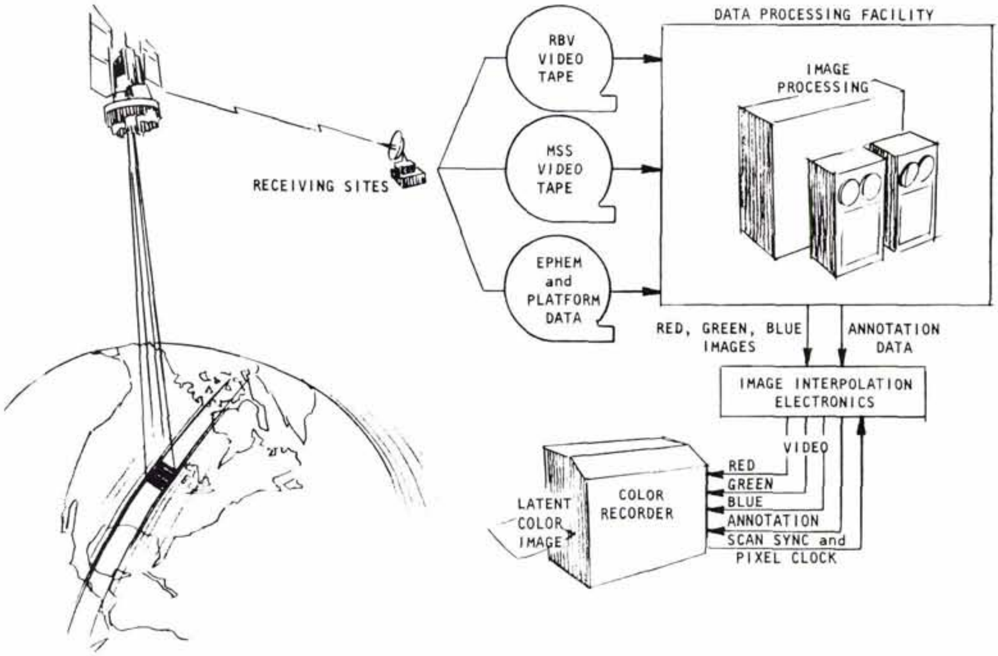

FIG. 1. A color-image recorder for Earth Resources Program.

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Video-to-Film Color-Image Recorder

Designed so that registration and linearity errors over the image format area do not exceed 0.0002 inch.

(*Abstract on nex page*)

INTRODUCTION

AN EXPERIMENTAL film recorder is being developed for use in recording color imagery (both real and false) or black-and-white imagery produced under the Earth Resources Satellite Program. The recorder is being developed by Image Information Inc. for NASA, Goddard Space Flight Center, and is currently in the final stages of integration and testing. The cognizant technical officer for NASA is Mr. James Billingsley.

As the name implies, the Video-to-Film Color Image Recorder converts three input video signals into a full-color image on photographic film. The recorder combines three chromatically separated light beams, one each for red, green and blue information, into a single, full-color beam which exposes respective spectrally sensitized layers of the color film in proportion to the primary color mixture values specified for each picture element (*pixel*). The three input video signals can be derived from any source of spectrally separated video images such as, for example, the multispectral outputs of both of the sensor subsystems scheduled for the ERTS A and B satellites (i.e., the Return

ABSTRACT: *A precision video-to-film recorder for use in image data processing systems, being developed for the National Aeronautics and Space Administration (Goddard Space Flight Center, Contract NAS5-11323), will convert three video input signals (red, blue, green) into a single full-color light beam for image recording on color film. Argon Ion and Krypton lasers are used to produce three spectral lines which are independently modulated by the appropriate video signals, combined into a single full-color light beam, and swept over the recording film in a raster format for image recording. A rotating multi-faceted spinner mounted on a translating carriage generates the raster, and an annotation head is used to record up to 512 alphanumeric characters in a designated area outside the image area.*

Beam Vidicon Camera Subsystem and the Multispectral Scanner Subsystem)*. In Figure 1 the ERTS sensors are used as examples to illustrate what the flow of image information between the satellite borne sensors and the Color Image Recorder might typically be for select, registered imagery.

The Video-to-Film Color Image Recorder described in the remainder of this paper is not the down-link recorder. Instead, it is an experimental device that receives input signals from a data-processing facility that pre-processes the multi-spectral image data in accordance with specific output requirements. In the ERTS application, the Data Processing facility will receive video data on magnetic tapes from the Tracking and Receiving Stations and perform the video-to-film conversion. Some of these images will then be selected for reproduction in color on the Video-to-Film Color Image Recorder.

Images selected for production on the Color Recorder will undergo special digital processing at the Data Processing facility in order to register the three primary color images on a pixel-by-pixel basis, correct for known sensor geometric and photometric distortions, and manipulate or enhance data to emphasize selected earth surface features. The output of these special processing functions will be a serial-bit stream containing red, green, and blue image information. A secondary output, also shown in the diagram, is the annotation data derived from the ephemeris and platform data. It is also to be recorded on the film and can be merged into the image format and/or entered into a specific area outside the precision image format, as will be discussed later.

The Image Interpolation Electronics shown in the diagram serve as the interface between the general-purpose computer and the Color Recorder. This unit, which is also under development, has several functions to perform including:

- Separation of the serial bit stream, by color, into three parallel streams.
- Interpolation between pixels to derive exposure values for additional points needed to fill the resolution capability of the Color Recorder.†
- Conversion from digital to analog video form.
- Character generation for the annotation which is to be merged into the precision image format.
- Tic-mark generation.
- Video mixing (image, character and tic mark).
- Interface control, including the transfer of data between the computer and the recorder.

In concluding the introductory remarks the reader is again referred to Figure 1 where the input to the Video-to-Film Color Recorder is shown to be three video signals and, if auxiliary data is to be included in an annotation area outside the precision image format, a digital bit stream. The remainder of this paper will be concerned with the design features of the Recorder itself.

RECORDING CONCEPT

The Video-to-Film Color Image Recorder is a recording system which permits precise

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* The Return Beam Vidicon (RBV) Camera Subsystem is comprised of three RBV cameras which image a common 100 × 100-mile ground area in different spectral bands (475–575, 580–680, 690–830 nanometers [nm]) and generate three spectrally separated video signals. The Multispectral Scanner Subsystem is a cross-track line scanner which provides four or five spectrally separated channels simultaneously.

† The Color Recorder is capable of recording a 9500 × 9000 matrix of picture elements, whereas the maximum resolution of the RBV Camera Subsystem, for example, is approximately 4,500 TV lines.

chromatic control of the recording spot at addressable raster points and, thus, the recording of specified color values at high speed under computer control. The recording concept utilized is depicted in Figure 2. Two lasers, an Argon Ion and a Krypton Laser, are used to produce three spectral lines (457.9 nm, 520.8 mn, and 647.1 nm). The beam from the Krypton laser that provides two of the lines, is split into its red and green components by a dichronic beam splitter before being directed into the modulators, whereas the blue beam from the Argon laser is folded directly into its modulator. Each light beam is independently modulated by the appropriate video signal and then the three are combined into a single full-color light beam and swept over the recording film in a raster format for image recording.

A rotating, multi-faceted spinner mounted on a translating carriage is utilized to generate the precision raster. After the three modulated beams have been conbined, the composite beam is expanded and focused by a catadioptric lens system (shown in Figure 3) such that it fills two facets of the spinner that folds the converging bundle and scans it across the recording format.

In addition to the pictorial information contained in the video signals, the Recorder also has facilities to record an alphanumeric data field of 512 characters (8 rows of 64 characters) composed of any of 42 characters selected by the data processing system.

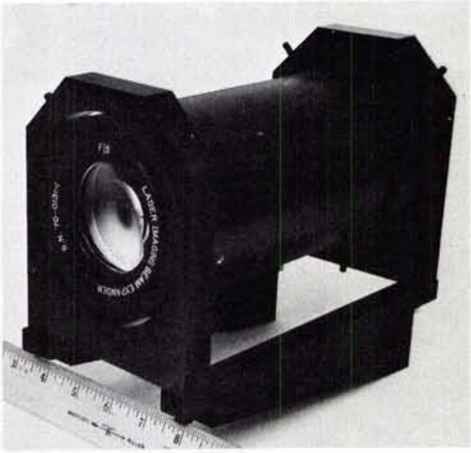

FIG. 3. Catadioptric lens system.

The recording format is comprised of three fields as shown in Figure 4. The 7.5-inch square Picture Format depicted allows the RBV images, to be presented at approximately a 1:1,000,000 scale. The Secondary Annotation Field is reserved in this particular application for color calibration charts. This format area, however, is also within the boundaries of the precision scanning system and therefore can be used for

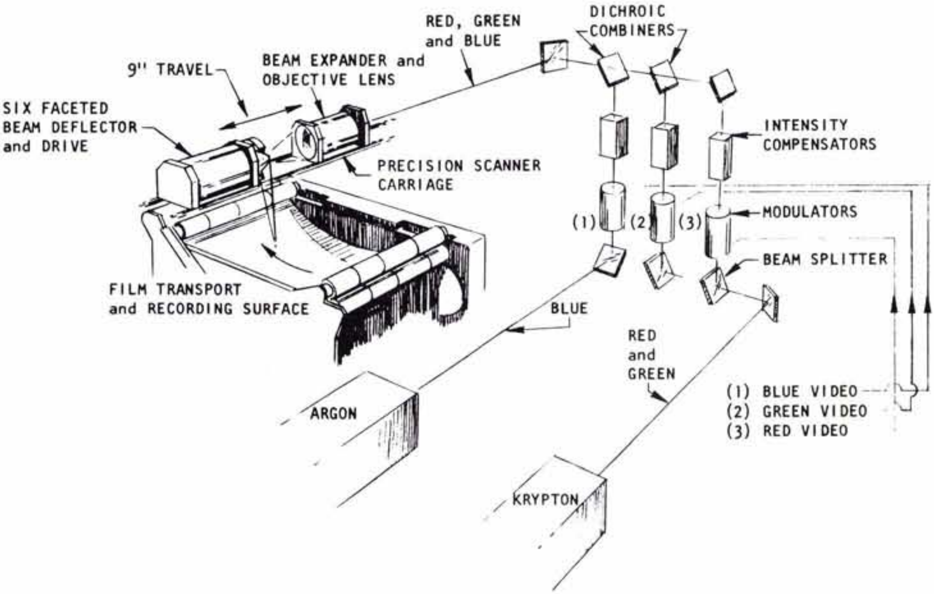

FIG. 2. Recording concept.

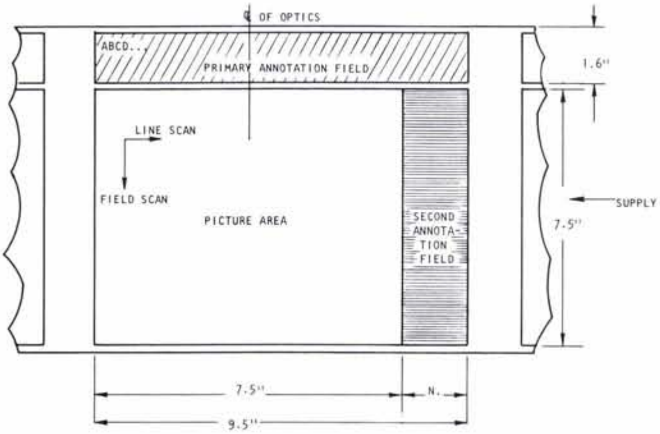

FIG. 4. Recording format.

additional imagery or any other information that can be inserted into the video signal. The equivalent of 2,000 additional picture elements per scan line are available in this area. Data, such as sensor, time of exposure, orbit number, subsatellite point, picture center location, sun azimuth and elevation angles, spacecraft heading and attitude, and ground receiving site identification will be recorded in the Primary Annotation Field by an annotation device. It should be noted, however, that the precision scanner is also capable of extending the picture area 1,500 scan lines into the Primary Annotation Field, if so desired.

The annotation head is carried on the same carriage that transports the spinner and lens assemblies. However, the annotation is recorded while the carriage is returning to the starting position, after the image has been recorded. Up to 512, 6-bit binary-coded characters can be stored within an integral buffer before or during an image recording cycle. The appropriate alphanumerics are then strobed onto the film, with positioning within the field accomplished through the coordinated action of the carriage transport and a deflection mirror.

DESIGN FEATURES

The Color Recorder features modularized construction in a rigid frame. The console enclosure is shown in Figure 5. Access panels are provided for loading and unloading the film magazines and to facilitate service and maintenance procedures.

FILM HANDLING

Film supply and take-up spools are contained in detachable canisters to enable rapid recorder loading and unloading in ambient light. Both the take-up and supply magazines can accommodate 500 feet of 9.5 inch film. They are interchangeable and can be adapted for 5-inch and 70-mm wide films with a modification kit.

The film transport shown in Figure 6 accepts 9.5-inch, 5-inch and 70-mm wide photographic films on a nominal 4- to 5-mil base. Film advancement after each exposure is automatic, but a manual override switch is provided to allow the operator to cycle as many frames as desirable. Film is transported into and out of the recording area by driven rollers. It is pulled into the take-up cassette by a DC torquer that interlocks with the cassette when attached to the recorder. A counter and associated electronics control the length of the film advanced. A complete frame is advanced and a vacuum drawn to hold the film for the next exposure in less than 10 seconds.

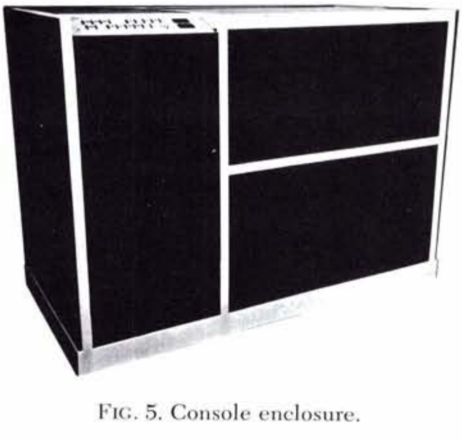

FIG. 5. Console enclosure.

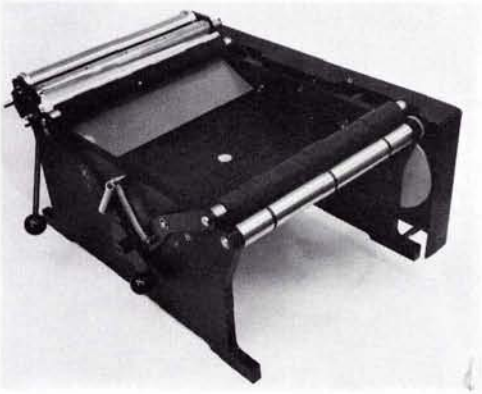

FIG. 6. Film-transport and recording platen.

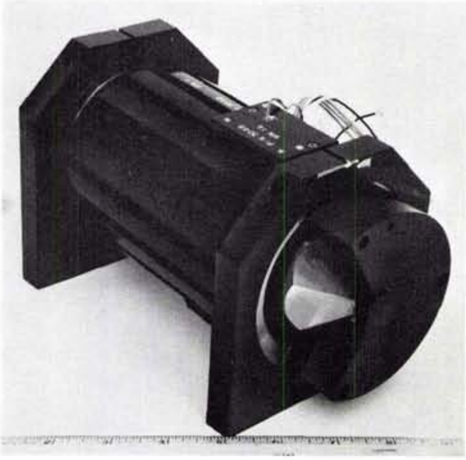

FIG. 7. Scanner subassembly.

A manual film cutter is also provided on the take-up side of the transport.

THE SCANNER SUB-ASSEMBLY

The scanner mechanism shown in Figure 7 consists of a precision optical head with six integral mirrors or facets, a direct-drive hysteresis synchronous motor, a magnetic tachometer and precision rolling element bearings. The F/8 effective aperture of the spinner facets, in conjunction with Kodak SO-360 Ektachrome Aerographic Duplicating Film results in a system transfer response of 70 percent at 20 cycles per millimeter.

The magnetic tachometer mounted on the spinner shaft generates start-of-line synchronization and individual pixel counts which are utilized to control spinner speed and the video transfer from the data-processing system.

A continuously variable speed drive allows scan rates between 135 and 1,350 lines per second to be utilized.

THE TRANSLATING CARRIAGE ASSEMBLY

The translating carriage assembly shown in Figure 8 carries the spinner, beam-expanding optics, and an annotation device on two precision ways. It is driven by a DC Torquer and controlled through a closed-loop servo and linear encoder. Linear trans-

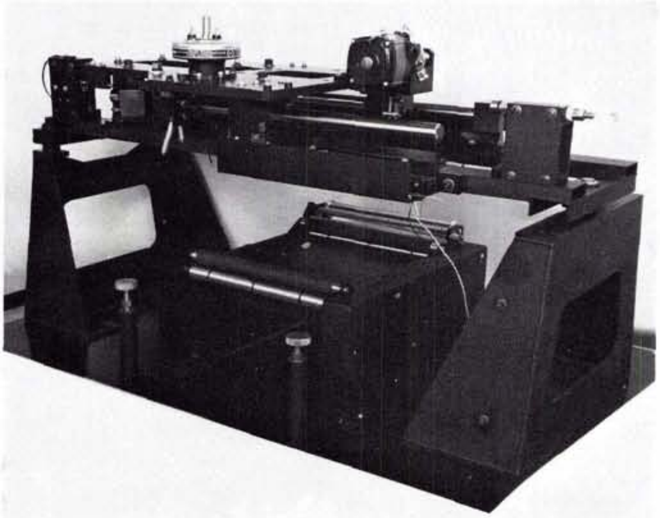

FIG. 8. Translating carriage assembly.

mission is developed through a precision puck drive which provides a range of continuously variable carriage velocities, between 0.1215 and 1.215 inches per second to coincide with the variable line scan rate of the scanner.

PRECISION AND LINEARITY

The Color Recorder was designed to be a precision instrument, both from the electronic and mechanical aspects of the design, because it is important in color-image recording that the computer-specified color values be accurately positioned throughout the format. As there are several potential contributing sources to the recording spot position errors such as geometric manufacturing tolerances in the scanner optical head, the scanner bearings, the translating carriage ways and the carriage drive, they had to be carefully accounted for in the design. The Color Recorder has been designed such that beam placement repeatability and linearity errors over the image format area do not exceed 20 percent of a resolution element, or 0.0002 inch.

SUMMARY

The major characteristics of the Video-to-Film Color Image Recorder are summarized in Table 1.

TABLE 1. RECORDER CHARACTERISTICS

Film Size	9.5 inch roll
Film Type	Kodak Ektachrome Aerographic Duplicating, Type SO-360
Scan Area	9.5 × 9 inches
System MFT (with SO-360 Film)	70% response @ 20 cy/mm
Repeatability	0.0002 inch over Format
Scan Rate	135 to 1,350 lines/second
Pixel Rate	1 M to 10 M bytes/sec.
Bandwidth	DC to 35 MHz
Annotation	8 rows of 64 alphanumeric characters

In closing, it should be noted that one of the major advantages inherent in the recording concept used in this device, as opposed to the more conventional method of sequentially exposing three monochrome images through appropriate filters, relates to the long-standing problem of registration during the color compositing step. In this recorder, the three color beams are registered to each other within 10 percent of a resolution element over the entire format, and are deflected simultaneously, as a single bundle, to expose the film.

Meetings Schedule

ANNUAL CONVENTIONS

March 1974,* Chase-Park Plaza, St. Louis, Mo.

March 7–12, 1975,* Washington Hilton, Washington, D. C.

FALL TECHNICAL MEETINGS

Oct. 2–5, 1973,* Disneyworld, Orlando, Florida; Jon S. Beazley, Florida Dept. of Transportation, H. Burns Bldg., Tallahassee, Florida 32304.

Sept. 8–13, 1974,† Washington Hilton, Washington, D. C.

1975,* (open), Phoenix, Arizona.

Sept. 28–Oct. 1, 1976,* Olympic Hotel, Seattle, Wash.: C. E. Buckner, 803 Seattle Municipal Bldg., Seattle, Wash. 98104.

Oct. 18–21, 1977, Little Rock, Arkansas.

SEMINARS AND SYMPOSIUMS

July 1973, Univ. of Maine, Orono, Maine. Fourth Biennial Workshop–Color Aerial Photography in the Plant Sciences.

October 1973, Sioux Falls, S. Dak. Management & Utilization of Remote Sensing Data. Convention Center and USGS EROS Data Center. Cosponsored by AIAA, IEEE and AGI. Dr. Marold T. Rib, 10129 Glenmere Road, Fairfax, Va. 22030.

INTERNATIONAL MEETINGS

July 1973, Mexico City, Mexico. Joint Technical Meeting with the Mexican Society of Photogrammetry.

Sept. 9–16, 1974, Washington Hilton, Washington, D. C., *14th Congress of the International Federation of Surveyors* (FIG); Jeter P. Battley, Jr., P.O. Box 14262, Washington, D. C. 20044.

* Jointly with the American Congress of Surveying and Mapping.

† To be held as part of the International Congress of FIG.