LENS DATABASE

LENS and CONFIGS and SPFIT and SPSRF (REFERENCE MANUAL SECTIONS) COMMAND PROMPTS

NEW LENS INPUT
LENS – Starts new lens input mode. (Issue from CMD level)
END or **EOS** – Terminates new lens input mode. (Issue from LENS level)
LENS UPDATE
UPDATE LENS or **U L** – Starts lens update mode. (Issue from CND level)
END or **EOS** – Terminates lens update mode. (Issue from ULN level)
UPDATE LENS COMMANDS (from ULN level only)
INS , i , n – Inserts surfaces."i" is the surface to insert. "n" repeats the insertion process. Default for "n" is 1. Default for "i" is the "current" surface.
DEL , i , j – Deletes surfaces. "i" is the first surface to delete. "j" is the last surface to delete. Default for "i" is the "current" surface. Jefault for "j" is j = i. (Issue from ULN level)
CHG , i – Makes a surface the "current" surface. "i" is the surface which is to be made the "current" surface.
ZERO – Takes no argument. It "zeros out" all of the surface data on the "current" surface as if the surface had just been inserted.
LENS INPUT/LENS UPDATE COMMANDS (not tied to a specific lens database surface) (Issued from the LEN and ULN levels)
AUTOFUNC , n – It specifies that the macro function "n" is to be automatically issued each time an END or EOS command is issed at the LEN and ULN levels.
LI , (lens identifier up to 79 characters) – It specifies that the current lens will be named with the included string.
LIC , (lens identifier up to 79 characters) – It specifies that the current lens will be named with the included string as a continued lens identifier. Four of these may be issued for four lines of continued lens identifier.
INI , (designer identifier up to 70 characters) – Allows a designer name to be stored with the lens data.
WV , λ1 , λ2 , λ3 , λ4 , λ5 – Input values are the first five program wavelengths. Units are "microns". Default input results in no wavelength changes. Initial program default wavelengths are: 0.58756, 0.48613, 0.65627, 0.43584 and 0.70652 microns.
WV , λ6 , λ7 , λ8 , λ9 , λ10 – Input values are the second five program wavelengths. Units are "microns". Default input results in no wavelength changes. Defaults are initially all 0.0 microns.
UNITS (units name) – Valid input is: IN, INCH, INCHES, MM, CM or M (for meters) Program default is IN for inch units.
PCW , i , j – Specifies the wavelength numbers to be used for primary chromatic aberration calculations. Defaults are initially all 2 and 3.
SCW , i , j – Specifies the wavelength numbers to be used for secondary chromatic aberration calculations. Defaults are initially all 2 and 1.
CW , i – Specifies the wavelength number to be used as the main control wavelength. Default is 1.
SPECIFYING THE SIZE OF THE OBJECT AT THE OBJECT SURFACE (issuable from the LEN and ULN levels)
SCY , Y0 , Y1 – (for near objects < 1.0×10^{10}) Y0 specifies a reference object height at surface 0. Y1 is an optional way of specifying the height of the chief ray at surface 1 and is rarely used since better ways of specifying chief ray aiming exist. For non-infinite object distances, the defaults are Y0=1.0, Y1 = 0.0.
SCX , X0 , X1 - Same as the SCY command but works in the XZ-plane. If not used, the XZ-plane values are the same as the YZ-plane values.
SCY FANG , U0 , Y1 – (for far objects >1.0×10^{10}) U0 specifies a reference object angle in degrees as seen from surface 1. Y1 is an optional way of specifying the height of the chief ray at surface 1 and is rarely used since better ways of specifying chief ray aiming exist. For infinite object distances, the defaults are U0=1.0, Y1 = 0.0.
SCX FANG , U0 , X1 - Same as the SCY FANG command but works in the XZ-plane. If not used, the XZ-plane values are the same as the YZ-plane values.
or
PYIM , y – (for near objects < 1.0×10^{10}) "y" specifies the object height in terms of the paraxial image height in the YZ-plane.
PXIM , x - Same as the PXIM Y command but works in the XZ-plane. If not used, the XZ-plane values are the same as the YZ-plane values.
PYIM FANG , uy – (for far objects >1.0×10^{10}) "uy" specifies the object height in terms of a paraxial chief ray slope in degrees at the image surface.
PXIM FANG , ux - Same as the PXIM FANG command but works in the XZ-plane. If not used, the XZ-plane values are the same as the YZ-plane values.
or
RYIM , y – (for near objects < 1.0×10^{10}) "y" specifies the object height in terms of the real ray image height in the YZ-plane.
RXIM , x - Same as the RYIM Y command but works in the XZ-plane. If not used, the XZ-plane values are the same as the YZ-plane values.
RYIM FANG , uy – (for far objects >1.0×10^{10}) "uy" specifies the object height in terms of a real ray chief ray slope in degrees at the image surface.
RXIM FANG , ux - Same as the RYIM FANG command but works in the XZ-plane. If not used, the XZ-plane values are the same as the YZ-plane values.
SPECIFYING THE SIZE OF THE INPUT PUPIL ON SURFACE 1 (issuable from the LEN and ULN levels)
SAY (FLOAT or **NOFLOAT) , say** - Sets the semi-height of the marginal paraxial ray at surface 1 to the "say" value. If FLOAT is in effect and if the ASTOP surface has a clear aperture assigned, the "say" value will automatically "float" to make the paraxial marginal ray height at the stop surface equal to the clear aperture in the YX-plane. With a new lens, "FLOAT" is the default.
EPD (FLOAT or **NOFLOAT) , epd** - Same as SAY except the entrance pupil diameter at surface 1 is input where "epd" is twice the "say" value.
SAX (FLOAT or **NOFLOAT) , sax** - Same as SAY but applies to the XZ-plane. If not issued, the YZ-plane values apply to the XZ-plane.
or
NAOY, naoy - Sets the semi-height of the marginal paraxial ray at surface 1 so that the object space numerical aperture is "naoy".
NAOX , naox - Same as NAOY but applies to the XZ-plane. If not issued, the YZ-plane values apply to the XZ-plane.
or
FNOY, fnoy - Sets the semi-height of the marginal paraxial ray at surface 1 so that the object space numerical aperture is "naoy".
FNOX , fnox - Same as FNOY but applies to the XZ-plane. If not issued, the YZ-plane values apply to the XZ-plane.
GAUSSIAN BEAM DATA (issuable from the LEN and ULN level)
WRY, wry - Sets the YZ-plane gaussian beam $1/e^2$ semi-diameter at surface 1 to the value "wry". (Units are "lens units")
WRX , wrx - Same as WRY but applies to the XZ-plane. If not issued, the YZ-plane values apply to the XZ-plane.
BDY, bdy - sets YZ-plane beam divergence half-angle of the gaussian beam at surface 1 to the value "bdy". (Units are "milliradians")
BDX , bdx - Same as BDY but applies to the XZ-plane. If not issued, the YZ-plane values apply to the XZ-plane.
BDY TEM00 - Sets YZ-plane beam divergence half-angle of the gaussian beam at surface 1 to the value which corresponds to a TEM00 mode laser beam. The divergence is computed at the control wavelength.
BDX TEM00 - Same as BDY TEM00 but applies to the XZ-plane. If not issued, the YZ-plane values apply to the XZ-plane. The half-angle beam divergence

in radians is given by the following equation. R_0 is the $1/e^2$ semi-diameter of the beam at surface 1 and assumes that a true beam waist exists at that surface.

$$\theta = \frac{\lambda}{\pi \times R_0}$$

LENS INPUT/LENS UPDATE COMMANDS (surface specific data associated with the "current" surface and issuable from the LEN and ULN levels)

REAL - By default, all lens database surfaces are REAL. If one was set to "PARAXIAL" with the PARAX command, it can be set back to "REAL" with the REAL command.

PARAX - parax sets the current surface to "PARAXIAL". During ray tracing, the depth of curvature or sag of a PARAXIAL surface is ignored.

SURFACE SHAPE COMMANDS (including surface shape solves)

CV , c - Sets the curvature on the "current" surface to "c".

CC , κ - Sets the conic constant on the "current" surface to "c". Surface must not be plano.

RD , r - Sets the conic constant on the "current" surface to "c". Surface must not be plano.

APY - Adjusts the curvature on the "current" surface so the YZ-plane paraxial marginal ray angle sum of i + o = 0, thus setting up a paraxial marginal ray aplanatic surface condition.

APX - Same as APY but works in the XZ-plane of the current surface.

APCY - Adjusts the curvature on the "current" surface so the YZ-plane paraxial chief ray angle sum of i + o = 0, thus setting up a paraxial chief ray aplanatic surface condition.

APCX - Same as APCY but works in the XZ-plane of the current surface.

PIY , j - Adjusts the curvature on the "current" surface so the tangent of the YZ-plane paraxial marginal ray angle of incidence is equal to "j".

PIX , j - Same as PIY but works in the XZ-plane of the current surface.

PICY , j - Adjusts the curvature on the "current" surface so the tangent of the YZ-plane paraxial cheif ray angle of incidence is equal to "j".

PICX , j - Same as PICY but works in the XZ-plane of the current surface.

PUY (optional qualifier FN) , j - Adjusts the curvature on the "current" surface so the tangent of the YZ-plane paraxial marginal ray slope angle is equal to "j". If the optional qualifier "FN" is used, then "j" is initially interpreted as an f/number. After the curvature adjustment, the solve's target is replaced by the tangent of the slope angle which is equivalent to the requested f/number.

PUX (optional qualifier FN) , j - Same as PUY but works in the XZ-plane of the current surface

PUCY , j - Adjusts the curvature on the "current" surface so the tangent of the YZ-plane paraxial cheif ray slope angle is equal to "j".

PUCX , j - Same as PUCY but works in the XZ-plane of the current surface.

COCY, j - Adjusts the curvature on the "current" surface so the center of curvature of the "current" surface lies at the lo cal coordinate system vertex of surface "i". Paraxial thickness solves between the "current" surface and surface "j" are not allowed in this case.

COCX , j - Same as COCX but works in the XZ-plane of the current surface.

CSD , i , j - Deletes all curvature solves between surfaces "i" and "j". The default for "i" is the "current" surface. The defailt for "j" is "j"="i". (Only valid at the ULN level).

CSD ALL - Deletes all curvature solves. (Only valid at the ULN level).

CSD , i , j - Deletes all YZ-plane curvature solves between surfaces "i" and "j". The default for "I" is the "current" surface. The defailt for "j" is "j"="i". (Only valid at the ULN level).

CSDY ALL - Deletes all YZ-plane curvature solves. (Only valid at the ULN level).

CSDX , i , j - Same as CSDY but in the XZ=plane. (Only valid at the ULN level).

CSDX ALL - Same as CSDY ALL but in the XZ-plane. (Only valid at the ULN level).

ASPH , ad , ae , af , ag , ac - Sets the 4^{th}, 8^{th}, 6^{th}, 10^{th} and 2^{nd} order aspheric coefficients on the "current" surface to "ae", "ad", "af", "ag" and "ac". "ac" may only be set on plano surfaces.

ASPH , ah , ai , aj , ak , al - Sets the 12^{th}, 14^{th}, 16^{th}, 18^{th} and 20^{th} order aspheric coefficients on the "current" surface to "ah", "ai", "aj", "ak" and "al".

ASPHD , i , j - deletes all aspheric coefficients from surface "i" through "j" By default, "i" is the "current" surface and "j"="i". (Only valid at the ULN level).

AC , ac - Sets the 2^{nd} order aspheric coefficient on the "current" surface to "ac". Valid only on plano surfaces.

AD , ad - Sets the 4^{th} order aspheric coefficient on the "current" surface to "ad".

AE , ae - Sets the 6^{th} order aspheric coefficient on the "current" surface to "ae".

AF , af - Sets the 8^{th} order aspheric coefficient on the "current" surface to "af".

AG , ag - Sets the 10^{th} order aspheric coefficient on the "current" surface to "ag".

AH , ah - Sets the 12^{th} order aspheric coefficient on the "current" surface to "ah".

AI , ai - Sets the 14^{th} order aspheric coefficient on the "current" surface to "ai".

AJ , aj - Sets the 16^{th} order aspheric coefficient on the "current" surface to "aj".

AK , ak - Sets the 18^{th} order aspheric coefficient on the "current" surface to "ak".

AL , al - Sets the 20^{th} order aspheric coefficient on the "current" surface to "al".

XTORIC - Sets the "current" surface to be an X-toric with the toric axis parallel to the local x-axis.

YTORIC - Sets the "current" surface to be an Y-toric with the toric axis parallel to the local y-axis.

CVTOR , c' - Sets the toric curvature on the "current" surface to "c'".

TASPH , ad' , ae' , af' , ag' – Sets the 4^{th}, 6^{th}, 8^{th} and 10^{th} order toric, aspheric coefficients to "ad'", "ae'", "af'" and "ag'".

RDTOR , r' - Sets the toric radius of curvature on the "current" surface to "r'".

CCTOR , κ' - Sets toric conic constant on the "current" surface to "κ' ".

ADTOR , ad' - Sets the 4^{th} order toric aspheric coefficient on the "current" surface to "ad'".

AETOR , ae' - Sets the 6^{th} order toric aspheric coefficient on the "current" surface to "ae'".

AFTOR , af' - Sets the 8^{th} order toric aspheric coefficient on the "current" surface to "af'".

TORD , i , j - Deletes all toric data and definitions on surface "i" to "j". By default, "i" is the current surface and "j"="i". (Only valid at the ULN level).

TASPHD , i , j - Deletes all toric aspheric data and definitions on surface "i" to "j". By default, "i" is the current surface and "j"="i". (Only valid at the ULN level).

DEFORMABLE SURFACES - The Deformable Surface is a surface definition which may be added to any other regular surface definition. It simulates the effect of a rectangular grid of deformable surface actuators, each of which have a deformation influence function which is in general of the form:

$$f(\chi) = A_0 e^{-\left(\frac{\zeta^2}{2}\right)} + A_3 + A_4\chi + A_5\chi^2$$

where:

$$\zeta = \frac{(\chi - A_1)}{A_2}$$

and:

A_0	1.08342
A_1	-0.0069
A_2	0.486
A_2	-0.063
A_2	0.005
A_2	0.005

The "χ" value represents the absolute value of the average distance to each actuator in units of "average actuator spacing". The "average actuator spacing" in "lens units" is computed from the actuator locations input in deformable surface data file described below. Influence function data courtesy of Xinetics Inc., 37 MacArthur Ave., Devens, MA 01432, (978) 772-0352 (April,1998) The "average actuator spacing" in "lens units" is an arithmetic average of the average x-spacing and the average y-spacing based on the x and y-locations of the actuators specified in the deformable mirror surface. In general, the actuators will be on a square grid. The extent of the deformable mirror will be established by the clear aperture assigned to the surface in the lens database.

DEFORM F1 to F10 , n , z-scale factor - The "DEFORM" command, at the LENS or UPDATE LENS levels, is used to specify that a surface is to be defined as a deformable surface. F01 to F10 is a qualifier word that specifies that the ASCII file named DEFORM01.DAT to DEGORM10.DAT holds the actuator locations and normalized actuator extention values for this surface. Normalized actuator extensions can range from -1.0 to 1.0. "n" is the total number of actuators (max. allowable is 3969). "z-scale" is the actuator scale factor representing the physical surface deformation at any actuator location when the normalized actuator extension reaches a value of 1.0. If the "DEFORM" command is issued followed only by a "?", the current deformation input settings will be displayed. If a DEFORMxx.DAT file exists and if it has exactly "n" entries, then this file will be read into the deformable surface array. Actuator numbering (used in optimization) is illustrated in the following figure. Normalized actuator extension entries in the DEFORMxx.DAT file appear with their associated actuator X and Y-positions. The x and y-coordinates of each actuator are assumed to be relative to the center of the clear aperture assgned to the deformable surface. Each line entry in the file consists of the X-actuator location (real value), the Y-actuator location (real value) and the associated normalized actuator extension value (real value).
Example: File DEFORM01.DAT with 9 actuators

-4.5 -4.5 0.0 "actuator # 0001"
-4.5,0.0,0.0 "actuator # 0002"
-4.5,4.5,0.0 "actuator # 0003"
0.0, -4.5 0.0 "actuator # 0004"
0.0,0.0,0.0 "actuator # 0005"
0.0,4.5,0.0 "actuator # 0006"
4.5 -4.5 0.0 "actuator # 0007"
4.5,0.0,0.0 "actuator # 0008"
4.5,4.5,0.0 "actuator # 0009"

would be appropriate for a mirror with "average actuator spacing" of 4.5 lens units and with a rectangular clear aperture of 9.0 lens units (semi-extent). Deformable surfaces may not be assigned special surface characteristics. The 4-digit numbers in parantheses are the variable number designators used when calling out an actuator number to be an optimization variable. (See the OPTIM section for more details).
DELDEFOR - The "DELDEFOR" command, at the LENS or UPDATE LENS levels, is used to delete an existing DEFORM definition at the current surface.
ARRAY (ODD or EVEN) , dx , dy – Defines the current surface as array surface with array spacings "dx" and "dy".
ARRAYD – Deletes an array definition from the current surface. (Only valid at the ULN level).
SURFACE SEPARATION COMMANDS (including thickness solves)
TH , t – Sets the thickness of the "current" surface to "t".
THM , thm – Sets the mirror thickness of the "current" surface to "thm".
PY , h – Adjusts the thickness of the "current" surface so that the YZ-plane paraxial marginal ray height at the next following surface will be equal to "h".
PX , h – Same as PY except in the XZ-plane.
PCY , h – Adjusts the thickness of the "current" surface so that the YZ-plane paraxial chief ray height at the next following surface will be equal to "h".
PCX , h – Same as PCY except in the XZ-plane.
CAY , t – Adjusts the thickness of the "current" surface to satisfy non-interference conditions with the surface following the "current" surface.
CAX , t - Same as CAX but in the XZ-plane.
TSD i , j – Deletes all thickness solves between surfaces "i" and "j". By default, "i"is the "current surface and the default for "j" is "j"="i". (Only valid at the ULN level).
TSD ALL - Deletes all thickness solves. (Only valid at the ULN level).
TILTS AND DECENTERS
DEC , yd , xd , zd – Sets the decenters on the current surface to "yd", "xd" and "zd". The order of input copies that of HEXAGON.
XD , xd – Sets the X-decenters on the current surface to "xd".
YD , yd – Sets the Y-decenters on the current surface to "yd".
ZD , zd – Sets the Z-decenters on the current surface to "zd".
PIVAXIS VERTEX – This is the program default. Leave it set this way unless you have read and understand the operation of the PIVAXIS NORMAL command described in the Reference Manaul.
PIVAXIS NORMAL – Should not be used unless you have read the description of the command in the Reference Manual.
TILT , alpha , beta , gamma – This rotates the current surface first about the X-axis by "alpha", then about the new Y-axis by "beta" and then about the new

Z-axis by "gamma". If decenters are assigned to the surface, they are applied first.
RTILT , alpha , beta , gamma – This rotates the current surface frist about the Z-axis by negative "gamma", then about the new Y-axis by negative "beta" and then about the new X-axis by negative "alpha". If decenters are assigned to the surface, they are applied with a negative sign after the rotations have been applied.
TILT AUTO , alpha , beta , gamma – This rotates the current surface so that the local Z-axis is aligned parallel to the central chief ray generated with an FOB 0 0 0 command. If "alpha", "beta" and "gamma" are input, then act in a TILT command sense to "offset" the surface orientation set by the automatic Z-axis/chief ray alighment.
TILT AUTOM , alpha , beta , gamma – This rotates the current surface so that the local Z-axis is aligned anti-parallel to the central chief ray generated with an FOB 0 0 0 command. If "alpha", "beta" and "gamma" are input, then act in a TILT command sense to "offset" the surface orientation set by the automatic Z-axis/chief ray alighment.
TILTD , i , j – This deletes all TILT definitions on surfaces "i" to "j". The default for "i" is the current surface. The default for "j" is "j"="i". (Only valid at the ULN level).
TILT AUTOD – This command converts the TILT AUTO or TILT AUTOM on the "current" surface into an ordinary TILT. All angles assigned with the auto-alignment operation of TILT AUTO or AUTOM are maintained. (Only valid at the ULN level).
TILT BEN , alpha , beta – "TILT BEN" may not be placed on the object surface or on surface #1. If you think you need it on surface #1, make surface #1 a dummy surface and put it on surface #2. Defines a special TILT which keeps the local Z-axis aligned with the cheif ray. This allows defining fold mirrors with one surface. It was copied from the BEN option in CODE-V. Issued without numeric input, "TILT BEN" converts any existing tilt to a TILT BEN and leaves existing alpha,beta abd gamma values unchanged.
The Gamma angle is automatically assign in accordance with the following equation.
TILT BEND – Converts a TILT BEN to a simple tilt followed by a tilted, freshly inserted dummy surface. This is necessary when converting a TILT BEN into a format which can be read by one of the inferior optical design programs like ZEMAX. (Only valid at the ULN level).

$$\cos(\gamma) = \frac{\cos(\alpha) + \cos(\beta)}{1 + \cos(\alpha)\cos(\beta)}$$

$$\sin(\gamma) = \frac{-\sin(\alpha)\sin(\beta)}{1 + \cos(\alpha)\cos(\beta)}$$

TILT DAR , alpha , beta , gamma – "TILT DAR" may not be placed on the object surface or on surface #1. If you think you need it on surface #1, make surface #1 a dummy surface and put it on surface #2. Defines a special TILT which restores the optical axis after performing the TILT assignment. This too was copied from the DAR option for TILTS in CODE-V. Issued without numeric input, "TILT DAR" converts any existing tilt to a TILT DAR and leaves existing alpha,beta abd gamma values unchanged.
TILT DARD – Converts a TILT DAR to a simple tilt followed by a tilted, freshly inserted dummy surface. This is necessary when converting a TILT DAR into a format which can be read by one of the inferior optical design programs like ZEMAX. (Only valid at the ULN level).
TILT REV , alpha , beta , gamma - "TILT REV" may not be placed on the object surface or on surface #1. If you think you need it on surface #1, make surface #1 a dummy surface and put it on surface #2. The "TILT REV" command works exactly the same as an "RTILT" command except that all rays intersect the surface to which the "TILT REV" command is assigned, before the reverse tilts and decentrations are applied. After ray intersection, "TILT REV" causes the local coordinate system of the surface to which the "TILT REV" is assigned, to be rotated by successive surface angle rotations negative "gamma", negative "beta" and then negative "alpha". If the surface is decentered, negative decentrations are performed after the rotations. "gamma", "beta" and "alpha" are always expressed in degrees. This command is valid at both the LENS input and the UPDATE LENS levels. If the foregoing tilt commands are issued followed only by "?", the current tilt definition type and associated angles will be displayed. Issued with no numeric input, the "TILT REV" command converts any existing tilt type to a TILT REV and leaves existing alpha,beta and gamma values unchanged.
TILT REVD - The "TILT REVD" command is used to convert a "TILT REV" assignment on the current surface into an untilted surface followed by a new surface with an "RTILT". Appropriate tilts and decenters are assigned to the second surface such that the two surfaced work as the single "TILT REV" originally worked. All appropriate solves and thicknesses are transferred to the new surface. Since "TILT REVD" adds a lens surface, it is best to use "TILT REVD" from the highest surface number to the lowest, when replacing multiple occurrences of "TILT REV" during the same lens modification session.
TILT RET , i – "TILT RET" may not be placed on the object surface or on surface #1. If you think you need it on surface #1, make surface #1 a dummy surface and put it on surface #2. Automatically relocates the surface to which it is assigned to the location of surface "i". This too was copied from the RET option for TILTS in CODE-V.
TILT RETD – Converts a TILT RET to a simple TILT and should be used with caution. (Only valid at the ULN level).
SPECIAL "TILT RET" RULES:
1. A "TILT RET" may only be made to a previous surface.
2. No "TILT AUTO" or "TILT AUTOM" commands may appear on surfaces preceding surfaces with "TILT RET"s assigned.
3. A "TILT RET" may not be made to a surface which itself has a "TILT RET" or "TILT RETGO" assigned.
4. All "TILT RET" are resolved sequentially from the object surface to the image surface in one, single resolution pass. Circular return references will be ignored or interpreted incorrectly.
PIVOT , pivx , pivy , pivz – Sets the pivot point to the user specifiec off-sets from the "current" surface's vertex. Ignored by TILT RET.
PIVX , pivx– Sets the x-pivot point to the user specifiec x-off-set.
PIVY , pivy– Sets the y-pivot point to the user specifiec x-off-set.
PIVZ , pivz– Sets the z-pivot point to the user specifiec x-off-set.
PIVOTD– Sets the pivot point back to the "current" surface vertex. (Only valid at the ULN level).

CMD LEVEL TILT UTILITY
VERTS command. Sometimes the position of a following surface, and it's orientation, is not be specified in terms of XD, YD, TH, ALPHA, BETA and GAMMA with respect to the previous surface but will instead be specified by XD, YD, ZD and a set of direction cosines of the X, Y and Z local coordinate axis of the following surface with respect to the previous surface. The "VERTS" command will convert that type of specification into XD, YD, ZD, ALPHA, BETA and GAMMA (assuming a TILT definition is used on the following surface). Before issuing the VERTS command, the following data must be stored in the first 24 general purpose storage registers using the STO (register number) , (value to be stored). The data for both surfaces must, of course, be specified in

the same shared coordinate system).

Register 1	X-position of the previous surface
Register 2	Y-position of the previous surface
Register 3	Z-position of the previous surface
Register 4	XL-L-dircos of previous surface's local X-axis
Register 5	XM-M-dircos of previous surface's local X-axis
Register 6	XN-N-dircos of previous surface's local X-axis
Register 7	YL-L-dircos of previous surface's local Y-axis
Register 8	YM-M-dircos of previous surface's local Y-axis
Register 9	YN-N-dircos of previous surface's local Y-axis
Register 10	ZL-L-dircos of previous surface's local Z-axis
Register 11	ZM-M-dircos of previous surface's local Z-axis
Register 12	ZN-N-dircos of previous surface's local Z-axis
Register 13	X-position of the next surface
Register 14	Y-position of the next surface
Register 15	Z-position of the next surface
Register 16	XL-L-dircos of next surface's local X-axis
Register 17	XM-M-dircos of next surface's local X-axis
Register 18	XN-N-dircos of next surface's local X-axis
Register 19	YL-L-dircos of next surface's local Y-axis
Register 20	YM-M-dircos of next surface's local Y-axis
Register 21	YN-N-dircos of next surface's local Y-axis
Register 22	ZL-L-dircos of next surface's local Z-axis
Register 23	ZM-M-dircos of next surface's local Z-axis
Register 24	ZN-N-dircos of next surface's local Z-axis

RELATIVE GLOBAL SURFACE POSITIONING

GDX , gdx– Sets the relative global surface position to "gdx".
GDY , gdy– Sets the relative global surface position to "gdy".
GDZ , gdz– Sets the relative global surface position to "gdz".
GALPHA , galpha– Sets the relative global surface tilt to "galpha".
GBETA , gbeta– Sets the relative global surface tilt to "galpha".
GGAMA , ggamma– Sets the relative global surface tilt to "galpha".

SURFACE PIKUPS

PIKUP (parameter name) , (j =surface # to pick up from) , (a=multiplier) , (b = additive const) , , (configuration flag) – Established a link between the surface parameter on surface j such that the same parameter on the current surface will be equal to the surface parameter on surface "j" multiplied by "a" and then incremented by "b". The following table is a list of all parameters that may be picked up:

Parameter Name	Parameter
CV	surface profile curvature (c)
RD	surface profile radius of curvature (r)
CC	surface conic constant (cc)
CVTOR	surface profile toric curvature (c')
RDTOR	surface profile toric radius of curvature (r')
AC	2nd order aspheric coefficient (ac)
AD	4th order aspheric coefficient (ad)
AE	6th order aspheric coefficient (ae)
AF	8th order aspheric coefficient (af)
AG	10th order aspheric coefficient (ag)
AH	12th order aspheric coefficient (ag)
AI	14th order aspheric coefficient (ag)
AJ	16th order aspheric coefficient (ag)
AK	18th order aspheric coefficient (ag)
AL	20th order aspheric coefficient (ag)
ADTOR	4th order anamorphic aspheric coefficient (adtor)
AETOR	6th order anamorphic aspheric coefficient (aetor)
AFTOR	8th order anamorphic aspheric coefficient (aftor)
AGTOR	10th order anamorphic aspheric coefficient (agtor)
CCTOR	surface toric conic constant (cctor)
XD	X-decentration (xd)
YD	Y-decentration (yd)
ZD	Z-decentration (zd)
ALPHA	tilt angle about the X-axis (alpha)
PRO	complete surface profile (no "a" or "b") (Includes special surface definitions and deformable surface definitions)
NPRO	PRO , cv and aspheric signs reversed (no "a" or "b" input) (Excludes special surface definitions and deformable surface definitions)
GLASS	surface glass definition (no "a" or "b" input)
CLAP	complete surface clear aperture data (no "a" or "b" input)

COBS	complete surface obscuration data (no "a" or "b" input)
BETA	tilt angle about the Y-axis (beta)
GAMMA	tilt angle about the Z-axis (gamma)
TH	axial thickness (t)
THOAL	overall length pikup
PIVX	alternate x-pivot point location for a "TILT"
PIVY	alternate y-pivot point location for a "TILT"
PIVZ	alternate z-pivot point location for a "TILT"
GDX	global coordinate surface x-decenter (used with TILT RET)
GDY	global coordinate surface y-decenter (used with TILT RET)
GDZ	global coordinate surface z-decenter (used with TILT RET)
GALPHA	global coordinate surface alpha tilt (used with TILT RET)
GBETA	global coordinate surface beta tilt (used with TILT RET)
GGAMMA	global coordinate surface gamma tilt (used with TILT RET)
GRT	diffraction grating definition
COATING	coating file number 0=no coating, 1 to 1000 valid coating file numbers

SPECIAL PIKUP OPTION

For any "PIKUP" command requiring entry of the additive constant "b", an option for specifying "b" implicitly is provided. This implicit definition of "b" is selected by entering a "1" in the 4th numeric word of the "PIKUP" command. The explicit entry for "b" may be left in the default input form as shown above or an explicit value may be entered. In either case, the entry for "b" is ignored. A new value for "b" is calculated by the relation:

$$b = P' - aP'(j)$$

where:

a=(multiplicative constant)
P'=(parameter value at PIKUP surface)
P'(j)=(parameter value at surface "j")

OVERALL LENGTH PIKUP

PIKUP THOAL , j , k , a , b , cfflag – The thickness assigned to the current surface is set equal to the sum of the axial thicknesses from surface "j" to surface "k" multiplied by the multiplicative constant "a" and then increased by the additive constant "b". The current surface may not lie between "j" and "k".
NOTE: The "cfflag" is normally left blank. If "cfflag" is left blank, then the source value for the pikup will be data from the current lens configuration. If "cfflag" is not left blank, then the source value for the pikup will be data from lens configuration #1, otherwise known as the main configuration.
PIKD , i , j – Causes all pikups between surface "i" and surface "j" to be deleted. The default for "i" is the "current" surface. The default for "j" is: j = i. (Only valid at the ULN level).
PIKD (parameter name) , i , j – Causes any pikup of the named parameter between surface "i" and surface "j" to be deleted. The default for "i" is the "current" surface. The default for "j" is: j = i. (Only valid at the ULN level).

FOOTPRINT ANALYSIS SETTINGS

FOOTBLOK (YES/ON or **NO/OFF)** – Sets the beam footprint blocking control. The default is NO.

WEIGHT AND PRICE

SPGR , spgr – Sets the specific gravity of the material at the "current" surface to "spgr" in grams/cc.
PRICE , price – Sets the price per Kg.

APERTURE STOP AN REFERENCE SURFACE

ASTOP (EN or **EX** or **ENEX)** – Sets the current surface to be the aperture stop. The qualifiers cause various adjustments to the dummy surfaces at the front and rear of the prescription.
REFS , theta – Sets the current surface to be the reference surface. "theta" is an optional gamma rotation for the ray aiming grid at the reference surface.

SURFACE LABELS

LABEL or **LBL , (surface label string)** – Sets the label on the "current" surface to be equal to the string which may be up to 79 characters long.

INR ASSIGNMENTS

INR , inr – Sets the "inr" value on the current surface for use as the normalization radius for Zernike polynomials. See the reference manual for default values.
INRD – Removes the user-defined "inr" value on the "current" surface. (Only valid at the ULN level).

DUMMY SURFACES

NODUM ("YES/ON" or "NO/OFF") – Forces a normally "dummy" surface to be treated as non-dummy.

OPTICAL MATERIALS COMMANDS

AIR – Sets the optical material following the "current" surface to be AIR with INDEX = 1.0.
REFL – Sets the current surface to be a mirror.
REFLTIRO – Sets the current surface to be a mirror is a Total Internal Reflection exists.
MYGLASS (user defined name) , n1 , n2 , n3 , n4 , n5 – Sets the material following the "current" surface to be named "user defined name (up to 13 characters) with refractive index values at the first 5 wavelengths set to "n1" to "n5".
N(1 to **10) , n** – Sets the refractive index of the "current" surface's MYGLASS glass type at the indicated wavelength number (1 to 10) to be "n". The material must have been defined using a MYGLASS command before the refractive index value can be changed.
(Catalog Name) (Glass Name or Glass Number)– Sets the optical material following the "current" surface to be set to the Named or Numbered glass in the Named Catalog.

Valid Glass Catalog Name	Type of Material Stored	Wavelength Band
SCHOTT	Schott Optical Glasses	0.3126 μ - 2.3254 μ
SCH2000	Schott Optical Glasses (Post 2000)	0.3126 μ - 2.3254 μ
HOYA	Hoya Optical Glasses	0.365 μ - 1.1 μ
HIKARI	Hikari Optical Glasses NOTE: For Lead and Arsenic free glasses, enter the 6-digit glass code instead of the glass name.	0.365 μ - 1.1 μ
OHARA	Ohara Optical Glasses (except I-LINE glasses)	0.365 μ - 1.1 μ for glasses using the Schott Formula or 0.3126 μ - 2.3254 μ for glasses using the Sellmeier Formula
OHARA	Ohara I-LINE glasses	0.250 μ - 1.1 μ
CHANCE	Chance-Pilkington Optical Glasses	0.365 μ - 1.1 μ
CORNIN	Corning-France Optical Glasses	0.365 μ - 1.1 μ
RUSSIAN	SOVOPTIKS Glasses	0.3126 μ - 2.3254 μ
RADHARD	Assorted radiation hard glasses	varies with material
USER	User Defined Glass Catalog	All (NO RESTRICTIONS)
MATL	Assorted IR, UV, and VIS materials	varies with material
GLCAT or GLASS	Schott, Schott(Post-2000) Hoya, Ohara, Corning-France, Chance-Pilkington, SOVOPTIKS, USER and then MATL specified by glass name or glass number only. After the glass is found, the manufacturer/catalog name replaces the word GLCAT or GLASS in the lens database. This is used when the manufacturer/catalog name is initially unknown.	varies with limits on specific glass catalog referenced (see above list)

RUSSIAN GLASS NAMES - The following table list equivalent english alphabet names for the glasses in the Russian glass catalog (SOVOPTIKS USA, ,1983):

Description	English Designation	Russian Designation
Light Crown	LK	ЛК
Phosphate Crown	FK	ФК
Dense Phosphate Crown	TFK	ТФК
Crown	K	К
Barium Crown	BK	БК
Extra Dense Crown	STK	СТК
Special Crown	OK	ОК
Crown Flint	KF	КФ
Barium Flint	BF	БФ
Dense Barium Flint	TBF	ТБФ
Light Flint	LF	ЛФ
Flint	F	Ф
Dense Flint	TF	ТФ
Special Flint	OF	ОФ
Dense Crown	TK	ТК

USER-DEFINED GLASS CATALOG - The user-defined glass catalog, which is referenced by catalog name "USER", is stored in the ASCII file "USER.DAT". It is stored in the same directory into which the main program was installed and from which the main program runs. It is an ASCII file whose entries are free format and are expected to be of the form: **GLASS_NAME, A0, A1, A2, A3, A4, A5**. "GLASS NAME" is a one to thirteen character, user-defined glass name, and A0 through A5 are the six interpolation coefficients used with the following equation: $n^2 = A_0 + A_1*\lambda^2 + A_2*\lambda^{-2} + A_3*\lambda^{-4} + A_4*\lambda^{-6} + A_5*\lambda^{-8}$. All input in the file USER.DAT should be separated by spaces or commas. If the user only has a table of index versus wavelength, then SPFIT routines (see the SPFIT section of this manual) may be used to determine the coefficients. A sample "USER.DAT" exists in the main program directory. λ is always assumed to be represented in microns. An example of fitting index data and automatic assigning the fitting coefficients to a new user-defined glass type is given in the SPFIT section of the manual.

MODEL (user supplied name) , Nd , Vd , Delta-partial Dispersion - Sets the optical material following the "current" surface to be set to a model glass prior to glass optimization.

INDEX , Nd – If the "current" surface has been defined as a "Model" glass, then this command is used to change the "Nd" value.

VNUM , Vd – If the "current" surface has been defined as a "Model" glass, then this command is used to change the "Vd" value.

DPARTL , Delta-partial Dispersion – If the "current" surface has been defined as a "Model" glass, then this command is used to change the "Delta-partial Dispersion" value.

FINDING REAL GLASSES

After optimization, it is usually necessary to replace the "MODEL" glass with a real glass. This is done with the help of the following CMD level command:

FINDGLASS (cat name or ALL) , i , n – This is a CMD level command which finds the "n" closest real catalog glasses to the Model Glass on surface "i". This is used after glass optimization.

CMD LEVEL GLASS COMMANDS

FINDING REAL GLASSES - After optimization, it is usually necessary to replace the "MODEL" glass with a real glass. This is done with the help of the following CMD level command:

FINDGLASS (catalog name or ALL) , i , n - The "FINDGLASS" command, issued at the CMD program level, searches the SCHOTT, SCH2000, OHARA, HOYA, CHANCE PILKINGTON, CORNING FRANCE, and/or HIKARI glass catalogs for the closest "n" glasses to the MODEL glass on surface "i" and displays them. The valid qualifier words are: "SCHOTT", "SCH2000", "HOYA", "OHARA", "CORNIN", "CHANCE", "HIKARI" or "ALL" (to search all the catalogs).

TOMODEL i - The "TOMODEL" command converts any glass in the SCHOTT, SCH2000, OHARA, HOYA, CHANCE PILKINGTON, CORNING FRANCE, HIKARI, RUSSIAN and RADHARD glass catalogs into a MODEL glass with the correct values of Nd , Vd , ΔPartial Dispersion. "I" is the surface number.

SURFACE COATINGS

COATING , n - The "COATING" command specifies that the surface coating data designated by coating file number "n" will be associated with the current surface. This command is valid at both the LENS input and the UPDATE LENS levels. Surface coating data is stored in the files COAT0001.DAT THROUGH COAT1000.DAT (file numbers 1 to 1000) which are ASCII files stored in the main program directory. The default coating is an uncoated surface with no losses.

SURFACE COATING DATABASE - The SURFACE COATING database consists of user-generated ASCII files COAT0001.DAT through COAT1000.DAT. These files hold the complete description of all the types of single and multi-layer coatings available for use in the program. Up to 1000 individual coating files may be defined and redefined by the user.

NATURE OF THE COATING DESCRIPTIONS - Unlike most other optical design and analysis codes, the program contains a flexible syntax for describing optical surface coatings in many different ways. Each coating definition consists of a series data lines in an ASCII file which describe the type of coating and its characteristics. All coatings are prepared ahead of time by the user using any text editor. The syntax of every coating definition file begins with the header line which contains a single integer that specifies the coating type. The program currently has 4 coating types availabe. Any of these 4 coating types may be used in any of the 1000 different coating database files.

COATING TYPES - Valid coating types are defined below. Coatings are used for energy throughput calculations when surface coating dependent ray trace options are in are in effect. When performing polarization type calculations, only type 1 (no effect on ploarization) or type 4 coatings will be used.

COATING TYPE 1 – No coating and no coating losses. Transmissions and reflections are 100% efficient. This is the program default and requires no coating definition file. If this type of coating is to be explicitly set in a coating definition file, only one entry, the coating type number 1 is needed as shown below:

```
1
ABSORB
(ABSORPTION COEFFICIENT FOR WAVELENGTH  1)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  2)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  3)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  4)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  5)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  6)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  7)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  8)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  9)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 10)
```

COATING TYPE 2 - Coating type 2 is an uncoated surface with Fresnel losses. Uncoated transmissive surfaces exhibit simple Fresnel reflection losses. Reflections will experience no energy loss. A coating file used to define a type 2 coating has only one entry as shown below:

```
2
ABSORB
(ABSORPTION COEFFICIENT FOR WAVELENGTH  1)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  2)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  3)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  4)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  5)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  6)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  7)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  8)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  9)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 10)
```

COATING TYPE 3 - Coating type 3 is a simple "e"% efficient coating where the default value for "e" is 100%. If a "TIR" condition is found, perfect 100% reflection will always occur. If reflection occurs at a surface with a type 3 coating (other than case of TIR), the reflectivity will be assumed to be "e"%. The file entry for this specific coating, if the efficienct were to be 85% is:

```
3
85
ABSORB
(ABSORPTION COEFFICIENT FOR WAVELENGTH  1)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  2)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  3)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  4)
(ABSORPTION COEFFICIENT FOR WAVELENGTH  5)
```

(ABSORPTION COEFFICIENT FOR WAVELENGTH 6)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 7)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 8)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 9)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 10)

COATING TYPE 4 - Coating type 4 is the program general coating type. The first line in the coating file must be a **4**. The next N lines in the file comprise the user-supplied data for each of the N-layers of the coating. Each line starting at line 2 consists of a user supplied material name (up to 13 characters) followed by 10 real and then 10 imaginary refractive index values and then the layer thickness in microns. In multiple layer coatings, the first layer is the layer farthest from the substrait. As in regular program input, nested commas represent default values which are 1.0 for the real part and 0.0 for the imaginary part of the complex refractive index. As an example, a type 4 coating defined in the ASCII coating file COAT0025.DAT and consisting of a single layer of MGF2 with a complex refractive index at wavelength #1 of (1.38,0.0) and having a thickness of 0.34 microns would be defined using the following two lines in file COAT0025.DAT.

4
MGF2,1.38, , , , , , , , , ,0.0, , , , , , , , , ,0.34
ABSORB
(ABSORPTION COEFFICIENT FOR WAVELENGTH 1)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 2)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 3)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 4)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 5)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 6)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 7)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 8)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 9)
(ABSORPTION COEFFICIENT FOR WAVELENGTH 10)

"ABSORB" is an optional entry. If used it may be followed by up to 10 entries which are interpreted as the absorption coefficients at the 10 program wavelengths. The absorbtion coefficients are interpreted as belonging to the material into which the ray advances after interacting with the surface to which the coating is attached. Defaults and missing values are assumed to be zero. The ray energy is reduced by the factor:

$$\mathbf{EXP}\left(-\mathbf{COEF}\times\mathbf{RPL}\right)$$

where RPL is the ray path length in the absorbing material and COEF is the absorbtion coefficient. The user is responsible for using a COEF value that is correct for the current lens units (INCH, MM, CM or METER).

IDEALIZED SURFACES

PERFECT – Sets the surface immediately preceeding the final surface to be a CODE-V-like "Perfect" lens.
IDEAL , efl – Sets the surface immediately preceeding the final surface to be an IDEAL lens with an EFL equal to "efl".

DIFFRACTION GRATINGS

GRT – Sets the "current" surface to be a linear diffraction grating.
GRO , order – Sets the "current" surface diffraction grating to order "order". (default is 0).
GRS , spacing – Sets the "current" surface diffraction grating line spacing to "spacing" in lens units.
GRX , x-grating direction number – Sets the "current" surface x-direction number for the parallel planes generating the grating. **GRY , y-grating direction number** – Sets the "current" surface y-direction number for the parallel planes generating the grating. **GRZ , z-grating direction number** – Sets the "current" surface z-direction number for the parallel planes generating the grating.
GRTD – Deletes a grating definition on the "current" surface. (Only valid at the ULN level).

APERTURES, OBSCURATIONS AND ERASES

(CLAP or **COBS) , ca , Yd , Xd , (radius to flat) , Δz** – Sets the "current" surface circular clear aperture or obscuration to radius "ca" with off-sets Yd and Xd. See reference manual for the 4th and 5th numeric input values. (radius to flat) and Δz are only used by CLAP, not COBS.
(CLAP or **COBS) RECT , cay , cax , Yd , Xd**– Sets the "current" surface rectangular clear aperture or obscuration to semi-side lengths "cay" and "cax" and with off-sets Yd and Xd.
(CLAP or **COBS) ELIP , cay , cax , Yd , Xd**– Sets the "current" surface elliptical clear aperture or obscuration to semi-axis lengths "cay" and "cax" and with off-sets Yd and Xd.
(CLAP or **COBS) RCTK , cay , cax , Yd , Xd , r**– Sets the "current" surface racetrack clear aperture or obscuration to semi-side lengths "cay" and "cax" and with off-sets Yd and Xd and corner radius "r".
(CLAP or **COBS) POLY , r , n , Yd , Xd**– Sets the "current" surface regular polygon clear aperture or obscuration values. See reference manual for full description of input values.
CLAP IPOLY , file# , n , maxr , Yd , Xd - Sets the "current" surface polygon irregular clear aperture or obscuration values. See reference manual for full description of input values.
CLAP POLY (CONFORMAL or **NONCONFORMAL)** – The "CLAP POLY" command can also be used to specify whether or not the polygon clear aperture is to be understood to lie in the tangent plane of the surface (NONCONFORMAL) or if is to be considered to lie in a tangent plane, tangent to the surface and located at the center of the clear aperture (CONFORMAL). If "CONFORMAL" is set, the polygonal clear aperture will lie "in the surface" rather than in the surface tangent plane at the surface vertex. If the polygonal clear aperture is not decentered or if there are no multiple clear apertures defined, then "CONFORMAL" and "NONCONFORMAL" yield the same results. This command is valid at both the LENS input and the UPDATE LENS levels.
(CLAP or COBS) TILT , gamma– Sets the "current" surface clear aperture or obscuration to have a gamma rotation of "gamma".

CLEAR APERTURE ERASE If a ray falls within the boundary of a clear aperture erase, and if that ray had been blocked by a clear aperture on that surface, the fact that it was blocked by the clear aperture on that surface is then ignored.

OBSCURATION ERASE If a ray falls within the boundary of a cobs erase, and if that ray had been blocked by an obscuration on that surface, the fact that it was blocked by the obscuration on that surface is then ignored.

(CLAP or **COBS) ERASE , ca , Yd , Xd**– Sets the "current" surface circular clear aperture or obscuration erase to radius "ca" with off-sets Yd and Xd.
(CLAP or **COBS) RECTE , cay , cax , Yd , Xd**– Sets the "current" surface retangular clear aperture or obscuration erase to semi-side lengths "cay" and "cax" and with off-sets Yd and Xd.
(CLAP or **COBS) ELIPE , cay , cax , Yd , Xd**– Sets the "current" surface elliptical clear aperture or obscuration erase to semi-axis lengths "cay" and "cax" and with off-sets Yd and Xd.
(CLAP or **COBS) RCTKE , cay , cax , Yd , Xd , r**– Sets the "current" surface racetrack clear aperture or obscuration erase to semi-side lengths "cay" and "cax" and with off-sets Yd and Xd and corner radius "r".
(CLAP or **COBS) POLYE , r , n , Yd , Xd**– Sets the "current" surface regular polygon clear aperture or obscuration erase values. See reference manual for full description of input values.
(CLAP or **COBS) IPOLYE , file# , maxr , Yd , Xd**– Sets the "current" surface irregular polygon clear aperture or obscuration erase values. See reference manual for full description of input values.
(CLAP or **COBS) TILTE , gamma**– Sets the "current" surface clear aperture or obscuration erase to have a gamma rotation of "gamma".
(CLAPD or **COBSD) i , j** – Deletes all CLAP or COBS definitions (including erases) from surfaces "i" to "j". The default for "i" is the current surface. The default for "j" is j = i. (Only valid at the ULN level).

MULTIPLE CLEAR APERTURES
(MULTCLAP or **MULTCOBS) , n , x , y , gamma** – Specifies that the current clear aperture or obscuration definition on the "current" surface is to be repeated with new center coordinates "x" and "y" with added "gamma" rotation. "n" sets the counter for the multiple CLAP or COBS and "n" may range from 1 to 100.
(MULTCLAP or **MULTCOBS) DELETE**– Deletes all multiple (CLAP or COBS) assignments on the current surface. (Only valid at the ULN level).

SPIDERS
SPIDER , n , W , L , gamma – Specifies that a spider surrort structure is to be assigned to the "current" surface. "W" is the full width of a vane. "L" is the full length of a vane. "n" specifies the number of vanes. Vanes are equally spaced angularly. Each vane has one end anchored to the local coordinate system origin.
SPIDER DELETE– Deletes all spider assignments on the current surface. (Only valid at the ULN level).

LENS, UPDATE LENS/CMD LEVEL COMMANDS (issuable from all three levels)
MODE (FOCAL or UFOCAL or AFOCAL or UAFOCAL) – Specifies that the mode of the lens will be FOCAL or AFOCAL. UFOCAL and UAFOCAL are provided for ACCOS-V and HEXAGON users. Issued without input results in the spectral weights being displayed to the screen.
SPTWT , W1 , W2 , W3 , W4 , W5 – Sets the relative spectral weights for the first five wavelengths. (Used in polychromatic calculations such as MTF and PSF).
SPTWT2 , W6 , W7 , W8 , W9 , W10 – Sets the relative spectral weights for the second five wavelengths. (Used in polychromatic calculations such as MTF and PSF). Issued without input results in the spectral weights being displayed to the screen.

CMD LEVEL LENS DATABASE COMMANDS
MAGY , M , i , j – Adjusts YZ-plane paraxial magnification "M" between surfaces "i" and "j" by altering "object" and "image distances. See Reference Manual for more details.
MAGX , M , i , j – Adjusts XZ-plane paraxial magnification "M" between surfaces "i" and "j" by altering "object" and "image distances. See Reference Manual for more details.
FNBY(HLD or DEL), f-number – Adjusts YZ-plane paraxial f-number by altering the paraxial marginal ray height at surface 1 with all solves temporarily suspended. HDL causes the f-number hold to be established and DEL deletes the HLD. This can not be used if SAY or SAX are "floating". This should only be used in "FOCAL" systems.
FNBX(HLD or DEL), f-number – Same as FNBY but in the XZ-plane.
ERY(HLD or DEL), f-number – Adjusts YZ-plane exit pupil diameter by altering the paraxial marginal ray height at surface 1 with all solves temporarily suspended. HDL causes the exit pupil hold to be established and DEL deletes the HLD. This can not be used if SAY or SAX are "floating". This should only be used in "AFOCAL" systems.
ERX(HLD or DEL), f-number – Same as FNBY but in the XZ-plane.

RAY AIMING AND TELECENTRIC COMMANDS (issuable from the CMD program level)
AIMRAY (ON/YES or OFF/NO) – Sets iterative ray aiming "on" or "off". "ON" is the default and should not be shut off without very good reasons.
TEL (ON/YES or OFF/NO) – Sets telentric ray aiming "on" or "off". "OFF" is the default. This should be set to "ON" is it is desired to have all chief rays from all object positions parallel to each other. This only applies to non-infinite objects.
AIMAPL (ON/YES or OFF/NO) – Sets aplanatic ray aiming "on" or "off". "OFF" is the default. See the reference manual for a description of when it should be used.

MULTIPLE FOV DEFINITIONS (issuable from the CMD program level)
The multiple field-of-view definition commands are issued from the CMD level only. They are used to specify multiple field-of-view positions which are used by some of the CMD level commands which can generate data at multiple field-of-views. These multiple field-of-view definitions are stored with the lens database.
FLDS MAX , n - The "FLDS MAX" command specifies that there will be "n" fields-of-view active at the current lens database configuration. "n" may be set to from 1 to 10. The multiple field-of-view data will be interpreted as object field of view angles. By default, if none are defined, three field of view positions will be defined at 0.0, 0.7 and 1.0 degrees in the YZ-plane.
FLDS , i , x , y - The "FLDS" command is used to specify the xz and yz-plane input values for the "i" th multiple field of view.
FLDSARE - The "FLDSARE" command is used to display the current multiple field-of-view definitions contained in the current lens database.

ENVIRONMENTAL ANALYSIS COMMANDS (issuable from the CMD program level)
THERMAL ANALYSIS
THERM (qualifier) , i , j , DeltaT , coef – Modifies the parameters specified by the qualifier word on surfaces "i" to "j" to reflect the effects of a Delta Temperature in Kelvin units with a thermal coefficient equal to "coef". See the Reference Manual for details.

"qualifier"	PARAMETER(S) MODIFIED	COEFFICIENT USED
SHAPE	RD/CV, RDTOR/CVTOR, AC, AD, AE, AF, AG, AH, AI, AJ, AK, AL, ADTOR, AETOR, AETOR and AFTOR (Toric and non-toric curvatures and aspheric deformations)	Coefficient of linear expansion per degrees C or K. (Must be supplied by the user.)
THICK	TH (surfaces with absolute values of the refractive indices greater 1.1)	Coefficient of linear expansion per degrees C or K. (Must be supplied by the user.)
SPACE	TH (surfaces with absolute values of the refractive indices less than or equal to 1.1)	Coefficient of linear expansion per degrees C or K. (Must be supplied by the user.)
GLASS	N1 through N10 (Refractive indices at all ten wavelengths)	dN/dT (degrees C or K). (Must be supplied by the user.)
GAS	N1 through N10 (Refractive indices on air spaces at all ten wavelengths) (Spaces with refractive indices less than or equal to 1.1)	The operation of this command is explicitly defined in the equation above this table. (The coefficient must be supplied by the user.)
AIR, OXYGEN, NITROGEN, HELIUM, HYDROGEN, ARGON, ETHANE, and METHANE	N1 through N10 (Refractive indices on air spaces at all ten wavelengths) (Spaces with refractive indices greater than 1.1)	(All coefficients are supplied by the program.)

PRESSURE

PRES (qualifier) , i , j , DeltaP , coef – Modifies the parameters specified by the qualifier word on surfaces "i" to "j" to reflect the effects of a Delta Pressure change in mm of Hg units with a pressure coefficient equal to "coef". See the Reference Manual for details.

"qualifier"	PARAMETER(S) MODIFIED	COEFFICIENT USED
GAS	N1 through N10 (Refractive indices on air spaces at all ten wavelengths) (Spaces with refractive indices less than or equal to 1.1)	The operation of this command is explicitly defined in the equation above this table. (Must be supplied by the user.)
AIR, OXYGEN, NITROGEN, HELIUM, HYDROGEN, ARGON, ETHANE, and METHANE	N1 through N10 (Refractive indices on air spaces at all ten wavelengths) (Spaces with refractive indices greater than 1.1)	(All coefficients are supplied by the program)

SAVING AND RESTORING LENS PRESCRIPTIONS (issuable from the CMD program level)

LENLOC (6-character directory name) – Used to change and interrogate the current directory name used by the "LENSSAVE" and "LENSREST" commands.. Issued with no directory name, the current lens directory name will be displayed. The program default is "LENSES".
LENSDIR – Displayes the file contents of the current lens directory.
LENSSAVE (filename) – Stores the "current" lens is file = filename.PRG into the lens directory.
LSAVE (filename) – Works just like LENSSAVE except that no optimization, tolerancing, fields or rays data is saved in the file.
LENSREST (filename) – Restores the "current" lens from file = filename.PRG in the lens directory.

THE LENS LIBRARY (issuable from the CMD program level)

ILF – First half of the lens library initialization process.
PROCEED – Second half of the lens library initialization process. (use with caution)
LIB P , i , j – Displays the contents of lens library entries "i" to "j". By default, if "i" is entered, "j" defaults to "i". If neither "i" nor "j" is entered, the entire library is listed.
LIB PUT , i (Optional string which becomes the new Lens Identifier LI which is used as the new lens library label) – Stores the "current" lens into library location "i". If "i " is not supplied, the first empty library location is used.
LIB GET , i – Makes the lens in library location "i" the new "current" lens.
LIB DEL , i , j – Deletes the contents of lens library entries "i" to "j". By default, if "i" is entered, "j" defaults to "i". If neither "i" nor "j" is entered, no action is taken.
LSTAT – Displays the current status of the lens library.
LIBSAVE – Saves the entire contents of the lens library to file LIBSAV.DAT.
LIBREST – Restores the lens library from the file LIBSAV.DAT.

COMMERCIAL LENS MANUFACTURER LIBRARY COMMANDS (issuable from the CMD program level)

LIB PMG , i , j – Displays the contents of the Mellet Griot library entries "i" to "j". By default, if "i" is entered, "j" defaults to "i". If neither "i" nor "j" is entered, the entire library is listed.
LIB PES , i , j – Displays the contents of the Edmund Scientific library entries "i" to "j". By default, if "i" is entered, "j" defaults to "i". If neither "i" nor "j" is entered, the entire library is listed.
LIB PNC , i , j – Displays the contents of the Newport library entries "i" to "j". By default, if "i" is entered, "j" defaults to "i". If neither "i" nor "j" is entered, the entire library is listed.
LIB PRO , i , j – Displays the contents of the Rolyn library entries "i" to "j". By default, if "i" is entered, "j" defaults to "i". If neither "i" nor "j" is entered, the entire library is listed.
LIB PSH , i , j – Displays the contents of the Spindler and Hoyer library entries "i" to "j". By default, if "i" is entered, "j" defaults to "i". If neither "i" nor "j" is entered, the entire library is listed.
LIB GETMG , i – Makes the lens in the Melles Griot library location "i" the new "current" lens.
LIB GETES , i – Makes the lens in the Edmund Scientific library location "i" the new "current" lens.
LIB GETNC , i – Makes the lens in the Newport library location "i" the new "current" lens.

LIB GETRO , i – Makes the lens in the Rolyn library location "i" the new "current" lens.
LIB GETSH , i – Makes the lens in the Spindler and Hoyer library location "i" the new "current" lens.
OPTICAL GLASS CATALOGS (issuable from the CMD program level)
GLASSP – Displays the names of all program glass catalogs.
GLASSP (catalog name) – Displays the names of all the glasses in the named glass catalog)
GLASSP (catalog nemae) (glass name or number) – Displays specific data about the named glass.
LENS SCALING COMMANDS (issuable from the CMD program level)
SC , factor , i , j – Scales all appropriate lens data in the "current" lens by "factor" between surfaces "i" and "j". By default, "i" = 0 and "j" = final surface.
WSC , factor , i , j – Scales all appropriate lens data in the "current" lens by "factor" between surfaces "i" and "j". No SCX, SCY, SAX or SAY data is scaled. By default, "i" = 0 and "j" = final surface.
SC FY , efl , i , j – Scales all appropriate lens data so that the paraxial effective focal length in the YZ-plane from surface "i" to "j" will equal "efl". By default, "i" = 0 and "j" = final surface.
SC FY , efl , i , j – Scales all appropriate lens data so that the paraxial effective focal length in the YZ-plane from surface "i" to "j" will equal "efl". No SCX, SCY, SAX or SAY data is scaled By default, "i" = 0 and "j" = final surface.
LENS OUTPUT AND MANIPULATION (issuable from the CMD program level)
LENO – Outputs the "current" lens to the default output device in a format which is "program readable"
LENO RD– Outputs the "current" lens to the default output device in a format which is "program readable" Surface radius of curvature is output instead of curvature.
LENO AC– Outputs the "current" lens to the default output device in a ACCOS-V format. Main configuration only.
LENO CV– Outputs the "current" lens to the default output device in a CODE-V format. Main configuration only.
LENO EXCEL (i , j , glo , cfg) - The "LENO EXCEL" command outputs the lens data of the current lens in a tab delimited file which may be read into Microsoft Excel. Data items which are all default, are omitted. For example, if there are no conics in the surface range requested, no conic column is output. Data is output from surface "i" to surface "j". Defaults for "i" and "j" are surfaces 1 and the image surface. "glo" specifies the global reference surface for global vertex data. The default is surface 1. "cfg" specifies the configuration to output. The default is cfg 1.
LENO NOOPT – Qutputs the "current" lens to the default output device in a format which is "program readable" but leaves off all optimization and tolerance definitions.
LENO REVERSE – Qutputs the "current" lens to the default output device in reverse order. Only outputs main configuration and tilts and decenters are not converted. This is just a starting point in the lens reversal process.
CV2PRG – Converts a CODE-V WRL sequence file to become the "current" lens.
ZMX2PRG – Converts a ZEMAX file to become the "current" lens.
LENADD , i , j , k - Adds lens databases together. See Reference Manual for details.
LENS DATABASE DISPLY (issuable from the CMD program level)
The following commands control and display lens database data in a human readable format:
HEADINGS (ON or **OFF)** - Causes even single lines of output to be displayed with the same headings as are used when output is generated using the ALL qualifier. The default is "OFF".
The following commands display surface dependent lens database items in a human readable format. All of the following commands may be followed by a lens database surface number or by the qualifiers: OB or OBJ for the object surface or ALL for a display of the data for all surfaces in the lens database.
RTG (OB or **OBJ** or **ALL** or surface number **i)** – Outputs Radius, Thickness, Glass name, refractive index at the control wavelength and the active V-number of the glass.
CTG (OB or **OBJ** or **ALL** or surface number **i)** – Same as RTG but curvature rather than radius of curvature is displayed.
RTGLBL (OB or **OBJ** or **ALL** or surface number **i)** – Same as RTG except that surface label are also displayed.
CTGLBL (OB or **OBJ** or **ALL** or surface number **i)** – Same as CTG except that surface label are also displayed.
TAD (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface tilt and decenter data.
ASPH (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface aspheric data to 10^{th} order.
ASPH2 (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface aspheric data from 12^{th} to 20^{th} order.
TASPH (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface anamorphic aspheric data.
TR (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface toric data.
SLV (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface solve data.
PIK (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface PIKUP data.
CAOB (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface clear aperture and obscuration data.
RIN (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface refractive index data for the first 5 wavelengths.
RIN2 (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface refractive index data for the 6^{th} to 10^{th} wavelengths.
DUMOUT (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface forced dummy settings.
INR (OB or **OBJ** or **ALL** or surface number **i)** – Outputs surface "inr" values.
The following commands display surface independent lens database items in a human readable format.
LI– Outputs the lens identifier string assigned to the lens database.
LIC– Outputs the continuation of the lens identifier string if it was explicitly input during lens input or update.
INI– Outputs the initials of the designer if it was explicitly input during lens input or update.
LTYPE– Outputs the lens type identifier if it was explicitly input during lens input or update.
ASTOP– Outputs the ASTOP surface number and any special ASTOP conditions if they were set.
REF– Outputs the reference surface number as well as other refererece data.
UNITS– Outputs the units being used in the lens database.
CW– Outputs the control wavelength number.
PCW– Outputs the wavelength numbers of the primary wavelength pair.
SCW– Outputs the wavelength numbers of the secondary wavelength pair.
SPC– Outputs any special conditions or holds assigned to the lens database.
MODE– Outputs the current evaluation MODE of the lens (FOCAL, UFOCAL, AFOCAL or UAFOCAL)
SPTWT– Outputs the spectral weighting factors assigned to the first 5 wavelengths.
SPTWT2– Outputs the spectral weighting factors assigned to the second 5 wavelengths.
SAY or **EPD**– Outputs the YZ-plane "say" value.

SAX – Outputs the XZ-plane "sax" value.
WRY– Outputs the "wry" gaussian beam value.
WRX – Outputs the "wrx" gaussian beam value.
BDY– Outputs the "bdy" gaussian beam value.
BDX – Outputs the "bdx" gaussian beam value.
SCY– Outputs the "scy" reference object height value.
SCX– Outputs the "scx" reference object height value.
SCY FANG– Outputs the "scy" reference object angle value.
SCX FANG– Outputs the "scx" reference object angle value.

COMPLETE LENS LISTING (issuable from the CMD program level)

LEPRT or **LIS , (i)**– Outputs all lens database data for surface "i". If the surface "i" is ommitted, the entire lens database is displayed.

FULL SCREEN EDITING OF LENS DATA

Lens data for the current lens may be edited using the program full screen editor without leaving the program. By using the "EDIT" command (described in the CMD section), the file EDITTEXT.DAT may be edited using the current program full screen editor. To edit the current lens, simply use the output redirection command "OUTPUT ED" (described in the CMD section) and the "LENO" command (described in this section) to output the current lens data to the EDITTEXT.DAT file. Use the "EDIT" command to edit this file, making any desired changes. After filing the modified "EDITTEXT.DAT" file and leaving the editor, read in the modified EDITTEXT.DAT file using the "INPUT ED" command (described in the CMD section). The changes made during the edit session will be manifested in the new current lens. This method provides full screen edit capability for lens data, but it lacks the sophisticated built-in error checking of the standard lens input and lens update procedures.

PARAMETER CHANGE COMMANDS (issuable from the ULN program level only)

The following commands, when issued from the LENS UPDATE LEVEL, may be issued with the optional qualifier words "CENT" or "DELT". If one of these commands is issued with the "CENT" qualifier word, the current lens parameter value referenced by the command will be increased or decreased by the percentage specified by the value of numeric word #1. If one of these commands is issued with the "DELT" qualifier word, the current lens parameter value referenced by the command will be changed by the value of numeric word #1. Additionally, the "CV", "RD", "CVTOR" and "RDTOR" commands may be issued with the qualifier word "DELTFR". "DELTFR" is used to modify the curvature, radius of curvature, toric curvature or toric radius of curvature of a surface to represent a change by a specified number of "fringes". By default, the wavelength used is 0.5461 microns. If no clear aperture is assigned, then the default aperture height used for "DELTFR" is the sum of the absolute values of the paraxial marginal and paraxial chief ray heights in the YZ-plane for the previous paraxial ray trace. If a clear aperture is assigned, then the default aperture height used for "DELTFR" is the larger of the Y and X-clear aperture heights, ignoring clear aperture decentrations and clear aperture tilts. The wavelength in microns may be explicitly entered via an explicit entry for numeric word #2. The clear aperture height in lens units may be explicitly entered via an explicit entry for numeric word #3. Furthermore, the "CV" and "RD commands may be issued with the qualifier word "SAG". "SAG" is used to modify the curvature or radius of curvature of a surface so that it has a specific SAG value (in lens units) given by the value input in numeric word #1. If no clear aperture is assigned the surface, then the default aperture height used for "SAG" is the sum of the absolute values of the paraxial marginal and paraxial chief ray heights in the YZ-plane for the previous paraxial ray trace. If a clear aperture is assigned, then the default aperture height used for "SAG" is the larger of the Y and X-clear aperture heights, ignoring clear aperture decentrations and clear aperture tilts. A temporary clear height in lens units may be explicitly entered via an explicit entry for numeric word #2. The conic constant is used as part of this SAG calculation. The following table lists these thirty-nine commands and the parameter values which will be modified by them:

COMMAND	VALUE MODIFIED
RD or CV	Radius of curvature or curvature only.
RDTOR or CVTOR	Toric radius or curvature or toric curvature
CC	Conic constant
AC	2nd order aspheric coefficient
AD	4th order aspheric coefficient
AE	6th order aspheric coefficient
AF	8th order aspheric coefficient
AG	10th order aspheric coefficient
AH	12th order aspheric coefficient
AI	14th order aspheric coefficient
AJ	16th order aspheric coefficient
AK	18th order aspheric coefficient
AL	20th order aspheric coefficient
CCTOR	Toric conic constant
ADTOR	4th order toric aspheric coefficient
AETOR	6th order toric aspheric coefficient
AFTOR	8th order toric aspheric coefficient
AGTOR	10th order toric aspheric coefficient
TH	Thickness
YD	Y-decenter
XD	X-decenter
ALPHA	Alpha surface tilt
BETA	Beta surface tilt
GAMMA	Gamma surface tilt
INR	Zernike reference radius
N1	Refractive index at λ1
N2	Refractive index at λ2
N3	Refractive index at λ3

N4	Refractive index at λ4
N5	Refractive index at λ5
N6	Refractive index at λ6
N7	Refractive index at λ7
N8	Refractive index at λ8
N9	Refractive index at λ9
N10	Refractive index at λ10
SAY	SAY or EPD value
SAX	SAX value
INDEX	index value for a "model" glass
VNUM	V-number for a "model" glass
DPARTL	ΔPartial dispersion for a "model" glass
PIVX	Tilt X-pivot position
PIVY	Tilt Y-pivot position
PIVZ	Tilt Z-pivot position
GDX	global x-decenter (with TILT RET)
GDY	global y-decenter (with TILT RET)
GDZ	global z-decenter (with TILT RET)
GALPHA	global alpha tilt (with TILT RET)
GBETA	global beta tilt (with TILT RET)
GGAMMA	global gamma tilt (with TILT RET)

LENS DATABASE INDEPENDENT GLASS COMMANDS (issuable from the CMD program level)

Up to this point, all of the commands which relate to glass catalog data have connected the glass catalog data to the "current" lens. The next few commands are completely independent of the "current" lens.

GLASSWV (LENS) , λ1 , λ2 , λ3 , λ4 , λ5 - The "GLASSWV" command is used to establish five wavelengths at which a glass catalog glass refractive index will be evaluated. In the absence of a "GLASSWV" command, the following values are assumed for "λ_1" to "λ_5":

λ1	**λ2**	**λ3**	**λ4**	**λ5**
0.58756 μ	0.48613 μ	0.65627 μ	0.43584 μ	0.70652 μ
λ6	λ7	λ8	λ9	λ10
0.0 μ	0.0 μ	0.0 μ	0.0 μ	0.0 μ

If optional qualifiers are used, then any numeric input is ignored. If the qualifier word “LENS” is used, then the ten wavelengths are the ten wavelengths in the current lens. λ is always assumed to be represented in microns.

(glass catalog name) (glass name) - A valid glass catalog name is the command word of this command. Glass names or number codes are the valid qualifier words. This command causes the refractive indices at the ten wavelengths established with the "GLASSWV" command to be placed in the general purpose storage registers 1 to 10. These refractive indices may then be recalled, displayed or used in a macro or macro function.

CMD LEVEL CHANGE COMMANDS (issuable from the CMD program level)

The following commands are issued from the CMD level only. They are used to introduce complex surface and element displacements, tilts and re-positionings. They are most useful in examining the effect of optical alignment errors. They are implemented without the use of additional dummy surfaces. Assignment of multiple complex surface or element tilts should be done with care since rotations, in general, do not commute. The following commands are not, in general, compatible with "TILT BEN", "TILT DAR" and "TILT RET". All occurrences of "TILT BEN", "TILT DAR" and "TILT RET" should be removed via the "TILT BEND", "TILT DARD" and "TILT RETD" commands before using "DISP", "STILT", "BTILT", "ROLL" and the associated "PIVOT" commands.

DISP , i , j , Δx , Δy , Δz - The "DISP" command is used to move surfaces "i" through "j" by the amounts Δx, Δy and Δz while leaving all other surfaces in the lens database in their original locations. Displacements are always assumed to be in current lens units.

STILT , i , Δalpha , Δbeta , Δgamma - The "STILT" command is used to rotate surface "i" through angles Δalpha, Δbeta and Δgamma while leaving all other surfaces in the lens database in their original locations. Rotations are always assumed to be measured in degrees. The default pivot position for "STILT" is the origin of the local coordinate system of surface "i".

STILT PIVOT , Δx , Δy , Δz - The "STILT PIVOT" command must be issued before an "STILT" command for it to be effective. It specifies an alternate x, y and z-location, specified with respect to the vertex of surface "i", as the pivot point for the next "STILT" command.

STILT PIVAUTO, Δx , Δy , Δz - The "STILT PIVAUTO" command must be issued before an "STILT" command for it to be effective. It specifies that the alternate x, y and z -location of the pivot point to be used in the next "STILT" command will be equal to the x, y and z-intersection of the last chief ray traced with the surface to which the following "STILT" is applied. The automatically calculated pivot location will then be incremented by the Δx, Δy and Δz values, if they are included. If no chief ray data is available, a warning message will be issued and no action will be taken.

ROLL , i , j , Δx , Δy , k - The "ROLL" command is used to "roll" surfaces "i" through "j" by Δx and Δy measured at surface "k". This "roll" is performed internally as a tilt about a pivot point located at the center of curvature of surface "k" where "k" must be set equal to either "i" or "j". If not explicitly entered, "k" is assumed to be equal to "i". This "roll" is performed while leaving all other surfaces in the lens database in their original locations. Rolls are always specified in current lens units of effective decentration at surface "k". For the purposes of determining the pivot point for the roll, it is assumed that there are no x or y displacements or alpha, beta or gamma tilts between surfaces "i" and "j".

BTILT , i , j , Δalpha , Δbeta , Δgamma - The "BTILT" command is used to rotate surfaces "i" though "j" through angles Δalpha, Δbeta and Δgamma while leaving all other surfaces in the lens database in their original locations. The default pivot point for this rotation is located at the vertex of surface "i" unless the command is immediately preceded by a "BTILT PIVOT" command. Rotations are always assumed to be measured in degrees.

BTILT PIVOT , Δx , Δy , Δz - The "BTILT PIVOT" command must be issued before a "BTILT" command for it to be effective. It specifies an alternate x, y and z-location, specified with respect to the vertex of surface "i", will be the pivot point for the next "BTILT" command.

FLIP i , j - The "FLIP" command reverses the order in which the lens database surfaces "i" through "j" appear in the current lens database. During the "FLIP" process, all tilts, decenters, solves and pikups are deleted in the surface number range. "FLIP" only acts on the main configuration of the lens so if there are alternate configuration definitions assigned to the surfaces in the surface number range, they are not changed by the "FLIP" command. "FLIP" also does not

change any special surface definitions.

HUMAN EYE MODELS

Many times it is important to be able to simulate the aberrations of the human eye when evaluating the performance of an optical system. Two long standing optical models of the human eye have been included in this program. The models are taken from MIL-HDBK-141 and from the Handbook of Optics. The prescriptions are stored in the files HUMEYE01.DAT and HUMEYE02.DAT respectively. They may be retrieved as the current lens using the "INPUT FILE (file name)" command and then manipulated with the "LENADD" command and the lens library commands.

LENS DATABASE GRAPHICS

All graphical displays and representations of the lens database are described in the GRAPHICS section of the manual.

RAY ERROR SURFACE FLAG

RAYERROR , ray error in arc-sec - The "RAYERROR" command designates the current surface to be an imperfectly manufactured surface for which random surface errors such as surface roughness exist. The error is expressed as the one sigma ray angle deviation in arc-seconds. The angular distribution of the error is assumed to be gaussian but the gamma orientation is distributed uniformly. The error is applied to a ray and to its associated differential rays (if they exist). The error is applied after any other ray surface interactions occurr. Issued from the CMD level, this command lists all the non-zero RAYERROR settings in the current lens configuration. If all RAYERROR settings are zero, no output is produced.

SPECIAL NSS SURFACES

CCR , apex_length , error12_arcsec , error23_arcsec , error31_arcsec - The "CCR" command causes a special type of single surface corner cube reflector to be inserted as new surface "i". This is a "pre-packaged" type of NSS surface which acts and is drawn as a real corner cube reflector but only takes one lens database surface to model. The "apex_length" is the perpendicular distance from the base to the apex. The surface location is at the CCR apex. The "apex_length" is only used to determine the location of the base of the CCR for CAD and plotting purposes and is measured along the local Z-axis. The nominal roof angles are always 90 degrees. The 1-2 lies in the local YZ-plane. The 2-3 edge lies on the +X-side of the local YZ-plane and the 3-1 edge lies on the -X-side of the local YZ-plane. Angle "errors" are entered in arc-sec and is an error applied to the nominal 90 degree roof angles. The reflection mode will set by the use of "REFL" or "REFLTIRO" in the lens database.

ROO , apex_length , error_arcsec - The "ROO" command causes a special type of single surface "roof" type of surface to be inserted as new surface "i". This is a "pre-packaged" type of NSS surface which acts and is drawn as a roof reflector but only takes one lens database surface to model. The "apex_length" is the perpendicular distance from the roof base to the roof apex. The nominal roof angle is always 90 degrees. The "apex_length" is the perpendicular distance from the base to the apex. The surface location is at the ROOF apex. The "apex_length" is only used to determine the location of the base of the roof for CAD and plotting purposes and is measured along the local Z-axis. The "error" is entered in arc-sec and is an error applied to the nominal 90 degree roof angles. The reflection mode will set by the use of "REFL" or "REFLTIRO" in the lens database.

CONFIGS SECTION (REFERENCE MANUAL) COMMAND PROMPTS

CONFIGS-GENERAL INFORMATION

The alternate configurations (CONFIGS) section describes the establishment and manipulation of alternate versions or configurations of the lens database. These alternate configurations are stored with the lens database.

CREATING A NEW CONFIGS DATABASE

CONFIGS - The "CONFIGS" command causes the program to leave the CMD level and enter the CONFIGS input level. The alternate configuration database is wiped clean and is ready for new input. Between "CONFIGS" and "EOS" or "END", any CONFIGS input level command may be entered. The "CONFIGS" command also wipes clean any optimization and tolerance definitions which were in effect prior its issuance.

EOS or **END** - The "EOS" or "END" command, issued from the CONFIGS level, causes the program to return to the CMD level. The alternate configuration database is left in memory and is ready for analysis.

MODIFYING A CONFIGS DATABASE

UPDATE CONFIGS or **U CF** - The "UPDATE CONFIGS" command, or its abbreviated form "U CF", causes the program to leave the CMD level and enter the UPDATE CONFIGS level. The alternate configuration database is opened and is ready for modification. Between "UPDATE CONFIGS" or "U CF" and "EOS" or "END", any UPDATE CONFIGS level command may be entered.

EOS or **END** - The "EOS" or "END" command, issued from the UPDATE CONFIGS level, causes the program to return to the CMD level. The alternate configuration database is left in memory and is ready for analysis.

CONFIGS AND UPDATE CONFIGS SPECIFIC COMMANDS

CFG , i - The "CFG" command, issued from the CONFIGS or UPDATE CONFIGS level, designates that configuration "i" will be the configuration to which all the following CONFIGS or UPDATE CONFIGS commands are to be applied. Configuration "i" remains the configuration for input until another CFG command is entered or until the CONFIGS or UPDATE CONFIGS levels are exited via the "EOS" or "END" command. Valid values for "i" range from "2" to "75". If this command is not issued, all alternate configuration input will be made to configuration number 2.

CFG - The "CFG" command, issued with no numeric input, simply causes the current configuration number to be displayed.

CMD LEVEL CONFIGS MANIPULATION

CONFIGS DISPLAY COMMANDS

CF , i - The "CF" command, when issued at the CMD level, causes the "i"th configuration data to be displayed. If "i" is not explicitly entered, all of the alternate configuration data from all currently defined configurations will be displayed. Each item in the alternate configuration database is numbered sequentially within each configuration. These sequential position values are the first items listed in this data display. Should an item need to be removed from the alternate configuration database, the item is referred to by the configuration number and entry number.

REMOVE , i , j , k - The "REMOVE" command can be used to manually delete alternate configuration data items number "j" through the "k" in configuration number "I".

DELCFG , i - The "DELCFG" command deletes the "i"th configuration from the current configuration database attached to the lens.

CFG , i - The "CFG" command, when issued at the CMD level, causes the "i"th configuration to become the "current" configuration represented as a new "current" lens. Only the "current" configuration in the form of the "current" lens can be used in ray trace or other forms of analysis.

DEZOOM , i - The "DEZOOM" command, when issued at the CMD level, causes the "i"th configuration to become the "permanent lens" and the "current" lens. All other alternate configuration data is deleted! The "DEZOOM" command also wipes clean any optimization and tolerance definitions which were in effect prior its issuance.

AUTOMATIC DATA MANAGEMENT

Many items which can be made part of an alternate configuration definition are mutually exclusive. A "TH" definition is mutually exclusive to a "PY" or a "PIKUP TH" definition. Mutually exclusive items will be automatically deleted with the last item entered taking precedence. The exceptions to this rule are the "THERM" and "PRES" commands. Since the user may wish to enter several identical "THERM" and "PRES" commands in order to produce a specific lens configuration, no automatic removal of "THERM" or "PRES" commands will be performed. Only through the use of the "REMOVE" command can individual "THERM" or "PRES" commands be removed from alternate configuration data.

SPSRF SECTION (REFERENCE MANUAL) COMMAND PROMPTS

SPECIAL SURFACE DEFINITIONS

The special surfaces (SPSRF) section describes the establishment and manipulation of specialized surface definitions which may be attached to the existing lens database surfaces. This special surfaces database is stored with the lens database. Some of the commands described here are CMD level commands issued at the CMD level. These CMD level commands are described here instead of in the CMD section because they act to modify or in other ways manipulate the special surfaces database. The other commands described here are SPSRF input level and UPDATE SPSRF level commands which can only be issued at one or both of these levels.

CREATING A NEW SPSRF DATABASE

SPSRF - The "SPSRF" command causes the program to leave the CMD level and enter the SPSRF input level. The special surfaces database is wiped clean and is ready for new input. Between "SPSRF" and "EOS" or "END", any SPSRF input level command may be entered.

EOS or **END** - The "EOS" or "END"command, issued from the SPSRF level, causes the program to return to the CMD level. The special surfaces database is left in memory and is ready for analysis.

MODIFYING AN SPSRF DATABASE

UPDATE SPSRF or **U SP** - The "UPDATE SPSRF" command, or its abbreviated form "U SP", causes the program to leave the CMD level and enter the UPDATE SPSRF level. The special surfaces database is opened and is ready for modification. Between "UPDATE SPSRF" or "U SP" and "EOS" or "END", any SPSRF level command may be entered

EOS or **END** - The "EOS" or "END" command, issued from the UPDATE SPSRF level, causes the program to return to the CMD level. The special surface database is left in memory and is ready for analysis.

SPSRF SPECIFIC COMMANDS

SPECIAL or GENL , i , j - The "SPECIAL" or "GENL" command, issued from the SPSRF or UPDATE SPSRF level, designates that the lens database surface "i" will be defined as a type "j" special surface. All coefficient values for surface "i" are initialized to 0.0. Valid values for "j" range from "1" to the current maximum number of special surfaces implemented in the program.

C1 i , c through **C96 , i , c** - The "C1" through "C96" commands are used to assign coefficient values to any of the 96 special surface coefficients. "i" specifies the surface number and "c" is the coefficient value. Not every surface uses all 96 coefficients.

SPDEL , i - The "SPDEL" command deletes special surface definitions from surface "i".

SPSRF ON , i - The "SPSRF ON" command causes a lens database surface "i", which has a special surface definition, to have that special surface definition considered during CMD level ray tracing and other analysis. "SPSRF ON" is the default condition when a special surfaces definition is applied to a surface.

SPSRF OFF , i - The "SPSRF OFF" command causes a lens database surface "i", which has a special surface definition, **NOT** to have that special surface definition considered during CMD level ray tracing and other analysis.

SPSRF CMD LEVEL COMMANDS (issuable from the CMD level

SPSRF ON , i - The "SPSRF ON" command causes a lens database surface "i", which has a special surface definition, to have that special surface definition considered during CMD level ray tracing and other analysis. "SPSRF ON" is the default condition when a special surfaces definition is applied to a surface. This command behaves exactly the same as it does at the SPSRF or UPDATE SPSRF level.

SPSRF OFF , i - The "SPSRF OFF" command causes a lens database surface "i", which has a special surface definition, **NOT** to have that special surface definition considered during CMD level ray tracing and other analysis. This command behaves exactly the same as it does at the SPSRF or UPDATE SPSRF level.

PRSPR ALL or **PRSPR , i** - The "PRSPR" command produces a display of the surface number, the special surface type and the value of the 96 coefficients C1 through C96. "ALL" produces a full listing for the entire lens. Input of the surface number "i" generates output for just surface "i".

SPECIAL SURFACE TYPES

The specific characteristics and descriptions of the use of each special surface type can be complex. The user is directed to the Reference Manual for the specific interpretations of each special surface coefficient for each specific special surface type.

NOTE: See Reference Manual for notes on NEXAGON/ACCOS-V compatability.

SPFIT SECTION (REFERENCE MANUAL) COMMAND PROMPTS

SPFIT-FITTING DATA TO SURFACES

The special function fitting, or SPFIT level, is used for fitting tabular data to predefined functional forms. The coefficients resulting from these data fits may either be displayed or, in some cases, assigned to a special surface functional form attached to a lens surface in the lens database through use of special surface definitions (see the SPSRF section of the manual for details regarding these assignments). All fitting is done using a least squares fitting routine. The resulting normal equations are solved using a single-value decomposition routine which avoids the problem of inverting a singular or near singular matrix.

SPFIT COMMANDS

SPFIT - The "SPFIT" command is issued at the CMD level. It causes the program to enter the SPFIT sub-level where the rest of the SPFIT commands may be issued.

TYPE , i - The "TYPE" command is used when numerical data is to be fit to a functional form without the coefficients of the fit being automatically assigned to a lens database surface. The numerical input value "i" designates the type of functional form to be used for the current fit. The functional forms associated with values of "i" are identified in the table of contents for this section. Detailed descriptions of each functional form are found at the end of this section.

SURF , i - The "SURF" command is used when numerical data is to be fit to a functional form with the coefficients of that fit being automatically assigned to a lens database surface. The numerical input value "i" designates the surface number of the surface to which the fit coefficients are to be assigned. The special surface type, which must already have been assigned to the desired surface using SPSRF program level commands, defines the functional form of the fit. See the SPSRF section for a listing of the current special surface types. Either the "TYPE" command or the "SURF" command must be the first command issued following the "SPFIT" command. Special surface types 2, 3, 7, 8, 9, 10, 14 and 15 may be entered as surface types during fitting. Special surface types 2 and 9 will be fit using functional form TYPE 1. Special surface types 2 and 9 will be fit using functional form 2. Special surface types 3 and 10 will be fit using functional form 3. Special surface types 7 and 8 will be fit using functional form 4. Special surface types 14 and 15 will be fit using functional form 5. When special surface fitting to special surface types 2, 3, 9, 10, 14 and 15, the x and y-inputs to the fit must be relative coordinates on a circle with unit (1.0) radius. The "inr" value associated with the lens database surface will be used to automatically scale these relative coordinates to true physical coordinates on the surface before a ray is traced.
COEF , i , j , value - The "COEF" command is used in order to designate that coefficient number "i" should either be included in the current fit using "j" = 1 or omitted from the current fit "j" = 0. The default "j" value for all coefficients is 0. This command must precede data input and data fitting and should follow either the "TYPE" command or the "SURF" command. For the "data fitting" process, the coefficient "value" will normally not be entered explicitly. Entry of explicit coefficient values, using the "value" entry, is normally performed only when values of a function associated with a predetermined set of coefficients need to be calculated in the absence of an actual "data fit". Although the program has a provision for a total of 96 coefficients, not all coefficients apply to all functional forms or special surface types.
DATA , y , x , fn , wt - The "DATA" command is used to enter data which will be used in the fitting process. The functional value is "fn". It is assumed to be associated with variables "y" and "x". A weighting factor "wt" may be included, if desired. The default value for the "wt" is 1.0. Up to 2000 data entries may be input for fitting.
READ - The "READ" command is used to read data which will be used in the fitting process from the file "DATA.DAT". This file must only be a series of data statements. The file is an ASCII file, and it should be placed in the same directory which contains the "PROGRAM.EXE" file. Misreads due to input errors will cause the read to abort with an error message. The program will be left in the SPFIT level. This "READ" method provides a method of preparing large amounts of data outside the main program which then may be fitted from within the program. The same limit of 2000 data entries applies as in the description of the "DATA" command. The data must be all explicitly input in decimal form including the weights, "wt", even if the weights are all 1.0. A valid line in the file might look like: **DATA 1.23 3.238 4.3 1.0.** The data in the file "DATA.DAT" is read as list directed input as a sequence of SPFIT "DATA" commands.
FIT - The "FIT" command is used to initiate the least squares fitting process and the calculation of the coefficients.
LIST - The "LIST" command is used to list the input function, the fitted function and the fitting error. The functional values are tabulated for the set of input data points "y" and "x". The "LIST" command must be entered after the "FIT" command.
COEFS - The "COEFS" command is used to list the resulting coefficients of the current fit, in groups of four.
LISTCOEFS - The "LISTCOEF" command is used to list the resulting coefficients of the current fit, one per line in D23.15 format.
EVAL , y , x - The "EVAL" command is used to evaluate the fitted function at the point y = "y" and x = "x". The evaluated functional value is displayed and placed into the accumulation (X-register).
EOS or **END** - The "EOS" or "END" command is used to exit the SPFIT level and return the program to the CMD level.

SPECIAL FITTING FUNCTIONAL FORMS

The specific characteristics of each special surface type are can be complex. The user is directed to the Reference Manual for the specific interpretations of each special surface coefficient for each specific special surface type.