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MODIFIED USER'S MANUAL
OPTICAL SIMULATION FOR IMAGING RECONNAISSANCE AND INTELLIGENCE SENSORS
OSIRIS
HIGH FIDELITY SENSOR SIMULATION TEST BED

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Optical Simulation for Imaging Reconnaissance and Intelligence Sensors

O S I R I S

USER'S MANUAL

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I. INTRODUCTION

The OSIRIS program is an imaging optical simulation program which has been developed to predict the output of space-borne sensor systems. The simulation is radiometrically precise and includes highly realistic laser, atmosphere, and earth background models, as well as detailed models of optical components. This system was developed by Rockwell Power Services for the Los Alamos National Laboratory. It is based upon the LARC (Los Alamos Radiometry Code, also by Rockwell), and uses a similar command structure and 3d coordinate system as LARC. At present OSIRIS runs on the Cray 1 computer under the CTSS operating system, and is stored in the OSIRIS root directory on LANL CTSS mass storage. To use it, acquire it into local file space and type **OSIRIS** <ENTER>

The code will respond with:

Welcome to OSIRIS 1.0

OSIR>

The OSIRIS prompt is 'OSIR>' which indicates that OSIRIS commands may now be entered.

OSIRIS produces image files which contain picture data. To examine this data requires an IBM PC or compatible computer with an EGA card and an AT&T TARGA 8 or TARGA M8 display adapter. The files are written in the Rockwell Digital Image Standard file format which permits a high degree of portability between machines such as the CRAY and PCs. Once an image file or files has been generated, it is recommended that the KERMIT utility be used to transfer those files from the CRAY to the user's PC. For instructions on this, see the KERMIT Help Manual regarding binary file transfer. (The KERMIT documentation and PC software disk may be obtained from LANL C Division.)

A program called RIWS (Rockwell Imaging Work Station) is available for the PC to display this imagery. (This software may be obtained either from Rockwell Power Services or from Ed Sklar LANL CLS-8.) To use it, start the program by typing "RIWS E" after the MS-DOS prompt. The program will then display a menu. Press F3 and enter the path and name of the file in response to the inquiry. For example:

Enter image file name to be read: **C:EARTH.VU** <ENTER>

The program will display a message indicating the image size, and whether the file has been successfully read. To display the image on the TARGA, press F7. The RIWS program may also be used on an IBM PS/2 using "RIWSV <ENTER>" to evoke it, and pressing F1 to view the image. The display quality on the PS/2 will be of inferior quality to the TARGA display because of limited resolution on the PS/2 display. Images created by OSIRIS should be limited to 310,000 pixels total or less in order to fit on a PC. (512 x 480 is the standard image size and it occupies 245,760 pixels.) However, the image size need not be the same as the display, as RIWS will automatically interpolate it to fit the display.

II. OSIRIS - HOW IT WORKS

Unconstrained Ray Tracing Methodology

There is one feature that separates OSIRIS from other currently existing photometric codes. It is the method used by OSIRIS to compute the paths taken by rays through the simulated environment. Unlike conventional ray trace codes, the ray path in OSIRIS is unconstrained by an arbitrary "expected" component order. Instead, all possible ray/surface intercepts are considered and the closest real intercept is logically selected. While this is computationally intensive, it is an extremely powerful technique for photometric calculations because it is far more realistic and physically correct than previous methods.

It is useful to know a bit more about this method in order to make best use of this code. Because any surface may be reflective, transmissive or both, a binary tree exists which contains all the possible descendant segments for any initial ray (called a parent ray). See Figure 1. At first glance it is apparent that any ray may have 2^N descendants where N is the number of subsequent intersections or trace depth in our terminology. Fortunately, this is a worst case number of descendants only occurring in situations in which every surface intercepted is both reflective and transmissive. There are several user definable parameters in OSIRIS to help control the ray tracing process so that only the necessary rays are traced. This is useful in keeping good code throughput and in limiting the amount of space required.

The user may reset the maximum trace depth via the SET command. This determines the maximum number of intercepts for any ray. If this number is reached, the trace is terminated. The minimum accumulated transmissivity (MAT) is another way of 'pruning' the ray tree of spurious branches. The MAT is an aggregate variable that indicates the fraction of the original light, which will remain at the end of a ray path. If the effective transmissivity along any path falls below the MAT, the ray is terminated on the assumption that this ray path cannot pass enough light to significantly affect the calculation. By changing this threshold, one can reduce the number of descendants, increase run speed by increasing the MAT, or sacrifice speed for sensitivity by decreasing this number.

Figure 1. Ray Descent Tree

Another useful trace control function is the maximum number of ghost rays. A ghost ray is just another name for the secondary branch of a binary intercept point. It is assumed that the amount of light transmitted through and reflected off a surface may be unequal. The branch with the greater amount of light is primary descendant. The branch with the lesser amount is the secondary ray or ghost. If a ghost ray encounters another binary intersection, a second generation ghost ray (ghost of a ghost) may be formed. This may be carried out infinitum; however, most likely, the descendants of third generation ghosts are not important and, in fact, may seriously clutter the output information. Therefore, setting the maximum number of ghosts to three terminates with the third generation. To understand these effects, see Figure 2.

By using these three trace control functions, one may tune the precision, speed and flexibility of the code.

Figure 2. Ghost Ray Limits Set to 0, 1, and 2 (top to bottom)

III. OSIRIS - HOW TO USE IT

This section provides a general description of the Los Alamos Radiometry Code. It describes important concepts of the code that are vital to the user. These include setting up the optical system (also thought of as a workbox), element definition and placement, and important options available to the user. Although some specific commands are mentioned in this section, the complete descriptions of the commands are located in Section V, Command Descriptions.

Coordinate Systems

There are several important concepts and conventions the user must understand in order to gain full use of OSIRIS's software. The workbox and all components in OSIRIS, light sources, detectors and objects are described mathematically within a coordinate system. All coordinate systems involved in this code are right-handed coordinate systems. There are four types of coordinate systems used in OSIRIS: global, subassembly, object, and surface local.

For each optical system, there is only one global coordinate system, which represents the workbox where components may be located and ray tracing takes place. The individual OSIRIS components are located in their own local coordinate system.

The placement and orientation of a component in the workbox is determined by the relation of its local coordinate system to the global coordinate system of the workbox. Each type of component has a standard placement and orientation within its local coordinate system. The default orientation of each element type in its coordinate system can be found in Figure 3. Subassembly global coordinates are used to define subassemblies, as described later.

The placement of a component in the workbox is determined by the location and orientation of its local coordinate system with respect to the global coordinate system. In addition, a component and its local coordinate system may be rotated or translated after the component is located in the workbox. These rotations and translations may be with respect to any of the three axes.

Component placement in the workbox can be completed using any one of three methods. The three placement options are absolute, relative (local), or parallel. These three placement options are briefly described below:

Absolute: Components are placed using three translation distances measured with respect to absolute reference frame (the workbox coordinate system). The local coordinate has the same orientation as the global coordinate system.

Relative (Local): Components are placed using three translation distances measured with respect to the local coordinate system of a previously placed component. The local coordinate system of the newly placed component has the same orientation as the local coordinate system of the previously placed object.

Figure 3. OSIRIS Coordinate System and Positive Rotation Angles

Parallel: Components are placed using three translation distances measured with respect to the local coordinate system of a previously placed component. The local coordinate system has the same orientation as the global coordinate system.

The user may specify the dimensions of the optical system (workbox). All ray tracing will occur within the workbook. Rays that leave the workbook will be clipped at the point at which they hit the workbook.

Object Definition

OSIRIS provides the user with a choice of many components that may be defined for use in the optical system. These components include mirrors, lenses, absorptive elements, detectors and light sources. To define a component, the user specifies necessary parameters for it: size, shape, material, etc. Once a component is defined, it can be placed in the workbook at that time, or placement can be done once all the components for the system have been defined. Every component in the workbook will have a unique number, even if there are identical components in the system. It is not necessary to place all the defined components in the workbook to perform the ray tracing or photometric calculations. A component

can be removed from the workbox, but remain defined, or it can be redefined and left in the workbox. If a desired component is not available in OSIRIS's element list, the user may add a new element type by following the directions in Appendix A.

IV. MODELING THE ATMOSPHERE AND ATMOSPHERIC EVENTS

The DEFINE/ATMOSPHERE and DEFINE/LASER commands are used to create objects which model the earth's atmosphere and a laser signature in that atmosphere. In addition, details of the surface of the earth may be included in the atmospheric description. The capability to add more detailed atmospheric models, laser signatures, and ground truth data are provided for in the current code.

The DEFINE/ATMOSPHERE command defines an object which models the earth's surface and atmosphere by means of a series of concentric spheres. The number of atmospheric surfaces, NSHELLS, is user selectable to provide various levels of fidelity. The object consists of a central sphere representing the earth's surface, a set of NSHELLS enclosing spheres evenly spaced between the altitudes of 1 and 25 km., and a final sphere placed at an altitude of 120 km. The space between a pair of spheres contains a medium which models the atmospheric conditions at the altitude of the sphere with the smaller radius.

In addition, the sphere representing the earth and the first two atmospheric spheres may be associated with "maps". In the case of the earth, a map represents an area of the earth for which ground truth data is available, at a specific level of detail. When rays are traced to the earth and hit a mapped area, the surface characteristics at the intersection point are obtained and used to generate an image of that point on the surface. Likewise, maps associated with the first two atmospheric layers may be used to represent cloud cover or haze. At present, no elevation data is contained in the earth surface map, so that the earth surface information is mapped directly onto the innermost sphere.

If an image of the earth/atmosphere model is generated which includes the terminator, an additional object representing the earth's shadow must be defined and placed relative to the earth. This may be accomplished by means of the DEFINE/SHADOW and PLACE/SHADOW commands. It should be noted that only a single shadow may be defined.

The currently implemented atmosphere models Rayleigh scattering and is reasonably accurate to an altitude of 25 km. The amount of scattering is dependent on the angle between the direction of the sun's light and the direction in which the detector is pointed. The sun direction is determined by the direction of the light source specified for diffuse surfaces. This may be set by the SET/DSOURCE command. This light source direction is also used to orient the earth's shadow, if one is defined. Scattering amplitude is also dependent of the wavelength of light involved. The wavelength used is determined by the SET/WAVELENGTH command.

As stated above, the medium between two atmospheric shells is assumed to have constant properties, determined by the altitude of the smaller shell. These properties determine the amount of scattering that a ray will experience in travelling through this layer. This scattering results in two effects which affect the amount of luminosity accumulated by the ray. These two effects are absorption, which diminishes the luminosity, and back scattering of sunlight, which increases it. The absorption caused by an atmospheric layer reduces the amount of light received from luminous objects further along the ray path, eg.

light from the earth's surface. This will result in the obscuration of a an object if the atmospheric model lies between the object and the detector. Scattering of sunlight results in the addition of luminance to that already accumulated by the ray. This will produce the effect of air glow in a simulated image, which will be particularly noticeable in areas near the horizon.

The DEFINE/LASER command produces an object which models a ground based laser signature. The object consists of a truncated cone which is divided into layers by a series of planes perpendicular to the long axis of the cone. The radius at the apex of the cone, which is placed on the earth's surface, represents the original beam radius, and may be selected by the user. The angle of divergence of an actual laser beam with the specified radius and wavelength determines the amount of divergence of the cone as the distance from the base increased. As with an atmosphere object, the number of partition planes (NSEG) may be selected by the user. The NSEG planes are evenly spaced between the distances of 1 km. and 25 km. from the base of the cone. An additional partition is placed at an altitude of 120 km. If the specified propagation distance is greater than 120 km., a final plane is placed at this distance. Again, the medium between a pair of planes models the atmosphere at the altitude of the lower plane.

Only a single laser may be defined at one time. To place the laser in the system, the PLACE/LASER command must be used. This allows the placement of the laser model at any point on the earth's surface with a specified orientation with respect to the normal to the earth at that point. When a laser is in place and active, and a photometric ray trace is performed, only the laser itself and the sphere representing the earth's surface are considered active surfaces. In addition, any mapping function associated with the earth is not considered when calculating luminance. Thus, only an image of the laser signature is generated.

The laser model incorporates the same atmospheric scattering model as the atmosphere. The direction of light used to calculate scattering is the same as the direction of the laser, i.e., parallel to the long axis of the cone. The wavelength used is specified when the laser is defined.

ACTIVATE

Purpose: This command activates an object or subassembly in the system.

Modifiers:

(Default) /OBJECT - Activates object
/SUBASSEMBLY - Activates subassembly

Syntax:

ACTIVATE/OBJECT Object
ACTIVATE/SUBASSEMBLY Subassembly

Parameters:

Object - Object number to be activated
Subassembly - Subassembly number to be activated

Default: None

DEACTIVATE

Purpose: This command deactivates an object or subassembly.

Modifiers:

(Default) /OBJECT - Activates object
/SUBASSEMBLY - Activates subassembly

Syntax:

DEACTIVATE/OBJECT Object
DEACTIVATE/SUBASSEMBLY Subassembly

Parameters:

Object - Object number to be activated
Subassembly - Subassembly number to be activated

Default: None

DEFINE

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Purpose: This command defines various types of system elements, including reference axes, lenses, mirrors, apertures and detectors.

Modifiers:

- /LENS - Specifies that object to be defined is a lens
- /MIRROR - Specifies that object to be defined is a mirror
- /AXIS - Specifies that object to be defined is an axis
- /DETECTOR - Specifies that object to be defined is a photometric detector
- /ROD - Object to be defined is transmissive right circular cylinder
- /APERTURE - Object to be defined is an aperture
- /BARREL - Object to be defined is a reflective "barrel" in the shape of an ellipsoid with the equation:

$$\frac{x^2}{A^2} + \frac{y^2}{B^2} + \frac{z^2}{C^2} = 0$$

- /CONE - Object to be defined is a reflective elliptical cone, with the equation:

$$\frac{x^2}{A^2} + \frac{y^2}{B^2} = \frac{z^2}{C^2}$$

- /ASPHERE - Object to be defined is a reflective aspheric surface defined by a conic constant K and a curvature C, with the equation:

$$Z = \frac{C p^2}{1 + \sqrt{1 - (k+1)C^2 p^2}}$$

where $P = x^2 + y^2$

DEFINE (continued)

/LUMINOUS_BODY - Object to defined is a luminous plane or a luminous ellipsoidal volume with the equation:

$$\frac{x^2}{A^2} + \frac{y^2}{B^2} + \frac{z^2}{C^2} = 0$$

- /GRATING - Object to be defined is a defraction grating
- /ATMOSPHERE - Object to be defined is a model of the earth with atmosphere
- /CAMERA - Object to be defined is a camera, which consists of a finite size rectangular film plane and a rectangular aim window at a specified distance from the film plane.
- /SHADOW - Object to be defined is the earth's shadow.
- /HROD - Object to be defined is a hollow rod.
- /LASER - Object to be defined is a model of a laser signautre, to be placed relative to a model of the earth. The laser signature consists of a truncated cone, divided into segments which represent different atmospheric densities. If a laser signature is active, only the laser and the earth's surface will be considered when tracing rays.
- /RECTANGLE - Indicates that the outer edge of the object is a rectangle
- /ELLIPSE - Indicates that the outer edge of the object is an ellipse
- /HRECTANGLE - Indicates that the aperture hole is rectangular
- /HELLIPSE - Indicates that the aperture hole is elliptical
- /FLAT - Indicates that a mirror surface is flat or that a luminous body is a plane
- /VOLUME - Indicates that a luminous body is a volume (ellipsoid)
- /TROUGH - Indicates that a mirror is a parabolic trough
- /SPHERICAL - Indicates that a mirror is spherical
- /PARABLOID - Indicates that a mirror is a parabloid

DEFINE (continued)

- /CONCAVE - Indicates that the reflective side of a mirror is the concave side
- /CONVEX - Indicates that the reflective side of a mirror is the convex side
- /DOUBLE_SIDED - Indicates that both sides of the mirror are reflective
- /FRONT - Indicates that a flat mirror is reflective on the side facing the positive z direction.
- /BACK - Indicates that a flat mirror is reflective on the side facing the negative z direction.
- /INSIDE - Indicates that a barrel or cone is reflective on the inside.
- /OUTSIDE - Indicates that a barrel or cone is reflective on the outside.
- /BOTH_SIDES - Indicates that a flat mirror, barrel, or cone is reflective on both sides.
- /PLEDGE - Indicates that the edge of a parabolic mirror is defined by the intersection of a plane normal to the z axis with the paraboloid.
- /ELLEDDGE - Indicates that the edge of a parabolic mirror is defined by the intersection of an elliptic cylinder parallel to the z axis with the paraboloid.
- /RECEDGE - Indicates that the edge of a parabolic mirror is defined by the intersection of a rectangular cylinder parallel to the z axis with the paraboloid.
- /ZDEPTH - Indicates that the size of a parabolic mirror is specified as its depth along the z axis (only valid with the /PLEDGE modifier)
- /XHW - Indicates that the size of a parabolic mirror is specified as its half width in the x direction (only valid with the /PLEDGE modifier)
- /YHW - Indicates that the size of a parabolic mirror is specified as its half width in the y direction (only valid with the /PLEDGE modifier)

DEFINE (continued)

- /MATERIAL - Indicates that index of refraction will be computed from material table
- /REFLECTIVE - Indicates that a diffraction grating should be a reflection grating.
- /TRANSMISSIVE - Indicates that a diffraction grating should be a transmission grating.

Syntax:

DEFINE/DETECTOR

DEFINE/AXIS Length

DEFINE/ROD Length Diameter N

DEFINE/ROD/MATERIAL=Matname Length Diameter

DEFINE/LENS R1 R2 Thickness Diameter N

DEFINE/LENS/MATERIAL=Matname R1 R2 Thickness Diameter N

DEFINE/APERTURE/RECTANGLE/HRECTANGLE Xhw Yhw Hxcen Hycen Hxhw Hyhw

DEFINE/APERTURE/RECTANGLE/HELLIPSE Xhw Yhw Hxcen Hycen Hxhw Hyhw

DEFINE/APERTURE/ELLIPSE/HRECTANGLE Xhw Yhw Hxcen Hycen Hxhw Hyhw

DEFINE/APERTURE/ELLIPSE/HELLIPSE Xhw Yhw Hxcen Hycen Hxhw Hyhw

DEFINE/BARREL/INSIDE A B C Zmin Zmax

DEFINE/BARREL/OUTSIDE A B C Zmin Zmax

DEFINE/BARREL/BOTH_SIDES A B C Zmin Zmax

DEFINE/CONE/INSIDE A B C Zmin Zmax

DEFINE/CONE/OUTSIDE A B C Zmin Zmax

DEFINE/CONE/BOTH_SIDES A B C Zmin Zmax

DEFINE/ASPHERE/INSIDE K C Radius

DEFINE/ASPHERE/OUTSIDE K C Radius

DEFINE/ASPHERE/BOTH_SIDES K C Radius

DEFINE/LUMINOUS_BODY/FLAT/ELLIPSE Xhw Yhw Luminance

DEFINE/LUMINOUS_BODY/FLAT/RECTANGLE Xhw Yhw Luminance

DEFINE/LUMINOUS_BODY/VOLUME A B C Luminance Sluminance Absorbtivity

DEFINE/MIRROR/TROUGH/CONCAVE F1 Length Width

DEFINE/MIRROR/TROUGH/CONVEX F1 Length Width

DEFINE/MIRROR/TROUGH/DOUBLE_SIDED F1 Length Width

DEFINE/MIRROR/FLAT/RECTANGLE/FRONT Xhw Yhw

DEFINE (continued)

DEFINE/MIRROR/FLAT/RECTANGLE/BACK	Xhw Yhw
DEFINE/MIRROR/FLAT/RECTANGLE/BOTH_SIDES	Xhw Yhw
DEFINE/MIRROR/FLAT/ELLIPSE/FRONT	Xhw Yhw
DEFINE/MIRROR/FLAT/ELLIPSE/BACK	Xhw Yhw
DEFINE/MIRROR/FLAT/ELLIPSE/BOTH_SIDES	Xhw Yhw
DEFINE/MIRROR/SPHERICAL/PLEDGE/CONCAVE	F1 Radius
DEFINE/MIRROR/SPHERICAL/PLEDGE/CONVEX	F1 Radius
DEFINE/MIRROR/SPHERICAL/PLEDGE/DOUBLE_SIDED	F1 Radius
DEFINE/MIRROR/SPHERICAL/ELLEDGE/CONCAVE	F1 Xhw Yhw
DEFINE/MIRROR/SPHERICAL/ELLEDGE/CONVEX	F1 Xhw Yhw
DEFINE/MIRROR/SPHERICAL/ELLEDGE/DOUBLE_SIDED	F1 Xhw Yhw
DEFINE/MIRROR/SPHERICAL/RECEDEGE/CONCAVE	F1 Xhw Yhw
DEFINE/MIRROR/SPHERICAL/RECEDEGE/CONVEX	F1 Xhw Yhw
DEFINE/MIRROR/SPHERICAL/RECEDEGE/DOUBLE_SIDED	F1 Xhw Yhw
DEFINE/MIRROR/PARABALOID/PLEDGE/ZDEPTH/CONCAVE	Flx Yf1 Size
DEFINE/MIRROR/PARABALOID/PLEDGE/ZDEPTH/CONVEX	Flx Yf1 Size
DEFINE/MIRROR/PARABALOID/PLEDGE/ZDEPTH/DOUBLE_SIDED	Flx Yf1 Size
DEFINE/MIRROR/PARABALOID/PLEDGE/XHW/CONCAVE	Flx Yf1 Size
DEFINE/MIRROR/PARABALOID/PLEDGE/XHW/CONVEX	Flx Yf1 Size
DEFINE/MIRROR/PARABALOID/PLEDGE/XHW/DOUBLE_SIDED	Flx Yf1 Size
DEFINE/MIRROR/PARABALOID/PLEDGE/YHW/CONCAVE	Flx Yf1 Size
DEFINE/MIRROR/PARABALOID/PLEDGE/YHW/CONVEX	Flx Yf1 Size
DEFINE/MIRROR/PARABALOID/PLEDGE/YHW/DOUBLE_SIDED	Flx Yf1 Size
DEFINE/MIRROR/PARABALOID/RECEDEGE/CONCAVE	Flx Yf1 Xhw Yhw
DEFINE/MIRROR/PARABALOID/RECEDEGE/CONVEX	Flx Yf1 Xhw Yhw
DEFINE/MIRROR/PARABALOID/RECEDEGE/DOUBLE_SIDED	Flx Yf1 Xhw Yhw
DEFINE/MIRROR/PARABALOID/ELLEDGE/CONCAVE	Flx Yf1 Xhw Yhw
DEFINE/MIRROR/PARABALOID/ELLEDGE/CONVEX	Flx Yf1 Xhw Yhw
DEFINE/MIRROR/PARABALOID/ELLEDGE/DOUBLE_SIDED	Flx Yf1 Xhw Yhw
DEFINE/GRATING/RECTANGLE/REFLECTIVE	Xwidth Ywidth D Efficiency
DEFINE/GRATING/ELLIPSE/REFLECTIVE	Xwidth Ywidth D Efficiency
DEFINE/GRATING/RECTANGLE/TRANSMISSIVE	Xwidth Ywidth D Efficiency
DEFINE/GRATING/ELLIPSE/TRANSMISSIVE	Xwidth Ywidth D Efficiency
DEFINE/ATMOSPHERE	Map1 Map2 Map3 Nshells
DEFINE/CAMERA	Xhw Yhw Axhw Ayhw Adist
DEFINE/SHADOW	
DEFINE/HROD	Length R1 R2 Luminance Absorbitivity N
DEFINE/HROD/MATERIAL=Matname	Length R1 R2 Luminance Absorbitivity
DEFINE/LASER	Wavelen Rad0 Energy Propdis Nseg

DEFINE (continued)

Parameters:

R1	- Radius of curvature of first lens surface
R2	- Radius of curvature of second lens surface
Thickness	- Center thickness of lens
N	- Index of refraction of lens
Matname	- Name of material to be used in computing index of refraction from material table
F1	- Mirror focal length
Flx	- Focal length in the x-z plane of a parabolic mirror
Yf1	- Focal length in the y-z plane of a parabolic mirror
Radius	- Radius (measured from z axis) of a spherical or aspheric mirror
Diameter	- Diameter of lens or rod
Length	- Length of an axis or the size in the X direction of a rod or trough
Width	- Rectangular extent of trough along the Y axis
Xhw	- X half width of object's outer edge
Yhw	- Y half width of object's outer edge
Hxcen	- X center of hole in aperture
Hycen	- Y center of hole in aperture
Hxhw	- X half width of hole in aperture
Hyhw	- Y half width of hole in aperture
Zmin	- Minimum Z extent of a barrel or cone
Zmax	- Maximum Z extent of a barrel or cone
Size	- Size of a parabolic mirror defined with the /PLEDGE modifier. Its meaning depends on the additional modifier:

DEFINE (continued)

/ZDEPTH	-- Size is the depth of the mirror along the z axis
/XHW	-- Size is the mirror half width in the x direction
/YHW	-- Size is the mirror half width in the y direction
A, B, C	- Quadric coefficients for barrel, cone and volume luminous object
K, C	- Conic constant and curvature for aspheric mirror
Luminance	- Surface luminance of a flat luminous object or luminance per unit length for a volume luminous object.
Sluminance	- Surface luminance of a volume luminous object.
Absorbtivity	- Absorbtion coefficient for a volume luminous object.
Xwidth	- X half width of diffraction grating
Ywidth	- Y half width of diffraction grating
D	- Diffraction grating line spacing
Efficiency	- Diffraction grating efficiency
Map1	- Number of the look up mapping to use for the earth's surface
Map2	- Number of the look up mapping for the first atmospheric layer
Map3	- Number of the look up mapping for the second atmospheric layer
Nshells	- Number of shells used to model the earth's atmosphere
Axhw	- X half width of camera aim window
Ayhw	- Y half width of camera aim window
Adist	- Distance from camera film plane to aim window
R1	- Inner radius of a hollow rod
R2	- Outer radius of a hollow rod

DEFINE (continued)

Wavelen	- Wavelength in microns of a laser signature
Rad0	- Radius of a laser signature at the altitude 0, ie. at the earth's surface
Energy	- Energy of a laser in Joules
Propdis	- Laser signature propagation distance. This is the length of the cone representing the laser
Nseg	- Number of segments used to model a laser signature

DELETE

Purpose: DELETE is used to "undefine" an object or subassembly.

Modifiers:

(Default) /OBJECT - Item to be deleted is an object.

/SUBASSEMBLY - Item to be deleted is a subassembly.

Syntax:

DELETE/OBJECT Object

DELETE/SUBASSEMBLY Subassembly

Parameters:

Object - Object number to be deleted

Subassembly - Subassembly number to be deleted

DISPLAY

Purpose: DISPLAY prints a table of information on elements in the system. This may be at the level of subassembly, object or surfaces. It may also be used to show photometric calculation data. The display data may be saved to a file by using SET/DISPFIL.

Modifiers:

- /ALL - Displays all items (objects, surfaces or subassemblies) in the system
- (Default) /OBJECT - Displays specified object in the system
- /SURFACE - Displays the specified surface in the system
- /SUBASSEMBLY - Displays the specified subassembly
- /GEOMETRY - Displays geometric information about an object. The information displayed consists of a displacement: X, Y and Z, and three rotation angles: Alpha, Beta and Gamma. To place an object I in the same local coordinate as an object whose geometry is shown by DISPLAY/OBJECT/GEOMETRY command, use the sequence of commands:

PLACE I X Y Z
ROTATE/Z I Alpha
ROTATE/Y I Beta
ROTATE/Z I Gamma
- /PHOTOCALC - Redisplays the results of the last photometry calculation
- /FILE - Sends display information to file opened with the SET/DISPFIL command

Syntax:

DISPLAY/ALL
DISPLAY/OBJECT Object
DISPLAY/OBJECT/GEOMETRY Object
DISPLAY/SURFACE Surface
DISPLAY/SUBASSEMBLY Subassembly
DISPLAY/OBJECT/ALL

DISPLAY (continued)

DISPLAY/SURFACE/ALL

DISPLAY/SUBASSEMBLY/ALL

DISPLAY/PHOTOCALC

DISPLAY/any previous modifier/FILE

Parameters:

Object - Object number to be displayed

Surface - Surface number to be displayed

Subassembly - Subassembly number to be displayed

ECHO

Purpose: ECHO causes every input line to be echoed to the input console as it is processed. Echoed line may be in raw or expanded form.

Modifiers:

- (Default) /ON - Activates ECHO
- /OFF - Deactivates ECHO
- (Default) /RAW - Data is echoed the same way as typed in
- /EXPANDED - Command lines are preprocessed and expressions are expanded before echoing

Syntax:

ECHO/RAW/ON
ECHO/RAW OFF
ECHO/EXPANDED/ON
ECHO/EXPANDED/OFF

Parameters: None

Purpose: The IMAGE command is used to generate an image by tracing rays from an object of type Camera. The rays are traced in multiple bundles from distinct locations of the camera's film plane. Each location represents a pixel on the film plane. The bundles are regularly spaced on the film plane. Each bundle is wide enough to fill the aim window of the camera. The rays are distributed and the brightness calculations are made as if each pixel was a photometric differential area detector and a PHOTOMETRY command was given.

Modifiers:

(Default) /ANGLE - Rays will be equally spaced in angle space
/DCOSINE - Rays will be equally spaced in direction cosines
/CENTER - A single ray will be traced from each pixel, and aimed to pass through the center of the aim window.

Syntax:

IMAGE/ANGLE	Object Npx Npy Nrx Nry
IMAGE/DCOSINE	Object Npx Npy Nrx Nry
IMAGE/CENTER	Object Npx Npy

Parameters:

Object - Object number of the camera from which the image should be generated.

Npx - Number of pixels in the X direction.

Npy - Number of pixels in the Y direction.

Nrx - Number of rays to trace from each pixel in the X direction

Nry - Number of rays to trace from each pixel in the Y direction

MACRO

Purpose: The MACRO command allows the user to perform a group or series of LARC commands stored in files.

Modifiers:

/RUN/NAME

/END

/CHECK

Syntax:

MACRO/RUN/Name=Filename Iterations

Purpose: Runs the macro contained in the file filename.

Parameters: Iterations - Number of times to execute the macro

MACRO/END or EXIT

Purpose: Indicates the end of the macro file.

Examples:

MACRO/RUN/N=PERISCOP.LRC

Executes the macro contained in the file PERISCOP.LRC

Purpose: This command is used to modify the parameters of a given surface.

Modifiers:

(Default) /ATTRIBUTES - Modify optical surface attributes
 /HOLE - Modify geometric attributes of a hole in an object
(Default) /ADD - Add a hole to a surface
 /DELETE - Delete a hole from a surface
(Default) /RECTANGULAR - Rectangular hole
 /ELLIPTICAL - Elliptical hole

Syntax:

MODIFY/ATTRIBUTES Surface Refl Absor Lumin Diff
MODIFY/HOLE/DELETE Surface
MODIFY/HOLE/ADD/RECTANGULAR Surface Xcenter Ycenter Xhw Yhw
MODIFY/HOLE/ADD/ELLIPTICAL Surface Xcenter Ycenter Xhw Yhw

Parameters:

Surface - Surface number to be modified
Refl - Fractional reflectance
Absor - Fractional Absorption
Lumin - Luminance in Watts
Diff - Diffuse luminosity coefficient for the surface. Diff must be between 0 and 1.

Xcenter - Hole center with respect to X origin
Ycenter - Hole center with respect to Y origin
Xhw - X half-width of hole
Yhw - Y half-width of hole

PHOTOMETRY

Purpose: The PHOTOMETRY command is used to initiate solution of the photometric integral, given the identity of a detector to be simulated.

Modifiers:

(Default) /DA - Detector is a differential detector (like a plane)
/POINT - Detector is a point detector (like a molecule)
(Default) /ANGLE - Rays will be equally spaced in angle space
/DCOSINE - Rays will be equally spaced in direction cosines

Syntax:

PHOTOMETRY/POINT/DCOSINE Object Nx Ny Hfov Vfov
PHOTOMETRY/DA/DCOSINE Object Nx Ny Hfov Vfov
PHOTOMETRY/POINT/ANGLE Object Nx Ny Hfov Vfov
PHOTOMETRY/DA/ANGLE Object Nx Ny Hfov Vfov

Parameters:

Object - Object i.d. of the detector to be simulated
Nx, Ny - Number of rays in x and y directions to be modeled over the solid angle of the detector
Hfov, Vfov - Horizontal and vertical fields of view in degrees which constitute the solid angle of the detector view

Examples:

PHOTOMETRY 7 32 24 64 48

Model Object 7 as a detector with 64 degree horizontal field of view (fov) and 48 degree vertical fov, using a bundle of 32 horizontal by 24 vertical rays, evenly space over the rectangular solid angle.

Purpose: This command places an item in the workbox and activates it. The item is placed in the workbox at a location in one of four reference coordinate systems. (See geometric conventions.)

Modifiers:

- (Default) /ABSOLUTE - Location is specified in the global coordinate system.
- /PARALLEL - Location is specified in terms of displacement with respect to the origin of the local coordinate system of the reference item.
- /RELATIVE - Location is specified in the local coordinate system of the reference item.
- /INSIDE - Location is specified in the local coordinate system of the reference item and the object is considered to be inside of the reference item. This allows an object to be surrounded by the index of refraction different than that of air. The reference items must be a lens, rod, or luminous volume.
- /SHADOW - Used to place a previously defined model of the earth's shadow with respect to a previously defined earth/atmosphere type object. The shadow is placed relative to the earth. The shadow orientation is determined by the current direction of the diffuse luminous light source (specified by the SET/DSOURCE command), so that the shadow is on the side of the earth opposite this direction.
- /LASER - Used to place a previously defined model of a laser signature with respect to a previously defined earth/atmosphere type object. The laser is placed on the earth's surface at the position and orientation specified by the parameters.

Syntax:

PLACE/OBJECT/ABSOLUTE	Item X Y Z
PLACE/OBJECT/RELATIVE	Refitm Item X Y Z
PLACE/OBJECT/PARALLEL	Refitm Item X Y Z
PLACE/OBJECT/INSIDE	Refitm Item X Y Z
PLACE/SHADOW	Earth
PLACE/LASER	Earth Latitude Longitude Aximuth Zangle

PLACE (continued)

Parameters:

Item	- Object number to be placed
X	- X location
Y	- Y location
Z	- Z location
Refitm	- Reference item for parallel, relative and inside coordinate system placement
Earth	- Object number of the earth.
Latitude	- Earth latitude in degrees at which to place a laser
Longitude	- Earth longitude in degrees at which to place a laser
Azimuth	- Azimuth angle in degrees. Used to orient a laser. Measured counter clockwise from east.
Zangle	- Zenith angle in degrees. Used to orient a laser. A zenith angle of 0 is perpendicular to the earth's surface.

REMOVE

Purpose: REMOVE deactivates and displaces an object or subassembly. After removal, the object is still defined, but is not active and is not located in the workbox.

Modifiers:

(Default) /OBJECT - Item to be removed is an object.

/SUBASSEMBLY - Item to be removed is a subassembly.

Syntax:

REMOVE/OBJECT Object

REMOVE/SUBASSEMBLY Subassembly

Parameters:

Object - Object number to be removed

Subassembly - Subassembly number to be removed

RESTORE

Purpose: To recover a previously defined system from a file.

Modifiers:

/FILE=fname

Syntax:

RESTORE/FILE=fname

Parameters:

fname - name of file to recover system from

ROTATE

July 13, 1987

Purpose: This command rotates an item about one of three axes in the workbox.

Modifiers:

- (Default) /OBJECT - Item to be rotated is an object
- /SUBASSEMBLY - Item to be rotated is a subassembly
- (Default) /LOCAL - Rotation is with respect to local coordinate system origin
- /GLOBAL - Rotation is with respect to global coordinate system origin
- /RELATIVE - Rotation is with respect to the coordinate system of a specified reference object.
- /X - Rotation will be about the X axis
- /Y - Rotation will be about the Y axis
- /Z - Rotation will be about the Z axis

Syntax:

ROTATE/OBJECT/LOCAL/X* Item Theta
ROTATE/OBJECT/RELATIVE/X* Item Refitem Theta
ROTATE/OBJECT/GLOBAL/X* Item Theta
ROTATE/SUBASSEMBLY/LOCAL/X* Item Theta
ROTATE/SUBASSEMBLY/GLOBAL/X* Item Theta

*Can be X, Y or Z with any other modifier combo.

Parameters:

Item - Object or subassembly number to be rotated
Refitem - Reference object for relative rotation.
Theta - Amount of rotation in degrees

SAVE

July 13, 1987

Purpose: To save the currently defined system to a file so that it may be recalled later using RESTORE. Also used to save the image generated by the last PHOTOMETRY or CAMERA command. The image is saved in an ascii format which is suitable for transmission to and display on a remote graphics device.

Modifiers:

/SYSTEM - indicates that the system should be saved.
/IMAGE - indicates that an image should be saved.
/FILE=fname - identifies the file to write to

Syntax:

/SAVE/SYSTEM/FILE=fname
/SAVE/IMAGE/FILE=fname Ngrey

Parameters:

fname - String containing the file name to which the data will be written.
Ngrey - Indicates the number of grey levels that the saved image should contain.

SET

July 13, 1987

Purpose: The SET command allows the user to modify a variety of LARC configurations, workbox size and location, display filename, and ray trace limit parameters. (Also, see the SHOW command.)

Modifiers:

- /WORKBOX - Sets 3-D workbox center and half-widths
- /TLIMITS - Sets ray trace limit parameters, including maximum trace depth, maximum number of ghost rays and minimum transmissivity. These parameters determine whether potential descendant rays are traced or not. If, for example, maximum ghost rays = 2, only 2 secondary descendants will be traced in the ray tree. The idea behind these limitations is to control the number of ray trace operations in a realistic way.
- /DEFAULT - Resets workbox size and location to defaults: (center at (0., 0., 0.), half-widths (75., 50., 100.))
- /DISPFILE - The name of a file to which display data will be sent
- /OVERWRITE - If the display file name given already exists, overwrite it with new display information.
- /WAVELENGTH - Sets the current wavelength
- /DSOURCE - Sets the direction and intensity of the light source used with surfaces with a diffuse luminous property. Also used as the sun direction for atmospheric traces.

Syntax:

```
SET/TLIMITS Maxdepth Mintrans Maxghost
SET/WORKBOX Xcenter Ycenter Zcenter Xsize Ysize Zsize
SET/WORKBOX/DEFAULT
SET/DISPFILE=Displayfile
SET/DISPFILE=Displayfile/OVERWRITE
SET/WAVELENGTH Wavelength
SET/DSOURCE          Xdir Ydir Zdir Bright
```

Parameters:

Maxdepth - Maximum number of descendant rays to be traced.

SET (continued)

Mintrans	- Minimum transmissivity for tracing rays. If the cumulative transmissivity of a ray being traced falls below Mintrans, the trace of that ray is terminated.
Maxghost	- The maximum number of ghost, or secondary, rays to be traced.
Xcenter	- X position of workbox center.
Ycenter	- Y position of workbox center.
Zcenter	- Z position of workbox center.
Xsize	- X half width of workbox.
Ysize	- Y half width of workbox.
Zsize	- Z half width of workbox.
Displayfile	- String containing the file name to which displayed data will be written.
Wavelength	- The current wavelength in microns.
Xdir	- X component of the direction of the diffuse light source.
Ydir	- Y component of the direction of the diffuse light source.
Zdir	- Z component of the direction of the diffuse light source.
Bright	- Brightness of the diffuse light source.

Purpose: SHOW informs the user regarding the current LARC configuration, including workbox size and location, display filename, and ray trace control limits. (See the SET command.)

Modifiers:

- (Default) /ALL - Shows all categories of data
- /WORKBOX - Shows workbox size and center location
- /TLIMITS - Shows ray trace limits including maximum trace depth, maximum number of ghost descendant rays, minimum transmissivity for ray continuation
- /DISPFILE - Shows name of file to which display data is sent
- /WAVELENGTH - Shows the current wavelength
- /DSOURCE - Shows the direction and intensity of the light source for diffuse luminous surfaces.

Syntax:

SHOW/ALL
SHOW/WORKBOX
SHOW/TLIMITS
SHOW/DISPFILE
SHOW/WAVELENGTH
SHOW/DSOURCE

Parameters: None

SHOW (continued)

Examples:

SHOW/TLIM

May result in:

Ray Trace Limits:

Maximum trace depth = 10

Maximum number of ghost rays = 2

Minimum transmissivity = 0

TRANSLATE

Purpose: TRANSLATE moves an item from its current position to some new position in three spaces. This may be a relative (LOCAL) or an absolute (GLOBAL) displacement.

Modifiers:

- /LOCAL - Translation is with respect to item local coordinate system
- (Default) /GLOBAL - Translation is with respect to global coordinate system
- (Default) /OBJECT - Item to be translated is an object
- /SUBASSEMBLY - Item to be translated is a subassembly

Syntax:

```
TRANSLATE/OBJECT/LOCAL      Item X Y Z
TRANSLATE/OBJECT/GLOBAL     Item X Y Z
TRANSLATE/SUBASSEMBLY/LOCAL Item X Y Z
TRANSLATE/SUBASSEMBLY/GLOBAL Item X Y Z
```

Parameters:

Item - Object or subassembly number to be translated

- X - X displacement
- Y - Y displacement
- Z - Z displacement

USER1-USER5

Purpose: This command is used to call user-defined FORTRAN routine via LARC. If no user routines have been linked with the code and the command USER1 is entered, the system responds with the message "subroutine USER1 not implemented".

Modifiers, Parameters, and Syntax: User-defined

VARIABLE

Purpose: The VARIABLE command provides access to the LARC intrinsic variables.

Modifiers:

Modifier	Operation	Legal Variable Types	Number of Operands
/ADD	computes a sum	I, R, C	2
/SUB	computes a difference	I, R, C	2
/MUL	computes a produce	I, R, C	2
/DIV	computes a division	I, R, C	2
/IDIV	computes an integer division	I, R	2
/PWR	computes a value raised to a power	I, R, C	2
/MOD	computes a modulus	I, R	2
/SQRT	computes square root	I, R, C	1
/ABS	computes absolute value	I, R	1
/NEG	computes the negative of a value	I, R, C	1
/EXP	computes 'e' to a power	I, R, C	1
/LOG	computes a natural logarithm	I, R, C	1
/SIN	computes a sine	I, R, C	1
/COS	computes a cosine	I, R, C	1
/TAN	computes a tangent	I, R	1
/ASIN	computes an arcsine	I, R	1
/ACOS	computes an arccosine	I, R	1
/ATAN	computes an arctangent	I, R	1
/SET	sets a variable to a given value	All	1 (0 for string variables)
/SHOW	shows variable contents	All	0

VARIABLE (continued)

- /VALUE - indicates value to which a string variable is to be set
- /Vid - indicates which variable to operate upon. The Vid may begin with C, I, R, or S (for Complex, Integer, Real or String), and is followed by an integer number between 1 and 50. For example 'r13' refers to real variable 13.

Syntax:

- VARIABLE/SHOW - Shows the values of all variables
- VARIABLE/SHOW/Vid - Shows the variable specified by Vid
- VARIABLE/SET/Vid/VALUE=Str_value - Sets the string variable specified by Vid to Str_value
- VARIABLE/SET/Vid value - Sets an integer or real variable to value.
- VARIABLE/SET/Vid rvalue ivalue - Sets a complex variable to the value (rvalue,ivalue), where rvalue is the real part and ivalue is the imaginary part.

The rest of the modifiers perform an operation on a variable. The general form of these commands is:

VARIABLE/Vid/Operation Operands

The operation is performed on the given operands, and the value computed is assigned to the variable specified by Vid. The form of Operands depends on the type of the variable and the number of operands required by the operation, as in the following table:

Variable Type	Number of Operands	Form of Operands
I (integer)	1	Op1
I (integer)	2	Op1 Op2
R (real)	1	Op1
R (real)	2	Op1 Op2
C (complex)	1	Rop1 Iop1
C (complex)	2	Rop1 Iop1 Rop2 Iop2

VARIABLE (continued)

Parameters:

Value	- Numeric value to which a real or integer variable is to be set
Rvalue	- Real part of the numeric value to which a complex variable is to be set
Ivalue	- Imaginary part of the numeric value to which a complex variable is to be set
Op1	- First real or integer operand
Op2	- Second real or integer operand
Rop1	- Real part of first complex operand
Iop1	- Imaginary part of first complex operand
Rop2	- Real part of second complex operand
Iop2	- Imaginary part of second complex operand

VIEW

Purpose: VIEW provides a 3-dimensional perspective view of the optical system, optionally displaying ray paths, workbox, etc. It also provides a Maxwellian view (after photometry calculations are done) which shows the system as it appears illuminated before a detector.

Modifiers:

(Default) /SYSTEM	- view all components in system in 3-D perspective
/FROM_OBJECT	- system perspective as seen from an object
/ORTHOGONAL	- a 4 plot composite showing x, y, and z views and a 3-D perspective
/MAXWELLIAN	- displays an intensity pattern (not a system view) as would be seen from a detector given luminous objects in the system. This works only after a photometric calculation has been done
/RAYS	- displays rays in addition to optical components
/SAVE	- Saves the plot to a file instead of displaying it

Syntax:

VIEW/SYSTEM Azimuth Elevation
VIEW/ORTHOGONAL Azimuth Elevation
VIEW FROM_OBJECT Object
VIEW/any previous modifier/RAYS
VIEW/any previous modifier/BOX
VIEW/MAXWELLIAN Object
VIEW/any previous modifier/SAVE

VIEW (continued)

Parameters:

Default

Azimuth	- Viewpoint Azimuth angle in degrees	45 (or last value)
Elevation	- Viewpoint elevation angles in degrees	30 (or last value)
Object	- Number of the object from which a Maxwellian view or view from a detector is to be made. The object must be a photometric detector for a Maxwellian view.	

APPENDIX A

COMMAND SUMMARY

ACTIVATE: activates an object or subassembly in the system.

DEACTIVATE: deactivates an object or subassembly.

DEFINE: defines various types of system elements, including reference axes, lenses, mirrors, apertures and detectors.

DELETE: used to "undefine" an object or subassembly.

DISPLAY: prints a table of information on elements in the system. This may be at the level of subassembly, object or surfaces. It may also be used to show photometric calculation data. The display data may be saved to a file by using SET/DISPFIL.

ECHO: causes every input line to be echoed to the input console as it is processed. Echoed line may be in raw or expanded form.

IMAGE: generates an image by tracing rays from an object of type Camera.

MACRO: allows the user to perform a group or series of LARC commands stored in files.

MODIFY: used to modify the parameters of a given surface.

PHOTOMETRY: used to initiate solution of the photometric integral, given the identity of a detector to be simulated.

PLACE: places an item in the workbox and activates it. The item is placed in the workbox at a location in one of three reference coordinate systems. (See geometric conventions.)

REMOVE: deactivates and displaces an object or subassembly. After removal, the object is still defined, but is not active and is not located in the workbox.

RESTORE: recovers a previously defined system from a file.

ROTATE: rotates an item about one of three axes in the workbox.

SAVE: saves the currently defined system to a file so that it may be recalled later using RESTORE.

SET: allows the user to modify a variety of LARC configurations, including graphics display device control, workbox size and location, display filename, and ray trace limit parameters. (Also, see the SHOW command.)

SHOW: informs the user regarding the current LARC configuration, including current graphics output devices, workbox size and location, display filename, and ray trace control limits. (See the SET command.)

TRANSLATE: moves an item from its current position to some new position in three spaces. This may be a relative (LOCAL) or an absolute (GLOBAL) displacement.

USER1-USER5: used to call user-defined FORTRAN routine via LARC. If no user routines have been linked with the code and the command USER1 is entered, the system responds with the message "subroutine USER1 not implemented".

VARIABLE: provides access to the LARC intrinsic variables.

VIEW: provides a 3-dimensional perspective view of the optical system, optionally displaying ray paths, component labels, workbox, etc. It also provides a Maxwellian view (after photometry calculations are done) which shows the system as it appears illuminated before a detector.

GLOSSARY

<u>Bounding Volume:</u>	A mathematical object used to snugly enclose another more complicated object. The purpose of bounding volumes is to reduce the number and complexity of intercept calculations which must be done in tracing groups of rays.
<u>Materials Table:</u>	A file which contains a data base of commonly needed optical material names, and the media properties (i.e. index of refraction) associated with each name. Some such properties are wavelength dependent.
<u>Maxwellian View:</u>	An image which defines the distribution of light falling on a point in space. This view simulates what would be perceived looking through a "perfect pinhole" at the objects in the system.
<u>Media:</u>	A substance occupying a volume which possesses uniform optical properties such as index of refraction, opacity/unit dist, color, absorption, scattering, etc.
<u>Object:</u>	A volume of media bounded by 1 or more surfaces.
<u>Ray:</u>	A mathematical entity representing the path of light as a series of line segments in 3 space. (Sometimes referred to as parent ray.)
<u>Ray Descendant:</u>	Any ray segment (3-D line with end points) generated as a result of bouncing off or refracting through an object.
<u>Ray Intercept:</u>	The 3 space point at which a surface is intercepted by a ray.
<u>Ray Tracing:</u>	The process of mathematically calculating the movement of rays of light through a simulated optical environment.
<u>Subassembly:</u>	A group of objects located relative to one another. Similar to a mini-workbox which can be located as an object in the global workbox.
<u>Surface:</u>	An interface between 2 volumes in 3 dimension. A surface may possess optical qualities including specular and diffuse reflectance, transmittance, color, etc.
<u>System View:</u>	A 3-D plot showing the physical location of components and rays with respect to each other.

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4 January 1988

In reply refer to 88RPS011

Los Alamos National Laboratory
PO Box 1663
Los Alamos, NM 87545

Attention: Dr. Ed Sklar

Subject: MODIFIED USER'S MANUAL (OSIRIS)

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The attached document is forwarded for your information and retention.

Should there be any questions regarding this transmittal, please contact the author of the document.

Very truly yours,

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ROCKWELL POWER SERVICES COMPANY

J. M. Gromek
Resident Director

JMG/cjb

AUG 01 1988

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