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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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FIGURES

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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.

 [redacted]

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.

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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

* 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. <u>Consideration should be given to developing specific bi-color exploitation equipment</u>. 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. <u>Consideration should be given to the development of higher resolution color films.</u> 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] Handle Via TALENT-KEYHOLE Control Systems Jointly 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

 [redacted]

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

 [redacted]

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.

 [redacted]

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).

 [redacted]

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

*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 GORONA 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 cf 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).

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.

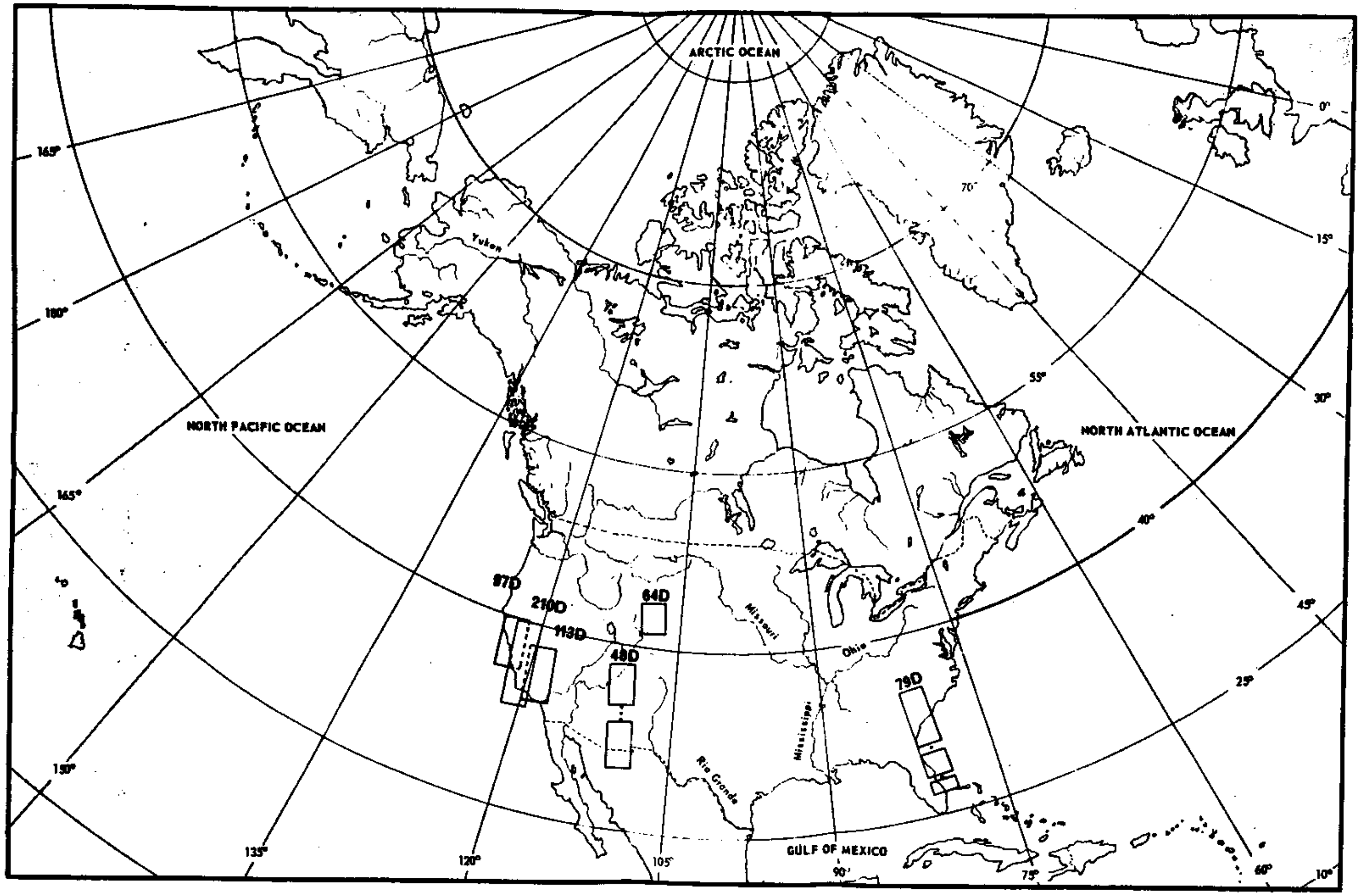


Fig. 4-1 — Ground tracks for the mission 1102 bi-color passes over the United States

 [redacted]

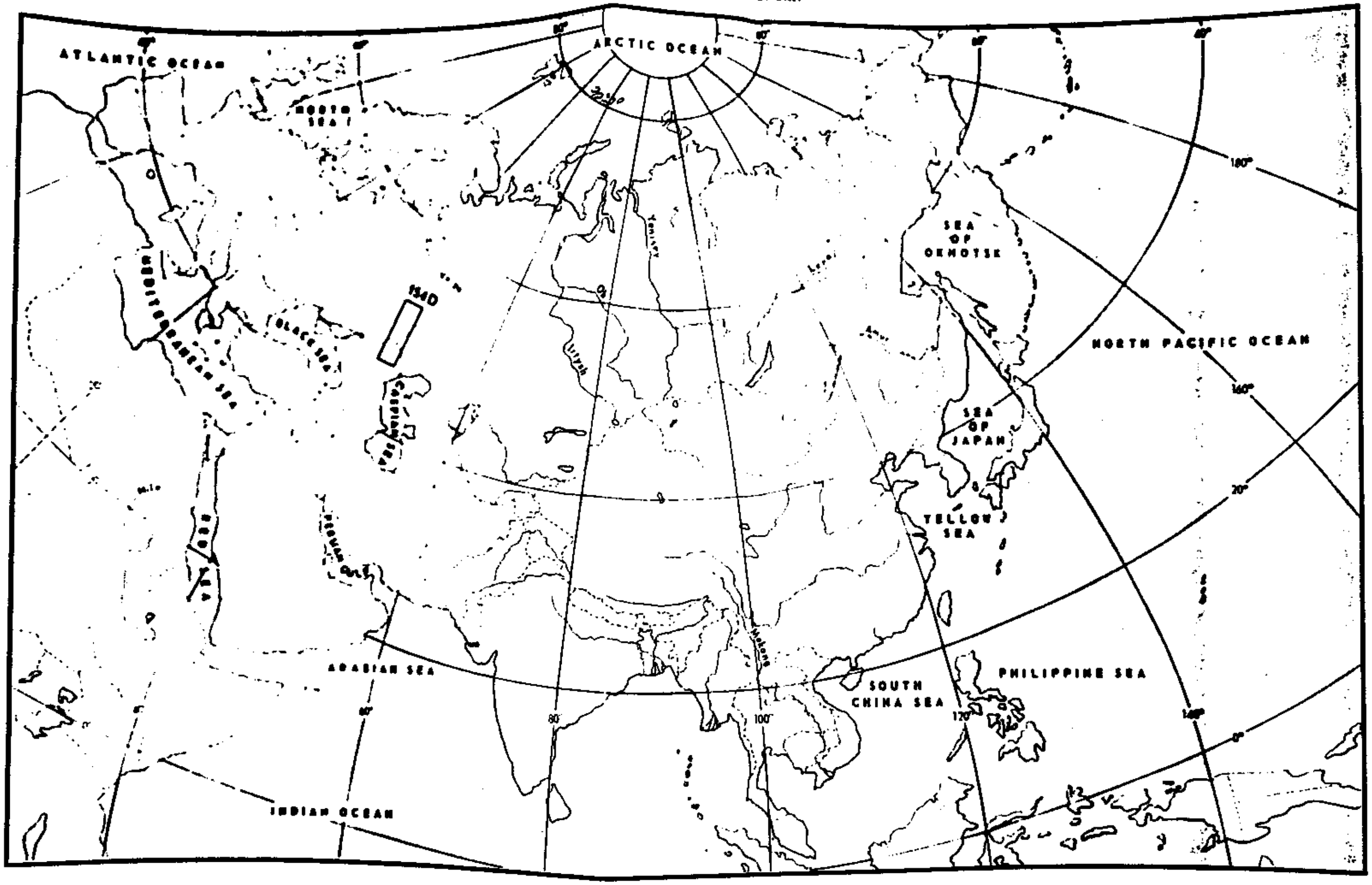
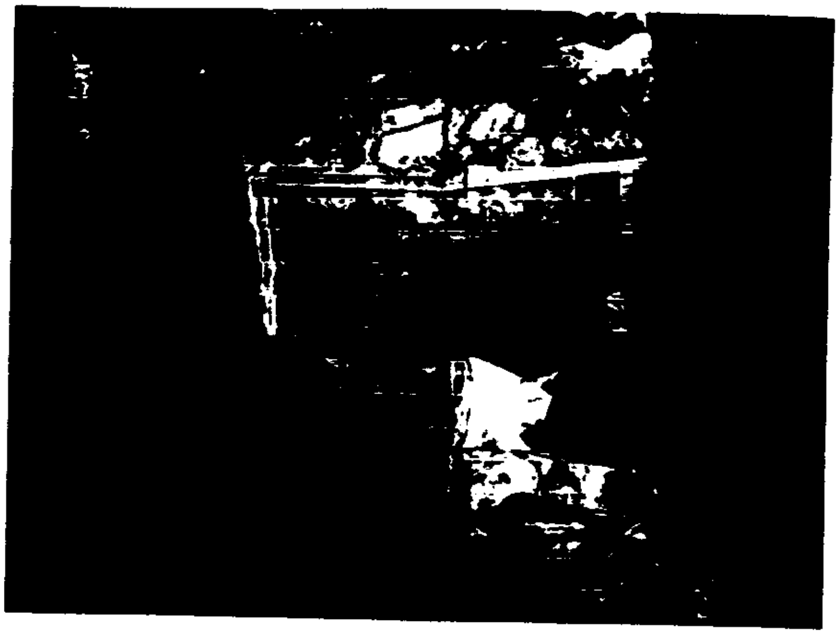


Fig. 4-2 — Ground track for the mission 1102 bi-color pass over the Soviet Union

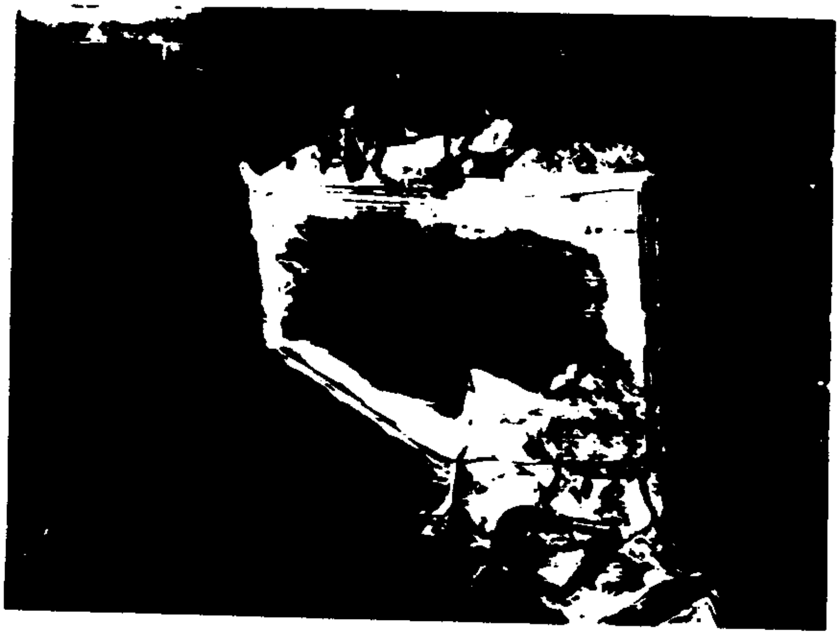
 [redacted] Handle Via TALENT-KEYHOLE Control System Jointly

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



(a) 20× orthoprint from red filtered negative



(b) 20× orthoprint from green filtered negative

Fig. 4-3 — Copper mine slurry, Arizona

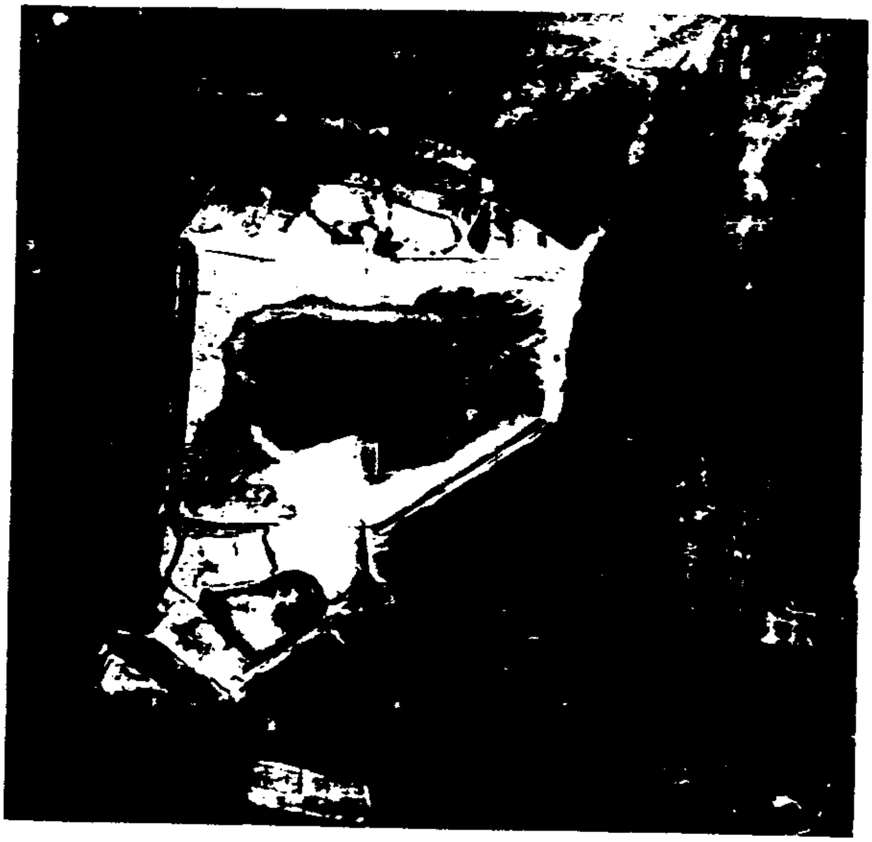


Fig. 4-4 — 20× bi-color integration made from green and red orthoprints