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Microdensity Correction for CORN Target Contrast Estimation

PFA TECHNICAL REPORT NO. 7

PHOTO RECONNAISSANCE SYSTEMS DIVISION
OFFICE OF DESIGN AND ENGINEERING

TCS 363508-73

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MICRODENSITY CORRECTION FOR
CORN TARGET CONTRAST ESTIMATION

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This report has been reviewed and is approved.

[redacted] (b)(3)

Task Chairman, BRIDGEHEAD

ROBERT J. KOHLER
Chairman, Post Flight Analysis Team

FOREWORD

Throughout a major portion of the history of the National Reconnaissance Program (NRP), CORN Tribar Targets have been employed for the purpose of determining ground resolved distance (GRD). While these targets suffer many deficiencies (subjectivity, lack of statistical significance, etc.), they continue to be deployed as they remain the only direct way to measure the GRD. CORN target values can be extremely misleading, however, as the value achieved is a direct function of the target contrast. Hence, good values of GRD can occur when the atmospheric conditions are very good (high contrast), while poor GRD values usually result when the atmospheric conditions are poor. In cases such as these, the values of GRD obtained are rarely indicative of camera system performance. In ground testing, this problem is handled by using a constant contrast target, normally at 2:1. The PFA has desired for some time to devise a procedure for adjusting operationally acquired CORN tribars to 2:1 contrast so that meaningful and comparable values can be achieved. This effort has been underway since before Mission 1201. The task is greatly complicated by the basic non-linearities of the photographic process and the resultant disparities between micro and macro contrast related edge enhancement caused by the viscous process.

A successful laboratory experiment was constructed which allowed development of a technique for making such contrast adjustments. This report describes the resultant techniques for determining the contrast of acquired CORN targets which can be used by system evaluators to produce 2:1 adjusted contrast resolution values.

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SECTION I

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

1.1 SUMMARY

A laboratory experiment was designed and conducted which sought to develop empirical relationships between micro and macro image densities for 3414 under simulated mission flight conditions. Gray scale images of sizes corresponding to the Five-Step Gray Scale (5GS) and Two-Step Gray Scale (2GS) CORN targets were photographed at KH-8 and KH-9 scales using a lens closely approximating the MTF of both orbital systems. The gray scales were placed against different backgrounds corresponding to commonly experienced deployment surfaces in the field. Haze and atmospheric transmittance were simulated by means of beamsplitters and a haze box.

The resultant imagery was processed with dual gamma chemistry typical of the KH-8 and KH-9 mission processes up through 1203-2. Microdensitometry of the processed imagery was used to develop a set of calibration curves relating the measured microdensity of the various panels to the equivalent macro-area density for each reflectance level.

Although there was a chemistry change after 1203-2, the results of this experiment were valid as these calibrations were successfully used on 1204 CORN acquisitions to estimate the true aerial image contrast of tribar targets.

1.2 CONCLUSIONS

A. The laboratory experiment simulated actual mission photographic conditions closely such that conclusions can be drawn about significant parameter effects and function relationships between micro and macrodensity.

B. Both background and target size strongly affect the relationship between micro and macrodensity. Atmospheric contrast attenuation can also have a significant effect on this relationship.

C. The micro-to-macrodensity functions developed from this test were applied successfully to Mission 1204. No absolute reference exists to evaluate the accuracy of the estimated contrasts, but agreement with KSCOPE predicted contrast was satisfactory.

D. Tribar resolution reading from CORN acquisitions is affected by atmospheric contrast attenuation and target surround reflectance. A large high reflectance field appears to reduce target contrast by virtue of increased optical flair energy.

1.3 RECOMMENDATIONS

A. The resultant equations from this study relating microdensity to equivalent large area macrodensity should be used as an interim method of determining CORN target tribar contrast.

B. A study should be undertaken to determine if micro-step tablets currently available for the

1B sensitometer could be used to affect the type of calibrations developed from this experiment.

C. Micro tone recording should be monitored on each mission by means of micro-step tablets exposed on a system simulating mission optics. This experiment should be repeated to account for recent alterations to KH-9 processing and to serve as a control for the study mentioned in B above.

SECTION II

MICRO AND MACRO IMAGE DENSITY EXPERIMENT

2.1 INTRODUCTION

Several attempts have been made to describe micro edge effects in a manner usable in mathematical models. If treated from a purely mathematical standpoint, the equation describing edge effects are complex and involve difficult calculations. It is desired to simply relate measurements made with a microdensitometer of targets of known size and background to equivalent macro-area measurements, the empirical laboratory simulation approach seems more practical than the strict mathematical treatment.

Recent tests by other agencies approached the problem from this empirical standpoint by means of a parametric study of edge effects. The resultant relationships, however, were complicated by experimentally introduced effects which diminished the test results value in a math modeling situation. This experiment was designed so that the target and photographic configuration would be as nearly identical to the actual situation as possible, thus minimizing the number of assumptions of experimental "equivalencies" to actual mission acquisitions. Reflection type targets were used and atmospheric attenuation introduced to make the simulation as realistic as possible.

2.2 DESCRIPTION OF EQUIPMENT

The test configuration, as illustrated in Figure 2-1, was arranged on a three-meter optical bench in a black photographic lab. A brief discussion of each of the central components of the configuration is given below.

2.2.1 Camera

The camera employed was an M-3 Leica which was specially fitted with a vacuum platen to hold thin base film flat. It was also fitted with an f/1.4 Cine Ektar Lens with a 1" focal length. The lens was stopped down to f/4.0 which made it virtually diffraction limited at this aperture. Over its normal area coverage, it closely approximated the current optical performances of the KH-8 and KH-9 systems. The film used was Kodak High Definition Aerial Estar Thin Base Type 3414. This film was given dual gamma processing typical of actual mission chemistry. Because 3200°K lamps were used to illuminate the target, a daylight conversion filter (Corning 5900) was used over the lens. A Wratten 2E Filter simulating common lens spectral cut off was also used.

2.2.2 Targets

Five targets measuring 17" by 20" in size were used in the experiment. Three of these five targets consisted of a tribar target array and two gray scales corresponding to 20' and 50' panels. Figure 2-2 is an illustration of the test target. Of the other two, one was a combination of panels used for calibration; and the other a specially coated panel used to measure exposures with simulated haze. The

LABORATORY CONFIGURATION FOR CORN TARGET SIMULATION

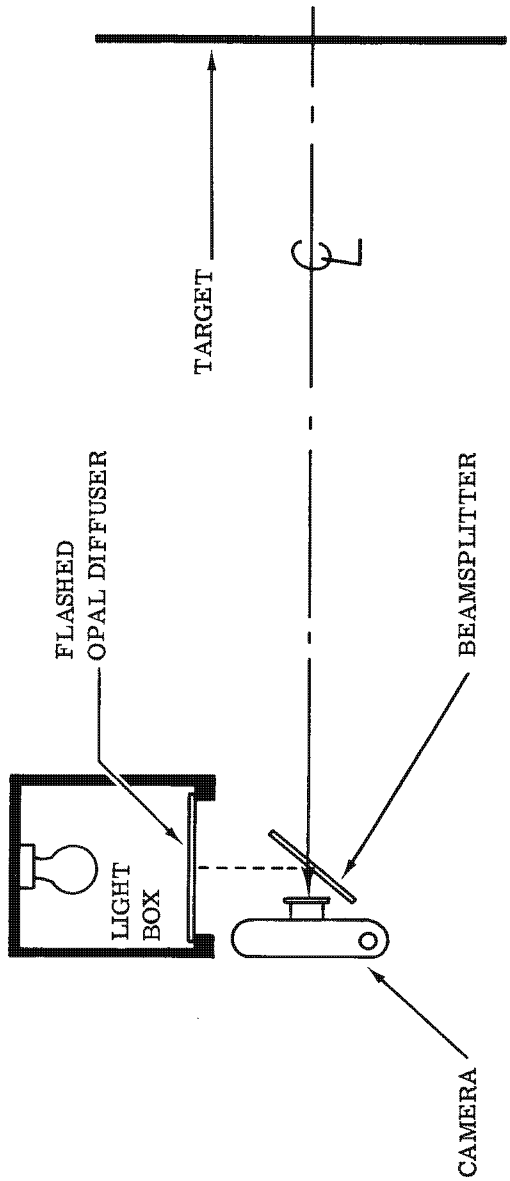

FIGURE 2-1

TEST TARGET USED IN KH-8 AND KH-9 SIMULATION PHOTOGRAPHY

(Vegetation Surround)

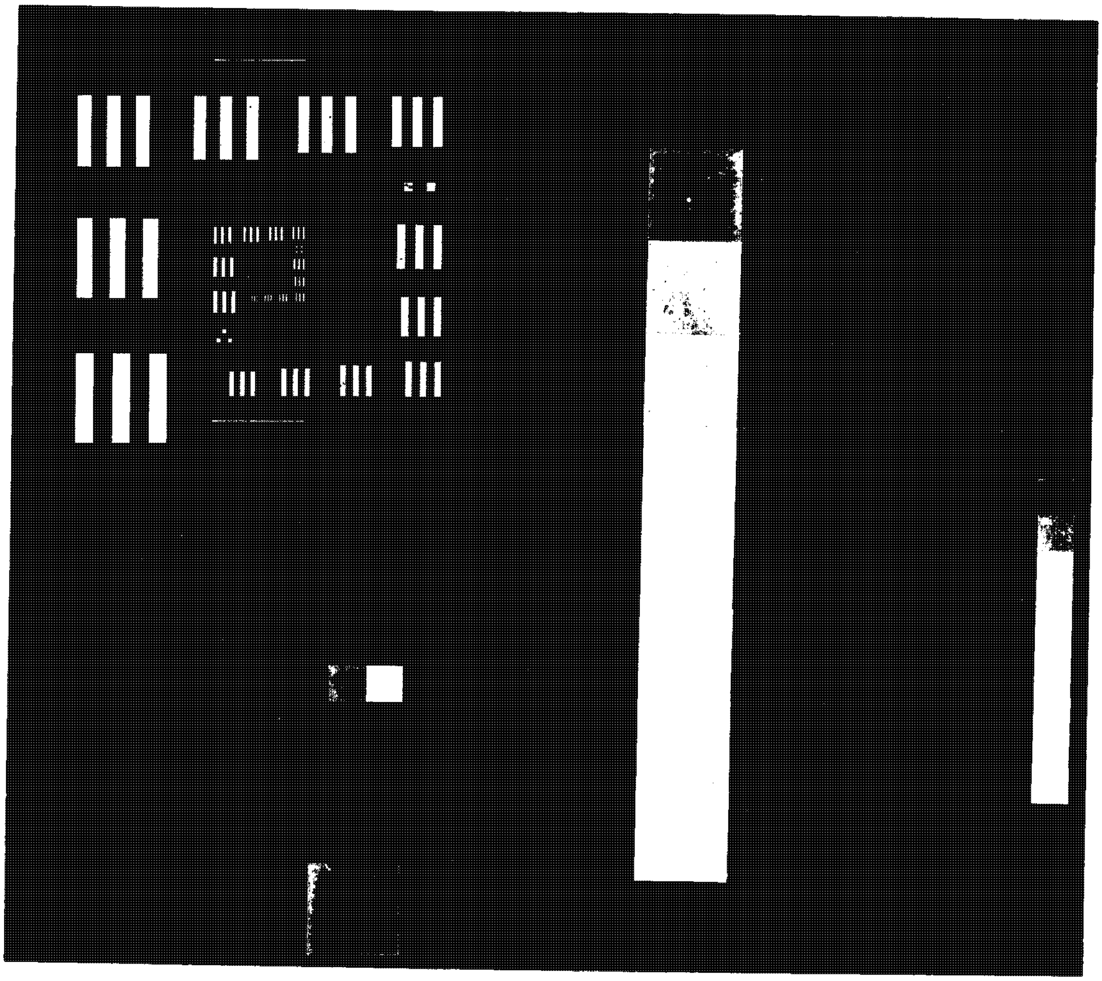

FIGURE 2-2

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three tribar/gray scale targets were identical except for the backgrounds (surround) which were as follows:

A. Dark gray, 12% reflectance (.92 density), simulating vegetation.

B. Medium gray, 28% reflectance (.56 density), simulating desert.

C. White, 68% reflectance (.16 density), simulating snow.

These reflectances were selected to correspond to the three normal ground cover conditions (grass, sand, and snow) on which CORN targets are displayed.

The tribar array, except for its configuration, corresponded very nearly to the actual CORN tribars, as well as the Mil Std 150A Targets. The reflectances of the bars and spaces were 36% and 7%, respectively, giving a contrast ratio of 5:1. The spatial frequency increment was the $\sqrt[6]{2}$ and the frequency range was from .1 to 8 cycles/mm, corresponding to the two simulations as follows:

A. KH-8 - 5 to 400 cycles/mm (50X reduction)

B. KH-9 - 16.7 to 1336 cycles/mm (167X reduction)

The two sizes of the reflectance patches were: (1) one centimeter square each (corresponding to a 20' x 20' square panel), and (2) one inch square (corresponding to 50' x 50' panel). The squares were made from Munsell gray chips and corresponded very closely to the reflectances of the CORN panels. These patches were designed to configure 20' Five-Step and 50' Two-Step Gray Scales as well as full 16-Step tone scales of each size. Table 2-1 lists the Munsell values with their corresponding reflectance.

TABLE 2-1

TARGET REFLECTANCES

— Five-Step Target —

Step	Munsell Values	Reflectance (%)
1	2.5	4.58
2	3.5	9.00
3	4.5	15.60
4	6.5	36.20
5	8.0	58.60

— Two-Step Target —

Step	Munsell Values	Reflectance (%)
1	3.0	6.30
2	6.5	36.20

TABLE 2-1 (CONT'D)

— Sixteen-Step Target —

Step	Munsell Values	Reflectance (%)
1	2.0	2.23
2	2.5	4.58
3	3.0	6.30
4	3.5	9.00
5	4.0	12.10
6	4.5	15.60
7	5.0	19.80
8	5.5	24.60
9	6.0	29.60
10	6.5	36.20
11	7.0	42.90
12	7.5	50.70
13	8.0	58.60
14	8.5	68.40
15	9.0	78.70
16	9.5	88.80

NOTE: There were two sizes of panels used for these 16-Step Targets: (1) one centimeter square, and (2) one inch square.

As previously stated, the descriptions above refer to three of the five targets used in the experiment. The fourth target consisted of 4" x 4" panels of the 16-Step, plus three 4" x 5 1/4" panels corresponding to the three backgrounds. This target was used for calibration purposes and resulted in macrodensities when reduced 50X. The fifth target consisted of a panel coated with a heavy matte layer of Barium Sulfate which served as a standard of scene exposure against which exposures with haze simulation were monitored.

2.3 HAZE SIMULATION

Haze was simulated by means of a diffuse illuminator and beamsplitter. The illuminator consisted of a light box, 10" x 10" x 18" deep, coated inside with Barium Sulfate paint. Light was provided by one Daylight Type No. 1 Photoflood Lamp which was diffused by a 10" x 10" panel of flashed opal glass. The box was set next to the camera so that the light was radiating from the left side. The beamsplitter was mounted directly in front of the lens at a 45° angle to the vertical axis. This was configured so that the light from the diffuse source could be reflected back into the lens while the target was being photographed through the beamsplitter, thus creating the artificial "haze" condition, see Figure 2-1.

To simulate a light and heavy haze condition, two beamsplitters were employed. They were 4" x 4" in size, made of high grade water-white polished plate glass, and inconel coated on the side facing the lens. The side facing the target was anti-reflection coated. Table 2-2 presents the characteristics of these two beamsplitters.

TABLE 2-2

BEAMSPLITTER CHARACTERISTICS

Beamsplitter	Density	Transmission (%)	Reflectance (%)	Absorption or Loss (%)
"Light" Haze	.09	81	8	11
"Heavy" Haze	.21	61	13	26

The transmittance characteristics are constant throughout the visible spectrum, and correspond to the upper and lower atmospheric transmittances reported in an earlier study, Final Report PAR 24-9-8S/R1, Study the Characteristics and Uses of Suitable Materials for High Altitude Acquisition (BIF 008-B-00088-I-70).

The entire simulation experiment was conducted in a room painted dull black. A large number of baffles faced with coffin paper were used to eliminate unwanted reflections and areas of light. These precautions were necessary for adequate control over the experiment and made it possible to isolate, measure, and photograph the "haze" by itself.

2.4 CALIBRATION AND ADJUSTMENT OF ILLUMINATION LEVELS

Before photography of the targets could begin, it was necessary to measure and calibrate the illumination and haze. To accomplish this, an E.G. & G. Radiometer was mounted in the target laboratory configuration temporarily replacing the camera. After calibrating the instrument to the Barium Sulfate panel using a standard precalibrated lamp, measurements were made of the panel illuminated by the 3200°K floodlights used for the target photography. Measurements were made through the .09 and .21 inconel beamsplitters. Measurements were then made of the "haze" reflected from the diffuse illuminator by both beamsplitters. All radiometric measurements covered the spectral range of 350 to 700 nanometers.

For the heavy haze condition, the voltage on the light box lamp was adjusted so that when reflected from the opal diffuser by the .21 inconel into the radiometer, a radiance ratio of 1:7.38 was obtained relative to the Barium Sulfate panel as measured through the same .21 inconel beamsplitter. All radiances were spectrally weighted by the Film Type 3414 response.

For the light haze condition, the .21 inconel was replaced by the .09 inconel. Voltage on the light box lamp remained the same, but a .19 Neutral Density Wratten 96 Gelatin Filter was used over the opal diffuser to adjust the same radiance ratio to 1:24.7.

2.5 SEQUENCE OF EXPOSURES

The following exposures were made of the targets, first at the KH-8 and then at the KH-9 reduction with three different exposure levels. Table 2-3 lists the haze condition, beamsplitter, target, and condition for each exposure.

TABLE 2-3

SEQUENCE EXPOSURES

Exposure	Haze Condition	Beamsplitter	Target and Conditions
1	None	None	$BaSO_4$ Standard.
2	None	.09	$BaSO_4$ Standard.
3	None	.21	$BaSO_4$ Standard.
4	Light	.09	None; haze only; haze box + .19 N.D.
5	Heavy	.21	None; haze only; haze box alone.
6	Light	.09	$BaSO_4$ Standard + haze box + .19 N.D.
7	Heavy	.21	$BaSO_4$ Standard + haze box alone.
8	None	None	Macro reflectance scale.
9	Light	.09	Macro reflectance scale + haze box + .19 N.D.
10	Heavy	.21	Macro reflectance scale + haze box alone.
11	None	None	CORN array (vegetation surround).
12	None	None	CORN array (desert surround).
13	None	None	CORN array (snow surround).
14	Light	.09	CORN array (vegetation surround); haze box + .19 N.D.
15	Light	.09	CORN array (desert surround); haze box + .19 N.D.
16	Light	.09	CORN array (snow surround); haze box + .19 N.D.
17	Heavy	.21	CORN array (vegetation surround); haze box alone.
18	Heavy	.21	CORN array (desert surround); haze box alone.
19	Heavy	.21	CORN array (snow surround); haze box alone.

The resultant imagery was a close approximation to actual CORN target acquisitions. Since not only backgrounds were varied but also haze level, a comprehensive study was possible of all factors affecting CORN target images including the radiometric effects of the atmosphere. This close similarity between the actual and simulated array is shown in Figure 2-3. The KH-9 acquisition chosen was Mission 1205, Op 313, Frame 026, Forward Camera. This frame was selected on the basis of high resolution and the near nadir position where the simulation of scale was most accurate.

2.6 ANALYSIS OF EXPERIMENTAL RESULTS

2.6.1 Densitometry

The 4" x 4" patches, when photographed in the laboratory experiment, resulted in an image size large enough to be measured with a .5 mil aperture of a MacBeth TD-203 Densitometer. This data served as the macrodensity control for the micro-step tablets. Figure 2-4 compares the TD-203 measured macrodensity scale of the "no haze" imagery to the characteristic curves derived from the 1B Sensitometer. The macro control curve approximates that of the sensitometer closely enough to be in the realm of experimental error. There is, however, enough disparity between the two curves to conclude that previous minor differences between the optical system of the 1B Sensitometer and the camera system it approximates are becoming more significant as the state-of-the-art requirements on mission control sensitometry become more stringent. Although similar characteristic control curves were produced to the "haze" imagery, it is misleading to compare them to standard 1B sensitometry. Therefore, they are not included in Figure 2-4.

Microdensitometry was measured on the GAF-650 Microdensitometer using an 11.5 micron circular aperture. The instrument was calibrated in the analog mode using a standard Film Type 3414 sensitometric strip. The resultant densities obtained from the analog traces were compared to their corresponding macrodensities for each of three levels of haze (no haze, light haze, and heavy haze), and three types of background (vegetation, sand, and snow).

The Five-Step and Two-Step scales were compared against the corresponding reflectance steps of the Sixteen-Step scales to determine if a significant systematic difference could be detected between the partial and full tone scale. It was found that the resultant density of the smaller scales did in fact match those of the longer scales indicating that differences in adjacent step reflectance were not significant at those levels of contrast. Note that in Figure 2-2, the Five and Two-Step scales represent selected patches from the full scale and are separated from one another by other reflectance levels. On the basis of this conclusion, the analysis of the experiment proceeded on the premise that data derived from the full scale would be indicative of the "real world" shorter scale data. Therefore, it was used in the regressions.

2.6.2 Parameter Analysis of Variance

The analysis of the relationship between the macro and microdensities proceeded in three

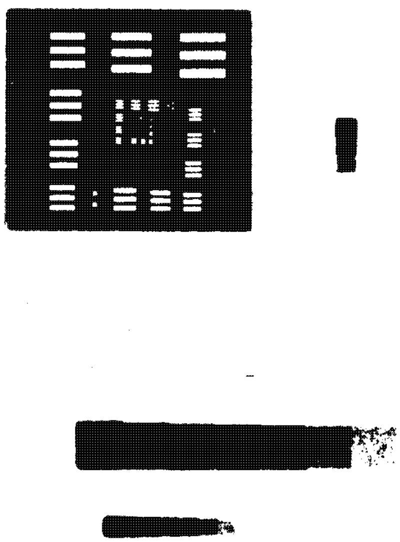
COMPARISON OF ACTUAL AND SIMULATED KH-9 CORN TARGET ACQUISITIONS

ACTUAL

(1205, Op 313, Frame 026, Fwd)

SIMULATED

(Light Haze, Sand Surround)

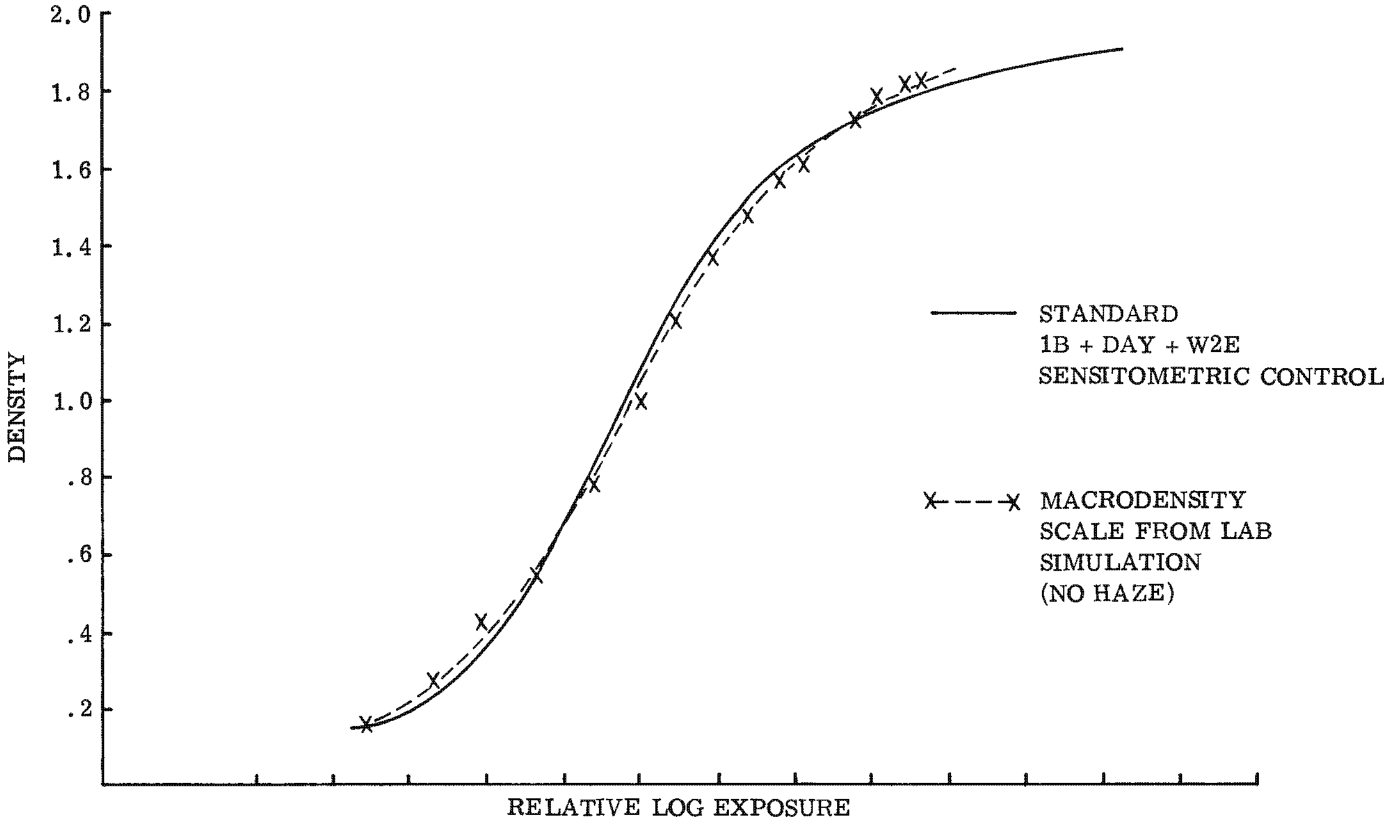


40X

FIGURE 2-3

FIGURE 2-4

COMPARISON OF 1B SENSITOMETRIC CURVE TO
THE MACRODENSITY CONTROL OF THE LABORATORY TEST



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stages. Initially, a regression was performed for each system using a model which included atmospheric contrast attenuation, background density, and target size (either 50' or 20') in various combinations with the predictor variable microdensity. The first model included curvature and interactions between the parameters.

A computer program called REGANA was used to perform the regression analysis. This program has essentially three measures of significance in the model:

A. Standard Student's T-test of the parameter coefficient.

B. An ANOVA table by parameter.

C. Successive standard errors of the residual as each parameter combination is added to the model.

All three tests were applied to reduce the equation down to its simplest statistical form. Only those terms which satisfied all three tests were included in the second regression.

In all, three regressions had to be run before all the remaining parameter combinations satisfied all three tests of significance. The final equations for the KH-8 and KH-9 systems are as follows:

A. KH-8

$$D_{macro} = \left[.938 - .00127C\right] D_{\mu} + \left[.0200\,(B-B_S) + .000629S\right] D_{\mu}^2 \qquad \text{(Equation 1)}$$

$$\sigma_{error} = .051$$

B. KH-9

$$D_{macro} = -.135 + \left[1.304 + .00354\,(B-B_S)\,C\right] D_{\mu} + \left[-.186 + .0135\,(B-B_S) + .000295\,S\right] D_{\mu}^2 \qquad \sigma_{error} = .063 \qquad \text{(Equation 2)}$$

where: D_{μ} = measured microdensity.

D_{macro} = corresponding macrodensity for the same exposure.

B = background density.

B_S = background density of sand surround.

C = C-factor of atmosphere in percent.

S = target size on ground in feet.

As can be observed from equations 1 and 2, both system simulations demonstrated a sensitivity to background and target size. Additionally, the equations show a small interaction effect of the atmospheric contrast attenuation C-factor on the linear density term indicating that target surround effects can be altered by overall contrast reduction of the atmosphere. Those terms which involved background density were normalized by the background density of sand surround. For computational use, the background density of the sand surround for the test can be taken as 1.40, and the C-factor as 8% for an average atmospheric condition. See Appendix A for graphic presentations of the actual data and regression curve fit for each combination of system, panel size, and surround at all haze levels.

2.6.3 Tribar Resolution

Included in the target arrays were sixth root of two 5:1 tribar targets matched in reflectance to those used in an actual CORN deployment. These were used to: (1) monitor the quality simulation to actual mission performance, and (2) assess the effect of the parameters background and atmospheric attenuation on resolution reading.

Table 2-4 compares the observed resolution under the light haze condition for the lab simulation versus the best resolution observed from both the KH-8 and KH-9 systems.

TABLE 2-4

OBSERVED TRIBAR RESOLUTION FROM LAB SIMULATIONS
VERSUS BEST TRIBAR RESOLUTION FROM MISSION MATERIAL
(cycles/mm)

Resolution Source	KH-8	KH-9
Simulation (light haze)	[redacted]	221
Mission 4337 (Second highest performance within this program)		-
Mission 1203 (Highest of first three missions within this program)	-	232

An analysis of variance was performed on the laboratory resolution data to test for significant parameter effects, see Table 2-5. It was not anticipated that the two photo scales would result in a significant difference in resolution; however, it was observed that the KH-9 simulation imagery was in fact better than the KH-8. No explanation is offered for this difference except that it is possible that a slightly better focus was achieved during the KH-9 photography. (b)(1) (b)(3)

TABLE 2-5

TRIBAR RESOLUTION AS A FUNCTION OF TEST PARAMETERS
(cycles/mm)

	KH-8 Haze Condition			KH-9 Haze Condition		
Background	No	Light	Heavy	No	Light	Heavy
Vegetation	[redacted]			221	221	187
Sand				221	210	166
Snow				197	176	166

The following conclusions were drawn from the ANOVA Program analysis of this data:

A. A significant difference existed between the photo scales (.005 significance level).

B. Haze has a significant effect on resolution (.025 significance level).

C. Surround reflectance has a significant effect on resolution (.05 significance level).

NOTE: The significance level is defined as the probability or risk of rejection of a hypothesis that is true.

Conclusion B comes as no surprise, as we expect resolution to drop as input target contrast is decreased. The third conclusion, however, is unexpected and indicates that the general surround reflectance can affect image quality even though there is no immediate contact and thus no edge effects. One possible explanation for the loss in resolution with increased background reflectance would be the loss of contrast resulting from camera optical flare when presented with a large field of high reflectance.

SECTION III

KH-9 APPLICATION OF MICRO-TO-MACRODENSITY CONVERSION

3.1 CONTRAST DETERMINATION

A CORN target contrast analysis on Mission 1204 provided an opportunity to apply the micro-macrodensity relationships determined in the laboratory. The specific task was to determine the film plane contrast of CORN tribar targets acquired on Mission 1204.

At KH-9 mission scales, images of the largest tribars are generally too small for accurate microdensitometry. However, their contrasts can be determined from imagery of the Two-Step Gray Scale, whose patches of minimum and maximum reflectance, nominally at 7% and 33%, are the same as that of the CORN tribar targets. These 50' square patches give images of approximately 150 microns square at nadir which is sufficient for obtaining reliable density data.

3.2 PROCEDURE

The plan for establishing the film plane contrast was to: (1) measure the microdensity of the two gray scale patches, (2) convert the microdensity values to macrodensity values, and (3) using the appropriate process curve, establish the log exposure differential of the two patches.

The microdensities of the gray scale images and their immediate surrounds were determined from analog traces by a Mann-Data microdensitometer utilizing a 10 micron aperture. The laboratory-determined curve of microdensity versus macrodensity values for the appropriate background density was then used to determine the conversion. The specific calibration curve used was the one which had a background density closest to the background density measured as the regression equations were not yet available. The macrodensities thus determined were then converted to log E values from the KH-9 mission R-2 process curve. The antilog of the log E differential between the two patches was the film plane contrast.

3.3 COMPARISON WITH CALCULATED CONTRAST

The gray scale contrasts were also calculated using the KSCOPE Radiometric Computer Model. Upon inputting the pertinent camera geometry, CORN target reflectance data, and solar geometry into this model, it calculated the log exposure and macrodensities of each gray patch. Using the R-2 process curve, the calculated values of film plane gray scale contrast were obtained. A comparison of the measured and calculated 7% and 33% CORN patch contrasts appears in Table 3-1. It cannot be proven which method gives more correct contrasts. It is encouraging, however, that 9 out of 11 comparisons produced values that differed by less than 20 percent. Furthermore, the two estimates of contrast have a correlation coefficient of .81 which is significant at the .99 level.

TABLE 3-1

ESTIMATED TRIBAR CONTRAST FOR 1204 MEASURED VIA MICRO/MACRO RELATIONSHIPS VERSUS KSCOPE PREDICTION

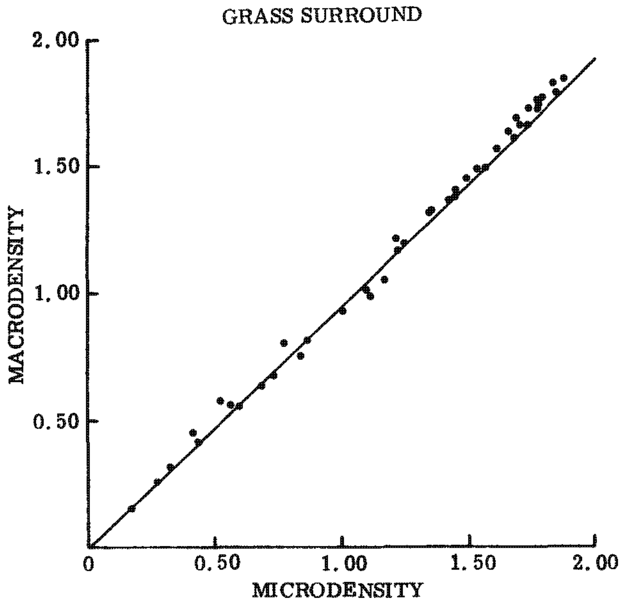
Operation	Frame	Camera	Solar Altitude (degrees)	Scan Angle (degrees)	Measured Contrast	KSCOPE Contrast
302	003	Fwd	34.9	-24	2.82	-
302	004	Fwd	35.0	-24	2.88	-
408	003	Fwd	31.4	-55	2.29	1.97
408	002	Fwd	31.3	-55	2.51	1.97
408	003	Aft	33.2	-53	1.91	2.19
498	003	Fwd	30.4	48	1.78	1.97
467	005	Fwd	30.6	-52	1.74	2.05
467	005	Aft	31.8	-52	1.91	2.22
498	004	Aft	30.4	48	1.86	2.21
408	004	Aft	33.2	10	2.95	3.19
546	004	Aft	29.4	30	2.51	2.40
546	003	Fwd	28.2	29	3.02	2.51
703	008	Aft	28.7	15	3.98	3.16

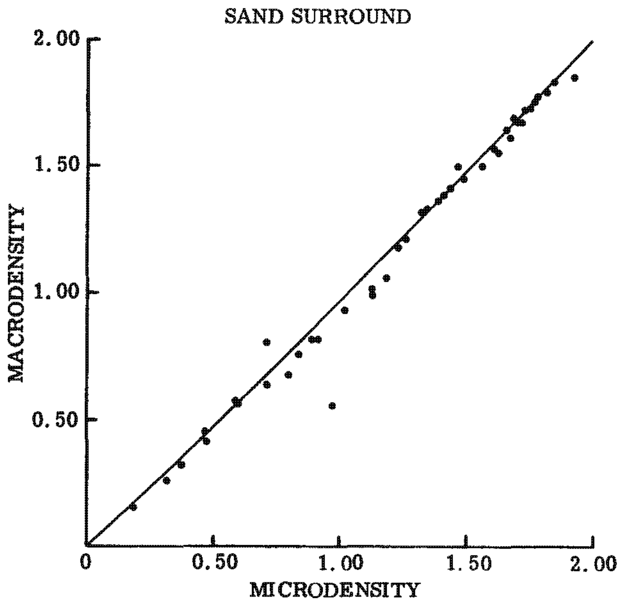
APPENDIX A

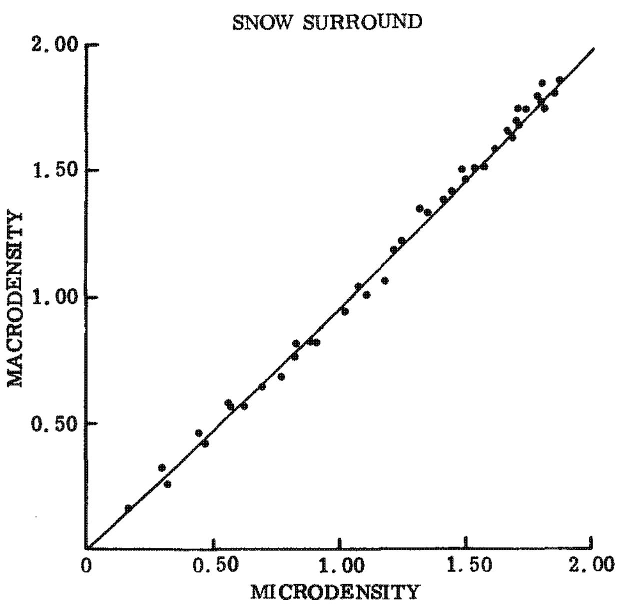
This appendix presents graphs which show the actual data and regression curve fit for each combination of system, panel size, and background (surround) type at all haze levels. The haze level is not graphed individually as it has a minor effect relative to the other parameters.

KH-8 MICRODENSITY-TO-MACRODENSITY REGRESSION

FROM 50' PANEL

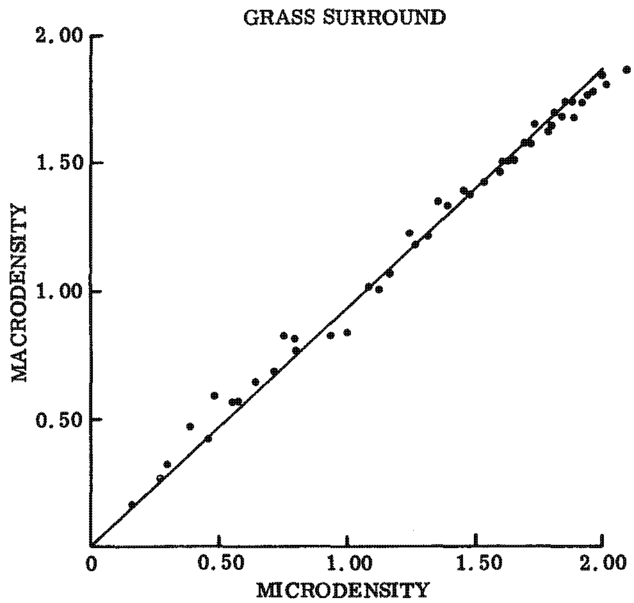


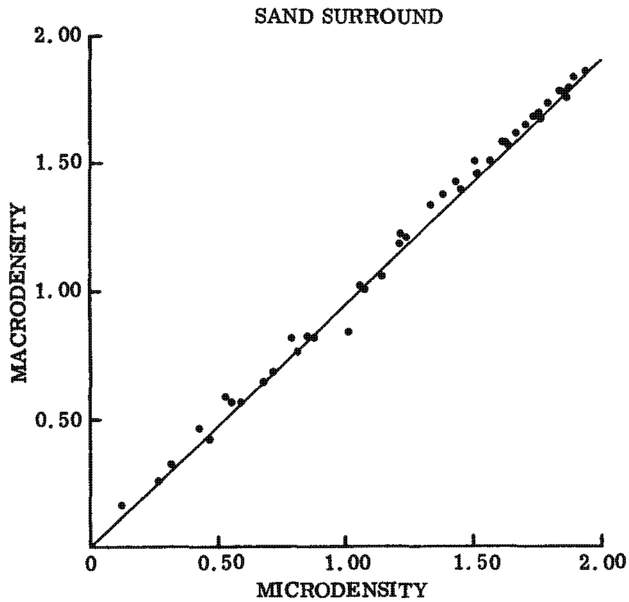


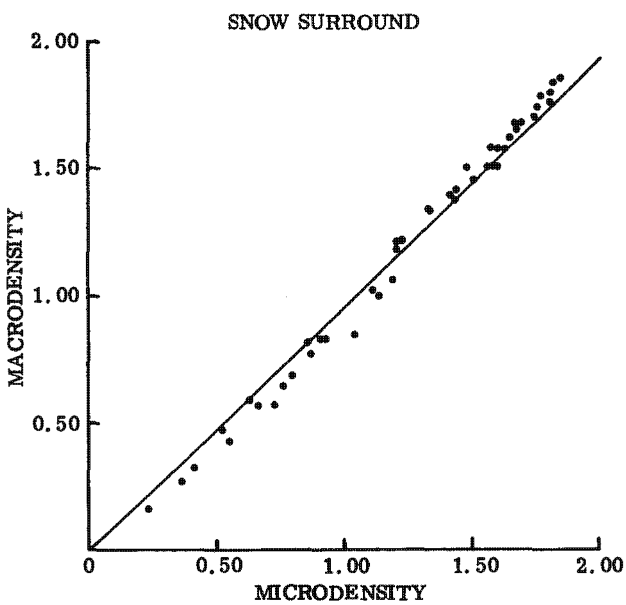


KH-8 MICRODENSITY-TO-MACRODENSITY REGRESSION

FROM 20' PANEL

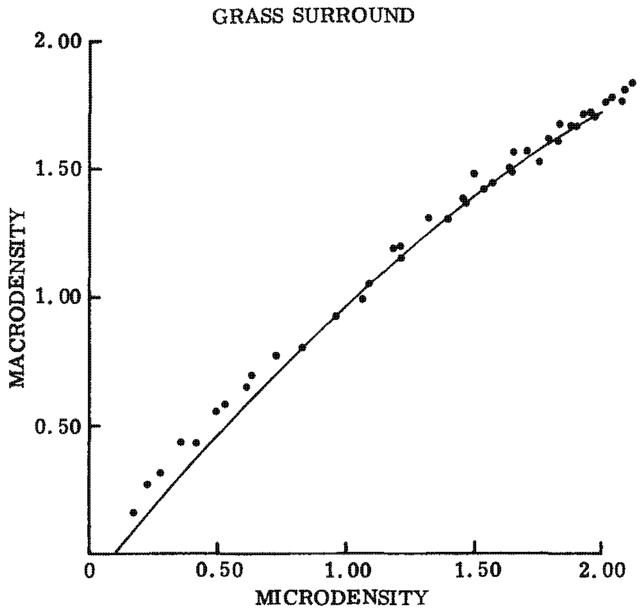


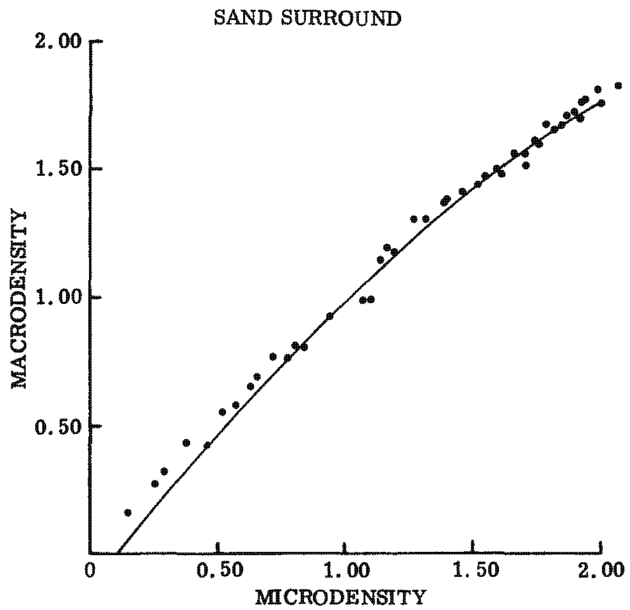


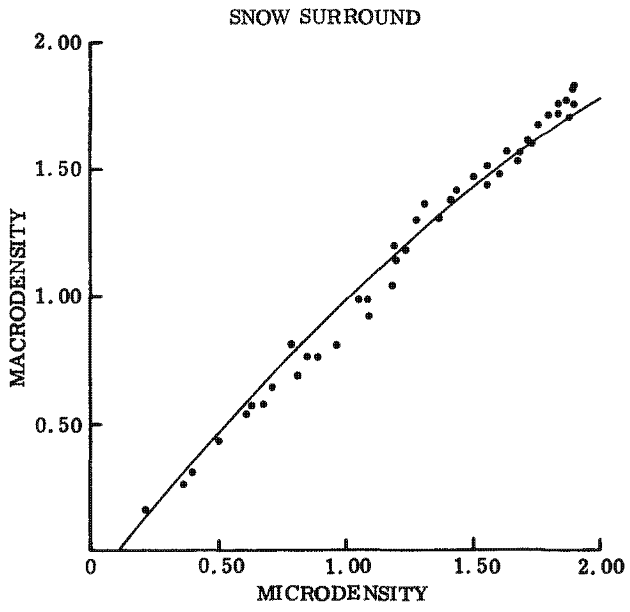


KH-9 MICRODENSITY-TO-MACRODENSITY REGRESSION

FROM 50' PANEL







KH-9 MICRODENSITY-TO-MACRODENSITY REGRESSION

FROM 20' PANEL