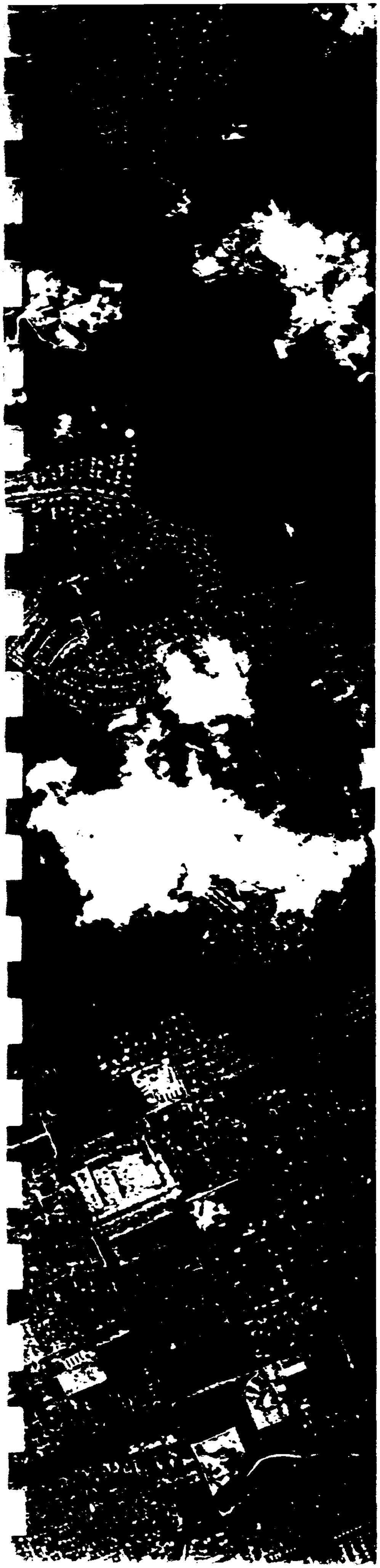

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EKIT REPORT NO. 16 (EKIT FLIGHT NO. 2)

BICOLOR EVALUATION

15 SEPTEMBER 1967

CONTRIBUTORS: [redacted]

APPROVED BY:

[redacted]

Itek

ITEK CORPORATION LEXINGTON 73, MASSACHUSETTS

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1. INTRODUCTION

Bicolor photography has been evaluated successfully in theoretical studies, and it has been demonstrated in both laboratory tests and in-flight tests using frame type cameras at moderately high altitudes. It was the purpose of this effort, however, to test the feasibility of obtaining bicolor photography from a panoramic, stereo type of camera system, flown in an aircraft at high altitudes, for the purpose of preparing for a similar test on the KH-4B System.

The test was conducted by flying the 112B Camera System with a red filter on one camera and a green one on the other. The negatives from this test were rectified and orthoprinted (separately) by ACIC. These images were then additively printed on Itek's Additive Color Viewer Printer (ACVP) in order to obtain bicolor prints. A subjective analysis was also performed on the negative to ascertain the loss in quality by using a green filter on a second generation Petzval lens. Unfortunately, no CORN targets were covered in this mission and a thorough tone reproduction analysis was not possible.

The following list presents the conclusions of this report. These conclusions are discussed in greater detail in Section 6.

1. Color photography is obtainable from this type of panoramic photograph using standard black and white film as original negative material.
2. Perfect registration will not be possible in the KH-4B System due to the nature of providing stereo imagery.
3. The image quality of the original negative produced with the Wratten no. 57 green filter is somewhat less than that of the Wratten no. 25 filter with a second generation Petzval lens.
4. The effect of haze can be more easily controlled in bicolor photography than with reversal color film by processing each of the records to its optimum gamma.
5. A bicolor test is recommended on a KH-4B engineering flight.

2. TEST PLAN

This report contains the bicolor analysis that was performed on type 3404 film incorporating the Wratten nos. 25 and 57 separation filters. Originally, EKIT flight no. 2 was to provide the necessary imagery for the complete test, however, in the analysis stage it became evident that additional imagery would be needed. EKIT flight nos. 2A and 2B were flown, therefore, one incorporating type 3404 film and the other type SO-230 film. From these flights, the required imagery was obtained. This section describes the basic camera configuration and the specific details of the camera settings and flight lines that were used for these three tests.

2.1 112B CAMERA

A brief description of the 112B Camera is warranted to introduce the system used in this EKIT test. The camera, a panoramic scanning type of system, has been designed around a diffraction-limited Petzval type lens of 24-inch focal length with an f/3.5 aperture that covers a 6-degree field angle. To obtain stereo, a pair of these cameras is tilted from the nadir at 13 degrees each, and set face to face so that each camera scans in opposing directions. The lens is continuously rotated about its operational nodal point and scans across the line of flight and is translated against the flight direction for image motion compensation.

During approximately 70 degrees of the lens rotation, a capping shutter is opened to permit the aerial image to expose the 70-millimeter film through a slit. This slit controls the exposure time, e.g., at a 20-inch per second scan rate, a 0.040-inch slit produces an effective exposure of 1/500 second. At the completion of the photographic scan, the capping shutter is closed.

The film is continuously being transported in from the supply spool and out to the takeup spool. A frame-metering roller controls the frame length, the correct amount of film is placed in the format area, and clamps at each end of the format hold the film stable and in the approximate focus position. The excess film is accounted for by a shuttle assembly that gives or takes according to demand.

The focal position is determined by a scan head assembly mounted on a precise arm from the nodal point to the focus. This scan head gently lifts the film from the rails to the image plane during exposure and returns it to the rails after exposure. The rails are required only to hold the film at the approximate focus and to guide film during transport.

Recorded on the film edge outside of the format area on each frame are frame number, binary time, and timing pips of 125 cycles per second. These timing pips are scanned on the film across the 70-degree format length with one pip blanked out to indicate when the binary time data block is printing out. Three scanning rates are built in to match the V/h requirements while maintaining approximately 10-percent overlap at the format center. Increased overlap is acquired on both sides of nadir as the off vertical scan angle increases.

The exposure slit and filter are preselected for the V/h requirement and subject illumination and consistently produce the correct exposure.

A major consideration of all EKIT testing is that no modification be made to the camera that was not compatible with the normal operation of the KH-4B System. The camera is, therefore, not changed in any mechanical sense. Other restrictions placed on the test series were: (1) that exposure times be short enough to prevent any vehicle disturbance to the image, and (2) that the exposure slits remain sufficiently wide to prevent any diffraction effects. For this test no unusual camera settings were required other than using a green filter on one camera.

2.2 FLIGHT TEST PLAN DETAILS

The three flights necessary for this test were flown over the Fresno/Bakersfield/Long Beach areas in early August 1966, and late May 1967. A summary of the camera settings is given in Table 2-1.

Table 2-1 — Specific Camera Details for EKIT Flight Nos. 2, 2A, and 2B

	[redacted] EKIT Flight No. 2		[redacted] EKIT Flight No. 2A		[redacted] EKIT Flight No. 2B	
Camera	Master (I-3)	Slave (I-4)	Master (I-7)	Slave (I-8)	Master (I-7)	Slave (I-8)
Film	3404	3404	3404	3404	SO-230	3404
Filter	44A + 2E*	W-21	W-57	W-25	W-57	W-25
Slit width	0.049	0.049	0.150	0.075	0.075	0.075
Exposure time	1/400	1/400	1/125	1/250	1/250	1/250
f/no.	3.5	3.5	3.5	3.5	3.5	3.5
Scan mode	II	II	II	II	II	II
Processing	Full	Full	Full	Full	Full	Full
Flight date	5 August 1966		23 May 1967		24 May 1967	
Time of photography	1808 to 2127 Z		1728 to 1847 Z		1729 to 1848 Z	
Sun angle	67° 15" to 70° 36"		50° 19" to 71° 07"		56° 25" to 71° 16"	
Area covered	Bakersfield Fresno Long Beach		Bakersfield Fresno Long Beach		Bakersfield Fresno Long Beach	

*This material was severely underexposed and not suitable for the required analysis.

3. THEORETICAL CONSIDERATIONS OF BICOLOR PHOTOGRAPHY

Color photography is ordinarily obtained by imaging a scene on an emulsion containing three records, each of which is sensitive to approximately one third of the visible spectrum, i.e., blue, green, and red. Generally, these sensitive records are contained in one emulsion called a tripack. In the case of a reversal color film, the final image is obtained on the same material used in the camera. Color photography can also be obtained by photographing the same scene with three sensitive records, each in a separate camera. All three emulsions could be the same; wavelength separation is obtained with the appropriate red, green, and blue filters. With this type of photography, a laboratory analysis must be performed in order to reconstitute the color image, since the records are contained on three separate films. The procedure is to make positive images and project them onto a screen for viewing or onto a color film for a permanent color record. This process is called tricolor additive photography, even though it also employs a subtractive process in producing the final color image.

Color theory dictates that three primary colors are required for this type of photography to yield a full range of colors. It is possible, though, to obtain color photography with only two photographic records. This type of photography has been called bicolor additive photography, or simply bicolor. The process is almost exactly analogous to tricolor photography in that negatives are made, positives are printed, and a color record formed through the superimposed projections of these positives through color filters. The prime difference is that there are only two records involved instead of three. Color theory also states that photographs produced in this manner cannot contain the full range of colors evident in the original scene. A very important point to be considered, however, is whether or not full color is required to obtain a significant gain in information. This question will be discussed in later sections of this text.

Experiments in bicolor photography have been carried on at Itek for the past 3 years. During that time, a solid foundation has been obtained for bicolor photographic theory through extensive use of computer programming. These theoretical studies have been supplemented by several laboratory experiments. This work has been carried to the stage where very good images have been obtained from aircraft tests with frame-type cameras. A special integrating type of enlarger, the Additive Color Viewer Printer (ACVP), has been built specifically for this type of photography. It simultaneously exposes up to four records on one surface, in registration for either viewing or printing.

In order to get a better theoretical understanding of bicolor photography, an effort was undertaken to program the entire additive photographic process for a digital computer. The initial work was done with an additive tricolor system in order to obtain results from a photographic process that was more standard than the bicolor. The same concept was carried through the year of programming for the bicolor program. When a new idea was thought out, it was first used on the tricolor program. When it worked and was thoroughly understood, it was tried on the bicolor program.

The computer used was the CDC 924, which is considered by today's standards to be a medium speed machine. Associated with the computer is an on-line digital plotter that was used as the prime output. The complete theoretical background for the computer program is beyond the scope of this report. However, a brief explanation of the graphical output is warranted.

The following description relates to the seven quadrant, bicolor tone reproduction plot illustrated in Fig. 3-1. The tone reproduction display represents the reproduction of tones from a neutral gray scene on the ground through each of the successive stages in the photoreproduction process. The original scene (as represented by a reflection gray scale for instance) is termed the "subject log reflectance" scale and is one of the axes of Quadrant I. The other axis of this quadrant is the effective log exposure to the film in the camera. The curve in Quadrant I, therefore, represents the transfer from the original ground object to the film's effective exposure. The curve contains all of the atmospheric and camera effects that influence the energy transfer.

Once the image has been formed on the negative film, the effect is a series of densities. These are determined by the particular characteristic curve for the negative material that is used in Quadrant II. The duplication process is represented by Quadrant III (the dupe material) and Quadrant IV (the final reproduction). The fourth quadrant is, therefore, the black and white objective tone reproduction for this particular negative-positive system. Since this program deals with the bicolor photographic problem, there have been two curves in each quadrant, one for the cyan and one for the orange record. The two records in Quadrant IV must be printed onto a color reversal material in order to see the color image. The sixth quadrant contains the color sensitometric curves for a reversal material. There are three curves in this quadrant, one for each of the three sensitive layers of the film. The densities in the fourth quadrant become a series of log exposures to the color material.

If each series of the densities was directly related to the log exposure axis of the color material, Quadrant V would merely be a 45-degree line. However, since there is an overlap in the spectral sensitivity of the three layers in the color film, the line is not at a 45-degree angle. There is a very extensive overlap in that the blue sensitive record is exposed primarily by the cyan record, the red sensitive layer by the orange record, and the green sensitive layer by the overlap from the cyan and orange exposures. There are four lines in Quadrant V, each one relating the effective exposure produced to the record from which it came. Since the effective green exposure has come from two sources, two lines were plotted, each relating the single green effective exposure to the two records. This quadrant, therefore, represents the transfer of energy from the black and white portion of the process to the color section.

The final color reproduction is determined by plotting the resulting color densities versus the original subject log reflectance scale as illustrated in Quadrant VII. This shows the color image densities as they relate to the original scene. Any departure from the three superimposed curves means that neutrals have not been reproduced as neutrals. The contrast and toe and/or shoulder detail can be interpreted in the same manner as with black and white photography.

The eighth quadrant is used in an analysis of the total range of colors that can be obtained with the particular bicolor system under test. This range of colors is termed the color gamut. The CIE coordinate system is used for displaying these gamuts. With tricolor photography, the range of colors that can be obtained consists of a three-dimensional solid. The range is quite large, consisting of approximately 100 different distinct hues, almost all of which can occur at several hundred intensity levels and at many degrees of purity. The bicolor gamut, however, is considerably more restricted in size. It is a two-dimensional plane suspended within the color solid. It has, generally speaking, a greater range of intensities of a neutral nature than of colors

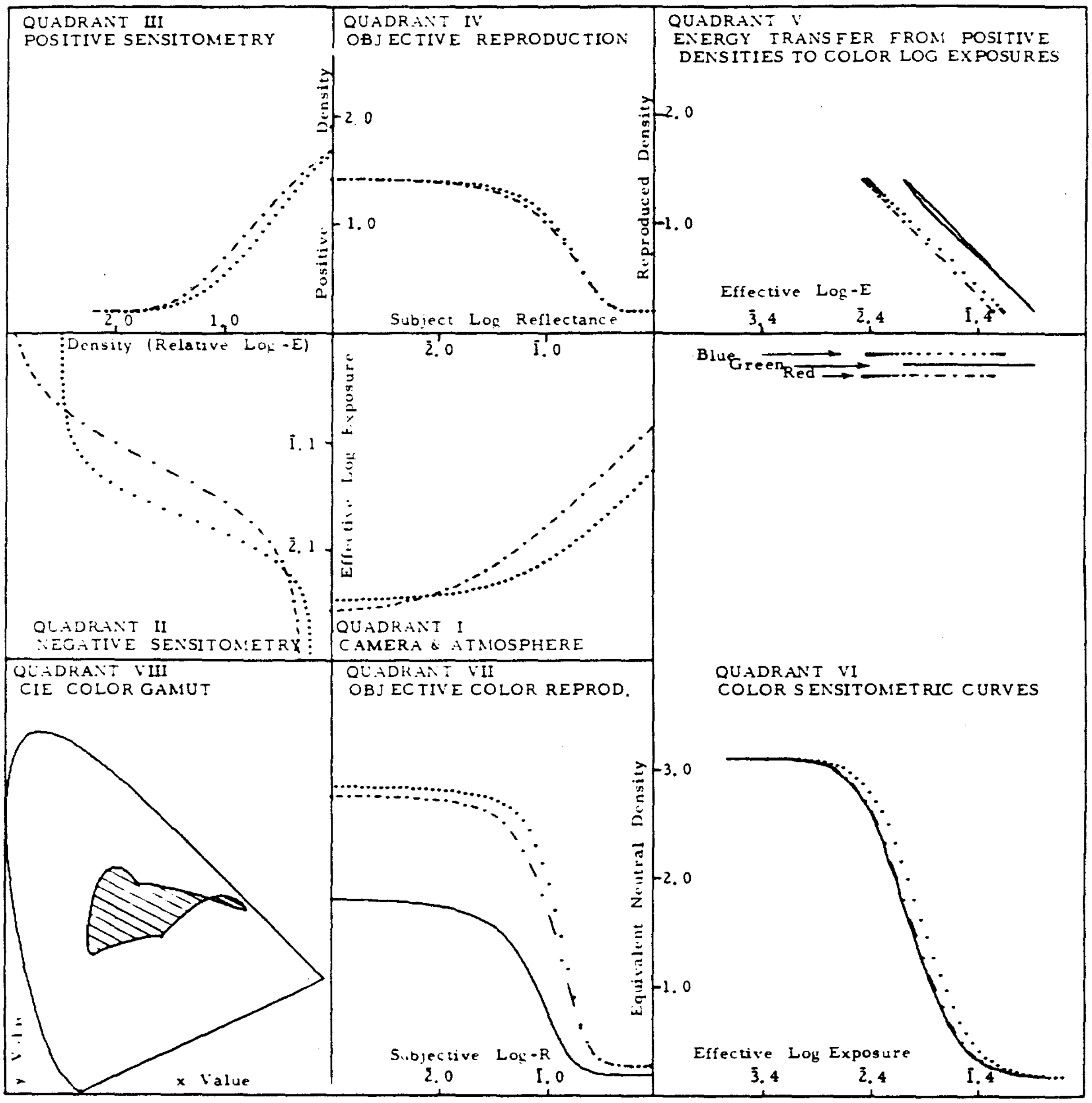

Fig. 3-1 — Tone reproduction cycle for the bicolor photographic system themselves. There are perhaps only one third to one half as many distinct hues (in some cases one tenth as many). There are only a few levels of purity, the most pure of which is considerably less pure than that of its tricolor counterpart.

3.1 APPLICATION AND THEORETICAL WORK

One of the unique aspects of a computer is that it will do exactly what it is told to do—no more and no less. An unfortunate drawback to this is that it must be told to do a specific task in the correct way, with no last minute changes in thought. It must also be supplied with the proper data. This fact alone is the one that makes the application of this type of computer program to the real world very difficult. For example, the program may state exactly how specific colored objects will be reproduced under a given set of conditions of atmosphere and sensitometry. In order for this prediction to work in a flight test, those gammas must be attained, that printing time must be attained, those atmospheric conditions must prevail, etc. The computer program has been put to more practical use, during the past year at Itek. It can tell what will happen in general, or on the average, for a given test. With this capability, it can recommend the best filter of a set of haze-attenuating filters; and it can recommend the best range of gammas to process the negatives to under some general atmospheric conditions.

Another area where the computer program has been useful is in original theoretical studies, several of which have been undertaken in conjunction with actual laboratory samples to better illustrate the effect. The most notable such study was one in which the bicolor gamut of colors was first learned. The classic shape of this gamut is a "bow tie" or "figure eight on its side" suspended within the color solid. A laboratory test was performed to verify this finding, which was, in fact, true.

Other theoretical tests have been performed in order to improve the color printing stage of the process, and to obtain a better understanding of the mechanism involved in relating the two exposing sources to the three dye images that are formed.

The photographic work performed to date has taken three forms: (1) simulations of an aerial photographic problem, (2) color printing experiments, and (3) handling flight material from the camera to the final bicolor print from frame type cameras. The aerial photographic simulations have been used primarily for obtaining images that could be used in general bicolor experiments, i.e., the best filters to be used under certain types of haze conditions. These images have also been used in laboratory printing experiments. These experiments have included answering questions such as what printing filters should be used, what gamma to process the dupe, what relative exposure times to use, etc.

3.2 PROBLEMS ASSOCIATED WITH BICOLOR PHOTOGRAPHY IN THE 112B CAMERA SYSTEM

The pan scanning type of photography presents new problems for the operational use of the bicolor techniques. The most difficult problem has been in the method that will be used to view the images. With frame photography, all portions of the two images are at the same scale and are taken at the same time. With the type of pan photography used in the 112B System the images are taken from different look angles and at different times.

This presents two types of problems. First, since the imagery has been made at two different times, some portions of the scene will have moved, i.e., people, cars, or trees in a strong breeze. Also, slight changes in scale occur from varying altitudes over this time period. The second problem is that with two different look angles the photography is more applicable to stereo and not superimposition; for example, each of the images may show a different side of a building.

In order to avoid this second problem, some sort of image rectification and/or orthoprinting may be required. ACIC rectified and made orthoprints from several images from this test. These images were then used in the ACVP for producing the bicolor images.

Other problems are exposure and focus. An additional stop was required for good exposure through the green Wratten no. 57 filter over that of the red Wratten no. 25 filter. The Petzval lens, being designed for the Wratten no. 21 filter, does not perform as well with a Wratten no. 57 filter. Its resolution in this spectral region can be improved by refocusing, though the images (even at best focus) may not be as sharp as with the Wratten no. 21. With a focus change, though, is an associated scale change that must be considered in the printing stage. This is a small problem, though, for it has been our experience that good bicolor photography has been obtained when one of the records was not as sharp as its mate.

Another problem to be faced is the requirement for matched (or nearly so) density ranges of the images from the two records. Since the prevailing atmospheric effects interfere with images made in the green spectral region, the green record has less contrast than the red record. The gamma of the green negative should, therefore, be higher than that of the red record in order to counter the atmospheric degradation. This results in better matched density ranges, and subsequently better color rendition.

As stated earlier, full color reproduction cannot be obtained from a bicolor photographic system. This may or may not be a serious disadvantage. If one were looking for "excellent color reproduction," then bicolor photography is not the method to use. But, if some color can be added to ordinary black and white images with essentially no loss in resolution, there may be an increase in the intelligence potential of the system. If one considers the range of colors that could be reproduced with any type of color photographic system from these altitudes, one immediately realizes that it is quite limited. The best illustrations available are the recent Gemini flights. A color reversal material was used for these photographs. Though the images were striking, actually there were not many different colors. With higher resolution, though, smaller colored objects would have stood out as being quite colorful.

The advantages of bicolor photography may outweigh the disadvantages. The most beneficial quality of bicolor photography is the fact that color can be obtained without suffering the loss in resolution that is ordinarily associated with switching to a color emulsion. In fact, there is the possibility that resolution may increase. Since there are two images that are fused into one photograph, the signal is strengthened with respect to the random grain pattern. The increase in the signal-to-noise ratio is theoretically 41 percent with the perfect registration of two such images. One would then assume that there would also be an increase in resolution. This has been shown to be a fact. A second advantage is that the ordinarily used Wratten nos. 21 or 25 black and white record is not lost, since this image is one of the required two, for bicolor photography.

4. SUBJECTIVE EVALUATION

This section deals with a photointerpreter's evaluation of the red and green negative image qualities and that of the bicolor integration itself. This section also includes a 16× enlargement of the red record negative, the green record negative, and the bicolor integration of these two images from a rectified positive. In addition, there is an 8× enlargement of the bicolor print from orthoprinted positives of the same area. Samples of these prints are included as Figs. 4-1 through 4-4. One thing should be noted in viewing these bicolor images. The machine used, the Additive Color Viewer Printer, is a "one-of-a-kind" instrument and, unfortunately, became defective in the middle of this test. The results are, therefore, not as good as could have been obtained if more time was available to make repairs to the machine.

4.1 SUBJECTIVE COMPARISON OF WRATTEN NOS. 25 AND 57 BICOLOR RECORDS

This evaluation was concerned primarily with the differences in the image quality of the Wratten nos. 25 and 57 records. The two records used for the bicolor evaluation were examined side by side to determine what difference, if any, would be apparent.

The initial overall impression is that the Wratten no. 25 record is of higher contrast. This was expected based on past experience. The relative contrast between two areas, particularly adjacent ones, is an extremely variable factor. There is a dependency on the spectral reflectance of the objects involved as well as on the brightness.

Areas of negative cover are particularly affected, and areas of average or high contrast in the Wratten no. 25 record are shown as having low or no contrast difference from the Wratten no. 57 record.

Cultural areas show some differences in response that can be recognized. Low contrast, neutrally hued areas such as railroad yards and older industrial complexes, show a decided increase in information content with a Wratten no. 25 filter. Buildings of all types show up better, in general, with the Wratten no. 25. However, there are cases where color has apparently been a contributing factor in having a Wratten no. 57 record of a structure look better. In the negative stage there are many instances of lower density of the green record presenting information that is blocked up on the red record. This is basically an exposure problem and, providing the density is not too high on the shoulder of the characteristic curve, it can be corrected in printing.

Residential areas are shown to best overall advantage in the red record, but drives, walks, fences, and again, roofs, show up to good advantage in the green.

Aircraft on concrete parking strips have very high contrast in the red filtered negative, and a lower contrast in the green provides a more comfortably viewed image.

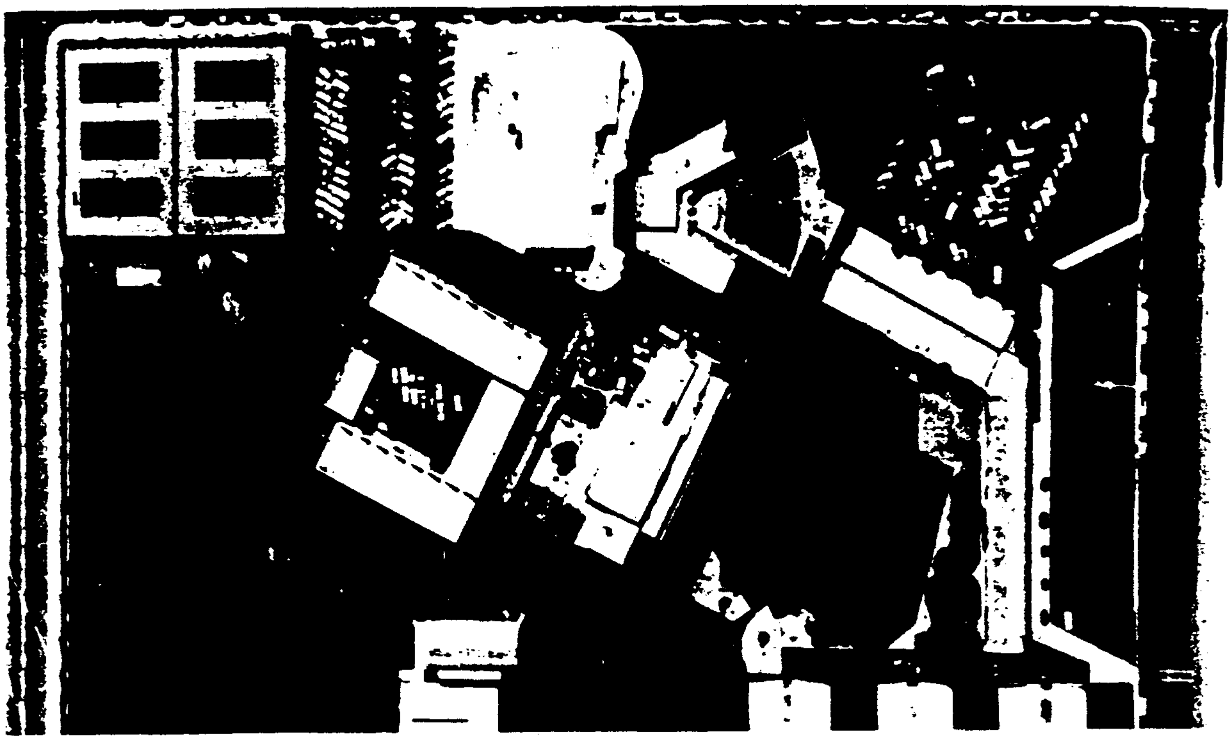

Fig. 4-1 — A 16× enlargement from the Wratten no. 25 negative

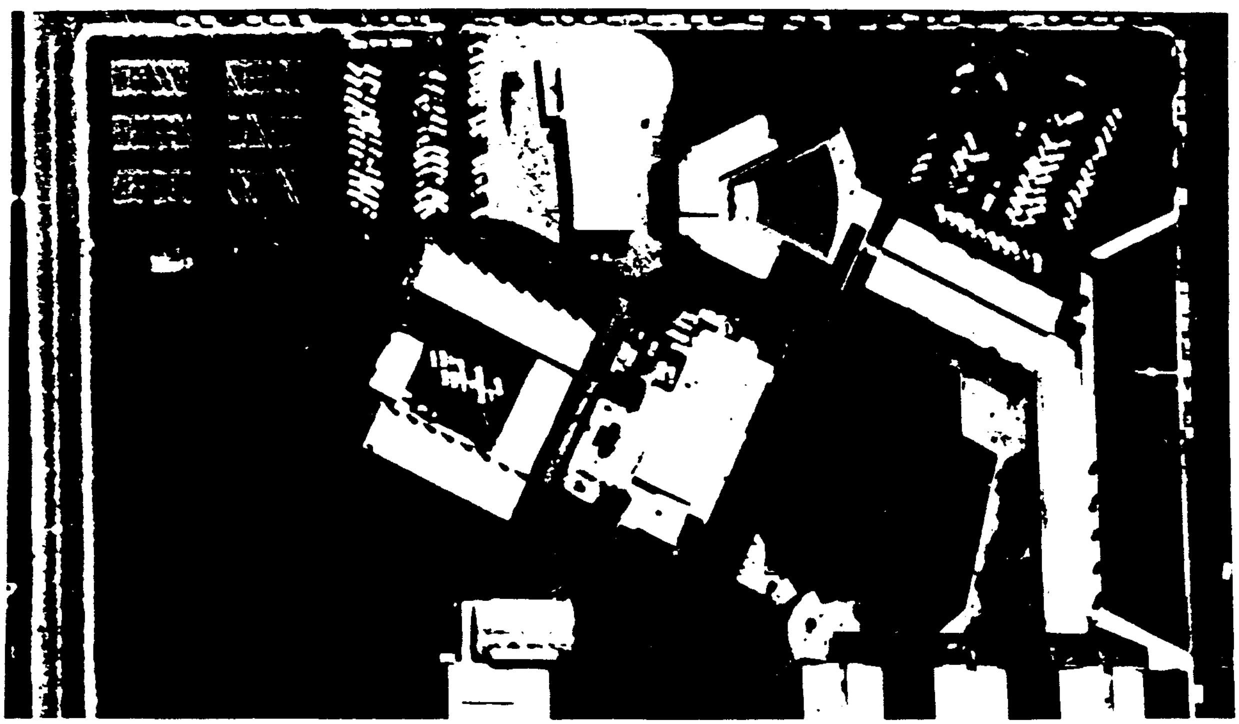

Fig. 4-2 — A 16× enlargement from the Wratten no. 57 negative

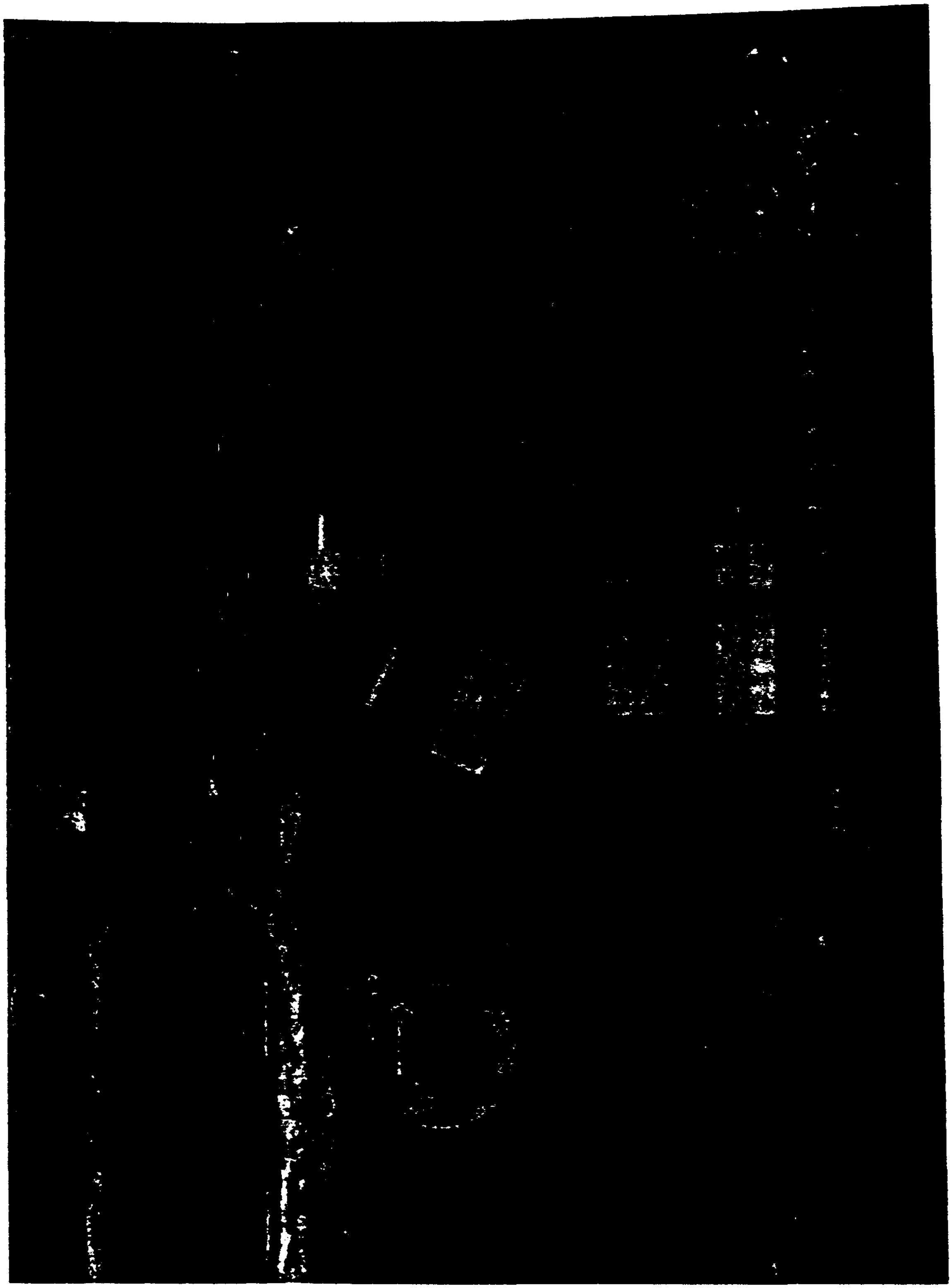

Fig. 4-3 — Bicolor print made with cyan (Wratten no. 44A) and orange (Wratten no. 21) filter from the rectified positives (net enlargement 16×)

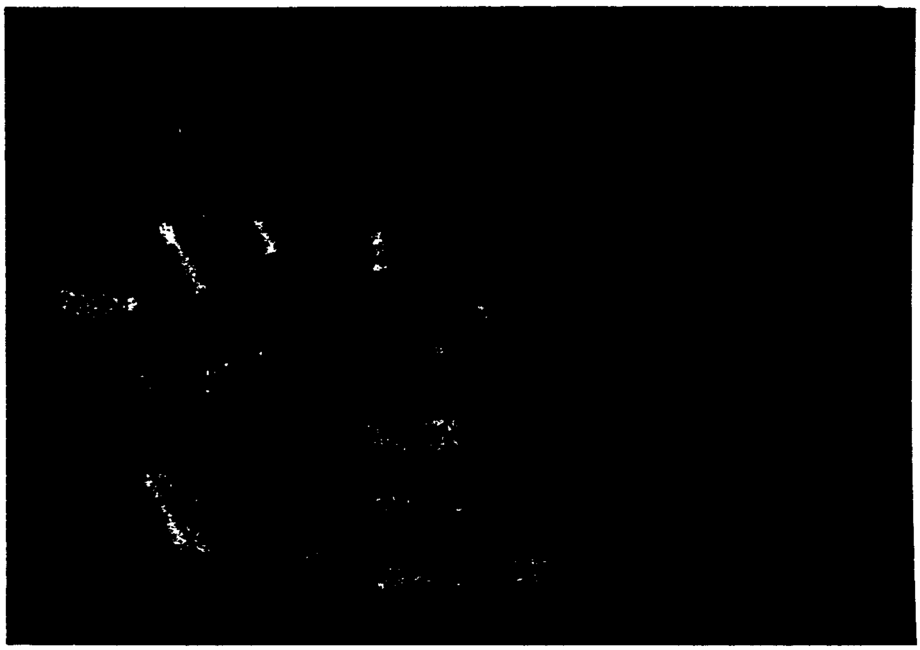

Fig. 4-4 — Bicolor print made with red (Wratten no. 25) and green (Wratten no. 57) filter from the orthoprinted positives (net enlargement 8×)

At lower magnifications, to about 15 diameters, both records appear to have good resolution and edge acuity with comparable graininess. When higher magnifications are used, particularly 40×, there is an apparent loss of both resolution and acuity in the green record. It should be noted that both cameras were set to the normal focus position. The green filtered image could have been better had the focus been adjusted for optimum results with the Wratten no. 57 filter.

4.2 SUBJECTIVE COMPARISON BETWEEN PANORAMIC RECORDS AND THE BICOLOR RECORD

Rectification of the original negative and integration of the positive imagery has produced a bicolor print with a fair transfer of detail. Color is limited mostly to orange and green and makes a distinction between grass covered and unvegetated areas. Uncorrected relief is depicted by color fringing. In the bicolor print that has only geometric rectification, it is caused by a difference in the viewing angle of the two cameras.

The orthophoto bicolor integration (Fig. 4-4) is severely degraded. Detail transfer is very poor and the scan lines of the printer are obvious. Color saturation and contrast are considerably higher (though this is attributed to the different printing filters that were used), but no appreciable amount of information is gained over the rectified print in this aspect.

Color fringing is still present around buildings, a factor that is commonly degrading to both techniques. Orthoprinting will remove most geometric relief displacements, but the sides of the buildings shown as a result of an oblique angle of view are photoimages and cannot be eliminated by any means. Higher altitude coverage would minimize the amount of fringing in a given frame area, but could not eliminate it completely.

What this bicolor does offer, that was not previously available, is color itself. One must not be mislead, though, into thinking that this is accurate color reproduction. For example, the tennis courts in Figs. 4-3 and 4-4 appear to be a form of orange. By the nature of bicolor photography, those courts that appear orange could have been yellow, orange, red, or any shade in between. Fine color discrimination such as this is not possible. However, one can easily distinguish between warm-toned and cold-toned colors, i.e., grass and clay tennis courts.

4.3 CONCLUSIONS

With the exception of a few instances noted in Section 4.1, the tonal quality of the Wratten no. 25 record is superior to the Wratten no. 57 for information content. The Wratten no. 25 record is apparently superior at the high levels of magnification that this emulsion allows for interpretation or mensuration. The fact that the focus was not at the optimum for the Wratten no. 57 means that the results should be better in the KH-4B System where the focus for that particular unit can be put at its optimum position.

The bicolor print made from the rectified positive was superior to that of the orthoprinted image. Both bicolor images (Figs. 4-3 and 4-4) have color fringing due to the fact that the cameras have different viewing angles. At smaller scales where the misregistration/ground resolution ratio has changed, this effect should be considerably smaller.

The color produced in these images is not "true" in the normal sense. For example, warm-toned objects will be clearly distinguished from cold-toned objects. Discrimination between various shades of a color, though, is not possible in bicolor as it is with a normal reversal color film in the camera.

5. IMAGE QUALITY OF THE GREEN AND RED RECORD

Since the current generation of the Petzval lens is designed for the Wratten no. 21, it is not expected to perform as well with the green Wratten no. 57. The purpose of this effort was to determine if there is any measurable difference in the resolution of the operational system when using the two Wratten filters.

The MTF/AIM technique was used to obtain resolution values. The MTF's of the systems were obtained from the bicolor records by scanning several edges for three conditions: 3404 exposed with a Wratten no. 25 filter, 3404 with a Wratten no. 57 filter, and SO-230 with a Wratten no. 57 filter. The MTF's were averaged to obtain the mean MTF's from the scanned edges. The emulsion MTF for type 3404 was divided out from the previously calculated MTF to give the system MTF. Since the emulsion MTF for SO-230 was not available, the same MTF as the one for 3404 was used. It was felt to be a reasonable approximation since there is only a slight difference in the quality of the two films (as evidenced by EKIT report no. 9).

A plot of MTF on a log/log scale (Fig. 5-1) superimposed on a plot of a previously determined emulsion threshold (again obtained from EKIT report no. 9) can then be used to determine the mean resolution for the system. This illustration also shows the 3-sigma variation of the mean resolution threshold. It is included to point out that the threshold crossing of the system MTF is, at best, an estimate of the probable mean resolution.

The resolution value for 3404 with the Wratten no. 25 filter is 65 lines per millimeter, for the Wratten no. 57 it is 62 lines per millimeter. With SO-230 and the Wratten no. 57 filter, the value is 64 lines per millimeter. It should be pointed out that, considering the inherent variability of the readers in determining the threshold curves, any differences that may have been there have been masked. These resolution values are not significantly different since they fall well within the 3-sigma spread of the threshold crossing.

In the photointerpreter's evaluation, a difference was observed due to edge sharpness and contrast between the various film and filter combinations. This indicates that the differences that are present (as indicated by the photointerpreters) are small, since the MTF/AIM technique has not picked up these differences.

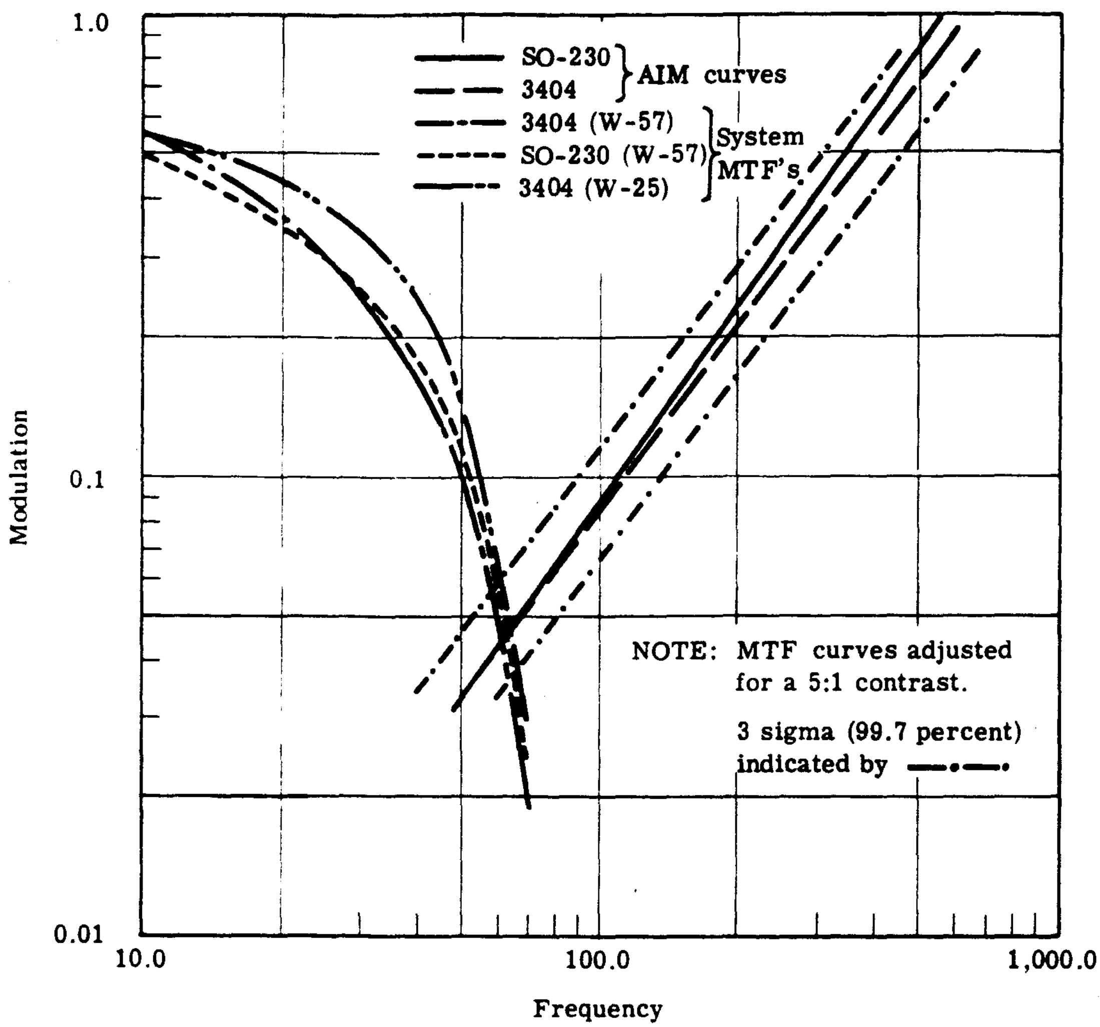

Fig. 5-1 — System MTF's after dividing out the emulsion MTF's (from operational 112B flights 2A and 2B) crossed with the emulsion threshold of the lens/film

6. CONCLUSIONS

This test enables several conclusions to be made that relate to the KH-4B System. It should be noted, though, that because of the differences in scale it is expected that much better results will be obtained from the KH-4B System than in this test using the 112B System. The conclusions follow.

1. Color photography is obtainable from this type of panoramic photograph using standard black and white film as original negative material. The color is not as accurate as in normal color reversal material due to the two component nature of the bicolor system. Though reversal color film can produce full color at ground levels, they also are severely limited at high altitudes due to the prevailing atmospheric haze. The fact that bicolor produces limited color is not, therefore, considered a major drawback.

2. Perfect registration will not be possible in the KH-4B System due to the necessity of providing stereo imagery. Neither rectification or orthoprinting eliminates the photographic image of the different sides of the building for each camera. The misregistration is shown by color fringing. This problem will tend to disappear at smaller scales when the ratio of the misregistration to ground resolution is more favorable.

3. The image quality of the original negative produced with the Wratten no. 57 green filter is somewhat less than that of the Wratten no. 25 filter with a second generation Petzval lens. This difference was not measurable with the MTF/AIM technique, but it was picked up by a subjective analysis.

4. The effect of haze can be more easily controlled in bicolor photography than with reversal color film by processing each of the records to its optimum gamma. In addition, the contrast loss due to atmospheric haze is much less, since a green filter is used rather than a blue sensitive record as in standard reversal color film.

5. A bicolor test is recommended on a KH-4B engineering flight.