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CANOPY SUN GLINT EVALUATION AND DISPLAY STANDARD

BOEING VERTOL COMPANY
A DIVISION OF THE BOEING COMPANY
P. O. Box 16858
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Prepared for

EUSTIS DIRECTORATE
U. S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY
Fort Eustis, Va. 23604

EUSTIS DIRECTORATE POSITION STATEMENT

This report describes a standarized technique for the evaluation of the sun-glint signature of Army helicopter canopies. It can also be used as a tool in the development of canopies that are required to have low sun-glint signature levels so as to increase combat survivability of the aircraft.

Earl C. Gilbert of the Military Operations Technology Division served as project engineer for this effort.

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This document describes a standard procedure for empirically determining canopy sun-glint signatures, a standard display format for the sun-glint signatures, and a procedure for analytically deriving canopy sun-glint signatures.

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1. Background

Sun glinting from the canopy is a major cue in the visual detection of aircraft. An aircraft canopy reflects the sun--produces sun glints--at azimuth and elevation angles which are a function of the geometry of the canopy and the orientation of the aircraft with respect to the sun. As the aircraft rotates, as shown in Figure 1, the sun glint also moves; and, as the orientation of the aircraft changes with respect to the sun, more or different canopy panels can become the reflecting surfaces. At any one instant, canopy sun glints may be visible at more than one set of azimuth and elevation coordinates with respect to the aircraft.

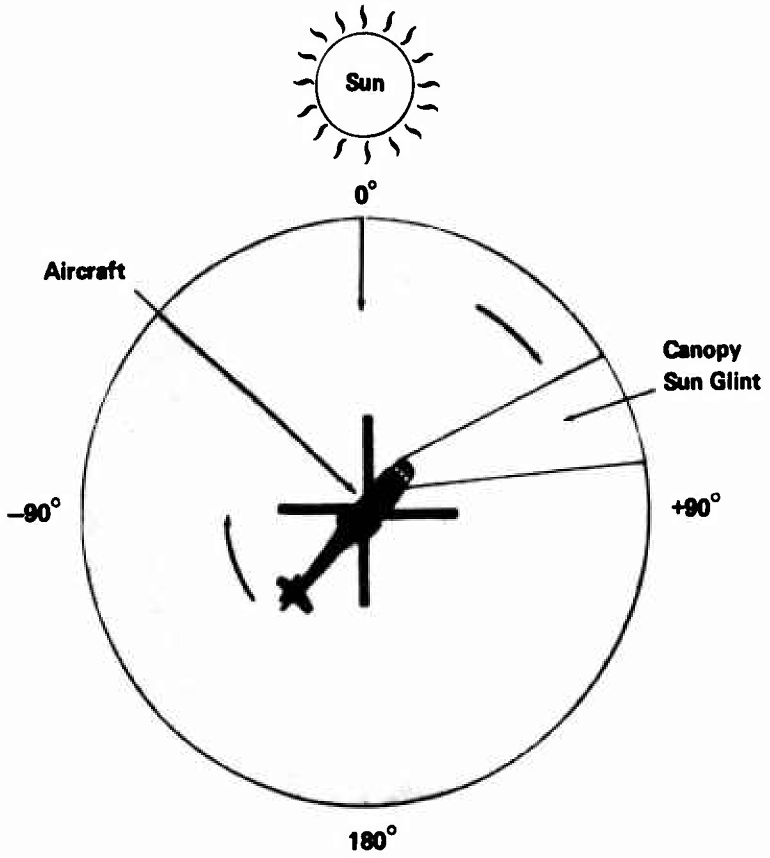


Figure 1. Mechanism of Canopy Sun Glint

To reduce the chance of visual detection, aircraft canopies should be designed such that no sun glints fall within the band of coordinates which are probable positions for hostile observers. This document helps to meet this design objective by presenting:

- A standard experimental procedure for determining canopy sun-glint signatures
- A standard format for documenting canopy sun-glint signatures
- An analytical procedure for determining canopy sun-glint signatures

2. Experimental Equipment

Determination of canopy sun-glint signatures is performed using a scale model of the aircraft being studied, a simulated sun source, and provisions for observing and recording glint patterns. A typical test facility, shown in Figure 2, contains these necessary elements:

- Aircraft model
- Model-mounting fixture
- Viewing screen
- Viewing-screen support
- Sun simulator
- Sun-simulator support

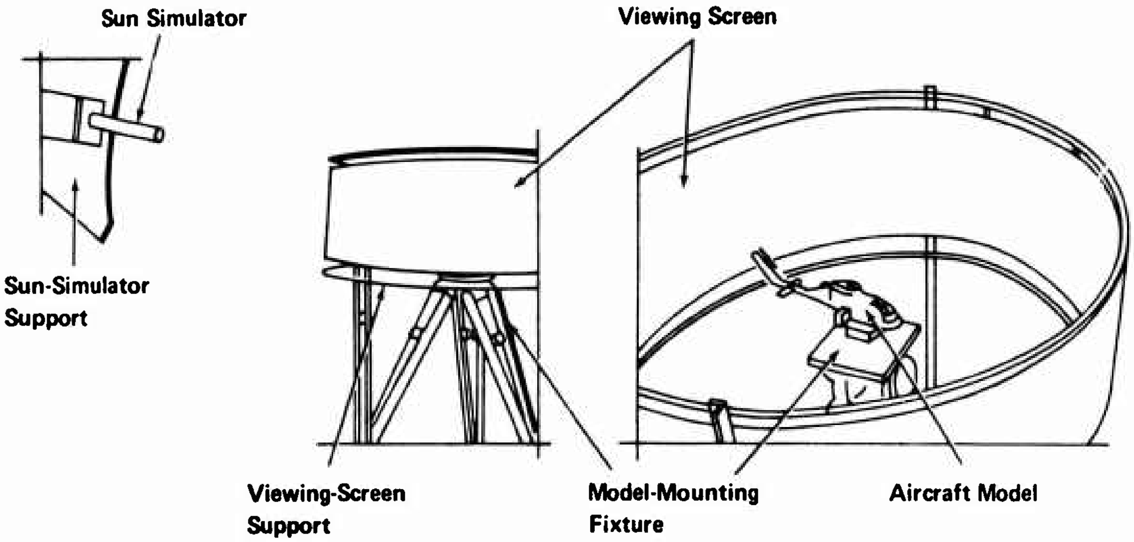


Figure 2. Test Setup for Determining Canopy Sun-Glint Signatures

AIRCRAFT MODEL

A 1/32-scale model is convenient for these tests. If another scale is selected, the diameter of the viewing screen must be changed proportionally. Surfaces other than those being studied should be coated with flat black paint to eliminate extraneous glints. Since this procedure for determining sun-glint signatures does not measure absolute glint intensities, only position and coverage, glint intensity may be enhanced, when practical, to improve visibility. For example, painting the interior surfaces of transparent canopies with glossy paint increases glint intensity without changing their size or shape.

MODEL-MOUNTING FIXTURE

Any convenient mounting fixture with a head which rotates in azimuth can be used. The rotating head should be calibrated and marked in degrees. A vertical-adjustment capability is required in either the model-mount fixture or the viewing-screen support.

VIEWING SCREEN

The screen must be translucent to permit viewing the projected sun glints from outside the cylinder. Since glint patterns are manually marked directly on the exterior surface of the screen, the screen must have the strength and the ability to accept marking. The screen must be replaceable since a new screen is used for each sun elevation angle studied. Drawing Mylar has been used successfully as a screen material. A screen diameter of 48 inches (1.22 meters) is used for 1/32-scale models.

VIEWING-SCREEN SUPPORT

The viewing-screen support must be sufficiently rigid to prevent movement with respect to the model as a result of marking the viewing screen while outlining reflected sun glints. The screen support must also permit installation and removal of the viewing screens.

SUN SIMULATOR

The sun simulator is an incandescent light source, apertured by a long, internally absorbing tube to provide a narrow beam of relatively collimated light. The beam dispersion must be sufficient to cover the model.

SUN-SIMULATOR SUPPORT

The sun-simulator support must permit movement of the sun simulator through an angle in the vertical plane sufficient to encompass the range of sun-elevation angles to be tested. It must be possible to clamp the sun simulator at desired test elevation angles. A fixed radius from the model is not required.

3. Experimental Procedure

The model is mounted on its mounting fixture with the center of gravity of the aircraft on the nominal rotation axis of the mounting fixture. The model is raised or lowered until the centerline of the sun-simulator axis at an elevation angle of 0 degrees passes through the nominal eye level of a pilot seated within the aircraft. This position is marked as the 0-degree line on the viewing screen. The sun simulator is next positioned at the desired test elevation angle. The aircraft is positioned with its nose pointed at the sun simulator and its waterline parallel to the viewing-screen support base. The room lights are extinguished to improve visibility, and all glints visible on the viewing screen are outlined with a marking pen. The model is then rotated to the right 20 degrees and the glint-outlining process repeated. The sequence of rotating the model 20 degrees and marking sun glints is repeated until the model has completed 360 degrees of rotation. For aircraft which possess left-right symmetry, 0- to 180-degree rotation of the model is sufficient. For other sun-elevation angles, the screen is replaced, the sun-elevation angle is changed, and the procedure is repeated. At low sun-elevation angles, a gap must be left in the viewing screen to permit illumination of the model. It may be necessary to extrapolate for glint signatures reflected at the 0-degree azimuth in such cases.

4. Display Format

Figure 3 is a top view of the test setup shown in Figure 2. As indicated, the sun is fixed and always located along the 0-degree azimuth. Any observer position can then be defined uniquely in terms of an azimuth and elevation measured relative to the aircraft rotational axis and referenced to the sun position. Aircraft headings are also referenced to the sun direction and are measured positive to the right. If canopy sun glints are marked on the screen, then the outlines of the sun glints on the screen define the azimuths and elevations where

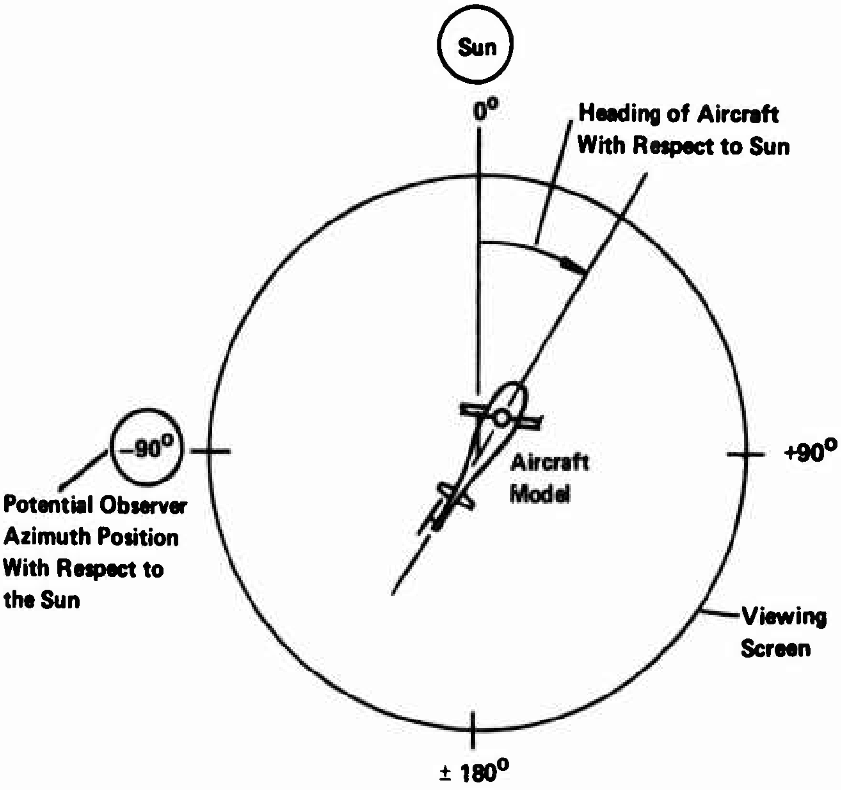


Figure 3. Top View of Experimental Test Setup

sun glints can be seen for each aircraft heading. If the viewing screen is opened at the 180-degree azimuth and flattened with the outside of the screen face up, there is a panoramic display of the sun glints produced by the aircraft for the set of heading angles selected. This display defines all possible observer locations where sun glint may be seen. By specifying the markings on the flattened viewing screen, a standard display format for test data can be obtained. Figure 4 is a standard display developed in just this way.

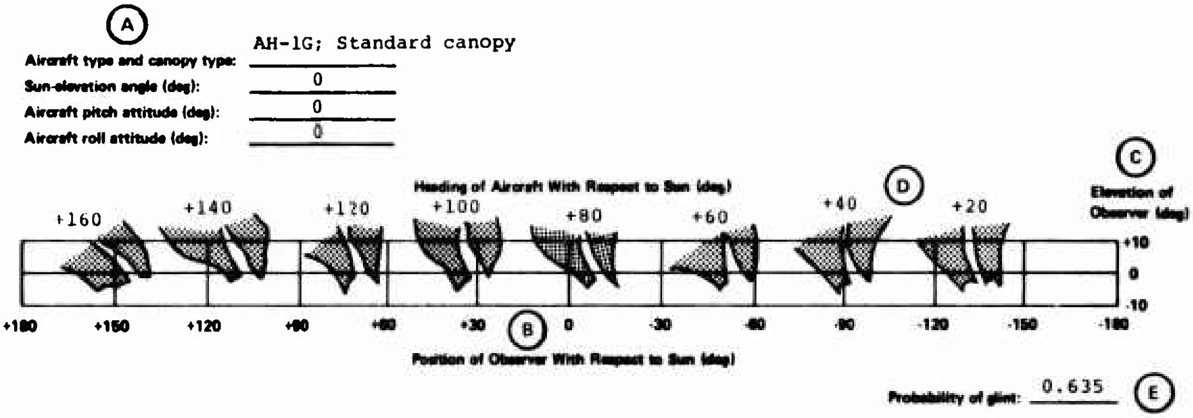
Figure 4 presents the canopy sun-glint signature of the AH-1G in standard format. This display contains the elements which shall be included in the documentation of canopy sun-glint signatures:

- Aircraft and canopy identification
- Sun-elevation angle and aircraft pitch and roll attitude
- Scale ranging from 0 to -180 and 0 to 180 degrees of azimuth locations from the aircraft, referenced to the direction of the sun

- Analyst-specified band of potential observer locations with respect to the aircraft

- Canopy sun-glint signatures, together with the aircraft heading with respect to the sun which produced them

- Probability of sun glint occurring in the display area bounded by the observer locations and the 0 to -180 and 0 to 180-degree azimuth boundaries



Aircraft type and canopy type: AH-1G; Standard canopy
Sun-elevation angle (deg): 0
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0

Probability of glint: 0.635

Figure 4. Standard Format for Presenting Canopy Sun-Glint Signature

SUN-ELEVATION ANGLE AND AIRCRAFT PITCH ATTITUDE

The sun elevation angle shall be presented above and on the left side of the display as shown in Figure 4 (A). Aircraft pitch attitude and roll attitude shall be presented directly below the sun elevation angle.

AZIMUTH

The horizontal space devoted to the display shall be divided into twelve equal segments as shown in Figure 4 (B) and the azimuth position of the sun glints with respect to the sun marked in 30-degree increments at the bottom of the display. The display is viewed as an opened right circular cylinder with 0 degrees being in the direction of the sun and the angles increasing positively to the right and negatively to the left as seen from the inside of the cylinder. The cylinder axis is vertical

POTENTIAL LOCATIONS OF OBSERVERS

The observer-elevation angles shall be shown as in Figure 4 (C). The minimum observation band shall be ±10 degrees from the aircraft horizon. The eye level of the aircraft pilot is nominally taken as 0 degrees.

AIRCRAFT HEADING

With two exceptions, each canopy sun glint which falls within the display angular boundaries as the aircraft is rotated on its yaw axis in 20-degree increments shall be shown as in Figure 4 (D). If the canopy sun-glint signature is so extensive that rotating the aircraft causes considerable overlapping, a single heading may be selected for display. (The OH-6 data of this report is an example of this exception.)

If the canopy signature changes little with aircraft rotation, other than a translation, data may be shown in increments of 40 degrees. (The OH-58 data of this report is an example of this exception.)

Aircraft heading shall be given as 0 degrees with the nose pointed at the sun. Rotation shall be positive to the right. For right-left symmetric canopies, only the sun glints generated for 0 to 180 degrees of aircraft heading rotation need be displayed. Further rotation would only yield the mirror image of the glint signatures generated in the first 0 to 180 degrees of rotation.

PROBABILITY OF SUN GLINT

For each display, the probability of a glint, Figure 4 (E), existing within the observer elevation band shall be computed. Probability of glint is defined as the fraction of the panorama area between 0 and -180 degrees and 0 and 180 degrees with respect to the sun and between the upper and lower observer elevation angle limits which is swept by the reflected canopy sun glint as the aircraft is rotated 360 degrees in heading. A swept area is counted only once. For example, if the area between 60 degrees and 90 degrees with respect to the sun and 0 degrees and 10 degrees of observer elevation angle is the position of a glint with aircraft heading at both 20 degrees and 340 degrees, the fact that there is an overlap is ignored in the computation. For the limits shown on Figure 1, there is 360 degrees x 20 degrees = 7,200 degrees^2 total area. The sun glint sweeps over 305 degrees x 15 degrees or 4,575 degrees^2. The probability of glint is therefore 4,575/7,200 = 0.6354. The glint probability shall be displayed below and to the right of the glint panorama as shown in Figure 4 (E).

5. Experimentally Derived Canopy Sun-Glint Signatures

The following four figures display canopy sun-glint signatures of four different canopy configurations in standard format. Sun-elevation angles were chosen to bracket the sun-elevation angles occurring in the Fulda Gap area of the Federal Republic of Germany. Figure 5 is the canopy sun-glint signature of the AH-1G with the standard canopy. Figure 6 is the canopy sun-glint signature of the AH-1G equipped with a canopy having vertical sides, flat top panel and front windshield, and a canopy centerline fence. Figures 7 and 8 display the canopy sun-glint signatures of the OH-6 and OH-58 respectively.

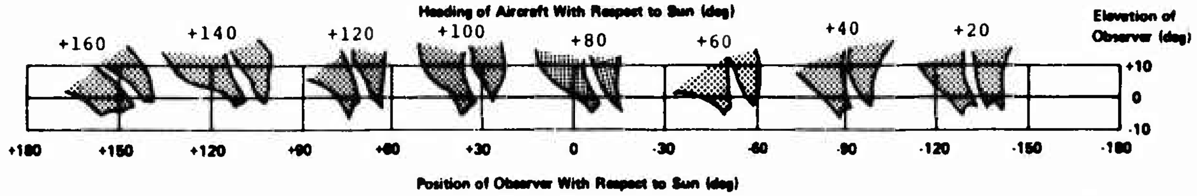
6. Analytical Procedure

BASIC CALCULATIONS

The sun glint from a reflecting surface depends upon the reflection angles of the sun's rays from each boundary point of the surface. Determination of these angles depends on the angle of incidence of the sun's rays and the normal to the reflecting surface. The angle of incidence is given by the specified sun elevation and sun azimuth, while the normal to the surface depends on the type of surface and, in general, the coordinates of any point. For example, in the case of a geometric plane, or flat surface, the normal to the surface has the same direction at every point. However, the quadratic or second-order surface has a normal which varies in direction from point to point. These two types of surfaces were considered to be representative of most canopy shapes. Combinations of these two types would generate more complex shapes.

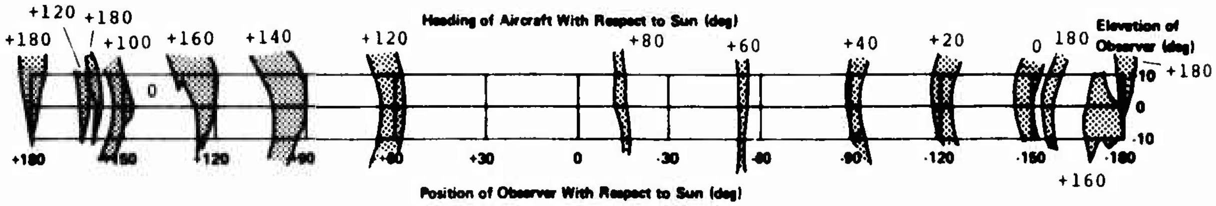
Surface normals and the angles of incidence must be referred to a common axis system in order to permit the calculation of reflection angles. A convenient axis system is one which is fixed in space (see Figure 9). The positive Z-axis points toward the center of the earth. The X-axis is chosen perpendicular to the Z-axis and in such a direction as to cause the sun to lie in the X-Z plane. In other words, a sun elevation angle of less than 90 degrees means that the sun has a positive X and negative Z direction. It will also have zero azimuth referred to this axis system. Finally, the Y-axis is chosen so as to complete a right-handed coordinate system.

Aircraft type and canopy type: AH-1G; Standard canopy
Sun-elevation angle (deg): 0
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



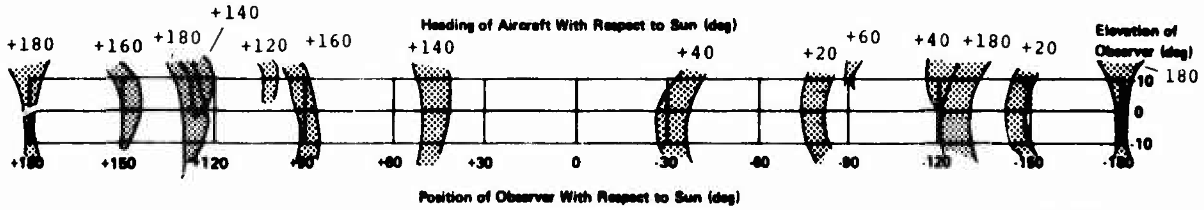
Probability of glint: 0.635

Aircraft type and canopy type: AH-1G; Standard canopy
Sun-elevation angle (deg): 30
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 0.875

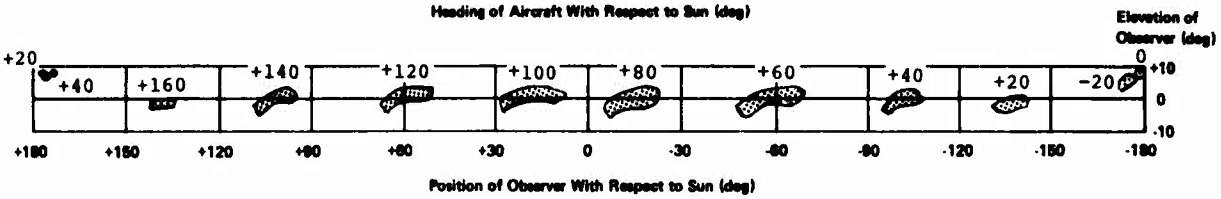
Aircraft type and canopy type: AH-1G; Standard canopy
Sun-elevation angle (deg): 60
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 0.875

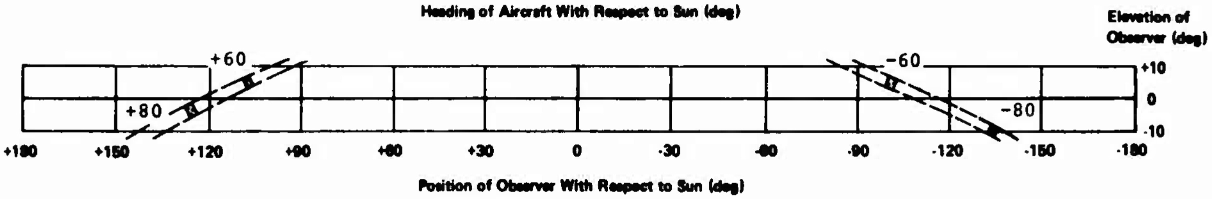
Figure 5. Canopy Sun-Glint Signature of AH-1G With Standard Canopy

Aircraft type and canopy type: AH-1G; Vertical-side canopy with centerline fence
Sun-elevation angle (deg): 0
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



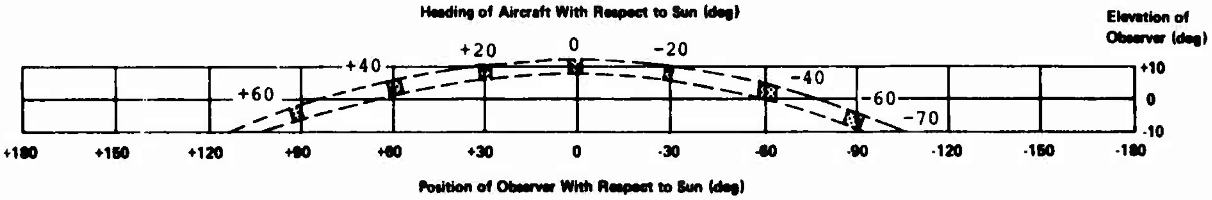
Probability of glint: 0.175

Aircraft type and canopy type: AH-1G; Vertical-side canopy with centerline fence
Sun-elevation angle (deg): 30
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 0.058

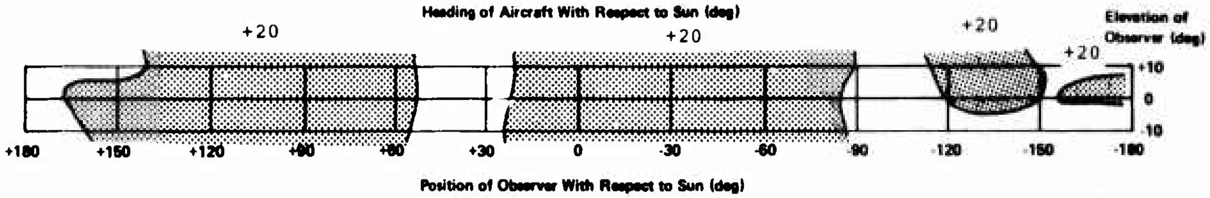
Aircraft type and canopy type: AH-1G; Vertical-side canopy with centerline fence
Sun-elevation angle (deg): 60
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 0.117

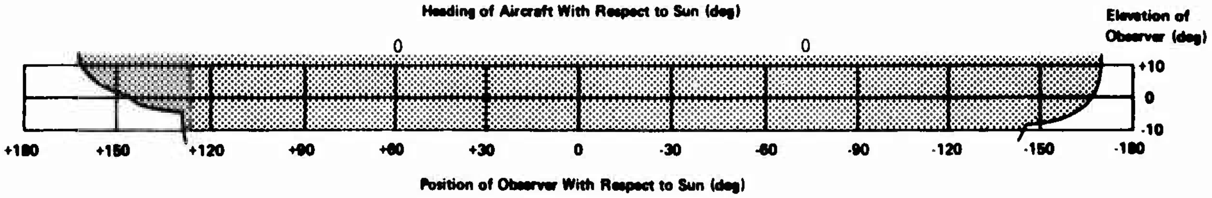
Figure 6. Canopy Sun-Glint Signature of AH-1G With Flat-Side Canopy and Centerline Fence

Aircraft type and canopy type: OH-6; Standard canopy
Sun-elevation angle (deg): 0
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



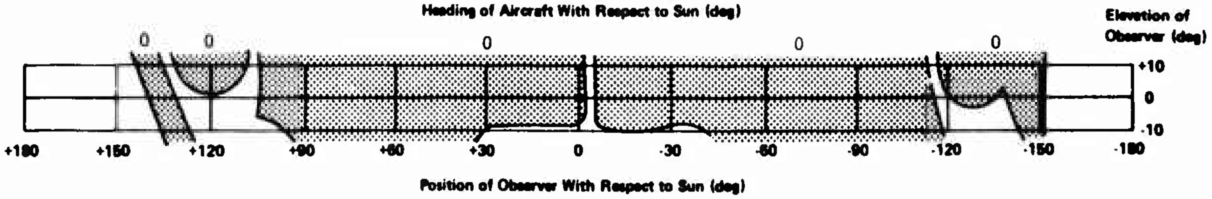
Probability of glint: 1.0

Aircraft type and canopy type: OH-6; Standard canopy
Sun-elevation angle (deg): 30
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 1.0

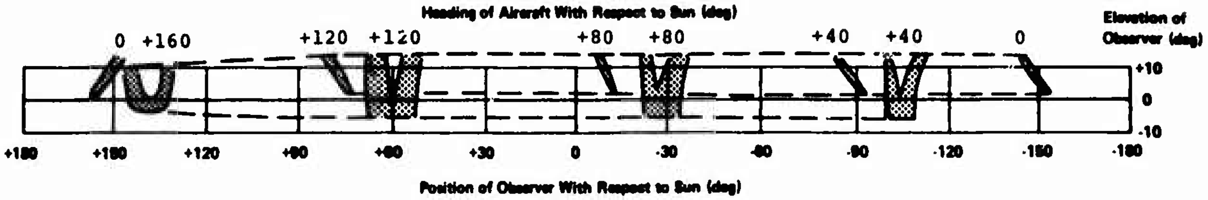
Aircraft type and canopy type: OH-6; Standard canopy
Sun-elevation angle (deg): 60
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 1.0

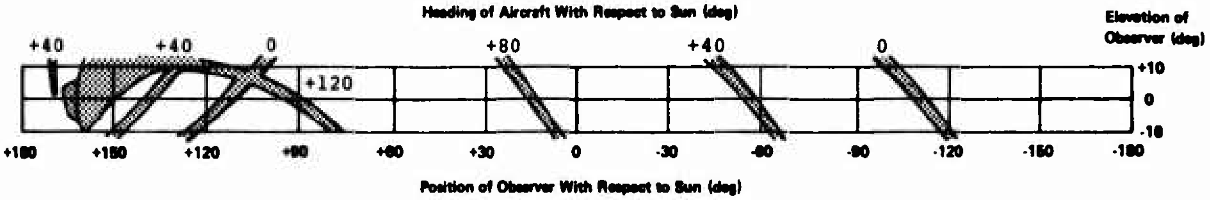
Figure 7. Canopy Sun-Glint Signature of OH-6 With Standard Canopy

Aircraft type and canopy type: OH-58; Standard canopy
Sun-elevation angle (deg): 0
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



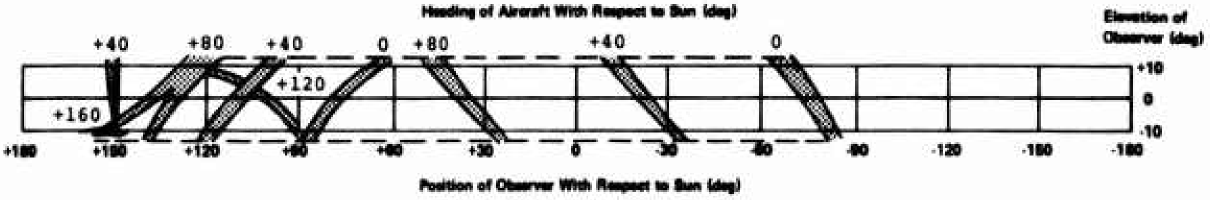
Probability of glint: 0.65

Aircraft type and canopy type: OH-58; Standard canopy
Sun-elevation angle (deg): 30
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 0.76

Aircraft type and canopy type: OH-58; Standard canopy
Sun-elevation angle (deg): 60
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 0.65

Figure 8. Canopy Sun-Glint Signature of OH-58 With Standard Canopy

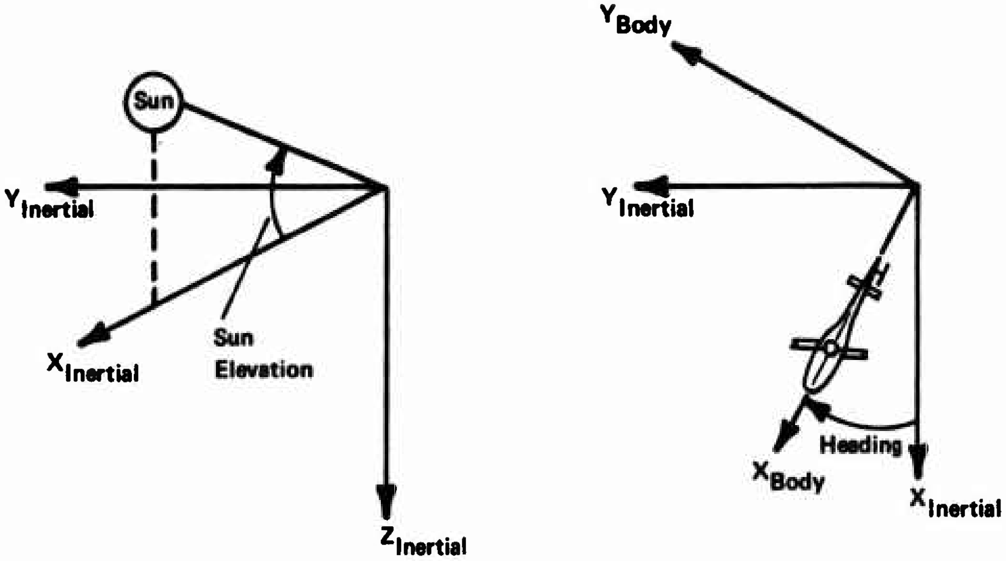


Figure 9. Fixed-Coordinate System for Angular Measurements

Since the reflecting surface is normally described in terms of an axis system fixed to the aircraft, a transformation of points and curves from one axis system to the other is needed. This transformation of body-fixed axes to earth-fixed axes consists of three aircraft rotations (roll, pitch, and yaw). It is assumed that the origins of both axis systems coincide.

Next, if there exist one or more fences on the aircraft, the effect of shadows cast by these fences must be analyzed. This is done by projecting the boundary points from both the fences and reflecting surface along the sun's rays onto a plane perpendicular to these rays. The intersection of the shadow and the reflecting surface on this plane will determine a new set of boundary points for the reflecting surface. This new set of points will represent the portion of the surface remaining outside of the shadow.

The normal to the surface at each remaining or new boundary point is then calculated based on the geometric shape of the surface. Generally, it is assummed that a great deal is known about the reflecting surface. Either an exact mathematical representation or general shape should be known. However, if this is not so, the boundary points may be curve-fitted to a specified type of surface using a modified least-squares error procedure. This surface equation then enables the rapid determination of surface normals.

As was mentioned, the reflection vectors from each boundary point are determined using the surface normal and angle of incidence of the sun's rays. Assuming a smooth reflecting surface, the reflection vector is equal to the sun vector with its normal component to the surface negated. It must now be determined if the reflection vector intersects any fences on its way to the observer. This is done by extending the vector until it intersects the plane of the fence. If this intersection lies within the boundary points of the fence, then the observer will not view the reflection.

Using all the remaining reflection vectors, a sun glint at an assumed observer distance can be calculated. This glint is referred to a specific reference point. Determination of this sun glint is obtained by extending each reflection vector until it intersects a cylinder whose radius equals the distance to the observer. By measuring the elevation and azimuth angles of the line-of-sight vector from the reference point to each intersection, a sun glint is formed.

DIGITAL COMPUTER PROGRAM

A digital computer program was written to solve in detail the above-described glint problem. It was coded in FORTRAN IV and has been made operational on the IBM 360 system. The main (executive) routine controls the general flow of the program. It reads in the desired helicopter angles, plot information, observer distance, and boundary points in body axes of both fences and reflecting surfaces. It sets up necessary DO loops and calculates surface normals. Figure 10 is a flow chart for the main program.

A general description of all the subroutines used in the entire program follows:

- CFIT--Sets up boundary points in desired form to be curve fitted.
- CURFIT--Sets up necessary matrices for least-square curve fitting of given points. Calculates standard-deviation error for calculated fit.
- EQNSOL--Solves a system of linear equations, either homogeneous or inhomogeneous. This subroutine, along with CFIT and CURFIT, curve fits boundary points to either a plane or a quadratic surface, depending on type specified by input.
- CVBI--Uses the body-to-inertial-axes transformation to convert coefficients of our surfaces in body axes to coefficients in inertial axes.

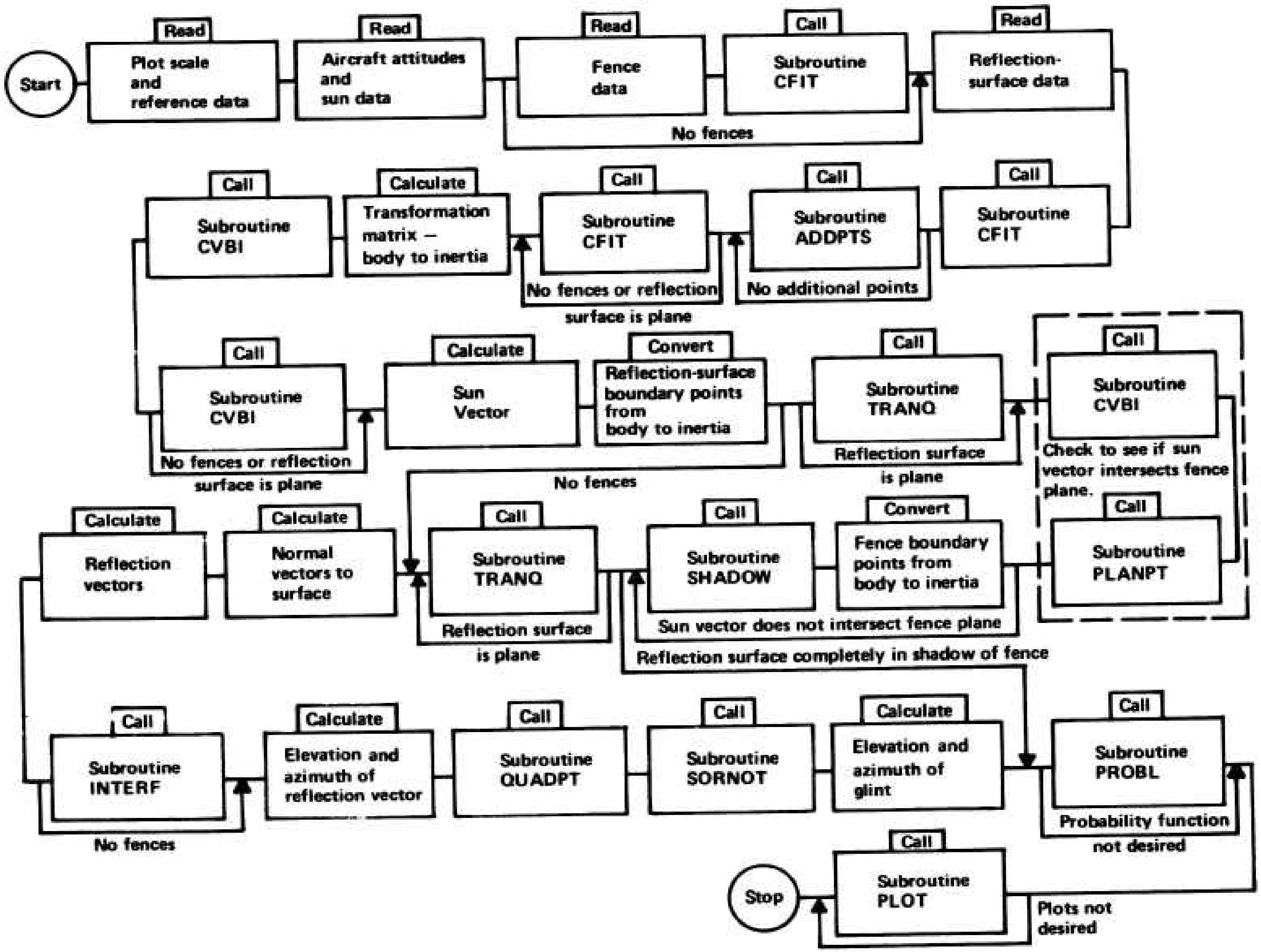


Figure 10. Flow Chart of the Digital-Computer Program for Canopy Sun Glint

- SHADOW--Determines the intersection of a shadow from a fence with reflection surface. Defines new reflection surface boundary points based on portion of surface outside of shadow.

- PLANPT--Calculates the intersection of a line with a plane. The inputs are a point in space on the line and direction numbers for the line along the coefficients of the plane.

- INTERC--Finds intersections, if any, of a line given by two points in a plane with set of lines given by a set of connected points in same plane.

- CHECK3--Checks to see whether a particular set of X and Y values of a point lie outside of a given range.

- SORNOT--Determines whether a particular boundary point of a fence is between sun and reflection surface or behind it. It is also used in regard to finding intersection of reflection vector with cylinder of radius equal to observer distance. In this latter case it is used to choose between two possible solutions by determining which solution lies in positive direction of reflection vector.

- TRANSP--Contains transformation that takes inertial axes into set of axes where the Z-axis lies in the same direction as the sun vector. If a set of points lies in a plane perpendicular to the sun, this subroutine converts this set of three-dimensional inertial coordinate of points to a set of two-dimensional coordinates of points in this new axis system. It also provides inverse for transforming points back to inertial axes.

- CLOSE--Determines which point in set of points is closest to a given point.

- CHECK1--Determines whether a given point is already contained in a set of points.

- CHECK2--Similar in function to CHECK1 except that the given point must first be transposed to same coordinate system that set of points is in.

- CIRCLE--Determines whether a given point is enclosed by a given set of points if each point in the set is connected by a straight line.

- INTERF--Calculates whether reflection from any particular boundary point intersects any fence.

- TRANQ--Projects points on quadratic surface to points in plane, where the plane is a best-fit plane through a set of quadratic surface boundary points. Projection is along sun rays. This subroutine will also perform reverse projection assuming that nearest intersection of quadratic surface preserves one-to-one mapping.

- QUADPT--Calculates intersection or intersections of a line with a quadratic surface. Inputs to the subroutine are a point on a line, direction numbers of the line, and coefficients of the quadratic surface.

- PLOT--An on-line digital plot of glints from a reflecting surface for a range of helicopter headings for a given sun elevation and helicopter pitch and roll attitudes.

- PROBL--Calculates swept-out area between glints on an elevation-versus-azimuth basis. Minimum and maximum elevation angles are used with straight lines drawn between corresponding values for different glints. Area is calculated using triangular area law of points.

- ADDPTS--Will, if desired, supply additional boundary points along curved portions of quadratic surfaces.

A detailed description of all input variables and their format is contained in Appendix A. A complete FORTRAN IV listing of the program appears in Appendix B. Basically the inputs are desired aircraft attitudes, sun elevations, observer elevations, and boundary points. An assumption was made that all fences could be handled as combinations of flat surfaces only. For the purpose of calculating shadows, it was felt that this was sufficient. As mentioned before, reflecting surfaces were assummed to be combinations of flat and quadratic shapes. It was also necessary, in order to save some sorting and execution time, to require that the boundary points be simply connected. That is, point 1 is connected to point 2 and point 2 is connected to point 3, and so on, with the last point connected to point 1. No other combination is allowed.

In calculating the intersection of a shadow with a reflecting surface, the assumption was made that the points could be connected by straight lines. An input to the program will cause the generation of additional boundary points for curved portions, if necessary, thus minimizing the error resulting from this straight-line assumption.

An example of a complete set of inputs is tabulated in Figure 11. These inputs are for the AH-1G with straight sides. The configuration is symmetric with respect to the X-Z plane, so only the top, front, and left side are needed to generate the glint signature. Also, only 180 degrees of aircraft rotation is needed.

Output to the program is in the form of tables and on-line plots, as shown in Figures 12 through 16. The tables consist of all necessary input information along with reflection vector and glint angles. Figure 12 is a tabulation of boundary points for the center fence and the resulting curve-fit. Figure 13 is a tabulation of boundary points for the first reflection surface and the resulting curve-fit. Figure 14 is a tabulation of the output reflection vector and glint angles as a function of aircraft azimuth for constant sun elevation and aircraft pitch and roll. This table is for reflection surface number one. The information contained in Figures 13 and 14 is repeated for each reflection surface. Also, if on-line plots are requested, Figure 15 shows the plot for the first reflecting surface corresponding to the data of Figure 14. There will be an on-line plot for each surface at each sun elevation with the numbered points corresponding to the different input aircraft yaw azimuths, as shown in Figure 15. In addition to a plot for each separate surface, there will be a composite plot of all surfaces for each desired sun elevation, as is shown in Figure 16.

VERIFICATION OF ANALYTICAL PROCEDURE

The first step in verifying the above-described computer program was to input simple shapes with known solutions. Once this was done successfully, the next step was to input canopy configurations for which experimental data was available. Results for three configurations were compared. The three configurations were the AH-1G with vertical sides, the OH-6, and the OH-58.

Figure 17 is the glint signature for the AH-1G with vertical sides as shown in Figure 6 with the computer results spotted on. As can be seen, the comparison is good. This is to be expected since all surfaces are planes and thus have constant normal directions. Some discrepancies appear in the range of azimuths corresponding to glints resulting from side window reflections at zero sun elevation. There are at least three possible causes. The plastic canopy used in generating the experimental data was not smooth, causing some dispersion. The light source used in the experiment had some associated dispersion. The third error could be in the computer input data, in that the dimensions were not generated from a detailed drawing but calculated from a partially scaled drawing.

```
Input
Card                          Input Data
Type

 1  -180.      180.      -100.      100.

 2  0.00       0.0       0.0        64.       -10       10.

 3  -4.0       0.0
 4  6.0        5.        2.

 6    14       0.00      10.0       20.0      30.0      40.0

 7  50.        60.       70.        80.       90.

 7  100.       120.      140.       160.

 8     1

 9     4

10  13,170     0.        1.         11.       0.        -1.88

10  4.0        0.        -1.88      4.        0.        1.

11     4    0    1    1    0

12     1    4    0    0

13  12,79      -1,5      1.         12,79     1,5       1.

13  11.         1,5       -1.38      11.       -1.5      -1.38

12     1    4    0    0

13  11.        -1,5      -1.38      11.       1,5       -1.38

13  4.         1,5       -1.38      4.        -1.5      -1.38

12     1    3    0    0

13  12,79      -1,5      1.         11.       -1.5      -1.38

13  11.        -1,5      1.0

12     1    4    0    0

13  11.        -1,5      -1.38      4.        -1,5      -1.38

13  4.         -1,5      1.         11.       -1.5      1.
```

Figure 11. Computer Printout of Inputs for the AH-1G With Flat-Side Canopy and Centerline Fence

```
FENCE NUMBER  1

     BOUNDARY POINTS - BODY AXES

                 X            Y            Z                    X            Y            Z
        ( 1)   13.17         0.0         1.00          ( 2)   11.00         0.0        -1.88
        ( 3)    4.00         0.0        -1.88          ( 4)    4.00         0.0         1.00

     COEFFICIENTS OF FITTED CURVE

        ( 1)  0.0          ( 2)  1.0000          ( 3)  0.0          ( 4)  0.0

     SIGMA ERROR OF FIT=  0.0
```

Figure 12. Computer Printout of Boundary Points for Center Fence

```
REFLECTION PANEL NUMBER  1                      TYPE 1

     BOUNDARY POINTS - BODY AXES

                 X            Y            Z                    X            Y            Z
        ( 1)   12.79        -1.50        1.00          ( 2)   12.79         1.50        1.00
        ( 3)   11.00         1.50       -1.38          ( 4)   11.00        -1.50       -1.38

     COEFFICIENTS OF FITTED CURVE

        ( 1)  0.0631       ( 2)  0.0          ( 3) -0.0625       ( 4) -1.0000

     SIGMA ERROR OF FIT=  0.3249D-15
```

Figure 13. Computer Printout of Boundary Points for First Reflection Surface

```
                              SUN GLINT SIGNATURE FOR SURFACE NO.  1

SUN ELEVATION          30.00                                                                XREF      0.0
A/C PITCH ATTITUDE    -4.00                                                                 YREF      0.0
A/C ROLL ATTITUDE       0.0                                                                 ZREF      0.0
                                                                                            XDISTG   64.00

A/C YAW        SUN DISPERSION       BOUNDARY POINTS-BODY AXES       REFLECTION VECTOR          GLINT
                VERT     LAT           X       Y       Z          ELEVATION  AZIMUTH     ELEVATION  AZIMUTH

  0.0           0.0      0.0         12.79   -1.50    1.00          35.89      0.0         28.83     -1.34
  0.0           0.0      0.0         12.79    1.50    1.00          35.89      0.0         28.83      1.34
  0.0           0.0      0.0         11.00    1.50   -1.38          35.89      0.0         31.29      1.34
  0.0           0.0      0.0         11.00   -1.50   -1.38          35.89      0.0         31.29     -1.34
 10.00          0.0      0.0         12.79   -1.50    1.00          35.05     20.59        28.24     17.18
 10.00          0.0      0.0         12.79    1.50    1.00          35.05     20.59        28.02     19.82
 10.00          0.0      0.0         11.00    1.50   -1.38          35.05     20.59        30.48     20.08
 10.00          0.0      0.0         11.00   -1.50   -1.38          35.05     20.59        30.70     17.44
 20.00          0.0      0.0         12.79   -1.50    1.00          32.59     40.58        26.27     35.32
 20.00          0.0      0.0         12.79    1.50    1.00          32.59     40.58        25.88     37.84
 20.00          0.0      0.0         11.00    1.50   -1.38          32.59     40.58        28.35     38.35
 20.00          0.0      0.0         11.00   -1.50   -1.38          32.59     40.58        28.74     35.84
 30.00          0.0      0.0         12.79   -1.50    1.00          28.71     59.58        23.09     52.79
 30.00          0.0      0.0         12.79    1.50    1.00          28.71     59.58        22.58     55.14
 30.00          0.0      0.0         11.00    1.50   -1.38          28.71     59.58        25.05     55.86
 30.00          0.0      0.0         11.00   -1.50   -1.38          28.71     59.58        25.55     53.51
 40.00          0.0      0.0         12.79   -1.50    1.00          23.66     77.43        18.86     69.43
 40.00          0.0      0.0         12.79    1.50    1.00          23.66     77.43        18.32     71.58
 40.00          0.0      0.0         11.00    1.50   -1.38          23.66     77.43        20.79     72.47
 40.00          0.0      0.0         11.00   -1.50   -1.38          23.66     77.43        21.33     70.32
 50.00          0.0      0.0         12.79   -1.50    1.00          17.69     94.13        13.79     85.22
```

Figure 14. Computer Printout of Output Reflection and Glint Angles for First Reflection Surface

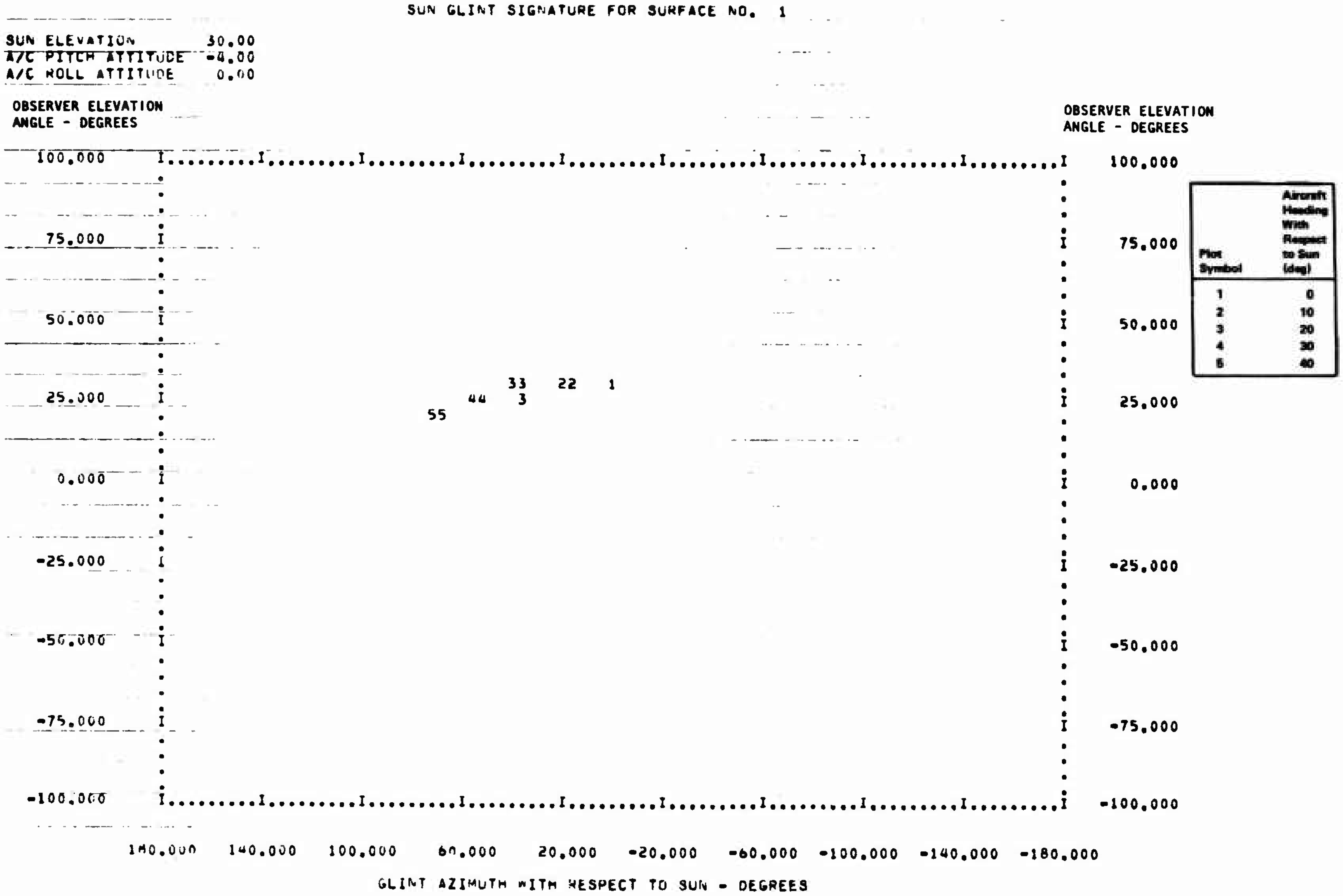


Figure 15. Computer Plot of Output Reflection and Glint Angles for First Reflection Surface

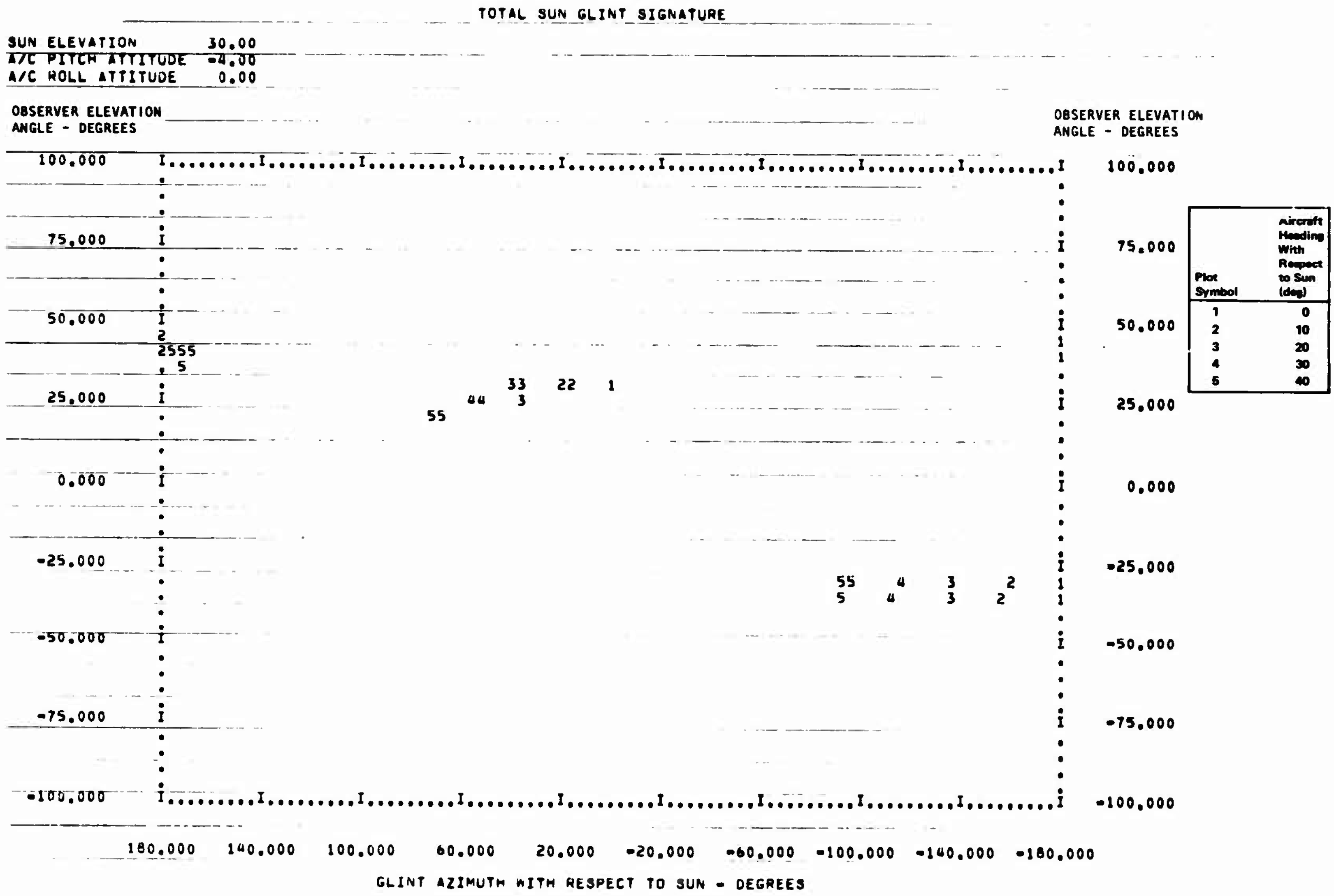
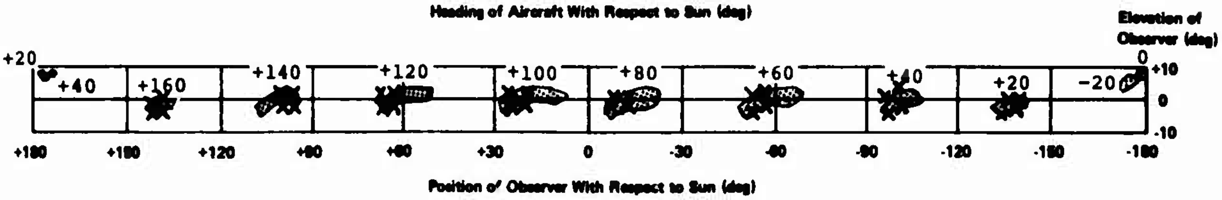


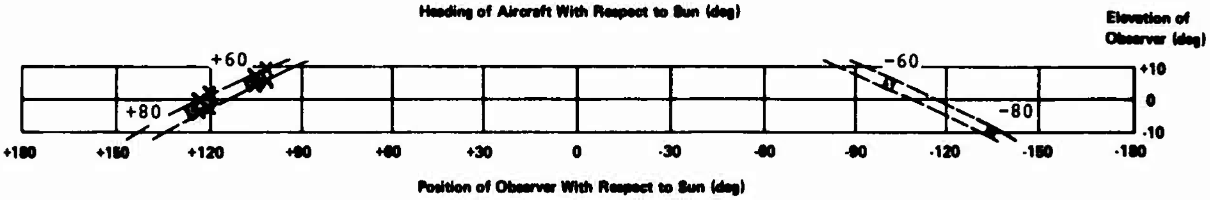
Figure 16. Computer Plot of Total Sun-Glint Signature

Aircraft type and canopy type: AH-1G; Vertical-side canopy with centerline fence
Sun-elevation angle (deg): 0
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



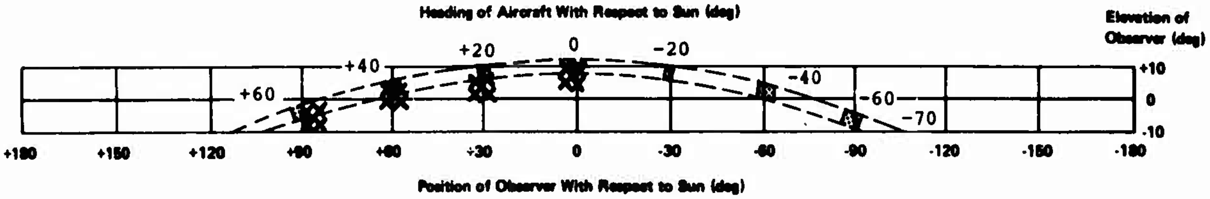
Probability of glint: 0.175

Aircraft type and canopy type: AH-1G; Vertical-side canopy with centerline fence
Sun-elevation angle (deg): 30
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 0.056

Aircraft type and canopy type: AH-1G; Vertical-side canopy with centerline fence
Sun-elevation angle (deg): 60
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 0.117

Figure 17. Computer Results Superimposed on Sun-Glint Signature of AH-1G With Flat-Side Canopy and Centerline Fence

Figure 18 is the superimposed computer results for the OH-6 at specified aircraft azimuths. Here, as can be seen, the digital results are not nearly as good as the AH-1G with vertical sides. Possible causes are:

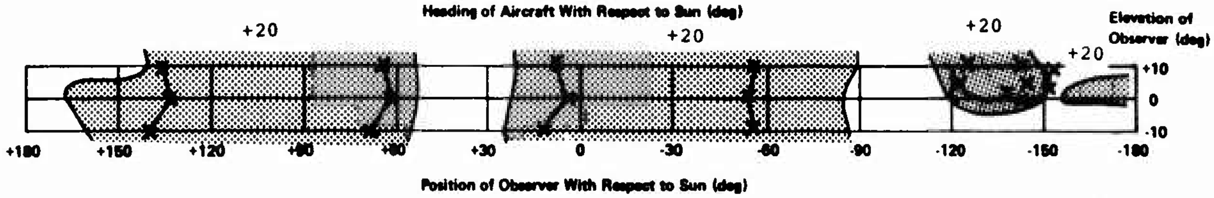
- The plastic model may not have been completely representative of the OH-6. Slight changes in certain dimensions can cause apparently large changes in results. For instance, a change of 0.05 inch in the model cutout of the front windshield could cause a 20-degree shift in azimuth of one of the glint boundaries.
- The exact location of the reference point used in the generation of the experimental data was not known.
- The mathematical representation for the reflecting surfaces was obtained from three-view drawings with some necessary simplification.

However, the general location and shape of the glints were in agreement. It must also be remembered that a 1-degree error in calculation of surface normal will result in a 2-degree error in the position of the reflection. For rapidly changing normals, this multiplying factor becomes significant.

Figure 19 is the glint signature for the OH-58 with computer results plotted on top. Of the three configurations, the mathematical expression of the windshield of the OH-58 was the most difficult to determine and thus the most questionable. Also,the question of model exactness must be raised again. The windshield is not a simple shape, and without detailed cross-sectional drawings, the representation of the windshield as a combination of simple shapes was difficult. The reference point again was not known. However, as with the OH-6, the results show general agreement.

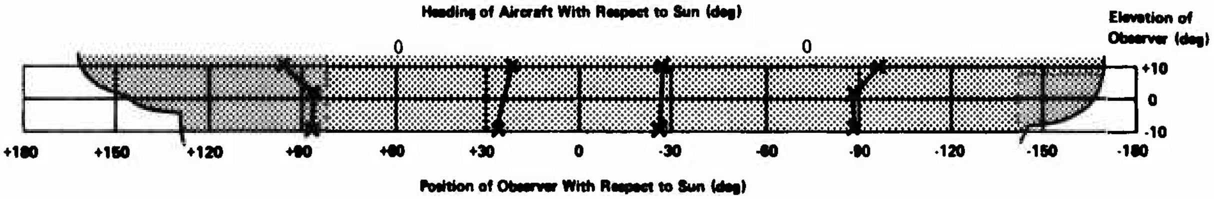
The conclusion from these comparisons is that if one is looking for relative merits or problems of a particular canopy design, then curve-fitting of relatively crude inputs will yield adequate results. However, if absolute answers in terms of precise location of each glint corresponding to each aircraft and sun location are desired, then a very good grasp is needed on the mathematical expression of the canopy design. This last statement is not as confining as it may seem, for if a person is designing a canopy, he will normally know the precise shape of his canopy.

Aircraft type and canopy type: OH-6; Standard canopy
Sun-elevation angle (deg): 0
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



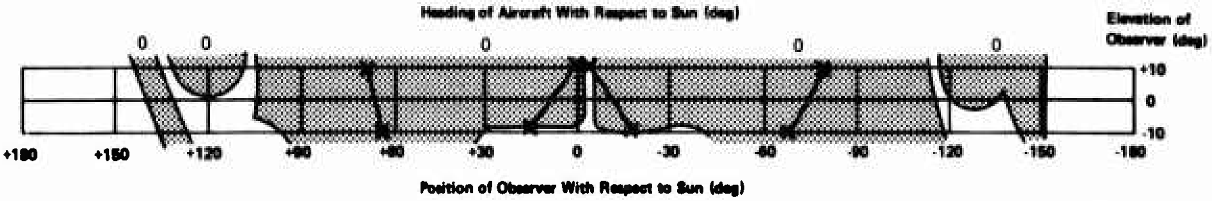
Probability of glint: 1.0

Aircraft type and canopy type: OH-6; Standard canopy
Sun-elevation angle (deg): 30
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 1.0

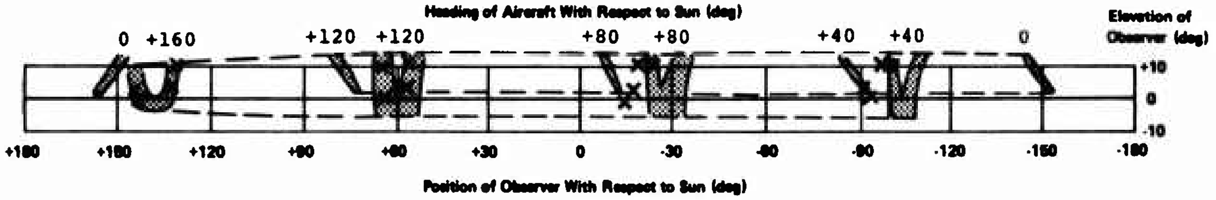
Aircraft type and canopy type: OH-6; Standard canopy
Sun-elevation angle (deg): 60
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 1.0

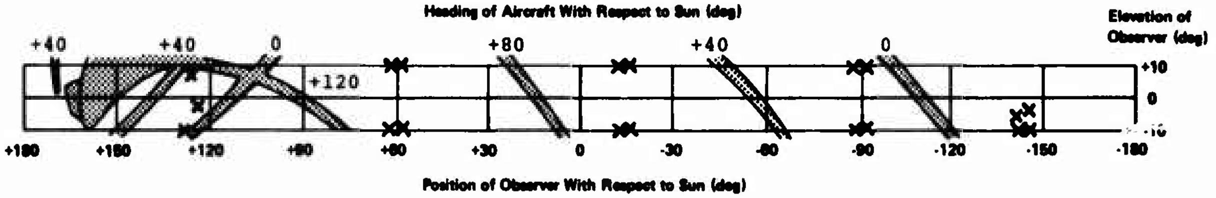
Figure 18. Computer Results Superimposed on Sun-Glint Signature of OH-6 With Standard Canopy

Aircraft type and canopy type: OH-58; Standard canopy
Sun-elevation angle (deg): 0
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



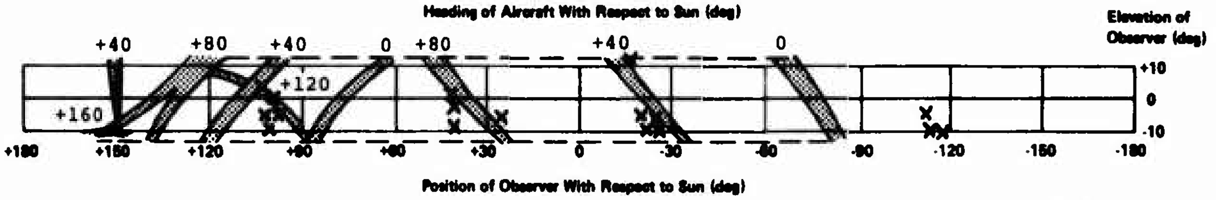
Probability of glint: 0.65

Aircraft type and canopy type: OH-58; Standard canopy
Sun-elevation angle (deg): 30
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 0.76

Aircraft type and canopy type: OH-58; Standard canopy
Sun-elevation angle (deg): 60
Aircraft pitch attitude (deg): 0
Aircraft roll attitude (deg): 0



Probability of glint: 0.65

Figure 19. Computer Results Superimposed on Sun-Glint Signature of OH-58 With Standard Canopy

Appendix A

Input and Output of Digital-Computer Program

INPUT

All card types with (*) are optional, depending on the type and number of inputs.

Card Type 1--Format 4E10.0

XSCMIN	Lower limit for glint azimuths for on-line plots
XSCMAX	Upper limit for glint azimuths for on-line plots
YSCMIN	Lower limit for observer angles for on-line plots
YSCMAX	Upper limit for observer angles for on-line plots

Card Type 2--Format 6E10.0

XREF	X distance along X-body axis to reference point, reference point being point from which glint angles are measured
YREF	Y distance to reference point
ZREF	Z distance to reference point
DISTG	Distance in X-Y inertia plane to assumed observer
OBSMIN	Lower limit on observer elevation angle used in calculating probability function
OBSMAX	Upper limit on observer elevation for probability calculation

Card Type 3--Format 2E10.0

THETA	Pitch attitude of aircraft (positive up)
PHI	Roll attitude of aircraft (positive right wing down)

Card Type 4--Format 15,5X,5E10.0

NGAM	Number of sun-elevation angles for which data is desired
GAM	Array containing desired sun elevations

Card Type 5--Format 5E10.0

GAM	If NGAM > 5, additional values of sun elevations

Card Type 6--Format 15, 5X, 5E10.0

NPSI	Number of aircraft azimuths for which data is desired
PS	Array containing desired aircraft azimuths

Card Type 7--Format 5E10.0

PS	If NPSI > 5, additional values of aircraft azimuths

Card Type 8--Format 15

NFENCE	Number of fences for which boundary point will be read in

Card Type 9*--Format 15

NFPTS	Array containing number of boundary points for each fence

Card Type 10*--Format 6E10.0

FPTS	Array containing boundary points for each fence. X,Y.Z locations in body axis are read in with two points on a card. This card type is continued to be read until all points for a particular fence are read in. Then another type-9 card is read, and so on, until all fences are read in. Card types 9 and 10 are used only if NFENCE > 0.

Card Type 11--Format 515

NPANEL	Number of reflecting surfaces to be read in
IANGL	Determines form of glint azimuths in print out: IANGL = 0 ±180 degrees IANGL = 1 0 degrees to 360 degrees

IPLOT Are on-line plots desired?

IPLOT = 0 No
IPLOT = 1 Yes

IPROB Is probability function to be calculated?

IPROB = 0 No
IPROB = 1 Yes

NDISP Is sun dispersion of 0.5 degrees to be used?

NDISP = 0 No, parallel rays
NDISP = 1 Yes

Card Type 12--Format 5I5

ITYPE Type of reflecting surface:

ITYPE = 1 Flat surface
ITYPE = 2 Quadratic surface

NPTS Number of boundary points for reflecting surface

ICOEFS Determines whether coefficients for reflecting surface will be read in or curve-fitted from boundary points. Also can be used to specify shape of fit:

ICOEFS = 0 Curve fit data using built-in method of selecting terms
ICOEFS = 1 Read in coefficients
ICOEFS = 2 Particular terms to be fitted will be specified

NBETW Are additional boundary points along curved surfaces desired?

NBETW = 0 No
NBETW = N Yes. N = Number of additional points between each pair of points read in

INTERN Are internal cockpit reflections permitted?

INTERN = 0 Yes
INTERN = 1 No

Card Type 13--Format 6E10.0

XPTSB Array containing boundary points of reflecting surface in body axis. X,Y,Z components of each point are read in with two points to an input card. This card type is continued to be read in until all points are used.

Card Type 14*--Format 1015

NCOEFS Number of coefficients in desired curve fit

IFIT Array containing location of each desired term in basic equation. This card type used only if ICOEFS = 2 and ITYPE = 2. The following is an example of how this is inputed. The basic quadratic surface equation as assumed by the program is

$$AX^2+BY^2+CZ^2+DXY+EXZ+FYZ+GX+HY+KZ+L = 0$$

If it is desired to curve fit boundary points to the equation

$$AX^2+CZ^2+HY+KZ+L = 0$$

Then the inputs would be NCOEFS = 4, IFIT(1) = 1, IFIT(2) = 3, IFIT(3) = 8, IFIT(4) = 9.

Constant term is not counted. Also, IFIT must contain integers in ascending magnitudes only.

Card Type 15*--Format 6D10.0

COEFB Array containing coefficient of reflecting surface equation

For ITYPE = 1, $COEFB(1)X + COEFB(2)Y + COEFB(3)Z + COEFB(4) = 0$

For ITYPE = 2, $COEFB(1)X^2 + COEFB(2)Y^2 + COEFB(3)Z^2 + COEFB(4)XY + COEFB(5)XZ + COEFB(6)YZ + COEFB(7)X + COEFB(8)Y + COEFB(9)Z + COEFB(10) = 0$

This card type is used only if ICOEFS = 1. Two cards of this type are required to input the 10 coefficients. Zeros must be included for undesired coefficients.

OUTPUT

The output to the program is simply a tabulation and, if desired, an on-line plot of the elevation and azimuth angles of each glint boundary point associated with each reflection surface boundary point. Reflection boundary points which are read in but lie in a shadow of a fence will not appear in output, and points whose reflection vector intersects a fence will have reflection vector angles and glint angles printed as a row of asterisks.

The elevation and azimuth angles are calculated for each desired sun elevation and aircraft yaw angle, and are referred to a particular reference point. An additional output, if requested, is a simplified estimate of the area covered by the sun glints as the aircraft rotated through a range of azimuths. This is put in terms of a ratio to total area and is termed the "probability function".

Appendix B
Program Listing

SUGGESTIONS FOR PROGRAM USERS

The analytical procedure given in this report is sensitive to errors in canopy geometry. It is suggested that the user take advantage of defined fuselage lines from engineering design data when available for the aircraft canopy under consideration. For flat-panel canopies, this degree of precision is not required.

The analytical procedure is designed to operate using simply connected boundary points of the individual canopy panels. For curved canopies, it is suggested that an initial run be made with boundary points and nonboundary points included in order to obtain a good equation for the surface of the canopy. For this purpose request a 0-degree sun elevation and a 0-degree aircraft heading and check the output to see if the reflection vectors are in the expected direction. For example, if the canopy is parabolic so that a normal to the highest point on the canopy is perpendicular to the aircraft waterline, then the reflection vector should be at nominally 180 degrees azimuth and a low elevation--0 to 10 degrees. Similarly, if a normal to the outermost point on the canopy in the Y direction is perpendicular to the X-Z plane, the reflection vector should be at nominally 180 degrees azimuth and 0 degrees elevation. By continuing this procedure for other points on the canopy where the normal to the canopy is known, the user can assure himself that the equation for the canopy is reasonable. As a starting point, specifying only equation terms 2, 3, 7, and 9 on card type 14 has been found useful for parabolic canopies. Once the canopy equation has been defined, the user can remove the nonboundary points from the data set and specify the canopy equation terms for further runs. The added runs would encompass all sun positions and aircraft positions desired.

There is a note of warning when running with fences. Boundary points which were inputted may not appear in the output; boundary points which were not inputted may appear in the output. This is due to the fact that a new set of boundary points is generated whenever the shadow of the fence intersects the reflective surface. Additional boundary points may also appear in the output when the shadow does not intersect the reflective surface if the reflective surface is curved (ITYPE = 2). This occurs because the intersection of the sun's vector with the curved surface, under a given condition, may have two solutions.

```
      DIMENSION FPTS(5,30,3), NRPTS(5),RPSI(5,30,3),
     1 FPSI(30,3),NFPTS( 5),GAM(4),PS(18)
      DIMENSION COEFI(10),DIRCOS(3,3),VNORM(3),SUN(3),REFLTN(3)
      DIMENSION XPTSB(30,3)
      DATA TOL/1.0E-04/
      REAL*8 SIG,COEFB(10),COEFD(10)
      REAL*8 COEFBQ(10),COEFBF(5,4)
      DIMENSION COEFS(10),COEFIF(10)
      COMMON/CTR02/DIRCOS,XPTSB,XMIN(3),XMAX(3),NPTS
      REAL*8 DIRCOS,COEFS,COEFI,COEFIF,SUN,REFLTN,DISC,X,Y,Z,X1,Y1,Z1,
     1 XI2,YI2,ZI2,DQ2,DATAN2,DABS,DSQRT
      COMMON/FENCE/COEFBF
      DIMENSION ALPHA2(1000),BETA2(1000),NPSPTS(7,4,18)
      COMMON/FIT/ICOEFS,NCOEFS,IFIT(9)
      COMMON/PLPR/MGAMS(7,4)
      RAD=57.29578
      READ(5,100) XSCMIN,XSCMAX,YSCMIN,YSCMAX
      READ(5,100) XREF,YREF,ZREF,DISTG,OBSMIN,OBSMAX
 10   READ(5,100) THETA,PHI
      READ(5,103) NGAM,(GAM(I),I=1,NGAM)
      READ(5,103) NPSI, (PS(I),I=1,NPSI)
103   FORMAT(I5,5X,(5E10.0))
      SUMW=360.*(OBSMAX-OBSMIN)
      IF(SUMW.EQ.0.0) SUMW=1.0
      READ(5,101) NFENCE
      IF(NFENCE.EQ.0) GO TO 14
      LINES=51
      ICOEFS=0
      DO 12 I=1,NFENCE
      READ(5,101) NFPTS(I)
      N=NFPTS(I)
      READ(5,100) ((FPTS(I,J,K),K=1,3),J=1,N)
      DO 11 J=1,N
      DO 11 K=1,3
 11   XPTSB(J,K)=FPTS(I,J,K)
      CALL CFIT(XPTSB,N,COEFB,1,SIG)
      IF(LINES.GT.30) WRITE(6,210)
      IF(LINES.GT.30) LINES=0
210   FORMAT(1H1)
      WRITE(6,211) I
211   FORMAT(1H0,'FENCE NUMBER',I3)
      WRITE(6,212)
212   FORMAT(1H0,5X,'BOUNDARY POINTS - BODY AXES'   /1H0,2(20X,'X',
     1 11X,'Y',11X,'Z',2X))
      NP=N
      IF(2*(N/2).LT.N) NP=NP-1
      DO 150 J=1,NP,2
      JP1=J+1
150   WRITE(6,213) (M,(XPTSB(M,K),K=1,3),M=J,JP1)
213   FORMAT(1H ,2(11X,'(',I2,')',1X,2(F7.2,5X),F7.2))
      IF(2*(N/2).LT.N) WRITE(6,214) N,(XPTSB(N,K),K=1,3)
214   FORMAT(1H ,11X,'(',I2,')',1X,3(F7.2,5X))
```

```
      WRITE(6,215) (J,COEFB(J),J=1,4)
  215 FORMAT(1H0,5X,'COEFFICIENTS OF FITTED CURVE'/1H0,10X,4('(',I2,
     1 ')',F10.6,8X))
      WRITE(6,216) SIG
  216 FORMAT(1H0,5X,'SIGMA ERROR OF FIT=',D12.4)
      LINES=LINES+12+N-N/2
      DO 12 K=1,4
   12 COEFBF(I,K)=COEFB(K)
   14 CONTINUE
   15 READ(5,101) NPANEL,IANGL,IPLOT,IPROB,NDISP
      IF(NDISP.EQ.1) NDISP=4
      IF(NDISP.EQ.0) NDISP=1
  101 FORMAT(12I5)
      MAS=0
      DO 2000 I=1,NPANEL
      READ(5,101) ITYPE,NPTS,ICOEFS,NBETW,INTERN
      READ(5,100) ((XPTSB(L,J),J=1,3),L=1,NPTS)
      IF(ITYPE.EQ.1) GO TO 26
      IF(ICOEFS.EQ.1) GO TO 20
      IF(ICOEFS.EQ.2) GO TO 25
      NCOEFS=5
      DO 17 L=1,6
      K=L
      IF(L.GT.5) K=L+3
   17 IFIT(L)=K
      GO TO 25
   20 READ(5,102) (COEFB(L),L=1,10)
      NCOEFS=9
  102 FORMAT(6D10.0)
   25 CONTINUE
      IF(ICOEFS.EQ.2) READ(5,101) NCOEFS,(IFIT(L),L=1,NCOEFS)
   26 CALL CFIT(XPTSB,NPTS,COEFB,ITYPE,SIG)
      SIG3=3.*SIG
      IF(ITYPE.EQ.2.AND.NBETW.GT.0) CALL ADDPTS(XPTSB,NPTS,COEFB,
     1 SIG,NBETW)
      WRITE(6,217) I,ITYPE
  217 FORMAT(1H1,'REFLECTION PANEL NUMBER',I3,20X,'TYPE',I2)
      WRITE(6,212)
      NP=NPTS
      IF(2*(NPTS/2).LT.NPTS) NP=NP-1
      DO 160 J=1,NP,2
      JP1=J+1
  160 WRITE(6,213) (M,(XPTSB(M,K),K=1,3),M=J,JP1)
      IF(2*(NPTS/2).LT.NPTS) WRITE(6,214) NPTS,(XPTSB(NPTS,K),K=1,3)
      IF(ICOEFS.EQ.1) WRITE(6,219)
  219 FORMAT(1H0,5X,'COEFFICIENTS FOR FITTED CURVE ARE BEING READ-IN')
      WRITE(6,215) (J,COEFB(J),J=1,4)
      IF(ITYPE.EQ.2) WRITE(6,218) (J,COEFB(J),J=5,10)
  218 FORMAT(1H ,10X,4('(',I2,')',F8.4,10X)/1H ,10X,2('(',I2,')',F8.4,
     1 10X))
      WRITE(6,216) SIG
      IF(NFENCE.EQ.0.OR.ITYPE.NE.2) GO TO 30
```

```
      CALL CHECK5(X,Y,Z,X1,Y1,Z1,INTC5,1)
      ICOEFS=0
      CALL CFIT(XPTSR,NPTS,COEFRQ,1,SIG)
C     WRITE(6,432) (COEFRQ(LL),LL=1,4)
C432  FORMAT(1H0,4D20.4)
   30 CONTINUE
      DO 2000 IGAM=1,NGAM
      MGAMS(I,IGAM)=MAS
      LINES=51
      GAMMA=GAM(IGAM)
      DO 1000 IPSI=1,NPSI
      NPSPTS(I,IGAM,IPSI)=0
      PSI= PS(IPSI)
      SNPH=SIN(PHI/RAD)
      CSPH=COS(PHI/RAD)
      SNTH=SIN(THETA/RAD)
      CSTH=COS(THETA/RAD)
      SNPS=SIN(PSI/RAD)
      CSPS=COS(PSI/RAD)
      DIRCOS(1,1)=CSTH*CSPS
      DIRCOS(1,2)=CSTH*SNPS
      DIRCOS(1,3)=-SNTH
      DIRCOS(2,1)=SNPH*SNTH*CSPS-SNPS*CSPH
      DIRCOS(2,2)=SNPH*SNTH*SNPS+CSPH*CSPS
      DIRCOS(2,3)=SNPH*CSTH
      DIRCOS(3,1)=CSPH*SNTH*CSPS+SNPS*SNPH
      DIRCOS(3,2)=CSPH*SNTH*SNPS-SNPH*CSPS
      DIRCOS(3,3)=CSPH*CSTH
      CALL CVRT(COEFR,DIRCOS,COEFI,ITYPE)
      IF(NFENCE.EQ.0.OR.ITYPE.NE.2) GO TO 40
      DO 35 L=1,10
   35 COEFS(L)=COEFI(L)
      CALL CVRT(COEFRQ,DIRCOS,COEFI,1)
   40 CONTINUE
      DO 1000 IDISP=1,NDISP
      GAMV=GAMMA
      GAML=0.0
      IF(NDISP.EQ.1) GO TO 45
      IF(IDISP.LE.2) GAMV=GAMV+(-1)**IDISP/4.
      IF(IDISP.GT.2) GAML=(-1)**IDISP/4.
   45 CONTINUE
      GV=GAMMA-GAMV
      SUN(1)=-COS(GAMV/RAD )*COS(GAML/RAD )
      SUN(2)=COS(GAMV/RAD )*SIN(GAML/RAD )
      SUN(3)=SIN(GAMV/RAD )
      DO 51 L=1,NPTS
      DO 51 J=1,3
      RPSI(1,L,J)=0.0
      DO 51 K=1,3
   51 RPSI(1,L,J)=RPSI(1,L,J)+DIRCOS(K,J)*XPTSR(L,K)
      NRPLS=1
      NRPTS(1)=NPTS
```

```
      IF(NFENCE.EQ.0) GO TO 54
      IF(ITYPE.EQ.2) CALL TRANQ(RPSI,1,NPTS,COEFI,SUN,1)
      DO 53 L=1,NFENCE
      DO 510 J=1,4
  510 COEFD(J)=COEFHF(L,J)
      CALL CVHI(COEFD,DIRCOS,COEFIF,1)
      CALL PLANPT(COEFIF(1),COEFIF(2),COEFIF(3),COEFIF(4),SUN(1),SUN(2),
     1 SUN(3),DISC,0.0D00,0.0D00,0.0D00,X,Y,Z)
      IF(DABS(DISC).LT.TOL) GO TO 53
      NFPS=NFPTS(L)
      DO 52 N=1,NFPS
      DO 52 J=1,3
      FPSI(N,J)=0.0
      DO 52 K=1,3
   52 FPSI(N,J)=FPSI(N,J)+DIRCOS(K,J)*FPTS(L,N,K)
      CALL SHADOW(RPSI,NRPLS,NRPTS,FPSI,NFPS,SUN,COEFI,GAMV,GAML)
      IF(NRPLS.EQ.5) GO TO 535
      IF(NRPLS.EQ.0) GO TO 900
   53 CONTINUE
  535 IF(ITYPE.EQ.1) GO TO 54
      DO 540 IRPL=1,NRPLS
      LPTS=NRPTS(IRPL)
      CALL TRANQ(RPSI,IRPL,LPTS,COEFS,SUN,2)
      NRPTS(IRPL)=LPTS
  540 CONTINUE
      DO 545 L=1,10
  545 COEFI(L)=COEFS(L)
   54 DO 850 IRPL=1,NRPLS
      LPTS=NRPTS(IRPL)
      DO 800 K=1,LPTS
      MAS=MAS+1
      X1=RPSI(IRPL,K,1)
      Y1=RPSI(IRPL,K,2)
      Z1=RPSI(IRPL,K,3)
      IF(ITYPE.EQ.2) GO TO 56
      DO 55 L=1,3
   55 VNORM(L)=COEFI(L)
      GO TO 58
   56 VNORM(1)=2.*COEFI(1)*X1+COEFI(4)*Y1+COEFI(5)*Z1+COEFI(7)
      VNORM(2)=2.*COEFI(2)*Y1+COEFI(4)*X1+COEFI(6)*Z1+COEFI(8)
      VNORM(3)=2.*COEFI(3)*Z1+COEFI(5)*X1+COEFI(6)*Y1+COEFI(9)
   58 ASN=0.0
      ABSNSQ=0.0
      DO 70 L=1,3
      ASN=ASN+SUN(L)*VNORM(L)
   70 ABSNSQ=ABSNSQ+VNORM(L)*VNORM(L)
      IF(INTERN.EQ.1.AND.ASN.GT.0.0) GO TO 85
      ASN=ASN/ABSNSQ
      IF(ABS(ASN).LT.1.0E-08) ASN=0.0
      DO 80 L=1,3
   80 REFLTN(L)=SUN(L)-2.0*ASN*VNORM(L)
      ICLEAR=0
```

```
      IF(NFENCE.EQ.0) GO TO 90
      CALL INTERF(FPTS,DIRCOS,NFENCE,NFPTS,X1,Y1,Z1,REFLTN,ICLEAR)
      IF(ICLEAR.EQ.0) GO TO 90
 85   ALPHA=10000.
      BETA=10000.
      GO TO 98
 90   CONTINUE
      IF(DABS(REFLTN(3)).GT.0.9999) GO TO 97
      ALPHA=    DATAN2(-REFLTN(3),DSQRT(REFLTN(1)**2+REFLTN(2)**2))
      BETA=     DATAN2(REFLTN(2),REFLTN(1))
 95   ALPHA=RAD *ALPHA
      BETA= RAD *BETA
      DQ2=-DISTG*DISTG
      CALL QUADPT(1.0D00,1.0D00,0.0D00,0.0D00,0.0D00,0.0D00,0.0D00,
     X 0.0D00,0.0D00,DQ2,REFLTN(1),
     1 REFLTN(2),REFLTN(3),X1,Y1,Z1,X,Y,Z,XI2,YI2,ZI2,INTC)
      IF(INTC.EQ.1) GO TO 96
      CALL SORNOT(REFLTN(1),REFLTN(2),REFLTN(3),X1,Y1,Z1,X,Y,Z,ISHAD)
      IF(ISHAD.EQ.1) GO TO 96
      X=XI2
      Y=YI2
      Z=ZI2
 96   ALPHA2(MAS)=RAD*DATAN2(-Z+ZREF,DSQRT((X-XREF)**2+(Y-YREF)**2))
      BETA2(MAS)=DATAN2(Y-YREF,X-XREF)*RAD
      IF(IANGL.EQ.1.AND.BETA.LT.0.0) BETA=360.+BETA
      IF(IANGL.EQ.1.AND.BETA2(MAS).LT.0.0) BETA2(MAS)=360.+BETA2(MAS)
      GO TO 795
 97   ALPHA=-REFLTN(3)*90./DABS(REFLTN(3))
      BETA=0.0
 98   ALPHA2(MAS)=ALPHA
      BETA2(MAS)=BETA
795   X1B=DIRCOS(1,1)*X1+DIRCOS(1,2)*Y1+DIRCOS(1,3)*Z1
      Y1B=DIRCOS(2,1)*X1+DIRCOS(2,2)*Y1+DIRCOS(2,3)*Z1
      Z1B=DIRCOS(3,1)*X1+DIRCOS(3,2)*Y1+DIRCOS(3,3)*Z1
      CALL CHECK4(XPTSB,NPTS,X1B,Y1B,Z1B,SIG3)
      IF(LINES.LT.50) GO TO 796
      WRITE(6,200) I,GAMMA,XREF,THETA,YREF,PHI,ZREF, DISTG
200   FORMAT(1H1,40X,'SUN GLINT SIGNATURE FOR SURFACE NO.',I3/
     X 1H0,5X,'SUN ELEVATION',F12.2,76X,'XREF',F9.2/1H ,5X,
     1 'A/C PITCH ATTITUDE',F7.2,76X,'YREF',F9.2/1H ,5X,
     2 'A/C ROLL ATTITUDE',F8.2,76X,'ZREF',F9.2/1H ,106X,'XDISTG',F7.2)
      WRITE(6,202)
202   FORMAT(1H0,5X,'A/C YAW',8X,'SUN DISPERSION',8X,
     1 'BOUNDARY POINTS-BODY AXES',9X,'REFLECTION VECTOR',16X,
     2 'GLINT'/1H ,21X,'VERT',5X,'LAT',13X,'X',7X,'Y',7X,'Z',12X,
     3 'ELEVATION',3X,'AZIMUTH',8X,'ELEVATION',3X,'AZIMUTH')
      LINES=9
796   WRITE(6,201) PSI,GV,GAML,X1B,Y1B,Z1B,ALPHA,BETA,ALPHA2(MAS),
     1 BETA2(MAS)
      LINES=LINES+2
201   FORMAT(1H0, 4X,F7.2,9X,F5.2,3X,F5.2,8X,3F8.2,11X,F6.2,4X,F7.2,10X,
     1 F6.2,4X,F7.2)
```

```
  800   CONTINUE
        NPSPTS(I,IGAM,IPSI)=NPSPTS(I,IGAM,IPSI)+LPTS
  850   CONTINUE
        GO TO 1000
  900   CONTINUE
        DO 950 K=1,2
        MAS=MAS+1
        ALPHA2(MAS)=10000.
  950   BETA2(MAS)=10000.
        NPSPTS(I,IGAM,IPSI)=NPSPTS(I,IGAM,IPSI)+2
 1000   CONTINUE
        IF(NPANEL.EQ.1) GO TO 2000
        IF(IPLOT.EQ.1) CALL PLOT(BETA2,ALPHA2,GAMMA,I,NPSI,NDISP,
       1 NPSPTS,XSCMIN,XSCMAX,YSCMIN,YSCMAX,PHI,THETA,IGAM,I,IANGL)
 2000   CONTINUE
        IF(IPROB.EQ.0.AND.IPLOT.EQ.0) GO TO 2050
        DO 2020 IGAM=1,NGAM
        GAMMA=GAM(IGAM)
        IF(IPLOT.EQ.1) CALL PLOT(BETA2,ALPHA2,GAMMA,1,NPSI,NDISP,NPSPTS,
       1 XSCMIN,XSCMAX,YSCMIN,YSCMAX,PHI,THETA,IGAM,NPANEL,IANGL)
        IF(IPROB.EQ.0) GO TO 2020
        CALL PROBL(ALPHA2,BETA2,GAMMA,NPSI,NDISP,NPSPTS,OBSMIN,
       1 OBSMAX,SUMW,IGAM,NPANEL)
 2020   CONTINUE
 2050   READ(5,101) ICONT
        IF(ICONT.NE.1) STOP
        GO TO 10
  100   FORMAT(6E10.0)
        END
```

```
      SUBROUTINE CHECK4(XPTSB,NPTS,X1B,Y1B,Z1B,SIG3)
      DIMENSION XPTSB(30,3)
      IF(SIG3.LT.1.0E-04) SIG3=0.0001
      DISCS=SIG3
      DO 10 I=1,NPTS
      DIST=SQRT(XPTSB(I,1)**2+XPTSB(I,2)**2+XPTSB(I,3)**2)
      DIST2=SQRT((XPTSB(I,1)-X1B)**2+(XPTSB(I,2)-Y1B)**2+(XPTSB(I,3)-
     1 Z1B)**2)
      DISC=DIST2/(DIST+SIG3)
      IF(DISC.GT.SIG3) GO TO 10
      IF(DISC.GE.DISCS) GO TO 10
      X1B=XPTSB(I,1)
      Y1B=XPTSB(I,2)
      Z1B=XPTSB(I,3)
      DISCS=DISC
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CFIT(XPTSB,NPTS,COEFB,ITYPE,SIG)
      DIMENSION XPTSB(30,3)
      REAL*8 SIG,DET,TOL
      REAL*8 A(9,9),B(9),XCURF(9,30),F(30),COEFB(10),COEFS(9)
      COMMON/FIT/ICOEFS,NCOEFS,IFIT(9)
      DATA TOL/1.0D-02/
      IC=0
      IF(ITYPE.EQ.2) GO TO 32
      DO 20 L=1,NPTS
      F(L)=1.0
      DO 20 J=1,3
   20 XCURF(J,L)=XPTSB(L,J)
      CALL CURFIT(F,XCURF,3,NPTS,COEFB,A,B,DET,SIG)
      IF(ICOEFS.EQ.1) RETURN
      COEFB(4)=-DET
      RETURN
   32 DO 35 L=1,NPTS
      XCURF(1,L)=XPTSB(L,1)**2
      XCURF(2,L)=XPTSB(L,2)**2
      XCURF(3,L)=XPTSB(L,3)**2
      XCURF(4,L)=XPTSB(L,1)*XPTSB(L,2)
      XCURF(5,L)=XPTSB(L,1)*XPTSB(L,3)
      XCURF(6,L)=XPTSB(L,2)*XPTSB(L,3)
      XCURF(7,L)=XPTSB(L,1)
      XCURF(8,L)=XPTSB(L,2)
      XCURF(9,L)=XPTSB(L,3)
   35 F(L)=1.0
      IF(NCOEFS.EQ.9) GO TO 460
   44 DO 46 I=1,NCOEFS
      K=IFIT(I)
      IF(K.EQ.I) GO TO 46
      DO 45 L=1,NPTS
   45 XCURF(I,L)=XCURF(K,L)
   46 CONTINUE
  460 CALL CURFIT(F,XCURF,NCOEFS,NPTS,COEFB,A,B,DET,SIG)
      IF(ICOEFS.EQ.1) RETURN
      IF(NCOEFS.EQ.9) GO TO 50
      IF(ICOEFS.EQ.2) GO TO 47
      IF(NPTS.LT.(NCOEFS+3).OR.SIG.LT.TOL) GO TO 47
      NCOEFS=NCOEFS+3
      IF(NCOEFS.EQ.6) GO TO 44
      GO TO 32
   47 DO 48 I=1,NCOEFS
   48 COEFS(I)=COEFB(I)
      DO 40 I=1,9
   40 COEFB(I)=0.0
      DO 49 I=1,NCOEFS
      K=IFIT(I)
      COEFB(K)=COEFS(I)
   49 CONTINUE
   50 COEFB(10)=-DET
      RETURN

      END
```

```
      SUBROUTINE CURFIT(F,X,N,M,COEF,A,B,DET,SIG)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X(9,30),F(30),COEF(10),A(9,9),B(9)
      COMMON/FIT/ICOEFS,NCOEFS,IFIT(9)
      IF(ICOEFS.EQ.1) GO TO 25
      DO 10 I=1,N
      B(I)=0.0
      DO 10 J=1,N
   10 A(I,J)=0.0
      DO 20 I=1,M
      DO 20 J=1,N
      B(J)=B(J)+F(I)*X(J,I)
      DO 20 L=1,N
   20 A(L,J)=A(L,J)+X(J,I)*X(L,I)
      CALL EQNSOL(A,B,N,COEF,DET,1)
   25 SIG=0.0
      IF(ICOEFS.EQ.1) DET=-COEF(10)
      DO 40 I=1,M
      SUM=0.0
      DO 30 J=1,N
   30 SUM=SUM+COEF(J)*X(J,I)
      SUM=SUM-DET
   40 SIG=SIG+SUM*SUM
      SIG=DSQRT(SIG/M)
      RETURN
      END
```

```
      SUBROUTINE EQNSOL(A,B,N,X,DET,NHOMO)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION A(9,9),B(9),X(10)
      DATA TOL/1.0D-08/
      NRANK=N
      DO 10 I=1,N
   10 X(I)=0.0
      I=0
      ICOL=0
   12 I=I+1
      ICOL=ICOL+1
      IP1=I+1
   14 AMAXI=A(I,ICOL)
      L=I
      IF(IP1.GT.N) GO TO 150
      DO 15 K=IP1,N
      IF(DABS(A(K,ICOL)).GT.DABS(AMAXI)) L=K
   15 AMAXI=A(L,ICOL)
  150 IF(DABS(AMAXI).GT.TOL) GO TO 16
      X(ICOL)=1.0
      NRANK=NRANK-1
      IF(ICOL.EQ.N) GO TO 45
      ICOL=ICOL+1
      GO TO 14
   16 IF(L.EQ.I) GO TO 25
      DO 20 J=1,N
      SWAP=A(I,J)
      A(I,J)=A(L,J)
   20 A(L,J)=SWAP
      SWAP=B(I)
      B(I)=B(L)
      B(L)=SWAP
   25 XDIV=A(I,ICOL)
      DO 30 J=ICOL,N
   30 A(I,J)=A(I,J)/XDIV
      B(I)=B(I)/XDIV
      IF(IP1.GT.N) GO TO 42
      DO 40 K=IP1,N
      XMUL=A(K,ICOL)
      DO 35 J=ICOL,N
   35 A(K,J)=A(K,J)-XMUL*A(I,J)
   40 B(K)=B(K)-XMUL*B(I)
      IF(ICOL.LT.N) GO TO 12
   42 IF(NRANK.EQ.N.OR.NHOMO.EQ.0) X(ICOL)=B(I)/A(I,ICOL)
   45 IJUMP=ICOL-I
      DO 50 I=2,N
      K=N-I+1
      IF(X(K).EQ.0.0) GO TO 47
      IJUMP=IJUMP-1
      GO TO 50
   47 IF(NRANK.EQ.N.OR.NHOMO.EQ.0) X(K)=B(K)
      KP1=K+1
```

```
      DO 48 J=KP1,N
   48 X(K)=X(K)-A(K-IJUMP,J)*X(J)
   50 CONTINUE
      DET=1.0
      IF(NRANK.LT.N) DET=0.0
      RETURN
      END
```

```
      SUBROUTINE ADDPTS(XPTSB,NPTS,COEFB,SIG,NBETW)
      REAL*8 COEFB(10),COEFP(10)
      REAL*8 SIG,SIG2
      DIMENSION XPTSB(30,3),XPTS(30,3),XSTORE(30,3)
      REAL*8 A2,B2,C2,D2,E2,F2,G2,H2,K2,L2,A1,B1,C1,D1,A3,B3,C3,D3,E3,
     1 F3,G3,H3,K3,L3,SA,SB,SC,DABS,FACT,DISC,DSQRT
      DATA TOL/1.0E-04/
      A2=COEFB(1)
      B2=COEFB(2)
      C2=COEFB(3)
      D2=COEFB(4)
      E2=COEFB(5)
      F2=COEFB(6)
      G2=COEFB(7)
      H2=COEFB(8)
      K2=COEFB(9)
      L2=COEFB(10)
      IFLAG=0
      M=0
      DO 100 I=1,NPTS
      M=M+1
      DO 15 K=1,3
   15 XSTORE(M,K)=XPTSB(I,K)
      IP1=I+1
      IF(I.EQ.NPTS) IP1=1
      IF(IFLAG.EQ.1) GO TO 200
    5 X=(XPTSB(I,1)+XPTSB(IP1,1))/2.
      Y=(XPTSB(I,2)+XPTSB(IP1,2))/2.
      Z=(XPTSB(I,3)+XPTSB(IP1,3))/2.
      DEL=A2*X**2+B2*Y**2+C2*Z**2+D2*X*Y+E2*X*Z+F2*Y*Z+G2*X+
     1 H2*Y+K2*Z+L2
      IF(ABS(DEL).LE.3.*SIG) GO TO 100
      IP2=IP1+1
      IF(IP1.EQ.NPTS) IP2=1
      DO 20 K=1,3
      XPTS(1,K)=XPTSB(I,K)
      XPTS(2,K)=XPTSB(IP1,K)
   20 XPTS(3,K)=XPTSB(IP2,K)
      CALL CFIT(XPTS,3,COEFP,1,SIG2)
      A1=COEFP(1)
      B1=COEFP(2)
      C1=COEFP(3)
      D1=COEFP(4)
      GO TO 208
  200 DEL=A1*XPTSB(IP1,1)+B1*XPTSB(IP1,2)+C1*XPTSB(IP1,3)+D1
      IF(ABS(DEL).LE.TOL) GO TO 204
      IFLAG=0
      GO TO 5
  204 DO 205 K=1,3
      XPTS(1,K)=XPTSB(I,K)
  205 XPTS(2,K)=XPTSB(IP1,K)
  208 IF(DABS(B1).GT.DABS(A1).AND.DABS(B1).GE.DABS(C1)) GO TO 30
```

```
      IF(DABS(C1).GT.DABS(A1).AND.DABS(C1).GT.DABS(B1)) GO TO 40
      IF(IFLAG.EQ.1) GO TO 209
      B3=B2+A2*(B1/A1)**2-D2*B1/A1
      C3=C2+A2*(C1/A1)**2-E2*C1/A1
      F3=F2+2.*A2*C1*B1/A1**2-D2*C1/A1-F2*B1/A1
      H3=H2+2.*A2*D1*B1/A1**2-D2*D1/A1-G2*B1/A1
      K3=K2+2.*A2*D1*C1/A1**2-E2*D1/A1-G2*C1/A1
      L3=L2+A2*(D1/A1)**2-G2*D1/A1
209   IF(ABS(XPTS(2,2)-XPTS(1,2)).GT.ABS(XPTS(2,3)-XPTS(1,3))) GO TO 24
      DO 230 N=1,NBETW
      M=M+1
      Z=XPTS(1,3)+FLOAT(N)*(XPTS(2,3)-XPTS(1,3))/FLOAT(NBETW+1)
      SA=B3
      SB=F3*Z+H3
      SC=C3*Z*Z+K3*Z+L3
      IF(DABS(SA).LT.1.0D-08) GO TO 23
      FACT=1.0
      DISC=SB**2-4.*SA*SC
      IF(DISC.LT.0.0) WRITE(6,600) DISC
      IF(DISC.LT.0.0) DISC=0.0
600   FORMAT(///,15('*'),5X,'DISCRIMINANT IS LESS THAN ZERO IN ADDING BO
     1UNDARY POINTS, ZERO ASSUMED'/1H0,20X,'ACTUAL VALUE IS',D18.4)
 210   Y=-SB/2./SA+FACT*DSQRT(DISC)/2./SA
      DIST=ABS(XPTS(1,2)-Y)+ABS(XPTS(2,2)-Y)
      IF(Y.LT.XPTS(1,2).AND.Y.LT.XPTS(2,2)) GO TO 22
      IF(Y.GT.XPTS(1,2).AND.Y.GT.XPTS(2,2)) GO TO 22
215   XSTORE(M,2)=Y
      XSTORE(M,1)=-D1/A1-C1*Z/A1-B1*Y/A1
      XSTORE(M,3)=Z
      GO TO 230
 22   IF(FACT.LT.0.0) GO TO 220
      FACT=-1.0
      DIST1=DIST
      GO TO 210
220   IF(DIST.LT.DIST1) GO TO 215
      Y=-SB/2./SA+DSQRT(DISC)/2./SA
      GO TO 215
 23   IF(DABS(SB).LT.TOL) GO TO 500
      Y=-SC/SB
      GO TO 215
230   CONTINUE
      GO TO 90
 24   DO 28 N=1,NBETW
      M=M+1
      Y=XPTS(1,2)+FLOAT(N)*(XPTS(2,2)-XPTS(1,2))/FLOAT(NBETW+1)
      SA=C3
      SB=F3*Y+K3
      SC=B3*Y*Y+H3*Y+L3
      IF(DABS(SA).LT.1.0D-08) GO TO 25
      FACT=1.
      DISC=SB**2-4.*SA*SC
      IF(DISC.LT.0.0) WRITE(6,600) DISC
```

```
      IF(DISC.LT.0.0) DISC=0.0
  240 Z=-SB/2./SA+FACT*DSQRT(DISC)/2./SA
      ~~DIST=ABS(XPTS(1,3)-Z)~~+ABS(XPTS(2,3)-Z)
      IF(Z.LT.XPTS(1,3).AND.Z.LT.XPTS(2,3)) GO TO 242
      IF(Z.GT.XPTS(1,3).AND.Z.GT.XPTS(2,3)) GO TO 242
  ~~241~~ ~~XSTORE(M,3)=Z~~
      XSTORE(M,2)=Y
      XSTORE(M,1)=-D1/A1-C1*Z/A1-B1*Y/A1
      GO TO 28
  242 IF(FACT.LT.0.0) GO TO 243
      FACT=-1.
      ~~DIST1=DIST~~
      GO TO 240
  243 IF(DIST.LT.DIST1) GO TO 241
      Z=-SB/2./SA+DSQRT(DISC)/2./SA
      GO TO 241
   25 IF(DABS(SB).LT.TOL) GO TO 500
      Z=-SC/SB
      GO TO 241
   28 CONTINUE
      GO TO 90
   30 IF(IFLAG.EQ.1) GO TO 309
      A3=A2+B2*(A1/B1)**2-D2*A1/B1
      C3=C2+B2*(C1/B1)**2-F2*C1/B1
      E3=E2+2.*B2*A1*C1/B1**2-D2*C1/B1-F2*A1/B1
      G3=G2+2.*B2*D1*A1/B1**2-D2*D1/B1-H2*A1/B1
      K3=K2+2.*B2*D1*C1/B1**2-F2*D1/B1-H2*C1/B1
      L3=L2+B2*(D1/B1)**2-H2*D1/B1
  309 IF(ABS(XPTS(2,1)-XPTS(1,1)).GT.ABS(XPTS(2,3)-XPTS(1,3))) GO TO 34
      DO 330 N=1,NBETW
      M=M+1
      Z=XPTS(1,3)+FLOAT(N)*(XPTS(2,3)-XPTS(1,3))/FLOAT(NBETW+1)
      SA=A3
      SB=E3*Z+G3
      SC=C3*Z*Z+K3*Z+L3
      IF(DABS(SA).LT.1.0D-08) GO TO 33
      FACT=1.
      DISC=SB*SB-4.*SA*SC
      IF(DISC.LT.0.0) WRITE(6,600) DISC
      IF(DISC.LT.0.0) DISC=0.0
  310 X=-SB/2./SA+FACT*DSQRT(DISC)/2./SA
      DIST=ABS(XPTS(1,1)-X)+ABS(XPTS(2,1)-X)
      IF(X.LT.XPTS(1,1).AND.X.LT.XPTS(2,1)) GO TO 32
      IF(X.GT.XPTS(1,1).AND.X.GT.XPTS(2,1)) GO TO 32
  315 XSTORE(M,1)=X
      XSTORE(M,2)=-D1/B1-A1*X/B1-C1*Z/B1
      XSTORE(M,3)=Z
      GO TO 330
   32 IF(FACT.LT.0.0) GO TO 320
      FACT=-1.
      DIST1=DIST
      GO TO 310
```

```
320   IF(DIST.LT.DIST1) GO TO 315
      X=-SB/2./SA+DSQRT(DISC)/2./SA
      GO TO 315
 33   IF(DABS(SB).LT.TOL) GO TO 500
      X=-SC/SB
      GO TO 315
330   CONTINUE
      GO TO 90
 34   DO 38 N=1,NBETW
      M=M+1
      X=XPTS(1,1)+FLOAT(N)*(XPTS(2,1)-XPTS(1,1))/FLOAT(NBETW+1)
      SA=C3
      SB=E3*X+K3
      SC=A3*X*X+G3*X+L3
      IF(DABS(SA).LT.1.0D-08) GO TO 35
      FACT=1.
      DISC=SB*SB-4.*SA*SC
      IF(DISC.LT.0.0) WRITE(6,600) DISC
      IF(DISC.LT.0.0) DISC=0.0
340   Z=-SB/2./SA+FACT*DSQRT(DISC)/2./SA
      DIST=ABS(XPTS(1,3)-Z)+ABS(XPTS(2,3)-Z)
      IF(Z.LT.XPTS(1,3).AND.Z.LT.XPTS(2,3)) GO TO 342
      IF(Z.GT.XPTS(1,3).AND.Z.GT.XPTS(2,3)) GO TO 342
341   XSTORE(M,1)=X
      XSTORE(M,2)=-D1/B1-A1*X/B1-C1*Z/B1
      XSTORE(M,3)=Z
      GO TO 38
342   IF(FACT.LT.0.0) GO TO 343
      FACT=-1.
      DIST1=DIST
      GO TO 340
343   IF(DIST.LT.DIST1) GO TO 341
      Z=-SB/2./SA+DSQRT(DISC)/2./SA
      GO TO 341
 35   IF(DABS(SB).LT.TOL) GO TO 500
      Z=-SC/SB
      GO TO 341
 38   CONTINUE
      GO TO 90
 40   IF(IFLAG.EQ.1) GO TO 409
      A3=A2+C2*(A1/C1)**2-E2*A1/C1
      B3=B2+C2*(B1/C1)**2-F2*B1/C1
      D3=D2+2.*C2*A1*B1/C1**2-E2*B1/C1-F2*A1/C1
      G3=G2+2.*C2*D1*A1/C1**2-E2*D1/C1-K2*A1/C1
      H3=H2+2.*C2*D1*B1/C1**2-F2*D1/C1-K2*B1/C1
      L3=L2+C2*(D1/C1)**2-K2*D1/C1
409   IF(ABS(XPTS(2,2)-XPTS(1,2)).GT.ABS(XPTS(2,1)-XPTS(1,1))) GO TO 44
      DO 430 N=1,NBETW
      M=M+1
      X=XPTS(1,1)+FLOAT(N)*(XPTS(2,1)-XPTS(1,1))/FLOAT(NBETW+1)
      SA=B3
      SB=D3*X+H3
```

```
      SC=A3*X*X+G3*X+L3
      IF(DABS(SA).LT.1.0D-08) GO TO 43
      FACT=1.
      DISC=SB*SB-4.*SA*SC
      IF(DISC.LT.0.0) WRITE(6,600) DISC
      IF(DISC.LT.0.0) DISC=0.0
  410 Y=-SB/2./SA+FACT*DSQRT(DISC)/2./SA
      DIST=ABS(XPTS(1,2)-Y)+ABS(XPTS(2,2)-Y)
      IF(Y.LT.XPTS(1,2).AND.Y.LT.XPTS(2,2)) GO TO 42
      IF(Y.GT.XPTS(1,2).AND.Y.GT.XPTS(2,2)) GO TO 42
  415 XSTORE(M,1)=X
      XSTORE(M,2)=Y
      XSTORE(M,3)=-D1/C1-A1*X/C1-B1*Y/C1
      GO TO 430
   42 IF(FACT.LT.0.0) GO TO 420
      FACT=-1.
      DIST1=DIST
      GO TO 410
  420 IF(DIST.LT.DIST1) GO TO 415
      Y=-SB/2./SA+DSQRT(DISC)/2./SA
      GO TO 415
   43 IF(DABS(SB).LT.TOL) GO TO 500
      Y=-SC/SB
      GO TO 415
  430 CONTINUE
      GO TO 90
   44 DO 48 N=1,NBETW
      M=M+1
      Y=XPTS(1,2)+FLOAT(N)*(XPTS(2,2)-XPTS(1,2))/FLOAT(NBETW+1)
      SA=A3
      SB=D3*Y+G3
      SC=B3*Y*Y+H3*Y+L3
      IF(DABS(SA).LT.1.0D-08) GO TO 45
      FACT=1.
      DISC=SB*SB-4.*SA*SC
      IF(DISC.LT.0.0) WRITE(6,600) DISC
      IF(DISC.LT.0.0) DISC=0.0
  440 X=-SB/2./SA+FACT*DSQRT(DISC)/2./SA
      DIST=ABS(XPTS(1,1)-X)+ABS(XPTS(2,1)-X)
      IF(X.LT.XPTS(1,1).AND.X.LT.XPTS(2,1)) GO TO 442
      IF(X.GT.XPTS(1,1).AND.X.GT.XPTS(2,1)) GO TO 442
  441 XSTORE(M,1)=X
      XSTORE(M,2)=Y
      XSTORE(M,3)=-D1/C1-A1*X/C1-B1*Y/C1
      GO TO 48
  442 IF(FACT.LT.0.0) GO TO 443
      FACT=-1.
      DIST1=DIST
      GO TO 440
  443 IF(DIST.LT.DIST1) GO TO 441
      X=-SB/2./SA+DSQRT(DISC)/2./SA
      GO TO 441
```

```
 45   IF(DABS(SB).LT.TOL) GO TO 500
      X=-SC/SB
      GO TO 441
 48   CONTINUE
 90   IFLAG=1
100   CONTINUE
      NPTS=M
      DO 110 I=1,NPTS
      DO 110 J=1,3
110   XPTSB(I,J)=XSTORE(I,J)
      RETURN
500   WRITE(6,610) SA,SB,SC
      STOP
610   FORMAT(///,15('*'),5X,'QUADRATIC EQUATION SOLUTION FAILS IN ADDING
     1 BOUNDARY POINTS- CHECK INPUT - PROGRAM WILL STOP HERE'//1H0,20X,
     2 'VALUES OF COEFFICIENTS OF QUADRATIC EQUATION ARE A=',D15.4,2X,
     2 'B=',D15.4,2X,'C=',D15.4)
      END
```

```
      SUBROUTINE CVBI(COEFB,DIRCOS,COEFI,ITYPE)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION DIRCOS(3,3),COEFI(10),COEFB(10)
      IF(ITYPE.EQ.2) GO TO 502
      DO 50 L=1,3
      COEFI(L)=0.0
      DO 50 J=1,3
   50 COEFI(L)=COEFI(L)+DIRCOS(J,L)*COEFB(J)
      COEFI(4)=COEFB(4)
      RETURN
  502 CONTINUE
      DO 506 L=1,3
      SA=DIRCOS(1,L)
      SB=DIRCOS(2,L)
      SC=DIRCOS(3,L)
      COEFI(L)=COEFB(1)*SA*SA+COEFB(2)*SB*SB+COEFB(3)*SC*SC+COEFB(4)*
     1 SA*SB+COEFB(5)*SA*SC+COEFB(6)*SB*SC
      IF(L.EQ.3) GO TO 504
      SA2=DIRCOS(1,L+1)
      SB2=DIRCOS(2,L+1)
      SC2=DIRCOS(3,L+1)
      GO TO 505
  504 SA2=DIRCOS(1,2)
      SB2=DIRCOS(2,2)
      SC2=DIRCOS(3,2)
  505 COEFI(L+3)=2.*COEFB(1)*SA*SA2+2.*COEFB(2)*SB*SB2+2.*COEFB(3)*SC*
     1 SC2+ COEFB(4)*(SA*SB2+SA2*SB)+COEFB(5)*(SA*SC2+SA2*SC)+COEFB(6)*
     1 (SB*SC2+SB2*SC)
      COEFI(L+6)=0.0
      DO 506 K=1,3
  506 COEFI(L+6)=COEFI(L+6)+DIRCOS(K,L)*COEFB(K+6)
      COEFI(10)=COEFB(10)
      RETURN
      END
```

```
      SUBROUTINE TRANQ(RPSI,IRPL,NPTS,COEFI,SUN,IC)
      DIMENSION COEFI(10),SUN(3),RPSI(5,30,3)
      REAL*8 COEFI,SUN,A,B,C,D,E,F,G,H,CK,CL,SL,SM,SN,DISC,X1,Y1,Z1,
     1 X,Y,Z,XQ2,YQ2,ZQ2,DSQRT
      DATA TOL/1.0E-04/
      COMMON/SAVE/SL,SM,SN,DISC,CSTH
      A=COEFI(1)
      B=COEFI(2)
      C=COEFI(3)
      D=COEFI(4)
      GO TO (10,30), IC
   10 SL=SUN(1)
      SM=SUN(2)
      SN=SUN(3)
C     WRITE(6,200) A,B,C,D,SL,SM,SN
      CSTH=(A*SL+B*SM+C*SN)/DSQRT(A*A+B*B+C*C)
      IF(ABS(CSTH).LT.0.17) RETURN
      DO 20 I=1,NPTS
      X1=RPSI(IRPL,I,1)
      Y1=RPSI(IRPL,I,2)
      Z1=RPSI(IRPL,I,3)
      CALL PLANPT(A,B,C,D,SL,SM,SN,DISC,X1,Y1,Z1,X,Y,Z)
C     WRITE(6,200) X1,Y1,Z1,X,Y,Z,DISC
C200  FORMAT(1H0,7D16.4)
      IF(DABS(DISC).LT.TOL) RETURN
      RPSI(IRPL,I,1)=X
      RPSI(IRPL,I,2)=Y
   20 RPSI(IRPL,I,3)=Z
      RETURN
   30 IF(DABS(DISC).LT.TOL) RETURN
      IF(ABS(CSTH).LT.0.17) RETURN
      E=COEFI(5)
      F=COEFI(6)
      G=COEFI(7)
      H=COEFI(8)
      CK=COEFI(9)
      CL=COEFI(10)
C     WRITE(6,200) A,B,C,D,E,F,G,H,CK,CL,SL,SM,SN
      L=0
      DO 50 I=1,NPTS
      X1=RPSI(IRPL,I,1)
      Y1=RPSI(IRPL,I,2)
      Z1=RPSI(IRPL,I,3)
      CALL QUADPT(A,B,C,D,E,F,G,H,CK,CL,SL,SM,SN,X1,Y1,Z1,X,Y,Z,
     1 XQ2,YQ2,ZQ2,INTC)
      IF(INTC.EQ.0) WRITE(6,500)
      IF(INTC.EQ.0) GO TO 50
C     WRITE(6,200) X,Y,Z,XQ2,YQ2,ZQ2
      IF(INTC.EQ.1) GO TO 45
      CALL CHECKS(X,Y,Z,XQ2,YQ2,ZQ2,INTCS,2)
      IF(INTCS.EQ.0) WRITE(6,500)
      IF(INTCS.EQ.0) GO TO 50
```

```
      IF(INTC5.EQ.1) GO TO 45
      L=L+1
      RPSI(IRPL,L,1)=XQ2
      RPSI(IRPL,L,2)=YQ2
      RPSI(IRPL,L,3)=ZQ2
   45 L=L+1
      RPSI(IRPL,L,1)=X
      RPSI(IRPL,L,2)=Y
      RPSI(IRPL,L,3)=Z
   50 CONTINUE
      NPTS=L
  500 FORMAT(1H0,10('*'),'DUE TO CURVATURE OF SURFACE ',
     1 'CERTAIN BOUNDARY POINTS WILL BE MISSING IN OUTPUT'/
     2 1H ,10X,'FOR THIS COMBINATION OF SUN ANGLE AND A/C AZIMUTH')
C
      RETURN
      END
```

```
      SUBROUTINE CHECK5(X,Y,Z,XQ2,YQ2,ZQ2,INTC5,IC)
      COMMON/CTRQ2/DIRCOS(3,3),XPTSB(30,3),XMIN(3),XMAX(3),NPTS
      DIMENSION XB(3),XQ2B(3)
      REAL*8 X,Y,Z,XQ2,YQ2,ZQ2,DIRCOS
      GO TO (10,30), IC
   10 DO 20 I=1,3
      XMAX(I)=XPTSB(1,I)
      XMIN(I)=XMAX(I)
      DO 20 J=2,NPTS
      IF(XPTSB(J,I).LT.XMIN(I)) XMIN(I)=XPTSB(J,I)
   20 IF(XPTSB(J,I).GT.XMAX(I)) XMAX(I)=XPTSB(J,I)
      RETURN
   30 XB(1)=DIRCOS(1,1)*X+DIRCOS(1,2)*Y+DIRCOS(1,3)*Z
      XB(2)=DIRCOS(2,1)*X+DIRCOS(2,2)*Y+DIRCOS(2,3)*Z
      XB(3)=DIRCOS(3,1)*X+DIRCOS(3,2)*Y+DIRCOS(3,3)*Z
      XQ2B(1)=DIRCOS(1,1)*XQ2+DIRCOS(1,2)*YQ2+DIRCOS(1,3)*ZQ2
      XQ2B(2)=DIRCOS(2,1)*XQ2+DIRCOS(2,2)*YQ2+DIRCOS(2,3)*ZQ2
      XQ2B(3)=DIRCOS(3,1)*XQ2+DIRCOS(3,2)*YQ2+DIRCOS(3,3)*ZQ2
      IX=0
      IX2=0
      INTC5=0
      DO 40 K=1,3
      IF(XB(K).LT.(XMIN(K)-0.05*(XMAX(K)-XMIN(K))-0.01)) IX=1
      IF(XB(K).GT.(XMAX(K)+0.05*(XMAX(K)-XMIN(K))+0.01)) IX=1
      IF(XQ2B(K).LT.(XMIN(K)-0.05*(XMAX(K)-XMIN(K))-0.01)) IX2=1
   40 IF(XQ2B(K).GT.(XMAX(K)+0.05*(XMAX(K)-XMIN(K))+0.01)) IX2=1
      IF(IX.EQ.1) GO TO 60
      IF(IX2.EQ.1) GO TO 50
      INTC5=2
      RETURN
   50 INTC5=1
      RETURN
   60 IF(IX2.EQ.1) RETURN
      INTC5=1
      X=XQ2
      Y=YQ2
      Z=ZQ2
      RETURN
      END
```

```
      SUBROUTINE PLANPT(A,B,C,D,SL,SM,SN,DISC,X1,Y1,Z1,X,Y,Z)
      IMPLICIT REAL*8 (A-H,O-Z)
      ABS(XX)=DABS(XX)
      DATA TOL/1.0E-04/
      IF(ABS(SL).GE.ABS(SN).AND.ABS(SL).GE.ABS(SM)) DISC=A+B*SM/SL+
     1 C*SN/SL
      IF(ABS(SL).LT.ABS(SN).AND.ABS(SM).LE.ABS(SN)) DISC=A*SL/SN+
     1 B*SM/SN+C
      IF(ABS(SL).LT.ABS(SM).AND.ABS(SN).LT.ABS(SM)) DISC=A*SL/SM+
     1 B+C*SN/SM
      IF(ABS(DISC).LT.TOL) RETURN
      IF(ABS(SL).LT.ABS(SN).AND.ABS(SM).LE.ABS(SN)) GO TO 10
      IF(ABS(SL).LT.ABS(SM).AND.ABS(SN).LT.ABS(SM)) GO TO 20
      X=(-D-B*Y1+B*X1*SM/SL-C*Z1+C*X1*SN/SL)/DISC
      Y=Y1+SM*(X-X1)/SL
      Z=Z1+SN*(X-X1)/SL
      RETURN
   10 Z=(-D-A*X1+A*Z1*SL/SN-B*Y1+B*Z1*SM/SN)/DISC
      X=X1+SL*(Z-Z1)/SN
      Y=Y1+SM*(Z-Z1)/SN
      RETURN
   20 Y=(-D-A*X1+A*SL*Y1/SM-C*Z1+C*SN*Y1/SM)/(A*SL/SM+B+C*SN/SM)
      X=X1+SL*(Y-Y1)/SM
      Z=Z1+SN*(Y-Y1)/SM
      RETURN
      END
```

```
      SUBROUTINE SHADOW(RPSI,NRPLS,NRPTS,FPSI,NFPTS,SUN,COEFI,GAMV,GAML)
      DIMENSION RPSI(5,30,3),NRPTS(5),FPSI(30,3),SUN(3),
     1 COEFI(10),RPSIN(5,30,3) ,RPS(30,2),NRPTSN( 5),SPS(30,2),
     2 SPSI(30,3)
      DIMENSION RPSN(30,2)
      REAL*8 SUN,COEFI,A,B,C,D,SL,SM,SN,DISC,X4,Y4,Z4,XX,YY,ZZ,DSQRT
      DATA TOL/1.0E-04/
      A=COEFI(1)
      B=COEFI(2)
      C=COEFI(3)
      D=COEFI(4)
      SL=SUN(1)
      SM=SUN(2)
      SN=SUN(3)
      CSTH=(A*SL+B*SM+C*SN)/DSQRT(A*A+B*B+C*C)
      IF(ABS(CSTH).LT.0.17) RETURN
      NS=0
      DO 10 I=1,NFPTS
      X4=FPSI(I,1)
      Y4=FPSI(I,2)
      Z4=FPSI(I,3)
      CALL PLANPT(A,B,C,D,SL,SM,SN,DISC,X4,Y4,Z4,XX,YY,ZZ)
      IF(DABS(DISC).LT.TOL) RETURN
      CALL SORNOT(SL,SM,SN,X4,Y4,Z4,XX,YY,ZZ,ISHAD)
      IF(ISHAD.EQ.0) GO TO 10
      NS=NS+1
      CALL PLANPT(SL,SM,SN,0.0D00,SL,SM,SN,DISC,X4,Y4,Z4,XX,YY,ZZ)
      SPSI(NS,1)=XX
      SPSI(NS,2)=YY
      SPSI(NS,3)=ZZ
   10 CONTINUE
      IF(NS.LE.2) RETURN
      NRPLSN=0
      DO 120 IRPL=1,NRPLS
      IC=2
      IF(IRPL.EQ.1) IC=1
      NR=NRPTS(IRPL)
      DO 15 I=1,NR
      X4=RPSI(IRPL,I,1)
      Y4=RPSI(IRPL,I,2)
      Z4=RPSI(IRPL,I,3)
      CALL PLANPT(SL,SM,SN,0.0D00,SL,SM,SN,DISC,X4,Y4,Z4,XX,YY,ZZ)
      RPSI(IRPL,I,1)=XX
      RPSI(IRPL,I,2)=YY
   15 RPSI(IRPL,I,3)=ZZ
      CALL TRANSP(RPSI,IRPL,NR,SPSI,NS,RPS,SPS,IC,GAMV,GAML)
      IR=1
   16 XC=RPS(IR,1)
      YC=RPS(IR,2)
      CALL CIRCLE(SPS,NS,XC,YC,INCR)
      IF(INCR.NE.2) GO TO 17
      IF(IR.EQ.NR) GO TO 120
```

```
      IR=IR+1
      GO TO 16
   17 IFLAG=5
      IF(INCR.EQ.1) IFLAG=6
      NEXT=0
      IF(IFLAG.EQ.6) NRN=0
      IF(IFLAG.EQ.6) GO TO 25
      NRPLSN=NRPLSN+1
      NRN=1
      RPSN(1,1)=XC
      RPSN(1,2)=YC
      IFLAG=1
   25 IRP1=IR+1
      IF(IR.EQ.NR) IRP1=1
      IDOUBL=0
   30 X1=RPS(IR,1)
      Y1=RPS(IR,2)
   35 X2=RPS(IRP1,1)
      Y2=RPS(IRP1,2)
      CALL INTERC(SPS,NS,X1,Y1,X2,Y2,X,Y,KL,IFAULT,IDOUBL,
     1 XALSO,YALSO)
      IF(IFLAG.EQ.6.AND.IFAULT.EQ.0) GO TO 70
      IF(IFLAG.EQ.1.AND.IFAULT.EQ.0) GO TO 40
      IF(IFLAG.EQ.4.AND.IFAULT.EQ.0) GO TO 40
      IF(IFLAG.EQ.6) GO TO 38
      CALL CHECK1(X2,Y2,RPSN,NRN,ICHK)
      IF(ICHK.EQ.1) GO TO 90
      IFLAG=1
      NRN=NRN+1
      RPSN(NRN,1)=X2
      RPSN(NRN,2)=Y2
   38 IR=IRP1
      IF(IRP1.EQ.1.AND.IFLAG.EQ.6) GO TO 90
      IRP1=IR+1
      IF(IR.EQ.NR) IRP1=1
      IDOUBL=0
      GO TO 30
   40 IFLAG=2
      NEXT=IRP1
      XSEP=X
      YSEP=Y
      CALL CHECK1(X,Y,RPSN,NRN,ICHK)
      IF(ICHK.EQ.1) GO TO 90
      NRN=NRN+1
      RPSN(NRN,1)=X
      RPSN(NRN,2)=Y
      IS=KL
      ISP1=IS+1
      IF(IS.EQ.NS) ISP1=1
      IDOUBL=1
      XALSO=X
      YALSO=Y
```

```
      KDIR=0
50    X1=SPS(IS,1)
      Y1=SPS(IS,2)
      X2=SPS(ISP1,1)
      Y2=SPS(ISP1,2)
      CALL INTERC(RPS,NR,X1,Y1,X2,Y2,X,Y,KL,IFAULT,IDOUBL,XALSO,YALSO)
      IF(IFLAG.EQ.2.AND.IFAULT.EQ.0) GO TO 75
      IF(IFLAG.EQ.3.AND.IFAULT.EQ.0) GO TO 75
      IF(IFLAG.EQ.3.AND.KDIR.EQ.1) GO TO 60
      IF(IFLAG.EQ.3) GO TO 56
      IF(IFLAG.EQ.7.AND.IFAULT.EQ.0) GO TO 75
      IF(IFLAG.EQ.7.AND.KDIR.EQ.1) GO TO 54
      CALL CIRCLE(RPS,NR,X1,Y1,INCR)
      IF(INCR.EQ.1) GO TO 56
      IF(IFLAG.EQ.1) GO TO 30
54    CALL CIRCLE(RPS,NR,X2,Y2,INCR)
      IF(INCR.EQ.1) GO TO 60
      IF(IFLAG.EQ.7) IFLAG=1
      IF(IFLAG.EQ.1) GO TO 30
      IF(IFLAG.EQ.7) IFLAG=1
      IFLAG=7
      IDOUBL=1
      XALSO=X
      YALSO=Y
      IF(INCR.EQ.0) GO TO 58
      GO TO 68
56    NRN=NRN+1
      RPSN(NRN,1)=X1
      RPSN(NRN,2)=Y1
      IDOUBL=0
      IFLAG=3
58    ISP1=IS
      IS=IS-1
      IF(IS.EQ.0) IS=NS
      KDIR=-1
      GO TO 50
60    NRN=NRN+1
      RPSN(NRN,1)=X2
      RPSN(NRN,2)=Y2
      IDOUBL=0
      IFLAG=3
68    IS=ISP1
      ISP1=IS+1
      IF(IS.EQ.NS) ISP1=1
      KDIR=1
      GO TO 50
70    IF(NRPLSN.EQ.0) GO TO 74
      CALL CHECK2(X,Y,RPSIN,NRPLSN,NRPTSN,ICHK2)
      IF(ICHK2.EQ.1) GO TO 120
74    NRPLSN=NRPLSN+1
      GO TO 76
75    CALL CHECK1(X,Y,RPSN,NRN,ICHK)
```

```
      IF(ICHK.EQ.1) GO TO 90
   76 NRN=NRN+1
      RPSN(NRN,1)=X
      RPSN(NRN,2)=Y
      X1=X
      Y1=Y
      IDOUBL=1
      XALSO=X
      YALSO=Y
      IF(IFLAG.EQ.6) IFLAG=1
      IF(IFLAG.EQ.1) GO TO 35
      IRP1=KL+1
      IF(KL.EQ.NR) IRP1=1
      IFLAG=4
      GO TO 35
   90 IF(NRN.EQ.0) GO TO 120
      IF(NRN.LE.2) NRPLSN=NRPLSN-1
      IF(NRN.LE.2) GO TO 120
      IF(NEXT.EQ.0) GO TO 100
      NRPTSN(NRPLSN)=NRN
      CALL TRANSP(RPSIN,NRPLSN,NRN,SPSI,NS,RPSN,SPS,3,GAMV,GAML)
      NRN=0
      X1=XSEP
      Y1=YSEP
      IFLAG=6
      IRP1=NEXT
      IDOUBL=1
      XALSO=XSEP
      YALSO=YSEP
      IF(NRPLSN.EQ.5) GO TO 120
      GO TO 35
  100 X1=SPS(1,1)
      Y1=SPS(1,2)
      CALL CIRCLE(RPSN,NRN,X1,Y1,INCR)
      IF(INCR.EQ.0) GO TO 110
      X1=RPSN(NRN,1)
      Y1=RPSN(NRN,2)
      CALL CLOSE(SPS,NS,X1,Y1,KN)
      X1=RPSN(1,1)
      Y1=RPSN(1,2)
      CALL CLOSE(SPS,NS,X1,Y1,K1)
      DO 103 KDIR=1,2
      K=KN
      IFACT=(-1)**(KDIR+1)
      DO 102 I=1,NS
      L=K+IFACT*(I-1)
      IF(L.GT.NS) L=1
      IF(L.LT.1) L=NS
      IF(L.EQ.1.AND.KDIR.EQ.1) K=2-I
      IF(L.EQ.NS.AND.KDIR.EQ.2) K=NS+I-1
      M=NRN+I
      DO 101 J=1,2
```

```
 101   RPSN(M,J)=SPS(L,J)
       IF(L.EQ.K1) GO TO 1020
 102   CONTINUE
1020   DO 1025 KK=1,NS
       X1=SPS(KK,1)
       Y1=SPS(KK,2)
       CALL CIRCLE(RPSN,M,X1,Y1,INCR)
       IF(INCR.EQ.1) GO TO 103
1025   CONTINUE
       GO TO 104
 103   CONTINUE
       WRITE(6,200)
 200   FORMAT(1H1,'SOMETHING WRONG SHADOW SUBROUTINE')
       STOP
 104   NRPTSN(NRPLSN)=M
       CALL TRANSP(RPSIN,NRPLSN,M,SPSI,NS,RPSN,SPS,3,GAMV,GAML)
       DO 105 J=1,2
 105   RPSN(1,J)=RPS(NRN,J)
       K=KN
       DO 107 I=1,NS
       L=K-IFACT*(I-1)
       IF(L.GT.NS) L=1
       IF(L.LT.1) L=NS
       IF(L.EQ.1.AND.IFACT.EQ.-1) K=2-I
       IF(L.EQ.NS.AND.IFACT.EQ.1) K=NS+I-1
       M=I+1
       DO 106 J=1,2
 106   RPSN(M,J)=SPS(L,J)
       IF(L.EQ.K1) GO TO 108
 107   CONTINUE
 108   M=M+1
       DO 109 J=1,2
 109   RPSN(M,J)=RPS(1,J)
       NRPLSN=NRPLSN+1
       GO TO 115
 110   M=NRN
 115   NRPTSN(NRPLSN)=M
       CALL TRANSP(RPSIN,NRPLSN,M,SPSI,NS,RPSN,SPS,3,GAMV,GAML)
 120   CONTINUE
       NRPLS=NRPLSN
       IF(NRPLS.EQ.0) RETURN
       DO 130 L=1,NRPLS
       NN=NRPTS (L)
       NRPTS(L)=NN
       DO 130 I=1,NN
       X4=RPST (L,I,1)
       Y4=RPST (L,I,2)
       Z4=RPST (L,I,3)
       CALL PLNPT(A,B,C,D,SL,SM,SN,DISC,X4,Y4,Z4,XX,YY,ZZ)
       RPSI(L,1,1)=XX
       RPSI(L,1,2)=YY
 130   RPSI(L,I,3)=ZZ

       RETURN
       END
```

```
      SUBROUTINE INTERF(FPTS,DIRCOS,NFENCE,NFPTS,X1,Y1,Z1,REFLTN,ICLEAR)
      DIMENSION AFT(2,3),SL(3)
      ~~DIMENSION FPTS(5,30,3),  DIRCOS(3,3),NFPTS( 5),~~
     1 XI(3),XB(3),REFLTN(3),COEFB(4),FPS(30,2)
      REAL*8 COEFBF( 5,4)
      ~~COMMON/FENCE/COEFBF~~
      DATA TOL/1.0E-04/
      REAL*8 DIRCOS,X1,Y1,Z1,REFLTN,COEFB,SL,XB,XI,X,Y,Z,DISC,DABS,DARSIN
      ~~XI(1)=X1~~
      XI(2)=Y1
      XI(3)=Z1
      ~~DO 5 I=1,3~~
      XB(I)=0.0
      SL(I)=0.0
      DO 5 J=1,3
      XB(I)=XB(I)+DIRCOS(I,J)*XI(J)
    5 SL(I)=SL(I)+DIRCOS(I,J)*REFLTN(J)
      ~~DO 50 K=1,NFENCE~~
      DO 10 J=1,4
   10 COEFB(J)=COEFBF(K,J)
      CALL PLANPT(COEFB(1),COEFB(2),COEFB(3),COEFB(4),SL(1),SL(2),
     1 SL(3),DISC,XB(1),XB(2),XB(3),X,Y,Z)
      IF(DABS(DISC).LT.TOL) GO TO 50
      ~~CALL SORNOT(SL(1),SL(2),~~SL(3),XB(1),XB(2),XB(3),X,Y,Z,INT)
      IF(INT.EQ.0) GO TO 50
      IF(INT.EQ.2) GO TO 55
      DIST=0.0
      DO 12 I=1,3
   12 DIST=DIST+COEFB(I)*COEFB(I)
      DIST=SQRT(DIST)
      DO 14 I=1,3
   14 COEFB(I)=COEFB(I)/DIST
      IF(DABS(COEFB(1)).GT.TOL.OR.DABS(COEFB(2)).GT.TOL) GO TO 16
      GV=1.570796
      GL=0.0
      GO TO 18
   16 GV=DARSIN(COEFB(3)*0.9999)
      GL=DARSIN(COEFB(2)/COS(GV)*0.9999)
   18 SNGV=SIN(GV)
      CSGV=COS(GV)
      SNGL=SIN(GL)
      CSGL=COS(GL)
      AFT(1,1)=SNGV
      AFT(1,2)=0.0
      AFT(1,3)=CSGV
      AFT(2,1)=CSGV*SNGL
      AFT(2,2)=CSGL
      AFT(2,3)=-SNGV*SNGL
      NF=NFPTS(K)
      DO 40 IF=1,NF
      DO 40 J=1,2
      FPS(IF,J)=0.0
```

```
      DO 40 KK=1,3
40    FPS(IF,J)=FPS(IF,J)+AFT(J,KK)*FPTS(K,IF,KK)
      X1P=AFT(1,1)*X+AFT(1,3)*Z
      Y1P=AFT(2,1)*X+AFT(2,2)*Y+AFT(2,3)*Z
      CALL CIRCLE(FPS,NF,X1P,Y1P,INCR)
      IF(INCR.EQ.1) GO TO 55
50    CONTINUE
      RETURN
55    ICLEAR=1
      RETURN
      END
```

```
      SUBROUTINE QUADPT(A,B,C,D,E,F,G,H,CK,CL,SL,SM,SN,X1,Y1,Z1,XI1,YI1,
     1 ZI1,XI2,YI2,ZI2,INTC)
      IMPLICIT REAL*8 (A-H,O-Z)
      SQRT(XX)=DSQRT(XX)
      ABS(XX)=DABS(XX)
      DATA TOL/1.0E-08/
      INTC=0
      IF(ABS(SL).LT.ABS(SN).AND.ABS(SM).LE.ABS(SN)) GO TO 30
      IF(ABS(SL).LT.ABS(SM).AND.ABS(SN).LT.ABS(SM)) GO TO 50
      SA=A+B*(SM/SL)**2+C*(SN/SL)**2+D*SM/SL+F*SM*SN/SL**2+E*SN/SL
      SB=2.*B*Y1*SM/SL-2.*B*X1*(SM/SL)**2+2.*C*Z1*SN/SL-2.*C*X1*
     1 (SN/SL)**2+D*Y1-D*X1*SM/SL+E*Z1-E*X1*SN/SL+F*Z1*SM/SL-F*X1*SM*
     2 SN/SL**2+F*Y1*SN/SL-F*X1*SM*SN/SL**2+G+H*SM/SL+CK*SN/SL
      SC=B*Y1*Y1+B*X1*X1*(SM/SL)**2+C*Z1*Z1-2.*B*Y1*X1*SM/SL+C*X1*X1*
     1 (SN/SL)**2-2.*C*X1*Z1*SN/SL+F*Y1*Z1-F*X1*Y1*SN/SL-F*X1*Z1*SM/SL+
     2 F*X1*X1*SM*SN/SL**2+H*Y1-H*X1*SM/SL+CK*Z1-CK*X1*SN/SL+CL
      ICONTR=1
    5 DISC=SB*SB-4.*SA*SC
C     WRITE(6,200) ICONTR,                                      X1,Y1,Z1,SA,
C    1 SB,SC,DISC
C200  FORMAT(1H0,I5,5X,6E15.4/1H0,10X,4E15.4)
      IF(DISC.LT.DABS(SA)/10.) RETURN
      IF(DISC.LT.0.0) RETURN
      IF(ABS(SA).GE.TOL) GO TO 10
      IF(ABS(SB).LT.TOL) RETURN
      XI1=-SC/SB
      INTC=1
      IF(ICONTR.EQ.2) GO TO 60
      IF(ICONTR.EQ.3) GO TO 40
      GO TO 20
   10 XI1=-SB/SA/2.+SQRT(DISC)/SA/2.
      XI2=-SB/SA/2.-SQRT(DISC)/SA/2.
      INTC=2
      IF(ICONTR.EQ.2) GO TO 60
      IF(ICONTR.EQ.3) GO TO 40
   20 YI1=Y1+SM*(XI1-X1)/SL
      ZI1=Z1+SN*(XI1-X1)/SL
      IF(INTC.EQ.1) RETURN
      YI2=Y1+SM*(XI2-X1)/SL
      ZI2=Z1+SN*(XI2-X1)/SL
      RETURN
   30 SA=C+B*(SM/SN)**2+A*(SL/SN)**2+F*SM/SN+E*SL/SN+D*SM*SL/SN**2
      SB=2.*B*Y1*SM/SN-2.*B*Z1*(SM/SN)**2+2.*A*X1*SL/SN-2.*A*Z1*
     1 (SL/SN)**2+F*Y1-F*Z1*SM/SN+E*X1-E*Z1*SL/SN+D*X1*SM/SN-D*Z1*SM*
     2 SL/SN**2+D*Y1*SL/SN-D*Z1*SM*SL/SN**2+CK+H*SM/SN+G*SL/SN
      SC=B*Y1*Y1+B*Z1*Z1*(SM/SN)**2-2.*B*Y1*Z1*SM/SN+A*X1*X1+A*Z1*Z1*
     1 (SL/SN)**2-2.*A*X1*Z1*SL/SN+D*Y1*X1-D*Y1*Z1*SL/SN-D*X1*Z1*SM/SN+
     2 D*Z1*Z1*SM*SL/SN**2+H*Y1-H*Z1*SM/SN+G*X1-G*Z1*SL/SN+CL
      ICONTR=3
      GO TO 5
   40 ZI1=XI1
      YI1=Y1+SM*(ZI1-Z1)/SN
```

```
      XI1=X1+SL*(ZI1-Z1)/SN
      IF(INTC.EQ.1) RETURN
      ZI2=XI2
      YI2=Y1+SM*(ZI2-Z1)/SN
      XI2=X1+SL*(ZI2-Z1)/SN
      RETURN
   50 SA=B+A*(SL/SM)**2+C*(SN/SM)**2+D*SL/SM+E*SL*SN/SM**2+F*SN/SM
      SB=2.*A*X1*SL/SM-2.*A*Y1*(SL/SM)**2+2.*C*Z1*SN/SM-2.*C*Y1*
     1 (SN/SM)**2+D*X1-D*Y1*SL/SM+E*X1*SN/SM+E*Z1*SL/SM-2.*E*Y1*SL*SN/
     2 SM**2+F*Z1-F*Y1*SN/SM+G*SL/SM+H+CK*SN/SM
      SC=A*X1*X1+A*Y1*Y1*(SL/SM)**2-2.*A*Y1*X1*SL/SM+C*Z1*Z1+C*Y1*Y1*
     1 (SN/SM)**2-2.*C*Y1*Z1*SN/SM+E*X1*Z1-E*X1*Y1*SN/SM-E*Y1*Z1*SL/SM+
     2 E*Y1*Y1*SL*SN/SM**2+G*X1-G*Y1*SL/SM+CK*Z1-CK*Y1*SN/SM+CL
      ICONTR=2
      GO TO 5
   60 YI1=XI1
      XI1=X1+SL*(YI1-Y1)/SM
      ZI1=Z1+SN*(YI1-Y1)/SM
      IF(INTC.EQ.1) RETURN
      YI2=XI2
      XI2=X1+SL*(YI2-Y1)/SM
      ZI2=Z1+SN*(YI2-Y1)/SM
      RETURN
      END
```

```
SUBROUTINE SORNOT(SL,SM,SN,X1,Y1,Z1,X,Y,Z,ISHAD)
IMPLICIT REAL*8 (A-H,O-Z)
ABS(XX)=DABS(XX)
DATA TOL/1.0E-04/
ISHAD=2
SL1=X-X1
SM1=Y-Y1
SN1=Z-Z1
IF((ABS(SL1)+ABS(SM1)+ABS(SN1)).LT.TOL) RETURN
DIR=0.0
IF(ABS(SL).GT.TOL) DIR=SL1/SL
IF(ABS(SM).GT.TOL) DIR=DIR+SM1/SM
IF(ABS(SN).GT.TOL) DIR=DIR+SN1/SN
ISHAD=1
IF(DIR.LT.0.0) ISHAD=0
RETURN
END
```

```
      SUBROUTINE PROBL(ALPHA2,BETA2,GAMMA,    NPSI,NDISP,NRPTS,
     1 YSCMIN,YSCMAX,SUMW,IGAM,NPANEL)
      DIMENSION ALPHA2(1000),BETA2(1000),NRPTS(7,4,18),IMNMX(18,2),
     1 BPTS(4,2),SPS(30,2),PTS(30,2)
      COMMON/PLPR/MGAMS(7,4)
      AREA(X1,Y1,X2,Y2,X3,Y3)=ABS((X1*Y2+X2*Y3+X3*Y1-X3*Y2-
     1 X1*Y3-X2*Y1)/2.)
      IF(NPSI.EQ.1) RETURN
      WRITE(6,200) GAMMA,YSCMIN,YSCMAX
  200 FORMAT(1H1,49X,'PROBABILITY FUNCTIONS'/1H0,43X,'RATIOS OF SWEPT AR
     1EA TO TOTAL AREA'/1H0,5X,'SUN ELEVATION',F20.2/1H ,5X,'MINIMUM OBS
     2ERVER ELEVATION',F7.2/1H ,5X,'MAXIMUM OBSERVER ELEVATION',F7.2//
     3 1H0,30X,'SURFACE NO.',5X,'SWEPT AREA',5X,'PROBABILITY FUNCTION')
      DO 2000 KL=1,NPANEL
      TOTA=0.0
      M=MGAMS(KL,IGAM)
      DO 20 L=1,NPSI
      NPTS=NRPTS(KL,IGAM,L)
      IMNMX(L,2)=0
      JJ=0
      DO 20 K=1,NDISP
      DO 20 J=1,NPTS
      M=M+1
      IF(ALPHA2(M).GT.90.) GO TO 20
      JJ=JJ+1
      IF(JJ.GT.1) GO TO 10
      IF(L.GT.1) GO TO 5
      BMIN=BETA2(M)
      BMAX=BMIN
    5 IMNMX(L,1)=M
      IMNMX(L,2)=M
      YMAX=ALPHA2(M)
      YMIN=YMAX
      GO TO 20
   10 IF(ALPHA2(M).LT.YMIN) IMNMX(L,1)=M
      IF(ALPHA2(M).GT.YMAX) IMNMX(L,2)=M
      IF(M.EQ.IMNMX(L,1)) YMIN=ALPHA2(M)
      IF(IMNMX(L,2).EQ.M) YMAX=ALPHA2(M)
      IF(BETA2(M).LT.BMIN) BMIN=BETA2(M)
      IF(BETA2(M).GT.BMAX) BMAX=BETA2(M)
   20 CONTINUE
      SPS(1,1)=BMIN-5.
      SPS(1,2)=YSCMIN
      SPS(2,1)=BMAX+5.
      SPS(2,2)=YSCMIN
      SPS(3,1)=BMAX+5.
      SPS(3,2)=YSCMAX
      SPS(4,1)=BMIN-5.
      SPS(4,2)=YSCMAX
      NM1=NPSI-1
      DO 1000 L=1,NM1
      IF(IMNMX(L,2).EQ.0) GO TO 1000
```

```
      LP1=L+1
      IF(IMNMX(LP1,2).EQ.0) GO TO 1000
      DO 30 I=1,2
      M=IMNMX(L,I)
      BPTS(I,1)=BETA2(M)
   30 BPTS(I,2)=ALPHA2(M)
      DO 40 I=1,2
      N=3-I
      M=IMNMX(LP1,I)
      BPTS(N+2,1)=BETA2(M)
   40 BPTS(N+2,2)=ALPHA2(M)
      IDOUBL=0
      ICHK=0
      LINE=0
      NPTS=0
      IR=1
   50 XC=BPTS(IR,1)
      YC=BPTS(IR,2)
      CALL CIRCLE(SPS,4,XC,YC,INCR)
      IF(INCR.NE.2) GO TO 80
      IF(IR.EQ.4) GO TO 60
      IR=IR+1
      GO TO 50
   60 DO 70 I=1,4
      DO 70 J=1,2
   70 PTS(I,J)=BPTS(I,J)
      NPTS=4
      GO TO 900
   80 IFLAG=1
      IF(INCR.EQ.0) IFLAG=2
      IF(IFLAG.EQ.2) GO TO 85
      NPTS=1
      PTS(NPTS,1)=BPTS(IR,1)
      PTS(NPTS,2)=BPTS(IR,2)
   85 IRP1=IR+1
      IF(IR.EQ.4) IRP1=1
   90 X1=BPTS(IR,1)
      Y1=BPTS(IR,2)
      X2=BPTS(IRP1,1)
      Y2=BPTS(IRP1,2)
      CALL INTERC(SPS,4,X1,Y1,X2,Y2,X,Y,JL,IFAULT,IDOUBL,
     1 XALSO,YALSO)
      IF(IFAULT.EQ.0) GO TO 110
      IF(IFLAG.EQ.2.OR.IFLAG.EQ.3) GO TO 100
      IF(NPTS.GT.0) CALL CHECK1(X2,Y2,PTS,NPTS,ICHK)
      IF(ICHK.EQ.1) GO TO 900
      NPTS=NPTS+1
      PTS(NPTS,1)=X2
      PTS(NPTS,2)=Y2
      IDOUBL=0
      IFLAG=1
  100 IF(IFLAG.EQ.3) IFLAG=2
```

```
      IF(IRP1.EQ.1) GO TO 900
  105 IR=IR+1
      IRP1=IR+1
      IF(IR.EQ.4) IRP1=1
      GO TO 90
  110 IF(NPTS.GT.0) CALL CHECK1(X,Y,PTS,NPTS,ICHK)
      IF(ICHK.EQ.1) GO TO 900
      NPTS=NPTS+1
      PTS(NPTS,1)=X
      IF(IFLAG.EQ.4) IFLAG=2
      IF(IFLAG.EQ.2) GO TO 105
      IDOUBL=1
      XALSO=X
      YALSO=Y
      IF(IFLAG.EQ.1) IFLAG=3
      IF(IFLAG.EQ.2) IFLAG=4
      GO TO 105
  900 IF(NPTS.LE.2) GO TO 1000
      N=NPTS-2
      X1=PTS(1,1)
      Y1=PTS(1,2)
      DO 950 I=1,N
      X2=PTS(I+1,1)
      Y2=PTS(I+1,2)
      X3=PTS(I+2,1)
      Y3=PTS(I+2,2)
  950 TOTA=TOTA+AREA(X1,Y1,X2,Y2,X3,Y3)
 1000 CONTINUE
      PRTOT=TOTA/SUMW
      IF(PRTOT.GT.1.0) PRTOT=1.0
      WRITE(6,201) KL,TOTA,PRTOT
  201 FORMAT(1H0,34X,'(',I1,')',9X,F7.2,16X,F5.3)
 2000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PLOT(XPTS,YPTS,GAMMA,IPANEL,NPSI,NDISP,NRPTS,
     1 XSCMIN,XSCMAX,YSCMIN,YSCMAX,PHI,THETA,IGAM,NPANEL,IANGL)
      DIMENSION XPTS(1000),YPTS(1000),NRPTS(7,4,18),SYMBOL(18)
      DIMENSION XPR(10),OUT(91)
      DATA SYMBOL/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1HA,1HB,1HC,1HD,
     1 1HE,1HF,1HG,1HH,1HK/
      DATA BLANK,PERIOD,FI/1H ,1H.,1HI/
      COMMON/PLPH/MGAMS(7,4)
      IF(IPANEL.EQ.NPANEL) WRITE(6,208) IPANEL
      IF(IPANEL.NE.NPANEL) WRITE(6,209)
      WRITE(6,200)        GAMMA,THETA,PHI
      DELX=(XSCMAX-XSCMIN)/90.
      DELY=(YSCMAX-YSCMIN)/40.
      KPRINT=5
      TY2=YSCMAX+DELY/2.
      DO 140 I=1,41
      TY1=TY2-DELY
      DO 30 J=1,91
   30 OUT(J)=BLANK
      IF(KPRINT.EQ.5) OUT(1)=FI
      IF(KPRINT.NE.5) OUT(1)=PERIOD
      IF(KPRINT.EQ.5) OUT(91)=FI
      IF(KPRINT.NE.5) OUT(91)=PERIOD
      IF(I.NE.1.AND.I.NE.41)  GO TO  50
      L=9
      DO 40 J=1,91
      L=L+1
      OUT(J)=PERIOD
      IF(L.EQ.10) OUT(J)=FI
   40 IF(L.EQ.10) L=0
   50 DO 90 KL=IPANEL,NPANEL
      M=MGAMS(KL,IGAM)
      DO 90 L=1,NPSI
      NPTS=NRPTS(KL,IGAM,L)
      DO 90 K=1,NDISP
      DO 90 J=1,NPTS
      M=M+1
      IF(YPTS(M).GT.90.) GO TO 90
      Y=YPTS(M)
      IFLAG=1
      MM1=M-1
      IF(J.EQ.1) MM1=M+NPTS-1
      MP1=M+1
      IF(J.EQ.NPTS) MP1=M-NPTS+1
      IF(I.EQ.1.AND.Y.GE.(YSCMAX+DELY/2.)) GO TO 52
      IF(I.EQ.41.AND.Y.LT.(YSCMIN-DELY/2.)) GO TO 56
      IF(Y.GE.TY2.OR.Y.LT.TY1) GO TO 90
      X=XPTS(M)
      GO TO 60
   52 IF(YPTS(MM1).GE.(YSCMAX+DELY/2.)) GO TO 54
      IFLAG=2
      X=XPTS(MM1)+(YSCMAX-YPTS(MM1))*(XPTS(M)-XPTS(MM1))/(YPTS(M)-
```

```
     1 YPTS(MM1))
      GO TO 60
   54 IF(YPTS(MP1).GE.(YSCMAX+DELY/2.)) GO TO 90
      IFLAG=3
      X=XPTS(MP1)+(YSCMAX-YPTS(MP1))*(XPTS(M)-XPTS(MP1))/(YPTS(M)-
     1 YPTS(MP1))
      GO TO 60
   56 IF(YPTS(MM1).LE.(YSCMIN-DELY/2.)) GO TO 58
      IFLAG=4
      X=XPTS(M)+(YSCMIN-YPTS(M))*(XPTS(MM1)-XPTS(M))/(YPTS(MM1)-
     1 YPTS(M))
      GO TO 60
   58 IF(YPTS(MP1).LE.(YSCMIN-DELY/2.)) GO TO 90
      IFLAG=5
      X=XPTS(M)+(YSCMIN-YPTS(M))*(XPTS(MP1)-XPTS(M))/(YPTS(MP1)-
     1 YPTS(M))
   60 TX2=XSCMIN+DELX/2.
      DO 70 KK=1,91
      TX1=TX2-DELX
      IF(X.GE.TX1.AND.X.LT.TX2) GO TO 80
   70 TX2=TX2+DELX
   80 LL=KK+(1-IANGL)*(92-2*KK)
      OUT(LL)=SYMBOL(L)
      GO TO (90,54,90,58,90), IFLAG
   90 CONTINUE
      YPLOT=TY2-DELY/2.
      IF(KPRINT.EQ.5) WRITE(6,201) YPLOT,OUT,YPLOT
      IF(KPRINT.NE.5) WRITE(6,205) OUT
      IF(KPRINT.EQ.5) KPRINT=0
      KPRINT=KPRINT+1
  140 TY2=TY2-DELY
      XPR(1)=XSCMIN
      IF(IANGL.EQ.0) XPR(1)=XSCMAX
      DO 150 I=2,10
  150 XPR(I)=XPR(I-1)+(-1)**(1-IANGL)*10.*DELX
      WRITE(6,204)
      WRITE(6,202) XPR
      WRITE(6,207)
  208 FORMAT(1H1,40X,'SUN GLINT SIGNATURE FOR SURFACE NO.',I3)
  200 FORMAT(1H0,'SUN ELEVATION',
     1 F12.2/1H ,     'A/C PITCH ATTITUDE',F7.2/1H ,
     2 'A/C ROLL ATTITUDE', F8.2//1H ,'OBSERVER ANGLE',93X,
     3 'OBSERVER ANGLE'/1H ,3X,'DEGREES',100X,'DEGREES'/)
  207 FORMAT(/,38X,'GLINT AZIMUTH WITH RESPECT TO SUN - DEGREES')
  201 FORMAT(1H ,F10.3,5X,91A1,1X,F10.3)
  205 FORMAT(1H ,15X,91A1)
  202 FORMAT(1H ,9X,10F10.3)
  204 FORMAT(/)
  209 FORMAT(1H1,47X,'TOTAL SUN GLINT SIGNATURE')
      RETURN
      END
```

```
      SUBROUTINE TRANSP(RPSI,IRPL,NR,SPSI,NS,RPS,SPS,IC,GAMV,GAML)
      DIMENSION RPSI(5,30,3) ,SPSI(30,3),RPS(30,2),SPS(30,2)
      COMMON/TRAN/AT(2,3),ATINV(3,2)
      GO TO (10,110,130), IC
   10 SNGV=SIN(GAMV/57.3)
      CSGV=COS(GAMV/57.3)
      SNGL=SIN(GAML/57.3)
      CSGL=COS(GAML/57.3)
      AT(1,1)=SNGV
      AT(1,2)=0.0
      AT(1,3)=CSGV
      AT(2,1)=CSGV*SNGL
      AT(2,2)=CSGL
      AT(2,3)=-SNGV*SNGL
      DO 15 I=1,3
      DO 15 J=1,2
   15 ATINV(I,J)=AT(J,I)
      DO 100 I=1,NS
      DO 100 J=1,2
      SPS(I,J)=0.0
      DO 100 K=1,3
  100 SPS(I,J)=SPS(I,J)+AT(J,K)*SPSI(I,K)
  110 DO 120 I=1,NR
      DO 120 J=1,2
      RPS(I,J)=0.0
      DO 120 K=1,3
  120 RPS(I,J)=RPS(I,J)+AT(J,K)*RPSI(IRPL,I,K)
      RETURN
  130 DO 140 I=1,NR
      DO 140 J=1,3
      RPSI(IRPL,I,J)=0.0
      DO 140 K=1,2
  140 RPSI(IRPL,I,J)=RPSI(IRPL,I,J)+ATINV(J,K)*RPS(I,K)
      RETURN
      END
```

```
      SUBROUTINE CHECK2(X1,Y1,ARRAY,NPLS,NPTAR,ICOMP)
      DIMENSION ARRAY(5,30,3) ,NPTAR(5)
      COMMON/TRAN/AT(2,3),ATINV(3,2)
      DATA TOL/1.0E-04/
      ICOMP=0
      X2=ATINV(1,1)*X1+ATINV(1,2)*Y1
      Y2=ATINV(2,1)*X1+ATINV(2,2)*Y1
      Z2=ATINV(3,1)*X1+ATINV(3,2)*Y1
      DO 10 L=1,NPLS
      NPTS=NPTAR(L)
      DO 10 I=1,NPTS
      X=ARRAY(L,I,1)
      Y=ARRAY(L,I,2)
      Z=ARRAY(L,I,3)
      IF(ABS(X2-X).GE.TOL) GO TO 10
      IF(ABS(Y2-Y).GE.TOL) GO TO 10
      IF(ABS(Z2-Z).GE.TOL) GO TO 10
      ICOMP=1
      RETURN
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CLOSE(ARRAY,NPTS,X1,Y1,K)
      DIMENSION ARRAY(30,2)
      K=1
      DIST=(ARRAY(1,1)-X1)**2+(ARRAY(1,2)-Y1)**2
      IF(NPTS.EQ.1) RETURN
      DO 10 I=2,NPTS
      DIST2=(ARRAY(I,1)-X1)**2+(ARRAY(I,2)-Y1)**2
      IF(DIST2.LT.DIST)  K=I
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INTERC(POINTS,NPTS,X1,Y1,X2,Y2,X,Y,KL,IFAULT,
     1 IDOUBL,XALSO,YALSO)
      DATA TOL/1.0E-04/
      DIMENSION POINTS(30,2),IPTS(30),XINT(30),YINT(30)
      NINTC=0
      IFAULT=1
      DO 74 I=1,NPTS
      IP1=I+1
      IF(I.EQ.NPTS) IP1=1
      X3=POINTS(I,1)
      Y3=POINTS(I,2)
      X4=POINTS(IP1,1)
      Y4=POINTS(IP1,2)
      XMIN=X3
      XMAX=X3
      YMIN=Y3
      YMAX=Y3
      IF(X4.LT.X3) XMIN=X4
      IF(X4.GT.X3) XMAX=X4
      IF(Y4.LT.Y3) YMIN=Y4
      IF(Y4.GT.Y3) YMAX=Y4
      DEL1=X2-X1
      DEL2=X4-X3
      IF(ABS(DEL1).LT.TOL) GO TO 10
      SA1=(Y2-Y1)/DEL1
      SB1=Y1-SA1*X1
   10 IF(ABS(DEL2).LT.TOL) GO TO 20
      SA2=(Y4-Y3)/DEL2
      SB2=Y3-SA2*X3
   20 IF(ABS(DEL1).GE.TOL) GO TO 40
      IF(ABS(DEL2).GE.TOL) GO TO 30
      GO TO 74
   30 NINTC=NINTC+1
      XINT(NINTC)=X1
      YINT(NINTC)=SA2*X1+SB2
      IPTS(NINTC)=I
      GO TO 70
   40 IF(ABS(DEL2).GE.TOL) GO TO 50
      NINTC=NINTC+1
      XINT(NINTC)=X3
      YINT(NINTC)=SA1*X3+SB1
      IPTS(NINTC)=I
      GO TO 70
   50 DIFFA=SA1-SA2
      IF(ABS(DIFFA).LT.TOL) GO TO 74
      NINTC=NINTC+1
      XINT(NINTC)=(SB2-SB1)/DIFFA
      YINT(NINTC)=SA1*XINT(NINTC)+SB1
      IPTS(NINTC)=I
   70 CONTINUE
      CALL CHECK3(XMIN,XMAX,YMIN,YMAX,XINT(NINTC),YINT(NINTC),IRETW)
      IF(IRETW.EQ.1) IPTS(NINTC)=0
```

```
74   CONTINUE
     IF(NINTC.GT.0) IFAULT=0
     IF(IFAULT.EQ.1) RETURN
     XMIN=X1
     XMAX=X1
     YMIN=Y1
     YMAX=Y1
     IF(X2.LT.X1) XMIN=X2
     IF(X2.GT.X1) XMAX=X2
     IF(Y2.LT.Y1) YMIN=Y2
     IF(Y2.GT.Y1) YMAX=Y2
     DO 80 I=1,NINTC
     IF(IDOUBL.EQ.0) GO TO 75
     IF(ABS(XINT(I)-XALSO).LT.TOL.AND.ABS(YINT(I)-YALSO).LT.
    1 TOL) IPTS(I)=0
75   IF(XINT(I).LT.XMIN) IPTS(I)=0
     IF(XINT(I).GT.XMAX) IPTS(I)=0
     IF(YINT(I).LT.YMIN) IPTS(I)=0
     IF(YINT(I).GT.YMAX) IPTS(I)=0
80   CONTINUE
     IFAULT=1
     DO 90 I=1,NINTC
     IF(IPTS(I).EQ.0) GO TO 90
     IF(IFAULT.EQ.0) GO TO 85
     IFAULT=0
     DIST=(XINT(I)-X1)**2+(YINT(I)-Y1) **2
     M=I
     GO TO 90
85   DIST2=(XINT(I)-X1)**2+(YINT(I)-Y1)**2
     IF(DIST2.LT.DIST) M=I
     IF(M.EQ.I) DIST=DIST2
90   CONTINUE
     IF(IFAULT.EQ.1) RETURN
     KL=IPTS(M)
     X=XINT(M)
     Y=YINT(M)
     RETURN
     END
```

```
      SUBROUTINE CHECK3(XMIN,XMAX,YMIN,YMAX,X,Y,IBETW)
      IBETW=0
      IF(X.LT.XMIN) IBETW=1
      IF(X.GT.XMAX) IBETW=1
      IF(Y.LT.YMIN) IBETW=1
      IF(Y.GT.YMAX) IBETW=1
      RETURN
      END
```

```
      SUBROUTINE CIRCLE(POINTS,NPTS,XC,YC,INCR)
      DIMENSION POINTS(30,2)
      DATA TOL1/1.0E-04/
      NPC=0
      NNC=0
      DO 10 I=1,NPTS
      IP1=I+1
      IF(I.EQ.NPTS) IP1=1
      DISX1=POINTS(I,1)-XC
      DISY1=POINTS(I,2)-YC
      DISX2=POINTS(IP1,1)-XC
      DISY2=POINTS(IP1,2)-YC
      IF(ABS(DISX1).LT.TOL1.AND.ABS(DISY1).LT.TOL1) GO TO 20
      IF(ABS(DISX2).LT.TOL1.AND.ABS(DISY2).LT.TOL1) GO TO 20
      IF(ABS(DISX1).GE.TOL1) GO TO 3
      IF(ABS(DISX2).GE.TOL1) GO TO 1
      IF((DISY1/DISY2).GT.0.0) GO TO 10
      GO TO 20
    1 IF(ABS(DISY2).GE.TOL1) GO TO 2
      X=DISX2
      GO TO 8
    2 IF(ABS(DISY1-DISY2).LT.TOL1) GO TO 10
      GO TO 5
    3 IF(ABS(DISY1).GE.TOL1) GO TO 32
      IF(ABS(DISX2).LT.TOL1) GO TO 10
      IF(ABS(DISY2).GE.TOL1) GO TO 10
      IF((DISX1/DISX2).GT.0.0) GO TO 10
      GO TO 20
   32 IF(ABS(DISX2).GE.TOL1) GO TO 34
      GO TO 36
   34 IF(ABS(DISY2).GE.TOL1) GO TO 36
      X=DISX2
      GO TO 8
   36 IF(ABS(DISY2-DISY1).LT.TOL1) GO TO 10
      IF(ABS(DISX2-DISX1).GE.TOL1) GO TO 5
      IF((DISY1/DISY2).GT.0.0) GO TO 10
      X=DISX2
      GO TO 8
    5 SA=(DISY2-DISY1)/(DISX2-DISX1)
      SB=DISY1-SA*DISX1
      X=-SB/SA
      IF(X.LT.DISX1.AND.X.LT.DISX2) GO TO 10
      IF(X.GT.DISX1.AND.X.GT.DISX2) GO TO 10
    8 IF(ABS(X).LT.TOL1) GO TO 20
      IF(X.LT.0.0) NNC=NNC+1
      IF(X.GT.0.0) NPC=NPC+1
   10 CONTINUE
      INCR=0
      IF(2*(NPC/2).EQ.NPC) RETURN
      IF(2*(NNC/2).EQ.NNC) RETURN
      INCR=1
      RETURN

   20 INCR=2
      RETURN
      END
```

```
      SUBROUTINE CHECK1(X1,Y1,ARRAY,N,ICOMP)
      DIMENSION ARRAY(30,2)
      DATA TOL/1.0E-04/
      ICOMP=0
      DO 10 I=1,N
      X=ARRAY(I,1)
      Y=ARRAY(I,2)
      IF(ABS(X-X1).LT.TOL.AND.ABS(Y-Y1).LT.TOL) GO TO 15
   10 CONTINUE
      RETURN
   15 ICOMP=1
      RETURN
      END
```