Mission 110a

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REPORT NO. 3

J-3 SYSTEM CAPABILITY

CR-2 Bi-Color Experiment

27 SEPTEMBER 1968

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REPORT NO. 3

J-3 SYSTEM CAPABILITY

CR-2 Bi-Color Experiment

27 SEPTEMBER 1968

AUTHORS: [redacted]

Itek OPTICAL SYSTEMS DIVISION

ITEK CORPORATION • 10 MAGUIRE ROAD • LEXINGTON, MASSACHUSETTS 02173

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CORONA

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1. INTRODUCTION AND SUMMARY

Mission 1102 was launched on 9 December 1967; the cameras were equipped with alternate filters for carrying out two experiments—polarization and bi-color. The polarization experiment was the subject of Capability Report No. 1,* and this report, the third in this series, discusses the bi-color experiment.

The bi-color experiment was designed to test the feasibility of obtaining color photography through additive color techniques. The primary advantage of this approach to color photography is that color films need not be used. Rather, when the vehicle covers a target, all that is required during the acquisition stage is a simple filter switch. This technique avoids the practically insurmountable problems inherent in attempting to splice a section of color film into the mission film so that it will be exposed exactly at the time the vehicle is over the desired target. Another possibility for obtaining color photography would be to commit one half of a mission (or a substantial portion of it) to color film. This technique must be considered undesirable since it requires that a high number of targets that are not needed in color nevertheless be photographed in color at a substantial loss in resolution. However, with bi-color, all but the few passes that required color will yield the normally expected high resolution results, and even these few bi-color passes will suffer minimal resolution loss in comparison with the resolution levels attainable with conventional color film.

In order to perform the bi-color test, a special filter that efficiently transmits the green portion of the spectrum was fabricated. During seven photographic passes of mission 1102, this alternate filter (called an SF-05) was commanded into position; the other camera maintained the Wratten no. 25 red filter. These seven passes, therefore, yielded negatives containing all the spectral information necessary for bi-color images.

Generally, bi-color photography is obtained from a camera system that takes two pictures of the same object (1) at the same time, and (2) from the same look angle. Under these conditions, the color synthesis process is relatively simple. In order to carry out the bi-color experiment on the J-3 system, however, the distortions due to different camera aspects must either be removed or at least reduced in magnitude. Three distortion correction techniques were used—rectification, orthoprinting, and direct viewing with the ARES viewer. It was found that the rectification process did not correct enough of the distortion to provide satisfactory bi-color prints. Orthoprinting was very effective and must be considered the best technique available to date for providing a hard copy print.† For rapid access viewing, the ARES viewer with a bi-color attachment has been fairly effective; however, this instrument has a severe area-of-viewing limitation, giving the operator a viewing area between 1/8 and 3/8 nautical mile (nm) on a side from a 10× enlargement.

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*Report No. 1, J-3 System Capability, CR-2 Polarizer Experiment (11 May 1968).

† Further advances have been made since the date of this report, and a summary has been included in the appendix.

The black and white imagery from the seven test passes was examined to evaluate the effect of the special filter on the normal mission photography. There was a slight loss in resolution and edge definition; further, there was a lessening of contrast. In general, however, it was felt that the bi-color portion of the mission was comparable in quality to a typical J-1 mission and that the normal photointerpreter needs would be satisfied.

It should be pointed out that the key to bi-color photography is through special filtration when using conventional black and white aerial films (i.e., Type 3404). New black and white materials (i.e., Types SO-380, SO-230, and SO-205) have become available and may be used on J-3 systems in the near future. The substitution of these films for Type 3404 will have no effect on the bi-color acquisitions.

The mission 1102 test was considered very successful, and it is recommended that this approach to color photography be used over those operational targets for which there is a need for color information.

2. BASICS OF BI-COLOR

The basic principles of bi-color photography and the general techniques used for obtaining bi-color pictures are discussed in this section. In addition, the advantages and disadvantages of this technique as it applies to the J-3 camera system are examined.

2.1 BI-COLOR PRINCIPLES AND TECHNIQUES

Color photography is ordinarily obtained by exposing a scene onto a film with three layers, each of which is sensitive to approximately one-third of the visible spectrum—blue, green, and red; this film is generally referred to as an integral tripack. With reversal color film, the final image is obtained on the same material as used in the camera, and the reversal is accomplished in the processing stage. Color photography can also be achieved by photographing the same scene with three individual black and white emulsions, each altered with the appropriate filtration to record the blue, green, and red components of the spectrum. With this type of color photography, the reconstitution of the image is accomplished in a laboratory where the three black and white records are superimposed and exposed through the appropriate filter. This process is called tricolor additive photography.

Color theory dictates that it is necessary to use three primary colors—red, green, and blue—to produce a print with a full range of colors. It is possible, however, to obtain a color print using only two records—green and red. This type of photography is called bi-color, since the color record is formed by superimposing only two records. Although it is impossible to obtain a full range of colors with the bi-color technique, theoretical tone reproduction studies have shown that the range of colors that can be achieved is large enough to produce a reasonable approximation of normal color photography, considering the degrading effects that the atmosphere has on conventional reversal color film.

The two J-3 cameras provide a stereo pair with a 30-degree convergence angle at the center of format. The stereo pair presents some difficulties in the exploitation process; this problem is discussed in more detail in Sections 2.2 and 4. In order to obtain the required negatives for bi-color photography, the in-flight filter switching capability is used. The forward-looking unit uses a conventional Wratten no. 25 filter, and the aft-looking unit uses a green filter (SF-05) from the alternate position of the filter holder. A series of special filters (dichroic coatings on thin quartz) has been fabricated for this and other tests. Some of these filters are spectral equivalents of Eastman Kodak Wratten filters and some, like the SF-05, have nonequivalent spectral characteristics. The SF-05 filter is similar to a Wratten no. 57 filter; however, the SF-05 has a much higher transmittance giving it a filter factor half that of a Wratten no. 57. At the appropriate time during the mission, the alternate (green) filter is switched into place, and the slit width is changed to obtain proper exposure. The entire revolution is then taken in bi-color. The next time the vehicle passes over a command station, the filter is switched again to the primary position.

Once the original negatives have been processed, there are several stages necessary before color printing can be performed. The stereo convergence angle causes a problem at this point, since the camera-induced distortions and relief due to local ground elevations must be corrected in order to make color prints that are in register. A rectifier can be used to eliminate the panoramic distortions; however, this is not suitable even for large flat areas near the center of format. In order to completely correct the distortions, the relief displacement must be removed through orthoprinting. Once this has been accomplished, the images can be color printed by either an integrating enlarger or a pin register board, a process that will be explained in more detail in Section 4.4. This process uses conventional color processing technology and requires special filtration in the printing stages to obtain satisfactory color balance.

2.2 ADVANTAGES AND DISADVANTAGES OF BI-COLOR

There are several advantages afforded to the J-3 system with the bi-color approach to color photography, the greatest advantage being the capability to acquire color pictures with a minimum of operational problems. It is unnecessary to attempt the practically impossible task of splicing a conventional color material at the exact position in the film load that would ensure the targets of interest being color photographed. The bi-color filter switching technique allows changes in the operational program due to variations in the orbital parameters and changing weather patterns so that color photography can be acquired even over those areas that, prior to launch, were not intended to be covered in color.

A second advantage to the bi-color approach is that a color print can be made from a chip of photography at the interpreter's option. Once the target of interest has been covered in bi-color, this option of having a color print is available at any time in the future. In the meantime, these targets are recorded on black and white 3404 film and can be used in the routine analysis stage with the normal viewing techniques. The fact that one record has been taken with a green filter does not substantially alter the information on the black and white record, although some loss in definition and slight tonal changes can be expected.

Another advantage of the bi-color process is that in retaining the normal Wratten no. 25 imagery, the inherent high resolution is still present. The passes that do not use the bi-color mode also retain the Wratten no. 21 or 23A high resolution imagery. For the particular revolution that does use bi-color, there is a slight loss in resolution on the green record, a loss that is more in the form of a lowering of contrast which indirectly lowers resolution. The laboratory resolution for lenses with a green SF-05 filter has been the same as the resolution with a Wratten no. 21 filter. Even though the operational resolution is lower, the bi-color process still has a fundamentally higher resolution than conventional color films (such as SO-121) in the J-3 system. This slight loss in quality is not fundamental to the bi-color process. It is possible to design a lens specifically for the wavelength region of the SF-05 type filter. Since this is a shorter wavelength than those conventionally used, the theoretical resolution limit is even higher than currently available lenses.

The bi-color flown to date has used the green filter on a second generation Petzval lens, which normally uses a Wratten no. 21 filter. If the green filter were to be used on a third generation lens, which normally uses a Wratten no. 25 filter, there would be a noticeable loss in resolution.

Future camera systems will employ both second and third generation lenses. The focal shift as a function of wavelength is quite different for these two lenses, the third generation lens being designed for a Wratten no. 25 filter, whereas the second generation was designed for a Wratten no. 21 filter. Fig. 2-1 compares both cases. Therefore, since the curve is shifted away from the spectral region of the green filter, the focus shift will be considerably worse with a third generation lens. However, if the time does come when bi-color is to be acquired with a green filter on the third generation lens, a more complete test will have to be performed to see how serious this problem would be.

There are several disadvantages of bi-color that must be considered. First, one should be aware of the fact that the color obtained is not accurate; however, neither is it absolutely accurate with conventional color films. This drawback is not serious as long as one keeps in mind the concept of bi-color photography giving color "clues" and not necessarily accurate color information. For example, reddish-yellow objects would be clearly distinguishable from blue-cyan objects. However, it may not always be possible to distinguish a red from an orange or to distinguish a green from a green-blue. In short, bi-color does not have as wide a chromatic dynamic range as tri-color photography.

The second disadvantage of bi-color is that although the prints are available at the interpreter's option, it does take considerable time and effort to produce them; at present, it takes several days due to the transportation of the materials involved. However, with the right type of equipment located in the right place, it seems reasonable to expect that a 1-day service could be established.

The advantages and disadvantages of bi-color photography can be summarized as follows:

<u>Advantages</u>

1. Bi-color can be acquired at any time in orbit by operational commands.
2. Color "clues" are available at the interpreter's option.
3. High resolution black and white imagery is maintained.

<u>Disadvantages</u>

1. Contrast of the green filtered imagery is slightly lower.
2. Absolutely accurate color reproduction is impossible.
3. Synthesis process is slow at this time.

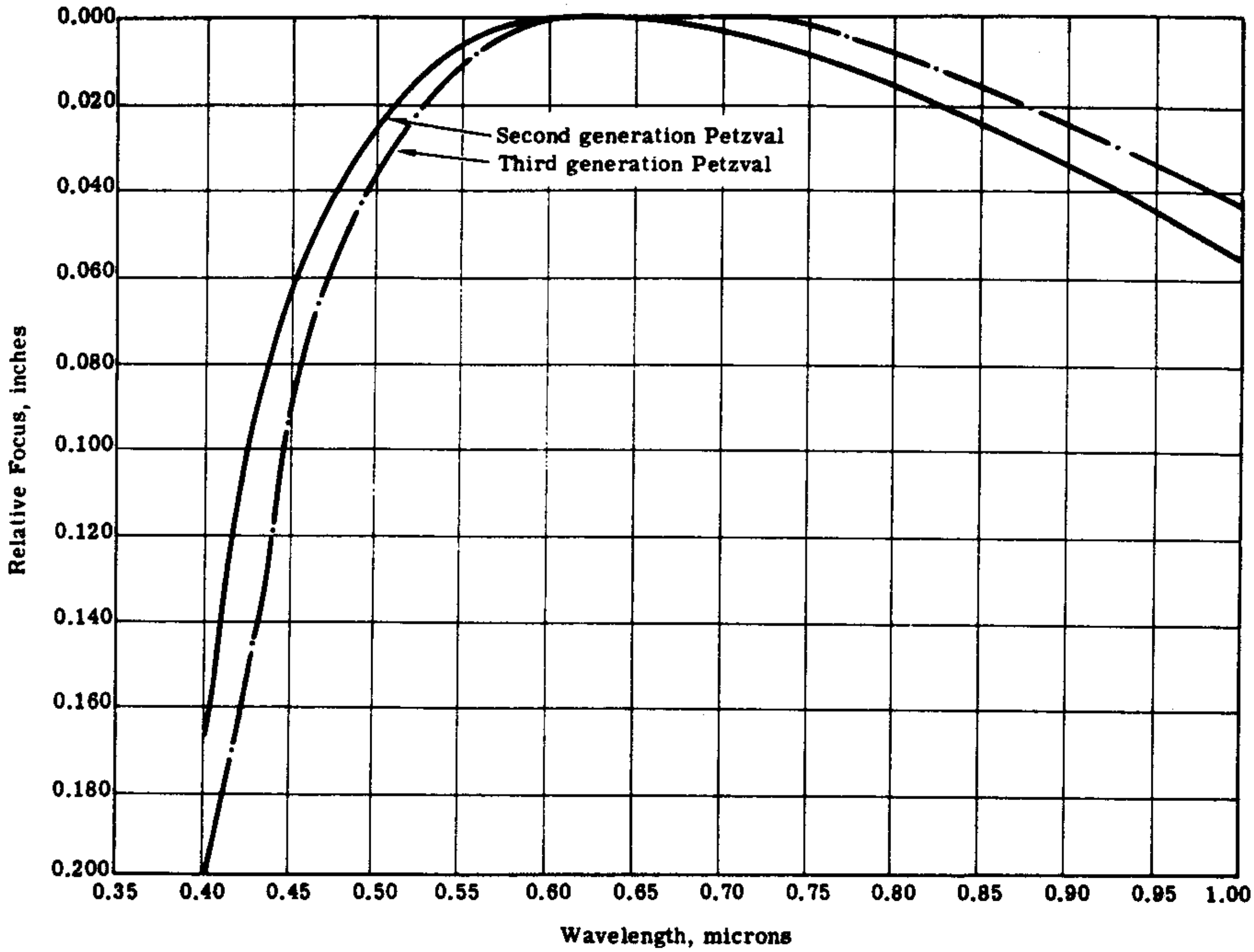


Fig. 2-1 — Focus versus wavelength for 24-inch Petzval lenses

3. MISSION 1102 BI-COLOR TEST

3.1 PURPOSE

The intent of the mission 1102 bi-color test was to obtain, for the first time, satellite color photography in the J-3 system through the bi-color mode. This was a test of the compatibility of the bi-color technique with the entire taking and exploitation stages of the process.

In order to be considered usable, the technique must first work properly in the acquisition stage of the system. This means that it must be possible to command the alternate filter into position at the right time. The imagery thus obtained must be usable for normal photointerpretation purposes, and it must also have retained the spectral information necessary to make a bi-color print. In addition to acquisition, the bi-color process must work properly in the synthesis stages; that is, it must be possible to make a bi-color print from the J-3 photography. The distortions must be corrected and the color must be suitable for the interpretation needs.

The purpose of this experiment was to deal with these problems and to recommend the best method for obtaining useful photography from the J-3 reconnaissance system.

3.2 BI-COLOR FILTER

In order to obtain bi-color photography, a special filter must be used on one of the cameras, while the normal Wratten no. 25 filter is used on the other camera. Consideration must be given to many characteristics of the total system in order to select the best spectral transmittance band of this filter for bi-color photography. This filter, fundamentally, must be blue or green. Experience has shown that the exact nature of filters is not as important as might be suspected as far as the color reproduction is concerned. The basic filter requirement for bi-color is that one filter allow passage of the long wavelengths, and the other allow passage of the short wavelengths.

For successful bi-color photography, the filters must be chosen with one prime consideration, namely, image quality. Blue or blue-green filters must be eliminated, therefore, due to the severe loss in resolution caused by using the lenses in spectral regions for which they were not designed. A green filter, however, can be used with little or no loss in resolution with a second generation Petzval lens. Extending the filter further into the green-yellow spectral region would not substantially increase system resolution, but would cause a significant loss in color information since the color discrimination would be lowered.

With the filter choice limited to a green filter, a very practical problem must be solved. Dye filters that transmit in the blue-green spectral region characteristically have high filter factors. One filter that works quite well (although it has a filter factor of 6) is a Wratten no. 57. It has been used to obtain bi-color photography in the EKIT* bi-color test. The filter factor, however, is too high for use in the J-3 system.

---

* EKIT Report No. 16, Bi-Color Evaluation (15 Sept. 1967).

In order to solve this problem, a special green dichroic filter (SF-05) was fabricated and used in this mission to acquire the bi-color imagery. The filter is visually similar to a Wratten no. 57, though at a much higher transmittance level to give an acceptable filter factor of 2.8.

A plot of the three filters is shown in Fig. 3-1. As can be seen, the SF-05 has a much higher transmittance than the Wratten no. 57. The filter factor of the SF-05 is comparable to the Wratten no. 25 which has a filter factor of 3.0 when using type 3404 film under simulated daylight conditions.

3.2.1 Test Details

The bi-color experiment on mission 1102 was performed on seven passes, six over domestic areas, and one over the Soviet Union. During each bi-color operation, the forward-looking camera employed the Wratten no. 25 red filter, and the aft-looking camera employed the SF-05 green filter.

An attempt was made to photograph several strategically important areas in the USA; however, weather problems (snow and clouds) obscured these targets. There were several other target areas in the United States that proved to be very interesting in bi-color even though they are of little strategic significance. The most startling was the copper mine slurry located near Bisbee-Douglas, Arizona. This is discussed in more detail in Section 3.3.3.

Table 3-1 gives the specific locations and camera system parameters for the bi-color acquisitions. The ground tracks for these missions are shown in Fig. 3-2.

3.2.2 Special Glass Filters and Their Performance With the Petzval Lenses

An effort has been undertaken by the contractor to fabricate glass filters to be used in both the primary and alternate positions in the J-3 system. This task started with the goal of possibly improving system performance by replacing Wratten gelatin filters with high quality glass filters, of which the SF-05 is one. Problems encountered in the production of these glass filters have to date precluded their qualification for use in the primary position. The glass, 0.005-inch fused quartz, is so thin that the polishing has not been sufficient to produce results any better than normal Wratten filters. Table 3-2 lists the filters that have been produced thus far; some may be used in future tests and are listed in ephemeris printouts and messages with their "SF" designation.

As stated, the SF-05 green filter was used on the aft-looking camera of mission 1102; this camera used a second generation lens. The question of resolution performance was answered in two ways, theoretically and by laboratory experiment. The laboratory experiment indicated that resolution values were practically identical for the Wratten no. 21 and SF-05 filters when using a second generation lens at optimum focus for each filter.

The 2:1 contrast resolution for the Wratten no. 21 was 135 lines per millimeter, while the SF-05 was 130 lines per millimeter. However, as pointed out earlier, the contrast reduction due to the effective increase in atmospheric haze light with the green filter will indirectly lower the resolution. In addition, the higher filter factor (2.8 as opposed to 2.0 for the Wratten no. 21) forces longer exposure times which decrease the system dynamic performance due to image blur. Finally, the SF-05 filtered imagery is acquired operationally in the focal position for the Wratten no. 21 filter, which is not quite optimum for the SF-05, and this lowers the resolution performance to some degree.

3.3 ANALYSIS OF RESULTS

An analysis of the photography obtained from mission 1102 was undertaken by both NPIC and this contractor. The NPIC analysis was summarized in a message which is quoted in its entirety in paragraph 3.3.1.

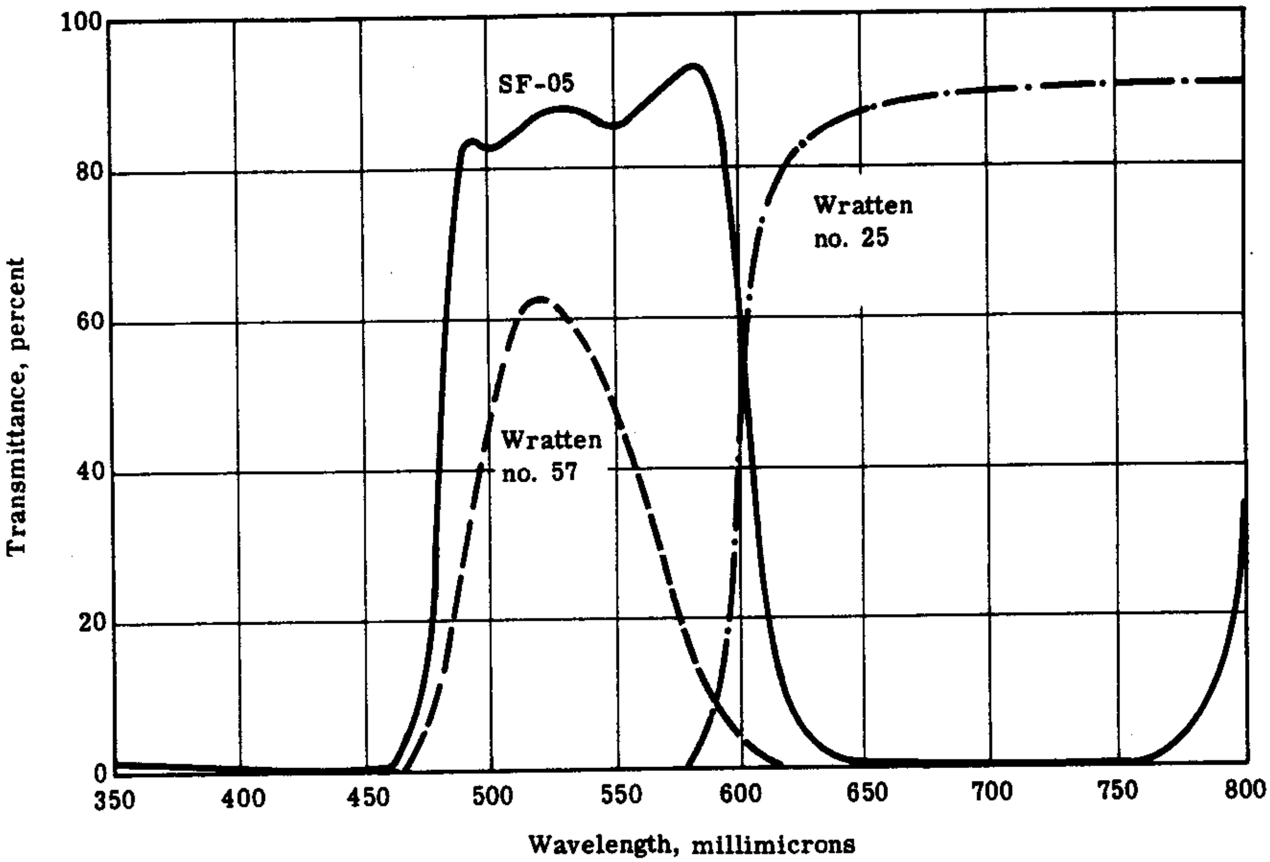


Fig. 3-1 — Spectral transmittance of the SF-05, Wratten no. 25, and Wratten no. 57 filters

Table 3-1 — Specific Mission Parameters for the Seven Bi-Color Passes

	Beginning of Pass		End of Pass	
PASS D-048				
Frame	1		61	
Date	12 Dec 1967		12 Dec 1967	
Hr, min, sec (GMT)	21, 21, 0.125		21, 22, 52.813	
Solar Elevation	22°42'		28°25'	
Solar Direction	38°48'		40°48'	
Geographic Location, center format, forward only	Colorado		New Mexico	
Latitude	37°32.5'N		29°53.5'N	
Longitude	110°44.8'W		109°35.1'W	
Weather Conditions	50% clouds; 50% clear		20% clouds; 80% clear	
Exposure	Slit	Time	Slit	Time
Forward	0.340	1/237	0.340	1/242
Aft	0.270	1/298	0.270	1/308
Filters				
Forward	Wratten no. 25		Wratten no. 25	
Aft	SF-05		SF-05	
PASS D-064				
Frame	1		16	
Date	13 Dec 1967		13 Dec 1967	
Hr, min, sec (GMT)	20, 57, 08.437		20, 57, 38.937	
Solar Elevation	19°8'		20°47'	
Solar Direction	35°30'		35°48'	
Geographic Location, center format, forward only	Wyoming		Wyoming	
Latitude	43°6.7'N		41°3.2'N	
Longitude	108°26.3'W		108°1.1'W	
Weather Conditions	10% clouds; 90% clear		100% clear	
Exposure	Slit	Time	Slit	Time
Forward	0.340	1/234	0.340	1/239
Aft	0.270	1/295	0.270	1/298
Filters				
Forward	Wratten no. 25		Wratten no. 25	
Aft	SF-05		SF-05	

Table 3-1 — Specific Mission Parameters for the Seven Bi-Color Passes (Cont.)

	Beginning of Pass		End of Pass	
PASS D-079				
Frame	1		49	
Date	14 Dec 1967		14 Dec 1967	
Hr, min, sec (GMT)	19, 7, 57.250		19, 9, 51.250	
Solar Elevation	26°41'		32°46'	
Solar Direction	35°24'		37°18'	
Geographic Location, center format, forward only	South Carolina		Florida (Cape Kennedy)	
Latitude	34°36.7'N		26°51.6'N	
Longitude	81°10.3'W		80°6.8'W	
Weather Conditions	100% clear		100% clear	
Exposure	Slit	Time	Slit	Time
Forward	0.340	1/239	0.340	1/245
Aft	0.270	1/298	0.270	1/305
Filters				
Forward	Wratten no. 25		Wratten no. 25	
Aft	SF-05		SF-05	
PASS D-097				
Frame	1		27	
Date	15 Dec 1967		15 Dec 1967	
Hr, min, sec (GMT)	21, 40, 47.625		21, 41, 36.687	
Solar Elevation	23°50'		26°37'	
Solar Direction	31°36'		32°12'	
Geographic Location, center format, forward only	North of San Francisco, California		South of San Francisco, California	
Latitude	39°8.9'N		35°49.4'N	
Longitude	122°57.6'W		122°23.2'W	
Weather Conditions	100% clear		100% clear	
Exposure	Slit	Time	Slit	Time
Forward	0.340	1/242	0.340	1/248
Aft	0.270	1/305	0.270	1/312
Filters				
Forward	Wratten no. 25		Wratten no. 25	
Aft	SF-05		SF-05	

Table 3-1 — Specific Mission Parameters for the Seven Bi-Color Passes (Cont.)

	Beginning of Pass		End of Pass	
PASS D-113				
Frame	1		36	
Date	16 Dec 1967		16 Dec 1967	
Hr, min, sec (GMT)	21, 18, 45.125		21, 18, 44.937	
Solar Elevation	25°50'		25°11'	
Solar Direction	29°48'		30°36'	
Geographic Location, center format, forward only	Bakersfield, Fresno, California		Bakersfield, Fresno, California	
Latitude	37°34.7'N		38°20.2'N	
Longitude	119°18.5'W		119°29.3'W	
Weather Conditions	25% clouds; 20% haze; 55% clear		50% clouds; 10% haze; 40% clear	
Exposure	Slit	Time	Slit	Time
Forward	0.340	1/245	0.340	1/248
Aft	0.270	1/305	0.270	1/312
Filters				
Forward	Wratten no. 25		Wratten no. 25	
Aft	SF-05		SF-05	
PASS D-154				
Frame	1		47	
Date	19 Dec 1967		19 Dec 1967	
Hr, min, sec (GMT)	9, 46, 55.980		9, 48, 23.117	
Solar Elevation	13°27'		18°55'	
Solar Direction	22°0'		22°18'	
Geographic Location, center format, forward only	Classified		Classified	
Latitude	–		–	
Longitude	–		–	
Weather Conditions	80% clear; 15% haze; 5% clouds		92% clear; 3% haze; 5% clouds	
Exposure	Slit	Time	Slit	Time
Forward	0.340	1/236	0.340	1/243
Aft	0.215	1/373	0.215	1/383
Filters				
Forward	Wratten no. 25		Wratten no. 25	
Aft	SF-05		SF-05	

Table 3-1 — Specific Mission Parameters for the Seven Bi-Color Passes (Concl.)

	Beginning of Pass		End of Pass (with comparable aft-looking photography)	
PASS D-210*				
Frame	1		21	
Date	22 Dec 1967		22 Dec 1967	
Hr, min, sec (GMT)	20, 31, 32.625		20, 32, 7.875	
Solar Elevation	29°56'		32°15'	
Solar Direction	15°24'		15°42'	
Geographic Location, center format, forward only	Bakersfield, Fresno, California		Santa Barbara, California	
Latitude	36°11.9'N		33°48.1'N	
Longitude	120°48.3'W		120°25.5'W	
Weather Conditions	Not evaluated		Not evaluated	
Exposure	Slit	Time	Slit	Time
Forward	0.215	1/396	0.215	1/396
Aft	0.134	1/628	0.134	1/643
Filters				
Forward	Wratten no. 25		Wratten no. 25	
Aft	SF-05		SF-05	

*Partial mono coverage, therefore bi-color possible on only a portion of this pass.

Fig. 3-2 — Plots of bi-color passes over the United States

Table 3-2 — Special Filter Designation and Description

Filter Designation	Description	50 Percent Transmittance Points, millimicrons	Nominal Filter Factor With 3404	Nearest Wratten Equivalent
SF-01	Long-wave pass, orange	550	1.8	W-21
SF-02	Long-wave pass, orange-red	580	2.3	W-23A
SF-03	Long-wave pass, red	600	2.5	W-25
SF-04	Visual-band pass, orange	570 to 680	3.1	None, visually looks like a W-23A
SF-05	Visual-band pass, green	490 to 600	2.8	W-57, but higher transmittance
SF-06*	Long-wave pass, yellow	530	NA	W-15 + 1.0 ND
SF-07†	Polarizer, 0° axis	Neutral	3 to 6	0.45 ND
SF-08†	Polarizer, 10° axis	Neutral	3 to 6	0.45 ND
SF-09†	Polarizer, 20° axis	Neutral	3 to 6	0.45 ND

*This filter is for use with camouflage detection color films such as SO-180.
†Axis of polarization measured from the long dimension of the filter.

Whereas the NPIC analysis dealt with only the black and white imagery, this contractor's analysis was concerned with both the black and white imagery (paragraph 3.3.2) and the production of color images (paragraph 3.3.3). In that analysis, three specific scenes have been analyzed, two of which were orthoprinted and a third which was only rectified prior to color printing. Also, an additional set of images has been included to indicate the improvement that has taken place since the EKIT bi-color test was performed.

3.3.1 NPIC Analysis

NPIC analysis of the mission 1102 bi-color experiment was reported by TWX on 28 February 1968. This message is quoted in the following pages.

> "IN RESPONSE TO REFERENCE, NPIC HAS COMPLETED THE FIRST PHASE OF ITS BI-COLOR EVALUATION. THIS CONSTITUTES A DETERMINATION OF DEGRADATION TO THE PHOTOGRAPHY EXPOSED IN THE BI-COLOR MODE COMPARED TO THAT OF THE NORMAL MODE OF OPERATION. THE PROCEDURE AND RESULTS FOLLOW:
>
> A. SUBJECTIVE COMPARISON OF WRATTEN NUMBERS 25, 21 AND SF-05 RECORDS:
>
> 1. PHOTO-SCIENCE EVALUATION: TO ESTABLISH A BASIS FOR THE BI-SPECTRAL IMAGE EVALUATION, THE MISSION MATERIAL EXPOSED THROUGH THE PRIMARY FILTERS WAS ANALYZED. THE MATERIAL SELECTED FOR ANALYSIS HAD ESSENTIALLY THE SAME ACQUISITION PARAMETERS AS THE BI-SPECTRAL MATERIAL. DIFFERENCES IN DENSITY, CONTRAST AND IMAGE QUALITY ARE NEGLIGIBLE. THE PHOTO-INTERPRETATION REPORTS INDICATE SIMILAR QUALITY RATINGS FOR BOTH RECORDS. ASSUMING NO CAMERA MALFUNCTIONS, SUBJECTIVE AND OBJECTIVE RESULTS BASED ON THIS EVALUATION INDICATE THAT ANY DIFFERENCE IN THE SF-05 RECORD AS COMPARED TO THE WRATTEN 21 AND WRATTEN 25 RECORDS IS THE RESULT OF THE FILTER. THE OBJECTIVE EVIDENCE IS CONTAINED IN PART B OF THIS REPORT.
>
> THE SF-05 RECORD AND CONJUGATE IMAGERY FROM THE WRATTEN 25 RECORD WERE VISUALLY COMPARED. A COMPRESSION OF DENSITY EXTREMES IS READILY APPARENT IN THE GREEN FILTER RECORD. DUE TO THIS COMPRESSION, LOW CONTRAST AREAS SHOW A DECIDED INCREASE IN INFORMATION CONTENT ON THE WRATTEN 25 MATERIAL. WHILE IN SOME INSTANCES THERE IS MORE APPARENT DETAIL IN THE SHADOWS ON THE POSITIVE MADE FROM THE SF-05 RECORD, THIS DIFFERENCE IS ATTRIBUTED TO THE PRINT DENSITY DICTATED BY COMPROMISE OF THE D-MAX AND D-MIN.
>
> THE IMAGE QUALITY OF THE WRATTEN NO. 25 RECORD IS SUPERIOR TO THE SF-05 FOR INFORMATION CONTENT. OBJECTS THAT APPROACH THE RESOLUTION CAPABILITY OF THE SYSTEM APPEAR MUCH SHARPER. APPARENT EDGE SHARPNESS OF OBJECTS VIEWED AT LOW MAGNIFICATION IS GENERALLY COMPARABLE. HOWEVER, THE WRATTEN NO. 25 RECORD RETAINS THIS APPARENT SHARPNESS MUCH LONGER AS MAGNIFICATION IS INCREASED.

2. PI REPORT: THE PHOTO-INTERPRETERS PREFERRED THE WRATTEN NO. 25 RECORD OVER THE SF-05. HIGHER CONTRAST AND OVERALL SHARPER IMAGERY WERE THE TWO MAJOR REASONS FOR THIS PREFERENCE. THEY ALSO EXPRESSED THE OPINION THAT WHEN SHADOW DETAIL IS NEEDED, A LIGHTER PRINT FROM THE WRATTEN NO. 25 RECORD WOULD BE MORE DESIRABLE THAN THE LOWER CONTRAST OF THE SF-05 MATERIAL, WHICH SEEMS TO PROVIDE MORE SHADOW DETAIL ON A NORMAL PRINT. SMALL OBJECTS PRESENT IN THE WRATTEN NO. 25 RECORD CAN BE DETECTED IN THE SF-05 RECORD; HOWEVER, IDENTIFICATION OF THESE OBJECTS IS MUCH MORE DIFFICULT. THE GENERAL CONCLUSION OF THE PHOTO-INTERPRETERS IS: THE MAJORITY OF THE REQUIREMENTS LEVIED FOR THE J-3 SYSTEM COULD BE ANSWERED WITH PHOTOGRAPHY GENERATED IN THE BI-COLOR MODE BECAUSE WHEN USED IN STEREO, THE TWO RECORDS COMPLEMENT EACH OTHER. IN ADDITION, THE OVERALL INFORMATION CONTENT OF THE PHOTOGRAPHY EXPOSED THROUGH THE GREEN FILTER IS COMPARABLE TO AN AVERAGE J-1 MISSION.

B. OBJECTIVE ANALYSIS:

1. MICRO-D TRACES: TO SUBSTANTIATE THE RESULTS OF THE SUBJECTIVE ANALYSIS, MICRODENSITOMETRIC TRACES OF 11 TARGETS WERE GENERATED. SIX TARGETS WERE SELECTED FROM THE NON BI-COLOR PORTION OF THE MISSION AND FIVE TARGETS WERE CHOSEN FROM THE BI-COLOR PORTION. EACH TARGET WAS TRACED. THE TRACES WERE GENERATED BY THE MANN MICRODENSITOMETER WITH AN EFFECTIVE SLIT APERTURE OF 10 MICRONS. VISUAL COMPARISONS OF THE TRACES FROM NON BI-COLOR MATERIAL INDICATED THE SIMILARITY THAT EXISTS BETWEEN THE WRATTEN NO. 25 AND 21 RECORDS. HOWEVER, COMPARISONS OF THE TRACES FROM THE BI-COLOR MATERIAL INDICATE THAT A SUBSTANTIAL DIFFERENCE IN DENSITY AND CONTRAST EXIST BETWEEN THE WRATTEN NO. 25 AND SF-05 MATERIALS.

THE MINIMUM DENSITY, MAXIMUM DENSITY, AND THE DENSITY RANGE OF EACH TARGET HAS BEEN DERIVED FROM THE TRACES AND IS TABULATED BELOW. THE SIMILARITY OF THE WRATTEN NO. 25 AND NO. 21 RECORDS, AND THE NON-SIMILARITY OF THE WRATTEN NO. 25 AND SF-05 RECORDS IS EVIDENCED BY THE VALUES IN THE TABLE.

FIGURE	PASS	FRAME	FILTER	D-MIN	D-MAX	DELTA
1	D-16	6 FWD	25	0.72	2.37	1.65
2	D-16	12 AFT	21	0.70	2.48	1.78
3	D-16	12 FWD	25	0.75	1.64	0.89
4	D-16	18 AFT	21	0.78	1.78	1.00
5	D-16	13 FWD	25	0.65	1.60	0.95
6	D-16	20 AFT	21	0.92	1.85	0.93
7	D-79	7 FWD	25	0.45	1.15	0.73

FIGURE	PASS	FRAME	FILTER	D-MIN	D-MAX	DELTA
8	D-79	13 AFT	SF-05	0.58	0.93	0.35
9	D-79	7 FWD	25	0.35	0.98	0.63
10	D-79	13 AFT	SF-05	0.42	0.72	0.30
11	D-97	12 FWD	25	0.62	1.27	0.65
12	D-97	19 AFT	SF-05	1.00	1.32	0.32
13	D-97	38 FWD	25	0.36	1.13	0.77
14	D-97	44 AFT	SF-05	0.40	0.88	0.48
15	D-129	4 FWD	25	0.80	2.47	1.67
16	D-129	10 AFT	21	0.75	2.47	1.72
17	D-129	27 FWD	25	0.70	1.65	0.95
18	D-129	33 AFT	21	0.75	1.77	1.02
19	D-129	32 FWD	25	0.95	1.57	0.62
20	D-129	39 AFT	21	1.20	1.92	0.72
21	D-154	4 FWD	25	0.84	1.92	1.08
22	D-154	10 AFT	SF-05	0.75	1.44	0.69

2. RESOLUTION TARGETS: FOUR RESOLUTION TARGETS WERE PHOTOGRAPHED DURING THE NON BI-SPECTRAL PORTION OF THE MISSION. SEVEN TARGETS WERE PHOTOGRAPHED DURING THE BI-SPECTRAL PORTION; HOWEVER, DUE TO WEATHER CONDITIONS AND/OR FORMAT LOCATION, ONLY ONE OF THE TARGETS IMAGED IN THE BI-COLOR MODE IS SUITABLE FOR THIS EVALUATION. THE AVERAGE GROUND RESOLUTION OF THESE TARGETS AS DETERMINED FROM THE ORIGINAL NEGATIVE IS PRESENTED BELOW:

CAMERA	PASS	IMC	SCAN	FILTER
FWD	16-D	5.7	6.3	25
AFT	16-D	5.7	8.0	21
FWD	16-D	8.0	8.0	25
AFT	16-D	9.0	9.0	21
FWD	32-D	12.0	12.0	25
AFT	32-D	12.0	10.0	21
FWD	129-D	7.6	8.7	25
AFT	129-D	7.6	8.7	21
FWD	48-D	6.3	5.7	25
AFT	48-D	9.0	8.0	SF-05

AS CAN BE DETERMINED FROM THE ABOVE LIST, THE NON BI-SPECTRAL PASSES (16-D, 32-D, AND 129-D) INDICATE VERY LITTLE RESOLUTION DIFFERENCES BETWEEN THE FWD AND AFT CAMERA RECORDS; HOWEVER, THE BI-SPECTRAL MATERIAL (PASS 48-D) SHOWS A DIFFERENCE OF 2.7 FEET IN THE IMC DIRECTION AND 2.3 FEET IN THE SCAN DIRECTION BETWEEN THE FORWARD AND AFT CAMERA RECORDS. THIS DIFFERENCE, ALTHOUGH SUBSTANTIAL, REPRESENTS

ONLY ONE BAR GROUP. ALSO, IT SHOULD BE NOTED THAT THE 9.0 FEET AND 8.0 FEET READINGS ARE COMPARABLE TO A NORMAL J-1 MISSION.

C. SUMMARY AND CONCLUSIONS:

1. THE CONTRAST RANGE IS SIGNIFICANTLY REDUCED WHEN THE SF-05 IS USED IN PLACE OF THE WRATTEN NO. 21 OR THE WRATTEN NO. 25.

2. APPARENT IMAGE SHARPNESS IS REDUCED BY A NOTICEABLE DEGREE ON THE SF-05 PHOTOGRAPHY COMPARED TO THE WRATTEN NO. 21 AND WRATTEN NO. 25.

3. THE ONLY SUITABLE RESOLUTION TARGET DISPLAY IMAGED DURING THE BI-COLOR ACQUISITION INDICATES A SIGNIFICANT DIFFERENCE IN GROUND RESOLUTION BETWEEN THE SF-05 PHOTOGRAPHY COMPARED TO THAT OF THE WRATTEN 25.

4. THE EFFECT OF IMAGE QUALITY DEGRADATION CAUSED BY THE USE OF THE SF-05 FILTER IS MINIMIZED WHEN THE PHOTOGRAPHY IS VIEWED IN STEREO WITH THE HIGHER QUALITY, HIGHER RESOLUTION PHOTOGRAPHY EXPOSED THROUGH THE WRATTEN 25.

5. THE RESOLUTION OF THE GREEN FILTERED RECORD IS GENERALLY COMPARABLE TO THAT OF A NORMAL J-1 MISSION."

3.3.2 Contractor Analysis of Black and White Imagery

In general, exposure times were approximately 1/300 second for the SF-05 green filter and 1/250 second for the Wratten no. 25 filter. While the SF-05 record seemed to lack the expected increase in shadow areas, a compensating increase in exposure would almost certainly produce an overexposed negative. Shadow details, in most cases, were about equal for both the SF-05 and Wratten no. 25 records.

There is full snow cover in the pass number D-154, and the shorter exposure time compensated for the high ground reflectance in the SF-05 frames. The Wratten no. 25 frames were exposed at 1/250 second, which was common exposure time for the other areas, and, as a consequence, were slightly overexposed.

Comparison of the two camera records for D-210 on a point-by-point basis is not possible because of the mono operation of the camera during the pass. However, a comparison of the SF-05 records of D-097, 1/300 second, and D-210, 1/600 second, shows considerable differences. The shorter exposure time produced negatives that lacked contrast and low reflectance detail. Highlights fall well below the shoulder of the characteristic curve and only very large items were shown in a usable manner. Considerable haze in the area helped degrade the 1/600-second frames, but it was very obvious that the shorter exposure time only detracted from the results.

Edge quality was noticeably inferior in the green SF-05 filtered photography. This shortcoming was consistent throughout all the bispectral passes. Resolution, based on fixed and CORN target readings of eight observers, is higher for the Wratten no. 25 than for the SF-05 record. The best resolution is predominantly in the FMC direction as opposed to the scan direction, usually by approximately one target element.

The tonal reproduction qualities of the two filter records is heavily in favor of the Wratten no. 25 record. There is much better separation of tonal differences in rocks and soil, more contrast between vegetation (particularly grasses) and top soil, and slightly more shadow detail in mountain valleys. Structural details of man-made objects are well separated and generally better defined. Urban areas, particularly residential ones, are shown to better advantage with buildings, trees, fences, etc., being more easily detected. Delineation of interfaces between two different bodies of water is far superior with the Wratten no. 25 filter.

The SF-05 record is more useful for delineating the texture in large stands of timber and tidal estuary vegetation.

Snow fields stimulate approximately the same response in both filter records, but contrast is particularly high in the Wratten no. 25 photography when there are urban areas or villages.

The spectral separation of certain objects is particularly noticeable in the areas of mineral processing when the red and the green filtered imagery are compared. Processing tanks at copper refineries show marked differences, and salt pans along San Francisco Bay provide extreme examples of tonal differences caused by the two different spectral responses.

Exposures made with the SF-05 filter are limited in image quality, but at the same time provide a tool for detection of spectral differences either by direct black and white comparison or by additive color techniques. The multispectral aspect of bi-color has a potential for gaining information about a subject. However, it is quite difficult to determine these spectral differences from black and white imagery unless they are quite pronounced. The specific areas where good separation occurs are limited. The bi-color reproduction, however, brings the subtle differences out, aiding the eye in this type of analysis.

Many of the shortcomings of the green record are eliminated or minimized when it is used in stereo with the Wratten no. 25 record. The resolution and contrast of the Wratten no. 25 coverage dominates, and the textural delineation of the SF-05 coverage adds to the overall information content.

3.3.3 Contractor Analysis of Bi-Color Prints

Copper Mine and Refinery (10× Orthoprinted Enlargement) Figs. 3-3 and 3-4

The film positive color integration of the red and green spectral records is a good example of how the information stored in each record can be combined to form a graphic chromatic representation of these differences.

This scene has been balanced to present the subject as a bispectral record, and at the same time keep the color in a frame of reference with the impression of what it should look like. Use of more extreme printing colors might possibly make the density differences more pronounced, but it would remove it from the "real" world of color photography. Extremes have a definite use, particularly in cases of difficult interpretation. Being able to perceive a somewhat natural scene and at the same time detect spectral differences would appear to be the more desirable alternative.

The hues present in the transparency are generally related to the subject with which they are associated. Scrub and desert vegetation appear green; sand and aggregates appear neutral and light; and slurry from the refining of the copper ore appears red or green, colors that are normally associated with this metal. However, there are areas of artifically induced colors, such as the reddish color (in Fig. 3-4) from a cloud shadow. In this case, one camera has recorded the ground terrain while the other has recorded the cloud.

The density differences that show as hue differences in the transparency are also detectable in the film positives as obvious density differences. By viewing them stereoscopically, a three-dimensional image is presented, and careful comparison will show where and to what degree the differences manifest themselves. However, this is a tedious process for extensive analysis and is best used as a cooperative procedure in conjunction with a bi-color presentation.

Airfield, Support Facilities, and Surrounding Area (10× Orthoprinted Enlargement) Figs. 3-5 and 3-6

The overwhelming characteristic of this scene is the green hue that dominates the area. This is not a saturation of the image by the color of one of the printing filters at the expense of other hues since good neutral taxiways and natural colored soils are present. Vegetative cover is very well defined and delineated, and barren areas are equally well defined by the reddish brown soil color.

The delineation of structures at the airfield is enhanced by the red record to a degree not possible with the green record alone. Finely resolved detail is lost, and there is overall degradation of the image by the method of restitution and superimposition parallax contributed by the integrating printer. The integration of the two spectral records in a graphic color presentation is an important contribution to the analysis of the scene.

Saturn V Assembly Building at Cape Kennedy, Florida (20× Rectified Enlargement) Figs. 3-7 and 3-8

Comparison of the film positive bispectral records with the bi-color integration shows a marked overall degradation of image quality and information content. Both black and white film positives show the subject area in great detail. The red record appears to be superior to the green in most areas including vegetative delineation and at least as good in rendering shadow details visible. This last factor is of dubious importance since few objects have shadow areas large enough to hide details at this scale.

The bi-color integration presents no additional information except that the area has scrub ground cover over the undeveloped areas. Resolution is extremely low as demonstrated by the automobiles which are visible in the individual positives but completely obscured in the bi-color print. Relief displacement of the assembly building is so extreme that when ground detail is in coincidence, the structure is an incomprehensible jumble of red, cyan, and neutral tones. Clearly, this type of subject is not compatible with bi-color integration constructed from rectified images.

Conclusion

The quality of the bi-color record has generally been shown to be acceptable from a practical as well as an operational standpoint. Although the SF-05 record has a significantly lower contrast than the Wratten no. 21 record (the filter it replaces on the aft-looking camera), this factor does not deter the information content of the scene when the SF-05 filter record is viewed in a stereo mode with the Wratten no. 25 record. It should be noted that the contrast can be brought up to the level of the Wratten no. 25 image in the duplication stage. From an operational standpoint, the SF-05 has a filter factor of 2.8, which is acceptable for the present camera system. The system resolution capability of the SF-05 with the second generation Petzval lens when the lens is focused at the Wratten no. 21 filter position is slightly lower than that of the Wratten no. 21 filter. However, this reduction in resolution does not appear to be a significant factor in influencing the filter's usefulness. Image quality losses on SF-05 records in Wratten no. 21 focal position with third generation lenses are expected to be more serious.

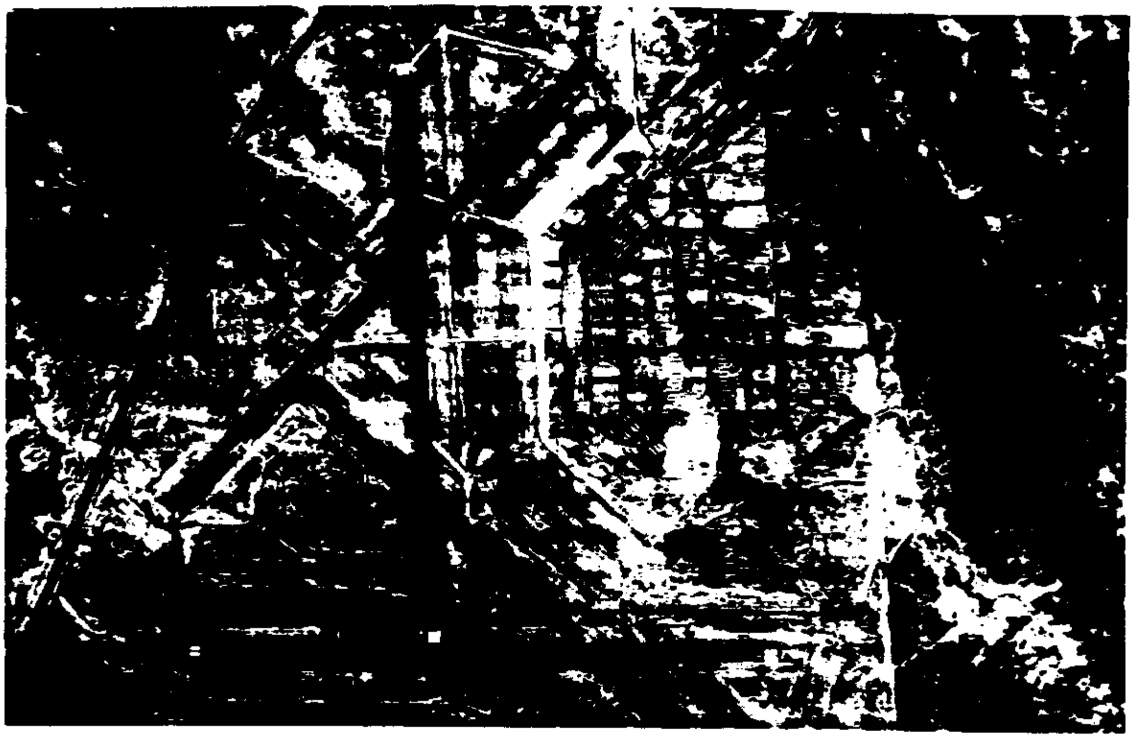
The various deformations introduced by camera geometry, spatial parallax, and relief displacements must be minimized for best results. Optical geometric rectification will remove camera and parallax deformations and still produce a high resolution positive with good tonal range. Optical orthophotographic instruments will remove positional errors induced by relief in the scene as well as rectify the positive. This also produces a good positive for integration. Electronic orthophotographic reproduction will also remove relief distortions, but the image suffers an information loss in the process. Scan lines and sweep paths both introduce "noise" which results in density differences across each scan line. The amount of information masked in electronic orthoprinting is dependent on the scale and target types of the scene. Lower altitude or larger scale photography with their larger image sizes are less affected since the scan lines cover a smaller percentage of each object. Definition of fine detail does suffer to some extent. At higher altitudes and with smaller scale photography, the items that were considered gross at lower altitudes are much smaller and more easily degraded by scan lines. As a result, the information loss appears to be greater with small scale photography than with large when electronic orthoprinting techniques are used.

(a) 20× orthoprint from red filtered negative

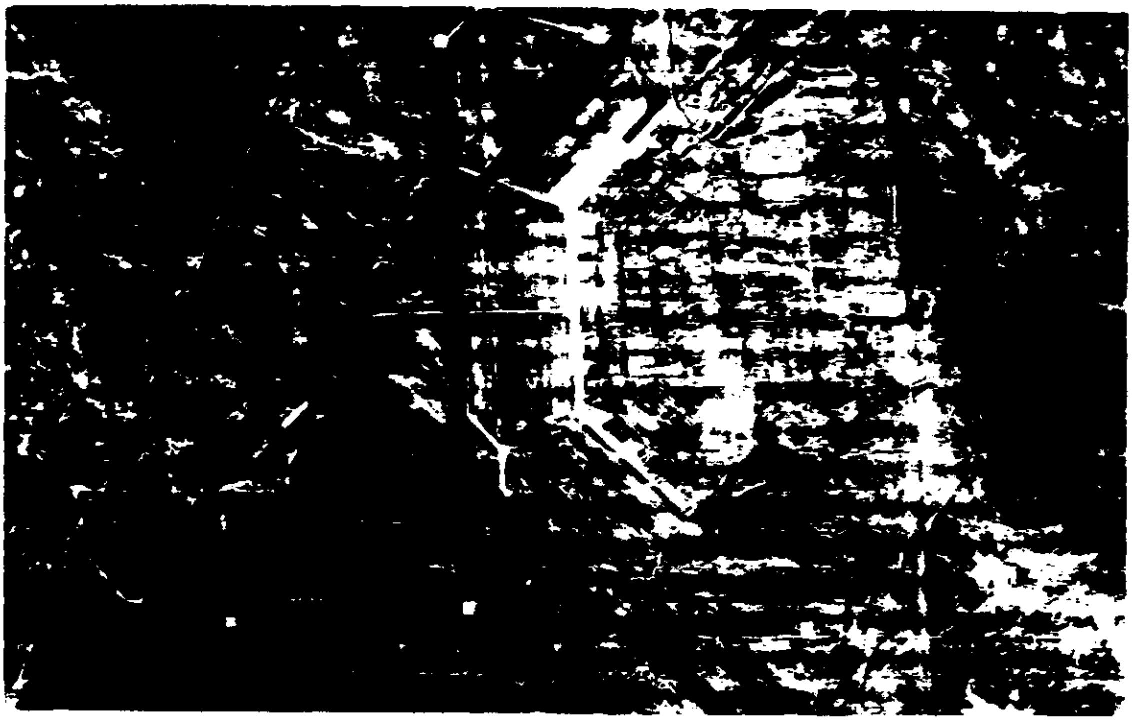
(b) 20× orthoprint from green filtered negative

Fig. 3-3 — Copper mine slurry, Arizona, 20× orthoprints

Fig. 3-4 — 20× bi-color integration made from green and red orthoprint records



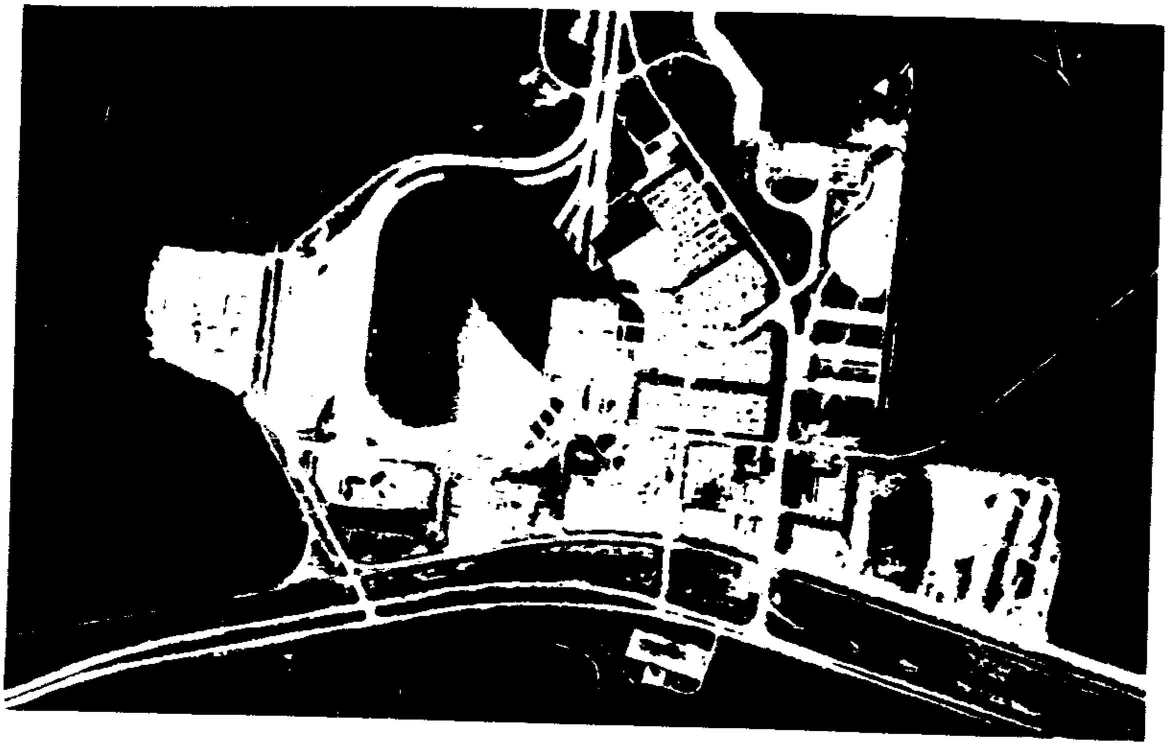
(a) 20× orthoprint from red filtered negative



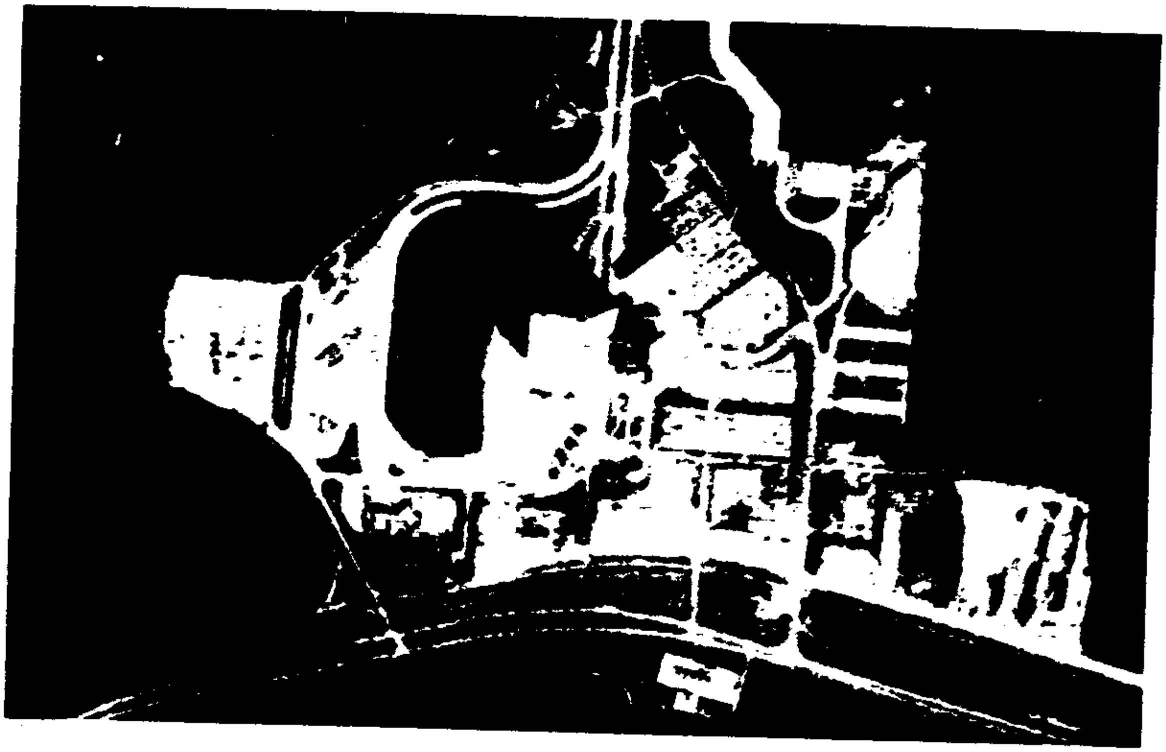
(b) 20× orthoprint from green filtered negative

Fig. 3-5 — Bisbee/Douglas International Airport, Arizona, 20× orthoprints

Fig. 3-6 — 20× bi-color integration made from green and red orthoprint records



(a) 20× rectified print from red filtered negative



(b) 20× rectified print from green filtered negative

Fig. 3-7 — Cape Kennedy, 20× rectified prints

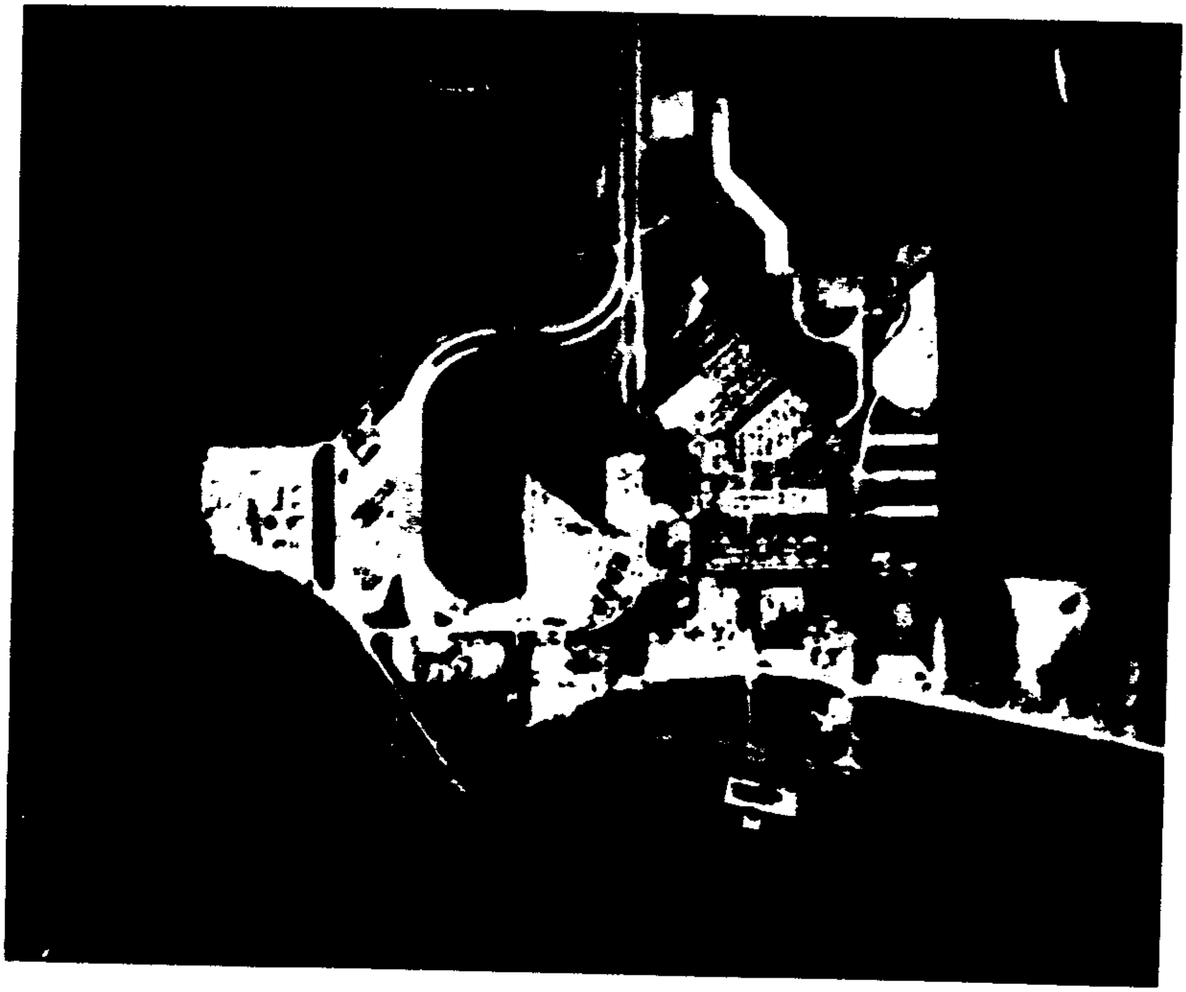


Fig. 3-8 — 20× bi-color integration made from green and red rectified records

4. EXPLOITATION TECHNIQUES AVAILABLE FOR BI-COLOR ACQUISITIONS

The successful use of bi-color photography is dependent upon the ability to precisely register the two color records during the simultaneous printing operation. This need for perfect registration requires that the relative positions of all image points within the printing area be identical on both records. The two original negatives will meet this requirement only if they are taken from the same point in space relative to the target and if they are taken with the same camera or two identical cameras; only then will the combined effects of geometric camera distortions, relief displacement, and target perspective be the same for both images. With any other camera configuration, these distortions will combine in completely dissimilar ways and result in two geometrically dissimilar images.

This dissimilarity of images will occur when using the J-3 convergent panoramic system. Although the two cameras are identical, the coverage of a given target is obtained from two widely separated points in space and consequent separation in time. In order to generate images suitable for registration under these conditions, it is necessary to remove or correct the dissimilar image displacements caused, in this case, by panoramic distortion, relief displacement, and perspective or convergent distortion. The precision with which the bi-color records can be registered is dependent upon the amount of correction that can be attained with the various techniques available.

Three techniques were considered for producing bi-color imagery—orthoprinting, rectification, and veiwing on the Automatic Registration Electronic Stereoscope (ARES) with a bi-color attachment. Each of these techniques corrects the image distortions to a different degree, and each presents the bi-color image to the photointerpreter in a different mode. Of the three, orthoprinting is the most sophisticated in that it corrects all three distortions. The rectification and ARES techniques will correct for the panoramic and perspective distortions, but will not compensate for the relief displacement.

The area of coverage can best be described by Fig. 4-1. In this illustration, a 0.8-inch square section of the panoramic frame was enlarged 10×. This chip covers an area of 3 nm on a side. The entire 8- by 8-inch image can be put on the ARES viewer; however, only a 1- by 1-inch area of this enlargement can be seen at one time with minimum zoom. This is equivalent to 3/8 nm on a side. At maximum zoom, the area of coverage is 1/8 nm on a side.

A description of these techniques and discussions of their advantages and disadvantages are provided in the following paragraphs.

4.1 RECTIFICATION

While orthophotography has the capability of removing all three J-3 image distortions, rectification can correct only the panoramic and perspective distortions. The relief displacement would remain uncorrected and cause problems in bi-color registration. For this reason, rectification is not generally as desirable as orthoprinting.

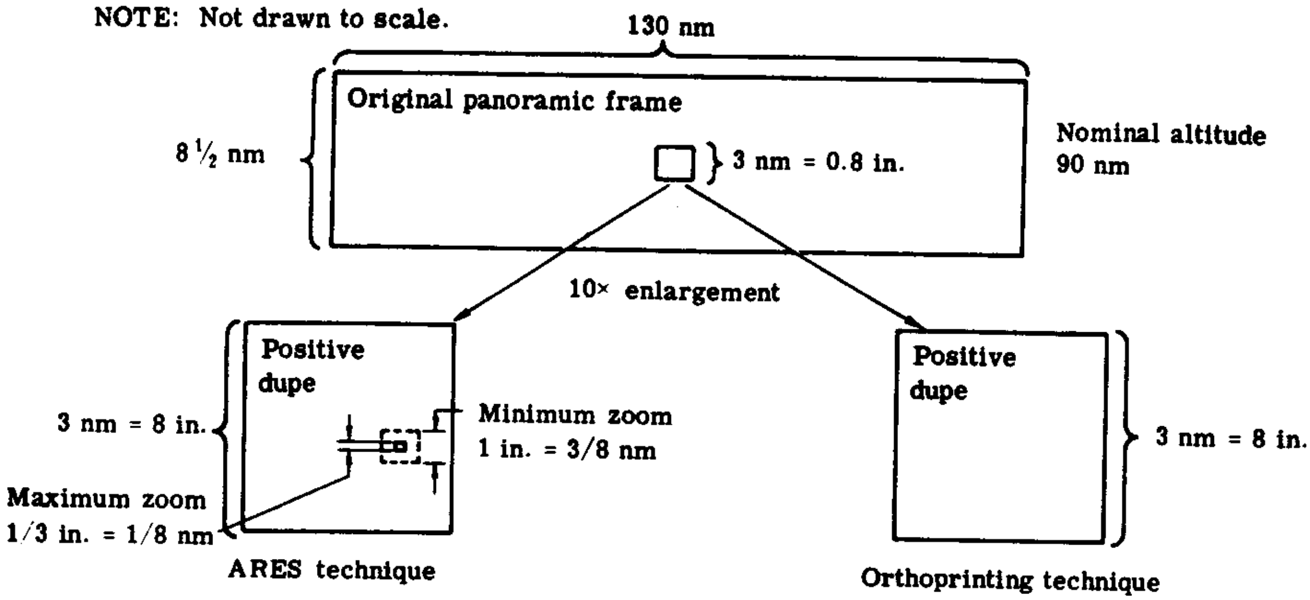


Fig. 4-1 — Illumination of area of coverage using the ARES viewer

The equipment used to perform the rectification is the Gamma I Rectifying Printer. This unit transforms tilted panoramic photography into enlarged, uniform scale prints which are of normal photographic quality and exhibit no serious defects with respect to content, density, and resolution. The printer is designed to duplicate the physical aspects of the taking camera, but in a reversal manner (i.e., reprojecting the images from a curved platen, through the scanning lens, and onto the copy easel).

The rectified bi-color print of the Vertical Assembly Building at Cape Kennedy, shown in Figs. 3-7 and 3-8 and discussed in Section 3.3.3, was made in the following manner. Rectified positives were made from the original negatives using the Gamma I Rectifier. The original negatives were used instead of the conventional third generation duplicate negatives in order to preserve as much image quality as possible. Since the Gamma I focus is adjusted for a 0.007-inch-thick negative material, and since original negatives are only 0.003 inch thick, a 0.004-inch piece of clear acetate was used to back up the negatives to produce the correct thickness for proper focus. This adjustment apparently succeeded in bringing the image into focus. The red and green rectified positives were then placed in an additive color printer and a bi-color print was made. Since the rectified positive is a 2× enlargement and the additive color printer is a 10× enlarger. the net effect is a 20× enlargement.

Photography of the Vertical Assembly Building was chosen to test the rectification process because of the abrupt elevation change from the ground level to the top of the building. The strange appearance of this building on the bi-color print demonstrates the effect of uncorrected relief displacement. Because of the relief of the building and the convergence of the cameras, each camera has seen a different side of the building. Therefore, either the top of the building or the surrounding terrain may be registered properly, but not both at the same time. In making this print, the operator has sacrificed the appearance of the building for the appearance of the majority of the scene.

An attempt was made by ACIC to orthoprint this image. However, the relief was too abrupt, and the machines were not able to function properly with the time available.

4.2 ORTHOPRINTING

An orthophotograph is produced by removing the geometric camera distortions, perspective distortions, and relief displacements from an aerial photograph. This is accomplished in special devices developed for this purpose. The instrument which has been used to produce the orthophoto separation positives for the bi-color test is a Bendix AS-11C Automatic Analytical Stereo-Plotter and Orthophoto System. This instrument is located at ACIC in St. Louis, Missouri.

The AS-11C operates in the following manner. A small area on each of the stereo pairs (in this case, the green and red separation negatives) is scanned electro-optically. As these corresponding areas of the two photographs are scanned in synchronism, two video signals are produced and sent to an image correction system which determines the x and y parallax errors existing between the images scanned on the two photographs. The x parallax error is eliminated by continuously adjusting the model elevation, and the y parallax error is eliminated by continuously adjusting a y parallax correction which is mathematically applied to the y component of one photograph. Accommodation for local distortion of images due to terrain slope and camera geometry must be incorporated. The image distortion due to camera geometry is obtained from the camera orientation information. The image distortion due to terrain slope is determined from estimated terrain slope components as derived from the simultaneously scanned stereo pairs in conjunction with the partial derivation of photographic coordinates with respect to model elevation. To accommodate these distortions, the scanning pattern upon each photograph is adjusted to the appropriate shape. This information is subsequently supplied to the output scanner, which produces the corrected orthophotograph. It should be noted that good correlation between the two images can be made without accurate knowledge of flight parameters. Although this is necessary information for the mapping purposes of this instrument, it is a luxury for the bi-color operation.

The AS-11C has the capability of scanning the image with a CRT scan width from 0.5 to 5.0 millimeters. As the width is reduced, the sophistication of the orthotransformation is increased, and the corrected orthoprint will be of higher quality.

The orthoprint approach to the problem has another control which can be used to improve the final bi-color print. The instrument's electronic gamma control can be used to adjust the individual record contrast, making the red and green record contrasts more closely matched.

There is a time problem associated with this equipment. Approximately 12 hours are required to produce a satisfactory set of orthoprinted positives for bi-color printing. This includes setup time, actual operation, and processing and presents two problems. First, it would take several days to orthoprint several scenes, and second, it consumes a significant proportion of time on machines that have production schedules to meet. For this technique to be useful in the future, additional machines must be made available in the Washington, D.C. area.

The technique that has been used to date involves making 10 and 20× enlargements from the original negatives to produce positive transparencies for use on the AS-11C. The AS-11C is then used in the positive-position mode to produce the orthographic positive images necessary for color printing. Then the positive images from the orthoprinter are superimposed to form the color print. This operation is performed on a pin register board. The color printing process is discussed in Section 4.4. By first making the 10 or 20× enlargement, the original negative's high resolution has been maintained, and the scan lines have minimal effect. If the original negative had 150-line-per-millimeter resolution at a 10-foot ground resolved distance, the 10× enlargement would maintain the 10-foot GRD; however, at only 15 lines per millimeter, the effect of further degradation (i.e., scan lines) is therefore small.

4.3 AUTOMATIC REGISTRATION ELECTRONIC STEREOSCOPE (ARES) WITH BI-COLOR ATTACHMENT

The ARES, as the name implies, is primarily a stereoscope. It differs from conventional stereoscopes in that its operations are performed automatically by electronic means. In the ARES operations, y parallax is reduced essentially to zero at all points in the image area. The x parallax is reduced, at all points, to values compatible with comfortable ocular convergence. The tonal range of the observed image and the sine wave response characteristic of the imaging system are both subject to automatic adjustment to improve the appearance and interpretability of the stereo model.

As stated, the ARES corrects for panoramic and tipped panoramic distortions and does not correct for relief displacement.

The registration of photographic images is basic to practical bi-color operations. The ARES accomplishes the registration by utilizing a series of electronic manipulations. The following is a brief description of each of these procedures.

Transformation: A systematic operation to alter the scale, orientation, or overall shape of an image. Fig. 4-2 illustrates the four first-order transformations which are considered prime. Shown also are various combinations of these transformations, some of which are more familiar than those regarded as prime. In this system of nomenclature, relative displacement of an image is regarded as a zero-order transformation.

Parallax: The separation between corresponding points in similar images when they are superimposed.

Registration: The act of transforming one or both of a pair of similar images so as to reduce all parallaxes to zero when the images are superimposed.

Relative distortion: A difference in size or shape of similar images such that a transformation of one or both images is required to achieve registration.

The ARES viewer is used primarily for the examination of convergent and panoramic stereo photography, and in this regard, the machine does an excellent job of registering. In very hilly regions, registration is frequently lost, probably because of the appreciable difference between left and right imagery and the absence of sufficient detail. Skillful use of the zoom control enables registration to be held even in unfavorable areas.

It was noticed that registration tended to be uncertain in areas containing dominant structural detail oriented at ±45 degrees. This is no doubt due to the 45-degree scanning angle of the raster. Good results are also possible with a pair of convergent panoramic photographs. The distortion in this case is mainly skew, and it is precisely this type of distortion that the ARES can readily correct in contrast to conventional optical stereoscopes which cannot make this type of correction at all.

The resultant bi-color image is subsequently displayed on a CRT in the bi-color viewer attachment. The brightness and tonal range of each record can be adjusted separately to facilitate maximum color discrimination. The saturation and density of the filters can also be adjusted independently.

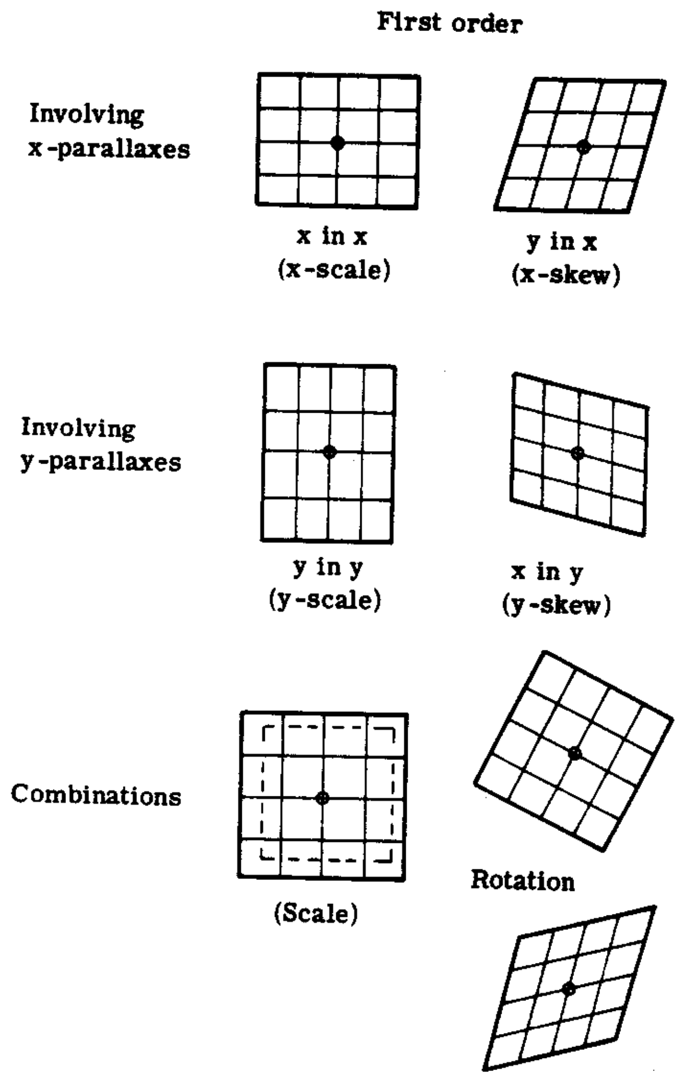


Fig. 4-2 — Prime transformations

4.4 COLOR PRINTING PROCESS

Fig. 4-3 describes the basic bi-color printing process for either the enlarging or the contact approach. The two techniques are basically very similar.

As stated in Section 2, the final bi-color print is made using rather elementary color printing techniques. There are, however, several unique aspects of this color printing process that should be discussed. The rectified or orthoprinted positive images for both the forward- and aft-looking cameras are printed onto a piece of reversal color film. The positive image made from the negatives that were exposed through a red filter is also printed through a red filter. The same is true with the green filtered image. Once this is done, a bi-color has been made. However, this print then has an unacceptable yellow cast since red light plus green light forms a yellow color. In order to cancel some of this yellow color, a blue exposure is given. This is not an overall fogging blue light since that will not correct the yellow cast properly. Rather, it is a blue exposure through the positive made from the green filtered negative. This has the result of very effectively cancelling the yellow cast. It also serves as another control on the color balance in this process. The blue and green exposures through the same positive have a net result of simulating a cyan (blue light plus green light forms cyan) exposure through a single green positive record. Cyan light and red light form a neutral which accounts for this combination cleaning up the yellow overtone.

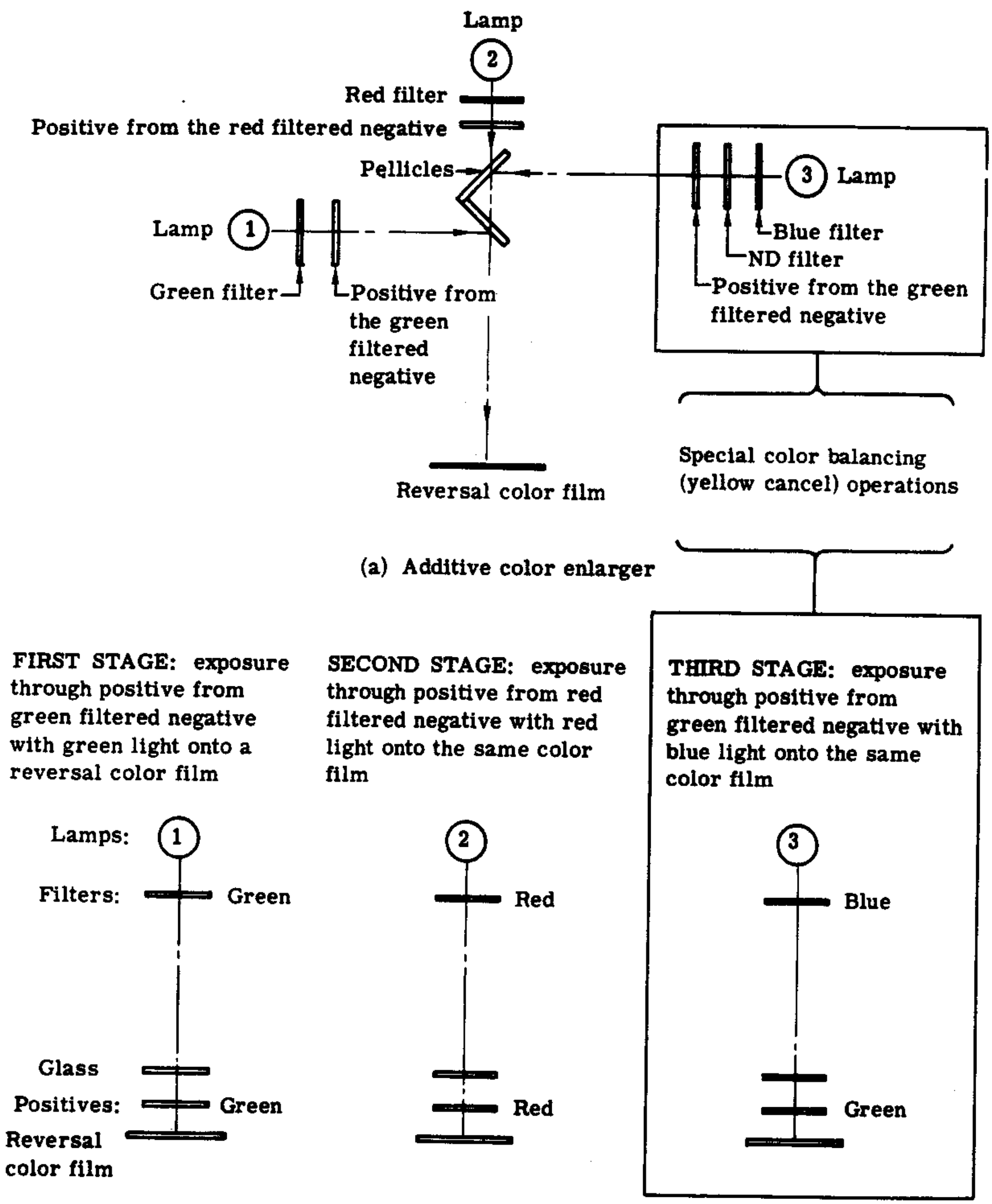
There is one further advantage of using the blue-green exposure system. It is possible to control exposure time and illumination level very accurately. However, the available dye filters constrain the printing process to just a few filter combinations. By making one of these filters a combination of variable proportions of two fixed filters (blue and green), a whole family of cyan filters is created. This gives the added flexibility necessary for good color balance control.

The contact method of printing requires a pin register board. Although this method might appear quite crude, it is a very good system, provided that the positive images are first enlarged at least 10×. This makes a nominal 10-foot, 150-line-per-millimeter picture equivalent to a 10-foot, 15-line-per-millimeter system. It is much easier, therefore, to maintain satisfactory registration with such low line per millimeter resolution levels.

The discussion thus far has dealt with the use of a direct reversal color film as the means of reproducing the bi-color image. This is only one of several techniques available. If the bi-color image is to be reproduced as a paper print, an internegative stage can be used. In general, the exposure for a good Ektachrome type B transparency is the same required for an Ektacolor negative that will make a good paper print on Ektacolor professional paper. Variations in the filtration will be necessary, though, when printing the Ektacolor negative material.

Another approach that can be used to obtain a hard copy transparency is to use the Ektacolor negative and print with Ektacolor print film in a similar manner as the Ektacolor professional paper. Experience has shown that the filtration required for a good color transparency is very similar to that required for a good paper print. With either of these two techniques, a permanent bi-color negative is obtained from which future color prints can be made without the necessity of returning to additive printing techniques.

Finally, the color printing can be accomplished with the 3M Electronic Color Printer. Tests have recently begun with this device as described in the appendix of this report.



(a) Additive color enlarger

(b) Pin register board

Fig. 4-3 — Schematic for color printing technique

5. RECOMMENDED METHOD FOR ACQUISITION AND EXPLOITATION OF SATELLITE BI-COLOR PHOTOGRAPHY

This section deals with the suggested methods for handling the entire bi-color photographic process on future J-3 missions. Consideration is first given to the acquisition of the imagery and then to exploitation required for immediate and future missions.

5.1 RECOMMENDED PROCEDURE FOR ACQUISITION OF BI-COLOR PHOTOGRAPHY

Acquisition of good image quality bi-color photography through Petzval lenses can only be accomplished with a green filter in one camera and a red or an orange filter in the other camera. Unfortunately, there are no suitable green dye filters commercially available due to the excessively high filter factors. However, a special dichroic filter can be deposited on glass suitable for flight. This filter is made such that the spectral bandpass is between 490 and 600 millimicrons. The exact bandpass need not be controlled to a more accurate degree than ±10 millimicrons on each cutoff side as far as the color reproduction is concerned. In general, the transmittance within this spectral band should be as high as possible, i.e., 85 to 90 percent. However, the net effect of the bandpass width and the nominal transmittance should result in a filter factor almost the same as the primary filter on that particular camera. This compatibility will enable the slit width programmer to operate at all latitudes as if the primary filter were in place, thus maintaining proper exposure over denied areas. This consistency of exposure is an important consideration for an operational bi-color acquisition since the slit cannot be changed over denied areas by any means other than that programmed for the primary filter.

Another consideration in the acquisition stage is the camera lens that is to be used. The SF-05 type of filter will perform better on the second generation Petzval lenses because they were designed for a Wratten no. 21 filter. The SF-05 filter will not perform as well on a third generation lens (which is designed for a Wratten no. 25) because the high quality performance portion of the lens has been shifted further away from the green toward the red portion of the spectrum. Thus far, only second generation lenses have been used with the SF-05 filter in the aft-looking cameras. It has been the practice to use a Wratten no. 25 filter on the forward-looking camera and a Wratten no. 21 on the aft-looking camera. All 1100 series missions after 1103 will employ a third generation lens on the forward-looking camera. Missions 1110, 1113, and up will employ third generation lenses on both cameras. The most desirable arrangement, then, would be an SF-05 filter in the aft-looking camera with a second generation lens and a Wratten no. 25 filter in the forward-looking camera with a third generation lens. This will be possible, therefore, on all 1100 missions up to 1112, excluding 1110.

5.2 RECOMMENDED PROCEDURE FOR EXPLOITATION OF BI-COLOR PHOTOGRAPHY IN THE IMMEDIATE FUTURE

With the equipment available at this writing, the recommended procedure for producing bi-color prints is almost exactly the same as that used to make the illustrations in this report.

The first step is to select the target areas and determine the maximum magnification that can be used to enlarge the target area of interest to 9 × 9 inches. If the targets chosen have partial clouds and/or shadows, serious problems will be encountered in producing the color prints. Since clouds can be quite high, they are seen over different ground terrain with respect to the two cameras. The result will be similar to the problems that occurred on the Cape Kennedy image (Fig. 3-7). A much more serious problem is thin clouds, which would have only a slight effect and might not be detected as such, thereby falsifying the interpretation. The enlargements are then made to form 9- × 9-inch transparencies. Two sets of transparencies from both cameras should be made. It is recommended that the best possible enlarger be used at this stage since it is the first stage of a series of duplication processes. With magnifications of 10× or greater, there is negligible resolution loss during the subsequent stages (except for the scan lines introduced by the orthoprinter). The Eastman Kodak 10-20-40 enlarger has been used on the 1102 samples and appears to be the best equipment available for this task. The initial transparencies should have a density range of 1.0 with D_{min} and D_{max} values of approximately 0.3 and 1.3, respectively. These values are important, since there must be sufficient contrast for the orthoprinter to function properly and, at the same time, not so much contrast as to impair the color reproduction. The exact tolerance on this density range is not known. It should, however, be on the lower side (i.e., $\Delta D = 0.8$ or 0.9) if exactly 1.0 cannot be achieved.

The next stage in the exploitation procedure is to use one set of the positive transparencies on the ARES viewer for an immediate readout of the targets chosen. At this point, the final selection of prints can be made. At the same time, the other set of transparencies can be sent to the nearest orthoprinting equipment (probably ACIC in St. Louis). The final decision on which scenes are to be used can then be relayed to ACIC after they receive all of the enlargements.

The orthoprinting portion of this effort should be carried out in the following manner. The AS-11C should be set for the positive-to-negative mode in order to obtain a third generation negative after orthoprinting. A 5-millimeter scan width has been used successfully in the past. Finer scan widths may be required if the detail of interest is very small. It is at this point that an active interplay is needed between the operators of the orthoprinting equipment and the user of the bicolor pictures. The processing of these images should be done to a gamma of 1.0 to 1.5, but no higher. The fidelity of the color reproduction can be completely destroyed if the contrast is allowed to go too high before the color printing process.

The next step is to send the orthoprint negatives to NPIC for further duplication. The final stage is a color printing process that requires dupe positive images; for this, the negatives from the AS-11C would then have to be duplicated.

An alternate approach is to use the positive-to-positive mode in the orthoprinting stage, which eliminates the need for a subsequent duplication process. As inviting as this method appears, it levies one very critical requirement upon the orthoprinter. The output density range must be optimum for color printing. The disadvantage to this approach is that there is no chance to correct for an error unless two additional duplication stages are used. Further, it is not possible to specify the exact contrast range desired since the best color reproduction is a function of the type of scene and the minute details within this scene. The positive-to-negative orthoprint approach gives a negative from which an entire family of positives can be made, the best of which is selected for color printing.

Once a good set of positive images has been made, the color printing can be performed with a pin register board. An additive enlarging technique can be used if the magnification is not too great. A 2 or 3× enlargement would make the net minimum enlargement 20 or 30×. The Itek additive color viewer/printer has a fixed 8× magnification. Since the total of 80× would be objectionable, this particular instrument is not recommended. The recommended color approach is to use an Ektachrome type B process and perform the color printing as outlined in Section 4.4.

The entire process as discussed in Section 5 is shown schematically in Fig. 5-1. Included in this figure are quantitative (where possible) specifications for each step.

5.3 LONG TERM EXPLOITATION

The optimum equipment for bi-color photography from the J-3 convergent system does not exist today. One could envision, though, the desired characteristics of such an instrument. It would:

1. Correct for all distortions
2. Make these corrections with a minimum amount of resolution loss
3. Have a visual scanning capability
4. Enable the operator to see stereo at the same time as color
5. Be able to produce a hard copy print.

In all probability no such instrument will ever exist. There is, though, a piece of equipment under development that may satisfy most of these objectives; it is called the Automatic Stereo Scanner. It will have the capability of scanning J-3 photography while maintaining the two webs in position for stereo viewing. The distortion corrections are made with anamorphic lenses rather than with a CRT scanning system. It has, therefore, the capability of higher resolution. A device could be built for this instrument similar to the ARES bi-color attachment that enables the basic ARES to work with bi-color. In addition, it would be possible to fabricate a hard copy attachment for production of hard copy prints. There are, however, many problems to such an instrument, and one must not presume with 100 percent certainty that such a device could even be made and function as expected.

The future of good bi-color photography from J-3 system will lie in an optical rather than an electronic orthophotographic system. One such instrument that is currently available is the Gigas-Zeiss Orthophotoprinter (GZ-1). Initial tests have been performed on this instrument by NPIC and ACIC, and a brief description of this equipment is included in the appendix.

Flow of Operation	Specifications
Original negatives	SF-05 and Wratten no. 21, 23A, or 25 images
Dupe positive enlargements (2 sets)	Precision enlargements greater than 10×, density range 1.0 or less, D_{min} and D_{max} nominally 0.3 to 1.3
ARES viewing	
Orthoprint negatives	Equipment: AS-11C at ACIC output density range 1.0 to 1.5 (gamma 1.0 to 1.5, no higher) scan width, 5 mm
Dupe positives (fourth generation)	Made with respect to color printing process to follow, no exact specifications can be made; probably density range between 1.0 and 1.5
Additive color printing	Pin register board Ektachrome Type B material
User	

Fig. 5-1 — Schematic of operation and specification for the recommended procedure for bi-color exploitation

6. CONCLUSIONS

The results of the bi-color experiments on mission 1102 lead to the following conclusions:

1. Satisfactory green filters (dichroic coatings on thin quartz with a low filter factor) can be produced for the operational acquisition of bi-color photography.

2. Bi-color photography can be successfully acquired with the J-3 system.

3. The laboratory resolution with the special bi-color filters and a second generation lens using 3404 film at the Wratten no. 21 focus position is slightly lower than this lens/film combination with a Wratten no. 21 filter.

4. The operational resolution of the special green filter (SF-05) is lower than the Wratten no. 21 filter due to the 1.4× longer exposure time required, the lowering of aerial contrast due to the increased haze light effects in the green portion of the spectrum, and the nonoptimum focal position.

5. The image quality degradation with the SF-05 filter in the system is not nearly as severe when the photography is viewed in stereo with a higher quality red record.

6. Special printing operations are required to remove the distortion introduced by the panoramic camera convergence angle and the terrain elevation changes in the scene. Rectification alone will not correct for the elevation changes, which cause the most severe problems. Orthoprinting removes the major distortions due to the elevation changes, although very small objects (such as aircraft) still present problems for full correction.

7. Immediate readout of bi-color photography can be performed using the ARES viewer with a bi-color attachment.

8. Stereo and bi-color can not be seen at the same time. The acquisition of bi-color does not preclude the availability of stereo viewing; however, the two techniques must be used separately.

7. RECOMMENDATIONS

The following recommendations are made as a result of this bi-color experiment:

1. Bi-color techniques should be used over operational targets in order to increase knowledge of the general color characteristics of these areas.
2. Studies should be undertaken to improve the exploitation process. In particular, an examination should be made to see if the Automatic Stereo Scanner can be adapted for bi-color viewing.
3. Until improved exploitation techniques are developed, the method outlined in Section 5.2 should be used to produce bi-color prints. The ARES with a bi-color viewer should be used as an immediate readout for newly acquired targets in bi-color.

APPENDIX

During the initial analysis effort for the mission 1102 bi-color test, it becomes obvious that the technique could produce good results. An operational test was therefore performed on the next J-3 mission, 1103. Twenty-five passes were acquired in bi-color. Enlargements of 10× magnification were made and shipped to ACIC for orthoprinting. After orthoprinting, the images were sent to this contractor for color printing. Unfortunately, the individual steps in the chain of events were not performed under optimum conditions. The enlargements were of too high a contrast, and there were nonuniformities in the orthoprinting. As a result, the final synthesis into a color print was not satisfactory.

In order to examine the problem in more detail, a National committee was established. As a result of the committee action, a test plan was devised to compare several orthoprinting techniques on a limited number of bi-color samples. This test is aimed at comparing the following orthoprinters—AS-11C, UNIMACE, and Gigas-Zeiss Orthophotoprinter (GZ-1). By adding the second two pieces of equipment, a more complete test will be performed taking advantage of all the sources of talent and hardware available to the Government.

As a second phase effort, Air Force Special Projects Production Facility (AFSPPF) is examining the potential of the 3M Electrocolor device for making the bi-color prints. The machine has been modified to print the individual records in register and may serve as a useful fast color printing process for the bi-color exploitation. A print can be made in approximately 15 minutes once the machine is initially set up. Although one print in 15 minutes is slow by large volume batch processing standards, it is quite good for bi-color. The most time-consuming part of bi-color printing is the color balancing. Repeated test runs are necessary, and having the opportunity to see color tests quickly is of tremendous value.

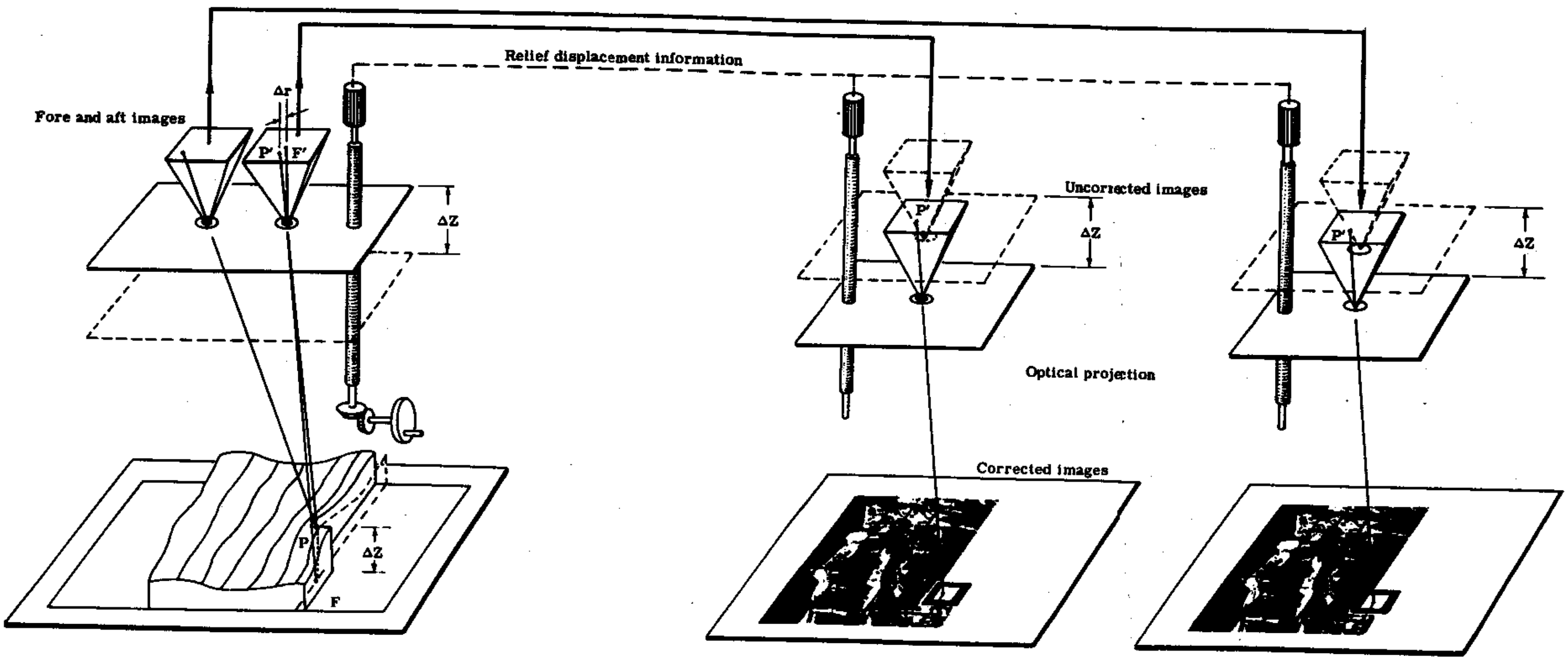
As a result of establishing the National committee, a series of experiments was proposed, whereby various equipments and techniques used in the color-record preparation were to be evaluated. Up to that time, the majority of target samples had been prepared by the superimposition of differentially rectified images from the AS-11 B/C and the UNIMACE. As preceding descriptions have shown, these instruments electronically (CRT) print the orthophotograph, form the relief model numerically in a computer, and are limited in the "size," not scale, of output to the size of the plotter stage plate. Obviously, the advantage of using these instruments was that an analytically and therefore photographically complete solution of panoramic geometry could be achieved by on-line digital computation and incremental control of the orthoprinting device. However, both ACIC and AMS have an optical printing device which has since been incorporated in the series of experiments. This instrument, developed in 1964 by the Carl Zeiss Photogrammetric Division, is known as the Gigas-Zeiss Orthophotoprinter (GZ-1) and is designed for the production of "photomaps" by strip by strip optical transformation of photographs from perspective projection to orthographic projection.

The basic operation of the technique incorporating the GZ-1 is illustrated in Fig. A-1. In function A, the three-dimensional model is formed by the forward and aft stereo records. This function may be performed numerically in the AS-11 B/C or UNIMACE, or it may be performed in an analog sense in a spindle-driven optical-mechanical plotter. If an analogue plotter is employed, the panoramic records should first be transformed to equivalent near-vertical photographs using an instrument such as the Gamma I Panoramic Rectifier.

The GZ-1 has projective camera cones up to 12 inches in focal length, but since the Gamma Rectifier has a nominal isometric magnification of 1.87×, the resulting output focal length of the 24-inch camera is approximately 45 inches. Most target areas are then enlarged an additional amount. Because the material (target chip) focal length does not match the GZ-1 projective geometry, the output is not a true orthophotograph, but the imagery in the forward and aft records is displaced to similar positions in the differentially rectified output resulting in bi-color records readily superimposed for color printing. In functions B and C, the image is optically divided into strips, displaced, and printed in the corrected position. A final function, D (not illustrated) would be the superimposing of the output records of B and C. The major disadvantage of the GZ-1 technique is the requirement for rectification; however the availability of the Gamma I (15 units in operation in the community) plus the fact that photographic enlargement is normally a desired step, partially offset this consideration. The advantages of this technique are:

1. High resolution optical printing; the Topogon O (a newly designed lens) has a high contrast input plane resolution of 90 lines per millimeter.
2. Input chip widths of up to 9 inches with magnification up to 4×, allowing an 8× overall magnification of the full 70-millimeter film width.
3. Off-line photographic operation allowing the following:
    a. Correction of mismatch or errors without repeating displacement (stereo model) measurement.
    b. Interpolation between profiles for higher quality and no banding.
    c. One printer can service a series of off-line plotters located at remote facilities.
    d. Printing speed is not controlled by plotter speed; 100 square inches of input can be printed in less than 2 hours.
4. After Gamma rectification, existing inexpensive plotters can be used to prepare displacement data for GZ-1.

Since the GZ-1 experimental results have been received, it has been brought to our attention that the GZ-1 printing slit can be fitted with a fiber optic "rectifier" which will correct the remaining mismatches in the output record. It would appear that the high quality results of the recent GZ-1 experiment plus the relatively inexpensive instrumentation and high production rate would place this technique high in future consideration.



FUNCTION A: Formation of stereo model which provides quantitative differences in bi-color fore and aft images

FUNCTION B: Using difference information (displacement from mean position), print corrected image

FUNCTION C: Same as B in function but opposite in displacement

Fig. A-1 — GZ-1 Orthoprojector bi-color printing operations