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In the past two years, the Office of Special Projects has had numerous requests, and has given several briefings, on unconventional techniques for overhead reconnaissance. In the main, these requests have been concerned with color and night photography. In order to provide a reference to the intelligence offices on these subjects, we have published the attached report, which summarizes the most significant tests done in these areas in the last several years.

The report is up to date as of the current time; however, tests are still being run which will be included in the report at the appropriate time. For example, Mission 4324 includes a test (600 feet) of a new high resolution color film, SO-242, the results of which will be added to this book. Other new films are in process of development (a high resolution Infrared color film, for example) which also will be tested and the results included in this report.

I sincerely hope that this document assists the intelligence offices in their evaluation of these new techniques, and I solicit your comments or questions on any of the techniques discussed therein.

JOHN J. CROWLEY
Director of Special Projects

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SUMMARY REPORT

SPECIAL PURPOSE PHOTOGRAPHIC TECHNIQUES FOR OVERHEAD RECONNAISSANCE

OCTOBER 1969

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SUMMARY REPORT

SPECIAL PURPOSE PHOTOGRAPHIC TECHNIQUES FOR OVERHEAD RECONNAISSANCE

OCTOBER 1969

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FOREWORD

Since 1966, the Office of Special Projects, DD/S&T, has sponsored a variety of photographic tests to determine the flexibility of various photographic collection systems and their potential application to certain intelligence needs. The vast amount of data has proven useful to this office and in several instances has been useful to the intelligence community. Many briefings and reports have served to convey pertinent information to the intelligence community at opportune times.

This office recently decided to summarize the variety of techniques assessed to date to serve as a ready reference to analytical and tasking components within the intelligence community. Detailed reports on each topic have been widely distributed throughout the community. If further information is at any time desired, feel free to contact the Office of Special Projects.

This book summarizes the contributions of many people and many organizations. While we cannot list all of these groups, special mention and recognition is made of the contributions of the Office of Special Activities, DD/S&T; the National Photographic Interpretation Center, and the United States Air Force.

John J. Crowley
Director of Special Projects

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TABLES

Notice of Page Substitution

1. INTRODUCTION

For the purposes of electronic archiving, this page is a substitute for an unscannable page.

1. INTRODUCTION

Over the years, a number of tests have been run aimed at evaluating unconventional photographic acquisition techniques. These tests have been accomplished with the ultimate intent of increasing the tools available to the analyst for intelligence collection. It is the intent of this summary book to present the analyst with a capsule summary of the significant tests run in the last 5 years. In this regard, the summary book is partly for reference and partly for education. It does not attempt to arrive at any conclusion(s) relative to the intelligence value of any of the techniques, but does attempt to set down what has been done. In this regard, we hope to present detail sufficient to allow the analyst to arrive at a conclusion relative to the potential use of any of these techniques for his problems. The ultimate use of any of these techniques resides, of course, primarily with the user and not the collector.

The book contains results from primarily four programs: 112B, KH-4, KH-7, and KH-8. While numerous tests have been conducted on other vehicles, these four have produced the preponderance of usable and significant data. Also, we have not included results of all the tests, but only those which were (1) successful, and (2) considered of interest to the user community.

Sections 2 through 4 deal with the subject of color, a topic of considerable debate in the community at the present time. Section 2 deals with normal color, Section 3 with the infrared or false color, and Section 4 with bi-color (the producing of color from black and white records). Section 5 deals with night detection and low sun angle photography. Finally, Section 6 deals with the subject of exposure with the KH systems. While this section does not deal with tests per se, it was included because exposure does have an effect on information recording, and the intelligence community might want to use the exposure control available on the KH systems to enhance the recording of a particular target or area.

You will notice that the book has been organized so that it can be periodically updated. It is our intent to update the book when new tests are run that might be of interest to the analyst. In this manner, we hope to assist the community by providing a ready reference of what has been done and what is the latest status of these unconventional overhead reconnaissance techniques.

While the examples in this book are the best representations of the original materials that we could make, they are not necessarily as good as the original materials themselves. The duplication materials available today do not have as high a resolution level as the camera film, and some color balance distortion generally occurs in reproducing successive generations of color images.

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2. COLOR

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2.1 COLOR DISCUSSION

The world as viewed from a very high altitude cannot be considered a "riot" of color. Indeed, it appears rather monolithic. What is of interest to strategic reconnaissance, in terms of color, are the ways in which man disturbs this color monolith. He does this in a number of ways: by what he grows, mines, manufactures, processes; by what he produces in terms of waste from his manufacturing and processing; the color signatures he produces when he is in the process of building; and the manner in which he uses color to identify objects. For each of these cases, it has been demonstrated that a color record contains additional information not available in a single black and white record.

The principal objections to the use of color materials in high resolution satellite acquisition systems has been the low spatial resolution exhibited by these materials. In general, this problem is not connected with the kinds of color information sought, but with the information normally sought with high resolution black and white materials. For the time being, the use of color is necessarily aimed at solving color-oriented problems and not general reconnaissance problems. This is somewhat unfortunate since there are indications that color can also provide more rapid location of targets in the search mode due to the added dimension of color differences.

There are basically three techniques for obtaining color photography in satellite systems:

1. Conventional color films
2. False color films
3. Multispectral techniques.

Conventional color films such as SO-121, SO-242, and SO-255 provide a color image that is similar to the ground scene. These materials are designed to reproduce color cues visually through the use of three separate emulsions coated on a single base. For applications in high altitude photography, elimination of degrading blue atmospheric hazelight is accomplished with filtration. A Wratten no. 2E with some color correction filtration is necessary to optimize color rendition with SO-121, while the more advanced SO-242 and SO-255 are self-contained with proper filtration built into the emulsion layers. These color films have been used on various KH missions, and details of the results are reported in the following pages. The SO-121 and SO-242 are both versions of Kodak Aerial Color film on Estar thin base. The SO-255 is a version of the SO-242 emulsion tri-pack on polyester ultrathin base (UTB). Higher resolving power and lower granularity are characteristic of the SO-242/SO-255 as compared with the SO-121. Commensurately, when SO-121 is used in a system with 3404, neutral density filtration is necessary on the color film to match the speed of the panchromatic film, whereas the speed of SO-242/SO-255 is similar to that of 3404.

The second technique for obtaining color photography—"false color" films—also involves a multilayer-coated film on a single base. Kodak Infrared Aero Ektachrome, SO-180, is one such film. The spectral sensitivity of this film provides an image recording capability in the near infrared region of the spectrum. The SO-180 has green, red, and NIR sensitive layers comparable to the blue, green, and red sensitive layers of SO-121 and SO-242. With such a sensitivity arrangement, color information is effectively translated down the spectrum—NIR information is recorded as red, red information is recorded as green, and green information is recorded as blue.

The third category—multispectral (or bi-color in the case of two records)—does not employ a single film. 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 the laboratory where the three black and white records are superimposed and exposed through the appropriate filters. This process is called tri-color additive photography.

Classical 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 pseudo color print using only two records—green and red. This type of photography is called bi-color (or bi-spectral), 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 films. The KH-4B camera system has the capability to acquire bi-color photography by using the normal red filter in the FWD-looking camera and an alternate green filter in the AFT-looking camera.

Proper assessment of the value of a particular approach to color acquisition requires that it be considered in the context of the color problem as a whole. This is necessary to keep from going off on expensive and nonproductive tangents. Many of the specific color materials or color techniques have their worth either in expedience or in the solution of very specific color problems, but should not be considered as "general" solutions to the color acquisition problem. For example, there is no doubt that the bi-color approach is particularly attractive with the mechanics of current satellite acquisition. However, synthesis and exploitation of the resulting color photography is difficult to accomplish. This is particularly true for convergent stereo panoramic systems. Moreover, it now appears, from the color tests that have been run in satellite systems, that three spectral bands are required for general reconnaissance color photography. However, some applications require only information on the degree of color shading, for which the bi-color approach is acceptable. Concerning conventional tri-pack emulsions now available (e.g., Ektachrome), the color "resolution" limits their utility in very small scale photography. For example, while a very large field or settling pond may be represented properly in terms of its color, it is not possible to distinguish color bands on aircraft or the color of a missile warhead at KH-4B scales.

Perhaps the most valuable color material in connection with small scale photography such as the KH-4 system is the SO-180 IR sensitive color material. The kinds of problems which are solvable with this material do not necessarily require high resolution either in the sense of cycles per millimeter or color "resolution."

It is the opinion of this office that color reconnaissance is a valuable tool as an adjunct to black and white high resolution photography. Also, there are certain requirements for which color provides the only answer. The importance of color and the degree to which it can be practically implemented in real systems are questions yet to be answered. For this reason it is hoped that the analysts for whom this book is primarily intended will consider color as a means of answering questions about their own targets.

2.2 COMPARATIVE EVALUATION OF EIGHT COLOR MATERIALS

2.2.1 Test Type

A laboratory analysis was conducted for the comparative evaluation of eight color materials.

2.2.2 Test Objectives

Test objectives were as follows:

1. Perform a laboratory evaluation of the physical characteristics of eight commercially available color materials.
2. Determine the relative image quality characteristics of these materials under static pictorial conditions.

2.2.3 Test Details

The eight materials evaluated under this task are listed in Table 2.2-1. The test consisted of determining the basic photographic characteristics of these eight materials. Dye separations were made through selective exposure to the various dye-forming layers. From these samples, both the spectral sensitivity and the dye curve shapes were measured.

The shapes of the spectral sensitivity curves are all approximately the same except for SO-121. This film does not have a yellow filter layer between the top and middle layers as do the other seven films. The yellow filter layer is ordinarily used to prevent the blue light from exposing the blue sensitivity of the bottom two layers. Without this mechanism to effectively desensitize this unwanted blue sensitivity, the manufacturer probably relies on special desensitizing dyes. These are apparently not as good as one would like since the green-sensitive layer is almost as sensitive to blue as the blue layer itself.

The dye curves for the films are quite different. This difference is predominant in each material's cyan dye. The cyan dye peak for Kodachrome II is approximately 640 nanometers, while that of Agfachrome CT-18 is approximately 690 nanometers, a 50-nanometer shift toward the red. The Kodachrome II cyan dye curve is also considerably narrower than the remaining film layers. In all cases, the yellow dye curves are almost identical. This difference would affect the duplication capability of the materials.

The resolution of the materials was determined for samples balanced for a neutral image. The procedures involved were the same as those in the proposed USASI standard for resolution of black and white materials. A resolution camera that employed a microscope lens known to have a resolution in excess of 2,000 cycles per millimeter was used. Table 2.2-1 gives the resulting resolution values.

The END sensitometric curves for the materials as well as the constants for relating integral spectral density values to equivalent neutral density were found. The general observation from these data is that Kodachrome II has the highest contrast and the shortest exposure latitude.

In order to test these materials under simulated photographic conditions, a scale model was used. Each of the films was used to photograph this model under simulated daylight conditions with a 35-millimeter camera. Figs. 2.2-1 and 2.2-2 contain 75× enlargements of sections of these pictures.

The first observation that one makes when viewing these pictures is that the Kodachrome II imagery is sharper than that of any other material. This is the most significant conclusion of this analysis. The SO-121 and Agfachrome CT-13S assume second place as far as image quality is concerned. The two GAF products exhibit the poorest image quality of the materials tested. However, one should not draw the same general conclusion to all GAF products. The color balance of each of these materials is different; however, with the exception of SO-121, the films have approximately the same color rendition capability.

2.2.4 Results and Conclusions

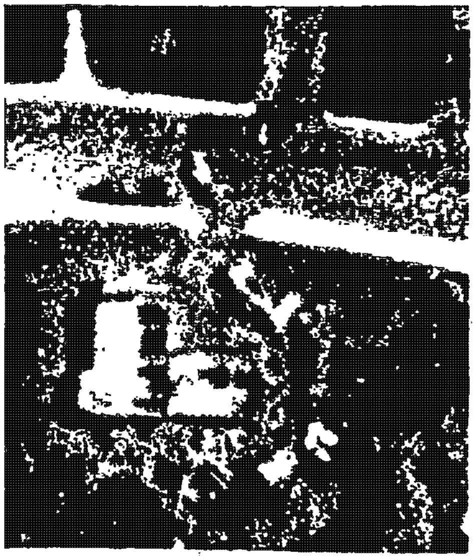
1. Kodachrome II has the highest image quality of the eight materials tested.

2. The color reproduction characteristics of the materials are different; however, the correction available in the duplication process can be used to make these differences small.

3. The processing of Kodachrome II is limited by equipment design to 35-millimeter film widths. Processing of 70-millimeter Kodachrome is achieved by slitting the material into 35-millimeter widths. With no great demand for the larger format, it would be a costly requirement to design equipment to process other than 35-millimeter Kodachrome II.

Table 2.2-1 — High and Low Contrast Resolution for the Eight Films Tested

Film	1,000:1	1.6:1
Kodachrome II	180	82
SO-121	130	73
Ektachrome High Speed	65	41
Ektachrome -X	100	58
Anscochrome D/50	92	48
Anscochrome D/100	82	46
Agfachrome CT-13S	180	65
Agfachrome CT-18	50	41



(a) Kodachrome II

(b) Kodak SO-121

(c) Ektachrome High Speed

(d) Ektachrome X

Fig. 2.2-1 — Small section of the model (75×)

(a) Anscochrome D/50

(b) Anscochrome D/100

(c) Agfachrome CT-13S

(d) Agfachrome CT-18

Fig. 2.2-2 — Small section of the model (75×)(Cont.)

2.3 EVALUATION OF SO-121 AT LOW SOLAR ALTITUDES

2.3.1 Test Type

The aircraft-112B camera system was used for this test.

2.3.2 Test Objectives

Test objectives were as follows:

1. Examine the color reproduction of SO-121 at low solar altitudes.
2. Obtain an estimate of the image quality obtainable with this material.
3. Estimate the performance of SO-121 in the KH-4B system.

2.3.3 Test Details

The photography from this test was obtained on 28 July 1966 using the 112B camera system at 65,000 feet. This produced a scale of 1:33,000 at the center of format for the original negatives. The flight line consisted of a repeated pattern over Bakersfield, California as indicated in Fig. 2.3-1. The flight started early in the morning in order to acquire photography at very low solar altitudes. The photography continued from 5 degrees solar altitude to midmorning when the solar altitude was 37 degrees. In order to obtain well exposed photography over this wide range of solar altitudes, a neutral density filter was used in one camera to make a full stop difference in exposure between the two instruments. The specific camera parameters for the flight are listed in Table 2.3-1.

2.3.4 Discussion of Examples

Two photographic illustrations have been included to show the resultant photography at the extremes of the solar altitudes covered (see Fig. 2.3-2). These illustrations have been printed to look as much like the original SO-121 film as possible. It is interesting to note that in making these images many of the test prints had a much better color balance. However, they were not used since they were not good representations of the original material.

At the low solar altitude, sufficient quality is present to clearly locate small aircraft. There is little improvement in the recognition of these aircraft (or support vehicles) at the higher solar elevation. The overall color cast of the material at low solar altitudes is bluish. However, there are areas of warm tone where the sunlight strikes the area directly. In the shadow areas, such as near wooded terrain, there is a severe loss due to underexposure.

At the higher solar altitudes, the image has a warmtone cast, principally brown. Almost the entire scene is illuminated by direct sunlight. As such, there is detail prevalent in the wooded areas. High reflectance objects are really not that much easier to identify and recognize. This can be noted in the light aircraft, the terminal area, the swimming pool, and the parking lot.

2.3.5 Results and Conclusions

The following results and conclusions were obtained from this evaluation:

1. SO-121 can generally be used at solar altitudes as low as 10 degrees with 112B. Certain types of information can be recorded at solar altitudes as low as 5 degrees.

2. A full load of SO-121 could be properly exposed at solar altitudes as low as 13 degrees in the KH-4B system. Only slight underexposure would occur at 10 degrees. A partial load, however, would be more severely limited since one of the filters would have to be used for the

black and white film. Thus, neutral density on one of the filters could not be used for an exposure control. The range in exposure available on KH-4B is 1⅓ stops, which does not encompass the speeds of both 3404 and SO-121.

3. The Petzval lens is not optimized for the entire visible spectrum. The 2:1 resolution performance to be expected from a split load of 3404 - SO-121 is 40 to 50 lines per millimeter for the SO-121. There would be no loss in the 3404. The resolution expected from a full load of SO-121, where the lens can be set at peak focus for this material, is approximately 50 to 60 lines per millimeter. It would be worth considering a lens design corrected for the entire visible wavelength band if color is to be used extensively in the KH-4B system.

4. Color reproduction is poor at the low solar altitudes when using the nominal color-compensating filter pack. For a full load, where both prime and alternate filter positions can be devoted to the color film, a separate filter pack should be used at low solar altitudes. However, this is not practical for a partial load of color film since one filter position would have to be used for the black and white emulsion.

5. Poor color balance (from either improper filtration, inadequate exposure or low solar elevations) can be partially corrected in the duplication stage.

6. The blue component of the color image is severely affected by atmospheric haze, resulting in very low contrast. A stronger haze-cutting filter (such as the Wratten no. 4) would be useful in improving the contrast. However, there must be an appropriate color correction filter used to offset the yellow cast that would result in the highlights.

Table 2.3-1 — Specific Camera Data for the Bakersfield SO-121 Flight

	AFT-Looking Camera	FWD-Looking Camera
Film	SO-121	SO-121
Slit width	0.031 in.	0.031 in.
Exposure time	1/600 sec	1/600 sec
Color correction filter	30CCB	30CCB
Haze-attenuating filter	Wratten no. 2E	Wratten no. 2E
Neutral density filter	None	0.35
Scan mode	II	II
f/number	3.5	3.5

NOTE: A 0.9 neutral density filter was placed over the frequency markers and frame counter on both cameras.

Fig. 2.3-1 — Flight lines for SO-121 test over Bakersfield, California

Fig. 2.3-2 — Photographic samples at 5.9- and 37.3-degree solar altitudes (from SO-121)

2.4 METRIC COMPARISON BETWEEN SO-121 AND 3404

2.4.1 Test Type

The aircraft-112B camera system was used for this test.

2.4.2 Test Objective

The objective of this test was to indicate what change, if any, is to be expected in image mensuration precision when SO-121 color film is used in conjunction with or in place of the standard black and white film (3404).

2.4.3 Test Details

Complete black and white and color stereo coverage of a suitable target area was acquired with an aircraft flight employing the two 24-inch stereo cameras of the 112B system. These 13-degree convergent cameras were flown at 65,000 feet, giving a scale at center of format of 1:33,000. The 3404 was used in the FWD-looking camera and the SO-121 was used in the AFT-looking camera. Additional details concerning these cameras are listed in Table 2.4-1. The flight paths consisted of two cloverleaf patterns over Phoenix and Tucson, Arizona (see Figs. 2.4-1 and 2.4-2). The photography used for this test was selected from the Phoenix flight and consisted of one stereo pair (2 frames) of each film type giving almost identical coverage of the same target area.

Prior to the mensuration phase of the test, a variety of different types of duplicates of the original photographs were made. These dupes were made from the original 3404 and SO-121 imagery. The dupes from the color film were made through a series of filters—red, green, and blue—and also with white light. All of these dupes were analyzed for relative image quality and image content. The mensuration phase of the test was limited to the black and white positives of the 3404, the black and white positives (white light) of the SO-121, and the original SO-121 color positives. These were felt to best represent the types of materials to be used by the dimensional intelligence and mapping communities.

Within the area covered, a group of measuring points was selected. These points were then measured on a Wild STK-1 Stereocomparator, making monoscopic pointings, stereo pointings, and stereo parallax measurements. The black and white and color materials were used both independently and in combination for these measurements. All of the measurements were repeated a number of times to provide sufficient statistical data for a metric comparison of the materials.

2.4.4 Discussion of Figures

Figs. 2.4-3 and 2.4-4 contain the images made from the separation records. The most immediately noticed feature is the very unsharp blue record image. Notice the large amount of specular reflection from one of the commercial aircraft at the terminal. The "ballooning" is considerably reduced in the red separation record, even though both were made from the same original SO-121 image. The CORN target resolution values for the various prints are listed in Table 2.4-2. For optimum results with SO-121, the camera focus should be shifted slightly. This was not done in this test, and, as a result, the color film resolution was 48 cycles per millimeter (as determined from mobile CORN targets) instead of the expected maximum of 60 cycles per millimeter.

The red and green records have resolutions of 24 and 30 cycles per millimeter when made from the 48-cycle per millimeter color material. The green is slightly higher because the green-sensitive layer in SO-121 film is coated on the top and the lens performance in both of these regions is almost equal. The blue, however, suffers considerably, having a resolution of only 9 cycles per millimeter.

Although there is not a great amount of color in this scene, one aspect of the tonal rendition is easily seen. The ground in this area is principally brown, as evidenced by the color print. This means that the ground is very dark with respect to the blue filter and light with respect to the red filter. The best example of this is in the region of the CORN targets. In the red record, the white panels of the CORN edge almost blend in with the dirt surroundings. However, the reverse is true in the blue separation record. The white panels stand out and the black ones almost blend in with the background.

Figs. 2.4-5, 2.4-6, and 2.4-7 show the results of the mensuration analysis. The ordinate on these three figures is the standard deviation of the repeated measurements on each target point. Fig. 2.4-5 shows the precision of the monocular pointings and indicates that those made on the 3404 images are consistently better than those on either the SO-121 original or the black and white print of the SO-121. Since the average precisions on the latter two materials are approximately equal, and the deviations between them for individual targets do not correlate to the color of the targets, it would appear that the lower pointing precisions for these materials are related solely to their lower resolutions. This same conclusion might be drawn from Fig. 2.4-7 which illustrates the precision of stereoscopic parallax measurements made in balanced stereo models formed by two images on similar materials. This conclusion, however, is not substantiated by the results of the stereoscopic pointings as illustrated in Fig. 2.4-6. In this case, the two black and white materials show equal precision despite their differing resolutions. The plots of the pointings and parallax measurements made in the combined or unbalanced stereo models (not shown) illustrate similar conflicting results.

2.4.5 Results and Conclusions

1. Black and white separation positives can be made from SO-121 film. The tonal relationship in these positives can be made to be nearly identical to 3404 by using a red filter in the printer. In the contact duplication employed in this test, the resolution of the red separation positive was 50 percent of the original SO-121 level. The green separation was higher—75 percent. The blue record resolution was only 20 percent of the SO-121 level.

2. In this test, none of the pointing or parallax measurements showed any definite dependencies upon the color of the target. This held true even for the mobile CORN target color panels.

3. Although this test indicates a trend for the measurements on the higher resolution material to be somewhat more precise than those on the lower resolution material, the magnitude and significance of the numbers associated with these precisions need some qualification. The average measuring precisions on the 3404 and SO-121 materials differ by approximately 1/2 micron while the precisions of the individual targets on both materials differ as much as 1.5 to 2.0 microns. The magnitudes of the average precisions, then, may vary through this 2-micron range depending on the particular selection of targets. The average value for both materials, however, should vary together, thus maintaining a spread of approximately 0.5 micron. This would indicate then that the choice between the two materials for the measurement of intelligence type targets would only be important in the most precise operations where a difference in measuring precision of 0.6 micron or even 1.0 micron would be significant.

4. No conclusions from this test should be extrapolated to SO-180 (infrared color film) since its image formation and system resolution are not the same as SO-121.

Table 2.4-1 — Specific Camera Settings for Metric Flight

	AFT-Looking Camera	FWD-Looking Camera
Camera	I3	I4
Film	SO-121	3404
Slit width	0.049 in.	0.049 in.
Shutter speed	1/385 sec	1/385 sec
Haze-cutting filter	Wratten no. 2E	Wratten no. 21
Color correction filter	30CCB	—
Neutral density filter	0.68	—
f/number	3.5	3.5
Scan mode	II	II

Table 2.4-2 — Resolution Values From Mobile CORN Target

Image	Resolution, cycles per millimeter
Blue separation	9
Green separation	30
Red separation	24
White light print	30
Original 3404	77
Original SO-121	48

Fig. 2.4-1 — Flight lines for metric coverage of Phoenix and Tuscon, Arizona, and Los Angeles, California

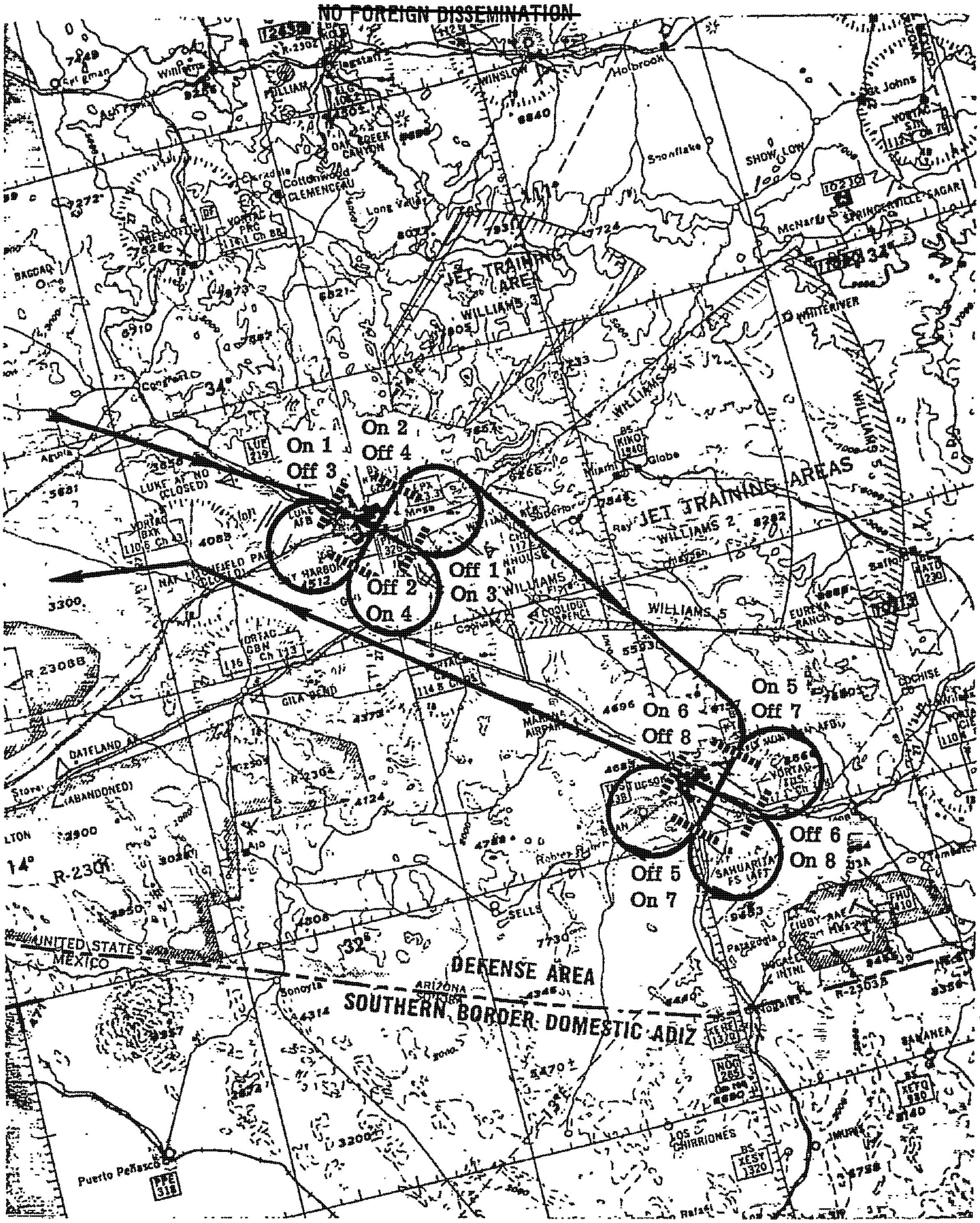


Fig. 2.4-2 — Flight lines for metric coverage of Pheonix and Tuscon, Arizona, and Los Angeles, California (Cont.)

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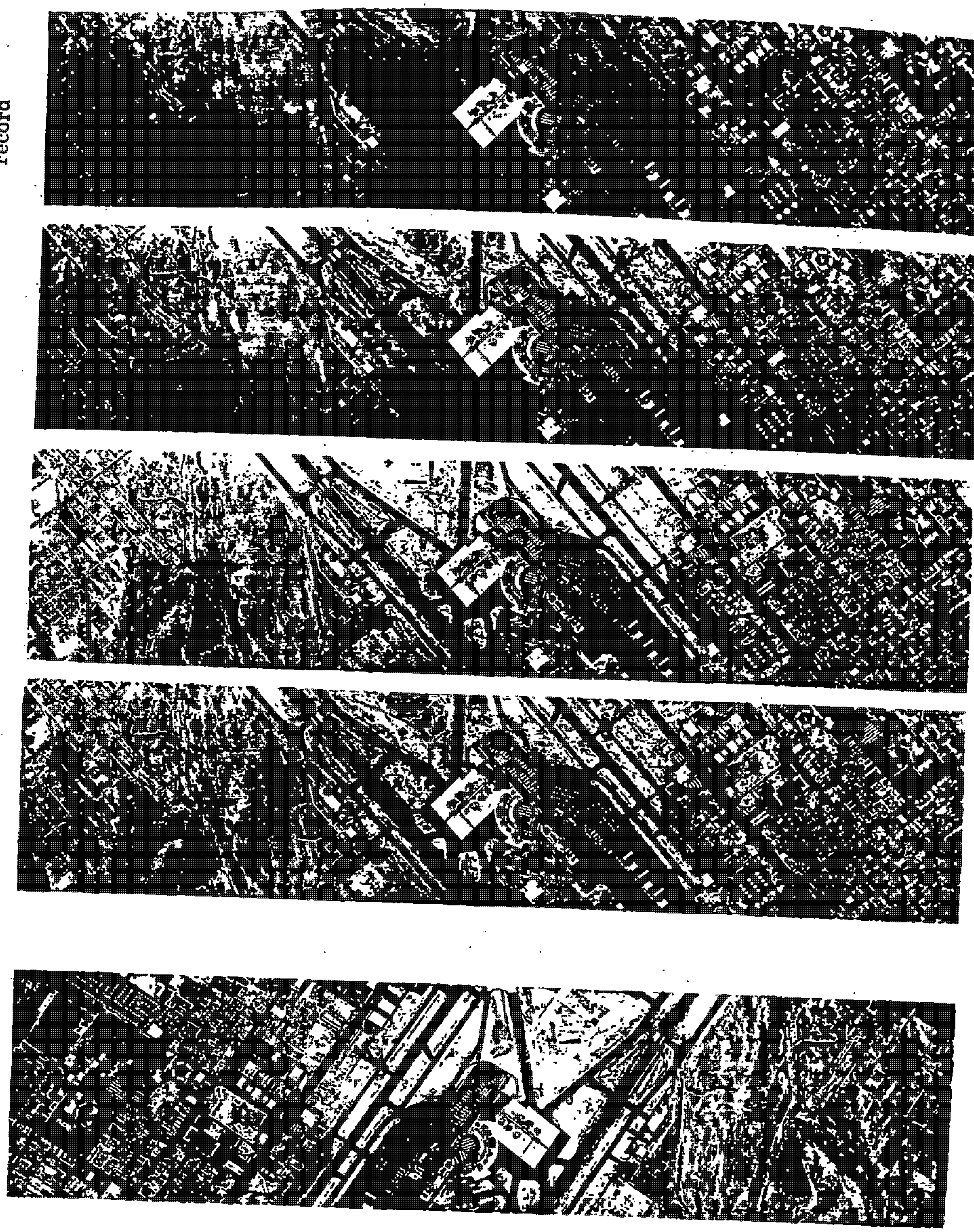

Blue separation record

Green separation record

Red separation record

White separation record

From 3404 original

Fig. 2.4-3 — Black and white images from SO-121 and 3404 original materials

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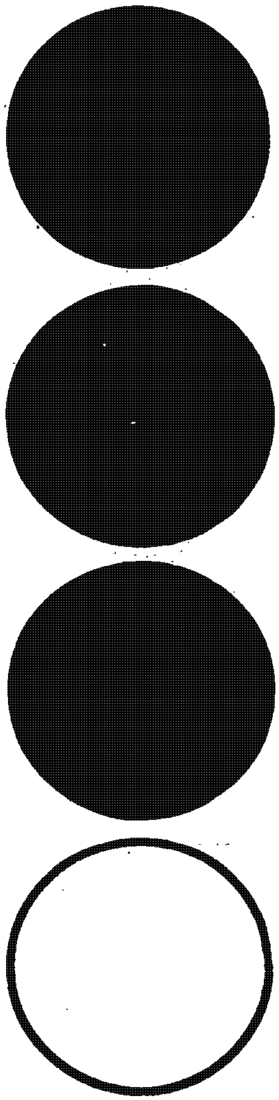

NOTE

The black and white images on the previous page were made by contact printing the SO-121 original transparency (through separation filters) on a black and white panchromatic sensitive film. These negatives were then duplicated on the paper to make these figures.

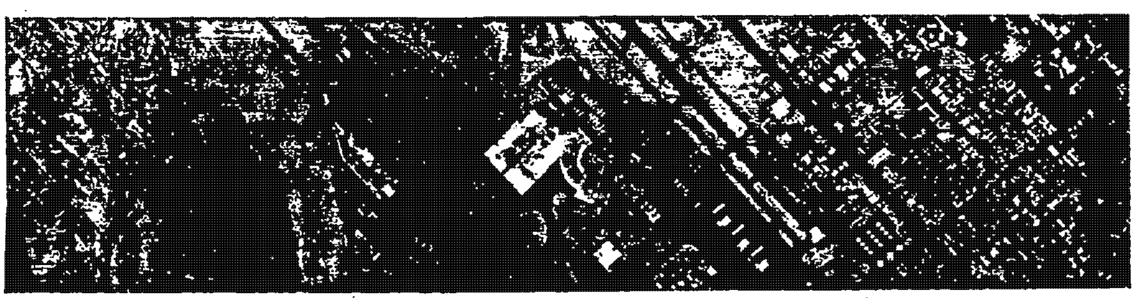

Fig. 2.4-4 — SO-121 film

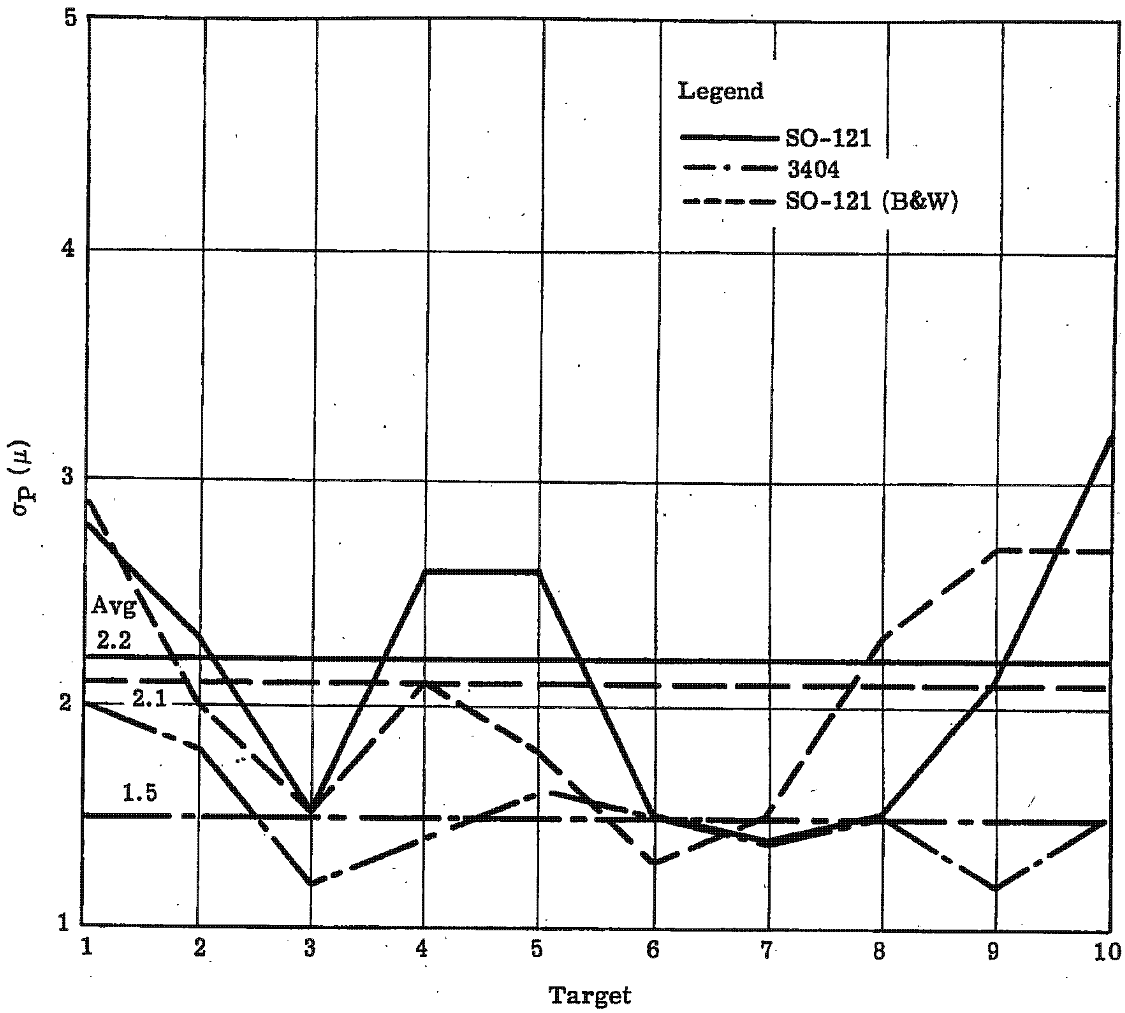

Fig. 2.4-5 — Error from monocular pointing ($\sigma_P^2 = \sigma_x^2 + \sigma_y^2$)

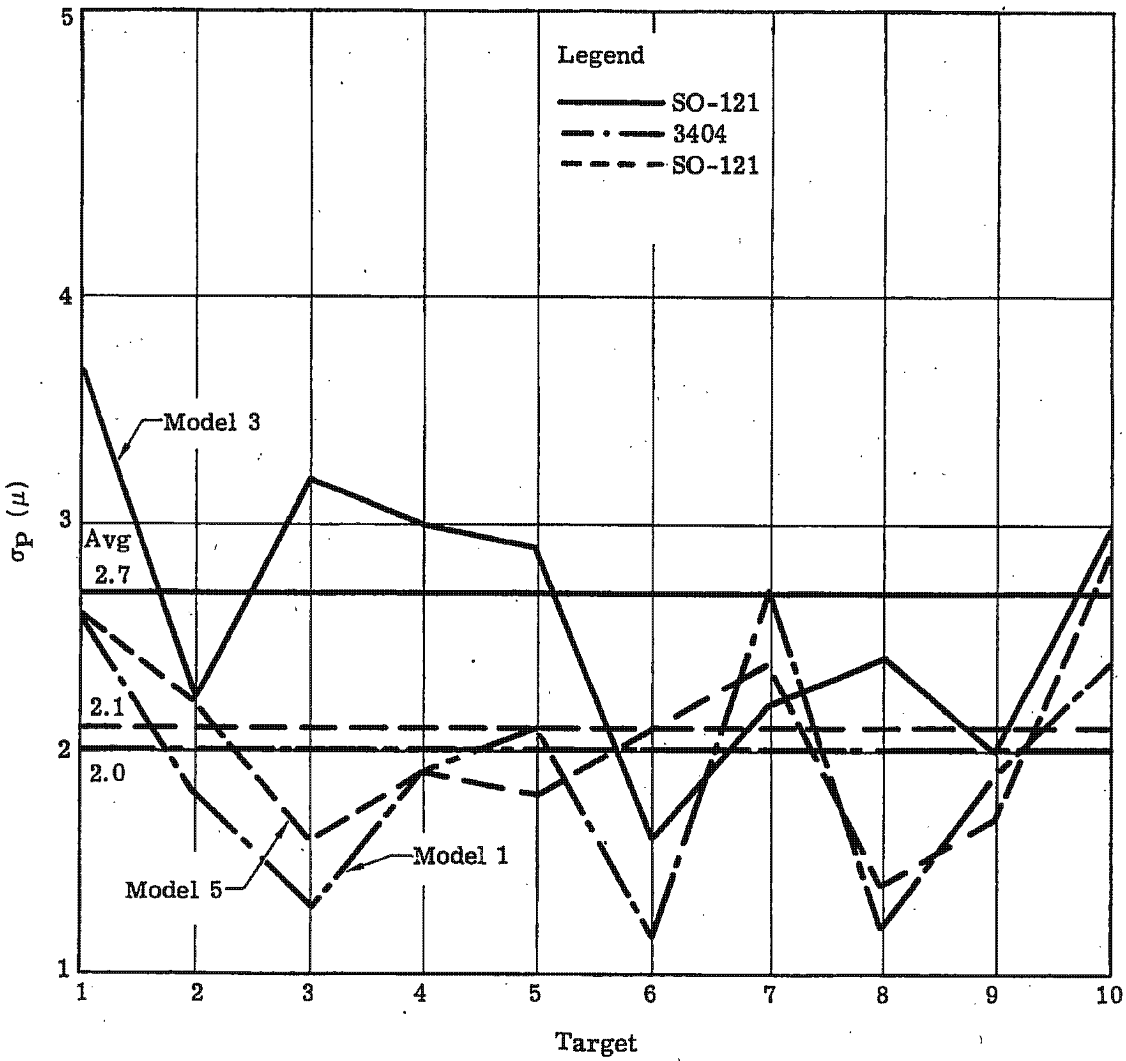

Fig. 2.4-6 — Error from stereoscopic pointing of balanced models ($\sigma_P^2 = \sigma_x^2 + \sigma_y^2$)

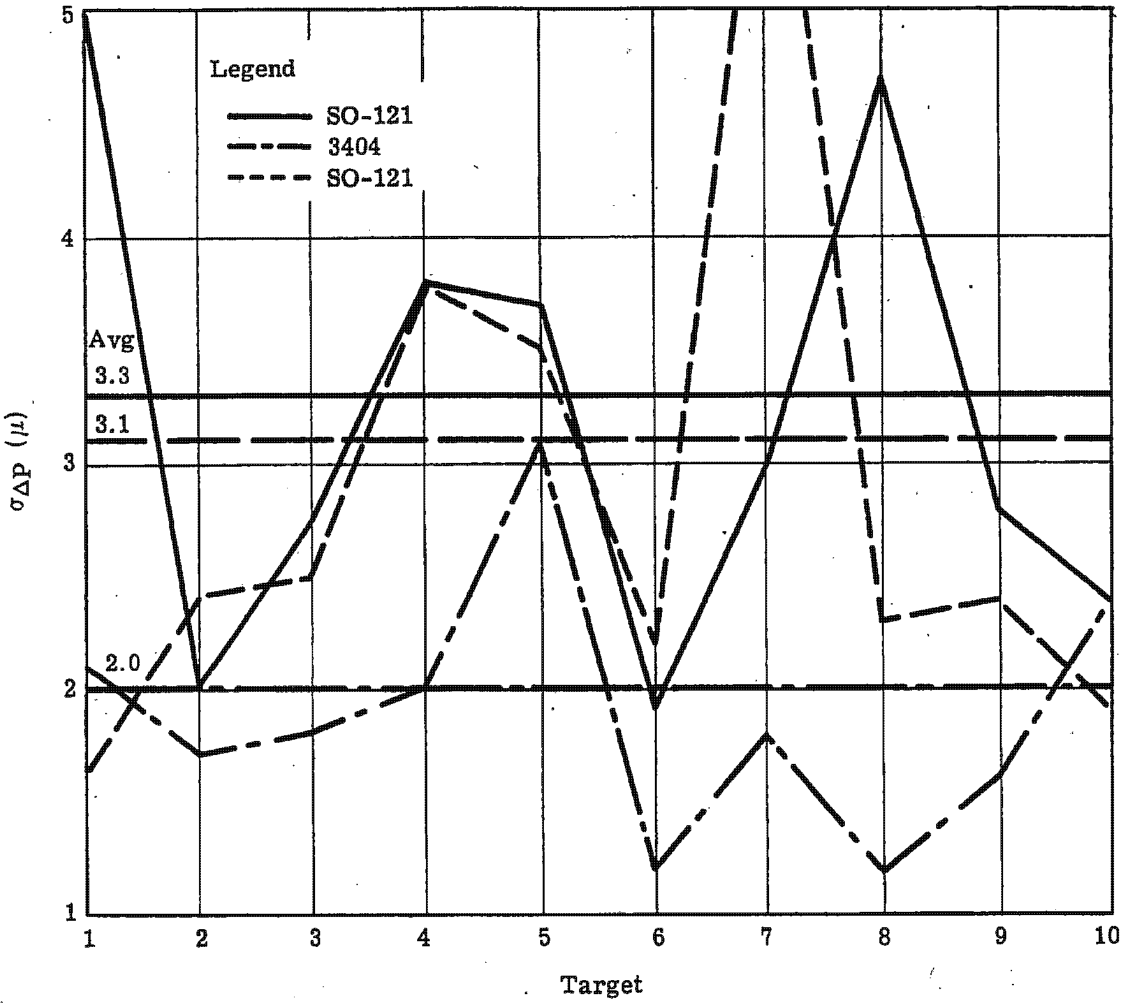

Fig. 2.4-7 — Error from stereoscopic parallax of balanced models ($\sigma^2_{\Delta P} = \sigma^2_{\Delta P_x} + \sigma^2_{\Delta P_y}$)

2.5 KH-7 COLOR EXPERIMENT

2.5.1 Test Type

The KH-7 satellite system was used for this test.

2.5.2 Test Objectives

Test objectives were as follows:

1. Determine the best filtration and exposure for color photography (SO-121) in the KH-7 camera system.

2. Evaluate the stereo pair combinations provided. Some pairs were programmed to be all color stereo, some pairs were to have the forward in color and the aft in black and white, others were to have the forward in black and white and the aft in color, some were to have portions of a frame in color and the balance in black and white, and still others were to be all black and white stereo. This test was intended to provide information to determine:

   a. Effects of various solar elevations and azimuths
   b. Comparative resolution
   c. Value of color and black and white stereo pairs
   d. Value of all color stereo pairs.

2.5.3 Test Details

Test details are described below.

1. The color acquisitions [see Figs. 2.5-1 and 2.5-1(a)] were experimental and provide color photographs of both operational and domestic terrain.

2. Ten feet of color, 10 feet of 3404 (black and white), 10 more feet of color, 10 feet of 3404, and 200 feet of color were spliced to the tail of the mission film load.*

3. A special test slit was fitted with the four experimental filters. Each section of the slit varied in width to compensate for the filter employed. Filters and slit width data are listed below.

a. Polaroid filter and 0.0056-inch slit. This filter does not selectively absorb any portion of the visible spectrum. On this mission, the area recorded through the Polaroid filter represents a no filter condition. Supersaturation of the blue sensitive emulsion negates the detection of red or green images in the SO-121 material recorded through this filter. All images recorded are formed by the magenta and cyan dyes and provide monochromatic blue imagery.

b. Wratten no. 12 filter and 0.0023-inch slit. This filter absorbs that portion of the visible spectrum below 500 nanometers. It is a bright yellow (minus blue) filter conventionally used to reduce atmospheric haze in black and white aerial photography. On this mission, the area recorded through the Wratten no. 12 filter provided an overall yellowish-orange cast. Nearly all images in this area are formed by the yellow dye, with a little magenta dye producing the yellow-orange imagery.

*Heavy clouds in the area where the transition (black and white to color) occurred preclude a comprehensive study.

c. Wratten no. 4 filter and 0.0022-inch slit. This filter absorbs that portion of the visible spectrum below 460 nanometers. It is a yellow filter conventionally used to correct for the overabundance of blue introduced by sky light. It is not normally used in aerial photography. The Wratten no. 4 filter transmits between 10 and 25 percent of the blue portion of the spectrum. On this mission, the area exposed through the Wratten no. 4 filter provides the best color balance of the filters employed. Images can be detected in all three dye layers, and the reproductions provide good renditions of the visible spectrum.

d. Wratten no. 2E filter and 0.0019-inch slit. This filter absorbs only that portion of the visible spectrum below 410 nanometers. It is a light (almost colorless) yellow filter, rarely used except for scientific and experimental projects involving ultraviolet. The predominance of blue restricts the value of the material exposed through this filter. However, a more accurate exposure through this filter could provide more suitable imagery.

e. Bausch and Lomb Y-10 filter. This filter has characteristics similar to those of the Wratten no. 12. It is used with the 3404 black and white film used on this mission. Its primary purpose is to absorb atmospheric blue radiation that is detrimental to all high, super, and hyper-altitude photography. This filter was used on only a few frames of the color material and was intended to be used in conjunction with the 3404 film that was spliced between the sections of color material.

4. The color material was separated from the black and white during the preprocessing inspection and processed in the Grafton processor.

2.5.4 Discussion of Figure

The accompanying illustration (Fig. 2.5-2) is a contact reproduction of an operational frame obtained with the SO-121 film. (Specific camera parameters for this figure can be found in Table 2.5-1.) It shows the terrain imagery acquired with each filter of the special slit. A brief description of the imagery provided with each filter is found in Section 2.5.3.

2.5.5 Results and Conclusions

Mission 4024 provided the intelligence community with the first qualitative and quantitative color photography from a satellite camera system. The results indicate that color material can be used at these altitudes to provide intelligence data that cannot be detected on black and white emulsions.

An analysis of the color material from this mission indicates that ground resolutions of 3 to 4 feet can be detected by stereoscopic viewing.

The color portion of the mission provided 39 stereo pairs and 4 mono strips of plottable photography. The coverage includes selected areas from 58.5°N to 40.3°N in the northern hemisphere and from 3.2°N in the equatorial area to 43.4°S in the southern hemisphere. Solar elevations ranged from 12.2 to 83.6 degrees.

The color material, with proper exposure and filtration, appears to have sufficient latitude to faithfully record color at the solar elevations experienced on this mission. It further appears that satisfactory color may be recorded at lower solar elevations. However, acquisitions at lower solar elevations would necessitate modified filtration and exposure to compensate for the difference in the quality and quantity of the light. It was noticed that the color and texture of the terrain has a marked influence on the quality of the final product.

The bearing of the solar azimuth relative to the principal ray of the optical system affects the quality of the color photography more than this relative bearing affects black and white photography acquired under similar conditions.. This is due primarily to the latitude of the material. A well planned color mission should consider the solar azimuth as well as the quantity and quality of the available light.

Table 2.5-1 — Specific Camera Parameters for Fig. 2.5-2 (mission 4024).

Rev	79
Frame	17
Effective T stop	6.2
Date of photography (GMT)	24 Jan 1966
Enlargement factor	Contact
Type of coverage	Stereo
Altitude, nm	94.3
Mirror crab, degrees	3.500
Cone angle, degrees	16.5562
Mirror position	Forward
Slit width, inches	(a) 0.0056; (b) 0.0023; (c) 0.0022; (d) 0.0019
Film velocity, inches per second	3.1229
Exposure, seconds	(a) 1/558; (b) 1/1,358; (c) 1/1420; (d) 1/1,640
Solar elevation, degrees	75.8
Solar azimuth, degrees	156.5
Vehicle azimuth, degrees	183.9
Azimuth of the principal ray, degrees	28.9
Vehicle roll, degrees	−10.635
Local sun time	1134

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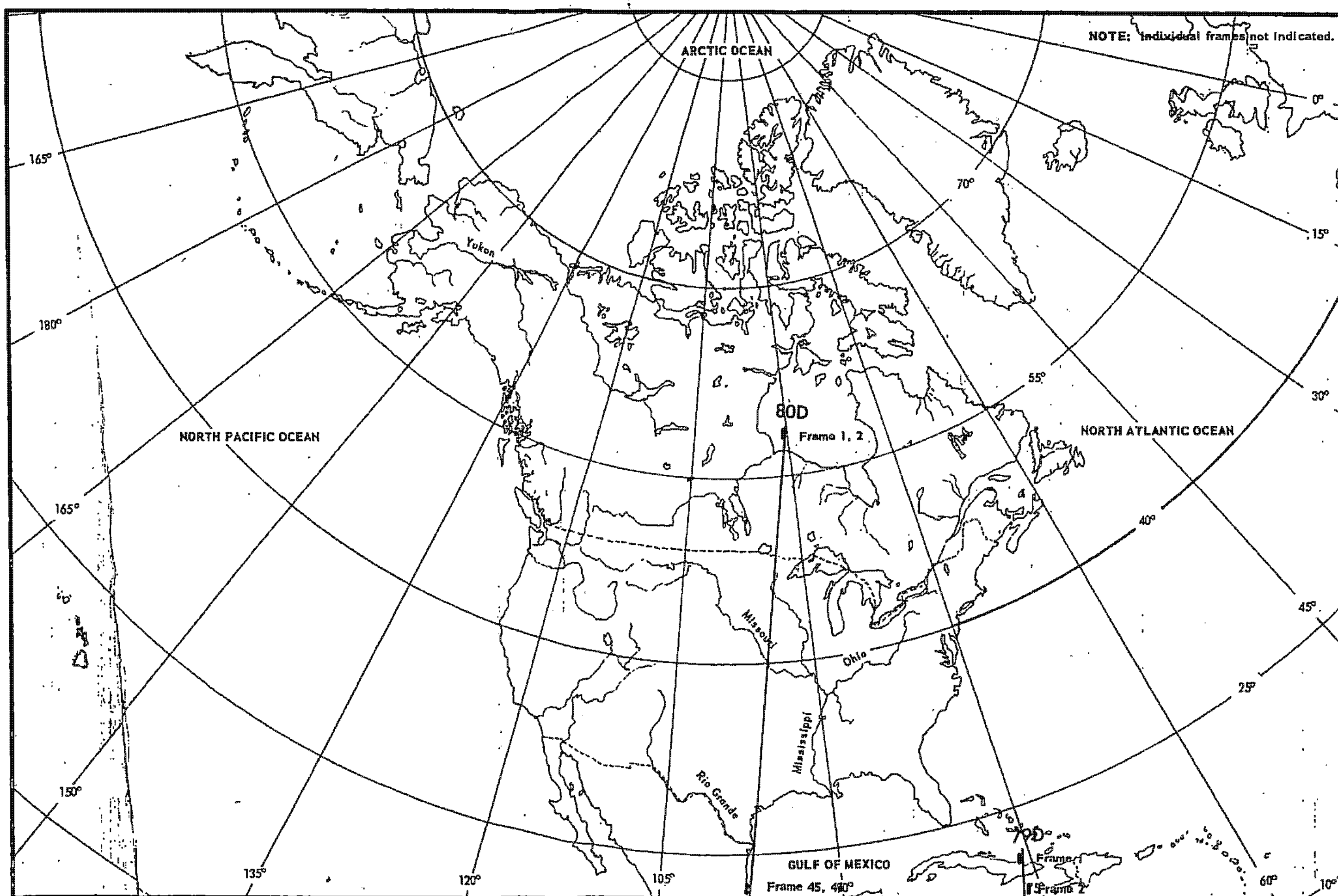

Fig. 2.5-1 — Ground tracks over North America for the KH-7 SO-121 color experiment, mission 4024

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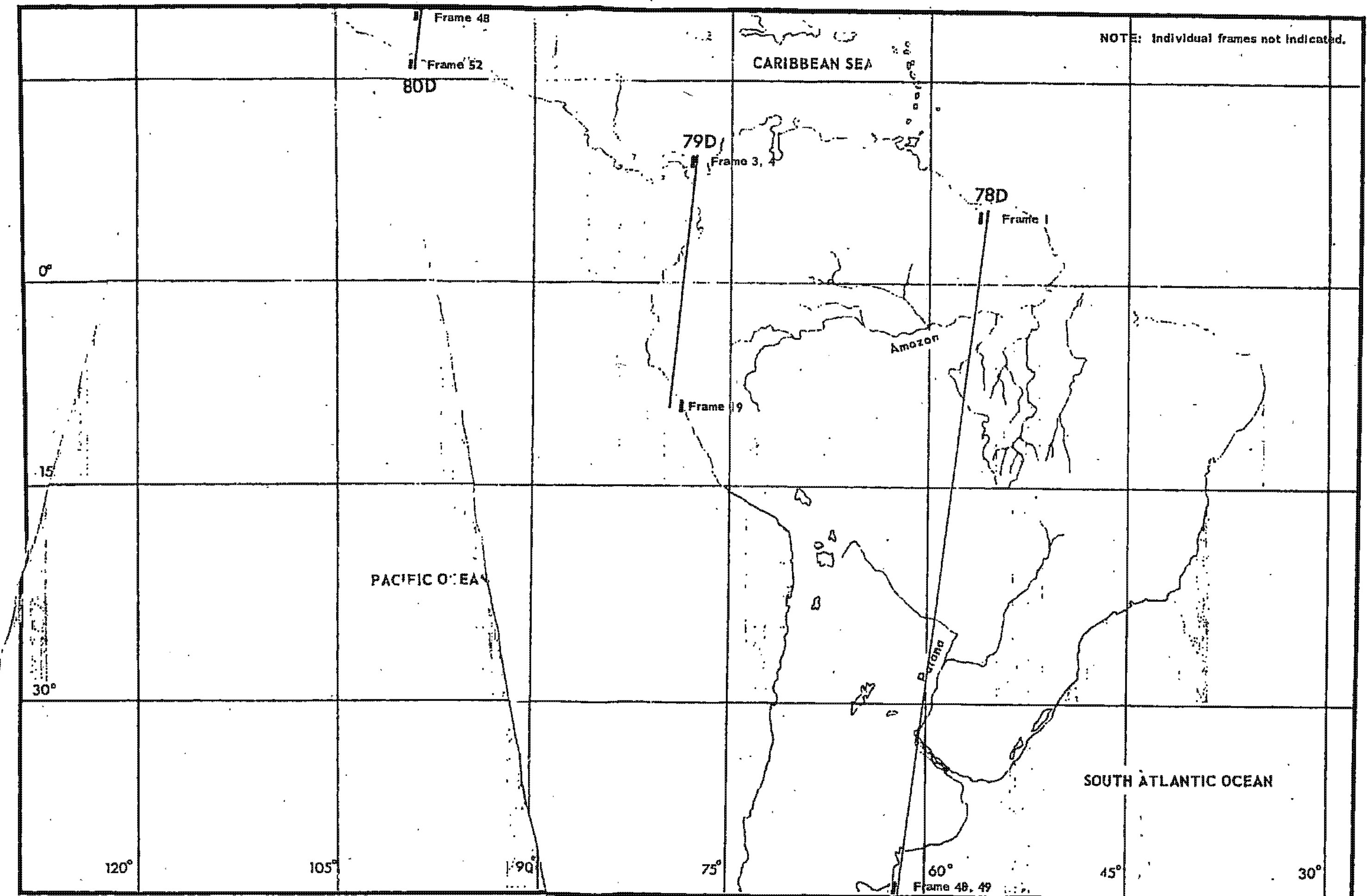

Fig. 2.5-1(a) — Ground tracks over South America for the KH-7 SO-121 color experiment, mission 4024

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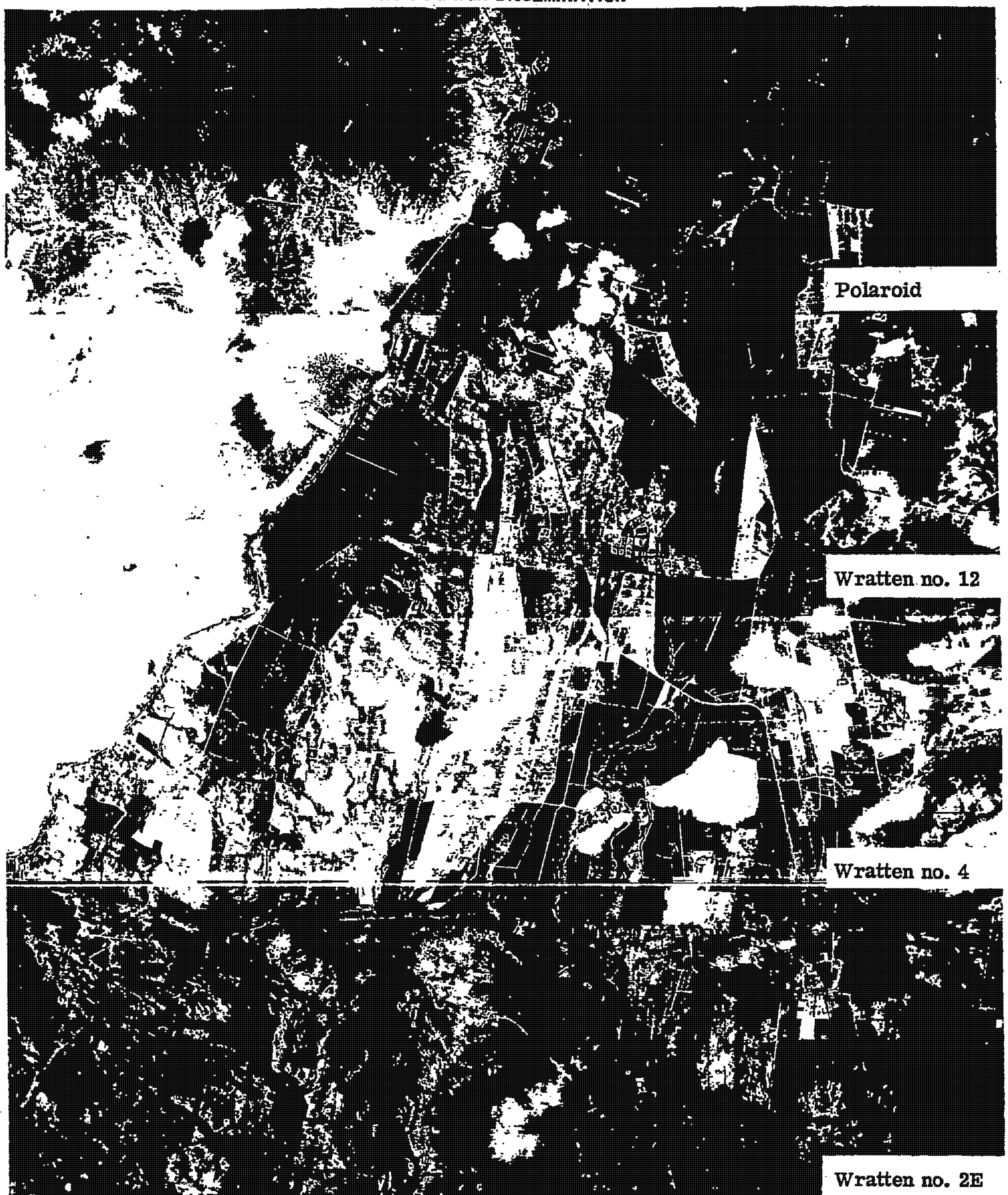

Fig. 2.5-2 — KH-7, SO-121 filter test; mission 4024

2.6 KH-8 COLOR EXPERIMENT

2.6.1 Test Type

The KH-8 camera system was used for this test.

2.6.2 Test Objectives

Test objectives were as follows:

1. Test operationally the capability of the KH-8 camera transport and focus systems with SO-121 film
2. Evaluate the material and determine its acceptability and suitability as an additional tool in information extraction.

2.6.3 Test Details

The last 400 feet of the mission 4316 flight load was SO-121 color film. The filter incorporated in the camera system for black and white film acquisitions was the only filtration used with the color film. Changes in process were used to achieve proper color balance. No specific intelligence targets were programmed for the color film portion of the mission.

2.6.4 Discussion of Figures

The photographs shown here are representative of overall results. They cover areas of the central United States and Southwest and Southeast Asia. Specific camera parameters for each photograph are tabulated in Table 2.6-1. The ground tracks for this portion of the mission are shown in Figs. 2.6-1, 2.6-2, and 2.6-2(a).

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2.6.5 Results and Conclusions

The color imagery generated by the test does not exhibit the spatial resolution obtained on the black and white film (22 inches versus 13 inches best) of this mission. The color acquisitions do provide certain information that could not be determined from the black and white material, i.e., subtle differences in vegetation and the identification of chemical-industrial waste providing information as to the function of a facility.

The SO-121 film is compatible with the KH-8 camera system. The film/camera combination provided ground resolutions of 22 to 26 inches and recorded object colors ranging from red to blue.

Table 2.6-1 — Specific Camera Parameters for Revs 144 to 154 (mission 4316)

	Fig. 2.6-3	Fig. 2.6-4	Fig. 2.6-5	Fig. 2.6-6	
Rev	144	154	154	154	154
Frame	8	21	25	26	27
Effective T stop	4.215	4.144	4.144	4.635	4.144
Date of photography (GMT)	19 Sept 1968	20 Sept 1968	20 Sept 1968	20 Sept 1968	20 Sept 1968
Enlargement factor	10×	10×	10×	10×	10×
Type of coverage	Strip	Stereo	Strip	Stereo	Stereo
Altitude, nm	78.4	75.0	76.1	77.7	77.9
Mirror crab, degrees	2.419	2.419	2.419	2.419	2.419
Cone angle, degrees	1.7193	25.2889	20.4602	Unknown	Unknown
Mirror position	Vertical	Aft	Aft	Forward	Aft
Filter band, nanometers	450 to 720	450 to 720	450 to 720	450 to 720	450 to 720
Slit width, inches	0.00354	0.00354	0.00354	0.00354	0.00354
Film velocity, inches per second	8.6946	8.1083	8.2514	8.5709	8.8270
Exposure, seconds	1/2,500	1/2,500	1/2,500	1/2,500	1/2,500
Solar elevation, degrees	54.2	46.7	49.1	52.7	52.7
Solar azimuth, degrees	168.5	176.0	174.1	171.5	171.6
Vehicle azimuth, degrees	200.0	202.4	201.5	200.5	200.4
Azimuth of the principal ray, degrees	289.1	132.8	137.0	18.3	209.3
Vehicle roll, degrees	−0.700	−26.250	−21.00	−2.10	−1.050
Local sun time	1133	1149	1144	1139	1139

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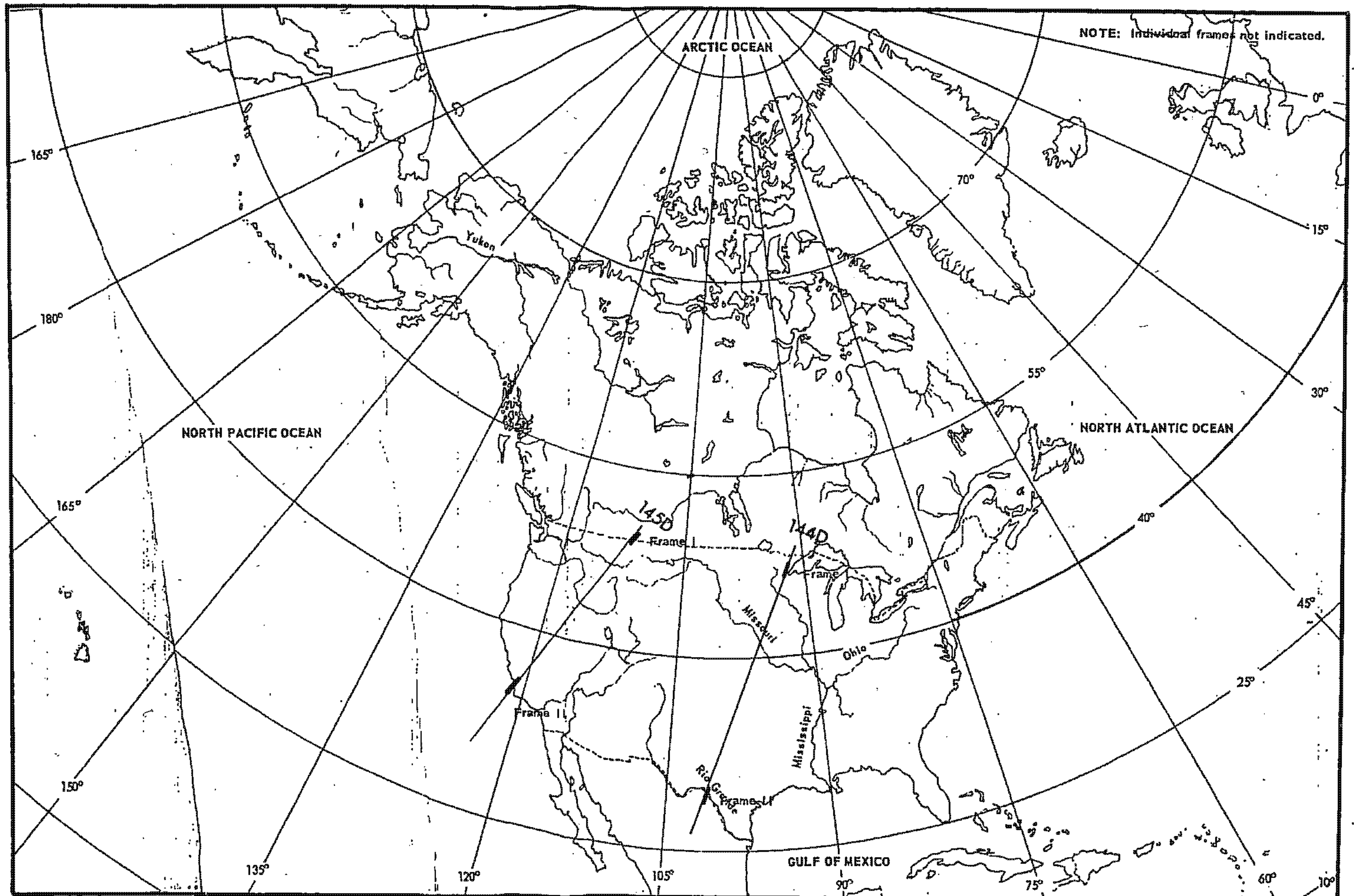

Fig. 2.6-1 — Ground tracks over the United States for the KH-8 SO-121 color experiment, mission 4316

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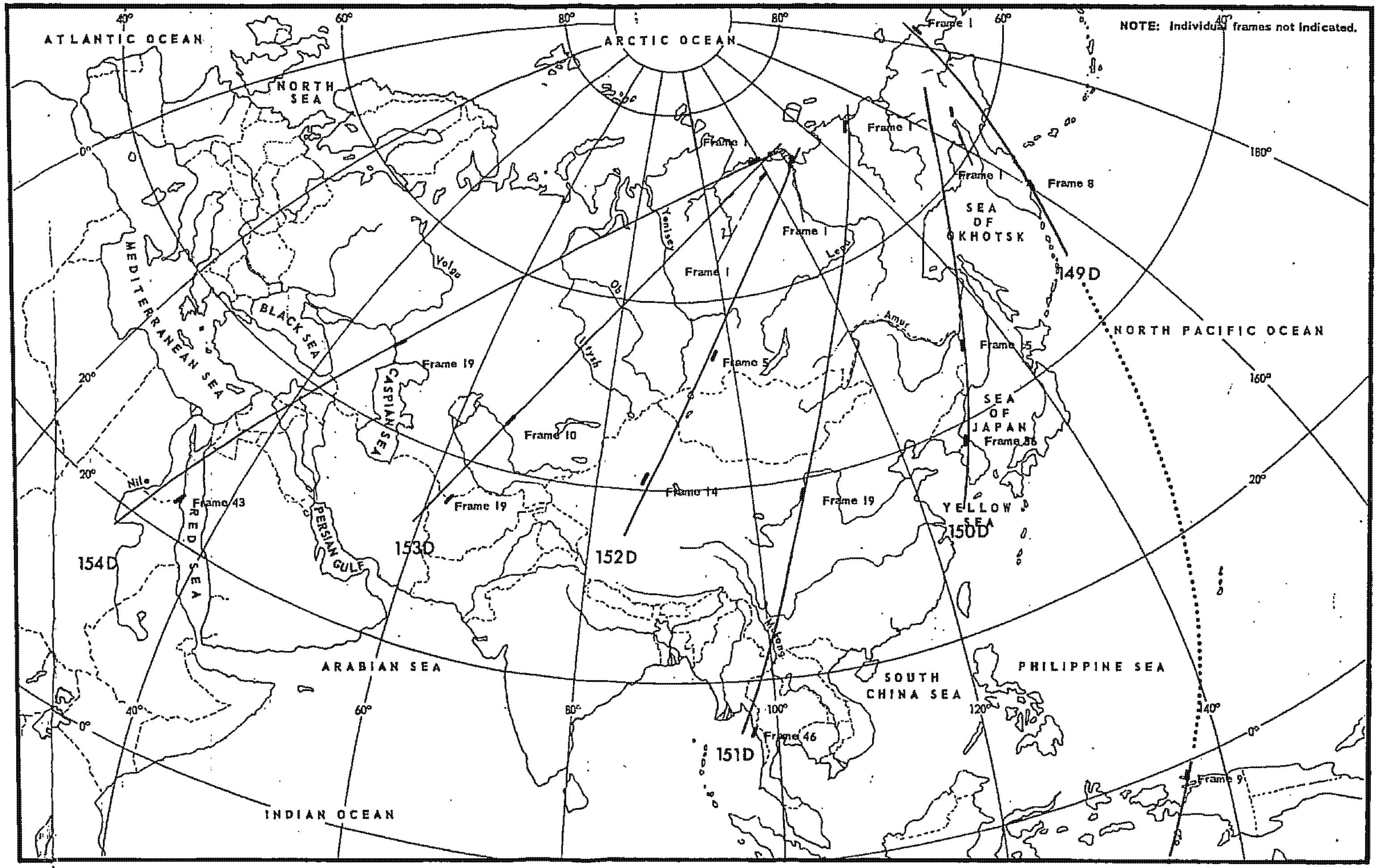

Fig. 2.6-2 — Ground tracks over Eurasia for the KH-8 SO-121 color experiment, mission 4316

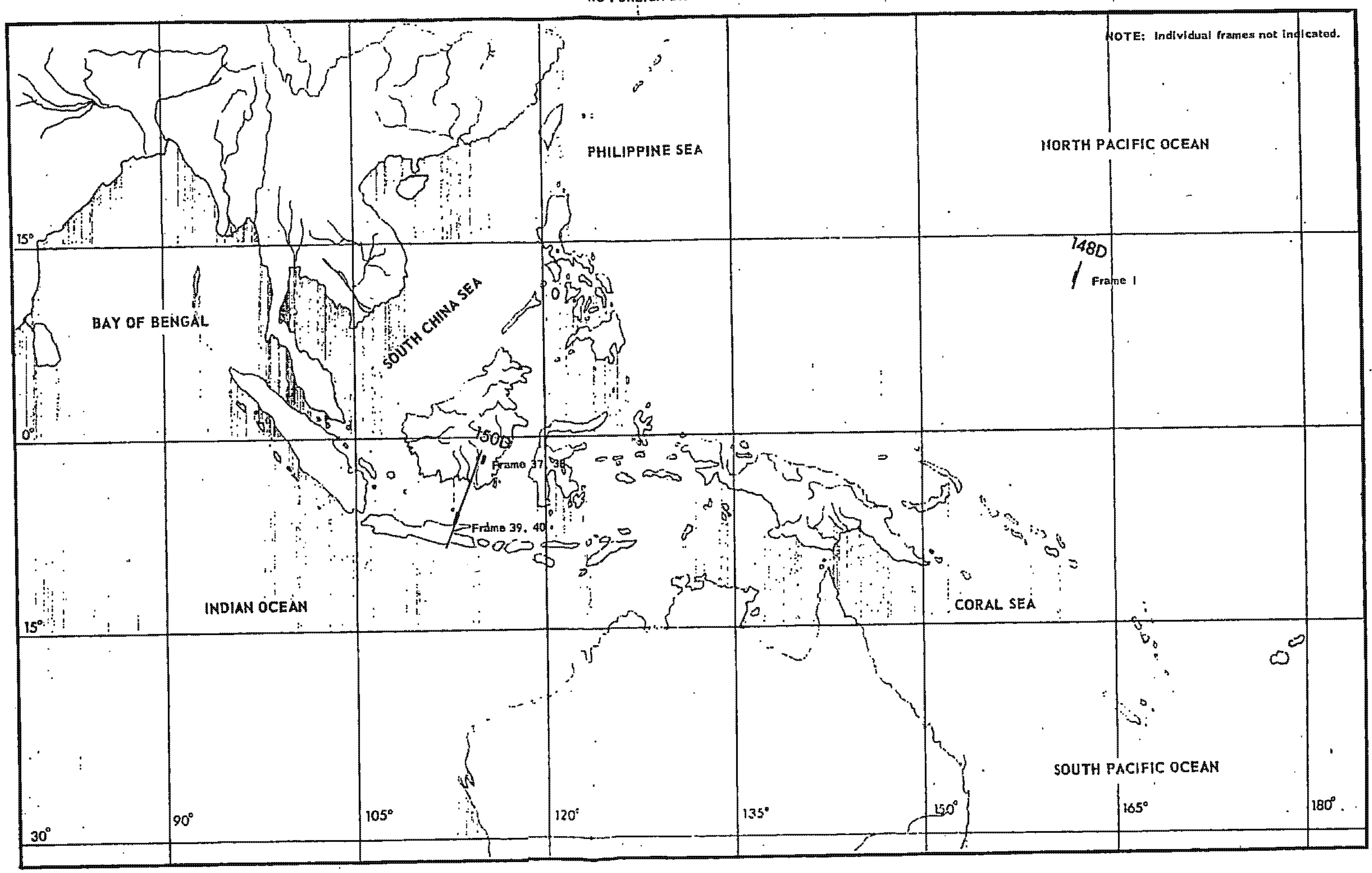

Fig. 2.6-2(a) — Ground tracks over Southeastern Asia for the KH-8 SO-121 color experiment, mission 4316

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2.7 CR-5 AND CR-6 SO-121 FLIGHTS

2.7.1 Test Type

The satellite KH-4B camera system was utilized for this test.

2.7.2 Test Objectives

The mission 1105 SO-121 test was intended to: (1) obtain for the first time conventional color photography from the KH-4B system; and (2) demonstrate the capability of the KH-4B camera system to handle SO-121.

The COMIREX requirement for SO-121 on mission 1106 was to obtain color-oriented intelligence over central China.

2.7.3 Test Details

2.7.3.1 Mission 1105 SO-121 Flight

Mission 1105 contained 500 feet of SO-121 spliced to the end of the primary mission film load of SO-380 on the AFT-looking camera. A material change detector on board the vehicle automatically brought the alternate filter into position when the color film was in use. Color coverage was obtained on five photographic passes as indicated in Figs. 2.7-1 and 2.7-2. The film change occurred on revolution no. 273 as the vehicle passed over the central USA. The color imagery from this pass provided the best resolution from the color film of this mission. The next revolution, no. 274, covered the coast of California on almost the same ground track as the SO-180 flight of mission 1104. Thus, comparable coverage of the same area (however, at different seasons) was obtained on the two basic types of color films available—conventional color (SO-121) and false color (SO-180). Clear weather photography was obtained over Korea. Of the two remaining passes over the Soviet Union, one was cloud covered and the other was partially cloud/snow covered. Representative black and white and color samples for this mission are shown in Figs. 2.7-3 and 2.7-4. Camera parameters are listed in Table 2.7-1.

2.7.3.2 Engineering Test

In order to maintain maximum quality with the KH-4 systems, the filtration must be accomplished with a single filter. However, in order to obtain the most suitable color balance and exposure, a combination of several different types of filters is required. Therefore, Eastman Kodak fabricated a special filter for this flight. It consisted of the proper haze filtration (Wratten no. 2E), the proper color-balancing filter (20CC cyan), and the proper amount of neutral density (0.40 density Inconel coating). Although SO-121 is faster than SO-380, this speed differential cannot be used practically when the mission contains a split load of SO-380/SO-121 films because the slit width range on the KH-4B system is only 1⅓ stops, and cannot, therefore, encompass satisfactory exposures for two films of such speed differential. Therefore, the philosophy adopted was to employ filters with neutral density coatings for the color film to make the speed effectively the same as the SO-380/Wratten filter combinations for that particular camera. This afforded maximum operational convenience and minimized the chances for an exposure error.

2.7.3.3 Mission 1106 SO-121 Flight

In January 1969, a requirement was levied upon the KH-4B system to obtain color-oriented information in central China. The quality of color photography obtained from mission 1105 was judged to be adequate to satisfy this requirement. However, the film separated before color coverage of the target was acquired. The requirement was satisfied with bi-color photography of the target area acquired on mission 1103. In order to have a high probability of acquiring this target in color, 2,000 feet of SO-121 were authorized as a tag-on film load; 911 feet of SO-121 photography were obtained in three passes (also indicated in Fig. 2.7-2) over the Sino-Soviet area. The tensions were set back to the normal level for this mission. The color balance and exposure were good. In addition, the film remained flat in the exposing plane, providing a uniform quality across the format. Although not a test, per se, the capability of using SO-121 in the KH-4B camera system was further proven. Representative black and white and color samples from cloud/snow-free areas of this mission are shown in Figs. 2.7-5 and 2.7-6.

2.7.4 Discussion of Figures

The high resolution print (Fig. 2.7-3) shows the strategic nature of the airfield. The strike aircraft are identifiable and a count can be made. Tonal gradations present in the surrounding countryside indicate the extent of cultivation and soil difference, while the drainage and road patterns are well defined.

Color photography of the same area (Fig. 2.7-4) lacks the resolution capability of the black and white record, but contains a wealth of information not present in it. The pattern of the airfield denotes its use, but aircraft types are not identifiable and only the larger craft can be counted. The various colors in the surrounding areas give unmistakable information as to the state of cultivation, the presence of vegetation along drainage, and the soil distribution pattern.

The Kun Yang Hai Lake area illustration (Fig. 2.7-5) covers essentially natural features and cultivation. It has excellent resolution and delineates the field, irrigation system, villages, and natural drainage pattern in a superior manner.

The color record (Fig. 2.7-6) while lacking in the profuse fine detail of the panchromatic record provides information of a totally different nature. The fields and irrigation are adequately shown; the villages are delineated to a lesser degree than in black and white, but the calibration and natural features of the area are accentuated. The soils, indigenous vegetation, and hydrology are depicted in a manner not possible using only density differences. Of particular note is the presence of red soils in various areas that are not detectable in black and white.

2.7.5 Results and Conclusions

The following is a quote from a portion of the mission 1105 PEIR*, message relative to the SO-121 product.

> "... THE MISSION CONTAINED 500 FEET OF AERIAL COLOR FILM TYPE SO-121 AT THE END OF THE AFT CAMERA SUPPLY. THE EXPOSURE AND COLOR BALANCE OF THE SO-121 WERE GOOD. THE IMAGE QUALITY OF THE SO-121 RECORD WAS EXTREMELY VARIABLE, AND RANGED FROM GOOD TO VERY POOR. THE AMOUNT OF GOOD QUALITY IMAGERY IS LIMITED AND IS GENERALLY RESTRICTED TO THE EDGES AND ENDS OF THE FORMAT. THE CENTER PORTION OF

*NPIC message no. 5212, 10 December 1968.

THE FORMAT IS GENERALLY POOR. THIS CONDITION WOULD APPEAR TO HAVE BEEN CAUSED BY THE FILM BEING CURLED AWAY FROM THE FOCAL PLANE DURING EXPOSURE. THE BEST IMAGERY APPEARS TO BE COMPARABLE TO THE BEST THAT COULD BE ACHIEVED WITH THE KH-4 CAMERA AND SO-121 FILM. THE BEST GROUND RESOLVED DISTANCE IS ESTIMATED TO BE ABOUT 15 TO 20 FEET. PRELAUNCH SYSTEM TESTING INDICATED THAT A POTENTIAL 15 FEET GRD (LOW CONTRAST) COULD HAVE BEEN ACHIEVED. WHILE BOTH GLOW AND DENDRITIC TYPE STATIC MARKING PATTERNS WERE EVIDENT ON THE SO-121, THEY ARE EXTREMELY MINOR IN NATURE."

The main problem encountered with SO-121 on mission 1105 was the film curl during exposure. The reason for this film curl was the fact that the system tensions were reduced by approximately 20 percent on this mission to accommodate the primary film load—SO-380 ultrathin base. However, as pointed out in the PEIR message, the edge of format contained photography (see Figs. 2.7-3 and 2.7-4) equal to the maximum that could be expected from preflight tests. Fig. 2.7-4 represents the best "spatial" resolution imagery located on the SO-121 of mission 1105.

The mission 1106 PEIR* stated that:

"... THIS IS THE FIRST KH-4 SYSTEM IN WHICH COLOR MATERIAL WAS USED OPERATIONALLY TO SATISFY A SPECIFIC INTELLIGENCE REQUIREMENT. HOWEVER, DUE TO THE FILM SEPARATION ON PASS D105 THIS REQUIREMENT WAS NOT FULFILLED. THE 911 FEET OF SO-121 RECOVERED WAS EXPOSED ON REVS D103, D104, AND D105. ALTHOUGH THERE WERE SOME AREAS OF THE SO-121 FROM MISSION 1105 THAT WERE BETTER THAN THIS MISSION, THE OVERALL IMAGE QUALITY OF THIS FLIGHT WAS BETTER THAN THE 1105 COLOR. THE IMPROVED OVERALL IMAGE QUALITY OF MISSION 1106 IS CREDITED TO (1) INCREASED SYSTEM TENSIONS PULLING THE FILM FLAT AND/OR (2) THE SHORT TIME PERIOD BETWEEN LAUNCH AND EXPOSURE LIMITING POTENTIAL DRYING-OUT OF THE COLOR FILM IN VACUUM. THE PET ESTIMATES THAT THE GROUND RESOLUTION IS 20 - 25 FEET. MINOR CORONA AND DENDRITIC STATIC MARKINGS WERE RECORDED. THESE MARKINGS ARE CHARACTERISTICALLY GREEN AND OCCASIONALLY RECORDED AS RED WHEN EXPOSURE IS MADE THROUGH THE BASE OF THE MATERIAL. THE COLOR BALANCE AND EXPOSURE ARE CONSIDERED TO BE GOOD EXCEPT FOR PHOTOGRAPHY OVER SNOW COVERED TERRAIN AT HIGHER SOLAR ELEVATIONS. THE PHOTOGRAPHY IN THIS REGION IS CONSIDERED BY BOTH THE PHOTOINTERPRETERS AND THE PET TO HAVE BEEN OVEREXPOSED."

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*NPIC message no. 5779, 2 February 1969.

The following conclusions have been drawn:

1. The KH-4B system has demonstrated its capability to handle SO-121.

2. The ground resolution achievable with SO-121 in this system is, at best, 16 feet. Although no resolution targets were acquired, the best color coverage from mission 1105 is estimated to have reached this maximum. An average ground resolution of 20 to 25 feet would be expected on future KH-4B missions.

3. Electrostatic markings are not a problem with SO-121. Although this was a severe problem with the SO-180 flight, mission 1104, the sensitivity of SO-121 to the radiation causing these markings is below the threshold for causing fog.

Table 2.7-1 — Specific Details of Missions 1105 and 1106

Parameter	Fig. 2.7-3	Fig. 2.7-4	Fig. 2.7-5	Fig. 2.7-6
Mission	1105-2	1105-2	1106-2	1106-2
Camera	FWD	AFT	FWD	AFT
Rev	D-273	D-273	D-103	D-103
Frame	056	063	175	181
Date	20 Nov 1968	20 Nov 1968	12 Feb 1969	12 Feb 1969
Film	3404	SO-121	3404	SO-121
Filter	Wratten no. 25	2E + 20C + 0.5ND	Wratten no. 23A	2E + 20C + 0.5ND
Exposure time, seconds	1/270	1/450	1/363	1/484
Altitude, feet	513,000	513,000	468,000	468,000
Scale	1:256,500	1:256,500	1:234,000	1:234,000
Solar altitude	33° 51'	33° 57'	51° 30'	51° 30'
Latitude (CF)	35° 29.1' N	35° 23.7' N	24° 42' N	24° 42' N
Longitude (CF)	98° 16.1' W	98° 17.5' W	102° 31' E	102° 31' E
Universal grid coordinates	9.2, 1.8	67.8, 0.6	53.0, 3.6	22.6, 4.0
Magnification	5×	5×	5×	5×

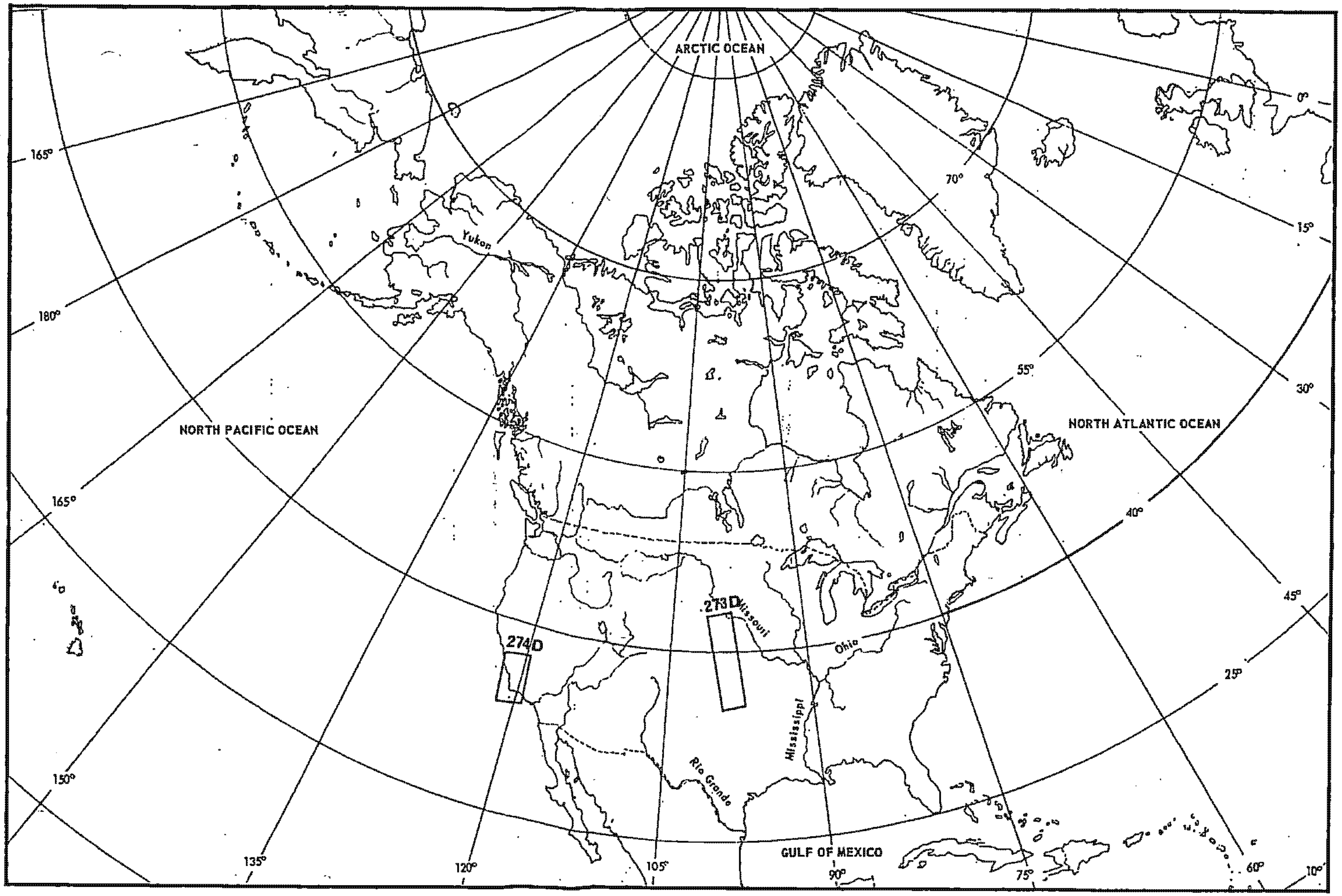

Fig. 2.7-1 — Ground tracks for the mission 1105 SO-121 passes over the United States

of lights in the surrounding areas as seen in the night coverage can be correlated and identified in the day reference print [Fig. 5.1-5(a)].

5.1.5 Conclusions

The following is a brief summary of the conclusions from the night detection tests.

1. High speed black and white photography at night has a potential as a nighttime activity indicator from satellite altitudes.
2. Comparable day coverage is desirable for specific target identification.
3. Viewing by stereo (day combined with night) or overlaying the two images is an interesting technique for interpreting the images.
4. Panoramic distortion makes precise location of targets difficult, particularly over distances of more than 5 to 10 inches on the film.
5. The very large dynamic range present suggests that other processing (i.e., low gamma) or a dual speed emulsion would be useful for recording more information.
6. The overriding characteristic of an emulsion used in night photography as an activity indicator is its speed. Resolution and/or color are of secondary importance.
7. The principal target area, Vandenberg Air Force Base, was located. At satellite altitudes, it will also be possible to detect and identify parts of the illuminated missile complex.
8. Static, fog, and corona discharge may be a problem with the higher speed emulsions.

Table 5.1-1 — Summary of Six Flights

EKIT Flight Test No.	Date	Test
4	1 Sept 1966	Initial day coverage for first night flight, partially cloudy
5	2 Sept 1966	First night flight, partially cloudy over Vandenberg
4A	6 Sept 1966	Second day flight, partially cloudy over Vandenberg
5A	6 Sept 1966	Second night flight, also cloudy over Vandenberg
4B	13 Jan 1967	Third day coverage, clear weather, color film in one camera
5B	13 Jan 1967	Third night flight, successfully covered Vandenberg though at higher shutter speed than in previous night mission

Table 5.1-2 — Specific Details for the Three Day Flights

EKIT flight no.	4*	4A*	4B†
GT no.	349-66	306-66	0047A
Date	1 Sept 1966	6 Sept 1966	13 Jan 1967
Master unit			
AFT-looking camera	I5	I5	I3
Film	3404	3404	SO-121
Slit width	0.049 in.	0.049 in.	0.0009 in.
Exposure time	1/385 sec	1/385 sec	1/2,400 sec
Haze filter	Wratten no. 21	Wratten no. 21	Wratten no. 2E
Color correction filter	None	None	30CCB
Scan mode	II	II	III
Slave unit			
FWD-looking camera	I6	I6	I4
Film	3404‡	3404	3404
Slit width	0.049 in.	0.049 in.	0.075 in.
Exposure time	1/385 sec	1/385 sec	1/300 sec
Haze filter	Wratten no. 21	Wratten no. 21	Wratten no. 21
Color correction filter	None	None	None
Scan mode	II	II	III

*Flight lines shown in Fig. 5.1-1(a).
† Flight lines shown in Fig. 5.1-1.
‡ Camera malfunctioned, no exposures made.

Table 5.1-3 — Specific Details for the Three Night Flights

EKIT flight no.	5*	5A*	5B†
GT no.	304-66	307-66	0057A
Date	2 Sept 1966	6 Sept 1966	13 Jan 1967
Time	01:00 to 05:00	20:00 to 24:00 (approximately midnight photography)	20:00 to 23:15
Master unit			
AFT-looking camera	I5	I5	I3
Film	SO-180	SO-180	SO-121
Slit width	0.375 in.	0.375 in.	0.150 in.
Exposure time	1/50 sec	1/50 sec	1/120 sec
Haze filter	None	None	None
Color correction filter	None	None	None
Scan mode	I	I	I
Slave unit			
FWD-looking camera	I6	I6	I4
Film	SO-340	SO-340	SO-340
Slit width	0.375 in.	0.375 in.	0.150 in.‡
Exposure time	1/50 sec	1/50 sec	1/120 sec
Haze filter	None	None	None
Color correction filter	None	None	None
Scan mode	I	I	I

*Flight lines shown in Fig. 5.1-1(a).
†Flight lines shown in Fig. 5.1-1.
‡Shutter speed faster than on previous night flight.

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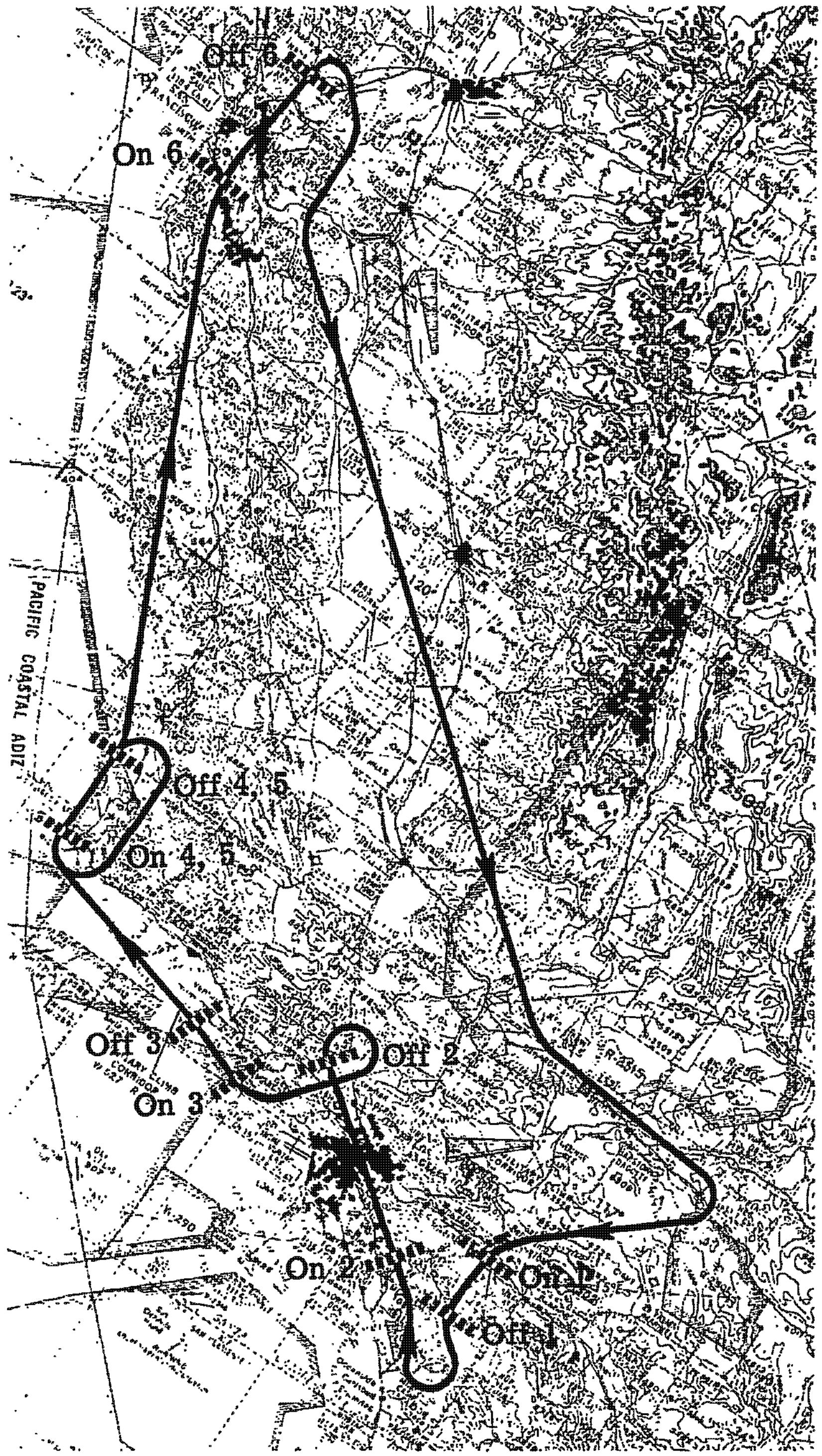

Fig. 5.1-1(a) — Flight lines used in day and night coverage, flight nos. 4, 4A, 5, 5A

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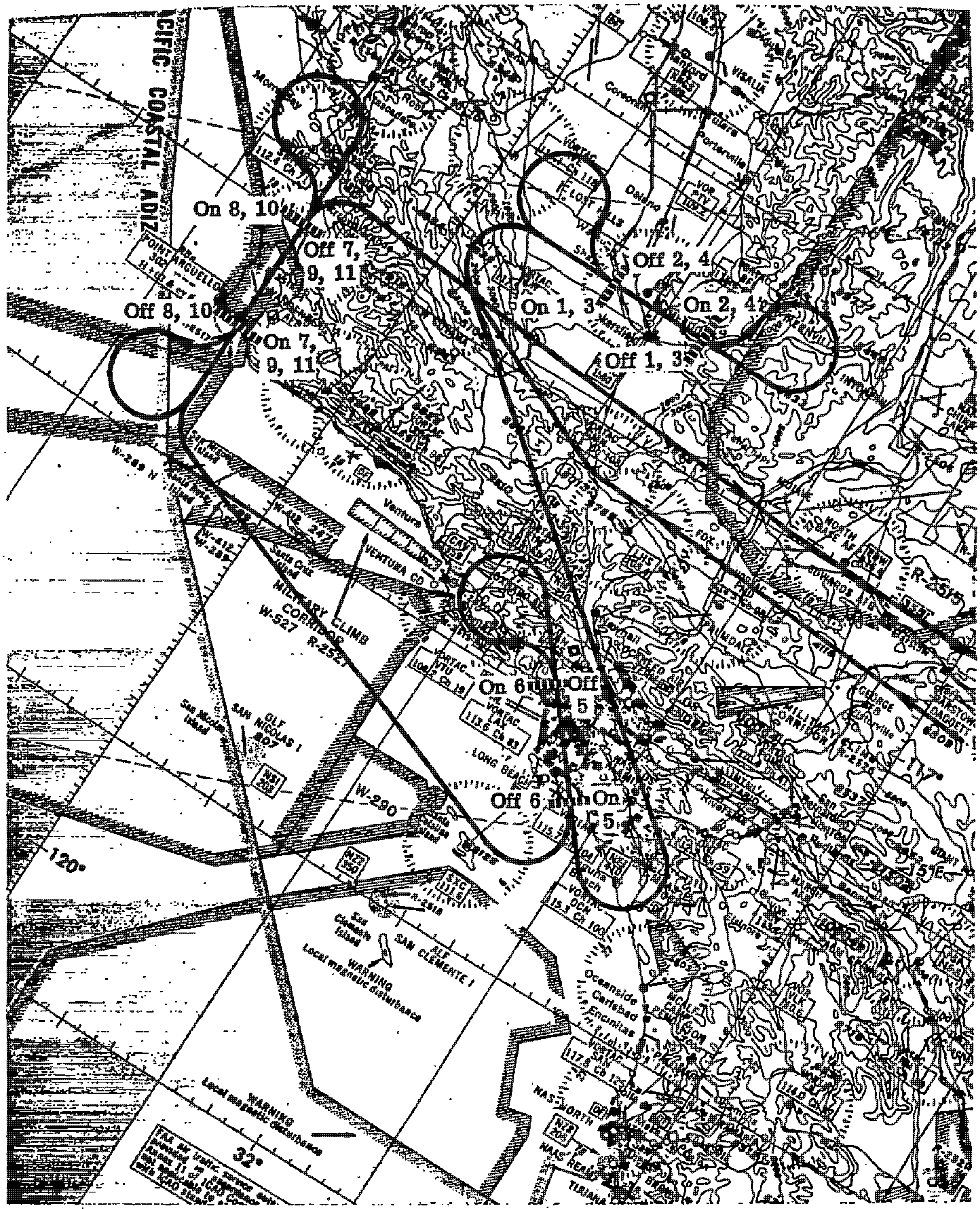

Fig. 5.1-1 — Flight lines used in day and night coverage, flight nos. 4B, 5B

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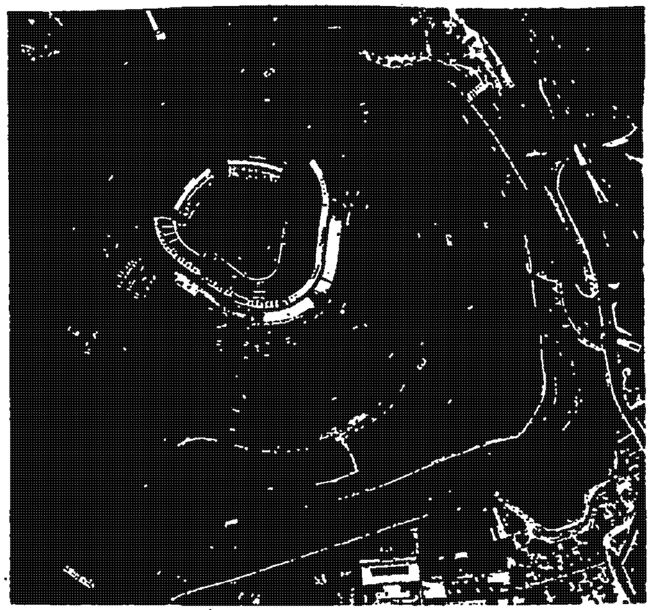
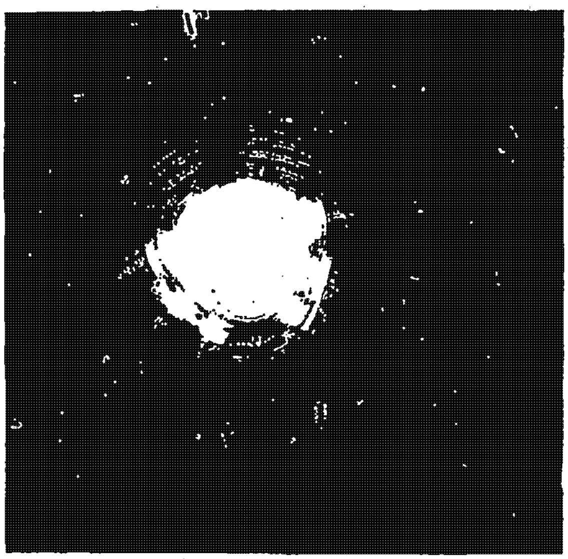
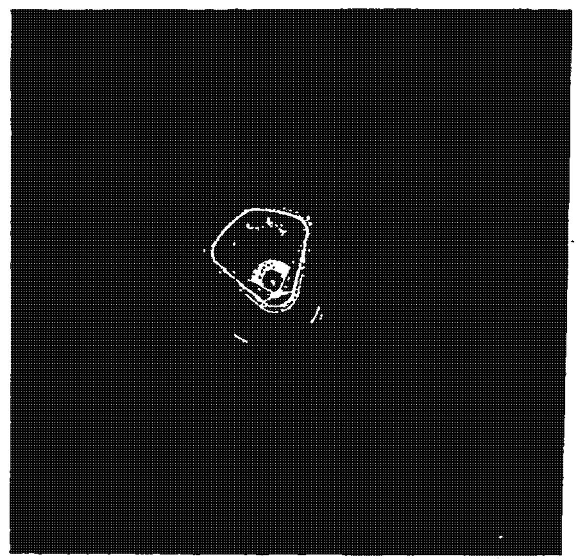


(a) Day, 3404 film, 3.5× enlargement



(b) Night, SO-340 film, 3.5× enlargement (printed for shadows



(c) Night, SO-340 film, 3.5× enlargement (printed for highlights)

Fig. 5.1-2 — Chavez Ravine

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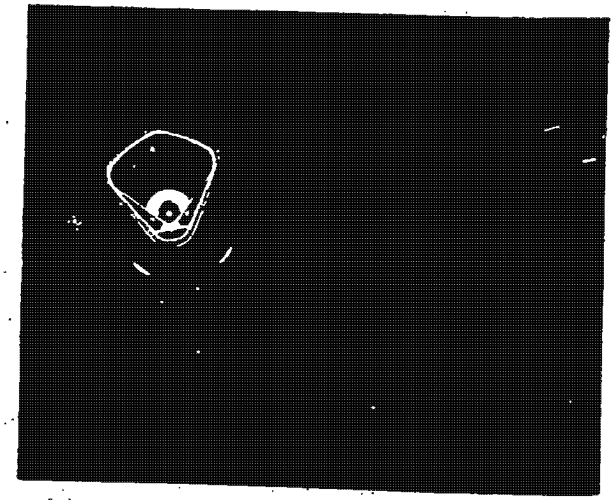
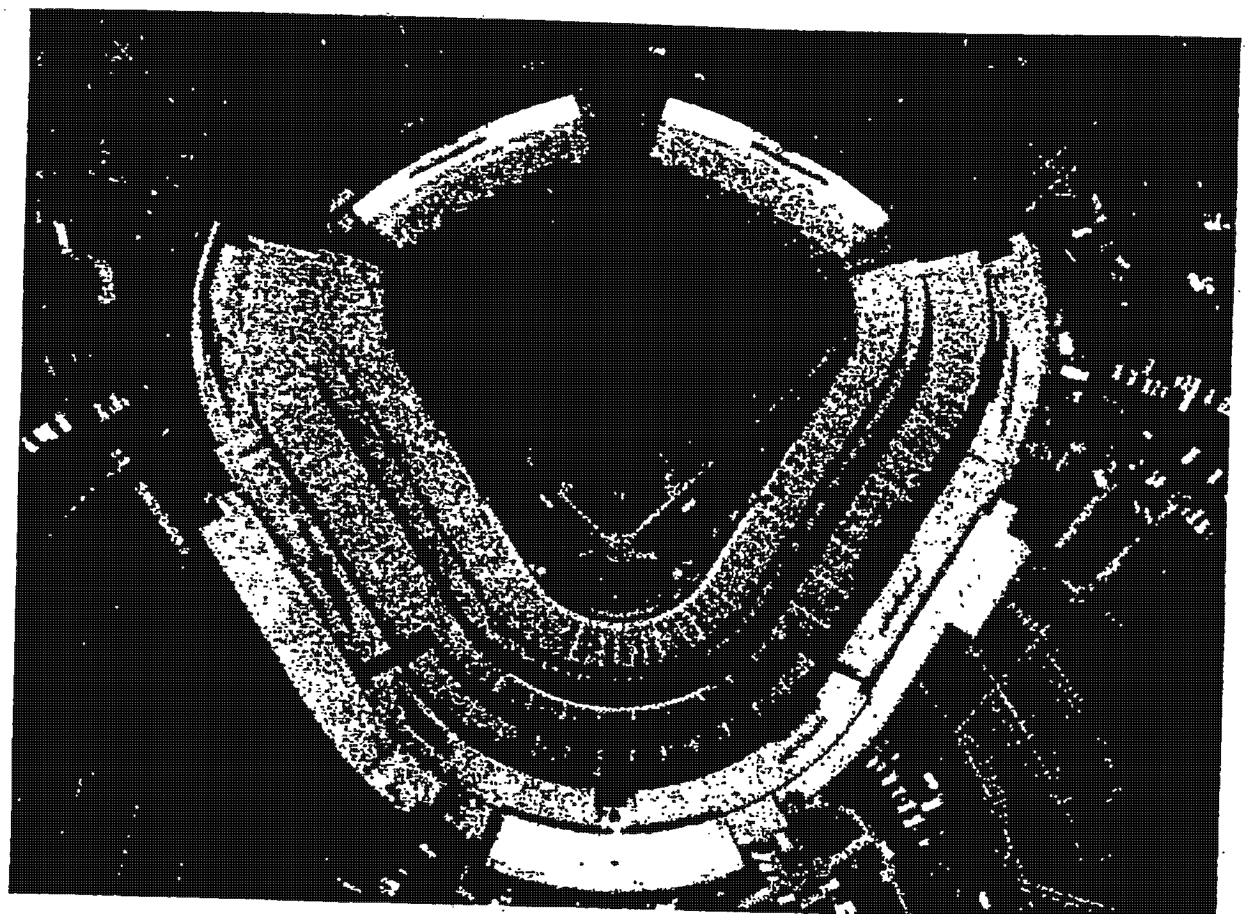


(a) Night, SO-180 film, 3.5× enlargement



(b) Day, SO-121 film, 17× enlargement

Fig. 5.1-3 — Chavez Ravine (Cont.)

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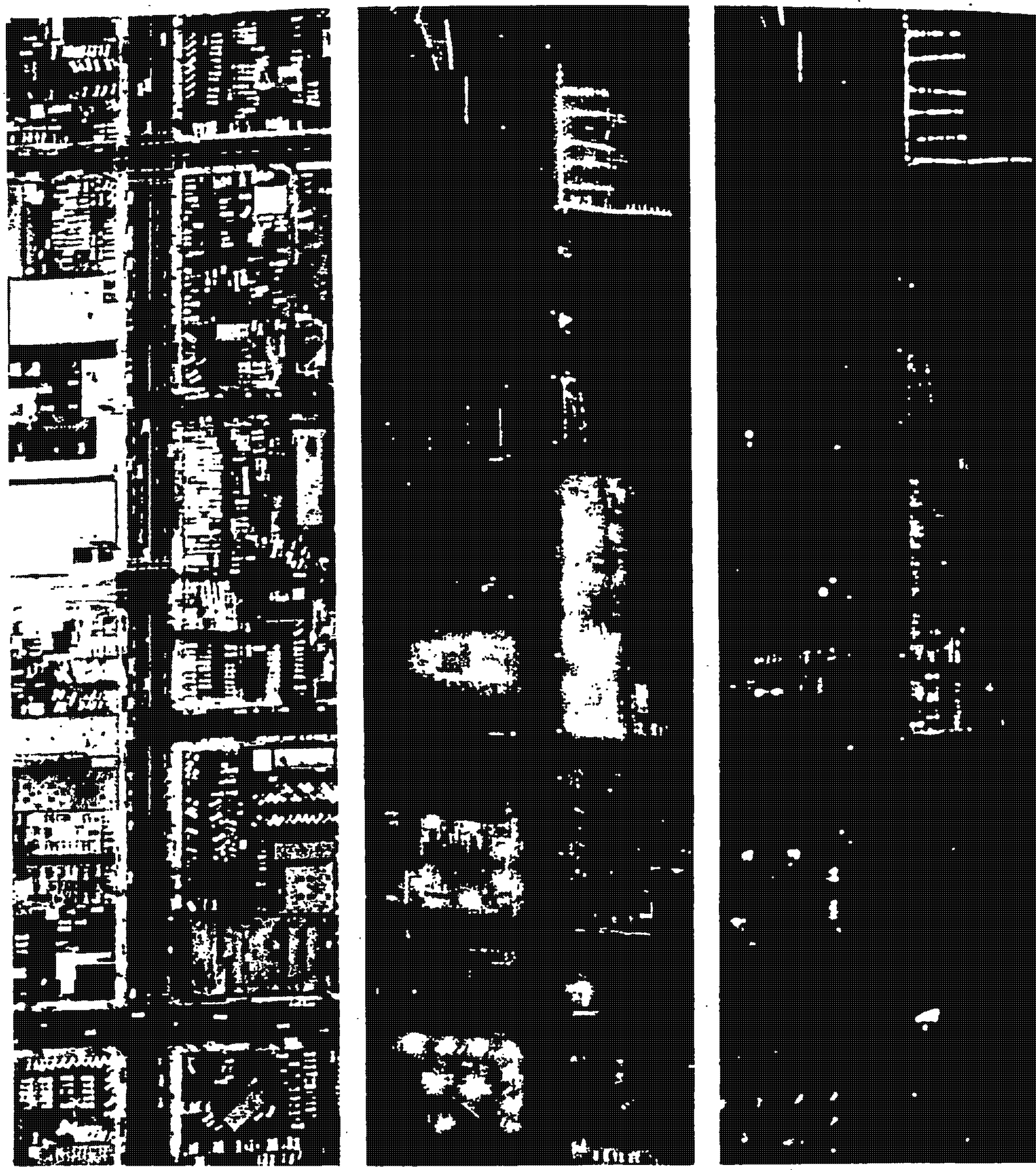

(a) Day, 3404 film, 14× enlargement

(b) Night, SO-340 film, 14× enlargement

(c) Night, SO-180 film, 14× enlargement

Fig. 5.1-4 — Parking lots

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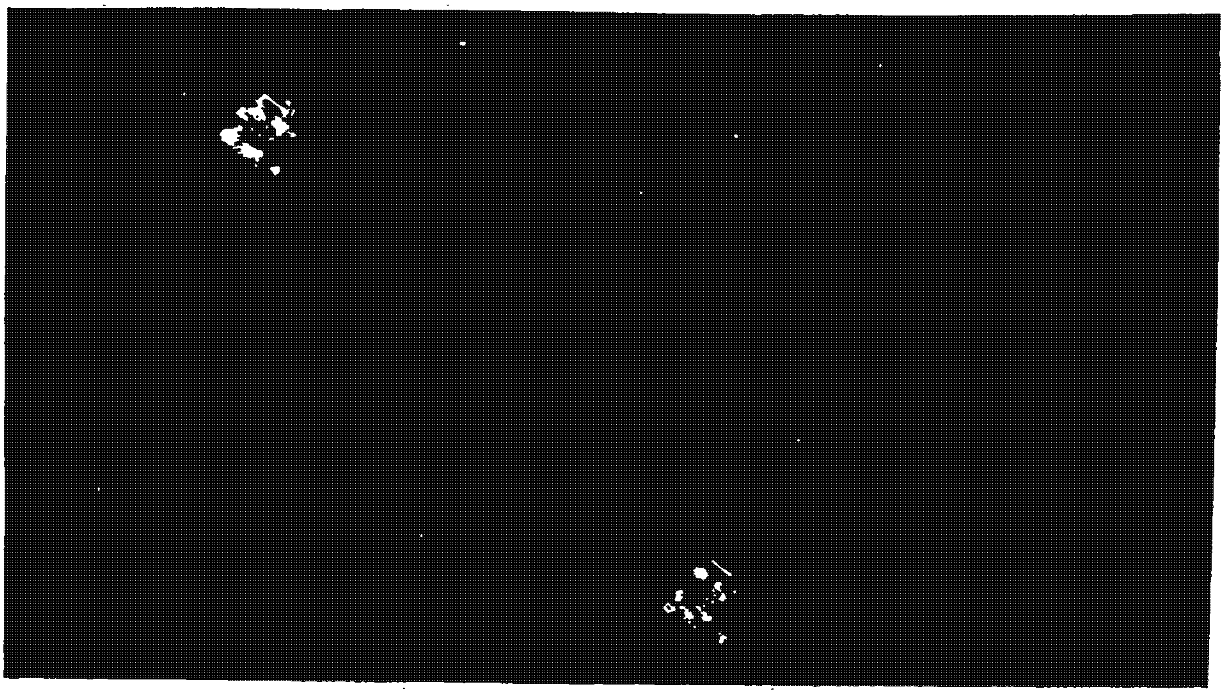
(a) Day, 3404 film, 6× enlargement



(b) Night, SO-340 film, 6× enlargement

Fig. 5.1-5 — Vandenburg AFB—launch facility

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5.2 KH-7 NIGHT PHOTOGRAPHY

5.2.1 Test Type

The KH-7 camera system was used for this test.

5.2.2 Test Objective

The test objective was to determine the ability of the KH-7 system to record imagery at night on 3400 film.

5.2.3 Test Details

Night photography was attempted on an operational mission over the eastern seaboard of the United States [see Figs. 5.2-1 and 5.2-1(a)] with a high speed emulsion, 3400, and a special (wide) slit. The physical slit width was 0.300 inch, but the effective slit width was only 0.170 inch due to a camera design limitation providing an exposure time of 1/16 second.

5.2.4 Discussion of Figures

The accompanying figure (Fig. 5.2-2) is a reproduction showing the ground lights recorded on one frame during the experiment. This frame covers the Boston, Massachusetts, area with the lights of both ends of the Sumner Tunnel and the shore highway. Camera parameters are listed in Table 5.2-1.

5.2.5 Results and Conclusions

Streaked images of point sources and some artificially illuminated ground imagery were recorded. In the exploitation analysis, these light patterns were correlated to specific cultural features.

The image streaking is attributed to the effects of earth rotation during the long exposure and to yaw smear. A design limitation in the camera system precludes yaw smear compensation on frames acquired during ascending revolutions. The system's design does not provide for negative crab of the stereo mirror which is needed to eliminate this form of image degradation.

Table 5.2-1 — Specific Camera Parameters for Fig. 5.2-2 (mission 4036)

Rev	102
Frame	2
Effective T-stop	6.2
Date of photography (GMT)	9 Feb 1967
Enlargement factor	Contact
Type of coverage	Strip
Altitude, nm	106.4
Mirror crab, degrees	1.4743
Cone angle, degrees	26.9984
Mirror position	Vertical
Filter	B&L Y-10
Slit width, inches	0.300*
Film velocity, inches per second	2.6899
Exposure, seconds	1/16
Solar elevation, degrees	58.1
Solar azimuth, degrees	323.0
Vehicle azimuth, degrees	342.4
Azimuth of the principal ray, degrees	71.5
Vehicle roll, degrees	25.524
Local sun time	2243
Development level	Full

*Effective slit width is 0.1700 inch due to baffle design.

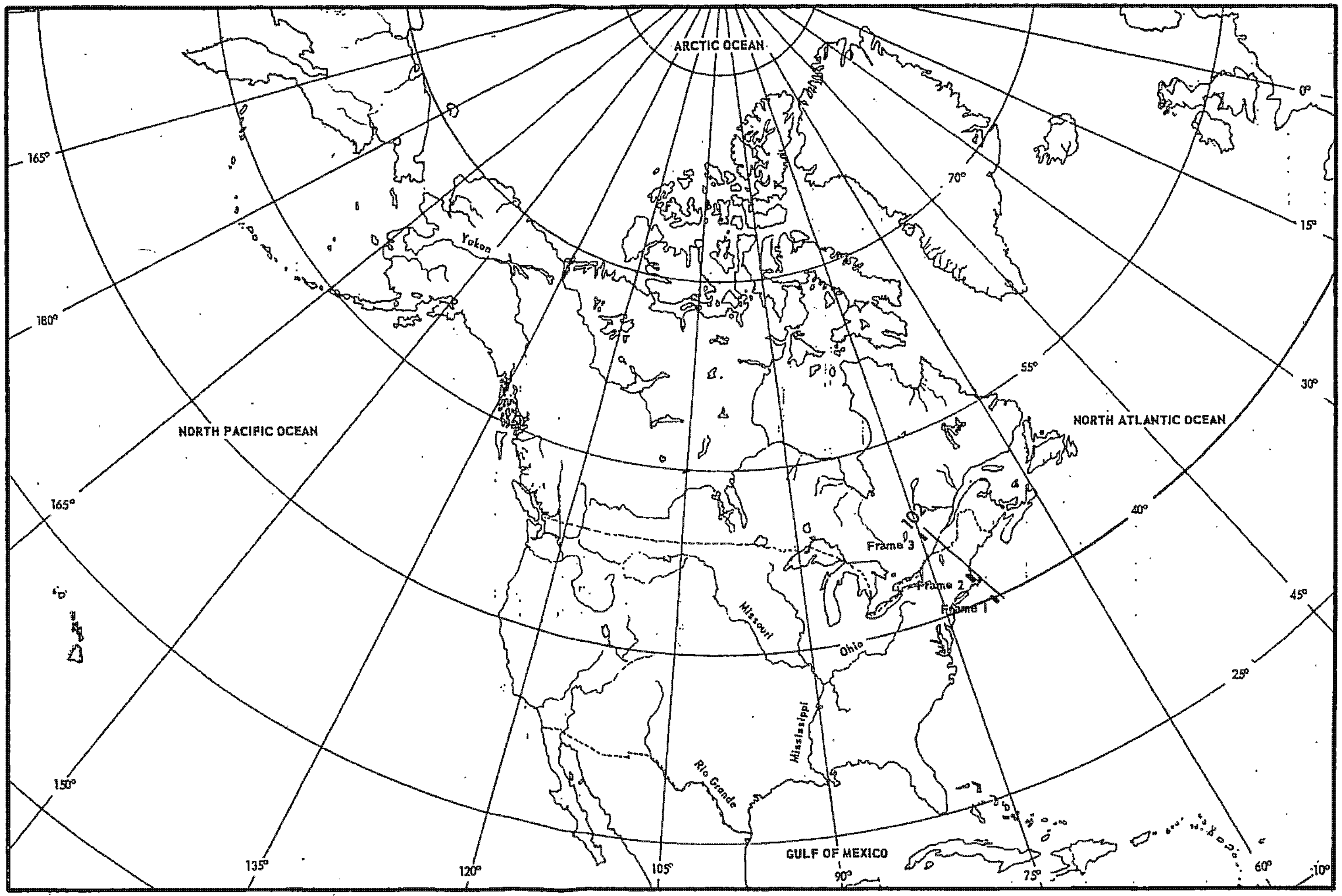

Fig. 5.2-1 — Ground tracks for the KH-7 night photography test with 3400 film, mission 4036

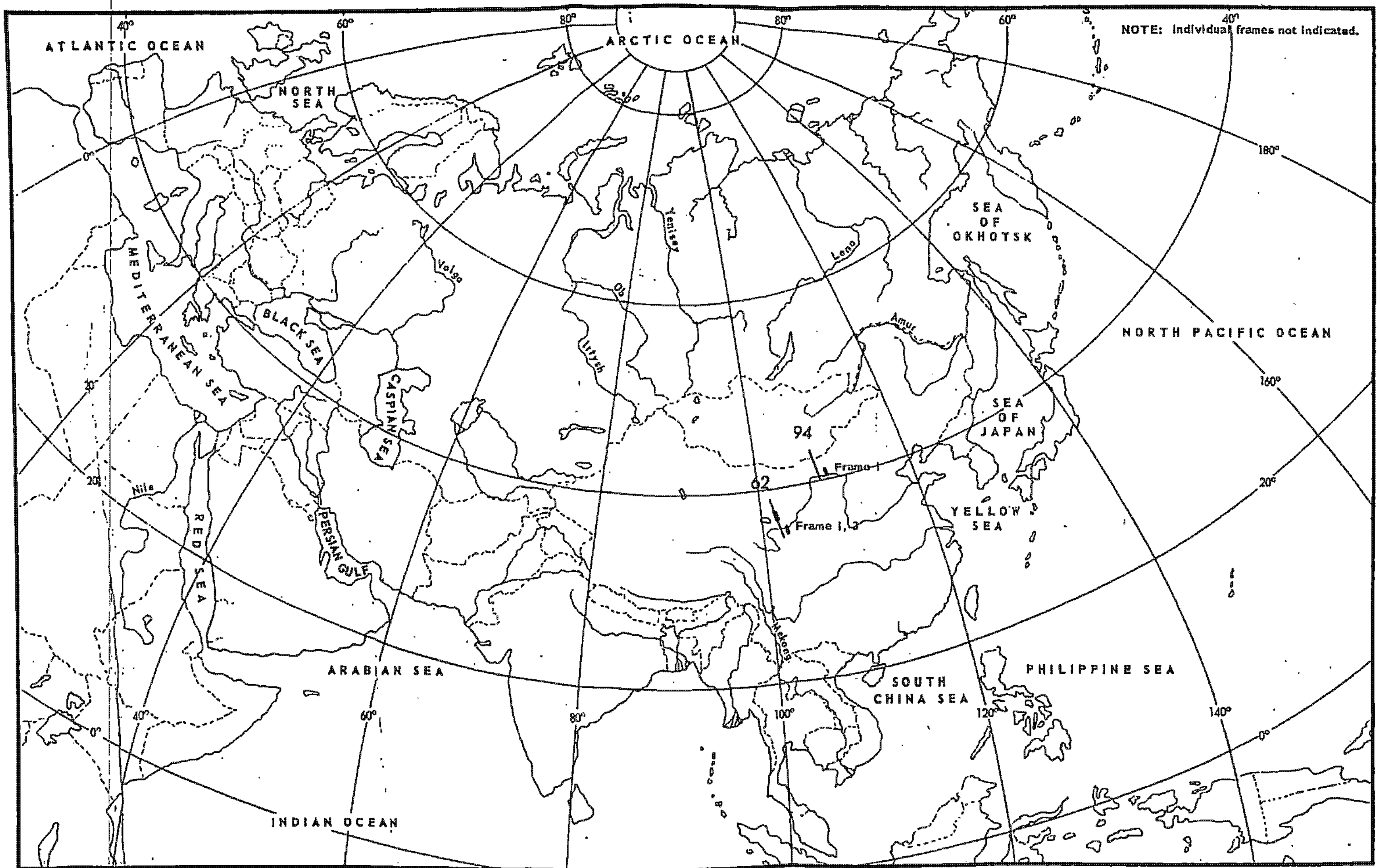

Fig. 5.2-1(a) — Ground tracks for the KH-7 night photography test with 3400 film, mission 4036

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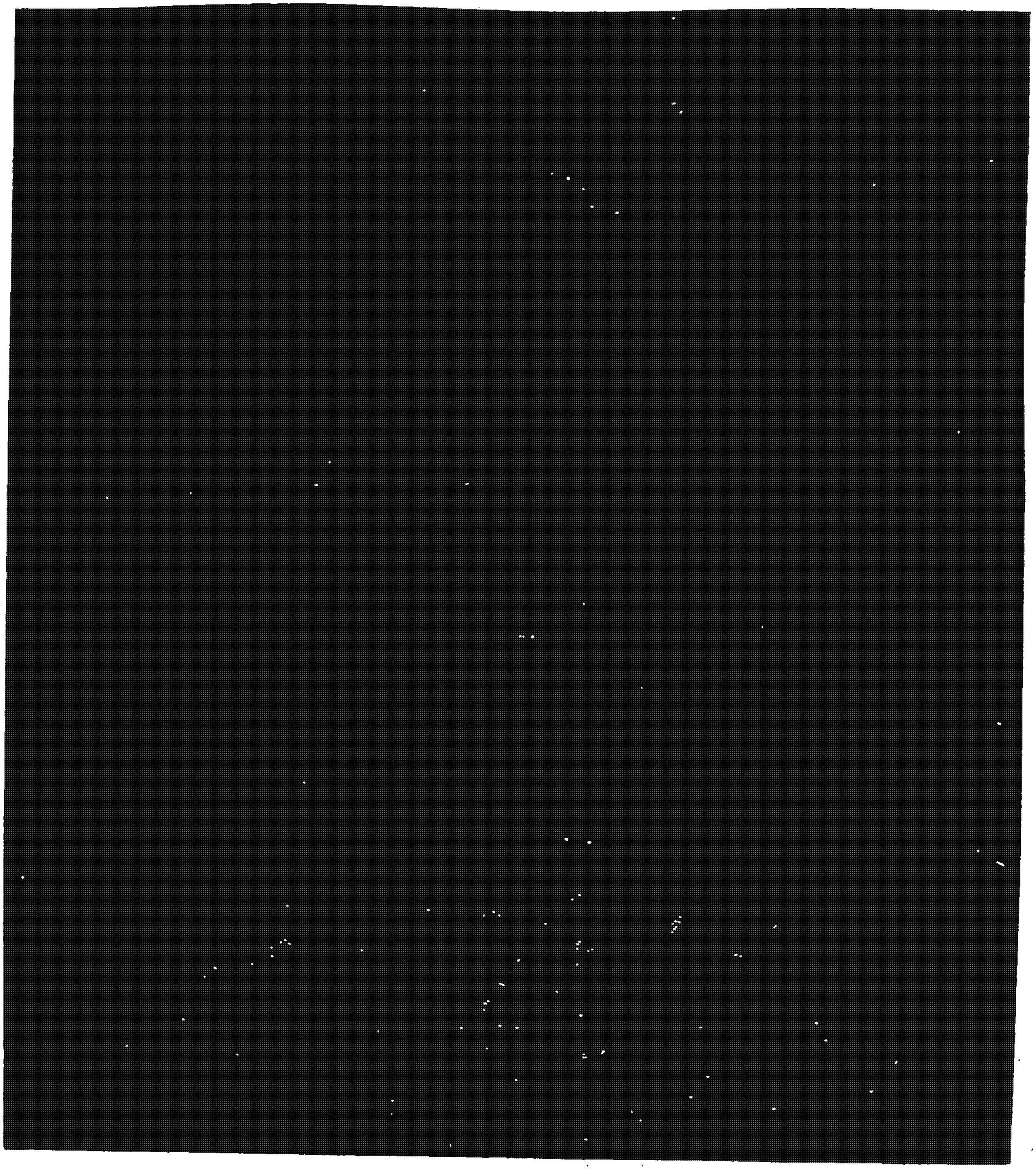

Fig. 5.2-1 — Night photography of Boston, Massachusetts, mission 4036

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5.3 KH-8 SUN ANGLE EXPERIMENT

5.3.1 Test Type

1. The KH-8 camera system was used for this test.

5.3.2 Test Objectives

Test objectives were as follows:

1. Evaluate exposure quality of 3400 film with respect to particular low solar elevations.
2. Determine the solar elevation at which usable imagery is obtained with 3400 film in the KH-8 camera system.

5.3.3 Test Details

Eleven consecutive frames were acquired, each at a solar elevation of increased increments from −3.0 to 5.9 degrees. (Flight lines for this segment of the mission are shown in Fig. 5.3-1.) Test data for this experiment are shown in Table 5.3-1.

5.3.4 Discussion of Figures

Six photographic illustrations (Figs. 5.3-2 to 5.3-4) have been included to show the photography at the tested solar altitudes. These illustrations have been printed to enhance the imagery recorded in the original negative. Table 5.3-2 contains specific camera parameters for the imagery shown.

5.3.5 Results and Conclusions

The following results and conclusions were obtained from this evaluation.

1. 3400 film with the above listed exposure range and terrain conditions can be used at a solar elevation as low as zero degrees and still provide usable terrain imagery.
2. Major terrain features can be detected on photography acquired at a sun angle of −3.0 degrees.
3. A slight overexposure of the material is noted to have occurred using a 1/250-second exposure at a solar elevation of 2.9 degrees.

Table 5.3-1 — Test Data* for Sun Angle Experiment

Rev	Frame	Exposure, seconds	Sun Angle, degrees	Remarks
159	22	1/243	−3.0	Terrain features just barely discernible
	23	1/243	−2.1	Major terrain features discernible
	24	1/243	−1.5	Terrain features readily discernible
	25	1/243	−1.1	Terrain features readily discernible
	26	1/250	−0.1	Usable terrain imagery
	27	1/250	0.9	Usable terrain imagery
	28	1/250	1.9	Usable terrain imagery
	29	1/250	2.9	Slightly overexposed
	30	1/256	4.0	Overexposed
	31	1/256	4.9	Overexposed
	32	1/256	5.9	Severely overexposed

*Information pertains to original negative.

Table 5.3-2 — Specific Camera Parameters for Mission 4312

Parameter	Fig. 5.3-2(a)	Fig. 5.3-2(b)	Fig. 5.3-3(a)	Fig. 5.3-3(b)	Fig. 5.3-4(a)	Fig. 5.3-4(b)
Rev	159	159	159	159	159	159
Frame	22	24	26	28	30	32
Effective T stop	4.46	4.46	4.46	4.46	4.46	4.46
Date of photography (GMT)	23 Mar 1969	23 Mar 1969	23 Mar 1969	23 Mar 1969	23 Mar 1969	23 Mar 1969
Enlargement factor	Contact	Contact	Contact	Contact	Contact	Contact
Type of coverage	Strip	Strip	Strip	Strip	Strip	Strip
Altitude, nm	86.6	85.8	85.1	84.1	83.1	82.3
Mirror crab, degrees	−0.320	−0.320	−0.320	−0.032	0.086	0.086
Cone angle, degrees	0.0384	0.0384	0.0400	0.0400	0.9643	0.0893
Mirror position	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical
Slit width, inches	0.03192	0.03192	0.03192	0.03192	0.03192	0.03192
Film velocity, inches per second	7.7593	7.8317	7.9055	7.9958	8.0882	8.1828
Exposure, seconds	1/243	1/243	1/250	1/250	1/256	1/256
Solar elevation, degrees	−3.0	−1.5	−0.1	1.9	4.0	5.9
Solar azimuth, degrees	292.7	285.4	277.5	266.1	253.9	244.1
Vehicle azimuth, degrees	297.5	290.3	282.4	270.9	258.8	249.0
Azimuth of the principal ray, degrees	348.8	341.6	299.3	217.8	170.2	323.4
Vehicle roll, degrees	0.350	0.350	0	0	1.050	0
Local sun time	1930	1901	1826	1741	1652	1612

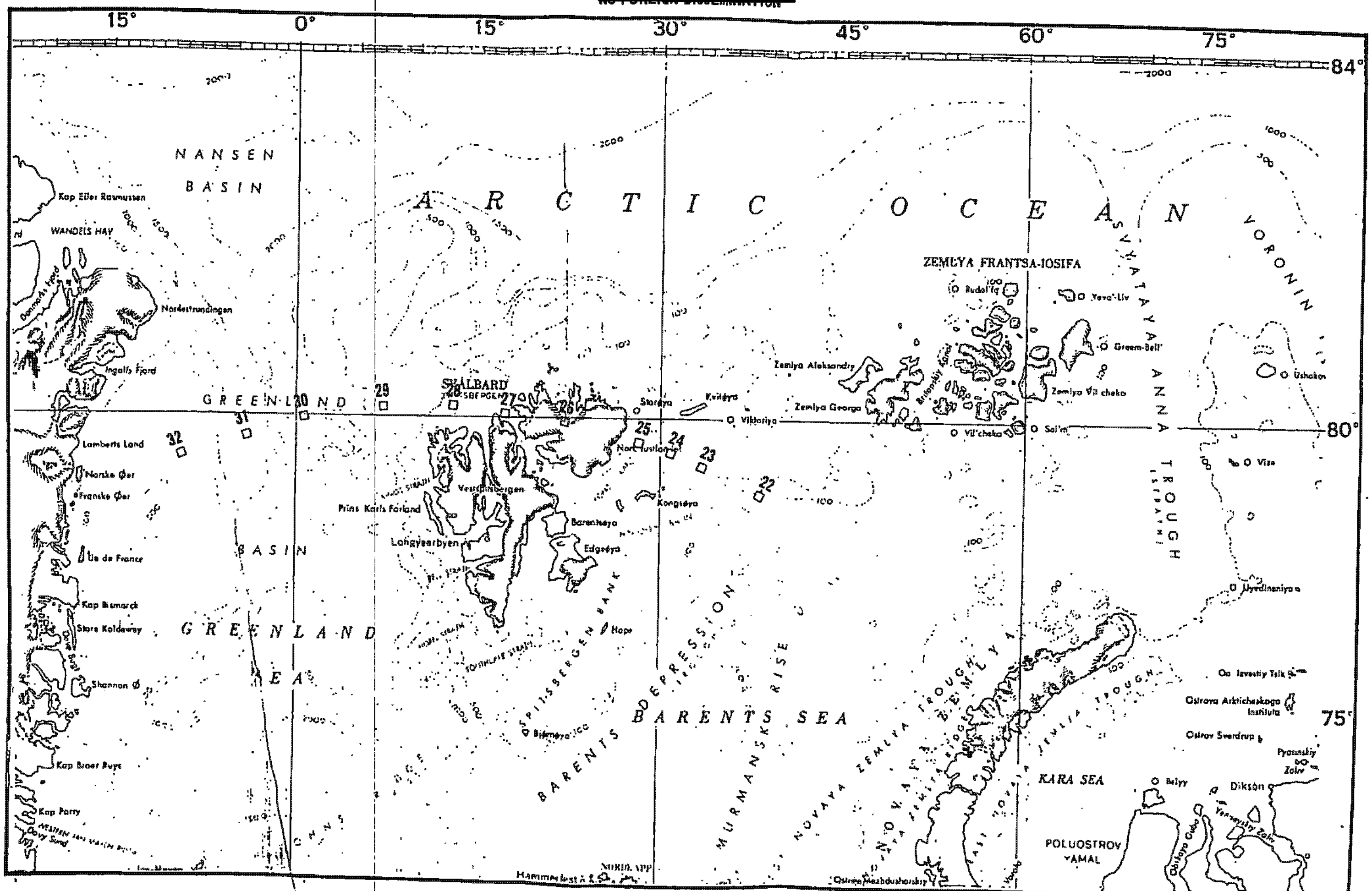

Fig. 5.3-1 — Ground tracks for the KH-8 sun angle experiment, mission 4312

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5.4 KH-8 WITH 3401 FILM

5.4.1 Test Type

Estar thin base Plus-X Aerial film, type 3401, was used in the KH-8 satellite camera system, mission 4326-2, flown in April 1970.

5.4.2 Test Objective

The objectives of this test were: (1) to determine the extent of activity that can be detected at night, and (2) to evaluate the quality of the photography obtained at very low sun angle with 3401 film in the KH-8 system.

5.4.3 Test Details

The film supplied for mission 4326-2 included 236 feet of 3401 high speed black and white film as a final tag on. It was exposed on 29 April 1970 during revs 220 through 225. Ground tracks for these acquisitions are plotted in Fig. 5.4-1.

A total of 234 frames were exposed but only 28 percent contained imagery. The remainder are reported to be either incorrectly exposed or obscured by clouds.

No static patterns were detected on any of the 3401 original negatives. For the purposes of this study, imagery exposed between solar elevations of −5 degrees and 10 degrees were considered to be of low solar elevation, and those below −5 degrees were to be considered as night coverage.

In this context, there were 86 frames of night photography. Of these, 13 frames recorded images of lights, 48 were underexposed and 25 were overexposed. Both the underexposed and overexposed frames contained no imagery. Exposure times ranged from 0.0526 second to 0.0712 second, utilizing the widest (0.30-inch) slit available. There were 91 frames of low solar attitude photography. Of these, 32 contained ground detail, 19 were overexposed and 40 were completely cloud filled. It was noted that all overexposures occurred when the solar elevation was between −5 and 0 degrees.

Microdensitometric measurements were made and used to determine ground luminances from the night imagery. The final calculations showed a range of 0.30 foot-lambert at the minimum to 46.8 foot-lamberts at the maximum. This entire range of target brightnesses was properly exposed on the 3401 film since the densities are encompassed by the straight line portion of the film's characteristic curve.

Ground imagery, as distinct from light source imagery, was recorded on 3401 film at solar elevations as low as −4.1 degrees. However, below 0 degrees solar elevation, only broad detail such as airfields, roads, shorelines, and high reflectance items are visible. Resolution estimates for this imagery is on the order of 20 to 30 feet.

Earlier in the mission several frames of photography were acquired at low solar elevations on SO-380, the primary film. This imagery was compared to that obtained on 3401 film. Generally, the imagery acquired on SO-380 at greater than 2.0 degrees solar elevation is better. No imagery was acquired on this material below 2.0 degrees. SO-380 was preferred primarily for its higher resolution and ability to hold detail at magnifications to 25×; 3401 is limited to about 10× enlargement.

The best emperical ground resolution on 3401 is about 5 feet on rev 224, frame 48, where the solar elevation was 9.7 degrees. With SO-380, an estimated ground resolved distance of about 3 feet was acquired on rev 190, frame 4, where the solar elevation was 2.6 degrees. Indications are that SO-380 should be tested at solar altitudes below 2.0 degrees for intelligence accessment.

5.4.4 Discussion of Figures

Frame 225/8 (see Fig. 5.4-2 and Table 5.4-1) is of the Ashkhabad, Turkmenskaya S.S.R. and appears to cover the Ashkhabad S.E. Airport. The location is based on a plot of the coordinates and the general configurations of the light pattern.

Items recorded are generally only those that are self-illuminating but there are some faint images of structures. The impression is that they are revetments or paved areas of sufficient reflectance to record on the film.

The frame has information content to the extent that the facility is active at night as is indicated by the presence of lights. Correlations of these illumination sources with specific structures would require daytime coverage for comparison.

Frame 224/19 (see Fig. 5.4-3 and Table 5.4-2) shows the Przhevalsk Army Barracks, Kirgiziya, S.S.R., as in frame 225/8. The only obvious information present in the sample is that lights are on in the subject area.

The only imagery recorded is that of the light sources themselves. Other items that would record by reflected illumination are at so low a level as to be absent from this record. The images have a noticeable amount of smear which further degrades any use to which the record might be put. Without supplementary daytime photography this imagery is of little practical value.

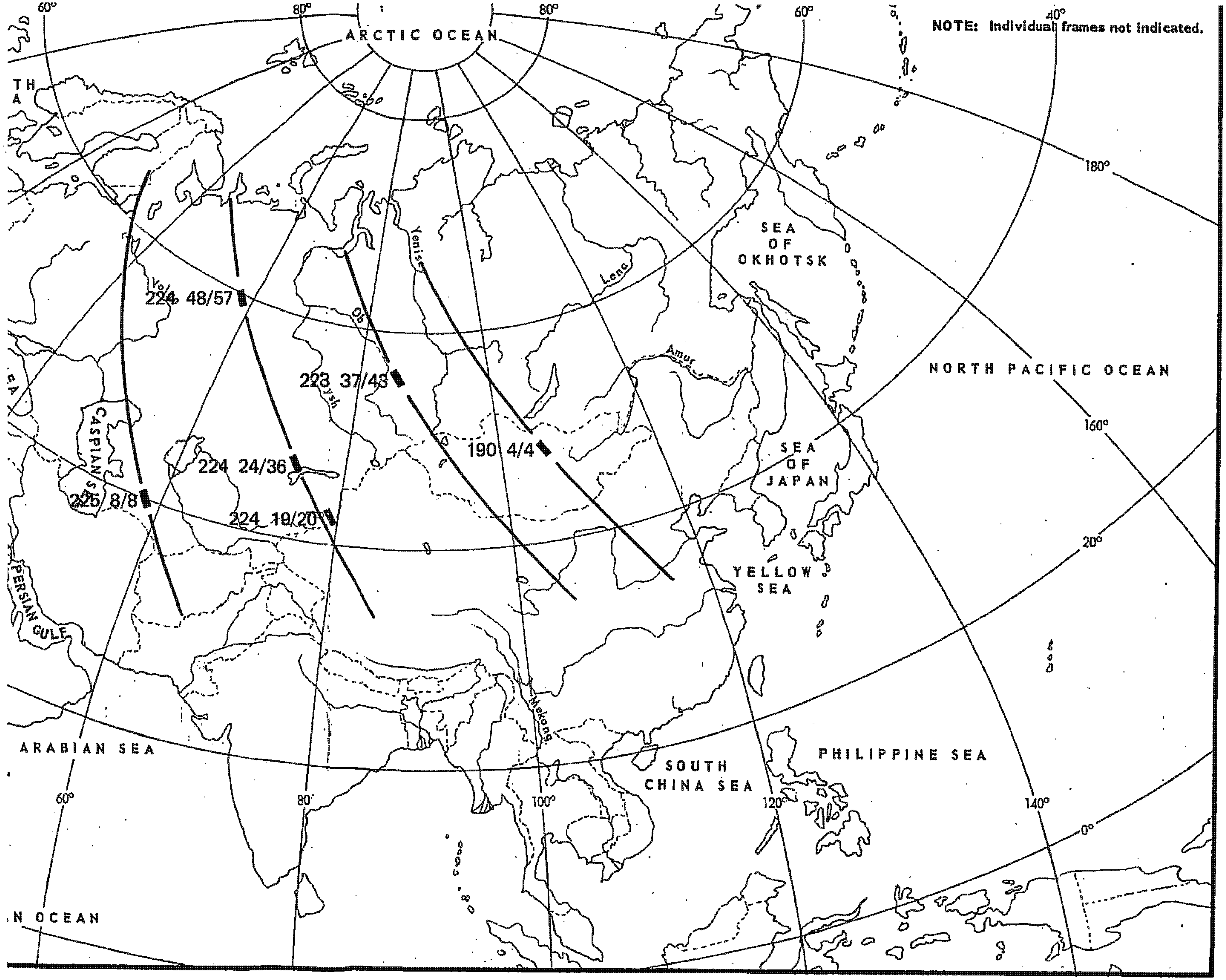
Additional specific camera parameters are presented in Tables 5.4-3 through 5.4-6.

5.4.5 Results and Conclusions

Nighttime photography on 3401 film is essentially useless. For any use at all it should have complementary daytime coverage for reference. There was very little imagery acquired on this mission.

The estimated ground resolved distances were from 20 to 30 feet at solar elevations of 0 to −5 degrees. Best ground resolved distance is 5 feet at 10-degree solar elevation. SO-380 showed a ground resolved distance of 3 feet at 2.5-degree solar elevation. At magnifications of 10 diameters, the imagery is degraded by graininess and excessive image motion.

If further tests are to be made, a faster film such as SO-340, an improved Tri-X material, should be used. SO-380 should be tested at solar elevations lower than 2 degrees.



.4-1 — Ground tracks for KH-8 night and low solar altitude photography test with 3401 film, mission 4326-2

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Table 5.4-1 — Specific Camera Parameters for Fig. 5.4-2 (Mission 4326-2)—Ashkhabad, Turkmenskaya S.S.R.

Rev	225
Frame	8
Index	8
Date of photography	29 April 1970
Universal grid coordinates	62.0 – 11.0
Geographic coordinates	37° 35′ 50″ N - 058° 22′ 20″ E
Enlargement factor	10×
Type of photography	Stereo
Altitude, nm	121.201
Mirror crab, degrees	–2.473
Cone angle, degrees	25.2662
Mirror position	2A
Scale (in-flight direction/ across-flight direction)	62336/67104
Slit width, inches	0.3000
Film velocity, inches per second	4.8800
Exposure, seconds	0.0614
Solar elevation, degrees	–11.9
Solar azimuth, degrees	298.8
Vehicle azimuth, degrees	333.194
Azimuth of the principal ray, degrees	264.194
Vehicle roll, degrees	–21.350
Local time	1950

Table 5.4-2 — Specific Camera Parameters for Fig. 5.4-3 (Mission 4326-2)—Przhevalsk Army Barracks, Kirgiziya, S.S.R.

Rev	224
Frame	19
Index	20
Date of photography	29 April 1970
Universal grid coordinates	54.8 – 16.2
Geographic coordinates	42° 29′ 00″ N - 078° 27′ 18″ E
Enlargement factor	10×
Type of photography	Stereo
Altitude, nm	116.614
Mirror crab, degrees	–2.120
Cone angle, degrees	40.6969
Mirror position	1A
Scale (in-flight direction/ across-flight direction)	71753/92314
Slit width, inches	0.3000
Film velocity, inches per second	4.2496
Exposure, seconds	0.0705
Solar elevation, degrees	–8.3
Solar azimuth, degrees	298.4
Vehicle azimuth, degrees	331.323
Azimuth of principle ray, degrees	256.165
Vehicle roll, degrees	–37.800
Local time	1944

Table 5.4-3 — Specific Camera Parameters—Ulaan Baatar Airfield, Mongolia

Rev	190
Frame	4
Index	4
Date of photography	27 April 1970
Universal grid coordinates	59.0 – 14.6
Geographic coordinates	47° 50′ 45″ N - 106° 45′ 45″ E
Enlargement factor	10×
Type of photography	Strip
Altitude, nm	117.896
Mirror crab, degrees	–0.710
Cone angle, degrees	40.3162
Mirror position	2F
Scale (in-flight direction/ across-flight direction)	72095/93305
Slit width, inches	0.03180
Film velocity, inches per second	4.2114
Exposure, seconds	0.0075
Solar elevation, degrees	2.6
Solar azimuth, degrees	287.70
Vehicle azimuth, degrees	327.566
Azimuth of principal ray, degrees	69.194
Vehicle roll, degrees	40.250
Local time	1846

Table 5.4-4 — Specific Camera Parameters—Kemerovo, West Siberian Region, USSR

Rev	223
Frame	37
Index	43
Date of photography	29 April 1970
Universal grid coordinates	63.0 – 8.3
Geographic coordinates	55° 23′ 14″ N - 086° 04′ 53″ E
Enlargement factor	5×
Type of photography	Strip
Altitude, nm	102.983
Mirror crab, degrees	–1.767
Cone angle, degrees	26.5557
Mirror position	2F
Scale (in-flight direction/ across-flight direction)	53200/58624
Slit width, inches	0.00580
Film velocity, inches per second	5.7454
Exposure, seconds	0.0010
Solar elevation, degrees	5.2
Solar azimuth, degrees	287.9
Vehicle azimuth, degrees	321.911
Azimuth of principal ray, degrees	213.004
Vehicle roll, degrees	–23.450
Local time	1847

Table 5.4-5 — Specific Camera Parameters—Sary-Shagan Airfield, Kazakhstan, SSR

Rev	224
Frame	24
Index	26
Date of photography	29 April 1970
Universal grid coordinates	68.5 – 5.0
Geographic coordinates	45° 56′ 11″ N - 073° 26′ 25″ E
Enlargement factor	5×
Type of photography	Stereo
Altitude, nm	112.962
Mirror crab, degrees	−2.120
Cone angle, degrees	13.2971
Mirror position	1F
Scale (in-flight direction/ across-flight direction)	53560/53917
Slit width, inches	0.3000
Film velocity, inches per second	5.6757
Exposure, seconds	0.0528
Solar elevation, degrees	−3.8
Solar azimuth, degrees	295.3
Vehicle azimuth, degrees	329.529
Azimuth of principal ray, degrees	199.055
Vehicle roll, degrees	−8.050
Local time	1850

Table 5.4-6 — Specific Camera Parameters—Berezniki Chemical Combine, Ural Region, USSR

Rev	224
Frame	48
Index	57
Date of photography	29 April 1970
Universal grid coordinates	51.5 – 3.0
Geographic coordinates	59° 24′ 33″ N - 056° 44′ 08″ E
Enlargement factor	5×
Type of photography	Stereo
Altitude, nm	97.893
Mirror crab, degrees	–1.413
Cone angle, degrees	22.9802
Mirror position	1A
Scale (in-flight direction/ across-flight direction)	49297/52244
Slit width, inches	0.00370
Film velocity, inches per second	6.2391
Exposure, seconds	0.00059
Solar elevation, degrees	9.7
Solar azimuth, degrees	282.1
Vehicle azimuth, degrees	316.666
Azimuth of the principal ray, degrees	204.232
Vehicle roll, degrees	9.950
Local time	1823

Notice of Page Substitution

6. EXPOSURE

For the purposes of electronic archiving, this page is a substitute for an unscannable page.

6.1 EXPOSURE AND PROCESSING

Ground targets that are recorded from an orbiting vehicle are subject to the influence of the atmosphere and to photographic processes that alter the information that is presented to the interpreter. The information alteration that occurs first is caused by the atmosphere. The atmosphere has two effects on the light reflected from the target: (1) it reduces the target brightness somewhat because the atmosphere does not transmit all of the light, and (2) it adds some light in the form of haze. This effect is not uniform over an entire target complex and the result is a loss of contrast that is particularly bad in the target's shadow areas.

The second alteration involves the film that is used in the camera. After processing the film, an image of the target that consists of shades of gray is obtained. These shades of gray are reversed in that a bright portion of the target is dark on this negative and dark portions of the target are light. This reverse of polarity is corrected when the negative is duplicated. The distortion that occurs, though, in this stage is that the shades of gray do not bear the same relationship to one another as do the target reflectances that they are supposed to represent. Again, the shadow areas that have already been reduced in contrast have their contrast reduced even further in this process. Fig. 6-1 represents this situation.

If the curve in this figure, which is called a D-log E or H&D curve, were to be a straight line, this part of the recording process would not introduce any distortions in the target information. As can be seen, this slope is low in the shadow region, reducing the shadow contrast. The slope is greater than 1 in the midregion and this actually enhances the contrast of the image. The final step in the sequence of events that produces a duplicate positive is to duplicate the negative. This provides an image in which the tones are in the correct order; the shadows are dark and the highlights are white. This process introduces the same types of distortions as the negative D-log E curve of Fig. 6-1.

Fig. 6-2 represents a typical duplication film D-log E curve. The portion of the curve that reproduces the shadows is low contrast, and this shadow information is further compressed, although not nearly so much as in the negative stage. The midtone region, though, has a higher slope and the contrast is again expanded. With careful control of the various stages in this process, imagery of high quality can be maintained.

Two basic controls can be used to ensure that the photographic product has as high a quality level as possible—exposure and processing. The early KH system cameras used a single slit for the entire mission which provided almost a constant exposure time for the mission. Since the photography was taken over a very wide geographic latitude range, some of the pictures were underexposed (northern latitude) and some were overexposed (near the equator). In order to avoid this problem, a processing technique was formulated that could correct for the inability to set proper exposure over the mission lifetime. The basic principle was that the slit was set prior to launch for a good exposure at the northern latitudes. The pictures exposed in this region were then processed normally. As the vehicle approached the equator, the pictures became more and more overexposed. When the film was processed, these pictures were not allowed to develop fully, and this underdevelopment tended to correct for the overexposure. The Trenton Processor was used. It employed an infrared scanning device at the very early stages of the processing. The machine then made a decision as to whether or not the picture should be fully developed. Fig. 6-3 illustrates the characteristic D-log E curves for this technique. At the time that this technique was implemented, it was an ingenious solution to a difficult problem. Although the best way to correct for exposure errors is to use the proper exposure, this technique provided satisfactory results for 3 years. Improved versions of the KH systems evolved that incorporated a variable exposure control mechanism. Therefore, instead of using a wide slit for the entire mission, the appropriate slit for the illumination conditions to be encountered could be employed. Therefore, a narrower slit would be used as the vehicle approached the equator. This had another beneficial effect; the shorter exposure times reduced the image smear and provided sharper images.

In July 1963, the KH-7 became operational; this system was capable of using a variable exposure time. In July 1966, KH-8 was flown and it used eight slits. Six slits are used for most of the mission with a factor of approximately 1.5× between each setting. One slit provides an exposure time 10× greater than the widest of the six normally used. The final position is used for special experimental purposes. The KH-1 through KH-4A systems employed a fixed slit. In 1967, the KH-4B system was first flown; this system incorporated a five-position slit mechanism. Four are used for the normal mission photography and encompass a range in exposure of approximately a factor of 2.5×. They can be set in any increments within this range. The remaining position is a failsafe condition, and would be used if the adjustable slit mechanism became inoperative.

With the availability of selectable exposures on orbit, the importance of using a three-level interrupted processing technique diminished. However, this approach was continued since changes in scene characteristics (i.e., atmospheric conditions, terrain reflectance, recent snow-fall, etc.) still occurred, and both exposure and processing adjustments were useful.

One factor was not taken into account when the process change decision was made. The infrared densitometer was not capable of finding and measuring targets from KH-4. As a result, some frames would be processed to maximum speed even when they contained bright targets, causing the target to appear overexposed. In 1968, a single-level process was instituted on KH-4B that had distinctly different sensitometric characteristics than the tri-level process (see Fig. 6-4). This process is currently used on KH-8 also.

The exposure latitude that this processing provided was substantially greater than any one of the three curves in Fig. 6-3, being similar to all three at once. With this wider latitude and the current systems that employ variable exposure times, a greater control is available to record targets in the best way possible. Studies currently in progress are designed to learn more about individual target characteristics. This information will be used in the near future to tailor the exposure to specific questions.

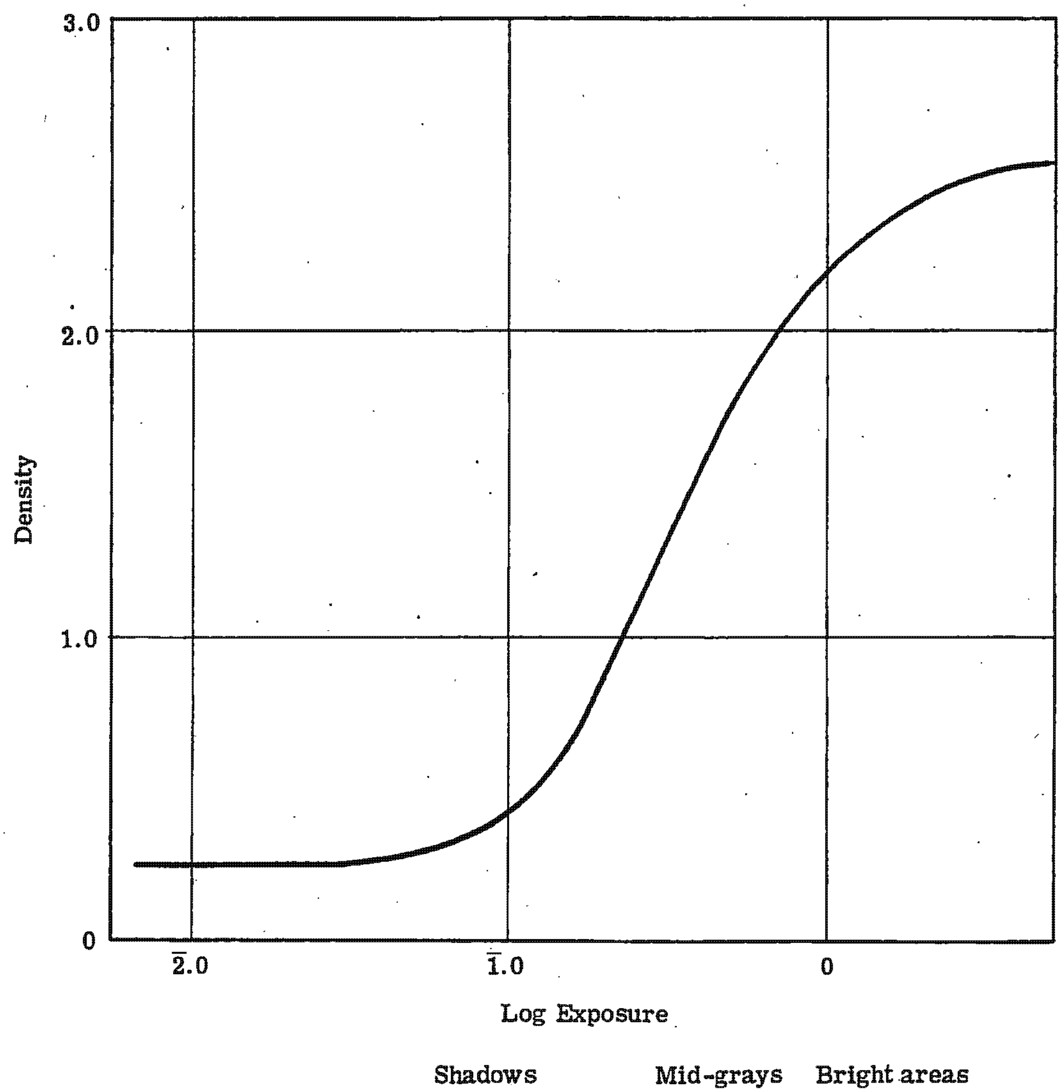

Fig. 6-1 — A general characteristic curve for 3404

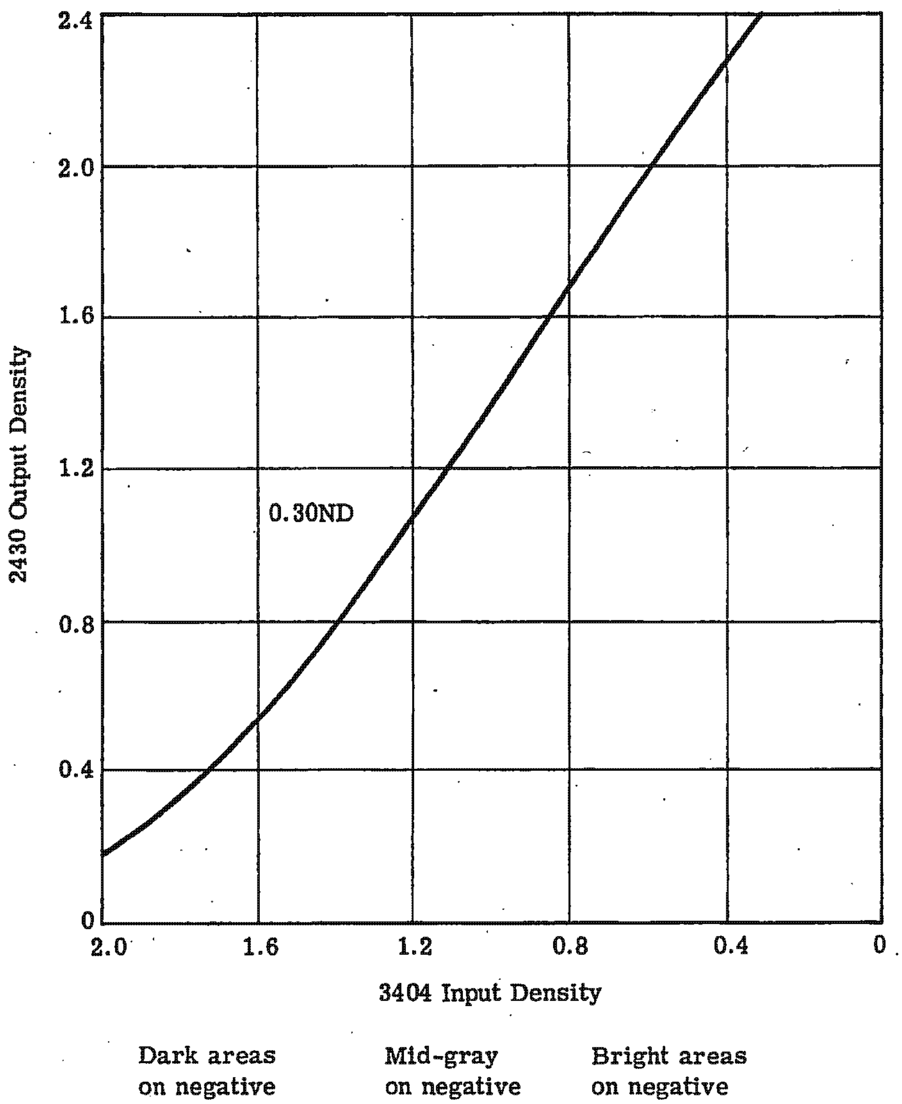

Fig. 6-2 — A typical duplicating film D-log E curve

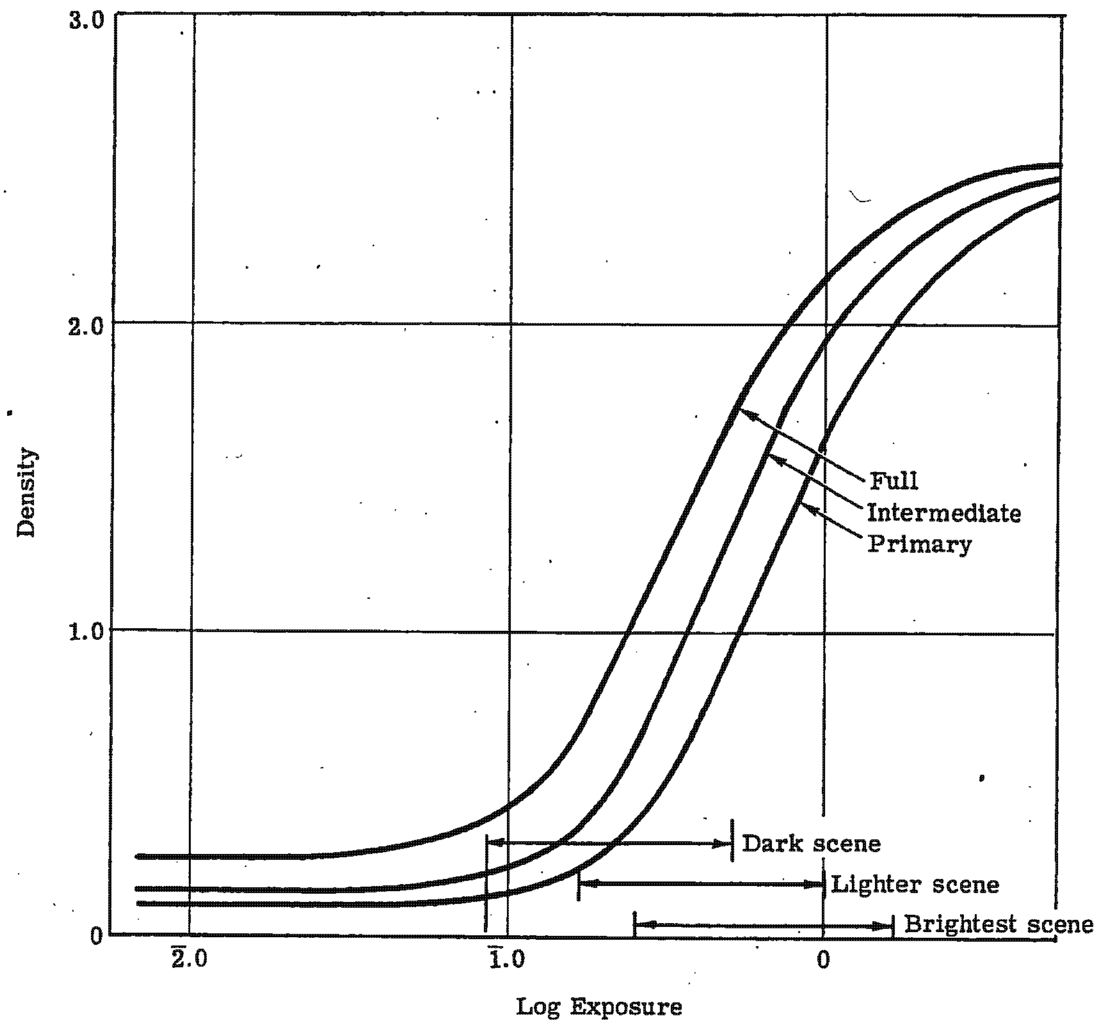

Fig. 6-3 — Process control curve for tri-level processing of 3404 film on the Trenton Processor

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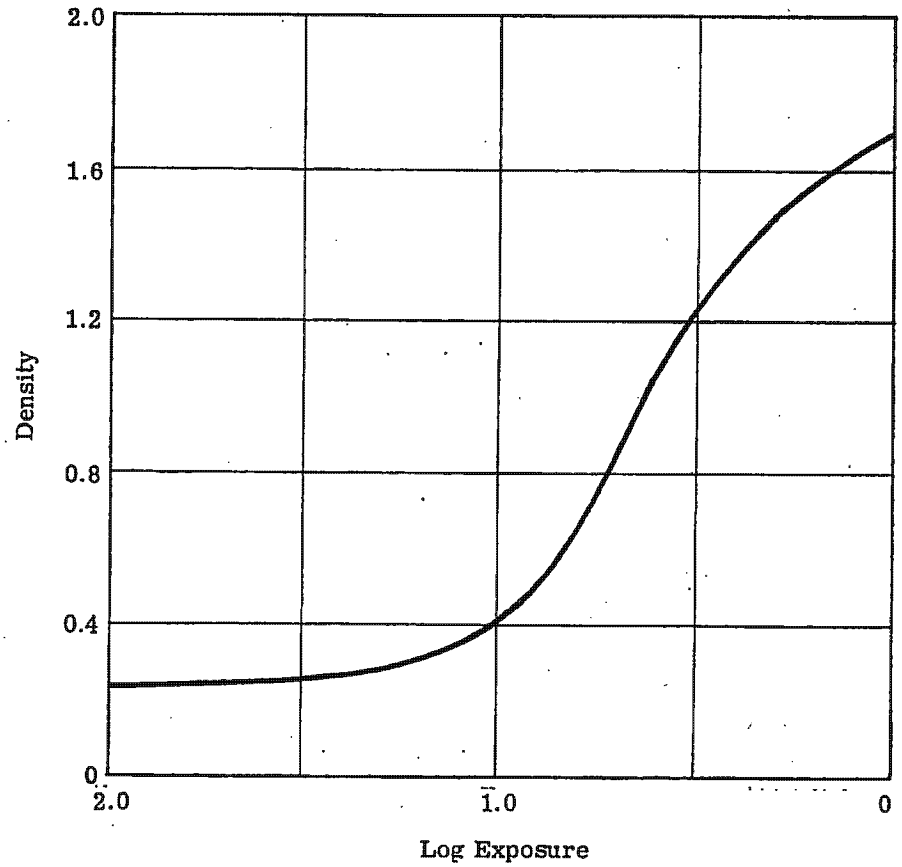

Fig. 6-4 — 3404 processed in the Dual Gamma on the Yardleigh Processor

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Fig. 2.7-4 — 5× enlargement of Clinton Sherman AFB, Oklahoma, from the AFT-looking camera of mission 1105 using SO-121 film (edge of frame)

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Fig. 2.7-5 — 5× enlargement of Kun Yang Hai Lake area (Southeast China) from the FWD-looking camera of mission 1106 using 3404 film

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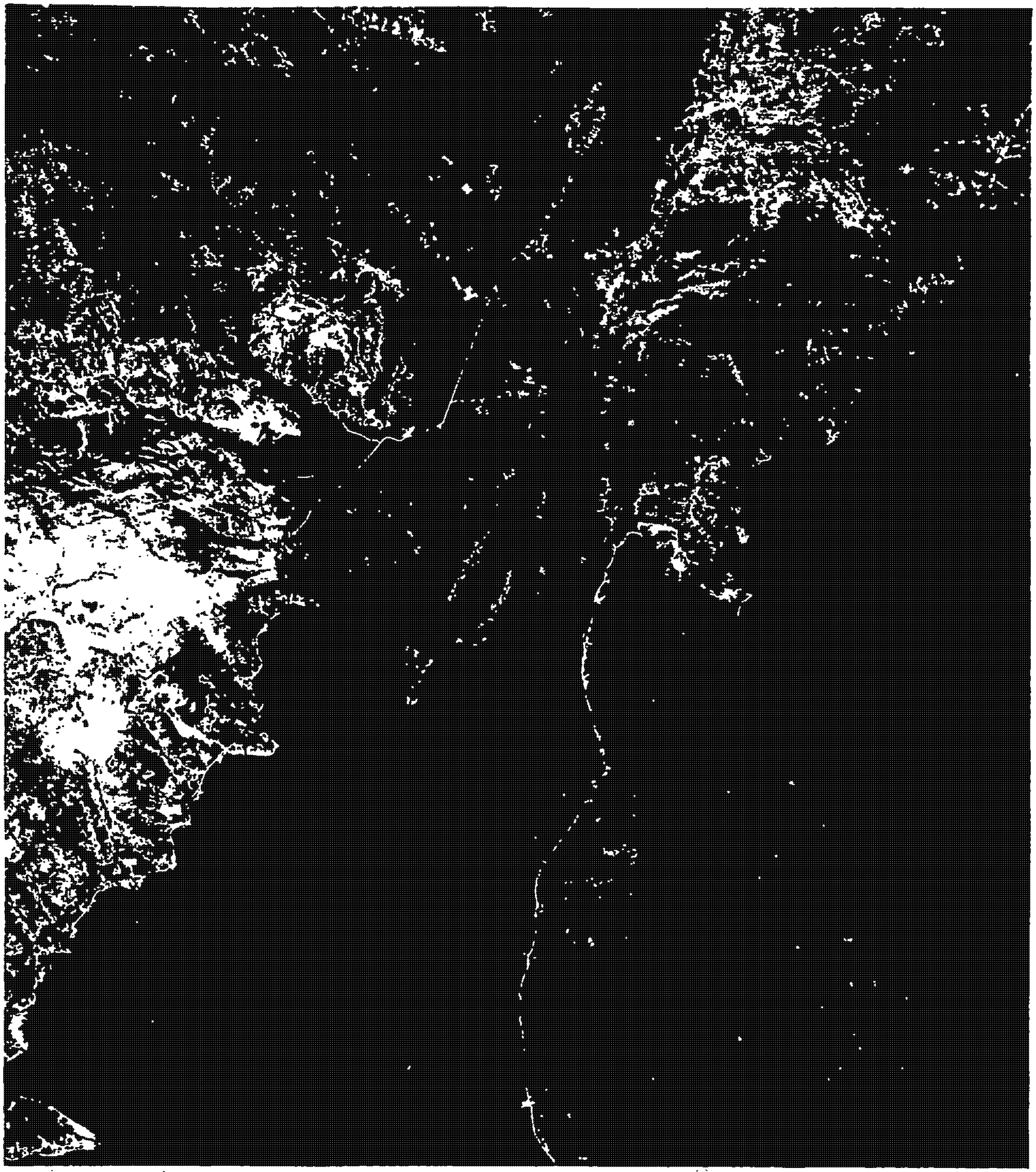

Fig. 2.7-6 — 5× enlargement of Kun Yang Hai Lake area (Southeast China) from the AFT-looking camera of mission 1106 using SO-121 film (center of frame)

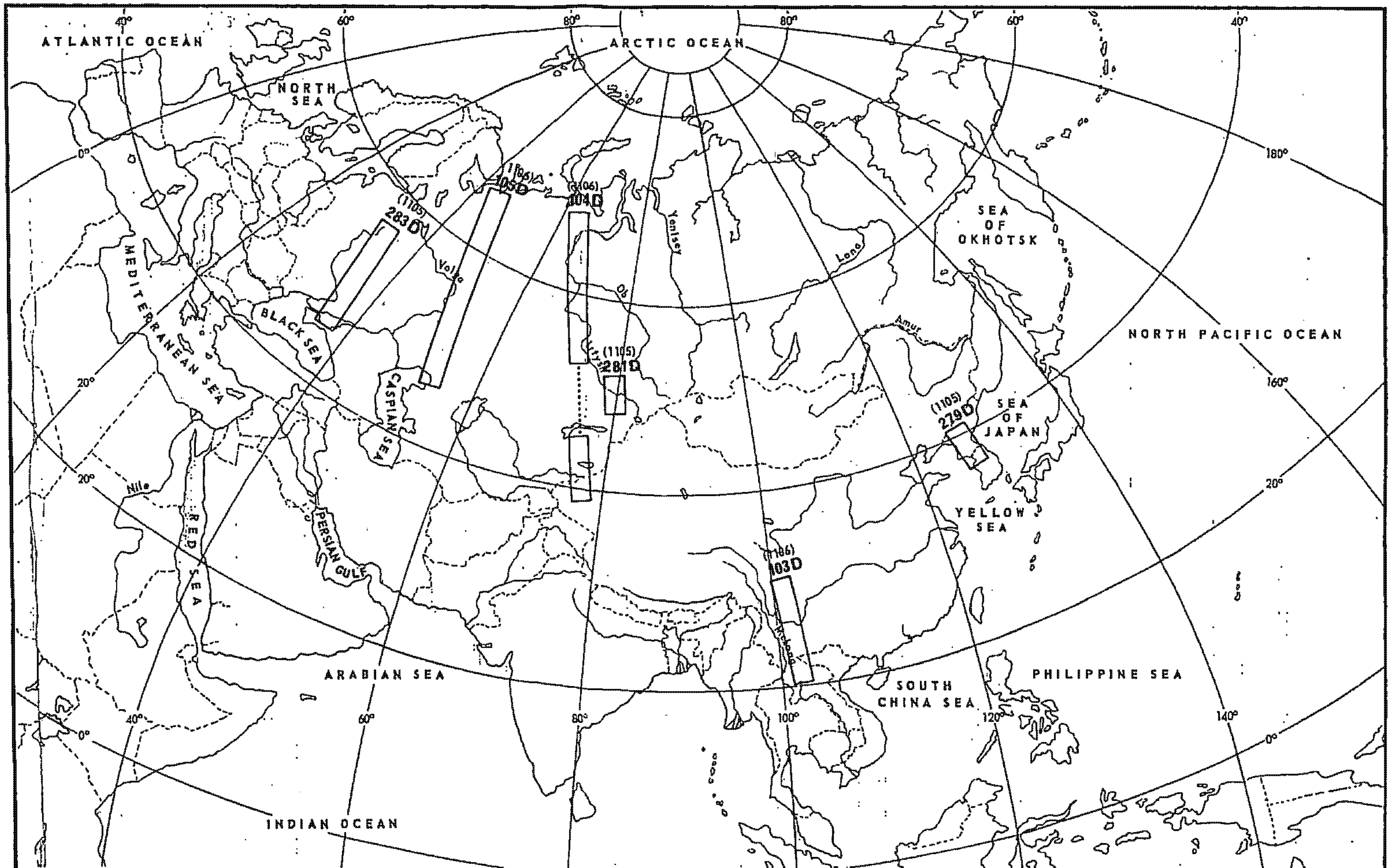

Fig. 2.7-2 — Ground tracks for the mission 1105 and 1106 SO-121 passes over Eurasia

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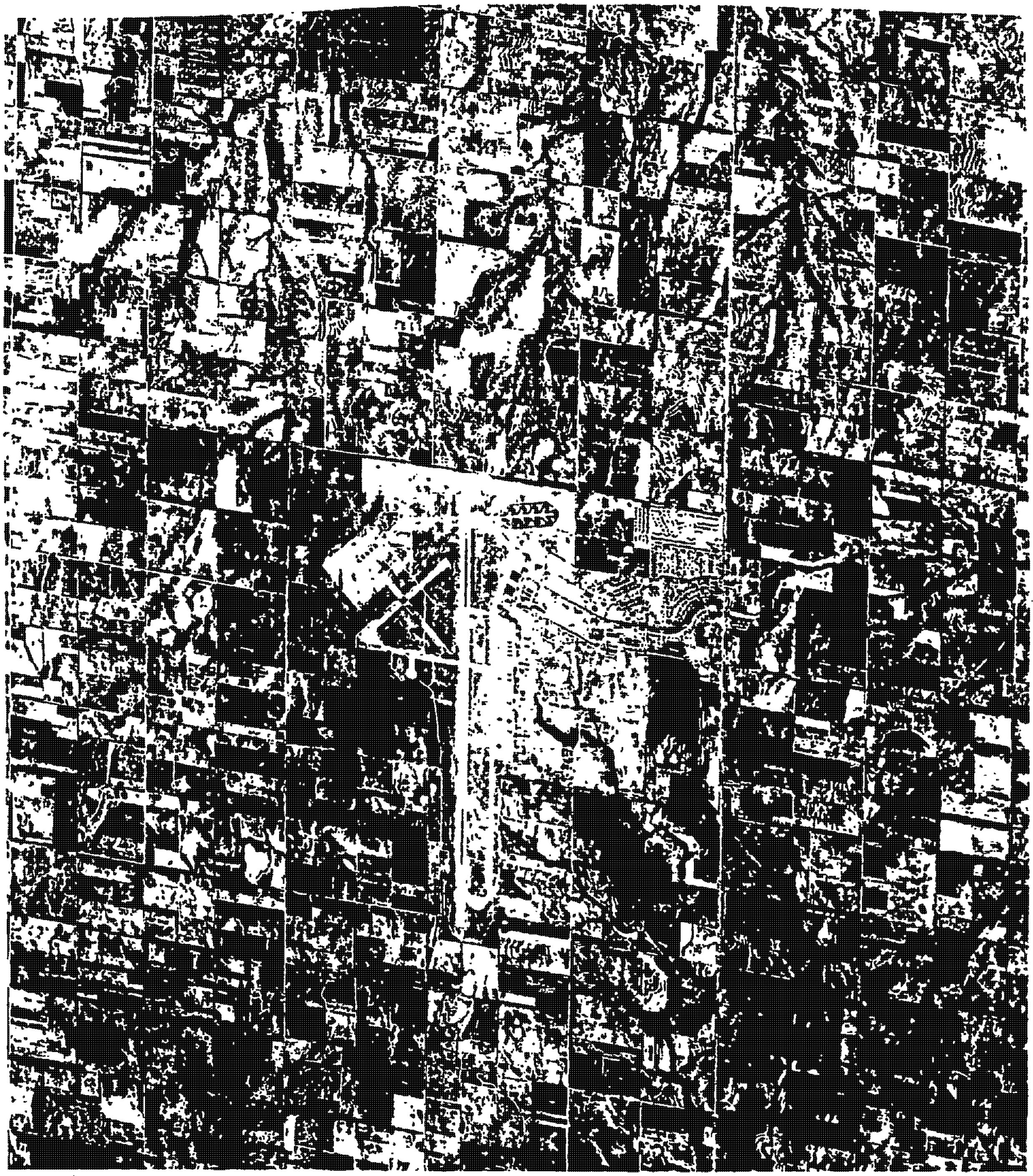

Fig. 2.7-3 — 5× enlargement of Clinton Sherman AFB, Oklahoma, from the FWD-looking camera of mission 1105 using 3404 film

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2.8 SO-242 COLOR WITH KH-8

2.8.1 Test Type

Estar thin base Aerial Color film SO-242 was used in the KH-8 satellite camera system, mission 4324-2, flown in November 1969.

2.8.2 Test Objective

The objective of this test was to determine if high resolution color photography can be acquired with the KH-8 camera system.

2.8.3 Test Details

The last 600 feet of the mission 4324 flight load, approximately 1 day's operation, was SO-242 color film. Both operational and domestic acquisitions were programmed and acquired on this film The test began in rev 196 and ended in rev 215. A total of 371 frames were acquired. Only 289 frames contain terrain imagery. The 82 frames totally obscured by clouds and the 170-foot segment slewed through the camera between revs 196 and 197 were removed from the reproduction cycle to conserve time and reproduction material. The normal requirements, including some color-oriented questions, were assigned to the exploitation of the color portion of the mission.

2.8.4 Discussion of Figures

Pertinent ground tracks for mission 4324-2 are shown in Figs. 2.8-1 and 2.8-2. Color coverage for this experiment included areas of both the United States and Russia. Shown also on these plots are the locations of the photographic illustrations, Figs. 2.8-3 through 2.8-6. Specific camera parameters for the four color photographic illustrations are listed in Table 2.8-1.

2.8.5 Results and Conclusions

The SO-242 color film is designed for high altitude camera systems containing color corrected lenses without special filtration. The KH-8 system at present contains a partially color corrected lens with an equivalent Wratten no. 3 filter coated on the lens. The color acquisitions were affected to a slight degree by these optics, but the effects introduced were compensated for in the reproduction cycle to provide good color-balanced reproductions.

The original color imagery generated by this test exhibits the best spatial resolutions in color acquired with this system. The interpreters, utilizing both the original and the reproductions, answered most of the intelligence requirements. However, they reported that the sample provided was not sufficient to determine definitive answers to some of the color-oriented questions. The test indicates that less is known of interpreting color signatures than is desirable. Several target categories were not covered, and thus determination of the value of color for these types of targets remains unknown. The target categories exploited showed some additional information attributed to the use of color film, but no significant new intelligence can be related directly to color signatures. Color contributes to the ease of detection especially in recognizing disturbed terrain being readied for construction. It also shows potential in the interpretation of other construction phases. Color coding of defensive weapons and related support equipment is of interest and again indicates a need for further study of the meaning of color signatures.

The major complaint from the photointerpreters relative to the reproductions from the SO-242 is the loss in resolution when compared with reproductions from black and white originals. Investigation into methods of providing better resolution reproductions from the SO-242, however, has been highly successful. Black and white separation negatives were made from four revolutions and black and white prints reproduced from each of the emulsion layers. The separation prints were made using narrow band color separation filters (Wratten nos. 92, 93, and 94) in the Beacon Precision Enlarger. Focus was changed for each of the three layers in the SO-242. Density and contrast of the reproductions were controlled within stringent specifications for this test to ensure that the gamma of the reproductions would not influence the comparison. These reproductions were then examined by the photointerpreters, who concluded that the reproductions of the green-sensitive layer compared favorably with the reproductions normally received from black and white missions.

Thus, good quality photography with excellent color fidelity can be acquired with the KH-8 system, and dye layer separation black and white dupes from the original color do not suffer loss in operational resolution.

Table 2.8-1 — Specific camera parameters

	Fig. 2.8-3	Fig. 2.8-4	Fig. 2.8-5	Fig. 2.8-6
Rev	198	211	210	204
Frame	21	6	11	5
Effective T stop	4.25	4.25	4.48	4.33
Date of photography (GMT)	6 Nov 1969	7 Nov 1969	7 Nov 1969	6 Nov 1969
Enlargement factor	10×	10×	10×	10×
Type of coverage	Stereo	Stereo	Stereo	Strip
Altitude, nm	70.4	70.8	69.9	70.3
Mirror crab, degrees	2.092	1.743	1.743	2.092
Cone angle, degrees	9.4818	23.9313	34.9038	22.7420
Mirror position	AFT	AFT	FWD	Vertical
Equivalent wratten filter	4	4	4	4
Slit width, inches	0.0321	0.0321	0.0321	0.0204
Film velocity, inches per second	9.5009	8.7685	7.9115	9.0320
Exposure, seconds	0.0034	0.0037	0.0041	0.0023
Solar elevation, degrees	26.6	21.8	30.5	34.8
Solar azimuth, degrees	184.7	190.5	182.0	180.7
Vehicle azimuth, degrees	207.0	209.5	204.9	203.4
Azimuth of the principal ray, degrees	183.2	278.4	99.0	293.9
Vehicle roll, degrees	−6.0	20.7	−35.7	20.7
Local sun time, hours	1216	1239	1202	1201

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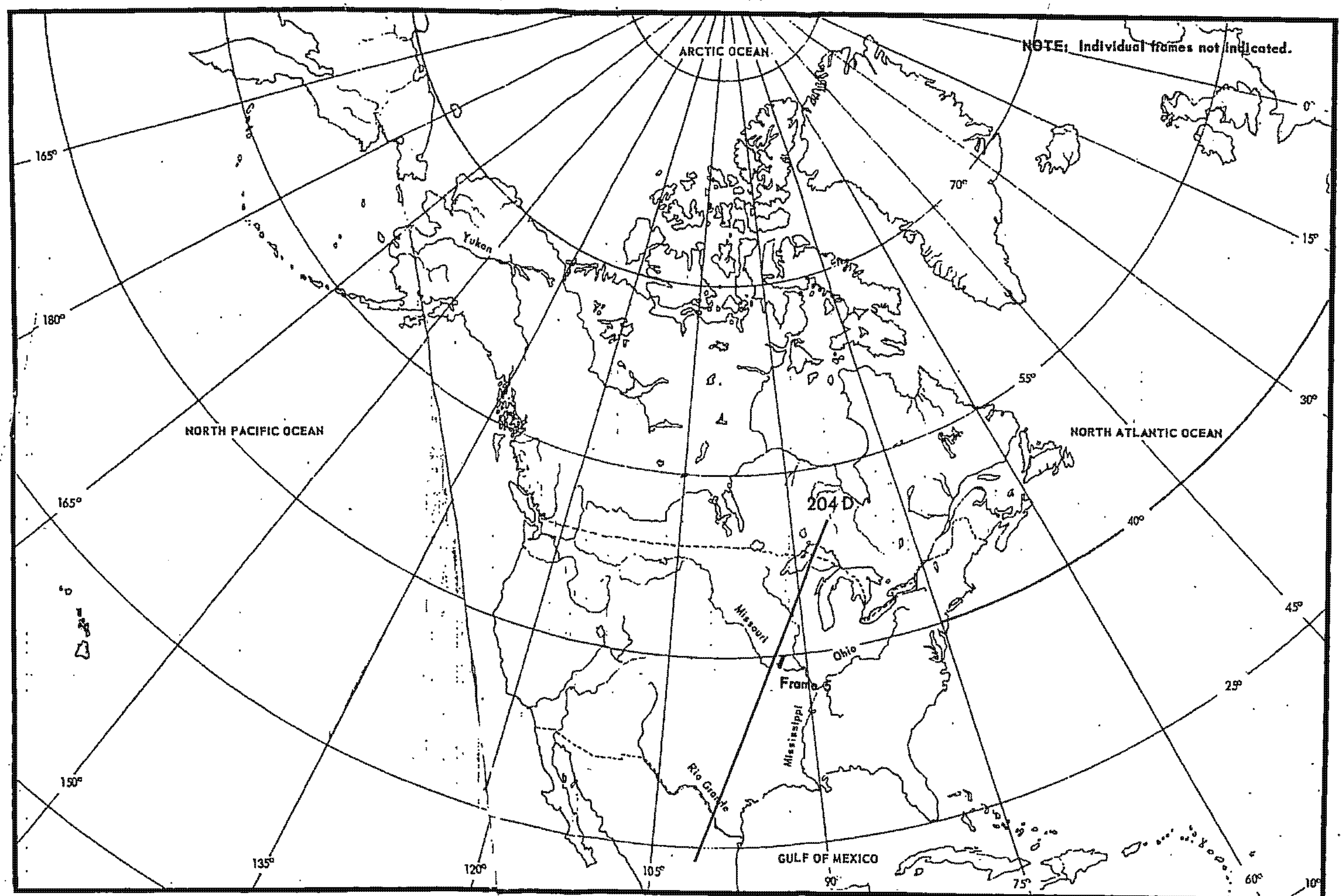

Fig. 2.8-1 —Ground track and exposure location over the United States in the KH-8/). 242 color experiment, mission 4324-2

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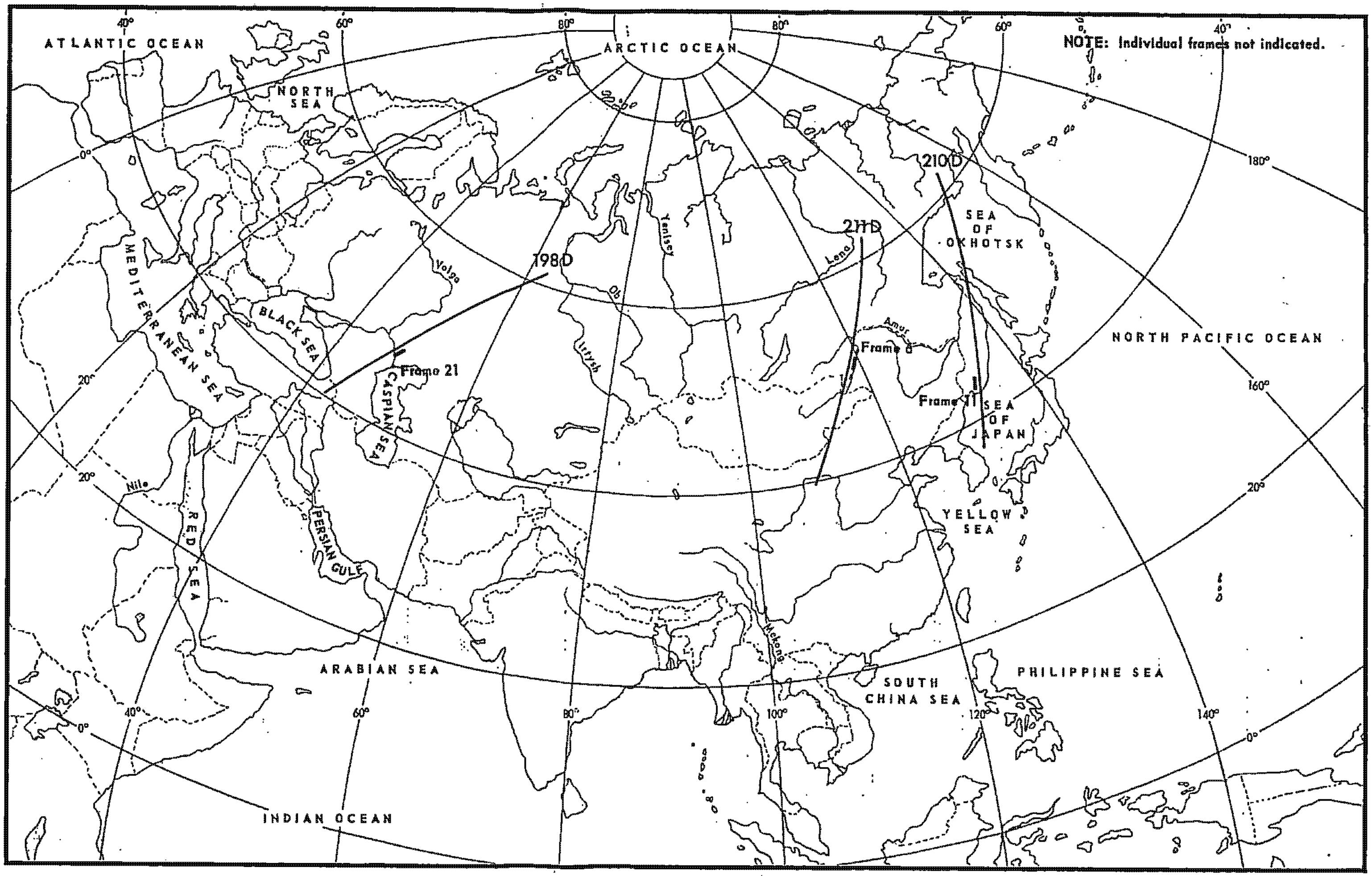

Fig. 2.8-2 — Ground tracks and exposure locations over the USSR in the KH-8/SO-242 color experiment, mission 4324-2

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2.9 SO-242 COLOR WITH KH-4B

2.9.1 Test Type

The satellite KH-4B camera system was utilized for this test.

2.9.2 Test Objectives

The mission 1108/SO-242 test was intended to: (1) obtain improved conventional color photography with the KH-4B system; and (2) demonstrate the capability of the KH-4B camera system to operate with an improved Ektachrome color film designated SO-242.

2.9.3 Test Details

2.9.3.1 Mission 1108-2/SO-242 Flight

Mission 1108-2 was launched on 4 December 1969 and was recovered on 21 December 1969, during rev D-276. As a tag-on to the AFT-looking camera film supply 819 feet of SO-242 color film was included as an experiment. A material change detector (MCD) system automatically removed the primary (Wratten no. 21) filter and replaced it with an alternate (Wratten no. 2B) filter. Because SO-242 is autonomously filtered within its own structure, the Wratten no. 2B filter was used only to maintain the focal setting of the lens.

Color coverage was obtained on 13 photographic passes (213 frames) as indicated on Figs. 2.9-1 and 2.9-2. The SO-242 color portion began on frame 28 of rev D-242 (as the vehicle passed over southwest USA) and continued to the end of the mission, frame 2 of rev D-274. Because no CORN target imagery was acquired, ground resolution had to be estimated indirectly. Test analysis is illustrated with four photographs, Figs. 2.9-3 through 2.9-6, and the system parameters associated with these examples are listed in Table 2.9-1.

2.9.3.2 Laboratory Work

Selective printing of the individual dye layers of the SO-242 color film containing Petzval lens resolution target images indicates unequal image quality. The blue-sensitive, bottom-most layer is extremely grainy and the lens MTF is very poor in this spectral region, such that extremely low resolution results. The top-most, green-sensitive layer has a fine grain structure and is unimpeded by other scattering layers, but the lens transfer function in this spectral region is poorer than in the red spectral region. The result is that resolution and contrast in this layer is not maximum for the tri-pack.

The middle, red-sensitive layer has a fine grain structure but is somewhat masked by the light-scattering layer above it. However, because this layer is the receptor for the spectral region for which the Petzval lens response is optimized, the highest resolution and contrast is produced in this layer. Enhancement in image quality by isolating the red-sensitive layer from the tri-pack presentation, however, is minimal for this reconnaissance system.

2.9.4 Discussion of Figures

Military airfields are targets of prime importance for intelligence evaluations. Their location can be determined using almost any contemporary camera/film combination; but facility function, as well as aircraft identification and support capability require high resolution. To satisfy present search and surveillance requirements, the KH-4B system operationally utilizes

3404 High Definition Aerial film. An example of this performance is illustrated in Fig. 2.9-3, mission 1108-2/3404 coverage with the FWD-looking camera of Davis-Monthan AFB. Comparable coverage of this same area, acquired five frames later with the AFT-looking camera utilizing SO-242 color film, is illustrated on the facing page, Fig. 2.9-4. The color resolution loss results in a significant reduction in aircraft information.

Support facilities and aircraft do not show any significant color coding, but in the urban area adjacent to the base a number of color clues are evident. Buildings are well defined and in a number of cases colored roofs are noted. A count can be made of larger aircraft and identification of type is possible in some cases. This was not so in the previously tested color films, SO-121 and SO-180. This being a desert area, the delineation of vegetative cover and paving is often quite difficult, but the color record provides this capability.

With regard to the relationship of mineral and oil deposits to economic intelligence, accurate geologic information is of prime importance. Figs. 2.9-5 and 2.9-6 illustrate the comparative values of 3404 black and white film and SO-242 color film for this purpose. The area covered in these photographs is in the Tsaidam Basin area of Tsinghai Province, China. For this application, there is an inverse capability over the preceding example. For geomorphic analysis, the SO-242 is distinctly superior to the 3404. The geologic structure evident in the figures is an uplifted anticlinal fold along the southern foothills of the Altin Tagh Mountain. The stratigraphic banding visible on the 3404 record is identified as Jurassic-Cretaceous beds only in the SO-242 record. The reddish brown hues are typical of this continental sequence and provide the information needed to determine the lithologic character of the various strata.

The resolution capability of the KH-4B/SO-242 system is adequate for detailed evaluation of geology showing all the features necessary for analysis; i.e., drainage, stratification, texture, faulting, contact zones, and rock type color signatures. A prime advantage of the KH-4B system for this purpose is the wide swath coverage which establishes good geological perspective.

2.9.5 Results and Conclusions

The first evaluation of the color imagery (at the processing site) appeared in the mission 1108-2 Reagin-31 message*:

> "BALANCE AND COLOR SATURATION IS CONSIDERED GOOD. THE BEST GROUND RESOLUTION OF THE SO-242 FROM THIS MISSION APPEARS COMPARABLE TO THE BEST COLOR PROVIDED BY MISSION 1106. ALTHOUGH THE OVERALL COLOR BALANCE IS GOOD AND SLIGHT SHIFT TOWARD CYAN IS APPARENT ON SOME PASSES, THE DENSITY RANGES FROM GENERALLY MEDIUM TO SLIGHTLY HEAVY.
>
> DEGRADATIONS TO THE COLOR MATERIAL ARE MINOR; HOWEVER, SEVERAL BLUISH COLORED MARKS ARE PRESENT INTERMITTENTLY THROUGHOUT THE MISSION. REPETITIVE SMALL YELLOW SPOTS ARE PRESENT 3.1 INCHES APART AND 1.2 INCHES FROM THE CAMERA NUMBER EDGE THROUGHOUT THE COLOR MATERIAL. THE LAST FOUR FRAMES OF THE MATERIAL CONTAIN CREASES AND ABRASIONS ASSOCIATED WITH FILM WRAP UP."

---

*Processing contractor message no. 3934, 24 December 1969.

The mission 1108 PET produced its characteristically more thorough evaluation in its PEIR message*:

> "EARLY EVALUATIONS OF THE COLOR MATERIAL FROM THIS MISSION WERE CONDUCTED FROM THE COLOR DUPES AND THE RESULTING COMMENTS WERE GENERALLY NEGATIVE. THE PHOTOINTERPRETERS REPORTED THE PI SUITABILITY OF THE COLOR RECORD AS POOR FOR FIRST PHASE EVALUATIONS BECAUSE OF THE SMALL SCALE AND LOWER RESOLUTION LEVELS. THE PET FELT THAT THE BEST IMAGE QUALITY AND COLOR BALANCE OF THE ORIGINAL SO-242 ARE GOOD, BUT NOTED THAT THERE IS A SIGNIFICANT RESOLUTION LOSS FROM THE ORIGINAL TO THE DUPLICATES. MUCH OF THE SO-242 PHOTOGRAPHY APPEARED TO BE DEGRADED BY HAZE, PARTICULARLY AT THE LOW SOLAR ALTITUDES (LESS THAN 15 DEGREES). THE BEST COLOR IMAGE QUALITY WAS TAKEN AT THE HIGHER SOLAR ALTITUDES (40 DEGREES). THIS COLOR PHOTOGRAPHY IS BETTER THAN ANY OTHER COLOR PHOTOGRAPHY OBTAINED TO DATE FROM THE CORONA SYSTEM, EVEN THOUGH THIS FLIGHT WAS FLOWN AT 15 PERCENT HIGHER ALTITUDE. PARTICULARLY NOTABLE WAS THE FINER DYE STRUCTURE OF THE SO-242 MATERIAL WHEN COMPARED WITH SO-121. ELECTROSTATIC FOGGING DOES NOT APPEAR TO BE A PROBLEM WITH SO-242 IN THE CORONA SYSTEM."

Finally, it is concluded that:

1. The KH-4B system has demonstrated its capability to handle SO-242 color film.
2. The SO-242 film is superior to the SO-121 film with regard to filtration convenience, fine grain structure, resolution, and color discrimination.
3. Neither electrostatic discharge marking nor individual layer speed stability is a problem in the KH-4B system with SO-242 film.
4. Low contrast ground resolution of 15 feet is the expected best performance level for the KH-4B system with SO-242 film.
5. The KH-4B system with SO-242 cannot provide the fine detail required for military intelligence to the extent that the KH-4B system with 3404 does.
6. The potential for economic intelligence through geologic interpretation is greater on SO-242 records than on 3404 records imaged in the KH-4B camera.

*NPIC message no. 7815, 19 January 1970.

Table 2.9-1 — Specific Details of Mission 1108-2 Photographic Illustrations

	Fig. 2.9-3	Fig. 2.9-4	Fig. 2.9-5	Fig. 2.9-6
Mission	1108-2	1108-2	1108-2	1108-2
Camera	FWD	AFT	FWD	AFT
Rev	D-242	D-242	D-249	D-249
Frame	030	035	021	027
Date	19 Dec 1969	19 Dec 1969	20 Dec 1969	20 Dec 1969
Film	3404	SO-242	3404	SO-242
Filter	Wratten no. 25	Wratten no. 2B	Wratten no. 25	Wratten no. 2B
Exposure time, seconds	1/290	1/450	1/290	1/775
Altitude, feet	605,178	604,645	606,420	605,566
Scale	1:302,589	1:302,323	1:303,210	1:302,783
Solar altitude	33° 55'	33° 44'	27° 16'	27° 14'
Latitude (CF)	32° 7.7'N	32° 18.4'N	38° 31'N	38° 32.7'N
Longitude (CF)	111° 59.5'W	112° 4.2'W	91° 0.2'E	90° 56'E
Universal grid coordinates	— —	x = 5.6, y = 4.8	x = 30.5, y = 2.5	x = 45.0, y = 3.6
Magnification	10×	10×	5×	5×

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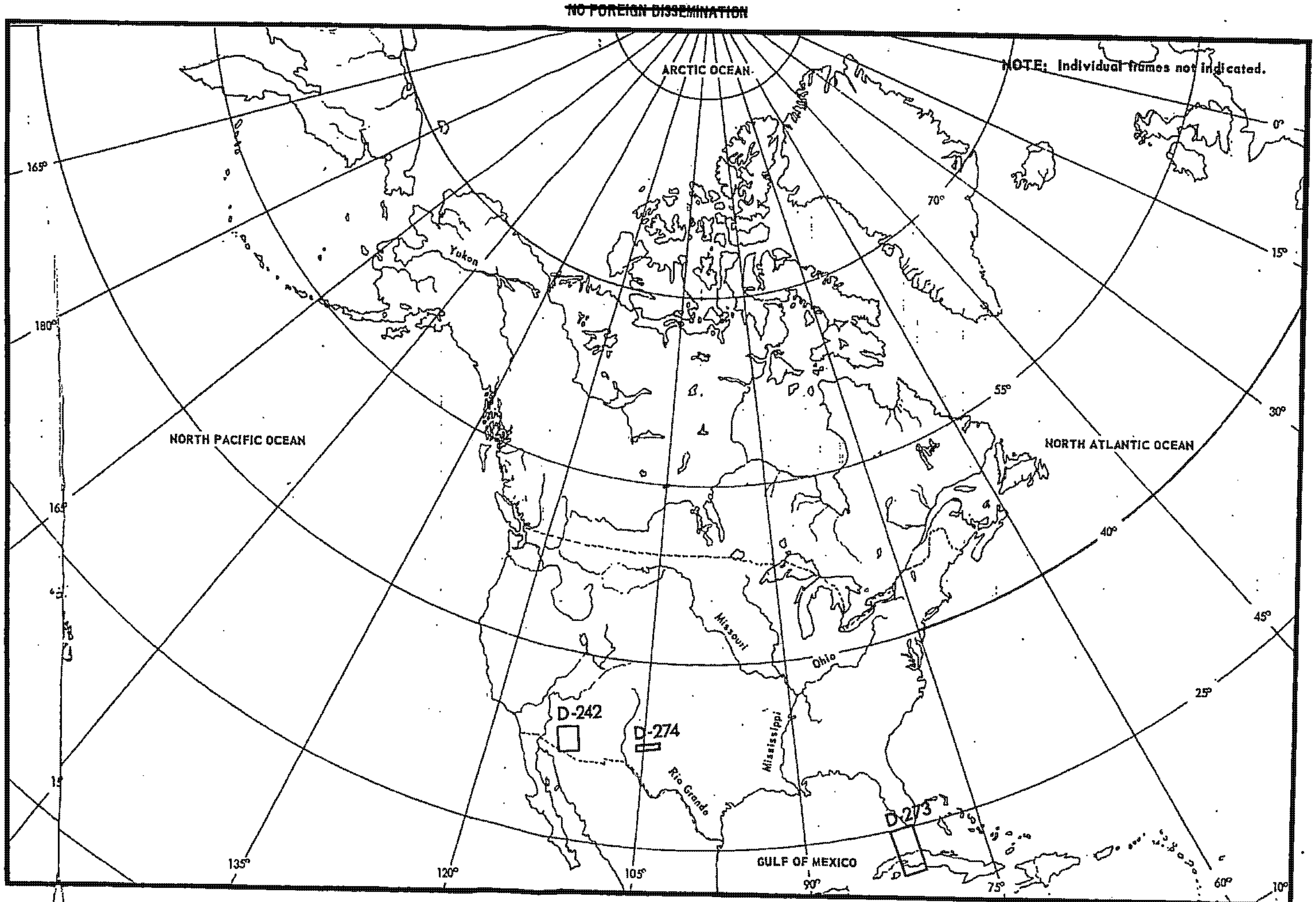

Fig. 2.9-1 — Ground tracks for mission 1108 SO-242 passes over the United States and Cuba

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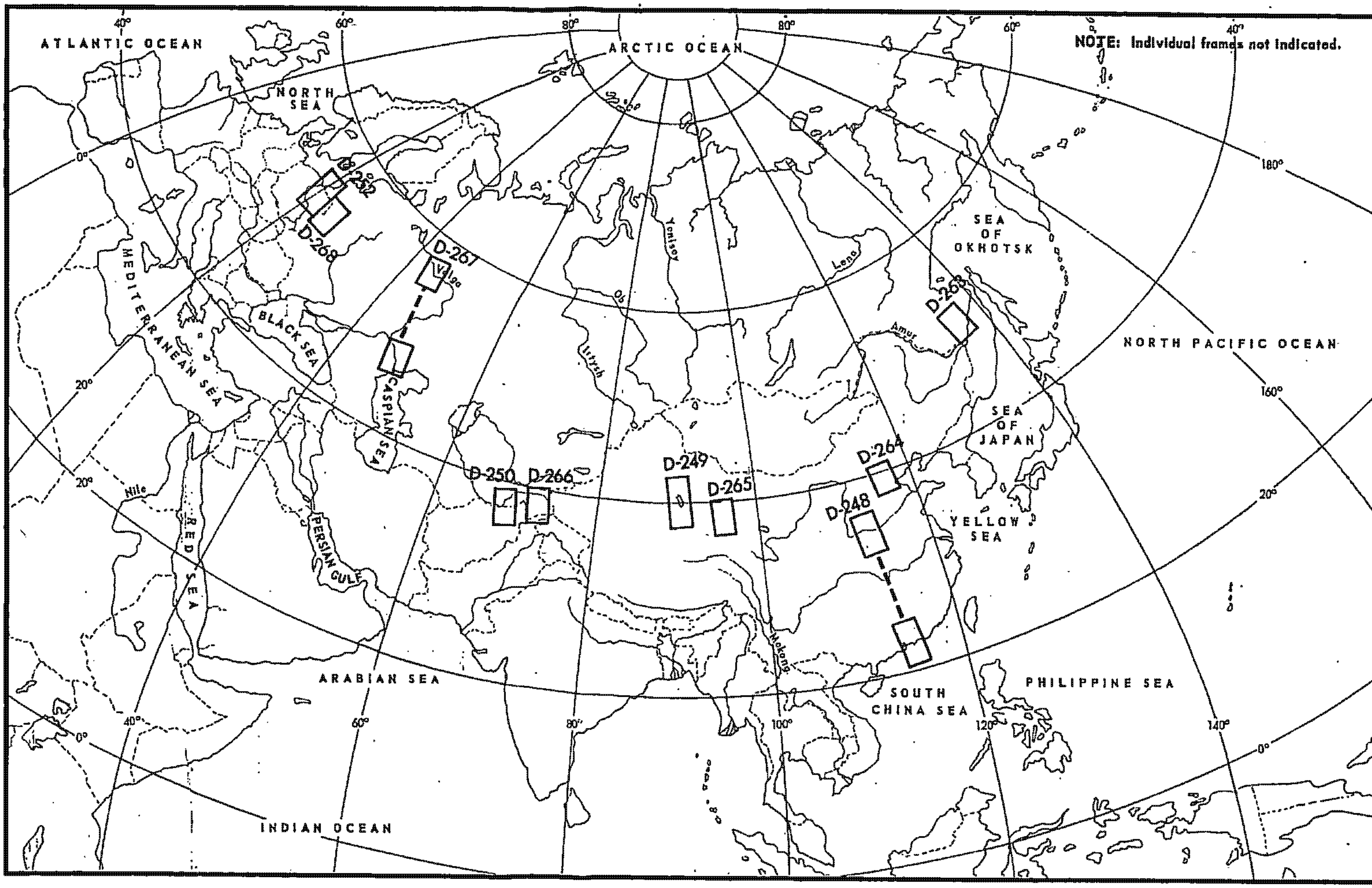

Fig. 2.9-2 — Ground tracks for mission 1108 SO-242 passes over Eurasia

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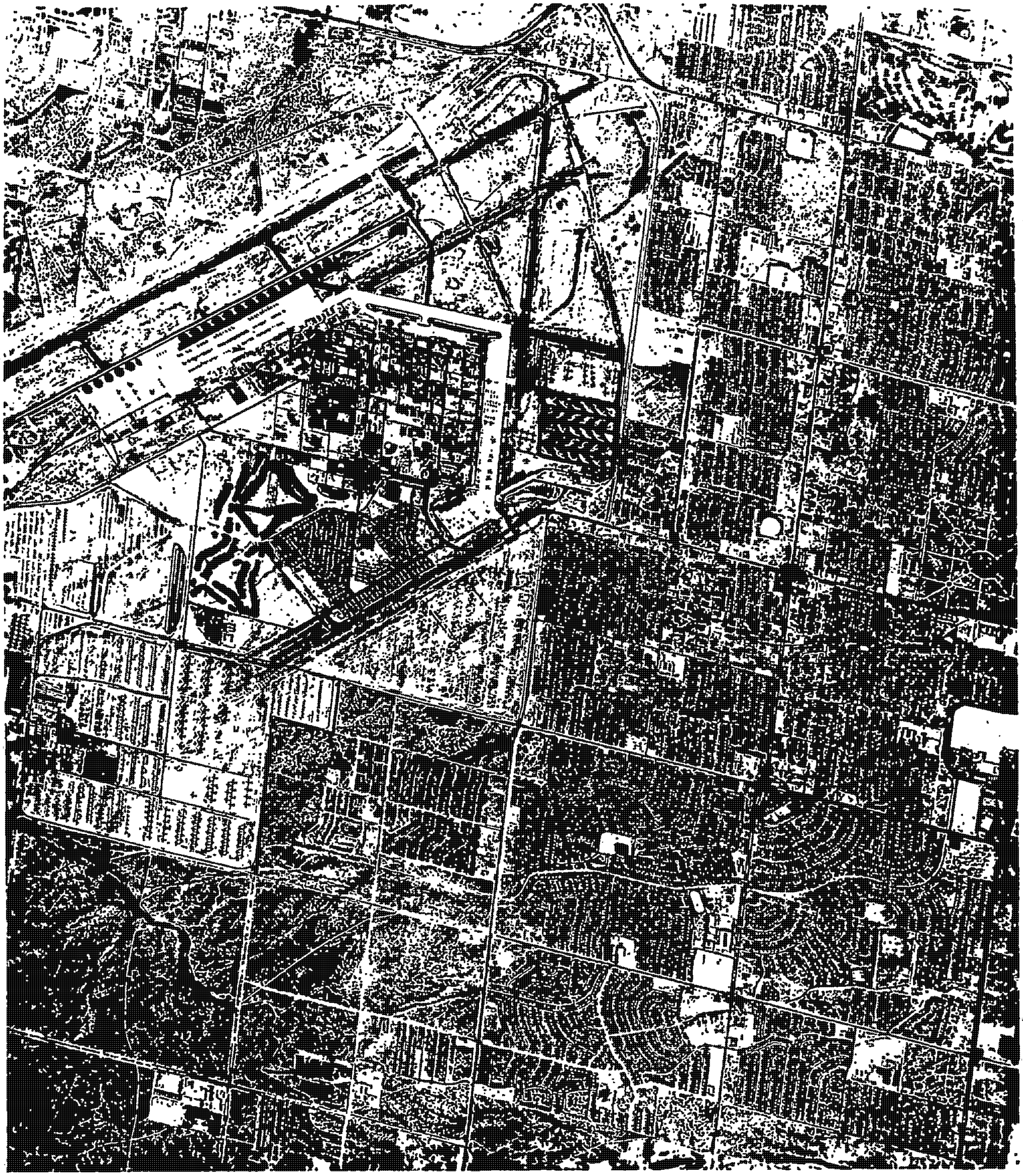

Fig. 2.9-3 — 10× enlargement of Davis-Monthan AFB and Tucson, Arizona from the FWD-looking camera of mission 1108 using 3404 film

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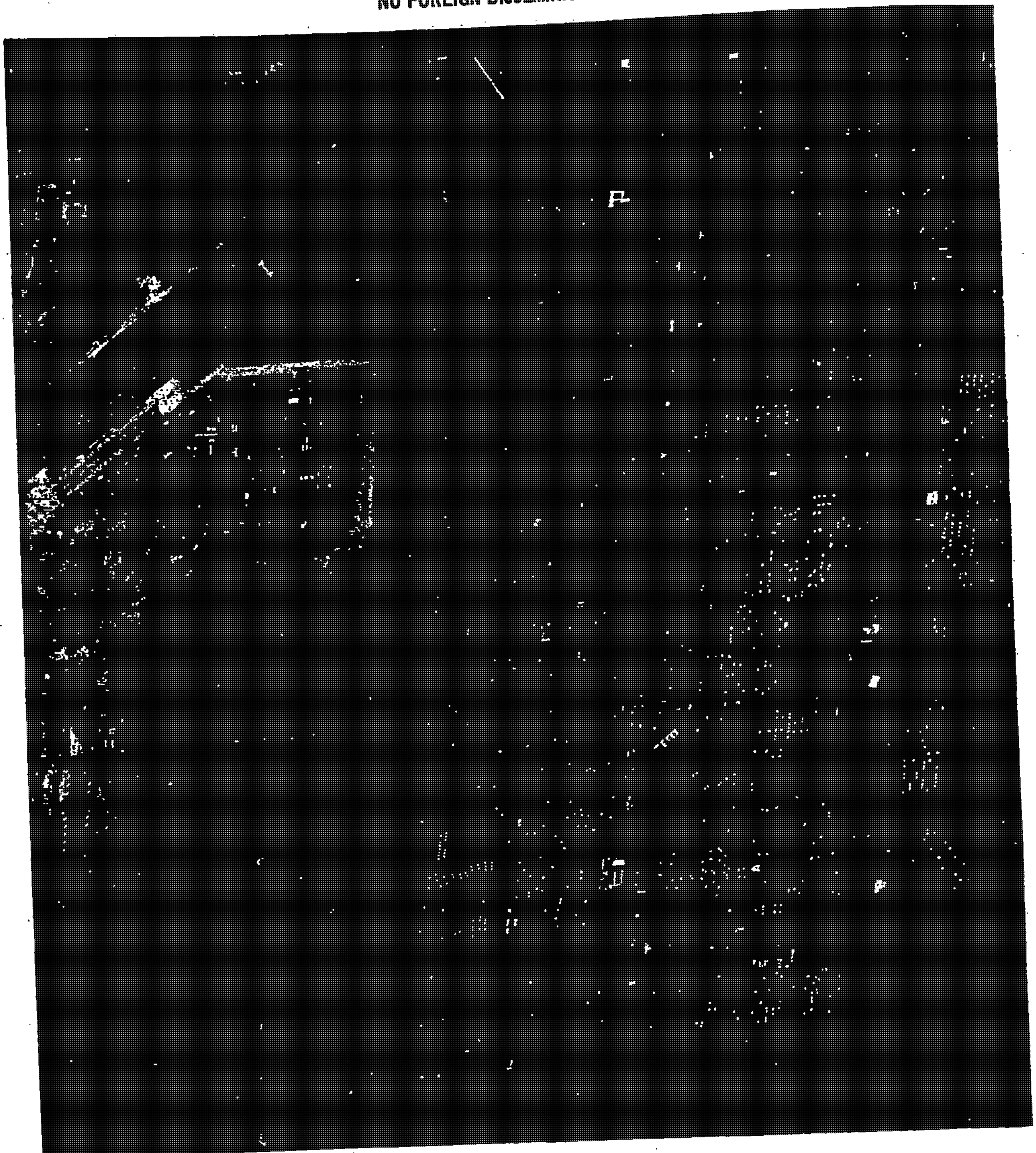

Fig. 2.9-4 — 10× enlargement of Davis-Monthan AFB and Tucson, Arizona from the AFT-looking camera of mission 1108 using SO-242 film

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Fig. 2.9-5 — 5× enlargement of an uplifted anticlinal fold in the Tsaidam Basin, China from the FWD-looking camera of mission 1108 using 3404 film

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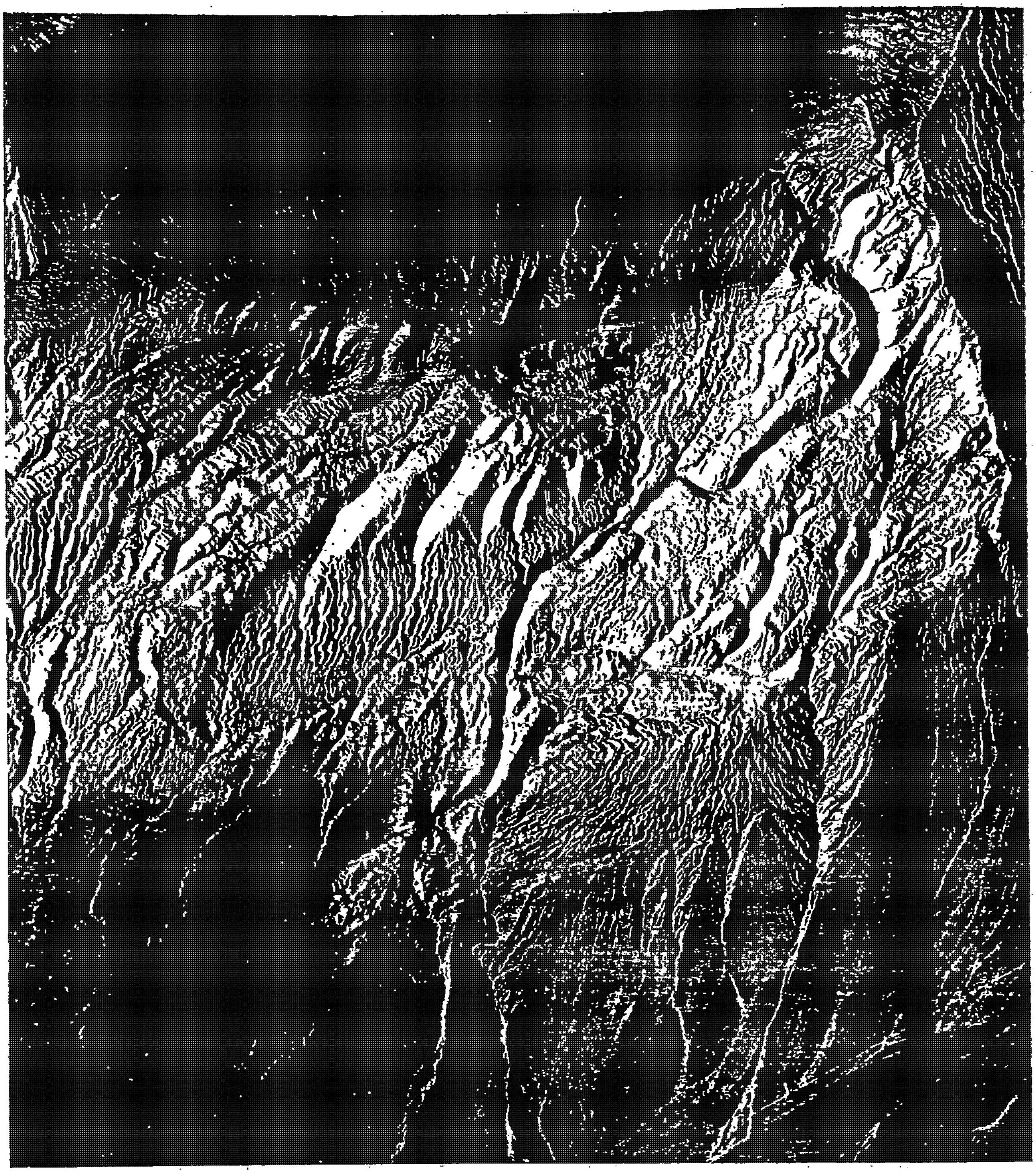

Fig. 2.9-6 — 5× enlargement of an uplifted anticlinal fold in the Tsaidam Basin, China from the AFT-looking camera of mission 1108 using SO-242 film

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3. FALSE COLOR

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3.1 TECHNICAL DISCUSSION ~~NO FOREIGN DISSEMINATION~~

The capability of aerial photography to record vasts amounts of information can be considerably enhanced by the judicious use of various film types. Black and white film, the most commonly used medium, has the capability to record an extreme aggregate of detail by virtue of its high resolution capability and broad tonal range.

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.

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. The primary factor is the type of application for which the imagery is to be used. The prevailing argument for conventional color is that it presents an image to the photointerpreter in a format similar to his natural environment. 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 on the black and white film. However, it is evident that the color emulsion will have no difficulty in differentiating between these objects.

Infrared sensitive films provide information which is based on the spectral distribution of an object, specifically, its infrared radiation content.

The photographic spectrum is divided into five regions, including ultraviolet, blue, green, red, and infrared. SO-121 (conventional color film) has three principal layers of 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 during exposure. Similar dye layers are used in SO-180 as in SO-121, but the film's spectral sensitivities have been shifted approximately 100 nanometers 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 colors are reproduced as long as the infrared reflectance is known.

Direct subjective comparison of SO-121, SO-180, and 3404 indicates marked differences 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 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.

SO-121 and SO-180 will accept scene contrasts which are equal, while 3404 will record a wider contrast range 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. Generally, 3404 is used with Wratten no. 21, 23A, or 25 filters. A Wratten no. 15 is used with SO-180, and Wratten no. 2E plus some color-correction with SO-121. The reproduction of contrast with SO-121 will be lower than that with SO-180. Although it has an equal acceptance latitude, the exposing filtration does not increase the original scene contrast to the extent of the SO-180 filter.

As previously indicated, with knowledge of the film characteristics and the spectral reflectance of objects, some generalizations can be made as to how these objects will be reproduced. Table 3.1-1 lists various types of objects and the colors (in general) that are reproduced from them. Most are predictable based on the object's color and film spectral sensitivity. However, there are several that are somewhat unusual. For example, since red colors are reproduced as green, red flowers showed therefore also be reproduced as green. However, some red flowers also have a high infrared reflectance and the resultant color is yellow (green from red plus red from infrared produces yellow). Another interesting phenomenon is grass. Normally live (green) vegetation is recorded as a red color on this film. This is due to the absence of cyan dye (leaving yellow and magenta which look red) from the infrared exposure of grass that has a high infrared reflectance. However, if the grass is a bright green, there is also a significant exposure affecting the green sensitive layer of the film that limits the formation of yellow dye. Therefore, the only remaining dye is magenta, which gives a pink appearance.

Table 3.1-1 — Objects and Their General Reproduction on SO-180

Object	Reproduction Color
Yellow flowers	Green
Red flowers	Yellow
Live (dark green) grass	Red
Bright green grass	Pink-magenta
Dead trees	Blue-purple
Broad leaf trees	Reddish brown-cyan brown
Pine trees	Reddish brown
Urban areas, concrete, buildings, etc.	Neutral to slight cyan cast
Red brick roof tops	Greenish yellow
Metallic aircraft	Neutral
Dirt roads	Neutral
Hot top roads	Cyan
Sand	Neutral
Coastal water	From light green to cyan to dark blue (depth depending)
Salt water	White, light blue, dark blue, light and dark green
Fresh water	Blues and greens, cyan
Tidal water	Greens to blue
Tidal water (contaminated)	Yellow to blue
Deep ocean	Dark blue
River beds with gravel	Cyan to blue
Clouds	White (neutral)
Cultivated fields	Red through neutral (depending on state of growth)
Growing hay fields	Red
Fallow fields	Neutral to cyan
Volcanic mountains	Black to gray
Rocks	Greens, brown, grays
Swimming pools	Turquoise-blue
Gray gravel	Neutral

3.2 EVALUATION OF SO-180 (INFRARED COLOR FILM)

3.2.1 Test Type

The aircraft-112B camera system was used for this test.

3.2.2 Test Objectives

Test objectives were as follows:

1. Compare SO-180 with SO-121 and 3404
2. Evaluate potential uses of SO-180 in the KH-4B camera system.

3.2.3 Test Details

Three flights were required for this analysis. Each flight was obtained at 65,000 feet which produced a scale of 1:33,000. The initial flight (GT-0077A-67) was used to investigate the question of detecting the launch of a missile, after the fact, with SO-180 used in one camera and 3404 in the other. This test involved flying over a missile complex before the launch and then with a repeated flight pattern over it for several hours after the launch. This flight line is given in Fig. 3.2-1. The specific camera settings for this and the two subsequent flights are given in Table 3.2-1. The second and third flights (see Fig. 3.2-2) were intended to allow a general comparison between SO-180 and SO-121-3404 films. These two flights were made on successive days over the same ground terrain, from San Francisco to Los Angeles following the San Andreas fault. The weather on both days was excellent, and well exposed, color-balanced, focused imagery was obtained.

3.2.4 Discussion of Figures

Infrared sensitive films provide information which is based on the spectral distribution of an object, i.e., its infrared radiation content. The information resulting from this form of radiation can help in detecting damage due to insect or fungus disease upon forest vegetation, in determining the health and condition of orchards and wheat crops, in tracing water courses, and in the evaluation of soil conditions.

Figs. 3.2-3 to 3.2-14 illustrate and compare the various results that can be obtained with SO-180 (infrared sensitive), SO-121 (normal color), and 3404 (high definition black and white) films.

One of the prime questions investigated in this test was whether or not activity around a missile launch could be detected with SO-180. A comparison was made of several samples of SO-180 infrared color film that were exposed over a period of time after a missile launch. Figs. 3.2-3 and 3.2-4 are the SO-180 and 3404 samples taken over the missile complex on the first pass after the launch. Comparisons of the successive flights failed to produce any noticeable change in the area that could be used as after-the-fact evidence of a vehicle launch. SO-180 showed no apparent change in the ecology or physical makeup of the launch area. The presence of water in the flone basket coolant catch basin and the position of the gantry away from the launch end of the complex were the only indicators of recent activity.

The next set (Figs. 3.2-5 and 3.2-6) shows a lake and its surrounding drainage pattern. The 3404 and SO-121 records are quite similar in spite of the green hue apparent in the vegetation. However, with SO-180, the overall green observed on SO-121 is recorded as variations in red saturation and brightnesses. This is indicative of live foliage. The variation in saturation is related to the IR absorption of each particular foliage type. The lake in this figure blends in with the background of the SO-121 and 3404 records; however, it is well delineated in the SO-180 record. This identical situation is apparent in Figs. 3.2-7 and 3.2-8. Again the 3404 and SO-121 fail to delineate and separate the shoreline from the wood area. However, the shoreline and the two bodies of water, as well as the wood areas, are readily apparent with SO-180.

Another case of color translation is presented in Fig. 3.2-9, which is an industrial area having a tidal zone with salt pan ponds. The red (SO-121) and the green (SO-180) enclosed areas are salt pans that change color as the salt content increases. Normally, the SO-180 records water as blue, while SO-121 records it as blue-green. However, since this area is reddish in reality, it is reproduced as green in SO-180 due to the color translation.

A pond and several areas of vegetation are hidden in the monochromatic rendition of the area of Fig. 3.2-10. The response of SO-180 accentuates both areas for easier detection.

Fig. 3.2-11 shows a suburban neighborhood. Of interest in this scene is the rendition of the various ground cover and foliage types on SO-121 and SO-180. On SO-121 the color is normal, while on SO-180 the false color increases contrast and separates paved areas from cultivated areas.

Infrared radiation is reflected from plant life and is dependent for the most part on the presence of chlorophyll. A disease attacking a tree often lowers the leaf's chlorophyll-producing function, resulting in a reduced reflectance of infrared radiation. The fruit tree in the middle of the orchard of Fig. 3.2-12 is apparently diseased since the color has shifted from the normal red (SO-180 rendition of foliage) to a purple color which is typical of a diseased or deteriorated vegetation.

The quarry operation depicted in Fig. 3.2-13 is well recorded on all three records. However, the SO-180 has enhanced the contrast and increased the delineation of the pond and the vegetation.

3.2.5 Results and Conclusions

1. SO-180 has a significant potential application in satellite reconnaissance.
2. SO-180 was not helpful in detecting the activity around a missile launch. No local changes in vegetation were observed.
3. SO-180 will not detect heat.
4. SO-180 has a potential for crop assessment. Examples were found where SO-180 clearly showed the differences between planted and fallow fields. Neither the high resolution black and white nor SO-121 showed these differences.
5. SO-180 has an obvious use in the detection of waterways. This may be potentially useful in urban areas to locate effluents associated with industrial plants and/or sources of pollution.
6. SO-180 is useful for rapid location of cultural areas. Once located, however, detailed interpretation is accomplished with 3404.

Table 3.2-1 — Specific Camera Settings for the Three SO-180 Flights

	AFT	FWD	AFT	FWD	AFT	FWD
Flight no.	GT-0077A-67 (EKIT flight no. 11)		GT-214-67 (EKIT flight no. 11A)		GT-217-67 (EKIT flight no. 11B)	
Camera	I3	I4	I7	I8	I7	I8
Film	SO-180	3404	3404	SO-180	SO-121	SO-180
Slit width	0.009 in.	0.075 in.	0.037 in.	0.009 in.	0.009 in.	0.009 in.
Exposure time	1/2,200 sec	1/300 sec	1/450 sec	1/2,200 sec	1/2,200 sec	1/2,200 sec
f/no.	3.5	3.5	3.5	3.5	3.5	3.5
Haze filter	W-15	W-21	W-21	W-15	W-2E	W-15
Color correction filter	—	—	—	—	—	30cc Blue
Date	14 January 1967		17 May 1967		18 May 1967	

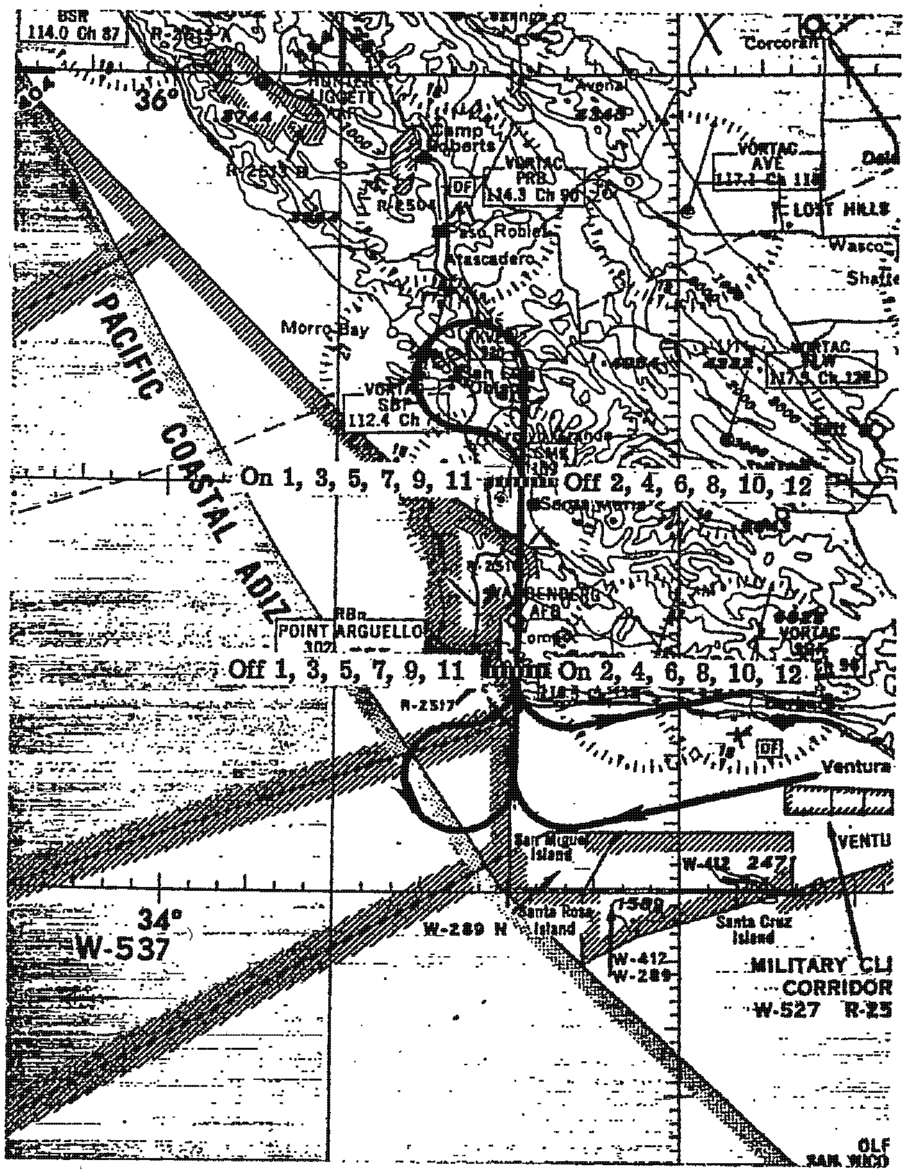


Fig. 3.2-1 — Flight lines for SO-180 evaluation coverage of Vandenberg AFB, California

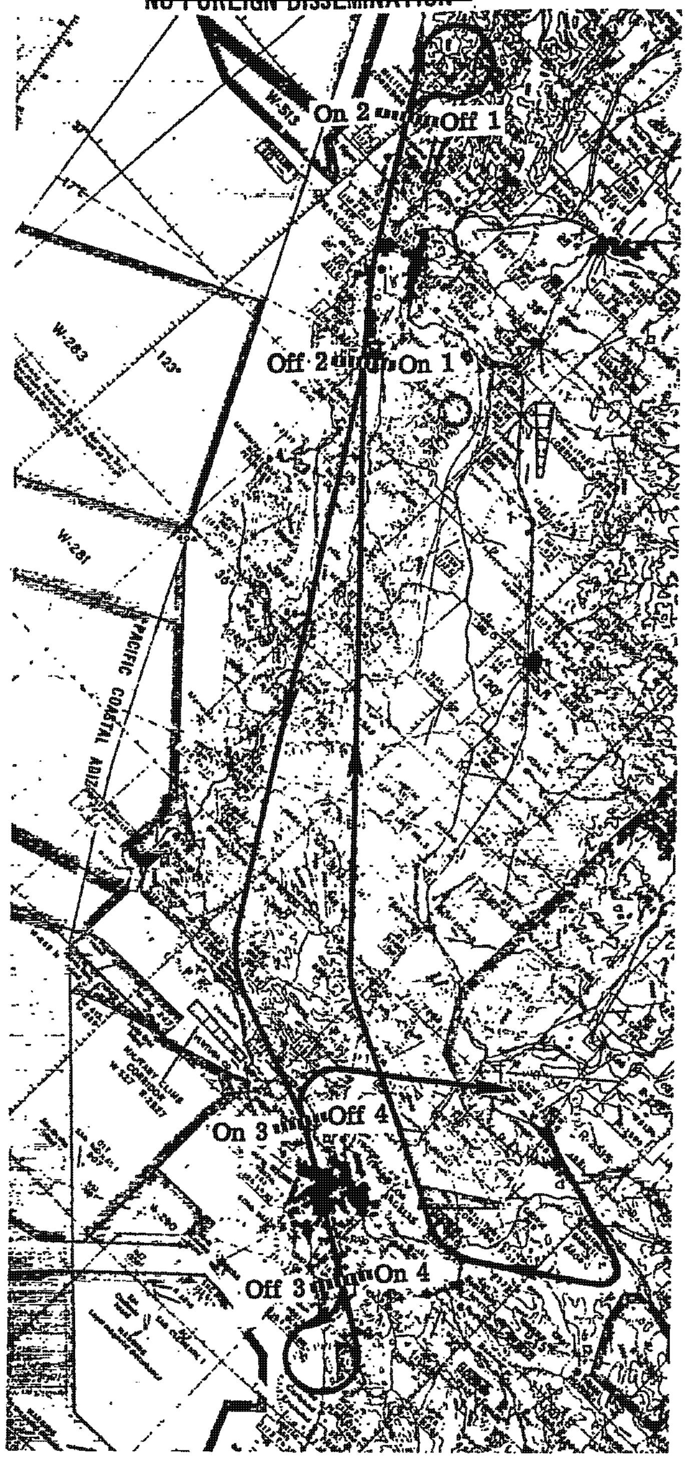


Fig. 3.2-2 — Flight lines for SO-180 evaluation coverage of Los Angeles and San Francisco, California

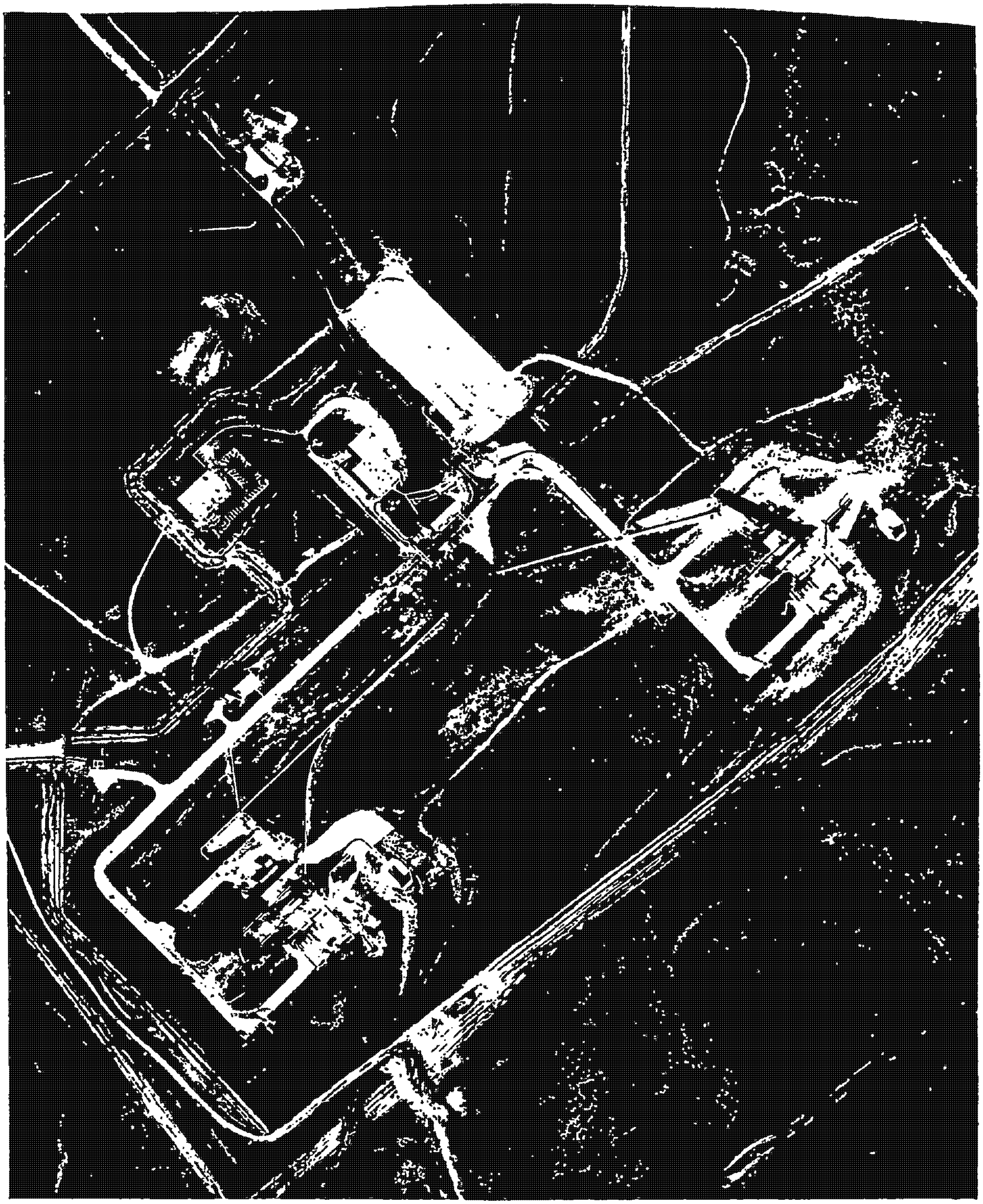


Fig. 3.2-3 — Missile launch complex after launch; 3404 film

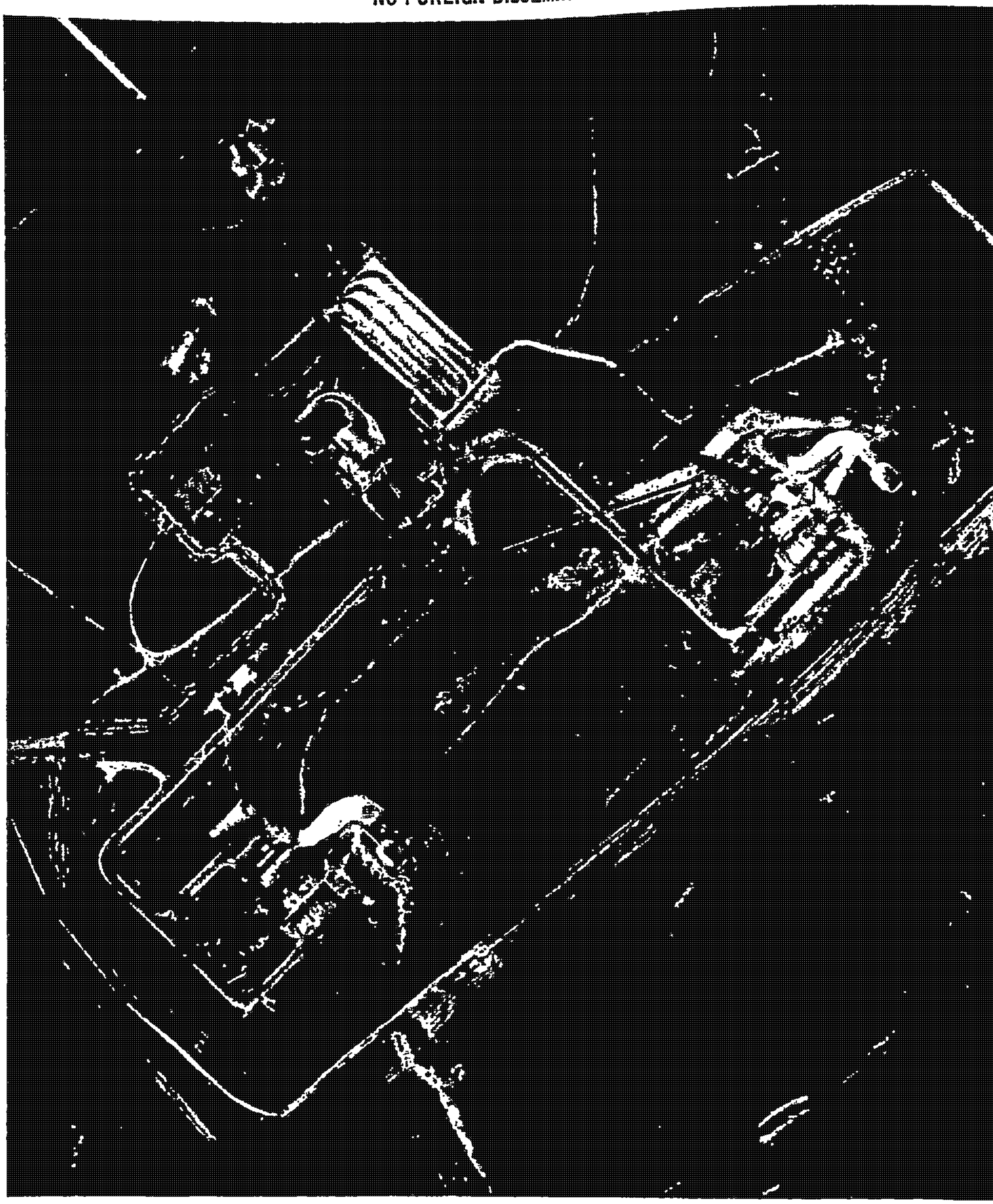
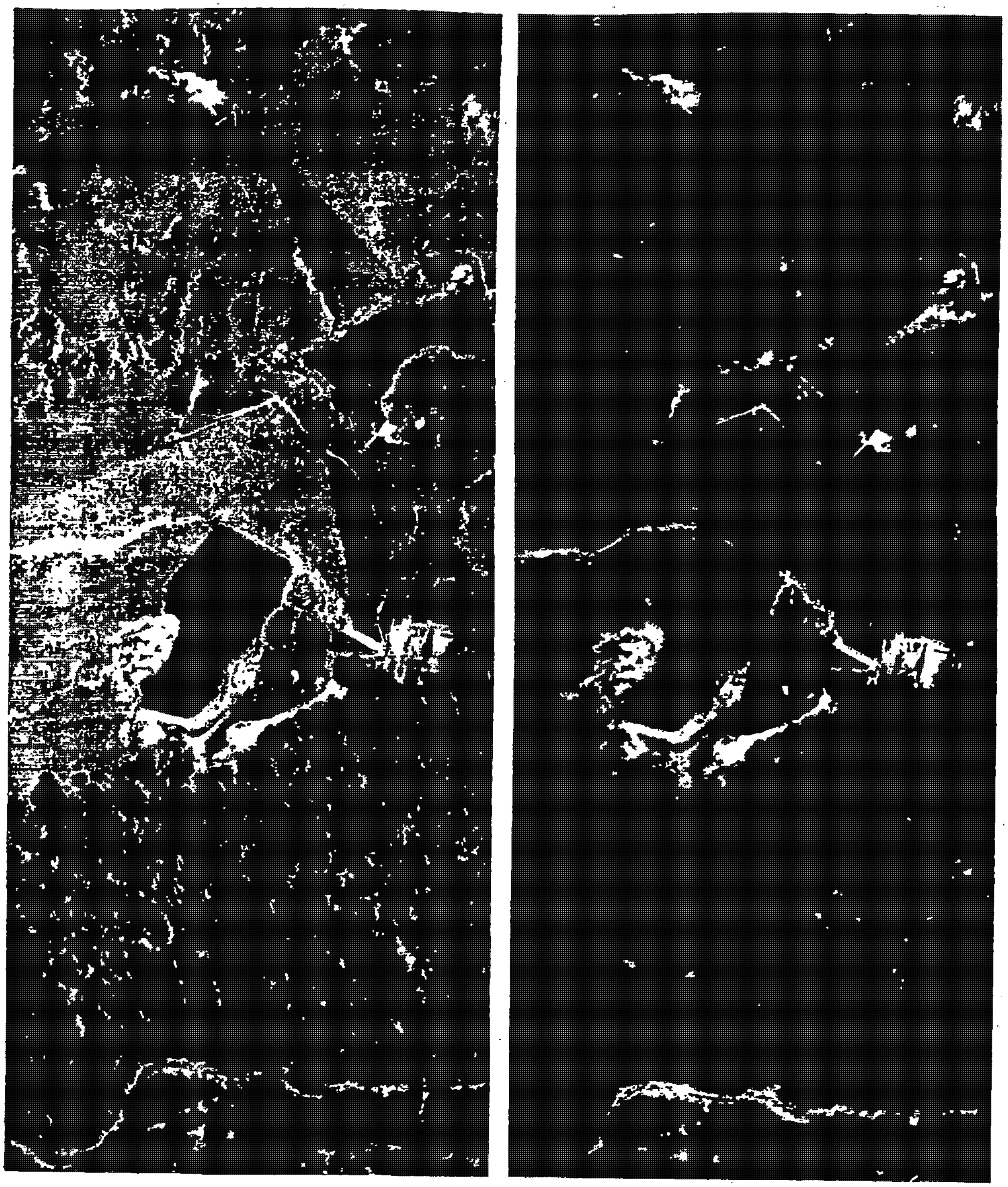


Fig. 3.2-4 — Missile launch complex after launch; SO-180 film

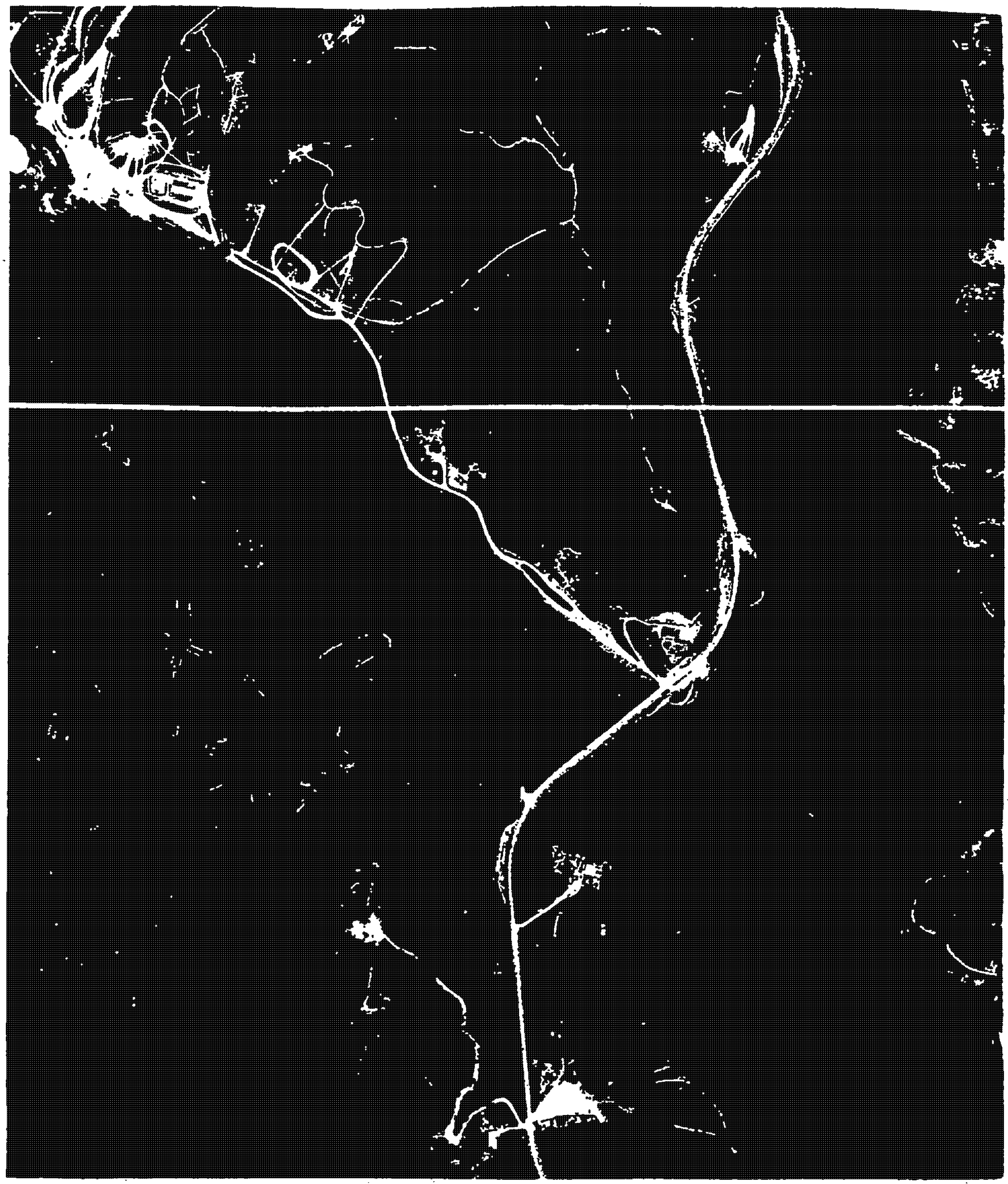
(a) 3404

Fig. 3.2-5 — Detection of lake and drainage pattern



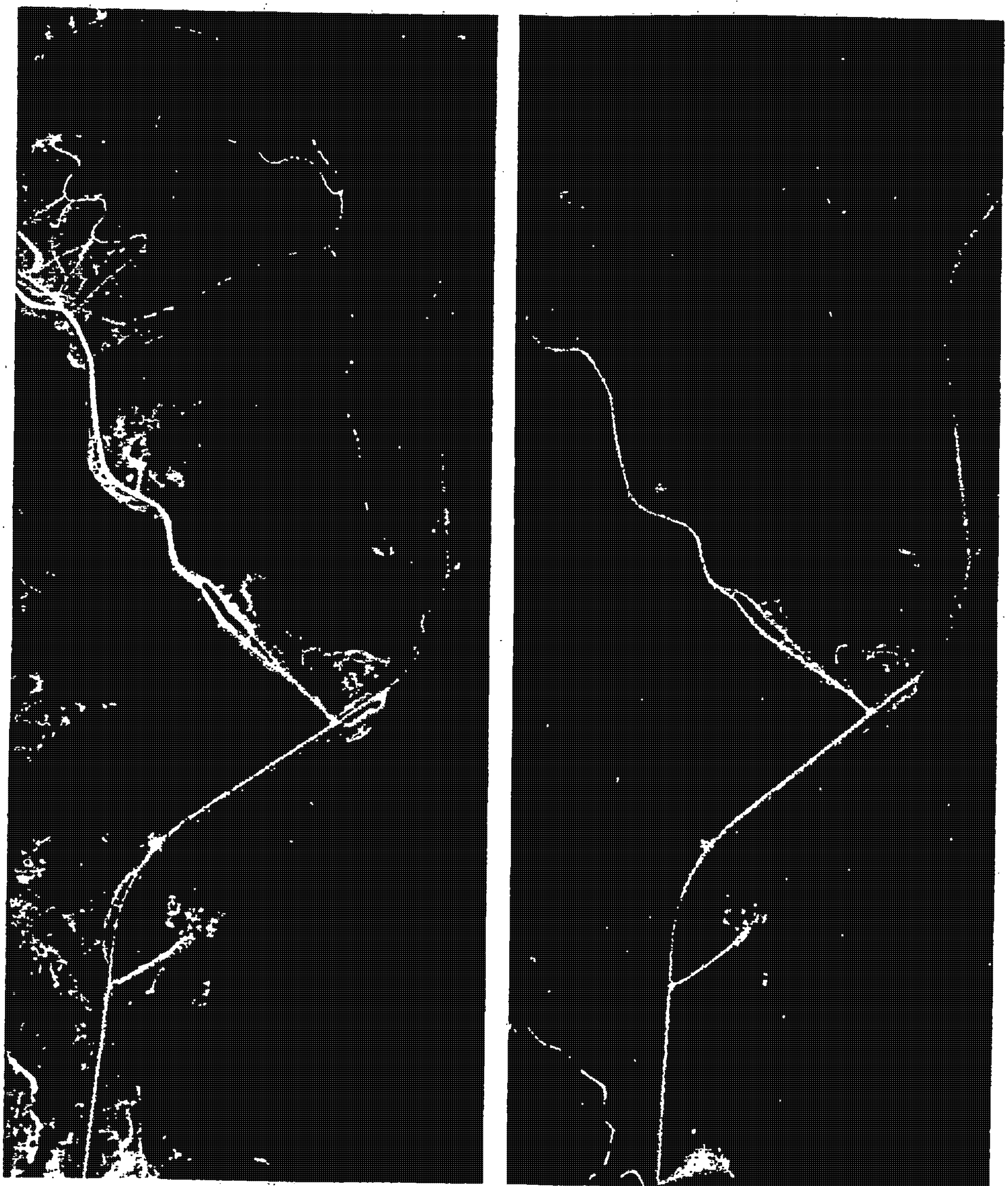
(b) SO-180 (c) SO-121

Fig. 3.2-6 — Detection of lake and drainage pattern (Cont.)



(a) 3404

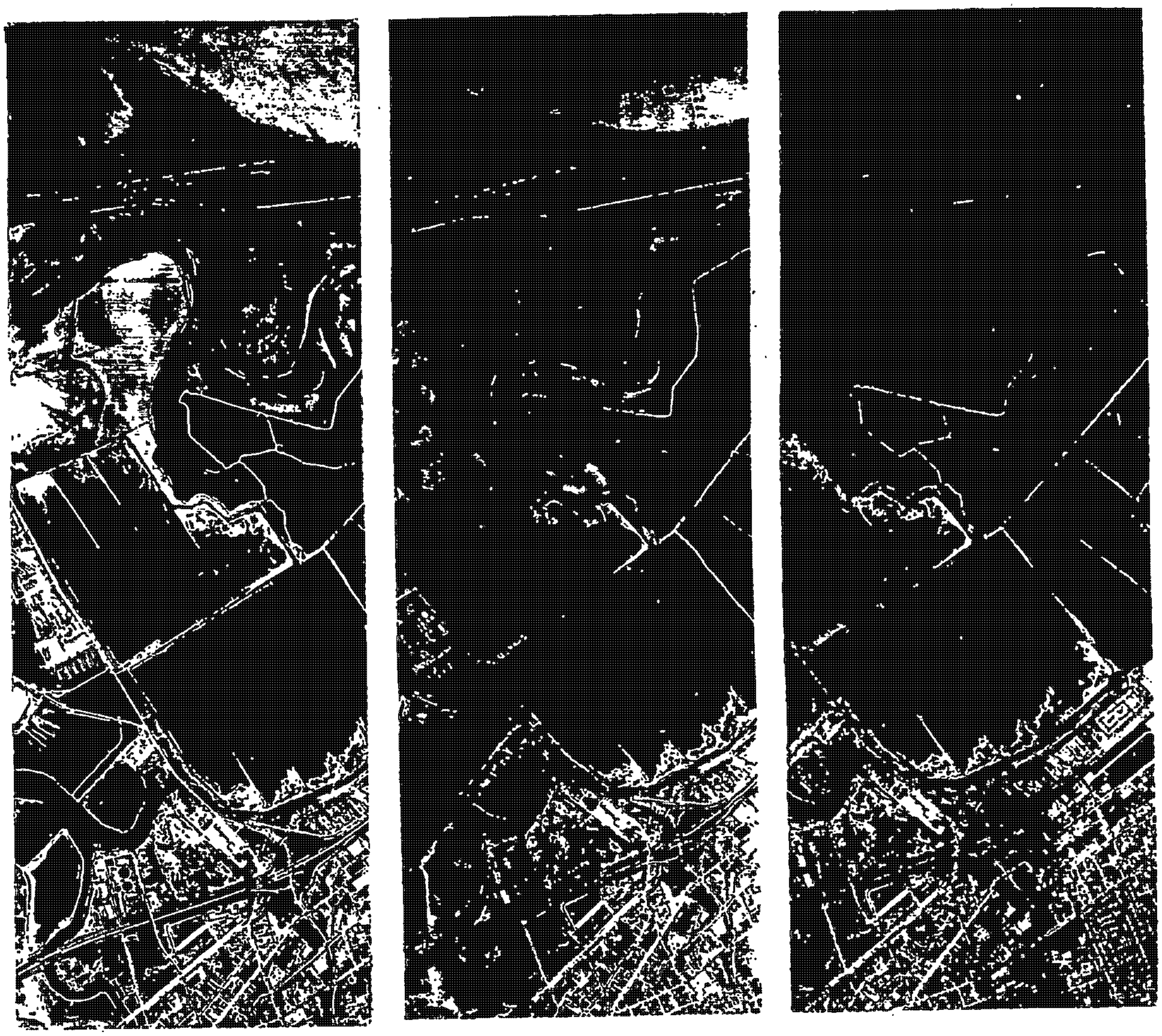
Fig. 3.2-7 — Delineation of reservoir shore line and stream



(b) SO-180

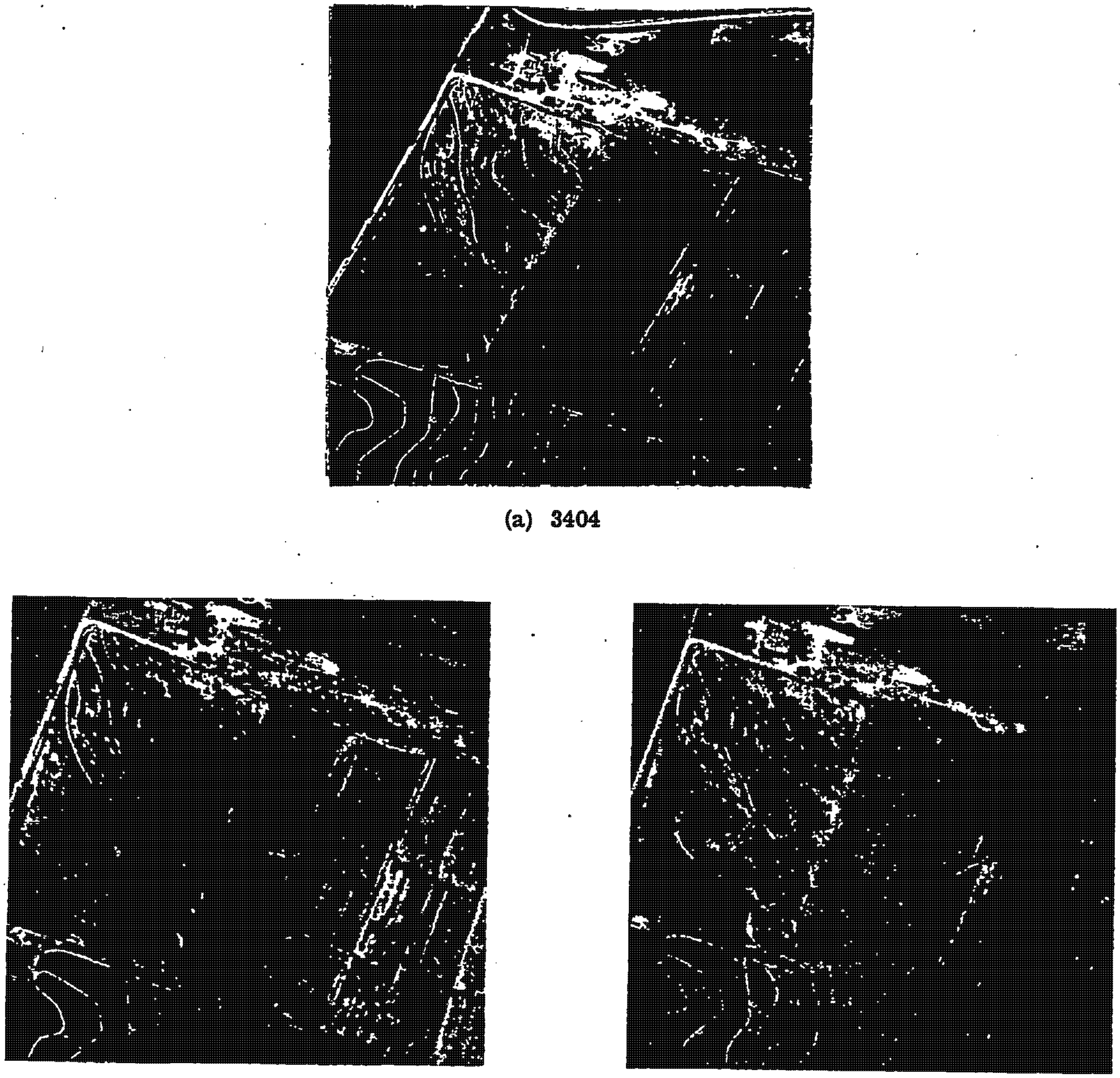
(c) SO-121

Fig. 3.2-8 — Delineation of reservoir shore line and stream (Cont.)



(a) 3404 (b) SO-180 (c) SO-121

Fig. 3.2-9 — Color translation of salt pans and contrast enhancement of the tidal zone and adjacent industrial area



(a) 3404

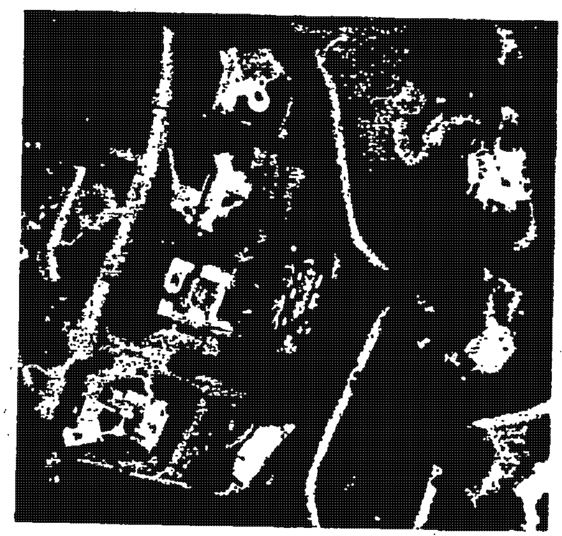
(b) SO-180

(c) SO-121

Fig. 3.2-10 — Presence of infrared reflecting chlorophyll and a pond in an otherwise monochromatic area

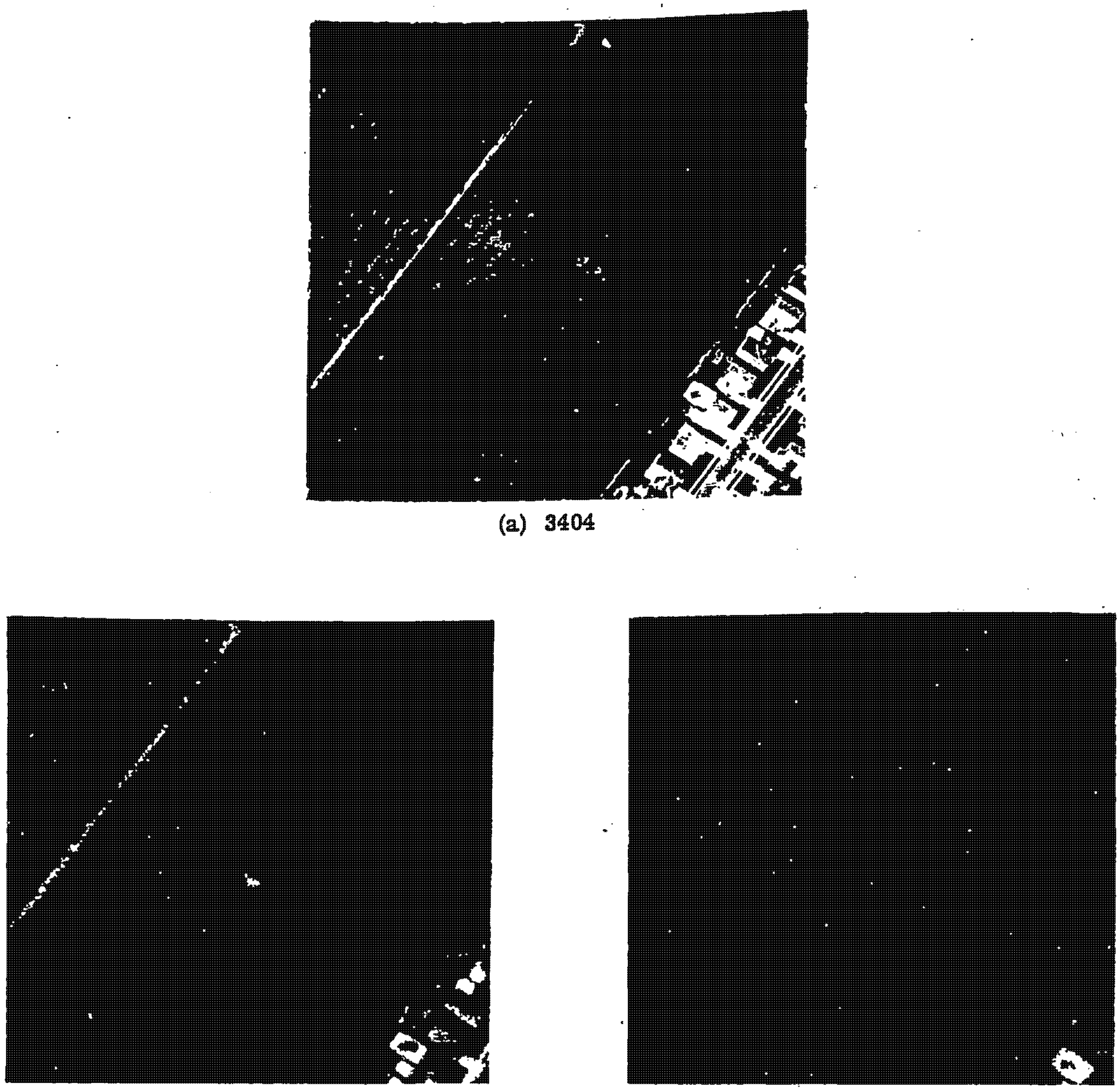
(a) 3404

(b) SO-180



(c) SO-121

Fig. 3.2-11 — Color contrast comparison and delineation of the various ground cover and foliage types



(a) 3404

(b) SO-180

(c) SO-121

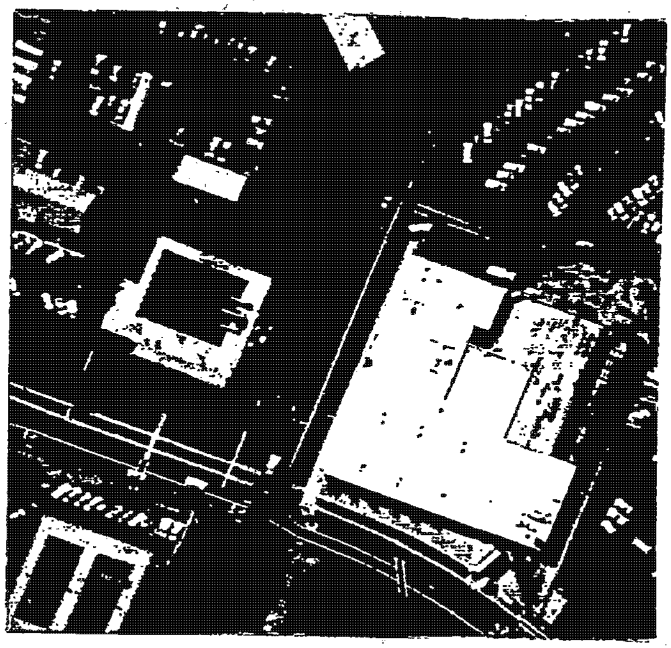
Fig. 3.2-12 — Detection of diseased fruit tree in a healthy orchard

(a) 3404

(b) SO-180

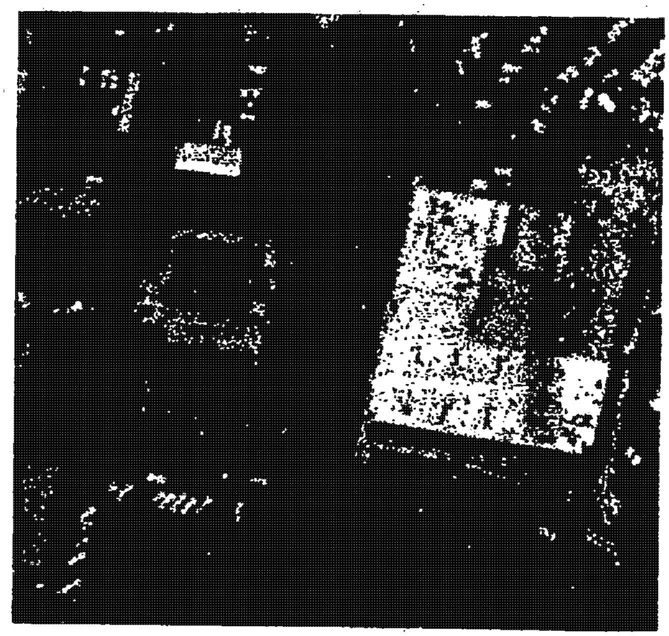
(c) SO-121

Fig. 3.2-13 — Color translation, vegetation delineation and contrast enhancement of a productive quarry



(a) 3404

(b) SO-180



(c) SO-121

Fig. 3.2-14 — Moffet Field recreation area

3.3 KH-4B SO-180 EVALUATION

3.3.1 Test Type

The satellite-KH-4B system was used for this test.

3.3.2 Test Objectives

The objectives of this test were:

1. To demonstrate the feasibility of using SO-180 in the KH-4B system under operational conditions
2. To acquire color translation records of specific targets for intelligence analysts.

3.3.3 Test Details

The KH-4B system used for this test provided 301 frames of SO-180 at an altitude of 80 to 90 nm, resulting in a scale of approximately 1:280,000. The total area of coverage therefore yielded approximately 40,000 square nautical miles of color coverage.

The SO-180 was exposed in the FWD-looking camera, and was spliced to the 15,200-foot principal study of 3404 film. A material change detector at the splice initiated a change from the Wratten no. 25 (red) filter for the 3404 to the special Wratten no. 15 (yellow) plus 0.9 neutral density filter for the SO-180.

During the final 38 revolutions of mission 1104, eight photographic passes were made with the SO-180 film, one over domestic territory (California) and seven more over denied areas. For a precise identification of ground tracks, see Figs. 3.3-1 and 3.3-2. Color photography began with frame 20 on revolution 199 and ended with frame 30 on revolution 236. Because of the increase in film thickness of SO-180 (3.9 mils) as compared with 3404 (3.0 mils), photographic coverage during passes D-215 and D-217 was obtained with the AFT-looking camera only. All color coverage was obtained with comparable black and white coverage from the other camera. The film was successfully recovered on 22 August 1968.

Imagery acquired on the SO-180 film (with comparative 3404 acquisition) of unique target/terrain features for color translation exploitation was sufficient to support critical evaluation. For this test purpose, the following acquisitions proved to be the most valuable:

1. D-200 covering south China and north Vietnam in two operations
2. D-201 covering the Soviet Union in the north at the Ob River estuary and in the south at Lake Balkhash, also a two-operation pass
3. D-203 covering the Soviet Crimea and Israel-Jordan in two operations
4. D-210 covering California from Monterey to the Santa Barbara Channel islands in one operation.

Considerable variations in climate, geographic location, and cultural difference are included in the areas observed. Semideciduous tropical forests, scant population, and numerous rivers were apparent in pass D-200. The arctic tundra, middle latitude steppes, and mountains with extensive glaciation were covered in pass D-201. The fertile Crimea, the populated coast of Israel and the deserts of southern Jordan and Israel were shown in pass D-203. Pass D-210 covered the

California coast, a well populated area which contained many items of military interest. The wooded cover is primary Mediterranean scrub forest. Thus, sufficient material was available for a detailed evaluation of SO-180.

3.3.4 Discussion of Figures

Figs. 3.3-3 and 3.3-4 show 1.5× enlargements of a mineral deposit washout. Several areas of the Sinai Desert provide SO-180 film with unique signature characteristics. On 3404 film, a slight tonal difference is detected in the outwash area. With SO-180, this identical area is translated into color differences capable of separating parent rock structure from mineral outwash. The hue is recorded as yellow on the record; however, it would translate itself to red-orange on the original.

Figs. 3.3-5 and 3.3-6 show 10× enlargements of Lompoc, California. This area is a recognized seed-growing community with large cultivated fields undergoing various stages of growth. Both the 3404 and SO-180 films recorded cultivated fields at various stages of growth quite clearly.

Figs. 3.3-7 and 3.3-8 show a number of interesting features of Chinese river drainage. Of particular interest are the confluence of main and tributary streams. Each reflects different sediment loads. The added dimension of color increases the interface characteristics of the streams. It also indicates through color translation that the tributary flow is below the surface of the main stream.

The south end of the Dead Sea is divided by dikes into areas used for the extraction of chemical salts by evaporation. Both the black and white and color records make unique contributions of information. The 3404 (Fig. 3.3-9) details the physical structure of the retaining walls, canals, processing plant, and even the patterns of rake marks in the shallower areas. SO-180 (Fig. 3.3-10) shows the presence of water with greater certainty and the low incidence of vegetation in the area.

The vivid multicolor responses noted on SO-180 when photographing salt pans in other areas are noticeably absent in the Dead Sea items. The colors are biologically produced by plankton sized plants or animals that have a tolerance to and thrive in the warm, shallow waters. Because of the excessive salinity and other factors, the Dead Sea is barren of all life forms except a few small fish found at the north end where there is a fresh water influx from the Jordan River.

3.3.5 Conclusions

1. Despite the limited footage, extensive cloud cover, and severe corona fogging, a reasonable amount of excellent imagery was acquired on the SO-180 material. Portions of the SO-180 imagery obtained on this mission closely approximate the expectations of this lens-film combination.

2. Despite the poorer image quality of SO-180 as compared with the 3404 film, there are instances in which the SO-180 record contains color translation information that is absent on the 3404 comparative coverage.

3. Acceptable exposure and color balance for summer illumination conditions were achieved on the SO-180 portion of mission 1104.

4. The cyan cast on initial footage of SO-180 was a result of a speed loss in the infrared sensitive layer induced by exposure to vacuum during long sit periods.

5. Electro-static discharge fogging was caused by a failure in the regulator of the CR-4 PMU that generated an internal camera pressure above the 20-micron window for SO-180. However, not all the static fogging was detrimental to information extraction. There are instances where low level fogging enhances vegetation information content.

6. There is higher potential in the mission 1104 SO-180 records for economic intelligence and earth resources than for military intelligence.

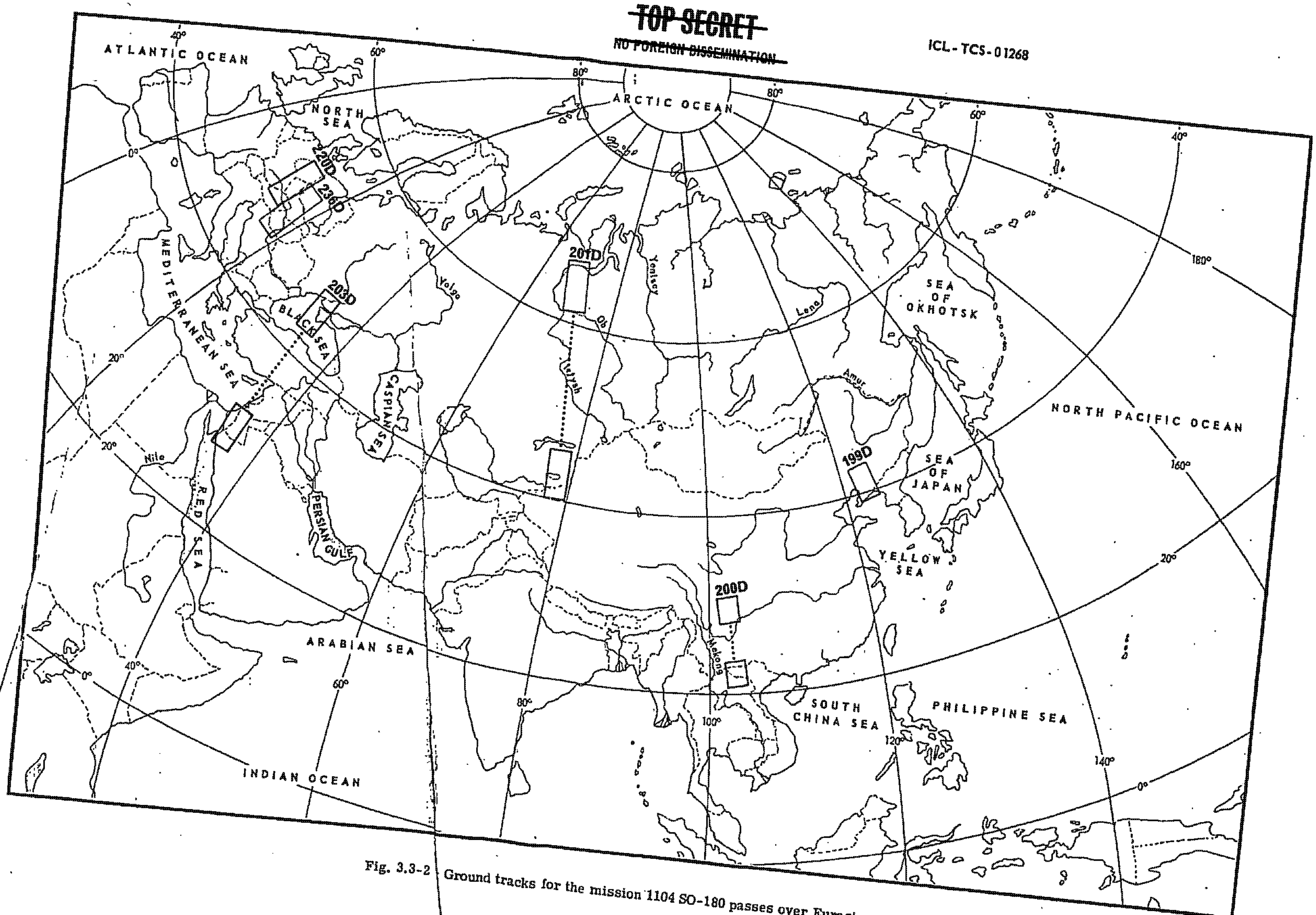


Fig. 3.3-2 Ground tracks for the mission 1104 SO-180 passes over Eurasia

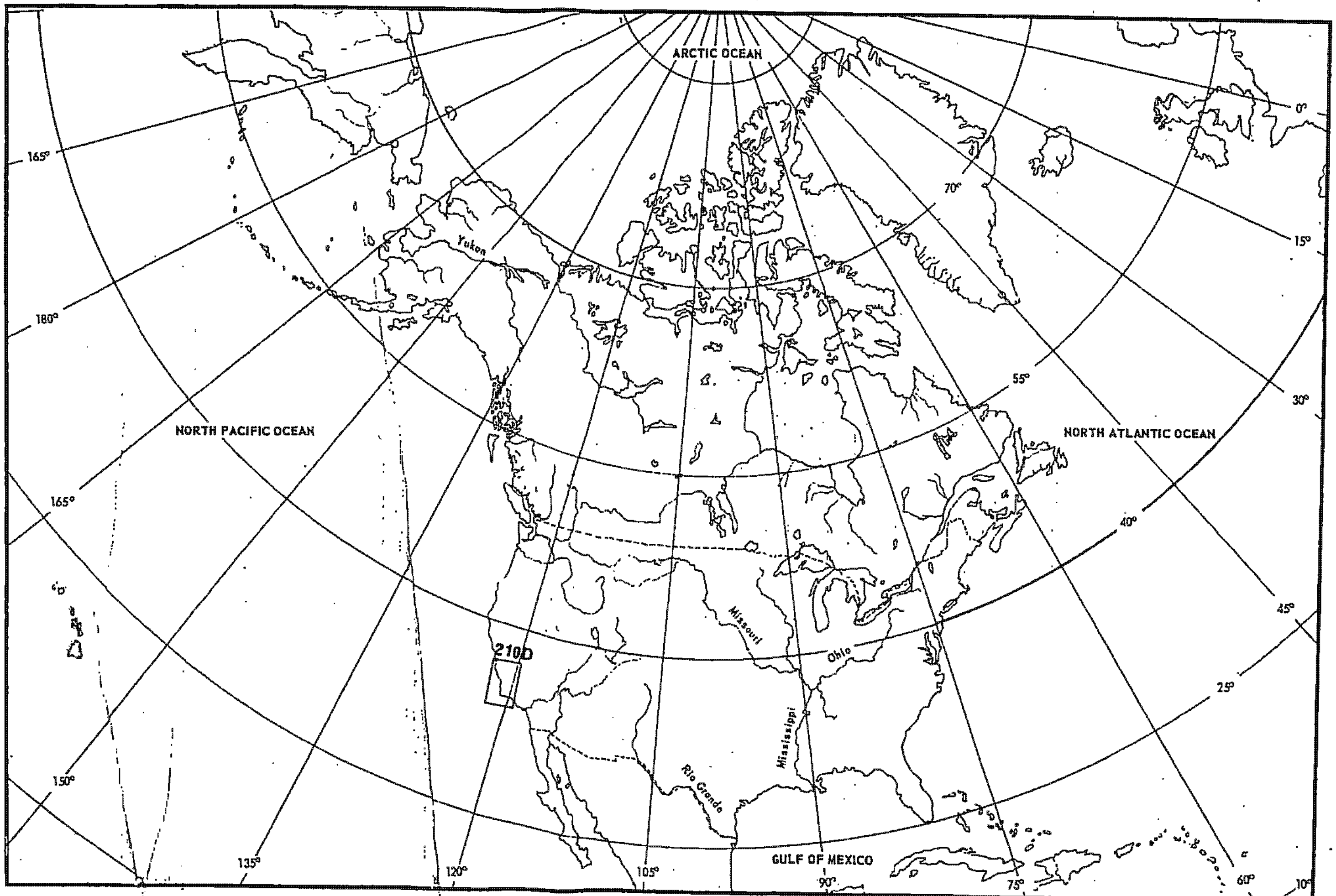


Fig. 3.3-1 —Ground track for the mission 1104 SO-180 pass over the United States

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Fig. 3.3-3 — 1.5× enlargement of a mineral deposit washout from the AFT-looking camera of mission 1104 using 3404 film

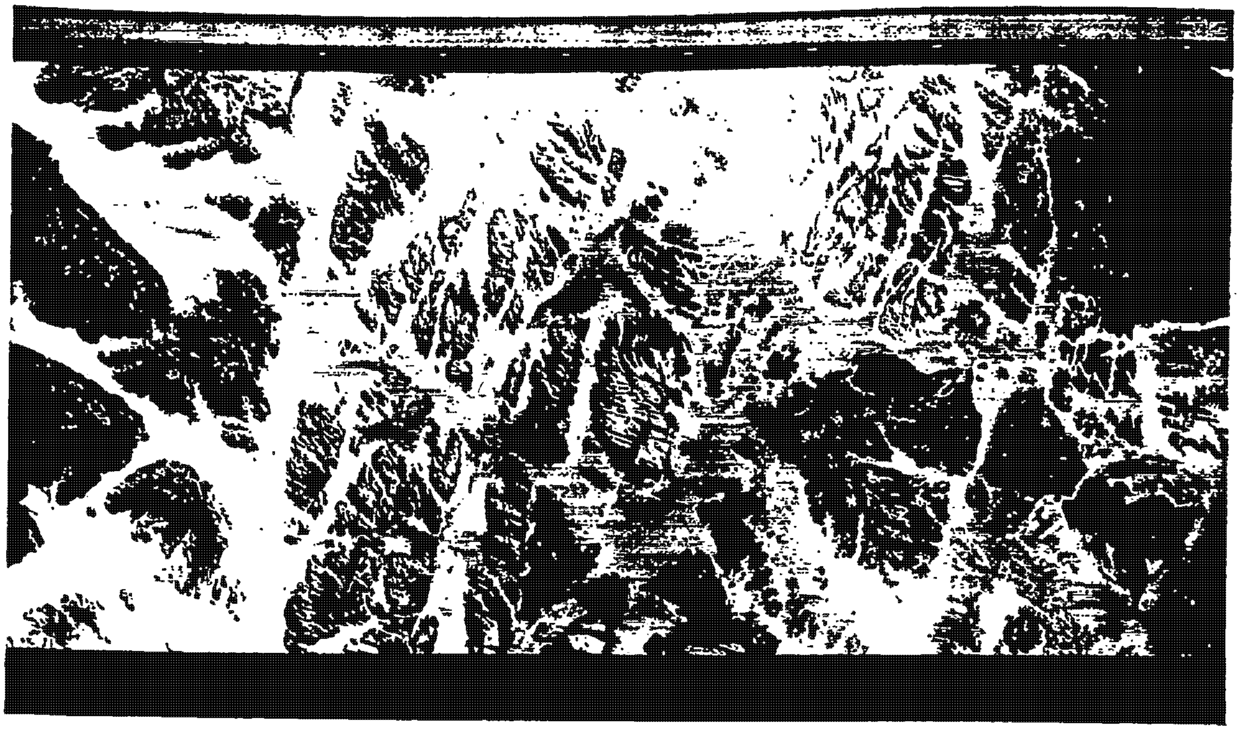

Fig. 3.3-4 — 1.5× enlargement of a mineral deposit washout from the FWD-looking camera of mission 1104 using SO-180 film

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Fig. 3.3-5 — 10× enlargement of Lompoc, California from the AFT-looking camera of mission 1104 using 3404 film

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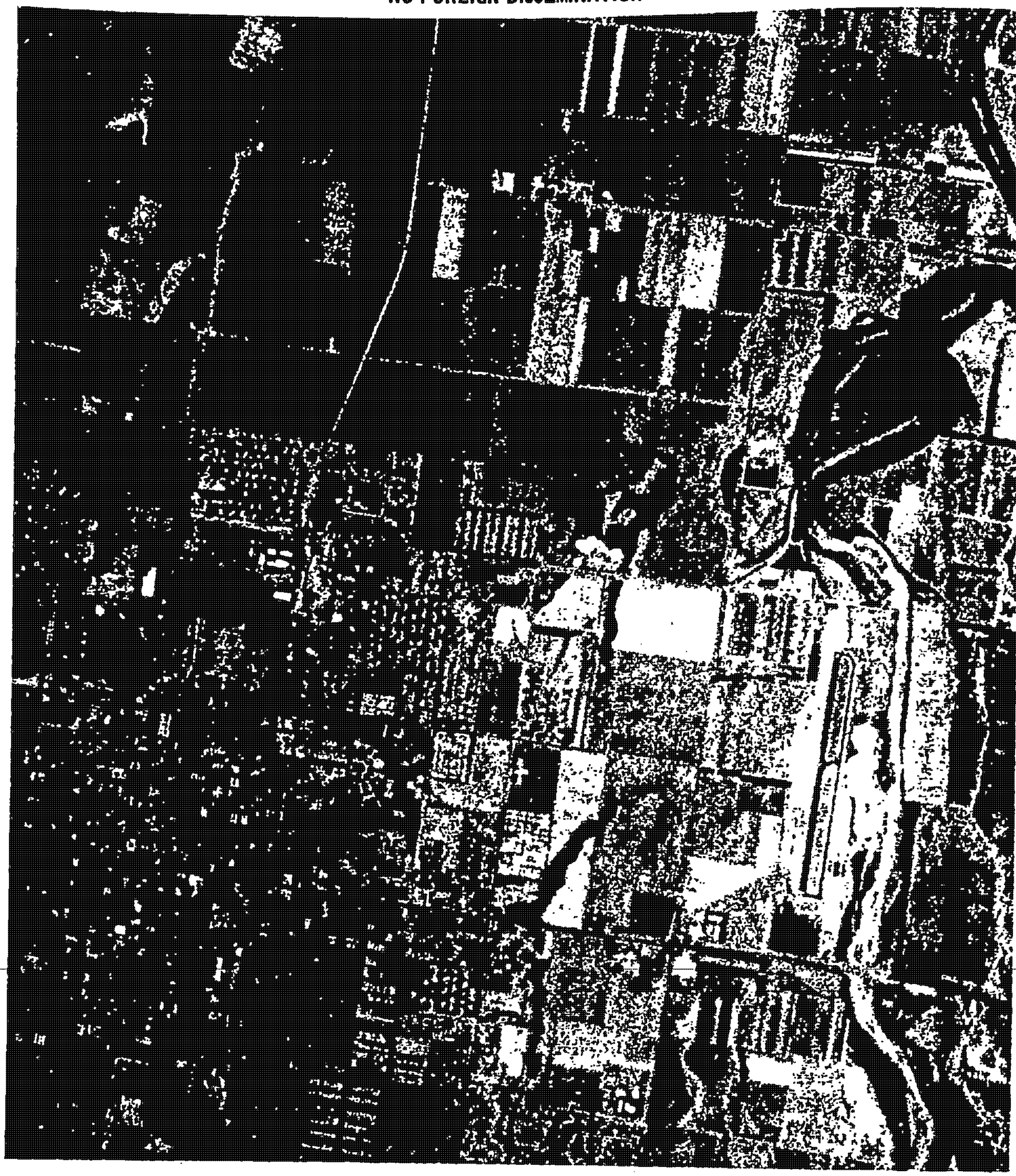

Fig. 3.3-6 — 10× enlargement of Lompoc, California from the FWD-looking camera of mission 1104 using SO-180 film

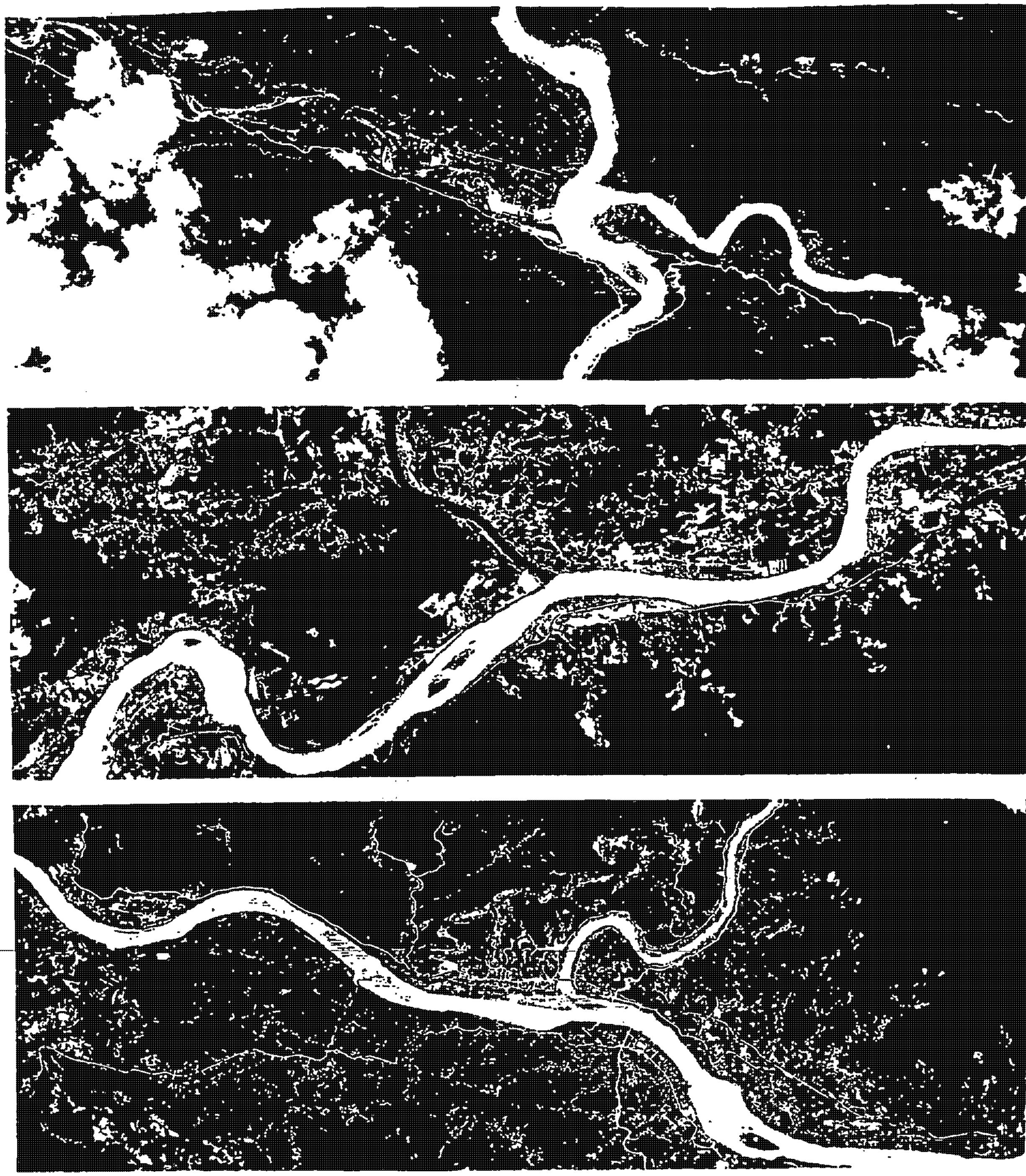

Fig. 3.3-7 — 5× enlargement of river intersection from the AFT-looking camera of mission 1104 using 3404 film

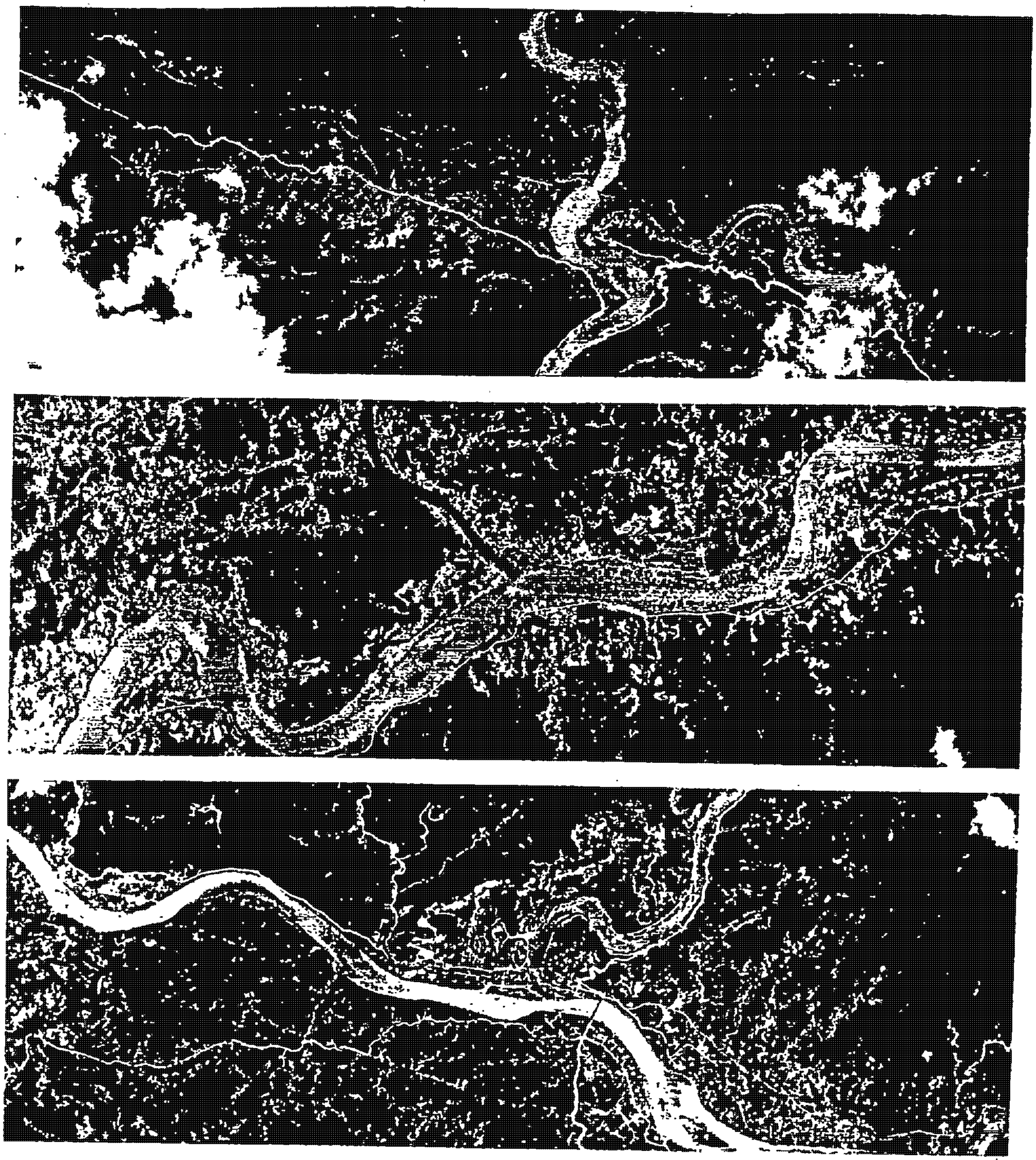

Fig. 3.3-8 — 5× enlargement of river intersection from the FWD-looking camera of mission 1104 using SO-180

Fig. 3.3-9 — 7× enlargement from 3404 record showing mineral-salt evaporation facility located on southern end of Dead Sea, Israel (mission 1104-2, FWD camera)

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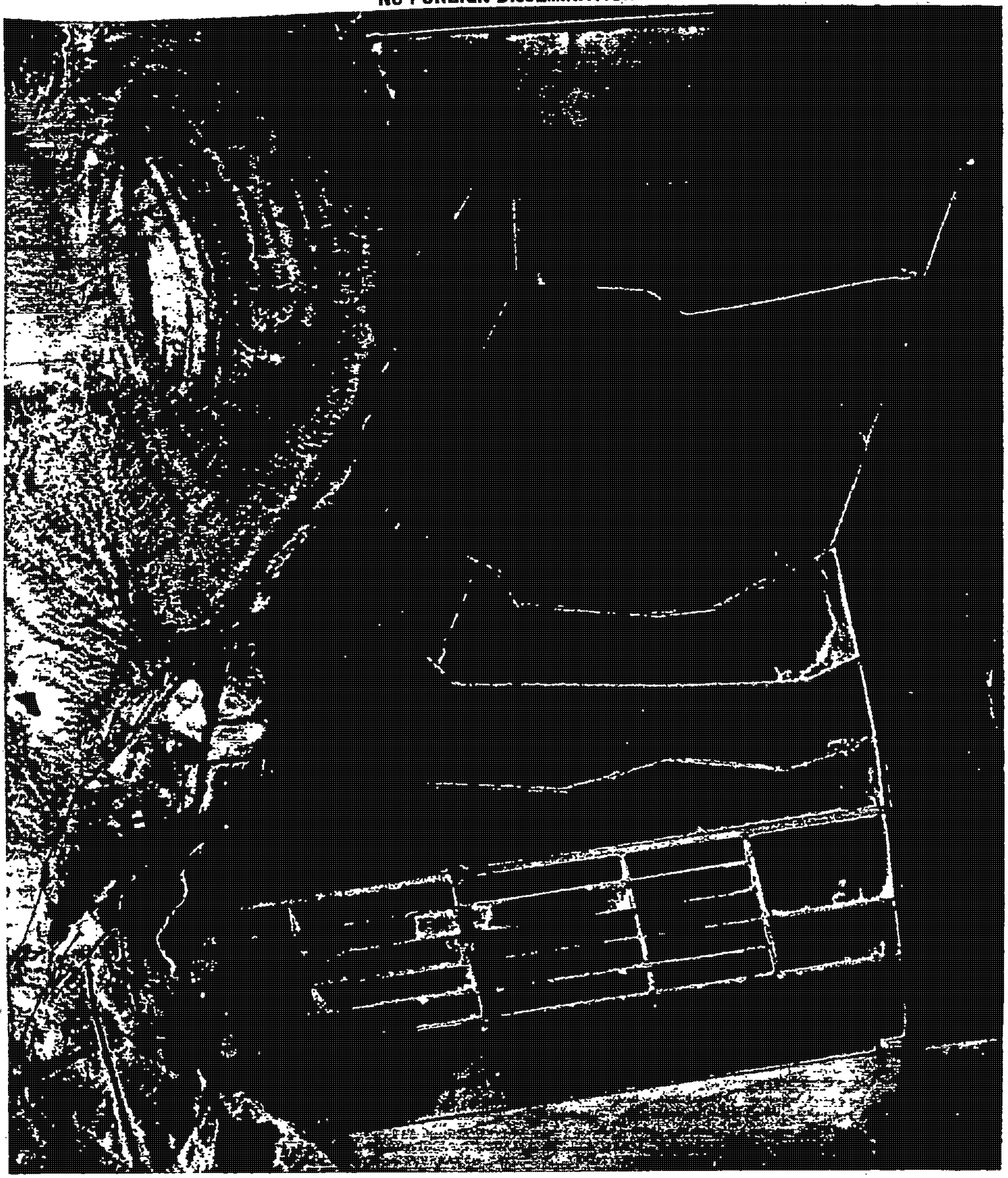

Fig. 3.3-10 — 7× enlargement from SO-180 color record showing mineral-salt evaporation facility located on southern end of Dead Sea, Israel (mission 1104-2, AFT camera)

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Notice of Page Substitution

4. BI-COLOR

For the purposes of electronic archiving, this page is a substitute for an unscannable page.

4.1 TECHNICAL DISCUSSION

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 KH-4B camera system are examined.

4.1.1 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 tri-pack. 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 each separately exposed through the appropriate filter. This process is called tri-color 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 KH-4B cameras provide a stereo pair with a 30-degree convergence angle at the center of format. However, the stereo pair presents some difficulties in the exploitation process. In order to obtain the required negatives for bi-color photography, the in-flight filter switching capability is used. The FWD-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 using elementary color printing techniques. The rectified or orthoprinted positive images for both the FWD- 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 done, a bi-color print 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.

4.1.2 Advantages and Disadvantages of Bi-Color

There are several advantages afforded to the KH-4B 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 KH-4B 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 lens was designed for a Wratten no. 21 filter. 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 geenration 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 listed below.

Advantages

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.

Disadvantages

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.

4.2 EKIT BI-COLOR

4.2.1 Test Type

The aircraft-112B camera system was used for this test.

4.2.2 Test Objectives

Test objectives were as follows:

1. Test the feasibility of obtaining bi-color photography from a panoramic, stereo camera system.
2. Explore the problems in providing hard copy bi-color images.

4.2.3 Test Details

The photography for this test consisted of three flights over the Fresno, Bakersfield, and Long Beach areas on 5 August 1966, 23 May 1967, and 24 May 1967, respectively. The flight lines are shown in Fig. 4.2-1.

The 112B system was flown using 3404 film, with a Wratten no. 25 filter on one camera and a bi-color filter on the other. The altitude was 65,000 feet, providing a scale of 1:33,000. This first flight was to provide the necessary imagery for the complete test; however, it became evident that additional imagery was required, so two additional flights were flown, one with 3404 film and one with 3404/SO-230 films. Table 4.2-1 contains specific camera details for EKIT flight nos. 2, 2A, and 2B.

The resulting negatives were rectified and orthoprinted (separately) by the Aeronautical Chart and Information Center. The images were then additively printed on the Additive Color Viewer Printer (ACVP) to obtain bi-color prints. Later prints (Figs. 4.2-2 and 4.2-3) were orthoprinted from enlargements and then contact printed using a pin register board. The resultant quality with this technique was far superior to the 1:1 orthoprints. In addition, a subjective analysis was performed on the negatives to determine any loss in system resolution resulting from the use of a Wratten no. 57 filter with a second generation Petzval lens.

4.2.4 Discussion of Examples

Figs. 4.2-2 and 4.2-3 show examples of the red and green record orthoprint images and the combined bi-color print that was made from these orthophotographs. The orthoprint from the red filtered negative has higher contrast than the one from the green record. In general, the Wratten no. 25 (red filter) record exhibits more information content than the Wratten no. 57 (green filter) image. However, there are many areas where it is an advantage to have the lower contrast afforded by the green filter.

It has been found from this test that the best method to date for obtaining a hard copy color print with the bi-color technique is to make 10×, 20×, or 40× enlargements (20× enlargements in Fig. 4.2-2) and then make 1:1 orthoprints. At these magnifications, the scan lines, although immediately visible, do not severely interfere with the ground detail. There is some loss in image quality, but this loss does not affect the larger areas that show the color.

One must be careful in interpreting the color from this type of bi-color photography. Exact color rendition is not achieved (nor is it achieved with conventional color films at high altitude) due to the two-component nature of this photography. There is, however, the distinct advantage of reducing the atmospheric haze effects by eliminating the blue portion of the spectrum. Conventional color films are severely limited by the prevailing atmospheric hazelight.

4.2.5 Results and Conclusions

1. Color photography can be obtained from this type of panoramic photography using standard black and white film as the original negative material. The color is not as accurate as in normal color reversal material due to the two-component nature of the bi-color system. Although reversal color films can produce full color at ground levels, they also are limited at high altitudes due to the prevailing atmospheric haze. The fact that bi-color 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 stereo convergence of the cameras. Neither rectification nor orthoprinting eliminates the recorded stereo effect of a single small ground object. This misregistration is shown by color fringing and will tend to disappear at smaller scales when the ratio of the misregistration to ground resolution is more favorable. Orthoprinting, however, removes all of the distortions except those due to small structures such as buildings.

3. The image quality of the original negative produced with the Wratten no. 57 green filter is somewhat lower than that of the Wratten no. 25 filter with the 112B camera lenses. This difference is so small that it was not measured with the MTF-AIM technique, but was observed by subjective analysis.

4. The effect of haze can be more easily controlled in bi-color 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.

Table 4.2-1 — Specific Camera Details for EKIT Flight Nos. 2, 2A, and 2B

	GT-270-66 EKIT Flight No. 2		GT-222-67 EKIT Flight No. 2A		GT-224-67 EKIT Flight No. 2B	
Camera	Master (I3)	Slave (I4)	Master (I7)	Slave (I8)	Master (I7)	Slave (I8)
Film	3404	3404	3404	3404	SO-230	3404
Filter	Wratten no. 44A + 2E*	Wratten no. 21	Wratten no. 57	Wratten no. 25	Wratten no. 57	Wratten no. 25
Slit width	0.049 in.	0.049 in.	0.150 in.	0.075 in.	0.075 in.	0.075 in.
Exposure time	1/400 sec	1/400 sec	1/125 sec	1/250 sec	1/250 sec	1/250 sec
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	1808 to 2127Z		1728 to 1847Z		1729 to 1848Z	
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 flight was seriously underexposed due to the high filter factor (on the order of 12 to 15) of the Wratten no. 44A filter. In addition, the images were not at all sharp due to the lens performance in the blue-green portion of the spectrum. On the remaining flights, the Wratten no. 57 filter was substituted for the Wratten no. 44A. This provided sharp images and the filter factor was more reasonable, being approximately 5 ½ to 6.

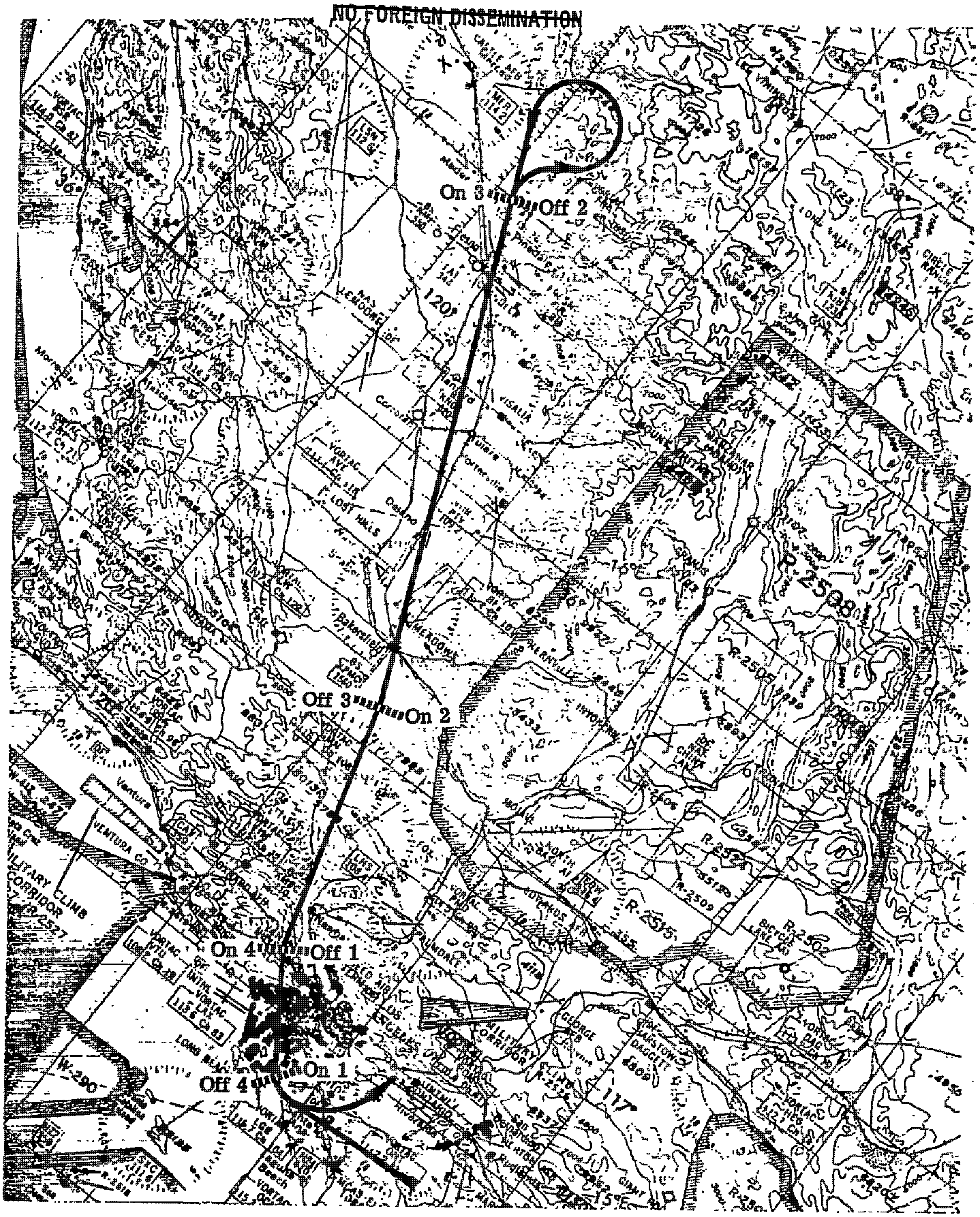
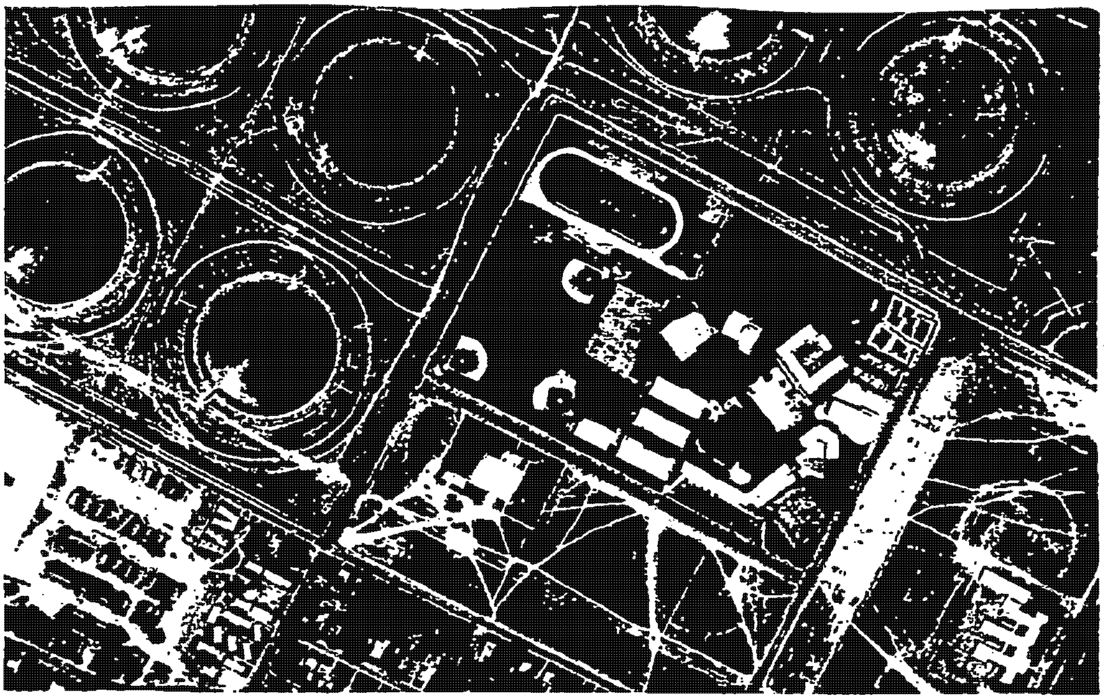
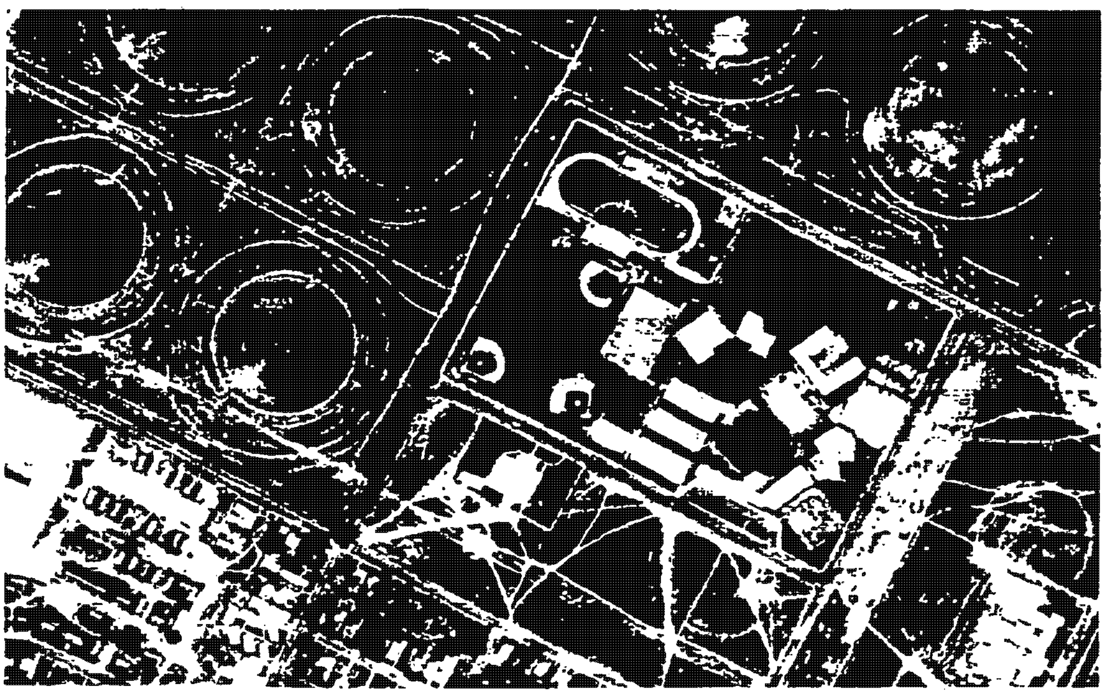


Fig. 4.2-1 — Flight lines for bi-color coverage of Fresno and Bakersfield, California



(a) 20× orthoprint from red filtered negative



(b) 20× orthoprint from green filtered negative

Fig. 4.2-2 — Oildale, California, 20× orthoprints

Fig. 4.2-3 — 20× bi-color integration made from green and red orthoprint records

4.3 KH-4B BI-COLOR EVALUATION

4.3.1 Test Type

The KH-4B system was used for this test.

4.3.2 Test Objectives

Test objectives were as follows:

1. Obtain, for the first time, satellite color photography through the bi-color mode.
2. Test the compatibility of the bi-color technique with the entire collection and exploitation process.
3. Deal with any problems and recommend the best method for obtaining useful bi-color photography with the KH-4B reconnaissance system.

4.3.3 Test Details

The photography for this experiment was obtained from the KH-4B System at an altitude of 80 to 90 nm, thus providing imagery at a scale of approximately 1:280,000. This experiment was performed on eight passes. of mission 1102; seven of these passes were flown over domestic areas, and one was flown over the Soviet Union. During each bi-color operation, the FWD-looking camera employed the Wratten no. 25 red filter, and the AFT-looking camera employed the SF-05 green filter.

Conventional gelatin-dye filters have high filter factors in the blue-green spectral region. In order to obtain a green filter that had an acceptable filter factor for this test, a special dichroic coating on glass was employed. This filter, which visually appears as a "bright" Wratten no. 57 filter, has a filter factor of 2.8.

Poor weather conditions prohibited photographing several domestic nuclear production facilities; however, several other target areas in the United Sates proved to be very useful, a most dramatic example being the copper slurry located near Bisbee-Douglas, Arizona. The ground tracks for the domestic bi-color passes are shown in Fig. 4.3-1; the single overflight pass is shown in Fig. 4.3-2. During each of these passes, the alternate filter (SF-05) of the AFT-looking camera was commanded into position. The photography was, therefore, acquired with both green (AFT-looking) and red (FWD-looking) filters. At the end of these passes, this alternate filter was replaced by the primary filter, and the mission continued normally.

Following acquisition, the bi-color process must work properly in the synthesis stages; i.e., it must be possible to correct distortion between the stereo pairs in order that suitable bi-color prints can be reproduced. The initial testing to correct these distortions took place at ACIC using two pieces of equipment: (1) the Itek Gamma I Rectifier, and (2) the Bendix AS-11C Orthoprinter. Sample photography was taken from the 1102 bi-color and printed on these two instruments. The AS-11C is an electro-optical device which is capable of removing the relief type distortions introduced by local ground elevation changes as well as correcting the distortions introduced by the camera geometry. The Gamma I has the capability of removing only the camera-induced distortions and was found to be unsuitable for bi-color application. After the orthoprinting techniques were worked out at ACIC, the images were printed into bi-color images with somewhat conventional color printing materials.

4.3.4 Discussion of Figures

Figs. 4.3-3 and 4.3-4 are from prints made from rectified positives. This scene was chosen as a test case for very tall structures, the vertical assembly building being more than 400 feet in height. As can be seen in the two black and white prints (Fig. 4.3-3) the two cameras "look at" different sides of the building. Thus, even the rectification process could not correct this aspect of the photography for the superimposition required for making a bi-color print. However, the relatively flat ground scene around the building is in fairly good register. The next figures (4.3-5 and 4.3-6) have a somewhat more reasonable registration. This was accomplished with the orthoprinter, which incidentally introduces the scan lines. The scene is representative of good color balance for bi-color photography. Note, however, that there still exists color fringing around manmade objects that have abrupt changes in height over a short distance. The final samples from this mission (Figs. 4.3-7 and 4.3-8) are of a copper mine slurry. This area has reproduced with quite a startling color pattern which is related to the copper deposits and the copper sulfate around the surrounding area. In Fig. 4.3-8, there is also a color distortion, when cloud and cloud shadow have been recorded differently with the two different look angles of the FWD- and AFT-looking cameras. In one area it is reddish, and in the other it is somewhat cyan. Although there is some color distortion in this sample, it does give the necessary supporting clues toward identification of the process involved at this location.

4.3.5 Results and Conclusions

1. Bi-color photography can be successfully acquired with the KH-4B system.

2. Satisfactory green filters can be produced for the operational acquisition of bi-color photography. These filters are dichroic coatings on thin quartz that have substantially lower filter factors than normal green dye filters.

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 that of this lens/film combination with a Wratten no. 21 filter. The operational resolution of the special green filter (SF-05) is lower than that of the Wratten no. 21 filter due to the slightly 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.

4. The resultant green filtered negative can provide the photointerpreter with not only the normal black and white record, but, if desired, the option of color positives from the bi-color technique. The SF-05 filter in the KH-4B system provides a green record image of lower quality than that available from the normal high quality red record. However, the degradation is not noticeable when the photography is viewed in stereo with the higher quality red record. Stereo and bi-color cannot be seen simultaneously. The acquisition of bi-color does not preclude the availability for stereo viewing; however, the two techniques must be used separately.

5. The major problem with the use of bi-color, at the moment, is the difficulty of exploiting it, i.e., techniques currently available for making bi-color prints are very time-consuming and laborious. This results primarily from the fact that there is no currently available equipment specifically designed for bi-color exploitation.

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~~NO FOREIGN DISSEMINATION~~

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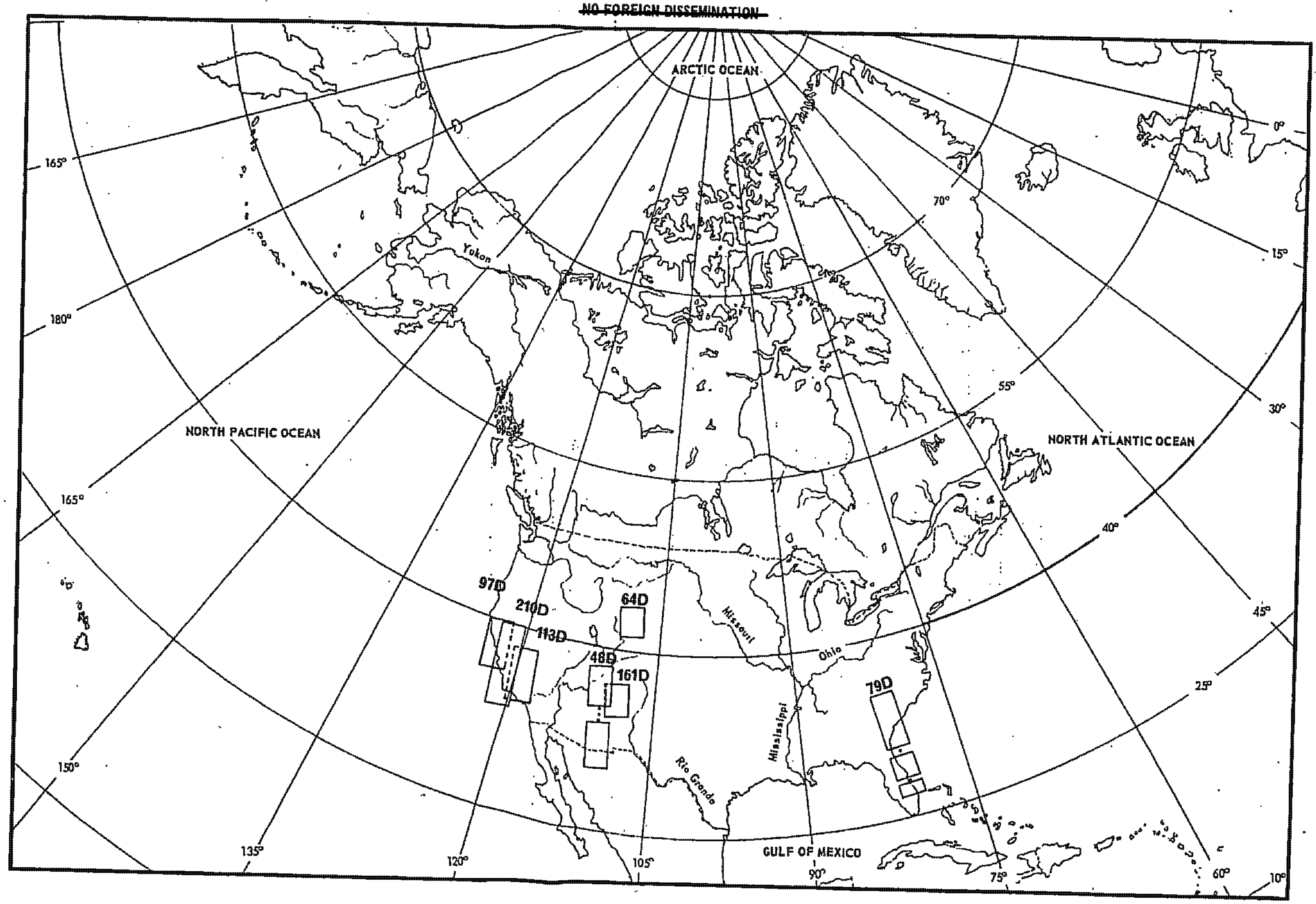

Fig. 4.3-1 — Ground tracks for the mission 1102 bi-color passes over the United States

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CONTROL SYSTEM ONLY

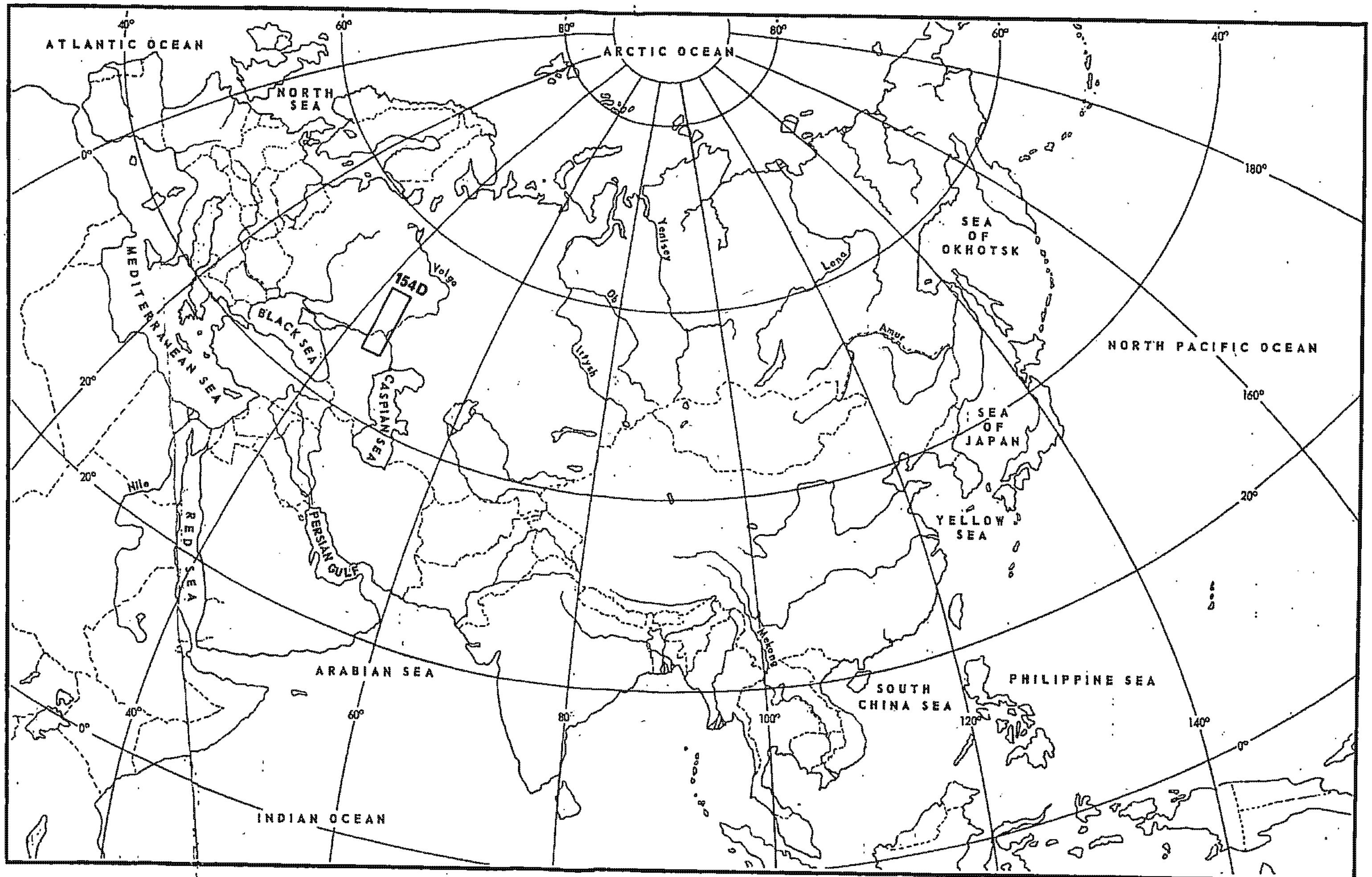
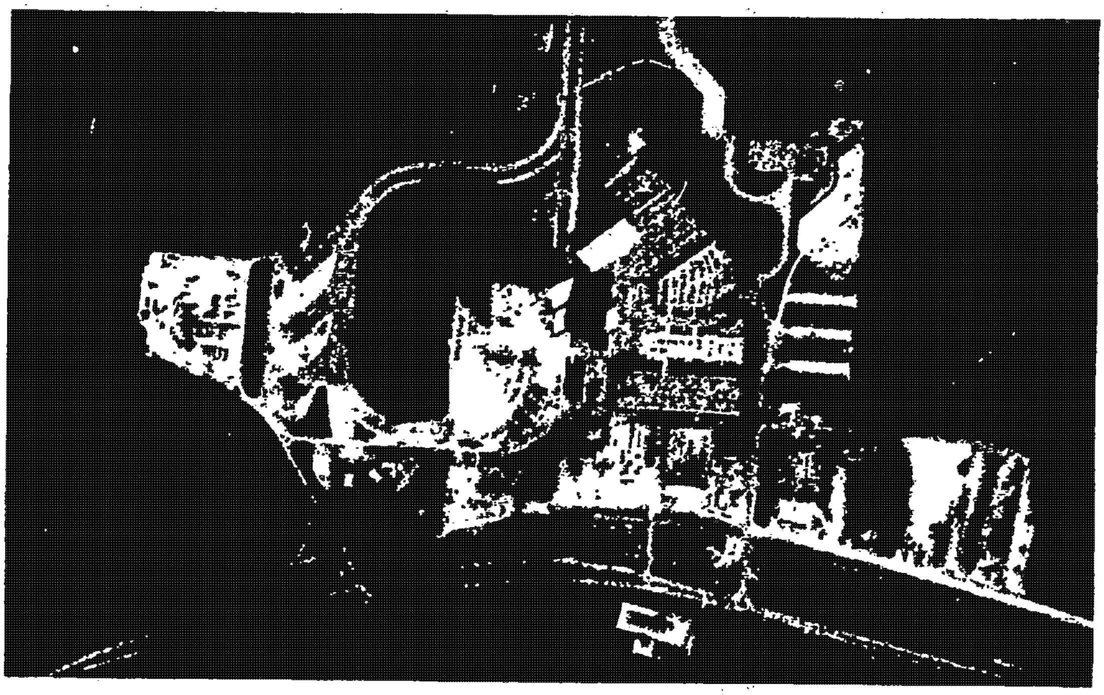


Fig. 4.3-2 — Ground track for the mission 1102 bi-color pass over the Soviet Union

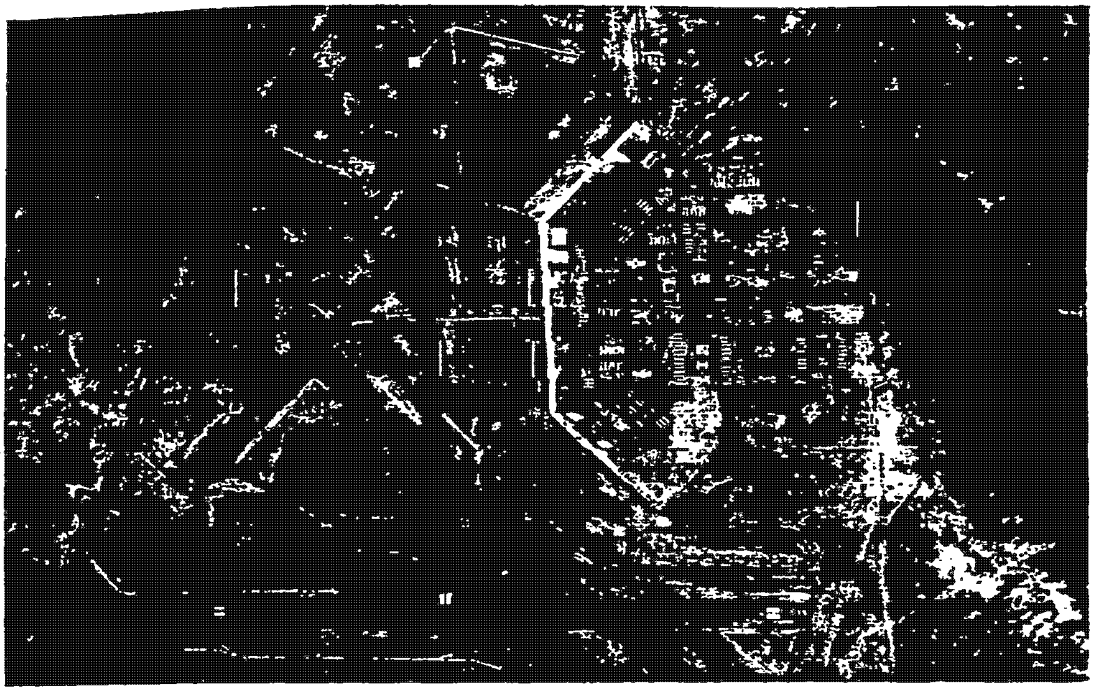
(a) 20× rectified print from red filtered negative



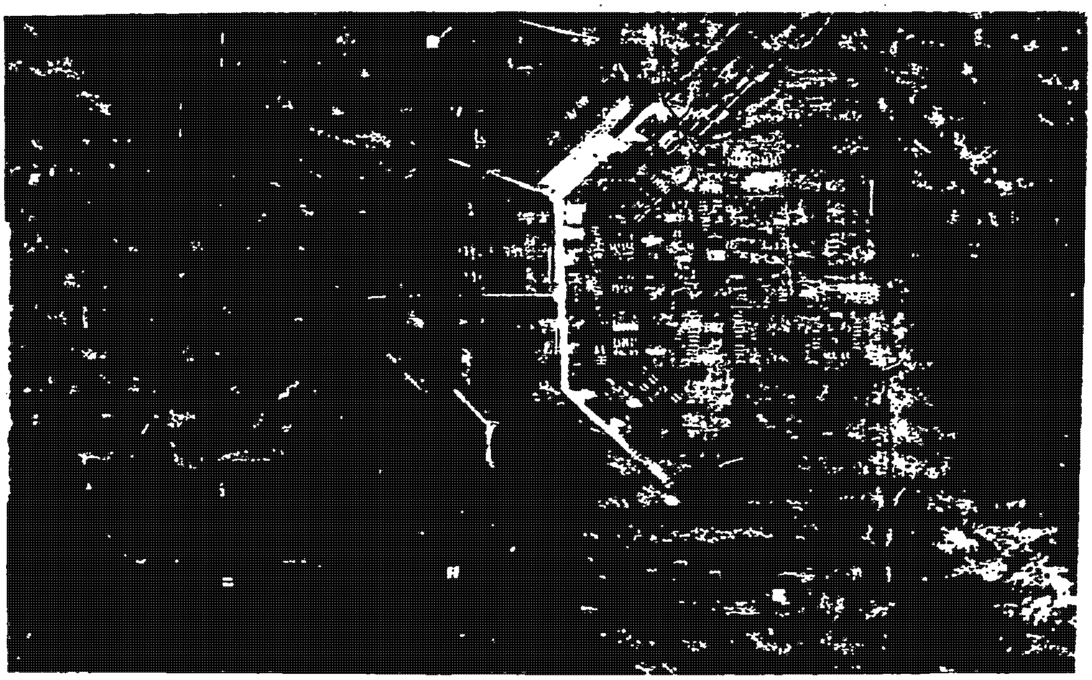
(b) 20× rectified print from green filtered negative

Fig. 4.3-3 — Cape Kennedy, 20× rectified prints

Fig. 4.3-4 — 20× bi-color integration made from green and red rectified records



(a) 20× orthoprint from red filtered negative



(b) 20× orthoprint from green filtered negative

Fig. 4.3-5 — Bisbee/Douglas International Airport, Arizona, 20× orthoprints

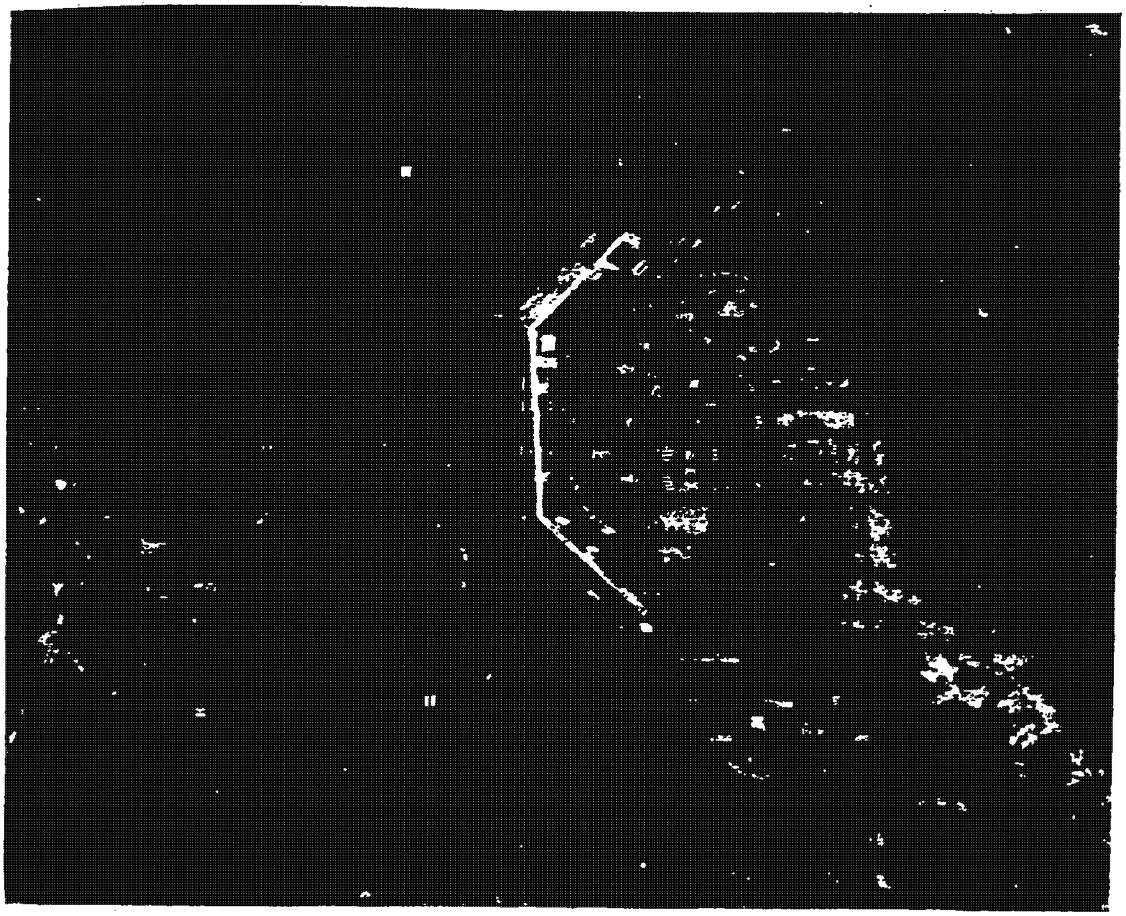


Fig. 4.3-6 — 20× bi-color integration made from green and red orthoprint records

(a) 20× orthoprint from red filtered negative

(b) 20× orthoprint from green filtered negative

Fig. 4.3-7 — Copper mine slurry, Arizona, 20× orthoprints

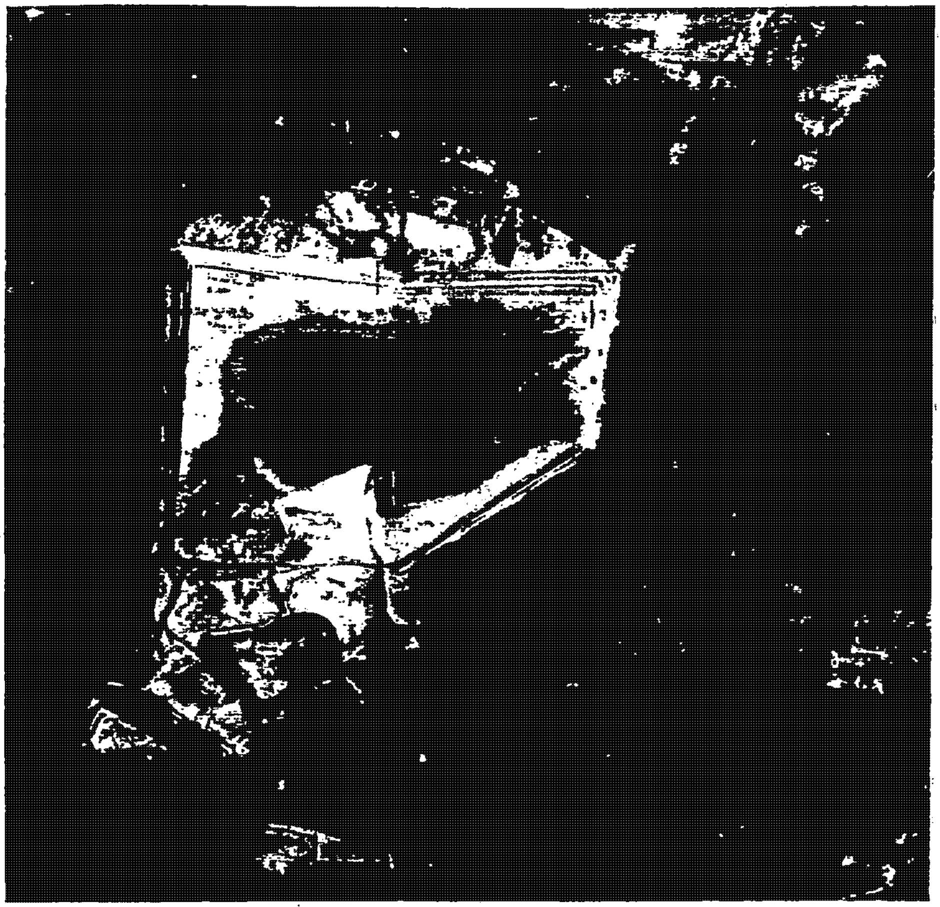


Fig. 4.3-8 — 20× bi-color integration made from green and red orthoprint records

Notice of Page Substitution

5. NIGHT PHOTOGRAPHY

For the purposes of electronic archiving, this page is a substitute for an unscannable page.

5.1 EKIT NIGHT TEST

5.1.1 Test Type

The aircraft-112B camera system was used for this test.

5.1.2 Test Objectives

The prime objective was to detect missile launch activity at night; the main target was Vandenberg Air Force Base, California. Another objective was the evaluation of three photographic materials:

1. SO-340, an improved Tri-X material
2. SO-180, false color film used in detecting camouflaged objects by their infrared reflection characteristics
3. SO-121, a high resolution color material.

5.1.3 Test Details

Since the prime objective was to detect missile launch activity at night, the primary target area chosen was Vandenberg Air Force Base, California. Although three separate night tests were run, the main mission was flown on 13 January 1967. This was the evening before a KH-4 launch (mission 1038), and it was suspected that there would be activity on the pad at night in preparation for the launch on 14 January 1967.

In order to use the available flight time to the maximum, several other areas were covered. The photographic portion of the flight line included the Los Angeles area, Vandenberg, and the San Francisco-Vallejo areas. The photography was obtained with the 112B camera system at a nominal altitude of 65,000 feet providing a scale of 1:33,000 at center of format. Three night missions were required to complete the effort. Two day-coverage missions that were flown over the same flight lines as their night counterparts were used as a control. The first two flights used a camera in which the entire slit mechanism could be removed, thus providing an effective exposure time of 1/50 second. In the third flight, a different 112B camera was used. The slit bar on this particular unit could not be removed to provide an effective exposure time of 1/50 second as on previous flights. The exposure was therefore approximately 1/120 of a second.

A total of six flights were needed to satisfactorily complete this test. The original plan called for only two flights; however, bad weather conditions interfered with the test and further flights were required (see Tables 5.1-1, 5.1-2, and 5.1-3).

The initial test flights, 4, 4A, 5, and 5A, covered Los Angeles, Vandenberg, and the San Francisco-Vallejo area [see Fig. 5.1-1(a)]. The flight line purposely skirted the prime target (Vandenberg) to avoid direct overflight requirements, and, as such, was intended to obtain imagery of the target at the edge of the format. However, due to either the cloudy weather over Vandenberg or the skirting flight line, no imagery was obtained. The third set of imagery flights (4B and 5B), resulted from a direct overflight of Vandenberg. The weather was clear and good imagery was obtained. Detailed flight lines are presented in Fig. 5.1-1 for these flights.

Note also that SO-180 was replaced with SO-121 for the last night for the following reasons:

1. The flight was made in conjunction with another EKIT flight that required all of the available SO-180.

2. Preliminary analysis of the first flights of SO-180 provided enough information concerning its performance at night.

3. The use of SO-340 in both cameras was thought to be an unnecessary duplication.

4. Extra SO-121 was available, and it was decided to test its usefulness at night.

5.1.4 Discussion of Figures

The series represented by Figs. 5.1-2(a), 5.1-2(b), 5.1-2(c), and 5.1-3(a), 5.1-3(b) is the Dodger home field, Chavez Ravine. In Figs. 5.1-2(b) and 5.1-2(c), illumination of the field is much greater than in other areas of the scene, resulting in a blocking up of the subject by high density in the black and white and by a very impressive red image on the SO-180 color film.

Selective use of exposure in printing the black and white scene is illustrated in Figs. 5.1-2(b) and 5.1-2(c). A shorter printing time results in a print as shown in Fig. 5.1-2(b). The playing field is blocked up, but much detail is seen in the parking lot and silhouetting of two buildings by internal light spilling out on the surrounding ground. Fig. 5.1-2(c) was printed with a longer exposure time to bring out the playing field and stand detail at the expense of the other information.

The color recording in Fig. 5.1-3(a) is very good. The level of illumination is high enough in this case to be used effectively by the film. Although no details surrounding the field are discernible, worn spots in the grass of the outfield made by the players can be seen. Note that the worn spots can be directly correlated with similar spots on the black and white print [Figs. 5.1-2(a) and 5.1-2(c)]. Fig. 5.1-3(b) is a daytime color record on a normal aerial color emulsion for comparison with Fig. 5.1-3(a). It was obtained by chance from another flight crossing these flight lines at Chavez Ravine and has been included as a comparison with the SO-180 at night. It is interesting to note that the worn spots in the field are not as evident on the normal color record. Camouflage detection film works under the principle that the three colors (blue, green, and red) in the image are formed in the same manner as in regular color films. However, the energy that forms these colors is green, red, and infrared. Therefore, objects of high infrared reflection look red on the final image. The chlorophyll ingreen grass reflects more infrared than it does green. The green (highly reflective in infrared) grass illuminated by the tungsten lamps (with high infrared emission) combined to present a tremendous amount of infrared to the film, thus producing the vivid red ball field shown in Fig. 5.1-3(a).

Night coverage of the parking lots (Fig. 5.1-4) in color and black and white provide two quite different types of information. The black and white provides the most detail, and superimposition of day and night records is possible.

Since the automobiles in the night coverage are in essentially the same number and order, it is reasonable to assume that these are automobile sales lots.

Color loses much of the detail that is recorded in black and white. Automobile positioning is still visible on the better illuminated lost, but the outstanding feature is the color of the lighting. The response of the various layers of the SO-180 separates the illuminants by spectral output, a potentially useful characteristic.

Fig. 5.1-5 shows the Vandenburg AFB launch complex. Both elements of the launch facility that were illuminated are shown in Fig. 5.1-5(b) and present an outstanding target area. Most of the illumination is on the deck area, with the gantries essentially being dark although several small lights are seen at their tops. Structural detail and limits are clearly defined, but the most important fact is that night activity is detectable. The orientation of the launch complex and the location