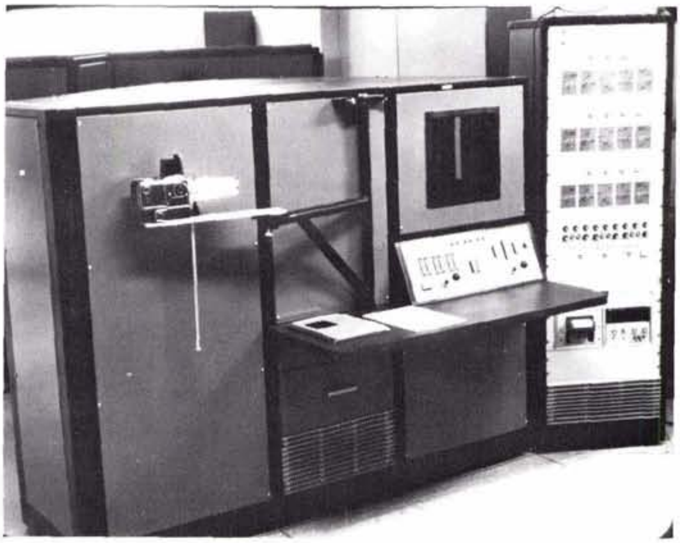

FIG. 1. The multiband camera film viewer.

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Electronic Viewer for Multiband Imagery

The system supplies real-time 1,000-line performance for three channels of input data with a wide range of processing capability.

(*Abstract on next page*)

INTRODUCTION

BASED ON the needs created by the large amounts of multiband imagery generated in current aircraft programs, and the expected quantities of data to be generated by the ERTS and *Skylab* programs, a sophisticated electronic viewer was developed under NASA contract NAS9-11028. This viewer provides real-time viewing with a 1023-line color display and has processing electronics to aid the photointerpretation process. In certain applications the viewer can be used to study and to optimize the photographic processing of the multispectral imagery. In particular, the viewer provides for the conversion of the image from photographic positive to negative and has variable gamma for best camera-viewer system performance.

The Multiband Camera Film Viewer (MCFV) shown in Figure 1, accepts three channels of input data in either roll or cut film form. A single cathode ray tube scanner is used to scan the three images simultaneously to guarantee that the scanning raster is in registration on the three multispectral images. The scanned area on the film covers up to 56 mm × 56 mm at any point on a standard 5-inch film. The film transports will take 70 mm or 5-inch roll film, or cut film of any size up to 5 inches. The scanned area can be reduced to a 10 mm × 10 mm square and that square can be located anywhere on the 4.5-inch square format of the 5-inch film.

* The system described in this article was developed for NASA/MSC on contract NAS 9-11028. Presented at the Annual Convention of the American Society of Photogrammetry, Washington, D.C., March 1972.

ABSTRACT: *A prerequisite for detailed analysis and interpretation of multiband imagery is an adequate viewing system. In general, viewers using conventional closed-circuit television components and line rates are limited in resolution 525 TV lines. Considering the inherent resolution of most aerial survey films, 525-line systems cannot fully utilize the information in the film. The Multiband Camera Film Viewer described here is a first step in overcoming this limitation by providing full viewing capability for three channels of multiband information at 1023-line rates. The MCFV provides natural color viewing, false-color analog viewing, and density false-color slicing all with 1023 TV line resolution. The measured performance of the system is in excess of 35 line pairs/mm at the film in a 10-mm square scanned area.*

To scan the image in this manner, the film is moved with respect to the scan beam in the *X* and *Y* direction (the film plane). These translations are also necessary to register the three images, one with respect to the other. In addition, ±5° rotation is provided in each channel, as well as ±5 percent scale change.

A simple block diagram of the MCFV is shown in Figure 2. The transmission of the film is converted to an electrical signal in each channel photomultiplier and each signal is *calibrated* to compensate for CRT drift, lens fall-off, and CRT phosphor noise.

Each of the three channels of processing electronics is the same with the following selections for processing:

- Signal – Internal/Test
- Mode – Transmission/Exposure
- Contrast – Normal/Sliced (Enhanced)
- Sign – Plus or minus.

The processed signal can be displayed directly or digitized for false color enhancement. The combiner in the Analog Signal Processor (ASP) provides these channel signals to the display in any combination of red, green, and blue, for full color mixing. The interpreter may experiment to his heart's content with the color mixing in the three channels to get the best possible presentation of the data. Further, each channel's output is digitized for false-coloring, and the false-colored data overlaid on the analog data.

The resulting data is displayed on a high-resolution three-color display with a 12 × 12-inch viewing area. The display presents 1023-line information at a 60 fields/30 frame-per-second rate, and functions by superimposing the output of three separate monochrome (red, green and blue) displays to generate the full color output. This display was especially designed for the MCFV program and represents the state of the art in high resolution color displays.

Perhaps the most important feature of the viewer is the real-time aspect of its use. That is, the reaction to any of the controls is instantly observed at the screen. Processing and positioning controls share this real-time

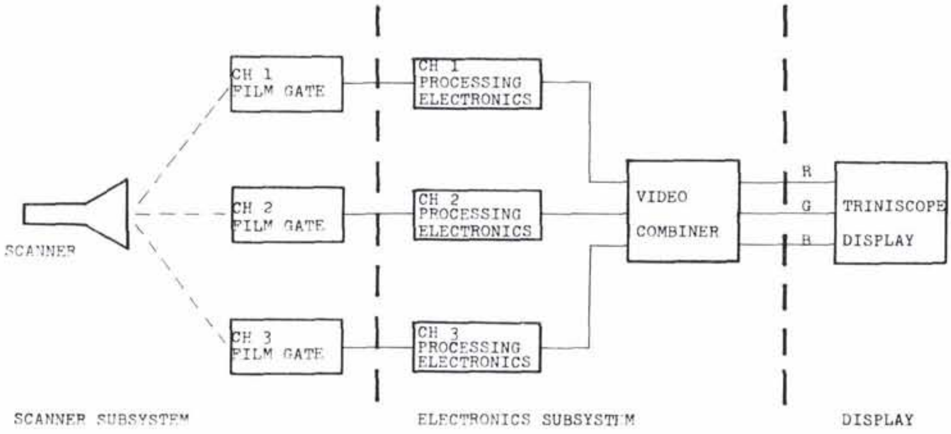

FIG. 2. Block diagram for the multiband camera film viewer.

aspect so that registration and image processing are both carried out in rapid order.

The elements of this viewer are functionally and physically separated into the scanner subsystem, the display, and the processing electronics. These elements are described in detail in the paragraphs below.

SCANNER SUBSYSTEM

The first part of the viewing process is to convert the film information to electrical signals in a scanner. Figure 3 is a block diagram of the scanner. A single CRT scans the three channels of information through an optical system of beamsplitters and fixed focal-length relay lenses. The advantage of this system configuration is that distortion can be kept to a minimum by proper design of the lens and the CRT deflection system. We are guaranteed that the scans on the film are registered and synchronized because a single scanning source is used.

The scanned format on the film ranges from 56 mm square down to 10 mm square. The format can be located at any point of a 4.5-inch square, and the distortion is less than 1 percent for any location in the format. The differential distortion between channels is less than 0.25 percent due to the beamsplitter elements. Lens distortion is less than 0.05 percent, and lens-to-lens variation is negligible. A combination of two techniques is used to cover the *zoom* range. The raster is shrunk over the largest possible range to cover part of the range. The optical path length from CRT to film is changed to get the complete range. The minimum useable raster size is 1.25 inch, corresponding to a 1.25-mil spot-size maximum over that raster size. That is, for full beam power and the 1.25-inch square deflection, the spot growth over the tube nominal 0.75 mil gives the 1.25-mil spot. On the maximum side, the raster is limited to 4 inches square by the useful diameter of the tube. The range of optical magnification required is 0.562:1 to 0.312:1, to cover 56 mm by the 4-inch raster and 10 mm by the 1.25-inch raster. The philosophy here, of course, is to keep the optical range as small as possible.

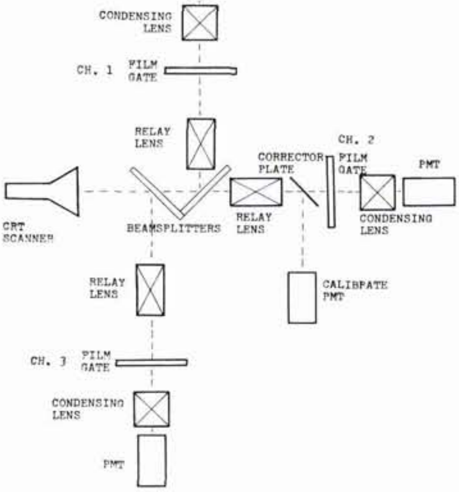

FIG. 3. Block diagram for the scanner.

The registration process, and the motion of the scanned area on the film plane are both accomplished by moving the film with respect to the scanning raster. This involves moving the roll film transport in X, Y and θ, and the entire film gate is moved in the Z-direction to accomodate relative scale differences between channels and to effect the overall magnification change.

Figure 4 shows one entire film gate assembly. The gate is designed for 5-inch film and provides translation so that any point on a 4.5×4.5-inch format can be positioned on the optical axis. In the Y-direction an additional $\frac{1}{4}$-inch motion is provided so that a step or density wedge may also be used in the high-resolution mode. The step size required to obtain a good registration capability is $\frac{1}{4}$ the minimum line width, or about 0.1 mil. A corresponding capability in the rotational mode is a $\Delta\theta_{min}$ of 2.66×10^{-4} deg.

The drive is a stepper motor driving a precision lead screw/follower through a multiple-pass gear reduction. In the rotational drive, this linear motion is converted to rotation by using a pivoting link. The step sizes above are altered slightly in the implementation because of the use of standard gears and components. The drive speed is a function of the stepping frequency selected, with a maximum of approximately 175 steps/sec.

The translation suspension consists of V-rollers riding on ground circular ways. Ball bearings are used throughout, and the entire suspension is spring-loaded to remove play and provide wear compensation. The rotation suspension is dry lubricated, large diameter, four-point contact, internally preloaded, slimline ball bearings.

The basic drives for X, Y and rotation θ are essentially the same and for the most part utilize the same components, thus minimizing spare part requirements.

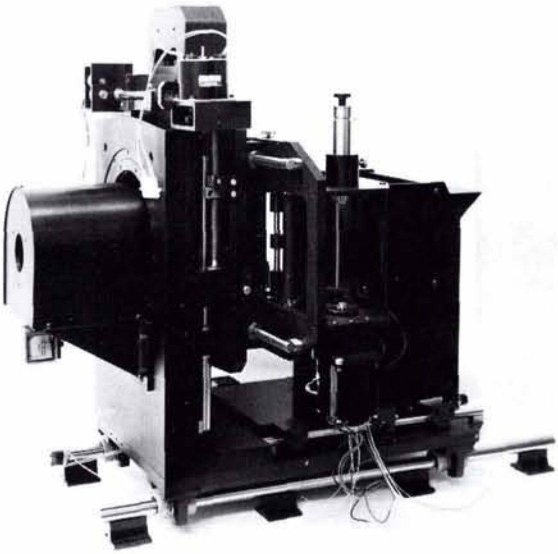

FIG. 4. Gate assembly.

ROLL FILM TRANSPORTS

The film transports are suspended on the filmgates, allowing either 70-mm or 5-inch, 100-foot rolls. 70-mm or 5-inch individual frames may also be used in aperture cards if manually loaded. The film transport mechanism consists of a solenoid-operated transparent platen, two metering rollers, and take-up and supply roll drives. Each roll and metering roller is driven by its own motor.

The metering rollers are positioned on either side of the platen and the film is pulled through by one or the other depending on the translation direction. The roll-drive motor operates in conjunction with its corresponding metering roller and drives through a slip clutch, thus taking up the film as it is metered out. The minimum amount of film motion is 0.03 inch resulting in a slew rate of about 3 inches/second.

TRACK AND FOCUS DRIVE

To accomplish the optical magnification change the total optical track length as well as the lens to film conjugate must be variable. The required track lengths lens/film conjugates are:

$$T = f_1 \frac{(m+1)^2}{m}$$

$$L = f_1 \, (m+1)$$

where m is the magnification/minification and f_1 is the lens focal length.

The required change in track length is 8.3 inches, and the requirement in lens/film conjugate is 1.78 inches.

The lens position drive is carried on the movable portion of the track position drive. The lens drive consists of a stepper motor gear reducer and lead screw. The suspension is a dovetail way. The minimum focus step is 0.0001 inch.

FILM GATE DRIVES

The drives for all of the gate motions are stepping-motor powered and are driven from a common driver with the specific motor selection to be made by relay switching. At the control panel the selection is made to drive any combination of gates at one of three selectable speeds. The motion of the film is real-time, that is, no lag occurs between the operator command and the film motion.

PROCESSING ELECTRONICS

The block diagram illustrated in Figure 5 demonstrates the component interconnect configuration for a single channel. All three channels are identical, hence, the operation on only one channel will be discussed.

The aperture corrector receives its input directly from its respective film gate photomultiplier tube. The Aperture Corrector normalizes the video for further use, as follows:

★ Compensates for the flying-spot-scanner phosphor decay with special pre-emphasis circuitry.

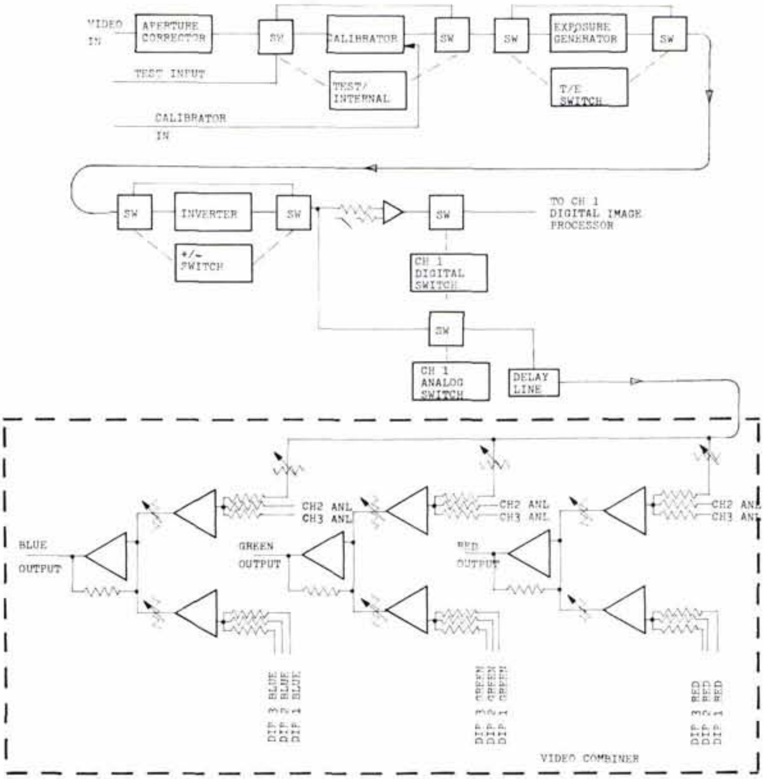

FIG. 5. Block diagram for the analog signal processor.

★ Provides aperture correction.
★ Integrates the un-blanking signal into the video for synchronization with the monitor.

The Test/Internal Switch provides for entry of a test signal into the viewer.

The Calibrator Circuit receives two inputs; a data input and a calibrate input. The Test/Internal Switch determines the nature of these two inputs as shown in Table 1. The Calibrator board functions as a Wideband Gain Controlled Amplifier and is used to correct the video data for irregularities resulting from the optical path characteristics. Hence, the Calibrate Photomultiplier tube, via the Calibrate Aperture Corrector, provides the necessary gain control to the Calibrator board for accomplishing this task. When the Test/Internal Switch is in the *test* position, no requirement exists for a variable gain control; hence, a stable 1 VDC level is substituted.

The output of the Calibrator board is routed directly to the *T/E* (Transmission/Exposure) switch. If in the Exposure position, the Exposure Generator is activated; otherwise, it is directly by-passed. The Exposure Generator is generally selected if a photographic inverse is desired, such as converting a Positive to a Negative, or the reverse.

The output of the *T/E* Switch is routed to the input of the +/− Switch. With the Switch to the minus position, the video will be routed through the Invert Control Board and electronically inverted. With the switch to the plus position, the Invert Control Board is bypassed. In addition to the inverting operation produced by this board, the Invert Control Board also generates the 1 VDC Cal level for the Calibrator Board and houses the respective relays for both the Analog and Digital select switches.

The output of the +/− Switch is routed to the input of the Sliced/Normal Switch and enables the video either to by-pass or to be fed directly into the slicer. The slicer operation is joystick-controlled at the Central Control Panel in conjunction with the motor-driven Offset and Width pots. The *Offset* mode enables the operator to select the center of the video slice desired and the *Width* mode allows the operator to select the

TABLE 1. THE CALIBRATOR CIRCUIT RECEIVES TWO INPUTS

	Calibrator	
Test/Internal	*Sig. In*	*Cal. In*
Test	Test Signal	1 VDC
Internal	Aperture Output	Cal Aperture Out

width or gain of the slice. As the width is broadened, less slices can be accommodated and vice-versa.

The output of the Sliced/Normal Switch is fed to the junction of the Digital Image Processor (DIP) Line Drive Amplifier (LDA), and the respective Channel Analog switch. The DIP-LDA is a wideband, non-inverting unity gain buffer Amplifier, capable of driving the interconnect to the DIP with minimal loss or degradation in signal characteristics. With the ANALOG switch in its *Closed* position, video will be routed to the Video Combiner.

The Video Combiner combines the Analog Video from each Analog switch, along with the Digital Video from each DIP. Each DIP has a red, a green and a blue output, and these are summed with the respective red, green and blue analog signals assigned from each channel. The composite signals are individually controlled at the monitor.

DIGITAL IMAGE PROCESSORS

One Digital Image Processor is required for each channel. The DIP is a very high speed processor utilizing emittercoupled logic to achieve rates compatible with 1000-line video. The DIP performs level-selective false coloring on the video, and, as described above, operates with a number of color assignment algorithms. Each DIP consists of a high-speed *A/D* converter, a matrix switch, matrix decoder, *D/A* Converter, and video combiners. The DIP outputs red, green and blue video to the Combiner in the ASP.

The *A/D* converter is a 4-bit, 40-megaword/sec unit developed for this program. The matrix switch functions to allow the assignment of any RGB mix to each of the 16 levels. The switch outputs are decoded, converted to analog, and sent to the ASP.

STATUS RECORDER

The Status Recorder is necessary in order to regenerate system conditions for future analysis. If operated in conjunction with the Digital Voltmeter and Recorder, it will sequentially monitor and print-out, if desired, up to 100 test voltages in numeric test-point order. Two modes of operation are available, Scan and Discrete. The Scan mode enables automatic printout of all assigned test point voltages in numeric order. Discrete mode enables manual selection of test point voltages and printout if desired.

DISPLAY

The display system consists of an enclosure containing three display channels, each of which provides one of the primary colors. The CRT's are standard rectangular units with diagonal screen dimension of 21 inches. The actual raster size is limited to a 12 × 12-inch area to decrease the deflection angle to approximately 70° and reduce the effect of face plate curvature in the picture area. A schematic arrangement of the display system components is shown in Figure 6.

The CRT mounts are arranged so that the axes of the blue and red tubes intersect the axis of the green tube. The green image is viewed directly (through the mirrors) whereas the blue and red images are viewed by reflection in the mirrors. Dichroic mirrors are supported by mountings at approximately 45°. The CRT mounts and the mirrors are adjusted to result in precise image super-

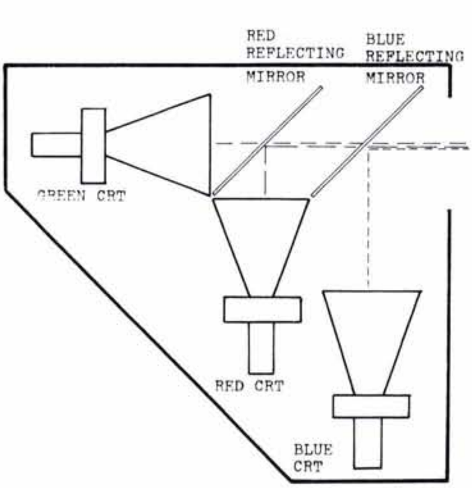

FIG. 6. Triniscope display.

position. Additional electronic adjustments of the position of the individual rasters in the *X* and *Y* directions aid in the display alignment.

The overall adjustment capability of the system includes *X*, *Y*, *Z* in the CRT mounts, pitch and yaw in the dichroic mirror mounts, and *X*, *Y* and rotation in the CRT electronics by deflection yoke positioning and electrical centering adjustments.

CRT DISPLAY ELECTRONICS

Each of the three CRT displays is a CONRAC type RQA 21R. The outstanding features of the unit are its multi-standard display capability (525 standard line rate to 1203 scanning lines per frame), wide video bandwidth and resolution, and very flexible linearity, centering and raster size adjustment capability. Pertinent specifications are:

Line Rates—525 through 1203
Video Bandwidth—30 MHz
Horizontal Resolution—800 TV lines with 1000 line rasters
Geometric Accuracy—1 percent.

Of special importance to the triniscope application are the excellent raster size, position and linearity adjustment capabilities which include:

- *Height and Width.* Two pairs of height and width controls are provided. Each control allows independent adjustment of at least 10 percent overscan and 40 percent underscan without degradation of linearity.
- *Vertical Centering.* Vertical raster position may be adjusted ±20 percent.
- *Horizontal Phase.* This allows horizontal adjustment of video information on the raster by ±10 microseconds.
- *Vertical Linearity Control.* Two independent adjustments for vertical linearity in the upper and lower half of the raster are available.
- *Horizontal Linearity Control.* A gain control to adjust the amount of horizontal linearity correction and an offset control to adjust the operating point of the horizontal linearity corrector are provided.

By proper adjustment of the horizontal and vertical linearity and width and height adjustments this monitor has shown geometric accuracy of 0.5 percent overall with excellent long-term stability.

CONCLUSION

The viewer described in this paper is a very complete system in its application to multiband camera data study and viewing. The MCFV performs all of its functions in real time and is, for that reason, very convenient to use. Analyses and interpretation are instantly available to the user. It is certainly feasible to extend the system capabilities even more to supply and display digital computer data for more detailed analyses. However, the system as it stands supplies real-time, 1000-line performance for three channels of input data with a wide range of processing capability.