

Introductory Exercise - Landscape Lens

INTRODUCTION

This is a very basic tutorial that covers how to enter lens data in OSLO and perform a simple optimization. The end of this tutorial describes how to use slider wheels in order to explore changing some of your system parameters. While not true optimization, slider wheels can be a valuable asset to understanding how your system behaves with different design conditions.

This tutorial is written so that it can be performed using all editions of OSLO (including OSLO LT). As a result, the optimization section does not describe some of the fuller (and more convenient) features found in OSLO Standard and Premium. However, the optimization section of this tutorial does provide some initial insight into using the OCM operand array which is available as a user defined error function element in all editions of OSLO.

The overall goal is not only to learn the mechanics of entering data, but also to learn how to apply some of the standard tools in OSLO to gain an understanding of the optical performance of a simple landscape lens. You will see during the exercise that design with OSLO is quite different from most software. You don't set up the system and then press an *Auto* key that lets the computer optimize it for you. Instead, you work in a highly interactive mode, taking small steps so you can understand what is happening as you progress towards a solution.

OUTLINE

The steps in the exercise are as follows:

- **Lens entry** - Enter a single convex-plano lens with a displaced aperture stop behind the lens.
 - The system will be used with an object placed at infinity, an entrance beam radius of 10mm and a field angle of ± 20 degrees
 - The initial radius of curvature of the convex front face will be 50. The thickness of the BK7 lens will be 4mm.
 - The initial distance to the displaced aperture behind the lens will be 10.
 - Set the thickness from the aperture stop to the image surface using a marginal ray height solve
- **Lens Drawing** - Set up the lens drawing conditions to show desired ray trajectories.
 - Remember to force the image surface to be drawn
- **Optimization** - Optimize the lens so it has no coma, and a focal length of 100
 - Create an error function that:
 - Controls the effective focal length to be 100 (remember that you can do this by controlling the exiting slope of the marginal (axial) ray)
 - Forces the 3rd order coma to be zero.
 - Remember to allow some system parameters to vary during the optimization. Good candidates are the curvature of the first surface (will change the power of the lens) and the position of the aperture stop (the location of the stop directly affect coma).
- **Slider-wheel design** - Attach sliders to parameters so you can analyze system trade-offs (Remember to place a thickness solve on the aperture stop surface).
 - Attach one slider to the curvature of the 2nd lens surface and one slider to the curvature of the final image plane.

- Experiment with adjusting the sliders and observe what happens to the on-axis and off-axis spot diagrams.
- By adjusting the curvature of the image surface try to observe the positions of the vertically and horizontally astigmatic off-axis spots

DETAIL

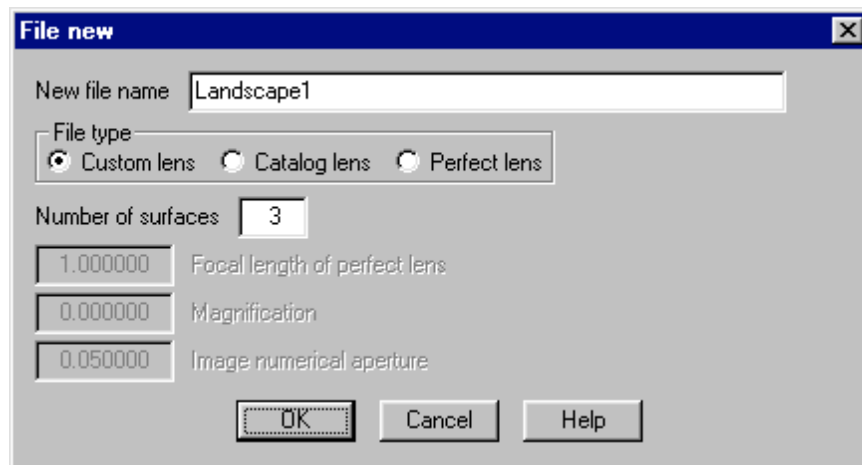
It is important that you start this Detail section with the same OSLO configuration as we did when the tutorial was written. If you have changed many preferences before starting this exercise, you can restore your preferences to factory-default condition by deleting the file `oslo.ini` in your private/bin directory. Normally this will not be required.

In the following detailed steps, many of the words you need to type and actions you need to perform will be highlighted with "quotes" so they stand out from the rest of the tutorial text. The quotes are only there to increase readability of this document. Do not type the quotes.

Lens entry

This first part of the Detail section of the tutorial deals with entering the basic elements of a new lens. Using the following detailed steps.

- 1) Choose "File>>New Lens..." from the OSLO menu



- 2) In the resulting "File new" dialog box, enter the file name "Landscape1", select Custom lens and enter 3 surfaces, then click on the OK button.

A new spreadsheet will appear where you can enter data in almost all the spreadsheet cells. Note that at the top of the spreadsheet, permanent text and user editable text exist in the same cell.

Field angle	20.000000	F
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- 3) Fill out the fixed portion spreadsheet (the top section above the double line) with the following data.
 - 3a) At the top of the spreadsheet type "Landscape 1" in the cell directly to the right of "Lens:".
 - 3b) Changes the entrance beam radius to 5
 - 3c) Changes the field angle to 20.
 - 3d) Leave the other cells with their default values.
- 4) In the scrolled area of the spreadsheet (the section below the double line) make the following changes
 - 4a) Enter "BK7" in the "GLASS" column on surface 1. This will make the material between surfaces 1 and 2 be the optical glass material "BK7". If this is confusing, re-read the Quick Start chapter in the OSLO Optics Reference describing how the Surface Data Spreadsheet works.

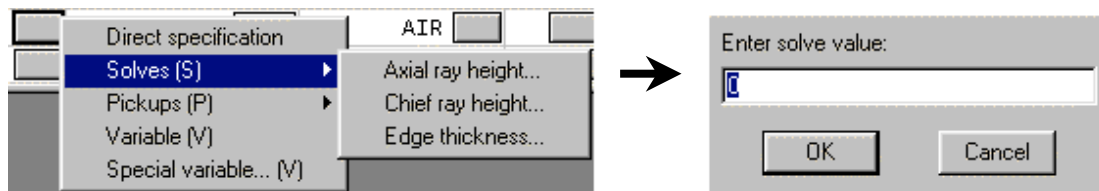
4b) In row 3, click the button in the "APERTURE RADIUS" cell, then click "Aperture Stop" from the resulting pop-up list. Note that the row button for row 3 will now say "AST", and A will be added to the button in the "APERTURE RADIUS" column.

4c) Click in the "RADIUS" cell of row 1, enter 50 for the radius of curvature

4d) Click on the thickness cell in row 1 and enter 4 for the thickness

4e) Click on the thickness cell in row 2 and enter 10 for the thickness there.

5) In row 3, instead of entering a thickness directly, click on the button in the thickness cell, and select "Solves(S)>>Axial ray height..." from the pop-up menus. This will cause a data-entry box to pop-up prompting for the value of the solve. Accept the default value (0) by clicking OK. This will assure that the thickness of surface 3 will be constantly updated so that the **height** of the **axial ray** will be **zero (0)** on the next surface (surface 4).

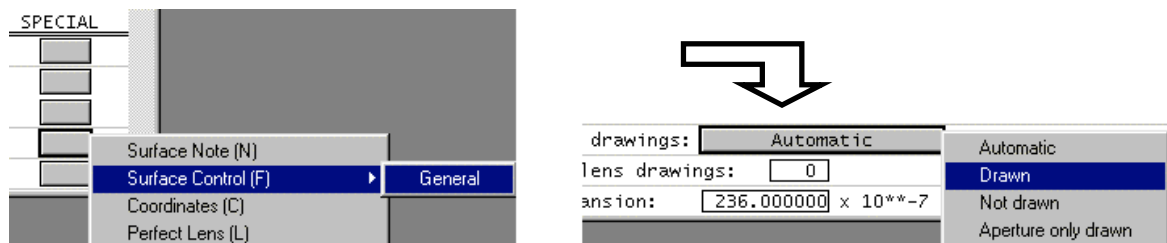


6) Click the button in the "SPECIAL" column for row 3. Select "Surface Control(F)>>General" from the resulting pop-up menu. This will cause a whole new spreadsheet to cover up the current spreadsheet.

6a) Click the button that says "Automatic" in the 8th row, and then choose "Drawn" from the resulting pop-up list. This will force OSLO drawings to explicitly **draw** surface 3.

6b) Then click the Green check mark in the upper left-hand corner of the spreadsheet to close the spreadsheet and return to the surface data spreadsheet.

6c) You will now see an F on the special button for row 3.



7) Repeat the sequence of steps 6 through 6c for the special button in row 4.

This completes the basic data entry for your lens. At this point, your spreadsheet should look like the following.

Surface Data						
SRF	RADIUS	THICKNESS	APERTURE RADIUS	GLASS	SPECIAL	
OBJ	0.000000	1.0000e+20	3.6397e+19	AIR		
1	50.000000	4.000000	10.290581	BK7	C	
2	0.000000	10.000000	9.050250	AIR		
AST	0.000000	84.112075	4.346913	AIR		F
IMS	0.000000	0.000000	35.213831			F

8) As a check to make sure everything is correct, make sure you have the same Efl (effective focal length), and that the buttons have the same labels. The S on the thickness button means that the value is determined by a solve (the axial ray height solve). The S on the aperture buttons also means that the apertures are determined by solves. This is the default action for apertures and is based on the entrance beam radius and the field angle.

9) Click on the Green check mark in the upper left-hand corner to close the spreadsheet and save the lens by choosing "File>>Save Lens..." from the OSLO menu. You have already indicated that the file name was to be "Landscape1.len" in step #2 above. The lens will be saved in the current lens directory, which is normally your private directory.

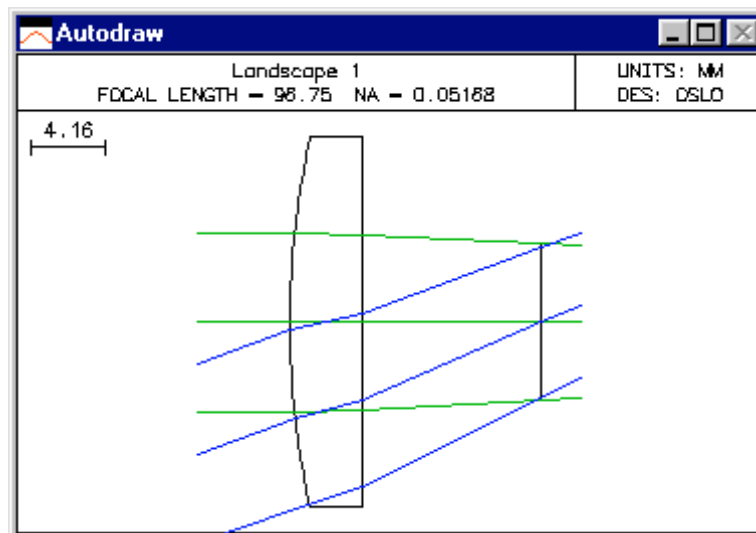
10) If you want to confirm that the lens is saved there, choose "File>>Open Lens..." from the OSLO menu. Click on the "Private" Library Directory button at the bottom of the "Open Lens File" dialog. Your lens "Landscape1.len" should be listed there.

See the section Sideline #1 if you want to learn more about where your lenses are saved.

Lens Drawing

This next part of the Detail section of the tutorial will concentrate on controlling how to draw your lens in OSLO.

11) Click the "Draw Off" button in the fixed area (top portion) of the lens spreadsheet. A window labeled "Autodraw" will appear showing the lens that you have entered. If you click on any cell on surface 2 of the spreadsheet, you will see that the surface corresponding to surface 2 in the "Autodraw" window becomes dotted. If you were to change any data item for the lens in the surface data spreadsheet, the picture would be updated automatically.

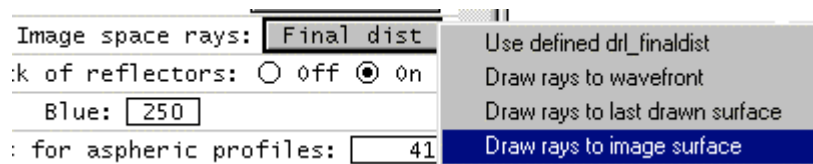


The Autodraw window is a special window that does not have the full functionality of a regular graphics window, but is updated automatically, which is not the case for ordinary graphics windows. The lens picture that is shown is drawn according to the standard lens conditions used for all lens drawings. In order to illustrate this exercise better, we are going to change one of the operating conditions so that the ray trajectories are drawn all the way to the image surface.

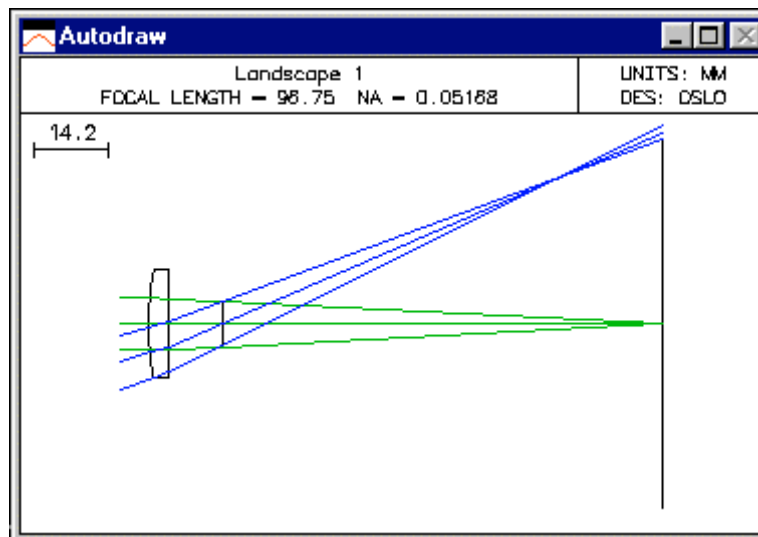
12) From the Lens menu on the main tool bar, select the bottom item, Lens Drawing Conditions. This will cause the following spreadsheet to cover the lens spreadsheet:

Initial distance:	<input type="text" value="0.000000"/>	Final distance:	<input type="text" value="0.000000"/>						
Horizontal view angle:	<input type="text" value="240"/>	Vertical view angle:	<input type="text" value="30"/>						
First surface to draw:	<input type="text" value="0"/>	Last surface to draw:	<input type="text" value="0"/>						
X shift:	<input type="text" value="0.000000"/>	Y shift:	<input type="text" value="0.000000"/>						
DXF/IGES view:		<input type="text" value="Unconverted"/>							
Apertures:	<input type="text" value="Quadrant"/>	Rings:	<input type="text" value="3"/>						
Spokes:	<input type="text" value="4"/>	Image space rays:	<input type="text" value="Final dist"/>						
Draw aperture stop:	<input checked="" type="radio"/> off <input type="radio"/> on	Hatch back of reflectors:	<input type="radio"/> off <input checked="" type="radio"/> on						
Shaded solid color - Red:	<input type="text" value="175"/>	Green:	<input type="text" value="185"/>						
Blue:	<input type="text" value="250"/>								
Number of field points for ray fans:	<input type="text" value="3"/>	Points for aspheric profiles:	<input type="text" value="41"/>						
Frac Y Obj	Frac X Obj	Rays	Min Pupil	Max Pupil	Offset	FY	FX	Wvn	Cfg
<input type="text" value="0.000000"/>	<input type="text" value="0.000000"/>	<input type="text" value="3"/>	<input type="text" value="-1.000000"/>	<input type="text" value="1.000000"/>	<input type="text" value="0.000000"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text" value="1"/>	<input type="text" value="0"/>
<input type="text" value="0.700000"/>	<input type="text" value="0.000000"/>	<input type="text" value="0"/>	<input type="text" value="0.000000"/>	<input type="text" value="0.000000"/>	<input type="text" value="0.000000"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text" value="1"/>	<input type="text" value="0"/>
<input type="text" value="1.000000"/>	<input type="text" value="0.000000"/>	<input type="text" value="3"/>	<input type="text" value="-1.000000"/>	<input type="text" value="1.000000"/>	<input type="text" value="0.000000"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text" value="1"/>	<input type="text" value="0"/>

13) The item to change on this spreadsheet is called "Image space rays:" You should change it from "Final dist" to "Draw to image surface".



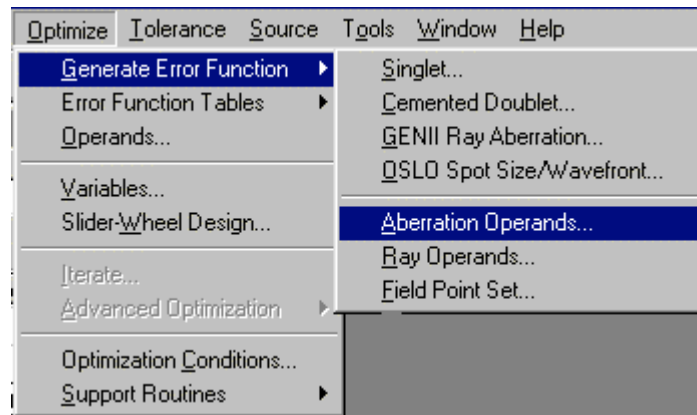
14) After making the modification, click the Green check to close the spreadsheet. The lens spreadsheet will reappear, and the Autodraw window will be updated as follows.



Now you can see the details of image formation by the lens. Obviously the off-axis image is not so good. The main aberration that you see is field curvature; the off-axis image is not formed on a plane surface perpendicular to the axis, but rather on a curved surface. Unfortunately, there is not too much that can be done about this.

Optimization

This next part of the Detail section of the tutorial will concentrate on a small optimization task with your lens. We will define an error function that makes the focal length exactly 100mm, and also eliminates the Seidel (3rd order) coma from the image.



15) Choose "Optimize>>Generate Error Function>>Aberration Operands..." from the OSLO menu. You have just created an error function that OSLO will be able to optimize on.

OP	MODE	WGT	NAME	DEFINITION
1	Min	1.000000	PY	OCM1
2	Min	1.000000	PU	OCM2
3	Min	1.000000	PYC	OCM3
4	Min	1.000000	PUC	OCM4
5	Min	1.000000	PAC	OCM5
6	Min	1.000000	PLC	OCM6
7	Min	1.000000	SAC	OCM7
8	Min	1.000000	SLC	OCM8
9	Min	1.000000	SA3	OCM9
10	Min	1.000000	CMA3	OCM10
11	Min	1.000000	AST3	OCM11
12	Min	1.000000	PT23	OCM12
13	Min	1.000000	DIS3	OCM13
14	Min	1.000000	SA5	OCM14
15	Min	1.000000	CMA5	OCM15
16	Min	1.000000	AST5	OCM16
17	Min	1.000000	PT25	OCM17
18	Min	1.000000	DIS5	OCM18
19	Min	1.000000	SA7	OCM19
20	Min	1.000000	TOTAL_SPH	OCM20
21	Min	1.000000	EFL	OCM21

As a result of step 16, the current spreadsheet will be replaced with the "Operands Data Editor" shown above. This is the operand list that makes up the error function you just created. The "NAME" column identifies the role of each of the operands in the list. The "DEFINITION" column refers to the OCM array element where the value for each operand is defined. At this point we will skip the explanation of what is happening in the background to fill the array variables OCM1 through OCM21 with the correct data values. For now it is only sufficient to understand that each operand in your list controls some system

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parameter defined by the mnemonic in the "NAME" column. For example operand #6 "PLC" controls "Paraxial Lateral Color".

Unfortunately we do not want to control all these parameters at once during our optimization, and we need to decide which of the terms will be used for the error function. The initial spreadsheet lists all of the possibilities, and you must delete the ones you don't want. In this case, the operands to keep are CMA3 and EFL. All the other should be deleted.

16) To do this, first click and drag from row buttons 11-20, then press the delete key

17) Next click and drag from row buttons 1-9, and then press the delete key again

18) Check that the spreadsheet appears as follows. CMA3 stands for the 3rd order term of the aberration "Coma", and EFL stands for "Effective Focal Length".

OP	MODE	WGT	NAME	DEFINITION
1	Min	1.000000	CMA3	OCM10
2	Min	1.000000	EFL	OCM21

It is important to understand that in OSLO, all operands are targeted to zero. That is, the optimization algorithm will minimize all of its individual terms. Since the EFL operand is the effective focal length, we don't want the EFL to be zero, but rather the value of 100.

19) We accommodate this by modifying the definition of the second operand to be OCM21-100, and we will also change the name to EFL_ERR. Click on the NAME and DEFINITION cells and enter the new data.

OP	MODE	WGT	NAME	DEFINITION
1	Min	1.000000	CMA3	OCM10
2	Min	1.000000	EFL_ERR	OCM21-100.0

20) Now click the Green check mark in the upper left-hand corner to close the spreadsheet, and click the "Ope" button in the text window. The current operand values, together with the current value of the error function, will be listed in the Text window.

```
*OPERANDS
OP  MODE  WGT    NAME          VALUE  %CNTRB  DEFINITION
O 1    M     1.000000 CMA3          0.001694 0.00    OCM10
O 2    M     1.000000 EFL_ERR      -3.250795 100.00  OCM21-100.0
MIN RMS ERROR:      2.298659
```

The operands of the error function are now defined. From the output in the text window we can see that currently, the error in the EFL makes up nearly 100% of the total error in the error function. But as we start to optimize the system and the EFL is corrected, the balance between controlling the EFL to 100 and the third order coma to zero will be re-established.

Controlling the axial ray slope as it exits the last surface of your lens is an alternate way of controlling the system EFL for a certain entrance beam radius. To find out how to use the axial ray angle operand to control your system focal length, see Sideline #2.

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We now need to specify the system parameters that will be varied in order to achieve a good system optimization. The parameters that we will use are the curvature of the first surface (CV 1), and the distance between the lens and the aperture stop (TH 2).

21) In the lens spreadsheet, click on the button in the "RADIUS" of Curvature column for surface 1, and select "Variable(V)" from the options list.

RADIUS	THICKNESS	APERTURE
0.000000	1.0000e+20	3.6397e+:
50.000000		
0.000000		
0.000000		
0.000000		

Direct specification
Solves (S)
Curvature pickup... (P)
Minus curvature pickup... (P)
Variable (V)
Special variable... (V)

22) Repeat step 21 using the button in the "THICKNESS" cell for surface 2.

RADIUS	THICKNESS
0.000000	1.0000e+20
50.000000	4.000000
0.000000	10.000000
0.000000	84.112075

23) Check that the appropriate buttons on surface 1 and 2 should now have V's for "Variable" on them.

24) You are now be ready to optimize the lens. But before doing this, close the lens spreadsheet (Green check) and immediately re-open it. This action saves the current system to an interim buffer (it acts as a sort of quick save). If something were to go wrong during the optimization, OSLO gives you the capability, by canceling (red X) from a spreadsheet, to revert to the system that existed when you last opened the spreadsheet (after closing it with a Green check). By closing and opening the spreadsheet in this way, you establish a base system to revert to.

25) To optimize, click the "Ite" button in the text window. This button will optimize your system through 10 **iteration** cycles, if that many are required. You may have noticed that this button was disabled until you entered both operands and variables.

The text window should show the following output although you might see slightly different numbers in the columns. You see that the error function has been reduced to essentially zero, indicating that the variables were appropriate for solving the problem.

The screenshot shows a text window titled "TW 1" with a menu bar containing: Len Spe Rin Ape Wav Pxc Abr Mrg Chf Tra Ref Fan Spd Auf Var Ope Ite. The main text area displays the following output:

```

*ITERATE FULL 10
NBR    DAMPING    MIN ERROR    CON ERROR    PERCENT CHG.
0      1.0000e-08    2.298659    --           --
1      1.0000e-08    0.082382    --           96.416077
2      1.0000e-12    1.0707e-05  --           99.987004
3      1.0000e-12    1.1064e-08  --           99.896663
4      1.0000e-12    1.1435e-11  --           99.896642
5      1.0000e-12    1.0049e-14  --           99.912126
6      1.0000e-12    1.0049e-14  --           5.5879e-05
7      1.0000e-12    1.0049e-14  --           1.8626e-05
    
```


26) Check that the lens spreadsheet below matches your spreadsheet following the optimization. You can see in the lens spreadsheet that the Efl is exactly 100, as it must be in order to correct the operands.

Gen	Setup	Wavelength	Field Points	Variables	Draw Off	Group	Notes
Lens: Landscape 1				Zoom	1 of 1	Efl	100.000000
Ent beam radius		5.000000	Field angle	20.000000	Primary wavln		0.587560
SRF	RADIUS	THICKNESS	APERTURE RADIUS	GLASS	SPECIAL		
OBJ	0.000000	1.0000e+20	3.6397e+19	AIR			
1	51.680011	4.000000	9.856783	BK7	C		
2	0.000000	9.135802	8.637010	AIR			
AST	0.000000	88.227067	4.411353	AIR	F		
IMS	0.000000	0.000000	36.397023		F		

27) Click the "Abr" button in the text window, and you see all the **aberration** data for the lens, showing that PU = -0.05, and that the Seidel coma CMA3 is zero, as requested in the error function operands.

```

TW 1 *
Len Spe Rin Ape Wav Pxc Abr Mrg Chf Tra Ref Fan Spd Auf Var Ope Ite

*PARAXIAL TRACE
SRF PY PU PI PYC PUC PIC
4 -- -0.050000 -0.050000 36.397023 0.412538 0.412538

*CHROMATIC ABERRATIONS
SRF PAC SAC PLC SLC
SUM -0.077222 -0.053466 0.069914 0.048406

*SEIDEL ABERRATIONS
SRF SA3 CMA3 AST3 PTZ3 DIS3
SUM -0.013612 4.3368e-18 -0.313405 -0.218345 1.101908

*FIFTH-ORDER ABERRATIONS
SRF SA5 CMA5 AST5 PTZ5 DIS5 SA7
SUM -9.6466e-05 -5.9253e-05 -0.020638 0.017274 0.070480 -7.7081e-07

```

At this point, the initial task has been completed.

28) Close the spreadsheet (Green check) and save the lens.

This will become the base system for the next phase of the exercise, which shows how to use OSLO's slider window to study the effects of changing other lens parameters. You might want to save another copy of this system under a different file name (e.g. landscape_bkp.len) so you can always return to a defined starting point, even if the current lens data is somehow corrupted.

Slider-wheel design

A singlet such as the landscape lens doesn't have very many degrees of freedom, but in this exercise, we have constrained the back surface of the lens to be a plane. A landscape lens is normally a meniscus form. Now we will see how to use OSLO's slider-wheel window to find the optimum form. We will also see the effects of using a curved image surface.

First, we set up a basic slider-wheel window, attaching the curvatures of surfaces 2 and 4 to sliders. Later, we show how to use the full power of OSLO's optimization callback to continuously optimize the system while dragging a slider or rotating the mouse wheel.

29) With the landscape lens as set up in the preceding portion of this exercise, choose "Optimize>>Slider-Wheel Design..." from the OSLO menu to open the Slider-Wheel Setup spreadsheet.

30) Initially, set the options shown in the figure below.

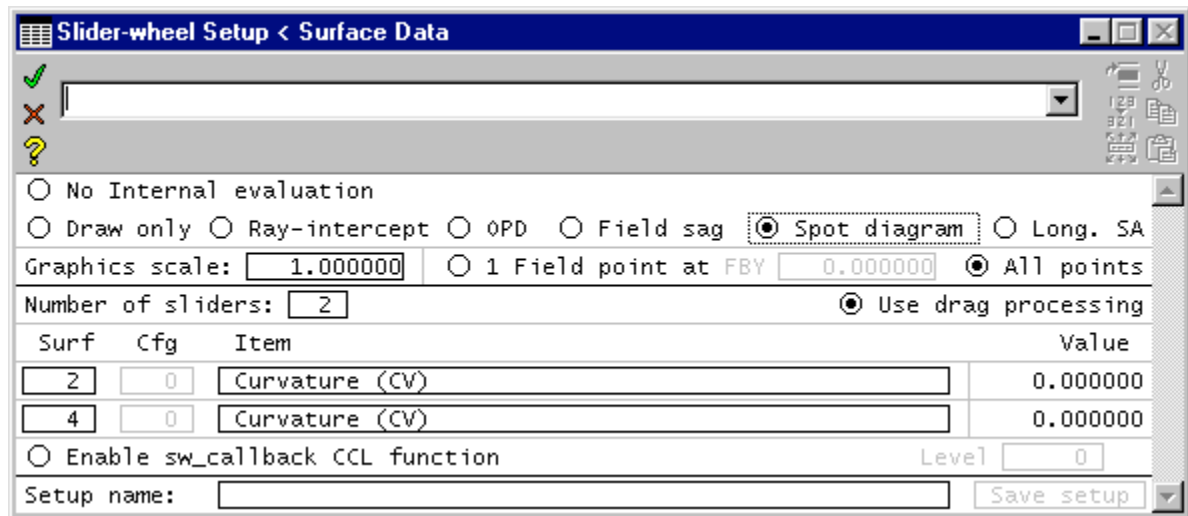
30a) Click "Spot diagram"

30b) Set "Graphics scale" to 1.0

30c) Select "All points"

30d) Leave the number of sliders at the default (2)

30e) Enter 2 and 4 in the Surfs column, and set the parameters to "Curvature (CV)" for both sliders. You can do this either by typing "CV" in the cell, or by double clicking in the cell and choosing "Curvature (CV)" from the resulting pop-up list.

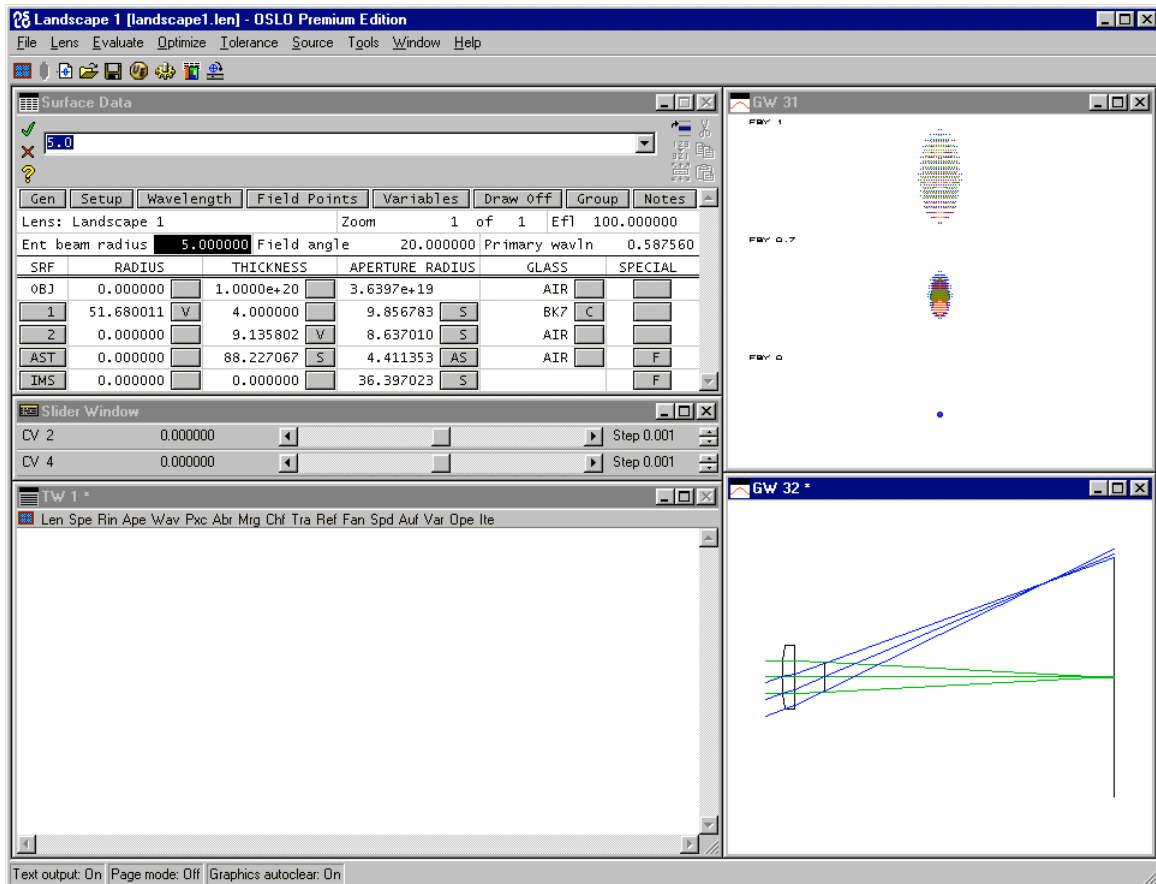


31) Close the spreadsheet (Green check)

You should now see a slider-wheel window and two additional graphics windows (GW 31 & GW 32) on your screen.

32) If the "GW 31" and "GW32" windows have toolbars, remove them by left-clicking to select a window, then right-clicking in the window and choosing the Remove Toolbar item.

33) Since the slider-wheel maintains its own graphics windows, you should minimize the normal graphics output window (GW1). Next, use the Tile windows command on the main window toolbar to tile the windows. Your overall screen should look similar to the one below.



The slider-wheel window appears below the spreadsheet. It contains the two sliders that we just set up.

34) Try manipulating the sliders by dragging or clicking as you would with a normal scroll bar (the sliders are in fact scroll bars), or by using the mouse wheel. To use the mouse wheel with a slider, place the pointer *anywhere* in a slider and rotate the wheel.

The mouse wheel is usually preferred (if it is installed and properly supported on your computer). For a quick description on how to manipulate the slider as well as determine and control the settings of your mouse wheel, see *Sideline #3*

35) Note that the spot diagrams show what the image looks like at the center, zone, and edge of the field. The elliptical shape is characteristic of a system with astigmatism, but no coma. Now you can drag the sliders or rotate your mouse wheel to see what happens. Actually, if you do not use the mouse wheel, you would be better advised to click on a button at the end of a slider rather than drag, so you can move in small enough steps.

36) Move the slider to make CV[2] negative. The lens becomes positive and the focal length gets smaller. This is pretty much what you would expect. The image quality changes, since the system is no longer free of coma. If you change the curvature too much (< -0.033) the ray trace will fail. If this happens, click OK to dismiss the error box, then move the slider back towards the center.

37) Move the slider to make CV[2] positive. The lens becomes first a meniscus with a long focal length, but eventually the lens becomes negative; the beam diverges and the display blows up. After you have experimented with CV[2], set it back to zero.

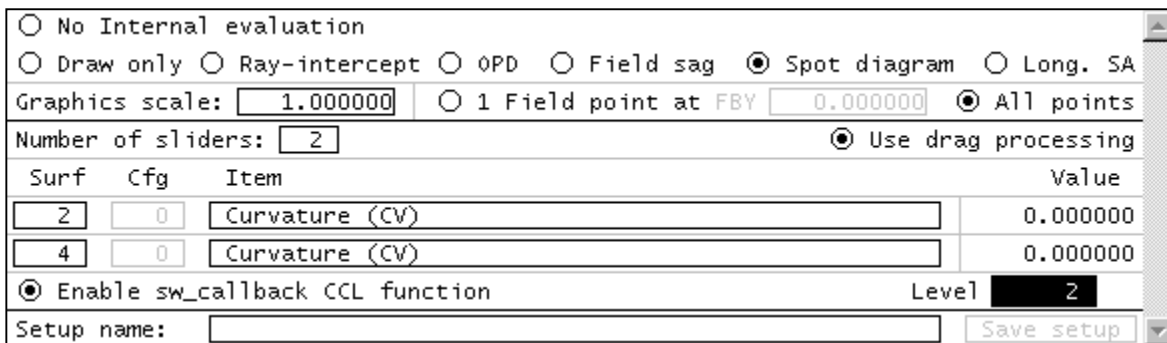
38) Try changing CV[4] (the curvature of the image surface). you see that by making it negative, you can improve the size of the image off-axis, and in fact you can find a position where there is a line focus in the

horizontal direction (tangential focus), or the vertical direction (sagittal focus). This is indicative of a system with no coma. If you set CV[2] to a value where the system has substantial coma (try -.020) you will not be able to achieve this. This shows what designers mean when they say that you can't focus out coma.

The slider-wheel analysis you have observed so far is perhaps interesting, but the real power of sliders in OSLO comes when you allow the program to re-optimize the system as you drag a slider.

39) Reset the curvatures to zero. If you have adjusted other system parameters during this process, you may want to re-open the lens that you saved at step 29.

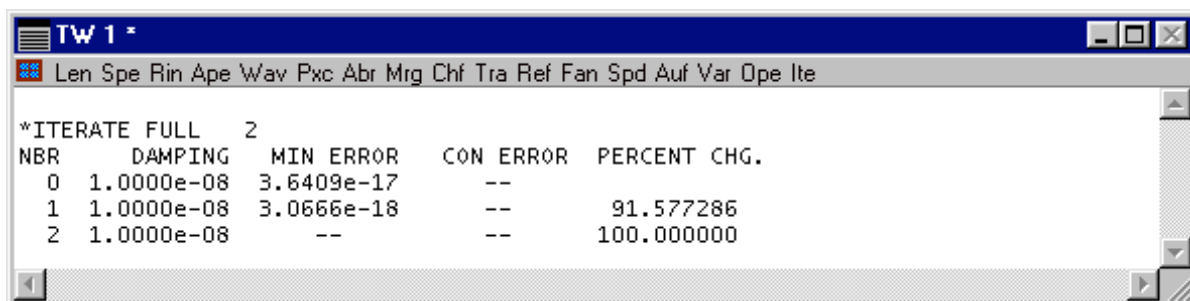
40) Re-open the slider spreadsheet (Optimize>>Slider Wheel Design). In the Slider-wheel-Setup dialog, set "Enable sw_callback CCL function" to On, and set the "Level" to 2.



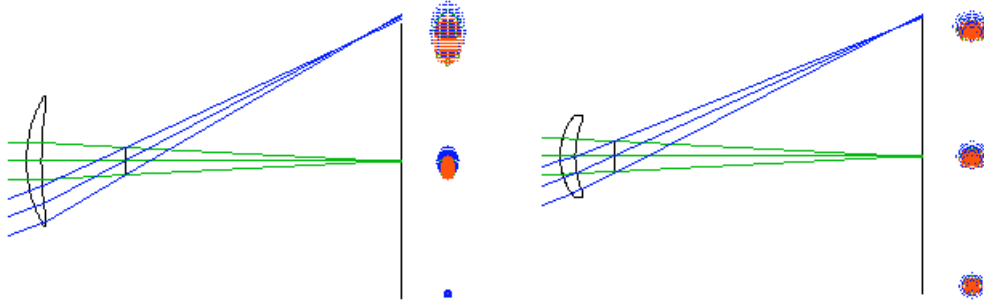
41) To invoke this new change to the slider setup, choose the Green Check to close the Slider-wheel Setup.

A callback function is a command that gets executed whenever some event happens in the program. Callback functions are the essence of a windows program, and OSLO has several of them, many written in CCL (such as sw_callback.ccl). Generally, these are not complicated routines written by computer programmers, but simple actions set up by users. For more information on exploring the callback routine used here, see Sideline #4

42) To see what this does, close the slider window. You should not see any change in the system, because it was already optimized, but you will see text out similar to the following. As you move a slider, you will see the numbers flash in the text output window as the system is re-optimized.



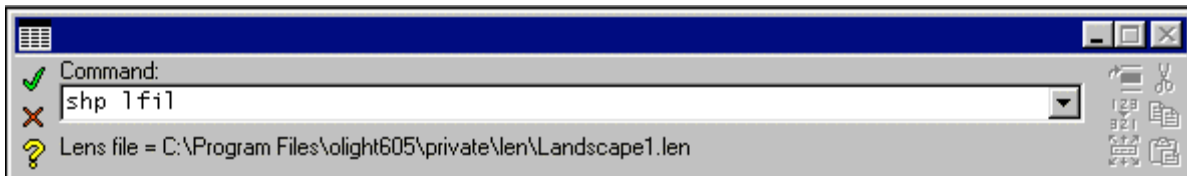
43) In the graphics windows, you will see a quite different scenario from before. To begin, drag the CV[2] slider to make it more positive. This makes the lens into a meniscus, but now the focal length is held constant by virtue of the first curvature's being continually re-optimized. Moreover, the aperture stop surface moves as the coma is continually re-optimized to zero. The image surface is held in the paraxial image plane by the height solve on surface 3, and the diameter of the lens is adjusted by the aperture solves so that the beam from the edge of the field of view can pass through the system. The effect of all of this is that the stop initially moves away from the lens as it becomes a meniscus, but as the bending becomes larger, the stop shift reverses and the aperture stop moves back towards the lens. The following shows what you should observe when the surface 2 curvature has values 0.01, and 0.04 (n.b. the images pertain to center-to-edge, not to bottom-to-top; the bottom spot is the on-axis image).



Of course, the spherical aberration of the system is not constant, and the improvement in image quality at the edge of the field comes at the expense of a poorer on-axis image. This leads to a consideration of what might be accomplished by using an aspheric lens, but that is beyond the scope of this introductory exercise, whose purpose is to introduce OSLO data entry and the general steps for using the slider-wheel window.

SIDELINE #1

If you want to confirm where the lens is saved, you can enter the command *shp lfil* (*show_preference lensfile*) in the command line. The file name will appear in the message area.



SIDELINE #2

In step #15 above, we found that by choosing "Optimize>>Generate Error Function>>Aberration Operands..." from the OSLO menu, we generated the following operand set:

OP	MODE	WGT	NAME	DEFINITION
1	Min	1.000000	PY	OCM1
2	Min	1.000000	PU	OCM2
3	Min	1.000000	PYC	OCM3
4	Min	1.000000	PUC	OCM4
5	Min	1.000000	PAC	OCM5
6	Min	1.000000	PLC	OCM6
7	Min	1.000000	SAC	OCM7
8	Min	1.000000	SLC	OCM8
9	Min	1.000000	SA3	OCM9
10	Min	1.000000	CMA3	OCM10
11	Min	1.000000	AST3	OCM11
12	Min	1.000000	PTZ3	OCM12
13	Min	1.000000	DIS3	OCM13
14	Min	1.000000	SA5	OCM14
15	Min	1.000000	CMA5	OCM15
16	Min	1.000000	AST5	OCM16
17	Min	1.000000	PTZ5	OCM17
18	Min	1.000000	DIS5	OCM18
19	Min	1.000000	SA7	OCM19
20	Min	1.000000	TOTAL_SPH	OCM20
21	Min	1.000000	EFL	OCM21

Instead of controlling EFL, here we want to control the slope of the paraxial axial ray as it leaves the lens (PU). So in this case we want to keep the PU and CMA3 operands. All the other should be deleted.

16) To do this, first click and drag from row buttons 11-21, then press the delete key

17) Next click and drag from row buttons 3-9, and then press the delete key again. Finally, click row button 1 and press the delete key

18) Check that the spreadsheet appears as follows. PU stands for the paraxial axial ray slope leaving the lens (the term PU is standard optics convention and is used frequently in OSLO), and CMA3 stands for the 3rd order term of the aberration "Coma".

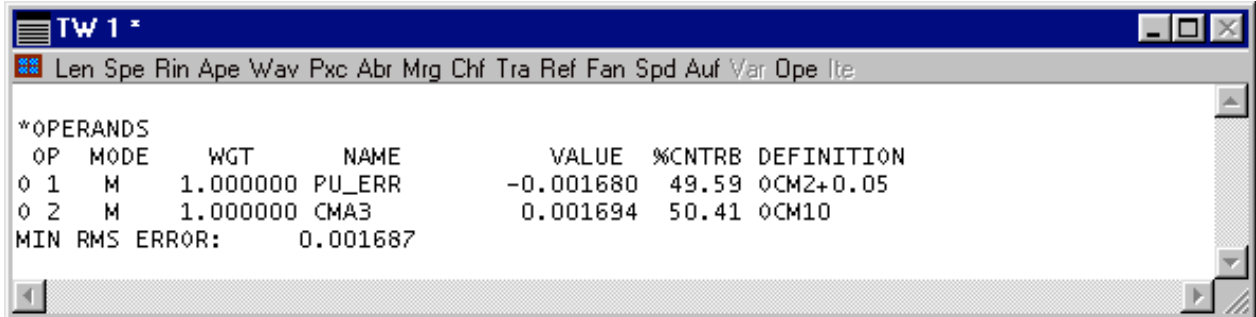
OP	MODE	WGT	NAME	DEFINITION
1	Min	1.000000	PU	OCM2
2	Min	1.000000	CMA3	OCM10

We will be using the slope of the axial ray leaving the lens to control the lens f-number. So we need to modify the definition of the first operand, PU. In OSLO, all operands are targeted to zero. That is, the optimization algorithm will minimize all of its individual terms. Since the PU operand is the axial ray slope leaving the lens. We don't want this to be zero, but rather the value that will make the lens have an f-number of 10, which was prescribed in the initial data.

19) Since the f-number is $-1/2*PU$ (when the object is at infinity) the desired value for PU is $-.05$. We accommodate this by modifying the definition of the first operand to be $OCM2+0.05$, and we will also change the name to PU_ERR. Click on the NAME and DEFINITION cells and enter the new data.

OP	MODE	WGT	NAME	DEFINITION
1	Min	1.000000	PU_ERR	OCM2+0.05
2	Min	1.000000	CMA3	OCM10

20) Now click the Green check mark in the upper left-hand corner to close the spreadsheet, and click the "Ope" button in the text window. The current operand values, together with the current value of the error function, will be listed in the Text window.

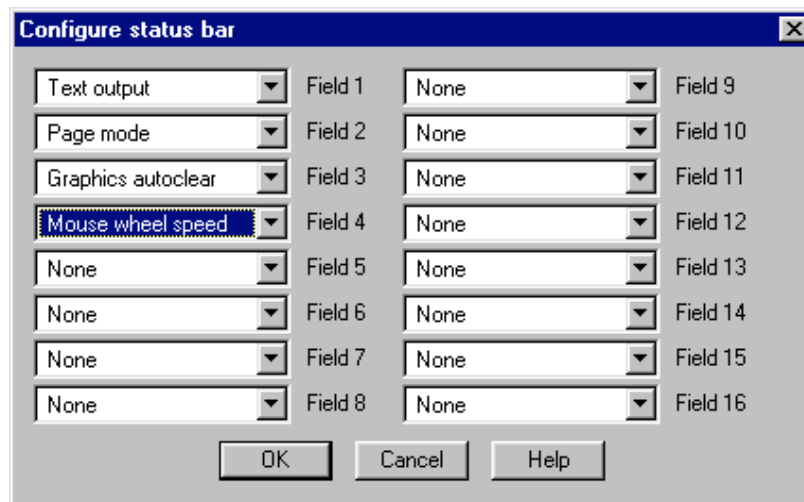


The operands of the error function are now defined. As a sanity check, let's go over what we did in the last few steps. If the error function is minimized to zero, the value of PU will be forced to -0.05. This is because the relevant operand $PU+.05$ (remember that OCM2 contains the value of PU) will be forced to zero. We know that the focal length of a lens is $-PU*EBR$ (where EBR is the Entrance Beam Radius) so this, in turn, will force the focal length to be 100. We also know that the system f-number is equal to $EFL/(2*EBR)$ and this equals 10 which is the desired value. Through the use of the OCM10 array variable, we will also force the system 3rd order coma to be zero during the optimization.

You can now return to the regular tutorial and continue starting with step #21.

SIDELINE #3

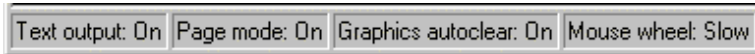
To change the settings of your mouse wheel, you need to first find out what they are at present. To do this, double click on the status bar in the main OSLO window. This will pop up a dialog box as shown below. Navigate to the first empty field, click on the combo box, and select Mouse wheel speed, as shown.



Click OK to dismiss the box. You should see an additional field in the status bar, as shown. OSLO supports two mouse-wheel speeds: fast and slow. Slow means one event per wheel notch; fast means several events per wheel notch (however many you set up in the mouse dialog in your computer's control panel). You change between fast and slow by clicking the mouse button itself. Generally in OSLO, you will prefer Slow.

If you experiment, you will see that the slider-wheel window can be dragged anywhere on the display, even outside the OSLO window. Also, you will see that you can drag the window width down to the point where the slider itself completely disappears. If you use the mouse wheel, this setting may be preferable because it minimizes the use of screen space while still providing full functionality. You will see that the step size in the parameter taken per click can be adjusted using the Step control at the right-hand end of the window.

For now, it is best to leave the slider window where the Tile windows command puts it, with its default settings. To reset these, enter the original values (0) of CV[2] and CV[4] in the lens spreadsheet, then click the slider-window tool in the main toolbar and close the slider-wheel setup spreadsheet immediately to update the slider-wheel window (note that the settings for the analysis options are not changed).



SIDELINE #4

When *Enable sw_callback CCL function* is turned on, this routine is executed every time a graphic slider is moved, or the mouse-wheel is rotated when the pointer is in the slider-wheel window. The arguments of this function are *cblevel*, the value entered in the Level field in the slider-wheel spreadsheet; *item*, the type of variable (CV = 1, TH = 3, etc.) that was changed, and *srf*, the number of the surface associated with that variable. These arguments can be used to produce whatever action you want. In the present case, the function only looks to see if *cblevel* is non-zero, and if it is, the function carries out that many design iterations.

The default *sw_callback* routine is as follows.

```
Cmd Sw_callback(int cblevel, int item, int srf)
{
    if (cblevel)
        ite cblevel;
}
```