File J-3

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TECHNICAL PROPOSAL
SYSTEM ANALYSIS STUDIES

J-3 PHOTOGRAPHIC SYSTEM

15 MAY 1967

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TECHNICAL PROPOSAL
SYSTEM ANALYSIS STUDIES

J-3 PHOTOGRAPHIC SYSTEM

15 MAY 1967

Itek

ITEK CORPORATION LEXINGTON 73, MASSACHUSETTS

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CONTENTS

Appendices

FIGURES

TABLES

1. SUMMARY

This proposal is primarily concerned with the evaluation of the operational performance level of the J-3 reconnaissance system. This evaluation concerns itself with the analysis of equipment operation, the assessment of atmospherics, a study of the pertinent photographic processes, and the scrutiny of the resultant imagery.

A secondary but very important section of the proposal deals with the reduction of the data obtained from the experimental portions of the first four J-3 flights.

Another evaluation proposed is that which deals with the validation of the geometric fidelity of the camera system.

Separate from the above analysis, but still a part of the total evaluation program, Itek proposes that a pair of Petzval lenses be subjected to nonuniform thermal loading such that the effects on best focal position and resolution can be observed.

The equipment analysis includes the consideration of the vehicle as well as the camera, since in essence they become one during operation. The data for this study will be supplied by the telemetry links and tape records included in the diagnostic flights. After the data are reduced, a comparison of the actual data with the error budget expectation will be made to identify the validity of the original budget, and, more importantly, to assess the effects of the disturbance sources on quality. Wherever possible, computer techniques will be used to facilitate handling of the large mass of data.

The atmospheric effects on performance, for the most part, can only be assessed from a qualitative standpoint, and the imagery obtained with the DISIC as well as prior DFC material will be useful here. One of the diagnostic flights will provide information on polarization within the atmosphere, and this will be considered. Some quantitative data will be available from the ground measurements made at the CORN target sites.

Itek will also conduct a theoretical analysis of the effects of atmospherics on the resolution. Unlike other atmospheric investigations which have been conducted by various groups for various reasons, this analysis will be specifically oriented toward atmospheric effects on photography.

Included in the study of photographic processes will be examinations of exposure, development, and reproduction. Considerable emphasis will be placed on the scrutiny of operational targets as opposed to an assessment of the general terrain. The exposure evaluation will of course consider the relationships of the film characteristics and solar illuminance as related to achieving the theoretically proper position on the exposure density curve, but it will also consider what this proper position really should be, considering all mission requirements. An excellent relationship exists between the Itek personnel who would be involved and the government communities who would provide necessary measurements and opinions as to the relative quality of imagery.

The study of the development processes will also remain closely related to the aim of achieving the best possible output for the interpreter. It is realized that any possible recommended modifications in this area must be consistent with the need for expeditious handling of large quantities of film.

An examination of the reproduction techniques is proposed since it is at this stage of the process that a great deal of information can be lost. It is impossible to have all interested parties view the original negative and only a few first generation positives are made from it. Therefore, a large portion of the community has access only to second generation positives and intelligence gathering or judgment of the original quality from this record can be very misleading unless the reproduction job has been superlatively done. Some agencies utilize the material for purposes other than intelligence and they are as interested in good data display as in imagery. Rather than compromise to satisfy all users, it may be best to make separate reproductions which best fit the needs of each.

The ultimate evaluation of the J-3 reconnaissance system will be made by scrutiny of imagery on the original negatives. It is recommended that the CORN targets be displayed as widely as possible, since they allow a direct quantitative evaluation of system performance, and the measurements taken by the attendant ground crews supply valuable supplementary data.

Another important evaluation technique which will be used is a comparison of edge traces. This method compares edge traces obtained from resolution targets photographed during camera acceptance testing with edge traces derived from scanning suitable edges in the operational imagery. Computer techniques will be employed to reduce the labor and time involved in edge comparison.

The material from the experimental portion of the J-3 flights will be evaluated and reports will be published. The first will report on the effects of different filtration on the information content as judged by the interpreter. The second report will provide information on the usefulness of near infrared camouflage detection film for assessing agricultural, mineralogical, and industrial processes. Another portion of this report will describe the results of the night light-detection test. The third will report on the J-3 operation which will make use of ultrathin base film at the mission's end. Also during this operation, a split, polarizing filter will be used on the forward-looking camera. The effect of the polarization will also be discussed in the third report. The last diagnostic mission will also provide information on bicolor photography and on the feasibility of replacing the present operational 3404 film with the higher speed but hopefully equal quality SO-230. The report will carefully consider the tradeoffs between any possible loss of quality due to power resolution with the gain resulting from shorter exposures.

The J-3 camera system has intelligence gathering as its basic purpose, but it has long been realized that the system also provides much useful mensurational and geometric data. Itek proposes that one of the system analysis studies concern itself with validating the calibrations of stereo angles, determining the relationship of the horizon optics to the panoramic optics, and performing postflight measurements which will indicate the stability of the panoramic geometry calibration.

Obviously a great deal of data must be handled if the task is to be done properly. We propose that Itek have timely access to all sources of information such as telemetric and tape recorded data. If this information cannot be provided in a directly usable form, we propose that we utilize the necessary methods of data reduction. We also propose that we have access to and working space in Westover Air Force Base and NPIC. This space will only be necessary while Itek personnel are at the site. Since we are already acquainted and on good terms with the personnel in these facilities, there should be no problem in instituting the cooperative effort required.

Another cooperative effort required is that with Eastman Kodak in the evaluation of development and reproduction. Here again our long association will be of benefit.

Itek fully expects that these system analysis studies will provide specific quantitative data on J-3 performance and will also demonstrate the flexibility that the many improvements over the J-1 system make possible.

2. INTRODUCTION

The J-3 Panoramic Camera System development was initiated because the general community realized that sufficient understanding of the J-1 system existed to allow an extension of the basic J-1 concept which would increase the information-gathering capability in both quality and quantity. The physical restriction of vehicle diameter which previously had prevented this evolution was removed when the Thorad vehicle became available.

The constantly rotating lens/drum concept used in the J-3 camera should be inherently less susceptible to noise than the J-1 design. This improvement, when paired with the capability of lower altitude operation, should materially improve the intelligence content of the photography. Additionally, the availability of exposure and filter control will aid in optimizing the photographic processes which are so vital if maximum information content is to be attained. Having the facility to make use of different films will probably not improve the quality of performance but it will allow us to perform specialized tasks.

The J-3 system incorporates the techniques developed in the J-1 system for providing a geometric framework which makes it possible to use the panoramic photography for mapping, charting, and geodetic work. Calibration equipment has been fabricated to allow the determination of the relative orientation of the panoramic cameras and the ancillary horizon recording cameras. The more stable operation of the constantly rotating camera and the additional calibration should strengthen the mensurational aspects of the system.

It is not unreasonable, if one has faith in the evolutionary improvements, to expect a more consistent and better product. Faith alone, however, can not replace the scientific approach to the evaluation of any new piece of hardware. The scientific evaluation of the level of this J-3 improvement is therefore a reasonable task to undertake, and it is the subject of this proposal. Such an assessment must consider all system factors and conditions, whenever and however they may occur, which affect the final quality of the product. These elements must be assessed so that their individual contribution to the attained performance level can be identified. Only in this way will we be able to make a valid judgment as to how successful one development has been.

The results of the parametric analysis will identify those factors which are most detrimental to the achievement of the theoretically established quality level. Recommendations can then be made for the control of these degradations to a reasonable degree.

Itek believes that such a system analysts study is as fundamental to the total accomplishment of the J-3 program aims as the development of the equipment itself, and sincerely urges favorable consideration of this proposal.

3. SYSTEM PERFORMANCE GOALS

The question of whether a specific system has fulfilled its requirements can only be answered by observing and evaluating its performance. In the case of the J-3 system, the primary requirement is to produce "sharp pictures." Specifically, the system, through its panoramic cameras, should achieve certain ground resolution at the center of the format for a given altitude. Independent of the altitude and the vehicle, the panoramic cameras should achieve a minimum resolution on operational film (3404) of 110 lines per millimeter for low contrast targets (2:1).

Various factors affect the resolution of the panoramic cameras: the resolution capacity of the optics (Petzval lens); the resolution capacity of the film; the focus condition of the lens; the exposure and development of the film; and the blur which, in general, results from the motion of the aerial image across the film during exposure. The quality of the lens and film determines the upper limit of resolution that can be achieved by any camera using the same lens/film combination. Thus, each Petzval lens is statically tested with 3404 film, and it must achieve a low contrast resolution of at least 140 line pairs per millimeter before it is accepted for assembly in a J-3 camera.

A significant advantage of the J-3 camera design (that is seldom appreciated) is its modular or subsystem construction, which allows better control of subsystem construction and performance. It consists of independent subassemblies that are basically interchangeable. Thus, the lens includes the field flattener element and the focal plane rollers and forms a complete optics subsystem.

The lens is designed in such a way that its basic resolution will not be degraded in a normal operational environment. The cell and tail cone supporting all the optical elements are rigid enough to withstand the vibration environment of the booster rocket. Furthermore, the metals of the cell and tail cone as well as their physical dimensions have been selected carefully so that there is a minimum of focus shift over the operational temperature (70 ± 30 °F). Various vibration tests have proven the suitability of the lens cell design. Furthermore, each lens undergoes a vibration test as a check on its ability to retain its resolution after it has been subjected to a vibration environment.

3.1 CURRENT ERROR BUDGET

Blur degrades the basic resolution of the lens/film combination, and this blur can be attributed to the following general sources.

1. Dynamic operation of the camera
2. Interface between the J-3 cameras and the vehicle
3. Vehicle motions
4. Command errors

The error budget that is contained in Tables 3-1, 3-2, and 3-3 is essentially a compilation of all substantial sources of image motion and the calculated blur values which they introduce. (All tables in this section are located at the back of this section.) Atmospheric effects and improper exposure of film are not considered. The error budget provides a means for controlling the large blurs through proper design of the complete J-3 system. It also allows one to make predictions concerning the dynamic resolution that the system will achieve under operating conditions.

It must be pointed out, however, that the error budget attempts to predict the performance of the average J-3 system and not the performance of every system. Considerably better predictions of the operational performance of a specific camera result from the simulated dynamic resolution tests performed at Boston and Advanced Projects (A/P).

It should also be pointed out that the error budget does not account for quality variation in the film, which is a separate quality control problem of the film manufactures. Specifically, the film manufacturer must control the emulsion turbidity (numerically described by the modulation transfer function), and the population distribution of grain sizes, as well as other properties of the emulsion. The effects of the variations in the emulsion become more pronounced in the limitation they impose on the resolution of the film, which is determined by the emulsion turbidity, by the gamma, and by the granularity.

The resolution of the film is obtained by photographing targets with lenses whose modulation transfer functions are considerably higher than that of the film. A rough rule of thumb is that the modulation transfer function of the lens should not be less than 90 percent of the resolution frequency of the film.

The rules for measuring the resolution of a film are essentially those established by ASA committee PH2-16. According to the ASA committee rules, for those films with a high contrast resolution of less than 300 cycles per millimeter, a specific 0.30 numerical aperture, 16-millimeter objective lens is to be used. For films with high contrast resolutions greater than 300 cycles per millimeter, a 0.65 numerical aperture, 8-millimeter microscope objective is to be used.

The modulation transfer function of the 8-millimeter lens reaches 0.90 at 301 cycles per millimeter and its cutoff frequency is 3,020 cycles per millimeter. The resolution of 3404 film is measured using this lens. The resolution target is photographed 168 times and an equal number of resolution data points are obtained. The frequency of occurrence of the data points at the various resolution levels is plotted, resembling the familiar Gaussian distribution. The calculated mean of the plotted distribution is 316 lines per millimeter and the standard deviation is 20 lines per millimeter. Obviously, the variation in the measured resolution must be attributed to variations in the film emulsion, since the optical system was identical for all data points.

The significance of the above discussion to the J-3 system should not be misinterpreted. One should not expect a standard deviation of 20 lines per millimeter in the operational resolution of the J-3 system, due to variations in the film quality, since the resolution of the system is lower than the film resolution. It is estimated that a change in the film resolution of 20 cycles per millimeter will produce a change of approximately 1 cycle per millimeter in the system resolution.

Improper exposure and film development also degrade the resolution of the film, and they are not accounted for in the error budget. Several tests have been performed to determine how exposure affects film resolution. These tests show that the film achieves maximum resolution for an optimum exposure of the target. Overexposure or underexposure of the target appreciably reduces the film resolution below the maximum value.

It is obvious from the above discussion that any comparison of the operational system resolution to that predicted in the error budget or that obtained with laboratory tests would not be valid unless the performance of the operational film were determined. Therefore, it is proposed that a piece of the operational film (5 feet long, unexposed, and not developed) be removed from the flight spool at Vandenburg and delivered to the Itek photography department. The rest of the operational film would then be developed; subsequently the film would be analyzed, sensitometrically, by the photography department to determine the exposure conditions of the CORN targets. Then it would be the task of the photography department to provide all interested groups with a film threshold curve obtained by performing resolution tests on the 5-foot length of film which would be exposed under conditions simulating those of the operational film (CORN targets). The significance of this threshold curve to the analysis of system resolution is that it would permit one to separate the effects of film quality and exposure from the effects of camera operation, vehicle dynamics, and operational control of the system. This threshold curve would be used for making more accurate predictions of system performance. These predictions would be compared to the performance predictions of the error budget, Tables 3-1, 3-2, and 3-3, and the resolution numbers obtained from the CORN target images.

3.2 DETERMINATION OF OPERATIONAL RESOLUTION

The system analysis studies must provide us with the means for determining: (1) the resolution of the operational material, and (2) whether any malfunctions which affect resolution occurred during the mission.

Before resolution can be determined, one must define "resolution" since, in fact, there are several interpretations. Ordinarily, resolution is the spatial frequency at which the modulation transfer function of the complete system (all the blur sources are included) intersects the threshold curve of the film. The threshold curve is determined experimentally and indicates the minimum modulation of a sinusoidal image at which the signal is barely discernible from the noise (granularity) of the film. Since the grains of the film are much smaller than the image detail, the film noise tends to have high frequency content; and the required modulation for a barely discernible high frequency signal is much greater than that of a low frequency signal. Therefore, the threshold curve increases rapidly with spatial frequency.

Experimentally, resolution is determined as the reciprocal of the smallest dimension of some pattern that can just be seen in a photograph. Unfortunately, this type of resolution depends on pattern contrast, the configuration of the pattern, and unknown human factors, since man becomes the measuring instrument in this case. Thus, it becomes necessary to identify the specific pattern used in determining resolution. Therefore, the term "resolution," as used in conjunction with the J-3 system, denotes the reciprocal of the smallest dimension of the standard USAF three-bar target that can just be seen in a photograph. Beyond this definition lie serious questions concerning the suitability of the three-bar target for determining the resolution of the system, and, more significantly, the adequacy of resolution itself as a system performance criterion.

There are several advantages in utilizing resolution as a system performance criterion. Of first importance is the fact that resolution has been employed through the years, and the values obtained have a commonly understood meaning throughout the photo-optical community. Second, it is easier to test for resolution than for sine-wave response. Although the basic data gathering procedure is the same in both techniques (i.e., photographing a special target), the evaluation of resolving power data is considerably more simple than sine-wave evaluations. For resolution data evaluation, only a microscope is required, whereas a microdensitometer is necessary for sine-wave evaluations. Third, for the aerial photographic case, resolution has some meaning in that it is an attempt to measure the capability of a film to record fine detail. Fourth, resolution measures the combined effect of all the information transmitting or degrading parameters in the system. It can take into account the performance of the lens, the FMC error, vibration, film performance, exposure, processing, viewing, and the observer. No other system performance indicator covers as many aspects of system performance in one measurement.

On the other hand, resolution has several drawbacks, one of which is its all-encompassing measuring ability. It often is difficult with a simple resolution test to pinpoint the cause of degradation in a system. Conversely, it is difficult to combine the resolution capabilities of each component of a system to obtain a valid indicator of total system performance. It must be remembered that resolving power is only a measure of the ability of a system or film to transmit or record a particular object of a particular configuration, contrast, and size.

Resolution, like all single number critieria, is not a universal indicator of picture quality. Image quality and resolution most noticeably conflict when using optical systems that possess unusual apertures or significant amounts of spherical aberration. It is not necessarily true that a doubling of the resolution of a system means a doubling of the information gathering capabilities of the system.

These fundamental questions concerning the use of resolution, however, do not concern the system analyst whose main objective is to determine whether the complete J-3 system has met the design requirements, because the requirements are specified in terms of resolution determined by the three-bar target. Therefore, the starting point of the system analysis studies should be with the results of the resolution tests performed on each instrument at Boston and A/P.

3.2.1 Ground Targets

The question concerning the determination of the resolution of a specific J-3 system (the complete system including the vehicle) as evidenced from the operational material can be answered fairly easily if the operational film includes images of resolution targets. To accomplish this, one would have to lay resolution targets somewhere on the ground. There is a serious practical problem associated with this technique. The targets can only be laid at certain locations in friendly territory. Thus, they can only be photographed during engineering passes, and then they are more useful to enemy reconnaissance satellites than to our own because they do not lie on the territory that requires photography.

In addition to the problem of placing targets, most of the targets are obscured by cloud cover. It is reported that an average of about two resolution targets per mission are photographed by the J-1 system.

It is proposed that a large number of resolution targets be prepared for each mission so that at least 12 targets might be photographed on the average. It is obvious that the most significant advantage of the ground targets is that they provide a simple and direct measurement of system resolution. At the same time it must be remembered that resolution is a statistical quantity and cannot be determined accurately by a single measurement or a small number of measurements.

The resolution information obtained from the ground targets should be compared with the results of the laboratory resolution tests. While this comparison is being made, a small but significant detail should be kept in mind. Though the ground target may have a reflectance contrast of 2:1, its optical image projected on the film will have a lower contrast due to atmospheric luminance. The atmosphere (excluding cloudiness or heavy haze conditions) affects the system performance mainly by reducing the contrast of ground objects. Thus, it is important that the ground targets consist of resolution and gray scale targets. The images of the gray scale targets should be traced with a microdensitometer and, by utilizing the D-log E curve generated from the operational film, the density measurements should be converted to log E values. Then it will be possible to determine the apparent contrast of the resolution target as it appears through the atmosphere to the panoramic cameras.

The edge trace technique for determining the operational system resolution is discussed in the following section. This technique avoids some of the practical difficulties of photographing ground targets, but it presents problems of its own. The most significant drawback of this technique is that it is an indirect method for determining resolution. Since neither of the two methods (photographing ground targets and edge trace analysis) is satisfactory by itself, it is proposed that both be used in the system analysis studies that they may complement each other.

3.2.2 Edge Trace Technique

The resolution of the operational film could be obtained more conveniently if a technique were available that would permit one to make some density measurements on the film, process them, and come up with a number which is approximately equal to the true resolution of the material. This seems quite feasible since the basic information is present on the developed film. In fact, edge trace measurements and proper analysis of these measurements should provide the answer.

An edge trace is obtained by measuring and recording, with a microdensitometer, the change in density between two areas of contrast density in the developed film which appear to be separated by a "sharp" edge. During the measurement, the microdensitometer's aperture is moved perpendicularly to the edge and the change in density from one level to the other and across the edge is recorded.

While the nature of the edge trace measurements is well understood, the methods of processing the measurements have been rather controversial. In several cases, some of the methods have been known to give erroneous and inconsistent answers. There is no doubt, however, that the edge trace measurements contain the needed information, and the proper conclusions can be drawn by developing a sufficiently refined data reduction technique. Some of the difficulties arise from the presence of film noise (granularity) and others from the fact that "resolution" is not well defined mathematically.

For several years, different groups in the country have used the edge trace technique for obtaining the modulation transfer function and the resolution of a system. The modulation transfer function is the Fourier transform of the system's response to a spatial impulse, while the edge trace is the system's response to a spatial step function. A spatial impulse is the derivative of a spatial step function. Therefore, one could obtain the response of the system to an impulse by taking the derivative of the edge trace. Then, the modulation transfer function is the Fourier transform of the derivative of the edge trace. The resolution is then obtained from the modulation transfer function by observing its intersection with the threshold curve of the film.

This technique, though straightforward and theoretically sound, has been rendered useless by the presence of film noise in the edge trace. When the derivative of the edge trace is taken, the film noise is tremendously enhanced; and accurate, repeatable modulation transfer function cannot be obtained. Attempts were made to filter the noise before differentiating the edge trace, but they failed to improve the repeatability of the final product. In fact, experience with edge traces has shown that good results can be obtained only when a minimum number of operations are performed on the edge traces. Thus, what is needed is a technique of relating the edge trace profile directly to resolution by one or, at the most, two operations and definitely without differentiating the edge trace. Theoretically, this has not been accomplished yet, because neither resolution nor the film threshold curve are defined mathematically but instead are experimentally determined quantities.

It is possible, however, to experimentally correlate resolution and edge trace profile. In fact, this is the solution to the problem of determining resolution from edge traces. Even though the relationship between edge trace profile and resolution may not be explainable theoretically, it can nevertheless be established experimentally. Therefore, it is proposed that the first part of the system analysis studies begin immediately with the development of a reliable edge trace technique. This should be divided into two tasks. First, a technical literature investigation would be conducted, (since considerable accomplishments have been made in previous work) to provide the theoretical basis for the development of the edge trace data reduction technique. Task two, to be run almost simultaneously with task one, would be an experimental investigation which would establish the correlation between resolution and edge trace profile. The film to be used for task two would be 3404 film which contained images of sharp edges and resolution targets which were photographed simultaneously.

Actually, photographing the standard USAF target should be satisfactory, because the target includes a large square. Unfortunately the targets used with the target wheel for determining the resolution of the J-3 panoramic cameras are only small portions of the standard USAF target and do not contain satisfactory edges. The requirement for photographing targets and edges can be met on either an optical bench or in the dynamic tests, provided that acceptable targets are mounted on the target wheel. The optical bench requires only one target, an experimental Petzval lens, and a good collimator. The target must be photographed many times and in such a way that a range of resolutions from 20 to 140 lines per millimeter is achieved. This can be accomplished by properly focusing and defocusing the collimator. Obviously, the collimator's modulation transfer function must be considerably higher than that of the Petzval lens.

A somewhat different method of obtaining images of resolution targets that display variations in resolution (20 to 140 lines per millimeter) would be to run photographic tests in the L-block with a panoramic camera and purposely mismatch the target wheel speed to the camera's FMC rate. The result would be a loss in resolution due to the artificially induced image motion in the FMC direction. For a specified resolution value (less than 140 lines per millimeter) the corresponding edge trace profile obtained by defocusing the collimator would be different than that obtained by image motion. Since it is anticipated that, in the J-3 system, the loss of resolution will most probably be due to image motion, it is recommended that instrument number 299 be utilized in conjunction with the dynamic simulator at the Itek 128 facility for obtaining resolution photographs that contain various amounts of image motion. Targets can be provided for the target wheel such that both resolution targets and edges can be photographed simultaneously.

It is expected that the edge trace profile will change slowly with resolution. As many edge traces as possible will be obtained from each resolution target using a microdensitometer. These edge traces will be identified with the group number and target number which is barely resolvable in the target; rather than resolution in lines per millimeter. Then, all edge traces identified with the same target number in all the photographed targets will be averaged to filter the film noise and to obtain a standard profile for that target number. Thus, the end product of task two shall be a set of standard edge trace profiles, each one associated with a specific target number.

Having developed a set of standard edge trace profiles, a question now arises as to its use with the operational material. An edge appearing on the film cannot be analyzed unless it can be verified that the edge was produced by a sudden change in reflectance between two areas of a ground object. Natural objects seldom display such abrupt changes in reflectance, except perhaps where a body of water is separated from dry land. On the other hand, man-made objects, which are definitely more interesting to the photointerpreter, abound with straight edges and sharp changes in reflectance. Unfortunately, due to the scale involved, satisfactory edge traces can be obtained only from objects larger than approximately 80 by 50 feet. Under these circumstances it appears that one should be able to record good edge traces from shadows of buildings falling across a street or an open field.

Thus, it seems possible to state some of the requirements that might be imposed on a ground object which is expected to produce acceptable edge traces. First, it should consist of two areas having separate and approximately constant reflectances separated by a straight edge at least 80 feet long. The two areas should be at least 80 by 30 feet each. The reflectances of the areas need not have a 2:1 contrast. The contrast could, theoretically, be any number because the resolution obtained by any legitimate technique can be interpolated for a 2:1 contrast by utilizing the resolution threshold curve of the film. Furthermore, the edge trace will be normalized when compared to the standard edge trace profiles. However, due to the presence of film noise, it is very important that the contrast of the two areas separated by the edge be as high as possible, because high contrast results in a high signal-to-noise ratio. In addition, the actual edge where the change from one reflectance level to the other occurs need not be infinitely sharp. Since the ground resolution of the system is not expected to be better than 6 feet, the real edge may actually be an area as wide as 1 foot without seriously affecting the accuracy of the edge trace data reduction.

It is obvious from the preceding discussion that one should be very selective when trying to decide which of the edges appearing on the film should be analyzed. In fact, one would have to search the film for proper images. However, it should not be difficult to find acceptable images if the operational film includes pictures of populated areas photographed at low solar altitudes. Alternately plowed and cultivated fields may produce acceptable edge traces even though the change in reflectance level, and subsequent contrast between two adjacent fields, may be rather low.

After the edge image on the film has been selected, it will be traced with a microdensitometer and an edge trace will be obtained, both graphically and in numerical form (computer cards) so that it can be processed in a computer. Then, the computer would compare the edge trace to the standard edge trace profiles determined in task two and select the profile that best fit the edge trace in a least-squares adjustment. It is then assumed that the target number associated with the best profile would have been the barely resolvable target, if a standard three-bar target had been photographed. Thus, the spacing of the bars in this target would provide the system resolution in lines per millimeter.

The edge trace technique for determining resolution should be at least as accurate as photographing and reading three-bar targets. Many people ascribe accuracy to the three-bar target that does not really exist. A simple examination of the three-bar target shows that each target number is larger than the previous one by a factor which is the sixth root of two (1.122). Thus, the scale change from one target number to the next is approximately 12 percent. When the standard three-bar target is used, the target number which is barely resolvable determines the resolution. Therefore, due to the quantized nature of the three-bar target, a system's resolution is described by one number from a given set of numbers where successive numbers differ by approximately 12 percent. Hence, the accuracy of resolution determined by the three-bar target cannot be greater than 12 percent.

3.3 ANALYSIS OF SYSTEM PERFORMANCE

After the operational resolution of a J-3 system has been determined, the task of the system analysis studies becomes a search for facts and clues as to what transpired during the mission which affected the general performance of the system, and specifically, what occured which might have degraded the resolution.

At first, the operational resolution must be compared to the preflight resolution tests in order to determine whether the mission appeared to be normal or whether there was obvious evidence of malfunction. Then, the photographic record, diagnostic tapes, telemetry data, and orbital data must be examined closely for clues to abnormalities during the mission.

3.3.1 Examination of the Photographic Record

3.3.1.1 Panoramic Camera Imagery

Examination of the data recorded on the panoramic frames will disclose important information about the operation of the panoramic cameras. The timing marks and the nod dots will be used for this purpose.

The number of timing marks over a specified section of the format can be converted to a cycle time or period of a complete scan rotation which will indicate if the camera was operating at a scan rate consistent with the correct V/h. In fact, the relationship between the cycle period and the number of timing marks over this section of the format is:

$$T_c = 2.57 \times 10^{-2} N_t \tag{3.1}$$

where T_c = cycle period in seconds
N_t = number of timing marks over 70 degrees of scan angle

Large, slow variations in timing mark spacing over the length of the frame would indicate that while the camera was operating the scan servo may have been out of control. However, abrupt changes in the timing mark spacing, like extra or missing pulses, would indicate probable malfunction or noise in the timing mark circuits.

The nod dots essentially monitor the operation of the nodding or FMC system. Variations in the spacing of nod dots are expected and indicate mechanical vibration in the camera structure or FMC mechanism. The nod dot spacing can be analyzed for the purpose of determining if the FMC mechanism is operating properly. Missing or extra pulses most likely result from electrical noise in the xenon flashtube circuits.

It may happen that some instruments have higher resolution in the FMC direction than in the scan direction (at the center of format). This effect could result from large blurs in the scan direction due to excessive roll rates of the vehicle, whose least stable axis is the roll axis. In this case, it is possible to verify the existence of large roll rates by examining and correlating the panoramic photography. If the vehicle was rolling, both panoramic cameras would be affected, and each of the two panoramic cameras would show reduced resolution in the scan direction.

3.3.1.2 DISIC Imagery

The DISIC imagery, especially that of the index camera, can be very useful in explaining resolution loss in the panoramic imagery. Because of its large coverage (one frame of the index camera covers several frames of the panoramic cameras), the index camera will more clearly show a weather front and areas of cloudiness and haze. This can be used to provide an indication as to where, in the panoramic imagery, one would expect to see a reduction in resolution due to haziness or the proximity of cloud cover.

3.3.2 Diagnostic Tapes

The diagnostic tapes are magnetic tapes on which is recorded, in digital form, data acquired during the mission. These tapes contain extremely valuable information about the operation of the system, and are expected to provide positive answers about various factors that bear upon system performance. The information that is being recorded in the diagnostic tapes includes the firing of the attitude jets and time data, as well as the outputs of 120 system function monitors.

3.3.2.1 Attitude Jet Firing

The knowledge of when the attitude jets have fired will answer questions as to whether the vehicle was experiencing large disturbing torques. Also, changes in the resolution of the panoramic cameras from before to after jet activation might be correlated to and explained by the jet firings. Initially, the purpose of recording the jet firings was to monitor any sudden changes in attitude that would affect the accuracies of making maps. Obviously, the recording of the jet firings also provides information as to the changes of the vehicle rates resulting from the operation of the vehicle control system.

3.3.2.2 Time Data

The recording of time data is valuable because it allows one to correlate the information recorded by the tape recorder, panoramic imagery, DISIC imagery, telemetry data, and the tracking and orbital data.

3.3.2.3 System Function Monitors

As mentioned, the diagnostic tapes record the outputs of 120 system function monitors. The outputs of these monitors are sampled by utilizing commutators, and recorded on two channels. Thus, 60 monitors sequentially time-share one channel and the other 60 monitors time-share the other channel. The system function monitors are described in Tables 3-4 and 3-5.

3.3.3 Telemetry Data

A significant amount of information about the system operation is telemetered to ground stations during a portion of each orbit. A large part of the telemetered data is pertinent to the system analysis studies. This data is generated by monitors and sensors located at various points in the system. The monitors relevant to the panoramic camera operation and the temperature sensors are discussed separately in the following paragraphs.

3.3.3.1 Monitors Relevant to Panoramic Camera Operation

The operation of the following panoramic camera components is monitored and transmitted through the telemetry system:

1. Filter position
2. Slit width position

3. Slit width failsafe
4. Film change detector
5. Tachometer feedback voltage
6. Servoamplifier output voltage
7. Drive motor voltage
8. Cycle counter
9. Center-of-format switch
10. Horizon optics platen position
11. Metering roller potentiometer
12. Idler roller potentiometer
13. Framing roller potentiometer
14. Shuttle position
15. Center-of-scan switch
16. Supply spool motor voltage
17. Takeup spool motor voltage
18. 99/101 clutch operation
19. Clock serial word
20. Real Time Command and Stored Program Command status monitors
21. Yaw programmer
22. Horizon optics platen solenoid
23. Horizon optics shutter solenoid
24. V/h control voltage
25. Voltage and current monitors

3.3.3.2 Temperature Sensors

The recording of the temperature of various critical components of the system indicates directly whether these components remained within their designed operational temperature range. Some components, like transistors, fail when they are overheated. Others, like the Petzval lens, suffer a deterioration in performance either under extreme temperatures or under extreme temperature gradients. There are about 60 temperature sensors in the J-3 system, of which 24 are allocated to the cameras.

Temperature sensors are placed at the mounting points of the delta structure to the vehicle for the purpose of testing the paint pattern applied on the external surface of the vehicle. These sensors also provide information about changes in the distance between the nodding shaft and the upper mounting point of the FMC linkage. This is a critical dimension in the FMC linkage. An increase of this distance from its ambient dimension reduces the stereo angle. Thus, temperature variations in the delta structure affect the stereo angle, but in the magnitude of arc-seconds. The performance of the system is not degraded, but since the stereo angle is calibrated at the West Coast, it is desirable to determine whether the stereo angle has undergone small changes during the mission. Actually, if the stereo angle has undergone changes, the changes would be detected by the nodding shaft encoders of both panoramic cameras.

Thus, very accurate measurements of the change of the stereo angle will be provided by the displacement of the zero nod dots of both cameras from their initial positions on the format. Therefore, the temperature data related to the stereo angle should be correlated with the information provided by the nod dots.

A temperature sensor is located on the scan drive motor to record any overheating of the motor due either to excessive overloading of the motor or insufficient heat dissipation.

A temperature sensor is attached to the power amplifier portion of the scan servo electronics. A very high temperature measurement by this sensor could be correlated with a possible failure in the scan servo, and it would identify the overheating of the transistors as the source of the failure.

There are temperature sensors on the film guide rails for the purpose of monitoring the dimensional changes of the rails and thus the changes in the panoramic geometry calibration of the rail holes.

Finally, there are two temperature sensors on the Petzval lens because it is known that the lens resolution is reduced when there are large temperature gradients either along or across the lens system.

It has been mentioned that, in the J-1 system, the temperature data has usually been reduced so that the average temperature per orbit of a temperature sensor was obtained. Though this type of information may be useful for testing the temperature control system, it has very little value for the system analysis studies. The temperature sensors should be sampled frequently during the photographic passes so that fast temperature oscillations may be recorded faithfully.

3.3.4 Ephemeris and Tracking

The orbital information provided by the ephemeris and by the tracking stations is very valuable because it allows one to establish the correct orbit as a function of time and, thus, the true V/h as a function of time. Knowledge of the altitude as a function of time is also important because it is necessary to determine the scale factor between panoramic image dimensions and ground distances. The scale factor permits correlation between image resolution in lines per millimeter and ground resolution in feet.

3.4 ANALYSIS OPERATIONS

It is obvious from the above discussion that a significant amount of data is to be examined, processed, and evaluated. This can be accomplished efficiently only by utilizing a computer. Therefore, the computer programs described in the following paragraphs must be written and checked out.

1. A computer program must be developed for averaging the edge traces obtained from the resolution tests performed at Boston. The output of this program would be the standard edge trace profiles.

2. A computer program which fits edge traces obtained from operational material to the standard edge trace profiles in a least squares sense must be developed. This program is also needed to check the standard edge trace profiles obtained from item 1 (above) and to statistically establish the variance of determining the resolution by the edge trace technique. It should also be made clear that, when the edge trace technique is used for determining the resolution of the operational material, as many edge traces as possible should be processed with this computer program, and the final resolution should be the mean of all the resolutions obtained by individual edge traces. In this manner, the final resolution will be a statistically determined quantity.

3. Separate computer programs are needed for examining the diagnostic tapes and the telemetry data. As far as it is possible, this search will be conducted by developing a typical data output for each of the two sources of data and comparing it with the data obtained during the mission. Thus, one should be able to scan the data rapidly in the computer and check it for abnormalities. If the data differs significantly from the standard data, it would then have to be examined more closely.

The orbital data will be recorded according to pass number so that V/h and altitude would be readily available.

3.5 DATA REQUIREMENTS AND ACCESS TO FACILITIES

For the resolution analysis, it is required that a first generation positive of the operational material (panoramic and DISIC photograph record) be available at the National Photographic Interpretation Center (NPIC) or Westover Air Force Base for scrutiny by the systems analysis group. This positive will be visually examined by the group for the purpose of selecting appropriate images for edge tracing. It is also necessary to have access to the original negative for the purpose of evaluating the CORN target images and obtaining the desired edge traces. It is proposed that Westover Air Force Base provide adequate space and equipment for the systems analysis group to view the negative. (A similar area may have to be provided in Washington.) At the present time it is anticipated that an illuminated viewing table, a bench, and a desk would be sufficient. The base would also supply the systems analysis group with the desired edge traces obtained with a microdensitometer from the original negative, and occasionally supply the group with a small number of special prints reproduced under various magnifications from the original negative.

A complete description of the CORN targets and photometric and atmospheric measurements made at the time of operation as well as mission plan information is required. The orbital data is processed by A/P and should be made available to the systems analysis group, both in the form of IBM cards and copies of the computer prints. The telemetric data should be recorded both on visicorder paper and analog magnetic tape, since it will be necessary to convert it to either IBM cards or computer magnetic tape. The data of the recoverable tape recorder should be made available on visicorder paper and IBM cards.

Table 3-1 — Cross-Track Blur Budget, 2.44-Millisecond Exposure, 3σ Values, 3404 Film

	Error Type	Image Blur, 80 nm	Microns, 100 nm	Accuracies Assumed
Camera Sources				
Vibration	R	2.0	1.0	
Film lift	S	1.78	1.42	0.007-inch film lift
Lens distortion	S	0.83	0.64	5 microns distortion at edge of format
Nodal point location	F	0.44	0.36	±0.002 inch
Cross-track image motion	S	$9.8 \sin 2\theta$	$7.9 \sin 2\theta$	
Interface Sources				
Yaw alignment	F	$0.24 \cos^2 \theta$	$0.19 \cos^2 \theta$	11 minutes
Pitch alignment	F	$0.11 \sin 2\theta$	$0.086 \sin 2\theta$	11 minutes
Vehicle Sources				
Roll attitude	R	$0.17 \sin^2 \theta$	$0.13 \sin^2 \theta$	0.54 degree
Yaw attitude	R	$1.11 \cos^2 \theta$	$0.89 \cos^2 \theta$	0.84 degree
Yaw programmer	R	$1.29 \cos^2 \theta$	$1.06 \cos^2 \theta$	1 degree
Pitch attitude	R	$0.42 \sin 2\theta$	$0.33 \sin 2\theta$	0.70 degree
Roll rate	R	0.12	0.12	10 degrees per hour

Table 3-2 — Along-Track Blur Budget, 2.44-Millisecond Exposure, 3σ Values, 3404 Film

	Error Type	Image Blur, 80 nm	Microns, 100 nm	Accuracies Assumed
Camera Sources				
Vibration	R	2.0	1.2	
IMC servo	R	2.23 cos θ	1.78 cos θ	3 percent
IMC cam error	R	2.23 cos θ	1.78 cos θ	3 percent
Uncompensated image motion	S	1.85	1.48	At edge of format
Interface Sources				
Orbital determination	R	2.23 cos θ	1.78 cos θ	3 percent
V/h command	R	2.23 cos θ	1.78 cos θ	3 percent
Roll alignment	F	0.24 sin θ	0.19 sin θ	11.4 minutes
Pitch alignment	F	0.120 cos θ	0.095 cos θ	11 minutes
Vehicle Sources				
Roll attitude	R	0.68 sin θ	0.54 sin θ	0.54 degree
Pitch attitude	R	0.47 cos θ	0.37 cos θ	0.70 degree
Pitch rate	R	0.10 cos θ	0.10 cos θ	14.4 degrees per hour
Yaw rate	R	0.10 sin θ	0.10 sin θ	14.4 degrees per hour
Terrain height variation	R	0.36	0.29	3,000 feet

Table 3-3 — Performance Predictions, 2.44-Millisecond Exposure, 2:1 Contrast, 2σ Values, 3404 Film

	Along-Track Position in Format		Cross-Track Position in Format	
At 100 nm	0°	30°	0°	30°
Blur, microns	2.52	2.24	2.60	9.28
Resolution, lines per millimeter	135	137	134	80
Ground resolution, feet	7.6	8.7	7.7	14.9
At 80 nm				
Blur, microns	3.28	2.93	3.56	11.90
Resolution, lines per millimeter	128	132	126	72
Ground resolution, feet	6.4	7.2	6.5	13.2

Table 3-4 — System Function Monitors, Electronic Commutator Ring A

Pin	Description
1	Calibrate one-half
2	Program select—fives
3	Program select—units
4	Left and right stellar platen position
5	Pan no. 1 and no. 2 exposure cont.—fives
6	Pan no. 1 and no. 2 exposure—units
7	Terrain platen position
8	Yaw programmer enable/disable—units
9	Yaw and oblateness operate
10	Recovery mode and fairing separate
11	Eccentricity function position
12	4-cycle counter
13	Operation select control
14	Pan no. 1 and no. 2 slit width failsafe
15	Calibrate zero
16	Pan no. 1 cycle counter—1,000's
17	Pan no. 1 cycle counter—100's
18	Pan no. 1 cycle counter—10's
19	Pan no. 1 cycle counter—1's
20	Calibrate zero
21	Pan no. 2 cycle counter—1,000's
22	Pan no. 2 cycle counter—100's
23	Pan no. 2 cycle counter—10's
24	Pan no. 2 cycle counter—1's
25	DISIC control selector
26	DISIC terrain cycle counter—1,000's
27	DISIC terrain cycle counter—100's
28	DISIC terrain cycle counter—10's
29	DISIC terrain cycle counter—1's
30	Calibrate plus
31	FMC function output voltage
32	V/h eccentricity start command and operate relay
33	Pan no. 1 slit position
34	Pan no. 2 slit position
35	DISIC—1 mode and terrain exposure
36	Pan no. 1 filter position
37	Pan no. 2 filter position
38	Emergency bypass enable/disable
39	Pans exposure command
40	Pan no. 1 and no. 2 film change detector
41	Exposure control delay select—fives
42	Exposure control delay select—ones
43	No. 1 takeup spool and film diameter
44	Pan no. 1 operate voltage
45	No. 2 takeup spool and film diameter
46	Pan no. 2 operate voltage
47	Stellar spool and film diameter
48	DISIC operate command and 1 RPC cam
49	Terrain spool and film diameter
50	Operate selector no. 1—fives
51	Operate selector no. 1—ones
52	Operate selector no. 2—fives
53	Operate selector no. 2—ones
54	Camera control and operate mode select—fives
55	Camera control and operate mode select—ones
56	DISIC mode select
57	Calibrate zero
58	Sync
59	Sync
60	Sync

Table 3-5 — System Function Monitors, Electronic Commutator Ring B

Pin	Description
1	Calibrate one-half
2	115-volt, 400-cycle voltage (C phase)
3	Pan film door and DISIC C & S position
4	PMU outlet pressure switch
5	PMU bottle pressure
6	Total payload unregulated current
7	24-volt unregulated voltage
8	Pyro current
9	Pan no. 1 drive motor voltage A
10	Pan no. 1 tachometer feedback voltage
11	Pan no. 1 drive motor voltage B
12	Pan no. 2 drive motor voltage A
13	Pan no. 2 tachometer feedback voltage
14	Pan no. 2 drive motor voltage B
15	Clock internal 24 volts
16	DISIC motor voltage
17	Yaw and oblateness position
18	Yaw resolver output
19	Total payload unregulated current
20	Pan no. 1 supply motor voltage
21	Pan no. 2 supply motor voltage
22	Pan no. 1 H.O. platen positions
23	Pan no. 2 H.O. platen positions
24	Pan no. 1 H.O. platen and shutter command
25	Pan no. 2 H.O. platen and shutter command
26	Left and right stellar capping command
27	Pan no. 1 and no. 2 launch mode
28	Terrain and stellar clutch commands
29	Calibrate plus
30	Left and right stellar door separation
31	Pan and terrain door separation
32	Total payload unregulated current
33	Terrain capping command
34	A and B SRV separations
35	“A” SRV recovery battery voltage
36	“A” SRV water seal positions
37	“B” SRV recovery battery voltage
38	“B” SRV water seal positions
39	V/h start level selector—fives
40	V/h start level selector—ones
41	V/h half-cycle level select—fives
42	V/h half-cycle level select—ones
43	V/h delay start selector—fives
44	V/h delay start selector—ones
45	Total payload unregulated current
46	Pan no. 1 output idler rotation, 99/101 clutch command
47	Pan no. 2 output idler rotation, 99/101 clutch command
48	Pan no. 1 angular position, CF command
49	Pan no. 2 angular position, CF command
50	Calibrate plus
51	Pan no. 1 output idler
52	Pan no. 2 output idler
53	Pan no. 1 frame metering rotation
54	Pan no. 2 frame metering rotation
55	Pan no. 1 supply metering rotation
56	Pan no. 2 supply metering rotation
57	Calibrate zero
58	Sync
59	Sync
60	Sync

4. PHOTOGRAPHIC ANALYSIS

Whereas Section 3 dealt with the first portion of the overall J-3 performance analysis (i.e., the identification of the reasons for variations in the J-3 photographic quality induced by the hardware), this section deals with the effects on image quality emanating from factors external to the equipment. This general category of photographic variables includes exposure, filter selection, atmospheric haze, and film processing (reproduction). The prime objective of this portion of the system analysis studies will be to identify these photographic variables and assess their effect on the overall performance of the J-3 system. This effort is described in Section 4.1.

The secondary objective of the photographic analysis will be concerned with the evaluation of the satellite test program. At present, four J-3 missions (CR-1 through CR-4) are scheduled to allow operational type testing of the most promising of the new reconnaissance techniques investigated to date under the EKIT program. The basic goal of the EKIT program has been to evaluate new and promising photographic techniques for use in satellite reconnaissance. Such techniques as night photography, bi-color, new films, etc., have been evaluated for their potential J-3 use. The basic approach of the EKIT series has been to use a high-flying aircraft, with a camera similar to the J-3 camera, to gather the test photography. From the analysis of this photography, a recommendation has been made on the applicability of each of these techniques for satellite use.

These satellite tests will be evaluated somewhat separately from the general system analysis studies since the emphasis on the satellite test evaluation is somewhat different. The satellite test evaluation is concerned mainly with the value of the material or technique itself (i.e., is night photography feasible at satellite altitudes), whereas the system analysis studies are concerned primarily with system evaluation. The satellite test evaluation effort is described in Section 4.2.

It is the ultimate goal of the photographic analysis work to establish a data base and computer programs which will allow the routine analysis of J-3 photography. In this manner we will be able to continually monitor the performance of the J-3 system on a mission by mission basis. It is important, however, that this be done on a timely basis so that improvements can be programmed as soon as possible. This computer modeling work is described in Section 4.3.

4.1 PHOTOGRAPHIC EVALUATION

The work involved in evaluating the overall photographic performance of the J-3 system is somewhat difficult to clearly define, since photographic quality is not a precisely defined concept. Many factors enter into a discussion as to whether or not an image is good or bad, or better or worse than another. However, the major factors which effect photographic performance are known, can be isolated, and will be evaluated.

The major areas of investigation in this portion of the proposed effort are as follows

Exposure Analysis. It is commonly known that exposure (or exposure variation) alters image quality. It is not commonly agreed, however, as to what constitutes proper exposure. The problem of adequately defining proper (or best) exposure has been with us for some time. The exposure control of J-3 affords the first real opportunity to investigate exposure effects in a scientific manner.

Reproduction Analysis. An analysis of the reproduction process and materials is necessary for a total system evaluation. The first generation positives are an integral portion of the Corona system, since these are the main outputs viewed by the photo-interpreter. Any degradation introduced by the duping process must be known to allow them to be factored in (or, better yet, out of) the J-3 camera analysis. It will not be our purpose to evaluate the physical duplication process per se, but only to evaluate it from the standpoint of its effect on the assessment of camera performance.

Atmospherics. As with the exposure problem, it is well known that atmospherics play a significant role in the quality of satellite photography. Further, as with exposure, the practical relationships between atmospherics and image quality are not known.

4.1.1 Exposure Analysis

The problem of assessing the adequacy of exposure obtained with the Corona system has been a continuing difficulty. There are groups in the community who feel that the photography is underexposed, and there are others who feel that it is properly exposed (and in fact for some targets,* nearly always overexposed). Many hours of discussion have been directed to this question, without much positive result. The difficulty lies in the fact that there is little useful quantitative data upon which to base a meaningful decision.

The main technique used today for quantitatively assessing exposure is the density analysis being conducted by Eastman Kodak and Westover AFB. In these analyses, minimum and maximum "terrain" densities are measured within a number of frames

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*Unless otherwise stated, references to targets refer to ground objects (airfields, missile bases, etc.), that were an objective of the mission.

for each mission. This information is summarized to show the percentage of over/underprocessed, and over/underexposed original material. Further, the data are summarized into histograms in the attempt to define the percentage of minimum densities recorded as too low, and the percentage of maximum densities recorded as too high. A sample of this data summary for mission 1029-2 is shown in Fig. 4-1.

This data is used for several types of analysis, but most frequently it is used to aid in the assessment of correct exposure. Fig. 4-2 demonstrates a summary plot that has been recently generated to illustrate the overall density relationship for the past several missions. This is compared with the amount of each processing level (primary, intermediate, and full), in order to illustrate (or at least suggest) that more exposure is needed, and that we are dangerously close to the absolute minimum exposure that can be given. Perhaps this is true, and perhaps it is not. The point is that this type of analysis does not really give the information desired for an exposure decision. This is not to say that the density analysis work is of no value, for it has a real application for evaluating apparent object luminances and brightness ratios as seen by a satellite photographic system. More details on the determination of exposure by means of density analysis are contained in Appendix A.

The results of this investigation and work done in conjunction with NPIC leads us to propose that the main emphasis for photographic evaluation be centered in an analysis of targets rather than terrain. In support of this hypothesis, the following pages discuss the work done with NPIC.

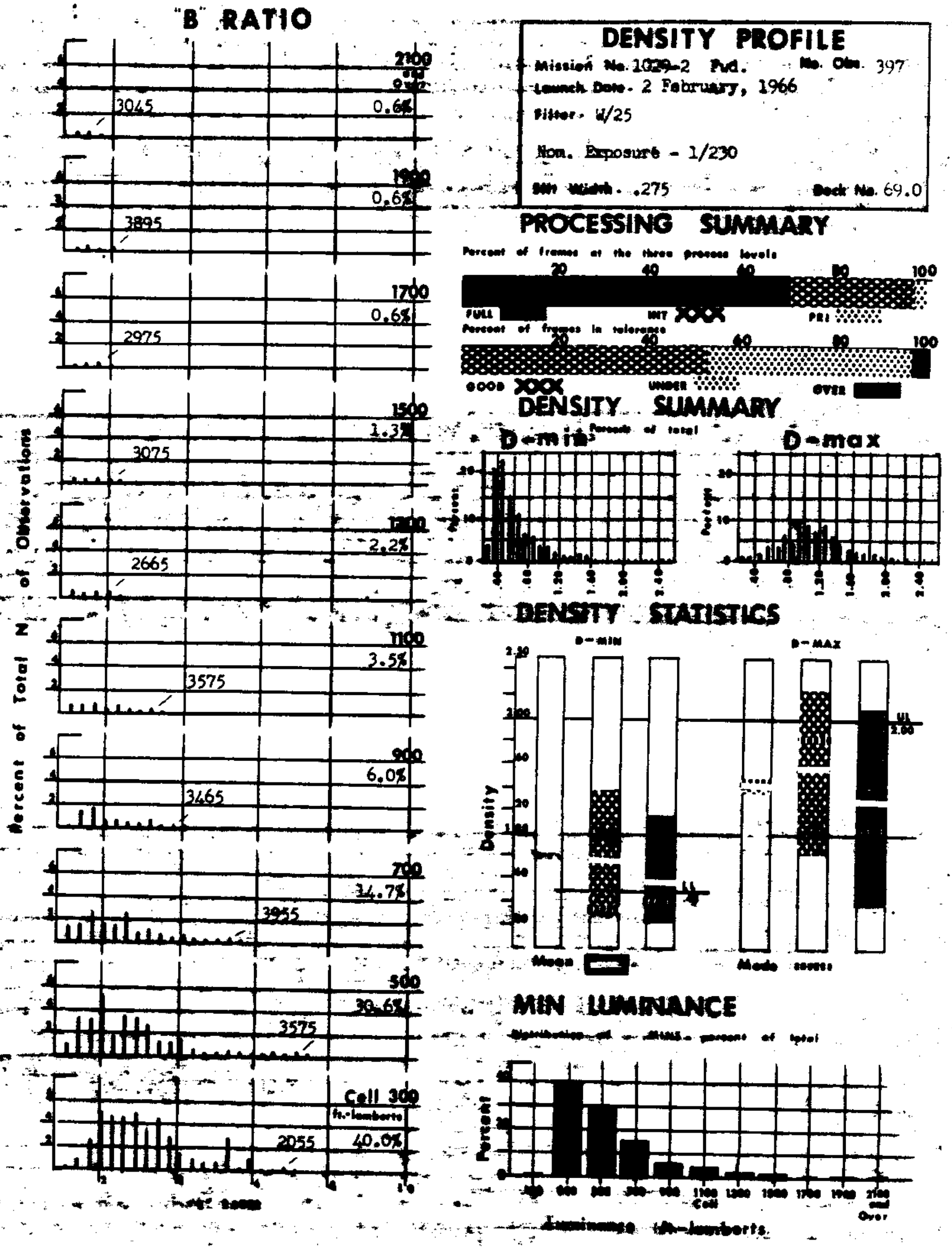
4.1.1.1 Prior Mission Evaluation

Some work has been done in conjunction with NPIC to evaluate the relationships between target and terrain minimum and maximum deviation. This work was done on two missions, selected at random, 1023 and 1034. The basic analysis procedure of both missions was to make microdensitometer traces (using 10- × 10-micron aperture) of operational COMOR priority targets. These targets were selected by NPIC. The peaks and valleys on the traces were chosen as the D_{max} and D_{min} respectively for the target. The result of these analyses are discussed below.

Mission 1023-1

Mission 1023-1 was initially selected for analysis since it was reputed to be significantly underexposed by the processing contractor, while the photointerpreter reputed that it was an excellent mission. The processor was basing his conclusions, of course, on the terrain density measurements.

One of NPIC's analysts randomly selected COMOR priority targets and these were measured on the microdensitometer. The results are shown in Table 4-1 where they are compared with the ASFPPR terrain measurements. This comparison provides some interesting observations.



Mission No. 1029-2 Fwd.
No. Obs. 397
Launch Date 2 February, 1966
Filter W/25
Nom. Exposure - 1/230
Slit Width .275
Back No. 69.0

Fig. 4-1 — Density profile

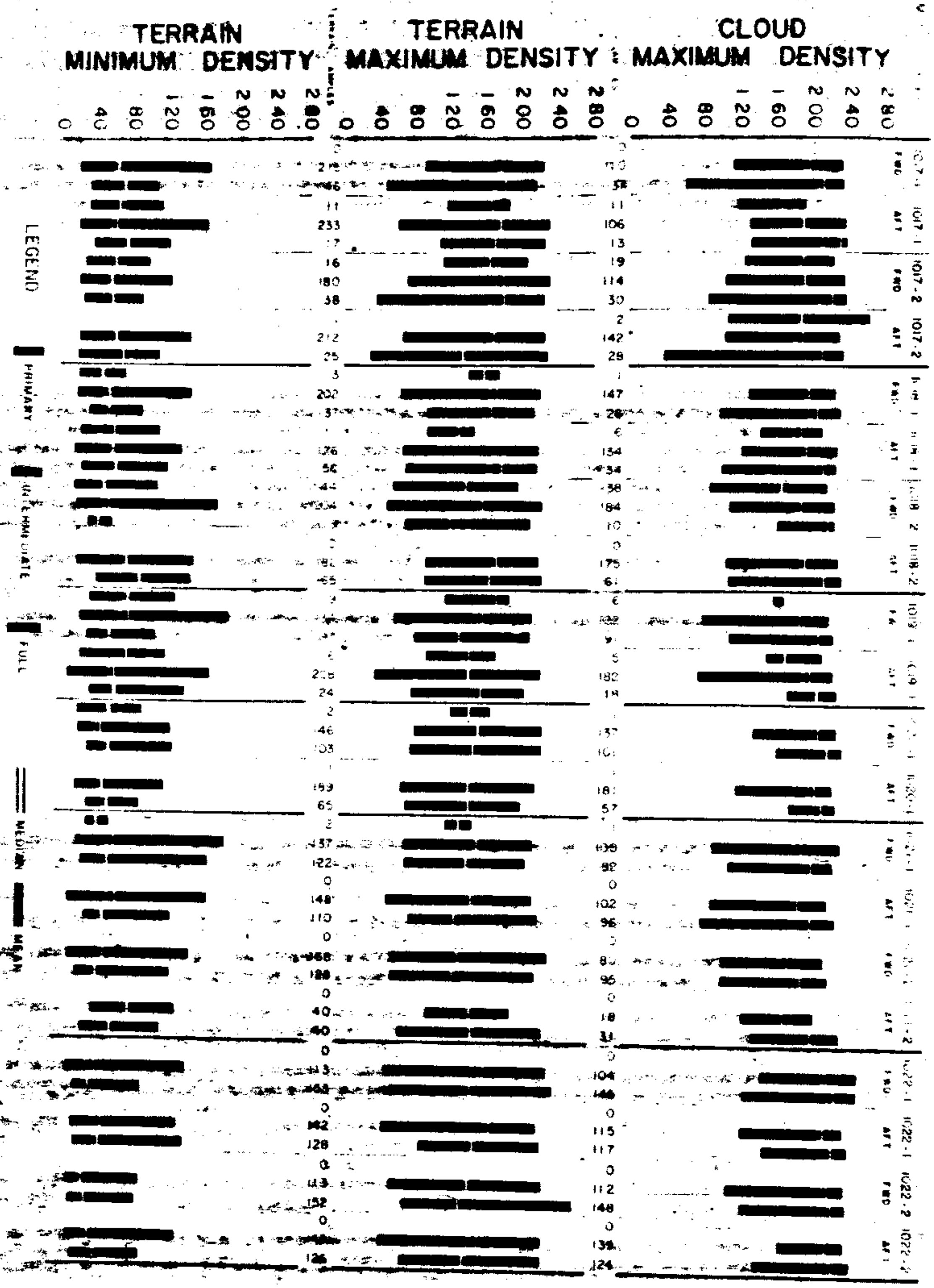


Fig. 4-2 — J-mission density ranges

Table 4-1 — Mission 1023-1 Density Analysis

Mission 1023-1	Measurement	D_{min} Range	D_{min}, average	$D_{min}\sigma$	Number of Samples
Forward	AFSPPF/Terrain	0.15 to 1.26	0.39	0.17	278
	NPIC/Target	0.18 to 1.41	0.76	0.37	16
Aft	AFSPPF/Terrain	0.20 to 1.40	0.53	0.21	269
	NPIC/Target	0.77 to 0.99	0.85	0.10	5

Mission 1023-1	Measurement	D_{max} Range	D_{max}, average	$D_{max}\sigma$	Number of Samples
Forward	AFSPPF/Terrain	0.43 to 2.41	1.22	0.36	278
	NPIC/Target	1.22 to 2.05	1.61	0.27	16
Aft	AFSPPF/Terrain	0.41 to 2.21	1.31	0.34	269
	NPIC/Target	1.33 to 1.61	1.44	0.12	5

First, in general, the target D_{min} values are higher than those of the terrain D_{min}. This is verified by the higher average D_{min} value for the targets.

Second, the lower levels of the target D_{max} values are higher than those for terrain values. The upper limit of the D_{max} values for the targets are, however, lower than that for the terrain areas. What is significant, however, is that the average density level of the targets is higher than that of the terrain areas.

Third, it is most significant that both the D_{min} and D_{max} value of the target areas are higher (from 0.1 to 0.4 density units higher) than their comparable terrain values. What this suggests is that, in fact, the target areas are more heavily exposed than the terrain areas. This fact could explain why the photointerpreters thought this was a good mission whereas the processing contractor thought it was underexposed. They were making observations on different things, the photointerpreter on targets and the processing contractor on terrain areas.

Fourth, what is particularly interesting is that the target density analysis seems to agree more with the photointerpreter even though the sampling was considerably smaller than the terrain density analysis.

Mission 1034

It was realized that the mission 1023-1 analysis was somewhat limited in its scope, hence, a further study was undertaken. NPIC made similar measurements, on mission 1034, on 60 operational target airfields. Again the targets were selected by an NPIC analyst. The results of this evaluation are shown in Table 4-2. In this case the comparison is against the Eastman Kodak measured density values. As with 1023-1, some interesting observations are possible.

First, and again in general, the target D_{min} values are higher than the terrain D_{min} values. In fact, on the 1034-2 portion, the target average D_{min} values were over 0.90 (0.93 and 1.28), whereas the terrain measured values were relatively less being 0.50. It is interesting to note here that, by the analysis of terrain density data, the exposure/processing is in specification (i.e., D_{min} between 0.48 and 0.90). The target D_{min} information says we are out of specification, being either overexposed or overprocessed for the targets.

Second, on the target D_{max} analysis, targets on three of the four portions of the mission went to absolute D_{max} (2.60). The target average D_{max} values were considerably higher than the terrain D_{max} values by an average of about 0.5-density units.

Third, and again as with 1023-1, the analysis of target densities yields a different picture of the exposure given the material as compared to the terrain density analysis. The analysis in general illustrates what many have claimed, that target areas are overexposed or at least of a higher density than the typical terrain areas.

Table 4-2 — Mission 1034 Density Analysis

Mission 1034-1	Measurement	D_{min} Range	D_{min}, average	$D_{min}\sigma$	Number of Samples
Forward	EK/Terrain	0.25 to 1.45	0.53	*	
	NPIC/Target	0.48 to 1.35	0.78	0.26	12
Aft	EK/Terrain	0.38 to 1.35	0.50	*	
	NPIC/Target	0.41 to 0.80	0.54	0.16	6

Mission 1034-1	Measurement	D_{max} Range	D_{max}, average	$D_{max}\sigma$	Number of Samples
Forward	EK/Terrain	0.55 to 2.20	1.20	*	
	NPIC/Target	1.39 to 2.69	2.14	0.46	12
Aft	EK/Terrain	0.52 to 2.25	1.30	*	
	NPIC/Target	0.74 to 1.65	1.30	0.42	6

Mission 1034-2	Measurement	D_{min} Range	D_{min}, average	$D_{min}\sigma$	Number of Samples
Forward	EK/Terrain	0.38 to 1.25	0.50	*	
	NPIC/Target	0.74 to 1.85	1.28	0.30	34
Aft	EK/Terrain	0.35 to 1.55	0.50	*	
	NPIC/Target	0.35 to 1.39	0.93	0.32	8

Mission 1034-2	Measurement	D_{max} Range	D_{max}, average	$D_{max}\sigma$	Number of Samples
Forward	EK/Terrain	0.69 to 2.0	1.4	*	
	NPIC/Target	1.78 to 2.69	2.14	0.22	34
Aft	EK/Terrain	0.55 to 2.30	1.30	*	
	NPIC/Target	1.52 to 2.69	1.82	0.38	8

*Data estimated from histograms, σ and number of samples not available.

This initial work tends to confirm the original hypothesis that exposure analysis should be made from target areas and not typical terrain areas. By using this approach we feel that a more accurate indication of system performance will be attained.

4.1.1.2 Use of Exposure Data

The two specific goals of the exposure analysis work, are: (1) to evaluate the validity of the exposure control system, and (2) to evaluate the exposure vis-a-vis the targets and their locations.

Validity of Exposure Control System

The intent of the exposure control system is to provide proper exposure over a greater range than is currently achieved with the J-1 system. How well the exposure control system performs, however, is a valid question that needs to be evaluated. Two prime questions will be answered in this analysis: (1) over what solar altitude range (and therefore latitude range) does the exposure control system give proper exposure, and (2) are the exposure changes made at the proper place. The exposure cam changes the exposure at preprogrammed intervals. Whether or not the proper intervals have been selected can only be determined from a quantitative analysis of the resultant photography.

Exposure Vis-A-Vis the Targets

The exposure for the J-3 system is programmed based primarily on solar altitude. No input is made regarding the type or location of the target. In the previous discussion the point was made that exposure analysis should be done from target density readings instead of typical terrain areas. We plan to use this approach for all our proposed exposure work. To obtain target density traces from operational material we feel that we can work with NPIC as in the past.

By knowing the geographical location of the priority targets and their reproduction, a very meaningful analysis can be performed. For example, the current J-3 exposure change is based primarily on solar altitude. It is possible, however, that this may not be the best method for making exposure changes. If a large percentage of targets are in a given latitude band (and not distributed), then it may be desirable to bias the exposure control in favor of the best exposure for the largest percentage of targets.

In support of this work we recommend strongly that the CORN targets be used liberally on these missions. The CORN data will allow correction of the target density traces to known luminances. Also it will allow quantitative evaluation of the exposure latitude of the system. Most important, however, it will allow the specification of how objects are being reproduced; i.e., for example, the lowest and highest reflectance object that can be recorded and whether or not this is sufficient for the purpose of the Corona system. Some details on the analysis of CORN targets are contained in Appendix B.

4.1.2 Reproduction

The system analysis studies will include some analysis of the reproduction process used to duplicate the original negatives. This work is required since the main product used by the photointerpreter is the dupe positive, and all his statements regarding J-3 performance (quality) will be made from the dupe positives. To factor the photointerpreter comments into the analysis of J-3 system performance properly, we should at least be aware of what affect the duping process had on the imagery. The point is that image quality can be affected by the manner in which the tone reproduction process is put together. What we are concerned with, therefore, is the relationship of the reproductive process to image quality.

It is not envisioned that considerable work is needed on this area since the basic question is simple, that is, have the dupes reproduced all that is on the original negative or is there a disparity between the two that would significantly reduce the information content and lead the photointerpreter to a faulty judgment of camera performance. Appendix C presents the detailed data relative to the reproduction analysis.

4.1.3 System Performance and Atmospherics

To optimize system performance, a closer look must be taken into the field of atmospheric optics. The atmosphere, of course, acts as a light scattering medium between the camera and the ground, and its effect on the photography is one of degradation. Since the scattering is wavelength dependent and for most atmospheres is predominantly blue, the classical approach in aerial photography has been to incorporate a minus blue haze reducing filter in the camera system. This approach is basically sound for general application. However, in attempting to optimize system performance, a more scientific approach should be taken to the selection of a spectral filter. For a given system and a given application, the spectral filter should be chosen so as to give the maximum statistical haze reduction with accompanying increase in object contrast. Also to be considered in this selection are the tradeoffs of exposure time (as it affects image motion) and the possible loss of shadow detail due to over-attenuation of the predominantly blue shadow light.

In the Corona system, the problem is complicated by the fact that the two main cameras look at the earth from different directions, one looking forward (generally into the sun) and one looking aft (away from the sun). The question arises as to if and how seeing conditions vary in these two directions. Obviously, much will depend on the position and solar altitude of the sun relative to the camera system. Under certain conditions, optimization of performance may require the same filter in each camera or different filters in each camera. It may even be advantageous to change filters from time to time in one or both of the cameras.

Another consideration in optimizing the system might be the use of a polarizing filter.* The degree of polarization and its affect on a camera system is dependent on many factors such as the composition of the atmosphere, the altitude and azimuth of the sun, the position of the camera, the look angle of the camera, the ground illumination, the reflectance of the ground objects, etc. A careful evaluation of this problem should reveal the degree of polarization in a given direction and how effective a polarizing filter would be in reducing unwanted energy and thereby in enhancing optical performance.

To answer these and other questions pertaining to the effects of the atmosphere on the Corona system performance and to increase our overall knowledge in this field, Itek proposes an effort which will attack the problem on both a practical and theoretical basis. The practical effort will be directed towards evaluating existing Corona photography and the photography of the new Corona system. This effort is discussed in paragraph 4.1.3.1. The theoretical effort will be directed by Richard Barakat, an internationally known authority in the field of physical optics. It will be directed at the basics of atmospheric radiative transfer, and its goal will be the possible establishment of models for satellite photography. This effort is discussed in paragraph 4.1.3.2.

4.1.3.1 Analysis of the Index Camera Photography

Itek feels that the information potential of the index camera photography has not been fully exploited in the J-1 system. The index photography provides large area coverage of strategic regions throughout the year. As such, it naturally provides a graphic record of these areas which can be used to extract both quantitative and qualitative information. In addition, however, the index camera also has the potential for being a well calibrated photographic photometer. Utilization of these two potentials makes data available for studying the seasonal and temporal variations of large areas throughout the year. These data provide information on the effects on the photographic parameters of weather, ground scene reflectance characteristics, solar azimuth and elevation, latitude and longitude, etc. This information, handled statistically, can then be applied to the main panoramic cameras to optimize exposure and filtration conditions for specific targets and target areas.

Years of experience with the Corona system have shown that there exists a correlation between the visual appearance of the index photography and the image quality of the high resolution panoramic cameras. When the index photography looks flat due to heavy atmospheric haze, invariably the panoramic photography is poor. The converse is true, i.e., when the index material looks sharp with good contrast, the panoramic photography is generally excellent. It would, therefore, seem only natural to exploit this correlation.

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*Fraiser, R. S., Apparent Contrast of Objects on the Earth's Surface As Seen From Above the Earth's Atmosphere, J. Opt. Soc. Am., Ser. 3, 54 (March 1964).

The index photography with its $1\frac{1}{2}$-inch lens and 70-millimeter format produces photography at a scale of 1:5,000,000 at nominal altitudes.* This amounts to a ground area coverage of roughly 200 by 200 miles. The optical parameters of the lens (T-number) and the shutter exposure time are well calibrated. The 3400 film is sensitometrically processed to a gamma of 1.0. It can, therefore, be used to acquire absolute photometric data about the characteristics of the ground scene and the intervening atmosphere.

The two major uses of the index camera photography are seen to be: (1) analysis of weather, and (2) analysis of terrain characteristics. Although the Corona system does not provide hourly or daily coverage of points on the earth, it does cover the same general areas on a fairly repetitive basis. There is generally one mission per month with photographic acquisition for 1 to 2 weeks during the month. Thus, enough coverage is obtained to study the gross weather and terrain characteristics throughout the year and to determine if there are predictable patterns to the changes. If, indeed, these factors can be predicted, then steps can be taken to improve the system performance through biased filtration and exposure with the result of a statistically higher information yield per mission.

In terms of weather, the most obvious analysis is that of cloud cover. By evaluating the amount of cloud cover on an area basis, one can determine the percentage of cloud cover and deduce the probability of covering a target in a given area.

The index photography is useful for evaluating photographically not only impenetrable cloud cover, but also thin cloud layers through which some photography is possible. Often, because of the larger scale, thin clouds are not readily discernible on the panoramic photography. The resulting poor imagery is often diagnosed as either poor system performance or unusual haze conditions.

When there are clouds, there are obviously cloud shadows on the ground. The area covered by the cloud shadow will depend on the sun elevation and the camera look angle. Since the shadowed area receives less light than the direct illuminated area, the exposure is affected; the exposure, in turn, affects image quality. These data should be added to the weather picture.

The index photography can also prove useful for studying the haze conditions of the atmosphere over certain regions. The cause of haze is well known; it is due to water vapor and foreign particles in the atmosphere. Certain regions have normally typical haze conditions associated with them. Jungle regions have hazy atmosphere due to the high water vapor injection. Deserts, in contrast, have generally clear dry atmospheres, except when the wind is blowing to create dust storms. Industrial areas have haze

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*For J-3, of course, the DISIC has different parameters, although the area coverage is about the same.

produced by heavy combustion byproducts. Temporate regions have generally clearer, dryer air in the fall and winter as the cooler atmosphere holds less water vapor.

Haze particles affect the scattering characteristics of the atmosphere both quantitatively and qualitatively. An increase in haze particles causes increased scattering and an accompanying loss in image contrast due to increased nonimage-forming light. The type of haze particles, and particularly their size, affect the spectral nature of the scattering. For a given haze condition, one type of spectral filter will be more effective than another. Certain target areas may be characterized by a particular type of haze formation which analysis of the index photography might discover. Such knowledge could then be applied to future missions.

Atmospheric haze as it affects image quality can be evaluated either quantitatively, i.e., calculated from measured values, or determined indirectly by the effect it produces, i.e., a reduction in scene contrast. The simplest and most common method of measuring scene contrast is D_{max}-D_{min} determination. The density difference on a comparative basis is a measure of scene contrast. On a hazy day the density difference will be reduced. This technique can be extended through controlled sensitometry to determine the scene brightness range or the effective scene contrast as seen by the camera. Though this technique has drawbacks due to (1) the possibility of human error in selecting the D_{max}-D_{min} values, and (2) the selection of a proper size measuring aperture, it does have the advantage of simplicity, plus the fact that these measurements have been routinely made on the index photography. We, therefore, propose initially to use these data to evaluate haze conditions for selected regions of index/Corona coverage.

In the future, a more complex, yet possibly a more accurate assessment of haze might be made by determining syzygetic scene contrast (see Appendix D).

4.1.3.2 Theoretical Investigations

The advent of very high altitude photographic platforms for viewing the earth has introduced a number of new factors into the problem of determining the quality of the photographic imagery involved. At lower altitudes, the main factors affecting the image are turbulence and haze. However, at higher altitudes the turbulence problem is no longer the limiting factor and it becomes of paramount interest to determine just what the relative value of these limiting factors are. To a great extent, the problem is one of radiative transfer in the atmosphere. However, it is a peculiar area of investigation in that the main problem is the determination of the relative amounts of scattered and diffusely reflected radiation directed outward from the atmosphere into the camera system of the platform, and the relative quantities do not remain constant.

Although a number of investigators have begun work on this problem, it cannot be said that any final conclusions have been reached. In fact, if anything, the conflicting claims of investigators have tended to obscure the main issues. Very high altitude photography of the earth is ultimately limited by the degradation of the object contrast by the intervening atmosphere, and this loss in contrast results from nonimage-forming light in the optical path between the camera and the object (due to atmospheric scattering of molecular and aerosol origin). In the former case, the scattering is termed Rayleigh scattering. The conflicting influence of these two scattering regions is one of the principal causes of difficulty. Rayleigh scattering usually occurs on clear days, whereas aerosol scattering is prominent in a hazy atmosphere. Of course these results have been known for some time, and with the advent of high-speed computers, detailed calculations have been performed for various Rayleigh atmospheres. No serious calculations have as yet been performed using aerosol scattering and its influence, although important, is still not known quantitatively. The people who have carried out the vast majority of these calculations are geophysicists and meteorologists. Optical physicists have not as yet undertaken studies in this area and it is for this reason that we strongly feel that it is necessary to assess the influence of the atmosphere upon photographic image quality.

We propose to devote the first 4 months to a detailed review of the pertinent literature and to the preparation of a critical review of the state of the art with emphasis on problems that need to be solved. At present a critical review of the literature on high altitude photography does not exist, so that the preparation of the review in itself will be a worthwhile topic. After this review has been prepared we intend to begin investigation into various problems which we feel need studying. For example, because the light scattered from the atmosphere is polarized, the use of polarizing filters in one form or another has been advocated. However, in the calculation of the diffraction image, one of the main assumptions is that the incident radiation be unpolarized. In fact, all of the calculations performed have, without exceptions, been based on this unpolarized premise. Therefore, one topic seriously in need of investigation is the development of a theory which allows one to calculate diffraction effects in polarized light. A second topic of practical importance is the determination of optimum filter combinations.

It must be strongly emphasized that the development of photographic models which allow one to predict working parameters for actual field use is presently a near impossibility. Examination of some of the literature indicates that there have been two main lines of attack. The first being an ad hoc empirical parameterization. The philosophy has been that if enough parameters are chosen, one can possibly obtain useful results. Unfortunately, this method, by its very nature, cannot possibly succeed because the underlying physical theories are not utilized. Any correlation with actual data is probably more of a coincidence than anything else. The other line of attack, which is just coming into prominence, is to assume a Rayleigh atmosphere (or some modification of it) and to utilize the radiative transfer equations to calculate various quantities which are of possible interest. This approach is, of course, the more powerful of the two. However, it has not been carried to its logical conclusion. The people who have investigated this area have in themselves not been optically or photographically oriented and have omitted the effect of the incident radiation upon the actual viewing system, i.e., camera system and photographic film.

The important work of a number of authors with respect to the Rayleigh atmosphere must be tempered somewhat by the realization that the characteristics of the radiation field have been obtained on the basis of primary scattering only. However, it is obvious that primary scattering alone is not sufficient to be anything more than of qualitative interest. We must commence the study of the influence of higher order scattering if we are to obtain a realistic insight into the influence of the atmosphere on very high altitude photography. In addition, the complete state of polarization of the incident and emergent radiation must be included in the analysis as well as the employment of the exact fresnel reflection and refraction coefficient. We realize that in an undertaking of this order of magnitude one cannot hope for complete answers, however, a beginning must be made and we feel that we are capable of undertaking such a study in view of the fact that we have worked extensively in optical diffraction theory as well as the effects of atmospheric turbulence upon the optical image. Both Mr. Barakat and his assistants are conversant with radiative transfer theory and have published extensively in optical diffraction theory and image evaluation. It must be emphasized that the long range goal of this study will be to develop models which will enable us to optimize high altitude platform photography systems.

4.2 PROPOSED ANALYSIS OF CR SATELLITE TESTS

The EKIT test series were developed to evaluate promising photographic techniques by utilizing a photographic system similar to the J system in a high flying aircraft. The philosophy, generally, was that if a technique proved to be unsuccessful in the aircraft, it would not be recommended for a satellite test. The EKIT tests and results are summarized in Appendix E.

The object of the proposed CR satellite tests is to provide a practical test of the most promising results of certain of the EKIT tests. The results of the satellite series will allow us to draw conclusions as to the validity of the original premise, and establish whether or not further testing is warranted.

The following pages describe the analysis techniques that are to be used on each of the missions. The end product is to be a report for each of the missions summarizing the test itself, the analysis performed, and recommendations concerning the usefulness of that technique.

A summary of the tests to be performed on the first four Corona missions is given in Table 4-3.

4.2.1 Filter Comparison Test (CR-1)

The majority of Corona photography is acquired in the descending mode over northern latitudes. This means that practically all of the photography is taken with

Table 4-3 — Summary of Satellite Test Conditions

System	Camera	Film	Filter	Purpose
CR-1	Forward-looking	3404	W23A W25	Filter comparison
	Aft-looking	3404	W21 W23A	
CR-2	Forward-looking	3404 SO-180	W23A W15 plus W96	Use of camouflage detection film
	Aft-looking	3404 SO-340	W21 None	Night photography
CR-3	Forward-looking	3404 SO-380	W25 Polarizer	Ultrathin base, evaluation of polarizer
	Aft-looking	3404 SO-380	W21 W25	Ultrathin base
CR-4	Forward-looking	3404 SO-230	W25 W25	Evaluation of SO-230, bicolor, and wide bandpass filter
	Aft-looking	3404 SO-230	W21 W57	Evaluation of SO-230, bicolor, and wide bandpass filter

the sun in front of the vehicle. Under this condition, the forward-looking camera is looking into the sun while the aft-looking camera is looking away from the sun. Occasionally, however, ascending photography is taken as the vehicle approaches the northern latitudes from a southerly direction. This affords a good opportunity to compare camera filtration as it applies to camera look angle. The CR-1 test is planned to determine what filtration is best under these conditions.

4.2.1.1 Test Procedure

The first CR test flight will involve switching the Wratten filters during the last portion of the flight. For most of this mission the forward-looking camera will have the Wratten no. 23A filter, and the aft-looking camera the Wratten no. 21. The second filter position for each camera will contain the alternate filter. During approximately 12 percent of the mission, the filters will be switched so that the forward-looking camera will have the no. 21, and the aft the no. 23A. When the switch is made in the filters, an appropriate change will be made in the slit width to take into account the change in filter factors.

Though identical coverage with the filters in the new position will not be possible, there will be a sufficient number of areas covered in common to carry out the analysis. Since the filters in the second position will have the limited amount of coverage, they will be used as the reference, and corresponding areas on the remaining 87 percent of the mission will be sought for the comparison.

One factor that will complicate the analysis is the element of weather. It will be impossible to tell how much a comparison of the filters over any one area at different times is affected by weather. However, by taking advantage of the statistical nature of the problem when many different target areas are used, this difficulty becomes a smaller factor to consider. If, indeed, one filter is better than the other for a particular camera, this difference will show up over the average of all of the comparisons. The analysis to be performed for this test is outlined in the following section.

4.2.1.2 Analysis of CR-1

The prime criteria for determining the best filter for each camera will come from the photointerpreter's evaluations of the material. Since the improvements are oriented toward him, it will be primarily his decision as to which is best.

In support of his conclusions, several physical evaluations will be performed. There is a tradeoff between the filters (their effect on the image quality from the contrast and sharpness aspects) and the slit width (the effect of image blur) necessary to use these filters.

Edge analysis will be performed to determine the resolution obtainable with the different filters. With the subjective analysis, the prime difficulty will be in obtaining the same area covered under the two conditions of filtration. Once found, these same target areas can be used for edge analysis.

The quantitative data analysis has the unique advantage of being able to use mobile CORN targets when domestic passes are made. With maximum deployment of mobile CORN targets, sufficient edge samples can be obtained for a sound quality estimate of the resolution performance with each of the filters.

The second quantitative measure that will be useful is a contrast analysis using the CORN gray scale. If sufficient coverage is available, the effects on contrast of each camera and filter combination can be made. The tone reproduction techniques employed will be similar to the first four quadrants of the graph described in the bi-color work of Section 4.3. Density readings of the CORN targets will give the required measurements for the fourth quadrant. With the sensitometry of the negative and sensitive materials, the atmospheric (quadrant I) effects can be determined. This, then, would give an estimate of the effects of the two filters on the contrast independent of the processing condition.

J-1 operations which have had filtration under conditions similar to the CR-1 test conditions provide an additional source of data. This material will be utilized as complementary information to strengthen the conclusions drawn from the CR-1 test.

It will be necessary to go through the flight logs and pick out those missions where different filters were used. Next it will be necessary to select those frames where comparative spectral imagery exists. CORN targets, if displayed, or a large building would make good targets. In selecting frames for comparison, attempts should be made to match frames as closely as possible for look angle and solar attitude and azimuth. Similar weather (atmospheric) conditions can be obtained by referencing to the index camera photography. Once a well correlated set of frames is obtained for the different filter conditions, the same methods of analysis would be applied as are used in the CR-1 test. We will request NPIC to provide both microdensitometric traces of selected targets in these frames from the original negative, and high quality dupes and enlargements. Utilizing the microdensitometer traces and the controlled mission sensitometry, we will then be able to compare the effective object contrast and MTF for the varying spectral filters used, and thus determine if there is a difference in fore and aft seeing, and, if so, which spectral filter should be used to optimize the performance of each camera. A photointerpreter's evaluation of the microdensitometrically evaluated target area from the prints and enlargements should tend to corroborate the objective findings.

4.2.2 Color Infrared and Night Photography Test (CR-2)

In this test, the first 14,500 feet of the second bucket will be flown with the Wratten no. 23A on the forward-looking camera, and a no. 21 on the aft-looking camera. The last 1,500 feet of the forward-looking camera will be type SO-180, which is camouflage detection color film on a thin base. As this film is used, the filter will be changed to a no. 15, plus the appropriate neutral density and slit width combination to account for the increase in speed. Of the remaining 1,500 feet in the aft-looking camera, 1,000 feet will be type 3404 still using the same filter, the no. 21. This will provide 1,000 feet of film that can be used for a comparison of the black and white and infrared color film. This will also allow the two materials to be viewed in stereo. The remaining 500 feet of type SO-180 will be used in mono as additional coverage with this material.

During the ascending night passes of the last portion of the flight (500 feet) the aft-looking camera will be used as a night activity detector with type SO-340. The specific analyses to be performed on each of these tasks are discussed in the following sections.

4.2.2.1 Analysis of Infrared Color Film (CR-2)

As in the first CR test, the prime analysis will be subjective in nature. Areas of interest will be sought by photointerpreters with the goal of answering the question of what type of information has the CD film given that the black and white could not keep in mind. What interesting characteristics will show up is difficult to predict. There have been a limited number of tests performed by the manufacturers of this film to evaluate its potential. It is known, for example, that this material is not useful for water penetration due to the relatively high degree of infrared absorbed by water. The material is useful for detecting objects that reflect a large amount of near infrared energy. The best naturally occurring object in this category is living vegetation that contains chlorophyll. This is perhaps the material's greatest potential as a source of information that cannot be obtained with the ordinary panchromatic materials. The tests that the manufacturer of the film have performed also indicate that the results from ground photography do not correlate well with aerial photographs taken under the same conditions. The manufacturer's belief is that at ground photographic distance, the individual leaves and details of the vegetation are resolved, thereby presenting to the film an entirely different subject than at higher altitudes. This may be an asset when the material is used at orbital altitude. The small difference within one general crop area, for example, would then be averaged out, giving one general appearance to that area. If domestic coverage is obtained with this imagery, a field survey could be undertaken to assess the particular characteristics of the crops and farmlands in that area. As an initial attempt, this would be a good way to correlate the photographic results with some ground truth.

Stereo coverage with black and white and CD films will enable an examination to be made with respect to the merits of this technique for viewing the imagery. Previous tests have shown that when these stereo images are viewed, the good characteristics of each material are presented to the eye. The observer sees an almost full color image with high resolution detail superimposed on the color. This CR flight will be a good test of this viewing technique from satellite photographic scales.

If the photographic portions of this flight can be programmed for domestic coverage, mobile CORN targets can be deployed to obtain an estimate of the system's performance. In this case, the evaluation would be kept entirely to the resolution target since MTF techniques have not been adequately developed for color materials.

With an engineer at the mobile CORN location with a radiometer, such as the EG&G 580/585 instrument, data can be obtained for the spectral energy reflected from the gray scale patches. The procedure is straightforward with black and white material using photographic photometry, and two patches of known reflectance on the ground. It is not too difficult to alter the procedure to make it apply to color material using radiometry. With this information, a very complete tone reproduction analysis can be performed to evaluate the exposure and filtration used. In the EKIT flight no. 1 (EKIT Report No. 4), a technique was used that theoretically predicted a more suitable CC filter for color photography at low solar altitudes. This same technique can be expanded with an estimate of the atmospheric haze effect to predict not only the CC filters, but the haze attenuating filter. Since this is not an ordinary type of color film, it normally does not use a CC filter, but does use a yellow Wratten no. 15. For optimum results, though, there may be a requirement for CC filters.

4.2.2.2 Analysis of Night Detection Photography (CR-2)

The night coverage will be obtained by using the aft-looking camera in mono with a Tri-X type emulsion, SO-340. EKIT flight test nos. 4 and 5, described in Appendix E, has made some specific recommendations for this flight. One of the most important conclusions was to look into lower gamma processing of the original negative.

The analysis of the night detection flight will be primarily subjective in nature. It will give data that will help answer the fundamental question as to whether Soviet missile launch activity can be detected at night. However, it is possible that the target areas will be cloudy, or just inactive. Because these conditions could occur, a negative answer does not necessarily mean this is a useless technique. A method that could be used, though, is to photograph Vandenburg AFB at night with the lights on for formal launch activity. Thus, the predictions of the EKIT night detection test can be verified. This could be used as a control to avoid problems of weather and/or nonactivity. There is, though, still not necessarily a one-to-one correlation between ours and the Soviet's nighttime launch activity.

If the Vandenburg area can be covered, then in all probability the Los Angeles area would be covered and this too could be used for a control point. The conclusions of the EKIT night report were also that cars, though not resolved at orbital scales, could be detected and probably be counted from imagery made at satellite altitudes. Since the location of several well illuminated parking lots are presently known, personnel at the area could count the cars and make ground truth photography. These personnel can also give a detailed weather report for that time period also.

The system resolution from night photography would be a useful number to know. It can aid in interpretation of the detection curve that was used in EKIT Report No. 6 (i.e., reflected illumination versus ground size necessary for detection of images in night photography). For such future calculations, and perhaps refinements on this curve, it would be helpful to have a double check on the system's high contrast resolution. Therefore, if mobile CORN targets were to be placed in some well illuminated (both high intensity and even distribution over a large area) terrain, this support data would be available. The most logical place for these targets would be in Chavez Ravine Stadium, since it has been shown in the EKIT tests to be a well illuminated stadium in the Los Angeles area that could be covered if these areas previously described are programmed into the flight.

Since a lower gamma developer will have been formulated by the time of this test, it is suggested that it be used on the night material of CR-2. A tone reproduction analysis will be performed to see how well this formulation has worked in : (1) improving the useful log exposure range, and (2) enabling one positive duplicate to be made which has all of the tonal range present.

4.2.3 Polarization Filter (CR-3)

The third CR test is to test the effect of a polarizer at various solar altitudes to be used in place of the Wratten no. 21 haze-cutting filter. There are two specific areas in which a polarizer filter may be of help. Specular reflections are polarized, therefore, if these occur (as they do on aircraft wings, off rivers, etc.), the polarizer set at the correct orientation should reduce their intensity. These high intensity reflections, though still bright, would not be so bright to cause the "ballooning" effect that distorts the aircraft shapes and prevents precise identification of these aircraft. The second area of improvement should be in the reduction of the polarized hazelight. The advantage of using a spectral filter (i.e., Wratten no. 21) for haze penetration, is that most of the scattered light in the atmosphere is in the spectral region that is attenuated by this filter.

The polarizer filter should also reduce the hazelight, but by a different mechanism. Even if both filters may have the same effect on the hazelight, there will be distinct differences in the final images. The sharpness from image motion should be about the same since there is only a slight difference in their filter factor (2 for Wratten no. 21, 2½ for polarizer). Since the entire spectral region is used, it may very well be that, even at an adjusted focus position, the lens may not perform as well as with the Wratten no. 21.

A possible advantage though could be the improvement in the tonal rendition due to the increased dimension of spectral discrimination. The Wratten no. 21 haze filter does not allow discrimination between blues and greens, for example, since both are effectively black to the film when photographed through this filter. The polarizer, though, does not have this characteristic, and having these additional tones from various colored objects may be an advantage.

Since the effects of polarization are a function of the viewing angle, there will be a different effect at each of the solar altitudes. The nature of satellite photography is that photography will be made at almost all solar altitudes at some time. Therefore, the analysis of the effect will have to be made as a function of solar altitudes. The initial evaluation will consist of viewing the imagery and looking for gross effects.

Most likely these effects will be immediately evident and the best type of analysis would then consist of making a series of prints of the comparisons at the various solar altitudes. The problem will be more difficult if the differences are small. In addition to a detailed photointerpreter's evaluation, physical measures will have to be used to support his findings. Mobile CORN targets should be used as a system resolution check, though analysis from edges found within the photography will have to be used to account for the variable of solar altitudes. This will give an estimate of the system's performance from an image quality standpoint. The CORN gray scale can be used for a basic tone reproduction analysis.

If the effect of polarization is a function of solar altitude and if the polarizing filter does a better job at the lower solar altitudes, then the filter switching capability of the J-3 system will be of great value. One filter could be used up to some specific solar altitude (to be determined by this test) and then the other one shifted into place to complete the mission. The results could in both cases, be good haze penetration, and in one case, an additional benefit of better tonal rendition.

4.2.4 Bicolor Photography (CR-4)

The theory behind bicolor photography is covered in Section 4.3. The reader is referred to these sections for the details on this subject.

The images from this mission will have to first be rectified. ACIC has offered to perform this service. They will then be additively recombined, either as small areas on our additive color viewer/printer (ACVP) or as a whole frame in a contact mode. The analysis in this case will again be predominantly subjective: What type of information does this technique offer that they could not have obtained in any other way? Are the colors available in bicolor photography too restricted, or are they sufficient to improve the interpretation?

The bicolor printing will be a key factor in this work. Since the full range of colors cannot be reproduced at the same time as neutrals, images will be made under each of the several combinations that our recent laboratory work has developed. For example, neutrals can be formed (with a considerably restricted range of colors) or an almost full range of colors can be made at the expense of the neutral tones. The photointerpreter's analysis will be used to decide which technique is best.

Even though the cyan filtered image may not be as sharp as the orange (for the lens was not designed for that spectral region), the effect on the final image quality may be very small. With the superimposition of two film images, the signal (the image) remains the same and the noise (random grain pattern) is averaged out. There is a 41 percent improvement of the signal-to-noise ratio. If perfect registration is obtained, there should be a corresponding increase in resolution. Therefore, the fact that one lens has not performed as well as the other may not be a serious problem. With mobile CORN targets in the imagery, this effect on system resolution can be determined. The color response patch will also be used in determining the accuracy of color reproduction with this technique. This will enable a controlled test to be made of the accuracy of color reproduction for this system. Natural objects such as trees, water, sand, etc., can be used to determine the reproduction characteristics of these types of objects.

4.3 PHOTOGRAPHIC ANALYSIS MODEL

The goal of this effort will be to develop a computer program that will recommend the best exposure for a particular filter, geographical location, and local sun time. The basic program will be elementary in that it will be based on data that is currently available, but it will have the capability of being continually refined as new information becomes available. As data becomes available from density analysis of strategically important targets from the panoramic cameras, and as studies are made as to the relation between types of weather and its effect on the photographs, the computer program will be expanded to give more meaningful exposure recommendations. As data becomes available for other types of photography (i.e., color and infrared color) the program will be appropriately expanded for exposure and filter recommendations with these materials. The actual program will take the form of smaller separate programs (modular form) that are linked together in a logical manner. Advantage will be taken of existing programs, or sections of existing programs, that have a direct relationship to the particular problem at hand. With this computer program, the capability of the variable exposure/filter mechanism can be used to effectively increase the intelligence gathering potential of the J-3 system.

4.3.1 Computer Facilities and Past Work in Photocomputer Analysis

There are two completely independent computer units at Itek. The complete facility is shown on the next page. The main unit is a CDC-3300 that is used for lens design and large photographic tasks; it is also available for other engineering efforts throughout the company. It is a high-speed digital computer complete with tape units, disc files, and large memory banks, and it has input/output capabilities through a card reader, card punch, line printer, and digital plotter. The other computer facility is a CDC-924, which is the predecessor of the larger machine. It is a medium speed computer, by today's standards, and has the following prime functions: (1) a backup machine for downtime on the CDC-3300 and for smaller programs that do not need high speed, large storage capacity, and (2) a research tool for photo-optical problems.

The CDC-924 has all of the peripheral equipment that the larger machine has, plus an on-line CRT display unit. This is a 20-inch diameter scope that provides a very convenient method for research with photo-optical computer problems. It has been used over the past year in theoretical photographic research where real time communication with the computer is essential. This theoretical work has been performed in color photography, tone reproduction analysis, and MTF determination. EKIT Report No. 4 includes such an analysis where a better color correction filter was recommended, based on data from a mission using color film at low solar altitudes. In this analysis,

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CDC 3300-924 computer facility

the criteria for a better reproduction were met when filters were used that resulted in a neutral image. In a related area, several programs have been developed to simulate photographic tone reproduction problems. In an effort to determine the capabilities of bicolor photography, a computer program was written that simulated the tone reproduction characteristics of a bicolor additive process. This was a study designed to learn how to program photographic problems for a computer and to get a better theoretical understanding of bicolor photography.

The programs discussed above have been written in modular form so that any one section can be pulled out of the main program and used as a small program by itself. For example, one could be used to compute filter factors, and another could be broken down for black and white tone reproduction or calculation of the CIE coordinates of images. Sections of a third program could be used for manipulating D-log E curves or for smoothing experimental data.

Since many of these subroutines have already been developed, they can also be put together to form other larger programs. It is the intent that sections of these programs, and many others in our computer library, be used as the basic building blocks for the proposed model.

4.3.2 Factors Influencing the Model

Computers are not being used to their fullest capability in the selection of exposure and filters for orbital surveillance systems. Perhaps one reason is that not enough is known about all of the parameters that have a significant influence on the final image. A basic reason for this type of program not being written is that the criteria for good exposure are not precisely defined. Although there are many quantitative measures of photographic speed, these are all derived from some qualitative basis. Eliminating the dozen or so photographic speed measures for amateur photographs, there are three speed criteria for aerial photography: (1) half-gamma speed, (2) 0.6-gamma speed, and (3) aerial exposure index. The fact that there are several different measures indicates that there is a question as to which one is the best. In fact, none of these criteria are at all related to the optimum exposure required in specific cases, since they don't take into account the cameras involved.

The decision of what haze cutting filter to use is also difficult. It has been the policy in the past to use a stronger haze cutting filter on the forward-looking camera. This decision was made primarily because the majority of the photography is obtained in the northern latitude on descending orbits. In this situation the forward-looking camera is looking approximately in the direction of the sun. The results with this camera may be good in some areas and not good in others. For example, a Siberian cold front may clear the air over the Soviet Union, while a humid atmosphere in Southern China may cause a serious loss in contrast from all of the light-scattering particles in the air.

In the following discussions, the term weather is not used to mean general cloud cover, but rather that aspect of the weather that has a significant effect on the imagery that is obtained, for example, the ever present haze or the thin veiling of clouds that are not apparent on the main cameras but obvious on the index material. Weather is a major factor that has not been fully taken into account in previous satellite missions for the selection of the best exposure level and haze cutting filter. Of course there is good reason for this; only one exposure setting and one filter could be used, since there were no adjustable mechanisms on previous cameras. With the J-3 system, four exposure positions are available. There is also the option of one of two filters on each camera. These will be controlled by a device on the vehicle and real time commands from ground stations.

The current method of adjusting the density level of subject material is done through a three-level developing process. Although this is an ingenious approach to the problem, with the lack of flexibility on the camera, it is perhaps not the best way to solve the problem from an image viewpoint when camera adjustments are possible. With this processing method, the exposure must be set for the minimum luminance that is to be recorded. These areas would receive full processing. Target areas of higher luminance must necessarily be overexposed (by full processing standards) and compensated for by under-processing. With the adjustable slit widths in the J-3 system, these compensation processing techniques would not be necessary. With variable speed processing, the infrared densitometer makes the decision of processing level based on its interpretation of the scene's luminance level. For proper use of the variable slit widths, a decision as to what luminance level is being photographed must be made without such an aid.

Historically, the image quality from the forward-looking cameras has been lower than from the aft-looking cameras. Explanations for this have been given but no concrete evidence supporting any of these has been published. Such degraded imagery might be due to the lens looking into the sun, or that a filter for which the lens was not originally designed was used, or that longer shutter speeds were used, etc.

This problem is intimately related to the choice of filter and exposure level. There is a tradeoff between the image quality characteristics and the haze attenuating and spectral qualities of the filters that are used.

In choosing the proper filter, one should take into account the contrast that is necessary in the image and the image quality that is also required. The exact relationship between these two filters are not presently known. By studying the past imagery, both the main panoramic scanning cameras and the index camera trends in target contrast can be seen. If there is a relationship between the two, then this can be programmed into the mathematical model. These considerations and how they relate to the mathematical model will be discussed in the following paragraphs.

4.3.4 Generation of the Model

Two considerations must be accounted for in the model: (1) the factors influencing the image formation, and (2) the evaluation criteria for a suitable density level of the target. At this time there are many unknown elements in these two considerations. The target density analysis and tone reproduction studies outlined in the previous paragraphs will be used for the second consideration.

The first consideration will constitute the bulk of the program. The initial phases of the program can be written from currently available data. Geographical position and local sun time will be taken into account in order to compute the solar altitude. This stage in the process can be accomplished by taking advantage of the computer's large storage space, and storing the tabulated values required for this initial phase of the program. The exposure levels determined will have to be quantized to the nearest of the four exposure levels available. The exposure information will be basically the EV curve for the material involved, with the feature of automatically determining the solar altitude at any time and place. The essential difference will be in the criteria that are used for the particular EV curve in question, as discussed in the target density analysis.

An analysis of the index material will be designed to find any weather patterns that have a significant effect on the photography. If such an effect does in fact occur in a predictable pattern, then a compensating change in the exposure and/or filtration can be made. For example, the monsoon season in Southeast Asia may have some far reaching effects in the north that would degrade or improve the ground scene imagery through changes in atmospheric contrast. If this type of occurrence does have some particular effect on the photography, appropriate corrections can be programmed to account for it. Both panoramic cameras and the index camera will be used in conjunction. The panoramic cameras can sometimes "look through" light cloud formations which are not immediately obvious unless the index material is used. It is this relationship that will provide the most meaningful data.

Section 4.1.3 details the index camera analysis. It is intended that this imagery be used continually to increase our understanding of the periodic weather patterns that occur, and to update the program so that it can provide more accurate exposure and filter recommendations. As new index material becomes available, the past predictions of weather patterns can be verified as photographically significant. Thus, the computer program can be expanded or reduced in size.

When photographically significant patterns are found, they can be fed into the computer and stored in the form of global maps, such as that illustrated in Fig. 4-3. This map was plotted by the computer from storage of the appropriate data points representing the countries. This type of plot can be used to store and study the data from the index material.

With the flexibility that has been built into the J-3 system, materials other than 3404 can be used. Color photography with either a standard color material or an infrared color (camouflage detection) emulsion, or high speed black and white emulsions for night photography might be used. There are very special problems involved in using color materials at high altitudes that are not present when using 3404. Color material photography cannot use the deep orange or red haze-cutting filters, since the images will look orange or red. Instead, a pale yellow haze-cutting filter (i.e., Wratten no. 2E or Wratten no. 4) must be used. Though this effectively cuts the sensitivity of the blue-sensitive record, its use is necessary to reduce the bluish hazelight to a tolerable level. When this is done, the image produced is yellow. To compensate for this, a blue CC filter must be used. Though this seems like a paradox, the use of both a blue and a yellow filter (which to the eye may look neutral) does not affect the film/haze relationship as if it were neutral. The filter combination corrects for the haze, with the only significant disadvantage that deep blues may not be recorded accurately.

Though the computer techniques available at this time cannot give the correct filter combinations for different weather and/or solar altitude conditions, it is expected that as more data becomes available, this programming system can be used effectively. The fact that the computer programs discussed previously have been written in modular form permits reassembly into other forms.

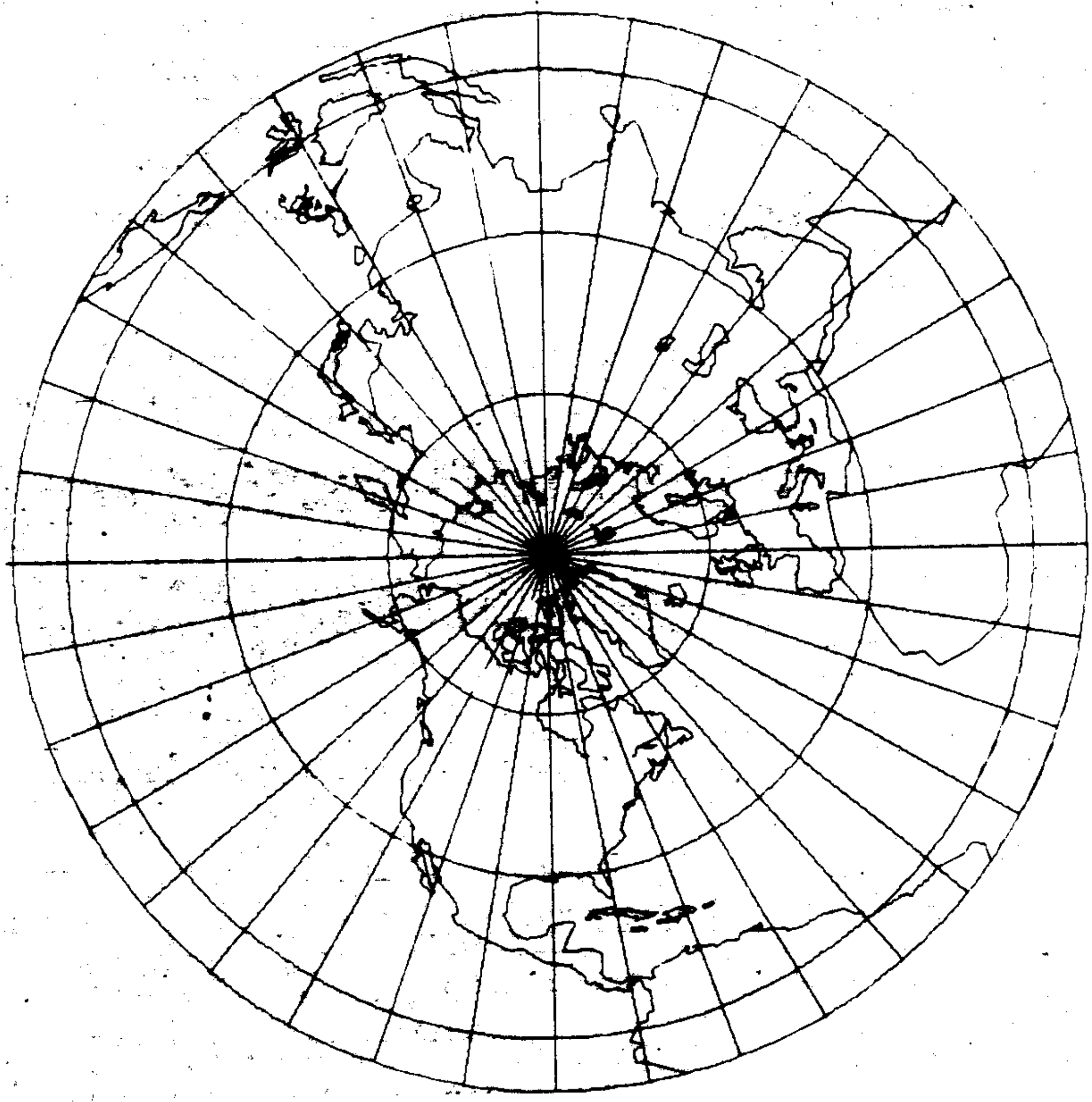

Fig. 4-3 — Sample global map

5. GEOMETRIC VERIFICATION

The geometric integrity of the J-3 panoramic camera system has a direct influence on both the intelligence and mensurational potential of the output photographic imagery. This integrity is primarily maintained to fulfill the fundamental requirement of the acquisition system, i.e., to provide extensive stereoscopic photographic coverage of the ground with sufficient detail to allow a photointerpreter to recognize, evaluate, and monitor selected targets. The quality of the resultant photography verifies this primary geometric integrity.

Inherent in the fundamental requirement, and as the subject of the secondary requirement of the J-3 system, is the geometric integrity related to the mensurational tasks of dimensional intelligence and mapping, charting, and geodetic (MC&G) operations. System provisions (stability and calibration) have been made for these latter requirements and, just as it is proposed in Sections 3 and 4 to perform system analysis studies on the primary system requirement, it is proposed in this section to perform system analysis studies for the purpose of verifying these metric system provisions.

The proposed analysis will be divided into two subphases: relative system orientation (described in Section 5.1) and internal calibration stability (Section 5.2).

5.1 PHASE 1—RELATIVE SYSTEM ORIENTATION

The total acquisition system contains nine photographic subsystems, six of which are contained in the main J-3 system assembly and three of which are contained in the DISIC assembly. Each assembly is provided with a preflight relative system orientation calibration; however, the separate assemblies are in no way calibrated with respect to each other. The primary effort in this phase will be the postflight verification of the preflight-calibrated relative orientation angles between the main J-3 camera subassemblies, i.e., panoramic stereo angle and auxiliary optics angles. A secondary effort in this phase will be an analysis of the relative change in orientation between the two major assemblies (J-3/DISIC).

The principal beneficiary of this phase will be the intelligence community at whose request the relative orientation calibration is performed. The rapid orientation and data reduction techniques employed by this community are based on direct utilization of the angular values to be verified. As a confirmation of the scope of this phase, the investigations proposed in paragraph 5.1.1 were discussed with a cognizant member of the intelligence community. His opinions and experience are reflected in the proposed effort.

It is proposed that phase 1 operations be performed on the first four operational missions. The reasons for this are: (1) the first four missions will carry a diagnostic tape which will provide collateral data on geometry, influencing environmental effects and will also provide data on attitude "jet" firings to indicate object-space "breaks" in the geometry, and (2) a sampling of four missions will allow a sufficient statistical analysis of the relative orientation parameters.

5.1.1 Main System Relative Orientation

The objective of this portion of the system analysis studies is to determine the relative orientation between the camera subsystems that comprise a complete J-3 system. This is to be accomplished from recovered photographic records, and will serve to verify the preflight calibration of the relative orientations.

It is proposed to accomplish this determination through the use of both frame and panoramic imagery that has been exposed over known terrain, in which sufficient photo-identifiable ground control is located. The procedure for carrying out this determination is described in the following paragraphs.

A relative orientation log for each system will be provided. This log presents the data defining the intercamera relationships obtained from the assembled camera/vehicle system, and forms the basis for checking this calibration. These relationships are illustrated in Figs. 5-1, 5-2, 5-3, and 5-4.

Materials from all camera systems, taken during passes over areas of geodetic control, must be furnished.

The panoramic imagery that is proposed for use in this analysis will consist of samples of fore and aft panoramic records that have been exposed at essentially the same time. This is not to say that times of midexposure must coincide, but that there is some overlapping time interval during which some portion of both panoramic frames is being exposed. In other words, exact synchronization of the panoramic cameras is not necessary.

The number of frame photographs with which the panoramic records overlap may be as large as four consecutive exposures. It is recommended that all frame photographs that overlap the panoramic imagery be processed.

Ground control points will be identified on the selected imagery, and survey coordinate values will be established. This can be done either over areas for which accurate maps exist, or over one of the Government maintained test areas, e.g., the Arizona Test Area Photogrammetric Range which is situated at 33° 15' N, 112° 11' W, and extends East, West, and South of Phoenix, Arizona. Designed for the test and

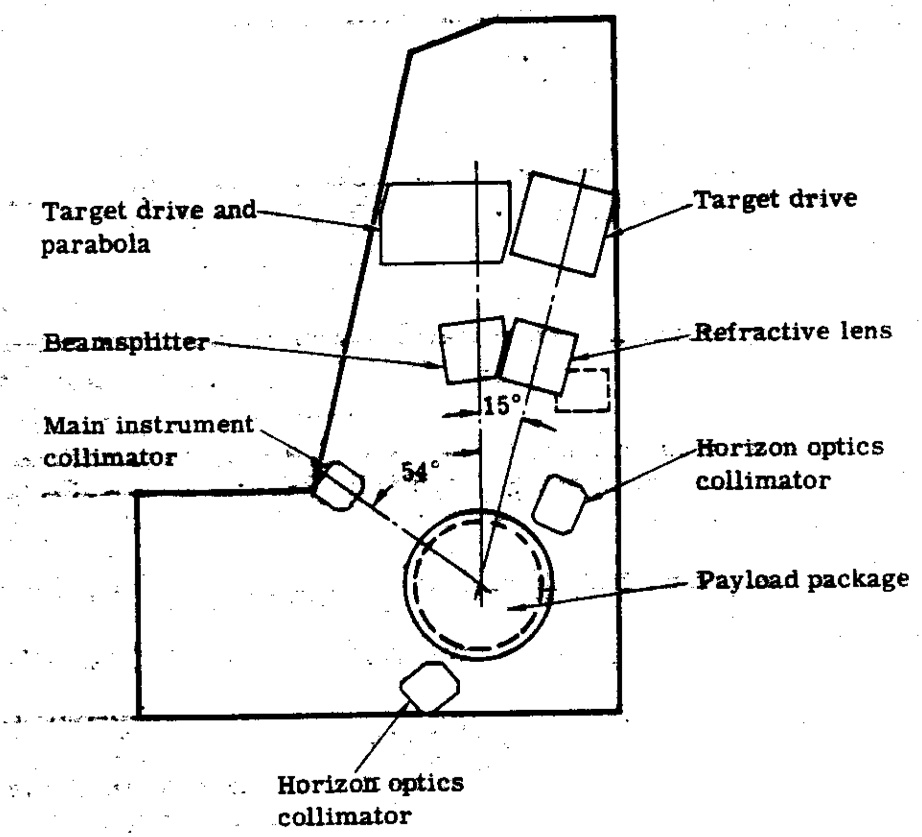

Fig. 5-1.— A/P simulator plan view

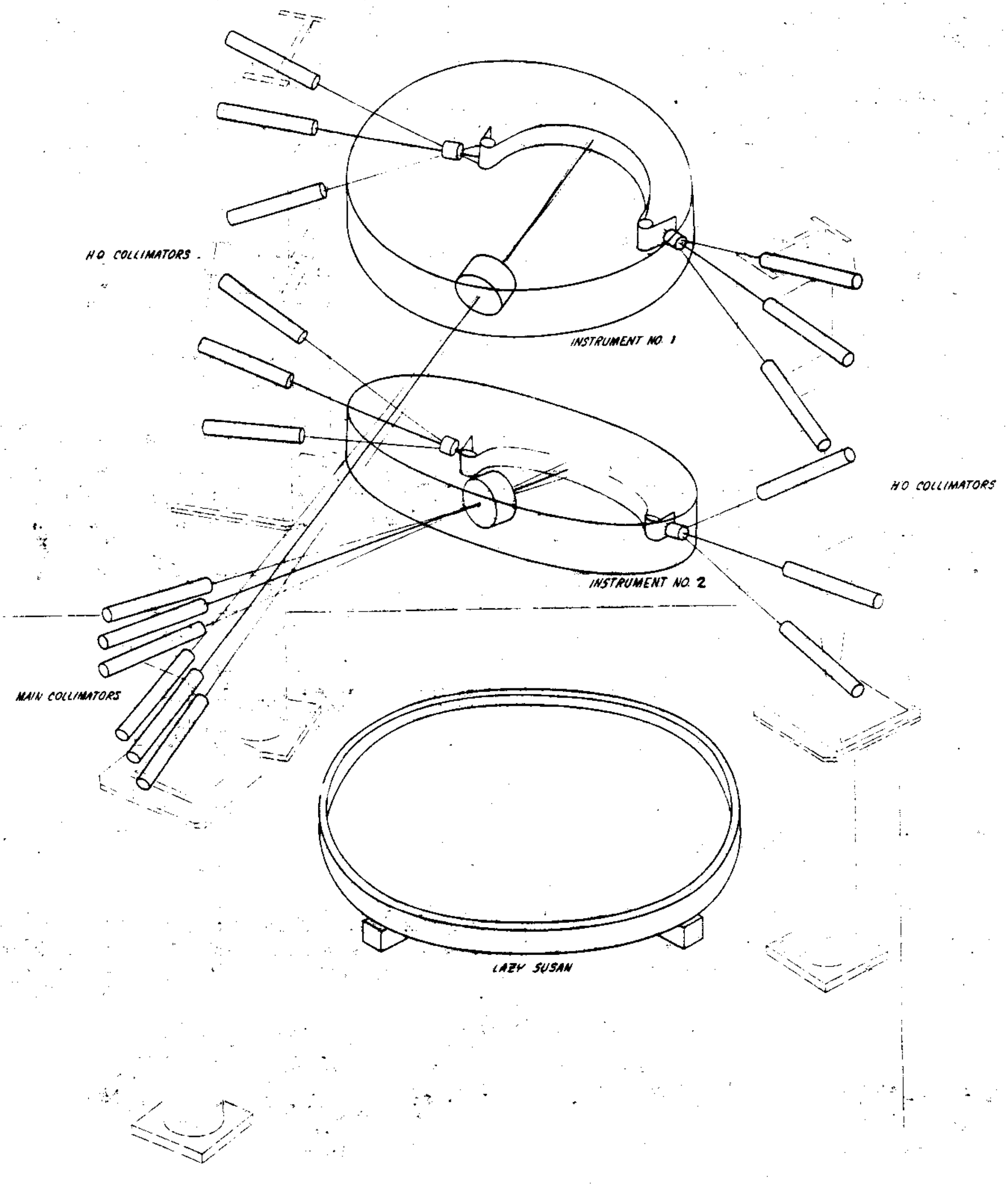

Fig. 5-2 — Isometric of optical calibration system

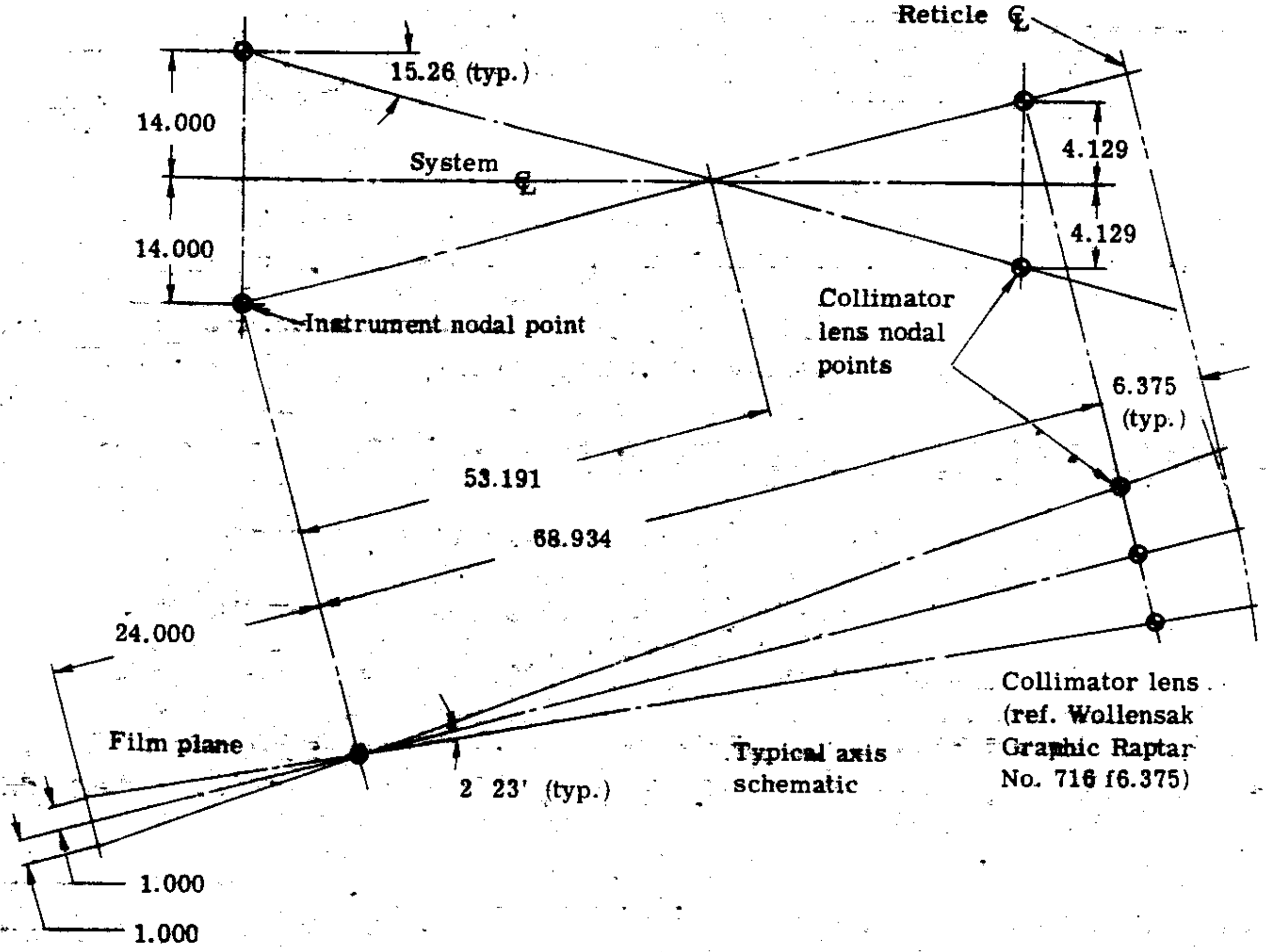

Fig. 5-3 — Main collimator optical schematic

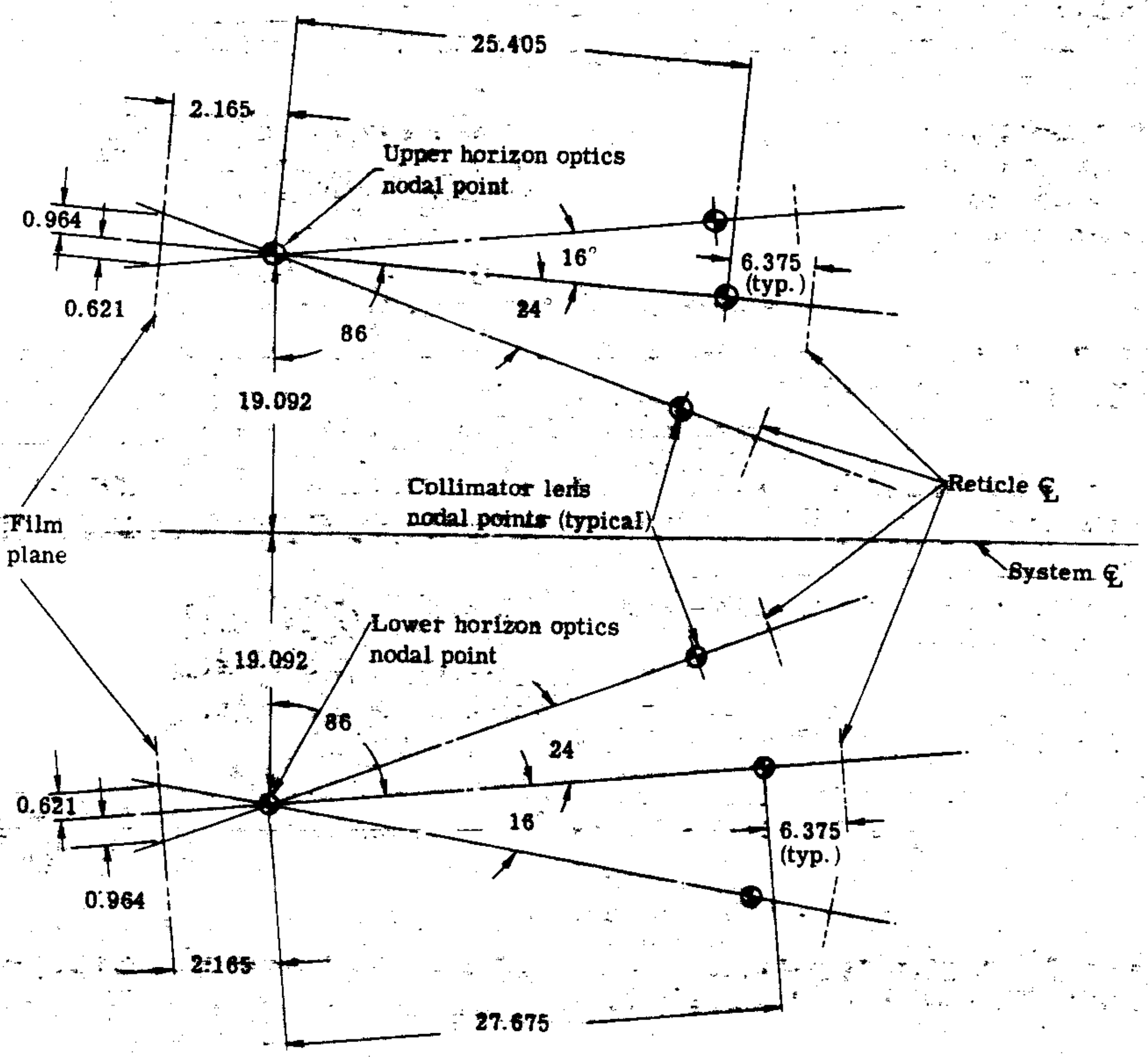

Fig. 5-4 — Horizon optics collimator optical schematic evaluation of aerial cameras and mapping techniques, this range is based on existing road networks and utilizes precision ground surveys to achieve a high degree of accuracy in the knowledge of point position.

Each station of this range consists of a monument and a companion photographic point. Complete data on each station within the surveyed area is available, in card form, to Department of Defense agencies on a "no charge," loan basis from the Army Map Service.

Measurements from these photographs can be processed by Itek's FOTO 3 program, which is essentially a block triangulation that simultaneously processes frame photographs and imagery obtained from the J-3 panoramic camera. This program is a completely weighted solution that is constrained to the appropriate orbital parameters. It is capable of accepting any number of frame and panoramic exposures, subject to the storage limitations of the data processing equipment.

The application of the FOTO 3 program to the panoramic and frame records will provide the orientations of each exposure at the middle of scan, i.e., $\alpha = 0$, for the panoramic photographs, together with the coefficients of a time dependent polynomial that expresses the vehicular attitude in terms of the angular velocities, accelerations, and rate of change of acceleration. Consequently it is a matter of arithmetic manipulation to reduce the camera orientations to some reference time during the interval of common exposure.

The panoramic camera orientations are then transformed into the two orientations that correspond to the midpoints of scans, but free from the different vehicular attitudes that might exist at these separate times. The reduced orientation matrices are readily transformed into the relative orientation matrix and compared with that obtained from the preflight calibrations.

Since all reductions will be performed with the concurrent propagation of the relevant variance-covariance matrices, the statistical significance of any difference from the preflight relative orientation is readily determined.

The present panoramic/metric FOTO program for J-1 panoramic geometry photography is fully described in [redacted]

5.1.2 Horizon Optics Check

The procedure described above can be utilized to give information regarding the calibration of the angles between the horizon optics (HO) and the associated panoramic instruments. Calibration of these angles is performed in the A/P laboratory prior to flight. This calibration data can be used with the horizon images to determine pitch and roll of the panoramic camera at an instant of exposure. These same angles can be determined from the block adjustment (FOTO 3 program) described above.

Comparison of these should reveal validity of the preflight calibration. Significant differences can be attributed to either a change in HO angles after calibration, or to an invalid calibration procedure.

The problem of evaluating the third orientation angle, yaw, remains insoluble. This angle can only be determined from the horizon photograph if clearly identifiable terrain features are also visible.

When discussing the HO check with the primary user of this data, he concurred with the desire to check these angles; however, he reminded us that the measurement of the horizon image would limit our analysis to input values well in excess of (much poorer than) the calibrated values. Therefore, the usefulness of this check is questionable.

5.1.3 Performance

Although it is desirable to perform this postflight geometric investigation for each system that is flown, consideration of time and cost seems to rule this out, since one month is intended for the reduction. Therefore, we propose to perform this adjustment as a check on the first four systems. Should difficulties be revealed and remedial action taken on successive systems, the reduction would be repeated. Iteration of this kind should reduce all deviations to within the preset tolerance levels.

The block adjustment programs discussed above are capable of imposing camera orientations during the adjustment, if these are established apriori. The most complete adjustment would require imposing the orientation given by the stellar cameras. At present we propose that the information on the pertinent frames be made available to us within a week of the recovery of the material. Time considerations would require that the stellar frames for this analysis be reduced before any other of the stellar photography.

5.1.4 Main System/DISIC Relative Orientation

The purpose of this task is to evaluate the magnitude of vehicle "hot dogging" (bending due to unequal thermal expansion) between the main system and the DISIC system. The end result will determine the value of calibration (bore sighting) of the two subsystems with respect to each other. A negative result (excessive flexure) will eliminate further consideration of this calibration. A positive result (relative rigidity) may enable direct use of stellar attitude data for panoramic orientation.

The model developed for Section 5.1.1 is directly applicable to this analysis. It is only necessary to be able to perform the block adjustment for different passes over controlled areas, to reveal differences in relative orientation between panoramic and stellar/index cameras.

5.2 PHASE 2—INTERNAL GEOMETRY ANALYSIS

Each of the camera subassemblies constituting a J-3 system is provided with a panoramic geometry (PG) calibration. This calibration of internal camera geometry not only provides a means of recovering correct image coordinate data of ground points, but conversely provides a means of determining physical camera operations as reflected in the geometric (PG) record.

The goal of this phase of the proposed system analysis studies will be to determine the stability of the operation of the camera. It should be emphasized that the work proposed for this phase cannot establish the accuracy of the PG calibration, but it is rather an analysis of camera dynamics (vibration, film motion, etc.) as evidenced by the distribution of PG calibration data (rail holes and PG traces) along the format. This, in turn, will provide insight for PG utilization and possible camera engineering improvements.

The beneficiaries of this phase will be the users of PG in MC&G operations and the users of PG for camera performance analysis. The scope of the investigation proposed in Section 5.2.1 has been found (through experience on J-1 PG systems at the Data Analysis Center, Army Map Service, and Aerial Chart and Information Center) to provide the greatest amount of information for the effort involved.

It is proposed that phase 2 be performed on every mission. It is believed that the engineering benefits to be derived and the "preapplication" information on image geometry will be invaluable to the total community.

5.2.1 Camera Dynamics Analysis

One of the goals of the system analysis studies will be to determine the stability of the camera's operation. The means to determine data with respect to stability must be based upon the α angles of the rail holes and the β angles of the scan traces as established during preflight calibration. Additionally, the test sample must be large enough (say six frames per camera per bucket) so that the results are statistically significant.

It is proposed that the following procedure be used to extract, reduce, and analyze the necessary data.

1. A Mann 880 comparator will be used to measure the coordinates of rail holes and a similar distribution of points on the scan traces. Since the Mann 880 has an 18-inch stage, the panoramic images will be measured in two segments which overlap at the center of the frame. Observations will be made in duplicate in two separate passes to ensure the elimination of errors and the improvement of coordinate values.

2. Using a digital computer, the measurements from the two passes will be averaged and erroneous measurements will be eliminated. The logic for the latter operation must be built into the computer program. This logic will comprise the

setting of a limit on the differences from the mean, and the elimination of points when the limit is exceeded.

3. Using a digital computer and a least-squares program, the segment coordinates will be transformed into a single coordinate system by translation and rotation.

4. Also using a digital computer and a least-squares program, coordinates will be transformed to a rectangular coordinate system wherein the ordinate passes through the center-of-scan rail hole, the origin is at the imaginary trace of the principal point, and the abscissa is the best straight line parallel to the scan traces.

5. A digital computer, a least-squares Fourier analysis program, and the preflight calibration data will be used to determine transformation parameters which will reduce the residuals in Y at rail holes, and the residuals in X at scan trace points, to negligible proportions.

6. Coordinates will be transformed into the theoretical cylindrical calibration system using a digital computer and the transformation found in step 5 above.

7. Using a digital computer, the average transformation coefficients for all samples processed for each camera will be determined.

8. Using a digital computer and the average transformation coefficients, the coordinates found in step 4 for all samples will be transformed into the theoretical cylindrical system.

9. The digital computer will be used to calculate the determinational precision for each rail hole as based on an average transformation.

10. In sequence, the higher frequency terms will be eliminated from the average transformation found in step 7, and steps 8 and 9 will be repeated.

11. An evaluation will be made of the frequency components found in step 5 and their variation, sample to sample, with respect to phenomena within the camera/film system. This evaluation is directed toward camera improvement and should be correlated with data taken concerning image quality.

12. The results of step 9 and subsequent iterations of step 10 will be evaluated and related to the problems of operational data reduction in the user community.

The above procedure requires the preparation of computer programs for steps 2 through 9.

5.2.2 Environmental Influence

The procedures described above provide methods for determining the effect of the operational environment on the camera dynamic operations as related to the distribution of the calibration data over the format. Environmental influences on resolution, structural stability, and thermal sensitivity can be detected by the application of these procedures, and by correlation of the observed anomalies with environmental data which is recorded on the diagnostic tapes.

These tapes contain digitally recorded flight data indexed on a time word, including temperature, certain mechanical functions, and monitoring of attitude jet firings. It is understood that these tapes are produced in a format which is not directly computer readable, but that can be converted to a form which is acceptable by the computer. It is assumed that the converted data will be made available for this investigation.

The technique employed will be to scan these tapes for anomalous data and, if any is found, the materials exposed during these periods will be investigated for resolution and for panoramic geometry stability. Should no obvious environmental anomalies be detected, a sampling technique will be developed to select a random sample of imagery from the total flight duration. This sample will be reduced as in Section 5.2.1, and we will attempt to determine if deviations from calibration can be correlated with environmental conditions.

6. PETZVAL THERMAL VACUUM TESTING

6.1 BACKGROUND

Temperature gradients are to be expected in the Petzval lens cells when used in flight applications. During the passive phases of a mission, a linear temperature gradient may occur along the principal axis of the cell. As a result of the construction and mounting provisions of the cell, it may be assumed that such gradients will be axisymmetric. The lens cell and tailcone have been designed to be thermally self-compensating and, over the course of a mission, uniform temperature level changes of ±10 °F are permitted. However, during an operating cycle, transient temperature responses of the optical train can be expected as a result of exposure to varying quantities of reflected solar energy (albedo) and earthshine; these responses may be nonsymmetric. The above-mentioned factors may result in a thermally induced image degradation.

6.2 PROGRAM

Itek proposes to modify the experimental equipment for the existing thermal/optical research facility to permit a series of experiments in which two Petzval lens cells will be subjected to an identical set of thermal-vacuum optical performance tests in autocollimation. The proposed test configuration is illustrated schematically in Fig. 6-1.

A vacuum of at least 10^{-5} torr will be utilized to eliminate the effects of gaseous conduction and convection heat transfer, pressure, and turbulence. Tests will also be run at a pressure of 20 microns to assess the effect of the pressure makeup system. Thermal testing will include: uniform temperature level changes of ±10, ±20, and ±30 °F; and axial temperature gradients in the cell elements (achieved during transient operation). Both absolute and differential temperatures will be recorded during these tests.

Itek's laser unequal path interferometer will be used to obtain interference fringe patterns, and thus evaluate the changes in these patterns resulting from the imposed thermal conditions. By incorporating additional optical equipment (such as a bar target) together with a remotely operated detector, other thermally induced changes in optical parameters will be evaluated; these will include changes in equivalent focal length and resolution.

The results of the proposed testing will be completely reported and will include the supporting thermal and optical analyses of the test data.

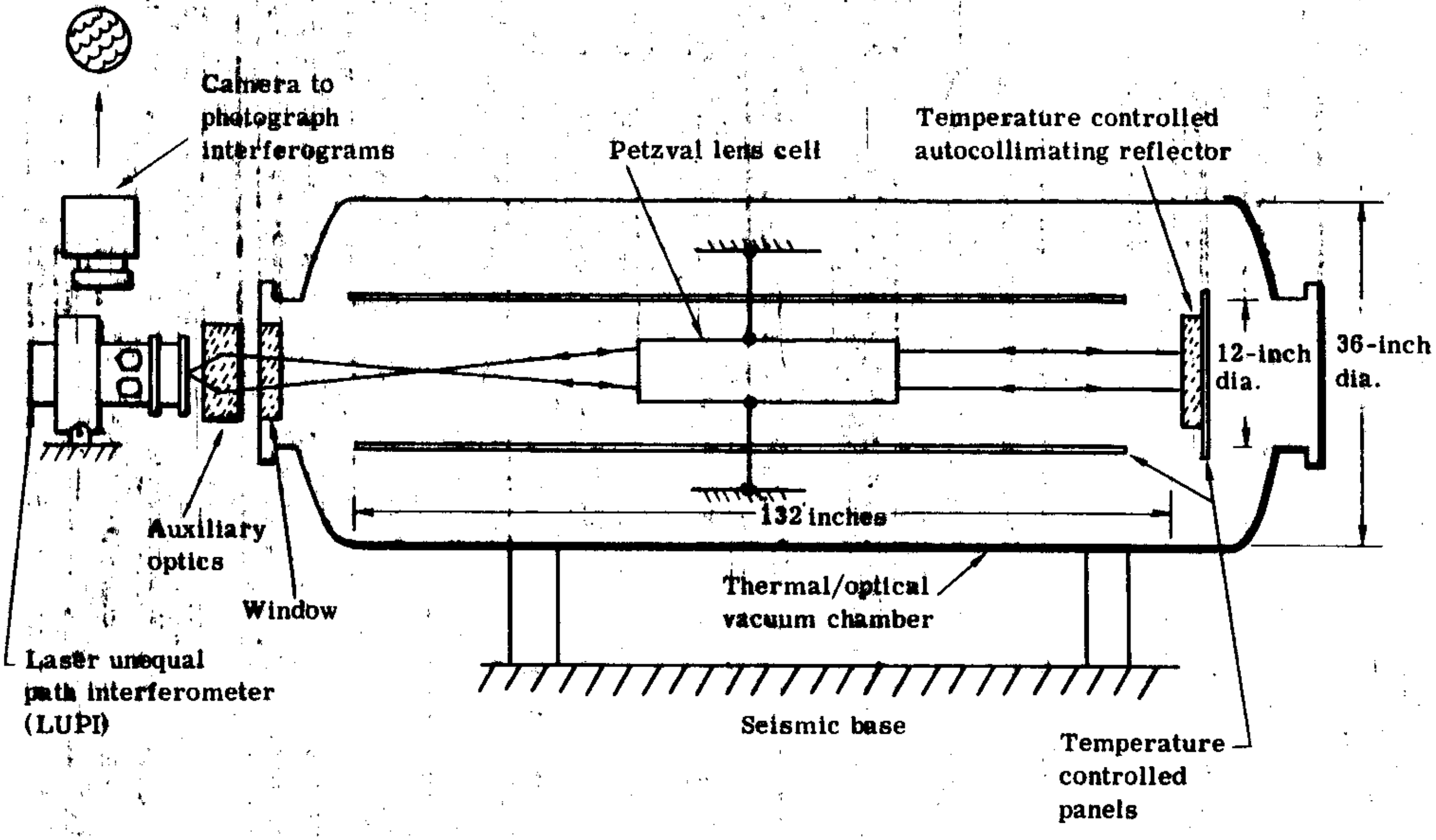

Fig. 6-1 — Petzval lens cell test setup using the Itek thermal/optical vacuum chamber

Appendix A

DETERMINATION OF EXPOSURE BY MEANS OF DENSITY ANALYSIS

In order to validly apply the type of density analysis presently utilized to the exposure problem, the following assumptions must also be valid.

1. The minimum and maximum acceptable density levels chosen have a physical meaning
2. "Terrain-measured" density values have a direct correspondence with "target-measured" density values
3. The placing of a minimum brightness at some specified level on the D-log E curve is important

Let us consider each one of these assumptions.

1. MINIMUM AND MAXIMUM DENSITY LEVELS

Fig. A-1 illustrates the principle behind assumption 1. In order to make any interpretations from the density data one must make an assumption as to what is a "good" density and what is a "bad" density. Fig. A-1 illustrates the assumption currently being employed in practice. That is, that minimum densities below 0.48 are too low and that maximum densities above 2.0 are too high. At the high end there is probably little disagreement. At the low end, however, there is considerable disagreement as to what is an acceptable (i.e., usable) minimum density. For example, if we refer back to Fig. 4-1, we can make a useful comparison. Table A-1 shows what the calculated percentage of underexposed material would be with different minimum acceptable D_{min}.

It is seen that the density that is chosen as the minimum acceptable plays an important role in trying to draw conclusions about exposure and its adequacy. However, the fact alone that minimum acceptable densities are assumed a priori is not, by itself, justification for discrediting the density analysis technique. It is perhaps more important to investigate its relation (or lack thereof) to the targets.

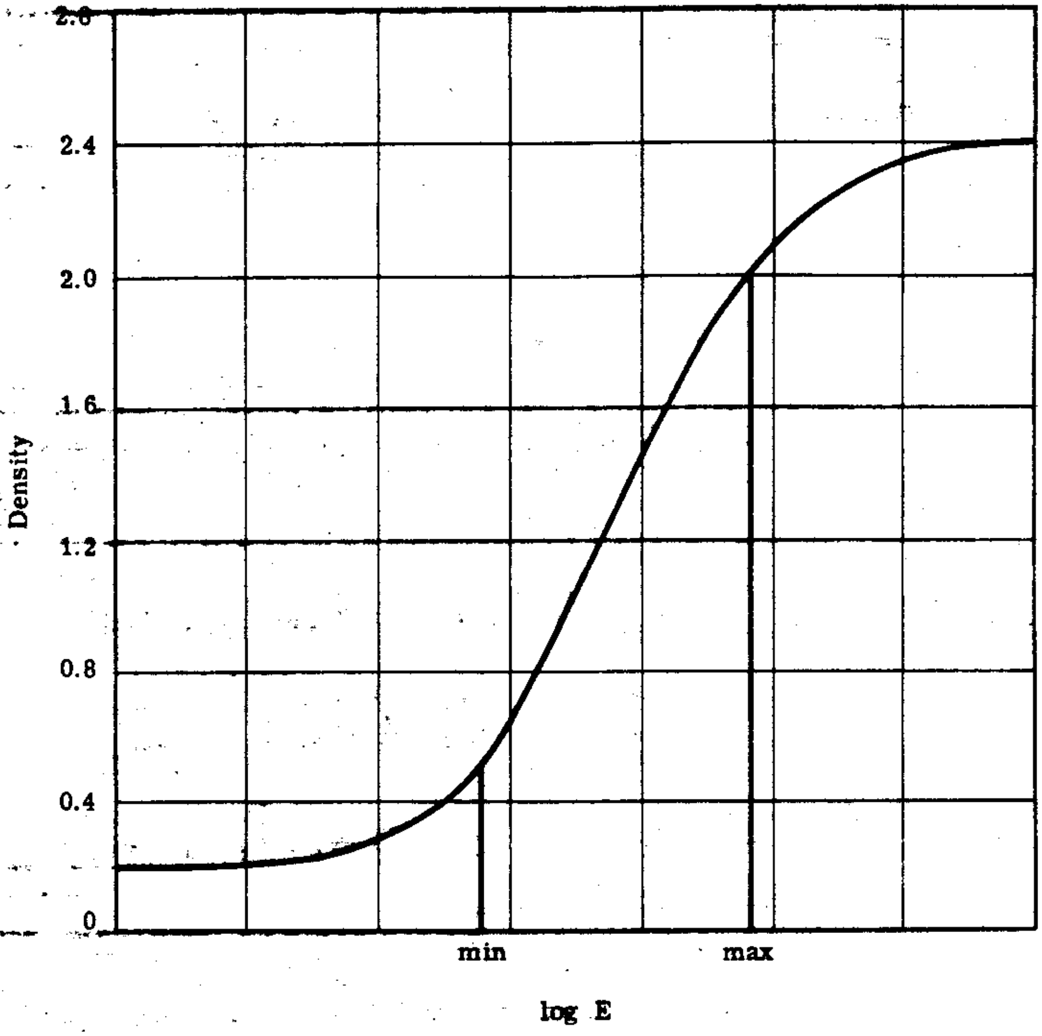

Fig. A-1 — Assumed acceptable minimum and maximum density points for 3404 film

Table A-1.—Calculated Percentage of Underexposed Material for Different Minimum Acceptance D_{min}

D_{min}	Underexposed, percent
0.48	63
0.40	25
0.30	4

2. TERRAIN MEASURED DENSITY VALUES

The density analysis values reported are measured from "terrain" areas. The densitometer operator reviews the material and makes D_{min} and D_{max} measurements in "terrain areas of interest." These areas do not necessarily contain targets, and in fact there is no assurance that any of the measurements have been made in target areas. The assumption here is that this is a statistical process anyway, and it doesn't really make any difference if targets are measured since they will fall somewhere in the population measured. It is not necessarily true that this is a statistical process. A statistical process depends upon the random occurrence of events. The targets of interest do not fall randomly within the frame, nor are they necessarily random in terms of their luminance distribution. The targets photographed with the Corona system are not a random collection of items but a rather well-defined series of nearly exclusively man-made objects. Because they are not necessarily random (but are specific) in nature, it follows that their brightness distribution may not be randomly distributed. Once one comes to this conclusion, it can be seen that there is not necessarily a correlation between arbitrary "terrain D_{min}'s," their adequacy, and the target densities, and their adequacy. Statistical analysis is not necessarily valid just because there is a great quantity of data.

3. MINIMUM BRIGHTNESS UTILITY

Referring once again to Fig. 4-1, we can assess the utility of the minimum luminance concept in exposure control analysis. The data presented in Fig. 4-1 represents the distribution of minimum luminances determined from the measured minimum densities. These are determined by "back calculating" to take into account the film sensitometry, camera characteristics, etc., and thus determine the apparent luminance as seen by the camera above the atmosphere. This type of analysis is excellent for studies of brightness ratios above the atmosphere. But to relate this to exposure determination requires three assumptions:

1. The data is meaningful and physically relatable (or extrapolatable) to targets
2. The data is accurate to a reasonable tolerance
3. We are interested in basing exposure criteria on luminance per se

There is some question that any of these assumptions can be made. Fig. A-2 serves to illustrate the basic argument that one can make when using minimum luminance data to draw conclusions regarding exposure adequacy. Referring to the figure (which is only an example for illustrative purposes) the argument would be as follows:

1. The D-log E curve shown is the process curve to which we must work. We would like to expose the majority of detail of interest between the D_{min} and D_{max} limits indicated.

2. The resolving power versus log E curve tells us where on the D-log E curves we want to optimize our exposure for, after we consider the latitude available.

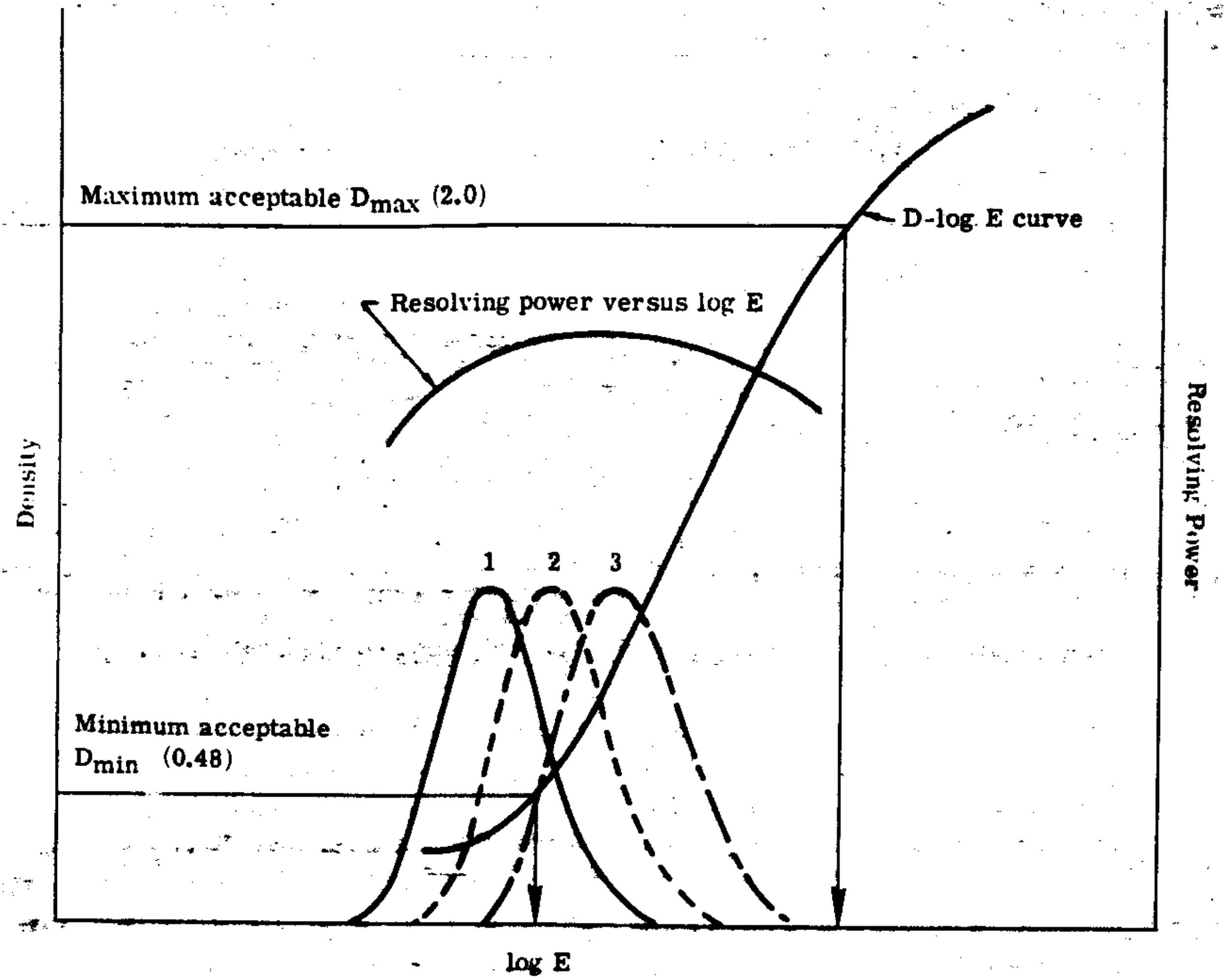

Fig. A-2 — Example of exposure argument based on minimum luminance

3. It is now a question of properly placing our scene brightness on the curve within the constraints of 1 and 2 above. Curve 1 shows a large percent of the minimum luminances recorded below the 0.48 level and hence partly underexposed. Curves 2 and 3 indicate greater exposure with curve 3 being the most acceptable, since the vast majority of the minimum luminance values are recorded above the 0.48 density level.

This type of analysis is intended to prove that, if the frequency of occurrence of low minimum luminance values is high, the photography is underexposed. As stated, this conclusion is valid only if the above three assumptions are valid. Let us now consider these assumptions.

The question of whether or not the data is meaningful relates directly to the question that was discussed above. This type of analysis is meaningful if the randomly gathered "terrain" data relates directly to the targets. That is, if we can assume (from Fig. 4-1) that 40 percent of the targets had a minimum luminance in the 300-foot-lambert cell, then the analysis can lead to conclusions about exposure. If, however, it is not assured that the targets are in the same population as the "terrain-measured" values, then the extrapolation is invalid. The possibility exists that a minimum luminance histogram for target areas would look quite different from that for random terrain areas. The assumption, then, that the calculated minimum luminance values have a physical relation to the targets is, at best, questionable.

The second assumption, that the data is accurate to a realistic tolerance, is also questionable. Photographic photometry is at best a difficult task. Even with an extremely well-calibrated camera system, precisely controlled processing, and careful analysis, the very best accuracy that can be hoped for is ±10 percent. Unfortunately, in the case of the Corona system, the conditions are not ideal. We know much less than we would like to about the characteristics of the camera while flying, and the processing control is not completely adequate.*

The point is, that to make truly accurate luminance measurements from photographic photometry requires that: (1) we know the exact exposure time, (2) we accurately know the lens transmission, (3) the actual filter factor for the filter used is known, (4) the lens f/stop is well known, (5) the sensitometry for the frame processed is well known, and (6) we know something about the target. Although we know all of these factors to some extent, they are not well enough known (nor can they be measured) for their orbital situation. Certainly they are not well enough known to certify that we can calculate the object luminance to ±10 percent. In fact, if one carefully analyzes the errors that could exist in the knowledge of the above, the calculations of minimum luminance could be off by as much as 100 percent.

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*In this context this implies only that true sensitometric processing with the ultimate in controls is not being given. It is realized that this is impossible under operational conditions.

Attacking the third assumption is somewhat like attacking a sacred cow. Historically, exposure calculations have been made by placing some minimum luminance at some density on the D-log E curve. But the luminance values themselves are not the important factor, but only a means by which to make entry to the D-log E curve. What is important is the reflectance of the objects, or better yet, the lowest reflectance objects of interest. In other words, in exposure considerations it is not important that some minimum luminance is reproduced at a given density, but rather it is important that the minimum reflectance object of interest is reproduced at some density. It is obvious why this is true when one considers that a given object with a given reflectance will have a continuum of luminance values depending on the solar elevation, cloud cover, haze, etc. Therefore, to make conclusions about exposure from minimum luminance data is somewhat dubious since the luminance values measured say nothing about the reflectance of the target.

The above argument is somewhat oversimplified, for, in fact, one is not really interested in the minimum reflectance object of interest, but in the total frequency distribution of target reflectances to be encountered on the mission. It is realized that there is a limited exposure latitude available on the film, and that under any conditions, exposure selection is a compromise. To make the best possible compromise, it would ultimately be desirable to know the frequency distribution of the known targets to be covered. With this information, one could now bias the exposure selection low if a percentage of targets are of low reflectance, or high if a large percentage of the targets are of high reflectance.

Appendix B

ANALYSIS OF CORN TARGETS

The controlled range network (CORN) is a series of instrumented permanent and mobile optical reconnaissance target displays located throughout the United States. The mobile arrays contain a medium contrast "T" bar target, edge analysis targets (which can also be used for photometric analysis), a gray scale, a high contrast "T" bar target, a modified MIL-STD-150A, a tricolor target, and a point source target. The targets of importance to this study are the gray scales and the photometric targets. The physical dimensions of these are shown in Fig. B-1.

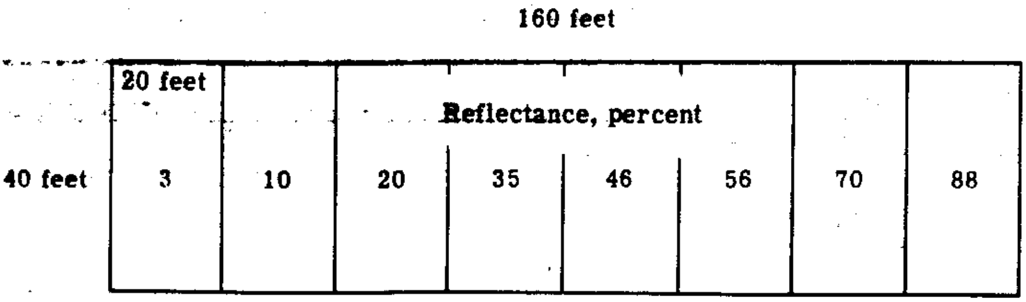
For each mission these targets can be, and often are, displayed and monitored. If photographed, we then have a control in that we know how the system recorded objects of known reflectance. We now plan to analyze these step wedges and photometric patches to establish a curve of original negative density versus object reflectance. The analysis will be made by microdensitometry. A first analysis indicates that the microdensitometry may not be too much of a problem. We need, of course, to use the largest slit we can to reduce noise in the trace due to film granularity.

In the process of preparing this proposal, we reviewed the AFSPPF reports on Corona missions to observe their traces of gray scales. These traces were very difficult to evaluate because of the noise that was present. SPPF traces the gray scales with a 1.58-micron slit, which we feel is too small, particularly in view of the fact that the 40- by 160-foot gray scales are reproduced as 40 by 160 microns at a scale of 1:300,000. With this in mind, we felt that a larger slit could be used. To prove our point we conducted a simple experiment.

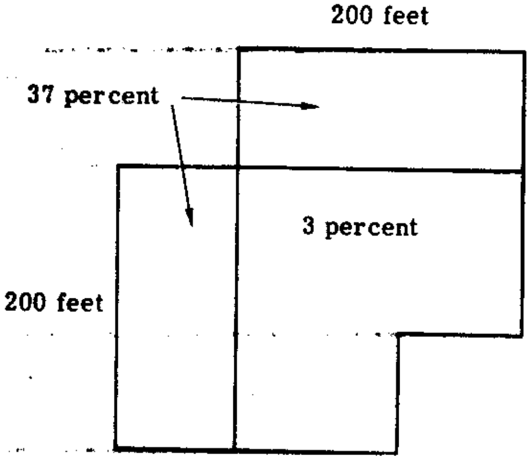
A target array was made up consisting of a low contrast (2:1) resolving power target and a gray scale. These were photographed on 3404 film to give a reduced gray scale equal to 40 by 160 microns at approximately 100 lines per millimeter low contrast resolution. This, it was felt, would simulate the operational case. The reduced step tablet was traced on an Intectron microdensitometer. Portions of the actual traces are shown in Fig. B-2. From this preliminary laboratory analysis it would appear that a 16-micron slit would be better for tracing the gray scales on the original negatives.

From this test it is obvious that it will be difficult to detect the individual steps in the wedges. The individual steps could be determined by a measurement technique, since we will know the exact scale and size of the targets on the 3404 film. However, for more useful analysis of the CORN step tablets, a minor alteration of the CORN array would seem in order. Specifically, we suggest that the steps of the wedge be physically separated, and surrounded by a black background. In this manner, we can eliminate the influence of adjacent targets and/or ground terrain luminance on the density recorded from the CORN step wedge.

There is a second approach that could be used, however, if tracing the step tablet becomes too difficult because of the noise. This approach would involve a multiple tracing and computer-averaging technique. We have developed techniques for performing and feeding into a computer multiple microdensitometer traces of a target. The computer averages the multiple inputs and plots out a smoother trace. If necessary this approach will be employed.



(a) step wedge showing percent reflectances and dimensions



(b) edge analysis (photometric) target showing percent reflectances and dimensions

Fig. B-1 — CORN step wedge and edge analysis (photometric) targets

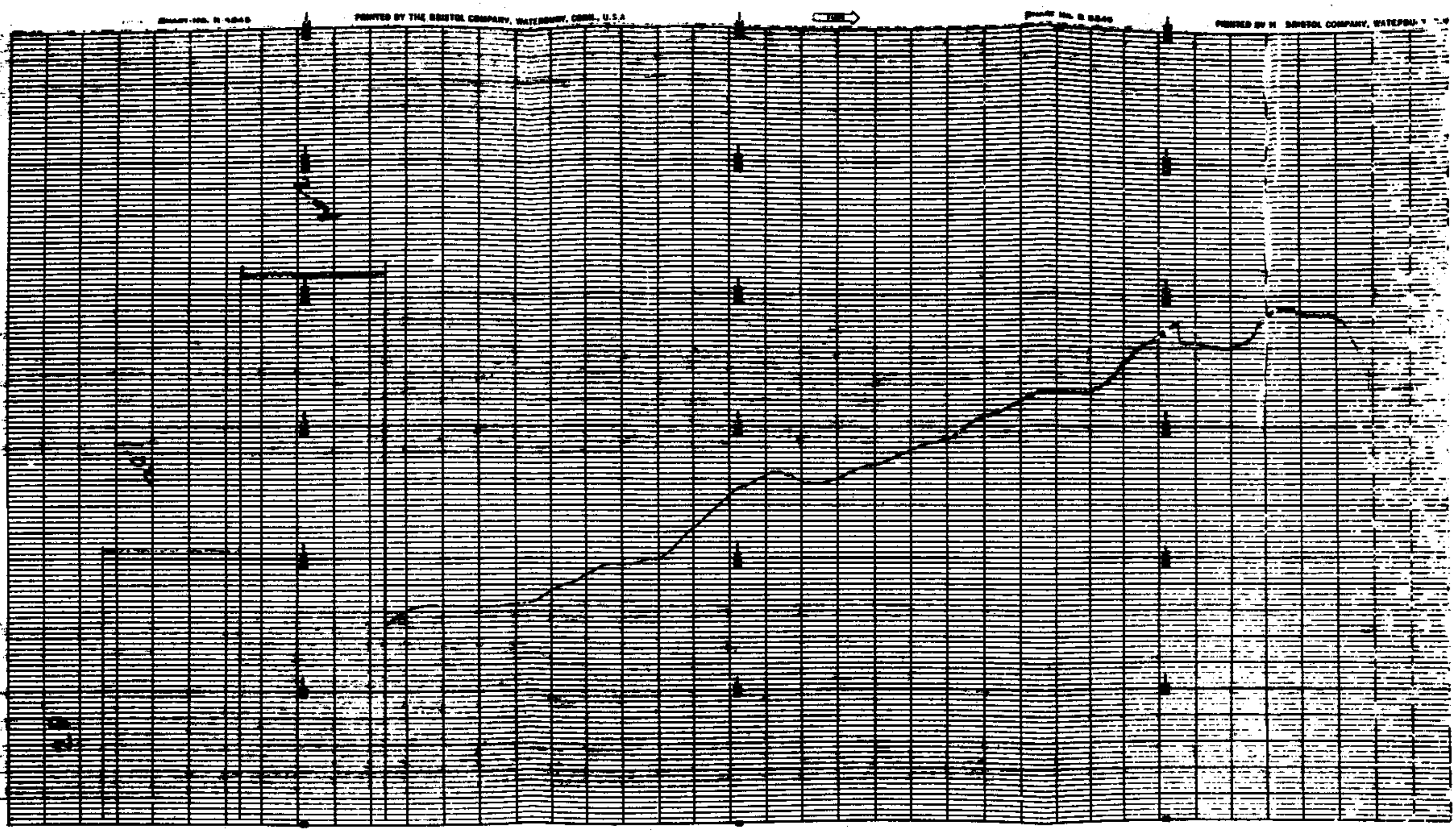


Fig. B-2(a) — Intectron microdensitometer traces of experimental target array: 16.0-micron slit

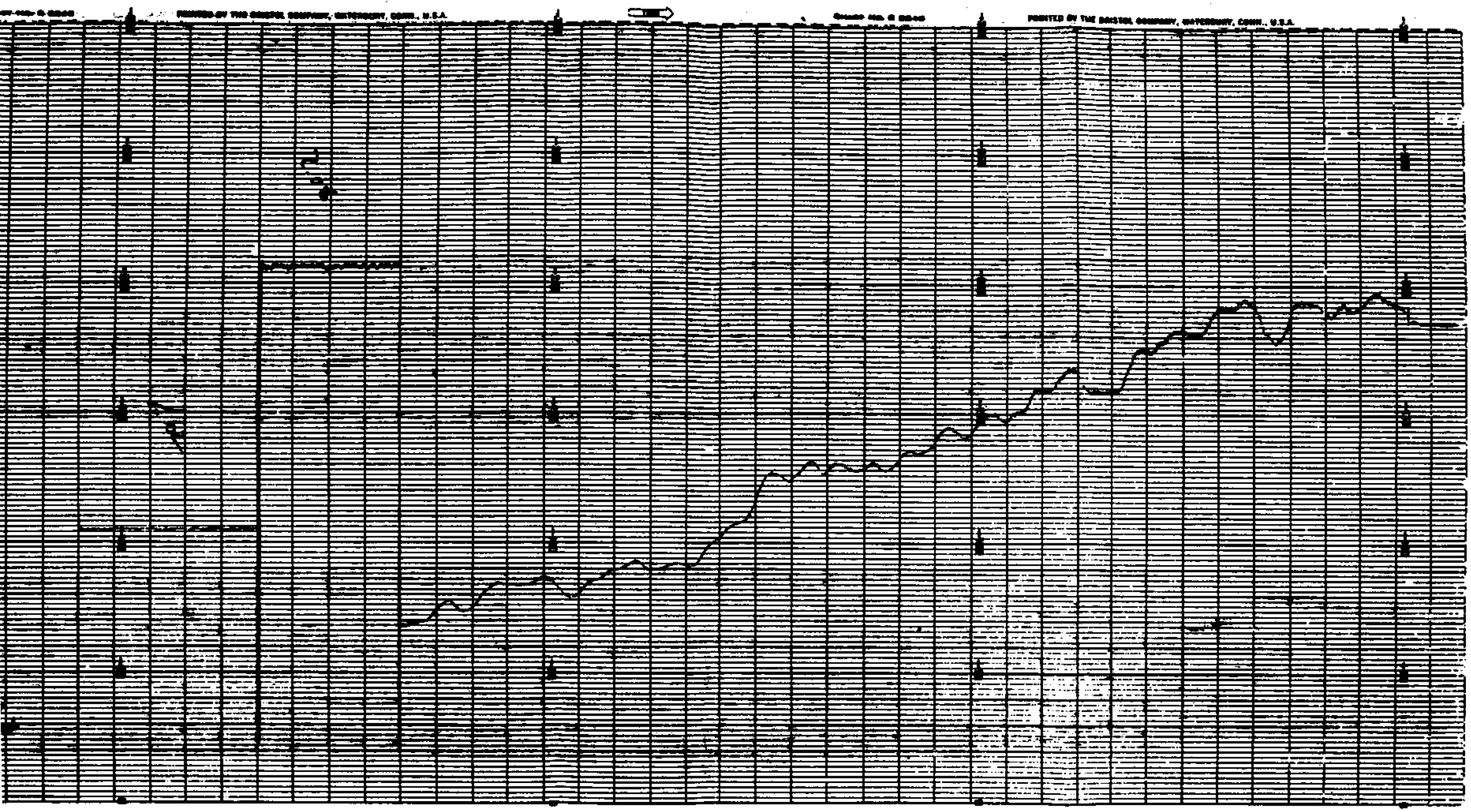


Fig. B-2(b) — Intectron microdensitometer traces of experimental target array: 10.0-micron slit

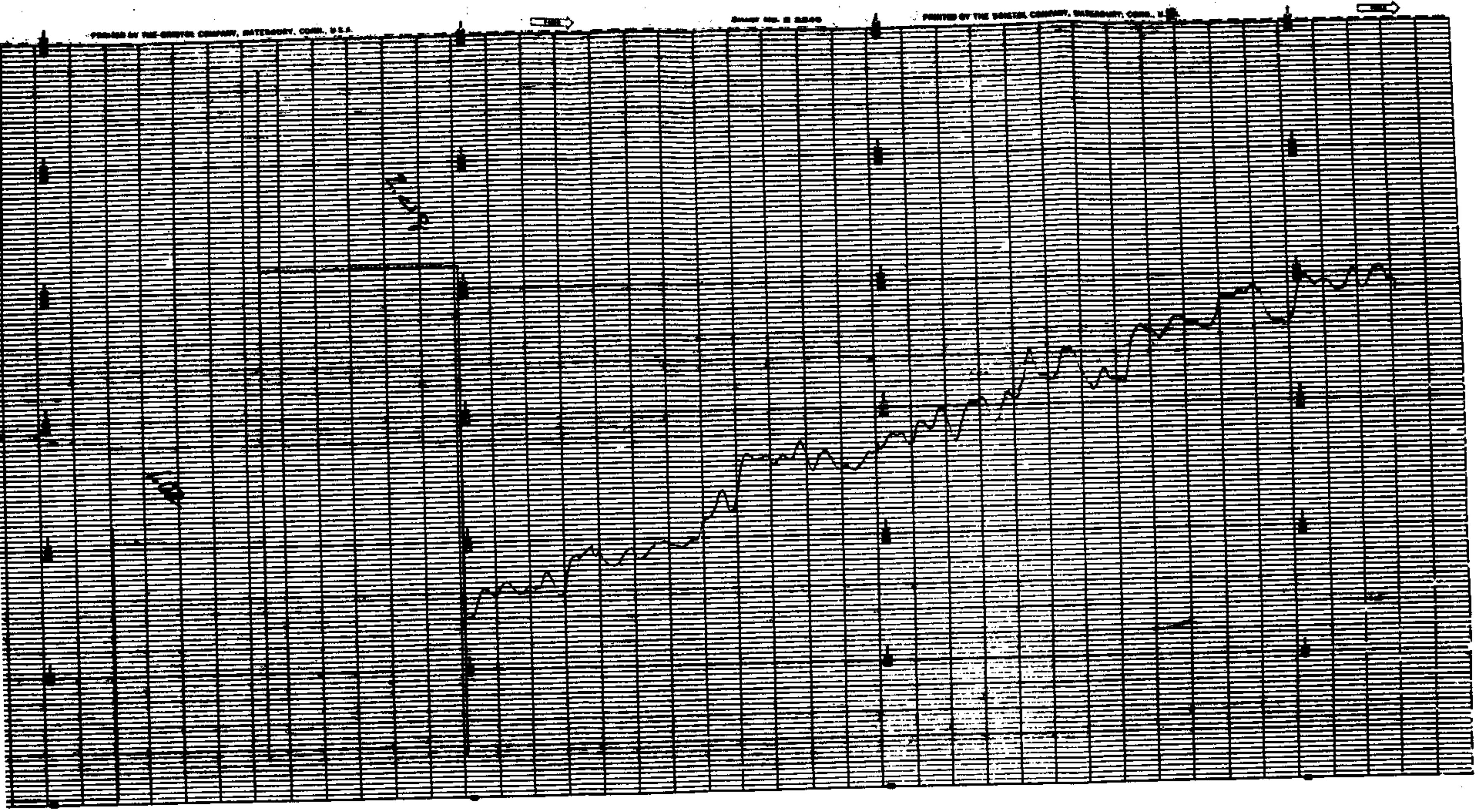


Fig. B-2(c) — Intectron microdensitometer traces of experimental target array: 2.0-micron slit

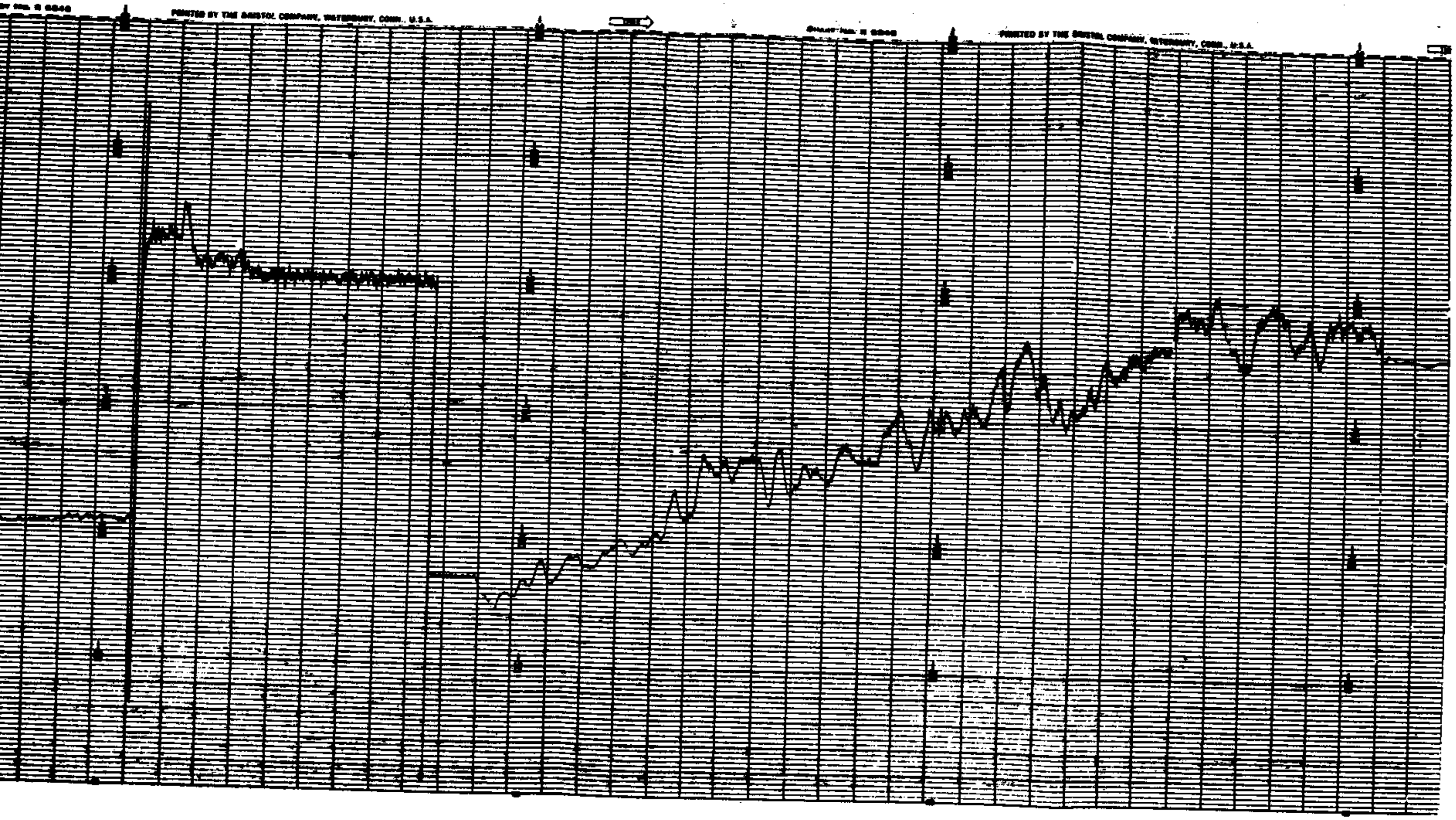


Fig. B-2(d) — Intectron microdensitometer traces of experimental target array: 0.6-micron slit

Appendix C

REPRODUCTION ANALYSIS

1. DISCUSSION OF PROBLEM

The purpose of a reconnaissance camera is to record as faithfully as possible information concerning the ground scene. For the purposes of high altitude panchromatic aerial reconnaissance, this information is in the form of luminance distribution and geometrical configurations. Unfortunately, the photographic recording process alters both of these basic image characteristics.

1.1 Effect of Atmosphere on Photographic Contrast Attenuation

The atmosphere complicates the photorecording process in two ways: (1) it reduces object luminance through scatter and absorption, and (2) it increases object luminance through the addition of its own energy. This phenomenon can be expressed mathematically as

$$B_0 = I_s R_g T_a + B_a \qquad (1)$$

where B_0 = luminance of the object above the atmosphere
I_s = solar illumination
R_g = object reflectance
T_a = atmospheric transmission
B_a = atmospheric luminance

If there were no atmosphere and no camera flare, there would be a linear relationship between camera exposure and ground object luminance. Because of the atmosphere and camera flare, however, the relationship is nonlinear. A simple relationship can be established to calculate the effect of atmospheric luminance on a given camera system.

On-axis light losses through a lens can be expressed as

$$I_f = \frac{B_0 T_l}{4(f/no.)^2 F} \qquad (2)$$

where I_f = illumination in focal plane
T_l = lens transmission
f/no. = relative aperture
F = filter factor
B_s = object luminance

Substituting Equation (1) in Equation (2), and taking camera exposure time into account, we obtain

$$E = \frac{t(I_s R_g T_a + B_a)T_l}{4(f/no.)^2 F} \qquad (3)$$

where E = exposure in foot-candle-seconds
t = exposure time
F = filter factor
f/no. = relative aperture
I_s = solar illumination
R_g = object reflectance
T_a = atmospheric transmission
B_a = atmospheric luminance
T_l = lens transmission

Equation (3) can be made to yield exposure in meter-candle-seconds (a term more commonly employed in film evaluation), by the multiplication of the numerator by 10.76 (1 foot-candle = 10.76 meter-candles). Thus, Equation (3) becomes

$$E = \frac{2.7t\ (I_s R_g T_a + B_a)T_l}{(f/no.)^2 F} \qquad (4)$$

Equation (4) can now be used to calculate the effect on a given atmosphere on the ground scene and to illustrate how this effect alters the camera exposure. Fig. C-1 illustrates the point. The effect on a constant atmosphere was calculated for a given range of ground luminance. The assumed lens and atmospheric conditions are noted on the figure. From this figure, the exposure resulting after atmospheric attenuation is clearly demonstrated. The contrast loss accrued by the atmosphere is illustrated by object b and its background b', which are presented to the film as a and a'. There is a definite loss in contrast.

The figure further emphasizes an important point: the atmospheric attenuation, being uniform, produces a nonlinear alteration of object luminances. This nonlinear degradation of the original scene complicates the recording process in that a simple increase in gamma, to increase the recorded object contrast, does not truly compensate for the alteration in original object contrast. The purpose of the reconnaissance mission is to record information about the ground scene and, ultimately, the greatest

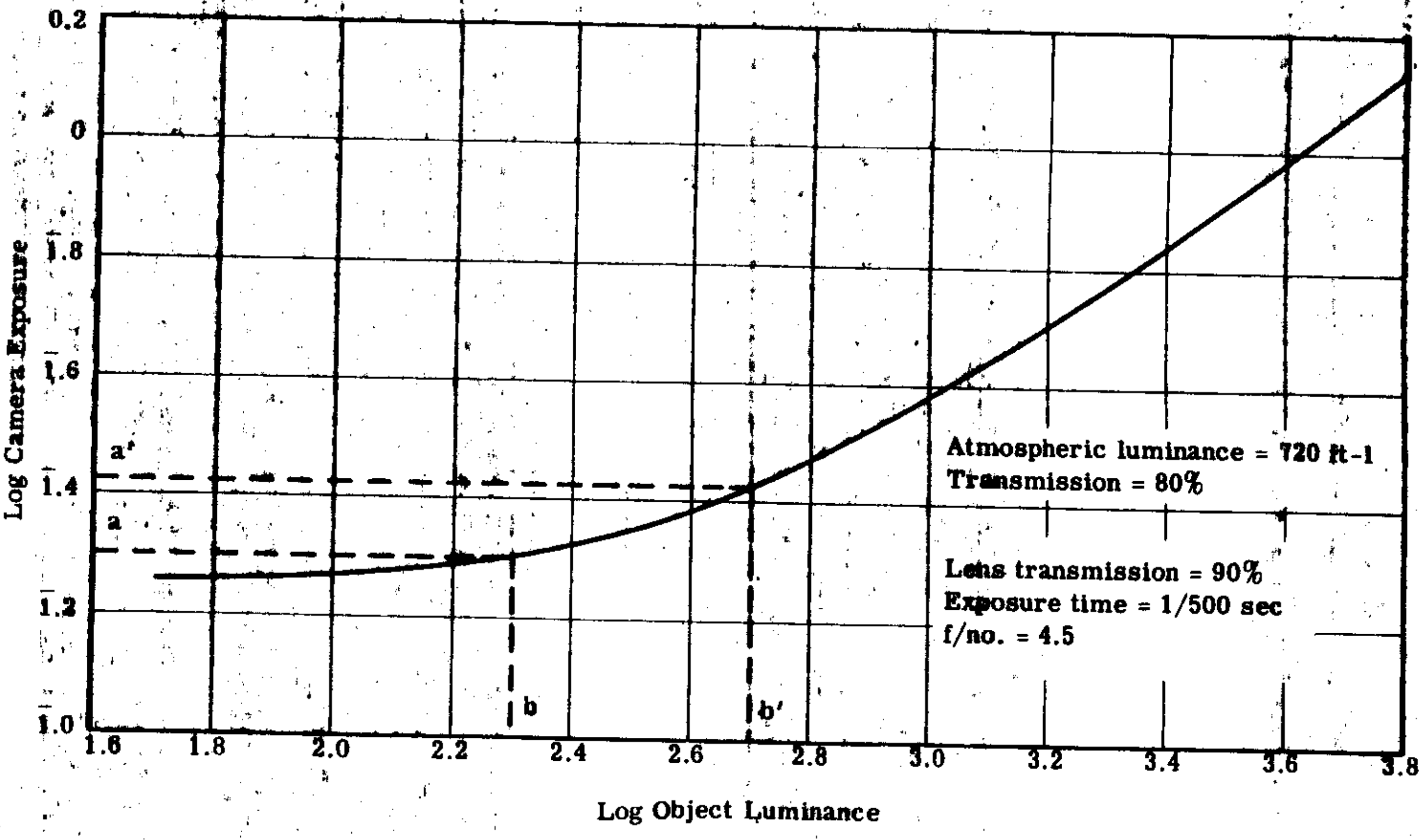


Fig. C-1 — Effect of sample atmospheric luminance on log camera exposure information will be recorded when the ground scene is perfectly reproduced. Obtaining a perfect reproduction is difficult, however, unless one considers not only the taking material but the duplicating material as well. For optimum reproduction of ground scene detail (from the tone reproduction standpoint), it is necessary to select both the proper negative and positive duplicating films.

To aid in the selection of the appropriate camera negative film for a given mission, tone reproduction theory can gainfully be employed. Fig. C-2 shows a typical tone reproduction cycle in aerial photography. The original object luminance is altered by the atmosphere and, as shown on the figure, presents the film with an altered camera exposure. This camera exposure becomes, of course, the exposure for the negative material. When processed, the density of the camera negative images becomes the log exposure for the positive stage. If the first generation positive is the last stage in the reproduction process, then the reproduction can be characterized by a plot of density versus log luminance of the original ground objects.

Figs. C-2 and C-3 illustrate sample tone reproduction cycles for high altitude aerial reconnaissance under conditions of moderate haze. Fig. C-2 illustrates taking on 3404 film and duplication on 8430 film, whereas Fig. C-3 illustrates taking on SO-190 film and duplication on 8430 film. The examination of each of the figures demonstrates the imperfection of the final reproduction in both cases. Although the shadow detail has been somewhat enhanced, it is still recorded at a contrast lower than the original contrast, while the highlights, in both cases, have been seriously degraded due to the limitations in the photographic materials. In particular, SO-190 film produces a serious loss of highlight information since the excessive gamma yields a density range which cannot be accepted by the duplicating film.

Consider now the case of extremely clear weather. The atmospheric contrast degradation is less, making the reproduction even worse than for the moderate haze condition if conventional aerial film processing is employed. Figs. C-4 and C-5 illustrate the point, again for SO-190 and 3404 film duplicated on 8430 film. As can be seen from the reproduction quadrant, the reproductions are worse than for the moderate haze condition, particularly in the highlight and middle tone region of the ground luminance range. This result can be directly attributed to the fact that the increased object contrast due to the reduced haze, reaching the film plane, produces a density range too great to be duplicated on the 8430 film. This is particularly true with SO-190 film, which seriously distorts highlight detail. Through the appropriate selection of film processing conditions, however, the reproduction can be considerably improved. Consider again the clear weather case, this time as illustrated in Fig. C-6. The 3404 camera film has now been processed such that the resultant gamma is 1.2 instead of the normal 2.2. This reduction of the process gamma significantly reduces the density range that the duplicating material must record. The resulting reproduction is considerably improved, as illustrated on the figure. In this case, the highlights are nearly perfectly reproduced, while the mid-tones and the shadows maintain a slight reproduction error.

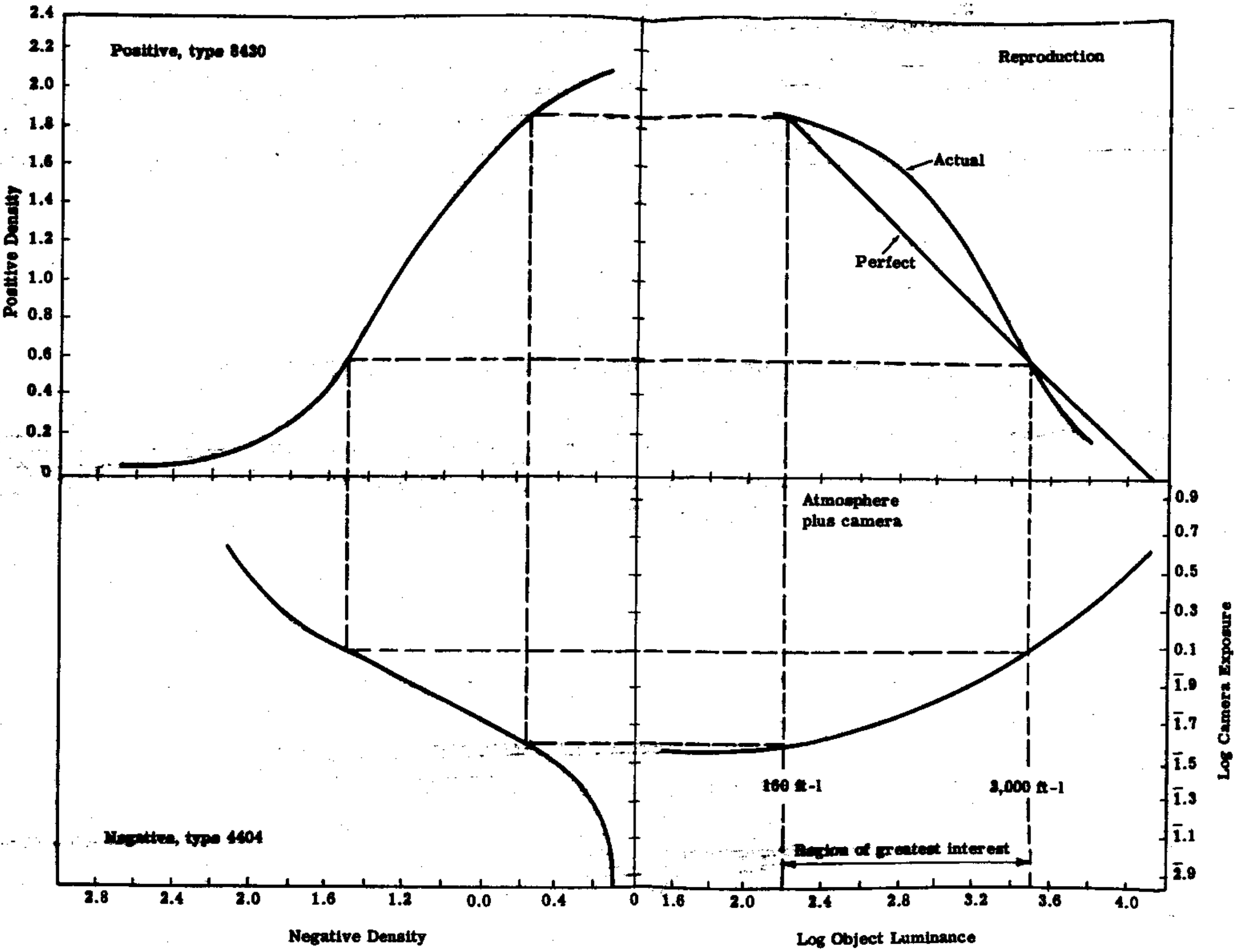
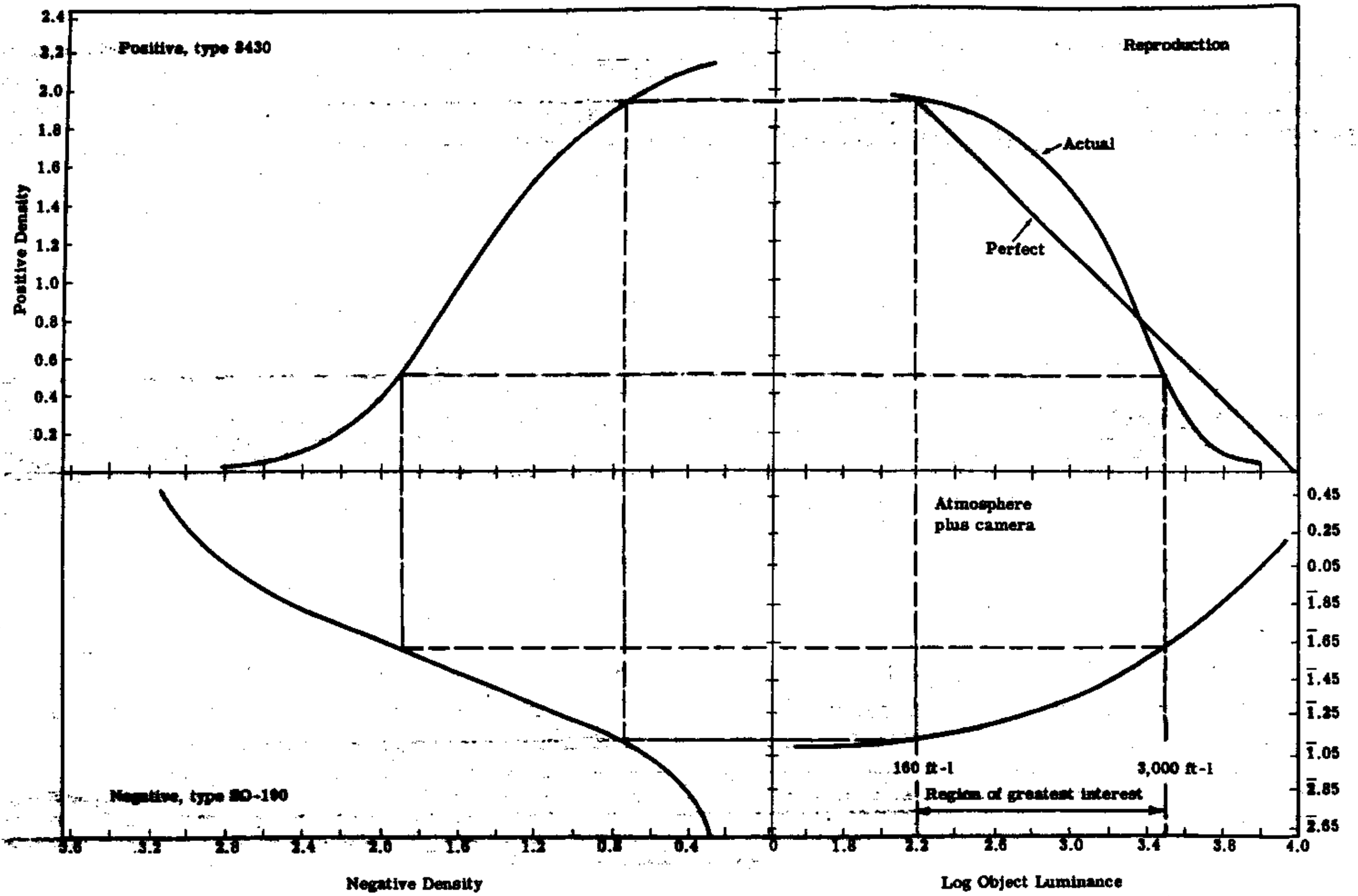


Fig. C-2 — Typical tone reproduction cycle in high altitude aerial photography (moderate haze condition), showing perfect and actual reproduction of original scene

Conditions

1. **Atmosphere**
    - Luminance = 720 ft-lamberts
    - Transmission = 60%
2. **Camera**
    - Flare = none
    - f/no. = 4.5
    - Transmission = 90%
    - Exposure time = 1/250 sec
3. **Negative**
    - Film type = 4404
    - Processing = 6 min, D-19 at 68°F
    - Gamma = 1.95
4. **Positive**
    - Film type = 8430
    - Processing = 6 min, D-19 at 68°F
    - Gamma = 1.5

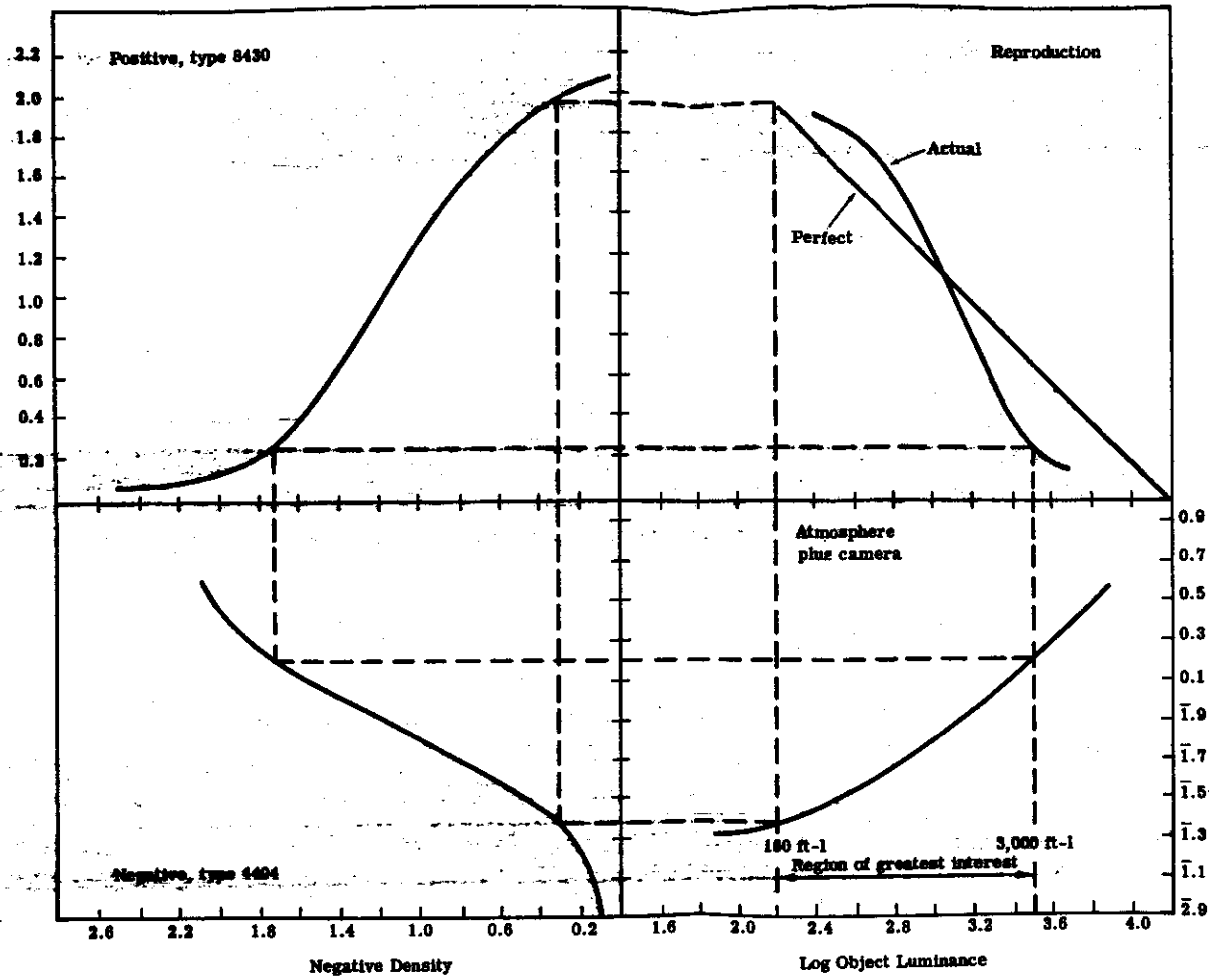
[redacted]



Conditions

1. Atmosphere
   Luminance = 720 ft-lamberts
   Transmission = 60%
2. Camera
   Flare = none
   f/no. = 4.5
   Transmission = 90%
   Exposure time = 1/700 sec
3. Negative
   Film type = SO-190
   Processing = 6 min, D-19 at 68 °F
   Gamma = 2.5
4. Positive
   Film type = 8430
   Processing = 6 min, D-19 at 68 °F
   Gamma = 1.5

Fig. C-3 — Typical tone reproduction cycle in high altitude aerial photography (moderate haze condition), showing perfect and actual reproduction of original scene

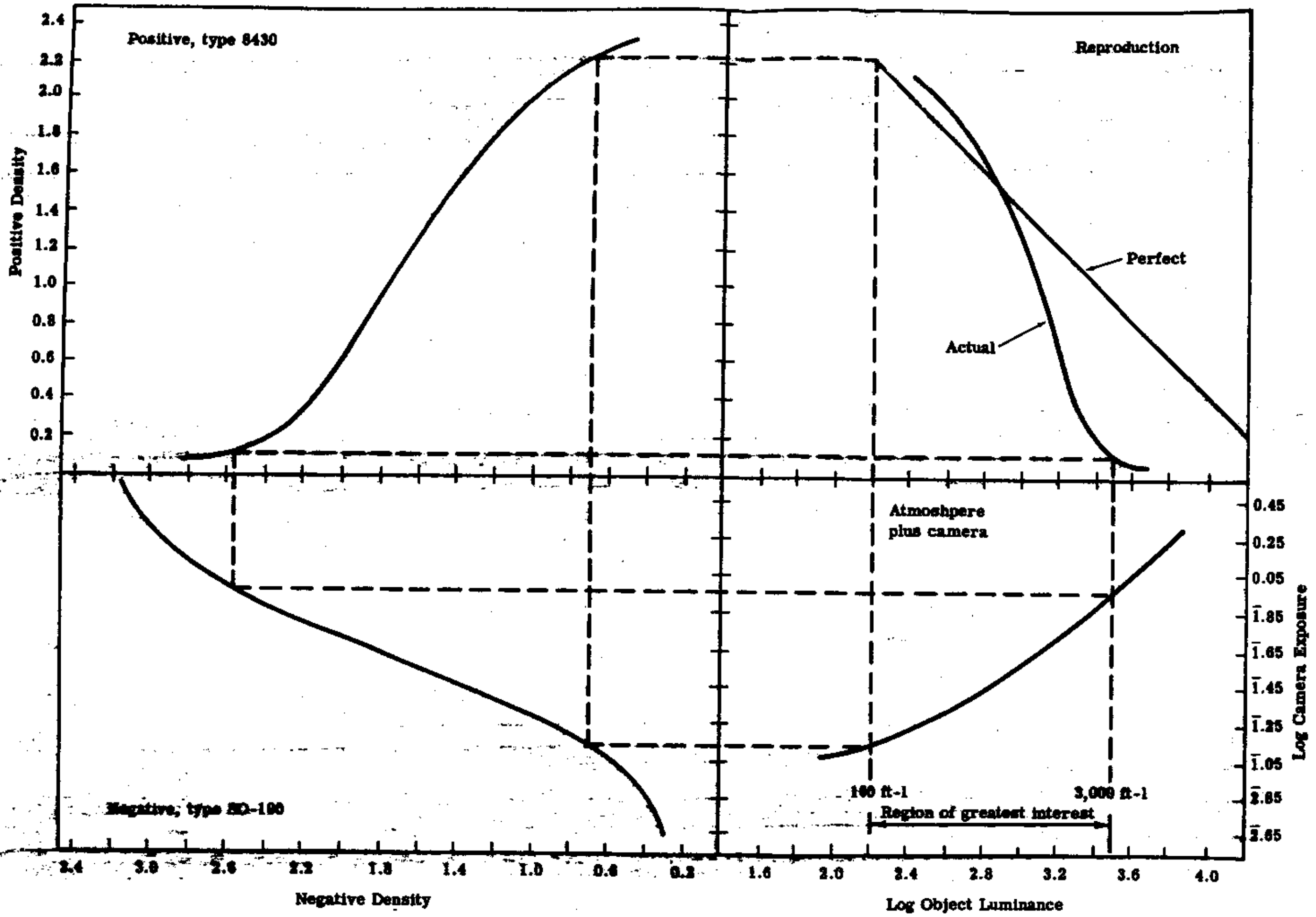


Conditions

1. Atmosphere
   Luminance = 300 ft-lamberts
   Transmission = 80%
2. Camera
   Flare = none
   f/no. = 4.5
   Transmission = 90%
   Exposure time = 1/225 sec
3. Negative
   Film type = 4404
   Processing = 6 min, D-19 at 68 °F
   Gamma = 1.95
4. Positive
   Film type = 8430
   Processing = 6 min, D-19 at 68 °F
   Gamma = 1.5

Fig. C-4 — Typical tone reproduction cycle in high altitude aerial photography (extremely clear weather), showing perfect and actual reproduction of original scene

[redacted]

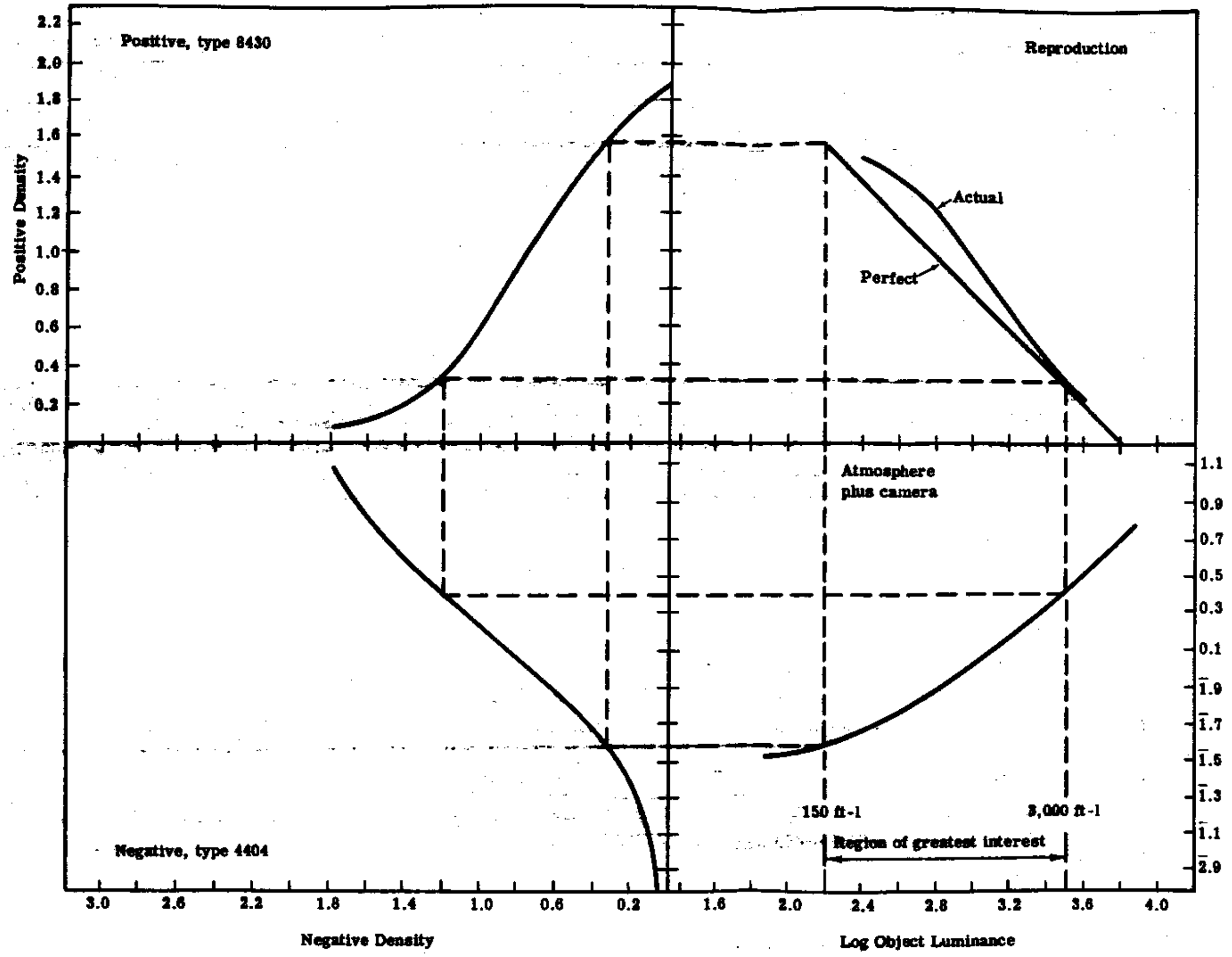


Conditions

1. Atmosphere
   - Luminance = 300 ft-lamberts
   - Transmission = 80%
2. Camera
   - Flare = none
   - f/no. = 4.5
   - Transmission = 90%
   - Exposure time = 1/600 sec
3. Negative
   - Film type = 4404
   - Processing = 6 min, D-19 at 68°F
   - Gamma = 2.5
4. Positive
   - Film type = 8430
   - Processing = 15 min, D-19 at 68°F
   - Gamma = 1.6

Fig. C-5 — Typical tone reproduction cycle in high altitude aerial photography (extremely clear weather), showing perfect and actual reproduction of original scene

[redacted]



Conditions

1. Atmosphere
   Luminance = 300 ft-lamberts
   Transmission = 80%
2. Camera
   Flare = none
   f/no. = 4.5
   Transmission = 90%
   Exposure time = 1/225 sec
3. Negative
   Film type = 4404
   Processing = 3 min, Cramer HD at 68 °F
   Gamma = 1.2
4. Positive
   Film type = 8430
   Processing = 6 min, D-19 at 68 °F
   Gamma = 1.5

Fig. C-8 — Typical tone reproduction cycle in high altitude aerial photography (extremely clear weather), showing perfect and actual reproduction when using low-gamma camera negative material

[redacted]

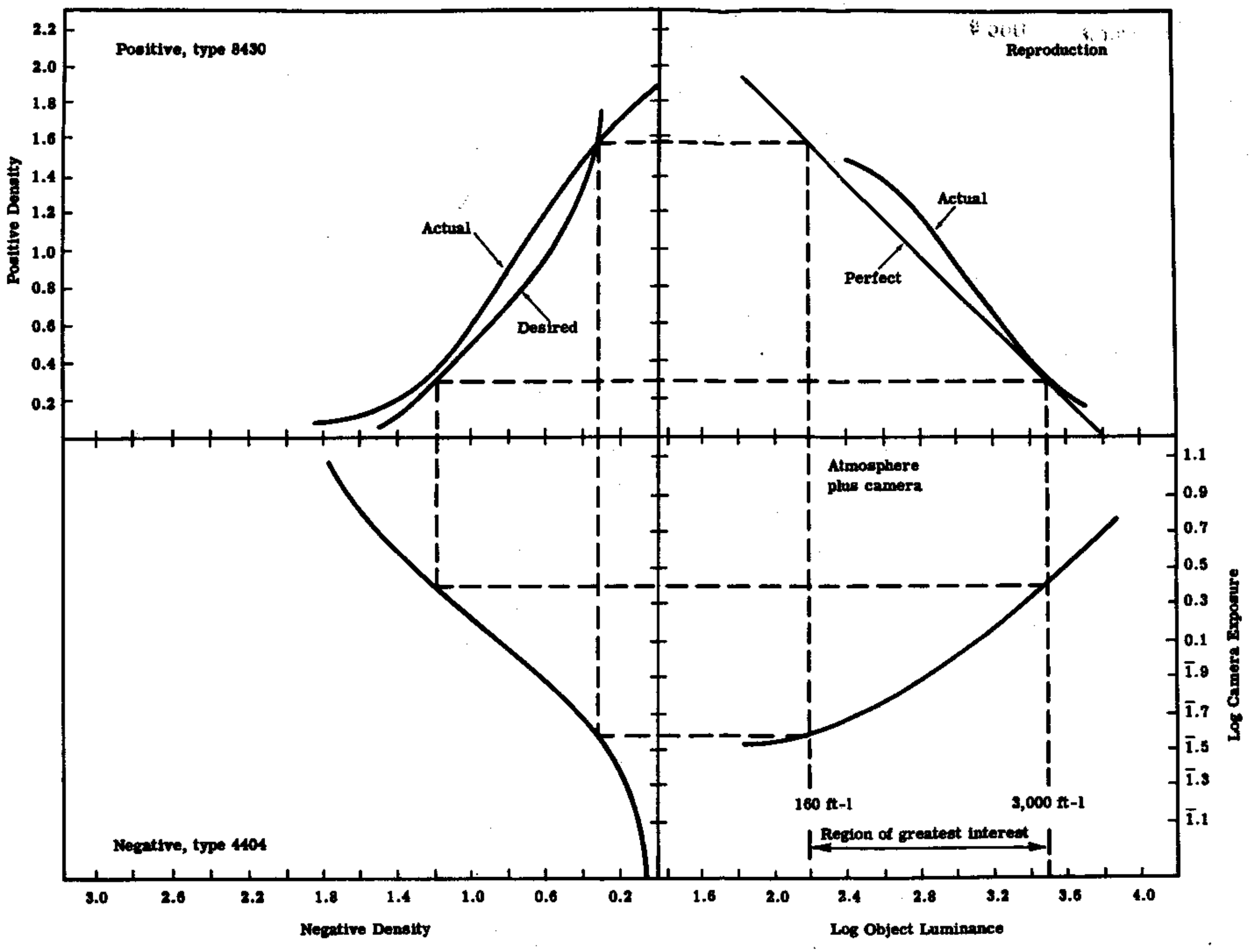


Fig. C-7 — Typical reproduction cycle for high altitude aerial photography showing actual reproduction for sample case, and desired characteristics of positive duping film for perfect reproduction

Conditions

1. Atmosphere
   Luminance = 300 ft-lamberts
   Transmission = 80%
2. Camera
   Flare = none
   f/no. = 4.5
   Transmission = 90%
   Exposure time = 1/225 sec
3. Negative
   Film type = 4404
   Processing = 3 min, Cramer HD at 68 °F
   Gamma = 1.2
4. Positive-Actual
   Film type = 8430
   Processing = 6 min, D-19 at 68 °F
   Gamma = 1.5

[redacted]

The advantage of this approach to the selection of appropriate film and processing is that one can also determine the appropriate film characteristics for a perfect reproduction. Fig. C-7 demonstrates such a determination for the clear weather case. In the positive quadrant, the actual 8430 film curve is shown along with the desired characteristic curve for perfect tone reproduction of the original scene. Although the desired curve appears anomalous for photographic emulsions, in practice such a curve is not impossible. With special processing, SO-105 duplicating film will produce a characteristic curve quite similar to the desired curve of Fig. C-7.

For a variety of haze conditions, then, one could determine the desired duplicating film characteristic curve for perfect tone reproduction. Fig. C-8 shows such a family of curves for light, moderate, and heavy haze conditions.

The above discussion illustrates two points. First, that simple contrast enhancement through increased gamma does not, of itself, correct for the distortions introduced in the aerial photorecording process by atmospheric haze. Second, that for maximum information transfer and optimum tone reproduction, the selection of a camera negative film cannot be made independently of the duplication process.

1.2 Tone Reproduction and Microimage Quality

The prior discussion was somewhat idealized, and is only intended to lay the groundwork for a more realistic analysis of the problem. Simple tone reproduction analysis of a system is fine, assuming that there is no effect on image quality as the way in which the tone reproduction process is put together is varied. That is, classical tone reproduction theory says that if two end product tone reproduction curves are the same, the pictures viewed will look the same. Recent work by Itek and others has demonstrated that this is not necessarily the case. This work is most interesting as it indicates that the manner by which the tone reproduction for a system is put together is extremely important, and can have a direct bearing on the physical image quality. It is even more interesting to note that current satellite reconnaissance photography reproduction practices (i.e., high gamma negative processing with low gamma duplication) may degrade the image quality over other reproduction techniques.

Experiment Background

Maximization of the performance of photo-optical reconnaissance systems requires optimization of photographic processing and reproduction techniques. There is evidence indicating that the present high-gamma processing of the negative is not the best way to reproduce the aerial image. Simonds et al* report that in a negative-positive

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* Simonds, J. L., Kelch, J. R., and Higgens, G. C., Analysis of Fine-Detail Reproduction in Photographic Systems. Paper presented at Spring Meeting of Optical Society of America at Jacksonville, Florida (25-27 March 1963).

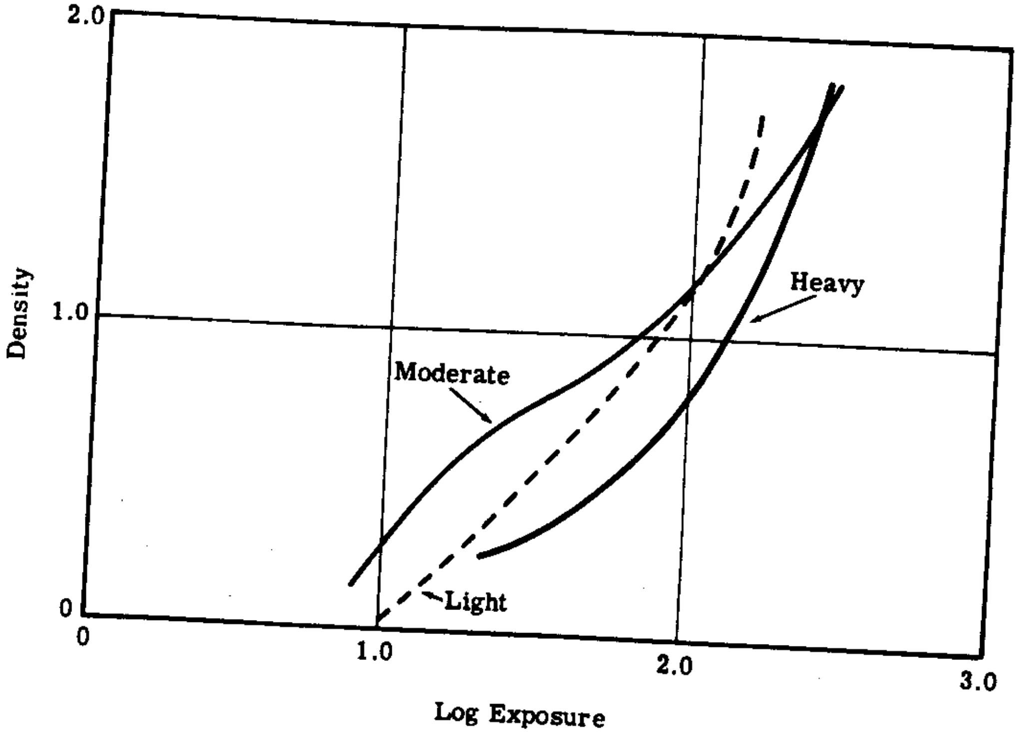


Fig. C-8 — Desired characteristic curves of positive duping film for perfect reproduction of ground scene tonal relationships for three haze conditions and 3404 negative material as shown in Fig. 3-7 photographic system, microimage quality is influenced by the order in which the processing gammas occur. They find that when the printing modulation transfer function has a cut-off near 20 cycles per millimeter, low gamma processing followed by high gamma processing gives better quality than the reverse order. This difference is apparent upon visual inspection of the final prints. The authors find that, with better printing conditions, the order of the gammas makes no difference. Although the printing methods used in the processing of satellite reconnaissance film are far better than those mentioned above, it is possible that this effect still occurs if the quality of the negative is commensurately better. If this is the case, optimization of the reproduction cycle would provide improvement in the microimage quality of satellite reconnaissance photography. Itek has been investigating this phenomenon, and this work is discussed below.

Experiment Performed

A master positive was assembled which included an aerial scene, a sine wave target, and a sensitometric step wedge. Negatives were made from this at both high and low gamma, and under two different printing conditions. The intent was to represent an aerial system with the master positive representing the original scene, and the negative printing conditions simulating the actual taking conditions. To emphasize this, the negative printing conditions will hereafter be referred to as the "taking" conditions. The high gamma reproductions were made by developing Tri-X Aerecon film in D-19, while the low gamma ones were made by using the same film with D-76 developer. The development was carefully controlled so that the low gamma was near 0.70 and the high near 1.40. The good taking condition was normal contact printing, and the poor was through a spacer of Cronar matte surface drafting film. Two replicate negatives were made for each of the four experimental conditions given above.

From each of these eight negatives, two positives were made. The four low gamma negatives were reproduced at high gamma (near 1.40), and the four high gamma negatives were reproduced at low gamma (near 0.70). Each pair of negative replicates was used to make four positives under the two printing conditions mentioned above (see Table C-1).

It should be noted that in both cases, the gamma product is approximately 1.4 times 0.7 (a value close to 1). This means that the system tone reproduction is, in all cases, nearly perfect. Also, the product of the component MTF's gives the same system MTF for all cases. If the order of gammas and the order of printing conditions MTF's makes no difference, then the final images should all be similar.

The measurement of the modulation transfer functions was made from microdensitometer traces of the images of the sine wave targets. The procedure was to measure the maximum and minimum microdensity along the trace, convert these specular densities into diffuse densities (as measured on the TD-100 densitometer) by using an empirically determined conversion formula, and then use the appropriate

Table C-1 — Listing of the Final Images Which Were Analyzed

	Negative Stage		Positive Stage	
No.	Taking Conditions	Gamma	Printing Conditions	Gamma
1	Good	High	Bad	Low
2	Bad	Low	Good	High

D-log E curve to find the maximum and minimum log exposure. The difference between these last two numbers is called the exposure range, R. Modulation is given by the following relation.

$$\text{modulation} = (10^R - 1)/(10^R + 1) \tag{5}$$

The ratio between this output modulation and the input modulation of the sine wave target is the value of the MTF for the particular sine wave traced.

The photographic noise present in the microdensitometer traces made it difficult to estimate the maximum and minimum values of the microdensity. As an indication of the difficulties the noise causes, the modulation that could be mistakenly ascribed to a noise variation of ±0.01 density units was calculated. If the gamma of the characteristic curve is unity, then the exposure range due to the noise is as much as 0.02. The modulation is calculated as follows:

$$\begin{aligned} \text{modulation} &= \frac{10^{0.02} - 1.0}{10^{0.02} + 1.0} \\ &= \frac{1.047 - 1.00}{1.047 + 1.00} \\ &= 0.045 \end{aligned}$$

With noise of ±0.01 density units, one cannot expect to measure any modulation smaller than 4½ percent.

An attempt was made to alleviate this difficulty by superimposing the microdensitometer traces of many sine wave cycles in order to average out the noise. Microdensitometer traces were digitized and recorded on paper tape. A program was written which directed the CDC computer to read this information from the tape, superimpose up to 10 sine wave cycles, and plot the computer average sine wave cycle. This averaging facilitated the selection of a maximum and minimum density.

Even by using this superimposition technique, it was not possible to distinguish one MTF from another. This technique is presently in a state of refinement. In order to complete the analysis from a practical standpoint, the images of the simulated aerial scene were compared. As predicted by Simonds et al, and shown by the theoretical analysis in this work, there was one image that was significantly poorer than the remaining three. Processing at high gamma in the negative portion of a two-stage process produces inferior quality images if the printing MTF is poor relative to the quality of the original negative.

The following is a technical discussion of the phenomenon.

Theoretical Discussion

A simple mathematical model for the photographic process presumes that the incident image is first blurred by scattering of light in the taking system and in the emulsion, and that this effective exposure distribution is then transformed into a photographic density distribution according to some D-log E relation. The scattering of incoherent light waves is a linear transformation of the incident distribution of electromagnetic intensity, and hence the methods of Fourier analysis are applicable. The photographic transformation represented by the D-log E relation is not linear. This fact makes it difficult to formulate general conclusions about this transformation. It is most convenient to use quantities proportional to electromagnetic intensity as inputs and outputs in this analysis. For this reason, the D-log E relation is expressed as an equivalent transmittance-exposure relation. The simple photographic response

$$D = \gamma\ (\log\ E - \log\ E_0) \tag{6}$$

is equivalently stated as

$$T = (E/E_0)^{-\gamma} = kE^{-\gamma} \tag{7}$$

Fig. C-9 illustrates a model for a negative-positive photographic system which is merely a cascading of two of the above models.

As an example of the use of this model, the procedure for calculating the output pattern resulting from a one-dimensional input exposure pattern is as follows:

1. Take Fourier transform of input exposure pattern
2. Multiply this spectrum by the first MTF to get effect of light scattering in taking system and negative emulsion
3. Reconstitute the effective exposure by taking the inverse Fourier transform of above
4. Calculate transmittance pattern due to the effective exposure pattern by using the first T-E relation
5. Take the Fourier transform of this pattern
6. Multiply by second MTF to get result of light scattering in printing system and positive emulsion
7. Take the inverse Fourier transform to reconstitute the effective exposure pattern for the positive
8. Calculate the transmittance pattern due to above by using the second T-E relation. This is the output pattern.

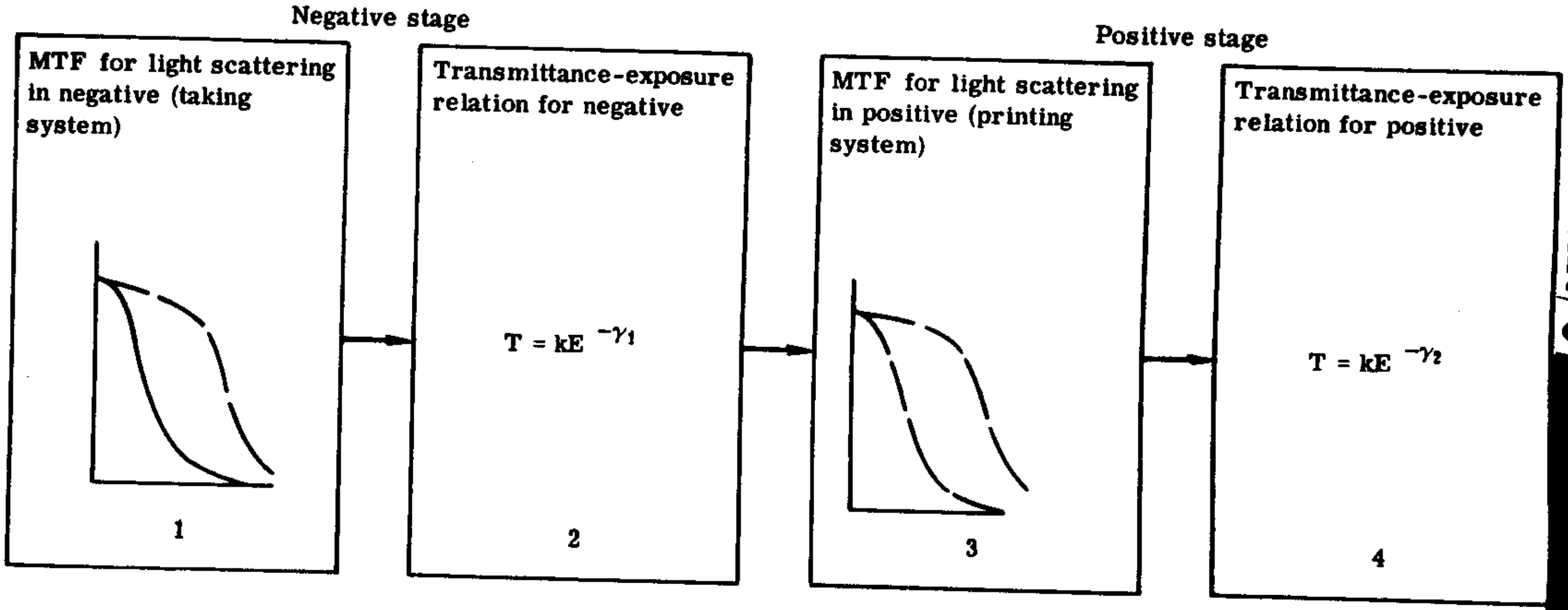


Fig. C-9 — Model for negative-positive photographic system

Needless to say, electronic data processing facilities are required for such an analysis.

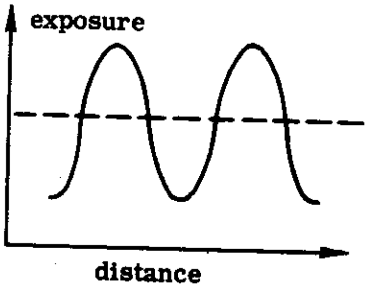
This model is not suitable for simulating adjacency effects. If these are prominent, the more complex model used by Kelley* is applicable. Extreme agitation during development minimized these effects in this experiment.

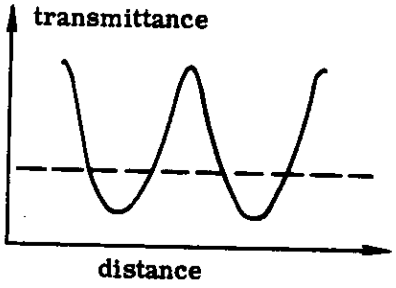
If a sinusoidal input pattern is acted upon by a transformation which is both linear and spatially uniform (in the photographic context, this means that emulsion is uniform and that the printing system does not affect one area of the image differently than another), then the output pattern must be sinusoidal and of the same spatial frequency as the input. The MTF for such a transformation is the ratio of output modulation to input modulation as a function of spatial frequency. For such a transformation, the sine wave response, as expressed by the MTF, determines the response to any other input.

The MTF concept does not strictly apply to two-stage photographic systems because of the nonlinear step intervening between the two linear steps. A sine wave input does not produce a sine wave output, though in practice, the difference is often so small as to defy detection. More important, the "sine wave response" for such a system does not determine what happens to other types of inputs. The transformation is said to be image dependent, because each image is a case unto itself. This is the reason for the theoretical poverty in this area of photography.

This model predicts that the microimage quality of the experimental system should depend upon the order of gammas, especially when the positive printing conditions are poor. This effect will be explained for the case of sinusoidal input patterns; analogous effects should hold for most other input patterns.†

Consider the transformation of a sine wave input pattern according to the nonlinear transmittance exposure characteristics of a typical film:





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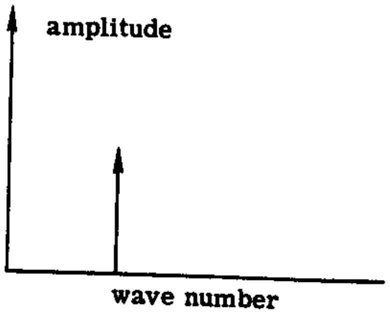
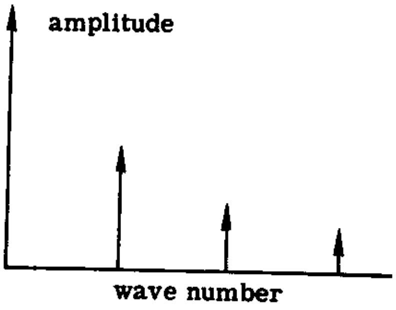
*Kelley, D. K., Systems Analysis of the Photographic Process. I. A Three-Stage Model, J. Opt. Soc. Am. 50(3):269 (1960).

†Simonds, loc. cit., carries out calculations for a square pulse input.

The purely sinusoidal input is distorted into a more complex type of periodic output. It is more enlightening to consider the same transformation in the spatial frequency domain. By using the Fourier theorems for periodic functions, it is possible to examine the harmonic content of both input and output.





The effect of the nonlinear T-E transformation is to introduce new spatial frequencies called harmonics into the output. These always occur at spatial frequencies (more properly called wave numbers) which are at all possible sums and differences of the input frequencies. Since the input exposure pattern varies sinusoidally about an average exposure, the input has components at wave numbers of zero and K_1, the fundamental spatial frequency. The output has Fourier components at wave numbers zero, k_1, $2k_1$, $3k_1$, . . .

A program was written to calculate the harmonic content of the periodic transmittance patterns which result from sinusoidal inputs. It was found that the harmonic content of the output increases as the input amplitude increases, and as the process gamma increases. This is quite reasonable, since high gamma amplitude inputs tend to fall more heavily upon the curved portions of the T-E graph. The harmonic content also depends upon the value of the average exposure. If this falls upon a relatively linear region of the T-E curve, the output will have little harmonic content; if it falls upon a more curved portion, the output will have more harmonic content.

When one nonlinear T-E transformation is followed immediately by another, and the gamma product for these two transformations is unity, then the cascaded transformation is linear. A gamma product of unity implies perfect tone reproduction. The output transmittance distribution is proportional to the input exposure distribution. Such a simple linear transformation should not distort a sine wave exposure pattern. It must be that the second nonlinear transformation eliminates all of the harmonics generated by the first. If a spatial frequency filter, like a typical printing MTF, intervenes between these two steps, then the second transformation cannot completely compensate for the distortion of the first.

When good taking conditions are followed by bad printing conditions, the order of the gammas is significant. If the order is low-high, then the harmonics generated in the negative stage are filtered somewhat by the bad printing conditions, and the positive T-E transformation is unable to reconstitute the image exactly. If the order of gammas is high-low, then degradation is much worse; the initial high gamma produces a larger spread of harmonics which are more strongly filtered by the bad positive printing MTF. The final nonlinear transformation fails to receive many of the harmonics which it requires to reconstitute the image. This indicates why low gamma negative processing followed by high gamma duplication should give better microimage quality than the reverse order of gammas. Fig. C-10 gives photographic evidence of this effect.

This effect is less significant when bad taking conditions are followed by good printing conditions. The initial bad MTF reduces the amplitude of the input signal, and fewer harmonics are generated in the negative T-E transformation. Since the positive printing MTF passes a wide band of spatial frequencies, the order of the gammas makes little difference. In both cases, the final nonlinear transformation passes most of the harmonics needed to reconstitute the image. This indicates why the order of gamma effect is most significant under poor printing conditions.

TOP SECRET/C [redacted]

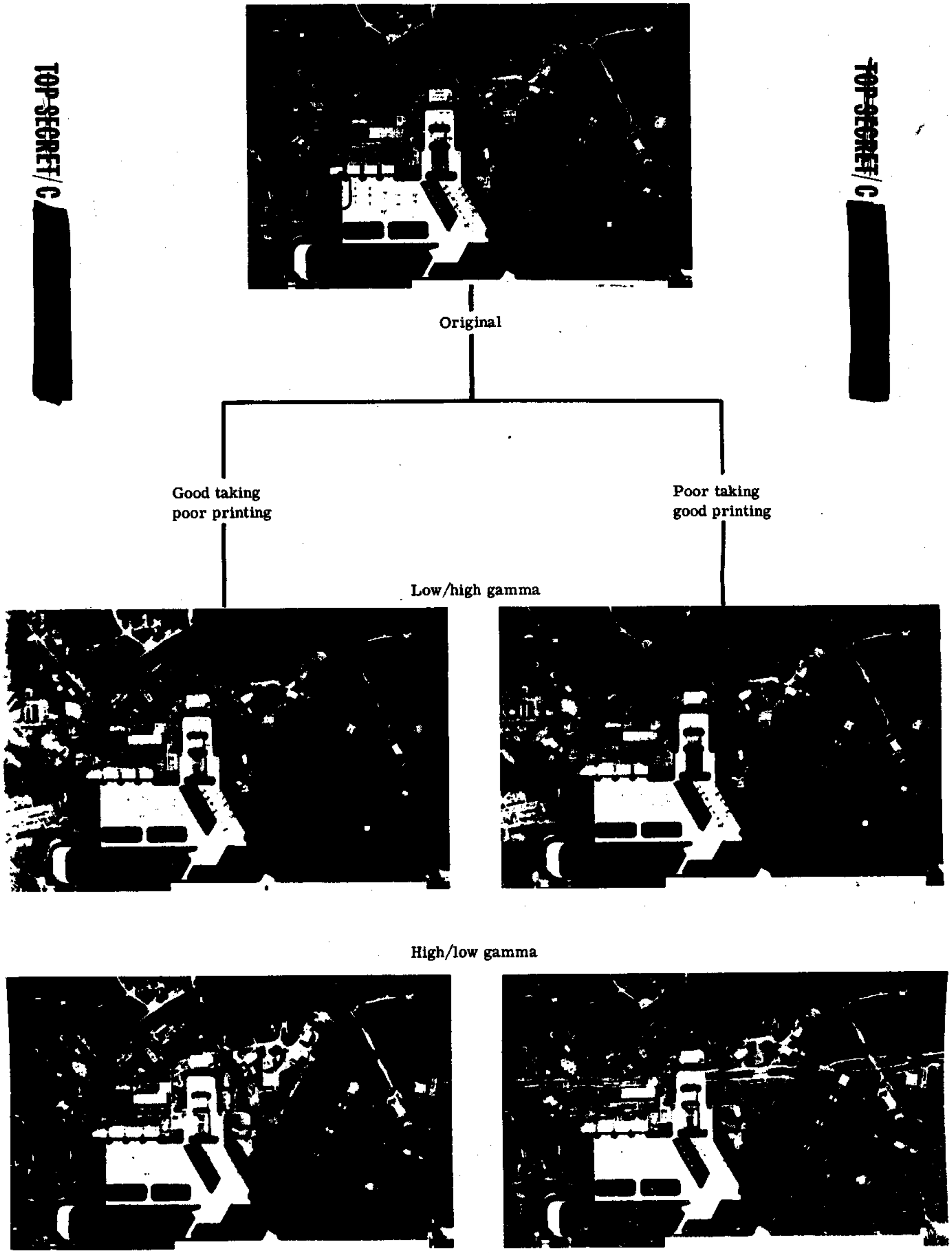


Fig. C-10 — Examples of effect of gamma on image quality

TOP SECRET/C [redacted]

Appendix D

SYZYGETIC DENSITY ANALYSIS

When attempting to make a measurement of contrast that hopefully relates to photointerpreter performance, it is first necessary to evaluate what it is that the photointerpreter sees. When the photointerpreter looks at an aerial photograph, he almost invariably uses some sort of magnification: a microscope, stereoscope, viewer, etc. The use of such auxiliary devices enables the photointerpreter to examine the information of interest, i.e., small detail. The main goal of the photointerpreter is then to examine, measure, identify, etc., microdetail. What is important to the photointerpreter is, then, the contrast of small adjacent detail. If he has optimum contrast in the microdetail areas, the contrast of large areas should be more than adequate. However, the converse is not necessarily true. Thus a measure of microcontrast logically appears to be the most meaningful technique from the photointerpreter's aspect. It is hoped that the syzygetic contrast technique will perform this function.

1. SYZYGETIC SCENE CONTRAST

Syzygetic* density differences are the differences between two adjacent or contiguous areas on the film (see Fig. D-1). This is not a new concept, and was originally proposed in 1951 by Jones and Higgins† as a technique for measuring film granularity in a manner that related to the visual sensation of graininess. The applicability of this technique to the photointerpreter case was noted, and it was decided to evaluate its connection with photointerpreter performance. Although this work is not complete, a computer program has been written by Itek that takes the microdensitometric input to produce a trace of SDD versus frequency of

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*The word "syzygy" (Latin "syzygia") is defined in Webster's New International Dictionary (second edition) as "a joining together, conjunction," and so is appropriate in referring to two elements that are intimately joined or immediately adjacent to each other. From this noun, the adjective "syzygetic" is derived, and the symbol SDD or SΔD has been adopted to refer to this type of density difference.

†Jones, L. A. and Higgins, G. C., "Photographic Granularity and Graininess VII. A Microphotometer for the Measurement of Granularity," J. Opt. Soc. Am., 41:192 (1951).

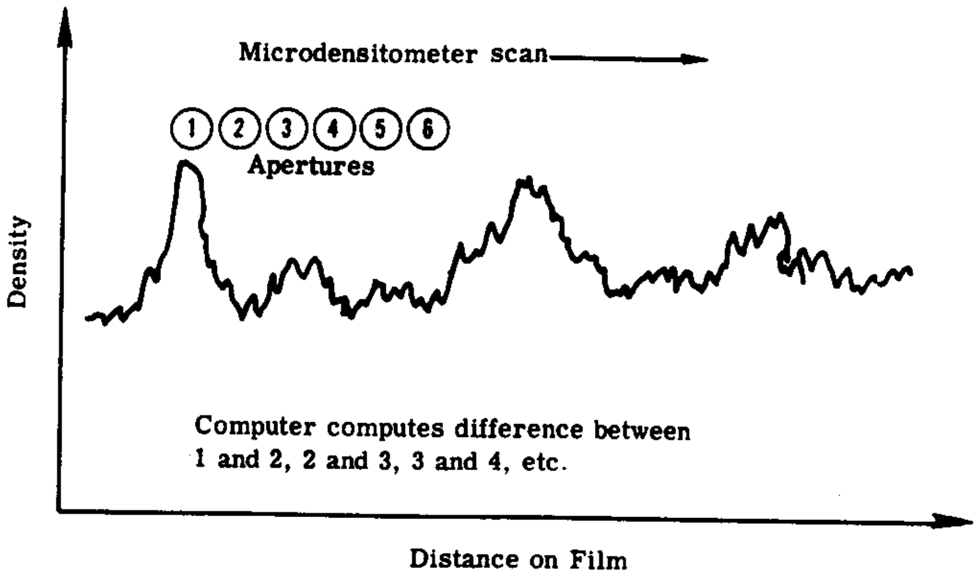


Fig. D-1 — Example of syzygetic density difference occurrence, and preliminary studies were carried out to determine if SDD traces related generally to scene contrast.

2. SDD COMPUTER PROGRAM

The SDD computer program uses the paper tape obtained from the microdensitometer trace of the film images. The densities should be taken at intervals equal to the scanning aperture diameter. For example, if the scanning aperture is 50 microns, then the sampling rate is one density point every 50 microns. These recorded densities are then the differences between the densities of the adjacent scene details for the scanning aperture used. The computer counts the number of each density difference that occurs and stores this information. The final output is the frequency of occurrence of the adjacent density differences.

The program also has the capability of determining the syzygetic exposure difference (SED) from the same paper tape, provided there is an accompanying density versus exposure table that has been fed in prior to the microdensitometer tape. The computer, in this case, determines the exposure difference from each of the density differences and counts them. The output from this part of the program is similar to the above, i.e., a plot of frequency of occurrence of exposure differences.

The SED has a use different from the SDD. Whereas SDD plots are to be used for photointerpreter correlative work, SED determinations can be used for film-filter studies. To study if certain filters give more information for certain types of detail, SDD information is practically meaningless. This is true because processing conditions greatly affect the resultant image. If, however, films taken with different filters are evaluated on the basis of exposure, then the results are "independent" of processing and directly relatable.

3. SAMPLE SDD ANALYSIS

To demonstrate the SDD program, three positive images, differing from each other only in contrast, were made. Figs. D-2, D-3, and D-4 show the three scenes used. A microdensitometer trace was made between two easily identifiable objects in each positive print. Since the traces were of the same objects at different contrasts, the final SDD output can be analyzed for contrast effects. A total of 1,400 data points were taken with a 50-micron diameter aperture in each print. The densities were digitized using the Itek microdensitometer digital output control unit. The paper tape was used with the computer program to calculate the SDD.

Fig. D-5 shows the final SDD traces from the three scenes. It can be seen that there is a high frequency of occurrence of small density differences in the low contrast scene. In fact, the largest density difference is 0.34, which is approximately the density range of the scene. The medium contrast scene has more density differences that are larger than those of the low contrast scene. However, the frequency of occurrence of smaller density differences is less. This trend continues with the high contrast scene.

Fig. D-2 — High contrast scene used in syzygetic density difference program

Fig. D-3 — Medium contrast scene used in syzygetic density difference program

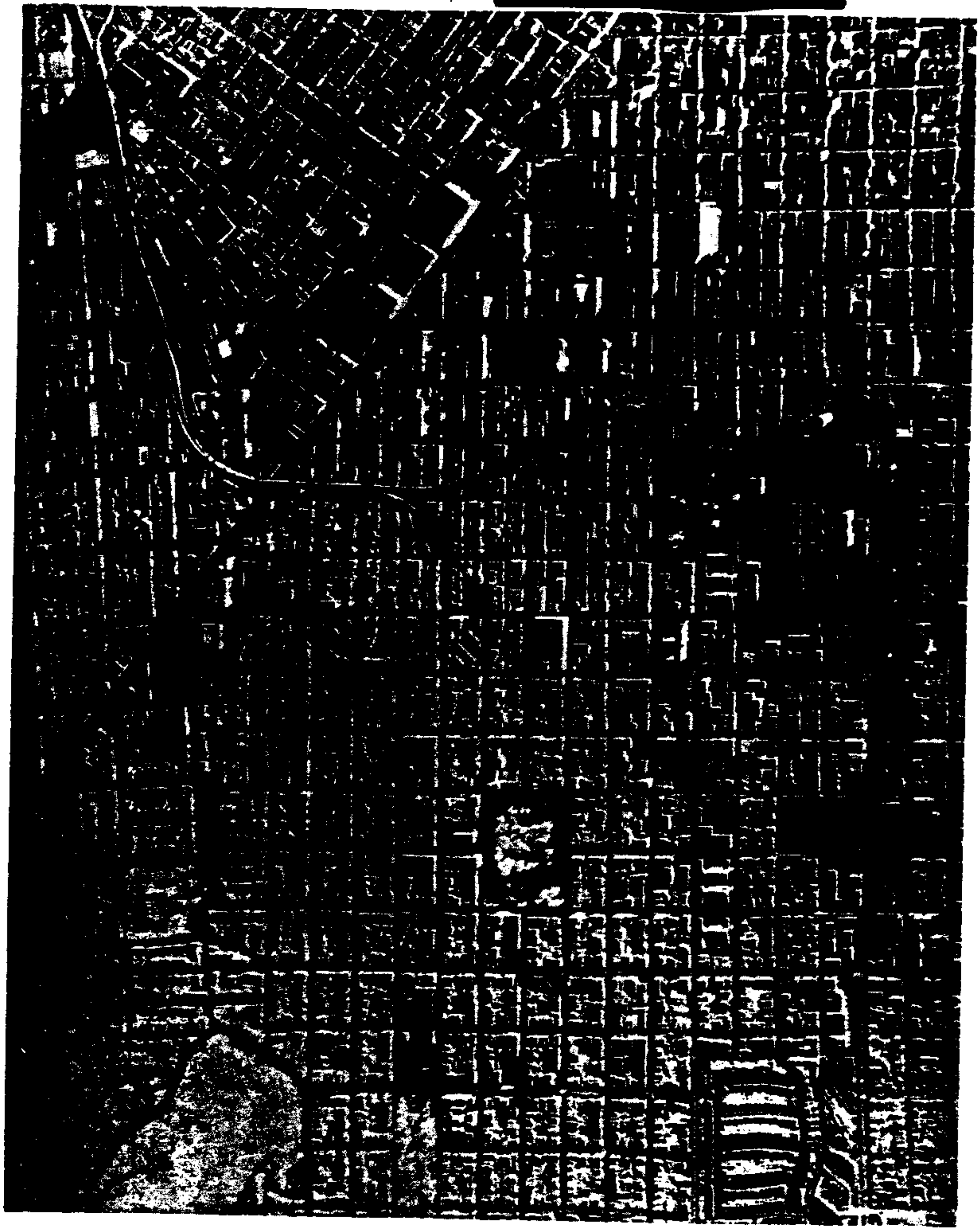


Fig. D-4 — Low contrast scene used in syzygetic density difference program

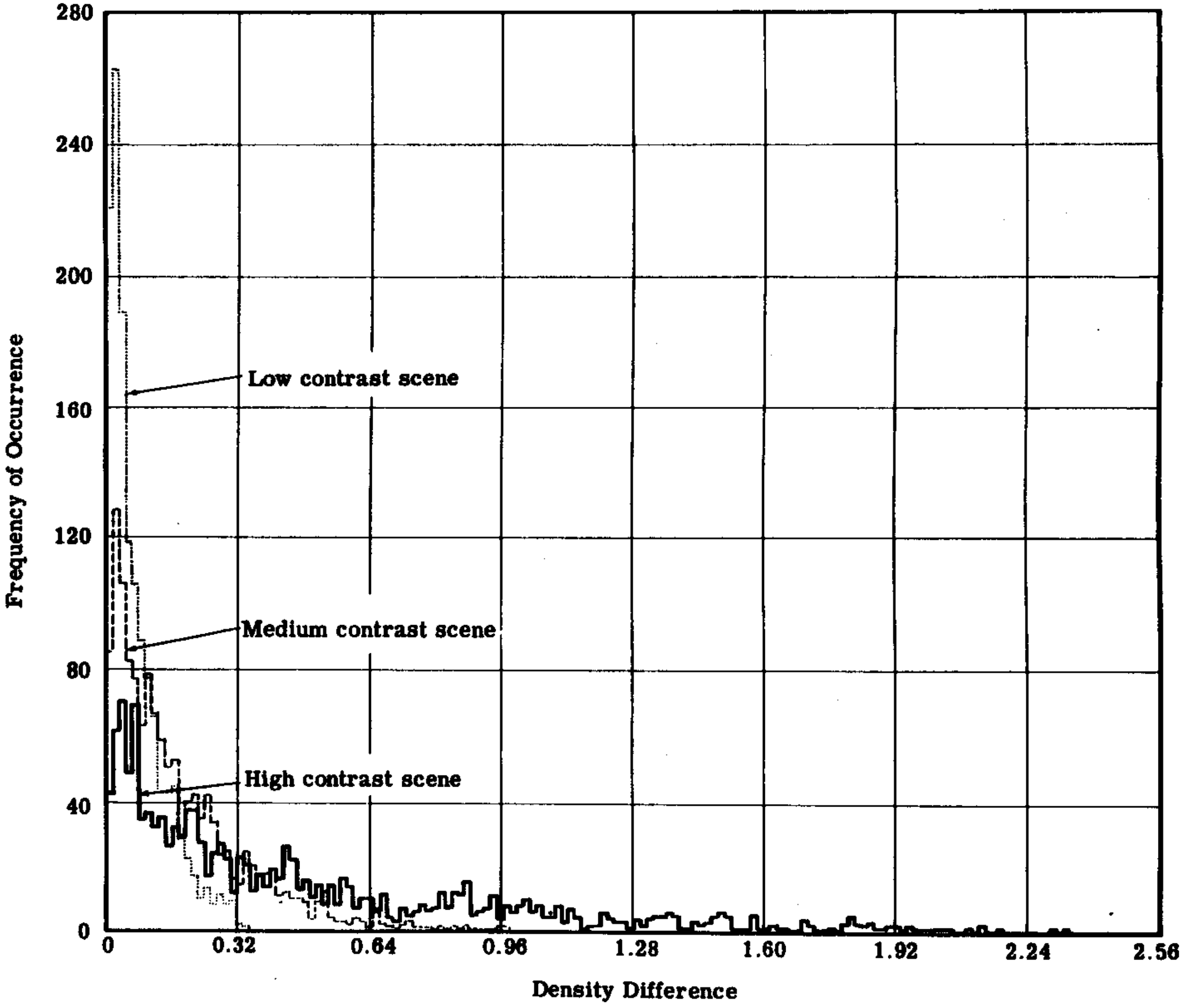


Fig. D-5 — Frequency of occurrence of syzygetic density differences for three contrasts of a given aerial scene

There are even less density differences in the 0.02 to 0.10 range than in either the low or medium contrast scenes. But, since the high contrast scene had a high density range, there are many density differences over 1.0. All this was known before, but this program will enable the operator to add quantitative estimates to hig prior qualitative knowledge.

The implication of this example is that scenes that are not different in terrain can be characterized according to contrast by their SDD plot. Research into this area is still necessary to determine if not only contrasts of scenes, but types of scenes can be characterized by their SDD plot. Also still to be determined is whether there is an optimum curve shape for maximum photointerpreter information retrieval, i.e., whether there is an optimum syzygetic density characteristic attendant to the "best" print for photointerpreter uses.

4. RADIANCE

If the radiance of two ground objects can be known, it is then possible to quantitatively determine the amount of atmospheric haze. From densitometric analysis of the two known objects, their apparent radiance can be determined. The apparent radiance, R_o, of an object as seen by a lens can be expressed by the relationship

$$R_o = RT_a + R_a$$

where R = original object radiance
T_a = atmospheric transmission along the image path
R_a = radiance of the atmospher along the path

Simultaneous solution of this equation for two objects of varying radiance can lead to determination of T_a and R_a. These two quantities are directly responsible for contrast attenuation.

Itek has successfully employed this technique in two recent contracts,[redacted] with RADC to determine the spectral radiance of ground objects from spectrally filtered photography, and [redacted] with AFCRL on satellite meterorology. In the latter study, a calibrated camera was flown in an aircraft at altitudes varying from 1,000 to 65,000 feet. With the above approach, the atmospheric transmission and hazelight were determined as a function of altitude, as shown in Figs. D-6 and D-7. Fig. D-8 shows the two areas (A and B) used as the targets.

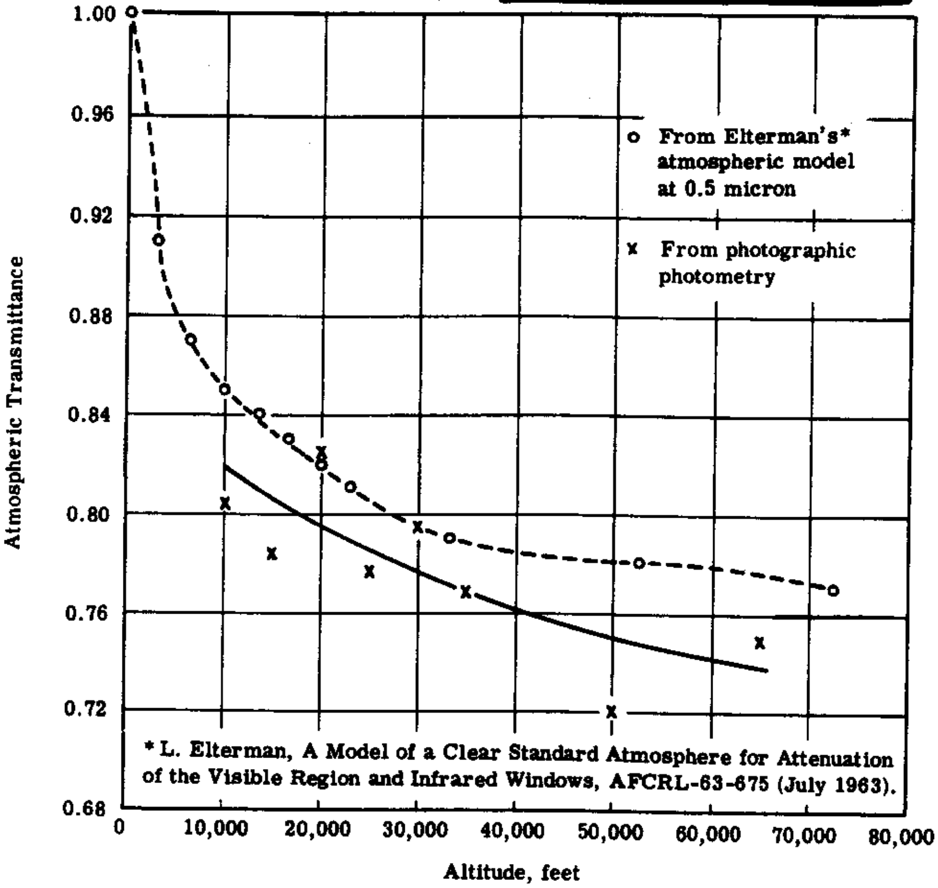
By the same technique, the reflectance characteristics of ground scenes can be determined. Again, the measurements can be either relative or absolute depending upon whether or not suitable known reflectance objects can be measured. The terrain reflectance characteristics change with vegetation which in temporate regions is seasonal. These changes are manifest both in the overall luminous reflectance and in the spectral reflectance. Thus, both exposure and spectral response are affected.

Known or potential targets may therefor be photographed against a changing background. To optimize performance in the recording of such targets, a knowledge of the background reflectance characteristics is as important as a knowledge of the atmospheric conditions.

In summary, we propose to investigate selected areas of past Corona index photography, initially on a limited scale, to determine if it is possible and feasible to catalogue and predict gross weather and terrain features. The analysis will be made from existing data on the original negative index records. Only a limited number of geographic areas will be selected for analysis. The flight logs will be screened to select those areas where enough repetitive coverage exists to perform a good statistical analysis.

Should the initial effort prove rewarding, we would then propose to extend the effort towards automatic scanning and computer analysis of the index photography. This would provide a means of statistically predicting optimum photographic parameters for any given mission.

Hopefully, the fallout from the preceding proposed evaluations will allow prediction of optimum filtration to be used for a given mission or target. With the ability in the J-3 system to change filters in flight, this extension is only logical. This filtration might be either of a spectral nature or of a polarizing nature, or both. It is quite conceivable, for example, that a specific target might only be covered at a low sun angle at a specific aximuth. This circumstance might dictate use of a polarizing filter for optimum imagery. In another case, haze of terrain characteristics might indicate a change in spectral filtration from a Wratten no. 21 filter to a Wratten no. 25 for best coverage. The possibilities are unlimited, but the advantages are unmistakable.



* L. Elterman, A Model of a Clear Standard Atmosphere for Attenuation of the Visible Region and Infrared Windows, AFCRL-63-675 (July 1963).

Fig. D-6 — Atmospheric transmittance

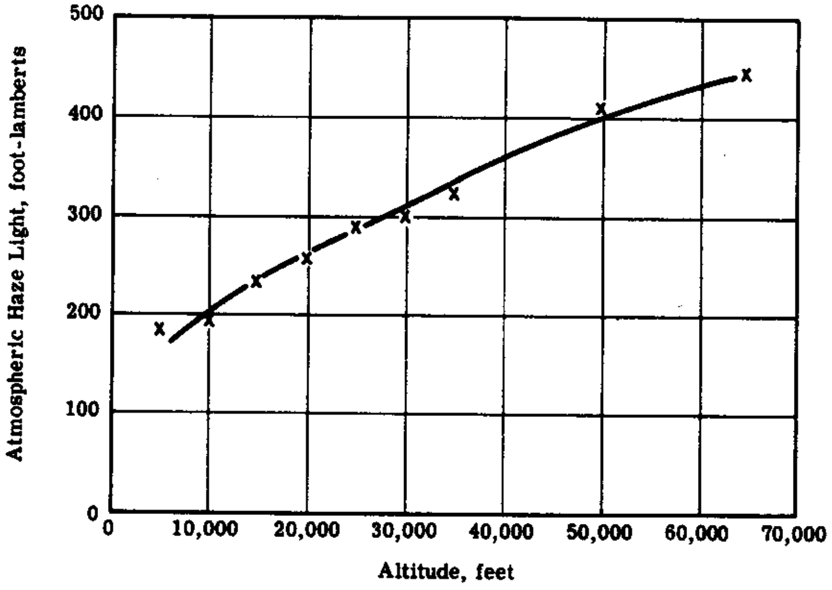


Fig. D-7 — Atmospheric hazelight

Fig. D-8 — Brightest (A) and darkest (B) target areas

Appendix E

EKIT PROGRAM EVALUATIONS

With the added flexibility of exposure and filter control in the J-3 system, new photographic techniques can be used in pursuit of more useful information. Though the exact plans concerning the use of this added capability were not formulated in the initial J-3 design, it was realized that these two remotely controlled features would be the basis for almost all new photographic techniques. Twelve basic questions concerning the usefulness of these techniques on the J-3 system were posed. In order to answer these questions, a high altitude aircraft test series was planned. The reasons for aircraft instead of satellite tests were that manned aircraft (1) could be more easily controlled (e.g., repeated passes over the same target area), (2) were less expensive and could be run presently instead of waiting until the J-3 satellite system was in operation, and (3) were amenable to specialized tests (e.g., split slits, dual filters, etc.), whereas the currently orbiting satellite systems could not be used this way without degrading the operational objectives.

The manned aircraft test series was designed to test all 12 of these questions with a camera system very similar to the J-3. The objectives of this test series were to limit those tests in the satellite system to the ones that have the most chance of success. The philosophy was that if a technique proved to be unsuccessful or showed no improvement in the aircraft, then it would not be recommended for a satellite test. This does not mean, however, that if successful in the aircraft test it would work with similar success in the satellite system. It means only.that these few techniques have a better chance of success than the others. A summary of the questions which were to be answered under the EKIT test series is given in Table E-1, followed by a discussion of each of the problems and the conclusions that have been reached at this writing.

1. EKIT FLIGHT TEST NO. 1 (EKIT REPORT NO. 4)—TYPE SO-121 AT LOW SOLAR ALTITUDES

By the nature of polar orbiting satellite photography, some pictures must be taken during the early hours of the day. There is, therefore, a very low level of illumination in the northern latitudes. Eastman Kodak type SO-121 is a high speed, high resolution Ektachrome type of color film. Exposure value curves are available down to solar altitudes of approximately 30 degrees. The performance of this material at lower

Table E-1 — Summary of EKIT Test Questions

Flight	Test Name	Specific Question to be Answered
1	SO-121 at low solar altitudes	Can type SO-121 color film be used at solar altitudes below 30 degrees?
2	Bicolor	Can pan scanning type photography be used to obtain bicolor imagery?
3	SO-362 versus 3404	Is there any real advantage in using type SO-362 over type 3404 in the Corona system?
4/5	Night detection	Can activity be detected at a missile launch complex at night?
6	Haze filters	What are the tradeoffs involved in using various wavelength haze-cutting filters with respect to spectral information and contrast?
7	Index	Is there another material that may be more useful in the index camera than type 3404?
8	3404 exposure	What is a good criterion for exposure using type 3404?
9	Comparative color	Which of several color reversal films is most suitable for high altitude reconnaissance?
10	Polarizer	Is there a significant gain in either contrast or aircraft specular reflection causing blooming with the addition of a polarizer?
11	Missile launch	Can type SO-180 (camouflage detection film) be used to detect a missile launch after the fact?
11A	Evaluation of SO-180	What in general are the advantages of using type SO-180?
12	Metric color	What are the advantages or disadvantages of using color materials in the J-3 system from a metric standpoint?
13	Low gamma	Is processing the original negative to a lower gamma advantageous?

At the conclusion of this test series, the most promising photographic techniques will be recommended for satellite testing.

solar altitudes was the subject of the first EKIT flight test. The flight test consisted basically of repeated flights over one location (Bakersfield, California with mobile CORN targets) from early in the morning when the solar altitude was 5 degrees to midmorning when the solar altitude was 37 degrees. Each camera was loaded with type SO-121, though the exposures were different by a factor of 2 in order to have adequate exposures over a wide range of solar altitudes. The flight test analysis has been completed and has been issued as EKIT report no. 4. The conclusions described below were drawn from the experiment.

1. SO-121 can be generally employed at solar altitudes as low as 10 degrees. For certain conditions SO-121 can be usefully employed at lower solar altitudes. Certain types of information are recorded at solar altitudes as low as 5 degrees. The one case of a picture taken with no direct illumination and a slow scan velocity illustrated what could be done if the system could operate under these conditions.

2. In the J-3 system, a full load of SO-121 could be properly exposed (by slit control) to solar altitudes as low as approximately 13 degrees. Exposures at 10-degrees solar altitude would be quite acceptable, being only about one-fifth of a stop underexposed.

3. The maximum resolution that could be expected with SO-121 in the J-3 camera (assuming correct exposure and correct lens) is approximately 60 lines per millimeter. The system will achieve a higher resolution with a Wratten no. 4 filter than with the Wratten no. 2E currently being used. This higher resolution is due to the fact that the MTF of the lens is higher with a Wratten no. 4; the apparent ground contrast will be somewhat higher, and the focus shift of the lens is smaller with the no. 4 than with the no. 2E. For a full color mission, the Petzval lens should be refocused for the combined color correction and haze attenuating filters.

4. Color reproduction is poor (restricted) at very low solar altitudes when using the nominal color compensating pack. A separate color correction pack should be used for these cases. This pack is practical for a full color mission, but impractical with a split load of black and white and color films.

5. Improper exposure affects both resolution and color balance. This, of course, is not startling but it is interesting to note that perfect color balance is not a prerequisite to obtaining useful photography for photointerpretation. Further, it should be noted that, by selective printing, many of the poor color balance originals could be corrected quite well to produce a properly balanced print.

6. The limitations on the quality of the resultant SO-121 photography due to the lens are apparent. The Petzval was not designed to be well corrected for the blue region. It would be worthwhile to consider what improvements might be effected by using a specially designed color corrected lens with the SO-121.

7. The contribution of the blue image is relatively small. The contrast attenuation of the atmosphere in this region is significant, and causes this effect. Information content would seem to be affected little, and color balance enhanced, by the use of a

Wratten no. 4 filter instead of a Wratten no. 2E. However, for a partial color mission (when only one filter pack could be used), the use of a Wratten no. 2E would be acceptable at low solar altitudes.

2. EKIT FLIGHT TEST NO. 2—BICOLOR PHOTOGRAPHY

Color photography is ordinarily obtained by using one film that has three emulsions, each sensitive to approximately one-third of the spectrum. Color photography can also be obtained by using three separate cameras, each with a black and white film and a filter that transmits the appropriate third of spectrum (e.g., red, green, and blue). The color image is reconstructed by additively projecting positive duplicates of these three negatives through their corresponding red, green, and blue filters. This is by no means a new technique since Maxwell did this over a hundred years ago. Since the EKIT test camera system and J-3 systems have only two cameras, this type of tricolor additive is impossible. However, tests have been performed using only two records to additively reconstruct a color image. Successful bicolor photography has been obtained: (1) in theoretical computer studies, (2) in laboratory tests, and (3) in airborne frame-type camera systems. The filters used in these works that have, in general, given the best results are the cyan (Wratten no. 44A) and orange (Wratten no. 21) filters. The cyan gives a record of the blue-green information and the orange record gives the green-red information. Since there are only two separation records, it is theoretically (and verified with practical tests) impossible to obtain full, and true color. It is subject to question, however, whether or not full and accurate color reproduction is necessary for an increased intelligence gain. There are several advantages to bicolor photography over that obtained by the standard color materials.

1. Color is added without the loss in high resolution of the black and white emulsion. With perfect registration (which may or may not be possible) resolution will be increased due to the 40 percent increase in signal-to-noise ratio.

2. The standard 3404 emulsion used with the Wratten no. 21 filter is still available since this is one of the records.

3. The cyan portion of the spectrum is not as much subject to atmospheric haze effects than the blue-sensitive record of the color materials.

4. The contrast differences in the two records (due to the atmosphere and inherent contrast variation as a function of wavelength) can be independently controlled since they are physically separate films. These contrast corrections must be adjusted in the camera filtration with standard color materials and therefore lessen the degree of control available.

Though successful bicolor photography has been obtained with airborne frame-type cameras, to date none has been attempted with pan-scanning type cameras. The basic problem, then, in carrying on the bicolor test is obtaining properly rectified images for the additive superimposition. There are other problems such as: (1) proper exposure, (2) image size change due to wavelength change, (3) focus, etc. ACIC has offered to rectify the images for this test. The images will then be additively printed on the Itek Additive Color Viewer/Printer (ACVP) to make the bicolor reconstruction.

This flight test has not been completed; therefore, there are no conclusions at this time.

3. EKIT FLIGHT TEST NO. 3—SO-362 VERSUS 3404

A question has been raised concerning the possibility that, if a faster film were to be used in the existing and future satellite systems, a real gain in the overall image quality would result. With the faster films, shorter exposure times that would reduce the image blur could be used. However, faster films are generally of a lower resolution and higher granularity. Therefore, there would be some degrading effects from the film. However, the question still remains that, if the faster film were to be used, would the increased image quality from shorter exposure times be offset by the lower quality film from the total system standpoint? The particular film in question was type SO-362, often referred to as Double-X 3404 since it has about twice the emulsion speed. The test was broken into three separate tasks:

Task 1: General sensitometric and image quality characteristics
Task 2: Static pictorial comparison for subjective image quality analysis
Task 3: Aircraft flights for a dynamic system test

Task 1 involved a sensitometric and image quality evaluation of type SO-362 in order to determine the material's basic characteristics. Standard sensitometric tests were performed to evaluate the emulsion speed as compared with type 3404. Relative spectral sensitivity, resolving power, and granularity measurements were made on the two materials.

Task 2 was a static pictorial comparison to obtain a subjective photointerpreter comparison of the relative image quality of the two materials. This test was performed using Itek's model which is a typical urban area built to HO scale. It provides the most realistic simulation of aerial photography that is possible in the laboratory. Photographs were taken of this model with both films at varying exposure conditions and evaluated by photointerpreters for their relative information content.

Task 3 was aimed at evaluating the two materials under dynamic flight conditions using a high altitude aircraft and the EKIT test series camera configuration. Both subjective photointerpreter evaluations and quantitive analysis were made on the materials from this test. The test consisted basically of flying a repeated flight line over several areas in California using both materials (split loads) in both cameras. In order to test at varying exposure levels, split slits were used, giving a total of four different effective exposure times on each film. This test has been completed and has been issued as EKIT report no. 5. The conclusions from this test are summarized below.

1. SO-362 is approximately 2.8 times faster than 3404. This varied from 2.3 to 3.4 times faster depending on the developer formulation.

2. SO-362 produces a higher fog level, at a greater rate, than does 3404. This effect is noticeably worse with high-energy developers such as Eastman Kodak MX-577.

3. In general, SO-362 produces a slightly lower gamma than 3404; however, the differences between the two films are minor.

4. SO-362 produces lower resolution than does 3404. In all evaluation tasks, SO-362 produced a lower resolving power. This was true even in the 112B flight test. In this case, the SO-362 produced a lower resolution even though the exposure time used was one-half that employed with the 3404. For example, flight test samples of 3404 exposed at 1/325 second had better image quality than the samples of SO-362 exposed at 1/800 second.

5. SO-362 possesses both a higher granularity and graininess than 3404. The rms granularity evaluations indicated that SO-362 was approximately 1.7× grainier than 3404. This was verified in the subjective photointerpreter evaluations where the increased graininess of SO-362 was apparent to the photointerpreters who commented on this. This causes both a loss of low contrast, fine detail, and a degradation of edge sharpness vis-a-vis 3404.

6. SO-362 did not hold up as well as 3404 to overexposure. The image quality of the resultant photography with SO-362 was noticeably poorer with overexposure. This was verified with both the objective and subjective analyses. The photointerpreters commented, on both the model test and the 112B test, that the SO-362 image quality was noticeably worse with overexposure. The MTF analysis verifies this subjective conclusion as does the resolving power data.

7. The fact that SO-362 has been discontinued by the manufacturer automatically precludes its use in the J-3 system. Even if it had not been discontinued, however, its characteristics would not have warranted its use in the J-3 system.

8. It should be noted that SO-362 was a difficult film for the manufacturer to make. The characteristics of the film changed from batch to batch. The SO-362 used for Task 1 had a higher Dmax than the SO-362 used for either the model test of the 112B test. We also understand from the manufacturer that SO-362 was a difficult film to make as concerns repeatability, i.e., from a quality control point of view.

9. SO-362 has been recently replaced with SO-230. The replacement material is intended to possess the characteristics originally intended for SO-362. It is recommended that SO-230 also be evaluated for its potential, and to determine if it is worthwhile to consider it for use in J-3.

4. EKIT FLIGHT TESTS 4 AND 5—NIGHT DETECTION

There have been several situations in recent satellite reconnaissance history in which seemingly unexplained events have taken place. One of the more confusing ones occurred on a recent mission in which the same target location in Russia was photographed once a day for almost two weeks. During that time several missiles were known to have been launched and there was no evidence on the satellite photography as to which pad they came from. A suggested answer to this problem has been that they are doing their work at night and therefore avoided detection. The question then arose as to what could be seen in a missile launch facility at night from the J-3 system. Since workers must have light to work by, parts of the complex should be illuminated, and if there are illuminated areas, they might be open to aerial surveillance. The purpose of this EKIT test was to determine if some activity could be detected around a missile launch complex at night. Several flights have been made that covered the Los Angeles, Vandenburg AFB, and San Francisco areas during the night. Repeated night coverage was necessary in order to get good photography over Vandenburg AFB which was clouded during most of the photography. The film used was type SO-340 which is an improved Tri-X type of emulsion on a thin base. The effective exposure time on the camera was 1/50 second for two night flights and 1/120 second on the third. The J-3 system will be able to use approximately 1/60-second exposure time with the same f/3.5 aperture.

This test was successfully completed by the photographic coverage of Vandenburg AFB on 13 January 1967; the night before the Corona missile launch for mission 1038. Night activity was clearly detected at this launch complex. In addition to detecting nighttime activity at the prime target area, activity was also detected in a Minuteman complex in the northern end of the base. The photointerpreters examining the material knew that there was a high degree of probability that there would be activity at the Corona vehicles' launch complex. They did not know, though, that there would be activity elsewhere on the base. By comparison daytime coverage, the photointerpreters could positively identify the type of complex. There was difficulty in pinpointing the exact complex location due to the large areas of nonimagery. Correlation with other points of light on the imagery fixed the location to one of two sites, with, according to the photointerpreters, a 90-percent probability of identifying the right one on the day coverage. It was found out later that they were correct and had properly identified the location. That particular Minuteman site had been used for a launch the day before and was being refurbished during the night. This showed clearly that the 112B system was capable of locating and identifying such types of targets. The fundamental question, though, was what would this detection capability be at orbital altitudes with a 7½ × decrease in scale.

A theoretical study was undertaken to use the data from these flights and extrapolate to obtain an estimate of the orbital detection capabilities. In general, the conclusion from this analysis was that large areas such as the concrete around the pad would be above the minimum detection level if illuminated as well as the Corona and Minuteman complex. Smaller areas could also be detected if sufficiently illuminated, though objects below the resolution (such as cars) could only be detected if they were very well illuminated. Since cars were below the resolution limit, they would be detected only as points of light. With precise correlation with day photography, these points of light represent the cars in the parking lots and should be countable.

In addition to satisfying the prime objective, other interesting observations were made. Sporting events were, on the 112B system, clearly visible due to the high illumination level on the playing field. Urban areas were very clearly outlined by the streetlights and store window illumination on the sidewalks and roads. Major roads (freeways) were not illuminated well enough to be seen on this photography.

Two viewing techniques were used in order to make valid correlations between the day and night coverage. By viewing the day positives in stereo with the night positives, the effect was to see the full day image with the light patterns superimposed on their respective locations. Since the majority of the night photography is black, it is almost like viewing the day photography with one eye closed. The second method was superimposition of the night negatives directly on the day positives. Since the negatives are essentially only at a base and fog density level it does not significantly interfere with locating targets on the day coverage which have been detected on the night imagery. Once the target has been located, the stereo approach is quite useful. The conclusions from this test are summarized below.

1. High speed black and white coverage at night has a potential for broadening the scope of photointerpretation of strategically important targets.

2. Comparable day coverage (preferably in the same portion of the format) is desirable for locating and identifying specific targets. Even if the precise location is known by calculated methods, the day coverage is still necessary in order to interpret the minute details of the image.

3. Viewing techniques such as stereo with the day and night imagery are very useful for locating specific areas and understanding sources of illumination. Viewing the day positive with the negative night coverage superimposed on top is also a useful technique. These techniques must be used with the materials on the viewing table since multiple printing of negatives from day and night coverage is not very effective. The technique utilizing slight movements in one of the negatives on the light table is also useful for identification of sources of illumination. This cannot be done when a multiple print is made.

4. The panoramic distortions in the photography made comparisons of day and night photography difficult if the images were not in the same format position. This became less of a problem as smaller and smaller areas were studied. The main problem came from locating images in one area, while targets 5 or 10 inches away could be displaced by 1/2 inch due to the differences in distortions across the format.

5. With the lack of hazelight and nature of the targets (intense lighting to black areas), the dynamic range of the SO-340 was not sufficient to record all of the information that was available. In addition, the entire density range of the negative material

was used. This meant that dual exposure level prints were necessary in order to use the information on the negative. It is suggested that a film processing study be undertaken before J-3 night missions are flown in order to improve the sensitometric characteristic of the film for this application. Another suggestion is that a low gamma developer be formulated. This would alleviate the problem of the large dynamic range on the negative and to some extent lengthen the usable log E range of the negative material.

6. The overriding characteristic of an emulsion used at night is its speed. Though there must be adequate resolution, without speed there is no image. This means that the relatively slow speed types SO-180 and SO-121 have only a very limited value.

7. The principal target, an illuminated missile launch complex, was detected on the night photography. Calculation based on the signal-to-noise ratios involved indicate that it will also be detectable on the satellite photography. The identification detail within the complex itself will, however, be quite limited. Night activity such as that at Vandenburg will be detectable. Objects as small as cars will be detected if they reflect more than 2.4 foot-lamberts. However, cars are smaller than the resolution limit and will show as points of light. Their location (i.e., in a parking lot) may indicate that they are cars, and if they are illuminated sufficiently, the photointerpreter should be able to count them.

8. Static and fog may be a problem, particularly for long missions at the low atmospheric pressures of orbital altitudes. Some modifications on the camera (e.g., less tension on the puck arm of the takeup spool) may eliminate some of the static. Chamber tests are recommended before a night flight is made with these high speed emulsions in order to properly assess the magnitude of static, corona discharge, and fog.

5. EKIT FLIGHT TEST NO. 6—HAZE CUTTING FILTERS

This test is designed to study the relative tradeoff between the information loss due to more hazelight versus that gained from the added spectral region used. Since the hazelight is primarily from the shorter wavelengths, the more of this energy that is filtered out, the less contrast attenuation occurs. With a deep red filter, the haze effects are minimal. But blue and green objects are effectively black with respect to the film as filtered by a red filter. Therefore, the cost of increased haze penetration is a loss in spectral discrimination. If no filter was to be used, the opposite would be true. The cost of spectral discrimination is very low contrast due to the unfiltered hazelight. Either extreme is probably not the best method for overall intelligence gathering purposes. The proper balance, though, between these two aspects is presently unknown and is the subject of test flight no. 6. The Itek nine-lens camera will be used for this flight test which is planned for April-May of this year. The filters chosen are Wratten nos. 29, 25, 23A, 21, 16, 15, 12, 8, and 106.

6. EKIT FLIGHT TEST NO. 7—INDEX COVERAGE

The index camera on J-1 presently uses type 3400 film. The processing of this material is rigidly held to a gamma of 1.0. It is therefore a direct representation of the ground as it was seen from the camera. Since its scale is approximately 8,000,000:1, it gives an overall view of the territory surrounding that imaged by the main pan cameras. Since this is not the prime instrument for gathering intelligence, its ground resolution is not of prime importance. The question is then raised as to why should this particular film be used. Possibly some other film type might be useful in gaining information that is not a resolution dependent medium. Perhaps a color film, either standard or false color, would be useful. An attempt to investigate these possibilities is the subject of this EKIT test. It is scheduled to be flown in the spring of this year.

7. EKIT FLIGHT TEST NO. 8—3404 EXPOSURE CRITERIA

For years, the exposure for satellite missions has been computed by standard tables. The results over this period have been good. There were few, if any, instances where underexposure has been a degrading factor. Unfortunately the criteria for these exposure calculations has been influenced by the criteria for the amateur market. These criteria are based heavily on the shadow information or on some minimum reflectance value. Though this may be a good criteria for pictorial purposes, there is question as to whether or not it is suitable for strategically important targets. If the targets of interest are of a high reflectance, then shadow type of criteria are not necessarily the best approach.

The objective of EKIT flight test no. 8 is to obtain several exposure levels of the same scene. The material would then be examined to give an indication of the exposure required to achieve a certain level of quality. The flight has been made and the analysis has begun. The flight consisted basically of flying a repeated flight line (over mobile CORN targets) using split slits in each of the two cameras. The film was processed to two levels (intermediate and full) resulting in two different exposures at each processing level. It is not the intent of this test to answer the question of the optimum exposure for type 3404. Rather its goal is to provide data on a controlled basis that can be used as a guide for a more detailed analysis into this problem. This effort is intimately related to the target density analysis described previously. The results as they apply to the J-3 system will take this into account. Microdensitometer scans have been made of strategic targets from operational material. These data will be very useful in determining the relative placement on the sensitometric curve of the areas of interest.

The analysis has begun and no conclusions have been reached at this date.

8. EKIT FLIGHT TEST NO. 9—COMPARATIVE COLOR

The question of what should be used, color or black and white, will probably never be answered when stated in such general terms. When asking such a question, reference must also be made to the particular application of the photography.

Maybe color would be good for indications of flood damage or output from a copper refinery plant from the color of the industrial disposal, or there may be other specific applications where color material can give information that is not available in black and white film. The overriding factor in a comparison of color and black and white is resolution of image sharpness. It is assumed a priori that at equal resolution the color will be better since it has the same image quality with the additional dimension of hue. However, normally color film does not have as high a resolution as black and white, and therefore the question is a very difficult one to answer. The problem is far larger than what a single EKIT test could cope with. The comparative color test is intended to be just that, a comparison between various color films themselves and not between color and black and white. If a decision is made that a mission is to be flown with a color material, then the color film flown should be the best one available. It is the purpose of this EKIT test to determine which of several commercially available films will perform the best in the J-3 system.

The test will consist of three tasks. This procedure was taken in the analysis of the new emulsion type SO-362. The first task will consist of a laboratory analysis of the materials to determine their inherent characteristics. This will consist of determining the spectral sensitivity, the dye curves, and the sensitometric curves. In addition, their physical characteristics such as layer orientation and physical dimensions, and their image quality characteristics such as principal resolving power will be studied. The third task will consist of a static test using the same model as used in EKIT report no. 5. The model is to HO scale and provides as real a photographic simulation as is possible. These two tasks will narrow the films to be flown in the camera system to approximately four. These are then to be flown in a B-52 using Itek's nine-lens camera to complete the third task. Work on the first task has begun, though no conclusions have been reached to date.

9. EKIT FLIGHT TEST NO. 10—POLARIZER

This test is designed to evaluate the effects of a polarizing filter in the 112B system and to extrapolate these results to the J-3 system. The specific effects sought were: (1) decreased image "ballooning" from specular reflections, and (2) decreased atmospheric hazelight from removing the polarized component of the scattered length.

One flight was made, though inconclusive results were obtained since a late aircraft takeoff did not allow testing at the desired solar altitudes; hence, a second flight is required.

10. EKIT FLIGHT NO. 11—EVALUATION OF TYPE SO-180

The evaluation of type SO-180 has taken two forms: (1) a general evaluation, and (2) a specific goal of "Can you tell from which launch pad a missile was fired from?"

(after the fact). The missile launch flight was made and the material is in the analysis stage. It should be noted that the detection of hot areas was not anticipated in this flight since temperatures on the order of 600 to 700 °F are required to form an image on this film.

Rather, the effects on the surrounding areas were to be studied: (1) would the heat temporarily effect the vegetation, or (2) would there be some other effect on the vegetation from the excess moisture created during the launch and subsequent water bath.

The other evaluation, general terrain, has not been flown yet. Though this film has been on the market for several years, the manufacturer has not yet made an extensive evaluation of its potential uses. The general evaluation would be designed to test this film's effects in the 112B system. For example, the system resolution and the effect of stereo viewing of color and black and white will be studied in a convergent stereo mode instead of an overlapping mode. This test will draw upon other sources of information for support material. For example, tests that have been performed at Wright-Patterson AFB, and at Eastman Kodak.

11. EKIT FLIGHT NO. 12—METRIC COLOR

The use of color materials for metric purposes in pan scanning types of cameras is relatively new. This EKIT test is primarily a state-of-the-art review of the problems associated with metric color analysis. The primary concern of this effort was the effect this type of material would have on the mapping services, and how their equipment would, or would not, be able to handle color. The EKIT flight itself is to be used as a single sample to test some of these problems. For example, once the color material has been obtained, can selective color printings form black and white images of the various types of information to be used. If a color film is printed onto a black and white duplicating stock with a magenta filter, for example, a lot of green detail would be printed. In this case, forestry and vegetation detail would be more apparent. Yellow light printing could show detail in water areas.

This flight has been made and the state-of-the-art report is in the writing stage. The analysis of the flight material has not been completed to date.