GRAPHICS

GRAPHICS (REFERENCE MANUAL SECTION) COMMAND PROMPTS

GRAPH-GENERAL INFORMATION - Many commands which generate image quality graphics are described in the Image Evaluation Prompting Guide section. All program graphical display options are described in this manual section. Most of the commands which generate graphical displays are issued only from the CMD level. A very few can be issued from the SPECT level. Except for the generation of the internal file, no other graphics output is supported in the "THE PROGRAM AS A SUBROUTINE" mode.

MODE OF OPERATION - The program performs all of its graphical output to an internal file. This file may be displayed on the display screen or printed to the current printer, if one is connected, by issuing specific drawing or printing commands.

DEVICE INDEPENDENT COORDINATES - The program uses a device independent graphical coordinate system for its communication with display and printing devices. The lower left-hand corner of each device has coordinates (X=0, Y=0), the upper left-hand corner of each device has coordinates (X=0, Y=7000), the upper right-hand corner of each device has coordinates (x=10000, Y=7000) and the lower right-hand corner of each device has coordinates (x=10000, y=0). Device independent coordinates are ALWAYS represented by integer values.

CMD LEVEL GRAPHICS COMMANDS

COLORSET (qualifier word) , color# - The "COLORSET" command issued with a "qualifier word" other than "RESET" is used to change the color of the graphic item designated by the "qualifier word" to the color value designated by "color#". The following table lists the allowed "qualifier words" with their meanings:

QUALIFIER	GRAPHIC ITEM	Default Color
RAYS	Ray color of rays in optical system plots	15 - (Black)
CLAP	Clear aperture color in optical system plots	3 - (Red)
COBS	Obscurations in optical system plots	9 - (Dark Yellow)
EDGE	Edge color in optical system plots	1 - (Yellow)
PROF	Surface profile color in optical system plots	1 - (Yellow)
AXIS	Axes drawn in optical system plots and ray positions drawn in beam footprint plots	15 - (Black)
GBAC	Graphics background color, all plots	0 - (White)
WAV1	1st wavelength used in a fan/spot plots and Primary Chromatic Difference fan plots	15 - (Black)
WAV2	2nd wavelength used in a fan/spot plots and Secondary Chromatic Difference fan plots	12 - (Dark Cyan)
WAV3	3rd wavelength used in a fan/spot plots	2 - (Light Magenta)
WAV4	4th wavelength used in a fan/spot plots	3 - (Light Red)
WAV5	5th wavelength used in a fan/spot plots	4 -(Light Cyan)
WAV6	6th wavelength used in a fan/spot plots	5 - (Light Green)
WAV7	7th wavelength used in a fan/spot plots	6 -(Light Blue)
WAV8	8th wavelength used in a fan/spot plots	7 - (Light Grey)
WAV9	9th wavelength used in a fan/spot plots	8 - (Dark Grey)
WAV10	10 wavelength used in a fan/spot plots	9 - (Dark Yellow)
FRAM	Graphic frame color in plots where a frame is used	15 - (Black)
LABL	Label color for all plot labels, notes and symbols	15 - (Black)
SPEC	Color of SPECT disk database plots	15 - (Black)
PEN	Color of pen in PLOT PEN commands	15 - (Black)

By default, the "LENS" command sets up the first five lens wavelengths to be 0.58756 μ, 0.48613 μ, 0.65627 μ, 0.43584 μ and 0.70652 μ. The first five wavelength colors are set in their default mode to simulate the appearance of these colors. There is no restriction on the order of wavelengths in the lens nor is there a restriction on the assignment of colors to various wavelengths.

COLORSET RESET - The "COLORSET RESET" command, issuable at any time from the CMD level, resets all graphics displays to their default colors. The following table lists the allowed "color#'s" with their associated colors:

color#	COLOR
-1	CURRENT BACKGROUND COLOR
0	WHITE
1	YELLOW
2	LIGHT MAGENTA
3	LIGHT RED
4	LIGHT CYAN
5	LIGHT GREEN
6	LIGHT BLUE
7	DARK GREY
8	LIGHT GREY
9	DARK YELLOW
10	DARK MAGENTA

11	DARK RED
12	DARK CYAN
13	DARK GREEN
14	DARK BLUE
15	BLACK

PLOT NEW - The "PLOT NEW" command initializes the program for new graphical output. WARNING: ANY EXISTING PLOT DATA IN THE INTERNAL FILE WILL BE OVERWRITTEN AFTER THE "PLOT NEW" COMMAND IS ISSUED. Plot scaling, used in optical system graphics, is reset to "automatic" by these commands. The "PLOT NEW" command utilizes the entire screen and should be used for most graphics.

PLOT NAME , plot name - up to 60 characters in length - The "PLOT NAME" command used to name the current plot with a name description of up to 60 characters long. The name will be used for identification purposes in the plot library.

PLOT ORIGIN , x , y - The "PLOT ORIGIN" command is used to reset the device independent coordinates of the current plot origin to the integer values "x" and "y". This new origin is remembered as the new plot origin. The program default values for the plot origin are x=0 and y=0. If "PLOT ORIGIN" is entered with blank input, the default values x=0 and y=0 will be used.

PLOT SYMBOL , i , H , IX , IY - The "PLOT SYMBOL" command is used to plot a point plot symbol at the pen position IX, IY in device independent coordinates. The symbol is designated by the integer numeric input "i" as designated in the following table:

SYMBOL NUMBER	SYMBOL
1	+ (plus sign)
2	x (small x)
3	(small square)
4	¦ (small triangle)
5	¦ (small inverted triangle)
6	quartered square
7	crossed triangle
8	crossed inverted triangle
9	square with x
10	triangle plus inverted triangle

The default symbol is number 1, a plus sign (+). The character height is specified with the integer numeric input value "H". "H" = integer print size value which can take on any integer value from 1 to 9 (smallest to largest). The height of a character in device independent units is always equal to the "H" value times 44 device independent units. The program default value for "H" is 1. This command generates graphical output.

PLOT LSTYLE , i - The "PLOT LSTYLE" command is used to set the line style used by the "PLOT PEN" command to the style specified by the integer numeric input "i" as designated in the following table:

LINE STYLE NUMBER	LINE STYLE NAME	LINE STYLE
0	SOLID	———————————————————
1	DOTS	....
2	SHORT DASH	-- -- -- -- -- -- -- -- -- -- -- -- -- --
3	DASH-DOT	--- - --- - --- - --- - --- - --
4	DASH-DOT-DOT	--- - - --- - - --- - - --- - - --- -
5	DASH-DOT-DOT-DOT	--- - - - --- - - - --- - - - --- - -
6	DASH-DASH-DOT-DOT	--- --- - - --- --- - - --- --- - -
7	DASH-DASH-DASH-DOT	--- --- --- - --- --- --- - --- ---
8	LONG DASH	----- ----- ----- ----- ----- -
9	LONG DASH-SHORT DASH	----- -- ----- -- ----- -- ----- --

The default line style is number 0, a solid line. This command does not generate graphical output by itself.

PLOT LWIDTH , (mult factor) - The "PLOT LWIDTH" command is used to adjust plotted line widths when plots are processed by the "GRAOUT" command. This command is ignored for screen graphics. The "mult factor" can be any positive number. Since different devices and have different default line widths assigned to them, it is best to use this command to adjust line widths after an initial "GRAOUT" has been performed without the use of this command. This command must preceed any line plotting for it to have an effect.

PLOT CHNOTE , H , THETA - The "PLOT CHNOTE" is used prior to the "PLOT NOTE" and "PLOT ACC" commands. It sets the character height with the integer numeric input value "H" and the printing angle to the integer value (in degrees) "THETA". The values set with this command remain in effect until the next "PLOT CHNOTE" or a "PLOT NEW" command is issued. "H" = integer print size value which can take on any integer value from 1 to 9 (smallest to largest). The height of a character in device independent units is always equal to the "H" value times 44 device independent units. "THETA" = integer text angle in degrees. Its default value is 0 degrees (range 0 to 360). Angles are measured counterclockwise from the positive X-axis (horizontal line pointing to the right) to the line of text. The program default value for "H" is 1. This command does not generate graphical output by itself.

PNOTE , character string of note - up to 79 characters in length- The "PNOTE" command established the content of the next note which will be plotted with "PLOT NOTE"

PLOT NOTE , IX , IY - The "PLOT NOTE" command annotates the plot with the last note established with the last "PNOTE" command (stripped of all leading and trailing blanks) beginning at the pen position IX, IY. This command generates graphical output by itself.

PLOT ACC , IX , IY , N , M - The "PLOT ACC" moves the pen to the location "IX" and "IY". The value in the macro accumulator (X-register) is then plotted beginning at this new pen position. N is an integer value from 1 to 10. It designates the number of positions to the right of the decimal place that are to be plotted. Decimal values are plotted in the "G" format form. If possible, the number is plotted in standard decimal form; otherwise,

it is represented in exponential form. For decimal values, the formats used range from a G8.1 (N=1) to a G17.10 (N=10). If M is not blank (any numeric value may be used to set this to non-blank), the accumulator value is represented as an integer from -99999999 to 999999999. Integers outside this range are plotted as ********** (10 asterisks). All leading and trailing spaces are stripped from these values before they are plotted. The program default value for character height value used is 1 and that value can be changed using the "PLOT CHNOTE" command. This command generates graphical output by itself.

PLOT PEN , IX , IY , i - The "PLOT PEN" command is the basic command used to draw lines in device independent coordinates. The "pen" is moved from its current position to the device independent coordinates "IX" (horizontal). and "IY" (vertical). The pen status is determined by the integer value of "i" as specified in the table below. Line styles are changed using the "PLOT LSTYLE" command already described. "IX" and "IY" must be integer values. This command generates graphical output by itself.

PEN STATUS VALUE ("i")	PEN STATUS WHILE MOVING
1	NO CHANGE IN STATUS
2	LOWER PEN BEFORE MOVE
3	LIFT PEN BEFORE MOVE

PLOT FRAME , xl , yl , xu , yu - The "PLOT FRAME" command is the command used to draw a rectangular frame in the current frame color. "xl", "yl", "xu" and "yu" are the x and y coordinates of the lower left and upper-right hand corners of the frame. These frame corner coordinates are represented in device independent integer coordinates. The default input values are 1, 1, 9999 and 6999.

FRAME (ON or YES or OFF or NO - The "FRAME" command is used to control the presence of a drawn frame in selected plots. The program default is not to plot the frame.

GRID (ON or YES or OFF or NO) - The "GRID (ON or YES or OFF or NO)" commands either activate or deactivate the plotting of dotted grid lines in functional data plots such as GOTF, DOTF, RED, LSF etc..The default is "OFF". If turned "ON", this switch stays "ON" until turned "OFF" or until the program terminates.

AUTOMATED OPTICAL SYSTEM GRAPHICS - The optical system graphics commands described earlier in this section allow the designer considerable freedom in the generation of graphical representations of the current optical system database (lens database). They may be issued interactively from the keyboard or included as part of a macro. For those times when only a "quick look" at the optical system is needed, the "VIE" command has been added. Just as in the "FAN" command, this command does not require the designer to explicitly issue either a "PLOT NEW" command or a "DRAW" command.

VIE (qualifier word) , sf , i , j , dflag or **VIECO (qualifier word) , sf , i , j , dflag** - The CMD level commands "VIE" and "VIECO" causes a one-page drawing of the current lens system to be generated. If "dflag" is zero (the default), the plot is automatically displayed on the screen. Afterward, the plot may be printed using the "GRAOUT" command. If "dflag" is set to any non-zero value, the automatic display is suppressed. The two commands are identical except that "VIE" performs NO clear aperture/obscuration violation checking and plots rays which would be blocked by clear apertures and obscurations. "VIECO" will not plot rays which are blocked by clear apertures and obscurations. The plot may still be displayed with the "DRAW" command and printed with the "GRAOUT" command. The following table lists all of the valid qualifier words and the associated plot orientations:

QUALIFIED WORD	ORIENTATION
(none) or YZ	YZ-view (X-axis into the screen)
XZ	XZ-view (Y-axis into of the screen)
XY	XY-view (Z-axis into the screen)
ORTHO	preset ortho-graphic view with the "look view" set to: elevation = 26.2 degrees azimuth = 232.2 degrees

The numeric inputs are:
NUMERIC WORD #1
"sf" is the scale factor. If "sf" is set to 0.5, for example, then the lens system will be drawn at one-half full size. If "sf" is omitted, the program will adjust the scale to fill the screen. The "sf" scale factor must be explicitly entered if the view is "XY".
NUMERIC WORD #2
"i" is the beginning surface number. If "i" is omitted, the plot will begin at the first non-infinite thickness surface. NUMERIC WORD #3
"j" is the final surface number. If "j" is omitted, the plot will stop at the last surface of the lens database.
The relative extent of the marginal rays and fields of view can be controlled by adjusting the X and Y-object heights and X and Y-relative aperture heights in the lens database.

SHIFTING A VIE PLOT
VIEOFF , x-offset , y-offset , rotation - The CMD level command "VIEOFF" is used to offset and rotate a display which is to be generated by the next "VIE" command. It is intended for cases when the "VIE" automatic offsets are not by themselves acceptable. The "x-offset" and "y-offset" for the display are specified in device independent coordinates.
The counterclockwise "rotation" about the display center is specified in degrees. The offsets are applied before the rotation. All offsets and the rotation are applied after the automatic offsets generated by "VIE". Remember that the bottom left-hand corner of the screen has device independent coordinates x=0, y=0 and the top right-hand corner has device independent coordinates x=10000, y=7000.

VIGNETTING IN A VIE PLOT
VIEVIG (YES or ON or NO or OFF) - The CMD level command "VIEVIG" is used to specify whether or not automatic vignetting factors should be calculated and applied to the rays being traced when "VIE" is issued. The default is to calculate vignetting factors (ON or YES) for each field point and to apply these in tracing the rays to be plotted. The vignetting factor calculation considers all ray blockage mechanisms except obscurations. The "ON" or "YES" and "OFF" or "NO" status is sticky and stays set until the program stops or until reset by the user. "VIEVIG (OFF

or NO)" causes rays at full 1.0 fractional reference surface heights to be traced (if they can be) and plotted, even if those rays pass outside clear apertures set in the system.

SYMMETRY IN A VIE PLOT

VIESYM (YES or ON or NO or OFF) - The CMD level command "VIESYM" is used to specify whether or not field of view symmetry should exist when "VIE" is issued. The default is to plot the upper and lower fields of view. If "VIESYM NO or OFF" is issued, then only one half of the field of view is plotted and the 0.7 FOB positions are also displayed.

OVERLAYING A VIE PLOT

VIEOVER - The CMD level command "VIEOVER" is used to overlay the next VIE over the previous VIE. Each time a VIE is to be overlaid upon a previous VIE, the "VIEOVER" command must be issued.

OPTICAL SYSTEM GRAPHICS - The next group of commands are used for graphically representing various aspects of the optical system stored in the program lens database. For the commands which take a starting surface number, the program default will be to start at the current object surface or the first lens surface beyond the current object surface whose absolute magnitude axial thickness is less than 1.0D+10. The default ending surface will always be the current image surface. No entry for the starting and ending surfaces will result in a plot of the entire lens system. Entry of the same value for the starting and ending surfaces will result in an attempted plot of just that one surface. Dummy surfaces without explicit clear apertures will not be plotted. Dummy surfaces are surfaces which have the identical refractive index of each side. These dummy surfaces will be drawn if they have explicit clear apertures assigned. The default in this case will be to draw them with dashed lines, however, the "PLOT NODASH" command will cause solid lines to be used instead. The object and image surfaces are never considered to be dummy surfaces. If no explicit clear aperture is assigned to a surface, the implicit aperture drawn by the profile and clear aperture plotting commands will be a circular clear aperture whose semi-diameter is equal to the sum of the paraxial marginal and paraxial chief ray heights at that surface. This implicit clear aperture will be centered at the location on the surface where the "FOB 0 0 0 1" chief ray intersects that surface.

PLOT SCALE , x , y - The "PLOT SCALE command sets the plot scale factors to values other than those automatically computed by the program. "y" is the number of thousands of device independent coordinate units which represent one lens unit in the Y (vertical) direction of the plot. A "y" scale factor of 10 would scale one unit of the object being plotted so that it plotted in 10,000 units of the device independent coordinate system. For most devices, 1000 units in the device independent coordinate system will be represented as 1.0 inch. "x" is the corresponding scale factor value in the X (horizontal) direction. The plot size values are also reset by the "PLOT SCALE" command. These size factors are just the reciprocal values of the scale factors. The default condition for scaling is automatic scaling. In automatic scaling, the program attempts to pick a set of scale factors which will fill the output device based upon the first plotting command requiring auto-scaling. After the scale factors are picked by the program or set by the user, they remain set until they are reset again using either the "PLOT SCALE", the "PLOT SIZE" or the "PLOT NEW" command. When making composite plots with auto-scaling, the data with the largest range should be plotted first.

PLOT NOSCALE - The "PLOT NOSCALE" command stops display of the scale factors on the current plot. If "PLOT SCALE" or "PLOT YESCALE" have been issued, scale factors will be displayed in the bottom left-hand corner of the plot.

PLOT YESCALE - The "PLOT YESCALE" command causes display of the scale factors in the lower left-hand corner of the current plot. This command is used to override the "PLOT NOSCALE" and "PLOT NOSIZE" commands without resetting the scale factors.

PLOT SIZE , x , y - The "PLOT SIZE" command sets the plot size factors to values other than those automatically computed by the program. "y" is the number of lens units per 1000 units of device independent coordinates. "x" is the corresponding size factor value in the X (horizontal) direction. The plot scale values are also reset by the "PLOT SIZE" command. These size factors are just the reciprocal values of the scale factors. The default condition for sizing is automatic. In automatic sizing, the program attempts to pick a set of size factors which will fill the output device based upon the first plotting command requiring auto-sizing. After the size factors are picked by the program or set by the user, they remain set until they are reset again using either the "PLOT SCALE", the "PLOT SIZE" or the "PLOT NEW" command. When making composite plots with auto-sizing, the data with the largest range should be plotted first.

PLOT NOSIZE - The "PLOT NOSIZE" command stops display of the size factors. If "PLOT SIZE" or "PLOT YESIZE" have been issued, size factors rather than scale factors will be displayed in the bottom left-hand corner of the plot. "PLOT NOSIZE" stops the plotting of size factors.

PLOT YESIZE - The "PLOT YESIZE" command causes display of the size factors in the lower left-hand corner of the current plot. This command is used to override "PLOT NOSIZE" and "PLOT NOSCALE" commands without resetting the size or scale factors.

PLOT AXIS - The "PLOT AXIS" command instructs the program that a coordinate axis is to be plotted on the current plot in the lower right-hand corner of the current plot. The axis will represent the current "PLOT LOOK"/"PLOT VIEW" setting.
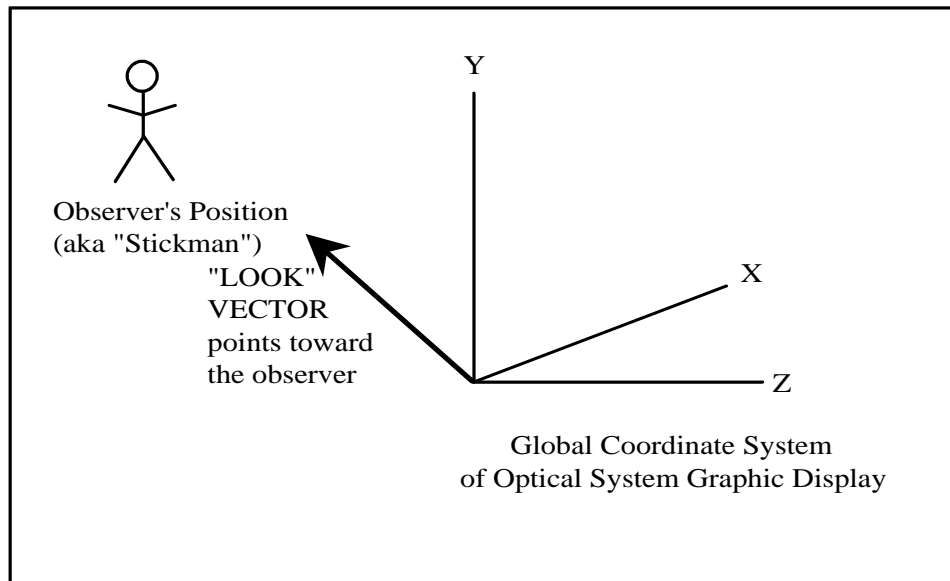
PLOT LOOK , Vx , Vy , Vz - The "PLOT LOOK" command changes the "LOOK" vector for the current optical system plot. The "LOOK" vector is represented by the direction cosines Vx, Vy and Vz of a vector which point toward the "observer's position" from the system under observation. The vector is represented in the coordinate system of the surface which is currently acting as the global coordinate reference surface of the system for plotting. (See the discussion in the CMD LEVEL manual section on global raytracing and global coordinate). The plotted view is always "isometric". No attempt at other projections is made. The global reference surface for plotting is automatically selected by the program. The default for "PLOT LOOK" is "PLOT LOOK , -1 , 0 , 0". This results in a graphical representation of the system with the global reference axis +Y pointing up, the global reference axis +Z pointing to the right, the global reference axis +X pointing into the graphics page and the global reference X-axis pointing toward the observer. The "LOOK" vector remains the same until it is changed using another "PLOT LOOK", "PLOT VIEW" or a "PLOT NEW" command. The "PLOT VIEW" values are always automatically adjusted by a "PLOT LOOK" command.

The direction cosine input values do not have to be true normalized to 1.0 direction cosines. The program takes the first three input values, calculates the sum of their squares and divides each value by this normalization factor. The resultant normalized values are then stored as the "look vector" values. If the "PLOT LOOK" command is entered followed by a space and a "?", the current "look vector" values will be displayed on the screen. The plot may also be shifted in x and y and rotated about its center using the "PLOT XSFIFY". "PLOT YSHIFT" and "PLOT GAMMA" commands described later in this section.

PLOT YESLOOK - The "PLOT YESLOOK" displays the current "look" vector information in the lower portion of optical system plots.

PLOT NOLOOK - The "PLOT NOLOOK" cancels the effect of a "PLOT YESLOOK" command in optical system plots.

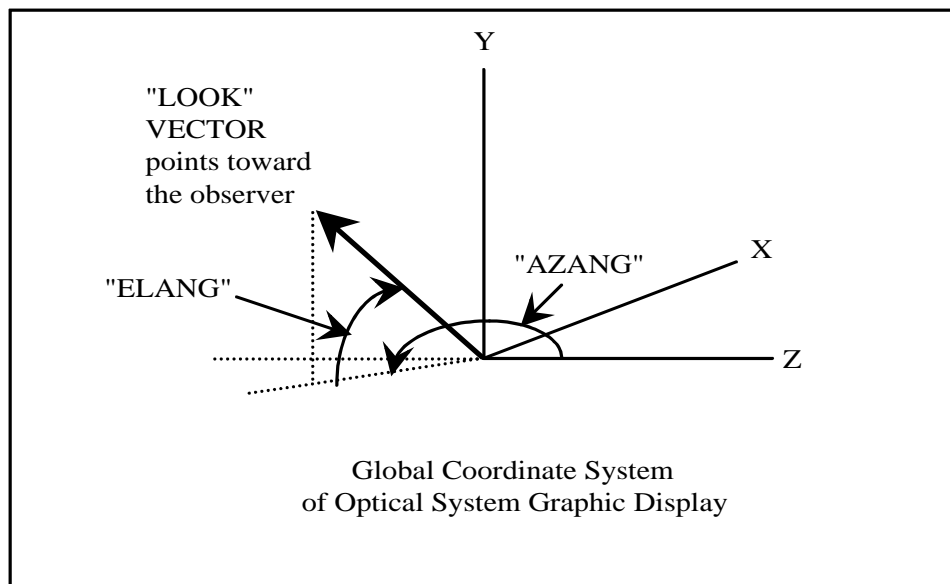The "LOOK" vector concept is illustrated in the following figure:

Y

X

Z

Observer's Position
(aka "Stickman")

"LOOK"
VECTOR
points toward
the observer

Global Coordinate System
of Optical System Graphic Display

The "LOOK" Vector

PLOT VIEW , ELANG , AZANG - The "PLOT VIEW" command changes the "look angle" for the current optical system plot. The "look view" is represented by elevation viewing angle "ELANG" and azimuth viewing angle "AZANG". Both angles are in units of degrees. The default "plot view" elevation and azimuth angles are: "ELANG" = 0.0 degrees and "AZANG" = 270.0 degrees, which correspond to the default "plot look" vector (-1, 0, 0). "ELANG" is measured from 0.0 degrees to +/- 90.0 degrees. Positive/negative "ELANG"s represent an observer positioned above/below the XZ-plane of the current global reference coordinate system. "AZANG" is measured from 0.0 to 360.0 degrees in a right-handed sense from the +Z axis toward the +X axis about the +Y axis of the current global reference coordinate system. The "look angle" remains the same until it is changed using another "PLOT VIEW", "PLOT LOOK" or a "PLOT NEW" command. The "PLOT LOOK" values are always automatically adjusted by a "PLOT VIEW" command. The plot may also be shifted in x and y and rotated about its center using the "PLOT XSFIFY". "PLOT YSHIFT" and "PLOT GAMMA" commands described later in this section.

PLOT YESVIEW - The "PLOT YESVIEW" displays the current view angle information in the lower portion of optical system plots.

PLOT NOVIEW - The "PLOT NOVIEW" cancels the effect of a "PLOT YESVIEW" command in optical system plots. The viewing angles "ELANG" and "AZANG" are illustrated in the following figure:

Y

X

Z

"LOOK"
VECTOR
points toward
the observer

"ELANG"

"AZANG"

Global Coordinate System
of Optical System Graphic Display

Viewing Angles "ELANG" and "AZANG"

ORIENT , i , shiftflag - The "ORIENT" command causes the "LOOK VECTOR" to be reset so that its X, Y and Z-components are equal to the L, M and N-direction cosines of the local Z-axis of surface "i". The "LOOK VECTOR" passes through the vertex of surface "i". "ORIENT" is used whenever the "LOOK VECTOR" needs to be set so as to look "normal" to a surface. The view angles are also reset. If "shiftflag" is set to any explicit value, the "ORIENT" command also does an automatic "PLOT XSHIFT" and "PLOT YSHIFT" so as to place the origin of the current global coordinate system at the center of the plot. This can then be subsequently modified by the user with "PLOT XSHIFT" and PLOT YSHIFT" commands. If "shiftflag" is not explicitly set to a value, the local origin of the surface is centered on the plot.

NORIENT , i , shiftflag - The "NORIENT" command causes the "LOOK VECTOR" to be reset so that its X, Y and Z-components are equal in magnitude but opposite in sign to the L, M and N-direction cosines of the local Z-axis of surface "i". The "LOOK VECTOR" passes through vertex of surface. "NORIENT" is used instead of the "ORIENT" command when the "ORIENT" command causes the observer to view from the "wrong" side of surface "i". The view angles are also reset. If "shiftflag" is set to any explicit valy, the "ORIENT" command also does an automatic

"PLOT XSHIFT" and "PLOT YSHIFT" so as to place the origin of the current global coordinate system at the center of the plot. This can then be subsequently modified by the user with "PLOT XSHIFT" and PLOT YSHIFT" commands. If "shiftflag" is not explicitly set to a value, the local origin of the surface is centered on the plot.

PLOT LI - The "PLOT LI" command sets an internal program flag which causes the current "Lens Identifier" to be plotted on the current plot in the lower center when the next command, which generates optical system graphical output, is issued. If the "LI" is blank, no action is taken.

PLOT NOLI - The "PLOT NOLI" command cancels the effect of the "PLOT LI" command.

PLOT LBL , i - The "PLOT LBL" command sets an internal program flag which causes the lens database surface label at surface "i" to be plotted on the current plot in the upper left corner when the next command, which generates optical system graphical output, is issued. If the "LBL" for surface "i" is blank, no action is taken.

PLOT PROFY , i , j , , , clapflag and **PLOT PROFX , i , j , , , clapflag** - The "PLOT PROFY" and "PLOT PROFX" commands are used to plot the YZ and XZ-plane lens surface profile. These profiles are the projections of the surface's local coordinate system Y and X-axes upon the lens surface. The profile is bounded by the explicit or implicit clear aperture on that surface. A blank space will be left if there is an assigned obscuration. Mirror surfaces which have a non-zero mirror thickness assigned, will have an additional profile drawn which represents the back and sides of this mirror. If "clapflag" is 0 (the default), profiles are drawn even if no clear aperture is assigned. If "clapflag" is set non-zero, profiles are only drawn when clear apertures are assigned.

PLOT PROF , i , j , theta , , clapflag - The"PLOT PROF" command is a general form of the commands "PLOT PROFX" and "PLOT PROFY". It is used to plot surface profiles in any azimuthal orientation. The third numeric word "theta" specifies the azimuthal orientation angle. "Theta" is measured positive, counter-clockwize from the local surface positive x-axis to the local surface positive y-axis. "Theta" can be assigned any angle between 0.0 and 360.0 degrees. The default value for "theta" is 0.0. This is equivalent to a "PLOT PROFX" command. A "PLOT PROFY" command may be simulated with "theta" set to 90.0 degrees. The profile is bounded by the explicit or implicit clear aperture on that surface. A blank space will be left if there is an assigned obscuration. Mirror surfaces which have a non-zero mirror thickness assigned, will have an additional profile drawn which represents the back and sides of this mirror. This command generates no graphics for POLYGON clear aperture/obscuration surfaces. If "clapflag" is 0 (the default), profiles are drawn even if no clear aperture is assigned. If "clapflag" is set non-zero, profiles are only drawn when clear apertures are assigned.

PLOT EDGEY , i , j , , , clapflag and **PLOT EDGEX , i , j , , , clapflag** - The "PLOT EDGEY" and "PLOT EDGEX" commands are used to plot edges connecting non-air spaces. The edges connect the ends of surface profiles. These commands generate no graphics for POLYGON clear aperture/obscuration surfaces. If "clapflag" is 0 (the default), edges are drawn even if no clear aperture is assigned. If "clapflag" is set non-zero, edges are only drawn when clear apertures are assigned.

PLOT CLAP , i , j , k , , clapflag - The "PLOT CLAP" command is used to plot surface clear apertures projected onto the surface. The optional third numeric word "k" is used to specify fractional clear aperture plotting. The default value for "k" is 1.0. "k" may be set to any value greater than 0.0 and less than or equal to 1.0. Mirror surfaces which have a non-zero mirror thickness assigned, will have an additional clear aperture drawn which represents the back of this mirror. If "clapflag" is 0 (the default), clear apertures are drawn even if no clear aperture is assigned. If "clapflag" is set non-zero, edges are only drawn when clear apertures are assigned.

PLOT COBS , i , j - The "PLOT COBS" commands are used to plot surface obscurations projected onto the surface profile. The area inside the obscuration will be filled with a program selected cross-hatched pattern.

PLOT NODASH - The "PLOT NODASH" command is used to plot clear apertures and surface profiles of dummy surfaces with explicitly assigned clear apertures as solid rather than dashed lines.

PLOT DASH - The "PLOT DASH" command cancels the effect of the "PLOT NODASH" command.

PLOT RAY , i , j - The "PLOT RAY" command causes the most recent ray traced to be plotted from lens surface "i" to lens surface "j" . The internal operation of the "PLOT RAY" command is such that if the ray to be plotted is a failed ray, the ray will be plotted through the optical system up to the surface for which ray data becomes unreliable. This allows for "diagnostic" ray trace plots to be made. Rays may fail for any of the valid failure reason recognized by the program including ray failures due to blockages by clear apertures and obscurations when the "RAY CAOB" command is used to trace the ray.

PLOT RAYS , i , j , n , λ# , orintation_flag - The "PLOT RAYS" command causes a group of rays to be traced and plotted. from lens surface "i" to lens surface "j". "n" is the number of rays in the group, with a default value of 11. "λ#" is the wavelength number used for the trace, the default being the control wavelength. A chief ray, traced with a previous "FOB" command must already exist. If VIEVIG is OFF, the group is traced so as to fill the reference surface and rays are not blocked by clear apertures but are blocked by obscurations. If "VIEVIG" is ON, the extent of the group will be modified by automatic, on-the-fly, vignetting calculations and rays will be blocked by obscurations. If "orientation_flag" is set to 0, the default, the group will be a "fan" traced in the YZ plane. If "orientation_flag" is set to 1, the group will be a fan traced in the XZ-plane. If "orientation_flag" is set to 2, an aperture filling cone will be traced.

PLOT RAYSCO , i , j , n , λ# , orintation_flag - The "PLOT RAYSCO1" is exactly like "PLOT RAYS" except that it drops failed rays reguardless of the VIEVIG setting.

PLOT PMRAYY , i , j - The "PLOT PMRAYY" command causes the upper and lower YZ-plane marginal generalized paraxial rays to be traced, referenced to the axial chief ray. Rays are drawn in "red". "i" and "j" are starting and ending surface numbers. The defaults are the object and image surfaces.

PLOT PMRAYX , i , j - The "PLOT PMRAYX" command causes the upper and lower XZ-plane marginal generalized paraxial rays to be traced, referenced to the axial chief ray. Rays are drawn in "red". "i" and "j" are starting and ending surface numbers. The defaults are the object and image surfaces.

PLOT PCRAYY , i , j - The "PLOT PCRAYY" command causes the upper and lower YZ-plane chief generalized paraxial rays to be traced, referenced to the axial chief ray. Rays are drawn in "red". "i" and "j" are starting and ending surface numbers. The defaults are the object and image surfaces.

PLOT PCRAYX , i , j - The "PLOT PCRAYX" command causes the upper and lower XZ-plane chief generalized paraxial rays to be traced, referenced to the axial chief ray. Rays are drawn in "red". "i" and "j" are starting and ending surface numbers. The defaults are the object and image surfaces.

VIRTRAY (ON or YES) or (OFF or NO)

The "VIRTRAY" command may be issued at any time from the CMD level. It sets a "sticky" switch which tells the program whether or not to draw "virtual" rays. "Virtual" rays are rays which go to and from dummy surfaces but which do not represent actual light paths in the optical system.. The

program must always trace these "virtual" rays in order to correctly track optical path length (OPL). The program default is to not plot "virtual" rays. Most of the time, the user will not need to see these "virtual" rays. If the user wishes to draw the "virtual" rays, the command "VIRTRAY YES" should be issued. If the user then wishes to stop drawing "virtual" rays, the command "VIRTRAY NO" should be issued. "VIRTRAY" followed by the interrogator "?", will cause the current "VIRTRAY" setting to be displayed. The "PLOT NEW" command need not be issued before the "VIRTRAY" command can be issued.

PLOT VERTLINE , i , j - The "PLOT VERTLINE" command causes the line connecting the surface vertex locations from surface "i" to lens surface "j" to be plotted.

PLOT (RIGHT or CENTER or LEFT) - The "PLOT (RIGHT or CENTER or LEFT)" command attempts to RIGHT, CENTER or LEFT justify optical system plotting which follows these commands.

PLOT XSHIFT , x or PLOT YSHIFT , y - The "PLOT XSHIFT" and "PLOT YSHIFT" commands shift all optical system plotting which follows these commands, "x" or "y" device independent units, from their default positions. Positive and negative integer values are expected here.

PLOT GAMMA , γ - The "PLOT GAMMA" command rotates all optical system plotting which follows this command by γ integer degrees, counterclockwise about the center of the display. This center is located at x=5000 and y=3500 device independent units.

FIGURE , (alpha numeric string) - The "FIGURE" command allows the user to input a figure name for a following plot. Up to 80 characters may be entered.

PLOT FIGURE , x , y The "PLOT FIGURE" command allows the user to place the current figure name on a graphic starting at coordinates "x" and "y" in the device independent coordinate system. If "x" or " y" are not input, their default values will be taken to be x=100 and y = 900.

PLOT LINE - The "PLOT LINE" command allows the user to draw a 3D line from coordinates X1, Y1, Z1 to coordinates X2, Y2 and Z2. The coordinates of these two points are always considered to be represented in the global coordinate system of the current optical system graphic in which the origin is either located at the vertex of surface 0 (for finit conjugate object points) or the vertex of surface 1 (for infinite conjugate object points). The coordinates of these two points are assigned using the following six commands. By default, both points are located at 0,0,0 when the program starts or when a new plot is initiated.

X1 or Y1 or Z1 or X2 or Y2 or Z2 - The "X1", "Y1", "Z1", "X2", "Y2" and"Z2" commands allows the user to specify the starting and ending coordinates of the next 3D line to be drawn. By default, the values are 0,0,0 when the program starts and when a new plot is initiated.

DISPLAYING GRAPHICS - The plotting commands discussed up to this point either set internal program flags or send graphics output to the disk internal file. At any time after issuing a "PLOT NEW" command and before issuing a "PLOT END" command, the current contents of the internal file may be displayed on the current screen display by issuing the "DRAW" command. After viewing this graphics display, pressing the <RETURN> key will clear these screen graphics and return the screen to the text mode for continued program input.

DRAW - The "DRAW" command is used to display graphics to the current screen device. Screen graphics is performed using an auxilliary piece of software named WDRAW.EXE.

GRAOUT - The "GRAOUT" command is used to generate monochrome (black and white) a hard copy of the current internal file to the default Windows printer controlled by the Windows Print Manager. Hardcopy graphics is performed using an auxilliary piece of software named WPLOT.EXE. "GRAOUT" is only included with the paid user support distribution of the program. It is a totally separate program.

GRAOUT COLOR - The "GRAOUT COLOR" command is used to generate color (color printers) or shaded grey scale (monchrome printers) hard copy of the current internal file to the default Windows printer controlled by the Windows Print Manager. If the default Windows printer is a PostScript printer, then EPS file capture is possible using custom settings in the Windows Print Manager set up windows.

GRAOUT WMF (optional file name up to 8 characters) - The "GRAOUT WMF" command is used to generate a monochrome (black and white) 16 bit Window's Metafile of the current internal file. The default file name is WMF.WMF. The file will always have the extension of WMF.

GRAOUT EMF (optional file name up to 8 characters) - The "GRAOUT EMF" command is used to generate a monochrome (black and white) 32 bit Extended Window's Metafile of the current internal file. The default file name is EMF.EMF. The file will always have the extension of WMF.

GRAOUT AMF (optional file name up to 8 characters) - The "GRAOUT AMF" command is used to generate a monochrome (black and white) 32 bit, Extended, Aldus Placeable Window's Metafile of the current internal file. The default file name is AMF.AMF. The file will always have the extension of WMF.

GRAOUT COLWMF (optional file name up to 8 characters) - The "GRAOUT COLWMF" command is used to generate a 16 bit Window's Metafile of the current internal file. The default file name is COLWMF.WMF. The file will always have the extension of WMF.

GRAOUT COLEMF (optional file name up to 8 characters) - The "GRAOUT COLEMF" command is used to generate a 32 bit Extended Window's Metafile of the current internal file. The default file name is COLEMF.EMF. The file will always have the extension of WMF.

GRAOUT COLAMF (optional file name up to 8 characters) - The "GRAOUT COLAMF" command is used to generate a 32 bit, Extended, Aldus Placeable Window's Metafile of the current internal file. The default file name is COLAMF.AMF. The file will always have the extension of WMF.

GRAOUT PCX (optional file name up to 8 characters) - The "GRAOUT PCX" command is used to generate a monochrome PCX file of the current internal file. The default file name is PCX.PCX. The file will always have the extension of PCX

GRAOUT COLPCX (optional file name up to 8 characters) - The "GRAOUT COLPCX" command is used to generate a color PCX file of the current internal file. The default file name is COLPCX.PCX. The file will always have the extension of PCX

GRAOUT BMP (optional file name up to 8 characters) - The "GRAOUT BMP" command is used to generate a monochrome BMP file of the current internal file. The default file name is BMP.BMP. The file will always have the extension of BMP.

GRAOUT COLBMP (optional file name up to 8 characters) - The "GRAOUT COLBMP" command is used to generate a color BMP file of the current internal file. The default file name is COLBMP.BMP. The file will always have the extension of BMP.

GRAOUT CBMP (optional file name up to 8 characters) - The "GRAOUT CBMP" command is used to generate a monochrome compressed BMP file of the current internal file. The default file name is CBMP.BMP. The file will always have the extension of BMP.

GRAOUT COLCBMP (optional file name up to 8 characters) - The "GRAOUT COLCBMP" command is used to generate a compressed color BMP file of the current internal file. The default file name is COLCBMP.BMP. The file will always have the extension of BMP.

GRAOUT EPS (optional file name up to 8 characters) - The "GRAOUT EPS" command is used to generate a monochrome EPS (Encapsulated Post Script) file of the current internal file. The default file name is EPS.EPS. The file will always have the extension of EPS.

GRAOUT COLEPS (optional file name up to 8 characters) - The "GRAOUT COLEPS" command is used to generate a color EPS file of the current internal file. The default file name is COLEPS.EPS. The file will always have the extension of EPS.

GRAPHICS SCREEN DISPLAY
YESDRAW - The "YESDRAW" command is used to turn "on" screen graphics in the screen graphics mode. "On" is the default setting.
NODRAW - The "NODRAW" command is used to turn "off" screen graphics in the screen graphics mode. "On" is the default setting.

AUTO WMF GRAPHICS
YESWMF -The "YESWMF" c ommand is used to turn "on" automatic generation of a color Windows Metafile named RRR.WMF each time the "DRAW" command is issued by the program or by the user. "Off" is the default setting.
NOWMF - The "NOWMF" command is used to turn "off" automatic generation of a color Windows Metafile named RRR.WMF each time the "DRAW" command is issued by the program or by the user. "Off" is the default setting.

PLOT TERMINATION
PLOT END - The "PLOT END" command stops all graphic input to the current internal file, sets the internal program graphics flag to "off" and, if no graphic input was ever written to the internal file, then internal file is deleted. If graphic input was written to the internal file , then the internal file is saved.

THE PLOT LIBRARY - Just as there is a lens library, a macro library and a glass library, the program has a plot library. This library is used to save and recall plot files (copies of the internal file) for future use. After a "PLOT NEW" command is issued, the following commands may be used to graphically display or manipulate the contents of the program plot library:
IPF - The "IPF" command is the first of a two-part procedure used to initialize the plot library. To avoid accidental destruction of the existing plot library, the "IPF" command performs no plot library initialization unless it is followed immediately by the command:
PROCEED - If the command "PROCEED" is not immediately entered following the "IPF" command, then the "IPF" command is ignored and canceled. THIS INITIALIZATION PROCEDURE SHOULD BE USED WITH CAUTION AS LARGE AMOUNTS OF DATA MAY BE LOST IF IT IS USED CARELESSLY. The "IPF" command is intended for a user who has no plot library or for a user who intentionally desires to clean the slate and begin anew with an empty plot library.
PSTAT - The "PSTAT" command displays the number of plot file library entries used and the number of empty spaces remaining. The plot library can hold up to 999 plot files.
PLIB P - The "PLIB P" command displays a listing of the plot library file names with their time and date stamps. The names are specified using the "PLOT NAME" command described earlier in this section.
PLIB GET , i - The "PLIB GET" command causes the plot library entry designated by the integer library number "i" to be the target file for subsequent "DRAW" or "GRAOUT" commands. "i" can range from 1 to 999.
PLIB PUT , i or **PLIB PUT** - The "PLIB PUT" command stores the current contents of the internal file into either the plot library position designated by the integer value "i" or into the next open spot in the library if "i" is not specified. "i" can range from 1 to 999 .
PLIB DEL , i , j - The "PLIB DEL" command deletes the plotting library entries starting at the "i"th entry and ending with, and including, the "j"th entry. If "j" is omitted, only the "i"th entry is deleted.
LINE STYLES FOR FAN PLOTS - All transverse and longitudinal ray aberration and OPD fan plots use specific line styles based upon the wavelength number. They are:

WAVELENGTH #	LINE STYLE #
1	0
2	1
3	2
4	3
5	4
6	5
7	6
8	7
9	8
10	9

USER-DEFINED PLOTTING - The user may always issue a "PLOT NEW" command followed by "PLOT PEN" and other low level plotting command in order to generate a "user-defined" graphic. Using the re-entrant nature of the program graphics, the user can check on the progress of these plots by issuing "DRAW" commands periodically during this type of "user-defined" plotting. Normally, unction plotting; i.e. f(x) as a function of x would be slow and and so the following commands have been added which make plotting f(x) versus x relatively simple. It will be assumed that the user has issued a "PLOT NEW" command before using the following commands:
PLOT UXAXRNG , xstart , xstop - The "PLOT UXAXRNG" defines the x-locations of the start and stop of the x-axis of a user defined plot. The defaults are 2.0 and 8.0 inches respectively.
PLOT UYAXRNG , ystart , ystop - The "PLOT UYAXRNG" defines the y-locations of the start and stop of the y-axis of a user defined plot. The defaults are 1.4 and 5.6 inches respectively.
PLOT UXAXIS , xlower , xupper , dx , iflag - The "PLOT UXAXIS" defines the lower and upper limits for the units and extent of the x-axis of the plot. The x-axis will be spread from x=2.0 inches to x=8.0 inches on the plot assuming an 8-1/2 by 11 sheet of paper in the landscape mode, unless changed by the "PLOT UXAXRNG command. The x-axis will be divided into "d" intervals. The default for "dx" is 5. If "iflag" is non-zero, only the end point ticks will value lables, otherwise all ticks will be labled.
PLOT UYAXIS , ylower , yupper , dy , iflag - The "PLOT UYAXIS" defines the lower and upper limits for the units and extent of the y-axis of the plot. The y-axis will be spread from y=1.4 inches to x=5.6 inches on the plot assuming an 8-1/2 by 11 sheet of paper in the landscape mode.,

unless changed by the "PLOT UYAXRNG command. The y-axis will be divided into "dy" intervals. The default for "dy" is 10. If "iflag" is non-zero, only the end point ticks will value lables, otherwise all ticks will be labled.

PLOT UXAXISLB (x-axis label up to 40 characters) - The "PLOT UXAXISLB" defines the x-axis label. The label can be up to 40 characters.

PLOT UYAXISLB (y-axis label up to 40 characters) - The "PLOT UYAXISLB" defines the y-axis label. The label can be up to 40 characters.

PLOT UYLINE , xvalue - The "PLOT UYLINE" draws a line in the y-direction, the full extent of the length of the y-axis but located at x= "xvalue".

PLOT UXLINE , yvalue - The "PLOT UXLINE" draws a line in the x-direction, the full extent of the length of the x-axis but located at y= "yvalue".

PLOT UPLOT   x-reglow , x-reghigh , y-reglow , y-reghigh , linestyle# - The "PLOT UPLOT" causes the functional values stored in general purpose storage registers numbered "y-reglow" to "y-reghigh" to be plotted versus the independent variable values stored in general purpose storage registers "x-reglow" to "x-reghigh". Straight line segments are used to connect all of the data points. Lines are drawn using the current color for plotted rays and in the line style designated "linestyle#". The default line style is a solid line, type 0. There are 10 available line styles designated as 0 to 9. Between issuances of "PLOT UPLOT" the values stored in the registers holding the functional values may be changed and as many user-defined functional plots as are desired can be plotted. The user may of course use "PLOT PEN" , "PLOT NOTE", and other user-defined plotting commands to augment these functional plots.

USER-PLOTTING EXAMPLE - The following macro named PLOTTEST generates a simple plot using 3 independent variable values 0, 2.5 and 5 and three associated dependent variable values 0, 1 and 10. The commands described above, used with the "SET X" command and the "STO" command are all that is required to generate a simple plot. The line style is set using the "PLOT LSTYLE" command. Line type 2 is a short dash type of line. To input this macro, simple type the following commands as they appear, each command followed by a press of the Enter key.

MACRO PLOTTEST
SET X 0
STO 1
SET X 2.5
STO 2
SET X 5
STO 3
SET X 0
STO 4
SET X 1
STO 5
SET X 10
STO 6
PLOT NEW
PLOT LSTYLE 2
PLOT UXAXIS 0 5
PLOT UYAXIS 0 10
PLOT UXAXISLB X-AXIS
PLOT UYAXISLB Y-AXIS
PLOT UPLOT 1 3 4 6
DRAW
EOM