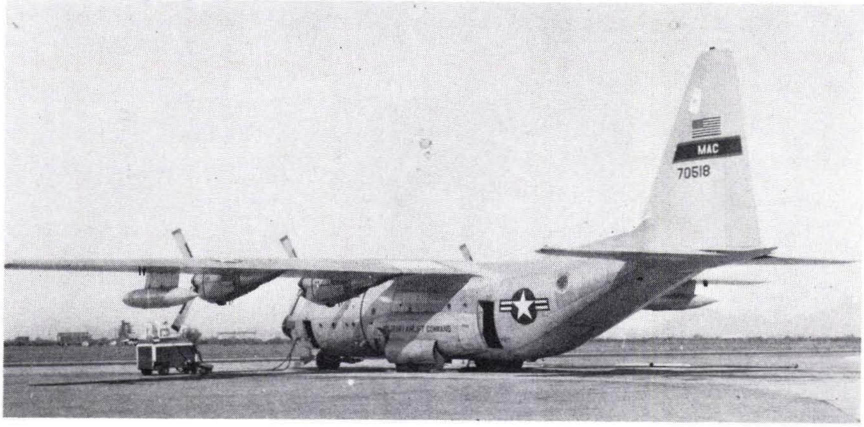

FIG. 1. U. S. Air Force RC-130 Hercules.

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Developments in Aerial Color Photography for Terrain Analysis

Tests near Phoenix, Arizona, in addition to other recent studies, indicate added potential for terrain evaluation.

INTRODUCTION

THE DEVELOPMENT OF HARDWARE for the employment of aerial color photography is proceeding more rapidly today than in the past to keep pace with the realization of the potential gain in terrain information. Manufacturers of photographic film in the United States have produced 9½-inch wide Aerographic films on an Estar base (Eastman Kodak) and a Gafstar base (General Aniline and Film Corporation). High performance, precision aerial cartographic cameras manufactured by Fairchild, Wild Heerbrugg, and Zeiss companies produce photographs which are corrected for a wide range of the visible spectrum in color reversal films as well as color negative films. Plotting equipment, not originally designed to accept aerial color photographs (for example, the dichromatic plotters) are being modified to enable stereoscopic viewing in color. New equipment such as stereocomparators are now designed for corrected viewing illumination. Light sources for existing plotters are being modified to take full advantage of the wide spectrum captured on color films.

The most obvious information gap is the optimum utilization of aerial color photography which requires special emulsions, precise cameras and special viewing equipment. Several tests have been conducted in which aerial color photography supplying unique information for terrain evaluation as well as indicating a need for a set of standards which can be applied to the acquisition of aerial color photography.

BENNETTSVILLE, SOUTH CAROLINA, TEST

The Bennettsville, South Carolina, Aerial Color Photography Test, conducted by the American Society of Photogrammetry Color Photography Committee, was the first joint effort in which several Government and industry organizations gave freely of their time and material to supply quantitative and qualitative data on the most effective use of

* Presented at the Annual Convention of the American Society of Photogrammetry, Washington, D. C., March 1968.

aerial color photography, by comparing its performance over the same terrain with the performance of panchromatic photography and false color photography (Ektachrome Infrared). A full report on that test was presented to the Society at its Semi-Annual Meeting in Dayton, Ohio, September 1965. The report was also published under the title "Color Photo Comparison" in the March 1966 issue of PHOTOGRAMMETRIC ENGINEERING (1). There were problems inherent in the execution of the plan because it required the cooperation of the Defense Intelligence Agency, the Air Force, Corps of Engineers, Coast and Geodetic Survey, Eastman Kodak Company, General Aniline and Film Corporation, Wild Heerbrugg Company, Fairchild Company and others. For example, instead of all of the photography being flown within a space of a few days, the flights stretched into three weeks from June 8 to 22, 1964. Two cameras were used and four types of film—Ektachrome, Anscochrome, Ektachrome Infrared, and Plus-X Aerial Film—were alternated. Ground control was not established in advance, but obtained between November and December 1964, four months after the flights when terrain conditions had changed somewhat.

ABSTRACT: *Progress is being made in the development of aerial cameras, filters, high-speed sensitive color emulsions, and rapid-processing equipment for the employment of aerial color photography for the extraction of terrain information. Some recent aerial color photography tests employed color films and false color films with attendant results. Loss of color detail from small-scale aerial color photography is often balanced by the overview of the terrain's tectonic structure, where dominant terrain hues aid in information extraction. Needs indicated are for government aerial color photography testing programs, in which all agencies participate.*

In spite of all of the above problems, some valid conclusions were obtained:

- Ektachrome Infrared photographs were superior to panchromatic photographs and color photographs for identifying and mapping drainage and moist soils.
- Color photographs, both Ektachrome and Anscochrome, were superior to panchromatic and Ektachrome Infrared for mapping culture and discriminating soils.
- The reflection characteristics of vegetation make Ektachrome IR a superior means of discriminating types of vegetation.

Geologists never having visited the ground sites could make an analysis of soil conditions with the aid of the 1:20,000-scale aerial photographs taken on that test. Color fidelity was determined *not* to be a limiting factor in the identification of terrain information. The Bennettsville Test also demonstrated the need for more controls on such a test to eliminate the numerous variables which are always present in an empirical field operation.

SIMILAR WORK IN OTHER AREAS

Since the photograph comparison work was performed in 1964, several similar tests have been performed in other parts of the world. Mott (1966) (2) reports in *The Photogrammetric Record*, London, England, on work being done by the Directorate of Overseas Surveys (DOS). Mr. Rees, DOS, makes the following observations from work in Africa:

Compared with panchromatic, Aerial Ektachrome prints in general have the following advantages:

- They enable a quicker and clearer understanding of land use pattern.
- They enable one to identify ground features more positively and conclusively.

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- They permit greater differentiations within the land use patterns.

For example, the field of bare soil is strikingly apparent on color prints but can be identified on panchromatic with some reservation. Small plots of bright green vegetation stand out clearly on color prints but cannot be separated on monochrome. Subtle color differences along a river bank not only differentiate vegetation but bring out fine ground detail. The color of tree crowns sharply distinguishes their outline from underlying shadow.

Black-and-white prints from color negatives are superior to those from panchromatic film, even though they are of less contrast; the differentiation of images on color prints are still evident.

Welch, (1966) (3), also reports in *The Photogrammetric Record* on a comparison test study of the Breidamerkur Glacier, Iceland (1965) where the combination of panchromatic, color and Ektachrome Infrared photographs were used for the extraction of terrain detail. Welch's conclusions were that color film, because of its sensitivity to the entire range of the visible spectrum, has proved to be most valuable. Although color film is not superior in all respects, it has no negative interpretation values except for a slight tendency to blur under high magnification. Its brightness properties and continuous range of tones can be regulated in processing to give close visual representation. If this is done, color film is superior for the interpretation of volcanic bedrock and gravels, glacial landforms, and glacier surfaces.

The detail recorded on false color film (Ektachrome Infrared) is excellent for soil moisture studies and the delineation of vegetation boundaries. Water appears in blue tones and vegetation in red-magenta and yellow (IR reflectivity). However blue-flat tones make it unsatisfactory for land-forms and ice-surface studies.

Prospecting with high-altitude false color photointerpretation has been reported by Paarma and Talvitie, (Finland, 1967) (4) in the Manual of Color Aerial Photography. The distribution of moisture and living vegetation is most important for tectonic interpretation where the terrain is covered with overburden. By timing the aerial photography with the correct season, the moist areas in Northern Finland could be identified by their infrared reflectances while the vegetation had not yet reached its peak for infrared reflectance. If the photographs are made from

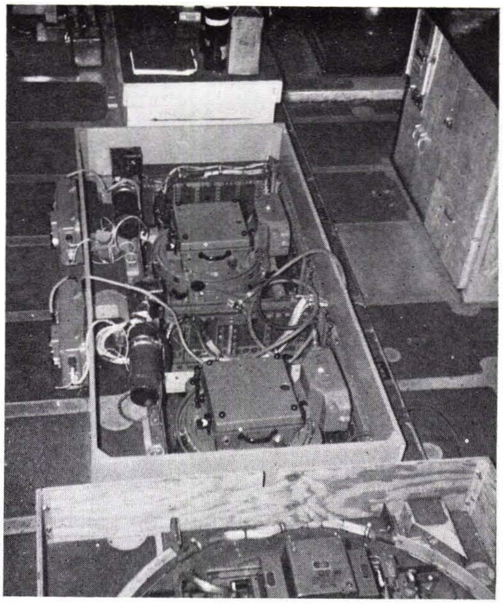

FIG. 2. Two matched RC-8 Wild cameras, mounted. KC-4 camera in foreground.

a high altitude (9 km) to yield a 1:60,000 scale, terrain patterns are discernible. With the aid of the false color photographs at the small scale, the lakes, wet bogs and eskers would easily be identified because the clear water appears black, whereas the wet bogs are bluish black.

In conventional mapping work it is difficult to map and judge the pattern of tectonic features and principal feature zones which are important for the location of rocks and ores of economic importance, because the scale is so large and the overburden conceals outcrops. Where the overburden is thin the faults and fractures are reflected in the form of lakes, bog regions, and humid spots with abundant vegetation and eskers. These bog regions and humid spots are difficult to recognize on black-and-white mosaics because the latter are less continuous and have less discrimination. With the false color photographs made into a 1:100,000-scale mosaic and accompanying airborne geophysical soundings, ores can be located in the investigated regions at certain principal fractures or at their intersections. Fractures are abundant in the region of the iron ore provinces. A correlation was found between aeromagnetic data and photolineaments.

PHOENIX, ARIZONA, TEST

From the experience gained in the Bennettsville, South Carolina, Test a more

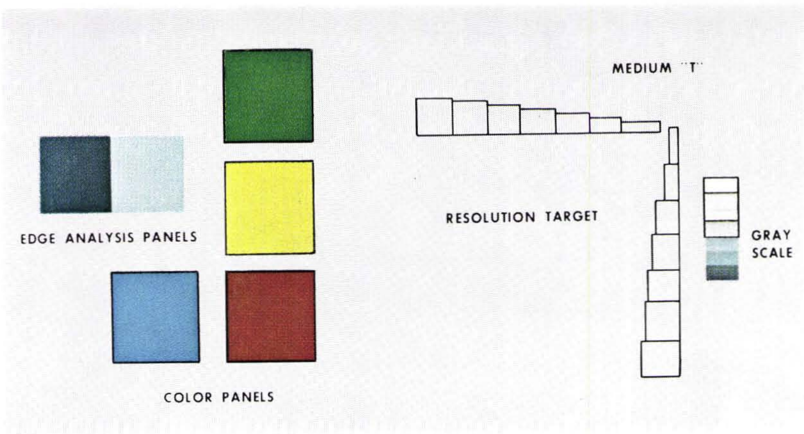

PLATE 1. Photogrammetric color target site.

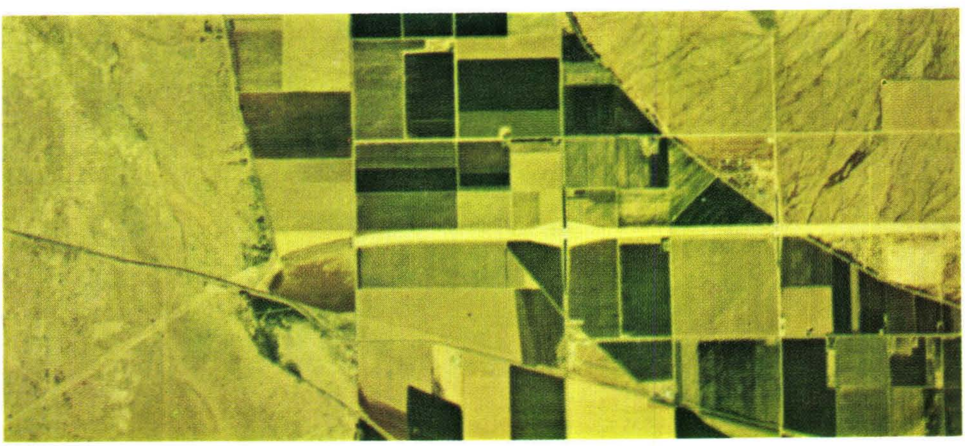

PLATE 2. Aerial Ektachrome photograph exposed 30,000 feet.

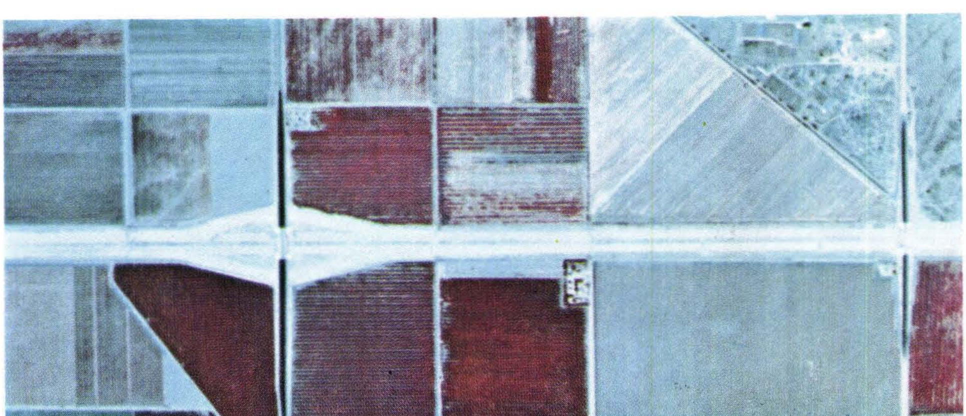

PLATE 3. Aerial Ektachrome Infrared photograph (enlarged portion) exposed at 10,000 feet.

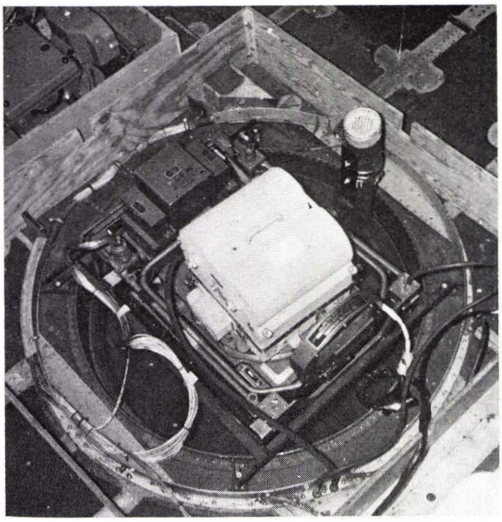

FIG. 3. Fairchild KC-4 camera, mounted.

rigidly controlled aerial color photography test was designed and executed by the American Society of Photogrammetry Color Photography Committee over the Arizona High Density Control Area in July 1966. This was another cooperative test by several participating Government agencies and industry and members of the Society. The test flights were made during the week of June 25–July 2, 1966, in an Air Force RC-130 Aircraft. (Figure 1). Three cameras were operated simultaneously—a pair of Wild RC-8 cameras, 6-inch focal length, 9×9-inch format, furnished by the National Aeronautics and Space Administration (Figure 2), and a KC-4 Fairchild camera, 6-inch focal length, 9×9-inch format, furnished by the Air Force and the U. S. Army Engineer Topographic Laboratories. (Figure 3). Film supplied by Eastman Kodak and General Aniline and Film Corporation included Ektachrome, Ektachrome Infrared, Anscochrome and Plus-X Aerial film in 9½-inch width. Flights were made at 10,000, 20,000 and 30,000 feet with all films and cameras interchanged to eliminate maximum variables.

Ground targets supplied by the Data Corporation under contract to the Air Force included (Plate 1): four canvas color panels, each one 100×100 feet displaying 10,000 square feet, painted with Minnesota Mining and Manufacturing velvet epoxy paint; one panel painted in dark red; another in dark green; a third in dark blue and the fourth in yellow. In addition to the color panels, a pair of edge analysis panels, black and gray, each one 80×80 feet with reflectance values of 4 percent and 37 percent were placed side by side. Nearby was placed an Air Force Medium Contrast *T*-Bar target with two arms at right angles containing seven sets of progressively smaller resolution patterns, and an 8-step gray scale; each gray scale was 25 feet by 50 feet. Reflectance measurements were made on gray scale patches as each flight was completed overhead. (Table 1).

In order to locate the horizontal and vertical control, each of the fixed bench marks in the area, a mile apart, were paneled with 12 feet by 12 feet panels of white Kaycel, a highly reflective durable paper (Figure 4). The panels showed up at all altitudes including the 1:60,000 scale photographs. Ground data sheets (Table 2) were prepared for all control points.

Studies for metric accuracy as compared to panchromatic photographs have been performed and are reported by Mr. Schallock of the Army Map Service on page 1063 of this issue. Studies on resolution of color photographs as compared to panchromatic photographs have been completed by the U. S. Geological Survey and report equal resolution. Evaluations have been performed on color photography regarding their value for soils information by Prof. Olin Mintzer of the Ohio State University. Never having visited the area, Professor Mintzer's knowledge was general: that landforms were developed as alluvial filled valleys, that the surface materials in grain size were anything from boulders to clay, and that only consolidated materials would be in the hills and buttes scattered in the test area (Figure 5). Vegetation types were mesquite, salt bush, mustard grass, and cactus.

A terrain data recording format was developed for soils information, to include geologic

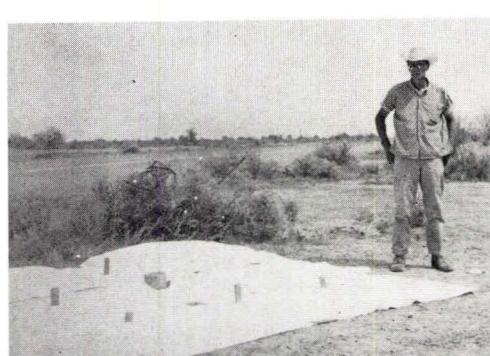

FIG. 4. Panelled bench mark.

TABLE 1. FORM FOR RECORDING REFLECTANCE MEASUREMENTS OF GRAY SCALES

PHOENIX PHOTOGRAMMETRIC COLOR TEST
LOCATION *Mission #2*

SITE MANNING REPORT
TGT TYPE *MED T, COLOR, GS, EDFE*
TARGET BRIGHTNESS IN FOOT LAMBERTS

DATE *30 June 1966* / *1 July 196*
OPERATOR *NEWMAN / WAITE*

Local Time	Estimated Cloud Cover and		Eight Step Gray Scale									Edge Analysis			REMARKS
	PIX	NR	DISC	BLACK	GRAY	GRAY	GRAY	GRAY	GRAY	GRAY	WHITE	DISC	04 BLACK	37% GRAY	
09:47	0%	1	9,300	770	1,500	2,100	3,200	3,900	4,600	5,900	8,000		590	3,000	ORIENTATION
10:00	0%	2	9,200	810	1,500	2,200	3,300	4,100	4,800	6,200	8,200		640	3,100	10 K
10:12	0%	3	9,700	850	1,700	2,300	3,500	4,200	5,000	6,400	8,700		690	3,300	10 K
10:32	10%	4	11,000	1,100	1,800	2,600	3,800	4,700	5,400	6,900	9,500		720	3,600	20 K
11:15	50%	5	12,000	1,100	1,900	2,900	4,300	5,100	6,000	7,700	10,000		850	4,100	30 K
MISSION NUMBER TWO CONTINUED 7-1-66															
09:42	0%	1	9,300	860	1,500	2,200	3,200	4,000	4,600	5,900	8,200		640	3,000	30 K
10:02	0%	2	10,000	890	1,600	2,300	3,400	4,300	4,900	6,300	8,700		630	3,200	30 K
10:19	0%	3	1,000	910	1,800	2,600	3,700	4,600	5,300	6,900	9,400		680	3,300	20 K
10:35	0%	4	10,000	1,000	1,700	2,600	3,800	4,700	5,500	7,100	9,800		750	3,500	10 K

WEATHER DATA	12:00 PHOENIX 30 JUNE 66	11:00 AM 1 JULY 66
TEMPERATURE	96°	96°
RELATIVE HUMIDITY	34%	27%
VISIBILITY	35 MILES	35 MILES
WINDS	EAST AT 7 MPH	SE AT 6 MPH
BAROMETRIC PRESSURE	29.81 FALLING	29.81 STEADY

FORM NO DC 65 8A SHEET 1 OF 2
4-9-65

TABLE 2. GROUND TRUTH DATA—PHOENIX, ARIZONA, TEST RANGE

GEOLOGY (Rock Type, Alluvium, Bedrock, Soils, etc.)
- a. Valley Fill. Small dry lake bed to northeast of point.
- b. Remarks: Slightly undulating surface

SOIL (Gravel, Rock, Clay, Silt, etc.)
- a. Sandy silt.
- b. Remarks:

COLOR OF TERRAIN (Violet, Purple, Blue, Bluish Green, Green, Yellow, Red, etc.)
- a. Light tan, grayish. Munsell-10YR 6/2
- b. Remarks:

MOISTURE (Perennially Dry, Wet, Marsh, Flooded, Irrigated, etc.)
- a. Always dry.
- b. Remarks:

SURFACE DRAINAGE (Ditches, Washes, Gullies, Streams, etc.)
- a. Very little.
- b. Remarks:

VEGETATION (Grass, Crops, Bush, Trees, etc.)
- a. Mustard 3 inches. Scattered saltbush, to 24 inches.
- b. Remarks: Widely scattered mesquite 12 feet.
- c. Base soil in small lakebed to northeast.

ROADS (Dirt, Gravel, Clay, Black Top, Concrete, etc.)
- a. Blacktop
- b. Remarks:

BUILDINGS (Wood, Stone, Adobe, Canvas, etc.)
- a. none
- b. Remarks:

CONTROL POINT	DATE	TIME	WEATHER	RECORDER
R-18	23 June 1966	0830	clear 98 Deg	Shepard

information, origin, landform, drainage pattern, gully shape and gradient erosional features, photone, landuse vegetation and surface materials. Cultural features were also recorded. Total time required to perform the photointerpretation and record natural and cultural features was 22.5 hours for 30,000 feet photography, 13 hours for 20,000 feet photography, and 13 hours for 10,000 feet photography. The interpreter was able to reach a conclusion as to the type of soils observed in the area when halfway through the study of 1:40,000-scale photographs. The predominant soil is silt with some sand ridges scattered throughout the area. This conclusion was reached through an analysis of pattern elements recorded in the data format. Important pattern elements and gully shapes were detectable in the 1:40,000-scale photographs. Figure 6 and Plates 2 and 3 show types of photographs made over the Arizona Test Area.

KEY WEST AERIAL COLOR PHOTOGRAPHY TEST

Employing the same techniques used in the Arizona Test, the Defense Intelligence Agency arranged for a Naval Oceanographic Test with color photography to be made over the offshore reefs near Key West, Florida, to determine water penetration capabilities of color and false color films as compared to panchromatic films for offshore bottom mapping. This work is covered in a preliminary report by Mr. William Vary, U. S. Naval Oceanographic Office, at the 1967 Semi-Annual Meeting in St. Louis, Missouri (13). The results of water-penetration capabilities for the color photography were not surprising; however what was surprising was the penetration capability of the Ektachrome Infrared. It was originally theorized that there would be very little infrared return from the ocean; yet from altitudes of 2,000 and 5,000 feet considerable bottom detail was recorded. In shallow water less than 15 feet deep, floating seaweed, when viewed stereoscopically, appeared to be suspended in space with no sign of the water except for change in color. Reflectance from shoreline sand and coral rock appears to be very high.

NEED FOR TESTING PROGRAM

In many of the preceding tests, the Government participated in order to obtain needed performance statistics; industry participated obviously to sell more products and build a market for future developments. Controls are sketchy when they are developed as each situation arises, with no clearcut central

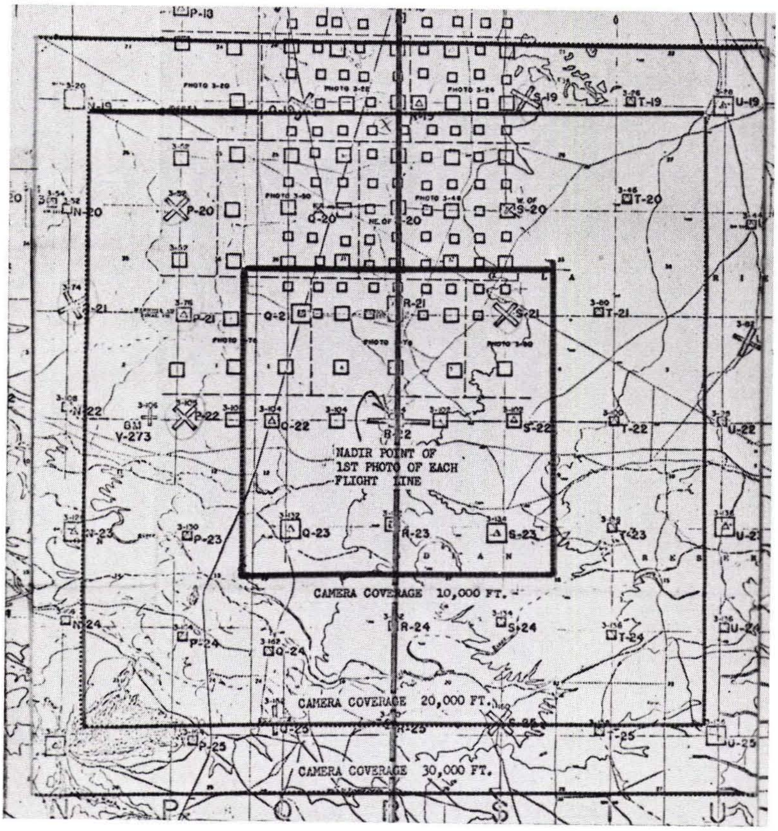

FIG. 5. Test area and photograph coverage for each flight height.

authority for monitoring the tests. The American Society of Photogrammetry Color Photography Committee filled a void which should not have existed. It did as well as it could, with no money or authority, by furnishing desirable guidance in the hope that each organization would fully participate, if only for its own interest.

In the opinion of the writer (not necessarily that of the Government), because mapping, resources exploration and military intelligence are recognized Government functions,

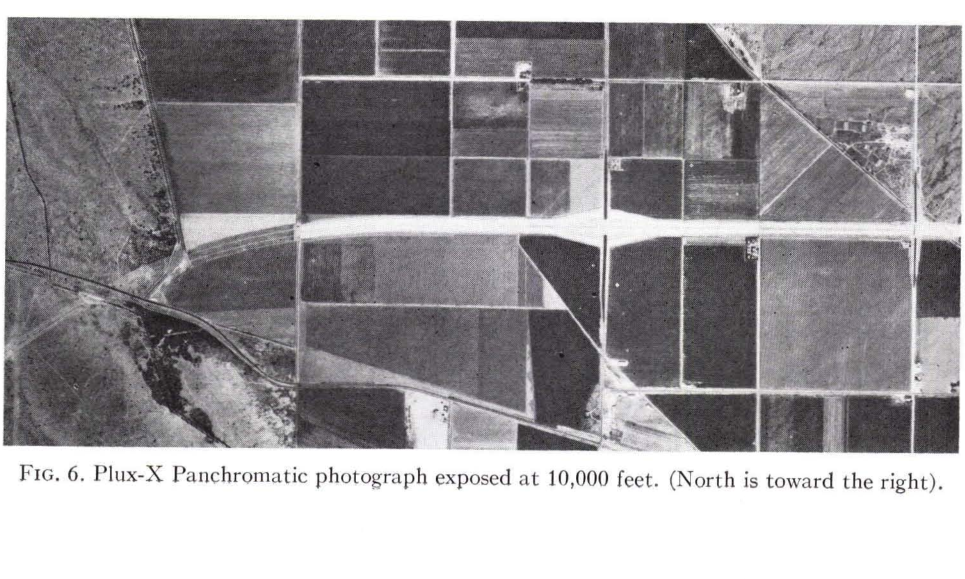

FIG. 6. Plux-X Panchromatic photograph exposed at 10,000 feet. (North is toward the right).

it is obvious that the Government must set standards, just as it does in other similar fields. As the Government serves all of us, the standards should be impartial with regard to industry versus Government or one Agency versus another.

The division of responsibility for the testing program in aerial color photography could be made the function of an Intergovernmental Remote Sensing Committee, with each Agency involved in its use participating as a member. Industry would be invited to participate as advisors in products; the division of work would be the same as has been done for black-and-white photography; camera specifications by one Agency, film standards by another. Specific test sites would be selected, standard control targets established and standards prepared for emulsions, cameras, and methods of processing aerial color photography.

With such standards prepared and in effect, more predictable results would be obtained when aerial color photography is used for a specific purpose; time and effort would be saved, improved terrain data should become available for mapping and photographic interpretation.

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5. Anson, A. "The Use of Aerial Color Photography for the Reconnaissance of Soils and Rocks," American Society for Testing and Materials, Committee D-18; presented at the Annual Meeting, Boston, Mass., 18 June 1967