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SOLAR PILOT PLANT, PHASE 1

PRELIMINARY DESIGN REPORT

Volume 2, Book 2

Central Receiver Optical Model Users Manual (CDRL Item 2)

May 1, 1977

Work Performed Under Contract No. EY-76-C-03-1109

Honeywell, Incorporated
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SOLAR PILOT PLANT
PHASE I

PRELIMINARY DESIGN REPORT

VOLUME II - BOOK 2

CENTRAL RECEIVER OPTICAL MODEL USERS MANUAL

CDRL Item 2

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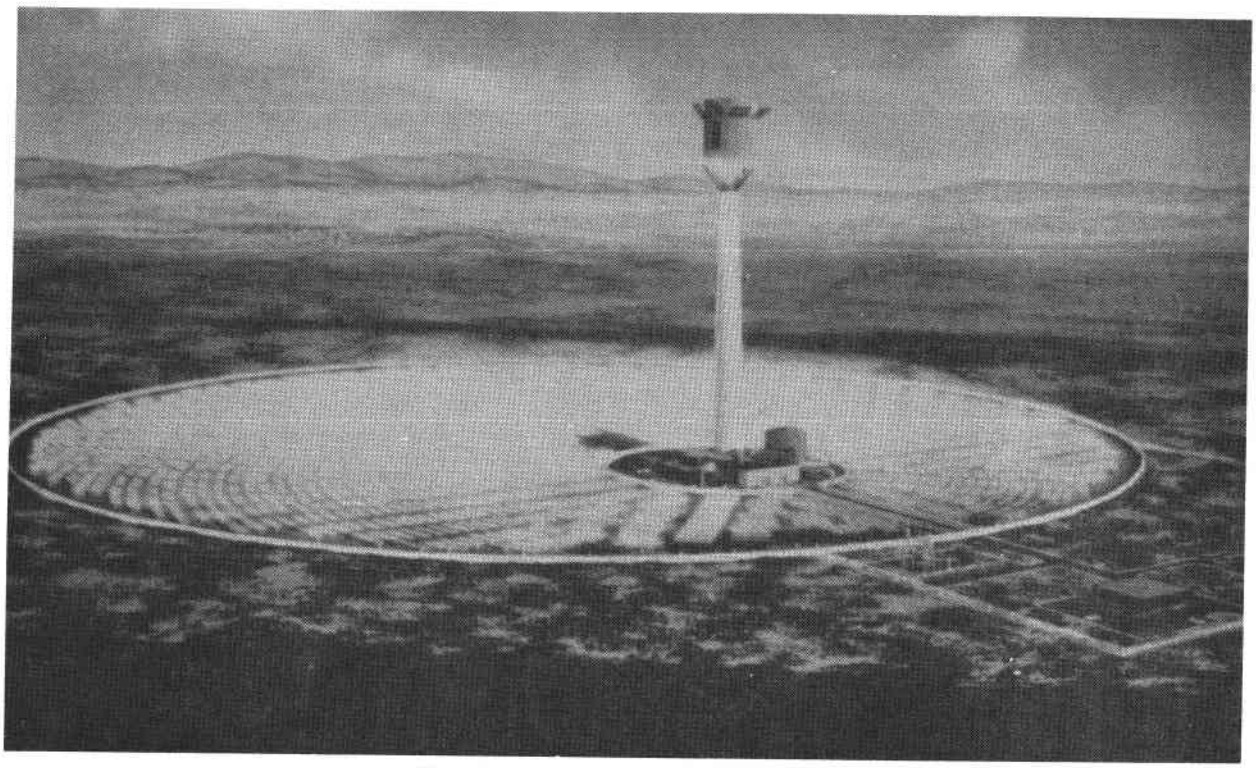
FOREWORD

This is the initial submittal of the Solar Pilot Plant Preliminary Design Report per Contract Data Requirement List Item 2 of ERDA Contract E(04-3)-1109. The report is submitted for review and approval by ERDA. This is Volume II-Book 2 of seven volumes.

Readers of this report and users of the Central Receiver Optical/Thermal Model program, HELIAKI, should be cautioned that, although the program has been used considerably and appears to be relatively error free, some "bugs" may well remain. Further, since this program evolved over a period of time in a step-by-step updating of the model, some unused variables may also remain. Needless to say, the authors cannot take responsibility for any versions of the program which do not correspond exactly to the program listing in this report.



10 MEGAWATT SOLAR PILOT PLANT
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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ILLUSTRATIONS

SECTION 1
INTRODUCTION

HELIAKI is a FORTRAN computer program which simulates the optical/thermal performance of a central receiver solar thermal power plant for the dynamic conversion of solar-generated heat to electricity. The solar power plant which this program simulates consists of a field of individual sun tracking mirror units, or heliostats, redirecting sunlight into a cavity, called the receiver, mounted atop a tower. The program calculates the power retained by that cavity receiver at any point in time or the energy into the receiver over a year's time using a Monte Carlo ray trace technique to solve the multiple integral equations. An artist's concept of this plant is shown in Figure 1-1.

Heliostats are arranged in the field around the tower in concentric circles. The ground cover, ratio of mirror area to field area, is varied by changing the spacing between heliostats in either or both the radial or azimuthal directions. Figure 1-2 shows the heliostat modeled in this program.

The receiver is modeled as an upright circular cylinder mounted atop a tower and held in place by three corbels. Sun rays from various parts of the field (redirected by the heliostats) enter the receiver cavity through the aperture and impinge on the interior surface of the receiver. Some heliostats close to the tower cutout perimeter may reflect, for part of day, the power onto the receiver roof, whereas the power from some heliostats farther away may whistle-through the aperture. The methodology of the program accounts for these phenomena as well as many more subtle phenomena. These are described in the methodology section of this manual.

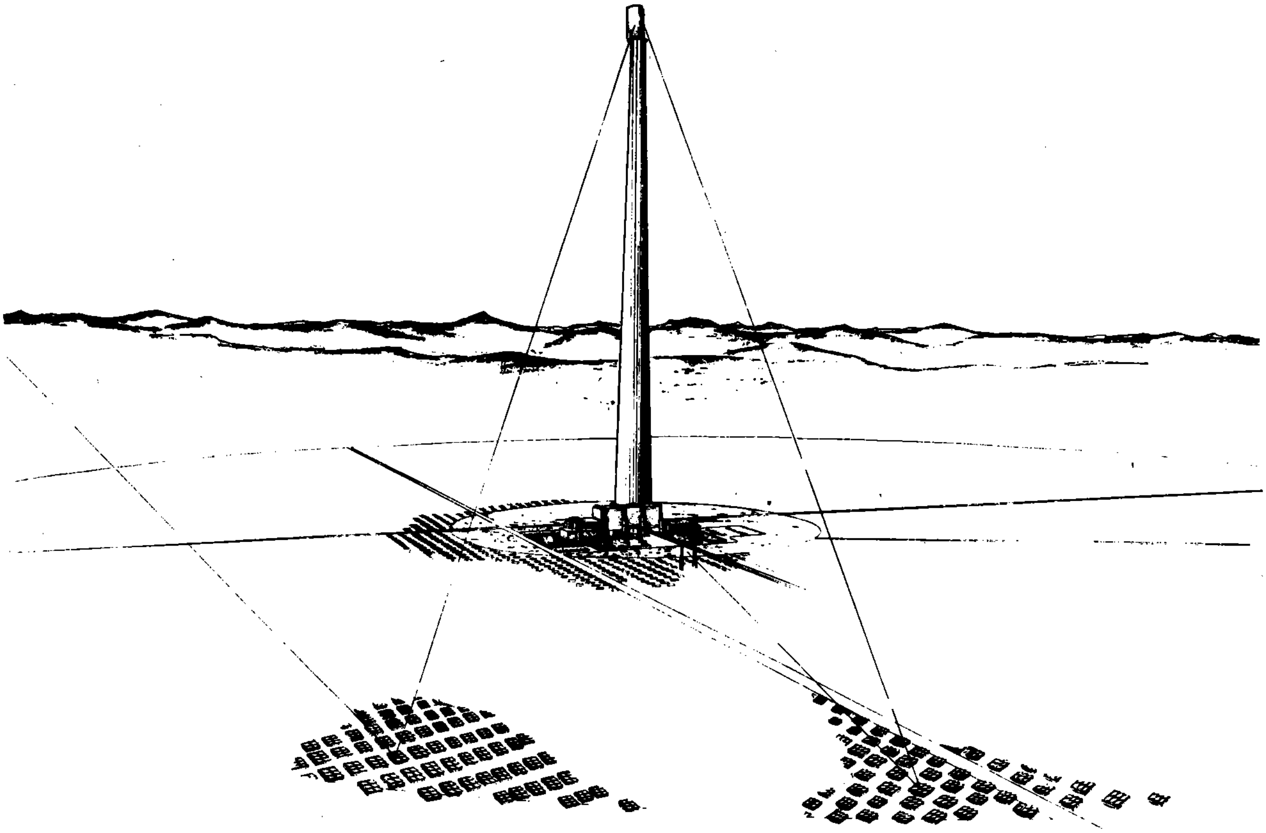


Figure 1-1. Solar Pilot Plant

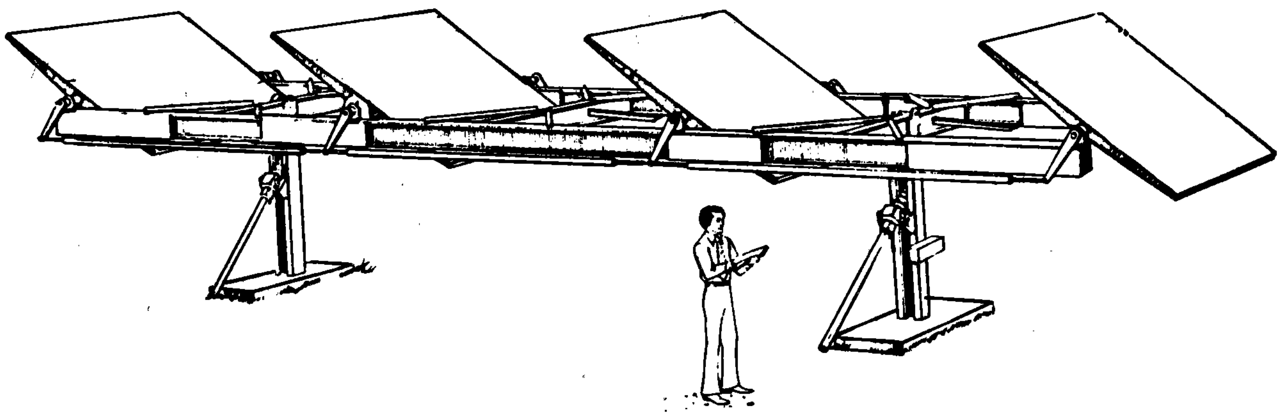


Figure 1-2. Experimental Heliostat Assembly

Although the Monte Carlo ray trace code described in this manual is quite design specific, the general program methodology and structure has been applied to a wide variety of designs. In the area of central receivers, the program has been used to model a number of receiver types, including an exposed surface sphere, cylinder, half cylinder, star or cone shape. A variety of aiming strategies has been used for each of these possible configurations. In addition, a planar target has been used for the tower top aperture opening when a cavity-type receiver is used.

For the heliostat, both Az-El and tilt-tilt gimbal sequences have been modeled. A single mirror facet per heliostat or multiple-mirror facets can be analyzed with either gimbal sequence. The code described in this manual has the tilt-tilt heliostat model which is restricted to a four-mirror facet configuration by the modeling of the frame structure. If the specific frame structure were eliminated, the code can be applied to any number of mirror facets, including a single facet design. The field layout of the heliostats has also been varied with past program versions. Rectilinear, both uniform and nonuniform, heliostat spacing has been modeled as well as hexagon packing. The version used in the present code orients each heliostat such that the outer tracking axis is normal to a line of sight to the tower. Both uniform and nonuniform field packing densities can be analyzed with the present code.

Other code versions have included options to perform flux mapping on a cavity aperture, a variety of mirror-focusing strategies, plant costing algorithms, reflectance analysis by wavelength and incidence angle and several techniques for analyzing design change impacts on performance. This program, however, is limited to the specific design described in this document.

Even though users of this program may not necessarily be acquainted with Monte Carlo methods, only an elementary explanation of the method is made. Further, no attempt is made at a rigorous derivation or mathematical justification of the vector identities or algebra. It is assumed any users are familiar with vector algebra techniques.

It is quite possible to obtain misleading results of the power or energy into the cavity by inappropriate choice of heliostat tracking errors and mirror surface errors or by selecting too few sun rays to be traced through the optical part of the model. However, repeated use of the program results in experience which is often the only helpful clue to the proper choice of magnitude of tracking and surface errors and number of rays.

Simulations are initiated by card input using the FORTRAN NAMELIST feature in a subroutine called INITCOL. All variables in the NAMELIST table are defaulted to a specific central receiver baseline model. Only those portions of the model which change from the baseline need be input by card.

It should be noted that units are mixed. English units are used for all dimensions and geometric descriptions while the SI system of units is used for the flux and energy descriptions.

HELIAKI, as listed in this report, is operational on the Control Data Corporation 6600 Computer.

SECTION 2
BASIC FORMULATION

Given a position of a heliostat relative to the receiver, the amount of energy carried from any point on the sun's surface monochromatically at any given instant depends on the exact path of the ray through the optical interfaces of the system. These interfaces are the mirrors on the heliostats and the actual surface of the receiver.

The angle made by any ray with respect to each mirror surface is a function only of the angular position on the solar disk whence the ray came and the impact point on the particular mirror.

Thus, for any wavelength and perfect optics, the energy carried from the sun to the receiver surface can be found by specifying the four coordinates of the ray, independent of the number of optical elements in the optics train.

If the sun's disk coordinates are δ_1 and δ_2 and the impact point coordinates are X_1 and X_2, then the total thermal power absorbed in a wavelength interval $d\lambda$ is

$$E_{d\lambda} = \int_{X_1} \int_{X_2} \int_{\delta_1} \int_{\delta_2} E(X_1, X_2, \delta_1, \delta_2)\, dX_1\, dX_2\, d\delta_1\, d\delta_2 \qquad (1)$$

where X_1 and X_2 are bounded by the actual surface extent of the mirror. To obtain the energy from the entire solar spectrum, integration over all wavelengths is required. This yields

$$E_p = \underbrace{\int_{\lambda}}_{\text{total spectrum}} \overbrace{\int_{X_1} \int_{X_2}}^{\text{mirror surface}} \overbrace{\int_{\delta_1} \int_{\delta_2}}^{\text{sun disk}} E(X_1, X_2, \delta_1, \delta_2, \lambda)\, dX_1\, dX_2\, d\delta_1\, d\delta_2\, d\lambda \quad (2)$$

Introducing finite quality optics into the model introduces uncertainty in tracking accuracy and mirror quality.

There are four uncertain optical parameters that are known only statistically. The first two parameters are uncertainties in the angular position of the two gimbaled tracking drives (θ_1, θ_2). The second two parameters are the angular uncertainties in the mirror surface normal at any point on the mirror surface (ϕ_1, ϕ_2). We assume that each of these four parameters is statistically independent of each other or any other design parameter. For example, a given error in the mirror normal is equally likely anywhere on the mirror surface. The mirror is not known as a continuous surface with smooth waves or ripples but rather as a probability distribution of mirror normals perturbed from the mathematically correct shape by an assumed probability distribution. For each statistically known variable, the distribution is understood to be a "normal" or "standard error" distribution.

Now consider a random-variable Z defined by the normalized probability distribution P(Z). If we wished to calculate the mean value of Z(=$\bar{Z}$) or its expected value, we would form the integral of the product of $P_Z(Z)$ times Z over all allowed values of Z, i.e.,

$$\bar{Z} = \int_{-\infty}^{\infty} P_Z(Z)\, Z dZ \qquad (3)$$

To simulate a specific error set (θ_1, θ_2, ϕ_1, ϕ_2), one would have to evaluate

$$E_p(\theta_1,\theta_2,\phi_1,\phi_2) = \int_\lambda \int_{X_1} \int_{X_2} \int_{\delta_1} \int_{\delta_2} E(X_1,X_2,\delta_1,\delta_2,\lambda,\theta_1,\theta_2,\phi_1,\phi_2)\,dX_1\,dX_2\,d\delta_1\,d\delta_2\,d\lambda \tag{4}$$

Then the expected value of the thermal power absorbed ($\bar{E}_p$) is given by:

$$\bar{E}_p = \int_{\theta_1} \int_{\theta_2} \int_{\phi_1} \int_{\phi_2} P_{\theta_1}(\theta_1) P_{\phi_2}(\theta_2) P_{\phi_1}(\phi_1) P_{\phi_2}(\phi_2) E_p(\theta_1,\theta_2,\phi_1,\phi_2)\,d\theta_1\,d\theta_2\,d\phi_1\,d\phi_2 \tag{5}$$

because each distribution is statistically independent. The above expression is:

$$\bar{E}_p = \underbrace{\int_{\theta_1} \int_{\theta_2}}_{\text{tracking errors}} \underbrace{\int_{\phi_1} \int_{\phi_2}}_{\text{mirror imperfections}} P_{\theta_1} P_{\theta_2} P_{\phi_1} P_{\phi_2} \underbrace{\int_\lambda}_{\text{total spectrum}} \underbrace{\int_{X_1} \int_{X_2}}_{\text{mirror area}} \underbrace{\int_{\delta_1} \int_{\delta_2}}_{\text{sun disk}} E\,d\delta_2\,d\delta_1\,dX_2\,d\lambda\,d\phi_2\,d\phi_1\,d\theta_2\,d\theta_1 \tag{6}$$

To calculate the total thermal power redirected from the field of heliostats onto the receiver, one sums over the total number of heliostats

$$E_T = \sum_{i=1}^{\text{number of mirrors}} \bar{E}_{p_i} \tag{7}$$

Furthermore, integration over the total number of hours of sunlight during any given time period results in the expression

$$W_T = \int_{\text{time period}} E_T \, dt \tag{8}$$

The stochastic nature of four of the independent variables in the ten-integrals of Equation (8) and the prime objective of performing a parametric study of the performance of the system led to the decision that the experimental Monte Carlo approach was more suitable to the problem.

SECTION 3
METHODOLOGY

Basically, the premise of the method used to solve Equations (7) and (8) of the previous section is a Monte Carlo technique. Any Monte Carlo computation that yields quantitative results may be considered as estimating the value of a multiple integral. The simplest Monte Carlo approach is to observe random numbers, selected in such a way that they directly simulate the physical random processes of the problem at hand, and to deduce the required solution from the behavior of these numbers. In this program, that process involves the incident flux on the receiver over the direct solar flux on the heliostat field being equal to the convergent ratio of randomly drawn rays which reach the receiver divided by the total number of rays drawn uniformly over the heliostat field. Appropriate scaling of each ray value for reflectance and absorptance losses, tracking and reflective surface errors, etc., is included in the Monte Carlo simulation.

The simulation is accomplished by randomly selecting a sufficient number of sun rays to statistically represent the sun's intensity pattern as seen from the earth's surface. Solar limb darkening and atmospheric losses are accounted for. These same rays are allowed to impinge upon the entire heliostat field randomly and are reflected to the receiver should they strike a properly aligned reflecting surface. The rays drawn must represent the sun's power at that time so each ray is given a relative weighted value as a function of the time and the number of rays drawn. If annual energy is being calculated then each ray carries the appropriate amount of energy.

The general program flow to follow the physics of each interaction of individual rays through the optics train is shown in Figure 3-1. All executive-level tests are shown in the flow chart, from the mirror hit test to the receiver hit test. A number of check points along the ray path are not shown

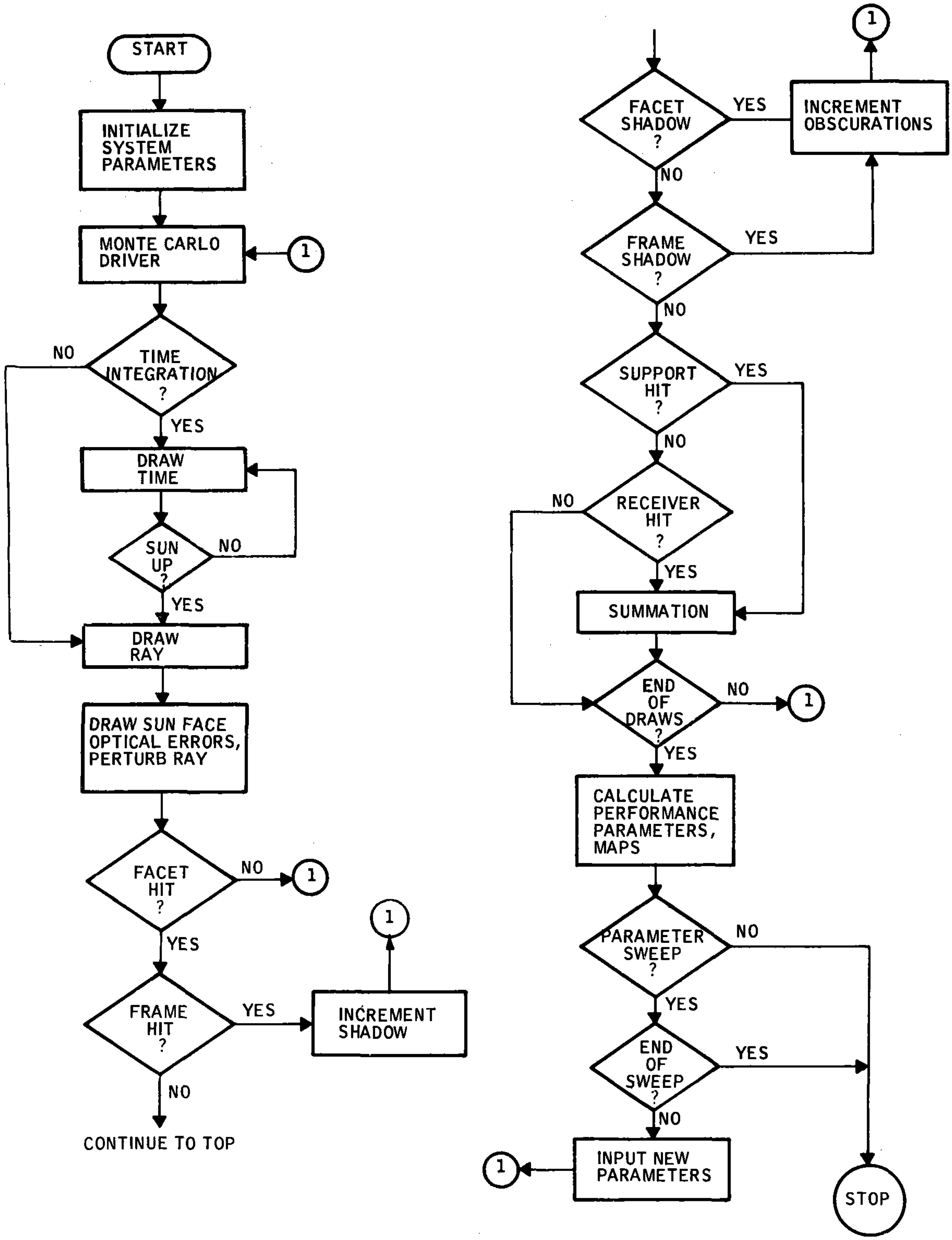


Figure 3-1. Optical Model Software Logic Flow

in this figure but are documented in Appendix A where detailed subroutine flow charts are presented. The interested reader is directed to these flow charts for a thorough understanding of the program. Each test of a specific ray interaction is accomplished using ray trace techniques. Given any one randomly determined individual ray start point, the ray may be traced to the ground or to a mirror or frame surface. If a mirror hit is found the individual ray is traced to its final destination.

The ray trace technique uses vector algebra to track each ray along its optical path. The following subsections describe the primary steps in the vector derivations, as well as the basic modeling philosophy. The sections are ordered to follow the actual program flow.

BASE VECTORS

The basic reference vectors in the ray trace code describe local vertical ($\vec{N}$), local north ($\vec{UN}$) and local east ($\vec{UE}$). Each of these vectors is a unit vector and the set ($\vec{N}$, $\vec{UN}$, $\vec{UE}$) is an orthonormal triad which can be thought of as originating at the tower center. Variations in the direction of these vectors with respect to position on the field are not considered. Thus, the heliostat field is assumed to be a flat plane tangent to the surface of the earth at the tower base. Figure 3-2 shows the field and reference vectors as well as a sun vector ($\vec{UR}$).

The sun vector is simply a unit vector along the ray path from the sun's center to the point on the earth's surface at which the tower is located. The sun vector is considered to be the same over the entire plane of the heliostat field. This introduces an error of less than 1 minute of arc per mile of distance from the tower base.

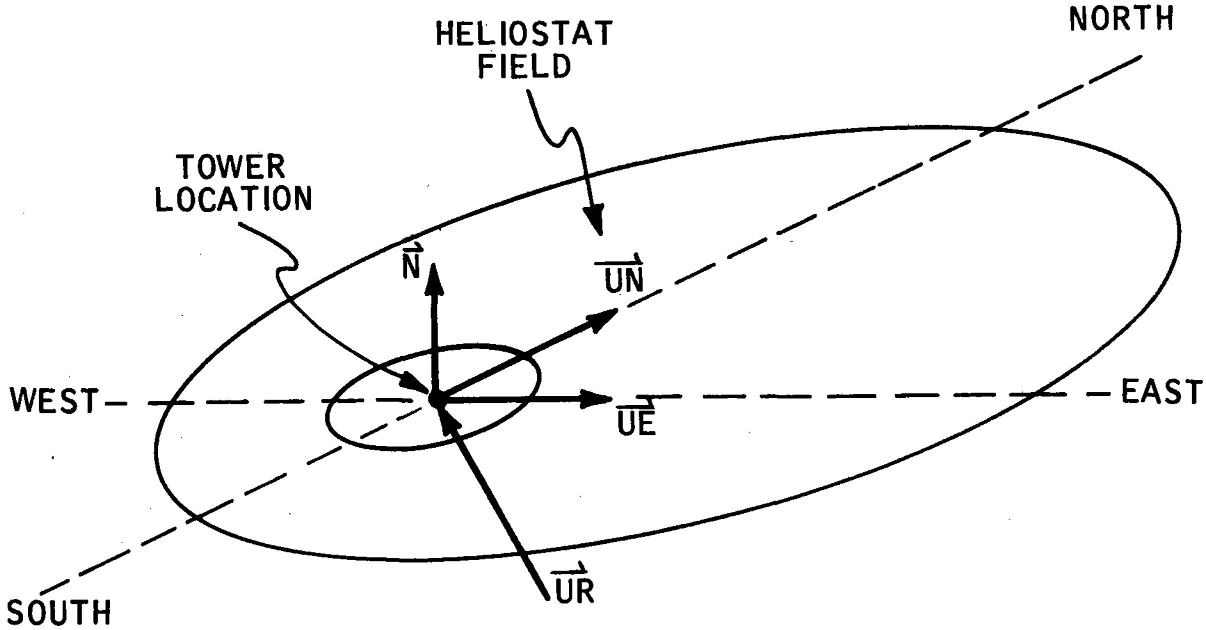


Figure 3-2. Field, Reference and Sun Vectors

Each of the reference vectors and the sun vector is calculated in subroutine VECTS. The vectors are calculated based on an initial vector triad located at the earth's center. However, the construction of all other vectors required in the ray trace analysis depends only on the ($\vec{N}$, $\vec{UN}$, $\vec{UE}$) triad and the earth center triad can be ignored.

HELIOSTAT FIELD MODEL

One of the first steps in the Monte Carlo simulation is the uniform draw of ray start points over the heliostat field. Specifically, points are drawn uniformly over an imaginery surface which covers the field of heliostats called the test plane. If the mirrors were allowed to assume all possible rotational attitudes, they could occupy all points within a cylinder centered around the heliostat center. If all such cylinders were bounded by planes tangent to the top and bottom of each cylinder, the test plane would be the upper plane and the ground plane would be the lower plane. Figure 3-3 shows an edge view of this. Once a ray start point is drawn, the trace of the ray from its start point on the test plane to its terminus on the ground plane can be found. The ray start points are drawn in subroutine MONTE or MONTE2.

Figure 3-4 shows that only those heliostats which are "close" or "along" the ray trace from the test plane to the ground plane could be involved in redirecting the ray. It is important to limit the number of "hit tests" (subroutine INHIT) to be numerically performed on each ray to those heliostats which lie along the ray path. Clearly, if all heliostats were tested for a hit for each ray drawn, the run time would be prohibitive. A simple algorithm performs the identification of the few (nominally 10) heliostats which can interact with the ray.

The identification algorithm (subroutine FINDIT) is based on two facts:

- The cylinders of influence of the individual heliostats do not overlap each other.
- The heliostat center locations can be uniquely and quickly identified.

Consider a top view of the test plane with a typical ray path drawn (see Figure 3-5). In this example, the heliostat boundaries on the field are shown as portions of circle arcs and radii. For our purposes the heliostats are simply numbered from 0 to 8. Heliostat number 1 is bounded by radii r_i and r_{i+1} as well as a boundary equidistant between heliostat number 0 and 1 and 1 to 2. The top view of the ray path shows that only heliostat number 4 can actually intercept the ray and redirect it toward the tower. The ray trace program uses a simple search along the ray path to identify the center of all closest heliostats from ray start to end. The search for closest centers is based on the zone boundaries and not the cylinders of influence. For the example in Figure 3-5, this implies that heliostats 1, 2, 4 and 6 will be included in the list for possible hits.

The method used to develop the list of heliostats is to first find the closest heliostat to the start point. Then the closest heliostat to the end point is found. If the closest heliostat to both the start and end point is the same, then the list is complete. We also have the case, as shown in Figure 3-4, where start and end points are closes to different heliostats. The program will then divide the ray path into many points and find the closest heliostat at each of these points along the ray path. The spacing of the test points along the line is not critical as long as it is less than one heliostat boundary dimension. When this test sweep is complete, the code has found a list of one, two or perhaps many different heliostats which could redirect the ray. The requirement that the heliostats cannot overlap guarantees that there are

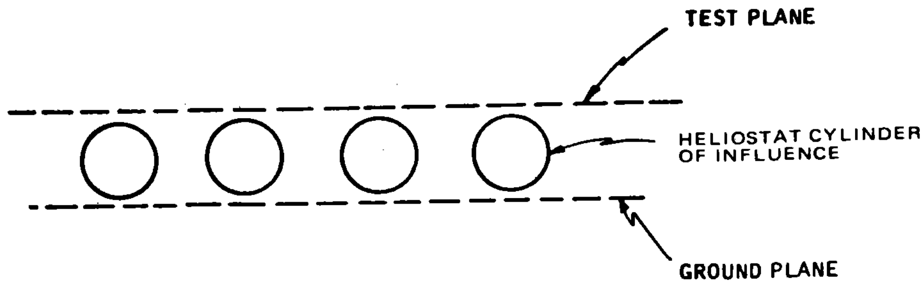


Figure 3-3. Test and Ground Planes

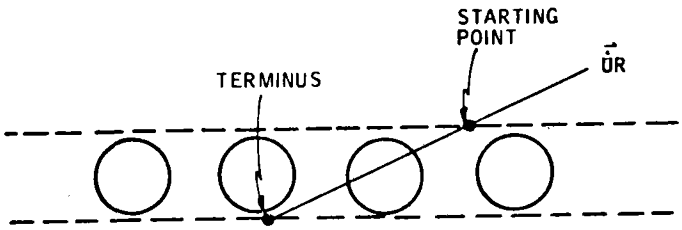


Figure 3-4. Heliostats Along Ray Path

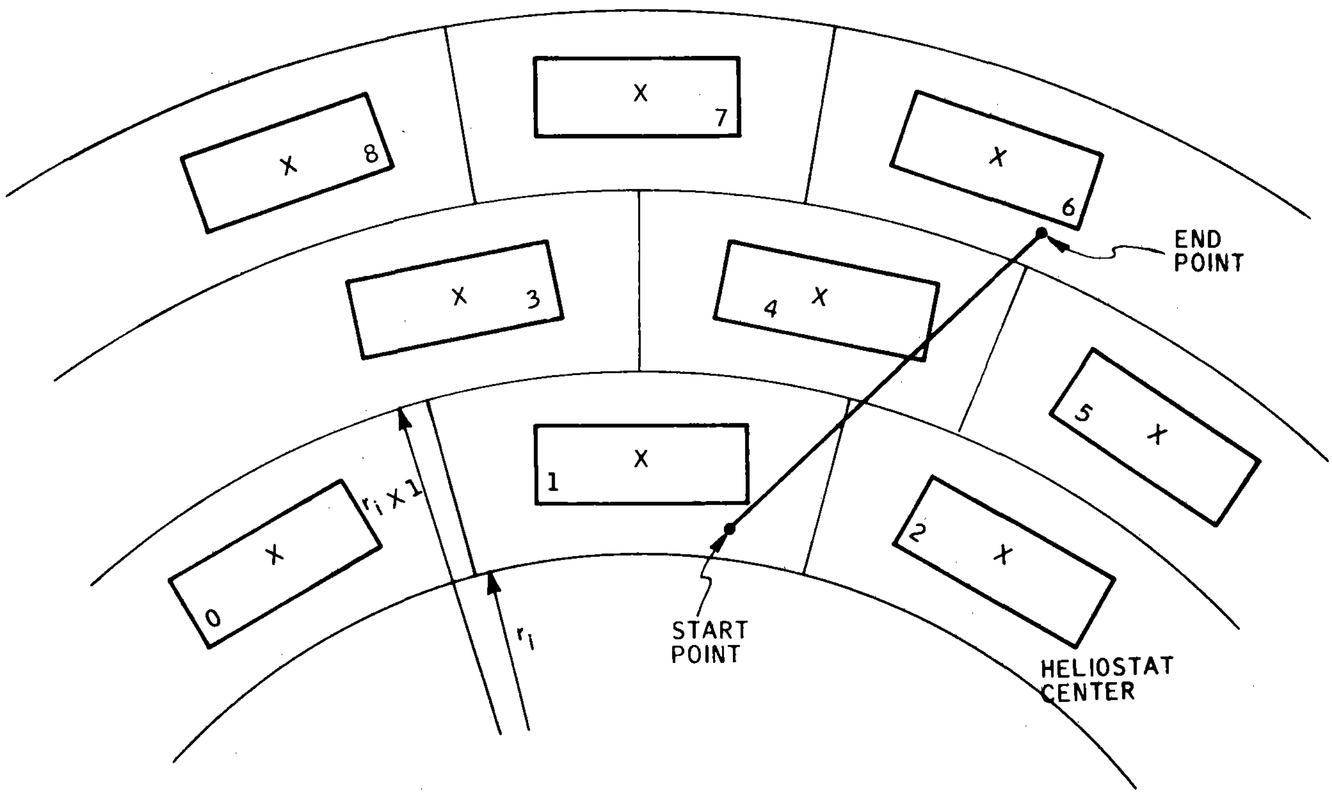


Figure 3-5. Top View of Ray Path and Cylinders of Influence

no other heliostats which could redirect the ray. This list of closest adjacent heliostats is more heliostats than could physically be involved with the ray.

It would be possible to further reduce the list of heliostats to be tested by using the distance formula to rule out any heliostats for which the closest ray approach lies outside the cylinder of influence. This was not done in the program because the distance formula requires as much computation time to execute as does the hit test itself and would add more complexity to the code.

HELIOSTAT HIT TEST

The next step in the process is to test all heliostats on the list of possibilities for a mirror hit. To establish a mirror hit or miss, the mirror normal must be constructed. This is done with knowledge of the sun vector, UR, and the mirror position and aim point relative to the tower base. As shown in Figure 3-6, a heliostat to be tested is at a position defined by the center coordinates X_c, Y_c, where the X axis lies along local east and Y is positive along local north. A vector from the heliostat center to the aim point on the aperture opening can be written as

$$\vec{T} = -X_c \vec{UE} - Y_c \vec{UN} + (TH-D_{col}/2) \vec{N} + \vec{\delta} \tag{9}$$

where $\vec{\delta}$ is a small vector from the tower top center out to the aim points (calculated in subroutine AIMPP). A unit vector pointing from the heliostat center to the aim point is

$$\vec{UT} = \vec{T}/|\vec{T}| \tag{10}$$

Using $\overrightarrow{UT}$ and $\overrightarrow{UR}$ the heliostat normal must be formed to redirect incoming rays along $\overrightarrow{UR}$ on the path to the aim point $\overrightarrow{UT}$. This is shown in Figure 3-7. The mirror normal, $\overrightarrow{UMN}$, is simply

$$\overrightarrow{UMN} = (\vec{UT} - \vec{UR}) / |\vec{UT} - \vec{UR}| \qquad (11)$$

as calculated in subroutine MIRRN.

The heliostat geometry used for all hit and blockage tests is shown in Figure 3-8. Honeywell's baseline heliostat consists of four mirror facets mounted on a single frame. The frame can be rotated about an outer axis to provide one tilt of the mirrors and an inner axis drive for each facet provides the other tilt function. The inner axis drive for all facets is provided by one motor such that the inner rotations are the same for all facets. However, the program does have an option to independently drive each inner axis (a separate motor for each facet).

The nominal mirror normal, UMN shown in Figure 3-7, is constructed as described above for the heliostat center position. This mirror normal is later rotated for a specified toe-in strategy (explained later) but, for the purpose of establishing a mirror hit the nominal mirror normal is assumed to be the normal for each facet. In addition to the mirror normal, a vector along the heliostat outer axis can be specified from knowledge of the heliostat center coordinates. The tilt-tilt baseline heliostat is oriented such that the outer axis is normal to the line of sight to the tower. This orientation is shown in Figure 3-9 and is considered advantageous with regard to mirror blockage losses and off-axis facet misalignment. Using this orientation rule, a unit vector along the outer axis is given by

$$\overrightarrow{UHV} = (Y_c \vec{UE} - X_c \vec{UN}) / \sqrt{Y_c^2 + X_c^2} \qquad (12)$$

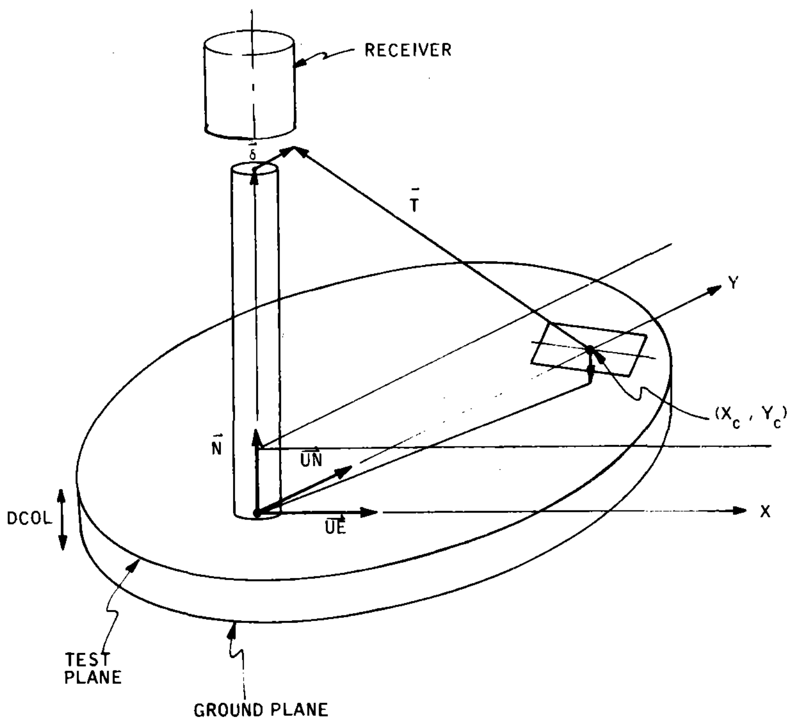


Figure 3-6. Construction of Tower Vector (T)

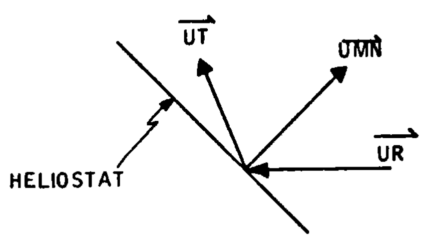


Figure 3-7. Unit Normal ($\overrightarrow{UMN}$)

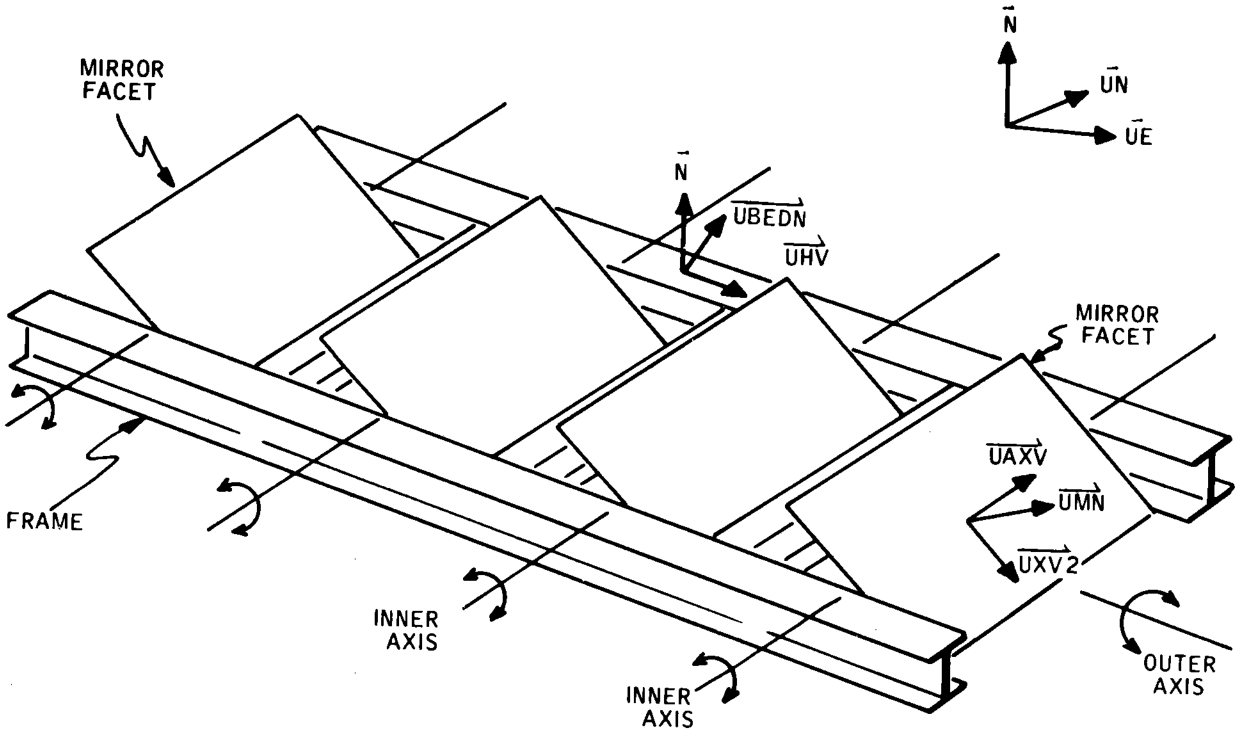


Figure 3-8. Heliostat Geometry (not to scale)

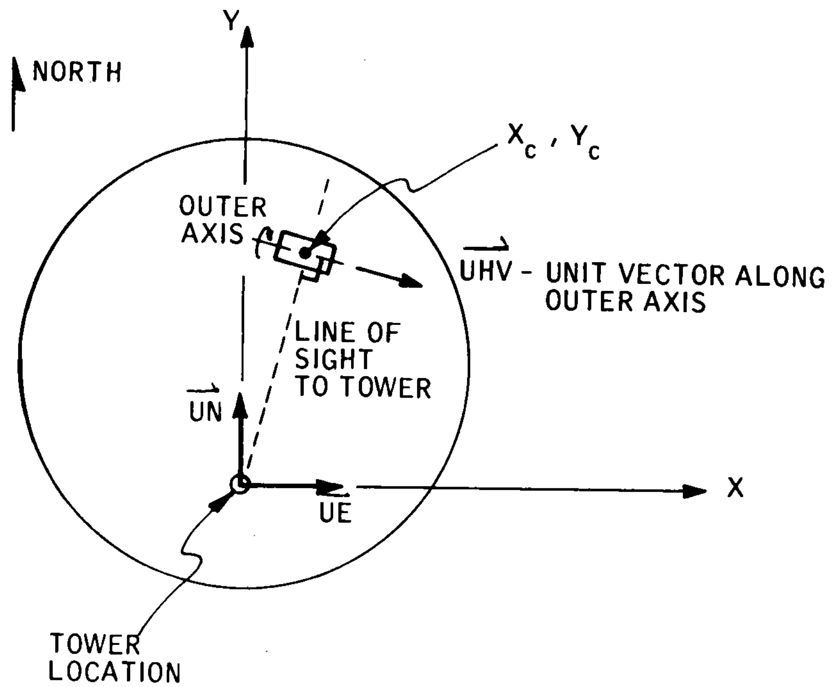


Figure 3-9. Heliostat Orientation

The remainder of the vectors needed to describe the heliostat frame and nominal facet orientations are found from $\overrightarrow{UMN}$ and $\overrightarrow{UHV}$ (as calculated in subroutine TRIADS). Referring to Figure 3-8, the vector along the inner axis of each facet is $\overrightarrow{UAXV}$, which is constructed by

$$\overrightarrow{UAXV} = \overrightarrow{UMN} \times \overrightarrow{UHV} \; / \; |\overrightarrow{UMN} \times \overrightarrow{UHV}| \tag{13}$$

The vector normal to the inner axis of each facet, and lying in the plane of the facet is $\overrightarrow{UXV2}$, which is simply

$$\overrightarrow{UXV2} = \overrightarrow{UAXV} \times \overrightarrow{UMN} \tag{14}$$

The last vector needed to define the frame orientation is $\overrightarrow{UBEDN}$, the normal to the top plane of the heliostat frame as found by

$$\overrightarrow{UBEDN} = \overrightarrow{UAXV} \times \overrightarrow{UHV} \tag{15}$$

Finally, the heliostat hit test can be most easily thought of as a series of four individual mirror facet hit tests. The geometry for each mirror hit test is shown in Figure 3-10, where $_{col}$ is the diameter of the cylinder of influence, (X_p, Y_p) are the east and north coordinates of the ray start point and $\overrightarrow{UR}$ is the sun vector.

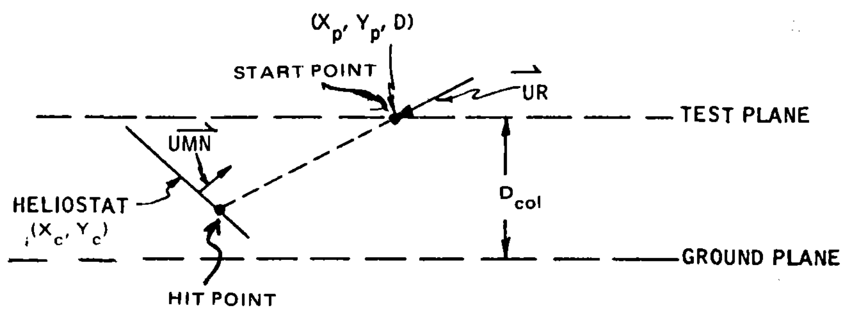


Figure 3-10. HIT Test Geometry

The vector from the start point to the hit point on the plane of the heliostat is given by

$$\vec{VR} = \vec{UR}\ L \qquad (16)$$

where L is an unknown length from the start point to the hit point on the plane.

Recall that any line not parallel to a plane must intersect the plane (not necessarily within the heliostat mirror boundary) at one and only one point. Thus, there will always be a real value of L. We can also write a vector from the ray start point to the center of the test facet (to be called $\vec{VC}$), which is given by

$$\vec{VC} = \vec{UE}\,(x_c - x_p) + \vec{UN}(y_c - y_p) + \vec{N}\ D_{col}/2 - D_{test}\ \vec{UHV} \qquad (17)$$

where ($\vec{UE}$) is a unit vector along the local east direction (positive east), ($\vec{UN}$) is a unit vector along local north (positive north) and ($\vec{N}$) is the unit normal to the earth surface (vertical up positive). The D_{test} term is the distance from the heliostat center to the test facet center.

Since both $\vec{VC}$ and $\vec{UR}$ go from the same point in space to the surface of a plane normal to $\vec{UMN}$ they must have the same projected length along $\vec{UMN}$ even though they do not enter the $\vec{UMN}$ plane at the same point. Thus, we can write the identity

$$\vec{VC} \cdot \vec{UMN} = \vec{VR} \cdot \vec{UMN} \qquad (18)$$

and substituting Equation((16) into Equation (18) we have

$$\vec{VC} \cdot \vec{UMN} = L\ \vec{UR} \cdot \vec{UMN} \qquad (19)$$

which is a scalar equation for the unknown L. Now that we know the vector $\vec{VR}$ we can calculate where $\vec{VR}$ touches the plane relative to the mirror facet center.

The vector in the mirror surface plane from the center of the facet out to the point where the ray hits the plane is given by

$$\overrightarrow{RRIF} = \vec{VR} - \vec{VC}$$

$$= L\,\vec{UR} - \vec{SC} \qquad (20)$$

The hit test is completed by simply comparing the hit point coordinates, as calculated from $\overrightarrow{RRIF}$, to the facet boundaries on the $\overrightarrow{UMN}$ plane. The order of heliostats tested in this way is from the ray start point to the end point. Thus the first time a hit is found the ray is redirected. Succeeding facets and heliostats (if any) are also tested and any hits are added to the shadow count.

Since the mirror facets are held in place by a frame structure as previously shown, it is possible that the frame may shadow the mirror surface. For any ray which is found to hit a mirror surface, the program will check for a prior hit on the frame structure. The frame modeled in the ray trace code consists of two "I" beam side supports, three "I" beam cross members and angle iron braces in the top frame plane. Figure 3-11 shows a sketch of the frame without mirror facets and some of the vectors required to test for a frame shadow. The "$\vec{VS}$" vectors start at the ray start point on the test plane and extend to a point on the frame corresponding to the middle of one of the seven different planes defined by the "I" beam structure. For example, the vector $\overrightarrow{VS5}$ goes from the ray start point (X_p, Y_p) to the middle of the plane defined by the vertical member of the first "I" beam cross member. Similarly, the $\overrightarrow{VS1}$ vector goes from the start point to the middle of the top plane as defined by the top piece of all "I" beams and the angle iron braces. The construction of the "$\vec{VS}$" vectors required for the frame shadow test is given below:

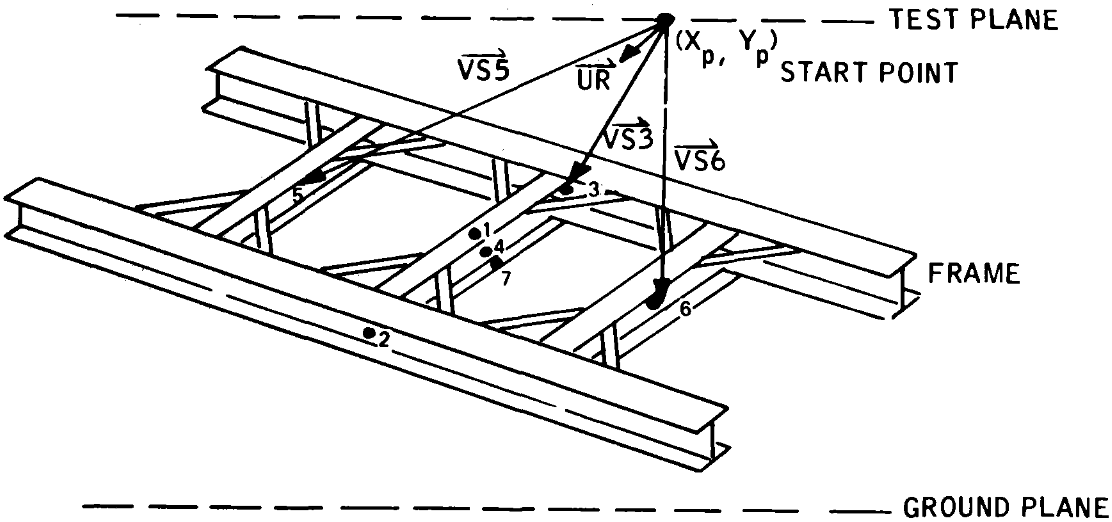


Figure 3-11. Heliostat Frame Model

$$\overrightarrow{VS1} = (X_c - X_p)\overrightarrow{UE} + (Y_c - Y_p)UN - \frac{DCOL}{2}\vec{N} - HTMIR\ \overrightarrow{UBEDN} \quad (21)$$

$$\overrightarrow{VS2} = \overrightarrow{VS1} + \left(\frac{WD+CAP+WLONG}{2}\right)\overrightarrow{UAXV} - \frac{WSIDE}{2}\overrightarrow{UBEDN} \quad (22)$$

$$\overrightarrow{VS3} = \overrightarrow{VS1} - \left(\frac{WD+CAP+WLONG}{2}\right)\overrightarrow{UAXV} - \frac{WSIDE}{2}\overrightarrow{UBDEN} \quad (23)$$

$$\overrightarrow{VS4} = \overrightarrow{VS1} - \frac{HTCROS}{2}\overrightarrow{UBEDN} \quad (24)$$

$$\overrightarrow{VS5} = \overrightarrow{VS4} - XDF\ \overrightarrow{UHV} \quad (25)$$

$$\overrightarrow{VS6} = \overrightarrow{VS4} + XDF\ \overrightarrow{UHV} \quad (26)$$

$$\overrightarrow{VS7} = \overrightarrow{VS1} - HTCROS\ \overrightarrow{UBEDN} \quad (27)$$

Where the definition of the scalar dimensional quantities may be found in Appendix C.

A frame hit test follows the logic of the mirror hit test very closely. Each plane of the frame structure is defined by a plane normal vector already constructed by our definition of the heliostat orientation vectors. For the top and bottom planes, $\overrightarrow{UBEDN}$ is the plane normal. For the vertical members of the "I" beam cross braces, the plane normal is defined by $\overrightarrow{UHV}$ and the side structures vertical member's plane normal is $\overrightarrow{UAXV}$.

As an example of the hit test, consider the frame top plane. A vector from the start point to the sun ray hit point on the plane is L $\overrightarrow{UR}$. As in the mirror hit test we have two vectors, L $\overrightarrow{UR}$ and $\overrightarrow{VS1}$, which start at a single location in space and end on a plane with known surface normal, in this case $\overrightarrow{UBEDN}$. The length L from the start point to the hit point along the sun vector $\overrightarrow{UR}$ is found by

$$L\,\overrightarrow{UR} \cdot \overrightarrow{UBEDN} = \overrightarrow{VS1} \cdot \overrightarrow{UBEDN} \tag{28}$$

which is a scalar equation for L. The vector from the plane center point (1) to the hit point is

$$\overrightarrow{RHIT} = -\overrightarrow{VS1} + L\,\overrightarrow{UR} \tag{29}$$

Then for an x, y coordinate system centered at point 1 of Figure 3-11, the coordinates of the hit point are:

$$XHIT = \overrightarrow{RHIT} \cdot \overrightarrow{UHV} \tag{30}$$

and

$$YHIT = \overrightarrow{RHIT} \cdot \overrightarrow{UAXV} \tag{31}$$

where $\overrightarrow{UAXV}$ is a unit vector along the facet axle and $\overrightarrow{UHV}$ is a unit vector along the heliostat outer axle. A simple check is made to determine if the ray hit a frame by comparing the values of XHIT and YHIT to the dimensions of that portion of the frame. Again the order of the heliostats tested in this way is from ray start to hit point. Thus, the first time a frame hit is found it is compared to the mirror hit to determine which came first along the ray path. If a frame hit is found prior to the mirror hit, then a frame shadow exists. If no frame shadow exists the ray will be reflected from the mirror surface.

REFLECTED RAY

To this point, the analysis has not involved the finite size of the sun or the tracking uncertainties of the heliostats. This simply means that the ray has been traced from its uniform draw start point to the mirror or the ground. Physically this means that we have ignored the finite size of the sun and the tracking errors in the shadow analysis. The finite sun and finite tracking errors tend to "blur" the edges of the mirrors and the edges of the shadows somewhat when taken on average over the whole field.

If at this point in the flow, one of the heliostats on the list of possibilities has in fact tested out to have a hit, we proceed to perturb $\overrightarrow{UR}$ and $\overrightarrow{UMN}$ for the finite sun size, the tracking errors and the mirror surface slope uncertainty. To begin the perturbation process a ray start point is drawn over the sun's face. The simplest case of this is the assumption that the sun is a "flat" disk of brightness in the sky. The plot of this is shown in Figure 3-12. The uniform draw over a disk is simply a uniform draw over the polar coordinate (θ) and a weighted draw over ρ (see Figure 3-13).

The weighted draw over ρ comes from the fact that more rays must be drawn in the annulus ρ to $\rho + d\rho$ at large values of ρ than at small values of ρ. Another way to consider this is to plot the sun's energy from 0 out to ρ versus ρ (see Figure 3-14). The formula for this curve is simply

$$E = E_T (\rho/\rho_{max})^2 \tag{32}$$

where E_T is the total energy from the sun's disk and ρ_{max} is the maximum angular extent of the sun.

Thus, if we want to draw uniformly over the area of the disk, we simply draw uniformly over the abscissa (energy axis) of Figure 3-14 and Equation (32) is inverted to find the ordinate value (ρ) which we want. Thus, if we draw the random number x_1 uniformly from 0 to 1 then the value of ρ for each x_1 is given by the inverse of Equation (32) or

$$\rho = \rho_{max} \sqrt{x_1} \tag{33}$$

The (θ) coordinate is found from another (independent) uniform number x_2 drawn from 0 to 1 by

$$\theta = 2\pi x_2 \tag{34}$$

If we arbitrarily define two axes in the sun face ($\overrightarrow{UX_1}$, $\overrightarrow{UX_2}$) then the rotation angles of $\overrightarrow{UR}$ about these axis ($\Delta\theta_1$, $\Delta\theta_2$) are shown in Figure 3-15, which are given by

$$\Delta\theta_1 = \rho \sin \theta \tag{35}$$

$$\Delta\theta_2 = \rho \cos \theta \tag{36}$$

Thus, we can perturb $\overrightarrow{UR}$ into $\overrightarrow{UR}'$ with

$$\overrightarrow{UR}' = \frac{(\overrightarrow{UR} - \text{Tan}\,\Delta\theta_2\,\overrightarrow{UX1} - \text{Tan}\,\Delta\theta_1\,\overrightarrow{UX2})}{\sqrt{1 + \text{Tan}^2\,\Delta\theta_2 + \text{Tan}^2\,\Delta\theta_1}} \qquad (37)$$

The three-space drawing from which this can be derived is shown in Figure 3-16. Notice that ($\overrightarrow{UR}$, $\overrightarrow{UX1}$, $\overrightarrow{UX2}$) form an orthonormal triad.

This is all the vector algebra necessary to incorporate the finite sun size into the analysis. The computer code includes a limb-darkening option and an option with limb darkening and scattering outside the geometric sun perimeter.

The process we have outlined here is the same for both of these options except that the weighted draw of ρ is weighted in such a way that the draw is again uniform over the new solar disk energy distribution. This involves plotting brightness versus angular distance from the sun's center and integrating energy as before. Then, the integrated energy curve is curve-fit and the fit function is inverted. This inverse function (analogous to Equation (33) is then the basis for the draw.

The next step in the trace process is to perturb the unit mirror normal $\overrightarrow{UMN}$ for the uncertainties in heliostat tracking (subroutine PERT3). This involves a first rotation of $\overrightarrow{UMN}$ about an axis (the outer axis) which is not normal to it. The essential vectors were previously described as the heliostat orientation vectors as shown in Figure 3-17. The rotation for outer axis tracking errors is a rotation about the $\overrightarrow{UHV}$ vector. The triad used for this rotation is ($\overrightarrow{UBEDN}$, $\overrightarrow{UAXV}$, $\overrightarrow{UHV}$) as shown in Figure 3-18. The rotation (tracking error) is shown as $\Delta\phi_1$ and the rotated heliostat orientation vectors are shown as dashed vectors $\overrightarrow{UBEDN}'$ and $\overrightarrow{UAXV}'$. The vectors are constructed by

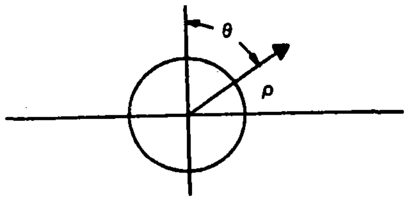


Figure 3-12. Ray Start Point Plot

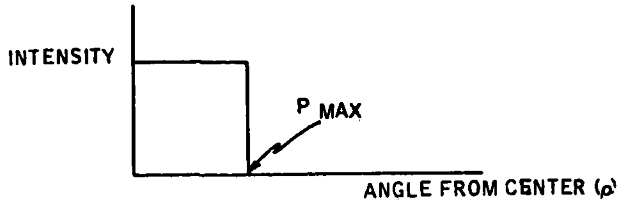


Figure 3-13. Uniform and Weighted Draw

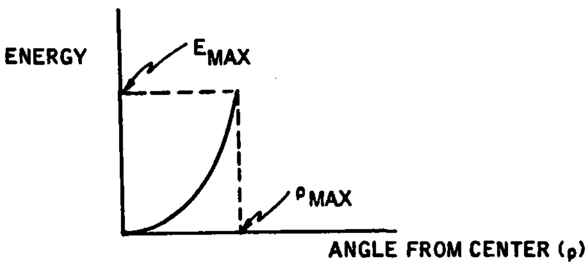


Figure 3-14. Energy Plot

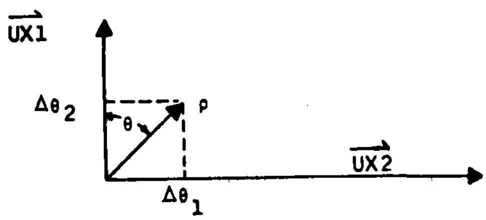


Figure 3-15. Rotation Angles

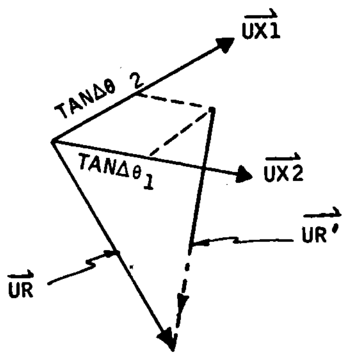


Figure 3-16. Three-Space Drawing

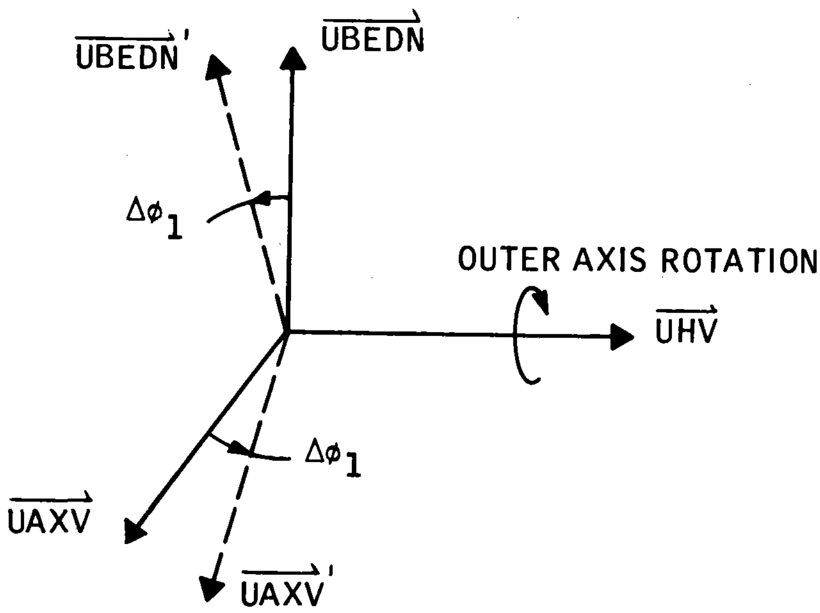


Figure 3-17. Heliostat Orientation Vectors

$$\overrightarrow{UBEDN'} = \cos \Delta\phi_1 \overrightarrow{UBEDN} + \sin \Delta\phi_1 \overrightarrow{UAXV} \qquad (38)$$

$$\overrightarrow{UAXV'} = \cos \Delta\phi_1 \overrightarrow{UAXV} - \sin \Delta\phi_1 \overrightarrow{UBEDN} \qquad (39)$$

Next, the effect of this rotation on the nominal mirror normal must be developed. Referring to Figure 3-18, the $\overrightarrow{UMN}$ and $\overrightarrow{UXV2}$ vectors must rotate around $\overrightarrow{UHV}$. With the rotation about $\overrightarrow{UHV}$ the components of $\overrightarrow{UMN}$ and $\overrightarrow{UXV2}$ along $\overrightarrow{UHV}$ are unchanged. The magnitude of the projections of $\overrightarrow{UMN}$ and $\overrightarrow{UXV2}$ onto $\overrightarrow{UBEDN}$ onto $\overrightarrow{UBEDN}$ and $\overrightarrow{UAXV}$ are the same as the projections onto the rotated frame normal and inner axis vectors, $\overrightarrow{UBEDN'}$ and $\overrightarrow{UAXV'}$.

Reference back to Figure 3-17 may aid in clarifying this fact. Therefore, the rotated vectors can be written as

$$\overrightarrow{UMN}' = (\overrightarrow{UMN} \cdot \overrightarrow{UHV})\, \overrightarrow{UHV} + (\overrightarrow{UMN} \cdot \overrightarrow{UBEDN})\, \overrightarrow{UBEDN}' \tag{40}$$

$$\overrightarrow{UXV2}' = (\overrightarrow{UXV2} \cdot \overrightarrow{UHV})\, \overrightarrow{UHV} + (\overrightarrow{UXV2} \cdot \overrightarrow{UBEDN})\, \overrightarrow{UBEDN}' \tag{41}$$

The second rotation is for tracking errors about the inner axis. The angular error is denoted as $\Delta\phi_2$. The rotation in this case is about the vector $\overrightarrow{UAXV}'$. Only the vectors associated with the mirror facet must be rotated. These vectors ($\overrightarrow{UMN}'$ and $\overrightarrow{UXV2}'$) and the rotation are shown in Figure 3-19. The fully rotated vectors are

$$\overrightarrow{UMN}'' = \cos \Delta\phi_2\, \overrightarrow{UMN}' + \sin \Delta\phi_2\, \overrightarrow{UXV2}' \tag{42}$$

$$\overrightarrow{UXV2}'' = \cos \Delta\phi_2\, \overrightarrow{UXV2}' - \sin \Delta\phi_2\, \overrightarrow{UMN}' \tag{43}$$

The error angles ($\Delta\phi_1$, $\Delta\phi_2$) are drawn at random with a normal distribution (standard error distribution) having a mean and variance specified by the user of the program. If the details of the heliostat drive mechanism can be more accurately modeled a distribution of error angles which more nearly matches the reality of the system could be substituted easily for the normal distribution.

Recall that the derived $\overrightarrow{UMN}''$ vector is the nominal mirror normal at the optical axis of the heliostat. In other words, it describes the position of an imaginary mirror facet located at the heliostat geometric center. The actual normal for any one of the individual heliostat facets differs slightly from this normal in that each facet may be toed-in, or canted slightly toward the heliostat center to improve the total heliostat focusing ability. A possible toe-in alignment is shown for a side view in Figure 3-20. The program may develop a toe-in angle, θ_t, for each facet of each heliostat in the field (subroutine TOEIN). The toe-in angle is specified by a reference sun position for which all mirror facets in the field are aligned to redirect incoming rays as nearly as possible to a single focal point. Given the toe-in angle for a specific mirror facet, the facet center normal and tangent vectors are constructed by

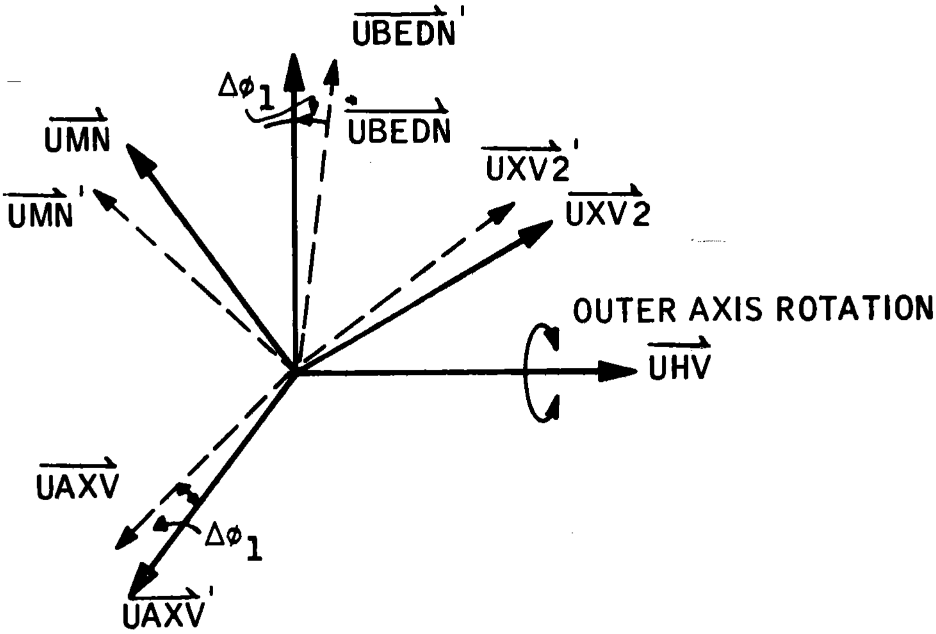


Figure 3-18. Rotated Heliostat Orientation Vector

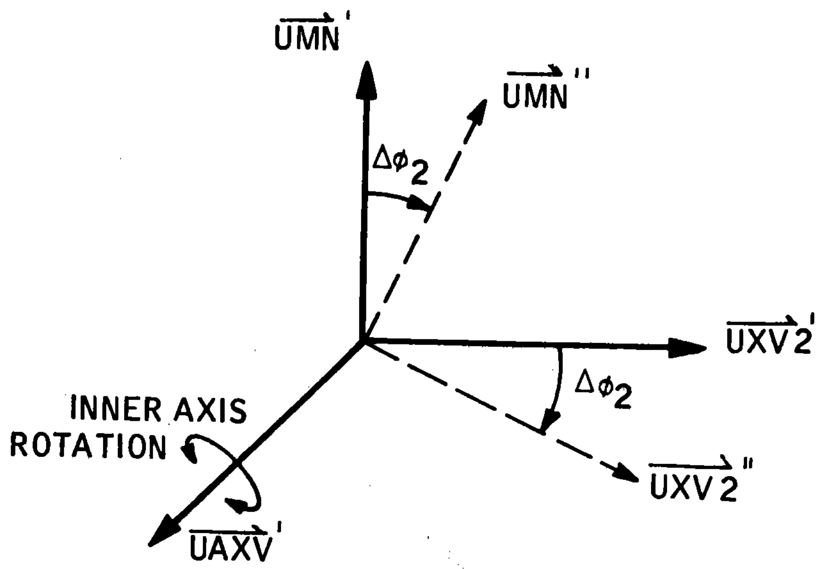


Figure 3-19. $\overrightarrow{UMN}$ and $\overrightarrow{UXV}2$ Rotation

$$\overrightarrow{UMN}_i'' = \cos\theta_t \, \overrightarrow{UMN}'' + \sin\theta_t \, \overrightarrow{UXVZ}'' \quad (44)$$

$$\overrightarrow{UXVZ}_i'' = \cos\theta_t \, \overrightarrow{UXVZ}'' - \sin\theta_t \, \overrightarrow{UMN}'' \quad (45)$$

This represents a simple rotation of the mirror facet orientation vectors about the inner axis and is quite similar to the rotation for tracking errors on the inner axis.

The mirror normal at the hit point on the facet surface is found from knowledge of the facet shape. For the baseline tilt-tilt heliostat, each facet has a spherical surface which focuses at a distance F_s such that the radius of curvature is $2F_s$. The facet surface and required vectors are shown in Figure 3-21. Recall that the vector from the facet center to the hit point, $\overrightarrow{RHS}$, was found in the mirror hit test derivation and was previously called $\overrightarrow{RRIF}$. By ignoring the small displacement between the hit point indicated by $\overrightarrow{RHS}$ and the actual mirror surface location, the mirror normal at the hit point ($\overrightarrow{UNN}''$) can be found by

$$\overrightarrow{UNN}'' = (-\overrightarrow{RHS} + 2F_s \, \overrightarrow{UMN}_i'')/(\overrightarrow{RHS} + 2F_s \, \overrightarrow{UMN}_i'') \quad (46)$$

Neglecting the small displacement can be thought of as modeling the facet surface as a fresnel mirror so that each element in the mirror is approximately in a single plane normal to the nominal mirror normal.

A local facet tangent vector is constructed as follows:

$$\overrightarrow{TT} = \overrightarrow{RHS} - (\overrightarrow{RHS} \cdot \overrightarrow{UNN}'') \, \overrightarrow{UNN}'' \quad (47)$$

and a unit vector tangent to the mirror surface at the hit point is

$$\overrightarrow{UTT}'' = \overrightarrow{TT}/|\overrightarrow{TT}| \quad (48)$$

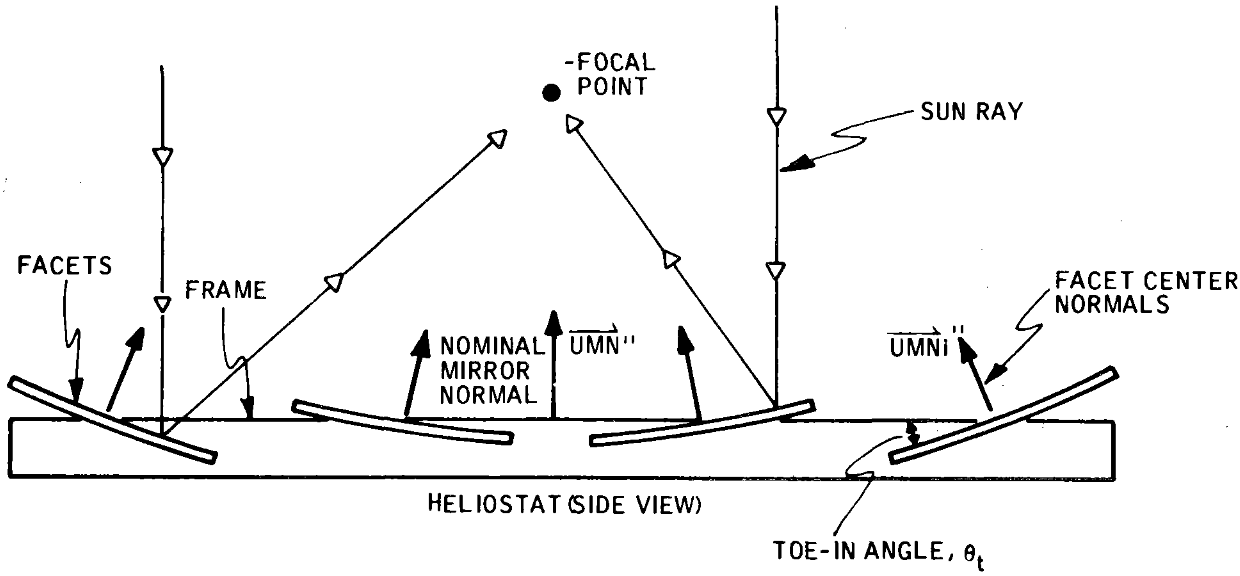


Figure 3-20. Heliostat Optical Model

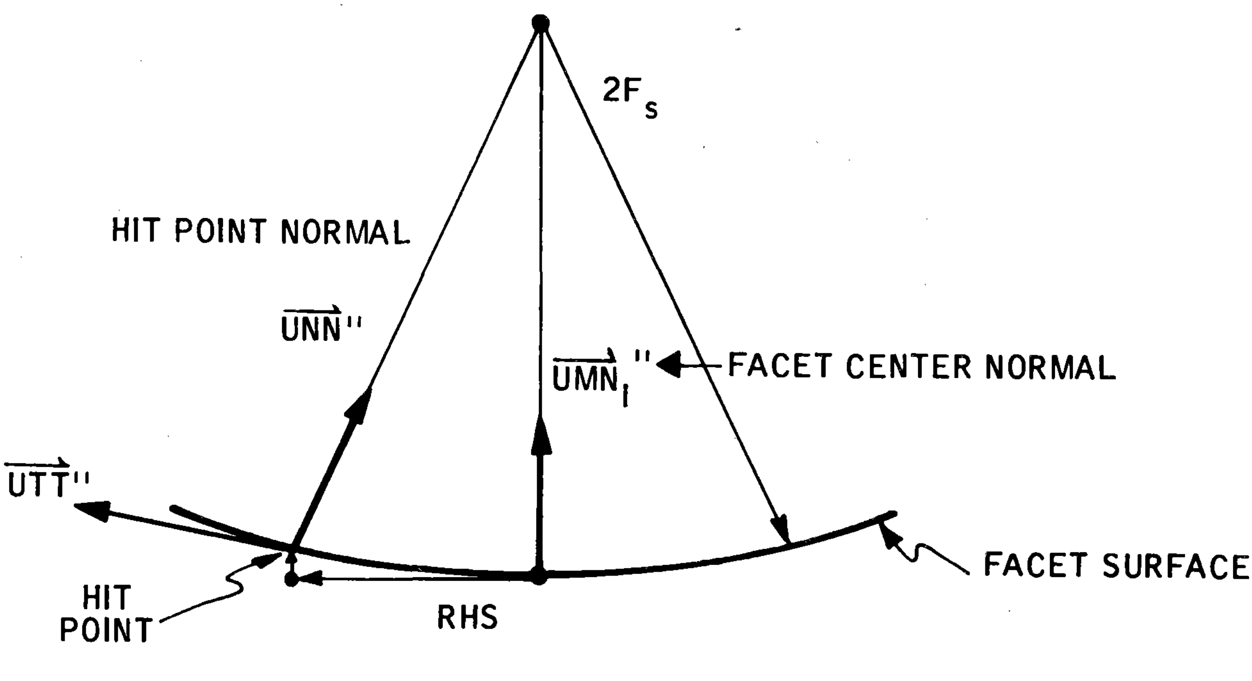


Figure 3-21. Heliostat Facet Vector

To complete a triad at the hit point, a second tangent vector is found by

$$\overrightarrow{UT2}'' = \overrightarrow{UTT}'' \times \overrightarrow{UNN}'' \quad (49)$$

The next and final perturbation of the heliostat mirror normal is the angular rotation which represents mirror surface irregularity. The sketch of this perturbation is shown in Figure 3-22. The final, fully perturbed mirror normal vector is called $\overrightarrow{UNNP}$ and is given by

$$\overrightarrow{UNNP} = \cos \delta_1 \overrightarrow{UNN}'' + \sin \delta_1 (\cos \delta_2 \overrightarrow{UTT}'' + \sin \delta_2 \overrightarrow{UT2}'') \quad (50)$$

where δ_2 is drawn uniformly from 0 to 360 degrees and δ_1 is drawn with a normal distribution having a specified mean and variance. Physically, what this last perturbation means is that the mirror surface normal is locally out of alignment with the average normal by an amount δ_1. The plane in which the δ_1 rotation occurs is equally likely to occur in any direction around the local azimuth. Recall that at this point in the ray trace we can find the position on the heliostat of the ray being traced from the vector $\overrightarrow{RRIF}$. With this we could include a perturbation of the normal which was a function of position on the heliostat surface. Such a position-dependent variation could be a gravity or wind load deflection. If the wind forces and deflections were known only stochastically, this also could be included in the analysis. The code, to date, has not been modified for these types of local errors.

The reflected ray vector can now be calculated from the mirror normal $\overrightarrow{UNNP}$ and the sun vector $\overrightarrow{URP}$. The vector algebra simply obeys Snell's Law as shown in Figure 3-23. The reflected ray unit vector $\overrightarrow{US1}$ is

$$\overrightarrow{US1} = -2(\overrightarrow{UR}' \cdot \overrightarrow{UNNP})\, \overrightarrow{UNNP} + \overrightarrow{UR}' \quad (51)$$

Thus, the $\overrightarrow{US1}$ vector represents a ray path which includes the effects of a finite sun size, imperfect tracking drives, a facet toe-in strategy, and mirror surface imperfections.

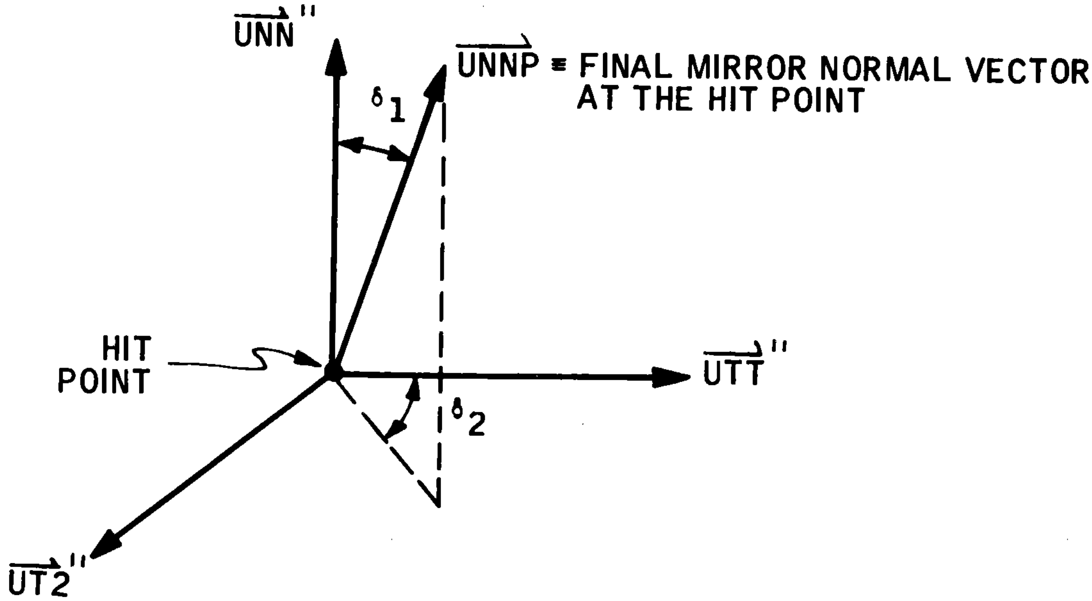


Figure 3-22. Mirror Normal Perturbation

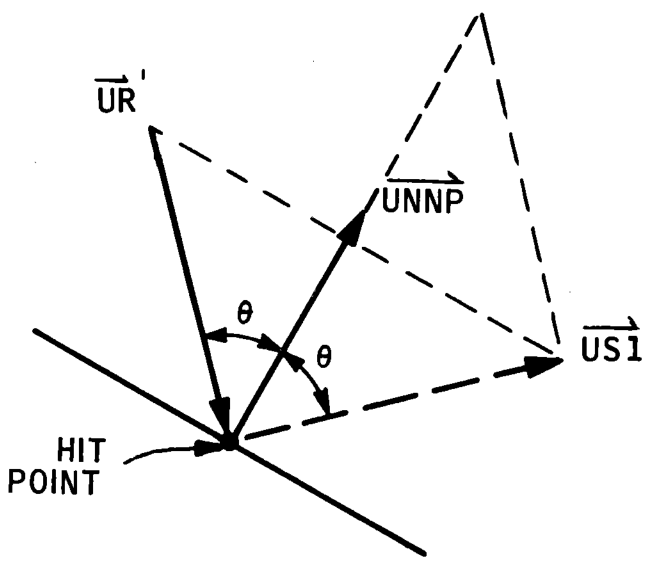


Figure 3-23. Reflected Ray Vector

BLOCKAGE

The next check point along the ray path is to determine whether or not the reflected ray ($\overrightarrow{US1}$) passes cleanly out of the mirror field. The first step in this process checks for a block by another mirror facet on the same heliostat as the hit facet, or by the frame structure which supports the facets.

The blockage test for mirror facet is much the same as the mirror hit test already described. The test consists of finding the intersection of the reflected ray $\overrightarrow{US1}$ with the plane of another mirror facet with normal $\overrightarrow{UMN}$. For the purposes of deciding whether or not $\overrightarrow{US1}$ is blocked, we ignore the effect of the small error rotations on the mirror normal vectors. This results in translations on the order of inches while pertinent facet dimensions are on the order of many feet.

The geometry for a mirror blockage test is shown in Figure 3-24. The vector $\overrightarrow{XC}$ starts at the middle of the hit facet and goes to the middle of the test facet. If the unknown length of the vector from the incoming ray hit point to the outgoing ray ($\overrightarrow{US1}$) blockage point is called L, then our basic hit test formulation for L is

$$L\ \overrightarrow{US1} \cdot \overrightarrow{UMN} = (\overrightarrow{XC} - \overrightarrow{RHS}) \cdot \overrightarrow{UMN} \tag{52}$$

from which we can easily solve for the length L. The vector from the test facet center to the blockage point is $\overrightarrow{RRB}$, which, by simple fector addition is

$$\overrightarrow{RRB} = -\overrightarrow{XC} + \overrightarrow{RHS} + L\ \overrightarrow{US1} \tag{53}$$

The blockage test is completed by comparing the blockage point coordinates as defined by $\overrightarrow{RRB}$ to the test facet mirror boundaries. If a block is found, the blockage test is completed. If no block is found on any test facet then we proceed to check for frame blocks.

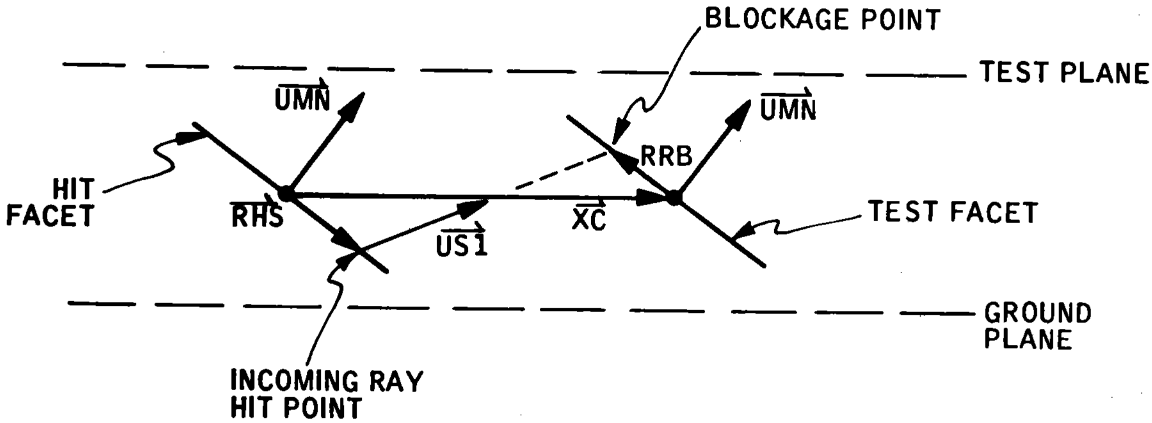


Figure 3-24. Mirror Blockage Test

The frame block test is again similar to the frame hit test and the method will not be repeated here. If a frame block is not found the program will go on to check for blockage by neighboring heliostat mirror facets or frames. These tests logically follow the procedures already discussed. The first step in the procedure is to find the list of all neighboring heliostats which could block the ray. The closest heliostats are found for a ray path extending from the mirror hit point to the test plane along $\overrightarrow{US1}$. As for incoming rays, the list of closest heliostats is developed by checking first the start and end point of the closest heliostats. For the blockage list, the first heliostat is the hit heliostat. If the last heliostat is the same as the first then no blockage by adjacent heliostats is possible and the procedure is terminated.

When other heliostats are in the outgoing ray path, the code checks one by one for blocks, with mirrors blocks checked first and frame blocks second. Tests for hit points are by now familiar to the reader. One brief example here should sufficiently describe the blockage test for adjacent heliostats. For instance, a block by the frame of a neighboring heliostat is shown in Figure 3-25. On this example, the incoming ray ($\overrightarrow{UR}$) hits the facet on the far left of the first heliostat and the reflected ray ($\overrightarrow{US1}$) is shown to strike the adjacent heliostat frame on the vertical plane of the near side "I" beam.

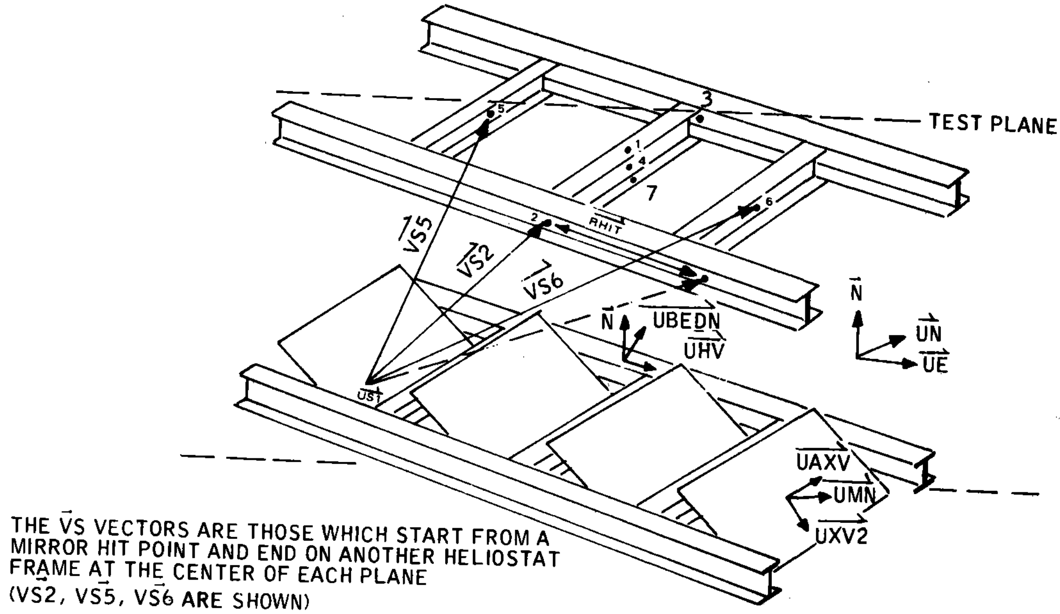


Figure 3-25. Frame Block by Neighboring Frame

The "$\overrightarrow{VS}$" vector from the hit point to the center of the test frame plane is $\overrightarrow{VS2}$. The length of the vector along $\overrightarrow{US1}$ from the hit point to the blockage point is L such that

$$L\ \overrightarrow{US1} \cdot \overrightarrow{UAXV} = \overrightarrow{VS2} \cdot \overrightarrow{UAXV} \tag{54}$$

where $\overrightarrow{UAXV}$ is normal to the test plane in this example. The above equation is solved for L and the vector from the test plane center to the blockage point ($\overrightarrow{RHIT}$) is

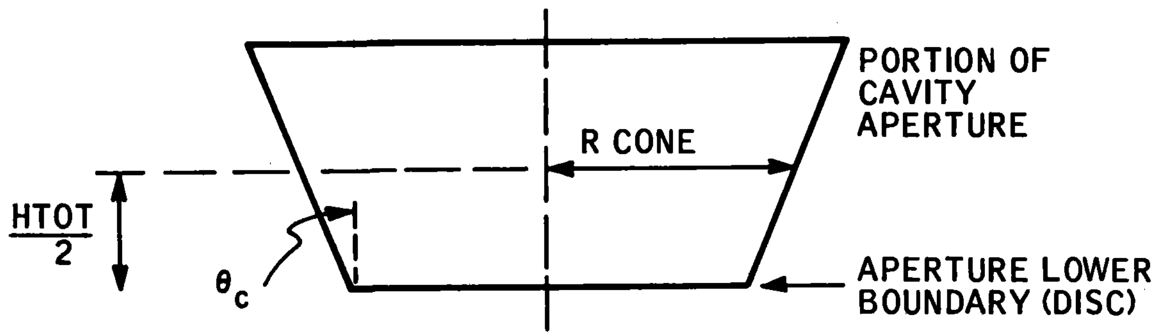
$$\overrightarrow{RHIT} = -\ \overrightarrow{VS2} + L\ \overrightarrow{US1} \tag{55}$$

By checking the end point of $\overrightarrow{RHIT}$ against the dimensions of the frame side member a block or no block is determined. If the blockage tests are completed and no blocks are found, then the redirected ray has cleared the test plane and can be checked for receiver hits.

RECEIVER HITS

Two routines, CONE and PIPE, are used to determine whether or not the ray hit the receiver and if it hit, where on the receiver the hit occurred. If the ray misses, another is drawn and the process starts over. If it hits, the hit total is incremented and sorted out by location on the receiver to obtain flux maps of the receiver surface. The ray trace code keeps track of the final ray disposition at the receiver by aperture misses high, misses wide or misses low, corbel hits, rays going through and cavity wall or receiver hits.

The cavity aperture is defined as a portion of a cone of angle θ_c, and a cone radius, R cone, at a set height up the aperture (HTOT/2). The nomenclature is shown below.



The cone can be located anywhere in space as defined by an orthonormal triad ($\overrightarrow{UN}$, $\overrightarrow{UE}$, $\vec{N}$) and vector $\vec{D}$ from the origin of the ray to be tested to the center of the lower disc of a cone frustum. Figure 3-26 shows the cone extended infinitely, and the test ray. The cone vertex is defined to be at height z_o where z is the distance along the cone axis such that z = 0 at the lower aperture disc. Then z_o is calculated as

$$Z_o = \frac{HTOT}{2} - \frac{Rcone}{\tan \theta_c} \qquad (56)$$

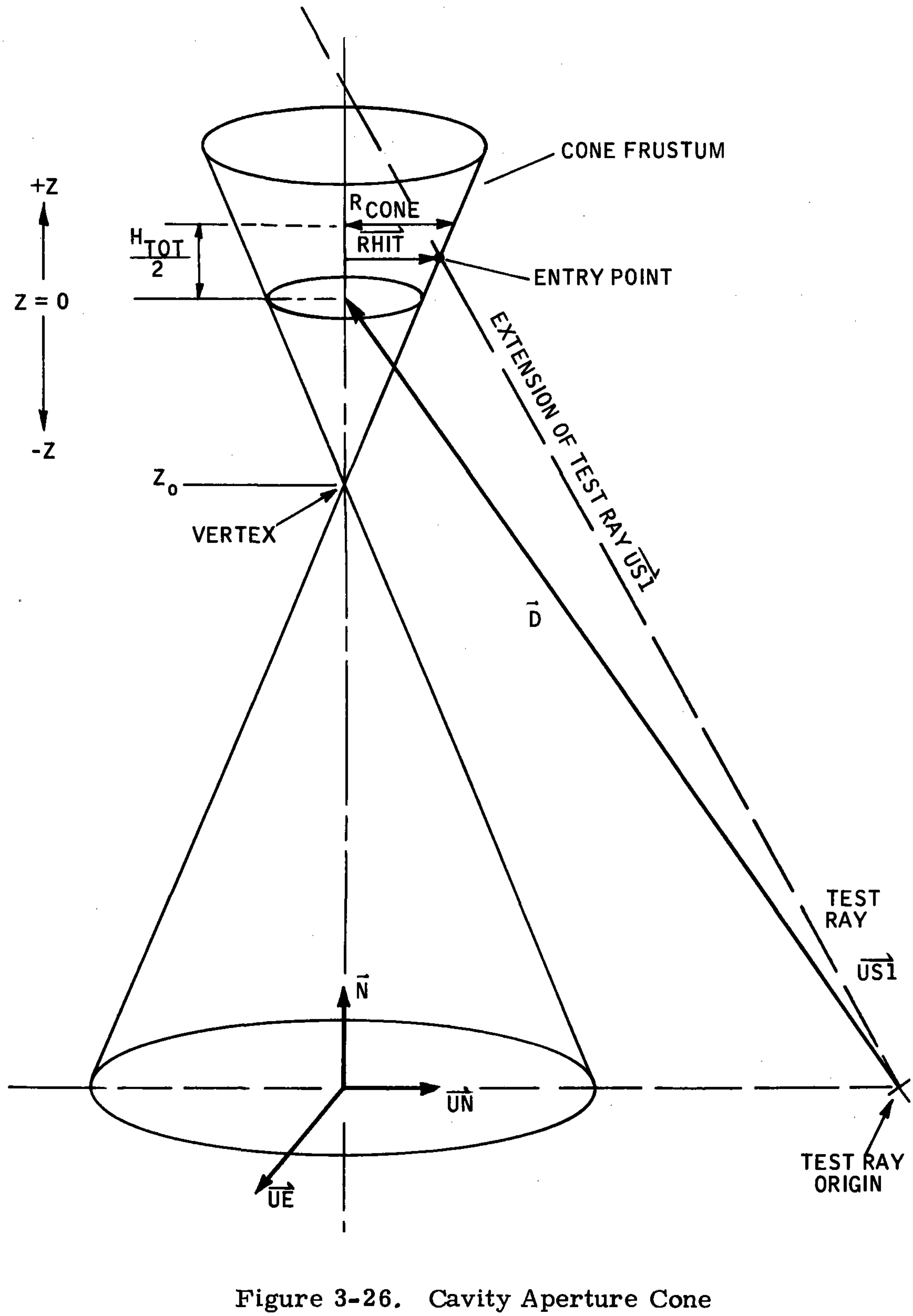


Figure 3-26. Cavity Aperture Cone

The ray to be tested for a hit is $\overrightarrow{US1}$ and unit vector $\vec{N}$ is required to be along the cone axis.

The vector algebra for the cone hit test needs the formulation of two other vectors which define a hit plane normal to the cone axis at a height z_{hit}, the distance from $z = 0$ to the test ray entry or exit point. The vector from the lower aperture disc center to the hit plane along the cone axis is simply $z_{hit} \cdot \vec{N}$ and the vector from the hit plane center to the actual test ray hit point is defined as $\overrightarrow{RHIT}$. From simple vector addition $\overrightarrow{RHIT}$ is,

$$\overrightarrow{RHIT} = -AL\ \overrightarrow{US1} + \vec{D} + Z_{hit}\ \vec{N} \qquad (57)$$

where AL is the distance from the test ray origin to the hit point on the cone. There are two hit points and thus two hit planes and hit vectors which will be solved for in the algebra. For now, only one hit point, defined by one set of $\overrightarrow{RHIT}$, AL and z_{hit} is carried.

Vector $\overrightarrow{RHIT}$ has a magnitude defined by the height of the hit plane from the cone vertex,

$$|\overrightarrow{RHIT}| = (Z_{hit} - Z_o) \tan \theta_c \qquad (58)$$

or since the magnitude of $\overrightarrow{RHIT}$ is defined by $\overrightarrow{RHIT} \cdot \overrightarrow{RHIT}$;

$$\begin{aligned} |\overrightarrow{RHIT}|^2 &= \overrightarrow{RHIT} \cdot \overrightarrow{RHIT} \\ &= (Z_{hit} - Z_o)^2 \tan^2 \theta_c \end{aligned} \qquad (59)$$

Using Equation (57) for the vector $\overrightarrow{RHIT}$ leaves one equation with two unknowns: Z_{hit} and AL. This distance AL can be calculated since both AL $\overrightarrow{US1}$ and $(\vec{D} + Z_{hit}\ \vec{N})$ extend from the same point in space to the surface of the hit plane with unit normal $\vec{N}$. Therefore, both AL $\overrightarrow{US1}$ and $\vec{D} + z_{hit}\ \vec{N}$ must have the same projected length along N. Expressed algebraically,

$$(\vec{D} + Z_{hit}\vec{N}) \cdot \vec{N} = AL\ \overrightarrow{US1} \cdot \vec{N} \tag{60}$$

Equations (57), (59), and (60) can be combined to yield a quadratic in Z_{hit} or AL. Substituting for AL gives:

$$Z_{hit}^2 \{1/(\overrightarrow{US1} \cdot \vec{N})^2 - 1 - \tan^2 \theta_c\}$$
$$+ Z_{hit} \{2(\vec{D} \cdot \vec{N})/(\overrightarrow{US1} \cdot \vec{N})^2 - 2(\overrightarrow{US1} \cdot \vec{D})/(\overrightarrow{US1} \cdot \vec{N}) + 2 Z_o \tan \theta_c\}$$
$$+ \left\{ -2 \frac{(\vec{D} \cdot \vec{N})(\overrightarrow{US1} \cdot \vec{D})}{\overrightarrow{US1} \cdot \vec{N}} + \frac{(\vec{D} \cdot \vec{N})^2}{(\overrightarrow{US1} \cdot \vec{N})^2} + (\vec{D} \cdot \vec{D}) - Z_o^2 \tan^2 \theta_c \right\} = 0 \tag{61}$$

The solution of the quadratic gives the two piercing points (entry and exit) of the test ray with the cone. Imaginary roots indicate that the test ray failed to hit the cone. The entry and exit heights of the test ray are all that is required to determine if the incoming ray hit a corbel, went through the aperture, missed the aperture opening high or low or is a valid ray entering the cavity opening.

The subroutine PIPE is used to determine the hit point of rays entering the cavity, which is a right circular cylinder. When a hit is established, the two piercing points on the cylinder are computed and this information is used in the cavity wall flux mapping routines. The general method for finding the hit points is established below.

A right circular cylinder of radius R_{CYL} can be located anywhere in space as defined by the orthogonal triad set ($\overrightarrow{UN}$, $\overrightarrow{UE}$, $\vec{N}$) and vector $\vec{D}$ from the origin of the ray to be tested. Figure 3-27 shows the cylinder and test ray nomenclature. Unit vector $\vec{N}$ is along the cylinder axis and $\overrightarrow{US1}$ is the ray to be tested for hits on the cylinder. The vector $\vec{D}$ must go from the test ray origin to the center of the cylinder. The plane defined by ($\overrightarrow{UN}$, $\overrightarrow{UE}$) at the terminal point of $\vec{D}$ is the reference height along the cylinder (z = 0).

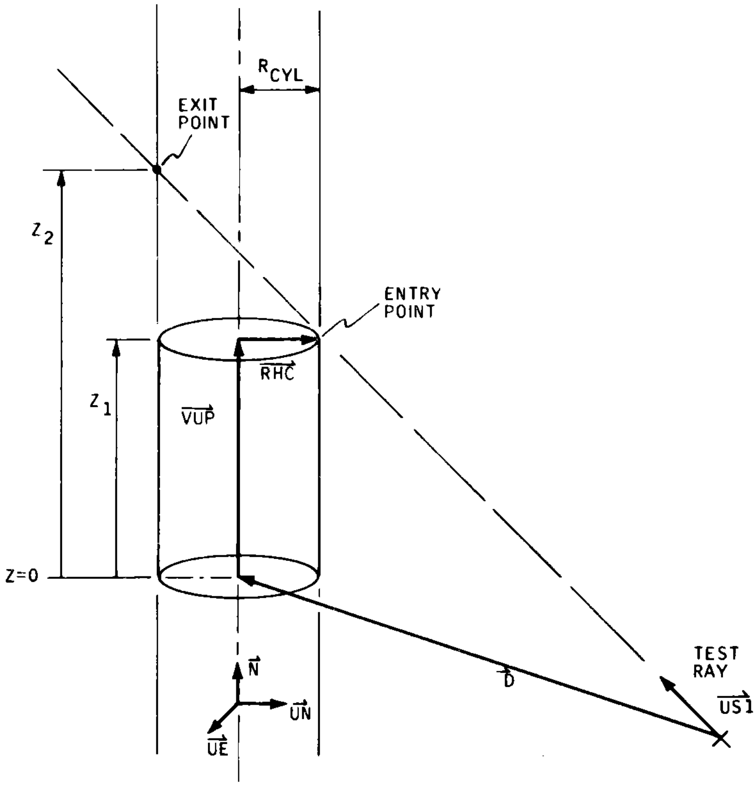


Figure 3-27. Cylinder and Test Ray Nomenclature

The vector algebra for the hit test requires that two other vectors be defined. First, a vector from the center of the reference plane to the center of a hit plane is defined as $\overrightarrow{VUP}$. Figure 3-27 shows the vector for one of the hit planes. There are two hit planes, one at height z_1 for the ray entry point and another at height z_2 for the ray exit point. For the ray entry test plane,

$$\overrightarrow{VUP} = Z_1\vec{N} \tag{62}$$

The second vector required is from the test plane center to the hit point on the cylinder. This vector is

$$\overrightarrow{RHC} = L_1 \ \overrightarrow{US1} - (Z_1 \ \vec{N} + \vec{D}) \tag{63}$$

where the test ray ($\overrightarrow{US1}$) must be a vector of unit magnitude. The distance from the test ray origin to the hit point on the cylinder is defined as L_1. This distance can be calculated since both L $\overrightarrow{US1}$ and ($\vec{D}$ + $\overrightarrow{VUP}$) extend from the same point in space to the surface of the test plane with normal $\vec{N}$. Under these conditions both L $\overrightarrow{US1}$ and ($\vec{D}$ + $\overrightarrow{VUP}$) must have the same projected length along $\vec{N}$, therefore:

$$L_1 \; \overrightarrow{US1}\cdot \vec{N} = (\vec{D} + \overrightarrow{VUP})\cdot \vec{N} \qquad (64)$$

or

$$L_1 = \frac{(\vec{D} + Z_1\vec{N})\cdot \vec{N}}{\overrightarrow{US1}\cdot \vec{N}} \qquad (65)$$

By substituting L_1 from Equation (65) into Equation (63) we obtain

$$\overrightarrow{RHC} = \left(\frac{\vec{D}\cdot \vec{N} + Z_1}{\overrightarrow{US1}\cdot \vec{N}}\right) \overrightarrow{US1} - (Z_1\vec{N} + \vec{D}) \qquad (66)$$

Since $\overrightarrow{RHC}$ goes from the axis of the cylinder to the hit point, it must have a magnitude equal to the radius of the cylinder.

$$\overrightarrow{RHC}\cdot \overrightarrow{RHC} = R_{cyl}^{\;2}$$

Substituting $\overrightarrow{RHC}$ from Equation (66) into Equation (67) yields a quadratic in Z

$$Z^2 \left[\frac{1}{(\overrightarrow{US1}\cdot \vec{N})^2} - 1\right] + Z \left[\frac{2(\vec{D}\cdot \vec{N})}{(\overrightarrow{US1}\cdot \vec{N})^2} - \frac{2(\vec{D}\cdot \overrightarrow{US1})}{\overrightarrow{US1}\cdot \vec{N}}\right]$$

$$+ \left[\frac{(\vec{D}\cdot \vec{N})^2}{(\overrightarrow{US1}\cdot \vec{N})^2} - \frac{2(\vec{D}\cdot \vec{N})(\vec{D}\cdot \overrightarrow{US1})}{\overrightarrow{US1}\cdot \vec{N}} + \vec{D}\cdot \vec{D} - R_{cyl}^{\;2}\right] = 0 \qquad (67)$$

The solution of the quadratic yields the heights Z_1 and Z_2 of two piercing points of the test ray. Imaginary roots indicate that the ray failed to hit the cylinder. The distances L_1 and L_2 may be found from Equation (65) and the $\overrightarrow{RHC}$ vectors from Equation (63). For cavity wall flux maps it is necessary to determine the location of the hit points in terms of local coordinates on the test plane. A scalar x and y may be found by

$$x = \overrightarrow{RHC} \cdot \overrightarrow{UE}$$

$$y = \overrightarrow{RHC} \cdot \overrightarrow{UN}$$

This x, y system is shown in Figure 3-28, the x axis being along UE and y along UN. The zoning of the cylinder is more commonly done in polar coordinates so the FORTRAN passes the angles θ_1 and θ_2 from the y axis to the hit points.

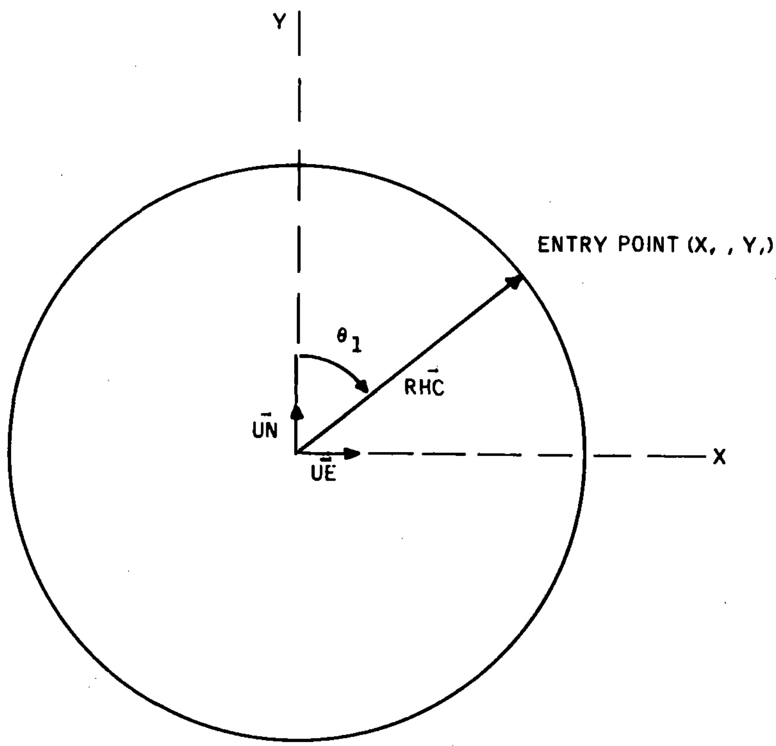
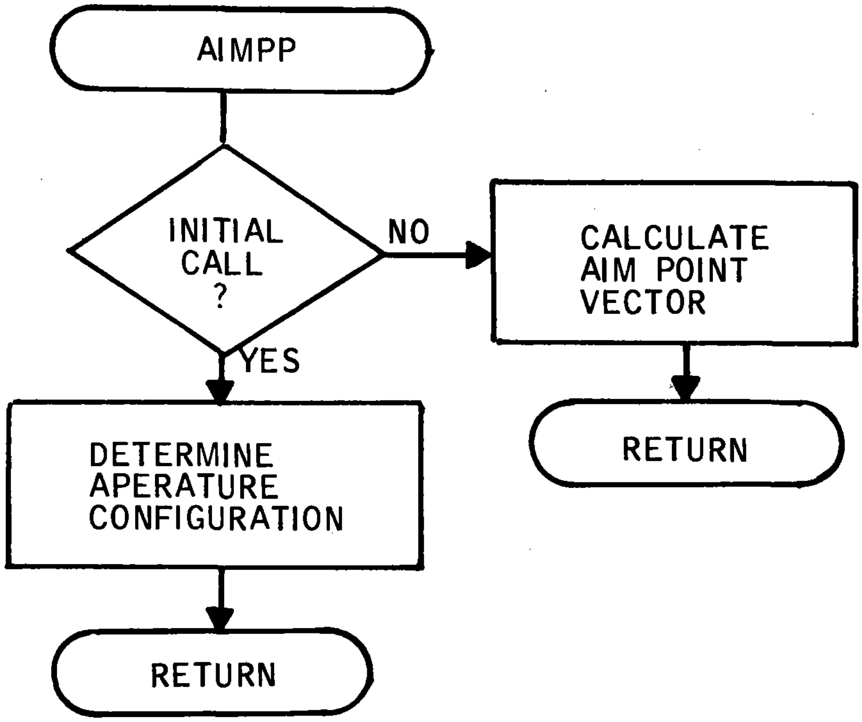


Figure 3-28. Test Plan Coordinate System

APPENDIX A
SUBROUTINE DESCRIPTIONS AND FLOWCHARTS

This appendix includes a description of all subroutines in the program with an associated program logic flowchart. The description of each subroutine is given on the same page as the flowchart to aid in understanding the logic flow of each.



AIMPP calculates a vector from the heliostat to the receiver aperature opening such that the heliostat will redirect the sun image to miss the corbels.

Figure A-1. AIMPP Program Flow

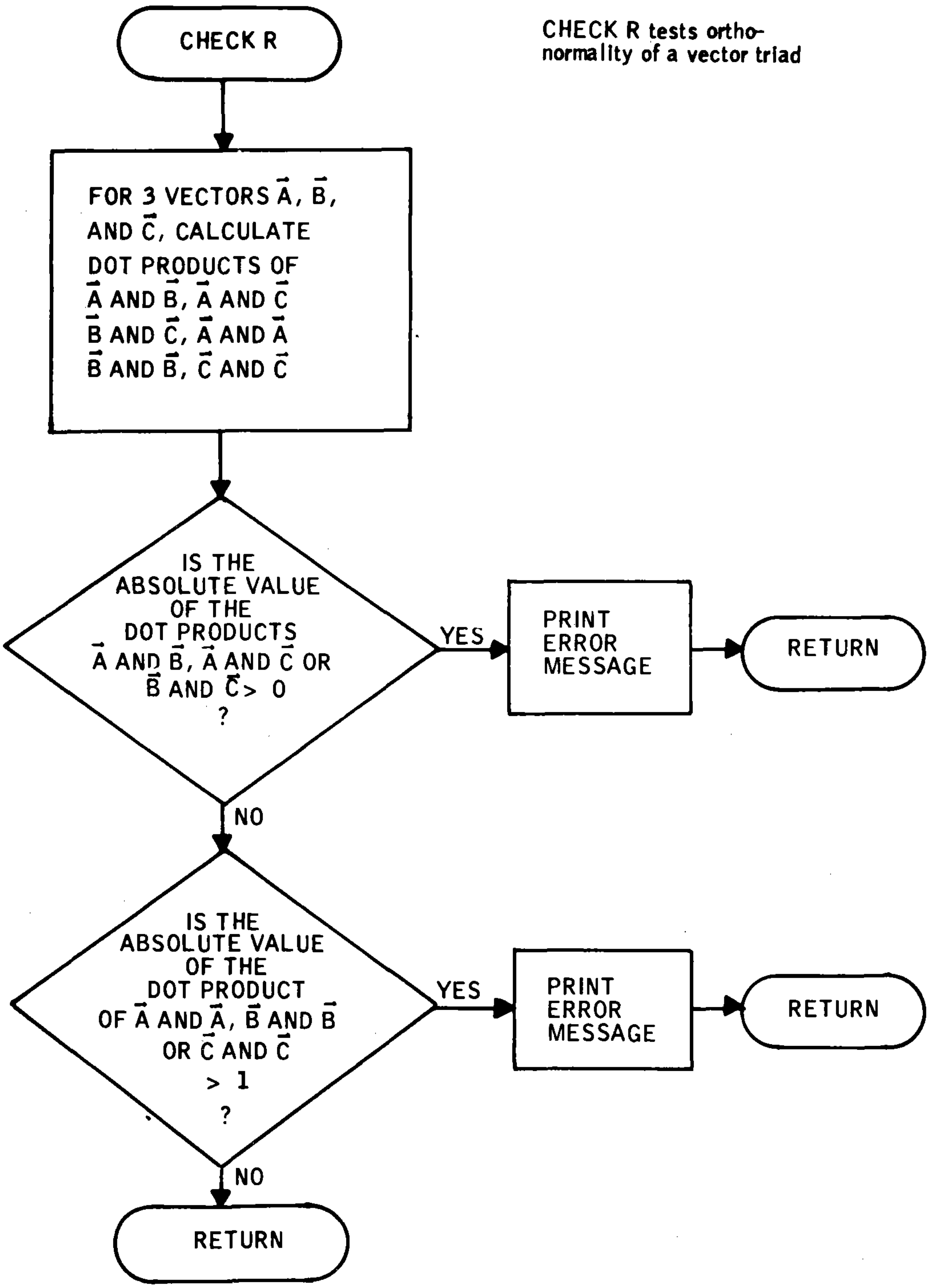
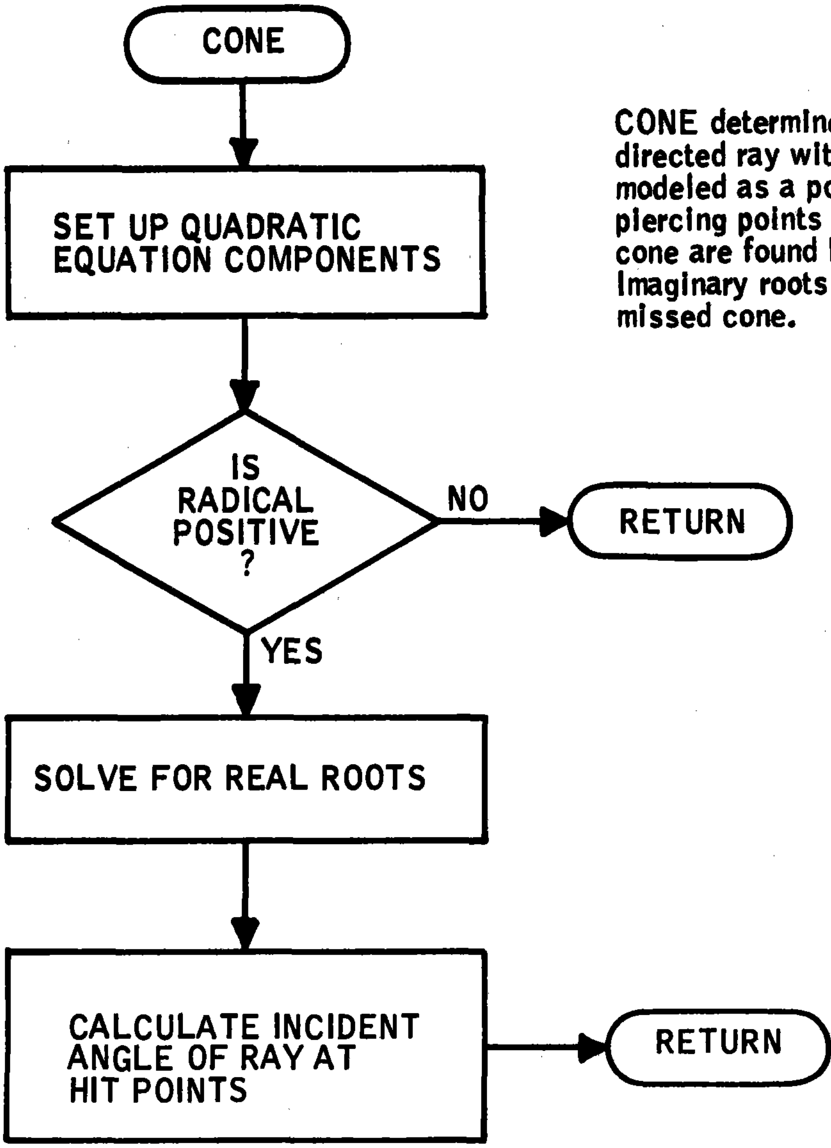
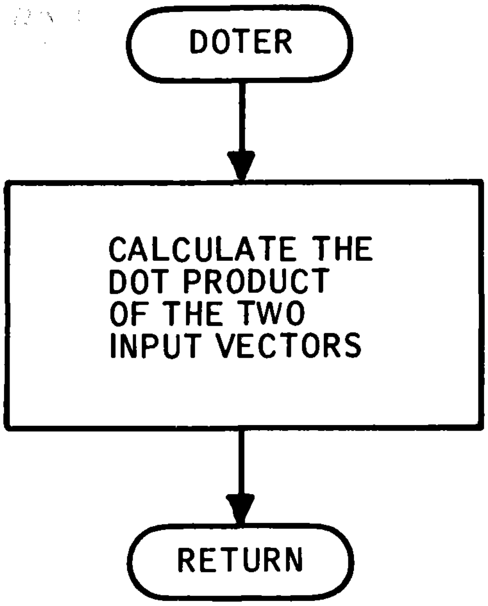


Figure A-2. CHECK R Program Flow



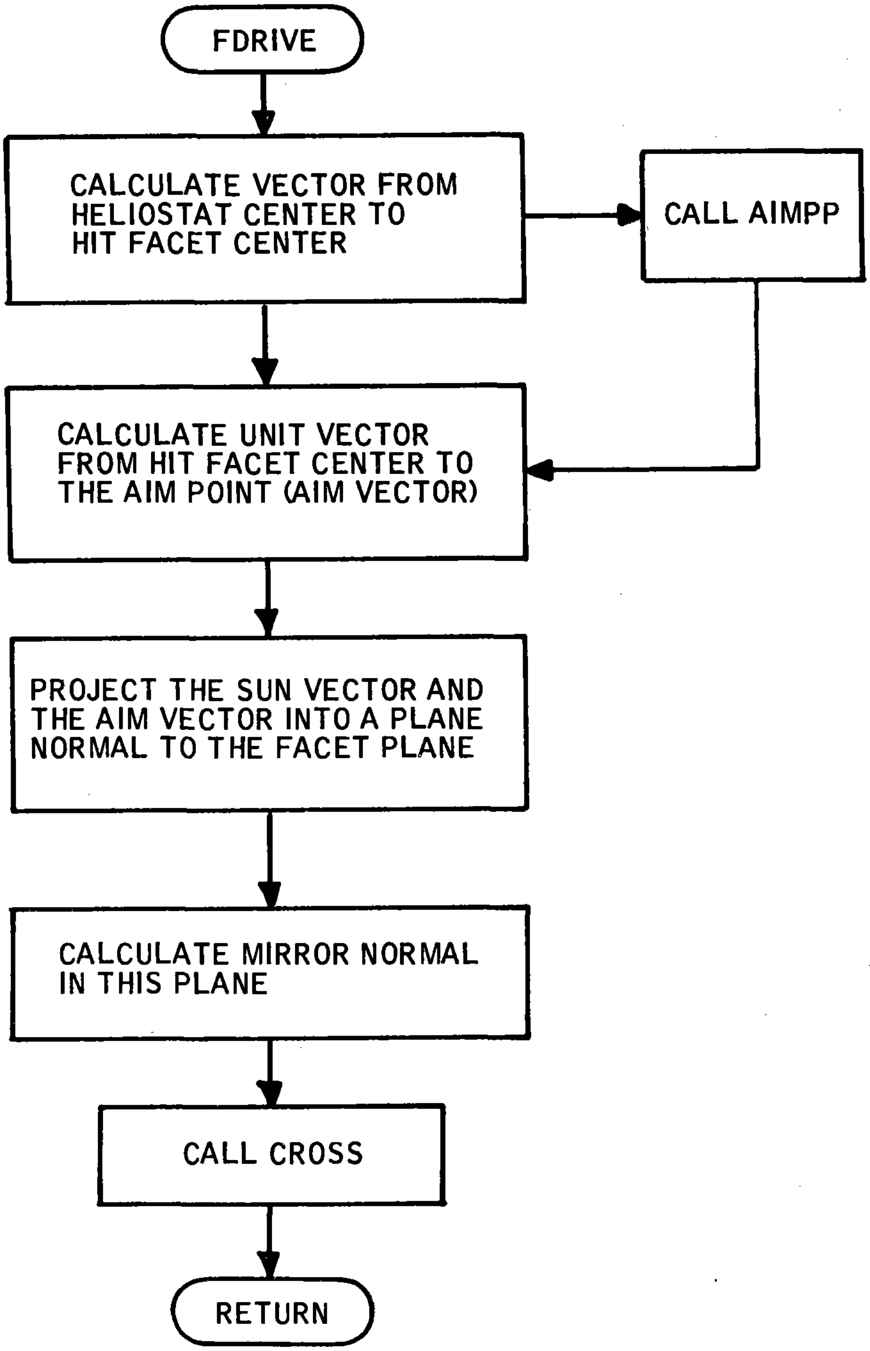
CONE determines the hit point of a redirected ray with the cavity aperture modeled as a portion of a cone. The piercing points (entry and exits) on the cone are found by solving a quadratic. Imaginary roots indicate that the ray missed cone.

Figure A-3. CONE Program Flow



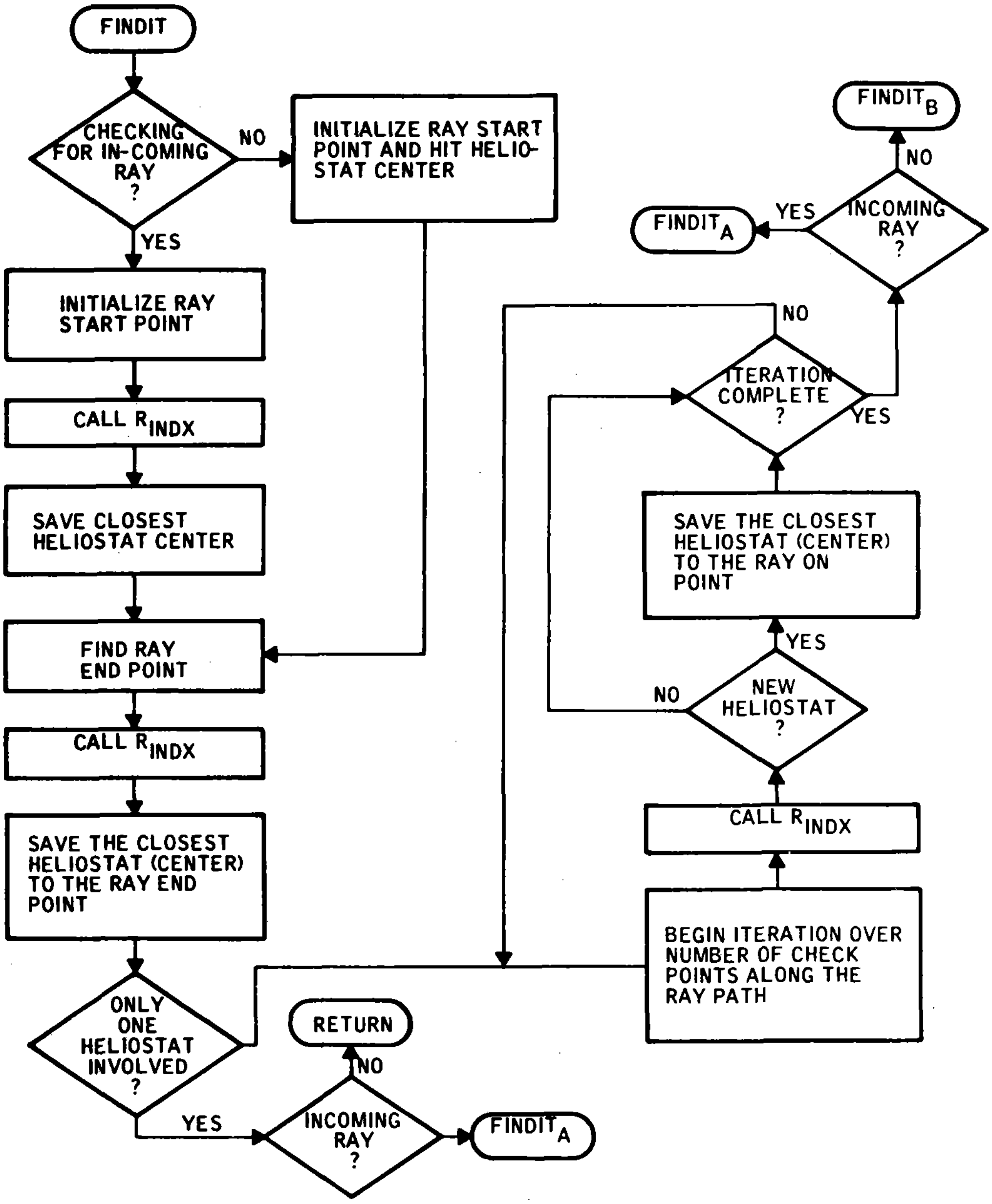
DOTER computes the dot product of two vectors.

Figure A-4. DOTER Program Flow



FDRIVE sets up the hit facets vector triad for heliostats with independent facet drives. The facet inner drive axis is rotated to a position such that the redirected beam is as close as possible (ignoring tracking errors) to the desired aim point.

Figure A-5. FDRIVE Program Flow



FINDIT generates a list of mirrors that lie along an incoming or outgoing ray path. It performs this function by calculating which mirrors could intersect the incoming or outgoing ray between a test plane and the ground plane.

Figure A-6. FINDIT Program Flow

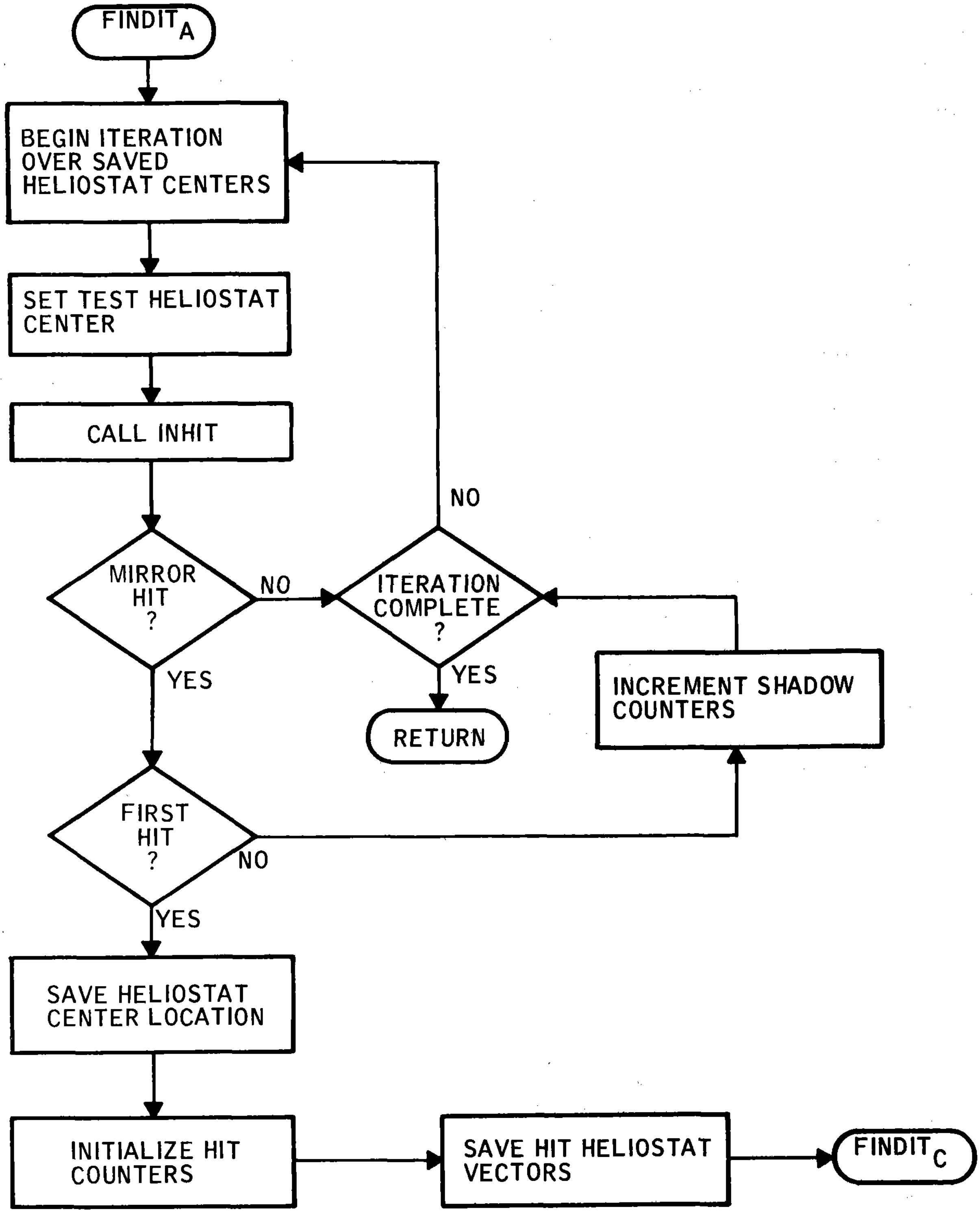


Figure A-6. (Continued)

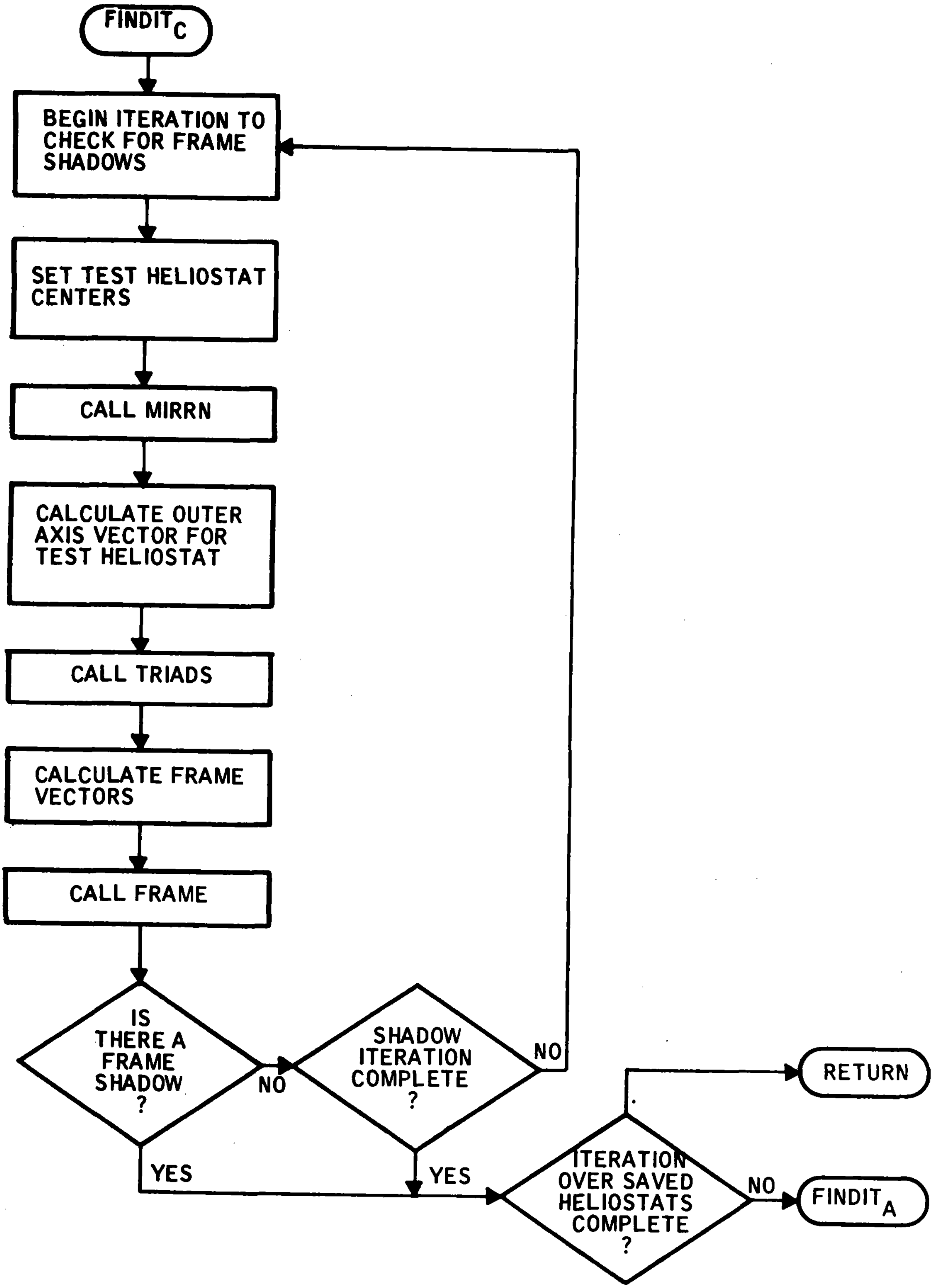


Figure A-6. (Continued)

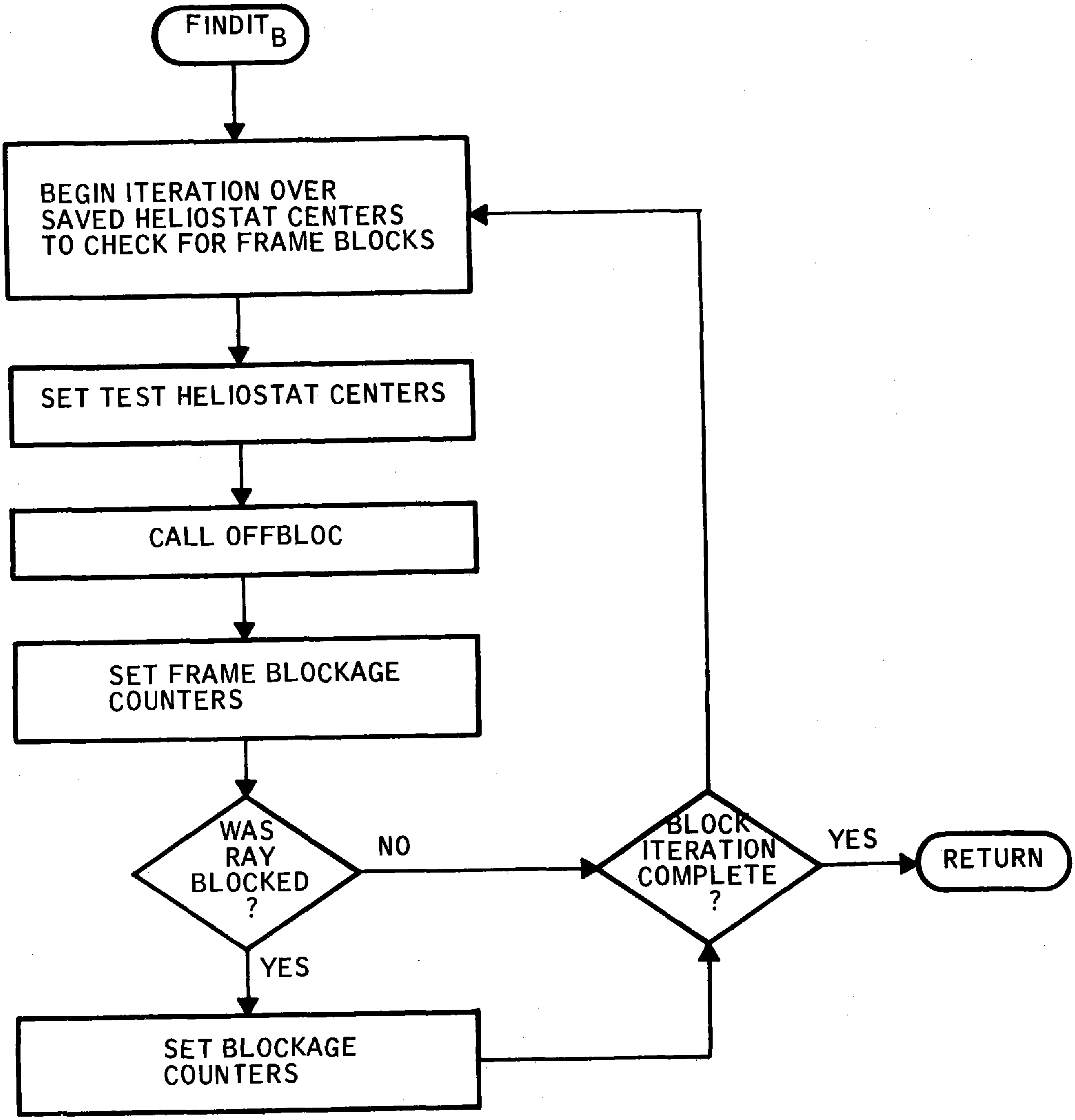
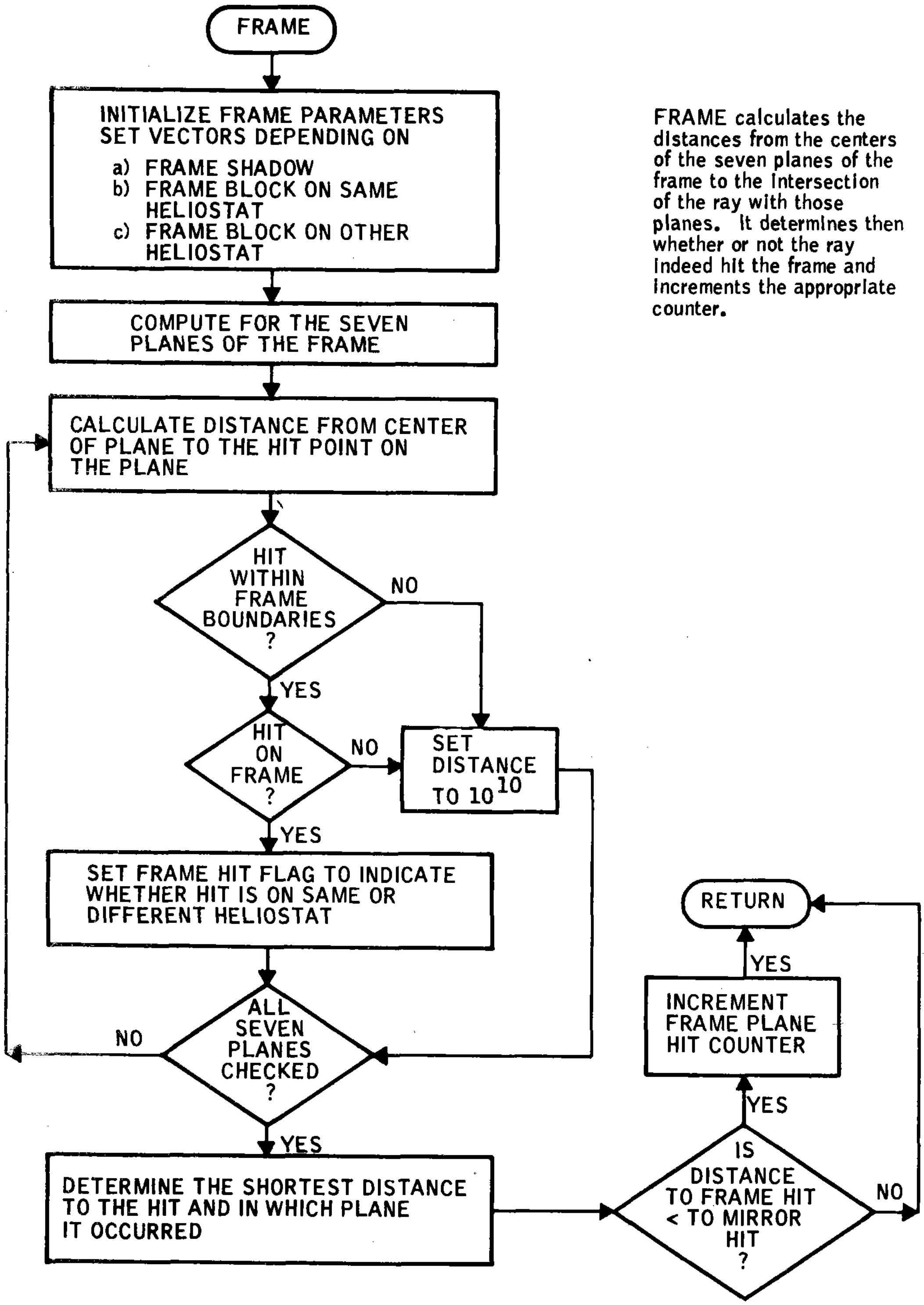
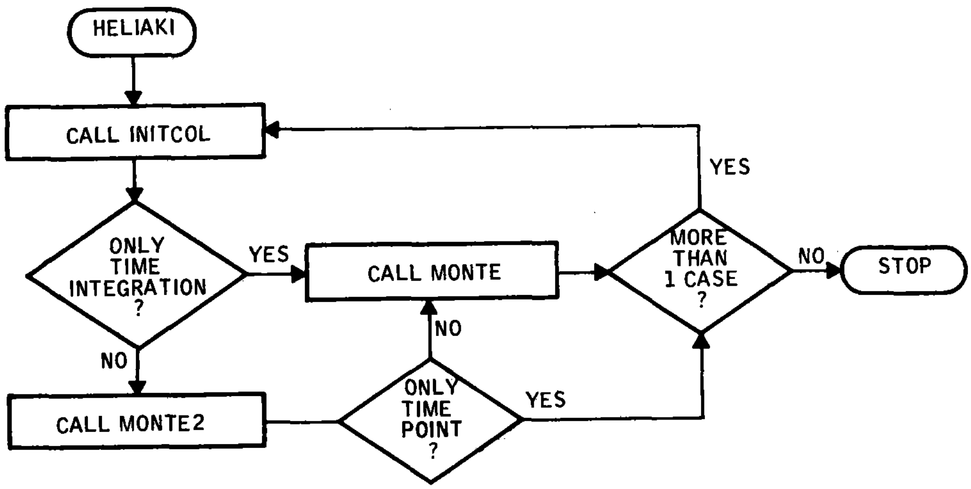


Figure A-6. (Concluded)



FRAME calculates the distances from the centers of the seven planes of the frame to the intersection of the ray with those planes. It determines then whether or not the ray indeed hit the frame and increments the appropriate counter.

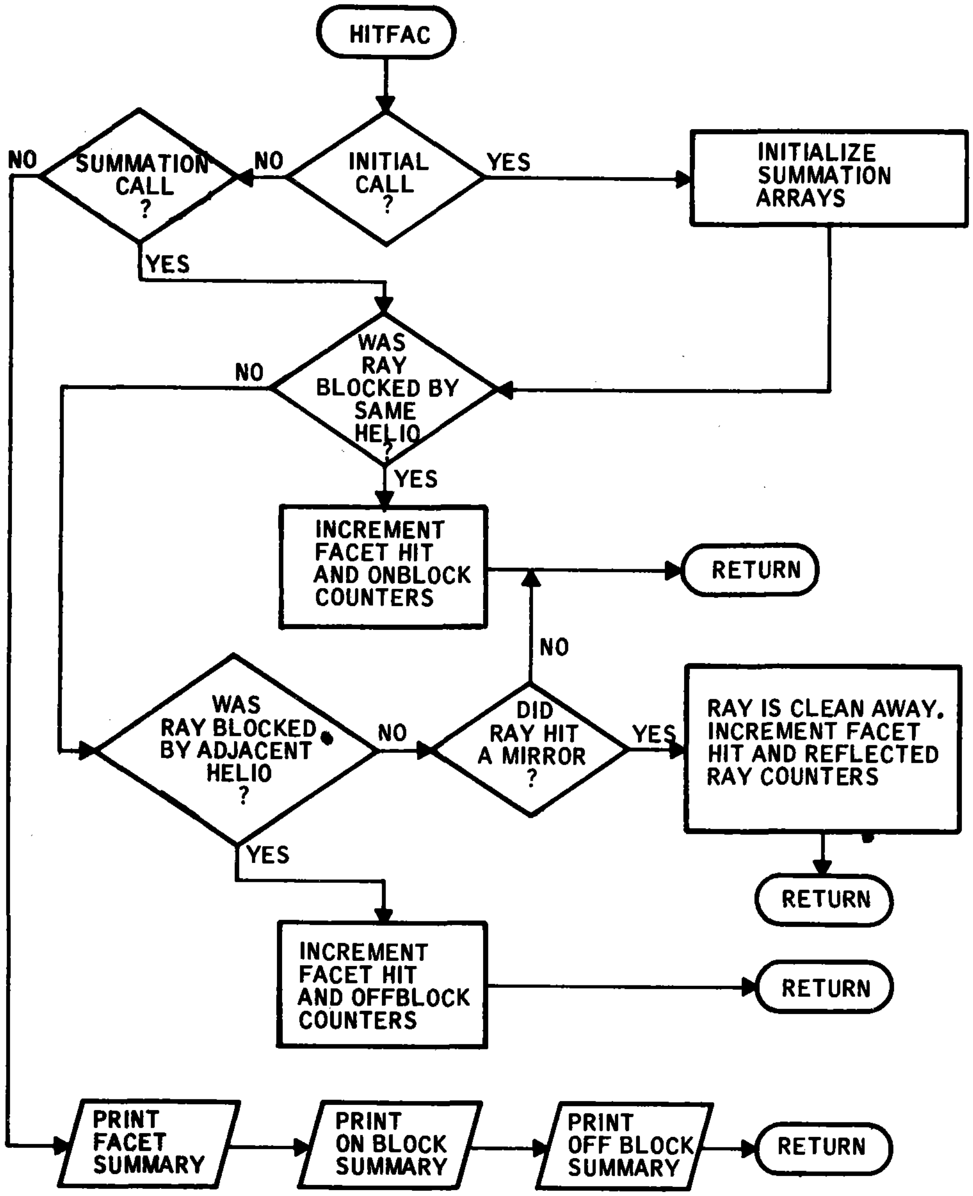
Figure A-7. FRAME Program Flow



HELIAKI is the controlling program. Depending on the program options selected, HELIAKI calls the appropriate routine to perform:

a. A time point simulation
b. A time integration simulation
c. Both a time point and time integration

Figure A-8. HELIAKI Program Flow



HITFAC keeps track of which facet a ray hits on a given heliostat. It performs this function for initial hits, as well as for shadowing and blockage counting.

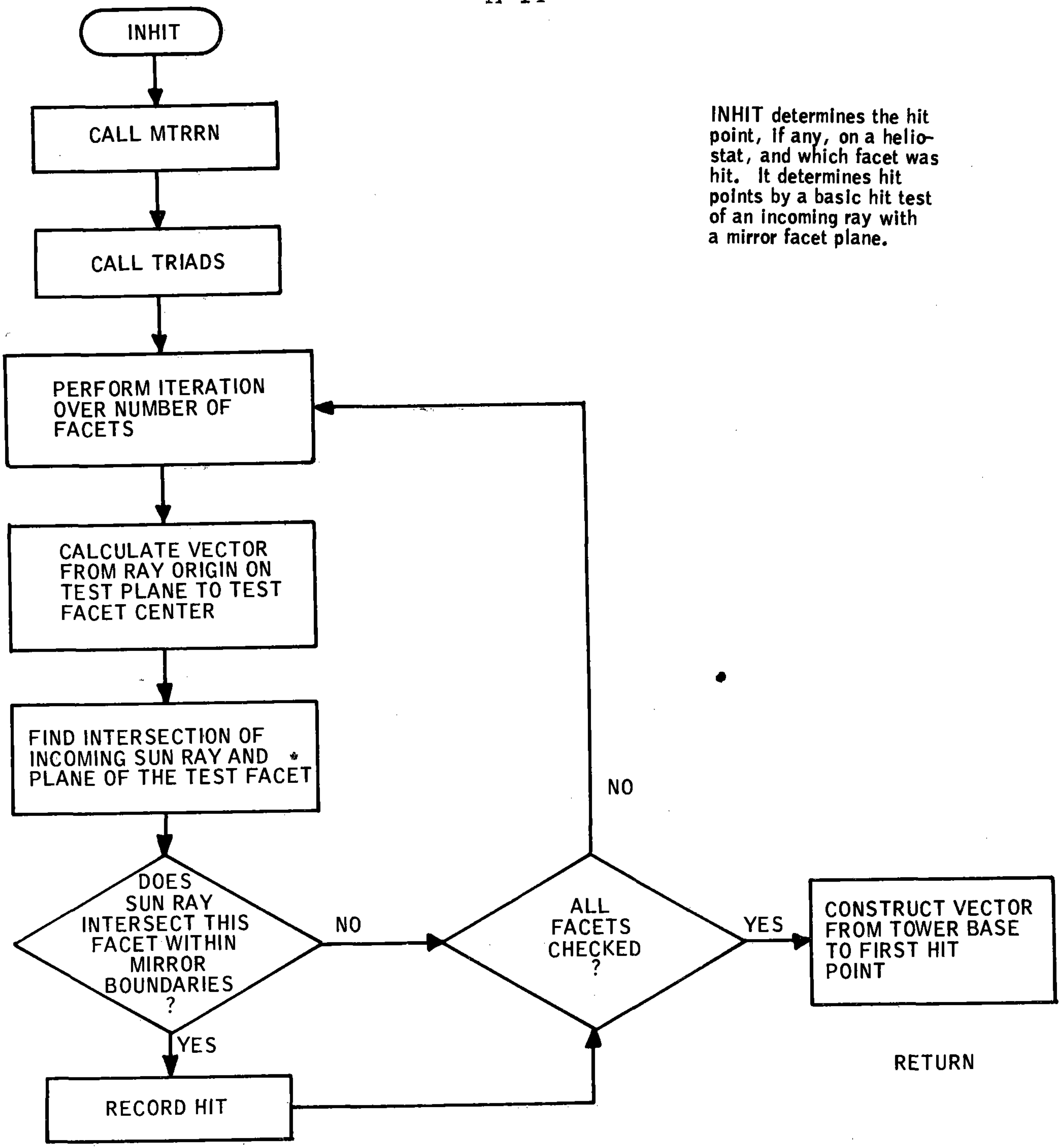
HITFAC can be called in one of three modes:

a. Initializations

b. Calculation and summation

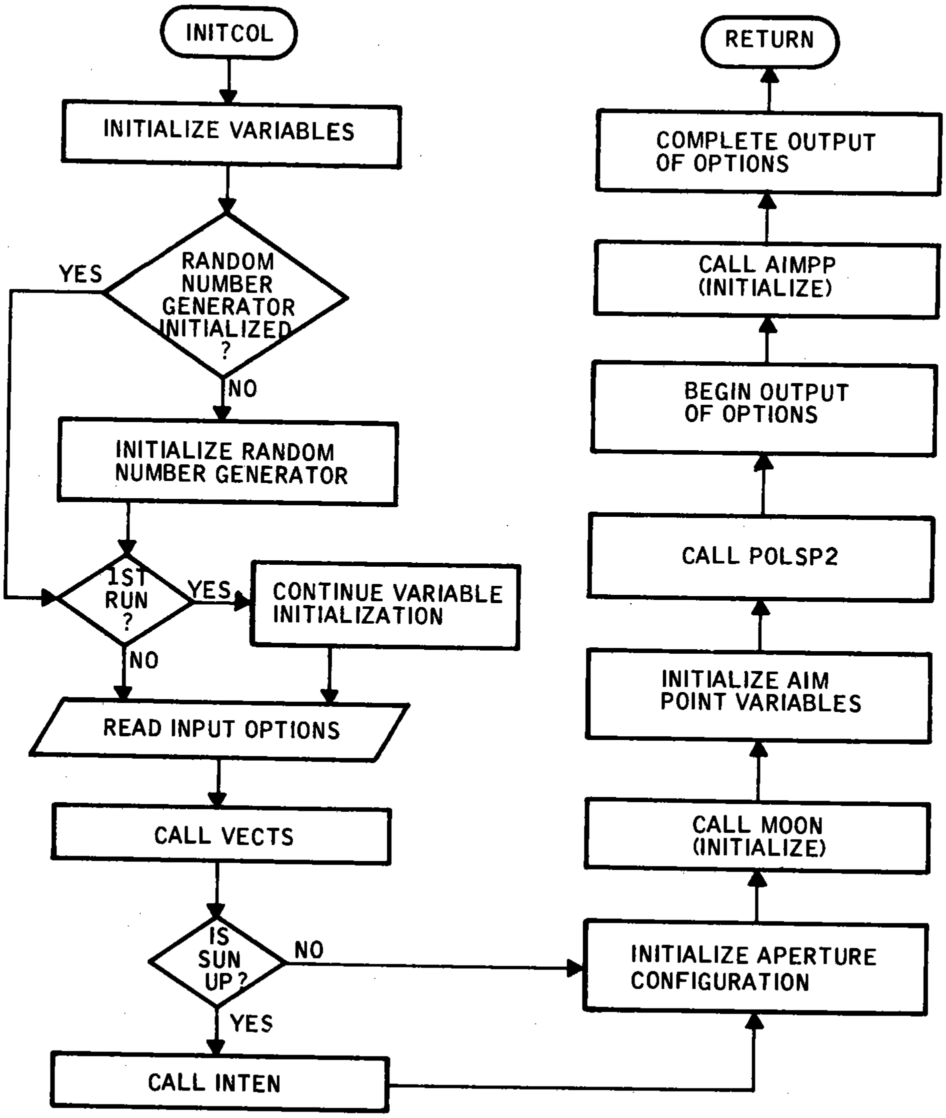
c. Output

Figure A-9. HITFAC Program Flow



INHIT determines the hit point, if any, on a heliostat, and which facet was hit. It determines hit points by a basic hit test of an incoming ray with a mirror facet plane.

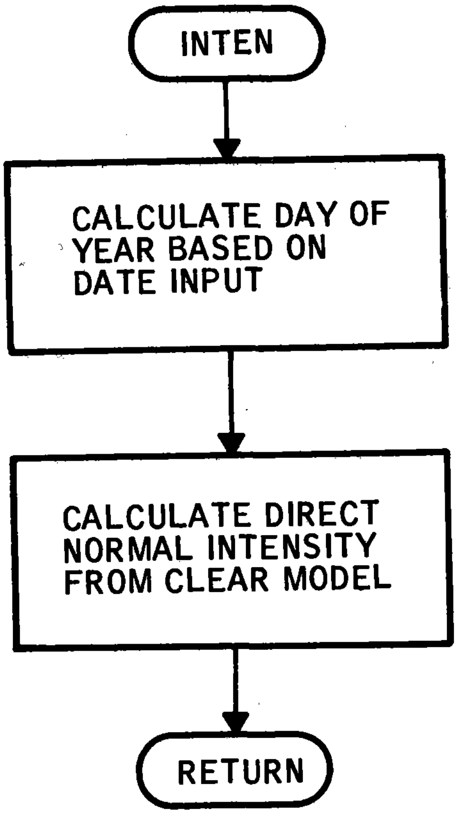
Figure A-10. INHIT Program Flow



INITCOL performs the following functions:

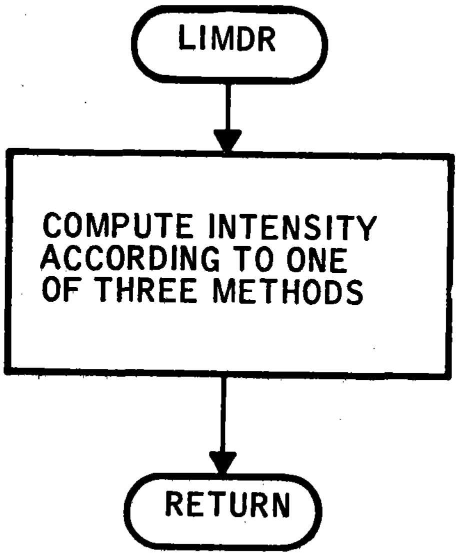
a. Initializations of variables
b. Initialization of the random number generator
c. Input of program options
d. Output summary of program options

Figure A-11. INITCOL Program Flow



INTEN calculates the direct normal intensity for a given month, day and hour of the year. The intensity is based on a clear air model using ASHRAE data for exoatmospheric intensity.

Figure A-12. INTEN Program Flow



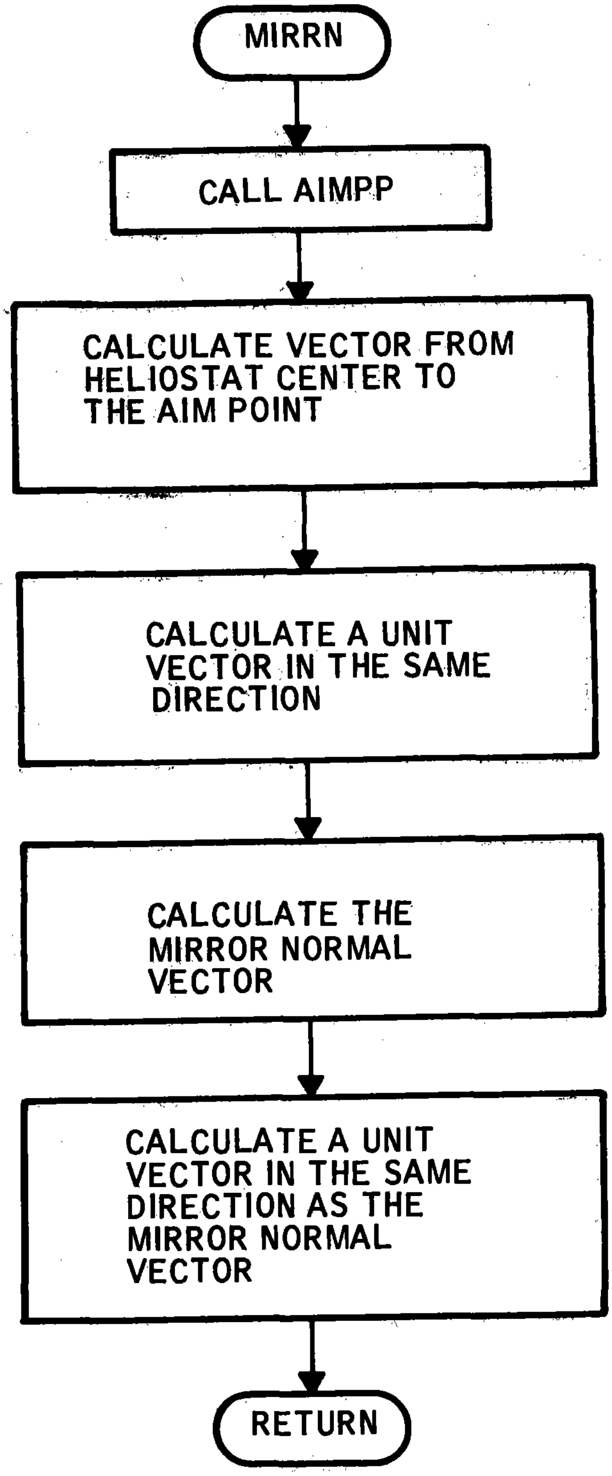
LIMDR calculates the intensity distribution of energy across the face of the sun. There are three options:

a. Flat sun

b. Sun with limb darkening and solar radiations

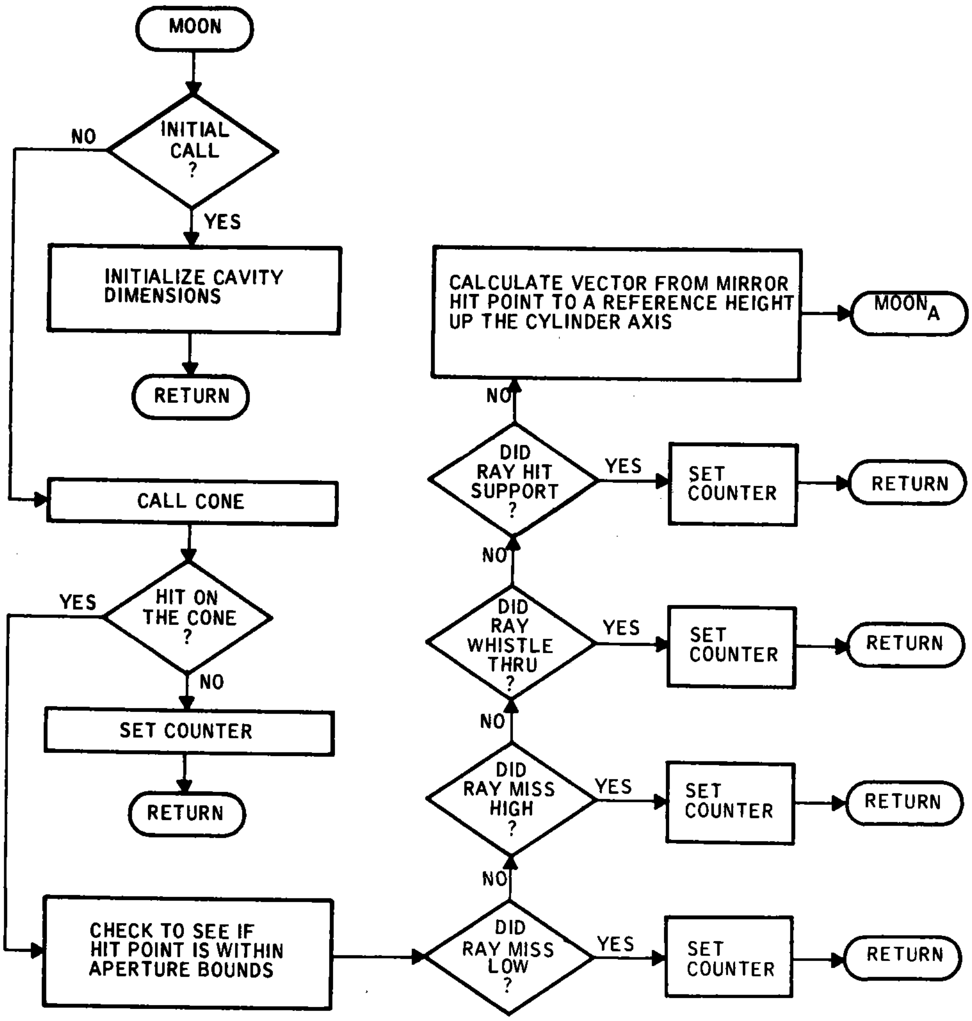
c. Sun with limb darkening

Figure A-13. LIMDR Program Flow



MIRRN Calculates a mirror normal given the sun vector the heliostat location and an aim point.

Figure A-14. MIRRN Program Flow



MOON checks for receiver hits for any ray which gets clearly away from the field. It checks for entry into the aperture, support hits, diffuser hits, cylinder hits, and whistle throughs. It maps all flux which hits the cylinder wall or roof.

Figure A-15. MOON Program Flow

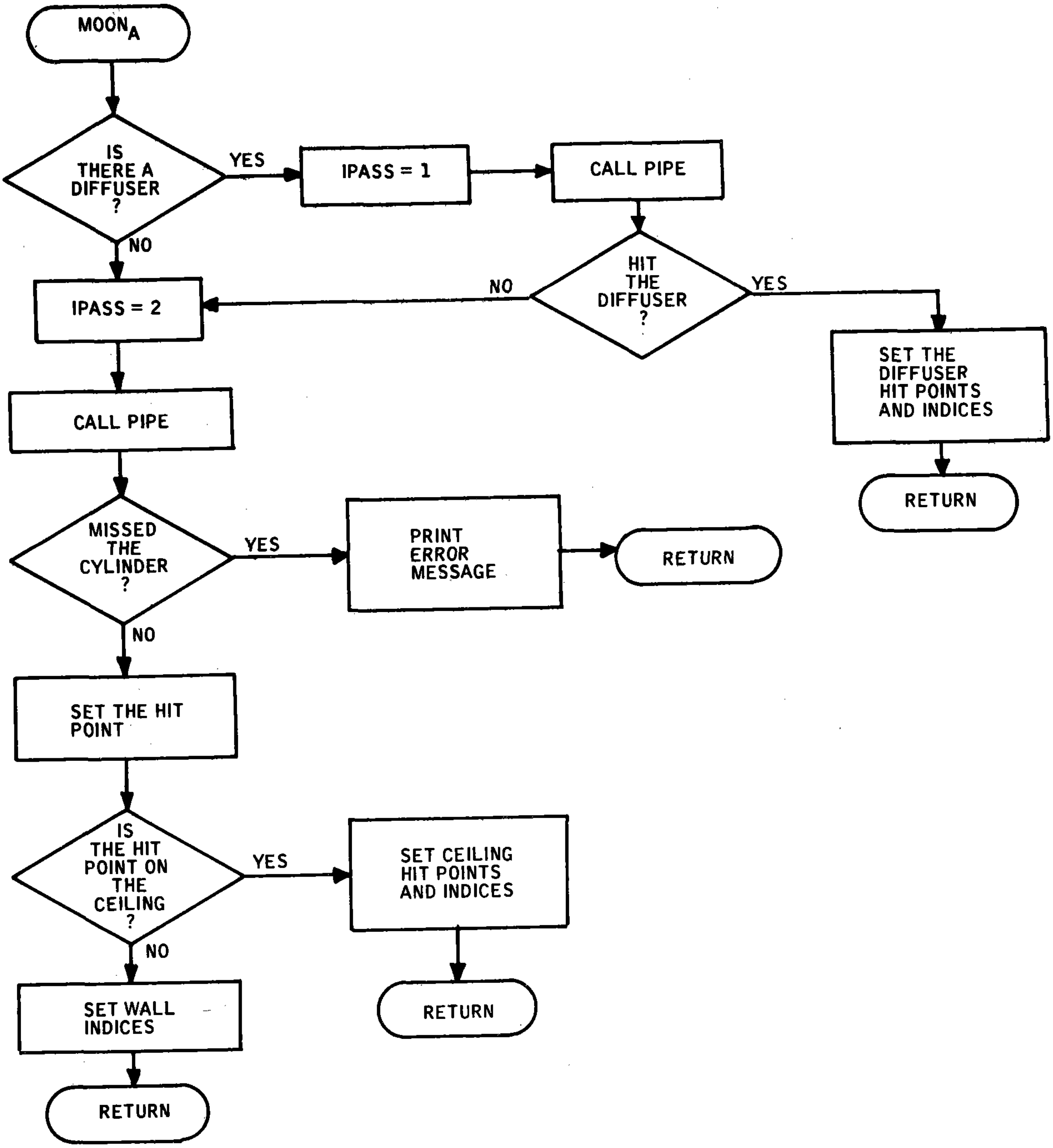
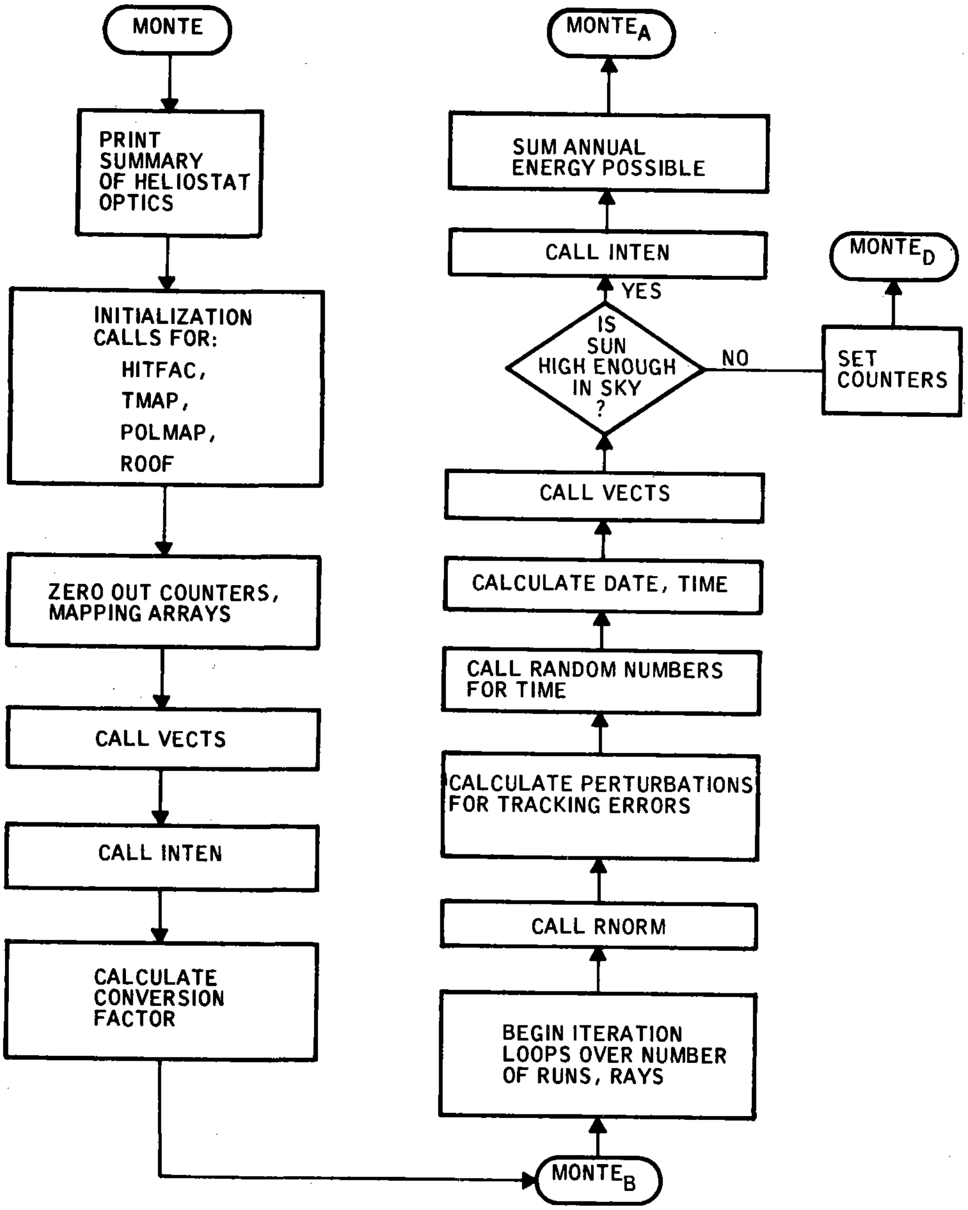


Figure A-15. (Concluded)



MONTE is the monte carlo driver routine for a yearly, time integration run.

Its major functions are:

a. Initialization calls for mapping and counting routines
b. Calls to the random number generator
c. Calls to the mapping and counting routines
d. Calls PTOWER, the controlling routine for the hit tests
e. Prints ray trace summary
f. Output calls for mapping and counting routines

Functions b, c and d are performed for each ray traced.

Figure A-16. MONTE Program Flow

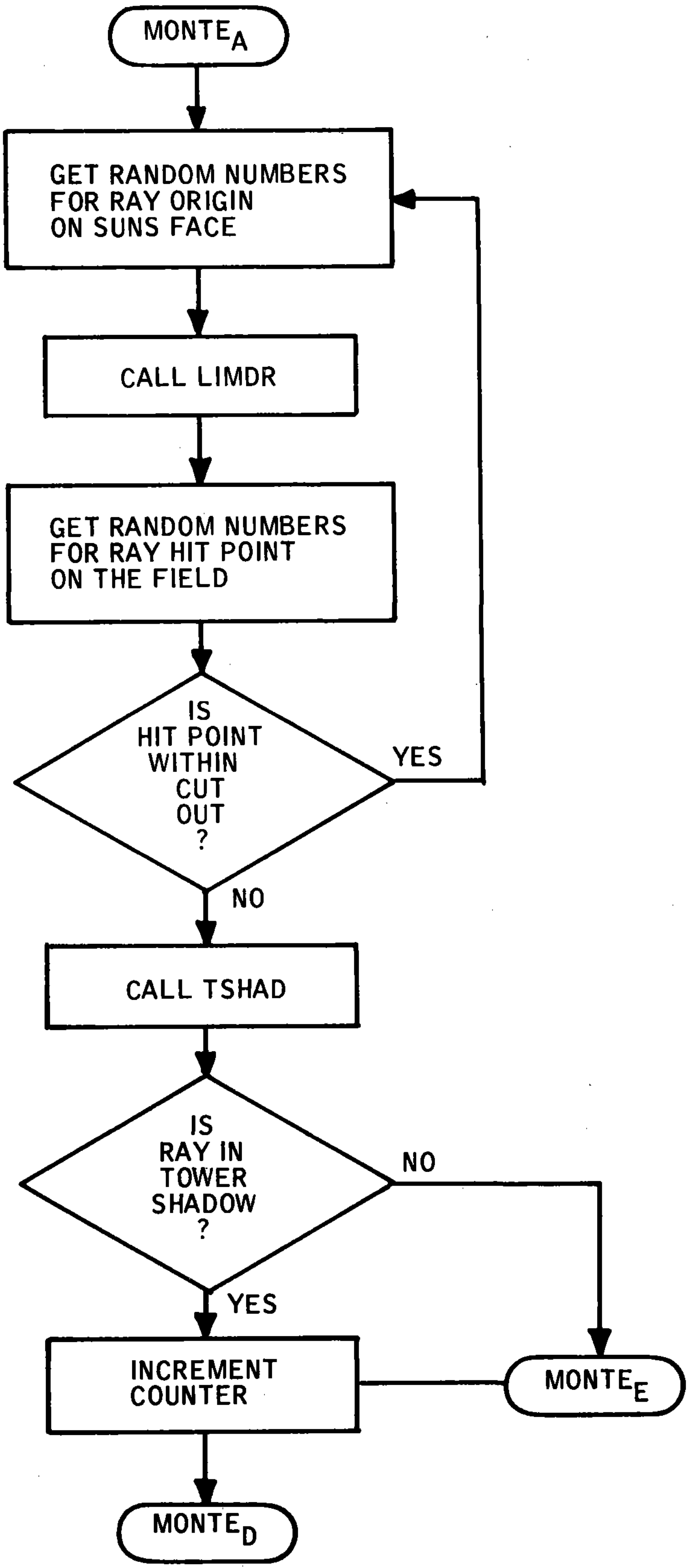


Figure A-16. (Continued)

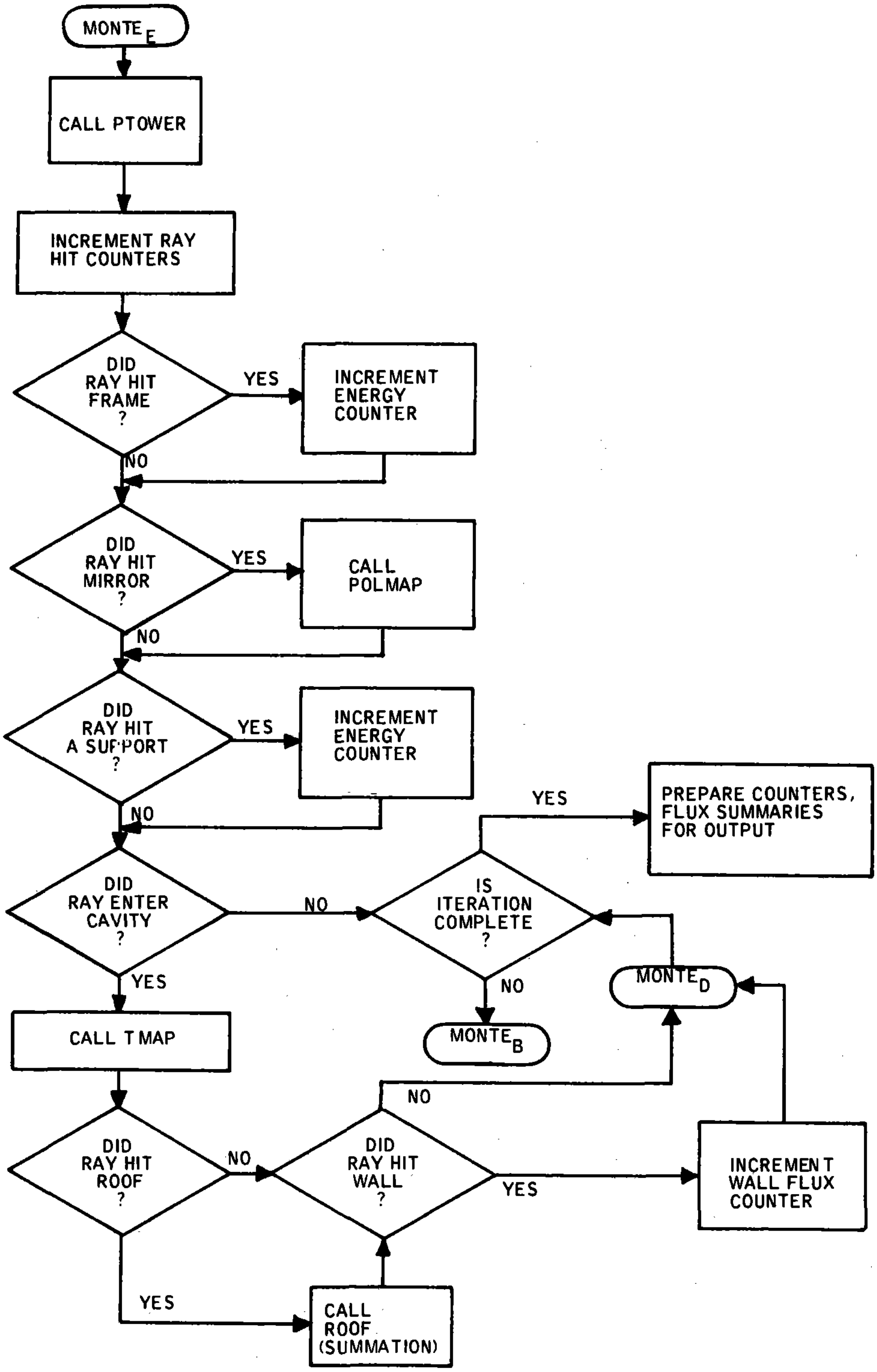


Figure A-16. (Continued)

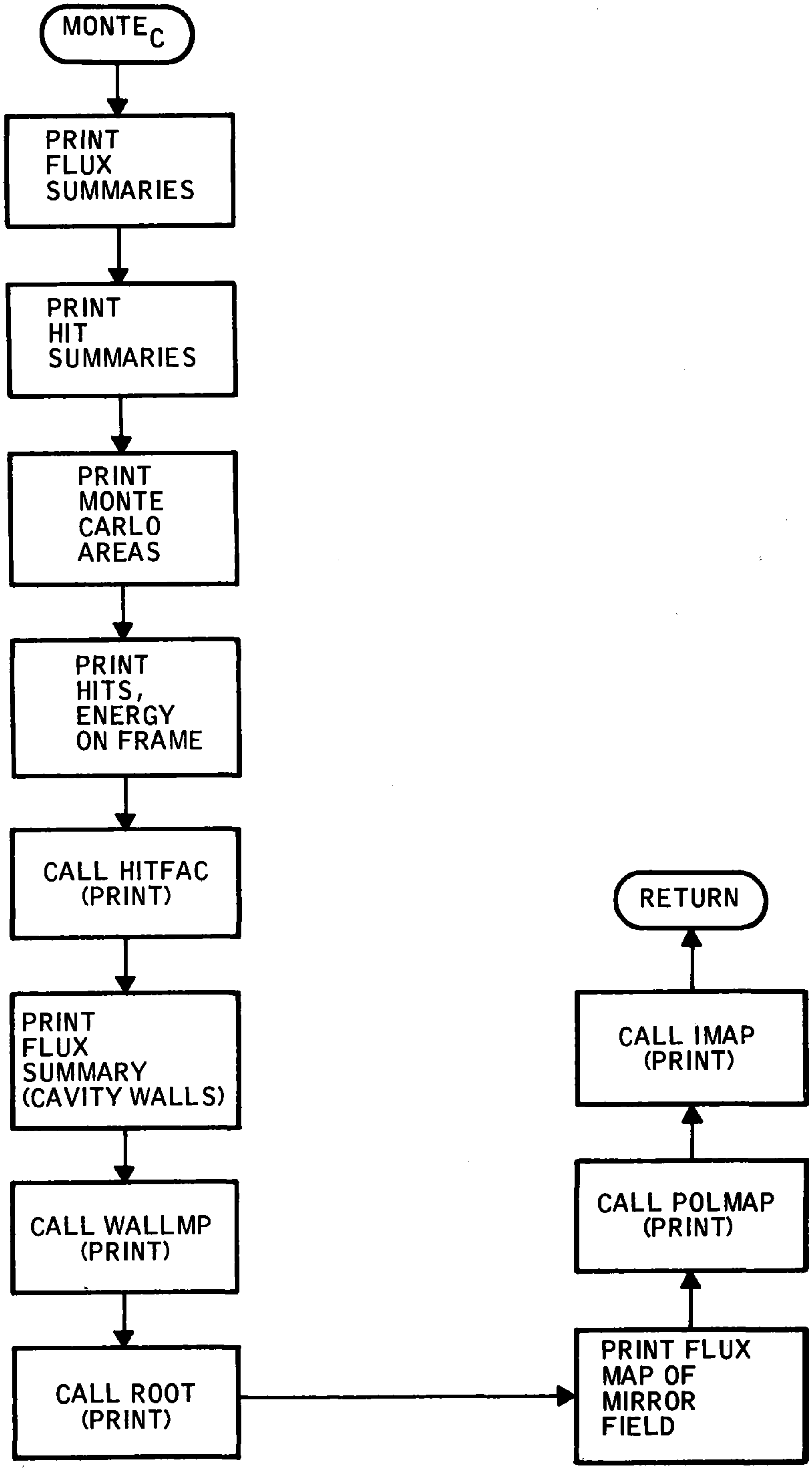


Figure A-16. (Concluded)

MONTE2 is the monte carlo driver routine to simulate a fixed time and day of the year. Its major functions are:

a. Initialization calls for mapping and counting routines
b. Calls the random number generator
c. Calls the mapping and counting routines
d. Calls PTOWER
e. Prints ray trace summary
f. Output calls for mapping and counting routines

Functions b, c and d are performed for each ray traced.

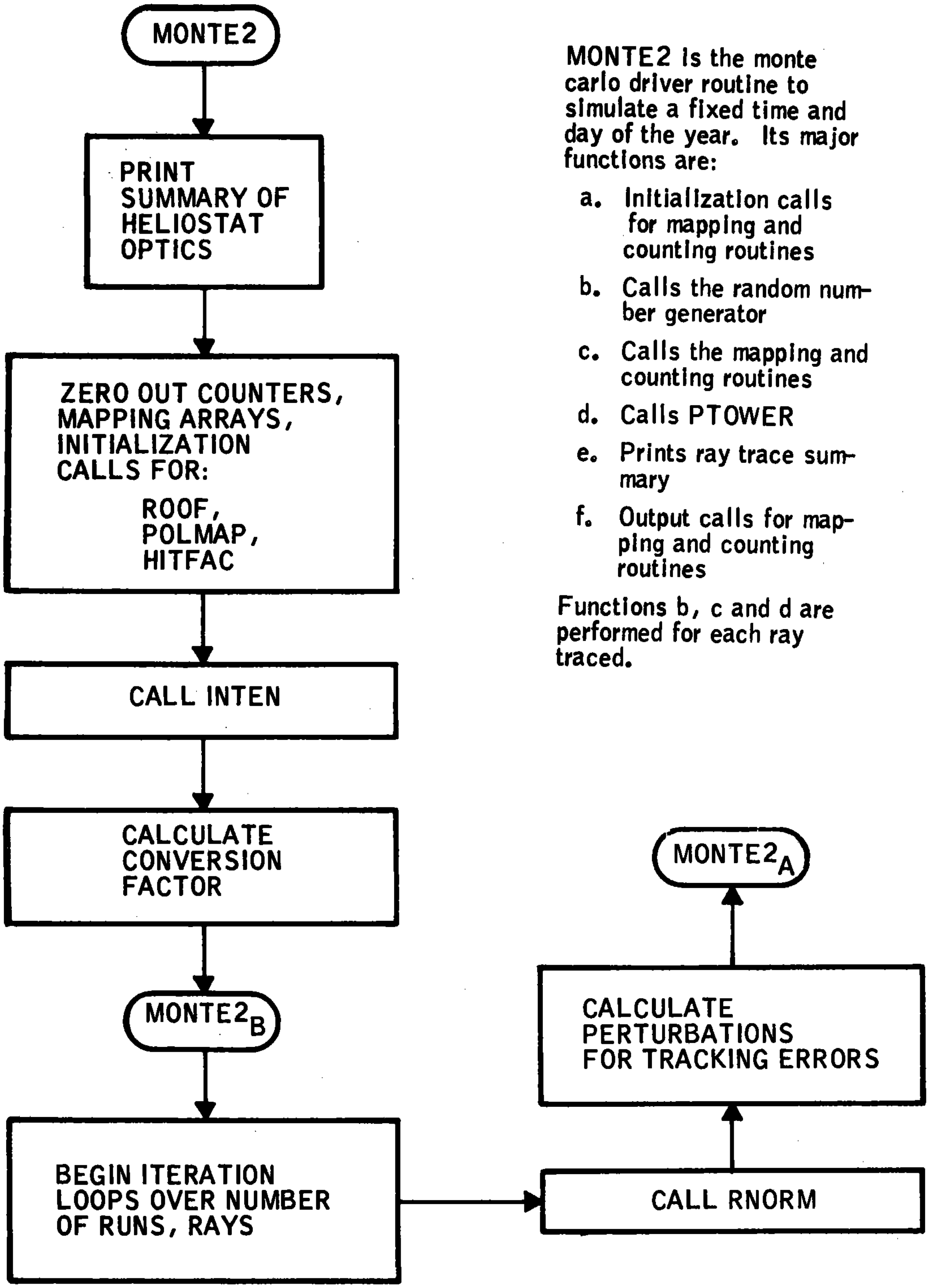


Figure A-17. MONTE2 Program Flow

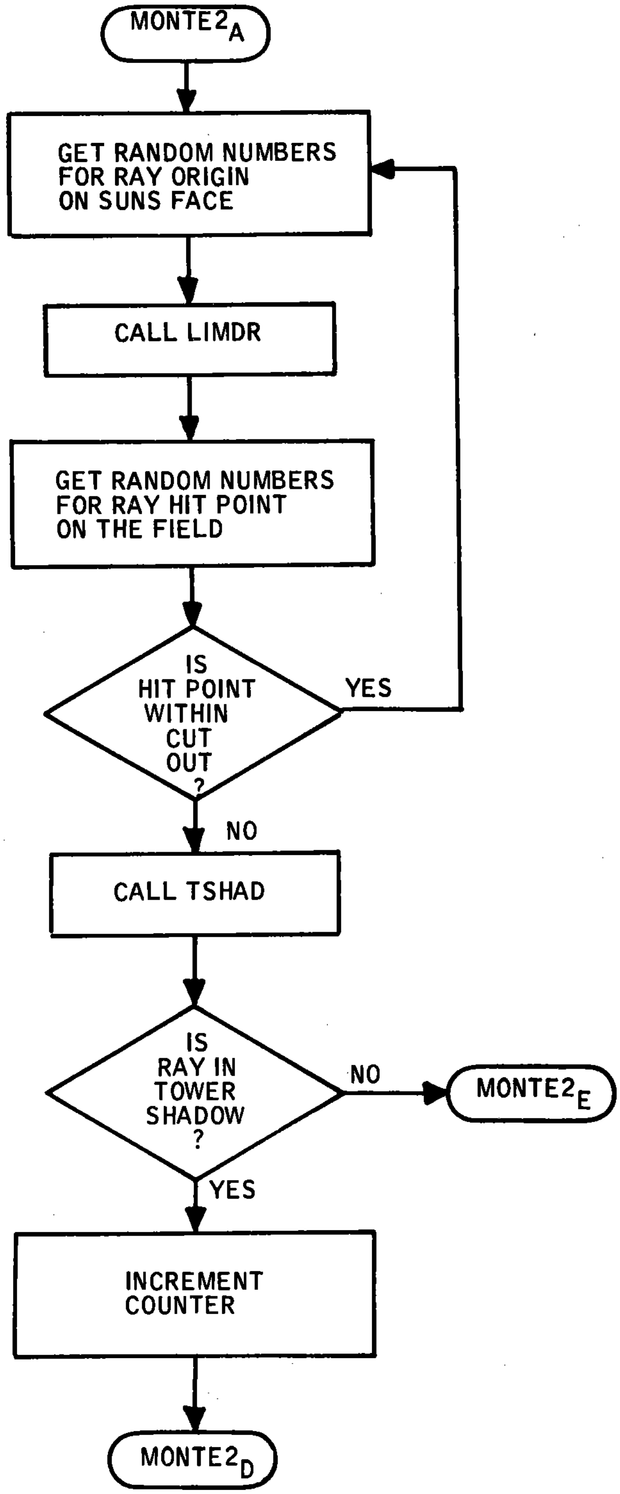


Figure A-17. (Continued)

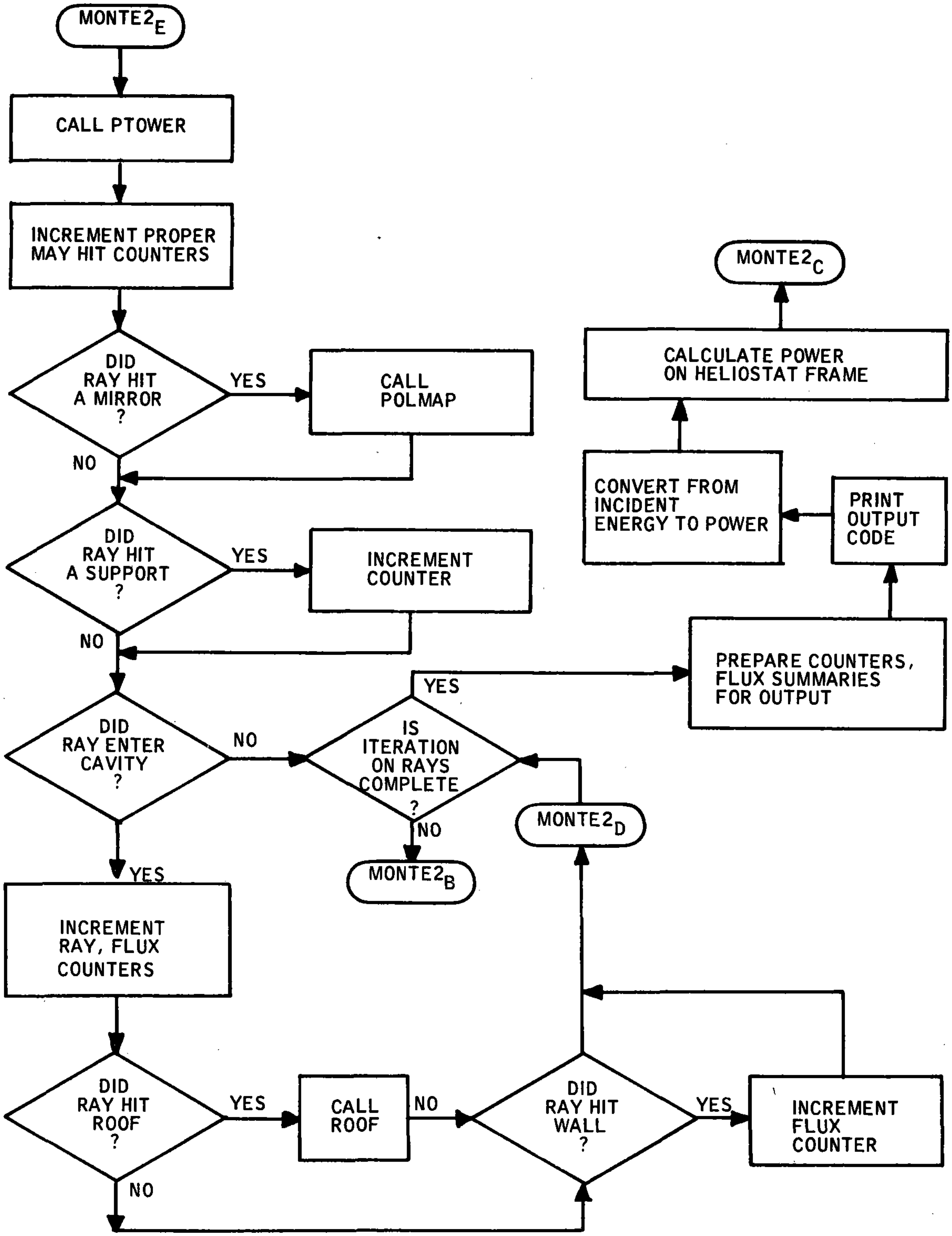


Figure A-27. (Continued)

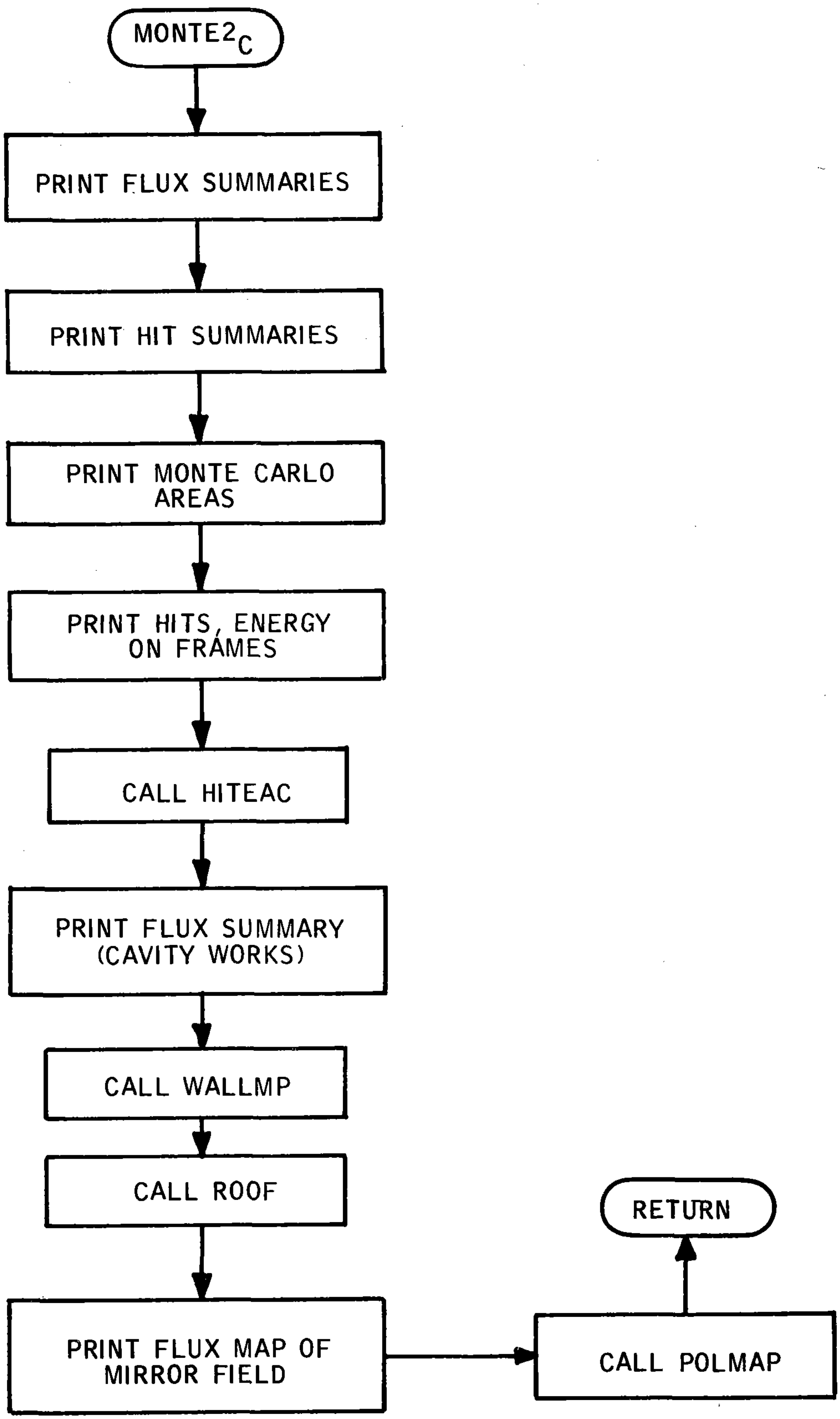
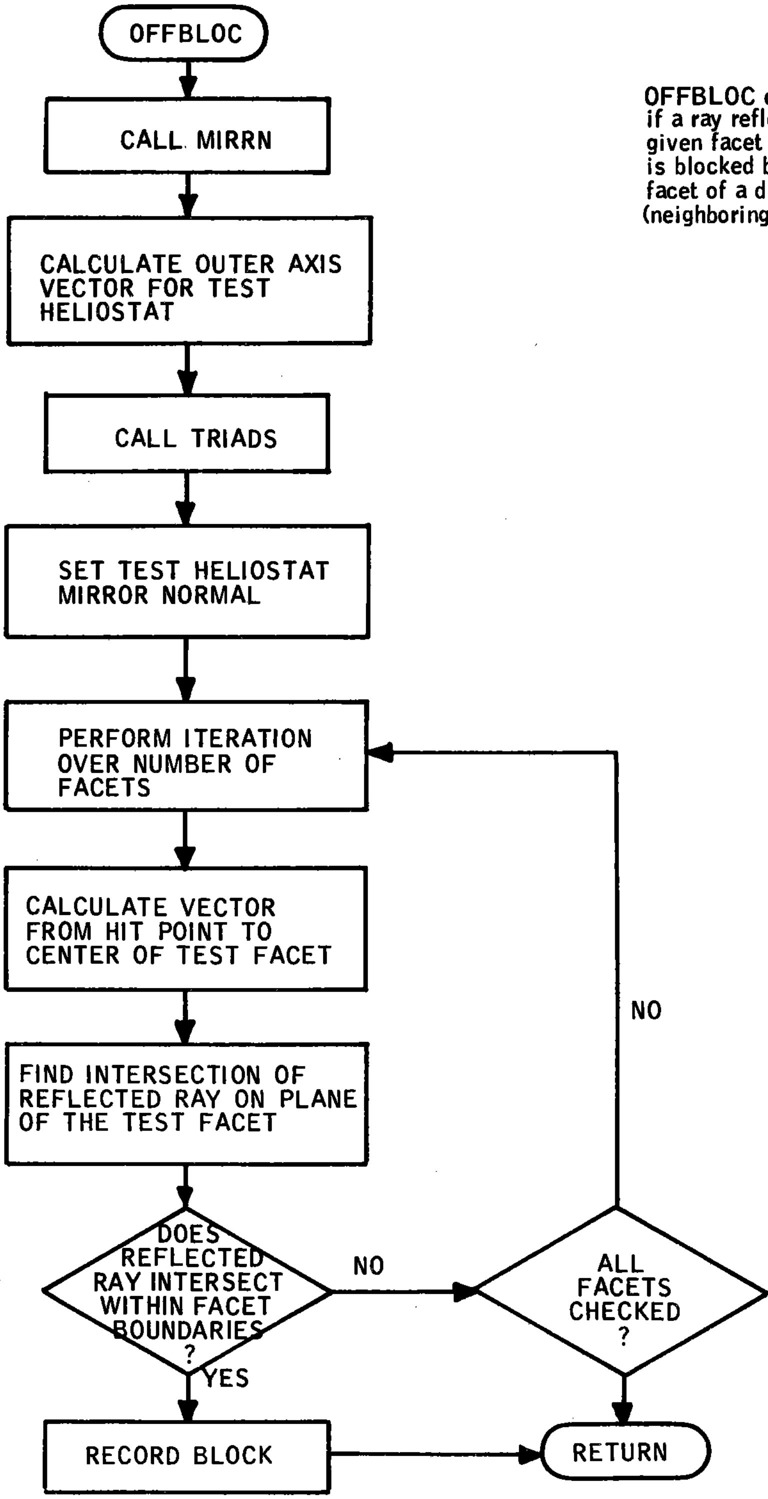


Figure A-17. (Concluded)



OFFBLOC checks to see if a ray reflected by a given facet of a heliostat is blocked by another facet of a different (neighboring) heliostat.

Figure A-18. OFFBLOC Program Flow

ONBLOCK determines if a ray reflected from a facet of a heliostat is blocked by another facet of the same heliostat.

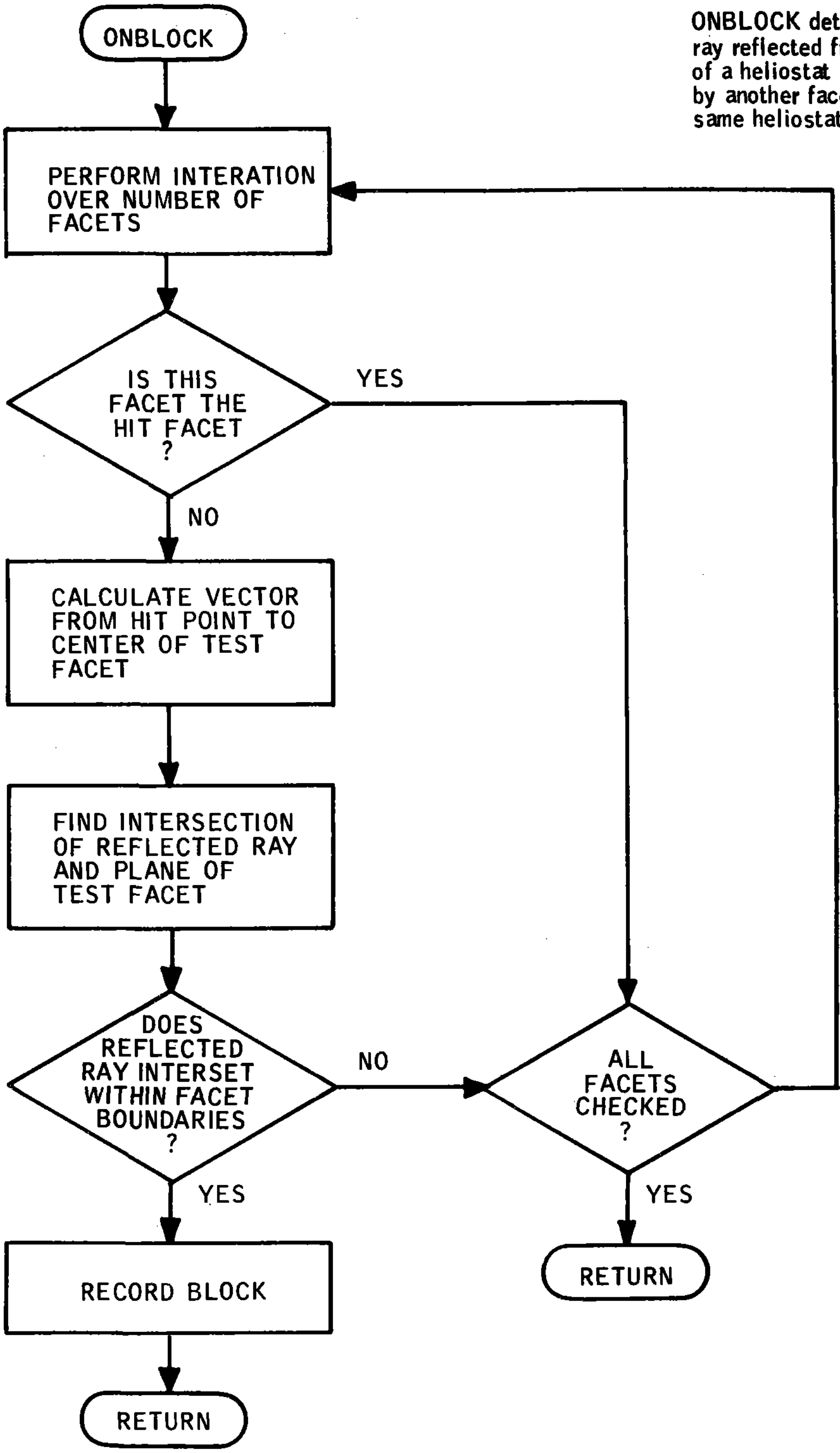


Figure A-19. ONBLOCK Program Flow

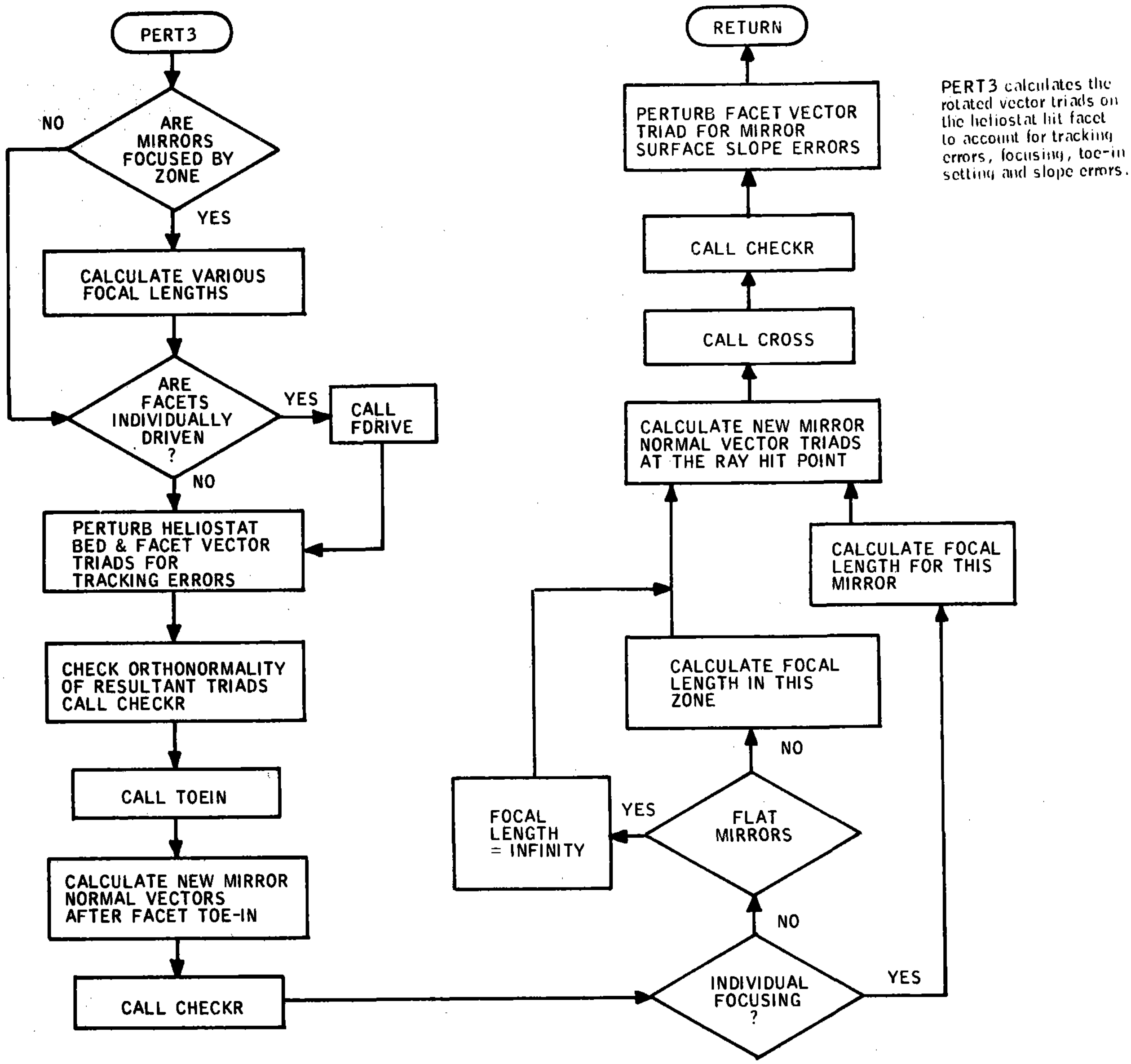
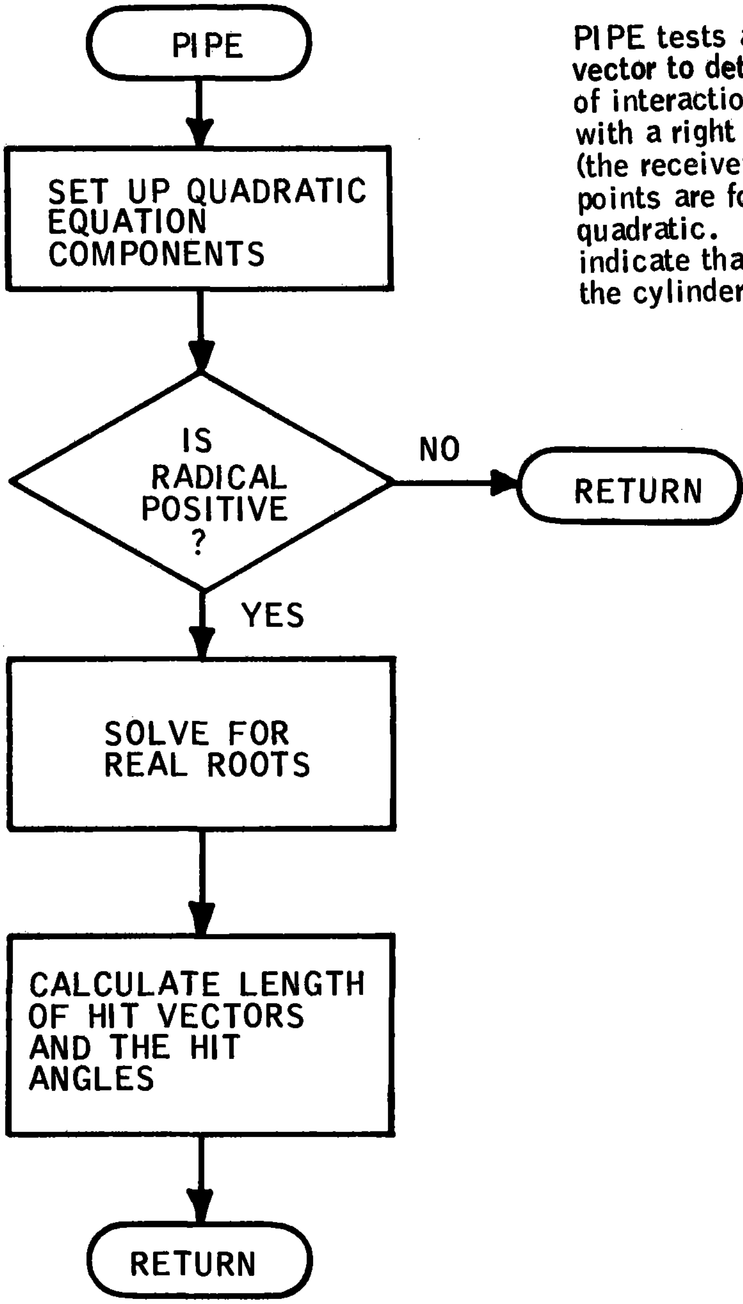
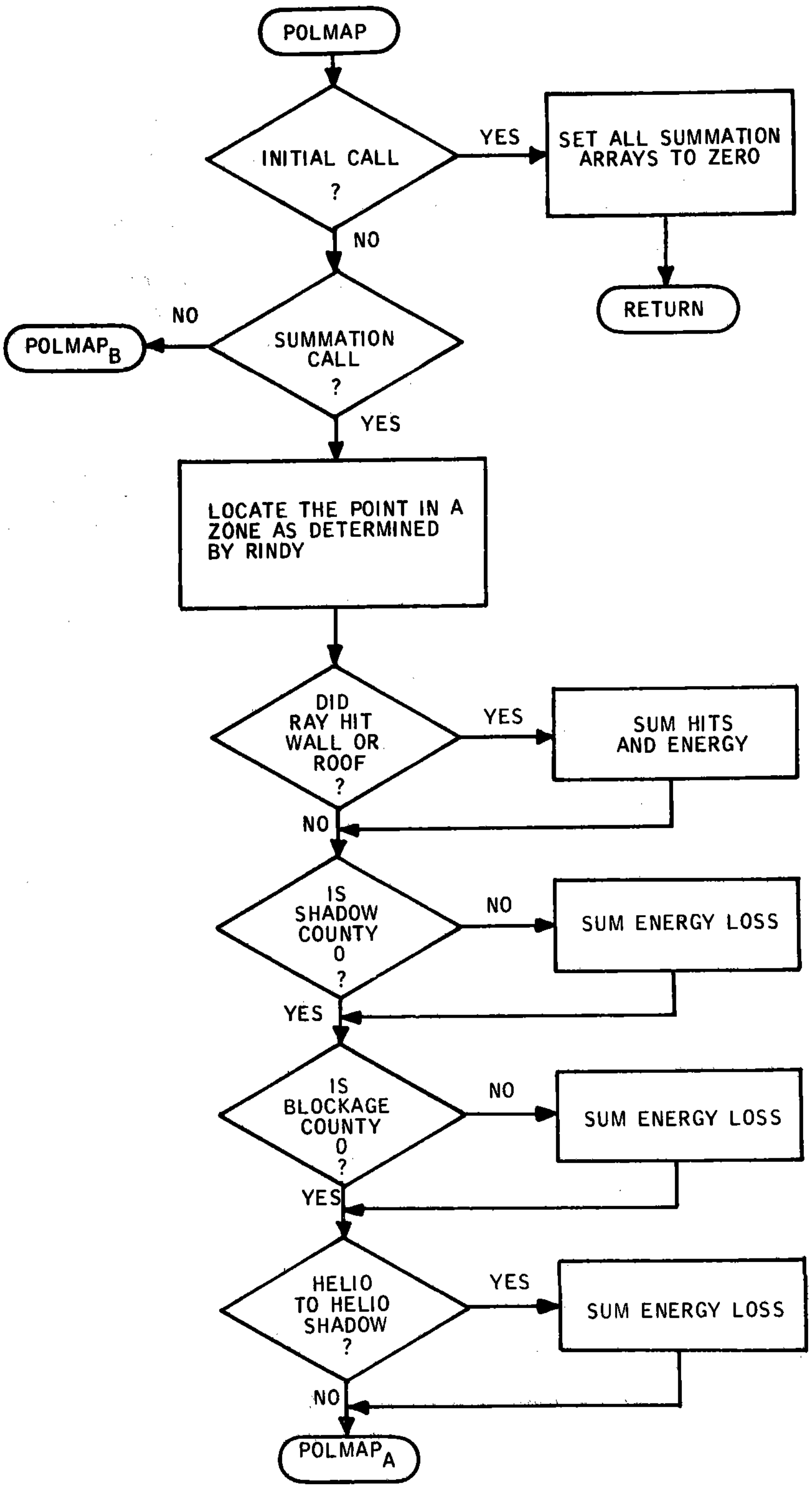


Figure A-20. PERT3 Program Flow



PIPE tests a reflected ray vector to determine its points of interaction (hit points) with a right circular cylinder (the receiver walls). Hits points are found by solving a quadratic. Imaginary roots indicate that the ray missed the cylinder.

Figure A-21. PIPE Program Flow



POLMAP sorts and sums energy totals and hits according to their origin on the mirror field. For each field zone, the following quantities are calculated:

a. mirror hits - rays that hit cavity walls or roof
b. reflected energy - rays that hit cavity walls or roof
c. energy lost to shadowing
d. energy lost to blockage
e. energy lost to heliostat to heliostat shading
f. corbel hits
g. whistle throughs
h. number of misses across the front
i. number of misses high
j. number of misses low

The routine can be called in one of three ways:

a. initialization
b. summation
c. output

Figure A-22. POLMAP Program Flow

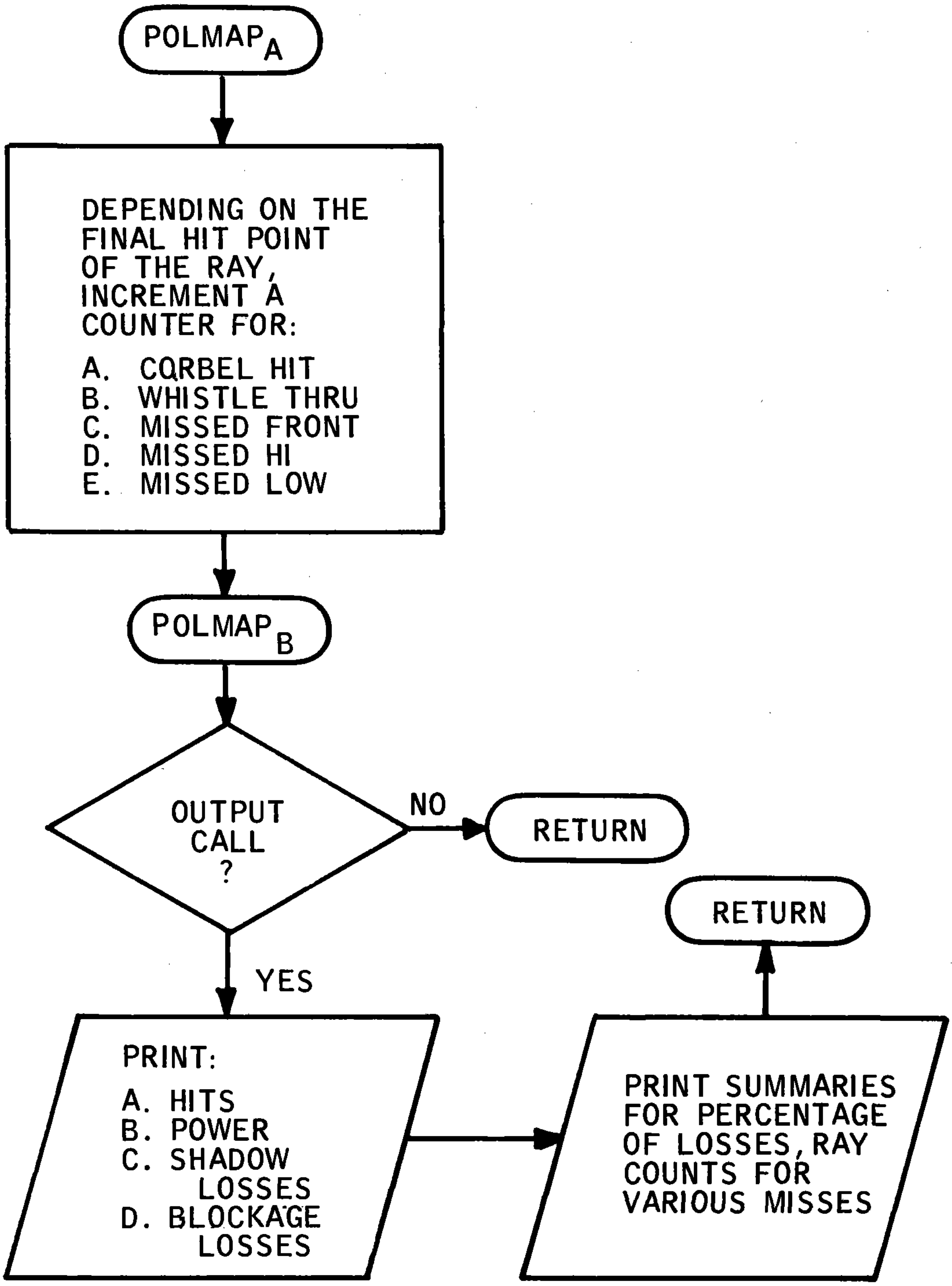
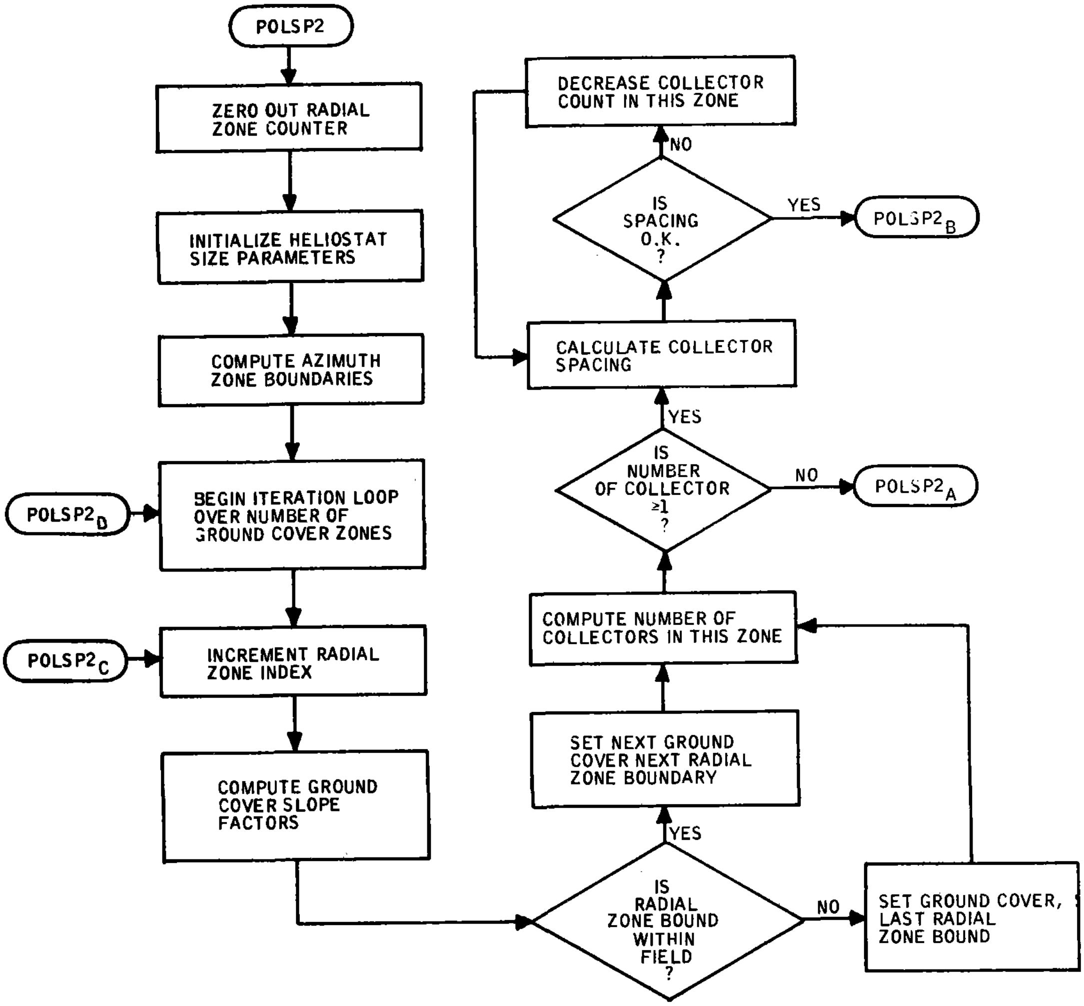


Figure A-22. (Concluded)



POLSP2 sets up the field for a non-uniform polar arrangement of the heliostats.

It calculates the radial spacing of every row and the number of heliostats in each zone.

Figure A-23. POLSP2 Program Flow

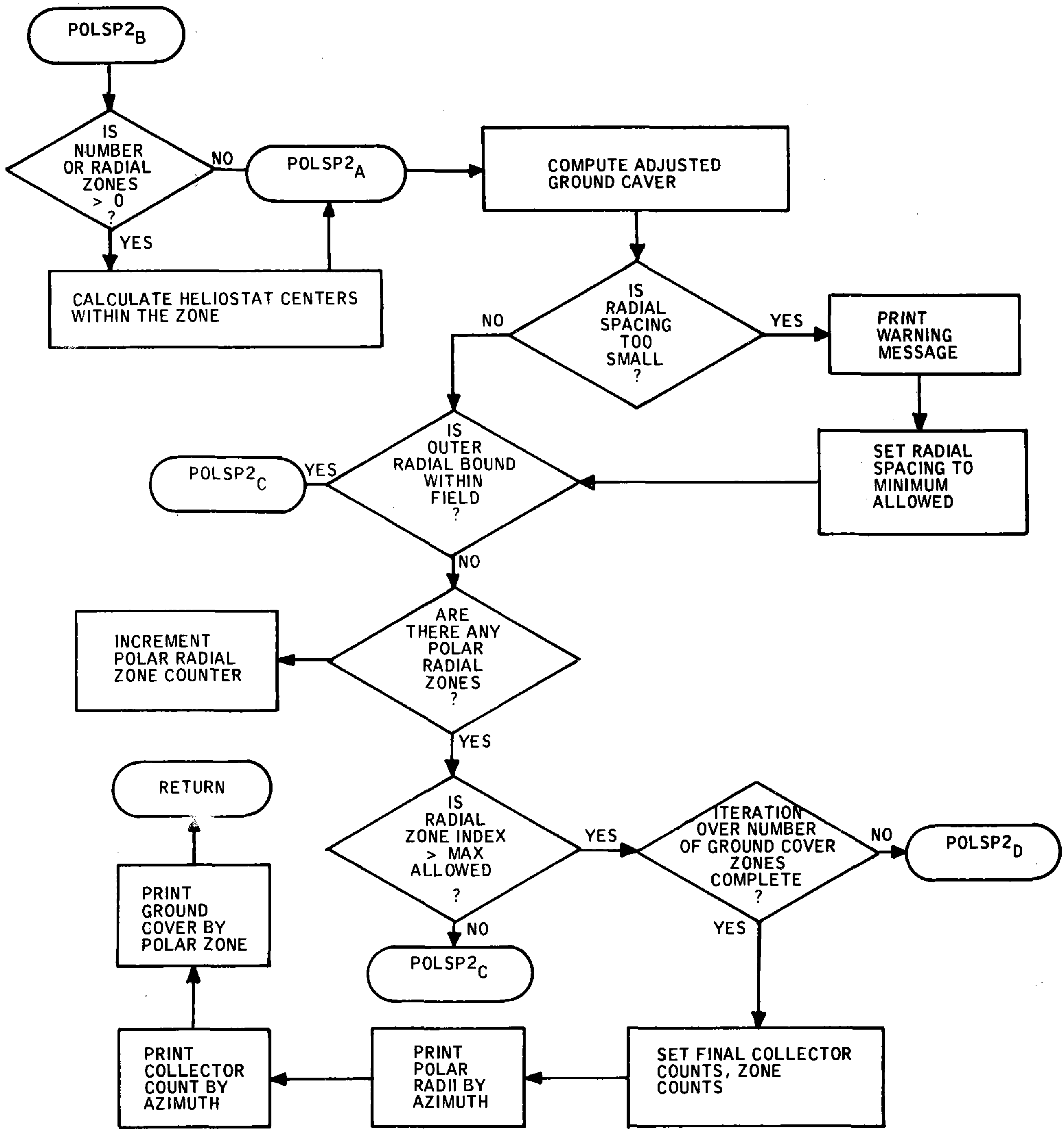
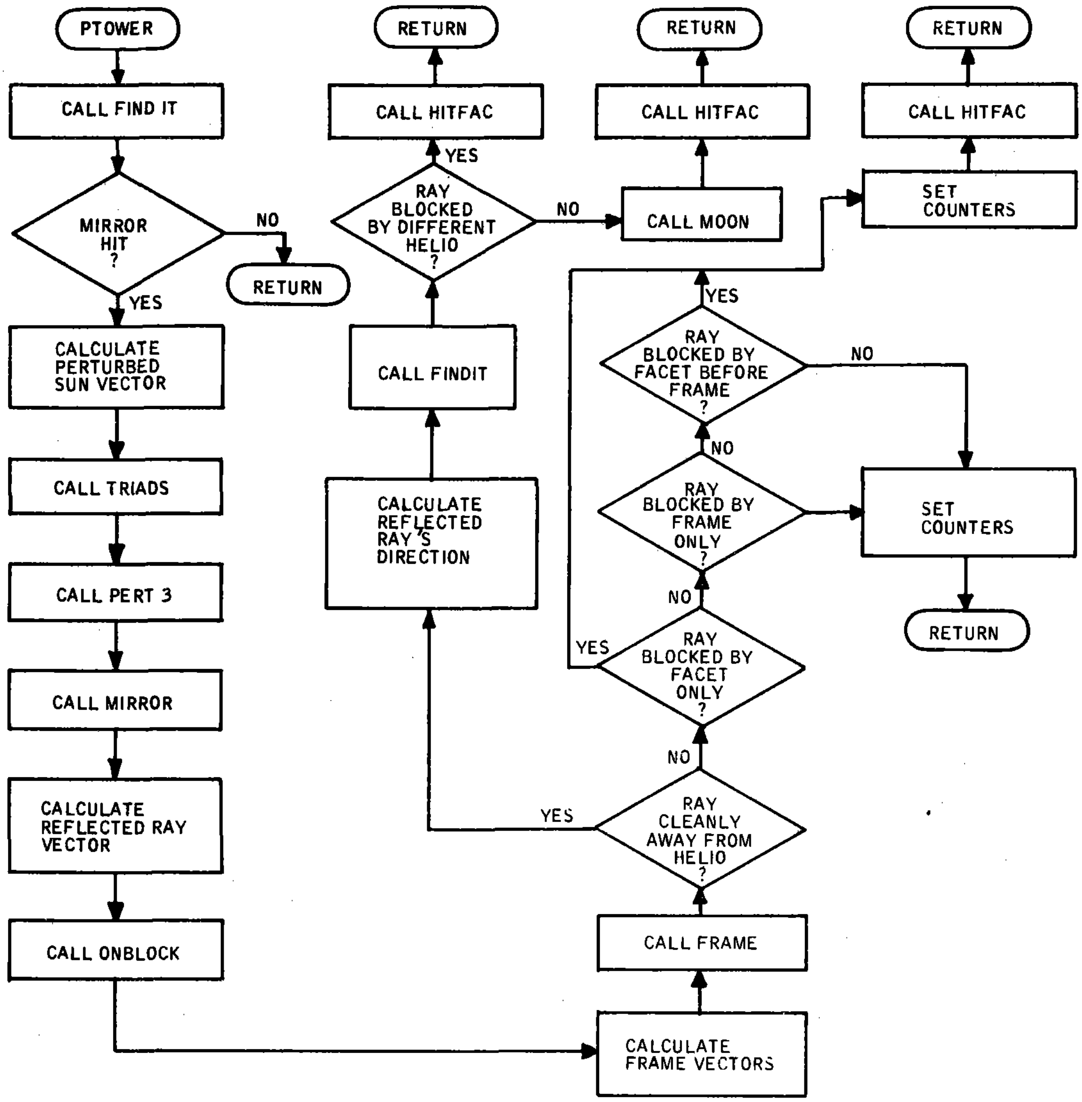


Figure A-23. (Concluded)



PTOWER controls the calls for all of the hit tests. The purpose of the hit tests is to determine the path taken by the ray. A ray (vector) and its hit point on the mirror field (as determined in one of the MONTE routine) are major inputs.

Figure A-24. PTOWER Program Flow

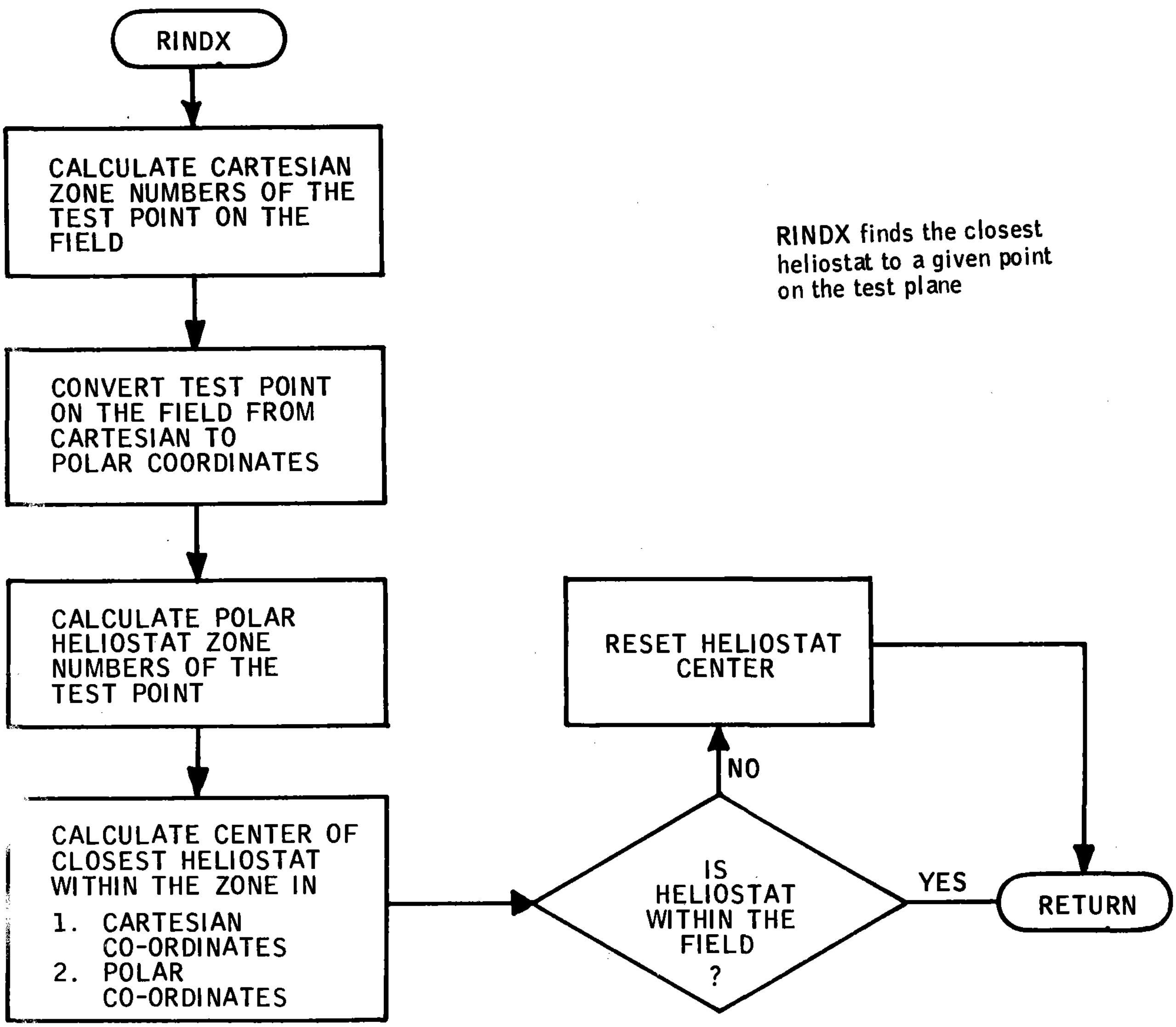
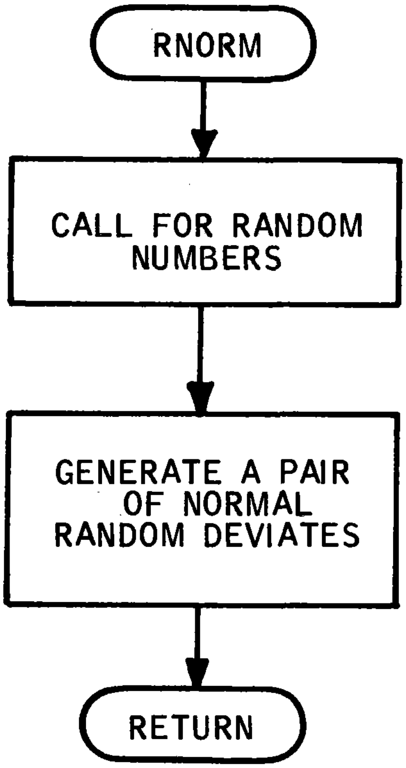
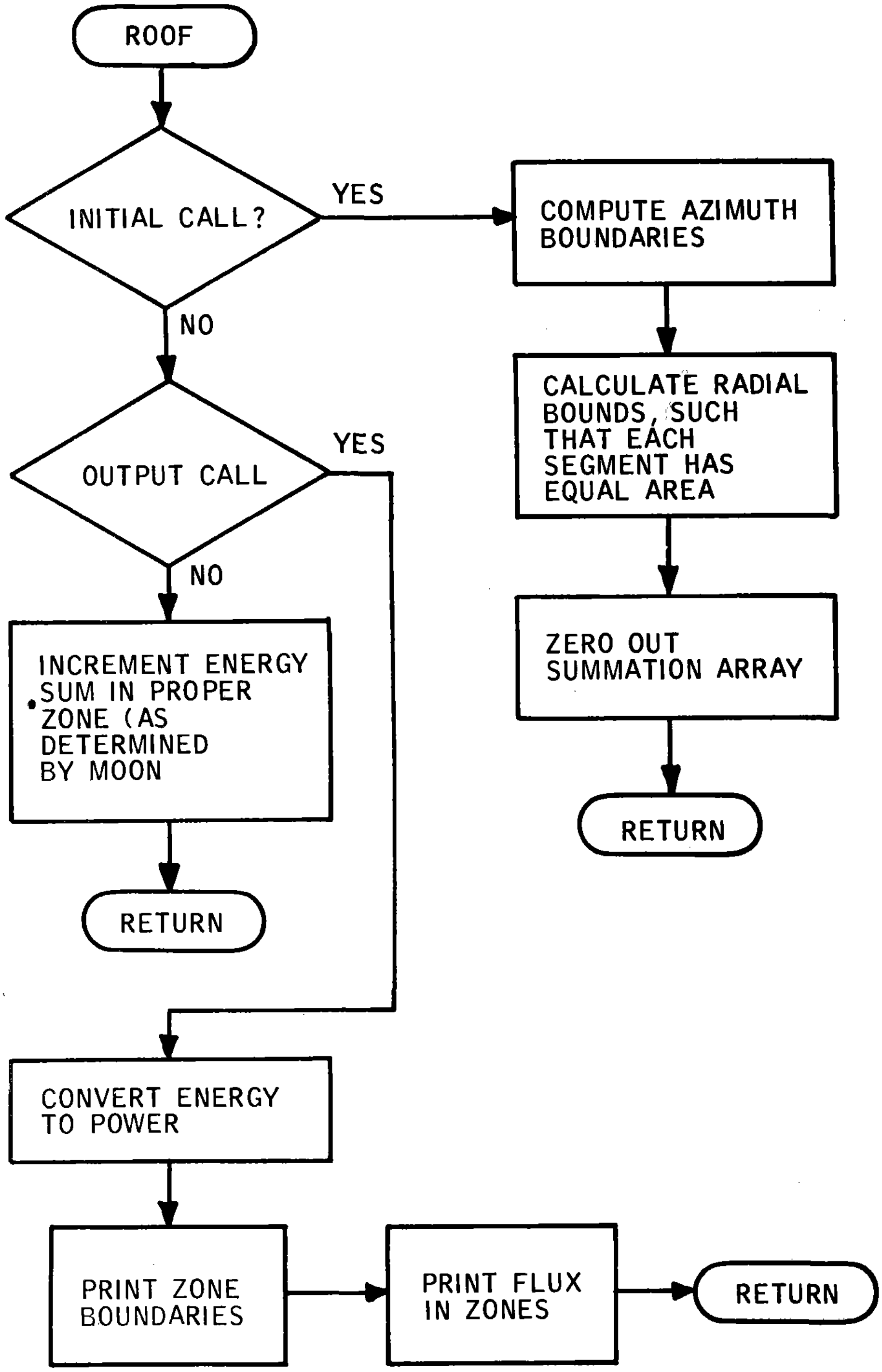


Figure A-25. RINDX Program Flow



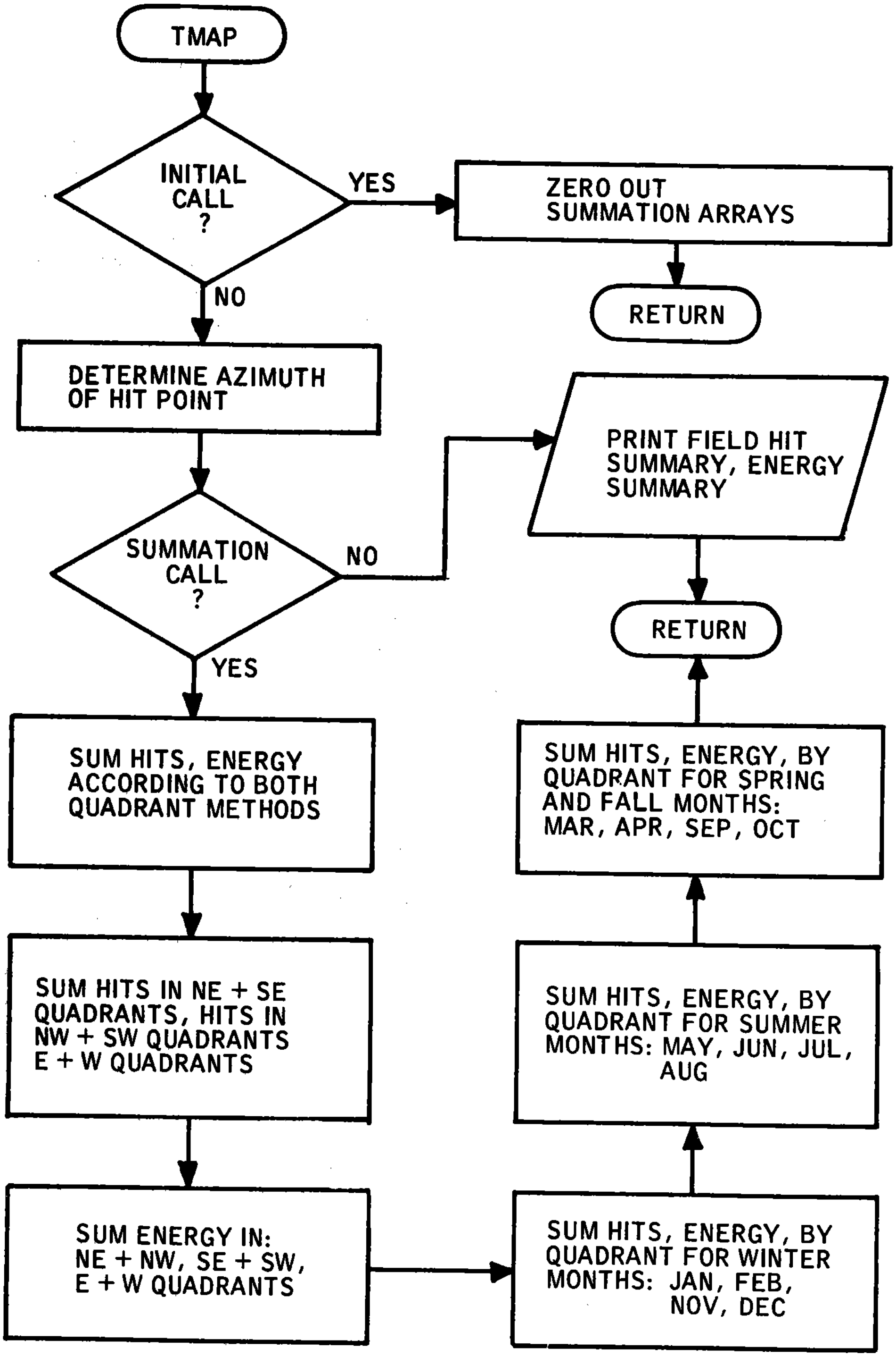
RNORM generates pairs of independent normal random deviates (mean = 0, standard deviation = 1). They are normally distributed on the interval ($-\infty$ to $+\infty$). Required input is a uniform random number generator.

Figure A-26. RNORM Program Flow



ROOF sorts the ray hits on the cavity ceiling by zone. These zones are concentric donuts divided further into azimuth zones. All zones are of equal area.

Figure A-27. ROOF Program Flow

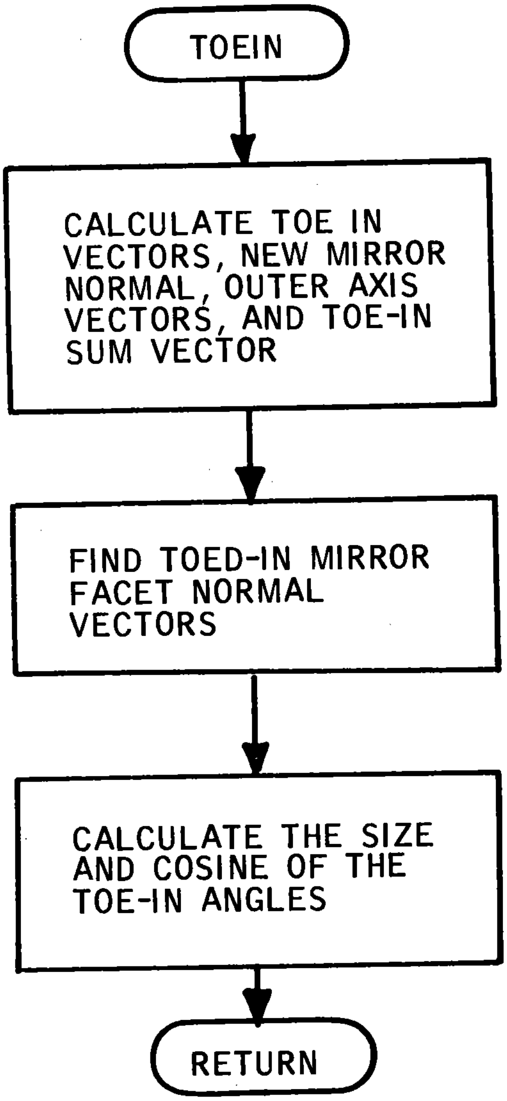


TMAP details the yearly performance of various segments of the field around the year. TMAP is called only for time integration runs. It produces four maps: two are hit summaries, two are energy summaries.

TMAP can be called in one of three modes:

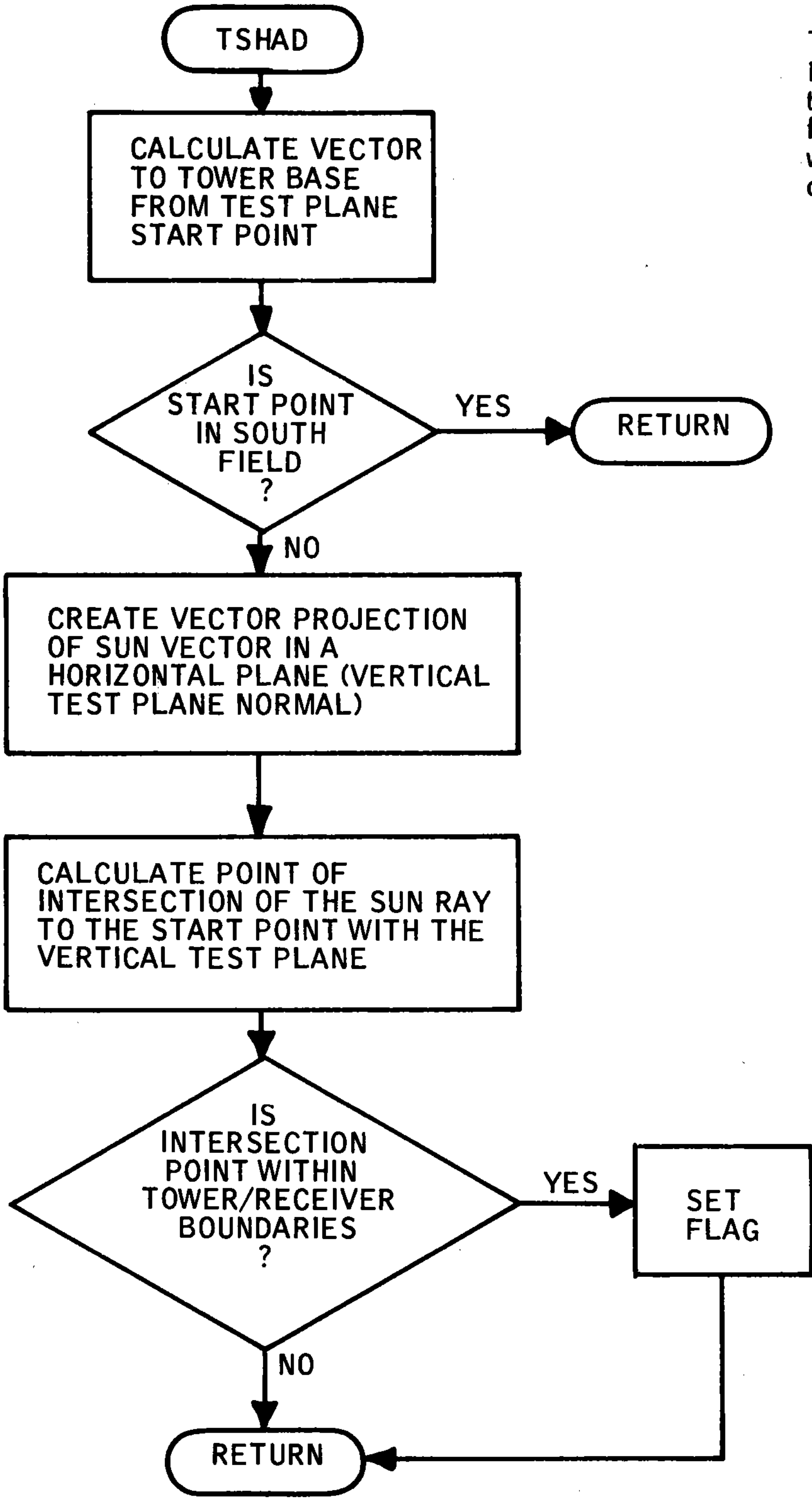
a. Initializations
b. Summations
c. Outputs

Figure A-28. TMAP Program Flow



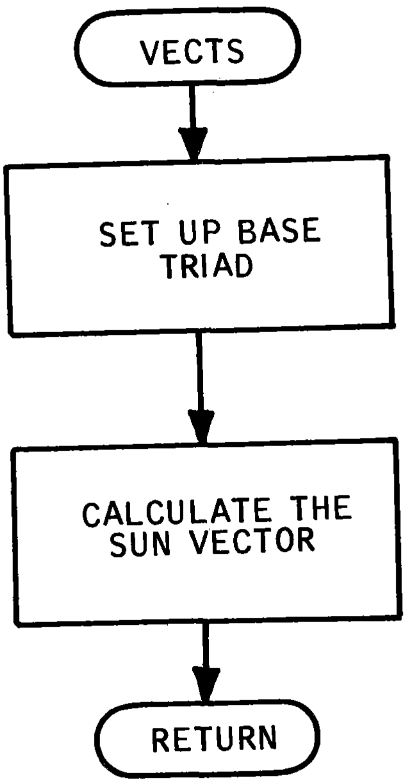
Calculates the angle of toe-in of the hit facet. The toe-in angle is the rotational angle which the net facet is moved from the horizontal frame top plane to focus at one point for a specified sum position. The sum position for the toe-in is a required input.

Figure A-29. TOEIN Program Flow



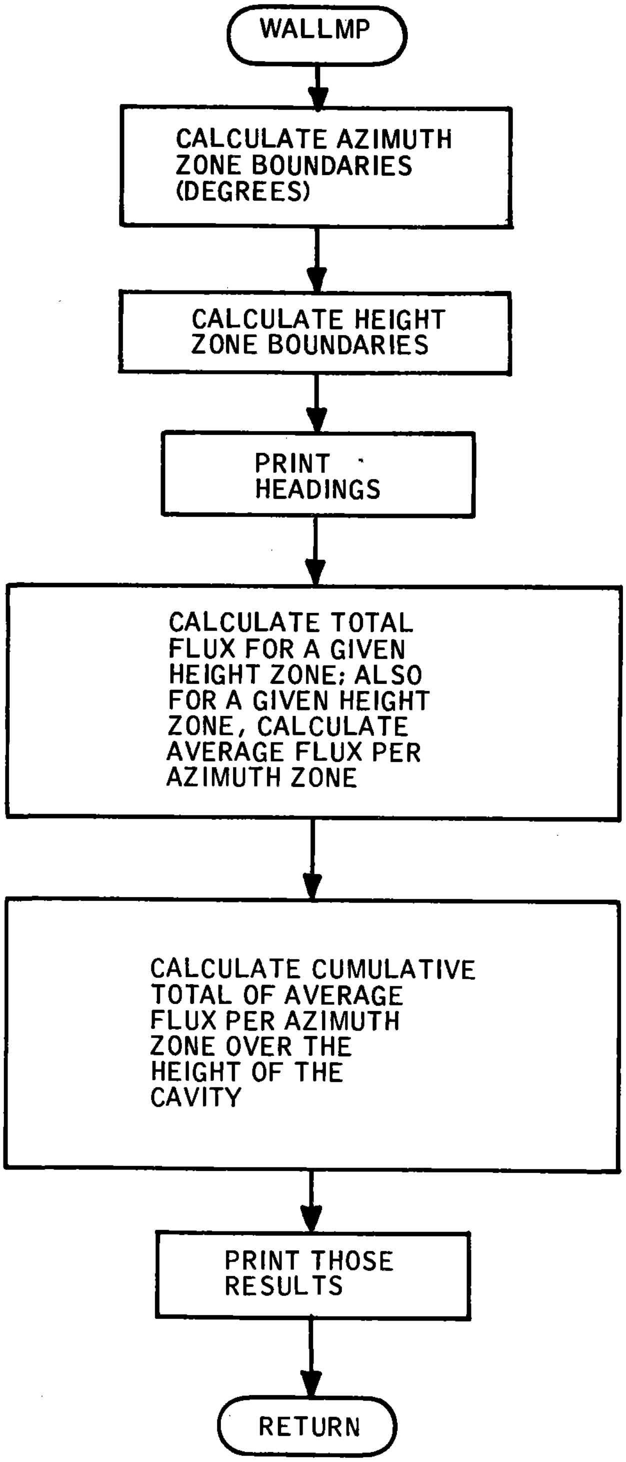
TSHAD determines if an incident ray is blocked by the tower. It performs this function by working backwards from the hit point on the field to the sun.

Figure A-30. TSHAD Program Flow



VECTS calculates the base orthonormal triad set ($\vec{N}$, $\vec{UN}$, $\vec{UE}$) located at the tower center. The sum vector ($\vec{UR}$) is also calculated for the desired month, day and hour of the year.

Figure A-31. VECTS Program Flow



WALLMP prints the cavity wall flux map. It does this by dividing the wall in zones according to height and azimuth. (Where 0° azimuth is North and 90° is east etc.)

Figure A-32. WALLMP Program Flow

APPENDIX B
FORTRAN LISTING

```
$$$$$$$    $$$$$ $   $$$$$$    $$$$$$    $$$$$$   $$$$$$$   $     $$
$$     $$  $$     $   $$     $$ $$     $$ $$     $$ $$     $$ $$    $$
$$     $$  $$    $$$  $$        $$     $$ $$     $$ $$     $$ $$$   $$
$$     $$  $$  $ $$   $$        $$     $$ $$     $$ $$     $$ $$$$  $$
$$     $$  $$ $$ $$   $$        $$     $$ $$     $$ $$     $$ $$ $$ $$
$$     $$  $$ $   $$  $$        $$     $$ $$     $$ $$$$$$$   $$  $$$$
$$     $$  $$$    $$  $$        $$     $$ $$     $$ $$  $$    $$   $$$
$$     $$   $     $$  $$     $$ $$     $$ $$     $$ $$   $$   $$    $$
$$$$$$$    $ $$$$$    $$$$$$    $$$$$$    $$$$$$   $$     $$  $$    $$
```

```
      PROGRAM HELIAKI(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)              HELIAKI    2
      DIMENSION XM(9)                                                     HELIAKI    3
      COMMON/RANDOM/NRUN,IRANC,IJUMP,MODE,ISRAN,IRAYS                     HELIAKI    4
     1     ,IT1,UDNI,LIMC,DINTV,YFRAC                                     HELIAKI    5
C** THIS IS THE CONTROLLING PROGRAM.  FROM IT INITCOL IS CALLED. THEN    HELIAKI    6
C ONE OF THE MONTE DRIVER ROUTINES, DEPENDING ON THE RESULTS DESIRED.    HELIAKI    7
      MODE=1                                                              HELIAKI    8
      IRANC=0                                                             HELIAKI    9
    1 CALL INITCOL                                                        HELIAKI   10
C                                                                         HELIAKI   11
C IJUMP CONTROLS THE MONTE CARLO SIMULATION                               HELIAKI   12
C IJUMP=0 TIME POINT ONLY                                                 HELIAKI   13
C IJUMP=1 TIME INTEGRATION ONLY                                           HELIAKI   14
C IJUMP=2 TIME POINT PLUS TIME INTEGRATION                                HELIAKI   15
      IF(IJUMP.EQ.1) GO TO 5                                              HELIAKI   16
      CALL MONTE2(XM)                                                     HELIAKI   17
      IF(IJUMP.EQ.0) GO TO 10                                             HELIAKI   18
    5 CALL MONTE(XM,HOURS)                                                HELIAKI   19
   10 IF(IT1.LT.3) GO TO 1                                                HELIAKI   20
      STOP                                                                HELIAKI   21
      END                                                                 HELIAKI   22
```

```
      SUBROUTINE INITCOL                                                HELIAKI   23
      REAL N                                                            INITCOL    2
      DIMENSION AIMP(3)                                                 INITCOL    3
      INTEGER CILAT                                                     INITCOL    4
      COMMON/DARKLE/DDTOP,DDBASE                                        INITCOL    5
      COMMON/CAVITY/SEP,DD1,DD2,RDIF,HDIF,HCAV,HSWTC(2),RSWTC(2),       INITCOL    6
     1 CILAT(2),CAVLAT(2,21),AIMHGT                                     INITCOL    7
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,    INITCOL    8
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,     INITCOL    9
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,       INITCOL   10
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM                          INITCOL   11
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,  INITCOL   12
     1     RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),           INITCOL   13
     2     UTT(3),UNNP(3),UXV2P(3)                                      INITCOL   14
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE                    INITCOL   15
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),                       INITCOL   16
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ         INITCOL   17
      COMMON/JOKER/URP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD  INITCOL   18
      COMMON /STATS/TPB,TSB,PHB,TPV,PHV,AVE,TSV,PAX1V,PAX1B,PAX2V,PAX2B INITCOL   19
                                                                        INITCOL   20
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)                 INITCOL   21
      COMMON/RANDOM/NRUN,IRANC,IJUMP,MODE,ISRAN,IRAYS                   INITCOL   22
     1      ,IT1,UDNI,LIMC,DINTV,YFRAC                                  INITCOL   23
      COMMON /CINDEX/ XPCOL,YPCOL,COSA,COSB,SLDUM,WCELL,ICELL,JCELL,    INITCOL   24
     1         XCSAV,YCSAV,XCM,YCM,ICELM,JCELM                          INITCOL   25
      COMMON/SUPPT/DELTM,THES,KSEG,APH,SW,NSUP,RCONE,THECON,HTOT        INITCOL   26
      COMMON/CEILING/NAZZ,NRZ,DTAZ(21),DRZ(10),DD3,IZR,IZAZ             INITCOL   27
      COMMON/MAPS/NRZF,NAZZF,NC(250,8),SRAD(250,8),NPRAD(8),DEG         INITCOL   28
      COMMON/TILTED/TTILT,UVT(3),U1(3),U2(3),WAPMAX,WAPMIN,OFFSET       INITCOL   29
      COMMON/STRUCT/GAP,WLONG,WSIDE,WTRI,XLTRI,B1,B2,WCROSS,WDUM,IFRAM  INITCOL   30
     *,HTMIR,HTCROS,WJCROS                                              INITCOL   31
      COMMON/TOE/CTAZT,STAZT,CTELT,IFOCUS,STELT,UTARG(3),DTARG(3)       INITCOL   32
C                                                                       INITCOL   33
C ********NAMELIST DICTIONARY                                           INITCOL   34
      NAMELIST /CHANGE/ RFIELD,TH,NSTOPS,TDISX,TDISY,IRAYS,TPB,TSB,PHB, INITCOL   35
     1          TPV,TSV,PHV,THETA,MON,IDAY,T,IJUMP,IT1,NRUN,ISRAN,      INITCOL   36
     2          PAX1V,PAX2V,SCDELT,NLONG,NLATC,GCOVER,RCO,RCONE,HCAV,   INITCOL   37
     3          SW,NSUP,DD3,NRZ,NRZF,NAZZF,WD,WFV,XDF,NPACK,SPACEF,     INITCOL   38
     4          IDRIVE,NNU,WAPMAX,WAPMIN,OFFSET,WLONG,WCROSS,WTRI,GAP,  INITCOL   39
     5          XLTRI,HTMIR,HTCROSS,WJCROS,ITOE,IFOCUS,TAZT,TELT,       INITCOL   40
     6          MONT,IDAYT,TIMET                                        INITCOL   41
      DATA WAVL/.39,.44,.48,.51,.54,.57,.60,.63,.66,.70,.74,.78,.82,.87,INITCOL   42
     1.96,1.02,1.08,1.22,1.48,1.68/                                     INITCOL   43
C        IT1=3  END OF RUN                                              INITCOL   44
C        MODE=1 AT FIRST ROUND                                          INITCOL   45
C        MODE=2 AFTER THAT                                              INITCOL   46
C** THIS IS THE INITIALIZING ROUTINE. IT INITIALIZES ALL OF THE         INITCOL   47
C VALUES IN THE ENTIRE PROGRAM.                                         INITCOL   48
C   VARIABLE LIST IN INITCOL.                                           INITCOL   49
C     SEP=DISTANCE BETWEEN LOWER AND UPPER DISK                         INITCOL   50
C   SW=SUPPORT WIDTH                                                    INITCOL   51
C    NSUP=NUMBER OF SUPPORTS                                            INITCOL   52
C     DD3=INNER CAVITY DIAMETER                                         INITCOL   53
C   WD=FACET LENGTH                                                     INITCOL   54
C    WFV=FACET WIDTH                                                    INITCOL   55
C      XDF=DISTANCE BETWEEN FACET AXES                                  INITCOL   56
C     AIMHGT=AIM CIRCLE HEIGHT UP CONE AXIS                             INITCOL   57
```

```
C     WAPMAX=MAXIMUM APERTURE WIDTH
C     WAPMIN=MINIMUM APERTURE WIDTH
C      IFOCUS=MIRROR FOCUSSING OPTION
C      0 MEANS INDIVIDUAL FOCUSSING
C       1-10 ARE NUMBER OF FOCUSSING ZONES FOR CONSTANT FOCUSSING
C       11 MEANS FLAT MIRRORS

C    HTCROSS IS THE VERTICAL DIMENSION OF A CROSS PIECE ON THE FRAME
C    WJCROS IS THE WIDTH OF THE CENTER CROSS PIECE OF THE FRAME
C    MON = MONTH
C    T=TIME OF DAY
C    IDAY=DAY OF THE MONTH
C    RFIELD=OUTER RADIUS OF THE FIELD IN FEET
C    TH=HEIGHT OF THE TOWER UP TO THE LOWER DISK
C    HCAV=CAVITY HEIGHT IN FEET
C    NLATC=NUMBER OF HEIGHT ZONES ON THE CAVITY WALLS
C    NLONG=NUMBER OF AZIMUTH ZONES ON THE CAVITY WALL
C       NSTOPS IS NUMBER OF CHECK POINTS ALONG RAY PATH FROM TEST PLANE
C       TO GROUND

C      NRZF=NUMBER OF RADIAL ZONES IN THE FIELD
C      NAZZF=NUMBER OF AZZIMUTH ZONES IN THE FIELD
C    ISRAN=INITIAL RANDOM SEED
C    TDISY=TOWER OFFSET FROM THE CENTER OF THE FIELD.  IT MUST BE ZERO
C     FOR A DONUT FIELD, IN A NORTH-SOUTH DIRECTION
C    TDISX=TOWER OFFSET FROM THE CENTER OF THE FIELD.  IT MUST BE ZERO
C     FOR A DONUT FIELD, IN A EAST-WEST DIRECTION
C    NRUN=NUMBER OF RUNS (10)
C    IRAYS=NUMBER OF RAYS IN 1 RUN
C    DINTV=INTERVAL OF HOURS THAT WE ARE INTIGRATING OVER FOR THE TIME
C     INTEGRATION
C    YFRAC=NUMBER OF DAYS IN A YEAR
C    GCOVER=GROUND COVER RATIO (AREA MIRRORS/GROUND AREA)
C    IT1-CONTROL VARIABLE. THE PROGRAM TERMINATES WHEN IT1 IS GREATER
C     THAN OR EQUAL TO 3
C    DRAD =CONVERSION FACTOR FROM DEGREES TO RADIANS
C    THETA=LATITUDE ANGLE OF THE SITE TESTED
C    TPB,TSB,PHB,TPV,TSV,PHV,PAX1V,PAX2V  = HELIOSTAT OPTICAL PROPERTIES
C     AND TRACKING DRIVE PROPERTIES FOR A NORMAL DISTRIBUTION.
C      (B=MEAN,V=VARIANCE)
C  NPACK DEFINES FIELD PACKING GEOMETRY
C  4 POLAR PACKING
C  5 POLAR NON-UNIFORM
C  IDRIVE CONTROLS FACET DRIVES
C     1  GANGED.
C     2  INDEPENDENT IN ONE AXIS.
C** NNU IS FOR NONUNIFORM POLAR PACKING OF
C** TILT-TILT HELIOSTATS.  IT IS THE NUMBER OF NONUNIFORM
C** AZIMUTH ZONES.  THIS CAN BE 1 OR 8.
C***WLONG IS THE WIDTH OF THE LONG PIECES ON THE FRAME
C***WCROSS IS THE WIDTH OF THE CROSS PIECES ON THE FRAME
C***GAP IS THE SPACE BETWEEN THE LONG PIECES MINUS WD
C***WTRI IS THE WIDTH OF THE CROSS BRACES
C***XLTRI IS THE LONGER EDGE OF THE CROSS BRACES
C ** TAZT=TOEIN AZIMUTH ANGLE (RADIANS)
C ** TELT=TOEIN ELEVATION ANGLE (RADIANS)
C ** TAZT AND TELT DEFAULT TO 3/21 NOON AT 33 DEGREES LATITUDE
```

```
      C      HTMIR IS THE DISTANCE OF THE FACET AXIS ABOVE THE TOP FRAME PLANE
      C    HTCROSS IS THE VERTICAL DIMENSION OF A CROSS PIECE ON THE FRAME
      C    WJCROS IS THE WIDTH OF THE CENTER CROSS PIECE OF THE FRAME
            MON=6
            DO 1953 ID=1,3
       1953 SCDELT(ID)=0.0
            T=12.
            IDAY=21
            AMAX=1.3
            LIMC=3
            ISRAN=27641
            DINTV=14.
            YFRAC=365.
            IT1=2
            DRAD=.01745
            CAPR=149.5*10.**6
            SMALR= 6357.0
            THETA=33.
            NRUN=10
            IF(IRANC.NE.0)  GO TO 1800
            WRITE(6,7002)
            WRITE(6,1811)  ISRAN,NRUN
       1811 FORMAT(5X,20HINITIAL RANDOM SEED=,I10,3X,19HNUMBER OF RUNS PER ,
           16HBATCH=,I5,/)
            DJEF=FLOAT(ISRAN)
            DJEF=RANF(DJEF)
            IRANC=1
       1800 CONTINUE
            TPB=0.
            TSB=0.
            PHB=0.
            TPV=.05
            TSV=.05
            PHV=.05
            NSTOPS=11
            DO  3460 I=1,3
       3460 SCDELT(I)=0.
            TDISX=0.
            PAX1B=0.
            PAX2B=0.
      C  SIDERIAL EARTH RATE
            OME= 0.2625159
            OMS=360./(365.25*57.3)
            XTH=THETA*DRAD
            STH=SIN(XTH)
            CTH=COS(XTH)
            XSEQ=23.5*DRAD
            SEQ=SIN(XSEQ)
            CEQ=COS(XSEQ)
            UA(1)=SEQ
            UA(2)=0.
            UA(3)=CEQ
            IF(MODE.GT.1) GO TO 4000
            IDRIVE=1
            PAX1V=.05
            PAX2V=.05
            WAPMAX=24.
```

```
      WAPMIN=18.
      AIMHGT=SEP/2.0
      GCOVER=.3
      RFIELD=826.
      TH=392.
      RCO=120.
      HCAV=46.1
      XDF=16.
      NHF=4
      IRAYS=2
      RCONE=20.0
      NCONHT=6
      NCONAZ=8
      TDISY=0.0
      NLATC=5
      F=1050.
      NLONG=8
      WFV=10.
      WD=10.
      IJUMP=1
      DD3=42.
      NSUP=3
      SPACEF=1.1
      NRZ=5
      NRZF = 7
      NPACK=5
      NNU=8
      NAZZF = 8
      SW = 2.
      GAP=0.25
      XLTRI=4.681
      WLONG=0.48
      WCROSS=0.385
      WTRI=0.177
      WSIDE=0.84
      HTMIR=0.833
      HTCROS=0.833
      WJCROS=0.224
      TAZT=3.14159
      TELT=0.9948
      MONT=3
      IDAYT=21
      TIMET=12.
      IFOCUS=0
 4000 READ(5,CHANGE)
      IF(MODE.LT.2) MODE=2
      WRITE(6,7002)
 7002 FORMAT(1H1)
      CALL VECTS
      IF(C.GT.0.0005) GO TO 6
      WRITE(6,7)
    7 FORMAT(///,10X,50HDAWN IS YET TO COME-NO TIME POINT CAN BE PERFORM
     1ED)
      IF(IJUMP.EQ.2) IJUMP=1
      GO TO 16
    6 DENOM=SQRT(A*A+B*B)
      ELZ=ATAN2(C,DENOM)
```

```
            CALL INTEN(MON,IDAY,ELZ,UDNI)
            UDNI=.00315*UDNI*C
      C     INITIALIZE CONE AND TILT ANGLES FOR FIELD GEOMETRY INPUT
       16   RN=RFIELD-TDISY
            RS=RFIELD+TDISY
            XN=SQRT(RN*RN*0.5+RCO*RCO*0.5)
            XS=SQRT(RS*RS*0.5+RCO*RCO*0.5)
            TAPE1=ATAN(TH/XN)
            TAPE2=ATAN(TH/XS)
            THECON=(TAPE1+TAPE2)*0.5
            TTILT=TAPE2-THECON
      C   TO UNTILT APERTURE SIMPLY SET& WHAT IS BEST THETA CONE
            TTILT=0.0
            THECON=27.0/57.3
            HTOT=(WAPMAX+WAPMIN)*0.5*COS(THECON)
            SEP=HTOT
            AIMHGT=SEP*0.5
            DELRC=(HTOT*0.5)*TAN(THECON)
            DD1=(RCONE-DELRC)*2.
            DD2=(RCONE+DELRC)*2.
            NAZZ = NLONG
            CALL MOON(0,9)
      C    INITIALIZATION OF AIM POINT SUBROUTINE
            HSWTC(1)=HDIF
            HSWTC(2)=HCAV
            RSWTC(1)=RDIF
            RSWTC(2)=.5*DD3
            XDUM=(WD+GAP-WCROSS)*0.5
            WDUM=(WD+GAP+WLONG)*0.5
            B1=XDUM-XLTRI*0.70711
            B2=XDUM-XLTRI*0.70711+WTRI/0.70711
            CTAZT=COS(TAZT)
            STAZT=SIN(TAZT)
            CTELT=COS(TELT)
            STELT=SIN(TELT)
            DDTOP=DD1
            DDBASE=DD1+20.0
            WD2=WD/2.
            WFV2=WFV/2.
            ALEN=(NHF-1)*XDF
            DCOL=WFV
            CXLAT=HCAV/FLOAT(NLATC)
            DO 9622  I=1,NLATC
     9622   CAVLAT(2,I)=HCAV-CXLAT*FLOAT(I)
           -WCELL=.2*RFIELD
            AFIELD=3.14159*(RFIELD*RFIELD-RCO*RCO)
            ACOL=(NHF*WD*WFV)
            GCMIR=ACOL/(WD*(ALEN+WFV))
            IF(GCOVER.GT.GCMIR) WRITE(6,1901)
     1901   FORMAT(//10X,48H***** GROUND COVER FACTOR,GCOVER,TOO LARGE *****)
            CALL POLSP2(ACOL,NNU,SPACEF,NTOTAL,GCOVER)
            AFIELD=3.14159*(RFIELD*RFIELD-RCO*RCO)
            NCOL=NTOTAL
            WRITE(6,7002)
            WRITE(6,1945) NSTOPS,NCOL,RFIELD,TH,GCOVER
     1945   FORMAT(/20X,51HHELIAKI VERSION 13, TIME POINT AND/OR ANNUAL ENERGY
           1/20X,39HROUND FIELD WITH LOW PROFILE HELIOSTATS//16X,
```

```
         26HNSTOPS,6X,4HNCOL,9X,6HRFIELD,8X,7HTOWER H,
         3 9X,6HGCOVER,/,10X,2I10,4F15.3,/)
          WRITE(6,1946) NHF,WFV,WD,XDF,ALEN,SPACEF
     1946  FORMAT(/,16X,3HNHF,12X,3HWFV,13X,2HWD,12X,3HXDF,11X,4HALEN,
         1 10X,6HSPACEF,/,9X,I10,5(5X,F10.2),/)
          WRITE (6,1949) GAP,WLONG,WCROSS,WTRI,XLTRI,WSIDE,WJCROS,HTMIR,
         * HTCROS
     1949 FORMAT (/,11X,3HGAP,9X,5HWLONG,8X,6HWCROSS,10X,4HWTRI,9X,
         ≠ 5HXLTRI,9X,5HWSIDE,8X,6HWJCROS,9X,5HHTMIR,8X,6HHTCROS,
         * /,9(4X,F10.3),/)
          WRITE(6,1111) (WAVL(ILOP),ILOP=1,20)
     1111 FORMAT(///,32X,43HTHE CENTER WAVELENGTHS OF THE TWENTY EQUAL ,
         112HENERGY BANDS,/,2(20X,10F10.5,/),/)
          WRITE(6,1948) TDISX,TDISY,AFIELD,RCO
     1948 FORMAT(/,20X,5HTDISX,10X,5HTDISY,9X,6HAFIELD,12X,3HRCO,/,10X,
         14F15.3,/)
          IHOUR=INT(T)
          AMIN=60.*(T-FLOAT(IHOUR))
          MIN=INT(AMIN)
          WRITE(6,5) MON,IDAY,THETA,IHOUR,MIN
     5    FORMAT(    ///,50X,I2,1H/,I2,3H/80,/,10X,9HLATITUDE=,F7.2,
         1  10X,4HHOUR,I5,5X,3HMIN,I5,/)
          CALL AIMPP(XC,YC,1,AIMP)
          WRITE(6,879) RCONE,THECON,HTOT,TTILT
     879  FORMAT (//,22X,5HRCONE,14X,6HTHECON,14X,4HHTOT,15X,5HTTILT,/,
         2  15X,F10.2,10X,F10.2,9X,F10.2,12X,F10.2)
          WRITE(6,1515) WAPMAX,WAPMIN,OFFSET
     1515 FORMAT(/,19X,6HWAPMAX,14X,6HWAPMIN,14X,6HOFFSET,/,15X,
         2 3(F10.1,10X))
          WRITE(6,21)
       21 FORMAT (/,5X,20HPROGRAM OPTIONS USED)
          IF (IFOCUS.EQ.0) WRITE (6,410)
          IF (IFOCUS.GT.0.AND.IFOCUS.LE.10) WRITE (6,420) IFOCUS
          IF (IFOCUS.GT.10) WRITE (6,430)
          WRITE (6,440)
          WRITE (6,450) MONT,IDAYT,TIMET
      450 FORMAT (10X,19HTOEIN STRATEGY FOR ,I2,1H/,I2,4H AT ,F4.1)
      410 FORMAT (10X,19HINDIVIDUAL FOCUSING)
      420 FORMAT (10X,I2,15H FOCUSING ZONES)
      430 FORMAT (10X,12HFLAT MIRRORS)
      440 FORMAT (10X,17HINDIVIDUAL TOE-IN)
          IF (IDRIVE .EQ. 1) WRITE (6,518)
          IF (IDRIVE .EQ. 2) WRITE (6,519)
      518 FORMAT(10X,13HFACETS GANGED)
      519 FORMAT(10X,23HINDEPENDENT FACET DRIVE)
          RETURN
          END
```

```
      SUBROUTINE AIMPP(XC,YC,INIT,AIMP)
C** THIS ROUTINE DRAWS A VECTOR FROM THE CENTER OF THE ANNULUS
C OUT TO THE AIM POINT.
      INTEGER CILAT
      REAL N
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ
      COMMON/CAVITY/SEP,DD1,DD2,RDIF,HDIF,HCAV,HSWTC(2),RSWTC(2),
     1 CILAT(2),CAVLAT(2,21),AIMHGT
      COMMON/SUPPT/DELTM,THES,KSEG,APH,SW,NSUP,RCONE,THECON,HTOT
      COMMON/TILTED/TTILT,UVT(3),U1(3),U2(3),WAPMAX,WAPMIN,OFFSET
      DIMENSION UPLAN(3),AIMP(3),UCON(3)
C  THIS FUNCTION RETURNS THE ITH COMPONENT OF THE AIM POINT ASSOCIATED
C  WITH HELIOSTATS LOCATED AT (XC,YC) RELATIVE TO  THE RECEIVER CENTER
      IF(INIT.GT.1) GO TO 100
      SEP2=AIMHGT
      RDC=DD1/2.0+AIMHGT*(DD2-DD1)/(2.0*SEP)
      THES=2.*3.14159/NSUP
      XDUM=(DD2-DD1)/2.
      APH=SQRT(SEP**2+XDUM**2)
      AMD=SW/2.+APH/2.
      THEMISS=ATAN(AMD/RDC)
      FRACTN=(THES-2.*THEMISS)/THES
      DD3=RSWTC(2)*2.
      WRITE (6,20) SEP,DD1,DD2,RDIF,HCAV,DD3,AIMHGT
   20 FORMAT (///+30X,21HCAVITY RECEIVER SPECS,//,17X,3HSEP,7X,3HDD1,
     1 7X,3HDD2,6X,4HRDIF,6X,4HHCAV,6X,4H DD3,5X,6HAIMHGT,/,10X,
     * 7F10.1,/)
      CTCON=COS(THECON)
      STCON=SIN(THECON)
      CTL=COS(TTILT)
      STL=SIN(TTILT)
      DO 25 I=1,3
      UVT(I)=CTL*N(I)-STL*UN(I)
      U1(I)=CTL*UN(I)+STL*N(I)
   25 U2(I)=UE(I)
      RETURN
  100 YCP=YC*CTL
      THEAZ=ATAN2(XC,YCP)+3.14159/3.0
      IF(THEAZ.LT.0.0) THEAZ=THEAZ+2.*3.14159
      IF(THEAZ.GT.6.283185) THEAZ=THEAZ-6.283185
      KSEG=INT(THEAZ/THES)+1
      THEMID=THES*(KSEG-1)+THES/2
      DELTM=THEAZ-THEMID
      THEAIM=THEMID+DELTM*FRACTN-3.14159/3.0
      IF(THEAIM.LT.0.0) THEAIM=THEAIM+6.283185
      CAIM=COS(THEAIM)
      SAIM=SIN(THEAIM)
      IF(THEAIM.GT.3.14159) THEAIM=2*3.14159-THEAIM
      WAP=WAPMIN
      IF (THEAIM.LT.2.0944) WAP=WAP+(WAPMAX-WAPMIN)*(1.0-THEAIM*0.4775)
      WDWN=SEP2/CTCON-WAP*0.5
      IF (THEAIM.LT.2.0944) WDWN=SEP2/CTCON-WAP*0.53
      DO 45 I=1,3
      UPLAN(I)=CAIM*U1(I)+SAIM*U2(I)
      UCON(I)=-CTCON*UVT(I)-STCON*UPLAN(I)
   45 AIMP(I)=SEP2*UVT(I)+RDC*UPLAN(I)+WDWN*UCON(I)
```

```
      RETURN                                                    AIMPP      59
      END                                                       AIMPP      60
```

```
      SUBROUTINE MONTE2(XM)                                             MONTE2     2
C** THIS IS THE MONTE CARLO DRIVER ROUTINE FOR A FIXED TIME AND DAY     MONTE2     3
C OF THE YEAR.  FROM IT INTEN, RNORM, LIMDR, AND PTOWER ARE CALLED.     MONTE2     4
      REAL N                                                            MONTE2     5
      DIMENSION TOP(15)                                                 MONTE2     6
      INTEGER CILAT                                                     MONTE2     7
      COMMON/CAVITY/SEP,DD1,DD2,RDIF,HDIF,HCAV,HSWTC(2),RSWTC(2),      MONTE2     8
     1 CILAT(2),CAVLAT(2,21),AIMHGT                                     MONTE2     9
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,  MONTE2    10
     1       RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),         MONTE2    11
     2       UTT(3),UNNP(3),UXV2P(3)                                    MONTE2    12
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE                    MONTE2    13
      COMMON/JOKER/URP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD  MONTE2    14
      COMMON /STATS/TPB,TSB,PHB,TPV,PHV,AVE,TSV,PAX1V,PAX1B,PAX2V,PAX2B MONTE2    15
                                                                        MONTE2    16
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)                 MONTE2    17
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),                       MONTE2    18
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ         MONTE2    19
      COMMON/RANDOM/NRUN,IRANC,IJUMP,MODE,ISRAN,IRAYS                   MONTE2    20
     1 , IT1,UDNI,LIMC,DINTV,YFRAC                                      FINAL      1
      COMMON/SUPPT/DELTM,THES,KSEG,APH,SW,NSUP,RCONE,THECON,HTOT         MONTE2    22
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,    MONTE2    23
     1         ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,    MONTE2    24
     2         DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,      MONTE2    25
     3         NLONG,ILONG,NLATC,RCO,NPACK,ENHM                         MONTE2    26
      COMMON /CINDEX/ XPCOL,YPCOL,COSA,COSB,SLDUM,WCELL,ICELL,JCELL,    MONTE2    27
     1          XCSAV,YCSAV,XCM,YCM,ICELM,JCELM                         MONTE2    28
      COMMON/STRUCT/GAP,WLONG,WSIDE,WTRI,XLTRI,B1,B2,WCROSS,WDUM,IFRAM  MONTE2    29
     *,HTMIR,HTCROS,WJCROS                                              MONTE2    30
      COMMON/PLANE/IPLAN(7)                                             MONTE2    31
      COMMON/TOE/CTAZT,STAZT,CTELT,IFOCUS,STELT,UTARG(3),DTARG(3)       MONTE2    32
      DIMENSION FRSHAD(4)                                               MONTE2    33
      DIMENSION XDFPR(9,15),XM(9),ITT(21)                               MONTE2    34
      DIMENSION  FLMAPC(21,36)                                          MONTE2    35
      DIMENSION AEBOTN(2,10),AFLUX(2),FIELD(12,12)                      MONTE2    36
      DIMENSION ETA(7),EPM(8)                                           MONTE2    37
      DIMENSION NDM(12),IO(36),SL(15)                                   MONTE2    38
      DATA NDM/31,28,31,30,31,30,31,31,30,31,30,31/                     MONTE2    39
      IF(C.LT.0.0005) GO TO 62                                          MONTE2    40
      WRITE(6,7532)                                                     MONTE2    41
 7532 FORMAT(1H1,/  ,39X,28HHELIOSTAT OPTICAL PARAMETERS,/)             MONTE2    42
      WRITE(6,7001)  PAX1B,PAX2B,TSB,PHB,PAX1V,PAX2V,TSV,PHV            MONTE2    43
 7001 FORMAT(15X,5HPAX1B,5X,5HPAX2B,7X,3HTSB,7X,3HPHB,5X,5HPAX1V,5X,    MONTE2    44
     15HPAX2V,7X,3HTSV,7X,3HPHV,/,10X,10F10.5,/)                        MONTE2    45
      NN1=NLATC                                                         MONTE2    46
      DO 8011 I=1,7                                                     MONTE2    47
 8011 IPLAN(I)=0                                                        MONTE2    48
      DO 412 I=1,4                                                      MONTE2    49
  412 FRSHAD(I)=0.0                                                     MONTE2    50
      DO 3010 I=1,20                                                    MONTE2    51
 3010 ITT(I)=0                                                          MONTE2    52
      XKNT=0.0                                                          MONTE2    53
      CALL ROOF(1,0.)                                                   MONTE2    54
      DO 6101 I=1,NN1                                                   MONTE2    55
      DO 6101 J=1,NLONG                                                 MONTE2    56
 6101 FLMAPC(I,J)=0.                                                    MONTE2    57
      TOPC=0.                                                           MONTE2    58
```

```
            CALL POLMAP (0.,0.,0.,1,0)
            DO 8101 I=1,12
            DO 8101 J=1,12
       8101 FIELD(I,J)=0.
            CALL HITFAC(0,0,0,1,0)
            SPPT = 0.0
            SHADL=0.0
            IDFL=2
            DO 7009 MAC=1,IDFL
       7009 AFLUX(MAC)=0.
            DO 3611 I=1,7
       3611 XM(I)=0.
            DAY=FLOAT(IDAY)
            DENOM=SQRT(A*A+B*B)
            ELZ=ATAN2(C,DENOM)
            CALL INTEN(MON,IDAY,ELZ,UDNI)
            XKWNI=.00315*UDNI
            THETAZ=ATAN2(B,A)*360.0/(2.0*3.14159)
            IF (THETAZ .LT. .0001) THETAZ=THETAZ+360.0
            TELZ=ELZ*360.0/(2.0*3.14159)
            WRITE (6,22) TELZ,THETAZ,XKWNI
            XMDNI=XKWNI
         22 FORMAT (/,7X,3HELZ,4X,6HTHETAZ,5X,5HXKWNI,/,3F10.5,/)
            UDNI=.00315*UDNI*C
            AVE=0.0
            ICOLO=0
            ICOLS=0
            ICOLH=0
            COLO=0.0
            COLH=0.0
      C     FOR POLAR PACKING THE DRAW RANGE IS EXTENDED FROM RCO/2 TO RFIELD+
            RFIELD=RFIELD+0.1*TH
            RCO=RCO/2.
            AREA=3.14159*(RFIELD*RFIELD-RCO*RCO)
            CONV=.0929*AREA*UDNI
            RCO2 = RCO*RCO
            DELRAD = RFIELD**2 - RCO2
            RFIELD=RFIELD-0.1*TH
            RCO=RCO*2.
      C THIS IS BECAUSE Q IS IN LANGLY/MIN.
            WRITE(6,1001) CONV
       1001 FORMAT (/,20X,10H**********,20H CONVERSION FACTOR =,E20.10,
           1    11H **********,//)
            DO 297 I=1,3
        297 UHV(I)=UE(I)
            DO 1004 NX=1,NRUN
            DO 7010 MAC=1,IDFL
       7010 AEDOTN(MAC,NX)=0.
            TOPCAV=0.
            DO 200 JJ=1,IRAYS
            ICELM=0
            JCELM=0
              XCM=0.
            YCM=0.
            CALL RNORM(R6,R7)
            THSL=TSV*R6+TSB
            PH=360.*RANF(0.0)
```

```
      CALL RNORM(R3,R4)
      PAX1=PAX1V*R3+PAX1B
      PAX2=PAX2V*R4+PAX2B
      R2=RANF(0.)
      R3=RANF(0.)
      CSRA=COS(6.28318*R2)
      SNRA=SIN(6.28318*R2)
      CALL LIMDR(R3,LIMC,ROERN)
      THSR=ROERN*CSRA
      THSU=ROERN*SNRA
  708 R6=RANF(0.)
      R7=RANF(0.)
      ND1=2
      COUNT=1.
      IAC=0
      CDUM1=COS(6.28318*R6)
      CDUM2=SIN(6.28318*R6)
      CDUM3=SQRT((RFIELD+0.1*TH)**2*R7)
      XP=CDUM1*CDUM3-TDISX
      YP=CDUM2*CDUM3-TDISY
      IF (SQRT(XP*XP+YP*YP) .LT. RCO/2.) GO TO 708
      CALL TSHAD(DDBASE,DDTOP,ICOD)
      IF (ICOD.EQ.0) GO TO 8000
      ITT(14)=ITT(14)+1
      GO TO 200
 8000 CALL PTOWER(ND1,IAC,ARATIO)
      ITT(ND1+1)=ITT(ND1+1)+1
      ICOLH=ICOLH+ICMH
      ICOLS=ICOLS+ICSH
      ICOLO=ICOLO+IOHIT
      COLH=COLH+COUNT*ICMH
      COLO=COLO+COUNT*IOHIT
C     ENERGY LOST IN MIRROR SHADOWS
      SHADL=SHADL+COUNT*ICSH
      IF(IFRAM.GT.0) FRSHAD(IFRAM)=FRSHAD(IFRAM)+COUNT
      IF (ND1 .GE. 4) CALL POLMAP(COUNT,CONV,NPP,2,ND1)
      IF (ND1.EQ.12) SPPT=SPPT+COUNT
      IF(IAC.EQ.0)  GO TO 200
      EDOTN=COUNT
      AVE=AVE+EDOTN
      AEDOTN(IAC,NX)=AEDOTN(IAC,NX)+EDOTN
      FIELD(ICELM,JCELM)=FIELD(ICELM,JCELM)+COUNT
      IF(IAC.EQ.3)    TOPCAV=TOPCAV+COUNT
      IF(IAC.EQ.3) CALL ROOF(2,DCONM)
      IF(IAC.EQ.2)  FLMAPC(CILAT(2),ILONG)=FLMAPC(CILAT(2),ILONG)+COUNT
  200 CONTINUE
      DNM=1./FLOAT(IRAYS)
      XDFPR(1,NX)=FLOAT(ICOLH)*DNM
      DNM2=FLOAT(ICOLS)
      DNM3=1./FLOAT(IRAYS+ICOLS)
      XDFPR(2,NX)=DNM2*DNM3
      DNM4=FLOAT(ICOLO)
      XDFPR(3,NX)=DNM4*DNM
      XDFPR(4,NX)=AVE*DNM
        TOP(NX)=TOPCAV*DNM
      DO 7004 MAC=1,IDFL
 7004 AEDOTN(MAC,NX)=AEDOTN(MAC,NX)*DNM
```

```
 1004 CONTINUE
      DO 1802 I=1,NRUN
      TOPC=TOPC+TOP(I)
      DO 7005 MAC=1,IDFL
 7005 AFLUX(MAC)=AFLUX(MAC)+AEDOTN(MAC,I)
 1802 CONTINUE
      DCONM=.001*CONV/FLOAT(NRUN*IRAYS)
      SPPT = SPPT*DCONM*1000.
      DO 6106 I=1,NN1
      DO 6106 J= 1,NLONG
 6106 FLMAPC(I,J) = FLMAPC(I,J)*DCONM
      XXR=1./FLOAT(NRUN*IRAYS)
      DO 8102 I=1,12
      DO 8102 J=1,12
 8102 FIELD(I,J)=FIELD(I,J)*XXR
      TOPC=TOPC/FLOAT(NRUN)
      DO 7006 MAC=1,IDFL
 7006 AFLUX(MAC)=AFLUX(MAC)/NRUN
      WRITE(6,1820)  NRUN,IRAYS
 1820 FORMAT(25X,15HSTATISTICS FOR ,I4,8H RUNS AT,I6,13H RAYS PER RUN,/)
      WRITE(6,1821)
 1821 FORMAT( /,40X,10H**********,11HOUTPUT CODE,10H**********,//,10X,
     144HETA1=FRACTION OF FIELD FLUX THAT HIT MIRRORS,/,10X,
     216HETA2=REFLECTANCE,/,10X,
     349HETA3=FRACTION OF FLUX NOT OBSCURED ON THE WAY OUT,/,10X,
     536HETA4=FRACTION OF FLUX THAT HIT TOWER,/,10X,
     652HETA5=FRACTION OF FIELD FLUX THAT HIT CAVITY          ,/,10X,
     753HETA6=FRACTION OF FIELD FLUX THAT HIT THE CAVITY WALLS,/,10X,
     852HETA7=FRACTION OF FIELD FLUX THAT WAS IN TOWER SHADOW,/)
      WRITE(6,9001)
 9001 FORMAT( /,10X,34HEFLUX1=TOTAL FLUX ON FIELD IN KW  ,/,10X,
     140HEFLUX2=TOTAL FLUX ON MIRRORS IN KW       ,/,10X,
     242HEFLUX3=TOTAL FLUX LEAVING MIRRORS IN KW    ,/,10X,
     355HEFLUX4=TOTAL FLUX CLEANLY AWAY FROM FIELD IN KW          ,/,10X,
     139HEFLUX5=TOTAL FLUX ON POWER TOWER IN KW ,/,10X,
     237HEFLUX6=FLUX ON CAVITY DIFFUSER IN KW ,/,10X,
     734HEFLUX7=FLUX ON CAVITY WALLS IN KW ,/,10X,
     837HEFLUX8=FLUX ON CAVITY CEILING IN KW ,/)
      WRITE(6,2799)
 2799 FORMAT(  10X,28HN1=RAYS DRAWN BEFORE SUNRISE,/,10X,
     138HN2=RAYS DRAWN WHEN THE SUN WAS TOO LOW,/,10X,
     237HN3=RAYS DRAWN THAT HIT THE OPEN FIELD,/,10X,
     347HN4=RAYS WHICH HIT MIRROR BUT WERE LOST IN SPACE,/,10X,
     443HN5=RAYS DRAWN THAT WERE BLOCKED IN ONBLOCKS,/,10X,
     538HN6=RAYS THAT WERE OBSCURED IN OFFBLOCK,/,10X,
     633HN7=RAYS WHICH HIT CAVITY DIFFUSER,/,10X,
     723HN8=RAYS WHICH HIT WALLS,/,10X,
     822HN9=RAYS WHICH HIT ROOF,/,10X,
     926HN10=RAYS WHICH MISSED HIGH,/,10X,
     138HN11=RAYS WHICH MISSED ACROSS THE FRONT,/,10X,
     125HN12=RAYS WHICH MISSED LOW,/,10X,
     227HN13=RAYS WHICH HIT SUPPORTS,/,10X,
     339HN14=RAYS WHICH WERE IN THE TOWER SHADOW,/,10X,
     *28HN15=RAYS WHICH WHISTLED THRU,/,10X,
     443HN16=RAYS WHICH FRAME SHADOWED ON SAME HELIO,/,10X,
     544HN17=RAYS WHICH FRAME SHADOWED ON OTHER HELIO,/,10X,
     642HN18=RAYS WHICH FRAME BLOCKED ON SAME HELIO,/,10X,
```

```
     743HN19=RAYS WHICH FRAME BLOCKED ON OTHER HELIO)
      TOPC=TOPC*CONV
      NTOT=NRUN*IRAYS
      XM(1)=CONV
      XM(2)=ICOLH*CONV/NTOT
      XM(3)=COLH*CONV/NTOT
      XMBLOC=COLO*CONV/NTOT
      XMSHAD=SHADL*CONV/FLOAT(NTOT)
      XM(5)=AVE/NTOT*CONV
      XM(6)=AFLUX(1)*CONV
      XM(7)=AFLUX(2)*CONV
      XM(8)=TOPC
      FRSHAD(1)=FRSHAD(1)*CONV/FLOAT(NTOT)
      FRSHAD(2)=FRSHAD(2)*CONV/FLOAT(NTOT)
      FRSHAD(3)=FRSHAD(3)*CONV/FLOAT(NTOT)
      FRSHAD(4)=FRSHAD(4)*CONV/FLOAT(NTOT)
C
C******FRSHAD(1)=ENERGY LOST FROM FRAME SHADOWS
C******ON THE SAME HELIOSTAT WHICH CONTAINS THE HIT FACET
C
C******FRSHAD(2)=ENERGY LOST FROM FRAME SHADOWS ON HELIOSTATS
C       OTHER THAN THE ONE WHICH CONTAINS THE HIT FACET
C
C******FRSHAD(3)=ENERGY LOST FOOM FRAME BLOCKS ON THE SAME
C       HELIOSTAT WHICH CONTAINS THE HIT FACET
C
C******FRSHAD(4)=ENERGY LOST FROM FRAME BLOCKS ON HELIOSTATS
C       OTHER THAN THE ONE WHICH CONTAINS THE HIT FACET
C
      XM(4)=XM(3)-XMBLOC
      XMABBE=XM(4)-XM(5)
      XMREFL=XM(2)-XM(3)
      ETA(1)=XM(2)/XM(1)
      ETA(2)=1.0-XMREFL/XM(2)
      ETA(3)=1.0-XMBLOC/XM(3)
      ETA(4)=1.0-XMABBE/XM(4)
      ETA(5)=XM(5)/XM(1)
      ETA(6)=XM(7)/XM(1)
      ETA(7)=FLOAT(ITT(14))/FLOAT(NRUN*IRAYS)
      DDUM=1./ETA(1)
      XXR=CONV/(.0929*WCELL*WCELL)
      DO 8103 I=1,12
      DO 8103 J=1,12
 8103 FIELD(I,J)=FIELD(I,J)*XXR
      WRITE(6,1005) (I,I=1,7)
 1005 FORMAT(/,10X,7(4X,3HETA,I1))
      WRITE(6,1006)  (ETA(I),I=1,7)
 1006 FORMAT(10X,14F8.5)
      KI=1
      WRITE(6,1007) (J,J=1,8)
 1007 FORMAT(/,8(9X,5HEFLUX,I1))
      WRITE(6,1008) (XM(I),I=1,8)
 1008 FORMAT(9F15.6)
 2001 FORMAT(/,10X,9(3X,1HN,I1),10(3X,1HN,I2))
      WRITE(6,2001) (I,I=1,19)
      WRITE(6,2002) (ITT(I),I=1,19)
 2002 FORMAT(10X,9I5,10I6,/)
```

```
 7002 FORMAT(1H1)                                                            MONTE2   287
      WRITE(6,20)                                                            MONTE2   288
 20   FORMAT( //,20X,14HTIME POINT RUN)                                      MONTE2   289
      AFIELD=DELRAD*3.14159                                                  MONTE2   290
      AREAM=NCOL*NHF*WD*WFV*0.0929                                           MONTE2   291
      EPM(1)=(XM(2)+XMSHAD+FRSHAD(1)+FRSHAD(2))/AREAM                        MONTE2   292
      DO 21 I=2,5                                                            MONTE2   293
   21 EPM(I)=XM(I)/AREAM                                                     MONTE2   294
      EPM(6)=EPM(5)*0.9                                                      MONTE2   295
      TE1=EPM(1)/XMDNI                                                       MONTE2   296
      TE2=EPM(4)/XMDNI                                                       MONTE2   297
      WRITE(6,27) AREAM,XMDNI                                                MONTE2   298
   27 FORMAT(/,9X,18HACTUAL MIRROR AREA,10X,20HDIRECT NORMAL ENERGY,         MONTE2   299
     * /,15X,F12.4,18X,F12.4)                                                MONTE2   300
      WRITE(6,23) (EPM(I),I=1,6)                                             MONTE2   301
   23 FORMAT(//,23X,26HENERGY (KWH) PER SQ. METER,                           MONTE2   302
     1/,20X,10HUNSHADOWED,10X,F12.4,                                         MONTE2   303
     2/,20X,8HSHADOWED,12X,F12.4,                                            MONTE2   304
     3/,20X,14HLEAVING MIRROR,6X,F12.4,                                      MONTE2   305
     4/,20X,12HCLEANLY AWAY,8X,F12.4,                                        MONTE2   306
     5/,20X,13HTHRU APERTURE,7X,F12.4,                                       MONTE2   307
     6/,20X,8HABSORBED,12X,F12.4)                                            MONTE2   308
      WRITE(6,24) TE1,TE2                                                    MONTE2   309
   24 FORMAT(//,15X,19HTRACKING EFFICIENCY,2X,12H(UNSHADOWED),7X,            MONTE2   310
     *F10.4,/,36X,14H(CLEANLY AWAY),5X,F10.4)                                MONTE2   311
      WRITE (6,5)                                                            MONTE2   312
 5    FORMAT(    /,11X,9HNUMBER OF,5X,7HSUPPORT,7X,6HKWH ON,/,12X,8HSUPP MONTE2   313
     1ORTS,7X,5HWIDTH,4X,8HSUPPORTS)                                         MONTE2   314
      WRITE (6,10) NSUP,SW,SPPT                                              MONTE2   315
 10   FORMAT (/,10X,I10,F12.1,F12.1,/)                                       MONTE2   316
      WRITE(6,8010) (IPLAN(IP),IP=1,7)                                       MONTE2   317
 8010 FORMAT (//,36X,20HHELIOSTAT FRAME HITS,//,20X,9HTOP FRAME,4X,          MONTE2   318
     2 11HSIDE FRAMES,4X,12HCROSS FRAMES,4X,12HBOTTOM FRAME,/,22X,           MONTE2   319
     3 I3,9X,I3,3X,I3,5X,3(I3,2X),6X,I3)                                     MONTE2   320
      WRITE(6,3150) FRSHAD(1),FRSHAD(2),FRSHAD(3),FRSHAD(4)                  MONTE2   321
 3150 FORMAT(//,40X,27HENERGY LOST ON FRAME IN KWH,//,28X,12HFRAME SHADO MONTE2   322
     *W,28X,11HFRAME BLOCK,/,16X,13HON SAME HELIO,7X,                        MONTE2   323
     113HON DIFF HELIO,7X,13HON SAME HELIO,7X,13HON DIFF HELIO,/,            MONTE2   324
     215X,F12.1,8X,F12.1,8X,F12.1,8X,F12.1)                                  MONTE2   325
      WRITE(6,7002)                                                          MONTE2   326
      CALL HITFAC(0,0,0,3,NHF)                                               MONTE2   327
      XZONE=6.283185*RSWTC(2)*HCAV*0.0929/FLOAT(NLONG*NLATC)                 FINAL      2
      PZONE=1./XZONE                                                         FINAL      3
      DO 6402 I=1,NN1                                                        FINAL      4
      DO 6402 J=1,NLONG                                                      FINAL      5
 6402 FLMAPC(I,J)=FLMAPC(I,J)*PZONE                                          FINAL      6
      CALL WALLMP(FLMAPC,NLONG,NLATC,HCAV)                                   MONTE2   328
      CALL ROOF(3,DCONM)                                                     MONTE2   329
      WRITE(6,8104)                                                          MONTE2   330
 8104 FORMAT(20X,44HKW/SQ.M FLUX MAP OF POWER TOWER MIRROR FIELD,/)          MONTE2   331
      DO 8105 J=1,10                                                         MONTE2   332
 8105 WRITE(6,8106) (FIELD(I,J),I=1,10)                                      MONTE2   333
 8106 FORMAT(10X,12F10.6)                                                    MONTE2   334
      CALL POLMAP(COUNT,CONV,NTOT,3,ND1)                                     MONTE2   335
      STEST=10.E+30                                                          MONTE2   336
      NMX=110                                                                MONTE2   337
      IS=NMX/10                                                              MONTE2   338
```

```
      K=0
      ISTOP=IS
      DO 3050 NN=1,NMX
      SMAX=0.0
      DO 3040 I=1,11
      DO 3040 J=1,10
 3040 IF(FIELD(I,J).GT.SMAX.AND.FIELD(I,J).LT.STEST) SMAX=FIELD(I,J)
      STEST=SMAX
      IF(NN.LT.ISTOP) GO TO 3050
      ISTOP=ISTOP+IS
      K=K+1
      SL(K)=SMAX
 3050 CONTINUE
      KK=K-1
      WRITE (6,3180) (SL(I),I=1,10)
 3180 FORMAT(1H1,//,10X,8HSL ARRAY,10F10.6,//)
      DO 61 J=1,10
      DO 73 I=1,11
 73   IO(I)=0
      DO 70 I=1,11
      DO 60 KL=1,KK
      KLX=KK-KL+1
      IF(FIELD(I,J).GT.SL(KLX)) GO TO 43
      GO TO 70
 43   IO(I)=KLX
   60 CONTINUE
   70 CONTINUE
      WRITE(6,65)   (IO(II),II=1,11)
   65 FORMAT(20X,20I4,//)
   61 CONTINUE
   62 CONTINUE
      RETURN
      END
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      SUBROUTINE MONTE(XM,HOURS)                                        MONTE     2
C** THIS IS THE TIME INTEGRATION ROUTINE. IT RANDOMLY CHOOSES A TIME    MONTE     3
C AND DAY OVER THE ENTIRE YEAR, AND USES THE RESULTS TO INTEGRATE       MONTE     4
C YEARLY ENERGY.  FROM IT, VECTS, INTEN, RNORM AND PTOWER ARE CALLED.   MONTE     5
      REAL N                                                            MONTE     6
      DIMENSION TOP(15)                                                 MONTE     7
      INTEGER CILAT                                                     MONTE     8
       COMMON/CAVITY/SEP,DD1,DD2,RDIF,HDIF,HCAV,HSWTC(2),RSWTC(2),      MONTE     9
     1 CILAT(2),CAVLAT(2,21),AIMHGT                                     MONTE    10
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,  MONTE    11
     1      RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),          MONTE    12
     2      UTT(3),UNNP(3),UXV2P(3)                                     MONTE    13
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEON(3),IFOC,IDRIVE                    MONTE    14
      COMMON/JOKER/URP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD  MONTE    15
      COMMON /STATS/TPB,TSB,PHB,TPV,PHV,AVE,TSV,PAX1V,PAX1B,PAX2V,PAX2B MONTE    16
                                                                        MONTE    17
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)                 MONTE    18
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),                       MONTE    19
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ         MONTE    20
      COMMON/RANDOM/NRUN,IRANC,IJUMP,MODE,ISRAN,IRAYS                   MONTE    21
     1 , IT1,UDNI,LIMC,DINTV,YFRAC                                      FINAL     7
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,    MONTE    23
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,     MONTE    24
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,       MONTE    25
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM                          MONTE    26
      COMMON /CINDEX/ XPCOL,YPCOL,COSA,COSB,SLDUM,WCELL,ICELL,JCELL,    MONTE    27
     1        XCSAV,YCSAV,XCM,YCM,ICELM,JCELM                           MONTE    28
      COMMON/SUPPT/DELTM,THES,KSEG,APH,SW,NSUP,RCONE,THECON,HTOT        MONTE    29
      COMMON/TILTED/TTILT,UVT(3),U1(3),U2(3),WAPMAX,WAPMIN,OFFSET       MONTE    30
      COMMON/STRUCT/GAP,WLONG,WSIDE,WTRI,XLTRI,B1,B2,WCROSS,WDUM,IFRAM  MONTE    31
     *,HTMIR,HTCROS,WJCROS                                              MONTE    32
      COMMON/TOE/CTAZT,STAZT,CTELT,IFOCUS,STELT,UTARG(3),DTARG(3)       MONTE    33
      DIMENSION FRSHAD(4)                                               MONTE    34
      COMMON/PLANE/IPLAN(7)                                             MONTE    35
      DIMENSION XDFPR(9,15),XM(9),ITT(21)                               MONTE    36
      DIMENSION  FLMAPC(21,36)                                          MONTE    37
      DIMENSION AEDOTN(2,10),AFLUX(2),FIELD(12,12)                      MONTE    38
      DIMENSION ETA(7),EPM(8)                                           MONTE    39
      DIMENSION NDM(12),IO(36),SL(15)                                   MONTE    40
      DATA NDM/31,59,90,120,151,181,212,243,273,304,334,365/            MONTE    41
      WRITE(6,7532)                                                     MONTE    42
 7532 FORMAT(1H1, /,39X,28HHELIOSTAT OPTICAL PARAMETERS,/)              MONTE    43
      WRITE(6,7001)  PAX1B,PAX2B,TSB,PHB,PAX1V,PAX2V,TSV,PHV            MONTE    44
 7001 FORMAT(15X,5HPAX1B,5X,5HPAX2B,7X,3HTSB,7X,3HPHB,5X,5HPAX1V,5X,    MONTE    45
     15HPAX2V,7X,3HTSV,7X,3HPHV,/,10X,10F10.5,/)                        MONTE    46
      NN1=NLATC                                                         MONTE    47
      DO 8011 I=1,7                                                     MONTE    48
 8011 IPLAN(I)=0                                                        MONTE    49
      DO 412 I=1,4                                                      MONTE    50
  412 FRSHAD(I)=0.0                                                     MONTE    51
      DO 3010 I=1,20                                                    MONTE    52
 3010 ITT(I)=0                                                          MONTE    53
      CALL HITFAC(0,0,0,1,0)                                            MONTE    54
      CALL TMAP(0.,0.,1,1.,0,0.,1)                                      MONTE    55
      CALL POLMAP (0.,0.,0.,1,0)                                        MONTE    56
      CALL ROOF(1,0.)                                                   MONTE    57
      DO 6102 I=1,NN1                                                   MONTE    58
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      DO 6102 J= 1,NLONG
 6102 FLMAPC(I,J) = 0.
      TOPC=0.
      TOTEN=0.0
      TOTDNI=0.
      COLH=0.0
      COLO=0.0
      ENHM=0.0
      FOPT=0.0
      SHADL=0.0
      NTOT=NRUN*IRAYS
      XKNT=0.0
C POINT D
      DO 8101 I=1,12
      DO 8101 J=1,12
 8101 FIELD(I,J)=0.
      IDFL=2
      CTILT=COS(TTILT)
      STILT=SIN(TTILT)
      SPPT = 0.0
      DO 7009 MAC=1,IDFL
 7009 AFLUX(MAC)=0.
      DO 3611 I=1,7
 3611 XM(I)=0.
      MON=6
      IDAY=21
      T=12.
      CALL VECTS
      DENOM=SQRT(A*A+B*B)
      ELZ=ATAN2(C,DENOM)
      CALL INTEN(MON,IDAY,ELZ,UDNI)
      UDNI=.00315*UDNI*C
C     FOR POLAR PACKING THE DRAW RANGE IS EXTENDED FROM RCO/2 TO RFIELD.
      RFIELD=RFIELD+0.1*TH
      RCO=RCO/2.
      AREA=3.14159*(RFIELD*RFIELD-RCO*RCO)
      CONV=.0929*UDNI*AREA*DINTV*YFRAC
      RCO2 = RCO*RCO
      DELRAD = RFIELD**2 - RCO2
      RFIELD=RFIELD-0.1*TH
      RCO=RCO*2.
C THIS IS BECAUSE Q IS IN LANGLY/MIN.
      WRITE(6,1001) CONV
 1001 FORMAT(/  ,20X,10H**********,20H CONVERSION FACTOR =,E20.10,
     1    11H **********,/)
      DO 1004 NX=1,NRUN
      AVF=0.
      ICOLO=0
      ICOLS=0
      ICOLH=0
      TOPCAV=0.
      DO 7010 MAC=1,IDFL
 7010 AEDOTN(MAC,NX)=0.
      DO 200 JJ=1,IRAYS
      ICELM=0
      JCELM=0
      XCM=0.
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      YCM=0.
      ND1=0
      CALL RNORM(R6,R7)
      THSL=TSV*R6+TSB
      PH=360.*RANF(0.0)
      CALL RNORM(R3,R4)
      PAX1=PAX1V*R3+PAX1B
      PAX2=PAX2V*R4+PAX2B
      XR2=RANF(0.)
      XR3=RANF(0.)
      NDAY=INT(XR2*365.)+1
      DO 5195 I=1,12
      IF(NDAY .LE. NDM(I)) GO TO 5101
 5195 CONTINUE
      GO TO 5102
 5101 MON=I
 5102 IF(MON.LE.1) GO TO 5196
      IDAY=NDAY-NDM(MON-1)
      GO TO 5197
 5196 IDAY=NDAY
 5197 CONTINUE
      T=XR3*14.+5.
      CALL VECTS
      IF (C .GT. 0.0) GO TO 8950
      COUNT=0.
      ITT(1)=ITT(1)+1
      GO TO 200
 8950 DENOM=SQRT(B*B+A*A)
      ELZ=ATAN2(C,DENOM)
      IF (C.GE. .005) GO TO 5198
      ITT(2)=ITT(2)+1
      COUNT=0.
      GO TO 200
 5198 CALL INTEN(MON,IDAY,ELZ,DNI)
      DNI=.00315*DNI*C
      COUNT=DNI/UDNI
      DO 297 I=1,3
      UVT(I)=CTILT*N(I)-STILT*UN(I)
      U1(I)=CTILT*UN(I)+STILT*N(I)
      U2(I)=UE(I)
  297 UHV(I)=UE(I)
      ND1=2
C  TOTAL ENERGY FALLING ON FIELD
      TOTEN=TOTEN+COUNT
C     TOTAL DIRECT NORMAL ENERGY
      TOTDNI=TOTDNI+DNI/C
      R2=RANF(0.)
      R3=RANF(0.)
      CSRA=COS(6.28318*R2)
      SNRA=SIN(6.28318*R2)
      CALL LIMOR(R3,LIMC,ROERN)
      THSR=ROERN*CSRA
      THSU=ROERN*SNRA
  708 R6=RANF(0.)
      R7=RANF(0.)
      IAC=0
      CDUM1=COS(6.28318*R6)
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      CDUM2=SIN(6.28318*R6)
      CDUM3=SQRT((RFIELD+.1*TH)**2*R7)
      XP=CDUM1*CDUM3
      YP=CDUM2*CDUM3
      XP=XP-TDISX
      YP=YP-TDISY
      IF (SQRT(XP*XP+YP*YP) .LT. RCO/2.) GO TO 708
      CALL TSHAD(DDBASE,DDTOP,ICOD)
      IF (ICOD.EQ.0) GO TO 8000
      ITT(14)=ITT(14)+1
      GO TO 200
 8000 CALL PTOWER(ND1,IAC,ARATIO)
      ITT(ND1+1)=ITT(ND1+1)+1
      ICOLH=ICOLH+ICMH
      ICOLS=ICOLS+ICSH
      ICOLO=ICOLO+IOHIT
C ENERGY AWAY FROM MIRRORS (REFLECTANCE INCLUDED)
      COLH=COLH+COUNT*ICMH
C ENERGY OBSCURED BY MIRROR BACKS
      COLO=COLO+COUNT*IOHIT
      SHADL=SHADL+COUNT*ICSH
      IF(IFRAM.GT.0) FRSHAD(IFRAM)=FRSHAD(IFRAM)+COUNT
      IF (ND1 .GE. 4) CALL POLMAP(COUNT,CONV,NPP,2,ND1)
      IF(ND1.EQ.12) SPPT=SPPT+COUNT
      IF(IAC.EQ.0)  GO TO 200
      EDOTN=COUNT
      FOPT=FOPT+EDOTN
      AVE=AVE+EDOTN
      AEDOTN(IAC,NX)=AEDOTN(IAC,NX)+EDOTN
      CALL TMAP(XCM,YCM,MON,COUNT,NTOT,CONV,2)
      FIELD(ICELM,JCELM)=FIELD(ICELM,JCELM)+COUNT
      IF(IAC.EQ.3)    TOPCAV=TOPCAV+COUNT
      IF(IAC.EQ.3) CALL ROOF(2,DCONM)
      IF(IAC.EQ.2)  FLMAPC(CILAT(2),ILONG)=FLMAPC(CILAT(2),ILONG)+COUNT
  200 CONTINUE
      DNM=1./FLOAT(IRAYS)
      XDFPR(1,NX)=FLOAT(ICOLH)*DNM
      DNM2=FLOAT(ICOLS)
      DDDS=1./FLOAT(IRAYS+ICOLS)
      XDFPR(2,NX)=DNM2*DDDS
      DNM4=FLOAT(ICOLO)
      XDFPR(3,NX)=DNM4*DNM
      XDFPR(4,NX)=AVE*DNM
        TOP(NX)=TOPCAV*DNM
      DO 7004 MAC=1,IDFL
 7004 AEDOTN(MAC,NX)=AEDOTN(MAC,NX)*DNM
 1004 CONTINUE
      DO 1802 I=1,NRUN
      TOPC=TOPC+TOP(I)
      DO 7005 MAC=1,IDFL
 7005 AFLUX(MAC)=AFLUX(MAC)+AEDOTN(MAC,I)
      DO 1802 J=1,4
 1802 XM(J)=XM(J)+XDFPR(J,I)
      DCONM=.001*CONV/FLOAT(NRUN*IRAYS)
      DO 6004 I=1,NN1
      DO 6004 J=1,NLONG
 6004 FLMAPC(I,J)=FLMAPC(I,J)*DCONM
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      SPPT = SPPT*DCONM*1000.
      XXR=1./FLOAT(NRUN*IRAYS)
      DO 8102 I=1,12
      DO 8102 J=1,12
 8102 FIELD(I,J)=FIELD(I,J)*XXR
      TOPC=TOPC*CONV/FLOAT(NRUN)
      DO 7006 MAC=1,IDFL
 7006 AFLUX(MAC)=AFLUX(MAC)/NRUN
      WRITE(6,1820)  NRUN,IRAYS
 1820 FORMAT(/,25X,15HSTATISTICS FOR ,I4,8H RUNS AT,I6,13H RAYS PER RUN,
     1/)
      WRITE(6,1821)
 1821 FORMAT(/ ,40X,10H**********,11HOUTPUT CODE,10H**********,//,10X,
     144HETA1=FRACTION OF FIELD FLUX THAT HIT MIRRORS,/,10X,
     216HETA2=REFLECTANCE,/,10X,
     349HETA3=FRACTION OF FLUX NOT OBSCURED ON THE WAY OUT,/,10X,
     536HETA4=FRACTION OF FLUX THAT HIT TOWER,/,10X,
     652HETA5=FRACTION OF FIELD FLUX THAT HIT CAVITY          ,/,10X,
     753HETA6=FRACTION OF FIELD FLUX THAT HIT THE CAVITY WALLS,/,10X,
     852HETA7=FRACTION OF FIELD FLUX THAT WAS IN TOWER SHADOW,/)
      WRITE(6,9001)
 9001 FORMAT(//,10X,34HEFLUX1=TOTAL FLUX ON FIELD IN KWH ,/,10X,
     140HEFLUX2=TOTAL FLUX ON MIRRORS IN KWH      ,/,10X,
     242HEFLUX3=TOTAL FLUX LEAVING MIRRORS IN KWH   ,/,10X,
     355HEFLUX4=TOTAL FLUX CLEANLY AWAY FROM FIELD IN KWH        ,/,10X,
     139HEFLUX5=TOTAL FLUX ON POWER TOWER IN KWH,/,10X,
     237HEFLUX6=FLUX ON CAVITY DIFFUSER IN KWH,/,10X,
     734HEFLUX7=FLUX ON CAVITY WALLS IN KWH,/,10X,
     837HEFLUX8=FLUX ON CAVITY CEILING IN KWH,/)
      WRITE(6,2799)
 2799 FORMAT(/,10X,28HN1=RAYS DRAWN BEFORE SUNRISE,/,10X,
     138HN2=RAYS DRAWN WHEN THE SUN WAS TOO LOW,/,10X,
     237HN3=RAYS DRAWN THAT HIT THE OPEN FIELD,/,10X,
     347HN4=RAYS WHICH HIT MIRROR BUT WERE LOST IN SPACE,/,10X,
     443HN5=RAYS DRAWN THAT WERE BLOCKED IN ONBLOCKS,/,10X,
     538HN6=RAYS THAT WERE OBSCURED IN OFFBLOCK,/,10X,
     633HN7=RAYS WHICH HIT CAVITY DIFFUSER,/,10X,
     723HN8=RAYS WHICH HIT WALLS,/,10X,
     822HN9=RAYS WHICH HIT ROOF,/,10X,
     926HN10=RAYS WHICH MISSED HIGH,/,10X,
     138HN11=RAYS WHICH MISSED ACROSS THE FRONT,/,10X,
     125HN12=RAYS WHICH MISSED LOW,/,10X,
     227HN13=RAYS WHICH HIT SUPPORTS,/,10X,
     339HN14=RAYS WHICH WERE IN THE TOWER SHADOW,/,10X,
     *31HN15=RAYS WHICH WHISTLED THROUGH,/,10X,
     443HN16=RAYS WHICH FRAME SHADOWED ON SAME HELIO,/,10X,
     544HN17=RAYS WHICH FRAME SHADOWED ON OTHER HELIO,/,10X,
     642HN18=RAYS WHICH FRAME BLOCKED ON SAME HELIO,/,10X,
     743HN19=RAYS WHICH FRAME BLOCKED ON OTHER HELIO)
      ETA(7)=FLOAT(ITT(14))/FLOAT(NRUN*IRAYS-ITT(1)-ITT(2))
C  HIT RECEIVER
      XM(6)=AFLUX(1)*CONV
      XM(7)=AFLUX(2)*CONV
      ENORTH = 0.0
      ESOUTH  = 0.0
      XMDNI=TOTDNI*DINTV*YFRAC/NTOT
      XM(8)=TOPC
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      XM(1)=TOTEN*CONV/NTOT
      XM(2)=ENHM*CONV/NTOT
      XM(3)=COLH*CONV/NTOT
      XMBLOC=COLO*CONV/NTOT
      XMSHAD=SHADL*CONV/FLOAT(NTOT)
      XM(5)=FOPT*CONV/NTOT
      FRSHAD(1)=FRSHAD(1)*CONV/FLOAT(NTOT)
      FRSHAD(2)=FRSHAD(2)*CONV/FLOAT(NTOT)
      FRSHAD(3)=FRSHAD(3)*CONV/FLOAT(NTOT)
      FRSHAD(4)=FRSHAD(4)*CONV/FLOAT(NTOT)
C
C******FRSHAD(1)=ENERGY LOST FROM FRAME SHADOWS
C******ON THE SAME HELIOSTAT WHICH CONTAINS THE HIT FACET
C
C******FRSHAD(2)=ENERGY LOST FROM FRAME SHADOWS ON HELIOSTATS
C       OTHER THAN THE ONE WHICH CONTAINS THE HIT FACET
C
C******FRSHAD(3)=ENERGY LOST FOOM FRAME BLOCKS ON THE SAME
C       HELIOSTAT WHICH CONTAINS THE HIT FACET
C
C******FRSHAD(4)=ENERGY LOST FROM FRAME BLOCKS ON HELIOSTATS
C       OTHER THAN THE ONE WHICH CONTAINS THE HIT FACET
C
      XM(4)=XM(3)-XMBLOC
      XMABBE=XM(4)-XM(5)
      XMREFL=XM(2)-XM(3)
      ETA(1)=XM(2)/XM(1)
      ETA(2)=1.0-XMREFL/XM(2)
      ETA(3)=1.0-XMBLOC/XM(3)
      ETA(4)=1.0-XMABBE/XM(4)
      ETA(5)=XM(5)/XM(1)
      ETA(6)=XM(7)/XM(1)
      DO 8202 I=1,10
      DO 8200 J = 1,5
 8200 ENORTH = ENORTH + FIELD(I,J)
      DO 8201 J = 6,10
 8201 ESOUTH = ESOUTH + FIELD(I,J)
 8202 CONTINUE
      ENORTH = ENORTH*0.001*CONV
      ESOUTH = ESOUTH*0.001*CONV
      XXR=.001*CONV/(.0929*WCELL*WCELL)
      DO 8103 I=1,12
      DO 8103 J=1,12
 8103 FIELD(I,J)=FIELD(I,J)*XXR
      WRITE(6,1005) (I,I=1,7)
 1005 FORMAT(/,10X,7(4X,3HETA,I1))
      WRITE(6,1006)  (ETA(I),I=1,7)
 1006 FORMAT(10X,14F8.5)
      WRITE(6,1007) (J,J=1,8)
 1007 FORMAT(/,8(9X,5HEFLUX,I1),/)
      WRITE (6.1008) (XM(I),I=1,8)
 1008 FORMAT(9E15.6)
 2001 FORMAT(/,10X,9(3X,1HN,I1),10(3X,1HN,I2))
      WRITE(6,2001) (I,I=1,19)
      WRITE(6,2002) (ITT(I),I=1,19)
 2002 FORMAT(10X,9I5,10I6,/)
C   CALCULATE HOURS OF SUNSHINE IN THE YEAR
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      HOURS=DINTV*YFRAC*(1.0-FLOAT(ITT(1))/FLOAT(NTOT))                  MONTE 344
      WRITE(6,7002)                                                      MONTE 345
 7002 FORMAT(1H1)                                                        MONTE 346
      WRITE (6,15)                                                       MONTE 347
   15 FORMAT(///,20X,20HTIME INTEGRATION RUN,//)                         MONTE 348
      WRITE(6,11) HOURS                                                  MONTE 349
   11 FORMAT(/,15X,31HHOURS OF SUNSHINE IN THE YEAR =,F10.1,/)           MONTE 350
      AFIELD=DELRAD*3.14159                                              MONTE 351
      NHITM=NTOT-ITT(1)-ITT(2)                                           MONTE 352
      AREAM=NCOL*NHF*WD*WFV*0.0929                                       MONTE 353
      EPM(1)=(XM(2)+XMSHAD+FRSHAD(1)+FRSHAD(2))/AREAM                    MONTE 354
      DO 21 I=2,5                                                        MONTE 355
   21 EPM(I)=XM(I)/AREAM                                                 MONTE 356
      EPM(6)=EPM(5)*0.9                                                  MONTE 357
      TE1=EPM(1)/XMDNI                                                   MONTE 358
      TE2=EPM(4)/XMDNI                                                   MONTE 359
      WRITE(6,27) AREAM,XMDNI                                            MONTE 360
   27 FORMAT(/,9X,18HACTUAL MIRROR AREA,10X,20HDIRECT NORMAL ENERGY,     MONTE 361
     * /,15X,F12.4,18X,F12.4)                                            MONTE 362
      WRITE(6,23) (EPM(I),I=1,6)                                         MONTE 363
   23 FORMAT(//,23X,26HENERGY (KWH) PER SQ. METER,                       MONTE 364
     1/,20X,10HUNSHADOWED,10X,F12.4,                                     MONTE 365
     2/,20X,8HSHADOWED,12X,F12.4,                                        MONTE 366
     3/,20X,14HLEAVING MIRROR,6X,F12.4,                                  MONTE 367
     4/,20X,12HCLEANLY AWAY,8X,F12.4,                                    MONTE 368
     5/,20X,13HTHRU APERTURE,7X,F12.4,                                   MONTE 369
     6/,20X,8HABSORBED,12X,F12.4)                                        MONTE 370
      WRITE(6,24) TE1,TE2                                                MONTE 371
   24 FORMAT(//,15X,19HTRACKING EFFICIENCY,2X,12H(UNSHADOWED),7X,        MONTE 372
     *F10.4,/,36X,14H(CLEANLY AWAY),5X,F10.4)                            MONTE 373
      WRITE (6,5)                                                        MONTE 374
 5    FORMAT(    /,11X,9HNUMBER OF,5X,7HSUPPORT,7X,6HKWH ON,/,12X,8HSUPP MONTE 375
     1ORTS,7X,5HWIDTH,4X,8HSUPPORTS)                                     MONTE 376
      WRITE(6,10) NSUP,SW,SPPT                                           MONTE 377
 10   FORMAT(/,10X,I10,F12.1,E12.3)                                      MONTE 378
      WRITE(6,8010) (IPLAN(IP),IP=1,7)                                   MONTE 379
 8010 FORMAT (//,36X,20HHELIOSTAT FRAME HITS,//,20X,9HTOP FRAME,4X,      MONTE 380
     2 11HSIDE FRAMES,4X,12HCROSS FRAMES,4X,12HBOTTOM FRAME,/,22X,       MONTE 381
     3 I3,9X,I3,3X,I3,5X,3(I3,2X),6X,I3)                                 MONTE 382
      WRITE(6,3150) FRSHAD(1),FRSHAD(2),FRSHAD(3),FRSHAD(4)              MONTE 383
 3150 FORMAT(//,40X,27HENERGY LOST ON FRAME IN KWH,//,28X,12HFRAME SHADO MONTE 384
     *W,28X,11HFRAME BLOCK,/,16X,13HON SAME HELIO,7X,                    MONTE 385
     113HON DIFF HELIO,7X,13HON SAME HELIO,7X,13HON DIFF HELIO,/,        MONTE 386
     215X,F12.1,8X,F12.1,8X,F12.1,8X,F12.1)                              MONTE 387
      WRITE(6,7002)                                                      MONTE 388
      CALL HITFAC(0,0,0,3,NHF)                                           MONTE 389
      XZONE=6.283185*PSWTC(2)*HCAV*0.0929/FLOAT(NLONG*NLATC)             FINAL 8
      PZONE=1./XZONE                                                     FINAL 9
      DO 6402 I=1,NN1                                                    FINAL 10
      DO 6402 J=1,NLONG                                                  FINAL 11
 6402 FLMAPC(I,J)=FLMAPC(I,J)*PZONE                                      FINAL 12
      CALL WALLMP(FLMAPC,NLONG,NLATC,HCAV)                               MONTE 390
      CALL ROOF(3,DCONM)                                                 MONTE 391
      WRITE(6,8104)                                                      MONTE 392
 8104 FORMAT(///,20X,                                                    MONTE 393
     147HMWH/SQ.M ENERGY MAP OF POWER TOWER MIRROR FIELD,/)              MONTE 394
      DO 8105 J=1,10                                                     MONTE 395
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      8105 WRITE(6,8106) (FIELD(I,J),I=1,11)
      8106 FORMAT(10X,11E11.3)
           WRITE(6,8203) ENORTH,ESOUTH
      8203 FORMAT(///,10X,24HNORTH HALF FIELD ENERGY=,3X,E10.4,5X,
          13HMWH,/,10X,24HSOUTH HALF FIELD ENERGY=,3X,E10.4,5X,3HMWH,///)
           CALL POLMAP(COUNT,CONV,NTOT,3,ND1)
           STEST=10.E+30
           NMX=121.
           IS=NMX/10
           K=0
           ISTOP=IS
           DO 3050 NN=1,NMX
           SMAX=0.0
           DO 3040 I=1,11
           DO 3040 J=1,11
      3040 IF(FIELD(I,J).GT.SMAX.AND.FIELD(I,J).LT.STEST) SMAX=FIELD(I,J)
           STEST=SMAX
           IF(NN.LT.ISTOP) GO TO 3050
           ISTOP=ISTOP+IS
           K=K+1
           SL(K)=SMAX
      3050 CONTINUE
           KK=K-1
           WRITE (6,3180) (SL(I),I=1,10)
      3180 FORMAT(1H1,//,10X,8HSL ARRAY,10E11.5,/)
           DO 61 J=1,11
           DO 73 I=1,11
      73   IO(I)=0
           DO 70 I=1,11
           DO 60 KL=1,KK
           KLX=KK-KL+1
           IF(FIELD(I,J).GT.SL(KLX)) GO TO 43
           GO TO 70
      43   IO(I)=KLX
        60 CONTINUE
        70 CONTINUE
           WRITE(6,65)    (IO(II),II=1,11)
        65 FORMAT(20X,20I4,//)
        61 CONTINUE
           CALL TMAP(1.,1.,MON,COUNT,NTOT,CONV,3)
           RETURN
           END
```

```
      SUBROUTINE PTOWER(ND1,IAC,ARATIO)
C** THIS PROGRAM CONTROLS ALL OF THE CALL FOR ALL OF THE HIT TESTS
C WHICH ARE DONE.  FROM IT, PERT, TRIADS, FINDIT, MIRROR, AND MOON
C ARE CALLED.
C ICMH=1      IF A MIRROR IS HIT.
C ICMH=0      IF A MIRROR IS NOT HIT.
      REAL N
      COMMON/BEDTST/ALBLOC,ICOD,UHV2(3),UAXV2(3)
      COMMON/STRUCT/GAP,WLONG,WSIDE,WTRI,XLTRI,BB1,B2,WCROSS,WDUM,IFRAM
     *,HTMIR,HTCROS,WJCROS
      DIMENSION YDUM(3),VS1(3),VS2(3),VS3(3),VS4(3),VS5(3),VS6(3),VS7(3)
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,
     1      RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),
     2      UTT(3),UNNP(3),UXV2P(3)
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE
      COMMON/JOKER/URP(3),USI(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD

      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ
      COMMON /STATS/TPB,TSB,PHB,TPV,PHV,AVE,TSV,PAX1V,PAX1B,PAX2V,PAX2B
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM
      COMMON /CINDEX/ XPCOL,YPCOL,COSA,COSB,SLDUM,WCELL,ICELL,JCELL,
     1        XCSAV,YCSAV,XCM,YCM,ICELM,JCELM
      COMMON/SUPPT/DELTM,THES,KSEG,APH,SW,NSUP,RCONE,THECON,HTOT
      COMMON/TILTED/TTILT,UVT(3),U1(3),U2(3),WAPMAX,WAPMIN,OFFSET
      COMMON/CAVITY/SEP,DD1,DD2,RDIF,HDIF,HCAV,HSWTC(2),RSWTC(2),
     *CILAT(2),CAVLAT(2,21),AIMHGT
      COMMON/TOE/CTAZT,STAZT,CTELT,IFOCUS,STELT,UTARG(3),DTARG(3)
      DUMA=-A
      DUMB=-B
      DUMC=C
      SMAX=DCOL*SQRT(1.-C*C)/C
      ICMH=0
      ICSH=0
      IOHIT=0
      IFC=1
      CALL FINDIT(ND1,IFVHS)
      IF(ICMH.GT.0) GO TO 2172
      RETURN
 2172 TDTHL=TAN(THSR*DRAD)
      TDTHU=TAN(THSU*DRAD)
      DUM2=SQRT(1.+TDTHL*TDTHL+TDTHU*TDTHU)
      DO 1983 I=1,3
 1983 URP(I)=-(TDTHL*UMNN1(I)+TDTHU*UMNN2(I)-UR(I))/DUM2
      CALL TRIADS(N,UMNS,UAXV,UHV,UXV2,UBEDN)
      CALL PERT3(IFVHS)
      CTT=DOTER(URP,UNNP)
      SN=SQRT(1.-CTT*CTT)
      XCTT=SN/CTT
      THNORM=ATAN(XCTT)/DRAD
      ENHM=ENHM*COUNT
      CALL MIRROR(THNORM,REF)
      COUNT=COUNT*REF
```

```
      DUM3= -XCM
      DUM4=YCM
      DUM5=TH-.5*DCOL
      DO 1984 I=1,3
      US1(I)=-2.*CTT*UNNP(I)+URP(I)
 1984 D(I)=DUM3*UE(I)-DUM4*UN(I)+DUM5*N(I)+SCDELT(1)*N(I)+SCDELT(2)*UE(I
     1)+SCDELT(3)*UN(I)-RRS(I)+SEP*0.5*(N(I)-UVT(I))
      ARATIO=DOTER(URP,N)/DOTER(UMNS,URP)
      CALL ONBLOCK(IBLOC,IFVHS,ALBLOC)
      ICOD=3
      DO 200 I=1,3
      YDUM(I)=(ALEN/2.-FLOAT(IFVHS-1)*XDF)*UHV(I)
      VS1(I)=-RHS(I)-YDUM(I)-HTMIR*UBEDN(I)
      VS2(I)=VS1(I)+WDUM*UAXV(I)-WSIDE*0.5*UBEDN(I)
      VS3(I)=VS1(I)-WDUM*UAXV(I)-WSIDE*0.5*UBEDN(I)
      VS4(I)=VS1(I)-HTCROS*0.5*UBEDN(I)
      VS5(I)=VS4(I)-XDF*UHV(I)
      VS6(I)=VS4(I) + XDF*UHV(I)
  200 VS7(I)=VS1(I) - HTCROS*UBEDN(I)
      CALL FRAME(VS1,VS2,VS3,VS4,VS5,VS6,VS7,ALFRAM,JK,M,ALBLOC)
      IF(IFRAM.EQ.0.AND.IBLOC.EQ.0) GO TO 100
      IF(IFRAM.EQ.0.AND.IBLOC.EQ.1) GO TO 20
      IF(IFRAM.EQ.1.AND.IBLOC.EQ.0) GO TO 30
      IF(ALBLOC.LE.ALFRAM) GO TO 20
   30 IBLOC=0
      IFRAM=3
      ND1=17
      IOHIT=1
      RETURN
   20 IBLOC=1
      IFRAM=0
      IOHIT=1
      ND1=4
      CALL HITFAC(IFVHS,IFV,ND1,2,NHF)
      RETURN
  100 DUM=.5*DCOL-DOTER(N,RRS)
      DUMC=DOTER(N,US1)
      DUMA=DOTER(UN,US1)
      DUMB=DOTER(UE,US1)
      SMAX=DUM*SQRT(1.-DUMC*DUMC)/DUMC
      B1=DOTER(UE,RRS)
      A1=DOTER(UN,RRS)
      XP=XCM+B1
      YP=YCM+A1
      IFC=2
      IOHIT=0
      CALL FINDIT(ND1,IFVHS)
      IF(IOHIT.EQ.0) GO TO 10
      CALL HITFAC(IFVHS,IFV,ND1,2,NHF)
      RETURN
   10  CALL MOON(ND1,IAC)
      CALL HITFAC(IFVHS,IFV,ND1,2,NHF)
      RETURN
      END
```

```
      SUBROUTINE PERT3(IFVH)
      COMMON/JOKER/URP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD

      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,
     1     RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),
     2     UTT(3),UNNP(3),UXV2P(3)
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE
      COMMON /CINDEX/ XPCOL,YPCOL,COSA,COSB,SLDUM,WCELL,ICELL,JCELL,
     1        XCSAV,YCSAV,XCM,YCM,ICELM,JCELM
      COMMON/TOE/CTAZT,STAZT,CTELT,IFOCUS,STELT,UTARG(3),DTARG(3)
      DIMENSION UMNIPP(3),FF(3),UX2IPP(3),RRT(3),RB(3)
C     UHOZ(3)=FIRST AXIS OF MURPHY BED
C     UBEDN(3)=NORMAL TO BED FRAME
C     UAXVP(3)=UAXV(3) WITH FIRST ERROR ROTATION
C     UBEDNP(3)=UBEDN(3) WITH FIRST ERROR ROTATION
C     UMNP(3)=UMN WITH FIRST ERROR ROTATION
C     UXV2PP(3)=UXV2P(3) WITH SECOND ERROR ROTATION
C     UMNPP(3)=UMNP(3) WITH SECOND ERROR ROTATION
C     SGN=SIGN OF UXV2*UHOZ
C     RRS(3)=SAVED VALUE OF VECTOR FROM HELIOSTAT CENTER TO HIT POINT
C   RHS(3)=VALUE OF VECTOR FROM FACET CENTER TO HIT POINT
C     RRF(3)=VECTOR FROM FRAME CENTER TO HIT POINT WITH FACETS FLAT
C     UNNPP(3)=MIRROR NORMAL AT HIT POINT WITH FACETS IN PLACE
C     UNNP(3)=MIRROR NORMAL AT HIT POINT WITH SLOPE ERROR
C     THIS ROUTINE FINDS THE ROTATIONS REQUIRED FOR TRACKING ERRORS,
C     FOCUSING,TOE IN, AND SLOPE ERRORS FOR THE MURPHY BED
C     HELIOSTAT
C     PH=UNIFORM 0 TO 360
C     THSL= (NORMAL) SLOPE ERROR
C     PAX1,PAX2=TRACKING ERRORS(NORMAL)
      DIMENSION UBEDNP(3),UNNPP(3),UTTPP(3),UT2PP(3),UHOZ(3)
      DIMENSION FMED(10),RFZ(11)
      IF (IDUMMY.GT.0) GO TO 23
      IF (IFOCUS.EQ.0.OR.IFOCUS.GT.10) GO TO 23
      IFOCP1=IFOCUS+1
      DLTRAD=(RFIELD-TDISY-RCO)/IFOCUS
      RFZ(1)=RCO
      DO 22 IFL=2,IFOCP1
      RFZ(IFL)=RFZ(IFL-1)+DLTRAD
   22 FMED(IFL-1)=SQRT(TH*TH+(RFZ(IFL)**2+RFZ(IFL-1)**2)/2.)
C   SET FOCAL LENGTH EQUAL TO LONGEST PATH WHEN IFOCUS=1
      IF (IFOCUS.EQ.1)
     1 FMED(1)=SQRT(TH*TH+(-TDISY+RFIELD)*(-TDISY+RFIELD))
   23 IDUMMY=12
      DO 5 I=1,3
      UMN(I)=UMNS(I)
    5 UHOZ(I)=UHV(I)
      IF (IDRIVE .EQ. 2) CALL FDRIVE(UHOZ,IFVH)
      CP1=COS(PAX1/57.3)
      CP2=COS(PAX2/57.3)
      SP1=SIN(PAX1/57.3)
      SP2=SIN(PAX2/57.3)
```

```
      D2H=DOTER(UXV2,UHOZ)
      DMB=DOTER(UMN,UBEDN)
      DMH=DOTER(UMN,UHOZ)
C     MAKE FIRST ROTATION (PAX1)
      D2B=DOTER(UXV2,UBEDN)
      DO 10 I=1,3
      UBEDNP(I)=CP1*UBEDN(I)+SP1*UAXV(I)
      UAXVP(I)=CP1*UAXV(I)-SP1*UBEDN(I)
      UMNP(I)=DMH*UHOZ(I)+DMB*UBEDNP(I)
      UXV2P(I)=D2H*UHOZ(I)+D2B*UBEDNP(I)
      UXV2PP(I)=CP2*UXV2P(I)-UMNP(I)*SP2
   10 UMNPP(I)=CP2*UMNP(I)+UXV2P(I)*SP2
      CALL CHECKR(UMN,UAXV,UXV2,ICD)
      IF(ICD.NE.0)  WRITE(6,15)
   15 FORMAT(10X,13HUMN UAXV UXV2)
      CALL CHECKR(UBEDN,UAXV,UHOZ,ICD)
      IF(ICD.NE.0) WRITE(6,20)
   20 FORMAT(10X.15HUBEDN UAXV UHOZ)
      CALL CHECKR(UBEDNP,UAXVP,UHOZ,ICD)
      IF(ICD.NE.0) WRITE(6,25)
   25 FORMAT(10X,17HUBEDNP UAXVP UHOZ)
      CALL CHECKR(UMNP,UXV2P,UAXVP,ICD)
      IF(ICD.NE.0)  WRITE(6,30)
   30 FORMAT(10X,16HUMNP UXV2P UAXVP)
      CALL CHECKR(UBEDNP,UAXVP,UHOZ,ICD)
      IF (ICD.GT.0) WRITE(6,35)
   35 FORMAT(10X.17HUBEDNP UAXVP UHOZ)
      CALL CHECKR(UMNPP,UXV2PP,UAXVP,ICD)
      IF(ICD.GT.0) WRITE(6,40)
   40 FORMAT(10X,18HUMNPP UXV2PP UAXVP)
      XF=ALEN*0.5-(IFVH-1)*XDF
      CALL TOEIN(XF,CTHETO,STHETO,UHV)
      DO 300 I=1,3
      UMNIPP(I)=CTHETO*UMNPP(I)+STHETO*UXV2PP(I)
  300 UX2IPP(I)=STHETO*UMNPP(I)+CTHETO*UXV2PP(I)
      CALL CHECKR(UMNIPP,UX2IPP,UAXVP,ICD)
      IF(ICD.GT.0) WRITE(6,800)
  800 FORMAT (10X,21HUMNIPP, UX2IPP,UAXVP )
C   CHECK UMN AND RHS FOR PERPENDICULARITY
      UTEST=DOTER(UMN,RHS)
      IF (ABS(UTEST).GT.0.0001) WRITE (6,710)
  710 FORMAT (10X,26HUMN AND RHS ARE NOT NORMAL)
C *** CALCULATE FACET NORMAL
C *** IFOCUS=0 FOCUS ALL FACETS INDIVIDUALLY
C *** IFOCUS=1 FOCUS FACETS BY ZONES
      IF (IFOCUS.EQ.0) GO TO 900
      IF (IFOCUS.GT.10) GO TO 950
      GRDIST=SQRT(XCM*XCM+YCM*YCM)
      IFLZ=INT((GRDIST-RCO)/DLTRAD)+1
      FS=FMED(IFLZ)
      GO TO 975
  900 CONTINUE
      DO 901 I=1.3
  901 FF(I)=DTARG(I)-XF*UHV(I)
      FT=SQRT(DOTER(FF,FF))
      FS=SQRT(FT*FT+XF*XF)
      GO TO 975
```

```
  950 FS=10E10
  975 CONTINUE
      DO 1000 I=1,3
 1000 RB(I)=-RHS(I)+2.0*FS*UMNIPP(I)
      RBU=SQRT(DOTER(RB,RB))
      DO 1100 I=1,3
 1100 UNNPP(I)=RB(I)/RBU
C *** CALCULATE LOCAL FACET TANGENT
      DO 1200 I=1,3
 1200 RRT(I)=RHS(I)-DOTER(RHS,UNNPP)*UNNPP(I)
      RRTU=SQRT(DOTER(RRT,RRT))
      DO 1300 I=1,3
 1300 UTTPP(I)=RRT(I)/RRTU
C *** CHECK UTTPP AND UNNPP FOR NORMALACY
      FNORM=DOTER(UTTPP,UNNPP)
      IF (ABS(FNORM).GT.0.0001) WRITE (6,1400)
 1400 FORMAT (10X,30HUTTPP AND UNNPP ARE NOT NORMAL)
 1500 CALL CROSS(UTTPP,UNNPP,UT2PP)
      CALL CHECKR(UNNPP,UTTPP,UT2PP,ICD)
      IF (ICD.GT.0) WRITE (6,1600)
 1600 FORMAT (10X,19HUNNPP, UTTPP, UT2PP)
C     NOW PUT THE SLOPE ERROR THSL ONTO UNNPP TO YIELD UNNP
      CSTHSL=COS(THSL/57.3)
      SNTHSL=SIN(THSL/57.3)
      CSPH=COS(PH/57.3)
      SNPH=SIN(PH/57.3)
      DO 85 I=1,3
 85   UNNP(I)=UNNPP(I)*CSTHSL+SNTHSL*(UTTPP(I)*CSPH+UT2PP(I)*SNPH)
      TEST = DOTER(UNNP,UNNP)-1.00
      IF(ABS(TEST).GT.0.0001) WRITE(6,90)
 90   FORMAT(10X,11HUNNP IS NOT,2X,13HA UNIT VECTOR)
      RETURN
      END
```

```
      SUBROUTINE TOEIN(XF,CTHETO,STHETO,UHV)                        TOEIN    2
      REAL N                                                        TOEIN    3
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),                   TOEIN    4
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ      TOEIN    5
      COMMON/TOE/CTAZT,STAZT,CTELT,IFOCUS,STELT,UTARG(3),DTARG(3)    TOEIN    6
      DIMENSION FF(3),UF(3),URT(3),UMNT(3),UMNTI(3),UHOZT(3),UFP(3), TOEIN    7
     * UHV(3),URTP(3),UMNF(3),UBEDNT(3),UAXVT(3),UXV2T(3)           TOEIN    8
C ** FOCUS THE NORMAL                                               TOEIN    9
C ** SET TOE-IN VECTOR URT                                          TOEIN   10
      DO 300 I=1,3                                                  TOEIN   11
      URT(I)=(CTAZT*(-UN(I))-STAZT*UE(I))*CTELT-STELT*N(I)          TOEIN   12
  300 UMNT(I)=UTARG(I)-URT(I)                                       TOEIN   13
C ** SET MIRROR NORMAL AND OUTER AXIS VECTOR FOR TOE-IN CALCULATIONS TOEIN   14
      UMAG=SQRT(DOTER(UMNT,UMNT))                                   TOEIN   15
      DO 400 I=1,3                                                  TOEIN   16
      UMNTI(I)=UMNT(I)/UMAG                                         TOEIN   17
  400 UHOZT(I)=UHV(I)                                               TOEIN   18
      CALL TRIADS(N,UMNTI,UAXVT,UHV,UXV2T,UBEDNT,2)                 TOEIN   19
      DO 500 I=1,3                                                  TOEIN   20
  500 FF(I)=DTARG(I)-XF*UHV(I)                                      TOEIN   21
      FMAG=SQRT(DOTER(FF,FF))                                       TOEIN   22
      DO 600 I=1,3                                                  TOEIN   23
  600 UF(I)=FF(I)/FMAG                                              TOEIN   24
C ** ROTATE UF AND URT INTO THE UBEDN AND UHV PLANE                 TOEIN   25
      CTX=DOTER(UF,UBEDNT)                                          TOEIN   26
      STX=DOTER(UF,UHOZT)                                           TOEIN   27
      CTXX=DOTER(URT,UBEDNT)                                        TOEIN   28
      STXX=DOTER(URT,UHOZT)                                         TOEIN   29
      DO 700 I=1,3                                                  TOEIN   30
      UFP(I)=UBEDNT(I)*CTX+UHOZT(I)*STX                             TOEIN   31
  700 URTP(I)=UBEDNT(I)*CTXX+UHOZT(I)*STXX                          TOEIN   32
C ** FIND FACET NORMAL                                              TOEIN   33
      AMAG=SQRT(DOTER(UFP,UFP))                                     TOEIN   34
      BMAG=SQRT(DOTER(URTP,URTP))                                   TOEIN   35
      DO 800 I=1,3                                                  TOEIN   36
  800 UMNF(I)=UFP(I)/AMAG-URTP(I)/BMAG                              TOEIN   37
      UMAG=SQRT(DOTER(UMNF,UMNF))                                   TOEIN   38
      DO 900 I=1,3                                                  TOEIN   39
  900 UMNF(I)=UMNF(I)/UMAG                                          TOEIN   40
      CTHETO=DOTER(UMNF,UMNTI)                                      TOEIN   41
      STHETO=DOTER(UMNF,UXV2T)                                      TOEIN   42
      RETURN                                                        TOEIN   43
      END                                                           TOEIN   44
```

```
      SUBROUTINE FDRIVE(UHOZ,IFVH)
      REAL N
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ
      COMMON/JOKER/URP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)

      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,
     1      RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),
     2      UTT(3),UNNP(3),UXV2P(3)
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE
      COMMON /CINDEX/ XPCOL,YPCOL,COSA,COSB,SLDUM,WCELL,ICELL,JCELL,
     1       XCSAV,YCSAV,XCM,YCM,ICELM,JCELM
C  THIS ROUTINE SETS UP THE TRIAL AT THE HIT FACET CENTER FOR
C  INDEPENDENT FACET DRIVES.
      DIMENSION UHOZ(3),XCC(3),DUTF(3),UTF(3),UTFPR(3),URPR(3),UMNF(3)
      DIMENSION UMNDUM(3),AIMP(3)
      DO 101 I=1,3
  101 XCC(I)=(ALEN/2.-(FLOAT(IFVH-1))*XDF)*UHOZ(I)
      CALL AIMPP(XCM,YCM,2,AIMP)
      DO 102 J=1,3
  102 DUTF(J)=-XCC(J)-XCM*UE(J)-YCM*UN(J)+(TH-(DCOL/2.0))*N(J)+AIMP(J)
      AMAG=SQRT(DOTER(DUTF,DUTF))
      DO 103 K=1,3
  103 UTF(K)=DUTF(K)/AMAG
      DO 106 L=1,3
      UTFPR(L)=(DOTER(UBEDN,UTF))*UBEDN(L)+(DOTER(UHOZ,UTF))*UHOZ(L)
  106 URPR(L)=(DOTER(UBEDN,UR))*UBEDN(L)+(DOTER(UHOZ,UR))*UHOZ(L)
      AMAG1=SQRT(DOTER(URPR,URPR))
      AMAG2=SQRT(DOTER(UTFPR,UTFPR))
      DO 107 M=1,3
  107 UMNF(M)=-URPR(M)/AMAG1+UTFPR(M)/AMAG2
      DO 109 I=1,3
      UMNDUM(I)=-UR(I)+UTF(I)
  109 CONTINUE
      AMAG3=SQRT(DOTER(UMNDUM,UMNDUM))
      DO 111 I=1,3
      UMNDUM(I)=UMNDUM(I)/AMAG3
  111 CONTINUE
      AMAG=SQRT(DOTER(UMNF,UMNF))
      DO 108 I=1,3
  108 UMN(I)=UMNF(I)/AMAG
      CALL CROSS(UAXV,UMN,UXV2)
      RETURN
      END
```

```
      SUBROUTINE FINDIT(ND1,IFVHS)
C** THIS ROUTINE FINDS THE LIST OF MIRRORS WHICH A RAY FROM THE SUN
C COULD POSSIBLY HAVE HIT.  IT ALSO FINDS THE LIST OF MIRRORS WHICH
C A REFLECTED RAY COULD POSSIBLY HIT.  FROM IT RINDX, INHIT, AND
C OFFRLOC ARE CALLED.
      REAL N
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,
     1      RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),
     2      UTT(3),UNNP(3),UXV2P(3)
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)

      COMMON /CINDEX/ XPCOL,YPCOL,COSA,COSB,SLDUM,WCELL,ICELL,JCELL,
     1        XCSAV,YCSAV,XCM,YCM,ICELM,JCELM
      COMMON/STRUCT/GAP,WLONG,WSIDE,WTRI,XLTRI,B1,B2,
     * WCROSS,WDUM,IFRAM,HTMIR,HTCROS,WJCROS
      COMMON/BEDTST/ALBLOC,ICOD,UHV2(3),UAXV2(3)
      DIMENSION VS1(3),VS2(3),VS3(3),VS4(3),VS5(3),VS6(3),VS7(3)
      DIMENSION XSAV(20),YSAV(20),ICELS(20),JCELS(20),UHVS(3)
      DIMENSION YDUM(3),XDUM(3)
C
C      ICMH=1 IF MIRROR WAS HIT
C      ICMH=0 IF NO MIRROR WAS HIT
C      ICSH= NUMBER OF MIRRORS
C      HIT AFTER FIRST HIT.  IF
C      NUMBER OF SHADOWS
C      UMNS  UNIT NORMAL OF THE
C      FIRST MIRROR HIT
C      RRS  VECTOR FROM MIRROR
C      CENTER TO HIT POINT ON
C      MIRROR, NONE UNIT
C      (IIM,JJM)   INDEXS OF HIT MIRROR
C
C      CHECK END POINTS OF S
C      START POINT FIRST
      IF(IFC.LT.2) GO TO 1974
      XPCOL=XP
      YPCOL=YP
      XSSS=XCM
      YSSS=YCM
      GO TO 8975
 1974 XPCOL=XP
      YPCOL=YP
      COSA=0.
      COSB=0.
      SLDUM=0.
      CALL RINDX
      XSAV(1)=XCSAV
      YSAV(1)=YCSAV
      ICELS(1)=ICELL
      JCELS(1)=JCELL
```

```
      XSSS=XCSAV
      YSSS=YCSAV
 8975 ICONT=1
C      SECOND END POINT
      COSA=DUMA
      COSB=DUMB
      SLDUM=SMAX
      CALL RINDX
      XSAV(2)=XCSAV
      YSAV(2)=YCSAV
      ICELS(2)=ICELL
      JCELS(2)=JCELL
C      MAKE TESTS
      TEST1=ABS(XSAV(2)-XSSS)
      TEST2=ABS(YSAV(2)-YSSS)
      IF(TEST1.GT.0.001) GO TO 40
      IF(TEST2.GT.0.001) GO TO 40
      IF(IFC.EQ.1) GO TO 50
      IOHIT=0
      RETURN
C      AT THIS POINT START AND END ARE
C     THE SAME MIRROR      CALL INHIT
C      END POINT AND START POINT
C      DIFFER BY MORE THAN ONE TEST
C      IN BETWEEN
   40 NSTD=NSTOPS-1
      DNM=FLOAT(NSTD)
      DO 45 K=1,NSTD
      SLDUM=SMAX*FLOAT(K)/DNM
      CALL RINDX
      TEST1=ABS(XSSS-XCSAV)
      TEST2=ABS(YSSS-YCSAV)
      IF (TEST1 .LT. 0.001 .AND. TEST2 .LT. 0.001) GO TO 45
      XSSS=XCSAV
      YSSS=YCSAV
      ICONT=ICONT+1
      XSAV(ICONT)=XCSAV
      YSAV(ICONT)=YCSAV
      ICELS(ICONT)=ICELL
      JCELS(ICONT)=JCELL
   45 CONTINUE
      IF(IFC.EQ.2) GO TO 2001
C      ALL POSSIBLE HITS HAVE BEEN FOUND
C     NOW CALL INHIT TO TEST
   50 ICSH=0
      IFRAM=0
      ICSH2=0
      ICMH=0
      DO 100 I=1,ICONT
      XC=XSAV(I)
      YC=YSAV(I)
      DMNH=SQRT(XC*XC+YC*YC)
      DO 5 KI=1,3
    5 UHV(KI)=(YC*UE(KI)-XC*UN(KI))/DMNH
      ISCEL=ICELS(I)
      JSCEL=JCELS(I)
      IF (XCSAV .GT. (9.*TH)) GO TO 100
```

```
      CALL INHIT(XC,YC,IFVH,ISHAD,ALMIN)
      IF(IHIT.EQ.0) GO TO 100
      IF(ICMH.EQ.1.OR.IFRAM.GT.0) GO TO 70
C      FOUND FIRST HIT
      ND1=3
      ICMH=1
      ICELM=ISCEL
      JCELM=JSCEL
      XCM=XC
      YCM=YC
      RHIT=SQRT(XC*XC+YC*YC)
      IFVHS=IFVH
      ICSH=ICSH+ISHAD
      DO 60 J=1,3
      RHS(J)=RPB(J)
      UHVS(J)=UHV(J)
      UMNS(J)=UMN(J)
   60 RRS(J)=RHS(J)+(ALEN/2.-(FLOAT(IFVH-1))*XDF)*UHV(J)
      M=1
      DO 103 JK=1,M
      XC=XSAV(JK)
      YC=YSAV(JK)
      XS=XP
      YS=YP
      CALL MIRRN(XC,YC)
      DO 107 JB=1,3
  107 UHV(JB)=(YC*UE(JB)-XC*UN(JB))/SQRT(XC*XC+YC*YC)
      CALL TRIADS(N,UMN,UAXV,UHV,UXV2,UBEDN)
      DO 113 JB=1,3
      VS1(JB)=(XC-XS)*UE(JB) + (YC-YS)*UN(JB) - DCOL*0.5*N(JB)
     * - HTMIR*UBEDN(JB)
      VS2(JB)=VS1(JB)+WDUM*UAXV(JB)-WSIDE*0.5*UBEDN(JB)
      VS3(JB)=VS1(JB)-WDUM*UAXV(JB)-WSIDE*0.5*UBEDN(JB)
      VS4(JB)=VS1(JB) - HTCROS*0.5*UBEDN(JB)
      VS5(JB)=VS4(JB) - XDF*UHV(JB)
      VS6(JB)=VS4(JB) + XDF*UHV(JB)
      VS7(JB)=VS1(JB) - HTCROS*UBEDN(JB)
  113 CONTINUE
      ICOD=1
      JKD=JK
      MDUM=M
      CALL FRAME(VS1,VS2,VS3,VS4,VS5,VS6,VS7,ALFRAM,JKD,MDUM,ALMIN)
      IF(ALFRAM.GT.ALMIN) IFRAM=0
      IF(IFRAM.EQ.0) GO TO 103
      ND1=15
      ICMH=0
      IF(IFRAM.GT.1) ND1=16
      GO TO 100
  103 CONTINUE
      GO TO 100
C      SECOND AND SUCCEEDING HITS
   70 ICSH=ICSH+ISHAD+1
      RSHAD=SQRT(XC*XC+YC*YC)
      IF (ABS(RSHAD-RHIT).GT.10.) ICSH2=ICSH2+ISHAD+1
  100 CONTINUE
      DO 6 I=1,3
    6 UHV(I)=UHVS(I)
```

```
      RETURN
 2001 DO 1973 KL=2,ICONT
      XC=XSAV(KL)
      YC=YSAV(KL)
      CALL OFFBLOC(XCM,YCM,XC,YC,IBLOC,IFVHS)
      ICOD=4
      DO 1971 I=1,3
      YDUM(I)=(XC-XCM)*UE(I)+(YC-YCM)*UN(I)
      XDUM(I)=(ALEN/2.-FLOAT(IFVHS-1)*XDF)*UHV(I)
      VS1(I)=-RHS(I)-XDUM(I)+YDUM(I)-HTMIR*UBEDN(I)
      VS2(I)=VS1(I)+WDUM*UAXV2(I)-WSIDE*0.5*UBEDN(I)
      VS3(I)=VS1(I)-WDUM*UAXV2(I)-WSIDE*0.5*UBEDN(I)
      VS4(I)=VS1(I)-HTCROS*0.5*UBEDN(I)
      VS5(I)=VS4(I) - XDF*UHV2(I)
      VS6(I)=VS4(I) + XDF*UHV2(I)
 1971 VS7(I)=VS1(I) - HTCROS*UBEDN(I)
      CALL FRAME(VS1,VS2,VS3,VS4,VS5,VS6,VS7,ALFRAM,JK,M,ALBLOC)
      IF(IFRAM.EQ.0.AND.IBLOC.EQ.0) GO TO 1973
      IF(IFRAM.EQ.0.AND.IBLOC.EQ.1) GO TO 7000
      IF(IFRAM.EQ.1.AND.IBLOC.EQ.0) GO TO 7010
      IF(ALBLOC.LE.ALFRAM) GO TO 7000
 7010 IBLOC=0
      IFRAM=4
      ND1=18
      IOHIT=1
      RETURN
 7000 IBLOC=1
      IFRAM=0
      IOHIT=1
      ND1=5
      GO TO 1976
 1973 CONTINUE
 1976 RETURN
      END
```

```
      SUBROUTINE TRIADS(N,UMN,UAXV,UHV,UXV2,UBEDN)                       TRIADS   2
C        THIS ROUTINE BUILDS THE TWO                                     TRIADS   3
C        TURNTABLE BASES (N,UHV,UAXV)                                    TRIADS   4
C        AND (UMN,UAXV,UXV2) FROM N                                      TRIADS   5
C        AND UMN.                                                        TRIADS   6
C        J.M. HAMMER       OCTOBER 23,1974                               TRIADS   7
      REAL N(3)                                                          TRIADS   8
      DIMENSION UMN(3),UAXV(3),UHV(3),UXV2(3)                            TRIADS   9
      DIMENSION UBEDN(3)                                                 TRIADS  10
C  THE TWO TRIADS FOR A MURPHY BED ARE BUILT FROM UMN AND UHV            TRIADS  11
      CALL CROSS(UMN,UHV,UAXV)                                           TRIADS  12
      AMAG=DOTER(UAXV,UAXV)                                              TRIADS  13
      AMAG=SQRT(AMAG)                                                    TRIADS  14
      DO 120 I=1,3                                                       TRIADS  15
  120 UAXV(I)=UAXV(I)/AMAG                                               TRIADS  16
      CALL CROSS(UAXV,UMN,UXV2)                                          TRIADS  17
      CALL CROSS(UAXV,UHV,UBEDN)                                         TRIADS  18
C   FIX SIGN OF BEDN                                                     TRIADS  19
      DBM=DOTER(UMN,UBEDN)                                               TRIADS  20
      SGN=DBM/ABS(DBM)                                                   TRIADS  21
      DO 130 I=1,3                                                       TRIADS  22
  130 UBEDN(I)=SGN*UBEDN(I)                                              TRIADS  23
      RETURN                                                             TRIADS  24
      END                                                                TRIADS  25
```

```
      SUBROUTINE INHIT(XC,YC,IFVH,ISHAD,ALMIN)                          INHIT   2
C        THIS SUBROUTINE FINDS THE                                      INHIT   3
C        HIT POINT, IF ANY, ON LOW                                      INHIT   4
C        PROFILE HELIOSTAT (IT,JT)                                      INHIT   5
C        AND WHICH FACIT                                                INHIT   6
C        J.M. HAMMER    SEPT. 23, 1974                                  INHIT   7
      REAL N                                                            INHIT   8
      DIMENSION RRIF(3),VC(3)                                           INHIT   9
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XOF,WD2,WFV2,  INHIT  10
     1      RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),          INHIT  11
     2      UTT(3),UNNP(3),UXV2P(3)                                     INHIT  12
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE                    INHIT  13
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),                       INHIT  14
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ         INHIT  15
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,    INHIT  16
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,     INHIT  17
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,       INHIT  18
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM                          INHIT  19
      COMMON/JOKER/URP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD  INHIT  20
      COMMON /STATS/TPB,TSB,PHB,TPV,PHV,AVE,TSV,PAX1V,PAX1B,PAX2V,PAX2B INHIT  21
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)                 INHIT  22
                                                                        INHIT  23
C        UMN(3)    UNIT MIRROR NORMAL                                   INHIT  24
C        PROVIDED BY CALLING ROUTINE                                    INHIT  25
C        (N,UAXV,UHV)    TRIAD IN TURNTABLE                             INHIT  26
C        UAXV(3)    FACIT ROTATION AXIS                                 INHIT  27
C        UHV(3)    HORIZONTAL IN TURNTABLE                              INHIT  28
C        (UMN,UAXV,UXV2)    TRIAD IN FACIT FACE                         INHIT  29
C        UXV2(3)    VECTOR PERP. TO UAXV IN FACIT PLANE                 INHIT  30
C        (IT,JT)    INDEX OF TURNTABLE TO BE TESTED                     INHIT  31
C        (XS,YS)    CORDS OF RAY START POINT ON TEST PLANE              INHIT  32
C        UR(3)    INCOMING RAY DIRECTION                                INHIT  33
C        IHIT   HIT CODE, 1 IF HIT, 0 IS NO HIT                         INHIT  34
C        IFVH   THE INDEX OF HIT FACIT                                  INHIT  35
C        ALEN   LENGTH OF TURNTABLE                                     INHIT  36
C        WD   WIDTH OF TURNTABLE AND                                    INHIT  37
C        LENGTH OF FACITS                                               INHIT  38
C        WFV   WIDTH OF FACITS                                          INHIT  39
C        NHF   NUMBER OF FACITS                                         INHIT  40
C        XOF   SPACING BETWEEN FACIT CENTERS                            INHIT  41
C        RHS(3)    VECTOR FROM FACIT CENTER                             INHIT  42
C        OUT TO HIT POINT ON FACIT                                      INHIT  43
C        ISHAD   NUMBER OF SHADOWS CAST                                 INHIT  44
C        RAYL   RAY LENGTH                                              INHIT  45
C        DELX   EAST WEST ROW SPACING                                   INHIT  46
C        DELY   NORTH SOUTH ROW SPACING                                 INHIT  47
C        RST(3)    VECTOR FROM ORIGIN TO RAY HIT                        INHIT  48
C        (XL,YL,ZL)    START POINT OF REFLECTED RAY                     INHIT  49
C        BUILD BOTH TRIADS                                              INHIT  50
      CALL MIRRN(XC,YC)                                                 INHIT  51
      CALL TRIADS(N,UMN,UAXV,UHV,UXV2,UBEDN)                            INHIT  52
      DNML=DOTER(UR,UMN)                                                INHIT  53
      IHIT=0                                                            INHIT  54
      IHTS=0                                                            INHIT  55
      IFVH=0                                                            INHIT  56
      XS=XP                                                             INHIT  57
      YS=YP                                                             INHIT  58
```

```
      ALMIN=10.E+10
C        SET UP DO LOOP OVER FACITS
      DO 500 IFV=1,NHF
      DO 30 I=1,3
      VC(I)=(XS-XC)*UE(I)+(YS-YC)*UN(I)-UHV(I)*(ALEN/2.-
     1 (FLOAT(IFV-1))*XDF)+DCOL*N(I)/2.0
C     ERROR FOUND IN SIGN OF VC(I) 8/12/75   CHANGE SIGN
   30 VC(I)=-VC(I)
      ALN=DOTER(UMN,VC)/DNML
      DO 40 I=1,3
   40 RRIF(I)=ALN*UR(I)-VC(I)
      XVF=DOTER(UAXV,RRIF)
      YVF=DOTER(UXV2,RRIF)
      IF(ABS(XVF).GT.WD2.OR.ABS(YVF).GT.WFV2) GO TO 500
C        THIS FACIT WAS HIT. RECORD HIT
      IHIT=1
      IHTS=IHTS+1
      IF(ALN.GT.ALMIN) GO TO 500
      ALMIN=ALN
      RAYL=ALN
      DO 65 I=1,3
   65 RRB(I)=   RRIF(I)
      IFVH=IFV
  500 CONTINUE
      IFV=NHF
      ISHAD=IHTS-1
      DO 80 I=1,3
   80 RST(I)=XC*UE(I)+YC*UN(I)+WFV2*N(I)+UHV(I)*(ALEN/2.-
     1 (FLOAT(IFV-1))*XDF)+RHS(I)
      XL=DOTER(RST,UE)
      YL=DOTER(RST,UN)
      ZL=DOTER(RST,N)
      RETURN
      END
```

```
      SUBROUTINE ONBLOCK(IBLOC,IFVH,ALBLOC)                             ONBLOCK   2
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,  ONBLOCK   3
     1      RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),          ONBLOCK   4
     2      UTT(3),UNNP(3),UXV2P(3)                                     ONBLOCK   5
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE                    ONBLOCK   6
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),                       ONBLOCK   7
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ         ONBLOCK   8
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,    ONBLOCK   9
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,     ONBLOCK  10
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,       ONBLOCK  11
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM                          ONBLOCK  12
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)                 ONBLOCK  13
                                                                        ONBLOCK  14
      COMMON/JOKER/UPP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD  ONBLOCK  15
      COMMON /STATS/TPB,TSB,PHB,TPV,PHV,AVE,TSV,PAX1V,PAX1B,PAX2V,PAX2B ONBLOCK  16
C        THIS ROUTINE FINDS IF US1 IS                                   ONBLOCK  17
C        BLOCKED ON THE TURNTABLE IT STARTS                             ONBLOCK  18
C        FROM    J.M. HAMMER   SEPT.26,1974                             ONBLOCK  19
C                                                                       ONBLOCK  20
C        IBLOC   BLOCKAGE CODE  0 IS NOT BLOCKED                        ONBLOCK  21
C        1 RAY WAS BLOCKED                                              ONBLOCK  22
      REAL N                                                            ONBLOCK  23
      DIMENSION XC(3),XCR(3)                                            ONBLOCK  24
      ALBLOC=10.E+10                                                    ONBLOCK  25
      IBLOC=0                                                           ONBLOCK  26
      DO 200 IFV=1,NHF                                                  ONBLOCK  27
      IF(IFV.EQ.IFVH) GO TO 200                                         ONBLOCK  28
      DO 20 I=1,3                                                       ONBLOCK  29
      XC(I)=UHV(I)*XDF*(FLOAT(IFVH-IFV))                                ONBLOCK  30
   20 XCR(I)=XC(I)-RHS(I)                                               ONBLOCK  31
      SIDE=DOTER(UMN,XC)                                                ONBLOCK  32
      IF(SIDE.LT.0.0) GO TO 200                                         ONBLOCK  33
      AL=DOTER(XCR,UMN)/DOTER(US1,UMN)                                  ONBLOCK  34
      DO 30 I=1,3                                                       ONBLOCK  35
   30 RRB(I)=AL*US1(I)-XCR(I)                                           ONBLOCK  36
      XVF=DOTER(RRB,UAXV)                                               ONBLOCK  37
      YVF=DOTER(RRB,UXV2)                                               ONBLOCK  38
      IF(ABS(XVF).GT.WD2.OR.ABS(YVF).GT.WFV2) GO TO 200                 ONBLOCK  39
C        THIS FACIT BLOCKED THE RAY                                     ONBLOCK  40
      IBLOC=1                                                           ONBLOCK  41
      ALBLOC=AL                                                         ONBLOCK  42
      GO TO 250                                                         ONBLOCK  43
  200 CONTINUE                                                          ONBLOCK  44
      IFV=NHF                                                           ONBLOCK  45
  250 RETURN                                                            ONBLOCK  46
      END                                                               ONBLOCK  47
```

```
      SUBROUTINE OFFBLOC (XCM,YCM,XC,YC,IBLOC,IFV1)
      COMMON/BEDTST/ALBLOC,ICOD,UHV2(3),UAXV2(3)
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,
     1      RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),
     2      UTT(3),UNNP(3),UXV2P(3)
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,
     1         ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,
     2         DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,
     3         NLONG,ILONG,NLATC,RCO,NPACK,ENHM
      COMMON/JOKER/URP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD
      COMMON /STATS/TPB,TSB,PHB,TPV,PHV,AVE,TSV,PAX1V,PAX1B,PAX2V,PAX2B
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)

C        THIS ROUTINE FINDS IF A RAY
C        FROM TURNTABLE (I1,J1) IS BLOCKED
C        BY A FACIT OF (I2,J2)
C        J.M. HAMMER       SEPT. 26,1974
C        IFV1   FACIT ON TURNTABLE (I1,J1)
C        FROM WHENCE THE RAY CAME
C
C        IBLOC   BLOCKAGE CODE.  0 NO BLOCK,
C        1 RAY IS BLOCKED
      REAL N
      DIMENSION VC(3),VCRH(3),UXV22(3),UMN2(3)
      CALL MIRRN(XC,YC)
      ALBLOC=10.E+10
      DMNH=SQRT(XC*XC+YC*YC)
      DO 7 I=1,3
    7 UHV2(I)=(YC*UE(I)-XC*UN(I))/DMNH
      CALL TRIAOS(N,UMN,UAXV2,UHV2,UXV22,UBEDN)
      DO 10 I=1,3
   10 UMN2(I)=UMN(I)
      IBLOC=0
      DO 200 IFV=1,NHF
      DO 20 I=1,3
      VC(I)=UE(I)*(XC-XCM)+UN(I)*(YC-YCM)+(ALEN/2.0-(FLOAT(IFV-1))
     1 *XDF)*UHV2(I)-(ALEN/2.0-(FLOAT(IFV1-1))*XDF)*UHV(I)
   20 VCRH(I)=VC(I)-RHS(I)
      AL=DOTER(VCRH,UMN2)/DOTER(US1,UMN2)
      DO 30 I=1,3
   30 RRB(I)=AL*US1(I)-VCRH(I)
      XVF=DOTER(RRB,UAXV2)
      YVF=DOTER(RRB,UXV22)
      IF(ABS(XVF).GT.WD2.OR.ABS(YVF).GT.WFV2) GO TO 200
C        THIS FACIT BLOCKED US1
      IBLOC=1
      ALBLOC=AL
      GO TO 250
  200 CONTINUE
      IFV=NHF
  250 RETURN
      END
```

```
      SUBROUTINE MIRRN(XC,YC)                                          MIRRN   2
      REAL N                                                           MIRRN   3
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2, MIRRN   4
     1     RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),          MIRRN   5
     2     UTT(3),UNNP(3),UXV2P(3)                                     MIRRN   6
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE                   MIRRN   7
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),                      MIRRN   8
     1   UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ         MIRRN   9
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,   MIRRN  10
     1       ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,     MIRRN  11
     2       DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,       MIRRN  12
     3       NLONG,ILONG,NLATC,RCO,NPACK,ENHM                          MIRRN  13
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)                MIRRN  14
                                                                       MIRRN  15
      COMMON/TILTED/TTILT,UVT(3),U1(3),U2(3),WAPMAX,WAPMIN,OFFSET      MIRRN  16
      COMMON/CAVITY/SEP,DD1,DD2,RDIF,HDIF,HCAV,HSWTC(2),RSWTC(2),      MIRRN  17
     *CILAT(2),CAVLAT(2,21),AIMHGT                                     MIRRN  18
      DIMENSION AIMP(3)                                                MIRRN  19
      COMMON/TOE/CTAZT,STAZT,CTELT,IFOCUS,STELT,UTARG(3),DTARG(3)      MIRRN  20
      REAL MN(3)                                                       MIRRN  21
      RC=.5*DCOL                                                       MIRRN  22
      YC1=YC                                                           MIRRN  23
      CALL AIMPP(XC,YC1,2,AIMP)                                        MIRRN  24
      DO 10 I=1,3                                                      MIRRN  25
      MN(I)=(TH-RC)*N(I)-XC*UE(I)-YC1*UN(I)+SEP*0.5*(N(I)-UVT(I))+     MIRRN  26
     * AIMP(I)                                                         MIRRN  27
   10 DTARG(I)=MN(I)                                                   MIRRN  28
      DNM = DOTER(MN,MN)                                               MIRRN  29
      DNM = SQRT(DNM)                                                  MIRRN  30
      DO 15 I = 1,3                                                    MIRRN  31
      UTARG(I)=MN(I)/DNM                                               MIRRN  32
   15 MN(I)=MN(I)/DNM-UR(I)                                            MIRRN  33
      XXR = DOTER(MN,MN)                                               MIRRN  34
      XXR=1./SQRT(XXR)                                                 MIRRN  35
      DO 5091 I=1,3                                                    MIRRN  36
 5091 UMN(I)=MN(I)*XXR                                                 MIRRN  37
      RETURN                                                           MIRRN  38
      END                                                              MIRRN  39
```

```
      SUBROUTINE RINDX                                                  RINDX   2
C** THIS ROUTINE FINDS THE CLOSEST HELIOSTAT TO A GIVEN POINT           RINDX   3
C XP, YP ON THE TEST PLANE.                                             RINDX   4
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)                 RINDX   5
                                                                        RINDX   6
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,    RINDX   7
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,     RINDX   8
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,       RINDX   9
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM                          RINDX  10
      COMMON /CINDEX/ XPCOL,YPCOL,COSA,COSB,SLDUM,WCELL,ICELL,JCELL,    RINDX  11
     1        XCSAV,YCSAV,XCM,YCM,ICELM,JCELM                           RINDX  12
      COMMON/MAPS/NRZF,NAZZF,NC(250,8),SRAD(250,8),NPRAD(8),DEG         RINDX  13
      XPD=XPCOL+SLDUM*COSB                                              RINDX  14
      YPD=YPCOL+SLDUM*COSA                                              RINDX  15
C   THIS ROUTINE WAS CHANGED MARCH 1975   J.M.HAMMER G.A.SMITH          RINDX  16
C   FIND MAP CELL                                                       RINDX  17
      ICELL=INT((XPD+RFIELD-TDISX)/WCELL)+1                             RINDX  18
      JCELL=INT((RFIELD-YPD-TDISY)/WCELL)+1                             RINDX  19
      IF(ICELL.LT.1 ) ICELL = 1                                         RINDX  20
      IF(JCELL.LT.1 ) JCELL = 1                                         RINDX  21
      IF(JCELL.GT.10) JCELL = 10                                        RINDX  22
      IF(ICELL.GT.10) ICELL = 10                                        RINDX  23
C   POLAR SPACED FIELD                                                  RINDX  24
C   PUT TEST POINT INTO POLAR COORDINATES                               RINDX  25
      RHIT=SQRT(XPD*XPD+YPD*YPD)                                        RINDX  26
      ANG=ATAN2(XPD,YPD)                                                RINDX  27
      IF (ANG.LT.0.0) ANG=ANG+2.*3.14159                                RINDX  28
      JZ=INT(ANG/DEG)+1                                                 RINDX  29
      IF (DEG . GT.6.) JZ=1                                             RINDX  30
      IF(RHIT.GT.RCO) GO TO 101                                         RINDX  31
      IR=1                                                              RINDX  32
      GO TO 56                                                          RINDX  33
  101 IR=INT((RHIT-RCO)/(SRAD((NPRAD(JZ)-1),JZ)-SRAD((NPRAD(JZ)-2),JZ))) RINDX  34
   10 IR=IR+1                                                           RINDX  35
      IF(IR.LT.1) IR=1                                                  RINDX  36
      IF (IR .GE. (NPRAD(JZ)-1)) IR=NPRAD(JZ)-1                         RINDX  37
      IF (IR.EQ. (NPRAD(JZ)-1)) GO TO 56                                RINDX  38
      IF(RHIT.GT.SRAD(IR+1,JZ)) GO TO 10                                RINDX  39
C   RADIAL ZONE FOUND IS IR                                             RINDX  40
   56 RZ1=(SRAD(IR+1,JZ)+SRAD(IR,JZ))/2.                                RINDX  41
C   FIND THE AZIMUTH ZONE                                               RINDX  42
      DELA=DEG/FLOAT(NC(IR,JZ))                                         RINDX  43
      IZ=INT((ANG-DEG*FLOAT(JZ-1))/DELA)+1                              RINDX  44
      AZ1=DEG*FLOAT(JZ-1)+DELA*(FLOAT(IZ)-.5)                           RINDX  45
C   THE CENTER OF THE HELIOSTAT IN ZONE IR IS                           RINDX  46
      XCSAV=RZ1*SIN(AZ1)                                                RINDX  47
      YCSAV=RZ1*COS(AZ1)                                                RINDX  48
      YCSAVP=YCSAV+TDISY                                                RINDX  49
      XCSAVP=XCSAV+TDISX                                                RINDX  50
      XMAGP=SQRT(XCSAVP*XCSAVP+YCSAVP*YCSAVP)                           RINDX  51
      IF (XMAGP .GT. RFIELD) XCSAV=10.*TH                               RINDX  52
      RETURN                                                            RINDX  53
      END                                                               RINDX  54
```

```
      SUBROUTINE CROSS(A,B,C)                                   CROSS      2
      DIMENSION A(3) ,B(3),C(3)                                 CROSS      3
      C(1) =  A(2)*B(3) - A(3)*B(2)                             CROSS      4
      C(2) = -(A(1)*B(3) - A(3)*B(1))                           CROSS      5
      C(3) =  A(1)*B(2) - A(2)*B(1)                             CROSS      6
      RETURN                                                    CROSS      7
      END                                                       CROSS      8
```

```
      SUBROUTINE MOON(ND1,IAC)                                          MOON   2
C     THIS SUBROUTINE CHECKS FOR RECEIVER HITS FOR ANY RAY WHICH        MOON   3
C     GETS CLEANLY AWAY FROM THE FIELD.  IT CHECKS FOR ENTRY INTO       MOON   4
C     THE APERTURE SUPPORT HITS AND CYLINDER HITS.  IT MAPS ALL         MOON   5
C     FLUX WHICH HITS CYLINDER WALLS OR THE ROOF.                       MOON   6
      INTEGER CILAT                                                     MOON   7
      REAL N                                                            MOON   8
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,    MOON   9
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,     MOON  10
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,       MOON  11
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM                          MOON  12
      COMMON/BABA/STH,CTH,SEO,OME,OMS,N(3),UE(3),                       MOON  13
     1   UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ          MOON  14
      COMMON/JOKER/URP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD  MOON  15
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)                 MOON  16
                                                                        MOON  17
      COMMON /STATS/TPB,TSB,PHB,TPV,PHV,AVE,TSV,PAX1V,PAX1B,PAX2V,PAX2B MOON  18
      COMMON/RANDOM/NRUN,IRANC,IJUMP,MODE,ISRAN,IRAYS                   MOON  19
     1     ,IT1,UDNI,LIMC,DINTV,YFRAC                                   MOON  20
       COMMON/CAVITY/SEP,DD1,DD2,RDIF,HDIF,HVAC,HSWTC(2),RSWTC(2),      MOON  21
     1 CILAT(2),CAVLAT(2,21),AIMHGT                                     MOON  22
      COMMON/CEILING/NAZZ,NRZ,DTAZ(21),DRZ(10),DD3,IZR,IZAZ             MOON  23
      COMMON/SUPPT/DELTM,THES,KSEG,APH,SW,NSUP,RCONE,THECON,HTOT        MOON  24
      COMMON/TILTED/TTILT,UVT(3),U1(3),U2(3),WAPMAX,WAPMIN,OFFSET       MOON  25
      COMMON/MOONMP/JWHIS,JCORB,JMISHI,JMISLO,JFRONT                    MOON  26
      DIMENSION TEMPD(3),ASUP(3),UPH(3),PV(3),UPV(3),RH(3),DD(3)        MOON  27
      DIMENSION VUP(3),DDP(3),RTH(3),UNA(3)                             MOON  28
      IF (IAC.LT.7) GO TO 333                                           MOON  29
C     CHECK FOR PROPER PIPE DIAMETER.                                   MOON  30
      DEW=2.*RCONE+(WAPMAX+WAPMIN)*0.5*SIN(THECON)                      MOON  31
      DN=2.0*(RCONE+WAPMAX*SIN(THECON)-0.5*SEP*TAN(THECON))             MOON  32
      IF(DN.GT.DEW) DEW=DN                                              MOON  33
      IF(DD3.GE.(1.01*(DEW+OFFSET))) GO TO 80                           MOON  34
      DD3=1.01*(DEW+OFFSET)                                             MOON  35
      WRITE(6,500) DD3                                                  MOON  36
  500 FORMAT(/,10X,42HINITIAL CAVITY DIAMETER TOO SMALL,RESET TO,       MOON  37
     *F10.1,3X,2HFT)                                                    MOON  38
   80 DIST=(WAPMAX+WAPMIN)*0.25*COS(THECON)+SEP*0.5                     MOON  39
      VERT=DIST*COS(TTILT)                                              MOON  40
      HTMIN=WAPMIN*COS(THECON)                                          MOON  41
      ABOT=0.0                                                          MOON  42
      RETURN                                                            MOON  43
  333 CONTINUE                                                          MOON  44
C     CHECK FOR HIT ON THE CONE.                                        MOON  45
      JWHIS=0                                                           MOON  46
      JCORB=0                                                           MOON  47
      JMISHI=0                                                          MOON  48
      JMISLO=0                                                          MOON  49
      JFRONT=0                                                          MOON  50
      CALL CONE(Z1,Z2,AL1,AL2,ANG1,ANG2,ICHIT,ZZERO)                    MOON  51
      IF(ICHIT.GT.0) GO TO 10                                           MOON  52
      ND1=10                                                            MOON  53
      JFRONT=1                                                          MOON  54
      RETURN                                                            MOON  55
C     FIND IF THE HIT IS WITHIN APERTURE BOUNDARIES.                    MOON  56
   10 IF(AL1.GT.AL2) GO TO 20                                           MOON  57
      IF(Z1.LE.ZZERO) GO TO 21                                          MOON  58
```

```
   23 ZHIT=Z1
      ZOUT=Z2
      ANG=ANG1
      ANGOUT=ANG2
      GO TO 30
   20 IF(Z2.LE.ZZERO) GO TO 22
   24 ZHIT=Z2
      ZOUT=Z1
      ANG=ANG2
      ANGOUT=ANG1
      GO TO 30
   21 IF(Z2.LE.ZZERO) GO TO 23
      ZHIT=Z2
      ANG=ANG2
      ZOUT=5000.
      GO TO 30
   22 IF(Z1.LE.ZZERO) GO TO 24
      ZHIT=Z1
      ANG=ANG1
      ZOUT=5000.0
   30 IF(ANG.GT.3.14159) ANG=2.*3.14159-ANG
      IF(ANGOUT.GT.3.14159) ANGOUT=2.*3.14159-ANGOUT
C     FIND WIDTH OF APERTURE AT THE HIT ANGLE.
      WAPE=WAPMIN
      IF(ANG.LT.2.0944) WAPE=WAPE+(WAPMAX-WAPMIN)*(1.0-ANG*0.4775)
C     FIND TOP AND BOTTOM OF SLANT DISTANCE ALONG THE APERTURE.
      ATOP=WAPE*COS(THECON)
      IF(ZHIT.GE.ABOT) GO TO 40
      ND1=11
      JMISLO=1
      RETURN
   40 IF(ZHIT.LE.ATOP) GO TO 50
      ND1=9
      JMISHI=1
      RETURN
   50 IF(ZOUT.GT.100.) GO TO 60
C     CHECK FOR A WHISTLE THROUGH
      WAP2=WAPMIN
      IF (ANGOUT.LT.2.0944) WAP2=WAP2+(WAPMAX-WAPMIN)*
     1 (1.0-ANGOUT*0.4775)
      ATOP2=WAP2*COS(THECON)
      IF(ZOUT.GT.ATOP2) GO TO 60
      ND1=14
      JWHIS=1
C   WHISTLE THROUGHS ARE NOT ACCOUNTED FOR IN MONTE
      RETURN
   60 CONTINUE
C     IF A HIT IS FOUND, CHECK FOR SUPPORT HIT.
      IF(DELTM.GE.0.) THAZS=THES*FLOAT(KSEG)-3.14159/3.0
      IF(DELTM.LT.0.) THAZS=THES*FLOAT(KSEG-1)-3.14159/3.0
      IF(THAZS.LT.0.0) THAZS=THAZS+6.283185
      CTHAZS=COS(THAZS)
      STHAZS=SIN(THAZS)
      DO 61 I=1,3
      TEMPD(I)=U2(I)*STHAZS+U1(I)*CTHAZS
      ASUP(I)=TEMPD(I)*(DD1+DD2)/4.+UVT(I)*SEP/2.
      DD(I)=D(I)+ASUP(I)
```

```
          UPH(I)=U2(I)*CTHAZS-U1(I)*STHAZS
       61 PV(I)=TEMPD(I)*(DD2-DD1)/4.+UVT(I)*SEP/2.
          PPV=SQRT(DOTER(PV,PV))
          DO 62 I=1,3
       62 UPV(I)=PV(I)/PPV
          CALL CROSS(UPH,UPV,UNA)
          CALL CHECKR(UPH,UPV,UNA,ICOD)
          AL=DOTER(DD,UNA)/DOTER(US1,UNA)
          DO 63 I=1,3
       63 RH(I)=AL*US1(I)-DD(I)
          SWP=2.*DOTER(RH,UPH)
          IF(ABS(SWP).GT.SW) GO TO 120
C         HIT SUPPORT
          ND1=12
          JCORB=1
          RETURN
      120 CONTINUE
C         THE RAY IS KNOWN TO HAVE ENTERED THRU THE UPPER APERTURE.
C         RESET THE D VECTOR TO AXIS OF THE PIPE.
          DO 90 I=1,3
       90 D(I)=D(I)+DIST*UVT(I)-OFFSET*UN(I)-VERT*N(I)
C         CHECK FOR PIPE HIT.
C         FIRST PASS CHECKS HITS ON DIFFUSER.
          IPASS=2
       33 RCYL=RSWTC(IPASS)
          CALL PIPE(Z1,Z2,AL1,AL2,ANGH1,ANGH2,RCYL,ICHIT)
          IF (ICHIT.NE.0) GO TO 777
          WRITE (6,778) XP,YP,ZHIT,ZOUT,ANG1,ANG2,ANG
      778 FORMAT (20X,2HXP,10X,2HYP,8X,4HZHIT,8X,4HZOUT,8X,4HANG1,8X,
         1 4HANG2,9X,3HANG,/,10X,7F12.3)
      777 CONTINUE
          IF(ICHIT.EQ.0) GO TO 85
          IF(IPASS.EQ.2.AND.AL1.LT.AL2) GO TO 81
C         CILAT(IAC)=NUMBER OF HEIGHT ZONE HIT
C         ILONG=NUMBER OF AZIMUTH ZONE HIT
          Z=Z1
          ANG=ANGH1
          GO TO 82
       81 Z=Z2
          ANG=ANGH2
       82 IF(Z.GT.(HSWTC(IPASS)+HTMIN)) GO TO 86
          DO 1900 I=1,NLATC
          CILAT(IPASS)=I
          IF(Z.GE.(CAVLAT(IPASS,I)+HTMIN)) GO TO 2000
     1900 CONTINUE
     2000 DELANG=2.*3.14159/FLOAT(NLONG)
          DO 1901 I=1,NLONG
          ILONG=I
          IF(ANG.GT.(FLOAT(I-1)*DELANG).AND.ANG.LE.(FLOAT(I)*DELANG))
         *GO TO 87
     1901 CONTINUE
C         IF NO HITS ARE ENCOUNTERED, ND1=3
       85 IF(IPASS.EQ.2) RETURN
       53 IPASS=2
          GO TO 33
       86 IF(IPASS.EQ.1) GO TO 53
C         HIT CAVITY CEILING, FIND ZONE.
```

```
      DO 4000 I=1,3
      VUP(I)=(HSWTC(2)+HTMIN)*N(I)
 4000 DDP(I) = D(I)+VUP(I)
      AL = DOTER(DDP,N)/DOTER(US1,N)
      DO 4005 I=1,3
 4005 RTH(I) = AL*US1(I)-D(I)-VUP(I)
      XHIT = DOTER(RTH,UE)
      YHIT = DOTER(RTH,UN)
      RHIT = SQRT(XHIT*XHIT+YHIT*YHIT)
      ANGHIT = ATAN2(XHIT,YHIT)
      IF (ANGHIT.LT.0.0) ANGHIT=ANGHIT+2.*3.14159
      IF (RHIT.GT.RSWTC(2)) WRITE(6,4010)
      TESTS = ABS(DOTER(RTH,N))
      IF (TESTS.GT.0.001) WRITE(6,4015)
 4010 FORMAT (//,5X,48HHIT VECTOR ON CAVITY CEILING IS LONGER THAN THE ,
     113HCAVITY RADIUS,/)
 4015 FORMAT (/,5X,42HHIT VECTOR ON CAVITY CEILING IS NOT NORMAL ,
     118H TO LOCAL VERTICAL,/)
      NAZZP = NAZZ+1
      DO 3000 I=1,NAZZP
 3000 IF (ANGHIT.GT.DTAZ(I).AND.ANGHIT.LT.DTAZ(I+1)) IZAZ=I
      NRZP = NRZ+1
      DO 3001 I=1,NRZP
 3001 IF (RHIT.GT.DRZ(I).AND.RHIT.LT.DRZ(I+1)) IZR=I
      IAC=3
      ND1=8
      RETURN
   87 IAC=IPASS
      ND1=5+IAC
      RETURN
      END
```

```
      SUBROUTINE PIPE(Z1,Z2,AL1,AL2,ANGHIT1,ANGHIT2,RCYL,ICHIT)
C
C THIS SUBROUTINE SOLVES FOR THE HIT POINTS (2) OF A VECTOR WITH A
C RIGHT CIRCULAR CYLINDER
C
C REQUIRED INPUTS
C        US1-UNIT VECTOR TO BE TESTED FOR HITS
C        D-VECTOR FROM SAME LOCATION IN SPACE AS US1 TO THE BASE OF THE
C CYLINDER
C        RCYL-RADIUS OF CYLINDER
C        N-UNIT VECTOR ALONG THE CYLINDER AXIS
C        UN-UNIT VECTOR UN A PLANE NORMAL TO UN
C        UE-UNIT VECTOR SUCH THAT N,UN,UE FORM AN ORTHONORMAL TRIAD SET
C
C OUTPUTS
C        Z1 AND Z2-LENGTHS ALONG CYLINDER AXIS TO THE HIT PLANES
C        AL1 AND AL2-SHORTEST AND LONGEST LENGTHS OF THE HIT VECTOR
C (US1 EXTENDED)
C        ANGHIT1 AND ANGHIT2-ANGLES FROM UN TO THE HIT POINT IN THE
C PLANE NORMAL TO N
C        ICHIT-CODE FOR HIT TEST
C              0 FOR MISSING THE CYLINDER
C              1 FOR HITTING
      DIMENSION RHC1(3),RHC2(3)
      REAL N
      COMMON/BABA/STH,CTH,SEO,OME,OMS,N(3),UE(3),
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ
      COMMON/JOKER/UPP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)

      ICHIT=0
      DUSN=DOTER(US1,N)
      DDD=DOTER(D,D)
      DDN=DOTER(D,N)
      DDUS=DOTER(D,US1)
      A=1.0/(DUSN*DUSN)-1.0
      B=2.0*DDN/(DUSN*DUSN)-2.0*DDUS/DUSN
      C=DDN*DDN/(DUSN*DUSN)-2.0*DDN*DDUS/DUSN+DDD-RCYL*RCYL
      B2=B*B
      FAC=4.0*A*C
      ARG=B2-FAC
      IF(ARG.LT.0.0) RETURN
      ICHIT=1
C HIT CYLINDER, SOLVE FOR HEIGHT
      SB2=SQRT(ARG)
      Z1=(-B-SB2)/(2.0*A)
      Z2=(-B+SB2)/(2.0*A)
C SOLVE FOR LENGHT OF HIT VECTORS
      AL1=(DDN+Z1)/DUSN
      AL2=(DDN+Z2)/DUSN
C SET UP VECTOR IN HIT PLANE NORMAL
C TO AXIS
      DO 10 I=1,3
      RHC1(I)=AL1*US1(I)-Z1*N(I)-D(I)
   10 RHC2(I)=AL2*US1(I)-Z2*N(I)-D(I)
C SOLVE FOR HIT ANGLES
      X1=DOTER(RHC1,UE)
```

```
      X2=DOTER(RHC2,UE)
      Y1=DOTER(RHC1,UN)
      Y2=DOTER(RHC2,UN)
      IF(ABS(X1).GT.0.0001) GO TO 100
      ANGHIT1=0.0
      IF(Y1.LT.0.0) ANGHIT1=3.14159
      GO TO 200
  100 ANGHIT1=ATAN2(X1,Y1)
  200 IF(ABS(X2).GT.0.0001) GO TO 300
      ANGHIT2=0.0
      IF(Y2.LT.0.0) ANGHIT2=3.14159
      GO TO 400
  300 ANGHIT2=ATAN2(X2,Y2)
  400 IF(ANGHIT1.LT.0.) ANGHIT1=ANGHIT1+2.0*3.14159
      IF(ANGHIT2.LT.0.0) ANGHIT2=ANGHIT2+2.0*3.14159
      TEST1=DOTER(RHC1,N)
      TEST2=DOTER(RHC2,N)
      IF(ABS(TEST1).GT.0.001.OR.ABS(TEST2).GT.0.001) WRITE(6,20)
   20 FORMAT(//,10X,48HHIT VECTOR FROM CENTER OF CYLINDER IS NOT NORMAL,
     1 7HTO AXIS./)
      RETURN
      END
```

```
      SUBROUTINE LIMDR(YRN,LIMC,ROERN)                              LIMDR    2
C** THIS SUBROUTINE GENERATES THE INTENSITY DISTRIBUTION OF ENERGY   LIMDR    3
C ACROSS THE SURFACE OF THE SUN.  IT HAS 3 DIFFERENT SUN MODES       LIMDR    4
C LIMC=1      FLAT SUN                                              LIMDR    5
C LIMC=2      SUN WITH LIMB DARKENING AND SOLAR RADIATION           LIMDR    6
C LIMC=3      SUN WITH LIMB DARKENING                               LIMDR    7
      GO TO (21,22,23),LIMC                                         LIMDR    8
   21 ROERN=.2665*SQRT(YRN)                                         LIMDR    9
      RETURN                                                        LIMDR   10
   22 Y=YRN*16.98                                                   LIMDR   11
      I=INT(Y/7.5) + 1                                              LIMDR   12
      GO TO (31,32,33),I                                            LIMDR   13
   31 ROERN=0.06408*(Y**.4878)                                      LIMDR   14
      RETURN                                                        LIMDR   15
   32 ROERN=0.010956*Y+0.092413                                     LIMDR   16
      RETURN                                                        LIMDR   17
   33 IF(Y.GT.16.7) GO TO 34                                        LIMDR   18
      ROERN=0.353-0.038345*(SQRT(-193.2-Y*Y+28.28*Y))               LIMDR   19
      RETURN                                                        LIMDR   20
   34 ROERN=0.3486*Y-5.5007                                         LIMDR   21
      RETURN                                                        LIMDR   22
   23 Y=YRN*15.94                                                   LIMDR   23
      IF(Y.GT.7.) GO TO 41                                          LIMDR   24
      ROERN=0.06408*(Y**.4878)                                      LIMDR   25
      RETURN                                                        LIMDR   26
   41 ROERN=.010956*Y+0.092413                                      LIMDR   27
      RETURN                                                        LIMDR   28
      END                                                           LIMDR   29
```

```
      SUBROUTINE VECTS
C** THIS ROUTINE CALCULATES THE SUNS VECTOR UR FOR A GIVEN MONTH, DAY
C AND TIME OF THE YEAR.
      REAL N
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,
     1       ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,
     2       DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,
     3       NLONG,ILONG,NLATC,RCO,NPACK,ENHM
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)

      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),
     1   UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ
      DIMENSION U(3), ITOTD(12)
      EQUIVALENCE  (U(1),UE(1))
      DATA ITOTD/0,31,59,90,120,151,181,212,243,273,304,334/
      ARG=OMS*(FLOAT(ITOTD(MON)+IDAY-1)+8.656)
C   SUBTRACT OMS*LONGITUDE/360. FROM ARG FOR LONG. CORRECTION
C  THIS WILL CHANGE THE SUNS POSITION BY NO MORE THAN 0.2 DEGREES
      ARGW = OME*(T - 12.0) + ARG +OMS*0.5 + 3.141592
C THE PHASE ANGLES IN ARGW INSURE SOLAR NOON TIME
      SW = SIN(ARGW)
      CW = COS(ARGW)
      N(1)=STH*SEQ+CTH*CEQ*CW
      N(2)=-CTH*SW
      N(3)=STH*CEQ-CTH*CW*SEQ
      UE(1)=-SW*CEQ
      UE(2)=-CW
      UE(3)=SW*SEQ
      UN(1) = (N(2)*U(3) - N(3)*U(2))
      UN(2) = -(N(1)*U(3) - U(1)*N(3))
      UN(3) = (N(1)*U(2) - U(1)*N(2))
      DO 10 I=1,3
   10 UN(I) = -UN(I)
      ARG=ARG+OMS*(T/24.)
      US(1)=-COS(ARG)
      US(2)= SIN(ARG)
      US(3)=0.
      DENOM=0.
      DO 20 I=1,3
      UR(I)=SMALR*N(I)-CAPR*US(I)
   20 DENOM=DENOM+UR(I)**2
      DO 30 I=1,3
   30  UR(I)=UR(I)/SQRT(DENOM)
      A=-DOTER(UN,UR)
      B=-DOTER(UE,UR)
      C=-DOTER(N,UR)
      DUM2=0.
      DO 1981 I=1,3
      UMNN1(I)=N(I)+C*UR(I)
 1981 DUM2=DUM2+UMNN1(I)*UMNN1(I)
      DUM2=SQRT(DUM2)
      DO 1982 I=1,3
 1982 UMNN1(I)=UMNN1(I)/DUM2
      CALL CROSS(UMNN1,UR,UMNN2)
      RETURN
      END
```

```
FUNCTION DOTER      74/74    OPT=1                  FTN 4.5+410A      03/21/77  21.51.16      PAGE    1

          FUNCTION DOTER (A,B)                                         DOTER     2
          DIMENSION A(3),B(3)                                          DOTER     3
          DOTER=0.                                                     DOTER     4
          DO 10 I=1,3                                                  DOTER     5
       10 DOTER=DOTER+A(I)*B(I)                                        DOTER     6
          RETURN                                                       DOTER     7
          END                                                          DOTER     8
```

```
SUBROUTINE CHECKR     74/74    OPT=1                FTN 4.5+410A      03/21/77  21.51.16      PAGE    1

          SUBROUTINE CHECKR (A,B,C,ICOD)                               CHECKR    2
C TEST ORTHONORMALITY OF TRIAD ABC  ICOD=0 IF OK  =1 OTHERWISE          CHECKR    3
          DIMENSION  A(3), B(3), C(3), ADB(6)                          CHECKR    4
          ADB(1)=DOTER(A,B)                                            CHECKR    5
          ADB(2)=DOTER(A,C)                                            CHECKR    6
          ADB(3)=DOTER(C,B)                                            CHECKR    7
          ADB(4)=DOTER(A,A)                                            CHECKR    8
          ADB(5)=DOTER(B,B)                                            CHECKR    9
          ADB(6)=DOTER(C,C)                                            CHECKR   10
          DO 10 I=2,6                                                  CHECKR   11
          IF(ABS(ADB(I)).GT.0.00001 .AND.I.LE.3) GO TO 20              CHECKR   12
          TEST =   ABS(ADB(I) - 1.0)                                   CHECKR   13
          IF (TEST .GT. 00001 .AND. I .GE. 4) GO TO 20                 CHECKR   14
       10 CONTINUE                                                     CHECKR   15
          ICOD=0                                                       CHECKR   16
          RETURN                                                       CHECKR   17
       20 ICOD=1                                                       CHECKR   18
          WRITE(6,21) (ADB(I),I=1,6)                                   CHECKR   19
       21 FORMAT(//, 10X  9HBAD TRIAD ,/,5X,6F10.5)                    CHECKR   20
          RETURN                                                       CHECKR   21
          END                                                          CHECKR   22
```

```
      SUBROUTINE RNORM(D1,D2)                                           RNORM        2
C *** THIS SUBROUTINE GENERATES PAIRS OF INDEPENDENT                     RNORM        3
C *** NORMAL RANDOM DEVIATES (MEAN=0,STANDARD DEVIATION=1).             RNORM        4
C *** D1 AND D2 ARE NORMALLY DISTRIBUTED ON THE                         RNORM        5
C *** INTERVAL (-INF,+INF).                                             RNORM        6
C *** IT ASSUMES A FUNCTION RANF(X) WHICH RETURNS A                     RNORM        7
C *** RANDOM NUMBER UNIFORMLY DISTRIBUTED ON (0,1).                     RNORM        8
   10 X=RANF(0.0)                                                       RNORM        9
      Y=2.0*RANF(0.0)-1.0                                               RNORM       10
      XX=X*X                                                            RNORM       11
      YY=Y*Y                                                            RNORM       12
      S=XX+YY                                                          /=RANF(0.0
RNORM 1              Y3
      IF(S-1.0) 20,20,10                                                RNORM       14
   20 XL=SQRT(-2.0*ALOG(RANF(0.0)))/S                                   RNORM       15
      D1=(XX-YY)*XL                                                     RNORM       16
      D2=2.0*X*Y*XL                                                     RNORM       17
      RETURN                                                            RNORM       18
      END                                                               RNORM       19
```



```
      SUBROUTINE MIRROR (ALPHA,R)                                       MIRROR       2
      R=0.90                                                            MIRROR       3
      RETURN                                                            MIRROR       4
      END                                                               MIRROR       5
```

```
      SUBROUTINE INTEN(MON,IDAY,BETA,DNI)                              INTEN   2
C** THIS ROUTINE CALCULATES THE DIRECT NORMAL INTENSITY FOR THE        INTEN   3
C THE GIVEN MONTH, DAY, AND TIME.                                      INTEN   4
      DIMENSION NDM( 13),A(14),B(14)   ,C(14)                          INTEN   5
      DATA NDM/31,31,28,31,30,31,30,31,31,30,31,30,31/                 INTEN   6
      DATA A/391.,390.,385.,376.,360.,350.,345.,344.,351.,365.,378.,387. INTEN   7
     1,391.,390./                                                      INTEN   8
      DATA B/.142,.142,.144,.156,.180,.196,.205,.207,.201,.177,.160,.149 INTEN   9
     1,.142,.142/                                                      INTEN  10
      DATA C/.057,.058,.060,.071,.097,.121,.134,.136,.122,.092,.073,.063 INTEN  11
     1,.057,.058/                                                      INTEN  12
      CLEAR=1.00                                                       INTEN  13
      J=MON+1                                                          INTEN  14
      DAE=FLOAT(IDAY)-21.                                              INTEN  15
      IF(IDAY.LT.21 ) GO TO 1                                          INTEN  16
      GO TO 2                                                          INTEN  17
    1 J=J-1                                                            INTEN  18
      DAE=FLOAT(IDAY+NDM(J))-21.                                       INTEN  19
    2 AINT=(A(J+1)-A(J))/(FLOAT(NDM(J)))*DAE+A(J)                      INTEN  20
      BINT=(B(J+1)-B(J))/(FLOAT(NDM(J)))*DAE+B(J)                      INTEN  21
      CINT=(C(J+1)-C(J))/(FLOAT(NDM(J)))*DAE+C(J)                      INTEN  22
C     CALCULATE DIRECT NORMAL INTENSITY                                INTEN  23
      DNI=(AINT/EXP(BINT/SIN(BETA)))*CLEAR                             INTEN  24
      RETURN                                                           INTEN  25
      END                                                              INTEN  26
```

```
      SUBROUTINE TSHAD(WBASE,WTOP,ICOD)                                 TSHAD      2
      REAL N                                                            TSHAD      3
      COMMON/DARKLE/DDTOP,DDBASE                                        TSHAD      4
       COMMON/CAVITY/SEP,DD1,DD2,RDIF,HDIF,HCAV,HSWTC(2),RSWTC(2),      TSHAD      5
     1 CILAT(2),CAVLAT(2,21),AIMHGT                                     TSHAD      6
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)                 TSHAD      7
                                                                        TSHAD      8
      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),                       TSHAD      9
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ         TSHAD     10
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,    TSHAD     11
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,     TSHAD     12
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,       TSHAD     13
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM                          TSHAD     14
C   THIS ROUTINE FINDS IF THE RAU HITS THE TOWER BASEV(3) WECTOR FORM   TSHAD     15
C    RAY UR TO THE TOWER BASE                                           TSHAD     16
C   WTOP= WIDTH OF TOWER TOP                                            TSHAD     17
C     WBASE= A WIDTH OF TOWER BOTTOM                                    TSHAD     18
C    ICOD  HIT CODE 0= MISS   1= HIT                                    TSHAD     19
      DIMENSION BASEV(3),UR1(3),RES(3)                                  TSHAD     20
      DO 5 I=1,3                                                        TSHAD     21
    5 BASEV(I)=-XP*UE(I)-YP*UN(I)                                       TSHAD     22
      WTOP=DDTOP                                                        TSHAD     23
      WBASE=DDBASE                                                      TSHAD     24
      ICOD=0                                                            TSHAD     25
C   THE TOWER CAN NO LONGER BE SHIFTED FROM THE CENTER OF THE FIELD     TSHAD     26
      TEST=-DOTER(BASEV,UR)                                             TSHAD     27
      IF (TEST.LT.0) RETURN                                             TSHAD     28
      DURUN=-DOTER(UR,UN)                                               TSHAD     29
      DURUE=-DOTER(UR,UE)                                               TSHAD     30
      DENOM=1.0/SQRT(DURUE*DURUE+DURUN*DURUN)                           TSHAD     31
C NORMAL TO THE TEST PLANE UR1                                          TSHAD     32
      DO 10 I= 1,3                                                      TSHAD     33
   10 UR1(I)=(DURUE*UE(I)+DURUN*UN(I))*DENOM                            TSHAD     34
      AL=-DOTER(BASEV,UR1)/DOTER(UR,UR1)                                TSHAD     35
      DO 20 I=1,3                                                       TSHAD     36
   20 RES(I)=-AL*UR(I)-BASEV(I)                                         TSHAD     37
C    TEST IF RES IS NORMAL TO UR1                                       TSHAD     38
      TEST=DOTER(RES,UR1)                                               TSHAD     39
      IF (ABS(TEST).GT.0.001) WRITE(6,130) TEST                         TSHAD     40
  130 FORMAT(/,10X,13H****ERROR****,5X,21HRES NOT NORMAL TO UR1,5X,5HTES TSHAD     41
     2T=,E10.3)                                                         TSHAD     42
C    PULL TEST AFTER DEBUG                                              TSHAD     43
      HX=DOTER(RES,UE)                                                  TSHAD     44
      HY=DOTER(RES,UN)                                                  TSHAD     45
      HOZ=SQRT(HX*HX+HY*HY)                                             TSHAD     46
      VERT=DOTER(RES,N)                                                 TSHAD     47
      WD=WBASE+(WTOP-WBASE)*VERT/TH                                     TSHAD     48
      WD2=WD/2.0                                                        TSHAD     49
      IF (VERT.GT.TH+SEP+HCAV) RETURN                                   TSHAD     50
      IF(VERT.GT.TH) WD2=(DD1+(DD2-DD1)*((VERT-TH)/SEP))/2.             TSHAD     51
      IF(VERT.GT.TH+SEP) WD2=RSWTC(2)                                   TSHAD     52
      IF (ABS(HOZ).LT.WD2) ICOD=1                                       TSHAD     53
      RETURN                                                            TSHAD     54
      END                                                               TSHAD     55
```

```
              SUBROUTINE WALLMP(FLUX,NAZ,NHT,HCAV)                          WALLMP    2
              COMMON/CEILING/NAZZ,NRZ,DTAZ(21),DRZ(10),DD3,IZR,IZAZ        WALLMP    3
              DIMENSION FLUX(21,36),DAZ(50),HCEL(50),IFRS(5),ISND(5)        WALLMP    4
              DIMENSION AVER(50),SFTOP(50),SFBOT(50)                        WALLMP    5
      C        BETH WILLIAMS AND J M HAMMER AUG. 16 1975                    WALLMP    6
      C     FIRST SUBSCRIPT HIGHT                                           WALLMP    7
      C      SECOND SUBSCRIPT IS AZZIMOUTH                                  WALLMP    8
      C      THIS IS THE CAVITY WALL FLUX MAP PRINTOUT ROUTINE              WALLMP    9
              I1=1                                                          WALLMP   10
              I2=NAZ                                                        WALLMP   11
              SFTOP(1)=0.0                                                  WALLMP   12
              SFBOT(1)=0.0                                                  WALLMP   13
              NAZP=NAZ+1                                                    WALLMP   14
              NHTP=NHT+1                                                    WALLMP   15
              DO 10 I=1,NAZP                                                WALLMP   16
           10 DAZ(I)=360.0*FLOAT(I-1)/FLOAT(NAZ)                            WALLMP   17
              DO 20 I=1,NHTP                                                WALLMP   18
           20 HCEL(I)=HCAV*FLOAT(I-1)/FLOAT(NHT)                            WALLMP   19
              IFRS(1)=1                                                     WALLMP   20
              ISND(1)=NAZ                                                   WALLMP   21
              NPTS=NAZ/10+1                                                 WALLMP   22
              IF (NPTS.EQ.1) GO TO 45                                       WALLMP   23
              DO 25 I=1,NPTS                                                WALLMP   24
              IFRS(I)=10*(I-1)+1                                            WALLMP   25
              ISND(I)=10*I                                                  WALLMP   26
           25 IF (ISND(I).GT.NAZ) ISND(I)=NAZ                               WALLMP   27
           45 DO 300 IPTS=1,NPTS                                            WALLMP   28
              I1=IFRS(IPTS)                                                 WALLMP   29
              I2=ISND(IPTS)                                                 WALLMP   30
              WRITE (6,50) (DAZ(I),I=I1,I2)                                 WALLMP   31
           50 FORMAT(     ///,5X,6HCAVITY,2X,4HWALL,2X,3HMAP,///,16X,4HFROM,  WALLMP   32
             1 10F10.1)                                                     WALLMP   33
              II1=I1+1                                                      WALLMP   34
              II2=I2+1                                                      WALLMP   35
              WRITE(6,55) (DAZ(I),I=II1,II2)                                WALLMP   36
           55 FORMAT (18X,2HTO,10F10.1)                                     WALLMP   37
              WRITE (6,61)                                                  WALLMP   38
           61 FORMAT (//,4X,3HTOP,/,4X,4HFROM,4X,2HTO)                      WALLMP   39
           60 FORMAT(//,4X,4HFROM,4X,2HTO,8X,8HAVE FLUX,13X,2HAT,6X,        WALLMP   40
             1 13HSUM BOTTOM UP,7X,2HAT,6X,12HSUM TOP DOWN)                 WALLMP   41
              DO 100 IHT=1,NHT                                              WALLMP   42
              M1=NHT-IHT+2                                                  WALLMP   43
              WRITE(6,75) HCEL(M1-1),HCEL(M1),(FLUX(IHT,J),J=I1,I2)         WALLMP   44
           75 FORMAT (2(2X,F6.1),4X,10F10.3)                                WALLMP   45
          100 CONTINUE                                                      WALLMP   46
              WRITE (6,62)                                                  WALLMP   47
           62 FORMAT (4X,6HBOTTOM)                                          WALLMP   48
          300 CONTINUE                                                      WALLMP   49
              WRITE(6,325)                                                  WALLMP   50
          325 FORMAT(///,10X, 15HCIRCUMFERENTIAL  ,2X, 3HAVE ,2X4HWALL      WALLMP   51
             1    ,2X,4HFLUX    )                                           WALLMP   52
              WRITE(6,60)                                                   WALLMP   53
              DO 400 I = 1,NHT                                              WALLMP   54
              AVE = 0.0                                                     WALLMP   55
              DO 350 J = 1,NAZ                                              WALLMP   56
          350 AVE = AVE + FLUX(I,J)                                         WALLMP   57
          400 AVER(I)=AVE/FLOAT(NAZ)                                        WALLMP   58
```

```
      AREA=.0929*DD3*HCEL(2)*3.14159
      DO 150 I=1,NHT
      SFBOT(I+1)=AVER(I)*AREA+SFBOT(I)
  150 SFTOP(I+1)=AVER(NHTP-I)*AREA+SFTOP(I)
      DO 450 I=1,NHT
      J=NHTP-I
  450 WRITE(6,76) HCEL(I),HCEL(I+1),AVER(I),HCEL(J+1),SFTOP(I),
     1 HCEL(I),SFBOT(I)
   76 FORMAT(2(2X,F6.1),4X,F10.3,10X,F6.1,4X,F10.3,8X,
     1 F6.1,4X,F10.3)
      WRITE(6,77) HCEL(1),SFTOP(NHTP),HCEL(NHTP),SFBOT(NHTP)
   77 FORMAT(40X,F6.1,4X,F10.3,8X,F6.1,4X,F10.3)
      RETURN
      END
```

```
      SUBROUTINE POLMAP(COUNT,CONV,NRAYS,ICOD,NDI)
C  (IANG,IRAD) ARE COORDINATES OF THE ZONE IN WHICH THE MIRROR LIES.
C THIS ROUTINE REWRITTEN 3/2/76.
C     RFIELD OUTER FIELD RADIUS IN FEET
C     RCO INNER FIELD RADIUS IN FEET
C    ALL ZONES HAVE EQUAL AREA
      DIMENSION IRRAY(10,10),ERRAY(10,10),SHRAY(10,10),
     1 BLRAY(10,10),SHHTH(10,10)
      DIMENSION FTAR(10,10),SHADP(10,10),BLP(10,10),TLOSP(10,10)
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,
     1       ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,
     2       DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,
     3       NLONG,ILONG,NLATC,RCO,NPACK,ENHM
      COMMON/MAPS/NRZF,NAZZF,NC(250,8),SRAD(250,8),NPRAD(8),DEG
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,
     1     RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),
     2     UTT(3),UNNP(3),UXV2P(3)
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE
      COMMON /CINDEX/ XPCOL,YPCOL,COSA,COSB,SLDUM,WCELL,ICELL,JCELL,
     1       XCSAV,YCSAV,XCM,YCM,ICELM,JCELM
      COMMON/MOONMP/JWHIS,JCORB,JMISHI,JMISLO,JFRONT
      DIMENSION IWHIS(10,10),ICORB(10,10),IMISHI(10,10),IMISLO(10,10),
     * IFRONT(10,10)
      IF(ICOD.GT.1) GO TO 420
C     INITIALIZE
C     SET ARRAY TO 0
      DO 410 I=1,10
      DO 410 J=1,10
      IRRAY(I,J)=0
      ERRAY(I,J)=0.
      SHRAY(I,J)=0.0
      BLRAY(I,J)=0.0
      SHHTH(I,J)=0.0
      ICORB(I,J)=0
      IWHIS(I,J)=0
      IFRONT(I,J)=0
      IMISLO(I,J)=0
      IMISHI(I,J)=0
  410 CONTINUE
  420 IF (ICOD.GT.2) GO TO 617
C     LOCATE THE POINT IN A ZONE
      IANG=ICELM
      IRAD=JCELM
C     SUM HITS AND ENERGY
      IF(NDI .EQ. 7 .OR. NDI .EQ. 8) IRRAY(IANG,IRAD)=IRRAY(IANG,IRAD)+1
      IF(NDI .EQ. 7 .OR. NDI .EQ. 8) ERRAY(IANG,IRAD)=ERRAY(IANG,IRAD)+
     1 COUNT
      SHRAY(IANG,IRAD)=SHRAY(IANG,IRAD)+COUNT*FLOAT(ICSH)
      BLRAY(IANG,IRAD)=BLRAY(IANG,IRAD)+COUNT*FLOAT(IOHIT)
      SHHTH(IANG,IRAD)=SHHTH(IANG,IRAD)+COUNT*FLOAT(ICSH2)
      ICORB(IANG,IRAD)=ICORB(IANG,IRAD)+JCORB
      IWHIS(IANG,IRAD)=IWHIS(IANG,IRAD)+JWHIS
      IFRONT(IANG,IRAD)=IFRONT(IANG,IRAD)+JFRONT
      IMISHI(IANG,IRAD)=IMISHI(IANG,IRAD)+JMISHI
      IMISLO(IANG,IRAD)=IMISLO(IANG,IRAD)+JMISLO
      IF(ICOD.LT.3) GO TO 1000
  617 FCONV=CONV/FLOAT(NRAYS)
```

```
      DO 70 I=1,10
      DO 70 J=1,10
      ERRAY(I,J)=FCONV*ERRAY(I,J)
      SHRAY(I,J)=SHRAY(I,J)*FCONV
      BLRAY(I,J)=BLRAY(I,J)*FCONV
      SHHTH(I,J)=SHHTH(I,J)*FCONV
   70 CONTINUE
C     OUTPUT HITS
      WRITE(6,205)
  205 FORMAT(///,25X,23HHITS ON THE HELIO FIELD,/)
      DO 240 I=1,10
  240 WRITE (6,248) (IRRAY(J,I),J=1,10)
  248 FORMAT (2X,10I10)
C
C OUTPUT ENERGY
      WRITE (6,39)
   39 FORMAT (///,5X,17HFLUX ON THE FIELD,/)
      DO 120 I=1,10
  120 WRITE (6,245) (ERRAY(J,I),J=1,10)
  245 FORMAT(2X,10E10.3)
      WRITE(6,246)
  246 FORMAT(/,/,/,1X,22HFLUX LOST TO SHADOWING,/)
      DO 247 I=1,10
  247 WRITE(6,298) (SHRAY(J,I),J=1,10)
  298 FORMAT(5X,10E12.5)
      WRITE(6,700)
 700  FORMAT(///,5X,43HFLUX LOST TO HELIOSTAT TO HELIOSTAT SHADING,/)
      DO 710 I=1,10
  710 WRITE (6,289) (SHHTH(J,I),J=1,10)
      WRITE(6,249)
  249 FORMAT(/,/,/,1X,21HFLUX LOST TO BLOCKAGE,/)
      DO 299 I=1,10
  299 WRITE(6,289) (BLRAY(J,I),J=1,10)
  289 FORMAT(5X,10E12.5)
      WRITE(6,550)
  550 FORMAT(///,5X,10HTOTAL FLUX,/)
      DO 560 I=1,10
      DO 560 J=1,10
      FTAR(I,J)=ERRAY(I,J)+SHRAY(I,J)+BLRAY(I,J)
      SHADP(I,J)=SHRAY(I,J)/FTAR(I,J)
      BLP(I,J)=BLRAY(I,J)/FTAR(I,J)
  560 TLOSP(I,J)=(SHRAY(I,J)+BLRAY(I,J))/FTAR(I,J)
      DO 570 I=1,10
  570 WRITE(6,289) (FTAR(J,I),J=1,10)
      WRITE(6,580)
  580 FORMAT(///,5X,28HPERCENT FLUX LOST TO SHADOWS,/)
      DO 585 I=1,10
  585 WRITE(6,289) (SHADP(J,I),J=1,10)
      WRITE(6,590)
  590 FORMAT(///,5X,29HPERCENT FLUX LOST TO BLOCKAGE,/)
      DO 595 I=1,10
  595 WRITE(6,289) (BLP(J,I),J=1,10)
      WRITE(6,599)
  599 FORMAT(///,5X,26HTOTAL PERCENT OF FLUX LOST,/)
      DO 123 I=1,10
  123 WRITE(6,289) (TLOSP(J,I),J=1,10)
      WRITE (6,310)
```

```
  310 FORMAT (///,5X,22HRAYS WHICH MISSED HIGH)                    POLMAP 116
      DO 315 I=1,10                                                POLMAP 117
  315 WRITE (6,248) (IMISHI(J,I),J=1,10)                           POLMAP 118
      WRITE (6,320)                                                POLMAP 119
  320 FORMAT (///,5X,21HRAYS WHICH MISSED LOW)                     POLMAP 120
      DO 325 I=1,10                                                POLMAP 121
  325 WRITE (6,248) (IMISLO(J,I),J=1,10)                           POLMAP 122
      WRITE (6,330)                                                POLMAP 123
  330 FORMAT (///,5X,30HRAYS WHICH MISSED ACROSS FRONT)            POLMAP 124
      DO 335 I=1,10                                                POLMAP 125
  335 WRITE (6,248) (IFRONT(J,I),J=1,10)                           POLMAP 126
      WRITE (6,340)                                                POLMAP 127
  340 FORMAT (///,5X,27HRAYS WHICH WHISTLED THROUGH)               POLMAP 128
      DO 345 I=1,10                                                POLMAP 129
  345 WRITE (6,248) (IWHIS(J,I),J=1,10)                            POLMAP 130
      WRITE (6,350)                                                POLMAP 131
  350 FORMAT (///,5X,22HRAYS WHICH HIT CORBELS)                    POLMAP 132
      DO 355 I=1,10                                                POLMAP 133
  355 WRITE (6,248) (ICORB(J,I),J=1,10)                            POLMAP 134
 1000 RETURN                                                       POLMAP 135
      END                                                          POLMAP 136
```

```
      SUBROUTINE HITFAC(NFHIT,NFBLOC,ND1,ICOD,NHF)
C     THIS ROUTINE TOTALS THE
C     NUMBER OF HITS AND BLOCKS
C     FOR AND FROM EACH HELIOSTAT
C     FACET
C     NFHIT=INDEX OF HIT FACET
C     NFBLOC=INDEX OF FACET WHICH BLOCKED THE RAY
C     ND1=EVENT CODE.  ND1=4, RAY IS BLOCKED BY FACET ON HIT
C        TURNTABLE.  ND1=5, RAY IS BLOCKED BY ADJACENT TURNTABLE.
C        ND1 .GT.5. RAY GOT AWAY CLEAN.
C     ICHIT(IF)=COUNT OF HITS ON FACET(IF).
C     ICHITM(IF)=COUNT OF HITS ON FACET (IF), NOT COUNTING BLOCKED RAYS.
C     INBLOC(I,J)=COUNT OF RAYS FROM FACET I WHICH WERE BLOCKED BY
C        FACET J ON THE SAME TURNTABLE.
C     IFBLOC(I,J)=COUNT OF RAYS FROM FACET I WHICH WERE BLOCKED BY
C        FACET J ON ADJACENT HELIOSTAT.
C     NHF=NUMBER OF HELIOSTAT FACETS.
C     ICOD=CONTROL CODE. ICOD,1,INITIALIZE. ICOD=2,INCREMENT
C     COUNTERS. ICODE=3,PRINT RESULTS.
      DIMENSION ICHIT(10),ICHITM(10),INBLOC(10,10),IFBLOC(10,10)
      GO TO (10,100,200),ICOD
   10 DO 20 I=1,10
      ICHIT(I)=0
      ICHITM(I)=0
      DO 20 J=1,10
      INBLOC(I,J)=0
   20 IFBLOC(I,J)=0
  100 IF(ND1.EQ.4) GO TO 180
      IF(ND1.EQ.5) GO TO 150
      IF(ND1.LT.4) RETURN
C     ND1 IS .GT. 5 SO INCREMENT ICHIT AND ICHITM.
      ICHIT(NFHIT)=ICHIT(NFHIT)+1
      ICHITM(NFHIT)=ICHITM(NFHIT)+1
      RETURN
  150 CONTINUE
C     ND1 IS 5 SO INCREMENT ICHIT AND IFBLOC.
      ICHIT(NFHIT)=ICHIT(NFHIT)+1
      IFBLOC(NFHIT,NFBLOC)=IFBLOC(NFHIT,NFBLOC)+1
      RETURN
  180 CONTINUE
C     ND1 IS 4 SO INCREMENT ICHIT AND INBLOC
      ICHIT(NFHIT)=ICHIT(NFHIT)+1
      INBLOC(NFHIT,NFBLOC)=INBLOC(NFHIT,NFBLOC)+1
      RETURN
  200 WRITE(6,210) (IFAC,IFAC=1,NHF)
  210 FORMAT(////,10X,7HSUMMARY,2X,2HOF,2X,3HHIT,2X,3HAND,2X,8HBLOCKAGE,
     1   2X,6HCOUNTS,2X,2HBY,2X,5HFACET,///,5X,5HFACET,5X,5HTOTAL,1X,
     2   9HHITS LESS,5X,4HHITS,2X,7HBLOCKED,2X,2HBY,/,5X,5HINDEX,6X,
     3   4HHITS,4X,6HBLOCKS,8(5X,I5))
      DO 215 IFAC=1,NHF
  215 WRITE(6,220) IFAC,ICHIT(IFAC),ICHITM(IFAC),(INBLOC(IFAC,JB),
     1   JB=1,NHF)
  220 FORMAT(11(5X,I5))
      WRITE(6,230) (IFAC,IFAC=1,NHF)
  230 FORMAT(///,5X,8HOFFBLOCK,2X,7HSUMMARY,//,5X,5HFACET,8(5X,I5))
      DO 250 IFAC=1,NHF
  250 WRITE(6,260) IFAC,(IFBLOC(IFAC,JB),JB=1,NHF)
```

```
          260  FORMAT(10(5X,I5))                                          HITFAC      59
               RETURN                                                     HITFAC      60
               END                                                        HITFAC      61
```

```
CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

   21       I                AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
```

```
      SUBROUTINE ROOF(ICOD,CONV)
      COMMON/CEILING/NAZZ,NRZ,DTAZ(21),DRZ(10),DD3,IZR,IZAZ
      COMMON/JOKER/URP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD
      DIMENSION TOPMAP(21,10), DRZAV(10)
C     DD3  DAMETER OF IN FEET
C     TOPMAP(I,J)  FLUX MAP
C     IZAZ  INDEX OF AZIMOUTH ZONE
C     IZR  INDEX OF RADIAL ZONE
C     AZIMOUTH ZONE INDEX FIRST
C     ALL ZONES HAVE EQUAL AREA
C     DTAZ(I)  ZONE BOUNDARY VECTOR(AZZ)
C     DRZ(I)  ZONE BOUNDARY VECTOR(RADIAL)
C     NAZZ  NUMBER OF AZIMOUTH ZONES
C     NRZ  NUMBER OF RADIAL ZONES
C     IAC  CODE FOR HIT . IT MUST BE 3
      GO TO (5,50,100),ICOD
    5 DELTA = 2.0*3.14159/FLOAT(NAZZ)
      NAZZP1 = NAZZ+1
      NRZP1 = NRZ+1
C
      DO 10 I = 1,NAZZP1
   10 DTAZ(I) = DELTA*FLOAT(I-1)
C     INITIALIZE
      NZONS = NAZZ*NRZ
      AZONE = 0.25*(DD3**2)/FLOAT(NRZ)
      DRZ(1) = 0.0
C     NOTE AZONE NEEDS A PI ABOVE
      DO 20 I = 2,NRZP1
      DRZAV(I-1) = SQRT( 0.50*AZONE + DRZ(I-1)**2)
   20 DRZ(I) = SQRT(AZONE+DRZ(I-1)**2)
      AZONE = 3.14159*AZONE*0.0929/FLOAT(NAZZ)
C     AZONE NOW HAS ITS PI VALUE IN M**2
      DO 30 I = 1,NAZZ
      DO 30 J = 1,NRZ
   30 TOPMAP(I,J) = 0.0
      RETURN
   50 CONTINUE
C     INCREMENT MAP CELL
      TOPMAP(IZAZ,IZR) = TOPMAP(IZAZ,IZR)+COUNT
      RETURN
  100 CONTINUE
C     CONVERT TO UNITS AND PRINT OUT
      DO 110 I=1,NAZZ
      DO 110 J=1,NRZ
  110 TOPMAP(I,J) = TOPMAP(I,J)*CONV/AZONE
      NRZM1 = NRZ
      WRITE(6,120) (DRZ(I),I=1,NRZM1)
  120 FORMAT (///,5X,6HCAVITY,2X,7HCEILING,2X,3HMAP,///,21X,4HFROM,10F10
     1.2)
      WRITE(6,121) (DRZ(I),I=2,NRZP1)
  121 FORMAT (23X,2HTO,10F10.2)
      WRITE(6,122) (DRZAV(I), I = 1,NRZ)
  122 FORMAT(22X, 3HAVE, 10F10.2)
      WRITE (6,125)
  125 FORMAT (//,4X,4HFROM,4X,2HTO,6X,3HAVE)
      DO 200 IAZ = 1,NAZZ
      AFROM = DTAZ(IAZ)*57.296
```

```
      ATO = DTAZ(IAZ+1)*57.296
      AVE = (AFROM+ATO)/2.0
      WRITE(6,130) AFROM,ATO,AVE,(TOPMAP(IAZ,I),I=1,NRZ)
  130 FORMAT (3(2X,F6.1),1X,10F10.4)
  200 CONTINUE
      WRITE(6,210)
  210 FORMAT(///,10X, 9HAZZIMOUTH , 2X, 3HAVE, 2X, 7HCEILING ,2X,4HFLUX)
      WRITE(6,125)
      DO 300  I=1,NRZ
      AVE = 0.0
      DO 250 IAZ = 1,NAZZ
  250 AVE = AVE + TOPMAP(IAZ,I)
      AVE = AVE/FLOAT(NAZZ)
  300 WRITE(6,130) DRZ(I), DRZ(I+1), DRZAV(I), AVE
      RETURN
      END
```

```
      SUBROUTINE TMAP(XC,YC,MON,COUNT,NRAYS,CONV,ICOD)
C     THIS ROUTINE MAPS THE YEARLY PERFORMANCE OF VARIOUS SEGMENTS OF TH
C     FIELD AROUND THE YEAR
      DIMENSION IARY(11,16),EARY(11,16)
      IF (ICOD.GT.1) GO TO 50
      DO 100 I=1,11
      DO 100 J=1,16
      IARY(I,J)=0
  100 EARY(I,J)=0.0
      GO TO 1000
   50 THETAZ=ATAN2(XC,YC)*57.3
      IF(ICOD.GT.2) GO TO 66
      IF (THETAZ.LT.0.0) THETAZ=THETAZ+360.
C     TEST THETAZ FOR WHICH QUADRANTS
      IQUAD=INT(THETAZ/90.0)+1
      IF (THETAZ.GE.315..OR.THETAZ.LT.45.) IQUAD2=7
      IF (THETAZ.GE.45..AND.THETAZ.LT.135.) IQUAD2=10
      IF (THETAZ.GE.135..AND.THETAZ.LT.225.) IQUAD2=9
      IF (THETAZ.GE.225..AND.THETAZ.LT.315.) IQUAD2=8
      IARY(IQUAD,MON)=IARY(IQUAD,MON)+1
      IARY(IQUAD2,MON)=IARY(IQUAD2,MON)+1
      EARY(IQUAD,MON)=EARY(IQUAD,MON)+COUNT
      EARY(IQUAD2,MON)=EARY(IQUAD2,MON)+COUNT
      DO 120 J=1,12
      IARY(5,J)=IARY(1,J)+IARY(2,J)
      IARY( 6,J)=IARY(4,J)+IARY(3,J)
      IARY(11,J)=IARY(10,J)+IARY(8,J)
      EARY(5,J)=EARY(1,J)+EARY(4,J)
      EARY( 6,J)=EARY(2,J)+EARY(3,J)
      EARY(11,J)=EARY(10,J)+EARY(8,J)
  120 CONTINUE
      DO 130 I=1,11
      IARY(I,13)=IARY(I,1)+IARY(I,2)+IARY(I,11)+IARY(I,12)
      EARY(I,13)=EARY(I,1)+EARY(I,2)+EARY(I,11)+EARY(I,12)
      IARY(I,14)=IARY(I,5)+IARY(I,6)+IARY(I,7)+IARY(I,8)
      EARY(I,14)=EARY(I,5)+EARY(I,6)+EARY(I,7)+EARY(I,8)
      IARY(I,15)=IARY(I,3)+IARY(I,4)+IARY(I,9)+IARY(I,10)
      EARY(I,15)=EARY(I,3)+EARY(I,4)+EARY(I,9)+EARY(I,10)
  130 CONTINUE
   66 IF (ICOD.LT.3) GO TO 1000
      DCONV=CONV/FLOAT(NRAYS)*0.001
      DO 150 I=1,11
      DO 150 J=1,15
      EARY(I,J)=DCONV*EARY(I,J)
  150 CONTINUE
      DO 160 I=1,11
      DO 160 J=13,15
  160 EARY(I,16) = EARY(I,16) + EARY(I,J)
      WRITE (6,200)
  200 FORMAT (1H1,////,25X,36HHITS IN EAST NORTH DIVIDED QUADRANTS,///,
     1 3X,5HMONTH,7X,3HE/N,6X,4H-E/N,5X,5H-E/-N,
     2 6X,4HE/-N,4X,7HN FIELD,3X,7HS FIELD)
      DO 300 J=1,15
  300 WRITE (6,250) J,(IARY(I,J),I=1,6)
  250 FORMAT (   5X,I2,6(5X,I5))
      WRITE (6,220)
  220 FORMAT (    ///,25X,28HHITS IN NORTHEAST NORTHWEST
```

```
     1 17HDIVIDED QUADRANTS,///,3X,5HMONTH,5X,                          TMAP     59
     2 5HNE/NW,5X,6H-NE/NW,5X,                                          TMAP     60
     3 7H-NE/-NW,4X,6HNE/-NW,2X,                                        TMAP     61
     4 13H-NE/NW+NE/-NW)                                                TMAP     62
      DO 310 J=1,15                                                     TMAP     63
  310 WRITE (6,250) J,(IARY(I,J),I=7,11)                                TMAP     64
      WRITE (6,270)                                                     TMAP     65
      WRITE (6,230)                                                     TMAP     66
  230 FORMAT (1H1,////,24X,38HENERGY IN EAST NORTH DIVIDED QUADRANTS,   TMAP     67
     1 ///,3X,5HMONTH,6X,                                               TMAP     68
     2 3HNE ,10X,4H SE ,9X,5H SW  ,                                     TMAP     69
     3 10X,4H NW ,8X,7HN FIELD,7X,7HS FIELD)                            TMAP     70
      DO 320 J=1,16                                                     TMAP     71
  320 WRITE (6,210) J,(EARY(I,J),I=1,6)                                 TMAP     72
  210 FORMAT (   5X,I2,6(5X,E9.3))                                      TMAP     73
      WRITE (6,240)                                                     TMAP     74
  240 FORMAT (    ////,24X,20HENERGY IN NORTHEAST                       TMAP     75
     1 27HNORTHWEST DIVIDED QUADRANTS,///,3X,5HMONTH,6X,                TMAP     76
     2 5HNORTH,8X,6H WEST ,8X,                                          TMAP     77
     3 7H SOUTH ,7X,6H EAST ,5X,                                        TMAP     78
     4 13H EAST + WEST )                                                TMAP     79
      DO 330 J=1,16                                                     TMAP     80
  330 WRITE (6,210) J,(EARY(I,J),I=7,11)                                TMAP     81
      WRITE (6,270)                                                     TMAP     82
  270 FORMAT (///,25X,23H13 IS THE WINTER MONTHS,//,25X,10H14 IS THE    TMAP     83
     1 13HSUMMER MONTHS,//,25X,32H15 IS THE SPRING AND FALL MONTHS,     TMAP     84
     1  //,25X,29H16 IS THE TOTAL YEARLY ENERGY)                        TMAP     85
 1000 RETURN                                                            TMAP     86
      END                                                               TMAP     87
```

```
      SUBROUTINE CONE(Z1,Z2,AL1,AL2,ANGHIT1,ANGHIT2,ICHIT,ZZERO)
C
C THIS SUBROUTINE SOLVES FOR THE HIT POINTS (2) OF A VECTOR WITH A
C  INVERTED CONE
C
C REQUIRED INPUTS
C      US1-UNIT VECTOR TO BE TESTED FOR HITS
C      D-VECTOR FROM SAME LOCATION IN SPACE AS US1 TO THE BASE OF THE
C
C   RCONE-RADIUS OF THE CONE HALFWAY TO THE POINT
C     HTOT-HEIGHT OF THE CONE
C     THECON=CONE ANGLE
C    N-UNIT VECTOR ALONG THE CONE AXIS
C      UN-UNIT VECTOR UN A PLANE NORMAL TO UN
C      UE-UNIT VECTOR SUCH THAT N,UN,UE FORM AN ORTHONORMAL TRIAD SET
C
C OUTPUTS
C   Z1 ANDZ2-LENGTHS ALONG CONE AXIS TO THE HIT PLANES
C      AL1 AND AL2-SHORTEST AND LONGEST LENGTHS OF THE HIT VECTOR
C (US1 EXTENDED)
C      ANGHIT1 AND ANGHIT2-ANGLES FROM UN TO THE HIT POINT IN THE
C PLANE NORMAL TO N
C      ICHIT-CODE FOR HIT TEST
C           0 FOR MISSING THE CONE
C            1 FOR HITTING
      DIMENSION RHC1(3),RHC2(3)
      REAL N
      COMMON/JOKER/URP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)

      COMMON/BABA/STH,CTH,SEQ,OME,OMS,N(3),UE(3),
     1    UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEQ
      COMMON/SUPPT/DELTM,THES,KSEG,APH,SW,NSUP,RCONE,THECON,HTOT
      COMMON/TILTED/TTILT,UVT(3),U1(3),U2(3),WAPMAX,WAPMIN,OFFSET
      ICHIT=0
      TTCON=TAN(THECON)
      DUSUV=DOTER(US1,UVT)
      DUVD=DOTER(UVT,D)
      DUSD=DOTER(US1,D)
      A1=1.
      ZZERO=HTOT/2.0-RCONE/TTCON
      FIX=DUSUV*DUSUV
      A2=TTCON*TTCON*FIX
      A=A1-A2-FIX
      B1=2.*DUVD
      B2=2.*DUSD*DUSUV
      B3=2.0*ZZERO*TTCON*FIX*TTCON
      B=B1-B2+B3
      C1=DUVD*DUVD
      C2=2.*DUVD*DUSD*DUSUV
      C3=DOTER(D,D)*FIX
      C4=ZZERO*ZZERO*A2
      C=C1-C2+C3-C4
      RAD=B*B/(4.*A*A)-C/A
      IF(RAD.LT.0.)  RETURN
      ICHIT=1
      IF (ABS(A).GT.0.0001) GO TO 44
```

```
      Z1=ZZERO                                                          CONE    59
      Z2=10000.                                                         CONE    60
      GO TO 46                                                          CONE    61
   44 Z1=-B/(2.0*A)+SQRT(RAD)                                           CONE    62
      Z2=-B/(2.0*A)-SQRT(RAD)                                           CONE    63
C SOLVE FOR LENGHT OF HIT VECTORS                                        CONE    64
   46 AL1=(Z1+DUVD)/DUSUV                                               CONE    65
      AL2=(Z2+DUVD)/DUSUV                                               CONE    66
      DO 10 I=1,3                                                       CONE    67
      RHC1(I)=AL1*US1(I)-D(I)-Z1*UVT(I)                                 CONE    68
   10 RHC2(I)=AL2*US1(I)-D(I)-Z2*UVT(I)                                 CONE    69
C SOLVE FOR HIT ANGLES                                                  CONE    70
      X1=DOTER(RHC1,UE)                                                 CONE    71
      X2=DOTER(RHC2,UE)                                                 CONE    72
      Y1=DOTER(RHC1,U1)                                                 CONE    73
      Y2=DOTER(RHC2,U1)                                                 CONE    74
      IF(ABS(X1).GT.0.0001) GO TO 100                                   CONE    75
      ANGHIT1=0.0                                                       CONE    76
      IF(Y1.LT.0.0) ANGHIT1=3.14159                                     CONE    77
      GO TO 200                                                         CONE    78
  100 ANGHIT1=ATAN2(X1,Y1)                                              CONE    79
  200 IF(ABS(X2).GT.0.0001) GO TO 300                                   CONE    80
      ANGHIT2=0.0                                                       CONE    81
      IF(Y2.LT.0.0) ANGHIT2=3.14159                                     CONE    82
      GO TO 400                                                         CONE    83
  300 ANGHIT2=ATAN2(X2,Y2)                                              CONE    84
  400 IF(ANGHIT1.LT.0.) ANGHIT1=ANGHIT1+2.0*3.14159                     CONE    85
      IF(ANGHIT2.LT.0.0) ANGHIT2=ANGHIT2+2.0*3.14159                    CONE    86
      TEST1=DOTER(RHC1,UVT)                                             CONE    87
      TEST2=DOTER(RHC2,UVT)                                             CONE    88
      IF(ABS(TEST1).GT.0.001.OR.ABS(TEST2).GT.0.001) WRITE(6,20)        CONE    89
   20 FORMAT(//,10X,48HHIT VECTOR FROM CENTER OF CYLINDER IS NOT NORMAL, CONE    90
     1 7HTO AXIS,/)                                                     CONE    91
      RETURN                                                            CONE    92
      END                                                               CONE    93
```

```
      SUBROUTINE POLSP2(ACOL,NNU,SPACEF,NTOTAL,GCOVER)                   POLSP2   2
C     THIS ROUTINE INITIALIZES THE PARAMETERS REQUIRED FOR               POLSP2   3
C     NON-UNIFORM POLAR PACKING.                                          POLSP2   4
      DIMENSION AAZ(4),GRC(250,8)                                         POLSP2   5
      COMMON /JEFF/ UMNS(3),PRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,      POLSP2   6
     1         ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,      POLSP2   7
     2         DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,        POLSP2   8
     3         NLONG,ILONG,NLATC,RCO,NPACK,ENHM                           POLSP2   9
      COMMON/STRUCT/GAP,WLONG,WSIDE,WTRI,XLTRI,BBD1,BBD2,WCROSS,          POLSP2  10
     1 WDUM,IFRAM,HTMIR,HTCROS,WJCROS                                     POLSP2  11
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,    POLSP2  12
     1RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),                  POLSP2  13
     2UTT(3),UNNP(3),UXV2P(3)                                             POLSP2  14
     3,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE                       POLSP2  15
      COMMON/MAPS/NRZF,NAZZF,NC(250,8),SRAD(250,8),NPRAD(8),DEG           POLSP2  16
      DO 5 I=1,8                                                          POLSP2  17
    5 NPRAD(I)=0                                                          POLSP2  18
      NTOTAL=0                                                            POLSP2  19
      PDA=SPACEF*(XDF-WFV)                                                POLSP2  20
      CL2=((NHF-1)*XDF+WFV)/2.                                            POLSP2  21
      CLT=2.*CL2+PDA                                                      POLSP2  22
      CWTH=WD+GAP+2.*WLONG                                                POLSP2  23
      A1=NHF*WFV*WD/CLT                                                   POLSP2  24
      AAZ(1)=0.0                                                          POLSP2  25
      JMAX=NNU                                                            POLSP2  26
      IF(NNU.LT.8) GO TO 70                                               POLSP2  27
      JMAX=4                                                              POLSP2  28
      DO 10 I=1,4                                                         POLSP2  29
   10 AAZ(I)=3.14159/4.*(FLOAT(I)-1.)                                     POLSP2  30
   70 DEG=2.*3.14159/FLOAT(NNU)                                           POLSP2  31
      DO 200 J=1,JMAX                                                     POLSP2  32
      SRAD(1,J)=RCO                                                       POLSP2  33
      I=0                                                                 POLSP2  34
   25 I=I+1                                                               POLSP2  35
C   AZIMUTH SPACING GROUND COVER WAS CHANGED BY GA SMITH 9/8/76           POLSP2  36
      A3=0.078*0.5/TH                                                     POLSP2  37
      A2=0.425+0.012*AAZ(J)                                               POLSP2  38
      IF((SRAD(I,J)/TH).LE.3.4) GO TO 50                                  POLSP2  39
      GCOV=0.12                                                           POLSP2  40
      DR=A1/GCOV                                                          POLSP2  41
      SRAD(I+1,J)=SRAD(I,J)+DR                                            POLSP2  42
      GO TO 110                                                           POLSP2  43
   50 A4=A2-2.*SRAD(I,J)*A3                                               POLSP2  44
      B1=-A4/A3                                                           POLSP2  45
      C1=A1/A3                                                            POLSP2  46
      ARG1=B1*B1-4.*C1                                                    POLSP2  47
      IF(ARG1.LE.0.0) GO TO 53                                            POLSP2  48
      DR=-B1*0.5-SQRT(ARG1)/2.                                            POLSP2  49
   53 IF(NPACK.EQ.4) DR=A1/GCOVER                                         POLSP2  50
      BR=1.3334*(SRAD(I,J)-CWTH*0.5)                                      POLSP2  51
      CR=1.3334*(SRAD(I,J)*CWTH+CWTH*CWTH*0.25+CL2*CL2)                   POLSP2  52
      DRPR=-BR*0.5+SQRT(BR*BR+4.*CR)*0.5                                  POLSP2  53
      IF(DR.LT.DRPR) DR=DRPR                                              POLSP2  54
      SRAD(I+1,J)=SRAD(I,J)+DR                                            POLSP2  55
      GCOV=A2-A3*(SRAD(I,J)+SRAD(I+1,J))                                  POLSP2  56
      IF(NPACK.EQ.4) GCOV=GCOVER                                          POLSP2  57
C   DR,SRAD(I+1), AND GCOV ARE SET                                        POLSP2  58
```

```
  110 RNC=DEG*GCOV*(SRAD(I+1,J)*SRAD(I+1,J)-SRAD(I,J)*SRAD(I,J))/
     *(2.*ACOL)
      NC(I,J)=INT(RNC+0.5)
C     CHECK FOR HELIOSTAT WITHIN ZONE BOUNDARIES
      IF(NC(I,J).LT.1) GO TO 64
      RTLE=(SRAD(I+1,J)+SRAD(I,J))/2.-CWTH*0.5
      THE2=ATAN2(CL2,RTLE)
   59 IF(THE2.LE.(DEG/FLOAT(2*NC(I,J)))) GO TO 62
      NC(I,J)=NC(I,J)-1
      GO TO 59
   62 IF(NPRAD(J).NE.0) GO TO 64
      NSC=NC(I,J)
      DO 63 IC=1,NSC
      THEI=DEG*((FLOAT(IC)-0.5)/NC(I,J)+FLOAT(J-1))
      XI=(RTLE+CWTH*0.5)*SIN(THEI)
      YIP=(RTLE+CWTH*0.5)*COS(THEI)+TDISY
      DIST=SQRT(XI*XI+YIP*YIP)
      IF(DIST.LE.RFIELD) NTOTAL=NTOTAL+2
   63 CONTINUE
   64 CONTINUE
      DELRAD=SRAD(I+1,J)-SRAD(I,J)
C     RESOLVE FOR GROUND COVER IN THIS ZONE
      GRC(I,J)=2.*ACOL*FLOAT(NC(I,J))/(DEG*(SRAD(I+1,J)*SRAD(I+1,J)
     *-SRAD(I,J)*SRAD(I,J)))
      RTLE=RTLE+CWTH
      DTOE=SQRT(RTLE*RTLE+CL2*CL2)
      IF(DTOE.GT.SRAD(I+1,J)) WRITE(6,90)
      IF (DTOE.GT.SRAD(I+1,J)) SRAD(I+1,J)=DTOE
   90 FORMAT(10X,24HRADIAL SPACING TOO SMALL)
      IF (SRAD(I+1,J) .GT. (RFIELD+ABS(TDISY)-DELRAD*0.5)) GO TO 6071
      GO TO 25
 6071 IF(NPRAD(J).GT.0) GO TO 201
      NPRAD(J)=I+1
  201 IF(I.GT.(NPRAD(J)+1)) GO TO 200
      GO TO 25
  200 CONTINUE
C     SET WEST FIELD RADII AND COLLECTOR COUNT PARAMETERS
      DO 1100 J1=1,JMAX
      J2=9-J1
      NLIM=NPRAD(J1)+2
      NPRAD(J2)=NPRAD(J1)
      DO 1100 I1=1,NLIM
      SRAD(I1,J2)=SRAD(I1,J1)
 1100 NC(I1,J2)=NC(I1,J1)
      JLIM=2*JMAX
      DO 1110 J1=1,JLIM
      NEND=NPRAD(J1)
      WRITE(6,1120) J1
 1120 FORMAT(//,10X,27HPOLAR RADII IN AZIMUTH ZONE,I5,/)
      WRITE(6,1130) ((I,SRAD(I,J1)),I=1,NEND)
 1130 FORMAT(8(1X,2HR(,I3,2H)=,F6.1,1X))
      WRITE(6,1140) J1
 1140 FORMAT(//,10X,37HPOLAR COLLECTOR COUNT IN AZIMUTH ZONE,I5,/)
      WRITE(6,1150) ((I,NC(I,J1)),I=1,NEND)
 1110 CONTINUE
 1150 FORMAT(8(1X,2HN(,I3,2H)=,I5,1X))
      DO 1210 J1=1,JMAX
```

```
                  NEND=NPRAD(J1)                                       POLSP2     116
                  WRITE(6,1220) J1                                     POLSP2     117
             1220 FORMAT(//,10X,26HGROUND COVER IN POLAR ZONE,I5,/)    POLSP2     118
                  WRITE(6,1240) ((I,GRC(I,J1)),I=1,NEND)               POLSP2     119
             1210 CONTINUE                                             POLSP2     120
             1240 FORMAT(7(1X,3HGC(,I3,2H)=,F5.3,1X))                  POLSP2     121
                  IF(NNU.EQ.1) NTOTAL=NTOTAL/2                         POLSP2     122
                  RETURN                                               POLSP2     123
                  END                                                  POLSP2     124
```

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```
      SUBROUTINE FRAME(VS1,VS2,VS3,VS4,VS5,VS6,VS7,ALFRAM,JK,M,ALENG)    FRAME       2
      COMMON/PLANE/IPLAN(7)                                              FRAME       3
      COMMON/BEDTST/ALBLOC,ICOD,UHV2(3),UAXV2(3)                         FRAME       4
      COMMON /JEFF/ UMNS(3),RRS(3),NSTOPS,A,B,C,SMAX,RFIELD,TH,ICMH,     FRAME       5
     1        ICSH,IFC,IHIT,ICSH2,NCOL,IHOUR,MIN,ELZ,T,TDISX,TDISY,      FRAME       6
     2        DUMA,DUMB,DUMC,UMNN1(3),UMNN2(3),UMN(3),IOHIT,NLAT,        FRAME       7
     3        NLONG,ILONG,NLATC,RCO,NPACK,ENHM                           FRAME       8
      COMMON/TABLE/UHV(3),UAXV(3),UXV2(3),RST(3),WFV,NHF,XDF,WD2,WFV2,   FRAME       9
     1     RHS(3),DELX,DELY,WD,IFV,RRB(3),UAXVP(3),UXV2PP(3),            FRAME      10
     2     UTT(3),UNNP(3),UXV2P(3)                                       FRAME      11
     3 ,UMNP(3),UMNPP(3),F,ALEN,UBEDN(3),IFOC,IDRIVE                     FRAME      12
      COMMON/BABA/STH,CTH,SEO,OME,OMS,N(3),UE(3),                        FRAME      13
     1   UN(3),US(3),UA(3),UR(3),THETA,MON,IDAY,SMALR,CAPR,CEO           FRAME      14
      COMMON /CINDEX/ XPCOL,YPCOL,COSA,COSB,SLDUM,WCELL,ICELL,JCELL,     FRAME      15
     1        XCSAV,YCSAV,XCM,YCM,ICELM,JCELM                            FRAME      16
      COMMON /BALL/ DCOL,SCDELT(3),XP,YP,PAX1,PAX2,D(3)                  FRAME      17
                                                                         FRAME      18
      COMMON/JOKER/URP(3),US1(3),THSL,PH,THSR,THSU,COUNT,WAVL(20),DRAD   FRAME      19
      COMMON/TILTED/TTILT,UVT(3),U1(3),U2(3),WAPMAX,WAPMIN,OFFSET        FRAME      20
      COMMON/STRUCT/GAP,WLONG,WSIDE,WTRI,XLTRI,B1,B2,WCROSS,WDUM,IFRAM   FRAME      21
     *,HTMIR,HTCROS,WJCROS                                               FRAME      22
      DIMENSION URDUM(3),UHVDUM(3),UAXVDUM(3)                            FRAME      23
      DIMENSION VS1(3),VS2(3),VS3(3),VS4(3),VS5(3),VS6(3),VS7(3),        FRAME      24
     *RHIT1(3),RHIT2(3),RHIT3(3),RHIT4(3),RHIT5(3),RHIT6(3),RHIT7(3)     FRAME      25
      REAL L,N                                                           FRAME      26
      L=0.0                                                              FRAME      27
      AL1=10.E+10                                                        FRAME      28
      AL2=10.E+10                                                        FRAME      29
      AL3=10.E+10                                                        FRAME      30
      AL4=10.E+10                                                        FRAME      31
      AL5=10.E+10                                                        FRAME      32
      AL6=10.E+10                                                        FRAME      33
      AL7=10.E+10                                                        FRAME      34
      GO TO (10,10,20,30),ICOD                                           FRAME      35
   10 DO 11 I=1,3                                                        FRAME      36
      URDUM(I)=UR(I)                                                     FRAME      37
      UHVDUM(I)=UHV(I)                                                   FRAME      38
   11 UAXVDUM(I)=UAXV(I)                                                 FRAME      39
      GO TO 1200                                                         FRAME      40
   20 DO 21 I=1,3                                                        FRAME      41
      URDUM(I)=US1(I)                                                    FRAME      42
      UHVDUM(I)=UHV(I)                                                   FRAME      43
   21 UAXVDUM(I)=UAXV(I)                                                 FRAME      44
      GO TO 1200                                                         FRAME      45
   30 DO 31 I=1,3                                                        FRAME      46
      URDUM(I)=US1(I)                                                    FRAME      47
      UHVDUM(I)=UHV2(I)                                                  FRAME      48
   31 UAXVDUM(I)=UAXV2(I)                                                FRAME      49
 1200 AL1=DOTER(VS1,UBEDN)/DOTER(URDUM,UBEDN)                            FRAME      50
C   TOP FRAME HIT TEST                                                   FRAME      51
      IF(AL1.LT.0.0) GO TO 50                                            FRAME      52
      DO 101 I=1,3                                                       FRAME      53
  101 RHIT1(I)=AL1*URDUM(I)-VS1(I)                                       FRAME      54
      XHIT=ABS(DOTER(UHVDUM,RHIT1))                                      FRAME      55
      YHIT=ABS(DOTER(UAXVDUM,RHIT1))                                     FRAME      56
C   CHECK FOR HIT IN BED BOUNDARIES                                      FRAME      57
      IF(XHIT.GT.(ALEN*0.5)) GO TO 50                                    FRAME      58
```

```
      IF (YHIT.GT.(WDUM+WLONG*0.5)) GO TO 50
C   FOLLOWING CHECKS FOR HITS - TRUE IS HIT
      IF (YHIT.GT.(WDUM-WLONG*0.5))GO TO 40
      IF(XHIT.GT.(XDF-WCROSS*0.5).AND.XHIT.LT.(XDF+WCROSS*0.5)) GO TO 40
      IF (XHIT.LT.(WJCROS*0.5))GO TO 40
C   CHECK FOR TRIANGLE HIT
      IF (XHIT.GT.(WCROSS*0.5+XLTRI*0.70711)) XHIT=ABS(XHIT-XDF)
      IF(YHIT.LT.(XHIT+B2).AND.YHIT.GT.(XHIT+B1)) GO TO 40
      GO TO 50
C******  HIT TOP FRAME
   40 IFRAM=1
      IF(JK.NE.M) IFRAM=2
      GO TO 51
C******  CHECK FRAME SIDES
   50 AL1=10.E+10
   51 CONTINUE
      AL2=DOTER(UAXVDUM,VS2)/DOTER(URDUM,UAXVDUM)
      IF(AL2.LT.0.0) GO TO 108
      DO 102 I=1,3
  102 RHIT2(I)=-VS2(I) + AL2*URDUM(I)
      YHIT=ABS(DOTER(RHIT2,UBEDN))
      XHIT=ABS(DOTER(RHIT2,UHVDUM))
      IF(XHIT.GT.(ALEN/2.)) GO TO 108
      IF(YHIT.GT.(WSIDE/2.)) GO TO 108
C****** NO.2 IS HIT
      IFRAM=1
      IF(JK.NE.M) IFRAM=2
      GO TO 109
  108 AL2=10.E+10
  109 CONTINUE
      AL3=DOTER(UAXVDUM,VS3)/DOTER(URDUM,UAXVDUM)
      IF(AL3.LT.0.0) GO TO 500
      DO 103 I=1,3
  103 RHIT3(I)=-VS3(I) + AL3*URDUM(I)
      YHIT=ABS(DOTER(RHIT3,UBEDN))
      XHIT=ABS(DOTER(RHIT3,UHVDUM))
      IF(XHIT.GT.(ALEN/2.)) GO TO 500
      IF(YHIT.GT.(WSIDE/2.)) GO TO 500
C****** NO.3 IS HIT
      IFRAM=1
      IF(JK.NE.M) IFRAM=2
      GO TO 510
  500 AL3=10.E+10
  510 CONTINUE
      AL4=DOTER(UHVDUM,VS4)/DOTER(URDUM,UHVDUM)
      IF(AL4.LT.0.0)GO TO 530
      DO 520 I=1,3
  520 RHIT4(I)=-VS4(I) + AL4*URDUM(I)
      XHIT=ABS(DOTER(RHIT4,UAXVDUM))
      YHIT=ABS(DOTER(RHIT4,UBEDN))
      IF(XHIT.GT.((WD+GAP)*0.5). OR.(YHIT.GT.HTCROS*0.5)) GO TO 530
C****** NO.4 IS HIT
      IFRAM=1
      IF(JK.NE.M) IFRAM=2
      GO TO 540
  530 AL4=10.E+10
  540 CONTINUE
```

```
      AL5=DOTER(UHVDUM,VS5)/DOTER(URDUM,UHVDUM)                         FRAME 116
      IF (AL5.LT.0.0) GO TO 560                                         FRAME 117
      DO 550 I=1,3                                                      FRAME 118
  550 RHIT5(I)=-VS5(I) + AL5*URDUM(I)                                   FRAME 119
      XHIT=ABS(DOTER(RHIT5,UAXVDUM))                                    FRAME 120
      YHIT=ABS(DOTER(RHIT5,UBEDN))                                      FRAME 121
      IF(XHIT.GT.((WD+GAP)*0.5). OR.(YHIT.GT.HTCROS*0.5)) GO TO 560     FRAME 122
C****** PLANE NO.5 IS HIT                                                FRAME 123
      IFRAM=1                                                           FRAME 124
      IF(JK.NE.M) IFRAM=2                                               FRAME 125
      GO TO 570                                                         FRAME 126
  560 AL5=10.E+10                                                       FRAME 127
  570 CONTINUE                                                          FRAME 128
      AL6=DOTER(UHVDUM,VS6)/DOTER(URDUM,UHVDUM)                         FRAME 129
      IF(AL6.LT.0.0) GO TO 590                                          FRAME 130
      DO 580 I=1,3                                                      FRAME 131
  580 RHIT6(I)=-VS6(I) + AL6*URDUM(I)                                   FRAME 132
      XHIT=ABS(DOTER(RHIT6,UAXVDUM))                                    FRAME 133
      YHIT=ABS(DOTER(RHIT6,UBEDN))                                      FRAME 134
      IF(XHIT.GT.((WD+GAP)*0.5). OR.(YHIT.GT.HTCROS*0.5)) GO TO 590     FRAME 135
C****** PLANE NO.6 IS HIT                                                FRAME 136
      IFRAM=1                                                           FRAME 137
      IF(JK.NE.M) IFRAM=2                                               FRAME 138
      GO TO 600                                                         FRAME 139
  590 AL6=10.E+10                                                       FRAME 140
  600 CONTINUE                                                          FRAME 141
      AL7=DOTER(UBEDN,VS7)/DOTER(URDUM,UBEDN)                           FRAME 142
      IF(AL7.LT.0.0) GO TO 620                                          FRAME 143
      DO 610 I=1,3                                                      FRAME 144
  610 RHIT7(I)=-VS7(I) + AL7*URDUM(I)                                   FRAME 145
      XHIT=ABS(DOTER(RHIT7,UHVDUM))                                     FRAME 146
      YHIT=ABS(DOTER(RHIT7,UAXVDUM))                                    FRAME 147
C******  CHECK FOR BOTTOM FRAME BOUNDARY                                 FRAME 148
      IF(XHIT.GT.(ALEN*0.5)) GO TO 620                                  FRAME 149
      IF (YHIT.GT.(WDUM+WLONG*0.5)) GO TO 620                           FRAME 150
C******  WITHIN FRAME BOUNDARY - CHECK FOR ACTUAL HIT                    FRAME 151
      IF (YHIT.GT.(WDUM-WLONG*0.5))GO TO 630                            FRAME 152
      IF(XHIT.GT.(XDF-WCROSS*0.5).AND.XHIT.LT.(XDF+WCROSS*0.5))GO TO 630 FRAME 153
      IF (XHIT.LT.(WJCROS*0.5))GO TO 630                                FRAME 154
      GO TO 620                                                         FRAME 155
  630 IFRAM=1                                                           FRAME 156
      IF(JK.NE.M) IFRAM=2                                               FRAME 157
      GO TO 625                                                         FRAME 158
  620 AL7=10.E+10                                                       FRAME 159
  625 CONTINUE                                                          FRAME 160
      L=AMIN1(AL1,AL2,AL3,AL4,AL5,AL6,AL7)                              FRAME 161
      ALFRAM=L                                                          FRAME 162
      IF(L.EQ.AL1) IP=1                                                 FRAME 163
      IF(L.EQ.AL2) IP=2                                                 FRAME 164
      IF(L.EQ.AL3) IP=3                                                 FRAME 165
      IF(L.EQ.AL4) IP=4                                                 FRAME 166
      IF(L.EQ.AL5) IP=5                                                 FRAME 167
      IF(L.EQ.AL6) IP=6                                                 FRAME 168
      IF(L.EQ.AL7) IP=7                                                 FRAME 169
      IF (L.GT.10E+06) GO TO 900                                        FRAME 170
      IF(ALENG.LT.ALFRAM) GO TO 900                                     FRAME 171
      IPLAN(IP)=IPLAN(IP)+1                                             FRAME 172
```

```
      900 RETURN                                                FRAME     173
          END                                                   FRAME     174
```

APPENDIX C
GLOSSARY OF VARIABLES APPEARING IN COMMON

This appendix contains those variables which appear in all common blocks in the program. The table lists the FORTRAN names in alphabetical order, the common block in which each occur, a description of each, and the subroutine in which the variable is defined. The figure numbers following the description indicates a figure to refer to for further definition.

FORTRAN Name	Common Block	Description	Subroutine Defined
A	JEFF	Cosine of angle between sun and local north (Figure 3-2)	VECTS
ACOL	None	Area of collector	INITCOL
AIMHGT	CAVITY	The height up the aperture at which all the mirrors are aimed (ft)	INITCOL
ALBLOC	BEDTST	Distance from ray hit on a facet to nearest block by another facet (Figure 3-25)	OFFBLOC
ALEN	TABLE	Length of a heliostat from outer mirror axle to mirror axle (ft) (Figure F-3)	INITCOL
APH	SUPPT	Average aperture slant height	AIMPP
B	JEFF	Cosine of angle between sun and local east (Figure 3-2)	VECTS
B1	STRUCT	Collector frame geometry constant (ft)	INITCOL
B2	STRUCT	Collector frame geometry constant (ft)	INITCOL
C	JEFF	Cosine of angle between sun and local vertical (Figure 3-2)	VECTS
CAPR	BABA	Mean radius of earth's orbit in nautical miles	INITCOL
CAVLAT	CAVITY	Height zone boundaries in the cavity (ft)	MOON
CEQ	BABA	Cosine of 23.5 deg, the solar declination angle for summer solstice	INITCOL
CILAT	CAVITY	Zone indices for height zones in the cavity	MOON
CONV	None	Conversion factor to weight each ray with a KW value	

FORTRAN Name	Common Block	Description	Subroutine Defined
COSA	CINDEX	North direction cosine of the sun ray	FINDIT
COSB	CINDEX	East direction cosine of the sun ray	FINDIT
COUNT	JOKER	The normalized value of a given ray	MONTE MONTE2
CTAZT	TOE	Cosine of the sun's azimuth angle at the toe-in setpoint	INITCOL
CTELT	TOE	Cosine of the sun's elevation angle at the toe-in set point	INITCOL
CTH	BABA	Cosine of the latitude	INITCOL
D	BALL	Vector from hit heliostat center to the tower top	PTOWER MOON
DCOL	BALL	Height of facet axis off the ground (ft)	INITCOL
DDBASE	DARKLE	Diameter of the tower base (ft) (Figure F-2)	INITCOL
DDTOP	DARKLE	Diameter of the tower top (ft) (Figure F-2)	INITCOL
DD1	CAVITY	Diameter of lower disc of annulus cavity (tower top diameter) (Figure F-4)	INITCOL
DD2	CAVITY	Average diameter of upper disc of annulus cavity (Figure F-4)	INITCOL
DD3	CEILING	Inner cavity diameter (ft) (Figure F-4)	NAMELIST
DEG	MAPS	Angle of one azimuth zone on the field	POLSP2
DELTM	SUPPT	Angle between the midpoint of the supports and the hit heliostat field position	AIMPP
DINTV	RANDOM	Number of hours per day that are integrated over in annual energy runs	INITCOL
DRAD	JOKER	Factor to convert degrees to radians	INITCOL

FORTRAN Name	Common Block	Description	Subroutine Defined
DRZ	CEILING	Distance of the radial borders on the ceiling of the receiver	ROOF
DTARG	TOE	Vector from heliostat center to the aimpoint	MIRRN
DTAZ	CEILING	Azimuthal borders on the ceiling (radians) of the receiver	ROOF
DUMA	JEFF	Same as A	PTOWER
DUMB	JEFF	Same as B	PTOWER
DUMC	JEFF	Same as C	PTOWER
ELZ	JEFF	Elevation of the sun at a given time	MONTE2 INITCOL
ENHM	JEFF	Sum of COUNT	MONTE MONTE2
F	TABLE	Focal length of a facet	NAMELIST
GAP	STRUCT	Space between the frame side beams not taken up by a facet (ft) (Figure F-3)	NAMELIST
GCOVER	None	Fraction of ground covered by heliostats	NAMELIST
HCAV	CAVITY	Height of the receiver caity (ft) (Figure F-4)	NAMELIST
HDIF	CAVITY	Height of the diffuser (ft)	NAMELIST
HSWTC	CAVITY	CAVITY heights (= to HCAV and HDIF)	INITCOL
HTCROS	STRUCT	Height of the frame cross beams (ft) (Figure F-4)	NAMELIST
HTMIR	STRUCT	Height of the facet axle above the top of the heliostat frame (ft) (Figure F-4)	NAMELIST

FORTRAN Name	Common Block	Description	Subroutine Defined
HTOT	SUPPT	Average distance from the tower top to the cavity bottom (Figure F-4)	INITCOL
ICELL	CINDEX	Field cell index	RINDX
ICELM	CINDEX	Field cell index	FINDIT
ICMH	JEFF	Mirror hit flag 0 - no mirror hit 1 - mirror hit	FINDIT
ICOD	BEDTST	Flag for setting the correct vectors 1 shading on different heliostat 2 shading on same heliostat 3 blocking on different heliostat 4 blocking on same heliostat	PTOWER FINDIT
ICSH	JEFF	A counter to indicate that a ray was shadowed by a facet 0 - no shadows 1 - number of shadow hits	FINDIT
ICSH2	JEFF	A flag to indicate that a ray was shadowed by a facet on a different heliostat than it would have encountered. 0 - no shadows 1 - number of shadow hits	FINDIT
IDAY	BABA	The day of the month to be run	NAMELIST
IDAYT	None	The day of the toe-in set	NAMELIST
IDRIVE	TABLE	Option code for facets to be driven on a heliostat individually or all together. 1 = ganged 2 = independent in one axis	NAMELIST
IFC	JEFF	Initialization flag 1 first call to FINDIT 2 second call to FINDIT	PTOWER
IFOC	TABLE	Option code for focal lengths of the facets (obsolete)	NAMELIST

FORTRAN Name	Common Block	Description	Subroutine Defined
IFOCUS	TOE	An option to model the curve of the facets individually or to zone the field into areas with the facets all having the same curve. IFOCUS=0 means each facet has its own focus. IFOCUS=1-10 means there are 1-10 zones in each of which the facets all have the same focal length. IFOCUS=11 means flat-mirrors.	NAMELIST
IFRAM	STRUCT	A flag to indicate whether or not a ray encountered the frame of a heliostat in its path. 0 - no encounter 1 - frame hit	FRAME
IFV	TABLE	Index of a facet on a heliostat	INHIT
IHIT	JEFF	A flag to indicate a ray hit a facet 0 - no facet hit 1 - facet hit	INHIT
IHOUR	JEFF	Hour of the day run	INITCOL
IJUMP	RANDOM	Option code for a time point or annual energy run 0 - time point 1 - time integration 2 - time point and time integration	NAMELIST
ILONG	JEFF	Index of azimuth zone hit on the cavity wall	MOON
IPLAN	PLANE	Counter for ray hits on each frame plane	FRAME
IOHIT	JEFF	A flag to indicate a ray block 0 - no block 1 - blocked	
IRANC	RANDOM	A flag to initialize the random number generator	INITCOL
IRAYS	RANDOM	Number of rays per NRUN to be drawn	NAMELIST

FORTRAN Name	Common Block	Description	Subroutine Defined
ISRAN	RANDOM	Initial random seed	NAMELIST
IT1	RANDOM	Control variable for terminating the program (= 3 to stop)	NAMELIST
ITOE	None	An option to adjust the facets relative to each other in zones or to adjust each heliostat separately. ITOE=0 means the facets are toed-in individually. ITOE=1-10 are the number of zones for similar toe-in relationships.	NAMELIST
ITT	None	Integer ray counter array	MONTE or MONTE2
IZAZ	CEILING	Index of azimuth zone on the ceiling	MOON
IZR	CEILING	Index of the radial zone on the ceiling	MOON
JCELL	CINDEX	Field cell index	RINDX
JCELM	CINCEX	Field cell index	FINDIT
JCORB	MOONMP	A flag to indicate a corbel hit 0 - the ray entered the cavity 1 - ray hit the corbel	MOON
JFRONT	MOONMP	A flag to indicate a ray missed the aperture completely 0 - ray entered cavity 1 - ray missed aperture	MOON
JMISHI	MOONMP	Flag to indicate a ray hit the receiver above the aperture 0 - ray entered cavity 1 - ray missed high	MOON
JMISLO	MOONMP	A flag to indicate a ray hit the tower below the aperture 0 - ray entered cavity 1 - ray missed low	MOON

FORTRAN Name	Common Block	Description	Subroutine Defined
JWHIS	MOONMP	A flag to indicate a ray entered the aperture but did not hit the cavity 0 - ray entered cavity 1 - ray entered aperture and exited without getting into the cavity	MOON
KSEG	SUPPT	Integer segment indice to indicate field position relative to corbel location	AIMPP
LIMC	RANDOM	Option code for choice of sun mode 1 - flat sun 2 - sun with limb darkening and solar radiation 3 - sun with limb darkening	INITCOL
MIN	JEFF	Minute of the hour of the day	INITCOL
MODE	RANDOM	A flag that indicates whether all variables need to be initialized or not 1 = initialize all variables 2 = read namelist	INITCOL
MON	BABA	Month of the year to be run	NAMELIST
MONT	None	Month of the toe-in set point	NAMELIST
N	BABA	Unit ray vertical to the ground plane (real variable)	VECTS
NAZZ	CEILING	Number of azimuth zones on the ceiling	INITCOL
NAZZF	MAPS	Number of azimuth zones in field	NAMELIST
NC	MAPS	Number of collectors in a zone	POLSP2
NCOL	JEFF	Number of collectors in the field	POLSP2
ND1	None	Disposition code for a given ray	
NHF	TABLE	Number of heliostat facets (must be 4 in this code version)	NAMELIST

FORTRAN Name	Common Block	Description	Subroutine Defined
NLAT	JEFF	Number of height zones on the diffuser	NAMELIST
NLATC	JEFF	Number of height zones on the cavity wall	NAMELIST
NLONG	JEFF	Number of azimuth zones on cavity walls	NAMELIST
NNU	None	Number of azimuth zones on the field (either 1 or 8)	NAMELIST
NPACK	JEFF	Option code for arrangement of heliostats in the field 4 - uniform polar packing 5 - nonuniform polar packing	NAMELIST
NPRAD	MAPS	Number of polar radial zones in an azimuth section (Figure F-5)	POLSP2
NRUN	RANDOM	Number of iterations on IRAYS to be run	NAMELIST
NRZ	CEILING	Number of radial zones on the cavity roof (Figure F-5)	NAMELIST
NRZF	MAPS	Number of radial zones on the field (Figure F-1)	NAMELIST
NSTOPS	JEFF	Number of points along a projected ray path to be checked for closest heliostat (Figure 3-4)	NAMELIST
NSUP	SUPPT	Number of cavity supports	NAMELIST
OFFSET	TILTED	North-south distance that the cavity center is offset from the upper aperture east-west axis	
OME	BABA	Hourly angular displacement of the earth about its rotation axis	INITCOL
OMS	BABA	Daily angular displacement of the earth in its orbit	INITCOL
PAX1	BALL	Tracking error in degrees, for the outer axis	MONTE2

FORTRAN Name	Common Block	Description	Subroutine Defined
PAX1B	STATS	Mean tracking error, in degrees, for the outer axis	INITCOL
PAX1V	STATS	Variance tracking error, in degrees, for the outer axis	NAMELIST
PAX2	BALL	Tracking error, in degrees, for the inner axis	MONTE2
PAX2B	STATS	Mean tracking error, in degrees, for the inner axis	INITCOL
PAX2V	STATS	Variance tracking error, in degrees, for the inner axis	NAMELIST
PH	JOKER	The angular rotation for mirror surface slope errors	MONTE MONTE2
PHB	STATS	Heliostat optical parameters	NAMELIST
PHV	STATS	Heliostat optical parameters	NAMELIST
RCO	JEFF	Radius of the heliostat field cutout around the tower (ft) (Figure F-1)	NAMELIST
RCONE	SUPPT	Radius of the conical aperture halfway between the tower and the cavity (ft) (Figure F-4)	NAMELIST
RDIF	CAVITY	Radius of the diffuser	NAMELIST
RFIELD	JEFF	Radius of the heliostat field (ft) (Figure F-1)	NAMELIST
RHS	TABLE	= RRB	FINDIT
RRB	TABLE	Vector from the ray start point to the heliostat hit point	INHIT
RRS	JEFF	Vector from facet center to hit-point of the ray	FINDIT
RST	TABLE	Vector from center of field to ray hit point on a facet	INHIT

FORTRAN Name	Common Block	Description	Subroutine Defined
RSWTC	CAVITY	Radius of the cavity or diffuser	INITCOL
SCDELT	BALL	Uncertainty vector in position of the aimpoint	NAMELIST
SEP	CAVITY	Distance of separation between the tower and the receiver (Figure F-4)	INITCOL
SEQ	BABA	Sine of 23.5 deg, the solar declination angle for summer solstice	INITCOL
SLDUM	CINDEX	Horizontal length along ray path from start point to the point to be checked for the closest heliostat	FINDIT
SMALR	BABA	Earth's diameter in nautical miles	INITCOL
SMAX	JEFF	Horizontal component of the ray from the start point to the hit point on a test plane	PTOWER
SPACEF	None	Spacing factor between heliostats	NAMELIST
SRAD	MAPS	Radial zones borders measured from the tower	POLSP2
STAZT	TOE	Sine of the sun's azimuth angle at the toe-in setpoint	INITCOL
STELT	TOE	Sine of the sun's elevation angle at the toe-in setpoint	INITCOL
STH	BABA	Sine of the latitude of the plant	INITCOL
SW	SUPPT	Support width	NAMELIST
T	JEFF	Time of the day to be run	NAMELIST
TAZT	None	Azimuth angle of the sun at the given toe-in time. It is used to vary the toe-in strategy (radians).	NAMELIST
TDISX	JEFF	Tower distance from center of the field in an east-west direction - where east is positive x (ft) (Figure F-2)	NAMELIST

FORTRAN Name	Common Block	Description	Subroutine Defined
TDISY	JEFF	Tower distance from center of the field in a north-south direction - where north is positive y (ft) (Figure F-1)	NAMELIST
TELT	None	Elevation angle of the sun at the given toe-in time. It is used to vary the toe-in strategy (radians).	NAMELIST
TH	JEFF	Tower height (ft) (Figure F-2)	NAMELIST
THECON	SUPPT	Aperture cone angle (radians) (Figure F-2)	INITCOL
THES	SUPPT	The angle between the supports	AIMPP
THETA	BABA	Latitude of the tower (degrees)	NAMELIST
THSL	JOKER	Mirror surface slope error angle	MONTE MONTE2
THSR	JOKER	Rotation angle of the sun vector to account for limb darkening	MONTE MONTE2
THSU	JOKER	Rotation angle of the sun vector to account for limb darkening	MONTE MONTE2
TIMET	None	Time of the toe-in setpoint	NAMELIST
TPB	STATS	Heliostat optical parameter	NAMELIST
TPV	STATS	Heliostat optical parameter	NAMELIST
TSB	STATS	Mean of mirror surface slope error (degrees)	NAMELIST
TSV	STATS	Variance of mirror surface slope error (degrees)	NAMELIST
TTILT	TILTED	Tilt of the aperture cone axis	INITCOL
UA	BABA	Vector at 235 deg in north-south vertical plane	INITCOL
UAXV	TABLE	Unit vector along the facet axle	TRIADS

FORTRAN Name	Common Block	Description	Subroutine Defined
UAXV2	BEDTST	Unit vector along the facet axle	TRIADS
UAXVP	TABLE	UAXV perturbed for tracking error	PERT3
UBEDN	TABLE	Unit vector perpendicular to the top plane of the heliostat (Figure 4-25)	TRIADS
UDNI	RANDOM	Direct normal intensity (Langleys)	INTEN
UE	BABA	Unit vector in the local east direction (Figure 3-2)	VECTS
UHV	TABLE	Horizontal unit vector along the heliostat outer axis (Figure 3-25)	MONTE2 MONTE
UHV2	BEDTST	Horizontal unit vector along the heliostat outer axis (Figure 3-25)	OFFBLOC
UMN	JEFF	Nominal unit mirror normal vector (Figure 3-25)	MIRRN
UMNN1	JEFF	Unit vector normal to the sun vector UR	VECTS
UMNN2	JEFF	Unit vector normal to the sun vector UR	VECTS
UMNP	TABLE	Heliostat unit normal vector rotated for the outer axis tracking error	PERT3
UMNPP	TABLE	Heliostat unit normal vector rotated for both axes tracking errors	PERT3
UMNS	JEFF	Same as UMN for the hit heliostat	FINDIT
UN	BABA	Unit vector in the local north direction (Figure 3-2)	VECTS
UNNP	TABLE	Mirror normal at hit point with slope error and tracking errors (Figures 4-22 and 3-23)	PERT3
UR	BABA	Unit ray from the center of the sun	VECTS

FORTRAN Name	Common Block	Description	Subroutine Defined
URP	JOKER	The sun's perturbed unit ray based on where on the sun the ray originated	PTOWER
US	BABA	Unit vector along the path from the center of the sun to the center of the earth	VECTS
US1	JOKER	Unit vector in the direction which the ray is reflected from a mirror surface	PTOWER
UTARG	TOE	Unit vector along path from heliostat center to the aimpoint	MIRRN
UTT	TABLE	Unit vector tangent to the hit point mirror normal	PERT3
UT2	TABLE	Unit vector tangent to the hit point mirror normal	PERT3
UVT	TILTED	Unit vector along the cone axis	AIMPP
UXV2	TABLE	Unit vector perpendicular to the facet axle in the plane of the facet	TRIADS
UXV2P	TABLE	UXV2 rotated for the outer axis tracking error	PERT3
UXV2PP	TABLE	UXV2 rotated for both tracking axes errors	PERT3
[illegible]1	TILTED	Unit vector normal to cone axis and in north direction	AIMPP
[illegible]2	TILTED	Unit vector normal to cone axis and in east direction	AIMPP
WAPMAX	TILTED	Maximum aperture width (ft)	NAMELIST
WAPMIN	TILTED	Minimum aperture width (ft)	NAMELIST
WAVL	JOKER	Wavelengths of solar spectrum divided in equal energy bands	INITCOL

FORTRAN Name	Common Block	Description	Subroutine Defined
WCELL	CINDEX	Width of a cell on a field with rectangular cells (ft)	INITCOL
WCROSS	STRUCT	Width of the frame cross beams (ft)	NAMELIST
WD	TABLE	Width of a mirror facet (ft)	NAMELIST
WDUM	STRUCT	Half of the collector width (ft)	INITCOL
WD2	TABLE	Half the width of a facet (ft)	INITCOL
WFV	TABLE	Length of a facet (ft)	NAMELIST
WFV2	TABLE	Half the length of a facet (ft)	INITCOL
WJCROS	STRUCT	Width of the center cross piece on the frame (ft)	NAMELIST
WLONG	STRUCT	Width of the frame side beams (ft)	NAMELIST
WSIDE	STRUCT	Height of the frame side beams (ft)	NAMELIST
WTRI	STRUCT	Width of the diagonal braces in the top plane of the frame (ft)	NAMELIST
XCM	CINDEX	The east-west coordinate of a heliostat center hit by a ray	FINDIT
XCSAV	CINDEX	The east-west coordinate of a heliostat center to be checked for an encounter with a ray	RINDX
XDF	TABLE	Facet axle to axle distance (ft)	NAMELIST
XLTRI	STRUCT	Length of the diagonal frame braces (ft)	NAMELIST
XM	None	Flux total array	MONTE MONTE2
XP	BALL	The east-west coordinate in the test plane from which a test ray originates	FINDIT

FORTRAN Name	Common Block	Description	Subroutine Defined
XPCOL	CINDEX	The east-west coordinate of a heliostat center	FINDIT
YCM	CINDEX	The north-south coordinate of a heliostat center hit by a ray	FINDIT
YCSAV	CINDEX	The north-south coordinate of a heliostat center to be checked for an encounter with a ray	RINDX
YFRAC	RANDOM	Number of days over which the program integrates	INITCOL
YP	BALL	The north-south coordinate in the test plane from which a test ray originates	FINDIT
YPCOL	CINDEX	The north-south coordinate of a heliostat center	FINDIT

APPENDIX D
INPUT INSTRUCTIONS

All input to this program is in the form of NAMELIST input cards.

The following variables are in NAMELIST CHANGE:

```
C ********NAMELIST DICTIONARY
      NAMELIST /CHANGE/ RFIELD,TH,NSTOPS,TDISX,TDISY,IRAYS,TPB,TSB,PHB,
     1            TPV,TSV,PHV,THETA,MON,IDAY,T,IJUMP,IT1,NRUN,ISRAN,
     2            PAX1V,PAX2V,SCDELT,NLONG,NLATC,GCOVER,RCO,RCONE,HCAV,
     3            SW,NSUP,DD3,NRZ,NRZF,NAZZF,WD,WFV,XDF,NPACK,SPACEF,
     4            IDRIVE,NNU,WAPMAX,WAPMIN,OFFSET,WLONG,WCROSS,WTRI,GAP,
     5            XLTRI,HTMIR,HTCROSS,WJCROS,ITOE,IFOCUS,TAZT,TELT,
     6            MONT,IDAYT,TIMET
```

Appendix C, glossary of variable names, and Appendix E, input default values and ranges, provides a description of these variables.

When preparing NAMELIST input cards, observe the following rules:*

1. The first column must be blank.

2. The second column must contain the character $.

3. This character is immediately followed by the NAMELIST name (change), with no embedded blanks.

*Reference FORTRAN IV Programming for Engineers and Scientists by Murril and Smith, copyright 1968 by International Textbook Company, page 159.

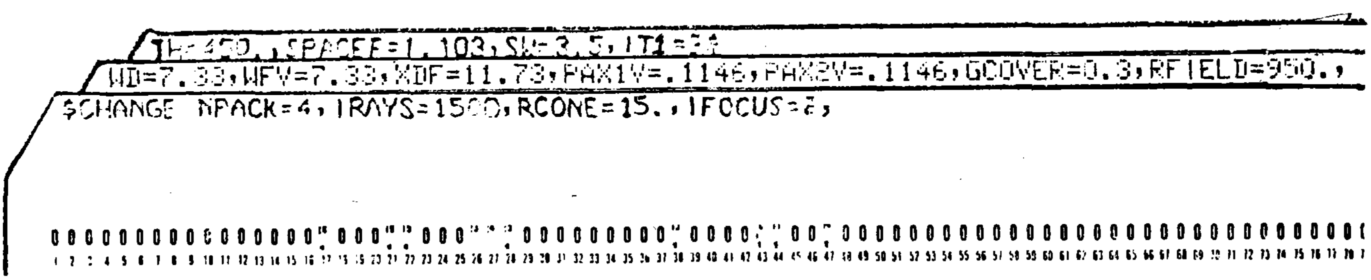
4. The NAMELIST name is followed by a blank.

5. The items in the list must be separated by commas.

6. The order is insignificant, but all variable and array names must have appeared in the NAMELIST list.

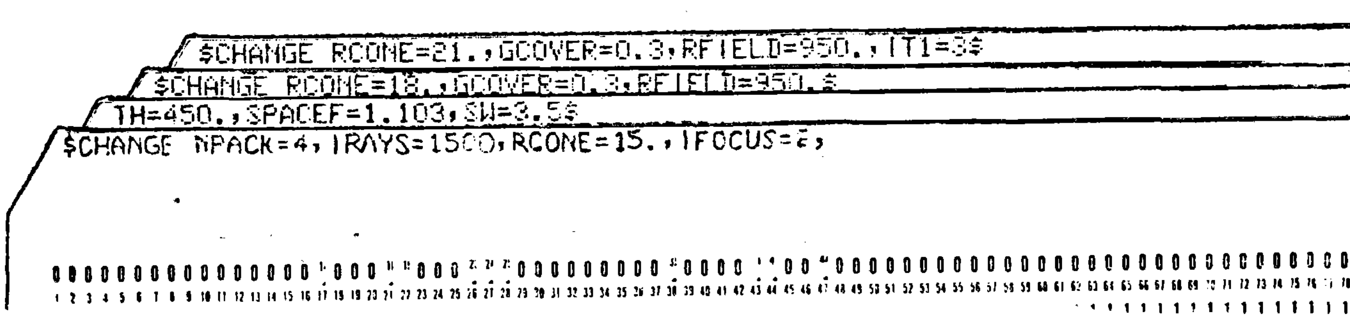
7. The list of items is terminated with $.

For example:



all input variables have a default value, thus those not appearing on these input cards, but listed in the NAMELIST dictionary, are set to the default value.

There must be one group of NAMELIST input cards for each design option to be investigated. For example:



This set of cards specifies three design options to be investigated. Variables changed by a NAMELIST input card maintain that value through subsequent option executions. Thus, in this case:

a. All variables not mentioned on the first group of NAMELIST cards take on their default values.

b. Only RCONE is changed for the second and third option executions. All other variables maintain either their default values, or the values specified in the first NAMELIST group.

c. IT1=3 is the stop flag. This variable must be set on the final option execution.

APPENDIX E
GLOSSARY OF NAMELIST VARIABLES AND DEFAULT VALUES

This appendix includes the NAMELIST dictionary variables along with their default values and meaningful range of value. Definition of these variables are given in Appendix C, Glossary of Variables Appearing in Common.

The default value of each variable shown in this appendix represents the baseline model which would be simulated upon execution of the program without input. Only those variables which are different from those given in this table need be changed with input cards to simulate a problem other than the baseline model.

Variable Name	Default	Range
DD3	42 ft	> 0
GAP	0.25 ft	> 0
GCOVER	0.3	0-1
HCAV	46.1 ft	> 0
HTCROSS	0.833 ft	> 0
HTMIR	0.833 ft	
IDAY	21	1-31
IDAYT	21	1-31
IDRIVE	1	1, 2
IFOCUS	0	0-11 by integer
IJUMP	1	0, 1, 2
IRAYS	2	Integer > 0
ISRAN	27641	Integer random II > 0
ITOE	0	0-11 by integer
IT1	2	1, 2, 3
MON	6	1-12 by integer
MONT	3	1-21 integer
NAZZF	8	1-16 integer
NLATC	5	1-16 integer
NLONG	8	1-16 integer
NNU	8	1 or 8 only
NPACK	5	4, 5
NRUN	10	Integer > 0
NRZ	5	1-16
NRZF	7	1-16
NSTOPS	11	Integer > 5
NSUP	3	Integer > 0
OFFSET	0	
PAXIV	0.05	> 0
PAX2V	0.05	> 0

Variable Name	Default	Range
PHB	0	
PHV	0	> 0
RCO	120 ft	> 0
RCONE	20 ft	> 0
RFIELD	826 ft	> RC0
SCDELT	0	
SPACEF	1.1	> 0
SW	2 ft	≥ 0
T	12 hr	0-24
TAZT	3.14159 rad	0-2π
TDISX	0 ft	
TDISY	0 ft	
TELT	0.4948 rad	0-2π
TH	392 ft	> 0
THETA	33 deg	-60 → +60
TIMET	12 hr	0-24
TPB	0	
TPV	0.05	> 0
TSB	0	
TSV	0.05	> 0
WAPMAX	24 ft	> 0
WAPMIN	18 ft	> 0
WCROSS	0.385 ft	≥ 0
WD	10 ft	≥ 0
WFV	10 ft	≥ 0
WJCROS	0.224 ft	≥ 0
WLONG	0.48 ft	≥ 0
WTRI	0.177 ft	≥ 0
XDF	16 ft	> WD
XLTRI	4.681 ft	≥ 0

APPENDIX F
SAMPLE PROBLEMS AND DESCRIPTION OF OUTPUT

This appendix includes two sample problems, a time point simulation and an annual energy time integration simulation, both of the same geometric configuration. A reproduction of the input cards for both samples, and a copy of the actual output for each sample is included.

```
$CHANGE RFIELD=278.,TH=415.,WFV=10.375,WD=10.375,XDF=16.6,SPAECF=1.0,
THETA=35.68,
TDISY=-439.,RCO=165.,MON=3,IDAY=81,T=12.,DD3=49.5,HCAV=54.,RCONE=18.06,
WAPMAX=25.,WAPMIN=18.8,PAX1V=.115,PAX2V=.115,PHV=0.5,IJUMP=0,IRAYS=800$
$CHANGE IJUMP=1,IT1=3,THETA=35.68$
```

Figures F-1 and F-2 show the field layout with tower location and the receiver/ tower configuration. Any variable shown on the input cards and not defined in the figures can be determined from Appendix C, Glossary of Variable Appearing in Common, and Appendix E, Namelist Variables and Default Values.

The output for each of the examples is numbered to the right of each major block of output. Following the listing is an explanation of those major blocks of output numbered to match those numbers in the output.

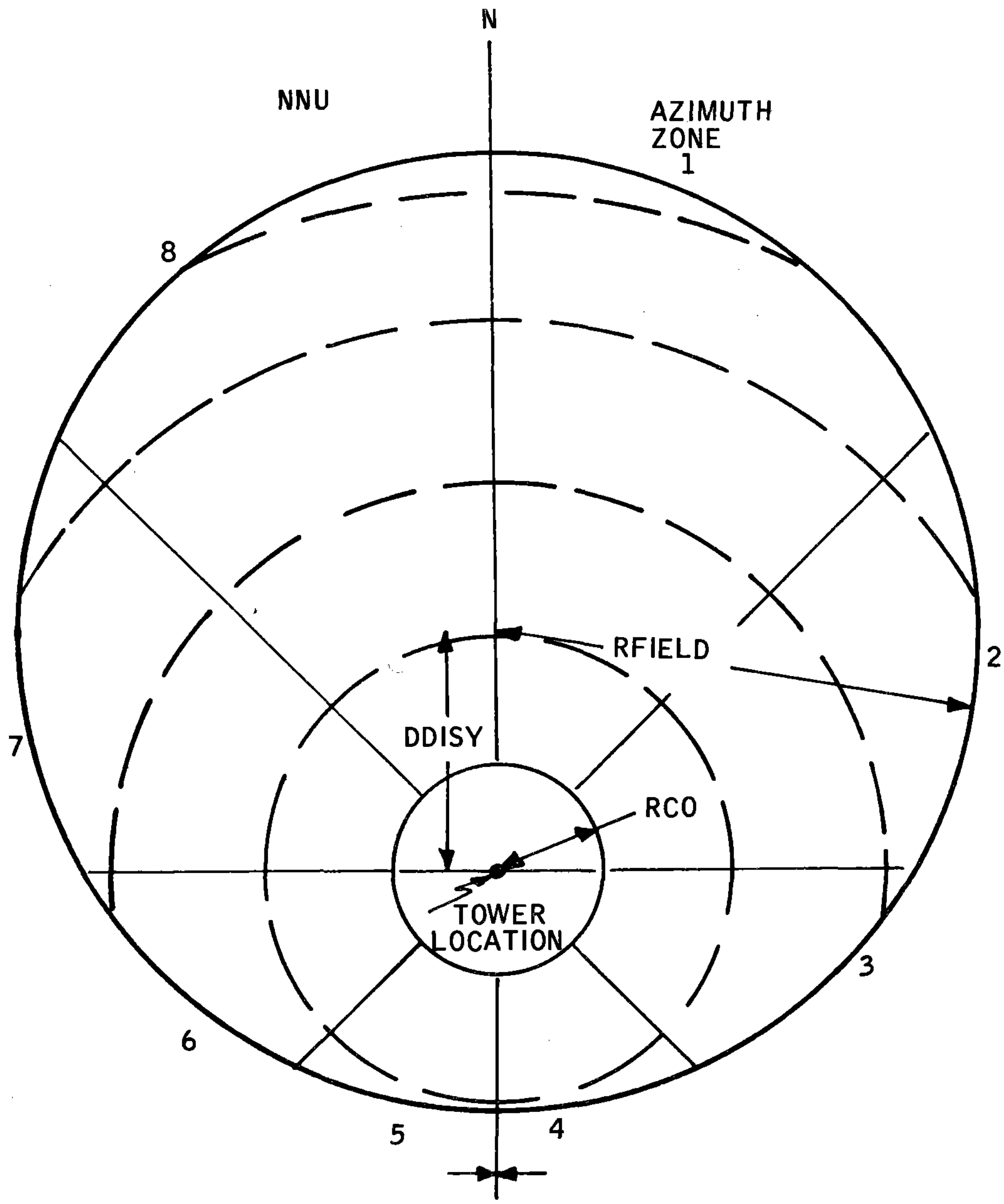


Figure F-1. Heliostat Field with Tower One-Half South of Center

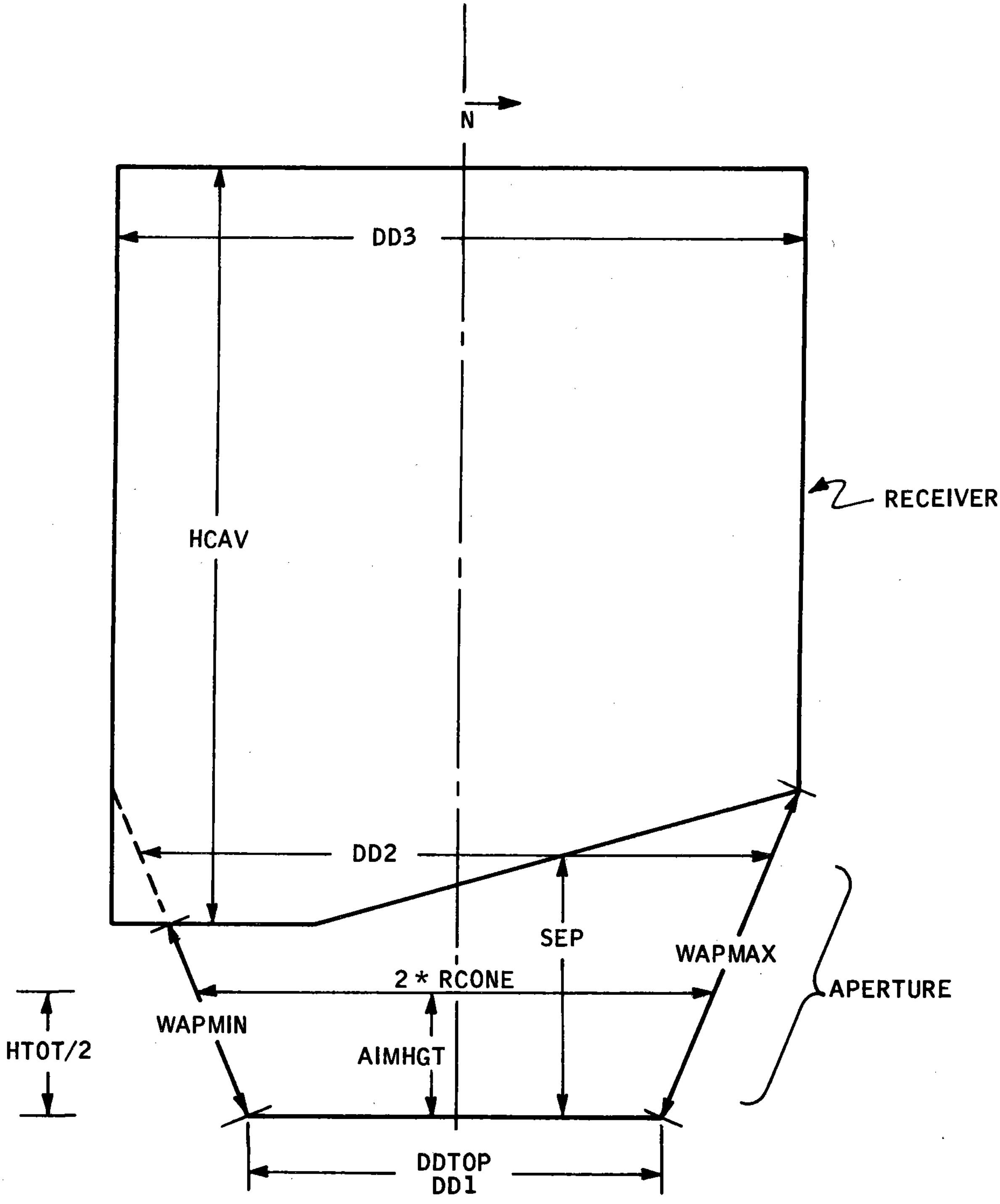


Figure F-2. Diagram of Receiver and Aperture

OUTPUT DESCRIPTION

1. Number with which the random number generator is initialized.

2. Warning message. Dimensions specified for the cavity diameter have been reset. (Does not appear in this sample.)

3. Summary of heliostat layout. The heliostats are arranged around the tower such that a line drawn from the center of a given heliostat to the center of the tower is perpendicular to the outer axis of the heliostat.

   For each of eight azimuth zones, heliostats are arranged in concentric arcs. "Polar radii in azimuth zone n" are the distances from the tower center to the heliostats' boundaries for each concentric arc. "Polar collector count in azimuth zone n" is the number of heliostats within each of these concentric arcs (see Figure F-1).

4. Ground cover summary. Since the field is symmetric for this heliostat arrangement, only four zones are listed. The ground cover ratio (area of mirror/ground area in a zone) is given for each arc of heliostats in an azimuth zone.

5. Field and heliostat description. See Appendix C for definition of terms. Figures F-1 through F-4 are diagrams of the model of the field, tower, and heliostat.

6. Center wavelengths of equal energy bands for the solar spectrum.

7. Continued summary of variables describing the field.

8. Plant locations, date and time of operation.

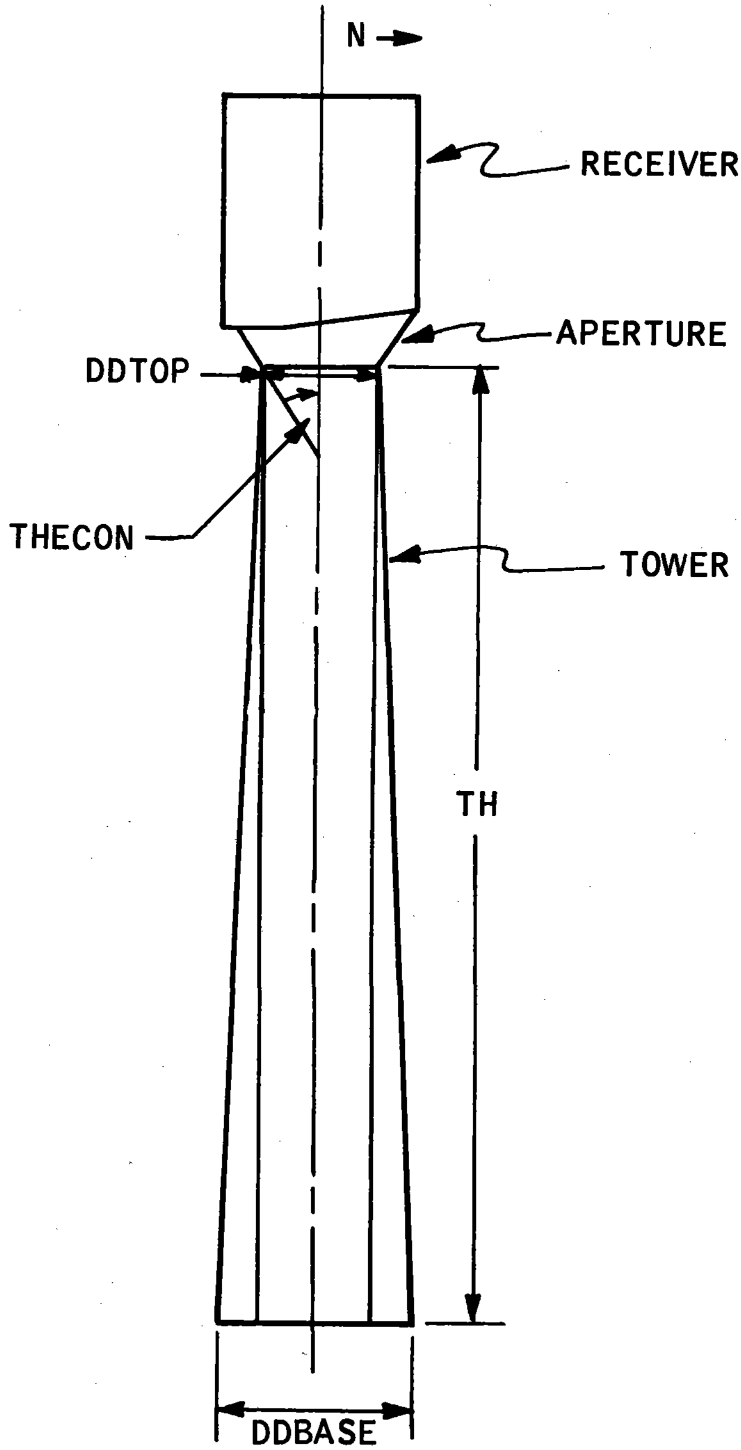


Figure F-3. Tower/Receiver Configuration

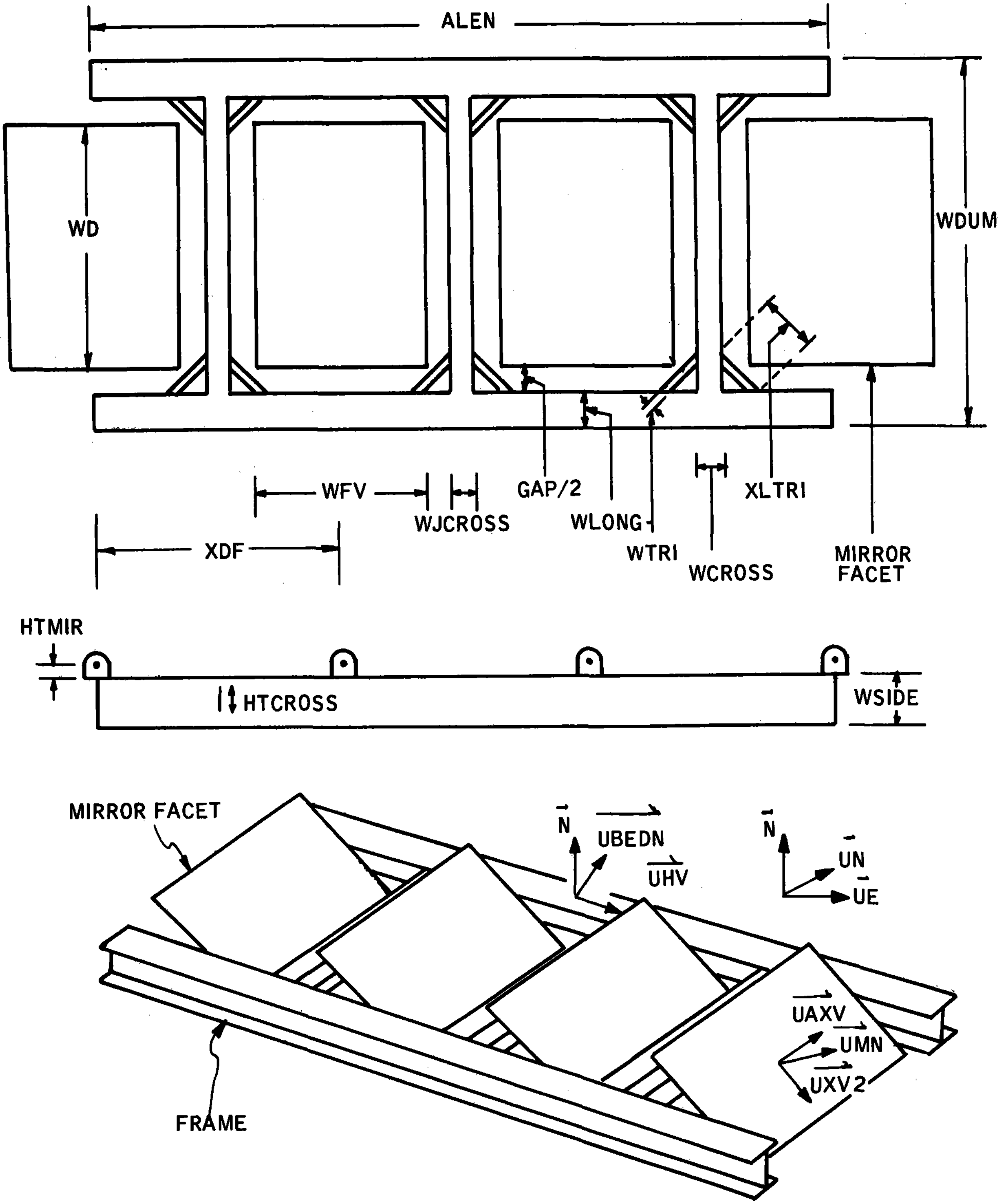


Figure F-4. Heliostat Model (not to scale) with Associated Unit Vectors and Variable Names

9 & 10. Receiver and aperture dimensions. Refer to diagram in Figure F-2. and Appendix C for definitions.

11. Short option summary.

12. Tracking error factors.

13. Elevation and azimuth angles of the sun. Direct normal intensity (KW/M^2).

14. Conversion factor = total possible power falling on the heliostat field.

15. Number of rays to be traced.

16. Description of headings for ray trace results. Most are self explanatory. Reflectance refers to that property of the mirrors.

Rays which "whistled thru" refers to those rays which entered on one side of the aperture and left on the opposite side, without entering the cavity.

"ONBLOCKS" are reflected rays that were blocked by a different part of the same heliostat.

"OFFBLOCKS" are reflected rays that were blocked by a part of a different heliostat.

"Cleanly away from field" refers to rays that are not blocked by any heliostat after being reflected.

17. Type of simulation.

18. Calculated mirror area and direct normal intensity of the sun (KW/M^2).

19. All values are given in KW/M^2 of mirror.

20. Tracking efficiency.

21. Summary of frame hits and blocks.

22. Onblock, offblock ray hit summaries: a grid showing a) the hit facet, b) the facet blocking the reflected ray (used mainly for debug).

23. A map of flux on the tower cavity, zoned by height up the wall and azimuth position. For time point the units are MW/M^2. For time integration the units are MWH/M^2. Figure F-5 is a diagram of the flux map structure of the receiver walls and roof.

24. Summary of flux on the cavity walls. Columns one and two show the range of the wall covered. Column three shows the average flux in this ring per square foot. Columns four and five show the resultant running sums of the total flux on the ring from bottom to top. Columns six and seven do the same thing from top to bottom. Flux is measured in MW for time point and MWH for time integration.

25. A map of flux (MW/M^2 for time point MWH/M^2 for time integration) over 90 equal area zones of the roof. The zones are divided into four radial sections and 16 azimuth sections (0° is north, 90° is east, etc.) (see Figure F-5).

26. A map of flux (MW/M^2 for time point, MWH/M^2 for time integration) on the roof. The roof is zoned into five equal area concentric doughnut shaped sections (see Figure F-5).

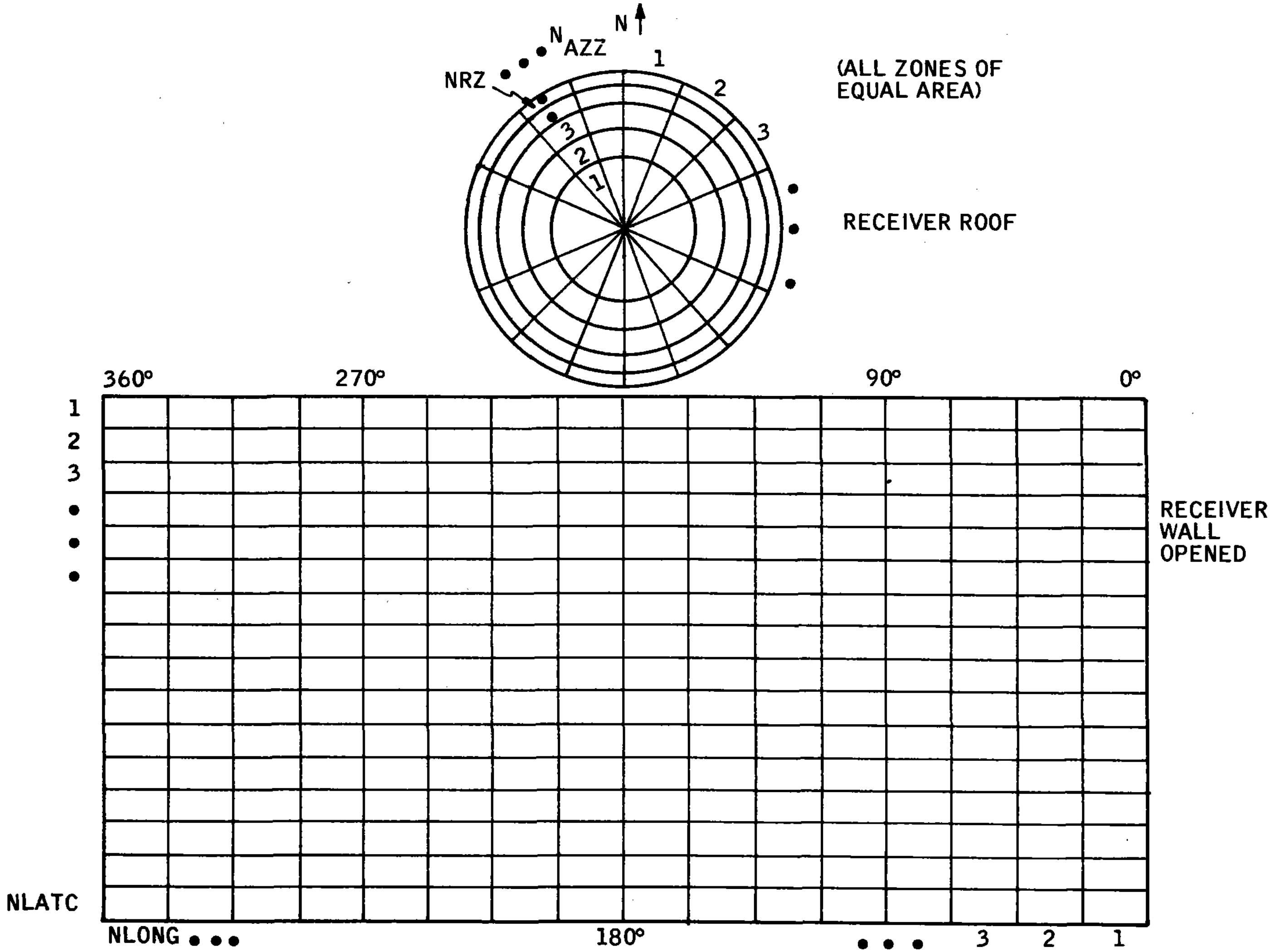


Figure F-5. Flux Map Structure

27. A map of incident flux on the mirrors. The field is zoned into a 10-by-10 rectangular grid. Units are MW/M^2 for time point and MWH/M^2 for time integration (see Figure F-6).

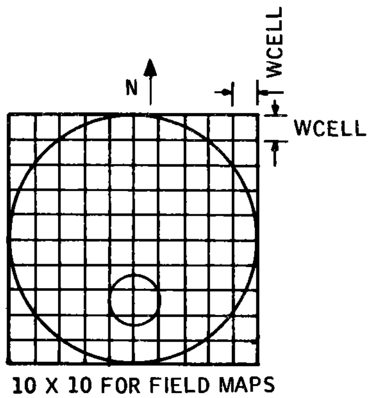


Figure F-6. Heliostat Field Zoning

28. A map of hits on the mirrors. The field is zoned into a 10-by-10 rectangular grid.

29. A map of redirected flux on the mirrors (KW for time point, KWH for time integration).

30. A map of flux lost to shadowing. Units are KW for time point and KWH for time integration. This map includes shadowing from heliostat to heliostat as well as facet-to-facet shading.

31. A map of flux lost due to heliostat-to-heliostat shading. Units are KW for time point and KWH for time integration.

32. A map of flux lost due to blockage. Units are KW for time point and KWH for time integration.

33. A map of total flux on the mirrors, i.e., the sum of grids 30, 31, 32 and 33. Units are KW for time point and KWH for time integration.

34a,b,c. Maps of losses divided by total flux on the mirrors (grid 33).

35a,b,c,d,e. Maps of the origin on the field of these rays which did not enter the cavity. That is, the origin of those rays which:

a. Missed high

b. Missed low

c. Missed across the front

d. Entered through one side of the aperture and went out the other side

e. Struck corbels

36. SL array is a weighted ranking (0-9) of the field in a 10x10 rectalinear array.

****additional output for time integration run****

37. A map showing origin of the redirected rays which entered the cavity by month of the year. The field is divided into four sections, where the axes are north-south and east-west. Column 2 shows hits in the NE, column 3 shows hits in NW, column 4 shows hits in SW, column 5 shows hits in SE, column 6 is the sum of columns 2 and 3, column 7 is the sum of columns 4 and 5 (see Figure F-7).

The row showing month 13 is the sum of months 1, 2, 11 and 12; row 14 is the sum of months 5, 6, 7, and 8; row 15 is the sum of 3, 4, 9 and 10.

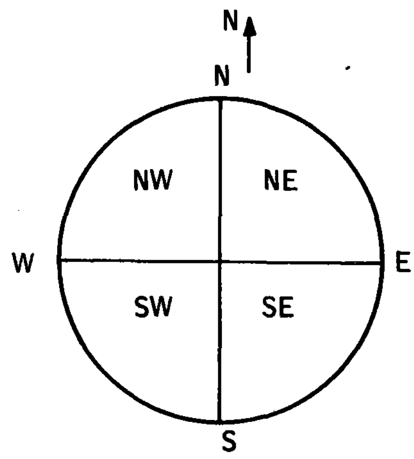


Figure F-7. Field Zoning

38. A map similar to the one described in 37, except the axes that define the quadrants of the field are diagonals, i.e., from NW to SE and NE to SW. See Figure F-8 for explanation of quadrant system.

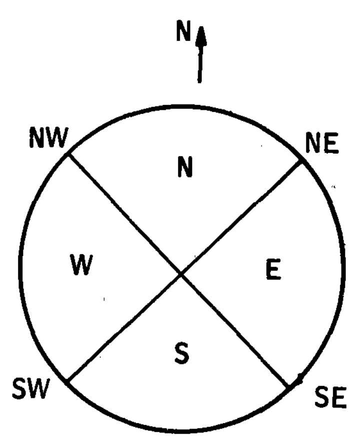


Figure F-8. Field Zoning

39. Maps of the origin of redirected energy (in KW) zoned in the same way as the ray count maps discussed in 37 and 38.

```
INITIAL RANDOM SEED=     27641    NUMBER OF RUNS PER BATCH=    10
```
(1)

INITIAL CAVITY DIAMETER (Does not appear in this sample) (2)

```
          POLAR RADII IN AZIMUTH ZONE     1
```
(3)

```
R(  1)= 165.0  R(  2)= 181.6  R(  3)= 198.3  R(  4)= 215.1  R(  5)= 232.0  R(  6)= 249.1  R(  7)= 266.3  R(  8)= 283.6
R(  9)= 301.2  R( 10)= 318.9  R( 11)= 336.7  R( 12)= 354.7  R( 13)= 372.9  R( 14)= 391.2  R( 15)= 409.8  R( 16)= 428.5
R( 17)= 447.4  R( 18)= 466.6  R( 19)= 485.9  R( 20)= 505.4  R( 21)= 525.2  R( 22)= 545.2  R( 23)= 565.4  R( 24)= 585.9
R( 25)= 606.6  R( 26)= 627.6  R( 27)= 648.8  R( 28)= 670.4  R( 29)= 692.2  R( 30)= 714.4  R( 31)= 736.8  R( 32)= 759.6
R( 33)= 782.8  R( 34)= 806.3  R( 35)= 830.2  R( 36)= 854.5  R( 37)= 879.3  R( 38)= 904.5  R( 39)= 930.1  R( 40)= 956.3
R( 41)= 983.0  R( 42)=1010.3  R( 43)=1038.2  R( 44)=1066.7  R( 45)=1096.0  R( 46)=1126.0  R( 47)=1156.8  R( 48)=1188.5
R( 49)=1221.1  R( 50)=1254.9  R( 51)=1289.7  R( 52)=1325.9  R(

          POLAR COLLECTOR COUNT IN AZIMUTH ZONE     1

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    5  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    6  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    7  N( 23)=    7  N( 24)=    7
N( 25)=    7  N( 26)=    8  N( 27)=    8  N( 28)=    8  N( 29)=    8  N( 30)=    9  N( 31)=    9  N( 32)=    9
N( 33)=    9  N( 34)=   10  N( 35)=   10  N( 36)=   10  N( 37)=   11  N( 38)=   11  N( 39)=   11  N( 40)=   11
N( 41)=   12  N( 42)=   12  N( 43)=   12  N( 44)=   13  N( 45)=   13  N( 46)=   14  N( 47)=   14  N( 48)=   14
N( 49)=   15  N( 50)=   15  N( 51)=   15  N( 52)=   16  N(

          POLAR RADII IN AZIMUTH ZONE     2

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 197.9  R(  4)= 214.3  R(  5)= 230.8  R(  6)= 247.4  R(  7)= 264.2  R(  8)= 281.1
R(  9)= 298.2  R( 10)= 315.4  R( 11)= 332.8  R( 12)= 350.3  R( 13)= 367.9  R( 14)= 385.8  R( 15)= 403.8  R( 16)= 422.0
R( 17)= 440.3  R( 18)= 458.8  R( 19)= 477.6  R( 20)= 496.5  R( 21)= 515.6  R( 22)= 534.9  R( 23)= 554.4  R( 24)= 574.2
R( 25)= 594.1  R( 26)= 614.3  R( 27)= 634.8  R( 28)= 655.5  R( 29)= 676.5  R( 30)= 697.7  R( 31)= 719.2  R( 32)= 741.1
R( 33)= 763.2  R( 34)= 785.6  R( 35)= 808.4  R( 36)= 831.5  R( 37)= 855.0  R( 38)= 878.9  R( 39)= 903.2  R( 40)= 927.9
R( 41)= 953.1  R( 42)= 978.8  R( 43)=1004.9  R( 44)=1031.6  R( 45)=1058.8  R( 46)=1086.7  R( 47)=1115.2  R( 48)=1144.4
R( 49)=1174.3  R( 50)=1205.1  R( 51)=1236.7  R( 52)=1269.3  R( 53)=1303.0  R(

          POLAR COLLECTOR COUNT IN AZIMUTH ZONE     2

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    5  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    6  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    6  N( 23)=    7  N( 24)=    7
N( 25)=    7  N( 26)=    7  N( 27)=    8  N( 28)=    8  N( 29)=    8  N( 30)=    8  N( 31)=    9  N( 32)=    9
N( 33)=    9  N( 34)=    9  N( 35)=   10  N( 36)=   10  N( 37)=   10  N( 38)=   11  N( 39)=   11  N( 40)=   11
N( 41)=   11  N( 42)=   12  N( 43)=   12  N( 44)=   12  N( 45)=   13  N( 46)=   13  N( 47)=   13  N( 48)=   14
N( 49)=   14  N( 50)=   14  N( 51)=   15  N( 52)=   15  N( 53)=   16  N(

          POLAR RADII IN AZIMUTH ZONE     3

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 197.8  R(  4)= 213.8  R(  5)= 229.9  R(  6)= 246.2  R(  7)= 262.5  R(  8)= 279.0
R(  9)= 295.7  R( 10)= 312.4  R( 11)= 329.4  R( 12)= 346.4  R( 13)= 363.6  R( 14)= 380.9  R( 15)= 398.4  R( 16)= 416.1
R( 17)= 433.9  R( 18)= 451.9  R( 19)= 470.0  R( 20)= 488.4  R( 21)= 506.9  R( 22)= 525.6  R( 23)= 544.5  R( 24)= 563.6
R( 25)= 582.8  R( 26)= 602.3  R( 27)= 622.1  R( 28)= 642.0  R( 29)= 662.2  R( 30)= 682.6  R( 31)= 703.3  R( 32)= 724.2
R( 33)= 745.4  R( 34)= 766.9  R( 35)= 788.7  R( 36)= 810.8  R( 37)= 833.2  R( 38)= 856.0  R( 39)= 879.1  R( 40)= 902.5
R( 41)= 926.4  R( 42)= 950.6  R( 43)= 975.3  R( 44)=1000.4  R( 45)=1026.0  R( 46)=1052.1  R( 47)=1078.7  R( 48)=1105.9
R( 49)=1133.6  R( 50)=1162.1  R( 51)=1191.2  R( 52)=1221.1  R( 53)=1251.7  R( 54)=1283.3  R( 55)=1315.7  R(

          POLAR COLLECTOR COUNT IN AZIMUTH ZONE     3

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    5  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    5  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    6  N( 23)=    7  N( 24)=    7
N( 25)=    7  N( 26)=    7  N( 27)=    7  N( 28)=    8  N( 29)=    8  N( 30)=    8  N( 31)=    8  N( 32)=    9
N( 33)=    9  N( 34)=    9  N( 35)=    9  N( 36)=   10  N( 37)=   10  N( 38)=   10  N( 39)=   11  N( 40)=   11
N( 41)=   11  N( 42)=   11  N( 43)=   12  N( 44)=   12  N( 45)=   12  N( 46)=   13  N( 47)=   13  N( 48)=   13
N( 49)=   14  N( 50)=   14  N( 51)=   14  N( 52)=   15  N( 53)=   15  N( 54)=   15  N( 55)=   16  N(

          POLAR RADII IN AZIMUTH ZONE     4

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 197.8  R(  4)= 213.6  R(  5)= 229.4  R(  6)= 245.3  R(  7)= 261.2  R(  8)= 277.3
R(  9)= 293.6  R( 10)= 309.9  R( 11)= 326.4  R( 12)= 343.0  R( 13)= 359.8  R( 14)= 376.6  R( 15)= 393.7  R( 16)= 410.8
R( 17)= 428.2  R( 18)= 445.6  R( 19)= 463.3  R( 20)= 481.0  R( 21)= 499.0  R( 22)= 517.1  R( 23)= 535.4  R( 24)= 553.9
R( 25)= 572.6  R( 26)= 591.4  R( 27)= 610.5  R( 28)= 629.7  R( 29)= 649.2  R( 30)= 668.9  R( 31)= 688.8  R( 32)= 708.9
R( 33)= 729.3  R( 34)= 749.9  R( 35)= 770.8  R( 36)= 792.0  R( 37)= 813.4  R( 38)= 835.2  R( 39)= 857.2  R( 40)= 879.6
R( 41)= 902.3  R( 42)= 925.3  R( 43)= 948.7  R( 44)= 972.5  R( 45)= 996.6  R( 46)=1021.2  R( 47)=1046.3  R( 48)=1071.8
R( 49)=1097.8  R( 50)=1124.3  R( 51)=1151.4  R( 52)=1179.1  R( 53)=1207.4  R( 54)=1236.4  R( 55)=1266.1  R( 56)=1296.6
R( 57)=1328.0  R(

          POLAR COLLECTOR COUNT IN AZIMUTH ZONE     4

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    4  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    5  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    6  N( 23)=    6  N( 24)=    7
N( 25)=    7  N( 26)=    7  N( 27)=    7  N( 28)=    8  N( 29)=    8  N( 30)=    8  N( 31)=    8  N( 32)=    9
N( 33)=    9  N( 34)=    9  N( 35)=    9  N( 36)=    9  N( 37)=   10  N( 38)=   10  N( 39)=   10  N( 40)=   11
N( 41)=   11  N( 42)=   11  N( 43)=   11  N( 44)=   12  N( 45)=   12  N( 46)=   12  N( 47)=   13  N( 48)=   13
N( 49)=   13  N( 50)=   13  N( 51)=   14  N( 52)=   14  N( 53)=   14  N( 54)=   15  N( 55)=   15  N( 56)=   16
N( 57)=   16  N(
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         POLAR RADII IN AZIMUTH ZONE    5

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 197.8  R(  4)= 213.6  R(  5)= 229.4  R(  6)= 245.3  R(  7)= 261.2  R(  8)= 277.3
R(  9)= 293.6  R( 10)= 309.9  R( 11)= 326.4  R( 12)= 343.0  R( 13)= 359.8  R( 14)= 376.6  R( 15)= 393.7  R( 16)= 410.8
R( 17)= 428.2  R( 18)= 445.6  R( 19)= 463.3  R( 20)= 481.0  R( 21)= 499.0  R( 22)= 517.1  R( 23)= 535.4  R( 24)= 553.9
R( 25)= 572.6  R( 26)= 591.4  R( 27)= 610.5  R( 28)= 629.7  R( 29)= 649.2  R( 30)= 668.9  R( 31)= 688.8  R( 32)= 708.9
R( 33)= 729.3  R( 34)= 749.9  R( 35)= 770.8  R( 36)= 792.0  R( 37)= 813.4  R( 38)= 835.2  R( 39)= 857.2  R( 40)= 879.6
R( 41)= 902.3  R( 42)= 925.3  R( 43)= 948.7  R( 44)= 972.5  R( 45)= 996.6  R( 46)=1021.2  R( 47)=1046.3  R( 48)=1071.8
R( 49)=1097.8  R( 50)=1124.3  R( 51)=1151.4  R( 52)=1179.1  R( 53)=1207.4  R( 54)=1236.4  R( 55)=1266.1  R( 56)=1296.6
R( 57)=1328.0  R(

         POLAR COLLECTOR COUNT IN AZIMUTH ZONE    5

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    4  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    5  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    6  N( 23)=    6  N( 24)=    7
N( 25)=    7  N( 26)=    7  N( 27)=    7  N( 28)=    8  N( 29)=    8  N( 30)=    8  N( 31)=    8  N( 32)=    9
N( 33)=    9  N( 34)=    9  N( 35)=    9  N( 36)=    9  N( 37)=   10  N( 38)=   10  N( 39)=   10  N( 40)=   11
N( 41)=   11  N( 42)=   11  N( 43)=   11  N( 44)=   12  N( 45)=   12  N( 46)=   12  N( 47)=   13  N( 48)=   13
N( 49)=   13  N( 50)=   13  N( 51)=   14  N( 52)=   14  N( 53)=   14  N( 54)=   15  N( 55)=   15  N( 56)=   16
N( 57)=   16  N(

         POLAR RADII IN AZIMUTH ZONE    6

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 197.8  R(  4)= 213.8  R(  5)= 229.9  R(  6)= 246.2  R(  7)= 262.5  R(  8)= 279.0
R(  9)= 295.7  R( 10)= 312.4  R( 11)= 329.4  R( 12)= 346.4  R( 13)= 363.6  R( 14)= 380.9  R( 15)= 398.4  R( 16)= 416.1
R( 17)= 433.9  R( 18)= 451.9  R( 19)= 470.0  R( 20)= 488.4  R( 21)= 506.9  R( 22)= 525.6  R( 23)= 544.5  R( 24)= 563.6
R( 25)= 582.8  R( 26)= 602.3  R( 27)= 622.1  R( 28)= 642.0  R( 29)= 662.2  R( 30)= 682.6  R( 31)= 703.3  R( 32)= 724.2
R( 33)= 745.4  R( 34)= 766.9  R( 35)= 788.7  R( 36)= 810.8  R( 37)= 833.2  R( 38)= 856.0  R( 39)= 879.1  R( 40)= 902.5
R( 41)= 926.4  R( 42)= 950.6  R( 43)= 975.3  R( 44)=1000.4  R( 45)=1026.0  R( 46)=1052.1  R( 47)=1078.7  R( 48)=1105.9
R( 49)=1133.6  R( 50)=1162.1  R( 51)=1191.2  R( 52)=1221.1  R( 53)=1251.7  R( 54)=1283.3  R( 55)=1315.7  R(

         POLAR COLLECTOR COUNT IN AZIMUTH ZONE    6

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    5  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    5  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    6  N( 23)=    7  N( 24)=    7
N( 25)=    7  N( 26)=    7  N( 27)=    7  N( 28)=    8  N( 29)=    8  N( 30)=    8  N( 31)=    8  N( 32)=    9
N( 33)=    9  N( 34)=    9  N( 35)=    9  N( 36)=   10  N( 37)=   10  N( 38)=   10  N( 39)=   11  N( 40)=   11
N( 41)=   11  N( 42)=   11  N( 43)=   12  N( 44)=   12  N( 45)=   12  N( 46)=   13  N( 47)=   13  N( 48)=   13
N( 49)=   14  N( 50)=   14  N( 51)=   14  N( 52)=   15  N( 53)=   15  N( 54)=   15  N( 55)=   16  N(

         POLAR RADII IN AZIMUTH ZONE    7

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 197.9  R(  4)= 214.3  R(  5)= 230.8  R(  6)= 247.4  R(  7)= 264.2  R(  8)= 281.1
R(  9)= 298.2  R( 10)= 315.4  R( 11)= 332.8  R( 12)= 350.3  R( 13)= 367.9  R( 14)= 385.8  R( 15)= 403.8  R( 16)= 422.0
R( 17)= 440.3  R( 18)= 458.8  R( 19)= 477.6  R( 20)= 496.5  R( 21)= 515.6  R( 22)= 534.9  R( 23)= 554.4  R( 24)= 574.2
R( 25)= 594.1  R( 26)= 614.3  R( 27)= 634.8  R( 28)= 655.5  R( 29)= 676.5  R( 30)= 697.7  R( 31)= 719.2  R( 32)= 741.1
R( 33)= 763.2  R( 34)= 785.6  R( 35)= 808.4  R( 36)= 831.5  R( 37)= 855.0  R( 38)= 878.9  R( 39)= 903.2  R( 40)= 927.9
R( 41)= 953.1  R( 42)= 978.8  R( 43)=1004.9  R( 44)=1031.6  R( 45)=1058.8  R( 46)=1086.7  R( 47)=1115.2  R( 48)=1144.4
R( 49)=1174.3  R( 50)=1205.1  R( 51)=1236.7  R( 52)=1269.3  R( 53)=1303.0  R(

         POLAR COLLECTOR COUNT IN AZIMUTH ZONE    7

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    5  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    6  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    6  N( 23)=    7  N( 24)=    7
N( 25)=    7  N( 26)=    7  N( 27)=    8  N( 28)=    8  N( 29)=    8  N( 30)=    8  N( 31)=    9  N( 32)=    9
N( 33)=    9  N( 34)=    9  N( 35)=   10  N( 36)=   10  N( 37)=   10  N( 38)=   11  N( 39)=   11  N( 40)=   11
N( 41)=   11  N( 42)=   12  N( 43)=   12  N( 44)=   12  N( 45)=   13  N( 46)=   13  N( 47)=   13  N( 48)=   14
N( 49)=   14  N( 50)=   14  N( 51)=   15  N( 52)=   15  N( 53)=   16  N(

         POLAR RADII IN AZIMUTH ZONE    8

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 198.3  R(  4)= 215.1  R(  5)= 232.0  R(  6)= 249.1  R(  7)= 266.3  R(  8)= 283.6
R(  9)= 301.2  R( 10)= 318.9  R( 11)= 336.7  R( 12)= 354.7  R( 13)= 372.9  R( 14)= 391.2  R( 15)= 409.8  R( 16)= 428.5
R( 17)= 447.4  R( 18)= 466.6  R( 19)= 485.9  R( 20)= 505.4  R( 21)= 525.2  R( 22)= 545.2  R( 23)= 565.4  R( 24)= 585.9
R( 25)= 606.6  R( 26)= 627.6  R( 27)= 648.8  R( 28)= 670.4  R( 29)= 692.2  R( 30)= 714.4  R( 31)= 736.8  R( 32)= 759.6
R( 33)= 782.8  R( 34)= 806.3  R( 35)= 830.2  R( 36)= 854.5  R( 37)= 879.3  R( 38)= 904.5  R( 39)= 930.1  R( 40)= 956.3
R( 41)= 983.0  R( 42)=1010.3  R( 43)=1038.2  R( 44)=1066.7  R( 45)=1096.0  R( 46)=1126.0  R( 47)=1156.8  R( 48)=1188.5
R( 49)=1221.1  R( 50)=1254.9  R( 51)=1289.7  R( 52)=1325.9  R(

         POLAR COLLECTOR COUNT IN AZIMUTH ZONE    8

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    5  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    6  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    7  N( 23)=    7  N( 24)=    7
N( 25)=    7  N( 26)=    8  N( 27)=    8  N( 28)=    8  N( 29)=    8  N( 30)=    9  N( 31)=    9  N( 32)=    9
N( 33)=    9  N( 34)=   10  N( 35)=   10  N( 36)=   10  N( 37)=   11  N( 38)=   11  N( 39)=   11  N( 40)=   11
N( 41)=   12  N( 42)=   12  N( 43)=   12  N( 44)=   13  N( 45)=   13  N( 46)=   14  N( 47)=   14  N( 48)=   14
N( 49)=   15  N( 50)=   15  N( 51)=   15  N( 52)=   16  N(
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          GROUND COVER IN POLAR ZONE     1                                                                        (4)

GC(  1)= .381  GC(  2)= .347  GC(  3)= .316  GC(  4)= .290  GC(  5)= .400  GC(  6)= .371  GC(  7)= .344
GC(  8)= .321  GC(  9)= .300  GC( 10)= .375  GC( 11)= .352  GC( 12)= .332  GC( 13)= .313  GC( 14)= .369
GC( 15)= .349  GC( 16)= .331  GC( 17)= .314  GC( 18)= .357  GC( 19)= .340  GC( 20)= .323  GC( 21)= .307
GC( 22)= .342  GC( 23)= .326  GC( 24)= .311  GC( 25)= .296  GC( 26)= .323  GC( 27)= .309  GC( 28)= .295
GC( 29)= .282  GC( 30)= .303  GC( 31)= .289  GC( 32)= .276  GC( 33)= .264  GC( 34)= .280  GC( 35)= .268
GC( 36)= .256  GC( 37)= .268  GC( 38)= .256  GC( 39)= .244  GC( 40)= .233  GC( 41)= .242  GC( 42)= .230
GC( 43)= .219  GC( 44)= .225  GC( 45)= .214  GC( 46)= .218  GC( 47)= .207  GC( 48)= .195  GC( 49)= .197
GC( 50)= .185  GC( 51)= .174  GC( 52)= .173  GC(

          GROUND COVER IN POLAR ZONE     2

GC(  1)= .381  GC(  2)= .355  GC(  3)= .325  GC(  4)= .298  GC(  5)= .413  GC(  6)= .383  GC(  7)= .356
GC(  8)= .333  GC(  9)= .311  GC( 10)= .390  GC( 11)= .367  GC( 12)= .346  GC( 13)= .326  GC( 14)= .386
GC( 15)= .365  GC( 16)= .346  GC( 17)= .329  GC( 18)= .375  GC( 19)= .357  GC( 20)= .340  GC( 21)= .324
GC( 22)= .309  GC( 23)= .344  GC( 24)= .329  GC( 25)= .314  GC( 26)= .300  GC( 27)= .328  GC( 28)= .314
GC( 29)= .301  GC( 30)= .288  GC( 31)= .310  GC( 32)= .296  GC( 33)= .284  GC( 34)= .272  GC( 35)= .289
GC( 36)= .277  GC( 37)= .265  GC( 38)= .279  GC( 39)= .266  GC( 40)= .255  GC( 41)= .243  GC( 42)= .254
GC( 43)= .242  GC( 44)= .231  GC( 45)= .239  GC( 46)= .227  GC( 47)= .216  GC( 48)= .221  GC( 49)= .210
GC( 50)= .199  GC( 51)= .201  GC( 52)= .190  GC( 53)= .191  GC(

          GROUND COVER IN POLAR ZONE     3

GC(  1)= .381  GC(  2)= .357  GC(  3)= .333  GC(  4)= .306  GC(  5)= .425  GC(  6)= .395  GC(  7)= .368
GC(  8)= .344  GC(  9)= .323  GC( 10)= .404  GC( 11)= .381  GC( 12)= .359  GC( 13)= .340  GC( 14)= .402
GC( 15)= .381  GC( 16)= .362  GC( 17)= .344  GC( 18)= .328  GC( 19)= .374  GC( 20)= .357  GC( 21)= .341
GC( 22)= .325  GC( 23)= .363  GC( 24)= .347  GC( 25)= .332  GC( 26)= .318  GC( 27)= .304  GC( 28)= .333
GC( 29)= .319  GC( 30)= .306  GC( 31)= .293  GC( 32)= .317  GC( 33)= .304  GC( 34)= .291  GC( 35)= .279
GC( 36)= .298  GC( 37)= .285  GC( 38)= .274  GC( 39)= .289  GC( 40)= .277  GC( 41)= .265  GC( 42)= .254
GC( 43)= .265  GC( 44)= .254  GC( 45)= .243  GC( 46)= .251  GC( 47)= .240  GC( 48)= .229  GC( 49)= .235
GC( 50)= .224  GC( 51)= .213  GC( 52)= .217  GC( 53)= .206  GC( 54)= .195  GC( 55)= .196  GC(

          GROUND COVER IN POLAR ZONE     4

GC(  1)= .381  GC(  2)= .357  GC(  3)= .336  GC(  4)= .314  GC(  5)= .437  GC(  6)= .406  GC(  7)= .379
GC(  8)= .355  GC(  9)= .333  GC( 10)= .418  GC( 11)= .394  GC( 12)= .373  GC( 13)= .353  GC( 14)= .334
GC( 15)= .397  GC( 16)= .377  GC( 17)= .359  GC( 18)= .342  GC( 19)= .392  GC( 20)= .374  GC( 21)= .357
GC( 22)= .342  GC( 23)= .327  GC( 24)= .365  GC( 25)= .350  GC( 26)= .335  GC( 27)= .321  GC( 28)= .352
GC( 29)= .338  GC( 30)= .324  GC( 31)= .312  GC( 32)= .337  GC( 33)= .323  GC( 34)= .311  GC( 35)= .298
GC( 36)= .287  GC( 37)= .306  GC( 38)= .294  GC( 39)= .282  GC( 40)= .298  GC( 41)= .287  GC( 42)= .275
GC( 43)= .264  GC( 44)= .276  GC( 45)= .265  GC( 46)= .254  GC( 47)= .264  GC( 48)= .253  GC( 49)= .242
GC( 50)= .231  GC( 51)= .238  GC( 52)= .227  GC( 53)= .217  GC( 54)= .221  GC( 55)= .210  GC( 56)= .213
GC( 57)= .202  GC(

                    HELIAKI VERSION 13. TIME POINT AND/OR ANNUAL ENERGY                                   (5)
                    ROUND FIELD WITH LOW PROFILE HELIOSTATS

               NSTOPS      NCOL        RFIELD        TOWER H         GCOVER
                 11        1596       878.000        415.000          .300

               NHF            WFV            WD            XDF           ALEN          SPACEF
                 4           10.38          10.38         16.60          49.80          1.00

       GAP        WLONG        WCROSS        WTRI        XLTRI        WSIDE        WJCROS        HTMIR        HTCROS
      .250         .480          .385         .177        4.681         .840          .224          .833          .833


                         THE CENTER WAVELENGTHS OF THE TWENTY EQUAL ENERGY BANDS                          (6)
                  .39000    .44000    .48000    .51000    .54000    .57000    .60000    .63000    .66000    .70000
                  .74000    .78000    .82000    .87000    .96000   1.02000   1.08000   1.22000   1.48000   1.68000


                                                                                                          (7)
                TDISX         TDISY        AFIELD          RCO
                0.000      -439.000     2336271.678      165.000


                                          3/21/80                                                          (8)
       LATITUDE=  35.68          HOUR   12      MIN    0



                         CAVITY RECEIVER SPECS                                                            (9)

              SEP        DD1        DD2       RUIF       HCAV        DD3       AIMHGT
             19.3       26.3       45.9        0.0       54.0       49.5        9.6


                  RCONE              THECON              HTOT              TTILT                         (10)
                  18.06                .47               19.29               0.00

                  WAPMAX             WAPMIN            OFFSET
                   25.0               18.3               0.0

    PROGRAM OPTIONS USED                                                                                 (11)
         INDIVIDUAL FOCUSING
         INDIVIDUAL TOE-IN
         TOEIN STRATEGY FOR  3/21 AT 12.0
         FACETS GANGED
```

HELIOSTAT OPTICAL PARAMETERS (12)

PAX1B	PAX2B	TSB	PHB	PAX1V	PAX2V	TSV	PHV
0.00000	0.00000	0.00000	0.00000	.11500	.11500	.05000	.05000

(13)

ELZ	THETAZ	XKWNI
55.76166	179.54158	.98072

********** CONVERSION FACTOR = .1984517112E+06 ********** (14)

STATISTICS FOR 10 RUNS AT 800 RAYS PER RUN (15)

**********OUTPUT CODE********** (16)

ETA1=FRACTION OF FIELD FLUX THAT HIT MIRRORS
ETA2=REFLECTANCE
ETA3=FRACTION OF FLUX NOT OBSCURED ON THE WAY OUT
ETA4=FRACTION OF FLUX THAT HIT TOWER
ETA5=FRACTION OF FIELD FLUX THAT HIT CAVITY
ETA6=FRACTION OF FIELD FLUX THAT HIT THE CAVITY WALLS
ETA7=FRACTION OF FIELD FLUX THAT WAS IN TOWER SHADOW

EFLUX1=TOTAL FLUX ON FIELD IN KW
EFLUX2=TOTAL FLUX ON MIRRORS IN KW
EFLUX3=TOTAL FLUX LEAVING MIRRORS IN KW
EFLUX4=TOTAL FLUX CLEANLY AWAY FROM FIELD IN KW
EFLUX5=TOTAL FLUX ON POWER TOWER IN KW
EFLUX6=FLUX ON CAVITY DIFFUSER IN KW
EFLUX7=FLUX ON CAVITY WALLS IN KW
EFLUX8=FLUX ON CAVITY CEILING IN KW .

N1=RAYS DRAWN BEFORE SUNRISE
N2=RAYS DRAWN WHEN THE SUN WAS TOO LOW
N3=RAYS DRAWN THAT HIT THE OPEN FIELD
N4=RAYS WHICH HIT MIRROR BUT WERE LOST IN SPACE
N5=RAYS DRAWN THAT WERE BLOCKED IN ONBLOCKS
N6=RAYS THAT WERE OBSCURED IN OFFBLOCK
N7=RAYS WHICH HIT CAVITY DIFFUSER
N8=RAYS WHICH HIT WALLS
N9=RAYS WHICH HIT ROOF
N10=RAYS WHICH MISSED HIGH
N11=RAYS WHICH MISSED ACROSS THE FRONT
N12=RAYS WHICH MISSED LOW
N13=RAYS WHICH HIT SUPPORTS
N14=RAYS WHICH WERE IN THE TOWER SHADOW
N15=RAYS WHICH WHISTLED THRU
N16=RAYS WHICH FRAME SHADOWED ON SAME HELIO
N17=RAYS WHICH FRAME SHADOWED ON OTHER HELIO
N18=RAYS WHICH FRAME BLOCKED ON SAME HELIO
N19=RAYS WHICH FRAME BLOCKED ON OTHER HELIO

ETA1	ETA2	ETA3	ETA4	ETA5	ETA6	ETA7
.29788	.90000	1.00000	.97944	.26257	.23670	.00363

EFLUX1	EFLUX2	EFLUX3	EFLUX4	EFLUX5	EFLUX6	EFLUX7	EFLUX8
.198452E+06	.591138E+05	.532024E+05	.532024E+05	.521085E+05	.267910E+06	.469735E+05	.513494E+04

N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19
0	0	5586	0	0	0	0	2104	230	14	3	4	3	29	25	2	0	0	0

TIME POINT RUN (17)

ACTUAL MIRROR AREA	DIRECT NORMAL ENERGY
63838.8130	.9807

(18)

ENERGY (KWH) PER SQ. METER	
UNSHADOWED	.9268
SHADOWED	.9260
LEAVING MIRROR	.8334
CLEANLY AWAY	.8334
THRU APERTURE	.8163
ABSORBED	.7346

(19)

TRACKING EFFICIENCY		
	(UNSHADOWED)	.9450
	(CLEANLY AWAY)	.8498

(20)

NUMBER OF SUPPORTS	SUPPORT WIDTH	KWH ON SUPPORTS
3	2.0	67.0

HELIOSTAT FRAME HITS (21)

TOP FRAME	SIDE FRAMES	CROSS FRAMES	BOTTOM FRAME
2	0 0	0 0 0	0

ENERGY LOST ON FRAME IN KWH

FRAME SHADOW		FRAME BLOCK	
ON SAME HELIO	ON DIFF HELIO	ON SAME HELIO	ON DIFF HELIO
49.6	0.0	0.0	0.0

SUMMARY OF HIT AND BLOCKAGE COUNTS BY FACET (22)

FACET INDEX	TOTAL HITS	HITS LESS BLOCKS	HITS BLOCKED BY 1	2	3	4
1	568	568	0	0	0	0
2	615	615	0	0	0	0
3	624	624	0	0	0	0
4	576	576	0	0	0	0

OFFBLOCK SUMMARY

FACET	1	2	3	4
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

CAVITY WALL MAP (23)

	FROM	0.0	45.0	90.0	135.0	180.0	225.0	270.0	315.0
	TO	45.0	90.0	135.0	180.0	225.0	270.0	315.0	360.0
TOP FROM	TO								
43.2	54.0	.019	.019	.031	.025	.022	.030	.015	.019
32.4	43.2	.039	.025	.062	.048	.035	.073	.019	.045
21.6	32.4	.019	.040	.117	.112	.117	.140	.038	.022
10.8	21.6	.003	.027	.200	.222	.242	.207	.029	.001
0.0	10.8	0.000	.008	.070	.119	.078	.064	.006	0.000
BOTTOM									

CIRCUMFERENTIAL AVE WALL FLUX (24)

FROM	TO	AVE FLUX	AT	SUM BOTTOM UP	AT	SUM TOP DOWN
0.0	10.8	.023	54.0	0.000	0.0	0.000
10.8	21.6	.043	43.2	6.720	10.8	3.527
21.6	32.4	.076	32.4	24.893	21.6	10.292
32.4	43.2	.116	21.6	36.681	32.4	22.080
43.2	54.0	.043	10.8	43.446	43.2	40.253
			0.0	46.973	54.0	46.973

CAVITY CEILING MAP (25)

		FROM	0.00	11.07	15.65	19.17	22.14
		TO	11.07	15.65	19.17	22.14	24.75
		AVE	7.83	13.56	17.50	20.71	23.48
FROM	TO	AVE					
0.0	45.0	22.5	.0200	.0150	.0300	.0200	.0200
45.0	90.0	67.5	.0300	.0300	.0200	.0250	.0500
90.0	135.0	112.5	.0300	.0400	.0200	.0200	.0450
135.0	180.0	157.5	.0200	.0250	.0050	.0350	.0050
180.0	225.0	202.5	.0250	.0450	.0350	.0150	.0250
225.0	270.0	247.5	.0450	.0500	.0300	.0599	.0500
270.0	315.0	292.5	.0400	.0500	.0250	.0150	.0200
315.0	360.0	337.5	.0250	.0250	.0250	.0250	.0150

AZZIMOUTH AVE CEILING FLUX (26)

FROM	TO	AVE	
0.0	11.1	7.8	.0293
11.1	15.7	13.6	.0350
15.7	19.2	17.5	.0237
19.2	22.1	20.7	.0268
22.1	24.8	23.5	.0287

KW/SQ.M FLUX MAP OF POWER TOWER MIRROR FIELD (27)

0.000000	0.000000	.046762	.093524	.155874	.163667	.085730	.031175	0.000000	0.000000
0.000000	.101318	.210429	.179255	.155874	.163667	.140286	.194842	.132493	0.000000
.046762	.179255	.194842	.280573	.241604	.202636	.264985	.202636	.148080	.054556
.132493	.194842	.296160	.218223	.241604	.257191	.296160	.163667	.187048	.163667
.116905	.249398	.179255	.264985	.296160	.257191	.202636	.288366	.187048	.187048
.264985	.327335	.202636	.428652	.241604	.296160	.342922	.327335	.311747	.210429
.163667	.218223	.280573	.311747	.179255	.264985	.288366	.350716	.272779	.163667
.085730	.233810	.257191	.202636	.038968	.023381	.319541	.327335	.187048	.101318
0.000000	.163667	.249398	.272779	.179255	.148080	.296160	.210429	.148080	0.000000
0.000000	0.000000	.116905	.241604	.381890	.264985	.163667	.077937	0.000000	0.000000

HITS ON THE HELIO FIELD (28)

0	0	6	12	20	21	11	4	0	0
0	13	27	23	20	21	18	25	17	0
6	23	25	36	31	26	34	26	19	7
17	25	38	28	31	33	38	21	24	21
15	32	23	34	38	33	26	37	24	24
34	42	26	55	31	38	44	42	40	27
21	28	36	40	23	34	37	45	35	21
11	30	33	26	5	3	41	42	24	13
0	21	32	35	23	19	38	27	19	0
0	0	15	31	49	34	21	10	0	0

FLUX ON THE FIELD (29)

0.	0.	.134F+03	.268E+03	.447E+03	.469E+03	.246E+03	.893E+02	0.	0.
0.	.290E+03	.603F+03	.513E+03	.447E+03	.469E+03	.402E+03	.558E+03	.390E+03	0.
.134E+03	.513E+03	.558F+03	.804E+03	.692E+03	.580E+03	.759E+03	.580E+03	.424E+03	.156E+03
.390E+03	.558E+03	.848E+03	.625E+03	.692E+03	.737E+03	.848E+03	.469E+03	.536E+03	.469E+03
.335E+03	.714E+03	.513E+03	.759E+03	.848E+03	.737E+03	.580E+03	.826E+03	.536E+03	.536E+03
.759E+03	.938E+03	.580E+03	.123E+04	.692E+03	.848E+03	.982E+03	.938E+03	.893E+03	.603E+03
.469E+03	.625E+03	.804E+03	.893E+03	.513E+03	.759E+03	.826E+03	.100E+04	.781E+03	.469E+03
.246E+03	.670E+03	.737F+03	.560E+03	.112E+03	.670E+02	.915E+03	.938E+03	.536E+03	.290E+03
0.	.469E+03	.714F+03	.781E+03	.513E+03	.424E+03	.848E+03	.603E+03	.424E+03	0.
0.	0.	.335E+03	.692E+03	.109E+04	.759E+03	.469E+03	.223E+03	0.	0.

FLUX LOST TO SHADOWING (30)

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

FLUX LOST TO HELIOSTAT TO HELIOSTAT SHADING (31)

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

FLUX LOST TO BLOCKAGE (32)

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TOTAL FLUX (33)

0.	0.	.13395E+03	.26791E+03	.44652E+03	.46884E+03	.24558E+03	.89303F+02	0.	0.
0.	.29024F+03	.60280E+03	.51349E+03	.44652E+03	.46884E+03	.40186E+03	.55815E+03	.37954E+03	0.
.13395E+03	.51349F+03	.55815E+03	.80373E+03	.69210E+03	.58047E+03	.75908E+03	.58047F+03	.42419E+03	.15628F+03
.37954E+03	.55815F+03	.84839E+03	.62512E+03	.69210E+03	.73675E+03	.84838E+03	.46884F+03	.53582E+03	.46884F+03
.33489E+03	.71443F+03	.51349E+03	.75908E+03	.84838E+03	.73675E+03	.58047E+03	.82606E+03	.53582E+03	.53582F+03
.75908E+03	.93768F+03	.58047E+03	.12279E+04	.69210E+03	.84838E+03	.98234E+03	.93768F+03	.89303E+03	.60280F+03
.46884E+03	.62512F+03	.80373E+03	.89303E+03	.51349E+03	.75908E+03	.82606E+03	.10047F+04	.78140E+03	.46884F+03
.24558E+03	.66977F+03	.73675E+03	.58047E+03	.11163E+03	.66977E+02	.91536E+03	.93768E+03	.53582E+03	.29024F+03
0.	.46884F+03	.71443E+03	.78140E+03	.51349E+03	.42419E+03	.84838E+03	.60280F+03	.42419E+03	0.
0.	0.	.33489E+03	.69210E+03	.10940E+04	.75908E+03	.46884E+03	.22326E+03	0.	0.

PERCENT FLUX LOST TO SHADOWS (34a)

```
          I      I 0.     0.     0.     0.     0.     0.            I      I
          I 0.     0.     0.     0.     0.     0.     0.     0.             I
  0.        0.     0.     0.     0.     0.     0.     0.     0.     0.
  0.        0.     0.     0.     0.     0.     0.     0.     0.     0.
  0.        0.     0.     0.     0.     0.     0.     0.     0.     0.
  0.        0.     0.     0.     0.     0.     0.     0.     0.     0.
  0.        0.     0.     0.     0.     0.     0.     0.     0.     0.
  0.        0.     0.     0.     0.     0.     0.     0.     0.            I
          I 0.     0.     0.     0.     0.     0.     0.            I      I
          I      I 0.     0.     0.     0.     0.
```

PERCENT FLUX LOST TO BLOCKAGE (34b)

	I	I 0.	0.	0.	0.	0.	0.		I	I
	I 0.	0.	0.	0.	0.	0.	0.	0.		I
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	I 0.	0.	0.	0.	0.	0.	0.	0.		I
	I	I 0.	0.	0.	0.	0.	0.		I	I

TOTAL PERCENT OF FLUX LOST (34c)

	I	I 0.	0.	0.	0.	0.	0.		I	I
	I 0.	0.	0.	0.	0.	0.	0.	0.		I
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	I 0.	0.	0.	0.	0.	0.	0.	0.		I
	I	I 0.	0.	0.	0.	0.	0.		I	I

RAYS WHICH MISSED HIGH (35a)

0	0	0	0	1	0	0	1	0	0
0	0	1	0	0	1	0	0	1	0
0	0	0	0	1	0	0	0	1	0
1	0	0	0	0	0	0	0	0	2
0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

RAYS WHICH MISSED LOW (35b)

0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0

RAYS WHICH MISSED ACROSS FRONT (35c)

0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	6	0	0	0	0	0

RAYS WHICH WHISTLED THROUGH (35d)

0	0	0	3	2	0	1	1	0	0
0	1	1	0	1	0	0	2	0	0
1	1	1	1	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	4
1	0	0	0	0	0	0	0	0	1
0	1	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

RAYS WHICH HIT CORBELS (35e)

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1
2	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

SL ARRAY .272779 .179255 .054556 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 (36)

0	0	4	3	3	3	3	4	0	0	0
0	3	2	3	3	3	3	2	3	0	0
4	3	2	1	2	2	2	2	3	4	0
3	2	1	2	2	2	1	3	2	3	0
3	2	3	2	1	2	2	1	2	2	0
2	1	2	1	2	1	1	1	1	2	0
3	2	1	1	3	2	1	1	2	3	0
3	2	2	2	4	4	1	1	2	3	0
0	3	2	2	3	3	1	2	3	0	0
0	0	3	2	1	2	3	3	0	0	0

Used only on nonsequential simulation (1) (2)

(3)

```
        POLAR RADII IN AZIMUTH ZONE    1

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 198.3  R(  4)= 215.1  R(  5)= 232.0  R(  6)= 249.1  R(  7)= 266.3  R(  8)= 283.6
R(  9)= 301.2  R( 10)= 318.9  R( 11)= 336.7  R( 12)= 354.7  R( 13)= 372.9  R( 14)= 391.2  R( 15)= 409.8  R( 16)= 428.5
R( 17)= 447.4  R( 18)= 466.6  R( 19)= 485.9  R( 20)= 505.4  R( 21)= 525.2  R( 22)= 545.2  R( 23)= 565.4  R( 24)= 585.9
R( 25)= 606.6  R( 26)= 627.6  R( 27)= 648.8  R( 28)= 670.4  R( 29)= 692.2  R( 30)= 714.4  R( 31)= 736.8  R( 32)= 759.6
R( 33)= 782.8  R( 34)= 806.3  R( 35)= 830.2  R( 36)= 854.5  R( 37)= 879.3  R( 38)= 904.5  R( 39)= 930.1  R( 40)= 956.3
R( 41)= 983.0  R( 42)=1010.3  R( 43)=1038.2  R( 44)=1066.7  R( 45)=1096.0  R( 46)=1126.0  R( 47)=1156.8  R( 48)=1188.5
R( 49)=1221.1  R( 50)=1254.9  R( 51)=1289.7  R( 52)=1325.9  R(

        POLAR COLLECTOR COUNT IN AZIMUTH ZONE    1

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    5  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    6  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    7  N( 23)=    7  N( 24)=    7
N( 25)=    7  N( 26)=    8  N( 27)=    8  N( 28)=    8  N( 29)=    8  N( 30)=    9  N( 31)=    9  N( 32)=    9
N( 33)=    9  N( 34)=   10  N( 35)=   10  N( 36)=   10  N( 37)=   11  N( 38)=   11  N( 39)=   11  N( 40)=   11
N( 41)=   12  N( 42)=   12  N( 43)=   12  N( 44)=   13  N( 45)=   13  N( 46)=   14  N( 47)=   14  N( 48)=   14
N( 49)=   15  N( 50)=   15  N( 51)=   15  N( 52)=   16  N(

        POLAR RADII IN AZIMUTH ZONE    2

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 197.9  R(  4)= 214.3  R(  5)= 230.8  R(  6)= 247.4  R(  7)= 264.2  R(  8)= 281.1
R(  9)= 298.2  R( 10)= 315.4  R( 11)= 332.8  R( 12)= 350.3  R( 13)= 367.9  R( 14)= 385.8  R( 15)= 403.8  R( 16)= 422.0
R( 17)= 440.3  R( 18)= 458.8  R( 19)= 477.6  R( 20)= 496.5  R( 21)= 515.6  R( 22)= 534.9  R( 23)= 554.4  R( 24)= 574.2
R( 25)= 594.1  R( 26)= 614.3  R( 27)= 634.8  R( 28)= 655.5  R( 29)= 676.5  R( 30)= 697.7  R( 31)= 719.2  R( 32)= 741.1
R( 33)= 763.2  R( 34)= 785.6  R( 35)= 808.4  R( 36)= 831.5  R( 37)= 855.0  R( 38)= 878.9  R( 39)= 903.2  R( 40)= 927.9
R( 41)= 953.1  R( 42)= 978.8  R( 43)=1004.9  R( 44)=1031.6  R( 45)=1058.8  R( 46)=1086.7  R( 47)=1115.2  R( 48)=1144.4
R( 49)=1174.3  R( 50)=1205.1  R( 51)=1236.7  R( 52)=1269.3  R( 53)=1303.0  R(

        POLAR COLLECTOR COUNT IN AZIMUTH ZONE    2

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    5  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    6  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    6  N( 23)=    7  N( 24)=    7
N( 25)=    7  N( 26)=    7  N( 27)=    8  N( 28)=    8  N( 29)=    8  N( 30)=    9  N( 31)=    9  N( 32)=    9
N( 33)=    9  N( 34)=    9  N( 35)=   10  N( 36)=   10  N( 37)=   10  N( 38)=   11  N( 39)=   11  N( 40)=   11
N( 41)=   11  N( 42)=   12  N( 43)=   12  N( 44)=   12  N( 45)=   13  N( 46)=   13  N( 47)=   13  N( 48)=   14
N( 49)=   14  N( 50)=   14  N( 51)=   15  N( 52)=   15  N( 53)=   16  N(

        POLAR RADII IN AZIMUTH ZONE    3

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 197.8  R(  4)= 213.8  R(  5)= 229.9  R(  6)= 246.2  R(  7)= 262.5  R(  8)= 279.0
R(  9)= 295.7  R( 10)= 312.4  R( 11)= 329.4  R( 12)= 346.4  R( 13)= 363.6  R( 14)= 380.9  R( 15)= 398.4  R( 16)= 416.1
R( 17)= 433.9  R( 18)= 451.9  R( 19)= 470.0  R( 20)= 488.4  R( 21)= 506.9  R( 22)= 525.6  R( 23)= 544.5  R( 24)= 563.6
R( 25)= 582.8  R( 26)= 602.3  R( 27)= 622.1  R( 28)= 642.0  R( 29)= 662.2  R( 30)= 682.6  R( 31)= 703.3  R( 32)= 724.2
R( 33)= 745.4  R( 34)= 766.9  R( 35)= 788.7  R( 36)= 810.8  R( 37)= 833.2  R( 38)= 856.0  R( 39)= 879.1  R( 40)= 902.5
R( 41)= 926.4  R( 42)= 950.6  R( 43)= 975.3  R( 44)=1000.4  R( 45)=1026.0  R( 46)=1052.1  R( 47)=1078.7  R( 48)=1105.9
R( 49)=1133.6  R( 50)=1162.1  R( 51)=1191.2  R( 52)=1221.1  R( 53)=1251.7  R( 54)=1283.3  R( 55)=1315.7  R(

        POLAR COLLECTOR COUNT IN AZIMUTH ZONE    3

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    5  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    5  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    6  N( 23)=    7  N( 24)=    7
N( 25)=    7  N( 26)=    7  N( 27)=    7  N( 28)=    8  N( 29)=    8  N( 30)=    8  N( 31)=    8  N( 32)=    9
N( 33)=    9  N( 34)=    9  N( 35)=    9  N( 36)=   10  N( 37)=   10  N( 38)=   10  N( 39)=   11  N( 40)=   11
N( 41)=   11  N( 42)=   11  N( 43)=   12  N( 44)=   12  N( 45)=   12  N( 46)=   13  N( 47)=   13  N( 48)=   13
N( 49)=   14  N( 50)=   14  N( 51)=   14  N( 52)=   15  N( 53)=   15  N( 54)=   15  N( 55)=   16  N(

        POLAR RADII IN AZIMUTH ZONE    4

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 197.8  R(  4)= 213.6  R(  5)= 229.4  R(  6)= 245.3  R(  7)= 261.2  R(  8)= 277.3
R(  9)= 293.6  R( 10)= 309.9  R( 11)= 326.4  R( 12)= 343.0  R( 13)= 359.8  R( 14)= 376.6  R( 15)= 393.7  R( 16)= 410.8
R( 17)= 428.2  R( 18)= 445.6  R( 19)= 463.3  R( 20)= 481.0  R( 21)= 499.0  R( 22)= 517.1  R( 23)= 535.4  R( 24)= 553.9
R( 25)= 572.6  R( 26)= 591.4  R( 27)= 610.5  R( 28)= 629.7  R( 29)= 649.2  R( 30)= 668.9  R( 31)= 688.8  R( 32)= 708.9
R( 33)= 729.3  R( 34)= 749.9  R( 35)= 770.8  R( 36)= 792.0  R( 37)= 813.4  R( 38)= 835.2  R( 39)= 857.2  R( 40)= 879.6
R( 41)= 902.3  R( 42)= 925.3  R( 43)= 948.7  R( 44)= 972.5  R( 45)= 996.6  R( 46)=1021.2  R( 47)=1046.3  R( 48)=1071.8
R( 49)=1097.8  R( 50)=1124.3  R( 51)=1151.4  R( 52)=1179.1  R( 53)=1207.4  R( 54)=1236.4  R( 55)=1266.1  R( 56)=1296.6
R( 57)=1328.0  R(

        POLAR COLLECTOR COUNT IN AZIMUTH ZONE    4

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    4  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    5  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    6  N( 23)=    6  N( 24)=    7
N( 25)=    7  N( 26)=    7  N( 27)=    7  N( 28)=    8  N( 29)=    8  N( 30)=    8  N( 31)=    8  N( 32)=    9
N( 33)=    9  N( 34)=    9  N( 35)=    9  N( 36)=    9  N( 37)=   10  N( 38)=   10  N( 39)=   10  N( 40)=   11
N( 41)=   11  N( 42)=   11  N( 43)=   11  N( 44)=   12  N( 45)=   12  N( 46)=   12  N( 47)=   13  N( 48)=   13
N( 49)=   13  N( 50)=   13  N( 51)=   14  N( 52)=   14  N( 53)=   14  N( 54)=   15  N( 55)=   15  N( 56)=   16
N( 57)=   16  N(

        POLAR RADII IN AZIMUTH ZONE    5

R(  1)= 165.0  R(  2)= 181.6  R(  3)= 197.8  R(  4)= 213.6  R(  5)= 229.4  R(  6)= 245.3  R(  7)= 261.2  R(  8)= 277.3
14.74. 8  R (R (3 8 )4=) =8 3251.32. 6  R (R (39)= 857.2    R5() =4 02)2=9 .84/ 9 .R6(
 6R)(=  4214)5=. 39 0 2R.(3     7R)(= 261.2  R(  4 28))==  922757..33
 (R (4 3 )9=) =9 4289.37. 6  R (R (4 41)0=) 972.5  R( =4 53)0=9 .999 6 .R6(   1R1() =4 63)2=61.042 1 .R2(   1R2() =4 73)4=3.0  R( 1 )1=
R( 49)=1097.8  R( 50)=1124.3  R( 51)=1151.4  R( 52)=1179.1  R( 53)=1207.4  R( 54)=1236.4  R( 55)=1266.1  R( 56)=1296.6
R( 57)=1328.0  R(

        POLAR COLLECTOR COUNT IN AZIMUTH ZONE    5

N(  1)=    2  N(  2)=    2  N(  3)=    2  N(  4)=    2  N(  5)=    3  N(  6)=    3  N(  7)=    3  N(  8)=    3
N(  9)=    3  N( 10)=    4  N( 11)=    4  N( 12)=    4  N( 13)=    4  N( 14)=    4  N( 15)=    5  N( 16)=    5
N( 17)=    5  N( 18)=    5  N( 19)=    6  N( 20)=    6  N( 21)=    6  N( 22)=    6  N( 23)=    6  N( 24)=    7
N( 25)=    7  N( 26)=    7  N( 27)=    7  N( 28)=    8  N( 29)=    8  N( 30)=    8  N( 31)=    8  N( 32)=    9
N( 33)=    9  N( 34)=    9  N( 35)=    9  N( 36)=    9  N( 37)=   10  N( 38)=   10  N( 39)=   10  N( 40)=   11
N( 41)=   11  N( 42)=   11  N( 43)=   11  N( 44)=   12  N( 45)=   12  N( 46)=   12  N( 47)=   13  N( 48)=   13
N( 49)=   13  N( 50)=   13  N( 51)=   14  N( 52)=   14  N( 53)=   14  N( 54)=   15  N( 55)=   15  N( 56)=   16
N( 57)=   16  N(
```

POLAR RADII IN AZIMUTH ZONE 6

R(1)= 165.0	R(2)= 181.6	R(3)= 197.8	R(4)= 213.8	R(5)= 229.9	R(6)= 246.2	R(7)= 262.5	R(8)= 279.0
R(9)= 295.7	R(10)= 312.4	R(11)= 329.4	R(12)= 346.4	R(13)= 363.6	R(14)= 380.9	R(15)= 398.4	R(16)= 416.1
R(17)= 433.9	R(18)= 451.9	R(19)= 470.0	R(20)= 488.4	R(21)= 506.9	R(22)= 525.6	R(23)= 544.5	R(24)= 563.6
R(25)= 582.8	R(26)= 602.3	R(27)= 622.1	R(28)= 642.0	R(29)= 662.2	R(30)= 682.6	R(31)= 703.3	R(32)= 724.2
R(33)= 745.4	R(34)= 766.9	R(35)= 788.7	R(36)= 810.8	R(37)= 833.2	R(38)= 856.0	R(39)= 879.1	R(40)= 902.5
R(41)= 926.4	R(42)= 950.6	R(43)= 975.3	R(44)=1000.4	R(45)=1026.0	R(46)=1052.1	R(47)=1078.7	R(48)=1105.9
R(49)=1133.6	R(50)=1162.1	R(51)=1191.2	R(52)=1221.1	R(53)=1251.7	R(54)=1283.3	R(55)=1315.7	R(

POLAR COLLECTOR COUNT IN AZIMUTH ZONE 6

N(1)= 2	N(2)= 2	N(3)= 2	N(4)= 2	N(5)= 3	N(6)= 3	N(7)= 3	N(8)= 3
N(9)= 3	N(10)= 4	N(11)= 4	N(12)= 4	N(13)= 4	N(14)= 5	N(15)= 5	N(16)= 5
N(17)= 5	N(18)= 5	N(19)= 6	N(20)= 6	N(21)= 6	N(22)= 6	N(23)= 7	N(24)= 7
N(25)= 7	N(26)= 7	N(27)= 7	N(28)= 8	N(29)= 8	N(30)= 8	N(31)= 8	N(32)= 9
N(33)= 9	N(34)= 9	N(35)= 9	N(36)= 10	N(37)= 10	N(38)= 10	N(39)= 11	N(40)= 11
N(41)= 11	N(42)= 11	N(43)= 12	N(44)= 12	N(45)= 12	N(46)= 13	N(47)= 13	N(48)= 13
N(49)= 14	N(50)= 14	N(51)= 14	N(52)= 15	N(53)= 15	N(54)= 15	N(55)= 16	N(

POLAR RADII IN AZIMUTH ZONE 7

R(1)= 165.0	R(2)= 181.6	R(3)= 197.9	R(4)= 214.3	R(5)= 230.8	R(6)= 247.4	R(7)= 264.2	R(8)= 281.1
R(9)= 298.2	R(10)= 315.4	R(11)= 332.8	R(12)= 350.3	R(13)= 367.9	R(14)= 385.8	R(15)= 403.8	R(16)= 422.0
R(17)= 440.3	R(18)= 458.8	R(19)= 477.6	R(20)= 496.5	R(21)= 515.6	R(22)= 534.9	R(23)= 554.4	R(24)= 574.2
R(25)= 594.1	R(26)= 614.3	R(27)= 634.8	R(28)= 655.5	R(29)= 676.5	R(30)= 697.7	R(31)= 719.2	R(32)= 741.1
R(33)= 763.2	R(34)= 785.6	R(35)= 808.4	R(36)= 831.5	R(37)= 855.0	R(38)= 878.9	R(39)= 903.2	R(40)= 927.9
R(41)= 953.1	R(42)= 978.8	R(43)=1004.9	R(44)=1031.6	R(45)=1058.8	R(46)=1086.7	R(47)=1115.2	R(48)=1144.4
R(49)=1174.3	R(50)=1205.1	R(51)=1236.7	R(52)=1269.3	R(53)=1303.0	R(		

POLAR COLLECTOR COUNT IN AZIMUTH ZONE 7

N(1)= 2	N(2)= 2	N(3)= 2	N(4)= 2	N(5)= 3	N(6)= 3	N(7)= 3	N(8)= 3
N(9)= 3	N(10)= 4	N(11)= 4	N(12)= 4	N(13)= 4	N(14)= 5	N(15)= 5	N(16)= 5
N(17)= 5	N(18)= 6	N(19)= 6	N(20)= 6	N(21)= 6	N(22)= 6	N(23)= 7	N(24)= 7
N(25)= 7	N(26)= 7	N(27)= 8	N(28)= 8	N(29)= 8	N(30)= 8	N(31)= 9	N(32)= 9
N(33)= 9	N(34)= 9	N(35)= 10	N(36)= 10	N(37)= 10	N(38)= 11	N(39)= 11	N(40)= 11
N(41)= 11	N(42)= 12	N(43)= 12	N(44)= 12	N(45)= 13	N(46)= 13	N(47)= 13	N(48)= 14
N(49)= 14	N(50)= 14	N(51)= 15	N(52)= 15	N(53)= 16	N(		

POLAR RADII IN AZIMUTH ZONE 8

R(1)= 165.0	R(2)= 181.6	R(3)= 198.3	R(4)= 215.1	R(5)= 232.0	R(6)= 249.1	R(7)= 266.3	R(8)= 283.6
R(9)= 301.2	R(10)= 318.9	R(11)= 336.7	R(12)= 354.7	R(13)= 372.9	R(14)= 391.2	R(15)= 409.8	R(16)= 428.5
R(17)= 447.4	R(18)= 466.6	R(19)= 485.9	R(20)= 505.4	R(21)= 525.2	R(22)= 545.2	R(23)= 565.4	R(24)= 585.9
R(25)= 606.6	R(26)= 627.6	R(27)= 648.8	R(28)= 670.4	R(29)= 692.2	R(30)= 714.4	R(31)= 736.8	R(32)= 759.6
R(33)= 782.8	R(34)= 806.3	R(35)= 830.2	R(36)= 854.5	R(37)= 879.3	R(38)= 904.5	R(39)= 930.1	R(40)= 956.3
R(41)= 983.0	R(42)=1010.3	R(43)=1038.2	R(44)=1066.7	R(45)=1096.0	R(46)=1126.0	R(47)=1156.8	R(48)=1188.5
R(49)=1221.1	R(50)=1254.9	R(51)=1289.7	R(52)=1325.9	R(			

POLAR COLLECTOR COUNT IN AZIMUTH ZONE 8

N(1)= 2	N(2)= 2	N(3)= 2	N(4)= 2	N(5)= 3	N(6)= 3	N(7)= 3	N(8)= 3
N(9)= 3	N(10)= 4	N(11)= 4	N(12)= 4	N(13)= 4	N(14)= 5	N(15)= 5	N(16)= 5
N(17)= 5	N(18)= 6	N(19)= 6	N(20)= 6	N(21)= 6	N(22)= 7	N(23)= 7	N(24)= 7
N(25)= 7	N(26)= 8	N(27)= 8	N(28)= 8	N(29)= 8	N(30)= 9	N(31)= 9	N(32)= 9
N(33)= 9	N(34)= 10	N(35)= 10	N(36)= 10	N(37)= 11	N(38)= 11	N(39)= 11	N(40)= 11
N(41)= 12	N(42)= 12	N(43)= 12	N(44)= 13	N(45)= 13	N(46)= 14	N(47)= 14	N(48)= 14
N(49)= 15	N(50)= 15	N(51)= 15	N(52)= 16	N(			

GROUND COVER IN POLAR ZONE 1 (4)

GC(1)= .381	GC(2)= .347	GC(3)= .316	GC(4)= .290	GC(5)= .400	GC(6)= .371	GC(7)= .344
GC(8)= .321	GC(9)= .300	GC(10)= .375	GC(11)= .352	GC(12)= .332	GC(13)= .313	GC(14)= .369
GC(15)= .349	GC(16)= .331	GC(17)= .314	GC(18)= .357	GC(19)= .340	GC(20)= .323	GC(21)= .307
GC(22)= .342	GC(23)= .326	GC(24)= .311	GC(25)= .296	GC(26)= .323	GC(27)= .309	GC(28)= .295
GC(29)= .282	GC(30)= .303	GC(31)= .289	GC(32)= .276	GC(33)= .264	GC(34)= .280	GC(35)= .268
GC(36)= .256	GC(37)= .268	GC(38)= .256	GC(39)= .244	GC(40)= .233	GC(41)= .242	GC(42)= .230
GC(43)= .219	GC(44)= .225	GC(45)= .214	GC(46)= .218	GC(47)= .207	GC(48)= .195	GC(49)= .197
GC(50)= .185	GC(51)= .174	GC(52)= .173	GC(			

GROUND COVER IN POLAR ZONE 2

GC(1)= .381	GC(2)= .355	GC(3)= .325	GC(4)= .298	GC(5)= .413	GC(6)= .383	GC(7)= .356
GC(8)= .333	GC(9)= .311	GC(10)= .390	GC(11)= .367	GC(12)= .346	GC(13)= .326	GC(14)= .386
GC(15)= .365	GC(16)= .346	GC(17)= .329	GC(18)= .375	GC(19)= .357	GC(20)= .340	GC(21)= .324
GC(22)= .309	GC(23)= .344	GC(24)= .329	GC(25)= .314	GC(26)= .300	GC(27)= .328	GC(28)= .314
GC(29)= .301	GC(30)= .288	GC(31)= .310	GC(32)= .296	GC(33)= .284	GC(34)= .272	GC(35)= .289
GC(36)= .277	GC(37)= .265	GC(38)= .279	GC(39)= .266	GC(40)= .255	GC(41)= .243	GC(42)= .254
GC(43)= .242	GC(44)= .231	GC(45)= .239	GC(46)= .227	GC(47)= .216	GC(48)= .221	GC(49)= .210
GC(50)= .199	GC(51)= .201	GC(52)= .190	GC(53)= .191	GC(		

GROUND COVER IN POLAR ZONE 3

GC(1)= .381	GC(2)= .357	GC(3)= .333	GC(4)= .306	GC(5)= .425	GC(6)= .395	GC(7)= .368
GC(8)= .344	GC(9)= .323	GC(10)= .404	GC(11)= .381	GC(12)= .359	GC(13)= .340	GC(14)= .402
GC(15)= .381	GC(16)= .362	GC(17)= .344	GC(18)= .328	GC(19)= .374	GC(20)= .357	GC(21)= .341
GC(22)= .325	GC(23)= .363	GC(24)= .347	GC(25)= .332	GC(26)= .318	GC(27)= .304	GC(28)= .333
GC(29)= .319	GC(30)= .306	GC(31)= .293	GC(32)= .317	GC(33)= .304	GC(34)= .291	GC(35)= .279
GC(36)= .298	GC(37)= .285	GC(38)= .274	GC(39)= .289	GC(40)= .277	GC(41)= .265	GC(42)= .254
GC(43)= .265	GC(44)= .254	GC(45)= .243	GC(46)= .251	GC(47)= .240	GC(48)= .229	GC(49)= .235
GC(50)= .224	GC(51)= .213	GC(52)= .217	GC(53)= .206	GC(54)= .195	GC(55)= .196	GC(

GROUND COVER IN POLAR ZONE 4

GC(1)= .381	GC(2)= .357	GC(3)= .336	GC(4)= .314	GC(5)= .437	GC(6)= .406	GC(7)= .379
GC(8)= .355	GC(9)= .333	GC(10)= .418	GC(11)= .394	GC(12)= .373	GC(13)= .353	GC(14)= .334
GC(15)= .397	GC(16)= .377	GC(17)= .359	GC(18)= .342	GC(19)= .392	GC(20)= .374	GC(21)= .357
GC(22)= .342	GC(23)= .327	GC(24)= .365	GC(25)= .350	GC(26)= .335	GC(27)= .321	GC(28)= .352
GC(29)= .338	GC(30)= .324	GC(31)= .312	GC(32)= .337	GC(33)= .323	GC(34)= .311	GC(35)= .298
GC(36)= .287	GC(37)= .306	GC(38)= .294	GC(39)= .282	GC(40)= .298	GC(41)= .287	GC(42)= .275
GC(43)= .264	GC(44)= .276	GC(45)= .265	GC(46)= .254	GC(47)= .264	GC(48)= .253	GC(49)= .242
GC(50)= .231	GC(51)= .238	GC(52)= .227	GC(53)= .217	GC(54)= .221	GC(55)= .210	GC(56)= .213
GC(57)= .202	GC(					

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HELIAKI VERSION 13, TIME POINT AND/OR ANNUAL ENERGY
ROUND FIELD WITH LOW PROFILE HELIOSTATS                                                          (5)

     NSTOPS      NCOL        RFIELD        TOWER H         GCOVER
       11        1596        878.000       415.000          .300

     NHF            WFV            WD            XDF            ALEN           SPACEF
      4            10.38          10.39         16.60           49.80           1.00

  GAP       WLONG       WCROSS       WTRI       XLTRI       WSIDE       WJCROS       HTMIR       HTCROS
 .250        .480        .395        .177       4.681        .840         .224        .833        .833


              THE CENTER WAVELENGTHS OF THE TWENTY EQUAL ENERGY BANDS                              (6)
       .39000   .44000   .48000   .51000   .54000   .57000   .60000   .63000   .66000   .70000
       .74000   .78000   .82000   .87000   .96000  1.02000  1.08000  1.22000  1.48000  1.68000


     TDISX         TDISY        AFIELD         RCO                                                   (7)
     0.000      -439.000    2336271.679     165.000


                                            6/21/80
LATITUDE=  35.68           HOUR   12       MIN    0                                              (8)


                    CAVITY RECEIVER SPECS                                                        (9)

     SEP       DD1       DD2       RDIF      HCAV      DD3      AIMHGT
     19.3      26.3      45.9      0.0       54.0      49.5      9.6


        RCONE              THECON             HTOT             TTILT                             (10)
        18.06               .47               19.29             0.00

        WAPMAX             WAPMIN             OFFSET
         25.0               19.3                0.0

PROGRAM OPTIONS USED                                                                             (11)
    INDIVIDUAL FOCUSING
    INDIVIDUAL TOE-IN
    TOEIN STRATEGY FOR  3/21 AT 12.0
    FACETS GANGED

                        HELIOSTAT OPTICAL PARAMETERS                                             (12)

    PAX1H     PAX2H     TSH      PHH      PAX1V     PAX2V     TSV      PHV
   0.00000   0.00000  0.00000  0.00000   .11500    .11500   .05000   .05000

          ********** CONVERSION FACTOR =    .1088949062E+10 **********                           (14)

               STATISTICS FOR   10 RUNS AT   800 RAYS PER RUN                                    (15)

                          **********OUTPUT CODE**********                                        (16)

  ETA1=FRACTION OF FIELD FLUX THAT HIT MIRRORS
  ETA2=REFLECTANCE
  ETA3=FRACTION OF FLUX NOT OBSCURED ON THE WAY OUT
  ETA4=FRACTION OF FLUX THAT HIT TOWER
  ETA5=FRACTION OF FIELD FLUX THAT HIT CAVITY
  ETA6=FRACTION OF FIELD FLU? THAT HIT THE CAVITY WALLS
  ETA7=FRACTION OF FIELD FLUX THAT WAS IN TOWER SHADOW


  EFLUX1=TOTAL FLUX ON FIELD IN KWH
  EFLUX2=TOTAL FLUX ON MIRRORS IN KWH
  EFLUX3=TOTAL FLUX LEAVING MIRRORS IN KWH
  EFLUX4=TOTAL FLUX CLEANLY AWAY FROM FIELD IN KWH
  EFLUX5=TOTAL FLUX ON POWER TOWER IN KWH
  EFLUX6=FLUX ON CAVITY DIFFUSER IN KWH
  EFLUX7=FLUX ON CAVITY WALLS IN KWH
  EFLUX8=FLUX ON CAVITY CEILING IN KWH,


  N1=RAYS DRAWN BEFORE SUNRISE
  N2=RAYS DRAWN WHEN THE SUN WAS TOO LOW
  N3=RAYS DRAWN THAT HIT THE OPEN FIELD
  N4=RAYS WHICH HIT MIRROR BUT WERE LOST IN SPACE
  N5=RAYS DRAWN THAT WERE BLOCKED IN ONBLOCKS
  N6=RAYS THAT WERE OBSCURED IN OFFBLOCK
  N7=RAYS WHICH HIT CAVITY DIFFUSER
  N8=RAYS WHICH HIT WALLS
  N9=RAYS WHICH HIT ROOF
  N10=RAYS WHICH MISSED HIGH
  N11=RAYS WHICH MISSED ACROSS THE FRONT
  N12=RAYS WHICH MISSED LOW
  N13=RAYS WHICH HIT SUPPORTS
  N14=RAYS WHICH WERE IN THE TOWER SHADOW
  N15=RAYS WHICH WHISTLED THROUGH
  N16=RAYS WHICH FRAME SHADOWED ON SAME HELIO
  N17=RAYS WHICH FRAME SHADOWED ON OTHER HELIO
  N18=RAYS WHICH FRAME BLOCKED ON SAME HELIO
  N19=RAYS WHICH FRAME BLOCKED ON OTHER HELIO

     ETA1     ETA2     ETA3     ETA4     ETA5     ETA6     ETA7
    .33905   .90000   .99895   .97835   .29820   .26431   .00810

    EFLUX1        EFLUX2        EFLUX3        EFLUX4        EFLUX5        EFLUX6        EFLUX7        EFLUX8

.471890E+09   .159994E+09   .143995E+09   .143829E+09   .140715E+09   .969703E+09   .124727E+09   .159886E+08

     N1    N2   N3    N4    N5    N6    N7   N8    N9   N10   N11   N12   N13   N14   N15   N16   N17   N18   N19
    1180   26 3860     0     0     0     0 2398   301    26     8     0    12    55    22    49    67     5     1
```

TIME INTEGRATION RUN (17)

HOURS OF SUNSHINE IN THE YEAR = 4356.3

ACTUAL MIRROR AREA	DIRECT NORMAL ENERGY
63838.8130	3200.7738

(18)

ENERGY (KWH) PER SQ. METER (19)

UNSHADOWED	2666.8241
SHADOWED	2505.2242
LEAVING MIRROR	2255.6018
CLEANLY AWAY	2253.0077
THRU APERTURE	2204.2306
ABSORBED	1983.8075

TRACKING EFFICIENCY (UNSHADOWED) .8332
(CLEANLY AWAY) .7039 (20)

NUMBER OF SUPPORTS	SUPPORT WIDTH	KWH ON SUPPORTS
3	2.0	.223E+06

HELIOSTAT FRAME HITS (21)

TOP FRAME	SIDE FRAMES		CROSS FRAMES			BOTTOM FRAME
60	5	32	5	3	4	13

ENERGY LOST ON FRAME IN KWH

FRAME SHADOW		FRAME BLOCK	
ON SAME HELIO	ON DIFF HELIO	ON SAME HELIO	ON DIFF HELIO
1194427.2	1059119.4	94570.6	71034.0

SUMMARY OF HIT AND BLOCKAGE COUNTS BY FACET (22)

FACET INDEX	TOTAL HITS	HITS LESS BLOCKS	HITS BLOCKED BY 1	2	3	4
1	675	675	0	0	0	0
2	683	683	0	0	0	0
3	675	675	0	0	0	0
4	725	725	0	0	0	0

OFFBLOCK SUMMARY

FACET	1	2	3	4
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

CAVITY WALL MAP (23)

	FROM	0.0	45.0	90.0	135.0	180.0	225.0	270.0	315.0
	TO	45.0	90.0	135.0	180.0	225.0	270.0	315.0	360.0
TOP FROM	TO								
43.2	54.0	85.226	22.860	76.608	74.040	25.568	67.789	54.565	73.681
32.4	43.2	105.390	104.024	145.489	132.249	133.061	162.898	79.266	96.638
21.6	32.4	68.469	79.847	337.637	300.875	321.063	304.394	130.438	71.842
10.8	21.6	2.072	54.752	616.153	572.452	509.792	561.005	94.744	0.000
0.0	10.8	0.000	14.762	146.523	276.797	275.742	198.715	17.806	0.000
BOTTOM									

CIRCUMFERENTIAL AVE WALL FLUX (24)

FROM	TO	AVE FLUX	AT	SUM BOTTOM UP	AT	SUM TOP DOWN
0.0	10.8	60.042	54.0	0.000	0.0	0.000
10.8	21.6	119.876	43.2	18144.635	10.8	9368.085
21.6	32.4	201.821	32.4	65166.090	21.6	28071.677
32.4	43.2	301.371	21.6	96655.137	32.4	59560.724
43.2	54.0	114.293	10.8	115358.728	43.2	105582.178
			0.0	124726.813	54.0	124726.813

CAVITY CEILING MAP (25)

		FROM	0.00	11.07	15.65	19.17	22.14
		TO	11.07	15.65	19.17	22.14	24.75
		AVE	7.83	13.56	17.50	20.71	23.48
FROM	TO	AVE					
0.0	45.0	22.5	104.7365	115.0195	75.7623	23.8508	114.5690
45.0	90.0	67.5	20.0659	109.0395	98.2583	115.5579	69.5975
90.0	135.0	112.5	174.7050	111.6968	168.1673	62.3136	33.3242
135.0	180.0	157.5	11.0233	104.7280	59.0258	32.9210	.8367
180.0	225.0	202.5	47.4252	143.0459	69.3164	48.6988	76.8450
225.0	270.0	247.5	96.9970	101.3623	144.5728	160.1393	114.9884
270.0	315.0	292.5	100.5537	76.7920	173.3405	46.2388	95.9889
315.0	360.0	337.5	37.8462	102.2829	144.7743	93.3370	107.5403

AZZIMOUTH AVE CEILING FLUX (26)

FROM	TO	AVE	
0.0	11.1	7.8	72.9191
11.1	15.7	13.6	107.9959
15.7	19.2	17.5	116.6522
19.2	22.1	20.7	72.8821
22.1	24.8	23.5	76.7112

MWH/SQ.M ENERGY MAP OF POWER TOWER MIRROR FIELD (27)

0.	0.	.869E-01	.315E+00	.296E+00	.530E+00	.357E+00	.677E-01	0.	0.	0.
0.	.185E+00	.367E+00	.426E+00	.372E+00	.534E+00	.502E+00	.530F+00	.226E+00	0.	0.
.143E+00	.474E+00	.588E+00	.781E+00	.607E+00	.652E+00	.590E+00	.525E+00	.144E+00	.945E-01	0.
.474E+00	.535E+00	.668E+00	.561E+00	.533E+00	.579E+00	.695E+00	.690F+00	.566E+00	.348E+00	0.
.412E+00	.515F+00	.794E+00	.860E+00	.799E+00	.696E+00	.822E+00	.758F+00	.700E+00	.686E+00	0.
.624E+00	.561E+00	.768E+00	.777E+00	.575E+00	.663E+00	.725E+00	.561F+00	.562E+00	.408E+00	0.
.461E+00	.635E+00	.556E+00	.882E+00	.748E+00	.728E+00	.842E+00	.758F+00	.666E+00	.341E+00	0.
.270E+00	.731E+00	.765E+00	.671E+00	.117E+00	.516E-01	.749E+00	.856E+00	.759E+00	.204E+00	0.
0.	.319E+00	.484E+00	.886E+00	.711E+00	.759E+00	.109E+01	.676F+00	.392E+00	0.	0.
0.	0.	.255E+00	.716E+00	.875E+00	.995E+00	.452E+00	.418F+00	0.	0.	0.

NORTH HALF FIELD ENERGY= .6326E+05 MWH
SOUTH HALF FIELD ENERGY= .7745E+05 MWH

HITS ON THE HELIO FIELD (28)

0	0	6	19	17	33	19	5	0	0
0	11	24	24	23	33	30	29	12	0
9	25	29	38	32	35	39	28	14	4
20	31	42	31	37	31	32	41	31	20
22	32	43	42	45	45	47	42	38	35
26	29	46	46	35	39	44	32	33	28
22	35	34	40	41	39	52	41	38	15
11	32	42	42	7	6	42	42	43	8
0	17	30	46	33	34	50	39	18	0
0	0	13	31	44	55	24	20	0	0

FLUX ON THE FIELD (29)

0.	0.	.249E+06	.903E+06	.849E+06	.152E+07	.102E+07	.194E+06	0.	0.
0.	.530E+06	.105F+07	.122E+07	.107E+07	.153E+07	.144E+07	.152E+07	.647E+06	0.
.410E+06	.136E+07	.168E+07	.224E+07	.174E+07	.187E+07	.169E+07	.150E+07	.413E+06	.271E+06
.136E+07	.153E+07	.191E+07	.161E+07	.153E+07	.166E+07	.199E+07	.198E+07	.162E+07	.997E+06
.118E+07	.147E+07	.228E+07	.246E+07	.229E+07	.199E+07	.235E+07	.217E+07	.201E+07	.197E+07
.179E+07	.161E+07	.220F+07	.222E+07	.165E+07	.190E+07	.208E+07	.161E+07	.161E+07	.117E+07
.132E+07	.182E+07	.159E+07	.253E+07	.214E+07	.208E+07	.241E+07	.217E+07	.191E+07	.976E+06
.775F+06	.209E+07	.219E+07	.192E+07	.336E+06	.148E+06	.214E+07	.245E+07	.217E+07	.585E+06
0.	.914E+06	.139E+07	.254E+07	.204E+07	.217E+07	.311E+07	.194E+07	.112E+07	0.
0.	0.	.730F+06	.205E+07	.251E+07	.285E+07	.130E+07	.120E+07	0.	0.

FLUX LOST TO SHADOWING (30)

0.	0.	.78748E+03	.12631E+05	.27254E+05	.16290E+06	.68899E+05	0.	0.	0.
0.	.50962F+05	.88511E+05	.74917E+05	.36877E+05	.10626E+06	.61120E+05	.17972E+06	.43112E+05	0.
.79932E+03	.60443F+05	.54690E+05	.11289E+06	.92924E+05	.75231E+05	.10868E+06	.18763E+05	.25617E+05	.31210E+05
.40695E+05	.90345F+05	.15209E+06	.45831E+05	.12829E+06	.57650E+05	.69418E+05	.38850F+05	.45071E+05	.14948E+06
.13641E+05	.21024F+06	.88198E+05	.17801E+06	.16165E+06	.16560E+06	.13740E+06	.63192E+05	.11381E+06	.49690E+04
.12108F+06	.58613F+05	.14208E+06	.24694E+06	.13279E+06	.20101E+06	.21229E+06	.10441E+06	.18475E+06	.51818E+05
.60797E+04	.60752E+05	.14717E+06	.11391E+06	.15066E+06	.11661E+06	.30647E+06	.88614E+05	.77398E+05	.23464F+05
0.	.57944F+05	.15871E+06	.54155E+05	.10545E+05	.21848E+05	.10387E+06	.22735F+06	.15076E+06	0.
0.	.44156E+05	.19170E+06	.13682E+06	.16495E+06	.74289E+05	.83894E+05	.87166F+05	.13530E+05	0.
0.	0.	.71176E+04	.33956E+05	.13223E+06	.15873E+06	.63268E+05	.25352E+05	0.	0.

FLUX LOST TO HELIOSTAT TO HELIOSTAT SHADING (31)

0.	0.	.64495E+02	.23610E+01	.51071E+02	.53514E+03	.69230E+03	0.	0.	0.
0.	.13576F+05	.11441E+05	.70580E+04	.96144E+04	.54712E+04	.14701E+05	.14449E+05	0.	0.
0.	.24329F+03	.22564E+01	.12925E+05	.18957E+05	.66181E+04	.25228E+05	.16411E+05	.24446E+05	.31210E+05
.40695E+05	.79876E+04	.71173E+05	.36249E+05	.16687E+05	.89012E+04	.23228E+05	.17883F+05	.33096E+05	.99065F+03
.13641E+05	.70291F+04	.32513E+05	.38023E+05	.69337E+05	.85207E+05	.78965E+05	.57883F+05	.11381E+06	.49690F+04
.49265E+05	.58613F+05	.10190E+06	.14522E+06	.75780E+05	.70777E+05	.96458E+05	.34808E+05	.10798E+06	.51818E+05
.60797E+04	.60752E+05	.14717E+06	.87546E+05	.14744E+06	.52176E+05	.20272E+06	.88614F+05	.77398E+05	.23464F+05
0.	.57944E+05	.15871E+06	.54155E+05	.10545E+05	.21848E+05	.10387E+06	.17078F+06	.83148E+05	0.
0.	.44156E+05	.71685E+05	.94446E+05	.27672E+05	.57025E+03	.72510E+05	.87166F+05	.13530E+05	0.
0.	0.	.63745E+04	.33956E+05	.37499E+05	.70729E+04	.19490E+05	.25352F+05	0.	0.

FLUX LOST TO BLOCKAGE (32)

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	.75656F+03	0.	0.	0.	0.	0.	0.	.71034E+05	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	.29420F+05	0.	0.	0.	0.	0.	0.	.33490E+05	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	.30903E+05	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TOTAL FLUX (33)

0.	0.	.24976E+06	.91606E+06	.87657E+06	.16802E+07	.10924E+07	.19385E+06	0.	0.
0.	.58135F+06	.11401E+07	.12954E+07	.11019E+07	.16368E+07	.14982E+07	.16968E+07	.69012E+06	0.
.41115F+06	.14179F+07	.17386E+07	.23489E+07	.18322E+07	.19441E+07	.17996E+07	.15221E+07	.43882E+06	.30185F+06
.13983E+07	.16240F+07	.20543E+07	.16530E+07	.16537E+07	.17158E+07	.20611E+07	.20146E+07	.16672E+07	.11461F+07
.11940E+07	.16850E+07	.23634E+07	.26419E+07	.24493E+07	.21593E+07	.24910E+07	.22340E+07	.21915E+07	.19705F+07
.19091E+07	.16651F+07	.23426E+07	.24715E+07	.17810E+07	.21007E+07	.22896E+07	.17115E+07	.17939F+07	.12208F+07
.13268E+07	.19098F+07	.17396E+07	.26404E+07	.22921E+07	.22012E+07	.27179E+07	.22593E+07	.20198E+07	.99965F+06
.77476E+06	.21528F+07	.23507E+07	.19762E+07	.34689E+06	.16975E+06	.22485E+07	.26791E+07	.23248E+07	.58530F+06
0.	.95839F+06	.15793E+07	.26761E+07	.22023E+07	.22492E+07	.32233E+07	.20233E+07	.11353E+07	0.
0.	0.	.73753E+06	.20839E+07	.26378E+07	.30082E+07	.13595E+07	.12223E+07	0.	0.

PERCENT FLUX LOST TO SHADOWS (34a)

I	I	.31530E-02	.13788E-01	.31091E-01	.96950E-01	.63069E-01	0.	I	I
I	.87661F-01	.77725E-01	.57832E-01	.33466E-01	.64915E-01	.40796E-01	.10592F+00	.62469E-01	I
.19441E-02	.42628F-01	.31456E-01	.48059E-01	.50719E-01	.38697E-01	.60393E-01	.12327E-01	.58377E-01	.10340F+00
.29104E-01	.55632F-01	.73674E-01	.27726E-01	.77574E-01	.33600E-01	.33680E-01	.19284E-01	.27034E-01	.13042F+00
.11424E-01	.12477F+00	.37319E-01	.67380E-01	.66000E-01	.76692E-01	.55159E-01	.28287E-01	.51932E-01	.25217F-02
.63424F-01	.35201F-01	.60548E-01	.99915E-01	.74561E-01	.95686E-01	.92719E-01	.61005E-01	.10299E+00	.42447F-01
.45821E-02	.31811F-01	.84599E-01	.43143E-01	.65730E-01	.52974E-01	.11276E+00	.39222F-01	.38321E-01	.23472F-01
0.	.26916F-01	.67517E-01	.27404E-01	.30400E-01	.12870E+00	.46195E-01	.84861E-01	.64852E-01	0.
I	.46073F-01	.12139E+00	.51126E-01	.74897E-01	.33029E-01	.26027E-01	.43082E-01	.11918E-01	I
I	I	.96506E-02	.16294E-01	.50131E-01	.52766E-01	.46538E-01	.20741E-01	I	I

PERCENT FLUX LOST TO BLOCKAGE (34b)

I	I	0.	0.	0.	0.	0.	0.	I	I
I	0.	0.	0.	0.	0.	0.	0.	0.	I
0.	0.	0.	0.	0.	0.	0.	0.	0.	I
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	.44901F-03	0.	0.	0.	0.	0.	0.	.32414E-01	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	.15405F-01	0.	0.	0.	0.	0.	0.	.16581E-01	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
I	0.	0.	0.	0.	0.	.95873E-02	0.	0.	I
I	I	0.	0.	0.	0.	0.	0.	I	I

TOTAL PERCENT OF FLUX LOST (34c)

I	I	.31530E-02	.13788E-01	.31091E-01	.96950E-01	.63069E-01	0.	I	I
I	.87661F-01	.77725E-01	.57832E-01	.33466E-01	.64915E-01	.40796E-01	.10592F+00	.62469E-01	I
.19441E-02	.42628F-01	.31456E-01	.48058E-01	.50719E-01	.38697E-01	.60393E-01	.12327F-01	.58377E-01	.10340F+00
.29104E-01	.55632F-01	.73674E-01	.27726E-01	.77574E-01	.33600E-01	.33680E-01	.19284F-01	.27034E-01	.13042F+00
.11424E-01	.12522F+00	.37319E-01	.57380E-01	.66000E-01	.76692E-01	.55159E-01	.28287E-01	.84346F-01	.25217F-02
.63424E-01	.35201E-01	.60648E-01	.99915E-01	.74561E-01	.95686E-01	.92719E-01	.61005E-01	.10299E+00	.42447F-01
.45821E-02	.47216F-01	.84599E-01	.43143E-01	.65730E-01	.52974E-01	.11276E+00	.39222F-01	.54902E-01	.23472F-01
0.	.26916F-01	.67517E-01	.27404E-01	.30400E-01	.12870E+00	.46195E-01	.84861F-01	.64852E-01	0.
I	.46073F-01	.12139E+00	.51126E-01	.74897E-01	.33029E-01	.35614E-01	.43082F-01	.11918E-01	I
I	I	.96506E-02	.16294E-01	.50131E-01	.52766E-01	.46538E-01	.20741E-01	I	I

RAYS WHICH MISSED HIGH (35a)

0	0	0	0	0	0	0	0	0	0
0	1	1	0	1	0	0	1	1	0
0	0	0	0	0	1	0	1	0	0
0	0	0	1	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0	0
1	0	0	1	0	0	0	0	1	1
0	2	1	1	0	0	0	0	2	1
0	0	1	3	0	0	1	0	0	0
0	1	1	0	0	1	0	0	0	0
0	0	0	0	1	0	0	0	0	0

RAYS WHICH MISSED LOW (35b)

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

RAYS WHICH MISSED ACROSS FRONT (35c)

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	2
2	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

RAYS WHICH WHISTLED THROUGH (35d)

0	0	1	0	1	0	0	1	0	0
0	1	1	0	0	1	0	1	0	0
1	2	0	0	0	0	1	0	0	1
0	1	0	0	0	0	0	0	1	2
3	0	0	0	0	0	0	0	0	1
1	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

RAYS WHICH HIT CORBELS (35e)

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1
3	0	0	0	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0	1
0	1	2	1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

SL ARRAY .78055E+00 .72517E+00 .56317E+00 .56103E+00 .47391E+00 .34791E+00 .11741E+000. 0. 0. (36)

0	0	8	7	7	5	6	6	0	0	0
0	7	6	6	6	5	5	5	7	0	0
7	6	4	2	4	4	4	5	7	8	0
6	5	3	4	5	4	3	3	4	7	0
6	5	1	1	1	3	1	2	3	3	0
4	5	2	2	4	4	3	5	4	6	0
6	4	5	1	2	2	1	2	3	7	0
7	2	2	3	8	8	2	1	2	7	0
0	7	5	1	3	2	1	3	6	0	0
0	0	7	3	1	1	6	6	0	0	0
0	0	0	0	0	0	0	0	0	0	0

(37)

HITS IN EAST NORTH DIVIDED QUADRANTS

MONTH	E/N	-E/N	-E/-N	E/-N	N FIELD	S FIELD
1	86	25	29	94	111	123
2	97	21	22	71	118	93
3	85	39	29	83	124	112
4	79	22	20	77	101	97
5	83	28	26	86	111	112
6	90	28	18	96	118	114
7	89	26	30	83	115	113
8	92	27	25	74	119	99
9	87	27	19	91	114	110
10	85	24	23	89	109	112
11	98	24	17	100	122	117
12	96	27	19	83	123	102
13	377	97	87	348	474	435
14	354	109	99	339	463	438
15	336	112	91	340	448	431

HITS IN NORTHEAST NORTHWEST DIVIDED QUADRANTS (38)

MONTH	NE/NW	-NE/NW	-NE/-NW	NE/-NW	-NE/NW+NE/-NW
1	113	64	14	43	107
2	109	39	18	45	84
3	102	52	21	61	113
4	101	41	17	39	80
5	101	51	24	47	98
6	103	55	17	57	112
7	111	38	24	55	93
8	100	45	19	54	99
9	113	46	15	50	96
10	110	45	15	51	96
11	138	38	15	48	86
12	124	35	13	53	88
13	444	176	60	189	365
14	415	189	84	213	402
15	426	184	69	201	385

13 IS THE WINTER MONTHS

14 IS THE SUMMER MONTHS

15 IS THE SPRING AND FALL MONTHS

16 IS THE TOTAL YEARLY ENERGY

ENERGY IN EAST NORTH DIVIDED QUADRANTS (39)

MONTH	NE	SE	SW	NW	N FIELD	S FIELD
1	.339E+04	.923E+03	.125E+04	.405E+04	.745E+04	.218E+04
2	.473E+04	.101E+04	.105E+04	.388E+04	.861E+04	.206E+04
3	.483E+04	.218E+04	.175E+04	.439E+04	.921E+04	.394E+04
4	.393E+04	.141E+04	.874E+03	.435E+04	.827E+04	.228E+04
5	.473E+04	.202E+04	.200E+04	.456E+04	.929E+04	.402E+04
6	.488E+04	.213E+04	.107E+04	.570E+04	.106E+05	.319E+04
7	.507E+04	.172E+04	.197E+04	.522E+04	.103E+05	.369E+04
8	.507E+04	.187E+04	.190E+04	.419E+04	.926E+04	.376E+04
9	.479E+04	.169E+04	.104E+04	.548E+04	.103E+05	.273E+04
10	.405E+04	.126E+04	.108E+04	.442E+04	.847E+04	.233E+04
11	.421E+04	.800E+03	.744E+03	.425E+04	.847E+04	.154E+04
12	.361E+04	.116E+04	.753E+03	.328E+04	.690E+04	.192E+04
13	.159E+05	.399E+04	.381E+04	.155E+05	.314E+05	.770E+04
14	.197E+05	.773E+04	.693E+04	.197E+05	.394E+05	.147E+05
15	.176E+05	.654E+04	.474E+04	.186E+05	.362E+05	.113E+05
16	.533E+05	.182E+05	.155E+05	.538E+05	.107E+06	.337E+05

ENERGY IN NORTHEAST NORTHWEST DIVIDED QUADRANTS

MONTH	NORTH	WEST	SOUTH	EAST	EAST + WEST
1	.459E+04	.294E+04	.459E+03	.163E+04	.457E+04
2	.509E+04	.217E+04	.873E+03	.254E+04	.471E+04
3	.555E+04	.328E+04	.138E+04	.294E+04	.622E+04
4	.533E+04	.214E+04	.888E+03	.220E+04	.434E+04
5	.575E+04	.305E+04	.183E+04	.267E+04	.572E+04
6	.570E+04	.339E+04	.113E+04	.356E+04	.695E+04
7	.632E+04	.257E+04	.155E+04	.354E+04	.611E+04
8	.549E+04	.254E+04	.139E+04	.360E+04	.614E+04
9	.643E+04	.277E+04	.879E+03	.293E+04	.570E+04
10	.552E+04	.213E+04	.682E+03	.247E+04	.460E+04
11	.571E+04	.169E+04	.636E+03	.197E+04	.366E+04
12	.485E+04	.143E+04	.585E+03	.195E+04	.338E+04
13	.202E+05	.823E+04	.255E+04	.809E+04	.163E+05
14	.233E+05	.115E+05	.590E+04	.134E+05	.249E+05
15	.228E+05	.103E+05	.383E+04	.105E+05	.209E+05
16	.663E+05	.301E+05	.123E+05	.320E+05	.621E+05

13 IS THE WINTER MONTHS

14 IS THE SUMMER MONTHS

15 IS THE SPRING AND FALL MONTHS

16 IS THE TOTAL YEARLY ENERGY

```
  TCY   TCY  SCOPE 3.4.3    406E.275  02/22/77
21.46.16.DOC00RN  FROM    /IN
21.46.16.IP  00000256 WORDS - FILE INPUT   , DC 00, IN
21.46.16.DOC,T1500,MT1,P4.
21.46.16.
21.46.17.USER(ZXF17TC,)
21.46.18.PROJECT(*819*)
21.46.19.ACCN, TM911, *819*
21.46.19.LABEL(SAMPLE,L=DOCMEN,VSN=X3058,R)
21.51.00.MT50 VOLUME SERIAL NUMBER IS  0X3058
21.51.00.MT50 ASSIGNED TO  SAMPLE
21.51.04.$VSN= 0X3058, RD ACCESS GRANTED
21.51.05. LABEL READ WAS       DOCMEN
21.51.05.   EDITION NUMBER    01
21.51.05.   RETENTION CYCLE   000
21.51.05.   CREATION DATE     77069
21.51.05.   REEL NUMBER       0001
21.51.05.UPDATE(P=SAMPLE,W,C,F)
21.51.15. UPDATE COMPLETE.
21.51.15.FTN(I=COMPILE)
21.53.02.     22.873 CP SECONDS COMPILATION TIME
21.53.02.LGO.
21.53.44.LOCKIN.
21.57.51.     STOP
21.57.51.OP  00075008 WORDS - FILE OUTPUT , DC 40, IN
21.57.51.ISEQ, ENTERED QUEUE 21.46.11  77080
21.57.51.ISSW,        275.270 EXECUTION TIME
21.57.51.MS  136192  WORDS  (  182784 MAX USED)
21.57.51.CPA      166.701 SEC.
21.57.53.IO       108.569 SEC.
21.57.53.CM     2208.491 KWS.
21.57.53.ISSN,        200.220 TOTAL SBUS NON-APPLICATION
21.57.53.PP        94.725 SEC.       DATE 03/21/77
21.57.53.EJ  END OF JOB, IN
```


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  TCY   TCY  SCOPE 3.4.3    406E.275  02/22/77
21.46.16.DOC00RN  FROM    /IN
21.46.16.IP  00000256 WORDS - FILE INPUT   , DC 00, IN
21.46.16.DOC,T1500,MT1,P4.
21.46.16.
21.46.17.USER(ZXF17TC,)
21.46.18.PROJECT(*819*)
21.46.19.ACCN, TM911, *819*
21.46.19.LABEL(SAMPLE,L=DOCMEN,VSN=X3058,R)
21.51.00.MT50 VOLUME SERIAL NUMBER IS  0X3058
21.51.00.MT50 ASSIGNED TO  SAMPLE
21.51.04.$VSN= 0X3058, RD ACCESS GRANTED
21.51.05. LABEL READ WAS       DOCMEN
21.51.05.   EDITION NUMBER    01
21.51.05.   RETENTION CYCLE   000
21.51.05.   CREATION DATE     77069
21.51.05.   REEL NUMBER       0001
21.51.05.UPDATE(P=SAMPLE,W,C,F)
21.51.15. UPDATE COMPLETE.
21.51.15.FTN(I=COMPILE)
21.53.02.     22.873 CP SECONDS COMPILATION TIME
21.53.02.LGO.
21.53.44.LOCKIN.
21.57.51.     STOP
21.57.51.OP  00075008 WORDS - FILE OUTPUT , DC 40, IN
21.57.51.ISEQ, ENTERED QUEUE 21.46.11  77080
21.57.51.ISSW,        275.270 EXECUTION TIME
21.57.51.MS  136192  WORDS  (  182784 MAX USED)
21.57.51.CPA      166.701 SEC.
21.57.53.IO       108.569 SEC.
21.57.53.CM     2208.491 KWS.
21.57.53.ISSN,        200.220 TOTAL SBUS NON-APPLICATION
21.57.53.PP        94.725 SEC.       DATE 03/21/77
21.57.53.EJ  END OF JOB, IN
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