ELECTRON BEAM RECORDING OF REMOTE SENSOR IMAGERY IN BRAZIL

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ABSTRACT

Electron Beam Recording has been used for processing and recording ERTS/LANDSAT and SPOT satellite remote sensor data into black and white and color imagery in the United States and Brazil for over 20 years.

The Electron Beam Image Recorder (EBIR) System installed at the Instituto De Pesquisas Expaciais (INPE) in Brazil, South America in 1983 is used to record color separation masters of the various remote sensor spectral bands from uncorrected LANDSAT and SPOT image data on five inch wide film. The EBIR images are optically enlarged and registered into color composite imagery up to 40" x 48" in size.

Correction coefficients for geometric errors caused by satellite orbit, the earth's rotation, and sensor configurations and radiometric calibration for the different sensors, the film recorder and film processing are introduced during the recording process with no loss of recording speed. No computer preprocessing of the satellite transmitted data is required.

Key Words: Remote Sensing, Receiving, Film Recording, Image Processing.

INTRODUCTION

Since 1973, the Instituto De Pesquisas Expaciais (INPE) in Brazil, South America has been receiving and recording images from Landsat and SPOT satellites within the range of its receiving antenna installed in Cuiabá, Mato Grosso State. This ground receiving station allows full coverage of Brazil and most of South America for a number of satellites as shown in Figure 1 and Table 1 (INPE Ministerio Da Cienciae Technogia).

Magnetic tapes recorded at Cuiabá are shipped to Cachoeira Paulista - INPE Sao Paulo State where Electron Beam Image Recorders (EBIR) are used to convert the digital data into high quality black and white color separations of the Landsat and SPOT remote sensor spectral bands. The EBIR master images on 5" wide film are optically enlarged up to 40" x 48" (102cm x 122cm) for a variety of black & white and color photographic products.

Figure 1. Range of Cuiabá Ground Station - Mato Grosso

Table 1. Remote Sensor Data Delivered By INPE

Satellite	LANDSAT			SPOT	
Sensor	TM	MSS		HRV	
Band	Interval µm	Band	Interval µm	Band	Interval µm
1	0.45-0.52	4	0.5-0.6	1	0.50-0.59
2	0.52-0.60	5	0.6-0.7	2	0.61-0.68
3	0.63-0.69	6	0.7-0.8	3	0.79-0.89
4	0.76-0.90	7	0.8-1.1	PAN.	0.51-0.73
5	1.55-1.75				
7	2.08-2.35				
6	10.4-12.5				
Resolution	30-120 m	80 m		10-20 m	

Satellite	GOES-NOAA		
Sensor	VISSR-SMS	AVHRR-TIROS-N	
Band	Interval µm	Band	Interval µm
1	0.55-0.76	1	0.58-0.68
2	10.5-12.6	2	0.72-1.9
		3	3.55-3.93
		4	10.3-11.3
		5	11.5-12.5
Resolution	800-8000 m	800-8000 m	

ELECTRON BEAM IMAGE RECORDER

The Image Graphics EBIR is part of the INPE Image Processing Subsystem developed by Society for European Propulsion (SEP) Paris, France. This subsystem converts the high density digital data tapes from Landsat and SPOT remote sensors into high resolution, geometric and radiometric corrected imagery on 5" wide film.

The EBIR system configuration shown in Figure 2 consists of six functional areas:

- o Input
- o Output
- o Control
- o Data Translator
- o Recorder
- o Software

Input

Typical input to the EBIR is thematic mapper high density digital tapes played back at real time rate (84.9 Mbits); subsampled to one spectral band with an instantaneous rate of 2 Mpixels/sec., from a full or partial passage of a satellite. Thematic mapper digital data may also be transferred to the EBIR from a 256 Mbyte disk. Auxiliary data around the border of the scene, geometric and radiometric corrections for earth orbit and sensors are introduced in real-time during the recording process. The correction coefficients are predetermined prior to image recording.

Output
The output of the EBIR is a black and white transparency image recorded on five inch film at full resolution of a scene 185Km x 185Km at a scale of 1/2,000,000 which has been radiometrically and bulk geometrically corrected. Examples of EBIR corrected Thematic Mapper spectral bands from Landsat 5 are shown in Figures 3a, 3b, 3c and 3d. Figure 4 is a photograph of a typical 40"x48" color Landsat image that is regularly produced from the 5" EBIR color separations.

The EBIR images also include geographical position ("tick") marks for latitude and longitude, gray scales and alphanumeric annotations of all the necessary information for satellite position, position of the sun, sensor type, spectral band, date, etc.

Control
A Digital Equipment Corporation VAX 11/780 is used to input data from the HDDT, provide controls, video timing and image correction coefficients. Image Graphics data translator circuits convert the digital recording instructions from the VAX computer into analog signals which drive the EBIR. The data translator circuits which provide real time, on-line corrections enable the use of this minicomputer rather than having to preprocess all of the image corrections and annotation data with a large main frame computer prior to the image recording process.

Data Translators
The Data Translator Circuits of the INPE EBIR are contained in the High Speed Buffer (HSB), the Raster Scan Translator (RST), the On-Line Data Processor (OLDP), and the Symbol/Vector Generator (SVG).

The HSB is a two line buffer memory that receives, controls and passes the video (digital image data) and set up functions from the VAX control computer or from external devices to the RST at data rates up to 1.5M words (16 bit word) per second. (Today's EBIRs are capable of recording at 25 Megapixels per second and higher)

The RST circuits convert and format the digital data from the HSB into exposure and deflection signals to scan modulated video raster lines on the EBIR film. Table 2 gives the characteristics of the RST.

Table 2
Raster Scan Translator Characteristics

Binary Data	B&W & Variable Density
Run Length Encoded Data	B&W & Variable Density
Density Control	256 Levels
Elements per Line	500 TO 32,000
Lines per Raster	500 TO 32,000
Data Rates	Up To 25 Megapixels per Second

The OLDP is used to introduce corrections into the video and raster scans in real time during the recording process as shown in Table 3.

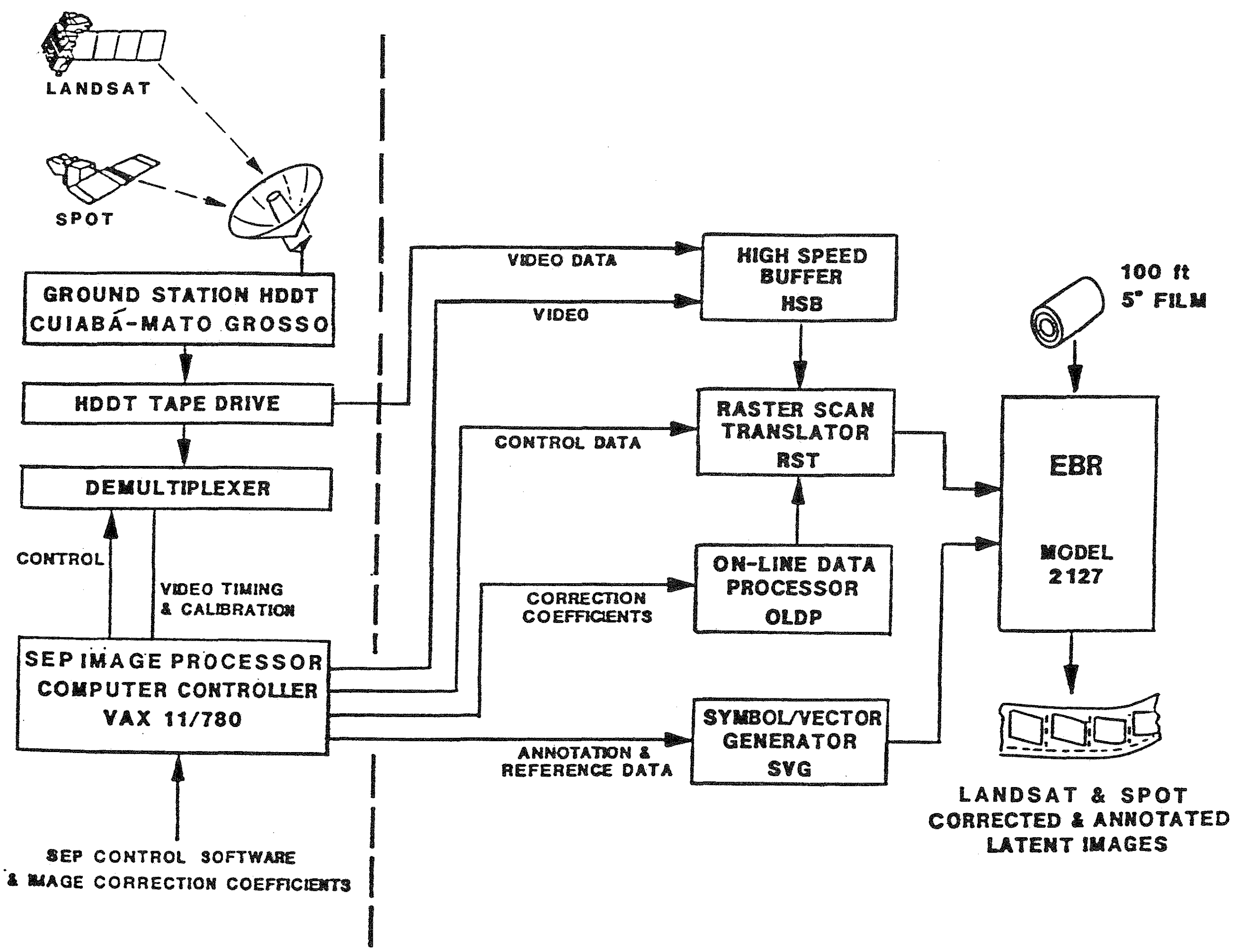


FIGURE 2 EBIR System for Image Processing Subsystem LPI Cachoeira Pulista INPE, Brazil

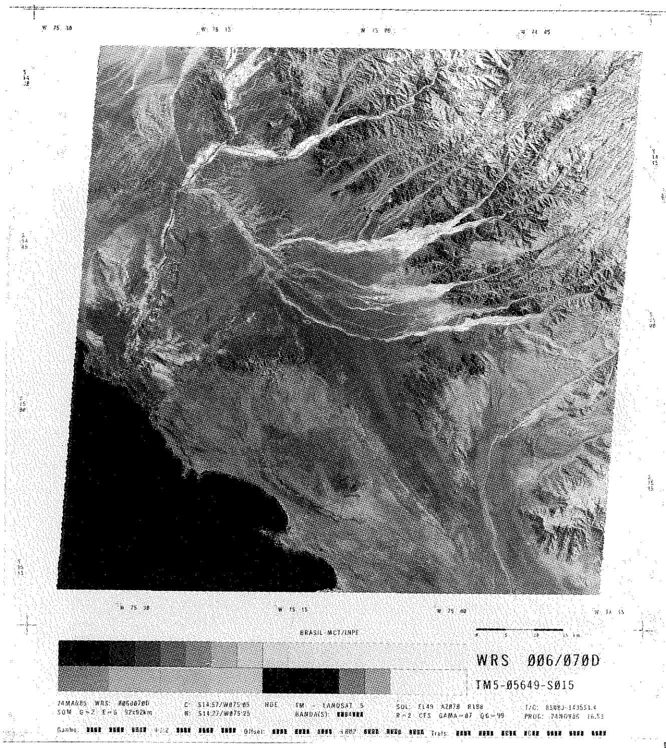


Figure 3a Band 4 0.76 - 0.90 μm

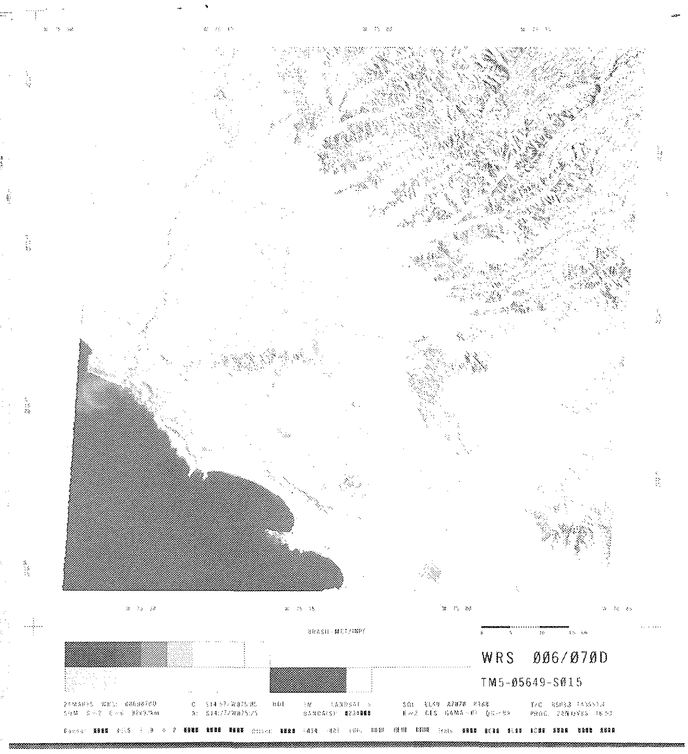


Figure 3b Band 5 1.55-1.75 μm

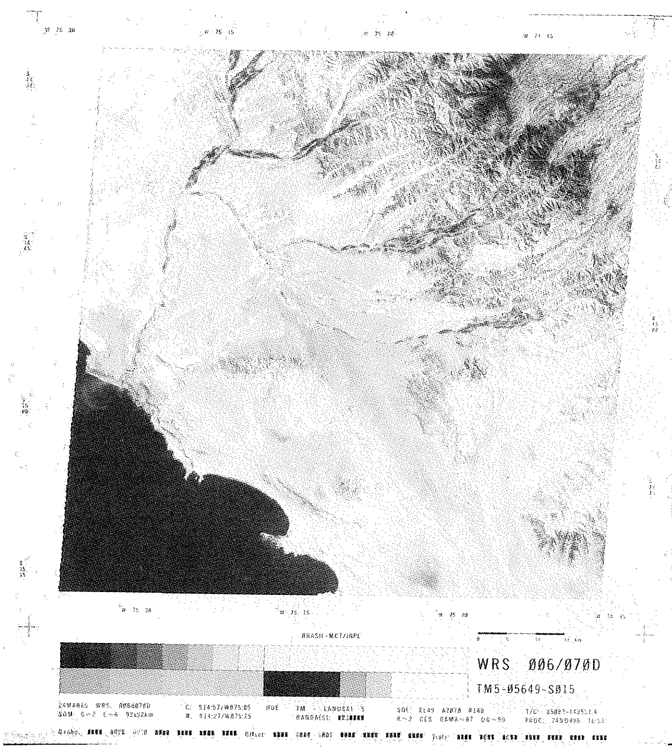


Figure 3c Band 6 10.4-12.5 μm

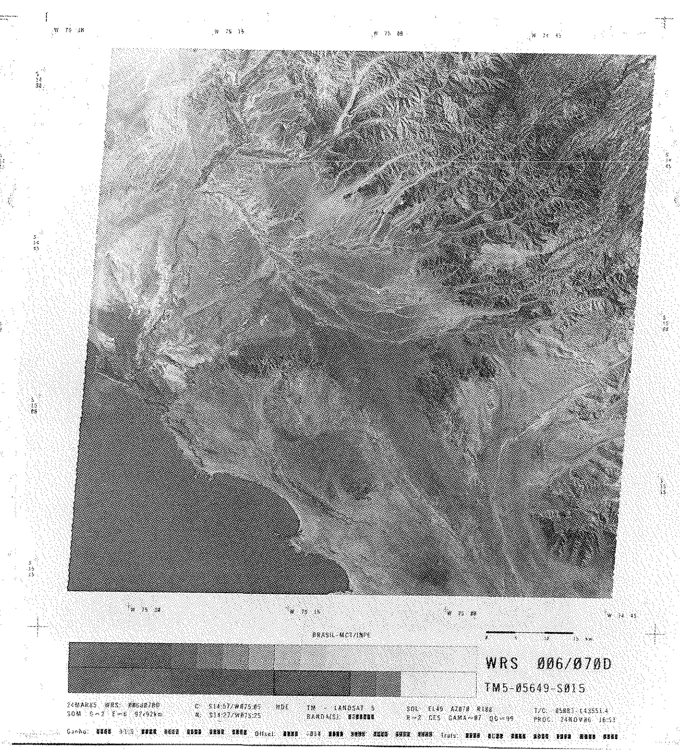


Figure 3d Band 7 2.08-2.35 μm

Figures 3a-d LANDSAT 5 Geometric and Radiometric Corrections using EBIR OLDP - B. de S. Nicolas, West Coast of Peru, South America

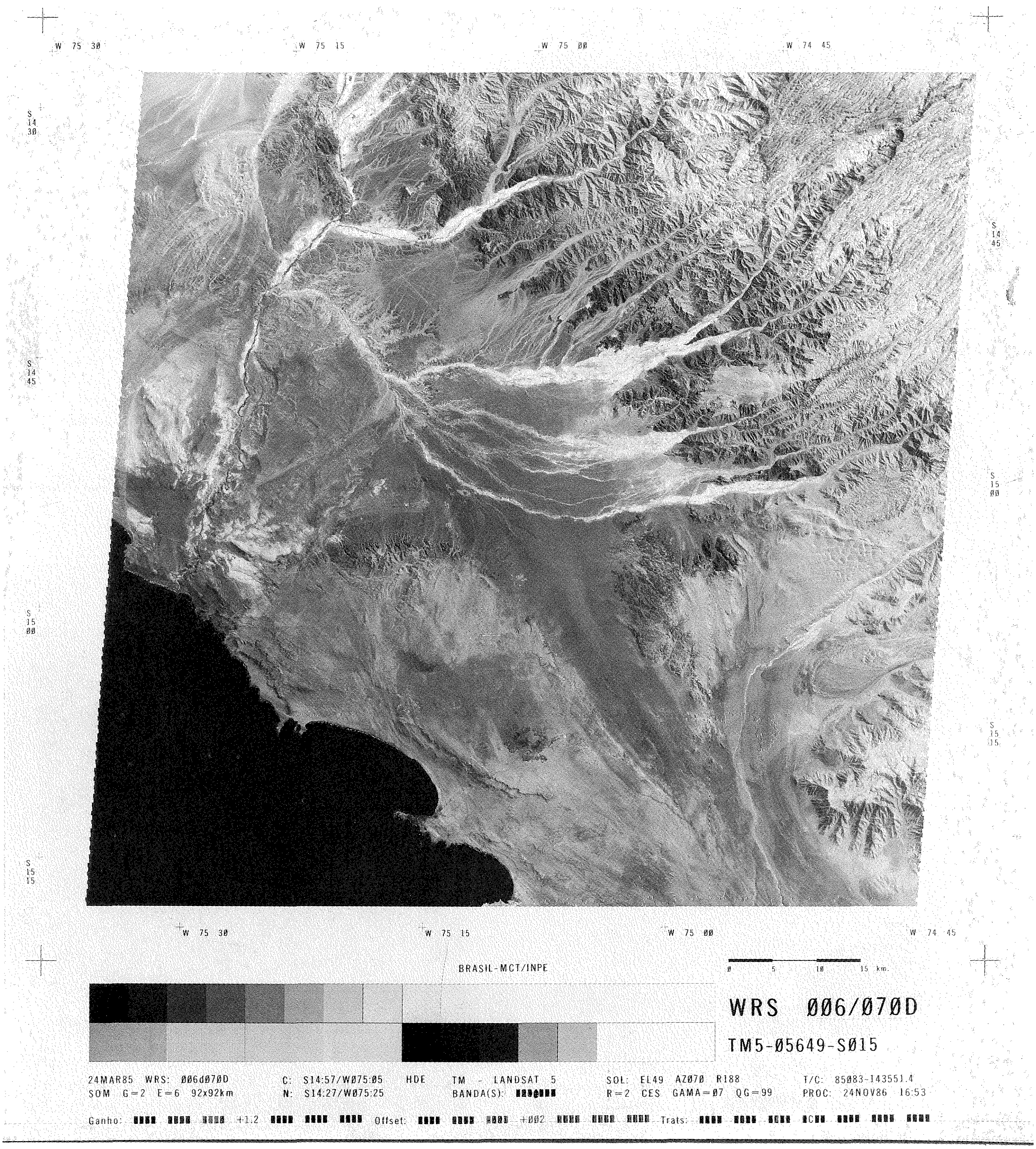


Figure 4 Photograph of a typical 40"x48" color composite from Thematic Mapper LANDSAT - 5 of B.de S.Nicolas West Coast of Peru, South America (original not provided with Paper)

The bulk geometric corrections applied to the EBIR images will correct for distortions due to:

- Satellite position and altitude reference to Earth
- Remote sensor errors
- Earth curvature and rotation
- Time bias between the satellite and Greenwich Mean Time
- Radiometric errors from the remote sensors and image processing

The geometric corrections, which account for space oblique mercator projection in the basic mode and universal transverse mercator projections are computed prior to recording and then the correction coefficients are introduced for each image data line during the EBIR recording process.

Table 3
Computer Controlled Correction During Recording

Correction or Control	Range	Discrete Levels
Exposure (Fine)	+/- 10%	64
Vertical Offset (Coarse)	+/- 10.24mm	4096
Vertical Offset (Fine)	+/- 1.28mm	4096
Horizontal Offset	+/- 10.24mm	4096
Horizontal Rate	+/- 10%	4096
Skew	+/- 10% (+/-TAN -1.1)	4096
Line Width (Spot Wobble)	16μm to 18μm	256
Video Polarity	Positive or Negative	2
Video Control	-------	256
Video Transfer	Linear or Gamma Corrected (.5 to 2)	16

The radiometric corrections which account for density variation and dynamic range of the system are determined prior to recording and introduced for each image during the recording process.

The SVG circuits translate digital code from the VAX computer into image annotation, reference data, and geographical position marks around the recorded image in a random character/symbol vector plotting mode. Table 4 lists the functional capability and performance characteristics of the SVG.

TABLE 4
Symbol/Vector Generation Characteristics

Symbol Character Control

Styles	Graphic Arts, Hershey, COM
Construction	Subraster, Vector
Number of Sizes	1023
Minimum Size	50μm (.002")
Maximum Size	72pt (1.000")
Size Increments	5μm(.0002")
Rotation	1 Degree Increments

Vector/Graphics Line Width Control

Number of Lines	256
Minimum	5μm (.0002")
Maximum With Wobble	260μm (.010")
Maximum With Vectors	Full Width of Format
Size Increments	1M (.00004")
Rotation	1 Degree Increments

Using the EBIR data translators, the EBIR can uniquely record raster, vector and text formatted data on the same image as individual data sets i.e.

o RST - raster image
o OLDP - real time geometric and radiometric corrections
o SVG - annotation, symbols and geographic marks around imaging border

Recorder (EBIR)
The EBIR is a high resolution electron beam film recorder which converts electrical signals from the data translators into a latent image on silver halide film. These signals are representative of the continuous tone satellite images, the geometric and radiometric corrections, the annotation, reference data and geographical positions. The silver halide film, which may be handled under bright yellow lights, is chemically processed into black and white film transparencies of the various remote sensor spectral bands. Performance characteristics of the EBIR are given in Table 5.

TABLE 5
EBIR Performance

Film Size	127mm (5") Wide
Image Format	115mm X 136mm (4.5" X 5.4")
Addressability	65K X 65K
Resolution	18,000 X 21,000 Pixels
Beam Diameter	5μm (0.0002")
Video Bandwidth	10 MHz
Raster Recording Rate	2.5 Megapixels per sec.
Density Range	0.1 TO 2.1 Du
Density Uniformity	.02 Du
Deflection Jitter	+/- 2μm
Scan Line Spacing Uniformity	1μm RMS
Geometric Fidelity	0.01%
Congruity of Sequential Images	5μm (0.003%)

The individual spectral bands which were sensed and transmitted by the satellite are accurately maintained and registered to prepare color composite image transparencies or prints. Radiometric calibration for the sensors, the film recorder, the film and the film processing were introduced by OLDP during the recording process.

The resolution accuracy and color registration of the EBIR enable enlargements of the 4.5"x5.4" to over 40"x48" and larger.

Software
In addition to the VAX computer system operating software, utility programs for controlling the Data Translators include:

o Raster Scan (RAS) - is the software package which controls all raster plot data supplied to the Raster Scan Translator for black or white or continuous tone imagery from the High Speed Buffer.

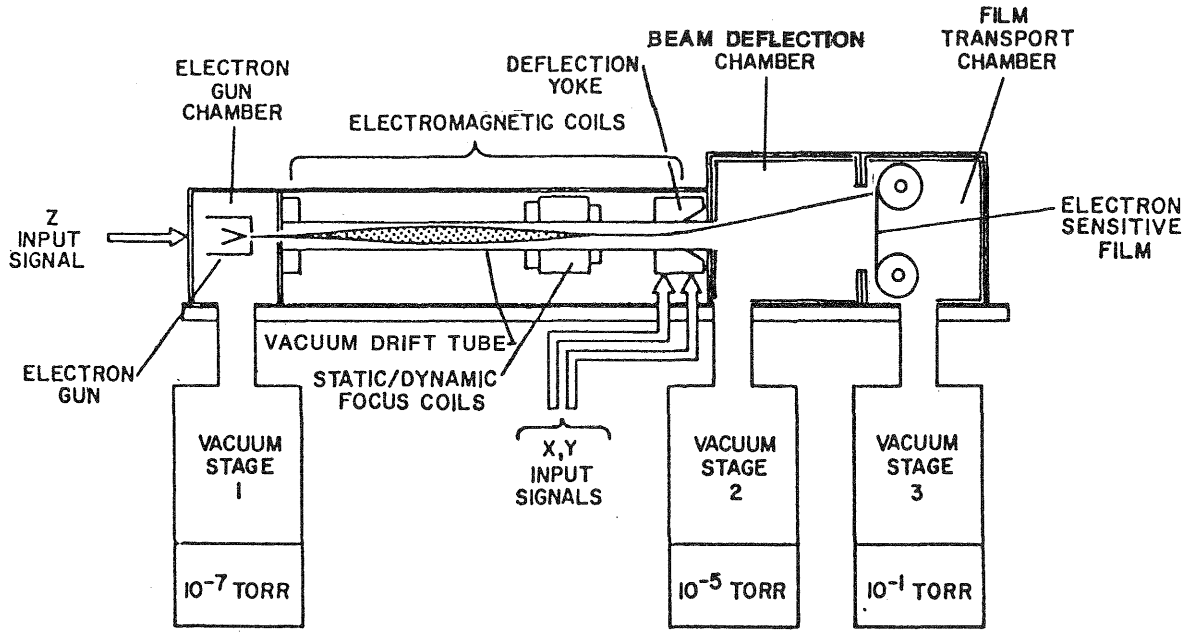
o Vector/Symbol Plot (VSP) - is the principle plot program which controls all plotting; and all names and text composition and placement from input data tapes.

o Font Library Update (FLU) - or the software package which is used to create digital font libraries of graphic arts quality, Hershey or COM characters on magnetic disk. FLU can be used to add, delete, display or list symbol data and perform minor editing on font data.

EBIR TECHNOLOGY OVERVIEW

The electron beam image recorder is analogous to a faceless cathode ray tube recorder where the film transport has been placed inside the vacuum. Exposing the film directly with electrons, eliminating the phosphor-coated faceplate of the CRT, and the lens which projects the image to film, removed the major causes of loss of image quality (resolution, edge acuity). Additionally the inherent problem of low exposure intensity of CRTs (which limits recording speed) was solved. Direct exposure of silver film with a high energy (15-20Kv) electron beam has thousands of times more efficiency than exposure by light or laser beam. This enables extremely high data recording rates for cost effective throughput.

A schematic layout of a typical EBIR is shown in Figure 5.



The electron gun assembly is a triode structure with a directly heated thermionic tungsten cathode. Small apertures in the grid and anode form an electron beam with a low divergence angle. The electron beam is accelerated at 15-20 Kilovolts through the vacuum drift tube and through the center of the electromagnetic focus and deflection coils. The beam is focused by the static focus coil into a small spot (typically 4-5 microns diameter at the film plane) which can be used to produce an image on a 5" x 5" format in excess of 30,000 x 30,000 pixels. Dynamic focus, dynamic astigmatism and geometric correction circuits are used to correct for spot shape and image geometry as the beam is deflected with the deflection yoke over the biaxis image format.

CONCLUSIONS

Electron beam recording technology has proven to be an effective method of producing LANDSAT, SPOT and other satellite remote sensor imagery for the past 20 years. Brazil has produced many tens of thousands of outstanding quality, black and white and color original images of South America from which millions of photographic products have been distributed.

The ability to mix raster, vector, and text data files directly without having to reformat the data into a single raster has reduced computer processing requirements and image production time.

The resolution and color registration of EBIR master images of remote sensor spectral bands recorded on 5" wide film enables optical enlargements up to 10x to produce 40"x48" black and white or color remote sensor image products.

The ability to make geometric and radiometric corrections and annotating the image in real time without showing the recording rate has allowed a very efficient method of producing hardcopy images.

ACKNOWLEDGMENTS

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