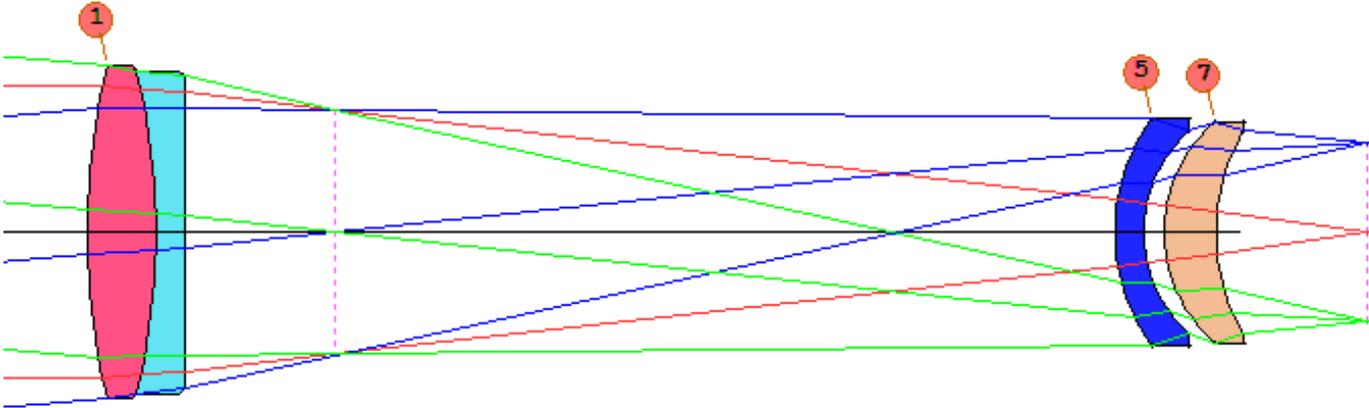


Lesson 28: Understanding Artificial Intelligence

In earlier lessons you have seen a few of the AI features available in SYNOPSIS™. No other optics code in the world has anything comparable. This lesson will present a more complete picture of what this remarkable tool can do and how you use it. AI mode is turned on by typing the command **AI**, or by clicking on the AI button . It can be turned off by the command **INTERACTIVE**, or clicking the AI Off button . Turn on AI, if it is not already on, and then **FETCH 2370** and make a checkpoint.



What is the airspace distance after surface 3? Ask AI:

```
SYNOPSIS AI>3 TH?
```

```
The thickness or spacing of surface number 3 is 26.3666993
```

Change it to 27.0:

```
SYNOPSIS AI>TH 3 = 27
```

```
The thickness or spacing of surface number 3 is 27.0000000
```

What is the third-order spherical aberration? Well, you actually can ask just that question:

```
SYNOPSIS AI>What is the third-order spherical aberration?
```

```
The third-order spherical aberration sum (SA3) is -0.02340108
```

Or you can type a much shorter sentence:

```
SYNOPSIS AI>SA3?
```

```
The third-order spherical aberration sum (SA3) is -0.02340108
```

The last question, "SA3?", is grammatically the same as the previous sentence, and of course you would prefer to do as little typing as possible, so that is what you would enter. But you see that the input is extremely flexible, and the way you type it is often not critical. The program parses the sentence, finds the subject and verb, satisfies any conditions, and then tries to answer the question.

Since many tasks in SYNOPSIS can be done in several ways, you naturally want to find the easiest one. Suppose you want to know the global Z-coordinate of surface 7. You can type the **ASY GLOBAL** command (also found in the dialog **MLL**):

```
SYNOPSIS AI>ASY GLOB
```

```
THIS LENS HAS NO SPECIAL SURFACE TYPES
THIS LENS HAS NO TILTS OR DECENTERS
Global mode has been turned on.
```

```
GLOBAL COORDINATE DATA
```

```
GLOBAL COORDINATE SURFACE LOCATION IN COORDINATE SYSTEM OF SURFACE 1
```

SURF	X	Y	Z	NOTES	ALPHA	BETA	GAMMA
1	0.000000	0.000000	0.000000		0.00000	0.00000	0.00000
2	0.000000	0.000000	12.000000		0.00000	0.00000	0.00000
3	0.000000	0.000000	17.000000		0.00000	0.00000	0.00000
4	0.000000	0.000000	43.366699		0.00000	0.00000	0.00000
5	0.000000	0.000000	179.512319		0.00000	0.00000	0.00000
6	0.000000	0.000000	184.512319		0.00000	0.00000	0.00000
7	0.000000	0.000000	188.168005		0.00000	0.00000	0.00000
8	0.000000	0.000000	197.168005		0.00000	0.00000	0.00000
9	0.000000	0.000000	223.717528		0.00000	0.00000	0.00000

But it's easier to just ask AI:

```
SYNOPSIS AI>7 ZG?
```

```
Surface number 7 is not controlled by any tilt or decenter.
Surface number 7 has a global Z-coordinate of 188.16800509
```

Suppose you want to change that value. The surface is not assigned global coordinates at present, so you could go to the SpreadSheet and enter data into submenus, or use the WorkSheet™ or a CHG file. In this case, however, AI is better:

```
7 ZG = 200
```

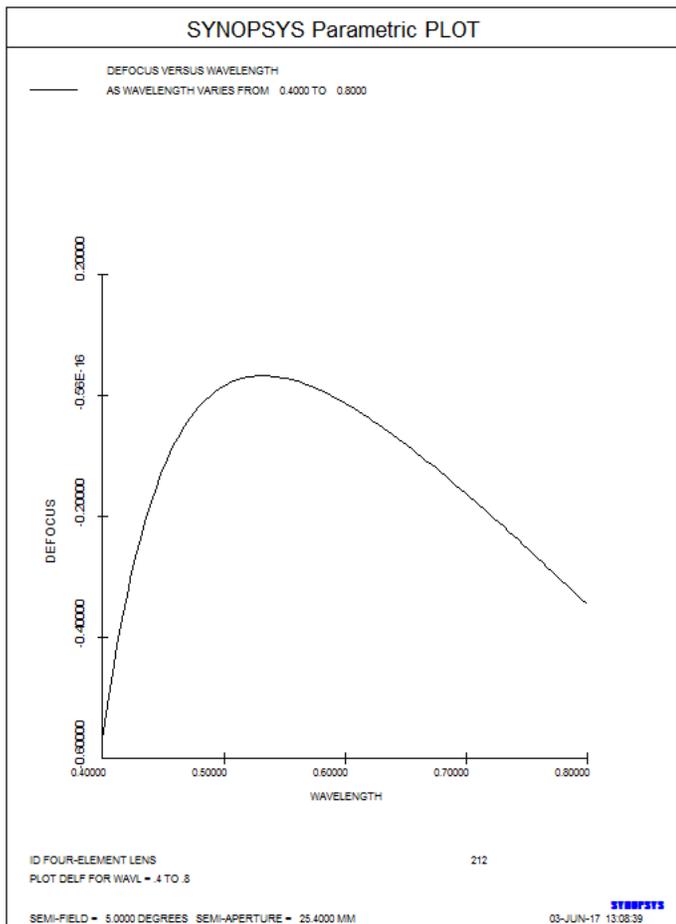
That simple sentence assigns the global coordinate.

Probably the most useful of the AI features is for making a plot of something against something else. Restore the lens to the checkpoint you made earlier, and then remove the paraxial solves.

```
CHG
NOP
END
```

Type the sentence below to look at the color correction:

```
PLOT DELF FOR WAVL = .4 TO .8
```



Since the lens has no solves now, the paraxial defocus (DELF) varies with wavelength. If the lens were assigned a YMT solve, then DELF would have been zero at all wavelengths, and we would instead have plotted the back focus (BACK). (Note that we removed the *curvature* solve, since we don't want the last radius to change with wavelength too!)

Suppose you are working on a lens where secondary color is an issue. You want to make this kind of plot more than once, but you don't want to type that long sentence every time. What can you do? Make a symbol, of course.

SC: PLOT BACK FOR WAVL = .4 TO .8

Now just type "SC", and the program gives you the plot again. You have, in effect, defined a whole new command. Put this definition in your CUSTOM.MAC MACro, and it will come back every time you start the program. Neat!

The principle is simple: ask AI for what you want with an English sentence. If that sounds too good to be true, you are right – probably all of the sentences in Shakespeare would baffle the program. But applied to a limited range of issues, it can do a great deal. There are five categories of sentences that the program recognizes:

1. Questions about something
2. Changes to something
3. Looping, changing something and evaluating something else each time through, usually making a plot of the results.
4. Assigning symbols to equal a character string.

5. Evaluating an equation.

All of this is explained in Chapter 15 of the User's Manual, and when you finish this lesson we recommend you read the Primer that starts in Section 15.2.

The AI vocabulary is a few hundred words, and you can see a list on the monitor if you ask AI to "SHOW SUBJECTS", "SHOW VERBS", or "SHOW CONDITIONS".

Changes are requested in an intuitive manner:

4 RAD = 123.456

Change radius 4 to 123.456

Increase 4 RD by 12.66

Increase 4 RAD to 33.5.

Note the difference between the last two examples. The last sentence actually will not work unless radius number 4 is currently *less* than 33.5. AI watches what you are doing and makes helpful suggestions if it sees what looks like an error.

Error Correction

And speaking of errors, as a new user you will probably make lots of them. That's one reason the program has an extensive set of menus and dialogs. Those dialogs submit commands for you when you click a button, and the format is of course correct in that case. But some features can be run with a very simple command, and we usually get those things done faster by typing those commands manually. And, yes, we make mistakes sometimes. But don't worry; simple errors can be corrected in a jiffy – and you usually don't have to type the whole sentence again. Suppose by mistake we typed

4 RRD = 123.456.

The characters "RRD" are not in the vocabulary, and the program will immediately ask you to reenter four characters starting at "RRD". So you type "RAD " (notice the space after RAD: the program replaces *four* characters with whatever you type). It repairs the sentence and proceeds correctly. This error correction works both for AI sentences and for ordinary SYNOPSIS™ commands. Thus, typing

DDW 0 1 123 hbar 0 1 -1

also produces the error message, and if you then type "DWG ", the drawing command is properly executed.

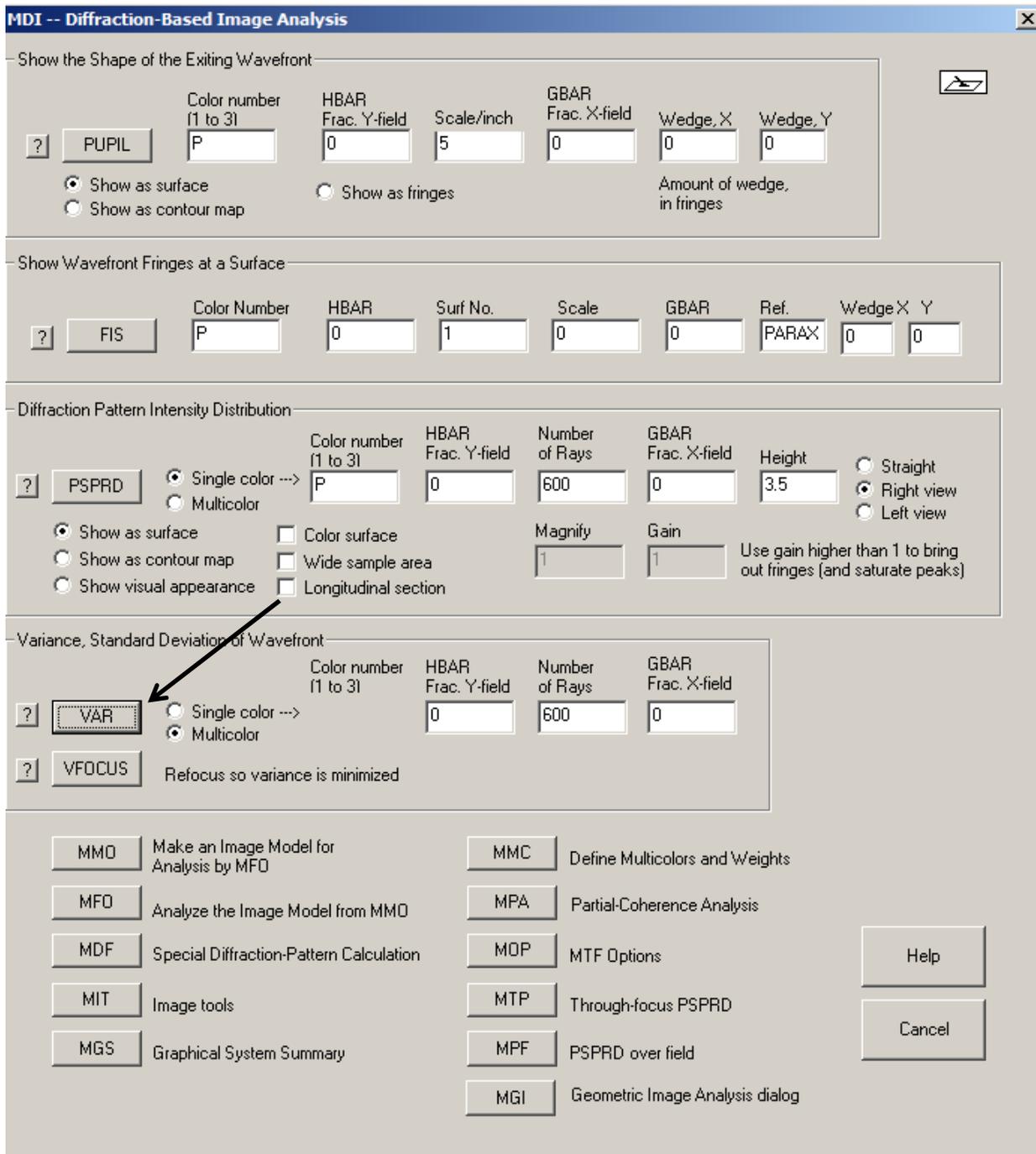
And lastly, if your input is so garbled up that you just want to start over, simply hit the <Esc> key. Then AI will discard the sentence.

MACro Loops

The AI looping feature is powerful and general. Suppose you want a plot of the wavefront variance over the field. There are many kinds of diffraction image analysis, which you will see in the dialog MDI, but if the one you want is not already there, you can make it yourself. Here we will make a plot of the variance over field.

There is also command to do the same analysis – but the lesson below is a good example of how to make your own feature using the tools of AI, for cases where there is no command.

Select the multicolor option on the VAR entry, and click the VAR button.



The program prints the VAR value

```

VARIANCE      STD. DEV.      STREHL R.      XIP      YIP
0.287577E-01  0.157605      0.428754      -0.492627E-20  0.874175E-21

```

VARIANCE IN EACH COLOR AT ABOVE IMAGE POINT:

```

WAVELENGTH, WEIGHT      0.587560      1.000000

```

```

VARIANCE      STD. DEV.      STREHL R.
0.591760E-01  0.243261      0.966967E-01
WAVELENGTH, WEIGHT  0.656270      1.000000
VARIANCE      STD. DEV.      STREHL R.
0.910363E-02  0.954130E-01  0.698097
WAVELENGTH, WEIGHT  0.486130      1.000000
VARIANCE      STD. DEV.      STREHL R.
0.179936E-01  0.134140      0.491468
Type <ENTER> to return to dialog.
IMAGE>

```

Like many other features of SYNOPSIS™, the VAR command puts a copy of its results into the AI buffer.

```
IMAGE>BUFF?
```

```
The current FILE BUFFER contains
```

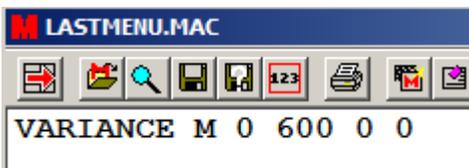
```

1      0.02875775  VARIANCE
2      0.15760478  STD. DEVIA.
3      0.42875398  STREHL R.
4      -4.92627452E-21  X IM. POINT
5      8.74175408E-22  Y IM. POINT
6      1.00000000  TRANS. FRAC.
7      0.05917602  VARIANCE
8      0.24326121  STD. DEVIA.
9      0.09669675  STREHL R.
10     0.58756000  WAVEL.
11     0.00910363  VARIANCE
12     0.09541296  STD. DEVIA.
13     0.69809714  STREHL R.
14     0.65627000  WAVEL.
15     0.01799359  VARIANCE
16     0.13414018  STD. DEVIA.
17     0.49146805  STREHL R.
18     0.48613000  WAVEL.

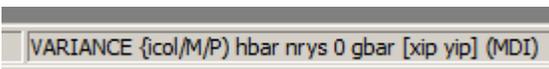
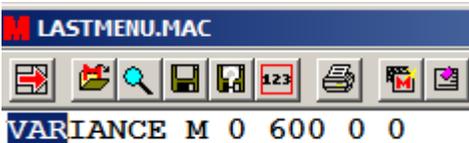
```

```
SYNOPSIS AI>
```

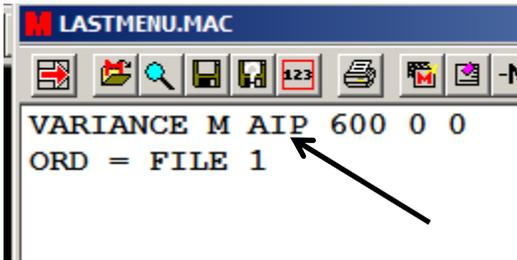
File location number 1 has the data we want. Now ask for a copy of the commands that were submitted by the VAR button. Type **LMM** (also found in the MACro menu dropdown list). The EE editor opens, with the VAR command properly formatted.



We need to tell AI to vary the relative field for every point on the plot. Which argument is that? *Select* the characters “VAR”, and then look down at the tray.



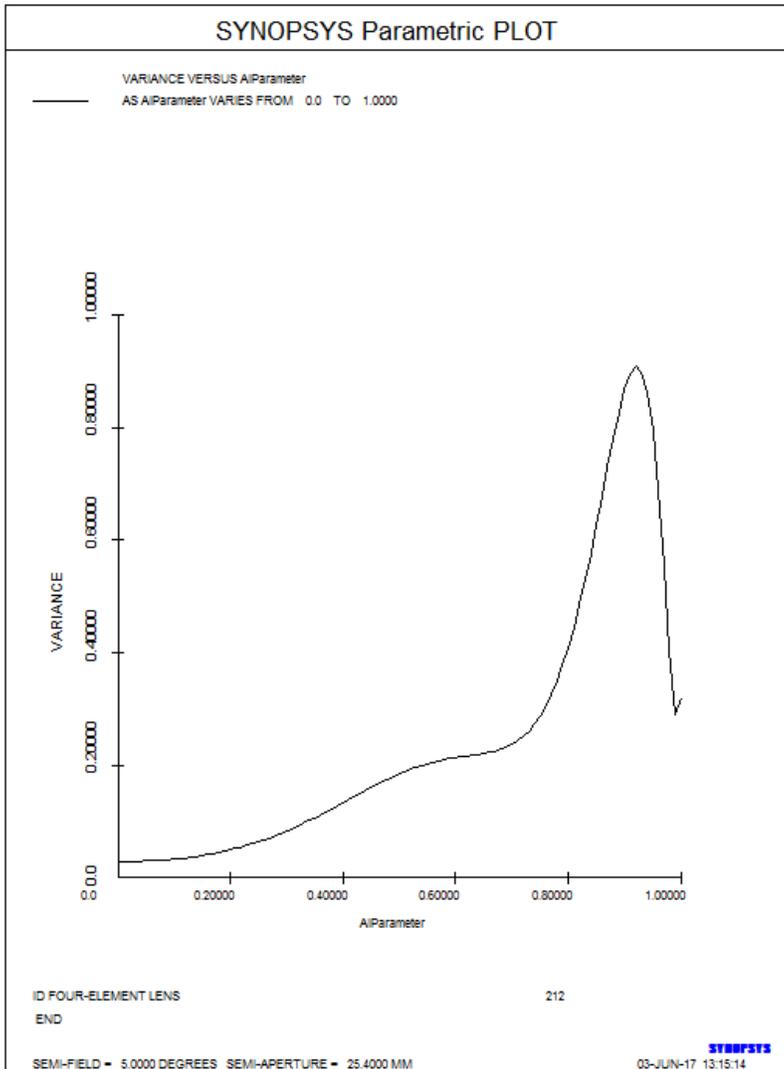
The program displays the format of the command, and you see that the relative field (hbar on the tray) is in word 3. Edit the command in the editor, replacing that word with the characters "AIP", which stands for "AI Parameter". Then tell AI that the ordinate on the plot is to be taken from file location 1 in the AI output buffer:



Run this MACro by clicking the button . We're almost there. The command runs with a default value of 0 for AIP. Now type the AI sentence

IMAGE>DO MACRO FOR AIP = 0 TO 1

The program loops for the default 100 cases and then displays the desired plot.



It's also easy to change the labels on the axes:

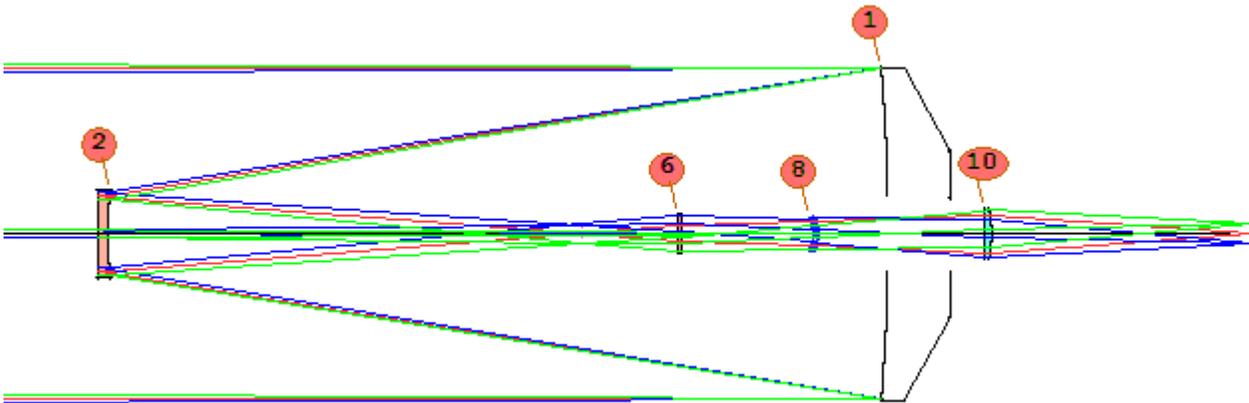
```
ALAB = "REL. FIELD"
AGAIN
```

Using the new command, one would simply go to the MDI dialog, select the **Over field** checkbox, enter the appropriate data, and click the **VAR** button.

You can loop over many kinds of things. For example, if you have designed a zoom lens, you could type

```
PLOT DISTORTION FOR ZOOM = 1 TO 9.
```

One more very useful feature of AI lets you do simple calculations involving output from other features. Fetch the lens saved as 4.RLE. (**FETCH 4**).



Look at the current clear apertures with the CAP command (also found in the dialog MLL).

```
SYNOPSIS AI>CAP
```

```
ID RELAY FLAT          141          01-APR-13   10:29:10
```

```
CLEAR APERTURE DATA
```

SURF	X OR R-APER.	Y-APER.	REMARK	X-OFFSET	Y-OFFSET	EFILE?
1	8.0014		Soft CAO			*
1	1.7500		*User CAI			*
2	2.0456		Soft CAO			*
3	2.0070		Soft CAO			*
4	1.9644		Soft CAO			*
5	0.4628		Soft CAO			*
6	0.8797		Soft CAO			*
7	0.8849		Soft CAO			*
8	0.7373		Soft CAO			*
9	0.7781		Soft CAO			*
10	1.1225		Soft CAO			*
11	1.1340		Soft CAO			*
12	0.4898		Soft CAO			*

Right now the mirror has an assigned clear aperture inside (CAI) of 1.75. Suppose you want that to equal the outside aperture of surface 2. AI can do it.

```
SYNOPTSYS AI>Z1 = CAO OF 2
```

```
The semi-aperture on surface number 2 is 2.04561850
```

```
SYNOPTSYS AI>CAI OF 1 = Z1
```

```
Surface number 1 has an inside semi-clear aperture 2.04561850
```

Here we use one of the 20 Z-parameters to transfer the value from one place to another.

Lastly, AI can do simple calculations. Just enter a sentence that starts with an equals sign "=", and involves only constants, the Z-parameters, and any currently defined symbols that equate to a number. For example,

```
SYNOPTSYS AI>aa: 3.66
```

```
SYMBOL 41 DEFINED: AA*
```

```
3.66
```

```
SYNOPTSYS AI>= z1 + aip + aa
```

```
= Z1 + 1.00000000 + AA
```

```
= Z1 + 1.00000000 + 3.66
```

```
The composite value is 6.70561850
```

This is just a taste of the power and flexibility of the artificial intelligence feature of SYNOPTSYS™. We encourage you to read Chapter 15 of the User's Manual, where you will find many other examples of how to use this unique feature.