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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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