FILM RECORDERS FOR RECEIPT, PROCESSING AND ARCHIVING REMOTE SENSING DATA

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ABSTRACT

Film Recorders for remote sensing ground receiving stations, product distribution agencies, image processing service centers and archival preservation are presented. A 241mm (9 1/2") and a 127mm (5") recorder are described which are capable of recording all present and future satellite sensor imagery for earth science and geographic information system applications. A 16mm, 35mm and 105mm recorder for high resolution microfilm image browse files and archival preservation of imagery is also described.

The software controllable flexibility of these recorders enable the recording of any remote sensor data to a selectable size including any necessary radiometric and spatial corrections. Image corrections and annotation around the border of an image are introduced during the image exposure process. The exceptional quality of the image is a result of the extremely high resolution of the recorder and electron beam exposure of the film. The high electron beam exposure energy enables very high throughput recording rates. Almost all satellite images can be recorded in a few seconds per scene.

Key Words: Remote Sensing, Image Quality, Film, Recording, Receiving

INTRODUCTION

Electron beam recording of ERTS/Landsatand SPOT satellite remote sensor data has proven to be a very productive method to obtain the highest possible quality images for over 20 years. The original Earth Resource Technology Satellite (ERTS) program used an Electron Beam Recorder (EBR) at NASA Goddard Space Flight Center. This EBR recorded all ERTS and then Landsatimages for over 10 years. The Instituto De Pesquisas Expaciais (INPE) in Brazil has used electron beam recorders from the beginning of their program in 1973 to the present for recording ERTS, Landsatand SPOT images.

Utilizing over 20 years experience in designing and manufacturing electron beam recorders for remote sensing, geophysical data, computer graphics and publishing applications, Image Graphics, Inc. has configured two electron beam recorder models specifically for remote sensing ground receiving stations and image product distribution and service centers. These EBRs incorporate the latest technology advances and open systems architecture to provide the capability to record all present and future satellite remote sensor in a wide variety of film product formats.

REMOTE SENSING ELECTRON BEAM IMAGE RECORDERS

The Image Graphics, Inc. Remote Sensing Electron Beam Recorders provide the capability to record satellite and aerial imagery for earth science and geographic information systems. The software controllable digital flexibility and connectivity allows interaction within mainframe environment as well as heterogeneous networks.

EBIR MODELS

Two models are available for remote sensing which primarily differ in recording format size.

Model 5241
The larger format model 5241 records up to a 216mm x 279mm image size on 241mm film which accommodates a standard LandsatThematic Mapper (TM) full scene at a 1:1,000,000 scale or an enlarged quarter scene at 1:500,000 scale. Figure 1 is a photograph of this EBIR.

Model 3127
The smaller format model 3127 records up to 121mm x 152mm image size on 127mm film which accommodates a full Landsatscene at 1:2,000,000 scale and quarter LandsatTM scene at 1:1,000,000 scale. This model can also record microform products described later in this paper.This Model EBIR is shown in Figure 2.

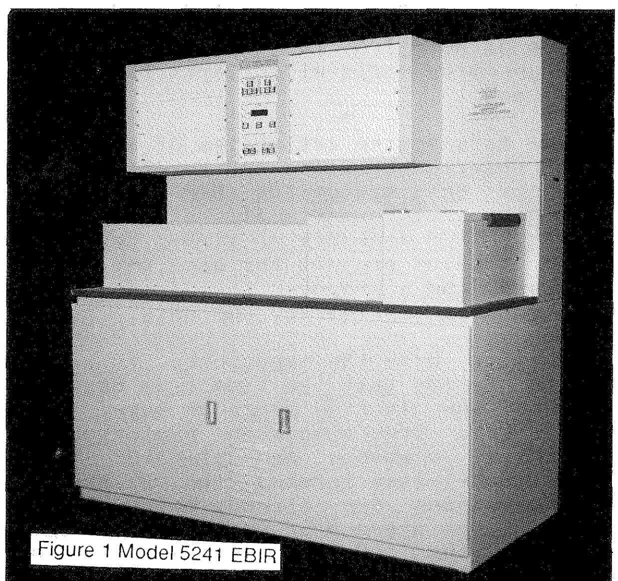
Figure 1 Model 5241 EBIR

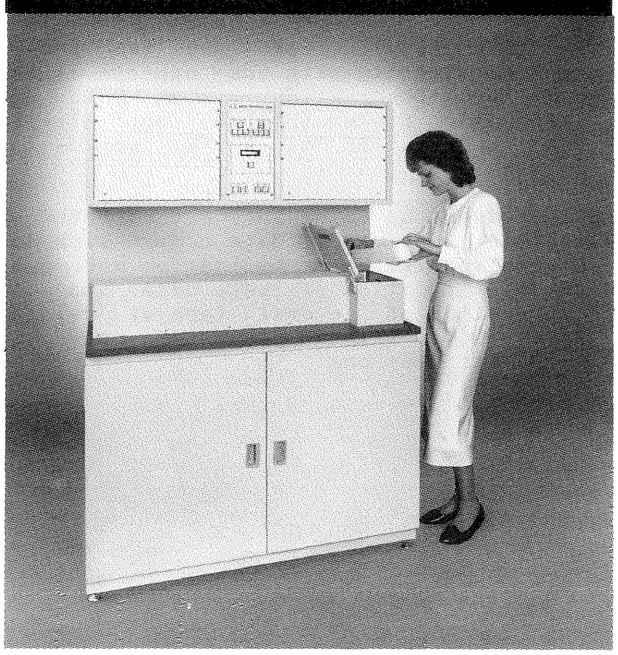
Figure 2 Model 3127 EBIR

The choice between the models is dependent upon the larger size needed for operational requirements. The smaller model economic advantage is the reduction of annual film usage cost to only 25% of that used by the larger model.

Although these models are frame by frame image recorders, a continuous motion film transport option is available for either model.

The framing recorder addresses the entire X, Y film format area for recording the image, then advances to the next frame. The continuous motion recorder moves the film at a steady pace in the Y direction while the electron beam scans across in the X direction. The continuous motion is more often used for synthetic aperture radar sensors.

RECORDING FLEXIBILITY

RESOLUTION

Both models of the Electron Beam Image Recorder (EBIR) offer a resolution which is variable up to a seven-to-one (7:1) range from the smallest spot to the largest. This is achieved by changing the recording spot pixel size and line-to-line spacing between the pixels. The resulting enlargement is a smooth continuous image which does not have the square pixel effect (aliasing) of replicated pixel enlargements. Also, because of the quality obtained with electron beam recording, a further optional enlargement up to 10X can be made to provide highest quality products at very low map scales. The following table illustrates the range of pixels and lines obtainable over the format by changing the resolution:

Table 1 - Resolution Range/Image Format

Specification	EBIR Model 3127	EBIR Model 5241
Film Size	127 mm (5")	241 mm (9 1/2")
Image Format	121 x 152 mm (4 3/4"x6")	216 x 279 mm (8 1/2"x11")
Resolution Range	27 to 4 microns	53 to 8 microns
Pixels Range	4534 to 30,250	4056 to 27,000
Number of Lines Range	5696 to 38,000	5239 to 34,875
Addressability	262,144	262,144
10X Enlargement	1210 x 1520 mm (47.5"x60")	2160 x 2790 mm (85"x110")

The variable recording resolution of these electron beam recorders is software controllable on a frame-by-frame basis. This flexibility and the small pixel capability allows the recorders to match the resolution of all existing and planned future satellite sensors. The unique digital control zoom capability allows a low resolution image to be enlarged to fill the entire format or stack a number of related images of interest on the same format. The excellent resolution also allows adjacent image scenes combined as a mosaic to be recorded for an overall synoptic view. Figure 3, illustrates recording a full scene aerial image, a 4X digital enlargement, enhancement and text/vector annotation on the same film format.

RASTER IMAGE CAPABILITIES

The origin of an image may be located anywhere within the recording format with an addressability of 262,144 x 262,144. The addressability may be lowered to meet lesser product placement accuracy or other considerations. Each axis may be scaled separately if necessary for the product.

The image may be recorded as normal or mirror to match the generation of film product distributed for the correct presentation and the data output format of the sensor. Including image rotation and mirror images, any one of eight ways are available.

The recording density range may be selected by setting the Dmin and Dmax and the number of grey scale steps from 256 to 4096. The recording may be positive or negative depending on the product requirements. A summary of these raster features is provided in Table 2 below.

Table 2 - Raster Recording Capability

Recording Sequence - any of 8 ways

Origin Select	X, Y, - 18 bit addressability
Video	Select positive or negative image
Density	Dmin, Dmax selectable .05 to 3 du
Grey Scale	8 to 12 bit selectable
Spot Size	7:1 Range, 18 bit increments
Line-to-Line Spacing	7:1 Range, 18 bit increments
Recording Rate	Up to 50 M/pixels, asynchronous

The seven to one (7:1) range for spot size and line-to-line spacing variation may be changed in 262,144 steps (18 bits) each, to adjust for any sensor aspect ratio.

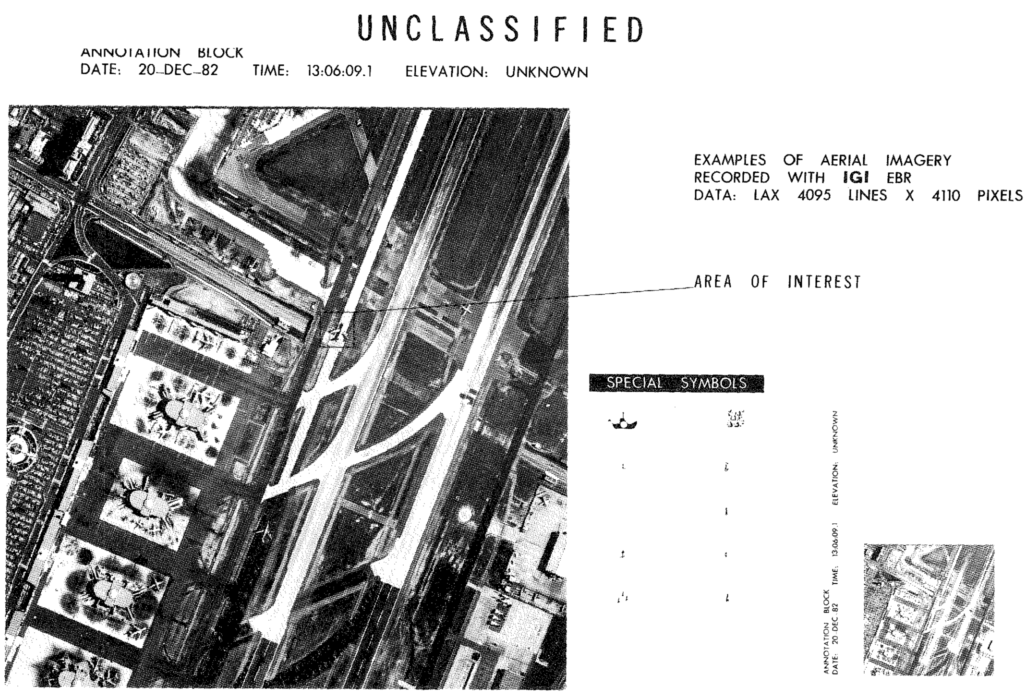

Figure 3 Digital Enlargement, Enhancement and Vector/Text Annotation

VECTOR RECORDING CAPABILITIES

The EBIR also records vector formatted data as an overlay on the raster image or as a color separation(s). This eliminates the rasterization and integration of the vector data as a process step and uses much less digital storage space. The vector recording capabilities are summarized in Table 3.

Table 3 Vector Plot/Text Capabilities

Plotting

Vector Line Widths	128 sizes
Vector Format Addressability	262,144 x 262,144
Angles	Any degree
Recording Rate	up to 500,000 vectors/second

Text

Type 1 Fonts	Adobe, Bitstream
Stroke Characters	Hershey
Character Rotation	360° in 1° increments
Size, Enlarged Scale	4 points to 72 points
Recording Rate	5000 graphic arts quality / sec

The vector plot addressability provides extremely smooth curves and circles with no discernible steps. Line width selectability enable plotting the correct line width at all map scales and the text allows graphic arts quality fonts in any language for annotation in and around the image area.

RADIOMETRIC CORRECTIONS

During recording, radiometric changes can be introduced on a pixel-by-pixel basis to correct for sensor radiance uniformity, the exposure film and subsequent processing steps for the final product, and any image enhancements so that the areas of interest stand out from the background. These can be stored as digital look-up tables for each sensor, film type and batch variations, and cataloged image processing enhancements which meet specified algorithms. The digital gamma control of the EBIR allows these changes on an image-by-image basis.

SPATIAL CHANGES

Spatial image changes made while recording will reduce the time and cost of computer preprocessing of the sensor data before it is sent to the recorder. The spatial corrections for sensor scan and platform errors are sent to the EBIR Controller with the imagery data and the corrections are made during recording. A much simpler computer controller is thereby used in place of a much more powerful mainframe type of computer. These spatial changes are a key feature of the Brazil INPE EBIR described in Poster Session Paper 1039 of these proceedings.

MODEL 3127 MICROFILM

The EBIR Model 3127 can also be provided with interchangeable film transport mechanisms for 16mm, 35mm or 105mm microfilm applications. These formats are applicable for reference and browse files, related temporal scenes of interest, various image enhancements of the same scene, and archival preservation. Figure 4 is an example of such a group of microimages recorded at full scene resolution.

The four micrometer resolution of this recorder allows the recording of an image at 24X onto 16mm or 105mm microfiche for a standard TM quadrant scene. Table 4 provides standard microimage reduction ratios, size and the number of pixels and lines which can be recorded onto these microform areas.

Table 4 - Standard Microimage Size and EBIR Model 3127 Image Resolution

Film	Reduction	Nominal Image Area	Pixels and Lines
16mm	24X	16.00 x 12.70mm	4000 x 3175
35mm	30X	30.40 x 41.02mm	7600 x 10,255
105mm fiche 63 Frames	24X	15.50 x 12.50mm	3875 x 3125

It should be noted that the EBIR records any size image anywhere over the microfiche format, thus four quadrant LTWG may be combined for a full TM scene and 12 full scenes could be recorded on a standard microfiche format with annotation. Because of this flexibility to record anywhere on the microfiche, special remote sensing products can be created for specific sensor and market needs by service centers.

Another possible new film product would be color movies. Three different sensor spectral bands could be recorded for each satellite orbit(s) and then exposed onto 35mm color film through red, green and blue filters. The processed color film could be used as a unique movie of earth orbits or browse files.

CONSISTENT EXPOSURE QUALITY

In order to insure repeatability of the recorded imagery grey scale, before each exposure of an image, the electron beam is deflected to an electrode and the beam current for a grey scale step is measured. The measured current is compared to a current established for the film, and film processing at that grey scale step level and reset to the correct current value, if necessary. Through the use of look-up tables to correct for batch to batch variations in manufacturing of the film and processing of the film, excellent repeatability is obtained to assure consistent repeatable density levels.

Careful attention to electronic design and shielding to eliminate generated and radiated noise results in a flat field exposure without banding or noise artifacts at all recorded resolutions.

RECORDING MEDIA

There are two recording films recommended for electron beam recording of continuous tone imagery. One is a silver halide film manufactured as SO-219 by Eastman Kodak which uses conventional film processing. The other is a completely processless film manufactured as "PERM" by International Specialty Products, manufacturers of GAF chemicals, which require no subsequent film processing whatsoever. Both films have extremely high resolution, over 1000 line pairs/mm, and a good linear density range of exposure. The SO-219 support archival storage of the processed film and the PERM provide instant access to the image and no environmental film processing concerns.

REGISTRATION PUNCHES

The EBIR has a unique feature for subsequent process steps of the film product. Registration holes are punched in the film prior to recording the image. The recorded image is registrated to these holes so that separation pins can be used to subsequently register scene images for color exposure. Through the use of bar code information recorded on an image, it is possible to set up an automatic color separation exposure process for product production efficiency.

HALFTONE GENERATOR

A halftone generator is available for service bureaus needing to prepare color separation images for publications and professional papers. These color separated halftone images may be used to provide printing plates for conventional lithographic printing. Used with registration holes punched by

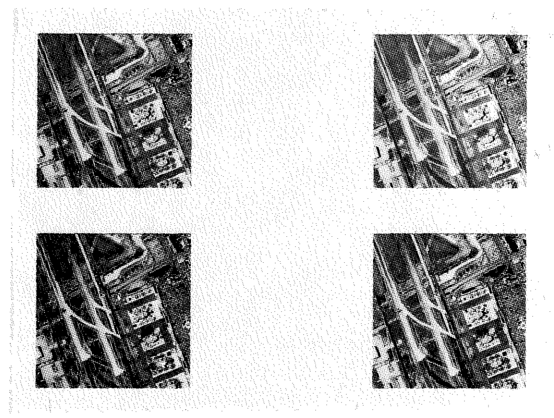

Figure 4 Group of Related Microimages

the EBIR, the labor intensive manual steps normally required are eliminated saving turnaround time and costs. Table 5 below lists the features of this halftone generator:

TABLE 5 HALFTONE CAPABILITIES

Dots	Round, Square, Elliptical
Line Screens	65 to 175 lpi
Angles	0, 15, 45, 75 Degrees
Enlarge/Reduce	15 to 300%
Output Rate	16 m/pixels/sec
Gray Shade Mode	8 bit

CONTROLLER/DATA INPUT

These EBIR models use an Electron Beam Recorder Interface Controller (EBRIC) which has a Motorola 630X0 Microprocessor with VMEbus architecture and the UNIX operating system. This open systems architecture allow integration with all system requirements and networking capability including SDLC, Token Ring or any TCP/IP system. The input image data may be 16, 32 or 48 bit differential input and all standard remote sensor formats as well as ANSI/ISO interchange standards.

ELECTRON BEAM EXPOSURE

Low inertia electron beam can be rapidly and precisely controlled over the recording format. The 20,000 volt electron beam exposure provides several advantages over photon (CRT or laser) exposure of film. The much higher energy of the electron beam allows faster exposure of images at megapixel rates with no reciprocity failure. The image sharpness due to exposure with the extremely small diameter electron beam is much superior to any method using a lens. Due to the constant resetting of the exposure beam current, the recorded grey scales are consistent from image-to-image and year-to-year. Figure 5 is an example of a LandsatMSS scene which can be recorded on an EBIR in a few seconds.

CONCLUSIONS

The high performance and versatility of these electron beam image recorders provide cost effective film product production for remote sensing receiving sites and service centers. The versatility allows one recorder to supply film products for all satellite types instead of needing a separate recorder for each type of satellite. The high resolution provides for future improvements of sensor resolution which eliminates the need for new recorders. The electron beam exposure allows very high volume product production which is equivalent to more than three conventional laser recorders.

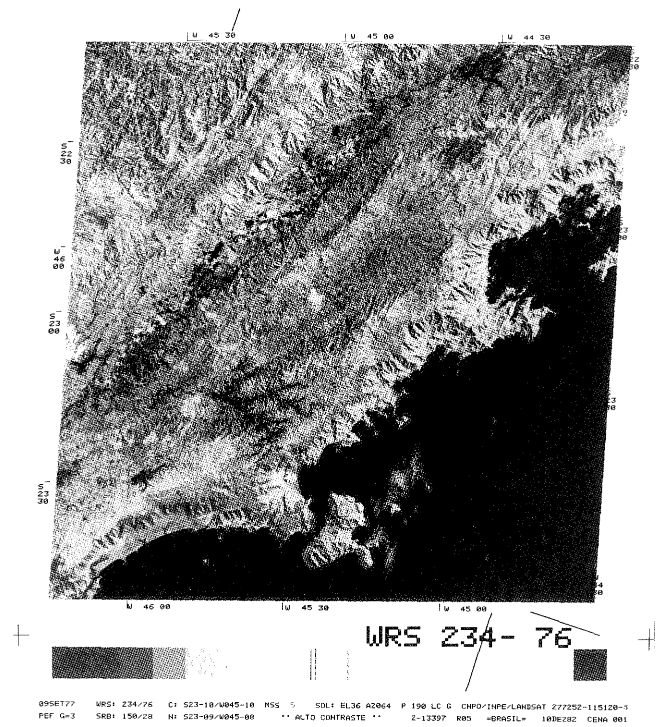

Figure 5 Landsat MSS Scene

REFERENCES

1. P. F. Grosso, J. P. Whitley, J. E. Turek, Image Graphics, Inc., "Recent Advances in Electron Beam Image Recording for Remote Sensor Data Processing and Analysis" ISPRS, Washington, D. C., August, 1992.

2. P. F. Grosso, A. A. Tarnowski, J. E. Turek, Image Graphics, Inc., "Electron Beam Recording of Remote Sensor Imaging in Brazil, ISPRS, Washington, D. C., August 1992.

3. J. P. Whitley, Image Graphics, Inc., "Electron Beam Image Processing Recorder", SPIE Volume 1252, Santa Clara, CA, 13-14 February 1990.