#225

DTN-72-6

TECHNICAL NOTE

TRIBAR RESOLUTION MEASUREMENT FOR SYSTEM PERFORMANCE EVALUATION

DEPENDENCE OF TARGET CONTRAST ON ACQUISITION ANGLE

(Data)

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Dependence of Target Contrast on Acquisition Angle

[redacted]

(b)(3)

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SECTION I

INTRODUCTION

A. BACKGROUND

The use of tribar resolution targets to establish system performance levels has yielded objective data to support both fee and engineering calculations. Like all measurement techniques, tribar measurements have an inherent variation which is a composite of small and uncompensated (or unknown) changes in the target, atmosphere, system, film, process, observer, etc. In recent years, substantial improvements have been made in hardware and techniques; if we are to continue making meaningful measurements, it is necessary that more exacting ground-truth techniques parallel these improvements.

While the ground-truth targets themselves represent only one element in a series of variables, they are an element over which CORN has direct control. Accordingly, we have instituted several in-house sponsored projects to track down and identify the variables associated with ground-truth targets and to find ways of eliminating, minimizing, or predicting them. This report deals with the results of a brief investigation of target reflectance which was carried out during operational CORN support activities in August and September of 1972.

B. CORN TARGET PHYSICAL CHARACTERISTICS

The present inventory of CORN targets may be divided into two categories: Those fabricated of nylon and those made from canvas.

1. <u>Canvas Targets</u>: Canvas targets have been used by CORN since its beginning nine years ago. Type 10/10 Army duck canvas is coated with a specially formulated acrylic emulsion, then cut and sewn to make the resultant target panels. Uncoated, the canvas weighs 8.98 ounces/square yard; four layers of acrylic coating add an additional 3 ounces. A 5:1 aspect ratio, 5:1 contrast ratio target having bar widths ranging from 8 feet 0 inch to 0.45 inch is 380 feet long and 80 feet wide, includes 4,120 square yards of fabric, and weighs 2,800 pounds. Displayed in two legs (Figure 1), the target can be displayed by a team of 6 men in 90 minutes. Bar and background reflectances, nominally 33% and 7% respectively, are illustrated in the spectral-reflectance profiles in Figure 2. The heavy fabric makes an attractive display since it tends to weight down long grass and small shrubs. Material weight, plus its porous nature, make the target panels easy to display on windy days; once displayed, the panels tend to stay in place rather than being lofted by high winds. Weight, and the possibility of mildew, are the major disadvantages of canvas.

2. <u>Nylon Targets</u>: Nylon targets are relatively new to CORN, having been instituted on a trial basis in 1969 and formally introduced into the inventory in 1971. Nylon fabric is coated with a urethane emulsion, then cut and sewn in a fashion similar to

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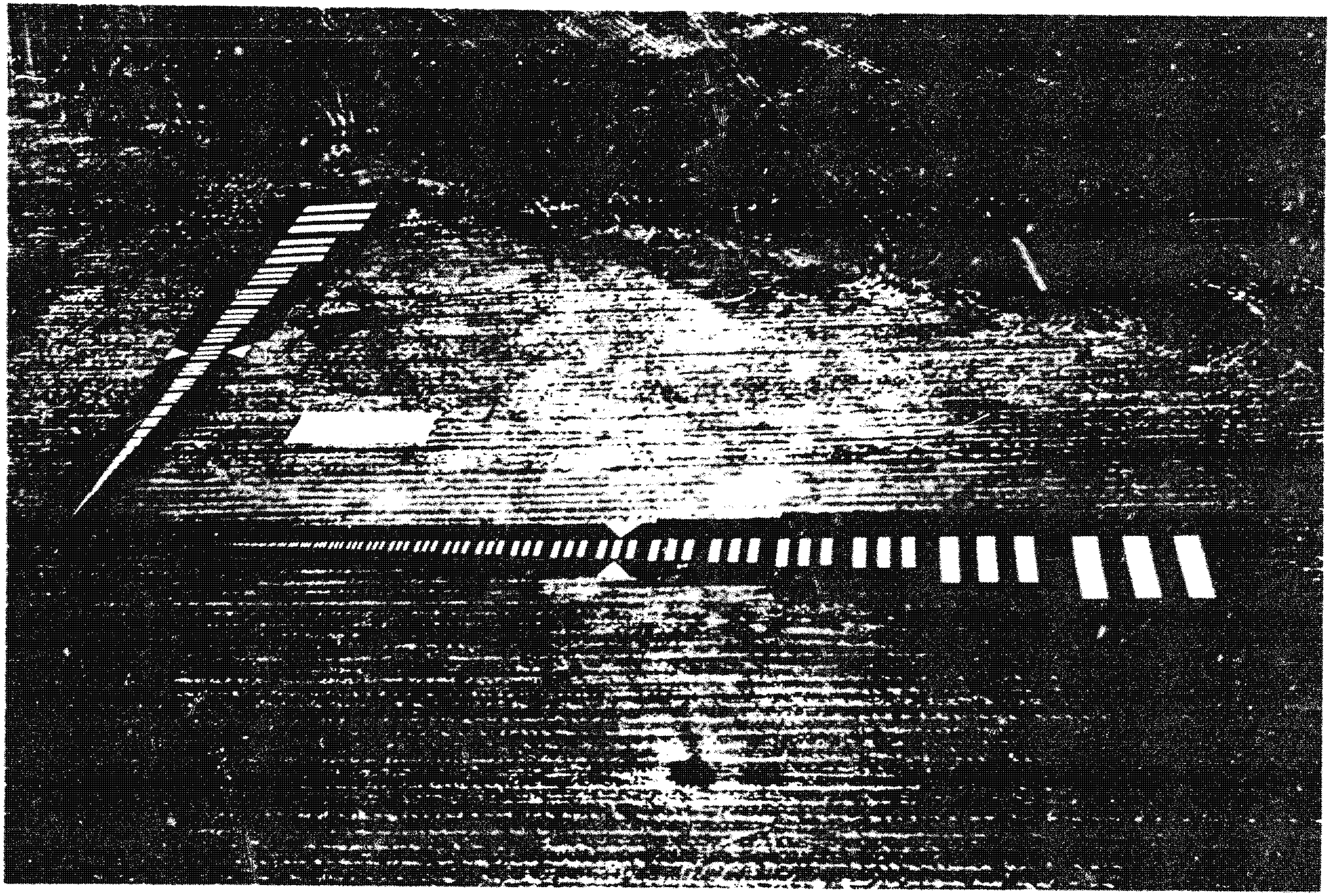

Figure 1 Display of CORN 51/51 Resolution Target

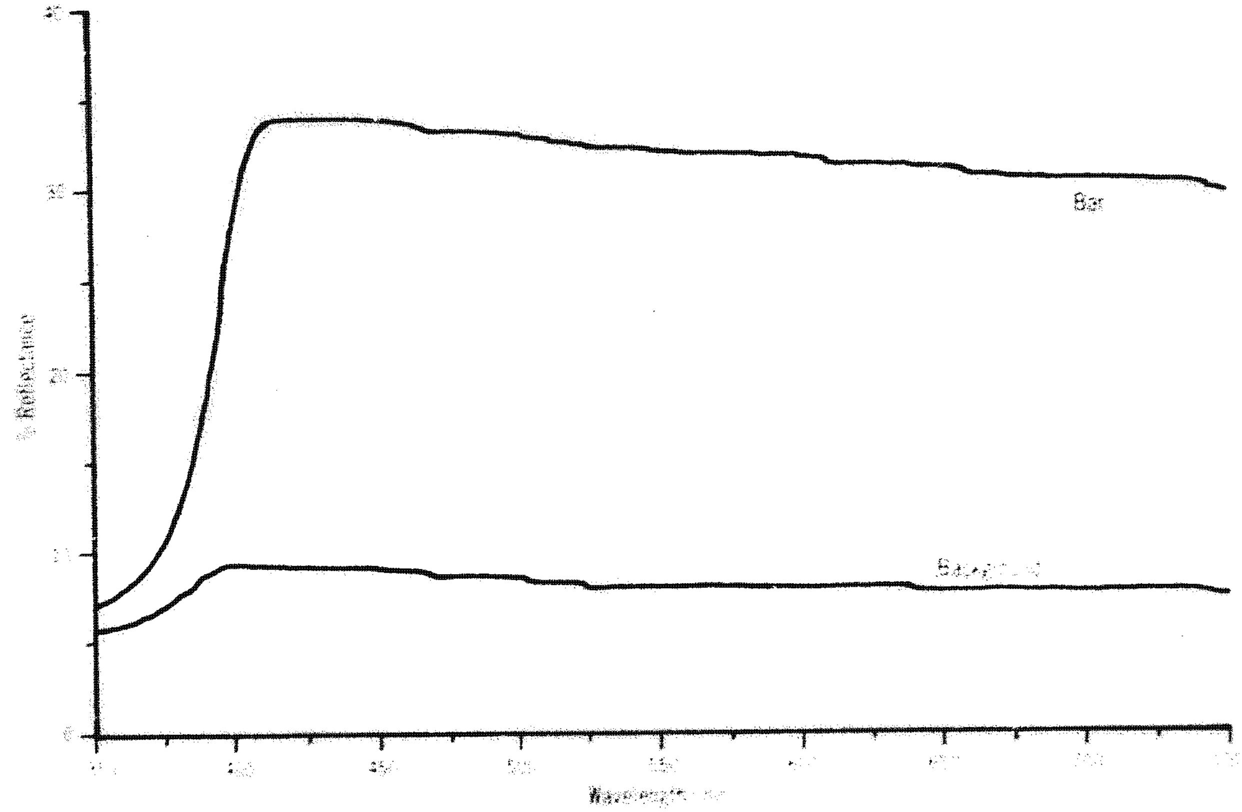

Figure 2. Bar/Background Spectral Reflectance

canvas. Coated nylon weights 4.95 ounces/square yard; the fabricated target then weighs 1,260 pounds, a decrease of 1,540 pounds compared to canvas. A team of 5 men displays the target in 90 minutes, but the lighter-weight fabric is more apt to lay atop grass and brush and sometimes results in a "lumpy" display. Wind is a problem; since the material is light and nonporous, it tends to act like a sail and may be both difficult to display and to keep in place after display. Nylon cannot mildew, and has demonstrated a longer useful lifetime than canvas. It is easier to transport and display because of its lighter weight, but there is legitimate doubt about the quality of the resulting display.

C. TRIBAR RESOLUTION VERSUS CONTRAST

A resolution measurement is a function of target contrast. Factors which may influence target contrast include:

1. Ground target contrast,
2. Atmospheric scattering,
3. Optical flare,
4. Optical and film spread functions,
5. Process gamma,
6. Duplicating gamma,
7. Observation conditions,
8. Human observer or microdensitometer system.

Changes in any of these factors which serve to increase the image contrast between a bar and a space will generally increase the resolution value. We are concerned here with the reflectance changes in a ground target which may influence resolution measurements.

Images of CORN tribars are acquired at a variety of solar altitudes, obliquity angles, and at various vehicle and solar azimuths. Ideally, one would like to have a target which maintains constant reflectance and contrast under all possible conditions of acquisition. Failing that, one must then be able to measure or predict these characteristics for known acquisition conditions. Once actual contrast is known, the mechanism exists to compensate resolution measurements for departures from expected target contrasts. The problem, however, is to know with certainty the effective contrast of the target as viewed by the camera at the moment of acquisition.

In order to determine whether this is being done properly, it is necessary to review present techniques and to consider the assumptions which are made in the process of using them.

D. PRESENT TECHNIQUES AND ASSUMPTIONS

Present target manufacturing techniques assure that the emulsions used in coating both canvas and nylon targets are adjusted to within 0.1% of the design reflectance of the target. Great care is exercised to assure that the reflectance of the coating is uniform throughout. Until recently, however, there has been little attention paid to surface optical characteristics, i.e., sheen or gloss. No specifications have been developed to describe the reflectance of a target as a function of the illuminating and viewing geometry.

Once targets are in the field, calibration is carried out every 60 days by spectrophotometric measurement of a small (1-inch square) patch which is cut from the target in the field. This is the latest in a series of calibration schemes which have employed photographic photometry (Hasselblads) and on-site photometric and radiometric instrumentation. At present, spectrophotometric data are collected at 50-nanometer intervals from 400 to 700 nanometers, and reported in absorptance units ($A = \log \frac{1}{R}$) to the Air Force. A program called SPECTNEW then weights the target spectral profile with the lens transmittance and integrates to determine the effective reflectances of each target. SPECTNEW's subsequent calculation of target contrast is assumed to describe that target for the next 60 days of field operations.

Given the above situation, one may then delineate the assumptions which are made in resolution measurement. The following list is in no particular order, but includes an arbitrary estimate of the <u>safety</u> of the assumption and the <u>impact</u> if the assumption is invalid. A scale of 1-5 has been selected to rank these attributes. In the <u>risk</u> column, higher scores indicate that the assumption is relatively unsafe at present. In the <u>impact</u> column, a high score indicates that the consequences of making an incorrect assumption are substantial.

We Currently Assume	Risk	Impact
1. That targets have a constant contrast ratio over a variety of sun angles and camera obliquities.	5	2-4
2. That targets are invariant with changes in solar or camera azimuth.	2-5	2
3. That a large target may be adequately described by a 1-inch sample used for calibration.	3	[illegible]
4. That, provided a target is once calibrated, it does not change significantly throughout a 60-day period.	5	5
5. That current calibration instruments simulate the real-world target/camera/sun situation.	2	2

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	Risk	Impact
6. That targets do not polarize light reflected from their surfaces.	3	3-4

E. OBJECTIVES OF THIS STUDY

This report treats only the first of the above assumptions, and only in a preliminary way. The experiment described here was agreed to in a meeting attended by [redacted] Maj. Pollard, Capt. Gordon, Capt. Riley, [redacted] and the author. (b)(3)
The meeting was held on 15 August 1972, and treated, as a part of the agenda, some current problems being experienced with resolution measurement at high oblique angles. A nylon resolution target and a nylon gray scale were being used in the field. After a discussion of target gloss, it was proposed that:

1. CORN simultaneously display a canvas as well as a nylon resolution target, and,

2. Field personnel make reflectance measurements of both nylon and canvas targets during the last segment of the mission.

The purpose of this report is to document and evaluate the field data collected. Recommendations are made concerning further studies of this and the other assumptions discussed previously.

SECTION II

D-3 FIELD MEASUREMENTS

A. SPECIFIC OBJECTIVES

Given a general objective of determining the nature of target reflectance at a variety of collection angles, we established the following specific objectives:

1. To determine the effective contrast of the nylon resolution target at the angle of acquisition by on-site measurement.

2. To determine the difference between nylon and canvas targets with regard to their reflection of light at angles to the source and surface.

Each of these objectives was satisfied by a separate series of tests. This section deals with only the first objective; Section III treats objective number 2.

B. LINE-SITE MEASUREMENTS

To obtain a better estimate of the actual target contrast at the moment of acquisition, field data were collected at Edwards AFB, California and at Kingman, Arizona during line target displays at those sites.

In all cases, the measurements were made using a Spectra-brightness spot meter which collects over a 0.5°-diameter cone and which yields photometric data in units of foot-lamberts. The unit was mounted on a tripod, approximately 60 inches from the ground. Collection angle was varied by means of a protractor affixed to one of the tilt arms of the tripod. For this reason, angles reported are probably ± 2°. In all cases, a change in the collection angle was accompanied by a move in the meter's position in order to assure that all data were collected from the same spot on the target. Since a constant meter height was used, the meter-to-target distance increased as the angle departed from a normal or 90° position. This also resulted in the meter viewing a slightly larger area of the target surface.

Since the brightness meter does not directly measure reflectance, it is necessary to use a calibrated reference panel as a standard. A magnesium oxide disc is frequently used for this purpose, since its reflectance is known and is very close to 100%. Here, however, we were measuring reflectances in the 5 to 40% domain and wanted maximum instrument accuracy in that area. We selected an especially flat sample of 33% canvas as a standard. In practice, each measurement of a bar or background area was accompanied by measurement of the standard panel. Raw data then consisted of brightness measurements from bars, background areas, and the standard panel.

C. FIELD DATA

Data collected during each day's display have been reduced to 7 charts (Figures 3 through 6) which illustrate, as a function of angle,

1. Reflectance of bar panels,
2. Reflectance of background panels,
3. Reflectance contrast ratio,
4. Brightness contrast ratio.

While data were actually collected every half hour during the display, only that collected closest to the time of acquisition have been included in this report.

Measurements were made of the nylon target at Edwards AFB on 19 August 1972, and at Kingman on 28 August and 1 September 1972. Data were also collected from a canvas target displayed at Kingman on 1 September.

D. SPECTNEW VERSUS FIELD CONTRAST

As indicated in Section I, part C, laboratory calibration data for each target are processed by a computer program (SPECTNEW) to predict target contrast for a 60-day period. Table I compares field contrast measurements with SPECTNEW contrast for the 3 displays documented in Section II, part C

TABLE I. FIELD DATA VERSUS SPECTNEW CONTRAST

Site/Date	Contrast: SPECTNEW Prediction	Contrast: Field Measurement*
Nylon - Kingman - 1 Sep 72	4.1	3.0
Nylon - Kingman - 28 Aug 72	5.4	3.7
Nylon - Edwards - 19 Aug 72	4.1	3.2
Canvas - Kingman - 1 Sep 72	3.3	3.3

*At actual acquisition incidence angle and time over target

E. CONCLUSIONS AND DISCUSSION

1. Reflectance: The reflectances of both the bar and background panels of the nylon targets vary markedly with the angle at which they are viewed by the sensor. Although the data reported here are for a relatively constant solar altitude, it can reasonably be assumed that changes in either solar altitude (SA) or acquisition incidence angle (IA) will affect the reflectance of the target.

SITE: EDWARDS
DATE: 19 AUG 1972
TIME INTERVAL: 1745 – 1755 GMT

TARGET TYPE: NYLON 5T
TARGET NO. I-5T-6-72T
STANDARD: 28% CANVAS

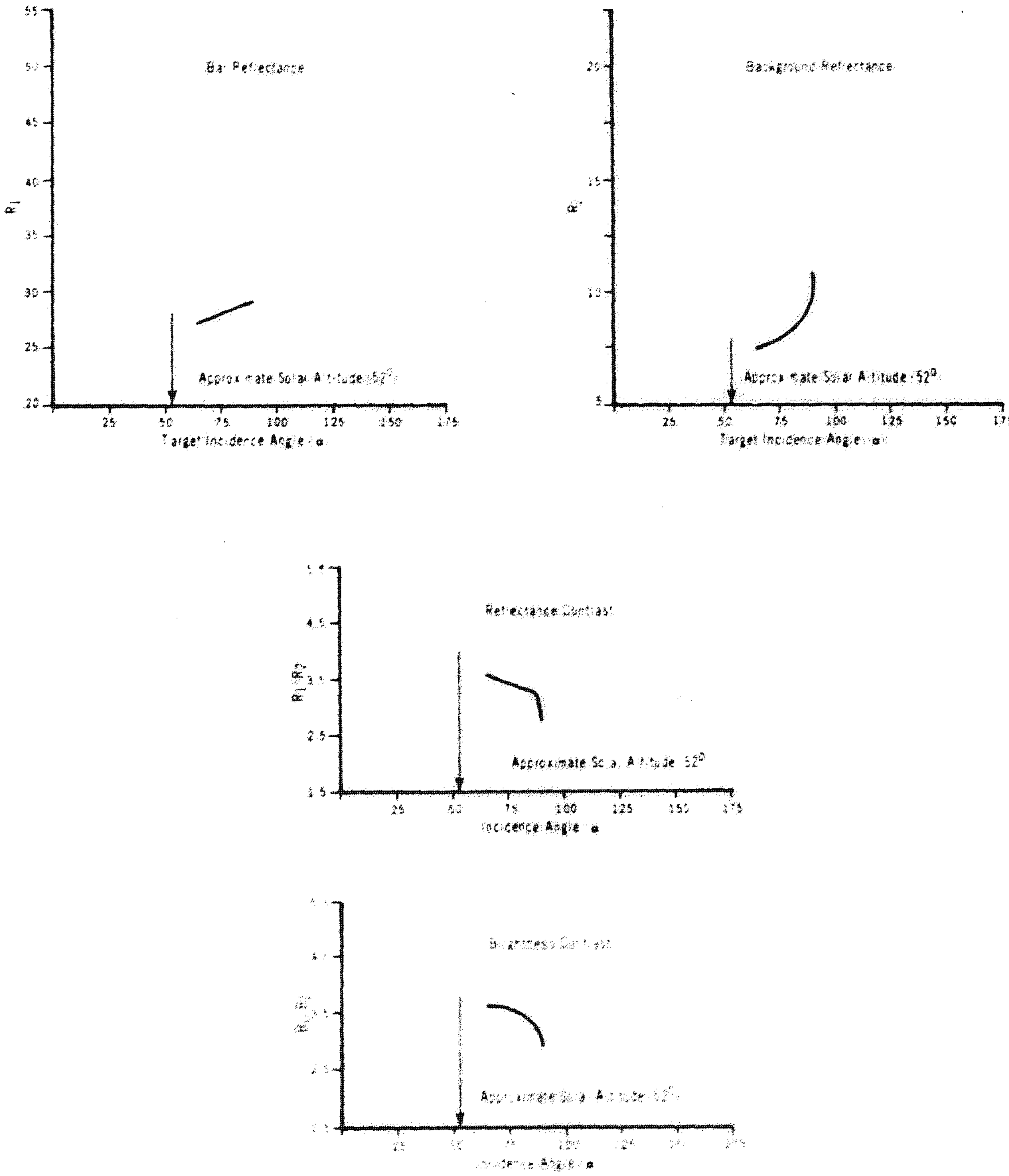

Figure 3. D-3 Field Data Summary

SITE: KINGMAN, ARIZONA
DATE: 28 AUG 1972
TIME INTERVAL: 1730 - 1745 GMT

TARGET TYPE: NYLON 5T
TARGET NO.: I-5T-6 72T
STANDARD: 28% CANVAS

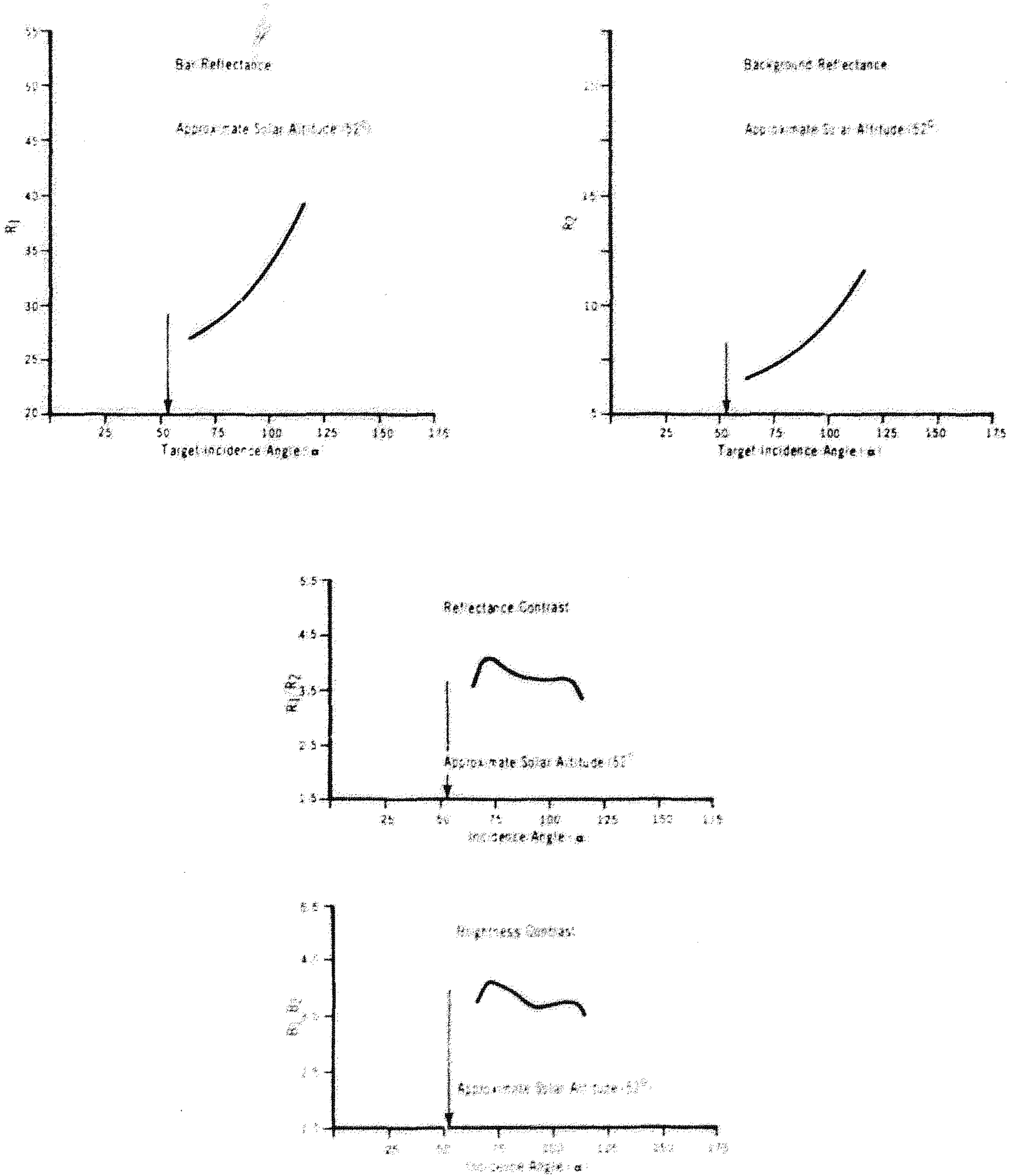

Figure 4. D-3 Field Data Summary

SITE: KINGMAN, ARIZONA
DATE: 1 SEP 1972
TIME INTERVAL: 1730 - 1745 GMT

TARGET TYPE: CANVAS 5T
TARGET NO.: V-5T-R 66
STANDARD: 28% CANVAS

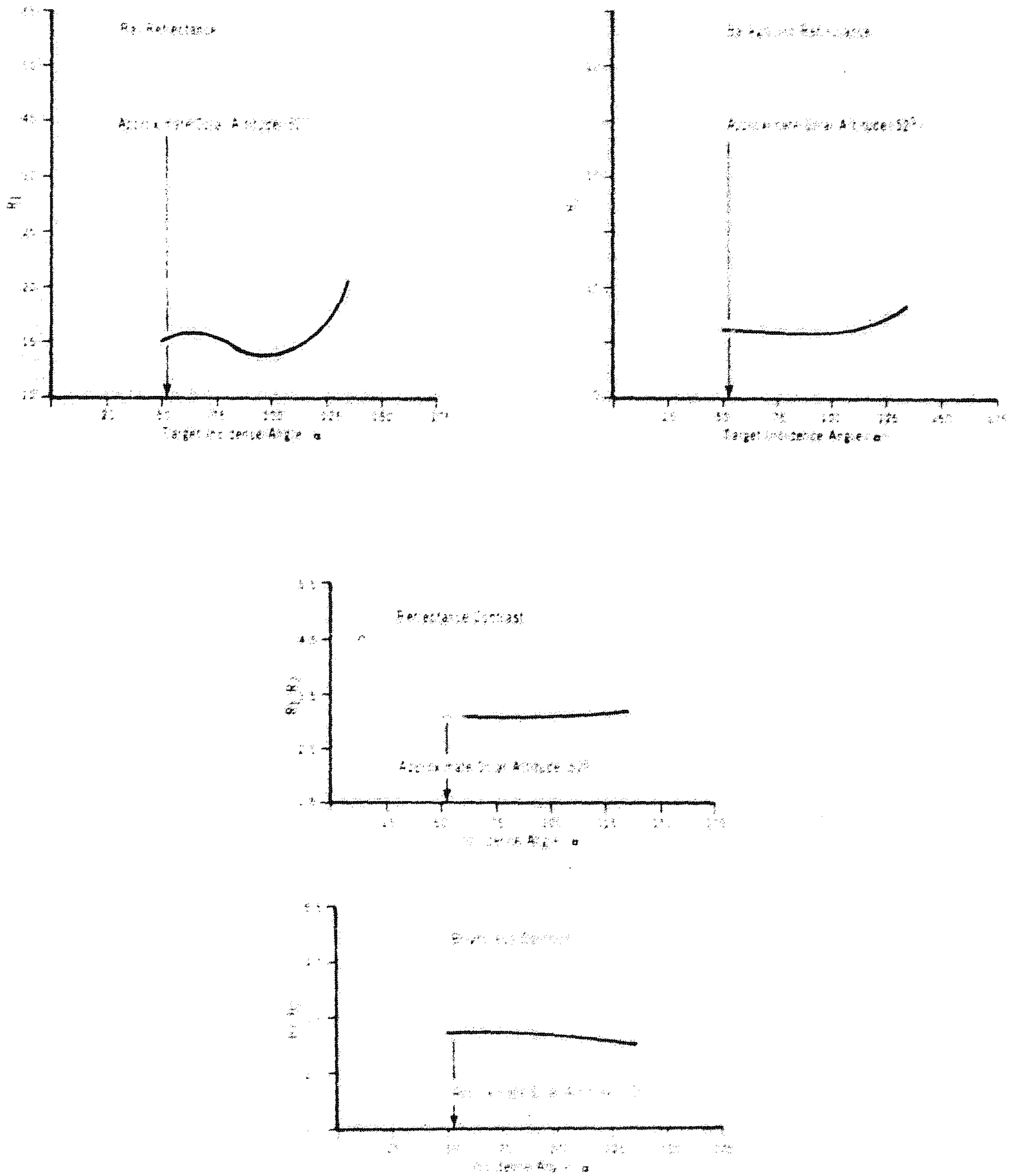

Figure 5. D-3 Field Data Summary

SITE: KINGMAN, ARIZONA
DATE: 1 SEP 1972
TIME INTERVAL: 1730 – 1745 GMT

TARGET TYPE: NYLON 5T
TARGET NO.: I-5T-6/72T
STANDARD: 28% CANVAS

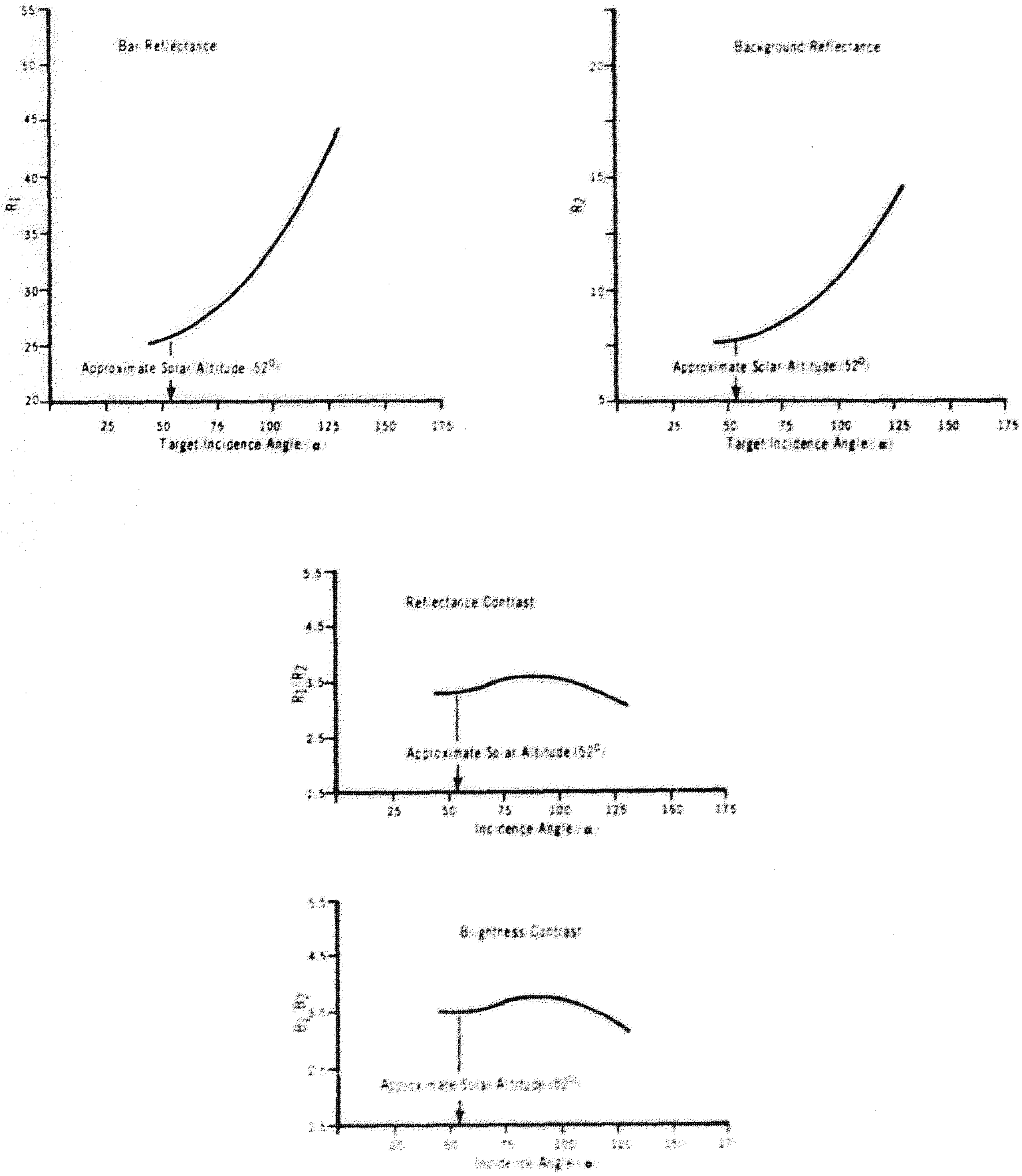

Figure 6. D-3 Field Data Summary

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Reflectance is generally lowest when IA is the same as SA, i.e., when the sun and the sensor view the target along essentially a common line of sight. As the incidence angle increases and departs from the solar altitude, reflectance rises rapidly. It is reasonable to hypothesize that reflectance would peak near an incidence angle of 180-SA, although the present data do not extend far enough to support this conclusively. It is important to restate, at this point, that for the purposes of this discussion, all incidence angles are measured from the east horizon, whether the vehicle was east or west of the target.

Acquisition at a high incidence angle would likely result in overexposure of the target unless the increased reflectance were compensated when exposure was set for that acquisition sequence. For example, the data collected from the nylon target at Kingman on 1 September 1972 indicate that R_1 (bar) increases from 25% to 44%, while R_2 (background) increases from 7.5% to 14.5%. At the higher angle, R_1 has increased by a factor of 1.76, while R_2 has increased by 1.93. The average log brightness increase of the target at the higher angle can be approximated by:

$$\log_{10} \frac{1.76 + 1.93}{2} = 0.26$$

Thus, acquisition at the higher incidence angle would require 0.26 log E less exposure (5/6 stop) than the same target acquired at a low incidence angle. If exposure were adjusted for some nominal situation, it is likely that the target would be either over- or underexposed, depending on the incidence angle.

Although only one set of data was collected from a canvas bar target, there is a strong indication that this problem is not nearly so severe as with nylon. It may, in fact, be sufficiently small that it is lost in the other errors of the measurement process. For the canvas target at Kingman on 1 September, R_1 increased from 25% to 30%, while R_2 increased from 8% to 9%. The average log brightness increase would require an exposure adjustment of 0.07, or slightly over 1/6 stop.

In summary, optimum exposure for the nylon bar targets is a function of solar altitude and incidence angle. The angle at which the target is to be acquired should be taken into account in setting exposure.

2. <u>Contrast:</u> The dependence of reflectance on incidence angle is not identical for the bar and background panels of the bar target. When reflectance is measured at increasing incidence angles, R_1 (bar) rises more rapidly than R_2 (background). For the Kingman example discussed previously, the nylon target contrast (R_1/R_2) decreased from 3.44 to 3.06 as the incidence angle increased. The canvas target decreased from 3.2 to 3.0 over the same set of incidence angles.

Since resolution data are collected from a variety of targets during a typical mission, and since target contrast varies from target to target, resolution measurements are adjusted to an effective resolution value at some standard contrast level (2:1). It is, therefore, important to know with accuracy the contrast of each target under the conditions of acquisition. Considering the experimental data, then, one must conclude that effective resolution measurements will be affected by failure to compensate for changes in target contrast which occur as a function of incidence angle. The error is greater for nylon than for canvas targets.

It is possible that this type of variation has been detected but unrecognized during previous missions. High incidence angles are generally experienced only at high scan angles when the increased vehicle/target distance serves to decrease scale and resolution. The effect of the target would be to further decrease resolution measurements; yet this might have been attributed to the nature of the system itself. The seriousness of this problem could be detected if one were to evaluate data collected at high scan angles from previous missions. In cases where the vehicle is east of the target, contrast and resolution should be higher than those cases where the vehicle is west of the target. While this experiment is not difficult, it could fail for the reasons explained in the following paragraphs.

3. SPECTNEW Versus Field Data: In correcting resolution data to determine effective resolution at a standard contrast level, the actual contrast of the target is generally presumed to be that predicted by SPECTNEW. For the Kingman example, SPECTNEW would have predicted a nylon bar target contrast of 4.1, while field measurements indicate an actual contrast (at the acquisition angle) of 3.0. The problem here is not with SPECTNEW itself, but the calibration technique which it represents.

SPECTNEW is updated at 60-day intervals, yet during that period, field targets are subjected to various types of treatment which serve to change reflectance and contrast markedly. Displays in dusty or sandy areas where there is even a light wind will result in a change in both reflectance and contrast. Subsequent washing of the target will result in yet another change. Since it is not possible to wash each target between every display, target reflectances change from day to day and cannot be typified by a single number for a 60-day period.

F. SUMMARY

1. Target reflectance and contrast are a function of the angle at which the target is acquired.

2. Average target brightness increases with increasing incidence angles, and is sufficiently different at high incidence angles to require a decrease in exposure if the target is to be consistently imaged at the same place on the film-process characteristic curve.

3. Target contrast decreases with increasing incidence angle, and will result in resolution measurements which indicate that system performance is lower than it actually is.

4. Target contrast varies daily and is better described by on-site measurements than by SPECTNEW contrast predictions.

Canvas target reflectance and contrast change somewhat with increasing incidence angle, but are substantially less affected than nylon targets. Experimental data are insufficient to determine whether canvas targets would require data compensation [illegible].

The data collected indicate that both nylon and canvas target reflectance and contrast show an orderly pattern of change with target incidence angle, and that resolution [illegible] easily be compensated, provided a data base existed to describe the targets.

SECTION III

NYLON/CANVAS COMPARISON

A. OBJECTIVE AND GENERAL APPROACH

To obtain an objective comparison of nylon and canvas optical properties, a series of semicontrolled measurements was made during a brief lull in D-3 field operations. The expression "semicontrolled" is used because the data were collected outdoors and were subject to minor changes in weather conditions. The absence of operational requirements on this particular day permitted more than usual time to be devoted to these measurements; they are, consequently, more accurate than usual.

The experiment was carried out at Edwards AFB on 23 August 1972 and involved three targets: Two nylon and one canvas. Of the two nylon targets, one had just been washed; the other had recently been used for a series of 6 consecutive displays and showed a considerable amount of surface dirt. All data were collected between 1730 and 1900 GMT in order to approximate the solar altitude conditions present in a typical CORN display situation.

B. DATA COLLECTION AND RESULTS

It is assumed that target acquisitions for program D operations seldom if ever occur at an incidence angle less than 30° or more than 150°. These correspond to ± 60° scan angles. In order to describe the complete range of angles typically experienced, measurements were made from 20° to 160°. Measurement apparatus and technique were identical with those described in Section II-B. Figures 7-9 represent reflectance and contrast data for canvas, nylon, and dirty nylon respectively.

C. CONCLUSIONS AND DISCUSSION

The following discussion first compares the reflectance characteristics of the three targets then presents a comparison of contrast characteristics.

1. <u>Reflectance</u>: Both nylon and canvas target reflectances vary as a function of incidence angle. Generally, the change is one of increasing reflectance with increasing incidence angle. Although bar and background panels do not necessarily increase at the same rate, the average reflectance at any one angle serves to indicate the exposure adjustment which would be necessary to assure that target images acquired at different angles were placed on the same portion of the characteristic curve. If

$$\frac{RI_a - RI_b}{RI_a} = F_1$$ (the factor by which the bar reflectance increased between angles a and b)

SITE: EDWARDS
DATE: 23 AUG 1972
TIME INTERVAL: 1730 - 1900 GMT

TARGET TYPE: CANVAS 5T
TARGET NO. V-5T-8/66
STANDARD: 28% CANVAS

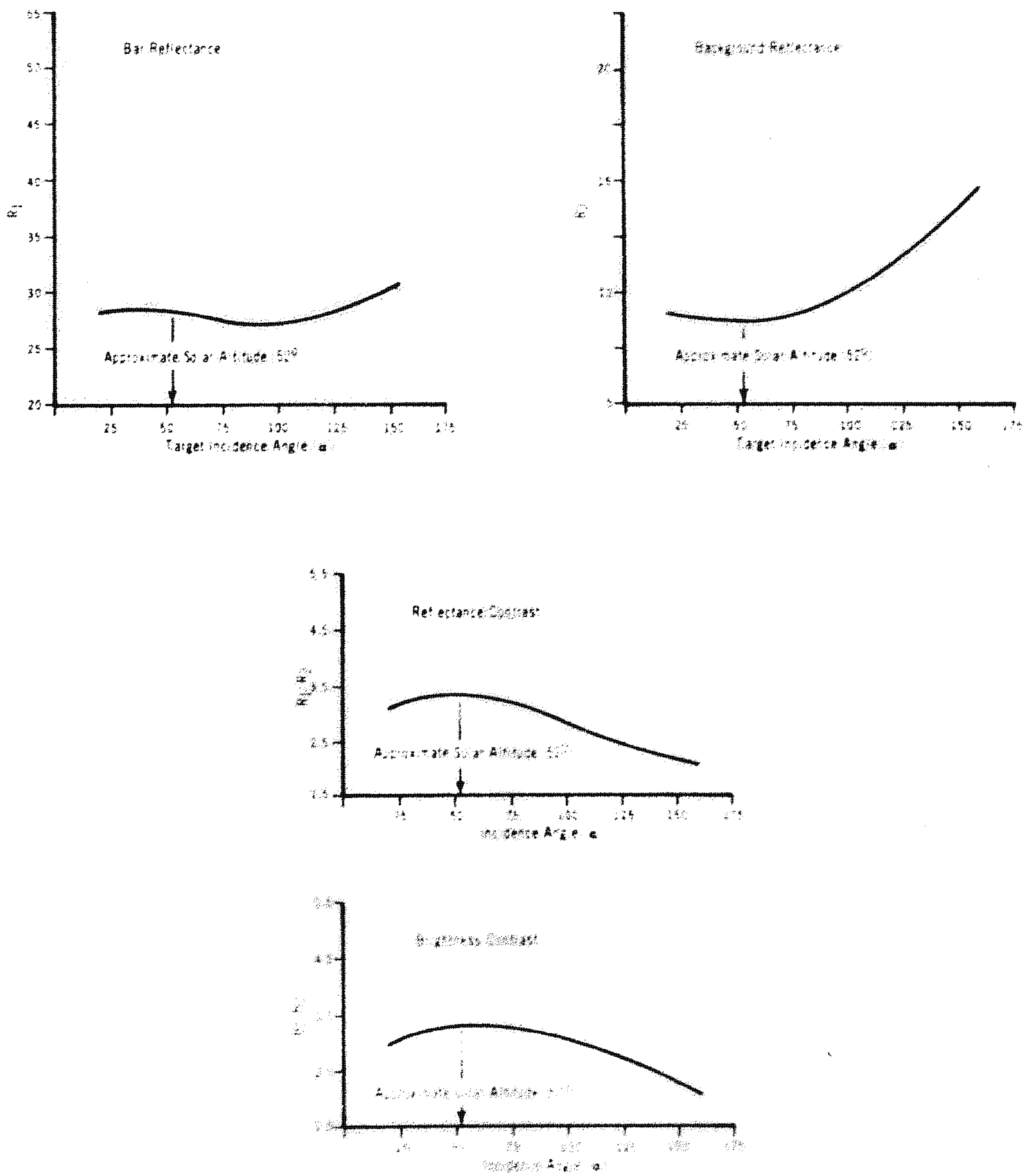

Figure 7. D-3 Field Data Summary

SITE: EDWARDS
DATE: 23 AUG 1972
TIME INTERVAL: 1730 – 1900 GMT

TARGET TYPE: NYLON 5T (CLEAN)
TARGET NO.: VIII-5T-5 72T
STANDARD: 28% CANVAS

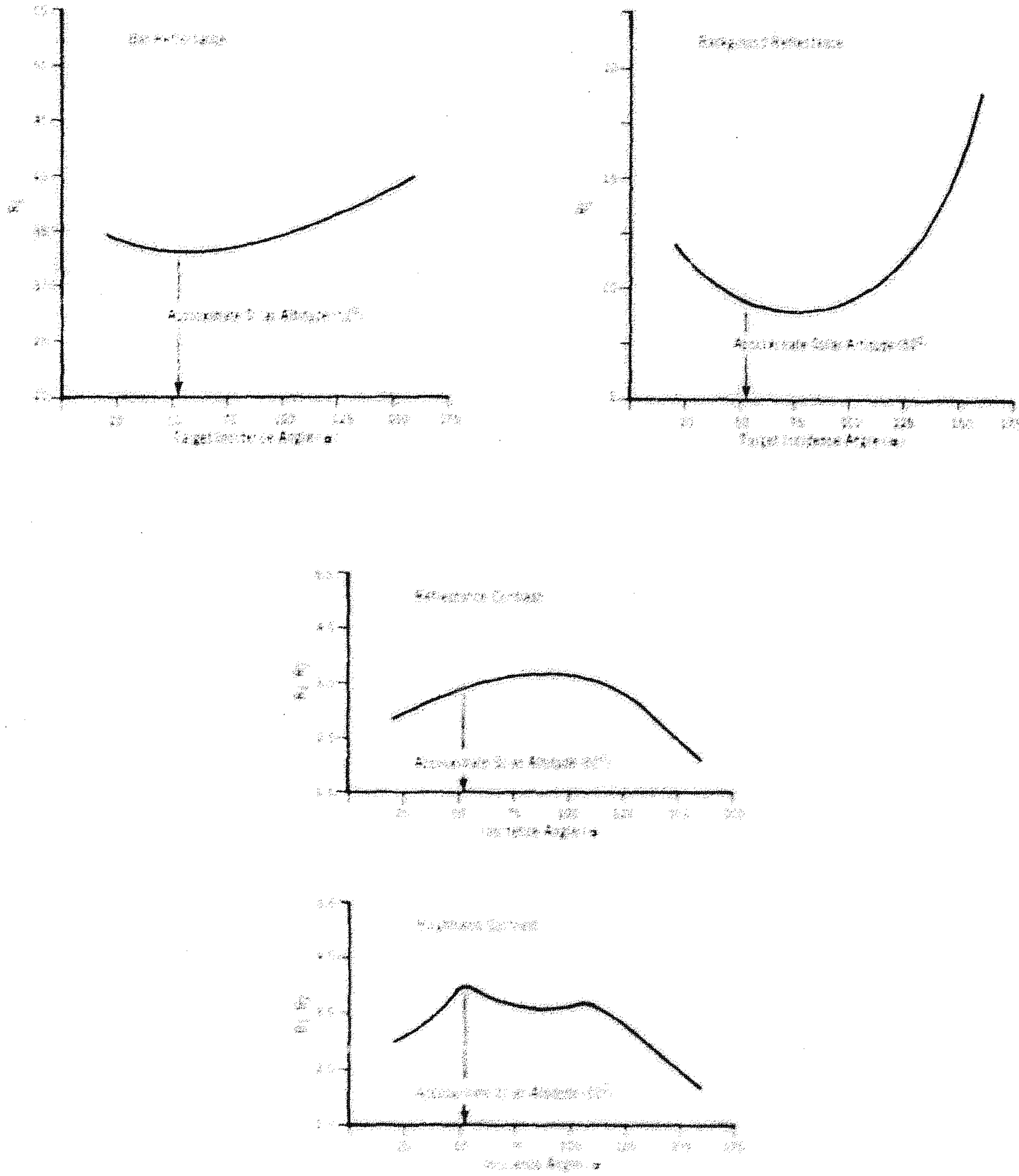

Figure 8. D-3 Field Data Summary

SITE: EDWARDS
DATE: 23 AUG 1972
TIME INTERVAL: 1730 – 1900 GMT

TARGET TYPE: NYLON ST (DIRTY)
TARGET NO.: VIII–ST–5 72T
STANDARD: 28% CANVAS

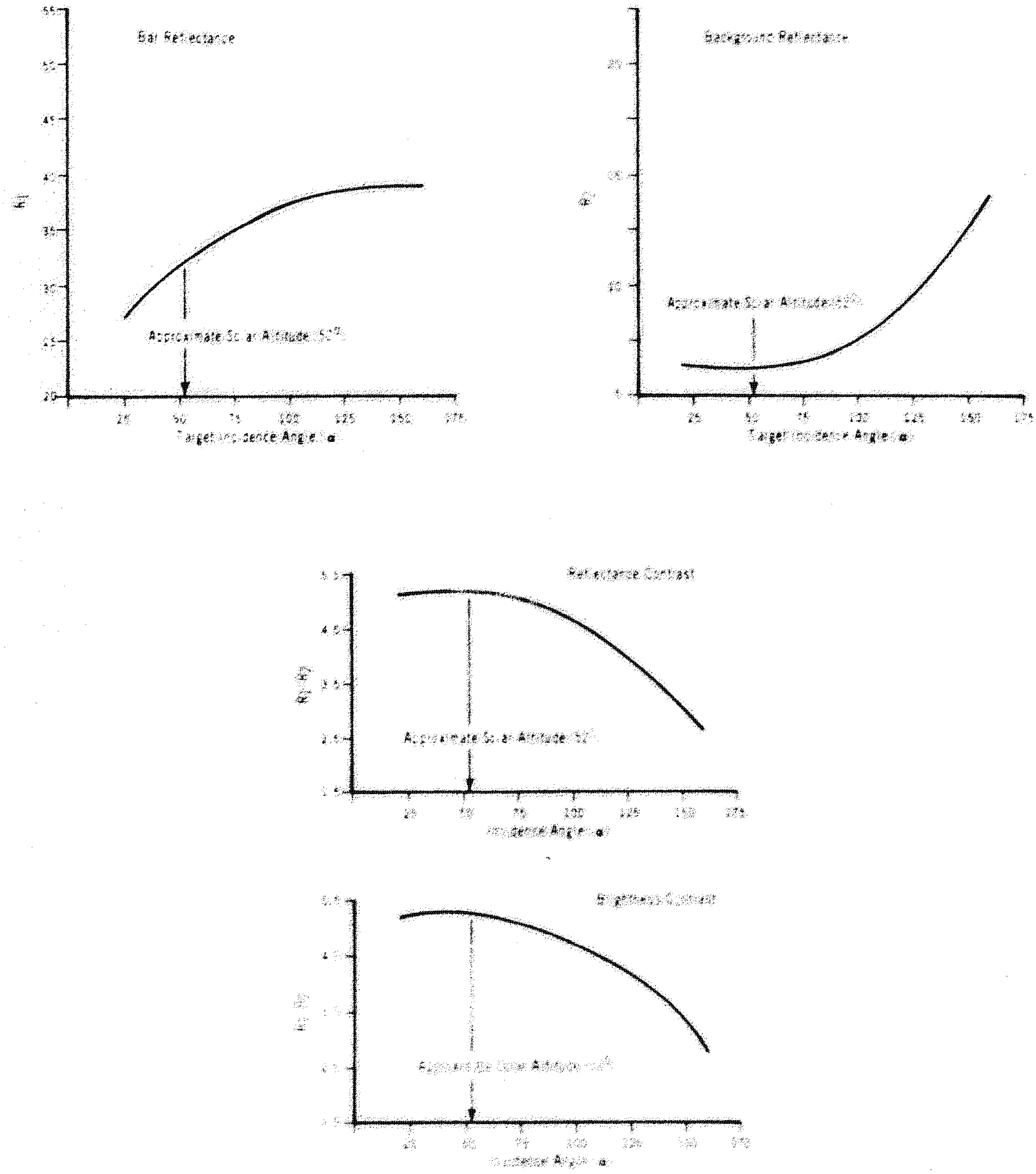

Figure 9. D-3 Field Data Summary

and $\frac{R2_a - R2_b}{R2_a} = F_2$ (the factor by which the background reflectance increased between angles a and b),

then $\log_{10} \frac{F1 + F2}{2}$ = the log exposure change required to compensate the change in reflectance with incidence angle.

The experimental data indicate that the maximum change in exposure required for nylon targets is on the order of 0.18 (greater than 1/2 stop) while the change required for canvas targets is 0.10 (1/3 stop). The cleanliness of the nylon target has little effect on the exposure adjustment required. In either case, the required change is sufficient to cause a change in the image position on the characteristic curve, and quite possibly a change in the observed resolution.

2. Contrast: The three target surfaces differ markedly in contrast when incidence angles are varied. To illustrate this point, data from Figures 7 through 9 have been summarized in the following table.

TABLE II. TARGET CONTRAST AT VARIOUS INCIDENCE ANGLES

	Incidence Angle			
	30°	90°	150°	% Change
Canvas	3.2	3.0	2.4	33.3%
Dirty Nylon	3.2	3.6	2.5	44.0%
Clean Nylon	5.1	4.4	2.8	82.1%

Both the canvas and the clean nylon decrease in contrast with increasing incidence angle. The dirty nylon first increases, peaks around 90 degrees, then decreases in a manner very similar to the canvas target.

If the three targets had been acquired at an incidence angle of 150 degrees (essentially the situation which would exist at a 60-degree scan angle with the camera west of the targets), there might be little difference among the three resolution values observed.

On the other hand, acquisition at the same scan angle but with the camera east of the targets should result in similar resolution observations from the canvas and dirty nylon, but in a significantly higher resolution from the clean nylon target.

Vertical acquisition would result in different resolution values for the three targets, with canvas being the lowest and clean nylon the highest.

D. SUMMARY

1. Target reflectance and contrast are a function of the angle of acquisition for both canvas and nylon targets. Canvas is the least affected, while nylon variations are quite significant.

2. When dirty, nylon targets behave more like canvas than like clean nylon.

3. Exposure changes are required to compensate for changes in target reflectance as the incidence angle changes. For a typical D program situation:

RELATIVE LOG EXPOSURE INCREASE REQUIRED

	Scan Angle		
	60° W	0°	60° E
Nylon (clean)	0	0.03	0.18
Canvas	0	0.02	0.11
Nylon (dirty)	0	0.03	0.18

4. Nylon and canvas are distinctly different in their reflectance properties, but both require compensation for general reflectance and contrast changes in order to obtain accurate resolution data. While canvas exhibits the effect least, there is no distinct advantage to it when compared to nylon.

5. The compensation required is neither complicated nor expensive, but does require more data than are presently at hand.

SECTION IV

RECOMMENDATIONS

The foregoing report is based on data collected over a brief interval near the conclusion of program D-3. It is sufficient to demonstrate that some uncompensated variables are affecting resolution measurement. Depending on the situation, these effects may exaggerate or underestimate actual system performance; on the whole, it is likely that we usually underestimate how well the system is performing. Compensation for these variables is not only possible, but appears to be fairly straightforward. It is likely that a data base can be accumulated which will permit routine compensation for target characteristics for all programs currently supported by CORN.

In order to acquire a better understanding of the nature of the target surfaces, and to prevent further misleading resolution computations, the following activities are recommended.

1. On-site field measurement of bar and background reflectances should be made during all future CORN deployments at the time and angle of acquisition. Instrumentation and procedures should follow essentially those described in this report until improvements can be effected.

2. In-house work carried out by Data Corporation should be accelerated to compile a routine for target reflectance prediction based on camera azimuth, acquisition angle, solar altitude, solar azimuth, and target warp/fill orientation. The objective should be to determine algorithms which may be used, on a routine basis, to provide the Air Force with more accurate reflectance information.

3. Work should be performed to breadboard and field test a target reflectance measuring device which is independent of daylight for its source of illumination. Present spot brightness meters must have a constant illumination level to permit the several brightness measurements required to calculate reflectance. Presence of evenly scattered cirrus clouds makes a constant illumination level nearly impossible to obtain. Initial designs exist for a device which would make spectral measurements at a variety of incidence angles using an internal, battery-powered source. The entire unit could be small, portable, and operable by relatively untrained field personnel. With appropriate care, the device could use a measurement geometry which simulates, to an extent, the sun/camera system. In this manner, multiple measurements could be made at a variety of positions on the target in order to obtain a more exact description of its overall surface properties.

Pursuit of these recommendations would resolve the assumptions discussed in Section I-D of this report, in order of decreasing importance. They should, however, be addressed almost simultaneously, since resolution calculations are an everyday activity on which a great deal depends; they should be upgraded to maximum accuracy and reliability as soon as is practically possible.