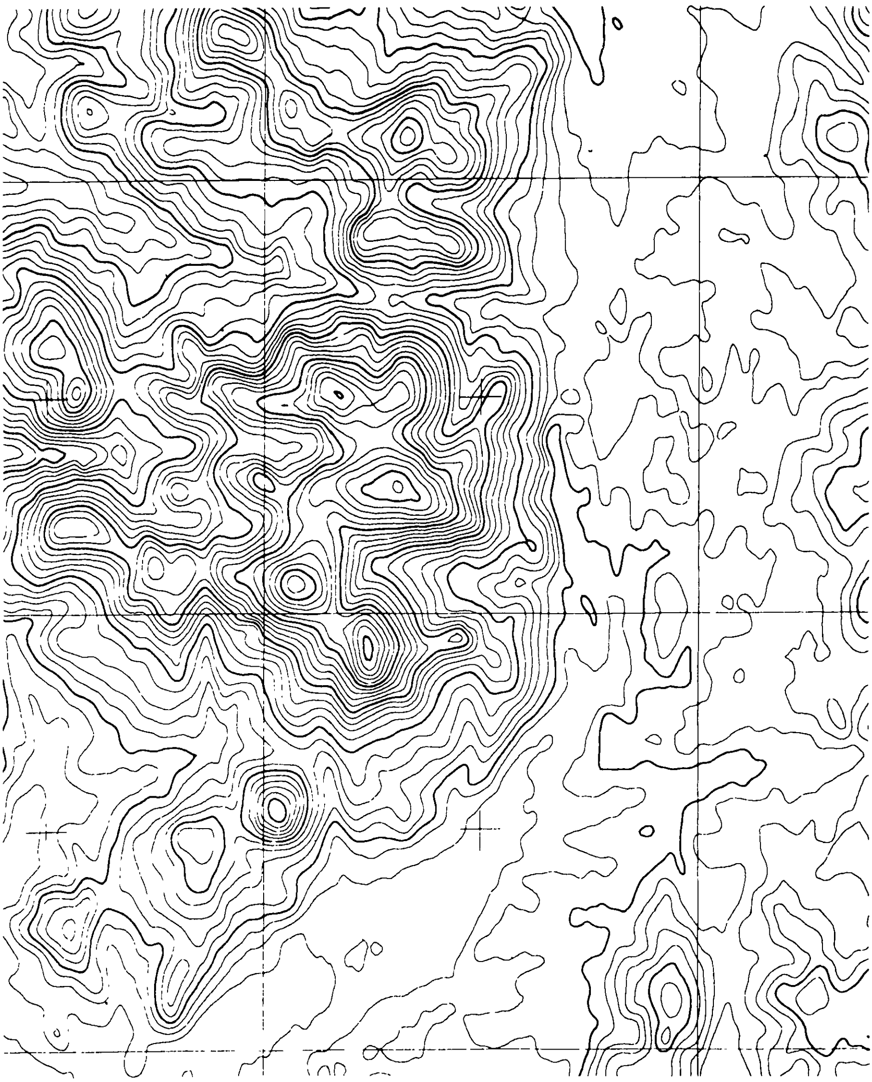


Figure 2

ENLARGEMENT OF 48X MICROFICHE
WITH GRAPHIC ARTS QUALITY CHARACTERS

H	I	J	K	L	M	N
T	U	V	W	X	Y	Z
	a	b	c	d	e	f
l	m	n	o	p	q	r
x	y	z	⌈⌉	■	⌖	

Figure 3

AUTOMATED EBR CARTOGRAPHIC/GRAPHIC ARTS TYPESETTING SYSTEM FOR PRODUCTION & REVISION OF COLOR MAP PRODUCTS

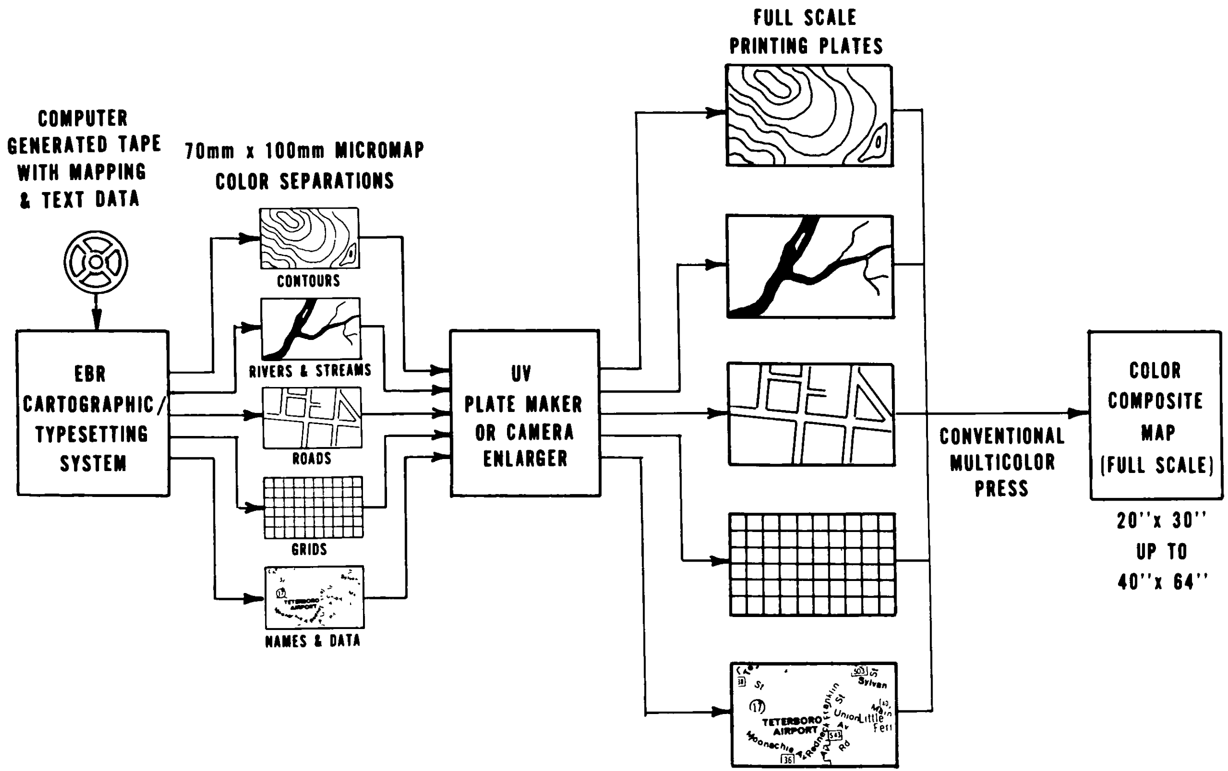
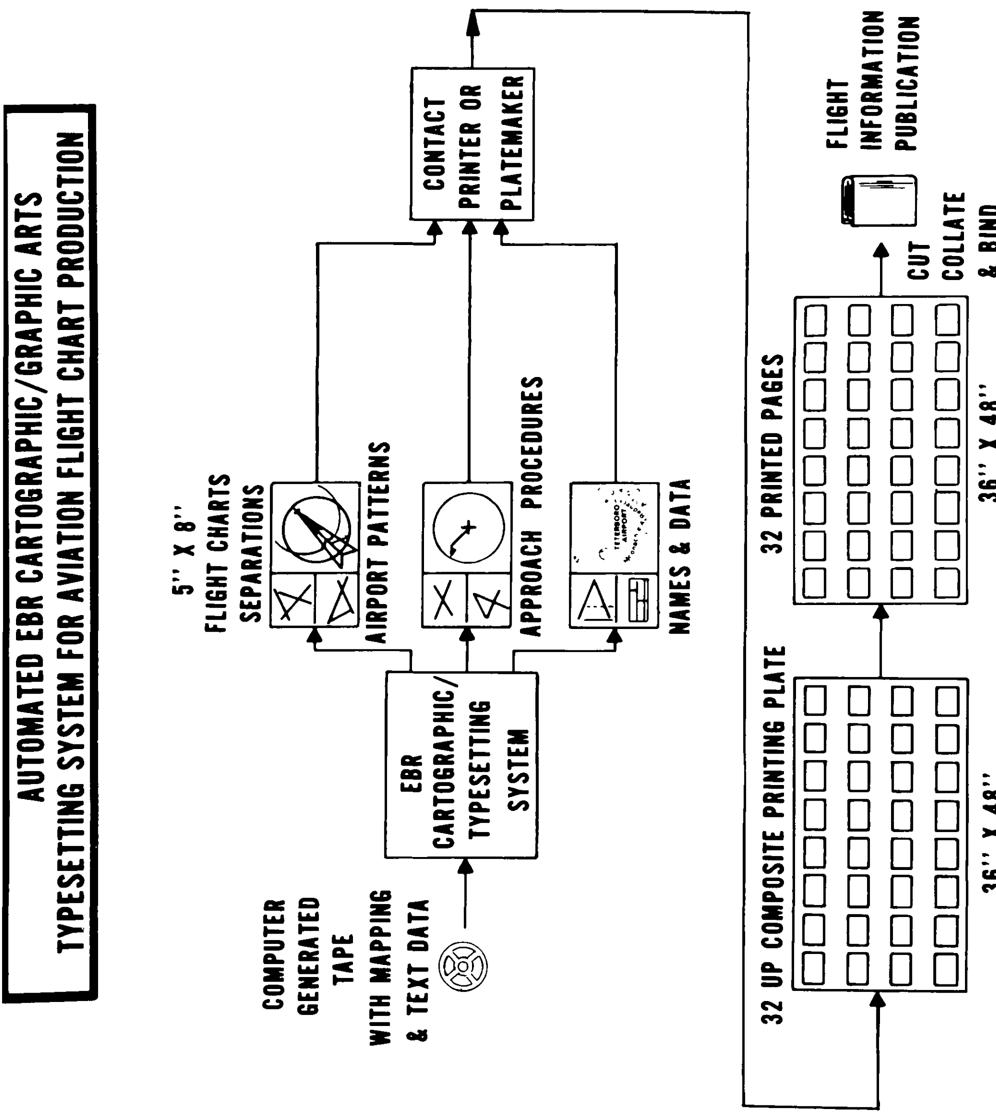


Figure 4



AUTOMATED EBR CARTOGRAPHIC/GRAPHIC ARTS
TYPESETTING SYSTEM FOR AVIATION FLIGHT CHART PRODUCTION
COMPUTER GENERATED TAPE WITH MAPPING & TEXT DATA
EBR CARTOGRAPHIC/ TYPESETTING SYSTEM
5'' X 8'' FLIGHT CHARTS SEPARATIONS
AIRPORT PATTERNS
APPROACH PROCEDURES
NAMES & DATA
CONTACT PRINTER OR PLATEMAKER
32 UP COMPOSITE PRINTING PLATE
36'' X 48''
32 PRINTED PAGES
36'' X 48''
CUT COLLATE & BIND
FLIGHT INFORMATION PUBLICATION

Figure 5

system has not been built, but the capability of recording to the accuracies and sizes required is in the basic EBR cartographic system. These map production techniques would be cost-effective operational procedures, which can be efficiently used to increase product output. In addition, combining the EBR cartographic capability with the ability to record high-quality, precision imagery from satellites such as ERTS will enable the automated production of new map products.

Figure 6 is a sectional view of a USGS "pictomap," where they have taken an ERTS image and manually superimposed a map overlay. By using a combination of EBR cartographic plotting and raster image recording as used on ERTS, you have the possibility of directly generating a new type of product. This would mean always having current information. ERTS images have shown us that land forms and water forms are changing continuously and make our mapping data outdated quickly.

You will be getting a sample image map in your registration packet. The EBR recording system offers the potential to produce this type of map in an automated fashion. I hope the sample will stimulate your interest in the use of a combination of ERTS imagery or aerial photography and cartographic point-by-point plotting.

Some performance capabilities of such a recording system are shown in figure 7. For cartographic applications in the vector plotting mode one can record variable line widths starting with a 3-μm spot; these recordings can be enlarged up to 30 times. As opposed to the gentlemen who said that sometimes too much resolution is just as much of a problem as no resolution, I think that when you have the resolution capability you certainly want to use it. For example, when you are drawing a 1-mil-wide line, you should not draw the line with a 1-mil spot; you should draw several 0.2 mil lines. This will produce the best edge sharpness. If the image quality warrants it, resolution should be the best possible, even at the expense of speed. Writing speed in this particular case was 125,000 points/sec, and the beam addressing was 32 k by 32 k. Again, beam diameter was 3 μm and can be enlarged well up to several mils, if necessary.

In addition to the vector mode, the EBR can be used in a raster plotting mode to generate continuous-tone imagery with at least 64 gray shades. The limitation is the film, not the recording system. EBR's have actually been built to record 256 discrete levels, but these gray levels are not distinguishable on film. The raster plotting mode will enable using the EBR for black-and-white line art with conventional software packages that are available, at writing soppeds of 250,000 points/sec and even faster if it were required. EBR's have been used in applications with band widths up to hundreds of megahertz.

The resolution in the EBR raster mode has none of the limitations of the cathode ray tube. Resolutions of 10 k to 15 k TV lines at 50-percent response on 70-mm format have been recorded. This performance level is very common for the EBR. In larger formats of 5 in, over 20,000 elements can be obtained. The EBR system can also have an electronic halftone capability, and we feel that 65 to 133 lines/in could be obtained. There is a wide range of film formats that can be used--16 mm, 35 mm, 70 mm, 105 mm, 5 in, 9 in, and the standard microfiche.

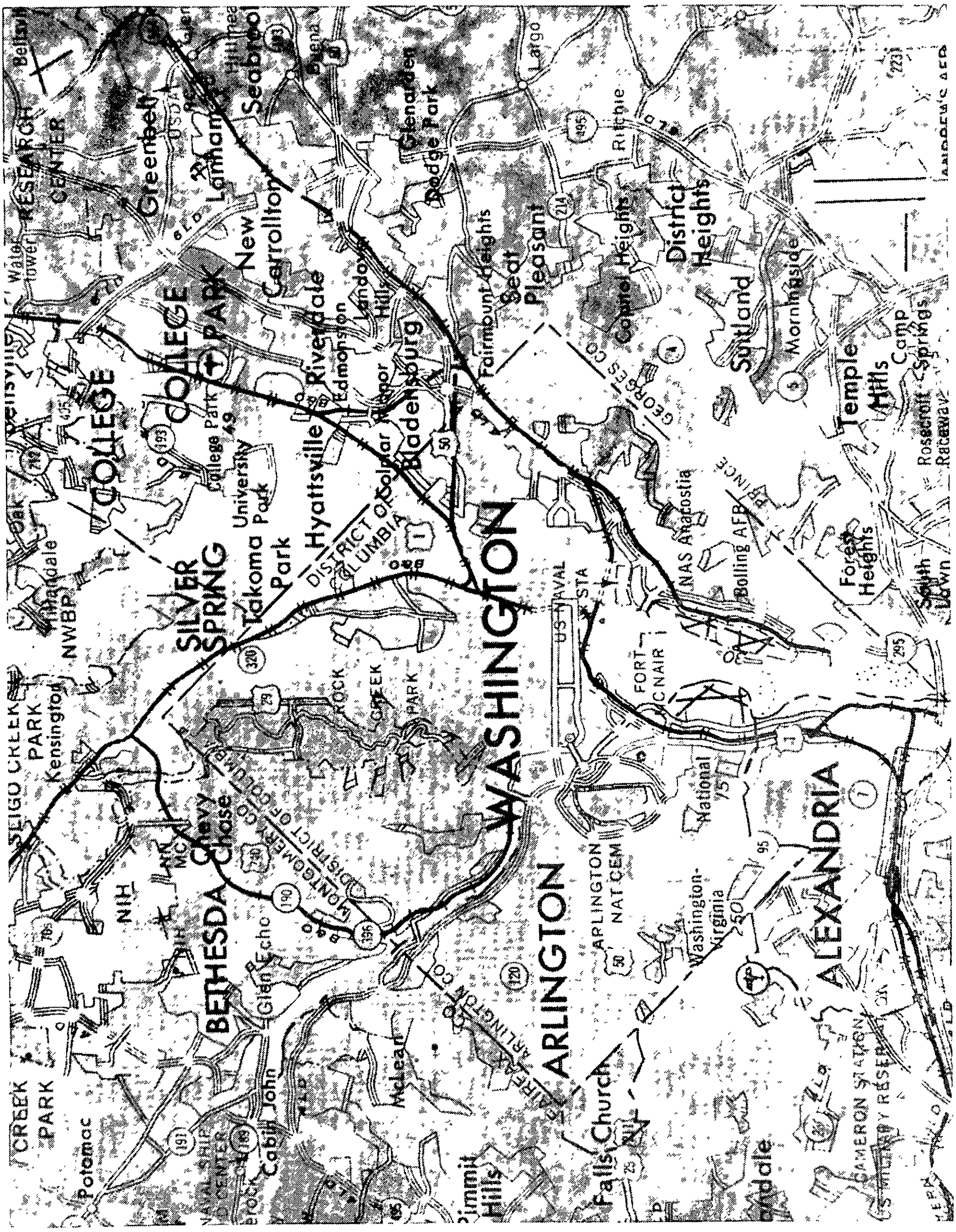

WASHINGTON
ARLINGTON
ALEXANDRIA
BETHESDA
SILVER SPRING
COLLEGE PARK
Hyattsville
Takoma Park
Greenbelt
Riverdale
Bladensburg
Chevy Chase
Falls Church
McLean
Seat Pleasant
District Heights
Suitland
Temple Hills
Forest Heights
Capitol Heights
New Carrollton
Potomac
Kensington
Glen Echo
University Park
Fairmount Heights
Morningside
DISTRICT OF COLUMBIA
ROCK CREEK PARK
ARLINGTON NAT CEM
FORT McNAIR
NAS Anacostia
Bolling AFB
Washington-National
Cabin John
NIH
Edmonston
Landover Hills
Camp Springs

Figure 6

TYPICAL EBR AUTOMATED CARTOGRAPHIC AND GRAPHIC ARTS TYPESETTING SYSTEM PERFORMANCE CAPABILITY

CARTOGRAPHIC/BUSINESS GRAPHICS

VECTOR PLOTTING MODE

a. Variable line widths - starting with 3 microns (1/8 mil X 30X = 4 mil line)

b. Writing speed - 125,000 points/sec

c. Beam Addressing - 32K x 32K

d. Resolution -3μ beam diameter spot

RASTER PLOTTING MODE

a. Continuous Tone Images with 64 Gray Shades

b. Black and White Line Art

c. Writing speed - 250,000 points/sec, faster speeds available

d. Resolution -8,000 to 15,000 TVL; 50% response on 70mm format to over 20,000 elements for larger formats

HALFTONE CAPABILITY

a. 65 - 133 screens/inch available

FILM FORMATS AVAILABLE

16mm, 70mm, 105mm, 5", 9", microfiche

Figure 7

Figure 8 shows performance of the graphic-arts character generation. You have great flexibility of point size--4 to 36 and larger--and you have random access by using the disk library. Characters can be rotated 360 degrees in 1-degree increments. Character writing speeds for graphic arts quality are 1360 characters/sec for 5 to 8 points; faster rates can be achieved if you are willing to give up a little bit of quality. The reason that one can use various point sizes and fonts and intermix them is the EBR automatic exposure control. Symbols may also be stored on the digital disk. Recordings of characters at 24X, 48X, and 96X reductions have been made for microfiche applications which still retain high graphic arts quality. The EBR is a new, versatile tool that has a place in automated cartography.

Wohlmut: Research and development efforts in the previous year have brought to the prototype stage a plotting device capable of writing on 5- by 5-ft film, and it is currently being modified for digitizing capability. Additional work in the field of video and digital storage on film has brought two other devices to the prototype stage--a film disk system capable of 10^{10}-bit storage and a roll film system capable of 10^{15}-bit storage. Each of these devices will be described, as well as pertinent current research and development.

Two types of high-density digital storage devices are under development at i/o Metrics. The LASCO device itself is capable of ultra-high storage of digital and/or visual information, but with relatively slow access. The video disk, first developed as an entertainment medium, has lower capability but fast access and low cost. Both devices are based on film storage of information and are part of the LASCO system (fig. 1).

LASCO may be used to record digital or graphic information on film in the plot mode and read it back in the digitizing mode. Its current capacity is conservatively in excess of 10^{15} bits of digital information. Table 1 shows the operating characteristics. The device operates

Table 1.--LASCO operating characteristics.

Format	Data frames $(105\ mm)^2$ on 105-mm roll film
Film load	3 rolls @ 660 m/roll, or 2000 m total
Maximum film slew rate	7 m/sec
Average frame access time	60 sec
Average access time at a fixed frame	25 msec
Data bit size	$(10\ \mu m)^2$
Distinguishable gray levels	8
Data record/retrieval rate at a fixed frame	600 k bits/sec
Total nonredundant data store	330 M bits/frame; 6.3 T bits/film load

GRAPHIC ARTS CHARACTER GENERATION

A. POINT SIZES

4 - 36 points, larger sizes available

B. CHARACTER ROTATION

0 - 359 in one degree increments

C. CHARACTER WRITING SPEED

(Up to 10 times faster speeds available at lower character resolution)

5 points - 8 points	1360 characters/sec
10 points - 18 points	450 characters/sec
36 points	225 characters/sec

D. CHARACTER FONT STORAGE

Approximately forty 18 point fonts on a 1.2 million word disk

E. AUTOMATIC EXPOSURE CONTROL

All point sizes can be intermixed, all fonts can be intermixed

F. CHARACTER DIGITIZATION AT HIGHEST RESOLUTION

1664 points per inch in the verticle direction

832 points in the horizontal direction

G. MICROFICHE REDUCTION RATIO

24X, 48X, 96X and greater for special applications

Figure 8

under computer control, holding up to 6000 ft of 105-mm film and recording and playing back with a 10-µm or smaller laser probe. Visual information (e.g., microfiche) may be interspersed with digital information. Editing may be performed on any 105-mm frame. All display facilities of the digitizer are accessible thus permitting digital input or output on any peripheral, visual display on a large screen or closed circuit TV, and diagnostic information on oscilloscopes and storage tubes. Operator intervention is possible at all times to override automatic file transport, modify data, or inspect visual data.

The film-based video disk can store in excess of 10^{10} bits. It is interfaced through a PDP-11 board to other computers. The PDP-11 handles the i/o and servo controls for accessing the disk, serving as a controller for this device. Operating characteristics are shown in table 2.

Table 2.--Video disk operating characteristics.

Format	32 cm diameter disk, written 5 to 15.5 cm radius
Track spacing, center-to-center	2.0 µm
Rotation rate	1800 rpm
Smallest data bit size	2.0 µm
Distinguishable gray levels	8
Data recording/retrieval rate	14 M bits/sec
Total nonredundant data store	19 G bits/disk
Access time	30 ms
Readout	Incandescent lamp

In increasing order of sophistication, there are four ways to encode the signal.

1. As little pictures on the disk. This approach has been used (on strip film) numerous times and uses the dynamic range of the film to maximum advantage. It is an inherently clumsy format for disk applications.

2. As an analog of the NTSC signal. This approach has also been tried numerous times. Figure 1 shows a portion of a video disk written in the analog mode at the Stanford Research Institute a decade ago. The track spacing is 6 µm; note the significant grain structure that was present in what was then the finest grain, commercially available emulsion. Figure 2 is a high contrast photograph of an i/o Metrics film disk with an 8-µm track spacing. The tracks are several micrometers wide; the video signal recorded here was the standard multiburst with temporal frequencies of 0.5 to 4.2 MHz. The corresponding spatial frequencies are

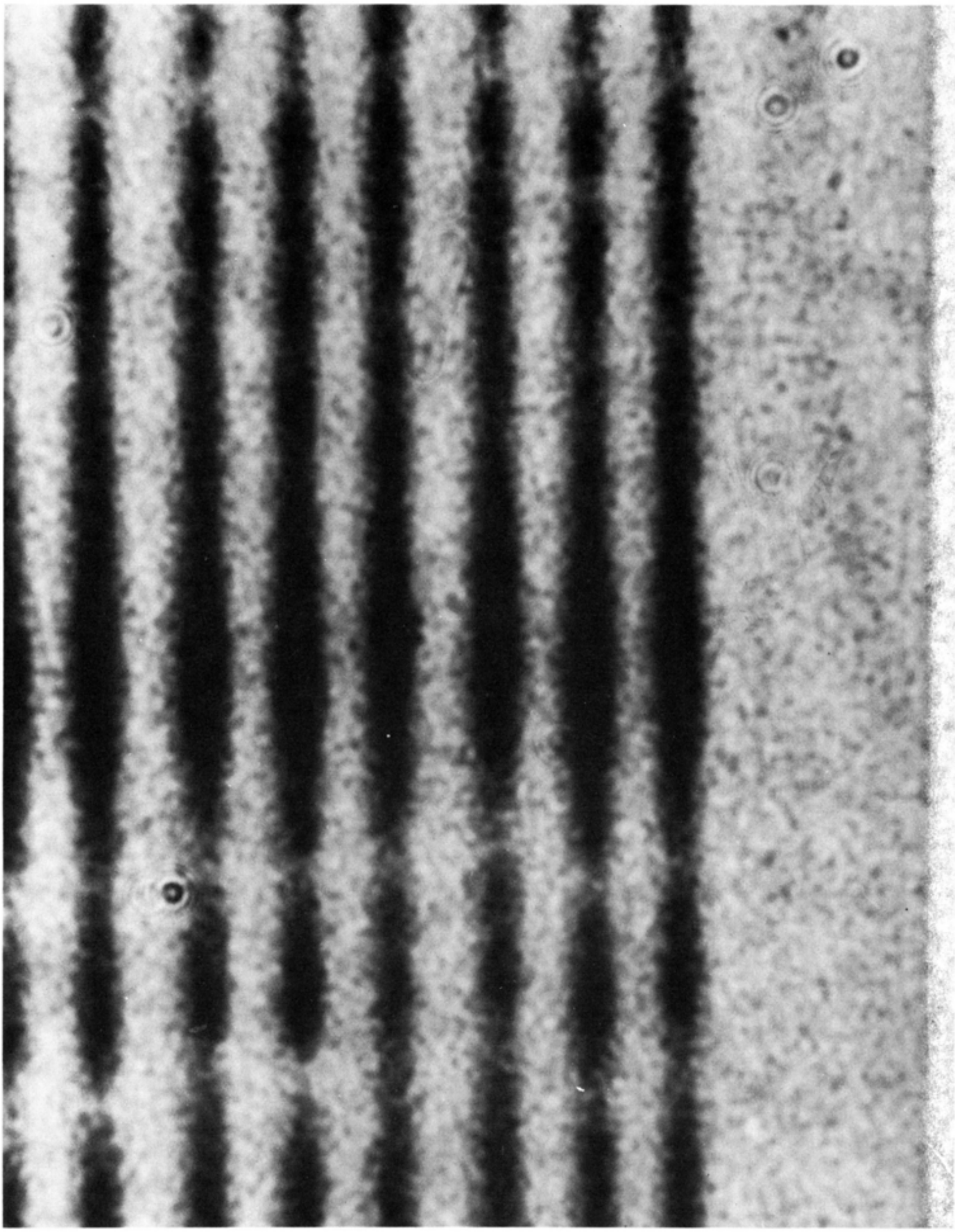


Figure 1

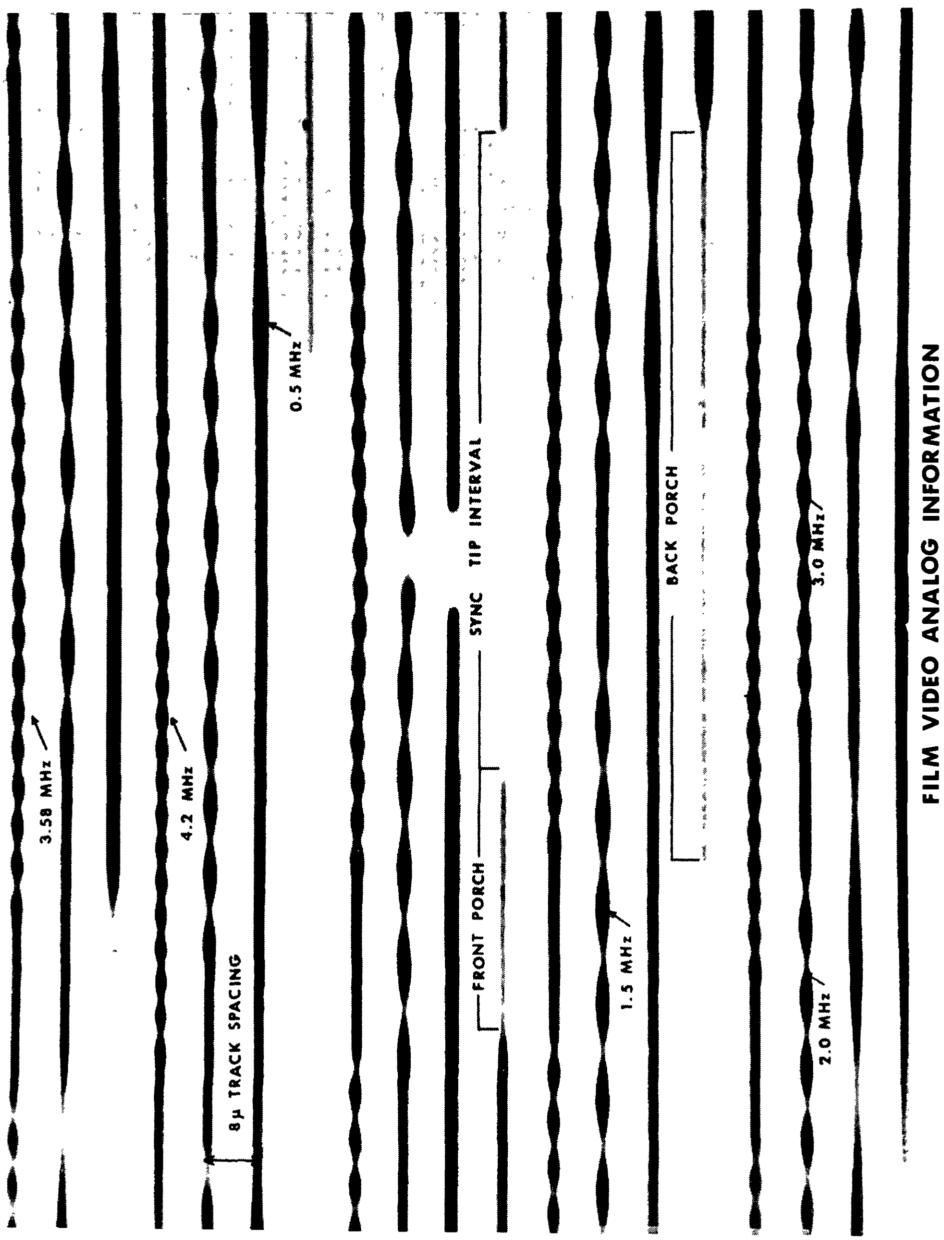

FILM VIDEO ANALOG INFORMATION
3.58 MHz
4.2 MHz
8μ TRACK SPACING
0.5 MHz
FRONT PORCH
SYNC TIP INTERVAL
BACK PORCH
1.5 MHz
2.0 MHz
3.0 MHz

Figure 2

0.025 cycles/μm and 0.21 cycles/μm. These frequencies encompass the required frequency spectrum needed for recording in the analog mode.

3. As a pulse encoded modulation of the NTSC signal. The most common pulse encoding technique is the frequency modulation mode, which is used in recording on magnetic tape. We have experimented with recording FM signals on film; figure 3 shows the same multiburst signal as recorded in the FM mode. The FM bandpass was 1.2 to 3.8 MHz--appropriate for black-and-white (luminance only) recording. Three other laboratories are currently developing optically read video disk systems with an encoded FM signal. These companies (Phillips, Zenith, and MCA) use a pressed plastic disk rather than a film disk. For comparison, figure 4 shows a segment of such a disk. Here the FM signal varies from about 6 to 9 MHz, with each pit several microns long and precisely one-half a micron deep. The two disks look very similar--these photos were made in our laboratory through the same microscope and under similar conditions.

4. As a Fourier transform (hologram) of the original picture. From some aspects, this is a very attractive way to encode the signal on film. The transformed image is insensitive to shifts in position and to translations along the detector axis. But again this is a highly cumbersome format for disk applications.

The comparative advantages and drawbacks of these four methods could be examined in great detail, but it is sufficient here to note that only the analog and the pulse coded techniques offer real promise at this time for disk applications. The transform techniques will eventually be of major interest, but for now they require diffraction limited optics and data stores of a quality difficult to maintain in the desired applications.

Of the two techniques, analog and FM, the analog signal is certainly the simplest in terms of the electronics required in recording and playback. The analog mode requires approximately one-half the bandpass of FM recordings; the latter technique, with its double bandwidth, is usually considered to have a better immunity to typical wideband video noise and to media and playback induced noise. However fingerprints, scratches, and other anomalies introduced in handling the video disk are not of this type, and we have found pulse encoding techniques become disadvantageous with respect to these latter types of noise. There is another advantage of the analog signal--it works very much like a standard projector: when the picture on the television screen is out of focus, the playback lens needs focusing; when the picture is too bright, the lamp needs to be turned down; when the picture is upside down, the disk is upside down; and so forth.

The actual apparatus which is used in a given video recording application depends on which of these encoding methods is chosen. When recording in the analog mode, a relatively straightforward hardware configuration may be used. Figure 5 shows our typical laboratory hardware. The laser beam is delivered to the acousto-optical modulator which introduces the video signal as an intensity modulation. The film disk is servo-controlled to rotate at the video framing rate; the light beam is delivered to the film surface by a simple microscope objective which is translated radially to write the spiral track of some 30 miles in length on a 40-min disk.

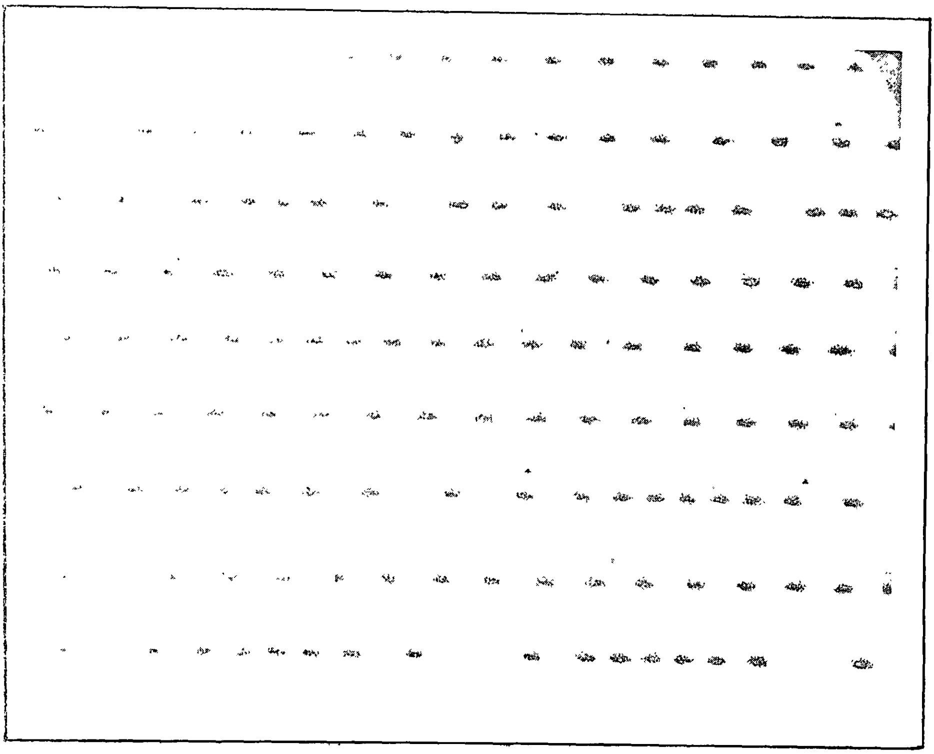


Figure 3

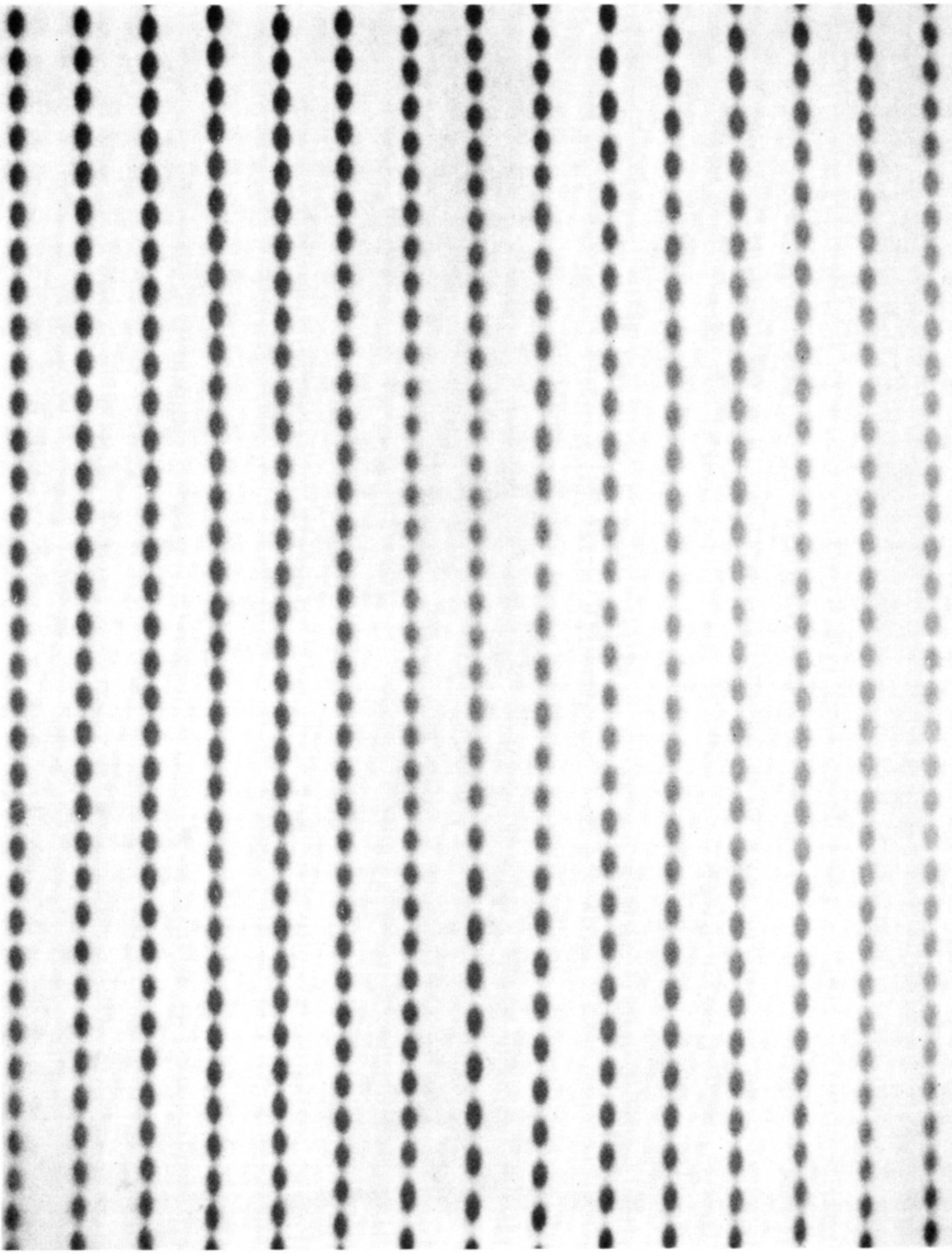


Figure 4

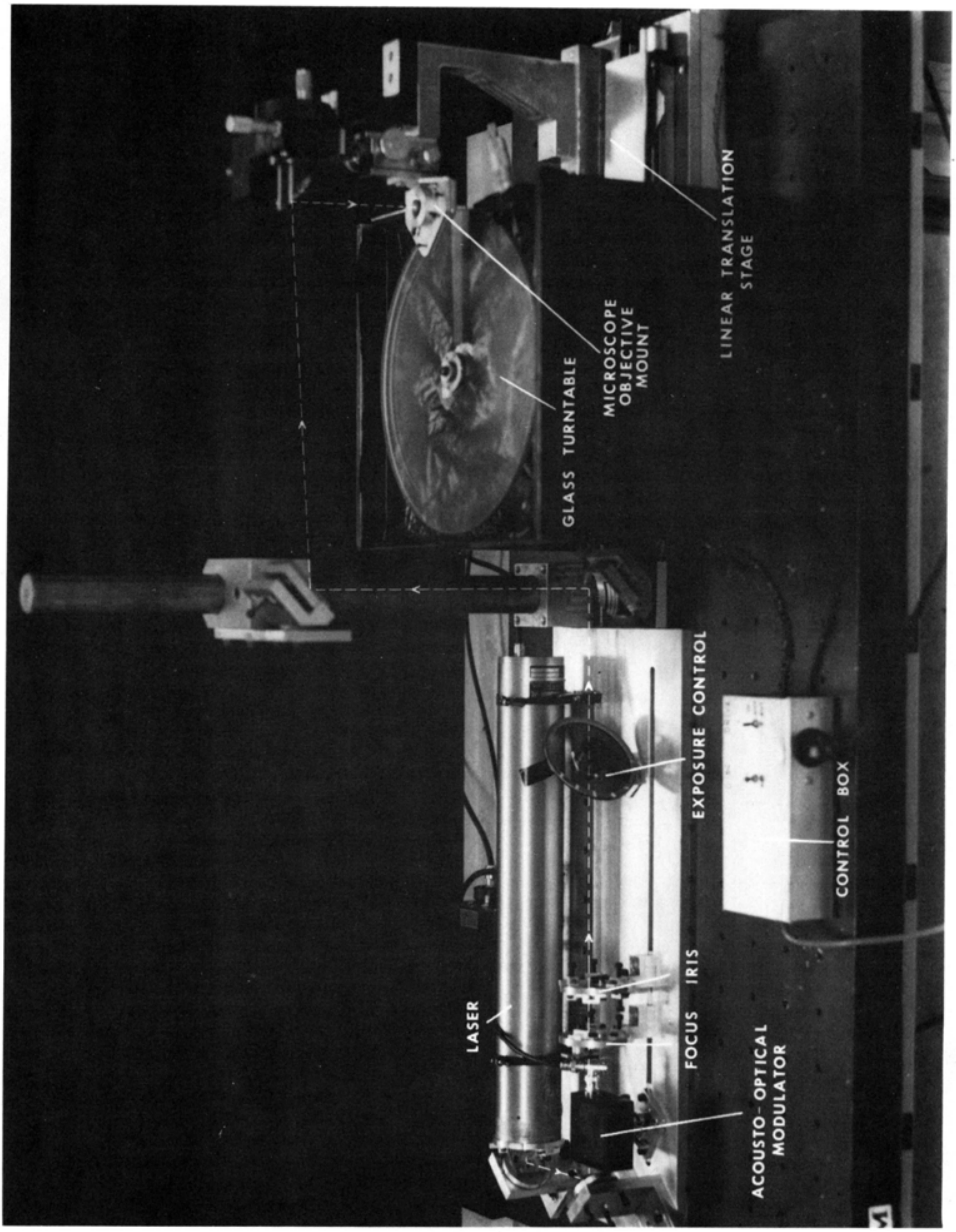

GLASS TURNTABLE
MICROSCOPE OBJECTIVE MOUNT
LINEAR TRANSLATION STAGE
LASER
FOCUS
IRIS
EXPOSURE CONTROL
ACOUSTO-OPTICAL MODULATOR
CONTROL BOX

Figure 5

The recorder is composed of relatively simple off-the-shelf components, and the limiting characteristics of the recorded signal reflect in most instances the choices made with respect to these components rather than the film itself. The frequency response of the modulated laser beam can easily be made to exceed 20 MHz. In our analog recording we typically use a modulator which is at -3dB at 7 MHz with an appropriately focused laser beam. This is more than adequate for the 4.2 MHz bandpass of the NTSC video signal. Thus, the laser spot size on the film, in combination with the minimum disk radius at which tracks are written, determines the bandpass of the recorded signal. We use a HeNe laser at 632.8 nm and microscope objectives with numerical apertures of 0.2 to 0.4. We find that we are able to obtain adequate response at a 2-in radius; the recorded signal has distinguishable frequencies to 4 MHz. With respect to recorded video signal to noise, the present limitation lies with our laser which has a beam ripple specified at 42 dB. Of course, this signal to noise ratio can be increased by any of a number of well-known techniques.

The energy required to adequately expose the typically very slow emulsions which we use is not excessive because the majority of the energy is focused into a spot on the order of a micrometer in diameter. Using a red extended response emulsion, 1 milliwatt is more than adequate. Figure 6 shows the actual appearance of the tracks in the emulsion of a video disk. This is a magnified view of a microtome cross-section of a very fine-grained emulsion 6-µm thick on a 4.5-mil Mylar base. Note that the tracks, spaced 18 µm apart, appear to have a rectangular cross-section. This rectangular profile arises because of the Gaussian distribution in energy density near the focus of the objective. With analog recording, linearity is required between the recorded and retrieved video signals. This linearity is attained by noting that at very low signal levels the track changes in opacity extremely rapidly with increasing signal level. At very high signal levels the interior portion of the track saturates and the track widens slowly with increasing signal level. Between these two regimes lies a range where the width at the track and the opacity gradient at its edge change in such a way that the recorded signal and the retrieved signal are linearly related. The exact range over which linearity is observed is dependent on the track geometry and the details of the playback configurations. In practice, the linear region is found by recording a linear staircase signal and adjusting the exposure levels for linearity on playback. Combining area and intensity modulation yields a linear system very insensitive to processing procedures. We have observed that variations in exposure by up to a factor of two have little effect on the video display of luminance. Once the latent image is recorded, the film can be developed at room temperature using standard darkroom techniques. The emulsion sets up quite rapidly and the disk can be spun dried in a few seconds. In all, the film disk can be on the playback machine within 10 min of the completion of recording.

We stress the ease of recording for it enables one to use the video film disk in those limited-run, 10- to 1,000-copy type of applications which cannot be suitable to other video disk technologies. It is instructive to compare the recording process just outlined using film with the typical process of recording for a video disk pressed from polyvinyl chloride. With this latter process, a 14-in optically flat glass master must be sputter coated with an ablatable metallic material such as rhodium. A spiral track containing the video information is generated by selectively burning away the metal coating with a high-

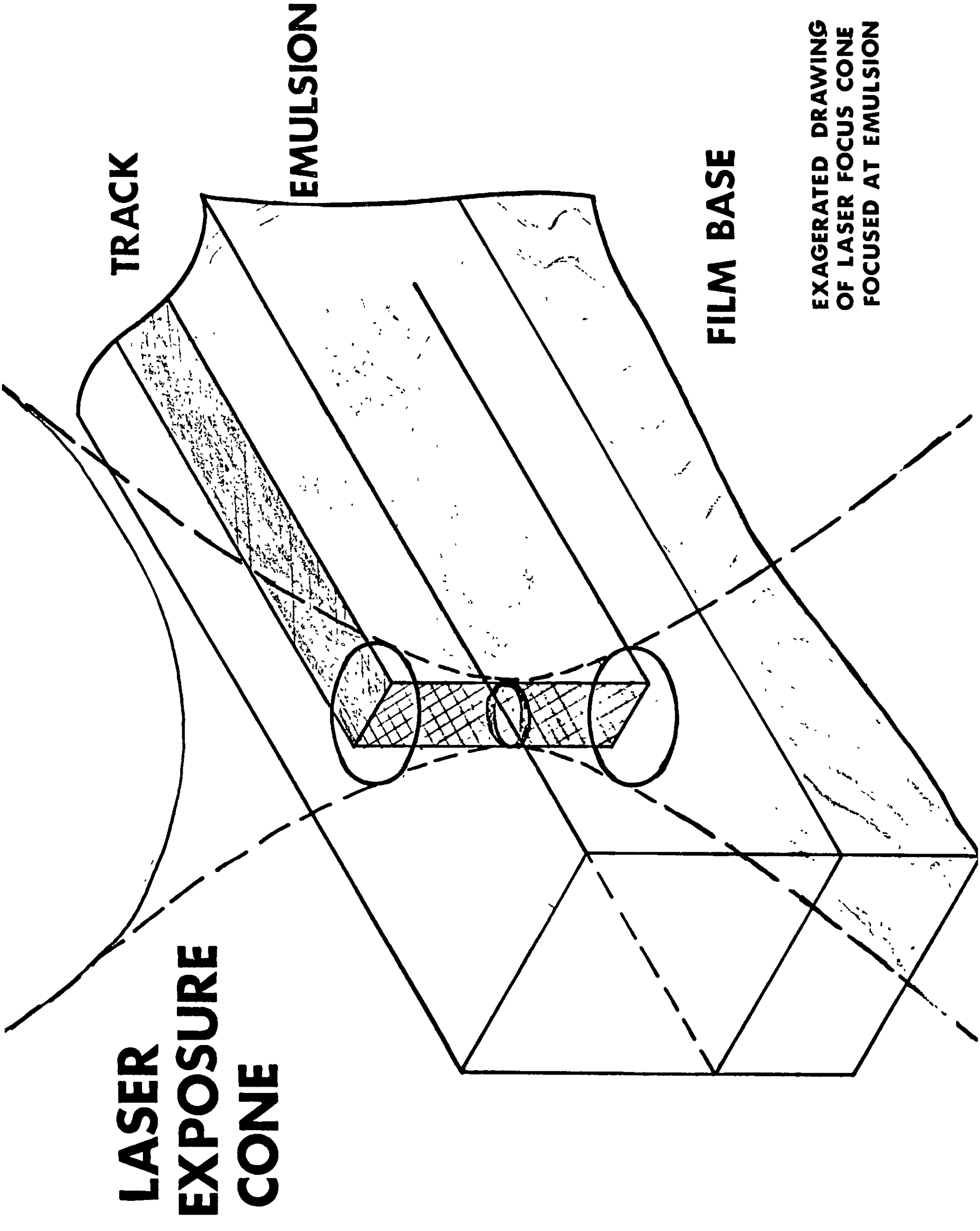

TRACK
EMULSION
FILM BASE
EXAGERATED DRAWING
OF LASER FOCUS CONE
FOCUSED AT EMULSION
LASER
EXPOSURE
CONE

Figure 6

power Argon laser. The master glass plate is demounted and coated with a photoresist material. The plate is then exposed from the rear to ultraviolet light. The unexposed photoresist material is washed away with an appropriate solvent, and this leaves a bumpy surface on the master with the video information encoded in the surface structure. This master is then treated by electrodeposition to form a metal tool from which the playable copies may be stamped from PVC disk. There is a final step required for some of the PVC video disk systems--the pressed disk copy must be metallized with a shallow metal coating. Obviously this complicated recording technique cannot be easily applied to those situations in which only a limited number of disks are needed.

An important characteristic of the recorded signal can be deduced immediately by examining the microscopic structure of the disk, namely the time base stability of the recorded signal. Whenever you see a portion of the disk with a horizontal retrace interval or some other characteristic feature of the video signal recorded you may deduce immediately that you have a built-in time reference. For example, we know the time interval associated with the horizontal retrace interval; looking at the wiggles in the radial direction of the disk we can see that there is a several-microsecond variation over a millimeter or so of the disk. This sets a lower limit on the time base stability of the signal and playback when a perfect playback instrument is used.

Playback of the video information stored in the spiral track of the film disk can be accomplished in a number of ways. One approach used in numerous other disk systems would be to focus a laser-generated light beam to a micrometer spot on the disk and detect the resulting intensity modulation as the beam is swept along the track. Another approach would utilize some form of coherent optical processing of a laser beam scattered through the film.

The simplest approach (fig. 7) is the most attractive. A small area of the film is flooded with white light. A microscope objective images the film surface with its track information back onto a micro-area light detector. As the disk is rotated the light source and objective traverse a radial path, reproducing the motion of the original write-hand. Essentiall the video playback device is a simple microscope. This approach has two major advantages: (1) An inexpensive white light-bulb may be used for illumination, and (2) the image of the area of interest on the disk surface is presented at increased magnification for subsequent processing. It is an easier task to extract the desired information from the appropriate video track in this magnified image than at the disk surface itself.

For the video detector, one can use a masked photomultiplier tube, a channeltron, or a silicon photodiode operated in the avalanche mode. The most important criterion is that a suitably small active detector area be used. Successful video operation has been attained by limiting detector areas to a maximum of 0.1 mm^2 with typical magnifications of 20X to 100X at numerical apertures of 0.4 to 0.7.

There are many tracks imaged into the vicinity of the video detector, on the order of 10 to 100 cm. The appropriate track is maintained on the detector against excursions due to mechanical tolerances by using an oscillating mirror in the optical path between the microscope objective and the detector. The servomechanism may be either a wideband,

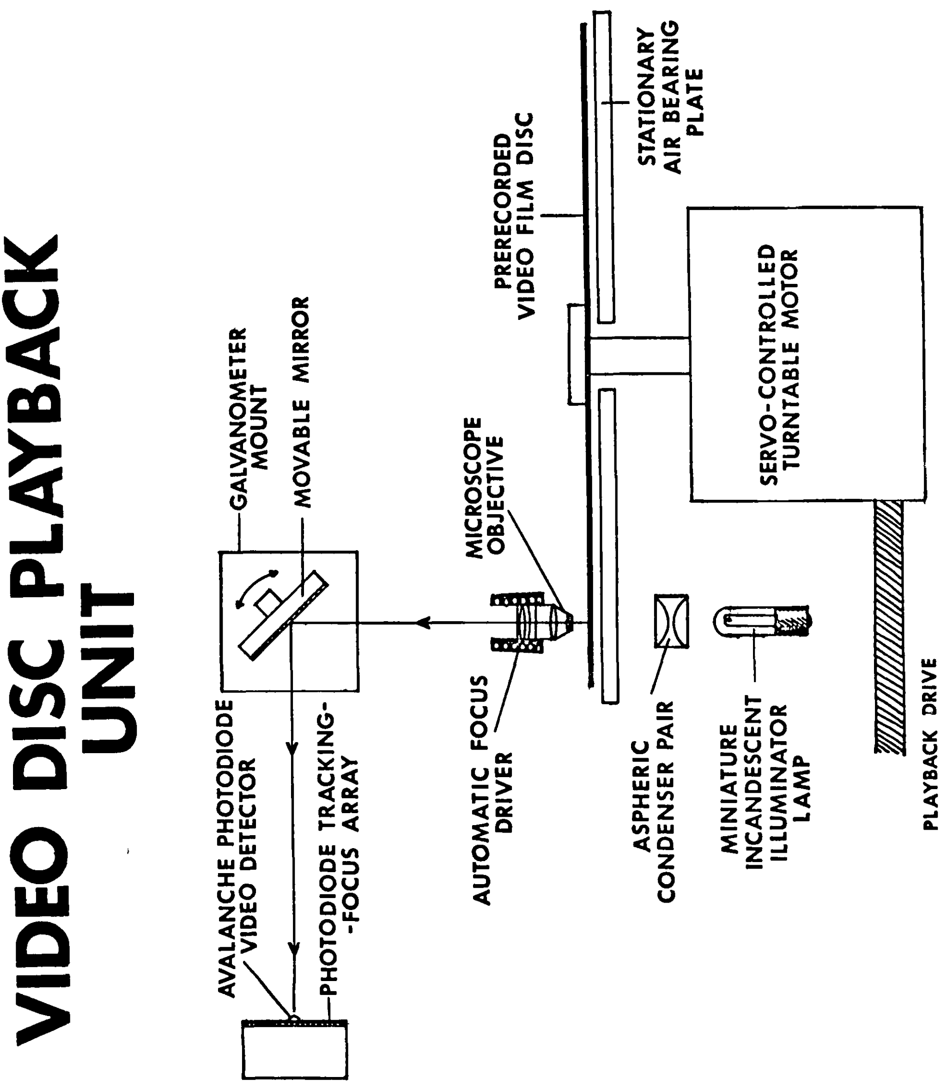

VIDEO DISC PLAYBACK UNIT
GALVANOMETER MOUNT
MOVABLE MIRROR
PRERECORDED VIDEO FILM DISC
STATIONARY AIR BEARING PLATE
MICROSCOPE OBJECTIVE
SERVO-CONTROLLED TURNTABLE MOTOR
AVALANCHE PHOTODIODE VIDEO DETECTOR
PHOTODIODE TRACKING-FOCUS ARRAY
AUTOMATIC FOCUS DRIVER
ASPHERIC CONDENSER PAIR
MINIATURE INCANDESCENT ILLUMINATOR LAMP
PLAYBACK DRIVE

Figure 7

closed-loop configuration or an open loop, tuned to the basic rotation rate of the disk. The position of the desired track is sensed by a linear detector array (in the simplest case a split photodiode), and an error signal is generated to drive the mirror to the appropriate angular position.

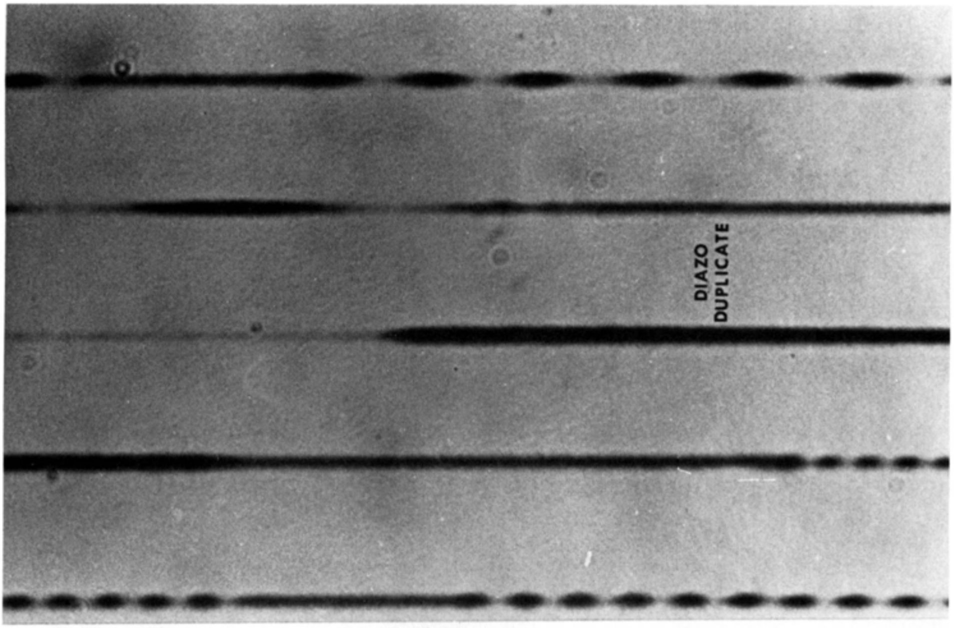
The use of an incandescent lamp as the source for reading the video disk is only a convenience, as any appropriate light can be used. Naturally we have experimented with a laser readout of the film disk, and we have seen very interesting results. The laser allows us to push the film to its limits of resolution, something which we are not doing in the present configuration. In conclusion on this point, the film appears directly compatible with the laser-based optical disk systems.

Given a perfect video disk recording, the signal to noise ratio in playback is determined by the intensity of the light source used. For an incandescent source a calculation of the expected signal to noise ratio must include consideration of the temperature of the filament, the transfer efficiency of the condensing optics, the maximum density of the film, the transmission efficiency of the viewing optics and its associated mirrors, and the sensitivity of the detector averaged over the emission wavelengths of the filament. Making the appropriate assumptions about these parameters suggest a 40-dB signal-to-noise ratio is attainable at frequencies below 4 MHz. Much higher values of signal to noise can be obtained simply by turning up the intensity of the light source, but with considerable penalty in terms of the lifetime of the bulb.

Duplication of the film master is by contact printing onto a silver halide film or a diazo copy. The latter material appears to offer distinct cost advantages with large runs. For best results in the usual playback configuration, a diazonium salt absorptive in the near infrared is needed. We have tested an experimental diazo of this type, currently available only with hand-applied emulsions. This emulsion offers nearly the same density range in the near infrared as the silver halide film and is appropriate for use in a video film disk application. Figure 8 shows the appearance of an original disk and its diazo copy.

The contact printing is done with a bellows press to insure intimate contact between master and copy. The equipment for copying may be scaled for application to extensive copy runs, although to date in our laboratory we have, of course, not carried out experiments at production levels.

A summary of some of the implications of the emerging video disk technology is given in table 3--hardware and materials costs associated with the storage of 10 k to 100 k frames of visual information, in a format suitable to video display--30 frames/sec at a bandpass of 2.5 MHz, approximately the capability of the system currently in use. (If the storage requirement is for audio rather than visual data, capacity can be increased by a factor of 100.) The table reflects our own laboratory exercises in producing a video film disk. Of special interest is the utility of the film video disk in the applications for only a limited number of copies. The cost of materials for making the master film disk is negligible, and the



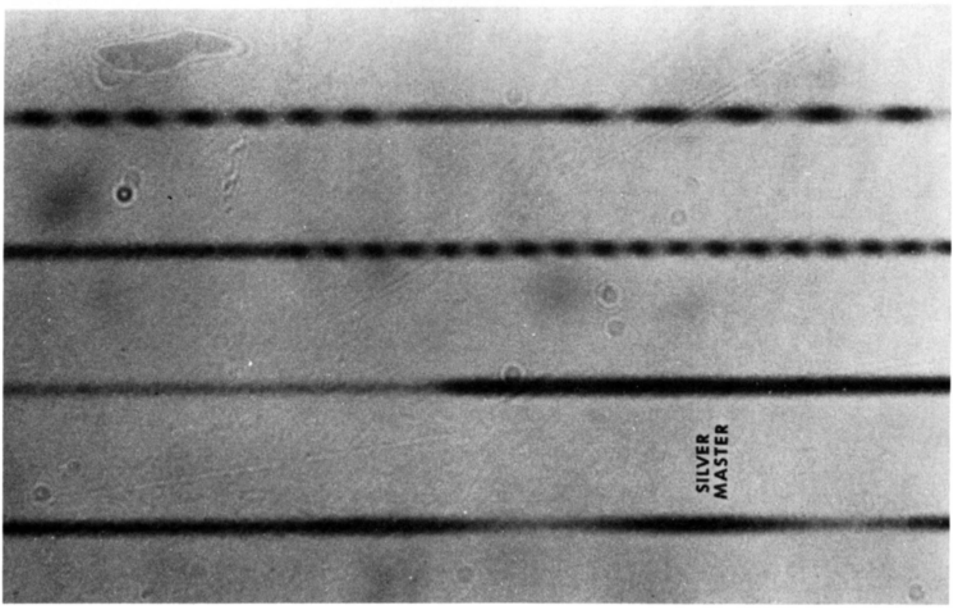


Figure 8

Table 3.--Hardware and costs for storing 10 video frames.

Process	Instrument	Medium	Time Requirement	Cost Equipment /Materials
1. Recording of visual data	Laser recorder w/NTSC input	Silver-halide, 12-m-diam. film disk	Real time	$15,000 /$2.00
2. Development master	Darkroom and apparatus	"	10 min	$500 /pennies
3. Duplication, 1-1000 copies	Low-speed duplicator	"	1 min/copy	$5,000 /$0.40/copy
4. Duplication, >1000 copies	High-speed duplicator	Diazo 12-m-diam. film disk	2 sec/copy*	$20,000* /$0.19/copy
5. Playback of visual data	Video disk player	Video monitor	Real time	$300 /NA

*Estimated, Oct. 1974

recorder itself is inexpensive. The technique is easily practiced. The resulting disk can be used in the usual video applications, to amuse, entertain, educate, and inform. Or, in a more typical audio/visual application, one video disk can contain tens of thousands of distinct pictures relating to catalog stores, voucher files, financial accounts, text materials, personal memorabilia, historical documentation, inventory lists, data repositories, and related informational resources.

Peucker: For those who are not familiar with the whole thing, we should be aware that this was not a hardware session but a "bigware" session. There is a lot of machinery around which we--the little guys--can use. The emphasis is heavy on large systems; except for the last two papers which were development reports. The first three talks represented the kind of IBM mentality that we find so often in the American government--think big, charge the taxpayer, but leave your brain at home. I think that is the basic idea.

Schwartz (Jet Propulsion Laboratory): Some of the speakers have talked about the precision of the EBR--3-μm and 12-μm--but as for accuracy, not much has been said. I wonder what is the geometrical accuracy of these devices? My experience is that it tends not to be anywhere near as good.

Carr: We have various kinds of accuracies.

Grosso: The 3 μm that we talked about was the recording spot size. The accuracy that they are getting with the ERTS EBR from film to film, day to day, is about on the order of 1 part in 5,000. Geometrical accuracy can be achieved towards 0.01 percent, but this takes a lot of carefully controlled conditions.

Constantine: I would say that the accuracy depends on how much time and money that you want to invest in all the components back of the final display. As Pat mentioned, 0.01 percent is not unreasonable today in terms of the precision deflection yokes, amplifiers, and linearity correction systems available. Then you get into the problem of how large a word you are going to use in the computer. Everything gets bigger and more costly as you try to improve accuracy.

Healey: The type of work that we do is concerned with gray level in systems that record data as from ERTS, which have already been digitized. My experience has been that CRT devices have about a 5-pixel error over 1,000 to 2,000 pixels, where the beam is degraded on the edge of the CRT more than the center.

Carr: With ERTS imagery, the basic image is not digitized and corrected--this is done during the recording. The EBR is programed beforehand, and these corrections are introduced--that accounts for its very high throughput. If you had to go back and digitally correct each image from the ERTS sensors, it would cut down the throughput tremendously, and it would be very costly.

Snow: On the 14- by 14-in large-format scanner, we guarantee accuracy of 0.05 percent or about 1 spot size.

Edson: I am going to respond to Peucker's comment about equipment cost. I think that, by and large, we should be looking to industry to provide capabilities in the future. I think it is true that systems are very expensive and have tremendous capability, and the small user cannot possibly afford this sort of thing. Industry should be able to provide service facilities for the small user.

Chrisman: If I may answer for Puecker: I think that when you get these "megadevices" and such absolutely phenomenal laser memory storing data bases, we will never be able to get them on the sort of machines that are used for day-to-day analytical work in municipalities or in academic environments. Those devices are for a very long time and very few installations. I think that we should be talking about hardware in terms of something that is reproducible at more than 2 or 3 sites in the whole world. That is what Puecker and I are really saying.

Carr: That is an interesting idea. Maybe with the world of mini-computers coming on us, we will see more and more of that in the next 10-yr period. i/o Metrics has a very interesting device for storing digital data; I think that we will see optical storage replacing magnetic storage in a few years. Hopefully, the problems of bigness will become ones of smallness.

Boyle: I've heard a number of people say that they wished there was more time for discussion, the panels this afternoon will give somewhat shorter presentations. If they don't cover everything, forgive them and ask the questions. I felt that we were just getting to the stage where we might have a nice little battle, and I was sorry to see us break for lunch at that point. The only thing that we will limit is Tom Peucker to about 4 appearances; don't take his words seriously about being the little man--he is only jealous.

The next panel we have is probably the present love of my life--interactive editing, the interactive graphic manipulation of cartographic data. We have a very good panel to lead into questions; they are involved in the work at the moment and have good ideas.

Connecting with this morning's discussion about the raster-scan plotters and so on: From the hardware point of view there were 2 sorts of displays which are used for interaction. One is the normal refreshed display, that is, the standard sort of television display where you have raster lines, which is used very frequently. This is very much better for alphanumeric line-by-line displays than for true cartographic displays. Certainly, the storage displays seem to be much better and preferable for most cartographic uses. You can store much more detailed data; you don't have to get everything there in 1/60 sec; and you have quite a lot of advantages.

A problem also discussed was converting from an ordinary data bank of line vectors to the scan mode for drum plotters. I haven't been involved with drum plotters, but we have done a lot of experiments using standard television displays on computers. It is somewhat of a similar problem, I am sure. We convert from our line data in the PDP-8, a small computer, to the scan line form, and we have to produce a scan line every 60 μs; yet, this can be done. It is a smaller amount of data which you are converting, but you have to do it faster than for a raster plotter. There is not a great deal of difficulty. Our aim is to be able to use standard color displays which serve lots of uses. Unfortunately, we don't have any storage displays which work in color.

Just to mention two people who were not able to come--Laser Scan from Cambridge, England, and Tektronix. We are not leaving out the ordinary, such as the plotters. We didn't ask CalComp, Gerber, and Xynetics, not because their equipment isn't very useful in this area, but we felt that most people knew about them and would like to learn something about the newer devices that are coming.

Now I am going to hand the session over to the moderator of the editing methods panel, a person with a great deal of experience working with David Beckmore at the Royal College of Arts in London, in the experimental cartography unit. He has now left there and is a professor of geography at the University of Durham in England. He will certainly point out all the possibilities and variations.