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APOLLO 9 MULTISPECTRAL PHOTOGRAPHIC INFORMATION

Compiled by John L. Kaltenbach

Manned Spacecraft Center
Houston, Texas

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16. ABSTRACT

The NASA Experiment S065 multispectral photography flown on the Apollo 9 mission provided orbital photography of the earth. The photography was taken by four cameras, each of which contained a different film-filter combination. Special color viewing and reproduction systems are being used to determine the use and value of multispectral photography to the earth resources disciplines and to apply these findings to the design of future imaging systems.

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I. INTRODUCTION

By Robert O. Piland
Acting Chief, Earth Resources Division
NASA Manned Spacecraft Center
Houston, Texas

The Apollo 9 multispectral cameras provided 127 frames of photography in four different bands of the visible and near-infrared portions of the spectrum. These cameras provided the first NASA multispectral photography of the earth taken from an orbiting spacecraft.

The purpose of this document is to explain the four-camera experiment (hereafter referred to as Experiment S065), to discuss the method the investigators plan for use and analysis of multispectral photography, and to provide an index of the photography. Since the major advantage of multispectral photography is realized when the reflectivity of an object can be compared simultaneously in two or more portions of the spectrum, the last section of this document demonstrates a method whereby a simple and inexpensive additive color viewer can be constructed.

Investigators in the NASA Earth Resources Program may obtain duplicates of the Apollo 9 multispectral photography by writing to the Earth Resources Division, NASA Manned Spacecraft Center (MSC), Houston, Texas. All other requests for this photography may be made to the following address:

Technology Application Center
University of New Mexico
Albuquerque, New Mexico 87106

II. THE RATIONALE GOVERNING THE SELECTION OF CERTAIN WAVELENGTH BANDS FOR USE IN OBTAINING AERIAL AND SPACE PHOTOGRAPHY UNDER THE NASA EARTH RESOURCES SURVEY PROGRAM

By Robert N. Colwell
Forestry Remote Sensing Laboratory
University of California
Berkeley, California

The energy sensed when obtaining aerial or space photography of the earth surface is electromagnetic radiative energy. The primary source of electromagnetic radiative energy is the sun, which illuminates objects on the earth surface. These objects reflect the illuminated energy, which is sensed when the objects are photographed.

Electromagnetic energy travels in a wavelike motion, and the distance from one wave crest to the next is termed the wavelength. Typically, a beam of electromagnetic energy is composed of many wavelengths comprising a spectrum. The energy spectrum used in obtaining aerial and space photography of the earth surface is comprised of wavelengths ranging from approximately 400 to 900 millimicrons. Because of excessive scattering by haze particles, wavelengths shorter than 400 millimicrons can rarely be used when taking aerial or space photography of the earth surface. This phenomenon is related to Rayleigh's law. Wavelengths longer than approximately 900 millimicrons can rarely be used because of the problems involved in preparing thermostable photographic emulsions of sufficiently fine grain size.

The 400- to 900-millimicron range of wavelengths embraces all colors of the visible spectrum (violet, indigo, blue, green, yellow, orange, and red) together with wavelengths slightly longer than the visible red region of the spectrum, known as the near-infrared region. The 400- to 900-millimicron range is composed of four wavelength bands, of which three are in the visible region and one is in the infrared region of the spectrum. The three visible bands correspond to the three primary colors: blue, green, and red. The wavelengths embraced by the four bands are approximately as follows:

Band	Wavelength range, mμ
Blue	400 to 500
Green	500 to 600
Red	600 to 700
Infrared	700 to 900

An aerial or space photograph can be taken in any one of these bands by (1) using a photographic film sufficiently sensitive to energy in that band and (2) using a filter which, while transmitting energy within that band, effectively excludes energy of all other wavelengths to which the film is sensitive.

To determine the most appropriate wavelength bands for taking aerial or space photography of the earth surface, two factors require consideration: (1) the degree to which objects on the earth surface reflect energy in the bands being considered and (2) the extent to which radiant energy from the bands is scattered by haze particles in the atmosphere. (The sharpness of the photographic image varies inversely with the amount of radiant energy scattered by the atmosphere.) In the following discussions, these two factors are discussed separately.

ENERGY REFLECTANCE FROM THE OBJECTS TO BE PHOTOGRAPHED

As previously stated, only the energy reflected by objects is used in photography. An increase in the energy reflected by an object to the camera in a given wavelength band causes an increase in the image brightness of the object photographed in that band. (That is, the object will display a lighter tone on the photographic positive.) Since the amount of energy reflected in a given band tends to be a function of the type of object, the tones obtained (object by object) when photographing in that band are important aids in the identification of the object.

In many instances, two types of objects may contain essentially the same reflectivity in one band, but different reflectivities in another band; that is, each type of object tends to exhibit a unique "tone signature" in multispectral photography. This tone signature is of great value in identifying the object.

The shape and texture of an object can also be used by the photographic interpreter as an identification aid. However, other factors being equal, the higher the altitude from which an aerial or space photograph is taken of the earth surface, the less detail of the object shape and texture can be seen. The inverse relationship of altitude to detail means that for high-altitude photographs, the photographic interpreter or the image-analyzing machine must rely on the tone signature for object identification.

ENERGY SCATTERING BY HAZE PARTICLES IN THE ATMOSPHERE

For haze particles of the size commonly encountered in the earth atmosphere, energy scattering conforms to Rayleigh's law, which states that energy scattering is inversely proportional to the fourth power of the wavelength of that energy. Since energy scattering causes a loss of image sharpness, short-wavelength bands (e.g., the blue band) are of less value when aerial or space photographs are taken of the earth surface. Consequently, the blue band was not recommended for use in the Experiment S065 multispectral photography.

SPECIFIC APPLICATIONS OF MULTIBAND PHOTOGRAPHY

To summarize the information presented previously, the following points should be made.

1. The wavelength range of the electromagnetic spectrum that is normally considered for direct photographic sensing of the earth surface is approximately 400 to 900 millimicrons.

2. The 400- to 900-millimicron range is comprised of four bands commonly called the blue, green, red, and infrared bands.

3. Most of the energy that characterizes any one of the four bands is derived from the central portion of that band.

4. The total energy spectrum is a continuum; therefore, each band overlaps a neighboring band. Consequently, various authorities disagree on the precise limits of each band. Such disagreement should cause no concern if the wavelengths comprising the central portion of each band are established. Table II-I provides three authoritative expressions of the wavelength range encompassed by each of the four bands. Table II-II indicates the photographic identification that can be accomplished by using the four bands. Figure II-1 provides the approximate spectral relative sensitivity of the film-filter combinations used on Experiment S065 (refs. II-1 and II-2). Of the three diagrams comprising figure II-1, figure II-1(c) shows the effective sensitivity of Ektachrome infrared film when used in conjunction with a Photar 15 orange filter, as on Experiment S065. An important objective of the experiment consists of determining whether more information is obtained by color combining the three black and white photographs than can be obtained from the matching Ektachrome infrared photograph. (One means of color combining is described in section IV of this report.) Because of the unusual colors with which features are rendered on Ektachrome infrared film, it is important that the unique properties of this film, as described in the following paragraphs, are understood. Emphasis is given to explaining why healthy vegetation appears red on photography taken with this film.

Ektachrome infrared type SO-180 is known as a "subtractive reversal" color film. In such a film, the dye responses, when the film is processed, are inversely proportional to the exposures received by the respective emulsion layers. In devising Ektachrome infrared film, the manufacturers had one major objective in mind — that of causing healthy vegetation to exhibit a strong photographic color contrast with respect to all other features. More specifically, it was decided that a subtractive-reversal photographic film should be devised on which healthy vegetation would appear bright red, while everything else would appear in colors other than red. To accomplish this objective, it was necessary to exploit the fact that healthy vegetation exhibits very high infrared reflectance and relatively low visible-light reflectance. Thus, when the manufacturers were devising the three-layer emulsion of Ektachrome infrared film, they linked a cyan dye to the infrared-sensitive layer of the film, and they linked yellow and magenta dyes to the green- and red-sensitive layers, respectively.

Consistent with the foregoing and with the reminder that the dye responses are inversely proportional to the exposures received, the following responses occur in each area of the Ektachrome infrared film on which healthy vegetation is imaged: (1) A large amount of the yellow and magenta dyes are left in the film after processing, because the film is only weakly exposed to red and green wavelengths to which the yellow and magenta dyes, respectively, are linked; and (2) little or no cyan dye is left in the film after processing because the film is strongly exposed by infrared wavelengths to which the cyan dye is linked.

When the processed Ektachrome infrared film, in transparency form, is viewed over a light table through which white light is shining (i.e., light which contains approximately equal amounts of blue, green, and red), the following factors are operative in the parts of the transparency where healthy vegetation is imaged: (1) The concentration of yellow dye is so high that blue light is almost completely absorbed, (2) the concentration of cyan dye is so high that green light is almost completely absorbed, and (3) the concentration of magenta dye is so low that red light is almost completely transmitted. The net result of these factors is to cause the healthy vegetation to appear red. Since virtually no other features have this peculiar combination of spectral reflectances, no other features appear red on the transparency.

REFERENCES

II-1. Colwell, R. N., et al.: An Evaluation of Earth Resources Using Apollo 9 Photography. (Final report by the Forestry Remote Sensing Laboratory, School of Forestry and Conservation, Univ. of California, under NASA contract NAS 9-9348), Sept. 30, 1968.

II-2. Keenan, P. B.; and Slater, P. N.: Preliminary Post-Flight Calibration Report on Apollo 9 Multiband Photography Experiment S065. Technical Memorandum 1, Optical Sciences Center, Univ. of Arizona, Tucson, Ariz., Sept. 12, 1969.

TABLE II-I. - CONVENTIONAL WAVELENGTH RANGES

Band	Wavelength range, mμ		
	Elementary physics	Apollo 9 Experiment S065	Proposed for ERTS[a]
Blue	400 to 500	--	--
Green	500 to 600	480 to 620	475 to 575
Red	600 to 700	590 to 720	580 to 680
Infrared (near infrared)	700 to 900	720 to 900	690 to 830

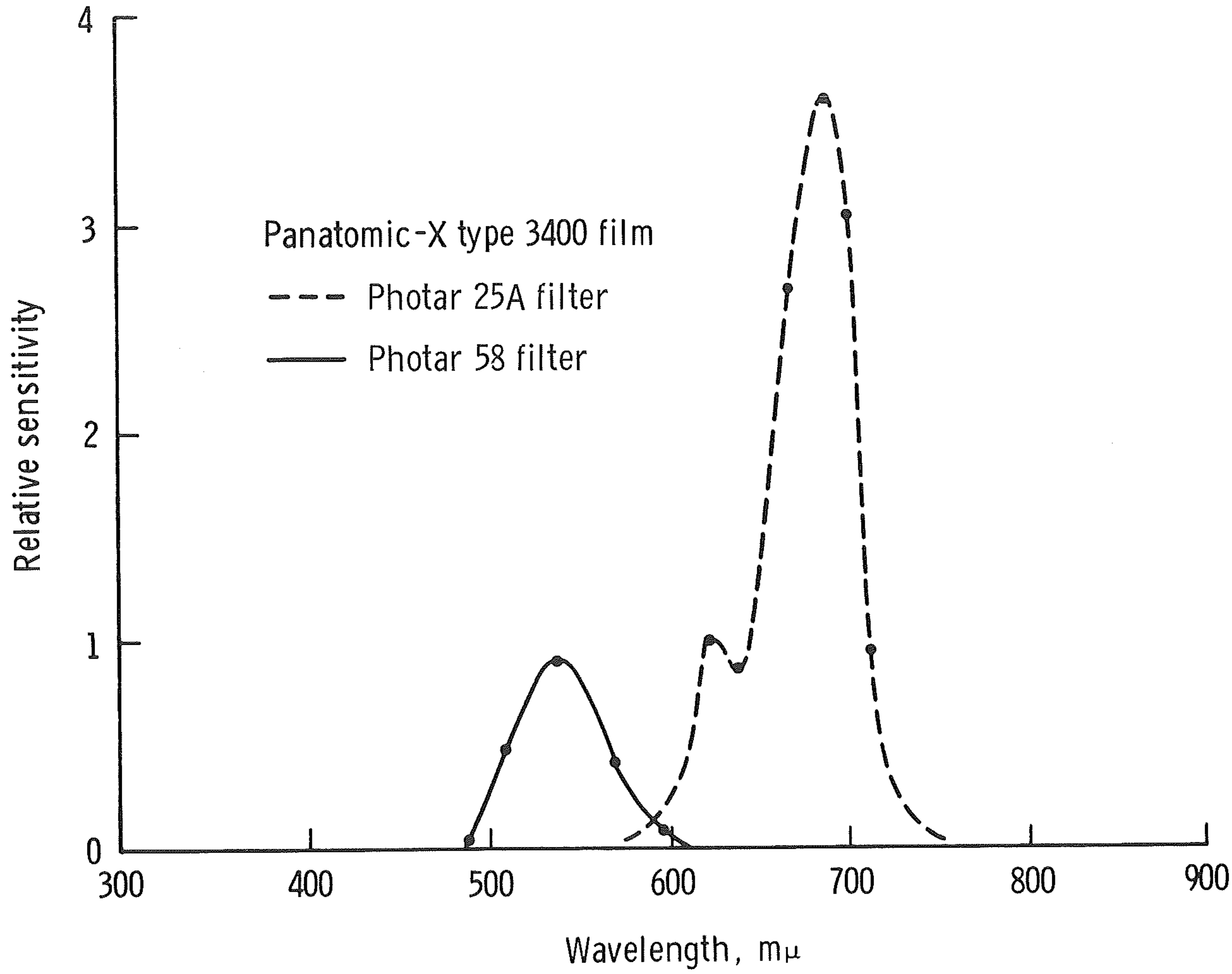
[a]Earth Resources Technology Satellite.

TABLE II-II. - OPTIMUM WAVELENGTHS FOR

PHOTOGRAPHING NATURAL PHENOMENA

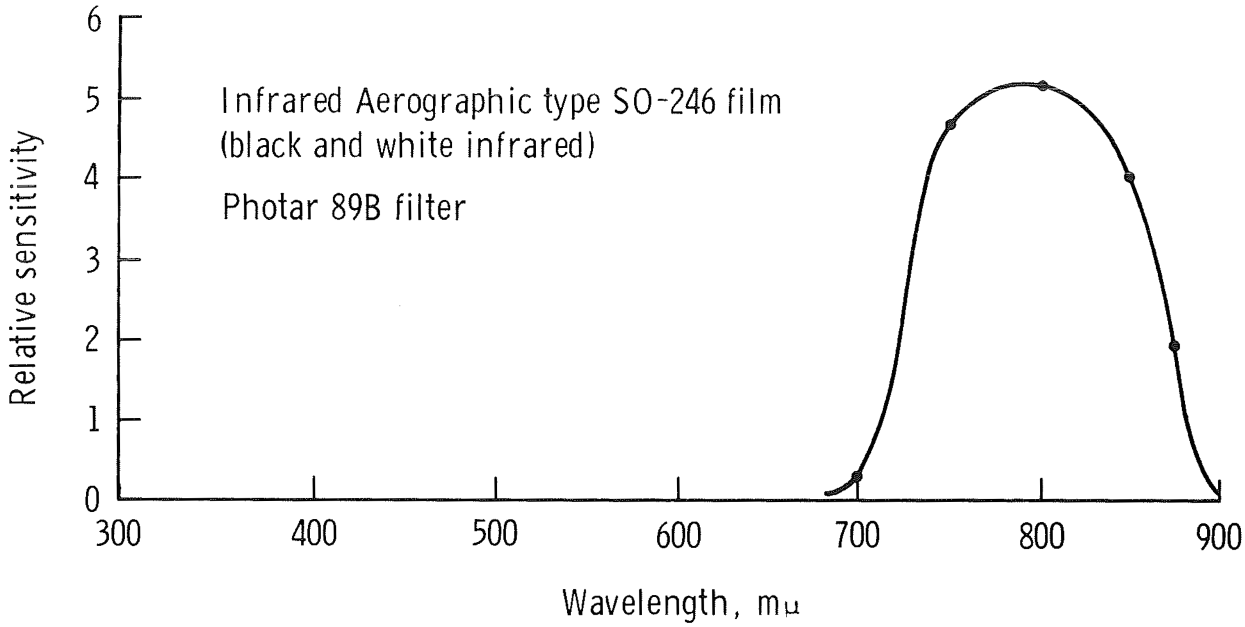
Photograph identification	Optimum wavelength band			
	Blue (a)	Green	Red	Infrared
Presence or absence of vegetation			X	X
Differentiation of conifers from broadleaf vegetation				X
Identification of individual plant species		X	X	X
Detection of earliest evidence of loss of vigor in vegetation				X
Identification of agent that causes loss of vigor		X	X	
Determination of the exact course of a meandering stream channel				X
Acquisition of maximum underwater detail (varies with turbidity)		X	X	
Determination of maximum detail in shaded areas on low-altitude photographs only	X			
Identification of geologic formations	X	X	X	X
Differentiation of urban area components		X	X	X

[a]No earth-orbital sensing in the blue band is contemplated because of excessive scattering of short wavelengths by atmospheric haze particles.

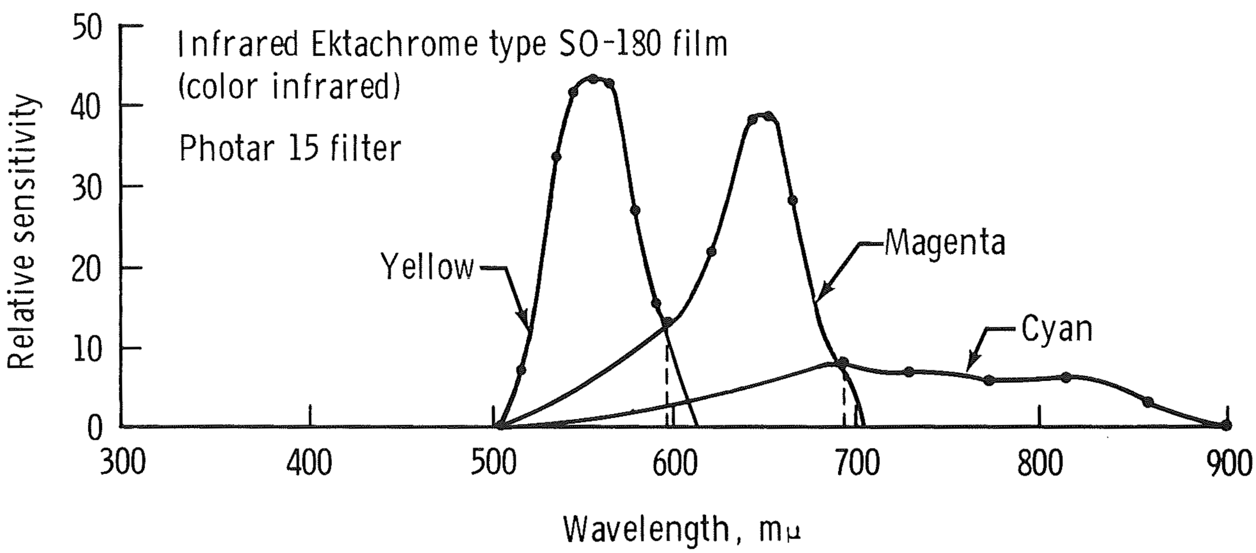


(a) Panatomic-X type 3400 film, Photar 25A red and Photar 58 green filters.

Figure II-1. - Relative sensitivity as a function of photographic film-filter combination.



(b) Aerographic type SO-246 infrared film (black and white), Photar 89B dark red filter.



(c) Ektachrome type SO-180 infrared film (color), Photar 15 orange filter.

Figure II-1. - Concluded.

III. GENERAL INFORMATION ON NASA EXPERIMENT S065 MULTISPECTRAL PHOTOGRAPHY

By Paul D. Lowman
NASA Goddard Space Flight Center
Greenbelt, Maryland

The value of color photography taken from an orbiting spacecraft was demonstrated by studies of photography taken of the earth during flights in the Mercury, Gemini, and early Apollo programs. The value of multispectral aerial photography in many fields has been demonstrated over the last several years. Experiment S065 flown on Apollo 9 was the first attempt to obtain multispectral photography from space and, thus, to combine the benefits of color photography and multispectral photography to remote sensing.

The purpose of Experiment S065 was to obtain simultaneous photographs of the earth from space, using four different spectral sensitivities (film-filter combinations) and a four-camera assembly mounted in the Apollo spacecraft hatch window (fig. III-1). The specific objectives of the experiment were (1) to investigate the feasibility and value of orbital multispectral photography for studies in meteorology and in the earth resources disciplines of agriculture, forestry, geography, geology, hydrology, and oceanography and (2) to apply the results of the investigation to future manned and unmanned photographic systems design.

EQUIPMENT

Electrically driven Hasselblad cameras, model 500 EL, equipped with the f/2.8 Zeiss 80-millimeter Planar lens, were used for Experiment S065. The cameras were modified for space use by the Hasselblad Company and MSC and were mounted coaxially on a metal bracket designed to fit the circular command module hatch window. The shutters were triggered simultaneously at predetermined intervals (generally between 5 and 10 seconds) by a manual electric switch controlled by the astronaut taking the photograph.

The following film-filter combinations were used:

1. Infrared Ektachrome type SO-180 film (color infrared), with a Photar 15 filter, sensitive in the 510- to 900-millimicron range

2. Panatomic-X type 3400 film (black and white panchromatic), with a Photar 58 filter, sensitive in the 460- to 610-millimicron range

3. Infrared Aerographic type SO-246 film (black and white infrared), with a Photar 89B filter, sensitive in the 700- to 900-millimicron range

4. Panatomic-X type 3400 film (black and white panchromatic), with a Photar 25A filter, sensitive in the 580-millimicron to infrared range

METHOD OF OPERATION

The following main steps were performed by the flightcrew for each Experiment S065 photographic pass:

1. Unstow and install the camera unit in the hatch window.

2. Orient the spacecraft vertically according to ground instructions.

3. Place the spacecraft in an orbital rate mode (to keep the spacecraft pointed in a given direction relative to the earth).

4. Take photographs beginning and ending at times specified by the Mission Control Center, Houston, Texas.

5. Record the ground elapsed time of the first exposure and the number of exposures in each sequence.

6. Terminate the orbital rate mode and stow the cameras (unless a second pass is scheduled subsequently).

The cameras were preset so that no adjustments by the flightcrew were necessary. Since the earth surface was visible through the side windows when the hatch window was parallel to the surface during several of the Experiment S065 passes, the flightcrew was able to take nearly simultaneous terrain photographs using the hand-held Hasselblad 500C camera loaded with Ektachrome SO-368 film.

RESULT

The flightcrew encountered no difficulty in conducting Experiment S065 and taking photographs during five passes over North America. The number of photographs obtained for each film type was as follows: Panatomic-X (both magazines), 159 photographs per magazine; infrared Aerographic, 127 photographs per magazine, and infrared Ektachrome, 139 photographs per magazine. The number of complete four-camera sets is 127. The regions photographed included southwestern United States (south of 34° north latitude), northwestern Mexico, south central and southeastern United States, southern Mexico, and the Caribbean-Atlantic region (figs. III-2 and III-3).

Experiment S065 was extremely successful, both in the quality and in the quantity of the photography obtained (fig. III-4). During the five passes over North America and the adjacent ocean areas, 372 photographs (the four-camera total) showing a significant portion of the cloud-free landmass were obtained. The quality of all the photographs ranged from very good to excellent. A few frames taken of northern Chihuahua, Mexico, appeared to be slightly overexposed, but this condition probably resulted from a high sun angle and a bright desert terrain, together with the fixed setting. Several of the NASA test sites, including those in the Imperial Valley and Phoenix, Arizona, were photographed at about the same time that aircraft underflights were being flown. A wide variety of terrain, including the Colorado, Yuma, Chihuahua, and Sonora Deserts; the forested mountains; the Great Plains; the Mississippi Valley; the southern Appalachians and the adjacent Piedmont; and the southeastern Coastal Plain, was photographed. The climatic-seasonal range (caused by elevation differences) spans early summer to winter with many regions remaining partly snow covered. Several large cities (including San Diego, California; southern Los Angeles, California; Phoenix, Arizona; Atlanta, Georgia; and Birmingham, Alabama) were photographed. The Experiment S065 photography taken during the Apollo 9 mission has scientific value for its areal coverage, scale, and general quality alone. However, the fact that the photography was taken as part of a systematic multispectral experiment with simultaneous underflights by NASA Earth Resources Program aircraft greatly increases its value. The current detailed analysis of Experiment S065 photography and supporting data is expected to be substantially beneficial to the Earth Resources Survey Program. A list of all the photographs taken during Experiment S065 is given in table III-I.

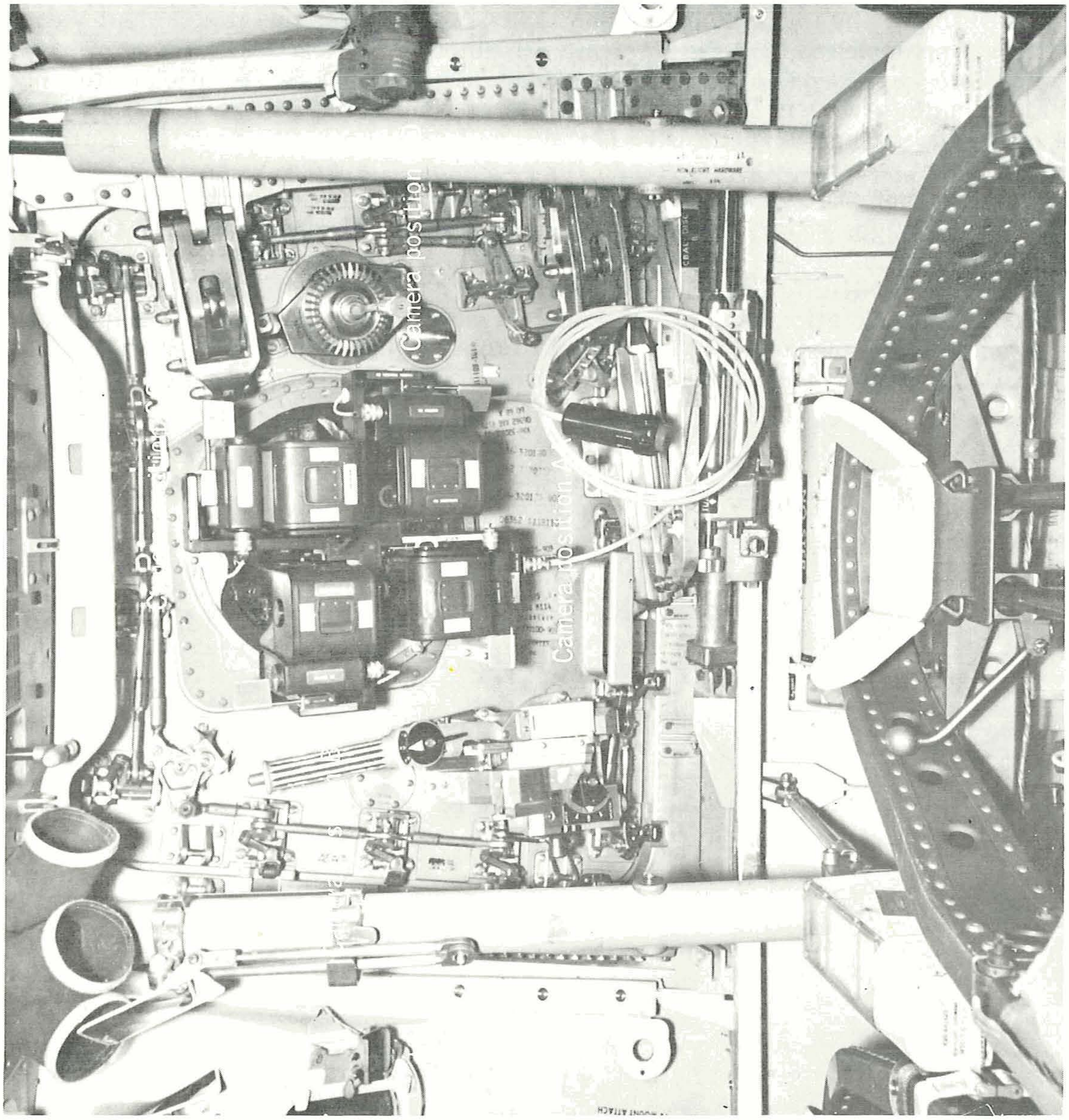


Figure III-1. - Experiment S065 camera arrangement relative to flight path.

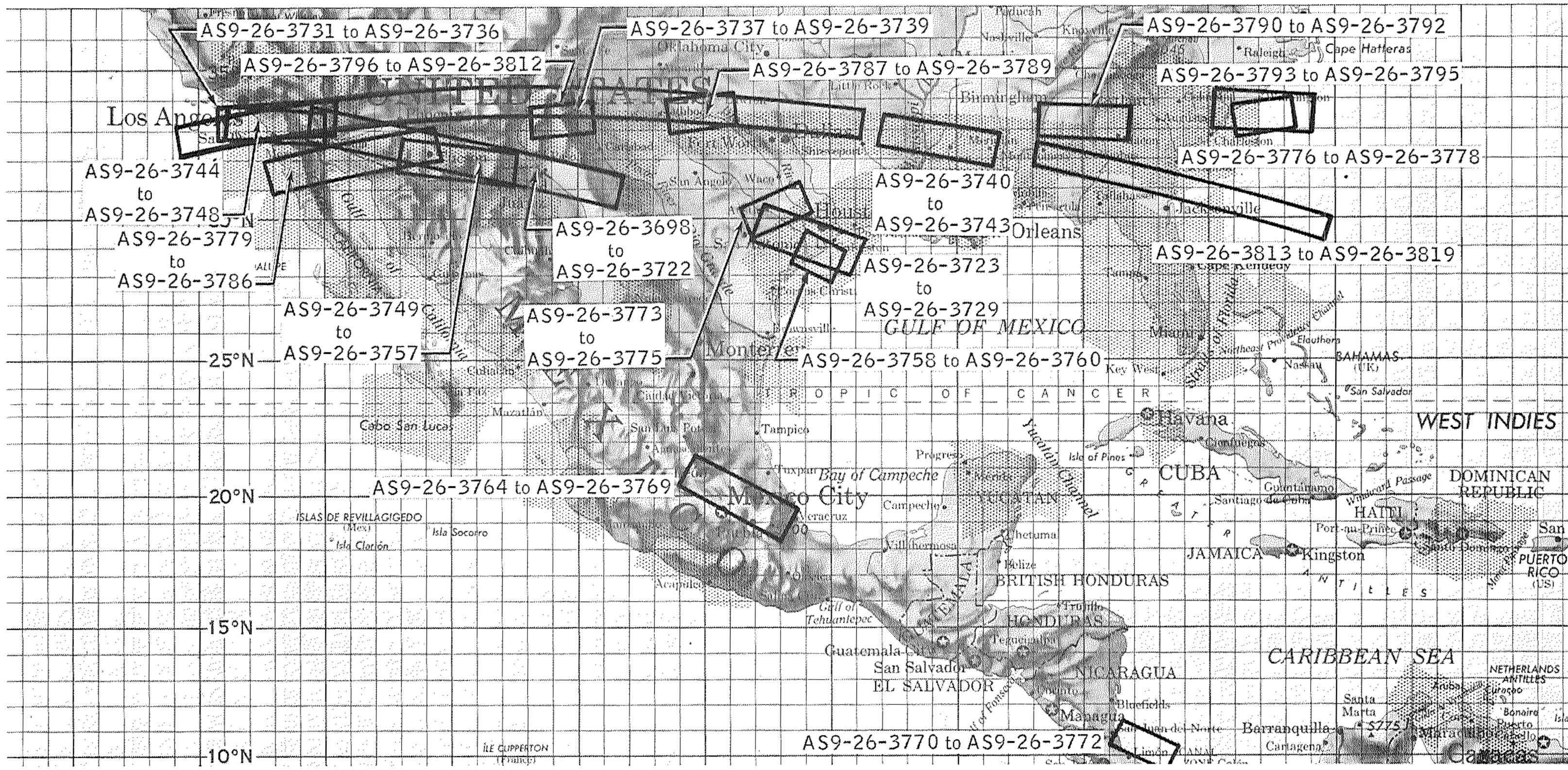


Figure III-2. - Apollo 9 Experiment S065 multispectral photography index map (southwestern United States, northwestern Mexico, south central and southeastern United States, and southern Mexico).

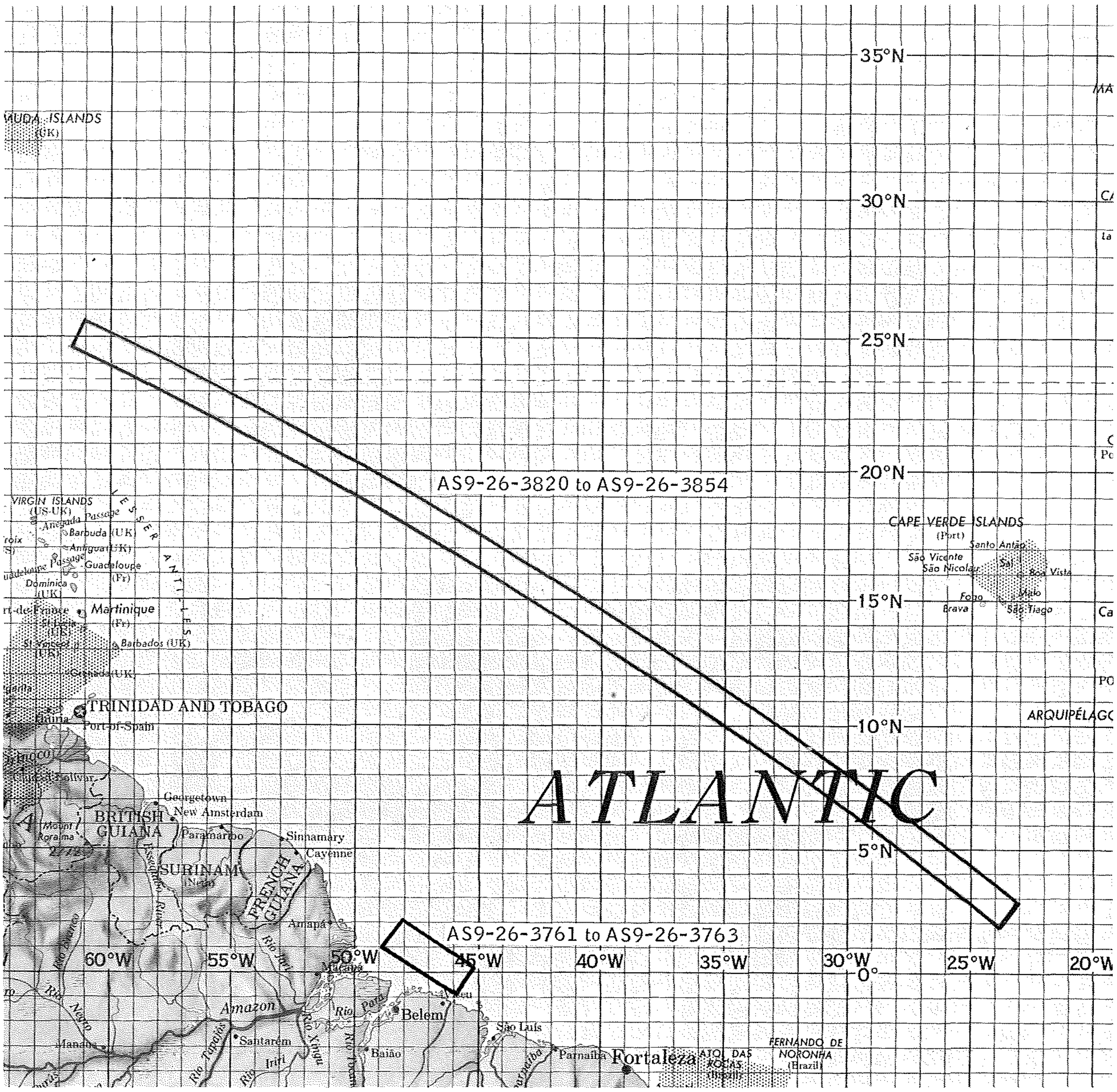
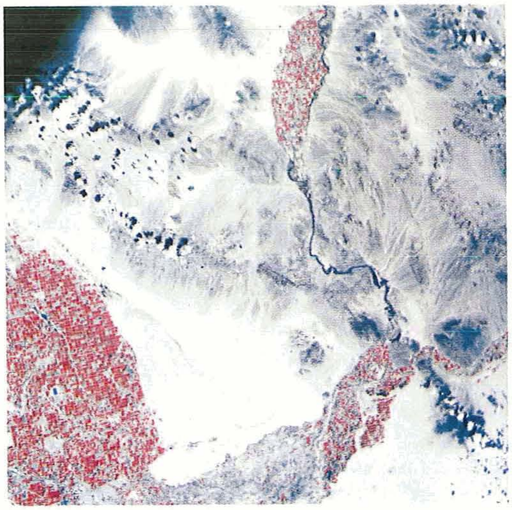
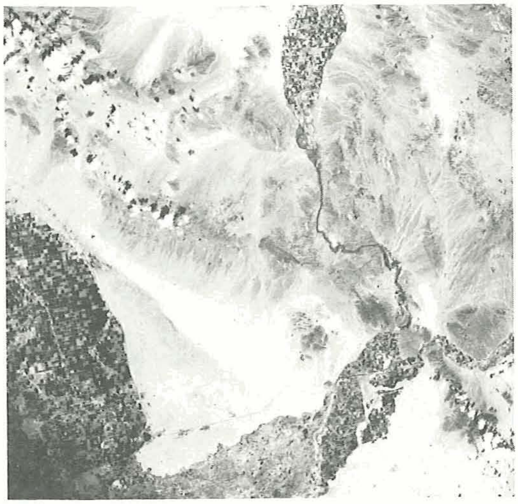


Figure III-3. - Apollo 9 Experiment S065 multispectral photography index map (Caribbean-Atlantic region).



(a) Photograph NASA AS9-26A-3699A taken with Ektachrome type SO-180 infrared aerial film (color) with a Photar 15 orange filter.

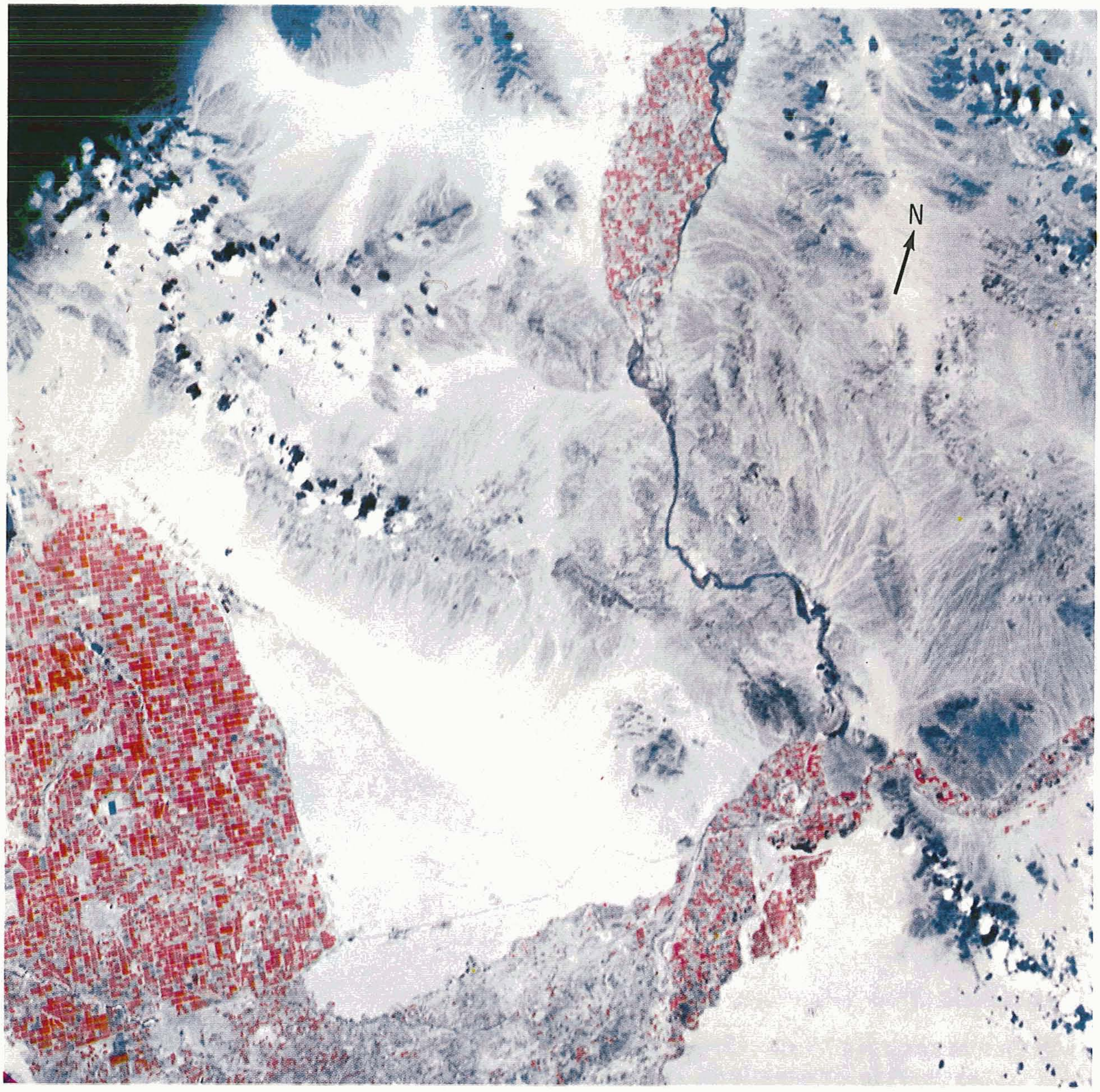
(b) Photograph NASA AS9-26B-3699B taken with Panatomic-X type 3400 aerial film (black and white) with a Photar 58 green filter.



(c) Photograph NASA AS9-26D-3699D taken with Panatomic-X type 3400 aerial film (black and white) with a Photar 25A red filter.

(d) Photograph NASA AS9-26C-3699C taken with Aerographic type SO-246 infrared film (black and white) with a Photar 89B dark red filter.

Figure III-4. - Examples for the NASA Experiment S065 multispectral photography on Apollo 9.



(e) AS9-26A-3699A. Imperial Valley of California and Mexico, Colorado River, Gila River, All-American Canal, Giant Sand Dunes.

Figure III-4. - Continued.

(f) AS9-26B-3699B.

Figure III-4. - Continued.

(g) NASA AS9-26D-3699D.

Figure III-4. - Continued.

(h) NASA AS9-26C-3699C.

Figure III-4. - Concluded.

TABLE III-I. - PHOTOGRAPHIC INDEX OF EXPERIMENT S065 MULTISPECTRAL PHOTOGRAPHS

[From magazine AS9-26]

Frame number	Date in March 1969	Principal point		Overlap, percent	Image evaluation	Sun elevation, deg	G. m. t.	Altitude, n. mi.	ONC WAC number (a)	Cloud cover, percent	Description
		Latitude	Longitude								
3696	8				Normal	53	20:01	105			Earth limb, clouds, oblique
3697	8				Normal	53	20:01	105			Earth limb, clouds, ocean, oblique
3698	8	33°00'' N	114°53'' W	80	Normal	53	20:01	105	G-18	5	California: Salton Sea, Imperial Valley, and El Centro Mexico: Mexicali and San Luis Arizona: Yuma and Cibola
3699	8	33°05'' N	114°50'' W	80	Normal	53	20:01	105	G-18	5	California: Imperial Valley and El Centro Mexico: Mexicali and San Luis Arizona: Yuma and Cibola
3700	8	33°04'' N	114°45'' W	80	Normal	53	20:01	105	G-18	5	California: Imperial Valley and El Centro Mexico: Mexicali and San Luis Arizona: Yuma and Cibola
3701	8	33°03'' N	114°26'' W	80	Normal	53	20:01	105	G-18	5	Arizona: Yuma and Cibola Mexico: San Luis
3702	8	32°55'' N	113°56'' W	80	Normal	53	20:01	105	G-18	5	Arizona: Yuma and Cibola
3703	8	32°53'' N	113°31'' W	80	Normal	53	20:01	105	G-18	7	Arizona: East of Yuma and Gila Bend
3704	8	32°47'' N	113°03'' W	80	Normal	53	20:01	105	G-18	10	Arizona: East of Yuma and Gila Bend
3705	8	32°44'' N	112°26'' W	80	Normal	53	20:01	105	G-18	20	Arizona: Gila Bend, Casa Grande, and south of Phoenix
3706	8	32°41'' N	111°50'' W	80	Normal	53	20:01	105	G-18	35	Arizona: Casa Grande and Williams
3707	8	32°40'' N	111°20'' W	80	Normal	53	20:01	105	G-18	45	Arizona: Williams
3708	8	32°35'' N	111°03'' W	80	Normal	53	20:01	105	G-19	55	Arizona: Williams
3709	8	32°33'' N	110°32'' W	80	Normal	53	20:01	105	G-19	75	Arizona: Tucson
3710	8	32°22'' N	110°04'' W	80	Normal	53	20:01	105	G-19	75	Arizona: Willcox Lake
3711	8	32°08'' N	109°27'' W	80	Normal	53	20:01	105	G-19	75	Arizona: Willcox Lake
3712	8	31°53'' N	108°51'' W	80	Normal	53	20:01	105	H-23	80	New Mexico and Mexico border, southwest of Deming
3713	8	31°43'' N	108°18'' W	80	Normal	53	20:02	105	H-23	80	New Mexico and Mexico border. south of Deming
3714	8	31°35'' N	107°48'' W	80	Normal	53	20:02	105	H-23	70	New Mexico and Mexico border, south of Deming
3715	8	31°26'' N	107°14'' W	80	Normal	53	20:02	105	H-23	70	Mexico and Texas border, southwest of El Paso
3716	8	31°16'' N	106°45'' W	80	Normal	53	20:02	105	H-23	60	Mexico and Texas, south-southwest of El Paso
3717	8	31°09'' N	106°10'' W	80	Normal	53	20:02	105	H-23	50	Texas: Rio Grande Valley and Quitman Mountains Mexico: Sierra San Martin Del Borracho
3718	8	31°08'' N	105°39'' W	80	Normal	53	20:02	105	H-23	40	Texas: Rio Grande Valley
3719	8	31°05'' N	105°09'' W	80	Normal	53	20:02	105	H-23	40	Texas: Rio Grande Valley and Van Horn
3720	8	31°04'' N	104°42'' W	80	Normal	53	20:02	105	H-23	30	Texas: Van Horn and Pecos
3721	8	31°02'' N	104°18'' W	80	Normal	53	20:02	105	H-23	25	Texas: Van Horn, Pecos, and Red Bluff Lake
3722	8	30°59'' N	103°57'' W	80	Normal	53	20:02	105	H-23	20	Texas: Pecos and Red Bluff Lake

[a]Operational Navigational Chart; World Aeronautical Chart.

TABLE III-I. - PHOTOGRAPHIC INDEX OF EXPERIMENT S065 MULTISPECTRAL PHOTOGRAPHS - Continued

[From magazine AS9-26]

Frame number	Date in March 1969	Principal point		Overlap, percent	Image evaluation	Sun elevation, deg	G. m. t.	Altitude, n. mi.	ONC WAC number (a)	Cloud cover, percent	Description
		Latitude	Longitude								
3723	8	29°40'' N	97°15'' W	80	Normal	54	20:05	105	H-23	0	Texas: Austin, Port Lavaca, and Beeville
3724	8	29°26'' N	96°49'' W	80	Normal	54	20:05	105	H-24	0	Texas: Port Lavaca and Matagorda Bay
3725	8	29°22'' N	96°24'' W	80	Normal	54	20:05	105	H-24	0	Texas: Matagorda and Eagle Lake
3726	8	29°16'' N	96°08'' W	80	Normal	54	20:05	105	H-24	1	Texas: Matagorda, Eagle Lake, and Freeport
3727	8	29°07'' N	95°43'' W	80	Normal	54	20:05	105	H-24	2	Texas: Matagorda, Galveston Bay, and Houston
3728	8	29°04'' N	95°24'' W	80	Normal	54	20:05	105	H-24	2	Texas: Matagorda and Galveston Bay
3729	8	28°42'' N	94°54'' W	80	Normal	54	20:05	105	H-24	5	Texas: Galveston and Freeport
3730					Normal					99	Clouds, unintentionally exposed
3731	9	33°05'' N	118°33'' W	60	Normal	45	18:02	106	G-18	15	California: San Clemente, Santa Catalina, and Santa Barbara Islands: San Pedro Bay
3732	9	33°09'' N	117°50'' W	60	Normal	45	18:02	106	G-18	20	California: San Clemente and Santa Catalina Islands, San Pedro Bay, and northern San Diego
3733	9	33°13'' N	117°07'' W	60	Normal	45	18:02	106	G-18	40	California: Santa Ana to San Diego
3734	9	33°20'' N	116°36'' W	60	Normal	45	18:02	106	G-18	30	California: San Diego and Salton Sea
3735	9	33°22'' N	116°04'' W	60	Normal	45	18:02	106	G-18	40	California: Salton Sea and Imperial Valley
3736	9	33°26'' N	115°22'' W	60	Normal	45	18:03	106	G-18	45	California: Salton Sea and Imperial Valley Arizona: Cibola
3737	9	33°36'' N	106°31'' W	60	Normal	50	18:05	105	G-19	10	New Mexico: Socorro and Carrizozo and lava beds
3738	9	33°37'' N	105°40'' W	60	Normal	50	18:05	105	G-19	10	New Mexico: Carrizozo and lava beds
3739	9	33°39'' N	105°07'' W	60	Normal	50	18:05	105	G-19	10	New Mexico: Ruidoso and Roswell
3740	9	32°44'' N	91°58'' W	60	Normal	55	18:08	105	G-20	0	Louisiana: Monroe and Mississippi Valley
3741	9	32°41'' N	91°13'' W	60	Normal	55	18:08	105	G-20	1	Mississippi: Vicksburg, Mississippi Valley, and Greenville Bend
3742	9	32°38'' N	90°34'' W	60	Normal	55	18:08	105	G-20	3	Mississippi: Vicksburg, Mississippi Valley, Greenville Bend, and Jackson
3743	9	32°34'' N	89°57'' W	60	Normal	55	18:08	105	G-20	5	Mississippi: Jackson and Yazoo Valley
3744	9	33°16'' N	118°12'' W	50	Normal	45	19:35	103	G-18	25	California: Santa Catalina and San Clemente Islands, San Pedro Bay region, and Oceanside
3745	9	33°15'' N	117°33'' W	50	Normal	45	19:35	103	G-18	35	California: Oceanside
3746	9	33°12'' N	116°56'' W	50	Normal	45	19:35	103	G-18	40	California: Oceanside and Santa Ysabeh
3747	9	33°09'' N	116°14'' W	50	Normal	45	19:36	103	G-18	35	California: Salton Sea and Imperial Valley
3748	9	33°03'' N	115°45'' W	50	Normal	45	19:36	103	G-18	30	California: Salton Sea and Imperial Valley Mexico: Mexicali
3749	9	32°05'' N	111°22'' W	70	Normal	55	19:37	103	G-19 H-22	35	Arizona: Tucson

[a]Operational Navigational Chart; World Aeronautical Chart.

TABLE III-I. - PHOTOGRAPHIC INDEX OF EXPERIMENT S065 MULTISPECTRAL PHOTOGRAPHS - Continued

[From magazine AS9-26]

Frame number	Date in March 1969	Principal point		Overlap, percent	Image evaluation	Sun elevation, deg	G. m. t.	Altitude, n. mi.	ONC WAC number (a)	Cloud cover, percent	Description
		Latitude	Longitude								
3750	9	32°05'' N	110°49'' W	70	Normal	55	19:37	103	G-19 H-22	30	Arizona: Tucson and Ft. Huachuca
3751	9	32°05'' N	110°20'' W	70	Normal	55	19:37	103	G-19 H-22	25	Arizona: Ft. Huachuca and Willcox Lake
3752	9	32°05'' N	109°52'' W	70	Normal	55	19:37	103	H-22 G-19	20	Arizona: Willcox Lake and Ft. Huachuca
3753	9	32°02'' N	109°21'' W	70	Normal	55	19:37	103	H-22 H-23 G-19	15	Arizona: Willcox Lake
3754	9	31°56'' N	108°57'' W	70	Normal	55	19:37	103	H-22 H-23 G-19	10	Arizona: southeast of Willcox Lake
3755	9	31°54'' N	108°40'' W	70	Normal	55	19:37	103	H-23 G-19	5	Arizona: southeast of Willcox Lake
3756	9	31°54'' N	108°20'' W	70	Normal	55	19:37	103	H-23 G-19	4	New Mexico: southwest of Deming
3757	9	31°53'' N	108°00'' W	70	Normal	55	19:38	103	H-23 G-19	2	New Mexico: southwest of Deming
3758	9	28°44'' N	95°58'' W	70	Normal	55	19:40	102	H-24	25	Texas: Matagorda Bay
3759	9	28°39'' N	95°38'' W	70	Normal	55	19:40	102	H-24	25	Texas: Matagorda Bay
3760	9	28°34'' N	95°18'' W	70	Normal	55	19:40	102	H-24	25	Texas: Matagorda Bay
3761	10	01°00'' N	48°00'' W	10	Normal	31	19:29	112	L-28 M-27	85	South America: clouds and ocean, mouth of Amazon River
3762	10	00°20'' N	47°00'' W	10	Normal	31	19:29	112	L-28 M-27	35	South America: clouds and ocean, mouth of Amazon River
3763	10	00°20'' S	46°00'' W	10	Normal	31	19:30	112	L-28 M-27	10	South America: clouds and ocean, mouth of Amazon River
3764	10	20°46'' N	100°15'' W	60	Normal	55	20:52	104	J-24	70	Mexico: northwest of Mexico City
3765	10	20°33'' N	99°38'' W	60	Normal	55	20:52	104	J-24	60	Mexico: northwest of Mexico City
3766	10	20°18'' N	99°00'' W	60	Normal	55	20:52	104	J-24	50	Mexico: north of Mexico City
3767	10	20°02'' N	98°24'' W	60	Normal	55	20:52	104	J-24	45	Mexico: northeast of Mexico City, Cerro La Malinche
3768	10	19°40'' N	97°49'' W	60	Normal	55	20:52	104	J-24	40	Mexico: Puebla and Cerro La Malinche Volcan
3769	10	19°11'' N	97°08'' W	60	Normal	55	20:52	104	J-24	75	Volcan Citlaltepeti
3770	10	10°31'' N	82°52'' W	41	Normal	41	20:57	124	K-25	35	Costa Rica: Limon and Caribbean Sea
3771	10	10°15'' N	82°52'' W	41	Normal	41	20:57	124	K-25	20	Costa Rica: Limon and Caribbean Sea
3772	10	09°57'' N	82°08'' W	41	Normal	41	20:57	124	K-25	20	Caribbean Sea
3773	11	30°05'' N	98°00'' W	60	Dark	22	14:42	126	H-23	100	Texas: clouds

[a]Operational Navigational Chart; World Aeronautical Chart.

TABLE III-I. - PHOTOGRAPHIC INDEX OF EXPERIMENT S065 MULTISPECTRAL PHOTOGRAPHS - Continued

[From magazine AS9-26]

Frame number	Date in March 1969	Principal point: Latitude	Principal point: Longitude	Overlap, percent	Image evaluation	Sun elevation, deg	G. m. t.	Altitude, n. mi.	ONC WAC number (a)	Cloud cover, percent	Description
3774	11	30°15'' N	97°10'' W	60	Dark	22	14:42	126	H-23	90	Texas: clouds
3775	11	30°30'' N	96°30'' W	50	Dark	22	14:43	126	H-23	80	Texas: College Station, clouds
3776	11	33°28'' N	78°23'' W	40	Normal	36	14:47	113	G-21	10	South Carolina: Cape Fear, Myrtle Beach, and Carolina Beach
3777	11	33°25'' N	77°58'' W	40	Normal	36	14:47	113	G-21	40	South Carolina: Cape Fear and Carolina Beach
3778	11	33°23'' N	77°22'' W	40	Normal	36	14:47	113	G-21	65	South Carolina: Carolina Beach
3779	11	31°19'' N	116°34'' W	50	Dark	31	16:14	126	H-22	30	Mexico: Baja California and Ensenada
3780	11	31°28'' N	115°42'' W	50	Dark	31	16:14	126	H-22	10	Mexico: Baja California Colorado River delta
3781	11	31°34'' N	115°04'' W	50	Normal	31	16:14	126	H-22	05	Mexico: Colorado River delta
3782	11	31°42'' N	114°13'' W	50	Normal	31	16:15	126	G-18 G-19 H-22	0	Mexico: Colorado River delta and Desierto Del Altar
3783	11	31°48'' N	113°30'' W	50	Normal	31	16:15	126	G-18 G-19 H-22	0	Mexico: Desierto Del Altar
3784	11	31°57'' N	112°39'' W	50	Normal	31	16:15	126	G-19 H-22	0	Mexico and Arizona: Desierto Del Altar
3785	11	32°06'' N	111°59'' W	50	Normal	31	16:15	126	G-19 H-22	03	Arizona: west of Tucson
3786	11	32°14'' N	111°18'' W	50	Normal	31	16:15	126	G-19 H-22	15	Arizona: Tucson and Casa Grande
3787	11	33°20'' N	100°41'' W	50	Normal	38	16:18	115	G-19	35	Texas: Paducah, north and northeast of Snyder
3788	11	33°22'' N	100°02'' W	50	Normal	38	16:18	115	G-19 G-20	45	Texas: Knox City and Lake Kemp
3789	11	33°26'' N	99°33'' W	50	Normal	38	16:18	115	G-19 G-20	45	Texas: Red River, Lake Kemp, and Seymour
3790	11	33°27'' N	86°00'' W	60	Normal	47	16:21	106	G-20 G-21	0	Alabama: Gadsden, Anniston, and Martin Lake
3791	11	33°23'' N	85°16'' W	60	Normal	47	16:21	106	G-21	0	Alabama: Anniston and northeast end of Martin Lake
3792	11	33°10'' N	84°40'' W	60	Normal	47	16:21	106	G-21	0	Georgia: Atlanta
3793	12	33°35'' N	79°03'' W	5	Normal	39	15:00	116	G-21	0	South Carolina: Georgetown, Myrtle Beach, and Winyeh Bay
3794	12	33°35'' N	77°39'' W	5	Normal	39	15:00	116	G-21	3	South Carolina: Cape Fear, clouds, and Atlantic Ocean
3795	12	33°30'' N	76°30'' W	5	Normal	39	15:00	116	G-21	70	South Carolina: Cape Fear and Atlantic Ocean
3796	12	32°55'' N	120°00'' W	7.5	Normal	25	16:27	133	G-18	80	California: San Nicolas Island
3797	12	32°57'' N	118°40'' W	7.5	Normal	27	16:27	132	G-18	60	California: Santa Catalina and San Clemente Islands and San Clemente coast

[a]Operational Navigational Chart; World Aeronautical Chart.

TABLE III-I. - PHOTOGRAPHIC INDEX OF EXPERIMENT S065 MULTISPECTRAL PHOTOGRAPHS - Continued

[From magazine AS9-26]

Frame number	Date in March 1969	Principal point		Overlap, percent	Image evaluation	Sun elevation, deg	G. m. t.	Altitude, n. mi.	ONC WAC number (a)	Cloud cover, percent	Description
		Latitude	Longitude								
3798	12	33°01'' N	116°55'' W	7.5	Normal	29	16:27	131	G-18	10	California: San Diego, tip of Salton Sea, and snow-capped mountains
3799	12	33°05'' N	115°18'' W	7.5	Normal	30	16:28	129	G-18	0	California: Salton Sea, Imperial Valley Mexico: Mexicali
3800	12	33°19'' N	113°49'' W	7.5	Normal	30	16:28	128	G-18	0	California: Yuma, Blythe, Cibola, and Colorado River
3801	12	33°25'' N	112°18'' W	7.5	Normal	32	16:28	127	G-18	0	Arizona: Phoenix, Globe, and snow
3802	12	33°32'' N	110°44'' W	7.5	Normal	33	16:29	125	G-19	0	Arizona: Globe
3803	12	33°37'' N	109°13'' W	7.5	Normal	34	16:29	124	G-19	0	Arizona: New Mexico border and snow
3804	12	33°44'' N	107°37'' W	7.5	Normal	35	16:29	123	G-19	0	New Mexico: north and west of Elephant Butte Reservoir and snow
3805	12	33°42'' N	106°10'' W	7.5	Normal	35	16:30	121	G-19	0	New Mexico: Carrizozo, lava flow, and snow
3806	12	33°42'' N	104°48'' W	7.5	Normal	37	16:30	120	G-19	0	New Mexico: Roswell
3807	12	33°42'' N	103°01'' W	7.5	Normal	38	16:30	119	G-19	0	New Mexico and Texas: between Roswell and Lubbock
3808	12	33°41'' N	101°29'' W	7.5	Normal	38	16:31	117	G-19	0	Texas: Lubbock
3809	12	33°40'' N	99°58'' W	7.5	Normal	39	16:31	116	G-19 G-20	25	Texas: Lake Kemp
3810	12	33°34'' N	98°37'' W	5	Normal	40	16:31	115	G-20	40	Texas: Wichita Falls
3811	12	33°27'' N	96°54'' W	3	Normal	41	16:32	114	G-20	25	Texas: Dallas, Fort Worth
3812	12	33°14'' N	94°23'' W	2	Normal	43	16:32	113	G-20	0	Texas: Texarkana region
3813	12	32°12'' N	85°42'' W	0	Normal	48	16:34	102	G-20 G-21 H-24 H-25	45	Alabama: Phoenix City, Martin Lake, and Walter F. George Lake
3814	12	31°58'' N	84°13'' W	0	Normal	49	16:35	102	G-21 H-25	45	Georgia: Americus
3815	12	31°38'' N	82°41'' W	0	Normal	50	16:35	102	G-21 H-25	30	Georgia: Waycross
3816	12	31°16'' N	81°17'' W	0	Normal	51	16:35	102	H-25	20	Georgia: Brunswick
3817	12	30°50'' N	79°40'' W	0	Normal	52	16:36	102	H-25	10	Atlantic Ocean
3818	12	30°20'' N	77°50'' W	0	Normal	53	16:36	102	H-25	45	Atlantic Ocean: clouds
3819	12	29°50'' N	76°10'' W	0	Normal	53	16:36	102	H-25	60	Atlantic Ocean: clouds
3820	12	[b]24°45'' N	60°45'' W	0	Normal	62	16:40	97	--	40	Atlantic Ocean: Barbados Oceanographic and Meteorological Experiment (Bomex) area
3821	12	[b]24°05'' N	59°20'' W	0	Normal	62	16:41	97	--	25	Atlantic Ocean: Bomex area
3822	12	[b]23°35'' N	58°05'' W	0	Normal	62	16:41	97	--	30	Atlantic Ocean: Bomex area

[a]Operational Navigational Chart; World Aeronautical Chart.

[b]Nadir point of camera.

TABLE III-I. - PHOTOGRAPHIC INDEX OF EXPERIMENT S065 MULTISPECTRAL PHOTOGRAPHS - Continued

[From magazine AS9-26]

Frame number	Date in March 1969	Principal point		Overlap, percent	Image evaluation	Sun elevation, deg	G. m. t.	Altitude, n. mi.	ONC WAC number (a)	Cloud cover, percent	Description
		Latitude	Longitude								
[c]3823	12	[b]23°00'' N	57°00'' W	0	Normal	62	16:41	97	--	30	Atlantic Ocean: Bomex area
3824	12	[b]22°25'' N	55°55'' W	0	Normal	61	16:42	97	--	70	Atlantic Ocean: Bomex area
3825	12	[b]21°50'' N	54°40'' W	0	Normal	61	16:42	97	--	40	Atlantic Ocean: Bomex area
3826	12	[b]21°15'' N	53 15'' W	0	Normal	61	16:42	97	--	20	Atlantic Ocean: Bomex area
3827	12	[b]20°45'' N	52°15'' W	0	Normal	61	16:43	97	--	15	Atlantic Ocean: Bomex area
3828	12	[b]20°05'' N	51°00'' W	0	Normal	61	16:44	97	--	35	Atlantic Ocean: Bomex area
3829	12	[b]19°35'' N	49°55'' W	0	Normal	60	16:43	98	--	35	Atlantic Ocean: Bomex area
3830	12	[b]19°00'' N	48°40'' W	0	Normal	60	16:44	98	--	5	Atlantic Ocean: Bomex area
3831	12	[b]18°20'' N	47°20'' W	0	Normal	60	16:44	98	--	30	Atlantic Ocean: Bomex area
3832	12	[b]17°30'' N	46°15'' W	0	Normal	60	16:44	98	--	70	Atlantic Ocean: Bomex area
3833	12	[b]16°45'' N	45°10'' W	0	Normal	60	16:45	99	--	45	Atlantic Ocean: Bomex area
[d]3834	12	[b]16°00'' N	44°00'' W	0	Normal	60	16:45	99	--	30	Atlantic Ocean: Bomex area
3835	12	[b]15°30'' N	43°15'' W	40	Normal	60	16:45	99	--	60	Atlantic Ocean: Bomex area
3836	12	[b]15°20'' N	43°00'' W	40	Normal	59	16:45	100	--	40	Atlantic Ocean: Bomex area
3837	12	[b]14°50'' N	41°55'' W	0	Normal	59	16:46	100	--	20	Atlantic Ocean: Bomex area
3838	12	[b]14°00'' N	40°40'' W	0	Normal	59	16:46	100	--	15	Atlantic Ocean: Bomex area
3839	12	[b]13°25'' N	39°45'' W	90	Normal	58	16:46	101	--	15	Atlantic Ocean: Bomex area
3840	12	[b]13°20'' N	39°30'' W	90	Normal	58	16:46	101	--	30	Atlantic Ocean: Bomex area
3841	12	[b]12°40'' N	38°25'' W	0	Normal	57	16:47	101	--	40	Atlantic Ocean: Bomex area
3842	12	[b]12°00'' N	37°15'' W	0	Normal	56	16:47	101	--	50	Atlantic Ocean: Bomex area
3343	12	[b]11°10'' N	36°05'' W	0	Normal	55	16:47	102	--	40	Atlantic Ocean: Bomex area

[a]Operational Navigational Chart; World Aeronautical Chart.

[b]Nadir point of camera.

[c]End of CC (black and white infrared film). Frame 3823 is only 20 percent of a full frame.

[d]End of magazine AA (color infrared SO-180 film).

TABLE III-I. - PHOTOGRAPHIC INDEX OF EXPERIMENT S065 MULTISPECTRAL PHOTOGRAPHS - Concluded

[From magazine AS9-26]

Frame number	Date in March 1969	Principal point		Overlap, percent	Image evaluation	Sun elevation, deg	G. m. t.	Altitude, n. mi.	ONC WAC number (a)	Cloud cover, percent	Description
		Latitude	Longitude								
3844	12	[b]10 25'' N	35 00'' W	10	Normal	54	16:48	104	--	40	Atlantic Ocean: Bomex area
3845	12	[b]09 45'' N	33 55'' W	0	Normal	53	16:48	105	--	40	Atlantic Ocean: Bomex area
3846	12	[b]08 55'' N	32 45'' W	0	Normal	52	16:48	106	--	40	Atlantic Ocean: Bomex area
3847	12	[b]08 05'' N	31 35'' W	0	Normal	51	16:49	106	--	40	Atlantic Ocean: Bomex area
3848	12	[b]07 25'' N	30 35'' W	0	Normal	50	16:49	107	--	40	Atlantic Ocean: Bomex area
3849	12	[b]06 40'' N	29 35'' W	0	Normal	49	16:49	108	--	40	Atlantic Ocean: Bomex area
3850	12	[b]06 00'' N	28 35'' W	0	Normal	48	16:50	109	--	40	Atlantic Ocean: Bomex area
3851	12	[b]05 10'' N	27 25'' W	0	Normal	47	16:50	110	--	40	Atlantic Ocean: Bomex area
3852	12	[b]04 20'' N	26 15'' W	0	Normal	46	16:50	111	--	40	Atlantic Ocean: Bomex area
3853	12	[b]03 40'' N	25 20'' W	0	Normal	45	16:51	111	--	40	Atlantic Ocean: Bomex area
3854	12	[b]02 55'' N	24 15'' W	0	Normal	44	16:51	112	--	40	Atlantic Ocean: Bomex area

[a]Operational Navigational Chart; World Aeronautical Chart.

[b]Nadir point of camera.

IV. SUGGESTIONS FOR MULTISPECTRAL PHOTOGRAPHY ANALYSIS

By Edward Yost and Sondra Wenderoth
Long Island University
Greenvale, New York

The NASA Experiment S065 multispectral photography provides the scientific community the first simultaneous satellite photography of the earth surface in three distinct spectral bands spanning the visible and near-infrared regions of the spectrum. The photography consists of four sets of photographs of identical surface locations, taken simultaneously. The images of surface objects appear in the same coordinate positions on all four photographs in the multispectral set. The multispectral set is within the opto-mechanical tolerances of the Hasselblad cameras in the Apollo 9 spacecraft. The set of four multispectral photographs is listed in the following table.

Band (NASA designation)	Film and filter	Mean wavelength of sensitivity	Nominal bandpass
A	Infrared Ektachrome, S0-180, Photar 15	Green, red, and infrared	Total sensitivity of all dye layers, 510 to 900 millimicrons
B	Panchromatic-X, type 3400, Photar 58	525 millimicrons, green	460 to 610 millimicrons
C	Infrared Aerographic type S0-246, Photar 89B	800 millimicrons, infrared	700 to 900 millimicrons
D	Panchromatic-X, type 3400, Photar 25A	645 millimicrons, red	580 to 700 millimicrons

Although a sequential or comparative interpretation of each of the four photographs comprising a multispectral set can yield significant information, a substantially more productive analysis can be made by simultaneous additive color viewing. Color viewing of the black and white multiband photographs can be accomplished by an experimenter who has access to at least three lantern-slide projectors.

The principles of additive color viewing of aerial and space photography are quite straightforward, although the experimenter must use ingenuity in order to set up and operate the equipment. The basic concept is simply that a color-composite image can be produced by optically projecting the positive photographic transparencies of images which are (1) taken in different parts of the spectrum, (2) projected through different colored filters, and (3) superimposed in accurate registration. The theory and experimental details of this technique are discussed in detail in appendix 1 of reference IV-1.

A simple arrangement of additive color viewing of the green, red, and infrared black and white multispectral positives is shown in figure IV-1. Three lantern-slide projectors are arranged with their optical axes parallel so that a projector screen placed approximately 10 feet away is illuminated. As indicated in figure IV-1, Variacs can be placed in the electrical circuit between the wall outlet and the projectors. Adjustment of the Variac controls the lamp brightness of each projector. This adjustment allows the experimenter to independently control the relative brightness of each spectral positive on the screen. However, the technique does change the color tone of the projection lamps, tending to make the screen image redder as the brightness is reduced.

Figure IV-2 presents a top view of the additive color projection arrangement. An essential feature of this arrangement is that the optical axes of the projectors are parallel and that the middle projector is centered on the screen. To achieve registration, one successful method was to place the red positive transparency in the center projector, with the green and infrared transparencies in the side projectors. By moving the transparencies slightly outward in the side projectors, as shown in figure IV-2, the screen can be placed close to the projector with no differential scale distortion in the image. The image may be made as bright as desired by moving the screen closer to the projector.

The procedural steps successfully accomplished using the additive color projection arrangement are as follows:

1. Arrange the projectors so that the rear legs, the front legs, and the screen are parallel. All the projectors should be placed close together.

2. Center the middle projector with respect to the screen and adjust the focus.

3. Place the photography in the lantern slides, making sure that the images are indexed with respect to the edges of the glass. (This step can be accomplished by holding the lantern slides near the light and ascertaining that the images are superimposed.)

4. Place the slides in the three projectors. Project the red positive transparency in the center projector, using a red filter (Photar 25). Then project the green filter (Photar 58). Adjust the green transparency in the projector so that the images are superimposed by the following methods:

   a. For the scale adjustment, move the projector lens and projector with respect to the screen. (Only small adjustments should be required if the projectors have the same focal length lenses.)

b. For the X-axis adjustment (horizontal plane), move the slide-changing mechanism.

c. For the Y-axis adjustment (vertical plane), place a thin layer of masking tape along the bottom of the slide.

d. For the rotational adjustment, tape the bottom of one corner. (The need for taping is minimized by accurately placing the photography in the lantern slides.)

5. Turn off the green projector. Repeat step 4, registering the infrared projector with another green filter. (It is difficult to register the images when using the blue filter.) Remove the green filter and replace it with a blue filter. Because of the higher transmission property, a Wratten 47A filter rather than the standard Wratten 47 filter is suggested for the projection arrangement.

6. Turn on the green projector. A well-registered color image should be produced on the screen. This composite image will contain all the colors, including the secondary colors (yellow, cyan, and magenta) and the primary colors (red, green, and blue). The hue of the screen image can be adjusted by (a) interchanging filters and (b) using filters different from those suggested previously. The image brightness can be controlled by Variac adjustment.

Figure IV-3 illustrates one possible method for holding the filters on the projector lenses. If Variacs are not available, Wratten neutral density filters placed with the color filters will hold the filters on the projector lenses. The following neutral density values for each projector should be sufficient: 0.1, 0.2, 0.3, 0.6, and 0.9. The availability of a fourth projector permits the infrared color transparency to be projected onto another screen alongside the multispectral composite color rendition, allowing simultaneous comparison of both images.

If a woodworking shop or a machine shop is available, a significant improvement in the image registration can be achieved by using the alternate projection arrangement shown in figure IV-4. The projectors are secured to a common base plate and placed on end, pointing toward the ceiling. A front surface mirror (not a rear surface household mirror) can be used to deflect the light to the screen. In figure IV-3 the image on the screen may have a "keystone" effect and may not focus sharply throughout the scene. By lowering or tilting the screen this obstacle can be eliminated.

The slide-changing mechanisms are removed from the projectors and are replaced by a common window glass cut to fit in the film gate of the projectors. The three images are then mounted in lantern slides and placed upon this glass. Because the slides are held on the glass by gravity, they are easily moved to achieve screen image registration.

Photogrammetric plotting equipment, such as the Kelsh or multiplex units, can also be used as multispectral viewing equipment. Although image registration should be easy to achieve, the illumination systems may require modification to provide a usable presentation.

REFERENCE

IV-1. Smith, John T.; and Anson, Abraham, ed.: Manual of Color Aerial Photography. American Society of Photogrammetry, 1968.

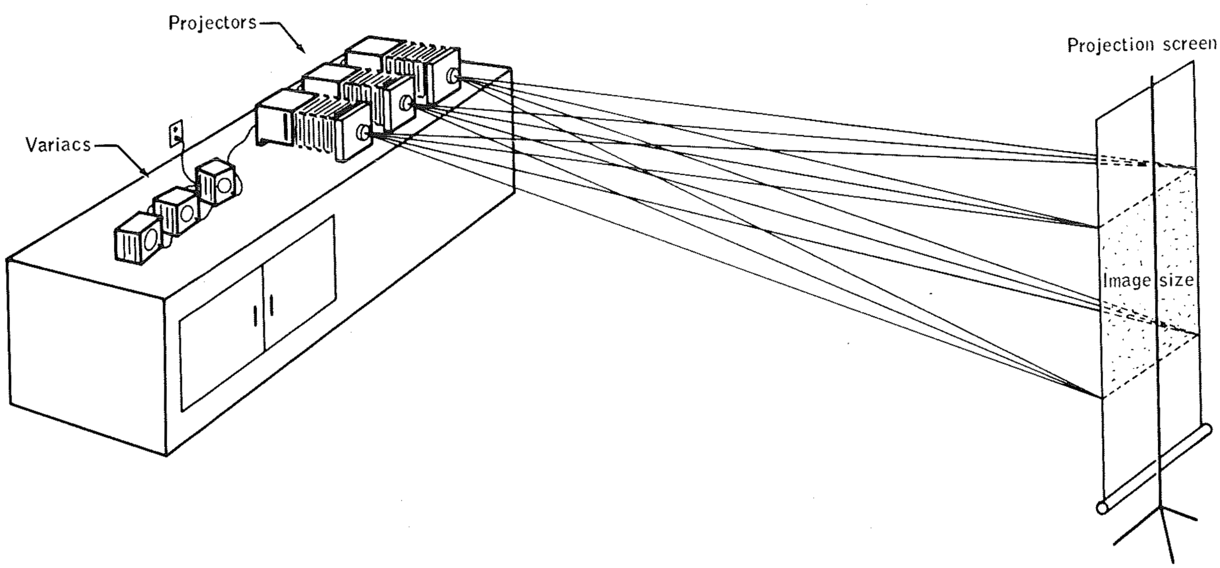


Figure IV-1. - Projector arrangement for additive color interpretation of Experiment S065 multispectral photography.

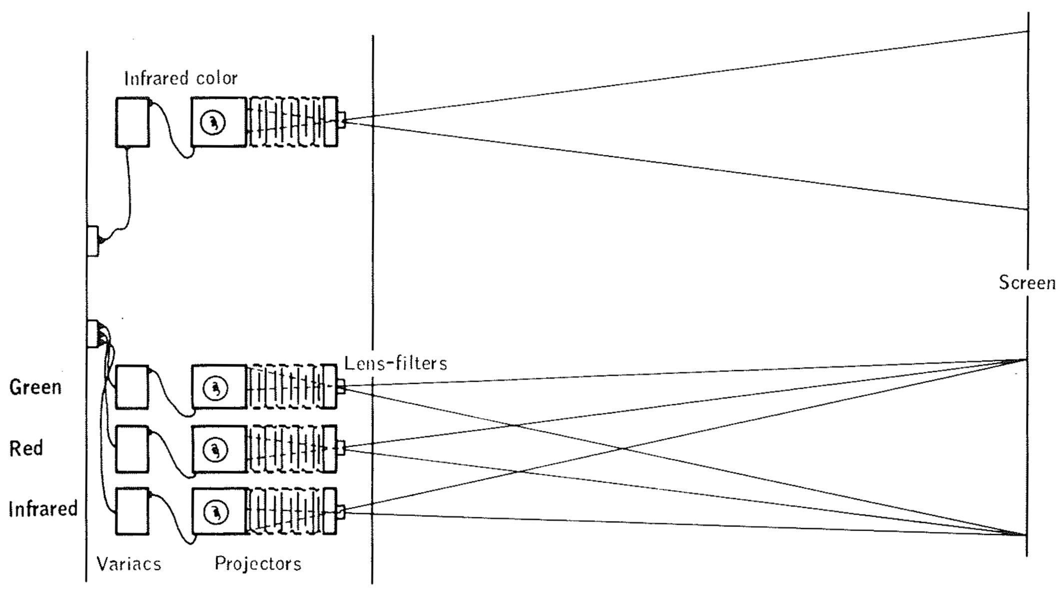


Figure IV-2. - Top view of an additive color projection arrangement.

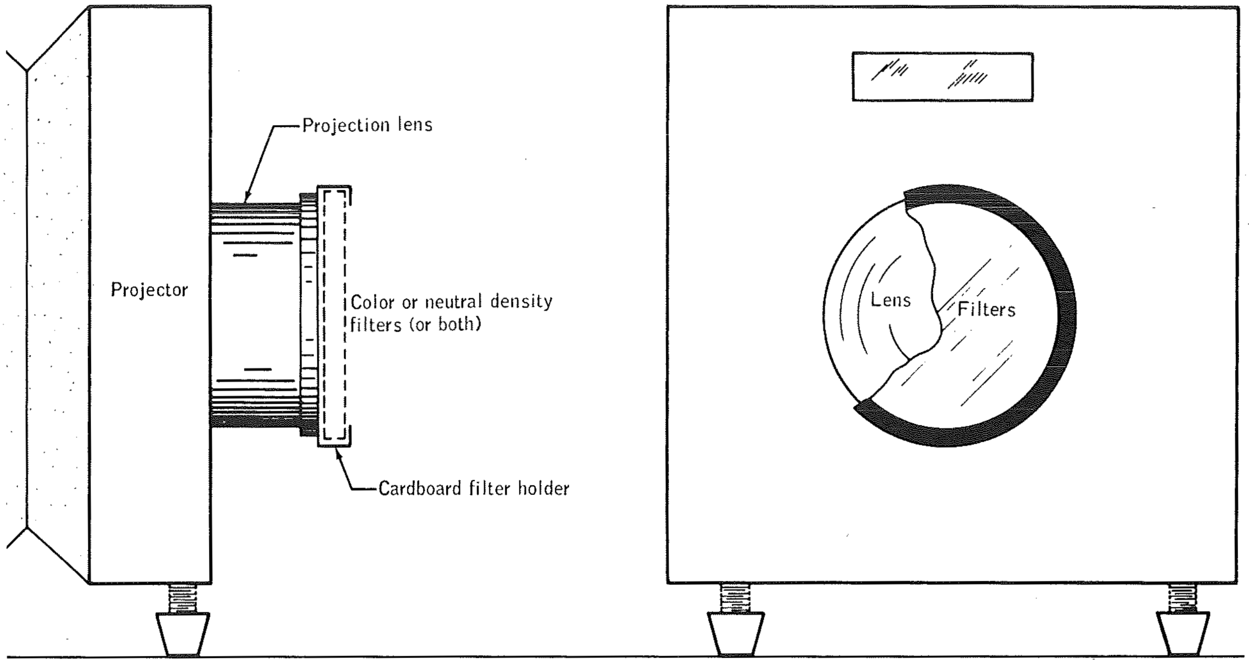


Figure IV-3. - Filter-holding apparatus.

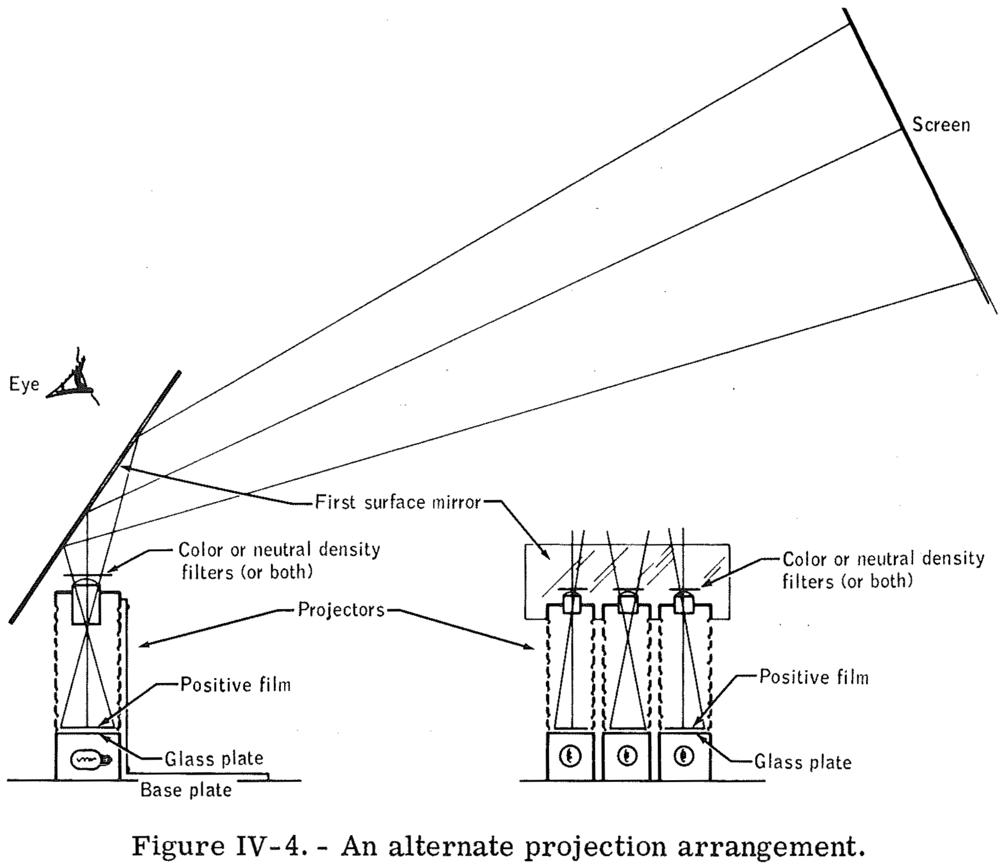


Figure IV-4. - An alternate projection arrangement.

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