TECHNICAL MEMORANDUM NO. LWL-CR-06P72B

COBRA GLINT MODEL AH-1G

by

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March 1974

Final Report

Contract No. DAAD05-72-C-0284

Work Assignment No. 2

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Prepared For

U.S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005
The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.
This report details the development of a computer simulation model of the Attack Helicopter to predict the visual detectivity of the aircraft by a ground observer due to sun reflections from its windows. In addition, the model was exercised to determine probabilities of detection versus angles of incident sunlight and also used to determine sunshade configuration for reducing reflections. The helicopter canopy was described by 1464 separate segments that were defined with respect to an earth-referenced coordinate.
system. This permitted the model to be used with various aircraft altitudes, attitudes and sun angle and zenith relationships.

The results showed that large glints occur at all angles of incidence and suggest that a combination of improved window design, improved anti-reflection window coatings, and a sunshade system may be required to reduce reflections to an acceptable level.

The model as developed to this point may also be used in evaluation of other canopy configurations by inputting the appropriate window information into the model.
FOREWORD

This effort was sponsored by the US Army Land Warfare Laboratory, Aberdeen Proving Ground, MD. It was initiated by, and performed under the technical supervision of, Mr. Harold C. Forst, Physicist, of the Advanced Development Division, Applied Physics Branch. The work was conducted to develop the capabilities required by LWL Task 06-P-72, entitled Glare Reduction, which involved various approaches to reduce the visible signature of the attack helicopter. The period of performance extended from August through December 1972 with the latter two months being under the technical supervision of Mr. Gerald E. Cook of the Applied Physics Branch due to reassignment of Mr. Forst.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction and Summary</td>
<td>1-1</td>
</tr>
<tr>
<td>2. The Helicopter Windows</td>
<td>2-1</td>
</tr>
<tr>
<td>3. The Computer Model</td>
<td>3-1</td>
</tr>
<tr>
<td>3.1 General</td>
<td>3-1</td>
</tr>
<tr>
<td>3.2 Normal Computation</td>
<td>3-3</td>
</tr>
<tr>
<td>3.3 Area Contour Plot</td>
<td>3-7</td>
</tr>
<tr>
<td>3.4 Brightness Plot</td>
<td>3-9</td>
</tr>
<tr>
<td>3.5 Helicopter Detection Range</td>
<td>3-10</td>
</tr>
<tr>
<td>3.6 Window Detection Range</td>
<td>3-12</td>
</tr>
<tr>
<td>3.7 Required Reflectivity</td>
<td>3-13</td>
</tr>
<tr>
<td>4. Exercising the Model</td>
<td></td>
</tr>
<tr>
<td>5. Conclusions</td>
<td>5-1</td>
</tr>
<tr>
<td>5.1 Effect of Visibility Range on Required Reflectivity</td>
<td>5-1</td>
</tr>
<tr>
<td>5.2 Effect of Detection Criteria on Required Reflectivity</td>
<td>5-1</td>
</tr>
<tr>
<td>5.3 Effect of Flat vs. Curved Windows</td>
<td>5-1</td>
</tr>
<tr>
<td>5.4 Use of Sunshades</td>
<td>5-2</td>
</tr>
<tr>
<td>APPENDIX A - Listing of Digital Computer Program for Cobra Window Model</td>
<td>A-1</td>
</tr>
<tr>
<td>APPENDIX B - Typical Results from Cobra Window Model</td>
<td>B-1</td>
</tr>
<tr>
<td>APPENDIX C - Required Reflectivity for Cobra Window</td>
<td>C-1</td>
</tr>
</tbody>
</table>
1. INTRODUCTION AND SUMMARY

Work Assignment #2 to Contract Number DAAD05-72-C-0284 is concerned with development of a Glint Model for the Cobra AH-1G to analyze glint off the windows. Sun glints off the rotor hub, fuselage and windows in level flight and while banking allow the visual observer to detect low flying aircraft at much longer ranges than is possible in nonglint conditions. Reflections and glints from the rotor blades, rotor hub and fuselage have been adequately taken care of by use of a non-reflecting light-dispersing paint. This task is then concerned with window areas.

The objectives of the task are to develop a simulation model of the Cobra AH-1G for use in predicting the visual detectivity of the aircraft by a ground observer due to sun glints from the windows; to exercise this model to determine probabilities of detection vs. angles of incidence of sunlight; and to use the model to determine the best sunshade configuration. These objectives were met by the model described in Section 3 which used the window configuration described in Section 2. The model included the parameters of sun angle, sun intensity, atmospheric transmission, sun-aircraft relationship, detection sensitivity of the human eye, background intensity and contrast between background and aircraft (to determine detection ranges for observer position relative to the aircraft). A 50% probability of detection criterion was used to determine the ranges. The required reflectivities for the windows were computed as a function of angle of incidence for reducing detection range to the nonglint detection range of the helicopter and for reducing detection range to 1500 meters.

The results showed that to reduce detection range to the nonglint detection range of the helicopter, the required reflectivity varied from less than...
.1% to more than 30% over all angles of incidence. To reduce detection range to 1500 meters, the required reflectivity varied from less than .001% to more than .5% over all angles. The most stringent requirements were due to large glints off the relatively flat overhead window. If this window was removed from the model, the low end requirements were relaxed by an order of magnitude to less than 2% and less than .01% respectively. These data indicate that large glints occur at all angles of incidence and that a combination of improved window design, improved window coatings and a sunshade system may be required to reduce glints to an acceptable level.

It is recommended that additional work in this area be performed on shutter designs and then use the model developed under this task as a basic tool in evaluating the shutter redesigns. The model should be modified for future use to consider cluttered and uncluttered backgrounds with high and low background reflectance. This modification is a minor one. In addition, the criteria for use in evaluating shutter designs must be determined and agreed upon.

The model as developed to this point may also be used in evaluation of other helicopter windows by inputting the appropriate window information into the model.
2. THE HELICOPTER WINDOWS

The Cobra AH-1G has five windows, two on each side and an overhead. The location of the windows is described by five outline drawings (listed below) and their contour is described by Bell Helicopter drawing 209-B3 Revision A.

<table>
<thead>
<tr>
<th>Window</th>
<th>Outline Drawing</th>
<th>Contour Drawing</th>
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</thead>
<tbody>
<tr>
<td>Pilot's Door</td>
<td>209-030-516</td>
<td></td>
</tr>
<tr>
<td>(Pilot's left side)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pilot's Window</td>
<td>209-030-507</td>
<td>209-B3</td>
</tr>
<tr>
<td>(Right side)</td>
<td></td>
<td></td>
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<tr>
<td>Gunner's Door</td>
<td>209-030-515</td>
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<tr>
<td>(Left side)</td>
<td></td>
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<tr>
<td>Gunner's Window</td>
<td>209-030-508</td>
<td>209-B3</td>
</tr>
<tr>
<td>(Right side)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overhead Window</td>
<td>209-030-509</td>
<td>209-B3</td>
</tr>
</tbody>
</table>

The contour drawing describes the mold used in making the windows. Although it describes only the right hand side and overhead windows, the left side windows are the mirror image of the right hand side windows. The format of the drawing is a series of twenty-seven full scale curves taken at various flight stations from 53.5 to 169.5 along the longitudinal axis of the Cobra at intervals of at least .5" and no more than 6".

In order to describe the windows for use in the model, xyz information was generated for 726 points on the right side windows and for 12 points on the overhead window using the curves on the Bell drawing. Points were generated only for those portions of each curve which fell within the outline of the windows as determined by the five outline drawings noted above.

The center of the coordinate system for the x, y, z values was taken as the 0, 0, 0 point for Flight Station 0, Bulkhead Line 0 and Water Line 0.
This point is shown in figure 2-1 which was taken from figure 12-2 of the Cobra Manual. This system assigns negative x values to Flight Station numbers, positive y values to left Bulkhead Line numbers and positive z values to Water Line numbers. The x y z points for the side windows were determined by plotting points at approximately 1" intervals along each of the twenty-seven curves of the contour drawing and noting their x, y, z values. Although this process could be done by a digitizing plotter with a printout in thousandths of an inch; it was done by hand for this task due to lead time requirements for the digitizer. x, y, z values were measured to the nearest hundredth of an inch, with an estimated accuracy of ±.01 inches. The errors in blueprint distortion were estimated to be 1/16" in 36" or less than .5%. The right hand window was assigned negative x values, negative y values and positive z values. Corresponding points on the left hand window had identical x and z values and identical y values with a positive rather than negative sign.

The overhead window was flat along y and curved in x and z with flats at the front and top. It was described by twelve points, with the first and second describing the front flat, the eleventh and twelfth describing the top flat and the second through eleventh describing the curved portion.
Figure 2-1. Helicopter Reference Points
3. THE COMPUTER MODEL

3.1 General

The computer model was programmed in Fortran IV and run on the Univac 1108 digital computer at the Westinghouse and Defense Center. The model output includes the following:

a) A listing of 726 side window surfaces and 12 center window surfaces with their x,y,z coordinates, x,y,z components of their normals and effective area.

b) A listing of the 1464 surfaces of both side windows and the center window by surface number with x,y,z coordinates for each surface.

c) An Area Contour Plot showing the projection of all normals in zenith and azimuth coordinates.

d) A listing of the azimuth and zenith coordinates of each normal.

e) A Brightness Plot showing the relative brightness of reflected rays in zenith and azimuth coordinates.

f) A Helicopter Detection Range contour plot showing the detection range of the helicopter along each reflected ray in zenith and azimuth coordinates.

g) A Window Detection Range contour plot showing the detection range of the glint along each reflected ray in zenith and azimuth coordinates.

h) A listing of the azimuth and zenith coordinates, the angle of incidence and the glint detection range for each reflected ray.

i) A listing of the required reflectivity for each angle of incidence.

j) A plot of required reflectivity vs. angle of incidence.

A flow chart of the model is shown in figure 3-1. Paragraph numbers are inserted in the flow chart to show where discussion on the various parts of the model can be found. In order to keep machine time and thus computer costs down, the model was divided into three segments. The first segment computed normals and effective areas. Its output is a) above. This output
INPUT XYZ OF 726 POINTS ON SIDE WINDOW

CALCULATE NORMALS \[3.2\] AND EFFECTIVE AREAS OF 726 SIDE WINDOW POINTS

LIST OF XYZ, NORMAL, AND AREA DATA FOR EACH POINT

DATA CARD FOR EACH POINT (726)

INPUT XYZ OF 12 POINTS ON OVERHEAD WINDOW

CALCULATE NORMALS \[3.2\] AND EFFECTIVE AREAS OF 12 OVERHEAD WINDOW POINTS

LIST OF XYZ, NORMAL, AND AREA DATA FOR EACH POINT

DATA CARD FOR EACH POINT (12)

SUN POSITION

CALCULATE BRIGHTNESS FACTOR FOR EACH REFLECTED RAY IN \( \alpha, \beta \) COORDINATES

CALCULATE AREA IN \( \alpha, \beta \) \[3.3\] COORDINATES FOR EACH OF 1464 NORMALS (726+726+12)

CALCULATE HELICOPTER DETECTION RANGE (WITHOUT WINDOW GLINT)

CALCULATE WINDOW DETECTION RANGE CONTOUR PLOT

CALCULATE REQUIRED REFLECTIVITY

REQUIRED REFLECTIVITY LISTING AND PLOT

CALCULATE BRIGHTNESS PLOT

AREA CONTOUR PLOT

LISTING OF \( \alpha, \beta \) FOR EACH NORMAL

CALCULATE HELICOPTER DETECTION RANGE CONTOUR PLOT

WINDOW DETECTION RANGE CONTOUR PLOT

LISTING OF \( \alpha, \beta, \) RANGE, AND ANGLE OF INCIDENCE FOR EACH NORMAL

Figure 3-1. Flow Chart for Cobra Model

3-2
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is fed into the second segment which computes an Area Contour Plot and an associated $\alpha, \beta$ (zenith, azimuth) plot. Its output is b), c) and d) above.

This output is required only once for a given window configuration. The output of the first segment is also fed into the third segment which computes brightness factors, detection ranges and required reflectivities for various sun positions, visibility conditions and reflectivity requirement criteria. Its output is e) through g) above. A listing of the three segments is provided in Appendix A.

3.2 Normal Computation

The normal computation segment of the model was performed in two different programs, one for the right side window and one for the overhead window. Both programs computed tangents on the window and used these tangents to compute $x, y, z$ components of the normals and effective areas. Since this data doesn't change for the same window, it was computed only once, and output on IBM cards which were then used as an integral part of the next program segments. The data generated for the right side window applied to the left side window when the signs of the $y$ position and the $y$ component of the normal were changed from - to +.

The 726 points on the side window were grouped in 27 sets of from 1 to 40 points which described contour curves of equal $x$ values. Figure 3-2 shows a representation of several of these lines. Data for each of these points was read into the program. The data was then ordered in first $x$ and then $z$. Then tangents along the $x$ curve were computed by computing the vectors between adjacent points along the $x$ curve. The tangents were described in $x$, $y$ and $z$ values. Each point, $P_x, y, z$, had tangents $T_1$ and $T_3$ computed where $T_1$ was the vector from $P_{x,y,z}$ to $P_{x,y,z-1}$, the point with the next lowest $z$ value on
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Figure 3-2. Tangents on Side Windows

\[ TBA = \overline{B} - \overline{A} = (B_x - A_x) x + (B_y - A_y) y + (B_z - A_z) z \]

\[ \overline{T_1} = 0.46y - 1.1z \]
\[ \overline{T_2} = -6x + 0.1y + 0.27z \]
\[ \overline{T_3} = -0.5y + 0.863 \]
\[ \overline{T_4} = 6x - 0.96y - 1.21z \]
that x curve, and T3 was the vector from \( p_{x,y,z} \) to \( p_{x,y,z+1} \), the point with the next highest z value on that x curve. At the end points, artificial vectors of length .001 were introduced to provide continuity. Tangents T2 and T4 across x curves were computed by finding the closest points on either side of the x curves and computing the vectors to them from \( p_{x,y,z} \). On the extreme points, artificial vectors of length .001 were introduced to provide continuity. An example of the four tangent vectors for one point is given in figure 3-2.

To obtain the normals, cross products between T1 and T2, T2 and T3, T3 and T4 and T4 and T1 were computed. The result of each cross product computation was an x value, y value, z value and an area. The x value of the normal was obtained by dividing the sum of the four x values by the sum of the four area values. The y and z values were obtained in a similar manner. The result was a unit normal which was unaffected by the artificial tangents since they had a small length and thus a near zero area. A representation of the four subnormals, \( N_{12}, N_{23}, N_{34} \) and \( N_{41} \) and the resultant normal \( \bar{N} \) is shown in figure 3-3.

The angle between each normal and its four subnormals was obtained by taking the dot product of the subnormal and the normal. The result was the cosine of the angle. This angle was then divided into 1/80 and the result multiplied by the area obtained from the cross product computation to obtain the effective area for the subnormal. The four subnormal effective areas for each area were then added to provide a total effective area for each normal. This area was a function of the area of the sector defined by the normal, the radius of curvature of the sector and the ±1/4° angular subtense of the sun.
Figure 3-3. Normals on Side Window
A similar but simplified method was used for the twelve points on the overhead window. Two tangents, T1 and T3, were computed for each point using the adjacent points. A third tangent, T2 of x=0, y=16, z=0 was used to represent the window width. The normals and effective areas were then generated using two cross products, T1 x T2 and T2 x T3.

The output of the two programs was a listing of 738 points by their x,y,z position with x,y,z components of their unit vectors and their effective areas. This output is presented in Appendix B. An IBM data card was generated for each point for use in the next segments of the model.

3.3 Area Contour Plot

This segment of the model converts the data of 738 window sectors into 1464 window sectors covering both side windows (726 sectors each) and the overhead window (12 sectors).

The Area Contour Plot shows the projections of the normals in azimuth and zenith coordinates for a trimmed helicopter. The zenith angle of the normal is called $\alpha$ and the azimuth angle is called $\beta$ on the plot. Figure 3-4 shows the $\alpha$, $\beta$ angular relationships. The zenith and azimuth angles are quantized in $3^\circ$ increments and the sum of all areas within $\pm1^{1/2}_o$ of each quantized zenith and azimuth point are plotted on the Area Contour Plot. Numbers on the plot are two place integers representing $10 \log_{10} (\text{Area} \times 1000)$. This representation was chosen to guarantee that all areas could be represented by a positive two place number.

The output of this segment of the model is a listing by surface number of the x,y,z, coordinates of each of the 1464 normals, a listing by surface number of the $\alpha$, $\beta$ coordinates of each normal, and the Area Contour Plot. By assigning surface numbers and listing the $\alpha$, $\beta$ of each normal, it is
Figure 3-4. Alpha, Beta Coordinate System
possible to find the point or points on the windows which a given \( \alpha, \beta \) or area corresponds to.

The surface \( x,y,z \) listing, the \( \alpha, \beta \) listing and the Area Contour Plot are presented in Appendix B.

The data from this segment of the model is generated only once because it does not change for a given window configuration. This information is then used in the third segment of the model.

3.4 Brightness Plot

This segment of the program computes the reflected sun rays off the helicopter window and computes a brightness factor which is used later to compute detection range. A Brightness Plot showing relative brightness as a function of the azimuth and zenith position of the reflected rays is generated.

Each sun position relative to the helicopter's trim position is considered as one case. For each case a new brightness plot is generated showing all of the reflected rays. The \( x,y,z \) components of the reflected ray are computed by equations (1), (2) and (3).

\[
\begin{align*}
\text{(1)} \quad RX &= SX - 2 \times SDN \times XN \\
\text{(2)} \quad RY &= SY - 2 \times SDN \times YN \\
\text{(3)} \quad RZ &= SZ - 2 \times SDN \times ZN
\end{align*}
\]

where:

\[
\begin{align*}
SX &= \text{sun rays x component} = -\cos(\text{sun azimuth}) \times \sin(\text{sun zenith}) \\
SY &= \text{sun rays y component} = -\sin(\text{sun azimuth}) \times \sin(\text{sun zenith}) \\
SZ &= \text{sun rays z component} = -\cos(\text{sun zenith}) \\
XN &= \text{x component of normal} \\
YN &= \text{y component of normal}
\end{align*}
\]
ZN = Z component of normal

SDN = dot product of normal and sun ray = cosine of angle of incidence between sun ray and surface normal

When SDN is negative, the angle of incidence is greater than 90° and the normal under consideration is in the shadow of the window. For these normals there is no reflected ray and no brightness factor.

The sun ray vector is defined as a unit vector and the normal vector is a unit vector, thus the reflected ray vector is a unit vector. This vector is used to calculate the $\alpha$, $\beta$ position of the reflected ray in a manner similar to that of the $\alpha$, $\beta$ position of the normal vector in section 3.3, with the $\alpha$, $\beta$ position quantized in 3° sectors.

The brightness factor is computed by equation (4).

\[(4) \quad BF = area \times SDN \times RO\]

where:

area = the area associated with the normal as computed in the normal computation

RO = coefficient of reflectivity of the window material (acrylic plastic) and the angle of incidence. This coefficient is computed in a continuous fraction subroutine which uses data supplied by LWL.

The highest brightness factor for each quantized $\alpha$, $\beta$ is printed on the Brightness Plot. Numbers on the plot are two place integers representing $10 \log_{10} (\text{Brightness Factor} \times 10^7)$. This representation was chosen to guarantee that all brightness factors could be represented by a positive two place number.

A typical Brightness Plot (sun zenith = 45°) is presented in Appendix B.

3.5 Helicopter Detection Range

Helicopter detection range is the 50% probability of detecting the
helicopter with the photopic eye and is calculated along each reflected ray. It is used in the determination of required reflectivity.

Two contrast equations are used in the calculations of detection range. The first equation (5) describes the contrast of the helicopter against an east horizon sky. The second equation (6) describes the contrast required in order to see the helicopter.

\[ CT_1 = \frac{BH \times ROE - BH}{BH} \times 100 \times e^{-3.9075 \times RT/RVIS} \]

where:

- \( BH \): horizon brightness = 0.0009 W/cm²/steradian
- \( ROE \): reflectivity of helicopter paint = 0.15
- \( RT \): detection range (50% probability) of helicopter in nautical miles
- \( RVIS \): visibility range in nautical miles
- \( e^{-3.9075} = \) two percent minimum contrast requirement

\[ CT_2 = 1.57 + 36.5 \frac{RT^2}{A} \]

where:

- \( A \): area in square feet

The area of the helicopter is calculated as the visible area of the helicopter along a reflected ray as calculated by equation (7).

\[ AP = RX \times 35 + RY \times 450 + RZ \times 157.5 \]

where:

- \( 35 \): frontal area in square feet
- \( 450 \): side area in square feet
- \( 157.5 \): top area in square feet
Equations (5) and (6) are transcendental when solving for $R$. Thus, equation (8) and its derivative, equation (9) were used to solve for $R$. The equations approach a solution as $F$ approaches 0. The pair of equations were iterated with initial $R = 0$ and $-F/F'$ being used as the correction factor. For each following iteration, $R$ was incremented by $-F/F'$ until $F/F'$ was less than .1 miles.

(8) \[ F = -CT_1 + 1.57 + 36 \times R/T^2/AP \]

(9) \[ F' = 3.9075 \times CT_1/RVIS + 2 \times 36.5 \times R/T/AP \]

The Helicopter Detection Range Contour is obtained by using an $\alpha$, $\beta$ plot similar to that for the Brightness Plot except that the maximum Helicopter Range in nautical miles is plotted for each quantized $\alpha$, $\beta$ position. A typical Helicopter Detection Range Contour Plot ($\text{sun zenith} = 45^\circ$, $\text{sun azimuth} = 45^\circ$) is presented in Appendix B.

3.6 Window Detection Range

The window detection range is the range at which there is a 50% probability of detecting the window glint with the photopic eye.

As with helicopter detection range, two contrast equations, (10) and (11) respectively, describe the contrast of the sun glint against an eastern horizon sky and the contrast required to detect the glint, and difference equation (12) and its derivative, equation (13), are used to solve equations (10) and (11).

(10) \[ CG \_1 = \frac{BS \times EYE \times RO - BH \times 100 \times e^{-3.9075 \times RG/RVIS}}{BH} \]

where:

- $BS = \text{sun brightness} = 2000 \text{ w/cm}^2/\text{steradian}$
- $EYE = \text{photopic response of eye to the sun} = .15$
RG = detection range (50% probability) of window glint in nautical miles

(11) \[ CG_2 = 1.57 + 36.5 \times \frac{RG^2}{ABF} \]
where: \( ABF = BF/(RO \times 144.) = \) effective area of window sector in square feet

(12) \[ F = -CG_1 + 1.57 + 36.5 \frac{RG^2}{ABF} \]

(13) \[ F' = 3.9075 \frac{CG_1}{RVIS} + 2 \times 36.5 \frac{RG^2}{ABF} \]

The Window Detection Range Contour is obtained by using an \( \alpha, \beta \) plot similar to that for the Brightness Plot except that the maximum Window Detection Range in nautical miles is plotted for each quantized \( \alpha, \beta \) position. A typical Window Detection Range Contour Plot (sun azimuth = 45\(^\circ\), sun zenith = 45\(^\circ\)) is presented in Appendix B.

The relationship between brightness factor and window detection range can be shown by letting \( CG_1 \) of equation (10) equal \( CG_2 \) of equation (11). After some algebraic manipulation, we obtain equation (14).

\[
(14) \quad BF = \frac{36.5 \times RG^2 \times BH}{(BS \times EYE - BH) \times 100 \times e^{-3.9075 \frac{RG}{RVIS}}} \]

Figure 3-5 shows the relationship for visibility ranges of 5, 10 and 20 nautical miles.

3.7 Required Reflectivity

Required reflectivity is defined as that reflectivity which the windows would need in order that the detection range (50% probability) of the glint would not exceed a specified range, possibly the detection range of the helicopter itself, or a constant range such as 1500 meters. It is generated as a function of the angle of incidence of the sun's rays on the window surfaces.

The required reflectivity is computed by equating \( CG_1 \) of equation (10)
Figure 3-5. Brightness Factor vs. Detection Range
and $CO_2$ of equation (11) and solving for RO with RT, the desired range, substituted for RG. When helicopter detection range is the desired criteria, its value as computed earlier is used. When a constant range is specified, that range is used for RT. The resulting equation for required reflectivity (ROG) is given as equation (14).

\[
(14) \quad \text{ROG} = \frac{1.57 + 36.5 \times RT^2}{\text{ABF}} \times \frac{\text{BH}}{\text{BS} \times \text{EYE} \times 100 \times e^{-3.9075 \, RT/\text{RVIS}}}
\]

The above calculation is made for each reflected ray. The angle of incidence of each ray is computed as arccosine (SDN) and rounded to the nearest degree. Then a lowest value of ROG is found for each angle of incidence from $0^\circ$ to $90^\circ$. Where there are no reflected rays for an angle of incidence, ROG is assumed to be an arbitrary number, 10, which is higher than the actual maximum reflectivity of which any passive surface can have.

A listing and a plot of required reflectivity as a function of angle of incidence is generated for each case. The plot includes a count of the number of rays at each incident angle. At the end of a run of multiple cases, a summary listing and plot is printed out. An example of the listing and plot of required reflectivities is presented in Appendix B.
4. EXERCISING THE MODEL

The first two segments of the model were used one time to compute the window normals and the effective area associated with each normal and to generate an Area Contour Plot. These results are presented in Appendix B.

In the third segment of the program, several sets of runs were made for various visibility ranges and required reflectivity criteria. Each set of runs included 17 sun position cases as shown in Table 4-1. These sun positions relative to the helicopter covered the range of possible sun position-helicopter relationships. For example, a helicopter banking at 45° against a horizon sun might have a zenith = 135°, azimuth = 90° sun position relationship. Six sets of data were run as tabulated in Table 4-2. Different runs at 20 and 5 nautical miles were made to show the effect of visibility range on required reflectivity. Different runs using Helicopter Detection Range and a constant 1500 meters showed the effect of choosing the different criteria for judging window design. The runs without the overhead windows were run because the largest glints were found to occur on the overhead windows and these large glints overpowered the effect of glints off the curved.

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<th>Zenith</th>
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<th>135</th>
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Table 4-2. Parameter Variation in Runs Made

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<th>Visibility Range N. Miles</th>
<th>Overhead Windows</th>
<th>Sun Position</th>
<th>Summary of Reflectivity Requirements</th>
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The output for each case in the 6 runs included the brightness plot, a listing of normal numbers, $\alpha$, $\beta$, angle of incidence and glint detection range, and a listing and plot of the required reflectivity vs. angle of incidence. The summary reflectivity listings and plots for cases 1 through 6 are shown in figures 4-1 through 4-6. The reflectivity listings and plots for the seventeen cases in run #1 are included in Appendix C.
REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE

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SUMMARY OF REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE FOR ALL SUN POSITIONS

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ANGLE OF INCIDENCE

RVIS = 5 n. mi.

RT = Helicopter Detection Range

Figure 4-1. Case #1 Reflectivity Requirements
**Figure 4-2. Case #2 Reflectivity Requirements**

\[
\begin{array}{cccccccc}
\text{ANGLE} & 0 & 10 & 20 & 30 & 40 & 50 & 60 & 70 \\
\text{RVIS} & 0 & 0.007476 & 0.1247 & 0.00734 & 0.007520 & 0.004124 & 0.150099 & 0.007520 \\
\text{RT} & 0 & 0.007476 & 0.1247 & 0.00734 & 0.007520 & 0.004124 & 0.150099 & 0.007520 \\
\end{array}
\]

RVIS = 20 n. miles

RT = Helicopter Detection Range
**UNCLASSIFIED**

## RECOMMENDED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE

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**SUMMARY OF REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE FOR ALL SUN POSITIONS**

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RVIS = 5 n. mi.

RT = Helicopter Detection Range

No Overhead Window

*Figure 4-3. Case #3 Reflectivity Requirements*
REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE

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SUMMARY OF REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE FOR ALL SUN POSITIONS

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<table>
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<tr>
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Figure 4-4. Case #4 Reflectivity Requirements
REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE

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SUMMARY OF REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE FOR ALL SUN POSITIONS

RVIS = 20 n. mi

RT = 1500 meters

Figure 4-5. Case #5 Reflectivity Requirements

4-7
REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE

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SUMMARY OF
REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE
FOR ALL SUN POSITIONS

RVIS = 5 n. mi.
RT = 1500 meters
No Overhead Windows

Figure 4-6. Case #6 Reflectivity Requirements
5. CONCLUSIONS

From the data obtained in exercising the model, we can obtain several conclusions about the nature of the window glint. These conclusions point the way to future work required in designing the window.

5.1 Effect of Visibility Range on Required Reflectivity

Figures 4-1 and 4-2 show the results of runs #1 and #2 with visibilities of 5 and 20 n. miles respectively and reflectivity requirements based on reducing detection range to that of the non-glint helicopter. This criteria produces more stringent reflectivity requirements for lower visibility ranges because the non-glint detection range is affected more by the reduced visibility than the glint detection range.

However, if the reflectivity requirement is based on reducing detection range to a fixed value, as done in runs #4 and #5 (figures 4-4 and 4-5), the more stringent reflectivity requirements occur at higher visibility ranges.

5.2 Effect of Detection Criteria on Required Reflectivity

A comparison of the results of runs #1 and #4 (figures 4-1 and 4-4) and of the results of runs #2 and #5 (figures 4-2 and 4-5), shows a marked difference in requirements based on the selection of either reducing detection range to the non-glint detection range of the helicopter or reducing detection range to a fixed range (1500 meters in runs #4 and #5) as the detection criteria. This result points out the importance of selecting the criteria to be used in evaluating window modifications or redesign early in any future work effort to guarantee the proper evaluation of proposed solutions.

5.3 Effect of Flat vs. Curved Windows

Early evaluation of the results of exercising the model showed the largest glints came from the large flat sections of the overhead and that as sun
position relative to the helicopter changed, these glints caused very stringent reflectivity requirements over all angles of incidence. When the overhead and thus the flats were removed from the models, as in cases #3 and #6 (see results in figures 4-3 and 4-6), the more stringent reflectivity requirements were reduced by an order of magnitude.

This implies that any window redesign should attempt to eliminate flats and should probably attempt to achieve a minimum value for radius of curvature.

5.4 Use of Sunshades

The goal of using sunshades would be to block off certain sections of the windows which caused the largest glints or to limit the angles of incidence over certain portions of the window to ease the reflectivity requirements. It appears that sunshades would be successful in achieving this goal, but that they alone would not solve the complete problem of reducing sun glints because of the large glints remaining over low angles of incidence. A more detailed investigation of the effects of sunshades on both reduction of glint and reduction of pilot visibility should be made before a final recommendation is made.
LISTING OF DIGITAL COMPUTER PROGRAM FOR COBRA WINDOW MODEL

Segment 1 - Normals and Effective Areas

COBWIN (side window) .............................................. A-2
COBNOR (overhead window) ........................................... A-8

Segment 2 - Area Contours

COBWIN ................................................................. A-11
NORMAL (data block for results of segment 1) ....................... A-15
PLOTT (subroutine for $\alpha$, $\beta$ plots) .......................... A-34

Segment 3 - Brightness Factors, Detection Ranges and Required Reflectivities

COBWIN (also uses NORMAL and PLOTT from segment 2) .......... A-37
CONFRA (subroutine for continued fraction expansion calculation of reflectivity) ............................................. A-46
MAIN PROGRAM

ENTRY POINT 000000

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 001327
0002 *DATA 004531
0002 *BLANK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 COS
0004 SIN
0005 SURT
0006 ATAN2
0007 NROTF
0010 N101B
0011 N102B
0012 NWOOD6
0013 NSTOPB

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 004531 12F
0001 006070 143F
0001 006252 224F
0001 006135 3L
0001 006475 42L
0000 R 004354 ANGLE
0000 R 00427 AN
0000 R 000000 ATAN
0000 R 00401 DELZ
0000 L 004355 I
0000 L 004375 11X
0000 L 004405 10DF
0000 L 004472 106F
0000 L 00451 2F
0000 L 00362 2G
0000 L 00531 3G
0000 L 00602 4L
0000 R 004450 ANOR
0000 R 00436 AR12
0000 R 00435 AR12
0000 R 00440 A23
0000 R 00442 DELFM
0000 R 00437 D23
0000 I 004370 II
0000 I 004344 IOUT
1. C
2. DIMENSION X(730), Y(730), Z(730), X(726), Y(726), Z(726)
3. DIMENSION XL(729), YL(29, 43), ZL(29, 43)
4. DIMENSION XT1(29, 42), YT1(29, 42), ZT1(29, 42)
5. DIMENSION XT2(29, 42), YT2(29, 42), ZT2(29, 42)
6. DIMENSION XT3(29, 42), YT3(29, 42), ZT3(29, 42)
7. DIMENSION XT4(29, 42), YT4(29, 42), ZT4(29, 42)
8. DIMENSION NUMXY(30)
9. I2 = 0
10. I2 = 0
11. I2 = 0
12. ZPOS = 12, *P200*
13. SLEN = 01749345*
14. SAZ = 01749313*
15. SX = COS(AZ) * SIN(SLEN)
16. SY = COS(AZ) * SIN(SLEN)
17. SZ = COS(2SLEN)
18. A2 = 125 * 017493
19. READ(1402)(XX(I), YY(I), ZZ(I), I = 1, 726)
20. FOR J = 1, 726
21. C = 1, 726
22. X(I) = -XA(I)
23. I CONTINUE
24. DO I = 1, 727
25. K = 0
26. DO 3 I = 1, 726
27. IF (X(I) = 0) 4, 5, 3
4. \( X'(M) = AX(1) \)
5. \( Z'(M) = ZZ(1) \)
6. \( Y'(M) = YY(1) \)
7. \( X_0 = XX(I) \)
8. \( Z_0 = ZZ(I) \)
9. \( K = I \)
10. GO TO 5
11. IF \((Z(I) - Z_0) < 0\) THEN 3
12. \( X(A) = XX(1) \)
13. \( Z(A) = ZZ(1) \)
14. \( Y(A) = YY(1) \)
15. \( Z_0 = ZZ(I) \)
16. \( K = I \)
17. CONTINUE
18. \( XX(K) = 1000 \)
19. CONTINUE
20. \( XA = X(M) \)
21. \( P = M \)
22. \( N = 1 \)
23. \( L = 1 \)
24. \( I = 4 + 1 \)
25. IF \((X(M) - AX) > 21, 22, 23\) THEN 22
26. \( I = I + 1 \)
27. GO TO 23
28. \( XL(I + 1) = X(L) \)
29. \( YL(I + 1) = Y(L) \)
30. \( ZL(I + 1) = Z(L) \)
31. \( N = N + 1 \)
32. \( XL(I + 1) = XL(I + 1) \)
33. \( YL(I + 1) = YL(I + 1) \)
34. \( ZL(I + 1) = ZL(I + 1) \)
35. \( I = I - 1 \)
36. \( XL(I + 1) = XL(I + 1) = XL(I + 1) \)
37. \( YL(I + 1) = YL(I + 1) = YL(I + 1) \)
38. \( ZL(I + 1) = ZL(I + 1) = ZL(I + 1) \)
39. \( I = I + 1 \)
40. \( P = P + 1 \)
24 CONTINUE
44 IVX1(IX) = N
25 XT3(I, X, N) = 0.
26 YT3(I, X, N) = -0.001
27 ZT3(I, X, N) = 0.
30 CONTINUE
49 IVX1(1) = 2
50 NUMX = (NUMX + 1) = 2
52 XL(1, E) = -159.5,01
53 XL(2, E) = -53.499
54 YL(1, E) = YL(2, E)
55 YL(2, E) = YL(28, E)
56 ZL(1, E) = ZL(2, E)
57 ZL(2, E) = ZL(28, E)
58 DO 40 IX = 2 * NUMX
59 IX = I, IVX1(IX)
60 DO 4A I = 2, IX
61 III = I - 1
62 DFL = 1.5 * (XL(IX, 2) - XL(III, 2))
63 NUMX = 0
64 IX = I - 1
65 DFL = 1.5 * (XL(IX, 2) - XL(III, 2))
66 DELX = XL(III, IXPL) - XL(IX, I)
67 DELY = YL(III, IXPL) - YL(IX, I)
68 DELZ = ZL(III, IXPL) - ZL(IX, I)
69 DELTEM = SQRT (DFL * DELX + DELY * DELY + DELZ * DELZ)
70 IF (DFL = DELTEM - 4.2, 42, 43)
71 40 DFL = DELTEM
72 XL(IX, I) = DELX
73 YL(IX, I) = DELY
74 ZL(IX, I) = DELZ
75 IX = IX + 1
76 CONTINUE
80 IF (IX, IXPL = 4, 44, 45
81 44 ZT2(IX, I) = 0.
82 YL(IX, I) = 0.
83 XL(IX, I) = 0.
84 45 CONTINUE
85 40 IXMIN = 2, NUM
86 DFL = XL(IXMIN, IXMIN) - XL(IX, I)
114. \( \text{DEL} \rightarrow \text{YL} \left( \text{ADDU} \cdot X \right) \) - YL(IX, I)

115. \( \text{DEL} \rightarrow \text{ZL} \left( \text{ADDU} \cdot X \right) \) - ZL(IX, I)

116. \( \text{DELX} \rightarrow \text{SRT} \left( \text{DELX} \cdot \text{DELX} + \text{DELY} \cdot \text{DELY} + \text{Z} \cdot \text{DELZ} \right) \)

117. \( \text{TF} \left( \text{DEL} \cdot \text{DELTEM} \right) \) 46, 46, 47

118. 47 \( \text{DEL} \rightarrow \text{DELTEM} \)

119. \( \text{XTI} \left( X, I \right) = \text{DELX} \)

120. \( \text{YTI} \left( X, I \right) = \text{DELY} \)

121. \( \text{ZTI} \left( X, I \right) = \text{DELZ} \)

122. \( \text{NO} \left( X, I \right) = \text{INXMIN} \)

123. 40 \( \text{CONTINUE} \)

124. \( \text{IF} \left( \text{OUT} \cdot \text{OUT} \right) = 0 \), 49, 41

125. \( \text{XTI} \left( X, I \right) = 0 \)

126. \( \text{XTI} \left( X, I \right) = 0 \)

127. 41 \( \text{CONTINUE} \)

128. 40 \( \text{CONTINUE} \)

129. \( \text{IF} \left( \text{OUT} \cdot \text{OUT} \right) = 102 \)

130. 102 \( \text{FORMAT} \left( 5X, 1X, 9X, 1HY, 9X, 1HZ, 5X, 8H \right) \) 2X, 8HY 2X, 8HY 2X, 8HY

131. 2X, 8HY 2X, 8HY 2X, 8HY

132. \( \text{LAB} \)

133. \( \text{DO} \) \( \text{BU} \left( IX \right) = 2 \), 40

134. \( \text{IX} = \text{IX} + 1 \left( IX \right) \)

135. \( \text{DO} \) \( \text{BU} \left( IX \right) = 2 \), 40

136. \( \text{IX} = \text{IX} + 1 \left( IX \right) \)

137. \( \text{XI} = \text{XI} + 1 \left( IX \right) \) \( \text{YTI} \left( IX, I \right) + \text{TY} \left( IX, I \right) = \text{TY} \left( IX, I \right) + \text{TY} \left( IX, I \right) \)

138. \( \text{XI} = \text{XI} + 1 \left( IX \right) \)

139. \( \text{XI} = \text{XI} + 1 \left( IX \right) \) \( \text{YTI} \left( IX, I \right) + \text{TY} \left( IX, I \right) = \text{TY} \left( IX, I \right) + \text{TY} \left( IX, I \right) \)

140. \( \text{XI} = \text{XI} + 1 \left( IX \right) \)

141. \( \text{XI} = \text{XI} + 1 \left( IX \right) \) \( \text{YTI} \left( IX, I \right) + \text{TY} \left( IX, I \right) = \text{TY} \left( IX, I \right) + \text{TY} \left( IX, I \right) \)

142. \( \text{XI} = \text{XI} + 1 \left( IX \right) \)

143. \( \text{XI} = \text{XI} + 1 \left( IX \right) \) \( \text{YTI} \left( IX, I \right) + \text{TY} \left( IX, I \right) = \text{TY} \left( IX, I \right) + \text{TY} \left( IX, I \right) \)

144. \( \text{XI} = \text{XI} + 1 \left( IX \right) \)

145. \( \text{XI} = \text{XI} + 1 \left( IX \right) \) \( \text{YTI} \left( IX, I \right) + \text{TY} \left( IX, I \right) = \text{TY} \left( IX, I \right) + \text{TY} \left( IX, I \right) \)

146. \( \text{XI} = \text{XI} + 1 \left( IX \right) \)

147. \( \text{XI} = \text{XI} + 1 \left( IX \right) \) \( \text{YTI} \left( IX, I \right) + \text{TY} \left( IX, I \right) = \text{TY} \left( IX, I \right) + \text{TY} \left( IX, I \right) \)

148. \( \text{XI} = \text{XI} + 1 \left( IX \right) \)

149. \( \text{XI} = \text{XI} + 1 \left( IX \right) \) \( \text{YTI} \left( IX, I \right) + \text{TY} \left( IX, I \right) = \text{TY} \left( IX, I \right) + \text{TY} \left( IX, I \right) \)

150. \( \text{XI} = \text{XI} + 1 \left( IX \right) \)

151. \( \text{XI} = \text{XI} + 1 \left( IX \right) \) \( \text{YTI} \left( IX, I \right) + \text{TY} \left( IX, I \right) = \text{TY} \left( IX, I \right) + \text{TY} \left( IX, I \right) \)

152. \( \text{XI} = \text{XI} + 1 \left( IX \right) \)

153. \( \text{XI} = \text{XI} + 1 \left( IX \right) \) \( \text{YTI} \left( IX, I \right) + \text{TY} \left( IX, I \right) = \text{TY} \left( IX, I \right) + \text{TY} \left( IX, I \right) \)

154. \( \text{XI} = \text{XI} + 1 \left( IX \right) \)

155. \( \text{XI} = \text{XI} + 1 \left( IX \right) \) \( \text{YTI} \left( IX, I \right) + \text{TY} \left( IX, I \right) = \text{TY} \left( IX, I \right) + \text{TY} \left( IX, I \right) \)

156. \( \text{XI} = \text{XI} + 1 \left( IX \right) \)
\[ V = \frac{(A_1 + A_2 + A_3 + A_4)}{4} \]
\[ X_{\text{NORM}} = \frac{(A_1 + A_2 + 2A_3 + A_4)}{(4 \cdot \text{AN})} \]
\[ Y_{\text{NORM}} = \frac{(A_1 + A_2 + A_3 + 2A_4)}{(4 \cdot \text{AN})} \]
\[ Z_{\text{NORM}} = \frac{(A_1 + A_2 + A_3 + A_4)}{(4 \cdot \text{AN})} \]
\[ D_{12} = \frac{(A_1 \cdot \text{NORM} + Y_{12} \cdot \text{NORM} + Z_{12} \cdot \text{NORM})}{(\text{AN} \cdot 12)} \]
\[ A_{12} = \text{TAN}^{-1}(\text{SORT}(1.00 - D_{12} \cdot D_{12}), D_{12}) \]
\[ A_{12} = \frac{(A_1 \cdot \text{ANGLE} + A_2 \cdot \text{ANGLE})}{A_{12}} \]
\[ D_{3} = \frac{(A_1 \cdot \text{NORM} + \text{NORM} + A_2 \cdot \text{NORM} + Z_{34} \cdot \text{NORM} + Z_{10} \cdot \text{NORM})}{(A_{34} \cdot \text{NORM})} \]
\[ A_{34} = \text{TAN}^{-1}(\text{SORT}(1.00 - D_{34} \cdot D_{34}), D_{34}) \]
\[ A_{34} = \frac{(A_1 \cdot \text{ANGLE} + A_2 \cdot \text{ANGLE})}{A_{34}} \]
\[ D_{41} = \frac{(A_1 \cdot \text{NORM} + \text{NORM} + A_2 \cdot \text{NORM} + Z_{41} \cdot \text{NORM} + Z_{10} \cdot \text{NORM})}{(A_{41} \cdot \text{NORM})} \]
\[ A_{41} = \text{TAN}^{-1}(\text{SORT}(1.00 - D_{41} \cdot D_{41}), D_{41}) \]
\[ A_{41} = \frac{(A_1 \cdot \text{ANGLE} + A_2 \cdot \text{ANGLE})}{A_{41}} \]
\[ A_{12} = \frac{(A_1 \cdot \text{NORM} + A_2 \cdot \text{NORM} + A_3 \cdot \text{NORM} + A_4 \cdot \text{NORM})}{A_{12}} \]
\[ A_{12} = \frac{(A_1 \cdot \text{NORM} + \text{NORM} + A_2 \cdot \text{NORM} + Z_{12} \cdot \text{NORM} + Z_{10} \cdot \text{NORM})}{(A_{12} \cdot \text{NORM})} \]
\[ A_{12} = \frac{(A_1 \cdot \text{ANGLE} + A_2 \cdot \text{ANGLE})}{A_{12}} \]
\[ A_{12} = \frac{(A_1 \cdot \text{NORM} + \text{NORM} + A_2 \cdot \text{NORM} + Z_{12} \cdot \text{NORM} + Z_{10} \cdot \text{NORM})}{(A_{12} \cdot \text{NORM})} \]
\[ A_{12} = \frac{(A_1 \cdot \text{ANGLE} + A_2 \cdot \text{ANGLE})}{A_{12}} \]

**END OF LISTING.**

© *DIAGNOSTIC* MESSAGE(S).
A FOR COBOL
COMPILED AT 1107 FOR TRAN-IV DATED JUNE 25, 1965 FOR THE
JIME DEC 72 AT 10:26:37

MAIN PROGRAM
ENTRY POINT 000000

STORAGE USED (BLOCK, NAME, LENGTH)

00001 *CODE 000447
00005 *DATA 000375
00002 *BLANK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

00003 SORT
00004 ATAN2
00005 NR
00006 N101B
00007 N102B
00010 N20B
00011 NSTOPS

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

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A-8
COBRA WIND=CLUSTER
DIMENSION XX(25),YY(25),ZZ(25),XH(25),YN(-5),ZN(25),AN(25)
I=0
INPUT=0
IT=7

ANG=1/25*017453
ZP05=12*200.
SZE=0117453*4.5
SP=0.
SAZ=.0117453*135.
READ(11IN,102)(XX(I),YY(I),ZZ(I),I=2,13)
FORMAT(9F8.3)
DO 101 I=2,13
XX(I)=XX(1)
101 CONTINUE
XX(1)=55.5
XX(14)=142.05
YY(1)=YY(1)
YY(14)=YY(13)
ZZ(1)=70.
ZZ(14)=100.9135
103 CONTINUE
ARIT(10UT+112)
112 FORMAT(1X,1H1,9X,1HY,9X,1HZ,RX,2:YN,8X,2:ZN,9X,1HA)
XT2=0.
YT1=0.
YT2=10.
YT3=0.
ZT2=0.
ZT1=1/25,13
XT1=XX(IH-1)-XX(I)
XT3=XX(IH-1)-XT1
ZT1=ZZ(IH-1)-ZZ(I)
ZT3=ZZ(IH-1)-ZT1
X12=TT2*YZ2-YT2*ZT1
Y12=XT2*YT2-ZT2*XT1
Y12=YT2
Z12=X12*YZ2-XT2*YT1
41. A12=1.5K(R1*X12+Y12*Y12+Z12*Z12)
41. 13 K73=T72*Z73+YT3*ZT2
42. \[ Y_{33} = A_{12}^* Z_{13} - X_{13}^* Z_{12} \]
43. \[ Y_{23} = Y_{23} \]
44. \[ Z_{23} = A_{12}^* Y_{13} - X_{13}^* Y_{12} \]
45. \[ A_{23} = \text{SORT}(X_{23}^* A_{23} + Y_{23}^* Y_{23} + Z_{23}^* Z_{23}) \]
46. \[ A_{11} = (A_{11} + A_{12} + A_{13}) / 2 \]
47. \[ X_{11} = (A_{11} + X_{12}) / (2 * \text{AN}(\text{IX})) \]
48. \[ Y_{11} = (Y_{11} + Y_{12}) / (2 * \text{AN}(\text{IX})) \]
49. \[ Z_{11} = (Z_{11} + Z_{12}) / (2 * \text{AN}(\text{IX})) \]
50. \[ \text{XOR}_m = X_{m}(\text{IX}) \]
51. \[ \text{YOR}_m = Y_{m}(\text{IX}) \]
52. \[ \text{ZOR}_m = Z_{m}(\text{IX}) \]
53. \[ \text{IF}(\text{IA} = 0, 2) \text{GO TO} 421 \]
54. \[ \text{IF}(\text{IA} = 0, 13) \text{GO TO} 421 \]
55. \[ A_{12} = A_{12} + \text{XNORM} + Y_{12}^* \text{YNORM} + Z_{12}^* \text{ZNORM} \] / \text{AN12} \]
56. \[ \text{IF}(\text{D12} = 0, 30, \text{J10}) \]
57. \[ \text{J10} \]
58. \[ A_{12} = \text{TANZ} \left( \text{SORT} \left(1 - A_{12}^* D_{12} \right) \right) \]
59. \[ \text{GO TO} 320 \]
60. \[ \text{IF}(\text{IA} = 0, 12) \text{GO TO} 320 \]
61. \[ A_{23} = (X_{23}^* \text{XNORM} + Y_{23}^* \text{YNORM} + Z_{23}^* \text{ZNORM}) / \text{AN23} \]
62. \[ \text{IF}(\text{D23} = 0, 0, 313) \]
63. \[ \text{J13} \]
64. \[ A_{23} = \text{TANZ} \left( \text{SORT} \left(1 - A_{23}^* D_{23} \right) \right) \]
65. \[ \text{GO TO} 420 \]
66. \[ \text{GO TO} 420 \]
67. \[ \text{GO TO} 420 \]
68. \[ \text{GO TO} 420 \]
69. \[ \text{IF}(\text{IA} = 0, 2) \text{ANJR} = A_{12} + \text{AN23} \]
70. \[ \text{IF}(\text{IA} = 0, 13) \text{ANJR} = A_{12} + \text{AN23} \]
71. \[ \text{FOR} \left(1, \text{OUT}, 111 \right) \text{XX} \left(\text{IX} \right), \text{YY} \left(\text{IX} \right), \text{ZZ} \left(\text{IX} \right), \text{XNORM}, \text{YNORM}, \text{ZNORM}, \text{ANOR} \]
72. \[ \text{FOR} \left(1, 10, 7 + 10, 5 \right) \]
73. \[ \text{FOR} \left(1, 11, 11 \right) \text{XX} \left(\text{IX} \right), \text{YY} \left(\text{IX} \right), \text{ZZ} \left(\text{IX} \right), \text{XNORM}, \text{YNORM}, \text{ZNORM}, \text{ANOR} \]
74. \[ \text{FOR} \left(1, 15, 11, 5 \right) \text{XX} \left(\text{IX} \right), \text{YY} \left(\text{IX} \right), \text{ZZ} \left(\text{IX} \right), \text{XNORM}, \text{YNORM}, \text{ZNORM}, \text{ANOR} \]
75. \[ \text{I} \text{CONTINUE} \]
76. \[ \text{STOP} \]
77. \[ \text{END} \]
**PORTABLE NUMERICAL LIBRARY FOR COMPUTER SCIENCE**

**UNCLASSIFIED**

*FOR COBOL*  

**COMPILATION BY UNIVAC 1108 FORTRAN-IV DATED JUNE 22, 1965 F4006**  

**THIS COMPILATION WAS DONE ON 04 DEC 72 AT 21:24:20**

**MAIN PROGRAM**  
**ENTRY POINT 000000**

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**A-11**

**UNCLASSIFIED**


```fortran
C C COORD WINDOW
2 DIMENSION XR(1464),YR(1464),ZR(1464)
20 DIMENSION SZE(20),SAZ(20),ROU(91)
40 COMM/BLN12/X(738),Y(738),Z(738),XN(738),YN(738),ZN(738),AN(738)
50 COMM/BLN2/1ALPH(1464),1BETA(1464),RT(1464),RG(1464),B(1464)
60 RADIUS=57.9578
70 NOK=738
80 NOKT=1464
90 ROUL(1)=0.
100 LIN=5
110 IOUT=0
120 SZE=2000.
130 ROU=10
140 SZE=2009
150 ELY=15
160 REAL (1IN,1J5)RA,RD,RC,RE,RF,RGG
170 10D FORMAT(F6.3,9DL12.7)
180 REAL (1IN*49)JD
190 49 FORMAT(13)
200 REAL (1IN+4) (SZE(JJD),SAZ(JJD),JJD=1,JJD)
210 10 FORMAT(2F5.2)
220 JJU 250 NOK=1,NMORT
230 HN=OK
240 IF (NOK.GT.738) NOK=738
250 XR(NOK)=X(NOK)
260 YR(NOK)=Y(NOK)
270 ZR(NOK)=Z(NOK)
280 IF (NOK.GT.738) YR(NOK)=-YR(NOK)
290 250 CONTINUE
300 RN=INT(NMORT/4)
310 WRITE(IOUT,1)
320 5 FORMAT(54A,21HSURFACE X,Y,Z LISTING)
330 U=U
340 JJU 240 L=1,RN
350 U=U+1
```

A-12

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30. \textbf{IF}(J*LL*1)\textbf{WRITE}(IOUT,1)
37. 1 \textbf{FORMAT}(2X*4(31H NUM X Y Z ))
38. JJ=L*4-3
39. JJ=JJ+3
40. WRITE(IOUT,241)(LL,XX(LL),YY(LL),ZZ(LL),LL=JJ,JJ)
41. \textbf{IF}(J*LL*4)\textbf{WRITE}(IOUT,250)
42. \textbf{IF}(J*LL*4)J=U
43. 250 \textbf{FORMAT}(1H1)
44. \textbf{CONTINUE}
45. \textbf{WRITE}(IOUT,250)
46. DO 2 N=1,N,1
47. \textbf{AN}(N)=\textbf{AN}(N)*1000.
48. ALPH(A)=ATAN2(SQRT(1-ZN(N)*ZN(N)),ZN(N))
49. ALPH(A)=ALPH(A)*KADIAN
50. IALPH(A)=3*INT(ALPH(A)/3.+.5)
51. BETA(ATAN2(YN(N),XN(N)))
52. BETA=BETA*KADIAN
53. \textbf{IF}(BETA)47,46,46
54. 47 I/BETA(.)=3*INT(BETA/3.+.5)
55. DD TO 2
56. 40 I/BETA(.)=3*INT(BETA/3.+.5)
57. \textbf{CONTINUE}
58. DO 44 N=1,NH,1
59. NN=
60. \textbf{IF}(N*O*738)NN=N-738
61. IALPH(.)=IALPH(NN)
62. IBETA(.)=IBETA(NN)
63. \textbf{IF}(N*O*738)IBETA(N)=IBETA(N)
64. NN=NN
65. \textbf{CONTINUE}
66. \textbf{WRITE}(IOUT,4)
67. \textbf{FORMAT}(52X*25H N H, NORMAL ALPH A,BETA L ISTING)
68. \textbf{WRITE}(IOUT,250)
69. 4 \textbf{FORMAT}(52X*25H N H, NORMAL ALPH A,BETA L ISTING)
70. \textbf{WRITE}(IOUT,243)
71. \textbf{CONTINUE}
72. \textbf{WRITE}(IOUT,341)(LL,IALPH(LL),IBETA(LL),LL=JJ,JJ)
73. \textbf{WRITE}(IOUT,341)(LL,IALPH(LL),IBETA(LL),LL=JJ,JJ)
74. 341 \textbf{FORMAT}(6(15,216,2X))
IF(J.EQ.40) WRITE (IOUT,250)
J = J + 1
CONTINUE
WRITE (IOUT,250)
WRITE (IOUT,11)
WRITE (IOUT,9)
WRITE (IOUT,12)
WRITE (IOUT,38)
WRITE (IOUT,39)
WRITE (IOUT,37)
STOP
END

END OF LISTING. J *DIAGNOSTIC* MESSAGE(S).
```
* FOR NORMAL
COMPILED BY UNIVAC 1108 FORTRAN-IV DATED JUNE 22, 1965 F4000
THIS COMPILATION WAS DONE ON 04 DEC 72 AT 21:24:24

BLOCK DATA

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A-17

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| 325. | 1-121.000 | 8.780 | 102.200 | .08182 | .38368 | .84555 | .07234 |
| 324. | 1-121.000 | 8.000 | 102.440 | .06838 | .29321 | .95353 | .18187 |
| 323. | 1-115.000 | 17.900 | 70.320 | .04397 | .98329 | .12529 | .14881 |
| 322. | 1-115.000 | 16.150 | 71.300 | .03793 | .97915 | .17147 | .39850 |
| 321. | 1-115.000 | 18.340 | 72.290 | .03037 | .99800 | .14206 | .50305 |
| 320. | 1-115.000 | 16.520 | 73.270 | .02469 | .98840 | .12914 | .53512 |
| 319. | 1-115.000 | 18.680 | 74.280 | .01961 | .99202 | .10664 | .63148 |
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| 310. | 1-115.000 | 18.850 | 83.290 | .01604 | .99676 | .06696 | .97852 |
| 309. | 1-115.000 | 18.740 | 84.290 | .02008 | .99461 | .08747 | .77873 |
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| 302. | 1-115.000 | 17.560 | 90.190 | .03721 | .97139 | .20384 | .34472 |
| 301. | 1-115.000 | 17.270 | 91.150 | .03631 | .96246 | .23302 | .29993 |
| 300. | 1-115.000 | 16.930 | 92.090 | .03928 | .95133 | .26595 | .26530 |
| 299. | 1-115.000 | 16.570 | 93.010 | .04011 | .94302 | .28701 | .24396 |
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SUBROUTINE PlOIT
ENTRY POINT 000265

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COMMON/BLK1/X(738), Y(738), Z(738), XN(738), YN(738), ZN(738), AN(738)
COMMON/BLK2/1ALPH(1464), 1BETA(1464), 1RT(1464), 1RG(1464), 1B(1464)
DATA (ICONV(N), N=1,100) /2H01, 2H02, 2H03, 2H04, 2H05, 2H06, 2H07, 2H08, 2H09, 2H10, 2H11, 2H12, 2H13, 2H14, 2H15, 2H16, 2H17, 2H18, 2H19, 2H20, 2H21, 2H22, 2H23, 2H24, 2H25, 2H26, 2H27, 2H28, 2H29, 2H30, 2H31, 2H32, 2H33, 2H34, 2H35, 2H36, 2H37, 2H38, 2H39, 2H40, 4H41, 4H42, 4H43, 4H44, 4H45, 4H46, 4H47, 4H48, 4H49, 4H50, 5H51, 5H52, 5H53, 5H54, 5H55, 5H56, 5H57, 5H58, 5H59, 5H60, 5H61, 5H62, 5H63, 5H64, 5H65, 5H66, 5H67, 5H68, 5H69, 5H70, 7H71, 7H72, 7H73, 7H74, 7H75, 7H76, 7H77, 7H78, 7H79, 7H80, 7H81, 7H82, 7H83, 7H84, 7H85, 7H86, 7H87, 7H88, 7H89, 7H90, 9H91, 9H92, 9H93, 9H94, 9H95, 9H96, 9H97, 9H98, 9H99, 9H00,
DATA 1BLNK/2H */
DATA 1ZERO/2H Z/
DATA 1HIGH/2H H/
IOUT=0
K=1
IC=1
DO 10 Y=3,360,3
10 IYY=103-IY
DO 20 IX=3,183,3
11 IX=IX/3
A=0.
20 DO 25 N=1,NNOR
25 IF (1ALPH(N) .NE. (IX-3)) GO TO 25
20 IF (1BETA(1N) .NE. IYY) GO TO 25
20 IF (J*EW+1) A=A+B(N)
30 IF (J*EU+2) GO TO 70
30 IF (J*EG+3) GO TO 75
30 IF (J*EH+4) GO TO 65
30 GU TO 25
30 70 IF (A-U(N)) 71,25,25
30 71 A=U(N)
30 70 GU TO 25
30 75 IF (A-K1(N)) 76,25,25
30 76 A=RT(N)
30 40 GU TO 25
40 50 IF (A-K5(N)) 60,25,25
40 60 A=G(N)
40 25 CONTINUE
40 IF (A)<1,21,22
40. 21 IA(IXA)=1BLNK
40. 30 GO TO 15
47. 22 IF(J.LE.2)ICON=INT(1U.*ALUG1U(A))
48.  IF(J.GE.3)ICON=INT(A+5)
47.  IF(ICON)'91,'91,'92
50. 91 IA(IXA)=IZERO
50. 30 GO TO 15
52. 92 IF(ICON)'93,'93,'94
50. 94 IA(IXA)=IHIGH
50. 30 GO TO 15
50. 95 IA(IXA)=ICONV(ICON)
50. 15 CONTINUE
57.  IF(IC-K)'30,'35,'30
50. 35 IU=1BU-(K-1)*3
59.  WRITE(OUT,18) IU, (IA(IIXX),IIXX=1,61)
60. 18 FORMAT(1X,14,1HY,61A2)
62.  IC=IC+5
60. 30 GO TO 40
60. 30 WRITE(OUT,19) (IA(IIXX),IIXX=1,61)
64. 19 FORMAT(5X,1HY,61A2)
65. 49 K=K+1
60. 10 CONTINUE
67.  RETURN
60. END

END OF LISTING. 0 *DIAGNOSTIC* MESSAGE(S).
**UNCLASSIFIED**

**FOR COMMENT**

**COMPILED BY UNIVAC 1108 FORTRAN-IV DATED JUNE 22, 1965 FOR IBM**

**THIS COMPILATION WAS DONE ON 17 NOV 72 AT 13:42:49**

**MAIN PROGRAM**

**ENTRY POINT 000000**

**STORAGE USED (BLOCK, NAME, LENGTH)**

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**A-37**

**UNCLASSIFIED**
Cobra Window

DIMENSION XC(6), YC(6)

DIMENSION IDATA(91), IC(91), IC10(91), RTOT(91)

DIMENSION XR(1464), YR(1464), ZR(1464)

DIMENSION ISD(1464)

DIMENSION SZE(20), SAZI(20), ROGL(91)

COMMON/BLK1/ (738), Y (738), Z (738), XN(738), YN(738), ZN(738), AN(738)

COMMON/BLK2/ IALPH(1464), IBETA(1464), RT(1464), RG(1464), B(1464)

DATA 1/ L/ 1H

DATA 1/ X/ 1H X/
<table>
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<tr>
<td>12.</td>
<td>RAULAN=57.29578</td>
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<tr>
<td>13.</td>
<td>NNORT=1464</td>
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<tr>
<td>14.</td>
<td>IN=5</td>
</tr>
<tr>
<td>15.</td>
<td>IOUT=0</td>
</tr>
<tr>
<td>16.</td>
<td>BS=2000</td>
</tr>
<tr>
<td>17.</td>
<td>RUE=15</td>
</tr>
<tr>
<td>18.</td>
<td>BH=0.009</td>
</tr>
<tr>
<td>19.</td>
<td>EYE=15</td>
</tr>
<tr>
<td>20.</td>
<td>READ(IN,105)(XC(K),K=1,NXY)</td>
</tr>
<tr>
<td>21.</td>
<td>READ(IN,105)(YC(K),K=1,NXY)</td>
</tr>
<tr>
<td>22.</td>
<td>105 FORMAT(6F8.3)</td>
</tr>
<tr>
<td>23.</td>
<td>READ(IN,49)JD</td>
</tr>
<tr>
<td>24.</td>
<td>49 FORMAT(13)</td>
</tr>
<tr>
<td>25.</td>
<td>READ(IN,48)(SZE(JJD),SAZI(JJD),JJD=1,JD)</td>
</tr>
<tr>
<td>26.</td>
<td>48 FORMAT(2F8.2)</td>
</tr>
<tr>
<td>27.</td>
<td>12 FORMAT(5H6ETA)</td>
</tr>
<tr>
<td>28.</td>
<td>38 FORMAT(5X,41(3HXXX))</td>
</tr>
<tr>
<td>29.</td>
<td>39 FORMAT(7X,1H0<em>8X,2H15</em>8X,2H30<em>8X,2H45</em>8X,2H60<em>8X,2H75</em>8X,2H90<em>8X,2H105</em>7X,3H120<em>7X,3H135</em>7X,3H150<em>7X,3H165</em>7X,3H180*)</td>
</tr>
<tr>
<td>30.</td>
<td>37 FORMAT(65X,5HALPHA)</td>
</tr>
<tr>
<td>31.</td>
<td>301 FORMAT(47X,34HHHELICOPTER DETECTION RANGE CONTOUR)</td>
</tr>
<tr>
<td>32.</td>
<td>302 FORMAT(43X,42HS SCALE FACTOR:VALUE=RANGE IN NAUTICAL MILES)</td>
</tr>
<tr>
<td>33.</td>
<td>401 FORMAT(49X,30HWINDOW DETECTION RANGE CONTOUR)</td>
</tr>
<tr>
<td>34.</td>
<td>DU 6UU 10A=1.91</td>
</tr>
<tr>
<td>35.</td>
<td>RTOT(10A)=10.</td>
</tr>
<tr>
<td>36.</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>37.</td>
<td>DU 8U 10A=1,JD</td>
</tr>
<tr>
<td>38.</td>
<td>SZE=N<em>017453</em>SZE(N)</td>
</tr>
<tr>
<td>39.</td>
<td>SAZ=N<em>017453</em>SAZI(N)</td>
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<tr>
<td>40.</td>
<td>SX=COS(SAZ)*SIN(SZE)</td>
</tr>
<tr>
<td>41.</td>
<td>SY=SIN(SAZ)*SIN(SZE)</td>
</tr>
<tr>
<td>42.</td>
<td>SZ=COS(SZ)</td>
</tr>
<tr>
<td>43.</td>
<td>DU 26U 10A=1.91</td>
</tr>
<tr>
<td>44.</td>
<td>ROGL(10A)=10.</td>
</tr>
<tr>
<td>45.</td>
<td>IC10(10A)=0.</td>
</tr>
<tr>
<td>46.</td>
<td>IC(10A)=0.</td>
</tr>
<tr>
<td>47.</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>48.</td>
<td>RVIS=0.</td>
</tr>
<tr>
<td>49.</td>
<td>CT=ABS(RUE*RH-BH)*100/BH</td>
</tr>
<tr>
<td>50.</td>
<td>CG=(BS<em>EYE</em>100.)/BH</td>
</tr>
<tr>
<td>51.</td>
<td>DU 10U N=1,NNORT</td>
</tr>
<tr>
<td>52.</td>
<td>N=N</td>
</tr>
<tr>
<td>53.</td>
<td>IF(N,0,738)NN=N-738</td>
</tr>
</tbody>
</table>
UNCLASSIFIED

55. XNORM=XN(NN)
56. YNORM=YN(NN)
57. ZNORM=ZN(NN)
58. IF(N+GT.738)YNORM=-YNORM
59. AREA=AN(NN)
60. SDN=SA*XNORM+SY*YNORM+SZ*ZNORM
61. RX=5X-2.*SDN*XNORM
62. RY=SY-2.*SDN*YNORM
63. RZ=SZ-2.*SDN*ZNORM
64. XR(N)=RX
65. YR(N)=RY
66. ZR(N)=RZ
67. SDN=-SDN
68. IF(SDN)101,101,102
69. 102 SD=ATAN2(SQRT(1-SUN*SDN),SDN)
70. SU=SL*RADIANS
71. ISU(N)=INT(SD+.5)
72. CALL CONFRA(NXY,XC,YC,SD,RO)
73. B(i)=AREA*SDN*RO
74. B(N)=B(N)*1.0E+07
75. GO TO 103
76. 101 B(N)=0.
77. RT(N)=0.
78. RU(N)=0.
79. ISU(N)=0
80. ILPH(N)=0
81. IBLTA(N)=0
82. GO TO 100
83. 103 CONTINUE
84. ALPHA=ATAN2(SQRT(1-ZR(N)*ZC(N)),ZC(N))
85. ALPHA=ALPHA*RADIANS
86. IALPH(N)=3*INT(ALPHA/3.+ .5)
87. BETA=ATAN2(YR(N),XR(N))
88. BETA=BETA*RADIANS
89. IF(BETA)44,43,43
90. 44 IBLTA(N)=3*INT(BETA/3.+ .5)
91. GO TO 42
92. 42 IBLTA(N)=3*INT(BETA/3.+ .5)
93. 43 CONTINUE
94. IF=2(N)/(44.*1.0E+07)
95. AP=ABS(RX*35.)+ABS(RY*45U.)+ABS(RZ*157.5)
96. K=0.
97. 452 E=EXP(-3.9075*R/R15)+CT
90. \[ F = E + 1.57 + R \times K \times 36.5 / AP \]
99. \[ F1 = 3.9075 \times L / RVIS \times 2 \times K \times 36.5 / AP \]
100. \[ IF (F/F1 + 1) = 460, 461, 461 \]
101. \[ R = F / F1 \]
102. \[ GO TO 462 \]
103. \[ RT(N) = R \]
104. \[ K = U \]
105. \[ E = \exp(-3.9075 \times K / RVIS) \times C6 \times R0 \]
106. \[ F = E + 1.57 + R \times K \times 36.5 / BF \]
107. \[ F1 = 3.9075 \times L / RVIS \times 2 \times K \times 36.5 / R0 / F \]
108. \[ IF (F/F1 + 1) = 470, 471, 471 \]
109. \[ R = K - R / F1 \]
110. \[ GO TO 472 \]
111. \[ KG(N) = K \]
112. \[ IC = INT(5U + 1.5) \]
113. \[ IC(IOA) = IC(IOA) + 1 \]
114. \[ RU0 = (1.57 + 36.5 \times RT(N) \times RT(N) \times R0 / BF) \times BH / (100 \times \exp(-3.9075 \times RT(N) / 2 \times RVIS)) \]
115. \[ IF (RU0 = ROGL(10A)) = 261, 262, 262 \]
116. \[ ROGL(IOA) = ROG \]
117. \[ IF (ROG = RTOT(IOA)) = 261, 262, 262 \]
118. \[ HTCT(IOA) = ROG \]
120. \[ CONTINUE \]
121. \[ WRITE(10U1, 25U) \]
122. \[ WRITE(10U1, 1H1) \]
123. \[ WRITE(10U1, 202) \]
124. \[ WRITE(10U1, 202) \]
125. \[ WRITE(10U1, 202) \]
126. \[ WRITE(10U1, 201) \]
127. \[ WRITE(10U1, 203) \]
128. \[ WRITE(10U1, 203) \]
129. \[ WRITE(10U1, 203) \]
130. \[ WRITE(10U1, 203) \]
131. \[ WRITE(10U1, 12) \]
132. \[ J = 2 \]
133. \[ CALL PLUTT(NNORTUJ) \]
134. \[ WRITE(10U1, 38) \]
135. \[ WRITE(10U1, 39) \]
136. \[ WRITE(10U1, 37) \]
137. \[ WRITE(10U1, 30U) \]
138. \[ WRITE(10U1, 30U) \]
139. \[ WRITE(10U1, 30U) \]
140. \[ WRITE(10U1, 12) \]
141. J=3
142. CALL PLOTT(NNORT,J)
143. WRITE(IOUT,38)
144. WRITE ( IOUT, 39)
145. WRITE ( IOUT, 37)
146. WRITE ( IOUT, 250)
147. WRITE ( IOUT, 401)
148. WRITE ( IOUT, 302)
149. WRITE ( IOUT, 12)
150. J=4
151. CALL PLOTT (NNORT,J)
152. WRITE ( IOUT, 38)
153. WRITE ( IOUT, 39)
154. WRITE ( IOUT, 37)
155. WRITE ( IOUT, 250)
156. WRITE ( IOUT, 560)
157. 500 FORMAT (29X,40HREFLECTED RAY ALPHA, BETA, ANGLE OF INCID.
158. EENCE, DETECTION RANGE LISTING)
159. NUM=INT(NNORT/4)
160. J=0
161. DO 340 L=1,NUM
162. J=J+1
163. IF (J<LL+1)WRITE ( IOUT, 243)
164. 243 FORMAT (1X,4(29H NUM ALPHA BETA ANGLE RANGE))
165. JJ=L*4-3
166. JJ=L+3
167. WRITE ( IOUT, 341) (LL,IALPH(LL),IBETA(LL),ISD(LL),RG(LL),LL=JJ,JJJ)
168. 341 FORMAT (1X,4(14,31B4,0,1X))
169. IF (J<LL+40)WRITE ( IOUT, 250)
170. IF (J<LL+40) J=0
171. 340 CONTINUE
172. WRITE ( IOUT, 250)
173. WRITE ( IOUT, 505)
174. 505 FORMAT (21X,40HREQUIRED REFLECTIVITY AS A FUNCTION OF A,
175. Z17HANGLE OF INCIDENCE)
176. WRITE ( IOUT, 510)
177. 510 FORMAT (1X,SHANGLE,8X,1H0,8X,1H1,8X,1H2,8X,1H3,8X,1H4,8X,1H5,8X,
178. 21H6,8X,1H7,8X,1H8,8X,1H9)
179. JJ=310 JU=1,9
180. JJJ=JJ*10-9
181. JJJ=JJ+9
182. JJJJJ=JJ*10-10
183. WRITE ( IOUT, 311) JJJJJ, (ROGL(LL),LL=JJJ,JJJJJ)
511 FORMAT (2X,I4,3X,10(F8.6,1X))
510 CONTINUE
510 WRITE (IOUT,342) ROGL(91)
512 FORMAT (4X,2H90,5X,F8.6)
510 WRITE (IOUT,506)
505 FORMAT (//)
505 WRITE (IOUT,505)
505 J=1,91
510 IC(J)=INT(10*IC10(J)+.1)
510 CONTINUE
590 WRITE (IOUT,449) (IC10(J),J=1,91)
590 WRITE (IOUT,449) (IC(J),J=1,91)
449 FORMAT (7X,9111)
449 WRITE (IOUT,436)
436 FORMAT (3X*2HR0)
436 UO 44U J=1,91
436 UO 43U J=1,91
436 JN=11-JJ
436 XRG=R0GL(J)*1.0E+09
436 XRG=INT(100*ALOG10(XRG))
436 IF (XRG*GL*J1*1.0U1)1DATA(J)=IBX
436 IF (XRG*LT*JA*1.0U)1DATA(J)=IBL
436 CONTINUE
436 IF(JJ.EQ.1) WRITE (IOUT,431) (1DATA(JJJ),JJJ=1,91)
205 IF (JJ.EQ.1) GO TO 445
210 IF (JJ.EQ.4) WRITE (IOUT,432) (1DATA(JJJ),JJJ=1,91)
210 IF (JJ.EQ.4) GO TO 445
210 IF (JJ.EQ.7) WRITE (IOUT,433) (1DATA(JJJ),JJJ=1,91)
210 IF (JJ.EQ.7) GO TO 445
214 IF (JJ.EQ.1) WRITE (IOUT,434) (1DATA(JJJ),JJJ=1,91)
215 IF (JJ.EQ.1) GO TO 445
215 WRITE (IOUT,435) (1DATA(JJJ),JJJ=1,91)
217 431 FORMAT (1X*6H10+1 Y,91A1)
218 432 FORMAT (1X*6H10-2 Y,91A1)
219 433 FORMAT (1X*6H10-5 Y,91A1)
220 434 FORMAT (1X*6H10-8 Y,91A1)
221 435 FORMAT (1X*6H Y,91A1)
222 435 CONTINUE
222 435 CONTINUE
224 WRITE (IOUT,437)
225 436 FORMAT (8A92(1H))
228 WRITE (IOUT,439)
439  FORMAT(7X,1HU,6X,2H1U,6X,2H2U,6X,2H3U,8X,2H4U,8X,2H5U,8X,2H6U,
     28X,2H7U,8X,2H8U,8X,2H90)

440  WRITE(OUT,438)

450  FORMAT(4UX,18ANGLE OF INCIDENCE)

491  JJ=1,JJ=13
      M=JJ
      WRITE(7,492) (ROGL(JK),JK=J,JJJ),M, JJ

492  FORMAT(2X,7F9.6,3X,I2,2X,I2)

493  CONTINUE

500  WRITE(OUT,505)
      WRITE(OUT,510)

501  DO 610 JJ=1,9
      JJJ=JJ*10-9
      JJJJ=JJJ+9

502  WRITE(OUT,511)JJJJ,(RTOT(YY),YY=JJJJ)

610  CONTINUE

503  WRITE(OUT,312)RTOT(J1)

504  WRITE(OUT,506)

505  WRITE(OUT,507)

506  FORMAT(4UX,1UH SUMMARY OF)

507  FORMAT(4UX,21HF OR ALL SUN POSITIONS)

508  WRITE(OUT,436)

509  DO 640 JJ=1,91
         JA=11-JJ
         ROG=RTOT(JJ)*1.02+0.9
         ROG=INT(100*ALOG10(ROG))

600  CONTINUE

601  IF(JJ.EQ.1) WRITE(OUT,431) (IADATA(JJJ),JJJ=1,91)

602  IF(JJ.EQ.1) GO TO 645

603  IF(JJ.EQ.4) WRITE(OUT,432) (IADATA(JJJ),JJJ=1,91)

604  IF(JJ.EQ.4) GO TO 645

605  IF(JJ.EQ.7) WRITE(OUT,433) (IADATA(JJJ),JJJ=1,91)

606  IF(JJ.EQ.7) GO TO 645

607  IF(JJ.EQ.10) WRITE(OUT,434) (IADATA(JJJ),JJJ=1,91)
270. IF(JJ.EQ.10) GO TO 645
271. WRITE(IOUT,435)(IDATA(JJJ),JJJ=1,91)
272. 645 CONTINUE
273. 640 CONTINUE
274. WRITE(IOUT,437)
275. WRITE(IOUT,438)
276. WRITE(IOUT,439)
277. WRITE(7,490)(RTOT(J),J=1,91)
278. 490 FORMAT(2X,7F9.0)
279. STOP
280. END

END OF LISTING.  U *DIAGNOSTIC* MESSAGE(S).
SUBROUTINE CONFRA
ENTRY POINT 000117
STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000161
0000 *DATA 000016
0002 *BLANK 000300

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000004 10JO 0001 000015 300L 0001 000025 310L
0001 000075 300L 0001 000114 700L 0001 000104 800L
0000 R 000004 C 0000 R 000003 C1 0000 I 000000 J

1. SUBROUTINE CONFRA(NXY,X,Y,XIN,YOUT)
2. DIMENSION X(10),Y(10)
3. 00 J=1,NXY
4. IF(XIN-X(J))300,35,35
5. 35 CONTINUE
6. 300 IF(J=J)370,310,310
7. 370 J=J+1
8. 310 YOUT=Y(J-2)
9. 710 A=(X(J)-X(J-1))/Y(J-1)-Y(J-2))
10. 710 IF(Y(J)-Y(J-1))/720,700,710
11. 720 A1=(X(J)-X(J-2))/Y(J)-Y(J-2)
12. 720 IF(A1-A)400,300,400
13. 300 C1=0,J
14. 30 TO 600
15. 400 CONTINUE
16. C=(X(J)-X(J-1))/(A1-A)
17. C1=(X1-X(J-1))/C

A-46
20. IF (A+C1) 000, 900, 800
21. YOU YOUT=1.
22. GO TO 700
23. 800 CONTINUE
24. YOUT=Y(J-2)+(X1N-X(J-2))/(A+C1)
25. 700 RETURN
26. END

END OF LISTING.

*DIAGNOSTIC* MESSAGE(S).
APPENDIX B

TYPICAL RESULTS

FROM

COBRA WINDOW MODEL

Segment 1 - Normals and Effective Areas

Listing of Window Surfaces, Normals, and Effective Areas .......... B-2

Segment 2 - Area Contours

Listing of Window Surfaces by Number and XYZ Coordinates ........ B-20
Listing of r,β Coordinates for Each Window Surface .............. B-30
Area Contour Plot .................................................. B-37

Segment 3 - Brightness Factors, Detection Ranges and Required
Reflectivities for Sun Azimuth = 45°, Sun Zenith = 45°,
and Visibility = 5 Nautical Miles

Brightness Plot ..................................................... B-38
Helicopter Detection Range Plot .................................. B-39
Window Detection Range Plot ...................................... B-40
Listing of r,β Coordinates, Angle of Incidence, and Window Detection
Range for Reflected Rays .......................................... B-41
Listing and Plot of Required Reflectivity as a Function of
Angle of Incidence ................................................. B-51
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### REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE

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**UNCLASSIFIED**

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**UNCLASSIFIED**
## Required Reflectivity

For Cobra Window

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Summary Chart ........................................... C-19
**REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE**

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**C-2**

Sun Zenith = 0°

Sun Azimuth = 0°
### Required Reflectivity as a Function of Angle of Incidence

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### Required Reflectivity as a Function of Angle of Incidence

- **Sun Zenith = 45°**
- **Sun Azimuth = 0°**
### Reflectivity as a Function of Angle of Incidence

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The table above represents the reflectivity of a material as a function of the angle of incidence in degrees. The values are rounded to four decimal places.

#### Calculations

- **Sun Zenith = 90°**
- **Sun Azimuth = 0°**

The calculations and methods for determining the reflectivity values are based on the incoming light angle and the material's properties. The data in the table is used to analyze the behavior of light reflectance under different angles.

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**UNCLASSIFIED**
### Reflectivity as a Function of Angle of Incidence

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**Sun Zenith = 135°**

**Sun Azimuth = 0°**
## REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE

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### Sun Zenith = 45°

### Sun Azimuth = 45°
### Required Reflectivity as a Function of Angle of Incidence

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### Required Reflectivity as a Function of Angle of Incidence

- **Sun Zenith = 90°**
- **Sun Azimuth = 45°**
### Required Reflectivity as a Function of Angle of Incidence

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### Required Reflectivity as a Function of Angle of Incidence

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### Sun Zenith = 135°

### Sun Azimuth = 45°
### REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE

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**Sun Zenith = 45°**

**Sun Azimuth = 90°**

---

C-9

UNCLASSIFIED
### Reflectivity as a Function of Angle of Incidence

**Angle of Incidence:**

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### Reflectivity as a Function of Angle of Incidence

**Angle of Incidence:**

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### Sun Zenith = 90°

### Sun Azimuth = 90°
### REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE

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**Sun Zenith = 135°**

**Sun Azimuth = 90°**
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### Sun Zenith = 45°

### Sun Azimuth = 135°
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### Required Reflectivity as a Function of Angle of Incidence

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- **Sun Zenith = 90°**
- **Sun Azimuth = 135°**
UNCLASSIFIED

REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE

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Sun Azimuth = 135°
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**REQUIRED REFLECTIVITY AS A FUNCTION OF ANGLE OF INCIDENCE**

Sun Zenith = 45°

Sun Azimuth = 180°
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#### Note
- Sun Zenith = 90°
- Sun Azimuth = 180°
## UNCLASSIFIED

**Required Reflectivity as a Function of Angle of Incidence**

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**Required Reflectivity as a Function of Angle of Incidence**

Sun Zenith = 135°

Sun Azimuth = 180°
### Required Reflectivity as a Function of Angle of Incidence

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Sun Zenith = 180°
Sun Asimuth = 0°
### Required Reflectivity as a Function of Angle of Incidence

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### Summary Chart

The summary chart provides a visual representation of the required reflectivity data for various angles of incidence.
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</table>
| US Army Materiel Command  
ATTN: AMCDL  
5001 Eisenhower Avenue  
Alexandria, VA 22304 |        |
| Commander         | 3      |
| US Army Materiel Command  
ATTN: AMCRD  
5001 Eisenhower Avenue  
Alexandria, VA 22304 |        |
| Commander         | 1      |
| US Army Materiel Command  
ATTN: AMCRD-P  
5001 Eisenhower Avenue  
Alexandria, VA 22304 |        |
| Director of Defense, Research & Engineering  
Department of Defense  
WASH DC 20301 | 1      |
| Director          | 3      |
| Defense Advanced Research Projects Agency  
WASH DC 20301 |        |
| HQDA (DARD-DDC)   | 4      |
| WASH DC 20310     |        |
| HQDA (DARD-ARZ-C) | 1      |
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| WASH DC 20310     |        |
| HQDA (DAMO-IAM)   | 1      |
| WASH DC 20310     |        |
| Commander         | 1      |
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Westinghouse Defense & Electronic Systems Center
Systems Development Division
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