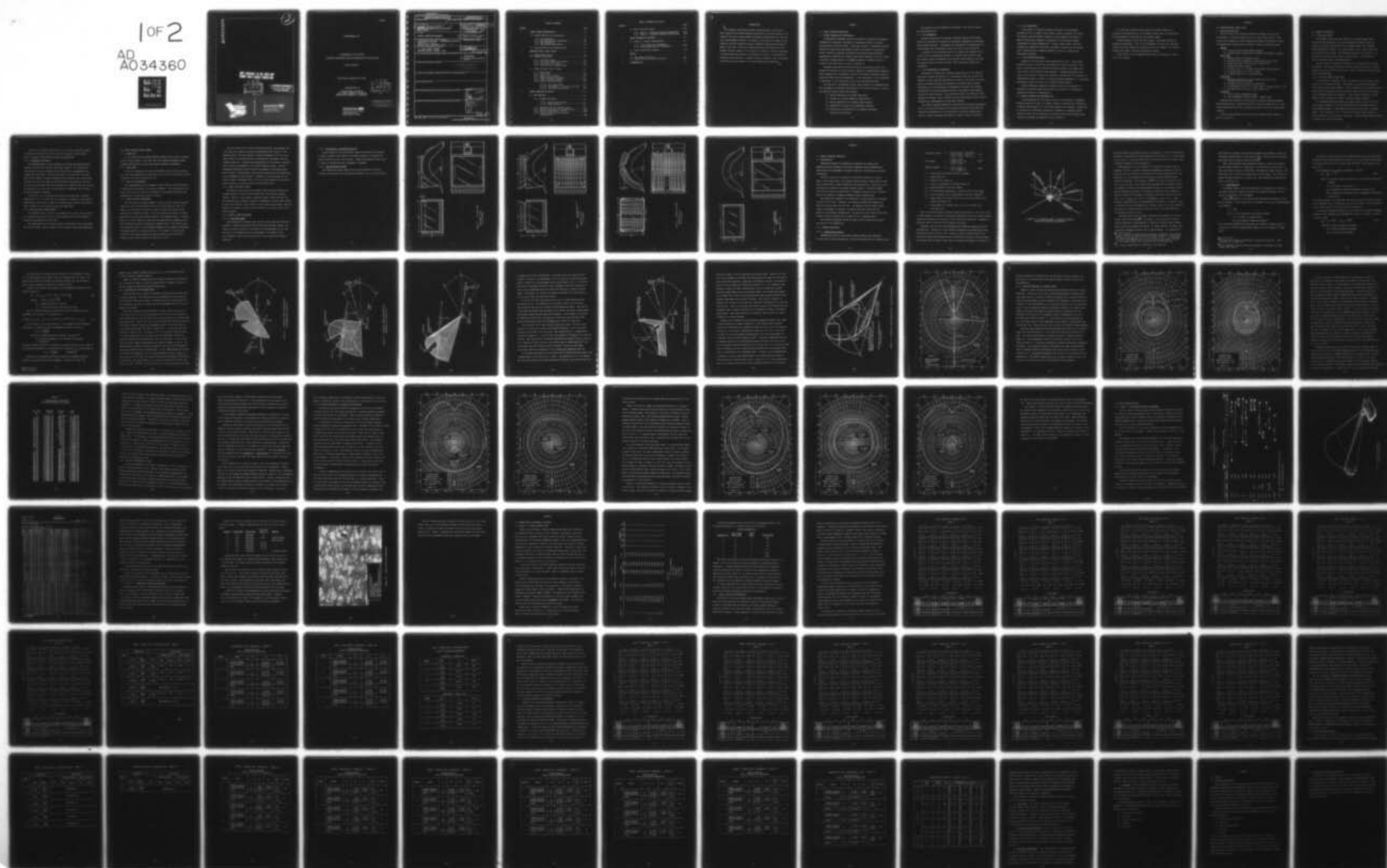
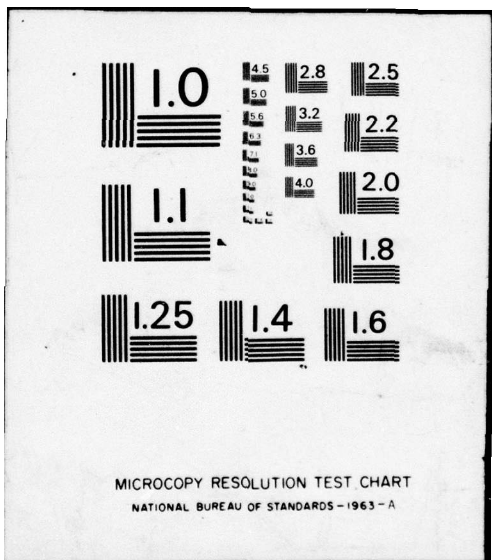
AD-A034 360 AERONUTRONIC FORD CORP NEWPORT BEACH CALIF AERONUTR--ETC F/G 17/8
CHAPARRAL ANTI-GLINT CONCEPT DEMONSTRATION/FEASIBILITY EVALUATI--ETC(U)
NOV 76 DAAH01-76-C-0583
UNCLASSIFIED U-6282 NL

1 OF 2
AD
A034360




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ADA034360

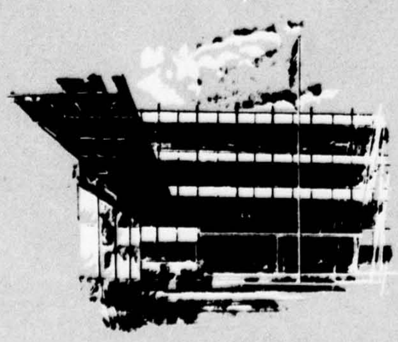
FC.

2

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

DDC
RECEIVED
JAN 13 1977
A

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited



Aeronutronic Ford
Aeronutronic Ford Corporation
Aeronutronic Division
Newport Beach, California

U-6282

9 NOVEMBER 1976

CHAPARRAL ANTI-GLINT

CONCEPT DEMONSTRATION/FEASIBILITY EVALUATION

FINAL REPORT

CONTRACT DAAH01-76-C-0583

DDC
RECEIVED
JAN 13 1977
A

SUBMITTED TO

COMMANDING GENERAL
U. S. ARMY MISSILE COMMAND
REDSTONE ARSENAL, ALABAMA

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

Aeronutronic Ford
Aeronutronic Ford Corporation
Aeronutronic Division
Newport Beach, Ca. 92663

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
CHAPARRAL ANTI-GLINT CONCEPT DEMONSTRATION/FEASIBILITY EVALUATION FINAL REPORT

5. TYPE OF REPORT & PERIOD COVERED
FINAL, FEB. 4, 1976 - NOV. 9, 1976

6. PERFORMING ORG. REPORT NUMBER
U-6282

7. AUTHOR(s)
VARIOUS CONTRACTOR PERSONNEL

8. CONTRACT OR GRANT NUMBER(s)
DAAH01-76-C-0583

9. PERFORMING ORGANIZATION NAME AND ADDRESS
AERONUTRONIC FORD CORP. - AERONUTRONIC DIVISION
FORD ROAD, P.O. BOX A
NEWPORT BEACH, CALIFORNIA 92663

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
U.S. ARMY MISSILE COMMAND
REDSTONE ARSENAL, ALABAMA 35809

12. REPORT DATE
9 NOVEMBER 1976

13. NUMBER OF PAGES
142

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
-

16. DISTRIBUTION STATEMENT (of this Report)

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

INTRODUCTION

This document constitutes the final reporting effort on activities which comprised the Concept Demonstration/Feasibility Evaluation phase of the Chaparral anti-glint canopy hardware development program under U.S. Army contract number DAAH01-76-C-0583. The report is structured as an update to the Chaparral Anti-Glint Evaluation Report (Breadboard Configuration Selection) dated 19 July 1976. Scope of the update reporting task reflected in this document has been limited to the inclusion of a phase II test data tabulation, a revised statistical analysis of the phase II test data, a bibliography of literature source material, a separate logistics evaluation study, and general clarification and/or expansion in critical areas of data reporting.

SECTION 1

1.0 CANOPY CONCEPT DETERMINATION

1.1 CONCEPT RESEARCH AND INVESTIGATION

An abbreviated literature search was performed to identify and accumulate information on conceptual techniques for reducing the amount of sunlight reflected from an optical surface. The primary sources of information acquired during this research and investigation process were reports of surveys and studies conducted by agencies contracted by the United States Government. Supplementary information was obtained from various abstracts as well as during a technical exchange meeting with USAMICOM personnel at Redstone Arsenal. A listing of pertinent sources is given in Appendix A.

Conceptual approaches discovered during the investigative process were grouped into specific sun glint reduction technique or mechanization categories. These categories were describable in terms of the primary reflectable light-ray processing feature and were designated: 1) ray elimination, 2) ray transmission or absorption, 3) ray interception, and 4) ray re-directionalization.

The objective of determining the most viable concepts for breadboard hardware development necessitated consideration of the following topics for individual candidate concepts within each category:

A) Concept feasibility for systems application

B) Forecast of sun glint signature characteristics

C) Concept adaptability to existing canopy framework

D) Variability of concepts for permutation evaluation

E) Availability and affordability of hardware fabrication materials and techniques.

The following sections summarize the findings of the concept research and investigation task.

1.1.1 RAY ELIMINATION

Concepts predicated on the complete or partial removal of the canopy surface were excluded on the basis of a prohibitive degradation in operations safety (gunner exposure). Accordingly, the development of mechanizations to restore weapon system operational control were seen as cost-ineffective.

A reduction in the reflection area of the surface was eliminated due to the fact that a corresponding decrease in the gunner search field of view would result, unless incorporation of an optical system capable of restoring the complete field of view was included. This concept also seemed cost-ineffective.

1.1.2 RAY TRANSMISSION OR ABSORPTION

Techniques of reducing the reflection characteristics of the canopy by improving the medium transmittance of illuminating light-rays included the changing of canopy material; application of single or multi-layer, low index, quarter wavelength coatings; and application of gradient index coatings. Significant cost and technological considerations precluded the continued investigation of canopy replacement materials and gradient index coating concepts as viable solutions. Single and multi-layer, anti-reflective (AR) coatings did, however, offer a partial solution, particularly as they could be considered for complimentary use with other concepts.

The similar conceptual approach of increasing the absorptive characteristics of the reflecting surface with techniques of tinting was excluded considering the significance of the proportional relationship between glint reduction (single wavelength absorption) and gunner visibility reduction.

1.1.3 RAY INTERCEPTION

A wide variety of mechanical shading techniques were investigated including the use of screens, fabric meshes, louvers or baffles, and visors. The separate trade-off between reduction in glint signature and impact on gunner visibility was examined in relationship to the physical strength requirements for system compatibility. Screens, fabric meshes, and visor concepts were eliminated during this investigation process, but the utilization of fixed-position, mechanical baffling was seen as a practical ray interception technique.

1.1.4 RAY RE-DIRECTIONALIZATION

Changes in the structural design characteristics of the canopy surface presented a means of controlling the dispersion of reflected sunlight. Flat facet or plate designs were considered desirable because of the highly directional nature of the reflected light signature. Although significant reductions in the detection envelope were promised by hemispherical and variations of hemispherical designs, the unique continuous signature regardless of the relative sun-observer position was seen to be a negative characteristic.

Surface etching and roughening techniques aimed at wide dispersal or scattering of reflected light were excluded on the basis of the associated significant reduction in transmittance.

1.2 CONCEPT SELECTION FOR BREADBOARD TEST

Final determination of the canopy concepts to be developed as breadboard models was made on the basis of forecast signature characteristics, feasibility of design, and availability of fabrication materials and processes. Recognizing the potential for performance improvements attainable by combining salient features of more than one candidate, the following three design concepts were selected for hardware development and test evaluation:

1) A flat plate redesign of the standard cylindrical canopy, 2) a cylindrical grid baffle add-on to the standard canopy, and 3) a single-layer AR coating applied to both sides of the standard canopy.

During development of the flat plate canopy, a grid baffle add-on was designed and fabricated. Prior to the commencement of field test evaluation, a second flat plate canopy was constructed and the two canopies, one incorporating the grid baffle, underwent simultaneous testing.

Design details of each breadboard model canopy are discussed in section 2.0 of this document.

2.0 BREADBOARD MODEL CANOPY DESIGN

2.1 DESIGN QUANTIFICATION

The first step in the breadboard hardware development process was the establishment of individual design criteria for each canopy concept. These criteria were formulated to enable engineering designers and analysts to quantify manufacturing specifications necessary to begin the fabrication task.

General

1) Utilize existing canopy assembly hardware.
2) Consider system interface and performance requirements in design.

Flat Plate

1) Minimize number of rectangular facets.
2) No greater than 5% reduction in gunner field-of-view (FOV).
3) Orient front plate 5^{o} off vertical (forward tilt).
4) Maintain interior clearance.
5) No greater than 2 mr of target line-of-sight (LOS) deviation.
6) No interference up to 30^{o} in elevation.
7) No greater than 6 mr of seam obstruction.

Grid Baffle

1) Eliminate reflections at angles greater than 20^{o} off the sun/canopy normal LOS vector.
2) No greater than 5% reduction in gunner FOV.
3) No interference within 5^{o} of reflex sight to elevation angle of 60^{o}
4) No greater than 6 mr single element obstruction.

AR Coating

1) Utilize existing plexiglass canopy.
2) Best performance coating available. (Single-layer)

Expansion and refinement of these criteria continued during the hardware manufacturing process. Applicable criteria for the grid baffle and flat plate canopy concepts were utilized to quantify the design of the flat plate baffle component.

Specific design information on each of the breadboard model canopies is given in Section 2.2.

2.2 HARDWARE DESCRIPTION

2.2.1 FLAT PLATE CANOPY

The breadboard model flat plate canopy is a semicubic shaped canopy constructed from transparent 1/2" thick plexiglass (MIL P8184) sheets and bonded to a portion of the surface of the standard canopy (the overlapped portion having been removed). All joints between the top, front, sides, and rear plates are miter joints. The cylindrical portion is butt joined to the rear and side plates and lap joined to the front plate. All joints were bonded using Rohm and Haas PS30 bonding agent.

When the canopy is installed on the fire unit, the top plate is oriented horizontally, the side and rear plates vertical, and the front plate is canted forward to an angle of 85^{o} from horizontal. Refer to Figure 2-1 for three-view layout and weight data.

2.2.2 FLAT PLATE CANOPY W/GRID BAFFLE

This candidate incorporates a flat grid baffle with the flat plate canopy described in the previous section. This baffle is fabricated from aluminum 1/16" sheet and tack welded together. Plastic materials for grid baffle construction have been researched and a few substances found feasible from a strength and environmental durability standpoint. Using a plastic material, the grid baffle would be assembled by solvent or thermal bonding techniques.

The breadboard model grid baffle was supported above the top of the flat plate canopy a distance of one inch (this distance was arbitrary) by way of four supporting members. These members were welded to the frame of the grid baffle. Bolts through the .8" x .8" pad of each support member joined the baffle assembly to the top plate of the canopy. Silicone rubber washers insulated the support pad from the plexiglass.

Spacing of the baffles ranged from 1.6 to 5.4 inches, with the elements positioned theoretically parallel to the array of gunner lines-of-sight. Refer to Figure 2-2 for three-view layout and weight data.

2.2.3 CYLINDRICAL GRID BAFFLE

The breadboard model of the cylindrical grid baffle was fabricated from aluminum 1/16" and 1/8" sheet and tack welded together. The louvers which form the frame of the grid baffle are 1/8" thick while the remaining louver elements are 1/16" thick. Four ball pins (two in front and two in the rear) mate the grid baffle to mounting brackets which are bolted to the canopy frame. The front ball pins are located so the grid baffle, upon removal of the rear ball pins, can be rotated away from the canopy for cleaning of the glass surface. By removing all four ball pins, the grid baffle is unfastened from the frame and may be removed or emplaced.

The louvers of the cylindrical grid baffle were spaced apart distances ranging from 1.4 to 4.4 inches and were arranged to be parallel to the gunner's incrementally varying line of sight for a nominal gunner in-mount head position. Refer to Figure 2-3 for three-view layout and weight data.

2.2.4 ANTI-REFLECTIVE COATING CANOPY

The breadboard model of the A.R. (Anti-Reflective) coated canopy consisted of a standard canopy which has had a 1/8 micrometer thick layer of magnesium fluoride vacuum deposited on both sides.

The canopy glass was cut in half in order to facilitate a more even deposition of the coating. Refer to Figure 2-4 for three-view layout and weight data.

2.3 DESIGN INTERFACE IMPACT STUDIES

2.3.1 BERNE GAUGE

It was determined from drawing #11069973 (Guided missile system, intercept aerial, carrier mounted: M-48) that none of the emplaced breadboard canopy concepts would conflict with the Berne gauge dimensional requirements.

2.3.2 CARGO COVER

It was also determined from drawing #11069973 that the flat plate canopy will clear the transportation cargo cover, but that the flat grid baffle and the cylindrical grid baffle canopies will not.

2.3.3 PHASE II AIR TRANSPORT

Air transportability of the Chaparral missile system on the C130 aircraft is unaffected by the addition of anti-glint hardware. The canopy assembly has in the past always been removed and strapped to the Chaparral decking during transport due to dimensional interface conflict.

2.3.4 CANOPY DEFOGGING PERFORMANCE

Since the flat plate canopy geometry is quite different from the standard canopy, and since this difference could cause the defroster air flow to be altered or less effective, there was reason to believe that the flat plate canopy may be difficult to defog. A test was developed to measure the defogging rate of the flat plate canopy relative to the standard canopy. A plywood model of the turret frame was constructed and equipped with a Chaparral heater unit and defroster ducts to simulate the Chaparral mount. The relative tests were conducted inside of an environmental chamber for the purpose of producing a repeatable amount of condensed moisture on the canopies. Tests were performed with and without experimental add-on defroster nozzles which were designed to more evenly dispense the defroster air flow.

The tests showed that by using the modified nozzles, the defogging time of the flat plate canopy was reduced by approximately 60% relative to the standard canopy. The time required to complete defogging of the flat plate canopy without the modified nozzles was approximately 16% greater than the standard canopy time. Present system requirements do not specify a readiness time criterion for defogging of the standard Chaparral canopy. The only requirement stipulated is that the mount environmental conditioning system must be capable of maintaining a clear canopy viewing area for the gunner once initial defogging has been achieved. Therefore, it was concluded that the relative change in defogging time for the flat plate canopy was not enough to warrant addition of an add-on nozzle to the defroster vents.

2.3.5 CANOPY STRUCTURAL SUPPORT

Preliminary stress analysis has revealed that the canopy frame has the strength required to carry the extra weight that the anti-glint hardware imposes. Analysis of the support linkage and canopy latches confirmed that the mechanisms are of adequate strength to accommodate the extra loads imposed by anti-glint hardware. Stress analysis of the canopy hinge assembly indicates however, a low margin of safety with the addition of flat plate and/or grid baffle hardware.

2.3.6 MISSILE LAUNCH ENVIRONMENT

2.3.6.1 Flat Plate Canopy

Stress analysis has indicated that the flat plate canopy has sufficient strength to withstand the missile rocket motor plume pressure loading. The thermal and chemical effects of the plume on the bonding agent used to join the plates of the canopy has yet to be addressed. The effects on all other components used in constructing the flat plate canopy are otherwise negligible.

2.3.6.2 Grid Baffles - Cylindrical and Flat

Stress analysis of the grid baffles, whether constructed from aluminum or plastic indicates they possess the strength necessary to withstand the missile rocket motor back blast pressure. Chemical and thermal effects offer no threat to the baffle material components or assembly.

2.3.6.3 Anti-Reflective Coating

The thermal and erosive effects of the missile exhaust on the anti-reflective coated canopy were studied and determined to be of no significance.

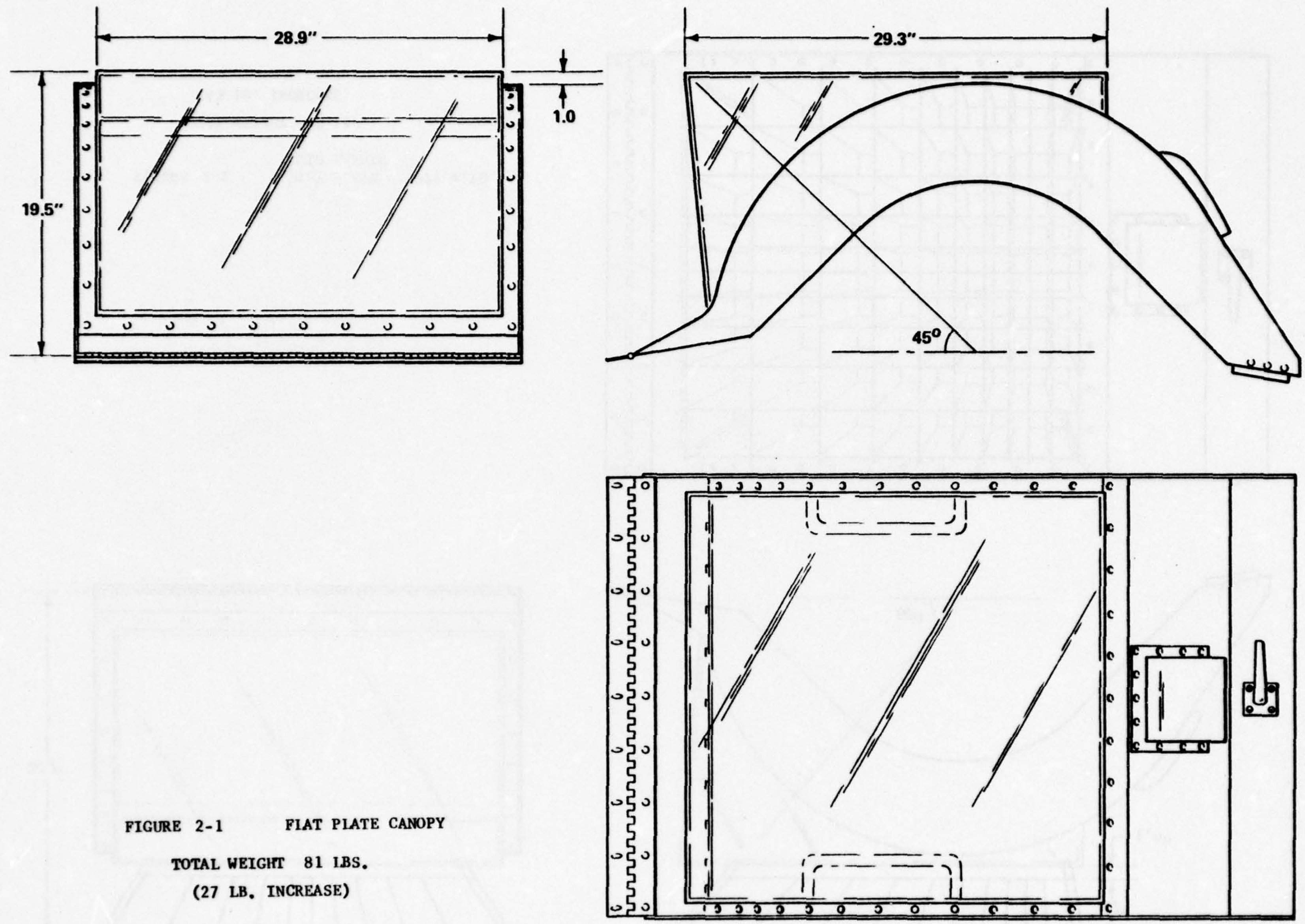


FIGURE 2-1 FIAT PLATE CANOPY

TOTAL WEIGHT 81 LBS.
(27 LB. INCREASE)

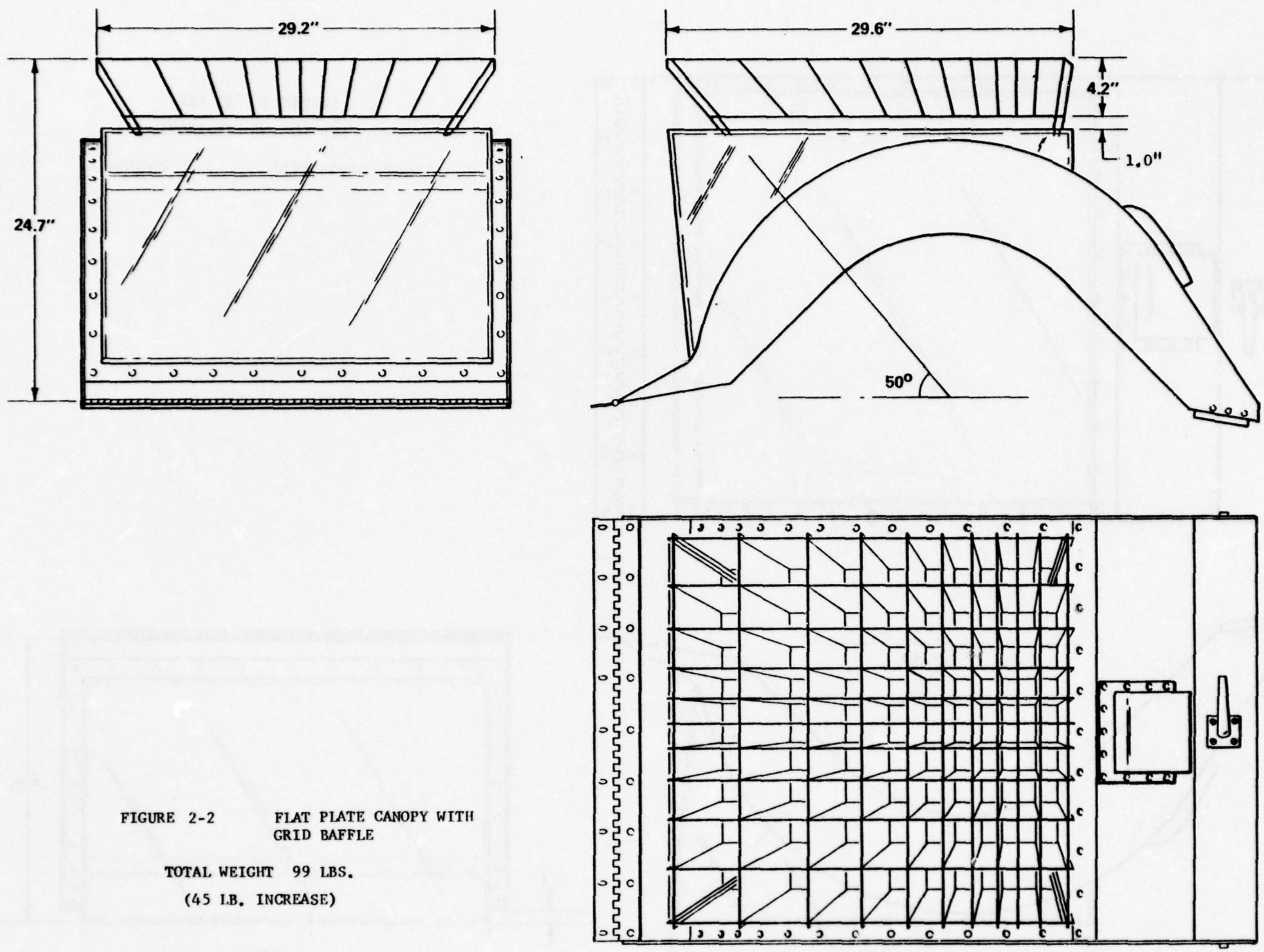


FIGURE 2-2 FLAT PLATE CANOPY WITH GRID BAFFLE

TOTAL WEIGHT 99 LBS.

(45 LB. INCREASE)

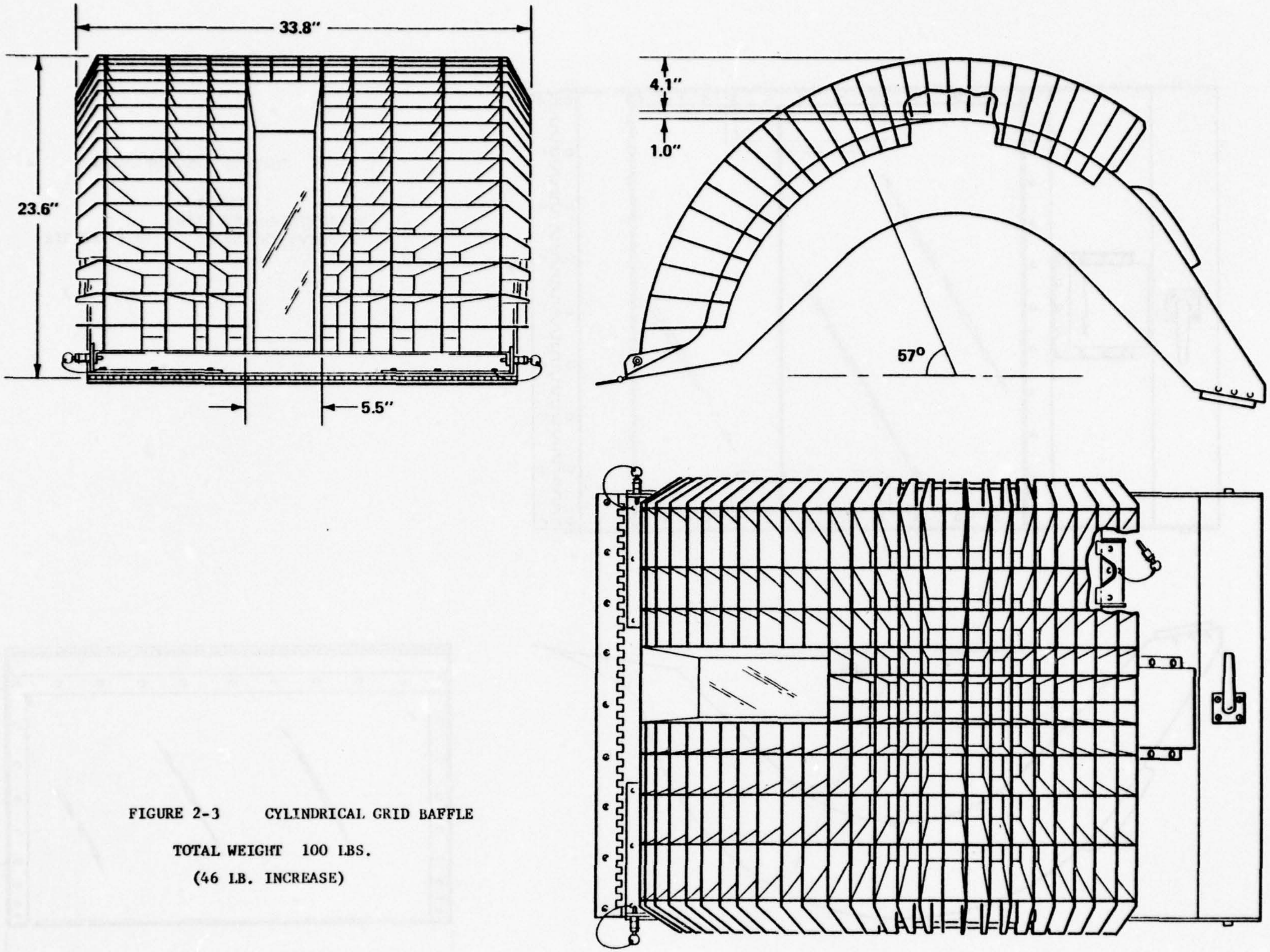


FIGURE 2-3 CYLINDRICAL GRID BAFFLE

TOTAL WEIGHT 100 LBS.

(46 LB. INCREASE)

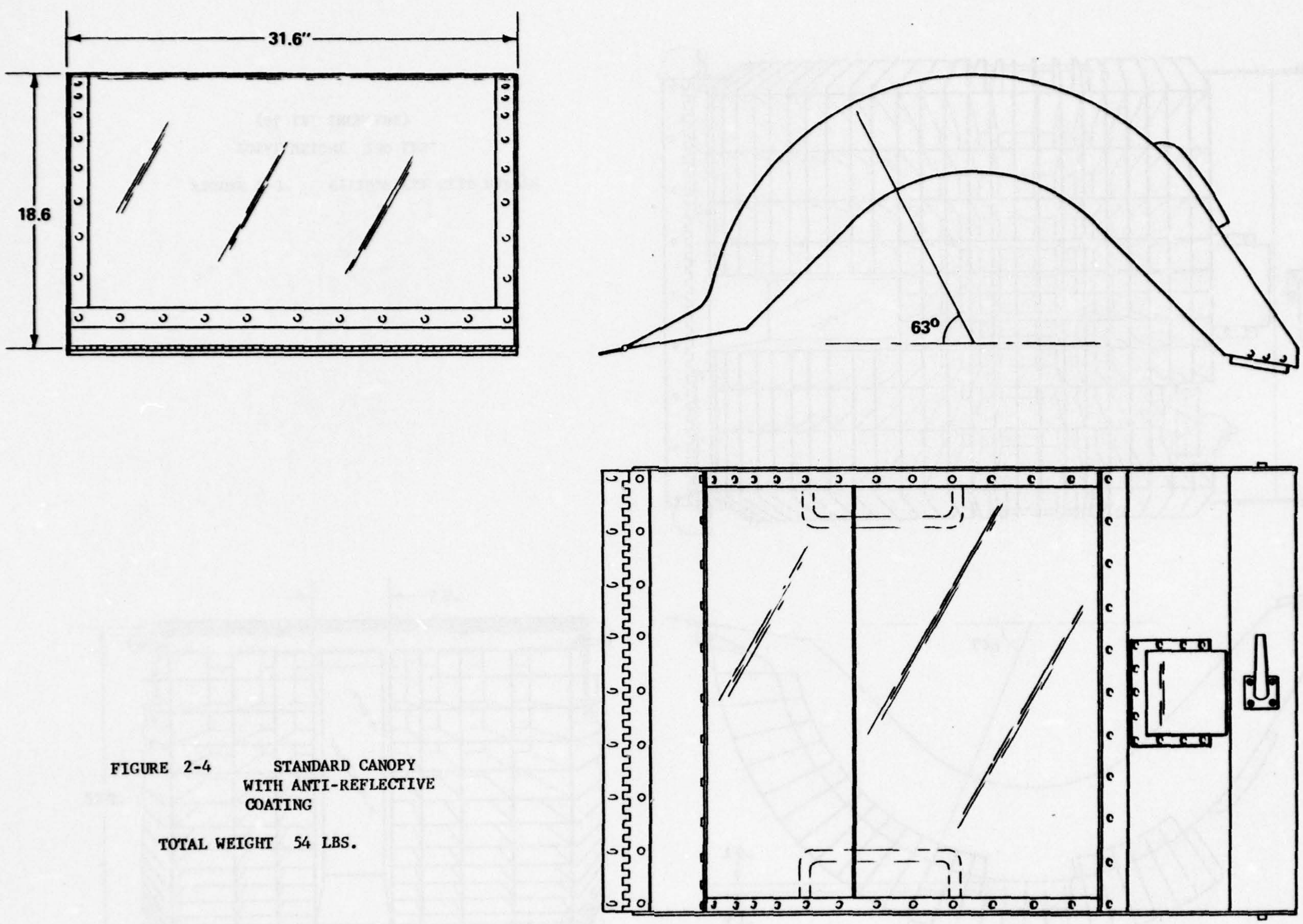


FIGURE 2-4 STANDARD CANOPY WITH ANTI-REFLECTIVE COATING

TOTAL WEIGHT 54 LBS.

SECTION 3

3.0 CANOPY SIGNATURE EVALUATION

3.1 MATH MODELING

Mathematical models were generated to represent the complex glint signature patterns produced by the various candidate canopy configurations. These models were programmed on a digital computer to facilitate the necessary calculations.

The first step was to calculate the directional intensity, or candle-power, of the canopy glint, the intensity pattern having a unique shape for each canopy configuration, canopy orientation, and solar position. From these intensity patterns, estimates of detection range were made. It should be emphasized that the detection ranges shown in subsequent figures are only estimates, made for the purpose of comparing different canopy configurations.

The canopy glint signature to an observer at a given altitude is of primary interest in this study. Therefore, the signature patterns were examined for specific altitudes above the fire unit. By imagining that the canopy rotates slowly, the boundary, or envelope, of expected detection ranges was computed for the different configurations. The majority of the figures which follow present the glint signature data as envelopes for a rotating canopy.

The following paragraphs develop the above line of reasoning and present the results of the computations.

3.1.1 PROGRAM DERIVATIONS

3.1.1.1 Canopy Glint Intensity

Mathematical models of directional luminous intensity were developed for the various canopy configurations. The resulting equations are presented below.

Cylindrical Canopy: $$J = \left(\frac{2\ Wr}{\pi\,\sigma_s}\right)\left(\frac{2\ \rho_c}{1+\rho_c}\right)\left(\frac{E_s \cos\theta}{\sin\alpha_s}\right) \quad (3\text{-}1)$$

Flat Canopy: $$J = \left(\frac{4\ LW}{\pi\,\sigma_s^2}\right)\left(\frac{2\ \rho_c}{1+\rho_c}\right) E_s \quad (3\text{-}2)$$

Spherical Canopy: $$J = \left(\frac{r^2}{4}\right)\left(\frac{2\ \rho_c}{1+\rho_c}\right) E_s \quad (3\text{-}3)$$

J = canopy glint directional intensity, candelas

W = canopy width, cm

L = length of flat canopy, cm

r = radius of cylindrical or spherical canopy, cm

σ_s = angular diameter of the sun, radians

ρ_c = the directional reflectance of a single surface of the canopy

E_s = solar illuminance (in a plane normal to the sun), lumens/cm^2

θ = angle between the incident solar ray and the local normal to the canopy (see figure 3-1)

α_s = angle between the incident solar ray and the cylinder axis (see figure 3-1)

Each of the above intensity equations contains three factors. The first is due to canopy geometry, the second is directional reflectance for the two canopy surfaces (inside and outside), and the third is solar directional illuminance. Computer programs were used to solve each of the intensity equations.

Equations (3-2) and (3-3) were developed from elementary geometrical optics considerations. Equation (3-1) was derived by considering the limiting rays from opposite portions of the sun's limb. These rays delimit a narrow strip of the cylindrical surface which reflects light into any given direction in the far field. It was shown that the width of that strip is inversely proportional to the sine of

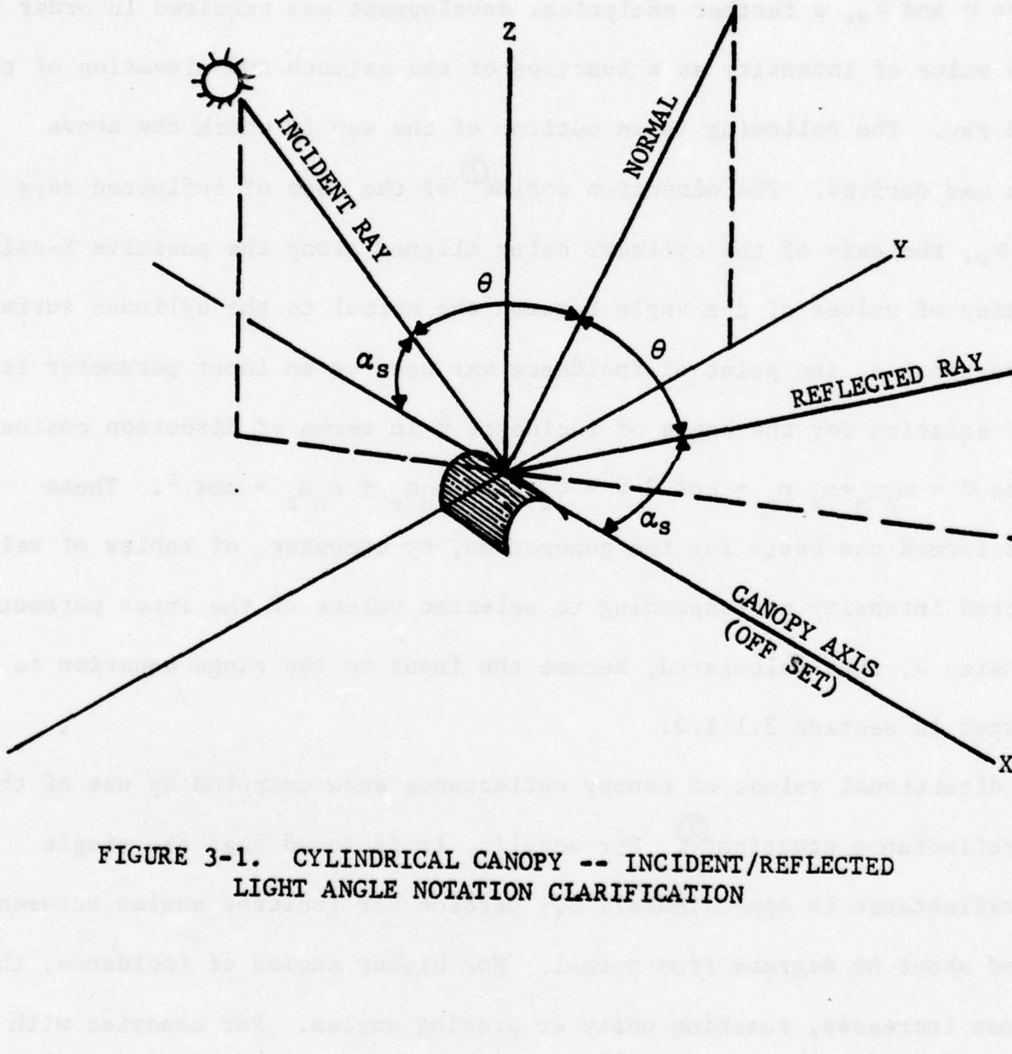


FIGURE 3-1. CYLINDRICAL CANOPY -- INCIDENT/REFLECTED LIGHT ANGLE NOTATION CLARIFICATION

the angle between the cylinder axis and the incident ray, and that the reflected intensity is proportional to the projected area of the strip - i.e., proportional to $\cos \theta / \sin \alpha_s$. It was also shown that the reflected rays form a conical shell of angular thickness σ_s and half-angle α_s.

While Equation (3-3) is a formula for the intensity in terms of the two parameters θ and α_s, a further analytical development was required in order to yield the value of intensity as a function of the azimuth and elevation of the reflected ray. The following is an outline of the way in which the above algorithm was derived. The direction cosine[1] of the cone of reflected rays is $\ell_r = \cos \alpha_s$, the axis of the cylinder being aligned along the positive X-axis. A succession of values of the angle between the normal to the cylinder surface and the vertical at the point of incidence was used as an input parameter to obtain an equation for the angle of incidence θ in terms of direction cosines, thus: $\cos \theta = m_s m_n + n_s n_n = \cos 2\theta + \ell_s^2$, and $m_n m_r + n_n n_r = \cos \theta$. These equations formed the basis for the generation, by computer, of tables of values of reflected intensity corresponding to selected values of the input parameters. The intensity J, thus calculated, became the input to the range equation to be discussed in section 3.1.1.2.

The directional values of canopy reflectance were computed by use of the Fresnel reflectance equations[2]. For acrylic, it is found that the single surface reflectance is approximately 3.9 percent for incident angles between normal and about 50 degrees from normal. For higher angles of incidence, the reflectance increases, reaching unity at grazing angles. For canopies with

---

[1] In this paragraph, standard analytical notation is employed. The direction angles α, β and γ are the angles between a line and the X-, Y- and Z- axes. The direction cosines are $\ell = \cos \alpha$, $m = \cos \beta$, $n = \cos \gamma$. The subscripts s, n and r refer respectively to (1) the line from the origin to the sun, (2) the outward normal to the cylinder and (3) the reflected ray.

[2] W. J. Smith, "Modern Optics", McGraw-Hill, 1966, page 167.

anti-reflection coatings, the reflectance equations were modified to match the reflectance characteristics of the coated surface. Values of solar illuminance were taken from the tables of Jones and Condit[3].

Each of the different canopy geometries produces a unique glint pattern. The flat canopy reflects as a plane mirror, so that there is only one line in space along which the glint is detectable. The spherical canopy reflects in all directions, with a much lower intensity than the flat canopy. The cylindrical canopy reflectance pattern is a conical fan. These concepts are explored more fully in Section 3.1.2.

3.1.1.2 Range Equations

The maximum range at which the canopy glint is detectable is a function of the canopy directional luminous intensity, the background luminance, and the optical transmittance of the atmosphere.

Middleton[4] presents a curve which relates detectable illuminance to background luminance. For daylight values of luminance, the curve can be approximated by an equation:

$$E_t = KB'_R$$

where E_t is the threshold of detectable luminance

K is a constant of proportionality

B'_R is the apparent background luminance.

For a 90 percent probability of detection, the constant of proportionality, K, is equal to 5×10^7 foot lamberts/foot candle (1.59×10^7 candela cm^{-2}/lumen cm^{-2}).

---

[3] "Sunlight and Skylight as Determinants of Photographic Exposure", JOSA, Volume 38, No. 2, Page 123.

[4] W.E.K. Middleton, "Vision Through the Atmosphere", University of Toronto Press, 1952, Page 97.

The concept of 90 percent detection probability means that the canopy would be detected by an average observer 9 times out of 10 if the observer were looking in the correct direction at the correct time, were alert, were looking for the glint, etc.

The illuminance which reaches the observer is given by

$$E_t = \frac{J}{R^2} e^{-\sigma_o \bar{R}} \qquad (3\text{-}4)$$

where J is luminous intensity (calculated in the preceding subsection), candelas

R is slant range to the target, cm

σ_o is atmospheric extinction coefficient at ground level

$\bar{R}$ is an equivalent slant range used for atmospheric transmittance calculations.

In the above equation, the illuminance reaching the observer has been set equal to the threshold value of illuminance; thus the slant range R can be interpreted as the maximum range for 90 percent detection probability.

The apparent background luminance can be related to the inherent background luminance by the following equation (apparent is seen at a distance R, inherent is seen up close):

$$B'_R = B'_o e^{-\sigma_o \bar{R}} + B_h (1 - e^{-\sigma_o \bar{R}}) \qquad (3\text{-}5)$$

where B'_R is apparent background luminance

B'_o is inherent background luminance

B_h is the horizon sky luminance.

The first term in the above equation accounts for the atmospheric attenuation of light coming to the observer from the background near the canopy. The second term accounts for sunlight and skylight scattered into the observation path, so that it appears to come from the canopy vicinity.

Finally, the equivalent slant range used for atmospheric attenuation calculations is given by

$$\bar{R} = k^{-1} \csc N_r \, e^{-k h_o} \left(1 - e^{-k R \sin N_r}\right) \tag{3-6}$$

where $k = 7.260 \times 10^{-6} \text{ cm}^{-1}$ ⑤

N_r = angular elevation of observer

h_o = elevation of ground point above sea level.

All of the above equations were combined to yield one equation which was programmed in the computer. This equation is:

$$\ln (KJR^{-2} + B_h - B_o') - \sigma_o k^{-1} \csc N_r \, e^{-k h_o} \left(1 - e^{-kR \sin N_r}\right) - \ln B_h = 0 \tag{3-7}$$

In the solution of the above equation, it was assumed that the background reflectance is 7 percent, so that the background luminance is given by

$$B_o' = \frac{0.07 \, E_{ss}}{\pi}$$

where B_o' is background inherent luminance, candelas cm^{-2}

E_{ss} is total illuminance due to sunlight plus skylight, lumens cm^{-2}.

In order to assess the effect of sunlight and scattered into the path of sight, it was assumed with Middleton, that the horizon sky luminance, B_h, is given simply by

$$B_h = \frac{0.2 \, E_{ss}}{\pi} \quad \text{candelas/cm}^2$$

Equation (3-7) expresses implicitly the value of the maximum detection range R as a function of the other parameters. Because of its form, the

⑤ op cit, page 74

equation is not readily solvable explicitly for R. It was therefore solved by use of iterative computer routines.

Again, it should be emphasized that the primary purposes of this exercise are to develop the shape of the glint signatures and to compare the relative detection ranges resulting from different approaches.

3.1.2 REFLECTION FAN FOR STANDARD CANOPY

When rays from the sun strike the standard cylindrical canopy, these rays are partly reflected. The reflected rays are dispersed into a fan because of the cylindrical shape of the canopy. An observer will see the canopy glint if he is looking at the canopy, is within the fan of dispersed rays, and is close enough to the canopy.

The locus of light rays reflected from a cylinder forms a conical shell or fan with the axis of the cone coincident with the axis of the cylinder and with the half-angle of the cone equal to the angle that the sun's rays make with the cylinder axis. Figures 3-2, 3-3, and 3-4 illustrate the manner in which the glint fan is formed in cases where the azimuth angles of the sun relative to the cylinder axis are 90°, 45°, and 0°, respectively. In each case the solar elevation is taken as 20°. In Figure 3-2, with the incident solar beam lying in a plane perpendicular to the cylinder axis, the fan (which delimits the region in which glint can be seen) lies in the vertical plane. It has a thickness of one-half degree corresponding to the angular subtense of the sun. The plane depicted in Figure 3-2 may be considered to be a cone of 90° half-angle whose axis coincides with the cylinder axis. As the angle between the sun and the cylinder axis decreases, the cone angle decreases as shown in Figure 3-3. Here the sun is at 20° above the horizon, and lies at an azimuth of 45° with the cylinder axis. The angle between the sun and the cylinder axis is 48.4° ($\cos 48.4^{\circ} = \cos 45^{\circ} \cdot \cos 20^{\circ}$). The conical fan within which the glint can be seen

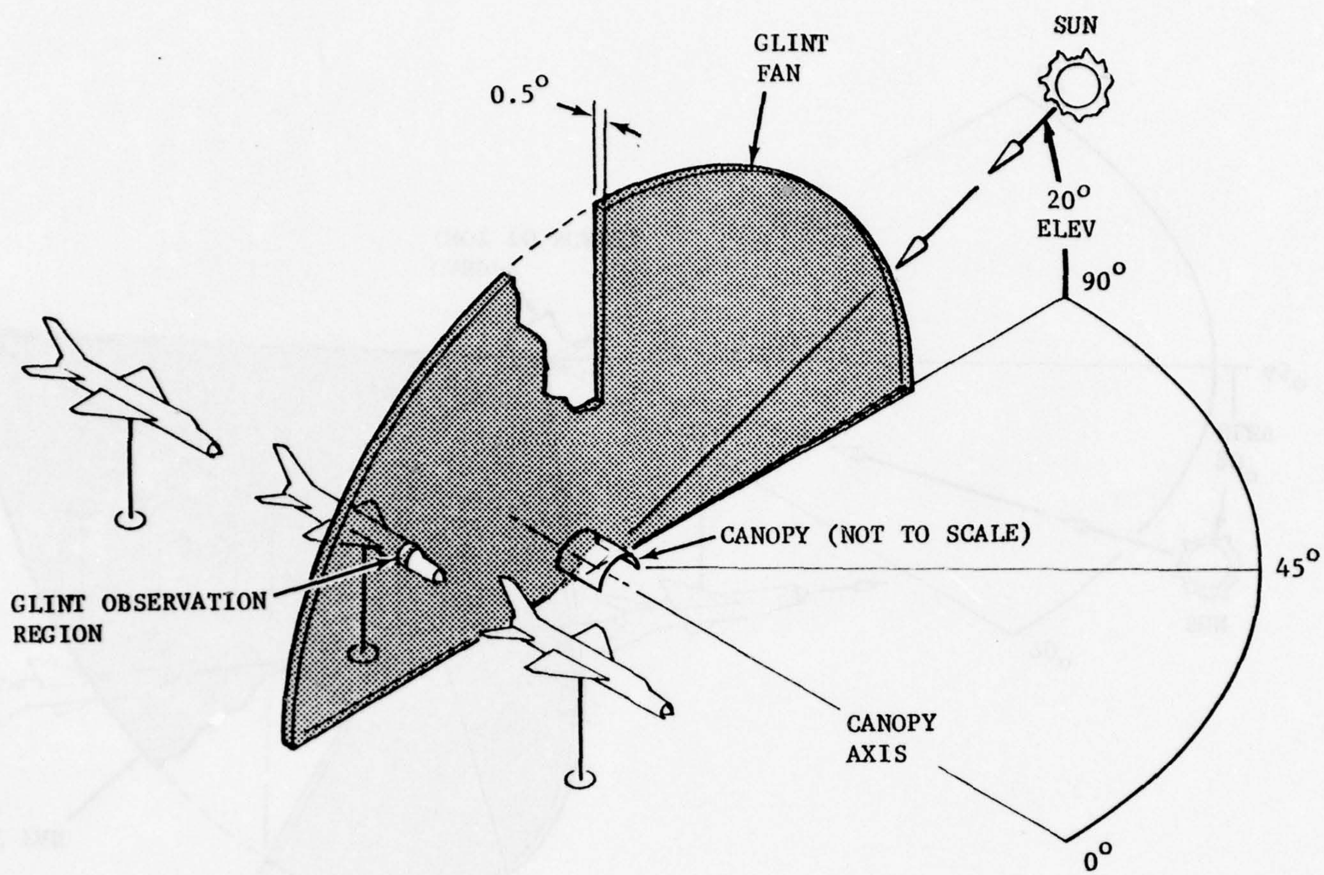


FIGURE 3-2. CYLINDRICAL CANOPY REFLECTION FAN
(SUN/CANOPY-AXIS AZIMUTH 90°)

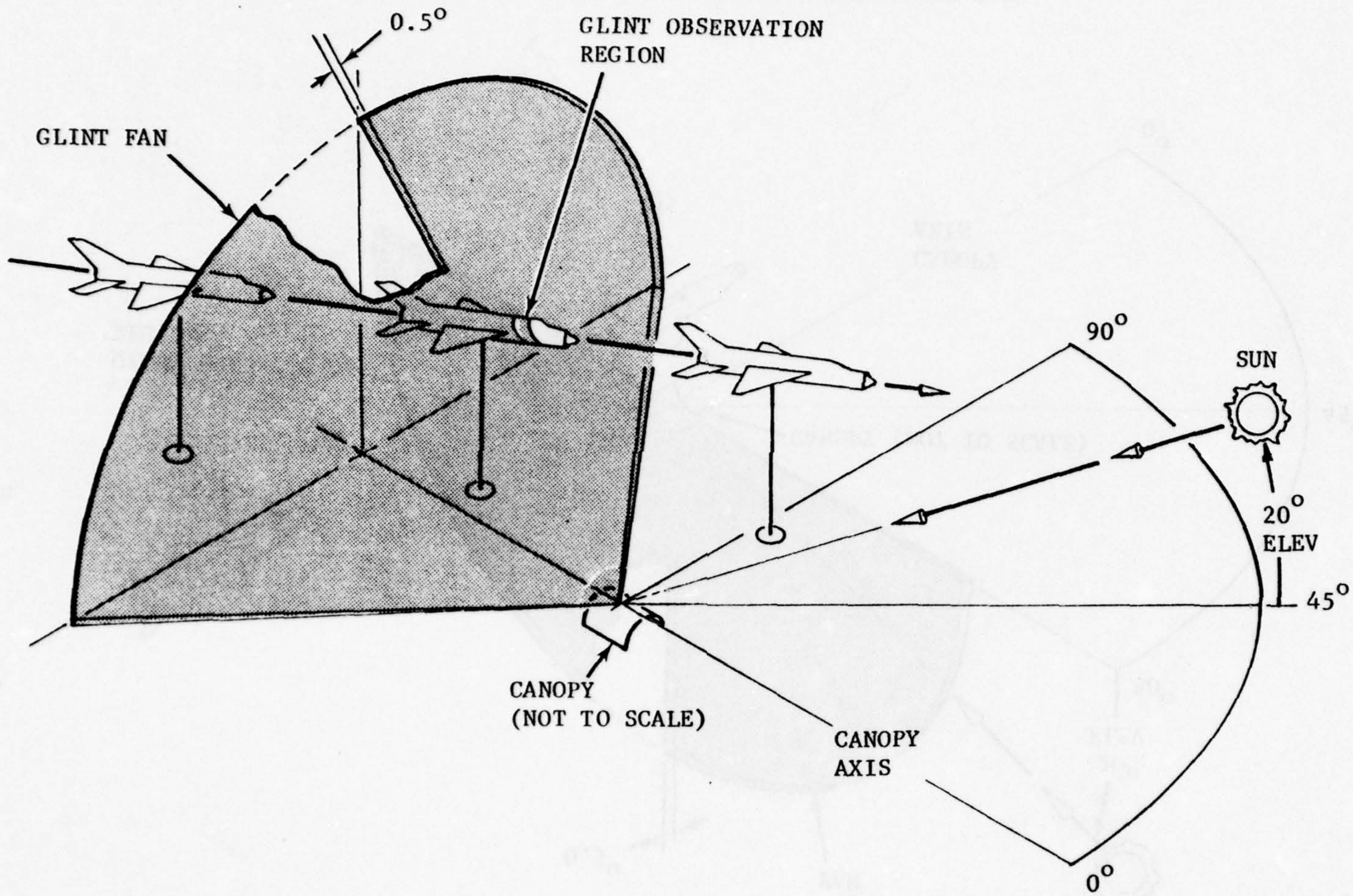


FIGURE 3-3. CYLINDRICAL CANOPY REFLECTION FAN
(SUN/CANOPY-AXIS AZIMUTH 45°)

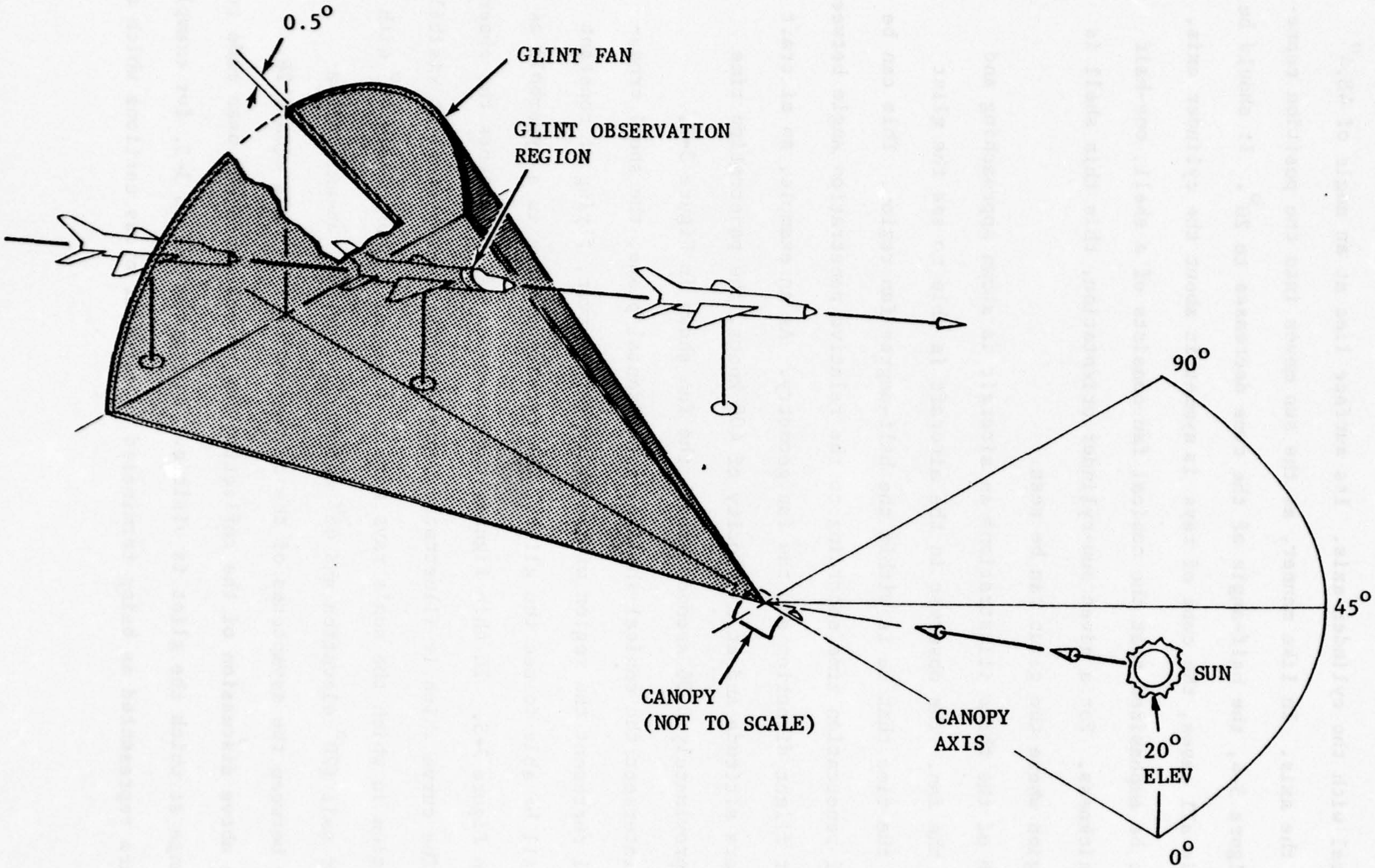


FIGURE 3-4. CYLINDRICAL CANOPY REFLECTION FAN
(SUN/CANOPY-AXIS AZIMUTH 0°)

is symmetrical with the cylinder axis. Its surface lies at an angle of 48.4° relative to the axis. In like manner, as the sun moves into the position represented in Figure 3-4, the half-angle of the cone decreases to 20°. It should be noted that in all cases, the cone of rays is symmetric about the cylinder axis. It must also be emphasized that the conical fan consists of a shell, one-half degree in thickness. For a given sun-cylinder orientation, this thin shell is the only region where the glint can be seen.

In each of the three illustrations an aircraft is shown approaching and penetrating the fan. The observer in the aircraft is able to see the glint only during the time that he is within the half-degree fan region. This can be a very brief penetration time according to the relative penetration angle between the aircraft flight direction and the fan geometry. As an example, an aircraft at 1500 meters altitude and at a velocity of 400 knots, the penetration time would be approximately 0.06 second through the fan shown in Figure 3-2.

If we intersect the conical shell by a horizontal plane, the shell cross-section will represent the region within which an observer, flying at constant altitude, will be able to see the glint. The resulting curve is a hyperbola as indicated in Figure 3-5. In this figure, the dimension "A" represents the observer altitude. The curve which is illustrated represents the region of glint visibility for a condition in which the sun's rays form an angle of approximately 48° with the cylinder axis (20° elevation and 45° azimuth). For any sun-axis angle θ the angle between the asymptotes of the corresponding hyperbola equals 2θ.

In the above discussion of the reflection fan no reference has been made to the limiting range at which the glint is visible. In Figures 3-3 to 3-5, for example, the cones are represented as being terminated by circular cross sections which are

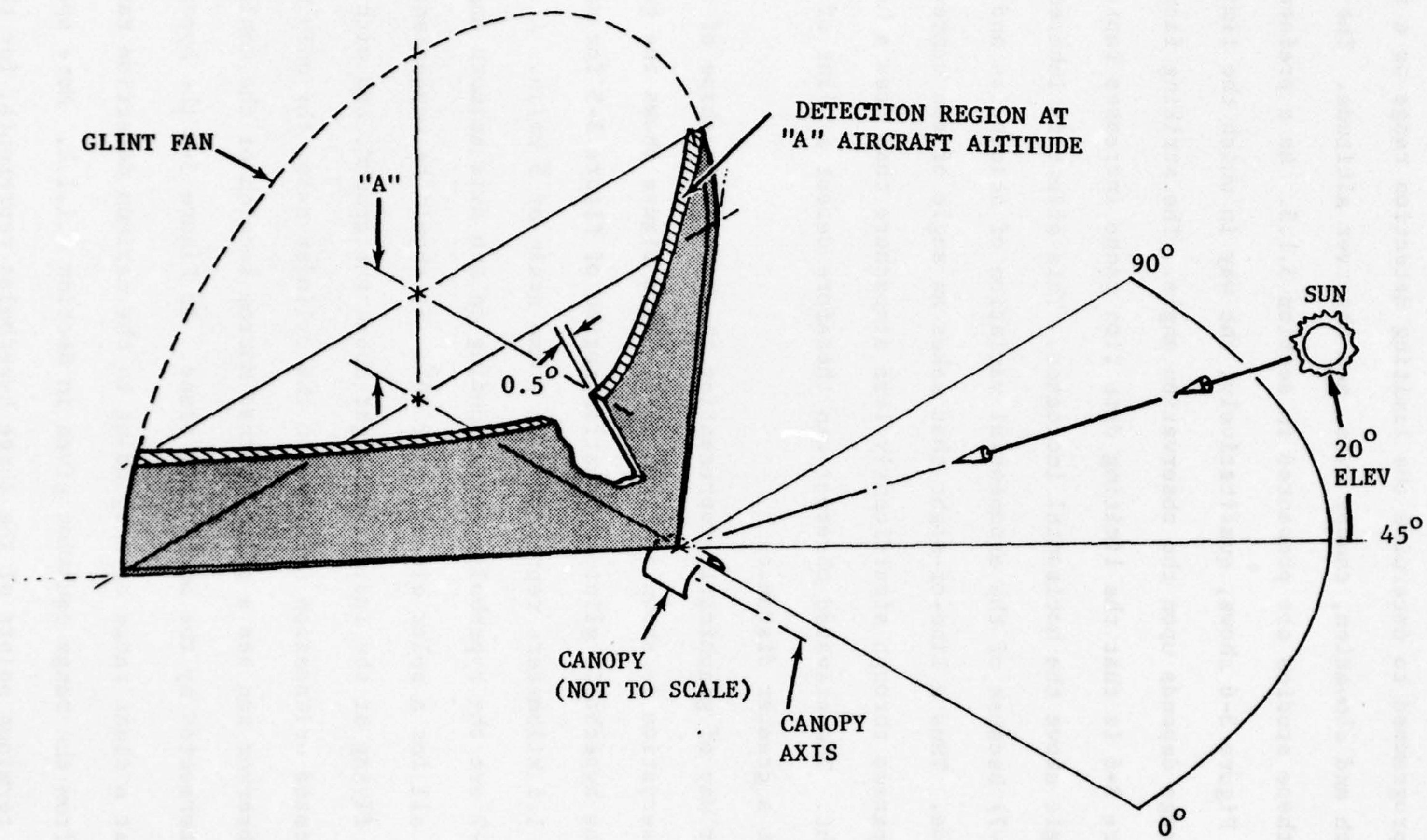


FIGURE 3-5. REFLECTION FAN/AIRCRAFT INTERCEPT REGION
(SUN/CANOPY-AXIS AZIMUTH 45°)

arbitrarily drawn to aid in visualizing the conical shapes. Equation (3-1) and (3-7) were programmed to determine the limiting detection range as a function of solar azimuth and elevation, canopy axis, and observer altitude. The detailed results of these studies are presented in section 3.1.3. As a preface to that discussion, Figure 3-6 shows, qualitatively, the way in which the limiting detection range depends upon the observation angle. The striking fact brought out in Figure 3-6 is that the limiting detection range increases rapidly as the observer angle above the horizontal increases. This effect is inherent in Equation (3-7) because of the exponential variation of absorption and scattering with altitude. Thus a line-of-sight that makes an angle of ten degrees with the horizontal passes through significantly less atmosphere than does a horizontal line-of-sight. The elevated observer can therefore detect a glint of a given intensity at a greater distance.

Another way of graphically representing the hyperbolic shape of the region of glint observation is shown in Figure 3-7. This figure shows the ground traces of the hyperbolic glint observation region of Figure 3-5 for an observer altitude of 1.5 kilometers represented on a map scale of 5 km/in. Also shown on Figure 3-7 are the hyperbolas corresponding to sun axis azimuth angles of 0^{o} and 90^{o}, all for a solar elevation of 20^{o}. It should be emphasized that with an observer flying at the indicated height above the ground, and with the sun at the indicated orientation relative to the cylinder axis, the only region within which the observer can see a glint is that narrow section of the conical shell which is intersected by the horizontal plane. In Figure 3-7 the hyperbolas are terminated at a slant range corresponding to the maximum detection range as calculated from the range equation given in Section 3.1.1.2. More specifically, each of the terminus points of the three hyperbolas represents, for the given

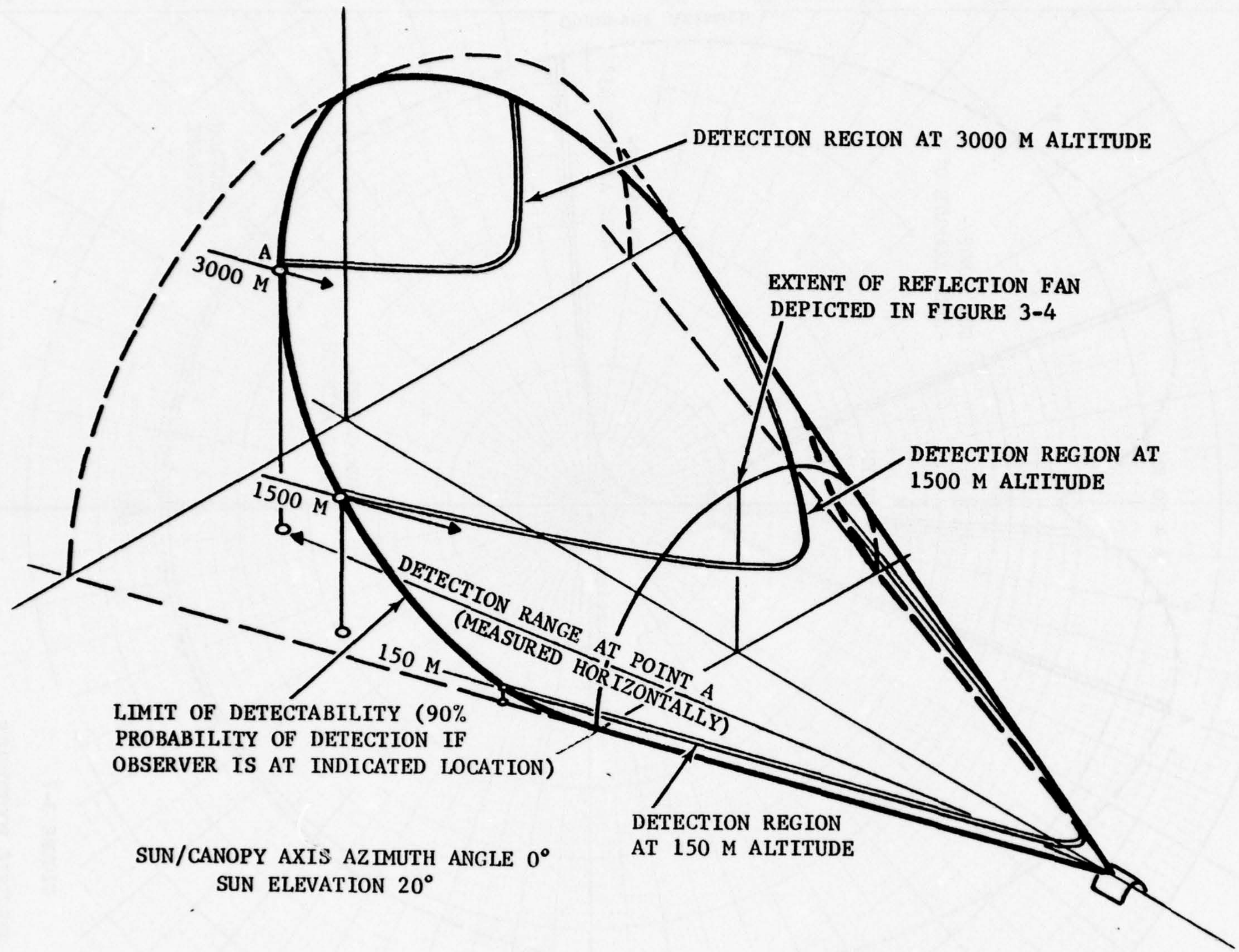


FIGURE 3-6. CYLINDRICAL CANOPY REFLECTION FAN - LIMIT OF DETECTABILITY

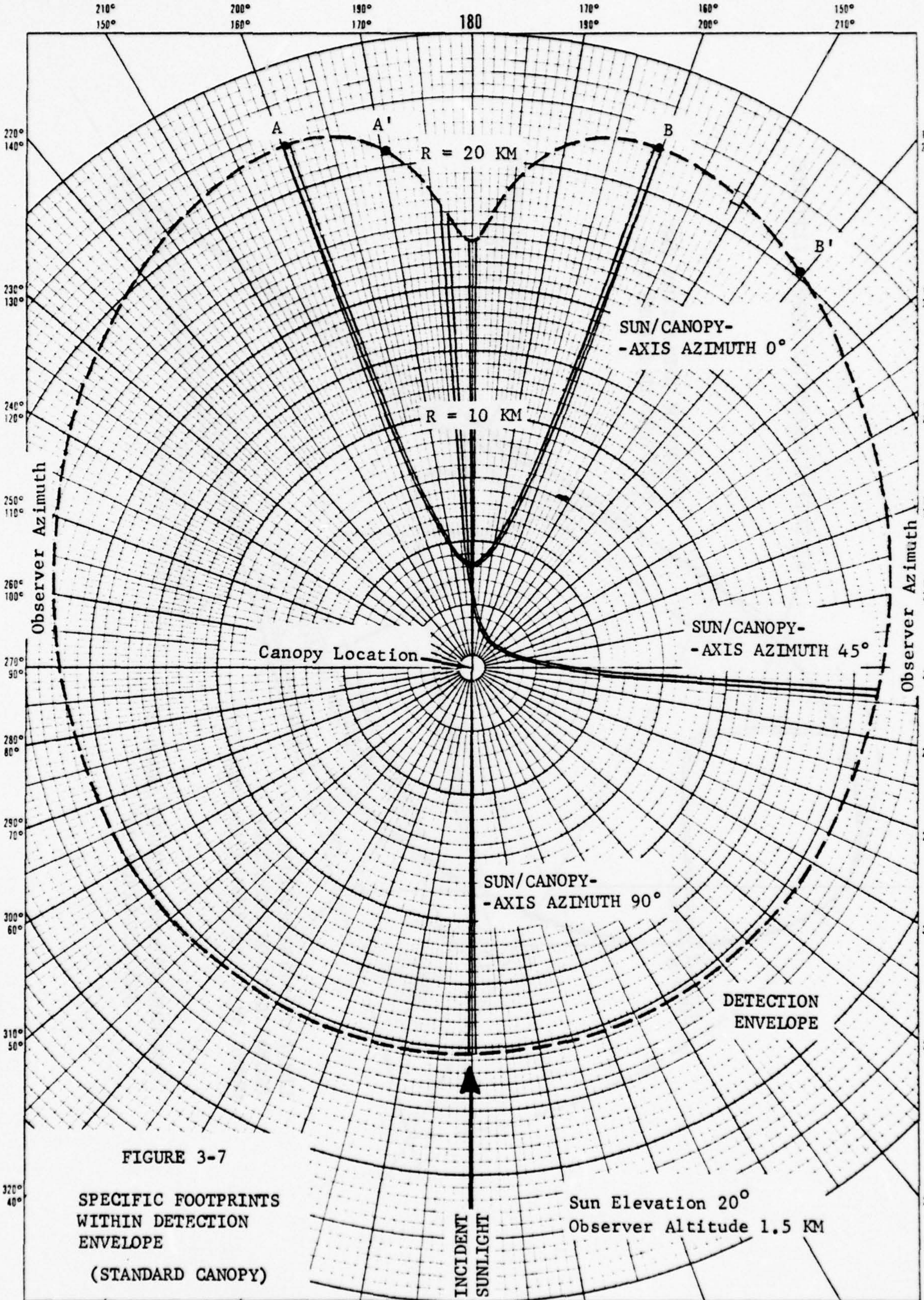


FIGURE 3-7

SPECIFIC FOOTPRINTS WITHIN DETECTION ENVELOPE

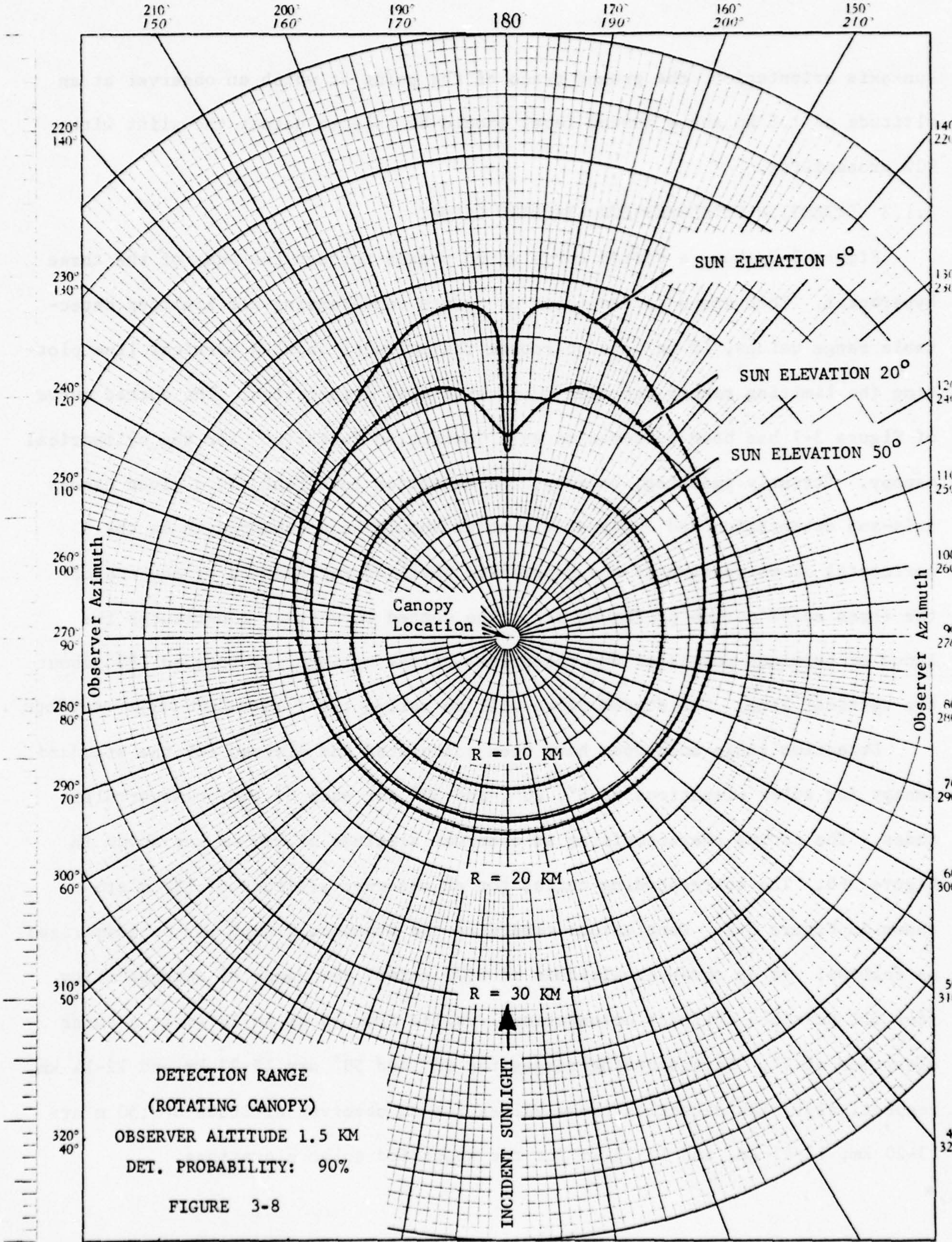
(STANDARD CANOPY)

sun-axis orientation, the ground trace of the point at which an observer at an altitude of 1.5 km above ground level should be able to detect the glint with 90% probability.

3.1.3 DETECTION ENVELOPES FOR STANDARD CANOPY

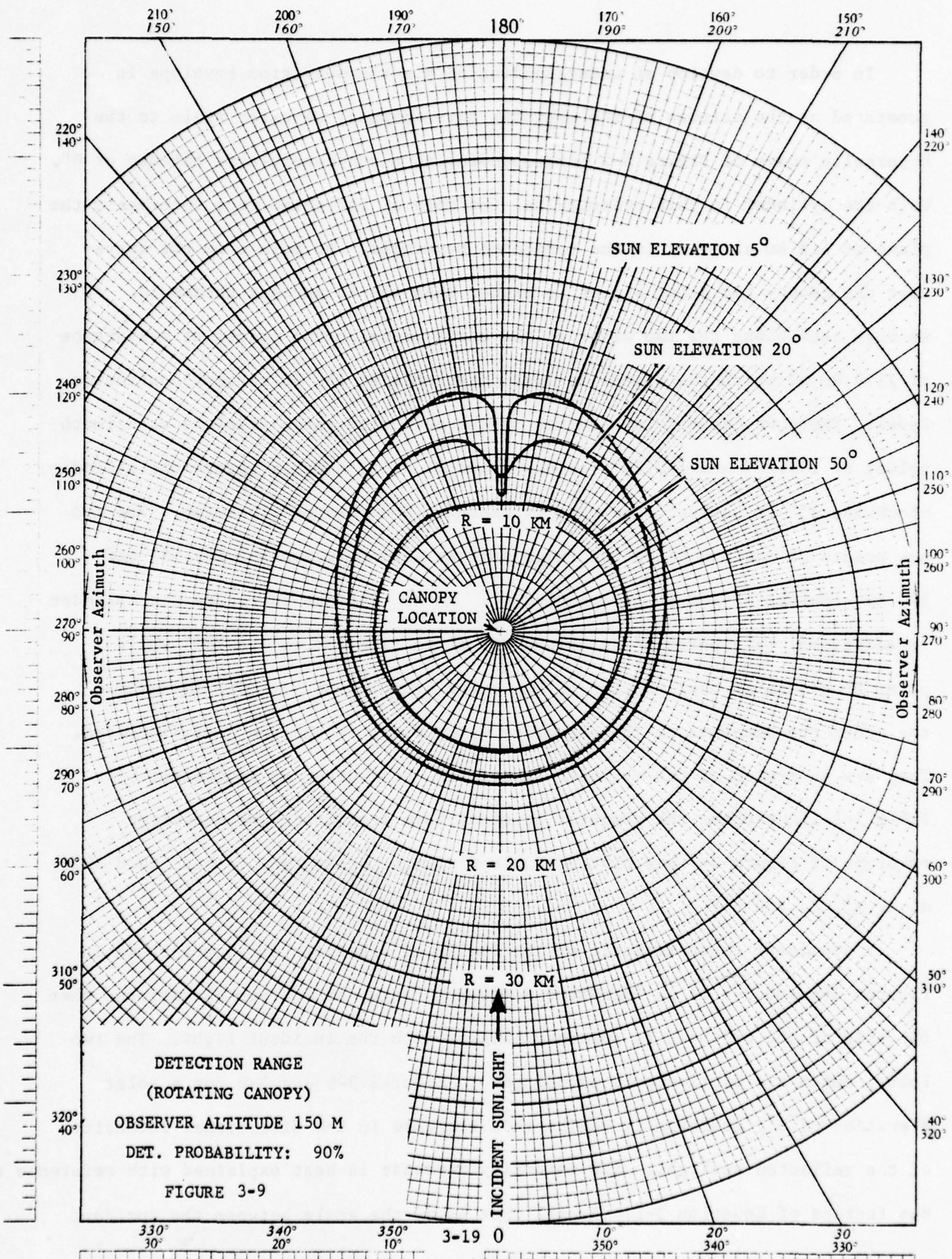
Figure 3-7 shows a dotted curve which passes through the ends of the three hyperbolas. This curve is the locus of points representing all limiting detectable range values, if we were to rotate the cylinder about a vertical line plotting the limiting ranges for each successive axis orientation. The dotted curve of Figure 3-7 has been referred to as a "detection footprint" for the cylindrical canopy. Strictly speaking, however, the detection footprint for a given canopy axis-sun orientation and observer elevation should be considered to be the horizontal cross section of the hyperbolic shell as represented by any one of the three solid curves of Figure 3-7. The dotted curve then constitutes the locus of terminus points of the footprints as the cylinder is rotated 180° about the vertical line. The dotted curve will be called the "detection range envelope".

Detection range envelopes have been calculated and plotted for the standard canopy for solar elevations of 5°, 20°, and 50° for each of two observer altitudes. The curves characterizing an observer altitude of 1500 m are shown in Figure 3-8. The corresponding curves for an observer altitude of 150 m are shown in Figure 3-9. Conclusions regarding the standard canopy may be summarized as follows. At an observer altitude of 1500 meters the range of detectability (for all possible cylinder orientations) varies from 16 km to 28 km at a solar elevation of 5°. Corresponding ranges for 20° and 50° are 15-22 km and 12-14 km, respectively. The detection range values for an observer altitude of 150 m are 13-20 km, 12-17 km, and 10-12 km for the specified solar elevations.



DETECTION RANGE
(ROTATING CANOPY)
OBSERVER ALTITUDE 1.5 KM
DET. PROBABILITY: 90%

FIGURE 3-8



DETECTION RANGE
(ROTATING CANOPY)
OBSERVER ALTITUDE 150 M
DET. PROBABILITY: 90%

FIGURE 3-9

In order to develop an understanding of how the detection envelope is generated as the azimuth of the cylinder axis changes, we refer again to the hyperbolic curve of Figure 3-7 corresponding to a sun/canopy-axis azimuth of 0°. With the cylinder in this orientation, the cone of reflected rays intersects the plane at 1.5 km altitude in the indicated hyperbola. At points on the curve near the canopy the glint signal is higher than the 90 percent threshold. As we move back along the two wings of the curve we reach two points at a distance of 21.7 km at which the signal is just detectable at the 90 percent confidence level. Thus, we identify two points on the detection range envelope at azimuth values of 199.63° and 160.39° (points A and B). If, now, we rotate the cylinder clockwise 15° in azimuth, the cone is expanded and rotated clockwise. The two new points of maximum detection range fall at azimuth values of 189.48° and 140.54° (points A' and B', respectively). As we continue to rotate the cylinder an additional 75°, point A' describes the curve from 189.48° to 180° while point B' describes that portion of the curve from 140.54° to 0°. Of course the other two segments of the curve are symmetrical to the two just discussed. They are generated as the cylinder is rotated, clockwise, an additional 90°. Table 3-1 illustrates the computer printout form from which the detection envelope of Figure 3-7 was plotted (note the azimuth data points described above as A, A', B, and B').

A prominent characteristic of the family of detection envelopes shown in Figures 3-8 and 3-9 is an increased detection range, at low sun elevations, when the axis of the cylinder is somewhat aligned with the incident light. The two lobes, which are particularly pronounced in Figures 3-8 and 3-9 for a solar elevation of 5°, graphically depict this increase in the directional intensity of the reflected sunlight. The intensity increase is best explained with reference to the factors of Equation 3-1. Recall that as θ, the angle between the incident

TABLE 3-1

INTENSITY/RANGE COMPUTATION FOR SOLAR ELEVATION OF 20 DEGREES

CYL. AXIS DEG	INTENSITY W/ST	AZIMUTH DEG	RANGE KM
.00	5.111E 05	160.39 - B	2.173E 01
5.00	4.914E 05	154.79	2.148E 01
10.00	4.413E 05	148.10	2.100E 01
15.00	3.764E 05	140.54 - B'	2.025E 01
20.00	3.120E 05	132.34	1.938E 01
25.00	2.571E 05	123.71	1.849E 01
30.00	2.145E 05	114.77	1.768E 01
35.00	1.834E 05	105.61	1.700E 01
40.00	1.617E 05	96.29	1.646E 01
45.00	1.472E 05	86.87	1.606E 01
50.00	1.378E 05	77.35	1.571E 01
55.00	1.319E 05	67.79	1.552E 01
60.00	1.284E 05	58.17	1.548E 01
65.00	1.264E 05	48.52	1.540E 01
70.00	1.253E 05	38.84	1.536E 01
75.00	1.249E 05	29.14	1.534E 01
80.00	1.247E 05	19.44	1.533E 01
85.00	1.246E 05	9.72	1.533E 01
90.00	1.246E 05	.00	1.533E 01
.00	5.112E 05	199.63 - A	2.157E 01
5.00	4.970E 05	195.21	2.157E 01
10.00	4.593E 05	191.92	2.107E 01
15.00	4.133E 05	189.48 - A'	2.071E 01
20.00	3.684E 05	187.70	2.000E 01
25.00	3.296E 05	186.33	1.955E 01
30.00	2.968E 05	185.29	1.902E 01
35.00	2.703E 05	184.44	1.872E 01
40.00	2.484E 05	183.76	1.823E 01
45.00	2.309E 05	183.18	1.800E 01
50.00	2.164E 05	182.69	1.764E 01
55.00	2.049E 05	182.25	1.747E 01
60.00	1.955E 05	181.86	1.721E 01
65.00	1.880E 05	181.51	1.699E 01
70.00	1.823E 05	181.17	1.697E 01
75.00	1.780E 05	180.87	1.684E 01
80.00	1.750E 05	180.57	1.674E 01
85.00	1.732E 05	180.28	1.669E 01
90.00	1.726E 05	180.00	1.667E 01

light ray and the normal to the reflecting surface, is increased beyond 50°, the single surface reflectance, ρ_c, rapidly increases toward a maximum value of unity; maximizing the second factor of equation 3-1 and thus increasing directional intensity J. Consider also along with the above reflectance condition, the effect of an increasing θ on the third factor of the equation. For any given $\alpha_s > 0°$, as θ increases, cos θ decreases causing a reduction in intensity J. This reduction effect is however, small in comparison with the intensity increase due to the reflectance condition. The result is that for a constand α_s, the directional intensity of reflected sunlight and thus the detection range of the sun glint, increases with θ.

Consider next, the initial case where θ is constant and α_s is small but non-zero. Under this condition, the cos θ/sin α_s factor of equation 3-1 takes on a maximum value. If the canopy is now rotated in either direction to the orientation where α_s equals 90° (canopy axis perpendicular to the incident ray), sin α_s increases to a value of one and the cos θ/sin α_s factor of intensity forces J to a minimum value. The relationship between α_s and detection range (a function of J) can easily be followed by referring to the envelope of Figure 3-7 and mentally rotating the canopy to the azimuth positions indicated and studying the progression of the hyperbolic curves.

3.1.4 TACTICAL SIGNIFICANCE OF GLINT

A complete assessment of the tactical significance of glint is beyond the scope of contracted effort to date. During a review meeting held in May 1976 between Aeronutronic and MICOM personnel, it was mutually recognized that the reconnaissance resources of the Tactical Air Command would have to be consulted to obtain meaningful conclusions regarding the tactical significance of glint. Aeronutronic is familiar with the deployment doctrine for the M48 Chaparral Fire Unit within the FEBA as well as protection of convoy routes and static installations such as air fields; however, reconnaissance information does not presently exist at Aeronutronic pertaining to: 1) the sophistication and mission of airborne ground surveillance systems, and 2) what tactical interpretation is placed upon glint signature observations made either by visual sightings or electronic surveillance systems from aircraft.

In the absence of needed reconnaissance information, Aeronutronic's critique of the tactical significance of glint primarily centers around the key consideration of equipment recognition as discussed in the following two paragraphs.

Sunlight has been shown in the above illustrations to be reflected from the Chaparral canopy in specific patterns; the observer passing through these patterns at nearly all altitudes will see a reflection as a flash of light (typically less than 1/2 second) from the fire unit, with high contrast to the background luminance. Sun glints or flashes are also observed from other sources such as truck windshields - even painted surfaces may have a high reflectance at grazing angles. Windows and vehicle windshields are certain to be present in a battle area in great number and variety. Therefore, while solar glint may contribute to long range <u>detection</u>, it does not presently serve for <u>recognition</u> or <u>identification</u> of a Chaparral fire unit. The films of the Fort Bliss test site taken from the helicopter amply illustrate these points.

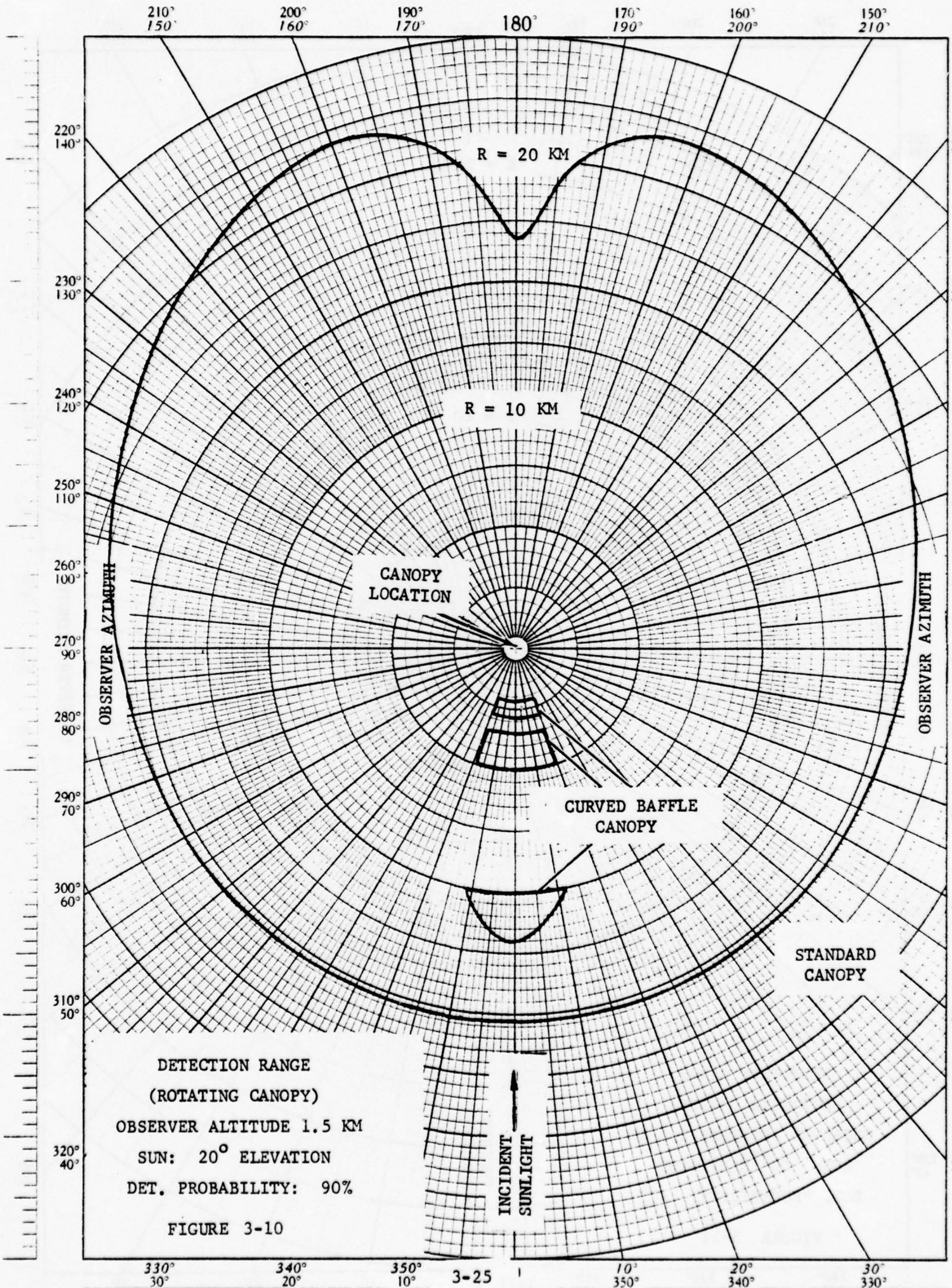
Visual recognition of a fire unit related to the usual parameters of angular size of the fire unit, contour shape, and contrast with the background -- again, glint is not a part of this visual recognition signature. Recognition of a Chaparral fire unit by the unaided eye probably requires closure to ranges of 1 to 3 kilometers, generally within the effective missile launch envelope. Further, recognition would be required before an enemy airborne observer could establish a glint detection as an air defense unit threatening his operation, establish its location, and initiate actions for evasion or air/artillery attack of the air defenses. As sun glint from a Chaparral canopy does not contribute to system identification, it does not appear to constitute a threat to the effectiveness or survivability of a fire unit.

3.1.5 DETECTION ENVELOPES FOR ALTERNATE CONFIGURATIONS

The detection envelopes presented in paragraph 3.1.4 were for the standard existing Chaparral fire unit canopy configuration. Several alternative configurations have been studied in this program. Each of these alternatives reduces the detection envelope in some manner, as is shown in the following discussions.

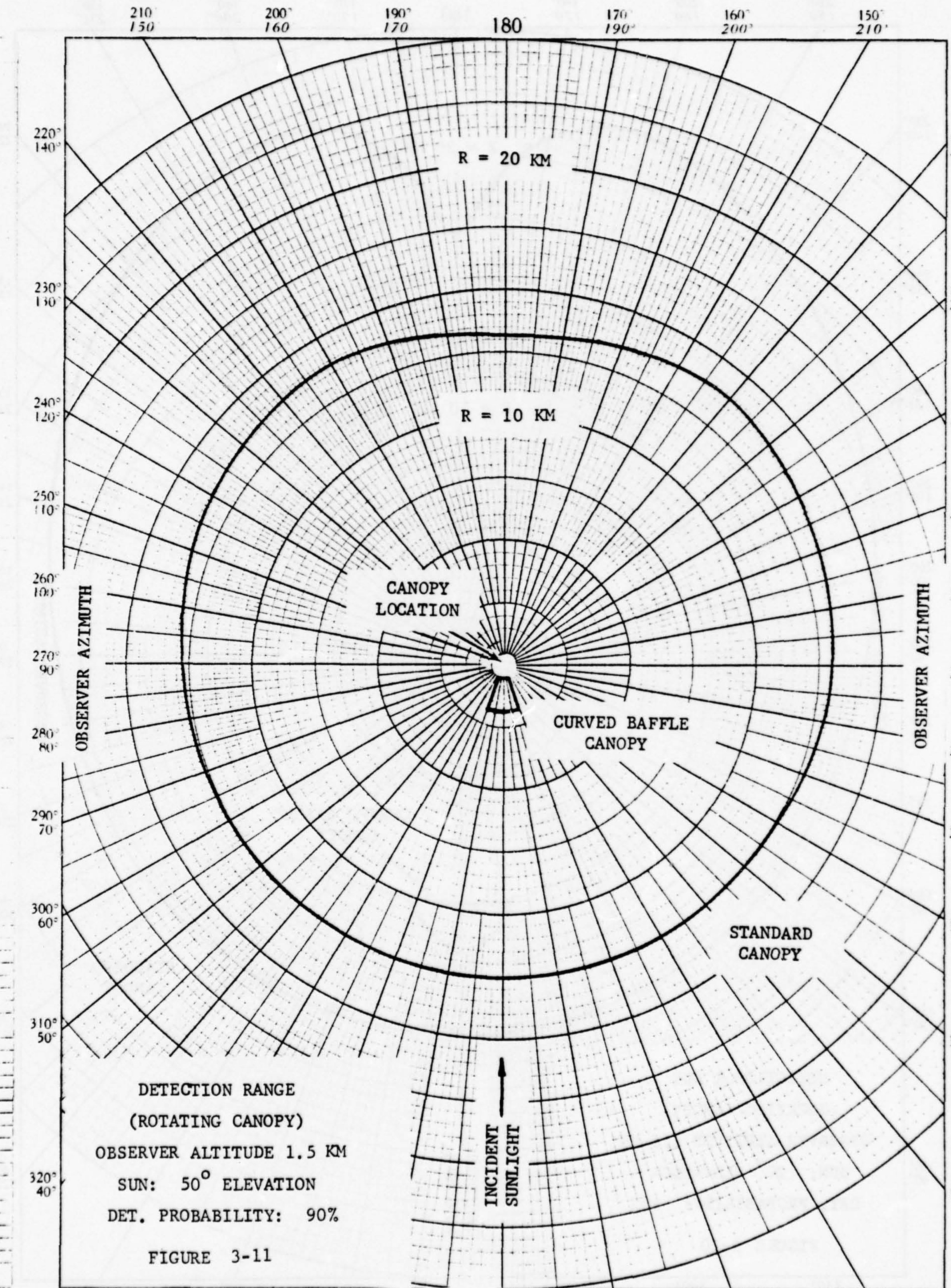
A cylindrical grid baffle was designed to fit over the standard Chaparral canopy (description contained in paragraph 2.2.3). The effect of this baffle is shown in Figures 3-10 and 3-11; it eliminates all glint outside the limiting angle of 20 degrees each side of the vertical solar plane. Within this 40° region, detection is possible over certain small area segments where the sunlight is able to shine between the slots and be reflected without being blocked. The resulting detection areas are represented in Figures 3-10 and 3-11. In Figure 3-10 the areas within which glint can be seen are shown for a solar elevation of 20° and observer altitude of 1.5 km. Three separate sections are shown corresponding to glint which is reflected between each of three adjacent horizontal slots of the baffle assembly. In the case of the 50° solar elevation, as shown in Figure 3-11, there is only one region of glint detection since, at ranges greater than 3 km, the glint intensity arising within the tracking slot is below the limit of detectability.

It should be emphasized that the areas shown in Figures 3-10 and 3-11, as in the case of the curves for the standard canopy, are envelopes encompassing the total area within which glint can be seen under any cylinder orientation. Thus, for a particular orientation for which the half-degree hyperbolic footprint of the standard canopy passes through the indicated area, the glint signature would be characterized by the common area occupied by both the hyperbolic footprint for



DETECTION RANGE
(ROTATING CANOPY)
OBSERVER ALTITUDE 1.5 KM
SUN: 20° ELEVATION
DET. PROBABILITY: 90%

FIGURE 3-10



DETECTION RANGE

(ROTATING CANOPY)

OBSERVER ALTITUDE 1.5 KM

SUN: 50° ELEVATION

DET. PROBABILITY: 90%

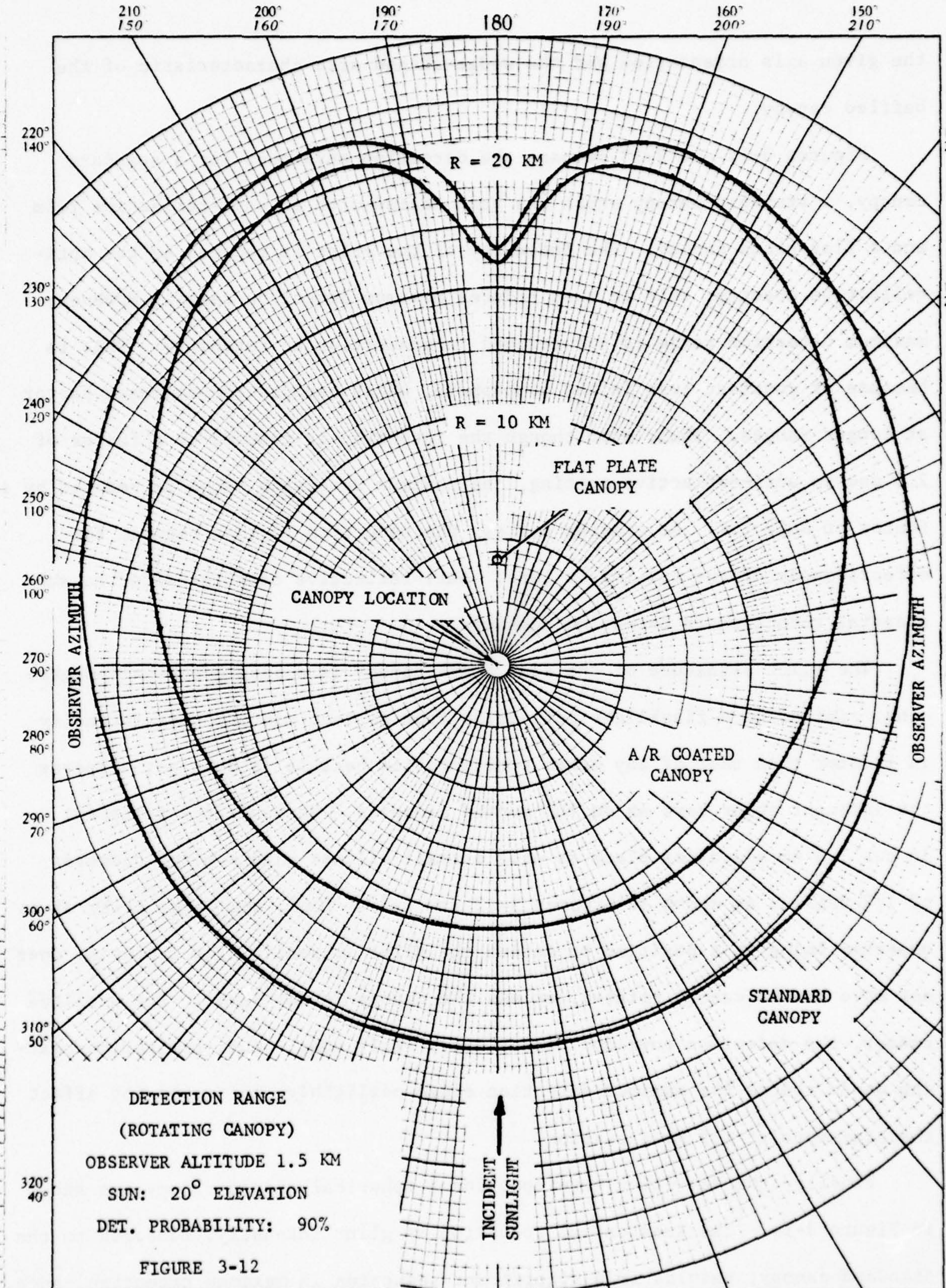
FIGURE 3-11

the given axis orientation and the wedge-shaped area characteristic of the baffled canopy.

Figures 3-12 and 3-13 compare the detection envelopes for a standard canopy, a standard canopy which has been coated with an anti-reflective film and a flat-plate canopy. The intensity of the glint is reduced by the anti-reflective coating; this in turn reduces maximum detection range. However, maximum detection range is not reduced in proportion to intensity. This is because of contrast loss in the atmosphere, which becomes the dominant factor at longer ranges. Thus, even though the intensity is reduced by a factor of 2.5 due to anti-reflective coating, the maximum detection range is reduced by a factor of only 1.4. At grazing angles, the reduction is less because the effectiveness of the coating is less. Anti-reflective coatings offer no substantial reduction in detection envelope.

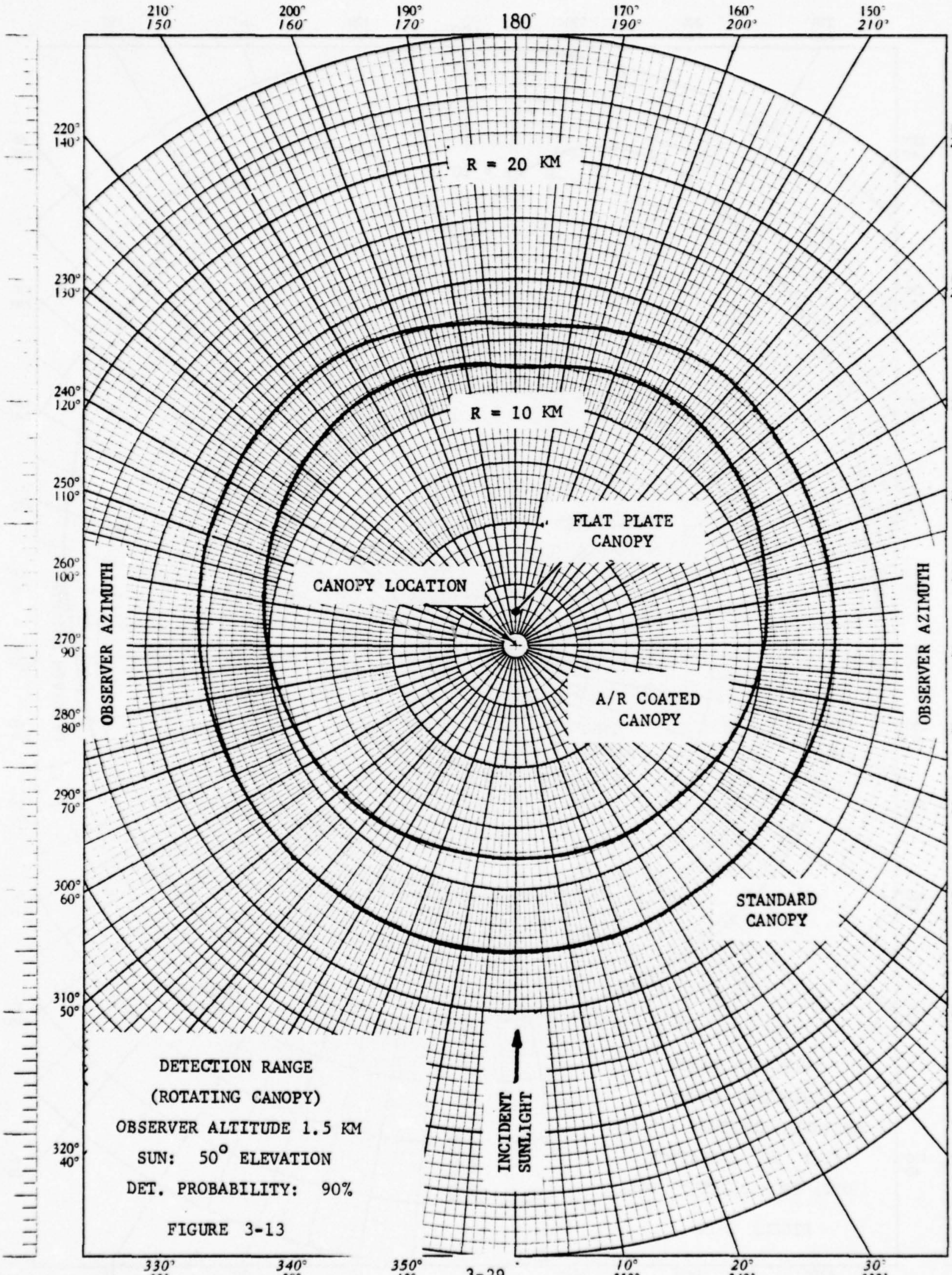
The glint signature of the flat plate canopy is a single one-half degree cone, similar to a flashlight reflection from a plane mirror. Its intensity is greater than that of any other configuration because it does not disperse the incident solar rays as do the curved canopies. However, the footprint in our 1.5 km elevation plane is only a small ellipse with a minor diameter of 1/2 degree, as shown in Figures 3-12 and 3-13. Thus, the probability of an observer being in a position to detect the glint is small. The footprint does not move as the canopy rotates, unless the canopy is not level. For a tilted canopy, the detection envelope traces out a small cone. Anti-reflection coating would reduce the maximum detection range negligibly, and would not affect the signature at 1.5 km elevation.

Finally, the detection envelopes for a spherical-shaped canopy are shown in Figure 3-14. The substantial reduction in glint intensity, compared to the standard canopy, results in a significant reduction in maximum detection range.



180
R = 20 KM
R = 10 KM
FLAT PLATE CANOPY
CANOPY LOCATION
A/R COATED CANOPY
STANDARD CANOPY
OBSERVER AZIMUTH
OBSERVER AZIMUTH
INCIDENT SUNLIGHT
DETECTION RANGE
(ROTATING CANOPY)
OBSERVER ALTITUDE 1.5 KM
SUN: 20° ELEVATION
DET. PROBABILITY: 90%

FIGURE 3-12



DETECTION RANGE
(ROTATING CANOPY)
OBSERVER ALTITUDE 1.5 KM
SUN: 50° ELEVATION
DET. PROBABILITY: 90%

FIGURE 3-13

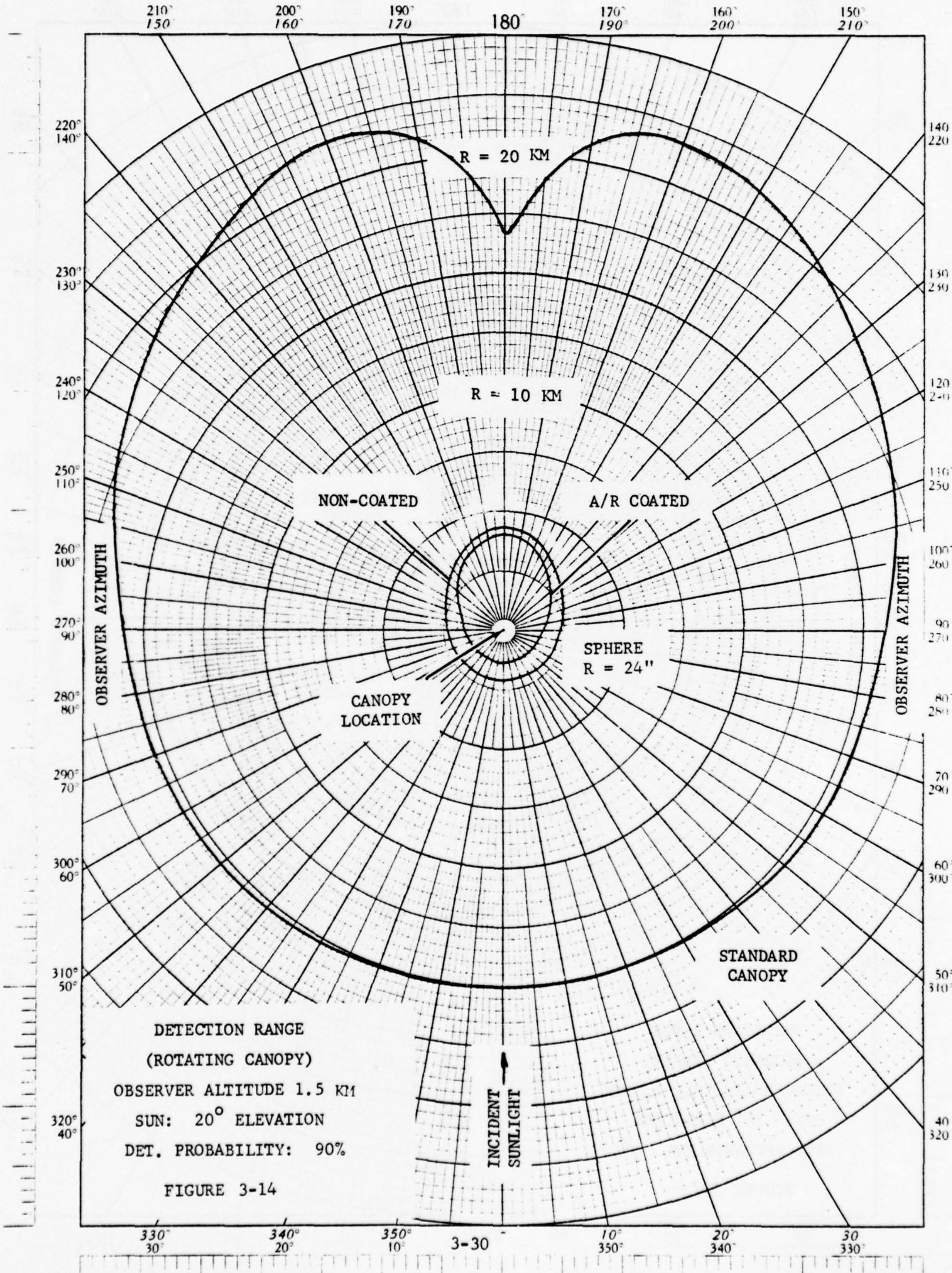

180°
R = 20 KM
R = 10 KM
NON-COATED
A/R COATED
OBSERVER AZIMUTH
SPHERE
R = 24"
CANOPY
LOCATION
STANDARD
CANOPY
INCIDENT
SUNLIGHT
DETECTION RANGE
(ROTATING CANOPY)
OBSERVER ALTITUDE 1.5 KM
SUN: 20° ELEVATION
DET. PROBABILITY: 90%

FIGURE 3-14

For the 24 inch radius sphere, the maximum detection range is approximately 5 km. Again, anti-reflective coating can be seen to offer very little improvement.

The reduction in intensity occurs because the spherical canopy disperses the incident solar radiation in all directions, rather than into a fan like the cylindrical canopy, or a beam like the flat canopy. As a consequence, the spherical canopy is visible from all sides at all times. Canopy orientation obviously has no effect because of the symmetry of the sphere. The standard canopy envelope shown in Figure 3-14 (and Figures 3-8 and 3-13 also), it must be remembered, is the locus of maximum detection ranges for all possible canopy orientations. The signature patterns for specific orientations were given in Figure 3-7. For proper spatial comparison, the hyperbolas of Figure 3-7 should be compared to the ellipses of Figure 3-14.

3.2 MODEL CORRELATION TESTS

3.2.1 PHASE I - ILLUMINANCE/LUMINANCE MEASUREMENTS

The first phase of Concept Demonstration/Feasibility Evaluation consisted of a series of absolute measurement tests. The objective of these tests was to obtain quantitative canopy luminance data for the purpose of validation of the modeling programs used to calculate the directional luminous intensity characteristics of the various breadboard canopies.

Table 3-2 documents the test canopy, geometry, and data measurement interval for each Phase I investigation. Figure 3-15 illustrates a typical test case geometry.

The rotatable test canopy platform (Chaparral fire unit) was located at a surveyed position relative to the tower observation point. Canopy peak luminance measurements were made from this observation point at regular intervals using the Gamma Scientific Model 2000 telephotometer. Concurrently, solar illuminance measurements were made using the Tektronix J16 photometer fitted with a J6511 illuminance probe. The azimuth orientation of the canopy was recorded each time a peak luminance measurement was made. Actual data compiled during the 11 May AR-coated canopy test are presented in Table 3-3 for information purposes.

Solar azimuth and elevation angles were later computed using tabulated ephemeris data to complete definition of the sun/canopy/observer geometric relationship at the time of each test measurement.

Analysis of Phase I test data confirms, with excellent correlation, the validity of the computer predicted sun glint fan geometry. Computer calculations for directional luminous intensity however were consistently lower than the values

TABLE 3-2

CONCEPT DEMONSTRATION/FEASIBILITY EVALUATION

- PHASE I -

PST (100's OF HOURS): SUNRISE 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 SUNSET

CANOPY	CONFIG.	POSITION	TEST DATES (PST)
STD	-	WEST	5/8; 5/19
STD	-	SOUTH	5/12
STD	-	EAST	6/17
AR	-	WEST	5/9 & 5/20
AR	-	SOUTH	5/11; 5/10
GRID	-	EAST	5/22 & 5/2?
GRID	SLOT	EAST	6/18 & 6/2?
FLAT	(1)	WEST	5/15 & 5/16
FLAT	AR (1)	WEST	5/16
FLAT	-	WEST	5/17
FLAT	(1), (2)	WEST	5/18
SPHERE	-	SOUTH	5/13

NOTES: (1) CANOPY ELEVATED FOR TOP-PLATE REFLECTION.

(2) TOP-PLATE PARTIALLY MASKED.

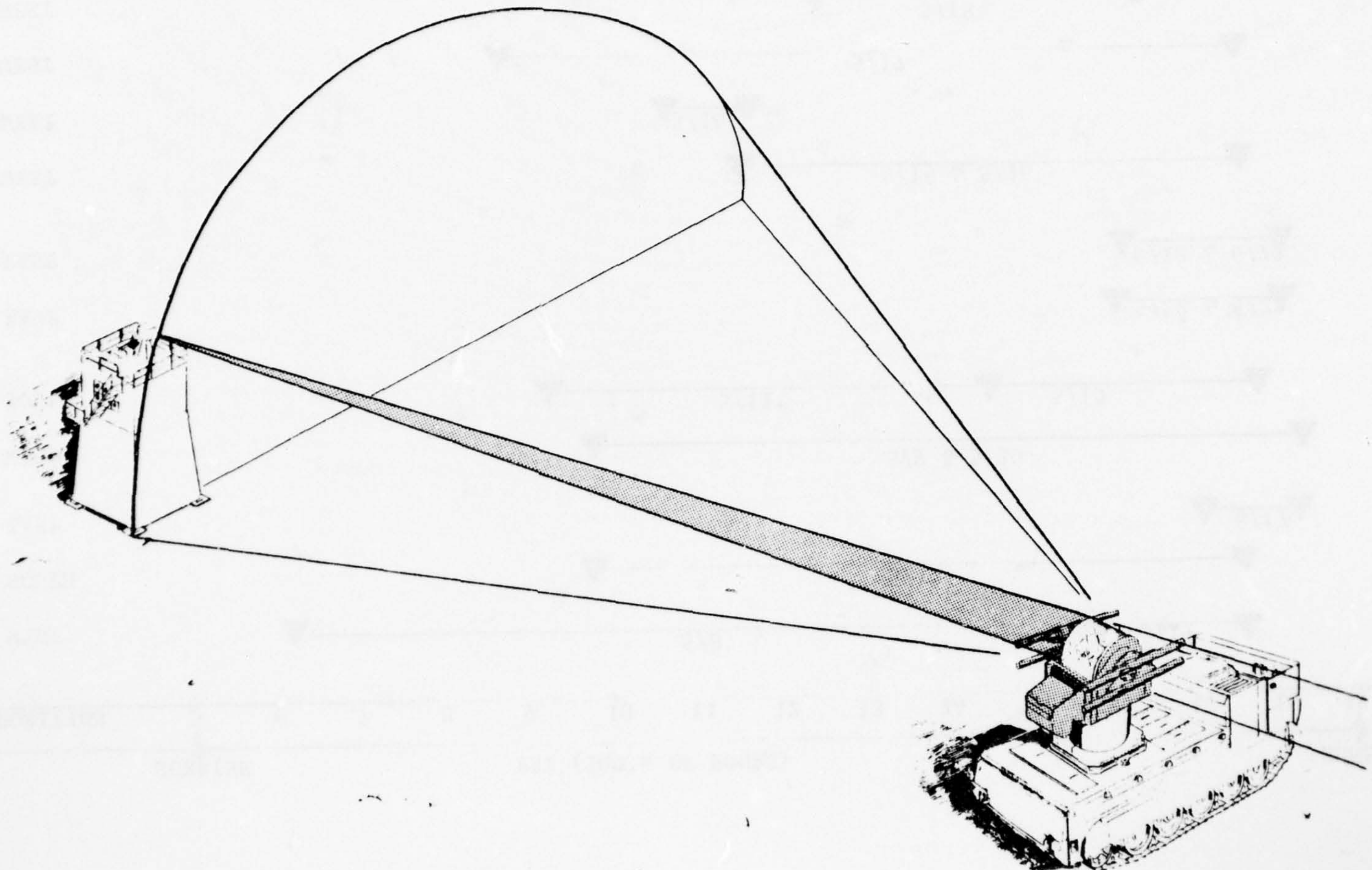


FIGURE 3-15. PHASE I TEST SITE ARRANGEMENT
(PHOTOMETRIC MEASUREMENT PROGRAM)

TABLE 3-3

AERONUTRONIC

F/U POS: (S) OR W

CANOPY: AR

DATE: 5/11/76

AZ. POS. (OBS) 9.476

AZ. POS. (SUN) 1.202 / 924 (time)

TOD (PST)	ILLUM. (FT-C)	SKY B.G. (FT-C)		LUM. (FT-L)	ATTEN. FACT.	CAN. AZ. (VOLTS)				
931	519	23		7.4K	4	10.66				
939	476	23		6.5K	4	10.56				
943	519	23		7.3K	4	10.53				
950	563	21		8.0K	4	10.48				
1004	581	19		9.1K	4	10.39				
1019	595	17		10.2K	4	10.27				
1032	588	17		9.5K	4	10.17				
1044	621	16		10.2K	4	10.05				
1051	636	16		10.5K	4	9.93				
1107	647	16		11.0K	4	9.80				
1115	663	16		11.2K	4	9.68				
1130	657	16		11.4K	4	9.56				
1141	632	17		10.7K	4	9.455				
1156	667	15		11.0K	4	9.281				
1211	669	14		13.1K	4	9.132				
1219	652	14		12.7K	4	9.031				
1234	673	12		11.7K	4	8.922				
1251	658	12		11.0K	4	8.782				
1304	632	14		9.3K	4	8.697				
1320	648	13		9.4K	4	8.599				
1336	645	13		8.9K	4	8.515				
1350	637	13		8.7K	4	8.455				
1405	647	13		8.7K	4	8.369				
1429	625	11		8.2K	4	8.303				

observed during the Phase I test. The discrepancy was too large (a factor of 3.7) to be attributed to measurement inaccuracies. After a considerable experimental effort to resolve the difficulty, and following discussions with representatives of Gamma Scientific Inc., manufacturer of the telephotometer which was used, it was determined that the intensity measurement of quasi-point sources in the presence of ambient daylight requires a more elaborate experimental design. The difficulty was further enchanced by the fact, unknown at the time that the experiment was designed, that a commercial telephotometer such as the Gamma Scientific instrument, designed to measure luminance or brightness, cannot be calibrated to measure intensity of sources which only partially fill the entrance pupil. It appears however that there is no reason to doubt the validity of the mathematical model or its applicability to the problem of comparing canopy designs.

It should be noted that an error of the magnitude found in the field tests would have a small effect on detection range.

Further, the existence of this discrepancy does not invalidate the conclusions drawn from the math models. As stated, the shapes of the detection envelopes are valid, as are the relative comparisons between the various configurations.

3.2.2 PHASE II - COMPARATIVE SIGNATURE OBSERVATIONS

During the second phase of Concept Demonstration/Feasibility Evaluation, a series of canopy sun glint photographic observation sorties were conducted from a UH-1 helicopter. The two objectives of this series of flights were: 1) to obtain a subjective comparative measure of the sun glint signatures of the various breadboard canopies under a common sun and skylight condition, and 2) to verify the sun glint detection range limits predicted by the modeling program for each canopy.

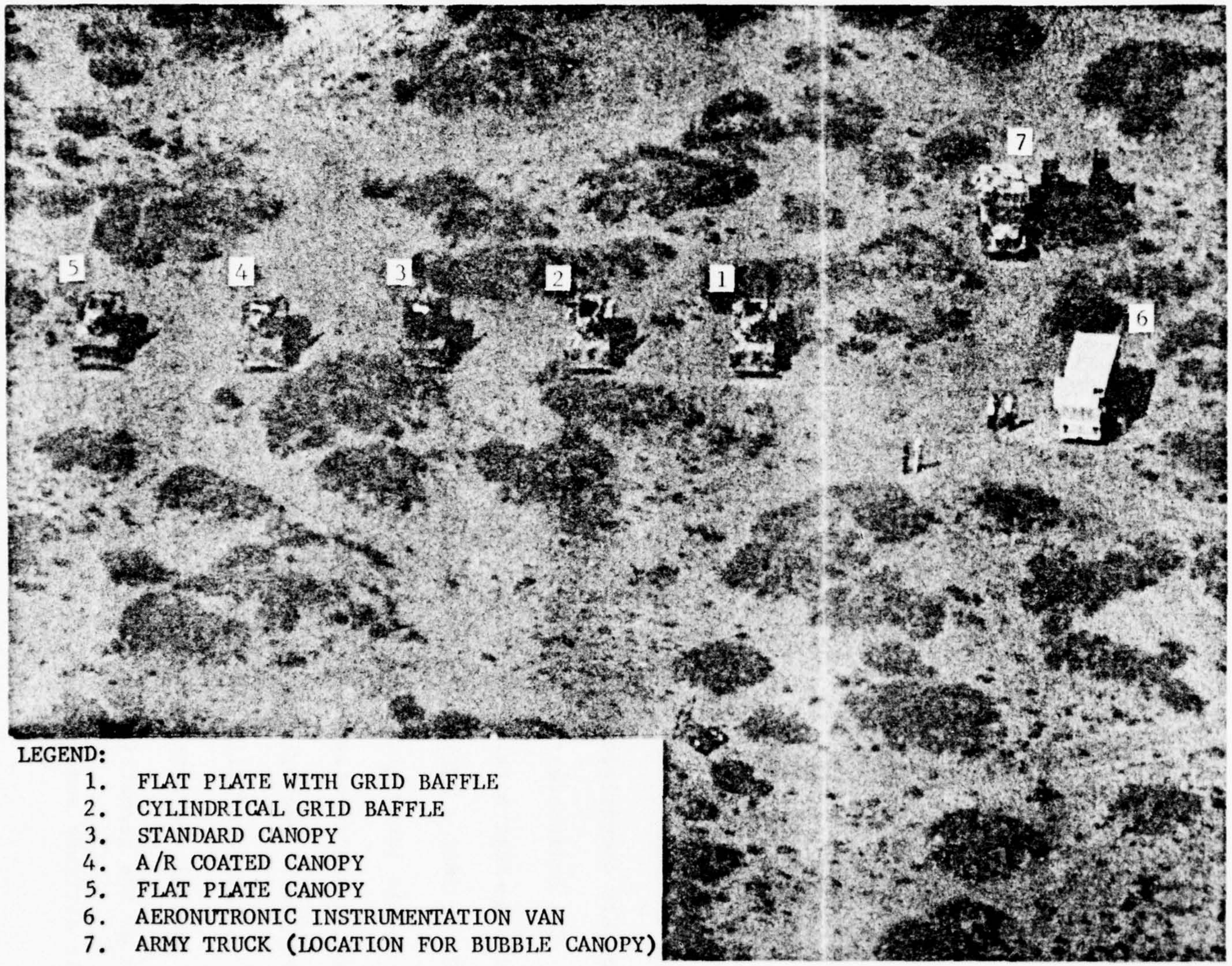
Figure 3-16 provides an airborne view of the Phase II test site layout at Fort Bliss, Texas. A schedule summarizing the UH-1 sortie activity is given below.

Sortie #	Sortie Date	Sortie Time	Valid Radar Pass #	Remarks
1	6/2	0700-0800	12	-
2	6/4	0900-1000	56-63	Camera Problem
3	6/7	0800-0900	-	Abort-Weather
4	6/7	1300-1400	96-104	-
5	6/8	0800-0900	119-128	-
6	6/9	0700-0800	167-173	-
7	6/11	0700-0800	-	Fire Units Manned

During each UH-1 sortie (with the exception of #7) the five fire units were unmanned and aligned to a specific azimuth heading. This procedure provided the common sun/canopy/observer orientation required for an unbiased signature comparison.

The helicopter was vectored to fly a 6 km slant range concentric course about the test site. The initial selection of course altitude (500, 1000, 1500, or 2000 m AGL) was made to most nearly match the solar elevation within the sortie interval. Upon entrance into the glint fan of any canopy, UH-1 position was identified by radar and 16 mm motion picture film documentation was made. Still photographs of selected sun glint conditions were also made.

A review of film and still photographic data from these missions confirmed the general characteristics predicted by each canopy model. Confirmation of the geometric air space of the signature utilizing computed values of solar altitude and relative observer position has been accomplished.



LEGEND:

1. FLAT PLATE WITH GRID BAFFLE
2. CYLINDRICAL GRID BAFFLE
3. STANDARD CANOPY
4. A/R COATED CANOPY
5. FLAT PLATE CANOPY
6. AERONUTRONIC INSTRUMENTATION VAN
7. ARMY TRUCK (LOCATION FOR BUBBLE CANOPY)

FIGURE 3-16. PHASE II TEST SITE ARRANGEMENT

Several attempts were made to address the second objective of the flight series; that is, to verify predicted maximum sun glint detection ranges. A variety of operations problems precluded this objective from being satisfactorily met; however, reasonably good correlation between one valid observation and the corresponding prediction (standard canopy) was achieved.

SECTION 4

4.0 GUNNER/CANOPY PERFORMANCE EVALUATION

4.1 PHASE II - AIRCRAFT TRACKING TEST

During the second phase of Concept Demonstration/Feasibility Evaluation, an extensive aircraft tracking test was conducted. The primary objective of this test was to determine the target acquisition related, gunner visibility characteristics of the various breadboard canopies. This was accomplished through the analytical comparison of specific event time delay data relating to target engagement for each of the various canopies under test. Originally, target range data was intended to be used for the analytical manipulations, however due to the programmed consistancy in target aircraft velocity, event time data was seen to be an adequate measure of test performance and therefore was used as the primary element in all subsequent Phase II data analysis.

A significant number of aircraft passes was required during this operation due to statistical considerations. Target support during the entire test interval was provided by a T-33 jet aircraft. Table 4-1 summarizes the T-33 target sortie activity.

Specific operating procedures were mandatory during all test passes. All gunners were provided ALERT and target vectoring information simultaneously. Vectoring updates were provided in the same manner. Each gunner attempted to engage the inbound target as soon as possible. Target visual acquisition was indicated by the gunner comment "CONTACT", and gunner/fire unit tracking by the comment "TRACKING". Gunners were directed to track the target throughout the run with minimum aiming error until disengagement was ordered. All fire unit intercom audio was concurrently monitored and recorded.

Range control vectoring information to the T-33 aircraft pilot was required throughout each test run to insure validity of the blind target ALERT and update vectoring callouts to the gunners.

TABLE 4-1

SUMMARY - T-33 TARGET SORTIE ACTIVITY

SORTIE #	RUNS	DATE	TIME		A/C	PERSONNEL				
			START	END		F.U. #1	F.U. #2	F.U. #3	F.U. #4	F.U. #5
1	1-11	6/1	1300	1500	T-33	3	4	2	5	1
2	13-22	6/2	1155	1255	T-33	3	4	2	5	1
3	23-37	6/3	1030	1130	T-33	3	4	2	5	1
4	38-55	6/3	1300	1500	T-33	1	3	4	2	5
5	64-81	6/4	1300	1500	T-33	1	3	4	2	5
6	82-95	6/7	1030	1130	T-33	5	1	3	4	2
7	105-118	6/7	1500	1600	T-33	5	1	3	4	2
8	129-148	6/8	1300	1400	T-33	2	5	1	3	4
9	149-166	6/8	1600	1700	T-33	2	5	1	3	4
10	174-184	6/10	0900	1000	T-33	4	2	5	1	3
11	185-202	6/10	1200	1300	T-33	4	2	5	1	3
12	203-219	6/10	1500	1600	T-33	3	4	2	5	1
13	220-239	6/11	0900	1000	T-33	3	4	2	5	1
14A	240-253	6/11	1200	1300	T-33	5	1	3	4	2
14B	254-260	6/11	1200	1300	T-33	2	5	1	3	4

FIRE UNIT

1 FLAT PLATE W/BAFFLE

2 GRID BAFFLE

3 STANDARD

4 AR-COATED

5 FLAT PLATE

During each scheduled sortie, the T-33 flew a programmed mixture of the following trajectories at a constant velocity of 300 knots:

TARGET PRESENTATIONS

Trajectory #	Alert Range (KM to XVR)	Offset (KM)	Altitude (M)
1	5	0	150
2	5	2	150
3	10	0	150
4	10	2	150
5	10	0	2000
6	10	2	2000

The order of trajectory variations was initially periodically altered in an attempt to more fully exercise the search techniques of each gunner/canopy combination. It became apparent however that the distribution of gunners was negatively affecting the results in spite of this normalization technique. Beginning with sortie number six, all gunners were advised of target presentation conditions (offset range, altitude) prior to initiation of the test pass. This approach helped re-establish a narrower distribution among the gunners.

All gunner personnel were rotated between fire units such that each gunner tracked at least two T-33 sorties from each unit. This approach was intended to normalize performance differences between the various gunners.

4.1.1 VISUAL ACQUISITION PREFORMANCE

The ability of the various gunner/canopy combinations under test to visually detect the target aircraft was evaluated in terms of the time delay between issuance of the ALERT order and receipt of the gunner CONTACT indication. Following screening of the total data sample (see Appendix B, part (1)), ALERT-CONTACT data (Appendix C) were segregated by trajectory and broken down to matrix format for application of the analysis procedures outlined in part (2) of Appendix B. Preliminary manipulations resulted in the generation of the matrices shown in Tables 4-2 through 4-7. Results of the two-way analysis conducted on each matrix appear immediately below the table matrix, where degrees of freedom (D.F.), sum-of-squares (S.S.), and mean square (M.S.) notations are used.

The first test of the two-way analysis of variance was that to determine if gunner/canopy interaction existed. This was accomplished by testing the hypothesis of zero interaction at the 10 percent significance level. The results of this test for each of the six trajectory matrices is shown in Table 4-8. It is seen that for trajectories 1, 2, 3, and 5, the hypothesis of zero interaction cannot be rejected at the 10 percent significance level. Further, in these cases, the hypothesis that the mean visual acquisition performance of all canopies are equal (canopy has no effect on visual acquisition performance) also cannot be rejected at the 10 percent significance level. This implies that differences in canopy means as large as those noted, would occur 10 percent of the time even if there were truly no performance differences between the canopies.

In the case of trajectories 4 and 6, tests of the null hypothesis showed gunner/canopy interaction to be significant at the 10 percent level, forcing the one-way analysis given in Tables 4-9 and 4-10, respectively. Results of individual (by gunner) null hypothesis tests that canopy mean differences were zero are indicated in Tables 4-11A and B. The analysis causes rejection of the null hypothesis at all levels of the gunner factor (Table 4-11A) for trajectory 4, but at only one level for trajectory 6 (Table 4-11B).

The hypothetical significant differences between canopies for the appropriate gunner levels was further explored via pair-wise mean comparisons

ALERT - CONTACT DATA - TRAJECTORY 1 TABLE 4-2

CANOPY (j)

GUNNER (i)	1	2	3	4	5	
1	$x_{11} = 28.4$ $\bar{x}_{11} = 9.467$ $n_{11} = 3$	$x_{12} = 8.4$ $\bar{x}_{12} = 8.4$ $n_{12} = 1$	$x_{13} = 36.1$ $\bar{x}_{13} = 9.025$ $n_{13} = 4$	$x_{14} = 55$ $\bar{x}_{14} = 18.333$ $n_{14} = 3$	$x_{15} = 46.4$ $\bar{x}_{15} = 11.6$ $n_{15} = 4$	$x_{1.} = 174.3$ $\bar{x}_{1.} = 11.62$ $n_{1.} = 15$
2	$x_{21} = 35$ $\bar{x}_{21} = 8.75$ $n_{21} = 4$	$x_{22} = 29.4$ $\bar{x}_{22} = 9.8$ $n_{22} = 3$	$x_{23} = 27.2$ $\bar{x}_{23} = 6.8$ $n_{23} = 4$	$x_{24} = 25.1$ $\bar{x}_{24} = 8.367$ $n_{24} = 3$	$x_{25} = 5.4$ $\bar{x}_{25} = 5.4$ $n_{25} = 1$	$x_{2.} = 122.1$ $\bar{x}_{2.} = 8.14$ $n_{2.} = 15$
3	$x_{31} = 7.4$ $\bar{x}_{31} = 3.7$ $n_{31} = 2$	$x_{32} = 16.6$ $\bar{x}_{32} = 5.533$ $n_{32} = 3$	$x_{33} = 6.1$ $\bar{x}_{33} = 6.1$ $n_{33} = 1$	$x_{34} = 39.1$ $\bar{x}_{34} = 9.775$ $n_{34} = 4$	$x_{35} = 20.6$ $\bar{x}_{35} = 6.867$ $n_{35} = 3$	$x_{3.} = 89.8$ $\bar{x}_{3.} = 6.9077$ $n_{3.} = 13$
4	$x_{41} = 27$ $\bar{x}_{41} = 9.0$ $n_{41} = 3$	$x_{42} = 44.2$ $\bar{x}_{42} = 11.05$ $n_{42} = 4$	$x_{43} = 20.9$ $\bar{x}_{43} = 6.967$ $n_{43} = 3$	$x_{44} = 12.9$ $\bar{x}_{44} = 12.9$ $n_{44} = 1$	$x_{45} = 18$ $\bar{x}_{45} = 4.5$ $n_{45} = 4$	$x_{4.} = 123$ $\bar{x}_{4.} = 8.2$ $n_{4.} = 15$
5	$x_{51} = 8.6$ $\bar{x}_{51} = 8.6$ $n_{51} = 1$	$x_{52} = 32.6$ $\bar{x}_{52} = 8.15$ $n_{52} = 4$	$x_{53} = 24.9$ $\bar{x}_{53} = 8.3$ $n_{53} = 3$	$x_{54} = 21.7$ $\bar{x}_{54} = 5.425$ $n_{54} = 4$	$x_{55} = 29.9$ $\bar{x}_{55} = 9.967$ $n_{55} = 3$	$x_{5.} = 117.7$ $\bar{x}_{5.} = 7.8467$ $n_{5.} = 15$
	$x_{.1} = 106.4$ $\bar{x}_{.1} = 8.1846$ $n_{.1} = 13$	$x_{.2} = 131.2$ $\bar{x}_{.2} = 8.7467$ $n_{.2} = 15$	$x_{.3} = 115.2$ $\bar{x}_{.3} = 7.68$ $n_{.3} = 15$	$x_{.4} = 153.8$ $\bar{x}_{.4} = 10.2533$ $n_{.4} = 15$	$x_{.5} = 120.3$ $\bar{x}_{.5} = 8.02$ $n_{.5} = 15$	$x_{..} = 626.9$ $\bar{x}_{..} = 8.5877$ $n_{..} = 73$

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4	61.2787	15.3197	47.0247	188.0989	4	GUNNERS ignoring CANOPIES
INTERACTION	16	327.3218	20.4576		327.3218	16	INTERACTION
GUNNERS	4	224.6390	56.1598	24.4547	97.8188	4	CANOPIES
BETWEEN cells	24	613.2395			613.2395	24	
WITHIN cells	48	656.2392	13.6716				
TOTAL	72	1269.4787					

ALERT - CONTACT DATA - TRAJECTORY 2 TABLE 4-3

CANOPY (J)

GUNNER (I)	1	2	3	4	5	
1	$x_{11} = 24.7$ $\bar{x}_{11} = 8.233$ $n_{11} = 3$	$x_{12} = 6.4$ $\bar{x}_{12} = 6.4$ $n_{12} = 1$	$x_{13} = 28.2$ $\bar{x}_{13} = 7.055$ $n_{13} = 4$	$x_{14} = 10.1$ $\bar{x}_{14} = 5.05$ $n_{14} = 2$	$x_{15} = 16$ $\bar{x}_{15} = 5.333$ $n_{15} = 3$	$x_{1.} = 85.4$ $\bar{x}_{1.} = 6.5692$ $n_{1.} = 13$
2	$x_{21} = 29.4$ $\bar{x}_{21} = 7.35$ $n_{21} = 4$	$x_{22} = 9.7$ $\bar{x}_{22} = 4.85$ $n_{22} = 2$	$x_{23} = 15.9$ $\bar{x}_{23} = 5.3$ $n_{23} = 3$	$x_{24} = 16.7$ $\bar{x}_{24} = 5.567$ $n_{24} = 3$	$x_{25} = 3.9$ $\bar{x}_{25} = 3.9$ $n_{25} = 1$	$x_{2.} = 75.6$ $\bar{x}_{2.} = 5.8154$ $n_{2.} = 13$
3	$x_{31} = 2.8$ $\bar{x}_{31} = 2.8$ $n_{31} = 1$	$x_{32} = 15.8$ $\bar{x}_{32} = 5.267$ $n_{32} = 3$	$x_{33} = 3.0$ $\bar{x}_{33} = 3.0$ $n_{33} = 1$	$x_{34} = 14.8$ $\bar{x}_{34} = 3.7$ $n_{34} = 4$	$x_{35} = 2.6$ $\bar{x}_{35} = 2.6$ $n_{35} = 1$	$x_{3.} = 39$ $\bar{x}_{3.} = 3.9$ $n_{3.} = 10$
4	$x_{41} = 10.8$ $\bar{x}_{41} = 5.4$ $n_{41} = 2$	$x_{42} = 20.3$ $\bar{x}_{42} = 6.767$ $n_{42} = 3$	$x_{43} = 17$ $\bar{x}_{43} = 5.667$ $n_{43} = 3$	$x_{44} = 3.3$ $\bar{x}_{44} = 3.3$ $n_{44} = 1$	$x_{45} = 22.4$ $\bar{x}_{45} = 5.6$ $n_{45} = 4$	$x_{4.} = 73.8$ $\bar{x}_{4.} = 5.6769$ $n_{4.} = 13$
5	$x_{51} = 3.2$ $\bar{x}_{51} = 3.2$ $n_{51} = 1$	$x_{52} = 36.8$ $\bar{x}_{52} = 9.2$ $n_{52} = 4$	$x_{53} = 9.0$ $\bar{x}_{53} = 4.5$ $n_{53} = 2$	$x_{54} = 15.1$ $\bar{x}_{54} = 5.033$ $n_{54} = 3$	$x_{55} = 19.5$ $\bar{x}_{55} = 6.5$ $n_{55} = 3$	$x_{5.} = 83.6$ $\bar{x}_{5.} = 6.4308$ $n_{5.} = 13$
	$x_{.1} = 70.9$ $\bar{x}_{.1} = 6.4454$ $n_{.1} = 11$	$x_{.2} = 89$ $\bar{x}_{.2} = 6.8462$ $n_{.2} = 13$	$x_{.3} = 73.1$ $\bar{x}_{.3} = 5.6231$ $n_{.3} = 13$	$x_{.4} = 60$ $\bar{x}_{.4} = 4.6154$ $n_{.4} = 13$	$x_{.5} = 64.4$ $\bar{x}_{.5} = 5.3667$ $n_{.5} = 12$	$x_{..} = 357.4$ $\bar{x}_{..} = 5.7645$ $n_{..} = 62$

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4	39.6464	9.9116	12.2729	49.0917	4	GUNNERS ignoring CANOPIES
INTERACTION	16	68.0470	4.2529		68.0470	16	INTERACTION
GUNNERS	4	49.1023	12.2756	9.9142	39.6570	4	CANOPIES
BETWEEN cells	24	156.7957			156.7957	24	
WITHIN cells	37	207.0685	5.5964				
TOTAL	61	363.8642					

ALERT - CONTACT DATA - TRAJECTORY 3 TABLE 4-4

CANOPY (J)

GUNNER (I)	1	2	3	4	5	
	x_{11} = 82.8	x_{12} = 225.1	x_{13} = 210.9	x_{14} = 208.7	x_{15} = 196.7	$x_{1.}$ = 924.2
1	$\bar{x}_{11}$ = 20.7	$\bar{x}_{12}$ = 32.157	$\bar{x}_{13}$ = 30.129	$\bar{x}_{14}$ = 34.783	$\bar{x}_{15}$ = 32.783	$\bar{x}_{1.}$ = 30.8067
	n_{11} = 4	n_{12} = 7	n_{13} = 7	n_{14} = 6	n_{15} = 6	$n_{1.}$ = 30
	x_{21} = 136.2	x_{22} = 258.7	x_{23} = 155.8	x_{24} = 126.8	x_{25} = 245.8	$x_{2.}$ = 923.3
2	$\bar{x}_{21}$ = 27.24	$\bar{x}_{22}$ = 43.117	$\bar{x}_{23}$ = 24.967	$\bar{x}_{24}$ = 31.7	$\bar{x}_{25}$ = 35.114	$\bar{x}_{2.}$ = 32.975
	n_{21} = 5	n_{22} = 6	n_{23} = 6	n_{24} = 4	n_{25} = 7	$n_{2.}$ = 28
	x_{31} = 163.9	x_{32} = 111.4	x_{33} = 249.1	x_{34} = 166.4	x_{35} = 124.7	$x_{3.}$ = 815.5
3	$\bar{x}_{31}$ = 27.317	$\bar{x}_{32}$ = 27.85	$\bar{x}_{33}$ = 35.586	$\bar{x}_{34}$ = 23.771	$\bar{x}_{35}$ = 20.783	$\bar{x}_{3.}$ = 27.1833
	n_{31} = 6	n_{32} = 4	n_{33} = 7	n_{34} = 7	n_{35} = 6	$n_{3.}$ = 30
	x_{41} = 266.8	x_{42} = 232.8	x_{43} = 154.8	x_{44} = 252.7	x_{45} = 240.3	$x_{4.}$ = 1147.4
4	$\bar{x}_{41}$ = 44.467	$\bar{x}_{42}$ = 38.8	$\bar{x}_{43}$ = 38.7	$\bar{x}_{44}$ = 36.1	$\bar{x}_{45}$ = 34.329	$\bar{x}_{4.}$ = 38.2467
	n_{41} = 6	n_{42} = 6	n_{43} = 4	n_{44} = 7	n_{45} = 7	$n_{4.}$ = 30
	x_{51} = 250.6	x_{52} = 232.2	x_{53} = 235.1	x_{54} = 143.3	x_{55} = 134.1	$x_{5.}$ = 995.3
5	$\bar{x}_{51}$ = 35.8	$\bar{x}_{52}$ = 33.171	$\bar{x}_{53}$ = 39.183	$\bar{x}_{54}$ = 23.883	$\bar{x}_{55}$ = 33.525	$\bar{x}_{5.}$ = 33.1767
	n_{51} = 7	n_{52} = 7	n_{53} = 6	n_{54} = 6	n_{55} = 4	$n_{5.}$ = 30
	$x_{.1}$ = 900.3	$x_{.2}$ = 1060.2	$x_{.3}$ = 1005.7	$x_{.4}$ = 897.9	$x_{.5}$ = 941.6	$x_{..}$ = 4805.7
	$\bar{x}_{.1}$ = 32.1536	$\bar{x}_{.2}$ = 35.34	$\bar{x}_{.3}$ = 33.5233	$\bar{x}_{.4}$ = 29.93	$\bar{x}_{.5}$ = 31.3867	$\bar{x}_{..}$ = 32.4709
	$n_{.1}$ = 28	$n_{.2}$ = 30	$n_{.3}$ = 30	$n_{.4}$ = 30	$n_{.5}$ = 30	$n_{..}$ = 148

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4	512.1964	128.0491	486.2449	1944.9797	4	GUNNERS ignoring CANOPIES
INTERACTION	16	3112.1413	194.5088		3112.1413	16	INTERACTION
GUNNERS	4	1959.4125	489.8531	131.6573	526.6292	4	CANOPIES
BETWEEN cells	24	5583.7502			5583.7502	24	
WITHIN cells	123	18254.7933	148.4130				
TOTAL	147	23838.5435					

ALERT - CONTACT DATA - TRAJECTORY 4 TABLE 4-5

CANOPY (J)

GUNNER (I)	1	2	3	4	5	
1	x_{11} = 96.4 $\bar{x}_{11}$ = 19.28 n_{11} = 5	x_{12} = 153.2 $\bar{x}_{12}$ = 30.64 n_{12} = 5	x_{13} = 244.1 $\bar{x}_{13}$ = 34.871 n_{13} = 7	x_{14} = 149.2 $\bar{x}_{14}$ = 21.314 n_{14} = 7	x_{15} = 156.2 $\bar{x}_{15}$ = 26.033 n_{15} = 6	$x_{1\cdot}$ = 799.1 $\bar{x}_{1\cdot}$ = 26.6367 $n_{1\cdot}$ = 30
2	x_{21} = 220 $\bar{x}_{21}$ = 31.429 n_{21} = 7	x_{22} = 178.7 $\bar{x}_{22}$ = 25.529 n_{22} = 7	x_{23} = 105.4 $\bar{x}_{23}$ = 17.567 n_{23} = 6	x_{24} = 158.4 $\bar{x}_{24}$ = 31.68 n_{24} = 5	x_{25} = 177.3 $\bar{x}_{25}$ = 35.46 n_{25} = 5	$x_{2\cdot}$ = 839.8 $\bar{x}_{2\cdot}$ = 27.9933 $n_{2\cdot}$ = 30
3	x_{31} = 73.6 $\bar{x}_{31}$ = 12.267 n_{31} = 6	x_{32} = 123 $\bar{x}_{32}$ = 24.6 n_{32} = 5	x_{33} = 122.5 $\bar{x}_{33}$ = 24.5 n_{33} = 5	x_{34} = 182.5 $\bar{x}_{34}$ = 26.071 n_{34} = 7	x_{35} = 126.2 $\bar{x}_{35}$ = 18.029 n_{35} = 7	$x_{3\cdot}$ = 627.8 $\bar{x}_{3\cdot}$ = 20.9267 $n_{3\cdot}$ = 30
4	x_{41} = 175.5 $\bar{x}_{41}$ = 25.071 n_{41} = 7	x_{42} = 178.6 $\bar{x}_{42}$ = 29.767 n_{42} = 6	x_{43} = 153.2 $\bar{x}_{43}$ = 30.64 n_{43} = 5	x_{44} = 169.6 $\bar{x}_{44}$ = 33.92 n_{44} = 5	x_{45} = 258.3 $\bar{x}_{45}$ = 36.9 n_{45} = 7	$x_{4\cdot}$ = 935.2 $\bar{x}_{4\cdot}$ = 31.1733 $n_{4\cdot}$ = 30
5	x_{51} = 138.6 $\bar{x}_{51}$ = 27.72 n_{51} = 5	x_{52} = 261.8 $\bar{x}_{52}$ = 37.4 n_{52} = 7	x_{53} = 145.8 $\bar{x}_{53}$ = 20.829 n_{53} = 7	x_{54} = 91.6 $\bar{x}_{54}$ = 15.267 n_{54} = 6	x_{55} = 208.7 $\bar{x}_{55}$ = 41.74 n_{55} = 5	$x_{5\cdot}$ = 846.5 $\bar{x}_{5\cdot}$ = 28.2167 $n_{5\cdot}$ = 30
	$x_{\cdot 1}$ = 704.1 $\bar{x}_{\cdot 1}$ = 23.47 $n_{\cdot 1}$ = 30	$x_{\cdot 2}$ = 895.3 $\bar{x}_{\cdot 2}$ = 29.8433 $n_{\cdot 2}$ = 30	$x_{\cdot 3}$ = 771 $\bar{x}_{\cdot 3}$ = 25.7 $n_{\cdot 3}$ = 30	$x_{\cdot 4}$ = 751.3 $\bar{x}_{\cdot 4}$ = 25.0433 $n_{\cdot 4}$ = 30	$x_{\cdot 5}$ = 926.7 $\bar{x}_{\cdot 5}$ = 30.89 $n_{\cdot 5}$ = 30	$x_{\cdot\cdot}$ = 4048.4 $\bar{x}_{\cdot\cdot}$ = 26.9893 $n_{\cdot\cdot}$ = 150

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4					4	GUNNERS ignoring CANOPIES
INTERACTION	16	5190.5960	324.4122	324.4122	5190.5960	16	INTERACTION
GUNNERS	4					4	CANOPIES
BETWEEN cells	24	8118.1071			8118.1071	24	
WITHIN cells	125	10552.1949	84.4176				
TOTAL	149	18670.3020					

ALERT - CONTACT DATA - TRAJECTORY 5 TABLE 4-6

CANOPY (J)

GUNNER (I)	1	2	3	4	5	
1	$x_{11} = 332.4$ $\bar{x}_{11} = 47.486$ $n_{11} = 7$	$x_{12} = 151.9$ $\bar{x}_{12} = 50.633$ $n_{12} = 3$	$x_{13} = 230.7$ $\bar{x}_{13} = 46.14$ $n_{13} = 5$	$x_{14} = 220.2$ $\bar{x}_{14} = 55.05$ $n_{14} = 4$	$x_{15} = 382.7$ $\bar{x}_{15} = 54.671$ $n_{15} = 7$	$x_{1\cdot} = 1317.9$ $\bar{x}_{1\cdot} = 50.6885$ $n_{1\cdot} = 26$
2	$x_{21} = 218.5$ $\bar{x}_{21} = 43.7$ $n_{21} = 5$	$x_{22} = 226.5$ $\bar{x}_{22} = 56.625$ $n_{22} = 4$	$x_{23} = 335.8$ $\bar{x}_{23} = 47.971$ $n_{23} = 7$	$x_{24} = 381$ $\bar{x}_{24} = 54.429$ $n_{24} = 7$	$x_{25} = 148.5$ $\bar{x}_{25} = 49.5$ $n_{25} = 3$	$x_{2\cdot} = 1310.3$ $\bar{x}_{2\cdot} = 50.3962$ $n_{2\cdot} = 26$
3	$x_{31} = 275.7$ $\bar{x}_{31} = 39.386$ $n_{31} = 7$	$x_{32} = 347.9$ $\bar{x}_{32} = 49.7$ $n_{32} = 7$	$x_{33} = 155.7$ $\bar{x}_{33} = 51.9$ $n_{33} = 3$	$x_{34} = 219.9$ $\bar{x}_{34} = 43.98$ $n_{34} = 5$	$x_{35} = 188.7$ $\bar{x}_{35} = 47.175$ $n_{35} = 4$	$x_{3\cdot} = 1187.9$ $\bar{x}_{3\cdot} = 45.6885$ $n_{3\cdot} = 26$
4	$x_{41} = 205.7$ $\bar{x}_{41} = 51.425$ $n_{41} = 4$	$x_{42} = 350.8$ $\bar{x}_{42} = 50.114$ $n_{42} = 7$	$x_{43} = 362.5$ $\bar{x}_{43} = 51.786$ $n_{43} = 7$	$x_{44} = 165.3$ $\bar{x}_{44} = 55.1$ $n_{44} = 3$	$x_{45} = 179.8$ $\bar{x}_{45} = 44.95$ $n_{45} = 4$	$x_{4\cdot} = 1264.1$ $\bar{x}_{4\cdot} = 50.564$ $n_{4\cdot} = 25$
5	$x_{51} = 194.9$ $\bar{x}_{51} = 64.967$ $n_{51} = 3$	$x_{52} = 221.2$ $\bar{x}_{52} = 44.24$ $n_{52} = 5$	$x_{53} = 214.7$ $\bar{x}_{53} = 53.675$ $n_{53} = 4$	$x_{54} = 424.3$ $\bar{x}_{54} = 60.614$ $n_{54} = 7$	$x_{55} = 421.1$ $\bar{x}_{55} = 60.157$ $n_{55} = 7$	$x_{5\cdot} = 1476.2$ $\bar{x}_{5\cdot} = 56.7769$ $n_{5\cdot} = 26$
	$x_{\cdot 1} = 1227.2$ $\bar{x}_{\cdot 1} = 47.2$ $n_{\cdot 1} = 26$	$x_{\cdot 2} = 1298.3$ $\bar{x}_{\cdot 2} = 49.9346$ $n_{\cdot 2} = 26$	$x_{\cdot 3} = 1299.4$ $\bar{x}_{\cdot 3} = 49.9770$ $n_{\cdot 3} = 26$	$x_{\cdot 4} = 1410.7$ $\bar{x}_{\cdot 4} = 54.2577$ $n_{\cdot 4} = 26$	$x_{\cdot 5} = 1320.8$ $\bar{x}_{\cdot 5} = 52.832$ $n_{\cdot 5} = 25$	$x_{\cdot\cdot} = 6556.4$ $\bar{x}_{\cdot\cdot} = 50.8248$ $n_{\cdot\cdot} = 129$

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4	788.1692	197.0423	403.5444	1614.1777	4	GUNNERS ignoring CANOPIES
INTERACTION	16	2323.3162	145.2073		2323.3162	16	INTERACTION
GUNNERS	4	1342.7631	335.6908	129.1886	516.7546	4	CANOPIES
BETWEEN cells	24	4454.2485			4454.2485	24	
WITHIN cells	104	16647.6058	160.0731				
TOTAL	128	21101.8543					

ALERT - CONTACT DATA - TRAJECTORY 6 TABLE 4-7

CANOPY (J)

GUNNER (I)	1	2	3	4	5	
1	$x_{11} = 120.3$ $\bar{x}_{11} = 60.15$ $n_{11} = 2$	$x_{12} = 256.8$ $\bar{x}_{12} = 64.2$ $n_{12} = 4$	$x_{13} = 230.7$ $\bar{x}_{13} = 57.675$ $n_{13} = 4$	$x_{14} = 198.9$ $\bar{x}_{14} = 49.725$ $n_{14} = 4$	$x_{15} = 100.7$ $\bar{x}_{15} = 50.35$ $n_{15} = 2$	$x_{1.} = 907.4$ $\bar{x}_{1.} = 56.7125$ $n_{1.} = 16$
2	$x_{21} = 213.6$ $\bar{x}_{21} = 53.4$ $n_{21} = 4$	$x_{22} = 200$ $\bar{x}_{22} = 50$ $n_{22} = 4$	$x_{23} = 98.1$ $\bar{x}_{23} = 49.05$ $n_{23} = 2$	$x_{24} = 94.1$ $\bar{x}_{24} = 47.05$ $n_{24} = 2$	$x_{25} = 219.3$ $\bar{x}_{25} = 54.825$ $n_{25} = 4$	$x_{2.} = 825.1$ $\bar{x}_{2.} = 51.5688$ $n_{2.} = 16$
3	$x_{31} = 90.1$ $\bar{x}_{31} = 45.05$ $n_{31} = 2$	$x_{32} = 84.8$ $\bar{x}_{32} = 42.4$ $n_{32} = 2$	$x_{33} = 238.4$ $\bar{x}_{33} = 59.6$ $n_{33} = 4$	$x_{34} = 213.1$ $\bar{x}_{34} = 53.275$ $n_{34} = 4$	$x_{35} = 170.2$ $\bar{x}_{35} = 42.55$ $n_{35} = 4$	$x_{3.} = 796.6$ $\bar{x}_{3.} = 49.7875$ $n_{3.} = 16$
4	$x_{41} = 174.2$ $\bar{x}_{41} = 43.55$ $n_{41} = 4$	$x_{42} = 100.7$ $\bar{x}_{42} = 50.35$ $n_{42} = 2$	$x_{43} = 85.2$ $\bar{x}_{43} = 42.6$ $n_{43} = 2$	$x_{44} = 239.8$ $\bar{x}_{44} = 59.95$ $n_{44} = 4$	$x_{45} = 220.5$ $\bar{x}_{45} = 55.125$ $n_{45} = 4$	$x_{4.} = 820.4$ $\bar{x}_{4.} = 51.275$ $n_{4.} = 16$
5	$x_{51} = 255.2$ $\bar{x}_{51} = 63.8$ $n_{51} = 4$	$x_{52} = 232.8$ $\bar{x}_{52} = 58.2$ $n_{52} = 4$	$x_{53} = 202.7$ $\bar{x}_{53} = 50.675$ $n_{53} = 4$	$x_{54} = 96.2$ $\bar{x}_{54} = 48.1$ $n_{54} = 2$	$x_{55} = 115.2$ $\bar{x}_{55} = 57.6$ $n_{55} = 2$	$x_{5.} = 902.1$ $\bar{x}_{5.} = 56.3812$ $n_{5.} = 16$
	$x_{.1} = 853.4$ $\bar{x}_{.1} = 53.3375$ $n_{.1} = 16$	$x_{.2} = 875.1$ $\bar{x}_{.2} = 54.6938$ $n_{.2} = 16$	$x_{.3} = 855.1$ $\bar{x}_{.3} = 53.4438$ $n_{.3} = 16$	$x_{.4} = 842.1$ $\bar{x}_{.4} = 52.6312$ $n_{.4} = 16$	$x_{.5} = 825.9$ $\bar{x}_{.5} = 51.6188$ $n_{.5} = 16$	$x_{..} = 4251.6$ $\bar{x}_{..} = 53.145$ $n_{..} = 80$

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4					4	GUNNERS ignoring CANOPIES
INTERACTION	16	2675.8915	167.2432	167.2432	2675.8915	16	INTERACTION
GUNNERS	4					4	CANOPIES
BETWEEN cells	24	3346.6730			3346.6730	24	
WITHIN cells	55	5458.6630	99.2484				
TOTAL	79	8805.3360					

ALERT - CONTACT DATA — SIGNIFICANCE TESTS - TABLE 4-8

TRAJ. NO.	INTERACTION		MAIN EFFECTS				
				GUNNER EFFECTS		CANOPY EFFECTS	
	$F_{.10}$ (D.F.)	F_{ACT} (SIGNIF.)	$F_{.10}$ (D.F.)	F_{GUN}	SIGNIF.	F_{CAN}	SIGNIF.
1	1.62 (16,48)	1.4964 (NO)	2.04 (4,64)	3.6543	YES	1.5912	NO
2	1.67 (16,37)	0.7599 (NO)	2.06 (4,53)	2.3648	YES	1.9099	NO
3	1.54 (16,123)	1.3106 (NO)	1.98 (4,139)	3.1867	YES	0.8565	NO
4	1.54 (16,125)	3.8429 (YES)	SEE TABLES 4-9, 4-11A				
5	1.54 (16,104)	0.9071 (NO)	1.99 (4,120)	2.1234	YES	0.8172	NO
6	1.62 (16,55)	1.6851 (YES)	SEE TABLES 4-10, 4-11B				

ALERT-CONTACT DATA — TRAJECTORY 4 - TABLE 4-9

ONE-WAY ANALYSIS
(CASE OF SIGNIFICANT INTERACTION)

GUNNER	SOURCE	D.F.	S.S.	M.S.
1	BETWEEN CANOPIES	4	1025.8678	256.4670
	WITHIN CANOPIES	25	2699.0216	107.9609
	TOTAL	29	3724.8894	
2	BETWEEN CANOPIES	4	1124.1009	281.0252
	WITHIN CANOPIES	25	2425.1577	97.0063
	TOTAL	29	3549.2586	
3	BETWEEN CANOPIES	4	825.2739	206.3185
	WITHIN CANOPIES	25	1243.9848	49.7594
	TOTAL	29	2069.2587	
4	BETWEEN CANOPIES	4	541.2420	135.3105
	WITHIN CANOPIES	25	1257.6767	50.3071
	TOTAL	29	1798.9187	
5	BETWEEN CANOPIES	4	2894.1779	723.5445
	WITHIN CANOPIES	25	2926.7833	117.0713
	TOTAL	29	5820.9612	

ALERT - CONTACT DATA — TRAJECTORY 6 - TABLE 4-10

ONE-WAY ANALYSIS
(CASE OF SIGNIFICANT INTERACTION)

GUNNER	SOURCE	D.F.	S.S.	M.S.
1	BETWEEN CANOPIES	4	527.8525	131.9631
	WITHIN CANOPIES	11	1224.6649	111.3332
	TOTAL	15	1752.5174	
2	BETWEEN CANOPIES	4	119.1969	29.7992
	WITHIN CANOPIES	11	1301.4373	118.3125
	TOTAL	15	1420.6342	
3	BETWEEN CANOPIES	4	797.355	199.3388
	WITHIN CANOPIES	11	731.4226	66.4930
	TOTAL	15	1528.7776	
4	BETWEEN CANOPIES	4	751.2375	187.8094
	WITHIN CANOPIES	11	1251.8321	113.8029
	TOTAL	15	2003.0696	
5	BETWEEN CANOPIES	4	503.7569	125.9392
	WITHIN CANOPIES	11	949.3077	86.3007
	TOTAL	15	1453.0646	

ALERT - CONTACT DATA — SIGNIFICANCE TESTS

CASES OF SIGNIFICANT INTERACTION

TRAJECTORY 4 — TABLE 4-11A

GUNNER	$F_{.10}$ (D.F.)	F_i	SIGNIF.
1	2.18 (4,25)	2.3756	YES
2	2.18 (4,25)	2.8970	YES
3	2.18 (4,25)	4.1463	YES
4	2.18 (4,25)	2.6897	YES
5	2.18 (4,25)	6.1804	YES

TRAJECTORY 6 — TABLE 4-11B

GUNNER	$F_{.10}$ (D.F.)	F_i	SIGNIF.
1	2.54 (4,11)	1.1853	NO
2	2.54 (4,11)	0.2519	NO
3	2.54 (4,11)	2.9979	YES
4	2.54 (4,11)	1.6503	NO
5	2.54 (4,11)	1.4593	NO

utilizing the t-test method. Results of these tests are contained in the following subsection, Table 4-28. Care must be exercised in the interpretation of these significance test findings because of their hypothetical basis. Nonetheless, they do provide additional insight into the probable areas of the mean discrepancies.

Based on results of the tests contained in Tables 4-8, 4-11A, and 4-11B, we conclude that no significant difference (10 percent significance level) exists between any of the canopies for all short range ALERT and zero offset long range ALERT target conditions tested. Differences apparent for the two kilometer offset long range ALERT test conditions are felt to be marginally significant at gunner levels 1 and 4 of trajectory 4 and at gunner level 3 of trajectory 6 as the null hypothesis cannot be rejected at the 5 percent level in these cases. From an overall visual acquisition standpoint, we must conclude, as analysis of test data supports, that over the range of gunners employed, no conclusive difference exists between any of the test canopies.

4.1.2 TRACKING/REACQUISITION PERFORMANCE

A measure of the various gunner/canopy combinations' ability to complete the target engagement test was evaluated in two parts, the first component being the time delay between gunner CONTACT and TRACKING indications and the second, the delay involved in reacquiring the target aircraft after zero offset crossover. Raw test data were screened and compiled (see Appendix C) for consolidation into the matrix-analysis format. The results of analyses are given in Tables 4-12 through 4-17 and 4-18 for CONTACT-TRACKING and REACQUISITION data, respectively. It should be noted that while CONTACT-TRACKING data was treated by individual trajectory, the REACQUISITION data sample was a consolidation of trajectory 1 and 3 data. This grouping was desirable because of the existence of a zero-cell condition (no data points for one (i,j)) in the trajectory 3

CONTACT - TRACKING DATA -- TRAJECTORY 1 - TABLE 4-12

CANOPY (j)

GUNNER (i)	1	2	3	4	5	
	$x_{11} = 12.3$	$x_{12} = 13.1$	$x_{13} = 7.1$	$x_{14} = 9.8$	$x_{15} = 10.4$	$x_{1\cdot} = 52.7$
1	$\bar{x}_{11} = 3.075$	$\bar{x}_{12} = 3.275$	$\bar{x}_{13} = 1.775$	$\bar{x}_{14} = 3.267$	$\bar{x}_{15} = 2.6$	$\bar{x}_{1\cdot} = 2.7737$
	$n_{11} = 4$	$n_{12} = 4$	$n_{13} = 4$	$n_{14} = 3$	$n_{15} = 4$	$n_{1\cdot} = 19$
	$x_{21} = 6.3$	$x_{22} = 3.9$	$x_{23} = 3.9$	$x_{24} = 9.5$	$x_{25} = 5.8$	$x_{2\cdot} = 29.4$
2	$\bar{x}_{21} = 1.575$	$\bar{x}_{22} = 1.3$	$\bar{x}_{23} = 0.975$	$\bar{x}_{24} = 2.375$	$\bar{x}_{25} = 1.45$	$\bar{x}_{2\cdot} = 1.5474$
	$n_{21} = 4$	$n_{22} = 3$	$n_{23} = 4$	$n_{24} = 4$	$n_{25} = 4$	$n_{2\cdot} = 19$
	$x_{31} = 1.5$	$x_{32} = 9.8$	$x_{33} = 3.4$	$x_{34} = 10.7$	$x_{35} = 2.3$	$x_{3\cdot} = 27.7$
3	$\bar{x}_{31} = 0.75$	$\bar{x}_{32} = 2.45$	$\bar{x}_{33} = 0.85$	$\bar{x}_{34} = 2.675$	$\bar{x}_{35} = 0.767$	$\bar{x}_{3\cdot} = 1.6294$
	$n_{31} = 2$	$n_{32} = 4$	$n_{33} = 4$	$n_{34} = 4$	$n_{35} = 3$	$n_{3\cdot} = 17$
	$x_{41} = 4.9$	$x_{42} = 9.9$	$x_{43} = 6.0$	$x_{44} = 5.7$	$x_{45} = 5.4$	$x_{4\cdot} = 31.9$
4	$\bar{x}_{41} = 1.633$	$\bar{x}_{42} = 2.475$	$\bar{x}_{43} = 1.5$	$\bar{x}_{44} = 1.425$	$\bar{x}_{45} = 1.35$	$\bar{x}_{4\cdot} = 1.6789$
	$n_{41} = 3$	$n_{42} = 4$	$n_{43} = 4$	$n_{44} = 4$	$n_{45} = 4$	$n_{4\cdot} = 19$
	$x_{51} = 5.8$	$x_{52} = 12.6$	$x_{53} = 7.1$	$x_{54} = 6.6$	$x_{55} = 16.0$	$x_{5\cdot} = 48.1$
5	$\bar{x}_{51} = 2.9$	$\bar{x}_{52} = 3.15$	$\bar{x}_{53} = 2.367$	$\bar{x}_{54} = 1.65$	$\bar{x}_{55} = 4.0$	$\bar{x}_{5\cdot} = 2.8294$
	$n_{51} = 2$	$n_{52} = 4$	$n_{53} = 3$	$n_{54} = 4$	$n_{55} = 4$	$n_{5\cdot} = 17$
	$x_{\cdot 1} = 30.8$	$x_{\cdot 2} = 49.3$	$x_{\cdot 3} = 27.5$	$x_{\cdot 4} = 42.3$	$x_{\cdot 5} = 39.9$	$x_{\cdot\cdot} = 189.8$
	$\bar{x}_{\cdot 1} = 2.0533$	$\bar{x}_{\cdot 2} = 2.5947$	$\bar{x}_{\cdot 3} = 1.4474$	$\bar{x}_{\cdot 4} = 2.2263$	$\bar{x}_{\cdot 5} = 2.1$	$\bar{x}_{\cdot\cdot} = 2.0857$
	$n_{\cdot 1} = 15$	$n_{\cdot 2} = 19$	$n_{\cdot 3} = 19$	$n_{\cdot 4} = 19$	$n_{\cdot 5} = 19$	$n_{\cdot\cdot} = 91$

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4					4	GUNNERS ignoring CANOPIES
INTERACTION	16	27.3684	1.7105	1.7105	27.3684	16	INTERACTION
GUNNERS	4					4	CANOPIES
BETWEEN cells	24	69.8149			69.8149	24	
WITHIN cells	66	60.2560	.9130				
TOTAL	90	130.0709					

CONTACT - TRACKING DATA -- TRAJECTORY 2 - TABLE 4-13

CANOPY (j)

GUNNER (i)	1	2	3	4	5	
1	$x_{11} = 7.6$ $\bar{x}_{11} = 2.533$ $n_{11} = 3$	$x_{12} = 10.9$ $\bar{x}_{12} = 2.725$ $n_{12} = 4$	$x_{13} = 7.8$ $\bar{x}_{13} = 1.95$ $n_{13} = 4$	$x_{14} = 5.4$ $\bar{x}_{14} = 2.7$ $n_{14} = 2$	$x_{15} = 6.6$ $\bar{x}_{15} = 2.2$ $n_{15} = 3$	$x_{1.} = 38.3$ $\bar{x}_{1.} = 2.3938$ $n_{1.} = 16$
2	$x_{21} = 5.4$ $\bar{x}_{21} = 1.35$ $n_{21} = 4$	$x_{22} = 1.7$ $\bar{x}_{22} = 0.85$ $n_{22} = 2$	$x_{23} = 3.5$ $\bar{x}_{23} = 1.167$ $n_{23} = 3$	$x_{24} = 8.9$ $\bar{x}_{24} = 2.967$ $n_{24} = 3$	$x_{25} = 6.0$ $\bar{x}_{25} = 1.5$ $n_{25} = 4$	$x_{2.} = 25.5$ $\bar{x}_{2.} = 1.5938$ $n_{2.} = 16$
3	$x_{31} = 0.9$ $\bar{x}_{31} = 0.9$ $n_{31} = 1$	$x_{32} = 6.3$ $\bar{x}_{32} = 2.1$ $n_{32} = 3$	$x_{33} = 3.1$ $\bar{x}_{33} = 0.775$ $n_{33} = 4$	$x_{34} = 5.3$ $\bar{x}_{34} = 1.325$ $n_{34} = 4$	$x_{35} = 1.3$ $\bar{x}_{35} = 0.65$ $n_{35} = 2$	$x_{3.} = 16.9$ $\bar{x}_{3.} = 1.2071$ $n_{3.} = 14$
4	$x_{41} = 3.9$ $\bar{x}_{41} = 1.95$ $n_{41} = 2$	$x_{42} = 4.7$ $\bar{x}_{42} = 1.567$ $n_{42} = 3$	$x_{43} = 7.8$ $\bar{x}_{43} = 2.6$ $n_{43} = 3$	$x_{44} = 8.0$ $\bar{x}_{44} = 2.0$ $n_{44} = 4$	$x_{45} = 7.0$ $\bar{x}_{45} = 1.75$ $n_{45} = 4$	$x_{4.} = 31.4$ $\bar{x}_{4.} = 1.9625$ $n_{4.} = 16$
5	$x_{51} = 12.4$ $\bar{x}_{51} = 6.2$ $n_{51} = 2$	$x_{52} = 8.6$ $\bar{x}_{52} = 2.15$ $n_{52} = 4$	$x_{53} = 4.2$ $\bar{x}_{53} = 2.1$ $n_{53} = 2$	$x_{54} = 5.3$ $\bar{x}_{54} = 1.767$ $n_{54} = 3$	$x_{55} = 11.8$ $\bar{x}_{55} = 3.933$ $n_{55} = 3$	$x_{5.} = 42.3$ $\bar{x}_{5.} = 3.0214$ $n_{5.} = 14$
	$x_{.1} = 30.2$ $\bar{x}_{.1} = 2.5167$ $n_{.1} = 12$	$x_{.2} = 32.2$ $\bar{x}_{.2} = 2.0125$ $n_{.2} = 16$	$x_{.3} = 26.4$ $\bar{x}_{.3} = 1.65$ $n_{.3} = 16$	$x_{.4} = 32.9$ $\bar{x}_{.4} = 2.0563$ $n_{.4} = 16$	$x_{.5} = 32.7$ $\bar{x}_{.5} = 2.0438$ $n_{.5} = 16$	$x_{..} = 154.4$ $\bar{x}_{..} = 2.0316$ $n_{..} = 76$

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4					4	GUNNERS ignoring CANOPIES
INTERACTION	16	42.6807	2.6675	2.6675	42.6807	16	INTERACTION
GUNNERS	4					4	CANOPIES
BETWEEN cells	24	75.5835			75.5835	24	
WITHIN cells	51	26.8210	.5259				
TOTAL	75	102.4045					

CONTACT - TRACKING DATA -- TRAJECTORY 3 - TABLE 4-14

CANOPY (j)

GUNNER (i)	1	2	3	4	5	
1	$x_{11} = 29.8$ $\bar{x}_{11} = 4.967$ $n_{11} = 6$	$x_{12} = 29.0$ $\bar{x}_{12} = 3.625$ $n_{12} = 8$	$x_{13} = 24.7$ $\bar{x}_{13} = 2.744$ $n_{13} = 9$	$x_{14} = 16.3$ $\bar{x}_{14} = 2.717$ $n_{14} = 6$	$x_{15} = 23.9$ $\bar{x}_{15} = 3.414$ $n_{15} = 7$	$x_{1.} = 123.7$ $\bar{x}_{1.} = 3.436$ $n_{1.} = 36$
2	$x_{21} = 17.1$ $\bar{x}_{21} = 2.138$ $n_{21} = 8$	$x_{22} = 8.5$ $\bar{x}_{22} = 1.214$ $n_{22} = 7$	$x_{23} = 22.2$ $\bar{x}_{23} = 3.171$ $n_{23} = 7$	$x_{24} = 20.5$ $\bar{x}_{24} = 3.417$ $n_{24} = 6$	$x_{25} = 20.8$ $\bar{x}_{25} = 2.6$ $n_{25} = 8$	$x_{2.} = 89.1$ $\bar{x}_{2.} = 2.475$ $n_{2.} = 36$
3	$x_{31} = 8.8$ $\bar{x}_{31} = 1.257$ $n_{31} = 7$	$x_{32} = 27.8$ $\bar{x}_{32} = 4.633$ $n_{32} = 6$	$x_{33} = 16.4$ $\bar{x}_{33} = 2.05$ $n_{33} = 8$	$x_{34} = 20.6$ $\bar{x}_{34} = 2.06$ $n_{34} = 10$	$x_{35} = 10.1$ $\bar{x}_{35} = 1.683$ $n_{35} = 6$	$x_{3.} = 83.7$ $\bar{x}_{3.} = 2.262$ $n_{3.} = 37$
4	$x_{41} = 12.7$ $\bar{x}_{41} = 1.814$ $n_{41} = 7$	$x_{42} = 16.7$ $\bar{x}_{42} = 2.386$ $n_{42} = 7$	$x_{43} = 11.1$ $\bar{x}_{43} = 2.22$ $n_{43} = 5$	$x_{44} = 20.7$ $\bar{x}_{44} = 2.588$ $n_{44} = 8$	$x_{45} = 17.8$ $\bar{x}_{45} = 1.78$ $n_{45} = 10$	$x_{4.} = 79.0$ $\bar{x}_{4.} = 2.135$ $n_{4.} = 37$
5	$x_{51} = 54.1$ $\bar{x}_{51} = 6.763$ $n_{51} = 8$	$x_{52} = 55.3$ $\bar{x}_{52} = 5.53$ $n_{52} = 10$	$x_{53} = 41.4$ $\bar{x}_{53} = 6.9$ $n_{53} = 6$	$x_{54} = 56.7$ $\bar{x}_{54} = 8.1$ $n_{54} = 7$	$x_{55} = 28.0$ $\bar{x}_{55} = 4.667$ $n_{55} = 6$	$x_{5.} = 235.5$ $\bar{x}_{5.} = 6.365$ $n_{5.} = 37$
	$x_{.1} = 122.5$ $\bar{x}_{.1} = 3.403$ $n_{.1} = 36$	$x_{.2} = 137.3$ $\bar{x}_{.2} = 3.613$ $n_{.2} = 38$	$x_{.3} = 115.8$ $\bar{x}_{.3} = 3.309$ $n_{.3} = 35$	$x_{.4} = 134.8$ $\bar{x}_{.4} = 3.643$ $n_{.4} = 37$	$x_{.5} = 100.6$ $\bar{x}_{.5} = 2.719$ $n_{.5} = 37$	$x_{..} = 611.0$ $\bar{x}_{..} = 3.3388$ $n_{..} = 183$

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4					4	GUNNERS ignoring CANOPIES
INTERACTION	16	125.0859	7.8179	7.8179	125.0859	16	INTERACTION
GUNNERS	4					4	CANOPIES
BETWEEN cells	24	601.1500			601.1500	24	
WITHIN cells	158	455.3728	2.8821				
TOTAL	182	1056.5228					

CONTACT - TRACKING DATA -- TRAJECTORY 4 - TABLE 4-15

CANOPY (j)

GUNNER (i)	1	2	3	4	5	
1	$x_{11} = 26.1$ $\bar{x}_{11} = 4.35$ $n_{11} = 6$	$x_{12} = 27.5$ $\bar{x}_{12} = 3.929$ $n_{12} = 7$	$x_{13} = 23.7$ $\bar{x}_{13} = 2.37$ $n_{13} = 10$	$x_{14} = 26.3$ $\bar{x}_{14} = 3.288$ $n_{14} = 8$	$x_{15} = 19.1$ $\bar{x}_{15} = 2.729$ $n_{15} = 7$	$x_{1.} = 122.7$ $\bar{x}_{1.} = 3.2289$ $n_{1.} = 38$
2	$x_{21} = 22.4$ $\bar{x}_{21} = 2.24$ $n_{21} = 10$	$x_{22} = 11.2$ $\bar{x}_{22} = 1.6$ $n_{22} = 7$	$x_{23} = 13.8$ $\bar{x}_{23} = 1.971$ $n_{23} = 7$	$x_{24} = 12.0$ $\bar{x}_{24} = 2.4$ $n_{24} = 5$	$x_{25} = 16.1$ $\bar{x}_{25} = 2.013$ $n_{25} = 8$	$x_{2.} = 75.5$ $\bar{x}_{2.} = 2.0405$ $n_{2.} = 37$
3	$x_{31} = 4.4$ $\bar{x}_{31} = 0.629$ $n_{31} = 7$	$x_{32} = 29.3$ $\bar{x}_{32} = 4.883$ $n_{32} = 6$	$x_{33} = 14.4$ $\bar{x}_{33} = 2.057$ $n_{33} = 7$	$x_{34} = 25.4$ $\bar{x}_{34} = 2.822$ $n_{34} = 9$	$x_{35} = 8.9$ $\bar{x}_{35} = 1.271$ $n_{35} = 7$	$x_{3.} = 82.4$ $\bar{x}_{3.} = 2.2889$ $n_{3.} = 36$
4	$x_{41} = 17.4$ $\bar{x}_{41} = 2.175$ $n_{41} = 8$	$x_{42} = 15.0$ $\bar{x}_{42} = 2.143$ $n_{42} = 7$	$x_{43} = 13.1$ $\bar{x}_{43} = 2.183$ $n_{43} = 6$	$x_{44} = 12.1$ $\bar{x}_{44} = 1.513$ $n_{44} = 8$	$x_{45} = 18.8$ $\bar{x}_{45} = 1.88$ $n_{45} = 10$	$x_{4.} = 76.4$ $\bar{x}_{4.} = 1.9590$ $n_{4.} = 39$
5	$x_{51} = 38.5$ $\bar{x}_{51} = 6.417$ $n_{51} = 6$	$x_{52} = 45.8$ $\bar{x}_{52} = 4.58$ $n_{52} = 10$	$x_{53} = 35.5$ $\bar{x}_{53} = 5.071$ $n_{53} = 7$	$x_{54} = 63.4$ $\bar{x}_{54} = 9.057$ $n_{54} = 7$	$x_{55} = 31.7$ $\bar{x}_{55} = 5.283$ $n_{55} = 6$	$x_{5.} = 214.9$ $\bar{x}_{5.} = 5.9694$ $n_{5.} = 36$
	$x_{.1} = 108.8$ $\bar{x}_{.1} = 2.9405$ $n_{.1} = 37$	$x_{.2} = 128.8$ $\bar{x}_{.2} = 3.4811$ $n_{.2} = 37$	$x_{.3} = 100.5$ $\bar{x}_{.3} = 2.7162$ $n_{.3} = 37$	$x_{.4} = 139.2$ $\bar{x}_{.4} = 3.7622$ $n_{.4} = 37$	$x_{.5} = 94.6$ $\bar{x}_{.5} = 2.4895$ $n_{.5} = 38$	$x_{..} = 571.9$ $\bar{x}_{..} = 3.0747$ $n_{..} = 186$

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4					4	GUNNERS ignoring CANOPIES
INTERACTION	16	159.7172	9.9823	9.9823	159.7172	16	INTERACTION
GUNNERS	4					4	CANOPIES
BETWEEN cells	24	603.6498			603.6498	24	
WITHIN cells	161	451.2218	2.8026				
TOTAL	185	1054.8716					

CONTACT - TRACKING DATA -- TRAJECTORY 5 - TABLE 4-16

CANOPY (j)

GUNNER (i)	1	2	3	4	5	
1	$x_{11} = 31.9$	$x_{12} = 32.5$	$x_{13} = 16.4$	$x_{14} = 11.0$	$x_{15} = 23.3$	$x_{1\cdot} = 115.1$
	$\bar{x}_{11} = 4.557$	$\bar{x}_{12} = 4.063$	$\bar{x}_{13} = 2.343$	$\bar{x}_{14} = 2.75$	$\bar{x}_{15} = 2.9125$	$\bar{x}_{1\cdot} = 3.3853$
	$n_{11} = 7$	$n_{12} = 8$	$n_{13} = 7$	$n_{14} = 4$	$n_{15} = 8$	$n_{1\cdot} = 34$
2	$x_{21} = 12.2$	$x_{22} = 8.1$	$x_{23} = 9.4$	$x_{24} = 22.1$	$x_{25} = 12.7$	$x_{2\cdot} = 64.5$
	$\bar{x}_{21} = 2.44$	$\bar{x}_{22} = 2.025$	$\bar{x}_{23} = 1.343$	$\bar{x}_{24} = 3.157$	$\bar{x}_{25} = 2.54$	$\bar{x}_{2\cdot} = 2.3036$
	$n_{21} = 5$	$n_{22} = 4$	$n_{23} = 7$	$n_{24} = 7$	$n_{25} = 5$	$n_{2\cdot} = 28$
3	$x_{31} = 12.9$	$x_{32} = 24.0$	$x_{33} = 23.5$	$x_{34} = 21.5$	$x_{35} = 4.1$	$x_{3\cdot} = 86.0$
	$\bar{x}_{31} = 1.613$	$\bar{x}_{32} = 3.429$	$\bar{x}_{33} = 2.938$	$\bar{x}_{34} = 2.389$	$\bar{x}_{35} = 1.025$	$\bar{x}_{3\cdot} = 2.3889$
	$n_{31} = 8$	$n_{32} = 7$	$n_{33} = 8$	$n_{34} = 9$	$n_{35} = 4$	$n_{3\cdot} = 36$
4	$x_{41} = 9.6$	$x_{42} = 15.9$	$x_{43} = 20.2$	$x_{44} = 15.9$	$x_{45} = 14.2$	$x_{4\cdot} = 75.8$
	$\bar{x}_{41} = 2.4$	$\bar{x}_{42} = 1.988$	$\bar{x}_{43} = 2.886$	$\bar{x}_{44} = 1.9875$	$\bar{x}_{45} = 2.029$	$\bar{x}_{4\cdot} = 2.2294$
	$n_{41} = 4$	$n_{42} = 8$	$n_{43} = 7$	$n_{44} = 8$	$n_{45} = 7$	$n_{4\cdot} = 34$
5	$x_{51} = 40.2$	$x_{52} = 19.7$	$x_{53} = 35.2$	$x_{54} = 35.5$	$x_{55} = 46.0$	$x_{5\cdot} = 176.6$
	$\bar{x}_{51} = 8.04$	$\bar{x}_{52} = 3.94$	$\bar{x}_{53} = 8.8$	$\bar{x}_{54} = 4.438$	$\bar{x}_{55} = 6.571$	$\bar{x}_{5\cdot} = 6.0897$
	$n_{51} = 5$	$n_{52} = 5$	$n_{53} = 4$	$n_{54} = 8$	$n_{55} = 7$	$n_{5\cdot} = 29$
	$x_{\cdot 1} = 106.8$	$x_{\cdot 2} = 100.2$	$x_{\cdot 3} = 104.7$	$x_{\cdot 4} = 106.0$	$x_{\cdot 5} = 100.3$	$x_{\cdot\cdot} = 518$
	$\bar{x}_{\cdot 1} = 3.6828$	$\bar{x}_{\cdot 2} = 3.1313$	$\bar{x}_{\cdot 3} = 3.1727$	$\bar{x}_{\cdot 4} = 2.9444$	$\bar{x}_{\cdot 5} = 3.2355$	$\bar{x}_{\cdot\cdot} = 3.2174$
	$n_{\cdot 1} = 29$	$n_{\cdot 2} = 32$	$n_{\cdot 3} = 33$	$n_{\cdot 4} = 36$	$n_{\cdot 5} = 31$	$n_{\cdot\cdot} = 161$

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4					4	GUNNERS ignoring CANOPIES
INTERACTION	16	145.9203	9.1200	9.1200	145.9203	16	INTERACTION
GUNNERS	4					4	CANOPIES
BETWEEN cells	24	479.5737			479.5737	24	
WITHIN cells	136	605.0378	4.4488				
TOTAL	160	1084.6115					

CONTACT - TRACKING DATA -- TRAJECTORY 6 - TABLE 4-17

CANOPY (j)

GUNNER (i)	1	2	3	4	5	
1	x_{11} = 30.8 $\bar{x}_{11}$ = 4.4 n_{11} = 7	x_{12} = 30.0 $\bar{x}_{12}$ = 4.286 n_{12} = 7	x_{13} = 17.2 $\bar{x}_{13}$ = 2.457 n_{13} = 7	x_{14} = 11.0 $\bar{x}_{14}$ = 2.75 n_{14} = 4	x_{15} = 9.2 $\bar{x}_{15}$ = 3.067 n_{15} = 3	$x_{1\cdot}$ = 98.2 $\bar{x}_{1\cdot}$ = 3.5071 $n_{1\cdot}$ = 28
2	x_{21} = 15.5 $\bar{x}_{21}$ = 2.214 n_{21} = 7	x_{22} = 4.7 $\bar{x}_{22}$ = 1.175 n_{22} = 4	x_{23} = 3.9 $\bar{x}_{23}$ = 1.3 n_{23} = 3	x_{24} = 21.3 $\bar{x}_{24}$ = 3.043 n_{24} = 7	x_{25} = 31.1 $\bar{x}_{25}$ = 4.443 n_{25} = 7	$x_{2\cdot}$ = 76.5 $\bar{x}_{2\cdot}$ = 2.7321 $n_{2\cdot}$ = 28
3	x_{31} = 4.5 $\bar{x}_{31}$ = 1.125 n_{31} = 4	x_{32} = 20.5 $\bar{x}_{32}$ = 2.929 n_{32} = 7	x_{33} = 10.8 $\bar{x}_{33}$ = 1.35 n_{33} = 8	x_{34} = 8.3 $\bar{x}_{34}$ = 1.186 n_{34} = 7	x_{35} = 5.6 $\bar{x}_{35}$ = 1.40 n_{35} = 4	$x_{3\cdot}$ = 49.7 $\bar{x}_{3\cdot}$ = 1.6567 $n_{3\cdot}$ = 30
4	x_{41} = 7.9 $\bar{x}_{41}$ = 1.975 n_{41} = 4	x_{42} = 6.4 $\bar{x}_{42}$ = 1.6 n_{42} = 4	x_{43} = 15.2 $\bar{x}_{43}$ = 2.533 n_{43} = 6	x_{44} = 14.3 $\bar{x}_{44}$ = 2.043 n_{44} = 7	x_{45} = 10.9 $\bar{x}_{45}$ = 1.817 n_{45} = 6	$x_{4\cdot}$ = 54.7 $\bar{x}_{4\cdot}$ = 2.0259 $n_{4\cdot}$ = 27
5	x_{51} = 44.5 $\bar{x}_{51}$ = 5.563 n_{51} = 8	x_{52} = 22.0 $\bar{x}_{52}$ = 3.667 n_{52} = 6	x_{53} = 17.3 $\bar{x}_{53}$ = 5.767 n_{53} = 3	x_{54} = 13.0 $\bar{x}_{54}$ = 4.333 n_{54} = 3	x_{55} = 21.0 $\bar{x}_{55}$ = 5.25 n_{55} = 4	$x_{5\cdot}$ = 117.8 $\bar{x}_{5\cdot}$ = 4.9083 $n_{5\cdot}$ = 24
	$x_{\cdot 1}$ = 103.2 $\bar{x}_{\cdot 1}$ = 3.44 $n_{\cdot 1}$ = 30	$x_{\cdot 2}$ = 83.6 $\bar{x}_{\cdot 2}$ = 2.9857 $n_{\cdot 2}$ = 28	$x_{\cdot 3}$ = 64.4 $\bar{x}_{\cdot 3}$ = 2.3852 $n_{\cdot 3}$ = 27	$x_{\cdot 4}$ = 67.9 $\bar{x}_{\cdot 4}$ = 2.425 $n_{\cdot 4}$ = 28	$x_{\cdot 5}$ = 77.8 $\bar{x}_{\cdot 5}$ = 3.2417 $n_{\cdot 5}$ = 24	$x_{\cdot\cdot}$ = 396.9 $\bar{x}_{\cdot\cdot}$ = 2.8971 $n_{\cdot\cdot}$ = 137

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4					4	GUNNERS ignoring CANOPIES
INTERACTION	16	84.0427	5.2527	5.2527	84.0427	16	INTERACTION
GUNNERS	4					4	CANOPIES
BETWEEN cells	24	268.1262			268.1262	24	
WITHIN cells	112	330.8715	2.9542				
TOTAL	136	598.9977					

REACQUISITION DATA -- TRAJECTORIES 1 AND 3 - TABLE 4-18

CANOPY (j)

GUNNER (i)	1	2	3	4	5	
1	$x_{11} = 39.3$ $\bar{x}_{11} = 4.367$ $n_{11} = 9$	$x_{12} = 73.9$ $\bar{x}_{12} = 6.158$ $n_{12} = 12$	$x_{13} = 62.9$ $\bar{x}_{13} = 4.493$ $n_{13} = 14$	$x_{14} = 36.5$ $\bar{x}_{14} = 4.056$ $n_{14} = 9$	$x_{15} = 49.3$ $\bar{x}_{15} = 4.482$ $n_{15} = 11$	$x_{1\cdot} = 261.9$ $\bar{x}_{1\cdot} = 4.7618$ $n_{1\cdot} = 55$
2	$x_{21} = 54.1$ $\bar{x}_{21} = 4.508$ $n_{21} = 12$	$x_{22} = 36.5$ $\bar{x}_{22} = 4.056$ $n_{22} = 9$	$x_{23} = 47.6$ $\bar{x}_{23} = 4.76$ $n_{23} = 10$	$x_{24} = 41.5$ $\bar{x}_{24} = 4.611$ $n_{24} = 9$	$x_{25} = 50$ $\bar{x}_{25} = 4.546$ $n_{25} = 11$	$x_{2\cdot} = 229.7$ $\bar{x}_{2\cdot} = 4.5039$ $n_{2\cdot} = 51$
3	$x_{31} = 52.2$ $\bar{x}_{31} = 5.8$ $n_{31} = 9$	$x_{32} = 36.9$ $\bar{x}_{32} = 4.613$ $n_{32} = 8$	$x_{33} = 58.6$ $\bar{x}_{33} = 4.883$ $n_{33} = 12$	$x_{34} = 51.6$ $\bar{x}_{34} = 3.686$ $n_{34} = 14$	$x_{35} = 33.9$ $\bar{x}_{35} = 3.767$ $n_{35} = 9$	$x_{3\cdot} = 233.2$ $\bar{x}_{3\cdot} = 4.4846$ $n_{3\cdot} = 52$
4	$x_{41} = 14$ $\bar{x}_{41} = 2.333$ $n_{41} = 6$	$x_{42} = 39.2$ $\bar{x}_{42} = 3.92$ $n_{42} = 10$	$x_{43} = 32.9$ $\bar{x}_{43} = 3.656$ $n_{43} = 9$	$x_{44} = 7.3$ $\bar{x}_{44} = 3.65$ $n_{44} = 2$	$x_{45} = 48.8$ $\bar{x}_{45} = 3.486$ $n_{45} = 14$	$x_{4\cdot} = 142.2$ $\bar{x}_{4\cdot} = 3.4683$ $n_{4\cdot} = 41$
5	$x_{51} = 43.3$ $\bar{x}_{51} = 4.33$ $n_{51} = 10$	$x_{52} = 65.9$ $\bar{x}_{52} = 4.7071$ $n_{52} = 14$	$x_{53} = 46.2$ $\bar{x}_{53} = 4.62$ $n_{53} = 10$	$x_{54} = 44.7$ $\bar{x}_{54} = 4.064$ $n_{54} = 11$	$x_{55} = 45.0$ $\bar{x}_{55} = 5.625$ $n_{55} = 8$	$x_{5\cdot} = 245.1$ $\bar{x}_{5\cdot} = 4.6245$ $n_{5\cdot} = 53$
	$x_{\cdot 1} = 202.9$ $\bar{x}_{\cdot 1} = 4.4109$ $n_{\cdot 1} = 46$	$x_{\cdot 2} = 252.4$ $\bar{x}_{\cdot 2} = 4.7623$ $n_{\cdot 2} = 53$	$x_{\cdot 3} = 248.2$ $\bar{x}_{\cdot 3} = 4.5127$ $n_{\cdot 3} = 55$	$x_{\cdot 4} = 181.6$ $\bar{x}_{\cdot 4} = 4.0356$ $n_{\cdot 4} = 45$	$x_{\cdot 5} = 227$ $\bar{x}_{\cdot 5} = 4.283$ $n_{\cdot 5} = 53$	$x_{\cdot\cdot} = 1112.1$ $\bar{x}_{\cdot\cdot} = 4.4131$ $n_{\cdot\cdot} = 252$

TWO-WAY ANALYSIS

	D.F.	S.S.	M.S.	M.S.	S.S.	D.F.	
CANOPIES ignoring GUNNERS	4					4	GUNNERS ignoring CANOPIES
INTERACTION	16	67.3326	4.2083	4.2083	67.3326	16	INTERACTION
GUNNERS	4					4	CANOPIES
BETWEEN cells	24	133.9757			133.9757	24	
WITHIN cells	227	291.8629	1.2857				
TOTAL	251	425.8386					

sample, which would have necessitated use of significantly more complex analytical procedures. Justification for the grouping was obtained in that both classes of data (trajectories) were in essence identical, that is to say, once gunner tracking had been established, trajectory 1 characteristics became the same as those of trajectory 3 from the standpoint of crossover reacquisition of the common velocity, low altitude, zero offset target. Trajectory 5 REACQUISITION data was eliminated entirely from the analysis due to the preponderance of zero-cell conditions and lack of justification for grouping.

For each treatment of CONTRACT-TRACKING and REACQUISITION data, the hypothesis of zero interaction was rejected at the 10 percent significance level (see Tables 4-19 and 4-20). One-way analyses conducted at every level of the gunner factor for each treatment are shown in Tables 4-21 through 4-26 for CONTACT-TRACKING delay data and in Table 4-27 for REACQUISITION data. The results of F-tests (10 percent significance level) of the hypothesis that the differences between canopy means are zero are also given in these tables and can be seen to vary quite freely. Pair-wise comparison test results for cases of significant differences between canopy means at the individual gunner level are given in Table 4-28, broken down under TRACKING (CONTACT-TRACKING) and REACQUISITION headings. Again, interpretation of these significance test results must be guarded.

Based on the variability in occurrence of significant canopy differences shown in Tables 4-21 through 4-27, we submit that no conclusive evidence of CONTACT-TRACKING or REACQUISITION delay differences between the test canopies can be shown to exist.

4.2 GUNNER QUESTIONNAIRE SUMMARY

At the conclusion of each T-33 tracking sortie, all gunners completed a Mount Operator's Debriefing Questionnaire wherein they documented their comments

CONTACT - TRACKING DATA — SIGNIFICANCE TESTS - TABLE 4-19

TRAJ. NO.	INTERACTION		MAIN EFFECTS				
				GUNNER EFFECTS		CANOPY EFFECTS	
	$F_{.10}$ (D.F.)	F_{ACT} (SIGNIF.)	$F_{.10}$ (D.F.)	F_{GUN}	SIGNIF.	F_{CAN}	SIGNIF.
1	1.59 (16,66)	1.8735 (YES)	SEE TABLE 4-21				
2	1.63 (16,51)	5.0722 (YES)	SEE TABLE 4-22				
3	1.53 (16,158)	2.7126 (YES)	SEE TABLE 4-23				
4	1.53 (16,161)	3.5618 (YES)	SEE TABLE 4-24				
5	1.54 (16,136)	2.0500 (YES)	SEE TABLE 4-25				
6	1.56 (16,112)	1.7780 (YES)	SEE TABLE 4-26				

REACQUISITION DATA — SIGNIFICANCE TEST - TABLE 4-20

TRAJ. NO.	INTERACTION		MAIN EFFECTS				
				GUNNER EFFECTS		CANOPY EFFECTS	
	$F_{.10}$ (D.F.)	F_{ACT} (SIGNIF.)	$F_{.10}$ (D.F.)	F_{GUN}	SIGNIF.	F_{CAN}	SIGNIF.
1 & 3	1.95 (16,227)	3.2732 (YES)	SEE TABLE 4-27				

CONTACT - TRACKING DATA — TRAJECTORY 1 - TABLE 4-21

ONE-WAY ANALYSIS
(CASE OF SIGNIFICANT INTERACTION)

GUNNER	SOURCE	D.F.	S.S.	M.S.	$F_{.10}$ (D.F.) F_i	SIGNIF.
1	BETWEEN CANOPIES	4	6.2087	1.5522	2.39	YES
	WITHIN CANOPIES	14	7.6680	0.5477	(4,14)	
	TOTAL	18	13.8767		2.8340	
2	BETWEEN CANOPIES	4	4.2749	1.0687	2.39	NO
	WITHIN CANOPIES	14	7.5924	0.5423	(4,14)	
	TOTAL	18	11.8673		1.9706	
3	BETWEEN CANOPIES	4	13.2744	3.3186	2.48	NO
	WITHIN CANOPIES	12	23.3808	1.9484	(4,12)	
	TOTAL	16	36.6552		1.7032	
4	BETWEEN CANOPIES	4	3.3600	0.8400	2.39	NO
	WITHIN CANOPIES	14	9.0514	0.6465	(4,14)	
	TOTAL	18	12.4114		1.2992	
5	BETWEEN CANOPIES	4	12.1077	3.0269	2.48	YES
	WITHIN CANOPIES	12	12.5724	1.0477	(4,12)	
	TOTAL	16	24.6801		2.8891	

CONTACT - TRACKING DATA — TRAJECTORY 2 - TABLE 4-22

ONE-WAY ANALYSIS
(CASE OF SIGNIFICANT INTERACTION)

GUNNER	SOURCE	D.F.	S.S.	M.S.	$F_{.10}$ (D.F.) F_i	SIGNIF.
1	BETWEEN CANOPIES	4	1.5849	0.3962	2.54	YES
	WITHIN CANOPIES	11	1.0845	0.0986	(4,11)	
	TOTAL	15	2.6694		4.0186	
2	BETWEEN CANOPIES	4	7.5829	1.8957	2.54	YES
	WITHIN CANOPIES	11	3.7666	0.3424	(4,11)	
	TOTAL	15	11.3495		5.5362	
3	BETWEEN CANOPIES	4	3.9093	0.9773	2.69	YES
	WITHIN CANOPIES	9	2.2001	0.2444	(4,9)	
	TOTAL	13	6.1094		3.9979	
4	BETWEEN CANOPIES	4	1.8750	0.4688	2.54	NO
	WITHIN CANOPIES	11	5.0824	0.4620	(4,11)	
	TOTAL	15	6.9574		1.0146	
5	BETWEEN CANOPIES	4	32.1559	8.0390	2.69	YES
	WITHIN CANOPIES	9	14.6874	1.6319	(4,9)	
	TOTAL	13	46.8433		4.9260	

CONTACT - TRACKING DATA — TRAJECTORY 3 - TABLE 4-23

ONE-WAY ANALYSIS
(CASE OF SIGNIFICANT INTERACTION)

GUNNER	SOURCE	D.F.	S.S.	M.S.	$F_{.10}$ (D.F.) F_i	SIGNIF.
1	BETWEEN CANOPIES	4	21.7645	5.4411	2.14	YES
	WITHIN CANOPIES	31	12.9365	0.4174	(4,31)	
	TOTAL	35	34.7030		13.0367	
2	BETWEEN CANOPIES	4	20.8795	5.2199	2.14	NO
	WITHIN CANOPIES	31	77.6680	2.5054	(4,31)	
	TOTAL	35	98.5475		2.0834	
3	BETWEEN CANOPIES	4	43.5790	10.8948	2.13	YES
	WITHIN CANOPIES	32	42.5680	1.3302	(4,32)	
	TOTAL	36	86.1470		8.1900	
4	BETWEEN CANOPIES	4	4.1003	1.0251	2.13	YES
	WITHIN CANOPIES	32	12.6440	0.3951	(4,32)	
	TOTAL	36	16.7443		2.5944	
5	BETWEEN CANOPIES	4	48.3276	12.0819	2.13	NO
	WITHIN CANOPIES	32	316.4767	9.8899	(4,32)	
	TOTAL	36	364.8043		1.2216	

CONTACT - TRACKING DATA — TRAJECTORY 4 - TABLE 4-24

ONE-WAY ANALYSIS
(CASE OF SIGNIFICANT INTERACTION)

GUNNER	SOURCE	D.F.	S.S.	M.S.	$F_{.10}$ (D.F.) F_i	SIGNIF.
1	BETWEEN CANOPIES	4	20.1265	5.0316	2.13	YES
	WITHIN CANOPIES	33	28.2517	0.8561	(4,33)	
	TOTAL	37	48.3782		5.8773	
2	BETWEEN CANOPIES	4	2.4423	0.6106	2.13	NO
	WITHIN CANOPIES	32	38.1669	1.1927	(4,32)	
	TOTAL	36	40.6092		0.5119	
3	BETWEEN CANOPIES	4	69.8500	17.4625	2.14	YES
	WITHIN CANOPIES	31	43.6256	1.4073	(4,31)	
	TOTAL	35	113.4756		12.4087	
4	BETWEEN CANOPIES	4	2.5650	0.6412	2.12	YES
	WITHIN CANOPIES	34	6.2294	0.1832	(4,34)	
	TOTAL	38	8.7944		3.4997	
5	BETWEEN CANOPIES	4	95.7160	23.9290	2.14	YES
	WITHIN CANOPIES	31	334.9804	10.8058	(4,31)	
	TOTAL	35	430.6964		2.2144	

CONTACT - TRACKING DATA — TRAJECTORY 5 - TABLE 4-25

ONE-WAY ANALYSIS
(CASE OF SIGNIFICANT INTERACTION)

GUNNER	SOURCE	D.F.	S.S.	M.S.	$F_{.10}$ (D.F.) F_i	SIGNIF.
1	BETWEEN CANOPIES	4	24.2918	6.0730	2.15	YES
	WITHIN CANOPIES	29	54.9308	1.8942	(4,29)	
	TOTAL	33	79.2226		3.2062	
2	BETWEEN CANOPIES	4	12.2402	3.0600	2.21	YES
	WITHIN CANOPIES	23	23.8294	1.0361	(4,23)	
	TOTAL	27	36.0696		2.9535	
3	BETWEEN CANOPIES	4	22.2418	5.5604	2.14	NO
	WITHIN CANOPIES	31	220.3538	7.1082	(4,31)	
	TOTAL	35	242.5956		0.7822	
4	BETWEEN CANOPIES	4	4.3497	1.0874	2.15	NO
	WITHIN CANOPIES	29	23.5209	0.8111	(4,29)	
	TOTAL	33	27.8706		1.3407	
5	BETWEEN CANOPIES	4	94.9538	23.7384	2.19	NO
	WITHIN CANOPIES	24	282.4131	11.7672	(4,24)	
	TOTAL	28	377.3669		2.0173	

CONTACT - TRACKING DATA — TRAJECTORY 6 - TABLE 4-26

ONE-WAY ANALYSIS
(CASE OF SIGNIFICANT INTERACTION)

GUNNER	SOURCE	D.F.	S.S.	M.S.	$F_{.10}$ (D.F.) F_i	SIGNIF.
1	BETWEEN CANOPIES	4	20.4205	5.1050	2.21	NO
	WITHIN CANOPIES	23	68.8781	2.9947	(4,23)	
	TOTAL	27	89.2986		1.7047	
2	BETWEEN CANOPIES	4	38.8968	9.7242	2.21	NO
	WITHIN CANOPIES	23	117.0843	7.6993	(4,23)	
	TOTAL	27	215.9811		1.2630	
3	BETWEEN CANOPIES	4	15.0290	3.7573	2.18	YES
	WITHIN CANOPIES	25	7.7247	0.3090	(4,25)	
	TOTAL	29	22.7537		12.1600	
4	BETWEEN CANOPIES	4	2.5427	0.6357	2.22	YES
	WITHIN CANOPIES	22	4.1691	0.1895	(4,22)	
	TOTAL	26	6.7118		3.3545	
5	BETWEEN CANOPIES	4	16.3460	4.0865	2.27	NO
	WITHIN CANOPIES	19	72.9923	3.8417	(4,19)	
	TOTAL	23	89.3383		1.0637	

REACQUISITION DATA — TRAJECTORIES 1 AND 3 - TABLE 4-27

ONE-WAY ANALYSIS
(CASE OF SIGNIFICANT INTERACTION)

GUNNER	SOURCE	D.F.	S.S.	M.S.	$F_{.10}$ (D.F.) F_i	SIGNIF.
1	BETWEEN CANOPIES WITHIN CANOPIES	4 50	31.1514 90.9184	7.7878 1.8184	2.06 (4,50) 4.2828	YES
	TOTAL	54	122.0698			
2	BETWEEN CANOPIES WITHIN CANOPIES	4 46	2.5843 49.2149	0.6461 1.0699	2.07 (4,46) 0.6039	NO
	TOTAL	50	51.7992			
3	BETWEEN CANOPIES WITHIN CANOPIES	4 47	31.1723 72.3954	7.7931 1.5403	2.07 (4,47) 5.0595	YES
	TOTAL	51	103.5677			
4	BETWEEN CANOPIES WITHIN CANOPIES	4 36	10.1613 14.4475	2.5403 0.4013	2.11 (4,36) 6.3302	YES
	TOTAL	40	24.6088			
5	BETWEEN CANOPIES WITHIN CANOPIES	4 48	12.4268 65.1513	3.1067 1.3573	2.07 (4,48) 2.2889	YES
	TOTAL	54	77.5781			

SIGNIFICANCE TEST RESULTS - PAIRWISE - TABLE 4-28

	TRAJ NO.	GUNNER (row i)	SIGNIFICANT AT 5% LEVEL (1,3)	(2,3)	(4,3)	(5,3)
CONTACT	4	1	YES	NO	YES	NO
		2	YES	NO	NO	YES
		3	YES	NO	NO	NO
		4	NO	NO	NO	NO
		5	NO	YES	NO	YES
	6	3	NO	NO	NO	YES
TRACKING	1	1	YES	YES	YES	NO
		5	NO	NO	NO	YES
	2	1	NO	YES	NO	NO
		2	NO	NO	NO	NO
		3	NO	YES	YES	NO
		5	NO	NO	NO	NO
	3	1	YES	YES	NO	YES
		3	NO	YES	NO	NO
		4	NO	NO	NO	NO
	4	1	YES	YES	YES	NO
		3	YES	YES	NO	NO
		4	NO	NO	YES	NO
		5	NO	NO	NO	NO
	5	1	YES	YES	NO	NO
		2	YES	NO	YES	YES
	6	3	NO	YES	NO	NO
		4	NO	YES	NO	YES
REACQ	1 & 3	1	NO	YES	NO	NO
		3	NO	NO	YES	YES
		4	YES	NO	NO	NO
		5	NO	NO	NO	NO

regarding utilization of the subject canopy during the just completed aircraft tracking sortie. Additionally, at the conclusion of the final test sortie, the gunners were also asked to complete a Mount Operator's Final Debriefing Questionnaire wherein they were asked to consider all canopies (four breadboard units plus the standard), rank them in order of preference, and explain the reasons for their ranking. These Final Debriefing Forms and individual Personnel Profiles, are contained in Appendix D.

The following is a summation of gunner comments relating to the utilization of each breadboard canopy.

(a) Flat Plate. The primary criticism of the flat plate canopy was the internal reflection/glare. This unit perhaps received more negative evaluation due to the fact that the fire unit air conditioning system was defective. Although the gunners were exposed to direct sunlight, the primary discomfort was heat. These negative criticisms far out-weighed the gunner-expressed positive feature associated with the design, that of spaciousness which the gunners felt was a positive feature.

(b) Flat Plate With Grid Baffle. The only criticism of this canopy was a minor internal reflection/glare condition. Addition of the grid baffle element provided the gunner with a partially shaded environment which they considered to be most beneficial. The sense of more freedom of movement attributed to the increase in internal volume of this canopy was repeatedly mentioned.

(c) Cylindrical Grid Baffle. This canopy received the widest range of positive and negative criticism. Blockage of the gunner field-of-view was the primary negative response. This was brought about in part by an apparent mechanical misalignment condition which existed in the upper portions (high LOS deviation) of the baffle area. The degree of misalignment experienced was definitely a function of gunner opinion. Eye fatigue was experienced by some grid baffle fire unit gunners during the tracking sortie. The positive statements were all related to gunner comfort. The most commonly mentioned positive feature was again, the near total absence of glare.

(d) AR Coated. Positive comments relayed by the gunner participants were merely, as expected, reductions in the primary problem associated with the standard canopy; that of internal-reflection/glare. The gunners indicated that the reduction in this problem offered by the AR coated canopy was apparent but not substantial.

The individual gunner ranking of the five test canopies is stated within Appendix D. The combined weighted ranking of canopies by the gunner group is presented here in conclusion:

(1) Flat plate w/grid baffle.

(2) AR coated.

(3) Cylindrical grid baffle.

(4) Standard.

(5) Flat plate.

SECTION 5

5.0 SUMMARY

5.1 MATH MODEL PREDICTIONS

Final confirmation of the computer-predicted detection envelopes for the breadboard canopies was not accomplished. Verification of the sun glint signature data presented in this document was, however, partially completed, and was proven to be in excellent agreement with actual test observations. Assurances can indeed be given that the impact of the unresolved error factor in the modeling program, with regards to detectability of the glint signature for each of the breadboard canopies, would be small.

Math model predictions may be correlated in a relative sense to provide the following sun glint reduction ranking of the breadboard canopies in order of increasing signature:

(a) Flat plate with grid baffle

(b) Flat plate

(c) Cylindrical grid baffle

(d) AR coated

(e) Standard

Predictions regarding the glint signature characteristics of the spherical-shaped canopy clearly indicated that in terms of its directional nature and spatial coverage, the spherical canopy actually presented an increase in glint signature over the standard configuration canopy. For this reason, the spherical-shaped canopy was ranked below the standard canopy and was eliminated as a breadboard development concept.

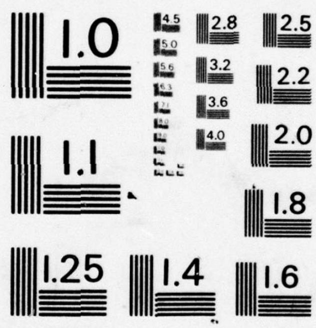
5.2 GUNNER/CANOPY PERFORMANCE EVALUATION

Consideration of performance data for all the categories of target acquisition data: ALERT-CONTACT, CONTACT-TRACKING, and REACQUISITION, leads to the judgment that all canopy designs are of equivalent performance. Based on the statistical analysis of the test data which indicates apparent marginal and variable statistical significance of canopy mean differences, it must be concluded that Phase II test data certainly does not support any preference between canopy designs.

AD-A034 360 AERONUTRONIC FORD CORP NEWPORT BEACH CALIF AERONUTR--ETC F/G 17/8
CHAPARRAL ANTI-GLINT CONCEPT DEMONSTRATION/FEASIBILITY EVALUATI--ETC(U)
NOV 76 DAAH01-76-C-0583
UNCLASSIFIED U-6282 NL

2 OF 2
AD
A034360

END
DATE
FILMED
2-77



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

SECTION 6

6.0 RECOMMENDATION

Based on the findings of the Concept Demonstration/Feasibility Evaluation Program with associated and supportive studies, Aeronutronic recommends the selection of the Flat Plate breadboard canopy concept for engineering model hardware development. Aeronutronic further recommends that early within the engineering model development phase, a limited hardware design study be completed for the purpose of refining canopy characteristics aimed at the reduction in or the elimination of the associated flat plate canopy internal reflection/glare. Preliminary studies in this area of internal reflection/glare reduction have already been conducted and have resulted in the design of the further optimized flat plate canopy concept shown in Figure 6-1.

The flat plate canopy recommendation is based on the fact that this concept presents one of the minimum spatial detection envelopes in conjunction with the least logistical impact (see Appendix E evaluation). Consideration of modification kit cost did not enter into the recommendation decision process. It is therefore urged that a comparative cost analysis be made addressing the standard and flat plate canopies.

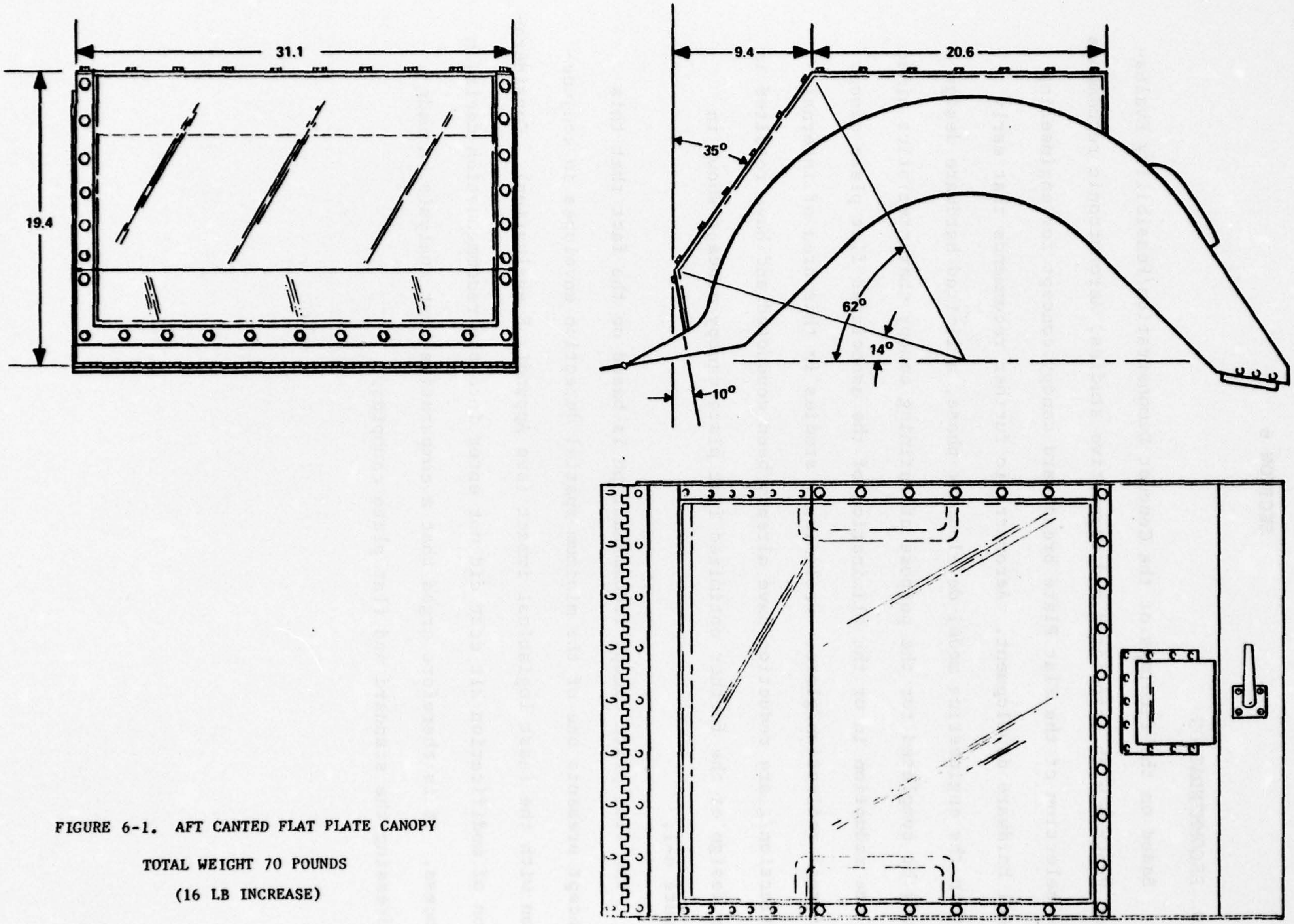


FIGURE 6-1. AFT CANTED FLAT PLATE CANOPY

TOTAL WEIGHT 70 POUNDS

(16 LB INCREASE)

APPENDIX A

BIBLIOGRAPHY OF LITERATURE SEARCH SOURCES

The following pertinent documents were utilized during studies conducted to determine the most viable sun glint reduction concepts applicable to canopy hardware development:

(1) Technical Report LWL-DR-06P72, Daumit, R.H. Kresel, J.B., Cobra Window Design Analysis and Noeglare Canopy Design, Westinghouse Defense and Electronic Systems Center, Systems Development Divison, Baltimore, Maryland, March 1974.

(2) Technical Report LWL-CR-06P73A, DeBenedictis, J.A., Woestman, J.W., Reduction of Reflections from Helicopter Windshields, Rotor Blades and Rotor Hub, Franklin Institute Research Laboratories, Philadelphia, Pennsylvania, April 1973.

(3) Test Report - MASSTER Test No. 1029, Material Test Directorate, Helicopter Disguise Evaluation, Ft. Hood, Texas, October 1972.

(4) Research Report CAMTEC-TR-1, Court, J.C. Trambull, H.E., The Development and Fabrication of Glare and Headlight Covers, Battelle Columbus Laboratories, Columbus, Ohio, November 1973.

(5) Interim Technical Report, ASE MOE, TR, SR and Associated Analyses (U), Work Unit #2 - Low Glare Canopy, Calspan, December 1974.

A significant number of additional documents in the form of journals and abstracts were consulted during the investigative process, but yielded no new conceptual findings.

APPENDIX B

PROCEDURE FOR ASSESSMENT OF

EFFECTS OF CANOPIES ON TARGET ACQUISITION

(1) Given total test data sample, determine valid data sample by applying the following criteria to individual runs of all sorties except those already eliminated on the basis of being a gunner learning process:

(a) Eliminate runs for which erroneous radar data exists (vectoring unconfirmed).

(b) Eliminate runs in which the target vectoring information was given early or late as defined below:

Short Range ALERT Cond (Nom. 5 km) -- 4 km $\leq R_s \leq$ 6 Km

R_s = Target ground range at short ALERT

Long Range ALERT Cond (Nom 10 k) -- 9 km $\leq R_L \leq$ 11 km

R_L = Target ground range at long ALERT.

(c) Eliminate runs in which vectoring information was erroneous as defined below (maximum Δ heading allowable 10^o):

Short ALERT

OFFSET (0) - $r_s \geq 1.0$ km

OFFSET (2 km) - $r_s \leq 1.5$ km

r_s = Target ground range (at crossover, short range ALERT cond.

Long ALERT

OFFSET (0) - $r_L \geq 1.0$ km

OFFSET (2 km) - 1.5 km $\leq r_L \geq$ 2.5 km.

r_L = Target ground range at crossover, Long Range ALERT cond.

(d) Eliminate runs in which any number of "NO CONTACTS" occurred (data bias).

(2) Perform the following analysis of variance for each class of data: (1) ALERT-CONTACT, (2) CONTACT-TRACKING, and (3) REACQUISITION at the individual trajectory matrix level.

<u>TYPE</u>: Two-way crossed classification with unequal numbers of observations in the cells (Type I Model).

<u>DEFINITION OF TERMS</u>:

η_{ij} = number of observations in the ijth cell

$X_{ij\eta}$ = nth observation in the ijth cell

X_{ij} = total of observations in the ijth cell

$\bar{X}_{ij}$ = ijth cell mean

$X_{i\cdot}$ = total of observations in the ith row

$X_{\cdot j}$ = total of observations in the jth column

$\eta_{i\cdot}$ = number of observations in the ith row

$\eta_{\cdot j}$ = number of observations in the jth column

$\bar{X}_{i\cdot}$ = ith row mean

$\bar{X}_{\cdot j}$ = jth column mean

$X_{\cdot\cdot}$ = total all observations

$\eta_{\cdot\cdot}$ = total number of observations

$\bar{X}_{\cdot\cdot}$ = grand mean

<u>COMPUTATION</u>:

(a) Compute terms of section II

(b) Calculate total sum-of-squares (TSS):

$$TSS = \sum_{ij\eta} (X_{ij\eta} - \bar{X}_{\cdot\cdot})^2$$

(c) Calculate total between-cells sum-of-squares (BSS):

$$\sum_{ij} (X_{ij}\bar{X}_{ij}) - X_{\cdot\cdot}\bar{X}_{\cdot\cdot} = BSS$$

(d) Calculate interaction sum-of-squares (ISS) as:

$$\sum_{ij} \frac{X_{ij}^{2}}{\eta_{ij}} - \sum_{i} a_{i} X_{i.} - \sum_{j} b_{j} X_{.j} = ISS$$

where a_i and b_j are obtained from solution of the simultaneous equations:

a_1	a_2	a_3	a_4	a_5	b_1	b_2	b_3	b_4	b_5		Marginal Total
$\eta_{1.}$	-	-	-	-	η_{11}	η_{12}	η_{13}	η_{14}	η_{15}	=	$X_{1.}$
-	$\eta_{2.}$	-	-	-	η_{21}	η_{22}	η_{23}	η_{24}	η_{25}	=	$X_{2.}$
-	-	$\eta_{3.}$	-	-	η_{31}	η_{32}	η_{33}	η_{34}	η_{35}	=	$X_{3.}$
-	-	-	$\eta_{4.}$	-	η_{41}	η_{42}	η_{43}	η_{44}	η_{45}	=	$X_{4.}$
-	-	-	-	$\eta_{5.}$	η_{51}	η_{52}	η_{53}	η_{54}	η_{55}	=	$X_{5.}$
η_{11}	η_{21}	η_{31}	η_{41}	η_{51}	$\eta_{.1}$	-	-	-	-	=	$X_{.1}$
η_{12}	η_{22}	η_{32}	η_{42}	η_{52}	-	$\eta_{.2}$	-	-	-	=	$X_{.2}$
η_{13}	η_{23}	η_{33}	η_{43}	η_{53}	-	-	$\eta_{.3}$	-	-	=	$X_{.3}$
η_{14}	η_{24}	η_{34}	η_{44}	η_{54}	-	-	-	$\eta_{.4}$	-	=	$X_{.4}$
η_{15}	η_{25}	η_{35}	η_{45}	η_{55}	-	-	-	-	$\eta_{.5}$	=	$X_{.5}$

(e) Test significance of interaction by computing the quotient F of the interaction mean square (MS) by the within-cells or residual MS (RMS).

$$F_{act} = \frac{IMS}{RMS}$$

where the interaction MS (IMS) = ISS/16 (d.f.)

and

$RMS = (TSS - BSS)/[(\eta_{..} - 1) - 24]$ (d.f.)

and comparing to F-distribution with degrees of freedom (d.f.) being $(16, (\eta_{..} - 1) - 24)$ for a significance level of $\alpha = .10$

(f) If F_{act} test shows interaction present, refer to step h below. If test shows interaction to be not significant, compute main effects between classes of both factors (CANOPIES & GUNNERS) by calculating the SS's,

$$\sum_j (X._j X._j) - X..\overline{X}.. = CSS \quad \text{(CANOPIES)}$$

and

$$\sum_i (X_i.X_i.) - X..\overline{X}.. = GSS \quad \text{(GUNNERS)}$$

then

SSG = BSS - CSS - ISS

(SS between GUNNERS)

and

SSC = BSS - GSS - ISS

(SS between CANOPIES)

(g) Test significance of main effects by computing the F quotients (variance ratios):

$$F_{can} = \frac{CMS}{ZMS}$$

and

$$F_{gun} = \frac{GMS}{ZMS}$$

where

CMS = SSC/4 (d.f.),

GMS = SSG/4 (d.f.),

and where ZMS =

(RSS + ISS)/(η.. - 9) (d.f.)

by comparing to F-distribution with d.f.'s being (4, η.. - 9) for the significance level of $\alpha = .10$.

(h) If F_{act} test shows interaction to be significant, or if CANOPY effects are significant, perform one-way analysis on CANOPIES for each GUNNER (row i) as follows:

(1) Calculate TSS_i,

$$TSS_i = \sum_{ij\eta} (X_{ij\eta} - \overline{X}_{i}.)^2$$

(2) If $\eta_{13} = \eta_{ij}$ for J = 1, 2, 4, 5,

Calculate BSS_i (between CANOPIES SS)

$$BSS_i = \eta \sum_j (\overline{X}_{ij} - \overline{X}_{i}.)^2$$

where $\eta_{ij} = \eta$

If $\eta_{13} \neq \eta_{ij}$ for j = 1, 2, 4, 5

Calculate BSS_i

$$BSS_i = \sum_j \eta_{ij} (\overline{X}_{ij} - \overline{X}_{i}.)^2$$

(3) Calculate RMS_i (within CANOPIES SS)

$$RMS = (TSS - BSS)/[5(\eta-1)] \quad \text{(d.f.)}$$

if $\eta_{13} = \eta_{ij}$

or

$$RMS_i = (TSS_i - BSS_i)/(\eta_i. - 5) \quad \text{(d.f.)}$$

for $\eta_{13} \neq \eta_{ij}$

(4) Test significance of differences between CANOPY means by computing the F quotient:

$$F_i = \frac{BMS_i}{RMS_i} \quad \text{(from (c) above)}$$

where

$$BMS_i = \frac{BSS_i}{4} \quad \text{(from (b) above)} \quad \text{(d.f.)}$$

and, comparing to F-distribution with d.f.'s being (4, 5 (η-1)) if $\eta_{i3} = \eta_{ij}$ or (4, (η_{i}. - 5)) if $\eta_{i3} \neq \eta_{ij}$ for a significance level of α = .10

(5) For significant differences, perform analysis to determine the difference between CANOPY pair (j, j):

(1,3),

(2,3),

(4,3),

and (5,3)

by using "t" test and computing

$$t = \frac{|\bar{X}_{ij} - \bar{X}_{i3}|}{s\sqrt{\frac{1}{\eta_{ij}} + \frac{1}{\eta_{i3}}}}$$

where

$$s = \frac{\sum_{\eta} (X_{ij\eta} - \bar{X}_{ij})^2 + \sum_{\eta} (X_{i3\eta} - \bar{X}_{i3})^2}{\eta_{ij} + \eta_{i3} - 2} \quad \text{(d.f.)}$$

for the appropriate pair (j, 3) under test,

and comparing to t-distribution (equal tails) with d.f. ($\eta_{ij} + \eta_{i3}$ - 2) for a significance level of α = .10/2 = .05

APPENDIX C

AIRCRAFT TRACKING TEST

DATA COMPILATION

Run #	Traj. #	Tgt. Slt. Range at 1st Contact (km)*	Alert-Contact Delay (sec) Canopy #					Contact-Tracking Delay (sec) Canopy #					Reacquisition Delay (sec) Canopy #					Remarks
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
1-37	Void	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	All data excluded from analysis — Gunner training interval —
38	3	5.5	30.6*	41.6	47.5	46.4	39.6	5.7	5.2	1.9	4.3	4.0	3.4	2.7	3.9	5.2	5.9	
39	4	—	16.3•	33.0•	40.2•	35.2•	32.3•	3.7	5.2	2.8	2.8	6.5	—	—	—	—	—	• Omit data - Incorrect Vectoring
40	6	—	66.7•	66.4•	70.8•	48.7•	N.C.	4.2	2.5	2.3	4.1	—	—	—	—	—	—	• Omit Data - No Contact
41	Void	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Late Alert - Abort
42	3	—	31.5•	17.9•	36.4•	16.0•	28.2•	4.9	3.9	2.7	2.2	4.6	5.9	5.1	4.8	5.6	7.0	• Omit Data - Late Alert
43	1	3.7	5.9*	8.7	8.8	13.4	17.1	3.4	2.4	1.3	1.6	3.9	5.1	—	4.1	3.6	4.7	
44	Void	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	No Vectoring - Abort
45	Void	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	No Vectoring - Abort
46	4	6.9	25.8	22.3*	40.4	47.6	54.5	6.8	5.0	2.3	3.7	3.5	—	—	—	—	—	
47	5	4.2	36.8	39.7	47.2	35.1*	53.2	3.7	2.5	2.0	3.0	10.4	11.7•	—	9.9•	8.1•	—	• Omit Data - Insufficient Sample
48	6	—	65.3•	53.8•	N.C.	43.8•	59.3•	10.0	2.0	—	1.3	3.0	—	—	—	—	—	• Omit Data - No Contact
49	3	7.5	11.5*	37.2	30.0	16.9	31.7	4.9	5.9	2.8	2.8	6.2	5.1	2.1	4.2	6.9	5.4	
50	2	4.5	13.8	10.2	8.5	5.5*	8.6	2.4	1.6	3.3	2.6	4.0	—	—	—	—	—	
51	4	6.9	30.1	17.7*	29.8	38.6	26.3	3.4	4.8	2.3	1.3	6.7	—	—	—	—	—	
52	1	—	21.9•	5.1•	19.9•	6.4•	8.7•	3.3	2.8	1.3	3.8	4.1	—	—	—	—	—	• Omit Data - Vectoring unverified
53	5	3.9	40.8*	44.4	51.6	45.1	46.8	6.8	6.4	2.1	2.0	3.9	—	—	—	—	—	
54	5	2.3	77.7	62.3*	65.6	77.8	72.0	1.7	2.0	2.0	2.6	7.5	—	—	—	—	—	
55	6	—	40.0•	54.0•	54.1•	63.8•	N.C.	3.2	2.4	2.1	0.8	—	—	—	—	—	—	• Omit Data - No Contact
56-63	Helo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
64	3	6.3	23.0	19.2*	38.1	37.0	34.0	4.8	5.0	2.1	2.3	4.3	3.4	6.5	3.6	4.6	—	
65	4	8.6	10.5	26.3	27.5	7.7*	24.6	3.4	6.9	2.0	3.1	6.4	—	—	—	—	—	

N.C. = No Contact Callout

N.T. = No Tracking Callout

Run #	Traj. #	Tgt. Slt. Range at 1st Contact (km)*	Alert-Contact Delay (sec) Canopy # 1	2	3	4	5	Contact-Tracking Delay (sec) Canopy # 1	2	3	4	5	Reacquisition Delay (sec) Canopy # 1	2	3	4	5	Remarks
66	6	—	54.5•	56.7•	57.0•	51.1•	N.C.	2.8	3.1	2.3	3.1	—	—	—	—	—	—	• Omit Data - No Contact
67	2	4.9	5.3	2.4*	4.3	6.2	3.7	2.3	3.2	1.4	4.2	5.0	—	—	—	—	—	
68	3	—	19.1•	0.9•	28.0•	4.8•	16.2•	3.6	5.1	1.6	4.5	4.8	4.1	5.3	3.3	3.9	7.6	• Omit Data - Incorrect Vectoring
69	1	4.4	8.8	3.3*	4.3	5.4	5.3	3.5	2.1	1.8	3.2	4.2	4.2	5.4	3.0	3.5	5.1	
70	5	3.1	68.4	46.5*	58.2	66.8	77.2	8.6	2.7	5.0	2.4	6.8	—	—	—	—	—	
71	6	4.1	65.4	43.8	41.3*	54.0	51.0	4.2	3.5	2.7	4.8	9.7	—	—	—	—	—	
72	4	7.7	12.9*	28.4	26.5	34.4	43.4	4.0	3.9	1.8	N.T.	4.4	—	—	—	—	—	
73	5	4.4	38.8*	47.3	44.2	59.2	69.5	3.3	4.0	2.1	3.5	3.4	7.5•	7.8•	9.5•	—	—	• Omit Data - Insufficient Sample
74	6	—	47.5•	47.3•	51.0•	53.7•	62.9•	3.1	3.7	3.6	3.7	3.8	—	—	—	—	—	• Omit Data - Incorrect Vectoring
75	3	7.1	17.7	13.4*	31.2	26.5	28.8	5.9	2.7	N.T.	4.4	4.1	4.5	7.0	3.4	4.4	4.7	
76	2	4.9	5.6	3.2*	4.2	5.0	7.2	2.9	1.5	3.1	2.1	2.8	—	—	—	—	—	
77	4	6.9	17.1*	28.3	29.0	30.1	59.9	4.8	3.5	1.9	1.1	4.2	—	—	—	—	—	
78	1	4.0	13.7	4.6*	7.8	6.3	7.5	2.1	2.5	1.6	0.9	3.8	3.6	2.8	2.6	3.8	3.6	
79	5	6.3	23.2*	41.0	41.1	42.9	49.1	3.8	3.0	2.1	1.9	9.2	7.4•	8.4•	5.5•	10.5•	—	• Omit Data - Insufficient Sample
80	5	2.9	46.7*	66.7	54.6	54.1	53.3	4.0	3.4	4.9	6.7	4.8	3.6•	—	—	—	—	• Omit Data - Insufficient Sample
81	6	4.3	54.9	41.0	43.9	40.1*	64.2	3.3	3.3	2.2	3.5	4.5	—	—	—	—	—	
82	3	5.3	35.0	30.7*	50.0	46.0	40.1	13.9	4.8	4.3	1.4	2.7	3.5	5.1	4.7	F/U Down	—	
83	3	7.1	37.0	24.6	19.3*	47.5	44.8	6.4	4.7	0.1	2.2	3.2	4.7	5.8	4.1	—	5.9	
84	4	6.7	27.4	25.1*	34.4	41.8	45.1	4.8	5.7	3.1	0.8	2.8	—	—	—	—	—	
85	4	—	20.6•	48.4•	N.C.	37.8•	55.9•	6.7	3.7	—	2.1	2.5	—	—	—	—	—	• Omit Data - No Contact
86	3	6.0	46.8	48.4	44.1	26.3	25.4*	3.8	3.6	1.6	2.2	2.0	4.0	9.2	4.2	—	3.2	
87	3	5.6	47.0	29.8*	53.2	33.7	36.3	4.2	3.5	1.2	3.3	2.7	3.9	4.1	4.6	—	4.8	

Run #	Traj. #	Tgt. Sit. Range at 1st Contact (KM)*	Alert-Contact Delay (sec) Canopy #					Contact-Tracking Delay (sec) Canopy #					Reacquisition Delay (sec) Canopy #					Remarks
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
88	4	6.3	32.8	30.1	23.5	25.6	23.2*	3.8	4.4	2.1	1.2	2.2	—	—	—	—	—	
89	4	7.2	21.4*	41.1	22.9	35.8	36.7	10.0	5.7	1.2	1.9	2.0	—	—	—	—	—	
90	1	—	14.9•	13.8•	9.8•	6.0•	5.4•	4.8	4.1	1.3	2.4	2.1	5.6	4.9	5.2	—	6.2	• Omit Data - Incorrect Vectoring
91	1	4.0	8.6	8.4	6.1	12.9	5.4*	1.0	2.9	0.9	1.2	1.4	3.4	4.5	4.4	—	4.4	
92	Void	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Late Alert - Abort
93	2	4.9	3.2	6.4	3.0*	3.3	3.9	4.2	2.4	1.1	2.4	1.5	—	—	—	—	—	
94	5	4.6	59.4	48.8	44.0	49.9	38.1*	9.9	4.4	1.2	2.0	2.2	—	—	—	—	—	
95	Void	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	T-33 Problem - Abort
96-104	Helo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
105	5	—	N.C.	60.8•	60.6•	82.8•	68.6•	—	7.2	1.3	2.5	3.5	—	—	—	—	—	• Omit Data - No Contact
106	5	4.1	55.2	42.8	42.0*	51.8	47.9	16.6	5.3	1.8	2.5	3.0	—	9.7•	6.5•	—	—	• Omit Data - Insufficient Sample
107	6	3.1	72.8	74.2	68.8	72.3	61.5*	5.1	3.4	2.7	2.1	2.1	—	—	—	—	—	
108	6	5.1	54.8	56.0	52.3	55.8	38.5*	4.1	6.3	1.3	2.6	15.9	—	—	—	—	—	
109	5	2.2	80.3	60.3*	69.7	63.6	62.5	N.T.	4.6	1.4	2.0	2.5	—	—	—	—	—	
110	5	—	32.0•	41.8•	36.0•	47.2•	51.1•	3.7	2.6	14.4	1.6	N.T.	10.7•	13.0•	—	—	—	• Omit Data - Incorrect Vectoring Insufficient Sample
111	6	3.2	78.2	77.8	67.3	65.4*	70.1	5.6	2.9	1.1	1.9	4.8	—	—	—	—	—	
112	6	4.1	49.4	48.8	50.0	46.3*	49.2	4.9	N.T.	1.4	1.7	1.9	—	—	—	—	—	
113	3	3.9	31.4*	44.3	34.0	40.3	40.4	4.6	2.6	1.1	1.8	3.3	4.8	4.6	4.5	—	5.0	
114	3	5.8	26.2	24.8*	32.3	27.5	40.2	5.5	3.2	1.3	2.7	2.9	3.5	8.0	7.8	—	4.4	
115	4	6.8	38.5	28.0	21.9*	30.9	38.0	5.0	2.5	1.4	1.5	1.8	—	—	—	—	—	
116	4	7.0	18.5*	28.9	19.8	35.5	34.3	8.2	2.7	4.7	1.4	1.5	—	—	—	—	—	
117	3	—	49.2•	41.5•	38.0•	39.5•	41.4•	7.4	3.5	4.3	4.7	2.0	5.9	5.8	6.2	—	4.4	• Omit Data - Early Alert

Run #	Traj. #	Tgt. Slt. Range at 1st Contact (km)*	Alert-Contact Delay (sec) Canopy # 1	2	3	4	5	Contact-Tracking Delay (sec) Canopy # 1	2	3	4	5	Reacquisition Delay (sec) Canopy # 1	2	3	4	5	Remarks
118	3	6.9	27.2	22.5	16.2	31.4	18.6*	8.3	3.1	2.5	2.4	2.0	4.0	5.0	5.2	—	3.3	
119-128	Helo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
129	3	5.8	27.0	30.2	25.2	24.3*	35.1	1.9	7.0	2.9	2.7	2.0	3.5	9.2	3.8	3.1	3.0	
130	3	7.0	19.3*	32.0	30.6	22.2	30.4	1.6	5.6	2.5	2.0	1.7	1.8	4.1	5.0	2.9	3.2	
131	4	7.1	20.7	40.4	19.6*	27.9	36.0	1.9	5.2	2.3	1.5	1.4	—	—	—	—	—	
132	4	—	26.7•	29.9•	14.3•	25.0•	27.9•	1.2	9.3	3.8	2.4	1.6	—	—	—	—	—	• Omit Data - Early Alert
133	3	—	8.1•	12.5•	24.2•	15.0•	16.5•	1.2	5.6	N.T.	4.3	2.8	4.4	4.9	5.6	2.9	2.9	• Omit Data - Late Alert
134	3	5.9	42.1	46.8	40.4	26.4*	37.2	1.5	4.3	2.8	1.9	1.3	3.8	4.4	4.9	3.2	3.4	
135	4	7.7	18.8	33.3	33.9	17.4*	32.2	1.2	3.1	2.4	3.6	1.9	—	—	—	—	—	
136	4	7.9	28.2	20.2	34.2	12.3*	19.4	2.0	2.9	2.3	4.8	2.7	—	—	—	—	—	
137	1	4.3	9.5	10.0	8.3	14.7	5.1*	1.3	4.1	2.4	6.8	1.4	4.8	3.7	3.2	2.9	5.1	
138	1	4.0	8.7	6.6	10.9	11.9	4.7*	1.3	2.8	1.7	1.4	1.5	3.6	5.0	4.8	3.5	4.3	
139	2	5.1	6.0	13.4	5.2	5.6	3.2*	1.2	2.7	2.0	1.5	1.3	—	—	—	—	—	
140	2	4.9	6.6	7.7	4.7	2.5*	4.0	1.4	3.1	2.4	1.4	1.7	—	—	—	—	—	
141	5	—	64.4•	N.C.	76.7•	55.3•	53.3•	N.T.	—	2.2	3.9	2.0	—	—	—	4.5•	3.7•	• Omit Data - No Contact, Insufficient Sample
142	5	3.4	40.8*	49.3	47.7	49.3	44.3	2.4	N.T.	2.6	8.7	1.9	—	—	—	—	4.3•	• Omit Data - Insufficient Sample
143	6	3.0	64.5	67.4	64.1	59.1*	66.4	2.3	4.5	2.5	1.6	1.9	—	—	—	—	—	
144	6	—	65.3•	N.C.	57.1•	50.6•	52.5•	1.5	—	3.3	1.6	2.0	—	—	—	—	—	• Omit Data - No Contact
145	5	—	N.C.	N.C.	N.C.	53.5•	73.4•	—	—	—	1.2	1.5	—	—	—	3.9•	—	• Omit Data - No Contact
146	5	—	—	—	—	—	—	N.T.	N.T.	1.7	1.5	3.0	—	—	—	—	—	Early Alert
147	6	2.8	66.3	63.4*	67.3	65.4	67.8	2.8	3.0	2.2	1.5	1.7	—	—	—	—	—	
148	Void	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	No Event Data Recorded

RUN #	TRAJ. #	TGT. SLT. RANGE AT 1ST CONTACT (KM)*	ALERT-CONTACT DELAY (SEC) CANOPY #					CONTACT-TRACKING DELAY (SEC) CANOPY #					REACQUISITION DELAY (SEC) CANOPY #					REMARKS
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
149	3	5.0	F/U DOWN	33.4	37.3	33.3*	44.0	—	4.8	3.1	1.4	1.5	—	4.5	6.3	4.6	3.4	
150	3	7.6	F/U DOWN	20.0	14.7	13.8*	36.7	—	9.2	2.9	1.2	1.6	—	3.9	4.7	3.3	2.8	
151	4	4.7	41.0	49.4	47.1	35.6*	43.6	1.9	4.0	2.2	2.1	2.1	—	—	—	—	—	
152	4	6.4	33.2	36.3	43.5	23.6*	40.0	3.8	2.9	2.2	5.1	1.7	—	—	—	—	—	
153	3	5.1	38.0	42.4	30.8*	31.0	31.9	5.4	3.1	3.1	1.3	1.9	5.7	3.4	4.4	4.4	4.5	
154	3	8.2	9.8*	27.4	31.9	15.4	25.0	2.8	6.2	1.8	2.0	1.6	5.2	5.9	4.4	4.8	2.9	
155	4	5.3	39.4	40.7	34.3*	37.5	40.7	4.3	6.9	2.3	3.5	1.9	—	—	—	—	—	
156	4	5.9	39.3	41.5	31.5	28.2*	46.4	3.4	4.1	2.5	1.7	1.4	—	—	—	—	—	
157	1	4.5	8.1	9.4	10.0	7.3	4.7*	2.0	2.9	1.3	1.1	1.5	4.7	4.1	4.1	5.1	4.0	
158	1	4.3	8.7	6.6	6.9	5.2	3.5*	1.7	2.8	1.7	1.4	1.0	5.0	4.2	3.7	4.2	3.7	
159	2	4.8	10.0	8.4	7.0	2.8*	8.9	1.1	2.0	1.8	1.0	1.1	—	—	—	—	—	
160	2	4.5	6.8	7.3	11.3	3.9*	6.3	1.7	0.8	1.6	1.4	2.9	—	—	—	—	—	
161	5	4.0	52.4	43.5	50.2	45.9	41.2*	3.8	3.1	2.6	1.3	1.5	7.2•	—	4.1•	8.0•	7.9•	• OMIT DATA - INSUFFICIENT SAMPLE
162	5	4.8	32.0*	40.6	46.5	39.8	47.8	1.7	4.8	3.0	1.0	2.3	14.1•	—	4.1•	5.3•	4.9•	• OMIT DATA - INSUFFICIENT SAMPLE
163	6	4.3	41.6*	47.1	52.2	46.6	44.3	2.1	4.2	2.1	0.8	2.1	—	—	—	—	—	
164	6	4.2	41.2	54.9	47.1	42.0*	42.0*	2.0	4.0	1.5	0.9	1.7	—	—	—	—	—	
165	5	3.5	55.3	56.5	49.5	46.5*	46.5*	2.5	4.3	1.7	1.3	2.0	5.5•	—	—	6.9•	—	• OMIT DATA - INSUFFICIENT SAMPLE
166	5	4.8	38.0	31.3*	37.1	38.4	F/U DOWN	1.8	3.5	2.6	1.5	—	8.3•	8.2•	6.0•	4.8•	—	• OMIT DATA - INSUFFICIENT SAMPLE
167-173	HELO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
174	3	2.9	63.2	78.3	57.5	63.7	51.3*	1.5	1.6	10.5	2.1	3.3	—	—	6.0	6.8	3.3	
175	4	7.9	32.9	36.3	29.8	16.3	15.5*	2.1	2.6	5.5	3.0	1.1	—	—	—	—	—	
176	4	9.4	25.2	26.6	5.9*	9.7	26.1	1.5	1.2	4.0	2.9	1.1	—	—	—	—	—	

RUN #	TRAJ. #	TGT. SLT. RANGE AT 1ST CONTACT (KM)*	ALERT-CONTACT DELAY (SEC) CANOPY #					CONTACT-TRACKING DELAY (SEC) CANOPY #					REACQUISITION DELAY (SEC) CANOPY #					REMARKS
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
177	3	—	24.8•	7.1•	9.2•	13.8•	21.8•	2.0	0.2	6.3	3.4	2.9	—	4.1	3.7	3.0	5.1	• OMIT DATA - VECTORING UNVERIFIED
178	3	7.8	40.3	23.6	27.6	42.3	14.7*	2.1	1.1	6.7	2.3	1.1	1.9	3.6	4.7	3.4	4.7	
179	4	7.9	18.5	13.2	21.1	32.1	13.1*	1.7	N.T.	3.4	3.2	N.T.	—	—	—	—	—	
180	4	—	18.9•	23.3•	26.4•	43.9•	18.1•	2.5	1.1	5.4	3.6	3.5	—	—	—	—	—	• OMIT DATA - INCORRECT VECTORING
181	1	3.7	6.4	6.3*	9.1	10.5	6.9	1.6	1.7	1.8	4.0	0.8	2.8	3.7	4.3	3.2	3.3	
182	1	4.7	15.0	5.1	5.8	26.1	8.7*	2.2	0.9	1.8	2.6	0.9	2.3	4.2	4.7	3.4	3.9	
183	2	4.6	4.1	4.8	4.4	4.4	2.6*	1.5	0.5	2.5	2.9	0.8	—	—	—	—	—	
184	2	4.7	6.7	4.9	4.6*	5.7	9.4•	2.4	1.2	1.7	2.5	0.5	—	—	—	—	—	• OMIT DATA - COMMO FAILURE
185	5	3.5	49.1	63.7	50.2	72.3	48.2*	1.6	1.5	5.7	2.3	0.9	—	—	7.6•	—	8.8•	• OMIT DATA - INSUFFICIENT SAMPLE
186	5	5.2	52.0	60.1	53.2	45.4	34.4*	2.8	2.6	16.9	2.5	1.3	—	—	—	—	—	REACQUISITION ABORT
187	6	4.1	43.9*	49.8	50.3	49.1	49.0	1.6	1.8	N.T.	3.9	1.4	—	—	—	—	—	
188	6	5.2	37.6	48.6	47.8	47.1	36.4*	2.0	1.4	6.8	2.9	1.1	—	—	—	—	—	
189	5	3.0	55.2*	56.1	61.9	58.1	57.9	2.5	2.0	7.3	3.0	0.9	—	—	—	—	—	
190	5	3.9	49.4	46.6	49.4	44.4*	48.2	2.7	2.0	5.3	3.2	1.0	—	—	4.6•	5.0•	—	• OMIT DATA - INSUFFICIENT SAMPLE
191	6	4.9	47.6	54.7	55.9	56.0	40.7*	2.3	0.8	6.1	2.3	1.6	—	—	—	—	—	
192	6	4.1	45.1	46.9	48.7	46.7	44.1*	2.0	0.7	4.4	1.9	1.5	—	—	—	—	—	
193	3	5.7	59.6	57.9	47.2	29.6*	32.3	1.6	2.4	5.7	2.3	1.4	—	4.2	5.1	3.4	3.0	
194	3	8.1	41.2	25.9	37.6	24.4	12.2*	1.5	1.0	7.4	N.T.	N.T.	2.2	4.1	3.0	3.8	2.8	
195	4	8.6	30.3	19.0	26.7	10.0*	18.0	2.7	1.1	N.T.	3.5	0.8	—	—	—	—	—	
196	4	9.4	16.1	23.1	16.3	23.8	4.3*	2.0	2.9	5.3	2.4	1.1	—	—	—	—	—	
197	3	8.9	19.5	42.5	31.6	15.2	4.8*	2.8	0.9	N.T.	3.7	0.9	—	5.0	4.4	5.6	4.7	
198	3	8.5	43.0	30.5	33.6	33.5	9.4*	1.2	1.3	4.8	2.5	0.5	2.6	2.8	5.8	—	—	

RUN #	TRAJ. #	TGT. SLT. RANGE AT 1ST CONTACT (KM)*	ALERT-CONTACT DELAY (SEC) CANOPY #					CONTACT-TRACKING DELAY (SEC) CANOPY #					REACQUISITION DELAY (SEC) CANOPY #					REMARKS
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
199	4	7.9	30.6	40.8	15.9*	29.8	26.9	2.9	1.0	6.6	2.9	0.6	—	—	—	—	—	
200	4	7.3	21.9	19.7*	30.1	27.5	22.3	2.0	1.3	5.3	4.8	0.7	—	—	—	—	—	
201	1	4.0	5.6*	18.0	10.6	18.4	11.0	1.1	1.3	3.5	3.2	0.6	2.2	4.8	4.5	3.9	3.1	
202	VOID	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	LATE ALERT - ABORT
203	3	5.9	46.1	53.3	43.8	25.8*	53.2	1.8	2.8	1.0	4.9	3.5	8.2	3.9	4.9	4.9	6.5	
204	3	6.9	24.3	31.5	21.0	19.7*	34.4	0.7	2.9	5.6	5.9	3.4	5.2	3.6	4.8	3.4	3.2	
205	4	9.2	3.6*	30.2	14.8	34.7	44.4	0.3	2.8	1.7	3.4	2.6	—	—	—	—	—	
206	4	8.8	12.6*	36.9	25.1	21.6	35.9	0.7	1.9	1.8	6.9	2.9	—	—	—	—	—	
207	3	—	23.0•	31.0•	9.0•	15.7•	8.5•	0.6	2.3	2.0	12.2	3.6	5.7	3.6	3.8	3.1	5.8	• OMIT DATA - LATE ALERT
208	3	8.8	7.2*	22.8	38.4	10.8	33.1	1.1	2.6	8.9	18.9	3.2	7.3	—	—	2.2	1.1	
209	4	8.9	10.1	38.4	24.6	15.6	4.3*	0.8	2.3	1.3	4.8	3.7	—	—	—	—	—	
210	4	—	11.1•	27.4•	15.8•	6.5•	39.7•	0.6	2.3	1.0	18.6	2.6	—	—	—	—	—	• OMIT DATA - INCORRECT VECTORING
211	1	3.9	3.9*	8.6	4.8	7.8	10.1	0.7	4.5	1.7	2.9	2.0	4.8	3.2	7.0	5.0	5.0	
212	1	4.3	3.5*	9.9	5.8	4.8	11.4	0.8	2.5	0.8	1.3	2.2	6.6	3.4	3.4	3.3	4.0	
213	2	4.3	2.8*	6.4	5.4	6.8	5.8	0.9	1.5	1.3	2.5	2.5	—	—	—	—	—	
214	5	2.7	53.2*	72.0	65.6	68.6	72.4	1.9	1.3	2.4	6.5	2.9	—	—	—	—	—	
215	5	—	20.2•	36.2•	N.C.	48.8•	42.9•	3.6	1.6	—	1.0	2.4	8.2•	—	—	8.0•	5.2•	• OMIT DATA - NO CONTACT, INSUFFICIENT SAMPLE
216	6	4.4	44.7*	61.1	52.0	47.9	61.5	1.0	2.0	2.0	2.8	2.4	—	—	—	—	—	
217	6	4.4	45.4	39.6	46.1	48.3	39.2*	2.1	1.3	0.7	4.4	3.6	—	—	—	—	—	
218	5	3.2	48.9	50.6	49.2	48.5*	66.7	1.4	1.0	1.2	4.0	2.2	6.8•	—	—	—	—	• OMIT DATA - INSUFFICIENT SAMPLE
219	5	7.5	17.7*	43.6	43.4	66.3	39.9	1.4	2.4	0.8	7.6	3.9	—	—	—	—	—	
220	3	6.8	34.1	37.9	20.4*	34.1	43.4	0.8	2.1	1.8	3.7	3.6	6.2	4.9	5.8	4.2	4.0	

RUN #	TRAJ. #	TGT. SLT. RANGE AT 1ST CONTACT (KM)*	ALERT-CONTACT DELAY (SEC) CANOPY #					CONTACT-TRACKING DELAY (SEC) CANOPY #					REACQUISITION DELAY (SEC) CANOPY #					REMARKS
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
221	VOID	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	INCORRECT VECTORING - ABORT
222	VOID	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	INCORRECT VECTORING - ABORT
223	4	9.3	11.2	25.1	11.5	5.2*	31.4	0.6	2.3	5.4	11.8	2.6	—	—	—	—	—	
224	3	8.3	17.2	38.9	15.8	10.0*	18.5	1.3	1.8	1.6	8.0	2.4	3.2	3.7	4.3	4.9	5.8	
225	3	7.9	35.0	48.4	16.4	42.9	14.1*	2.5	2.2	1.3	3.1	4.2	5.0	3.6	5.7	5.7	5.5	
226	4	9.3	17.8	27.9	12.1	4.0*	8.5	0.8	1.3	1.7	1.9	2.9	—	—	—	—	—	
227	4	8.7	18.3	20.1	17.3	10.5*	31.7	0.6	2.1	0.9	16.0	1.8	—	—	—	—	—	
228	1	4.4	F/U DOWN	10.7	6.7	4.8*	8.8	—	0.9	0.7	1.3	4.2	—	4.6	4.0	4.3	4.2	
229	1	4.2	F/U DOWN	15.0	9.9	4.3*	16.1	—	2.0	0.7	1.1	2.0	—	4.7	4.4	3.7	4.2	
230	2	4.6	F/U DOWN	7.5	5.4	5.0*	5.4	—	1.6	1.5	1.2	2.2	—	—	—	—	—	
231	2	4.8	F/U DOWN	6.4	5.1	3.3*	4.8	—	1.6	0.7	1.6	1.9	—	—	—	—	—	
232	5	2.8	60.3	60.9	59.0*	94.7	65.7	1.3	2.5	1.1	4.0	2.9	—	—	—	—	—	
233	5	4.8	34.3	32.6	32.1*	48.7	49.8	1.3	4.3	1.1	3.4	3.6	6.2•	8.8•	—	6.4•	—	• OMIT DATA - INSUFFICIENT SAMPLE
234	6	—	63.5•	73.4•	N.C.	N.C.	N.C.	0.7	2.3	—	—	—	—	—	—	—	—	• OMIT DATA - NO CONTACT
235	6	—	38.9•	N.C.	48.8•	41.7•	N.C.	0.7	—	1.2	5.8	—	—	—	—	—	—	• OMIT DATA - NO CONTACT
236	5	4.3	52.4	55.3	58.5	54.3	39.3*	0.7	1.4	1.3	4.4	2.5	5.0•	5.6•	—	4.8•	—	• OMIT DATA - INSUFFICIENT SAMPLE
237	5	8.5	8.9*	35.8	28.0	43.2	48.9	1.3	1.4	1.5	4.6	2.9	6.7•	—	—	7.7•	—	• OMIT DATA
238	6	—	N.C.	65.7•	N.C.	N.C.	N.C.	—	0.8	—	—	—	—	—	—	—	—	• OMIT DATA - NO CONTACT
239	6	—	N.C.	N.C.	42.9•	N.C.	35.1•	—	—	N.T.	—	3.2	—	—	—	—	—	• OMIT DATA - NO CONTACT
240	4	—	F/U DOWN	49.0•	5.5•	13.3•	15.0•	—	2.8	1.3	1.5	2.4	—	—	—	—	—	• OMIT DATA - VECTORING UNVERIFIED
241	4	—	F/U DOWN	N.C.	11.4•	12.5•	14.8•	—	—	0.6	1.7	0.9	—	—	—	—	—	• OMIT DATA - NO CONTACT
242	1	—	F/U DOWN	16.7•	3.5•	9.5•	6.7•	—	2.6	0.6	1.0	1.4	—	4.7	4.0	3.8	4.4	• OMIT DATA - VECTORING UNVERIFIED

Run #	Traj. #	Tgt. Slt. Range at 1st Contact (km)*	Alert-Contact Delay (sec) Canopy #					Contact-Tracking Delay (sec) Canopy #					Reacquisition Delay (sec) Canopy #					Remarks
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
243	1	—	F/U Down	10.9•	3.4•	7.9•	8.2•	—	3.5	0.6	1.1	0.9	—	7.2	3.7	3.5	4.0	• Omit Data - Vectoring Unverified
244	2	—	F/U Down	5.1•	2.1•	3.6•	6.0•	—	2.6	0.8	1.4	0.9	—	—	—	—	—	• Omit Data - Vectoring Unverified
245	2	—	F/U Down	6.6•	2.0•	3.1•	6.0•	—	2.8	0.5	2.1	1.9	—	—	—	—	—	• Omit Data - Vectoring Unverified
246	2	—	7.0•	6.0•	4.3•	3.1•	6.6•	8.2	3.1	0.7	2.1	1.7	—	—	—	—	—	• Omit Data - Vectoring Unverified
247	5	—	51.9•	52.9•	39.5•	46.9•	69.2•	3.2	3.7	1.6	1.5	N.T.	6.0•	—	3.6•	—	—	• Omit Data - Vectoring Unverified, Insufficient Sample
248	6	—	65.7•	50.2•	66.7•	61.5•	N.C.	5.7	2.5	1.8	2.1	—	—	—	—	—	—	• Omit Data - Vectoring Unverified, No Contact
249	6	—	57.2•	54.4•	38.3•	60.3•	57.9•	10.7	8.0	1.0	N.T.	2.3	—	—	—	—	—	• Omit Data - Vectoring Unverified
250	5	—	57.7•	53.2•	51.0•	54.9•	60.4•	6.8	2.5	1.3	2.1	N.T.	1.7•	1.7•	—	7.8•	—	• Omit Data - Vectoring Unverified, Insufficient Sample
251	5	—	48.2•	39.8•	59.4•	34.1•	39.2•	—	2.8	0.5	1.7	1.5	—	—	—	—	—	• Omit Data - Vectoring Unverified
252	6	—	63.6•	65.2•	64.7•	63.4•	70.5•	5.4	3.8	0.7	1.6	2.7	—	—	—	—	—	• Omit Data - Vectoring Unverified
253	6	—	56.2•	56.8•	56.2•	53.8•	53.8•	3.0	3.1	0.8	2.3	1.4	—	—	—	—	—	• Omit Data - Vectoring Unverified
254	5	—	51.3•	71.6•	N.C.	33.5•	N.C.	N.T.	4.0	—	1.1	—	—	—	—	—	—	• Omit Data - Vectoring Unverified, No Contact
255	6	—	67.0•	58.0•	58.6•	60.0•	N.C.	3.2	3.0	2.6	1.2	—	—	—	—	—	—	• Omit Data - Vectoring Unverified, No Contact
256	6	—	52.3•	51.7•	55.0•	52.0•	52.2•	1.6	3.3	3.0	0.7	1.5	—	—	—	—	—	• Omit Data - Vectoring Unverified
257	3	—	17.2•	17.4•	33.9•	29.4•	24.5•	1.0	5.0	2.4	3.1	1.9	4.8	4.0	3.4	4.6	3.0	• Omit Data - Vectoring Unverified, Late Alert
258	3	—	13.2•	16.6•	28.6•	8.2•	33.6•	1.7	4.5	3.2	0.7	1.5	6.8	4.6	4.6	2.1	2.6	• Omit Data - Vectoring Unverified
259	4	—	7.6•	30.1•	6.9•	23.0•	20.5•	1.4	3.9	2.1	N.T.	2.3	—	—	—	—	—	• Omit Data - Vectoring Unverified, Late Alert
260	4	—	21.7•	44.4•	39.2•	32.0•	23.5•	1.3	3.5	1.6	0.7	1.8	—	—	—	—	—	• Omit Data - Vectoring Unverified

APPENDIX D

MOUNT OPERATOR PERSONNEL PROFILES AND

FINAL DEBRIEFING QUESTIONNAIRES

PERSONNEL PROFILE

Test ID:	Gunner #1
Rank/MOS:	PFC/16-P-10
Length of Service:	10 mos.
Length of Chaparral Experience:	7 months
Type of Chaparral Experience:	Crewmember
Age:	18
Height:	5'6"
Weight:	130
Do you wear glasses?	No
Have you performed aircraft detection duties before?	Yes
If yes, please explain what you did and for how long.	Field exercises as gunner tracking A-7 Corsair for a few days.

MOUNT OPERATOR'S FINAL DEBRIEFING QUESTIONNAIRE

Test ID: Gunner #1

Date: 11 June 1976

Question	Answer	Explanation
1)* Did you have a preference for (1) Grid Baffle, (2) Flat Plate w/ Baffle, (3) Flat Plate w/o Baffle, (4) AR coated, or (5) Standard canopy? If yes, please give your reasons. Also, if you have a second choice, state it and your reasons for selecting it. Use the reverse side of this sheet for further explanation, if needed.	YES ____ NO ____ 1. Grid Baffle; 2. Flat Plate w/B. 3. AR Coated 4. Flat Plate w/o B. 5. Standard	1.) I prefer this baffle more than any because of the way it operates. It casts mostly all the glare of the sunlight away. It makes you more comfortable because you are in a shaded area and you are able to track better because of this shaded condition. Although it limits your vision the best thing that it does is cause you to be able to track farther away targets because it limits most of the glint so you can see farther away. see page 2
2) This question relates to using the system; that is (1) raising and lowering the canopy, (2) climbing on the platform during missile loading, (3) cleaning the canopy, (4) and mounting the bows and installing the vehicle protective cover. With respect to any one or more of the above jobs, do you have a preference for any one of the four systems? If yes, please state the advantages it has over the other systems. Use the reverse side of this sheet for further explanation if needed.	(1) YES X NO ____ (2) YES ____ NO X (3) YES X NO ____ (4) YES X NO ____	(1) Any preference I would have toward any of the canopies as far as raising and lowering is concerned I would choose all four except the grid baffle because of the weight. (2) My preference would be all of these canopies because none of them can stop you from performing because when loading missiles the canopy is not involved in any way. (3) My best preference for canopy cleaning would be the flat because it is just like the standard as far as cleaning is concerned and there is nothing to unbolt or unscrew. (4) The best one of these canopies that would suit this situation of putting cargo cover on is the flat plate with baffle which would be best for this purpose.

* Question was changed to: List in order of preference (from most preferred to least preferred), the five canopies and give reasons for your ordering.

Test ID: Gunner #1

Date: 11 June 1976

1)* (continued)

2) I like this one because it shades the top area of the canopy making it easier for you to still track without losing your target because of the glare.
3) This one is all right for conditions when sunlight is not as much of a problem, but it does give you just as much of a problem as the Standard does.
4) This canopy, although it offers more visibility, it doesn't offer any shade, nor *does it* block away the rays from the sun making glare a big problem.
5) This canopy is the type that offers no comfort at *all*. You can *easily* lose your target at crossover because of sunlight and it offers no type of shade.

PERSONNEL PROFILE

Test ID:	Gunner #2
Rank/MOS:	PFC/16-P-10
Length of Service:	1 yr. 3 months
Length of Chaparral Experience:	1 yr.
Type of Chaparral Experience:	Crewman - driver
Age:	21
Height:	5'8"
Weight:	131
Do you wear glasses?	No
Have you performed aircraft detection duties before?	No

MOUNT OPERATOR'S FINAL DEBRIEFING QUESTIONNAIRE

Test ID: Gunner #2

Date: 11 June 1976

Question	Answer	Explanation
1)* Did you have a preference for (1) Grid Baffle, (2) Flat Plate w/ Baffle, (3) Flat Plate w/o Baffle, (4) AR coated, or (5) Standard canopy? If yes, please give your reasons. Also, if you have a second choice, state it and your reasons for selecting it. Use the reverse side of this sheet for further explanation, if needed.	YES ____ NO ____ 1. Flat Plate w/B 2. Grid Baffle 3. AR Coated 4. Standard 5. Flat Plate w/o B.	I preferred Flat Plate w/Baffle because it reduces the sun problem some, its comfortable and it has quite a large scan of view. It can be improved. I preferred Grid Baffle because of all the canopies it reduces the sun problem better than any, but you have problem with the grid. The grid sometimes blocks your sight. I feel this type of canopy could be the best if the open space in the canopy was larger. My least favorite canopy is Flat Plate w/o Baffle because the sun is a big problem, reflections and you are very capable of getting eye fatigue. The track that this canopy was mounted on didn't help any. I feel this canopy could be improved by using a tinted glass on this type style canopy.
2) This question relates to using the system; that is (1) raising and lowering the canopy, (2) climbing on the platform during missile loading, (3) cleaning the canopy, (4) and mounting the bows and installing the vehicle protective cover. With respect to any one or more of the above jobs, do you have a preference for any one of the four systems? If yes, please state the advantages it has over the other systems. Use the reverse side of this sheet for further explanation if needed.	(1) YES ____ NO X (2) YES ____ NO X (3) YES ____ NO X (4) YES ____ NO X	

* Question was changed to: List in order of preference (from most preferred to least preferred), the five canopies and give reasons for your ordering.

PERSONNEL PROFILE

Test ID:	Gunner #3
Rank/MOS:	PFC/16-P-10
Length of Service:	11 months
Length of Chaparral Experience:	10 months
Type of Chaparral Experience:	Prime mover driver
Age:	19
Height:	5'6.5"
Weight:	148
Do you wear glasses?	No
Have you performed aircraft detection duties before?	Yes
If yes, please explain what you did and for how long.	On a field trip I was acting senior gunner for 3 days.

MOUNT OPERATOR'S FINAL DEBRIEFING QUESTIONNAIRE

Test ID: Gunner #3

Date: 11 June 1976

Question	Answer	Explanation
*1) Did you have a preference for (1) Grid Baffle, (2) Flat Plate w/ Baffle, (3) Flat Plate w/o Baffle, (4) AR coated, or (5) Standard canopy? If yes, please give your reasons. Also, if you have a second choice, state it and your reasons for selecting it. Use the reverse side of this sheet for further explanation, if needed.	YES ____ NO ____ 1. Flat Plate w/B. 2. AR Coated 3. Grid Baffle 4. Standard 5. Flat Plate w/o B.	I prefer (1) because it protects you from too much sun, but at the same time you get enough to track by. You don't get blinded by the sun at 0600 to 0735 - at those times of the morning the sun is worst at 6:00 to 8:00 on the dial. Also it makes me feel a lot more comfortable - it has more head space, more view power.* Note: I think if it were coated and baffled it would be a much better canopy.* I think (2) is second because of good sun reflection and it lets me see in light sun (cont p.2)
2) This question relates to using the system; that is (1) raising and lowering the canopy, (2) climbing on the platform during missile loading, (3) cleaning the canopy, (4) and mounting the bows and installing the vehicle protective cover. With respect to any one or more of the above jobs, do you have a preference for any one of the four systems? If yes, please state the advantages it has over the other systems. Use the reverse side of this sheet for further explanation if needed.	(1) YES ____ NO X (2) YES ____ NO X (3) YES X NO ____ (4) YES ____ NO X	(1) There's just no diff - except the Grid Baffle is a lot heavier than the rest. (2) Missile loading - There would be no trouble at all. (3) Clean Canopy-Flat Plate w/B would be alittle harder to clean, but it is the best canopy they have and it is to me easy to clean. Anyway, who minds cleaning a weapon that will save your life. (4) Putting the bows on track - Well, I feel like the Flat Plat w/B is the best canopy and if its going to save my life someday why not go through the trouble. Well its not really a problem cause by the time it takes to unhook the bows and install the first 2 it would be off and stored.

* Question was changed to: List in order of preference (from most preferred to least preferred), the five canopies and give reasons for your ordering.

Test ID: Gunner #3

Date: 11 June 1976

(cont. from page 1)
rays whereas most of the others wouldn't and I feel comfortable cause it is my system.
I hate (5) cause you just can't see a damn thing high or far out low - too much sun.

* Note: On a scale from 1 to 10:
the Flat Plate is best, rates 10
AR Coated rates a 7
Grid Baffle rates a 4
Standard rates a 3
Flat Plate w/o B. rates a 1

As for me, rating my tracking on a scale of 1 to 5 for the whole test about one.

PERSONNEL PROFILE

Test ID:	Gunner #4
Rank/MOS:	PFC/16-P-10
Length of Service:	2½ years
Length of Chaparral Experience:	2½ years
Type of Chaparral Experience:	No. 1, 2, 3 & 4 crewman
Age:	21
Height:	5'4"
Weight:	180
Do you wear glasses?	No
Have you performed aircraft detection duties before?	Yes
If yes, please explain what you did and for how long.	I was Gunner during ASP, fired once and tracked an A-7 for 15-20 min. I tracked during FTX for a day.

MOUNT OPERATOR'S FINAL DEBRIEFING QUESTIONNAIRE

Test ID: Gunner #4

Date: 11 June 1976

Question	Answer	Explanation
1)* Did you have a preference for (1) Grid Baffle, (2) Flat Plate w/ Baffle, (3) Flat Plate w/o Baffle, (4) AR coated, or (5) Standard canopy? If yes, please give your reasons. Also, if you have a second choice, state it and your reasons for selecting it. Use the reverse side of this sheet for further explanation, if needed.	YES ____ NO ____ 1. Flat Plate w/B. 2. AR Coating 3. Standard 4. Grid Baffle 5. Flat Plate w/o B.	In the flat plate w/baffle I had a very good view - I felt that I was contacting the target faster, and the internal reflection and glare didn't bother me very much. These are the reasons I preferred the Flat Plate w/Baffle and also the AR coating. I think those two were far better in these things than the other three. The reason I like the Flate Plate w/Baffle better is that I think I performed better in it than in the AR Coated.
2) This question relates to using the system; that is (1) raising and lowering the canopy, (2) climbing on the platform during missile loading, (3) cleaning the canopy, (4) and mounting the bows and installing the vehicle protective cover. With respect to any one or more of the above jobs, do you have a preference for any one of the four systems? If yes, please state the advantages it has over the other systems. Use the reverse side of this sheet for further explanation if needed.	(1) YES X NO ____ (2) YES ____ NO X (3) YES X NO ____ (4) YES X NO ____	(1) I think the AR Coated and Standard are a lot easier to handle, especially when you are already inside and you're trying to open it to get out. The other three are heavier. (2) I don't think that the canopy would make any difference in a missile reload. (3) I think that cleaning the AR Coated and the Standard would be a lot easier and the result would be a cleaner canopy. (4) With regard to mounting the bows and cover I would prefer the AR Coated canopy, but I still think the Flat Plate w/B is better in fulfilling the purpose of the Chaparral system.

* Question was changed to: List in order of preference (from most preferred to least preferred), the five canopies and give reasons for your ordering.

Test ID: Gunner #4

Date: 11 June 1976

1) continued

I liked the last one least of all because the top portion of the box had far too much reflection and glare. I could not spot the high targets and the sun was very hot on me. I don't think the last two offer any great improvement to the Standard.

PERSONNEL PROFILE

Test ID:	Gunner #5
Rank/MOS:	PFC/16-P-10
Length of Service:	6 months
Length of Chaparral Experience:	2 months
Type of Chaparral Experience:	Observer
Age:	24
Height:	6'3"
Weight:	189
Do you wear glasses?	Yes
Have you performed aircraft detection duties before?	No

MOUNT OPERATOR'S FINAL DEBRIEFING QUESTIONNAIRE

Test ID: Gunner #5

Date: 11 June 1976

Question	Answer	Explanation
1)* Did you have a preference for (1) Grid Baffle, (2) Flat Plate w/ Baffle, (3) Flat Plate w/o Baffle, (4) AR coated, or (5) Standard canopy? If yes, please give your reasons. Also, if you have a second choice, state it and your reasons for selecting it. Use the reverse side of this sheet for further explanation, if needed.	YES ____ NO ____ 1. Flat Plate w/B. 2. AR Coated 3. Standard 4. Grid Baffle 5. Flat Plate w/o B.	I like Flat Plate w/Baffle because it didn't affect my view and it had shade and room. AR coated lets you track overhead a little better, but there isn't much difference between AR coated and Standard. The Grid Baffle and Flat Plate w/o Baffle both are view blockers but for different reasons. The Grid Baffle - baffles get in the view and the Flat Plate w/o Baffle has a semi-blind area.
2) This question relates to using the system; that is (1) raising and lowering the canopy, (2) climbing on the platform during missile loading, (3) cleaning the canopy, (4) and mounting the bows and installing the vehicle protective cover. With respect to any one or more of the above jobs, do you have a preference for any one of the four systems? If yes, please state the advantages it has over the other systems. Use the reverse side of this sheet for further explanation if needed.	(1) YES ____ NO X (2) YES ____ NO X (3) YES X NO ____ (4) YES X NO ____	(1) No preference for raising or lowering of canopy. (2) No, I don't think either would hurt missile reload. (3) Standard and AR Coated should be the easiest to clean. (4) Standard and AR Coated should be best for mounting cargo cover.

* Question was changed to: List in order of preference (from most preferred to least preferred), the five canopies and give reasons for your ordering.

APPENDIX E

LOGISTICS EVALUATION REPORT

The addition of an anti-glint device to the Chaparral system presents a potential Logisitcs impact, depending on the concept chosen. A detailed analysis of the various concepts and their expected impact will contribute to the final selection process.

Logistics elements that must be reviewed include:

1. Maintenance Requirements
2. Maintainability Analysis
3. Supply - Support Impact
4. Retrofit Considerations
5. Travel and Transportation Impact Analysis
6. Packaging Requirements

A matrix is included in this appendix that provides a quick comparison of the more significant logistics aspects of each anti-glint concept.

A more detailed discussion of each logistics element, as it applys to anti-glint, is also included.

MAINTENANCE REQUIREMENTS

(1) Cylindrical Grid Baffle:

Field repair will be limited to straightening of the baffle sections and repainting as required.

G. S. repair includes welding cracks and replacing segments.

(2) Anti-Reflective Coating:

Special care may be required to clean coated surface.

(3) Flat Plate:

Field maintenance will be similar to the existing canopy.

(4) Flat Plate with Grid Baffle:

Field repair will be limited to straightening of baffle sections and repainting as required.

G. S. repair includes welding - replacing segments.

MAINTAINABILITY ANALYSIS
(Ranked according to maintainability preference)

(1) Cylindrical Grid Baffle - Ranked #4

Minor repair of baffles is simple and straightforward. Ordinary tools and skills available at field level are all that will be needed to straighten bent baffles and repaint as necessary. Frequency of repair expected to be high because of vulnerability to travel damage and difficulty in handling and stowing.

(2) Anti-reflective Coating - Ranked #2

Presents the same maintenance impact as the existing canopy except that coating is vacuum deposited under rigid conditions and may be difficult to clean without damage or wear.

(3) Flat Plate - Ranked #1

Repair is essentially the same as the existing canopy. Some increase in vulnerability is assigned because of added damage potential of the vertical plate and protruding corners. Travel past overhanging trees and maintenance or servicing actions present threatening situations. Installation of the vehicle cover and bows is an example.

(4) Flat Plate with Baffle Grid - Ranked #3

Conditions of both (1) and (3) above, are present. Vulnerability to damage by overhanging trees is even greater; however, handling, stowing, and repairing conditions are better.

SUPPLY - SUPPORT IMPACT

A. Documentation:

New documentation for provisioning purposes and maintenance support include:

DCN's for each new part and also for the canopy if a new part number is assigned because of anti-reflective coating or flat plate modification.

The cylindrical grid baffle will require DCN's for the attaching hardware, for the baffle itself, and for any new hardware devised for stowing. The same is true for the flat plate grid baffle.

B. Spares:

Initial spares estimates, based on expected vulnerability or usage, indicate that six (6) spare grid baffles will be needed for every 100 fire units in operation, for either the cylindrical or flat plate canopy versions.

Anti-reflective coating canopy spares will be the same as for existing canopies. (If existing canopies and spares are coated, then no new spares will be needed.) The flat plate version will require at least four (4) spares per 100 fire units.

Attaching and stowing hardware will also have to be supplied in matching quantities.

RETROFIT CONSIDERATIONS

All of the anti-glint versions can be installed in the field by user personnel with available tools. Fire unit down time and man hours required to install the anti-glint hardware will vary according to the version selected.

The cylindrical grid baffle will require locating and installing mounting brackets and hardware for stowing. An estimated four (4) hours will be required using one man for three (3) hours, and another man for one (1) hour (4 man hours).

Installation of the anti-reflective coated glass will require two (2) men for four (4) hours. The task involves removing the canopy glass from the frame and re-installing the modified glass. Repacking the old glass for salvage or rework is not included.

Estimates for the flat plate version are the same as for the AR coated canopy. Installation of the flat plate with grid baffle requires an additional one (1) man hour to locate and install stowing brackets for the baffle grid. (Five (5) hours elapsed time, nine (9) man hours total.)

One other retrofit consideration must be included in this narrative. The additional canopy weight involved in three of the four concepts may require reinforcing hardware to be added to the canopy retrofit kits. Task times would have to be extended accordingly. Any such hardware design must also take into account the canopy reinforcing modification currently being implemented.

TRANSPORTATION AND TRAVEL (MODE) IMPACT ANALYSIS

Transportation: (Baffle Types)

Transport by air (C-130 aircraft) will require removal and stowing of the baffle section as well as the canopy, as is now the case.

Truck and rail transport, Class A packaging, will require modification of the plywood housing to maintain clearance above the higher flat plate version. The baffle section would be stowed or packaged separately. The cylindrical grid baffle would only require stow capability or separate packaging. The plywood housing would not need altering.

Class B truck and rail transport will require additional packaging for the grid baffles. Canopy protection will remain the same except for the anti-reflective coated canopy. Special protection will have to be devised.

Travel Mode Considerations: (Baffle Types)

Installing the vehicle cover and bows requires removal of the baffle section. Stowing the baffle after removal will require additional hardware not yet developed.

PACKAGING REQUIREMENTS

New packaging requirements, in addition to those related to transportation, consist primarily of new containers for the grid baffles (with new Packaging Data Sheets) and revising the canopy container and PDS to accommodate the flat plate version.

ANTI-GLINT LOGISTIC IMPACT

ANTI GLINT CONCEPT	MWO STEPS	REPAIR PARTS QUANTITY	MWO INSTALLATION TIME	SUSCEPTABILITY	MAINTAINABILITY RANK[d]	TRAVEL MODE AND TRANSPORTATION IMPACT
CYLINDRICAL GRID BAFFLE *Note a,c	Drill Holes - Install MTG Brackets (Stow grid in Travel Mode)	Six per 100 EI's plus mounting and stowage brackets	3 hours, Down Time (4 man hours)	Can be damaged by tree branches	4	Requires removal and stowage of grid for installation of bows and cover.
ANTI-REFLECTIVE COATING *a,b	Replace Canopy Glass	Rework Existing Spares	4 hours, Down Time (8 man hours)	Coating vulnerable	2	Requires special cover for Class B surface transportation. No Change travel mode.
FLAT PLATE	Replace Canopy Glass	New Spares 4 per 100 EI's	4 hours, Down Time (8 man hours)	Front Plate might be damaged by tree branches	1	Modification of Class A packaging required. No Change to travel mode.
FLAT PLATE WITH GRID BAFFLE *a,b,c	Replace Canopy Glass (Stow grid in Travel Mode)	New Spares 6 grids per 100 EI's plus flat plate spares	5 hours, Down Time (9 man hours)	Grid and Front Plate can be damaged by tree branches.	3	Modification of Class A packaging required. Requires removal and stowage of grid for installation of bows and cover.

*a. NO SPECIAL TOOLS WILL BE REQUIRED FOR INSTALLATION.
b. REWORK OF CANOPY OR CANOPY GLASS MAY BE REQUIRED.
c. TRANSPORT BY AIR, OR WHEN IN THE TRAVEL MODE WITH VEHICLE COVER IN PLACE, REQUIRES INSTALLATION OF EXTRA BRACKET TO SECURE GRID TO DECK - OR OTHER PREFERRED LOCATION. THIS WOULD REQUIRE A MODIFICATION TO THE FIRE UNIT OVER AND ABOVE THE CANOPY REWORK
d. MAINTAINABILITY RANK - NO. 1 IS MOST DESIRABLE WITH LEAST IMPACT - NO. 4 IS LEAST DESIRABLE.

DISTRIBUTION

	Copies
Commanding General US Army Missile Command ATTN: DRCPM-CF, COL Howard C. Whittaker	1
DRCPM-CFE, Mr. Jackson	5
DRCPM-CFP	1
DRCPM-CFT	2
DRCPM-CFS	1
DRCPM-CFC	1
DRSMI-RCL, Mr. Woods	1
DRSMI-RLS, Mr. Bounds	1
DRSMI-QEA	1
DRSMI-NEC	1
DRSMI-O	1
DRXHE-MI, Mr. Chaikin Redstone Arsenal, AL 35809	1
Department of the Army ATTN: DAMO-RQA, MAJ Garner Washington, DC 20310	1
Department of the Army ATTN: DAMA-WSM-A, MAJ Horton Washington, DC 20310	1
Commander US Army Logistics Evaluation Agency ATTN: DALO-LEI, Mr. J. Wineke, Jr. New Cumberland, PA 17070	1
Commander US Army Materiel Development and Readiness Command ATTN: DRCDE-DA, Mr. Lyle 5001 Eisenhower Avenue Alexandria, VA 22333	1
Commander US Army Training & Doctrine Command ATTN: ATCD-CF-A Ft. Monroe, VA 23651	1
Commandant US Army Air Defense School ATTN: ATSA-CD-MS, CPT Tunks Ft. Bliss, TX 79916	1

Commander 1
Test and Evaluation Command
ATTN: DRSTE-AD, Mr. R. Fisher
Aberdeen Proving Ground, MD 21005

Commander 1
White Sands Missile Range
ATTN: STEWS-TE-MF, Mr. Sweem
White Sands, NM 88002

Commander 1
USAADS
ATTN: ATZC-D-MT, CPT R. Mornell
Ft. Bliss, TX 79916

US ARMY MISSILE COMMAND FIELD OFFICE 1
ATTN: Mr. V.F. Andrews, DRCPM-CFF
% Aeronutronic Ford Corporation
Ford Road
Newport Beach, CA 92663

Commander 1
MERADCOM
ATTN: DRXFB-R
Ft. Belvoir, VA 22060