A tutorial for the CAD program LayoutEditor

LayoutEditor is available from

www.layouteditor.net

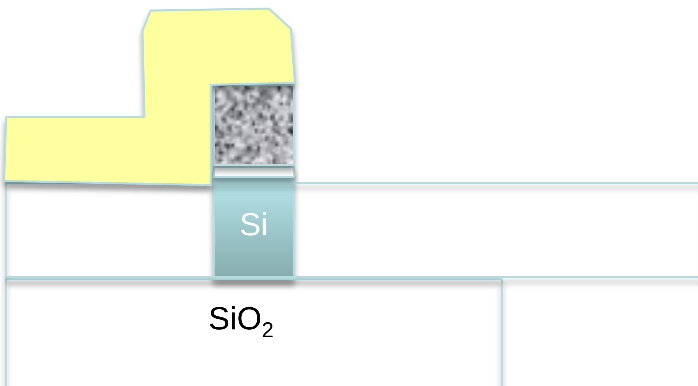
by Jürgen Thies, Juspertor UG, Munich

Common terminology

Layers	designate processing steps
Cells	are parts, or parts of parts
Top-level cell	contains the whole enchilada

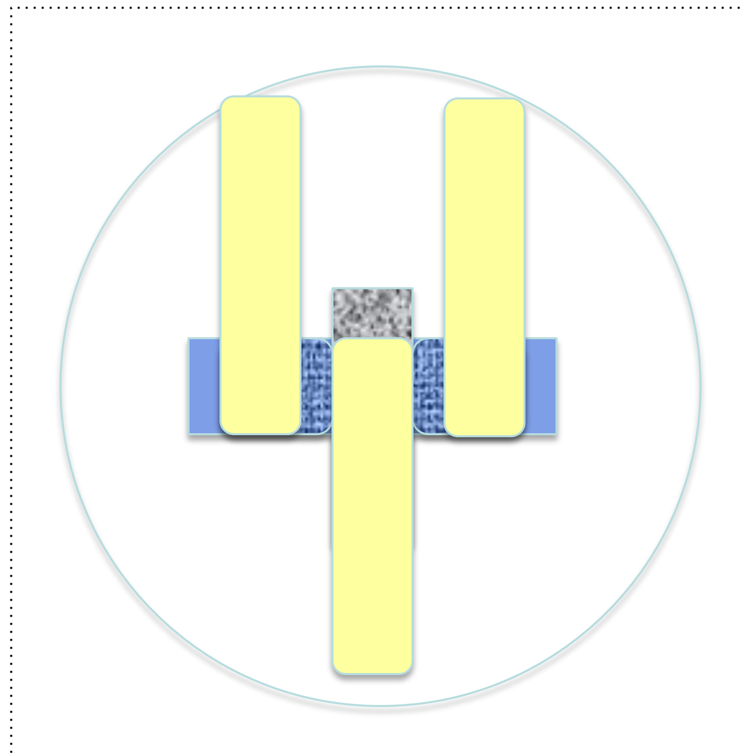
Typical example

Side view



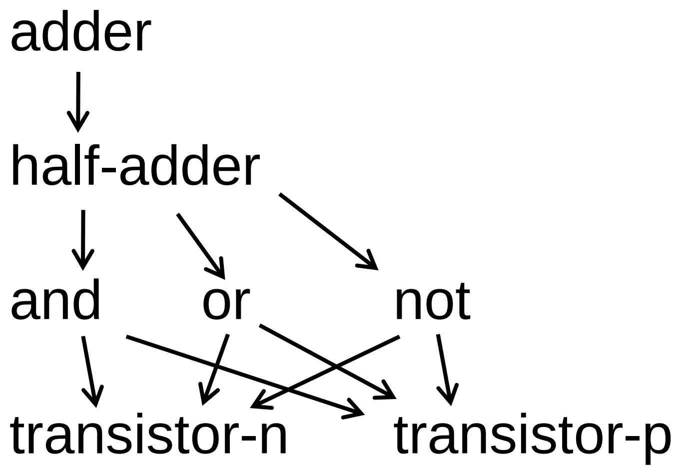
Top view

CELL "TRANSISTOR"



Fill/isolation oxide	LAYER 2
Gate oxide	LAYER 3
Gate polysilicon	LAYER 4
Implant dopants	LAYER 5
Metal wiring	LAYER 6

Your design should be a hierarchy of cells



Each cell may contain shapes on many layers,
describing how to build separate devices.

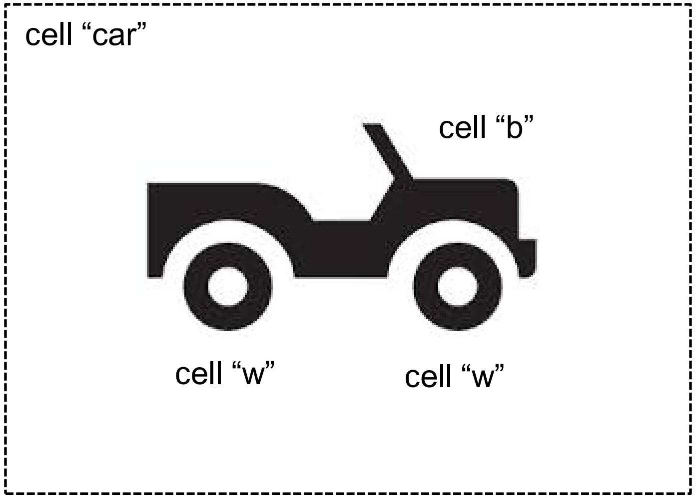
To produce one mask plate for one processing step,
we pull out one LAYER.

Get it? Cells = devices or parts
Layers = processing steps

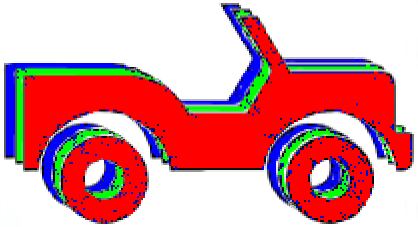
A lot of people don't understand this, so pay attention:

CAD cells are parts
of the final device

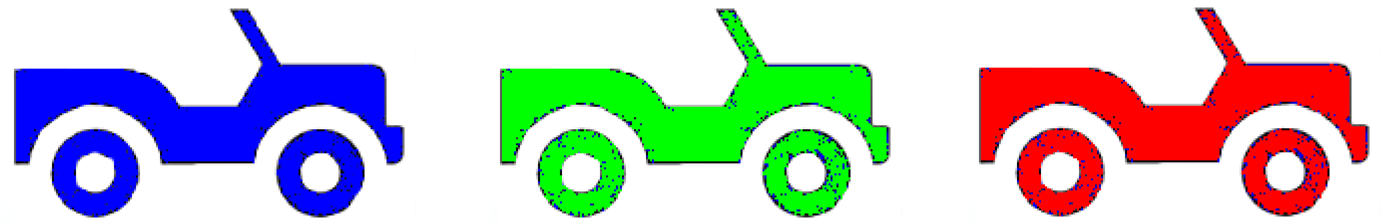
The cells are contained
inside higher level cells.



Inside each cell are found
layers which represent
steps in the manufacturing
process.



To build the device, the cells are “flattened” to remove hierarchy, then the layers are extracted into separate files.

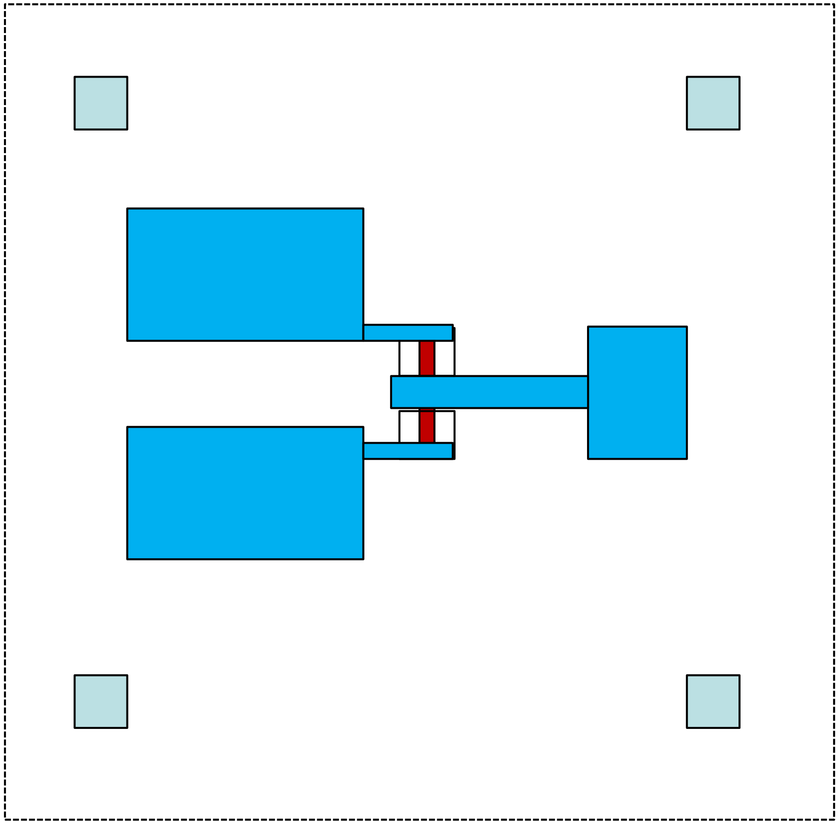


But not until later, and not with the CAD program.

There is a separate program for flattening and extracting layers, and then fracturing the shapes into simple forms that can be printed with the e-beam system.

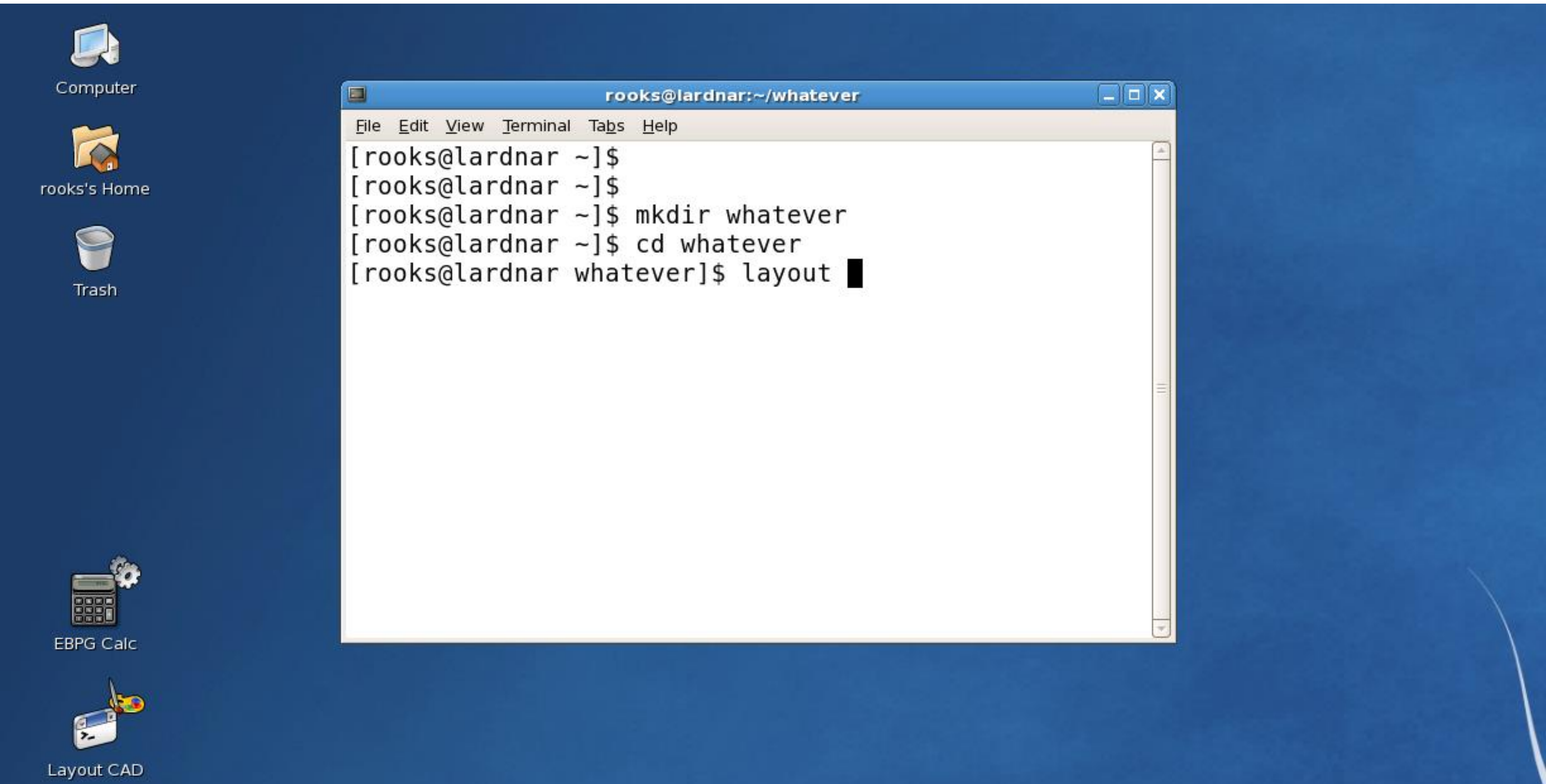
Remember this:

The top-level cell should look just like the final device.



e.g., alignment marks do not go into a separate FILE
they go on a separate LAYER. Do not make this typical, stupid mistake.

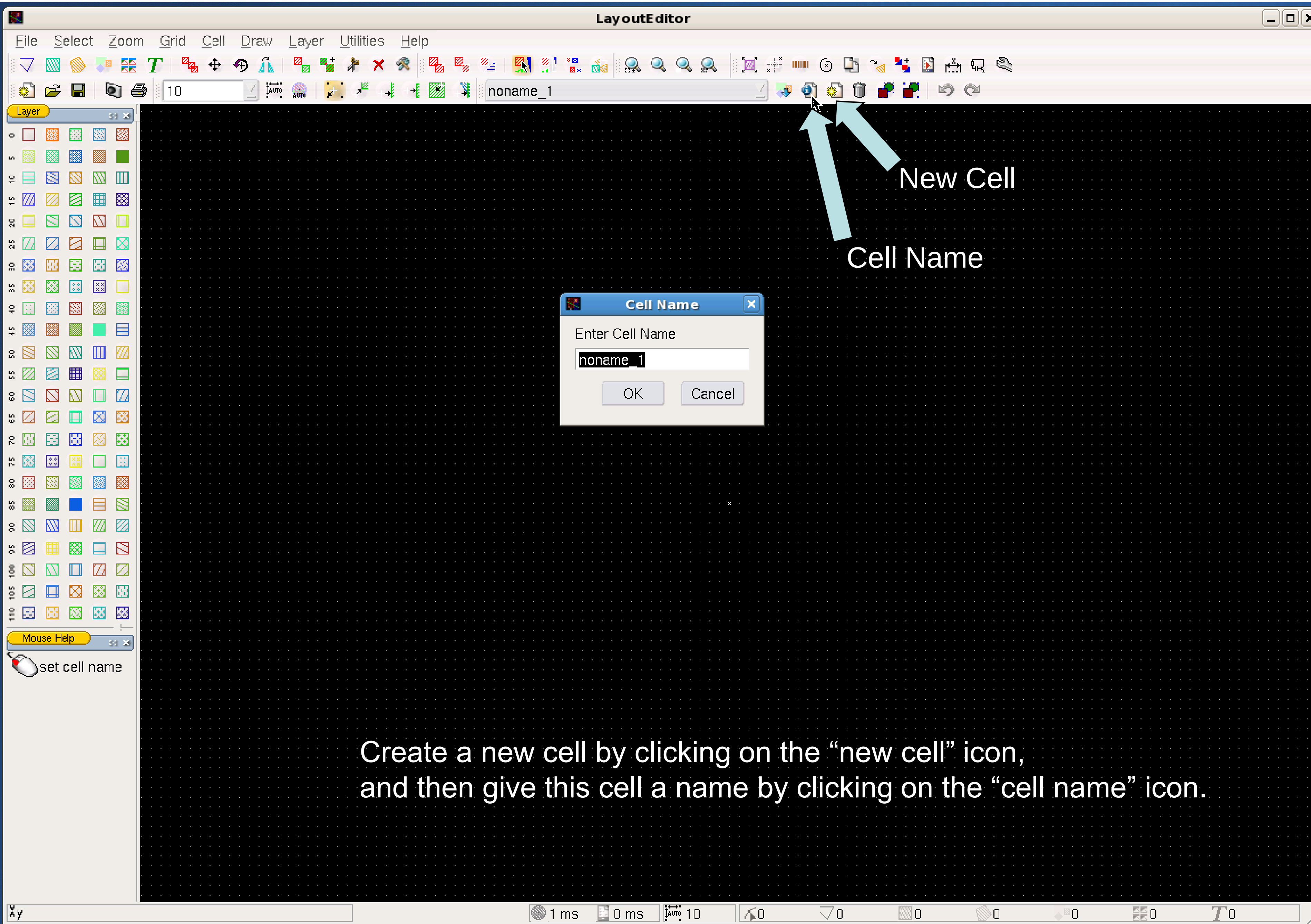
Now let's get started with
the CAD program Layout.



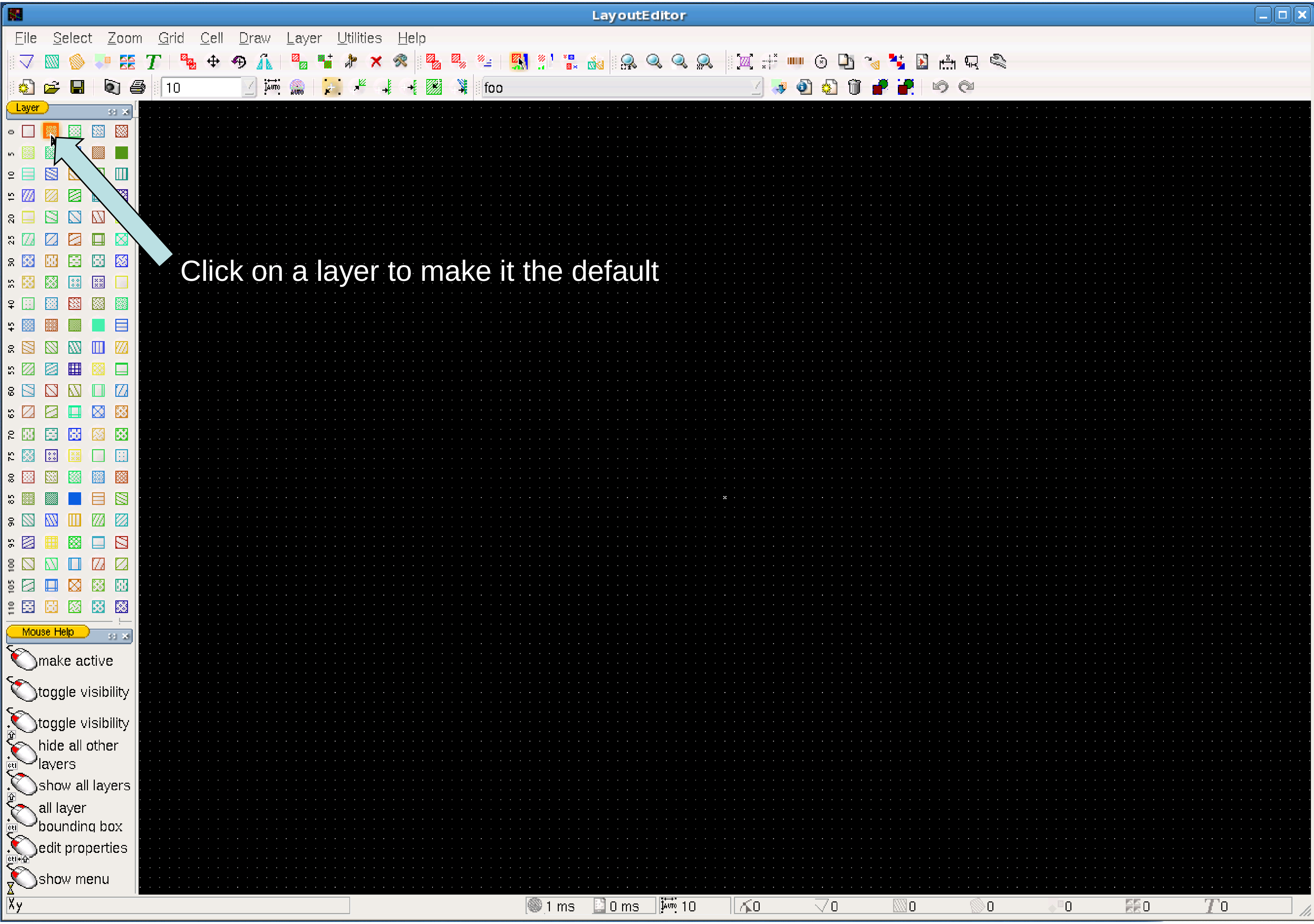
Log into the Linux server and open a terminal window (try the right-click menu).

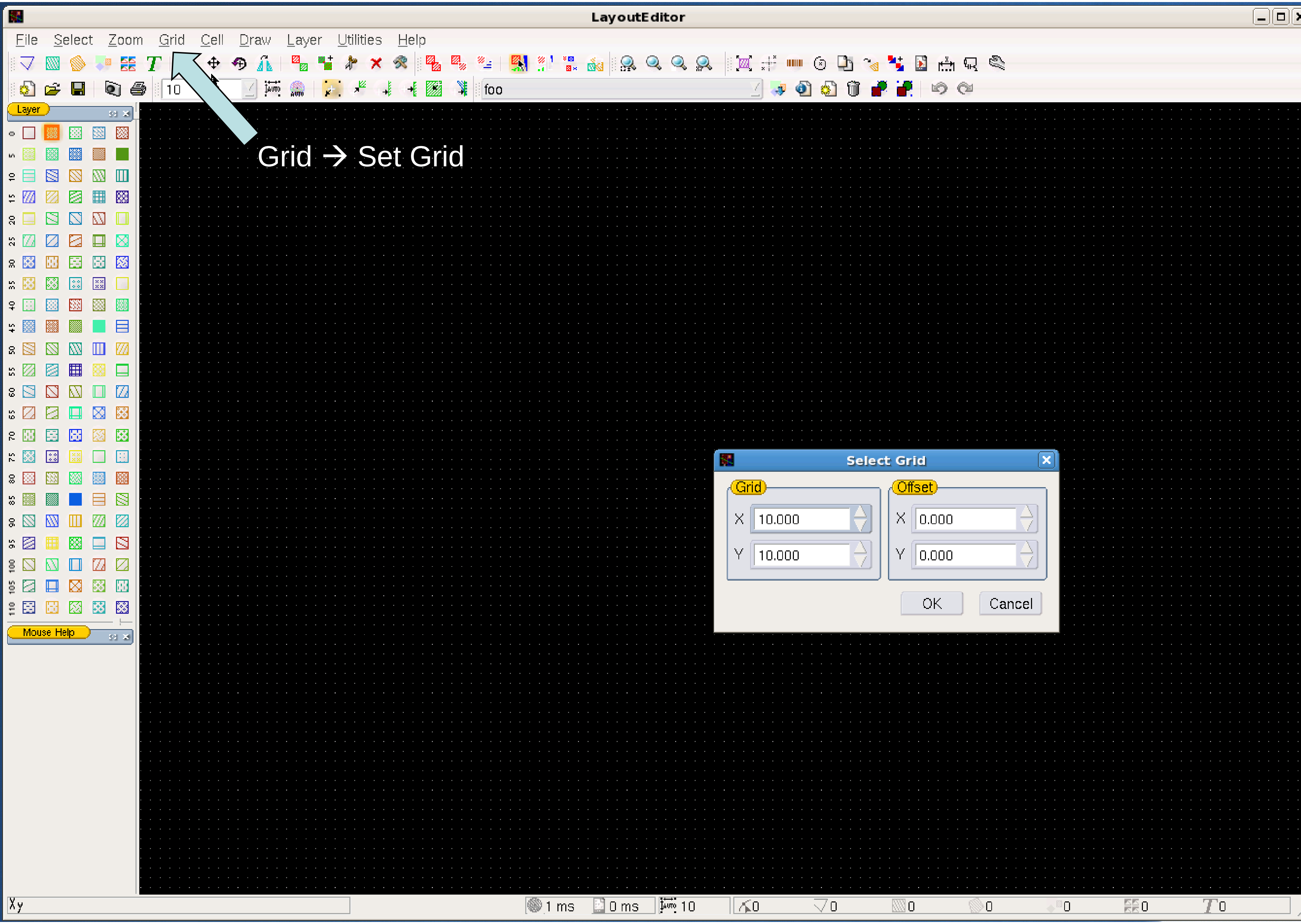
Use “mkdir” to create a directory for your project,
then use “cd” to make this the default directory.

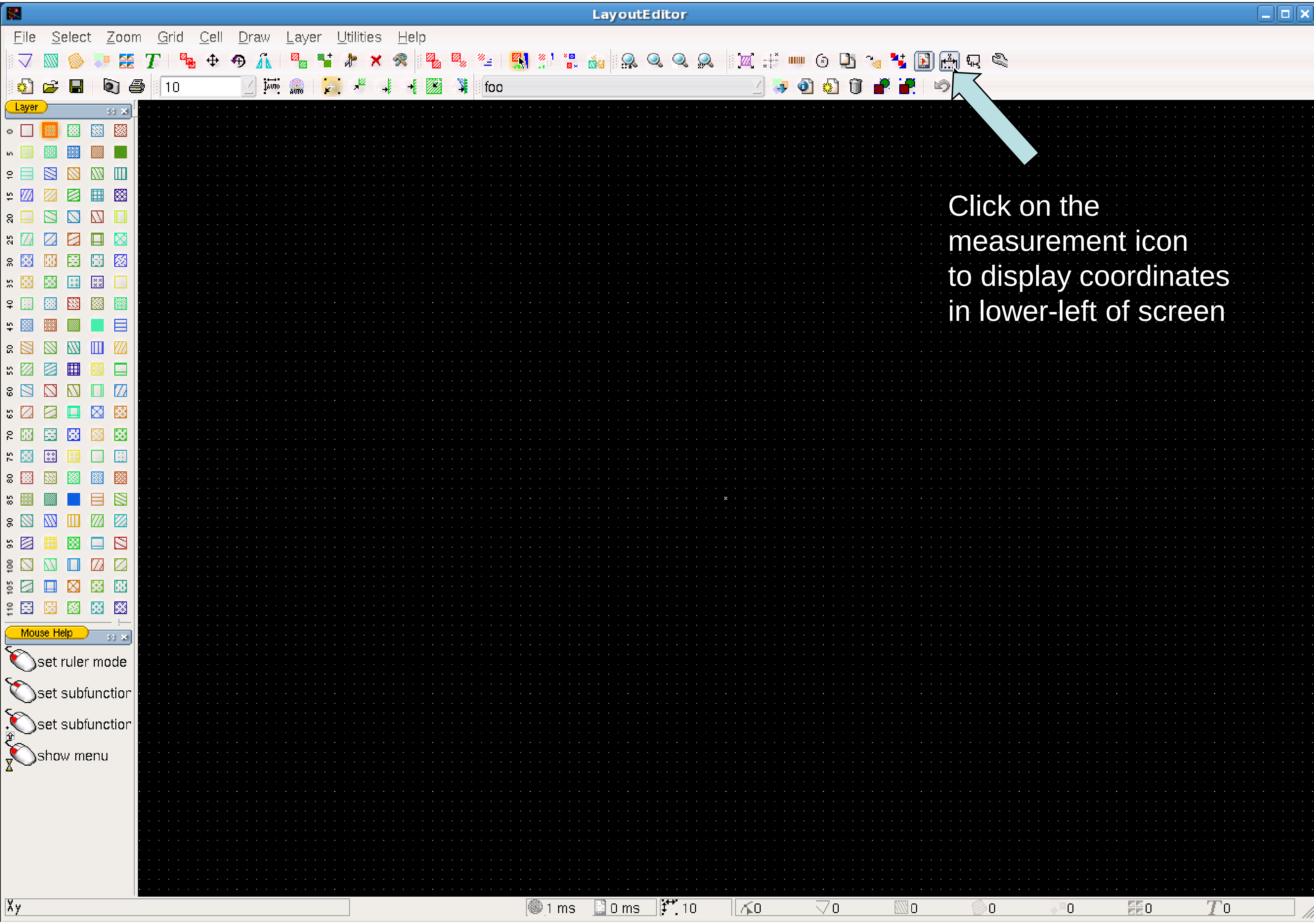
Type “layout” to fire up the CAD program.

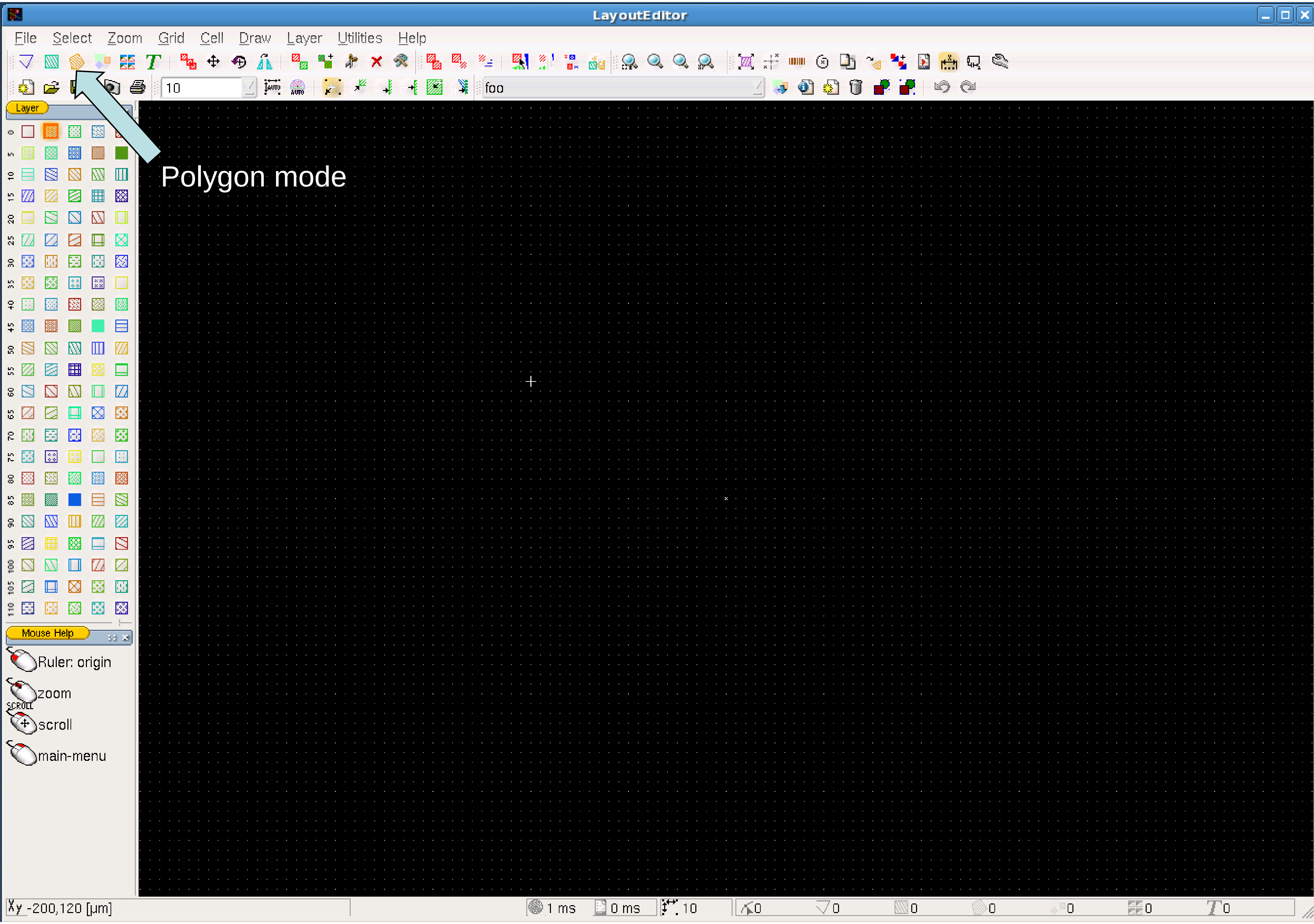


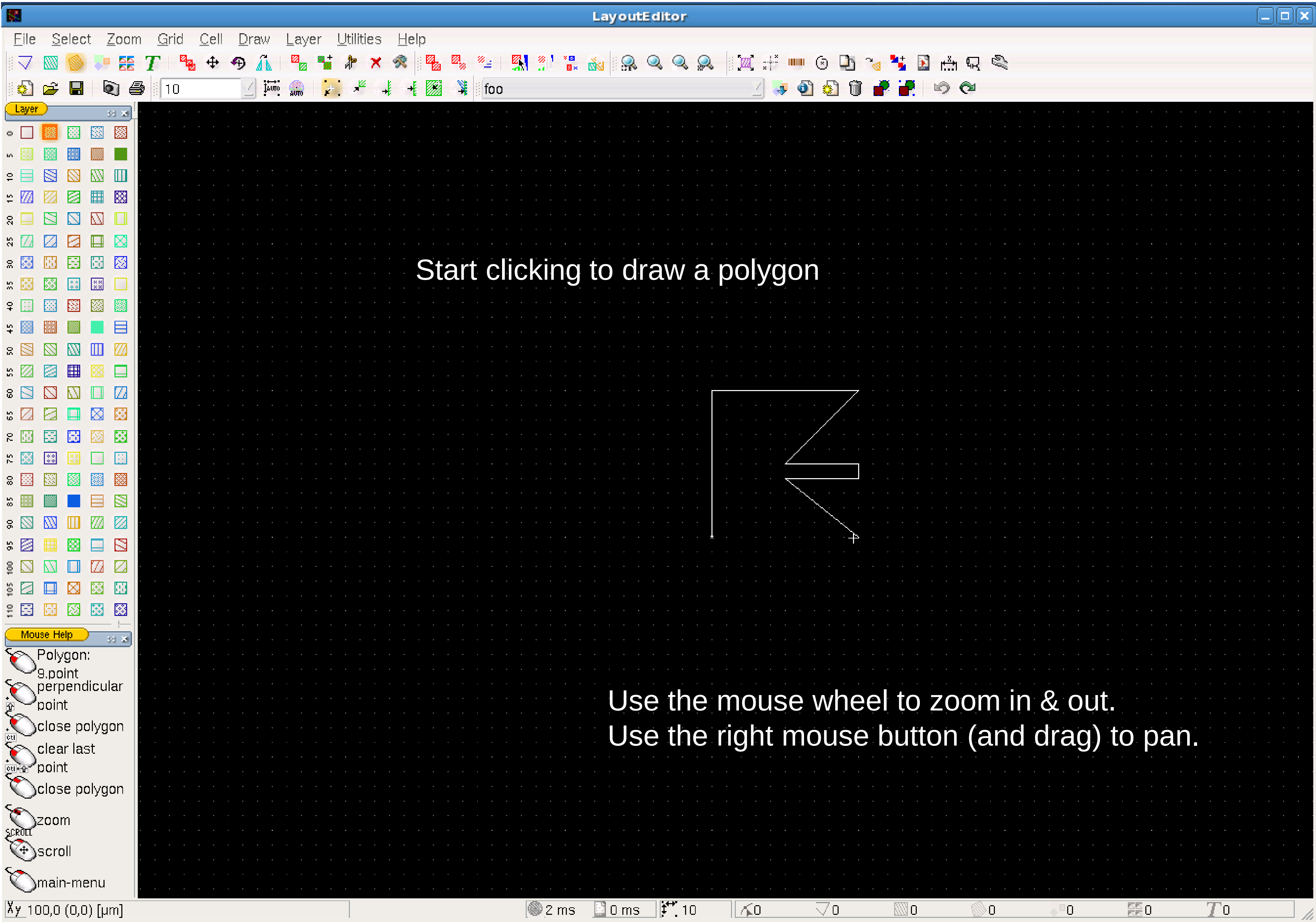
Create a new cell by clicking on the "new cell" icon,
and then give this cell a name by clicking on the "cell name" icon.

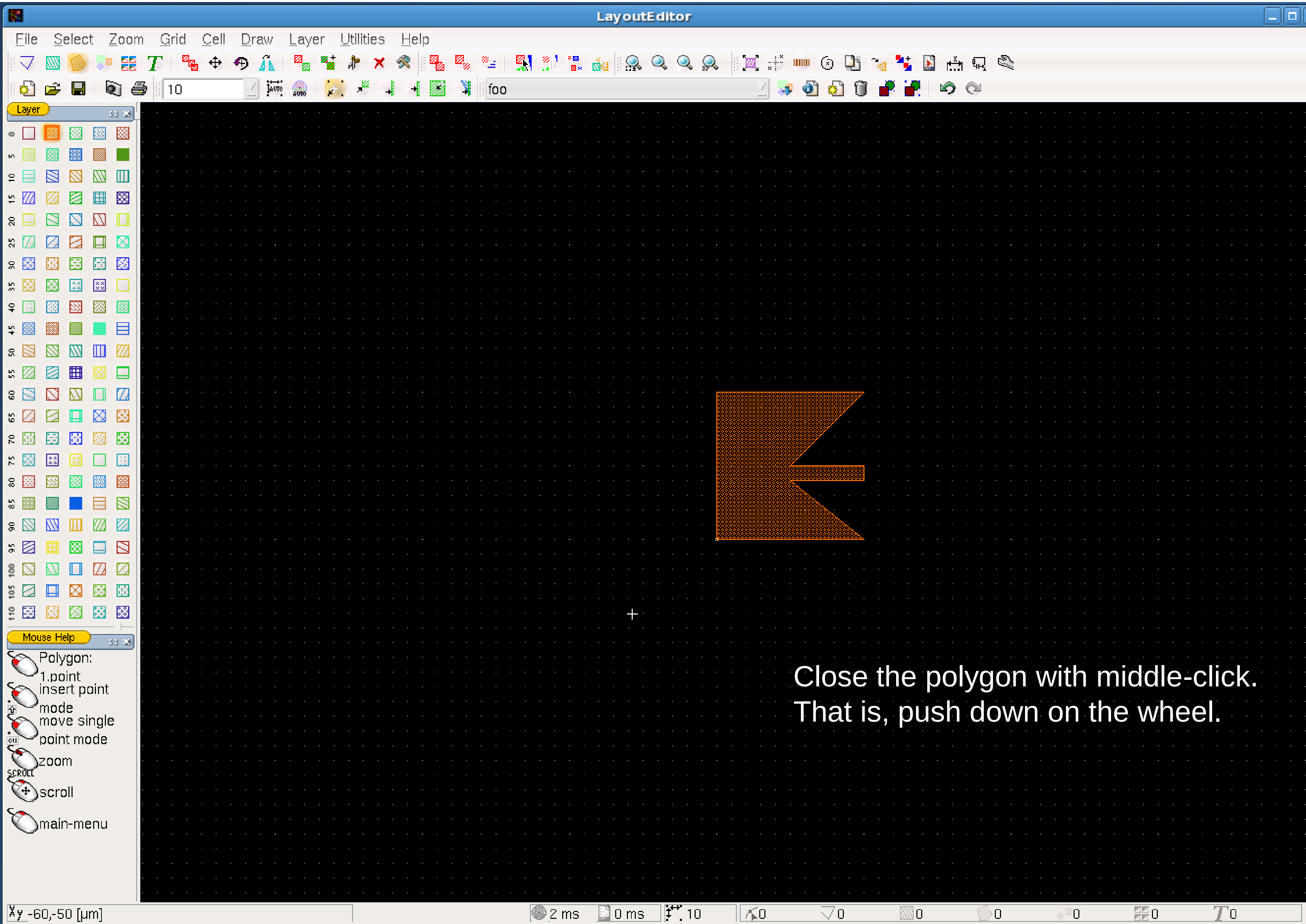

LayoutEditor
File Select Zoom Grid Cell Draw Layer Utilities Help
10
foo
Layer
Click on a layer to make it the default
Mouse Help
make active
toggle visibility
toggle visibility
hide all other layers
show all layers
all layer bounding box
edit properties
show menu
1 ms
0 ms
10

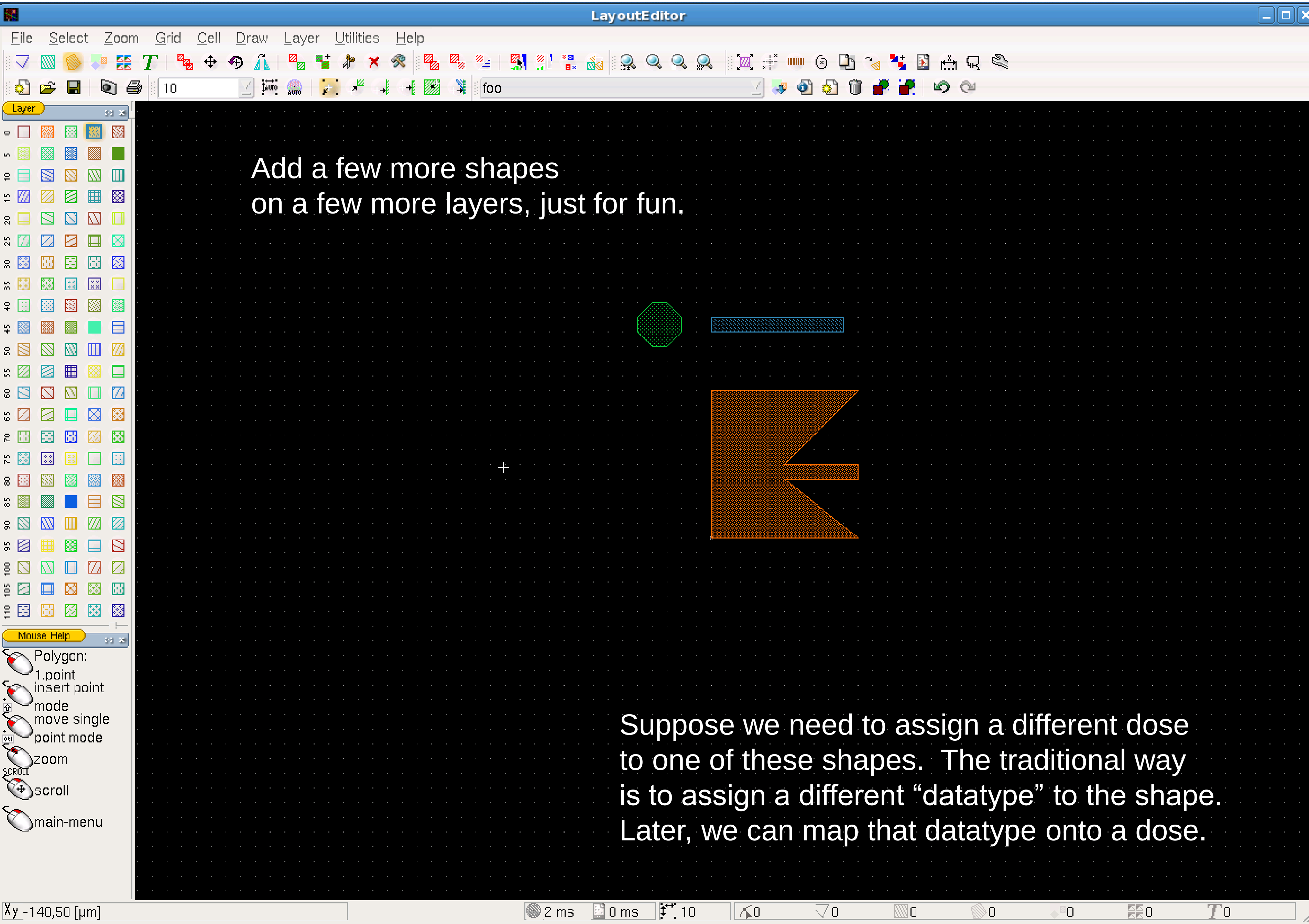

LayoutEditor
File Select Zoom Grid Cell Draw Layer Utilities Help
Grid → Set Grid
Layer
Mouse Help
foo
Select Grid
Grid
X 10.000
Y 10.000
Offset
X 0.000
Y 0.000
OK Cancel

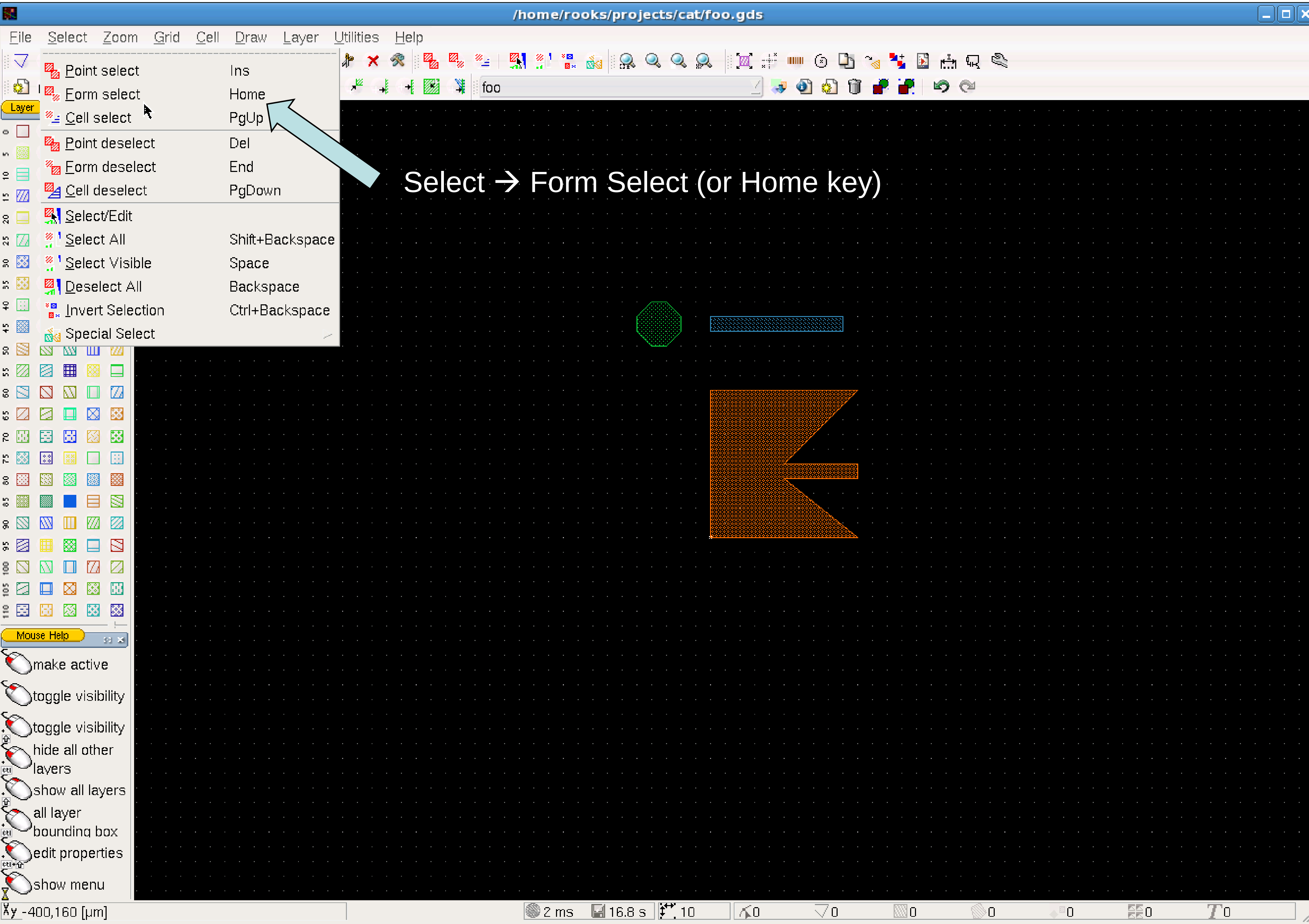

LayoutEditor
File Select Zoom Grid Cell Draw Layer Utilities Help
10
foo
Layer
Mouse Help
set ruler mode
set subfunction
set subfunction
show menu
Click on the measurement icon to display coordinates in lower-left of screen
1 ms
0 ms
10

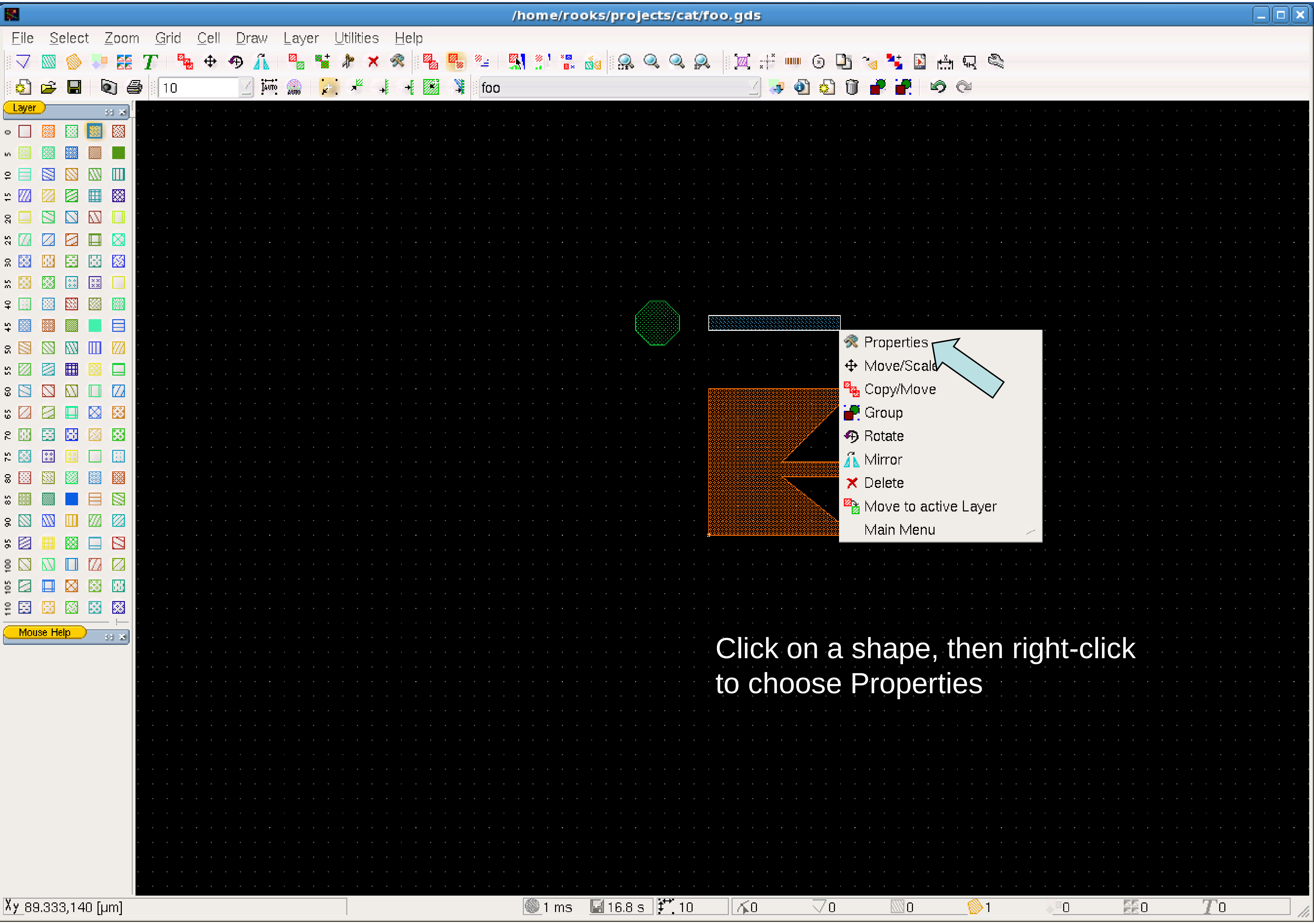

LayoutEditor
File
Select
Zoom
Grid
Cell
Draw
Layer
Utilities
Help
10
foo
Layer
Polygon mode
Mouse Help
Ruler: origin
zoom
scroll
main-menu
Xy -200,120 [µm]
1 ms
0 ms
10


LayoutEditor
File Select Zoom Grid Cell Draw Layer Utilities Help
10
foo
Layer
Start clicking to draw a polygon
Use the mouse wheel to zoom in & out.
Use the right mouse button (and drag) to pan.
Mouse Help
Polygon:
9.point
perpendicular point
close polygon
clear last point
close polygon
zoom
scroll
main-menu
100,0 (0,0) [µm]
2 ms
0 ms
10

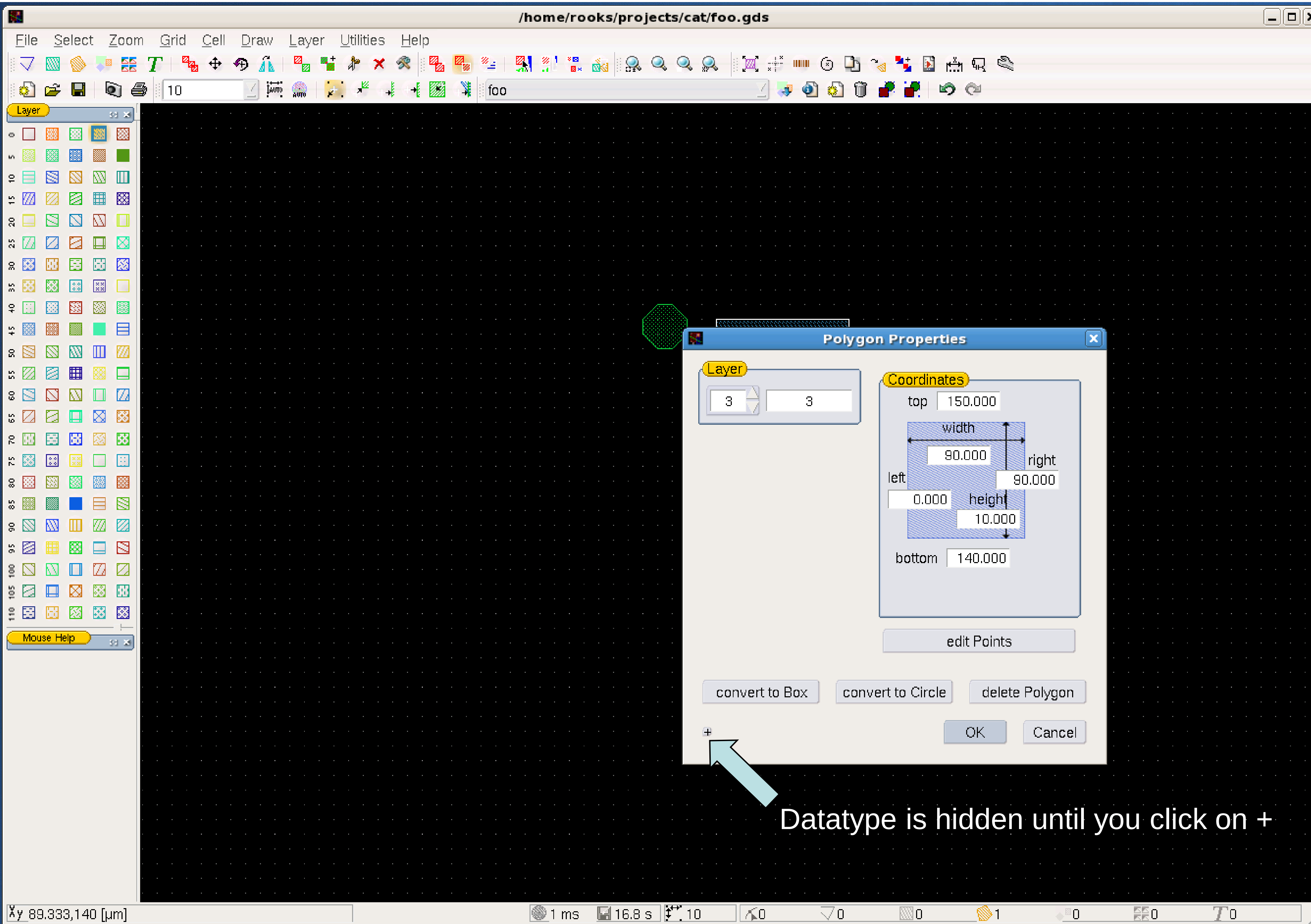

LayoutEditor
File Select Zoom Grid Cell Draw Layer Utilities Help
10
foo
Layer
Mouse Help
Polygon:
1.point
insert point mode
move single point mode
zoom
scroll
main-menu
Close the polygon with middle-click.
That is, push down on the wheel.
xy -60,-50 [µm]
2 ms
0 ms
10

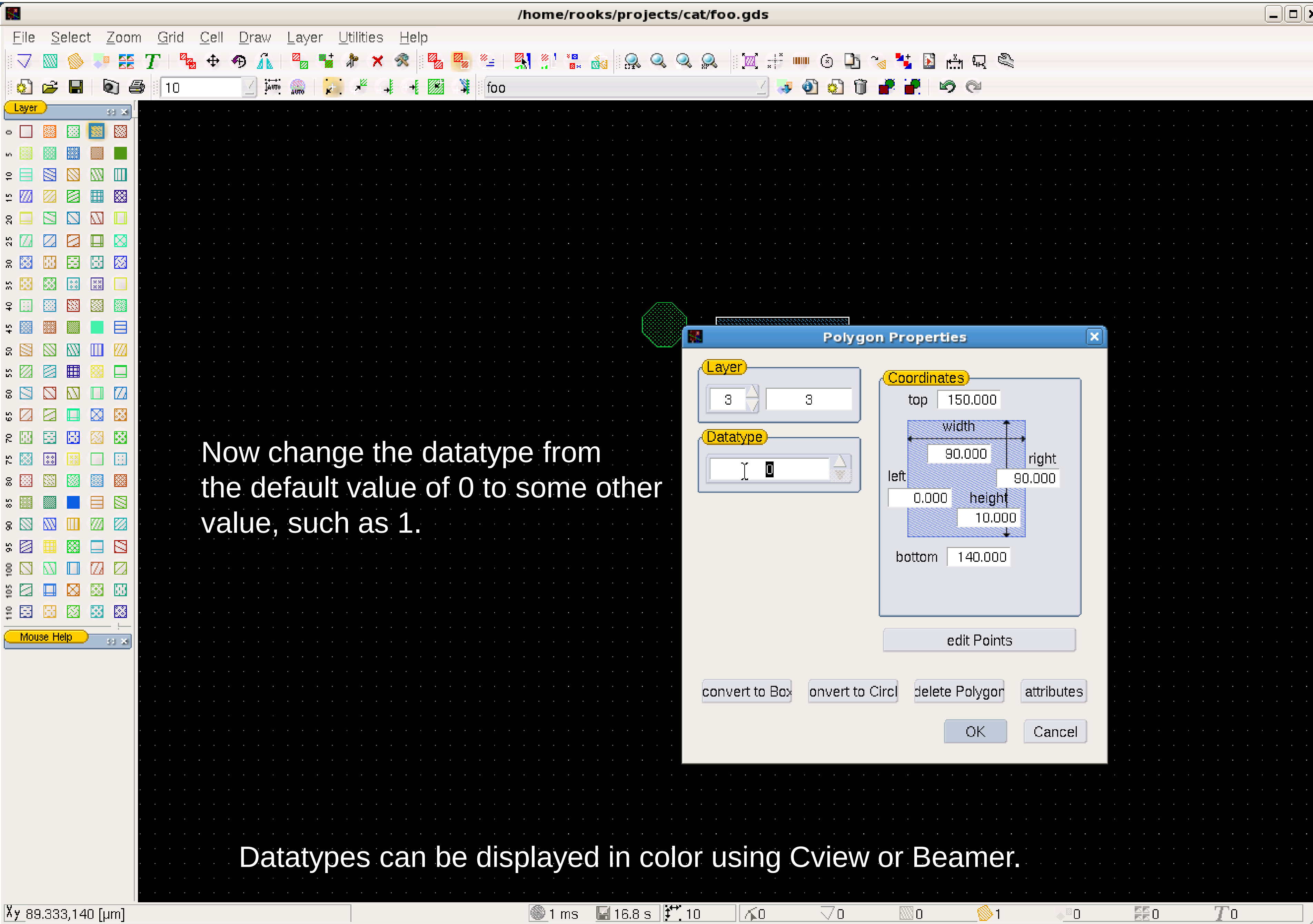

LayoutEditor
File Select Zoom Grid Cell Draw Layer Utilities Help
10
foo
Layer
Add a few more shapes
on a few more layers, just for fun.
Mouse Help
Polygon:
1.point
insert point
mode
move single
point mode
zoom
scroll
main-menu
Suppose we need to assign a different dose
to one of these shapes. The traditional way
is to assign a different “datatype” to the shape.
Later, we can map that datatype onto a dose.
xy -140,50 [µm]
2 ms
0 ms
10


/home/rooks/projects/cat/foo.gds
File Select Zoom Grid Cell Draw Layer Utilities Help
Point select Ins
Form select Home
Cell select PgUp
Point deselect Del
Form deselect End
Cell deselect PgDown
Select/Edit
Select All Shift+Backspace
Select Visible Space
Deselect All Backspace
Invert Selection Ctrl+Backspace
Special Select
foo
Layer
Select → Form Select (or Home key)
Mouse Help
make active
toggle visibility
toggle visibility
hide all other layers
show all layers
all layer bounding box
edit properties
show menu
xy -400,160 [µm]
2 ms
16.8 s
10



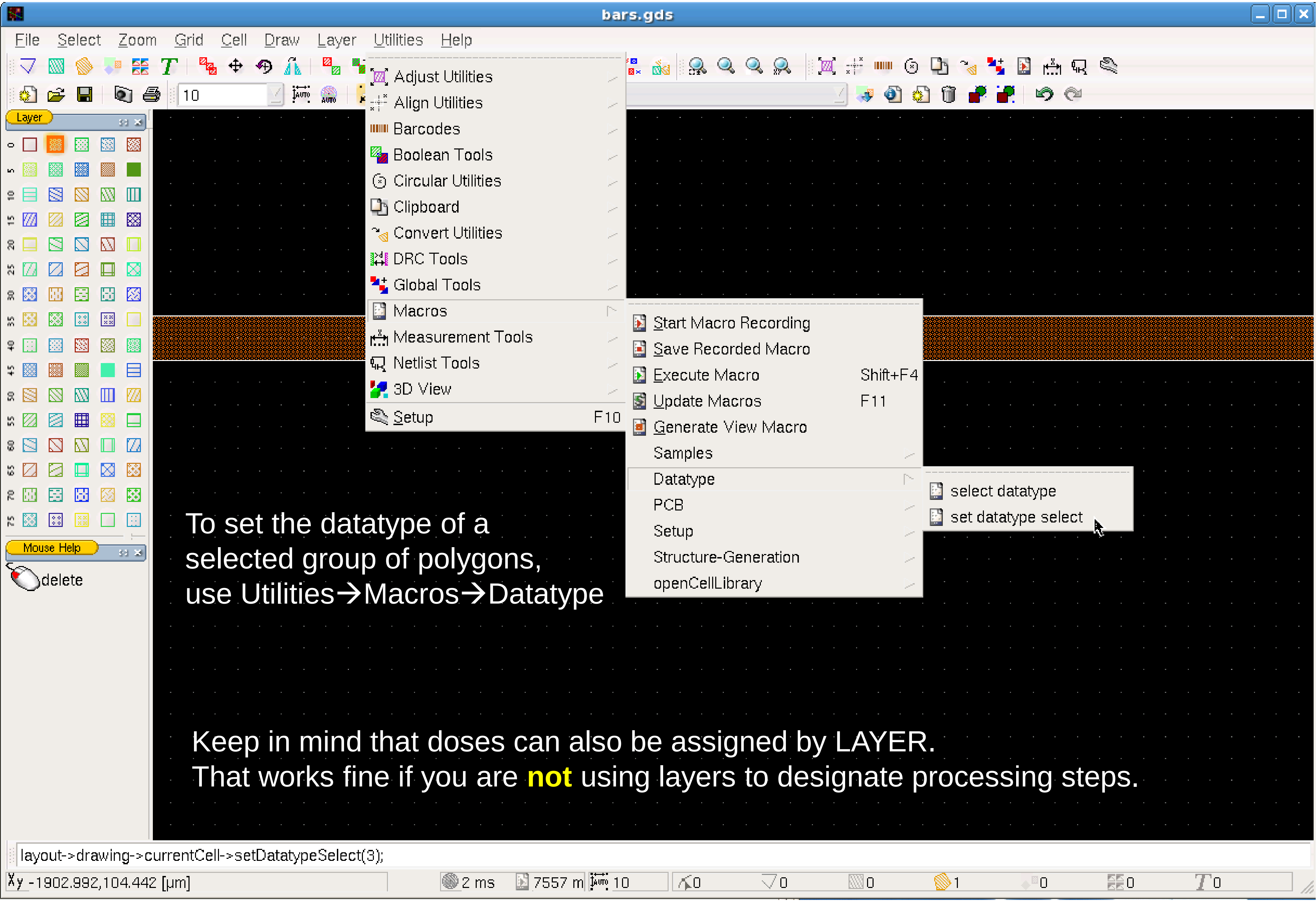
Click on a shape, then right-click to choose Properties

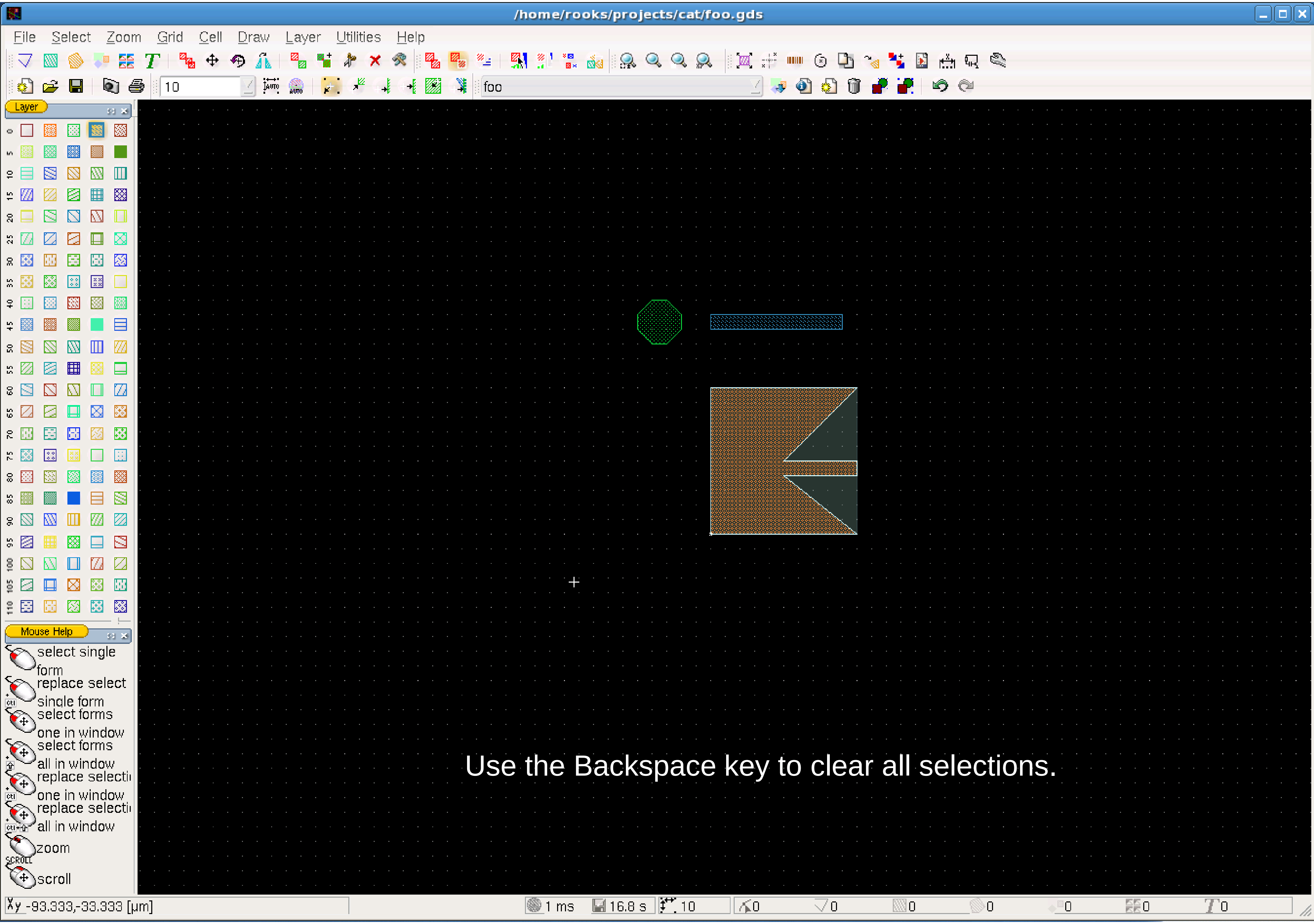

/home/rooks/projects/cat/foo.gds
File Select Zoom Grid Cell Draw Layer Utilities Help
Polygon Properties
Layer
3
3
Coordinates
top 150.000
width
90.000
right
90.000
left
0.000
height
10.000
bottom 140.000
edit Points
convert to Box
convert to Circle
delete Polygon
OK
Cancel
Datatype is hidden until you click on +
xy 89.333,140 [µm]



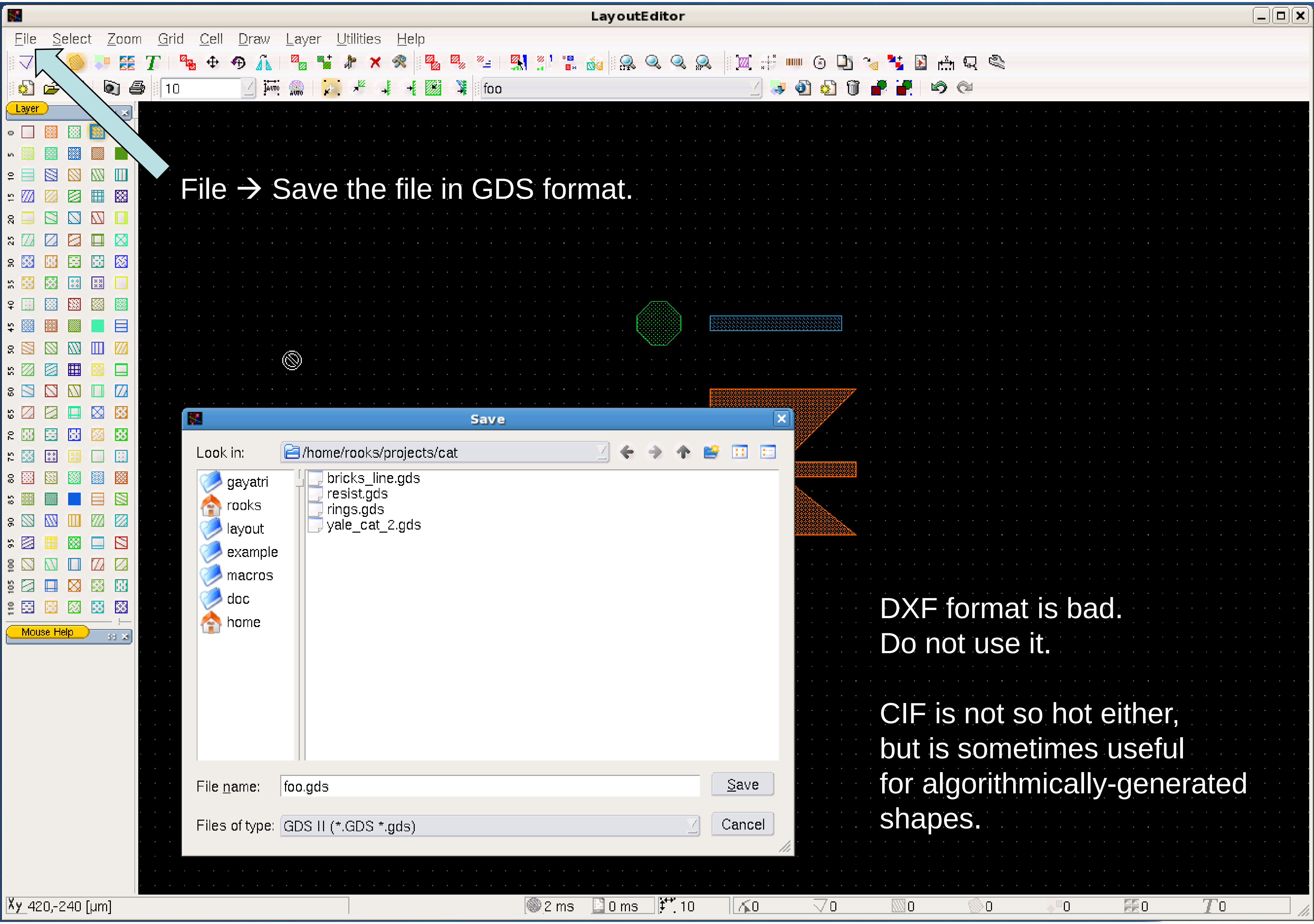
Now change the datatype from the default value of 0 to some other value, such as 1.

Datatypes can be displayed in color using Cview or Beamer.


bars.gds
File Select Zoom Grid Cell Draw Layer Utilities Help
Adjust Utilities
Align Utilities
Barcodes
Boolean Tools
Circular Utilities
Clipboard
Convert Utilities
DRC Tools
Global Tools
Macros
Measurement Tools
Netlist Tools
3D View
Setup F10
Start Macro Recording
Save Recorded Macro
Execute Macro Shift+F4
Update Macros F11
Generate View Macro
Samples
Datatype
PCB
Setup
Structure-Generation
openCellLibrary
select datatype
set datatype select
Layer
Mouse Help
delete
To set the datatype of a selected group of polygons, use Utilities→Macros→Datatype
Keep in mind that doses can also be assigned by LAYER.
That works fine if you are not using layers to designate processing steps.
layout->drawing->currentCell->setDatatypeSelect(3);
xy -1902.992,104.442 [µm]
2 ms
7557 m
10

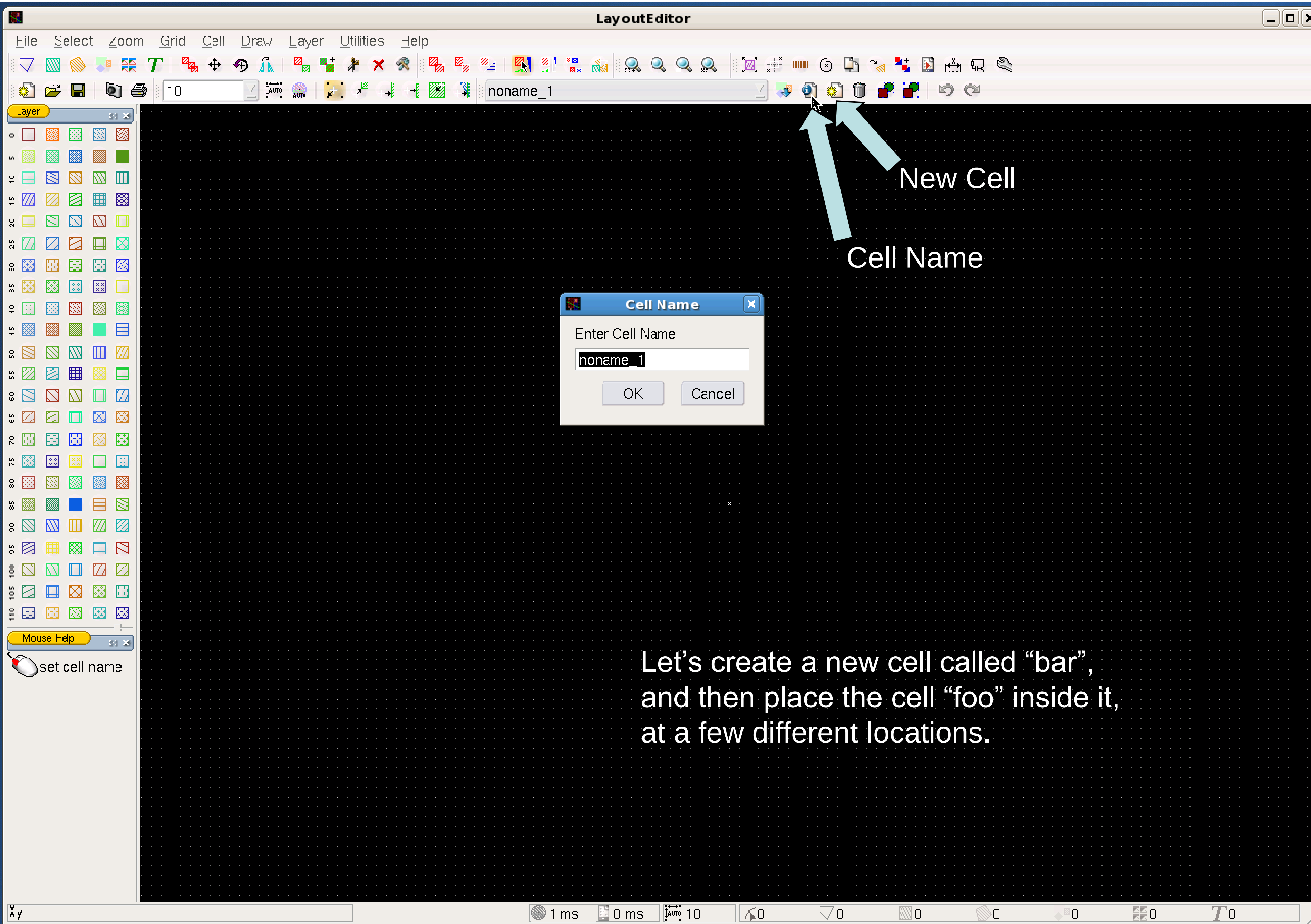

/home/rooks/projects/cat/foo.gds
File Select Zoom Grid Cell Draw Layer Utilities Help
10
foo
Layer
Mouse Help
select single form
replace select single form
select forms one in window
select forms all in window
replace selection one in window
replace selection all in window
zoom
scroll
Use the Backspace key to clear all selections.
xy -93.333,-33.333 [µm]
1 ms
16.8 s
10

File → Save the file in GDS format.

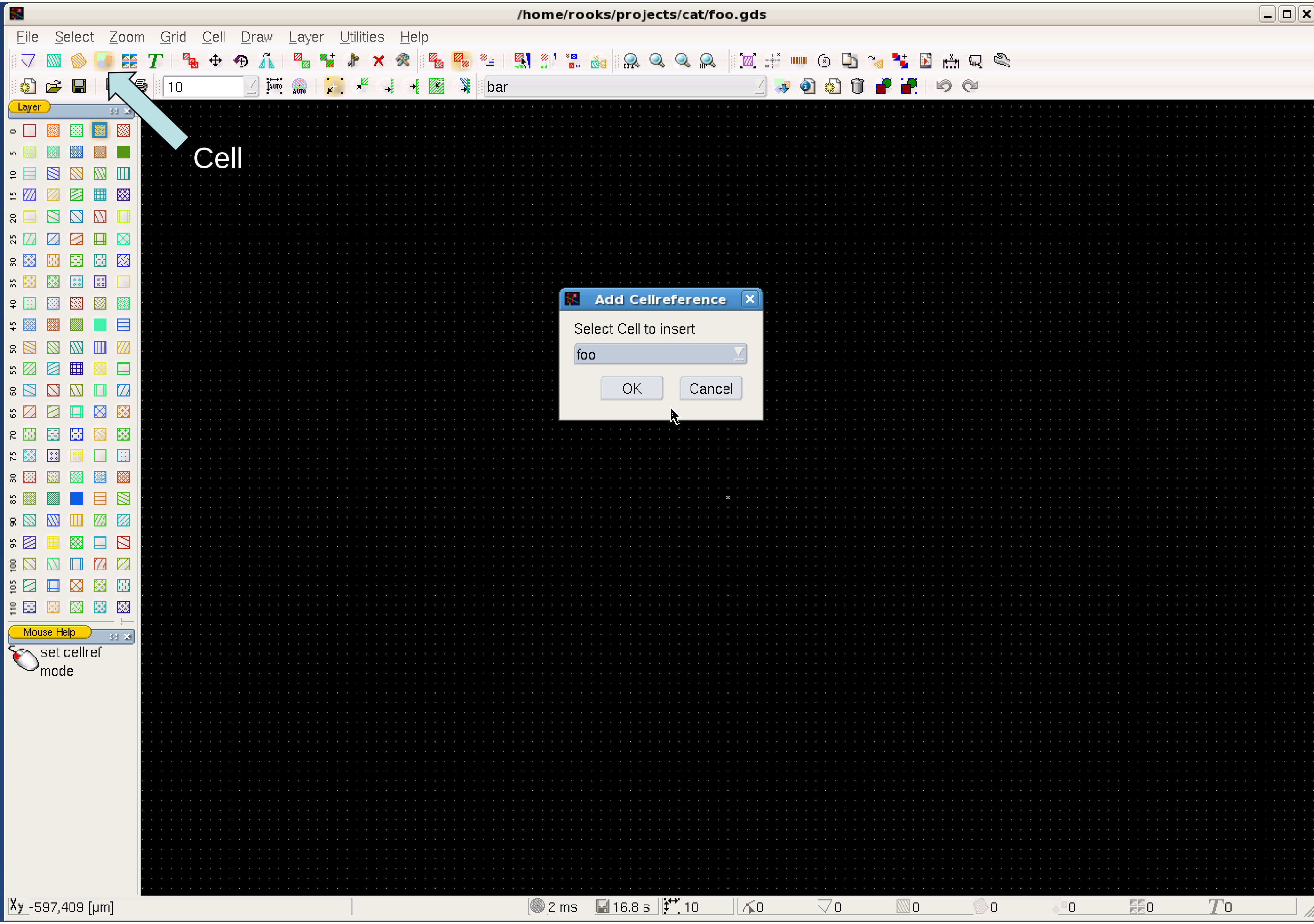


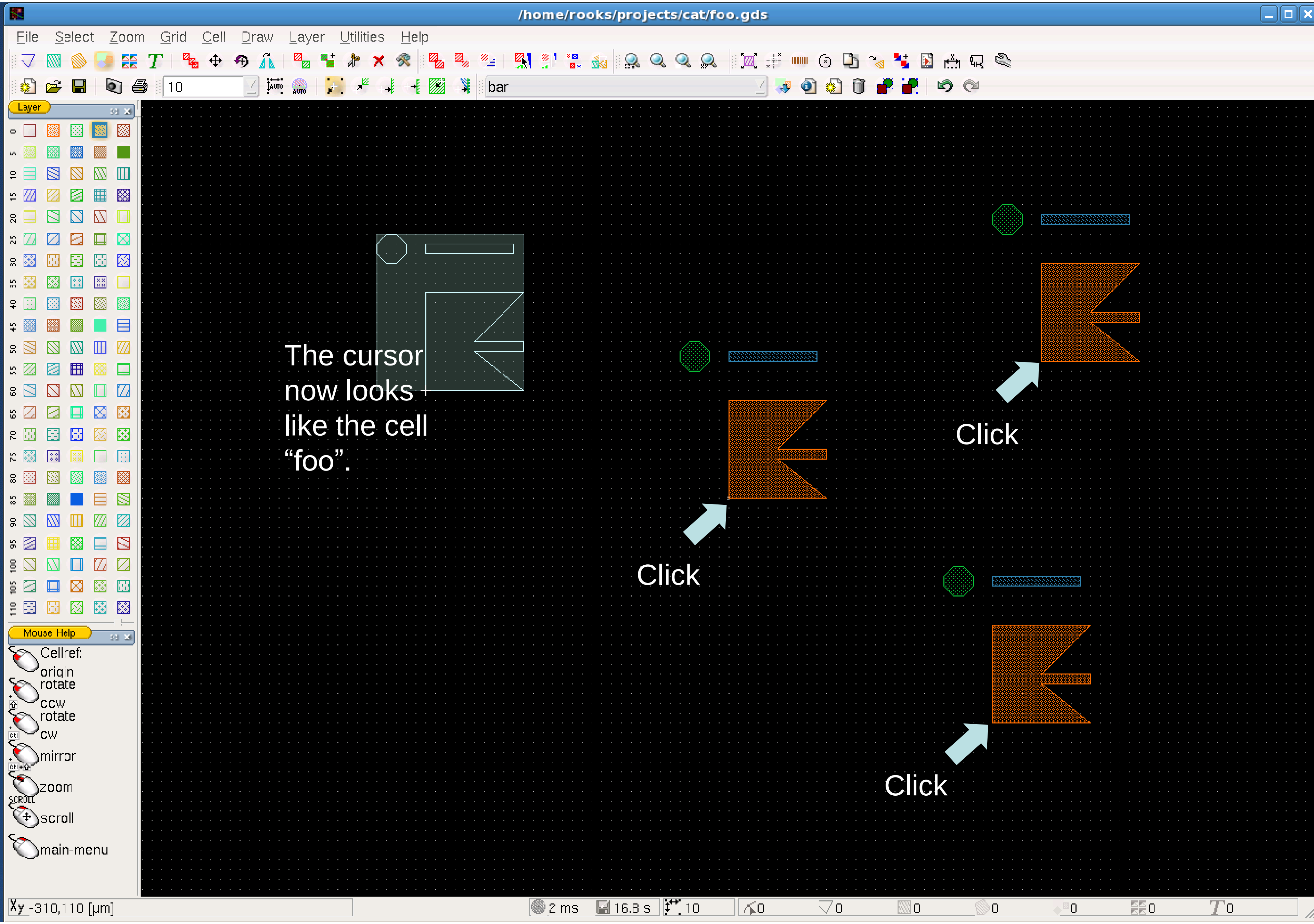
DXF format is bad.
Do not use it.

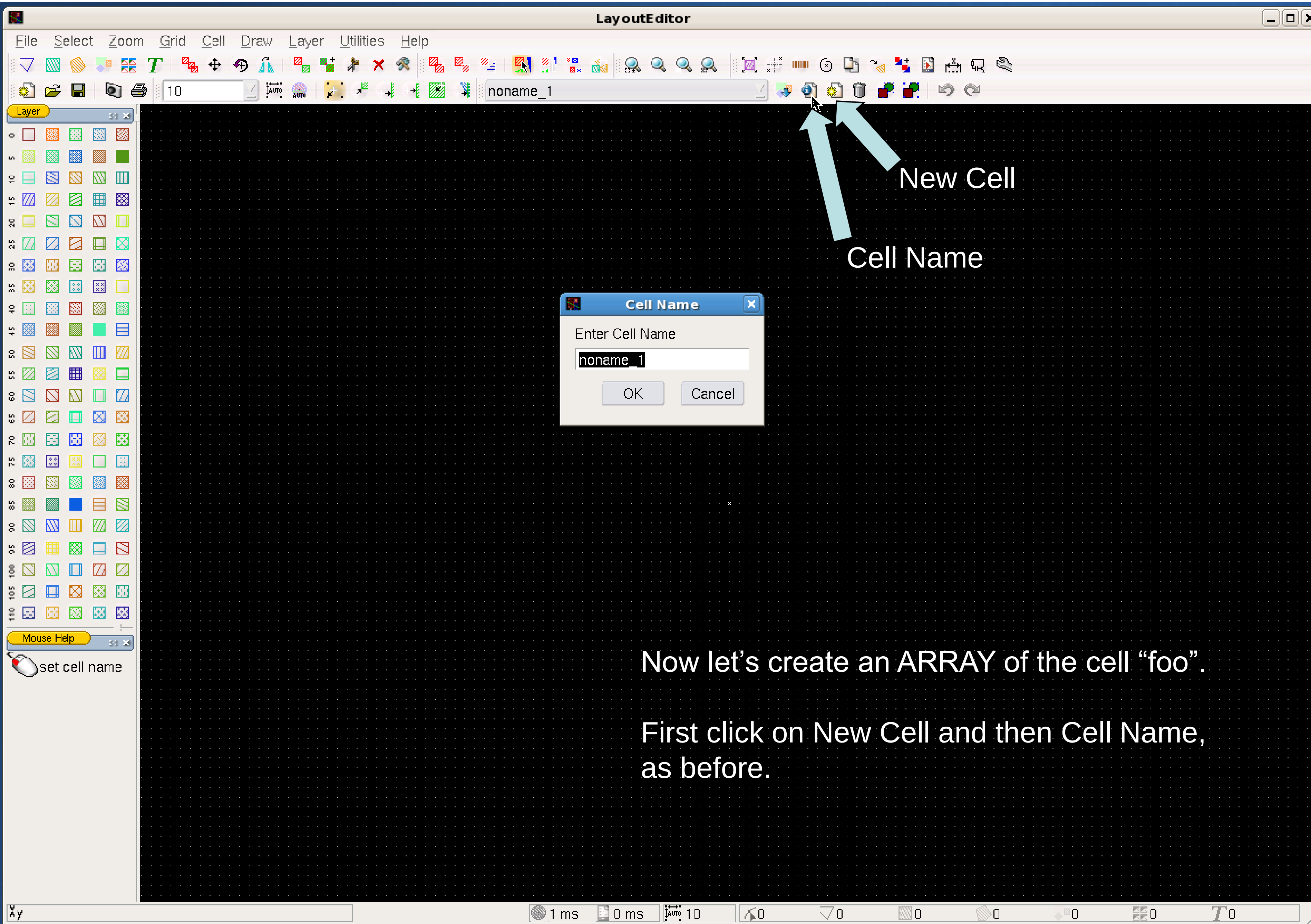
CIF is not so hot either,
but is sometimes useful
for algorithmically-generated
shapes.



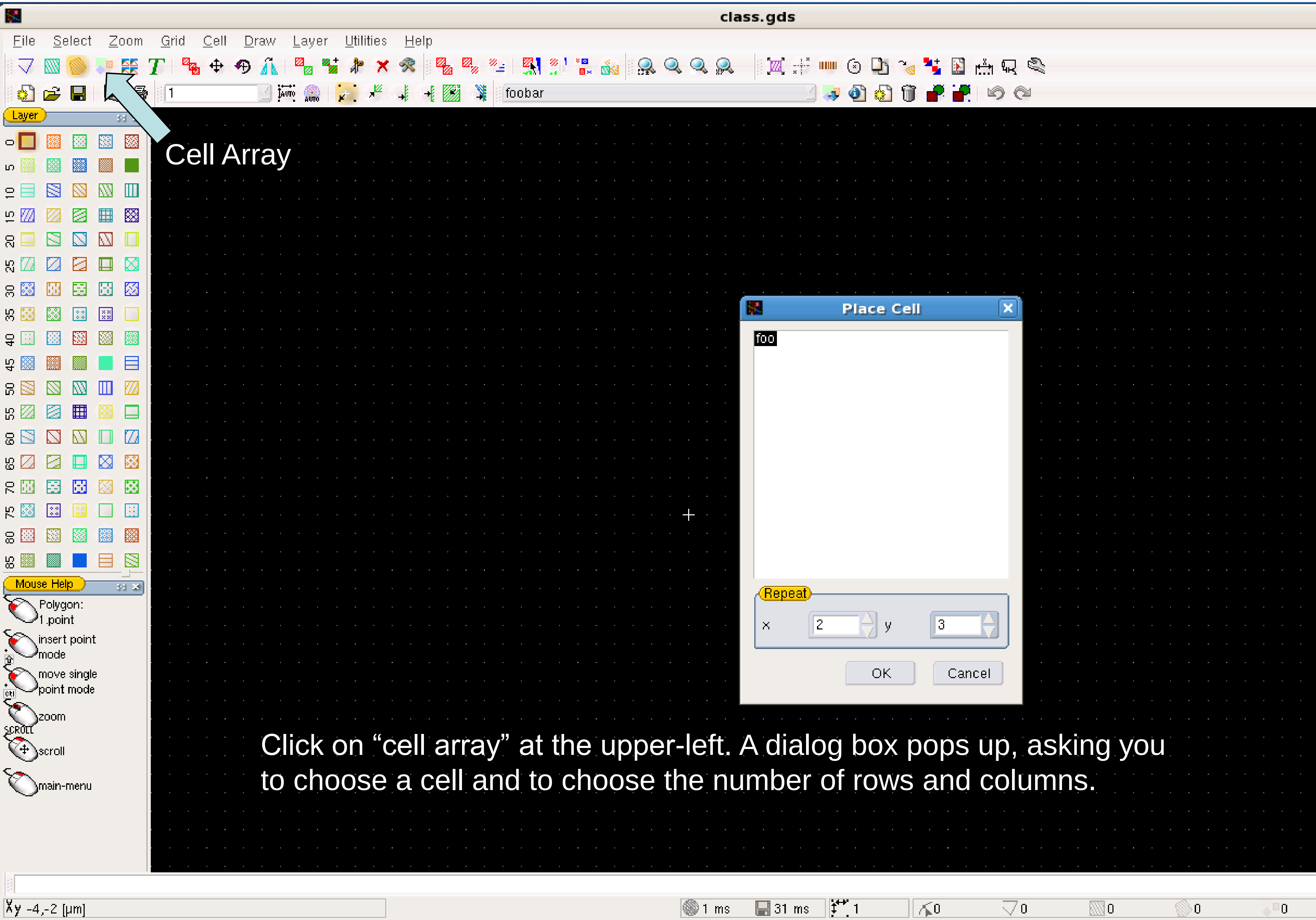
Let's create a new cell called "bar", and then place the cell "foo" inside it, at a few different locations.


/home/rooks/projects/cat/foo.gds
File Select Zoom Grid Cell Draw Layer Utilities Help
10
bar
Layer
Cell
Add Cellreference
Select Cell to insert
foo
OK
Cancel
Mouse Help
set cellref mode
Xy -597,409 [µm]
2 ms
16.8 s
10


/home/rooks/projects/cat/foo.gds
File Select Zoom Grid Cell Draw Layer Utilities Help
10
bar
Layer
Mouse Help
Cellref:
origin
rotate
ccw
rotate
cw
mirror
zoom
scroll
main-menu
The cursor now looks like the cell “foo”.
Click
Click
Click
Xy -310,110 [µm]
2 ms
16.8 s
10

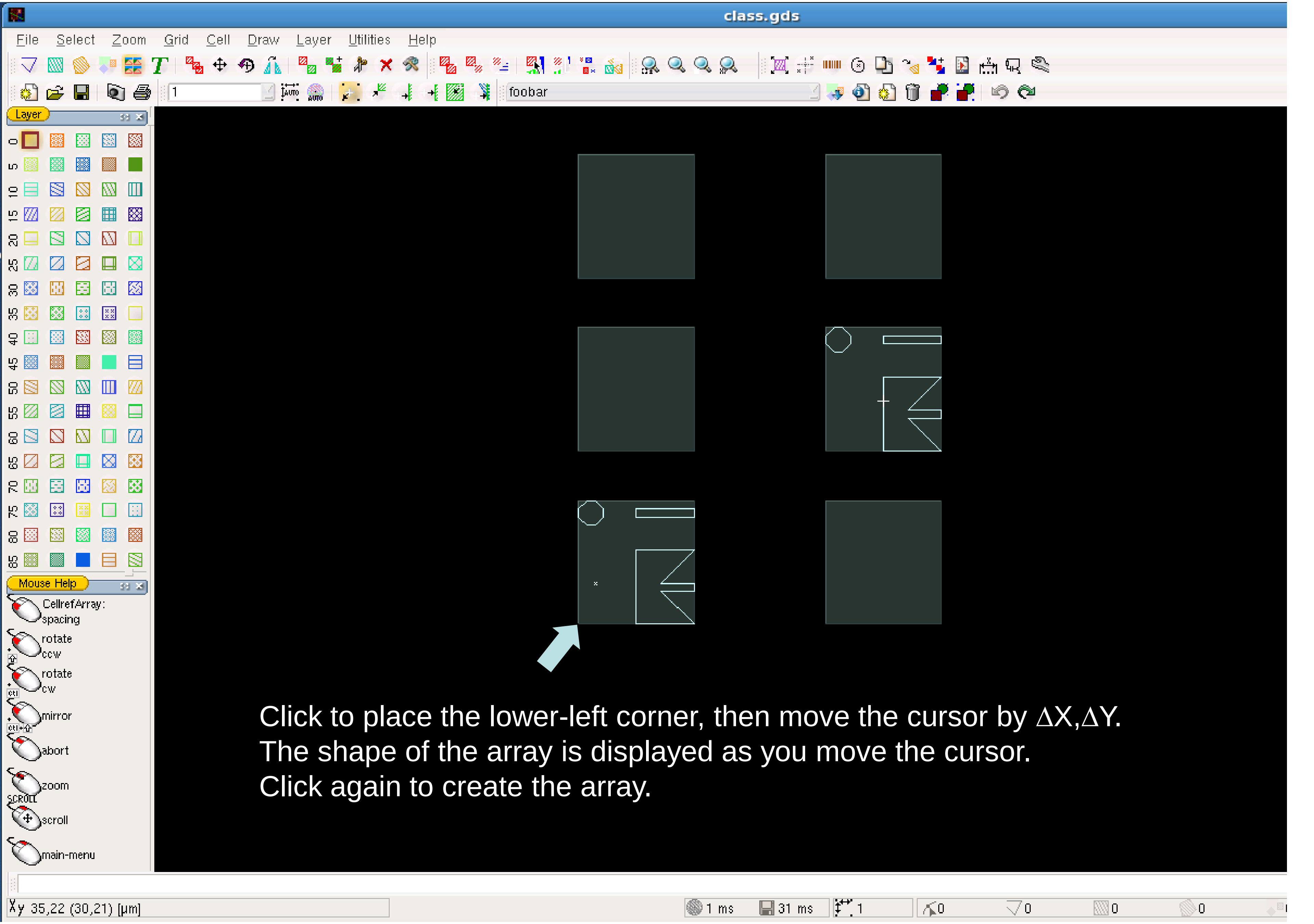


LayoutEditor
File Select Zoom Grid Cell Draw Layer Utilities Help
noname_1
New Cell
Cell Name
Cell Name
Enter Cell Name
noname_1
OK
Cancel
Layer
Mouse Help
set cell name
Now let's create an ARRAY of the cell "foo".
First click on New Cell and then Cell Name, as before.

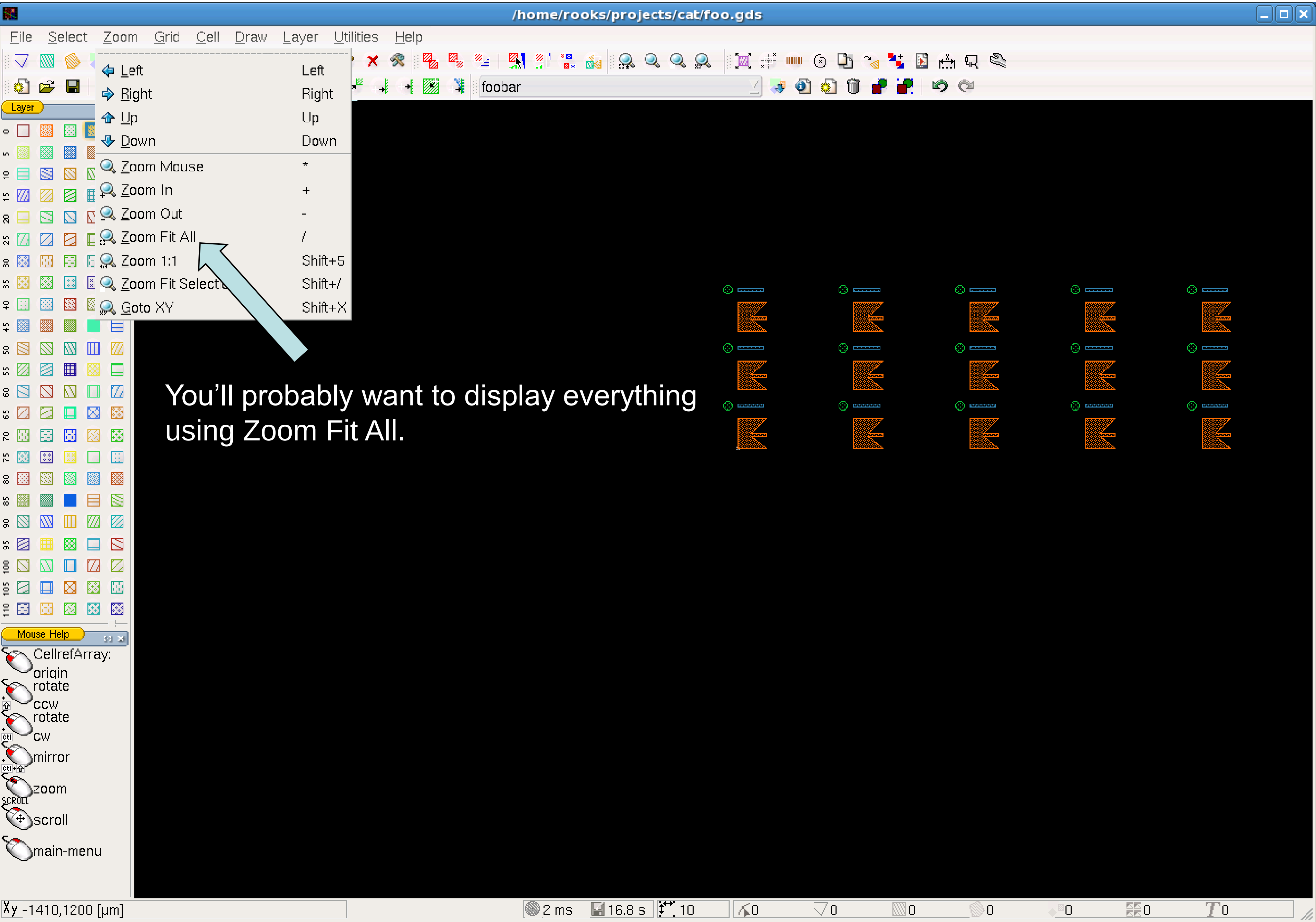


Cell Array

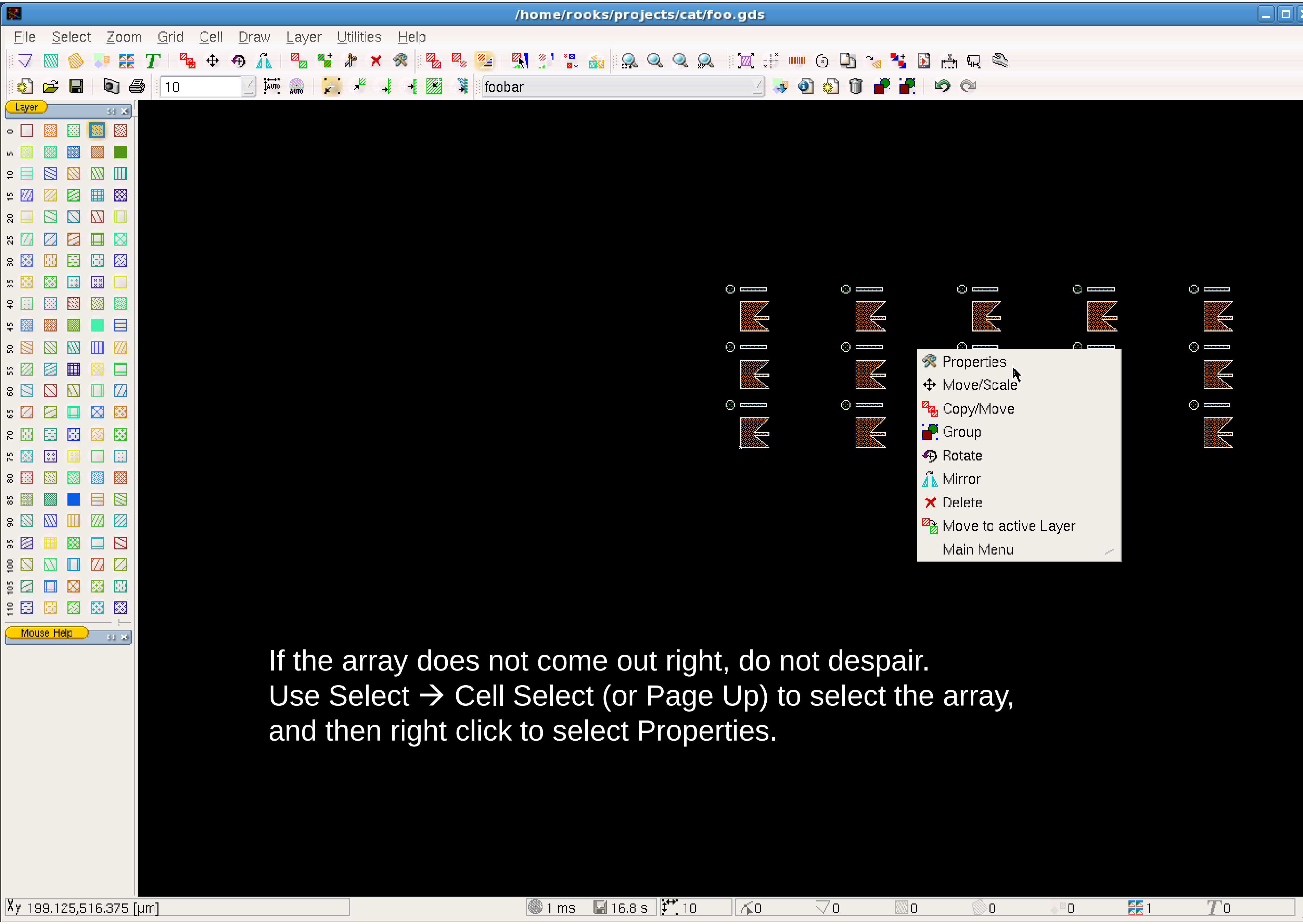
Click on “cell array” at the upper-left. A dialog box pops up, asking you to choose a cell and to choose the number of rows and columns.



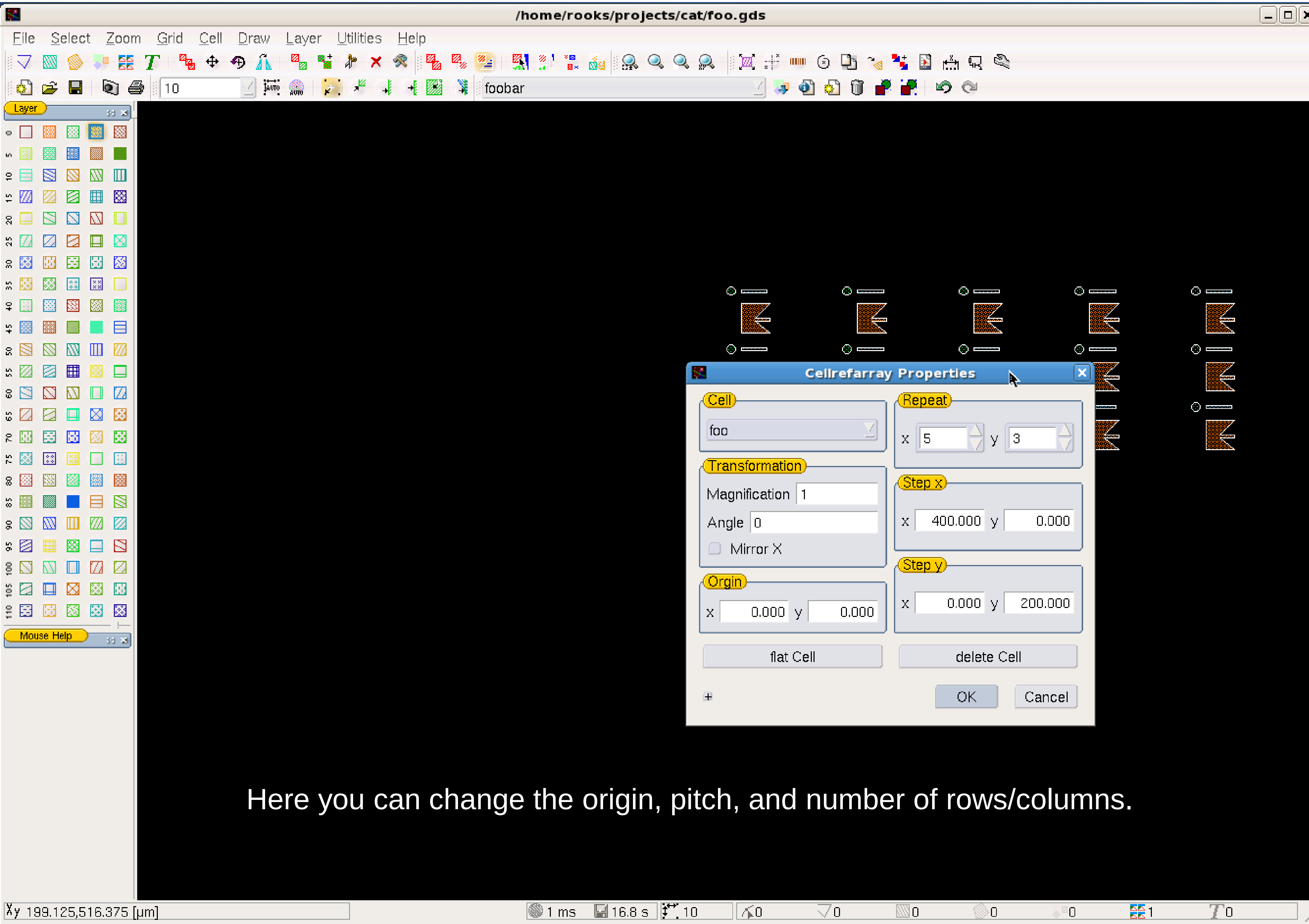
Click to place the lower-left corner, then move the cursor by ΔX,ΔY. The shape of the array is displayed as you move the cursor. Click again to create the array.



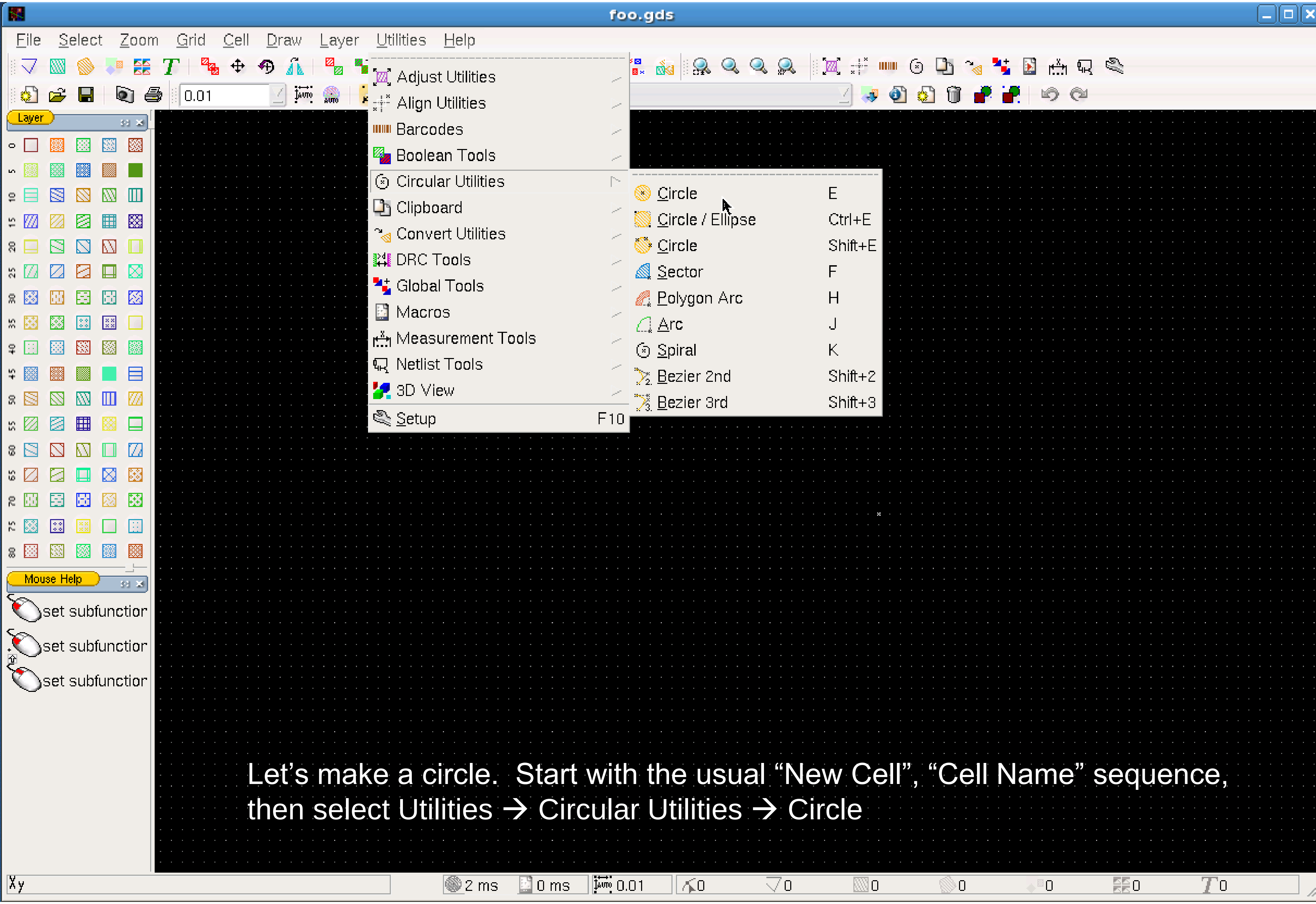
You'll probably want to display everything using Zoom Fit All.



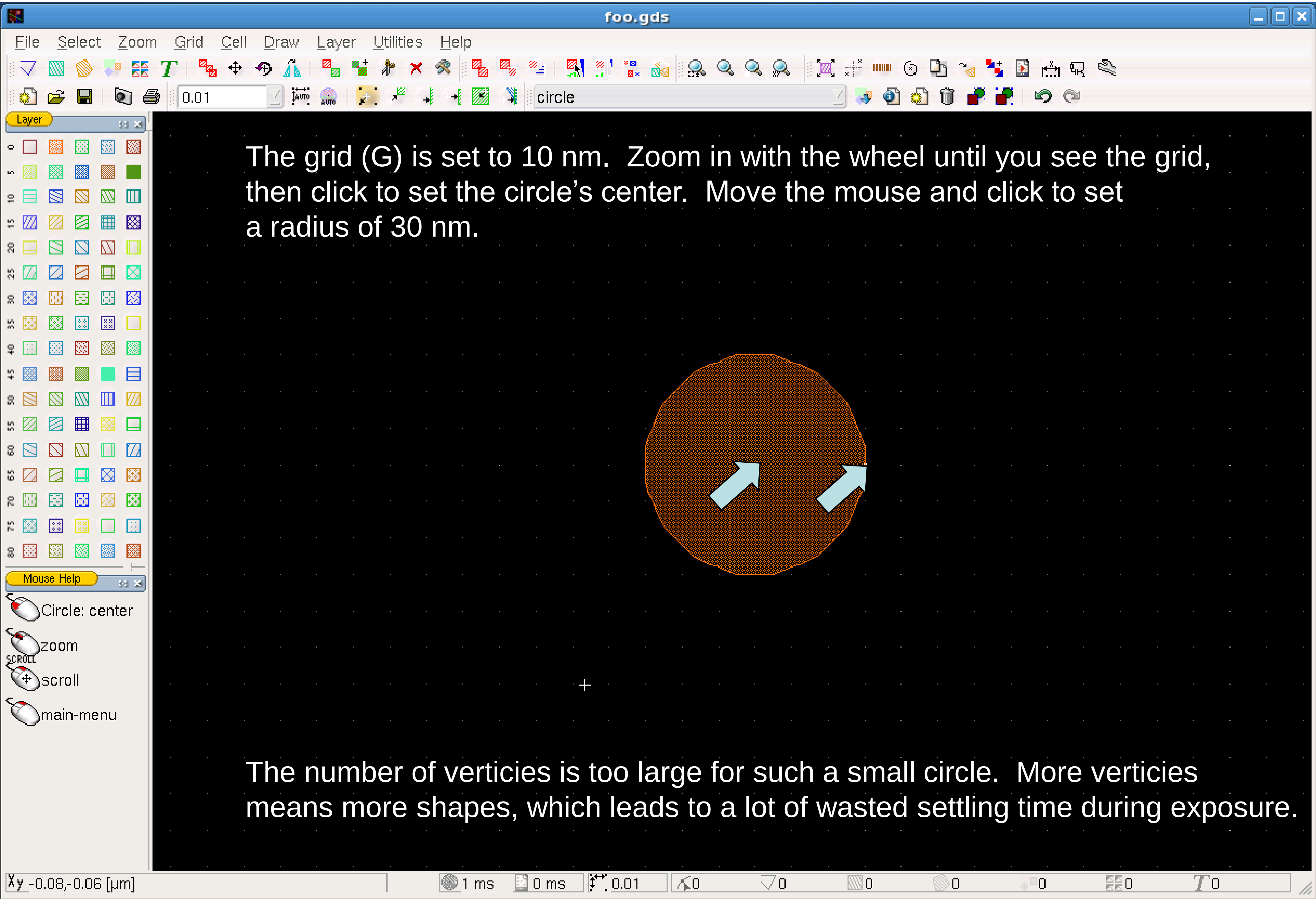
If the array does not come out right, do not despair.
Use Select → Cell Select (or Page Up) to select the array,
and then right click to select Properties.

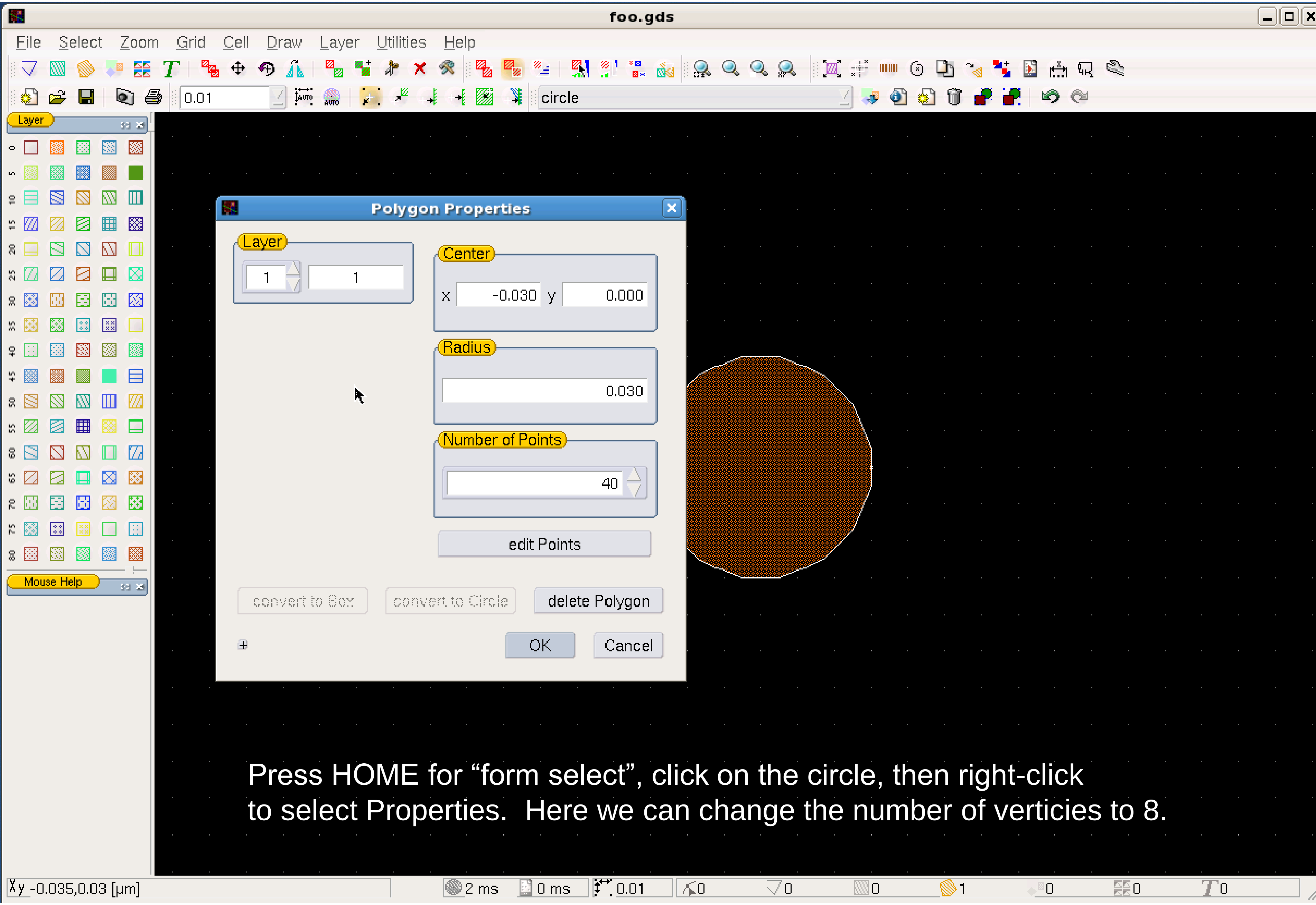


Here you can change the origin, pitch, and number of rows/columns.

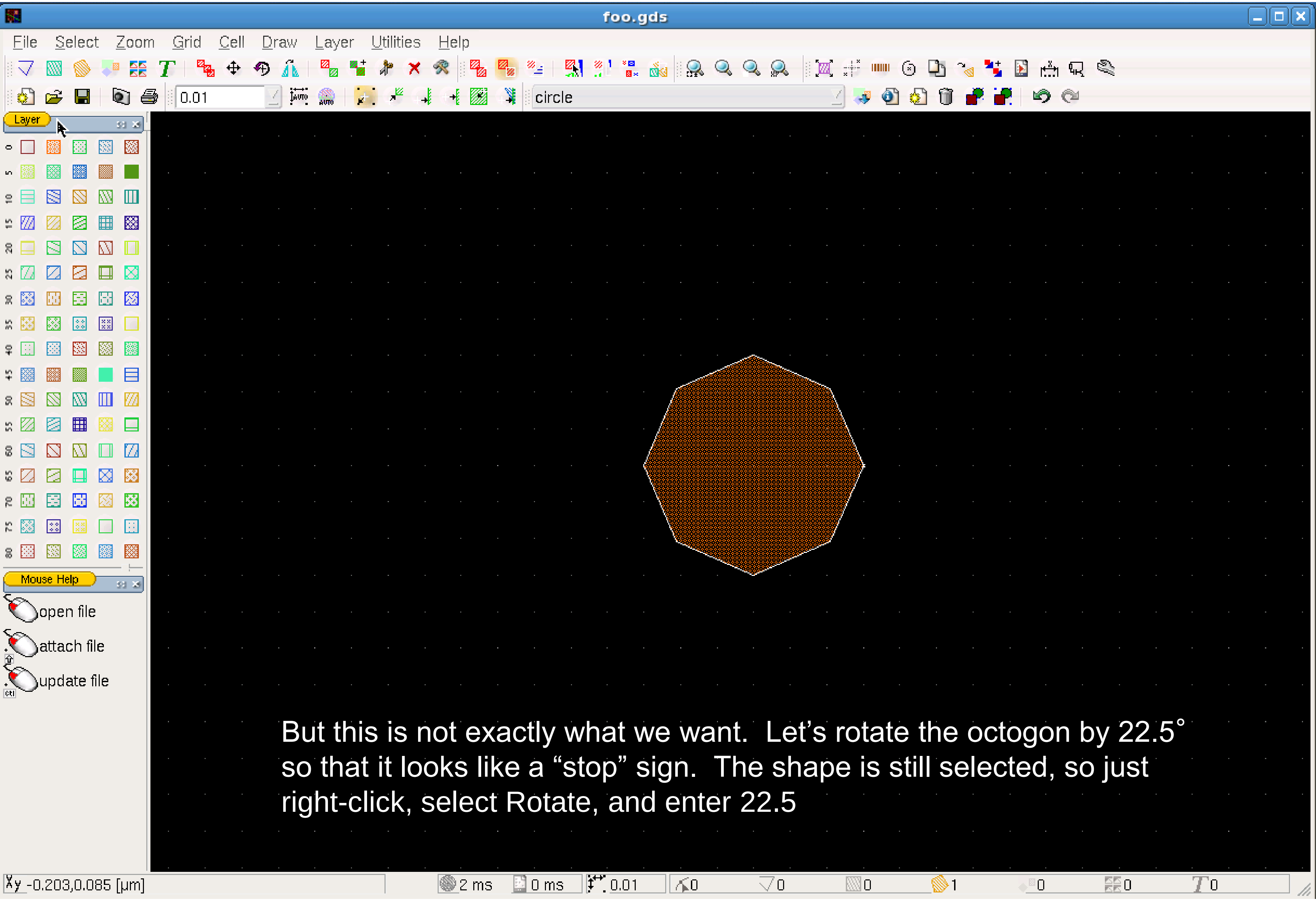


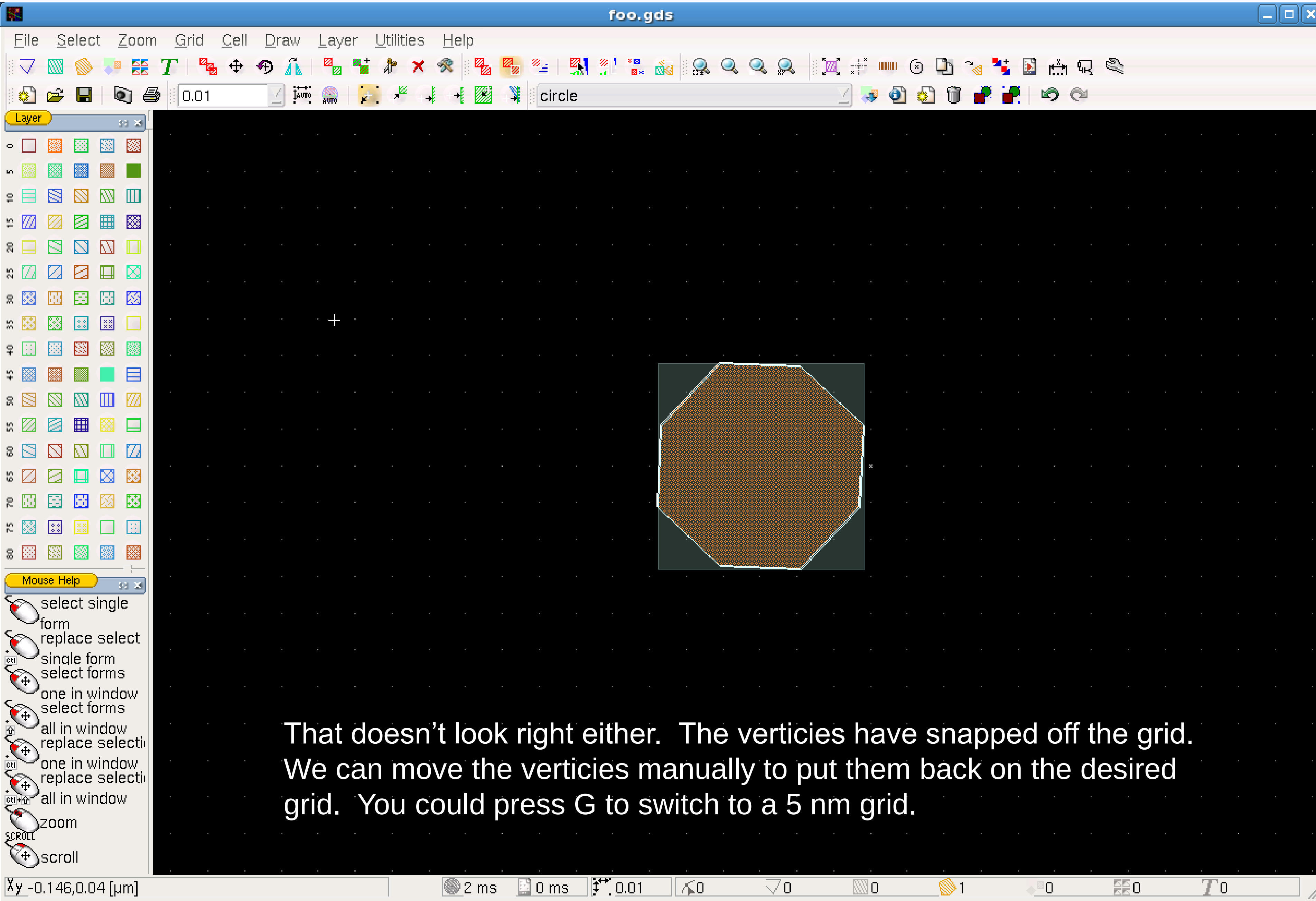
Let's make a circle. Start with the usual "New Cell", "Cell Name" sequence, then select Utilities → Circular Utilities → Circle


foo.gds
File Select Zoom Grid Cell Draw Layer Utilities Help
0.01
circle
Layer
Mouse Help
Circle: center
zoom
scroll
main-menu
The grid (G) is set to 10 nm. Zoom in with the wheel until you see the grid, then click to set the circle's center. Move the mouse and click to set a radius of 30 nm.
The number of verticies is too large for such a small circle. More verticies means more shapes, which leads to a lot of wasted settling time during exposure.
xy -0.08,-0.06 [µm]
1 ms
0 ms
0.01

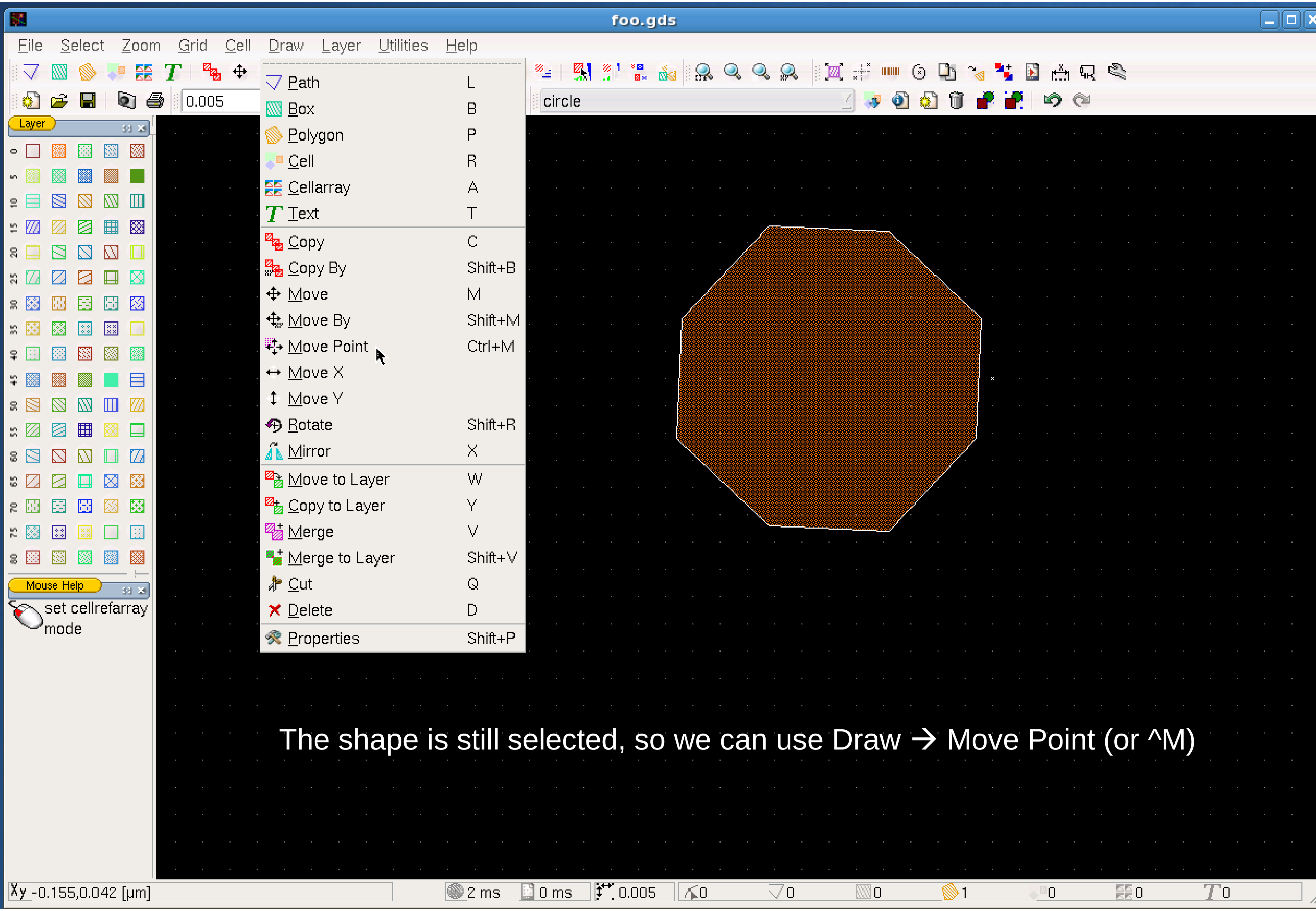


Press HOME for "form select", click on the circle, then right-click to select Properties. Here we can change the number of verticies to 8.

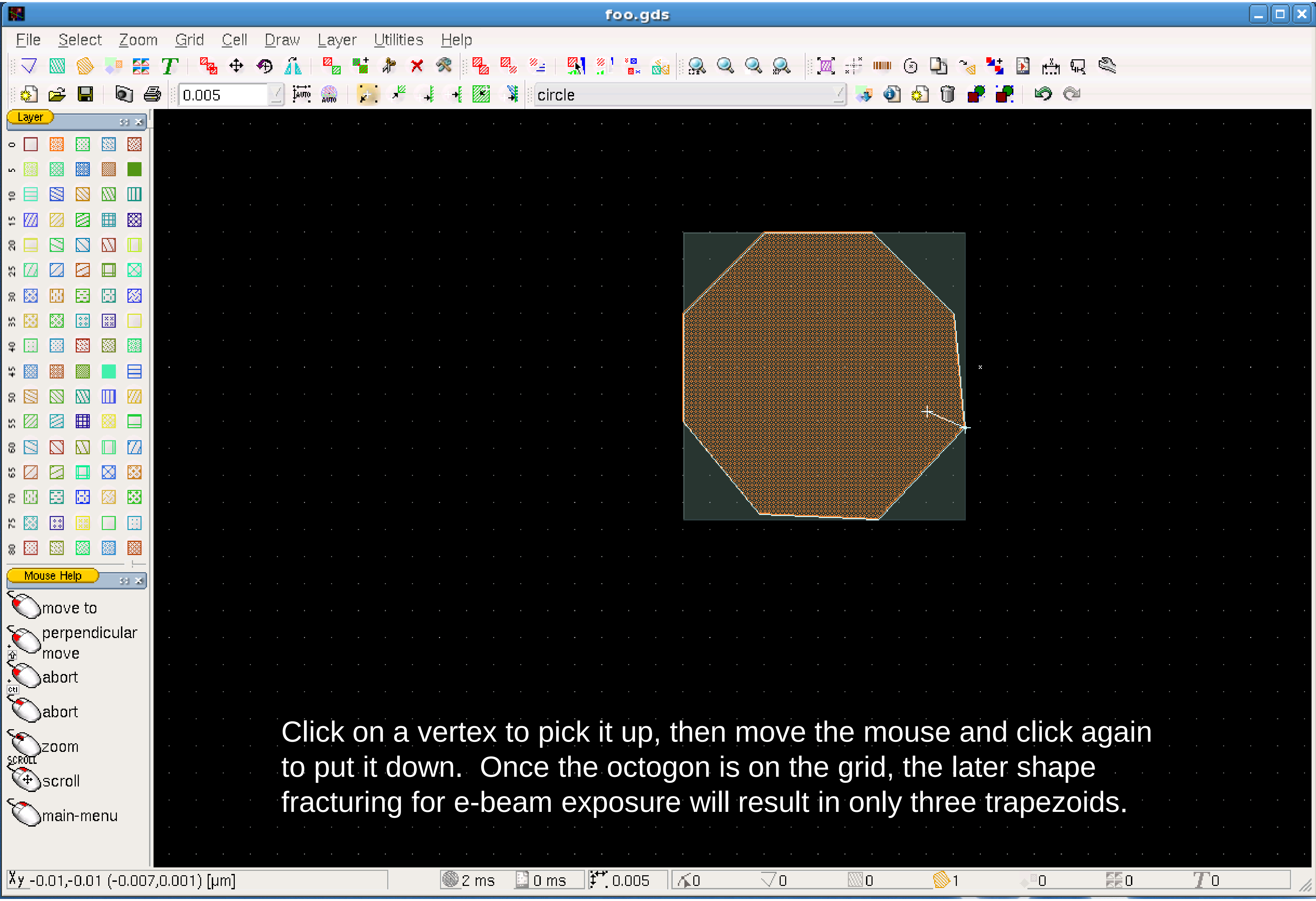

foo.gds
File Select Zoom Grid Cell Draw Layer Utilities Help
0.01
circle
Layer
Mouse Help
open file
attach file
update file
But this is not exactly what we want. Let's rotate the octogon by 22.5°
so that it looks like a "stop" sign. The shape is still selected, so just
right-click, select Rotate, and enter 22.5
xy -0.203,0.085 [µm]
2 ms
0 ms
0.01

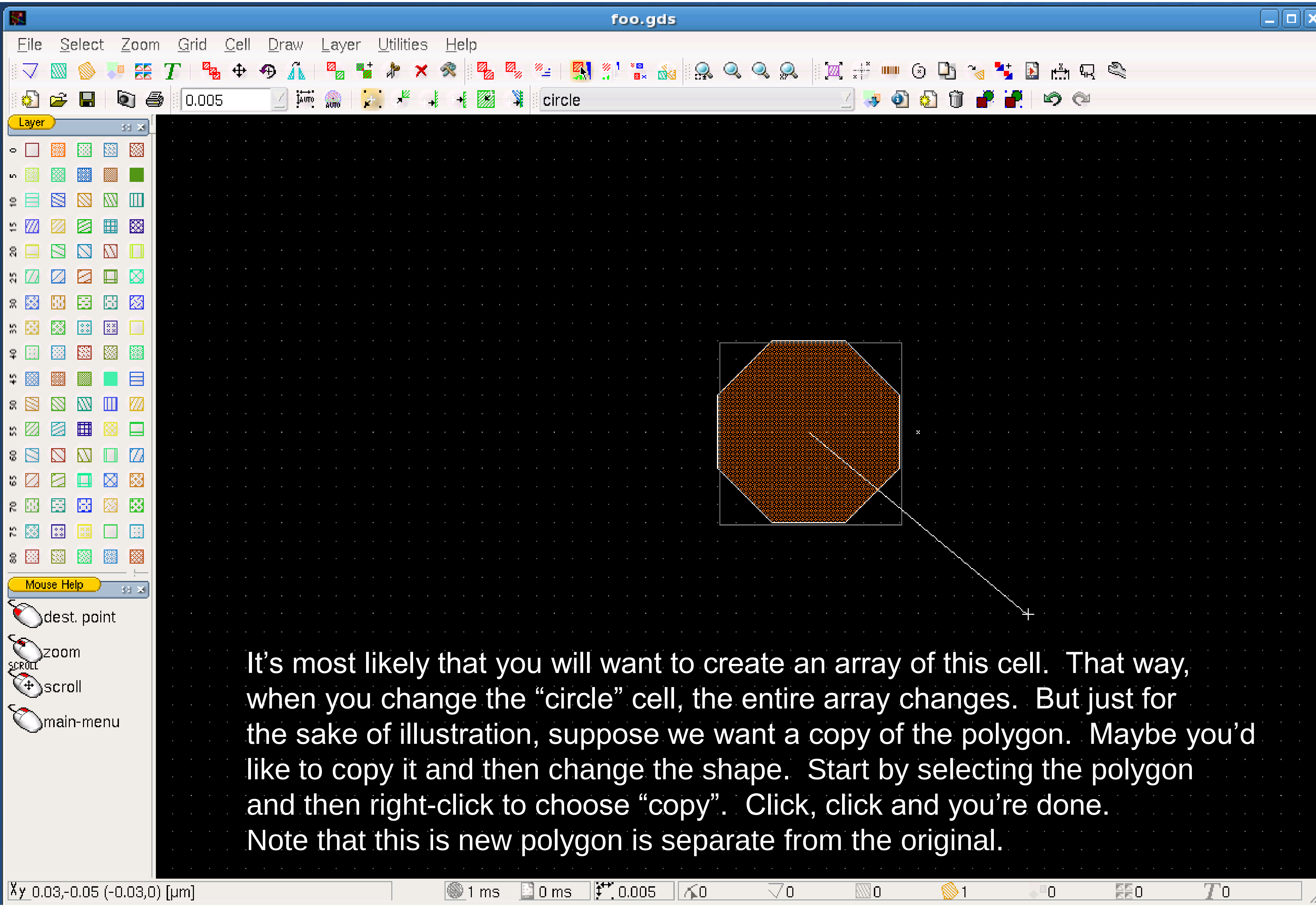


That doesn't look right either. The verticies have snapped off the grid. We can move the verticies manually to put them back on the desired grid. You could press G to switch to a 5 nm grid.

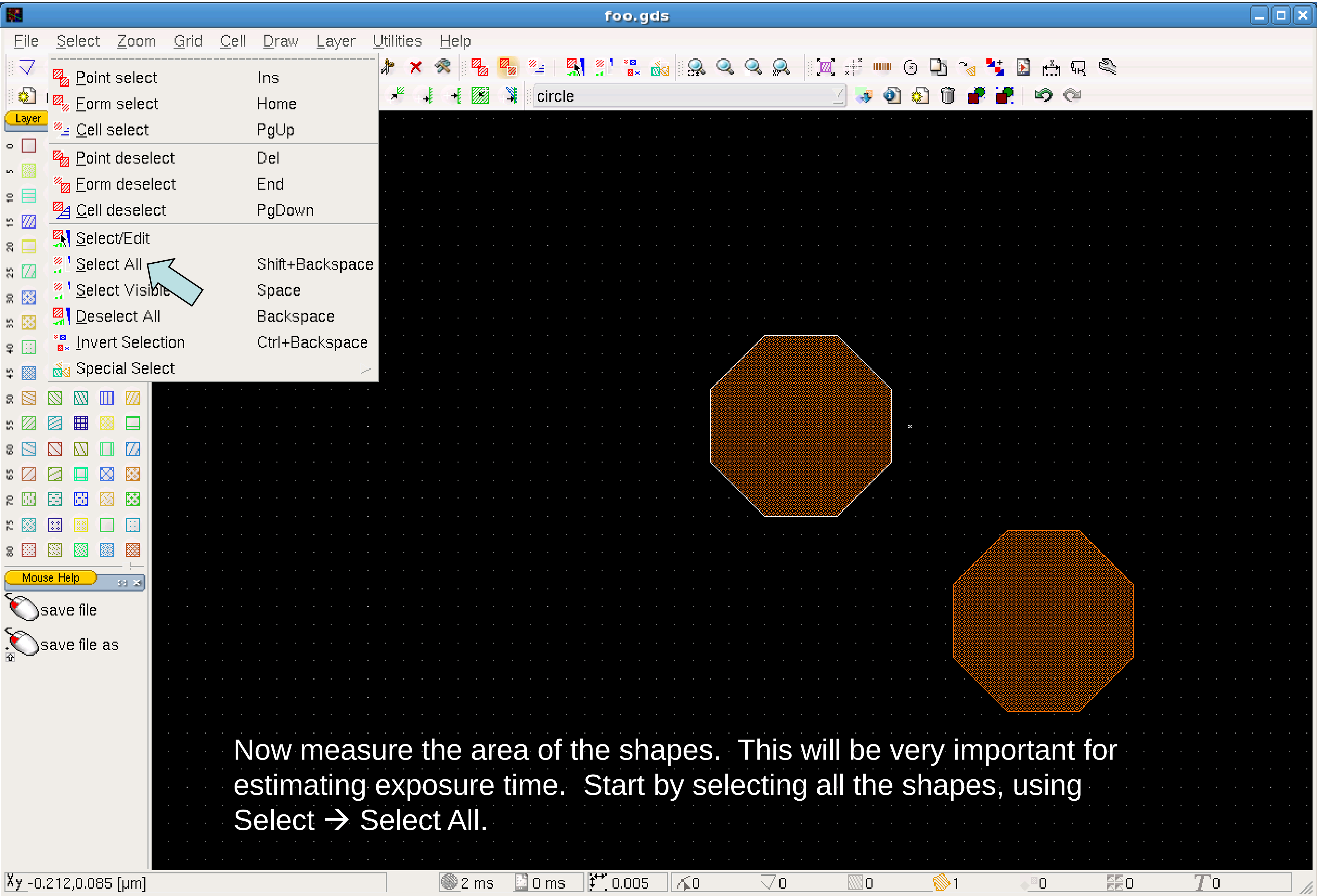


The shape is still selected, so we can use Draw → Move Point (or ^M)

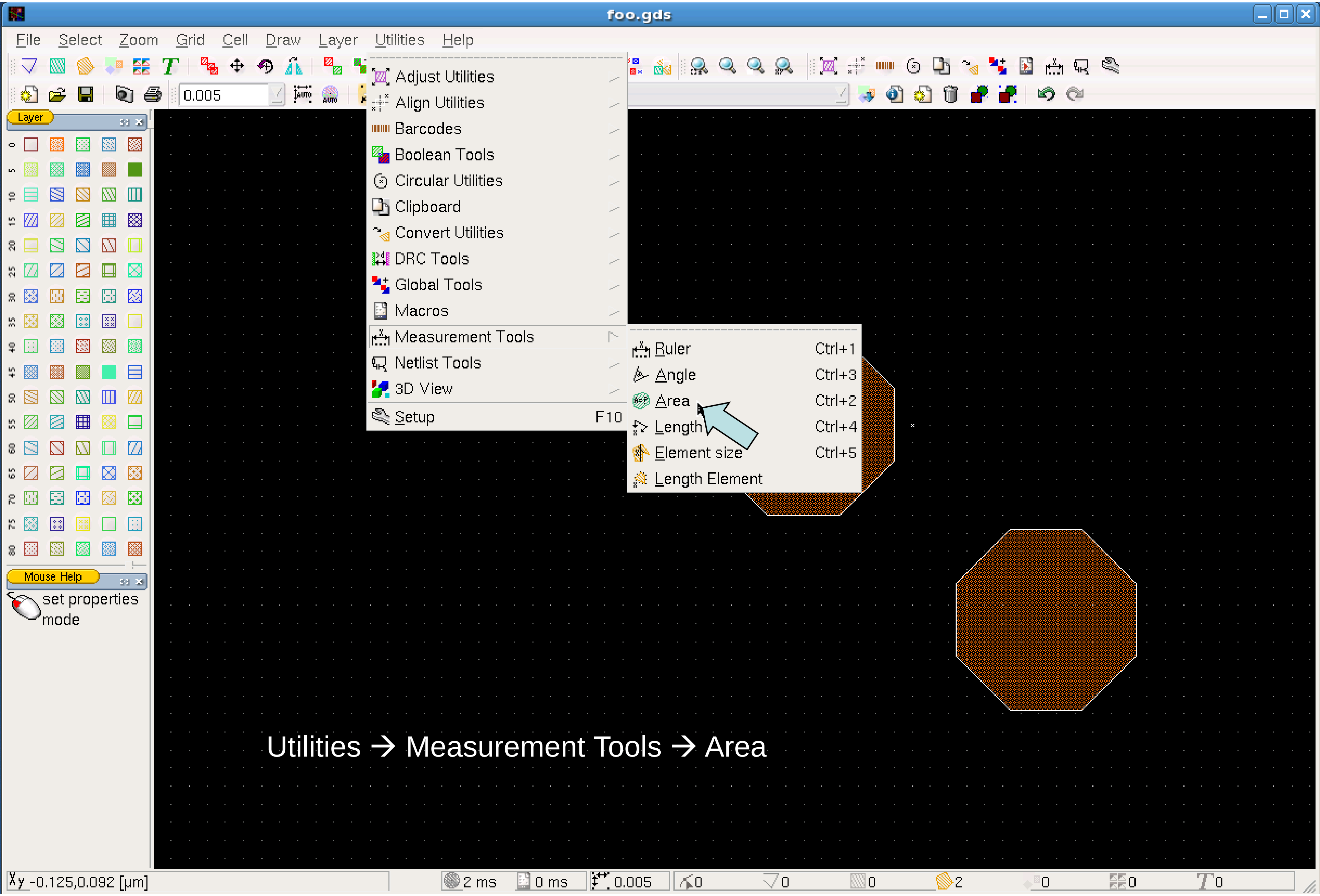

foo.gds
File
Select
Zoom
Grid
Cell
Draw
Layer
Utilities
Help
0.005
circle
Layer
Mouse Help
move to
perpendicular move
abort
abort
zoom
scroll
main-menu
Xy -0.01,-0.01 (-0.007,0.001) [µm]
2 ms
0 ms
0.005
Click on a vertex to pick it up, then move the mouse and click again to put it down. Once the octogon is on the grid, the later shape fracturing for e-beam exposure will result in only three trapezoids.



It's most likely that you will want to create an array of this cell. That way, when you change the "circle" cell, the entire array changes. But just for the sake of illustration, suppose we want a copy of the polygon. Maybe you'd like to copy it and then change the shape. Start by selecting the polygon and then right-click to choose "copy". Click, click and you're done. Note that this is new polygon is separate from the original.



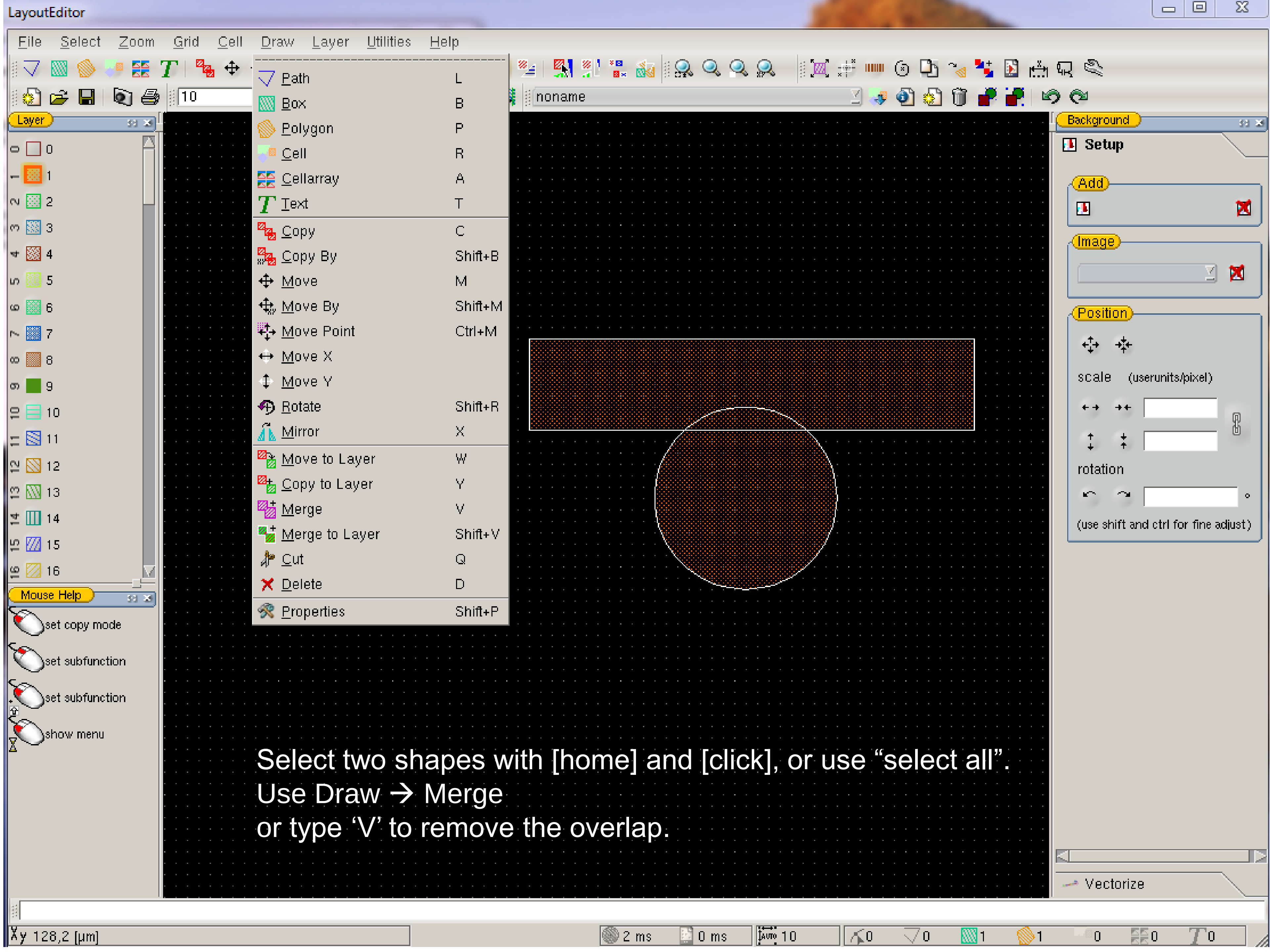
Now measure the area of the shapes. This will be very important for estimating exposure time. Start by selecting all the shapes, using Select → Select All.

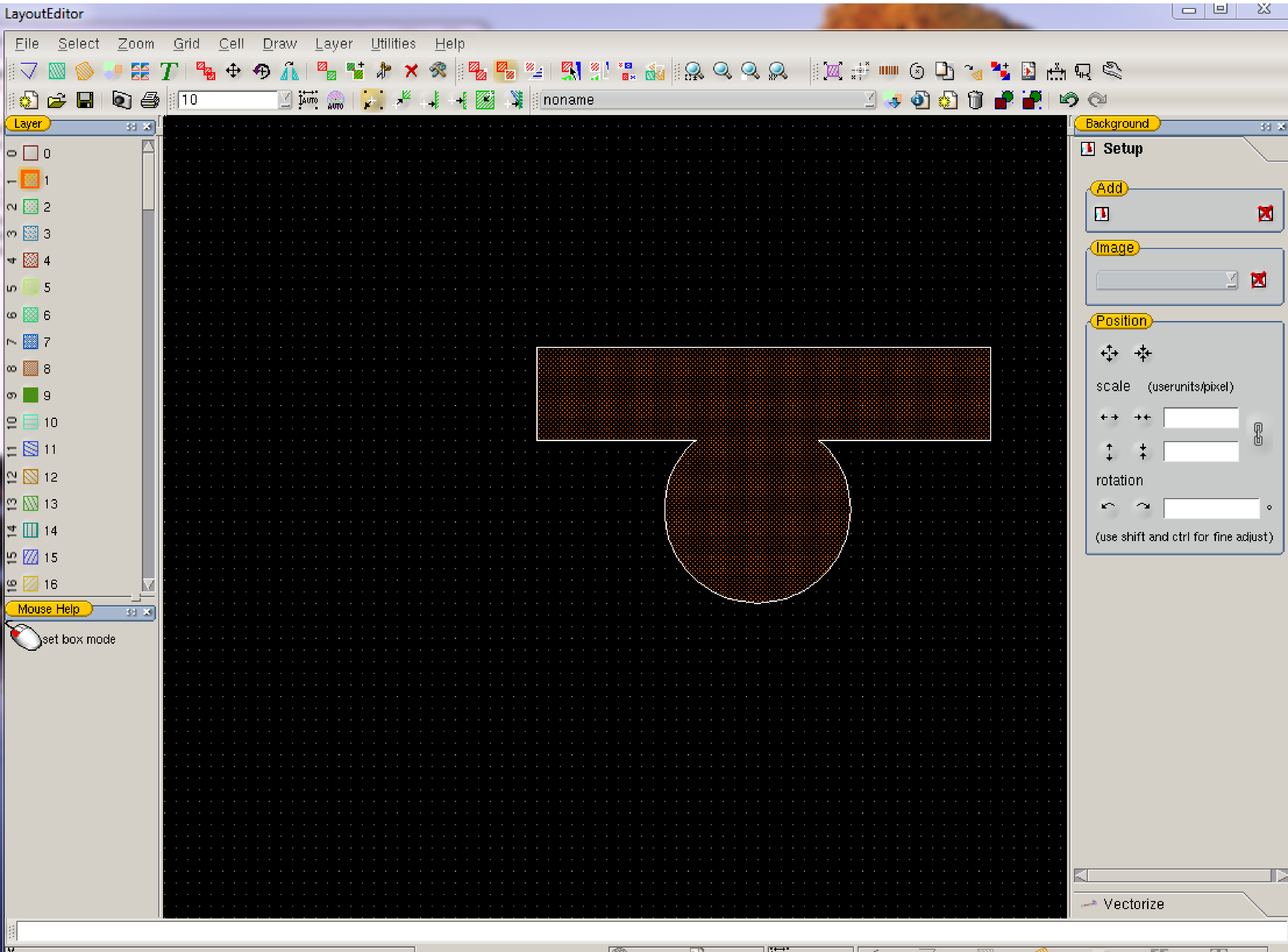

foo.gds
File Select Zoom Grid Cell Draw Layer Utilities Help
Adjust Utilities
Align Utilities
Barcodes
Boolean Tools
Circular Utilities
Clipboard
Convert Utilities
DRC Tools
Global Tools
Macros
Measurement Tools
Netlist Tools
3D View
Setup F10
Ruler Ctrl+1
Angle Ctrl+3
Area Ctrl+2
Length Ctrl+4
Element size Ctrl+5
Length Element
Layer
Mouse Help
set properties mode
Xy -0.125,0.092 [µm]
2 ms
0 ms
0.005
Utilities → Measurement Tools → Area

Overlap removal

Use the “merge” function to eliminate overlaps, thereby avoiding double exposures.

(Alternatively, you could use Beamer to remove all overlaps; but then you would lose all dose assignments.)


LayoutEditor
File Select Zoom Grid Cell Draw Layer Utilities Help
Path L
Box B
Polygon P
Cell R
Cellarray A
Text T
Copy C
Copy By Shift+B
Move M
Move By Shift+M
Move Point Ctrl+M
Move X
Move Y
Rotate Shift+R
Mirror X
Move to Layer W
Copy to Layer Y
Merge V
Merge to Layer Shift+V
Cut Q
Delete D
Properties Shift+P
noname
Layer
Mouse Help
set copy mode
set subfunction
set subfunction
show menu
Background
Setup
Add
Image
Position
scale (userunits/pixel)
rotation
(use shift and ctrl for fine adjust)
Vectorize
xy 128,2 [µm]
2 ms
0 ms
Select two shapes with [home] and [click], or use “select all”.
Use Draw → Merge
or type ‘V’ to remove the overlap.

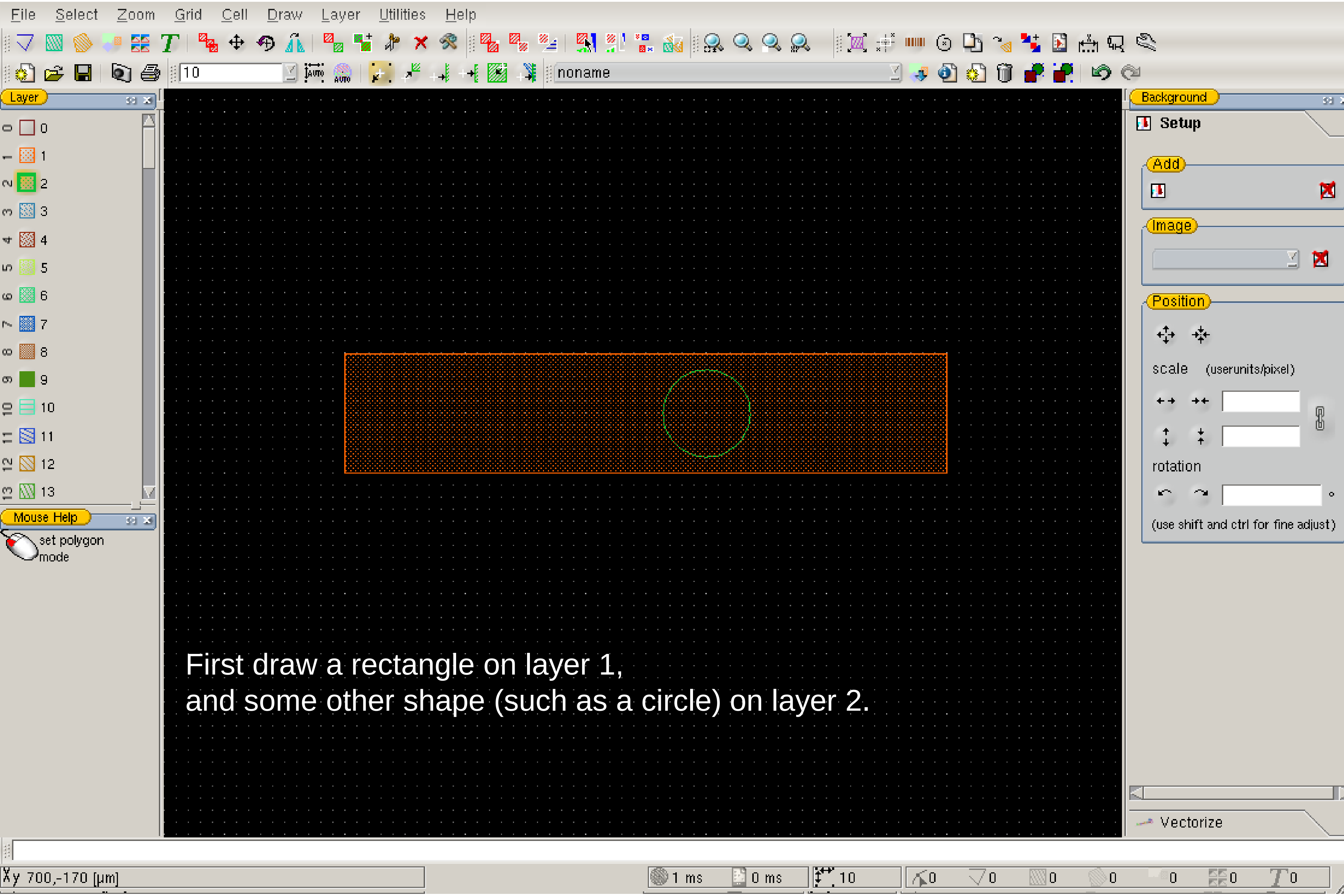

LayoutEditor
File Select Zoom Grid Cell Draw Layer Utilities Help
10
noname
Layer
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Mouse Help
set box mode
Background
Setup
Add
Image
Position
scale (userunits/pixel)
rotation
(use shift and ctrl for fine adjust)
Vectorize

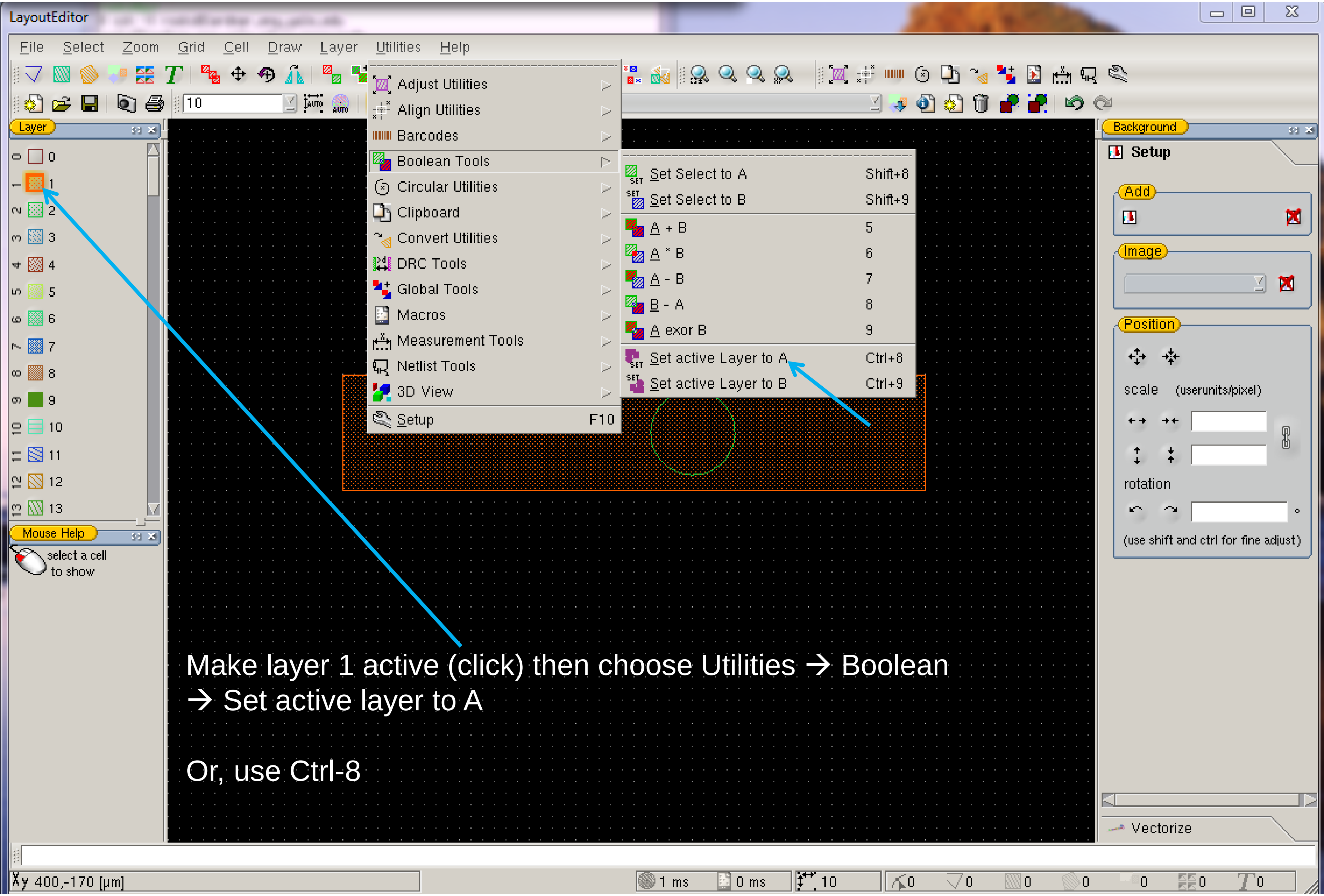
Boolean operations

Logical operations such as “and”, “or”, and “not”, as well as +/-, are very useful for designing complex designs.

Layout will let you perform Boolean operations on individual shapes, but this example shows you how to do these operations on entire layers.

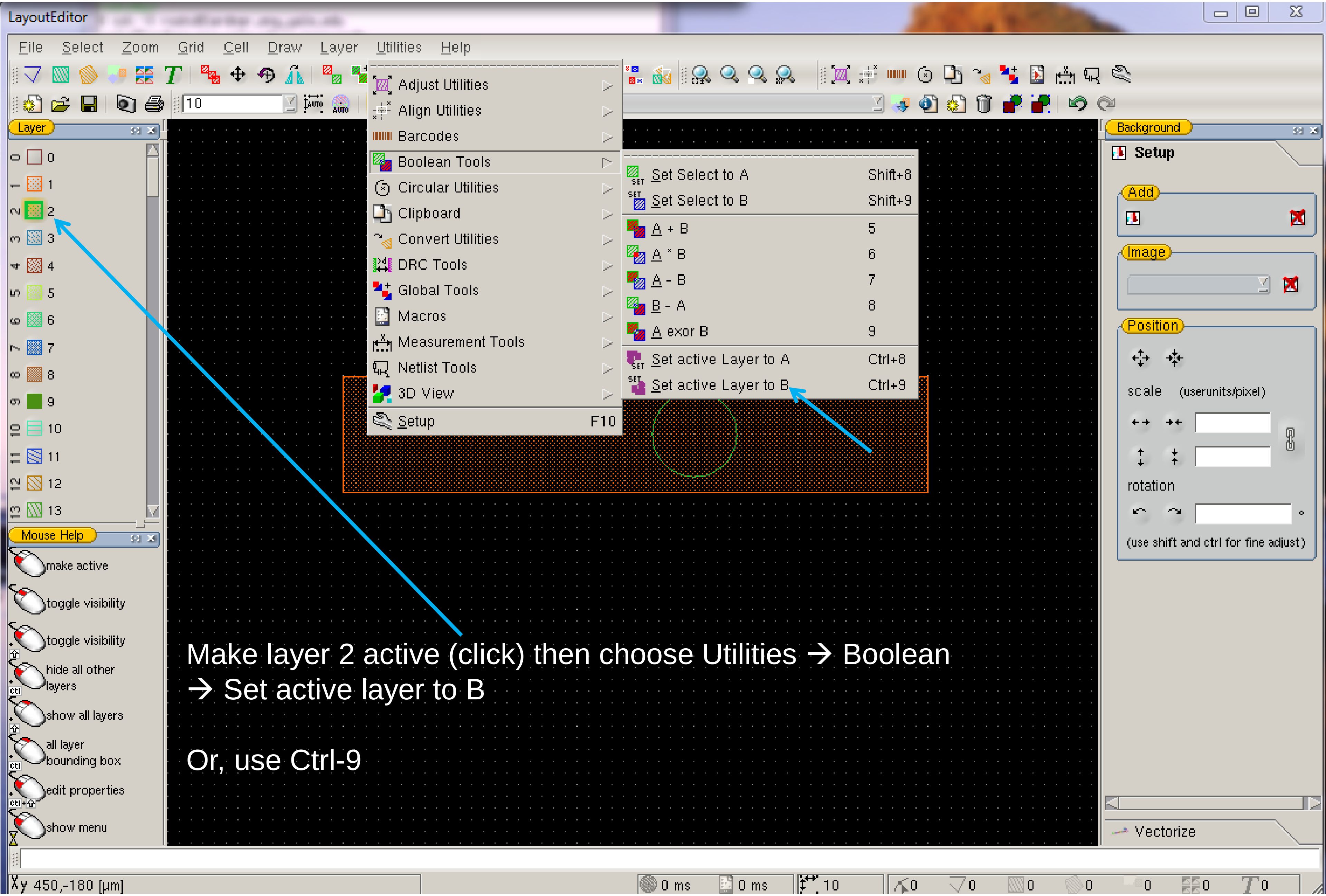
First we will assign the label “A” to one layer, and the label “B” to another layer. We will select a third layer to hold the results, and then we will perform an operation such as A – B.

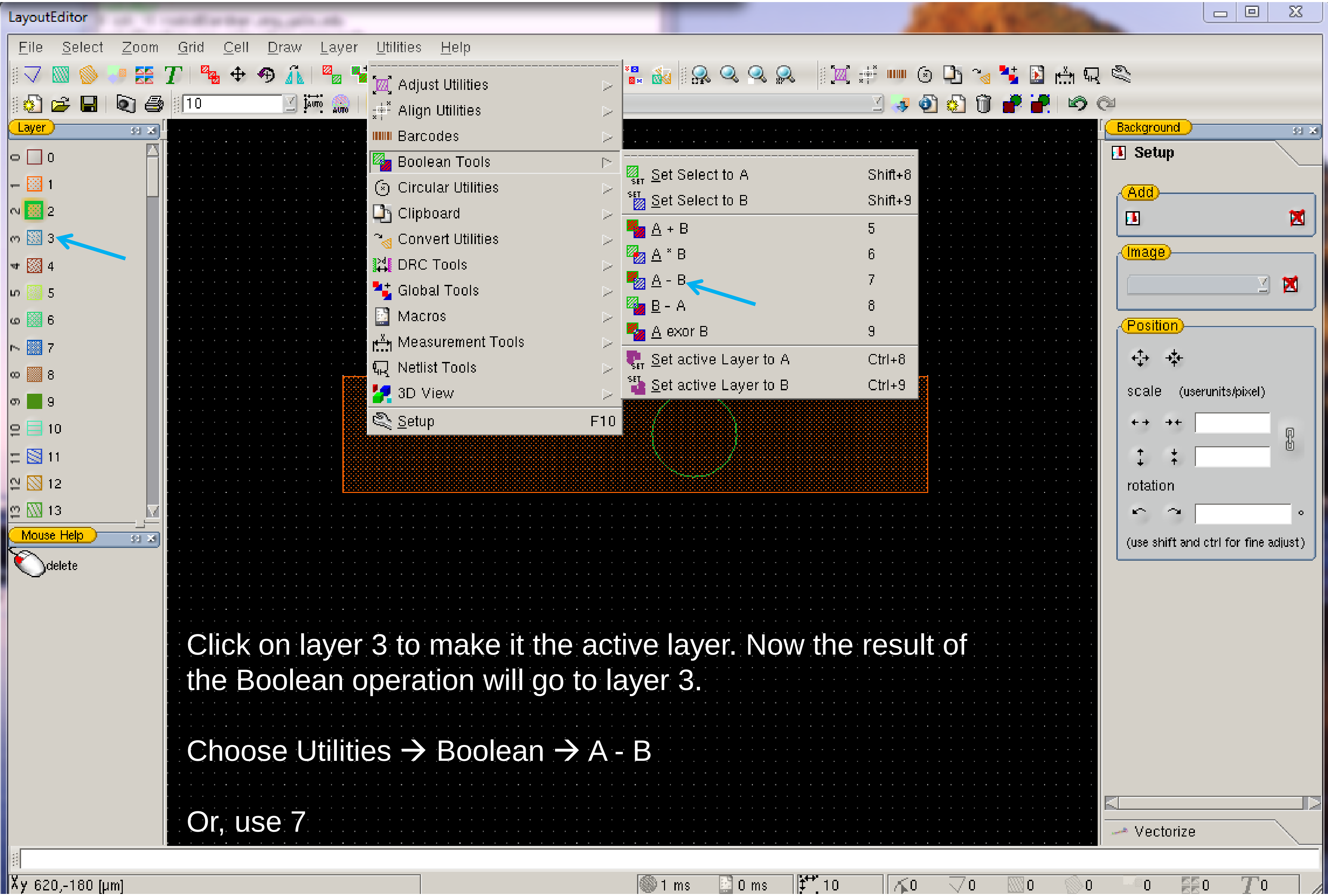

File
Select
Zoom
Grid
Cell
Draw
Layer
Utilities
Help
10
noname
Layer
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Mouse Help
set polygon mode
Background
Setup
Add
Image
Position
scale (userunits/pixel)
rotation
(use shift and ctrl for fine adjust)
Vectorize
xy 700,-170 [µm]
1 ms
0 ms
10
First draw a rectangle on layer 1,
and some other shape (such as a circle) on layer 2.



Make layer 1 active (click) then choose Utilities → Boolean → Set active layer to A

Or, use Ctrl-8

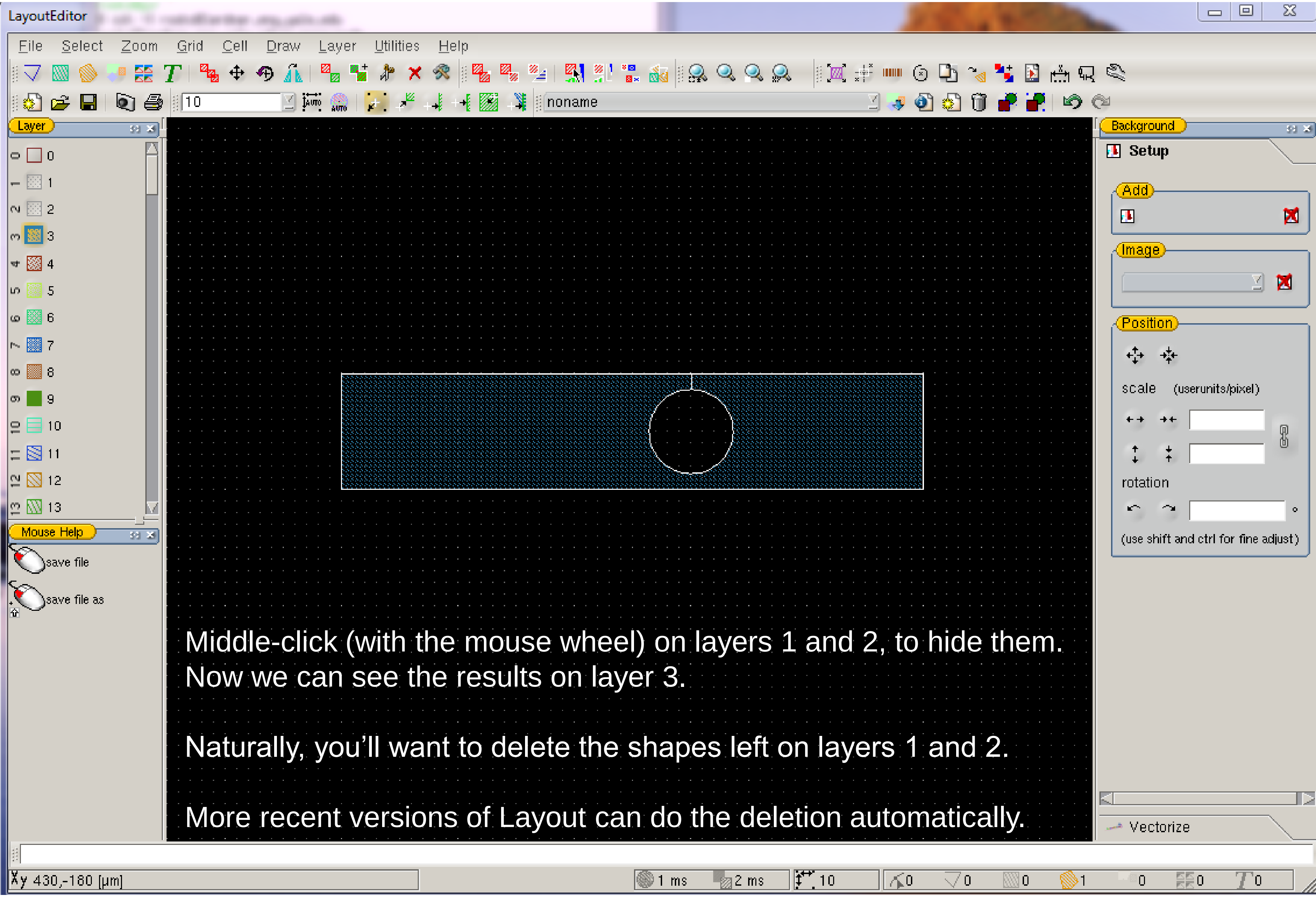

LayoutEditor
File Select Zoom Grid Cell Draw Layer Utilities Help
Layer
Adjust Utilities
Align Utilities
Barcodes
Boolean Tools
Circular Utilities
Clipboard
Convert Utilities
DRC Tools
Global Tools
Macros
Measurement Tools
Netlist Tools
3D View
Setup F10
Set Select to A Shift+8
Set Select to B Shift+9
A + B 5
A * B 6
A - B 7
B - A 8
A exor B 9
Set active Layer to A Ctrl+8
Set active Layer to B Ctrl+9
Background
Setup
Add
Image
Position
scale (userunits/pixel)
rotation
(use shift and ctrl for fine adjust)
Vectorize
Mouse Help
make active
toggle visibility
toggle visibility
hide all other layers
show all layers
all layer bounding box
edit properties
show menu
Make layer 2 active (click) then choose Utilities → Boolean → Set active layer to B
Or, use Ctrl-9



Click on layer 3 to make it the active layer. Now the result of the Boolean operation will go to layer 3.

Choose Utilities → Boolean → A - B

Or, use 7



Middle-click (with the mouse wheel) on layers 1 and 2, to hide them. Now we can see the results on layer 3.

Naturally, you'll want to delete the shapes left on layers 1 and 2.

More recent versions of Layout can do the deletion automatically.

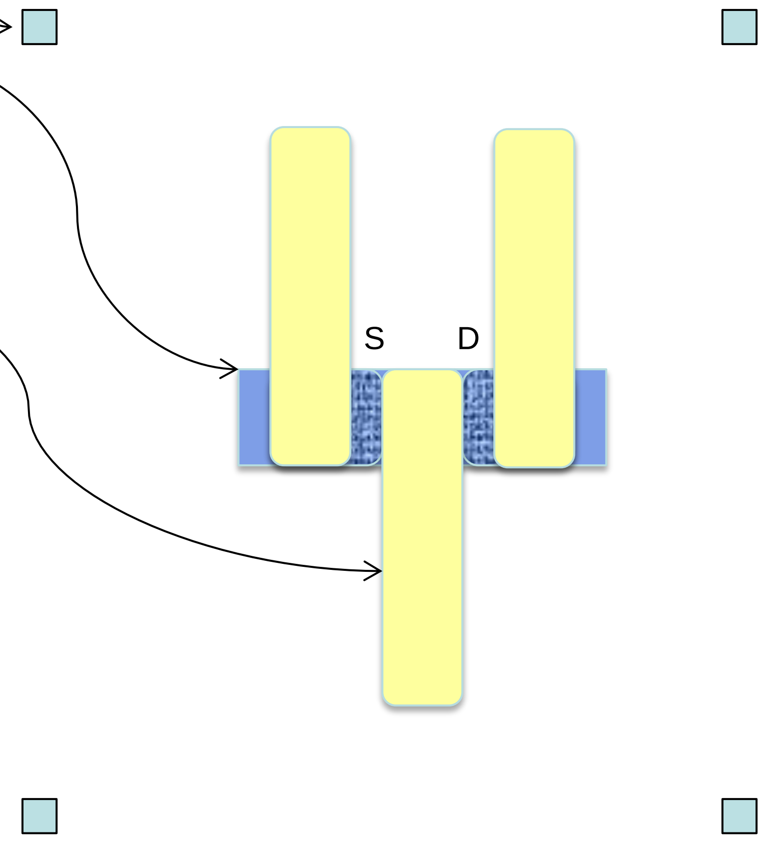
Homework: Design a simple transistor:

Put square alignment marks on layer 0.

Draw the mesa (silicon island) on layer 1.

Source and drain go on layer 2.

Metal pads go on layer 3.



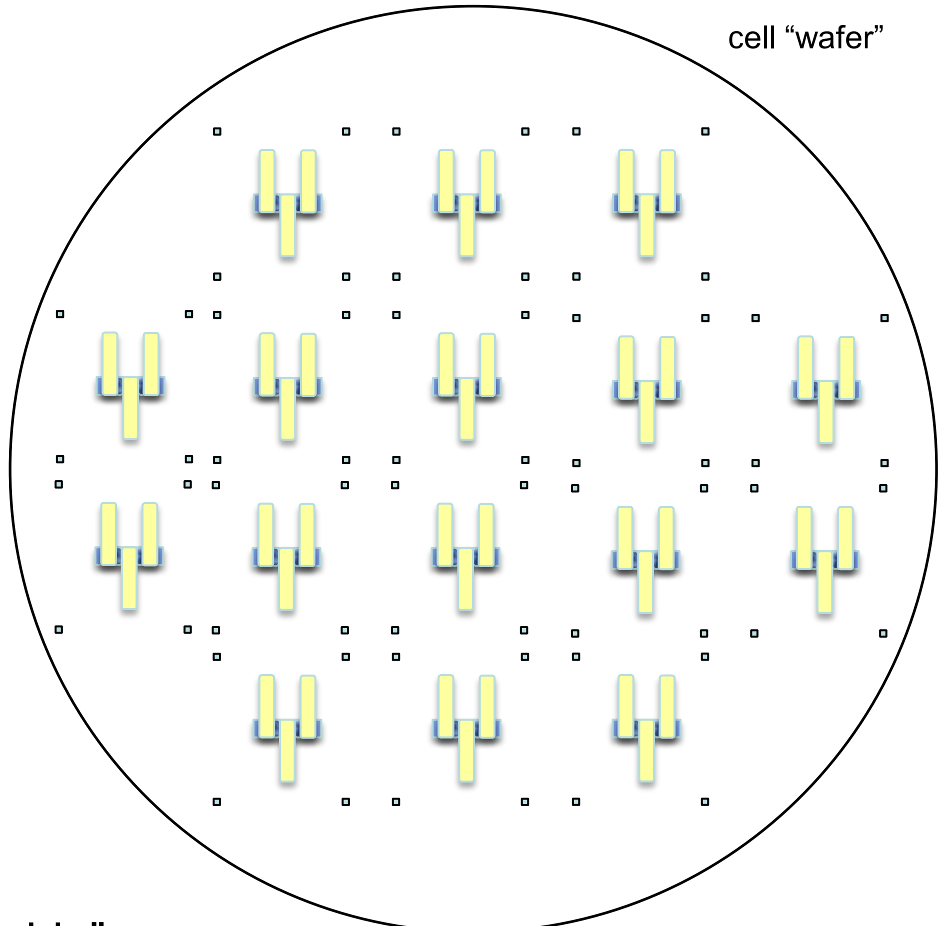
Alignment marks should be 20 um squares, in the corners. The center of each mark should fall on a 10 um grid; that is, the coordinate of each mark should be a multiple of 10 um.

Sometimes it is handy to mock up the full wafer by creating a higher-level cell.

But you would not print this version with the e-beam writer.

Instead, the e-beam writer will step out the unit cell.

Do not start thinking that you can simplify the job by creating one gigantic “chip” that covers the wafer. There are several reasons why this is not a good strategy.



Optional subjects:

Algorithmic pattern generation

Using photos in CAD

(you can stop here if you are not interested)

Algorithmic CAD

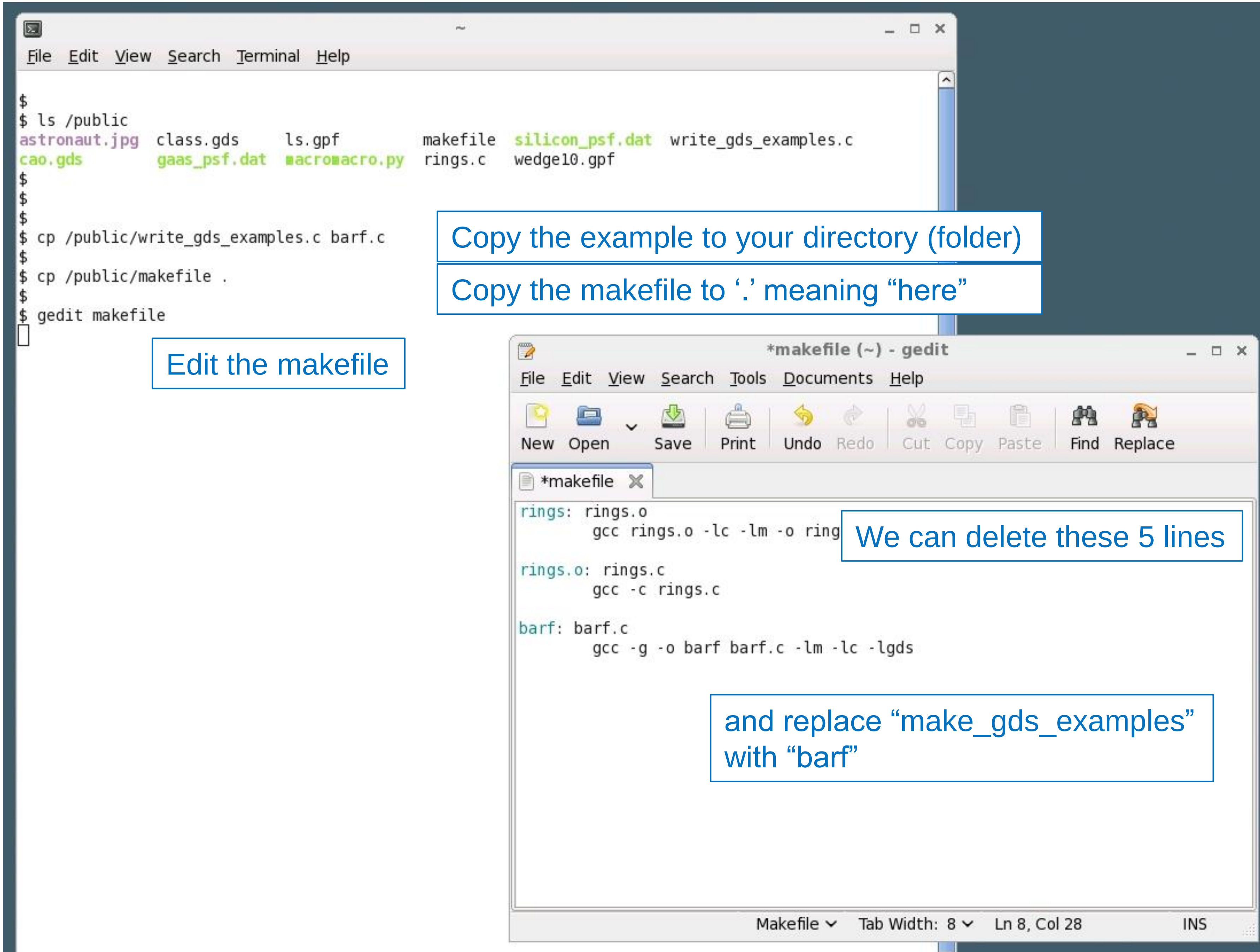
You will find an example C program on sizzlorr, in /public

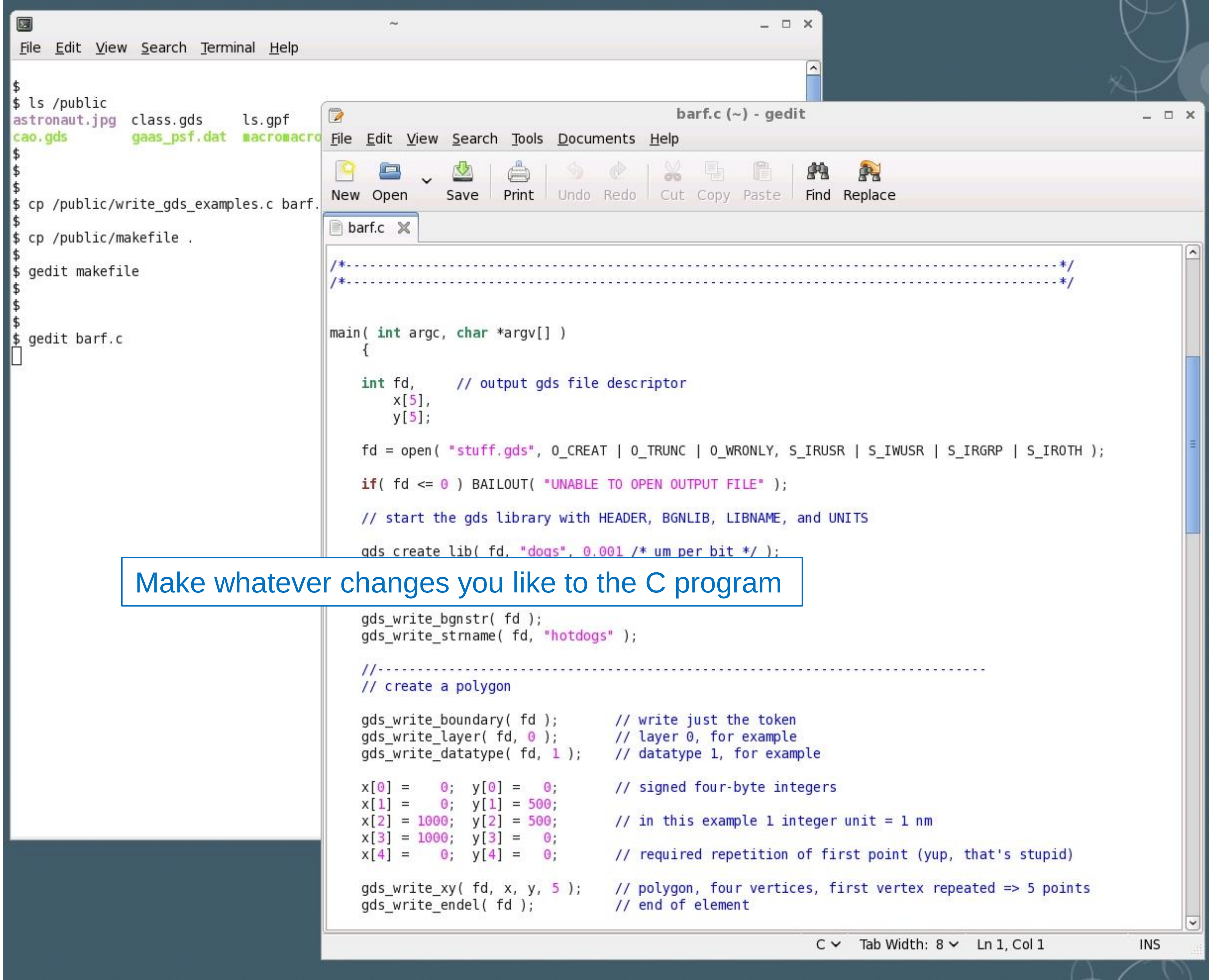
The program

write_gds_examples.c

can be compiled by copying this along with /public/makefile, then

make write_gds_examples


~
File Edit View Search Terminal Help
$
$ ls /public
astronaut.jpg class.gds ls.gpf makefile silicon_psf.dat write_gds_examples.c
cao.gds gaas_psf.dat macromacro.py rings.c wedge10.gpf
$
$
$
$ cp /public/write_gds_examples.c barf.c
$
$ cp /public/makefile .
$
$ gedit makefile
Copy the example to your directory (folder)
Copy the makefile to '.' meaning "here"
Edit the makefile
*makefile (~) - gedit
File Edit View Search Tools Documents Help
New Open Save Print Undo Redo Cut Copy Paste Find Replace
*makefile
rings: rings.o
gcc rings.o -lc -lm -o ring
rings.o: rings.c
gcc -c rings.c
barf: barf.c
gcc -g -o barf barf.c -lm -lc -lgds
We can delete these 5 lines
and replace "make_gds_examples" with "barf"
Makefile Tab Width: 8 Ln 8, Col 28 INS



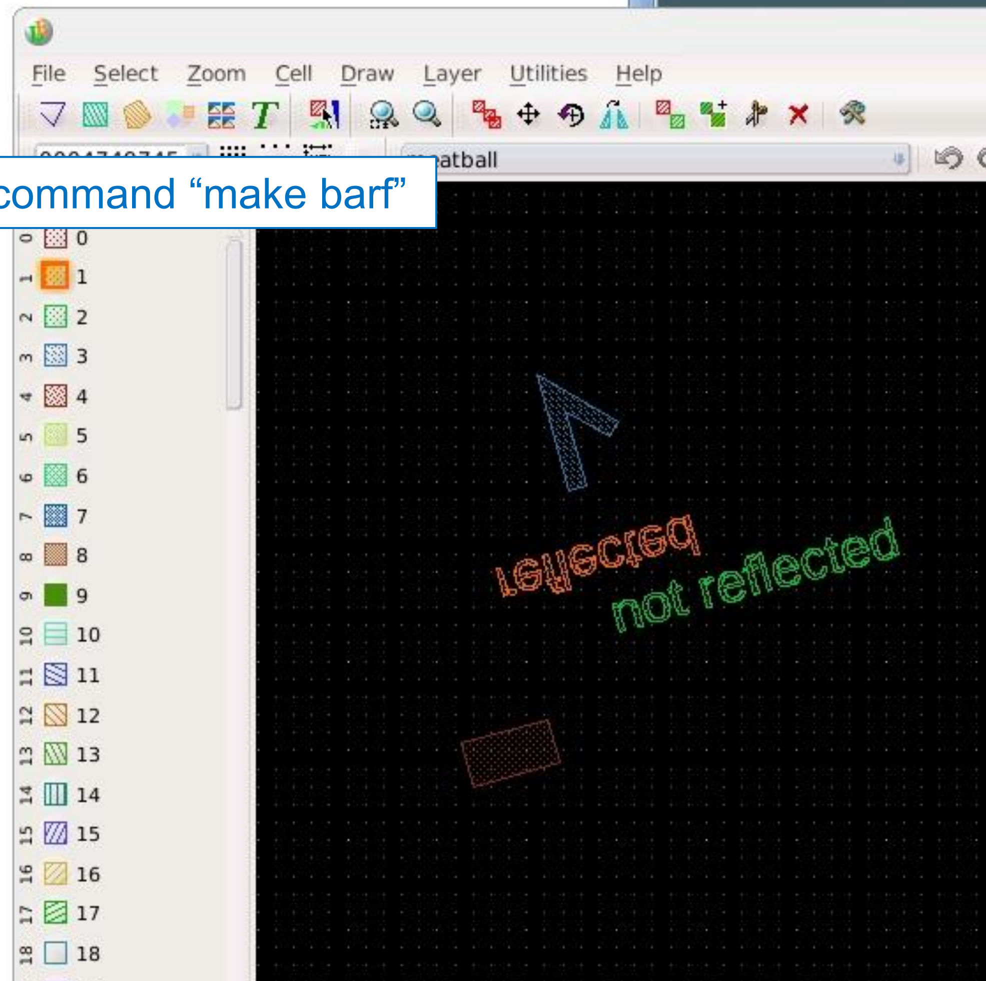
Make whatever changes you like to the C program

```
$
$ ls /public
astronaut.jpg   class.gds     ls.gpf          makefile   silicon_psf.dat   write_gds_examples.c
cao.gds         gaas_psf.dat  macromacro.py   rings.c    wedge10.gpf
$
$
$
$ cp /public/write_gds_examples.c barf.c
$
$ cp /public/makefile .
$
$ gedit makefile
$
$
$
$ gedit barf.c
$
$
$ make barf
gcc -g -o barf barf.c -lm -lc -lgds
$
$
$ ./barf

Done. Look at stuff.gds

$ layout stuff.gds
```

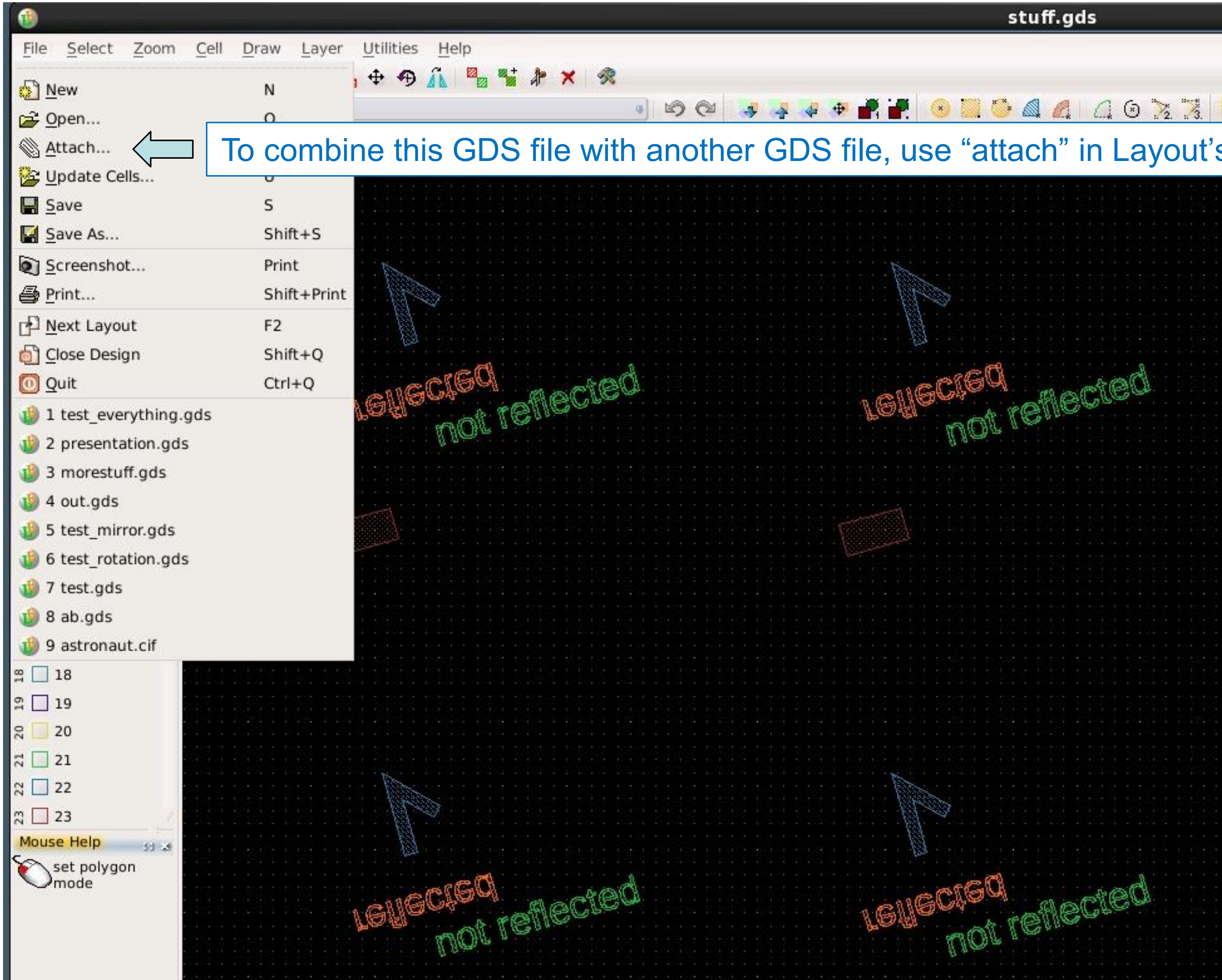
Compile barf.c with the command “make barf”

Run it by typing “barf”

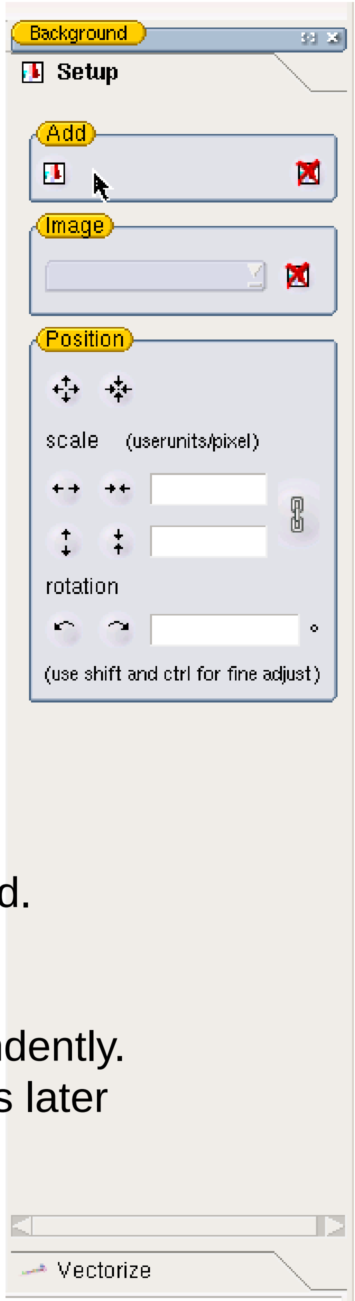
Look at the result with Layout or any other CAD program



To combine this GDS file with another GDS file, use “attach” in Layout’s File menu

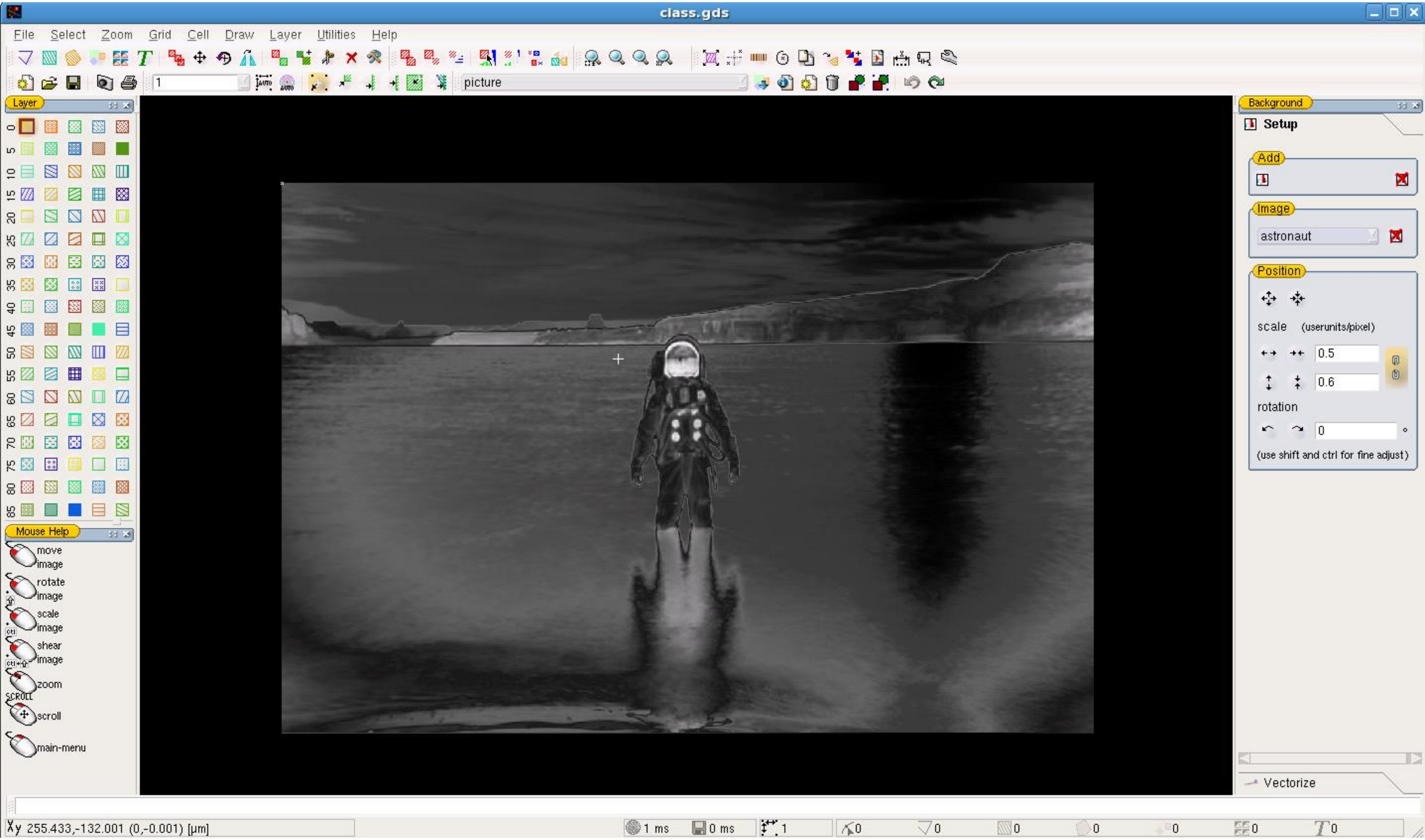


Using microscope images in CAD

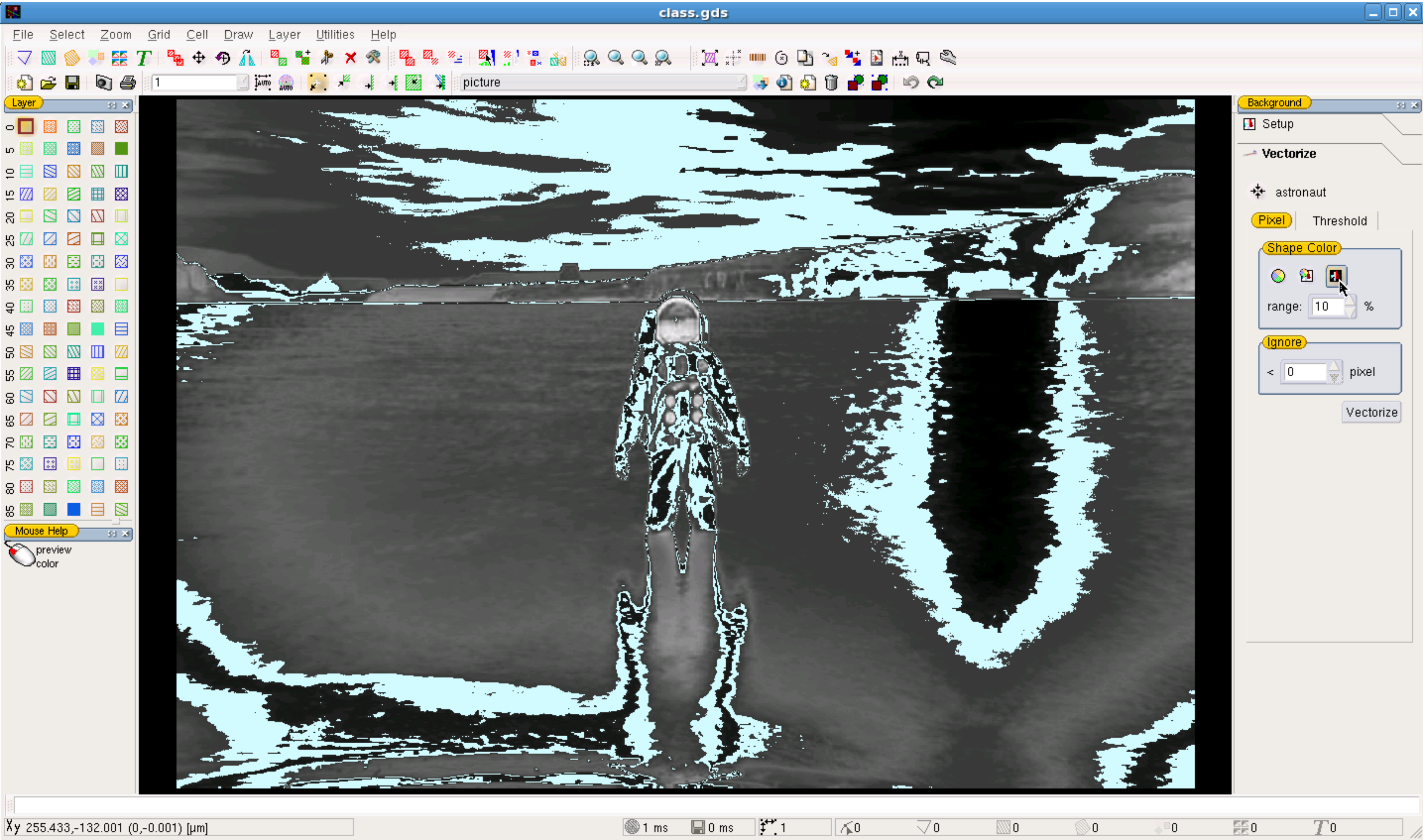


Start by adding an image to the background.
Look in /public for an image.

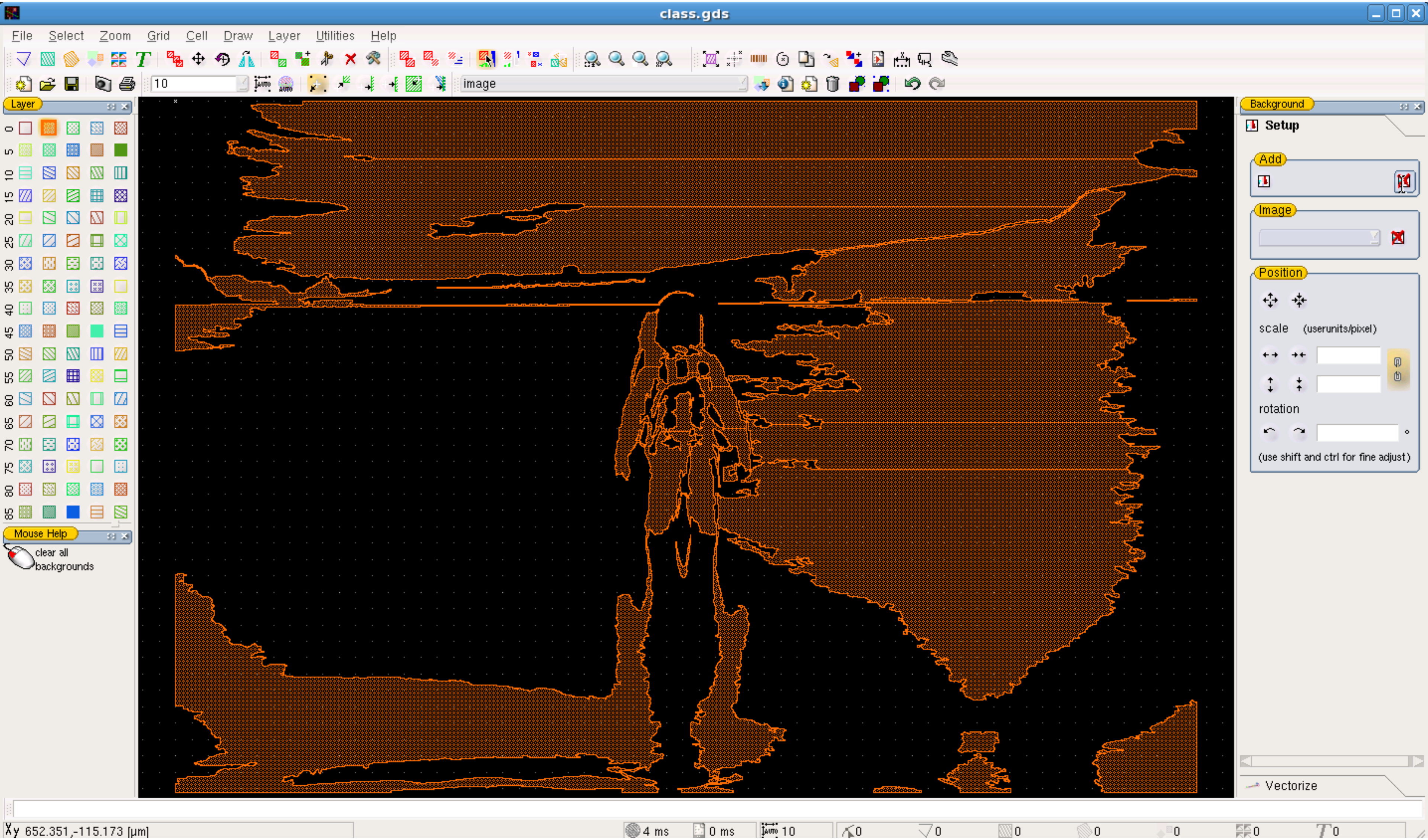
At this step X and Y can be scaled independently.
But rotation does not work right – so do this later
as part of cell placement.



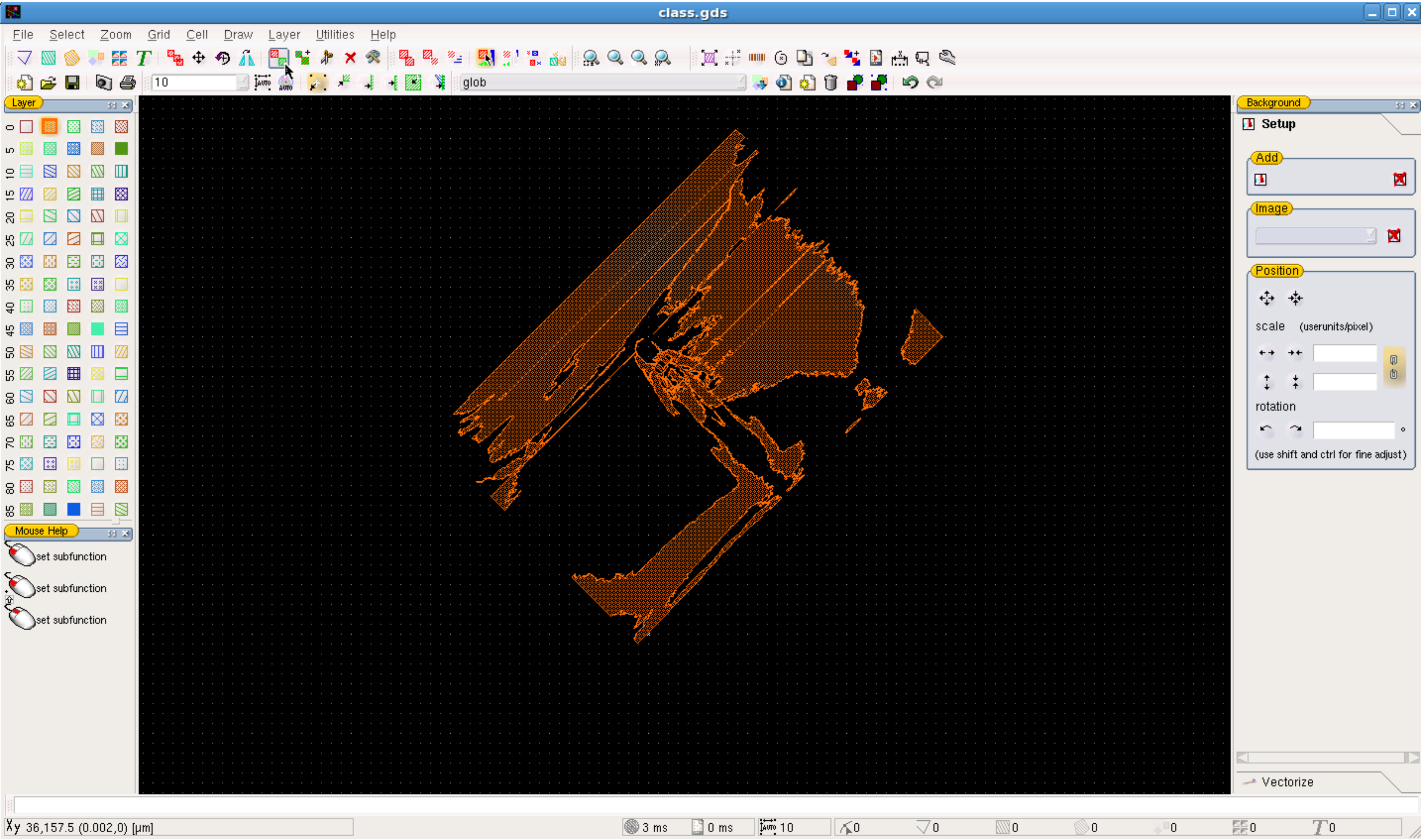
The image can be moved around in the background, but it is not part of the design and it is not inside any particular cell. If you need the image in a cell then use “vectorize”.



In the "vectorize" tab, choose "preview" and adjust the parameters. The chosen threshold will be used to turn the image into polygons. The "pixel" method seems to work better than the "threshold" method. Click on the Vectorize button and wait.



Go back to the Setup tab and delete the background image.
The resulting polygons are in the currently active layer.
Now the image is in a cell which can be scaled, rotated, or even exposed.



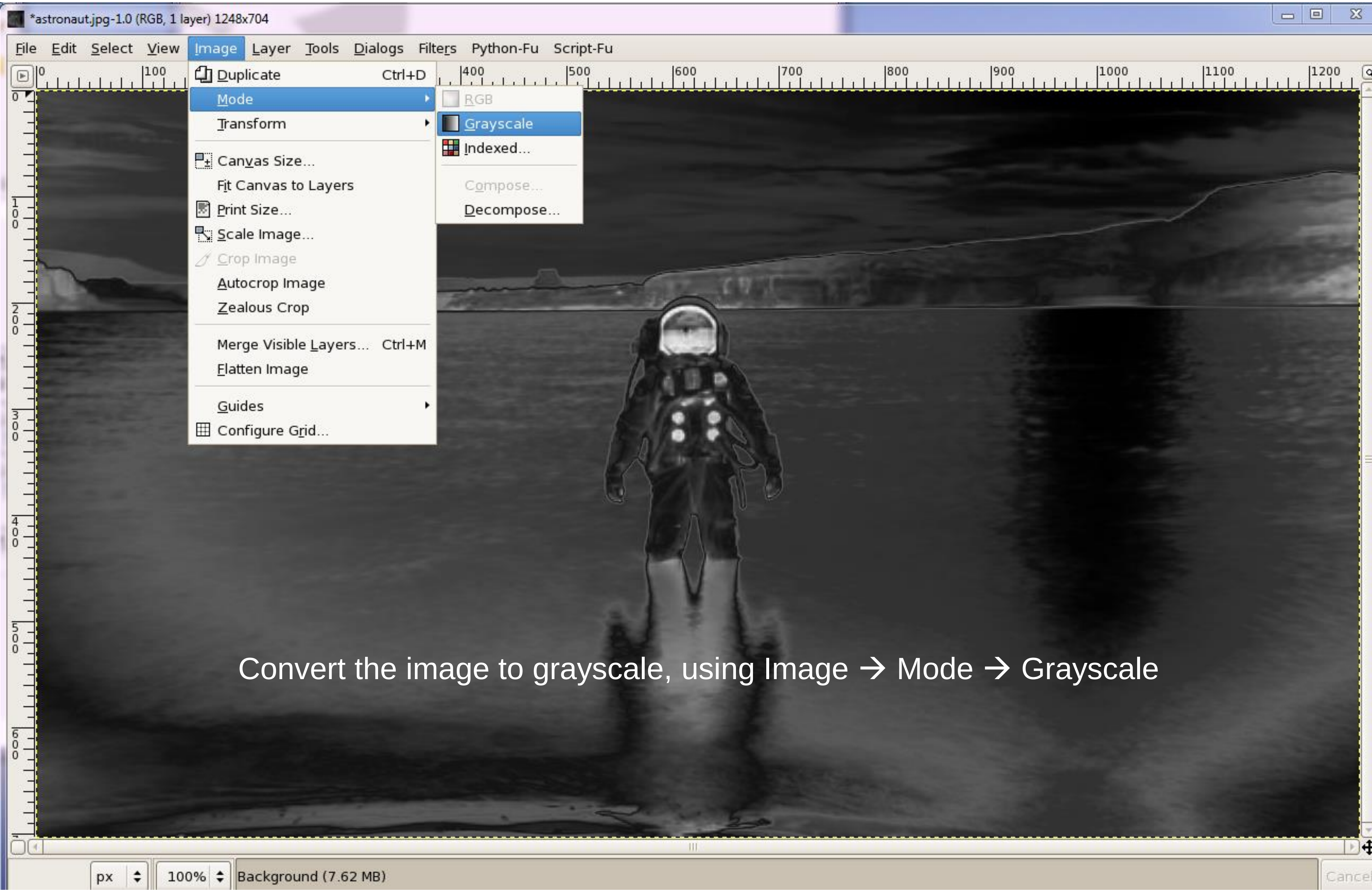
Create a new cell, then place the image cell inside. Select the cell (Page Up key) then right-click to change its properties. This is the best way to do rotation.

Converting images to exposable shapes

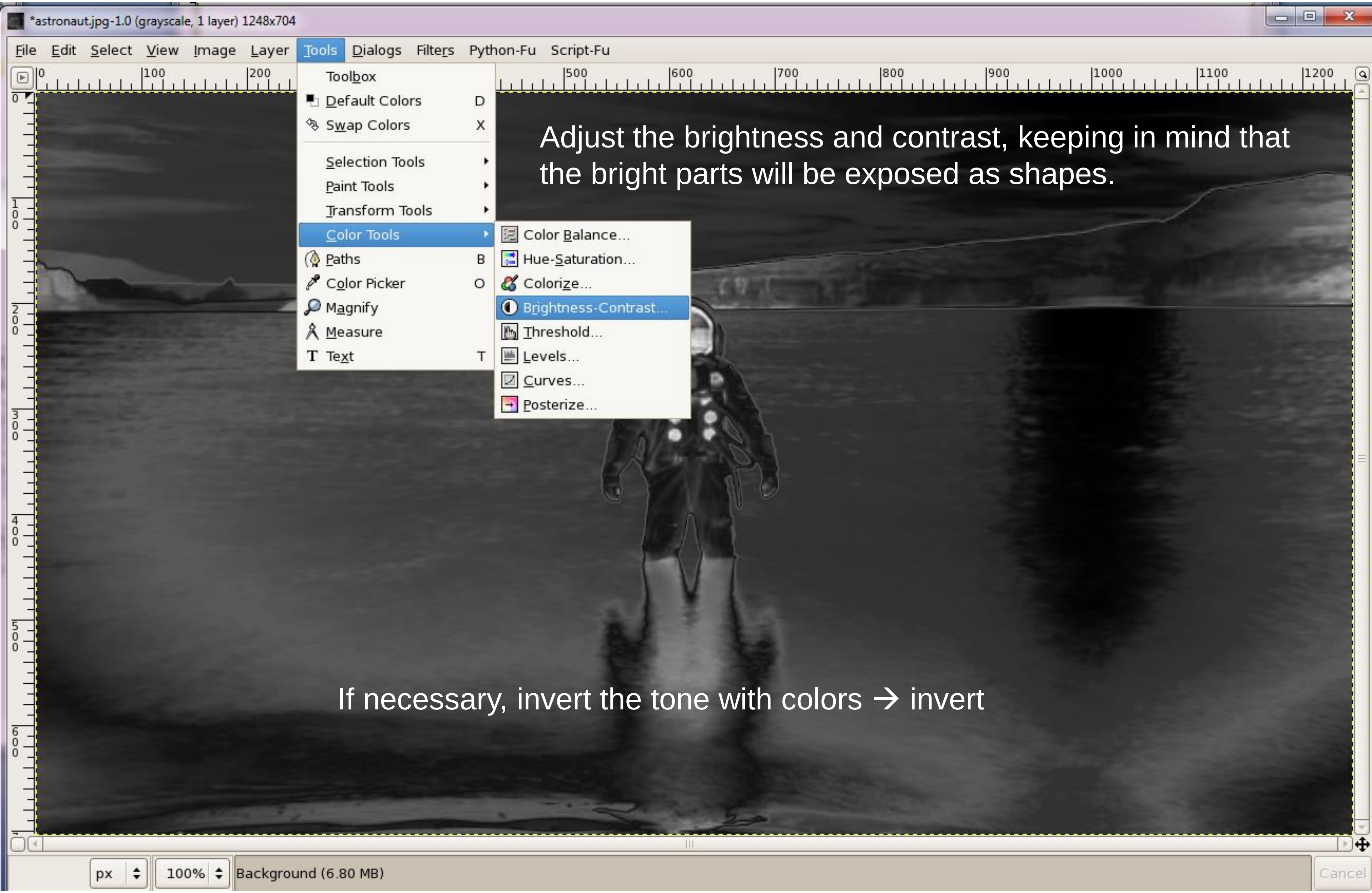
Simple thresholding, as shown above, is not a good way to prepare images for printing with e-beam or photo-lithography.

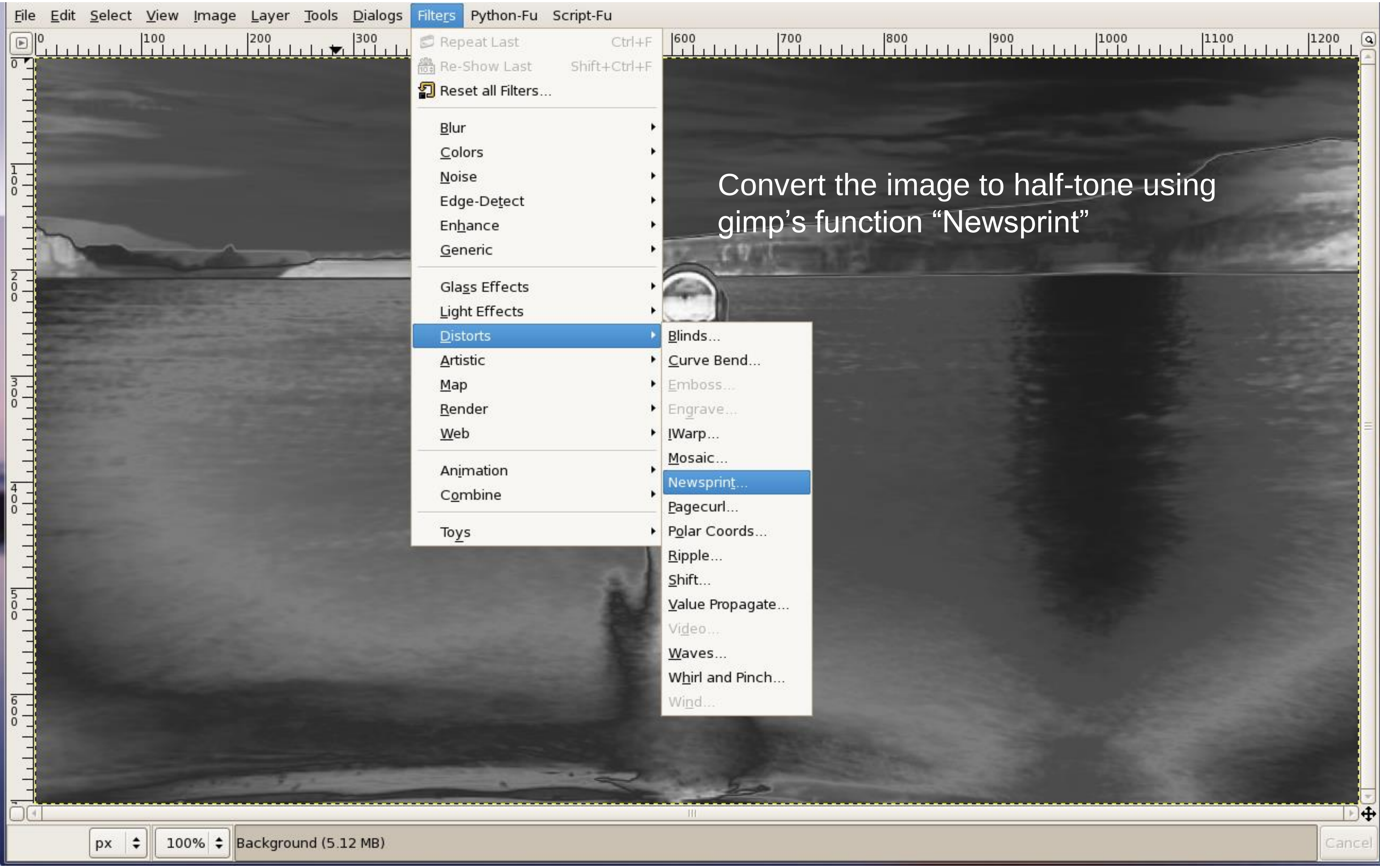
Since you are using a binary tone printing process, the image should be converted to grey-scale, and then the grey scales should be represented by different densities of dots. This dot representation is called “half tone” or “newsprint”.

Start by opening an image in gimp. (You could instead use Photoshop, but this tutorial uses gimp, which is free and runs on any operating system.)

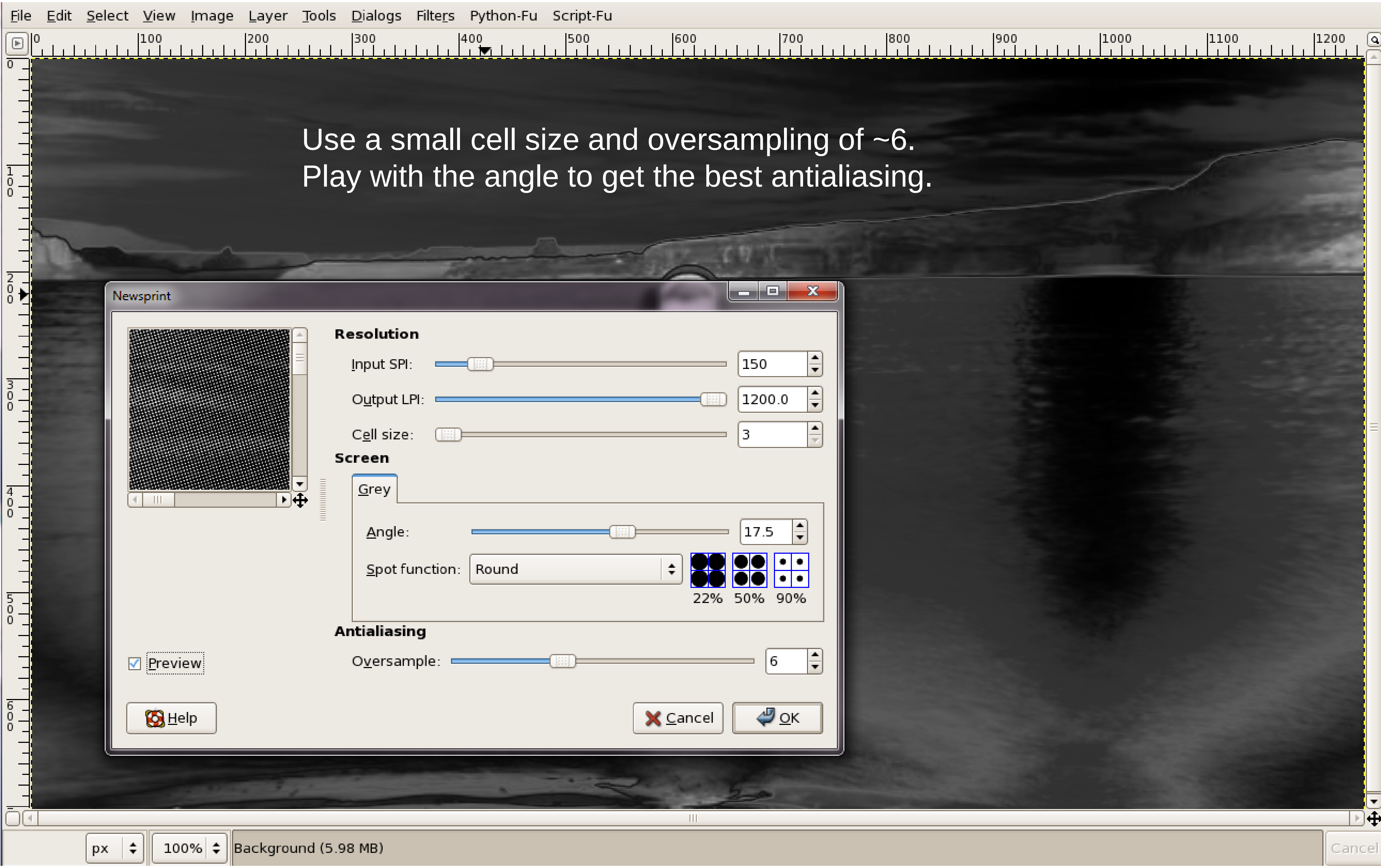


Convert the image to grayscale, using Image → Mode → Grayscale


*astronaut.jpg-1.0 (grayscale, 1 layer) 1248x704
File Edit Select View Image Layer Tools Dialogs Filters Python-Fu Script-Fu
Toolbox
Default Colors D
Swap Colors X
Selection Tools
Paint Tools
Transform Tools
Color Tools
Paths B
Color Picker O
Magnify
Measure
Text T
Color Balance...
Hue-Saturation...
Colorize...
Brightness-Contrast...
Threshold...
Levels...
Curves...
Posterize...
Adjust the brightness and contrast, keeping in mind that the bright parts will be exposed as shapes.
If necessary, invert the tone with colors → invert
px
100%
Background (6.80 MB)
Cancel



Convert the image to half-tone using gimp's function "Newsprint"


File Edit Select View Image Layer Tools Dialogs Filters Python-Fu Script-Fu
Use a small cell size and oversampling of ~6.
Play with the angle to get the best antialiasing.
Newsprint
Resolution
Input SPI: 150
Output LPI: 1200.0
Cell size: 3
Screen
Grey
Angle: 17.5
Spot function: Round
22% 50% 90%
Antialiasing
Oversample: 6
Preview
Help
Cancel
OK
px
100%
Background (5.98 MB)
Cancel


File
Edit
Select
View
Image
Layer
Tools
Dialogs
Filters
Python-Fu
Script-Fu
px
100%
Background (5.98 MB)
Cancel

Save the image in TIFF format (filename.tif)
then convert the bright pixels to polygons
in CIF format.

From a terminal window, use

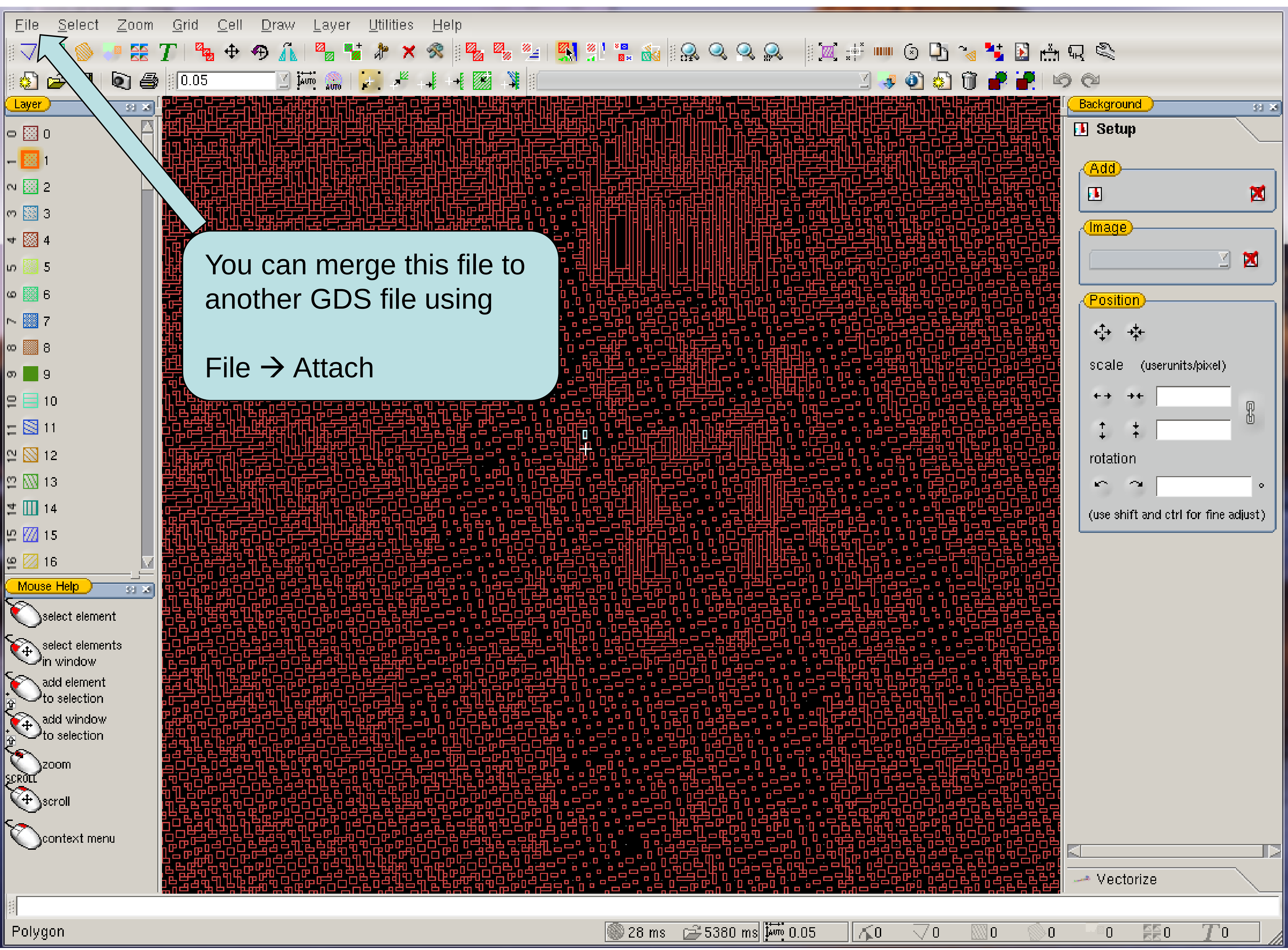
```
tif2gds filename
```

to convert filename.tif to filename.gds

Start the CAD program with the command

```
layout
```

then open the file filename.gds



File Select Zoom Grid Cell Draw Layer Utilities Help
0.05
Layer
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Mouse Help
select element
select elements in window
add element to selection
add window to selection
zoom
SCROLL
scroll
context menu
You can merge this file to another GDS file using
File → Attach
Background
Setup
Add
Image
Position
scale (userunits/pixel)
rotation
(use shift and ctrl for fine adjust)
Vectorize
Polygon
28 ms
5380 ms
0.05