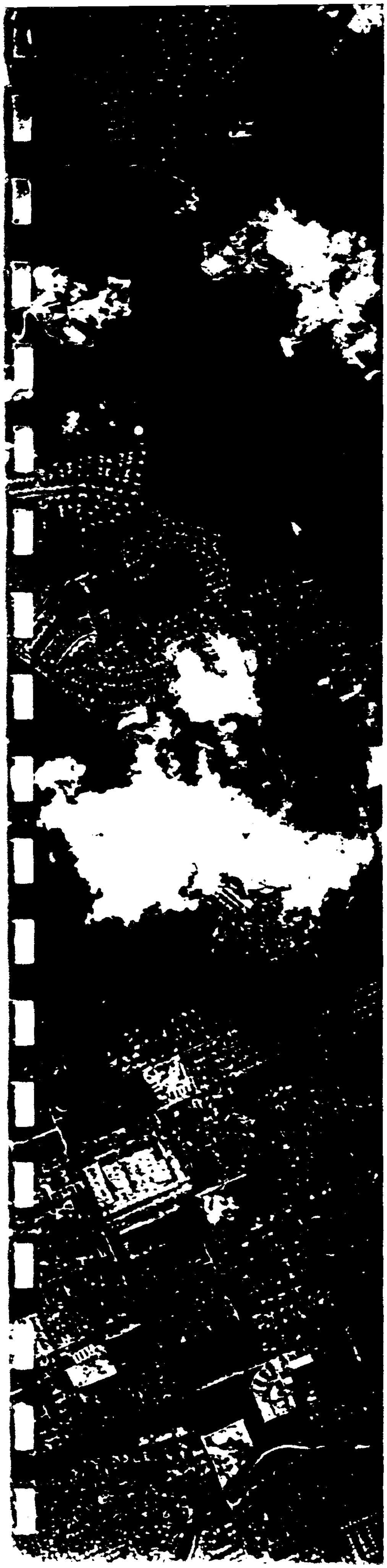

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EKIT REPORT NO. 12

EVALUATION OF SO-180 (INFRARED COLOR FILM)

14 AUGUST 1967

CONTRIBUTORS: [redacted]

APPROVED BY:

[redacted]

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1. SUMMARY

The use of color for aerial photography is still a relatively new and untried technique even though the methods have been available for many years. An explanation for this is the belief that the added advantages which could be attributed to the dimension of color could not compensate for the cost, complexity, and uncertainties associated with color materials, in addition, the lenses currently being used for aerial reconnaissance have not been designed specifically for color and do not perform as well in the blue and infrared spectral regions. This, added to the fact that the inherent resolution of today's color film is not as high as that of type 3404, results in a serious loss in resolution. However, in recent years the techniques for handling color have advanced to such a degree that the adaptability of color photography to aerial reconnaissance has been given serious consideration and in some cases been put into regular service.

The availability of present day color emulsions falls into two categories: true color rendition, which attempts to reproduce the scene without alteration of the color composition; and infrared sensitive materials, usually referred to as false color or CD films, which distort the color synthesis of the scene into meaningful groups to enhance detection of certain scene characteristics. Each group makes its own unique contribution toward the gathering of intelligence from aerial photography, and it is the purpose of this report to describe these assets.

The foremost question with regard to color aerial reconnaissance is whether or not the added dimension of color compensates for its reduction in resolution, as compared with panchromatic materials. A simplified answer is that in some situations it does and in others it does not and the controlling factor is the type of application for which the imagery is to be used. The prevailing argument for color is that is presents an image to the photointerpreter in a format similar to his natural environment. People are accustomed to identifying objects not only by size and shape, but also by color. A truck, for example, can be associated with an activity by its color, i.e., red being emergency, yellow perhaps being fuel. The identification of a tree is accomplished not only by its morphological features, but also by its color.

Color can also be used to separate two adjacent objects of different color which may appear as a unit with panchromatic photography. If these two objects have the same brightness and are located in the regions of the spectral sensitivity curve that have an equal response, there will be no discrimination of the black and white film. However, it is evident that the color emulsion will have no difficulty in differentiating between the objects.

Infrared sensitive films provide information which is based on the spectral distribution of an object; to be specific, its infrared radiation content. Some experts feel that this information is superior to that which can be contributed by true color photography. Its applications are as diverse as military reconnaissance; the detection of insect or fungus disease in forests, orchards, and wheat crops; the tracing of water courses; and the study of soil conditions.

Type SO-180 film does not have any application in the detection of heat. Its response to this type of radiation is negligible, and to record the slightest trace would require exposure times in the order of 15 to 20 minutes to a heat source of 600 to 700 °F. Its ability to detect recent activity around missile launch complexes, such as changes in temperature or vegetation, is inconsequential and is explained in detail in Section 4.

The speed of either SO-121 and SO-180, although six to eight times faster than 3404, is still too slow to make it a satisfactory medium for use in night photography.

Although the literature published on SO-180 indicates that the position of focus need not be altered from the normal, it is recommended that a focus series be run to verify this assumption. An explanation which negates the need to change focus can be found in Section 2, however, the application referred to in this discussion may be for specialized conditions. The coverage from orbital photography may require an alteration to the normal focus position.

Direct subjective comparison of SO-121, SO-180, and 3404 indicates marked changes in their recording and object discrimination capabilities. As expected, 3404 excels from the standpoint of recording fine detail. Normal color photography (SO-121) has the advantage of recording objects in their "true" color and gives the photointerpreter a correlation between the real world and the aerial imagery. Infrared sensitive film, type SO-180, has its greatest advantage in detecting water courses and foliage. Manmade objects do not record on SO-180 with sufficient contrast unless they are superimposed on natural features such as grass, parks, and trees.

The purpose of the index camera in the KH-4 System is to record general geological features. The detection of fine detail is not the prime objective. The recording characteristics of SO-180 are ideally suited to this type of imagery and, therefore, it is recommended that the infrared sensitive film be tested in this system.

2. MATERIALS DISCUSSION

2.1 FILM CHARACTERISTICS

2.1.1 Sensitometry

Although it is not the purpose of this report to give an exhaustive sensitometric description of SO-180 and SO-121, several sensitometric comparisons which are directly related to the two film's image forming capabilities will be presented. These factors are important to judgments made later concerning the usefulness of SO-121 and SO-180 for color aerial reconnaissance.

2.1.1.1 Integral Spectral Density

The integral spectral density curves for SO-180 and SO-121 are shown in Figs. 2-1 and 2-2, and the D-log E curve for 3404 is shown in Fig. 2-3. An examination of these curves provides insight into the reproduction capabilities of the three films.

The useful log E range of a film is a measure of its ability to accept scenes of varying brightness ranges. The density range of the scene as reproduced from the useful log E range of the original film is subsequently printed onto a duplicating material. This duplicating material, likewise, has a useful log E range. In a conventional tone reproduction procedure, the acceptance latitude of the duplicating material can be interpolated into the density scale of the original film. This range can then be carried through the D-log E curve and expressed as the acceptance range of the combination. If the brightness range of the scene is greater than the acceptance range (useful log E range), either the highlights or shadows or both will show no density difference, and the information in that region will be lost. It is obvious, therefore, that an extended log E range is a most desirable characteristic if a wide latitude of subjects is photographed.

The latitude of SO-271, the duplicating material for SO-121, and SO-180 is approximately 2.0. The manufacturer recommends that the minimum useful density of 3404 be 0.48 and the maximum be 2.0. From Figs. 2-1, 2-2, and 2-3, the useful log E range for the three films can be determined and the corresponding acceptable scene contrast can be calculated. This is shown in Table 2-1. Note that, in each case, the duplicating material will have no difficulty in reproducing the information on the original record.

SO-121 and SO-180 will accept scene contrasts which are equal, while 3404 will record one slightly higher than the previous two. It should be realized that the filtration used to expose these films will have a significant affect on the apparent scene contrast. The filters used in this mission where Wratten no. 21 with 3404, Wratten no. 15 with SO-180, and Wratten no. 2E plus CC30 Blue with SO-121. The first two will significantly increase the original scene contrast. SO-180 will have the greatest difficulty in reproducing good highlight and shadow detail because of its limited acceptance range and contrast increasing filtration. The reproduction of SO-121 is slightly better than SO-180. Though it has an equal acceptance latitude, the exposing filtration

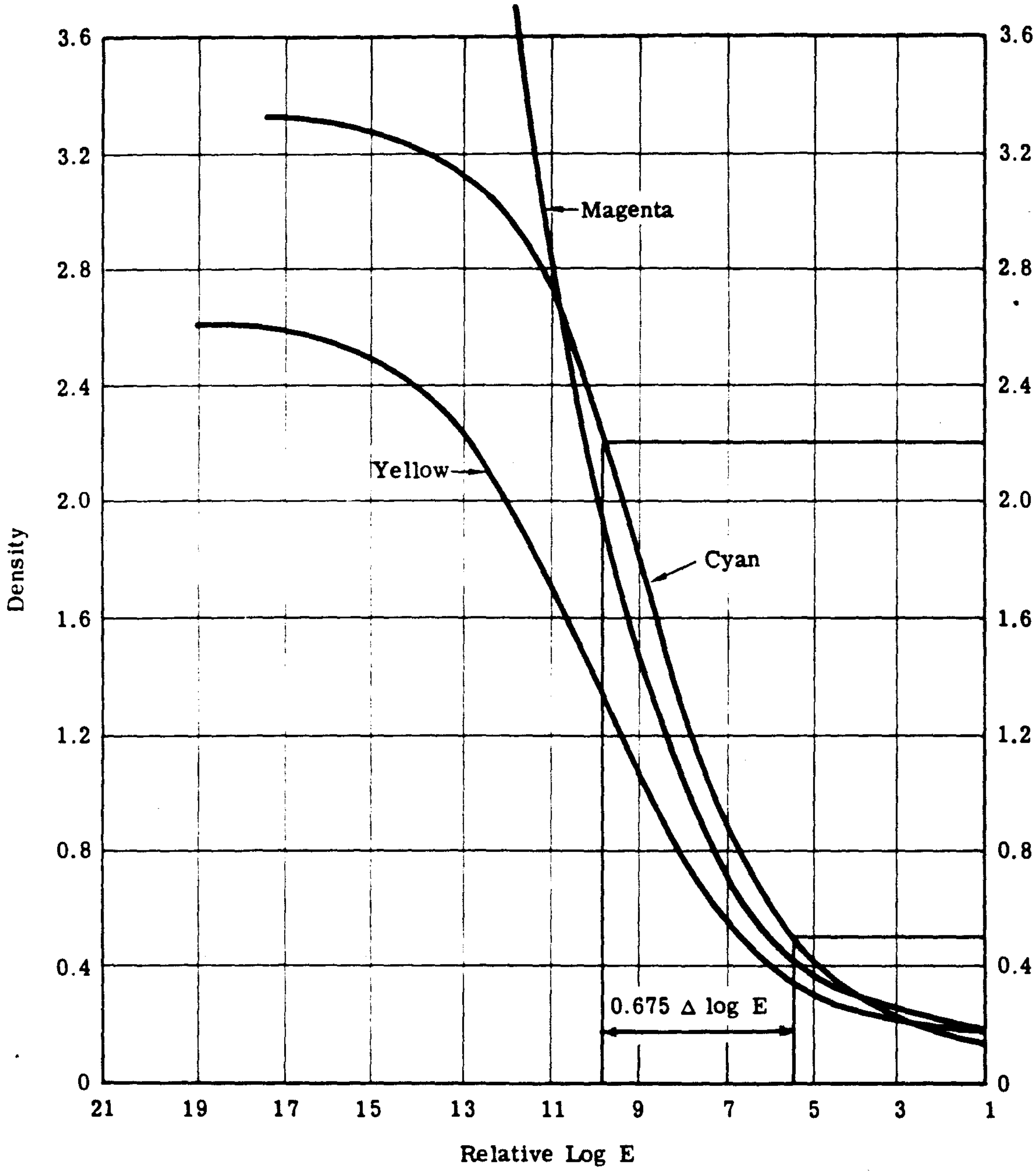


Fig. 2-1 — Integral spectral density curves of SO-180

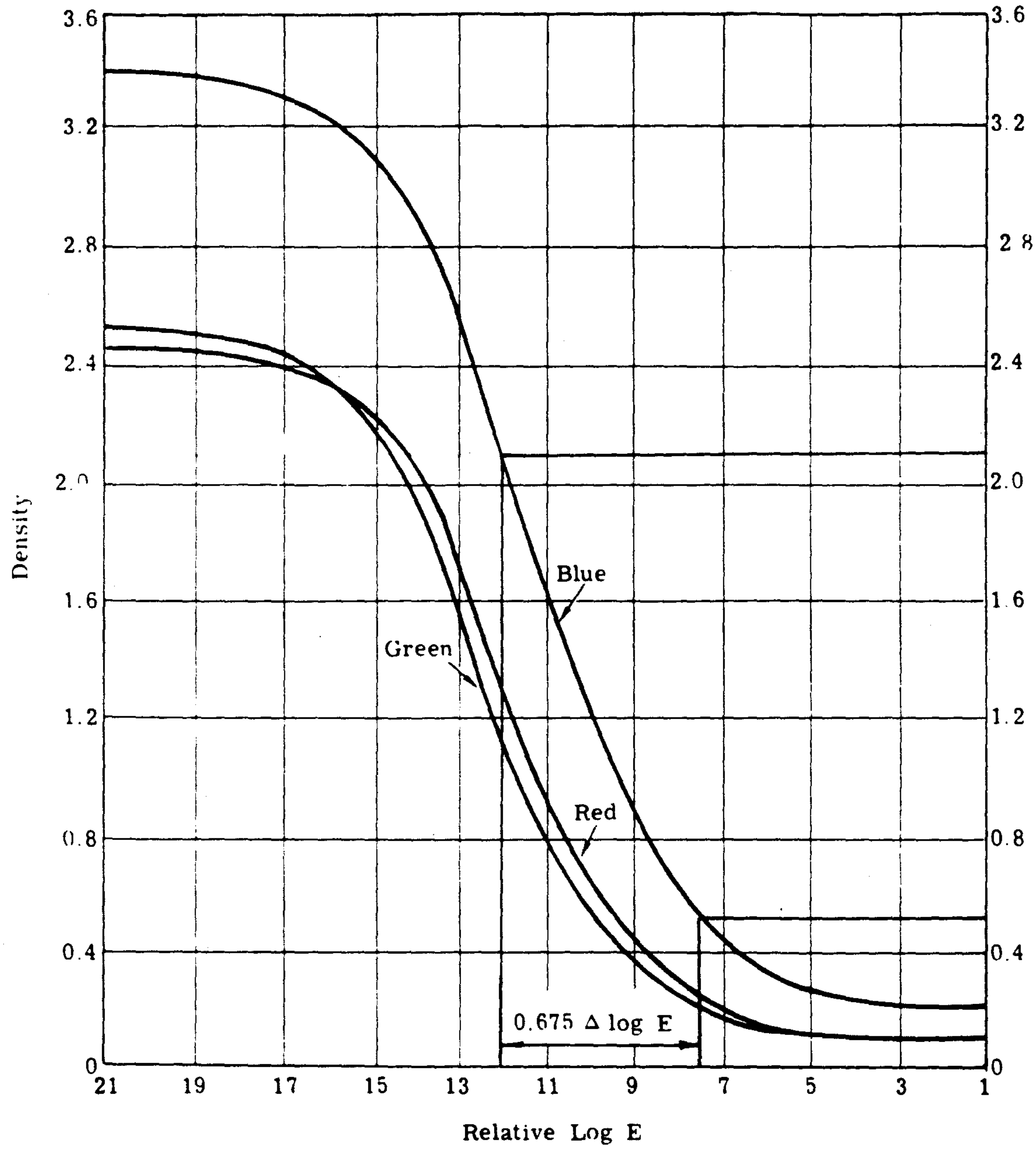


Fig. 2-2 — Integral spectral density curves of SO-121

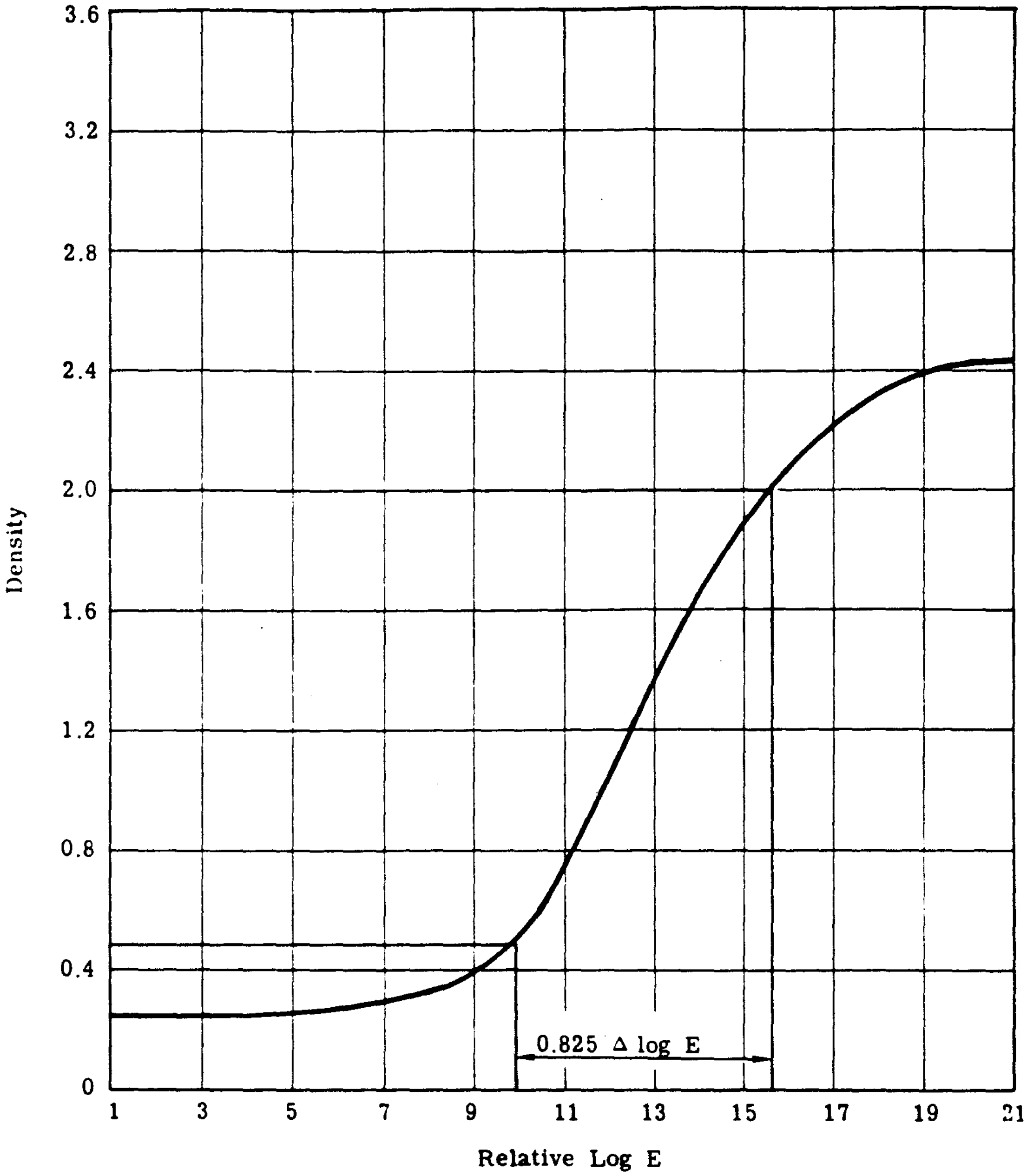


Fig. 2-3 — H&D curve for 3404

Table 2-1 — Useful Log E Range and Scene Contrast for SO-121, SO-180, and 3404

Film	Useful Log E Range	Scene Contrast
SO-121	0.675	4.7:1
SO-180	0.675	4.7:1
3404	0.825	6.7:1

does not increase the original scene contrast to the extent of the SO-180 filter. Type 3404 yields the imagery with the greatest highlight and shadow detail. These conclusions are verified by the subjective analysis of Section 4.

2.1.1.2 Emulsion Speed

The emulsion speed for SO-180 and SO-121 are approximately identical, while the 3404 is from six to eight times slower.

The speed has a direct bearing on the camera exposure time. Note that the speed of the SO-180 and SO-121 are almost identical and, with their appropriate filtration, received identical exposure in this EKIT mission. The 3404, however, not only has a speed approximately one-seventh that of the other two films, but uses heavy filtration (Wratten no. 21).

2.1.2 Film Construction

The dye layer orientation of SO-180 and SO-121 are shown in Figs. 2-4 and 2-5.

Type SO-180 has an orientation which results in a bottom layer sensitive to the red spectral region and, on processing, forms a magenta image; a middle layer sensitive to the green spectral region and forming a yellow image; and a top layer infrared sensitive and forming a cyan image. The tripack contains no yellow filter layer to prevent exposure of all three layers to blue light (all layers are inherently sensitive to blue radiation) so a yellow filter is always used over the camera lens. This is a slight inconvenience, but is helpful in reducing the effects due to atmospheric haze.

Type SO-121 is constructed in such a way as to place the green-sensitive magenta image forming layer on the surface. The blue-sensitive yellow image is in the middle and the red-sensitive cyan image forming layer on the bottom. There is no yellow filter layer, but with the proper short wavelength blocking filters such as Wratten nos. 2E or 4, it is possible to get sufficient separation between the three records to produce a good image.

As stated earlier, the high resolution of SO-121 is attributed to its layer orientation. The magenta layer, which contains the greatest visual detail, is located on the surface where there is less scattering to degrade the image.

2.1.3 Image Formation

The image formation characteristics of SO-180 and SO-121 will be explained with the aid of Fig. 2-6.

Yellow Filter	
Infrared-sensitive	Cyan positive image
Green-sensitive	Yellow positive image
Red-sensitive	Magenta positive image
Base	

Fig. 2-4 — Construction of SO-180

Green-sensitive	Magenta positive image
Blue-sensitive	Yellow positive image
Red-sensitive	Cyan positive image
Base	

Fig. 2-5 — Construction of SO-121

Spectral Regions	Ultraviolet	Blue	Green	Red	Infrared
SO-121					
Film sensitivities		Blue	Green	Red	
Dye layers		Yellow	Magenta	Cyan	
Color controlled by dye		Blue	Green	Red	
SO-180					
Film sensitivities with yellow filter			Green	Red	Infrared
Dye layers			Yellow	Magenta	Cyan
Color controlled by dye			Blue	Green	Red

Fig. 2-6 — Image forming characteristics of SO-121 and SO-180

The spectral regions are divided into five sections including ultraviolet, blue, green, red, and infrared. SO-121 has three principle layers in which one is sensitive to blue light, one to green, and one to red. Upon processing, positive images are formed of yellow, magenta, and cyan dyes respectively. The colors of the three dye layer images combine to form colors which closely match those of the original scene; blues are rendered as blues; greens are green, and reds are red.

With SO-180, one layer is sensitive to green, one to red, and the third to infrared radiation. In addition, all three layers are sensitive to blue light, which explains the need for a yellow filter upon exposure. The same three layers are used as in SO-121, but their spectral sensitivities have been shifted one region toward the longer wavelengths. As a result, the blue image is from the green exposure, the green image is from the red exposure, and the red image is from the infrared exposure. Based on this knowledge it is possible to predict how any color is reproduced as long as its infrared reflectance is known.

A characteristic example which demonstrates the application of infrared sensitive films is the detection of healthy and diseased trees. A healthy tree has a high infrared reflection component and its image will appear as a rich red. On the other hand, as the tree becomes diseased it loses infrared reflectance and the red color of the once healthy tree turns toward a blue/green color.

2.1.4 Spectral Sensitivity

Up to now the sensitivities of SO-180 and SO-121 were presented in terms of the broad regions of the spectrum. The actual spectral sensitivities as a function of wavelength are shown in Figs. 2-7 and 2-8. Plotted on Fig. 2-7 is the spectral transmission curve for the Wratten no. 15 filter, the filter required during exposure to eliminate the unwanted blue radiation.

2.1.5 Color Balance

One of the characteristics of SO-180 is the effect of age on the color balance. The infrared sensitive layer (cyan image) tends to decrease in speed while the green sensitive layer (yellow image) increases slightly. Therefore, as the film ages the color shifts toward the cyan. If kept at room temperature, the balance will tend to pass through the point of optimum color discrimination. This effect can be reduced considerably by storing the film in a refrigerator, and it can be virtually eliminated by freezing.

Since there is always a slight time delay between manufacture and processing, the cyan layer is coated slightly fast. By the time the film is used the layer speed should have slowed to the point of optimum color balance. If precise color balance is required, appropriate testing should be performed and the film balance adjusted by means of filters.

2.2 SCENE CHARACTERISTICS

One of the main applications of SO-180 at the present time is involved with the photography of foliage. The purpose for this falls into two catagories: determining the characteristics and/or type of tree or plant, and revealing the presence of disease or insect pests on the foliage. The reason that SO-180 is so useful in this connection is because the infrared reflectance varies between species of foliage and between stages in plant deterioration.

Fig. 2-9 shows the change in spectral reflectance of a dead white oak leaf that was kept wet. The measurements were taken at time intervals of 1/2 hour, 24 hours, 2 weeks, 4 weeks, 10 weeks.

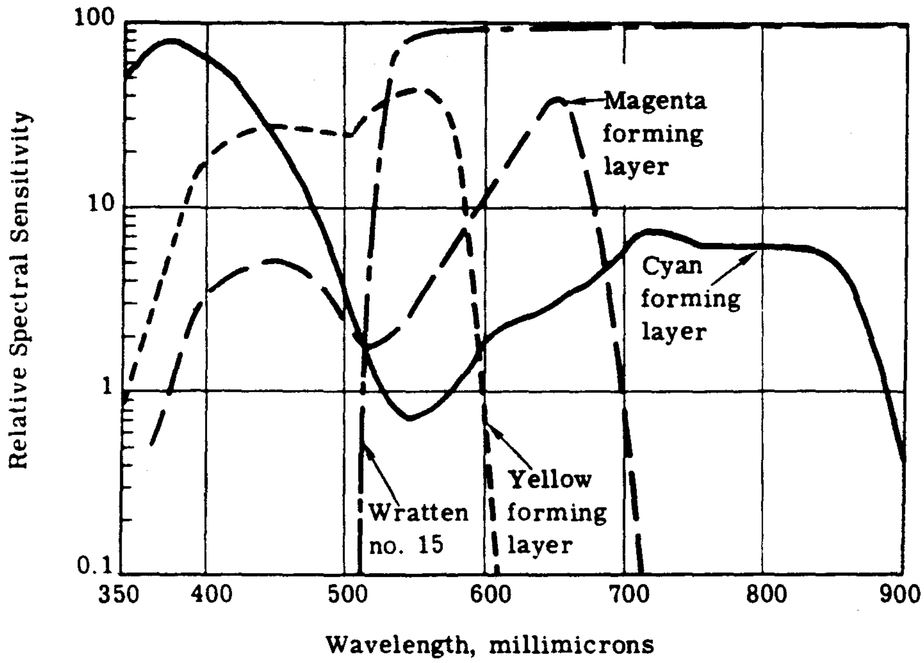


Fig. 2-7 — Spectral sensitivity of SO-180

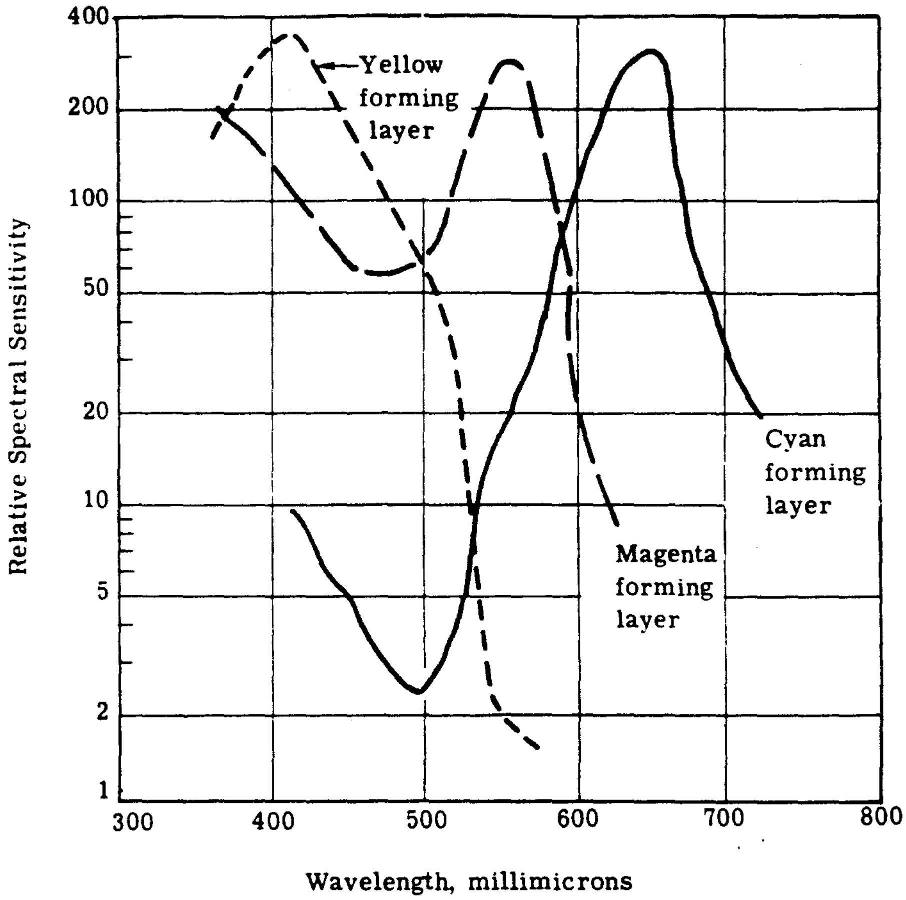


Fig. 2-8 — Spectral sensitivity of SO-121

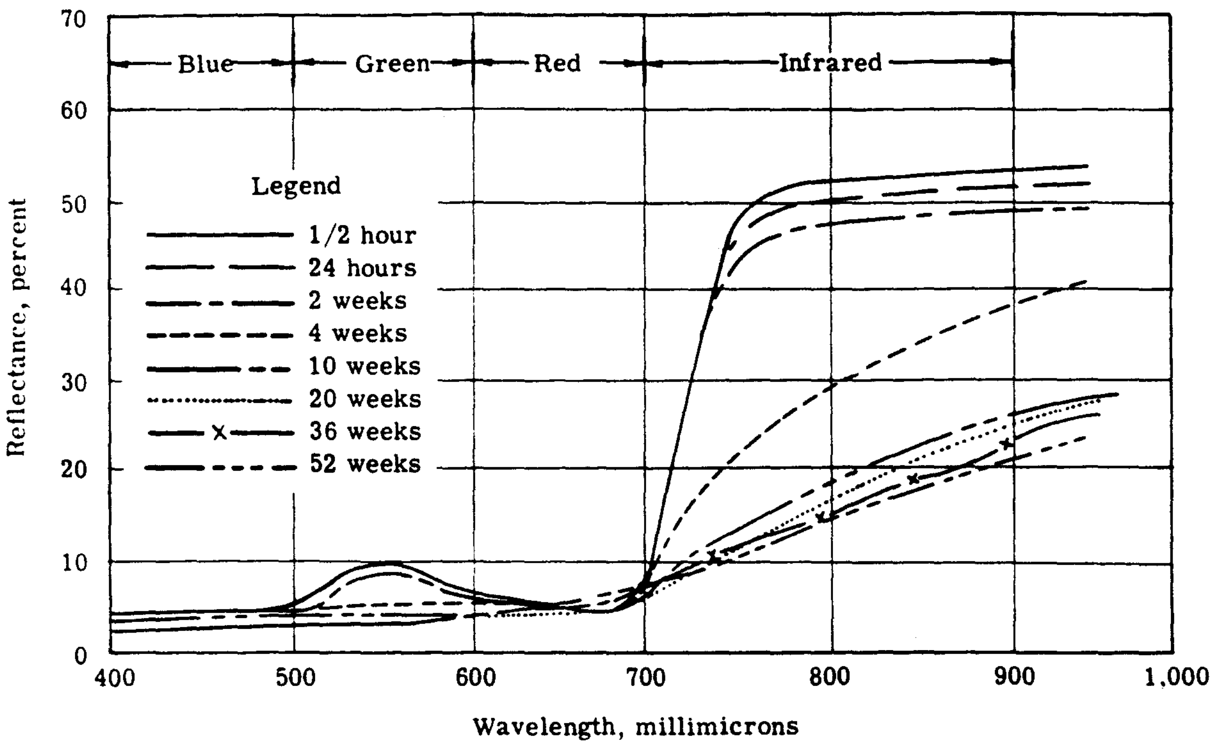


Fig. 2-9 — Spectral reflectance of white oak leaf, kept wet

20 weeks, 36 weeks, and 52 weeks. The leaf not only lost its green color, as indicated by the drop in transmission in the 500- to 600-millimicron range, but its infrared reflectance dropped steadily. It can readily be seen that an infrared image of these eight conditions would result in a leaf color ranging from bright red to almost neutral, while an SO-121 image would only show a slight change from dark green to neutral. The former would unquestionably show the deterioration to a much greater degree.

Various types of foliage have their own characteristic spectral transmittances as indicated in Fig. 2-10. Not only does the usual color of the foliage change, but so does its infrared reflectance. A mockernut hickory leaf transmits high in the red region and moderate in the green, giving it a reddish yellow color while its infrared reflectance is approximately equal to the white birch. The balsam poplar has a customary green color and transmits the highest in the infrared.

With SO-121, one would have a little trouble in detecting the mockernut hickory foliage from the other types, but only because of its unique color. The discrimination between the remaining five types would remain extremely difficult because the difference in green color is not pronounced. The ability of SO-121 to detect these small differences is limited. The infrared reflectances, however, are quite pronounced and the SO-180 image would provide no difficulty in discriminating between all six types.

The cyan layer has been deliberately made much slower than the other two. From examination of Figs. 2-9 and 2-10, the explanation for this is clear. If the film were exposed to provide proper reproduction of the 500- to 700-millimicron region (this region contains spectral reflections in the neighborhood of 5 to 20 percent), the infrared record (spectral reflectance of 20 to 70 percent) would be grossly overexposed and a majority of the imagery would be located in the toe of the characteristic curve. Any variation of infrared exposure would produce negligible cyan density change. All foliage, therefore, with the exception of those having low infrared transmission, would be recorded excessively red and small differences in infrared reflectance would not be detectable. The proper speed balance in the cyan layer allows the infrared exposure to fall well up on the characteristic curve where significant differences in cyan density result from small differences in exposure.

The detection capability for inland watercourses is also greatly enhanced by the use of infrared sensitive film. Water has a high absorption to red wavelengths, partial absorbtion to green, and low absorption to blue. The infrared radiation is almost totally absorbed. Radiation absorbed cannot be reflected and, therefore, exposure of water on infrared film results in the formation of maximum cyan dye and nearly maximum magenta dye and a subsequent blue image. The presence of algae or other infrared reflecting objects in the water will tend to reduce the cyan dye formation and produce an image which is increasingly more red.

2.3 PHOTOGRAPHIC CHARACTERISTICS

There are several characteristics of SO-180 which have a bearing on its differentiation capability. Two of these affect its performance in extremely hazy atmospheric conditions. A yellow filter, which is always used, absorbs the blue light which contributes most to the degradation of the image. This attribute for SO-180 is detrimental to SO-121 since the exposure requirements do not allow for use of a yellow filter.

A second characteristic of both SO-180 and SO-121 is that they have a high gamma. This high gamma tends to offset the reduction in contrast resulting from the haze. A consequence of the high gamma is that the film has a relatively short exposure range. This requires extreme

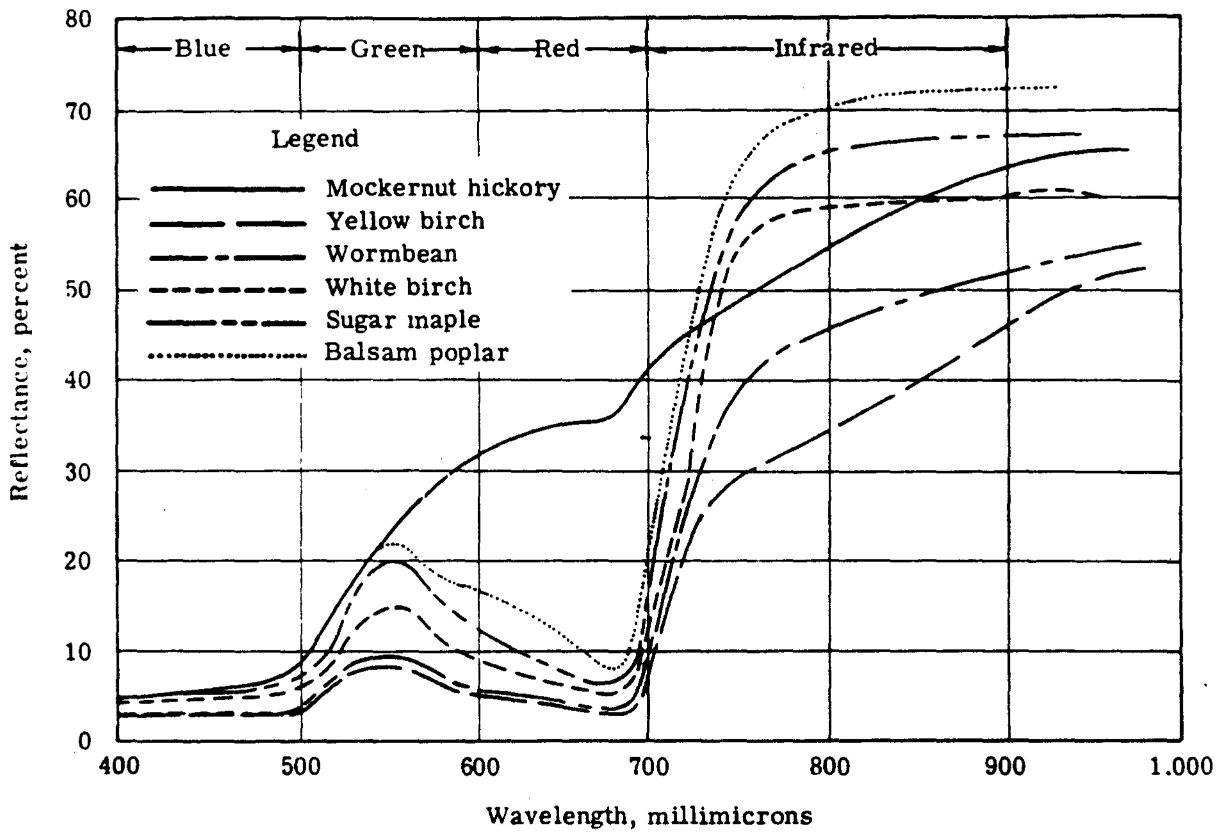


Fig. 2-10 — Spectral reflectance of various types of foliage care when exposing the films, since fluctuations as little as plus or minus one stop will result in blocked up highlights or shadows.

With previous systems, it had been recommended that the SO-180 be focused at the normal position rather than at an infrared setting. Two of the dye layers, being sensitive in the visible region of the spectrum, tend to offset the effects from the infrared sensitive cyan layer. Furthermore, the high infrared reflection of foliage usually will expose the cyan layers so the effective image is predominantly in the magenta and yellow layers.

A popular misconception is to equate infrared radiation with heat and to expect SO-180 to record temperature differences. Tests at Eastman Kodak have shown that, if no other source is available, an object heated to 650 °F will make an image which is just noticeable in the infrared sensitive layer if it is exposed for 15 minutes at f/2.0.

In an extremely cold atmosphere, there is a loss in speed and a shift in color balance toward cyan. At temperatures below -40 °F, the speed of the green and red sensitive layers decrease by 0.20 log E and the infrared by 0.60.

2.4 CONCLUSIONS

Based on this discussion it is evident that SO-180 may provide significant advantages to the acquisition of intelligence data from color aerial photography. Its unique method for recording this imagery and pronounced differentiation of certain target types provides extremely useful supplemental imagery for the high resolution 3404 record.

3. TEST PLAN

EKIT flight test no. 11 consisted of three flights with the 112B Camera System. This section deals with the camera system itself, the test plan, and the flight plan details.

3.1 112B CAMERA SYSTEM

Though discussed in previous EKIT reports, a description of this camera system will be again presented to familiarize the new reader with the system employed in this test series. The camera is a pan scanning type that has been designed around the 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. Each lens is continuously rotated about its operational nodal point scanning 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 numbers, 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.

3.2 SCOPE OF THE TEST

Three flights were required for the successful completion of this test. The initial flight was used to investigate the question of detecting the launch of a missile after the fact with a camouflage detection film in one camera, and 3404 in the other. The test involved flying over the missile complex once before the launch, and then a repeated flight pattern over it after the missile had been fired.

The second flight area was used to answer very general questions about SO-180, that is, how it responds to various types of terrain. Two of these flights were made over the same area. One flight used SO-121, an Ektachrome type emulsion, in comparison with SO-180, and the other used 3404 in comparison with SO-180.

3.3 TEST PLAN DETAILS

The specific camera settings and film loads for these three EKIT flights are listed in Table 3-1. The first flight consisted of repeated coverage of Vandenburg Air Force Base. The second covered a major portion of California, from San Francisco to Los Angeles. Flight 11B was the same as 11A, although it went in the reverse direction on the following day. The photography available, therefore, covered the same areas on two successive clear days with all three films.

Table 3-1 — Specific Camera Settings for EKIT
Flight Nos. 11, 11A, and 11B

EKIT flight no. 11 ([redacted] 14 January 1967)

Camera	I3 (Aft-Looking)	I4 (Forward-Looking)
Film	SO-180	3404
Slit width	0.009 inch	0.075 inch
Shutter speed	1/2,200 second	1/300 second
f/no.	3.5	3.5
Filter	Wratten no. 15	Wratten no. 21

EKIT flight no. 11A [redacted], 17 May 1967)

Camera	I7 (Aft-Looking)	I8 (Forward-Looking)
Film	3404	SO-180
Slit width	0.037 inch	0.009 inch
Shutter speed	1/450 second	1/2,200 second
f/no.	3.5	3.5
Filter	Wratten no. 21	Wratten no. 15

EKIT flight no. 11B [redacted] 18 May 1967)

Camera	I7 (Aft-Looking)	I8 (Forward-Looking)
Film	SO-121	SO-180
Slit width	0.009 inch	0.009 inch
Shutter speed	1/2,200 second	1/2,200 second
f/no.	3.5	3.5
Filter	Wratten no. 2E + CC30 Blue	Wratten no. 15

4. SUBJECTIVE COMPARISON OF SO-180, SO-121, AND 3404

The observer's reaction to a first viewing of SO-180 or any false color film, is one of surprise and skepticism. The translation of colors, particularly that of the infrared band, produces a vivid and very unreal image of the terrain below and the capability of such a spectrally distorted record for its probable use is questioned.

These negative attitudes are soon changed, however, when the interpreter applies his attention and analytical talents to the imagery. The dominant colors in temperate and tropical latitudes are red and blue. Red is the translational hue for the infrared band and is very apparent wherever chlorophyl is present. Blue is the translation of green hued objects (not including vegetation) and is almost always the recording color of water.

To the experienced photointerpreter or cartographer, the unnatural color relationships recorded by SO-180 should present no great problem of orientation, particularly to those experienced in multiband and extended spectral range photography or those with a background in non-photographic sensors such as infrared and radar systems. Specific areas of interest will be treated individually in the following sections.

4.1 DESERT AREAS

There is no apparent advantage to be gained using SO-180 rather than SO-121 for coverage of arid desert regions. The vegetation does not present the red chlorophyl response of broad leaf plants and the only difference between the two films is in the hues present; SO-180 has a dominant green cast with dark neutral plants, while SO-121 has a reddish brown cast with dark neutral plants. The desert pavement and rock outcrops have about the same contrast but the SO-121 has higher resolution capability. By comparison, 3404 has about 40 percent more resolution capability and better acuity but lacks hue discrimination that might be useful in interpreting geology and drainage outwash.

4.2 MOUNTAIN AREAS

The mountains in the area covered by the photography have both snow coverage at higher elevations and normal summer cover on lower slopes. The snow-covered areas show equal detail with both color films; snow is white and vegetation is in sharp contrast. Black and white 3404 shows the same items but in finer detail. On the lower slopes SO-180 assumes the advantage, providing better contrast between trees and the background. The amount of red coloring present in the trees is variable, depending on the species, coniferous cover being low in red and the broad leaf deciduous reflecting more infrared radiation with the attendant higher red image presentation. Distinction of rocks is more pronounced with SO-180, with better separation of parent material and surrounding soils.

Black and white materials show finer detail and the contrast between subjects depends to some degree on the filtration and the portion of the characteristic curve on which the densities fall.

4.3 AIRFIELDS

The overall coverage of airfields, the buildings situated on them, and the general population of aircraft lack contrast when recorded with SO-180. The hue range is almost monochromatic, blue grays, grays, and whites being dominant. Relief from these colors occurs predominantly in areas having vegetation cover in the form of grass or trees and where distinctive building or vehicle colors such as red, tiled roofs or yellow service trucks are present.

SO-121 is decidedly superior for delineation of detail and interpretation. Higher resolution is a helpful factor particularly where aircraft and test facilities are concerned. Natural color is almost essential and false color methods do not contribute appreciably except for vegetation delineation.

The 3404 is by far the superior film for recording information for structural interpretation and modification detection. Used in conjunction with a color record of the same area, the combination is an excellent intelligence tool.

4.4 RADAR SITES

No great advantage is obtained by using color film for observing radar installations as depicted in our project coverage. The sites are usually quite colorless with their white domes and neutral buildings. Structural detail is recorded far better on 3404 and only vehicles or ornamental foliage are apparent by their color.

4.5 WARSHIPS

Coverage of ships afloat adjacent to docks shows better separation from the background with SO-180. In dry dock, however, the SO-121 provides better contrast. The 3404, although highest in resolution and acuity, suffers from clutter due to the lack of color discrimination that the SO-121 and SO-180 provide. In stereo, however (viewing both the SO-180 and 3404 simultaneously), the resolution capability of 3404 allows for more precise spatial orientation of very fine detail.

4.6 RAILROAD FACILITIES

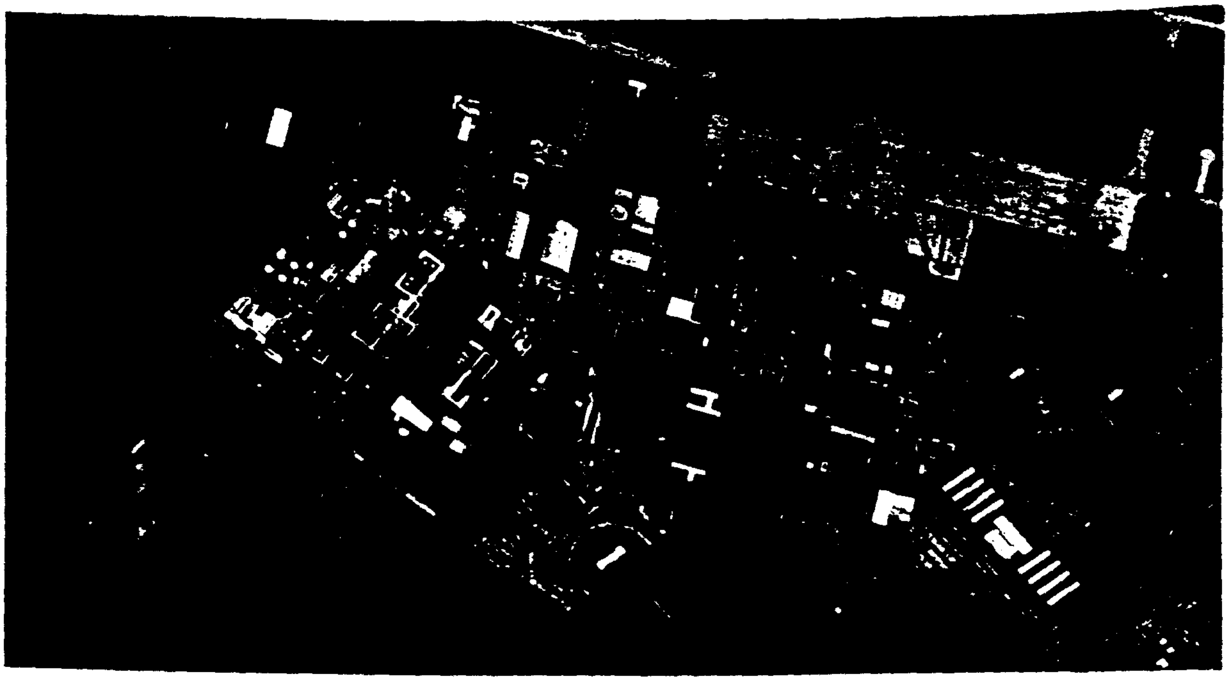
Low visual contrast of railroad rolling stock is quite apparent with SO-180. The SO-121 shows more color for contrast and identification. Maintenance, storage areas, and buildings show about equally well but, where vegetation occurs, even a scrub grass, the separation between object and background becomes more pronounced with SO-180. The 3404 has finer resolution capability in determining track counts, switch locations, and evaluating rolling stock and storage and transfer facilities.

4.7 URBAN AREAS

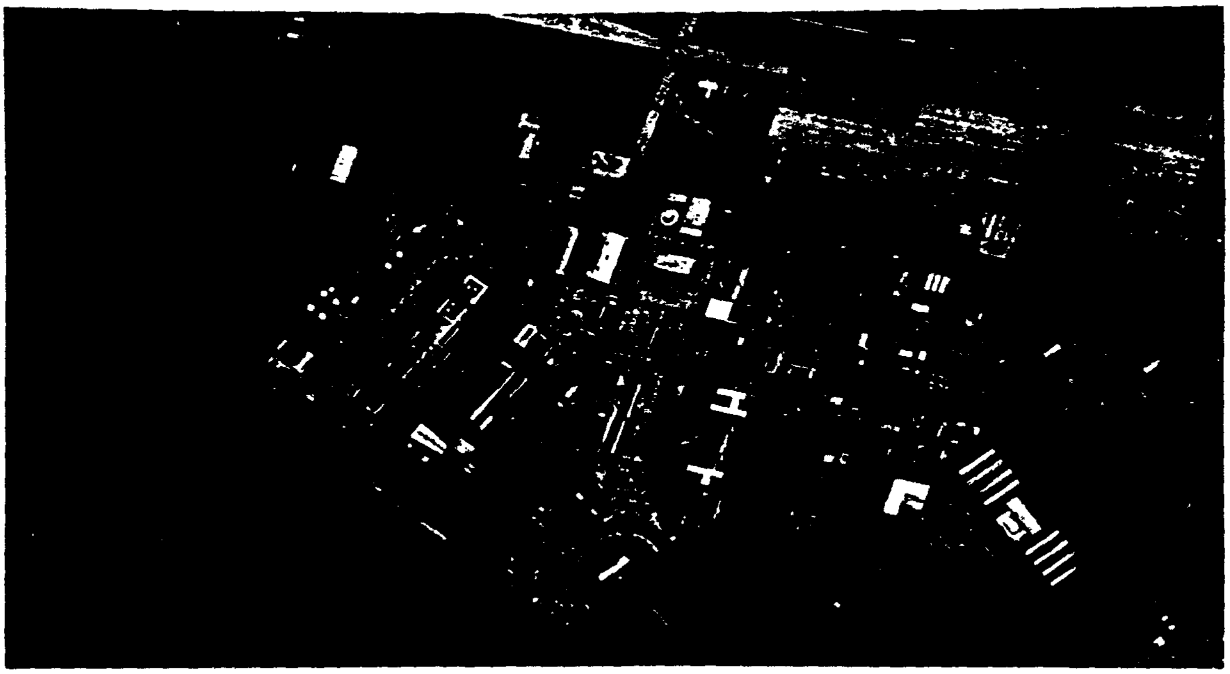
Records of dense urban areas are dependent on color and background. City areas are low in contrast due to the uniformity of building materials and neither SO-121 nor SO-180 shows a great deal of superiority over the other. The exception is when lawns, parks, or trees are present; then SO-180 produces more separation due to the red imagery produced.

(a) 3404

Fig. 4-1 — Aerial photograph of Moffet Field



(b) SO-121



(c) SO-180

Fig. 4-1 — Aerial photograph of Moffet Field (Cont.)

(a) 3404

Fig. 4-2 — Aerial photograph of an urban and tidal area

(b) SO-121

(c) SO-180

Fig. 4-2 — Aerial photograph of an urban and tidal area (Cont.)

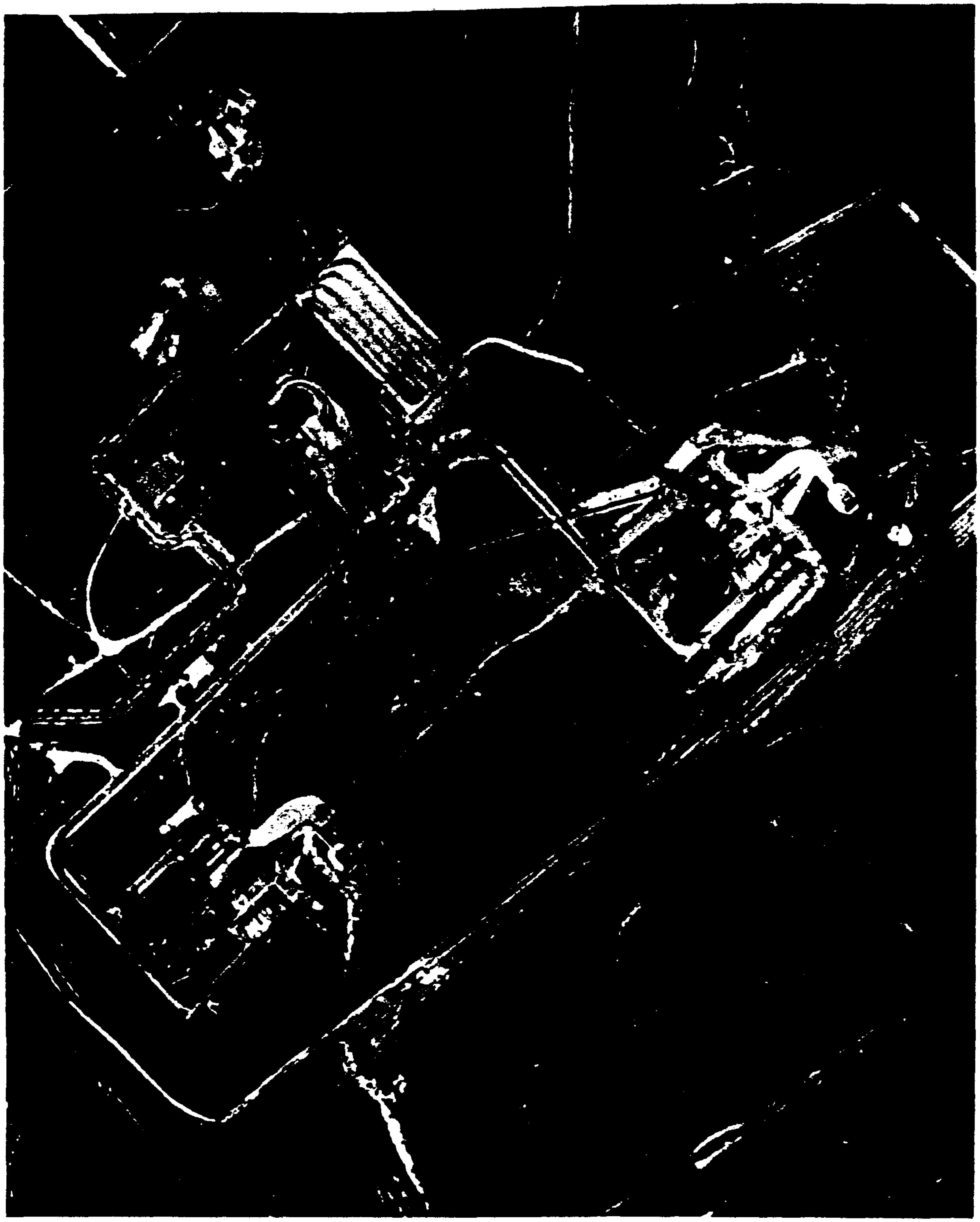


Fig. 4-3 — Missile launch complex after launch with SO-180

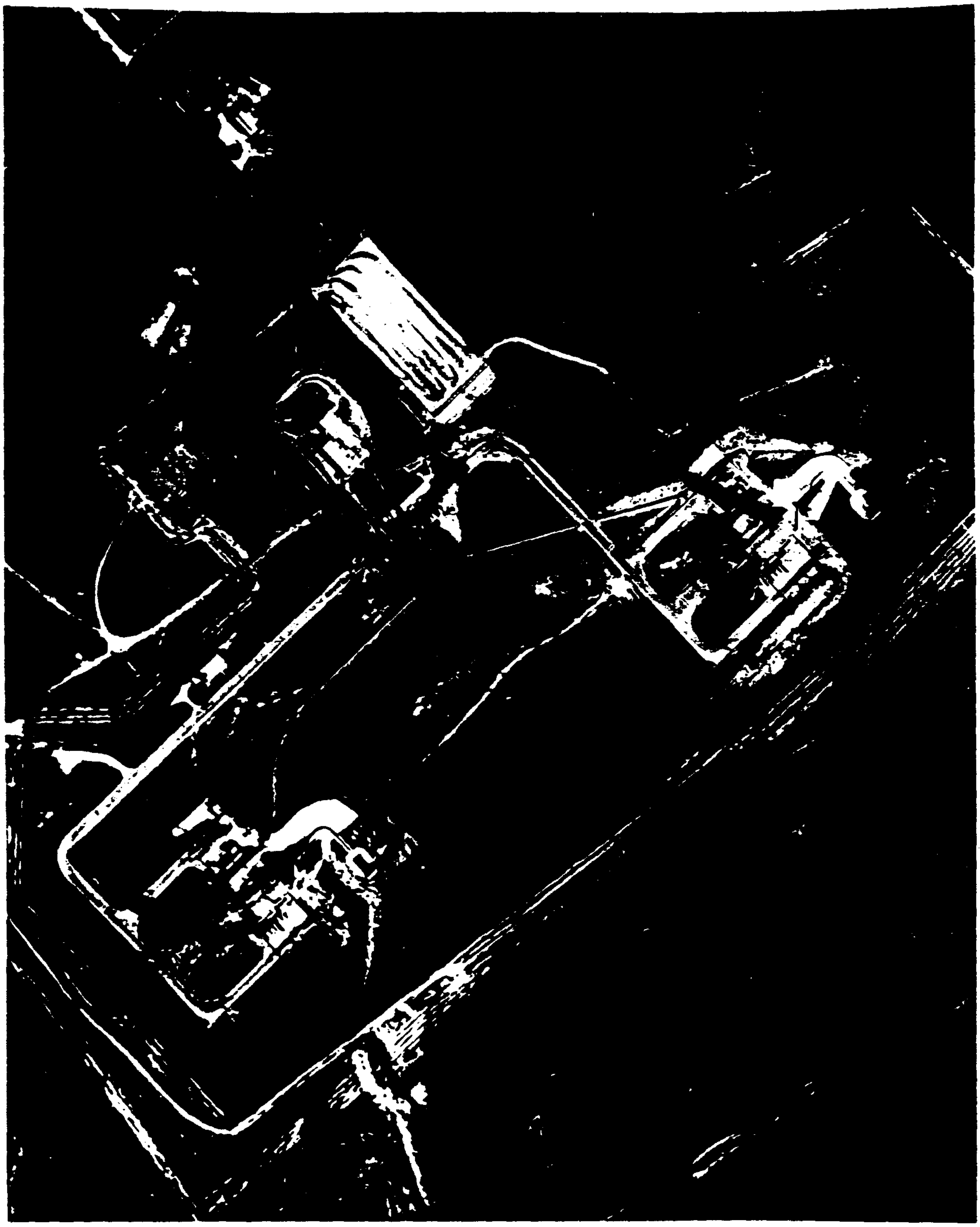
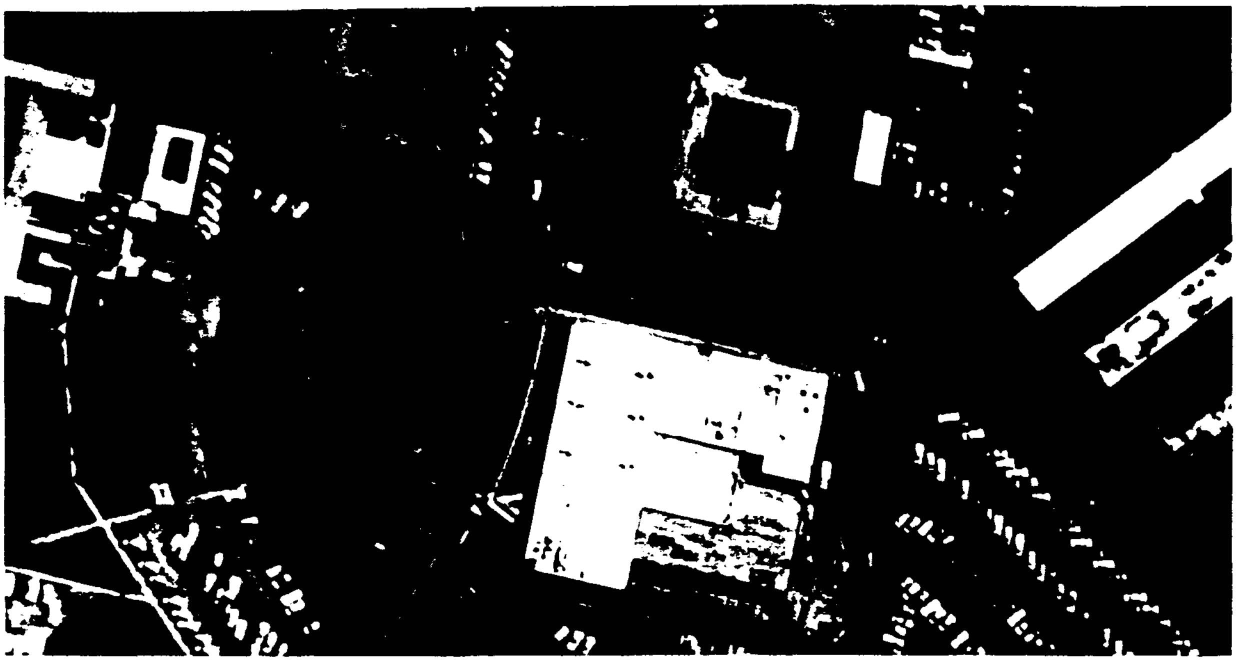


Fig. 4-4 — Missile launch complex after launch with 3404

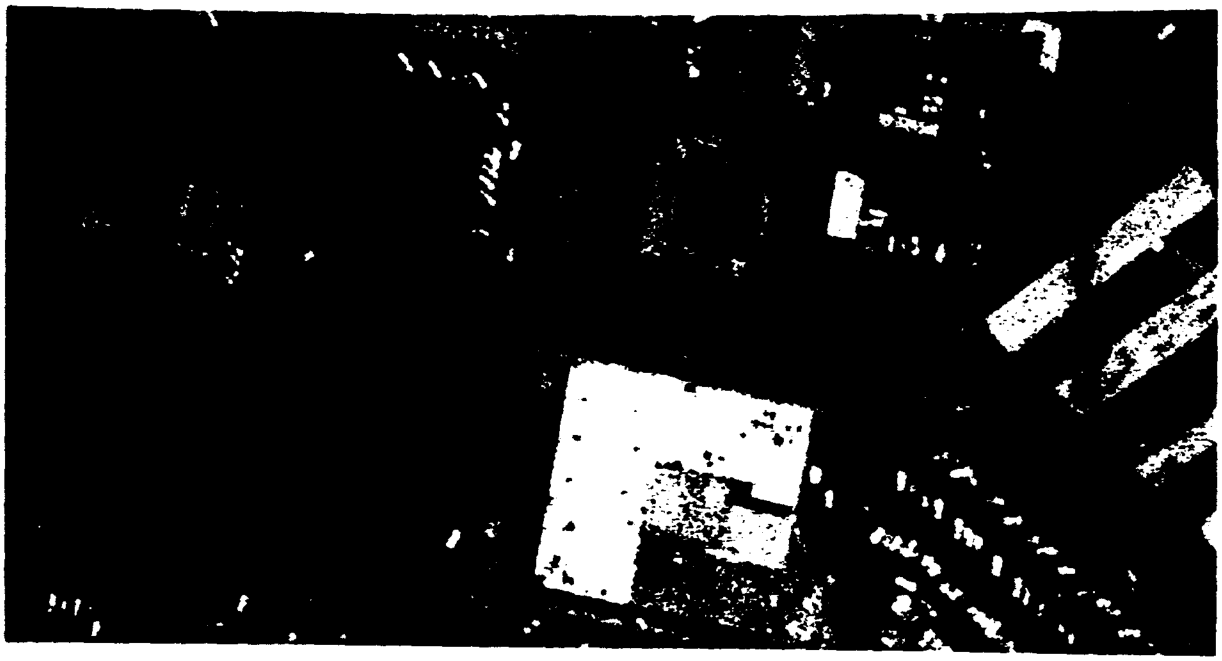
Fig. 4-5 — Aerial photograph of a missile launch complex, infrared passive image



(a) 3404

Fig. 4-6 — Aerial photograph of a Moffet Field recreation area

(b) SO-121



(c) SO-180

Fig. 4-6 — Aerial photograph of a Moffet Field recreation area (Cont.)

5. SYSTEM CONSIDERATIONS

The quality of a photographic system can be defined in terms of its modulation transfer function (MTF). This function measures the amount of light scattering created by the optical system and the imaging material; the resultant image is, in turn, a function of this light scattering. Although the phenomena does not explain the total mechanism of image quality, as the granularity and resolution are also important factors, it has been used in recent years to describe the performance of photographic systems.

The calculation of the MTF of a panchromatic image is a straightforward procedure. An edge exposure is traced with a microdensitometer and a complex series of mathematical operations is performed on this scan. With a color material the problem becomes more involved. The image is no longer made up of a simple mono-silver layer, but rather tri-dye layers. The question which should be considered, therefore, is whether the techniques applicable for black and white MTF apply to color emulsions. Itek has performed extensive research in this area and has arrived at the following conclusions:

1. The general techniques which are used for panchromatic MTF can be applied for color MTF analysis. The dye image can be treated, essentially, as a silver layer. The existence of the tri-layer rather than the mono-layer will be explained subsequently.

2. The MTF of the color image is independent of the orientation of the dye layers. The situation of the magenta layer on the surface has no effect on the MTF. When considering resolving power, the surface magenta layer does cause a significant increase, however, it must be remembered that visual resolution is different from MTF. The cognitive process is prone to searching out the best condition while the microdensitometer is completely unbias.

3. The MTF calculated from a color edge trace is indicative of the emulsion's poorest image forming dye layer. In all cases, this is the layer situated at the bottom of the tripack because the image forming light has, by the time it reaches that layer, been scattered by the two layers preceding it.

Fig. 5-1 showing a hypothetical microdensitometer scanning in the direction indicated would first encounter an increase in density at position A, the beginning of the poor edge. As it continued through position B to C, variations in the trace would result from the additional density caused by the good edge. The end of the edge would not be reached, however, until the scan reached position D, the conclusion of the poor edge. It is evident, therefore, that the trace from a tripack containing three edges of different quality will be indicative of the worst edge.

4. There are two recommended methods for obtaining a representative edge trace from a color emulsion, one is by tracing a neutral edge with any color microdensitometer source and the other is by tracing an edge exposed in the worst dye layer (the bottom) with any microdensitometer color source. Under actual flight conditions when the edge is located on the original imagery, the former method is the only usable technique.

The MTF's of the 24-inch, f/3.5, Petzval lens were measured under laboratory conditions for the spectral sensitivities of SO-180 and 8442 (similar to SO-121 though with conventional layer orientation) and they are shown in Figs. 5-2 and 5-3. It is evident that the order of MTF preference (worst to best) for SO-180 is infrared, green, and red, and for 8442 is blue, green, and red. The total preference for the lens over the four spectral regions is blue, infrared, green, and red.

As discussed previously, the MTF of the total emulsion is based on the worst dye layer imagery. The MTF of the SO-180, therefore, should be equivalent to the MTF on the infrared sensitive layer and the MTF of 8442 equal to that of the blue sensitive layer.

Fig. 5-4 is the MTF of the SO-180, SO-121 and 3404 in the system and measured from the actual flight film. There is no significant difference between the SO-180 and SO-121. The SO-180 function should be compared to the infrared curve of Fig. 5-2 and the SO-121 compared to the blue curve in Fig. 5-3. Note that the former comparison is extremely accurate with both curves falling to essentially zero modulation at 40 cycles per millimeter. There is a slight reduction in modulation in the 10- to 30-cycle per millimeter range of Fig. 5-4. This can be explained by the fact that it was obtained from actual flight films while the other is from a laboratory setup. The SO-121 and the measured blue layer MTF comparison show a greater difference. The fact that the SO-121 function is better is a result of the filtration used during the flight. A Wratten 2E + CC30 Blue filter was employed when exposing the film. This filter cuts off at about 420 to 430 millimicrons, which essentially blocks some of the degrading blue light. If the same filter were used when measuring the blue sensitivity of Fig. 5-3, the curves would undoubtedly be better matched.

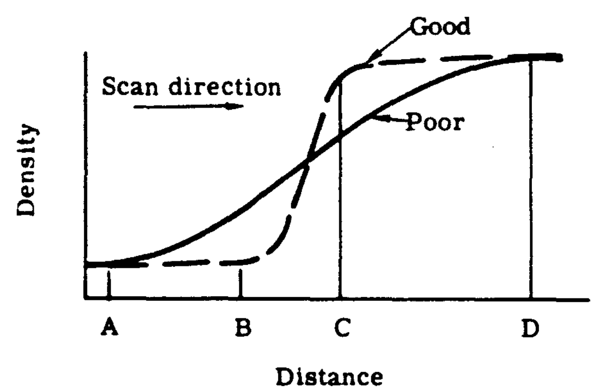


Fig. 5-1 — Hypothetical microdensitometer traces of a good and a poor edge image

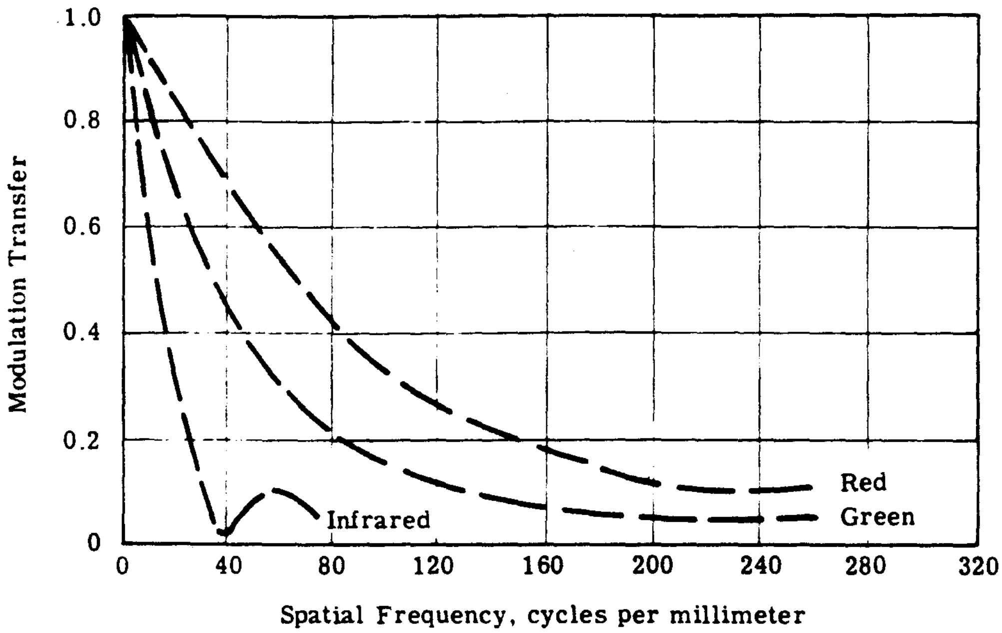


Fig. 5-2 — Measured MTF's of the 24-inch, f/3.5 Petzval lens for spectral sensitivities of Infrared Ektachrome SO-180 film

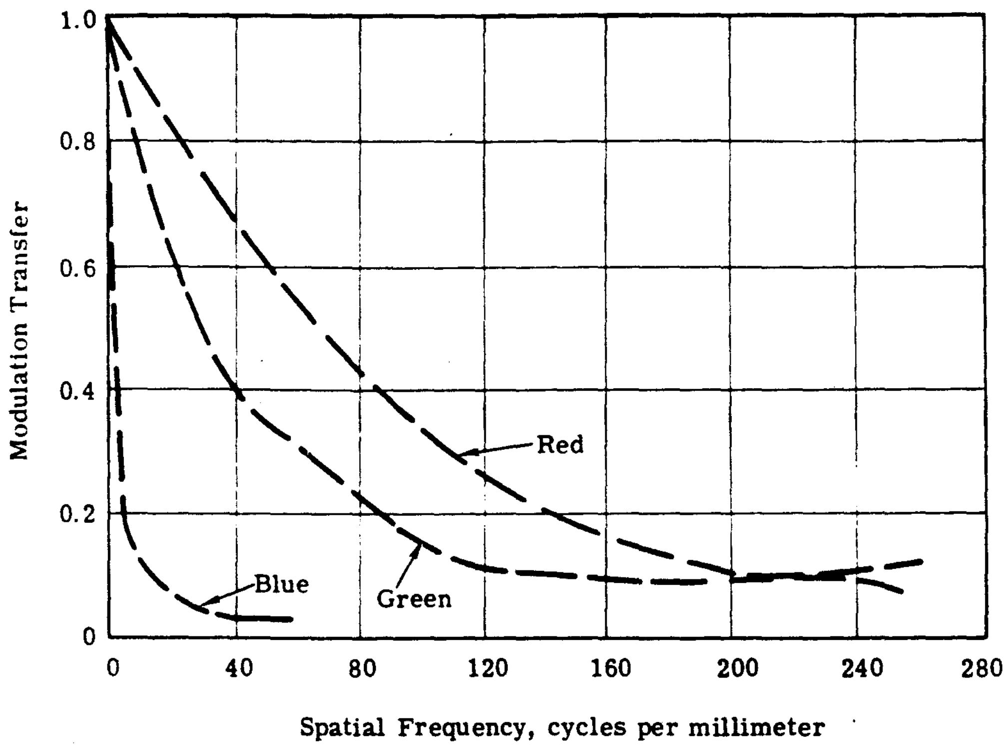


Fig. 5-3 — Measured MTF's of the 24-inch, f/3.5 Petzval lens for spectral sensitivities of Aero Ektachrome 8442 film

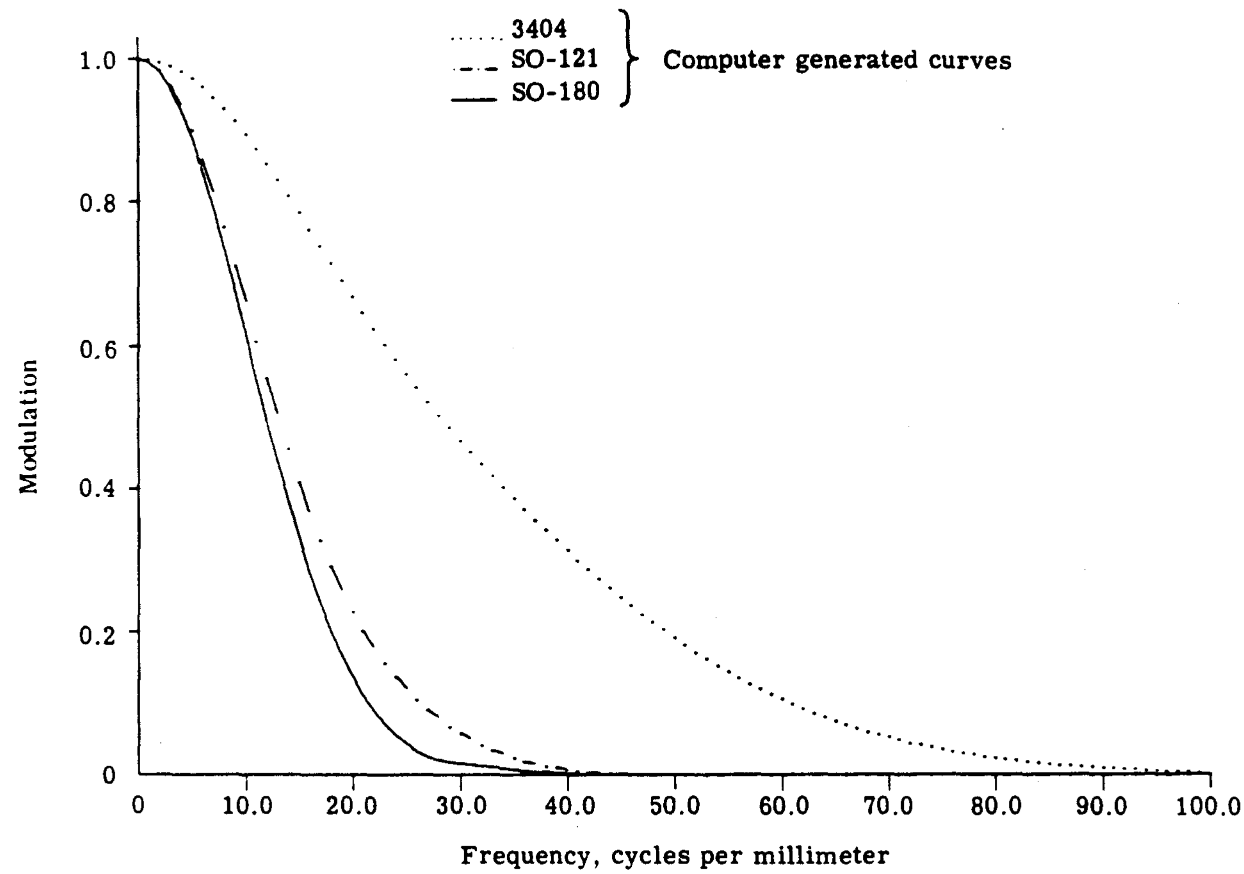


Fig. 5-4 — Modulation transfer functions of SO-180, SO-121, and 3404 as measured in the camera system

6. CONCLUSIONS

Several general conclusions can be drawn from these test results relative to SO-180 and its use, however, some important reservations and complications do exist. First, the conclusions based on this test are:

1. The resolving power of SO-180 is lower than that of SO-121 with a 24-inch Petzval lens.
2. SO-180 has a significant potential application in satellite reconnaissance.
3. SO-180 will not detect heat changes.
4. SO-180 is recommended for test in both the index (DISIC), and the main instruments on the KH-4B System.

The major reservation relative to these conclusions, and the report, is that these results have been obtained from two test flights. There is not a great deal of history associated with the use of SO-180 at high altitude, and, in many ways, we have just begun to evaluate the potential uses of this film as an intelligence tool. It is primarily for this reason that a satellite test should be run to gather more information on what SO-180 can do for the intelligence community.

With the limited information gained from this test, and knowledge gained from other similar tests, some of the potential uses of SO-180 can be postulated. For example:

1. There is little question that SO-180 will be very useful for rapid scanning and locating of strategic target complexes. On previous tests, for example, missile complexes (particularly minuteman sites) were considerably easier to locate on SO-180 than on 3404, even though once located, the detailed interpretation is done from the 3404. SO-180 is particularly useful in this regard when a complex is partially hidden in a remote area.

2. There is a real potential for using SO-180 for crop assessment and analysis. Examples were found in these EKIT tests where only the SO-180 clearly showed the difference between planted and fallow fields. Neither the high resolution black and white, nor the SO-121 showed these differences.

3. The SO-180 has an obvious use in the detection of water ways. This may be potentially most useful in urban areas to locate effluents associated with industrial plants and/or sources of pollution.