THE USE OF COLOR PHOTOGRAPHY IN THE NATIONAL RECONNAISSANCE PROGRAM

MAY 1971

Report of the NRO Color Task Force

Submitted to the Deputy Director, National Reconnaissance Office

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FOREWORD

This document constitutes the report of the Color Task Force established by the Deputy Director of the National Reconnaissance Office in October, 1969. We have attempted to make this document complete enough to show the basis for the major considerations, conclusions, and recommendations reached. In addition, references are made to the considerable quantity of backup material presently available.

The success of any undertaking of this complexity depends heavily on the cooperation received, and in this case community and individual support has been excellent. We wish to thank all those organizations and individuals who have assisted.

[redacted]

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(b)(3)

NRO Chairman

R. J. Kohler
ROBERT J. KOHLER
CIA

SAMUEL McCULLOCH, Major
DIA*

Garrett Cochran
GARRETT COCHRAN
COMIREX

John W. Cain
JOHN CAIN
NPIC

*Major McCulloch replaced Colonel Arthur Gaston, who served on this Task Force until July, 1970, when he retired from the USAF.

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BACKGROUND

1.1 INTRODUCTION

The use of color films in the National Reconnaissance Program has been a subject of debate and investigation for a number of years. In the main, these investigations have been inconclusive, or more precisely "negatively" inconclusive, because of the difficulty in resolving the spectral versus spatial resolution question. That is, the resolution of available color films was always substantially lower than the high resolution black/white materials. While most would agree that color offered the potential of providing additional information, few were willing to gain that information at such a sacrifice to spatial resolution. Quite logically and properly, therefore, the inclination was to stick with success---that is, high resolution black/white photography.

As Table 1 shows, there are five potential dimensions to any ground scene: physical dimension, geometric shape, depth/height, brightness, and color. In a photograph, geometric shapes are depicted as detail, and better resolution produces better detail. Stereo produces information about the ground scene which may or may not depend on resolution to be of value. Associated with geometric shape, and often stereo, is the capacity of quantification, i.e. measurement of its sizes. That property of quantitative sizing is important in that it allows for a fuller description of a facility or object. Accurate measuring often permits the identification of different models of weaponry, for example.

TABLE 1

PHOTOGRAPHIC INFORMATION PROCESS

Dimension	Nomenclature	Photograph
Geometric Shape	Resolution (l/mm)	Detail
Physical Dimension	Size	Mensuration
Depth/Height	Stereo	Stereo
Brightness/Contrast	Foot-Lamberts	Density Differences (Gray Levels)
Color/Spectral	Color	Color

The most fundamental information recorded about the ground scene is that relating to brightness and brightness differences (contrast). Even the highest resolution film will record essentially no information if it has no exposure latitude. Brightness differences result in density differences on the film and are the product of many factors, including spectral reflectance and the spectral sensitivity and discrimination of the detector. It is readily seen how color greatly expands the latitude of the recording medium, for while a black/white film is restricted to recording in tones of gray, a color film records a whole spectrum of hues in a range of chroma (saturation) and at various levels of brightness. Thus, while a black/white film can record perhaps 30 discernable tones of gray, color film has been known to record at least 267 distinct hues, and these hues can be recorded at various levels of saturation and brightness.

1.2 LIMITATIONS OF COLOR FILM

Three limitations associated with color film traditionally have prevented its being given serious consideration for regular use in photographic satellite and high-altitude reconnaissance aircraft. One has been the added expense connected with processing, duplicating, and exploiting color imagery. Another has been the reduction in film footage attendant with the use of color film, which is thicker than its black/white counterpart. The third cost, which until recently was by far the most significant, has stemmed from the fact that the technology for the manufacture of both original and duplicate color film is such that color photography from an aerial camera system does not yield as high a ground resolution as black and white photography obtained under the same conditions by the same system. Prior to mid-1969, the best available high resolution color film was SO-121. SO-121 had approximately one-third the resolving power of the black/white film then in use (SO-380) and nearly three times the granularity. Tests of SO-121 in both the medium resolution KH-4 System and the high resolution KH-8 permitted the ready detection of color differences that in some instances were not discernable on black/white coverage. It was obvious, however, that the information gain provided was far outweighted by the information loss associated with the lower resolution. Experiments with the SO-180 color infrared film led to a similar conclusion. Furthermore, the color duplicate copies of the SO-121 and SO-180 originals showed a resolution drop substantially greater than the loss normally encountered in the duplication of black/white originals.

1.3 IMPROVEMENT IN COLOR FILMS

While SO-121 and SO-180 clearly were not of a quality that could lead to their regular use in high-altitude reconnaissance systems, their experimental employment demonstrated the potential of color photography in the National Reconnaissance Program. Consequently, the National Reconnaissance Office took active steps to encourage industry to develop improved color original and duplicate films. On 9 December 1968, the Director of the National Reconnaissance Office in a letter to the one film manufacturer stated:

> *In the past, there has been considerable doubt expressed about the ability to collect high-resolution color photography of intelligence value from space....*
>
> *I understand that we are faced with an additional problem in that there is a loss of information inherent in the reproduction of color photography through successive generations of duplicates. Since there is only one original positive with high resolution, it is received and evaluated by only one of*

many users. Others who receive duplicate positives must be content with about a 50 percent loss in resolution.

On 12 March 1969, the film manufacturer responded as follows:

In your letter, you make reference to a significant resolution loss in color duplicating. We have been well aware of this problem for quite some time and are attempting to devise new duplicating films which better match the quality requirements imposed by the high resolution of the SO-121 original....

We further recognize that our first generation color films, of which SO-121 is a good example, are not optimum with respect to speed and resolution as compared with the current black and white films around which...systems have been designed. As a result, there are some losses in convenience and quality when color films are used in these systems. It is this mismatch that we are focusing our attention on at the present time. The goal is to devise new films and process chemistry, even if it be specialized and rather sophisticated chemistry, optimized for maximum quality in satellite reconnaissance.

On 22 August 1969, the Director of the National Reconnaissance Office further encouraged the film manufacturer:

In this regard, your most encouraging letter of March 12 to Dr. Flax has been brought to my attention. I want to assure you that I share Dr. Flax's interest in improving color materials and that the National Reconnaissance Office will continue to support experimental testing and other activities to the maximum extent possible.

We are also striving to encourage a broader exchange of information between the various elements of the intelligence community in relation to collection, processing, exploitation and analysis of the several types of color materials. The validation of requirements in this area and a clear understanding of the capabilities and limitations of all the present and potential films must result from thorough systems integration.

In October 1969, the film manufacturer announced the development of SO-242, a new standard-thin-base (STB) color acquisition film with properties far superior to SO-121. This is graphically indicated in Table 2. Development of SO-255, an ultra-thin-base (UTB) counterpart of SO-242, soon followed.

TABLE 2

COMPARISON OF FILM TYPES

Characteristics		SO-121	SO-180	SO-242/255	1414*
Contrast Ratios:	3.9:1	115 c/mm	50 c/mm	185 c/mm	420 c/mm
	1.7:1	63 c/mm	35 c/mm	135 c/mm	255 c/mm
AEI (Speed)		12	10	2.8	3.5

* 3414 and 1414 have replaced 3404 and SO-380 as the STB and UTB black/white films used in National Reconnaissance Program satellite programs.

1.4 ESTABLISHMENT OF THE COLOR TASK FORCE

With the development of this new film, it became obvious that the time had arrived to initiate exhaustive studies of the problems and benefits associated with the collection, processing, duplication, distribution, and analysis of color photography in the National Reconnaissance Program. On 22 September 1969, the Deputy Director of the NRO established[1] a task force to investigate a number of questions concerning color photography and to coordinate the effort required to insure the collection of the quantity and quality of color coverage needed to determine its long-term role and value to the National Reconnaissance Program.

[1] BYE-13210-69, "Use of Color in the National Reconnaissance Program," 22 September 1969.

SECTION II

SYNOPSIS

2.1 INTRODUCTION

This section summarizes the results and findings of the Color Task Force's work to date. Technical detail supporting the findings and the subsequent recommendations presented in Section III are found in Appendices I - VI. The work of the Color Task Force falls into several major categories:

a. Evaluating the ability of the various systems to employ color films and determining the performance to be expected.

b. Coordinating the collection of operational and test color photography, both satellite and aircraft.

c. Evaluating color reproduction techniques and procedures to identify the limitations inherent in, and problems associated with, these techniques and procedures.

d. Evaluating the impact of a significant color collection effort on the National Reconnaissance Program processing facilities.

e. Assisting the Exploitation Subcommittee of COMIREX in the establishment of exploitation guidelines.

f. Establishing requirements for, and assisting in, technical analysis of the quality of the acquired coverage.

2.2 COLLECTION PROGRAM

The color collection effort is divided into two major categories, satellite and aircraft.

2.2.1 Satellite Collection Program

While the resolution of SO-242/SO-255 is clearly superior to that of SO-121, it is noticeably poorer than SO-380 and SO-380's successor, 1414. Even before SO-242 was flown on operational missions, it was recognized that the determination of whether color coverage of a particular target was more valuable than black/white photography would vary. Determining factors include the nature of the intelligence problems associated with the target, the number of targets performing the same or a similar function, the season of the year, lighting conditions at the moment of coverage, the character of the terrain the target is located in, etc. It was also clear that determination of the net benefit of color coverage would be extremely difficult since targets vary greatly in importance, the satisfaction of some requirements necessitates much higher resolution than others, the relative values of most needs cannot be measured quantitatively, and each reconnaissance mission is tasked with collecting against a large number of requirements. It was with this understanding that collection was undertaken in the KH-8 System.

A request calling for the capability to fly limited amounts of film on satellite missions was submitted to the NRO by USIB in February 1970. The decision to limit the color coverage collected on KH-8 missions to about one day's take of SO-242/255 has been based on the fact that the program is still experimental, there are uncertainties associated with the processing and duplication of the color film within the tight time schedule intelligence needs demand, and the advantages of color coverage over black/white were unknown. In view of the number of variables influencing the net value of color coverage, however, the exposure of approximately 500 feet of SO-242 is a very small per mission increment in which to determine the merits of color versus black/white film. In addition, about half of the targets photographed during a typical orbit day of a KH-8 mission will be cloud-covered, some of the remaining targets will be unusable because of haze and the presence of cloud shadows and/or smoke in the target area, or some other limiting condition.

During passes over the Sino-Soviet area and the Middle East, the KH-8 is unable to photograph more than a small fraction of the targets coming within range, and the software program that selects the targets to be framed does not automatically take into account the special needs associated with color collection. Consequently, during each mission on which SO-242/SO-255 is exposed, the Imagery Collection Requirements Subcommittee of COMIREX, supported by the Satellite Operations Center, holds sessions that pinpoint those accessible targets whose coverage would be of special significance in the evaluation of the role of color photography. This arrangement, though time-consuming, has worked very well.

SO-242 was included on six consecutive KH-8 missions flown between October 1969 and November 1970. Unfortunately, the six missions yielded a disappointingly small quantity of color photography of the quality needed to allow a meaningful comparison with black/white film. The film bucket during Mission 4325-2 was lost during its recovery attempt. Quality control and exposure problems severely degraded the quality of the photography obtained on Mission 4326-2. A failure in the satellite command system prevented recovery of the color film carried on Mission 4327-2. On Mission 4328, a special filter used to improve the quality of the black/white coverage had a detrimental effect on the color film. Only on Mission 4324-2 and 4329-2 was a large portion of the recovered and processed color film of a quality one would expect regularly from a large-scale color collection program.

SO-242 was also exposed during one KH-4b mission (1108). The image quality obtained clearly showed that it would be unwise to attempt further tests, as the lenses of the KH-4b are not well color corrected.

2.2.2 Aircraft Collection Program

At the suggestion of the Color Task Force, SO-242 was exposed during three operational missions [redacted]

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The potential value of color photography was also pointed out to DIA personnel involved with the military attache collection program, and CIA personnel associated with clandestine operations. As a result of a Task Force recommendation, steps also have been taken to evaluate the use of color film on U-2 and SR-71 missions.

The investigations of the Task Force quickly revealed that a data base of known color-rated photographic signatures was needed to help photointerpreters identify installations and activities photographed in color in the course of intelligence collection operations. As a result, the assets of the Red Dot Program have been used to support sixteen U-2 flights that have photographed a wide variety of U.S. industrial and military installations in both color and black/white. Red Dot is a program of domestic flights that employs the U-2 carrying various sensors. It has been conducted for a number of years under the sponsorship of the CCB. It is intended to provide for the investigation of new films, high altitude exposure studies, etc. NPIC has indexed the coverage and has distributed target listings and maps, giving analysts and photointerpreters a ready reference of the domestic color coverage available.

2.2.3 Conclusions on Collection Efforts

The Color Task Force has reached the following conclusions relative to the color collection effort to date.

a. There still exists a deficiency in the adequacy of color coverage. For most target types we do not yet have the coverage, under different acquisition conditions, needed to allow the significant information gains and losses associated with color photography to be defined. There is a need to expand the color collection effort to include imagery applicable to the general search and surveillance function.

b. Greater use of winged color collection vehicles over denied areas should be studied. The aircraft programs (U-2, SR-71, and [redacted] have the capability of providing significant contributions to the color data base, and of furnishing information on the contribution of color to the general search and surveillance function. (b)(1) (b)(3)

2.3 TECHNICAL ANALYSIS OF PERFORMANCE

2.3.1 Extent of Analysis

An important aspect of the Color Task Force's responsibilities was to obtain a good assessment of the technical performance of the SO-242/SO-255 in the missions flown. The Task Force worked extensively with NPIC in delineating the extent and nature of technical analysis to be undertaken. Also, reports from contractors were obtained. The technical analysis considered not just the quality of the original and duplicate photography but also many of the operational and processing problems encountered.

In general, the technical analysis consisted of an evaluation of both objective (from CORN targets) and subjective resolution from both the original and several reproductions. In addition, assessment of the color balance of the original and its reproductions was accomplished. Evaluation of the impact of the several problems encountered during the flights was also accomplished.

2.3.2 Conclusions from Technical Analysis

The Color Task Force's conclusions from the several technical analyses are as follows:

a. A statistically valid determination of the best resolution and color balance obtainable by SO-242/SO-255 Film in the KH-8 System cannot be made at this time. This is traceable to the limited sample and numerous technical and practical problems experienced with several of the color missions recovered. However, current analysis indicates that the best resolution obtainable on the color original should be approximately 35% worse than the best resolution obtainable on the black/white original. This analysis also indicates, however, that the disparity in average resolution between the color and black/white should be less than 35% and most probably will be on the order of 20%.

b. The conditions of illumination under which useful color coverage can be acquired are more restricted than those limiting black/white collection. Furthermore, the contribution of color coverage to the solution of intelligence problems is more severely reduced by improper exposure, improper processing, or marginal weather conditions than is that of black/white photography subjected to the same degrading influence. The deterioration affects both resolution and color balance.

c. The loss in resolution between the color original and the color duplicate is proportionally greater than the loss in resolution between original and duplicate black/white films. Since the state of technology during these missions was such that the resolution on the duplicate film distributed to the photointerpreter organization was approximately 40% poorer than that of the original, direction was given to each NTP tasked organization to examine the original material in the course of its evaluation. Because of this significant loss in resolution from the color original to its duplicate, the Color Task Force worked with the film contractor to develop, on a priority basis, a higher resolution dupe film. Such a film, SO-356, was announced in October, 1970. There was not a sufficient supply of SO-356 manufactured in time to complete the color reproduction of Mission 4329-2; however, three copies were made for evaluation by the NPIC, IAS and DIA interpreter organizations. This dupe film improves resolution of the color duplicates by approximately 20%. Even with this new film, the losses in resolution due to duplication are still too great, and additional work on color reproduction materials and techniques is warranted.

d. Selective layer black/white printing, a process that uses the SO-242/SO-255 original to generate black/white duplicates having resolutions superior to full-color duplicates, has not lived up to the early expectations. These expectations were that it would yield duplicates roughly equivalent to those obtained from black/white originals. New techniques and proper selection of materials should result in substantial improvements over the results obtained to date, but whether this processing can match black/white coverage in overall quality is questionable. However, high volume selective-layer prints can be delivered in a much shorter time than can full-color reproductions.

e. SO-242 (SO-255) is, in terms of color emulsion technology, an excellent film. Even though this is true, the quality of SO-242 is not good enough to mitigate complaints about its lower resolution.

2.4 EXPLOITATION OF COLOR PHOTOGRAPHY

2.4.1 Requirements for Imagery Interpreter Assessment

Prior to the exposure of SO-242 on Mission 4324, the intelligence community had no exploitation guidance oriented specifically to color imagery. Such guidance has now been developed by the EXSUBCOM of COMIREX, assisted by the Color Task Force. In addition to the normal exploitation guidance aimed at the intelligence information contained in the imagery, a basic color exploitation guidance for mission readout (first and second-phase)[1] has been provided to NPIC, and an in-depth (third-phase) color exploitation guidance[2] (to include a limited number of color-oriented EEI's) was provided to the National Tasking Plan (NTP) imagery interpretation organizations.[3] This guidance was provided to develop a data base of the information potential from color film.

2.4.2 Preliminary Results of Imagery Interpreter Assessments

An exploitation evaluation of the color photography obtained on KH-8 Mission 4324-2 was made by COMIREX in July 1970 and an update to incorporate data through 4329-2 is currently nearing final community coordination. This analysis suggests that resolution trade-off continues to have a major impact on utility and that the value of color imagery relative to black/white varies considerably in accordance with the imagery interpretation function being performed.

2.4.2.1 General Search and Surveillance

The greatest value of color imagery seems at this time to be its potential contributions to this function through a realization of potential manpower savings in accomplishing mission search as well as easier and, perhaps, earlier detection of new activities. The objective of search is detection, which is enhanced by color in somewhat the same way it is enhanced by improved resolution. In this sense, color represents a trade for resolution.

2.4.2.2 Technical Search and Surveillance

Currently, the most uncertain value of color imagery relates to this function. The ground resolution of satellite color imagery collected to date has been consistently inadequate for required mensuration and identification of small object detail. However, the color balance of this imagery i.e., the color hues themselves, seems to enhance the interpreter capability and confidence in certain detailed descriptions of facilities and precise identification of their functions and activities, analyses which might otherwise require higher resolution black/white imagery.

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[1] EXSUBCOM memo to NPIC, "Color Film Evaluation Requirements," 20 November 1969, TCS-10443-69.

[2] EXSUBCOM memo to NTP Organizations, "Color Film Evaluation Requirements," 20 November 1969, TCS-10442-69.

[3] These include the National Photographic Interpretation Center (NPIC), the Imagery Interpretation Division of DIA (DI-8), the Imagery Analysis Service of the CIA (IAS), the Special Activities Division of Army USAIIC (SPAD), Naval Reconnaissance and Technical Support Center of Navy (NRTSC), and the Foreign Technology Division of Air Force (FTD).

2.4.2.3 Technical Engineering Analysis

The lowest value of color imagery seems to be its very limited potential for providing significant contributions to this function, which is primarily dependent upon ground resolution for precision measurements of components of objects.

2.4.3 Implications of Imagery Interpreter Assessments

The Color Task Force supports the following conclusions of the community relative to the interpreter assessment of color photography:

a. The potential benefits of color to the interpreter and analytical communities are such that continuation of the color collection program is clearly warranted. The additional information which color potentially can provide is obtainable at a relatively small dollar cost.

b. Those functions requiring relatively high resolutions, i.e., technical search and surveillance and technical engineering analysis, have to date demonstrated low potential for significant color-based information. On the other hand, color photography has demonstrated a potential for making significant contributions with regard to those functions that can be carried out with imagery of lesser resolutions, i.e., general search and surveillance.

c. The greatest potential for color collection with satellite systems appears to lie with the KH-9.

d. The final determination of the intelligence value of color photography probably will take a long time. The necessary limitation of one day's take during each KH-8 mission makes the collection of an adequate base of color photography from that system slow. The KH-9 will not be able to fly color before late 1972.

2.5 COMMUNITY IMPACT

Two aspects of the community impact question were addressed: the effect on the National Processing Centers and the effect on the imagery interpretation community.

2.5.1 National Processing Centers

The problems of having to handle significant amounts of color at either of the National Processing Centers (NPC)[4] are essentially the same:

a. Neither facility is particularly well equipped to process and duplicate color.

b. Sufficient research has not been done to define the "best" processing procedures and techniques.

c. The present production space will not accommodate any additional color processing or reproduction equipment.

In addition to the poor equipment and facilities currently available for color processing and reproduction, the production rate is very slow. The impact of this slow production rate, however, will depend on

[4] These include Bridgehead and the Air Force Special Projects Production Facility (SPPF).

how many color copies are needed and how fast these must be delivered to the customers. At present, it seems that the total number of color copies required will not equal that required for black/white. How fast customers need the color film is a function of the task to be performed. For example, if color coverage is needed for first-phase exploitation, then the color reproductions will be required in the same time frame as black/white. For second or third-phase readout, time is not as critical a factor. If the color program is to continue, further attention must be paid to the area of color processing and reproduction. The current color processing facilities are marginal and not suitable for expansion, color processing is not as advanced as it might be, and optimum color reproduction equipment has not been developed.

2.5.2 Conclusions on Processing and Reproduction

a. The National Film Processing Centers have neither the facilities nor equipment required for a time-responsive, high-volume color processing and reproduction capability. This can be said even though the required response times and numbers of color copies have not been firmly established. However, color reproductions should not be required in the same quantities as black/white.

b. High-volume black/white separation print (green record) reproductions from color film can be delivered in a much shorter time than the color reproductions.

c. Current color processing and reproduction capabilities are marginal, even for a continued limited test program, and a modest investment in new facilities and hardware is warranted. The specific recommendations from this conclusion are outlined in Section III.

d. Optimized color processing techniques need to be developed. Ektachrome processing techniques have not basically changed for many years. Current processes tend to produce large grain size and/or grain clumping, which reduces image quality (acuity and resolution). It is likely that a process optimized for resolution could be developed and that this would provide some improvement in the image quality of SO-242/SO-255.

2.5.3 Impact on NPIC

The impact of color photography on NPIC was addressed to the Task Force on 6 May 1971 in a memo from the Executive Director (TCS-13830-71). This memo concluded that:

a. The introduction of color photography has not had a significant exploitation effect on NPIC.

b. Current photointerpretation techniques and equipment are adequate for the current operational exploitation of this material, regardless of the volume acquired.

c. The basic photointerpretation processes associated with color and black/white photography are identical. In addition, the fact that photointerpreters are not trained in color exploitation is compensated for by the more natural appearance of the medium.

d. The greatest impact on NPIC has been their support on technical evaluations. Numerous NPIC personnel have been involved with developing and implementing a comprehensive color evaluation program and coordinating that program with the other elements of the intelligence community. NPIC photo-scientists have made extensive technical evaluations of the color film, and compared the relative merits of various color and black/white prints. The photointerpreters have also spent a great deal of time participating in the assessment of the value of color photography.

e. NPIC will continue its research and development efforts which are designed to explore those aspects of color that bear on photographic exploitation. New equipment and techniques may be required if there are significant improvements in color films and related systems.

f. NPIC has experienced a number of derivative benefits from color photography which indicate that its contribution to search and scan efficiency may be its greatest long range value. This attribute of color could have a significant effect on NPIC's first and second-phase responsibilities.

2.5.4 Impact on DOD Elements

The DOD organizations which exploit color imagery can be divided into three categories: units with mapping and charting responsibilities, those which use nationally acquired imagery primarily for intelligence purposes, and units which exploit other than nationally acquired imagery.

2.5.4.1 Mapping and Charting

The present color photo production capability at the U.S. Army Topographic Command is generally limited to manual printing in small quantities. However, a color roll processing system capable of processing both original and duplicate color films is currently being installed. Modifications to roll printing equipment which will provide an additional color printing capability have been requisitioned. Current requirements for reproduction of color materials by the Topographic Command are minimal. However, if large quantities of color were received in the near future, black/white materials would be produced from the color original and the mapping/charting activities would then proceed in the usual manner. Thus, either photo-based maps or "standard" line topo maps could be made from color photo inputs with little impact. However, while some of the manually oriented plotting instruments and support equipment can use color imagery as the input, the newer systems employing automatic electronic correlation would require considerable modification. If a requirement was levied for the production of color orthophoto maps, a large amount of additional equipment and equipment modifications would be required. The U.S. Air Force Aeronautical Chart and Information Center (ACIC) uses imagery primarily for target point determination and the production of line charts. A limited capability to process and duplicate color materials (cut paper and films) is available. As with the Topographic Command, some of ACIC's manually oriented plotting equipment can use color imagery as the input, but the newer automatic systems would require considerable modification. The Naval Reconnaissance Technical and Support Center (NRTSC) provides photo support for mapping and charting activities in the Naval Oceanographic Office. No adverse impact on compilation or related support operations is anticipated as a result of receiving increased amounts of color imagery. The primary impact would be in the NRTSC photo lab support requirements. This will be addressed in a later paragraph.

2.5.4.2 Nationally Acquired Imagery

NTP tasked organizations within DOD (DIA, FTD, NRTSC, and SPAD) seem reasonably well equipped to process and print limited quantities of color materials in cut film and paper formats. In addition, DIA, FTD, and NRTSC have a color roll film processing/duplicating capability for a limited production effort, and some additional procurement is underway. Film viewing equipment appears to be adequate in terms of optical quality, but considerable research and probable modification to viewing light sources is needed. Within the Unified and Specified Commands, SAC currently has a color processing and duplicating capability which can accomplish comparatively high production rates of either whole rolls (originals and duplicates) or cut film/paper prints and enlargements. At the present time, CINCPAC units, which exploit nationally acquired imagery, are only capable of limited color photo processing and reproduction support. However, the 548th RTG is currently installing and certifying equipment which should provide a capability to process and reproduce aerial color films in limited production quantities. The U.S. European Command (US EUCOM) has only one facility (497th RTG) which receives/exploits color imagery. Although a color roll film processor is currently being installed and some duplicating/support equipment is on hand or on order, achievement of a color film processing capability of any consequence remains several months---perhaps even a year away. Neither CINCLANT nor the Army portion (CONTIC) of the STRIKE Command has a color photo support capability. The 480th RTG (AFSTRIKE) has a limited production color processing/reproduction capability for whole roll or cut film paper materials. In most cases, the exploitation of color imagery by U&S Command units can be accomplished with existing equipment although viewing light sources probably will require modification.

2.5.4.3 Other Color Imagery

Several units in DOD, primarily in support of tactical operations/contingencies (CINCPAC/STRIKE), have a limited color photo support capability. These capabilities include facilities on board carriers and the recently developed color processing/interpretation mobility system for tactical operations.

2.5.4.4 Summary

Most units within DOD, which are assigned imagery exploitation tasks, appear to have on hand or under procurement a limited color processing/duplication capability that could probably provide the necessary support for some increased expansion in nationally acquired color imagery. A few units would have little or no means, as presently equipped, for in-house support using color materials. The mapping and charting organizations would initially be required to perform many of the purely mapping tasks utilizing older equipment or else convert the color imagery to black/white so that conventional techniques could be used. Aside from the impact on photo lab requirements, exploitation of color imagery for intelligence purposes would not appear to be a major problem, although research and subsequent modification of viewing light sources would likely be needed. The extra cost of color photo materials, as compared to black/white, would necessitate adjustments in unit budgets if significantly more color imagery were acquired.

2.6 FINAL CONCLUSION

The potential benefits of color to the interpreter and analytic communities, makes it clear that the color program should continue. The additional information which color provides is obtained at a relatively small dollar cost and is well worth the effort involved to continue the program.

SECTION III

RECOMMENDATIONS

The Color Task Force makes the following recommendations:

1. The limited KH-8 collection effort requested by USIB and COMIREX (approximately one day's operation per mission) should be maintained to support the continuing evaluation of the potential of color to satisfy technical search and surveillance requirements. Consideration should be given to intermixing the color film with the black/white.

2. In view of the apparent advantage of color coverage in the satisfaction of general search and surveillance requirements, the National Reconnaissance Office should investigate the practicability of using SO-242/SO-255 Film in the U-2R and SR-71 flights over denied territory. In this regard, the Task Force should undertake an analysis of winged vehicle performance similar to that presented in Appendix II.

3. The Color Task Force recommends that the National Reconnaissance Office should take the steps needed to include limited quantities of SO-255 on flights of the KH-9 System as soon as is practical, and that the USIB should be advised when this capability is available. The KH-9 Project Office should be requested to submit a plan for implementing this recommendation.

4. A plan for flight testing the soon-to-be announced infrared color film should be developed by the Task Force. Depending on the results of this test, satellite testing may be warranted. If so, an evaluation of the potential of this film in the National Reconnaissance Program, similar to the one conducted for SO-242/SO-255, should be undertaken and the results submitted to USIB.

5. Development of higher resolution color original and color duplicating films should be encouraged. At this time the greater emphasis should be placed on higher resolution duplicating films.

6. The development of better equipment and techniques for processing color film and for making full color and black/white duplicates should be pursued. There are specific studies and equipment developments that should be undertaken at this time to implement this recommendation. The CCB should be authorized to undertake the following:

a. Develop A Full Color Modulation Printer - $150,000

This would provide for fully color corrected copies on a frame-by-frame basis and insure that all customers get good duplicates.

b. Undertake A Color Duplicating Study - $170,000

This would allow a systematic review of the factors affecting color reproduction and methods for improving quality.

c. Color Optical Titling Feasibility Study - $50,000

This would allow for an initial look at the problems involved in optically titling color film.

d. Spectral Versus Spatial Resolution Discrimination Study - $100,000

The question of the relationship between spectral and spatial resolution has not been formally addressed. In the long term, this is an important question and is worth studying at this time.

e. Miscellaneous Studies And Developments - $300,000

At this point, it would seem advisable to allow the CCB to plan for the expenditure of additional limited funds for new studies and developments as the solution to the problems are better defined.

7. A modest expansion of the color processing capability at Bridgehead should be undertaken. The status of the current equipment, in concert with the recommendation to continue color collection, makes this recommendation necessary. The Task Force recommendations are consistent with the philosophy of undertaking only those activities which are essential to continuing in a prudent fashion. Specifically, we recommend the following:

a. 18,000 square feet of additional space contingent to Bridgehead should be brought within the Bridgehead perimeter. Of this, 6,000 square feet should be converted to finished processing space. The cost for this is estimated at $600,000.

b. The already developed MP^2 Color Processor should be installed in this space at an estimated cost of $200,000.

c. Appropriate chemical mix facilities should be installed, the cost of which is estimated at $250,000.

This plan provides for the availability of a new flexible color processing facility (at a modest cost of $1.1 million) in approximately 11 months from approval. This facility is capable of further expansion if later deemed necessary. The Task Force believes this will provide both the improvements in processing capability needed for continuing the experimental program and for the capability to conduct more meaningful tests on processing techniques as the MP^2 is a highly versatile machine.

8. The Color Task Force should be formally extended and directed to continue to coordinate the exploitation efforts with the EXSUBCOM, direct the flight test program, and direct the technical analysis effort. The Task Force should continue to report to the D/NRO when significant findings, conclusions, and recommendations are reached.

APPENDIX I

FILM CHARACTERISTICS

1.1 SO-242/SO-255

SO-242 is a color Ektachrome reversal film specifically designed for high-altitude photographic acquisition. Three light sensitive emulsion layers, a protective filter overcoat, and a clear gel backing are deposited on a 2.5 mil Estar base. The arrangement of the individual emulsion layers is unique in that the green sensitive layer is on top, the red sensitive layer in the middle, and the blue sensitive layer on the bottom.

SO-255 is the UTB equivalent of SO-242, being the same emulsion coated on a 1.5 mil Estar base. Figure 1 illustrates the differences in physical construction between SO-242 and SO-121.

FIGURE 1

CROSS SECTIONS OF SO-121 AND SO-242

SO-121
Green Sensitive Record → Magenta Dye Layer
Blue Sensitive Record → Yellow Dye Layer
Red Sensitive Record → Cyan Dye Layer
Base
Backing

SO-242
Green Sensitive Record → Magenta Dye Layer
Red Sensitive Record → Cyan Dye Layer
Blue Sensitive Record → Yellow Dye Layer
Base
Backing

Placing the blue sensitive emulsion layer beneath the red and green layers represents an important departure from conventional techniques of color film manufacture. The blue recording emulsion layer is usually placed on top in order to compensate for the sensitivity of all silver halide emulsions to blue radiation. In SO-242/255, a blue absorption filter is included above the red and green emulsion layers to restrict penetration of the blue radiation to these emulsions. In addition, the sensitivity of the red and green emulsion layers to blue radiation has been restricted sufficiently so that the blue sensitive layer can be placed on the bottom.

This layer arrangement optimizes the composite characteristics of the film, eye, camera optics, and atmosphere. For example, since the sensitivity and discriminativity of the human eye peak in the green region of the electromagnetic spectrum, the placement of the green sensitive emulsion layer on top minimizes the image degradation due to light scattering. This, of course, is of benefit primarily when one is viewing the original. In addition, it is a substantial advantage in duping to have direct contact between the highest resolution layer and the dupe film.

Note: This report discusses a variety of films, both original and duplicating types. For clarity, therefore, an indexed summary of the different film types is presented as Table 1.

TABLE 1

FILM CHARACTERISTICS SUMMARY

Film Type	Aerial Exposure Index	Relative Resolution	Application
		-Acquisition Emulsions (Black/White)-	
3400	20	63	Index Camera on KH-4 and KH-8 Systems
3401	64	40	Stellar Camera on KH-4 and KH-8 Systems
3414	3.5/5.0	250	Main Camera KH-4b (STB-3.0 mil)
1414	3.5/5.0	250	Main Camera KH-8 and KH-9 (UTB-2.0 mil)
SO-349			Forerunner to 3414
SO-236			Forerunner to 1414
		-Acquisition Emulsions (Color)-	
SO-242	2.8	100	TB-3.7 mil
SO-255	2.8	100	UTB
SO-180	10	60	Camouflage Detection Color
SO-276	10	80	Negative Color
		-Reproduction Emulsions (Black/White)-	
2420			For duping 3400 acquisition film
2430			Past standard for most reproductions
SO-192			New standard after March 1971 (Not yet available to all customers)
SO-239			Reversal reproduction (negative-to-negative or positive-to-positive)
2422			Will replace SO-239
6451			High contrast for special prints
SO-369			High contrast for special prints - same as SO-192
		-Reproduction Emulsions (Color)-	
SO-360			Standard
SO-356			SO-242 on 4 mil base
SO-271			High contrast
7271			Internegative

Furthermore, camera optics normally are designed to perform best in the red and green region of the spectrum; therefore, it is desirable to record the information included within this region in a manner that minimizes image degradation. Also, the atmosphere scatters the short blue wavelengths more than it does the longer green and red wavelengths; therefore, the potential information content within the blue region is not as great as that in the corresponding green and red regions.

The resolution capability of SO-242 is significantly improved over that of SO-121, as seen in Table 2. This improvement is primarily the result of the more optimum arrangement of the emulsion layers, better dye homogeneity, and a sacrifice in film speed as compared to SO-121. The decreased film speed is most compatible with the collection systems when mixed film loads are used since a faster film speed requires the use of a neutral density filter. This was the case on Missions 1105 and 1106 which utilized SO-121.

TABLE 2

FILM DATA COMPARISON

	Thickness (mils)		Resolving Power (l/mm)		AEI
	Base	Total	1.7:1	100:1	Unfiltered
SO-242	2.5 (STB)	3.5	135	205	2.8
SO-255	1.5 (UTB)	2.5			
3414	2.5 (STB)	3.0	255	710	3.5/5.0
1414	1.5 (UTB)	2.0			
SO-121	2.5 (STB)	3.5	63	154	12.0

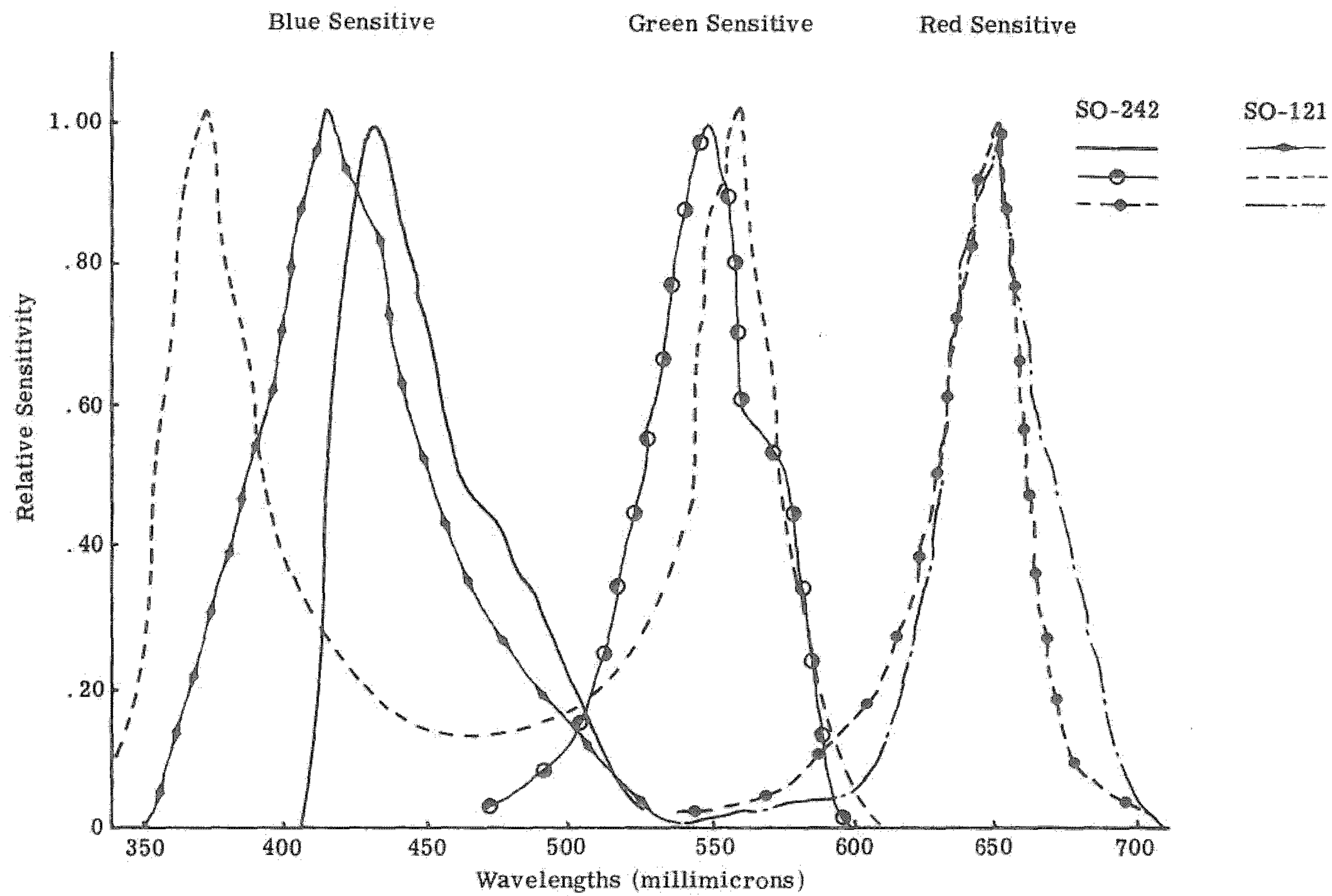
The spectral sensitivity of the individual emulsion layers of SO-242 and SO-121 are compared in Figure 2. Note particularly the sensitivity within the green region of SO-242 and the absence in this emulsion layer of an extended sensitivity within the blue and near ultra-violet region as compared to the green sensitive emulsion layer of SO-121.

1.2 RESOLUTION OF SO-242

SO-242/255 substantially reduced the resolution gap that exists between color and black/white films. Figure 3 illustrates the low contrast (1.7:1) resolving power versus log exposure for the three primary films under discussion. SO-242 is approximately twice as good as SO-121, but still only half as good as 3414/1414. This comparison tends to be misleading, however, as the ultimate resolution achieved on any film is a combination of many factors such as optical performance, smear, haze attenuation, etc. The fundamental characteristics that establish the ultimate resolution of any given camera system, however, is the inter-relationships between the film and optical performance. That is, because films are different by a factor of two does not mean that the camera performance will be different by a factor of two. With the R-5 Lens in the KH-8, for example, MTF/AIM analysis indicates that the best practical resolution with SO-242 and 3414 are 114 and 154 c/mm respectively, a difference of slightly less than 1.5. Thus,

FIGURE 2

SPECTRAL SENSITIVITY OF SO-121 AND SO-242 FILMS



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RESOLVING POWER COMPARISON AT 1.7:1 CONTRAST

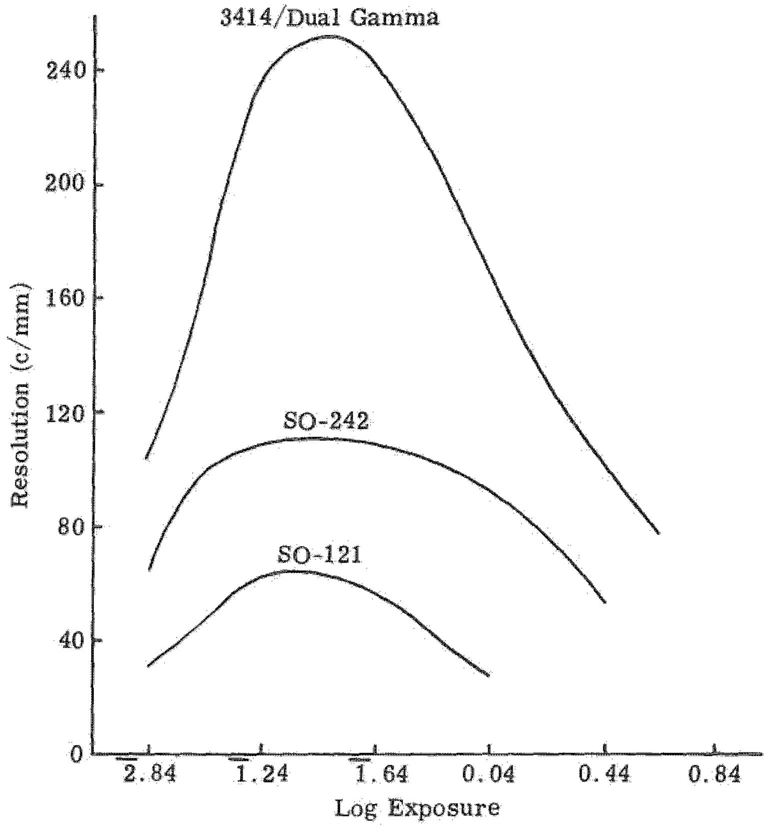

FIGURE 3

the resolutions of the films are not by themselves measures of the differences in performance between color and black/white.

1.3 REFERENCES

Additional data on the characteristics of SO-242/SO-255 can be found in the following documents:

a. FEAT Lab Report, "Technical Data for Camera and Duplicating Films."

b. BIF-008-B-100470-69, "Special Color Status Report," 15 January 1970.

c. TCS-6155/70, "Technical Evaluation of Color Material from Mission 4324-2," April 1970.

d. TCS-20034/70, "Photographic Evaluation Report, Mission 1108; Special Study: SO-242 Evaluation," July 1970.

e. TCS-20360/70, "Color Study Mission 4326-2," September 1970.

f. BYE-106600-70, "Color Photography in the National Reconnaissance Program; Report on Technical Capabilities of the Satellite Cameras to Handle Color Films," 25 March 1970.

APPENDIX II

CAMERA SYSTEM CAPABILITIES

2.1 INTRODUCTION

There are significant differences in the ability of the various camera systems to handle and employ color film. This section summarizes these factors. In particular, it contains discussions of the resolution that can be anticipated with each system and the percentage film loss with increasing amounts of color. The resolution estimates employed herein were arrived at by the use of standard MTF/AIM techniques. While this technique has been routinely applied to the evaluation of black/white films in several camera systems, it has not been used with color films. AIM curve techniques are based fundamentally on the concept of resolving power which has many limitations. The fundamental advantage of a color film, i.e. differentiation between colors, is not the basic purpose of a resolution test. The fact remains, however, that there is no other obvious technique available, and the results achieved with the KH-8 and CORN targets give one confidence in the values reported herein.

Figure 1 illustrates the several "white light" or polychromatic AIM curves generated during the Color Task Force's evaluation. An evaluation was undertaken by three independent photographic laboratories (Itek, Eastman Kodak, and Perkin-Elmer) to determine polychromatic AIM curves for SO-242. This work was coordinated by the Color Task Force. The Film Evaluation Analysis and Test (FEAT) Lab and Itek data tend to be more conservative than the Perkin-Elmer data. However, for the purpose of this study, the Perkin-Elmer data was used for two reasons:

1. The Perkin-Elmer data tends to predict resolution more in line with what has been achieved on the KH-8 missions. For example, the techniques employed herein predicted that Mission 4324-2 could achieve a best color resolution of approximately 16 inches, this included the defocus experienced on that mission. NPIC determined that the best actual resolution from 4324-2 was 18 inches.
2. Perkin-Elmer is generally more consistent in its AIM data than the other two organizations.

It was necessary to devise red layer and green layer AIM curves so that focusing trade-offs could be made. This was done by assuming that SO-242's red layer response was 20% worse than its white light response, and that its green layer response was 20% better. Later empirical testing indicates that these assumptions were reasonable. The AIM curves, adjusted for 2:1 contrast, used in this study are shown in Figure 2.

2.2 KH-8 CAMERA SYSTEM

The R-5 Lens, which will be employed for the first time on Mission 4332, is well color corrected and has the capability of providing excellent resolution color photography. There are two aspects of lens color correction that must be considered; the first is the basic quality as a function of wavelength and the

AIM CURVES FOR SO-242 FROM THREE DIFFERENT LABORATORIES
(HIGH CONTRAST)

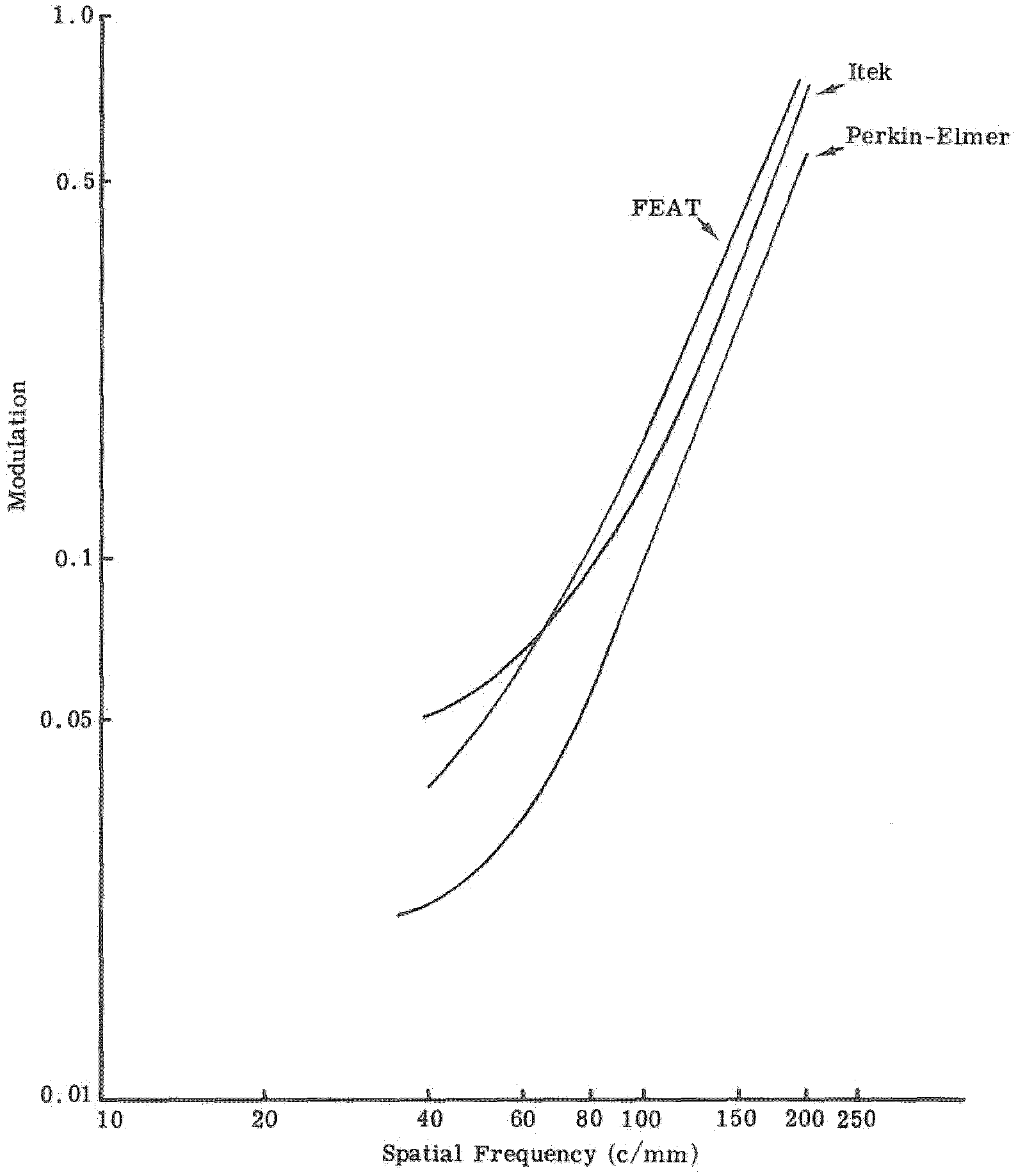

FIGURE 1

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2:1 AIM CURVES FOR SO-242/SO-255

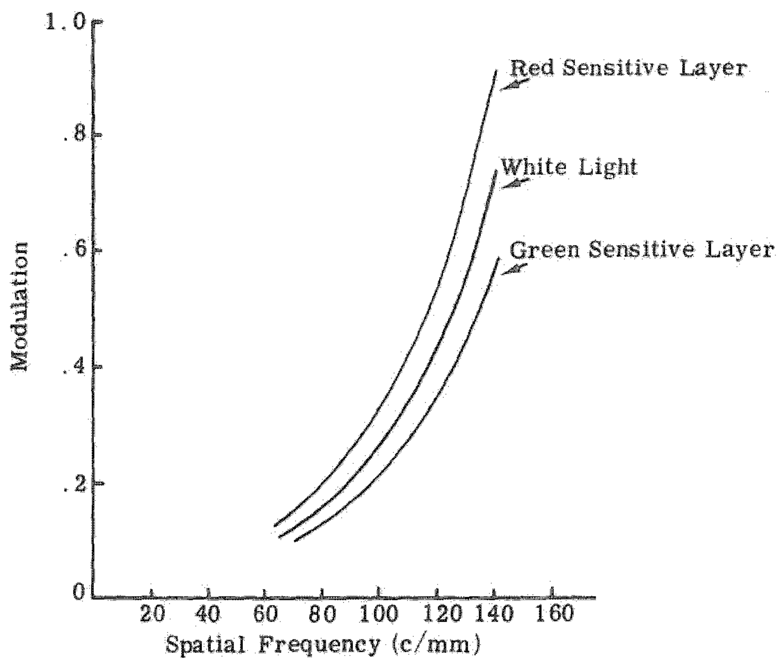


FIGURE 2

second is the longitudinal color, i.e. position of best focus as a function of wavelength. In both regards, the KH-8 Camera System performs well. Figure 3 illustrates the position of best focus for the R-5 Lens with respect to the physical depth of the SO-242 emulsion layer. One can see that the green and blue focus properly while the red is only two microns or so out-of-focus. Figure 4 then shows the actual MTF's for the R-5 Lens when considering the focus conditions illustrated in Figure 2. That is, the green and blue MTF's are best focus while the red MTF is that for an approximate two micron defocus.

Employing these transfer functions and the AIM curves permit the calculation of on-orbit performance. Such estimates are given in Table 1 for SO-242/SO-255 and the normal black/white 1414 Films. These estimates are for a 75 nm altitude, and the "best practical" figures show the results obtained at nadir. The "estimated 90% probable" values have been derived by extrapolation from black/white statistics and represent overall performance when roll and sun angles have been taken into account.

One potential problem that exists with the KH-8 is that it has no film-change detector. If the estimate of film usage is in error, the moment when the color film actually enters the exposure area will be misjudged. In one case, virtually 25% of the color film was wasted due to this problem. Normally, however, not more than fifty feet of film are improperly exposed.

TABLE 1

KH-8B WITH R-5 LENS PERFORMANCE ESTIMATES AT 2:1 TARGET CONTRAST

(ON-AXIS)

	Resolution (c/mm)		Ground Resolved (feet)	
Case	SO-242/255	1414	SO-242/255	1414
Best Practical Polychromatic	114	154	[redacted]	
Best Practical Green Record	123	-		
Best Practical Red Record	109	-		
*Estimated 90% Probable Polychromatic	-	-	≈2.1	≈1.75
*Estimated 90% Probable Green Record	-	-	≈2.0	-
*Estimated 90% Probable Red Record	-	-	≈2.2	-

(b)(1)
(b)(3)

Note: Ground resolved distance values were derived from an altitude of 75 nm.

*Estimated overall performance from black/white performance statistics.

The loss in film footage associated with the use of color film in the KH-8 System is shown in Figure 5.

APPROXIMATE FOCUS CONDITION FOR KH-8B (R-5) LENS
IN SO-242 WHEN FOCUSED FOR GREEN LAYER

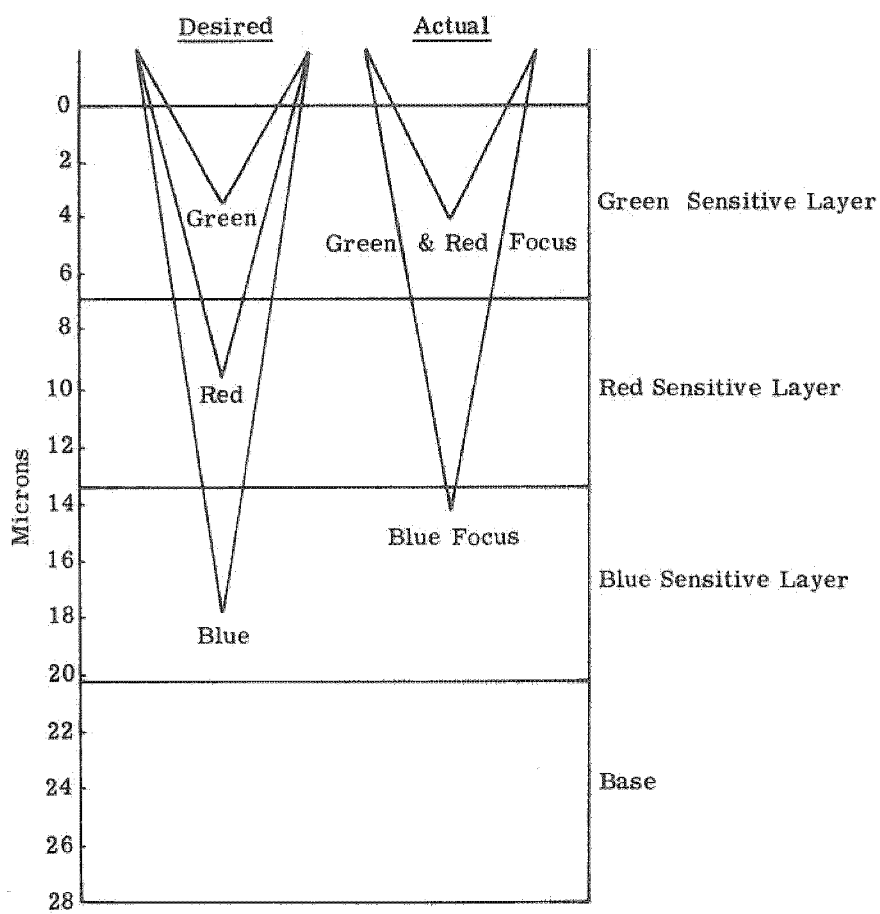
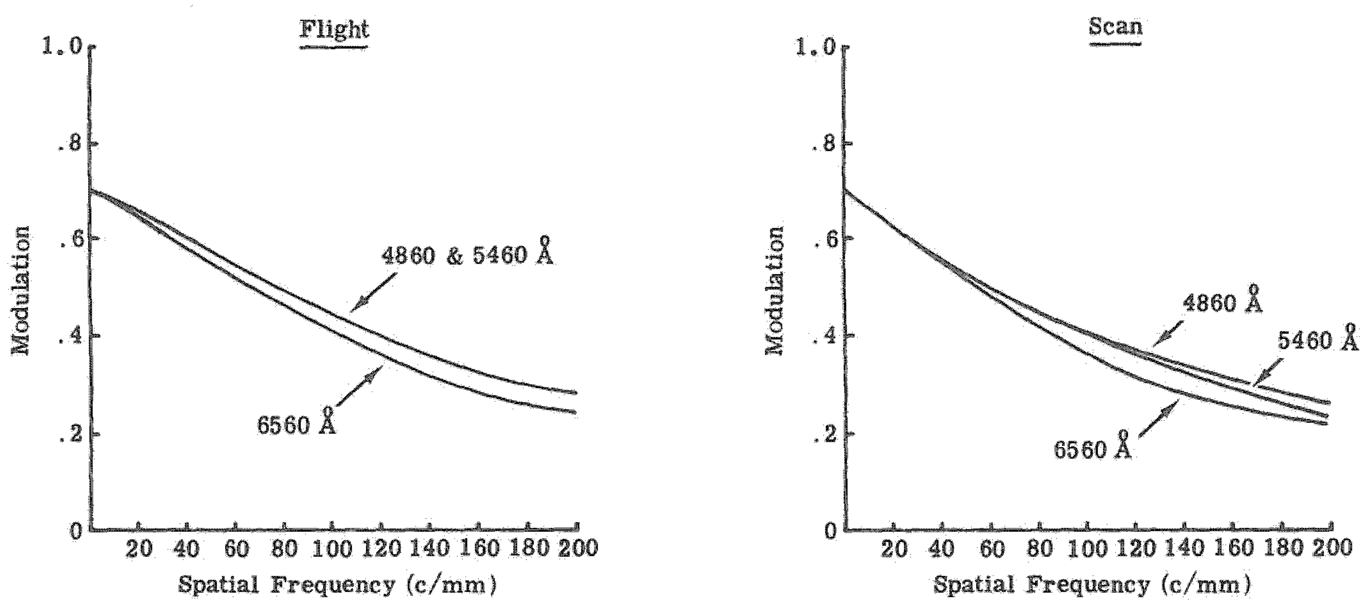


FIGURE 3

FIGURE 4

ACTUAL MTF'S OF KH-8B (R-5) DESIGN LENS IN SO-242 FOCUS POSITIONS
(INCLUDING OQF = 0.7)



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LOSS IN TOTAL FILM VERSUS INCREASING AMOUNTS OF UTB COLOR
(KH-8)

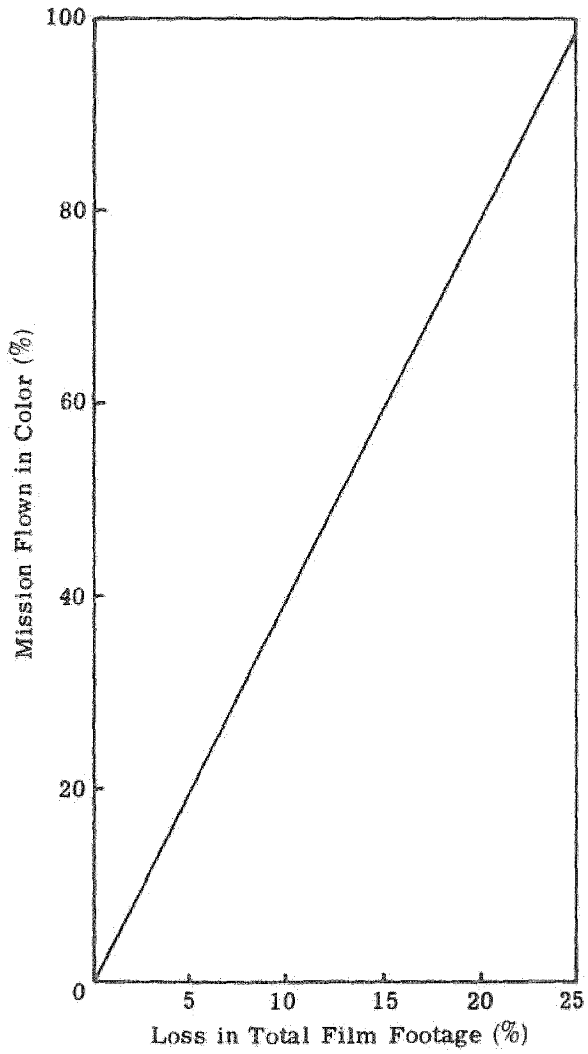


FIGURE 5

2.3 KH-9 CAMERA SYSTEM

The KH-9 Camera System cannot employ thicker color film until the fourth flight vehicle (Mission 1204) due to hardware constraints. The KH-9 lens is basically well color corrected. Improvements have been made in the lens design, which will further improve its color correction. These improvements are being instituted on the seventh flight vehicle. The original KH-9 design did not include an in-flight changeable filter. This fact made the use of color impossible as the normal black/white filter was a Wratten 12 type (minus blue) which is incompatible with SO-242. For this reason, an in-flight changeable filter mechanism is being installed on all flight vehicles starting with Mission 1207. The recent change in the black/white film from SO-380 to 1414, however, has allowed the use of SO-255 on KH-9 earlier than originally planned. The 1414 Film sensitivity in the region normally cut off by the Wratten 12 flight filter is substantially lower. As a result, a wide band filter such as a Wratten 2E or 3 type can be used with the 1414 Film. This will produce essentially the same photographic result as the old film with the Wratten 12 and will provide color balance on the KH-9 imagery similar to that obtained on the good KH-8 missions. This being the case, it was decided to make the minor mechanical adjustments necessary to employ SO-255 on earlier missions. These adjustments in no way endanger the black/white mission. It is interesting to note that the changes made in the lens design to improve color correction for flight seven and up also improved the overall black/white performance.

The focus of the KH-9 lens with respect to the SO-242 color film is shown in Figure 6. The green and red regions are in focus while the blue region is approximately 14 microns out-of-focus. The actual MTF's for the KH-9 lens, for the spectral region of interest, at the SO-242 focus position are shown in Figure 7. As was the case with the KH-8, the overall performance over the spectral region of interest is excellent.

Again, the MTF/AIM techniques can be employed to provide estimates of on-orbit performance. This data is shown, for the KH-9, in Table 2.

The significant advantage the KH-9 System holds over the KH-8 is, of course, that it is a dual camera system obtaining stereo coverage. This means that simultaneous color and high resolution black/white photography can be obtained, producing the best of both media.

The KH-9 Camera System, starting with the seventh vehicle, will incorporate a material change detector so that no loss in effective film utilization will occur.

The loss in film footage with the KH-9 using increasing amounts of color film is shown in Figure 8.

APPROXIMATE FOCUS CONDITION FOR KH-9 OPTICAL BAR
IN SO-242 WHEN FOCUSED FOR GREEN LAYER

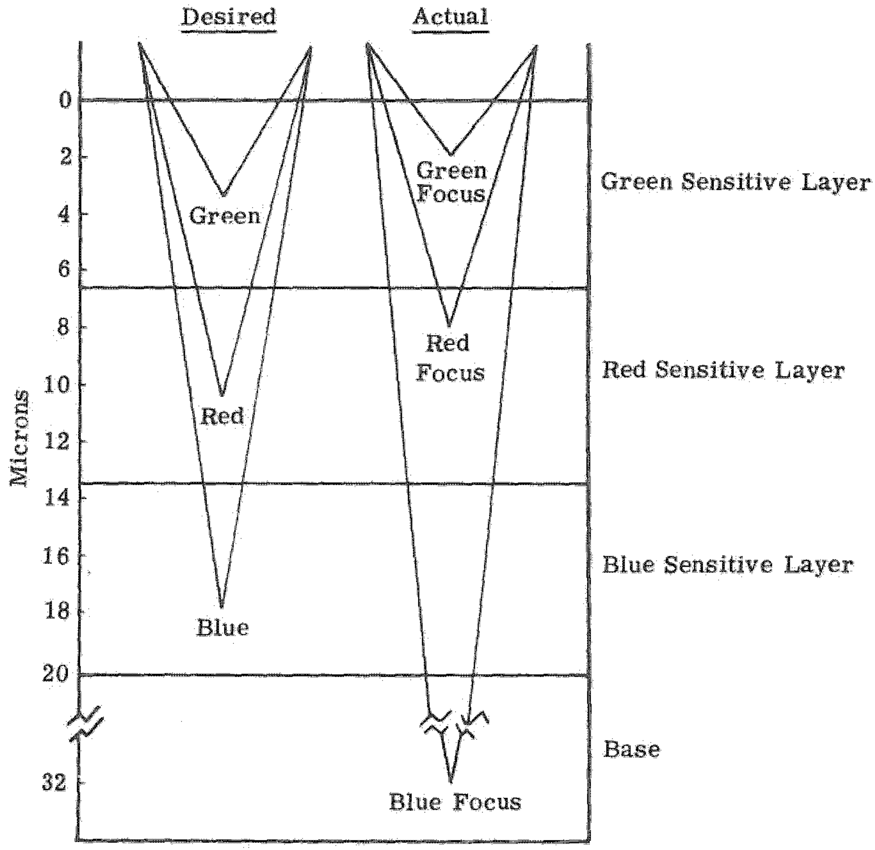
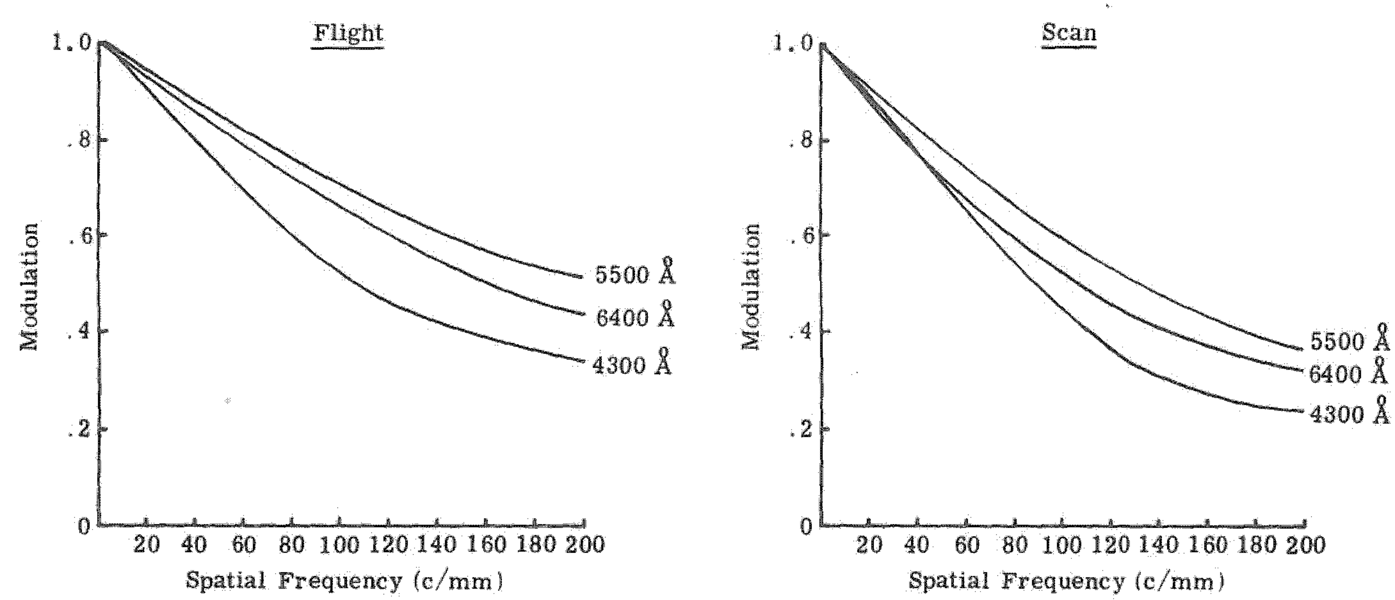


FIGURE 6

FIGURE 7

ACTUAL TRANSFER FUNCTIONS FOR KH-9 OPTICAL BAR AT SO-242 FOCUS
(ON-AXIS)



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LOSS IN TOTAL FILM VERSUS INCREASING AMOUNTS OF UTB COLOR
(KH-9)

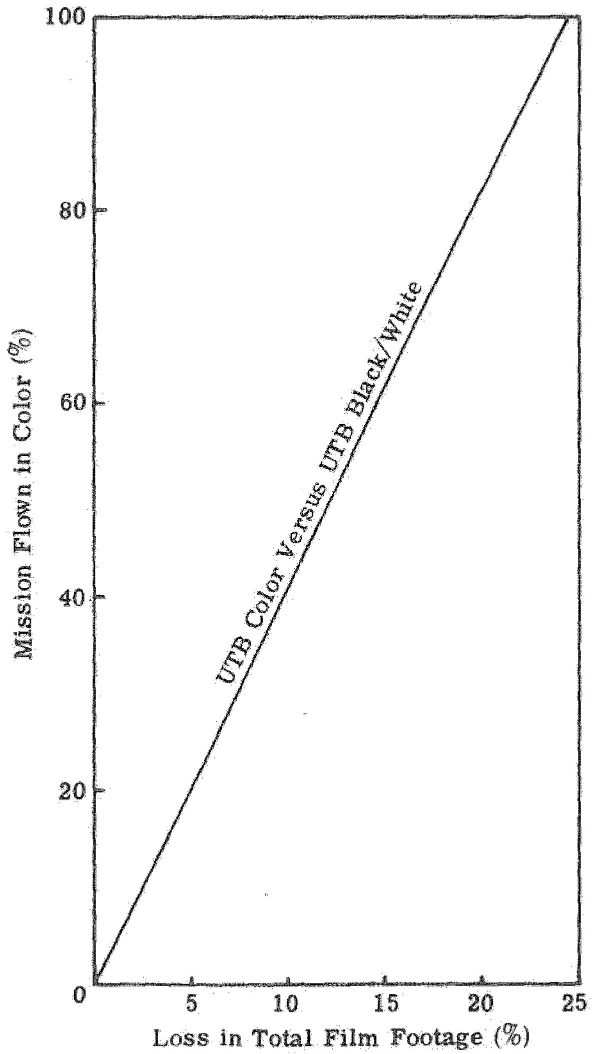


FIGURE 8

TABLE 2

KH-9 PERFORMANCE ESTIMATES AT 2:1 TARGET CONTRAST

(ON-AXIS)

	Resolution (c/mm)		Ground Resolved (feet)	
Case	SO-242/255	1414	SO-242/255	1414
Best Polychromatic	120	180	2.7	1.8
Best Green Record	141	-	2.4	-
*96% Probable Polychromatic	97	140	3.7	2.6
*96% Probable Green Record	120	-	2.7	-

Note: Resolution estimates were made for an 85 nm altitude.

* Approximately equal to the two sigma worst case.

2.4 KH-4B CAMERA SYSTEM

The KH-4b Camera System is poorly color corrected, particularly in the blue region of the spectrum. In the blue, there is virtually no image quality, the MTF being nearly zero. The MTF's for the current third generation Petzval are shown in Figure 9. These MTF's illustrate the performance relative to SO-242 when focused in the normal black and white (3414) focus position. The position of best focus could be changed (to focus for green, for example) which dramatically changes the relationship of the MTF's. Figures 10 and 11 illustrate the differences in the spectral MTF's as a function of position of best focus. These graphs illustrate that the KH-4b lens also possesses significant changes in the position of best focus as a function of wavelength. This drastic difference in quality and focus position as a function of wavelength is not fundamental to the Petzval design, this will be discussed later in this appendix.

Table 3 compares the expected color and black/white performance with the KH-4b System on-axis at an altitude of 85 nm.

As is shown, the color resolution with this system is significantly poorer than the black/white. The poor resolution, at KH-4b scales, makes the use of SO-242 in this system virtually useless for most normal intelligence purposes. The resolution is, however, adequate for other applications, such as economic/geographic intelligence.

TABLE 3

KH-4B PERFORMANCE ESTIMATES AT 2:1 TARGET CONTRAST

(ON-AXIS)

	Resolution (c/mm)		Ground Resolved (feet)	
Case	SO-242	3414	SO-242	3414
Polychromatic	83	180	10	4.6

TABLE 3 (CONT'D)

Case	Resolution (c/mm) SO-242	3414	Ground Resolved (feet) SO-242	3414
Red Layer in Best Focus	111	-	8	-
Green Layer When Lens Focused for Red	23	-	35	-
Red Layer When Lens Focused for Green	26	-	35	-
Green Layer in Best Focus	81	-	10	-

Note: Resolution estimates were made for an 85 nm altitude.

The loss in film footage associated with the use of color film in the KH-4b is shown in Figure 12.

2.5 AIRBORNE SYSTEMS

Similar types of detailed analysis have not been accomplished with the airborne systems used in national programs. It can be said, however, that in general the sensors are poorly color corrected, although most can physically employ color film. The severity of the lack of color correction depends on the airborne camera utilized. Also, many of these programs do not achieve the high resolution in cycles per millimeter that the satellite cameras are capable of; therefore, the difference between color and black/white is lessened.

This lack of good color correction with the airborne platforms has caused difficulties with domestic testing as the quality of the color is not as good as it could be and the relationship between the color and black/white coverage is distorted. It was this factor that led the Color Task Force to recommend that a color corrected (Apochromat) Petzval lens be fabricated and installed in a 112B Camera.

Figure 13 illustrates the design MTF's for the Apochromat Petzval. The design is probably the best that can be done with a Petzval type design, and this lens will provide an acceptable vehicle for U-2 domestic color film testing. While the blue response of this lens is still low, it is significantly better than that of the current lens design. In fact, this response is probably all that is needed, given the poor quality of the blue layer. The significant improvement in this design is the matching of the green and red MTF's. This should allow for significantly improved color performance by allowing both the red and green images to be in good focus simultaneously.

2.6 REFERENCES

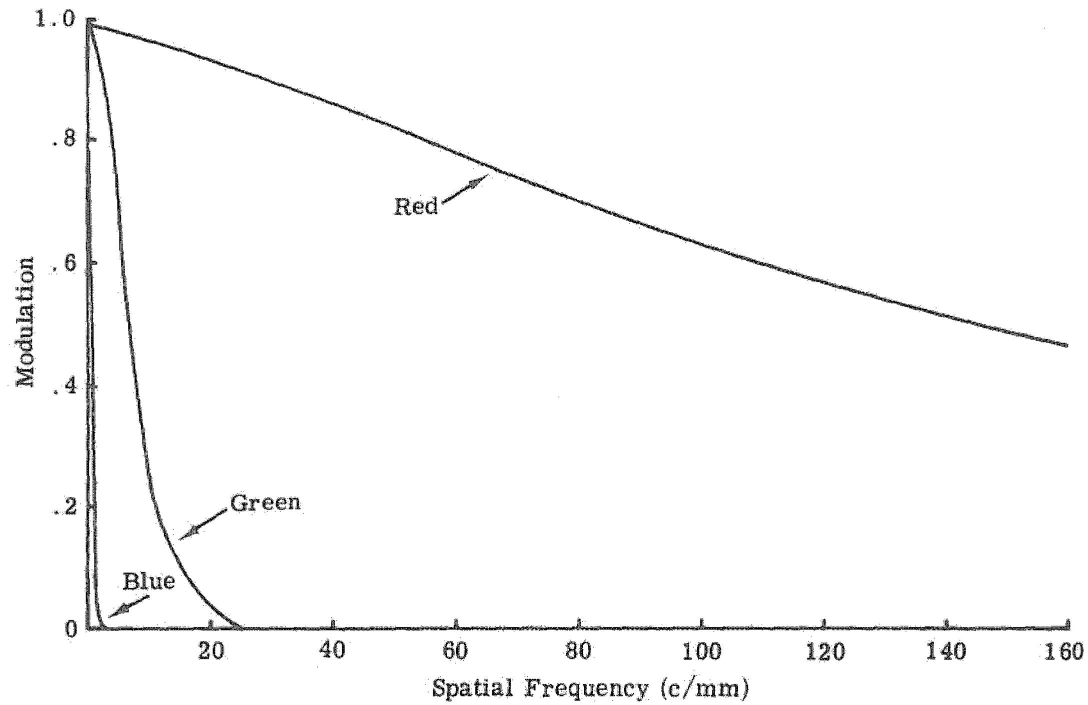
The following documents are references for this appendix:

a. BYE-106600-70, "Color Photography in the National Reconnaissance Program, Report on Technical Capabilities of the Satellite Cameras to Handle Color Films," 25 March 1970.

b. HEX-10470-69, "Color Utilization Study," TR-69-622, 2 October 1969.

FIGURE 9

MTF'S FOR THIRD GENERATION PETZVAL LENSES AS FUNCTION OF THE THREE SENSITIVITY LAYERS OF SO-242 FOCUSED FOR 3414 AND CONVENTIONAL HAZE CUTTING FILTERS



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BEST POSSIBLE PERFORMANCE ESTIMATES FOR KH-4B
THIRD GENERATION LENS/SO-242 FOCUSED FOR RED LAYER
(ON-AXIS)

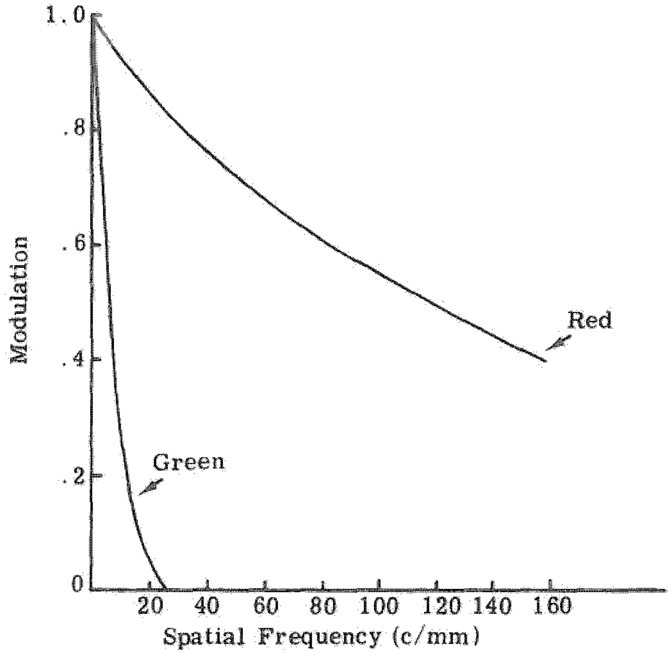

FIGURE 10

BEST POSSIBLE PERFORMANCE ESTIMATES FOR KH-4B
THIRD GENERATION LENS/SO-242 FOCUSED FOR GREEN LAYER
(ON-AXIS)

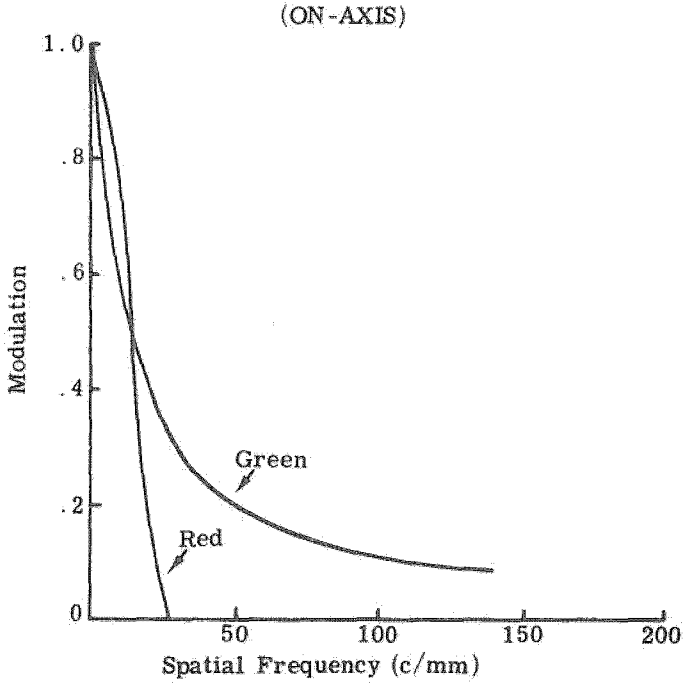

FIGURE 11

LOSS IN TOTAL FILM VERSUS INCREASING AMOUNTS OF STB COLOR
(KH-4B)

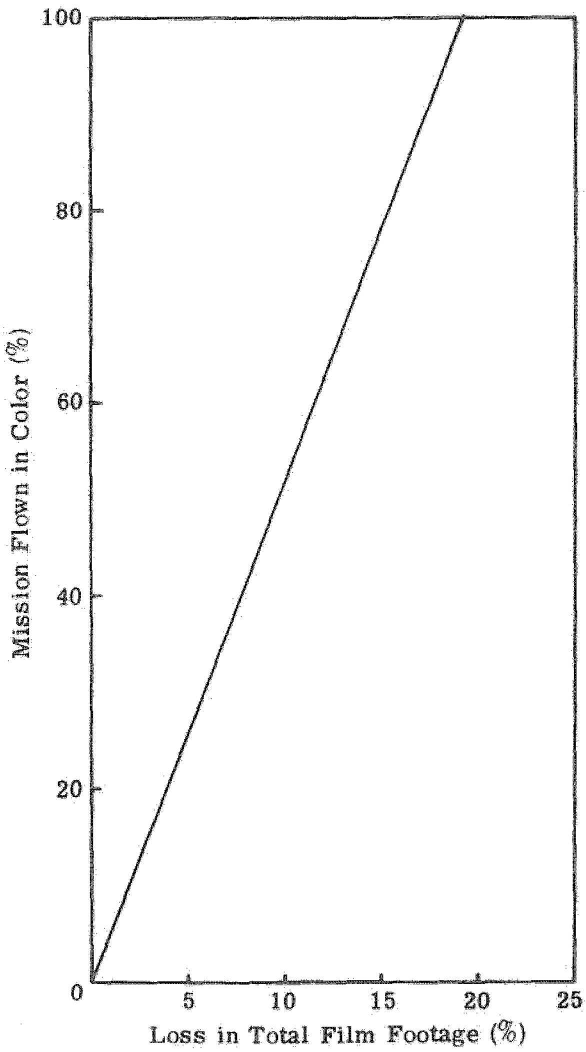

FIGURE 12

MTF'S FOR F/3.5, 24" APOCHROMAT OPTIMIZED FOR 3404
(MTF'S FOR THREE LAYERS WEIGHTED FOR SO-242 SENSITIVITY)

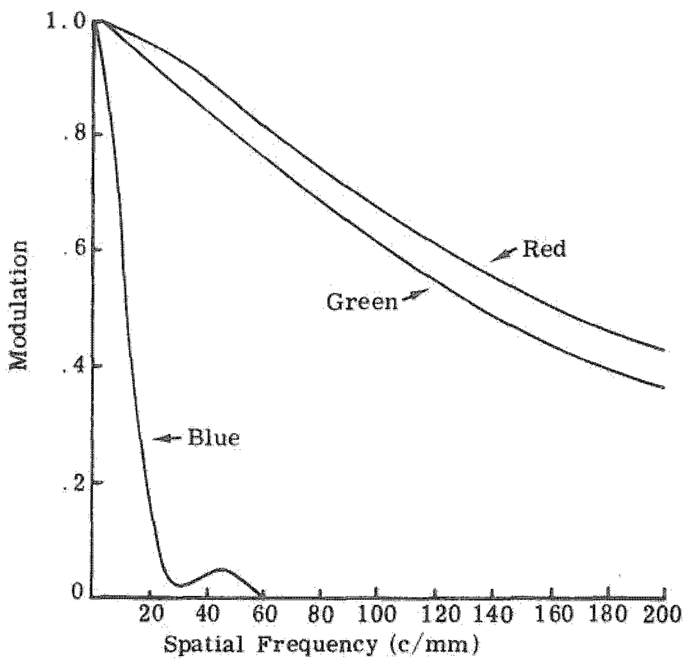

FIGURE 13

APPENDIX III

COLLECTION PROGRAM

Several collection efforts were initiated by the Color Task Force to gather the photography needed to enable color versus black/white film evaluations. This section discusses these collection efforts. The Color Task Force collection program is summarized in the following table:

TABLE 1

SUMMARY OF COLOR TASK FORCE COLLECTION PROGRAM

Mission	System	Launch Date	Color Acquisition Date(s)
4324	KH-8	23 Oct 69	7 Nov 69
4325	KH-8	14 Jan 70	-2 Not Recovered
4326	KH-8	15 Apr 70	29 Apr 70
4327	KH-8	25 Jun 70	-2 Not Recovered
4328	KH-8	18 Aug 70	3 Sep 70
4329	KH-8	23 Oct 70	10 Nov 70
1108	KH-4b	4 Dec 69	20/21 Dec 69
*GT-69-408	112B		4 Nov 69
*GT-69-437	112B		14 Nov 69
*GT-69-462	112B		3 Dec 69
*GT-69-474	112B		17 Dec 69
*GT-69-480	112B		23 Dec 69
*GT-70-019	112B		23 Jan 70
*GT-70-027	112B		29 Jan 70
*GT-70-036	112B		5 Feb 70
*GT-70-149	112B		22 Apr 70
*GT-70-157	112B		29 Apr 70
*GT-70-160	112B		1 May 70
*GT-70-164	112B		5 May 70
*GT-70-199	112B		27 May 70
*GT-70-214	112B		9 Jun 70
*GT-70-391	IRIS II		29 Dec 70
*GT-71-041	IRIS II		11 Feb 71

TABLE 1 (CONT'D)

Mission	System	Color Acquisition Date(s)
[redacted]		

(b)(1)
(b)(3)

* U-2 Aircraft

[redacted]

(b)(1)
(b)(3)

3.1 KH-8 COLLECTION

Consultations between COMIREX and the National Reconnaissance Office (NRO) have led to the inclusion of one day's acquisition of color on several KH-8 missions. To date, six such missions have flown with either SO-242 or SO-255, these missions are 4324-2 through 4329-2. The KH-8 collection program, while the most significant, also has been plagued with numerous problems, some related to color, others not. Missions 4325-2 and 4327-2 buckets were not recovered. Severe technical problems significantly limited the color quality of Missions 4326-2 and 4328-2. These problems will be discussed in the next appendix. Because of filter problems, color was not flown on Missions 4330 and 4331. To date, Missions 4324-2 and 4329-2 remain the only two which can be considered to have returned imagery typical of what would normally be expected from the SO-242 Film. These two missions provided approximately 1,000 feet of exposed color film, but only about 500 feet are useful due to cloud cover. This is a very limited amount of film and clearly makes it difficult to arrive at statistically valid statements about the value of color film versus black/white. Furthermore, these two color missions were both flown in November, a poor time of year for demonstrating the value of color coverage.

3.2 KH-4B COLLECTION

One color mission (1108) was flown with the KH-4b System. Approximately 800 feet of SO-242 was included at the end of this mission on the aft-looking camera. The resolution of this color photography was such that additional collection with the KH-4b was not deemed appropriate.

3.3 U-2 DOMESTIC COLLECTION PROGRAM

Sixteen U-2 flights have been flown under the Red Dot Program in support of ground truth collection efforts. The installations were those that photointerpreters and analysts felt were domestic analogues and desirable to have color ground truth on. They are listed in Table 2. Not all of these targets have been covered. The missions flown to date have been catalogued and an index published for the intelligence community.

(b)(1)
(b)(3)

Page Denied

(b)(1)
(b)(3)

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TABLE 2 (CONT'D)

[redacted]

(b)(1)
(b)(3)

3.5 ADEQUACY OF COVERAGE

The adequacy of the color coverage as a statistical data base is open to question. A few target categories have not been successfully covered while others require additional collection to enable definite conclusions. Table 3 shows the current status of fair-to-excellent color coverage with the KH-8 System. In general, the current satellite data base is insufficient to allow the information losses and gains associated with color to be adequately identified and evaluated. The present coverage deficiency is not limited to those target categories unsuccessfully photographed during the KH-8 missions. There is also a need for coverage of every category to be widely distributed with respect to season of the year, lighting and atmospheric conditions, terrain characteristics, and obliquity. Once this body of information is available, the organizations producing finished intelligence will be able to undertake the review needed to determine if a net information gain is provided by color photography.

TABLE 3

FAIR-TO-EXCELLENT COLOR COVERAGE BY
NATIONAL TASKING PLAN (NTP) TARGET CATEGORY

	4324 (SO-242)	4326 (SO-242)	4328 (SO-255)	4329 (SO-255)	Total
[redacted]	13	49	117	21	200
	-	-	2	-	2
	1	2	6	4	13
	5	3	9	19	36

(b)(1)
(b)(3)

TABLE 3 (CONT'D)

	4324 (SO-242)	4326 (SO-242)	4328 (SO-255)	4329 (SO-255)	Totals
[redacted]	29	31	36	33	129
	7	3	11	11	32
	49	47	45	45	186
	7	1	2	1	11
	4	8	24	7	43
	4	5	-	1	10
	-	1	4	2	7
	4	1	2	1	8
	1	1	3	1	6
	9	1	11	11	32
	-	7	2	1	10
	-	4	8	1	13
	-	-	-	1	1
	1	-	1	-	2
	-	-	-	-	0
	-	-	-	-	0
	-	-	-	-	0
	-	-	-	2	2
Totals	134	164	283	162	743

(b)(1)
(b)(3)

3.6 REFERENCES

a. NPIC/R-31/70, Mission Coverage Plots, Red Dot (CTF), 4 November 1969 through 5 February 1970; May 1970.

b. NPIC/R-2/71, Mission Coverage Plots, Red Dot (CTF), 22 April through 9 June 1970; February 1971.

c. [redacted]

(b)(1)
(b)(3)

APPENDIX IV

TECHNICAL EVALUATION OF MISSIONS

The Color Task Force requested NPIC to undertake a technical evaluation of each satellite color mission flown. This section summarizes the results of those evaluations.

4.1 MISSION 4324-2

Except for the variable defocus condition, Mission 4324-2 produced good quality color photography. While the resolution was not the best achieved of the several flights, the color balance was equal to the best yet achieved from the KH-8 missions.

Only one CORN target was recorded on the SO-242. The target was displayed at Columbia, Missouri. The camera was 2.0 mils out-of-focus at the time and better resolution was evident elsewhere in the frame. This same target array was acquired on SO-380. A comparison of the target readings follows:

	Resolution (inches)	
CORN Target Location	In-Track	Across-Track
SO-242 (Rev 204, Frame 005)	24.0	34.0
SO-380 (Rev 188, Frame 006)	12.0	17.1

NPIC noted that poor resolution and lack of detail in areas of cloud shadow were the photointerpreters' major concern with color. This was probably due to the fact that the photointerpreters had to work from poor quality reproductions.

To aid in the exploitation and evaluation of SO-242, the photointerpreters were given an opportunity to work from both the duplicate and original material. It was determined that for most of the targets photographed, the resolution of the color reproduction was adequate to answer normal requirements; in all cases, the information of the color original was preferred over that of the color reproduction.

The analysis of some targets was affected by the poorer resolution. These were mostly ground force facilities where fine detail is needed. Color, especially in the reproduction, tends to have poorer edge sharpness than black/white, causing vehicles and equipment to blend together, fence lines to fade into the shadows, and other small but significant objects to be lost. The causes of and solutions for these problems led to the development of special black/white reproductions from the various emulsions of the color material.

In summary, the NPIC report on 4324 color concluded that:

> *1. The test, though limited in quantity, provided sufficient material to determine that there may well be a need for color in the NRP.*

2. Color complements and can be used in conjunction with the black and white imagery presently used.

3. The SO-242 emulsion is compatible with the present camera systems.

4. The original color provides resolutions and color fidelity adequate to respond to existing requirements and meets the requirements and the specifications predicted by the (film) manufacturer.

5. Color provides unique and auxiliary information not available in black and white imagery.

6. Manipulation of the original material can provide B/W reproductions comparable to reproductions presently provided from high resolution B/W acquisition materials.

4.2 MISSION 4326-2

The color photography from Mission 4326-2 was adversely affected by three technical problems: (a) underexposure, (b) a slow blue sensitive emulsion layer in the SO-242 flown, and (c) a chemistry modification to correct for (b) which raised the contrast of the green sensitive emulsion layer.

Several CORN targets were acquired. The resolution readings of these targets are listed in Table 1.

TABLE 1

CORN TARGET DATA FROM SO-242 ORIGINAL

(MISSION 4326-2)

Rev	Frame	Roll Angle (degrees)	Resolution (inches) In-Track	Resolution (inches) Across-Track	Platen Position (mils)
209	036	-3.50	24.0	24.0	+1.7
209	037	-3.50	30.2	54.0	+1.7
209	038	+10.50	21.3	-	+0.7
209	039	+10.50	21.3	-	+0.7
209	040	+0.70	68.0	24.0	-0.4
209	041	+1.05	21.3	21.3	-0.4
209	042	+2.45	19.0	24.0	-1.4
209	043	+2.80	19.0	27.0	-1.4

Note: It was determined that the best focus position for the black/white portion of this mission was at -1.5 mils.

This particular emulsion batch of SO-242 color material, although of the same type used in previous missions, was considered "borderline" because of a lower than normal sensitivity in the blue record (yellow dye) layer. The spectral sensitivity and overall photographic speed were the same as those recorded for the emulsion used on Mission 4324-2. To increase the effective speed in the blue record layer, a modification in processing was employed. However, this processing change also increased the contrast in the green record (magenta dye) layer. Analysis of the five-step gray scale target shows the problems. Traces were made across the gray scale (recorded on the original color film) using a ten-micron aperture on the Mann Trichromatic Microdensitometer. When the images are compared with similar traces made from the color flown on Mission 4324-2, the following differences were apparent:

a. The density of the blue record layer on Mission 4326-2 is greater than that on Mission 4324-2, indicating the slower speed of this layer. The modification in the process only partially corrected the speed problem.

b. The contrast of the green record layer was higher on Mission 4326-2 than Mission 4324-2.

c. The contrast of the green record layer is also higher than either the red or blue layers. This high contrast has been identified as the cause for the poor quality of the black/white reproductions that were to provide high resolution information.

d. The contrast and density of the red record (cyan) layer show only a slight change from Mission 4324-2. However, this slight change increased the shoulder densities.

4.2.1 Color Balance

The color material from Mission 4324-2 contains an overall yellow cast. This was compensated for in the reproduction cycle. The overall yellow appearance of Mission 4326-2 is much more severe and is the result of the slow blue speed of this particular emulsion batch. The changes made in the process to correct for this caused the slopes of the characteristic curves to change, producing yellow-green highlights and magenta shadows. The color imbalance is further compounded by the limitation of the type SO-360 reproduction stock. If corrections were made to balance the highlight areas, the shadow areas shifted more toward magenta; if corrections were made to balance the shadow areas, the highlights shifted toward yellow-green. Consequently, very few frames contained good color balance, although good color balanced reproductions could be made of almost any individual target acquired.

4.2.2 Exposure

Another technical problem encountered on this mission was incorrect exposure. Approximately 80% of the original material was underexposed. Many of these frames were acquired at low solar elevations using the widest slit available. The remaining underexposed frames were apparently caused by an error in programming. Because of the narrow latitude of color film, this error caused a noticeable loss in system resolution (lines/mm). With correct exposure, the film is capable of resolving approximately 110 lines/mm, see Figure 1. On this mission, the best resolution was approximately 75 lines/mm.

There is a second effect on quality which is somewhat separate from the resolution question, it is the one that relates to the increase in graininess with underexposure. To understand this phenomena, it is necessary to understand the basics of color development. Figure 2 illustrates these basics. The steps are essentially:

a. Exposure - Same process as with black/white film.

b. First Development - Essentially the same as black/white. Here, the exposed image is developed to silver. A negative image results.

c. Color Development - The color developer develops the remaining unexposed positive image. Both silver and dye positive images are formed during this process.

d. Bleach - The bleach removes all the silver, leaving only the positive dye image.

Exposure affects this process as follows. All silver halide emulsions are composed of light-sensitive silver halide crystals of different sizes, the large crystals being faster than the smaller ones. With a reversal color film, this is an advantage; since the larger crystals are exposed first, the actual positive image is formed from the smaller, fine-grain crystals. Underexposure, therefore, does not eliminate all the larger crystals from the positive image formation process. The result is the dye modules formed will be larger and hence the image appears grainy. This is exactly what NPIC reported relative to this exposure/grain size relationship. While it is difficult to quantitatively substantiate, the above factors in all likelihood combined to produce a loss in resolution of at least 20% over what could have been achieved with proper exposure of the SO-242.

4.2.3 Duplication

The above problems multiplied in duplication. The black/white "green record" duplicates were excessively high in contrast. This high contrast was directly related to the high contrast of the green sensitive layer of the original SO-242 Film. In order to achieve timely deliveries, the film processing facility used a standardized black/white printing and processing system rather than the special low gamma internegative technique that should have been used to correct for the high green contrast.

The combination of underexposure, varying exposure, and high contrast made the color duplication problem difficult. The variability within a pass was so severe that in most instances even dual printing did not correct more than a small percentage of the frames. With the coverage obtained on one pass, the processor had to print at 15 different levels to properly duplicate all frames. Because of this difficulty and the fact that none of the duplicates distributed received this treatment, most of the SO-360 color dupes were of very poor quality. They tended to be blue in color balance, with the balance varying between yellow-green highlights (snow) to blue-magenta shadows in most frames.

RESOLUTION VERSUS LOG EXPOSURE OF SO-242 AT 1.7:1 CONTRAST

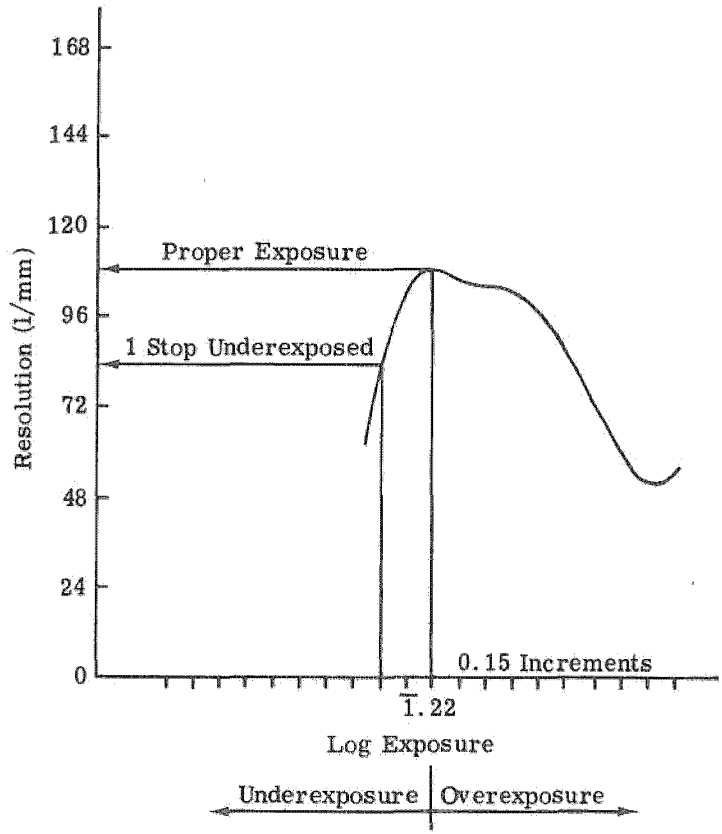

FIGURE 1

BASICS OF COLOR DEVELOPMENT

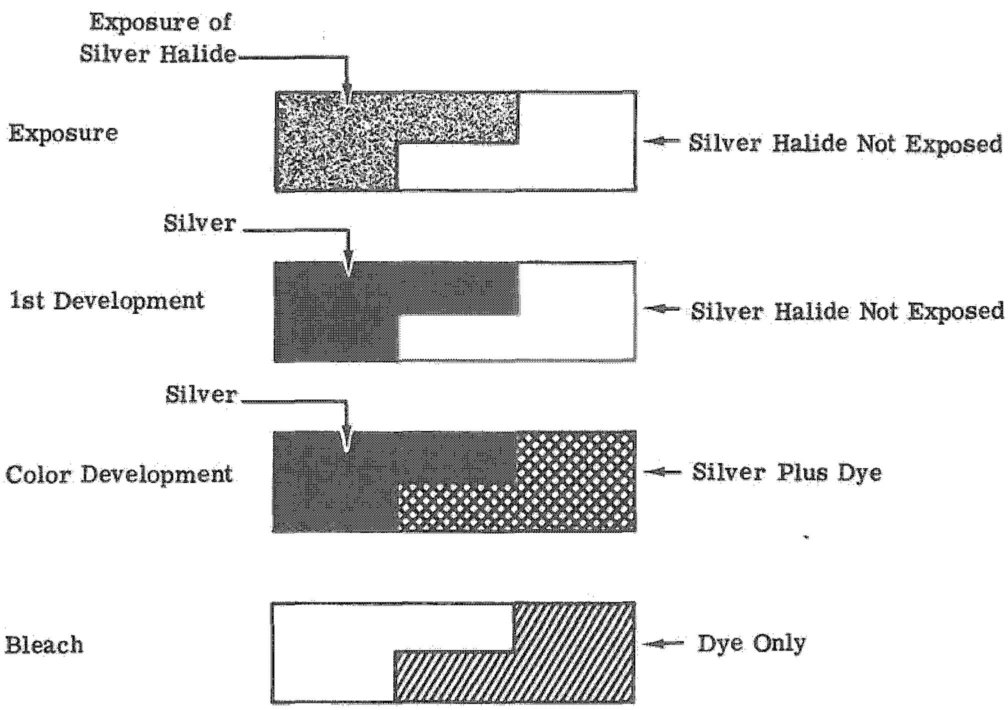

FIGURE 2

4.3 MISSION 4328-2

Mission 4328-2 was the first mission to employ SO-255, the UTB counterpart to SO-242. This mission also suffered from technical problems; however, these had little to do with the color film per se, but rather were the result of the use of a "minus red" filter. This filter essentially was employed to cut off the far red energy (past 685 millimicrons) in order to slightly improve black/white resolution. It affected color balance, however, as it reduced the exposure of the red layer. Before the mission, consideration was given to the effect of the filter on the color photography and, in fact, whether or not the SO-255 should be flown.[1] At the time, it was concluded that:

a. The resolution of the color film would not be hurt by the filter.

b. While the color balance of the original would be affected, it appeared that good quality color duplicates could be made.

The original SO-255 is very green, much more so than was originally envisioned. This is due to (a) the minus red filter cut further into the red than anticipated---it is highly likely that the minus red filter flown had different characteristics from the sample originally tested prior to flight, and (b) an inability to account for inter-image effects when the original estimates of color quality were made.

The estimate that the minus red filter would not affect the resolution of the SO-255 was correct, however, the color balance was seriously impaired, making the SO-255 of little value for color exploitation.

The color portion of the mission was also affected by other problems. Approximately 24% of the color record was severely underexposed, apparently due to the fact that it was acquired at sun angles of less than ten degrees; and the slits to give correct exposure were not available. Because of these factors, only about 19% of the SO-255 frames were considered acceptable.

4.4 MISSION 4329-2

The resolution of the SO-255 color on this mission was the best acquired from this camera system to date. A ground resolution of approximately 16 inches, 104 c/mm, was obtained on one of the CORN target displays, see Table 2. The best previous resolution was acquired on Mission 4326-2, which provided approximately 19 inches of ground resolution.

[1] It should be noted that this filter is also on Missions 4330 and 4331 and resulted in a decision by the Color Task Force not to employ color film on those missions.

TABLE 2

CORN TARGET DATA FROM SO-255 ORIGINAL

(MISSION 4329-2)

Rev	Frame	Roll Angle (degrees)	Resolution (inches) In-Track	Resolution (inches) Across-Track	Platen Position (mils)
273	009	+0.35	18	20	+2.0
273	010	+0.70	19	21	+2.0
273	011	0.00	17	19	+0.9
273	012	+0.35	18	22	+0.9
273	013	+0.70	16.5	25	0.0
273	014	+1.05	19	25	0.0
273	015	-1.75	28	25	-1.0
273	016	-1.05	21	21	-1.0

Note: It was determined that the best focus position for this portion of the mission was at +1.5 mils.

Color balance was not a serious problem on Mission 4329-2. The original exhibits an overall yellow cast due to the Wratten 4 Filter in the camera optics, but this imbalance was corrected in the reproduction process. Exposure for most frames was adequate; however, a small number were acquired at low solar elevations and were underexposed.

The good quality imagery exhibited by the CORN target frames is not representative of all the color. Some frames were acquired at high altitudes (maximum of 161 nm) and are, therefore, degraded by scale.

Figures 3 and 4 are examples of the good imagery obtained on this mission.

4.5 MISSION 1108-2

While collection has been concentrated on the KH-8, one test was run on the KH-4b (Mission 1108-2). The aft-looking camera of this mission contained 811 feet of SO-242. This film was flown both to (a) evaluate the performance characteristics of SO-242 with the KH-4b System, and (b) to satisfy a specific intelligence requirement. The color was exposed during acquisitions from Frames 028, Pass D242 through Frame 002, Pass D274 (end of the mission).

The major analysis effort at NPIC on the SO-242 of Mission 1108-2 was for its use in first phase readout.

The photointerpreters reported that the overwhelming disadvantage of SO-242 in the KH-4b System was the severe loss in resolution as compared to the black/white material; planes identified on black/white could not be detected on color, small villages present on the black/white were not detectable on the color, and mountain peaks appearing jagged and distinct on the black/white were rounded and smooth on the color. Numerous instances where items of interest that normally are detectable on the black/white were

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not detectable on the color; for example, tent foundations, aircraft, missiles, missile facilities, fences, tracks, roads, tanks, and pieces of armament.

The quality of the SO-242 in Mission 1108 was superior, however, to either of the two missions flown using SO-121 Film. The estimated ground resolution of the best color imagery was 12 to 15 feet. This is commensurate with what the calculations suggest would be obtained.

NPIC concluded that:

> *The primary constraint on using SO-242 in this system is the incompatibility between the intelligence community requirements and the spatial resolution afforded by SO-242 at this scale.*
>
> *The difference in ground resolution between the color and black/white material is approximately 2:1 in favor of the black/white.*
>
> *The current color reproduction material is unsatisfactory because of its loss in quality as compared to the original.*
>
> *Except for its stereo contribution, the color material was of no apparent value to first or second phase analysis.*
>
> *Color photography as provided by this system is expected to contribute most to regional, agricultural, and geological studies.*

The last conclusion made by NPIC prompted the undertaking of a specific study aimed at demonstrating the potential of the KH-4b for geologic studies. This report is listed as reference F to this appendix. The report points out that the value of color photography for photogeologic mapping cannot be overstated. It noted the following advantages of color over black/white:

a. Facilitates differentiating between rock units.

b. Allows for more accurate tracing of individual sedimentary beds.

c. Provides more definitive clues as to exact nature of lithology (rock type), and hence is far more valuable in areas of limited ground truth.

d. Allows for better signature identification of specific formations.

e. Reveals oxidation halos and discoloration zones indicative of possible mineralization.

The report further points out that while the loss in resolution is clearly unacceptable for strategic intelligence purposes, that for geologic analysis this loss is insignificant when compared to the interpretive value gained by color.

4.6 SYNOPSIS OF TECHNICAL EVALUATIONS

The results of the various technical evaluations can be summarized as follows:

a. Resolution of the SO-242/SO-255 and its reproduction films and processes are the biggest problems.

b. Color film appears to be, in many ways, more sensitive to degrading effects than is black/white film.

c. The KH-8 Camera System has the capability of providing very good quality (resolution and balance) color photography. The results achieved tend to confirm the predictions and analysis reported in Appendix II.

d. The KH-4b Camera System provides color coverage of a quality sufficient for many economic/geologic tasks.

Throughout the technical evaluations, statements were made that the color film was degraded due to scale, poor exposure, improper filters, haze, etc., suggesting that color is more sensitive to these influences than is black/white. The fact is that nearly any factor that degrades color performance will also degrade black/white performance. The one known exception to this is filtration. Minor changes in filtration by black/white standards can have significant effects on color balance.

The two significant areas for concern are the effects of exposure and haze on the color as compared to the black/white.

4.6.1 Loss in Quality Due to Poor Exposure

There are two effects on quality due to poor exposure: (a) a loss in spatial resolution, and (b) a loss in tonal rendition.

This loss in resolution can be addressed directly by comparing the resolution versus log exposure curves for both color and black/white. Such a comparison is made in Figure 5. The figure shows the peak resolution of each film and the resolution for a ±1 stop (100%) under and overexposure. Table 3 summarizes the results.

TABLE 3

RESOLUTION

	SO-242/SO-255		1414	
Exposure Setting	Resolution (c/mm)	Loss	Resolution (c/mm)	Loss
Peak	111	-	255	-
+1 Stop	109	2%	224	15%
-1 Stop	86	20%	204	20%

This table indicates that for overexposure the black/white loses substantially more resolution than the color, while for underexposure the losses are about equal. The fact is, however, that the black/white peak is higher, so losses in spatial resolution are not as severe for intelligence purposes even though they are greater in a percentage sense.

COMPARISON OF RESOLUTION LOSSES
WITH OVER/UNDEREXPOSURE AT 1.7:1 CONTRAST

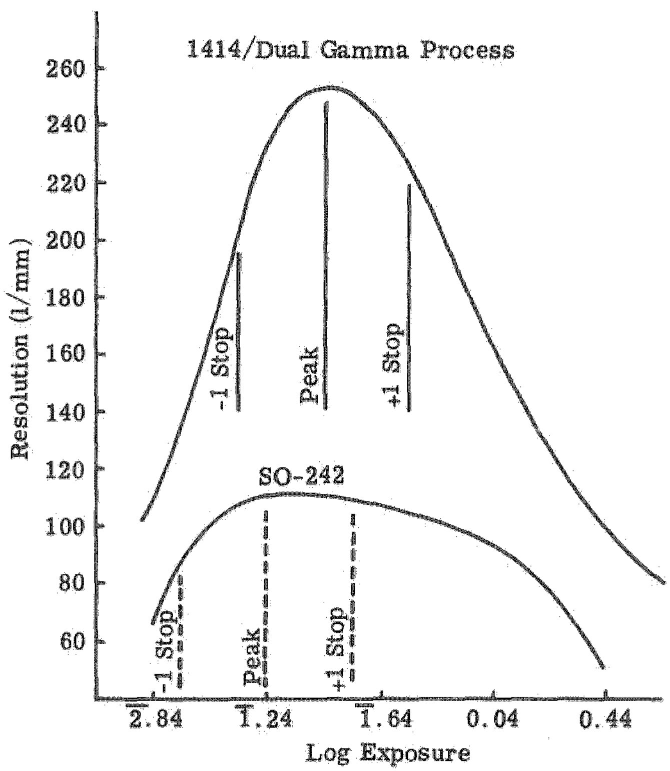


FIGURE 5

For example, while resolution does not change greatly with one stop overexposure, color balance does. The fact that a photograph was overexposed, therefore, is more readily apparent with color even though the effect may be less serious than a comparable change in black/white exposure. This is due to two facts (a) at present, the exposure latitude of color is less than that possessed by black/white, and (b) the gamma of the color is significantly higher than black/white.

To illustrate the point, assume a scene of 4:1 contrast. If this was properly exposed on SO-242, it would produce densities in the green record of approximately 0.8 Dmin and 2.2 Dmax or a ΔD of 1.4. If overexposed by one stop, these densities would become 0.5 Dmin and 1.5 Dmax or a ΔD of 1.0 versus the original 1.4, a significant loss in reproduced contrast. On 1414, however, the same scene, if properly exposed, would be reproduced at densities of 0.3 Dmin and 1.3 Dmax for a ΔD of 1.0. For the one stop overexposure case, the 1414 Dmin would be 0.8 and the Dmax 1.7 or a ΔD of 0.9, virtually no change in contrast. It is not this relative change in contrast that is so noticeable, but the resultant change in color balance since the D-log-E curves for the three color film layers cannot be perfectly matched, hence the changes are not equal.

4.6.2 Loss in Quality Due to Haze

The primary effect of haze on a scene is the reduction of contrast. All films, black/white or color, lose resolution with a loss in contrast. The loss of resolution (percentage) with color is no worse than with black/white. There is, however, an image quality effect on color film that is not present with black/white. As the haze increases, it tends to reduce the blue contrast more severely than the other layers. This makes the blue record (yellow dye) appear more grainy, which in effect reduces quality.

4.7 REFERENCES

The references pertinent to this section are:

a. TCS-6155/70, April 1970, "Technical Evaluation of Color Material from Mission 4324-2."

b. TCS-20360/70, September 1970, "Color Study, Mission 4326-2."

c. TCS-20034/70, July 1970, "Photographic Evaluation Report, Mission 1108."

d. ICL-TCS-0001-70, 4 August 1970, "Evaluation of SO-242 Film for Use with the KH-4b System."

e. TCS-20160/71, May 1971, "Color Study, Mission 4329-2."

f. ICL-TCS-0001-71, March 1971, "Appraisal of Geologic Value for Mineral Resources Exploration," KH-4b System Capability Report No. 9.

APPENDIX V

COLOR PROCESSING

5.1 INTRODUCTION

The problems of having to handle significant amounts of color at either of the National Processing Centers are essentially the same: (a) neither facility is particularly well equipped to process and duplicate color, and (b) neither group really knows the best processing procedures and techniques. This is primarily due to the proliferation of new color materials and techniques over the past year. AFSPPF has the least amount of color processing and reproduction equipment of the two National Processing Centers. The equipment on hand or programmed for installation at AFSPPF is limited in volume capability and flexibility of production. Further, the present production space will not accommodate any additional equipment. Any expansion of production space to accommodate additional equipment will require environmental and support services equal to or better than those available in the present facilities.

5.2 FACILITY ADEQUACY

The first problem of both AFSPPF and Bridgehead is one of space.

5.2.1 AFSPPF

At SPPF, the physical constraints of the buildings are such that a major color processing installation could not be included without the removal of significant black/white capabilities, an unacceptable alternative. The AFSPPF color production capability can only be considered a token effort. Facility modifications and additional processing equipment, which have been programmed for, will provide a modest increase in capability. This capability will be limited to the emulsions which can be processed in the 1811/1411 Versamat. AFSPPF will be able to provide production support in the processing and duplication of color film, but this support cannot be considered time-responsive for a volume requirement.

Use of the present production area to achieve a time-responsive and high volume color capability with current equipment would require the addition of processors, the reduction of the present black/white film production potential, and extensive facility modification.

A separate color production facility would be required to provide a viable alternate facility capable of volume and time-responsive production of both black/white and color film in significant amounts. Concurrent with construction of the facility would be the urgent need to develop new high speed color film processors. AFSPPF has proposed a facility with a family of high speed processors which would significantly increase their processing and reproduction capability.

5.2.2 Bridgehead

The space problems at Bridgehead are similar to those at AFSPPF. There is no space within the existing facility for significant color capability. The current color processing/reproduction capability is not located at Bridgehead, but at the Lincoln Plant. While there is space at Lincoln for expansion of the color capabilities, this is impractical as:

a. The building does not belong to the National Reconnaissance Office, but to the Navy. Each year there are questions as to whether or not the Navy is going to dispose of the building and force a move.

b. The interior of the building is made of timber and cannot hold any additional equipment loading without a serious possibility that the floors would collapse.

The problems are further complicated by the fact that very little, if any, of the current color processing equipment is really suitable. The two "production" color processors at the Lincoln Plant, the Grafton and the Ragdoll, are augmented by two 1411 Versamats and one 1811 Versamat on loan from the USAF. The Grafton is an original and duplicate color processing machine, while the Ragdoll is for processing duplicates only. Both pieces of equipment have been constructed of scrap parts and leftovers from discarded and/or obsolete black/white equipment. They are only marginally adequate for the current limited color test program and are subject to failure at any time.

To provide for the handling of significant amounts of color film, a new generation of film processors will be needed. Indeed, new processors may be needed just to carry out a limited experimental program. Fortunately, much of the printing equipment currently on hand for black/white is also usable for color.

With the use of the present equipment at the Lincoln Plant, the production rate for color processing is also slow. Both the Grafton and Ragdoll processors operate generally at 7.5 and 4 feet per minute respectively. The 1411 and 1811 are even slower and not compatible with some of the new color products. Figure 1 illustrates the time required in days to produce the full complement of color duplicates of varying amounts of original film. Figure 2 is a nomograph that allows determination of the time required to deliver duplicate copies from varying amounts of original, based on the current production capability. This figure shows, for example, that a full KH-8 bucket would take in excess of 45 days for delivery of all 34 color copies. This is, of course, a very long time. The severity of this time, however, depends on many factors. For example:

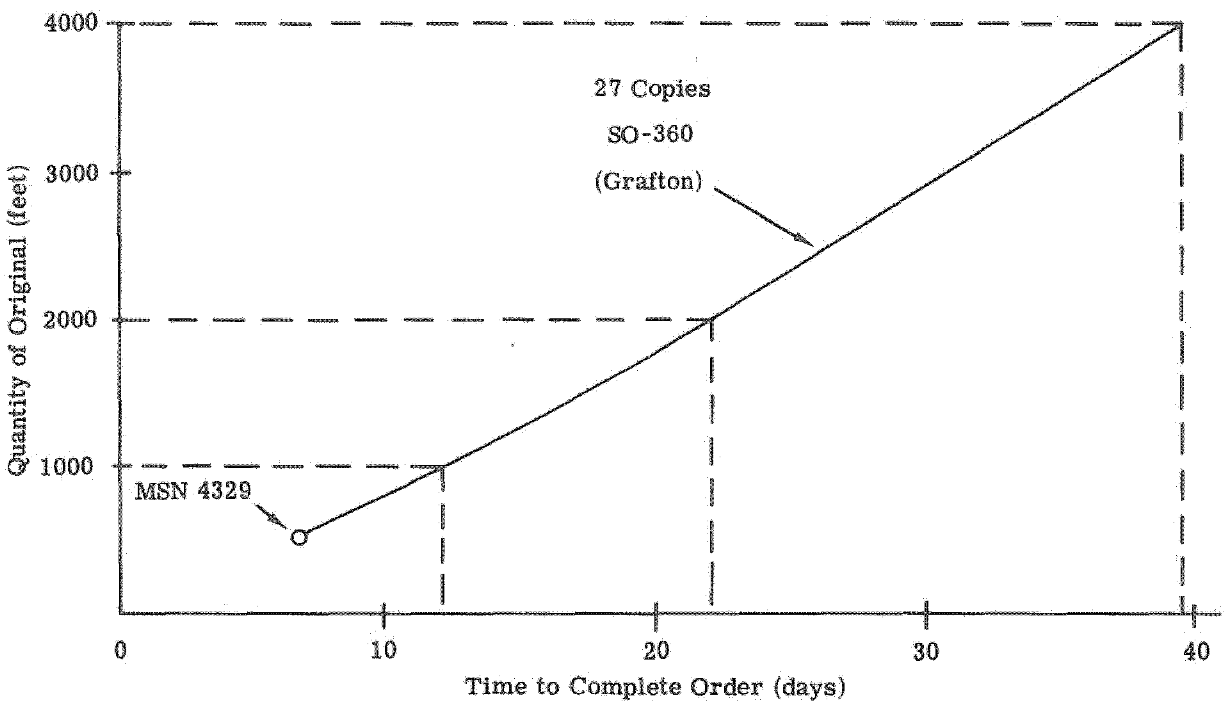
a. The 46.5 days does not mean that it is the first time the customer receives any mission material but only refers to the receipt of color copies. The green record black/white dupes can be delivered in a considerably shorter time.

b. How many color copies are really needed is uncertain. Color duplicates probably will not be delivered in the same quantities as black/white, except perhaps to the Washington community users. It is conceivable that there will only be a need for reproduction of specific frames or passes (selective printing). Selective printing requirements would be requested after the user has reviewed the black/white reproduction.

c. The reproduction speed necessary is also a function of the tasks to be performed. If the color were needed for first-phase readout, then the NPIC color duplicates would be required in a time frame

FIGURE 1

CURRENT REVERSAL DUPE DELIVERY CAPABILITY FOR KH-8 PHOTOGRAPHY



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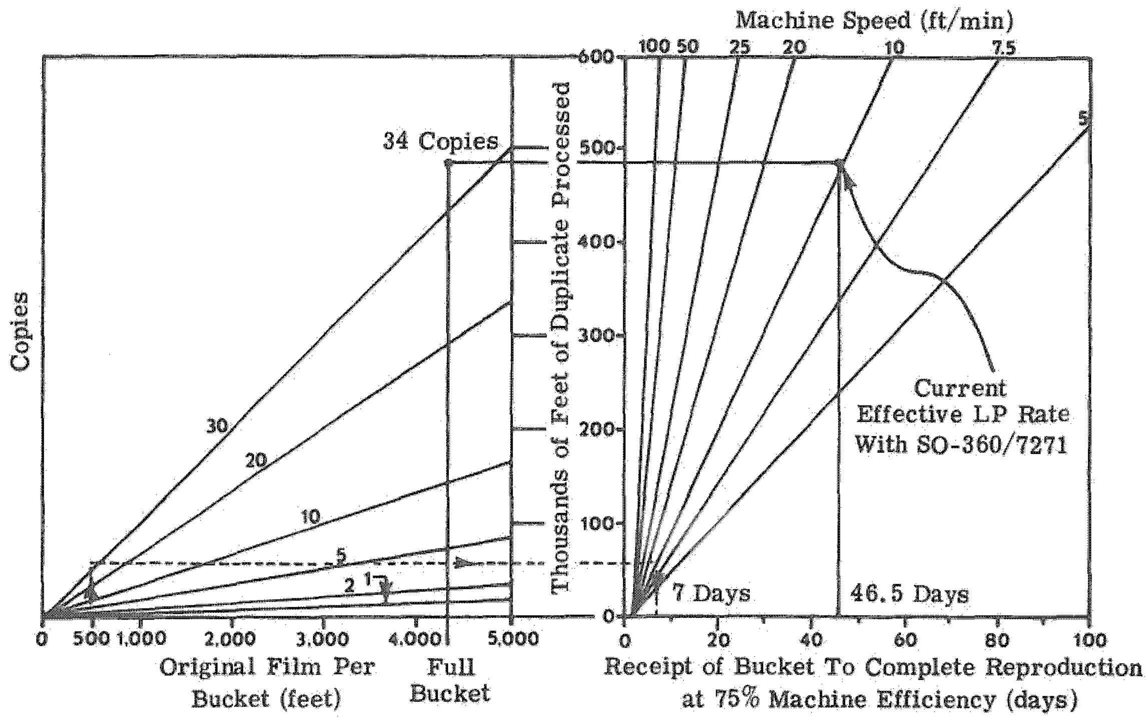
Handle via Talent - Keyhole Controls Only

~~TOP SECRET~~

DUPLICATION RATE PARAMETERS
(KH-8)



Note: These parameters are applied to process rates to determine delivery time from 500 feet to a full bucket.

FIGURE 2

identical to the black/white. For second-phase mission search, and third-phase readout, time is not usually a critical factor.

The above discussion points out, in summary, that for almost any expansion of a national color processing capability, significant new facility space must be located. The contractor studied what kinds of new facilities it would recommend, the equipment needed to operate these facilities, and the estimated costs involved. It has devised two plans that included a "minimum" (small) and an "optimum" (large) facility. The small facility would be 23,000 square feet and the large facility 35,000 square feet. The details of the plans for these facilities as well as the advantages and disadvantages of each will not be detailed here as they are covered in the PAR 182S final report.

Tables 1 and 2 illustrate the general facility costs between the two proposed plans. According to the contractor, the minimum facility cost would be $2.7 million. Table 3 presents a listing of the type of equipment (other than new processors) needed to make these new facilities operational. An important digression should be made at this point. The fact that Table 3 indicates that in some areas no equipment is needed is based on the assumption that a new color facility would be collocated with the black/white facility and, therefore, many common functions could be shared. This is an important consideration for many functions are common to black/white and color processing/reproduction. This advantage can only be taken, however, if the facilities are collocated. In the case of Bridgehead, this means a new color facility would have to be located in the Bridgehead building or from acquired contiguous space.

While certain functions are common, major ones are not, and considerable development would have to be undertaken and equipment built to operationally furnish such a facility.

TABLE 1

"SMALL" COLOR FACILITY

(ROM)

	Cost (K)	FY Requirements 71	72	73	74	75
Departmental Engineering	$ 150	3/4	1/4			
Detail Engineering	130	1/4	3/4			
Construction Production Area (16,000 sq ft x $100)	1,600		1/2	1/2		
Construction Personnel Area (7,000 sq ft x $60)	420		1/2	1/2		
Equipment Installation	400			1/1		
Total	$2,700					

TABLE 2

"LARGE" COLOR FACILITY

(ROM)

	Cost (K)	FY Requirements 71	72	73	74	75
Departmental Engineering	$ 150	3/4	1/4			
Detail Engineering	200	1/4	3/4			
Construction Production Area (27,000 sq ft x $100)	2,700		1/2	1/2		
Construction Personnel Area (8,000 sq ft x $60)	480		1/2	1/2		
Equipment Installation	500			1/1		
Total	$4,030					

TABLE 3

EQUIPMENT REQUIRED IN COLOR PRODUCTION FACILITY

	Total Required Large Facility	Total Required Small Facility
Pre-Splicer	0	0
Edge Flasher	1	1
Breakdown Tables	0	0
Mechanical Titlers	0	0
Print Level Determination		
Densitometers	3	3
Analyzers	2	2
Scanners	2	1
Secondary Breakdown Tables	4	2
Printers	6	4
Cleaners	2	2
Protectors	2	1
Inspection Tables	6	4
Shipping Equipment	0	0
Specials		
Enlargers	2	2

TABLE 3 (CONT'D)

	Total Required Large Facility	Total Required Small Facility
RT Processors	3-4	3-4
Automat	1	1

All the details of the development and equipment needs will not be presented as they are included in the PAR report. However, the contractor's summary of these costs is shown in Figure 3. This means that the total estimated cost, which includes the facility plus development and hardware, of the small plant is approximately $6,800,000 and the large facility is $9,630,000. The contractor's summary estimates for the costs to be incurred in such a facility through 1975, assuming the program is started now, are shown in Figure 4.

The contractor, in his study, concluded the following:

a. *Lincoln Plant expansion not cost effective.*

b. *Any expansion of present capability requires a new facility.*

c. *A new facility should be contiguous with Bridgehead for efficient use of manpower and equipment.*

d. *Parallel development and equipment efforts will be required along with facility expansion.*

e. *Course of action will depend on the conclusions of the Color Task Force.*

While the Color Task Force does not necessarily disagree with the data presented in these studies, it believes that there are other problems that need attention and other options that should be investigated.

5.3 IMAGE QUALITY

The technical problem associated with processing that clearly needs additional work is the one associated with the resultant image quality of the color film. Color film processing tends to be a very harsh, caustic process. This kind of process is prone to producing larger grain sizes and hence reduced image quality. Whether or not improvements in quality could be made with an altered process clearly needs to be studied. This should be studied prior to any further commitment to new processing machines. The factor of image quality, and not simply machine speed, needs to be considered in any new processor design studies.

DEVELOPMENT AND COLOR EQUIPMENT COSTS BY YEAR
(ROUGH ORDER OF MAGNITUDE-ROM)

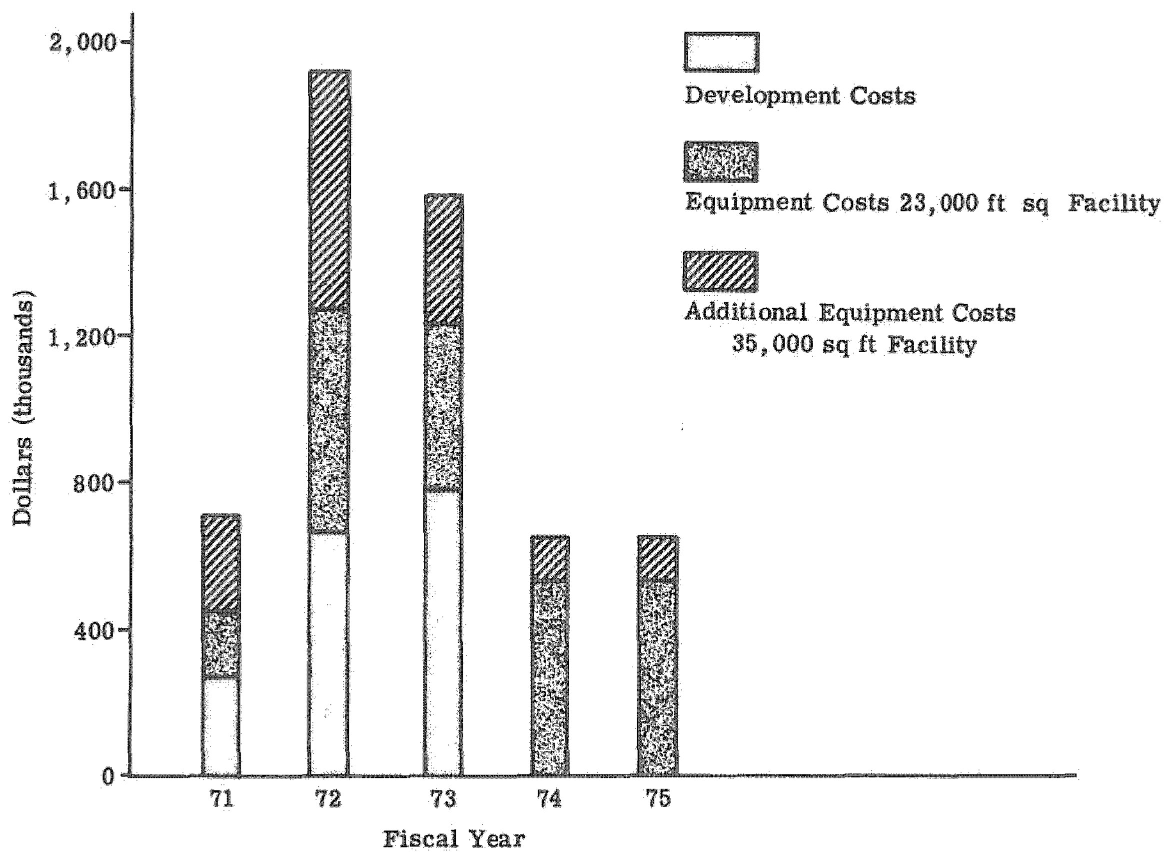


FIGURE 3

SUMMARY BY YEAR
(ROM)

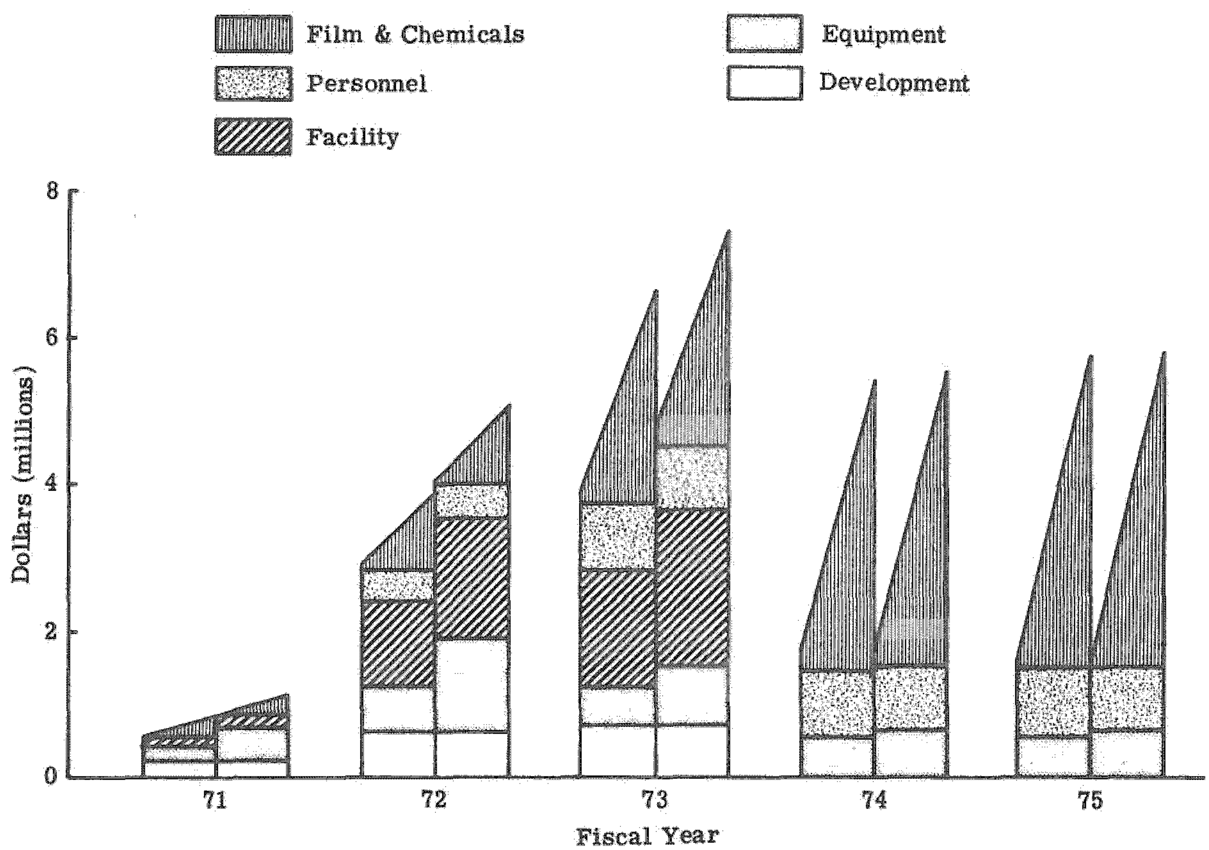


FIGURE 4

5.4 FUTURE CAPABILITIES

In summary, the most significant problem relating to the processing of color film is the inadequacy of current equipment and facilities. The Color Task Force has been, and is, reluctant to recommend greatly expanded facilities in the absence of a firm commitment to the use of color by the intelligence community. Unfortunately, however, there is a very real question in our minds as to the viability of existing equipment and facilities to even carry on a moderate experimental program. The equipment is simply too old. This does not mean, however, that the rather large investment outlined above is necessary to provide a more reasonable, albeit bare bone, facility for experimental use.

Some time ago, the National Reconnaissance Office and the CCB sponsored the development of the MP^2 Color Processor. The MP^2 is a highly versatile test processor built to enable the evaluation of a wide variety of film products and processes. This processor would be very compatible with either original or duplicate color processing. Even though this processor has been completed for approximately six months, there is no space available in Bridgehead in which to install the machine.

The CCB has been working with the contractor to reduce the cost of an improved facility to the absolute minimum. At the March CCB meeting, the contractor presented a plan for acquiring an additional 15,000 square feet of space for installing the MP^2 and basic color equipment. This minimum facility would provide for a new processor which would increase the assurance of high quality original processing as well as allow the use of the highly versatile MP^2 for processing improvement studies. The cost of this was estimated at approximately $1.5 million. This plan also had adequate growth potential for the future. The Color Task Force supports this plan.

The establishment of this very moderate color processing capability within the confines of Bridgehead should not restrict our future thinking and planning on color processing capabilities. If, in the future, a major expansion of national color processing capabilities is needed, its location should not now be fixed at Bridgehead. The Color Task Force and the CCB feel that one centralized color processing facility should be sufficient to handle the community's needs for the National Reconnaissance Program and that the need for two facilities, as with black/white, is not required at this time.

5.5 REFERENCES

The following documents are references to this section:

a. BIF-008B-M-00932-I-71, Interim Report, "Future Color Program Study," 14 February 1971, PAR 182S.

b. TCS-354005-70, "Processing and Duplication of Color Film," AFSPPF Report, February 1970.

c. TCS-354003-71, "AFSPPF Color Production Facility," March 1971.

APPENDIX VI

COLOR REPRODUCTION

6.1 INTRODUCTION

From the start of this effort, the Color Task Force has been deeply concerned about the reproduction of the color original. At the beginning of the test program, the only reversal color film available was SO-360, whose resolution is about half that of SO-242. The only internegative (contact) system available is 7271/7380, whose resolutions at a 1.7:1 contrast are 150 and 282 c/mm respectively. The difficulties with these internegative films are:

a. Their tone reproduction characteristics do not match well enough with SO-242.

b. The internegative system requires two printing operations to produce a positive (versus one printing stage with a reversal film), which introduces additional image quality losses due to the physical separation of the color layers.

The final result is that the image quality in resolution of the 7271/7380 system is about the same as that of the SO-360, even though the basic materials have significantly higher resolutions.[1]

6.2 REVERSAL COLOR DUPLICATION

6.2.1 SO-360

The resolution problems associates with SO-360 are illustrated in Table 1. A comparison of the resolution recorded on the SO-242/SO-255 original and the SO-360 duplicates is also listed. It is readily apparent from this table that significant losses in resolution occurred, in nearly all cases, by duplicating onto the SO-360. The average loss with the exception of two cases is approximately 43%. This value tends to be misleading, as the loss due to duplication is a function of the resolution on the original, and the better the resolution on the original the more significant the loss. For example, from Table 1 the average loss in resolution for all targets that had 30 inches or better on the original was 43%; for 25 inches or better, the loss was 50%; for 20 inches or better, the loss was 59%; and for 17 inches or better (only two targets), the loss was 79%. This data forms a reasonably smooth curve as shown in Figure 1. It also shows that even though there were several CORN target readings of 21 inches or better, the best SO-360 reading was 25 inches. Even the best SO-242 CORN resolution (16.5 inches) was recorded as 32 inches on the SO-360 copy. It is impossible to determine, however, how many of the photointerpreter complaints relative to resolution are due to the fact that they worked from inferior SO-360 duplicates.

[1] This discussion does not mean that there are no reproduction problems with black/white. There are losses in printing with the B/W system as well as the color. Also, there are problems with the adequacy of duplicating films. Hence the recent change from 2430 to SO-192. The loss with black/white is normally about 15%.

LOSS IN RESOLUTION DUE TO DUPLICATION
(MISSION 4329-2)

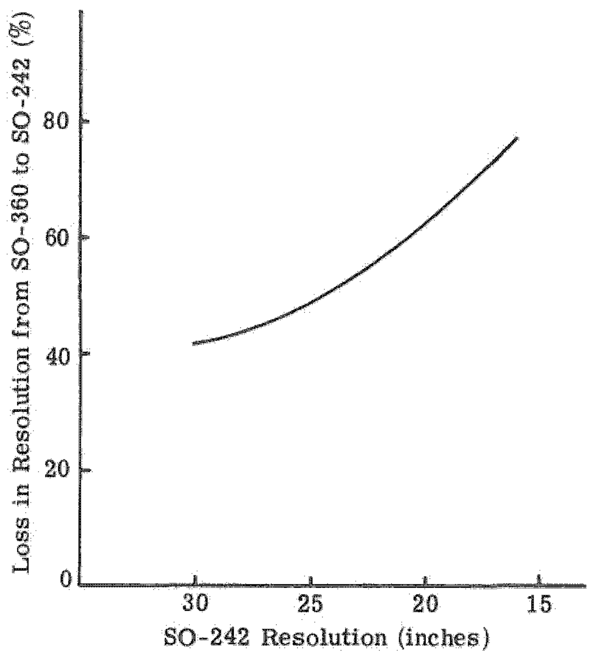


FIGURE 1

TABLE 1

RESOLUTION COMPARISON OF ORIGINAL SO-242/SO-255
VERSUS SO-360 DUPLICATES USING CORN TARGET DATA

		In-Track (inches)			Across-Track (inches)		
Mission	Rev/Frame	SO-242	SO-360	% Loss	SO-242	SO-360	% Loss
4324-2	204/005	24	30	25	34	34	0
4326-2	209/036	24	34	42	24	48	100
	037	30	38	27	54	54	0
	038	21	30	43	— Target Not Deployed —		
	039	21	34	62	— Target Not Deployed —		
	040	68	68	0	24	30	25
	041	21	30	43	21	30	43
	042	19	30	58	24	30	25
	043	19	27	42	27	30	11
4329-2	273/009	18	25	39	20	25	25
	010	19	32	68	21	32	52
	011	17	28	65	19	34	79
	012	18	28	56	22	31	41
	013	16.5	32	94	25	33	32
	014	19	31	63	25	34	36
	015	28	37	32	25	34	36
	016	21	34	62	21	34	62

6.2.2 SO-356

Because of the problem discussed above, the Task Force requested the film manufacturer to develop a higher resolution duplicating film. Such a film was developed virtually commensurate with the flight of Mission 4329. This film is a variant of SO-242 and has been named SO-356. It was not available in time to enable the complete reproduction of 4329 color, but three copies were made for evaluation by NPIC, CIA, and DIA. Selected frames were also sent to other recipients of satellite color material.

The improvement in resolution afforded by this film is tabulated in Table 2. The average improvement over SO-360 is approximately 21%; and while significant, the loss is still too great to be considered acceptable.

The NPIC evaluation of the SO-356 also considered factors other than resolution. It reported that the color balance of the SO-356 was acceptable although it tended to have the same green shadows and neutral highlights as SO-360 has. NPIC also reported that the contrast of the SO-356 was higher than that of the SO-360, which in general is beneficial. There were, however, several cases where highlight information was lost due to contrast. The shadow detail, image sharpness, and resolution of the SO-356 was judged to be superior to that of the SO-360. Because of the superiority of the SO-356, this film will be used for all future color reproduction.

TABLE 2

COMPARISON OF RESOLUTION PROVIDED BY SO-360 AND SO-356
ON MISSION 4329-2 AS DETERMINED FROM CORN TARGET DATA

	In-Track (inches)			Across-Track (inches)		
Frame	SO-360	SO-356	% Gain	SO-360	SO-356	% Gain
009	29	25	16	32	25	28
010	32	25	28	32	25	28
011	28	25	[redacted]	34	26	37
012	28	24	12	31	23	35
013	32	26	23	33	28	18
014	31	28	[redacted]	34	29	17
015	37	31	19	34	31	[redacted]
016	34	27	26	34	28	21

(b)(1)
(b)(3)

Note: All targets were acquired on Rev 273.

6.3 SELECTIVE LAYER PRINTING

Selective layer printing, which is the green record with the KH-8, is the printing of the green sensitive (magenta dye forming) layer in SO-242 onto a black/white medium. The procedure briefly is as follows: The SO-242 is printed onto a black/white negative film, such as 3414 or 3404, through an appropriate green filter. The internegative is dual-gamma processed and then handled as a regular negative, dupe positives being made on a normal dupe stock such as 2430 or SO-369. The advantage of this technique is related to the fact that the green layer is inherently the highest resolution of the three. In addition when using KH-8 optics, the green MTF is superior; so that the highest resolution print possible from the color should be achieved by employing this technique.

The technique was first conceived during the late stages of the 4324 color evaluation. One of the first targets to receive this treatment was the Nerchinskiy Zavod Army Barracks, USSR. There were difficulties in identifying the model of tank from the SO-360 copies. The green record print of this area satisfied the photointerpreters' needs, and NPIC reported that:

The green record can be used to secure the highest resolution inherent *in the film, quality comparable to that obtained with the black and white film used in the KH-8 system.*

NPIC further stated that:

> *Because of this loss in resolution* [sic due to duping], *a technique using reproduction of the green sensitive emulsion was developed to provide a high resolution reproduction to assist the interpreter in his analysis. Selected target areas were enlarged and the green sensitive emulsion (magenta dye image) was reproduced to a B/W negative image. A B/W reproduction was made from this separation negative and resolution equal to or better than the resolution detectable in the original SO-242 was available for exploitation. One area selected for this experiment was the Nerchinskiy Zavod Barracks area....The interpreter, when presented with this third generation reproduction, stated that it was typical of the normal second generation reproduction from B/W (SO-380) acquisition.*

These encouraging results led to the reproduction of all future KH-8 color missions by this technique. Unfortunately, the original promise of the green record printing was not as spectacular on subsequent missions. In retrospect, this is probably due to three factors:

a. The Task Force was too optimistic to begin with.

b. 4324 green record prints were made by enlarging from the SO-242 and not by contact, as were all subsequent ones.

c. The optimum procedures for green record printing were not carefully established.

Subsequent tests on the question of green record enlargements versus contacts clearly established that the enlargements were superior[2] and that if one required the highest resolution possible from the SO-242, an enlargement from the green record was called for. None of the subsequent missions used enlargements because it is not compatible with the mass production. However, green record prints were made for all customers. Further, the press of missions did not allow sufficient time to work out the optimized green record procedures. Initial testing, prior to 4326-2, concluded that the SO-242 to a 3414 dual-gamma internegative to a 2430 positive was the best technique. There are problems with this sequence, however,

[2] Again, this is not unique to color. Black/white enlargements of selected targets can always be made which are superior to the normal black/white contact reproduction. Given time, a selected target print can be optimized and will be superior to the mass production contact. In this regard, a prototype Production Oriented Color Enlarger (POCE) is being built under the sponsorship of the CCB. This will aid in very rapid production of high quality color or black/white prints.

which only now are being properly understood. There is evidence to indicate that significant improvements in the green record printing process can be made, and that most of the early promise can be recaptured.

The problems with green record printing received the greatest attention on Mission 4329-2 as this mission produced the highest resolution SO-242, yet produced poor green record prints.

The basic problem with the green record printing is shown in Table 3, where the resolution of the green record internegative and positive are compared with the SO-242. The green record internegative ought, conceptually, to be superior to the SO-242 original. It can be seen that the average loss was on the order of 40%, not much better than the SO-360, even though the films involved are of significantly higher resolution. The primary reasons for this poor quality are:

a. The 3414 internegatives were improperly made.

b. A two-step printing process was involved.

The green layer of the SO-255 on this mission was printed in such a way as to record the densities on the shoulder of the dual-gamma 3414 D-log-E Curve, see Figure 2. This caused a reduction in contrast, a significant loss in resolution, and an increase in granularity. In addition, this technique requires two printing steps which further reduces image quality.

TABLE 3

RESOLUTION COMPARISON OF SO-242 VERSUS COMPONENTS OF GREEN RECORD PRINTS USING MISSION 4329-2 CORN TARGET DATA

	In-Track (inches)			Across-Track (inches)		
Frame	SO-242	3414-Interneg	2430 Dupe	SO-242	3414-Interneg	2430 Dupe
009	18	23	25	20	26	27
010	19	24	25	21	30	29
011	17	26	25	19	26	27
012	18	26	25	22	29	31
013	16.5	27	28	25	27	31
014	19	28	34	25	32	34
015	28	30	34	25	33	34
016	21	29	26	21	31	31
Average	19	27	27	22	29	30
Average Loss from SO-242	-	42%	42%	-	32%	36%

Note: All targets were acquired on Rev 273.

3414 GREEN RECORD INTERNEGATIVE PRINTING
(MISSION 4329-2)

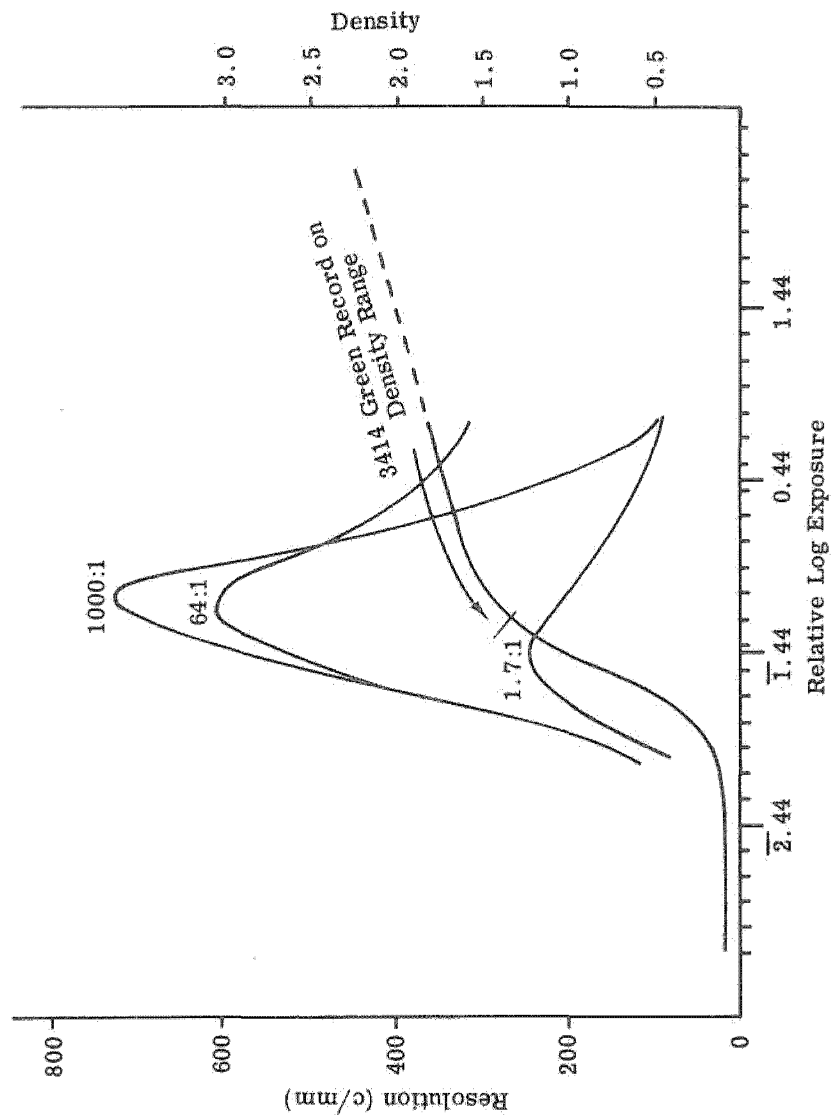


FIGURE 2

6.4 COLOR PRINTING

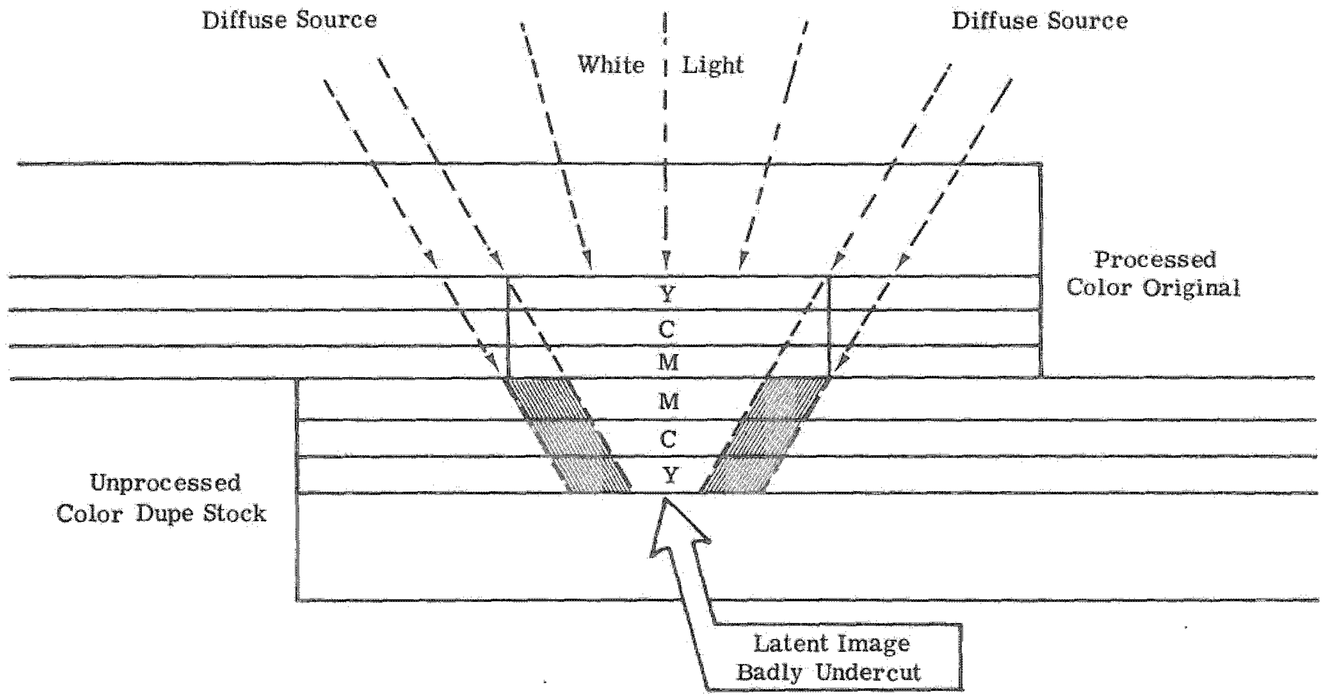
There is one basic problem that limits the image quality of color duplicates, and that is the basic separateness of the three color layers. The discrete divisions of the three color layers precludes achievement of the intimate layer-to-layer contact which is achieved in normal black/white printing. Figure 3 indicates a serious problem in printing color materials with diffuse light sources. In this figure, it is assumed that the processed color imagery contains a gray bar precisely the length of the space between the two vertical lines and that all three emulsion layers have some dye content. As a result of the diffuse light striking this gray bar from all angles, the latent image resulting on the unprocessed color dupe stock is badly undercut, particularly in the innermost emulsion layer. Obviously, specular illumination is needed to eliminate these undesirable effects. A small light source distantly positioned provides good specular illumination, but the loss in energy increases with the square of the distance. Another means of obtaining a specular light source is by using special optics that will collimate the rays of light so that every ray of light passing through the optics will fall on the precise centerline of a drum printer, such as a Niagara or Rainbow. Figure 4 indicates the principle involved. Optics for such a design are presently under construction. Projection printing is, of course, another way of providing specular illumination. In addition, the depth of focus of normal optics used in enlarging tends to help bridge the color layer displacements. For this reason, optical projection methods are presently preferred for translating maximum image quality onto a color duplicate film. In addition to increasing resolution of the final product, there are definite requirements for increased output speeds when processing and printing color materials. In general, the principles and techniques of achieving these ends are known. Of equal importance to speed and resolution improvement is the need for better color control. The ultimate would be an incremental exposure-control, color-correcting printer to automatically restore the true color balance of the scene to the imagery. Before a printer of this sophistication can even be conceived, there is a tremendous requirement for basic color knowledge. Firm, reliable, and accepted color criteria are needed to provide the guidelines for color correction and balance. Such knowledge and criteria will be evolutionary and will probably emcompass a protracted period of time.

6.5 ADDITIVE COLOR PRINTING

As a result of the difficulties on Mission 4326, the duplicates tended to be rather poor in color fidelity. For example, highlights tended to be magenta while shadows were cyanish in tone. This was due, of course, to the contrast mismatch in the three individual color layers. The best way to correct this is through additive printing. In additive printing, black/white separation negatives are made of each emulsion layer of the color material, which allows each record to be balanced for density and contrast individually. These are then individually printed through appropriate filters onto an appropriate color film. The

FIGURE 3

CONTACT COLOR PRINTING



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Approved for Release: 2021/02/11 C05132258

AN OPTICAL CONDENSING SYSTEM FOR CONTACT COLOR PRINTING

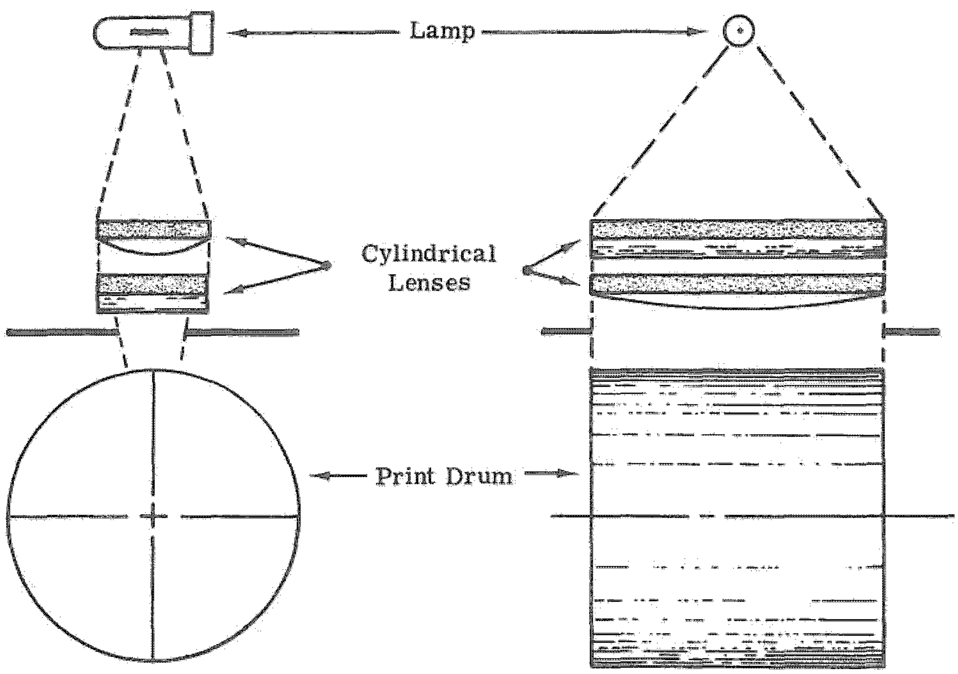


FIGURE 4

separation negatives have to be carefully registered since this is a sequential printing process. If the area of interest is enlarged, however, registration is rather easily accomplished with a pin register board. This technique is not new in photography, but it is laborious. Several prints and transparencies from 4326-2 were made this way, and the results were unquestionably superior to any other color reproduction technique. If the finest color print or transparency is desired, it should be made by the separation negative/additive printing process. NPIC is currently capable of making a limited number of these prints.

6.6 SYNOPSIS

Without question, the inadequacies of reproduction materials and techniques has been one of the greatest problems affecting the color program. The quality of the SO-360 copies delivered has been decidedly inferior in resolution to the original color film. The better the quality of the original, the greater the loss to the duplicate. The data has indicated that no matter what the resolution is on the original SO-242 that the best quality on the duplicate has not exceeded 25 inches. It is certain that this fact strongly influenced the photointerpreters' judgments concerning resolution obtainable with the color film. The advent of the SO-356 color duplicating film helps to minimize this problem, but not to the degree ultimately desired. It is likely, however, that the majority of the loss with the SO-356 is now due to the printing operation and not the film. This point was previously discussed in paragraph 6.4. Major improvements in the image quality of color duplicates will depend, therefore, on the future design and fabrication of specialized printers.

The quality of the color duplicates would not have been so important if the green record printing process had produced the quality of result originally anticipated. Such was not the case, and the resolution available on the SO-242 was never routinely transferred to any of the "mass production" copies.

Significant improvements to the green record printing process are possible, and studies to that effect are currently underway. Four basic systems are under investigation. These are shown in Figure 5. The 3414/2430 process is the one used now, this technique was discussed in paragraph 6.3. The new processes to be studied are:

a. 3414/SO-192 – Essentially the same as currently employed except the new high resolution dupe film will be used.

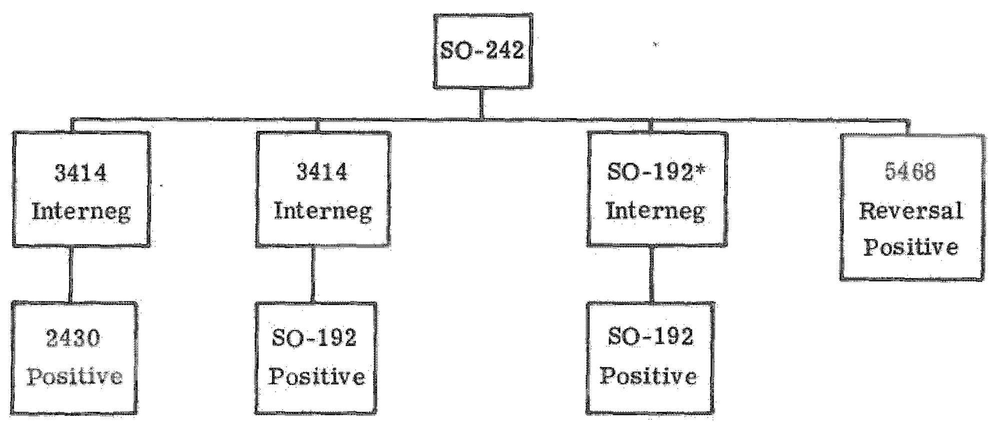
b. SO-192/SO-192 – A new process using a new orthochromatic (green) sensitive version of SO-192.

c. 5468 – A new process using a direct reversal orthochromatic film to reduce the number of printings required.

It is believed that one of these new processes will, in concert with proper exposure of the internegative, produce a significantly improved green record print.

Without question, if color is to receive serious consideration, attention will have to be paid to conventional and unconventional reproduction to the extent of designing and fabricating specific color oriented printers.

GREEN RECORD PRINTING PROCESSES UNDER INVESTIGATION



(Current Process)

Note: 1. SO-192 is a new high resolution dupe film.

2. 5468 is a direct reversal black/white dupe film.

* A new green-sensitive version of SO-192 will be made for this step.

FIGURE 5