RECENT ADVANCES IN ELECTRON BEAM IMAGE RECORDING FOR REMOTE SENSING DATA PROCESSING AND ANALYSIS

Patrick F. Grosso, President
John P. Whitley, Vice President
John E. Turek, Systems Engineering Manager

Image Graphics Inc.
Shelton, CT, 06484, U.S.A.
ISPRS Exhibitor's Showcase No. 987

ABSTRACT

Recent advances in micro-computers, software and electron beam imaging technology enables the recording of a variety of different satellite and aerial remote sensor imagery and geographic information system (GIS) products using the same Remote Sensing Electron Beam Image Recorder (EBIR). It may be operated as a stand-alone system from magnetic tape; over a local area network or in real time from an aerial or satellite downlink. The Remote Sensor EBIR has software selectable resolution, size, geometry control and recording rates which make it suitable for use as a primary ground station image recorder or as a data processing center master image recorder for various Airborne, LANDSAT, SPOT, ERS, EOS and meteorological satellite requirements.

The ability to record a mix of vectors, typeset quality text and raster data on the same image provides annotated satellite and aerial imagery information which can be integrated with environmental or GIS data. The Remote Sensor EBIR can be configured for 8 1/2" x 11" imagery at 1:1,000,000 scale on 9 1/2" wide film; 4 3/4" x 6" imagery at 1:2,000,000 scale on 5" wide film or 16, 35, 105mm microfiche image formats for browse files and archival storage. The 5" and 9" color separation image products may be enlarged into color composite images 40"x48" (1:150,000 scale) and larger on photographic paper or film transparencies for back lit displays used for earth resource studies and land/water management.

Key Words: GIS/LIS, Image Processing, LANDSAT, SPOT, Space Imagery, Aerial Imagery, Recording, Remote Sensing Applications

INTRODUCTION

During the past three decades, satellite and aerial remote sensor imagery has played an increasing important role in the study of the Earth and its environment. The United States and other countries activities in earth observation from airborne and space vehicles have been growing very rapidly. Numerous satellites and aircraft with different missions and different remote sensors are providing an overwhelming amount of image and other data which needs to be processed for use with computer softcopy displays, combined with other GIS and environmental data, and/or recorded as photographic products and.

Recent advances in microcomputer workstations, image processing software and electron beam image recording offer the capability to process and record data from many of the various remote sensors presently in operation now and planned for the future.

Image Graphics Inc. has developed an Electron Beam Image Recording System configured specifically for remote sensing data processing and analysis - Electron Beam Image Processing System EBIPS-3000.

System Configuration
A block diagram of the EBIPS-3000 system is shown in Figure 1. It consists of five functional areas:

- o Input Data
- o Computer Controller
- o Raster/Vector Generator
- o Electron Beam Image Recorder
- o Image Processing Workstation

Input Data. Input data to the System may be from satellite or aerial high density digital tape (HDDT); from a direct link through a 32 bit high speed raster video port; from remote sensor data archived on optical disks or from image processing workstations over local area networks such as Ethernet. Datasets may be any size or format from Landsat TM, Landsat MSS, SPOT Panachromic, SPOT XS, AVHRR, ERS-1, SAR, and Airborne magnetics, gravity, spectral scanners.

Computer Controller. A Motorola 68030 microprocessor is used in the Electron Beam Recorder Interface Control (EBRIC) of the Raster Vector Generator (RVG 450) for controlling all data input to the EBIR either from a direct link, off line, or over Ethernet; and all raster, vector or text image recording operations of the Raster/Vector Generator (RVG 450) as shown in Figure 2.

The Motorola 68030 microprocessor controller of EBRIC is assembled on a Heurikon (HK68G/V30XE-4MB-82F5 with 32D2) CPU Board with a SCSI interface, two RS232 serial ports, 4MBytes Memory (expandable to 16MBytes) and the Ethernet interface. The CPU has a UNIX System V5.3 with TCIP and NFS support. It has a 300 MByte SCSI Hard Drive, a 3.5" High Density Floppy Drive and 150 MByte 1/4" SCSI Magnetic Tape Drive for backup.

Raster Vector Generator. The Raster Vector Generator (RVG 450) contains the data translator circuits of the EBIR which convert raster, vector, text, halftone digital data and image correctiions from its EBRIC microprocessor controller into analog signals to drive the Electron Beam Image Recorder (EBIR).

The RVG 450 raster generator, vector generator, graphic arts character generator, halftone generator, image correction processor, and I/O control are assembled on six VME printed circuit boards in a VME chasis. Table 1 lists some of the functional features of the RVG 450.

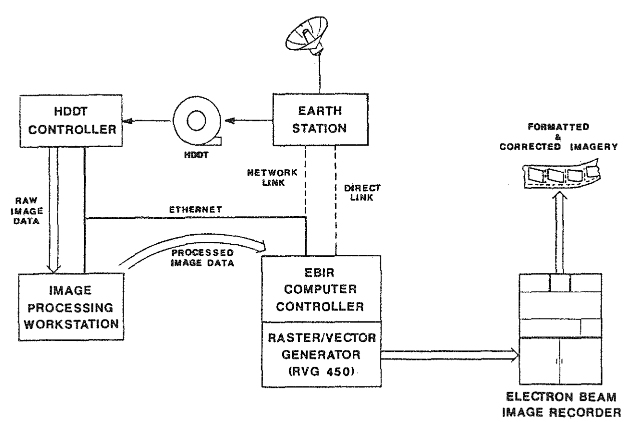

Figure 1 EBIPS-3000 System Configuration

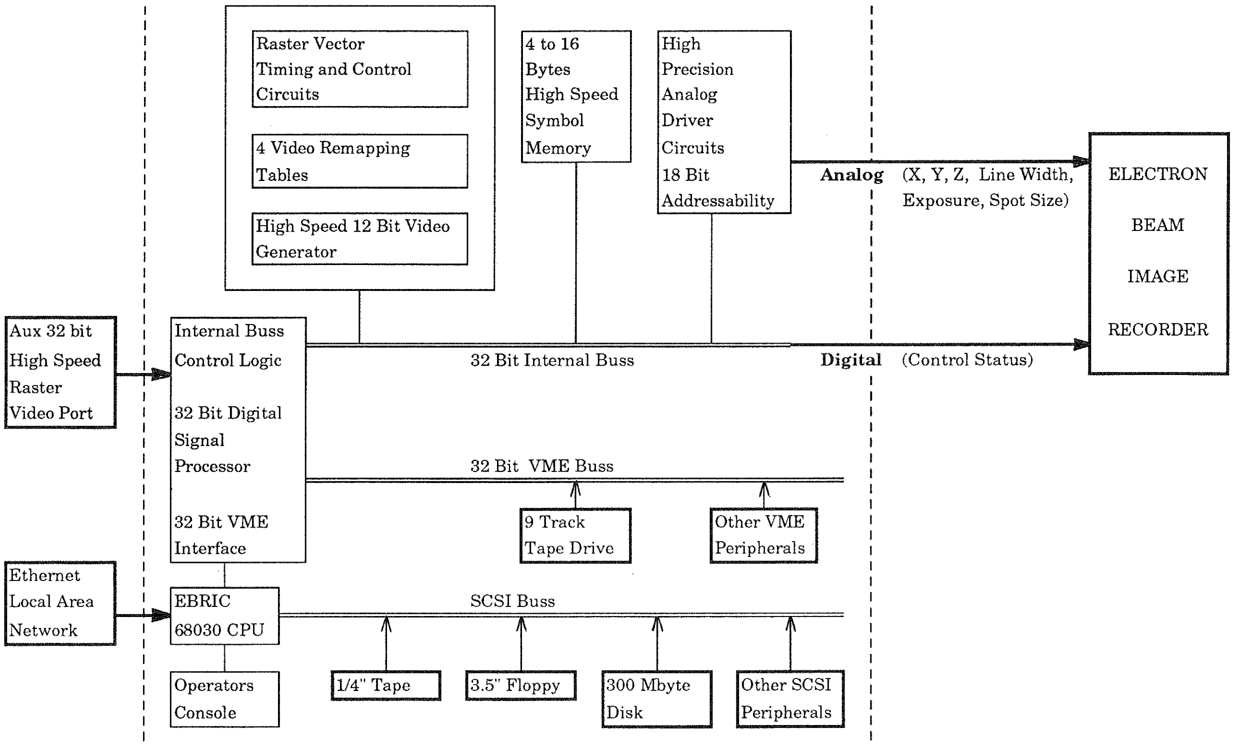

Figure 2 Block Diagram of RVG 450

Table 1 Functional Features of the RVG 450

RASTER DATA	
Addressability	X, Y, up to 18 bit (262,144)
Resolution	16 bit
Max Video Rate	Up to 50,000,000 Pixels per second
Video Gray Levels	8 to 12 Bit selectable Dmax
Aspect Ratios	Variable (independent scan & step control)
Digital Remapping	Four tables in hardware Unlimited number of disk based tables
Command Set	Binary Gray Binary B & W CCITT Group 3 B & W TIFF Custom Variable Origin Image Rotation, Mirror Image Image Scaling, Each Axis
VECTOR DATA	
Addressability	Up to 18 bit (262,144)
Resolution	16 bit
Line Widths	128 in 1.25 um steps
Vectors	50 to 500,000 per second
GRAPHIC ARTS CHARACTERS	
Fonts	Bitstream, PostScript Type I
Sizes	25um to 775um in 1 μm steps
Rotation	360^0 in 1^0 increments
Rates	Up to 5,000 per second
HALFTONES	
Dots	Round, Square, Elliptical
Line Screens (lpi)	65, 85, 100, 120, 33, 150, 175
Screen Angles	0, 15, 45, 75 degrees
Output Rate	16 MPixels/sec.
Enlargement Factors	15 to 600%
IMAGE CORRECTION PROCESSOR	
Exposure	+/- 10%
Video Transfer	Linear or Gamma Corrected
Geometry	Horizontal and Vertical Offsets

When the EBIR is used as a high production output device or for generating high resolution raster images with vector overlays, the RVG 450 utilizes Raster Vector Plotting (RVP) software which accepts EBIR formatted data files and controls the output plotting of the entire image file or selected images in the file. RVP may be used with Sun SPARCstation, Intergraph Interpro or MicroVAX workstations.

Electron Beam Image Recorder. The output film recorder for the EBIPS-3000 System is an IGI Remote Sensing Electron Beam Image Recorder (EBIR). Two Remote Sensing EBIR models are availabel: Model 5241 to record 8 1/2"x11" imagery on 9 1/2" wide film (1:1,000,000 scale) and Model 3127 to record 4 3/4"x6" imagery on 5" wide film (1:2,000,000 scale) and microformats on 16, 35mm, 105mm microfiche for reference and browse files and 35mm for color movies. The EBIR may be configured for full frame recording with intermittent film movement, with color registration punches, or with continuous motion film transports for strip recording.

The EBIR converts electrical signals received from the RVG-450 into latent images on silver halide film or blue visible images on PERM* film. The signals are representative of continuous tone remote sensor spectral bands, annotation, reference data and geographical positions in either raster, vector or text formats or all of the above formats. The silver halide film, which may be handled in bright yellow lights is chemically processed into black and white film transparencies of the various remote sensor spectral bands and/or merged GIS/LIS overlay data. The PERM is a processless electron beam recording media which produces a blue film transparency of the data instantaneously upon electron exposure. PERM is particularly useful for obtaining immediate imagery and for proofing processed imagery.

The performance characteristics and features of the 5" and 9 1/2" EBIRs are given in Table 2.

The model 3127 EBIR can also be used to record on microimage film sizes using interchangeable film transport mechanisms i.e. 105mm, 35mm and 16mm.

Table 2 Performance Characteristics and Features of the EBIR

INPUT DATA
Raster - MSS, TM, LTWG, FAST, TIFF, SPOT
Vector - Linear x-y plot, selectable line widths
Text - ASCII, EBCDIC, Type 1 Fonts and Bar Codes
RECORDING RATES
Raster - up to 50 Million Pixels/sec.
Vector - up to 250 Thousand Vectors/sec.
Text - up to 50 Thousand Stroke Characters/sec.
RECORDING FLEXIBILTY
Variable Spot Sizes and Line to Line Spacings (over 10:1 range)
Any Origin and Scan Direction
Selectable Digital Gamma
RESOLUTION
Model 3127 - 4 microns (0.00016")
Model 5241 - 8 microns (0.00032")
OUTPUT FORMATS
Model 3127 - 4 3/4" x 6" on 5" film 30,000 pixels x 38,000 lines
Microformats - 16, 35 and 105mm fiche
Model 5241 - 8 1/2" x 11" on 9 1/2" film 27,000 pixels x 34,000 lines
Strip Images from Continuous Motion Transports 4 3/4" and 8 1/2" wide

Since the Model 3125 recording spot is 4 microns diameter which equates to about 6350 pixels per inch, most of the currrent aerial and satellite remote sensor imagery can be recorded at full resolution on the 35mm microformat. This results in excellent quality imagery for microfilm browse files, for microfilm archiving and for recording 35mm color separations of the spectral bands for producing color movies of scenes from orbiting or airborne remote sensors.

Image Processing Workstation ER Mapper* 3.0 from Earth Resource Mapping Corporation, Perth Australia, is the primary image processing software package utilized in the EBIPS-3000 System. ER MAPPER is an advanced image processing software product which runs on a Sun SPARCstation 2 under UNIX X Windows (X11). It enables the integration of remote sensor raster images with vector GIS/LIS data. It links directly and interactively with GIS Data Base Management Systems (DBMS), and custom systems such as ARC/INFO*, Genamap* or Oracle*. ER Mapper can be used on a single workstation or over a multiuser network. It provides automatic strip printing to insure that the hardcopy is generated at the correct scale regardless of the input data or output device size or format.

The image processing workstation interfaced to the EBIPS-3000 over Ethernet through the EBRIC controller of the RVG 450 consists of a SPARCstation 2 (4/75FGX-32-P43) with:

- SPARCprocessor (25.0 SPECmarks/28.5 MIPS/4.2Mflops)
- 32 Mb Main Memory (Expandable to 128 Mbytes)
- Internal 424 Mbyte and External 1.3-Gbyte (X571W) SCSI Disks (total of 1.7-Gbyte)
- 1/4" Sun Front Loading 150 Mbyte Cartridge Tape Drive (X660W)
- SCSI Peripheral Interface
- 2 x Serial RS-423 ports
- GX Graphics Accelerator
- 16-inch Color Monitor (1152x900x8 resolution)
- 19" Color Monitor with RasterOps (Rasterops TC1) Frame Buffer (1152x900x24 resolution)
- Optical 3 Button Mouse & Keyboard
- Ethernet Interface
- Thin Ethernet Transceiver

ER Mapper was designed specifically for earth sciences datasets and it includes a map projection data base. Table 3 demonstrates the versatility of ER Mapper. ER Mapper can combine, process and display numerous GIS/LIS and remote sensor datasets including LandsatTM, LandsatMSS, SPOT Panchromatic, SPOT XS Multispectral, NOAA Advanced Very High Resolution Radiometer (AVHRR), Synthetic Aperture Radar (SAR), and Airborne sensors datasets for Magnetics, Radiometrics, Multispectral studies.

Table 3 ER MAPPER Features

RASTER DATASET FORMATS	
Data types	
Unsigned 8 bit, 16 bit, 32 bit	
Signed 8 bit, 16 bit, 32 bit	
Floating point, 64 bit	
Spectral Bands	No limits
Cell max X&Y	No limits
Header file	ASCII human/machine readable
Data file	BIL Binary with any byte order
VECTOR DATASET FORMATS	
No limit in number of files displayed as layers.	
Automatically scaled to fit Raster imagery	
REGISTRATION	
Automatic co-registration of datasets, regardless oftype (Vector or Raster), cell dimensions or data format	
DISPLAY OUTPUT	
Number of windows	No limit
Number of displays	No limit
Types of display	
X-window 1 bit monochrome	
X-window 8 bit 256 color	
X-window 24 bit 16 million color	
X-window 32 bit 16 million color and 256 overlay	

The software allows warping, rectification and rotation of the different datasets including raster, vector, dynamic links to GIS datasets, or a combination of all of these, so that they exactly coregister for further processing.

In addition to 250 standard algorithms, ER Mapper provides a Graphical Interface (Menu) which allows the user to create a variety of custom algorithms to generate the final image to be displayed or outputted to film. Once an algorithm has been created it can be stored and called up by name at any future date.

The algorithms contain the complete description of the processing to be carried out on the remote sensor dataset including:

- o Which input raster datasets to use and what order are they to be mosaiced and merged, if they overlap.
- o What processing is needed for individual spectral bands of the input datasets, such as transforms, filters and convolutions.
- o The formula needed to combine input spectral bands
- o How to combine input datasets
- o Dynamic links to external GIS systems
- o Classifications to be carried out on the satellite dataset
- o What filters, kernels and transformations are to be carried out
- o What statistics are to be used from which regions
- o How the classified data is to be shown
- o The input vector datasets to use and how they are to be displayed
- o How to display automatically generated vectors such as grid overlays
- o The format of output data and how it is to be displayed and where: to display, to hardcopy or to another dataset

ER Mapper may be used for mosaicing images from adjacent orbits or scenes and fusion of different sensor datasets. It will automatically merge, clip, subsample, rescale and mosaic multiple datasets. An example is combining different types of satellite remote sensor data such as LandsatTM over SPOT panchromatic data as shown in Figure 3.

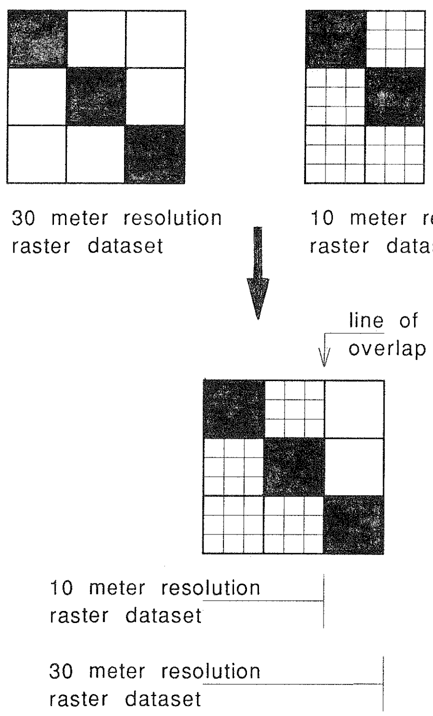

Figure 3 Mosaicing with Different Cell Sizes (Data Fusion)

In addition to its versatile computer display output, ER Mapper has the ability to generate hardcopy output in raster, vector or a combination of raster and vector formats such as:

- o Full rasterization of the remote sensor datasets and the dynamic link GIS vector overlays
- o ASCII controlled GIS and other vector files for editing and vector overlay of raster datasets
- o Full 24 bit RGB color imagery with vector overlays rasterized into the image
- o PostScript output from an internal Software Raster Image Process (RIP)

The ER Mapper processed imagery may be transmitted directly to a quick look low volume output device or to the EBIR for high volume production or raster/vector overlays.

EBIR REMOTE SENSOR PRODUCTS

The high resolution, high geometric accuracy, and the exact registration of the various remote sensor spectral bands by the EBIR enables enlargement of the EBIR original films to produce remote sensor products at a variety of scale factors as shown in Table 4.

Table 4 EBIR Product Scale Factors

1:2,000,000
1:1,000,000
1:500,000
1:250,000
1:150,000
1:100,000

The following are representative samples of the types of remote sensor imagery that can be produced by the EBIPS-3000 System. Figure 4 is an example EBIR recording from the Landsat Multispectral Scanner Remote Sensor. The scene is of Rio de Janeiro, Brazil.

Figure 5 is an example of an EBIR recording from Landsat 5 Thematic Mapper of Porto Alegre, Brazil. The spectral bands were annotated and recorded with the EBIR Model 3127 at 1:2,000,000 scale.These color separations may be enlarged into a false color composite at a scale of 1:150,000 (40"x48") and larger.

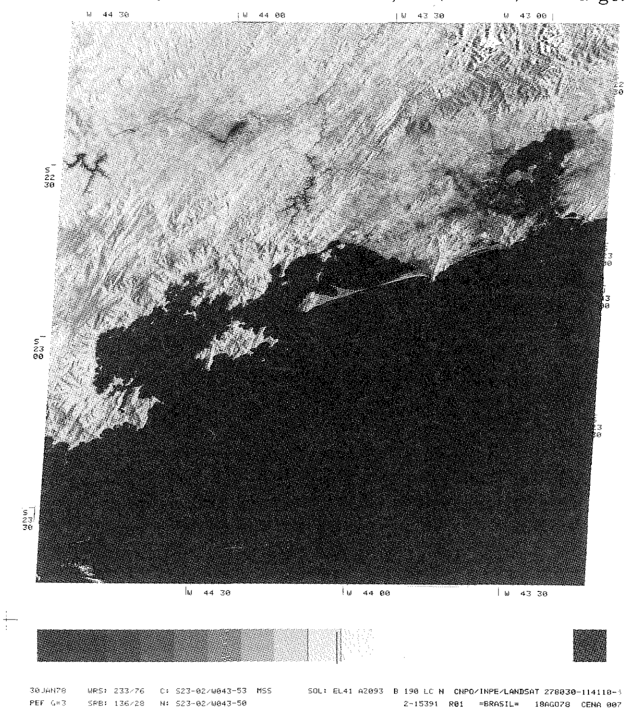

Figure 4 Landsat Multispectral Scanner Rio de Janerio, Brazil

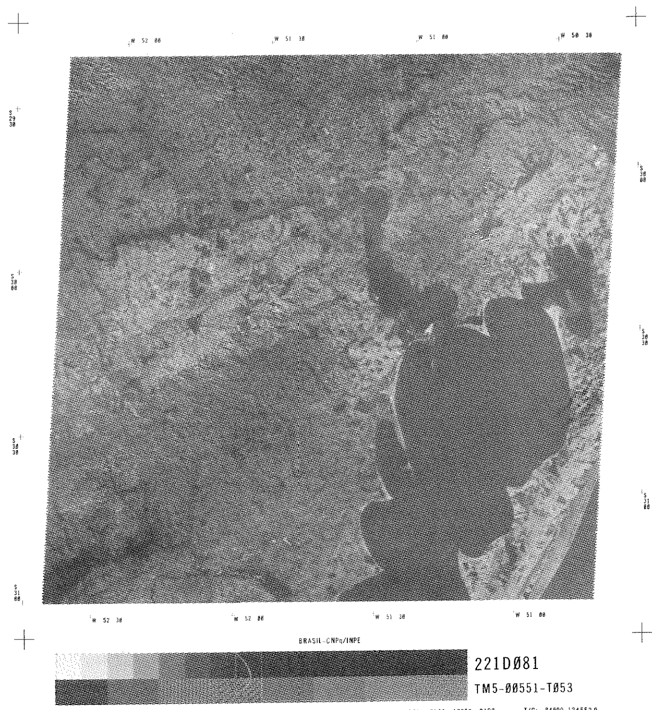

Figure 5 Landsat Thematic Mapper Porto Alegre, Brazil

All of the bulk geometric and radiometric corrections, geographical position marks, annotation, and reference data around the scenes in Figures 4 & 5 were introduced during the recording process. The correction coefficients were calculated prior to recording.

Figures 6 is an example of an aerial remote sensor image recorded on 5" film and enhanced using the gamma corrector of the EBIR. The image was enlarged in the EBIR from 1" X 1" to 4" X 4" by using pixel and line replication. The scene is of Dayton, Ohio.

Figure 7 is a photograph of a scene from the SPOT HRV2 Remote Sensor of the area around the Ji Parana' ou Machado River in Rondonia, Brazil. It was recorded at 1:2,000,000 scale with the EBIR on 5" film as individual spectral bands 1, 2 and 3 and enlarged to produce a color composite image 16" X 16".

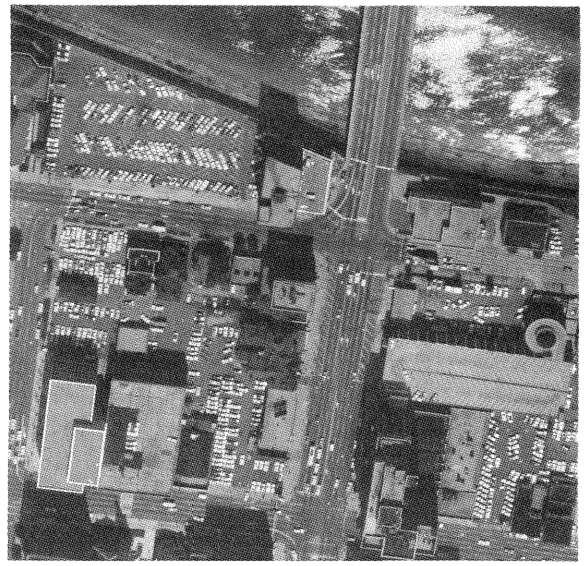

Figure 6 Example of an Aerial Remote Sensor Image Enhanced and Enlarged With the EBIR

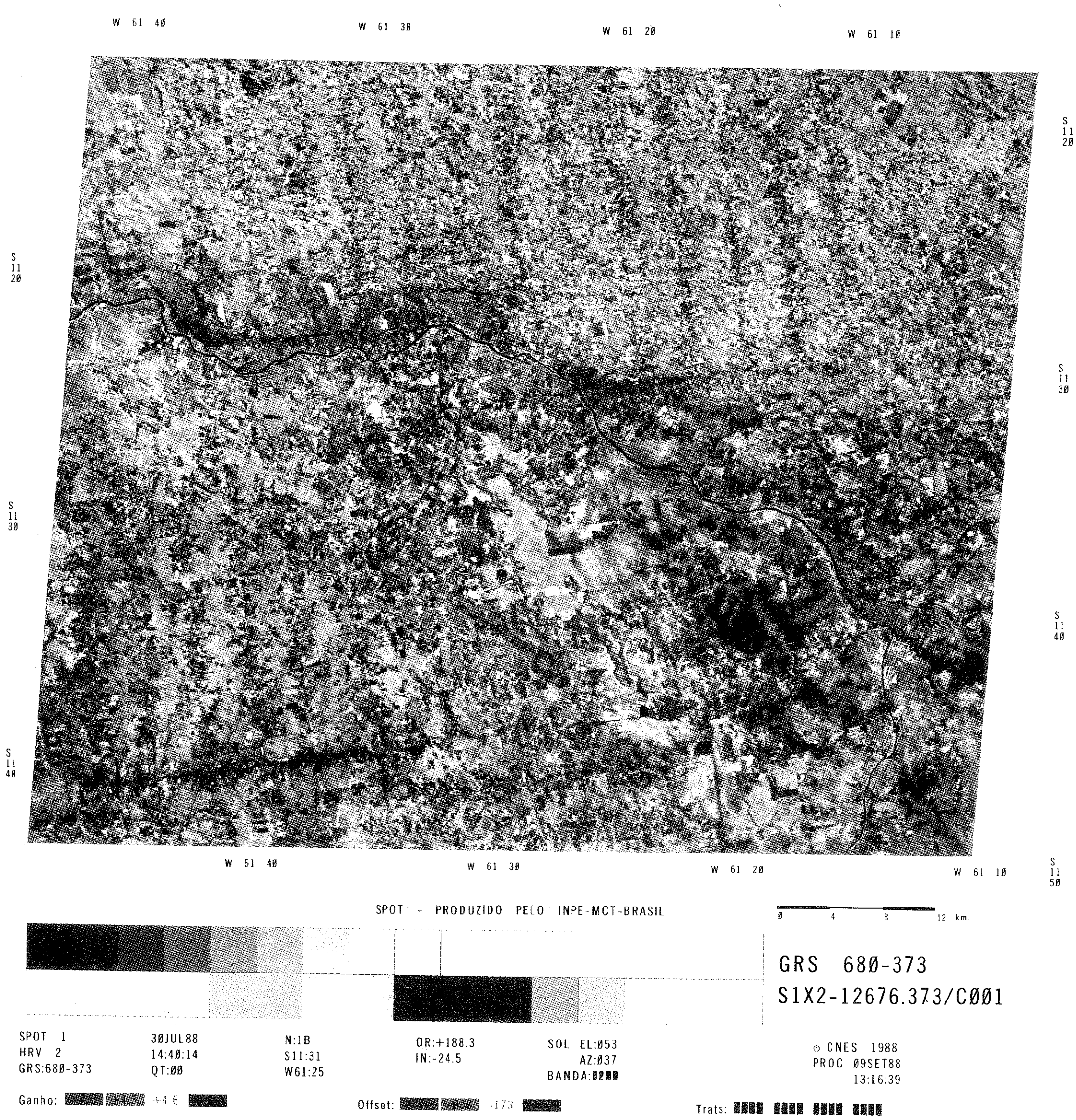

Figure 7 SPOT HRV2 Remote Sensor Rondonia, Brazil

Figure 8 is of image taken by a Meteorological Satellite remote sensor which was recorded with the 9 1/2" EBIR Model 5241. The larger image is an example of a remote sensor image that has been enlarged 600% and halftoned in the EBIR for lithographic printing.The smaller image is the original continuous tone image of the infrared band.

The Model 5241 EBIR recorded both images -continuous tone (1 1/2" X 1 1/2"), the halftone enlargement (8" X 8") - and the annotation on the same frame of 9 1/2" film intermixing raster, vector, and halftone data on the same image.

The digital data was supplied by the United States Defense Meteorlogical Satellite Program Office from the Defense Meteorlogical Satellite Operational Line Scan System (OLS) sensor in visible and infrared spectral bands. (Visible 0.9-1.1μm, Infrared 10-12 μm).

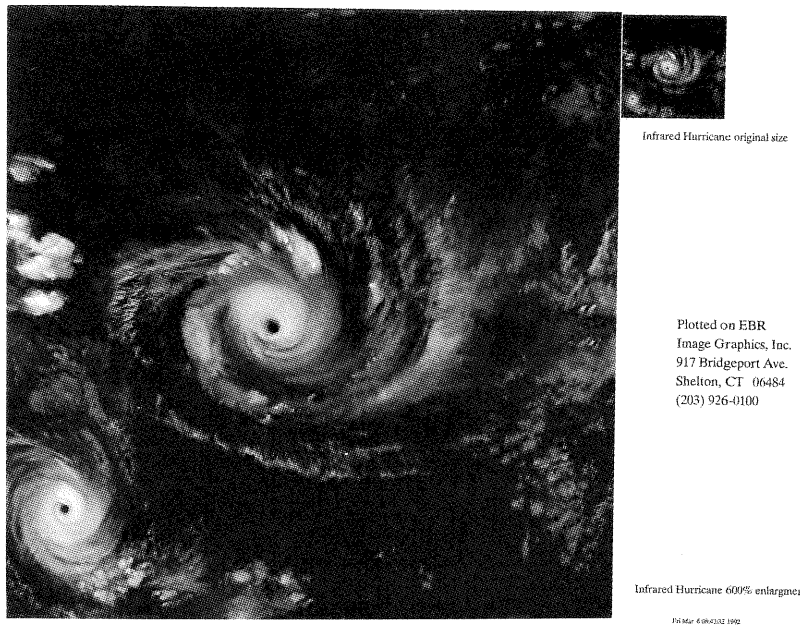

Figure 8 Example of Meteorlogical Satellite Sensor Data

Figures 9 a, b, & c illustrate remote sensor data, with annotation and vector overlays which were processed with ER Mapper software. Raster and vector data are maintained as separate datasets and can be merged during the recording process by the EBIR or premerged into raster with the ER Mapper Software prior to recording.

Figure 9a is a vector classification representing land ownership, soil types, and waterways of Loxton, Australia extracted from Landsat Thematic Mapper data.

Figure 9 b is from SPOT HRV sensor data of Perth, Australia with an area of interest identified.

Figure 9 c is an enlargement of the area of interest in 9 b which was enlarged and annotated prior to recording using the image processing workstation.

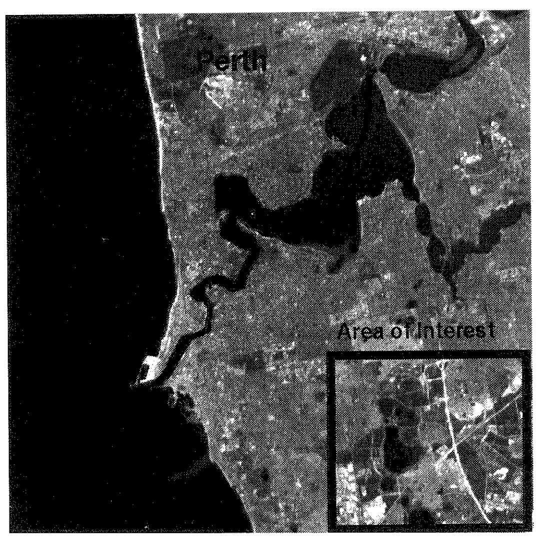

Figure 9 b SPOT HRV Sensor data -Perth, Australia

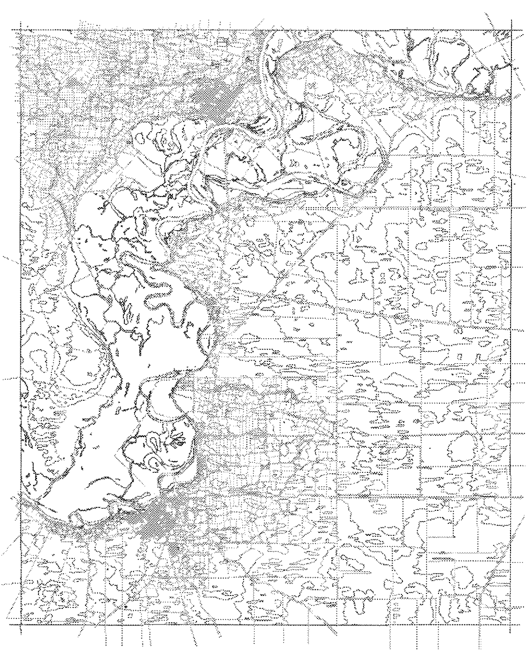

Figure 9 a Landsat Thematic Mapper- Vector Classification- Loxton, Australia

Figure 9 c Section of Perth Enlarged and Annotated

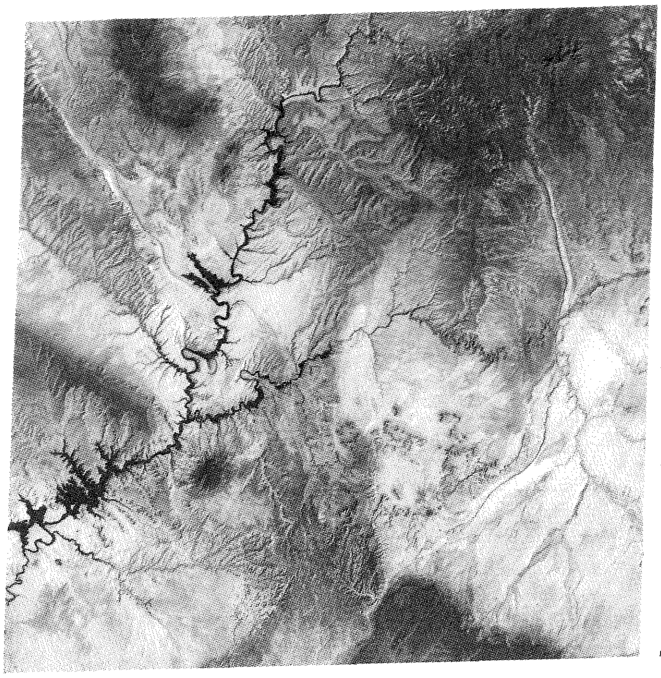

Figure 10 Landsat MSS 1:2,000,000 scale on 5" film

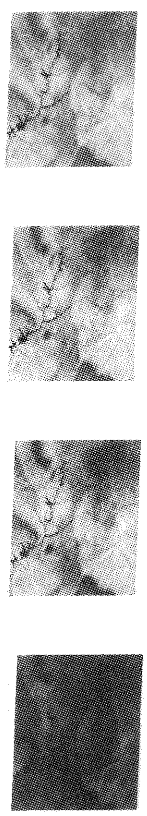

Figure 11 Example of Landsat Microimages on 35mm Film- Southeastern Utah

Figure 10 is a Landsat Multispectral Scanner view of Southeastern Utah recorded at 1:2,000,000 scale with EBIR. Individual spectral bands were enlarged to a 40" X 40" color film transparency.

Figure 11 is a sample of satellite imagery recorded on the 35mm microformat. Four Landsat spectral bands of Southeastern Utah are shown recorded at full resolution of the Landsat Multispectral Scanner. The same scene was recorded at 1:2,000,000 scale at full resolution in Figure 10..

Conclusions

The IGI Electron Beam Image Processing System 3000 provides the capability of recording all present and future airborne and satellite sensor imagery for earth science and geographic information system (GIS) applications. The EBIR is suitable for use as a primary ground station image recorder or for a remote sensor image processing service center. The software selectable variable resolution and format control flexibility with the high recording rate of electron beam exposure makes the EBIR the highest performance film recording system for Landsat,SPOT ERS, EOS and meteorological satellite and aerial sensor requirements.

The open systems architecture and the software selectable image size scaling capability, the digital gamma look up tables, and the full frame format control enable all present and future image recordings of remote sensing data for workstations and ground receiving sites. Halftone capability, higher recording rates and higher recording resolution, are also available for future requirements.

The ability to overlay a mix of vector, typeset quality test, and raster data on the same image provides the user with annotated image exploitation information for earth science or GIS usage. The recording format is software selectable on a frame by frame basis for recording all remote sensors.

The ER Mapper image processing software is a complete image processing system that can be used for remote sensor data fusion and integration from a variety of satellite and GIS data. It can also fuse, integrate and mosaic datasets of different cell size such as Landsat and Spot satellite data without regridding. ER Mapper may be used for a variety of applications such as agriculture, forestry, oil, gas, and mineral exploration, environmental studies, water and land use management, urban planning, etc.

References

1. J.P. Whitley, P.G. Grosso, V.P. Morgan, Image Graphics Inc., "Film Recorders for the Receipt, Processing and Archiving Remote Sensor Data", ISPRS, Washington, D.C. August 1992

2. P.F. Grosso et al, Image Graphics Inc., "Electron Beam Recording of Remote Sensor Data in Brazil", ISPRS, Washington, D.C. August 1992

3. Earth Resource Mapping, "ER Mapper Users Manual", Subiaco, Perth, Western Australia, 1991