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FINAL REPORT

CORONA PHOTOGRAPHIC EXPERIMENTS COMMITTEE

JUNE 1969

Basement Pentagon

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FOREWORD

This report constitutes the final summary report of the CORONA Photographic Experiments Committee, established by the Director, National Reconnaissance Office. This report has been kept as concise as possible; however, the essential information on the various tests and analyses conducted has been included. Considerable additional detail can be found in the in-depth reports on each test, referenced in the body of this report. In addition, an appendix containing references to these and other pertinent reports has been included. The committee wishes to express its appreciation to [redacted] who served as recording secretary of the group. This report is respectfully submitted.

[redacted]

J. Alkofer, Eastman Kodak Company

[redacted]

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Introduction

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1. INTRODUCTION

The CORONA J-3 Ad Hoc Committee* was informally convened by the Director, National Reconnaissance Office, on 4 December 1967 and formally constituted on 16 February 1968. The committee was established to†:

> "(1) *Analyze and evaluate the effectivity of photographic flight and processing experiments performed within the CORONA program (CR-1 and CR-5 inclusive)*
>
> (2) *Recommend standard future CORONA photographic configurations resultant from the above experimental program; and,*
>
> (3) *Recommend additional CORONA photographic flight and processing experiments.*"

The desire for a photographic test program was directly related to the additional photographic flexibility of the CORONA J-3 camera. This flexibility is provided by two changeable filters and four changeable exposure slits on each camera, and allows the use of mixed film loads and/or different filters.

The need for the Ad Hoc Committee resulted from a desire to coordinate the test program and subsequent analysis with the community, and thereby ensure the widest possible participation.

The test program was originally proposed‡ to the D/NRO by the CIA Director of Special Projects on 11 April 1967, and was subsequently approved by the D/NRO on 15 May 1967.§

The fundamental purpose of the test series was to demonstrate the capability of the CORONA J-3 camera to handle several new photographic techniques, and, in general, that purpose was accomplished.

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*CORONA Photographic Experiments Evaluation Committee.
†NRO Action Memorandum No. 16, [redacted] (Feb. 16, 1967).
‡Memo for: Dr. Flax, subject: CORONA J-3 Payload Engineering Evaluations, [redacted] (Nov. 4, 1967).
§NRO message no. [redacted] May 15, 1967.

These tests fell into three general categories:

1. Those concerned with increasing the kinds of information contained in the photographic image
2. Those concerned with overcoming operational, environmental, and mechanical constraints
3. Those concerned with improving the quality of the aerial image at the film plane.

The tests that were conducted are summarized below.

Mission 1101 — Exposure Analysis. The objective of this test was to examine densitometric data acquired from CORONA photography and thereby assess the current exposure criteria, the exposure prediction techniques, and a new criterion for setting system exposure.

Mission 1102 — Bi-Color Test. The objective of this test was to determine the feasibility of obtaining color photography from the spectrally filtered black and white records.

Mission 1102 — Polarizer Test. The objective of this test was to examine the merits of photography using a polarizing filter in place of the normal red or orange filters on J-3.

Mission 1102 — SO-230 Test. The objective of this tag-on film load test was to see if the higher speed film would provide a net system performance improvement through reduced smear.

Mission 1103 — SO-380 Test. The objective of this tag-on film load test was to determine how CORONA J-3 would handle an ultrathin-base film.

Mission 1104 — SO-180 Test. The objective of this tag-on film load test was to evaluate a near infrared sensitive color film.

Mission 1105 — SO-121 Test. The objective of this tag-on film load test was to evaluate a conventional aerial color film in the CORONA J-3 system.

It should be noted that several tests involved color films and/or color techniques. The use of color films in the satellite systems has been, and continues to be, the source of much discussion, study, and controversy. In this regard, an attempt was made to coordinate these tests more directly with the intelligence community, i.e., every attempt was made to direct the color acquisitions toward color-oriented intelligence problems. It was hoped that in this manner we could better demonstrate the capability of the CORONA J-3 camera to handle color and also demonstrate (or deny) in some way, the intelligence utility of satellite color photography. Generally, this latter goal was not achieved, due to the manner in which the tests had to be run. This is brought out here because it was a significant problem and must be considered in any future color tests.

The Ad Hoc Committee believes that it has served its major purpose; it is the intent of this report to summarize the tests, discuss the results, and present the committee's conclusions and recommendations. Because of the summary nature of this report, the reader may find insufficient detail on many of the tests. An attempt has been made to present only the major aspects and findings of these tests. In all cases, detailed technical reports have been issued (or will be issued shortly), and, for further information these are referenced in the body of this report. A final note of importance—although numerous tests were conducted on several missions, not one of the tests caused any failures which resulted in harm to the main intelligence purpose of these missions.

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Conclusions
Recommendations

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2. CONCLUSIONS AND RECOMMENDATIONS

This section presents the major conclusions and recommendations of the Ad Hoc Committee. All the specific conclusions and recommendations found in each individual section will not be repeated here.

2.1 CONCLUSIONS

As indicated in the introduction, the major purpose of this test series was to evaluate the performance and capability of the CORONA J-3 system with several new photographic techniques/films. Hence, the first set of conclusions relates to that major purpose.

1. Bi-color is an acceptable technique for use with the J-3 camera. This conclusion relates primarily to the acquisition phase and not necessarily to its exploitation. It is clear that the use of the green filter in the AFT-looking camera does not significantly affect the normal intelligence exploitation process. While the green record does possess lower image quality and contrast, its use with the normal high resolution red (FWD-looking) record compensates for this resolution loss.

The intelligence utility of the bi-color product has yet to be clearly demonstrated, and will have to wait for the final report of the Bi-Color Committee.* However, the fact that one positive intelligence report has been issued indicates that bi-color has, at least, some value for intelligence purposes.

It must be remembered that the major drawback to bi-color is the very real difficulty associated with its exploitation process, particularly with a panoramic type camera system. There is no equipment available that is specifically built for bi-color exploitation. So long as this is the case, bi-color exploitation will be time-consuming and the results will be of significantly lower quality than desired.

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*A separate committee was established to assess the intelligence utility of bi-color. This committee, known as the Bi-Color Committee, was constituted by agreement between the CIA member of the Committee on Image Requirements and Exploitation (COMIREX) and the executive officer of the National Photographic Interpretation Center (NPIC). The committee is chaired by a representative of the CIA's Office of Strategic Research and consists of two other members from NPIC.

One of the original conceptual advantages of the bi-color process was to produce "high resolution" color through use of the high resolution black and white records. While this goal is still fundamentally possible, it has not been demonstrated due to the lack of proper exploitation equipment and the inability to produce bi-color prints in near perfect register.

Taking cognizance of the above reservations, we still conclude that bi-color is an acceptable acquisition technique for use with the J-3 camera, as long as one is aware of its current limiting problems. The use of this technique should be limited to special problems.

2. Aerial Ektachrome, SO-121, is an acceptable film for use with the J-3 camera. We believe that the test series has demonstrated the ability of the J-3 camera to employ SO-121. Ground resolutions equivalent to the best that could be expected (approximately 15 feet) have been obtained, and acceptable exposure and color balance have been demonstrated.

3. Infrared Ektachrome, SO-180, has not yet been demonstrated to be an acceptable film for use with the J-3 camera. We come to this conclusion out of necessity. The mission 1104 test demonstrated two undesirable effects:

a. Severe fogging due to electrostatic discharge
b. Loss of IR layer speed with exposure to vacuum.

The severe static marking was a direct result of a PMU* failure on the system. Ground tests indicate, however, that the static marking can be eliminated if the proper internal camera pressures are maintained. The loss of IR speed with exposure to hard vacuum was unexpected and unknown prior to flight. For these reasons, the mission 1104 SO-180 test cannot be considered to have demonstrated the ability of the J-3 system to handle SO-180. More will be said about this in the recommendations section.

4. SO-230/SO-205 films are not recommended for use in the J-3 camera. SO-230/SO-205 produces 30 percent lower 2:1 contrast resolving power than 3404/SO-380, and this is unacceptable considering the J-3 resolution/scale characteristics. Current J-3 systems have been producing 170 to 180 cycles per millimeter average low contrast resolving power in dynamic test. Certain systems, in fact, have averaged nearly 200 cycles per millimeter (lens plus film) low contrast dynamic performance. SO-230/SO-205 produces at best 190 cycles per millimeter (film alone) low contrast resolving power (as compared with 265 cycles per millimeter for 3404/SO-380) which will certainly reduce this performance level even when considering the smear reduction due to a higher emulsion speed.

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*Pressure makeup unit.

5. SO-380 (UTB) has not yet been demonstrated to be compatible for use with the J-3 system. Mission 1105 demonstrated that the combination of UTB with the J-3 camera is not clearly understood. The CORONA UTB task team* has recommended that UTB not be used again until at least September 1969, after the completion of a recommended test program. This committee agrees with that recommendation.

6. Polarizing filters are not recommended for further use in the J-3 camera with black and white films. The original intent of the polarizing filter test was to evaluate haze attenuation and reduction of specular reflections. From a practical point of view, however, the test demonstrated that the majority of haze light with respect to the spectral response of this system is not appreciably plane polarized, and that as haze gets worse, the relative amount of polarized haze light decreases. The majority of plane-polarized haze light is from the Rayleigh scatter which the normally employed spectral filters reduce anyway. Polarizing filters do not significantly reduce the effects of specular reflections from aircraft since metallic objects do not polarize light to a significant degree.

7. The testing of color films and/or techniques must be done against specific intelligence problems. There is one further conclusion that does not relate to the specific tests themselves, but to the totality of experience gained from this test program.

As pointed out in the introduction, it was not within our charter to consider the intelligence value of any of the tests. By necessity, however, we felt that it was opportune to address intelligence utility as part of the test plans.

Enough color tests have now been run to clearly demonstrate that such testing must be performed differently than black and white tests. Whereas with black and white films, it is easy to demonstrate that a lower resolution film produces less intelligence, such is not the case with color films, since it is necessary to weigh spatial resolution (i.e., cycles per millimeter) versus "spectral resolution" (i.e., color).

The discussions we have held with a limited number of intelligence analysts clearly indicate that there are intelligence problems for which color photography is uniquely suited. The several quotations in this report relative to atomic energy requirements support this conclusion. On the other hand, the discussions we have had with photo-interpreters have demonstrated their preference for the higher resolution black and white records, unless they are specifically asked to read out the color record for its color information. Considerable progress must be made in acquainting the intelligence community with the potential value of color information from aerial photoreconnaissance. More detail on this subject is contained in the recommendations section.

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*See Section 9 for a discussion of the UTB task team and its purpose.

2.2 RECOMMENDATIONS

As in the preceding section, all the specific recommendations are not reported here since they are included in the body of the report. Only our major recommendations are presented here.

1. Further testing of color films and techniques is strongly recommended. This general recommendation leads to two specific further recommendations:

   a. That further color testing should be done against specific intelligence requirements

   b. That further engineering tests with SO-180 are indicated.

Color in General. It is the feeling of this committee that the most important aspect of our work was that associated with the implementation of color tests on the satellite systems. However, color tests are difficult to conduct. Generally (particularly with the color films), we have conducted "end of mission" tests, i.e., the color film was placed on the end of the mission film roll. While this is a convenient and conservative way in which to run the tests, it is usually not the optimum way. This report points out that when specifically queried, intelligence analysts have identified problems for which color is uniquely suited. One cannot, however, truly evaluate the utility of color unless coverage against analysts' specific problems (targets) is acquired. For example, while the SO-180 test plan called for photographing specific areas of China, for economic intelligence purposes, these areas were not covered because the color film was not available at that time in the orbit when coverage of these areas could be obtained. This has been a continuing problem. However, as more color film is added at the end of the mission, the higher the probability becomes that analysts' targets will be covered. The point is that the question of the utility of color film in the National Reconnaissance Program (NRP) will never be answered unless a well coordinated, concerted effort is made to acquire color photography against targets for which analysts judge it to be of benefit.

SO-180. While we concluded that SO-180 is not yet a recommended film for use with the J-3 cameras, this does not mean that further work is not indicated. We believe that the system problems with SO-180 are solvable, and at least one more engineering test is warranted to evaluate this film. The severe static marking reported was due to a PMU failure, and with proper PMU functioning, we believe that SO-180 will prove compatible with the J-3 system. More important, however, we believe that this film warrants further evaluation for its intelligence potential. SO-180, because of its peculiar spectral response, may play a unique role in the NRP. We are encouraged in this feeling by the NPIC analysis, part of which is quoted on the following page.

"Regardless of these factors (i.e., the problems experienced), portions of the SO-180 imagery obtained on this mission closely approximate the expectations of this lens/film combination. Some of the existing imagery contains significant added information from an intelligence standpoint (underlining ours), *provided the analyst is allowed sufficient time to interpret it, has a working knowledge of the film characteristics, and is familiar with the infrared reflectivity of the various objects photographed."* *

2. A special subcommittee of COMIREX should be constituted to evaluate the utility of satellite color photography. The use of color for intelligence purposes is considerably more complicated, at this point in time, than black and white. The utility of color requires close cooperation between the System Program Offices, the Satellite Operations Center (SOC), the intelligence analysts, the photointerpreters, and COMIREX. Such close cooperation is not easily established. Analysts do not always know the capabilities of the systems and films, nor do the System Program Offices always understand the intelligence community's problems.

This committee is now convinced that color will, in the long run, provide significant added information for the intelligence production process. However, it is not a question of color in place of black and white, but rather a question of when color should be used, and for what kind of targets it provides additional information. The most significant fact is that this question will not be answered with a haphazard test program, run essentially at the discretion of the System Program Offices. While the System Program Offices have been most instrumental and cooperative in the planning and conducting of the color tests, they are not in a position to undertake an intensive investigation of the intelligence utility of color photography.

Further, the problem of the proper exploitation of color acquisitions is a difficult one, since the use of color is more analytical than the use of black and white. For example, one of the most readily apparent uses of color reconnaissance is for the Atomic Energy Intelligence Program, where knowledge of the colors of ores, settling ponds, output products, and stains on roofs is important information. However, the identification of colors alone does not provide all the desired information, but rather provides added information that allows the analyst to identify (1) the amount of uranium produced, (2) the process used (to identify the type of uranium), (3) the functions of buildings, and (4) the source of the ores employed. In this case (as with many others) the cooperation between the photointerpreter and the analyst is crucial, since the meanings of colors, in an intelligence sense, are often beyond the scope of both the photointerpreter's normal job and his experience.

The point is that the color testing accomplished to date (regardless of system) has been done in a purely informal manner, with informal lines of communication established

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*Mission 1104 Photographic Evaluation Report, [redacted] Dec. 1968).

[redacted]

between the program offices, photointerpreters, and analysts. While this approach has been most effective in the past tests, further informal testing will probably be generally nonproductive in terms of answering the fundamental question concerning the determination of the targets and problems for which color provides increased information for the intelligence production process.

We strongly believe that what is now indicated is a well thought out color collection program consisting of several partial color missions on all NRP reconnaissance systems. The impetus of such a program should be to:

a. Work closely with intelligence analysts within the community to identify specific targets and problems for which they believe color would be of value

b. Work out a long range collection program to acquire color (on whatever system seems appropriate) against those targets and problems suggested

c. Ensure that photointerpreter readout is coordinated with the analysts to determine if the answers the analysts were looking for are in fact provided.

We believe that only COMIREX can provide the impetus and coordination needed for such a program, but that because of its complexity, the program should be handled by a specially and specifically constituted subcommittee. We further recommend that this subcommittee be constituted of both intelligence community personnel and technical representatives of the collection community, so that maximum understanding of the problems of each group can be achieved.

3. Consideration should be given to developing specific bi-color exploitation equipment. As repeatedly stated in this report, the bi-color exploitation process is not optimum due to the lack of equipment specifically suited for this technique. It is possible that from this test of the bi-color technique, the conclusion relative to the value of bi-color in the CORONA camera system with present day reproduction equipment may be distinctly different than the assessment of the potential of bi-color per se. It is important that one does not reach the wrong conclusion for the wrong reason, i.e., one may conclude that bi-color is of little or no value, when in fact its full potential has not even been approached. Bi-color still has the fundamental advantage of ease of acquisition, which cannot be overcome with tag-on film loads of conventional color film. However, this is an advantage only if exploitation of the product could be made routinely practical.

4. Consideration should be given to the development of higher resolution color films. The only consistent objection to the use of color films is their lower spatial resolution. We believe that there would be no arguments against the use of color if it produced the same spatial resolution as black and white. This is not now technically possible, but

[redacted]

the fact remains that currently available satellite color films do not represent the current state of the art of color films and considerable improvement can be made.

As with the analysis of bi-color, it is important to guard against arriving at the wrong conclusion for the wrong reason, i.e., it might well be true (although we do not so believe) that current color films are of limited intelligence value, but that higher resolution color films would be of significant value.

The fact that our major recommendations in this section relate only to color, and not to other aspects of the test program, is due to the further fact that there is no action indicated in the other areas. Generally, the other tests either fully accomplished their purpose, or the recommendations have already been implemented. However, we wish to encourage further testing of this general type on the satellite systems. The System Program Offices should be encouraged to look continually at new photographic techniques and/or films, since only in this way will we enhance our intelligence-gathering ability.

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Color Photography

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3. COLOR PHOTOGRAPHY

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 provide a color image that is very similar to the original ground scene. These materials attempt to reproduce colors as we see them through the use of three separate emulsions coated on one base. For high altitude photography, where there is prevailing blue haze light, these films must be used with a light yellow filter in order to reduce the effect of haze and provide a reasonable approximation of the ground scene. SO-121 is a medium speed color reversal film coated on an Estar standard thin base. It has been used in recent years in many low to intermediate altitude systems as well as in four [redacted] Although SO-121 is among the highest resolution color films available today, it is decidedly poorer than 3404. The best ground resolution that could be expected from SO-121 in the CORONA system is approximately 15 feet, while an average of 20 to 25 feet would be normal.

The second technique for obtaining color photography—false color films—also involves a multilayer coated film on a single base. Infrared Aero Ektachrome, SO-180, is representative of these materials. Unlike SO-121, it has a unique spectral sensitivity that enables the material to record in the near infrared region of the spectrum. The film has green, red, and near infrared sensitive layers. The sensitivity of the film has been designed so that the infrared layer records as red, the red records as green, and the green records as blue, thus providing a "false" color image.

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 CORONA J-3 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 CORONA J-3 scales.

Perhaps the most valuable color material in connection with small scale photography such as the CORONA 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 committee's opinion that color reconnaissance is a valuable tool as an adjunct to the black and white high resolution photography. However, 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, and, for this reason, this committee strongly recommended the establishment of a color committee under COMIREX.

4. BI-COLOR TEST — MISSION 1102*

The bi-color approach, as described in the introduction to the color section, obtains color photography from two separate filtered images.

The CORONA J-3 camera system has the capability to acquire bi-color photography by using the primary red filter in the FWD-looking camera and an alternate green filter in the AFT-looking camera.

There are several advantages afforded to the CORONA J-3 system with the bi-color approach to color photography, the greatest advantage being the capability to acquire color pictures with a minimum of operational difficulty. It is not necessary to attempt the practically impossible task of splicing a conventional color material at the exact position in the film load that would ensure color photography of the targets of interest. 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 which, 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 stereo 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 lowering of contrast can be expected with this camera system.

Another advantage of the bi-color process is that in retaining the normal Wratten no. 25 imagery, the inherent high resolution is still present in one of the records. The passes that do not use the bi-color mode also retain the Wratten no. 21 or 23A high resolution imagery. For the particular pass that does use bi-color, there is a slight loss in resolution on the green record.

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*A full evaluation of this bi-color mission can be found in KH-4B System Capability Report No. 3, CR-2 Bi-Color Experiment [redacted] (Sept. 27, 1968).

Although the minor image degradation associated with atmospheric attenuation is unavoidable, it is possible to design a lens specifically for the wavelength region of the required green filter, thereby eliminating the lens-associated component of degradation to spatial resolution.

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 clearly distinguish a red from an orange, a green from a green-blue, or even white from yellow. In short, bi-color does not have as wide a chromatic dynamic range as tri-color photography.

Another current disadvantage of bi-color is that although the prints are obtainable at the interpreter's option, it does take considerable time and effort to produce them. In addition to this problem, several days are needed for transportation of the materials involved. However, with the current equipment colocated, it seems reasonable to expect that a 1-day service could be established.

4.1 PURPOSE

It was the purpose of the mission 1102 bi-color test to:

1. Obtain, for the first time, satellite color photography in the CORONA system 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 CORONA reconnaissance system.

4.2 TEST CONSIDERATIONS

In view of the committee's philosophy, as stated in the introduction to the report, of attempting to run the color tests against color-oriented intelligence problems, several briefings on the test program were given to CIA intelligence analysts. The purpose of these briefings was to solicit, in an informal way, their suggestions for targets against which the bi-color test could be flown. The one potential use that continued to present itself was the atomic energy requirement. A suggestion* was made, therefore, to run

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*Possible Use of Modified Bi-Color Subject in Satellite Sensor for Atomic Energy Purposes, [redacted] (Oct. 30, 1967).

the bi-color test against selected domestic facilities in an attempt to demonstrate the ability of bi-color to answer certain specific AE intelligence requirements. For completeness, pertinent portions of [redacted] are quoted below.

> [redacted] revealed that the roof of the main building of the Dneprodzerzhinsk uranium ore concentration plant had a yellowish cast grading away from the vent pipe, and that a yellowish cast was visible along exit flumes from the trailing ponds to the Dnepr River.
>
> *It is suggested that the bi-color system might provide useful intelligence identification of specific uranium operations in foreign atomic facilities . . .*
>
> *Ultimate intelligence objectives could be, if the method* (i.e., bi-color) *should prove successful, the identification of those buildings and vent structures at atomic energy facilities which handle uranium chemistry in contradistinction to other associated processes. Major intelligence targets could include the identification of the uranium handling facilities (if any) at Paot'ou and area 1 and 2 at Chih Chin Asia (Yumen) in China. Of lesser importance would be the identification of buildings engaged in uranium chemistry at the Pierrelatte gaseous diffusion plant in France; the uranium metal facilities in Elektrostal, Glazov and Novosibirsk in the USSR; at the gaseous diffusion plants near Verkhnervinsk, Tomsk, Zaozerniy, and Angarsk in the USSR; and at the plutonium production centers near Marcoule in France and Kyshtym in the USSR.*
>
> *Any research (engineering pass) program should include foreign ore plants such as the one at Dneprodzerzhinsk in the USSR and the one at Hengyand in China.*
>
> *AE plants in the U. S. suitable for research into this possibility either through aircraft overflight or engineering passes would include: the several uranium ore concentration facilities five miles NW of Grants, New Mexico, or the rather ancient, converted sugar beet refinery used by the Climax-Molybdenum Company at Grand Junction, Colorado; or the several small uranium mills thirty-five miles east southeast of Riverton, Wyoming; the uranium metal manufacturing plant near Fernald, Ohio; and the uranium recovery facilities at Hanford, Washington."*

The suggested domestic targets were selected for engineering bi-color acquisition in the attempt to more directly evaluate the utility of the bi-color techniques.

4.3 ENGINEERING TESTS

An effort was undertaken by Itek to fabricate glass filters to be used in both the primary and alternate positions in the CORONA J-3 system. This task started with the goal of possibly improving system performance by replacing Wratten gelatin filters

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* One of the first satellite color tests, employing SO-121 Aerial Ektachrome.

with high quality glass filters. Problems encountered in the production of these very thin glass filters have to date precluded their qualification for use in the primary position. The glass, 0.005-inch fused quartz, is so thin that polishing has not been sufficient to produce results any better than normal Wratten filters.

However, this glass is satisfactory as a substrate for the green filter that is required for bi-color acquisitions. The only other (but less satisfactory) method would be to use a gelatin filter. However, green transmitting dye filters characteristically have high filter factors which preclude their use in the CORONA system. The green filter (designated SF-05) used for bi-color was a dichroic coating on this thin glass and was used in the alternate filter position on the AFT-looking camera of mission 1102. This glass dichroic filter had a filter factor of 2.8 which is compatible with the CORONA camera using 3404 film.

The question of resolution performance was answered in two ways—theoretically and by laboratory experiment. The laboratory experiment indicated that resolution values for the Wratten no. 21 and SF-05 filters were very close when using a second generation lens at optimum focus for each filter. The 2:1 contrast resolution for the Wratten no. 21 was 135 cycles per millimeter, while for the SF-05 it was 120 cycles per millimeter. However, the contrast reduction due to the effective increase in atmospheric haze light with the green filter further lowers the system resolution when the SF-05 is employed. In addition, although the filter factor for the SF-05 filter is much lower than for normal green dye filters, it is still somewhat higher than that of the Wratten no. 21 conventionally used on the AFT-looking camera. This necessitates longer exposure times, thus decreasing the system dynamic performance due to image blur. Finally, the SF-05 filtered imagery is acquired operationally in the focal position for the Wratten no. 21 filter, which is not quite optimum for the SF-05, and this lowers the resolution performance to some degree.

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 Air Force Aeronautical Chart and Information Center (ACIC) and at the Army Topographic Command (TOPOCOM) using three pieces of equipment: the Gamma I Rectifier, the AS-11C and the UNIMACE orthoprinters. Sample photography was taken from the 1102 bi-color and printed on these instruments. The AS-11C and UNIMACE are electro-optical devices which are 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 returned to Itek for color printing. This was accomplished with somewhat conventional color printing materials using bi-color printing techniques previously developed at Itek. Coordination was established between Itek and NPIC during this operation, which subsequently lead to the establishment of a bi-color printing capability at NPIC.

4.4 FLIGHT TEST DETAILS

The bi-color experiment on mission 1102 was performed on seven passes, six over domestic areas, and one over the Soviet Union. During each bi-color operation, the FWD-looking camera employed the Wratten no. 25 red filter, and the AFT-looking camera employed the SF-05 green filter. Poor weather conditions prohibited our photographing several domestic nuclear production facilities; however, several other target areas in the United States proved to be very useful, a most dramatic example being the copper mine slurry located near Bisbee-Douglas, Arizona. The ground tracks for the domestic bi-color passes are shown in Fig. 4-1; the single over flight pass is shown in Fig. 4-2. During each of these passes, the alternate filter (SF-05) of the AFT-looking camera was commanded into position. The photography was, therefore, covered 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.

4.5 FLIGHT RESULTS

Since the suggested domestic AE targets were not acquired due to unfavorable weather conditions, this aspect of the analysis was not possible. However, there was sufficient bi-color obtained to enable NPIC to evaluate the records from a photointerpreter's point of view. Excerpts from NPIC's message to the community are as follows.*

> "... *NPIC has completed the first phase of its bi-color evaluation. This constitutes a determination of degradation to the photography exposed in the bi-color mode compared to that of the normal mode of operation.*
>
> ... *PI Report: The photo-interpreters preferred the Wratten no. 25 record over the SF-05. Higher contrast and overall sharper imagery were the two major reasons for this preference. They also expressed the opinion that when shadow detail is needed, a lighter print from the Wratten no. 25 record would be more desirable than the lower contrast of the SF-05 material, which seems to provide more shadow detail on a normal print. Small objects present in the Wratten no. 25 record can be detected in the SF-05 record; however, identification of these objects is much more difficult. The general conclusion of the photo-interpreters is: the majority of the requirements levied for the J-3 system could be answered with photography generated in the bi-color mode because when used in stereo, the two records complement each other. In addition, the overall information content of the photography exposed through the green filter is comparable to an average J-1 mission.*

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*NPIC message no. [redacted] Feb. 28, 1968.

 [redacted]

. . . Resolution Targets: Four resolution targets were photographed during the non bi-spectral portion of the mission. Seven targets were photographed during the bi-spectral portion; however, due to weather conditions and/or format location, only one of the targets imaged in the bi-color mode is suitable for this evaluation. The average ground resolution of these targets as determined from the original negative is presented below:

Camera	*Pass*	*IMC*	*Scan*	*Filter*
FWD	16-D	5.7	6.3	25
AFT	16-D	5.7	8.0	21
FWD	16-D	8.0	8.0	25
AFT	16-D	9.0	9.0	21
FWD	32-D	12.0	12.0	25
AFT	32-D	12.0	10.0	21
FWD	129-D	7.6	8.7	25
AFT	129-D	7.6	8.7	21
FWD	48-D	6.3	5.7	25
AFT	48-D	9.0	8.0	SF-05

. . . It should be noted that the 9.0 feet and 8.0 feet readings (i.e., of the bi-color) *are comparable to a normal J-1 mission.*

. . Summary and Conclusions:

1. The contrast range is significantly reduced when the SF-05 is used in place of the Wratten no. 21 or the Wratten no. 25.

2. Apparent image sharpness is reduced by a noticeable degree on the SF-05 photography compared to the Wratten no. 21 and Wratten no. 25.

3. The only suitable resolution target display imaged during the bi-color acquisition indicates a significant difference in ground resolution between the SF-05 photography compared to that of the Wratten no. 25.

4. The effect of image quality degradation caused by the use of the SF-05 filter is minimized when the photography is viewed in stereo with the higher quality, higher resolution photography exposed through the Wratten no. 25.

5. The resolution of the green filtered record is generally comparable to that of a normal J-1 mission."

A bi-color photograph of a copper mine slurry and the black and white print of the red and green orthophoto negatives used to make that bi-color print are illustrated in Figs. 4-3 and 4-4. This orthophotographic technique is electro-optical in nature as evidenced by the scan lines. The colors appear to be somewhat exaggerated although it does resemble a copper deposit and the copper sulfate residues in the surrounding areas. The next set of illustrations shows the more realistic color that can be attained with bi-color (Figs. 4-5 and 4-6). Note that small aircraft, although not in perfect register, are recognizable. Since the original techniques were established by ACIC

 [redacted]

and Itek, newer and more refined orthoprinting methods have been found. Figs. 4-7 and 4-8 are the black and white and bi-color prints made by NPIC and ACIC using the Gigas-Zeiss optical orthoprinter to correct distortions. This technique eliminates the distracting scan lines and substantially improves the image quality. The techniques employed to make this print were developed after Itek completed its task using the best available equipment at that time. After the successful test on mission 1102, bi-color photography was acquired in a search for color-oriented information in denied territories from missions 1103 and 1104 (see Section 4.8). However, neither mission provided images as sharp as those of the bi-color photography from 1102. The green filter used on 1103 was virtually identical to that used on 1102, but the general mission performance, even with the standard Wratten filter, was lower than that of 1102. The green filter used on 1104, however, was of lower quality than that of 1102, while the general mission performance was better. These two factors contributed to the poorer general quality from the two subsequent bi-color flights. It is believed, however, that the capability exists to come very close to equaling the results of mission 1102 on any one of the five missions using CORONA cameras CR-7, CR-8, CR-9, CR-11, and CR-12. However, other units may provide photography substantially poorer in bi-color due to a new lens design, that has improved performance in the red region of the spectrum at a cost of quality in the green spectral region.

4.6 ADDITIONAL BI-COLOR ACQUISITIONS — MISSIONS 1103 AND 1104

As has been stated, operational bi-color photography was acquired on missions 1103 and 1104. The majority of this photography (30 passes) was acquired on mission 1103. This bi-color was flown for two reasons: (1) because of the success demonstrated in the 1102 test, and (2) because a requirement for its acquisition was submitted to and approved by COMIREX. For completeness of understanding, it is perhaps useful to summarize the requirement approved, and indicate the status of bi-color exploitation against this requirement.

The referenced requirement,* part of which is quoted on the following pages, was submitted to the chairman of COMIREX on 28 March 1968.

> *"A number of atomic energy targets appear suitable for bi-color exploitation and analysis. Targets have been selected so as to use bi-color both as an identification of bulk uranium operations and as a means of providing additional information through its pseudo-color capability.*
>
> *The real usefulness of bi-color in the identification of bulk uranium operations is not at known uranium ore concentration facilities, but at more complex atomic energy production sites where specific identification of those buildings engaged in bulk uranium operations should lead to additional important information."*

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*Use of Bi-Color (Bi-Spectral) Filters Against Certain Soviet Atomic Energy Facilities on KH-4B Mission 1103, [redacted] (Apr. 24, 1968).

[redacted]

The requirement then, in part, stated specifically:

"2. *Uranium Concentration Plants, USSR and China*

A. Requirement:

Determine if uranyl yellow is apparent on building or around edges of tailing ponds. The purpose here is to prove that KH-4B bi-color is useful for identifying bulk uranium operations. Note that Dneprodzerzhinsk (an old plant) is the type example. Hang Yang is included as a recently constructed plant.

3. Plants With Bulk Uranium Handling

A. Requirement:

(1) Determine if bi-color is useful in finding and identifying difficult to see objects such as traces of underground pipelines, manholes, and valve houses connected with underground pipelines, the color of smoke from stacks, stains on roof tops, vehicle tracks on roads or bare ground, etc.

(2) Locate the structures involved in bulk handling of uranium, though identification of uranyl yellow.

4. Priority AE Targets, Identifications of Major Importance (as many as possible should be covered)

A. Requirement:

To determine if instrumentation vans, underground test cables, areas of disturbed rock, etc., are more discernible in bi-color than in normal Kh-4B stereo. (e.g., at Semipalatinsk Nuclear Weapons Proving Grounds, USSR)

B. Requirement:

Attempt identification of the functions of areas 1 and 2 (e.g., at Yuen Nuclear Energy Complex in China)

C. Requirement:

Attempt identification of the functions of the complex or any portion thereof. (e.g., at Paot'ou Atomic Energy Complex in China)

D. Requirement

Attempt identification of the purpose of the new waste disposal basin (e.g., at Dimona Nuclear Research Center, Israel) "

Subsequent to mission 1103, COMIREX established a Bi-Color Committee to evaluate the bi-color acquisitions and to determine if the technique had intelligence value. The Bi-Color Committee was initially plagued with hardware problems (i.e., timely use of the Gigas-Zeiss Orthophotoprinter) which slowed its task. However, to date, one positive intelligence report has been produced on the 1103 bi-color. The abstract follows*:

> *"Bi-color photography of poor-to-fair interpretability permits the recognition of one positive key to the identification of the well managed Ispisar uranium ore concentration plant. This is the high tailings dump stained red by the presence of an appreciable amount of vanadium pentoxide and iron oxide and a lower, interior and narrower persistent yellowish-white annulus or girding belt of uranium oxide. Wind blowing on the tailings dump has created a pink dust mask down wind from the dump. A more debatable diagnostic indicator is a faint yellowish stain or dust seen on the roof of an ore-drying bay of an ore-acid mixing (lixiviation) building. The bi-color photography throws doubt on the close association of an ore yard north of the plant with the uranium plant and confirms the tentative conclusion that the water purification ponds, further north, are not low-grade ore-leveling basins. Several factors induce the possibility of recognizing other color features that should appear. They are the practice of moving ore piles frequently so that stains do not build up on the ground, the maintenance of tight connections in pipelines, and the absence of spillage. Also a centralized chemical laboratory is an indication of an ore concentration plant, has not yet been identified."*

4.7 CONCLUSIONS

1. Bi-color photography can be successfully acquired with the CORONA J-3 system. Photography of this type should be restricted to special problems.

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 be used for normal photointerpreter tasks. The image quality degradation with the SF-05 filter in the CORONA system is

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*Bi-Color Photography of the Leninabad (Ispisar) Uranium Ore Concentration Plant (USSR) [redacted] (Jan. 1969).

not as pronounced when the photography is viewed in stereo with the normal higher quality red record. Stereo and bi-color cannot be seen at the same time. The acquisition of bi-color does not preclude the availability for stereo viewing; however, the two techniques must be used separately.

5. One of the major problems 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.

6. The difference in apparent radiances of the same object when viewed from two stereo stations can cause erroneous color to result in the final bi-color print. Thus, the use of bi-color in an analytical sense is limited.

4.8 RECOMMENDATIONS

1. The bi-color technique should be used over selected operational targets when operational constraints preclude the use of conventional color film, and where color could increase knowledge of activities associated with those targets.

2. The ARES* with a bi-color viewer can be used as an immediate readout device for newly acquired bi-color targets.

3. Special printing operations are required to remove the distortion introduced by the panoramic geometry and stereo convergence angle as well as the terrain elevation changes in the scene. While rectification alone will not correct for the elevation changes, orthoprinting removes the major distortions due to the ground terrain elevation changes. Very small objects (such as aircraft), however, still present problems for full correction. If bi-color is judged to be useful for intelligence purposes, the need for new exploitation equipment is indicated.

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*ARES or automatic registration electronic stereoscope—is a device that corrects the panoramic and look angle distortions introduced by CORONA. One of these instruments has been modified to provide bi-color imagery. This modified instrument provides bi-color on a near real time basis, although a "hard" copy print is not available.

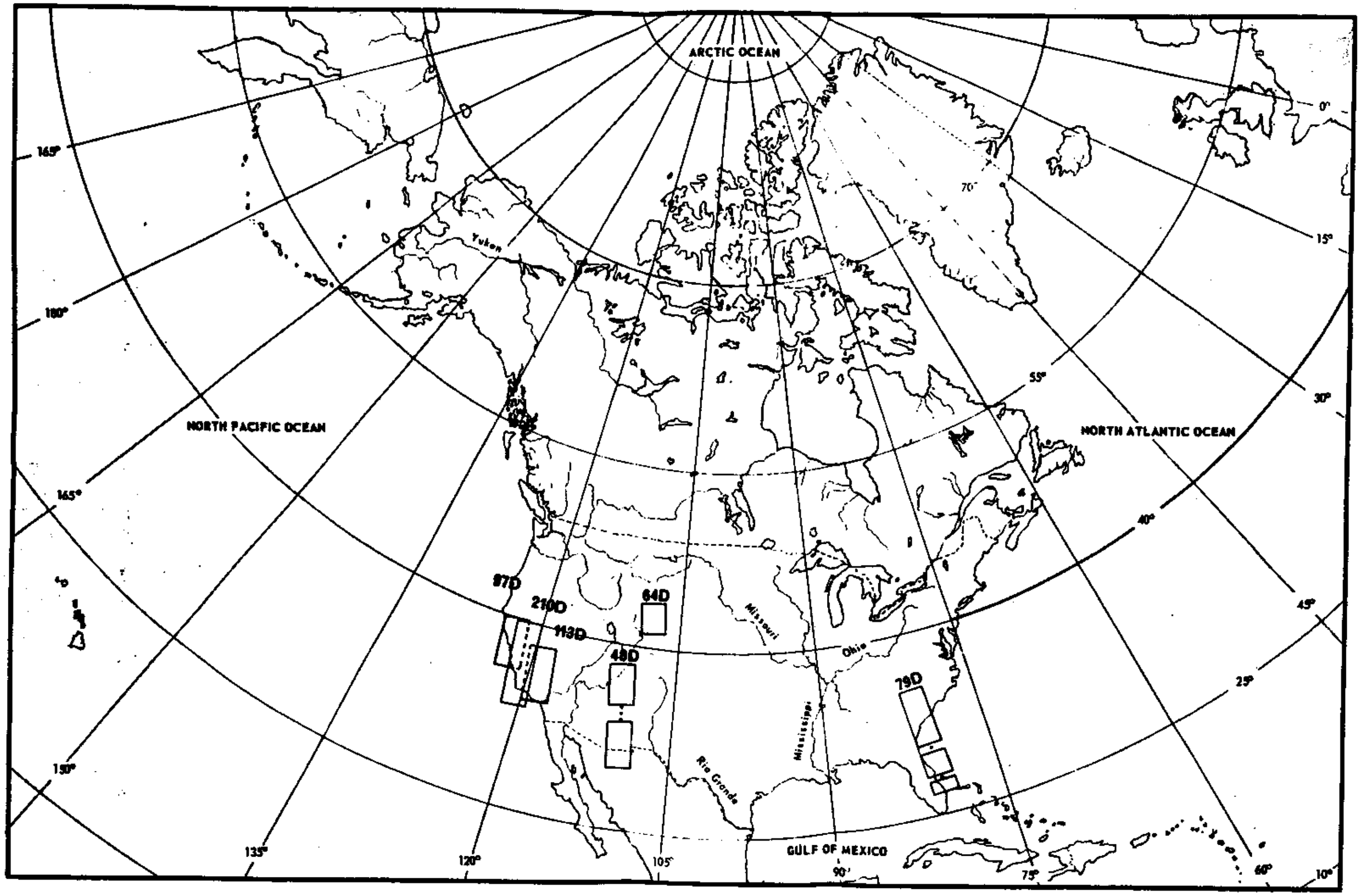


Fig. 4-1 — Ground tracks for the mission 1102 bi-color passes over the United States

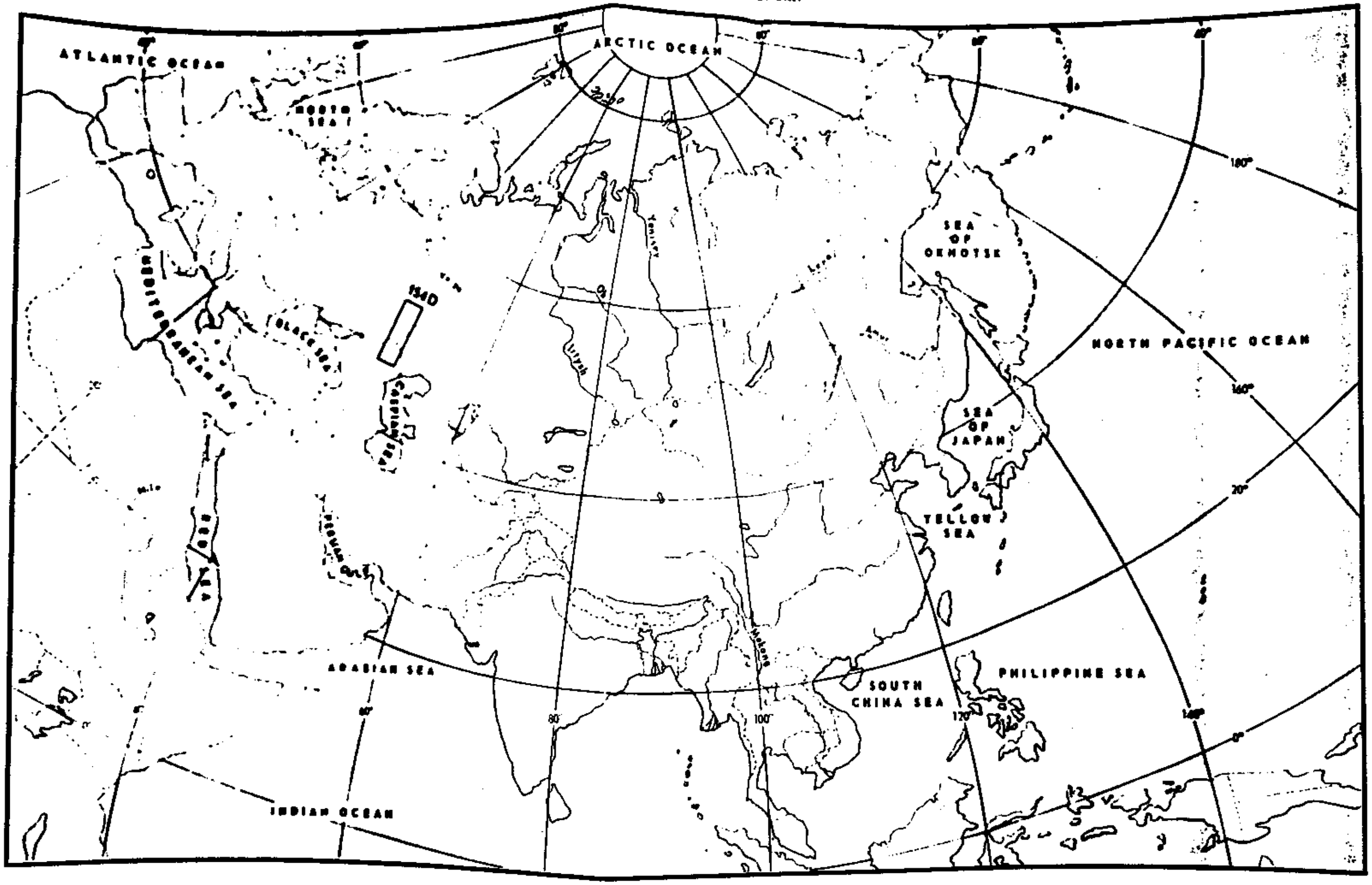
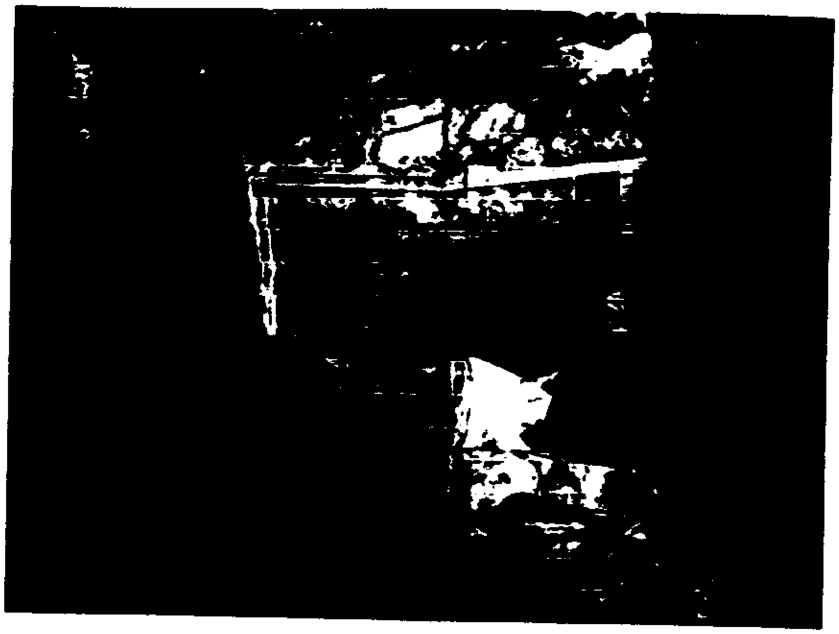


Fig. 4-2 — Ground track for the mission 1102 bi-color pass over the Soviet Union

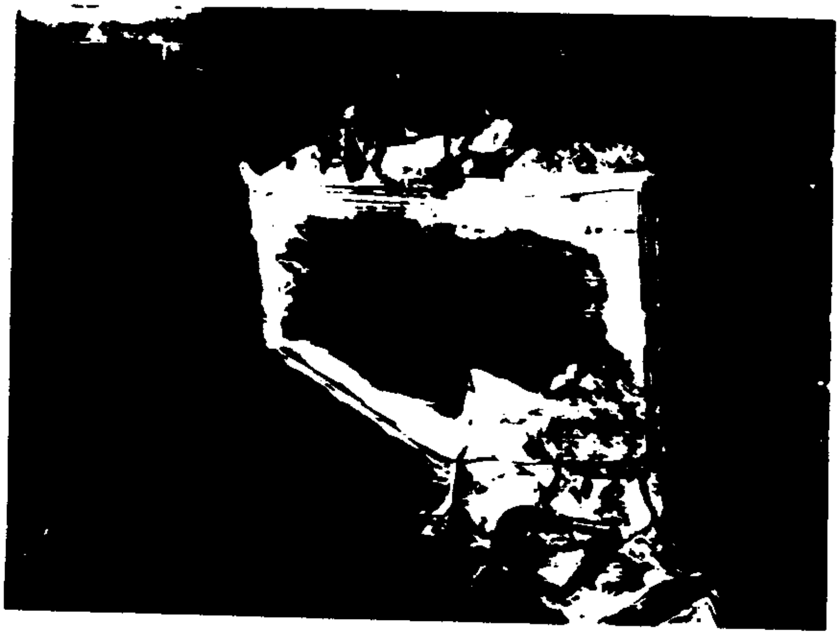
Copper Mine Slurry, Arizona

Figure number	4-3(a)	4-3(b)	4-4
Mission	1102-1	1102-1	1102-1
Camera	FWD no. 305	AFT no. 304	Integration
Rev	D-048	D-048	D-048
Frame	050	056	050, 056
Date	12 Dec 1967	12 Dec 1967	12 Dec 1967
Film	3404	3404	–
Filter	Wratten no. 25	SF-05	–
Exposure time	1/250 sec	1/300 sec	–
Altitude	519,000 ft	519,000 ft	–
Scale	1:259,500	1:259,500	–
Solar altitude	27° 18'	27° 16'	–
Latitude (CF)	31° 25.1'N	31° 26.6'N	–
Longitude (CF)	109° 47.8'W	109° 50.6'W	–
Universal grid coordinates	35.1, 2.5	35.1, 1.2	–
Magnification	20×	20×	20×
Note	Red bi-color record	Green bi-color record	Integrated bi-color print

[redacted]



(a) 20× orthoprint from red filtered negative



(b) 20× orthoprint from green filtered negative

Fig. 4-3 — Copper mine slurry, Arizona

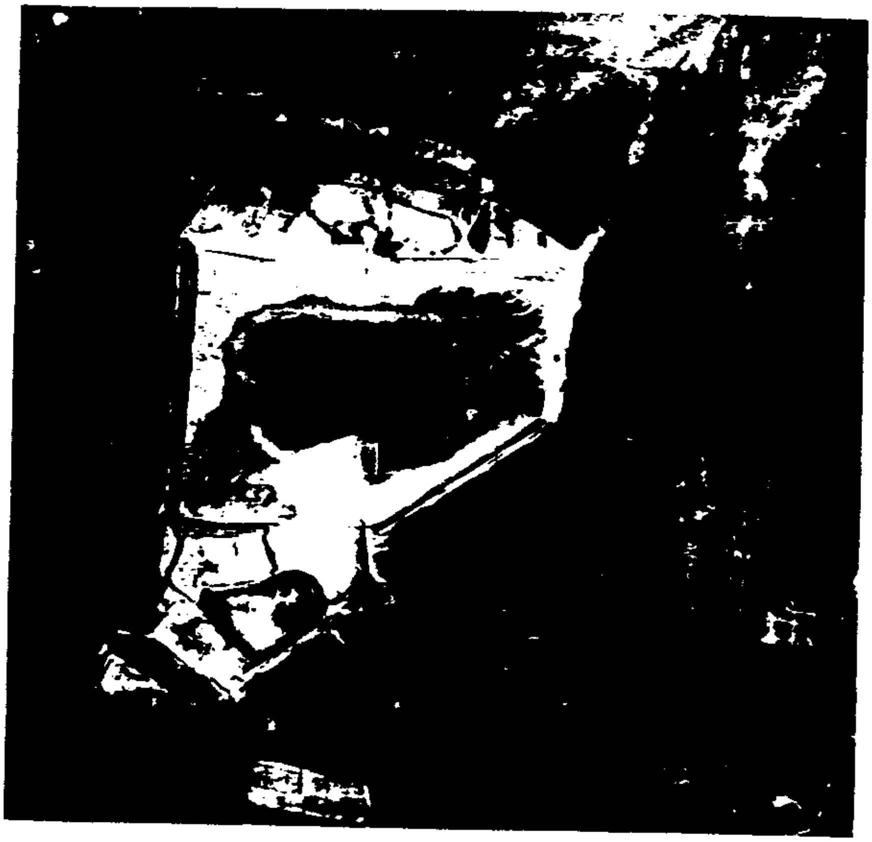


Fig. 4-4 — 20× bi-color integration made from green and red orthoprints

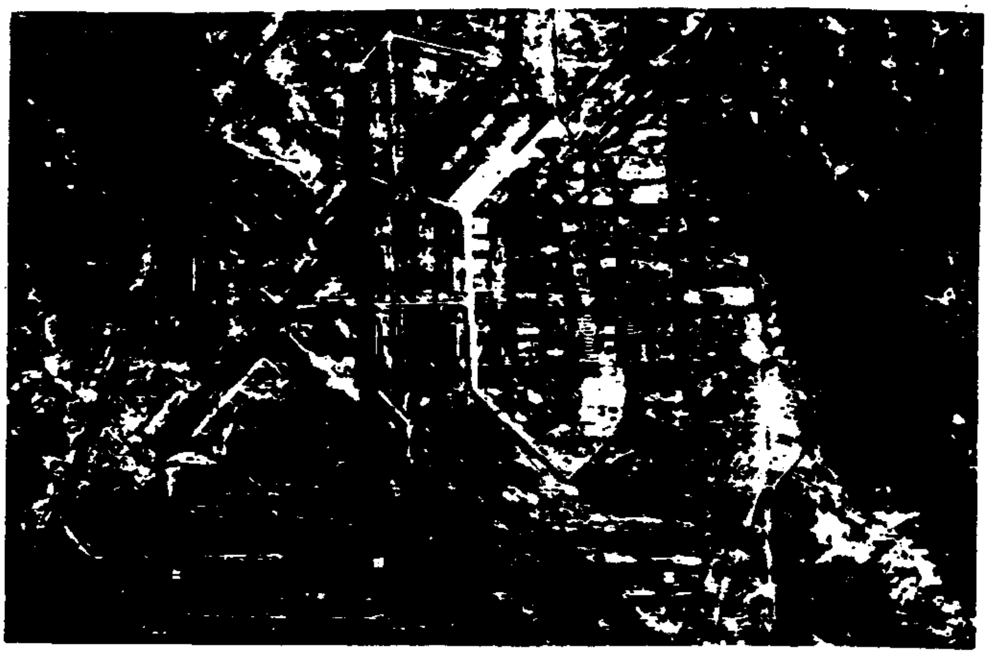
Bisbee-Douglas International Airport, Arizona

Figure number	4-5(a)	4-5(b)
Mission	1102-1	1102-1
Camera	FWD no. 305	AFT no. 304
Rev	D-048	D-048
Frame	050	056
Date	12 Dec 1967	12 Dec 1967
Film	3404	3404
Filter	Wratten no. 25	SF-05
Exposure time	1/250 sec	1/300 sec
Altitude	519,000 ft	519,000 ft
Scale	1:259,500	1:259,500
Solar altitude	27° 18'	27° 16'
Latitude (CF)	31° 25.1'N	31° 26.6'N
Longitude (CF)	109° 47.8'W	109° 50.6'W
Universal grid coordinates	45.8, 4.4	29.7, 2.4
Magnification	20×	20×
Note	Red bi-color record	Green bi-color record

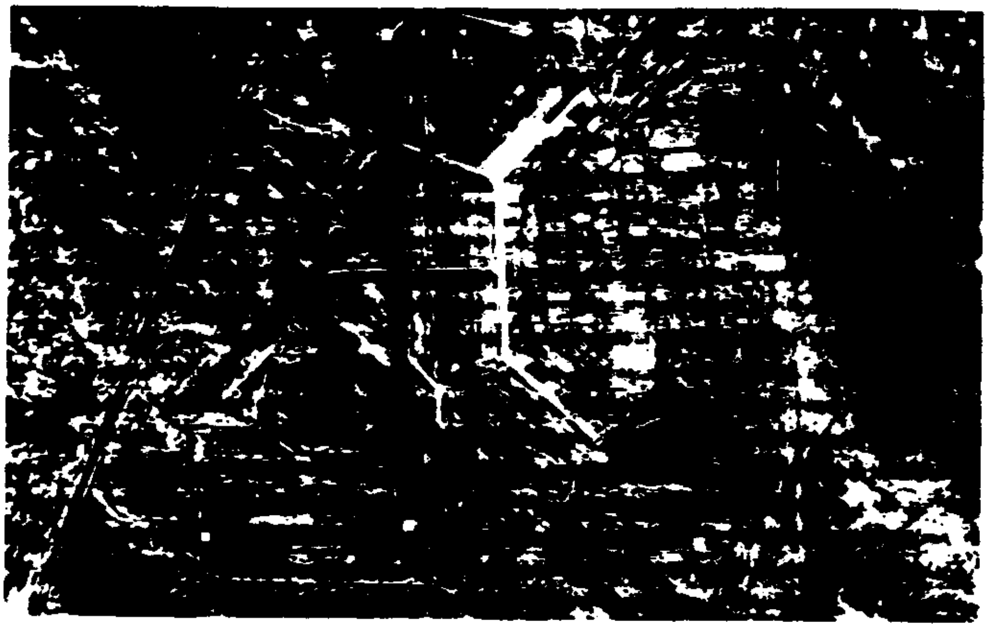
[redacted]

Bisbee-Douglas International Airport, Arizona

Figure number	4-6
Mission	1102-1
Camera	Integration
Rev	D-048
Frames	050, 056
Date	12 Dec 1967
Film	–
Filter	–
Exposure time	–
Altitude	–
Scale	–
Solar altitude	–
Latitude (CF)	–
Longitude (CF)	–
Universal grid coordinates	–
Magnification	20×
Note	Integrated bi-color print



(a) 20× orthoprint from red filtered negative



(b) 20× orthoprint from green filtered negative

Fig. 4-5 — Bisbee/Douglas International Airport, Arizona

Fig. 4-6 — 20× bi-color integration made from green and red orthoprints

Ispisar Uranium Ore Concentration Plant, Leninabad, USSR

Figure number	4-7
Mission	1103-2
Camera	FWD no. 307
Rev	D-153
Frame	047
Date	11 May 1968
Film	3404
Filter	Wratten no. 25
Exposure time	1/450 sec
Altitude	516,000 ft
Scale	1:258,000
Solar altitude	67° 29'
Latitude (CF)	40° 12.5' N
Longitude (CF)	68° 59.6' E
Universal grid coordinates	59.4, 1.7
Magnification	20×
Note	Red bi-color record

Ispisar Uranium Ore Concentration Plant, Leninabad, USSR

Figure number	4-8
Mission	1103-2
Camera	Integration
Rev	D-153
Frames	047, 053
Date	11 May 1968
Film	–
Filter	–
Exposure time	–
Altitude	–
Scale	–
Solar altitude	–
Latitude (CF)	–
Longitude (CF)	–
Universal grid coordinates	–
Magnification	–
Note	Integrated bi-color print

Fig. 4-7 — 20× enlargement of Ispisar uranium ore concentration plant, U.S.S.R., from mission 1103

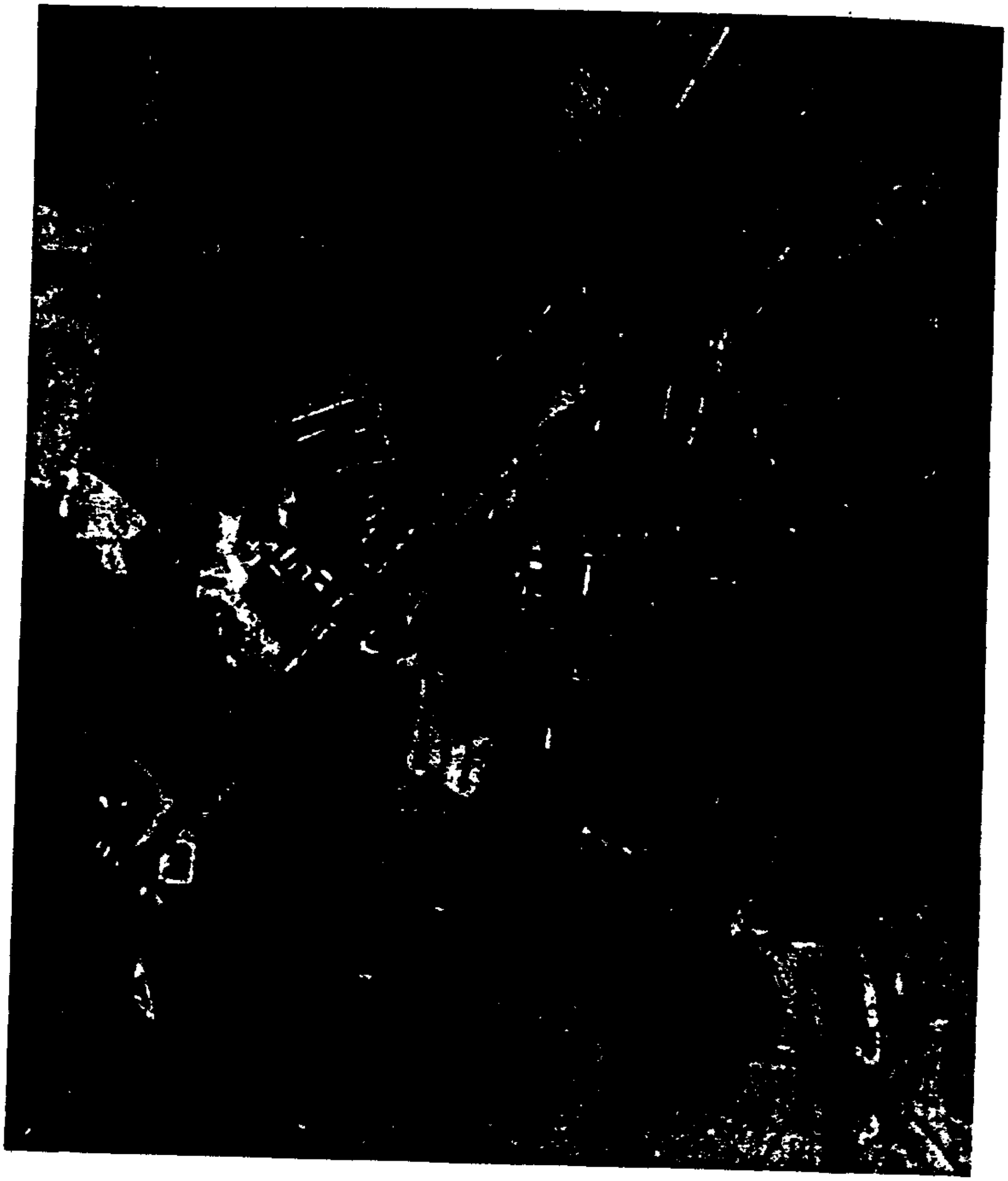


Fig. 4-8 — 20× enlargement bi-color reproduction of Ispisar uranium ore concentration plant, U.S.S.R., made with optical orthoprinting from mission 1103

5. SO-121 TESTS — MISSIONS 1105 AND 1106*

SO-121 Aero Ektachrome is a medium speed color reversal film coated on an Estar standard thin base. The EKIT† test series of 1966-67 indicated that SO-121 was useful in the 112B camera configuration which is virtually identical to the CORONA system. From this test series, it was shown that SO-121 could be used at rather low solar altitudes, which by the very nature of satellite photography is a necessity. This test also showed that the resolution obtained from a mobile CORN target was 48 lines per millimeter and that with proper focusing 60 lines per millimeter could have been achieved. Therefore, without refocusing the CORONA camera, it was anticipated that a ground resolution of 15 feet could be obtained.

Mission 1105 used 500 feet of SO-121 at the end of the film roll. Subsequently, mission 1106 was flown with 2,000 feet of SO-121. The best photography of these two missions is estimated to have achieved the 15-foot resolution level.

5.1 PURPOSE

The mission 1105 SO-121 test was intended to:

1. Obtain for the first time conventional color photography from the CORONA J-3 system.
2. Demonstrate the capability of the J-3 camera to handle SO-121.

5.2 TEST CONSIDERATIONS

In conjunction with the major purpose, actual targets supplied by CIA intelligence analysts were furnished to the Satellite Operations Center in an effort to realistically

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*Detailed report on these analyses will be issued shortly.

† EKIT was a test program undertaken by Itek in 1966-67; it was designed to evaluate potential engineering tests to be performed on J-3. This test series employed the 112B camera system (which is virtually identical to CORONA J-1) at an altitude of 65,000 feet. A total of 16 reports were issued, each evaluating the possible use of a new photographic technique to be used on J-3. The techniques that appeared most promising were then recommended for a flight test on J-3.

evaluate the film. These targets included the J-Complex at Tyura Tam, SA-2 and SA-5 sites in the USSR, Launch Complex A at Sary Shagan, and certain areas in Vietnam and China.

Finally, and of particular interest was Site A-1 at Kartaly, USSR, where the Soviets are suspected to be using camouflage. Unfortunately, these targets were not covered on the color portion of the mission.

5.3 ENGINEERING TESTS

In order to maintain maximum quality with the CORONA 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 filters (20CC cyan), and the proper amount of neutral density (0.40 density Inconel coating). Although SO-121 is faster than 3404, this speed differential cannot be used practically when the mission contains a split load of 3404/SO-121 films because the slit width range on CORONA J-3 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 3404/Wratten filter combinations for that particular camera. This afforded maximum operational convenience and minimized the changes for an exposure error.

The laboratory SO-121 resolution values for the particular filters used on mission 1105 (slightly above 50 lines per millimeter low contrast) indicated that the best image quality that could be expected was a ground resolution of approximately 15 feet.

5.4 MISSION TEST DETAILS

Mission 1105 contained 500 feet of SO-121 spliced to the end of the primary mission film load of SO-380 of the AFT-looking camera. A material change detector onboard 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. 5-1 and 5-2. 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.

5.5 TEST RESULTS

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 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 CORONA 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 on this flight was the apparent film curl during exposure. One of the contributing reasons for this film curl was the fact that the system tensions were reduced by approximately 20 percent for this mission.‡ However, as pointed out in the PEIR message, the edge of format contained photography (see Figs. 5-3 and 5-4) equal to the maximum that could be expected from preflight tests. Fig. 5-4 represents the best "spatial" resolution imagery located on the SO-121 of mission 1105.

5.6 MISSION 1106 SO-121 FLIGHT

In January 1969, a requirement was levied upon the CORONA 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. In order to have a high probability of acquiring this target in color, 2,000 feet of SO-121 was authorized as a tag-on film load. The filter was again obtained from Eastman Kodak. Since it was a different time of year, the neutral density had to be different from that of the previous color mission.

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*NPIC message no. [redacted] Dec. 10, 1968.

†The Performance Evaluation Team (PET) is a group specifically chartered to evaluate the engineering performance of each CORONA camera system post-flight. This group publishes a report [known as the Photographic Evaluation Interim Report (PEIR)] as a message. This report is distributed to the community approximately 2 weeks after the recovery of the second bucket. Several members of the Ad Hoc Committee are also members of the PET, and portions of PET analysis are included in this report, as appropriate.

‡This was done in an attempt to reduce the strain sensitivity marks on SO-380 which was the prime flight material for this mission.

The color photography from this mission was obtained in three passes (also indicated in Fig. 5-2) in 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. Representative black and white and color samples from cloud/snow-free areas of this mission are shown in Figs. 5-5 and 5-6. The mission 1106 PEIR* stated that:

> *". . . This is the first CORONA 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 (see remarks) 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."*

5.7 CONCLUSIONS

The following conclusions have been drawn:

1. The CORONA J-3 camera is capable of handling SO-121.
2. The ground resolution achievable with SO-121 in the CORONA J-3 camera is, at best, approximately 15 feet. Average ground resolutions of 20 to 25 feet are to be expected.
3. Electrostatic marking with SO-121 is not a problem.
4. The Ad Hoc Committee has no reservations relative to the compatibility of SO-121 with the CORONA camera.

---

*NPIC message no.[redacted] Feb. 2, 1969.

†In order to be sure of fulfilling this requirement, a two-part effort was undertaken. While the primary source of information was to be the color film from this mission, a secondary approach using the bi-color technique was also initiated. Mission 1103 had covered the target area in bi-color, and the requirement was satisfied by CORONA using that approach to color photography.

5.8 RECOMMENDATIONS

Further flight testing with SO-121 is recommended. However, future tests should be aimed primarily at assessing the intelligence use of color film in the CORONA J-3 system. As such, this material should be flown against targets for which there are specific color-oriented intelligence problems that can be answered within the scale and resolution constraints of the J-3 system.

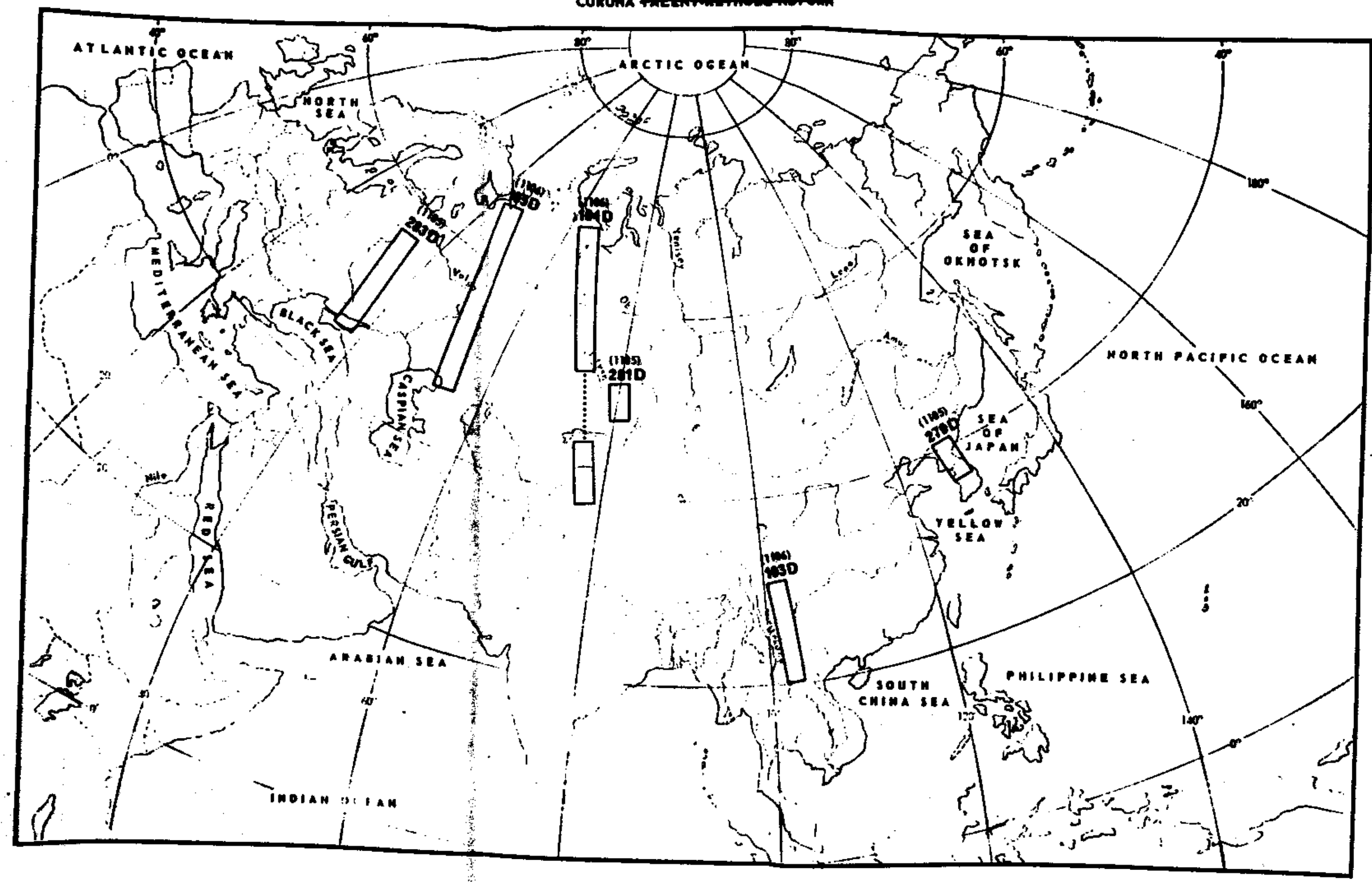

Fig. 5-2 — Ground tracks for the mission 1105 and 1106 SO-121 passes over Eurasia

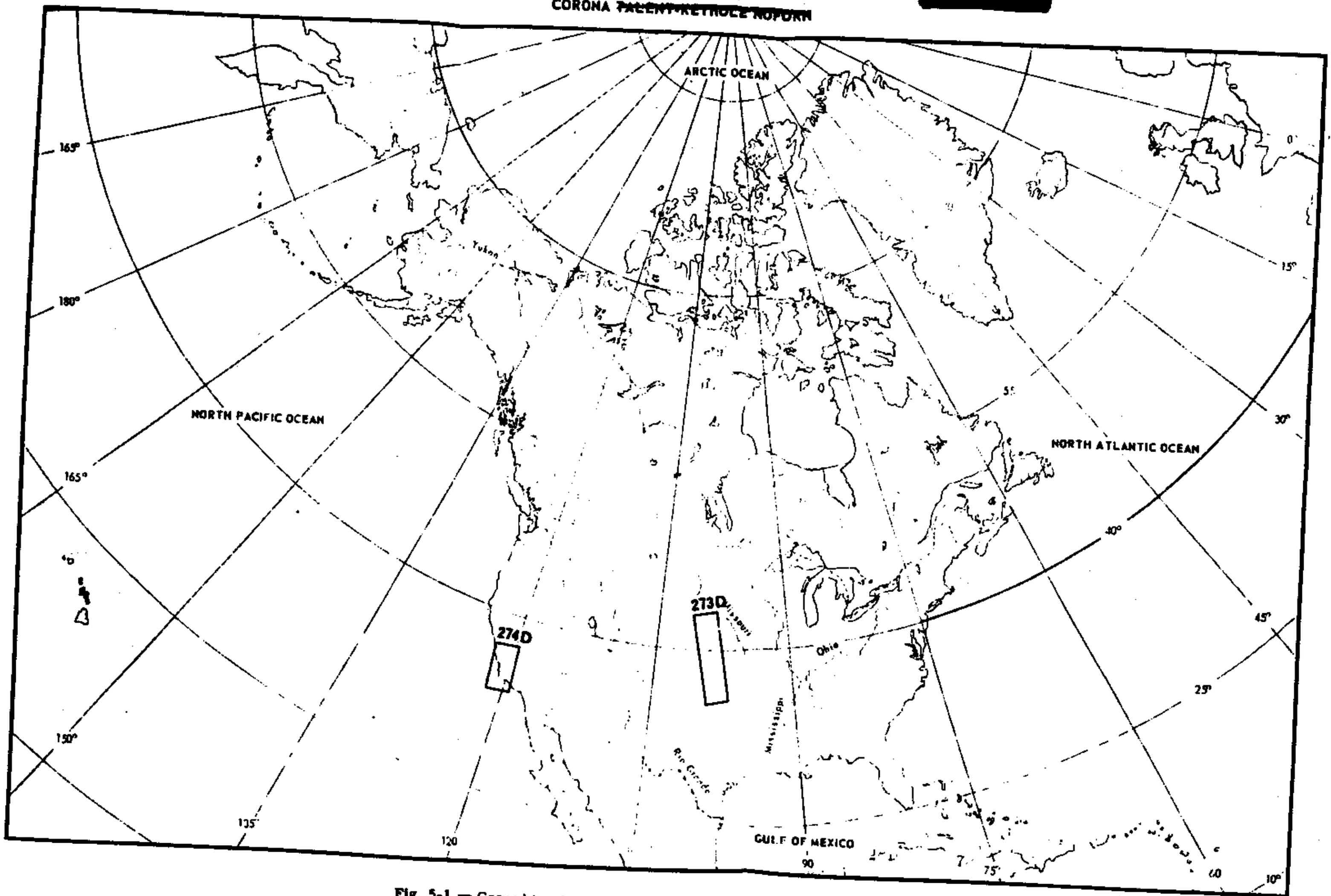

Fig. 5-1 — Ground tracks for the mission 1105 SO-121 passes over the United States

Clinton Sherman AFB, Oklahoma

Figure number	5-3	5-4
Mission	1105-2	1105-2
Camera	FWD no. 311	AFT no. 310
Rev	D-273	D-273
Frame	056	063
Date	20 Nov 1968	20 Nov 1968
Film	3404	SO-121
Filter	Wratten no. 25	2E + 20C + .5ND
Exposure time	1/270 sec	1/450 sec
Altitude	513,000 ft	513,000 ft
Scale	1:256,500	1:256,500
Solar altitude	33° 51'	33° 57'
Latitude (CF)	35° 29.1' N	35° 23.7' N
Longitude (CF)	98° 16.1' W	98° 17.5' W
Universal grid coordinates	9.2, 1.8	67.8, 0.6
Magnification	5×	5×

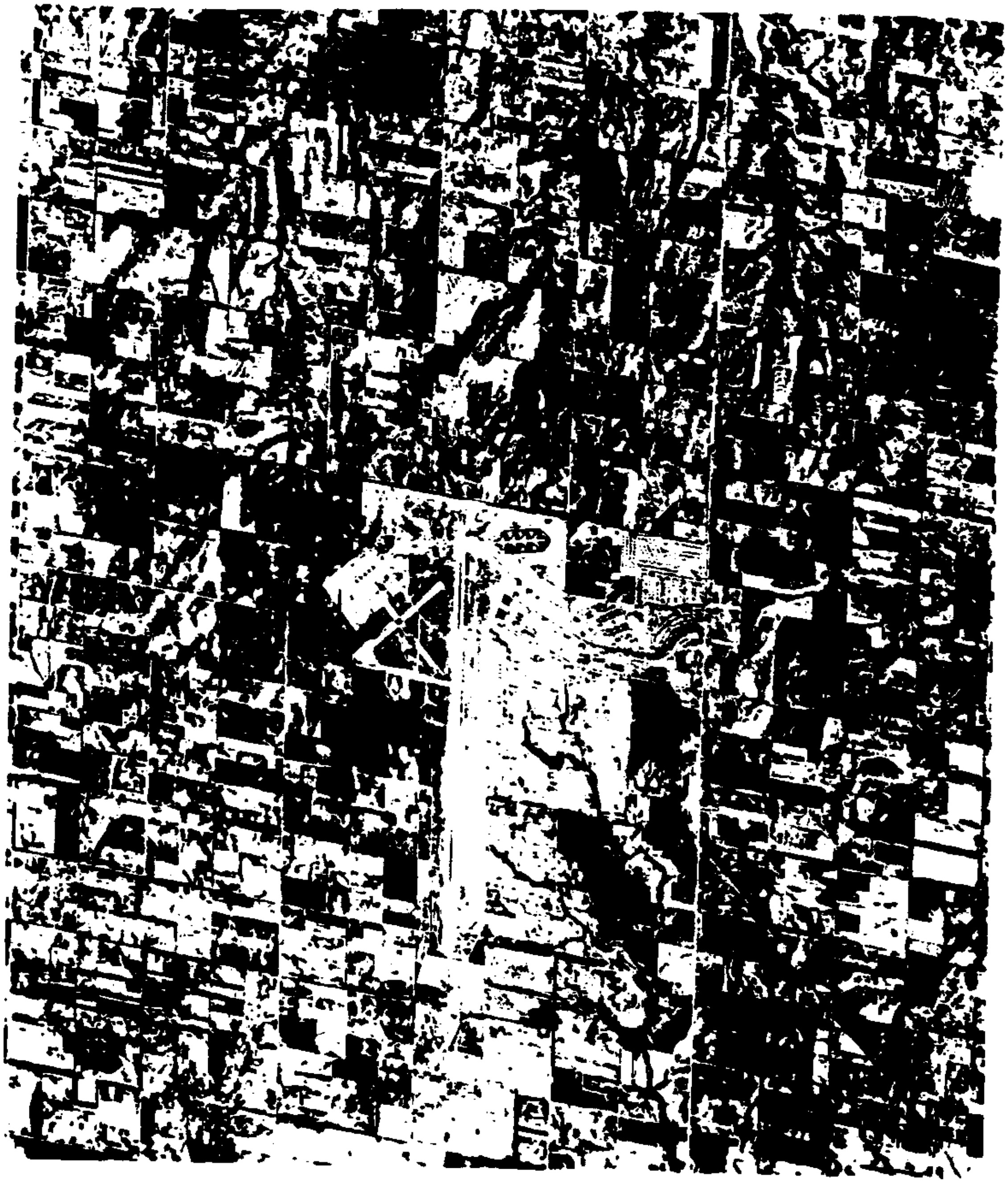

Fig. 5-3 — 5× enlargement of Clinton Sherman AFB, Oklahoma from the FWD-looking camera of mission 1105 using 3404 film

[redacted]

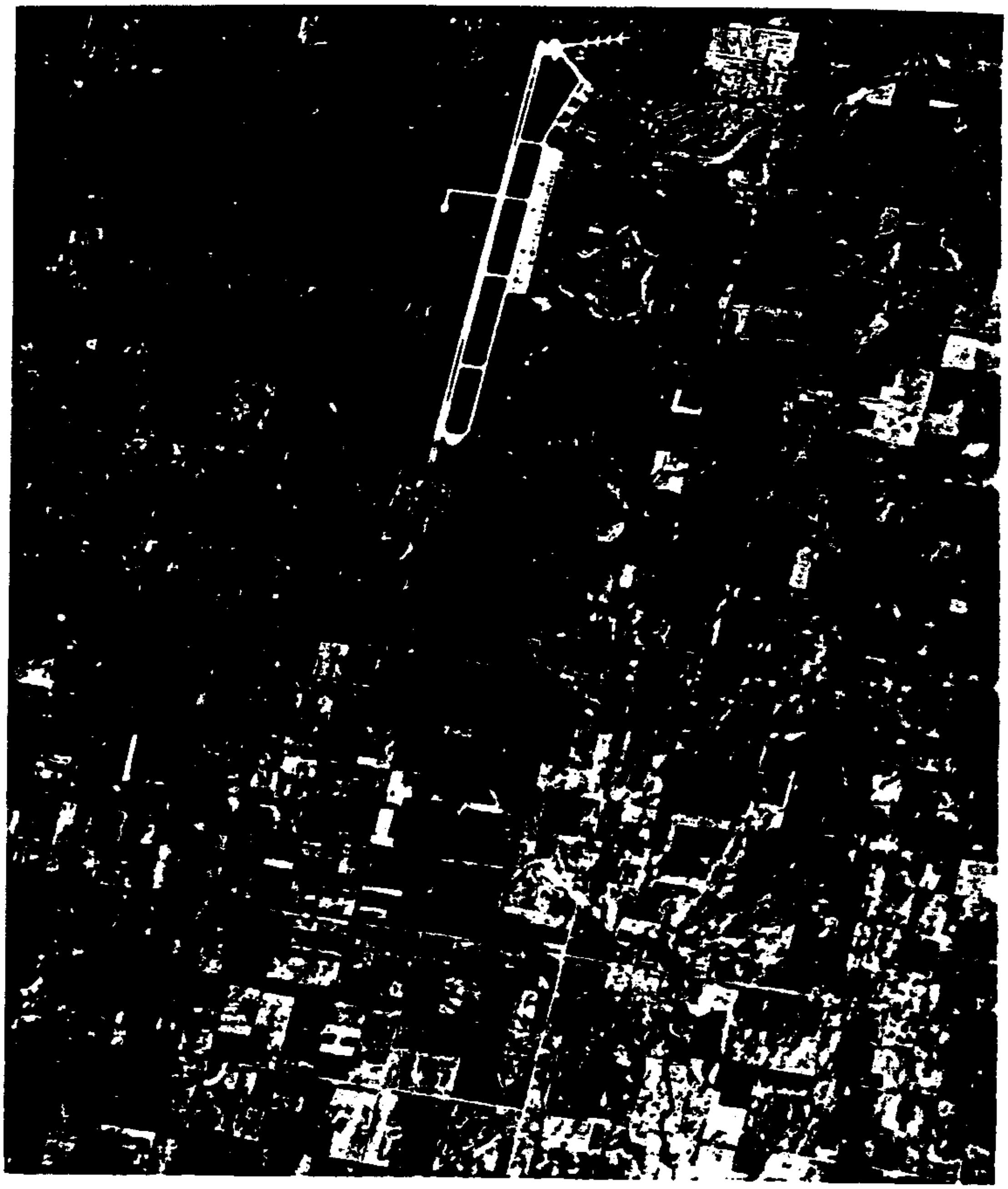

Fig. 5-4 — 5× enlargement of Clinton Sherman AFB, Oklahoma from the AFT-looking camera of mission 1105 using SO-121 film (edge of frame)

[redacted]

Kun Yang Hai Lake Area, Southeast China

Figure number	5-5
Mission	1106-2
Camera	FWD no. 313
Rev	D-103
Frame	175
Date	12 Feb 1969
Film	3404
Filter	Wratten no. 23A
Exposure time	1/363 sec
Altitude	468,000 ft
Scale	1:234,000
Solar altitude	51° 30'
Latitude	24° 42' N
Longitude	102° 31' E
Universal grid coordinates	53.0, 3.6
Magnification	5×

Kun Yang Hai Lake Area, Southeast China

Figure number	5-6
Mission	1106-2
Camera	AFT no. 312
Rev	D-103
Frame	181
Date	12 Feb 1969
Film	SO-121
Filter	2E + 20C + .5ND
Exposure time	1/484 sec
Altitude	468,000 ft
Scale	1:234,000
Solar altitude	51° 30'
Latitude	24° 42' N
Longitude	102° 31' E
Universal grid coordinates	22.6, 4.0
Magnification	5×

 [redacted]

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

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

6. SO-180 TEST — MISSION 1104*

Infrared Aero Ektachrome, SO-180, is a color reversal tri-pack emulsion coated on polyester standard thin base with a clear gelatin anticurl backing. The total thickness of the material is 3.0 mils. Unlike SO-121, it has a unique spectral sensitivity that enables the material to record the near infrared characteristics of ground targets. The film has a green sensitive layer, a red sensitive layer, and a near infrared sensitive layer. The sensitivity of the film has been designed so that the infrared layer records as red, the red records as green, and the green records as blue.

This technology took the form of World War II camouflage-detection (CD) film that evolved in 1962 into the acetate base 8443, Kodak Ektachrome Infrared Aerial. This same emulsion on a 2.5-mil Estar base is the SO-180 material.

Each of the three photographic layers has sensitivity to blue light in varying degrees: the near infrared sensitive layer actually has a greater blue sensitivity than the other two layers. Therefore, SO-180 must be supplemented with a minus-blue (Wratten no. 12 or 15) filter, with cutoff in the 500-millimicron region.

The cyan layer is designed to be slower than the other two layers because targets of interest for this material reflect comparatively more energy in the near infrared than in the red and green. Therefore, its prime value is in the detection of changes or differences in the 700-to 900-millimicron region which are not visually discernible. In addition, the unusual color contrasts produced by the spectral shift yield a high potential for rapid scanning exploitation.

Three EKIT† aircraft flights (January and May 1967) with SO-180 produced imagery suitable for interpretation and analysis to demonstrate a significant potential application in satellite reconnaissance. The film was especially effective with farm crops, water courses, and foliage. The effects of scale, altitude, and space environment, however, were not known such that an orbital mission was required to define its ultimate potential. The SO-180 tag-on experiment on mission 1104 in August 1968 provided the first satellite reconnaissance imagery on color film with the CORONA system.

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*A detailed report on this analysis will be issued shortly.

†EKIT Report No[redacted] Evaluation of SO-180 (Infrared Color Film).[redacted] (Aug. 14, 1967).

6.1 PURPOSE

The prime objectives of the experiment were:

1. To demonstrate the feasibility of using SO-180 film in the CORONA system under operational conditions
2. To acquire color translation records of specific targets for intelligence analysis.

6.2 TEST CONSIDERATIONS

Extensive coordination with the intelligence community resulted in an almost purely intelligence-oriented target list. These targets, in general, were in three basic categories:

1. Atomic energy facilities
2. Buried antennas
3. Economic intelligence.

In the first category, atomic energy facilities within the United States were used to establish a comparison between facilities of known characteristics and photography of these facilities on SO-180 in the CORONA camera system. Similar tests were flown with aircraft over the same targets to establish an additional SO-180 comparison between aircraft and satellite altitudes.

In the second category, a group of CIA analysts responsible for Soviet telecommunication is concerned with the identification of buried antennas and their locations. Four of the know locations are:

1. Svobodnyy
2. Barano-Orenburg Skoye
3. Anastasyevka
4. Kremovo.

In the third category of economic intelligence, requests were made to determine if SO-180 could be used for agricultural assessment. This interest started in 1966 when USIB stated*

> *"Agricultural production in Communist China is of considerable intelligence interest, and good data on this subject are lacking. CIA is working with NPIC to test the feasibility of using photographic techniques to estimate crop yield from satellite photography."*

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* Review of Photographic Coverage and Exploitation of Photography on China, [redacted] (Feb. 7, 1966).

The same document recommended that*:

> *"CIA proceed apace in seeking to develop techniques which will enable estimates of crop yield to be made from satellite photography."*

In attempt to tie the SO-180 test in with current intelligence problems, the Office of Economic Research of CIA provided a list of agricultural targets appropriate for SO-180 engineering evaluation. Excerpts follow.†

> *"Collection of imagery from these targets will:*
>
> *(a) Facilitate the monitoring of the condition of autumn-harvested crops in the specified areas of Communist China and analogous areas of Taiwan, Japan, and the U. S., for which ground truth is available. (The August timing of Mission 1104 precludes collection against winter wheat in the North China Plain, the harvesting of which will have been completed.)*
>
> *(b) Survey the water level of reservoirs and soil moisture conditions as a check against collateral weather information."*

6.3 ENGINEERING TESTS

In preparation for this experiment, SO-180 film received extensive altitude environmental and system capability tests at Itek and at A/P.‡ Initial tests had indicated that a corona fogging problem existed when SO-180 was used in J-3. It was known that these static markings varied with other films as a function of pressure. Therefore, a series of tests was performed in order to find a pressure window that would minimize the corona static marking on this film. The altitude tests were accomplished at camera internal pressures from less than 1 micron through 160 microns, utilizing incremental pressure steps and pressure sweeps. Results of the chamber tests with QR-2 indicated that SO-180 marks severely under most environmental pressures. The markings extended from edge to edge and continuously throughout the format. As a direct result of these tests, however, two corona-free "windows" were identified. One window extended from 12 to 22 microns and the other window was located above 160 microns. The 12- to 22-micron window was selected since a modification of the existing pressure makeup unit could be made to produce a 20-micron internal capsule pressure as well as the normal 50-micron pressure, depending on whether SO-180 or 3404 were in the format.

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*Review of Photographic Coverage and Exploitation of Photography on China, [redacted] (Feb. 7, 1966).

†Agricultural Targets for Inclusion in OSP Engineering Tests, [redacted] (June 7, 1968).

‡Advanced Projects—CIA facility where CORONA systems are assembled, tested, and prepared for flight.

As with most of the experiments on CORONA J-3, a special filter was fabricated for use with SO-180. The filter was a composite coating, similar to a Wratten no. 15 plus 0.9 neutral density and was designed and manufactured by Eastman Kodak. Although the full speed benefit of the SO-180 was not exploited, this procedure was necessary to obtain correctly exposed photography over denied areas where the exposure was programmed for the prime mission material, 3404.

Resolution tests on SO-180 with a third generation Petzval lens were carried out using this filter. Through-focus and through-exposure tests characterized the lens/filter/film combination response to high and low contrast resolution targets. With 35 cycles per millimeter low contrast resolution as a baseline, ground resolution was expected to be on the order of 25 feet. In the actual photography, ground resolution is estimated to be 25 to 35 feet.

6.4 TEST DETAILS

The final 811 feet (301 frames) exposed in the FWD-looking camera was SO-180 Infrared Ektachrome film, spliced to the 15,200-foot principal supply 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. 6-1 and 6-2. 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.

While extensive work was done to locate intelligence targets of interest for which the SO-180 might prove helpful (Section 6.2), few of these targets were actually acquired. This was caused by the fact that insufficient film (SO-180) was loaded on the camera to allow coverage of the desired areas when they were expected to be subject to acquisition. The film load of SO-180 was limited on the mission to 800 feet (the original plan was for 1,600 feet) due to other operational considerations.

Imagery acquired on the SO-180 (with comparative 3404 acquisition) of unique target/terrain features for color translation exploitation was sufficient, however, 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 populated areas, 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 in the CORONA system even though the original targets were not covered.

6.5 FLIGHT RESULTS

The following are excerpts from the 1104 PEIR message.*

> *"... SO-180 engineering test: This mission contained 800 feet of Type SO-180, Ektachrome Infrared Aero Color film, on the end of the FWD camera. This test was run as part of the J-3 system capability studies and has the prime purpose of investigating the capability of the CORONA system to handle Type SO-180 film. Portions of the SO-180 film exhibited excellent exposure, color balance and resolution compatible with the maximum that could be achieved with this film/camera combination. (The limiting performance factor was the recognized lower resolution capability of Type SO-180 film compared to Type 3404.) When the weather conditions were favorable, and there were no degrading effects (i.e., static marking) hte PET estimates the ground resolved distance of film Type SO-180 to have been approximately 25 feet. It has been reported previously that significant portions of the test was degraded by electrostatic discharge which recorded as a red image on film Type SO-180. There was a second anomaly that caused a heavy bluish/green cast on film Type SO-180 over the entire format on the first few frames of each operation. The CORONA discharge degradations can be attributed directly to the failure of the pressure makeup unit (PMU). Pertinent comments follow.*
>
> *(1) Static marking: some of the imagery contains corona and electrostatic fog which appears red on film type SO-180. This condition varies from no marking to extremely severe marking. This condition occurs on those operations when the PMU provided system pressures other than desired*

*NPIC message no [redacted] Sept. 16, 1968.

(2) Effect of sit time: As discussed earlier, the first three and one-half frames of each operation had a noticeable bluish/green cast to the imagery. This effect was directly relatable to the sit time between camera operations. During very long sit periods, the blue/green cast became heavy and during short sit periods it is not as severe. The blue/green cast was due to a loss in infrared layer sensitivity during these sit periods. It is like (sic. likely) *that the loss of moisture, from the IR layer during the sit period, caused a loss in photographic speed. Further analysis of this phenomenon is indicated.*"

6.6 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. The The following evaluation is contained in the NPIC mission 1104 report:

> "*Regardless of these factors, portions of the SO-180 imagery obtained on this mission closely approximate the expectations of this lens/film combination. Some of the existing imagery contains significant added information from an intelligence standpoint, provided the analyst is allowed sufficient time to interpret it, has a working knowledge of the film characteristics, and is familiar with the infrared reflectivity of the various objects photographed.*"*

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

3. 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.

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

5. Corona 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 corona fogging was detrimental to information extraction. There are instances where low level fogging enhances vegetation information content.

6. In cases where the corona fog is not present in each of the three dye layers, panchromatic duplication through selective filtering can be used to eliminate the fog and retrieve gray-scale tonal information.

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*Mission 1104 Photographic Evaluation Report, [redacted]68 (Dec. 1968).

7. The magenta dye layer imagery tends to exhibit the highest resolution. Because this imagery is formed by essentially red light, black and white reproduction of this tonal information is similar to a 3404 record made through a Wratten no. 25 filter. Detail rendition in the magenta dye layer reproduction, however, is far inferior to the 3404/Wratten no. 25 record.

8. There is a high potential with SO-180 for economic intelligence, camouflage detection, location of waterways, and shipping channels.

6.7 RECOMMENDATIONS

1. Additional SO-180 acquisitions are needed to verify the capability of the CORONA camera to use this material. In performing any additional experiments, we would recommend that emphasis be placed, if possible, on its use for economic intelligence. Of particular interest would be the winter wheat crop in the north China plain.

2. In view of the sensitometric changes that occur with SO-180 in vacuum, photographic passes should be initiated six frames prior to the beginning of the desired coverage. Further studies in vacuum sensitometry on SO-180 are required to learn more about speed losses in individual layers on a time base.

3. Research into exploitation uses of SO-180, especially in terms of its unusual signatures, should be undertaken.

4. In view of the corona fogging that can occur on SO-180 in the J-3 system, further environmental pressure studies on the film are necessary to specify more precisely the behavior of the corona-free windows.

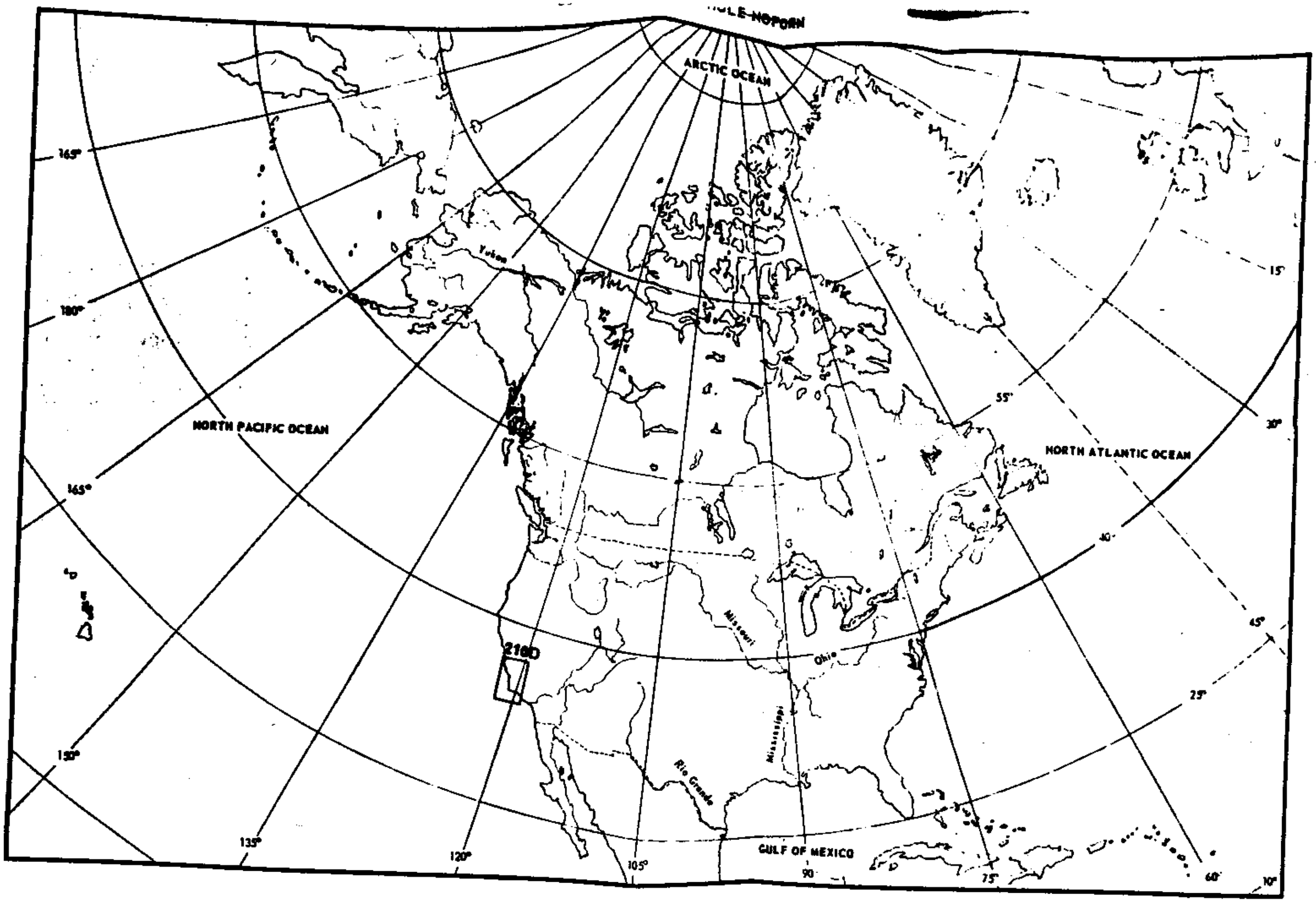

Fig. 6-1 — Ground track for the mission 1104 SO-180 pass over the United States

 [redacted]

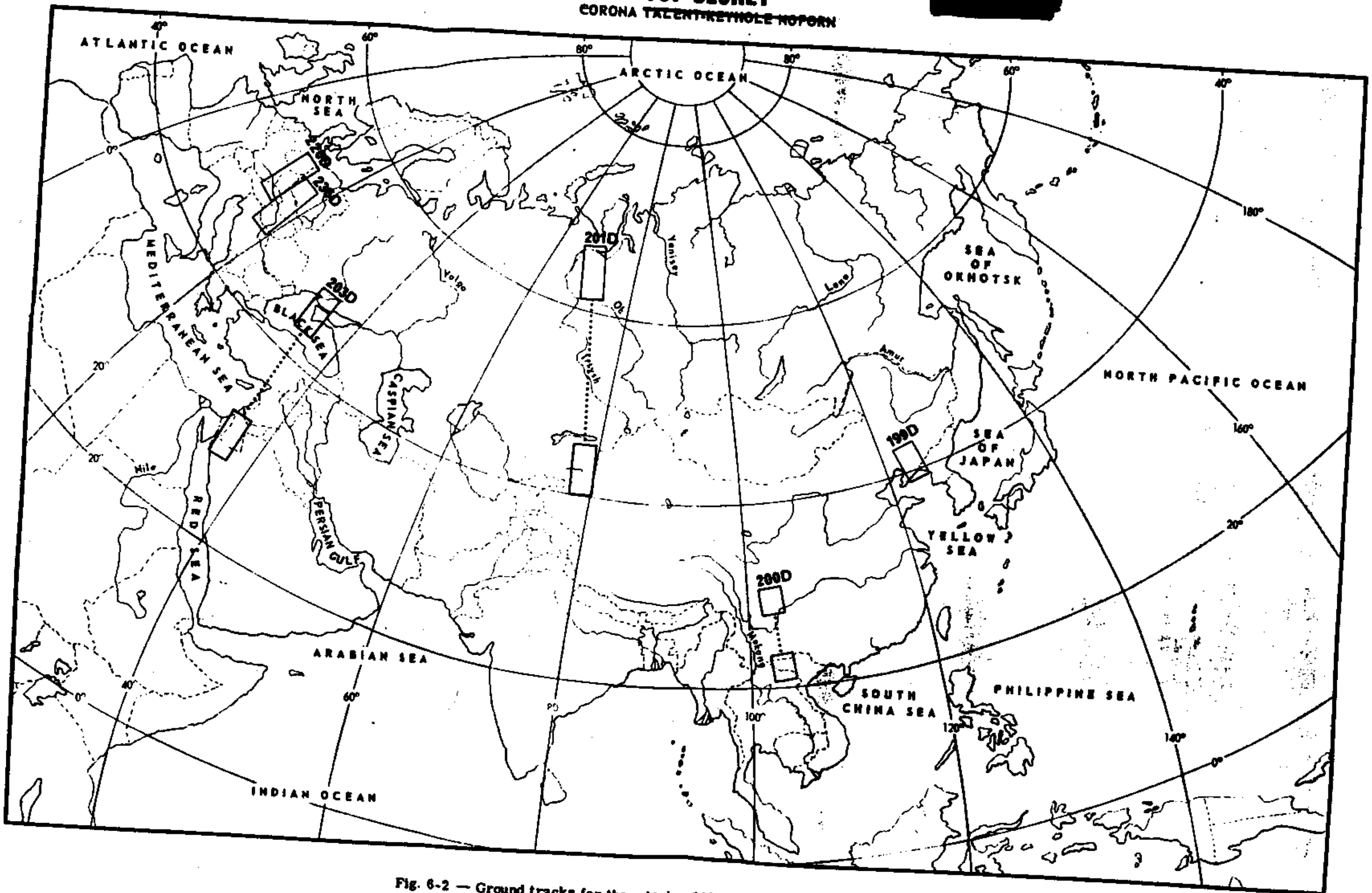

Fig. 6-2 — Ground tracks for the mission 1104 SO-180 passes over Eurasia

 [redacted]

Mineral Washout, Siani Deseart, Israel

Figure number	6-3	6-4
Mission	1104-2	1104-2
Camera	AFT no. 308	FWD no. 309
Rev	D-203	D-203
Frame	065	059
Date	20 Aug 1968	20 Aug 1968
Film	3404	SO-180
Filter	Wratten no. 21	Wratten no. 15 + .90ND
Exposure time	1/500 sec	1/500 sec
Altitude	502,000 ft	502,000 ft
Scale	1:251,000	1:251,000
Solar altitude	73°	73°
Latitude	29° 30' N	29° 30' N
Longitude	35° 20' E	35° 20' E
Universal grid coordinates	60.2, 2.5	15.0, 3.0
Magnification	1.5×	1.5×

[redacted]

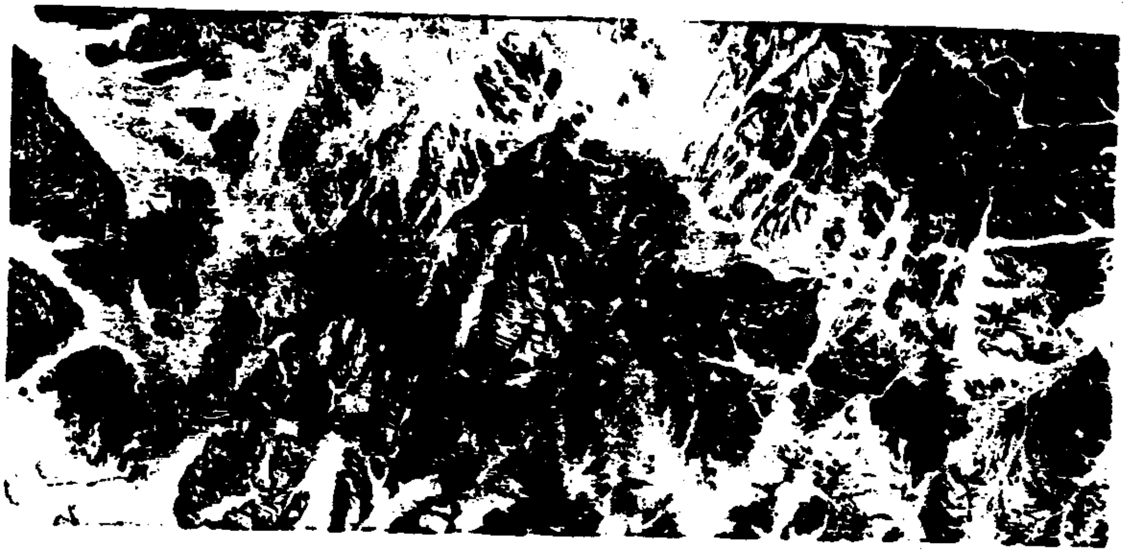

Fig. 6-3 — 1.5× enlargement of a mineral deposit washout from the AFT-looking camera of mission 1104 using 3404 film

Fig. 6-4 — 1.5× enlargement of a mineral deposit washout from the FWD-looking camera of mission 1104 using SO-180 film

[redacted]

Lompoc, California

Figure number	6-5
Mission	1104-2
Camera	AFT no. 309
Rev	D-210
Frame	019
Date	20 Aug 1968
Film	3404
Filter	Wratten no. 21
Exposure time	1/575
Altitude	486,000 ft
Scale	1:243,000
Solar altitude	67° 50'
Latitude	34° 40' N
Longitude	120° 30' W
Universal grid coordinates	32.9, 4.4
Magnification	10×

 [redacted]

Lompoc, California

Figure number	6-6
Mission	1104-2
Camera	FWD no. 308
Rev	D-210
Frame	013
Date	20 Aug 1968
Film	SO-180
Filter	Wratten no. 15 + .90ND
Exposure time	1/430
Altitude	486,000 ft
Scale	1:243,000
Solar altitude	67° 50'
Latitude	34° 40' N
Longitude	120° 30' W
Universal grid coordinates	42.2, 1.5
Magnification	10×

[redacted]

Fig. 6-5 — 10× enlargement of Lompoc, California from the AFT-looking camera of mission 1104 using 3404 film

[redacted] Handle Via
TALENT-KEYHOLE
Control Systems Jointly

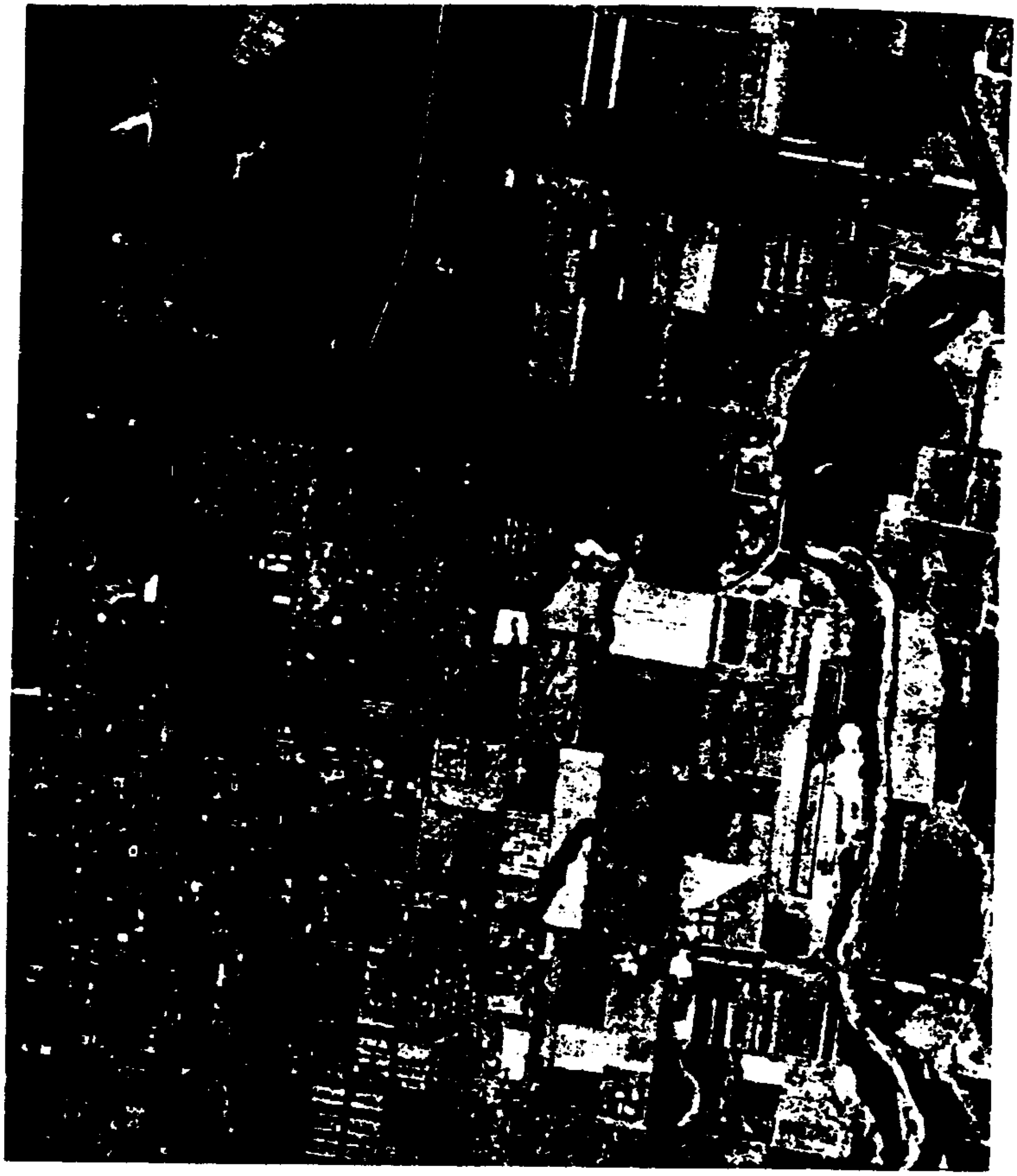

Fig. 6-6 — 10× enlargement of Lompoc, California from the FWD-looking camera of mission 1104 using SO-180 film

River System, North Viet Nam

Figure number	6-7
Mission	1104-2
Camera	AFT no. 309
Rev	D-200
Frames	036 034 033
Date	20 Aug 1968
Film	3404
Filter	Wratten no. 21
Exposure time	1/575 sec
Altitude	495,000 ft
Scale	1:247,500
Solar altitude	80°
Latitude	22 °N
Longitude	103 °E
Universal grid coordinates	50.8, 2.8 21.2, 3.1 50.2, 2.4
Magnification	5×

River System, North Viet Nam

Figure number	6-8
Mission	1104-2
Camera	FWD no. 308
Rev	D-200
Frames	030 028 027
Date	20 Aug 1968
Film	SO-180
Filter	Wratten no. 15 + .90ND
Exposure time	1/430 sec
Altitude	495,000 ft
Scale	1:247,500
Solar altitude	80°
Latitude	22 °N
Longitude	103 °E
Universal grid coordinates	17.3, 3.3 54.4, 3.0 25.4, 2.4
Magnification	5×

[redacted]

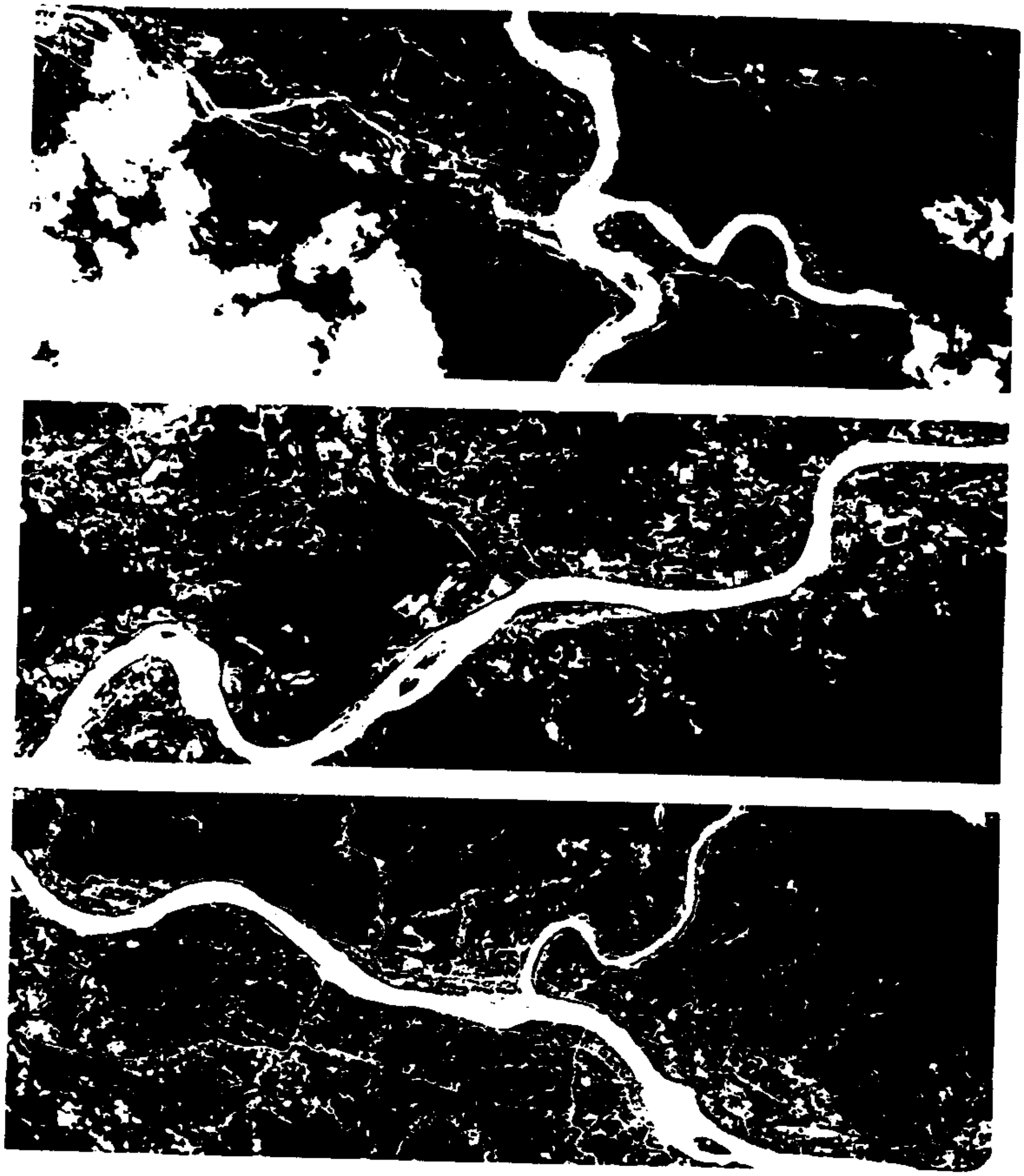

Fig. 6-7 — 5× enlargements of river intersections from the AFT-looking camera of mission 1104 using 3404 film

[redacted]

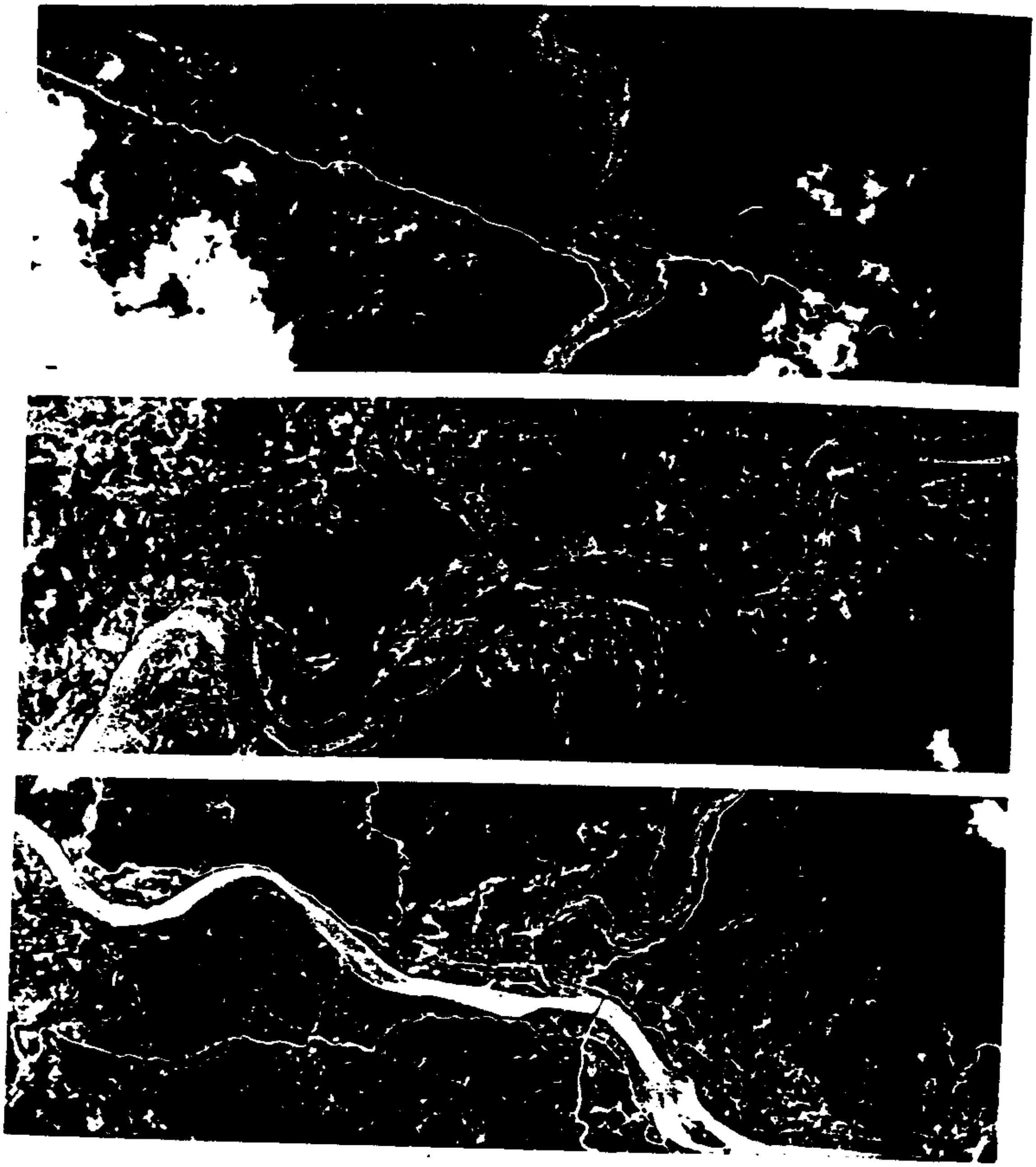

Fig. 6-8 — 5× enlargements of river intersections from the FWD-looking camera of mission 1104 using SO-180 film

[redacted]

Industrial Processing Plant, Krasnoperekopsk, USSR

Figure number	6-9
Mission	1104-2
Camera	AFT no. 309
Rev	D-203
Frame	018
Date	20 Aug 1968
Film	3404
Filter	Wratten no. 21
Exposure time	1/550 sec
Altitude	505,000 ft
Scale	1:252,500
Solar altitude	56°
Latitude	46 °N
Longitude	34 °E
Universal grid coordinates	23.8, 4.1
Magnification	5×

Industrial Processing Plant, Krasnoperekopsk, USSR

Figure number	6-10
Mission	1104-2
Camera	FWD no. 308
Rev	D-203
Frame	012
Date	20 Aug 1968
Film	SO-180
Filter	Wratten no. 15-.90ND
Exposure time	1/430 sec
Altitude	505,000 ft
Scale	1:252,500
Solar altitude	56°
Latitude	46°N
Longitude	34°E
Universal grid coordinates	51.3, 1.7
Magnification	5×

Fig. 6-9 — 5× enlargement of industrial processing plant with 3404 film from mission 1104

Fig. 6-10 — 5× enlargement of industrial processing plant with SO-180 film from mission 1104

Notice of Page Substitution

New B & W Films

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

7. NEW BLACK AND WHITE FILMS

The performance of any high acuity camera system is integrally dependent on its mechanical, optical, and film sensor components. Basic system improvements invariably involve one or more of these areas. For a given operational system, the most readily adaptable improvement (or at least the least costly one) to implement is the use of an improved film. Possible film improvements generally fall into three areas—sensitivity, image quality, and physical characteristics.

Improved film sensitivity and image quality really implies an improvement in the speed/resolution tradeoff, i.e., what one desires is not simply a faster film (since such films are available), but a film that is faster while maintaining essentially the same image quality characteristics as the film in current use. Improvements in the physical characteristics of the film are also desireable. A reduction in film thickness would mean that the payload could be larger with little increase in cost, the direct benefit being, of course, an increase in photographic coverage for a small increase in the cost of acquiring that coverage.

Improvements in film products are invariably achieved at some sacrifice in one or more areas. Increased film speed is normally achieved through an increase in grain size, which results in lower image quality. Conversely, increased film image quality is usually achieved at the sacrifice of film sensitivity. In like manner, "improvements" in film physical characteristics are often achieved at some sacrifice in system performance. For example, while thinner films have been made, their use in a satellite camera system would be more difficult if the system were not specifically designed to handle that film. In this case, although the film improvement is achieved, it might be achieved at the cost of lower system resolution due to film flatness problems in the focal plane.

The point is that the use of "improved" films in any camera system is not always as easy as it first seems, and the tradeoffs are not always simple. In any event, the purpose of this series of tests was to evaluate the use of two new films, SO-380* and SO-230,* with the J-3 camera system.

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*SO-380 is an ultrathin base version of 3404. The differences in base dimensions of 3404 (2.5 mils) and SO-380 (1.5 mils) produces a 50 percent difference in the total film thickness. SO-230 is a new film with sensitometric and image quality characteristics somewhat similar to those of 3404. The film is faster than 3404 by approximately 0.2 log E (2/3 stop). The ultrathin base version of SO-230 is SO-205 and has the same photographic characteristics as SO-230.

8. SO-230 TEST—MISSION 1102*

One of the fundamental limitations on the quality of photography from the CORONA systems is image smear. At CORONA scales, every micron of smear is an effective blur equal to 1 foot on the ground. It would only take 2 microns per millisecond of smear to limit the photography to a ground resolution of 10 feet at 1/400 second. If the exposure time could be reduced to 1/800 second, the smear would then be cut in half and the limiting ground resolution would become 5 feet, providing, of course, that the reduction in exposure time has been accomplished with no other sacrifice. However, the photographic process consists of many tradeoffs, and it is rarely possible to gain in one aspect without some sacrifice in another. Therefore, the goal of most analyses with high performance systems is to make a significant gain in one area without sacrificing too much in the others, thus providing a total system improvement.

Several years ago, Eastman Kodak manufactured a new film, SO-362, which was an attempt at such a tradeoff. The film was intended to be very similar in image quality to that of 3404, but have twice the emulsion speed. However, the film did not compare favorably with 3404 and was subsequently discontinued. In a continuing effort toward the same goal, Eastman Kodak recently started manufacturing another film, SO-230, which has been met with greater success in the community. The film has image quality closer to that of 3404 than did SO-362 and an increase in speed of approximately 2/3 of a stop. Therefore, the analysis undertaken by Itek was aimed at determining if there has, indeed, been a gain in total CORONA system performance by the use of this material rather than the normal 3404.

8.1 PURPOSE

The purpose of this analysis was to:

1. Evaluate the sensitometric, image quality, and physical characteristics of SO-230 relative to 3404 and
2. Compare the performance of the CORONA system in an operational mode using SO-230 as opposed to 3404.

---

*A full evaluation of this test is given in KH-4B System Capability Report No. 4, Evaluation of SO-230 film for use with the KH-4B System, [redacted] Oct 1, 1969).

8.2 ENGINEERING TESTS

Over a period of approximately 6 months, several engineering tests were performed with SO-230. Some took place before the first system flight with SO-230, and some we were undertaken afterward as a direct result of that first flight. Three of the more pertinent tests, listed below, deserve some attention in this text:

1. Theoretical total system resolution
2. "Real" speed increase of SO-230 over that of 3404
3. Emulsion dust buildup.

Initial studies were performed with data acquired from laboratory tests of SO-230 to predict the in-flight resolution. From these studies, it was predicted that there would be a measurable improvement in system resolution due to the reduced smear even though the film image quality itself was somewhat poorer than that of 3404. There were two difficulties with these early predictions: (1) the film granularity was not taken into consideration; and (2) the smear reduction was based on the photographic speed of the film. which was not precisely known. This was evidenced by the fact that various investigators had come to different conclusions as to the speed of SO-230. This was most likely due to the batch-to-batch differences in the emulsion which is to be expected with any new film.

After SO-230 had been flown, some observers considered the photography to have been overexposed. The prevailing thinking at that time was that the vacuum environment had caused a change in the photographic speed of SO-230, which caused this overexposure. Therefore, this would have had an effect on the theoretical resolution predictions. As a result, a test was performed that used the CORONA camera itself in a vacuum as a sensitometer. This test, however, indicated that the speed of SO-230 was the same in vacuum as it was in ambient conditions.

A problem encountered on mission 1046 appeared to be associated with an emulsion dust buildup in the camera, which may have caused the gradual out-of-focus condition observed on this mission. A test was undertaken with the CORONA J-3 qualification instrument to look into this problem. The tests indicated that there was an emulsion buildup problem with SO-230 on one of the cameras used, but not on the other. However, since the test was run on a J-3 unit, it did not precisely simulate the conditions encountered on mission 1046 which was a J-1 configuration.

The SO-230 emulsion dusting problem experienced during mission 1046 has never been completely identified. Exhaustive physical testing by Eastman Kodak on both 3404 and SO-230 has not shown any difference in physical hardness between the two films.

8.3 SO-230 MISSIONS

The first flight to use SO-230 was mission 1102. The test consisted of 2,012 feet of SO-230 on the end of the AFT-looking camera film load and 2,508 feet on the

FWD-looking camera film supply. When the film came into use during this mission, the adjustable slit mechanism was used to account for the increased film speed over that of the primary film supply, 3404. The ground tracks for the SO-230 coverage on this mission are shown in Figs. 8-1 and 8-2.

Subsequent to mission 1102, two J-1 missions—1046 and 1049—were flown with full loads of SO-230.

8.4 FLIGHT RESULTS

The results of the SO-230 studies are not limited to the information acquired on the mission 1102 flight. The results consist of information gathered from laboratory tests and missions 1102, 1046, and 1049. The results of an NPIC analysis of the tag-on mission 1102 test and excerpts from the PEIR messages of the full-load SO-230 missions, 1046 and 1049, are contained in the following sections.

8.4.1 Mission 1102, SO-230 Analysis*

> *"... Visual and photographic observations indicate very little difference between the two film types. The SO-230 imagery is of slightly lower contrast and when examined closely at higher magnifications (50x and above) appears to be slightly grainier; however, edge sharpness, shadow and highlight detail and overall information content are, for all practical purposes, identical.*
>
> *... The photointerpreter readout is accomplished at magnifications of 50x and below. Only occassionally is there a requirement for higher magnification. From all photointerpretation reports on mission 1102-2, no differences were noted between the SO-230 and 3404 records."*

8.4.2 Mission 1046, SO-230 Comments (Excerpts From PEIR Message†)

> *"... Slit widths of 0.110 and 0.140 inch used on this mission provided a 2/3 stop (0.20 log E) exposure reduction from the nominal 3404 slits. The resolving power of SO-230 compares to that of Type 3404. The combination of faster film speed with only slightly greater grain size makes Type SO-230 film a desirable film for both KH-4A and KH-4B use.*
>
> *Excellent system performance was achieved (to wit, MIP 90 on 1046-1); however, system performance was not maintained throughout the mission.*
>
> *... Some increase in graininess was observed on the mission. This may be due in part to the apparent overexposure observed on this mission. The mission received a significant proportion of primary processing (approximately 34 percent) and an unusually low amount of full processing ..."*

*NPIC message no. [redacted] June 11, 1968.
†NPIC message no. [redacted] May 2, 1968.

8.4.3 Mission 1049, SO-230 Comments (Excerpts From PEIR Message*)

> *". . . Mission 1049 was the second J-1 mission to be flown with a full load of SO-230 and was the first time that a flight load of this material was processed in the single level, dual-gamma process. PET considered* (that) *Type SO-230 film did not contribute to the lower performance of this mission, and* (that this film) *is considered acceptable for future missions. There are no reservations concerning use of this film with CORONA systems."*

8.4.4 Summary of Results

It should be noted that, of all the comments and analyses of SO-230 in these three missions, there exists no statement that any benefit was derived as a result of using SO-230.

As was pointed out, there has been considerable difference of opinion on the exact characteristics of SO-230/SO-205. This was caused mainly by the instability of the product at the beginning of its history, i.e., the characteristics of the film were significantly different from batch to batch, which is normal for any new film product, causing various investigators to come to different conclusions about its characteristics. The product was finally stabilized, allowing a more reasonable assessment of its characteristics. The following observations, some of which change the previous opinions, can now be made based on data from the FEAT† laboratory of 11 March 1969.

1. The original goal for SO-230/SO-205 (i.e., twice the speed, same resolution as 3404) was not achieved. SO-230/SO-205 is 0.20 log E (2/3 stop) faster than 3404, but possesses 30 percent poorer low contrast resolving power. Further, the granularity of SO-230/SO-205 is approximately 20 percent higher (i.e., poorer) than 3404.

2. The resolution analysis performed earlier was more nearly correct for Trenton interrupted processing than for the dual gamma. Mission 1102 was processed in the Trenton. Subsequently, the dual gamma process, which further altered the comparison of 3404 and SO-230, was introduced. Simply stated, the dual gamma process produced an improvement in the quality of 3404, but did not produce a similar improvement for SO-230. Table 8-1 clearly shows the improvement achieved with the dual gamma process and 3404. From the data in Table 8-1, it is also clear that SO-230/SO-205 is not as good in any event as 3404/SO-380.

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*NPIC message no.[redacted] Jan. 13. 1969.

†The Film Evaluation and Testing (FEAT) Laboratory is located at the [redacted] National Processing Center.

Table 8-1 — Resolving Power of 3404 With Dual Gamma Process

Target Modulation	Resolving Power, c/mm			
	3404		SO-205	
	Dual Gamma	Yardleigh Full	Dual Gamma	Yardleigh Full
0.99	680	630	491	532
0.73	525	480	372	356
0.53	400	365	285	268
0.36	290	260	200	199
0.26	223	197	162	165
0.20	180	158	122	120
0.12	118	103	79	80
0.07	76	65	51	50
0.04	48	40	30	31

3. The data in Table 8-1 invalidate the previous conclusions on the improvements to be expected with SO-230 in the J-3 system. The theoretical analysis discussed in an earlier section assumed a 10 percent difference in resolving power between the two films, not the 30 percent difference now reported for 2:1 contrast. Further, that analysis assumed similar granularities, an assumption which was not substantiated in subsequent tests. The fact remains that SO-230/SO-205 is not comparable to 3404/SO-380 in image quality. It is now believed that this film (i.e., SO-230/SO-205) should not be used in the CORONA J-3 and J-1 systems. At these scales and resolution levels, the use of a poorer resolution and grainier film is not logical.

8.5 CONCLUSION

Contrary to theoretical predictions, no evidence of a system improvement has been observed in any of the SO-230 flights.

8.6 RECOMMENDATION

The use of SO-230/SO-205 is not now recommeded for CORONA J-3 or J-1.

 [redacted]

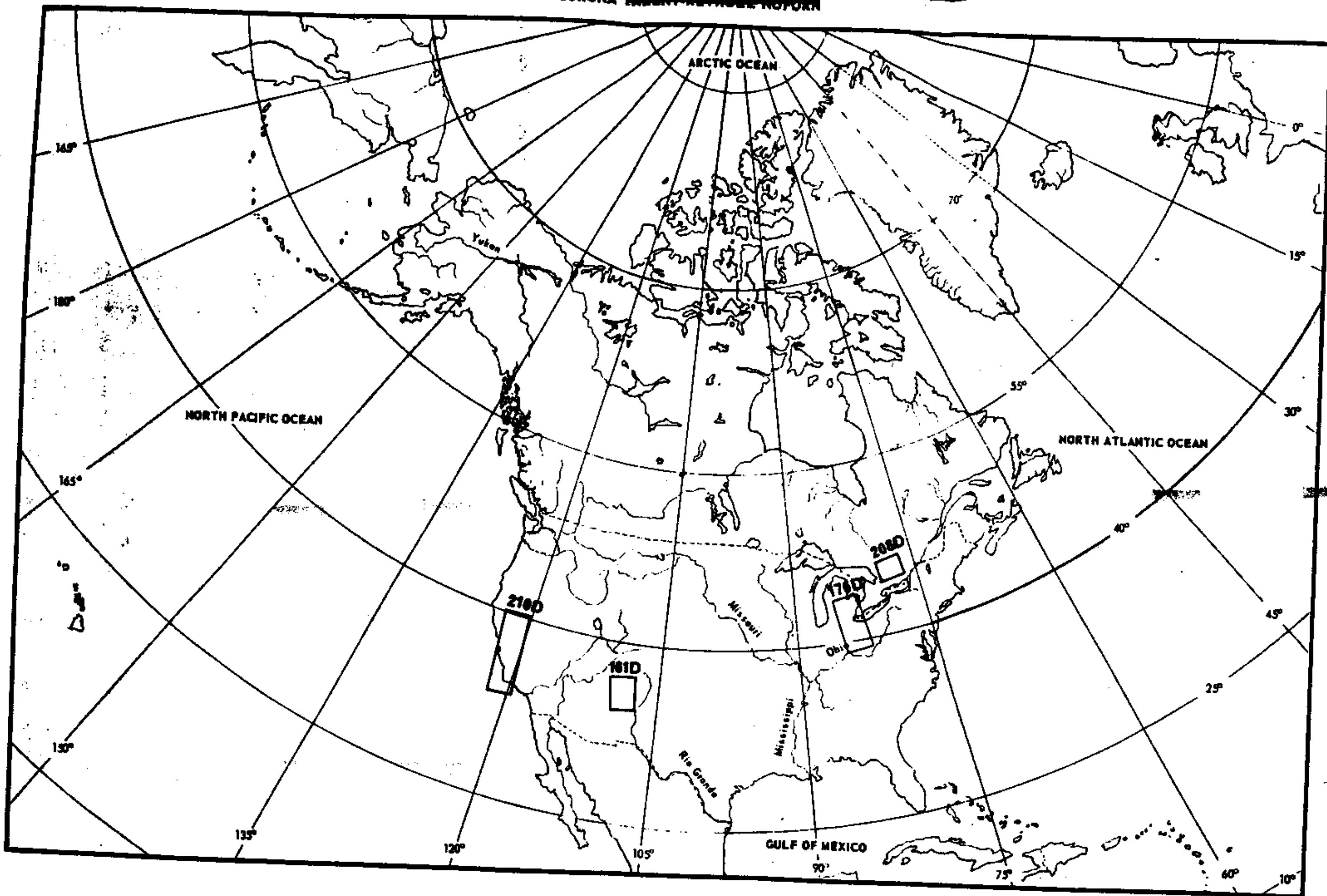

Fig. 8-1 — Ground tracks for the mission 1102 SO-230 passes over the United States

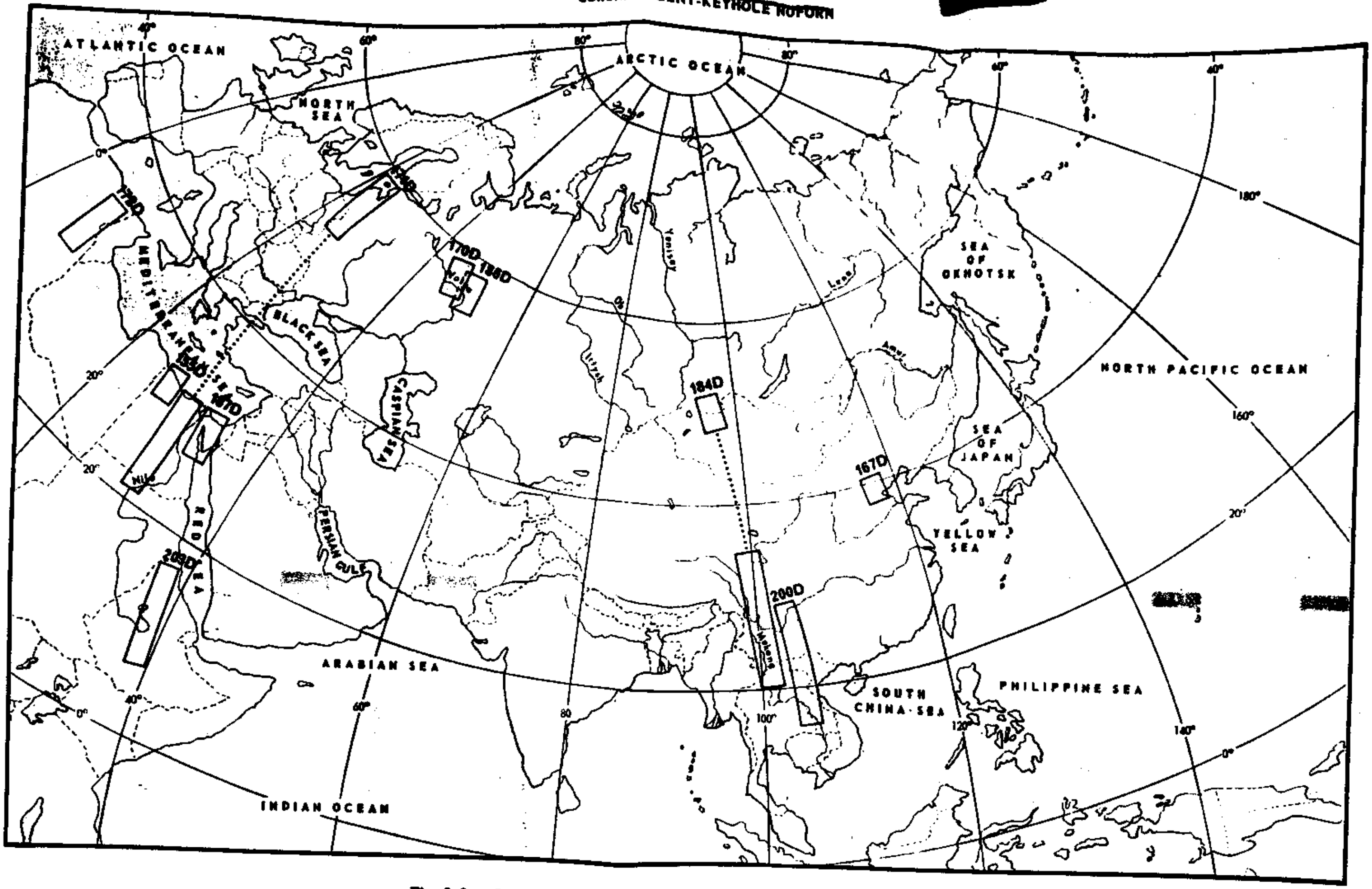

Fig. 8-2 — Ground tracks for the mission 1102 SO-230 passes over Eurasia

Forbidden City, Peking, China

Figure number	8-3	8-4
Mission	1102-2	1102-2
Camera	FWD no. 305	AFT no. 304
Rev	D-167	D-167
Frame	004	010
Date	20 Dec 1967	20 Dec 1967
Film	3404	SO-230
Filter	Wratten no. 25	Wratten no. 21
Exposure time	1/250 sec	1/500 sec
Altitude	514,000 ft	513,000 ft
Scale	1:257,000	1:256,500
Solar altitude	25° 28'	25° 27'
Latitude (CF)	39° 58.7' N	39° 59.8' N
Longitude (CF)	116° 53.5' E	116° 50.8' E
Universal grid coordinate	22.5, 3.1	53.2, 3.5
Magnification	20×	20×

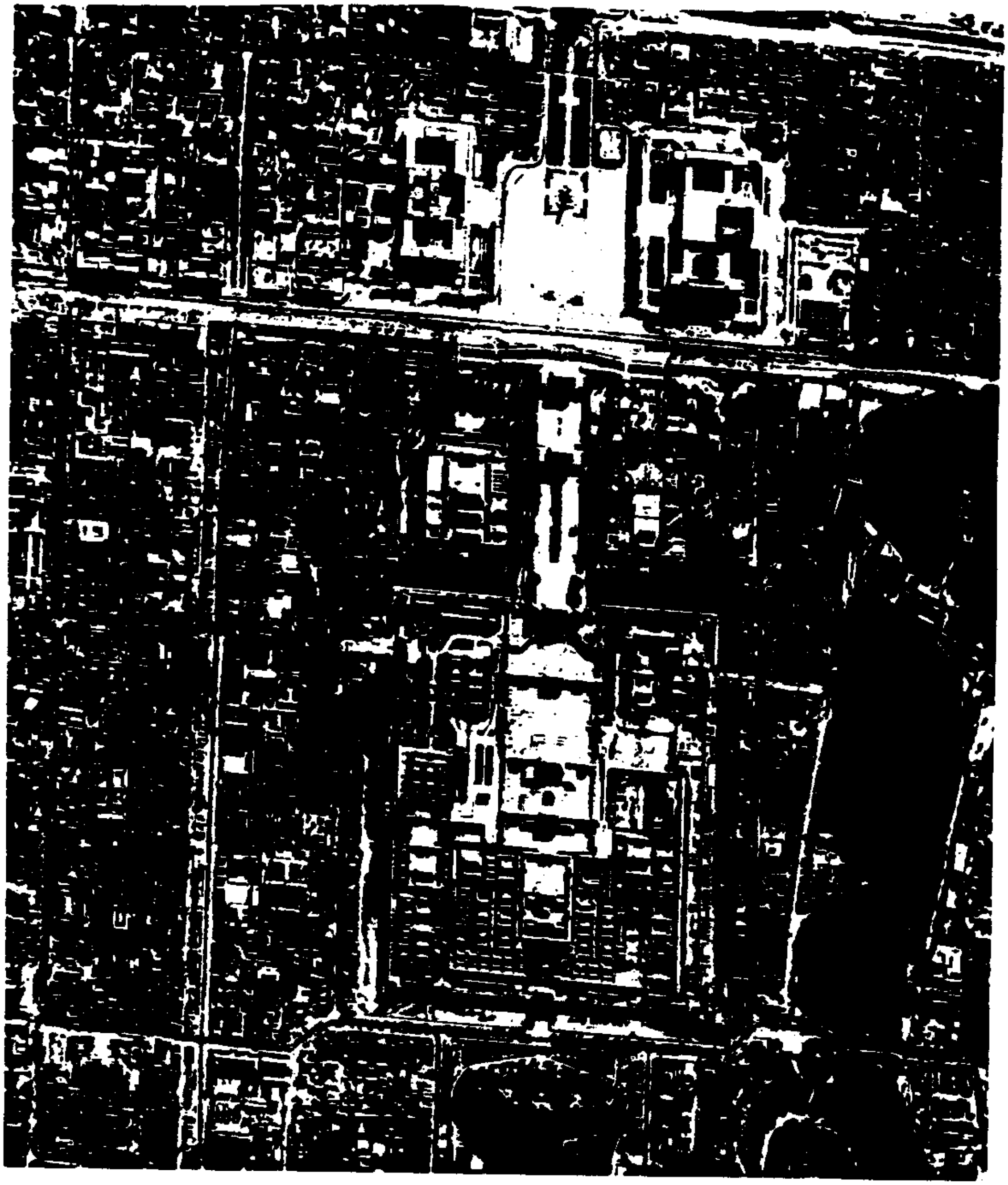

Fig. 8-3 — 20× enlargement of Peking, China from the FWD-looking camera of mission 1102 using 3404 film (1/250-second exposure)

Fig. 8-4 — 20× enlargement of Peking, China from the AFT-looking camera of mission 1102 using SO-230 film (1/500-second exposure)

9. SO-380 (UTB) ANALYSIS*

SO-380 is the ultrathin base (UTB) version of 3404 (STB). The photographic image quality and sensitometric characteristics of the two films are identical, and the only significant differences are in base thickness. SO-380 is on a 1.5-mil Estar base, while 3404 is on a 2.5-mil Estar base. The reason for using a film such as SO-380 in the CORONA J-3 camera is, of course, to allow an increase in the film load per mission (UTB—24,000 feet per camera versus 16,000 feet per camera for 3404 STB), thereby providing for a 50 percent increase in coverage per mission. For this reason, the use of SO-380 was made a design goal in the J-3 program, and emphasis was placed on implementing its use in the CORONA program at the earliest reasonable date.† This section covers two missions—1103 which was the first J-3 UTB test, and mission 1105 which was the first full load of UTB in the J-3 camera.

9.1 PURPOSE

The purpose of this analysis was to:

1. Demonstrate the inflight tracking and performance of the CORONA J-3 system with the ultrathin base film, SO-380 and
2. To explore any potential problems that arise from the use of SO-380 on this mission.

9.2 ENGINEERING TESTS

Considerable UTB testing was accomplished before mission 1103 was flown. Numerous laboratory photographic tests (i.e., speed, resolving power, granularity, and filter factors) were conducted at Itek; these tests ensured that the photographic performances of 3404 and SO-380 were, in fact, equal.

Of more concern, however, were the system aspects of the use of SO-380. In this regard, numerous system tests were run to evaluate tracking, film flatness, film lift, etc. During the development program, several problems were encountered that resulted in minor camera modifications which attempted to ensure reasonable UTB performance.

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*A full report of this test can be found in KH-4B System Capability Report No. 5, Evaluation of SO-380 Film for Use With the KH-4B System, [redacted] (Feb. 1969).

†NRO message no. [redacted] May 15, 1967.

It is not possible, within the scope of this report, to discuss these in detail. However, it should be noted that considerable testing with several J-3 systems was conducted before CR-3 was flown.

9.3 MISSION 1103

In this mission, approximately 1,750 feet of SO-380 were included on the end of both the AFT- and the FWD-looking cameras. The UTB was included at the end of the film spool to prevent any catastrophic failure to the majority of the mission take. The film was changed from 3404 to SO-380 in the 143rd frame of the 187th revolution for the FWD-looking camera, and in the 142nd frame of the 187th revolution for the AFT-looking camera. The mission vehicle altitude for this part of the mission varied from 82 to 90 nm. Most of the photographic acquisitions varied between 69 °N to 17 °N latitude. Sun elevation for this experimental part of mission 1103-2 was from 87 to 38 degrees. Generally, however, the acquisitions were at sun angles from 40 to 80 degrees. The ground tracks for the SO-380 portion of this mission are included in Figs. 9-1 and 9-2.

In general, analysis of the UTB performance was by critical visual comparison of the 3404 and SO-380 imagery. The PEIR message for this mission stated that

"The PET considers that UTB gave as good a product as 3404 Type film." *

The major and only important conclusions from the 1103 UTB test were that: (1) SO-380 appeared to produce results equal to 3404, and (2) there was no evidence, from these flight results, that precluded further use of UTB in the CORONA J-3 camera. Representative samples of 3404 and SO-380 photography from this mission are included in Figs. 9-3, 9-4, and 9-5.

9.4 MISSION 1105

As a result of the favorable results of UTB with 1103-2, mission 1105 was selected to be the first CORONA mission with a full load of UTB. A summary of 1105 is included here because of the difficulties encountered and the relevance of the mission results to the general intent of the test program. It should be pointed out that this section of the report is a very brief summary of a complicated problem. Considerable further detail is included in the CORONA UTB task team's final report.†

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*NPIC message no. [redacted] June 14, 1968.
†CORONA UTB Task Team Final Report, [redacted] (Feb. 21, 1969).

9.4.1 Mission 1105 Problem

The Performance Evaluation Team for mission 1105 reported in part:

> *"The PET feels that the imagery from this mission in general, is significantly degraded when compared with mission 1104 (CR-4). The image quality is extremely variable and evidences soft focus and image smearing."**

The magnitude of the variability problem ranged from good to unusable, and is clearly illustrated in Figs 9-5 and 9-6. The major problem was that SO-380 in CR-5 did not perform as expected on the basis of either the 1103 test or extensive ground testing. This leads to two fundamental questions:

1. Was there a system problem with mission 1105 that was independent of SO-380 (UTB)?
2. Why did the extensive ground testing of CR-5 not show the problem experienced?

Because of the importance of these questions, and the importance of using UTB on the J-3 camera, the CIA Director of Special Projects established (on 19 November 1968) a special task force to specifically study the use of UTB in the J-3 camera. The CORONA UTB task team therefore, had the specific goals listed below.

1. Evaluate CR-5's performance to define the nature of the problem.
2. Evaluate why extensive ground testing of the CR-5 system did not show the problem(s) experienced in flight.
3. Determine what course of action was necessary to gain confidence in the use of UTB in the CORONA J-3 camera.
4. Recommend to the Director of Special Projects (CIA) what course of action seemed most prudent relative to future UTB flights with the CORONA camera.

The task team observed that while the performance of UTB in CR-5 was unsatisfactory, the mission was by no means a total loss from an intelligence point of view. In fact, this mission received the highest percentage of good target ratings from the photointerpreters of any previous CORONA mission. One could be tempted to weigh the percentage of poor and/or unusable photography against the 50 percent increase

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*NPIC message no. [redacted] Dec. 10, 1968.

in coverage obtained with the UTB. This question was discussed at a COMIREX meeting where the NPIC representative stated*:

> *"... the impact of the UTB shortcomings on the first bucket of 1105 were analyzed strictly from a search standpoint. Ignoring specific target readout requirements, the product of 1105-1 was good; sufficiently good so that if NPIC had its choice it would suggest* (that) *another poor UTB* (mission) *would provide more information on the search problem than a J-3 with standard* (base) *film, provided it was no worse than 1105."*

The key statement here is, of course, provided it is no worse than 1105. At the moment, there is no basis for confidence that another UTB mission would be as good as or better than 1105. The fact remains that the exact cause of the UTB problems with the CORONA camera is unknown. Given this, it cannot be reasonably guaranteed that another UTB mission would not be worse than 1105, and perhaps even catastrophically so.

9.4.2 Task Team Findings

Perhaps the most important aspect of the UTB task team's findings was related to the first major question asked. There was no evidence to indicate that CR-5 had a camera problem that would have produced the variability experienced regardless of film, i.e., all analysis indicated that the problem experienced was a direct result of the UTB/J-3 interaction. A 50-foot strip of 3404 included on this mission (between the SO-380 and a tag on a strip of SO-121) did not assist in the analysis. While this 50-foot strip of 3404 was also of relatively poor quality, it was taken over an area with excessive haze and little cultural detail. The fact that extensive ground testing did not show the problems experienced was directly attributed to the fact that (in retrospect) normal CORONA testing does not test for the kind of problems experienced with UTB.

With this background, the following is a summary of the detailed findings of the UTB task team taken from the previously referenced [redacted] report.

> *"There were, admittedly, things different about CR-5 relative to following 'UTB Systems.' Certain UTB modifications were not installed (primarily lengthened air twists) which necessitated using a lower system takeup tension (i.e., 36 oz) than normal (46 oz with STB). While one would like to believe that bringing the tension back up to 46 oz would solve the UTB problems, there is no evidence currently available to confirm that this will happen. Further, if the conventional system test program did not identify the problems experienced at 36 oz tension, there is no guarantee that they will do so at 46 oz.*

[redacted] Nov. 21, 1968.

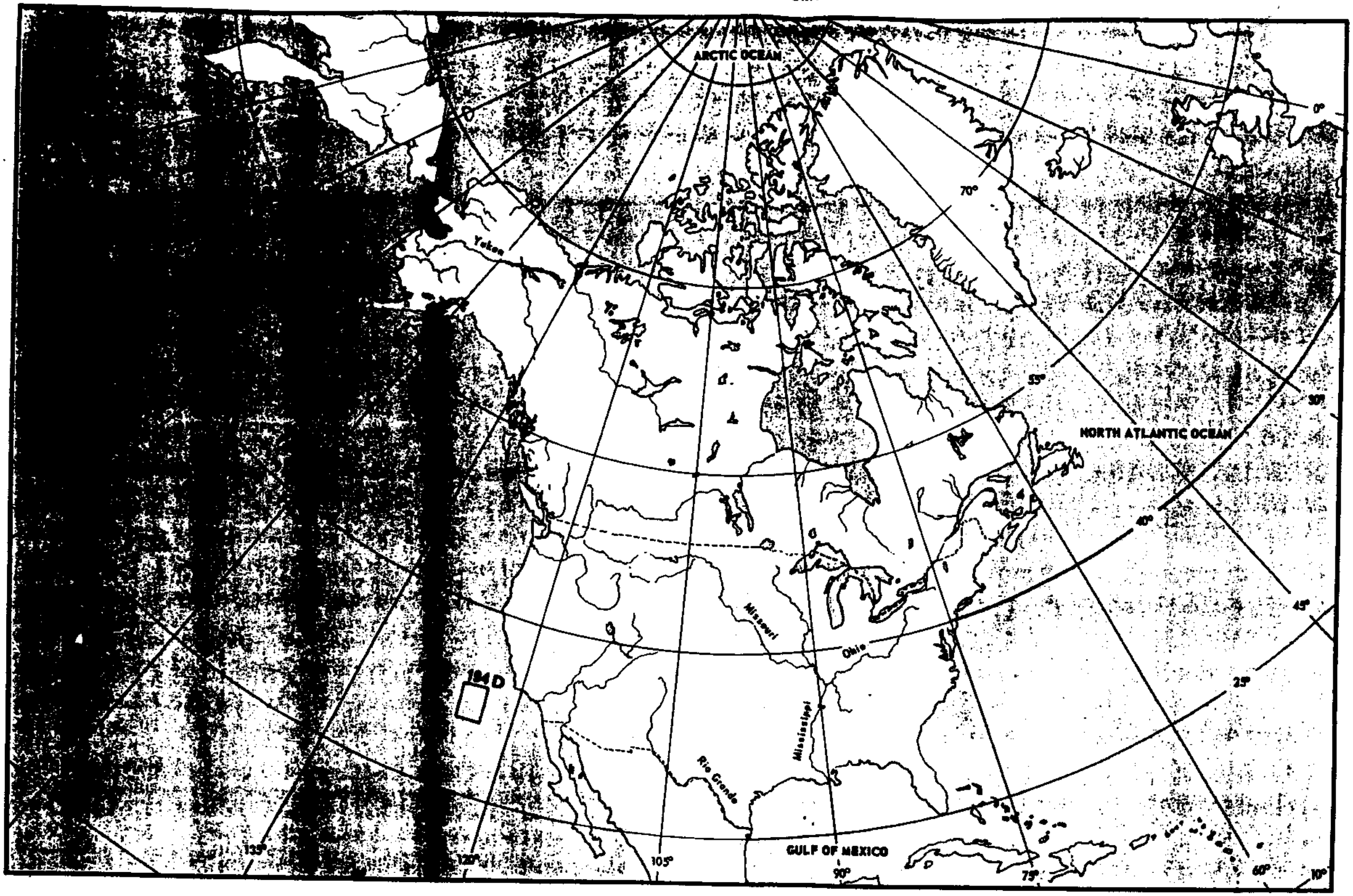

Fig. 9-1 — Ground track for the mission 1103 SO-380 pass near the United States

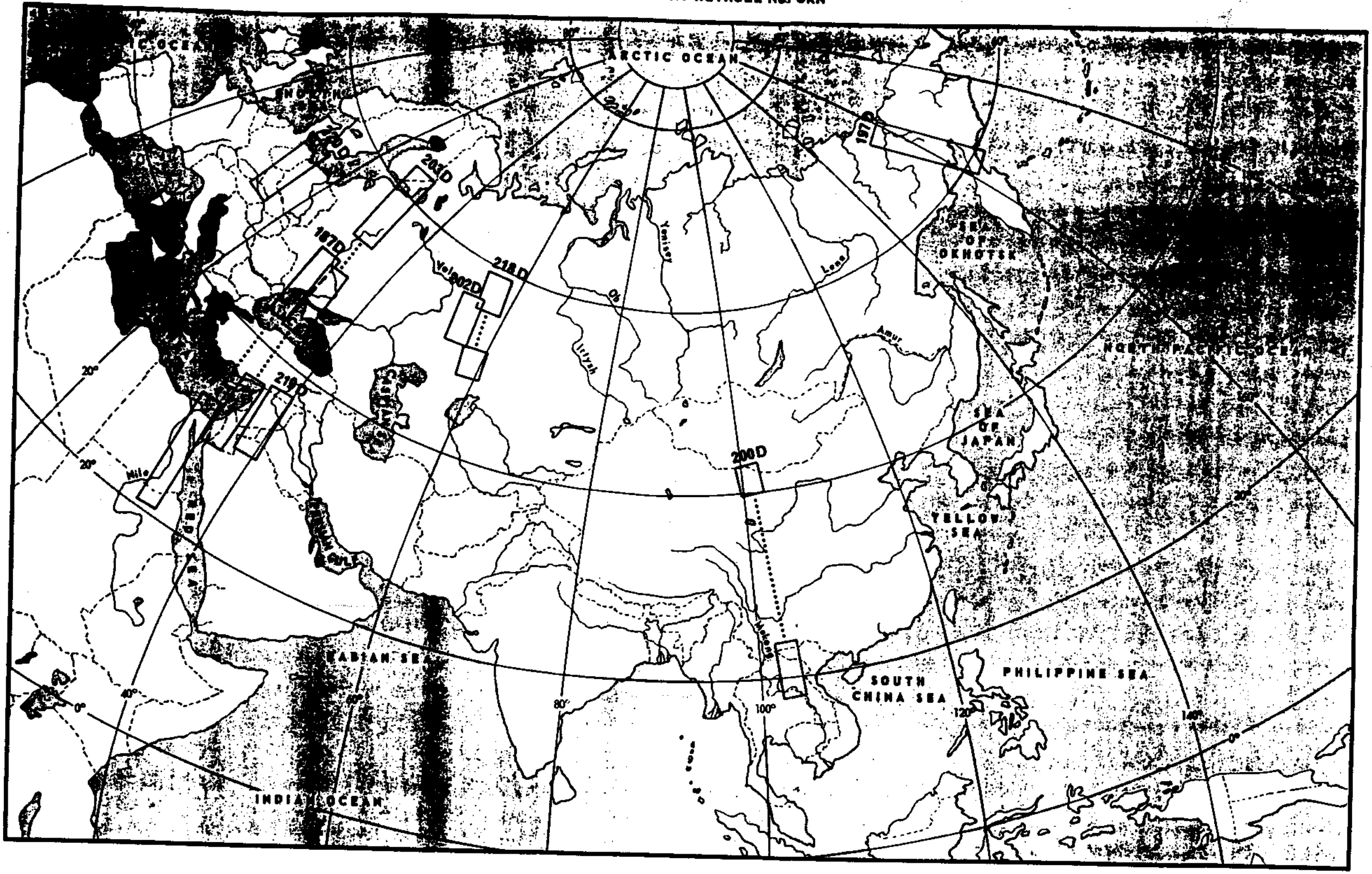

Fig. 9-2 — Ground tracks for the mission 1103 SO-380 passes over Eurasia

There are several major deficiencies in CORONA testing. Unfortunately, these discrepancies are directly related to those items needing most investigation for UTB testing and use. It is now clear that film plane excursions (causing focus changes) and film motions (causing smear) were primarily responsible for CR-5's problems. It is precisely these problems which the normal CORONA test program does not address, particularly in respect to UTB. There are no tests run which assess smear, in a critical sense, across the format length and width. The resolution tests done (at ambient only) assess smear in a general sense on axis, center of format only, which is the place in the format least sensitive to film-lift induced smear problems.*

However, in the main these have not been done in vacuum, and the sensitivity of the Dr. "A" test† is not fully established. In particular, the sensitivity of the Dr. "A" for assessing the impact of UTB film plane excursions with the third generation Petzval is not known. This lens has a very shallow depth of focus, making film flatness highly critical.

It can be seen, therefore, that since the CORONA Test Program is not particularly well set up for evaluating the factors which influence the behavior of UTB in the CORONA camera, conclusions on future actions cannot be obtained from existing data.

For this reason, a test program (was) *recommended, aimed at (1) determining proper J-3/UTB settings, and (2) establishing reasonable confidence in the next UTB flight.*

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*It should be pointed out that the normal CORONA photo test program evaluates dynamic resolution and film flatness in air. While STB has been found to behave essentially the same in vacuum as in air, it is clear that UTB does not. Further, smear caused by film motions was one of the major problems with the 1105 UTB, and this aspect of system performance is not normally specifically tested. This is not intended to be a criticism of the normal test program since it has proven to be perfectly adequate for STB, based on a long history of correlation with flight results. It is in retrospect that the test program appears deficient for UTB.

†Dr. "A" test is a test for determining film flatness and contour under dynamic transport conditions. It is performed by placing a special test plate in front of the image plane and illuminating the plate with two separated point sources. The test plate contains parallel clear lines on an opaque background. The lines are oriented parallel to the direction of scan. The presence of two light sources causes two displaced images of each line to be projected on the image plane. There is a fixed geometry for the distance between two lines. The separation of the lines is directly related to the film lift. These separations are measured directly with a comparator.

The tests recommended were as follows:

1. *Smear versus tension versus film lift*
2. *Image motion versus nodal offset*
3. *Dr. "A" sensitivity*
4. *Attitude effects on Dr. "A" results*
5. *Altitude effects on Dr. "A" results*
6. *Tension required to pull out of the rails*
7. *Temperature versus film lift*
8. *Humidity losses from UTB*
9. *Tension versus film curl*
10. *Humidity profiles across web."*

The task force considered three possible options:

"1. Execute the recommended test program before CR-8 flies to gain the confidence necessary to insure proper system settings. This approach, we believe, would allow maximum assurance of successful UTB/J-3 operation.

2. Do not do any further tests; set the system based on intuitive feelings, and fly CR-8 with UTB. This is, obviously, the most risky option as tests in the 'big collimator in the sky' are both costly and least amenable to engineering assessment of what went wrong.

3. Drop UTB completely from consideration as a CORONA flight film, and fly all future systems with STB. This option has much appeal from a pure engineering point of view as it is the one most likely to guarantee satisfactory performance of the remaining J-3 systems. For many reasons every J-3 mission to date has had either a special test and/or something different about the system. There is a tendency to want to at least stabilize on a film to be used."

9.5 CONCLUSIONS

With these options in mind, and given that (1) UTB in the CORONA system is an important goal, and (2) the task team believes that the UTB problems can be favorably resolved, the task force made the following conclusions and recommendations. This committee is in agreement with these conclusions.

"1. To establish confidence in the UTB/J-3 combination, a minimal test program is necessary.

2. QR-1 should be immediately refurbished and used for the major portion of the recommended test program.

3. September 1969 is the earliest possible date for the next UTB flight.

4. The next UTB flight should be SO-380 vice SO-205.

5. The next UTB flight should have both recovery vehicle tape recorders and a DISIC. "*

9.6 RECOMMENDATIONS

"1. Immediately refurbish QR-1 for use in the UTB test program.

2. Immediately approve and institute the UTB/J-3 test program recommended."

This committee agrees with these recommendations which were subsequently accepted by the Director of Special Projects. The recommended test program is currently underway.

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*Dual Improved Stellar Index Camera.

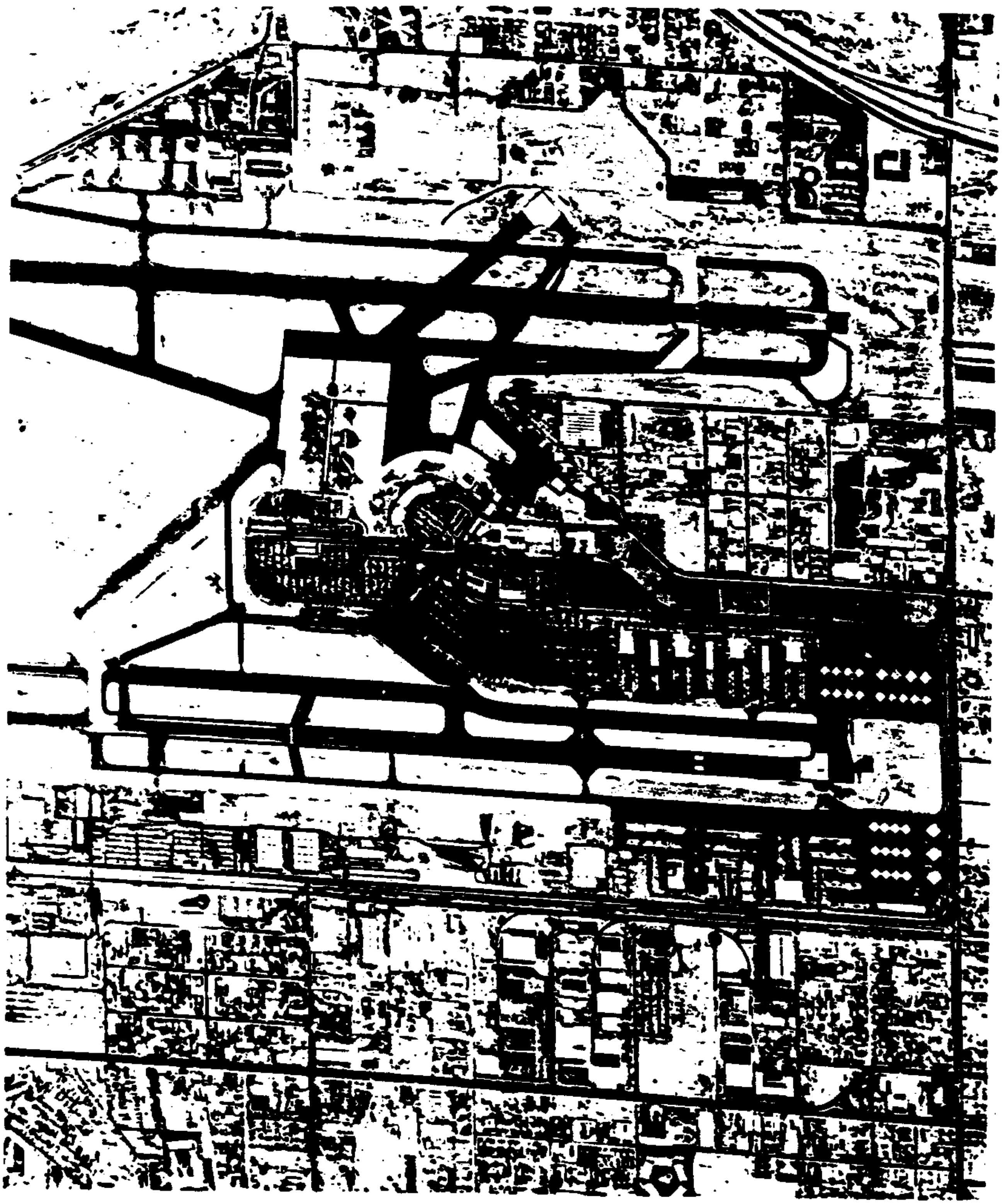

Fig. 9-3 — 20× enlargement of typical SO-380 photography from mission 1105

	Sky Harbor Airport, Pheonix, Arizona	Los Angeles International Airport, California	Soviet Village
Figure number	9-3	9-4	9-5
Mission	1105-1	1105-1	1105-1
Camera	AFT no. 310	AFT no. 310	AFT no. 310
Rev	D-048	D-016	D-041
Frame	036	020	005
Date	6 Nov 1968	4 Nov 1968	6 Nov 1968
Film	SO-380	SO-380	SO-380
Filter	Wratten no. 21	Wratten no. 21	Wratten no. 21
Exposure time	1/450 sec	1/450 sec	1/300 sec
Altitude	505,000 ft	499,000 ft	532,000 ft
Scale	1:252,500	1:249,500	1:266,000
Solar altitude	36° 20'	34° 50'	20° 7'
Latitude (CF)	33° 25.9'N	33° 56.1'N	52° 19'N
Longitude (CF)	112° 38.2'W	118° 10.2'W	39° 50'E
Universal grid coordinates	18.4, 4.0	47.2, 1.1	46.0, 5.2
Magnification	20×	20×	20×

[redacted]

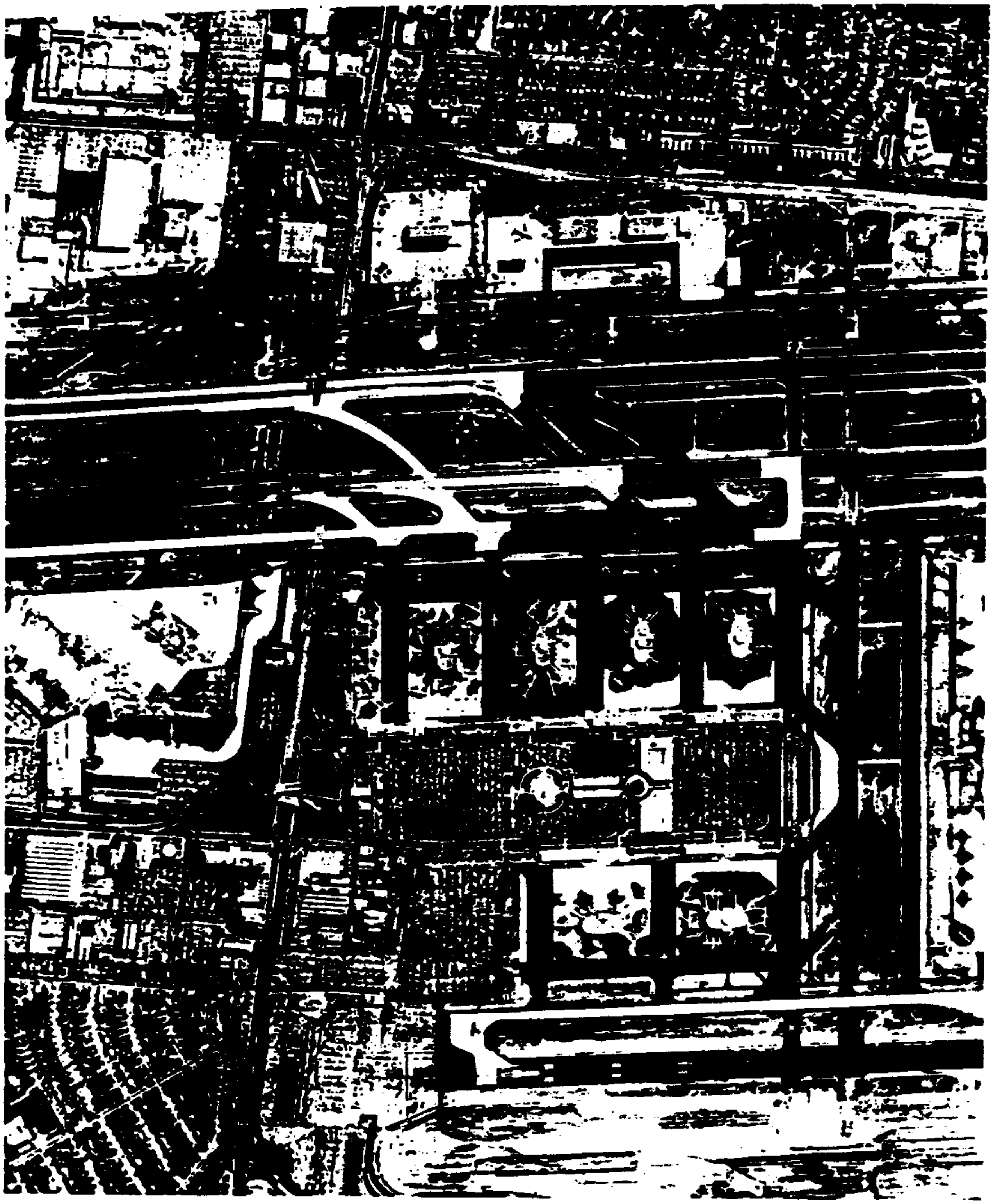

Fig. 9-4 — 20× enlargements of typical best SO-380 photography from mission 1105

Fig. 9-5 — 20× enlargement of typical worst SO-380 photography from mission 1105

Notice of Page Substitution

Miscellaneous Tests

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

10. ADDITIONAL TECHNIQUES FOR IMPROVED IMAGERY

In addition to the specific tests of color techniques and new black and white films, there were two tests that were concerned with improving the quality of the image at the film plane. As with any new film or technique, a tradeoff must be made between the benefits derived and those that must be sacrificed. The two experiments discussed in this section are of such a nature. The first, an exposure analysis, was an attempt to establish these tradeoffs in some quantitative fashion. As such, it did not deal with flight photography but with data derived from past missions and with applications of that data in theoretical and empirically derived relationships. The second analysis, a polarization test, was a much more practical test. It included a flight with a polarizing filter which, in one flight, provided answers to a myriad of questions for which there were opposing viewpoints. In addition, the tradeoffs between increased filter factor and reduced hazelight, and contrast attenuation, etc., were answered for the specific conditions encountered by the CORONA system.

11. EXPOSURE ANALYSES*

Historically, the question of correct exposure with the CORONA system has been a topic of much discussion. Quantitative density analysis has generally tended to show that the missions have been underexposed. On the other hand, photointerpreter and PET analyses have not tended to verify this quantitative data. There have been many meetings and discussions in the past devoted to this subject, none of which has concluded positively that more or less exposure was really indicated.

A primary purpose in the mission 1101 exposure tests was to exercise the new slit/filter change devices for mechanical verification. It was hoped that at the same time, measurable improvement in image smear could be associated with slit reduction. Since this was the first of a new generation of reconnaissance systems to be launched, this experiment was conservative in nature. The filter and exposure changes were chosen such that if they became stuck in any one position accidentally, it would not detrimentally affect the remainder of the mission. Due to the conservative nature of this experiment and the fact that an out-of-focus condition existed on mission 1101, any smear reductions that may have occurred were not observed.

The problem of judging the adequacy of exposure is difficult. Satellite photography is not acquired to produce pictures with "perfect" tone reproduction characteristics, but to produce pictures of maximum benefit to the ultimate users, i.e., the photointerpreters. There is certainly some relationship between the tone reproduction (and hence density) characteristics and photointerpreter preference, but this relationship is not yet clear. In any event, it is necessary to assess camera exposure and to perform quantitative analyses that allow its prediction and evaluation. Since the photography from mission 1101 was not suitable for an exposure/smear analysis, the goals of this effort were directed to a more fundamental analysis, that of examining the vast quantity of exposure data already acquired from past CORONA J-1 missions.

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*The full report on this evaluation is contained in KH-4B System Capability Report No. 2, Analysis of Exposure Criteria and Requirements for the KH-4 Systems, [redacted] (Aug. 19, 1968).

 [redacted]

11.1 PURPOSE

Itek, working in close coordination with Eastman Kodak, performed a comprehensive study to assess the following:

1. Evaluate whether or not the current technique for assessing the adequacy of exposure with the CORONA systems is valid.
2. Evaluate whether or not the current exposure prediction techniques are adequate for the primary purpose of the CORONA systems, i.e., intelligence targets.
3. Recommend, based on this analysis, new techniques and/or criteria for exposure evaluation.

In order to explore these points, a careful examination was made of the current criteria for evaluating exposure. Past data from both [redacted] and the Air Force Special Projects and Producation Facility (AFSPPF) have been used to show their estimations of overexposure and underexposure.

11.2 TEST CONSIDERATIONS

This analysis was undertaken as an exercise separate from any of the CORONA J-3 mission experiments. It involved an analysis of data that had been generated over a period of several years. Some of the factors taken into consideration were:

1. Source of the data
2. Criteria used for assessment of under/overexposure.

Past evaluations of the adequacy of exposure for the CORONA systems have been obtained from assessment of macrodensitometer data. Minimum and maximum terrain densities were obtained from a densitometer having a 0.5-millimeter aperture, which is equivalent to a circle on the ground of approximately 500 feet in diameter at CORONA scales. An assessment was then made as to the adequacy of the exposure based on an arbitrarily defined criterion.

However, the purpose of satellite reconnaissance photography is to photograph targets. Even with a search and surveillance system, this is the major function. In the surveillance mode, the system is photographing known targets, where as in the search mode, the system is after unknown targets. In either case, the intent is to acquire targets. This would indicate that exposure adequacy should be judged on the basis of targets and not the general surrounding terrain. The terrain density analysis used to assess the adequacy of the target exposure, therefore, is not consistent with the use of the system. The terrain density analysis is essentially a random process that must assume that target densities and terrain densities are, on the average, equal.

 [redacted]

A second consideration is the criteria on which the exposure assessment is made. The criteria established by Eastman Kodak had nine categories for the data:

1. Within tolerance
2. Overprocessed
3. Overexposed
4. Overprocessed and overexposed
5. Underprocessed
6. Underexposed
7. Underprocessed and underexposed
8. Too high contrast
9. Out of phase.

However, the mechanism by which the interrupted process changes its processing levels does not consider target density. These assessments, therefore are meaningless as far as the targets are concerned. Therefore, very simple criteria were established which assessed the mission's exposure adequacy based on only three categories:

1. Overexposure
2. Underexposure
3. Satisfactory exposure.

A minimum density criterion of 0.4 was selected for assessment of underexposure and 0.8 for overexposure. If a minimum density were to be less than 0.4, it was considered underexposed. If a minimum density were to be greater than 0.8, it was considered overexposed. The density value of 0.8 was chosen since images with minimum density greater than this could have received a full stop less exposure and yet not fall below the 0.4 value. An additional criterion for overexposure was set at a density of 2.0 for the maximum density value.

There has been much discussion in the community as to the criteria to be used in assessing over/underexposure. Each technique proposed had certain assets as well as certain deficiencies. One criticism of this particular 0.4 minimum density is that changes in fog level can have an influence on the results. Work is continuing to find new and better techniques for exposure assessment that apply to missions of differing sensitometric conditions.

In the past year several important findings in the area of exposure analysis have indeed been made. Of major importance has been the discovery of the constancy of the mean scene luminance of urban-industrial areas at a given solar altitude—regardless of haze level and look angle. Further analysis of Project Sunny* data indicates that the range of luminances and the mean luminance for targets, are close to the luminance range and mean values for an urban scene.

These findings may suggest further changes in exposure estimation. The pertinent reports concerning these studies are included in the Appendix.

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*See Appendix.

11.3 ANALYSES RESULTS

Terrain density assessment performed by Eastman Kodak on missions 1024 through 1044 indicates that the missions have been on the average underexposed 33 percent of the time. The average overexposure is less than 1 percent. An evaluation of the terrain density measurements performed by the AFSPPF indicates that these same missions have been underexposed 20 percent and overexposed 2 percent of the time. This is in good agreement with Kodak data even though the criteria for evaluation are slightly different.

A project was undertaken by Eastman Kodak to scan target images on the original negative with a microdensitometer. The targets used were selected by NPIC for this study. These data were used by Itek personnel in their analysis.

A statistical comparison of terrain and target density readings obtained from 786 frames indicated that there is a significant difference between the mean minimum and maximum density values from these two types of density measurements, target minimum and maximum densities being, on the average, higher than terrain density readings obtained from the same frames. The use of terrain density assessment techniques for evaluation of exposures for targets is therefore considered invalid. A re-examination of missions 1024 through 1044 was then undertaken to determine the percentage of over- and underexposure for the targets of these missions. The results of this evaluation indicated that the targets for these missions had been overexposed 38 percent and underexposed 14 percent of the time.

11.4 CONCLUSIONS

1. Terrain density readings and target density readings are not statistically the same. The target density readings are significantly higher than those produced from the terrain measurements.

2. It is more logical to use the target density analysis techniques to assess the correctness of exposure with the CORONA camera systems. It should be noted that even though a large percentage of the overexposed targets are theoretically within the correction capability of the interrupted process, this correction cannot be practically implemented. Therefore, targets which are overexposed will remain overexposed. There is no substitute for the correct camera exposure (This situation holds true for the three-level processing techniques. It may not be nearly as true for the dual-gamma process recently implemented.)

3. Targets from past CORONA missions have not been underexposed nearly to the extent implied by the terrain density analysis. In fact, targets measured in recent missions have tended to be overexposed, on the average, 44 percent of the time.

4. A general reduction of 1/3 stop in CORONA systems' exposure from that used in 1967 (up to mission 1102) is indicated. It would appear from a theoretical analysis

that this reduction would effect a more realistic tradeoff between target overexposure and underexposure and slit size.

5. For maximum CORONA camera resolution performance, every attempt should be made to reduce the slit size to 0.20 inch or less, since this is the region of minimum smear impact. For CORONA J-1, which has greater smear than J-3, the slit should also, obviously, be reduced as much as possible. However, since precise quantitative data on camera smear are not available for this system, the exact limits cannot be accurately calculated.

6. For a majority of the acquisitions, reducing the exposure by 1/3 stop will bring camera performance into the range of minimum smear and hence higher resolution.

11.5 RECOMMENDATIONS

1. Terrain density measurements for evaluating the adequacy of CORONA systems' exposure should be discontinued. (This recommendation has been implemented.) Target density analysis should be used instead. This analysis should be similar to that of Project Sunny and the Priority I target density analysis performed by Eastman Kodak and NPIC/Itek, respectively.

2. Immediately reduce the current exposure prediction technique by 1/3 stop. In addition, continue and expand Project Sunny to allow the preparation of a new set of exposure recommendations that are target-oriented. (Note: This recommendation has been implemented as of mission 1103.)

3. There are a number of questions which this report cannot address and which ultimately can be answered by practical testing. In this regard, additional CORONA J-3 exposure tests are recommended. Possible tests include:

a. Photographing a limited number of Sunny targets that have consistently been overexposed, with an appropriate exposure reduction.

b. Taking domestic photographic passes with considerably wider exposure variations than those in mission 1101.

c. Acquiring coverage of several domestic "targets" to allow a photointerpreter analysis of the practical gains from shorter exposure times.

12. POLARIZER TEST — MISSION 1102*

The light energy emerging from the atmosphere is partially polarized due to the natural molecular scattering process in the earth's atmosphere. By proper positioning of a polarizer in a satellite-borne camera, it was thought that it would be possible to take advantage of this phenomenon by removing the unwanted polarized component of the energy.

The EKIT† aircraft test of 1966 had indicated that substantial gains could be achieved in haze penetration with a polarizer. This test employed polarizing filters in both the FWD- and AFT-looking cameras, with the filter in two different orientations in one camera. The flight line consisted of a cloverleaf pattern which was in the azimuth of the sun; thus, all orthogonal combinations of flight line and sun direction were available for both cameras. One consistent pattern emerged—the polarizer improved contrast when the axis of polarization was parallel to the azimuth of the sun when the camera was looking into the sun. No other conditions produced such results. The application for CORONA satellite photography was then obvious. It should be on the FWD-looking camera in the winter months in the Northern Hemisphere. However, it was not known how much better the results would be than with the Wratten no. 25 filter, or how high a solar altitude could be employed. Thus, the CORONA test evolved.

12.1 PURPOSE

The objective of this test was to determine if a polarizing filter in the CORONA J-3 system, when used with high definition black and white panchromatic film, might, under certain conditions, provide increased intelligence data acquisition. The four categories of image quality improvement that were investigated included:

1. Possible increase in object contrast
2. Possible increased atmospheric haze penetration

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*A full report of this test is presented in KH-4B System Capability Report No. 1, CR-2 Polarizer Experiment [redacted] (May 11, 1968).

†EKIT Report No. 13, Evaluation of a Polarizing Filter in High Altitude Photography, [redacted] (Aug. 28, 1967).

 [redacted]

3. Possible decrease in image "blooming" resulting from directly plane-polarized reflected light
4. Possible increase in shadow detail with broadband photography.

12.2 ENGINEERING TESTS

To perform this experiment, a special polarizing filter (designated SF-09) compatible with the CORONA J-3 system was fabricated. The polarizing layer was deposited on a 0.005-inch fused silica optically polished substrate, had an average transmittance in the visible region of 43 percent, was essentially neutral spectrally, and had its polarization axis oriented to take maximum advantage of the preplanned mission. This glass substrate was the same type as used in the bi-color experiment on this same mission. Since the lenses of the CORONA J-3 system are designed and optically corrected for the long wavelength end of the visible spectrum, a decrease in system performance was expected with the polarizer. Preflight testing showed this to be the case. The resolution with the polarizer was approximately 15 percent less than with standard Wratten no. 21 or 25 filters. In addition, it was expected that a slight out-of-focus condition (on the order of 0.001 inch) might exist with the polarizer, causing additional resolution loss. A further degrading effect was expected from increased image smear as the result of having to use the largest system slit width with the polarizer, the effective filter factor being in the order of twice that of the normally used spectral filters. However, the expected resolution loss in no way compromised attaining the goals of the test.

The predicted performance of the polarizer in the system was also determined theoretically using lens design data, film sensitivity, daylight illumination, and AIM curve data for 3404. The computer data confirmed the dynamic test results predicting a 15 percent loss in resolution over that obtained with a Wratten no. 21 in the system. The data also predicted a slight out-of-focus condition of approximately 0.001 inch from the Wratten no. 21 because of a slight change in peak film-filter sensitivity, which would add another 5 to 10 percent to the resolution decrease.

12.3 TEST DETAILS

The polarizer experiment on mission 1102 was conducted during the period from 13 through 22 December 1967. Photography was obtained using the polarizer on eight orbital passes all over the Northern Hemisphere. The SF-09 polarizing filter was installed as the alternate filter in the FWD-looking camera. The prime filter for this camera was a Wratten no. 25. The photography taken through the polarizer was compared with the photography taken through the prime filter (Wratten no. 21) on the AFT-looking camera.

Approximately 365 frames of photography were taken through the polarizing filter. The first 310 were on 3404; the remaining 55 were on SO-230. The sun direction shifted from 18 degrees to the west of the polarization axis to 5 degrees to the east during the eight experimental passes. See Figs. 12-1 and 12-2 for ground tracks.

[redacted] Handle Via TALENT-KEYHOLE Control Systems Jointly

The solar elevations covered during the experiment were within the range of predicted maximum effect for a polarizing filter. The photography was taken from solar elevations varying from 02°19' to 32°51'. Within the coverage were snow-covered plains, farm areas, deserts, mountain areas, and forests, along with the military, and industrial targets and complexes. Weather conditions varied from cloud free to completely overcast and from excellent seeing conditions to heavy haze.

The polarizing photography was generally exposed at 1/250 second using a 0.340-inch slit. Most of the Wratten no. 21 photography in the AFT-looking camera was shot at 1/300 to 1/400 second with either a 0.270- or a 0.215-inch slit. With SO-230, some of the photography with the AFT-looking camera was taken with a 0.134-inch slit which was over a 1/600-second exposure. All the photography taken during the polarizer experiment on both cameras was given full processing for maximum film speed. Since all the processing was at the same level, processing was not considered as a factor to the comparative analysis. No significant difference in results would be expected if other processing levels were used.

12.4 FLIGHT RESULTS

NPIC had stated* that an evaluation of the photography from the mission 1102 polarizer test would appear as a special study in a later Photographic Evaluation Report (PER). However, NPIC subsequently reported that their analysis had resulted in the same conclusions as reported by Itek and therefore NPIC would not publish a separate report as had originally been planned.

The experimental photography was analyzed objectively and subjectively by Itek. The subjective analysis consisted of a careful scrutiny of the photography for areas which would point to increased intelligence data acquisition when photographing through a polarizing filter.

All analyses were made from original negative photography to preclude the possibility of introducing additional photographic variables. In all cases, the photography taken with the polarizing filter in the FWD-looking camera was compared with the Wratten no. 21 photography taken with the AFT-looking camera.

The polarizer did not improve image contrast in the low reflectance areas. The effective filter factor of the polarizer is too high at low sun elevations to be used most effectively with 3404 and SO-230. It ranged from 5 for clear weather photography to 3 for hazy photography. Below solar altitudes of 4 degrees, the exposure is too low to be of any use. In general, the imagery taken through the polarizer was underexposed up to solar elevations of 25 degrees. The higher the filter factor, the more effectively the polarizer performed. However, even under the most advantageous conditions, the

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*Mission 1103 Photographic Evaluation Report, [redacted] (Sept 1968).

polarizer did not penetrate the haze as well as a standard spectral type filter such as a Wratten no. 21 (see Figs. 12-3 through 12-6).

12.5 CONCLUSIONS

1. Commonly employed spectral filters remove all the blue-green haze light while the polarizer filters out only the polarized component. From the limited data taken, it appears that even under clear weather conditions, in a basically Rayleigh atmosphere, only approximately 40 percent of the light reaching a satellite-borne camera is polarized. Under light haze conditions, the degree of polarization decreases to 25 percent, while under hazy conditions it drops to near zero. Since the majority of the polarized energy is in the blue, the spectral filter does a better job of attenuating this unwanted energy for panchromatic black and white emulsions.

2. The polarizer, due to its high effective neutral density, filters out as much unpolarized red energy as it does unpolarized blue energy, with the effect being an undesirable overall reduction in exposure. The Wratten no. 21 filter transmits more than 90 percent of the red energy.

3. The polarizer has been found to degrade the CORONA photography significantly with no apparent return benefit. Contrast is lowered due to the use of blue image-forming light, image resolution is lower due to chromatic aberration and defocus, and image smear is increased due to longer exposure times caused by high filter factors.

4. The polarizer did not aid in reducing image blooming due to specular reflections from bright objects such as aircraft. These objects apparently have little or no polarization associated with them.

5. The filter factor itself appears to be a variable which depends on solar elevation, solar azimuth, and haze conditions. Thus, mission planning would become a most difficult task.

6. In some cases of certain acquisition geometry, the polarizer can actually eliminate information.

12.6 RECOMMENDATIONS

1. The use of a standard type polarizer is not recommended for the CORONA J-3 system when used in conjunction with slow speed, high definition, panchromatic black and white films. In all cases, a long wave-pass filter, such as a Wratten no. 21 or 25, provides better exposure, contrast, and image definition.

2. The use of a polarizer is recommended for testing with color films. This must be tested initially with aircraft systems before implementation in satellite systems. One application could be to enhance potential ground polarization changes for particular intelligence applications. For example, color films with polarizing filters might be useful in assessing the magnitude of underground nuclear tests. The thought is that

underground nuclear tests produce shock waves that disturb both surface vegetation and the soil in a manner similar to a diffraction pettern. It is possible that a polarizer might help to enhance these resultant differences.

3. A theoretical study is recommended to investigate optical image formation with polarized light. Very little work has been done in this area. It is possible that optical images formed by polarized light might be significantly different from those formed by normal unpolarized energy. The images may be further affected by any polarization properties of the lens/film combination. Employment of the polarization phenomenon may be a potential means of object differentiation, assuming that (1) two adjacent objects have the same reflectance, but different polarization characteristics, or (2) that surface disruption might change the polarizing properties of an object. Photographing these targets with polarizers oriented 90 degrees to each other would provide a means of exploiting these differences through density differences between the two records.*

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*Preliminary studies by both Eastman Kodak and [redacted] indicate the validity of this recommendation. Reports on these studies have not yet been published.

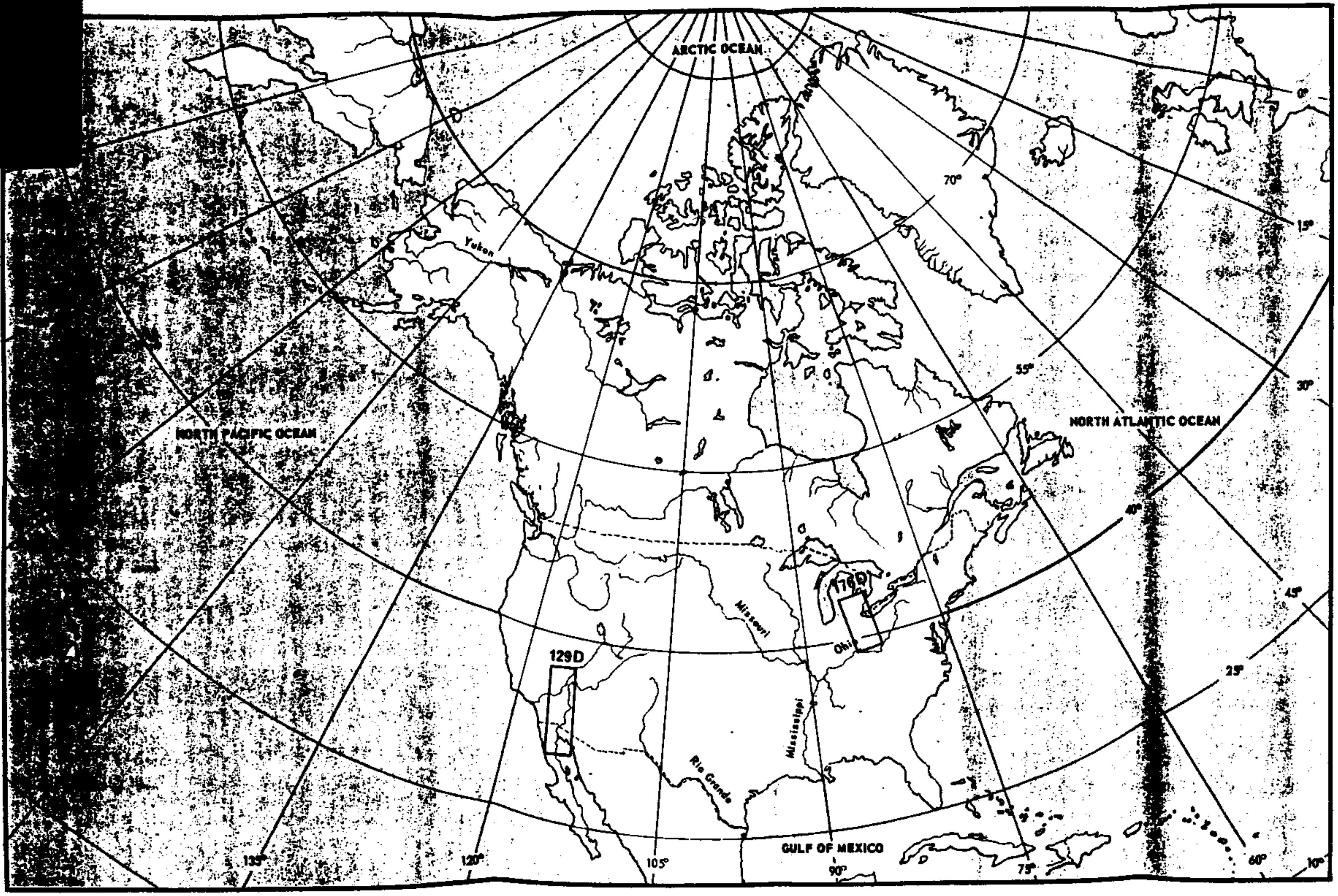

Fig. 12-1 — Ground tracks for the mission 1102 polarizer passes over the United States

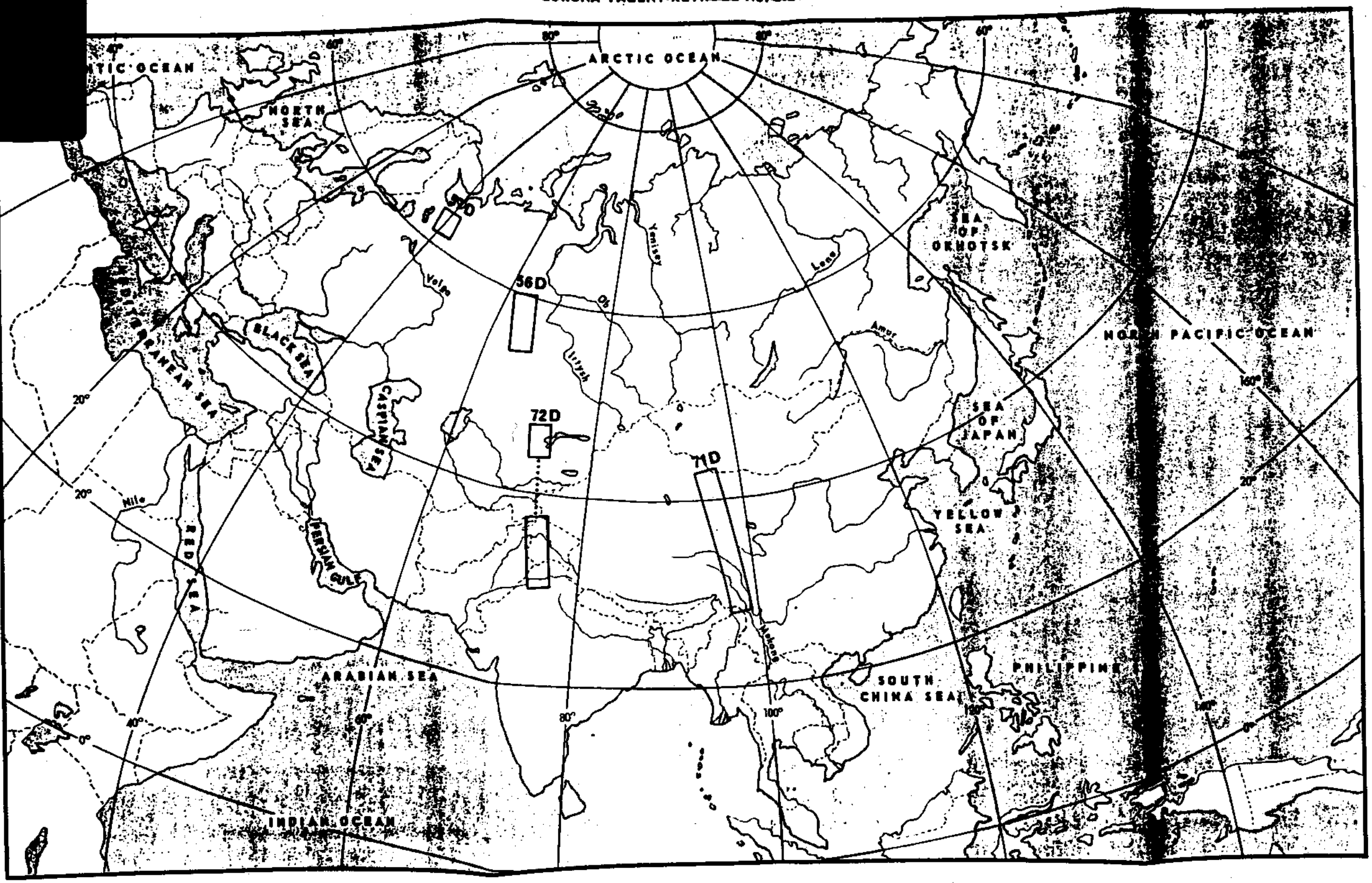

Fig. 12-2 — Ground tracks for the mission 1102 polarizer passes over Eurasia

Wright-Patterson AFB, Ohio

Figure number	12-3	12-4
Mission	1102-2	1102-2
Camera	FWD no. 305	AFT no. 304
Rev	D-176	D-176
Frame	026	032
Date	20 Dec 1967	20 Dec 1967
Film	3404	3404
Filter	SF-09 (polarizer)	Wratten no. 21
Exposure time	1/250 sec	1/500 sec
Altitude	508,000 ft	507,000 ft
Scale	1:254,000	1:253,500
Solar altitude	25° 48'	25° 46'
Latitude (CF)	39° 50.7'N	39° 52.8'N
Longitude (CF)	83° 39.8'W	83° 42.6'W
Universal grid coordinates	23.8, 3.2	52.0, 4.2
Magnification	10×	10×

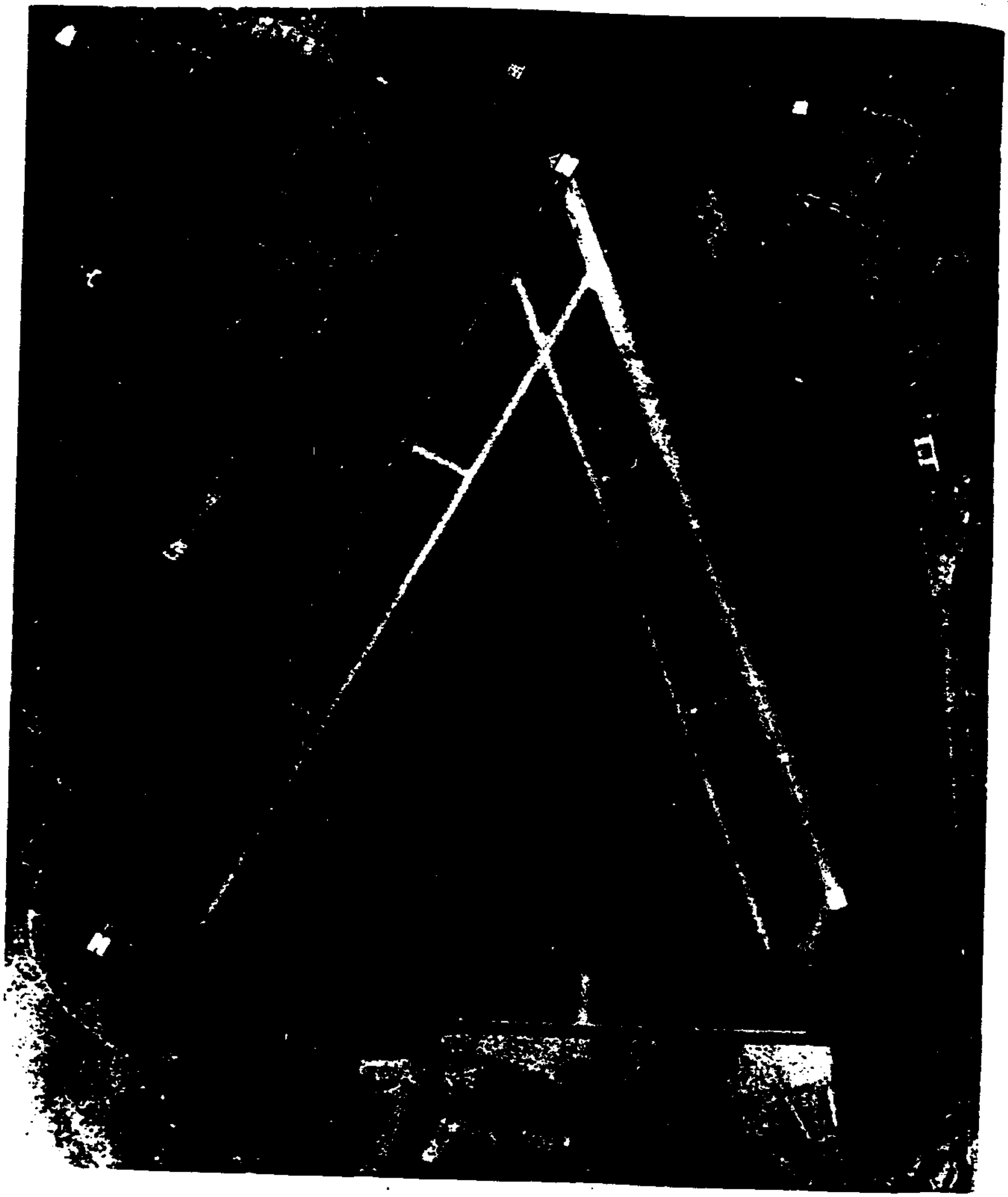

Fig. 12-3 — 20× enlargement of Wright-Patterson AFB, Ohio with polarizer filter on the FWD-looking camera (1/250-second exposure) under poor weather conditions, mission 1102

 [redacted]

Lockbourne AFB, Ohio

Figure number	12-5
Mission	1102-2
Camera	FWD no. 305
Rev	D-176
Frame	027
Date	20 Dec 1967
Film	3404
Filter	SF-09
Exposure time	1/250 sec
Altitude	508,000 ft
Scale	1:254,000
Solar altitude	25° 55'
Latitude (CF)	39° 43.6' N
Longitude (CF)	83° 38.8' W
Universal grid coordinates	60.7, 4.0
Magnification	20×
Note	Polarizer

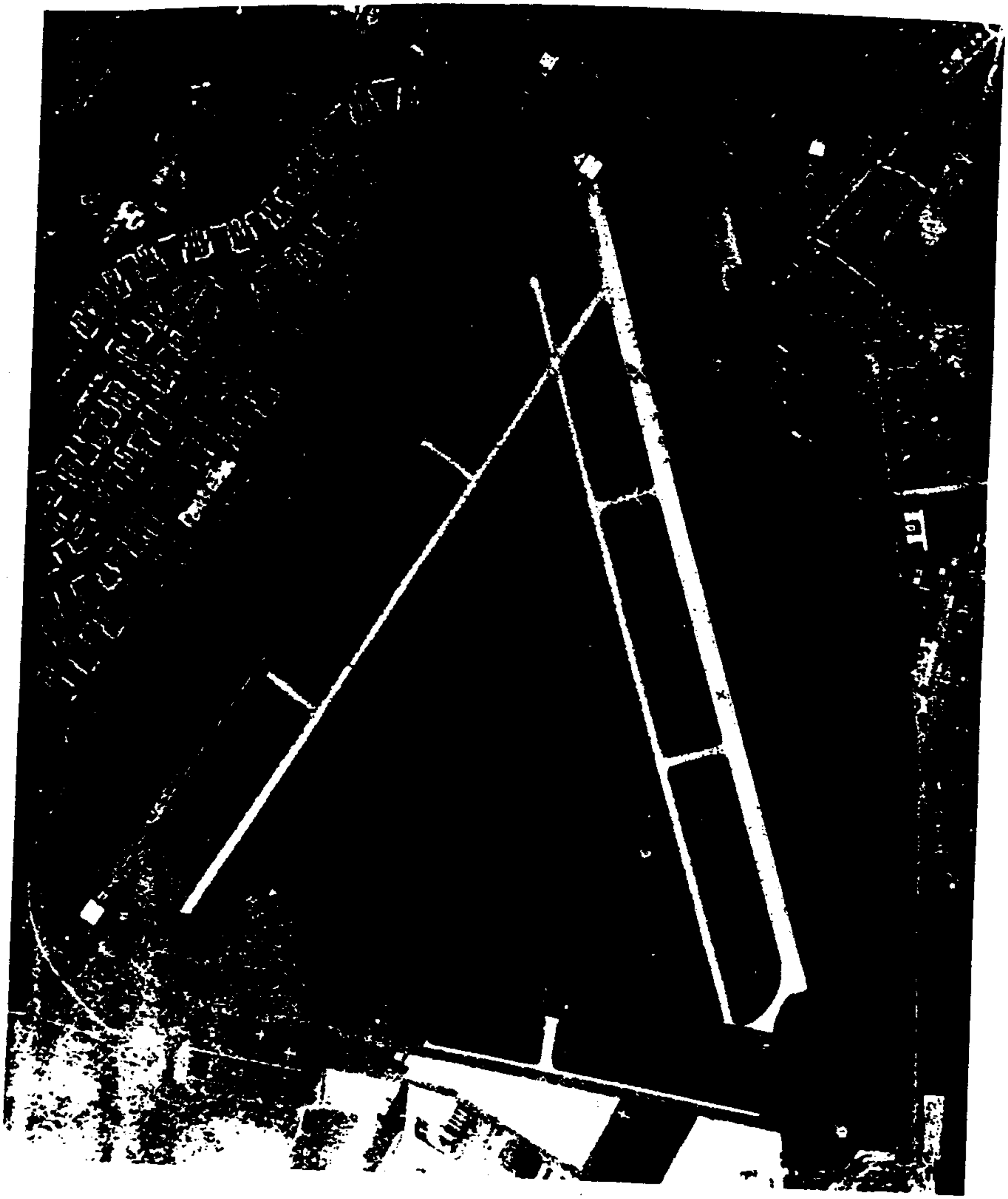

Fig. 12-4 — 20× enlargement of Wright-Patterson AFB, Ohio with Wratten no. 21 filter on the AFT-looking camera (1/500-second exposure) under poor weather conditions, mission 1102

Lockbourne AFB, Ohio

Figure number	12-6
Mission	1102-2
Camera	AFT no. 304
Rev	D-176
Frame	033
Date	20 Dec 1967
Film	3404
Filter	W-21
Exposure time	1/500 sec
Altitude	507,000 ft
Scale	1:253,500
Solar altitude	25° 53'
Latitude (CF)	39° 45.7'N
Longitude (CF)	83° 41.5'W
Universal grid coordinates	14.9, 3.3
Magnification	20×

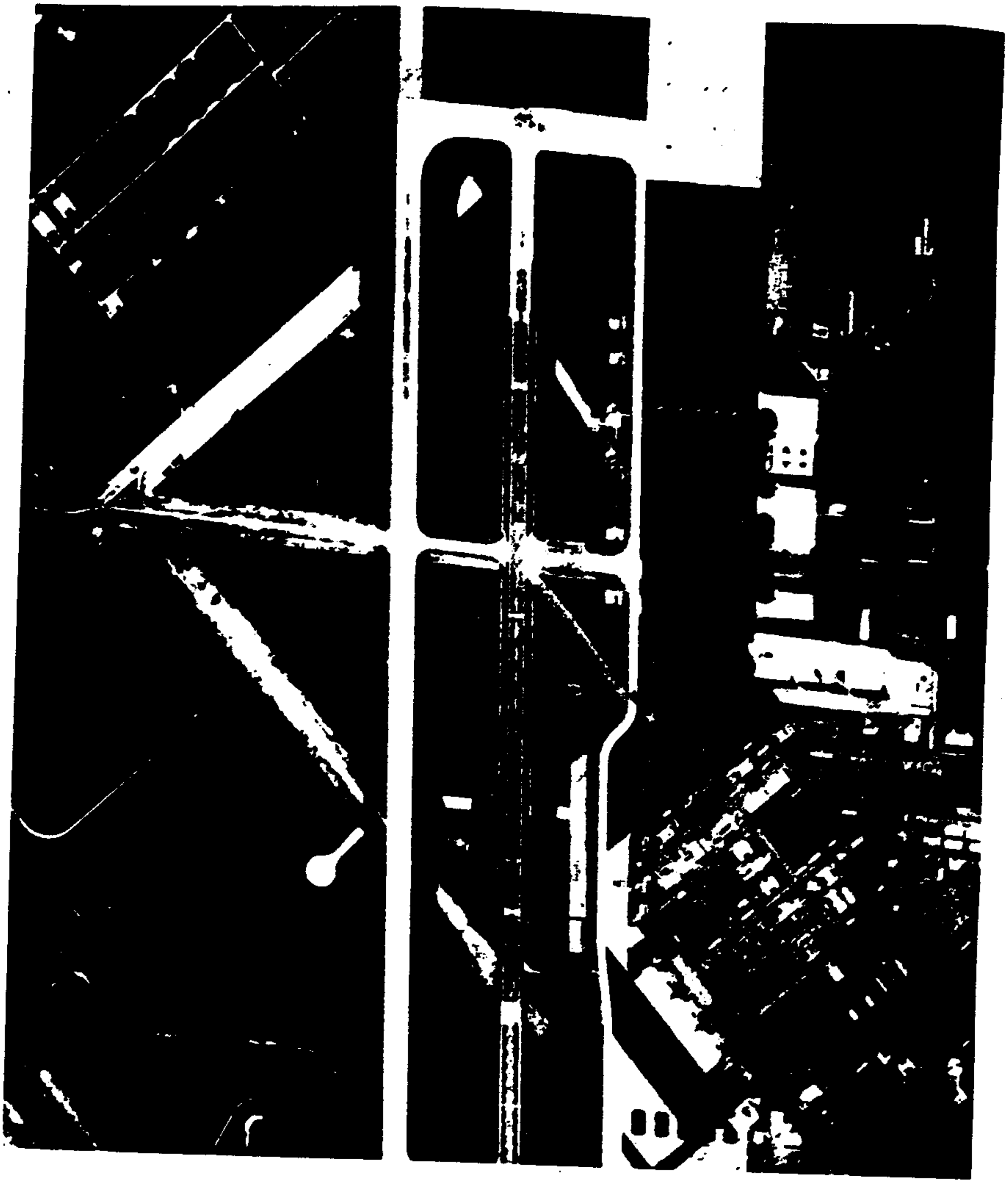

Fig. 12-5 — 20× enlargement of Lockbourne AFB, Ohio with polarizer filter on the FWD-looking camera (1/250-second exposure) under clear weather conditions, mission 1102

Fig. 12-6 — 20× enlargement of Lockbourne AFB, Ohio with Wratten no. 21 filter on the AFT-looking camera (1/500-second exposure) under clear weather conditions, mission 1102

Notice of Page Substitution

Appendix

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

Appendix

PERTINENT REPORTS

References and conclusions from pertinent Itek, Eastman Kodak, and NPIC reports and messages are included in the following pages.

1. ITEK REPORTS

1.1 EKIT Report No. 4

Evaluation of SO-121 at Low Solar Altitudes,
[redacted] 16 November 1966

This report contains an evaluation for the first time, of the capability of SO-121 color film at low solar altitudes. As such, it forms a basis for estimating the probable performance of SO-121 in the KH-4B system in terms of attainable resolution, exposure requirements, and other system tradeoffs. The report also contains an evaluation of the reproduction and image quality characteristics of SO-121 color film under low solar altitude conditions.

1.2 EKIT Report No. 5

Comparison of 3404 and SO-362,
[redacted] 23 January 1967

This two-part evaluation of SO-362 and 3404 contains descriptions of a laboratory test to determine sensitometric and image quality characteristics, and an in-flight test evaluating image quality in an operational system.

1.3 EKIT Report No. 6

Night Detection Photography,
[redacted] 28 February 1967

The prime purpose of this report was to evaluate the 112B system as a detector of nighttime activity in target areas illuminated by artificial means. Three film types were used: SO-340, a high-speed black and white emulsion; SO-180, an infrared sensitive color emulsion; and SO-121, a high resolution color film.

1.4 EKIT Report No. 7

Effects of Different Exposure Levels on Type 3404,
[redacted] 31 May 1967

The purpose of this evaluation was to determine the effects of exposure variations on the resolution and image quality of 3404 film in the 112B system. The analysis involved comparative evaluation of similar imagery in terms of subjective image quality, reproduction characteristics, and system considerations.

1.5 EKIT Report No. 8

Evaluation of Low Gamma Processing,
[redacted] 4 July 1967

This report contains a summary of low gamma processing theory and application, and a review of work done to date. However, it is supplemented with a discussion of the results obtained from a limited number of aircraft and satellite tests of image quality and reproduction characteristics of the process.

1.6 EKIT Report No. 9

Comparative Evaluation of SO-230 and 3404 Films,
[redacted] 1 August 1967

This report contains a comparative evaluation of basic sensitometric characteristics of SO-230 and 3404. Image quality was subjectively evaluated through image assessment of static simulated aerial scenes.

1.7 EKIT Report No. 10

Comparative Evaluation of Eight Color Materials,
[redacted] 1 August 1967

This report contains an analysis of the basic sensitometric and physical characteristics of eight commercially available color materials. The analysis is supplemented with a subjective comparison of model imagery.

1.8 EKIT Report No. 11

Comparative Evaluation of SO-340 and SO-166,
[redacted] 1 August 1967

This report contains a comparative evaluation, based on laboratory data, of SO-340 and SO-166 aerial films in terms of their potential use in satellite night photography.

1.9 EKIT Report No. 12

Evaluation of SO-180 (Infrared Color Film),
[redacted] 14 August 1967

This report contains an evaluation of the advantages of infrared sensitive color film (SO-180) as a unique information-gathering tool. For comparative purposes, the results are compared with similar black and white (3404) and conventional color (SO-121) imagery.

1.10 EKIT Report No. 13

Evaluation of a Polarizing Filter in High Altitude Photography,
[redacted] 28 August 1967

This report contains a study of panchromatic imagery from various solar azimuths and filter orientations to evaluate the effect of a polarizing filter on haze light and image contrast.

1.11 EKIT Report No. 14

Index Analysis,
[redacted] 1 September 1967

This report contains an examination of CORONA index material to determine visually the possible relationship between weather and camera performance.

1.12 EKIT Report No. 15

Metric Comparison Between SO-121 and 3404,
[redacted] September 1967

This report contains an evaluation of those factors that may or may not affect mensuration precision when color (SO-121) material is used in conjunction with or in place of 3404 material.

1.13 EKIT Report No. 16

Bi-Color Evaluation,
[redacted] 15 September 1967

This report contains an evaluation of the bi-color technique for obtaining color photography from two black and white images. This was the first bi-color test with stereo convergent cameras.

1.14 Report No. 1 — KH-4B System Capability

CR-2 Polarizer Experiment,
[redacted] 11 May 1968

The purpose of the CR-2 polarizer experiment was to evaluate whether or not a polarizing filter does provide increased performance in the CORONA J-3 system by improvement in object contrast, haze penetration, shadow penetration, and decreasing image blooming.

1.15 Report No. 2 — KH-4B System Capability

Analysis of Exposure Criteria and Requirements for the KH-4 Systems,
[redacted] 19 August 1968

This report describes an experimental study of exposure criteria and requirements of the KH-4 systems. A reassessment which examined the validity of exposure adequacy in current and past missions is also included. The analysis is extended to include current exposure prediction methods for intelligence targets.

1.16 Report No. 3 — KH-4B System Capability

CR-2 Bi-Color Experiment,
[redacted] 27 September 1968

This report contains an evaluation of the bi-color technique of obtaining color photography from spectrally filtered black and white films in a stereo convergent camera system. The analysis also considers various exploitation techniques for producing bi-color imagery.

 [redacted]

1.17 Report No. 4 — KH-4B System Capability

[redacted]Evaluation of SO-230 Film for Use With the KH-4B System,
[redacted] 1 October 1968

This analysis contains a detailed sensitometric and image quality evaluation of SO-230 film for both laboratory and mission conditions. The tradeoffs between the shorter exposure times (less blur) and lowered film resolution are also examined in a search for an improvement in total system performance.

1.18 Report No. 5 — KH-4B System Capability

[redacted]Evaluation of SO-380 Film for Use With the KH-4B System,
[redacted] 15 March 1969

This report describes a tag-on experiment designed to evaluate the compatibility of ultrathin base film, such as SO-380, with the CORONA system on mission 1103. It includes sensitometric and image quality evaluations of SO-380 for both laboratory and mission conditions. In addition, a statement of the background testing for mission 1105 is included due to the problems experienced on that mission.

1.19 Report No. 6 — KH-4B System Considerations

Evaluation of SO-180 Film

This report describes an experiment evaluating the potential use of SO-180 (infrared color) film for unique types of information gathering from orbital altitudes. The evaluation includes a study of the film's characteristics, image quality, and factors influencing color acquisitions in a space environment. This report is to be published shortly.

1.20 Report No. 7 — KH-4B System Capability

Evaluation of SO-121 Color Film

This report describes an experiment designed to examine the potential capability of high resolution color film (SO-121) in the CORONA J-3 system. The study analyzes results from both laboratory and mission conditions from both missions 1105 and 1106. This report will also be issued shortly.

2. EASTMAN KODAK REPORTS

2.1 Contract [redacted] Task 3, PAR 24-8-5S, Interim Report

Exposure Criteria for Acquisition Films; Haze Study, 20 December 1968

This study of urban scene brightness distributions from satellite photography tends to verify conclusions concerning the constancy of the mean scene luminance found in earlier investigations. Minimum variation of the mean luminance statistic with haze was observed as a result of the proximity of the mean scene reflectance to the "iso-best reflectance," or that reflectance whose luminance varies the least with haze condition, approximately 11.3 percent. Mean urban scene reflectance corresponded closely to the average reflectance of 21 military targets. Future exposure recommendations should be based on predictions of mean scene luminance, placing the mean at the maximum resolution exposure point of a film product.

2.2 Contract [redacted] Task 2, PAR 24-7-2S, Interim Report

Type SO-121 Film in the Delta III Configuration at Low Solar Altitudes, 20 January 1967

Type SO-121, High Definition Ektachrome Aero Film, was successfully exposed at solar altitudes below 20 degrees, thus verifying the 65,000-foot EV curve to as low as 5 degrees solar altitude. Because of a most favorable skylight illumination-to-haze ratio at low solar altitudes, it is recommended that photography of subjects found normally in shadows be obtained at the lowest possible solar altitude.

2.3 Contract [redacted] Task 2, PAR 24-7-6S/R2, Final Report

Target Brightness Studies, 10 March 1968

The study indicates the feasibility and value of collecting brightness data on specific target elements. Photographic quality of specific targets can be improved by consideration of average luminance as a basis for camera exposure settings. Methods for applying target brightness data are suggested for both exposure selection and analysis. Examples are given. The method of collecting target data is discussed.

2.4 Contract [redacted] Task 3, PAR 24-8-5S, Final Report

Exposure Criteria for Acquisition Films, 14 January 1969

A review of reports concerned with exposure evaluation of satellite missions and refinement of exposure criteria is included. Data collected on routine missions have indicated that no change of exposure should be made to compensate for haze conditions. No compensation of exposure should be made for view angle above a solar altitude of 10 degrees. A final exposure recommendation is presented based on placing the luminance corresponding to the mean reflectance of a target at the peak film resolution point. A full stop reduction of exposure is recommended for snow photography.

2.5 Contract [redacted] Task 2, PAR 131S, Final Report

Mathematical Color Duplication Model, 27 August 1968

A program has been written to simulate the acquisition and duplication stages of color aerial photography. A data bank of spectral sensitivities, reflectances, and transmissions is used in conjunction with an atmospheric model and light sources typical of those used in the duplication process to predict the resultant color of an object photographed from high altitude. The output includes the integrated energy, original and dupe dye densities, the CIE color coordinates, and the brightness of the object as seen by the eye.

2.6 Contract [redacted] Task 3, PAR 24-8-8S, Special Report

Correlation of Exposure Prediction Program, Crystal Ball and Operational BX Missions, 26 August 1968

Scene brightness distribution statistics, derived from microdensitometer raster scanning of mission material, were compared with values calculated in the computer acquisition model "Crystal Ball." Statistics showed the geometric mean scene brightness to be the least deviant for different haze conditions, and the most reliably predicted value from the model. Atmospheric contrast reduction primarily affects the high and low ends of the scene brightness distribution and does not shift the geometric mean appreciably. It is suggested that little is to be gained in changing exposure for haze condition.

2.7 Contract [redacted] Task 3, PAR 24-8-5S, Interim Report

Exposure Criteria for Acquisition Films; CATS Angle Study, 20 December 1968

No variation of brightness due strictly to changes of CATS (CAmera-Target-Sun) angle was found to exceed 0.10 log B_a above a solar altitude of 10 degrees. Comparison of brightnesses predicted by "Crystal Ball" with actual measurement indicated that the prediction program is a reliable and powerful tool for investigations into brightness, exposure, haze, and contrast. A discussion of the geometry of the camera-target-sun angle is included.

2.8 Contract [redacted] Task 3, PAR 24-8-8S, Final Report

Study the Characteristics and Uses of Suitable Materials for High Altitude Acquisition, 19 August 1968

A sensitometric curve shape was calculated based on empirical measurements of contrast reduction as functions of log exposure. Flight tests conducted with a sensitometric curve which obtained the general shape of the calculated curve demonstrated an improved photographic image. Spectral data are presented on daylight irradiance, atmospheric transmittance, and radiance. Description and theory of the instruments used to collect the data are included. The concept of the "Crystal Ball" atmospheric model is discussed. Comparisons of the predicted scene luminance statistics and those actually measured for several camera systems are made. Results showed that mean luminance statistics could be predicted within 1/3 stop 50 percent of the time.

3. NPIC REPORTS AND MESSAGES

3.1 Subjective Comparison of Wrattens no. 25 and 21 and SF-05 Filtered Records, Mission 1102

NPIC message no. [redacted] February 1968

Conclusions

The contrast range is significantly reduced when the SF-05 is used in place of either the Wratten no. 21 or the Wratten no. 25 filters.

Apparent image sharpness is reduced by a noticeable degree on the SF-05 photography compared with the Wratten nos. 21 and 25 filtered photography.

The effect of image quality degradation caused by the use of the SF-05 filter is minimized when the photography is viewed in stereo with the higher quality, higher resolution photography exposed through the Wratten no. 25 filter.

The resolution of the green filtered record is generally comparable to that of a normal J-1 mission.

3.2 Comparison of SO-230 and 3404 Film Types from Mission 1102-2

Photographic Evaluation Report, Mission 1046, [redacted] August 1968

Conclusion

The conclusions are based strictly on the operational material from mission 1102. SO-230 produces imagery which at higher magnifications (50× and above) appears slightly grainier. This apparent graininess, however, does not adversely affect the information content of the material at the magnifications normally used by the photointerpreters.

The potential advantage of SO-230 is in its additional emulsion speed (approximately 2/3 stop) which will allow shorter exposure times, thereby reducing the effects of uncompensated image motion.

3.3 SO-180 Evaluation, Mission 1104

Photographic Evaluation Report, Mission 1104, [redacted] December 1968

Conclusions

It should be emphasized that (1) the coverage obtained was not over the intended areas, (2) portions of the material are severely degraded by fog from corona static, and (3) approximately 30 percent of the SO-180 film is obscured by clouds.

Regardless of these factors, portions of the SO-180 imagery obtained on this mission closely approximate the expectations of this lens-film combination. Some of the existing imagery contains significant added information from an intelligence standpoint, provided the analyst is allowed sufficient time to interpret (study) it, has a working knowledge of the film characteristics, and is familiar with the infrared reflectivity of the various objects photographed.

3.4 SO-180 Supplement, Mission 1104, Image Restoration Techniques

Photographic Evaluation Report, Mission 1105, [redacted] April 1969

Conclusions

Comparisons of selective printing techniques (prints made through separation filters that represent the information contained in one or more emulsion layers of the SO-180 film where the film is degraded by corona fog) indicate that the prints made through the red filter are very poor in quality. Prints made through a green and/or a blue filter are fair in quality and appear comparable although those prints made through the green filter are slightly superior. Therefore, it is recommended that if high quality black and white reproductions are needed from the corona fog degraded areas of SO-180 film, a green filter be used to maximize the information.

3.5 SO-121 Evaluation, Mission 1105

Photographic Evaluation Report, Mission 1105, [redacted] April 1969

Conclusions

Twenty-two targets were nominated for color coverage on this mission, but only one of these targets was actually covered. No additional intelligence information concerning this target was obtained from the color photography.

The image quality and interpretability are poor due to a film curl (away from the focal plane) that prevails throughout the color acquisitions. This degraded condition precludes a detailed analysis of the potential of color photography in this system.

SO-121, approximately 1.5-mil thicker than SO-380 (UTB), results in a shorter film load capability and therefore reduced area coverage.

The color balance is good and the exposure is adequate.

The use of the color imagery from this mission as a stereo partner with the high resolution black and white imagery is limited due to the film curl condition of the color acquisitions.

The best ground resolution that can be expected from SO-121 in this system (approximately 15 feet) is not compatible with detailed target readout. Color-oriented requirements should be directed against targets which do not require resolutions beyond the capability of the system. The requirement for color must be color resolution-oriented rather than spatial resolution-oriented.

3.6 Photo Interpretability of SO-121, Mission 1106

Photographic Evaluation Report, Mission 1106, [redacted]

Conclusions

If only color film had been received, the 15 priority targets that were photographed would have been rated poor instead of fair, and most would have been categorized as "identification only." In most instances, no intelligence information was derived from the SO-121. This report is in the process of being published and will be issued shortly.