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Applications of Color and Multispectral Techniques*

The design of three different imaging systems for the acquisition of multispectral imagery is described.

Abstract: *The requirements for Military Geographic Intelligence are as broad and varied as the disparate elements of the terrain. The type of information required cannot always be extracted from conventional aerial sensors. With color aerial photography the dimension of hue is added to those of length, width, shape, texture, and shadow. A newly fabricated aerial cartographic camera with color correction capabilities (KC-4B) and equipped with Automatic Exposure Control is described. Another method of collecting aerial color photography, through the use of black-and-white imagery by multiband combination, is discussed. Design and fabrication of the multiband camera is complete; a viewer is under contract. A third method for extracting color information from the terrain by color coding techniques which are used to make an optical record of the spectral reflectances is also discussed; preliminary results are given. The purpose of the entire program is to optimize the collection of color aerial photography for man-machine processing with maximum resolution.*

Introduction

The discovery of photography in the 19th century and the subsequent invention and development of photographic terrain and aerial cameras provided a means for military topographers to make topographic maps much more rapidly and accurately than could be done with the previous time-consuming and laborious hand-drawn methods. Although tacticians over centuries have realized the advantage of terrain information, military geographic information has been neglected as a field of study and the military geographers have been slower to take advantage of stereoscopic techniques. Large-scale military movements of men and material that have occurred in recent history make the requirements for military geographic information more critical than ever before.

The Military Geographic Information Elements—natural, cultural, and industrial (Table 1)—are necessary to strategic and to tactical planning for any type of military operation involving the movement of men and materiel in a friendly or hostile environment. It is particularly important in the case of natural or man-made disasters that all elements of the terrain and its composition are made known in any zone of action.

Collection of Data

In the past, the principal means for the collection of MGI data has been conventional black-and-white aerial photography. However, recent experiments described in the literature [1,2,3] have shown that color aerial photography, multispectral photography, or a combination of both may yield more terrain information than could be obtained by

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TABLE 1. MILITARY GEOGRAPHIC INFORMATION WITH THE ANALYSES REQUIRED.

Natural Conditions	Cultural Conditions	Types of Military Evaluations
1. Surface Configuration	1. Railroads	1. Movement
		a. Via Established Routes
2. Soils	2. Roads and Trails	b. Cross-Country
		2. Construction Aspects
3. Rock Types	3. Navigable Inland Waterways	a. Natural Construction Materials
		b. Processed Materials
4. Vegetation	4. Ports	c. Construction Labor
		d. Construction Potential
5. Surface Drainage	5. Airfields	(1) Roads
		(2) Airfields
6. Water Resources	6. Pipelines	(3) Logistic Bases
7. Hydrology	7. Urban Areas and Public Utilities	3. Amphibious Landing Areas
8. Nearshore Hydrography	8. Non-Urban Features	4. Cover and Concealment
9. Climate	9. Political Boundaries	5. Fields of Fire
10. Special Geophysical Phenomena	10. Barriers and Defenses	6. Special Weapons Employment
11. State-of-Ground	11. Hydraulic Structures	7. Helicopter Landing Zones
12. Coasts	12. Trades and Construction Skills	8. Demolition Potential
	13. Industrial Installations	9. Maintenance and Reconstruction
		10. Terrain Masking
		11. Ambush Sites
		12. Guerilla Base Camps

black-and-white panchromatic photography alone. Three approaches to this problem have been studied at the Technology Development Branch, U.S. Army Engineer Topographic Laboratories (USAETL). Improved cameras have been developed for color aerial photography, a multiband camera has been developed and delivered, and a Technical Operations Color Coding Camera is being analyzed.

The development of a compatible aerial cartographic camera with a fully color-corrected capability to represent the state-of-the-art (Figure 1) was achieved by performing certain engineering tasks. The T/11 camera body was reengineered to accept a Geocon I lens with a high resolution capability (Figure 2). Three optical glass filters were provided and the resulting resolutions for the camera system are as follows: With the minus blue filter, 44.4 lines/mm, Area Weighted Average Resolution (AWAR) was achieved over a 9-by-9 inch format on 2402 black and white Aerographic Film; with a red glass filter, 43.8 lines/mm AWAR was achieved over the 9-by-9 inch format on 2402 film; and using the third, minus ultraviolet, filter, 42 lines/mm AWAR was achieved on 2448 Ektachrome Transparency Reversal Film. The uniformity of the resolution suggests that the optimum plane of focus was achieved for the lens-camera system. The negative stage platen of the camera was remachined to a flatness of 0.0002 inches and the resulting distortions were less than 10 micrometers.

A compact transistorized Automatic Exposure Control (AEC) was engineered by Fairchild Camera & Instrument Corporation (Figure 3). Not only is the actual exposure recorded, but the incorporation of a seven step grey scale provides a means for sensitometric control during processing.

Additional work to incorporate incident sky-lighting and ground reflectance calibration is being performed at USAETL with a K17 camera. This work has been reported by Mr. Roedel in a separate paper. If successful, this would also be incorporated in future cameras to insure uniform acquisition and development.

Preliminary tests of the KC-4B Aerial Camera, equipped with the AEC, have been completed. The results are shown in Plate 1. The increased amount of geographic information is readily apparent from exposure control done in the trilayer film, both the color film (Ektachrome MS) and the false color film (Ektachrome Infrared). No quantitative data are presently available.

Multiband Photography

A second method of collecting Military Geographic Information is by means of multiband photography. This can be defined as a means of isolating the electromagnetic

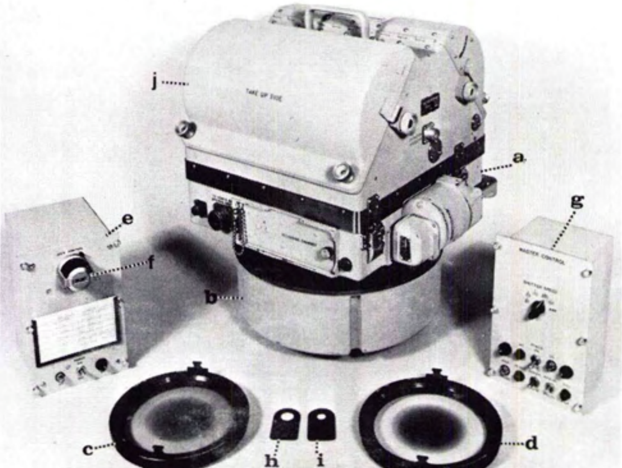


Fig. 1. KC-4B cartographic Mapping Camera. (a) Camera body assembly. (b) Camera cone cover. (c) Red filter, anti-vignetting. (d) Minus ultra-violet filter, anti-vignetting. (e) Automatic Exposure Control. (f) Exposure index/filter factor input dial. (g) Master control. (h) *f*/8 Waterhouse stop. (i) *f*/11 Waterhouse stop. (j) Film magazine.

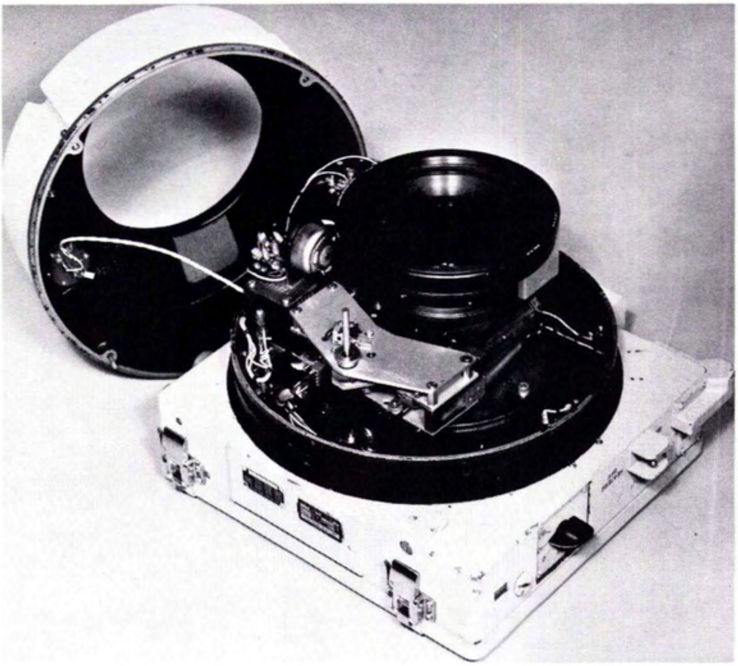


FIG. 2. Camera lens cone and shutter assembly.

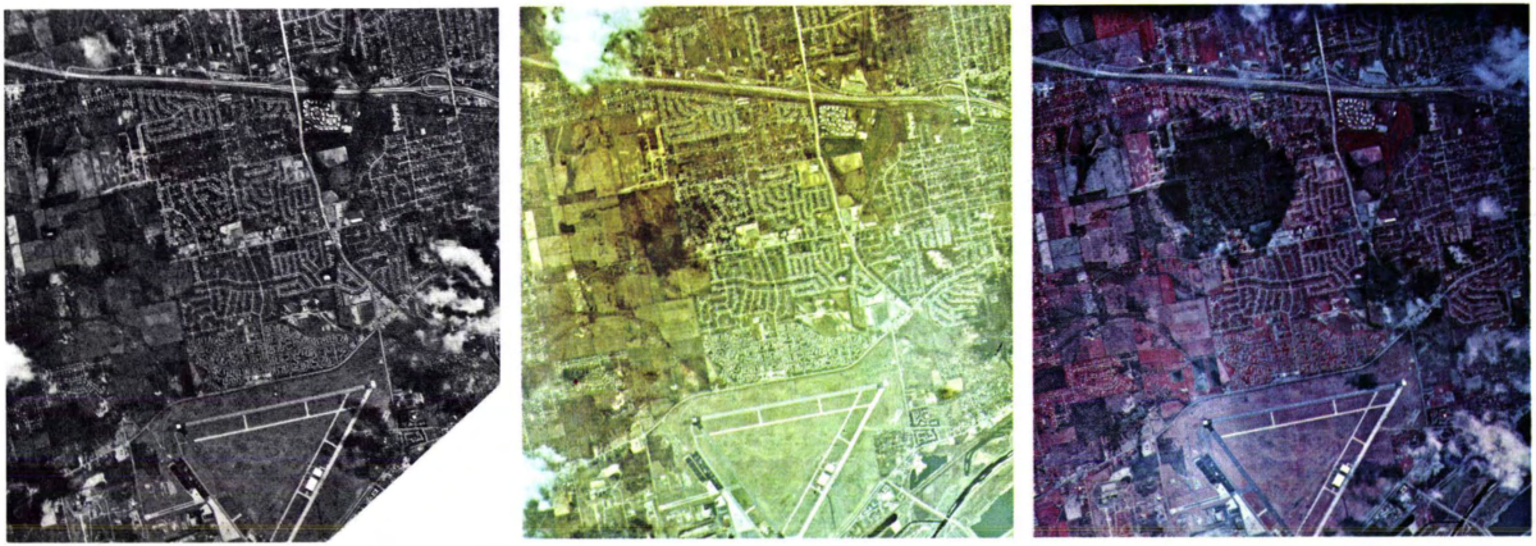
energy reflected from the surface into a number of spectral bands and recording each band separately on black-and-white film.[6] Although James Clerk Maxwell is regarded as being the accidental discoverer of color photography, in a sense he was employing spectrally filtered photography to demonstrate Young's tricolor theory and Newton's theory about the composition of white light. For those who are unfamiliar with Maxwell's work, he used three flat glass vials filled with different colored cupric solutions to achieve a blue filter, a green filter, and a red filter through which he successively photographed three black and white images of a colored plaid ribbon. After processing the three negatives, he reprojected the black-and-white images, one superposed on another, back through the filters onto a screen and achieved the original colored image. Thus was obtained a colored image through photography; however, it was a projected image and could only be observed visually.

FIG. 3. Automatic Exposure Control and master control.

There was no known method to record it on colored photographic paper. This gave the impetus to later work and the development of color photography as we know it today.

Since many materials reflect energy differently over the photographic spectrum, it has been postulated that, by selecting the proper film/filter combination for recording in areas of the spectrum where maximum differential energy reflectivity occurs, the contrast between materials of interest and background would be enhanced.

Karl-Heinz Lohse's work under the Multiband Photographic Extraction Techniques contract with the U.S. Army Engineer Topographic Laboratories demonstrated that the use of four spectral bands was the best compromise between redundancy of information and detectability of data. Furthermore, the bands could be broad, 150-200 nanometers, as opposed to very narrow bands which were advocated by some investigators.



(a) (b) (c)

PLATE 1. (a) Part of an aerial photograph taken at 20,000 feet over Area B. Wright-Patterson Air Force Base, April 15, 1971, on panchromatic 2402 film in the KC-4B camera. (b) Same part of a color photograph exposed an Ektachrome MS 2448 film in the KC-4B camera. (c) Same part of an infrared color photograph exposed on 8443 film in the KC-4B camera.

Experiments by Colwell, Yost, and Orr, as well as by others, have demonstrated that color, false color, and enhanced color displays could be achieved using the four primary bands (blue, green, red, and infrared) (see Figure 4 and Plate 2). The necessity to superimpose the four multiband colors into a color composite image for efficient viewing has resulted in providing color viewers as part of the multiband system.

ETL has developed a multiband camera with a single lens, beam splitters, and four magazines. The four photographs record the blue, green, red, and infrared energy reflected from the terrain. Two interchangeable lenses with 4- and 6-inch focal lengths will be used to study the effects of scale and field of view. The unique design of the single lens with four magazines eliminates the problems inherent in most multiband systems which depend upon a separate lens for each broad band, and boresighting to insure matching imagery. (Figure 5) The specifications for performance are much higher than for mapping cameras. Exact figures for resolution and registration are not releasable pending completion of confirming tests at ETL. The shutter speeds are from 1/25 to 1/400 second, lens aperture from *f*/4 to *f*/22, and the film capacity is 100 feet with 70mm format. (Figure 6) The mounting is compatible with the T/11 camera mount.

Under simultaneous development is a multiband viewer. The viewer will be used to superimpose the four multiband photographs onto a screen for analysis of a composite display for color, false color, and enhanced color. The multiband camera and viewer has been used to conduct experiments at selected military geographic test

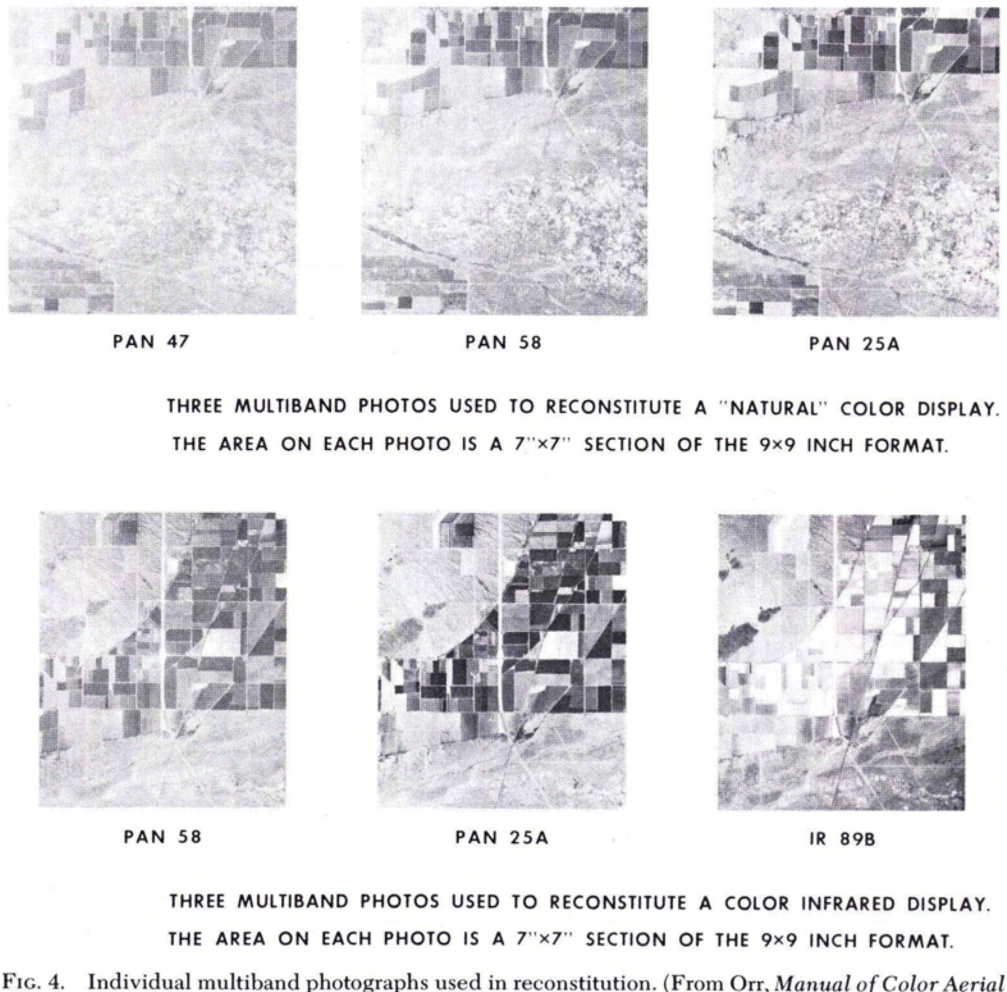


FIG. 4. Individual multiband photographs used in reconstitution. (From Orr, *Manual of Color Aerial Photography*, with permission of the American Society of Photogrammetry.)

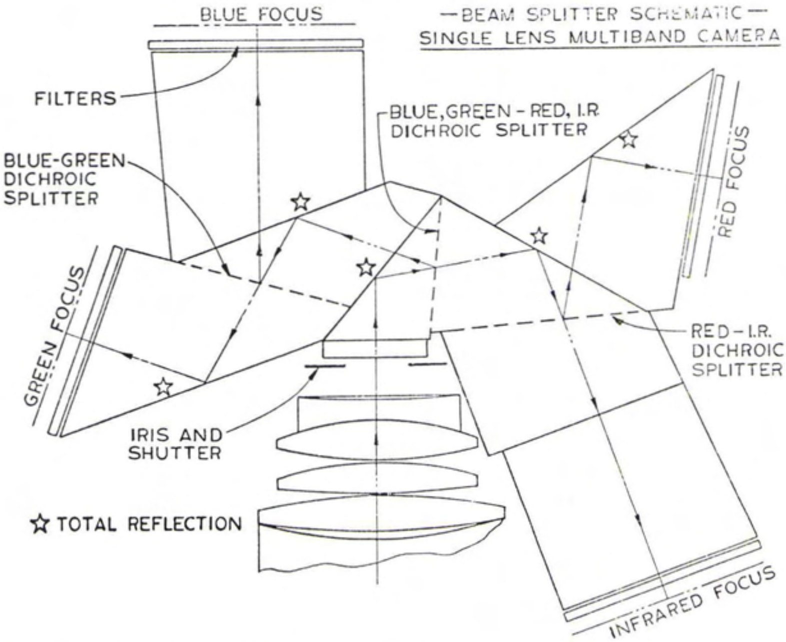


FIG 5. Design schematic showing the light ray path in the multiband camera. Beam splitters direct appropriate rays to their focal planes where film magazines record the images.

sites to determine the relative merits of this technique compared to other methods of data acquisition. Multiband photography has been analyzed for its application to automated pattern recognition and analysis. For this use, such cameras will also contain automatic exposure controls and other calibrations previously discussed. Results are shown by Brooke and Vogel.[7]

COLOR CODING TECHNIQUES

A third system for obtaining color information from the terrain by black and white

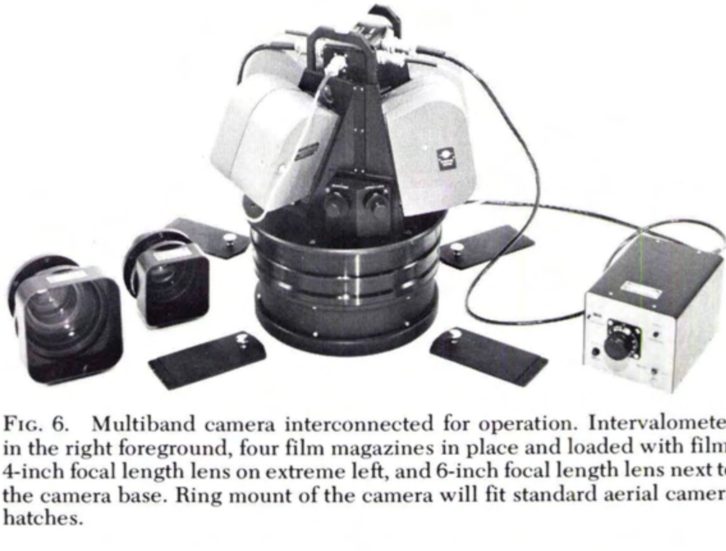
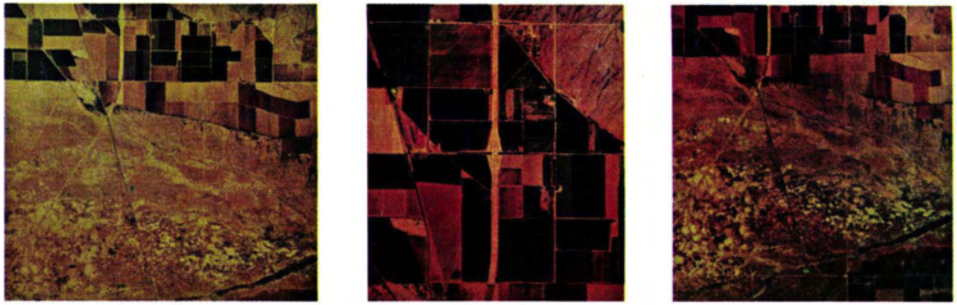
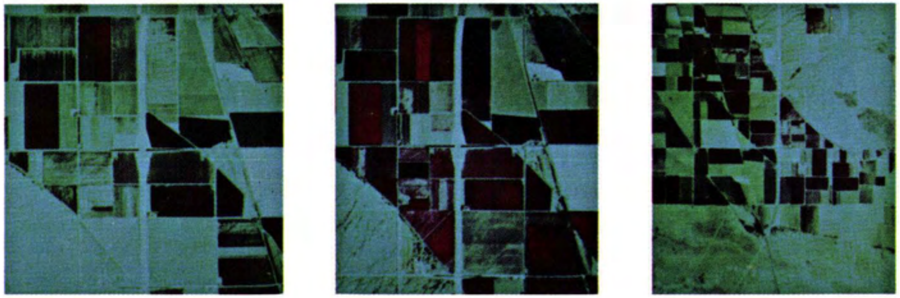


FIG. 6. Multiband camera interconnected for operation. Intervalometer in the right foreground, four film magazines in place and loaded with film, 4-inch focal length lens on extreme left, and 6-inch focal length lens next to the camera base. Ring mount of the camera will fit standard aerial camera hatches.



(A) Ektachrome MS (type SO-151) (B) Bi-color Projection (3″ × 3″ section) (C) Tri-color Projection (7″ × 7″ section)

Color images (B) and (C) were made from multiband photos in Figure 4 (upper). Image (A) is from the aerial photography taken over the Arizona Test Area at approximately the same time.



(A) Ektachrome IR (type 8443) (B) Ektachrome IR Display (3″ × 3″ section) (C) Ektachrome IR Display (7″ × 7″ section)

Color IR images (B) and (C) were made from multiband photos in Figure 4 (lower). Image (A) was made from the aerial photography taken over the Arizona Test Area at approximately the same time.

Plate 2. Reconstituted color photographs prepared from images in Figure 4. (From Orr, *Manual of Color Aerial Photography*, with permission of the American Society of Photogrammetry.)

photographic techniques is the Technical Operations Color Coding System, procured under contract for USAETL by Technical Operations, Inc. A current program is underway to evaluate the equipment which was delivered to USAETL in March 1971.

The acquisition camera is a 70 mm format Hasselblad 500C equipped with an 80 mm focal length lens. Like a variety of available multiband systems, the color coding camera can provide color, false color, or spectrally selective output for analysis and interpretation; however, the color coding system uses a single frame of black-and-white reversal film rather than multiple frames. This eliminates the need for superposition of several images for color display. Registration problems are thus eliminated. The system operates on the basic light filter grating and lens theory.

If a transmission grating is positioned at the plane of the camera when the film is exposed, the grating lines are superimposed on the latent image of the scene. (Figure 7) Processing the film and projecting with white light produces a pattern of the grating at the focal plane of the projection lens and an image of the scene at the image plane. The pattern and the image both contain all of the information originally recorded through the grating. (Figure 8) To record the red scene information with a hypothetical camera, a red filter would be placed in front of the lens; to record the green scene, a green filter would be placed in front of the lens; and to record the blue scene, a blue filter. The goal is to separate the red, green, and blue information and yet record on the same frame. This can be done by rotating the grating through a fixed angle prior to each exposure. The technological feat is to combine the sequential steps into a single operation. This is accomplished by depositing thin film filter coatings in a pattern of the three selectively oriented gratings on a single substrate (glass).

Now a single exposure can record the three primaries at one time and each is modulated by a different filter grating combination. The next objective is to reproduce the color image, which is done with a specially constructed binocular viewer. When the black-and-white reversal image, after processing, is projected, each grating produces an optical pattern, reoriented perpendicular to the direction of the grating lines, and each orientation of the pattern contains information pertaining to one of the primary colors in the origianl scene (Figure 8). In the focal plane of the projection lens, the color information is separated and can be manipulated to reintroduce color (Figure 9).

A color filter on a wheel is positioned to pass the light containing red information, thus introducing red information to the imaged scene. A similar operation images blue

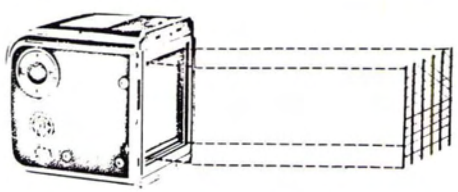


FIG. 7. Seventy-frame Hasselblad magazine with TOC ruled grating.

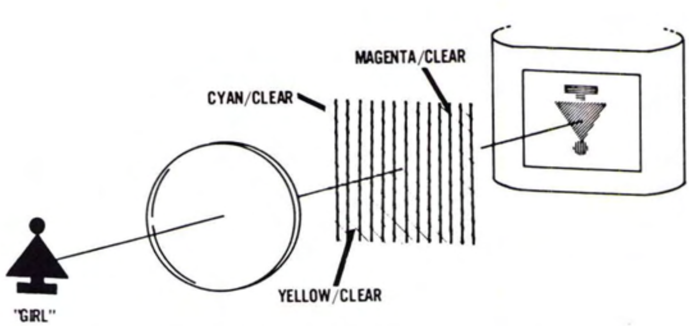


FIG. 8. Use of tricolor grating to allow full color scene to be recorded in one exposure.

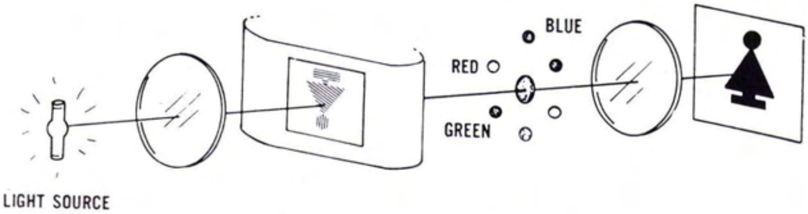


FIG. 9. Reconstruction of a color scene.

and green information. At the image plane the primaries are recombined to produce a color image. In the system developed for USAETL, variable neutral density filters permit the precise control of illumination levels for each color. False color displays can be produced and individual spectral channels emphasized. Displays have a 2-10× magnification. Grating spacing limits the present system resolution to 50 lines/mm. The present technology indicates that a new filter configuration will be required to extend the resolution of the color coding system.

Thus three systems for the application of color and multispectral techniques to the collection of military geographic information have been described. The task of applying these techniques, in a sense calibrating their accuracy, is a much greater one. For this purpose, highly controlled test ranges are laid out and special instrumentation is installed in order to determine the effects of all possible variables upon the collection of that imagery which will yield accurate information about photo imaging of the terrain in a controlled and quantitative frame. The results should provide a high degree of standardization of quality of image output required both for rapid human and machine aided uses.

Controlled Test Ranges

All of the above mentioned systems will be tested in flight above selected target areas in a tropical environment such as Puerto Rico; a mountain environment, Fort Carson, Colorado; a desert environment such as the Phoenix, Arizona test range; an urban environment such as Fort Belvoir, Virginia; and other characteristic geographic areas. At each of the test ranges ground truth, including temperature, soil moisture, humidity, etc., will be gathered by ground crews. Uniquely designed spectral and spatial targets, under fabrication, will serve to determine the spectral and spatial resolution of each of the systems.

Observations will be made of the terrain characteristics in the vicinity of each test range. Systems will be flown simultaneously and analyses made, then compared with each other for the optimum geographic information gained from each system. Thus it is only when strict controls are applied to ground truth that determinations can be made of the most useful system for the application of color and multispectral techniques for the collection of Military Geographic Information.

Conclusions

Imaging systems by themselves can collect the most obvious information, the existence and location of gross targets such as cities, rivers, oceans, and so forth. Calibrated imaging systems can collect and differentiate more specific geographic information such as wet and dry areas, soil types, deciduous or coniferous vegetation, dense murky waters or clear transparent waters, crop types, and grass lands.

Neutral gray scale wedges, exposed with the aerial photograph and mounted in the camera film stage, control exposure and processing. Ground truth teams, which record pertinent geographic data, control terrain information at the moment of photographic exposure.

With accurate aerial photographic control and accurate ground control, dependable terrain information for modern warfare can be rapidly collected.

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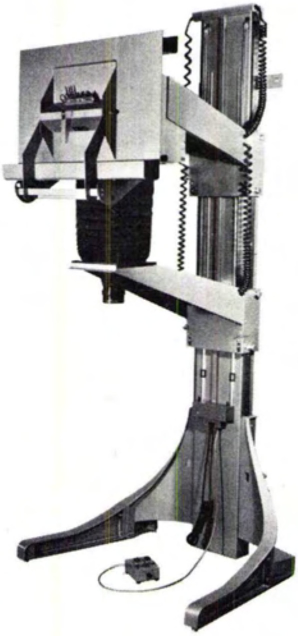
Engineering Reports

Business—Equipment—Literature

Gordon R. Heath

ALTEK Announces New Digitizer

ALTEK CORPORATION announces the *most significant* advancement in coordinate digitizing tables within the last five years. The "DATATAB" Model AC 90 electronic data tablet permits manual digitizing of any graphical data to a resolution of 0.001 inch using an *absolute coordinate system*. The tablet is designed so that the cursor may be removed from the table surface without loss of origin; all previous high resolution tables lost origin, requiring re-setting and associated decline in operating efficiency. The specifications include a repeatability of ±0.001 inch and an accuracy of ±0.005 inches. The DATATAB™ is available in sizes up to 42″ × 60″ with optional back-lighting. Users may purchase the tablet alone or with a variety of recording devices such as card punch or magnetic tape recorder. ALTEK also incorporates the new tablet into complete stand-alone graphics systems with computer, CRT, plotter, and software. Applications for the DATATAB include automated drafting and cartography, photogrammetry, strip chart digitizing, numerical control, engineering design, and town and county planning. For further information, contact the Graphic Sales Department of ALTEK Corporation at 2141 Industrial Parkway, Silver Spring, Maryland 20904.



New 55C-2 Mapping Projector Announced by Art-O-Graph

An increase of 50% illumination to 900 watts is one of several major engineering advancements in the new model 55C-2 Map-O-Graph. Other improvements are a new scale record/repeat system; solid steel tracks for close tolerance motion control; two-fan cooling; and adjusting devices for maintaining perfect plane relationships. The 55C-2 speeds up and simplifies map drafting, revision, and production. It has applications in geological exploration, land use, forestry, tax mapping, developmental planning, highway engineering, agriculture, pollution control, and many other areas. The 55-C, predecessor to the 55C-2, is now serving mapping projects in 60 countries. Twelve are on the job on Brazil's Projecto Radam; nine 55C-2's were recently shipped to the USSR. Price of the 55C-2 is $2,975 complete, for wall mounting. An accessory stand is available. A new, fully-illustrated 6-page folder, and 44-page booklet detailing 9 case histories of 55C's, is available free. Write to Art-O-Graph Inc., 529 S. 7th. St., Minneapolis, Minnesota 55415.

Bendix Commended by Air Force for Photogrammetry Breakthrough

The Bendix Corporation's Research Laboratories has been commended by the U. S. Air Force's Rome Air Development Center for its