

# The gcodepreview PythonSCAD library\*

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## Abstract

The gcodepreview library allows using PythonSCAD (Python in OpenSCAD) to move a tool in lines and arcs and output DXF and G-code files so as to work as a CAD/CAM program for CNC.

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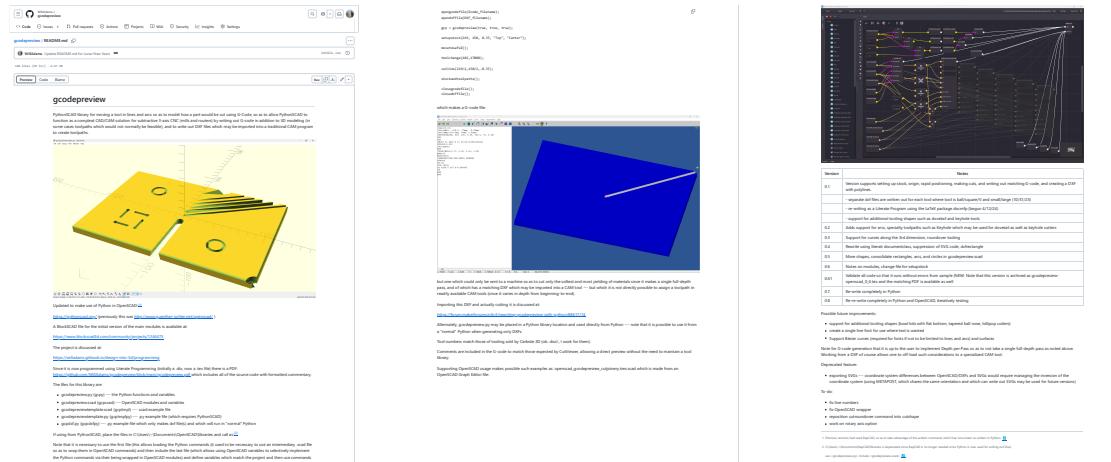
\*This file (gcodepreview) has version number v0.93, last revised 2025/11/30.<sup>1</sup>

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## 1 readme.md



```

1 rdme # gcodepreview
2 rdme
3 rdme OpenPythonSCAD library for moving a tool in lines and arcs so as to
      model how a part would be cut or extruded using G-Code, so as
      to allow use as a compleat CAD/CAM solution for subtractive or
      additive 3-axis CNC (4th-axis support may come in a future
      version) by writing out G-code in addition to 3D modeling (in
      certain cases toolpaths which would not normally be feasible in
      typical tools), and to write out DXF files which may be imported
      into a traditional CAM program to create toolpaths.
4 rdme
5 rdme ! [OpenSCAD gcodepreview Unit Tests](https://raw.githubusercontent.com/WillAdams/gcodepreview/main/gcodepreviewtemplate.png?raw=true)
6 rdme
7 rdme Uses Python in OpenSCAD: https://pythonscad.org/[^pythonscad]
8 rdme
9 rdme [^pythonscad]: Previously this was http://www.guenther-sohler.net/
      openscad/
10 rdme
11 rdme A BlockSCAD file for the initial version of the
12 rdme main modules is available at:
13 rdme
14 rdme https://www.blockscad3d.com/community/projects/1244473
15 rdme
16 rdme The project is discussed at:
17 rdme
18 rdme https://willadams.gitbook.io/design-into-3d/programming
19 rdme
20 rdme Since it is now programmed using Literate Programming (initially a
      .dtx, now a .tex file) there is a PDF: https://github.com/WillAdams/gcodepreview/blob/main/gcodepreview.pdf which includes
      all of the source code with commentary.
21 rdme
22 rdme The files for this library are:
23 rdme
24 rdme - gcodepreview.py (gcpy) --- the Python class/functions and
      variables
25 rdme - gcodepreview.scad (gcpscad) --- OpenSCAD modules and parameters
26 rdme
27 rdme And there several sample/template files which may be used as the
      starting point for a given project:
28 rdme
29 rdme - gcodepreviewtemplate.txt (gcptmpl) --- .txt file collecting all
      commands with brief comments which may be used as a quick
      reference or copy-pasting from
30 rdme - gcodepreviewtemplate.py (gcptmplpy) --- .py example file
31 rdme - gcodepreviewtemplate.scad (gcptmplscad) --- .scad example file
32 rdme - gcpdxf.py (gcpdxfpy) --- .py example file which only makes dxf
      file(s) and which will run in "normal" Python in addition to
      PythonSCAD
33 rdme - gcpgc.py (gcpgc) --- .py example which loads a G-code file and
      generates a 3D preview showing how the G-code will cut
34 rdme
35 rdme Note that additional templates are in: https://github.com/WillAdams/gcodepreview/tree/main/templates
36 rdme
37 rdme If using from PythonSCAD, place the files in C:\Users\\~\Documents

```

```

    \OpenSCAD\libraries or, load them from Github using the command:
38 rdme
39 rdme     nimport("https://raw.githubusercontent.com/WillAdams/
                  gcodepreview/refs/heads/main/gcodepreview.py")
40 rdme
41 rdme If using gcodepreview.scad call as:
42 rdme
43 rdme     use <gcodepreview.py>
44 rdme     include <gcodepreview.scad>
45 rdme
46 rdme Note that it is necessary to use the first file (this allows
      loading the Python commands and then include the last file (
      which allows using OpenSCAD variables to selectively implement
      the Python commands via their being wrapped in OpenSCAD modules)
      and define variables which match the project and then use
      commands such as:
47 rdme
48 rdme     opengcodefile(Gcode_filename);
49 rdme     opendxfile(DXF_filename);
50 rdme
51 rdme     gcp = gcodepreview("cut", true, true);
52 rdme
53 rdme     setupstock(219, 150, 8.35, "Top", "Center");
54 rdme
55 rdme     movetosafeZ();
56 rdme
57 rdme     toolchange(102, 17000);
58 rdme
59 rdme     cutline(219/2, 150/2, -8.35);
60 rdme
61 rdme     stockandtoolpaths();
62 rdme
63 rdme     closegcodefile();
64 rdme     closedxfile();
65 rdme
66 rdme which makes a G-code file:
67 rdme
68 rdme ! [OpenSCAD template G-code file](https://raw.githubusercontent.com/
      WillAdams/gcodepreview/main/gcodepreview_template.png?raw=true)
69 rdme
70 rdme but one which could only be sent to a machine so as to cut only the
      softest and most yielding of materials since it makes a single
      full-depth pass, and which has a matching DXF which may be
      imported into a CAM tool --- but which it is not directly
      possible to assign a toolpath in readily available CAM tools (
      since it varies in depth from beginning-to-end which is not
      included in the DXF since few tools make use of that information
      ).
71 rdme
72 rdme Importing this DXF and actually cutting it is discussed at:
73 rdme
74 rdme https://forum.makerforums.info/t/rewriting-gcodepreview-with-python
      /88617/14
75 rdme
76 rdme Alternately, gcodepreview.py may be placed in a Python library
      location and used directly from Python to generate DXFs as shown
      in gcpdxf.py (generating a 3D preview requires OpenPythonSCAD
      and generating G-code without a preview is not supported).
77 rdme
78 rdme In the current version, tool numbers may match those of tooling
      sold by Carbide 3D (ob. discl., I work for them) and other
      vendors, or, a vendor-neutral system may be worked up and used
      as desired.
79 rdme
80 rdme Comments are included in the G-code to match those expected by
      CutViewer, allowing a direct preview without the need to
      maintain a tool library (for such tooling as that program
      supports).
81 rdme
82 rdme Supporting OpenSCAD usage makes possible such examples as:
      openscad_gcodepreview_cutjoinery.tres.scad which is made from an
      OpenSCAD Graph Editor file:
83 rdme
84 rdme ! [OpenSCAD Graph Editor Cut Joinery File](https://raw.
      githubusercontent.com/WillAdams/gcodepreview/main/
      OSGE_cutjoinery.png?raw=true)
85 rdme
86 rdme | Version | Notes |
```

```

87 rdme | ----- | -----
88 rdme | 0.1           | Version supports setting up stock, origin, rapid
      |           positioning, making cuts, and writing out matching G-code, and
      |           creating a DXF with polylines.
89 rdme |           | - separate dxf files are written out for each
      |           tool where tool is ball/square/V and small/large (10/31/23)
      |
90 rdme |           | - re-writing as a Literate Program using the
      |           LaTeX package docmfp (begun 4/12/24)
      |
91 rdme |           | - support for additional tooling shapes such as
      |           dovetail and keyhole tools
      |
92 rdme | 0.2           | Adds support for arcs, specialty toolpaths such
      |           as Keyhole which may be used for dovetail as well as keyhole
      |           cutters
      |
93 rdme | 0.3           | Support for curves along the 3rd dimension,
      |           roundover tooling
      |
94 rdme | 0.4           | Rewrite using literati documentclass, suppression
      |           of SVG code, dxfractangle
      |
95 rdme | 0.5           | More shapes, consolidate rectangles, arcs, and
      |           circles in gcodepreview.scad
      |
96 rdme | 0.6           | Notes on modules, change file for setupstock
      |
97 rdme | 0.61          | Validate all code so that it runs without errors
      |           from sample (NEW: Note that this version is archived as
      |           gcodepreview-openscad_0_6.tex and the matching PDF is available
      |           as well)
98 rdme | 0.7           | Re-write completely in Python
      |
99 rdme | 0.8           | Re-re-write completely in Python and OpenSCAD,
      |           iteratively testing
      |
100 rdme | 0.801          | Add support for bowl bits with flat bottom
      |
101 rdme | 0.802          | Add support for tapered ball-nose and V tools
      |           with flat bottom
      |
102 rdme | 0.803          | Implement initial color support and joinery
      |           modules (dovetail and full blind box joint modules)
      |
103 rdme | 0.9           | Re-write to use Python lists for 3D shapes for
      |           toolpaths and rapids.
      |
104 rdme | 0.91          | Finish converting to native OpenPythonSCAD
      |           trigonometric functions.
      |
105 rdme | 0.92          | Remove multiple DXFs and unimplemented features,
      |           add hooks for 3D printing.
      |
106 rdme | 0.93          | Initial support for 3D printing.
      |
107 rdme
108 rdme Possible future improvements:
109 rdme
110 rdme - support for 4th-axis
111 rdme - support for post-processors
112 rdme - support for two-sided machining (import an STL or other file to

```

```
use for stock, or possibly preserve the state after one cut and
then rotate the cut stock/part)
113 rdme - support for additional tooling shapes (lollipop cutters)
114 rdme - create a single line font for use where text is wanted
115 rdme - Support for METAPOST and Bézier curves (latter required for
          fonts if not to be limited to lines and arcs) and surfaces
116 rdme
117 rdme Note for G-code generation that it is up to the user to implement
          Depth per Pass so as to not take a single full-depth pass as
          noted above. Working from a DXF of course allows one to off-load
          such considerations to a specialized CAM tool.
118 rdme
119 rdme To-do:
120 rdme
121 rdme - implement skin()
122 rdme - determine why one quadrant of arc command doesn't work in
          OpenSCAD
123 rdme - clock-wise arcs
124 rdme - add toolpath for cutting countersinks using ball-nose tool from
          inside working out
125 rdme - verify OpenSCAD wrapper and add any missing commands for Python
126 rdme - verify support for shaft on tooling
127 rdme - create additional template and sample files
128 rdme - fully implement/verify describing/saving/loading tools using
          CutViewer comments
129 rdme
130 rdme Deprecated features:
131 rdme
132 rdme - exporting SVGs --- coordinate system differences between
          OpenSCAD/DXF and SVGs would require managing the inversion of
          the coordinate system (using METAPOST, which shares the same
          orientation and which can write out SVGs may be used for future
          versions)
133 rdme - using linear/rotate_extrude --- 2D geometry is rotated to match
          the arc of the movement, which is appropriate to a 5-axis
          machine, but not workable for a 3-axis. Adding an option to
          support the use of such commands for horizontal movement is
          within the realm of possibility.
134 rdme - multiple DXF files
135 rdme - RapCAD support
```

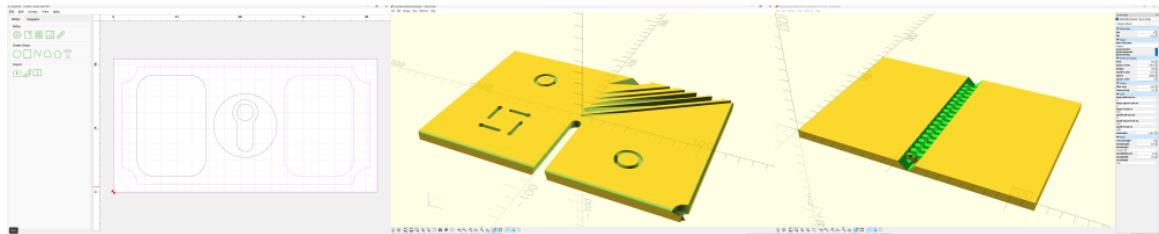
---

## 2 Usage and Templates

The gcodepreview library allows the modeling of 2D geometry and 3D shapes using Python or by calling Python from within Open(Python)SCAD, enabling the creation of 2D DXFs, G-code (which cuts a 2D or 3D part), or 3D models as a preview of how the file will cut. These abilities may be accessed in “plain” Python (to make DXFs), or Python or OpenSCAD in PythonSCAD (to make DXFs, and/or G-code with 3D modeling) for a preview. Providing them in a programmatic context allows making parts or design elements of parts (e.g., joinery) which would be tedious or difficult (or verging on impossible) to draw by hand in a traditional CAD or vector drawing application. A further consideration is that this is “Design for Manufacture” taken to its ultimate extreme, and that a part so designed is inherently manufacturable (so long as the dimensions and radii allow for reasonable tool (and toolpath) geometries).

The various commands are shown all together in templates so as to provide examples of usage, and to ensure that the various files are used/included as necessary, all variables are set up with the correct names (note that the sparse template in `readme.md` eschews variables), and that if enabled, files are opened before being written to, and that each is closed at the end in the correct order. Note that while the template files seem overly verbose, they specifically incorporate variables for each tool shape, possibly in two different sizes, and a feed rate parameter or ratio for each, which may be used (by setting a tool #) or ignored (by leaving the variable for a given tool at zero (0)).

It should be that the `readme` at the project page which serves as an overview, and this section (which serves as a collection of templates and a tutorial) are all the documentation which most users will need (and arguably is still too much). The balance of the document after this section shows all the code and implementation details, and will where appropriate show examples of usage which will be collected in a plain text template file which is concatenated to provide a usable example of each command with (brief) commentary (potentially serving as a how-to guide as well as documenting the code in a minimalistic fashion) as well as Indices (which serve as a front-end for reference).



Some comments on the templates:

- minimal — each is intended as a framework for a minimal working example (MWE) — it should be possible to comment out unused/unneeded portions and so arrive at code which tests any aspect of this project and which may be used as a starting point for a new part/project
- compleat — a quite wide variety of tools are listed (and probably more will be added in the future), but pre-defining them and having these “hooks” seems the easiest mechanism to handle the requirements of subtractive machining.
- shortcuts — as the various examples show, while in real life it is necessary to make many passes with a tool, an expedient efficiency is to forgo the `loop` operation and just use a `hull()` operation and avoid the requirement of implementing Depth per Pass (but note that this will lose the previewing of scalloped tool marks in places where they might appear otherwise)

One fundamental aspect of this tool is the question of *Layers of Abstraction* (as put forward by Dr. Donald Knuth as the crux of computer science) and *Problem Decomposition* (Prof. John Ousterhout’s answer to that question). To a great degree, the basic implementation of this tool will use G-code as a reference implementation, simultaneously using the abstraction from the mechanical task of machining which it affords as a decomposed version of that task, and creating what is in essence, both a front-end, and a tool, and an API for working with G-code programmatically. This then requires an architecture which allows 3D modeling (OpenSCAD), and writing out files (Python).

Further features will be added to the templates as they are created, and the main image updated to reflect the capabilities of the system.

### 2.1 gcpdxf.py

The most basic usage, with the fewest dependencies is to use “plain” Python to create dxf files. Note that this example includes an optional command `nimport(<URL>)` which if enabled/uncommented (and the following line commented out), will allow one to use OpenPythonSCAD to import the library from Github, sidestepping the need to download and install the library into an installation of OpenPythonSCAD locally. Usage in “normal” Python will require manually installing the `gcodepreview.py` file where Python can find it. A further consideration is where the file will be placed if the full path is not enumerated, the Desktop is the default destination for Microsoft Windows.

---

```

1 gcpdxfpy from openscad import *
2 gcpdxfpy      # nimport("https://raw.githubusercontent.com/WillAdams/
                  gcodepreview/refs/heads/main/gcodepreview.py")
3 gcpdxfpy from gcodepreview import *
4 gcpdxfpy
5 gcpdxfpy gcp = gcodepreview("no_preview", # "cut" or "print"
6 gcpdxfpy                      False, # generategcode
7 gcpdxfpy                      True   # generatedxf
8 gcpdxfpy
9 gcpdxfpy
10 gcpdxfpy # [Stock] */
11 gcpdxfpy stockXwidth = 100
12 gcpdxfpy # [Stock] */
13 gcpdxfpy stockYheight = 50
14 gcpdxfpy
15 gcpdxfpy # [Export] */
16 gcpdxfpy Base_filename = "gcpdxf"
17 gcpdxfpy
18 gcpdxfpy
19 gcpdxfpy # [CAM] */
20 gcpdxfpy large_square_tool_num = 102
21 gcpdxfpy # [CAM] */
22 gcpdxfpy small_square_tool_num = 0
23 gcpdxfpy # [CAM] */
24 gcpdxfpy large_ball_tool_num = 0
25 gcpdxfpy # [CAM] */
26 gcpdxfpy small_ball_tool_num = 0
27 gcpdxfpy # [CAM] */
28 gcpdxfpy large_V_tool_num = 0
29 gcpdxfpy # [CAM] */
30 gcpdxfpy small_V_tool_num = 0
31 gcpdxfpy # [CAM] */
32 gcpdxfpy DT_tool_num = 374
33 gcpdxfpy # [CAM] */
34 gcpdxfpy KH_tool_num = 0
35 gcpdxfpy # [CAM] */
36 gcpdxfpy Roundover_tool_num = 0
37 gcpdxfpy # [CAM] */
38 gcpdxfpy MISC_tool_num = 0
39 gcpdxfpy
40 gcpdxfpy # [Design] */
41 gcpdxfpy inset = 3
42 gcpdxfpy # [Design] */
43 gcpdxfpy radius = 6
44 gcpdxfpy # [Design] */
45 gcpdxfpy cornerstyle = "Fillet" # "Chamfer", "Flipped Fillet"
46 gcpdxfpy
47 gcpdxfpy gcp.opendxf(file(Base_filename))
48 gcpdxfpy
49 gcpdxfpy gcp.dxfrctangle(large_square_tool_num, 0, 0, stockXwidth,
                           stockYheight)
50 gcpdxfpy
51 gcpdxfpy gcp.setdxfcolor("Red")
52 gcpdxfpy
53 gcpdxfpy gcp.dxfarc(large_square_tool_num, inset, inset, radius, 0, 90)
54 gcpdxfpy gcp.dxfarc(large_square_tool_num, stockXwidth - inset, inset,
                       radius, 90, 180)
55 gcpdxfpy gcp.dxfarc(large_square_tool_num, stockXwidth - inset, stockYheight
                       - inset, radius, 180, 270)
56 gcpdxfpy gcp.dxfarc(large_square_tool_num, inset, stockYheight - inset,
                       radius, 270, 360)
57 gcpdxfpy
58 gcpdxfpy gcp.dxfline(large_square_tool_num, inset, inset + radius, inset,
                        stockYheight - (inset + radius))
59 gcpdxfpy gcp.dxfline(large_square_tool_num, inset + radius, inset,
                        stockXwidth - (inset + radius), inset)
60 gcpdxfpy gcp.dxfline(large_square_tool_num, stockXwidth - inset, inset +
                        radius, stockXwidth - inset, stockYheight - (inset + radius))
61 gcpdxfpy gcp.dxfline(large_square_tool_num, inset + radius, stockYheight -
                        inset, stockXwidth - (inset + radius), stockYheight - inset)
62 gcpdxfpy
63 gcpdxfpy gcp.setdxfcolor("Blue")
64 gcpdxfpy
65 gcpdxfpy gcp.dxfrctangle(large_square_tool_num, radius + inset, radius,
                           stockXwidth/2 - (radius * 4), stockYheight - (radius * 2),
                           cornerstyle, radius)
66 gcpdxfpy gcp.dxfrctangle(large_square_tool_num, stockXwidth/2 + (radius *
                           2) + inset, radius, stockXwidth/2 - (radius * 4), stockYheight -
                           inset)

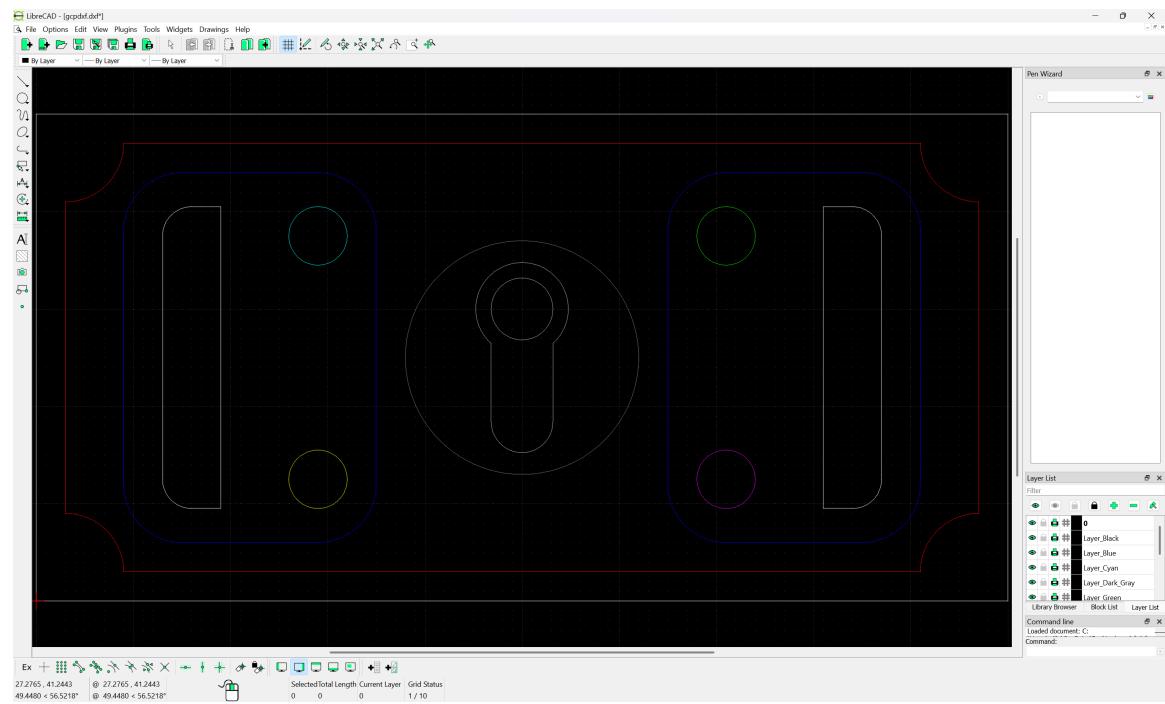
```

```

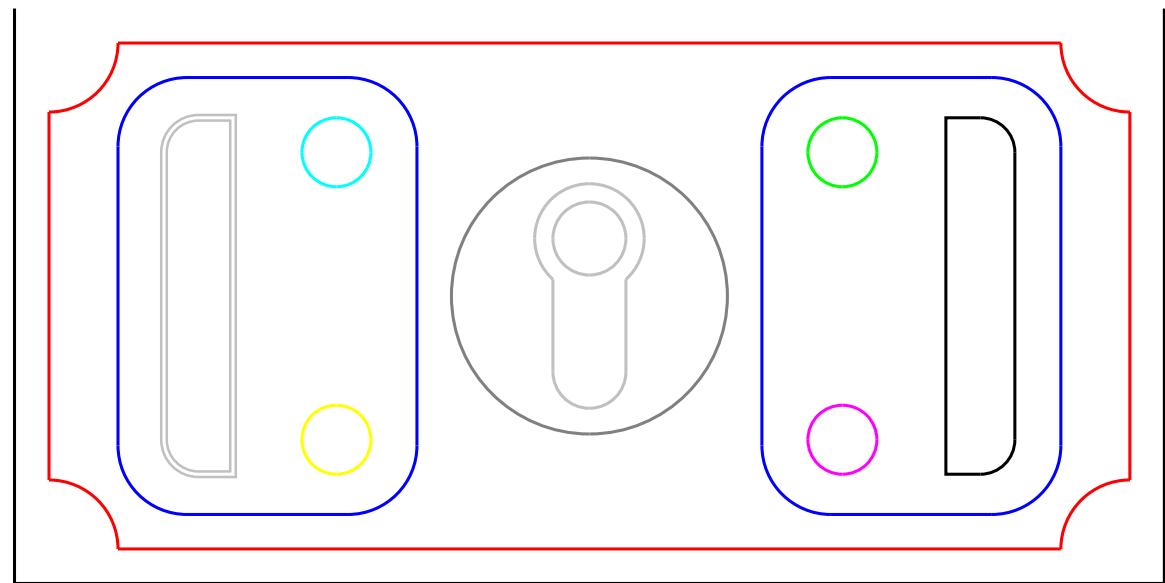
(radius * 2), cornerstyle, radius)
67 gcpdxfpy
68 gcpdxfpy gcp.setdxfcolor("Black")
69 gcpdxfpy
70 gcpdxfpy gcp.beginpolyline(large_square_tool_num)
71 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.75+radius*1.5,
    stockYheight/4-radius/2)
72 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.75+radius,
    stockYheight/4-radius/2)
73 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.75+radius,
    stockYheight*0.75+radius/2)
74 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.75+radius*1.5,
    stockYheight*0.75+radius/2)
75 gcpdxfpy gcp.closepolyline(large_square_tool_num)
76 gcpdxfpy
77 gcpdxfpy gcp.dxfarc(large_square_tool_num, stockXwidth*0.75+radius*1.5,
    stockYheight*0.75, radius/2, 0, 90)
78 gcpdxfpy
79 gcpdxfpy gcp.beginpolyline(large_square_tool_num)
80 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.75+radius*2,
    stockYheight*0.75)
81 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.75+radius*2,
    stockYheight/4)
82 gcpdxfpy gcp.closepolyline(large_square_tool_num)
83 gcpdxfpy
84 gcpdxfpy gcp.dxfarc(large_square_tool_num, stockXwidth*0.75+radius*1.5,
    stockYheight/4, radius/2, 270, 360)
85 gcpdxfpy
86 gcpdxfpy gcp.setdxfcolor("White")
87 gcpdxfpy
88 gcpdxfpy gcp.beginpolyline(large_square_tool_num)
89 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.25-radius*1.5,
    stockYheight/4-radius/2)
90 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.25-radius,
    stockYheight/4-radius/2)
91 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.25-radius,
    stockYheight*0.75+radius/2)
92 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.25-radius*1.5,
    stockYheight*0.75+radius/2)
93 gcpdxfpy gcp.closepolyline(large_square_tool_num)
94 gcpdxfpy
95 gcpdxfpy gcp.dxfarc(large_square_tool_num, stockXwidth*0.25-radius*1.5,
    stockYheight*0.75, radius/2, 90, 180)
96 gcpdxfpy
97 gcpdxfpy gcp.beginpolyline(large_square_tool_num)
98 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.25-radius*2,
    stockYheight*0.75)
99 gcpdxfpy gcp.addvertex(large_square_tool_num, stockXwidth*0.25-radius*2,
    stockYheight/4)
100 gcpdxfpy gcp.closepolyline(large_square_tool_num)
101 gcpdxfpy
102 gcpdxfpy gcp.dxfarc(large_square_tool_num, stockXwidth*0.25-radius*1.5,
    stockYheight/4, radius/2, 180, 270)
103 gcpdxfpy
104 gcpdxfpy gcp.setdxfcolor("Yellow")
105 gcpdxfpy gcp.dxfcircle(large_square_tool_num, stockXwidth/4+1+radius/2,
    stockYheight/4, radius/2)
106 gcpdxfpy
107 gcpdxfpy gcp.setdxfcolor("Green")
108 gcpdxfpy gcp.dxfcircle(large_square_tool_num, stockXwidth*0.75-(1+radius/2),
    stockYheight*0.75, radius/2)
109 gcpdxfpy
110 gcpdxfpy gcp.setdxfcolor("Cyan")
111 gcpdxfpy gcp.dxfcircle(large_square_tool_num, stockXwidth/4+1+radius/2,
    stockYheight*0.75, radius/2)
112 gcpdxfpy
113 gcpdxfpy gcp.setdxfcolor("Magenta")
114 gcpdxfpy gcp.dxfcircle(large_square_tool_num, stockXwidth*0.75-(1+radius/2),
    stockYheight/4, radius/2)
115 gcpdxfpy
116 gcpdxfpy gcp.setdxfcolor("DarkGray")
117 gcpdxfpy
118 gcpdxfpy gcp.dxfcircle(large_square_tool_num, stockXwidth/2, stockYheight/2,
    radius * 2)
119 gcpdxfpy
120 gcpdxfpy gcp.setdxfcolor("LightGray")
121 gcpdxfpy
122 gcpdxfpy gcp.dxfKH(374, stockXwidth/2, stockYheight/5*3, 0, -7, 270,
    
```

```
11.5875)
123 gcpdxfpy
124 gcpdxfpy gcp.closedxfile()
```

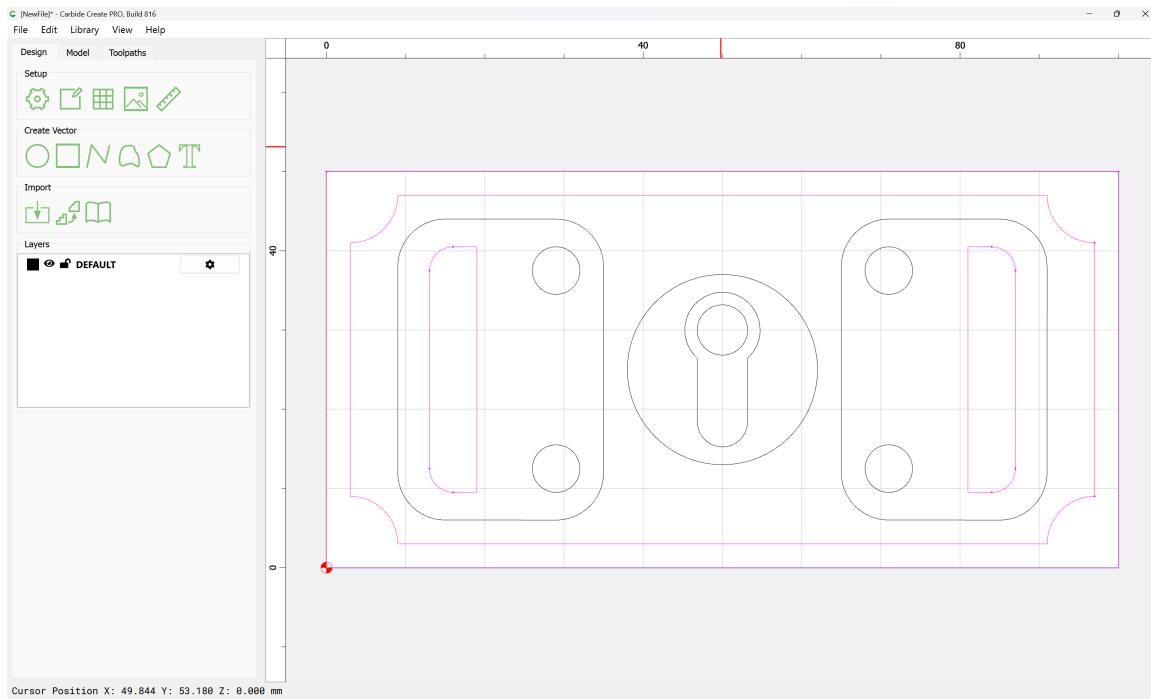
which creates a .dxf file which may be imported into any CAD program:



with the appearance (once converted into a .svg and then re-saved as a .pdf and edited so as to show the white elements):



and which may be imported into pretty much any CAD or CAM application, e.g., Carbide Create:



As shown/implied by the above code, the following commands/shapes are implemented:

- dxfrectangle (specify lower-left corner location and width (X)/height(Y))
  - dxfrectangleround (specified as “Fillet” and radius for the round option)
  - dxfrectanglechamfer (specified as “Chamfer” and radius for the round option)
  - dxfrectangleflippedfillet (specified as “Flipped Fillet” and radius for the option)
- dxfcircle (specifying their center and radius)
- dxfline (specifying begin/end points)
- dxfarcc (specifying arc center, radius, and beginning/ending angles)
- dxfKH (specifying origin, depth, angle, distance)

## 2.2 gpcutdxf.py

A notable limitation of the above is that there is no interactivity — the .dxf file is generated, then must be opened and the result of the run checked (if there is a DXF viewer/editor which will live-reload the file based on it being updated that would be obviated). Reworking the commands for a simplified version of the above design so as to show a 3D model in OpenPythonSCAD is a straight-forward task:

---

```

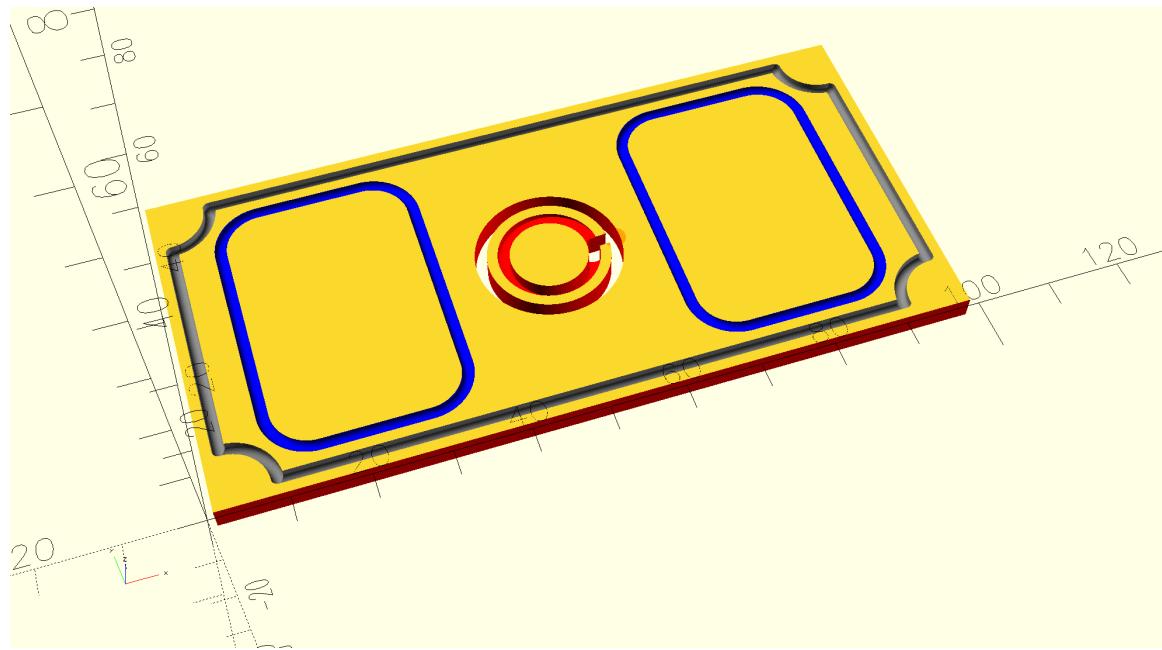
1 gpcutdxfpy from openscad import *
2 gpcutdxfpy # nimport("https://raw.githubusercontent.com/WillAdams/gcodepreview
   /refs/heads/main/gcodepreview.py")
3 gpcutdxfpy from gcodepreview import *
4 gpcutdxfpy
5 gpcutdxfpy fa = 2
6 gpcutdxfpy fs = 0.125
7 gpcutdxfpy
8 gpcutdxfpy gcp = gcodepreview("cut", # "print" or "no_preview"
   False, # generategcode
10 gpcutdxfpy True # generatedxf
11 gpcutdxfpy )
12 gpcutdxfpy
13 gpcutdxfpy # [Stock] */
14 gpcutdxfpy stockXwidth = 100
15 gpcutdxfpy # [Stock] */
16 gpcutdxfpy stockYheight = 50
17 gpcutdxfpy # [Stock] */
18 gpcutdxfpy stockZthickness = 3.175
19 gpcutdxfpy # [Stock] */
20 gpcutdxfpy zeroheight = "Top" # [Top, Bottom]
21 gpcutdxfpy # [Stock] */
22 gpcutdxfpy stockzero = "Lower-Left" # [Lower-Left, Center-Left, Top-Left,
   Center]
23 gpcutdxfpy # [Stock] */
24 gpcutdxfpy retractheight = 3.175
25 gpcutdxfpy
26 gpcutdxfpy # [Export] */

```



```
radius, 0, stockXwidth/2 - (radius * 4), stockYheight - (radius * 2), -stockZthickness/4, radius)
96 gpcutdxfpy
97 gpcutdxfpy gcp.rapid(stockXwidth/2 + (radius * 2) + inset + radius, radius, 0,
    "laser")
98 gpcutdxfpy
99 gpcutdxfpy gcp.cutrectanglerounddx( large_square_tool_num, stockXwidth/2 +
    radius * 2) + inset, radius, 0, stockXwidth/2 - (radius * 4),
    stockYheight - (radius * 2), -stockZthickness/4, radius)
100 gpcutdxfpy
101 gpcutdxfpy gcp.setdxfcolor("Red")
102 gpcutdxfpy
103 gpcutdxfpy gcp.rapid(stockXwidth/2 + radius, stockYheight/2, 0, "laser")
104 gpcutdxfpy
105 gpcutdxfpy gcp.toolchange(large_square_tool_num)
106 gpcutdxfpy
107 gpcutdxfpy gcp.cutcircleCC(stockXwidth/2, stockYheight/2, 0, -stockZthickness,
    radius)
108 gpcutdxfpy
109 gpcutdxfpy gcp.cutcircleCC(stockXwidth/2, stockYheight/2, -stockZthickness,
    -stockZthickness, radius*1.5)
110 gpcutdxfpy
111 gpcutdxfpy gcp.closedxfile()
112 gpcutdxfpy
113 gpcutdxfpy gcp.stockandtoolpaths()
```

which creates the design:



and which allows an interactive usage in working up a design such as for lasercutting, and which incorporates an option to the `rapid(x,y,z)` command which simulates turning a laser off, repositioning, then powering up the laser to resume cutting at the new position.

## 2.3 gcodepreviewtemplate.py

Note that since the v0.7 re-write, it is possible to directly use the underlying Python code. Using Python to generate 3D previews of how DXF or G-code will cut requires the use of PythonSCAD.

```
1 gcptmplpy #!/usr/bin/env python
2 gcptmplpy
3 gcptmplpy import sys
4 gcptmplpy
5 gcptmplpy try:
6 gcptmplpy     if 'gcodepreview' in sys.modules:
7 gcptmplpy         del sys.modules['gcodepreview']
8 gcptmplpy except AttributeError:
9 gcptmplpy     pass
10 gcptmplpy
11 gcptmplpy from gcodepreview import *
12 gcptmplpy
13 gcptmplpy fa = 2
14 gcptmplpy fs = 0.125
15 gcptmplpy
16 gcptmplpy # [Export] */
17 gcptmplpy Base_filename = "aexport"
```

```

18 gcptmplpy # [Export] */
19 gcptmplpy generatedxf = True
20 gcptmplpy # [Export] */
21 gcptmplpy generategcode = True
22 gcptmplpy
23 gcptmplpy # [Stock] */
24 gcptmplpy stockXwidth = 220
25 gcptmplpy # [Stock] */
26 gcptmplpy stockYheight = 150
27 gcptmplpy # [Stock] */
28 gcptmplpy stockZthickness = 8.35
29 gcptmplpy # [Stock] */
30 gcptmplpy zeroheight = "Top" # [Top, Bottom]
31 gcptmplpy # [Stock] */
32 gcptmplpy stockzero = "Center" # [Lower-Left, Center-Left, Top-Left, Center]
33 gcptmplpy # [Stock] */
34 gcptmplpy retractheight = 9
35 gcptmplpy
36 gcptmplpy # [CAM] */
37 gcptmplpy toolradius = 1.5875
38 gcptmplpy # [CAM] */
39 gcptmplpy large_square_tool_num = 201 # [0:0, 112:112, 102:102, 201:201]
40 gcptmplpy # [CAM] */
41 gcptmplpy small_square_tool_num = 102 # [0:0, 122:122, 112:112, 102:102]
42 gcptmplpy # [CAM] */
43 gcptmplpy large_ball_tool_num = 202 # [0:0, 111:111, 101:101, 202:202]
44 gcptmplpy # [CAM] */
45 gcptmplpy small_ball_tool_num = 101 # [0:0, 121:121, 111:111, 101:101]
46 gcptmplpy # [CAM] */
47 gcptmplpy large_V_tool_num = 301 # [0:0, 301:301, 690:690]
48 gcptmplpy # [CAM] */
49 gcptmplpy small_V_tool_num = 390 # [0:0, 390:390, 301:301]
50 gcptmplpy # [CAM] */
51 gcptmplpy DT_tool_num = 814 # [0:0, 814:814, 808079:808079]
52 gcptmplpy # [CAM] */
53 gcptmplpy KH_tool_num = 374 # [0:0, 374:374, 375:375, 376:376, 378:378]
54 gcptmplpy # [CAM] */
55 gcptmplpy Roundover_tool_num = 56142 # [56142:56142, 56125:56125, 1570:1570]
56 gcptmplpy # [CAM] */
57 gcptmplpy MISC_tool_num = 0 # [501:501, 502:502, 45982:45982]
58 gcptmplpy #501 https://shop.carbide3d.com/collections/cutters/products/501-
    engraving-bit
59 gcptmplpy #502 https://shop.carbide3d.com/collections/cutters/products/502-
    engraving-bit
60 gcptmplpy #204 tapered ball nose 0.0625", 0.2500", 1.50", 3.6"
61 gcptmplpy #304 tapered ball nose 0.1250", 0.2500", 1.50", 2.4"
62 gcptmplpy #648 threadmill_shaft(2.4, 0.75, 18)
63 gcptmplpy #45982 Carbide Tipped Bowl & Tray 1/4 Radius x 3/4 Dia x 5/8 x 1/4
    Inch Shank
64 gcptmplpy #13921 https://www.amazon.com/Yonico-Groove-Bottom-Router-Degree/dp
    /B0CPJPTMPP
65 gcptmplpy
66 gcptmplpy # [Feeds and Speeds] */
67 gcptmplpy plunge = 100
68 gcptmplpy # [Feeds and Speeds] */
69 gcptmplpy feed = 400
70 gcptmplpy # [Feeds and Speeds] */
71 gcptmplpy speed = 16000
72 gcptmplpy # [Feeds and Speeds] */
73 gcptmplpy small_square_ratio = 0.75 # [0.25:2]
74 gcptmplpy # [Feeds and Speeds] */
75 gcptmplpy large_ball_ratio = 1.0 # [0.25:2]
76 gcptmplpy # [Feeds and Speeds] */
77 gcptmplpy small_ball_ratio = 0.75 # [0.25:2]
78 gcptmplpy # [Feeds and Speeds] */
79 gcptmplpy large_V_ratio = 0.875 # [0.25:2]
80 gcptmplpy # [Feeds and Speeds] */
81 gcptmplpy small_V_ratio = 0.625 # [0.25:2]
82 gcptmplpy # [Feeds and Speeds] */
83 gcptmplpy DT_ratio = 0.75 # [0.25:2]
84 gcptmplpy # [Feeds and Speeds] */
85 gcptmplpy KH_ratio = 0.75 # [0.25:2]
86 gcptmplpy # [Feeds and Speeds] */
87 gcptmplpy RO_ratio = 0.5 # [0.25:2]
88 gcptmplpy # [Feeds and Speeds] */
89 gcptmplpy MISC_ratio = 0.5 # [0.25:2]
90 gcptmplpy
91 gcptmplpy # Note that the various ratios are simply declared as a possible

```

```

        hook
92 gcptmplpy # which might be useful and how are handled is left as an exercise
93 gcptmplpy # for the reader and that they are not applied below.
94 gcptmplpy # One naive option might be to multiply by the feed rate
95 gcptmplpy # and divide by speeds.
96 gcptmplpy
97 gcptmplpy gcp = gcodepreview("cut", # "print" or "no_preview"
98 gcptmplpy                         generategcode,
99 gcptmplpy                         generatedxf,
100 gcptmplpy                        )
101 gcptmplpy
102 gcptmplpy gcp.opengcodefile(Base_filename)
103 gcptmplpy gcp.opendxfxf(file(Base_filename))
104 gcptmplpy
105 gcptmplpy gcp.setupstock(stockXwidth, stockYheight, stockZthickness,
                           zeroheight, stockzero, retractheight)
106 gcptmplpy
107 gcptmplpy gcp.movetosafeZ()
108 gcptmplpy
109 gcptmplpy gcp.toolchange(102, 10000 * small_square_ratio)
110 gcptmplpy
111 gcptmplpy gcp.rapidZ(0)
112 gcptmplpy
113 gcptmplpy gcp.cutlinedxfgc(stockXwidth/2, stockYheight/2, -stockZthickness)
114 gcptmplpy
115 gcptmplpy gcp.rapidZ(retractheight)
116 gcptmplpy gcp.toolchange(201, 10000)
117 gcptmplpy gcp.rapidXY(0, stockYheight/16)
118 gcptmplpy gcp.rapidZ(0)
119 gcptmplpy gcp.cutlinedxfgc(stockXwidth/16*7, stockYheight/2, -stockZthickness
                               )
120 gcptmplpy
121 gcptmplpy gcp.rapidZ(retractheight)
122 gcptmplpy gcp.toolchange(202, 10000)
123 gcptmplpy gcp.rapidXY(0, stockYheight/8)
124 gcptmplpy gcp.rapidZ(0)
125 gcptmplpy gcp.cutlinedxfgc(stockXwidth/16*6, stockYheight/2, -stockZthickness
                               )
126 gcptmplpy
127 gcptmplpy gcp.rapidZ(retractheight)
128 gcptmplpy gcp.toolchange(101, 10000)
129 gcptmplpy gcp.rapidXY(0, stockYheight/16*3)
130 gcptmplpy gcp.rapidZ(0)
131 gcptmplpy gcp.cutlinedxfgc(stockXwidth/16*5, stockYheight/2, -stockZthickness
                               )
132 gcptmplpy
133 gcptmplpy gcp.setzpos(retractheight)
134 gcptmplpy gcp.toolchange(390, 10000)
135 gcptmplpy gcp.rapidXY(0, stockYheight/16*4)
136 gcptmplpy gcp.rapidZ(0)
137 gcptmplpy gcp.cutlinedxfgc(stockXwidth/16*4, stockYheight/2, -stockZthickness
                               )
138 gcptmplpy gcp.rapidZ(retractheight)
139 gcptmplpy
140 gcptmplpy gcp.toolchange(301, 10000)
141 gcptmplpy gcp.rapidXY(0, stockYheight/16*6)
142 gcptmplpy gcp.rapidZ(0)
143 gcptmplpy gcp.cutlinedxfgc(stockXwidth/16*2, stockYheight/2, -stockZthickness
                               )
144 gcptmplpy
145 gcptmplpy rapids = gcp.rapid(gcp.xpos(), gcp.ypos(), retractheight)
146 gcptmplpy gcp.toolchange(102, 10000)
147 gcptmplpy
148 gcptmplpy gcp.rapid(-stockXwidth/4+stockYheight/16, +stockYheight/4, 0)
149 gcptmplpy
150 gcptmplpy #gcp.cutarcCC(0, 90, gcp.xpos()-stockYheight/16, gcp.ypos(),
                           stockYheight/16, -stockZthickness/4)
151 gcptmplpy #gcp.cutarcCC(90, 180, gcp.xpos(), gcp.ypos()-stockYheight/16,
                           stockYheight/16, -stockZthickness/4)
152 gcptmplpy #gcp.cutarcCC(180, 270, gcp.xpos()+stockYheight/16, gcp.ypos(),
                           stockYheight/16, -stockZthickness/4)
153 gcptmplpy #gcp.cutarcCC(270, 360, gcp.xpos(), gcp.ypos()+stockYheight/16,
                           stockYheight/16, -stockZthickness/4)
154 gcptmplpy gcp.cutquarterCCNEdxf(gcp.xpos() - stockYheight/8, gcp.ypos() +
                           stockYheight/8, -stockZthickness/4, stockYheight/8)
155 gcptmplpy gcp.cutquarterCCNWdx(gcp.xpos() - stockYheight/8, gcp.ypos() -
                           stockYheight/8, -stockZthickness/2, stockYheight/8)
156 gcptmplpy gcp.cutquarterCCSWdx(gcp.xpos() + stockYheight/8, gcp.ypos() -
                           stockYheight/8, -stockZthickness/4, stockYheight/8)

```

```

    stockYheight/8, -stockZthickness * 0.75, stockYheight/8)
157 gcptmplpy gcp.cutquarterCCSEdx(gcp.xpos() + stockYheight/8, gcp.ypos() +
    stockYheight/8, -stockZthickness, stockYheight/8)
158 gcptmplpy
159 gcptmplpy gcp.movetosafeZ()
160 gcptmplpy gcp.rapidXY(stockXwidth/4-stockYheight/16, -stockYheight/4)
161 gcptmplpy gcp.rapidZ(0)
162 gcptmplpy
163 gcptmplpy
164 gcptmplpy #gcp.cutarcCW(180, 90, gcp.xpos()+stockYheight/16, gcp.ypos(),
    stockYheight/16, -stockZthickness/4)
165 gcptmplpy #gcp.cutarcCW(90, 0, gcp.xpos(), gcp.ypos()-stockYheight/16,
    stockYheight/16, -stockZthickness/4)
166 gcptmplpy #gcp.cutarcCW(360, 270, gcp.xpos()-stockYheight/16, gcp.ypos(),
    stockYheight/16, -stockZthickness/4)
167 gcptmplpy #gcp.cutarcCW(270, 180, gcp.xpos(), gcp.ypos()+stockYheight/16,
    stockYheight/16, -stockZthickness/4)
168 gcptmplpy
169 gcptmplpy #gcp.movetosafeZ()
170 gcptmplpy #gcp.toolchange(201, 10000)
171 gcptmplpy #gcp.rapidXY(stockXwidth/2, -stockYheight/2)
172 gcptmplpy #gcp.rapidZ(0)
173 gcptmplpy
174 gcptmplpy #gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos(), -stockZthickness)
175 gcptmplpy #test = gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos(), -stockZthickness)
176 gcptmplpy
177 gcptmplpy #gcp.movetosafeZ()
178 gcptmplpy #gcp.rapidXY(stockXwidth/2-6.34, -stockYheight/2)
179 gcptmplpy #gcp.rapidZ(0)
180 gcptmplpy
181 gcptmplpy #gcp.cutarcCW(180, 90, stockXwidth/2, -stockYheight/2, 6.34, -
    stockZthickness)
182 gcptmplpy
183 gcptmplpy
184 gcptmplpy gcp.movetosafeZ()
185 gcptmplpy gcp.toolchange(814, 10000)
186 gcptmplpy gcp.rapidXY(0, -(stockYheight/2+12.7))
187 gcptmplpy gcp.rapidZ(0)
188 gcptmplpy
189 gcptmplpy gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos(), -stockZthickness)
190 gcptmplpy gcp.cutlinedxfgc(gcp.xpos(), -12.7, -stockZthickness)
191 gcptmplpy
192 gcptmplpy gcp.rapidXY(0, -(stockYheight/2+12.7))
193 gcptmplpy gcp.movetosafeZ()
194 gcptmplpy gcp.toolchange(374, 10000)
195 gcptmplpy gcp.rapidXY(stockXwidth/4-stockXwidth/16, -(stockYheight/4+
    stockYheight/16))
196 gcptmplpy gcp.rapidZ(0)
197 gcptmplpy
198 gcptmplpy gcp.rapidZ(retractheight)
199 gcptmplpy gcp.toolchange(374, 10000)
200 gcptmplpy gcp.rapidXY(-stockXwidth/4-stockXwidth/16, -(stockYheight/4+
    stockYheight/16))
201 gcptmplpy gcp.rapidZ(0)
202 gcptmplpy
203 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2)
204 gcptmplpy gcp.cutlinedxfgc(gcp.xpos()+stockYheight/9, gcp.ypos(), gcp.zpos())
205 gcptmplpy
206 gcptmplpy gcp.cutline(gcp.xpos()-stockYheight/9, gcp.ypos(), gcp.zpos())
207 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), 0)
208 gcptmplpy
209 gcptmplpy #key = gcp.cutkeyholegcdxf(KH_tool_num, 0, stockZthickness*0.75, "E
    ", stockYheight/9)
210 gcptmplpy #key = gcp.cutKHgcdxf(374, 0, stockZthickness*0.75, 90,
    stockYheight/9)
211 gcptmplpy #toolpaths = toolpaths.union(key)
212 gcptmplpy
213 gcptmplpy gcp.rapidZ(retractheight)
214 gcptmplpy gcp.rapidXY(-stockXwidth/4+stockXwidth/16, -(stockYheight/4+
    stockYheight/16))
215 gcptmplpy gcp.rapidZ(0)
216 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2)
217 gcptmplpy gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos()+stockYheight/9, gcp.zpos())
218 gcptmplpy
219 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos()-stockYheight/9, gcp.zpos())
220 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), 0)
221 gcptmplpy
222 gcptmplpy gcp.rapidZ(retractheight)

```

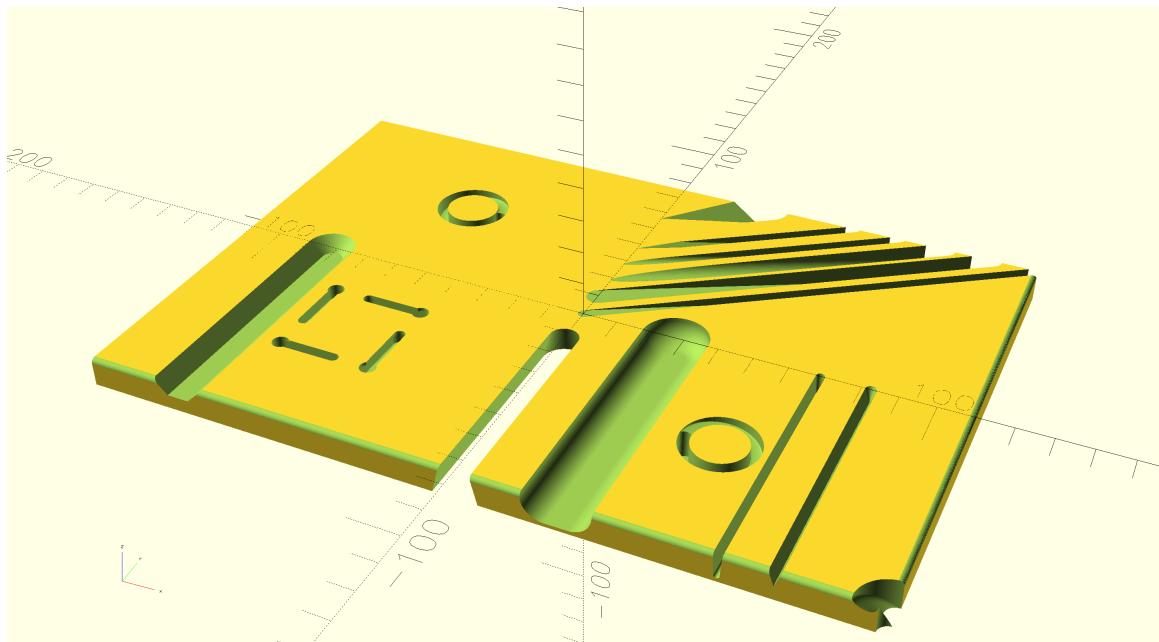
```

223 gcptmplpy gcp.rapidXY(-stockXwidth/4+stockXwidth/16, -(stockYheight/4-
    stockYheight/8))
224 gcptmplpy gcp.rapidZ(0)
225 gcptmplpy
226 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2)
227 gcptmplpy gcp.cutlinedxfgc(gcp.xpos()-stockYheight/9, gcp.ypos(), gcp.zpos())
228 gcptmplpy
229 gcptmplpy gcp.cutline(gcp.xpos()+stockYheight/9, gcp.ypos(), gcp.zpos())
230 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), 0)
231 gcptmplpy
232 gcptmplpy gcp.rapidZ(retractheight)
233 gcptmplpy gcp.rapidXY(-stockXwidth/4-stockXwidth/16, -(stockYheight/4-
    stockYheight/8))
234 gcptmplpy gcp.rapidZ(0)
235 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2)
236 gcptmplpy gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos()-stockYheight/9, gcp.zpos())
237 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos()+stockYheight/9, gcp.zpos())
238 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), 0)
239 gcptmplpy
240 gcptmplpy gcp.rapidZ(retractheight)
241 gcptmplpy gcp.toolchange(56142, 10000)
242 gcptmplpy gcp.rapidXY(-stockXwidth/2, -(stockYheight/2+0.508/2))
243 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), -1.531)
244 gcptmplpy gcp.cutlinedxfgc(stockXwidth/2+0.508/2, -(stockYheight/2+0.508/2),
    -1.531)
245 gcptmplpy
246 gcptmplpy gcp.rapidZ(retractheight)
247 gcptmplpy
248 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), -1.531)
249 gcptmplpy gcp.cutlinedxfgc(stockXwidth/2+0.508/2, (stockYheight/2+0.508/2),
    -1.531)
250 gcptmplpy
251 gcptmplpy gcp.rapidZ(retractheight)
252 gcptmplpy gcp.toolchange(45982, 10000)
253 gcptmplpy gcp.rapidXY(stockXwidth/8, 0)
254 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), -(stockZthickness*7/8))
255 gcptmplpy gcp.cutlinedxfgc(gcp.xpos(), -stockYheight/2, -(stockZthickness
    *7/8))
256 gcptmplpy
257 gcptmplpy gcp.rapidZ(retractheight)
258 gcptmplpy gcp.toolchange(204, 10000)
259 gcptmplpy gcp.rapidXY(stockXwidth*0.3125, 0)
260 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), -(stockZthickness*7/8))
261 gcptmplpy gcp.cutlinedxfgc(gcp.xpos(), -stockYheight/2, -(stockZthickness
    *7/8))
262 gcptmplpy
263 gcptmplpy gcp.rapidZ(retractheight)
264 gcptmplpy gcp.toolchange(502, 10000)
265 gcptmplpy gcp.rapidXY(stockXwidth*0.375, 0)
266 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), -4.24)
267 gcptmplpy gcp.cutlinedxfgc(gcp.xpos(), -stockYheight/2, -4.24)
268 gcptmplpy
269 gcptmplpy gcp.rapidZ(retractheight)
270 gcptmplpy gcp.toolchange(13921, 10000)
271 gcptmplpy gcp.rapidXY(-stockXwidth*0.375, 0)
272 gcptmplpy gcp.cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2)
273 gcptmplpy gcp.cutlinedxfgc(gcp.xpos(), -stockYheight/2, -stockZthickness/2)
274 gcptmplpy
275 gcptmplpy gcp.rapidZ(retractheight)
276 gcptmplpy
277 gcptmplpy gcp.stockandtoolpaths()
278 gcptmplpy
279 gcptmplpy gcp.closegcodefile()
280 gcptmplpy gcp.closeddfffile()

```

---

Which generates a 3D model which previews in PythonSCAD as:



## 2.4 gcodepreviewtemplate.scad

Since the project began in OpenSCAD, having an implementation in that language has always been a goal. This is quite straight-forward since the Python code when imported into OpenSCAD may be accessed by quite simple modules which are for the most part, a series of decorators/descriptors which wrap up the Python definitions as OpenSCAD modules. Moreover, such an implementation will facilitate usage by tools intended for this application such as OpenSCAD Graph Editor: <https://github.com/derkork/openscad-graph-editor>.

---

```

1 gcptmplscad //!OpenSCAD
2 gcptmplscad
3 gcptmplscad use <gcodepreview.py>
4 gcptmplscad include <gcodepreview.scad>
5 gcptmplscad
6 gcptmplscad $fn = $preview ? 32 : 256;
7 gcptmplscad fn = $preview ? 32 : 256;
8 gcptmplscad
9 gcptmplscad /* [Stock] */
10 gcptmplscad stockXwidth = 220;
11 gcptmplscad /* [Stock] */
12 gcptmplscad stockYheight = 150;
13 gcptmplscad /* [Stock] */
14 gcptmplscad stockZthickness = 8.35;
15 gcptmplscad /* [Stock] */
16 gcptmplscad zeroheight = "Top"; // [Top, Bottom]
17 gcptmplscad /* [Stock] */
18 gcptmplscad stockzero = "Center"; // [Lower-Left, Center-Left, Top-Left, Center]
19 gcptmplscad /* [Stock] */
20 gcptmplscad retractheight = 9;
21 gcptmplscad
22 gcptmplscad /* [Export] */
23 gcptmplscad Base_filename = "export";
24 gcptmplscad /* [Export] */
25 gcptmplscad generatedxf = true;
26 gcptmplscad /* [Export] */
27 gcptmplscad generategcode = true;
28 gcptmplscad
29 gcptmplscad /* [CAM] */
30 gcptmplscad toolradius = 1.5875;
31 gcptmplscad /* [CAM] */
32 gcptmplscad large_square_tool_num = 0; // [0:0, 112:112, 102:102, 201:201]
33 gcptmplscad /* [CAM] */
34 gcptmplscad small_square_tool_num = 102; // [0:0, 122:122, 112:112, 102:102]
35 gcptmplscad /* [CAM] */
36 gcptmplscad large_ball_tool_num = 0; // [0:0, 111:111, 101:101, 202:202]
37 gcptmplscad /* [CAM] */
38 gcptmplscad small_ball_tool_num = 0; // [0:0, 121:121, 111:111, 101:101]
39 gcptmplscad /* [CAM] */
40 gcptmplscad large_V_tool_num = 0; // [0:0, 301:301, 690:690]
41 gcptmplscad /* [CAM] */
42 gcptmplscad small_V_tool_num = 0; // [0:0, 390:390, 301:301]
43 gcptmplscad /* [CAM] */

```

```

44 gcptmplscad DT_tool_num = 0; // [0:0, 814:814, 808079:808079]
45 gcptmplscad /* [CAM] */
46 gcptmplscad KH_tool_num = 0; // [0:0, 374:374, 375:375, 376:376, 378:378]
47 gcptmplscad /* [CAM] */
48 gcptmplscad Roundover_tool_num = 0; // [56142:56142, 56125:56125, 1570:1570]
49 gcptmplscad /* [CAM] */
50 gcptmplscad MISC_tool_num = 0; // [648:648, 45982:45982]
51 gcptmplscad //648 threadmill_shaft(2.4, 0.75, 18)
52 gcptmplscad //45982 Carbide Tipped Bowl & Tray 1/4 Radius x 3/4 Dia x 5/8 x 1/4
   Inch Shank
53 gcptmplscad
54 gcptmplscad /* [Feeds and Speeds] */
55 gcptmplscad plunge = 100;
56 gcptmplscad /* [Feeds and Speeds] */
57 gcptmplscad feed = 400;
58 gcptmplscad /* [Feeds and Speeds] */
59 gcptmplscad speed = 16000;
60 gcptmplscad /* [Feeds and Speeds] */
61 gcptmplscad small_square_ratio = 0.75; // [0.25:2]
62 gcptmplscad /* [Feeds and Speeds] */
63 gcptmplscad large_ball_ratio = 1.0; // [0.25:2]
64 gcptmplscad /* [Feeds and Speeds] */
65 gcptmplscad small_ball_ratio = 0.75; // [0.25:2]
66 gcptmplscad /* [Feeds and Speeds] */
67 gcptmplscad large_V_ratio = 0.875; // [0.25:2]
68 gcptmplscad /* [Feeds and Speeds] */
69 gcptmplscad small_V_ratio = 0.625; // [0.25:2]
70 gcptmplscad /* [Feeds and Speeds] */
71 gcptmplscad DT_ratio = 0.75; // [0.25:2]
72 gcptmplscad /* [Feeds and Speeds] */
73 gcptmplscad KH_ratio = 0.75; // [0.25:2]
74 gcptmplscad /* [Feeds and Speeds] */
75 gcptmplscad R0_ratio = 0.5; // [0.25:2]
76 gcptmplscad /* [Feeds and Speeds] */
77 gcptmplscad MISC_ratio = 0.5; // [0.25:2]
78 gcptmplscad
79 gcptmplscad thegeneratedxf = generatedxf == true ? 1 : 0;
80 gcptmplscad thegenerategcode = generategcode == true ? 1 : 0;
81 gcptmplscad
82 gcptmplscad gcp = gcodepreview("cut", // or "print" (no preview not suited to
   OpenSCAD)
83 gcptmplscad           thegenerategcode,
84 gcptmplscad           thegeneratedxf,
85 gcptmplscad           );
86 gcptmplscad
87 gcptmplscad opengcodefile(Base_filename);
88 gcptmplscad opendxf(file(Base_filename));
89 gcptmplscad
90 gcptmplscad setupstock(stockXwidth, stockYheight, stockZthickness, zeroheight,
   stockzero);
91 gcptmplscad
92 gcptmplscad //echo(gcp);
93 gcptmplscad //gcpversion();
94 gcptmplscad
95 gcptmplscad //c = myfunc(4);
96 gcptmplscad //echo(c);
97 gcptmplscad
98 gcptmplscad //echo(getvv());
99 gcptmplscad
100 gcptmplscad cutline(stockXwidth/2, stockYheight/2, -stockZthickness);
101 gcptmplscad
102 gcptmplscad rapidZ(retractheight);
103 gcptmplscad toolchange(201, 10000);
104 gcptmplscad rapidXY(0, stockYheight/16);
105 gcptmplscad rapidZ(0);
106 gcptmplscad cutlinedxfgc(stockXwidth/16*7, stockYheight/2, -stockZthickness);
107 gcptmplscad
108 gcptmplscad
109 gcptmplscad rapidZ(retractheight);
110 gcptmplscad toolchange(202, 10000);
111 gcptmplscad rapidXY(0, stockYheight/8);
112 gcptmplscad rapidZ(0);
113 gcptmplscad cutlinedxfgc(stockXwidth/16*6, stockYheight/2, -stockZthickness);
114 gcptmplscad
115 gcptmplscad rapidZ(retractheight);
116 gcptmplscad toolchange(101, 10000);
117 gcptmplscad rapidXY(0, stockYheight/16*3);
118 gcptmplscad rapidZ(0);

```

```

119 gcptmplscad cutlinedxfgc(stockXwidth/16*5, stockYheight/2, -stockZthickness);
120 gcptmplscad
121 gcptmplscad rapidZ(retractheight);
122 gcptmplscad toolchange(390, 10000);
123 gcptmplscad rapidXY(0, stockYheight/16*4);
124 gcptmplscad rapidZ(0);
125 gcptmplscad
126 gcptmplscad cutlinedxfgc(stockXwidth/16*4, stockYheight/2, -stockZthickness);
127 gcptmplscad rapidZ(retractheight);
128 gcptmplscad
129 gcptmplscad toolchange(301, 10000);
130 gcptmplscad rapidXY(0, stockYheight/16*6);
131 gcptmplscad rapidZ(0);
132 gcptmplscad
133 gcptmplscad cutlinedxfgc(stockXwidth/16*2, stockYheight/2, -stockZthickness);
134 gcptmplscad
135 gcptmplscad
136 gcptmplscad movetosafeZ();
137 gcptmplscad rapid(gcp.xpos(), gcp.ypos(), retractheight);
138 gcptmplscad toolchange(102, 10000);
139 gcptmplscad
140 gcptmplscad //rapidXY(stockXwidth/4+stockYheight/8+stockYheight/16, +
               stockYheight/8);
141 gcptmplscad rapidXY(-stockXwidth/4+stockXwidth/16, (stockYheight/4));//+
               stockYheight/16
142 gcptmplscad rapidZ(0);
143 gcptmplscad
144 gcptmplscad //cutarcCW(360, 270, gcp.xpos()-stockYheight/16, gcp.ypos(),
               stockYheight/16, -stockZthickness);
145 gcptmplscad //gcp.cutarcCW(270, 180, gcp.xpos(), gcp.ypos()+stockYheight/16,
               stockYheight/16)
146 gcptmplscad //cutarcCC(0, 90, gcp.xpos()-stockYheight/16, gcp.ypos(),
               stockYheight/16, -stockZthickness/4);
147 gcptmplscad //cutarcCC(90, 180, gcp.xpos(), gcp.ypos()-stockYheight/16,
               stockYheight/16, -stockZthickness/4);
148 gcptmplscad //cutarcCC(180, 270, gcp.xpos()+stockYheight/16, gcp.ypos(),
               stockYheight/16, -stockZthickness/4);
149 gcptmplscad //cutarcCC(270, 360, gcp.xpos(), gcp.ypos()+stockYheight/16,
               stockYheight/16, -stockZthickness/4);
150 gcptmplscad
151 gcptmplscad movetosafeZ();
152 gcptmplscad //rapidXY(stockXwidth/4+stockYheight/8-stockYheight/16, -
               stockYheight/8);
153 gcptmplscad rapidXY(stockXwidth/4-stockYheight/16, -(stockYheight/4));
154 gcptmplscad rapidZ(0);
155 gcptmplscad
156 gcptmplscad //cutarcCW(180, 90, gcp.xpos()+stockYheight/16, gcp.ypos(),
               stockYheight/16, -stockZthickness/4);
157 gcptmplscad //cutarcCW(90, 0, gcp.xpos(), gcp.ypos()-stockYheight/16,
               stockYheight/16, -stockZthickness/4);
158 gcptmplscad //cutarcCW(360, 270, gcp.xpos()-stockYheight/16, gcp.ypos(),
               stockYheight/16, -stockZthickness/4);
159 gcptmplscad //cutarcCW(270, 180, gcp.xpos(), gcp.ypos()+stockYheight/16,
               stockYheight/16, -stockZthickness/4);
160 gcptmplscad
161 gcptmplscad movetosafeZ();
162 gcptmplscad
163 gcptmplscad rapidXY(-stockXwidth/4 + stockYheight/8, (stockYheight/4));
164 gcptmplscad rapidZ(0);
165 gcptmplscad
166 gcptmplscad cutquarterCCNEdxf(xpos() - stockYheight/8, ypos() + stockYheight/8,
               -stockZthickness/4, stockYheight/8);
167 gcptmplscad cutquarterCCNWdxf(xpos() - stockYheight/8, ypos() - stockYheight/8,
               -stockZthickness/2, stockYheight/8);
168 gcptmplscad cutquarterCCSWdxf(xpos() + stockYheight/8, ypos() - stockYheight/8,
               -stockZthickness * 0.75, stockYheight/8);
169 gcptmplscad //cutquarterCCSEdxf(xpos() + stockYheight/8, ypos() + stockYheight
               /8, -stockZthickness, stockYheight/8);
170 gcptmplscad
171 gcptmplscad movetosafeZ();
172 gcptmplscad toolchange(201, 10000);
173 gcptmplscad rapidXY(stockXwidth /2 -6.34, - stockYheight /2);
174 gcptmplscad rapidZ(0);
175 gcptmplscad //cutarcCW(180, 90, stockXwidth /2, -stockYheight/2, 6.34, -
               stockZthickness);
176 gcptmplscad
177 gcptmplscad movetosafeZ();
178 gcptmplscad rapidXY(stockXwidth/2, -stockYheight/2);

```

```

179 gcptmplscad rapidZ(0);
180 gcptmplscad
181 gcptmplscad //gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos(), -stockZthickness);
182 gcptmplscad
183 gcptmplscad movetosafeZ();
184 gcptmplscad toolchange(814, 10000);
185 gcptmplscad rapidXY(0, -(stockYheight/2+12.7));
186 gcptmplscad rapidZ(0);
187 gcptmplscad
188 gcptmplscad cutlinedxfgc(xpos(), ypos(), -stockZthickness);
189 gcptmplscad cutlinedxfgc(xpos(), -12.7, -stockZthickness);
190 gcptmplscad rapidXY(0, -(stockYheight/2+12.7));
191 gcptmplscad
192 gcptmplscad //rapidXY(stockXwidth/2-6.34, -stockYheight/2);
193 gcptmplscad //rapidZ(0);
194 gcptmplscad
195 gcptmplscad //movetosafeZ();
196 gcptmplscad //toolchange(374, 10000);
197 gcptmplscad //rapidXY(-(stockXwidth/4 - stockXwidth /16), -(stockYheight/4 +
    stockYheight/16))
198 gcptmplscad
199 gcptmplscad //cutline(xpos(), ypos(), (stockZthickness/2) * -1);
200 gcptmplscad //cutlinedxfgc(xpos() + stockYheight /9, ypos(), zpos());
201 gcptmplscad //cutline(xpos() - stockYheight /9, ypos(), zpos());
202 gcptmplscad //cutline(xpos(), ypos(), 0);
203 gcptmplscad
204 gcptmplscad movetosafeZ();
205 gcptmplscad
206 gcptmplscad toolchange(374, 10000);
207 gcptmplscad rapidXY(-stockXwidth/4-stockXwidth/16, -(stockYheight/4+
    stockYheight/16))
208 gcptmplscad //rapidXY(-(stockXwidth/4 - stockXwidth /16), -(stockYheight/4 +
    stockYheight/16))
209 gcptmplscad rapidZ(0);
210 gcptmplscad
211 gcptmplscad cutline(xpos(), ypos(), (stockZthickness/2) * -1);
212 gcptmplscad cutlinedxfgc(xpos() + stockYheight /9, ypos(), zpos());
213 gcptmplscad cutline(xpos() - stockYheight /9, ypos(), zpos());
214 gcptmplscad cutline(xpos(), ypos(), 0);
215 gcptmplscad
216 gcptmplscad rapidZ(retractheight);
217 gcptmplscad rapidXY(-stockXwidth/4+stockXwidth/16, -(stockYheight/4+
    stockYheight/16));
218 gcptmplscad rapidZ(0);
219 gcptmplscad cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2);
220 gcptmplscad cutlinedxfgc(gcp.xpos(), gcp.ypos()+stockYheight/9, gcp.zpos());
221 gcptmplscad cutline(gcp.xpos(), gcp.ypos()-stockYheight/9, gcp.zpos());
222 gcptmplscad cutline(gcp.xpos(), gcp.ypos(), 0);
223 gcptmplscad
224 gcptmplscad rapidZ(retractheight);
225 gcptmplscad rapidXY(-stockXwidth/4+stockXwidth/16, -(stockYheight/4-
    stockYheight/8));
226 gcptmplscad rapidZ(0);
227 gcptmplscad cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2);
228 gcptmplscad cutlinedxfgc(gcp.xpos()-stockYheight/9, gcp.ypos(), gcp.zpos());
229 gcptmplscad cutline(gcp.xpos()+stockYheight/9, gcp.ypos(), gcp.zpos());
230 gcptmplscad cutline(gcp.xpos(), gcp.ypos(), 0);
231 gcptmplscad
232 gcptmplscad rapidZ(retractheight);
233 gcptmplscad rapidXY(-stockXwidth/4-stockXwidth/16, -(stockYheight/4-
    stockYheight/8));
234 gcptmplscad rapidZ(0);
235 gcptmplscad cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2);
236 gcptmplscad cutlinedxfgc(gcp.xpos(), gcp.ypos()-stockYheight/9, gcp.zpos());
237 gcptmplscad cutline(gcp.xpos(), gcp.ypos()+stockYheight/9, gcp.zpos());
238 gcptmplscad cutline(gcp.xpos(), gcp.ypos(), 0);
239 gcptmplscad
240 gcptmplscad rapidZ(retractheight);
241 gcptmplscad toolchange(45982, 10000);
242 gcptmplscad rapidXY(stockXwidth/8, 0);
243 gcptmplscad cutline(gcp.xpos(), gcp.ypos(), -(stockZthickness*7/8));
244 gcptmplscad cutlinedxfgc(gcp.xpos(), -stockYheight/2, -(stockZthickness*7/8));
245 gcptmplscad
246 gcptmplscad rapidZ(retractheight);
247 gcptmplscad toolchange(204, 10000);
248 gcptmplscad rapidXY(stockXwidth*0.3125, 0);
249 gcptmplscad cutline(gcp.xpos(), gcp.ypos(), -(stockZthickness*7/8));
250 gcptmplscad cutlinedxfgc(gcp.xpos(), -stockYheight/2, -(stockZthickness*7/8));

```

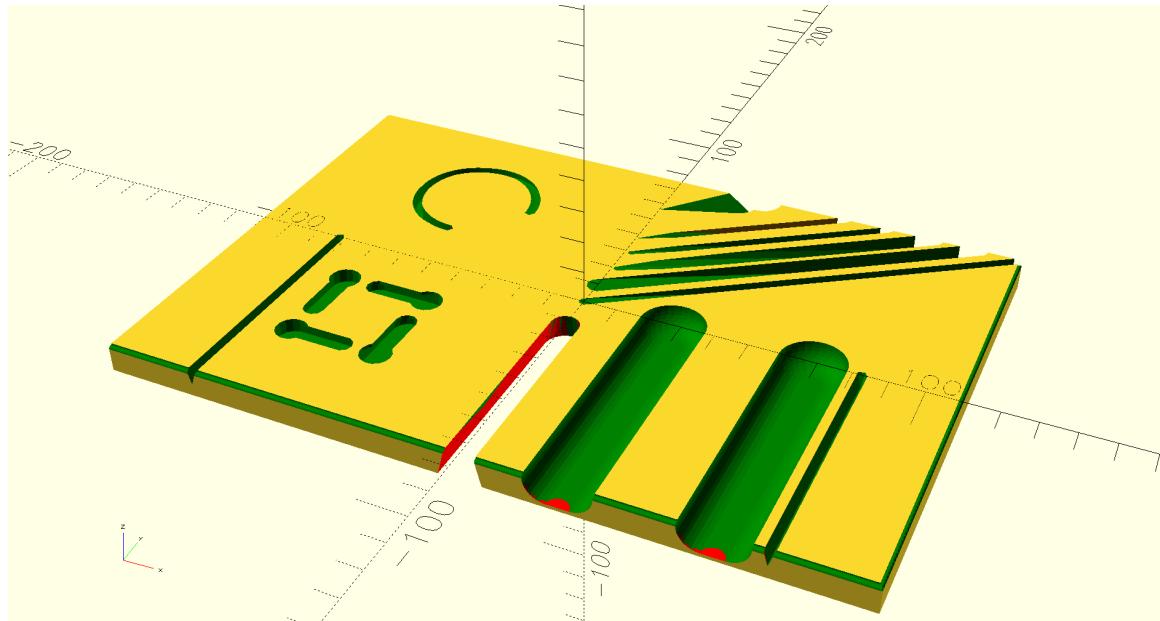
```

251 gcptmplscad
252 gcptmplscad rapidZ(retractheight);
253 gcptmplscad toolchange(502, 10000);
254 gcptmplscad rapidXY(stockXwidth*0.375, 0);
255 gcptmplscad cutline(gcp.xpos(), gcp.ypos(), -4.24);
256 gcptmplscad cutlinedxfgc(gcp.xpos(), -stockYheight/2, -4.24);
257 gcptmplscad
258 gcptmplscad rapidZ(retractheight);
259 gcptmplscad toolchange(13921, 10000);
260 gcptmplscad rapidXY(-stockXwidth*0.375, 0);
261 gcptmplscad cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2);
262 gcptmplscad cutlinedxfgc(gcp.xpos(), -stockYheight/2, -stockZthickness/2);
263 gcptmplscad
264 gcptmplscad rapidZ(retractheight);
265 gcptmplscad gcp.toolchange(56142, 10000);
266 gcptmplscad gcp.rapidXY(-stockXwidth/2, -(stockYheight/2+0.508/2));
267 gcptmplscad cutlineZgcfeed(-1.531, plunge);
268 gcptmplscad //cutline(gcp.xpos(), gcp.ypos(), -1.531);
269 gcptmplscad cutlinedxfgc(stockXwidth/2+0.508/2, -(stockYheight/2+0.508/2),
-1.531);
270 gcptmplscad
271 gcptmplscad rapidZ(retractheight);
272 gcptmplscad //#gcp.toolchange(56125, 10000)
273 gcptmplscad cutlineZgcfeed(-1.531, plunge);
274 gcptmplscad //toolpaths.append(gcp.cutline(gcp.xpos(), gcp.ypos(), -1.531))
275 gcptmplscad cutlinedxfgc(stockXwidth/2+0.508/2, (stockYheight/2+0.508/2),
-1.531);
276 gcptmplscad
277 gcptmplscad stockandtoolpaths();
278 gcptmplscad //stockwotoolpaths();
279 gcptmplscad //outputtoolpaths();
280 gcptmplscad
281 gcptmplscad //makecube(3, 2, 1);
282 gcptmplscad
283 gcptmplscad //instantiatecube();
284 gcptmplscad
285 gcptmplscad closegcodefile();
286 gcptmplscad closedxffile();

```

---

Which generates a 3D model which previews in OpenSCAD as:



## 2.5 gpcthreedp.py

Setting up 3D printing will require accommodating the requirements of both the printer *and* filament being used. The most straight-forward and expedient way to arrive at this is to leverage a traditional 3D printer slicer which has settings appropriate to the machine and filament being used which are tuned to the sort of part being made/printing being done, export the G-code, and use that as a template for setting up 3D printing.

Towards that end, a G-code file for a very basic 3D printer was output for printing PLA from an Orbot Quantum

```

1 gcptreedp #gcptreedp.py --- Template for 3D printing
2 gcptreedp #                                         Initial version.
3 gcptreedp #!/usr/bin/env python
4 gcptreedp
5 gcptreedp import sys
6 gcptreedp
7 gcptreedp try:
8 gcptreedp     if 'gcodereview' in sys.modules:
9 gcptreedp         del sys.modules['gcodereview']
10 gcptreedp except AttributeError:
11 gcptreedp     pass
12 gcptreedp
13 gcptreedp from gcodereview import *
14 gcptreedp
15 gcptreedp fa = 2
16 gcptreedp fs = 0.125
17 gcptreedp
18 gcptreedp # [Export] */
19 gcptreedp Base_filename = "aexport"
20 gcptreedp # [Export] */
21 gcptreedp generatedxf = False
22 gcptreedp # [Export] */
23 gcptreedp generategcode = True
24 gcptreedp # [3D Printing] */
25 gcptreedp nozzlediameter = 0.4
26 gcptreedp filamentdiameter = 1.75
27 gcptreedp extrusionwidth = 0.6
28 gcptreedp layerheight = 0.2
29 gcptreedp temperature = 200
30 gcptreedp
31 gcptreedp gcp = gcodereview("print", # "cut" or "no_preview"
32 gcptreedp                         generategcode,
33 gcptreedp                         generatedxf,
34 gcptreedp                         )
35 gcptreedp
36 gcptreedp gcp.opengcodefile(Base_filename)
37 gcptreedp
38 gcptreedp gcp.initializeforprinting(nozzlediameter,
39 gcptreedp                         filamentdiameter,
40 gcptreedp                         extrusionwidth,
41 gcptreedp                         layerheight)
42 gcptreedp
43 gcptreedp gcp.setandwaitforextrudertemperature(temperature)
44 gcptreedp gcp.liftandprimenozzle()
45 gcptreedp
46 gcptreedp gcp.moveatfeedrate(0,0,layerheight,20000)
47 gcptreedp gcp.extrude(10, 20, layerheight)
48 gcptreedp
49 gcptreedp gcp.stockandtoolpaths("toolpaths")
50 gcptreedp
51 gcptreedp gcp.closegcodefile()

```

---

## 2.6 gcodereviewtemplate.txt

Throughout this document, examples of commands will be shown and then collected in gcodereviewtemplate.txt for easy copy-pasting (insert old computer joke about how many original Cobol programs have been written).

---

```

1 gcptmpl #gcptemplate.txt --- this file will collect example usages of each
2 gcptmpl #                                         command with a brief commentary.

```

---

## 3 gcodereview

This library for OpenPythonSCAD works by using Python code to persistently store and access variables which denote the machine position and describe the characteristics of tools, and to write out files while both modeling the motion of a 3-axis CNC machine (note that at least a 4<sup>th</sup> additional axis may be worked up as a future option and supporting the work-around of two-sided (flip) machining by using an imported file as the Stock or preserving state and affording a second operation seems promising) and if desired, writing out DXF and/or G-code files (as opposed to the normal technique of rendering to a 3D model and writing out an STL or STEP or other model format and using a traditional CAM application). There are multiple modes for this, doing so may require loading up to two files:

- A Python file: gcodepreview.py (gcpy) — this has variables in the traditional sense which are used for tracking machine position and so forth. Note that where it is placed/loaded from will depend on whether it is imported into a Python file:

```
import gcodepreview_standalone as gcp
```

or used in an OpenSCAD file:

```
use <gcodepreview.py>
```

with an additional OpenSCAD module which allows accessing it and that there is an option for loading directly from the Github repository implemented in PythonSCAD

- An OpenSCAD file: gcodepreview.scad (gcpscad) — which uses the Python file and which is included allowing it to access OpenSCAD variables for branching

Note that this architecture requires that many OpenSCAD modules are essentially “Dispatchers” (another term is “Descriptors”) which pass information from one aspect of the environment to another, but in some instances it is expedient, or even will be necessary to re-write Python definitions in OpenSCAD rather than calling the matching Python function directly.

In earlier versions there were several possible ways to work with the 3D models of the cuts, either directly displaying the returned 3D model when explicitly called for after storing it in a variable or calling it up as a calculation (Python command ouput(<foo>) or OpenSCAD returning a model, or calling an appropriate OpenSCAD command), however as-of v0.9 the tool movements are modeled as lists of hull() operations which must be processed as such and are differenced from the stock. The templates set up these options as noted, and ensure that True == true.

**PYTHON CODING CONSIDERATIONS:** Python style may be checked using a tool such as: <https://www.codewof.co.nz/style/python3/>. Not all conventions will necessarily be adhered to — limiting line length in particular conflicts with the flexibility of Literate Programming. Note that numpydoc-style docstrings are added where appropriate to help define the functionality of each defined module in Python. <https://numpydoc.readthedocs.io/en/latest/>.

### 3.1 Cutviewer

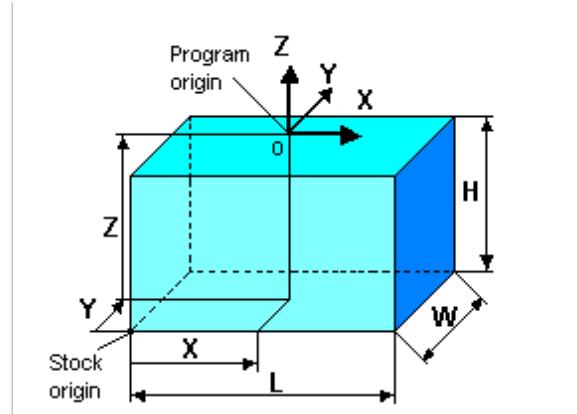
This problem space, showing the result of cutting stock using tooling in 3D has a number of tools addressing it, Camotics (formerly OpenSCAM) is an opensource option. Many tools simply create a wireframe preview such as <https://ncviewer.com/>. Cutviewer is a notable commercial program which has a unique approach centered on G-code where specially formatted comments fill in the dimensions needed for showing the 3D preview.

#### 3.1.1 Stock size and placement

Setting the dimensions of the stock, and placing it in 3D space relative to the origin must be done very early in the G-code file.

The CutViewer comments are in the form:

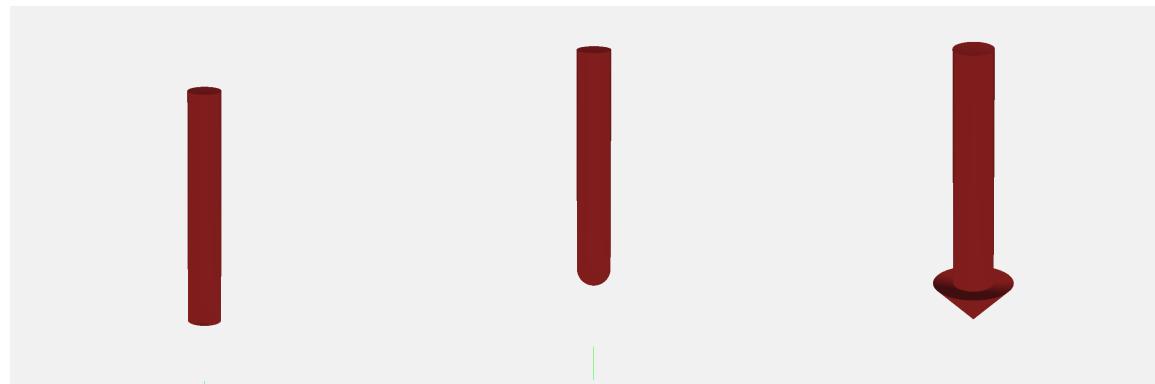
```
(STOCK/BLOCK, Length, Width, Height, Origin X, Origin Y, Origin Z)
```



#### 3.1.2 Tool Shapes

Cutviewer is unable to show tools which undercut, but other tool shapes are represented in a straight-forward and flexible fashion.

Most tooling has quite standard shapes as described by their profile as defined in the toolmovement command which simply defines/declares their shape and hull()s them together:

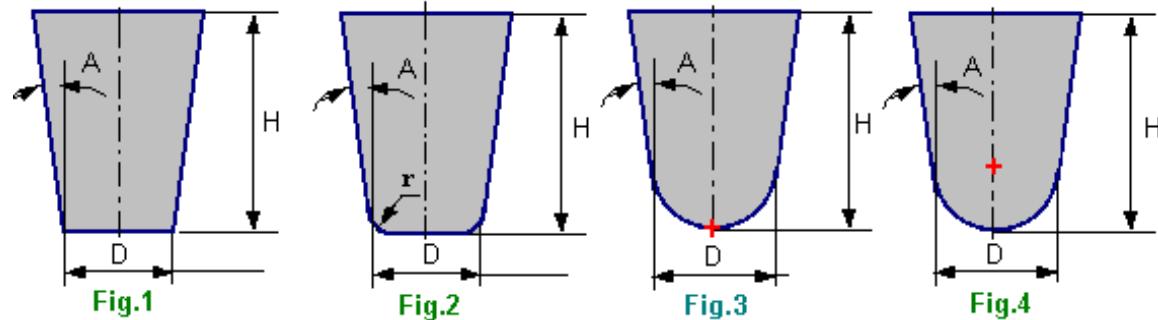


- Square (#201 and 102) — able to cut a flat bottom, perpendicular side and right angle, their simple and easily understood geometry makes them a standard choice
- Ballnose (#202 and 101) — rounded, they are the standard choice for concave and organic shapes
- V tooling (#301, 302, 311 and 312) — pointed at the tip, they are available in a variety of angles and diameters and may be used for decorative V carving, or for chamfering or cutting specific angles

Note that the module for creating movement of the tool will need to handle all of the different tool shapes, generating a list of hull() or rotate\_extrude commands which describe the 3D region which tool movement describes.

**3.1.2.1 Tool/Mill (Square, radiusied, ball-nose, and tapered-ball)** The CutViewer values include:

TOOL/MILL, Diameter, Corner radius, Height, Taper Angle

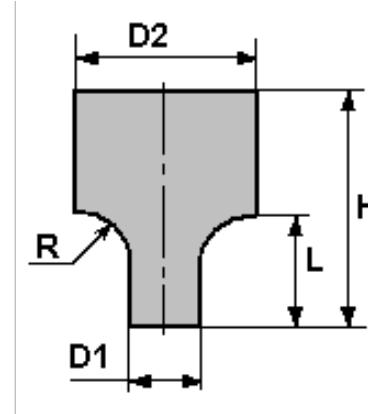


Note that it is possible to use these definitions for a wide variety of tooling, e.g., a Carbide 3D #301 V tool being represented as:

(TOOL/MILL,0.10, 0.05, 6.35, 45.00)

**3.1.2.2 Corner Rounding, (roundover)** One notable tool option which cannot be supported using the Tool/Mill description is corner rounding/roundover tooling:

TOOL/CRMILL, Diameter1, Diameter2, Radius, Height, Length



**3.1.2.3 V shaped tooling (and variations)** Cutviewer has multiple V shaped tooling definitions:

- ;TOOL/CHAMFER, Diameter, Point Angle, Height
- ;TOOL/CHAMFER, Diameter, Point Angle, Height, Chamfer Length (note that this is the definition of a flat-bottomed V tool)
- ;TOOL/DRILL, Diameter, Point Angle, Height
- ;TOOL/CDRILL, D<sub>1</sub>, A<sub>1</sub>, L, D<sub>2</sub>, A<sub>2</sub>, H

Since such tooling may be represented (albeit with a slight compromise which arguably is a nod to the real world) using the Tool/Mill definition from above, it seems unlikely that such tooling definitions will be supported.

## 3.2 Module Naming Convention

*The beginning of wisdom is to call things by their right names.*

— CONFUCIUS

Naming modules requires that the conventions of G-code, the various file types which are written to, and the actions which the system takes are all taken into due consideration so as to arrive at a consistent scheme.

Number will be abbreviated as num rather than no, and the short form will be used internally for variable names, while the compleat word will be used in commands.

In some instances, the will be used as a prefix.

Tool #s where used will be the first argument where possible — this makes it obvious if they are not used — the negative consideration, that it then doesn't allow for a usage where a DEFAULT tool is used is not an issue since the command currenttoolnumber() may be used to access that number, and is arguably the preferred mechanism. An exception is when there are multiple tool #s as when opening a file — collecting them all at the end is a more straight-forward approach.

In natural languages such as English, there is an order to various parts of speech such as adjectives — since various prefixes and suffixes will be used for module names, having a consistent ordering/usage will help in consistency and make expression clearer. The ordering should be: sequence (if necessary), action, function, parameter, filetype, and where possible a hierarchy of large/general to small/specific should be maintained.

- Both prefix and suffix
  - dxf (action (write out to DXF file), filetype)
- Prefixes
  - generate (Boolean) — used to identify which types of actions will be done (note that in the interest of brevity the check for this will be deferred until the last possible moment, see below)
  - write (action) — used to write to files, will include a check for the matching generate command, which being true will cause the write to the file to actually transpire
  - cut (action) — create tool movement removing volume from 3D object
  - extrude (action) — 3D printing equivalent to cut
  - rapid (action) — create tool movement of 3D object so as to show any collision or rubbing
  - open (action (file))
  - close (action (file))
  - set (action/function) — note that the matching get is implicit in functions which return variables, e.g., xpos()
  - current
- Nouns (geometry/shapes)
  - arc
  - line
  - rectangle
  - circle
- Suffixes
  - feed (parameter)
  - gcode/gc (filetype)
  - pos — position
  - tool
  - loop

- CC/CW
- number/num — note that num is used internally for variable names, while number will be used for module/function names, making it straight-forward to ensure that functions and variables have different names for purposes of scope

Further note that commands which are implicitly for the generation of G-code, such as `toolchange()` will omit gc for the sake of conciseness.

In theory, this means that the basic `cut...` and associated commands exist (or potentially exist) in the following forms and have matching versions which may be used when programming in Python or OpenSCAD:

	line			arc		
	cut	dxf	gcode	cut	dxf	gcode
cut	cutline		cutlinegc	cutarc		cutarcgc
dxf	cutlinedxf	dxfline		cutarcdxf	dxfarc	
gcode	cutlinegc		linegc	cutarcgc		arcgc
		cutlinedxfgc			cutarcdxfgc	

Note that certain commands (dxflinegc, dxfarcgc, linegc, arcgc) are either redundant or unlikely to be needed, and will most likely not be implemented (it seems contradictory that one would write out a move command to a G-code file without making that cut in the 3D preview). Note that there may be additional versions as required for the convenience of notation or cutting, in particular, a set of `cutarc<quadrant><direction>gc` commands was warranted during the initial development of arc-related commands.

The gcode and dxf columns and the matter of having specific commands which encompass generategcode those file types is tied up in having the internal variables generategcode, generatedxf and im- generatedxf plementations, and a strong argument could be made that this should simply be handled by generatecut if...then structures using those variables. The addition of a generatecut variable adds the nec- essary symmetry. Note that an early option to output a separate file for each tool used has since been deprecated and will eventually be removed. In its place there is a mechanism where each colour is offset by the stock dimensions multiplied by the colour number, so that they are arrayed on a diagonal — when opened each such set of objects may then be easily selected and moved to the appropriate layer, then aligned against the stock.

A further consideration is that when processing G-code it is typical for a given command to be minimal and only include the axis of motion for the end-position, so for each of the above which is likely to appear in a .nc/ .gcode file, it will be necessary to have a matching command for the combinatorial possibilities, hence:

cutlineXYZ	cutlineXYZwithfeed
cutlineXY	cutlineXYwithfeed
cutlineXZ	cutlineXZwithfeed
cutlineYZ	cutlineYZwithfeed
cutlineX	cutlineXwithfeed
cutlineY	cutlineYwithfeed
cutlineZ	cutlineZwithfeed

Principles for naming modules (and variables):

- minimize use of underscores (for convenience sake, underscores are not used for index entries)
- identify which aspect of the project structure is being worked with (`cut(ting)`, `dxf`, `gcode`, `tool`, etc.) note the `gcodepreview` class which will normally be imported as `gcp` so that module `<foo>` will be called as `gcp.<foo>` from Python and by the same `<foo>` in OpenSCAD

The following commands for various shapes either have been implemented (monospace) or have not yet been implemented, but likely will need to be (regular type):

- rectangle
  - `cutrectangle`
  - `cutrectangleround`

Another consideration is that all commands which write files will check to see if a given filetype is enabled or no, since that check is deferred to the last as noted above for the sake of conciseness.

There are multiple modes for programming PythonSCAD:

- Python — in `gcodepreview` this allows writing out dxf files and using mutable variables (this is done in current versions of this project)
- OpenSCAD — see: <https://openscad.org/documentation.html>

- Programming in Python, calling Python from OpenSCAD using dispatchers/descriptors (this is done in current versions of this project)
- Programming in OpenSCAD with variables and calling Python — this requires 3 files and was originally used in the project as written up at: [https://github.com/WillAdams/gcodepreview/blob/main/gcodepreview-openscad\\_0\\_6.pdf](https://github.com/WillAdams/gcodepreview/blob/main/gcodepreview-openscad_0_6.pdf) (for further details see below, notably various commented out lines in the source .tex file)
- Programming in OpenSCAD and calling Python where all variables as variables are held in Python classes (this is the technique used up through v0.8)
- Programming in Python and calling OpenSCAD — [https://old.reddit.com/r/OpenPythonSCAD/comments/1heczmi/finally\\_using\\_scad\\_modules/](https://old.reddit.com/r/OpenPythonSCAD/comments/1heczmi/finally_using_scad_modules/)

For reference, structurally, when developing OpenSCAD commands which make use of Python variables this was rendered as:

```
The user-facing module is \DescribeRoutine{FOOBAR}

\lstset{firstnumber=\thegpscad}
\begin{writecode}{a}{gcodepreview.scad}{scad}
module FOOBAR(...) {
    oFOOBAR(...);
}

\end{writecode}
\addtocounter{gpscad}{4}

which calls the internal OpenSCAD Module \DescribeSubroutine{FOOBAR}{oFOOBAR}

\begin{writecode}{a}{pygcodepreview.scad}{scad}
module oFOOBAR(...) {
    pFOOBAR(...);
}

\end{writecode}
\addtocounter{pyscad}{4}

which in turn calls the internal Python definition \DescribeSubroutine{FOOBAR}{pFOOBAR}

\lstset{firstnumber=\thegcpy}
\begin{writecode}{a}{gcodepreview.py}{python}
def pFOOBAR (...)

...

\end{writecode}
\addtocounter{gcpy}{3}
```

Further note that this style of definition might not have been necessary for some later modules since they are in turn calling internal modules which already use this structure.

Lastly note that this style of programming was abandoned in favour of object-oriented dot notation for versions after v0.6 (see below) and that this technique was extended to class nested within another class.

### 3.2.1 Parameters and Default Values

Ideally, there would be *no* hard-coded values — every value used for calculation will be parameterized, and subject to control/modification. Fortunately, Python affords a feature which specifically addresses this, optional arguments with default values:

<https://stackoverflow.com/questions/9539921/how-do-i-define-a-function-with-optional-arguments>

In short, rather than hard-code numbers, for example in loops, they will be assigned as default values, and thus afford the user/programmer the option of changing them when the module is called.

## 3.3 Implementation files and gcodepreview class

Each file will begin with a comment indicating the file type and further notes/comments on usage where appropriate:

---

```
1 gcpy #!/usr/bin/env python
2 gcpy #icon "C:\Program Files\PythonSCAD\bin\openscad.exe" --trust-python
3 gcpy #Currently tested with https://www.pythonscad.org/downloads/
      PythonSCAD_nolibfive-2025.06.04-x86-64-Installer.exe and Python
      3.11
4 gcpy #gcodepreview (gcpversion) 0.93, for use with PythonSCAD,
5 gcpy #if using from PythonSCAD using OpenSCAD code, see gcodepreview.
      scad
```

---

```

6 gcpy
7 gcpy import sys
8 gcpy
9 gcpy # add math functions (sqrt)
10 gcpy import math
11 gcpy
12 gcpy # getting openscad functions into namespace
13 gcpy #https://github.com/gsohler/openscad/issues/39
14 gcpy try:
15 gcpy     from openscad import *
16 gcpy except ModuleNotFoundError as e:
17 gcpy     print("OpenSCAD module not loaded .")
18 gcpy
19 gcpy def pygcpversion():
20 gcpy     thegcpversion = 0.93
21 gcpy     return thegcpversion

```

---

The OpenSCAD file must use the Python file (note that some test/example code is commented out):

---

```

1 gpcscad //!OpenSCAD
2 gpcscad
3 gpcscad //gcodepreview version 0.8
4 gpcscad //
5 gpcscad //used via include <gcodepreview.scad>;
6 gpcscad //
7 gpcscad
8 gpcscad use <gcodepreview.py>
9 gpcscad
10 gpcscad module gcpversion(){
11 gpcscad echo(pygcpversion());
12 gpcscad }
13 gpcscad
14 gpcscad //function myfunc(var) = gcp.myfunc(var);
15 gpcscad //
16 gpcscad //function getvv() = gcp.getvv();
17 gpcscad //
18 gpcscad //module makecube(xdim, ydim, zdim){
19 gpcscad //gcp.makecube(xdim, ydim, zdim);
20 gpcscad //}
21 gpcscad //
22 gpcscad //module placecube(){
23 gpcscad //gcp.placecube();
24 gpcscad //}
25 gpcscad //
26 gpcscad //module instantiatecube(){
27 gpcscad //gcp.instantiatecube();
28 gpcscad //}
29 gpcscad //

```

---

If all functions are to be handled within Python, then they will need to be gathered into a class which contains them and which is initialized so as to define shared variables and initial program state, and then there will need to be objects/commands for each aspect of the program, each of which will utilise needed variables and will contain appropriate functionality. Note that they will be divided between mandatory and optional functions/variables/objects:

- Mandatory
  - gcodepreview (init)
    - \* generatecut, generatedxf, generategcode
  - stocksetup:
    - \* stockXwidth, stockYheight, stockZthickness, zeroheight, stockzero, retractheight
  - gcpfiles:
    - \* basefilename
  - largesquaretool:
    - \* large\_square\_tool\_num, toolradius, plunge, feed, speed
  - currenttoolnum
    - \* endmilltype
    - \* diameter
    - \* flute
    - \* shaftdiameter
    - \* shaftheight

- \* shaftlength
- \* toolnumber
- \* cutcolor
- \* rapidcolor
- \* shaftcolor
- Optional
  - smallsquaretool:
    - \* small\_square\_tool\_num, small\_square\_ratio
  - largeballtool:
    - \* large\_ball\_tool\_num, large\_ball\_ratio
  - largeVtool:
    - \* large\_V\_tool\_num, large\_V\_ratio
  - smallballtool:
    - \* small\_ball\_tool\_num, small\_ball\_ratio
  - smallVtool:
    - \* small\_V\_tool\_num, small\_V\_ratio
  - DTtool:
    - \* DT\_tool\_num, DT\_ratio
  - KHtool:
    - \* KH\_tool\_num, KH\_ratio
  - Roundovertool:
    - \* Roundover\_tool\_num, RO\_ratio
  - misctool:
    - \* MISC\_tool\_num, MISC\_ratio

gcodepreview    The class which is defined is gcodepreview which begins with the `init` method which allows `init` passing in and defining the variables which will be used by the other methods in this class. Part of this includes handling various definitions for Boolean values.

---

```
3 gcptmpl #gcptemplate.txt --- this file will collect example usages of each
4 gcptmpl                                command with a brief commentary.
```

---

### 3.3.1 init

Initialization of the `gcodepreview` object requires handling a number of different cases, two of which are exclusive to each other. It must also take into account the possibility of being called from OpenSCAD

---

```
23 gcpy class gcodepreview:
24 gcpy
25 gcpy     def __init__(self,
26 gcpy         cutterprint = "cut", "#cut", "print", "no_preview"
27 gcpy         generategcode = False,
28 gcpy         generatedxf = False,
29 gcpy         gcpfa = 2,
30 gcpy         gcpfs = 0.125,
31 gcpy         steps = 10
32 gcpy         ):
33 gcpy         """
34 gcpy             Initialize gcodepreview object.
35 gcpy
36 gcpy             Parameters
37 gcpy             -----
38 gcpy                 cutterprint : string
39 gcpy                     Enables creation of 3D model for cutting or
40 gcpy                     printing.
41 gcpy                 generategcode : boolean
42 gcpy                     Enables writing out G-code.
43 gcpy                 generatedxf : boolean
44 gcpy                     Enables writing out DXF file(s).
45 gcpy
46 gcpy             Returns
47 gcpy             -----
48 gcpy                 object
49 gcpy                     The initialized gcodepreview object.
50 gcpy         """
51 gcpy         if cutterprint == "print":
```

```

51 gcpy           self.generatecut = False
52 gcpy           self.generateprint = True
53 gcpy           self.gcodefileext = ".gcode"
54 gcpy           elif cutoorprint == "cut":
55 gcpy               self.generatecut = True
56 gcpy               self.generateprint = False
57 gcpy               self.gcodefileext = ".nc"
58 gcpy           else: # no_preview
59 gcpy               self.generatecut = False
60 gcpy               self.generateprint = False
61 gcpy           if generategcode == True:
62 gcpy               self.generategcode = True
63 gcpy           elif generategcode == 1:
64 gcpy               self.generategcode = True
65 gcpy           elif generategcode == 0:
66 gcpy               self.generategcode = False
67 gcpy           else:
68 gcpy               self.generategcode = generategcode
69 gcpy           if generatedxf == True:
70 gcpy               self.generatedxf = True
71 gcpy           elif generatedxf == 1:
72 gcpy               self.generatedxf = True
73 gcpy           elif generatedxf == 0:
74 gcpy               self.generatedxf = False
75 gcpy           else:
76 gcpy               self.generatedxf = generatedxf
77 gcpy # unless multiple dxfs are enabled, the check for them is of course
78 gcpy               False
79 gcpy           self.generateddxfs = False
80 gcpy # set up 3D previewing parameters
81 gcpy           fa = gcpfa
82 gcpy           fs = gcpfs
83 gcpy           self.steps = steps
84 gcpy # initialize the machine state
85 gcpy           self.mc = "Initialized"
86 gcpy           self.mpx = float(0)
87 gcpy           self.mpy = float(0)
88 gcpy           self.mpz = float(0)
89 gcpy           self.tpz = float(0)
90 gcpy # initialize the toolpath state
91 gcpy           self.retractheight = 5
92 gcpy # initialize the DEFAULT tool
93 gcpy           self.currenttoolnum = 102
94 gcpy           self.endmilltype = "square"
95 gcpy           self.diameter = 3.175
96 gcpy           self.flute = 12.7
97 gcpy           self.shaftdiameter = 3.175
98 gcpy           self.shaftheight = 12.7
99 gcpy           self.shaftlength = 19.5
100 gcpy          self.toolnumber = "100036"
101 gcpy          self.cutcolor = "green"
102 gcpy          self.rapidcolor = "orange"
103 gcpy          self.shaftcolor = "red"
104 gcpy # the command definesquaretool(3.175, 12.7, 20) is used in the
105 gcpy          toolchange command
106 gcpy          self.tooloutline = polygon( points
107 gcpy              =[ [0,0],[3.175,0],[3.175,12.7],[0,12.7] ] )
108 gcpy          self.toolprofile = polygon( points
109 gcpy              =[ [0,0],[1.5875,0],[1.5875,12.7],[0,12.7] ] )
110 gcpy          self.shaftoutline = polygon( points
111 gcpy              =[ [0,12.7],[3.175,12.7],[3.175,25.4],[0,25.4] ] )
112 gcpy          self.shaftprofile = polygon( points
113 gcpy              =[ [0,12.7],[1.5875,12.7],[1.5875,25.4],[0,25.4] ] )
114 gcpy          self.currenttoolshape = cylinder(h = self.flute, r = self.
115 gcpy              shaftdiameter/2)
116 gcpy          sh = cylinder(h = self.flute, r = self.shaftdiameter/2)
117 gcpy          self.currenttoolshaft = sh.translate([0,0,self.flute])
118 gcpy # debug mode requires a variable to track if it is on or off
119 gcpy          self.debugenable = False
120 gcpy # the variables for holding 3D models must be initialized as empty
121 gcpy          lists so as to ensure that only append or extend commands are
122 gcpy          used with them
123 gcpy          self.rapids = []
124 gcpy          self.toolpaths = []
125 gcpy          print("gcodepreviewclassinitialized")
126 gcpy
127 gcpy
128 gcpy #     def myfunc(self, var):
129 gcpy #         self.vv = var * var

```

---

```

120 gcpy #           return self.vv
121 gcpy #
122 gcpy #   def getvv(self):
123 gcpy #       return self.vv
124 gcpy #
125 gcpy #   def checkint(self):
126 gcpy #       return self.mc
127 gcpy #
128 gcpy #   def makecube(self, xdim, ydim, zdim):
129 gcpy #       self.c=cube([xdim, ydim, zdim])
130 gcpy #
131 gcpy #   def placecube(self):
132 gcpy #       show(self.c)
133 gcpy #
134 gcpy #   def instantiatecube(self):
135 gcpy #       return self.c

```

---

### 3.3.2 Position and Variables

In modeling the machine motion and G-code it will be necessary to have the machine track several variables for machine position, the current tool and its parameters, and the current depth in the current toolpath. This will be done using paired functions (which will set and return the matching variable) and a matching variable.

The first such variables are for xyz position:

mpx	• mpx
mpy	• mpy
mpz	• mpz

Similarly, for some toolpaths it will be necessary to track the depth along the Z-axis as the toolpath `tpzinc` is cut out, or the increment which a cut advances — this is done using an internal variable, `tpzinc`.

It will further be necessary to have a variable for the current tool:

currenttoolnum	• currenttoolnum
----------------	------------------

Note that the `currenttoolnum` variable should always be accessed and used for any specification of a tool, being read in whenever a tool is to be made use of, or a parameter or aspect of the tool needs to be used in a calculation.

In early versions, the implicit union of the 3D model of the tool was available and used where appropriate, but in v0.9, this was changed to using lists for concatenating the hulled shapes `toolmovement` of tool movements, so the module, `toolmovement` which given begin/end position returns the appropriate shape(s) as a list.

`currenttool` The 3D model of the tool is stored in `currenttool`.

`xpos` It will be necessary to have Python functions (`xpos`, `ypos`, and `zpos`) which return the current `ypos` values of the machine position in Cartesian coordinates:  
`zpos`

---

```

137 gcpy   def xpos(self):
138 gcpy       return self.mpx
139 gcpy
140 gcpy   def ypos(self):
141 gcpy       return self.mpy
142 gcpy
143 gcpy   def zpos(self):
144 gcpy       return self.mpz

```

---

Wrapping these in OpenSCAD functions allows use of this positional information from OpenSCAD:

---

```

30 gpcscad function xpos() = gcp.xpos();
31 gpcscad
32 gpcscad function ypos() = gcp.ypos();
33 gpcscad
34 gpcscad function zpos() = gcp.zpos();

```

---

`setxpos` and in turn, functions which set the positions: `setxpos`, `setypos`, and `setzpos`.

---

setypos	def setypos(self, newypos):
setzpos	def setzpos(self, newzpos):

---

```

146 gcpy   def setxpos(self, newxpos):
147 gcpy       self.mpx = newxpos
148 gcpy
149 gcpy   def setypos(self, newypos):
150 gcpy       self.mpy = newypos
151 gcpy
152 gcpy   def setzpos(self, newzpos):
153 gcpy       self.mpz = newzpos

```

---

Using the `set...` routines will afford a single point of control if specific actions are found to be contingent on changes to these positions.

### 3.3.3 Initial Modules

Initializing the machine state requires zeroing out the three machine position variables:

- `mpx`
- `mpy`
- `mpz`

Rather than a specific command for this, the code will be in-lined where appropriate (note that if machine initialization becomes sufficiently complex to warrant it, then a suitable command will need to be coded). Note that the variables are declared in the `__init__` of the class.

`toolmovement` The `toolmovement` class requires that the tool be defined in terms of `endmilltype`, `diameter`, `endmilltype` `flute` (`length`), `ra` (radius or angle depending on context), and `tip`, and there is a mechanism `diameter` which defines an internal tool number as described below. Currently though, the interface calls `flute` the `toolchange` routine passing in a manufacturer tool number as an expedient/default/initial `ra` option.

`tip` There are two variables to record `toolmovement`, `rapids` and `toolpaths`. Initialized as empty `toolmovement` lists, `toolmovements` will be extended to the lists, then for output, the lists will be expanded and `rapids` subtracted from the stock separately so that `rapids` are colour-coded so that if there is an interaction with the stock at rapid speed it will be obvious. A similar method should be implemented for the shafts of tooling.

`gcodepreview` **3.3.3.1 setupstock** The first such setup subroutine is `gcodepreview setupstock` which is appropriately enough, to set up the stock, and perform other initializations — initially, the only thing done in Python was to set the value of the persistent (Python) variables (see `initializemachinestate()` above), but the rewritten standalone version handles all necessary actions.

`gcp.setupstock` Since part of a class, it will be called as `gcp.setupstock`. It requires that the user set parameters for stock dimensions and so forth, and will create comments in the G-code (if generating that file is enabled) which incorporate the stock dimensions and its position relative to the zero as set relative to the stock.

---

```

155 gcpy      def setupstock(self, stockXwidth ,
156 gcpy          stockYheight ,
157 gcpy          stockZthickness ,
158 gcpy          zeroheight ,
159 gcpy          stockzero ,
160 gcpy          retractheight):
161 gcpy          """
162 gcpy          Set up blank/stock for material and position/zero.
163 gcpy
164 gcpy          Parameters
165 gcpy          -----
166 gcpy          stockXwidth : float
167 gcpy              X extent/dimension
168 gcpy          stockYheight : float
169 gcpy              Y extent/dimension
170 gcpy          stockZthickness : boolean
171 gcpy              Z extent/dimension
172 gcpy          zeroheight : string
173 gcpy              Top or Bottom, determines if Z extent will
174 gcpy                  be positive or negative
175 gcpy          stockzero : string
176 gcpy              Lower-Left, Center-Left, Top-Left, Center,
177 gcpy                  determines XY position of stock
178 gcpy          retractheight : float
179 gcpy              Distance which tool retracts above surface
180 gcpy                  of stock.
181 gcpy
182 gcpy          Returns
183 gcpy          -----
184 gcpy          none
185 gcpy          """
186 gcpy          self.stockXwidth = stockXwidth
187 gcpy          self.stockYheight = stockYheight
188 gcpy          self.stockZthickness = stockZthickness
189 gcpy          self.zeroheight = zeroheight
190 gcpy          self.stockzero = stockzero
191 gcpy          self.retractheight = retractheight
192 gcpy          self.stock = cube([stockXwidth, stockYheight,
193 gcpy                  stockZthickness])

```

---

zeroheight A series of if statements parse the zeroheight (Z-axis) and stockzero (X- and Y-axes) parameters stockzero so as to place the stock in place and suitable G-code comments are added for CutViewer.

---

```

191 gcpy           if self.zeroheight == "Top":
192 gcpy             if self.stockzero == "Lower-Left":
193 gcpy               self.stock = self.stock.translate([0, 0, -self.
194 gcpy                 stockZthickness])
195 gcpy               if self.generategcode == True:
196 gcpy                 self.writegc("(stockMin:0.00mm, 0.00mm,",
197 gcpy                   str(self.stockZthickness), "mm)")
198 gcpy                   self.writegc("(stockMax:", str(self.stockXwidth
199 gcpy                     ), "mm, ", str(self.stockYheight), "mm, 0.00mm)")
200 gcpy                     self.writegc("(STOCK/BLOCK,",
201 gcpy                       str(self.
202 gcpy                         stockXwidth), ",", str(self.stockYheight),
203 gcpy                           ", ", str(self.stockZthickness), ", 0.00,",
204 gcpy                             str(self.stockZthickness), ")");
205 gcpy           if self.stockzero == "Center-Left":
206 gcpy             self.stock = self.stock.translate([0, -stockYheight
207 gcpy               / 2, -stockZthickness])
208 gcpy             if self.generategcode == True:
209 gcpy               self.writegc("(stockMin:0.00mm,",
210 gcpy                 str(self.stockYheight/2), "mm,",
211 gcpy                   str(self.stockZthickness), "mm)")
212 gcpy               self.writegc("(stockMax:", str(self.stockXwidth
213 gcpy                 ), "mm, 0.00mm, 0.00mm)")
214 gcpy               self.writegc("(STOCK/BLOCK,",
215 gcpy                 str(self.
216 gcpy                   stockXwidth), ",", str(self.stockYheight),
217 gcpy                     ", ", str(self.stockZthickness), "mm
218 gcpy                       )")
219 gcpy             if self.generategcode == True:
220 gcpy               self.writegc("(stockMin:0.00mm, 0.00mm, 0.00mm
221 gcpy                     )")
222 gcpy               self.writegc("(stockMax:", str(self.
223 gcpy                 stockXwidth), ", ", str(self.stockYheight),
224 gcpy                   ", ", str(self.stockZthickness), "mm")
225 gcpy             if self.stockzero == "Center-Left":
```

```

224 gcpy           self.stock = self.stock.translate([0, -self.
225 gcpy           stockYheight / 2, 0])
226 gcpy           if self.generategcode == True:
227 gcpy           self.writegc("(stockMin:0.00mm,-", str(self.
228 gcpy           stockYheight/2), "mm,0.00mm)")
229 gcpy           self.writegc("(stockMax:", str(self.stockXwidth
230 gcpy           ), "mm,", str(self.stockYheight/2), "mm,-"
231 gcpy           , str(self.stockZthickness), "mm)")
232 gcpy           self.writegc("(STOCK/BLOCK,", str(self.
233 gcpy           stockXwidth), ",,", str(self.stockYheight),
234 gcpy           ",,", str(self.stockZthickness), ",0.00,,",
235 gcpy           str(self.stockYheight/2), ",0.00mm)");
236 gcpy           if self.stockzero == "Top-Left":
237 gcpy           self.stock = self.stock.translate([0, -self.
238 gcpy           stockYheight, 0])
239 gcpy           if self.generategcode == True:
240 gcpy           self.writegc("(stockMin:0.00mm,-", str(self.
241 gcpy           stockYheight), "mm,0.00mm)")
242 gcpy           self.writegc("(stockMax:", str(self.stockXwidth
243 gcpy           ), "mm,0.00mm,", str(self.stockZthickness)
244 gcpy           , "mm)")
245 gcpy           self.writegc("(STOCK/BLOCK,", str(self.
246 gcpy           stockXwidth), ",,", str(self.stockYheight),
247 gcpy           ",,", str(self.stockZthickness), ",0.00,,",
248 gcpy           str(self.stockXwidth/2), ",,", str(self.
249 gcpy           stockYheight/2), ",0.00)")
250 gcpy           if self.generategcode == True:
251 gcpy           self.writegc("G90");
252 gcpy           self.writegc("G21");

```

---

Note that while the #102 is declared as a default tool, while it was originally necessary to call a tool change after invoking `setupstock`, in the 2024.09.03 version of PythonSCAD this requirement went away when an update which interfered with persistently setting a variable directly was fixed. The `setupstock` command is required if working with a 3D project, creating the block of stock which the following toolpath commands will cut away. Note that since Python in OpenPython-SCAD defers output of the 3D model, it is possible to define it once, then set up all the specifics for each possible positioning of the stock in terms of origin.

The OpenSCAD version is simply a descriptor:

```

36 gpcscad module setupstock(stockXwidth, stockYheight, stockZthickness,
37 gpcscad     zeroheight, stockzero, retractheight) {
38 gpcscad     gcp.setupstock(stockXwidth, stockYheight, stockZthickness,
38 gpcscad     zeroheight, stockzero, retractheight);
38 gpcscad }

```

---

**3.3.3.2 setupcuttingarea** If processing G-code, the parameters passed in are necessarily different, and there is of course, no need to write out G-code.

```

245 gcpy     def setupcuttingarea(self, sizeX, sizeY, sizeZ, extentleft,
246 gcpy     extentfb, extentd):
247 gcpy     self.initializemachinestate()
248 gcpy     c=cube([sizeX,sizeY,sizeZ])
249 gcpy     c = c.translate([extentleft,extentfb,extentd])
250 gcpy     self.stock = c
251 gcpy     self.toolpaths = []
252 gcpy     return c

```

---

**3.3.3.3 debug** Rather than endlessly add and then comment out `print()` commands, it is easier to have a variable for this, and a command which wraps the command which checks for that:

---

```

253 gcpy     def debug(self, *args: any, sep: str = " ", end: str = "\n", **print_kwarg
254 gcpy         """
255 gcpy             Print debug output if enabled.
256 gcpy
257 gcpy             Accepts the same arguments as built-in print (except file
258 gcpy                 is supported via print_kwarg).
259 gcpy
260 gcpy             if not self.debugenable:
261 gcpy                 return
262 gcpy             # Build the message and print under a lock to avoid
263 gcpy                 interleaving in multithreaded apps
264 gcpy             self.prefix = "DEBUG: "
265 gcpy             msg = self.prefix + sep.join(map(str, args))
266 gcpy             with self._lock:
267 gcpy                 print(msg, end=end, **print_kwarg)

```

---

Note that it will be necessary to manually use commands such as:

---

```

97 gcptmpl self.debugenable = True
98 gcptmpl
99 gcptmpl testvariable = 1
100 gcptmpl
101 gcptmpl self.outputdebugnote("Current value of testvariable is: ",
                                testvariable)

```

---

### 3.3.4 Adjustments and Additions

For certain projects and toolpaths it will be helpful to shift the stock, and to add additional pieces to the project.

Shifting the stock is simple:

---

```

266 gcpy     def shiftstock(self, shiftX, shiftY, shiftZ):
267 gcpy         self.stock = self.stock.translate([shiftX, shiftY, shiftZ
                ])

```

---

```

40 gpcscad module shiftstock(shiftX, shiftY, shiftZ) {
41 gpcscad     gcp.shiftstock(shiftX, shiftY, shiftZ);
42 gpcscad }

```

---

adding stock is similar, but adds the requirement that it include options for shifting the stock:

---

```

269 gcpy     def addtostock(self, stockXwidth, stockYheight, stockZthickness
                    ,
                    shiftX = 0,
                    shiftY = 0,
                    shiftZ = 0):
270 gcpy         addedpart = cube([stockXwidth, stockYheight,
                    stockZthickness])
271 gcpy         addedpart = addedpart.translate([shiftX, shiftY, shiftZ])
272 gcpy         self.stock = self.stock.union(addedpart)
273 gcpy
274 gcpy
275 gcpy

```

---

the OpenSCAD module is a descriptor as expected:

---

```

44 gpcscad module addtostock(stockXwidth, stockYheight, stockZthickness,
                           shiftX, shiftY, shiftZ) {
45 gpcscad     gcp.addtostock(stockXwidth, stockYheight, stockZthickness,
                           shiftX, shiftY, shiftZ);
46 gpcscad }

```

---

## 3.4 Tools and Shapes and Changes

Originally, it was necessary to return a shape so that modules which use a <variable>.union command would function as expected even when the 3D model created is stored in a variable.

Due to stack limits in OpenSCAD for the CSG tree, instead, the shapes will be stored in two rapids variables (rapids, toolpaths) as lists processed/created using a command toolmovement which toolpaths will subsume all tool related functionality. As other routines need access to information about the toolmovement current tool, appropriate routines will allow its variables and the specifics of the current tool to be queried.

It will be necessary to describe the tool in four different fashions:

- variables — a full set of variables is required to allow defining a shape and to determine the appropriate fashion in which to treat each tool at need

```
tooltype = "mill"
diameter = first
cornerradius = second
height = third
taperangle
length
```

- profile — the profile is a definition of the tool from the centerline to the outer edge which is used when necessary to `rotate_extrude()` the design
- outline — the outline is the entire definition of the tool shape which is used when `rotate_extrude`ing an arc (which will also require a 3D version of the rotated tool profile at each end)
- shape — originally the program used the tool shape and `hull()`ed it from beginning to end of a movement — having the shape pre-made allows it to be `union()`ed at need.

The base/entry functionality has the instance being defined in terms of a basic set of variables (one of which is overloaded to serve multiple purposes, depending on the type of endmill).

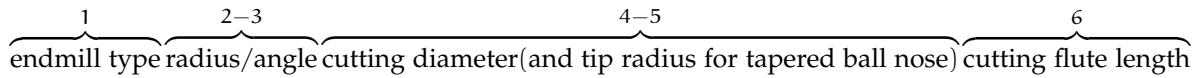
Note that it will also be necessary to write out a tool description compatible with the program CutViewer as a G-code comment so that it may be used as a 3D previewer for the G-code for tool changes in G-code. Several forms are available as described below.

#### 3.4.1 Numbering for Tools

Currently, the numbering scheme used is that of the various manufacturers of the tools, or descriptive short-hand numbers created for tools which lack such a designation (with a disclosure that the author is a Carbide 3D employee).

Creating any numbering scheme is like most things in life, a trade-off, balancing length and expressiveness/completeness against simplicity and usability. The software application Carbide Create (as released by an employer of the main author) has a limit of six digits, which seems a reasonable length from a complexity/simplicity standpoint, but also potentially reasonably expressive.

It will be desirable to track the following characteristics and measurements, apportioned over the digits as follows:



- 1st digit: endmill type:
  - 0 - manufacturer number
  - 1 - square (incl. "O"-flute)
  - 2 - ball
  - 3 - V
  - 4 - bowl
  - 5 - tapered ball
  - 6 - roundover
  - 7 - thread-cutting
  - 8 - dovetail
  - 9 - other (e.g., user-defined, or unsupported tools, keyhole, lollipop, &c.)
- 2nd and 3rd digits shape radius (ball/roundover) or angle (V), 2nd and 3rd digit together 10–99 indicate measurement in tenth of a millimeter. 2nd digit:
  - 0 - Imperial (00 indicates n/a or square)
  - any other value for both the 2nd and 3rd digits together indicate a metric measurement or an angle in degrees
- 3rd digit (if 2nd is 0 indicating Imperial)
  - 1 -  $1/32^{\text{nd}}$
  - 2 -  $1/16$
  - 3 -  $1/8$
  - 4 -  $1/4$
  - 5 -  $5/16$

- 6 - 3/8
- 7 - 1/2
- 8 - 3/4
- 9 - >1" or other
- 4th and 5th digits cutting diameter as 2nd and 3rd above except 4th digit indicates tip radius for tapered ball nose and such tooling is only represented in Imperial measure:
- 4th digit (tapered ball nose)
  - 1 - 0.01 in (this is the 0.254mm of the #501 and 502)
  - 2 - 0.015625 in (1/64th)
  - 3 - 0.0295
  - 4 - 0.03125 in (1/32nd)
  - 5 - 0.0335
  - 6 - 0.0354
  - 7 - 0.0625 in (1/16th)
  - 8 - 0.125 in (1/8th)
  - 9 - 0.25 in (1/4)
- 6th digit cutting flute length:
  - 0 - other
  - 1 - calculate based on V angle
  - 2 - 1/16
  - 3 - 1/8
  - 4 - 1/4
  - 5 - 5/16
  - 6 - 1/2
  - 7 - 3/4
  - 8 - "long reach" or greater than 3/4"
  - 9 - calculate based on radius
- or 6th digit tip diameter for roundover tooling (added to cutting diameter to arrive at actual cutting diameter — note that these values are the same as for the tip radius of the #501 and 502)
  - 1 - 0.01 in
  - 2 - 0.015625 in (1/64th)
  - 3 - 0.0295
  - 4 - 0.03125 in (1/32nd)
  - 5 - 0.0335
  - 6 - 0.0354
  - 7 - 0.0625 in (1/16th)
  - 8 - 0.125 in (1/8th)
  - 9 - 0.25 in (1/4)

Using this technique to create tool numbers for Carbide 3D tooling we arrive at:

- Square
 

```
#122 == 100012
#112 == 100024
#102 == 100036 (also #274 and #326 (Amana 46200-K))
#201 == 100047 (also #251 and #322 (Amana 46202-K))
#205 == 100048
#251 == 100047 (also #201 and #322 (Amana 46202-K))
#274 == 100036 (also #102 and #326 (Amana 46200-K))
#278 == 100047
#282 == 100204
#322 == 100047 (also #201 and #251)
#324 == 100048 (Amana 46170-K)
#326 == 100036 (also #102 and #274)
```

- Ball
 

```
#121 == 201012
#111 == 202024
#101 == 203036
#202 == 204047
#325 == 204048 (Amana 46376-K)
```

- V
 

```
#301 == 390074
#302 == 360071
#327 == 360098 (Amana RC-1148)
```

- Tapered Ball Nose
 

```
#501 == 530131
#502 == 540131
```

(note that some dimensions were rounded off/approximated)  
 Extending that to the non-Carbide 3D tooling thus implemented:

- V
 

```
#390
```
- Dovetail
 

```
814 == 814071
45828 == 808071
```
- Keyhole Tool
 

```
374 == 906043
375 == 906053
376 == 907040
378 == 907050
```
- Roundover Tool
 

```
56142 == 602032
56125 == 603042
1568 == 603032
1570
1572 == 604042
1574
```
- Threadmill
 

```
648
```
- Bowl bit
 

```
45981
45982
1370
1372
```

Tools which do not have calculated numbers filled in are not supported by the system as currently defined in an unambiguous fashion (instead filling in the manufacturer's tool number padded with zeros is hard-coded). Notable limitations:

- No way to indicate flute geometry beyond O-flute (which distinction will probably be removed)
- Lack of precision for metric tooling/limited support for Imperial sizes, notably, the dimensions used are scaled for smaller tooling and are not suited to typically larger scale tooling such as bowl bits
- No way to indicate several fairly common shapes including keyhole, lollipop, and flat-bottomed V/chamfer tools (except of course for using 9#####)

A further consideration is that it is not possible to represent tools unambiguously, so that given a tool definition it is possible to derive the manufacturer's tool number, *e.g.*, given a hypothetical command/instruction:

```
self.currenttoolshape = self.toolshapes("square", 6.35, 19.05)
```

it could be viewed as representing any of three different tools (Carbide 3D #201 (upcut), #251 (downcut), and #322 (Amana 46202-K downcut)), it is worth noting that #205E is differentiated due to its longer flute length as-is #324 (Amana 46170-K compression), though the fact of its compression cutting geometry is not recorded. Affording some sort of hinting to the user may be warranted, or a mechanism to allow specifying a given manufacturer tool # as part of setting up a job.

A more likely scheme is that manufacturer tool numbers will continue to be used to identify tooling, the generated number will be used internally, then the saved manufacturer number will be exported to the G-code file, or used when generating a DXF filename for a given set of tool movements.

---

```
277 gcpy     def currenttoolnumber(self):
278 gcpy         return(self.currenttoolnum)
```

---

**toolchange** The toolchange command will need to set several variables.  
Mandatory variables include:

- endmilltype
  - O-flute
  - square
  - ball
  - V
  - keyhole
  - dovetail
  - roundover
  - tapered ball
- diameter
- flute

and depending on the tool geometry, several additional variables will be necessary (usually derived from `self.ra`):

- radius
- angle

an optional setting of a `toolnumber` may be useful in the future.

**tool number 3.4.1.1 toolchange** This command accepts a `tool` number and assigns its characteristics as parameters. It then applies the appropriate commands for a toolchange. Note that it is expected that this code will be updated as needed when new tooling is introduced as additional modules which require specific tooling are added.

Note that the comments written out in G-code correspond to those used by the G-code previewing tool CutViewer (which is unfortunately no longer readily available). Similarly, the G-code previewing functionality in this library expects that such comments will be in place so as to model the stock.

A further concern is that early versions often passed the tool into a module using a parameter. That ceased to be necessary in the 2024.09.03 version of PythonSCAD, and all modules should read the `tool #` from `currenttoolnumber()`.

Note that there are many varieties of tooling and not all will be directly supported, and that at need, additional tool shape support may be added under `misc`.

The original implementation created the model for the tool at the current position, and a duplicate at the end position, wrapping the twain for each end of a given movement in a `hull()` command and then applying a `union`. This approach will not work within Python, so it will be necessary to instead assign and select the tool as part of the `toolmovement` command.

There are two separate commands for handling a tool being changed, the first sets the parameters which describe the tool and may be used to effect the change of a tool either in a G-code file `settoolparameters` or when making a 3D file, `settoolparameters` and a second version which processes a `toolchange` when presented with a tool number, `toolchange` (it may be that the latter will be set up to call the former).

**3.4.1.1.1 settoolparameters** Not currently used, this command is intended for a state where tools are defined in a vendor-neutral fashion.

---

```
280 gcpy     def settoolparameters(self, tooltype, first, second, third,
281 gcpy         fourth, length = 0):
282 gcpy             if tooltype == "mill":
283 gcpy                 diameter = first
284 gcpy                 cornerradius = second
```

---

```

284 gcpy           height = third
285 gcpy           taperangle = fourth
286 gcpy           if cornerradius == 0:
287 gcpy #M6T122 (TOOL/MILL,0.80, 0.00, 1.59, 0.00)
288 gcpy #M6T112 (TOOL/MILL,1.59, 0.00, 6.35, 0.00)
289 gcpy #M6T102 (TOOL/MILL,3.17, 0.00, 12.70, 0.00)
290 gcpy #M6T201 (TOOL/MILL,6.35, 0.00, 19.05, 0.00)
291 gcpy #M6T205 (TOOL/MILL,6.35, 0.00, 25.40, 0.00)
292 gcpy #M6T251 (TOOL/MILL,6.35, 0.00, 19.05, 0.00)
293 gcpy #M6T322 (TOOL/MILL,6.35, 0.00, 19.05, 0.00)
294 gcpy #M6T324 (TOOL/MILL,6.35, 0.00, 22.22, 0.00)
295 gcpy #M6T326 (TOOL/MILL,3.17, 0.00, 12.70, 0.00)
296 gcpy #M6T602 (TOOL/MILL,25.40, 0.00, 9.91, 0.00)
297 gcpy #M6T603 (TOOL/MILL,25.40, 0.00, 9.91, 0.00)
298 gcpy #M6T274 (TOOL/MILL,3.17, 0.00, 12.70, 0.00)
299 gcpy #M6T278 (TOOL/MILL,6.35, 0.00, 19.05, 0.00)
300 gcpy #M6T282 (TOOL/MILL,2.00, 0.00, 6.35, 0.00)
301 gcpy           self.endmilltype = "square"
302 gcpy           self.diameter = diameter
303 gcpy           self.flute = height
304 gcpy           self.shaftdiameter = diameter
305 gcpy           self.shaftheight = height
306 gcpy           self.shaftlength = height
307 gcpy #
308 gcpy           elif cornerradius > 0 and taperangle == 0:
309 gcpy #M6T121 (TOOL/MILL,0.80, 0.40, 1.59, 0.00)
310 gcpy #M6T111 (TOOL/MILL,1.59, 0.79, 6.35, 0.00)
311 gcpy #M6T101 (TOOL/MILL,3.17, 1.59, 12.70, 0.00)
312 gcpy #M6T202 (TOOL/MILL,6.35, 3.17, 19.05, 0.00)
313 gcpy #M6T325 (TOOL/MILL,6.35, 3.17, 25.40, 0.00)
314 gcpy           self.endmilltype = "ball"
315 gcpy           self.diameter = diameter
316 gcpy           self.flute = height
317 gcpy           self.shaftdiameter = diameter
318 gcpy           self.shaftheight = height
319 gcpy           self.shaftlength = height
320 gcpy #
321 gcpy           elif taperangle > 0:
322 gcpy #M6T301 (TOOL/MILL,0.10, 0.05, 6.35, 45.00)
323 gcpy #M6T302 (TOOL/MILL,0.10, 0.05, 6.35, 30.00)
324 gcpy #M6T327 (TOOL/MILL,0.10, 0.05, 23.39, 30.00)
325 gcpy           self.endmilltype = "V"
326 gcpy           self.diameter = Tan(taperangle / 2) * height
327 gcpy           self.flute = height
328 gcpy           self.angle = taperangle
329 gcpy           self.shaftdiameter = Tan(taperangle / 2) * height
330 gcpy           self.shaftheight = height
331 gcpy           self.shaftlength = height
332 gcpy #
333 gcpy           elif tooltype == "chamfer":
334 gcpy             tipdiameter = first
335 gcpy             radius = second
336 gcpy             height = third
337 gcpy             taperangle = fourth

```

---

**toolchange** **3.4.1.2 toolchange** The Python definition for toolchange requires the tool number (used to write out the G-code comment description for CutViewer and also expects the speed for the current tool since this is passed into the G-code tool change command as part of the spindle on command. A simple if-then structure, the variables necessary for defining the toolshape are (re)defined each time the command is called so that they may be used by the command toolmovement toolmovement for actually modeling the shapes and the path and the resultant material removal.

```

339 gcpy     def toolchange(self, tool_number, speed = 10000):
340 gcpy       self.currenttoolnum = tool_number
341 gcpy
342 gcpy       if (self.generategcode == True):
343 gcpy         self.writegc("(Toolpath)")
344 gcpy         self.writegc("M05")

```

---

**3.4.1.3 Square (including O-flute)** The simplest sort of tool, they are defined as a cylinder.

```

346 gcpy     if (tool_number == 102) or (tool_number == 100036): #
347 gcpy       102/326 == 100036
347 gcpy       self.writegc("(TOOL/MILL, 3.175, 0.00, 0.00, 0.00)")

```

---

---

```

348 gcpy           self.endmilltype = "square"
349 gcpy           self.diameter = 3.175
350 gcpy           self.flute = 12.7
351 gcpy           self.shaftdiameter = 3.175
352 gcpy           self.shaftheight = 12.7
353 gcpy           self.shaftlength = 19.5

```

---

The outline definitions for linear/rotate extrude are the same for this tool as in the default tool definition in `__init__`, but the commands `definesquaretool` and `defineshaft` are used:

```

354 gcpy           self.definesquaretool(self.diameter, self.shaftheight,
355 gcpy           self.defineshaft(self.diameter, self.shaftdiameter,
356 gcpy           self.flute, 0, self.shaftlength)
357 gcpy           self.toolnumber = 10003
358 gcpy           elif (tool_number == 201) or (tool_number == 100047): #
359 gcpy           201/251/322 (Amana 46202-K) == 100047
360 gcpy           self.writegc("(TOOL/MILL,\\6.35,\\0.00,\\0.00,\\0.00)")
361 gcpy           self.endmilltype = "square"
362 gcpy           self.diameter = 6.35
363 gcpy           self.flute = 19.05
364 gcpy           self.shaftdiameter = 6.35
365 gcpy           self.shaftheight = 19.05
366 gcpy           self.shaftlength = 20.0
367 gcpy           self.definesquaretool(self.diameter, self.shaftheight,
368 gcpy           self.shaftlength)
369 gcpy           self.defineshaft(self.diameter, self.shaftdiameter,
370 gcpy           self.flute, 0, self.shaftlength)
371 gcpy           self.toolnumber = "100047"
372 gcpy           elif (tool_number == 112) or (tool_number == 100024): #112
373 gcpy           == 100024
374 gcpy           self.writegc("(TOOL/MILL,\\1.5875,\\0.00,\\0.00,\\0.00)")
375 gcpy           self.endmilltype = "square"
376 gcpy           self.diameter = 1.5875
377 gcpy           self.flute = 6.35
378 gcpy           self.shaftdiameter = 3.175
379 gcpy           self.shaftheight = 6.35
380 gcpy           self.shaftlength = 12.0
381 gcpy           self.definesquaretool(self.diameter, self.shaftheight,
382 gcpy           self.shaftlength, (self.shaftdiameter - self.
383 gcpy           diameter)/2)
384 gcpy           self.defineshaft(self.diameter, self.shaftdiameter,
385 gcpy           self.flute, 0, self.shaftlength)
386 gcpy           self.toolnumber = "100024"
387 gcpy           elif (tool_number == 122) or (tool_number == 100012): #122
388 gcpy           == 100012
389 gcpy           self.writegc("(TOOL/MILL,\\0.79375,\\0.00,\\0.00,\\0.00)")
390 gcpy           self.endmilltype = "square"
391 gcpy           self.diameter = 0.79375
392 gcpy           self.flute = 1.5875
393 gcpy           self.shaftdiameter = 3.175
394 gcpy           self.shaftheight = 1.5875
395 gcpy           self.shaftlength = 12.0
396 gcpy           self.definesquaretool(self.diameter, self.shaftheight,
397 gcpy           self.shaftlength, (self.shaftdiameter - self.
398 gcpy           diameter)/2)
399 gcpy           self.defineshaft(self.diameter, self.shaftdiameter,
400 gcpy           self.flute, 0, self.shaftlength)
401 gcpy           self.toolnumber = "100012"
402 gcpy           elif (tool_number == 324): #324 (Amana 46170-K) == 100048
403 gcpy           self.writegc("(TOOL/MILL,\\6.35,\\0.00,\\0.00,\\0.00)")
404 gcpy           self.endmilltype = "square"
405 gcpy           self.diameter = 6.35

```

---

```

406 gcpy           self.shaftdiameter = 6.35
407 gcpy           self.shaftheight = 25.4
408 gcpy           self.shaftlength = 20.0
409 gcpy           self.definesquaretool(self.diameter, self.shaftheight,
410 gcpy                     self.shaftlength)
411 gcpy           self.defineshaft(self.diameter, self.shaftdiameter,
412 gcpy                     self.flute, 0, self.shaftlength)
413 gcpy           defineKeyholetool(self.diameter, self.flute, self.
414 gcpy                     shaftdiameter, self.shaftheight, self.shaftdiameter,
415 gcpy                     self.shaftlength)
416 gcpy           self.toolnumber = "100048"
417 gcpy #

```

---

The former distinction betwixt Square and O-flute tooling has been removed from the current version.

---

```

414 gcpy       elif (tool_number == 282) or (tool_number == 100204): #282
415 gcpy             == 000204
416 gcpy             self.writegc("(TOOL/MILL, 2.0, 0.00, 0.00, 0.00)")
417 gcpy             self.endmilltype = "O-flute"
418 gcpy             self.diameter = 2.0
419 gcpy             self.flute = 6.35
420 gcpy             self.shaftdiameter = 6.35
421 gcpy             self.shaftheight = 6.35
422 gcpy             self.shaftlength = 12.0
423 gcpy             self.definesquaretool(self.diameter, self.shaftheight,
424 gcpy                     self.shaftlength, (self.shaftdiameter - self.
425 gcpy                     diameter)/2)
426 gcpy             self.defineshaft(self.diameter, self.shaftdiameter,
427 gcpy                     self.flute, 0, self.shaftlength)
428 gcpy             self.toolnumber = "100204"
429 gcpy
430 gcpy
431 gcpy
432 gcpy
433 gcpy
434 gcpy
435 gcpy
436 gcpy       elif (tool_number == 274) or (tool_number == 100036): #274
437 gcpy             == 000036
438 gcpy             self.writegc("(TOOL/MILL, 3.175, 0.00, 0.00, 0.00)")
439 gcpy             self.endmilltype = "O-flute"
440 gcpy             self.diameter = 3.175
441 gcpy             self.flute = 12.7
442 gcpy             self.shaftdiameter = 3.175
443 gcpy             self.shaftheight = 12.7
444 gcpy             self.shaftlength = 20.0
445 gcpy             self.definesquaretool(self.diameter, self.shaftheight,
446 gcpy                     self.shaftlength)
447 gcpy             self.defineshaft(self.diameter, self.shaftdiameter,
448 gcpy                     self.flute, 0, self.shaftlength)
449 gcpy             self.toolnumber = "100036"
450 gcpy
451 gcpy
452 gcpy
453 gcpy
454 gcpy
455 gcpy #

```

---

**3.4.1.1.4 Ball-nose (including tapered-ball)** The elifs continue with ball-nose and tapered-ball tooling which are defined as one would expect by spheres and cylinders. Note that the Cutviewer definition of a the measurement point of a tool being at the center is not yet set up — potentially it opens up greatly simplified toolpath calculations and may be implemented in a future version.

---

```

448 gcpy       elif (tool_number == 202) or (tool_number == 204047): #202
449 gcpy             == 204047
450 gcpy             self.writegc("(TOOL/MILL, 6.35, 3.175, 0.00, 0.00)")
451 gcpy             self.endmilltype = "ball"
452 gcpy             self.diameter = 6.35
453 gcpy             self.flute = 19.05
454 gcpy             self.shaftdiameter = 6.35
455 gcpy             self.shaftheight = 19.05
456 gcpy             self.shaftlength = 20.0

```

---

```

456 gcpy           self.defineballnosetool(self.diameter, self.flute, self
457 gcpy           .shaftlength)
458 gcpy           self.defineshaft(self.diameter, self.shaftdiameter,
459 gcpy           self.flute, 0, self.shaftlength)
460 gcpy           self.toolnumber = "204047"
461 gcpy           elif (tool_number == 101) or (tool_number == 203036): #101
462 gcpy           == 203036
463 gcpy           self.writegc("(TOOL/MILL, 3.175, 1.5875, 0.00, 0.00)")
464 gcpy           self.endmilltype = "ball"
465 gcpy           self.diameter = 3.175
466 gcpy           self.flute = 12.7
467 gcpy           self.shaftdiameter = 3.175
468 gcpy           self.shaftheight = 12.7
469 gcpy           self.shaftlength = 20.0
470 gcpy           self.defineballnosetool(self.diameter, self.flute, self
471 gcpy           .shaftlength)
472 gcpy           self.defineshaft(self.diameter, self.shaftdiameter,
473 gcpy           self.flute, 0, self.shaftlength)
474 gcpy           self.toolnumber = "203036"
475 gcpy           elif (tool_number == 111) or (tool_number == 202024): #111
476 gcpy           == 202024
477 gcpy           self.writegc("(TOOL/MILL, 1.5875, 0.79375, 0.00, 0.00)"
478 gcpy           )
479 gcpy           self.endmilltype = "ball"
480 gcpy           self.diameter = 1.5875
481 gcpy           self.flute = 6.35
482 gcpy           self.shaftdiameter = 3.175
483 gcpy           self.shaftheight = 6.35
484 gcpy           self.shaftlength = 20.0
485 gcpy           self.defineballnosetool(self.diameter, self.flute, self
486 gcpy           .shaftlength, (self.shaftdiameter - self.diameter)
487 gcpy           /2)
488 gcpy           self.defineshaft(self.diameter, self.shaftdiameter,
489 gcpy           self.flute, 0, self.shaftlength)
490 gcpy           self.toolnumber = "202024"
491 gcpy           elif (tool_number == 121) or (tool_number == 201012): #121
492 gcpy           == 201012
493 gcpy           self.writegc("(TOOL/MILL, 3.175, 0.79375, 0.00, 0.00)")
494 gcpy           self.endmilltype = "ball"
495 gcpy           self.diameter = 0.79375
496 gcpy           self.flute = 1.5875
497 gcpy           self.shaftdiameter = 3.175
498 gcpy           self.shaftheight = 1.5875
499 gcpy           self.shaftlength = 20.0
500 gcpy           self.defineballnosetool(self.diameter, self.flute, self
501 gcpy           .shaftlength, (self.shaftdiameter - self.diameter)
502 gcpy           /2)
503 gcpy           self.defineshaft(self.diameter, self.shaftdiameter,
504 gcpy           self.flute, 0, self.shaftlength)
505 gcpy           self.toolnumber = "201012"
506 gcpy           elif (tool_number == 325) or (tool_number == 204048): #325
507 gcpy           (Amana 46376-K) == 204048

```

---

**3.4.1.1.5 V** Note that one V tool is described as an Engraver in Carbide Create. While CutViewer has specialty Tool/chamfer and Tool/drill parameters, it is possible to describe a V tool as a Tool/mill (using a very small tip radius).

---

```

504 gcpy           self.writegc("(TOOL/MILL, 0.10, 0.05, 6.35, 45.00)")
505 gcpy           self.endmilltype = "V"
506 gcpy           self.diameter = 12.7
507 gcpy           self.flute = 0.05

```

```

508 gcpy           self.flute = 6.35
509 gcpy           self.angle = 90
510 gcpy           self.shaftdiameter = 6.35
511 gcpy           self.shaftheight = 6.35
512 gcpy           self.shaftlength = 20.0
513 gcpy           self.defineVtool(self.diameter, self.flute, self.
                                shaftlength, self.shaftdiameter)
514 gcpy           self.toolnumber = "390074"
515 gcpy           elif (tool_number == 302) or (tool_number == 360071): #302
                    == 360071
516 gcpy           self.writegc("(TOOL/MILL,0.10,0.05,6.35,30.00)")
517 gcpy           self.endmilltype = "V"
518 gcpy           self.diameter = 12.7
519 gcpy           self.flute = 11.067
520 gcpy           self.angle = 60
521 gcpy           self.shaftdiameter = 6.35
522 gcpy           self.shaftheight = 11.067
523 gcpy           self.shaftlength = 20.0
524 gcpy           self.defineVtool(self.diameter, self.flute, self.
                                shaftlength, self.shaftdiameter)
525 gcpy           self.toolnumber = "360071"
526 gcpy           elif (tool_number == 390) or (tool_number == 390032): #390
                    == 390032
527 gcpy           self.writegc("(TOOL/MILL,0.03,0.00,1.5875,45.00)")
528 gcpy           self.endmilltype = "V"
529 gcpy           self.diameter = 3.175
530 gcpy           self.flute = 1.5875
531 gcpy           self.angle = 90
532 gcpy           self.shaftdiameter = 3.175
533 gcpy           self.shaftheight = 1.5875
534 gcpy           self.shaftlength = 20.0
535 gcpy           self.defineVtool(self.diameter, self.flute, self.
                                shaftlength, self.shaftdiameter)
536 gcpy           self.toolnumber = "390032"
537 gcpy           elif (tool_number == 327) or (tool_number == 360098): #327
                    (Amana RC-1148) == 360098
538 gcpy           self.writegc("(TOOL/MILL,0.03,0.00,13.4874,30.00)")
539 gcpy           self.endmilltype = "V"
540 gcpy           self.diameter = 25.4
541 gcpy           self.flute = 22.134
542 gcpy           self.angle = 60
543 gcpy           self.shaftdiameter = 6.35
544 gcpy           self.shaftheight = 22.134
545 gcpy           self.shaftlength = 20.0
546 gcpy           self.defineVtool(self.diameter, self.flute, self.
                                shaftlength, self.shaftdiameter)
547 gcpy           self.toolnumber = "360098"
548 gcpy           elif (tool_number == 323) or (tool_number == 330041): #323
                    == 330041 30 degree V Amana, 45771-K
549 gcpy           self.writegc("(TOOL/MILL,0.10,0.05,11.18,15.00)")
550 gcpy           self.endmilltype = "V"
551 gcpy           self.diameter = 6.35
552 gcpy           self.flute = 11.849
553 gcpy           self.angle = 30
554 gcpy           self.shaftdiameter = 6.35
555 gcpy           self.shaftheight = 11.849
556 gcpy           self.shaftlength = 20.0
557 gcpy           self.defineVtool(self.diameter, self.flute, self.
                                shaftlength, self.shaftdiameter)
558 gcpy           self.toolnumber = "330041"
559 gcpy #

```

---

### 3.4.1.1.6 Keyhole

Keyhole tooling will primarily be used with a dedicated toolpath.

```

560 gcpy           elif (tool_number == 374) or (tool_number == 906043): #374
                    == 906043
561 gcpy           self.writegc("(TOOL/MILL,9.53,0.00,3.17,0.00)")
562 gcpy           self.endmilltype = "keyhole"
563 gcpy           self.diameter = 9.525
564 gcpy           self.flute = 3.175
565 gcpy           self.radius = 6.35
566 gcpy           self.shaftdiameter = 6.35
567 gcpy           self.shaftheight = 3.175
568 gcpy           self.shaftlength = 20.0
569 gcpy           self.defineKeyholetool(self.diameter, self.flute, self.
                                shaftdiameter, self.shaftheight, self.shaftdiameter,
                                self.shaftlength)

```

```

570 gcpy           self.toolnumber = "906043"
571 gcpy   elif (tool_number == 375) or (tool_number == 906053): #375
572 gcpy       == 906053
573 gcpy       self.writegc("(TOOL/MILL, 9.53, 0.00, 3.17, 0.00)")
574 gcpy       self.endmilltype = "keyhole"
575 gcpy       self.diameter = 9.525
576 gcpy       self.flute = 3.175
577 gcpy       self.radius = 8
578 gcpy       self.shaftdiameter = 6.35
579 gcpy       self.shaftheight = 3.175
580 gcpy       self.shaftlength = 20.0
581 gcpy       self.defineKeyholetool(self.diameter, self.flute, self.
582 gcpy             shaftdiameter, self.shaftheight, self.shaftdiameter,
583 gcpy               self.shaftlength)
584 gcpy       self.toolnumber = "906053"
585 gcpy   elif (tool_number == 376) or (tool_number == 907040): #376
586 gcpy       == 907040
587 gcpy       self.writegc("(TOOL/MILL, 12.7, 0.00, 4.77, 0.00)")
588 gcpy       self.endmilltype = "keyhole"
589 gcpy       self.diameter = 12.7
590 gcpy       self.flute = 4.7625
591 gcpy       self.radius = 6.35
592 gcpy       self.shaftdiameter = 6.35
593 gcpy       self.shaftheight = 4.7625
594 gcpy       self.shaftlength = 20.0
595 gcpy   self.defineKeyholetool(self.diameter, self.flute, self.
596 gcpy             shaftdiameter, self.shaftheight, self.shaftdiameter,
597 gcpy               self.shaftlength)
598 gcpy       self.toolnumber = "907040"
599 gcpy   elif (tool_number == 378) or (tool_number == 907050): #378
600 gcpy       == 907050
601 gcpy       self.writegc("(TOOL/MILL, 12.7, 0.00, 4.77, 0.00)")
602 gcpy       self.endmilltype = "keyhole"
603 gcpy       self.diameter = 12.7
604 gcpy       self.flute = 4.7625
605 gcpy       self.radius = 8
606 gcpy       self.shaftdiameter = 6.35
607 gcpy       self.shaftheight = 4.7625
608 gcpy       self.shaftlength = 20.0
609 gcpy   self.defineKeyholetool(self.diameter, self.flute, self.
610 gcpy             shaftdiameter, self.shaftheight, self.shaftdiameter,
611 gcpy               self.shaftlength)
612 gcpy       self.toolnumber = "907050"

```

---

### 3.4.1.1.7 Bowl This geometry is also useful for square endmills with a radius.

```

605 gcpy   elif (tool_number == 45981): #45981 == 445981
606 gcpy #Amana Carbide Tipped Bowl & Tray 1/8 Radius x 1/2 Dia x 1/2 x 1/4
607 gcpy     Inch Shank
608 gcpy       self.writegc("(TOOL/MILL, 0.03, 0.00, 10.00, 30.00)")
609 gcpy       self.writegc("(TOOL/MILL, 15.875, 6.35, 19.05, 0.00)")
610 gcpy       self.endmilltype = "bowl"
611 gcpy       self.diameter = 12.7
612 gcpy       self.flute = 12.7
613 gcpy       self.radius = 3.175
614 gcpy       self.shaftdiameter = 6.35
615 gcpy       self.shaftheight = 12.7
616 gcpy       self.shaftlength = 20.0
617 gcpy       self.definebowltool(self.diameter, self.flute, self.
618 gcpy         radius, self.shaftdiameter, self.shaftlength)
619 gcpy       self.toolnumber = "445981"
620 gcpy   elif (tool_number == 45982): #0.507/2, 4.509
621 gcpy       self.writegc("(TOOL/MILL, 15.875, 6.35, 19.05, 0.00)")
622 gcpy       self.endmilltype = "bowl"
623 gcpy       self.diameter = 19.05
624 gcpy       self.flute = 15.875
625 gcpy       self.radius = 6.35
626 gcpy       self.shaftdiameter = 6.35
627 gcpy       self.shaftheight = 15.875
628 gcpy       self.shaftlength = 20.0
629 gcpy       self.definebowltool(self.diameter, self.flute, self.
630 gcpy         radius, self.shaftdiameter, self.shaftlength)
631 gcpy       self.toolnumber = "445982"
632 gcpy   elif (tool_number == 1370): #1370 == 401370
633 gcpy #Whiteside Bowl & Tray Bit 1/4"SH, 1/8"R, 7/16"CD (5/16" cutting
634 gcpy   flute length)

```

```

631 gcpy           self.writegc("(TOOL/MILL,11.1125,8,3.175,0.00)")
632 gcpy           self.endmilltype = "bowl"
633 gcpy           self.diameter = 11.1125
634 gcpy           self.flute = 8
635 gcpy           self.radius = 3.175
636 gcpy           self.shaftdiameter = 6.35
637 gcpy           self.shaftheight = 8
638 gcpy           self.shaftlength = 20.0
639 gcpy           self.definebowltool(self.diameter, self.flute, self.
                                         radius, self.shaftdiameter, self.shaftlength)
640 gcpy           self.toolnumber = "401370"
641 gcpy           elif (tool_number == 1372): #1372/45982 == 401372
642 gcpy #Whiteside Bowl & Tray Bit 1/4"SH, 1/4"R, 3/4"CD (5/8" cutting
          flute length)
643 gcpy #Amana Carbide Tipped Bowl & Tray 1/4 Radius x 3/4 Dia x 5/8 x 1/4
          Inch Shank
644 gcpy           self.writegc("(TOOL/MILL,19.5,15.875,6.35,0.00)")
645 gcpy           self.endmilltype = "bowl"
646 gcpy           self.diameter = 19.5
647 gcpy           self.flute = 15.875
648 gcpy           self.radius = 6.35
649 gcpy           self.shaftdiameter = 6.35
650 gcpy           self.shaftheight = 15.875
651 gcpy           self.shaftlength = 20.0
652 gcpy           self.definebowltool(self.diameter, self.flute, self.
                                         radius, self.shaftdiameter, self.shaftlength)
653 gcpy           self.toolnumber = "401372"
654 gcpy #

```

---

**3.4.1.1.8 Tapered ball nose** One vendor which provides such tooling is Precise Bits: <https://www.precisebits.com/products/carbidebits/taperedcarve250b2f.asp&filter=7>, but unfortunately, their tool numbering is ambiguous, the version of each major number (204 and 304) for their 1/4" shank tooling which is sufficiently popular to also be offered in a ZRN coating could be used. Similarly, the #501 and #502 PCB engravers from Carbide 3D are supported.

Outlines and profiles for these tools are stored in SVG files:

```

501_outline.svg
501_profile.svg
501_shaft_outline.svg
501_shaft_profile.svg
502_outline.svg
502_profile.svg
502_shaft_outline.svg
502_shaft_profile.svg

```

which are then imported into the appropriate variables when a tool is loaded.

```

655 gcpy           elif (tool_number == 501) or (tool_number == 530131): #501
                     == 530131
656 gcpy           self.writegc("(TOOL/MILL,0.03,0.00,10.00,30.00)")
657 gcpy #           self.currenttoolshape = self.toolshapes("tapered ball
                     ", 3.175, 5.561, 30, 0.254)
658 gcpy           self.tooloutline = osimport("501_outline.svg")
659 gcpy           self.toolprofile = osimport("501_profile.svg")
660 gcpy           self.endmilltype = "tapered_ball"
661 gcpy           self.diameter = 3.175
662 gcpy           self.flute = 5.561
663 gcpy           self.angle = 30
664 gcpy           self.tip = 0.254
665 gcpy           self.shaftdiameter = 3.175
666 gcpy           self.shaftheight = 5.561
667 gcpy           self.shaftlength = 10.0
668 gcpy           self.toolnumber = "530131"
669 gcpy           elif (tool_number == 502) or (tool_number == 540131): #502
                     == 540131
670 gcpy           self.writegc("(TOOL/MILL,0.03,0.00,10.00,20.00)")
671 gcpy #           self.currenttoolshape = self.toolshapes("tapered ball
                     ", 3.175, 4.117, 40, 0.254)
672 gcpy           self.endmilltype = "tapered_ball"
673 gcpy           self.diameter = 3.175
674 gcpy           self.flute = 4.117
675 gcpy           self.angle = 40
676 gcpy           self.tip = 0.254
677 gcpy           self.shaftdiameter = 3.175
678 gcpy           self.shaftheight = 4.117
679 gcpy           self.shaftlength = 10.0
680 gcpy           self.toolnumber = "540131"

```

```

681 gcpy #           elif (tool_number == 204):#
682 gcpy #               self.writegc("()")
683 gcpy #               self.currenttoolshape = self.tapered_ball(1.5875,
684 gcpy #                   6.35, 38.1, 3.6)
685 gcpy #               elif (tool_number == 304):#
686 gcpy #                   self.writegc("()")
687 gcpy #                   self.currenttoolshape = self.tapered_ball(3.175, 6.35,
688 gcpy #                       38.1, 2.4)
689 gcpy #

```

---

**3.4.1.1.9 Roundover (cove tooling)** Note that the parameters will need to incorporate the tip diameter into the overall diameter.

```

688 gcpy     elif (tool_number == 56125) or (tool_number == 603042):#
689 gcpy         0.508/2, 1.531 56125 == 603042
690 gcpy         self.writegc("(TOOL/CRMILL, 0.508, 6.35, 3.175, 7.9375,
691 gcpy             3.175)")
692 gcpy         self.endmilltype = "roundover"
693 gcpy         self.tipdiameter = 0.508
694 gcpy         self.diameter = 6.35 - self.tipdiameter
695 gcpy         self.flute = 8 - self.tipdiameter
696 gcpy         self.radius = 3.175 - self.tipdiameter/2
697 gcpy         self.shaftdiameter = 6.35
698 gcpy         self.shaftheight = 8
699 gcpy         self.shaftlength = 10.0
700 gcpy         self.defineRoundoverTool(self.diameter, self.
701 gcpy             tipdiameter, self.flute, self.radius, self.
702 gcpy                 shaftdiameter, self.shaftlength)
703 gcpy         self.toolnumber = "603042"
704 gcpy     elif (tool_number == 56142) or (tool_number == 602032):#
705 gcpy         0.508/2, 2.921 56142 == 602032
706 gcpy         self.writegc("(TOOL/CRMILL, 0.508, 3.571875, 1.5875, 5.55625, 1.5875)")
707 gcpy         self.endmilltype = "roundover"
708 gcpy         self.tip = 0.508
709 gcpy         self.diameter = 3.175 - self.tip
710 gcpy         self.flute = 4.7625 - self.tip
711 gcpy         self.radius = 1.5875 - self.tip/2
712 gcpy         self.shaftdiameter = 3.175
713 gcpy         self.shaftheight = 4.7625
714 gcpy         self.shaftlength = 10.0
715 gcpy         self.toolnumber = "602032"
716 gcpy     elif (tool_number == 312):#1.524/2, 3.175
717 gcpy         self.writegc("(TOOL/CRMILL, Diameter1, Diameter2,
718 gcpy             Radius, Height, Length)")
719 gcpy         self.currenttoolshape = self.toolshapes("roundover",
720 gcpy             3.175, 6.35, 3.175, 0.396875)
721 gcpy         self.endmilltype = "roundover"
722 gcpy         self.diameter = 3.175
723 gcpy         self.flute = 6.35
724 gcpy         self.radius = 3.175
725 gcpy         self.tip = 0.396875
726 gcpy         self.toolnumber = "603032"
727 gcpy     ##https://www.amanatool.com/45982-carbide-tipped-bowl-tray-1-4-
728 gcpy         radius-x-3-4-dia-x-5-8-x-1-4-inch-shank.html
729 gcpy     elif (tool_number == 1570):#0.507/2, 4.509 1570 == 600002
730 gcpy     elif (tool_number == 1570):#0.507/2, 4.509 1570 == 600002
731 gcpy     elif (tool_number == 1570):#0.507/2, 4.509 1570 == 600002
732 gcpy     elif (tool_number == 1572): #1572 = 604042
733 gcpy     elif (tool_number == 1572): #1572 = 604042
734 gcpy     elif (tool_number == 1572): #1572 = 604042
735 gcpy         self.endmilltype = "roundover"

```

---

```

736 gcpy #           self.diameter = 6.35
737 gcpy #           self.flute = 12.7
738 gcpy #           self.radius = 6.35
739 gcpy #           self.tip = 0.396875
740 gcpy #           self.toolnumber = "604042"
741 gcpy #       elif (tool_number == 1574): #1574 == 600062
742 gcpy ##FIX          self.writegc("(TOOL/CRMILL, 0.17018, 9.525,
    4.7625, 12.7, 4.7625)")
743 gcpy ##          self.currenttoolshape = self.toolshapes("roundover",
    9.525, 19.5, 9.515, 0.396875)
744 gcpy #           self.endmilltype = "roundover"
745 gcpy #           self.diameter = 9.525
746 gcpy #           self.flute = 19.5
747 gcpy #           self.radius = 9.515
748 gcpy #           self.tip = 0.396875
749 gcpy #           self.toolnumber = "600062"
750 gcpy #

```

---

**3.4.1.1.10 Dovetails** Unfortunately, tools which support undercuts such as dovetails are not supported by many CAM tools including Carbide Create and CutViewer (CAMotics will work for such tooling, at least dovetails which may be defined as "stub" endmills with a bottom diameter greater than upper diameter).

---

```

751 gcpy      elif (tool_number == 814) or (tool_number == 814071): #814
    == 814071
752 gcpy #Item 18J1607, 1/2" 14° Dovetail Bit, 8mm shank
753 gcpy          self.writegc("(TOOL/MILL,12.7,6.367,12.7,0.00)")
754 gcpy          # dt_bottomdiameter, dt_topdiameter, dt_height, dt_angle
    )
755 gcpy          # https://www.leevalley.com/en-us/shop/tools/power-tool-
    accessories/router-bits/30172-dovetail-bits?item=18J1607
756 gcpy #          self.currenttoolshape = self.toolshapes("dovetail",
    12.7, 12.7, 14)
757 gcpy          self.endmilltype = "dovetail"
758 gcpy          self.diameter = 12.7
759 gcpy          self.flute = 12.7
760 gcpy          self.angle = 14
761 gcpy          self.toolnumber = "814071"
762 gcpy      elif (tool_number == 808079) or (tool_number == 808071): #
    45828 == 808071
763 gcpy          self.writegc("(TOOL/MILL,12.7,6.816,20.95,0.00)")
764 gcpy          # http://www.amanatool.com/45828-carbide-tipped-dovetail
    -8-deg-x-1-2-dia-x-825-x-1-4-inch-shank.html
765 gcpy #          self.currenttoolshape = self.toolshapes("dovetail",
    12.7, 20.955, 8)
766 gcpy          self.endmilltype = "dovetail"
767 gcpy          self.diameter = 12.7
768 gcpy          self.flute = 20.955
769 gcpy          self.angle = 8
770 gcpy          self.toolnumber = "808071"
771 gcpy #

```

---

Each tool must be modeled in 3D using OpenSCAD commands, but it will also be necessary to have a consistent structure for managing the various shapes and aspects of shapes.

While tool shapes were initially handled as geometric shapes stored in Python variables, processing them as such after the fashion of OpenSCAD required the use of `union()` commands and assigning a small initial object (usually a primitive placed at the origin) so that the union could take place. This has the result of creating a nested union structure in the CSG tree which can quickly become so deeply nested that it exceeds the limits set in PythonSCAD.

As was discussed in the PythonSCAD Google Group (<https://groups.google.com/g/pythonscad/c/rtiYa38W8tY>), if a list is used instead, then the contents of the list are added all at once at a single level when processed.

An example file which shows this concept:

```

from openscad import *
fn=200

box = cube([40,40,40])

features = []

features.append(cube([36,36,40]) + [2,2,2])
features.append(cylinder(d=20,h=5) + [20,20,-1])
features.append(cylinder(d=3,h=10) ^ [[5,35],[5,35], -1])

```

```
part = difference(box, features)
show(part)
```

As per usual, the OpenSCAD command is simply a dispatcher:

---

```
48 gpcscad module toolchange(tool_number, speed){
49 gpcscad     gcp.toolchange(tool_number, speed);
50 gpcscad }
```

---

For example:

```
toolchange(small_square_tool_num, speed);
```

(the assumption is that all speed rates in a file will be the same, so as to account for the most frequent use case of a trim router with speed controlled by a dial setting and feed rates/ratios being calculated to provide the correct chipload at that setting.)

**3.4.1.11 closing G-code** With the tools delineated, the module is closed out and the toolchange information written into the G-code as well as the command to start the spindle at the specified speed.

One possible feature for the G-code for tool changes would be to have the various ratios available and then to apply the appropriate one. Directly applying them in the file generated by the user is sufficiently straight-forward that this expedient option seems a needless complexity unless a compelling reason comes up.

---

```
772 gcpy      self.writegc("M6T", str(tool_number))
773 gcpy #    if (self.endmilltype == "square"):
774 gcpy #        speed = speed *
775 gcpy      self.writegc("M03S", str(speed))
```

---

### 3.4.2 Laser support

Two possible options for supporting a laser present themselves: color-coded DXFs or direct G-code support. An example file for the latter:

<https://lasergrbl.com/test-file-and-samples/depth-of-focus-test/>

```
M3 S0
S0
G0X0Y16
S1000
G1X100F1200
S0
M5 S0
M3 S0
S0
G0X0Y12
S1000
G1X100F1000
S0
M5 S0
M3 S0
S0
G0X0Y8
S1000
G1X100F800
S0
M5 S0
M3 S0
S0
G0X0Y4
S1000
G1X100F600
S0
M5 S0
M3 S0
S0
G0X0Y0
S1000
G1X100F400
S0
M5 S0
```

### 3.5 Shapes and tool movement

With all the scaffolding in place, it is possible to model the tool and hull() between copies of the cut... 3D model of the tool, or a cross-section of it for both cut... and rapid... operations.

rapid... Alternately, describing tools in terms of outline will allow using linear/rotate\_extrude to be used which requires a description of the tools as profiles/outlines, but which matches the G0/G1 and G2/G3 G-code commands.

The majority of commands will be more general, focusing on tooling which is generally supported by this library, moving in lines and arcs so as to describe shapes which lend themselves to representation with those tools and which match up with both toolpaths and supported geometry in Carbide Create, and the usage requirements of the typical user.

This structure has the notable advantage that if a tool shape is represented as a list and always handled thus, then representing complex shapes which need to be represented in discrete elements/parts becomes a natural thing to do and the program architecture is simpler since all possible shapes may be handled by the same code/logic with no need to identify different shapes and handle them differently.

Note that it will be preferable to use extend if the variable to be added contains a list rather than append since the former will flatten out the list and add the individual elements, so that a list remains a list of elements rather than becoming a list of lists and elements, except that there will be at least two elements to each tool model list:

- cutting *tool* shape (note that this may be either a single model, or a list of discrete slices of the tool shape)
- *shaft*

and when a cut is made by hulling each element from the cut begin position to its end position, this will be done using different colors so that the shaft rubbing may be identified on the 3D surface of the preview of the cut.

#### 3.5.1 Tooling for Undercutting Toolpaths

There are several notable candidates for undercutting tooling.

- Keyhole tools — intended to cut slots for retaining hardware used for picture hanging, they may be used to create slots for other purposes Note that it will be necessary to model these thrice, once for the actual keyhole cutting, second for the fluted portion of the shaft, and then the shaft should be modeled for collision <https://assetssc.leevalley.com/en-gb/shop/tools/power-tool-accessories/router-bits/30113-keyhole-router-bits>
- Dovetail cutters — used for the joinery of the same name, they cut a large area at the bottom which slants up to a narrower region at a defined angle
- Lollipop cutters — normally used for 3D work, as their name suggests they are essentially a (cutting) ball on a narrow stick (the tool shaft), they are mentioned here only for completeness' sake and are not (at this time) implemented
- Threadmill — used for cutting threads, normally a single form geometry is used on a CNC.

#### 3.5.2 Generalized commands and cuts

The first consideration is a naming convention which will allow a generalized set of associated commands to be defined. The initial version will only create OpenSCAD commands for 3D modeling and write out matching DXF files. At a later time this will be extended with G-code support.

There are three different movements in G-code which will need to be handled. Rapid commands will be used for go movements and will not appear in DXFs but will appear in G-code files, while straight line cut (G1) and arc (G2/G3) commands may appear in both G-code and DXF files, depending on the specific command invoked.

#### 3.5.3 Movement and color

toolmovement The first command which must be defined is toolmovement which is used as the core of the other shaftmovement commands, affording a 3D model of the tool moving in a straight line. A matching shaftmovement command will allow modeling collision of the shaft with the stock should it occur. This differentiation raises the matter of color representation. Using a different color for the shape of the endmill when cutting and for rapid movements will similarly allow identifying instances of the tool crashing through stock at rapid speed.

---

```

776 gcpy      def setcolor(self,
777 gcpy          cutcolor = "green",
778 gcpy          rapidcolor = "orange",
779 gcpy          shaftcolor = "red"):
780 gcpy              self.cutcolor = cutcolor
781 gcpy              self.rapidcolor = rapidcolor
782 gcpy              self.shaftcolor = shaftcolor

```

---

The possible colors are those of Web colors ([https://en.wikipedia.org/wiki/Web\\_colors](https://en.wikipedia.org/wiki/Web_colors)), while DXF has its own set of colors based on numbers (see table) and applying a Venn diagram and removing problematic extremes we arrive at the third column above as black and white are potentially inconsistent/confusing since at least one CAD program toggles them based on light/dark mode being applied to its interface.

Table 1: Colors in OpenSCAD and DXF

Web Colors (OpenSCAD)	DXF	Both
Black	"Black" (0)	
Red	"Red" (1)	Red
Yellow	"Yellow" (2)	Yellow
Green	"Green" (3)	Green
	"Cyan" (4)	
Blue	"Blue" (5)	Blue
	"Magenta" (6)	
White	"White" (7)	
Gray	"Dark Gray" (8)	(Dark) Gray
	"Light Gray" (9)	
Silver		
Maroon		
Olive		
Lime		
Aqua		
Teal		
Navy		
Fuchsia		
Purple		

(note that the names are not case-sensitive)

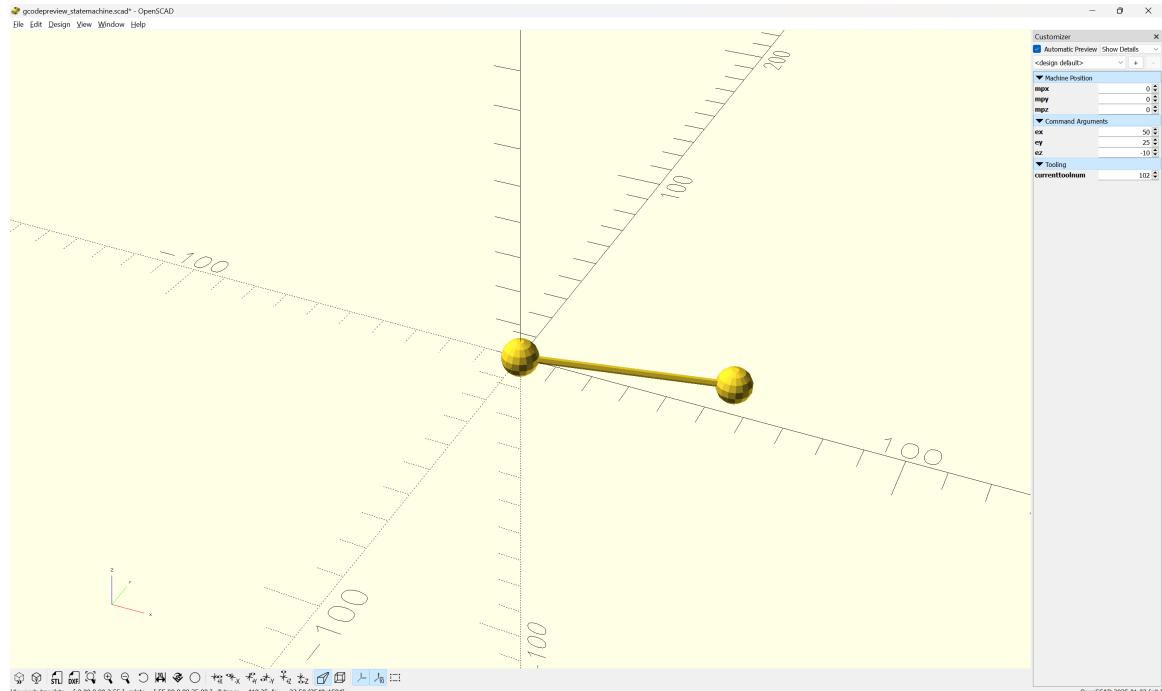
Most tools are easily implemented with concise 3D descriptions which may be connected with a simple hull operation. Note that extending the normal case to a pair of such operations, one for the shaft, the other for the cutting shape will markedly simplify the code, and will make it possible to color-code the shaft which may afford indication of instances of it rubbing against the stock.

Note that the variables `self.rapids` and `self.toolpaths` are used to hold the list of accumulated 3D models of the rapid motions and cuts as elements in lists so that they may be differenced from the stock.

**3.5.3.1 toolmovement** The `toolmovement` command incorporates the color variables to indicate cutting and differentiate rapid movements and the tool shaft.

Diagramming this is quite straight-forward — there is simply a movement made from the current position to the end. If we start at the origin,  $X_0, Y_0, Z_0$ , then it is simply a straight-line movement (rapid)/cut (possibly a partial cut in the instance of a keyhole or roundover tool), and no variables change value.

The code for diagramming this is quite straight-forward. A BlockSCAD implementation is available at: <https://www.blockscad3d.com/community/projects/1894400>, and the OpenSCAD version is only a little more complex (adding code to ensure positioning):



---

```

784 gcpy     def toolmovement(self, bx, by, bz, ex, ey, ez, step = 0):
785 gcpy         tslist = []
786 gcpy         if step > 0:
787 gcpy             steps = step
788 gcpy         else:
789 gcpy             steps = self.steps
790 gcpy #

```

---

endmill square **3.5.3.1.1 Square (including O-flute)** The endmill square is a simple cylinder:

---

```

791 gcpy     if self.endmilltype == "square":
792 gcpy         ts = cylinder(r1=(self.diameter / 2), r2=(self.diameter
793 gcpy             / 2), h=self.flute, center = False)
794 gcpy         tslist.append(hull(ts.translate([bx, by, bz]), ts.
795 gcpy             translate([ex, ey, ez])))
796 gcpy #
797 gcpy #
798 gcpy #         if self.endmilltype == "O-flute":
799 gcpy #             ts = cylinder(r1=(self.diameter / 2), r2=(self.
800 gcpy             diameter / 2), h=self.flute, center = False)
801 gcpy #             tslist.append(hull(ts.translate([bx, by, bz]), ts.
802 gcpy             translate([ex, ey, ez])))
803 gcpy #
804 gcpy #
805 gcpy #
806 gcpy #
807 gcpy #
808 gcpy #

```

---

ballnose **3.5.3.1.2 Ball nose (including tapered ball nose)** The ballnose is modeled as a hemisphere joined with a cylinder:

---

```

801 gcpy     if self.endmilltype == "ball":
802 gcpy         b = sphere(r=(self.diameter / 2))
803 gcpy         s = cylinder(r1=(self.diameter / 2), r2=(self.diameter
804 gcpy             / 2), h=self.flute, center=False)
805 gcpy         bs = union(b, s)
806 gcpy         bs = bs.translate([0, 0, (self.diameter / 2)])
807 gcpy         tslist.append(hull(bs.translate([bx, by, bz]), bs.
808 gcpy             translate([ex, ey, ez])))
809 gcpy #

```

---

**3.5.3.1.3 bowl** The bowl tool is modeled as a series of cylinders stacked on top of each other and hull()ed together:

---

```

809 gcpy     if self.endmilltype == "bowl":
810 gcpy         inner = cylinder(r1 = self.diameter/2 - self.radius, r2
811 gcpy             = self.diameter/2 - self.radius, h = self.flute)
812 gcpy         outer = cylinder(r1 = self.diameter/2, r2 = self.
813 gcpy             diameter/2, h = self.flute - self.radius)
814 gcpy #         outer = outer.translate([0,0, self.radius])
815 gcpy         slices = hull(outer, inner)
816 gcpy         slices = cylinder(r1 = 0.0001, r2 = 0.0001, h = 0.0001, center
817 gcpy             =False)
818 gcpy         for i in range(1, 90 - self.steps, self.steps):
819 gcpy             slice = cylinder(r1 = self.diameter / 2 - self.
820 gcpy                 radius + self.radius * Sin(i), r2 = self.

```

---

endmill v **3.5.3.1.4 V** The endmill v is modeled as a cylinder with a zero width base and a second cylinder for the shaft (note that Python's math defaults to radians, hence the need to convert from degrees if using it, but fortunately, trigonometric commands have been added to OpenPython-SCAD (Sin, Cos, Tan, Atan)):

---

```

821 gcpy     if self.endmilltype == "V":

```

---

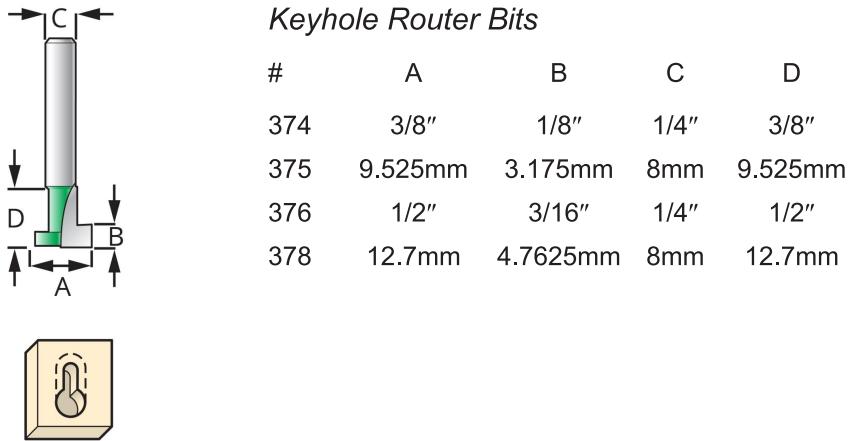
```

822 gcpy           v = cylinder(r1=0, r2=(self.diameter / 2), h=((self.
                      diameter / 2) / Tan((self.angle / 2))), center=False
                      )
823 gcpy #           s = cylinder(r1=(self.diameter / 2), r2=(self.
                      diameter / 2), h=self.flute, center=False)
824 gcpy #           sh = s.translate([0, 0, ((self.diameter / 2) / Tan
                      ((self.angle / 2)))]))
825 gcpy           tslist.append(hull(v.translate([bx, by, bz]), v.
                      translate([ex, ey, ez])))
826 gcpy           return tslist

```

---

**3.5.3.1.5 Keyhole** Keyhole toolpaths (see: subsection 3.8.1.1.3) are intended for use with tooling which projects beyond the narrower shaft and so will cut usefully underneath the visible surface. Also described as “undercut” tooling, but see below.



```

828 gcpy           if self.endmilltype == "keyhole":
829 gcpy             kh = cylinder(r1=(self.diameter / 2), r2=(self.diameter
                           / 2), h=self.flute, center=False)
830 gcpy             sh = (cylinder(r1=(self.radius / 2), r2=(self.radius /
                           2), h=self.flute*2, center=False))
831 gcpy             tslist.append(hull(kh.translate([bx, by, bz]), kh.
                           translate([ex, ey, ez])))
832 gcpy             tslist.append(hull(sh.translate([bx, by, bz]), sh.
                           translate([ex, ey, ez])))
833 gcpy             return tslist

```

---

**3.5.3.1.6 Tapered ball nose** The tapered ball nose tool is modeled as a sphere at the tip and a pair of cylinders, where one (a cone) describes the taper, while the other represents the shaft.

```

835 gcpy           if self.endmilltype == "tapered_ball":
836 gcpy             b = sphere(r=(self.tip / 2))
837 gcpy             s = cylinder(r1=(self.tip / 2), r2=(self.diameter / 2),
                           h=self.flute, center=False)
838 gcpy             bshape = union(b, s)
839 gcpy             tslist.append(hull(bshape.translate([bx, by, bz]),
                           bshape.translate([ex, ey, ez])))
840 gcpy             return tslist

```

---

dovetail **3.5.3.1.7 Dovetails** The dovetail is modeled as a cylinder with the differing bottom and top diameters determining the angle (though dt\_angle is still required as a parameter)

```

842 gcpy           if self.endmilltype == "dovetail":
843 gcpy             dt = cylinder(r1=(self.diameter / 2), r2=(self.diameter
                           / 2) - self.flute * Tan(self.angle), h= self.flute,
                           center=False)
844 gcpy             tslist.append(hull(dt.translate([bx, by, bz]), dt.
                           translate([ex, ey, ez])))
845 gcpy             return tslist
846 gcpy           if self.endmilltype == "other":
847 gcpy             tslist = []
848 gcpy #           def dovetail(self, dt_bottomdiameter, dt_topdiameter,
                           dt_height, dt_angle):

```

---

```
849 gcpy #           return cylinder(r1=(dt_bottomdiameter / 2), r2=(  
    dt_topdiameter / 2), h= dt_height, center=False)
```

---

**3.5.3.2 Concave toolshapes** While normal tooling may be represented with a one (or more) hull operation(s) betwixt two 3D toolshapes (or six in the instance of keyhole tools), concave tooling such as roundover/radius tooling require multiple sections or even slices of the tool shape to be modeled separately which are then hulled together. Something of this can be seen in the manual work-around for previewing them: <https://community.carbide3d.com/t/using-unsupported-tooling-in-carbide-create-roundover-cove-radius-bits/43723>.

Because it is necessary to divide the tooling into vertical slices and call the hull operation for each slice the tool definitions have to be called separately in the cut... modules, or integrated at the lowest level.

**3.5.3.2.1 Roundover tooling** It is not possible to represent all tools using tool changes as coded above which require using a hull operation between 3D representations of the tools at the beginning and end points. Tooling which cannot be so represented will be implemented separately roundover below, see paragraph 3.5.3.2 — roundover tooling will need to generate a list of slices of the tool shape hulled together.

---

```
851 gcpy     if self.endmilltype == "roundover":  
852 gcpy         shaft = cylinder(self.steps, self.tip/2, self.tip/2)  
853 gcpy         toolpath = hull(shaft.translate([bx, by, bz]), shaft.  
854 gcpy             translate([ex, ey, ez]))  
855 gcpy         shaft = cylinder(self.flute, self.diameter/2 + self.tip  
856 gcpy             /2, self.diameter/2 + self.tip/2)  
857 gcpy         toolpath = toolpath.union(hull(shaft.translate([bx, by,  
858 gcpy             bz + self.radius]), shaft.translate([ex, ey, ez +  
859 gcpy                 self.radius])))  
860 gcpy         tslist = [toolpath]  
861 gcpy         slice = cylinder(0.0001, 0.0001, 0.0001)  
862 gcpy         slices = slice  
863 gcpy         for i in range(1, 90 - self.steps, self.steps):  
864 gcpy             dx = self.radius*cos(i)  
865 gcpy             dxx = self.radius*cos(i + self.steps)  
866 gcpy             dzz = self.radius*sin(i)  
867 gcpy             dz = self.radius*sin(i + self.steps)  
868 gcpy             dh = dz - dzz  
869 gcpy             slice = cylinder(r1 = self.tip/2+self.radius-dx, r2  
870 gcpy                 = self.tip/2+self.radius-dxx, h = dh)  
871 gcpy             slices = slices.union(hull(slice.translate([bx, by,  
872 gcpy                 bz+dz]), slice.translate([ex, ey, ez+dz])))  
873 gcpy         tslist.append(slices)  
874 gcpy     return tslist
```

---

Note that this routine does *not* alter the machine position variables since it may be called multiple times for a given toolpath, e.g., for arcs. This command will then be called in the definitions for rapid and cutline which only differ in which variable the 3D model list is unioned with.

shaftmovement A similar routine will be used to handle the shaftmovement.

shaftmovement **3.5.3.3 shaftmovement** The shaftmovement command uses variables defined as part of the tool definition to determine the Z-axis position of the cylinder used to represent the shaft and its diameter and height:

---

```
870 gcpy     def shaftmovement(self, bx, by, bz, ex, ey, ez):  
871 gcpy         tslist = []  
872 gcpy         ts = cylinder(r1=(self.shaftdiameter / 2), r2=(self.  
873 gcpy             shaftdiameter / 2), h=self.shaftlength, center = False)  
874 gcpy         ts = ts.translate([0, 0, self.shaftheight])  
875 gcpy         tslist.append(hull(ts.translate([bx, by, bz]), ts.translate  
876 gcpy             ([ex, ey, ez])))  
877 gcpy     return tslist
```

---

**3.5.3.4 tool outlines** Defining the tools as outlines which may be scaled to different sizes and rotate\_extruded requires a series of modules which must define:

- self.tooloutline — the entire outline of the tool used for rotate\_extrude when cutting an arc (or a line if linear\_extrude is used)
- self.toolprofile — the profile of one half of the tool suited to creating a 3D model using rotate\_extrude
- self.shaftoutline

- self.shaftprofile
- self.currenttoolshape
- self.currenttoolshaft

Note that when defining tooling it is expedient to use a mix of the 2D and 3D systems.

The various self.<toolparameters> are defined in toolchange and may be used at need.

An expedient option would seem to be slicing the 3D model and hulling slices from the begin/end positions, but that may result in distortions for certain tool geometries (e.g., keyhole tooling).

There are several possible options for handling outlines and models — a hybrid approach governed by if branches will allow optimization of the resultant CSG commands.

- simple shape and straight move — 3D models of the tool at the begin and end points of the move are hulled
- complex shape and straight move — 3D models of the tool at the begin and end points of the move are connected by a linear\_extrude
- any shape and arc move — 3D models of the tool at the begin and end points of the move are connected by a rotate\_extrude

Similarly for the tool profiles and outlines and 3D shapes:

- polygon — defining the shape in terms of point positions (note the PythonSCAD has an option for rounding which may be used for some shapes)
- 2D — defining the shape using rectangles or polygons and circles and Boolean operations
- SVG — drawing up the outlines and profiles in a vector drawing tool so that they may be imported as SVG files allows any shape to be imported. Filenames would be mapped to the tool numbering scheme.

**3.5.3.4.1 defineshaft** A separate command for defining the shaft is expedient, and allows handling the case of the cutting diameter and the shaft diameter being different, and by including both diameters as arguments, allows the transition, if not abrupt, to be modeled. The parameters:

- toolingdiameter
- shaftdiameter
- flute
- transition
- shaft

are obvious except for shaft — rather than the O.A.L., this is the expected length of the tool as measured from the specified flute and transition lengths to the bottom of the collet. In the absence of a specified length, the flute length (assuming no transition) should be a workable approximation.

Frequently, tools will have different diameters for cutting end and shaft — when the former is smaller, the angle typically seems to be 60 degrees — since this should *not* be used for modeling, the expedient solution is to use an easily drawn angle which is obtuse enough to be obvious, so 45 degrees will be used.

---

```

877 gcpy      def defineshaft(self, toolingdiameter, shaftdiameter, flute,
878 gcpy          transition, shaft):
879 gcpy          if shaftdiameter == 0:
880 gcpy              self.shaftoutline = polygon(points=[[0, flute],
881 gcpy                  diameter, flute], [diameter, shaft],[0, shaft]])
882 gcpy              self.shaftprofile = polygon(points=[[0, flute],
883 gcpy                  diameter/2 ,flute], [diameter/2, shaft], [0, shaft]
884 gcpy                  ])
885 gcpy              sh = cylinder(h = shaft, r = diameter/2)
886 gcpy              self.currenttoolshaft = sh.translate([0,0,flute])
887 gcpy          if shaftdiameter > 0:
888 gcpy              self.shaftoutline = polygon(points=[
889 gcpy                  [shaftdiameter / 2 - toolingdiameter / 2, flute],
890 gcpy                  [0, flute + transition],
891 gcpy                  [0, flute + transition + shaft],
892 gcpy                  [shaftdiameter, flute + transition + shaft],
893 gcpy                  [shaftdiameter, flute + transition],
894 gcpy                  [shaftdiameter / 2 + toolingdiameter / 2, flute],
895 gcpy                  ])
896 gcpy          self.shaftprofile = polygon( points= [
897 gcpy                  [0, flute],
898 gcpy                  [0, flute],
899 gcpy                  [0, flute],
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1390 gcpy                  [0, flute],
1391 gcpy                  [0, flute],
1392 gcpy                  [0, flute],
1393 gcpy                  [0, flute],
1394 gcpy                  [0, flute],
1395 gcpy                  [0, flute],
1396 gcpy                  [0, flute],
1397 gcpy                  [0, flute],
1398 gcpy                  [0, flute],
1399 gcpy                  [0, flute],
1400 gcpy                  [0, flute],
1401 gcpy                  [0, flute],
1402 gcpy                  [0, flute],
1403 gcpy                  [0, flute],
1404 gcpy                  [0, flute],
1405 gcpy                  [0, flute],
1406 gcpy                  [0, flute],
1407 gcpy                  [0, flute],
1408 gcpy                  [0, flute],
1409 gcpy                  [0, flute],
1410 gcpy                  [0, flute],
1411 gcpy                  [0, flute],
1412 gcpy                  [0, flute],
1413 gcpy                  [0, flute],
1414 gcpy                  [0, flute],
1415 gcpy                  [0, flute],
1416 gcpy                  [0, flute],
1417 gcpy                  [0, flute],
1418 gcpy                  [0, flute],
1419 gcpy                  [0, flute],
1420 gcpy                  [0, flute],
1421 gcpy                  [0, flute],
1422 gcpy                  [0, flute],
1423 gcpy                  [0, flute],
1424 gcpy                  [0, flute],
1425 gcpy                  [0, flute],
1426 gcpy                  [0, flute],
1427 gcpy                  [0, flute],
1428 gcpy                  [0, flute],
1429 gcpy                  [0, flute],
1430 gcpy                  [0, flute],
1431 gcpy                  [0, flute],
1432 gcpy                  [0, flute],
1433 gcpy                  [0, flute],
1434 gcpy                  [0, flute],
1435 gcpy                  [0, flute],
1436 gcpy                  [0, flute],
1437 gcpy                  [0, flute],
1438 gcpy                  [0, flute],
1439 gcpy                  [0, flute],
1440 gcpy                  [0, flute],
1441 gcpy                  [0, flute],
1442 gcpy                  [0, flute],
1443 gcpy                  [0, flute],
1444 gcpy                  [0, flute],
1445 gcpy                  [0, flute],
1446 gcpy                  [0, flute],
1447 gcpy                  [0, flute],
1448 gcpy                  [0, flute],
1449 gcpy                  [0, flute],
1450 gcpy                  [0, flute],
1451 gcpy                  [0, flute],
1452 gcpy                  [0, flute],
1453 gcpy                  [0, flute],
1454 gcpy                  [0, flute],
1455 gcpy                  [0, flute],
1456 gcpy                  [0, flute],
1457 gcpy                  [0, flute],
1458 gcpy                  [0, flute],
1459 gcpy                  [0, flute],
1460 gcpy                  [0, flute],
1461 gcpy                  [0, flute],
1462 gcpy                  [0, flute],
1463 gcpy                  [0, flute],
1464 gcpy                  [0, flute],
1465 gcpy                  [0, flute],
1466 gcpy                  [0, flute],
1467 gcpy                  [0, flute],
1468 gcpy                  [0, flute],
1469 gcpy                  [0, flute],
1470 gcpy                  [0, flute],
1471 gcpy                  [0, flute],
1472 gcpy                  [0, flute],
1473 gcpy                  [0, flute],
1474 gcpy                  [0, flute],
1475 gcpy                  [0, flute],
1476 gcpy                  [0, flute],
1477 gcpy                  [0, flute],
1478 gcpy                  [0, flute],
1479 gcpy                  [0, flute],
1480 gcpy                  [0, flute],
1481 gcpy                  [0, flute],
1482 gcpy                  [0, flute],
1483 gcpy                  [0, flute],
1484 gcpy                  [0, flute],
1485 gcpy                  [0, flute],
1486 gcpy                  [0, flute],
1487 gcpy                  [0, flute],
1488 gcpy                  [0, flute],
1489 gcpy                  [0, flute],
1490 gcpy                  [0, flute],
1491 gcpy                  [0, flute],
1492 gcpy                  [0, flute],
1493 gcpy                  [0, flute],
1494 gcpy                  [0, flute],
1495 gcpy                  [0, flute],
1496 gcpy                  [0, flute],
1497 gcpy                  [0, flute],
1498 gcpy                  [0, flute],
1499 gcpy                  [0, flute],
1500 gcpy                  [0, flute],
1501 gcpy                  [0, flute],
1502 gcpy                  [0, flute],
1503 gcpy                  [0, flute],
1504 gcpy                  [0, flute],
1505 gcpy                  [0, flute],
1506 gcpy                  [0, flute],
1507 gcpy                  [0, flute],
1508 gcpy                  [0, flute],
1509 gcpy                  [0, flute],
1510 gcpy                  [0, flute],
1511 gcpy                  [0, flute],
1512 gcpy                  [0, flute],
1513 gcpy                  [0, flute],
1514 gcpy                  [0, flute],
1515 gcpy                  [0, flute],
1516 gcpy                  [0, flute],
1517 gcpy                  [0, flute],
1518 gcpy                  [0, flute],
1519 gcpy                  [0, flute],
1520 gcpy                  [0, flute],
1521 gcpy                  [0, flute],
1522 gcpy                  [0, flute],
1523 gcpy                  [0, flute],
1524 gcpy                  [0, flute],
1525 gcpy                  [0, flute],
1526 gcpy                  [0, flute],
1527 gcpy                  [0, flute],
1528 gcpy                  [0, flute],
1529 gcpy                  [0, flute],
1530 gcpy                  [0, flute],
1531 gcpy                  [0, flute],
1532 gcpy                  [0, flute],
1533 gcpy                  [0, flute],
1534 gcpy                  [0, flute],
1535 gcpy                  [0, flute],
1536 gcpy                  [0, flute],
1537 gcpy                  [0, flute],
1538 gcpy                  [0, flute],
1539 gcpy                  [0, flute],
1540 gcpy                  [0, flute],
1541 gcpy                  [0, flute],
1542 gcpy                  [0, flute],
1543 gcpy                  [0, flute],
1544 gcpy                  [0, flute],
1545 gcpy                  [0, flute],
1546 gcpy                  [0, flute],
1547 gcpy                  [0, flute],
1548 gcpy                  [0, flute],
1549 gcpy                  [0, flute],
1550 gcpy                  [0, flute],
1551 gcpy                  [0, flute],
1552 gcpy                  [0, flute],
1553 gcpy                  [0, flute],
1554 gcpy                  [0, flute],
1555 gcpy                  [0, flute],
1556 gcpy                  [0, flute],
1557 gcpy                  [0, flute],
1558 gcpy                  [0, flute],
1559 gcpy                  [0, flute],
1560 gcpy                  [0, flute],
1561 gcpy                  [0, flute],
1562 gcpy                  [0, flute],
1563 gcpy                  [0, flute],
1564 gcpy                  [0, flute],
1565 gcpy                  [0, flute],
1566 gcpy                  [0, flute],
1567 gcpy                  [0, flute],
1568 gcpy                  [0, flute],
1569 gcpy                  [0, flute],
1570 gcpy                  [0, flute],
1571 gcpy                  [0, flute],
1572 gcpy                  [0, flute],
1573 gcpy                  [0, flute],
1574 gcpy                  [0, flute],
1575 gcpy                  [0, flute],
1576 gcpy                  [0, flute],
1577 gcpy                  [0, flute],
1578 gcpy                  [0, flute],
1579 gcpy                  [0, flute],
1580 gcpy                  [0, flute],
1581 gcpy                  [0, flute],
1582 gcpy                  [0, flute],
1583 gcpy                  [0, flute],
1584 gcpy                  [0, flute],
1585 gcpy                  [0, flute],
1586 gcpy                  [0, flute],
1587 gcpy                  [0, flute],
1588 gcpy                  [0, flute],
1589 gcpy                  [0, flute],
1590 gcpy                  [0, flute],
1591 gcpy                  [0, flute],
1592 gcpy                  [0, flute],
1593 gcpy                  [0, flute],
1594 gcpy                  [0, flute],
1595 gcpy                  [0, flute],
1596 gcpy                  [0, flute],
1597 gcpy                  [0, flute],
1598 gcpy                  [0, flute],
1599 gcpy                  [0, flute],
1600 gcpy                  [0, flute],
1601 gcpy                  [0, flute],
1602 gcpy                  [0, flute],
1603 gcpy                  [0, flute],
1604 gcpy                  [0, flute],
1605 gcpy                  [0, flute],
1606 gcpy                  [0, flute],
1607 gcpy                  [0, flute],
1608 gcpy                  [0, flute],
1609 gcpy                  [0, flute],
1610 gcpy                  [0, flute],
1611 gcpy                  [0, flute],
1612 gcpy                  [0, flute],
1613 gcpy                  [0, flute],
1614 gcpy                  [0, flute],
1615 gcpy                  [0, flute],
1616 gcpy                  [0, flute],
1617 gcpy                  [0, flute],
1618 gcpy                  [0, flute],
1619 gcpy                  [0, flute],
1620 gcpy                  [0, flute],
1621 gcpy                  [0, flute],
1622 gcpy                  [0, flute],
1623 gcpy                  [0, flute],
1624 gcpy                  [0, flute],
1625 gcpy                  [0, flute],
1626 gcpy                  [0, flute],
1627 gcpy                  [0, flute],
1628 gcpy                  [0, flute],
1629 gcpy                  [0, flute],
1630 gcpy                  [0, flute],
1631 gcpy                  [0, flute],
1632 gcpy                  [0, flute
```

```

894 gcpy [0, flute + transition + shaft],
895 gcpy [shaftdiameter/2, flute + transition + shaft],
896 gcpy [shaftdiameter/2, flute + transition],
897 gcpy [toolingdiameter/2, flute]
898 gcpy ]
899 gcpy self.currenttoolshaft = rotate_extrude(self.
shaftprofile)

```

---

**3.5.3.4.2 Square (including O-flute)** The simplest sort of tooling, which is easily defined using a polygon and cylinder.

```

901 gcpy def definesquaretool(self, diameter, flute, shaft, offset = 0):
902 gcpy self.tooloutline = polygon( points=[[0 + offset,0],[diameter +
903 gcpy offset,0],[diameter + offset,flute],[0 + offset,flute]] )
904 gcpy self.toolprofile = polygon( points=[[0,0],[diameter/2,0],[diameter/2,flute],[0,flute]] )
905 gcpy self.currenttoolshape = cylinder(h = flute, r = diameter/2)
sh = cylinder(h = flute, r = diameter/2)

```

---

**3.5.3.4.3 Ball-nose (including tapered-ball)** Defined using 2D and 3D primitives which are unioned together, this allows the shape of the tool to be influenced by the variables fa/fs/fn.

```

907 gcpy def defineballnosetool(self, diameter, flute, shaft, offset =
908 gcpy 0):
909 gcpy s = square([diameter,flute - diameter/2])
910 gcpy sh = s.translate([0 + offset, diameter/2])
911 gcpy c = circle(d=diameter)
912 gcpy b = c.translate([diameter/2 + offset, diameter/2])
self.tooloutline = union(sh, b)
913 gcpy #
914 gcpy s = square([diameter/2,flute - diameter/2])
915 gcpy sh = s.translate([0, diameter/2])
916 gcpy c = circle(d=diameter)
917 gcpy b = c.translate([0, diameter/2])
918 gcpy bn = union(sh, b)
919 gcpy #
920 gcpy bns = bn.translate([0, diameter/2])
921 gcpy #
922 gcpy thein = square([diameter/2,flute])
923 gcpy #
924 gcpy theins = thein.translate([diameter/2, 0])
self.toolprofile = intersection(thein, bn)
925 gcpy #
926 gcpy #
927 gcpy #
928 gcpy self.currenttoolshape = rotate_extrude(self.toolprofile)
929 gcpy #
930 gcpy self.currenttoolshaft = sh.translate([0,0,flute])

```

---

**3.5.3.4.4 V tool outline** V shaped tooling often has the V cutting flutes attached to a cylindrical shaft.

```

932 gcpy def defineVtool(self, diameter, flute, shaft, shaftdiameter =
933 gcpy 0):
934 gcpy #
935 gcpy self.tooloutline = polygon([[diameter/2, 0], [diameter,
flute], [0, flute]])
936 gcpy self.toolprofile = polygon([[0, 0], [diameter/2, flute],
[0, flute]])
937 gcpy
938 gcpy #
939 gcpy if shaftdiameter == 0:
940 gcpy shaftdiameter = diameter
941 gcpy self.shaftprofile = polygon([[0, flute], [shaftdiameter/2,
flute], [shaftdiameter/2, flute + shaft], [0, flute +
shaft]])
942 gcpy
943 gcpy #
944 gcpy self.currenttoolshape = rotate_extrude(self.toolprofile)
945 gcpy #

```

---

```
946 gcpy           self.currenttoolshaft = rotate_extrude(self.shaftprofile)
```

---

**3.5.3.4.5 Keyhole outline** Keyhole outlines will require two cutting surfaces, since it is usual for the shaft to have cutting flutes for clearing the narrow region as part of their functionality.

---

```
948 gcpy     def defineKeyholetool(self, diameter, flute, narrowdiameter,
949 gcpy         narrowflute, shaftdiameter, shaftlength):
950 gcpy         self.tooloutline = polygon([[0, 0], [diameter, 0], [
951 gcpy #             diameter, flute], [diameter/2 + narrowdiameter/2, flute
952 gcpy #             ], [diameter/2 + narrowdiameter/2, flute + narrowflute],
953 gcpy #             [diameter/2 - narrowdiameter/2, flute + narrowflute], [
954 gcpy #
955 gcpy #             diameter/2 - narrowdiameter/2, flute], [0, flute]])
956 gcpy #
957 gcpy #
958 gcpy         self.toolprofile = polygon([[0, 0], [diameter/2, 0], [
959 gcpy #
960 gcpy #             diameter/2, flute], [narrowdiameter/2, flute], [
961 gcpy #
962 gcpy #             narrowdiameter/2, flute + narrowflute], [0, flute +
963 gcpy #
964 gcpy #
965 gcpy         self.currenttoolshape = rotate_extrude(self.toolprofile)
966 gcpy #
967 gcpy #
968 gcpy #
969 gcpy #
970 gcpy #
971 gcpy         self.currenttoolshaft = rotate_extrude(self.shaftprofile)
```

---

**3.5.3.4.6 Bowl outline** Bowl tooling is done using polygon() with the third value added so as to cause the rounding of the radius.

---

```
962 gcpy     def definebowltool(self, diameter, flute, radius, shaftdiameter,
963 gcpy #             shaftlength):
964 gcpy #
965 gcpy         self.tooloutline =
966 gcpy #
967 gcpy         self.toolprofile = polygon([[0,0], [diameter/2, 0, radius],
968 gcpy #
969 gcpy #             [diameter/2, radius], [diameter/2, flute], [0, flute]])
970 gcpy #
971 gcpy         self.shaftprofile = polygon([[0,flute], [shaftdiameter/2,
972 gcpy #
973 gcpy #             flute], [shaftdiameter/2, flute + shaftlength], [0,
974 gcpy #
975 gcpy #             flute + shaftlength]])
976 gcpy #
977 gcpy #
978 gcpy #
979 gcpy #
980 gcpy #
981 gcpy #
982 gcpy #
983 gcpy #
984 gcpy #
985 gcpy #
986 gcpy #
987 gcpy #             self.currenttoolshape = rotate_extrude(self.toolprofile)
988 gcpy #
989 gcpy #
990 gcpy #
991 gcpy #
992 gcpy #
993 gcpy #
994 gcpy #
995 gcpy #
996 gcpy #
997 gcpy #
998 gcpy #
999 gcpy #
999 gcpy #             self.currenttoolshaft = rotate_extrude(self.shaftprofile)
```

---

**3.5.3.4.7 Tapered ball nose** Creating outlines for Tapered ball nose tooling will require that the arc and tangent for the angle and rounding be calculated out if programmed, or instead, they may be drawn.

**3.5.3.4.8 Roundover (cove tooling)** The polygon() command does not afford an option for coves, so it will be necessary to over-draw the geometry, then remove the cove if programming, or, to simply draw the outline.

---

```
973 gcpy     def defineRoundovertool(self, diameter, tipdiameter, flute,
974 gcpy #             radius, shaftdiameter, shaftlength):
975 gcpy #             self.tip = 0.508
976 gcpy #             self.diameter = 6.35 - self.tip
977 gcpy #             self.flute = 8 - self.tip
978 gcpy #             self.radius = 3.175 - self.tip/2
979 gcpy #             self.shaftdiameter = 6.35
980 gcpy #             self.shaftheight = 8
981 gcpy #             self.shaftlength = 10.0
982 gcpy #
983 gcpy #
984 gcpy #
985 gcpy #
986 gcpy #
987 gcpy #             print(diameter)
988 gcpy #
989 gcpy #
990 gcpy #
991 gcpy #
992 gcpy #
993 gcpy #
994 gcpy #
995 gcpy #
996 gcpy #
997 gcpy #
998 gcpy #
999 gcpy #
999 gcpy #             self.tooloutline =
```

---

```

988 gcpy #
989 gcpy     self.toolprofile = polygon([[0,0], [tipdiameter/2, 0], [
990 gcpy #           diameter/2, flute], [0, flute]])
991 gcpy     self.shaftprofile = polygon([[0,flute], [shaftdiameter/2,
992 gcpy #           flute], [shaftdiameter/2, flute + shaftlength], [0,
993 gcpy #           flute + shaftlength]])
994 gcpy #
995 gcpy     self.currenttoolshape = rotate_extrude(self.toolprofile)

```

---

rapid **3.5.3.5 rapid and cut (lines)** A matching pair of commands is made for these, and rapid is used as the basis for a series of commands which match typical usages of G0.

Note the addition of a Laser mode which simulates the tool having been turned off before making a rapid movement — likely further changes will be required.

---

```

997 gcpy     def rapid(self, ex, ey, ez, laser = 0):
998 gcpy #         print(self.rapidcolor)
999 gcpy     if self.generateprint == True:
1000 gcpy         laser = 1
1001 gcpy     if laser == 0:
1002 gcpy         tm = self.toolmovement(self.xpos(), self.ypos(), self.
1003 gcpy             zpos(), ex, ey, ez)
1004 gcpy         ts = self.shaftmovement(self.xpos(), self.ypos(), self.
1005 gcpy             zpos(), ex, ey, ez)
1006 gcpy         ts = color(ts, self.rapidcolor)
1007 gcpy         self.toolpaths.extend([tm, ts])
1008 gcpy     self.setxpos(ex)
1009 gcpy     self.setypos(ey)
1010 gcpy     self.setzpos(ez)
1011 gcpy     def cutline(self, ex, ey, ez):
1012 gcpy #         print(self.cutcolor)
1013 gcpy #         print(ex, ey, ez)
1014 gcpy         tm = self.toolmovement(self.xpos(), self.ypos(), self.zpos
1015 gcpy             (), ex, ey, ez)
1016 gcpy         tm = color(tm, self.cutcolor)
1017 gcpy         ts = self.shaftmovement(self.xpos(), self.ypos(), self.zpos
1018 gcpy             (), ex, ey, ez)
1019 gcpy         ts = color(ts, self.rapidcolor)
1020 gcpy         self.setxpos(ex)
1021 gcpy         self.setypos(ey)
1022 gcpy         self.setzpos(ez)
1023 gcpy     if self.generatecut == True:
1024 gcpy         self.toolpaths.extend([tm, ts])

```

---

It is then possible to add specific rapid... commands to match typical usages of G-code. The first command needs to be a move to/from the safe Z height. In G-code this would be:

(Move to safe Z to avoid workholding)  
G53G0Z-5.000

but in the 3D model, since we do not know how tall the Z-axis is, we simply move to safe height and use that as a starting point:

---

```

1024 gcpy     def movetosafeZ(self):
1025 gcpy         rapid = self.rapid(self.xpos(), self.ypos(), self.
1026 gcpy             retractheight)
1027 gcpy     if self.generatepaths == True:
1028 gcpy         rapid = self.rapid(self.xpos(), self.ypos(), self.
1029 gcpy             retractheight)
1030 gcpy         self.rapids = self.rapids.union(rapid)
1031 gcpy     else:
1032 gcpy     if (generategcode == true) {
1033 gcpy //         writecomment("PREPOSITION FOR RAPID PLUNGE");Z25.650
1034 gcpy //         G1Z24.663F381.0, "F", str(plunge)
1035 gcpy         if self.generatepaths == False:
1036 gcpy             return rapid
1037 gcpy         else:
1038 gcpy             return cube([0.001, 0.001, 0.001])
1039 gcpy     def rapidXYZ(self, ex, ey, ez):
1040 gcpy         rapid = self.rapid(ex, ey, ez)

```

```

1041 gcpy #           if self.generatepaths == False:
1042 gcpy             return rapid
1043 gcpy
1044 gcpy     def rapidXY(self, ex, ey):
1045 gcpy         rapid = self.rapid(ex, ey, self.zpos())
1046 gcpy #           if self.generatepaths == True:
1047 gcpy #             self.rapids = self.rapids.union(rapid)
1048 gcpy #
1049 gcpy #
1050 gcpy     return rapid
1051 gcpy
1052 gcpy     def rapidXZ(self, ex, ez):
1053 gcpy         rapid = self.rapid(ex, self.ypos(), ez)
1054 gcpy #           if self.generatepaths == False:
1055 gcpy             return rapid
1056 gcpy
1057 gcpy     def rapidYZ(self, ey, ez):
1058 gcpy         rapid = self.rapid(self.xpos(), ey, ez)
1059 gcpy #           if self.generatepaths == False:
1060 gcpy             return rapid
1061 gcpy
1062 gcpy     def rapidX(self, ex):
1063 gcpy         rapid = self.rapid(ex, self.ypos(), self.zpos())
1064 gcpy #           if self.generatepaths == False:
1065 gcpy             return rapid
1066 gcpy
1067 gcpy     def rapidY(self, ey):
1068 gcpy         rapid = self.rapid(self.xpos(), ey, self.zpos())
1069 gcpy #           if self.generatepaths == False:
1070 gcpy             return rapid
1071 gcpy
1072 gcpy     def rapidZ(self, ez):
1073 gcpy         rapid = [self.rapid(self.xpos(), self.ypos(), ez)]
1074 gcpy #           if self.generatepaths == True:
1075 gcpy #             self.rapids = self.rapids.union(rapid)
1076 gcpy #
1077 gcpy #           if self.generatepaths == False:
1078 gcpy             return rapid

```

---

Note that rather than re-create the matching OpenSCAD commands as descriptors, due to the issue of redirection and return values and the possibility for errors it is more expedient to simply re-create the matching command (at least for the rapids):

```

52 gpcscad module movetosafeZ(){
53 gpcscad   gcp.rapid(gcp.xpos(), gcp.ypos(), retractheight);
54 gpcscad }
55 gpcscad
56 gpcscad module rapid(ex, ey, ez) {
57 gpcscad   gcp.rapid(ex, ey, ez);
58 gpcscad }
59 gpcscad
60 gpcscad module rapidXY(ex, ey) {
61 gpcscad   gcp.rapid(ex, ey, gcp.zpos());
62 gpcscad }
63 gpcscad
64 gpcscad module rapidXZ(ex, ez) {
65 gpcscad   gcp.rapid(ex, gcp.zpos(), ez);
66 gpcscad }
67 gpcscad
68 gpcscad module rapidZ(ez) {
69 gpcscad   gcp.rapid(gcp.xpos(), gcp.ypos(), ez);
70 gpcscad }

```

---

Similarly, there is a series of cutline... commands as predicted above.  
 cut... The Python commands cut... add the currenttool to the toolpath hulled together at the cutline current position and the end position of the move. For cutline, this is a straight-forward connection of the current (beginning) and ending coordinates:

```

1080 gcpy     def moveatfeedrate(self, ex, ey, ez, f):
1081 gcpy       self.writegc("G01\u21D3X", str(ex), "\u21D3Y", str(ey), "\u21D3Z", str(ez)
1082 gcpy         , "\u21D3F", str(f))
1083 gcpy       self.feedrate = f
1084 gcpy       return self.cutline(ex, ey, ez)
1085 gcpy
1086 gcpy     def cutlinedxf(self, ex, ey, ez):
1087 gcpy       self.dxfline(self.currenttoolnumber(), self.xpos(), self.
1088 gcpy         ypos(), ex, ey)

```

```

1087 gcpy           self.cutline(ex, ey, ez)
1088 gcpy
1089 gcpy     def cutlinedxfgc(self, ex, ey, ez):
1090 gcpy         self.dxfline(self.currenttoolnumber(), self.xpos(), self.
1091 gcpy             ypos(), ex, ey)
1092 gcpy         self.writegc("G01\u00d7X", str(ex), "\u00d7Y", str(ey), "\u00d7Z", str(ez)
1093 gcpy             )
1094 gcpy         self.cutline(ex, ey, ez)
1095 gcpy
1096 gcpy     def cutvertexdxf(self, ex, ey, ez):
1097 gcpy         self.addvertex(self.currenttoolnumber(), ex, ey)
1098 gcpy         self.writegc("G01\u00d7X", str(ex), "\u00d7Y", str(ey), "\u00d7Z", str(ez)
1099 gcpy             )
1100 gcpy         self.cutline(ex, ey, ez)
1101 gcpy
1102 gcpy     def cutlineXYZwithfeed(self, ex, ey, ez, feed):
1103 gcpy         return self.cutline(ex, ey, ez)
1104 gcpy
1105 gcpy     def cutlineXYZ(self, ex, ey, ez):
1106 gcpy         return self.cutline(ex, ey, ez)
1107 gcpy
1108 gcpy     def cutlineXYwithfeed(self, ex, ey, feed):
1109 gcpy         return self.cutline(ex, ey, self.zpos())
1110 gcpy
1111 gcpy     def cutlineXZwithfeed(self, ex, ez, feed):
1112 gcpy         return self.cutline(ex, self.ypos(), ez)
1113 gcpy
1114 gcpy     def cutlineXZ(self, ex, ez):
1115 gcpy         return self.cutline(ex, self.ypos(), ez)
1116 gcpy
1117 gcpy     def cutlineXwithfeed(self, ex, feed):
1118 gcpy         return self.cutline(ex, self.ypos(), self.zpos())
1119 gcpy
1120 gcpy     def cutlineX(self, ex):
1121 gcpy         return self.cutline(ex, self.ypos(), self.zpos())
1122 gcpy
1123 gcpy     def cutlineYZ(self, ey, ez):
1124 gcpy         return self.cutline(self.xpos(), ey, ez)
1125 gcpy
1126 gcpy     def cutlineYwithfeed(self, ey, feed):
1127 gcpy         return self.cutline(self.xpos(), ey, self.zpos())
1128 gcpy
1129 gcpy     def cutlineY(self, ey):
1130 gcpy         return self.cutline(self.xpos(), ey, self.zpos())
1131 gcpy
1132 gcpy     def cutlineZgcfed(self, ez, feed):
1133 gcpy         self.writegc("G01\u00d7Z", str(ez), "F", str(feed))
1134 gcpy         return self.cutline(self.xpos(), self.ypos(), ez)
1135 gcpy
1136 gcpy     def cutlineZwithfeed(self, ez, feed):
1137 gcpy         return self.cutline(self.xpos(), self.ypos(), ez)
1138 gcpy
1139 gcpy     def cutlineZ(self, ez):
1140 gcpy         return self.cutline(self.xpos(), self.ypos(), ez)

```

---

The matching OpenSCAD command is a descriptor:

```

72 gpcscad module cutline(ex, ey, ez){
73 gpcscad     gcp.cutline(ex, ey, ez);
74 gpcscad }
75 gpcscad
76 gpcscad module cutlinedxfgc(ex, ey, ez){
77 gpcscad     gcp.cutlinedxfgc(ex, ey, ez);
78 gpcscad }
79 gpcscad
80 gpcscad module cutlineZgcfed(ez, feed){
81 gpcscad     gcp.cutlineZgcfed(ez, feed);
82 gpcscad }

```

---

**3.5.3.6 Arcs** A further consideration here is that G-code and DXF support arcs in addition to the lines already implemented. Implementing arcs wants at least the following options for quadrant and direction:

- cutarcCW — cut a partial arc described in a clock-wise direction
- cutarcCC — counter-clock-wise
- cutarcNWCW — cut the upper-left quadrant of a circle moving clockwise
- cutarcNWCC — upper-left quadrant counter-clockwise
- cutarcNECW
- cutarcNECC
- cutarcSECW
- cutarcSECC
- cutarcNECW
- cutarcNECC
- cutcircleCC — while it won't matter for generating a DXF, when G-code is implemented direction of cut will be a consideration for that
- cutcircleCW
- cutcircleCCdx
- cutcircleCWdx

It will be necessary to have two separate representations of arcs — the G-code and DXF may be easily and directly supported with a single command, but representing the matching tool movement in OpenSCAD may be done in two different fashions. Originally, a series of short line movements which approximate the arc cutting in each direction and at changing Z-heights so as to allow for threading and similar operations was implemented, but instead representing the tool as an outline and using `rotate_extrude` to model the movement of the tool's outline representation through the arc movement.

- G-code — G2 (clockwise) and G3 (counter-clockwise) arcs may be specified, and since the endpoint is the positional requirement, it is most likely best to use the offset to the center (r and J), rather than the radius parameter (k) G2/3 ...
- DXF — `dxfarc(xcenter, ycenter, radius, anglebegin, endangle, tn)`
- approximation of arc using lines (OpenSCAD) in both clock-wise and counter-clock-wise directions

Cutting the quadrant arcs greatly simplifies the calculation and interface for the modules. A full set of 8 will be necessary, then circles will have a pair of modules (one for each cut direction) made for them.

Parameters which will need to be passed in are:

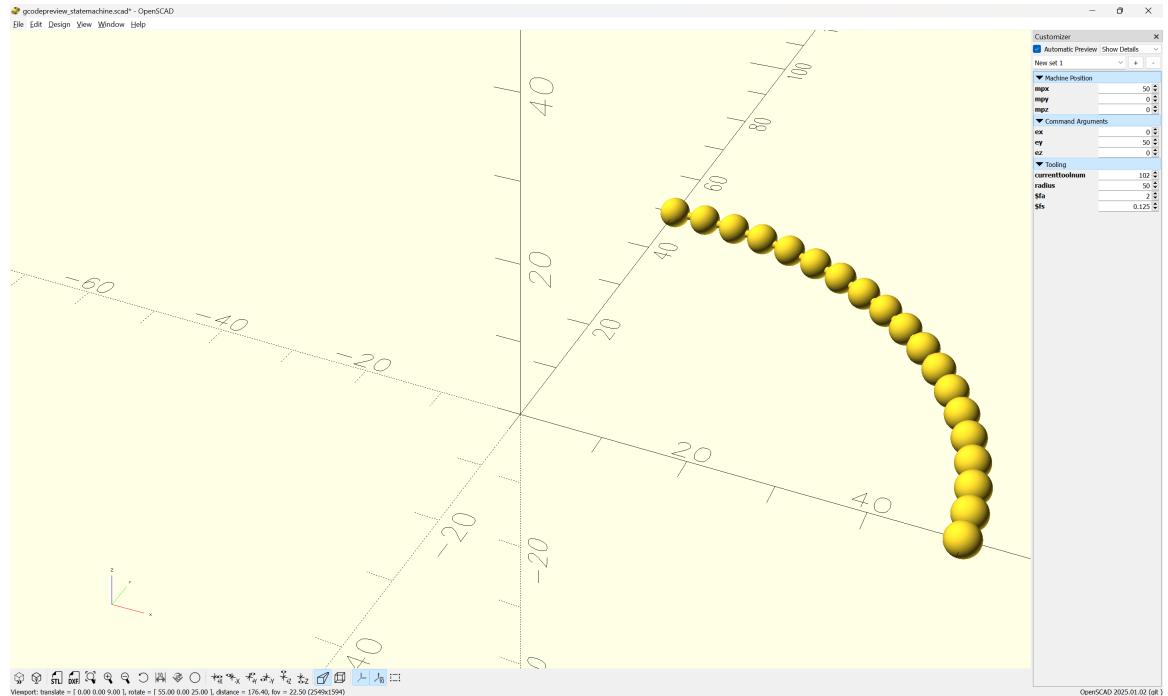
- ex — note that the matching origins (bx, by, bz) as well as the (current) toolnumber are accessed using the appropriate commands for machine position
- ey
- ez — allowing a different Z position will make possible threading and similar helical tool-paths
- xcenter — the center position will be specified as an absolute position which will require calculating the offset when it is used for G-code's IJ, for which `xctr/yctr` are suggested
- ycenter
- radius — while this could be calculated, passing it in as a parameter is both convenient and (potentially) could be used as a check on the other parameters
- tpzreldim — the relative depth (or increase in height) of the current cutting motion

There are two possibilities for arc movement:

- stepping through the arc and approximating with straight line movements
- using `rotate_extrude` to move an outline of the tool through the specified arc — this has the added complexity of being limited to the range of the arc, requiring that the round profile of the tool be instantiated in 3D at each end

`cutarcCW` Stepping through the arc manually is done by iterating through a loop: `cutarcCW` (clockwise) or `cutarcCC` (counterclockwise) to handle the drawing and processing of the `cutline()` toolpaths as short line segments which additionally affords a single point of control for adding additional features such as allowing the depth to vary as one cuts along an arc (the line version is used rather than shape so as to capture the changing machine positions with each step through the loop). Note that the definition matches the DXF definition of defining the center position with a matching radius, but it will be necessary to move the tool to the actual origin, and to calculate the end position when writing out a G2/G3 arc.

This brings to the fore the fact that at its heart, this program is simply graphing math in 3D using tools (as presaged by the book series *Make:Geometry/Trigonometry/Calculus*). This is clear in a depiction of the algorithm for the `cutarcCC/CW` commands, where the `x` value is the cos of the radius and the `y` value the sin:



The code for which makes this obvious:

```
/* [Machine Position] */
mpx = 0;
/* [Machine Position] */
mpy = 0;
/* [Machine Position] */
mpz = 0;

/* [Command Arguments] */
ex = 50;
/* [Command Arguments] */
ey = 25;
/* [Command Arguments] */
ez = -10;

/* [Tooling] */
currenttoolnum = 102;

machine_extents();

radius = 50;
$fa = 2;
$fs = 0.125;

plot_arc(radius, 0, 0, 0, radius, 0, 0, 0, radius, 0, 90, 5);

module plot_arc(bx, by, bz, ex, ey, ez, acx, acy, radius, barc, earc, inc){
for (i = [barc : inc : earc-inc]) {
union(){
hull()
{
translate([acx + cos(i)*radius,
acy + sin(i)*radius,
0]){
sphere(r=0.5);
}
translate([acx + cos(i+inc)*radius,
acy + sin(i+inc)*radius,
0]){
}
}
}
}
}
```

```

        sphere(r=0.5);
    }
}
translate([acx + cos(i)*radius,
           acy + sin(i)*radius,
           0]);
sphere(r=2);
}
translate([acx + cos(i+inc)*radius,
           acy + sin(i+inc)*radius,
           0]);
sphere(r=2);
}
}
}

module machine_extents(){
translate([-200, -200, 20]){
    cube([0.001, 0.001, 0.001], center=true);
}
translate([200, 200, 20]){
    cube([0.001, 0.001, 0.001], center=true);
}
}
}

```

Note that it is necessary to move to the beginning cutting position before calling, and that it is necessary to pass in the relative change in Z position/depth. (Previous iterations calculated the increment of change outside the loop, but it is more workable to do so inside.)

---

```

1142 gcpy      def cutarcCC(self, barc, earc, xcenter, ycenter, radius,
                           tpzreldim, stepsizearc=1):
1143 gcpy          tpzinc = tpzreldim / (earc - barc)
1144 gcpy          i = barc
1145 gcpy          while i < earc:
1146 gcpy              self.cutline(xcenter + radius * Cos(i), ycenter +
                           radius * Sin(i), self.zpos()+tpzinc)
1147 gcpy          i += stepsizearc
1148 gcpy #
1149 gcpy          self.setxpos(xcenter + radius * Cos(earc))
1150 gcpy          self.setypos(ycenter + radius * Sin(earc))

1151 gcpy      def cutarcCW(self, barc, earc, xcenter, ycenter, radius,
                           tpzreldim, stepsizearc=1):
1152 gcpy #
1153 gcpy #
1154 gcpy #
1155 gcpy #
1156 gcpy #
1157 gcpy #
1158 gcpy #
1159 gcpy     print(str(self.zpos()))
1160 gcpy #
1161 gcpy #
1162 gcpy #
1163 gcpy #
1164 gcpy #
1165 gcpy #
1166 gcpy #
1167 gcpy #
1168 gcpy #
1169 gcpy #
1170 gcpy #
1171 gcpy #
1172 gcpy #
1173 gcpy #
1174 gcpy #
1175 gcpy #
1176 gcpy #
1177 gcpy #
1178 gcpy #
1179 gcpy #
1180 gcpy #
1181 gcpy #
1182 gcpy #

          self.cutline(xcenter + radius * Cos(i), ycenter +
                           radius * Sin(i), self.zpos()+tpzinc)
          self.setxpos(xcenter + radius * Cos(i))
          self.setypos(ycenter + radius * Sin(i))
          print(str(self.xpos()), str(self.ypos()), str(self.zpos())
                ()))
          self.setzpos(self.zpos()+tpzinc)
          i += abs(stepsizearc) * -1
          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                      radius, barc, earc)
          if self.generatepaths == True:
              print("Unioning n toolpath")
              self.toolpaths = self.toolpaths.union(toolpath)
          else:
              self.setxpos(xcenter + radius * Cos(earc))
              self.setypos(ycenter + radius * Sin(earc))
              self.toolpaths.extend(toolpath)
          if self.generatepaths == False:
              return toolpath
          else:

```

---

```
1183 gcpy #           return cube([0.01, 0.01, 0.01])
```

---

Alternately, the command for using rotate\_extrude is quite straight-forward:

---

```
1185 gcpy def extrudearcCC(self, barc, earc, xcenter, ycenter, radius,
1186 gcpy #   tpzreldim, stepsizearc=1):
1187 gcpy #       tm = self.toolmovement(self.xpos(), self.ypos(), self.zpos
1188 gcpy #           (), ex, ey, ez)
1189 gcpy #       tm = union(self.toolshape.translate(self.xpos(), self.ypos
1190 gcpy #           (), self.zpos()))
1191 gcpy #               self.toolshape.translate(),
1192 gcpy #                   tooloutline.translate([r-3.175,0,0]).
1193 gcpy #   rotate_extrude(angle=ang2-ang1).rotz(ang1) + G3_center
1194 gcpy #
1195 gcpy #   tm = color(tm, self.cutcolor)
1196 gcpy #   ts = self.shaftmovement(self.xpos(), self.ypos(), self.zpos
1197 gcpy #       (), ex, ey, ez)
1198 gcpy #   ts = color(ts, self.rapidcolor)
1199 gcpy #   self.setxpos(ex)
1200 gcpy #   self.setypos(ey)
1201 gcpy #   self.setzpos(ez)
1202 gcpy #   self.toolpaths.extend([tm, ts])
```

---

Note that it will be necessary to add versions which write out a matching DXF element:

---

```
1202 gcpy def cutarcCWdxf(self, barc, earc, xcenter, ycenter, radius,
1203 gcpy #   tpzreldim, stepsizearc=1):
1204 gcpy #       self.cutarcCW(barc, earc, xcenter, ycenter, radius,
1205 gcpy #           tpzreldim, stepsizearc=1)
1206 gcpy #       self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
1207 gcpy #           radius, earc, barc)
1208 gcpy #   if self.generatepaths == False:
1209 gcpy #       return toolpath
1210 gcpy #   else:
1211 gcpy #       return cube([0.01, 0.01, 0.01])
1212 gcpy def cutarcCCdxf(self, barc, earc, xcenter, ycenter, radius,
1213 gcpy #   tpzreldim, stepsizearc=1):
1214 gcpy #       self.cutarcCC(barc, earc, xcenter, ycenter, radius,
1215 gcpy #           tpzreldim, stepsizearc=1)
1216 gcpy #       self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
1217 gcpy #           radius, barc, earc)
```

---

Matching OpenSCAD modules are easily made:

---

```
84 gpcscad module cutarcCC(barc, earc, xcenter, ycenter, radius, tpzreldim){
85 gpcscad     gcp.cutarcCC(barc, earc, xcenter, ycenter, radius, tpzreldim);
86 gpcscad }
87 gpcscad
88 gpcscad module cutarcCW(barc, earc, xcenter, ycenter, radius, tpzreldim){
89 gpcscad     gcp.cutarcCW(barc, earc, xcenter, ycenter, radius, tpzreldim);
90 gpcscad }
```

---

An alternate interface which matches how G2/G3 arcs are programmed in G-code is a useful option:

---

```
1211 gcpy def cutquarterCCNE(self, ex, ey, ez, radius):
1212 gcpy     if self.zpos() == ez:
1213 gcpy         tpzinc = 0
1214 gcpy     else:
1215 gcpy         tpzinc = (ez - self.zpos()) / 90
1216 gcpy #         print("tpzinc ", tpzinc)
1217 gcpy         i = 1
1218 gcpy         while i < 91:
1219 gcpy             self.cutline(ex + radius * Cos(i), ey - radius + radius
1220 gcpy                 * Sin(i), self.zpos()+tpzinc)
1221 gcpy             i += 1
1222 gcpy     def cutquarterCCNW(self, ex, ey, ez, radius):
1223 gcpy         if self.zpos() == ez:
1224 gcpy             tpzinc = 0
1225 gcpy         else:
1226 gcpy             tpzinc = (ez - self.zpos()) / 90
1227 gcpy #             tpzinc = (self.zpos() + ez) / 90
1228 gcpy             self.debug("tpzinc", tpzinc)
1229 gcpy             i = 91
```

```

1230 gcpy      while i < 181:
1231 gcpy          self.cutline(ex + radius + radius * Cos(i), ey + radius
1232 gcpy              * Sin(i), self.zpos()+tpzinc)
1233 gcpy          i += 1
1234 gcpy      def cutquarterCCSW(self, ex, ey, ez, radius):
1235 gcpy          if self.zpos() == ez:
1236 gcpy              tpzinc = 0
1237 gcpy          else:
1238 gcpy              tpzinc = (ez - self.zpos()) / 90
1239 gcpy #             tpzinc = (self.zpos() + ez) / 90
1240 gcpy #
1241 gcpy          print("tpzinc ", tpzinc)
1242 gcpy          i = 181
1243 gcpy      while i < 271:
1244 gcpy          self.cutline(ex + radius * Cos(i), ey + radius + radius
1245 gcpy              * Sin(i), self.zpos()+tpzinc)
1246 gcpy          i += 1
1247 gcpy      def cutquarterCCSE(self, ex, ey, ez, radius):
1248 gcpy          if self.zpos() == ez:
1249 gcpy              tpzinc = 0
1250 gcpy          else:
1251 gcpy #             tpzinc = (ez - self.zpos()) / 90
1252 gcpy #
1253 gcpy          print("tpzinc ", tpzinc)
1254 gcpy          i = 271
1255 gcpy      while i < 361:
1256 gcpy          self.cutline(ex - radius + radius * Cos(i), ey + radius
1257 gcpy              * Sin(i), self.zpos()+tpzinc)
1258 gcpy          i += 1
1259 gcpy      def cutquarterCCNEdxf(self, ex, ey, ez, radius):
1260 gcpy          self.cutquarterCCNE(ex, ey, ez, radius)
1261 gcpy          self.dxfarc(self.currenttoolnumber(), ex, ey - radius,
1262 gcpy              radius, 0, 90)
1263 gcpy      def cutquarterCCNWdxr(self, ex, ey, ez, radius):
1264 gcpy          self.cutquarterCCNW(ex, ey, ez, radius)
1265 gcpy          self.dxfarc(self.currenttoolnumber(), ex + radius, ey,
1266 gcpy              radius, 90, 180)
1267 gcpy      def cutquarterCCSWdxr(self, ex, ey, ez, radius):
1268 gcpy          self.cutquarterCCSW(ex, ey, ez, radius)
1269 gcpy          self.dxfarc(self.currenttoolnumber(), ex, ey + radius,
1270 gcpy              radius, 180, 270)
1271 gcpy      def cutquarterCCSEdxr(self, ex, ey, ez, radius):
1272 gcpy          self.cutquarterCCSE(ex, ey, ez, radius)
1273 gcpy          self.dxfarc(self.currenttoolnumber(), ex - radius, ey,
1274 gcpy              radius, 270, 360)

```

---

```

92 gpcscad module cutquarterCCNE(ex, ey, ez, radius){
93 gpcscad     gcp.cutquarterCCNE(ex, ey, ez, radius);
94 gpcscad }
95 gpcscad
96 gpcscad module cutquarterCCNW(ex, ey, ez, radius){
97 gpcscad     gcp.cutquarterCCNW(ex, ey, ez, radius);
98 gpcscad }
99 gpcscad
100 gpcscad module cutquarterCCSW(ex, ey, ez, radius){
101 gpcscad     gcp.cutquarterCCSW(ex, ey, ez, radius);
102 gpcscad }
103 gpcscad
104 gpcscad module cutquarterCCSE(self, ex, ey, ez, radius){
105 gpcscad     gcp.cutquarterCCSE(ex, ey, ez, radius);
106 gpcscad }
107 gpcscad
108 gpcscad module cutquarterCCNEdxf(ex, ey, ez, radius){
109 gpcscad     gcp.cutquarterCCNEdxf(ex, ey, ez, radius);
110 gpcscad }
111 gpcscad
112 gpcscad module cutquarterCCNWdxr(ex, ey, ez, radius){
113 gpcscad     gcp.cutquarterCCNWdxr(ex, ey, ez, radius);
114 gpcscad }
115 gpcscad
116 gpcscad module cutquarterCCSWdxr(ex, ey, ez, radius){
117 gpcscad     gcp.cutquarterCCSWdxr(ex, ey, ez, radius);

```

```

118 gpcscad }
119 gpcscad
120 gpcscad module cutquarterCCSEdx (self, ex, ey, ez, radius){
121 gpcscad     gcp.cutquarterCCSEdx (ex, ey, ez, radius);
122 gpcscad }
```

---

### 3.5.4 tooldiameter

It will also be necessary to be able to provide the diameter of the current tool. Arguably, this would be much easier using an object-oriented programming style/dot notation.

One aspect of tool parameters which will need to be supported is shapes which create different profiles based on how deeply the tool is cutting into the surface of the material at a given point. To accommodate this, it will be necessary to either track the thickness of uncut material at any given point, or, to specify the depth of cut as a parameter.

`tool diameter` The public-facing OpenSCAD code, `tool diameter` simply calls the matching OpenSCAD module which wraps the Python code:

```

124 gpcscad function tool_diameter(td_tool, td_depth) = otool_diameter(td_tool,
    td_depth);
```

---

`tool diameter` the Python code, `tool diameter` returns appropriate values based on the specified tool number and depth:

```

1274 gcpy     def tool_diameter(self, ptd_tool, ptd_depth):
1275 gcpy # Square 122, 112, 102, 201
1276 gcpy         if ptd_tool == 122:
1277 gcpy             return 0.79375
1278 gcpy         if ptd_tool == 112:
1279 gcpy             return 1.5875
1280 gcpy         if ptd_tool == 102:
1281 gcpy             return 3.175
1282 gcpy         if ptd_tool == 201:
1283 gcpy             return 6.35
1284 gcpy # Ball 121, 111, 101, 202
1285 gcpy         if ptd_tool == 122:
1286 gcpy             if ptd_depth > 0.396875:
1287 gcpy                 return 0.79375
1288 gcpy             else:
1289 gcpy                 return ptd_tool
1290 gcpy         if ptd_tool == 112:
1291 gcpy             if ptd_depth > 0.79375:
1292 gcpy                 return 1.5875
1293 gcpy             else:
1294 gcpy                 return ptd_tool
1295 gcpy         if ptd_tool == 101:
1296 gcpy             if ptd_depth > 1.5875:
1297 gcpy                 return 3.175
1298 gcpy             else:
1299 gcpy                 return ptd_tool
1300 gcpy         if ptd_tool == 202:
1301 gcpy             if ptd_depth > 3.175:
1302 gcpy                 return 6.35
1303 gcpy             else:
1304 gcpy                 return ptd_tool
1305 gcpy # V 301, 302, 390
1306 gcpy         if ptd_tool == 301:
1307 gcpy             return ptd_tool
1308 gcpy         if ptd_tool == 302:
1309 gcpy             return ptd_tool
1310 gcpy         if ptd_tool == 390:
1311 gcpy             return ptd_tool
1312 gcpy # Keyhole
1313 gcpy         if ptd_tool == 374:
1314 gcpy             if ptd_depth < 3.175:
1315 gcpy                 return 9.525
1316 gcpy             else:
1317 gcpy                 return 6.35
1318 gcpy         if ptd_tool == 375:
1319 gcpy             if ptd_depth < 3.175:
1320 gcpy                 return 9.525
1321 gcpy             else:
1322 gcpy                 return 8
1323 gcpy         if ptd_tool == 376:
1324 gcpy             if ptd_depth < 4.7625:
1325 gcpy                 return 12.7
1326 gcpy             else:
```

```

1327 gcpy           return 6.35
1328 gcpy       if ptd_tool == 378:
1329 gcpy           if ptd_depth < 4.7625:
1330 gcpy           return 12.7
1331 gcpy       else:
1332 gcpy           return 8
1333 gcpy # Dovetail
1334 gcpy       if ptd_tool == 814:
1335 gcpy           if ptd_depth > 12.7:
1336 gcpy           return 6.35
1337 gcpy       else:
1338 gcpy           return ptd_tool
1339 gcpy       if ptd_tool == 808079:
1340 gcpy           if ptd_depth > 20.95:
1341 gcpy           return 6.816
1342 gcpy       else:
1343 gcpy           return ptd_tool
1344 gcpy # Bowl Bit
1345 gcpy #https://www.amanatool.com/45982-carbide-tipped-bowl-tray-1-4-
           radius-x-3-4-dia-x-5-8-x-1-4-inch-shank.html
1346 gcpy       if ptd_tool == 45982:
1347 gcpy           if ptd_depth > 6.35:
1348 gcpy           return 15.875
1349 gcpy       else:
1350 gcpy           return ptd_tool
1351 gcpy # Tapered Ball Nose
1352 gcpy       if ptd_tool == 204:
1353 gcpy           if ptd_depth > 6.35:
1354 gcpy           return ptd_tool
1355 gcpy       if ptd_tool == 304:
1356 gcpy           if ptd_depth > 6.35:
1357 gcpy           return ptd_tool
1358 gcpy       else:
1359 gcpy           return ptd_tool

```

---

**tool radius** Since it is often necessary to utilise the radius of the tool, an additional command, `tool radius` to return this value is worthwhile:

```

1361 gcpy     def tool_radius(self, ptd_tool, ptd_depth):
1362 gcpy         tr = self.tool_diameter(ptd_tool, ptd_depth)/2
1363 gcpy         return tr

```

---

(Note that where values are not fully calculated values currently the passed in tool number (`ptd_tool`) is returned which will need to be replaced with code which calculates the appropriate values.)

### 3.5.5 Feeds and Speeds

**feed** There are several possibilities for handling feeds and speeds. Currently, base values for feed, plunge, and speed are used, which may then be adjusted using various `<tooldescriptor>_ratio` speed values, as an acknowledgement of the likelihood of a trim router being used as a spindle, the assumption is that the speed will remain unchanged.

The tools which need to be calculated thus are those in addition to the `large_square` tool:

- `small_square_ratio`
- `small_ball_ratio`
- `large_ball_ratio`
- `small_V_ratio`
- `large_V_ratio`
- `KH_ratio`
- `DT_ratio`

### 3.5.6 3D Printing

Support for 3D printing requires that there be G-code commands for non-mill/router aspects such as:

- fan(s) on/off
- extruder(s)
- Heater(s)

- temperature(s)
- accelerometers
- load cells
- Filament Sensor(s)
- Filament Cutter(s)
- Display Status
  - Message
  - Build Percentage
  - (Clear) Message
- any additional commands such as “Clean Nozzle”

Moreover, it will be necessary for all values to be adjusted for specific firmware, printer and filament type combinations. Probably the best beginning will be to create a simple file using a tested set of settings in a compatible slicer as a template and to adjust based on the values from such a file.

### 3.5.6.1 Sample 3D printing file

```

M106 S0
M106 P2 S0
;TYPE:Custom
;===== date: 20240520 =====
;printer_model:Elegoo Centauri Carbon
;initial_filament:PLA
;curr_bed_type:Textured PEI Plate
M400 ; wait for buffer to clear
M220 S100 ;Set the feed speed to 100%
M221 S100 ;Set the flow rate to 100%
M104 S140
M140 S60
G90
G28 ;home
M729 ;Clean Nozzle
M190 S60

;=====turn on fans to prevent PLA jamming=====

M106 P3 S255
;Prevent PLA from jamming

;enable_pressure_advance:false
;This value is called if pressure advance is enabled

M204 S5000 ;Call exterior wall print acceleration

G1 X128.5 Y-1.2 F20000
G1 Z0.3 F900
M73 P1 R0
M109 S210
M83
G92 E0 ;Reset Extruder
G1 F6000
G1 X-1.2 E10.156 ;Draw the first line
G1 Y98.8 E7.934
M73 P7 R0
G1 X-0.5 Y100 E0.1
M73 P11 R0
G1 Y-0.3 E7.934
G1 X78.5 E6.284
M73 P15 R0
G1 F1680
M73 P18 R0
G1 X98.5 E2
G1 F8400
M73 P21 R0
G1 X118.5 E2
G1 F1680
G1 X138.5 E2

```

```
G1 F8400
M73 P24 R0
G1 X158.5 E2
G1 F8400
M73 P25 R0
G1 X178.5 E2
;End PA test.

G3 I-1 J0 Z0.6 F1200.0 ;Move to side a little
M73 P27 R0
G1 F20000
G92 EO ;Reset Extruder
;LAYER_COUNT:1
;LAYER:0
G90
G21
M83 ; use relative distances for extrusion
; filament start gcode
M106 P3 S200

;LAYER_CHANGE
;Z:0.2
;HEIGHT:0.2
;BEFORE_LAYER_CHANGE
;0.2
G92 EO

G1 E-.8 F1800
;LAYER:1

;_SET_FAN_SPEED_CHANGING_LAYER
SET_VELOCITY_LIMIT ACCEL=500
EXCLUDE_OBJECT_START NAME=Disc_id_0_copy_0
G1 X135.645 Y128.74 F30000
M73 P31 R0
G1 Z.6
G1 Z.2
G1 E.8 F1800
;TYPE:Outer wall
;WIDTH:0.499999
G1 F3000
G3 X128.198 Y121.357 I-7.146 J-.24 E1.19765
M73 P34 R0
G3 X130.232 Y121.573 I.058 J9.145 E.07407
G3 X135.591 Y127.663 I-1.733 J6.927 E.31169
M73 P35 R0
G1 X135.643 Y128.7 E.03754
G1 E-.728 F1800
;WIPE_START
G1 F30000
G1 X135.585 Y129.458 E-.0456
G1 X135.504 Y129.891 E-.0264
;WIPE_END
G1 X132.262 Y122.981 Z.6
M73 P36 R0
G1 X132.077 Y122.586 Z.6
G1 Z.2
M73 P37 R0
G1 E.8 F1800
;TYPE:Bottom surface
;WIDTH:0.505817
G1 F6300
G1 X133.335 Y123.844 E.06511
G3 X134.64 Y125.803 I-4.602 J4.479 E.08662
G1 X131.189 Y122.353 E.17854
M73 P38 R0
G1 X130.445 Y122.073 E.02909
G1 X130.192 Y122.01 E.00954
G1 X134.995 Y126.813 E.24849
M73 P39 R0
G3 X135.149 Y127.621 I-3.921 J1.166 E.03018
G1 X129.378 Y121.851 E.29858
M73 P40 R0
G2 X128.676 Y121.803 I-.554 J2.949 E.02582
G1 X135.204 Y128.331 E.33779
M73 P41 R0
```

G3 X135.19 Y128.972 I-3.173 J.251 E.02348  
G1 X128.027 Y121.809 E.37065  
M73 P42 R0  
G2 X127.438 Y121.874 I.029 J2.945 E.02172  
M73 P43 R0  
G1 X135.124 Y129.56 E.39772  
M73 P44 R0  
G3 X135.017 Y130.108 I-2.76 J-.255 E.02045  
G1 X126.89 Y121.981 E.42051  
M73 P45 R0  
G1 X126.387 Y122.133 E.01923  
G1 X134.868 Y130.614 E.43887  
M73 P46 R0  
G3 X134.687 Y131.087 I-2.431 J-.66 E.01858  
G1 X125.912 Y122.313 E.45404  
M73 P47 R0  
G2 X125.463 Y122.518 I.79 J2.324 E.01811  
M73 P48 R0  
G1 X134.481 Y131.536 E.46662  
M73 P49 R0  
G3 X134.252 Y131.962 I-2.22 J-.918 E.01772  
G1 X125.038 Y122.748 E.47677  
M73 P50 R0  
G2 X124.646 Y123.01 I1.102 J2.07 E.01729  
G1 X133.99 Y132.354 E.4835  
M73 P52 R0  
G3 X133.707 Y132.726 I-1.979 J-1.213 E.01712  
G1 X124.273 Y123.292 E.48816  
M73 P53 R0  
G2 X123.918 Y123.592 I1.305 J1.903 E.01702  
G1 X133.406 Y133.079 E.49092  
M73 P54 R0  
G1 X133.077 Y133.405 E.01694  
G1 X123.595 Y123.923 E.49064  
M73 P56 R0  
G2 X123.291 Y124.274 I1.583 J1.677 E.01701  
G1 X132.725 Y133.708 E.48813  
M73 P57 R0  
G3 X132.354 Y133.992 I-1.59 J-1.689 E.01711  
G1 X123.006 Y124.643 E.48373  
M73 P58 R0  
G1 X122.75 Y125.042 E.01733  
M73 P59 R0  
G1 X131.959 Y134.251 E.47651  
M73 P60 R0  
G3 X131.534 Y134.481 I-1.349 J-1.984 E.0177  
G1 X122.519 Y125.466 E.46649  
M73 P61 R0  
G2 X122.31 Y125.912 I2.1 J1.254 E.01805  
G1 X131.087 Y134.688 E.45415  
M73 P62 R0  
G3 X130.615 Y134.871 I-1.138 J-2.244 E.01855  
M73 P63 R0  
G1 X122.127 Y126.383 E.43917  
M73 P64 R0  
G1 X121.985 Y126.896 E.01946  
G1 X130.105 Y135.016 E.42016  
M73 P65 R0  
G3 X129.558 Y135.123 I-.806 J-2.651 E.02043  
G1 X121.877 Y127.442 E.39747  
M73 P66 R0  
G2 X121.81 Y128.03 I2.87 J.626 E.02167  
G1 X128.97 Y135.19 E.37051  
M73 P68 R0  
G3 X128.33 Y135.204 I-.391 J-3.158 E.02348  
G1 X121.795 Y128.67 E.33813  
M73 P69 R0  
G2 X121.851 Y129.38 I3.542 J.078 E.02613  
G1 X127.619 Y135.149 E.29847  
M73 P70 R0  
G3 X126.809 Y134.992 I.366 J-4.085 E.03026  
G1 X122.009 Y130.193 E.24836  
M73 P71 R0  
G1 X122.057 Y130.392 E.00749  
G1 X122.28 Y131.031 E.02476  
G1 X122.356 Y131.195 E.00663  
G1 X125.802 Y134.641 E.17832  
M73 P72 R0

```

G3 X123.807 Y133.3 I2.526 J-5.915 E.0885
G1 X122.586 Y132.079 E.06316
M73 P73 R0
G1 E-.728 F1800
;WIPE_START
G1 F30000
G1 X123.435 Y132.928 E-.072
;WIPE_END
EXCLUDE_OBJECT_END NAME=Disc_id_0_copy_0
M106 S0
M106 P2 S0
;TYPE:Custom
; filament end gcode
===== date: 20250109 =====
M400 ; wait for buffer to clear
M140 S0 ;Turn-off bed
M106 S255 ;Cooling nozzle
M83
G92 E0 ; zero the extruder
G2 I1 J0 Z0.7 E-1 F3000 ; lower z a little
M73 P74 R0
G90
G1 Z100 F20000 ; Move print head up
M73 P94 R0
M204 S5000
M400
M83
G1 X202 F20000
M73 P95 R0
M400
G1 Y250 F20000
M73 P97 R0
G1 Y264.5 F1200
M73 P100 R0
M400
G92 E0
M104 S0 ;Turn-off hotend
M140 S0 ;Turn-off bed
M106 S0 ; turn off fan
M106 P2 S0 ; turn off remote part cooling fan
M106 P3 S0 ; turn off chamber cooling fan
M84 ;Disable all steppers

```

The various commands for machine functionality are quite straight-forward, with each added as a descriptive module.

---

```

1365 gcpy      def setfansoff(self):
1366 gcpy          self.writegc("M106\u00d7S0")
1367 gcpy
1368 gcpy      def setfanspeed(self, fan, speed):
1369 gcpy          self.writegc("M106\u00d7P", fan, "\u00d7S", speed)
1370 gcpy
1371 gcpy      def pauseforclearbuffer(self):
1372 gcpy          self.writegc("M400\u00d7; \u00d7wait\u00d7for\u00d7buffer\u00d7to\u00d7clear")

```

---

**3.5.6.2 Feed and Speed ratio** Note that certain commands will require setting values which will need to be tracked and used for calculations.

---

```

1374 gcpy      def setfeedratio(self, feedratio):
1375 gcpy          self.writegc("M220\u00d7S", feedratio)
1376 gcpy          self.feedratio = feedratio
1377 gcpy
1378 gcpy      def setspeedratio(self, speedratio):
1379 gcpy          self.writegc("M221\u00d7S", speedratio)
1380 gcpy          self.speedratio = speedratio

```

---

**3.5.6.3 Time and Firmware for 3D printers** The various G-code commands are specific to firmware implementations such as <https://www.klipper3d.org/G-Codes.html>

Where CNC operations normally only are concerned about time in the moment, and pausing until a given time has elapsed, 3D operations, with their control of heating up filament, melting it, and extruding thin ribbons of it require a greater control over time and duration.

---

```
1382 gcpy #Set extruder temperature: M104 [T<index>] [S<temperature>]
```

---

```

1383 gcpy     def setextrudertemperature(self, temperature):
1384 gcpy         self.writegc("M104\u0026S" + str(temperature))
1385 gcpy         self.extrudertemperature = temperature
1386 gcpy
1387 gcpy #Set extruder temperature and wait: M109 [T<index>] S<temperature>
1388 gcpy #Note: M109 always waits for temperature to settle at requested
           value
1389 gcpy     def setandwaitforextrudertemperature(self, temperature):
1390 gcpy         self.writegc("M109\u0026S" + str(temperature) + ";\"set"
           "temperature\u0026wait\u0026for\u0026it\u0026to\u0026be\u0026reached")
1391 gcpy         self.extrudertemperature = temperature
1392 gcpy
1393 gcpy #Set bed temperature: M140 [S<temperature>]
1394 gcpy     def setbedtemperature(self, temperature):
1395 gcpy         self.writegc("M140\u0026S" + str(temperature))
1396 gcpy         self.bedtemperature = temperature
1397 gcpy
1398 gcpy #Set bed temperature and wait: M190 S<temperature>
1399 gcpy #Note: M190 always waits for temperature to settle at requested
           value
1400 gcpy     def setandwaitforbedtemperature(self, temperature):
1401 gcpy         self.writegc("M190\u0026S" + str(temperature))
1402 gcpy         self.bedtemperature = temperature

```

---

Certain commands are only needed for initialization, so may be grouped together in a single command:

---

```

1408 gcpy     def initializeforprinting(self, nozzlediameter = 0.4,
           filamentdiameter = 1.75, extrusionwidth = 0.6, layerheight =
           0.2):
1409 gcpy         self.writegc("G21\u0026;\"set\u0026units\u0026to\u0026millimeters")
1410 gcpy         self.writegc("G90")
1411 gcpy         self.writegc("M82\u0026;\"use\u0026absolute\u0026distances\u0026for\u0026extrusion")
1412 gcpy         self.writegc("G28\u0026;\"home")
1413 gcpy         self.writegc("M729\u0026;\"Clean\u0026Nozzle")
1414 gcpy         self.nozzlediameter = nozzlediameter
1415 gcpy         self.extrusionwidth = extrusionwidth
1416 gcpy         self.layerheight = layerheight
1417 gcpy         self.toolpaths = []
1418 gcpy         self.feedrate = 0
1419 gcpy         fr = filamentdiameter/2
1420 gcpy         self.extrusion_normal_length = 1 / 3.14159 * (fr * fr)

```

---

```

1420 gcpy     def liftandprimenozzle(self, liftfeed = 5000, extrusionfeed =
           2400):
1421 gcpy         self.writegc("G1\u0026Z5\u0026F" + str(liftfeed) + "\u0026;\"lift\u0026nozzle")
1422 gcpy         self.writegc("G92\u0026E0")
1423 gcpy         self.writegc("G1\u0026E-2\u0026F" + str(extrusionfeed))
1424 gcpy         self.writegc("G92\u0026E0")
1425 gcpy
1426 gcpy #Set acceleration: M204 S<value> OR M204 P<value> T<value>
1427 gcpy #Note: If S is not specified and both P and T are specified, then
           the acceleration is set to the minimum of P and T. If only one
           of P or T is specified, the command has no effect.
1428 gcpy     def setacceleration(self, acceleration):
1429 gcpy         self.writegc("M204\u0026S", acceleration)
1430 gcpy         self.acceleration = acceleration
1431 gcpy
1432 gcpy #Use absolute/relative distances for extrusion: M82, M83
1433 gcpy     def setextrusionabsolute(self, acceleration):
1434 gcpy         self.writegc("M83")
1435 gcpy         self.extrusionabsolute = true

```

---

```

1431 gcpy #Set build percentage: M73 P<percent>
1432 gcpy     def setbuildpercentage(self, percent):
1433 gcpy         self.writegc("M73\u0026P", percent)
1434 gcpy         self.percent = percent

```

---

The program [https://github.com/FullControlXYZ/fullcontrol/blob/master/models/hex\\_adapter.ipynb](https://github.com/FullControlXYZ/fullcontrol/blob/master/models/hex_adapter.ipynb) suggests certain variables:

```

# printer/gcode parameters

design_name = 'hex_adapter'
nozzle_temp = 210

```

```
bed_temp = 40
print_speed = 1000
fan_percent = 100
printer_name='prusa_i3' # generic / ultimaker2plus / prusa_i3 / ender_3 / cr_10 / bambulab_x1 / toolchan
```

Movement commands add an E position aspect to the command which results in the Extruder advancing to that position so as to extrude a sufficient volume of filament to match the movement and the space which is intended to be filled. Modeling these in 3D without the complexity of managing the entire 3D model and tracking the elevation of the current position relative to the model at a given point in time will require that the user maintain the current layer thickness and ensure that if unsupported, the extruded plastic will be extruded with a fan speed and flow rate which will allow bridging from/to supported areas of the model.

Calculating the volume necessary/the amount extruded will require the nozzle size, the layer height, an estimate for how much the extruded filament will spread out/deform, and the diameter of the filament. Further potential complications include whether the first layer is being extruded (normally this is done at a quite slow speed to facilitate adhesion, which also serves as a chance to catch a problem at an early stage), or if a strand is an inside or outside wall or infill or bridging open space, if it is crossing an already extruded segment(?) and so forth.

```
; --- Start of G-code: Demonstration of Layer and Extrusion Concepts ---
G21 ; Set units to millimeters
G90 ; Use absolute positioning
M82 ; Set extruder to absolute mode
M104 S200 ; Set extruder temperature to 200°C
M140 S60 ; Set bed temperature to 60°C
M190 S60 ; Wait for bed to reach target temp
M109 S200 ; Wait for extruder to reach target temp
G28 ; Home all axes

; --- Initial test extrusion ---
G92 E0 ; Reset extruder position
G1 F100 E5 ; Extrude 5 mm of filament at low speed to prime the nozzle
; Purpose: Ensures clean flow and purges any residual filament

; --- First layer adhesion test ---
G1 Z0.2 ; Move nozzle to first layer height
G1 X10 Y10 F3000 ; Move to starting position
G1 F1800 ; Set slower speed for first layer
G1 E0.8 ; Slight retraction before starting
G1 X100 E10 ; Draw a line along X to test bed adhesion
; Comment: This line helps verify that the first layer sticks properly

; --- Outer wall generation ---
G1 Z0.2 ; Maintain layer height
G1 X100 Y100 E10 ; Move and extrude to start outer square
G1 X10 Y100 E10 ;
G1 X10 Y10 E10 ;
G1 X100 Y10 E10 ;
; Outer walls: Typically printed first to preserve dimensional accuracy

; --- Cornering adjustment ---
G1 F1200 ; Reduce speed at corners
G1 X100 Y100 E0.5 ;
; Comment: Slower cornering helps prevent blobbing and maintains sharp edges

; --- Inner wall generation ---
G1 F1800 ; Resume regular speed
G1 X95 Y95 E8 ;
G1 X15 Y95 E8 ;
G1 X15 Y15 E8 ;
G1 X95 Y15 E8 ;
; Comment: Inner walls follow outer walls to enhance structural strength

; --- Understanding extrusion width ---
; Parameters:
; - Nozzle = 0.4 mm
; - Layer height = 0.2 mm
; - Filament diameter = 1.75 mm

; Flow rate ~ (extrusion_width * layer_height) / ( * (filament_diameter/2)^2)
; Example calculation: (0.4 * 0.2) / ($\pi * (0.875)^2) 0.033 mm$²/mm

; --- Smooth top layer strategy ---
G1 Z0.4 ; Move to top layer height
G1 X20 Y20 ;
G1 F1500 ;
G1 X90 E3 ; Lay down parallel top layer strokes
G1 X90 Y90 E3 ;
```

```

G1 X20 Y90 E3 ;
G1 X20 Y20 E3 ;
G1 F3000 ;
G1 X20 Y20 ;
G1 F1500 ;
G1 X90 E3 ; Repeat for second pass for smoothing
; Tip: Overlapping infill with slightly lower extrusion helps achieve a smooth finish

; --- Wrap up ---
G92 E0 ; Reset extruder
G1 E-2 F1800 ; Retract filament to prevent stringing
M104 S0 ; Turn off hotend
M140 S0 ; Turn off bed
G28 X0 ; Home X-axis
M84 ; Disable motors
; --- End of G-code demonstration ---

```

3D printing requires control of the extruder, and matching volumetric calculations (or, more accurately, volumetric calculations which then determine the rate of extrusion).

Previewing in 3D/programming for 3D extrusion will likely want previewing not just the extruded shape, but also tracking the volume of material extruded and how it relates to the volume of the object being filled/the intersection of a just-extruded region with previously extruded material, and how large a void is left (presumably those two volumes would match up).

One concern is that G2/G3 support apparently is not common/guaranteed in 3D printer firmwares:

*available if a gcode\_arcs config section is enabled*

<https://www.klipper3d.org/G-Codes.html> While it is possible to separately control the feed rate of the extrusion, and the length of material extruded:

```
G1 F100 E5 ; Extrude 5 mm of filament at low speed to prime the nozzle
```

The normal usage is to move at a preset Feed rate in terms of motion, and while that movement is being made, extrude a given length of material:

```

; --- First layer adhesion test ---
G1 Z0.2 ; Move nozzle to first layer height
G1 X10 Y10 F3000 ; Move to starting position
G1 F1800 ; Set slower speed for first layer
G1 E0.8 ; Slight retraction before starting
G1 X100 E10 ; Draw a line along X to test bed adhesion
; Comment: This line helps verify that the first layer sticks properly

```

In theory, if one had a layer height equal to the diameter of the filament, and wanted to extrude a circular cross-section of filament, the value for E would be equal to the distance traveled.

Apparently, the firmware control is limited so that the extrusion rate cannot be varied relative to the feed rate so that it is not possible to for example, decrease the speed/increase the extrusion rate, resulting in a trapezoidal extrusion.

Given all that, the idealized (normalized?) shape and dimensions of the extrusion would be controlled by:

- layer height (for height along Z)
- extrusion rate (for width in X/Y)

which would be previewed as a rounded cross section, so it should work to create a preview by calculating the volume of material which is being extruded, then determining the volume of a circle of radius layer height/2, subtract that from the extruded volume, then determine what width of rectangle cross section would be necessary at the specified length to make up the difference.

---

```

1436 gcpy #Move (G0 or G1): G1 [X<pos>] [Y<pos>] [Z<pos>] [E<pos>] [F<speed>]
1437 gcpy     def extrude(self, ex, ey, ez, extrusionwidth = 0, layerheight =
0, feedrate = 0):
1438 gcpy         if extrusionwidth > 0:
1439 gcpy             self.extrusionwidth = extrusionwidth
1440 gcpy         if layerheight > 0:
1441 gcpy             self.layerheight = layerheight
1442 gcpy         if feedrate > 0:
1443 gcpy             self.feedrate = feedrate
1444 gcpy         if self.extrusionwidth == self.layerheight:
1445 gcpy             c = sphere(self.layerheight/2)
1446 gcpy         else:
1447 gcpy             ew = self.extrusionwidth
1448 gcpy             lh = self.layerheight
1449 gcpy             i = circle(lh/2)
1450 gcpy             j = i.translate([0, lh/2, 0])
1451 gcpy             k = intersection(j, square([lh, lh]))

```

```

1452 gcopy           l = k.translate([ew/2-lh/2,0,0])
1453 gcopy           m = union(l, square([ew/2-lh/2, lh]))
1454 gcopy           c = rotate_extrude(m)
1455 gcopy           c = c.translate([0,0,-self.layerheight])
1456 gcopy           tslist = hull(c.translate([self.xpos(), self.ypos(),self.
1457 gcopy           zpos()]), c.translate([ex, ey, ez]))
1458 gcopy           self.toolpaths.append(tslist)
1459 gcopy           #volume = r^2 length
1460 gcopy           #      + extrusionwidth-layerheight layerheight
1461 gcopy           length
1462 gcopy           distance = math.dist([self.xpos(), self.ypos(), self.zpos()]
1463 gcopy           ], [ex, ey, ez])
1464 gcopy           print("Distance=" , distance)
1465 gcopy           v = self.extrusionwidth-self.layerheight * self.layerheight
1466 gcopy           * distance + 3.14159 * self.layerheight/2 * self.
layerheight/2 * distance
1467 gcopy           print("Volume=" ,v)
1468 gcopy           el = self.extrusion_normal_length * v
1469 gcopy           print("Extrusionlength=" ,el)
1470 gcopy           self.writegc("G01 X" + str(ex) + "Y" + str(ey) + "Z" +
str(ez) + "E" + str(el) + "F" + str(self.feedrate))

```

---

The system Fullcontrolgcode <https://fullcontrolgcode.com/> affords a compleat system for programming a 3D printer. The implementation <https://py2g.com/> as announced at: [https://old.reddit.com/r/FullControl/comments/1mjgta3/i\\_made\\_an\\_online\\_ide\\_for\\_fullcontrol\\_py2gcom/](https://old.reddit.com/r/FullControl/comments/1mjgta3/i_made_an_online_ide_for_fullcontrol_py2gcom/) affords a straight-forward usage from which the following typical example code is pulled:

```

# see https://py2g.com/customize/grid-bins for a bonus interactive UI to use with this sketch

# =====#
# PARAMETERS
# =====#
layer_height = 0.4
line_width   = 1.2
start_x, start_y = 10, 10
grid_unit    = 25
units_x, units_y, units_z = 4, 8, 0.5
outer_radius = 5
tolerance = 0.05

flow_rate = 1.02 # fill in the gaps

bin_type_outer = True # set True to create a bin container

print_speed = 40 # highest speed you'd want to go
max_flow = 8 # in mm3/s
max_print_speed = max_flow / (layer_height*line_width) # highest speed you can go
print_speed = min(print_speed,max_print_speed)

printer_name = 'generic'
printer_settings = {
    'primer':         'travel',
    'print_speed':    print_speed*60,
    'travel_speed':   20*60,
    'nozzle_temp':    210,
    'bed_temp':       50,
    'fan_percent':   100,
    'extrusion_width': line_width,
    'extrusion_height': layer_height * flow_rate
}

# =====#
# DERIVED DIMENSIONS
# =====#
len_x = units_x * grid_unit
len_y = units_y * grid_unit
len_z = units_z * grid_unit

lim_left   = start_x + line_width/2 + tolerance/2
lim_right  = start_x + len_x - line_width/2 - tolerance/2
lim_bottom = start_y + line_width/2 + tolerance/2
lim_top    = start_y + len_y - line_width/2 - tolerance/2

# set up outer bin dimensions
if bin_type_outer:
    lim_left -= line_width + tolerance

```

```

        lim_right += line_width + tolerance
        lim_bottom -= line_width + tolerance
        lim_top += line_width + tolerance
        outer_radius += line_width + tolerance
        # make outer edge come to the same height as inner bins
        len_z += layer_height*2 + tolerance

        ilim_left = lim_left + line_width*2
        ilim_right = lim_right - line_width*2
        ilim_bottom = lim_bottom + line_width*2
        ilim_top = lim_top - line_width*2

        outer_left = lim_left
        outer_right = lim_right
        outer_bottom = lim_bottom
        outer_top = lim_top

# =====
# HELPERS: Roundedrectangle boundaryfinders
# =====

def find_boundary_x(y, going_right=True):
    if ilim_bottom + outer_radius <= y <= ilim_top - outer_radius:
        return ilim_right if going_right else ilim_left
    # bottom arc
    if y < ilim_bottom + outer_radius:
        cy = ilim_bottom + outer_radius
        dy = abs(y - cy)
        dx = math.sqrt(max(0, outer_radius**2 - dy**2))
        cx = (ilim_right - outer_radius) if going_right else (ilim_left + outer_radius)
        return cx + (dx if going_right else -dx)
    # top arc
    if y > ilim_top - outer_radius:
        cy = ilim_top - outer_radius
        dy = abs(y - cy)
        dx = math.sqrt(max(0, outer_radius**2 - dy**2))
        cx = (ilim_right - outer_radius) if going_right else (ilim_left + outer_radius)
        return cx + (dx if going_right else -dx)
    return ilim_right if going_right else ilim_left

def find_boundary_y(x, going_up=True):
    if ilim_left + outer_radius <= x <= ilim_right - outer_radius:
        return ilim_top if going_up else ilim_bottom
    # left arc
    if x < ilim_left + outer_radius:
        cx = ilim_left + outer_radius
        dx = abs(x - cx)
        dy = math.sqrt(max(0, outer_radius**2 - dx**2))
        cy = (ilim_top - outer_radius) if going_up else (ilim_bottom + outer_radius)
        return cy + (dy if going_up else -dy)
    # right arc
    if x > ilim_right - outer_radius:
        cx = ilim_right - outer_radius
        dx = abs(x - cx)
        dy = math.sqrt(max(0, outer_radius**2 - dx**2))
        cy = (ilim_top - outer_radius) if going_up else (ilim_bottom + outer_radius)
        return cy + (dy if going_up else -dy)
    return ilim_top if going_up else ilim_bottom

# =====
# BUILD STEPS
# =====

steps = []
arc_segs = 16
r = line_width/2

wall_taper = 1.4
if bin_type_outer:
    wall_taper = 0.4

# helper function to draw an outer wall
def add_rounded_rectangle_wall(zh, r, inset = 0):
    rect_left = outer_left + inset
    rect_right = outer_right - inset
    rect_bottom = outer_bottom + inset
    rect_top = outer_top - inset
    corners = [
        fc.Point(x=rect_right - r, y=rect_bottom + r, z=zh), # br

```

```

        fc.Point(x=rect_right - r, y=rect_top      - r, z=zh), # tr
        fc.Point(x=rect_left   + r, y=rect_top      - r, z=zh), # tl
        fc.Point(x=rect_left   + r, y=rect_bottom + r, z=zh)  # bl
    ]
    steps.append(fc.Point(x=rect_right - r, y=rect_bottom, z=zh))
    steps.extend(fc.arcXY(corners[0], r, -math.pi/2, +math.pi/2, arc_segs))
    steps.append(fc.Point(x=rect_right, y=rect_top - r, z=zh))
    steps.extend(fc.arcXY(corners[1], r,  0,           math.pi/2, arc_segs))
    steps.append(fc.Point(x=rect_left + r, y=rect_top, z=zh))
    steps.extend(fc.arcXY(corners[2], r,  math.pi/2,  math.pi/2, arc_segs))
    steps.append(fc.Point(x=rect_left, y=rect_bottom + r, z=zh))
    steps.extend(fc.arcXY(corners[3], r,  math.pi,     math.pi/2, arc_segs))

# turn extruder on
steps.append(fc.Extruder(on=True))

# -----
# LAYER 1: HORIZONTAL ZIG-ZAG
# -----
z = layer_height
y = ilim_bottom
dir_h = +1 # +1 = leftright, -1 = rightleft

# prime at first point
x0 = find_boundary_x(y, going_right=(dir_h>0))
steps.append(fc.Point(x=x0, y=y, z=z))

while True:
    # travel to boundary
    xt = find_boundary_x(y, going_right=(dir_h>0))
    steps.append(fc.Point(x=xt, y=y, z=z))
    current_x = xt

    # next scan-line
    next_y = y + line_width
    if next_y > ilim_top:
        break

    # U-turn semicircle of radius r
    center = fc.Point(x=current_x, y=y + r, z=z)
    if dir_h > 0:
        # right edge: CCW half-circle from bottom to top
        steps.extend(fc.arcXY(center, r, -math.pi/2, +math.pi, arc_segs))
    else:
        # left edge: CW half-circle from bottom to top
        steps.extend(fc.arcXY(center, r, -math.pi/2, -math.pi, arc_segs))

    y      = next_y
    dir_h = -dir_h

    # outline the first layer
    weld_offset = (wall_taper+0.5)*line_width
    add_rounded_rectangle_wall(z, outer_radius - weld_offset, weld_offset)

# -----
# LAYER 2: VERTICAL ZIG-ZAG
# -----
z += layer_height
x = ilim_left
dir_v = +1 # +1 = bottomtop, -1 = topbottom

# prime at first point
y0 = find_boundary_y(x, going_up=(dir_v>0))
steps.append(fc.Point(x=x, y=y0, z=z))

while True:
    # travel to boundary
    yt = find_boundary_y(x, going_up=(dir_v>0))
    steps.append(fc.Point(x=x, y=yt, z=z))
    current_y = yt

    # next scan-line
    next_x = x + line_width
    if next_x > ilim_right:
        break

    # U-turn semicircle of radius r
    center = fc.Point(x=x + r, y=current_y, z=z)

```

```

    if dir_v > 0:
        # top edge: CCW half-circle from left to right
        steps.extend(fc.arcXY(center, r, math.pi, -math.pi, arc_segs))
    else:
        # bottom edge: CW half-circle from left to right
        steps.extend(fc.arcXY(center, r, math.pi, +math.pi, arc_segs))

    x      = next_x
    dir_v = -dir_v

# =====
# WALLS WITH ROUNDED CORNERS (remaining layers)
# =====

weld_offset = (wall_taper+1.5)*line_width
add_rounded_rectangle_wall(z, outer_radius - weld_offset, weld_offset)
weld_offset = (wall_taper+0.75)*line_width
add_rounded_rectangle_wall(z, outer_radius - weld_offset, weld_offset)

while z < len_z:
    if wall_taper > 0:
        wall_taper -= layer_height/2
        wall_taper = max(wall_taper,0)
    add_rounded_rectangle_wall(z, outer_radius, wall_taper*line_width)
    z += layer_height

# repeat final wall and then quick ironing pass to smooth the top
add_rounded_rectangle_wall(z, outer_radius)
add_rounded_rectangle_wall(z, outer_radius)
steps.append(fc.Extruder(on=False))
z += layer_height/10 # lift a bit
add_rounded_rectangle_wall(z, outer_radius)
z += layer_height/10 # lift a bit
add_rounded_rectangle_wall(z, outer_radius)
z += layer_height # lift off
add_rounded_rectangle_wall(z, outer_radius) # maybe unnecessary
steps.append(fc.Point(z=z+20)) # lift after complete

```

### 3.6 Difference of Stock, Rapids, and Toolpaths

At the end of cutting it will be necessary to subtract the accumulated toolpaths and rapids from the stock.

For Python, the initial 3D model is stored in the variable stock:

---

```

1468 gcpy     def stockandtoolpaths(self, option = "stockandtoolpaths"):
1469 gcpy         if option == "stock":
1470 gcpy             show(self.stock)
1471 gcpy         elif option == "toolpaths":
1472 gcpy             show(self.toolpaths)
1473 gcpy         elif option == "rapids":
1474 gcpy             show(self.rapids)
1475 gcpy     else:
1476 gcpy         part = self.stock.difference(self.rapids)
1477 gcpy         part = self.stock.difference(self.toolpaths)
1478 gcpy         show(part)

```

---

A separate set of commands for showing the outline of the currently selected tool and/or its shaft is useful for checking that a tool outline definition is correctly formed.

---

```

1480 gcpy     def showtooloutline(self):
1481 gcpy         to = union(self.tooloutline, self.shaftoutline)
1482 gcpy         show(to)
1483 gcpy
1484 gcpy     def showtoolprofile(self):
1485 gcpy         to = union(self.toolprofile, self.shaftprofile)
1486 gcpy         show(to)
1487 gcpy
1488 gcpy     def showtoolshape(self):
1489 gcpy         to = union(self.currenttoolshape, self.currenttoolshaft)
1490 gcpy         show(to)

```

---

Note that because of the differences in behaviour between OpenPythonSCAD (the `show()` command results in an explicit display of the requested element) and OpenSCAD (there is an implicit mechanism where the 3D element which is returned is displayed), the most expedient mechanism is to have an explicit Python command which returns the 3D model:

---

```

1492 gcpy      def returnstockandtoolpaths(self):
1493 gcpy          part = self.stock.difference(self.toolpaths)
1494 gcpy          return part

```

---

and then make use of that specific command for OpenSCAD:

---

```

126 gpcscad module stockandtoolpaths(){
127 gpcscad     gcp.returnstockandtoolpaths();
128 gpcscad }

```

---

forgoing the options of showing toolpaths and/or rapids separately.

### 3.7 Output files

The gcodepreview class will write out DXF and/or G-code files.

#### 3.7.1 Python and OpenSCAD File Handling

The class gcodepreview will need additional commands for opening files. The original implementation in RapSCAD used a command writeln — fortunately, this command is easily re-created in Python, though it is made as a separate file for each sort of file which may be opened. Note that the dxf commands will be wrapped up with if/elif blocks which will write to additional file(s) based on tool number as set up above.

---

```

1496 gcpy      def writegc(self, *arguments):
1497 gcpy          if self.generategcode == True:
1498 gcpy              line_to_write = ""
1499 gcpy              for element in arguments:
1500 gcpy                  line_to_write += element
1501 gcpy                  self.gc.write(line_to_write)
1502 gcpy                  self.gc.write("\n")
1503 gcpy
1504 gcpy      def writedxf(self, toolnumber, *arguments):
1505 gcpy #          global dxfclosed
1506 gcpy          line_to_write = ""
1507 gcpy          for element in arguments:
1508 gcpy              line_to_write += element
1509 gcpy          if self.generatedxf == True:
1510 gcpy              if self.dxfclosed == False:
1511 gcpy                  self.dxf.write(line_to_write)
1512 gcpy                  self.dxf.write("\n")
1513 gcpy          if self.generatedxfs == True:
1514 gcpy              self.writedxfs(toolnumber, line_to_write)
1515 gcpy
1516 gcpy      def writedxfs(self, toolnumber, line_to_write):
1517 gcpy #          print("Processing writing toolnumber", toolnumber)
1518 gcpy #          line_to_write = ""
1519 gcpy #          for element in arguments:
1520 gcpy #              line_to_write += element
1521 gcpy          if (toolnumber == 0):
1522 gcpy              return
1523 gcpy          elif self.generatedxfs == True:
1524 gcpy              if (self.large_square_tool_num == toolnumber):
1525 gcpy                  self.dxflgsq.write(line_to_write)
1526 gcpy                  self.dxflgsq.write("\n")
1527 gcpy              if (self.small_square_tool_num == toolnumber):
1528 gcpy                  self.dxfsmssq.write(line_to_write)
1529 gcpy                  self.dxfsmssq.write("\n")
1530 gcpy              if (self.large_ball_tool_num == toolnumber):
1531 gcpy                  self.dxflgbl.write(line_to_write)
1532 gcpy                  self.dxflgbl.write("\n")
1533 gcpy              if (self.small_ball_tool_num == toolnumber):
1534 gcpy                  self.dxfsmbl.write(line_to_write)
1535 gcpy                  self.dxfsmbl.write("\n")
1536 gcpy              if (self.large_V_tool_num == toolnumber):
1537 gcpy                  self.dxflgV.write(line_to_write)
1538 gcpy                  self.dxflgV.write("\n")
1539 gcpy              if (self.small_V_tool_num == toolnumber):
1540 gcpy                  self.dxfsmV.write(line_to_write)
1541 gcpy                  self.dxfsmV.write("\n")
1542 gcpy              if (self.DT_tool_num == toolnumber):
1543 gcpy                  self.dxfDT.write(line_to_write)
1544 gcpy                  self.dxfDT.write("\n")
1545 gcpy              if (self.KH_tool_num == toolnumber):
1546 gcpy                  self.dxfKH.write(line_to_write)
1547 gcpy                  self.dxfKH.write("\n")

```

---

```

1548 gcpy           if (self.Roundover_tool_num == toolnumber):
1549 gcpy             self.dxfRt.write(line_to_write)
1550 gcpy             self.dxfRt.write("\n")
1551 gcpy           if (self.MISC_tool_num == toolnumber):
1552 gcpy             self.dxfMt.write(line_to_write)
1553 gcpy             self.dxfMt.write("\n")

```

---

which commands will accept a series of arguments and then write them out to a file object for the appropriate file. Note that the DXF files for specific tools will expect that the tool numbers be set in the matching variables from the template. Further note that while it is possible to use tools which are not so defined, the toolpaths will not be written into DXF files for any tool numbers which do not match the variables from the template (but will appear in the main .dxf).

`opengcodefile` For writing to files it will be necessary to have commands for opening the files: `opengcodefile` `opendxfile` and `opendxffile` which will set the associated defaults. There is a separate function for each type of file, and for DXFs, there are multiple file instances, one for each combination of different type and size of tool which it is expected a project will work with. Each such file will be suffixed with the tool number.

There will need to be matching OpenSCAD modules for the Python functions:

---

```

130 gpcscad module opendxfile(basefilename){
131 gpcscad     gcp.opendxfile(basefilename);
132 gpcscad }
133 gpcscad
134 gpcscad module opendxfiles(Base_filename, large_square_tool_num,
135 gpcscad     small_square_tool_num, large_ball_tool_num, small_ball_tool_num,
136 gpcscad     large_V_tool_num, small_V_tool_num, DT_tool_num, KH_tool_num,
137 gpcscad     Roundover_tool_num, MISC_tool_num) {
138 gpcscad     gcp.opendxfiles(Base_filename, large_square_tool_num,
139 gpcscad     small_square_tool_num, large_ball_tool_num,
140 gpcscad     small_ball_tool_num, large_V_tool_num, small_V_tool_num,
141 gpcscad     DT_tool_num, KH_tool_num, Roundover_tool_num, MISC_tool_num)
142 gpcscad }

```

---

`opengcodefile` With matching OpenSCAD commands: `opengcodefile` for OpenSCAD:

---

```

138 gpcscad module opengcodefile(basefilename, currenttoolnum, toolradius,
139 gpcscad     plunge, feed, speed) {
140 gpcscad     gcp.opengcodefile(basefilename, currenttoolnum, toolradius,
141 gpcscad     plunge, feed, speed);

```

---

and Python:

---

```

1555 gcpy     def opengcodefile(self, basefilename = "export",
1556 gcpy         currenttoolnum = 102,
1557 gcpy         toolradius = 3.175,
1558 gcpy         plunge = 400,
1559 gcpy         feed = 1600,
1560 gcpy         speed = 10000
1561 gcpy         ):
1562 gcpy         self.basefilename = basefilename
1563 gcpy         self.currenttoolnum = currenttoolnum
1564 gcpy         self.toolradius = toolradius
1565 gcpy         self.plunge = plunge
1566 gcpy         self.feed = feed
1567 gcpy         self.speed = speed
1568 gcpy         if self.generategcode == True:
1569 gcpy             self.gcodename = basefilename + self.gcodext
1570 gcpy             self.gc = open(self.gcodename, "w")
1571 gcpy             self.writegc("(DesignFile: " + self.basefilename + ")"
1572 gcpy
1573 gcpy     def opendxfile(self, basefilename = "export"):
1574 gcpy         self.basefilename = basefilename
1575 gcpy #         global generateddxfs
1576 gcpy #         global dxfclosed
1577 gcpy         self.dxfclosed = False
1578 gcpy         self.dxfcolor = "Black"
1579 gcpy         if self.generatedxf == True:
1580 gcpy             self.generateddxfs = False
1581 gcpy             self.dxffilename = basefilename + ".dxf"
1582 gcpy             self.dxf = open(self.dxffilename, "w")
1583 gcpy             self.dxfpreamble(-1)
1584 gcpy
1585 gcpy     def opendxfiles(self, basefilename = "export",

```

```

1586 gcpy
1587 gcpy
1588 gcpy
1589 gcpy
1590 gcpy
1591 gcpy
1592 gcpy
1593 gcpy
1594 gcpy
1595 gcpy
1596 gcpy #
1597 gcpy
1598 gcpy
1599 gcpy
1600 gcpy
1601 gcpy
1602 gcpy
1603 gcpy
1604 gcpy
1605 gcpy
1606 gcpy
1607 gcpy
1608 gcpy
1609 gcpy
1610 gcpy
1611 gcpy
1612 gcpy #
1613 gcpy
1614 gcpy
1615 gcpy #
1616 gcpy
1617 gcpy
1618 gcpy
1619 gcpy #
1620 gcpy
1621 gcpy
1622 gcpy
1623 gcpy #
1624 gcpy
1625 gcpy
1626 gcpy
1627 gcpy #
1628 gcpy
1629 gcpy
1630 gcpy
1631 gcpy #
1632 gcpy
1633 gcpy
1634 gcpy
1635 gcpy #
1636 gcpy
1637 gcpy
1638 gcpy
1639 gcpy #
1640 gcpy
1641 gcpy
1642 gcpy
1643 gcpy #
1644 gcpy
1645 gcpy
1646 gcpy
1647 gcpy #
1648 gcpy
1649 gcpy
    large_square_tool_num = 0,
    small_square_tool_num = 0,
    large_ball_tool_num = 0,
    small_ball_tool_num = 0,
    large_V_tool_num = 0,
    small_V_tool_num = 0,
    DT_tool_num = 0,
    KH_tool_num = 0,
    Roundover_tool_num = 0,
    MISC_tool_num = 0):
    global generateddxfs
    self.basename = basename
    self.generateddxfs = True
    self.large_square_tool_num = large_square_tool_num
    self.small_square_tool_num = small_square_tool_num
    self.large_ball_tool_num = large_ball_tool_num
    self.small_ball_tool_num = small_ball_tool_num
    self.large_V_tool_num = large_V_tool_num
    self.small_V_tool_num = small_V_tool_num
    self.DT_tool_num = DT_tool_num
    self.KH_tool_num = KH_tool_num
    self.Roundover_tool_num = Roundover_tool_num
    self.MISC_tool_num = MISC_tool_num
    if self.generateddxfs == True:
        if (large_square_tool_num > 0):
            self.dxflgsqfilename = basename + str(
                large_square_tool_num) + ".dxf"
            print("Opening ", str(self.dxflgsqfilename))
            self.dxflgsq = open(self.dxflgsqfilename, "w")
        if (small_square_tool_num > 0):
            print("Opening small square")
            self.dfxsmsqfilename = basename + str(
                small_square_tool_num) + ".dxf"
            self.dfxsmsq = open(self.dfxsmsqfilename, "w")
        if (large_ball_tool_num > 0):
            print("Opening large ball")
            self.dxflgblfilename = basename + str(
                large_ball_tool_num) + ".dxf"
            self.dxflgbl = open(self.dxflgblfilename, "w")
        if (small_ball_tool_num > 0):
            print("Opening small ball")
            self.dfxsmbfilename = basename + str(
                small_ball_tool_num) + ".dxf"
            self.dfxsmb = open(self.dfxsmbfilename, "w")
        if (large_V_tool_num > 0):
            print("Opening large V")
            self.dxflgVfilename = basename + str(
                large_V_tool_num) + ".dxf"
            self.dxflgV = open(self.dxflgVfilename, "w")
        if (small_V_tool_num > 0):
            print("Opening small V")
            self.dfxsmVfilename = basename + str(
                small_V_tool_num) + ".dxf"
            self.dfxsmV = open(self.dfxsmVfilename, "w")
        if (DT_tool_num > 0):
            print("Opening DT")
            self.dxfDTfilename = basename + str(DT_tool_num)
            self.dxfDT = open(self.dxfDTfilename, "w")
        if (KH_tool_num > 0):
            print("Opening KH")
            self.dxfKHfilename = basename + str(KH_tool_num)
            self.dxfKH = open(self.dxfKHfilename, "w")
        if (Roundover_tool_num > 0):
            print("Opening Rt")
            self.dxfRtfilename = basename + str(
                Roundover_tool_num) + ".dxf"
            self.dxfRt = open(self.dxfRtfilename, "w")
        if (MISC_tool_num > 0):
            print("Opening Mt")
            self.dxfMtfilename = basename + str(
                MISC_tool_num) + ".dxf"
            self.dxfMt = open(self.dxfMtfilename, "w")

```

For each DXF file, there will need to be a Preamble in addition to opening the file in the file system:

---

```

1650 gcpy           if (large_square_tool_num > 0):
1651 gcpy           self.dxfpreamble(large_square_tool_num)
1652 gcpy           if (small_square_tool_num > 0):
1653 gcpy           self.dxfpreamble(small_square_tool_num)
1654 gcpy           if (large_ball_tool_num > 0):
1655 gcpy           self.dxfpreamble(large_ball_tool_num)
1656 gcpy           if (small_ball_tool_num > 0):
1657 gcpy           self.dxfpreamble(small_ball_tool_num)
1658 gcpy           if (large_V_tool_num > 0):
1659 gcpy           self.dxfpreamble(large_V_tool_num)
1660 gcpy           if (small_V_tool_num > 0):
1661 gcpy           self.dxfpreamble(small_V_tool_num)
1662 gcpy           if (DT_tool_num > 0):
1663 gcpy           self.dxfpreamble(DT_tool_num)
1664 gcpy           if (KH_tool_num > 0):
1665 gcpy           self.dxfpreamble(KH_tool_num)
1666 gcpy           if (Roundover_tool_num > 0):
1667 gcpy           self.dxfpreamble(Roundover_tool_num)
1668 gcpy           if (MISC_tool_num > 0):
1669 gcpy           self.dxfpreamble(MISC_tool_num)

```

---

Note that the commands which interact with files include checks to see if said files are being generated.

Future considerations:

- Multiple Preview Modes:
- Fast Preview: Write all movements with both begin and end positions into a list for a specific tool — as this is done, check for a previous movement between those positions and compare depths and tool number — keep only the deepest movement for a given tool.
- Motion Preview: Work up a 3D model of the machine and actually show the stock in relation to it,

### 3.7.2 DXF Overview

Elements in DXFs are represented as lines or arcs. A minimal file showing both:

```

0
SECTION
2
ENTITIES
0
LWPOLYLINE
90
2
70
0
43
0
10
-31.375
20
-34.9152
10
-31.375
20
-18.75
0
ARC
10
-54.75
20
-37.5
40
4
50
0
51
90
0
ENDSEC
0
EOF

```

**3.7.2.1 Writing to DXF files** When the command to open .dxf files is called it is passed all of the variables for the various tool types/sizes, and based on a value being greater than zero, the

`dxfwrite` matching file is opened, and in addition, the main DXF which is always written to is opened as well. On the gripping hand, each element which may be written to a DXF file will have a user module as well as an internal module which will be called by it so as to write to the file for the current tool. It will be necessary for the `dxfwrite` command to evaluate the tool number which is passed in, and to use an appropriate command or set of commands to then write out to the appropriate file for a given tool (if positive) or not do anything (if zero), and to write to the master file if a negative value is passed in (this allows the various DXF template commands to be written only once and then called at need).

Each tool has a matching command for each tool/size combination:

- `writedxfLgBl` • Ball nose, large (l lbl) `writedxfLgBl`
- `writedxfSmbL` • Ball nose, small (s mbL) `writedxfSmbL`
- `writedxfLgSq` • Square, large (l g sq) `writedxfLgSq`
- `writedxfSmSq` • Square, small (s m sq) `writedxfSmSq`
- `writedxfLgV` • V, large (l g V) `writedxfLgV`
- `writedxfSmV` • V, small (s m V) `writedxfSmV`
- `writedxfKH` • Keyhole (K H) `writedxfKH`
- `writedxfDT` • Dovetail (D T) `writedxfDT`

`dxfpreamble` This module requires that the tool number be passed in, and after writing out `dxfpreamble`, that value will be used to write out to the appropriate file with a series of `if` statements.

---

```

1671 gcpy      def dxfpreamble(self, tn):
1672 gcpy #          self.writedxf(tn, str(tn))
1673 gcpy          self.writedxf(tn, "0")
1674 gcpy          self.writedxf(tn, "SECTION")
1675 gcpy          self.writedxf(tn, "2")
1676 gcpy          self.writedxf(tn, "ENTITIES")

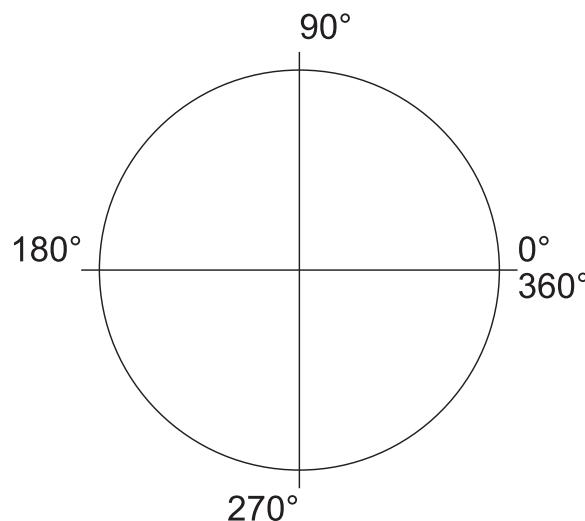
```

---

### 3.7.2.1.1 DXF Lines and Arcs

There are several elements which may be written to a DXF:

- `dxfline` • a line `dxfline`
  - `beginpolyline` • connected lines `beginpolyline/addvertex/closepolyline`
  - `addvertex`
  - `closepolyline`
  - `dxfarC`
  - `dxfcircle`
- DXF orders arcs counter-clockwise:**



Note that arcs of greater than 90 degrees are not rendered accurately (in certain applications at least), so, for the sake of precision, they should be limited to a swing of 90 degrees or less. Further note that 4 arcs may be stitched together to make a circle:

```

        dxfarc(10, 10, 5, 0, 90, small_square_tool_num);
        dxfarc(10, 10, 5, 90, 180, small_square_tool_num);
        dxfarc(10, 10, 5, 180, 270, small_square_tool_num);
        dxfarc(10, 10, 5, 270, 360, small_square_tool_num);

```

The DXF file format supports colors defined by AutoCAD's indexed color system:

Color Code	Color Name
0	Black (or Foreground)
1	Red
2	Yellow
3	Green
4	Cyan
5	Blue
6	Magenta
7	White (or Background)
8	Dark Gray
9	Light Gray

Color codes 10–255 represent additional colors, with hues varying based on RGB values. Obviously, a command to manage adding the color commands would be:

---

```

1678 gcpy      def setdxfcolor(self, color):
1679 gcpy          self.dxfcolor = color
1680 gcpy          self.cutcolor = color
1681 gcpy
1682 gcpy      def writedxfcolor(self, tn):
1683 gcpy          self.writedxf(tn, "8")
1684 gcpy          if (self.dxfcolor == "Black"):
1685 gcpy              self.writedxf(tn, "Layer_Black")
1686 gcpy          if (self.dxfcolor == "Red"):
1687 gcpy              self.writedxf(tn, "Layer_Red")
1688 gcpy          if (self.dxfcolor == "Yellow"):
1689 gcpy              self.writedxf(tn, "Layer_Yellow")
1690 gcpy          if (self.dxfcolor == "Green"):
1691 gcpy              self.writedxf(tn, "Layer_Green")
1692 gcpy          if (self.dxfcolor == "Cyan"):
1693 gcpy              self.writedxf(tn, "Layer_Cyan")
1694 gcpy          if (self.dxfcolor == "Blue"):
1695 gcpy              self.writedxf(tn, "Layer_Blue")
1696 gcpy          if (self.dxfcolor == "Magenta"):
1697 gcpy              self.writedxf(tn, "Layer_Magenta")
1698 gcpy          if (self.dxfcolor == "White"):
1699 gcpy              self.writedxf(tn, "Layer_White")
1700 gcpy          if (self.dxfcolor == "DarkGray"):
1701 gcpy              self.writedxf(tn, "Layer_Dark_Gray")
1702 gcpy          if (self.dxfcolor == "LightGray"):
1703 gcpy              self.writedxf(tn, "Layer_Light_Gray")
1704 gcpy
1705 gcpy          self.writedxf(tn, "62")
1706 gcpy          if (self.dxfcolor == "Black"):
1707 gcpy              self.writedxf(tn, "0")
1708 gcpy          if (self.dxfcolor == "Red"):
1709 gcpy              self.writedxf(tn, "1")
1710 gcpy          if (self.dxfcolor == "Yellow"):
1711 gcpy              self.writedxf(tn, "2")
1712 gcpy          if (self.dxfcolor == "Green"):
1713 gcpy              self.writedxf(tn, "3")
1714 gcpy          if (self.dxfcolor == "Cyan"):
1715 gcpy              self.writedxf(tn, "4")
1716 gcpy          if (self.dxfcolor == "Blue"):
1717 gcpy              self.writedxf(tn, "5")
1718 gcpy          if (self.dxfcolor == "Magenta"):
1719 gcpy              self.writedxf(tn, "6")
1720 gcpy          if (self.dxfcolor == "White"):
1721 gcpy              self.writedxf(tn, "7")
1722 gcpy          if (self.dxfcolor == "DarkGray"):
1723 gcpy              self.writedxf(tn, "8")
1724 gcpy          if (self.dxfcolor == "LightGray"):
1725 gcpy              self.writedxf(tn, "9")

```

---

```

142 gpcscad module setdxfcolor(color){
143 gpcscad     gcp.setdxfcolor(color);
144 gpcscad }

```

---

A further refinement would be to connect multiple line segments/arcs into a larger polyline, but since most CAM tools implicitly join elements on import, that is not necessary.

There are three possible interactions for DXF elements and toolpaths:

- describe the motion of the tool
- define a perimeter of an area which will be cut by a tool

- define a centerpoint for a specialty toolpath such as Drill or Keyhole

and it is possible that multiple such elements could be instantiated for a given toolpath.

When writing out to a DXF file there is a pair of commands, a public facing command which takes in a tool number in addition to the coordinates which then writes out to the main DXF file and then calls an internal command to which repeats the call with the tool number so as to write it out to the matching file.

---

```

1727 gcpy      def dxfline(self, tn, xbegin, ybegin, xend, yend):
1728 gcpy          self.writedxf(tn, "0")
1729 gcpy          self.writedxf(tn, "LINE")
1730 gcpy #
1731 gcpy          self.writedxfcolor(tn)
1732 gcpy #
1733 gcpy          self.writedxf(tn, "10")
1734 gcpy          self.writedxf(tn, str(xbegin))
1735 gcpy          self.writedxf(tn, "20")
1736 gcpy          self.writedxf(tn, str(ybegin))
1737 gcpy          self.writedxf(tn, "30")
1738 gcpy          self.writedxf(tn, "0.0")
1739 gcpy          self.writedxf(tn, "11")
1740 gcpy          self.writedxf(tn, str(xend))
1741 gcpy          self.writedxf(tn, "21")
1742 gcpy          self.writedxf(tn, str(yend))
1743 gcpy          self.writedxf(tn, "31")
1744 gcpy          self.writedxf(tn, "0.0")

```

---

In addition to dxfline which allows creating a line without consideration of context, there is also a dxfpolyline which will create a continuous/joined sequence of line segments which requires beginning it, adding vertexes, and then when done, ending the sequence.

First, begin the polyline:

---

```

1746 gcpy      def beginpolyline(self, tn):#, xbegin, ybegin
1747 gcpy          self.writedxf(tn, "0")
1748 gcpy          self.writedxf(tn, "POLYLINE")
1749 gcpy          self.writedxf(tn, "8")
1750 gcpy          self.writedxf(tn, "default")
1751 gcpy          self.writedxf(tn, "66")
1752 gcpy          self.writedxf(tn, "1")
1753 gcpy #
1754 gcpy          self.writedxfcolor(tn)
1755 gcpy #
1756 gcpy          self.writedxf(tn, "10")
1757 gcpy          self.writedxf(tn, str(xbegin))
1758 gcpy          self.writedxf(tn, "20")
1759 gcpy          self.writedxf(tn, str(ybegin))
1760 gcpy          self.writedxf(tn, "30")
1761 gcpy          self.writedxf(tn, "0.0")
1762 gcpy          self.writedxf(tn, "70")
1763 gcpy          self.writedxf(tn, "0")

```

---

then add as many vertexes as are wanted:

---

```

1765 gcpy      def addvertex(self, tn, xend, yend):
1766 gcpy          self.writedxf(tn, "0")
1767 gcpy          self.writedxf(tn, "VERTEX")
1768 gcpy          self.writedxf(tn, "8")
1769 gcpy          self.writedxf(tn, "default")
1770 gcpy          self.writedxf(tn, "70")
1771 gcpy          self.writedxf(tn, "32")
1772 gcpy          self.writedxf(tn, "10")
1773 gcpy          self.writedxf(tn, str(xend))
1774 gcpy          self.writedxf(tn, "20")
1775 gcpy          self.writedxf(tn, str(yend))
1776 gcpy          self.writedxf(tn, "30")
1777 gcpy          self.writedxf(tn, "0.0")

```

---

then end the sequence:

---

```

1779 gcpy      def closepolyline(self, tn):
1780 gcpy          self.writedxf(tn, "0")
1781 gcpy          self.writedxf(tn, "SEQEND")

```

---

For arcs, there are specific commands for writing out the DXF and G-code files. Note that for the G-code version it will be necessary to calculate the end-position, and to determine if the arc is clockwise or no (G2 vs. G3).

---

```

1783 gcpy     def dxfarc(self, tn, xcenter, ycenter, radius, anglebegin,
1784 gcpy         endangle):
1785 gcpy             if (self.generatedxf == True):
1786 gcpy                 self.writedxf(tn, "0")
1787 gcpy                 self.writedxf(tn, "ARC")
1788 gcpy                 self.writedxfcolor(tn)
1789 gcpy                 self.writedxf(tn, "10")
1790 gcpy                 self.writedxf(tn, str(xcenter))
1791 gcpy                 self.writedxf(tn, "20")
1792 gcpy                 self.writedxf(tn, str(ycenter))
1793 gcpy                 self.writedxf(tn, "40")
1794 gcpy                 self.writedxf(tn, str(radius))
1795 gcpy                 self.writedxf(tn, "50")
1796 gcpy                 self.writedxf(tn, str(anglebegin))
1797 gcpy                 self.writedxf(tn, "51")
1798 gcpy                 self.writedxf(tn, str(endangle))
1799 gcpy
1800 gcpy
1801 gcpy     def gcodearc(self, tn, xcenter, ycenter, radius, anglebegin,
1802 gcpy         endangle):
1803 gcpy             if (self.generategcode == True):
1804 gcpy                 self.writegc(tn, "(0)")

```

---

The various textual versions are quite obvious, and due to the requirements of G-code, it is straight-forward to include the G-code in them if it is wanted.

---

```

1805 gcpy     def cutarcNECCdxif(self, ex, ey, ez, xcenter, ycenter, radius):
1806 gcpy     global toolpath
1807 gcpy     toolpath = self.currenttool()
1808 gcpy     toolpath = toolpath.translate([self.xpos(), self.ypos(),
1809 gcpy         self.zpos()])
1810 gcpy         self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
1811 gcpy             radius, 0, 90)
1812 gcpy         if (self.zpos == ez):
1813 gcpy             self.settzpos(0)
1814 gcpy         else:
1815 gcpy             self.settzpos((self.zpos()-ez)/90)
1816 gcpy             self.setxpos(ex)
1817 gcpy             self.setypos(ey)
1818 gcpy             self.setzpos(ez)
1819 gcpy             if self.generatepaths == True:
1820 gcpy                 print("Unioning cutarcNECCdxif toolpath")
1821 gcpy                 self.arcloop(1, 90, xcenter, ycenter, radius)
1822 gcpy                 self.toolpaths = self.toolpaths.union(toolpath)
1823 gcpy             else:
1824 gcpy                 toolpath = self.arcloop(1, 90, xcenter, ycenter,
1825 gcpy                     radius)
1826 gcpy                 print("Returning cutarcNECCdxif toolpath")
1827 gcpy             return toolpath
1828 gcpy
1829 gcpy     def cutarcNWCCdxif(self, ex, ey, ez, xcenter, ycenter, radius):
1830 gcpy     global toolpath
1831 gcpy     toolpath = self.currenttool()
1832 gcpy     toolpath = toolpath.translate([self.xpos(), self.ypos(),
1833 gcpy         self.zpos()])
1834 gcpy         self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
1835 gcpy             radius, 90, 180)
1836 gcpy         if (self.zpos == ez):
1837 gcpy             self.settzpos(0)
1838 gcpy         else:
1839 gcpy             self.settzpos((self.zpos()-ez)/90)
1840 gcpy             self.setxpos(ex)
1841 gcpy             self.setypos(ey)
1842 gcpy             self.setzpos(ez)
1843 gcpy             if self.generatepaths == True:
1844 gcpy                 self.arcloop(91, 180, xcenter, ycenter, radius)
1845 gcpy                 self.toolpaths = self.toolpaths.union(toolpath)
1846 gcpy             else:
1847 gcpy                 toolpath = self.arcloop(91, 180, xcenter, ycenter, radius)
1848 gcpy             return toolpath
1849 gcpy
1850 gcpy     def cutarcSWCCdxif(self, ex, ey, ez, xcenter, ycenter, radius):
1851 gcpy     global toolpath
1852 gcpy     toolpath = self.currenttool()
1853 gcpy     toolpath = toolpath.translate([self.xpos(), self.ypos(),
1854 gcpy         self.zpos()])

```

---

```

1849 gcpy           self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
1850 gcpy           radius, 180, 270)
1851 gcpy           if (self.zpos == ez):
1852 gcpy           self.setzpos(0)
1853 gcpy           else:
1854 gcpy #           self.setzpos((self.zpos()-ez)/90)
1855 gcpy #           self.setxpos(ex)
1856 gcpy #           self.setypos(ey)
1857 gcpy           self.setzpos(ez)
1858 gcpy           if self.generatepaths == True:
1859 gcpy #               self.arcloop(181, 270, xcenter, ycenter, radius)
1860 gcpy #               self.toolpaths = self.toolpaths.union(toolpath)
1861 gcpy           else:
1862 gcpy           toolpath = self.arcloop(181, 270, xcenter, ycenter,
1863 gcpy           radius)
1864 gcpy           return toolpath
1865 gcpy #
1866 gcpy #
1867 gcpy #
1868 gcpy           def cutarcSECCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1869 gcpy           global toolpath
1870 gcpy           toolpath = self.currenttool()
1871 gcpy           toolpath = toolpath.translate([self.xpos(), self.ypos(),
1872 gcpy           self.zpos()])
1873 gcpy           self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
1874 gcpy           radius, 270, 360)
1875 gcpy           if (self.zpos == ez):
1876 gcpy           self.setzpos(0)
1877 gcpy           else:
1878 gcpy #               self.setzpos((self.zpos()-ez)/90)
1879 gcpy #               self.setxpos(ex)
1880 gcpy #               self.setypos(ey)
1881 gcpy #               self.setzpos(ez)
1882 gcpy           if self.generatepaths == True:
1883 gcpy           self.arcloop(271, 360, xcenter, ycenter, radius)
1884 gcpy #               self.toolpaths = self.toolpaths.union(toolpath)
1885 gcpy #
1886 gcpy #
1887 gcpy           else:
1888 gcpy           toolpath = self.arcloop(271, 360, xcenter, ycenter,
1889 gcpy           radius)
1890 gcpy           return toolpath
1891 gcpy #
1892 gcpy #
1893 gcpy #
1894 gcpy #
1895 gcpy           self.setzpos((self.zpos()-ez)/90)
1896 gcpy           self.setxpos(ex)
1897 gcpy #           self.setypos(ey)
1898 gcpy #           self.setzpos(ez)
1899 gcpy           if self.generatepaths == True:
1900 gcpy           self.narcloop(89, 0, xcenter, ycenter, radius)
1901 gcpy #               self.toolpaths = self.toolpaths.union(toolpath)
1902 gcpy           else:
1903 gcpy           toolpath = self.narcloop(89, 0, xcenter, ycenter,
1904 gcpy           radius)
1905 gcpy           self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
1906 gcpy           radius, 270, 360)
1907 gcpy           if (self.zpos == ez):
1908 gcpy           self.setzpos(0)
1909 gcpy           else:
1910 gcpy           self.setzpos((self.zpos()-ez)/90)
1911 gcpy #           self.setxpos(ex)
1912 gcpy #           self.setypos(ey)
1913 gcpy #           self.setzpos(ez)
1914 gcpy           if self.generatepaths == True:
1915 gcpy           self.narcloop(359, 270, xcenter, ycenter, radius)
1916 gcpy #               self.toolpaths = self.toolpaths.union(toolpath)

```

```

1917 gcpy      else:
1918 gcpy          toolpath = self.narcloop(359, 270, xcenter, ycenter,
1919 gcpy              radius)
1920 gcpy          return toolpath
1921 gcpy      def cutarcSWCWdxr(self, ex, ey, ez, xcenter, ycenter, radius):
1922 gcpy #          global toolpath
1923 gcpy #          toolpath = self.currenttool()
1924 gcpy #          toolpath = toolpath.translate([self.xpos(), self.ypos(),
1925 gcpy             self.zpos()])
1926 gcpy          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
1927 gcpy              radius, 180, 270)
1928 gcpy          if (self.zpos == ez):
1929 gcpy              self.setzpos(0)
1930 gcpy #          else:
1931 gcpy #              self.setzpos((self.zpos()-ez)/90)
1932 gcpy #          self.setxpos(ex)
1933 gcpy #          self.setypos(ey)
1934 gcpy #          self.setzpos(ez)
1935 gcpy #          if self.generatepaths == True:
1936 gcpy #              self.narcloop(269, 180, xcenter, ycenter, radius)
1937 gcpy #              self.toolpaths = self.toolpaths.union(toolpath)
1938 gcpy          else:
1939 gcpy              toolpath = self.narcloop(269, 180, xcenter, ycenter,
1940 gcpy                  radius)
1941 gcpy          return toolpath
1942 gcpy      def cutarcNWCWdxr(self, ex, ey, ez, xcenter, ycenter, radius):
1943 gcpy #          global toolpath
1944 gcpy #          toolpath = self.currenttool()
1945 gcpy #          toolpath = toolpath.translate([self.xpos(), self.ypos(),
1946 gcpy             self.zpos()])
1947 gcpy          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
1948 gcpy              radius, 90, 180)
1949 gcpy #          if (self.zpos == ez):
1950 gcpy #              self.setzpos(0)
1951 gcpy #          else:
1952 gcpy #              self.setzpos((self.zpos()-ez)/90)
1953 gcpy #          self.setxpos(ex)
1954 gcpy #          self.setypos(ey)
1955 gcpy #          self.setzpos(ez)
1956 gcpy #          if self.generatepaths == True:
1957 gcpy #              self.narcloop(179, 90, xcenter, ycenter, radius)
1958 gcpy #              self.toolpaths = self.toolpaths.union(toolpath)
1959 gcpy          else:
1960 gcpy              toolpath = self.narcloop(179, 90, xcenter, ycenter,
1961 gcpy                  radius)
1962 gcpy          return toolpath

```

Using such commands to create a circle is quite straight-forward:

```

cutarcNECCdxr(-stockXwidth/4, stockYheight/4+stockYheight/16, -stockZthickness, -stockXwidth/4, stockYh
cutarcNWCdxr(-(stockXwidth/4+stockYheight/16), stockYheight/4, -stockZthickness, -stockXwidth/4, stockYh
cutarcSWCDxr(-stockXwidth/4, stockYheight/4-stockYheight/16, -stockZthickness, -stockXwidth/4, stockYh
cutarcSECCdxr(-(stockXwidth/4-stockYheight/16), stockYheight/4, -stockZthickness, -stockXwidth/4, stockYh

```

---

```

1959 gcpy      def arcCCgc(self, ex, ey, ez, xcenter, ycenter, radius):
1960 gcpy          self.writegc("G03\u00D7X", str(ex), "\u00D7Y", str(ey), "\u00D7Z", str(ez),
1961 gcpy              "\u00D7R", str(radius))
1962 gcpy      def arcCWgc(self, ex, ey, ez, xcenter, ycenter, radius):
1963 gcpy          self.writegc("G02\u00D7X", str(ex), "\u00D7Y", str(ey), "\u00D7Z", str(ez),
1964 gcpy              "\u00D7R", str(radius))

```

---

The above commands may be called if G-code is also wanted with writing out G-code added:

---

```

1965 gcpy      def cutarcNECCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius):
1966 gcpy          :
1967 gcpy          self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1968 gcpy          if self.generatepaths == True:
1969 gcpy              self.cutarcNECCdxr(ex, ey, ez, xcenter, ycenter, radius)
1970 gcpy          else:
1971 gcpy              return self.cutarcNECCdxr(ex, ey, ez, xcenter, ycenter,
1972 gcpy                  radius)

```

```

1972 gcpy      def cutarcNWCCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1973 gcpy      :
1974 gcpy      self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1975 gcpy      if self.generatepaths == False:
1976 gcpy      return self.cutarcNWCCdxf(ex, ey, ez, xcenter, ycenter,
1977 gcpy      radius)
1978 gcpy      def cutarcSWCCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1979 gcpy      :
1980 gcpy      self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1981 gcpy      if self.generatepaths == False:
1982 gcpy      return self.cutarcSWCCdxf(ex, ey, ez, xcenter, ycenter,
1983 gcpy      radius)
1984 gcpy      def cutarcSECCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1985 gcpy      :
1986 gcpy      self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1987 gcpy      if self.generatepaths == False:
1988 gcpy      return self.cutarcSECCdxf(ex, ey, ez, xcenter, ycenter,
1989 gcpy      radius)
1990 gcpy      def cutarcNECWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1991 gcpy      :
1992 gcpy      self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1993 gcpy      if self.generatepaths == False:
1994 gcpy      return self.cutarcNECWdxf(ex, ey, ez, xcenter, ycenter,
1995 gcpy      radius)
1996 gcpy      def cutarcSECWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1997 gcpy      :
1998 gcpy      self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1999 gcpy      if self.generatepaths == False:
2000 gcpy      return self.cutarcSECWdxf(ex, ey, ez, xcenter, ycenter,
2001 gcpy      radius)
2002 gcpy      def cutarcNWCWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
2003 gcpy      :
2004 gcpy      self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
2005 gcpy      if self.generatepaths == False:
2006 gcpy      return self.cutarcNWCWdxf(ex, ey, ez, xcenter, ycenter,
2007 gcpy      radius)

```

---

```

146 gpcscad module cutarcNECCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
147 gpcscad     gcp.cutarcNECCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
148 gpcscad }
149 gpcscad
150 gpcscad module cutarcNWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
151 gpcscad     gcp.cutarcNWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
152 gpcscad }
153 gpcscad
154 gpcscad module cutarcSWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
155 gpcscad     gcp.cutarcSWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
156 gpcscad }
157 gpcscad
158 gpcscad module cutarcSECCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
159 gpcscad     gcp.cutarcSECCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
160 gpcscad }

```

---

### 3.7.3 G-code Overview

The G-code commands and their matching modules may include (but are not limited to):

Command/Module	G-code
opengcodefile(s)(...); setupstock(...)	(export.nc) (stockMin: -109.5, -75mm, -8.35mm) (stockMax: 109.5mm, 75mm, 0.00mm) (STOCK/BLOCK, 219, 150, 8.35, 109.5, 75, 8.35) G90 G21
movetosafez()	(Move to safe Z to avoid workholding) G53G0Z-5.000
toolchange(...);	(TOOL/MILL, 3.17, 0.00, 0.00, 0.00) M6T102 M03S16000
cutoneaxis_setfeed(...);	(PREPOSITION FOR RAPID PLUNGE) GOXOYO Z0.25 G1Z0F100 G1 X109.5 Y75 Z-8.35F400 Z9
cutwithfeed(...);	
closegcodefile();	M05 M02

Conversely, the G-code commands which are supported are generated by the following modules:

G-code	Command/Module
(Design File: ) (stockMin: 0.00mm, -152.40mm, -34.92mm) (stockMax: 109.50mm, -77.40mm, 0.00mm) (STOCK/BLOCK, 109.50, 75.00, 34.92, 0.00, 152.40, 34.92) G90 G21	opengcodefile(s)(...); setupstock(...)
(Move to safe Z to avoid workholding) G53G0Z-5.000	movetosafez()
(Toolpath: Contour Toolpath 1) M05 (TOOL/MILL, 3.17, 0.00, 0.00, 0.00) M6T102 M03S10000	toolchange(...);
(PREPOSITION FOR RAPID PLUNGE)	writecomment(...)
GOX0.000Y-152.400 Z0.250	rapid(...) rapid(...)
G1Z-1.000F203.2 X109.500Y-77.400F508.0 X57.918Y16.302Z-0.726 Y22.023Z-1.023 X61.190Z-0.681 Y21.643 X57.681 Z12.700	cutwithfeed(...); cutwithfeed(...);
M05 M02	closegcodefile();

The implication here is that it should be possible to read in a G-code file, and for each line/command instantiate a matching command so as to create a 3D model/preview of the file. This is addressed by making specialized commands for movement which correspond to the various axis combinations (xyz, xy, xz, yz, x, y, z).

A further consideration is that rather than hard-coding all possibilities or any changes, having an option for a "post-processor" will be far more flexible.

Described at: <https://carbide3d.com/hub/faq/create-pro-custom-post-processor/> the necessary hooks would be:

- onOpen
- onClose
- onSection (which is where tool changes are defined, since "section" in this case is segmented per tool)

**3.7.3.1 Closings** At the end of the program it will be necessary to close each file using the closegcodefile commands: closegcodefile, and closedxfile. In some instances it may be necessary to write closedxfile additional information, depending on the file format. Note that these commands will need to be within the gcodepreview class.

---

```

2007 gcpy     def dxffostamble(self, tn):
2008 gcpy #         self.writexf(tn, str(tn))
2009 gcpy         self.writexf(tn, "0")
2010 gcpy         self.writexf(tn, "ENDSEC")
2011 gcpy         self.writexf(tn, "0")
2012 gcpy         self.writexf(tn, "EOF")

```

---

```

2014 gcpy     def gcodepostamble(self):
2015 gcpy         if self.generatecut == True:
2016 gcpy             self.writegc("Z12.700")
2017 gcpy             self.writegc("M05")
2018 gcpy             self.writegc("M02")
2019 gcpy         if self.generateprint == True:
2020 gcpy             self.writegc("G92\u00E0")
2021 gcpy             self.writegc("M107\u00D7\u00D7; \u00D7turn\u00D7off\u00D7cooling\u00D7fans")
2022 gcpy             self.writegc("M104\u00D7S0\u00D7; \u00D7turn\u00D7off\u00D7temperature")
2023 gcpy             self.writegc("G28\u00D7X0\u00D7; \u00D7home\u00D7X\u00D7axis")
2024 gcpy             self.writegc("M84\u00D7\u00D7\u00D7; \u00D7disable\u00D7motors")

```

---

**dxffostamble** It will be necessary to call the dxffostamble (with appropriate checks and trappings so as to ensure that each dxf file is ended and closed so as to be valid.

---

```

2026 gcpy     def closegcodefile(self):
2027 gcpy         if self.generategcode == True:
2028 gcpy             self.gcodepostamble()
2029 gcpy             self.gc.close()
2030 gcpy
2031 gcpy     def closedxfile(self):
2032 gcpy         if self.generatedxf == True:
2033 gcpy #             global dxfclosed
2034 gcpy             self.dxffostamble(-1)
2035 gcpy #             self.dxfclosed = True
2036 gcpy             self.dxf.close()
2037 gcpy
2038 gcpy     def closedxfiles(self):
2039 gcpy         if self.generatedxfs == True:
2040 gcpy             if (self.large_square_tool_num > 0):
2041 gcpy                 self.dxffostamble(self.large_square_tool_num)
2042 gcpy             if (self.small_square_tool_num > 0):
2043 gcpy                 self.dxffostamble(self.small_square_tool_num)
2044 gcpy             if (self.large_ball_tool_num > 0):
2045 gcpy                 self.dxffostamble(self.large_ball_tool_num)
2046 gcpy             if (self.small_ball_tool_num > 0):
2047 gcpy                 self.dxffostamble(self.small_ball_tool_num)
2048 gcpy             if (self.large_V_tool_num > 0):
2049 gcpy                 self.dxffostamble(self.large_V_tool_num)
2050 gcpy             if (self.small_V_tool_num > 0):
2051 gcpy                 self.dxffostamble(self.small_V_tool_num)
2052 gcpy             if (self.DT_tool_num > 0):
2053 gcpy                 self.dxffostamble(self.DT_tool_num)
2054 gcpy             if (self.KH_tool_num > 0):
2055 gcpy                 self.dxffostamble(self.KH_tool_num)
2056 gcpy             if (self.Roundover_tool_num > 0):
2057 gcpy                 self.dxffostamble(self.Roundover_tool_num)
2058 gcpy             if (self.MISC_tool_num > 0):
2059 gcpy                 self.dxffostamble(self.MISC_tool_num)
2060 gcpy
2061 gcpy             if (self.large_square_tool_num > 0):
2062 gcpy                 self.dxflgsq.close()
2063 gcpy             if (self.small_square_tool_num > 0):
2064 gcpy                 self.dfxsmsq.close()
2065 gcpy             if (self.large_ball_tool_num > 0):
2066 gcpy                 self.dxflgbl.close()
2067 gcpy             if (self.small_ball_tool_num > 0):
2068 gcpy                 self.dfxsmbl.close()
2069 gcpy             if (self.large_V_tool_num > 0):
2070 gcpy                 self.dxflgV.close()
2071 gcpy             if (self.small_V_tool_num > 0):
2072 gcpy                 self.dfxsmV.close()
2073 gcpy             if (self.DT_tool_num > 0):
2074 gcpy                 self.dxfDT.close()

```

---

---

```

2075 gcpy           if (self.KH_tool_num > 0):
2076 gcpy             self.dxfKH.close()
2077 gcpy           if (self.Roundover_tool_num > 0):
2078 gcpy             self.dxfRt.close()
2079 gcpy           if (self.MISC_tool_num > 0):
2080 gcpy             self.dxfMt.close()

```

---

`closegcodefile` The commands: `closegcodefile`, and `closedxffile` are used to close the files at the end of a `closedxffile` program. For efficiency, each references the command: `dxfpostamble` which when called provides `dxfpostamble` the boilerplate needed at the end of their respective files.

---

```

162 gpcscad module closegcodefile(){
163 gpcscad     gcp.closegcodefile();
164 gpcscad }
165 gpcscad
166 gpcscad module closedxffiles(){
167 gpcscad     gcp.closedxffiles();
168 gpcscad }
169 gpcscad
170 gpcscad module closedxffile(){
171 gpcscad     gcp.closedxffile();
172 gpcscad }

```

---

## 3.8 Cutting shapes and expansion

Certain basic shapes (arcs, circles, rectangles), will be incorporated in the main code. Other shapes will be added as they are developed, and of course the user is free to develop their own systems.

It is most expedient to test out new features in a new/separate file insofar as the file structures will allow (tool definitions for example will need to consolidated in [3.4.1.1](#)) which will need to be included in the projects which will make use of said features until such time as they are added into the main `gcodepreview.scad` file.

A basic requirement for two-dimensional regions will be to define them so as to cut them out. Two different geometric treatments will be necessary: modeling the geometry which defines the region to be cut out (output as a DXF); and modeling the movement of the tool, the toolpath which will be used in creating the 3D model and outputting the G-code.

### 3.8.1 Building blocks

The outlines of shapes will be defined using:

- lines — `dxfline`
- arcs — `dxfarc`

It may be that splines or Bézier curves will be added as well.

**3.8.1.1 List of shapes** In the TUG presentation/paper: <http://tug.org/TUGboat/tb40-2/tb125adams-3d.pdf> a list of 2D shapes was put forward — which of these will need to be created, or if some more general solution will be put forward is uncertain. For the time being, shapes will be implemented on an as-needed basis, as modified by the interaction with the requirements of toolpaths. Shapes for which code exists (or is trivially coded) are indicated by **Forest Green** — for those which have sub-classes, if all are feasible only the higher level is so called out.

- 0
  - `circle` — `dxfcircle`
  - ellipse (oval) (requires some sort of non-arc curve)
    - \* egg-shaped
  - annulus (one circle within another, forming a ring) — handled by nested circles
  - superellipse (see astroid below)
- 1
  - cone with rounded end (arc)—see also “sector” under 3 below
- 2
  - semicircle/circular/half-circle segment (arc and a straight line); see also sector below
  - arch—curve possibly smoothly joining a pair of straight lines with a flat bottom
  - lens/vesica piscis (two convex curves)
  - lune/crescent (one convex, one concave curve)
  - heart (two curves)

- tomoe (comma shape)—non-arc curves
- 3
  - triangle
    - \* equilateral
    - \* isosceles
    - \* right triangle
    - \* scalene
  - (circular) sector (two straight edges, one convex arc)
    - \* quadrant ( $90^\circ$ )
    - \* sextants ( $60^\circ$ )
    - \* octants ( $45^\circ$ )
  - deltoid curve (three concave arcs)
  - Reuleaux triangle (three convex arcs)
  - arbelos (one convex, two concave arcs)
  - two straight edges, one concave arc—an example is the hyperbolic sector<sup>1</sup>
  - two convex, one concave arc
- 4
  - rectangle (including square) — dxfrectangle, dxfrectangleround
  - parallelogram
  - rhombus
  - trapezoid/trapezium
  - kite
  - ring/annulus segment (straight line, concave arc, straight line, convex arc)
  - astroid (four concave arcs)
  - salinon (four semicircles)
  - three straight lines and one concave arc

Note that most shapes will also exist in a rounded form where sharp angles/points are replaced by arcs/portions of circles, with the most typical being dxfrectangleround.

Is the list of shapes for which there are not widely known names interesting for its lack of notoriety?

- two straight edges, one concave arc—oddly, an asymmetric form (hyperbolic sector) has a name, but not the symmetrical—while the colloquial/prosaic “arrowhead” was considered, it was rejected as being better applied to the shape below. (It’s also the shape used for the spaceship in the game Asteroids (or Hyperspace), but that is potentially confusing with astroid.) At the conference, Dr. Knuth suggested “dart” as a suitable term.
- two convex, one concave arc—with the above named, the term “arrowhead” is freed up to use as the name for this shape.
- three straight lines and one concave arc.

The first in particular is sorely needed for this project (it’s the result of inscribing a circle in a square or other regular geometric shape). Do these shapes have names in any other languages which might be used instead?

These shapes will then be used in constructing toolpaths. The program Carbide Create has toolpath types and options which are as follows:

- Contour — No Offset — the default, this is already supported in the existing code
- Contour — Outside Offset
- Contour — Inside Offset
- Pocket — such toolpaths/geometry should include the rounding of the tool at the corners, c.f., dxfrectangleround
- Drill — note that this is implemented as the plunging of a tool centered on a circle and normally that circle is the same diameter as the tool which is used.
- Keyhole — also beginning from a circle, the command for this also models the areas which should be cleared for the sake of reducing wear on the tool and ensuring chip clearance

Some further considerations:

---

<sup>1</sup>[en.wikipedia.org/wiki/Hyperbolic\\_sector](https://en.wikipedia.org/wiki/Hyperbolic_sector) and [www.reddit.com/r/Geometry/comments/bkbzgh/is\\_there\\_a\\_name\\_for\\_a\\_3\\_pointed\\_figure\\_with\\_two/](https://www.reddit.com/r/Geometry/comments/bkbzgh/is_there_a_name_for_a_3_pointed_figure_with_two/)

- relationship of geometry to toolpath — arguably there should be an option for each toolpath (we will use Carbide Create as a reference implementation) which is to be supported. Note that there are several possibilities: modeling the tool movement, describing the outline which the tool will cut, modeling a reference shape for the toolpath
- tool geometry — support is included for specialty tooling such as dovetail cutters allowing one to get an accurate 3D model, including for tooling which undercuts since they cannot be modeled in Carbide Create.
- Starting and Max Depth — are there CAD programs which will make use of Z-axis information in a DXF? — would it be possible/necessary to further differentiate the DXF geometry? (currently written out separately for each toolpath in addition to one combined file) — would supporting layers be an option?

#### 3.8.1.1.1 circles Circles are made up of a series of arcs:

---

```

2082 gcpy     def dxfcircle(self, tool_num, xcenter, ycenter, radius):
2083 gcpy         self.dxfarc(tool_num, xcenter, ycenter, radius, 0, 90)
2084 gcpy         self.dxfarc(tool_num, xcenter, ycenter, radius, 90, 180)
2085 gcpy         self.dxfarc(tool_num, xcenter, ycenter, radius, 180, 270)
2086 gcpy         self.dxfarc(tool_num, xcenter, ycenter, radius, 270, 360)

```

---

Actually cutting the circle is much the same, with the added consideration of entry point if Z height is not above the surface of the stock/already removed material, directionality (counter-clockwise vs. clockwise), and depth (beginning and end depths must be specified which should allow usage of this for thread-cutting and similar purposes).

Center is specified, but the actual entry point is the right-most edge.

---

```

2088 gcpy     def cutcircleCC(self, xcenter, ycenter, bz, ez, radius):
2089 gcpy         self.setzpos(bz)
2090 gcpy         self.cutquarterCCNE(xcenter, ycenter + radius, self.zpos()
2091 gcpy             + ez/4, radius)
2092 gcpy         self.cutquarterCCNW(xcenter - radius, ycenter, self.zpos()
2093 gcpy             + ez/4, radius)
2094 gcpy         self.cutquarterCCSW(xcenter, ycenter - radius, self.zpos()
2095 gcpy             + ez/4, radius)
2096 gcpy         self.cutquarterCCSE(xcenter + radius, ycenter, self.zpos()
2097 gcpy             + ez/4, radius)

2098 gcpy     def cutcircleCCdxfs(self, xcenter, ycenter, bz, ez, radius):
2099 gcpy         self.cutcircleCC(self, xcenter, ycenter, bz, ez, radius)
2100 gcpy         self.dxfcircle(self, tool_num, xcenter, ycenter, radius)

```

---

A Drill toolpath is a simple plunge operation which will have a matching circle to define it.

#### 3.8.1.1.2 rectangles There are two obvious forms for rectangles, square cornered and rounded:

---

```

2099 gcpy     def dxfrectangle(self, tool_num, xorigin, yorigin, xwidth,
2100 gcpy         yheight, corners = "Square", radius = 6):
2101 gcpy         if corners == "Square":
2102 gcpy             self.dxfline(tool_num, xorigin, yorigin, xorigin +
2103 gcpy                 xwidth, yorigin)
2104 gcpy             self.dxfline(tool_num, xorigin + xwidth, yorigin,
2105 gcpy                 xorigin + xwidth, yorigin + yheight)
2106 gcpy             self.dxfline(tool_num, xorigin + xwidth, yorigin +
2107 gcpy                 yheight, xorigin, yorigin + yheight)
2108 gcpy             self.dxfline(tool_num, xorigin, yorigin + yheight,
2109 gcpy                 xorigin, yorigin)
2110 gcpy         elif corners == "Fillet":
2111 gcpy             self.dxfrectangleround(tool_num, xorigin, yorigin,
2112 gcpy                 xwidth, yheight, radius)
2113 gcpy         elif corners == "Chamfer":
2114 gcpy             self.dxfrectanglechamfer(tool_num, xorigin, yorigin,
2115 gcpy                 xwidth, yheight, radius)
2116 gcpy         elif corners == "Flipped_Fillet":
2117 gcpy             self.dxfrectangleflippedfillet(tool_num, xorigin,
2118 gcpy                 yorigin, xwidth, yheight, radius)

```

---

Note that the rounded shape below would be described as a rectangle with the “Fillet” corner treatment in Carbide Create.

---

```

2112 gcpy     def dxfrectangleround(self, tool_num, xorigin, yorigin, xwidth,
2113 gcpy                 yheight, radius):
2114 gcpy         # begin section

```

---

```

2114 gcpy           self.writedxf(tool_num, "0")
2115 gcpy           self.writedxf(tool_num, "SECTION")
2116 gcpy           self.writedxf(tool_num, "2")
2117 gcpy           self.writedxf(tool_num, "ENTITIES")
2118 gcpy           self.writedxf(tool_num, "0")
2119 gcpy           self.writedxf(tool_num, "LWPOLYLINE")
2120 gcpy           self.writedxf(tool_num, "5")
2121 gcpy           self.writedxf(tool_num, "4E")
2122 gcpy           self.writedxf(tool_num, "100")
2123 gcpy           self.writedxf(tool_num, "AcDbEntity")
2124 gcpy           self.writedxf(tool_num, "8")
2125 gcpy           self.writedxf(tool_num, "0")
2126 gcpy           self.writedxf(tool_num, "6")
2127 gcpy           self.writedxf(tool_num, "ByLayer")
2128 gcpy #
2129 gcpy           self.writedxfcolor(tool_num)
2130 gcpy #
2131 gcpy           self.writedxf(tool_num, "370")
2132 gcpy           self.writedxf(tool_num, "-1")
2133 gcpy           self.writedxf(tool_num, "100")
2134 gcpy           self.writedxf(tool_num, "AcDbPolyline")
2135 gcpy           self.writedxf(tool_num, "90")
2136 gcpy           self.writedxf(tool_num, "8")
2137 gcpy           self.writedxf(tool_num, "70")
2138 gcpy           self.writedxf(tool_num, "1")
2139 gcpy           self.writedxf(tool_num, "43")
2140 gcpy           self.writedxf(tool_num, "0")
2141 gcpy #1 upper right corner before arc (counter-clockwise)
2142 gcpy           self.writedxf(tool_num, "10")
2143 gcpy           self.writedxf(tool_num, str(xorigin + xwidth))
2144 gcpy           self.writedxf(tool_num, "20")
2145 gcpy           self.writedxf(tool_num, str(yorigin + yheight - radius))
2146 gcpy           self.writedxf(tool_num, "42")
2147 gcpy           self.writedxf(tool_num, "0.414213562373095")
2148 gcpy #2 upper right corner after arc
2149 gcpy           self.writedxf(tool_num, "10")
2150 gcpy           self.writedxf(tool_num, str(xorigin + xwidth - radius))
2151 gcpy           self.writedxf(tool_num, "20")
2152 gcpy           self.writedxf(tool_num, str(yorigin + yheight))
2153 gcpy #3 upper left corner before arc (counter-clockwise)
2154 gcpy           self.writedxf(tool_num, "10")
2155 gcpy           self.writedxf(tool_num, str(xorigin + radius))
2156 gcpy           self.writedxf(tool_num, "20")
2157 gcpy           self.writedxf(tool_num, str(yorigin + yheight))
2158 gcpy           self.writedxf(tool_num, "42")
2159 gcpy           self.writedxf(tool_num, "0.414213562373095")
2160 gcpy #4 upper left corner after arc
2161 gcpy           self.writedxf(tool_num, "10")
2162 gcpy           self.writedxf(tool_num, str(xorigin))
2163 gcpy           self.writedxf(tool_num, "20")
2164 gcpy           self.writedxf(tool_num, str(yorigin + yheight - radius))
2165 gcpy #5 lower left corner before arc (counter-clockwise)
2166 gcpy           self.writedxf(tool_num, "10")
2167 gcpy           self.writedxf(tool_num, str(xorigin))
2168 gcpy           self.writedxf(tool_num, "20")
2169 gcpy           self.writedxf(tool_num, str(yorigin + radius))
2170 gcpy           self.writedxf(tool_num, "42")
2171 gcpy           self.writedxf(tool_num, "0.414213562373095")
2172 gcpy #6 lower left corner after arc
2173 gcpy           self.writedxf(tool_num, "10")
2174 gcpy           self.writedxf(tool_num, str(xorigin + radius))
2175 gcpy           self.writedxf(tool_num, "20")
2176 gcpy           self.writedxf(tool_num, str(yorigin))
2177 gcpy #7 lower right corner before arc (counter-clockwise)
2178 gcpy           self.writedxf(tool_num, "10")
2179 gcpy           self.writedxf(tool_num, str(xorigin + xwidth - radius))
2180 gcpy           self.writedxf(tool_num, "20")
2181 gcpy           self.writedxf(tool_num, str(yorigin))
2182 gcpy           self.writedxf(tool_num, "42")
2183 gcpy           self.writedxf(tool_num, "0.414213562373095")
2184 gcpy #8 lower right corner after arc
2185 gcpy           self.writedxf(tool_num, "10")
2186 gcpy           self.writedxf(tool_num, str(xorigin + xwidth))
2187 gcpy           self.writedxf(tool_num, "20")
2188 gcpy           self.writedxf(tool_num, str(yorigin + radius))
2189 gcpy # end current section
2190 gcpy           self.writedxf(tool_num, "0")
2191 gcpy           self.writedxf(tool_num, "SEQEND")

```

---

So we add the balance of the corner treatments which are decorative (and easily implemented). Chamfer:

---

```

2193 gcpy     def dxfractanglechamfer(self, tool_num, xorigin, yorigin,
2194 gcpy         xwidth, yheight, radius):
2195 gcpy             self.dxfline(tool_num, xorigin + radius, yorigin, xorigin,
2196 gcpy                     yorigin + radius)
2197 gcpy             self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
2198 gcpy                     xorigin + radius, yorigin + yheight)
2199 gcpy             self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
2200 gcpy                     yheight, xorigin + xwidth, yorigin + yheight - radius)
2201 gcpy             self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
2202 gcpy                     yheight, xorigin + xwidth, yorigin + radius)
2203 gcpy             self.dxfline(tool_num, xorigin + radius, yorigin, xorigin +
2204 gcpy                     xwidth - radius, yorigin)
2205 gcpy             self.dxfline(tool_num, xorigin + xwidth, yorigin + radius,
2206 gcpy                     xorigin + xwidth, yorigin + yheight - radius)
2207 gcpy             self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
2208 gcpy                     yheight, xorigin + radius, yorigin + yheight)
2209 gcpy             self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
2210 gcpy                     xorigin, yorigin + radius)
2211 gcpy             self.dxfline(tool_num, xorigin + xwidth, yorigin + radius,
2212 gcpy                     xorigin + xwidth, yorigin + yheight - radius)
2213 gcpy             self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
2214 gcpy                     yheight, xorigin + radius, yorigin + radius)
2215 gcpy             self.dxfline(tool_num, xorigin + radius, yorigin, xorigin +
2216 gcpy                     xwidth - radius, yorigin)
2217 gcpy             self.dxfline(tool_num, xorigin + xwidth, yorigin + radius,
2218 gcpy                     xorigin + xwidth, yorigin + yheight - radius)
2219 gcpy             self.dxfline(tool_num, xorigin + xwidth, yorigin + yheight,
2220 gcpy                     bz - zdepth)
2221 gcpy             self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
2222 gcpy                     bz - zdepth)
2223 gcpy     def cutrectangledxf(self, tool_num, bx, by, bz, xwidth, yheight,
2224 gcpy                     zdepth):
2225 gcpy             self.cutrectangle(tool_num, bx, by, bz, xwidth, yheight,
2226 gcpy                     "Square")

```

---

#### Flipped Fillet:

---

```

2204 gcpy     def dxfractangleflippedfillet(self, tool_num, xorigin, yorigin,
2205 gcpy         xwidth, yheight, radius):
2206 gcpy             self.dxfarc(tool_num, xorigin, yorigin, radius, 0, 90)
2207 gcpy             self.dxfarc(tool_num, xorigin + xwidth, yorigin, radius,
2208 gcpy                     90, 180)
2209 gcpy             self.dxfarc(tool_num, xorigin + xwidth, yorigin + yheight,
2210 gcpy                     radius, 180, 270)
2211 gcpy             self.dxfarc(tool_num, xorigin, yorigin + yheight, radius,
2212 gcpy                     270, 360)
2213 gcpy             self.dxfline(tool_num, xorigin + radius, yorigin, xorigin +
2214 gcpy                     xwidth - radius, yorigin)
2215 gcpy             self.dxfline(tool_num, xorigin + xwidth, yorigin + radius,
2216 gcpy                     xorigin + xwidth, yorigin + yheight - radius)
2217 gcpy             self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
2218 gcpy                     yheight, xorigin + radius, yorigin + yheight)
2219 gcpy             self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
2220 gcpy                     xorigin, yorigin + radius)

```

---

Cutting rectangles while writing out their perimeter in the DXF files (so that they may be assigned a matching toolpath in a traditional CAM program upon import) will require the origin coordinates, height and width and depth of the pocket, and the tool # so that the corners may have a radius equal to the tool which is used. Whether a given module is an interior pocket or an outline (interior or exterior) will be determined by the specifics of the module and its usage/positioning, with outline being added to those modules which cut perimeter.

A further consideration is that cut orientation as an option should be accounted for if writing out G-code, as well as stepover, and the nature of initial entry (whether ramping in would be implemented, and if so, at what angle). Advanced toolpath strategies such as trochoidal milling could also be implemented.

`cutrectangle` The routine `cutrectangle` cuts the outline of a rectangle creating rounded corners.

---

```

2215 gcpy     def cutrectangle(self, tool_num, bx, by, bz, xwidth, yheight,
2216 gcpy         zdepth):
2217 gcpy             self.cutline(bx, by, bz)
2218 gcpy             self.cutline(bx, by, bz - zdepth)
2219 gcpy             self.cutline(bx + xwidth, by, bz - zdepth)
2220 gcpy             self.cutline(bx + xwidth, by + yheight, bz - zdepth)
2221 gcpy             self.cutline(bx, by + yheight, bz - zdepth)
2222 gcpy             self.cutline(bx, by, bz - zdepth)
2223 gcpy     def cutrectangledxf(self, tool_num, bx, by, bz, xwidth, yheight,
2224 gcpy                     zdepth):
2225 gcpy             self.cutrectangle(tool_num, bx, by, bz, xwidth, yheight,
2226 gcpy                     "Square")

```

---

#### The rounded forms instantiate a radius:

---

```

2227 gcpy     def cutrectangleround(self, tool_num, bx, by, bz, xwidth,

```

---

```

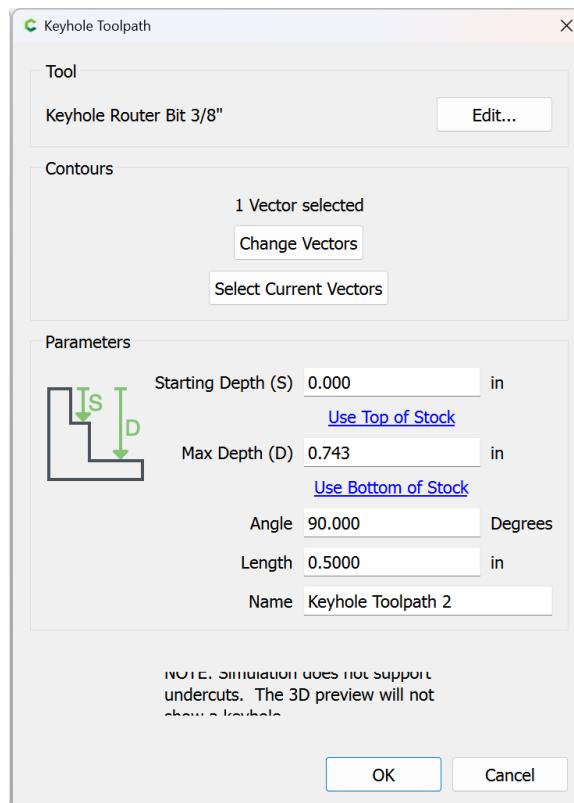
yheight, zdepth, radius):
2228 gcpy #
2229 gcpy
2230 gcpy
2231 gcpy
2232 gcpy
2233 gcpy
2234 gcpy
2235 gcpy
2236 gcpy
2237 gcpy
2238 gcpy
2239 gcpy
2240 gcpy
2241 gcpy
    self.rapid(bx + radius, by, bz)
    self.cutline(bx + radius, by, bz + zdepth)
    self.cutline(bx + xwidth - radius, by, bz + zdepth)
    self.cutquarterCCSE(bx + xwidth, by + radius, bz + zdepth,
                         radius)
    self.cutline(bx + xwidth, by + yheight - radius, bz +
                 zdepth)
    self.cutquarterCCNE(bx + xwidth - radius, by + yheight, bz
                        + zdepth, radius)
    self.cutline(bx + radius, by + yheight, bz + zdepth)
    self.cutquarterCCNW(bx, by + yheight - radius, bz + zdepth,
                         radius)
    self.cutline(bx, by + radius, bz + zdepth)
    self.cutquarterCCSW(bx + radius, by, bz + zdepth, radius)
def cutrectanglerounddx(self, tool_num, bx, by, bz, xwidth,
yheight, zdepth, radius):
    self.cutrectangleround(tool_num, bx, by, bz, xwidth,
                           yheight, zdepth, radius)
    self.dxrectangleround(tool_num, bx, by, xwidth, yheight,
                          radius)

```

**3.8.1.1.3 Keyhole toolpath and undercut tooling** The first topologically unusual toolpath is cutkeyhole toolpath — where other toolpaths have a direct correspondence between the associated geometry and the area cut, that Keyhole toolpaths may be used with tooling which undercuts and which will result in the creation of two different physical regions: the visible surface matching the union of the tool perimeter at the entry point and the linear movement of the shaft and the larger region of the tool perimeter at the depth which the tool is plunged to and moved along.

Tooling for such toolpaths is defined at paragraph [3.5.1](#)

The interface which is being modeled is that of Carbide Create:



Hence the parameters:

- Starting Depth == kh\_start\_depth
- Max Depth == kh\_max\_depth
- Angle == kht\_direction
- Length == kh\_distance
- Tool == kh\_tool\_num

Due to the possibility of rotation, for the in-between positions there are more cases than one would think — for each quadrant there are the following possibilities:

- one node on the clockwise side is outside of the quadrant
- two nodes on the clockwise side are outside of the quadrant
- all nodes are w/in the quadrant
- one node on the counter-clockwise side is outside of the quadrant
- two nodes on the counter-clockwise side are outside of the quadrant

Supporting all of these would require trigonometric comparisons in the if...else blocks, so only the 4 quadrants, N, S, E, and W will be supported in the initial version. This will be done by wrapping the command with a version which only accepts those options:

---

```

2243 gcpy      def cutkeyholegcdxf(self, kh_tool_num, kh_start_depth,
2244 gcpy          kh_max_depth, kht_direction, kh_distance):
2245 gcpy          if (kht_direction == "N"):
2246 gcpy              toolpath = self.cutKHgcdxf(kh_tool_num, kh_start_depth,
2247 gcpy                  kh_max_depth, 90, kh_distance)
2248 gcpy          elif (kht_direction == "S"):
2249 gcpy              toolpath = self.cutKHgcdxf(kh_tool_num, kh_start_depth,
2250 gcpy                  kh_max_depth, 270, kh_distance)
2251 gcpy          elif (kht_direction == "E"):
2252 gcpy              toolpath = self.cutKHgcdxf(kh_tool_num, kh_start_depth,
2253 gcpy                  kh_max_depth, 0, kh_distance)
2254 gcpy          elif (kht_direction == "W"):
2255 gcpy              toolpath = self.cutKHgcdxf(kh_tool_num, kh_start_depth,
2256 gcpy                  kh_max_depth, 180, kh_distance)
2257 gcpy #
2258 gcpy     if self.generatepaths == True:
2259 gcpy         self.toolpaths = union([self.toolpaths, toolpath])
2260 gcpy #
2261 gcpy     return toolpath
2262 gcpy #
2263 gcpy     else:
2264 gcpy         return cube([0.01, 0.01, 0.01])

```

---

```

174 gpcscad module cutkeyholegcdxf(kh_tool_num, kh_start_depth, kh_max_depth,
175 gpcscad     kht_direction, kh_distance){
176 gpcscad     gcp.cutkeyholegcdxf(kh_tool_num, kh_start_depth, kh_max_depth,
177 gpcscad         kht_direction, kh_distance);

```

---

`cutKHgcdxf` The original version of the command, `cutKHgcdxf` retains an interface which allows calling it for arbitrary beginning and ending points of an arc.

Note that code is still present for the partial calculation of one quadrant (for the case of all nodes within the quadrant). The first task is to place a circle at the origin which is invariant of angle:

---

```

2258 gcpy      def cutKHgcdxf(self, kh_tool_num, kh_start_depth, kh_max_depth,
2259 gcpy          kh_angle, kh_distance):
2260 gcpy          oXpos = self.xpos()
2261 gcpy          oYpos = self.ypos()
2262 gcpy          self.dxfKH(kh_tool_num, self.xpos(), self.ypos(),
2263 gcpy              kh_start_depth, kh_max_depth, kh_angle, kh_distance)
2264 gcpy          toolpath = self.cutline(self.xpos(), self.ypos(), -
2265 gcpy              kh_max_depth)
2266 gcpy          self.setxpos(oXpos)
2267 gcpy          self.setypos(oYpos)
2268 gcpy          if self.generatepaths == False:
2269 gcpy      return toolpath
2270 gcpy      else:
2271 gcpy          return cube([0.001, 0.001, 0.001])

```

---

```

2270 gcpy      def dxfKH(self, kh_tool_num, oXpos, oYpos, kh_start_depth,
2271 gcpy          kh_max_depth, kh_angle, kh_distance):
2272 gcpy          oXpos = self.xpos()
2273 gcpy          oYpos = self.ypos()
2274 gcpy #Circle at entry hole
2275 gcpy          self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius(
2276 gcpy              kh_tool_num, 7), 0, 90)
2277 gcpy          self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius(
2278 gcpy              kh_tool_num, 7), 90, 180)
2279 gcpy          self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius(
2280 gcpy              kh_tool_num, 7), 180, 270)
2281 gcpy          self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius(
2282 gcpy              kh_tool_num, 7), 270, 360)

```

---

Then it will be necessary to test for each possible case in a series of If Else blocks:

---

```

2278 gcpy #pre-calculate needed values
2279 gcpy           r = self.tool_radius(kh_tool_num, 7)
2280 gcpy #
2281 gcpy           print(r)
2282 gcpy #
2283 gcpy           rt = self.tool_radius(kh_tool_num, 1)
2284 gcpy #
2285 gcpy           print(rt)
2286 gcpy #Outlines of entry hole and slot
2287 gcpy           if (kh_angle == 0):
2288 gcpy #Lower left of entry hole
2289 gcpy           self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), self.
2290 gcpy           .tool_radius(kh_tool_num, 1), 180, 270)
2291 gcpy #Upper left of entry hole
2292 gcpy           self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), self.
2293 gcpy           .tool_radius(kh_tool_num, 1), 90, 180)
2294 gcpy #Upper right of entry hole
2295 gcpy           self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
2296 gcpy           41.810, 90)
2297 gcpy           self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
2298 gcpy           angle, 90)
2299 gcpy #Lower right of entry hole
2300 gcpy           self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
2301 gcpy           270, 360-angle)
2302 gcpy #
2303 gcpy           self.dxfarc(kh_tool_num, self.xpos(), self.ypos(),
2304 gcpy           self.dxfline(kh_tool_num, self.xpos(), self.ypos(),
2305 gcpy           self.xpos()+kh_distance, self.ypos())
2306 gcpy #upper right of end of slot (kh_max_depth+4.36))/2
2307 gcpy           self.dxfarc(kh_tool_num, self.xpos()+kh_distance, self.
2308 gcpy           ypos(), self.tool_diameter(kh_tool_num, (
2309 gcpy           kh_max_depth+4.36))/2, 0, 90)
2310 gcpy #lower right of end of slot
2311 gcpy           self.dxfarc(kh_tool_num, self.xpos()+kh_distance, self.
2312 gcpy           ypos(), self.tool_diameter(kh_tool_num, (
2313 gcpy           kh_max_depth+4.36))/2, 270, 360)
2314 gcpy #
2315 gcpy           self.dxfline(kh_tool_num, self.xpos()+(math.sqrt((self.
2316 gcpy           .tool_diameter(kh_tool_num, 1)^2)-(self.tool_diameter(
2317 gcpy           kh_tool_num, 5)^2))/2, self.ypos()+self.tool_diameter(
2318 gcpy           kh_tool_num, (kh_max_depth))/2, ((kh_max_depth-6.34))/2)^2-
2319 gcpy           self.tool_diameter(kh_tool_num, (kh_max_depth-6.34))/2)^2,
2320 gcpy           self.xpos()+(kh_distance, self.ypos()+
2321 gcpy           self.tool_diameter(kh_tool_num, (kh_max_depth))/2, kh_tool_num)
2322 gcpy #end position at top of slot
2323 gcpy #
2324 gcpy           hull(){
2325 gcpy           translate([xpos(), ypos(), zpos()]){
2326 gcpy           keyhole_shaft(6.35, 9.525);
2327 gcpy           }
2328 gcpy           translate([xpos(), ypos(), zpos()-kh_max_depth]){
2329 gcpy           keyhole_shaft(6.35, 9.525);
2330 gcpy           }
2331 gcpy           }
2332 gcpy           hull(){
2333 gcpy           translate([xpos(), ypos(), zpos()-kh_max_depth]){

```

```

2322 gcpy #           keyhole_shaft(6.35, 9.525);
2323 gcpy #
2324 gcpy #           translate([xpos()+kh_distance, ypos(), zpos()-kh_max_depth])
{
2325 gcpy #           keyhole_shaft(6.35, 9.525);
2326 gcpy #
2327 gcpy #
2328 gcpy #           cutwithfeed(getxpos(), getypos(), -kh_max_depth, feed);
2329 gcpy #           cutwithfeed(getxpos()+kh_distance, getypos(), -kh_max_depth,
2330 gcpy #               feed);
2331 gcpy #           setxpos(getxpos()-kh_distance);
2332 gcpy # } else if (kh_angle > 0 && kh_angle < 90) {
2333 gcpy # //echo(kh_angle);
2334 gcpy # dxfarc(getxpos(), getypos(), tool_diameter(KH_tool_num, (
2335 gcpy #   kh_max_depth))/2, 90+kh_angle, 180+kh_angle, KH_tool_num);
2336 gcpy # dxfarc(getxpos(), getypos(), tool_diameter(KH_tool_num, (
2337 gcpy #   kh_max_depth))/2, 180+kh_angle, 270+kh_angle, KH_tool_num);
2338 gcpy # dxfarc(getxpos(), getypos(), tool_diameter(KH_tool_num, (
2339 gcpy #   kh_max_depth))/2, 270+kh_angle, 360+kh_angle-asin((tool_diameter(KH_tool_num,
2340 gcpy #   (kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_num, (kh_max_depth
2341 gcpy #   ))/2)), 90+kh_angle, KH_tool_num);
2342 gcpy # dxfarc(getxpos(), getypos(), tool_diameter(KH_tool_num, (
2343 gcpy #   kh_max_depth))/2, 270+kh_angle, 360+kh_angle, KH_tool_num);
2344 gcpy # //echo("a", tool_diameter(KH_tool_num, (kh_max_depth+4.36))/2);
2345 gcpy # //echo("c", tool_diameter(KH_tool_num, (kh_max_depth))/2);
2346 gcpy # echo("Aangle", asin((tool_diameter(KH_tool_num, (kh_max_depth
2347 gcpy #   +4.36))/2)/(tool_diameter(KH_tool_num, (kh_max_depth))/2)));
2348 gcpy # cutwithfeed(getxpos()+(kh_distance*cos(kh_angle)), getypos()+
2349 gcpy #   kh_distance*sin(kh_angle), -kh_max_depth, feed);
2350 gcpy #   toolpath = toolpath.union(self.cutline(self.xpos()+
2351 gcpy #     kh_distance, self.ypos(), -kh_max_depth))
2352 gcpy #   elif (kh_angle == 90):
2353 gcpy # Lower left of entry hole
2354 gcpy #   self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius
2355 gcpy #   (kh_tool_num, 1), 180, 270)
2356 gcpy # Lower right of entry hole
2357 gcpy # left slot
2358 gcpy #   self.dxfline(kh_tool_num, oXpos-r, oYpos+ro, oXpos-r,
2359 gcpy #   oYpos+kh_distance)
2360 gcpy # right slot
2361 gcpy #   self.dxfline(kh_tool_num, oXpos+r, oYpos+ro, oXpos+r,
2362 gcpy #   oYpos+kh_distance)
2363 gcpy # upper left of end of slot
2364 gcpy #   self.dxfarc(kh_tool_num, oXpos, oYpos+kh_distance, r,
2365 gcpy #   90, 180)
2366 gcpy # upper right of end of slot
2367 gcpy #   self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 0, 90-angle)
2368 gcpy # Upper left of entry hole
2369 gcpy #   self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 90+angle,
2370 gcpy #   180)
2371 gcpy #   toolpath = toolpath.union(self.cutline(oXpos, oYpos+
2372 gcpy #   kh_distance, -kh_max_depth))
2373 gcpy #   elif (kh_angle == 180):
2374 gcpy # Lower right of entry hole

```

```

2370 gcpy           self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius
                           (kh_tool_num, 1), 270, 360)
2371 gcpy #Upper right of entry hole
2372 gcpy           self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius
                           (kh_tool_num, 1), 0, 90)
2373 gcpy #Upper left of entry hole
2374 gcpy           self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 90, 180-
                           angle)
2375 gcpy #Lower left of entry hole
2376 gcpy           self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 180+angle,
                           270)
2377 gcpy #upper slot
2378 gcpy           self.dxfline(kh_tool_num, oXpos-ro, oYpos-r, oXpos-
                           kh_distance, oYpos-r)
2379 gcpy #lower slot
2380 gcpy           self.dxfline(kh_tool_num, oXpos-ro, oYpos+r, oXpos-
                           kh_distance, oYpos+r)
2381 gcpy #upper left of end of slot
2382 gcpy           self.dxfarc(kh_tool_num, oXpos-kh_distance, oYpos, r,
                           90, 180)
2383 gcpy #lower left of end of slot
2384 gcpy           self.dxfarc(kh_tool_num, oXpos-kh_distance, oYpos, r,
                           180, 270)
2385 gcpy #
          toolpath = toolpath.union(self.cutline(oXpos-
                           kh_distance, oYpos, -kh_max_depth))
2386 gcpy elif (kh_angle == 270):
2387 gcpy #Upper left of entry hole
2388 gcpy           self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius
                           (kh_tool_num, 1), 90, 180)
2389 gcpy #Upper right of entry hole
2390 gcpy           self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius
                           (kh_tool_num, 1), 0, 90)
2391 gcpy #left slot
2392 gcpy           self.dxfline(kh_tool_num, oXpos-r, oYpos-ro, oXpos-r,
                           oYpos-kh_distance)
2393 gcpy #right slot
2394 gcpy           self.dxfline(kh_tool_num, oXpos+r, oYpos-ro, oXpos+r,
                           oYpos-kh_distance)
2395 gcpy #lower left of end of slot
2396 gcpy           self.dxfarc(kh_tool_num, oXpos, oYpos-kh_distance, r,
                           180, 270)
2397 gcpy #lower right of end of slot
2398 gcpy           self.dxfarc(kh_tool_num, oXpos, oYpos-kh_distance, r,
                           270, 360)
2399 gcpy #lower right of entry hole
2400 gcpy           self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 180, 270-
                           angle)
2401 gcpy #lower left of entry hole
2402 gcpy           self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 270+angle,
                           360)
2403 gcpy #
          toolpath = toolpath.union(self.cutline(oXpos, oYpos-
                           kh_distance, -kh_max_depth))
2404 gcpy #     print(self.zpos())
2405 gcpy #     self.setxpos(oXpos)
2406 gcpy #     self.setypos(oYpos)
2407 gcpy #     if self.generatepaths == False:
2408 gcpy #         return toolpath
2409 gcpy
2410 gcpy # } else if (kh_angle == 90) {
2411 gcpy #     //Lower left of entry hole
2412 gcpy #     dxfarc(getxpos(), getypos(), 9.525/2, 180, 270, KH_tool_num);
2413 gcpy #     //Lower right of entry hole
2414 gcpy #     dxfarc(getxpos(), getypos(), 9.525/2, 270, 360, KH_tool_num);
2415 gcpy #     //Upper right of entry hole
2416 gcpy #     dxfarc(getxpos(), getypos(), 9.525/2, 0, acos(tool_diameter(
                           KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), KH_tool_num);
2417 gcpy #     //Upper left of entry hole
2418 gcpy #     dxfarc(getxpos(), getypos(), 9.525/2, 180-acos(tool_diameter(
                           KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), 180, KH_tool_num
                           );
2419 gcpy #     //Actual line of cut
2420 gcpy #     dxfline(getxpos(), getypos(), getxpos(), getypos()+kh_distance
                           );
2421 gcpy #     //upper right of slot
2422 gcpy #     dxfarc(getxpos(), getypos()+kh_distance, tool_diameter(
                           KH_tool_num, (kh_max_depth+4.36))/2, 0, 90, KH_tool_num);
2423 gcpy #     //upper left of slot
2424 gcpy #     dxfarc(getxpos(), getypos()+kh_distance, tool_diameter(

```

```

2425 gcpy #           KH_tool_num, (kh_max_depth+6.35))/2, 90, 180, KH_tool_num);
2426 gcpy #           //right of slot
2427 gcpy #           dxfline(
2428 gcpy #               getxpos() + tool_diameter(KH_tool_num, (kh_max_depth))/2,
2429 gcpy #                   getypos() + (math.sqrt((tool_diameter(KH_tool_num, 1)^2)-
2430 gcpy #                       tool_diameter(KH_tool_num, 5)^2))/2), //((kh_max_depth-6.34))
2431 gcpy #                           /2)^2-(tool_diameter(KH_tool_num, (kh_max_depth-6.34))/2)^2,
2432 gcpy #                               getxpos() + tool_diameter(KH_tool_num, (kh_max_depth))/2,
2433 gcpy #                               //end position at top of slot
2434 gcpy #                               getypos() + kh_distance,
2435 gcpy #                               KH_tool_num);
2436 gcpy #           dxfline(getxpos() - tool_diameter(KH_tool_num, (kh_max_depth))
2437 gcpy #               /2, getypos() + (math.sqrt((tool_diameter(KH_tool_num, 1)^2)-
2438 gcpy #                   tool_diameter(KH_tool_num, 5)^2))/2), getxpos() - tool_diameter(
2439 gcpy #                       KH_tool_num, (kh_max_depth+6.35))/2, getypos() + kh_distance,
2440 gcpy #                           KH_tool_num);
2441 gcpy #           hull(){
2442 gcpy #               translate([xpos(), ypos(), zpos()]){
2443 gcpy #                   keyhole_shaft(6.35, 9.525);
2444 gcpy #               }
2445 gcpy #               translate([xpos(), ypos(), zpos() - kh_max_depth]){
2446 gcpy #                   keyhole_shaft(6.35, 9.525);
2447 gcpy #               }
2448 gcpy #               translate([xpos(), ypos(), zpos() - kh_max_depth]){
2449 gcpy #                   keyhole_shaft(6.35, 9.525);
2450 gcpy #                   cutwithfeed(getxpos(), getypos(), -kh_max_depth, feed);
2451 gcpy #                   cutwithfeed(getxpos(), getypos() + kh_distance, -kh_max_depth,
2452 gcpy #                       feed);
2453 gcpy #                   setypos(getypos() - kh_distance);
2454 gcpy #               } else if (kh_angle == 180) {
2455 gcpy #                   //Lower right of entry hole
2456 gcpy #                   dxfarc(getxpos(), getypos(), 9.525/2, 270, 360, KH_tool_num);
2457 gcpy #                   //Upper right of entry hole
2458 gcpy #                   dxfarc(getxpos(), getypos(), 9.525/2, 0, 90, KH_tool_num);
2459 gcpy #                   //Upper left of entry hole
2460 gcpy #                   dxfarc(getxpos(), getypos(), 9.525/2, 90, 90+acos(
2461 gcpy #                       tool_diameter(KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)),
2462 gcpy #                           KH_tool_num);
2463 gcpy #                   //Lower left of entry hole
2464 gcpy #                   dxfarc(getxpos(), getypos(), 9.525/2, 270-acos(tool_diameter(
2465 gcpy #                       KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), 270, KH_tool_num
2466 gcpy #                           );
2467 gcpy #                   //upper left of slot
2468 gcpy #                   dxfarc(getxpos() - kh_distance, getypos(), tool_diameter(
2469 gcpy #                       KH_tool_num, (kh_max_depth+6.35))/2, 90, 180, KH_tool_num);
2470 gcpy #                   //lower left of slot
2471 gcpy #                   dxfarc(getxpos() - kh_distance, getypos(), tool_diameter(
2472 gcpy #                       KH_tool_num, (kh_max_depth+6.35))/2, 180, 270, KH_tool_num);
2473 gcpy #                   //Actual line of cut
2474 gcpy #                   dxfline(getxpos(), getypos(), getxpos() - kh_distance, getypos()
2475 gcpy #                           );
2476 gcpy #                   //upper left slot
2477 gcpy #                   dxfline(
2478 gcpy #                       getxpos() - (math.sqrt((tool_diameter(KH_tool_num, 1)^2)-
2479 gcpy #                           tool_diameter(KH_tool_num, 5)^2))/2),
2480 gcpy #                           getypos() + tool_diameter(KH_tool_num, (kh_max_depth))/2,
2481 gcpy #                           //((kh_max_depth-6.34))/2)^2-(tool_diameter(KH_tool_num, (kh_max_depth-6.34))/2)^2,
2482 gcpy #                               getxpos() - kh_distance,
2483 gcpy #                               //end position at top of slot
2484 gcpy #                               getypos() + tool_diameter(KH_tool_num, (kh_max_depth))/2,
2485 gcpy #                               KH_tool_num);
2486 gcpy #                   //lower right slot
2487 gcpy #                   dxfline(
2488 gcpy #                       getxpos() - (math.sqrt((tool_diameter(KH_tool_num, 1)^2)-
2489 gcpy #                           tool_diameter(KH_tool_num, 5)^2))/2),
2490 gcpy #                           getypos() - tool_diameter(KH_tool_num, (kh_max_depth))/2,
2491 gcpy #                           //((kh_max_depth-6.34))/2)^2-(tool_diameter(KH_tool_num, (kh_max_depth-6.34))/2)^2,
2492 gcpy #                               getxpos() - kh_distance,
2493 gcpy #                               //end position at bottom of slot
2494 gcpy #                               getypos() - tool_diameter(KH_tool_num, (kh_max_depth))/2,
2495 gcpy #                               KH_tool_num);
2496 gcpy #               }
2497 gcpy #           }
2498 gcpy #       }
2499 gcpy #   }
2500 gcpy # }
```

```

2481 gcpy #      //end position at top of slot
2482 gcpy #          getypos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
2483 gcpy #          KH_tool_num;
2484 gcpy #      hull(){
2485 gcpy #          translate([xpos(), ypos(), zpos()]){
2486 gcpy #              keyhole_shaft(6.35, 9.525);
2487 gcpy #          }
2488 gcpy #          translate([xpos(), ypos(), zpos()-kh_max_depth]){
2489 gcpy #              keyhole_shaft(6.35, 9.525);
2490 gcpy #          }
2491 gcpy #
2492 gcpy #      hull(){
2493 gcpy #          translate([xpos(), ypos(), zpos()-kh_max_depth]){
2494 gcpy #              keyhole_shaft(6.35, 9.525);
2495 gcpy #          }
2496 gcpy #          translate([xpos()-kh_distance, ypos(), zpos()-kh_max_depth])
2497 gcpy #          {
2498 gcpy #              keyhole_shaft(6.35, 9.525);
2499 gcpy #
2500 gcpy #          cutwithfeed(getxpos(), getypos(), -kh_max_depth, feed);
2501 gcpy #          cutwithfeed(getxpos()-kh_distance, getypos(), -kh_max_depth,
2502 gcpy #          feed);
2503 gcpy #          setxpos(getxpos()+kh_distance);
2504 gcpy #      } else if (kh_angle == 270) {
2505 gcpy #          //Upper right of entry hole
2506 gcpy #          dxfarc(getxpos(), getypos(), 9.525/2, 0, 90, KH_tool_num);
2507 gcpy #          //Upper left of entry hole
2508 gcpy #          dxfarc(getxpos(), getypos(), 9.525/2, 90, 180, KH_tool_num);
2509 gcpy #          //lower right of slot
2510 gcpy #          dxfarc(getxpos(), getypos()-kh_distance, tool_diameter(
2511 gcpy #          KH_tool_num, (kh_max_depth+4.36))/2, 270, 360, KH_tool_num);
2512 gcpy #          //lower left of slot
2513 gcpy #          dxfline(getxpos(), getypos(), getxpos(), getypos()-kh_distance
2514 gcpy #          );
2515 gcpy #          //right of slot
2516 gcpy #          dxfline(
2517 gcpy #              getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
2518 gcpy #              getypos()-(math.sqrt((tool_diameter(KH_tool_num, 1)^2)-
2519 gcpy #              tool_diameter(KH_tool_num, 5)^2))/2, //((kh_max_depth-6.34)
2520 gcpy #              /2)^2-(tool_diameter(KH_tool_num, (kh_max_depth-6.34))/2)^2,
2521 gcpy #              getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
2522 gcpy #              //end position at top of slot
2523 gcpy #              getypos()-kh_distance,
2524 gcpy #              KH_tool_num);
2525 gcpy #          //left of slot
2526 gcpy #          dxfline(
2527 gcpy #              getxpos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
2528 gcpy #              getypos()-(math.sqrt((tool_diameter(KH_tool_num, 1)^2)-
2529 gcpy #              tool_diameter(KH_tool_num, 5)^2))/2, //((kh_max_depth-6.34)
2530 gcpy #              /2)^2-(tool_diameter(KH_tool_num, (kh_max_depth-6.34))/2)^2,
2531 gcpy #              getxpos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
2532 gcpy #              //end position at top of slot
2533 gcpy #              getypos()-kh_distance,
2534 gcpy #              KH_tool_num);
2535 gcpy #          //Lower right of entry hole
2536 gcpy #          dxfarc(getxpos(), getypos(), 9.525/2, 360-acos(tool_diameter(
2537 gcpy #          KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), 360, KH_tool_num
2538 gcpy #          );
2539 gcpy #          //Lower left of entry hole
2540 gcpy #          dxfarc(getxpos(), getypos(), 9.525/2, 180, 180+acos(
2541 gcpy #          tool_diameter(KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)),
2542 gcpy #          KH_tool_num);
2543 gcpy #          hull(){
2544 gcpy #              translate([xpos(), ypos(), zpos()]){
2545 gcpy #                  keyhole_shaft(6.35, 9.525);

```

---

```

2546 gcpy #      translate([xpos(), ypos()-kh_distance, zpos()-kh_max_depth])
{
2547 gcpy #      keyhole_shaft(6.35, 9.525);
2548 gcpy #
2549 gcpy #
2550 gcpy #      cutwithfeed(getxpos(), getypos(), -kh_max_depth, feed);
2551 gcpy #      cutwithfeed(getxpos(), getypos()-kh_distance, -kh_max_depth,
2552 gcpy #          feed);
2553 gcpy #      setypos(getypos()+kh_distance);
2554 gcpy #
}

```

---

**3.8.1.1.4 Dovetail joinery and tooling** One focus of this project from the beginning has been cutting joinery. The first such toolpath to be developed is half-blind dovetails, since they are intrinsically simple to calculate since their geometry is dictated by the geometry of the tool.

BlocksCAD project page at: <https://www.blockscad3d.com/community/projects/1941456> and discussion at: <https://community.carbide3d.com/t/tool-paths-for-different-sized-dovetail-bit-89098>

Making such cuts will require dovetail tooling such as:

- 808079 <https://www.amanatool.com/45828-carbide-tipped-dovetail-8-deg-x-1-2-dia-x-825-x-1.html>
- 814 <https://www.leevalley.com/en-us/shop/tools/power-tool-accessories/router-bits/30172-dovetail-bits?item=18J1607>

Two commands are required:

---

```

2556 gcpy     def cut_pins(self, Joint_Width, stockZthickness,
2557 gcpy         Number_of_Dovetails, Spacing, Proportion, DTT_diameter,
2558 gcpy         DTT_angle):
2559 gcpy         DTO = Tan(DTT_angle) * (stockZthickness * Proportion)
2560 gcpy         DTR = DTT_diameter/2 - DTO
2561 gcpy         cpr = self.rapidXY(0, stockZthickness + Spacing/2)
2562 gcpy         ctp = self.cutlinedxfgc(self.xpos(), self.ypos(), -
2563 gcpy             stockZthickness * Proportion)
2564 gcpy         ctp = ctp.union(self.cutlinedxfgc(Joint_Width / (
2565 gcpy             Number_of_Dovetails * 2), self.ypos(), -stockZthickness *
2566 gcpy             Proportion))
2567 gcpy         i = 1
2568 gcpy         while i < Number_of_Dovetails * 2:
2569 gcpy             print(i)
2570 gcpy             ctp = ctp.union(self.cutlinedxfgc(i * (Joint_Width / (
2571 gcpy                 Number_of_Dovetails * 2)), self.ypos(), -
2572 gcpy                 stockZthickness * Proportion))
2573 gcpy             ctp = ctp.union(self.cutlinedxfgc(i * (Joint_Width / (
2574 gcpy                 Number_of_Dovetails * 2)), (stockZthickness +
2575 gcpy                 Spacing) + (stockZthickness * Proportion) - (
2576 gcpy                     DTT_diameter/2), -(stockZthickness * Proportion)))
2577 gcpy             ctp = ctp.union(self.cutlinedxfgc(i * (Joint_Width / (
2578 gcpy                 Number_of_Dovetails * 2)), stockZthickness + Spacing
2579 gcpy                 / 2, -(stockZthickness * Proportion)))
2580 gcpy             ctp = ctp.union(self.cutlinedxfgc((i + 1) * (
2581 gcpy                 Joint_Width / (Number_of_Dovetails * 2)),
2582 gcpy                 stockZthickness + Spacing/2, -(stockZthickness *
2583 gcpy                 Proportion)))
2584 gcpy             self.dxfractangleround(self.currenttoolnumber(),
2585 gcpy                 i * (Joint_Width / (Number_of_Dovetails * 2))-DTR,
2586 gcpy                 stockZthickness + (Spacing/2) - DTR,
2587 gcpy                 DTR * 2,
2588 gcpy                 (stockZthickness * Proportion) + Spacing/2 + DTR *
2589 gcpy                 2 - (DTT_diameter/2),
2590 gcpy                 DTR)
2591 gcpy             i += 2
2592 gcpy             self.rapidZ(0)
2593 gcpy             return ctp

```

---

and

---

```

2579 gcpy     def cut_tails(self, Joint_Width, stockZthickness,
2580 gcpy         Number_of_Dovetails, Spacing, Proportion, DTT_diameter,
2581 gcpy         DTT_angle):
2582 gcpy         DTO = Tan(DTT_angle) * (stockZthickness * Proportion)
2583 gcpy         DTR = DTT_diameter/2 - DTO
2584 gcpy         cpr = self.rapidXY(0, 0)

```

---

```

2583 gcpy          ctp = self.cutlinedxfgc(self.xpos(), self.ypos(), -
2584 gcpy          stockZthickness * Proportion)
2585 gcpy          ctp = ctp.union(self.cutlinedxfgc(
2586 gcpy          Joint_Width / (Number_of_Dovetails * 2) - (DTT_diameter
2587 gcpy          - DTO),
2588 gcpy          self.ypos(),
2589 gcpy          -stockZthickness * Proportion))
2590 gcpy          i = 1
2591 gcpy          while i < Number_of_Dovetails * 2:
2592 gcpy          ctp = ctp.union(self.cutlinedxfgc(
2593 gcpy          i * (Joint_Width / (Number_of_Dovetails * 2)) - (
2594 gcpy          DTT_diameter - DTO),
2595 gcpy          stockZthickness * Proportion - DTT_diameter / 2,
2596 gcpy          -(stockZthickness * Proportion)))
2597 gcpy #        ctp = ctp.union(self.cutarcCWdx(180, 90,
2598 gcpy          i * (Joint_Width / (Number_of_Dovetails * 2)),
2599 gcpy          stockZthickness * Proportion - DTT_diameter / 2,
2600 gcpy          self.ypos(),
2601 gcpy          DTT_diameter - DTO, 0, 1))
2602 gcpy          ctp = ctp.union(self.cutarcCWdx(90, 0,
2603 gcpy          i * (Joint_Width / (Number_of_Dovetails * 2)),
2604 gcpy          stockZthickness * Proportion - DTT_diameter / 2,
2605 gcpy          self.ypos(),
2606 gcpy          DTT_diameter - DTO, 0, 1))
2607 gcpy          ctp = ctp.union(self.cutlinedxfgc(
2608 gcpy          (i + 2) * (Joint_Width / (Number_of_Dovetails * 2))
2609 gcpy          - (DTT_diameter - DTO),
2610 gcpy          0,
2611 gcpy          -(stockZthickness * Proportion)))
2612 gcpy          self.rapidZ(0)
2613 gcpy          self.rapidXY(0, 0)
2614 gcpy          ctp = ctp.union(self.cutlinedxfgc(self.xpos(), self.ypos(),
2615 gcpy          -stockZthickness * Proportion))
2616 gcpy          self.dxfarc(self.currenttoolnumber(), 0, 0, DTR, 180, 270)
2617 gcpy          self.dxfline(self.currenttoolnumber(), -DTR, 0, -DTR,
2618 gcpy          stockZthickness + DTR)
2619 gcpy          self.dxfarc(self.currenttoolnumber(), 0, stockZthickness +
2620 gcpy          DTR, DTR, 90, 180)
2621 gcpy          self.dxfline(self.currenttoolnumber(), 0, stockZthickness +
2622 gcpy          DTR * 2, Joint_Width, stockZthickness + DTR * 2)
2623 gcpy          i = 0
2624 gcpy          while i < Number_of_Dovetails * 2:
2625 gcpy          ctp = ctp.union(self.cutline(i * (Joint_Width /
2626 gcpy          Number_of_Dovetails * 2)), stockZthickness + DTO, -(

2627 gcpy          stockZthickness * Proportion)))
2628 gcpy          ctp = ctp.union(self.cutline((i+2) * (Joint_Width /
2629 gcpy          Number_of_Dovetails * 2)), stockZthickness + DTO, -(

2630 gcpy          stockZthickness * Proportion)))
2631 gcpy          self.dxfarc(self.currenttoolnumber(), i * (Joint_Width /
2632 gcpy          / (Number_of_Dovetails * 2)), 0, DTR, 270, 360)
2633 gcpy          self.dxfline(self.currenttoolnumber(),
2634 gcpy          i * (Joint_Width / (Number_of_Dovetails * 2)) + DTR
2635 gcpy          ,
2636 gcpy          0,
2637 gcpy          i * (Joint_Width / (Number_of_Dovetails * 2)) + DTR
2638 gcpy          , stockZthickness * Proportion - DTT_diameter / 2)
2639 gcpy          self.dxfarc(self.currenttoolnumber(), (i + 1) * (
2640 gcpy          Joint_Width / (Number_of_Dovetails * 2)),
2641 gcpy          stockZthickness * Proportion - DTT_diameter / 2, (
2642 gcpy          Joint_Width / (Number_of_Dovetails * 2)) - DTR, 90,
2643 gcpy          180)
2644 gcpy          self.dxfarc(self.currenttoolnumber(), (i + 1) * (
2645 gcpy          Joint_Width / (Number_of_Dovetails * 2)),
2646 gcpy          stockZthickness * Proportion - DTT_diameter / 2, (
2647 gcpy          Joint_Width / (Number_of_Dovetails * 2)) - DTR, 0,
2648 gcpy          90)
2649 gcpy          self.dxfline(self.currenttoolnumber(),
2650 gcpy          (i + 2) * (Joint_Width / (Number_of_Dovetails * 2))
2651 gcpy          - DTR,

```

---

```

2633 gcpy          0,
2634 gcpy          (i + 2) * (Joint_Width / (Number_of_Dovetails * 2))
                  - DTR, stockZthickness * Proportion -
                  DTT_diameter / 2)
2635 gcpy          self.dxfarc(self.currenttoolnumber(), (i + 2) * (
                  Joint_Width / (Number_of_Dovetails * 2)), 0, DTR,
                  180, 270)
2636 gcpy          i += 2
2637 gcpy          self.dxfarc(self.currenttoolnumber(), Joint_Width,
                  stockZthickness + DTR, DTR, 0, 90)
2638 gcpy          self.dxfline(self.currenttoolnumber(), Joint_Width + DTR,
                  stockZthickness + DTR, Joint_Width + DTR, 0)
2639 gcpy          self.dxfarc(self.currenttoolnumber(), Joint_Width, 0, DTR,
                  270, 360)
2640 gcpy          return ctp

```

---

which are used as:

```
toolpaths = gcp.cut_pins(stockXwidth, stockZthickness, Number_of_Dovetails, Spacing, Proportion, DTT_dia
```

```
toolpaths.append(gcp.cut_tails(stockXwidth, stockZthickness, Number_of_Dovetails, Spacing, Proportion, DTT_dia
```

Future versions may adjust the parameters passed in, having them calculate from the specifications for the currently active dovetail tool.

**3.8.1.1.5 Full-blind box joints** BlocksCAD project page at: <https://www.blockscad3d.com/community/projects/1943966> and discussion at: <https://community.carbide3d.com/t/full-blind-box-joints-in-carbide-create/53329>

Full-blind box joints will require 3 separate tools:

- small V tool — this will be needed to make a cut along the edge of the joint
- small square tool — this should be the same diameter as the small V tool
- large V tool — this will facilitate the stock being of a greater thickness and avoid the need to make multiple cuts to cut the blind miters at the ends of the joint

Two different versions of the commands will be necessary, one for each orientation:

- horizontal
- vertical

and then the internal commands for each side will in turn need separate versions:

---

```

2642 gcpy      def Full_Blind_Finger_Joint_square(self, bx, by, orientation,
2643 gcpy          side, width, thickness, Number_of_Pins, largeVdiameter,
2644 gcpy          smallDiameter, normalormirror = "Default"):
2645 gcpy          # Joint_Orientation = "Horizontal" "Even" == "Lower", "Odd" ==
2646 gcpy          "Upper"
2647 gcpy          # Joint_Orientation = "Vertical" "Even" == "Left", "Odd" == "
2648 gcpy          Right"
2649 gcpy          if (orientation == "Vertical"):
2650 gcpy              if (normalormirror == "Default" and side != "Both"):
2651 gcpy                  if (side == "Left"):
2652 gcpy                      normalormirror = "Even"
2653 gcpy                  if (side == "Right"):
2654 gcpy                      normalormirror = "Odd"
2655 gcpy          if (orientation == "Horizontal"):
2656 gcpy              if (normalormirror == "Default" and side != "Both"):
2657 gcpy                  if (side == "Lower"):
2658 gcpy                      Finger_Origin = width/2 - Finger_Width/2
2659 gcpy                  rapid = self.rapidZ(0)
2660 gcpy                  self.setdxffcolor("Cyan")
2661 gcpy                  rapid = rapid.union(self.rapidXY(bx, by))
2662 gcpy                  toolpath = (self.Finger_Joint_square(bx, by, orientation,
2663 gcpy                      side, width, thickness, Number_of_Pins, Finger_Origin,
2664 gcpy                      smallDiameter))
2665 gcpy          if (orientation == "Vertical"):
2666 gcpy              if (side == "Both"):
2667 gcpy                  toolpath = self.cutrectanglerounddxff(self.
2668 gcpy                      currenttoolnum, bx - (thickness - smallDiameter
2669 gcpy                      /2), by-smallDiameter/2, 0, (thickness * 2) -
2670 gcpy                      smallDiameter, width+smallDiameter, (
2671 gcpy                      smallDiameter / 2) / Tan(45), smallDiameter/2)

```

```

2666 gcpy
2667 gcpy
2668 gcpy
2669 gcpy
2670 gcpy
2671 gcpy
2672 gcpy
2673 gcpy
2674 gcpy
2675 gcpy
2676 gcpy
2677 gcpy
2678 gcpy
2679 gcpy
2680 gcpy
2681 gcpy
2682 gcpy
2683 gcpy
2684 gcpy
2685 gcpy
2686 gcpy
2687 gcpy
2688 gcpy
2689 gcpy
2690 gcpy
2691 gcpy
2692 gcpy
2693 gcpy
2694 gcpy
2695 gcpy
2696 gcpy
2697 gcpy
2698 gcpy
2699 gcpy
2700 gcpy
2701 gcpy
2702 gcpy
2703 gcpy
2704 gcpy
2705 gcpy
2706 gcpy
2707 gcpy
2708 gcpy
2709 gcpy
2710 gcpy
2711 gcpy
2712 gcpy
2713 gcpy
2714 gcpy
2715 gcpy
2716 gcpy
2717 gcpy
2718 gcpy
2719 gcpy
2720 gcpy
2721 gcpy
2722 gcpy
2723 gcpy
2724 gcpy
2725 gcpy
2726 gcpy

        if (side == "Left"):
            toolpath = self.cutrectanglerounddx( self.
                currenttoolnum, bx - (smallDiameter/2), by-
                smallDiameter/2, 0, thickness, width+
                smallDiameter, ((smallDiameter / 2) / Tan(45)),
                smallDiameter/2)
        if (side == "Right"):
            toolpath = self.cutrectanglerounddx( self.
                currenttoolnum, bx - (thickness - smallDiameter
                /2), by-smallDiameter/2, 0, thickness, width+
                smallDiameter, ((smallDiameter / 2) / Tan(45)),
                smallDiameter/2)
    toolpath = toolpath.union(self.Finger_Joint_square(bx, by,
        orientation, side, width, thickness, Number_of_Pins,
        Finger_Origin, smallDiameter))
    if (orientation == "Horizontal"):
        if (side == "Both"):
            toolpath = self.cutrectanglerounddx(
                self.currenttoolnum,
                bx-smallDiameter/2,
                by - (thickness - smallDiameter/2),
                0,
                width+smallDiameter,
                (thickness * 2) - smallDiameter,
                (smallDiameter / 2) / Tan(45),
                smallDiameter/2)
        if (side == "Lower"):
            toolpath = self.cutrectanglerounddx(
                self.currenttoolnum,
                bx - (smallDiameter/2),
                by - smallDiameter/2,
                0,
                width+smallDiameter,
                thickness,
                ((smallDiameter / 2) / Tan(45)),
                smallDiameter/2)
        if (side == "Upper"):
            toolpath = self.cutrectanglerounddx(
                self.currenttoolnum,
                bx - smallDiameter/2,
                by - (thickness - smallDiameter/2),
                0,
                width+smallDiameter,
                thickness,
                ((smallDiameter / 2) / Tan(45)),
                smallDiameter/2)
    toolpath = toolpath.union(self.Finger_Joint_square(bx, by,
        orientation, side, width, thickness, Number_of_Pins,
        Finger_Origin, smallDiameter))
    return toolpath

def Finger_Joint_square(self, bx, by, orientation, side, width,
    thickness, Number_of_Pins, Finger_Origin, smallDiameter,
    normalormirror = "Default"):
    jointdepth = -(thickness - (smallDiameter / 2) / Tan(45))
    # Joint_Orientation = "Horizontal" "Even" == "Lower", "Odd" ==
    "Upper"
    # Joint_Orientation = "Vertical" "Even" == "Left", "Odd" == "
    Right"
    if (orientation == "Vertical"):
        if (normalormirror == "Default" and side != "Both"):
            if (side == "Left"):
                normalormirror = "Even"
            if (side == "Right"):
                normalormirror = "Odd"
    if (orientation == "Horizontal"):
        if (normalormirror == "Default" and side != "Both"):
            if (side == "Lower"):
                normalormirror = "Even"
            if (side == "Upper"):
                normalormirror = "Odd"
    radius = smallDiameter/2
    jointwidth = thickness - smallDiameter
    toolpath = self.currenttool()
    rapid = self.rapidZ(0)
    self.setdxfcolor("Blue")
    toolpath = toolpath.union(self.cutlineZgcfeed(jointdepth
        ,1000))

```

```

2727 gcpy         self.beginpolyline(self.currenttool())
2728 gcpy         if (orientation == "Vertical"):
2729 gcpy             rapid = rapid.union(self.rapidXY(bx, by + Finger_Origin
2730 gcpy                 ))
2731 gcpy             self.addvertex(self.currenttoolnumber(), self.xpos(),
2732 gcpy                 self.ypos())
2733 gcpy             toolpath = toolpath.union(self.cutlineZgcfeed(
2734 gcpy                 jointdepth,1000))
2735 gcpy             i = 0
2736 gcpy             while i <= Number_of_Pins - 1:
2737 gcpy                 if (side == "Right"):
2738 gcpy                     toolpath = toolpath.union(self.cutvertexdxdf(
2739 gcpy                         self.xpos(), self.ypos() + smallDiameter +
2740 gcpy                             radius/5, jointdepth))
2741 gcpy                     if (side == "Left" or side == "Both"):
2742 gcpy                         toolpath = toolpath.union(self.cutvertexdxdf(
2743 gcpy                             self.xpos(), self.ypos() + radius,
2744 gcpy                             jointdepth))
2745 gcpy                     toolpath = toolpath.union(self.cutvertexdxdf(
2746 gcpy                         self.xpos() - jointwidth, self.ypos(),
2747 gcpy                         jointdepth))
2748 gcpy                     if (side == "Left"):
2749 gcpy                         toolpath = toolpath.union(self.cutvertexdxdf(
2750 gcpy                             self.xpos(), self.ypos() + smallDiameter +
2751 gcpy                             radius/5, jointdepth))
2752 gcpy                         i += 1
2753 gcpy # Joint_Orientation = "Horizontal" "Even" == "Lower", "Odd" ==
2754 gcpy             "Upper"
2755 gcpy             if (orientation == "Horizontal"):
2756 gcpy                 rapid = rapid.union(self.rapidXY(bx + Finger_Origin, by
2757 gcpy                     ))
2758 gcpy                 self.addvertex(self.currenttoolnumber(), self.xpos(),
2759 gcpy                     self.ypos())
2760 gcpy                 toolpath = toolpath.union(self.cutlineZgcfeed(
2761 gcpy                     jointdepth,1000))
2762 gcpy                 i = 0
2763 gcpy                 while i <= Number_of_Pins - 1:
2764 gcpy                     if (side == "Upper"):
2765 gcpy                         toolpath = toolpath.union(self.cutvertexdxdf(

```

```

2766 gcpy
2767 gcpy
2768 gcpy
2769 gcpy
2770 gcpy
2771 gcpy
2772 gcpy #
2773 gcpy
2774 gcpy
2775 gcpy
2776 gcpy
2777 gcpy
2778 gcpy
2779 gcpy
2780 gcpy
2781 gcpy
2782 gcpy
2783 gcpy
2784 gcpy
2785 gcpy
2786 gcpy
2787 gcpy
2788 gcpy
2789 gcpy
2790 gcpy
2791 gcpy
2792 gcpy
2793 gcpy
2794 gcpy
2795 gcpy
2796 gcpy
2797 gcpy
2798 gcpy
2799 gcpy
2800 gcpy
2801 gcpy
2802 gcpy
2803 gcpy
2804 gcpy
2805 gcpy
2806 gcpy
2807 gcpy
2808 gcpy
2809 gcpy
2810 gcpy
2811 gcpy
2812 gcpy
2813 gcpy

        toolpath = toolpath.union(self.cutvertexdxf(
            self.xpos(), self.ypos() - jointwidth,
            jointdepth))
        toolpath = toolpath.union(self.cutvertexdxf(
            self.xpos() + radius, self.ypos(),
            jointdepth))
    if (side == "Lower"):
        toolpath = toolpath.union(self.cutvertexdxf(
            self.xpos() + smallDiameter + radius/5, self
            .ypos(), jointdepth))
    if (side == "Upper" or side == "Both"):
        if (i < (Number_of_Pins - 1)):
            print(i)
        toolpath = toolpath.union(self.cutvertexdxf(
            (self.xpos() + radius, self.ypos(),
            jointdepth)))
        toolpath = toolpath.union(self.cutvertexdxf(
            (self.xpos(), self.ypos() - jointwidth,
            jointdepth)))
        toolpath = toolpath.union(self.cutvertexdxf(
            (self.xpos() + radius/5, self.ypos(),
            jointdepth)))
    toolpath = toolpath.union(self.cutvertexdxf(
        (self.xpos(), self.ypos() + jointwidth,
        jointdepth)))
    toolpath = toolpath.union(self.cutvertexdxf(
        (self.xpos() + radius, self.ypos(),
        jointdepth)))
    i += 1
self.closepolyline(self.currenttoolnumber())
return toolpath

def Full_Blind_Finger_Joint_smallV(self, bx, by, orientation,
side, width, thickness, Number_of_Pins, largeVdiameter,
smallDiameter):
    rapid = self.rapidZ(0)
    # rapid = rapid.union(self.rapidXY(bx, by))
    self.setdxfcolor("Red")
    if (orientation == "Vertical"):
        rapid = rapid.union(self.rapidXY(bx, by - smallDiameter
/6))
    toolpath = self.cutlineZgcfeed(-thickness,1000)
    toolpath = self.cutlinedxfgc(bx, by + width +
smallDiameter/6, - thickness)
    if (orientation == "Horizontal"):
        rapid = rapid.union(self.rapidXY(bx - smallDiameter/6,
by))
    toolpath = self.cutlineZgcfeed(-thickness,1000)
    toolpath = self.cutlinedxfgc(bx + width + smallDiameter
/6, by, -thickness)
    # rapid = self.rapidZ(0)

    return toolpath

def Full_Blind_Finger_Joint_largeV(self, bx, by, orientation,
side, width, thickness, Number_of_Pins, largeVdiameter,
smallDiameter):
    radius = smallDiameter/2
    rapid = self.rapidZ(0)
    Finger_Width = ((Number_of_Pins * 2) - 1) * smallDiameter *
1.1
    Finger_Origin = width/2 - Finger_Width/2
    # rapid = rapid.union(self.rapidXY(bx, by))
    # Joint_Orientation = "Horizontal" "Even" == "Lower", "Odd" ==
"Upper"
    # Joint_Orientation = "Vertical" "Even" == "Left", "Odd" ==
"Right"
    if (orientation == "Vertical"):
        rapid = rapid.union(self.rapidXY(bx, by))
        toolpath = self.cutlineZgcfeed(-thickness,1000)
        toolpath = toolpath.union(self.cutlinedxfgc(bx, by +
Finger_Origin, -thickness))
    rapid = self.rapidZ(0)
    rapid = rapid.union(self.rapidXY(bx, by + width -
Finger_Origin))
    self.setdxfcolor("Blue")
    toolpath = toolpath.union(self.cutlineZgcfeed(-
thickness,1000))

```

```

2814 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx, by +
2815 gcpy          width, -thickness))
2816 gcpy          if (side == "Left" or side == "Both"):
2817 gcpy          rapid = self.rapidZ(0)
2818 gcpy          self.setdxfcolor("DarkGray")
2819 gcpy          rapid = rapid.union(self.rapidXY(bx+thickness-(smallDiameter / 2) / Tan(45), by - radius/2))
2820 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-(smallDiameter / 2) / Tan(45),10000))
2821 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx+thickness-(smallDiameter / 2) / Tan(45), by + width + radius/2, -(smallDiameter / 2) / Tan(45)))
2822 gcpy          rapid = self.rapidZ(0)
2823 gcpy          self.setdxfcolor("Green")
2824 gcpy          rapid = rapid.union(self.rapidXY(bx+thickness/2, by +width))
2825 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-thickness/2,1000))
2826 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx+thickness/2, by + width -thickness, -thickness/2))
2827 gcpy          rapid = self.rapidZ(0)
2828 gcpy          rapid = rapid.union(self.rapidXY(bx+thickness/2, by ))
2829 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-thickness/2,1000))
2830 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx+thickness/2, by +thickness, -thickness/2))
2831 gcpy          if (side == "Right" or side == "Both"):
2832 gcpy          rapid = self.rapidZ(0)
2833 gcpy          self.setdxfcolor("DarkGray")
2834 gcpy          rapid = rapid.union(self.rapidXY(bx-(thickness-(smallDiameter / 2) / Tan(45)), by - radius/2))
2835 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-(smallDiameter / 2) / Tan(45),10000))
2836 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx-(thickness-(smallDiameter / 2) / Tan(45)), by + width + radius/2, -(smallDiameter / 2) / Tan(45)))
2837 gcpy          rapid = self.rapidZ(0)
2838 gcpy          self.setdxfcolor("Green")
2839 gcpy          rapid = rapid.union(self.rapidXY(bx-thickness/2, by +width))
2840 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-thickness/2,1000))
2841 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx-thickness/2, by + thickness/2, by -thickness, -thickness/2))
2842 gcpy          rapid = self.rapidZ(0)
2843 gcpy          rapid = rapid.union(self.rapidXY(bx-thickness/2, by ))
2844 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-thickness/2,1000))
2845 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx-thickness/2, by +thickness, -thickness/2))
# Joint_Orientation = "Horizontal" "Even" == "Lower", "Odd" ==
# "Upper"
2846 gcpy          if (orientation == "Horizontal"):
2847 gcpy          rapid = rapid.union(self.rapidXY(bx, by))
2848 gcpy          self.setdxfcolor("Blue")
2849 gcpy          toolpath = self.cutlineZgcfeed(-thickness,1000)
2850 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx + Finger_Origin, by, -thickness))
2851 gcpy          rapid = rapid.union(self.rapidZ(0))
2852 gcpy          rapid = rapid.union(self.rapidXY(bx + width - Finger_Origin, by))
2853 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-thickness,1000))
2854 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx + width, by, -thickness))
2855 gcpy          if (side == "Lower" or side == "Both"):
2856 gcpy          rapid = self.rapidZ(0)
2857 gcpy          self.setdxfcolor("DarkGray")
2858 gcpy          rapid = rapid.union(self.rapidXY(bx - radius, by + thickness-(smallDiameter / 2) / Tan(45)))
2859 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-(smallDiameter / 2) / Tan(45),10000))

```

```

2860 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx +
2861 gcpy          width + radius, by+thickness-(smallDiameter / 2)
2862 gcpy          / Tan(45), -(smallDiameter / 2) / Tan(45)))
2863 gcpy          rapid = self.rapidZ(0)
2864 gcpy          self.setdxfcolor("Green")
2865 gcpy          rapid = rapid.union(self.rapidXY(bx+width, by+
2866 gcpy          thickness/2))
2867 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-
2868 gcpy          thickness/2,1000))
2869 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx +
2870 gcpy          width -thickness, by+thickness/2, -thickness/2))
2871 gcpy          rapid = self.rapidZ(0)
2872 gcpy          rapid = rapid.union(self.rapidXY(bx, by+thickness
2873 gcpy          /2))
2874 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-
2875 gcpy          thickness/2,1000))
2876 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx +
2877 gcpy          thickness, by+thickness/2, -thickness/2))
2878 gcpy          if (side == "Upper" or side == "Both"):
2879 gcpy          rapid = self.rapidZ(0)
2880 gcpy          self.setdxfcolor("DarkGray")
2881 gcpy          rapid = rapid.union(self.rapidXY(bx - radius, by-
2882 gcpy          thickness-(smallDiameter / 2) / Tan(45)))
2883 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-
2884 gcpy          thickness/2,10000))
2885 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx +
2886 gcpy          width + radius, by-(thickness-(smallDiameter /
2887 gcpy          2) / Tan(45)), -(smallDiameter / 2) / Tan(45)))
2888 gcpy          rapid = self.rapidZ(0)
2889 gcpy          return toolpath

2890 gcpy #       def Full_Blind_Finger_Joint(self, bx, by, orientation, side,
2891 gcpy          width, thickness, largeVdiameter, smallDiameter,
2892 gcpy          normalormirror = "Default", squaretool = 102, smallV = 390,
2893 gcpy          largeV = 301):
2894 gcpy          Number_of_Pins = int(((width - thickness * 2) / (
2895 gcpy          smallDiameter * 2.2) / 2) + 0.0) * 2 + 1
2896 gcpy          print("Number of Pins: ", Number_of_Pins)
2897 gcpy          self.movetosafeZ()
2898 gcpy          self.toolchange(squaretool, 17000)
2899 gcpy          toolpath = self.Full_Blind_Finger_Joint_square(bx, by,
2900 gcpy          orientation, side, width, thickness, Number_of_Pins,
2901 gcpy          largeVdiameter, smallDiameter)
2902 gcpy          self.movetosafeZ()
2903 gcpy          self.toolchange(smallV, 17000)
2904 gcpy          toolpath = toolpath.union(self.
2905 gcpy          Full_Blind_Finger_Joint_smallV(bx, by, orientation, side
2906 gcpy          , width, thickness, Number_of_Pins, largeVdiameter,
2907 gcpy          smallDiameter))
2908 gcpy          self.toolchange(largeV, 17000)
2909 gcpy          toolpath = toolpath.union(self.
2910 gcpy          Full_Blind_Finger_Joint_largeV(bx, by, orientation, side
2911 gcpy          , width, thickness, Number_of_Pins, largeVdiameter,
2912 gcpy          smallDiameter))
2913 gcpy          return toolpath

```

---

### 3.9 (Reading) G-code Files

With all other features in place, it becomes possible to read in a G-code file and then create a 3D preview of how it will cut.

First, a template file will be necessary:

---

```

1 gcpncpy #Requires OpenPythonSCAD, so load support for 3D modeling in that
          tool:
2 gcpncpy from openscad import *
3 gcpncpy
4 gcpncpy #The gcodepreview library must be loaded, either from github (first
          line below) or from a local library (second line below),
          uncomment one and comment out the other, depending on where one
          wishes to load from
5 gcpncpy #nimport("https://raw.githubusercontent.com/WillAdams/gcodepreview/
          refs/heads/main/gcodepreview.py")
6 gcpncpy from gcodepreview import *
7 gcpncpy
8 gcpncpy #The file to be loaded must be specified:
9 gcpncpy #gc_file = "filename_of_G-code_file_to_process.gcodefileext"
10 gcpncpy #
11 gcpncpy #if using windows the full filepath should be provided with
          backslashes replaced with double backslashes and wrapped in
          quotes since it is provided as a string:
12 gcpncpy gc_file = "C:\\\\Users\\\\willia\\\\OneDrive\\\\Desktop\\\\19mm_1_32_depth.nc"
13 gcpncpy
14 gcpncpy #Create the gcodepreview object:
15 gcpncpy gcp = gcodepreview("cut", False, False)
16 gcpncpy
17 gcpncpy #Process the file
18 gcpncpy gcp.previewgcodefile(gc_file)

```

---

previewgcodefile Which simply needs to call the previewgcodefile command:

---

```

2901 gcpy     def previewgcodefile(self, gc_file):
2902 gcpy         gc_file = open(gc_file, 'r')
2903 gcpy         gcfilecontents = []
2904 gcpy         with gc_file as file:
2905 gcpy             for line in file:
2906 gcpy                 command = line
2907 gcpy                 gcfilecontents.append(line)
2908 gcpy
2909 gcpy         numlinesfound = 0
2910 gcpy         for line in gcfilecontents:
2911 gcpy             print(line)
2912 gcpy             if line[:10] == "(stockMin:":
2913 gcpy                 subdivisions = line.split()
2914 gcpy                 extentleft = float(subdivisions[0][10:-3])
2915 gcpy                 extentfb = float(subdivisions[1][-3:])
2916 gcpy                 extentd = float(subdivisions[2][-3:])
2917 gcpy                 numlinesfound = numlinesfound + 1
2918 gcpy             if line[:13] == "(STOCK/BLOCK,":
2919 gcpy                 subdivisions = line.split()
2920 gcpy                 sizeX = float(subdivisions[0][13:-1])
2921 gcpy                 sizeY = float(subdivisions[1][-1])
2922 gcpy                 sizeZ = float(subdivisions[4][-1])
2923 gcpy                 numlinesfound = numlinesfound + 1
2924 gcpy             if line[:3] == "G21":
2925 gcpy                 units = "mm"
2926 gcpy                 numlinesfound = numlinesfound + 1
2927 gcpy             if numlinesfound >=3:
2928 gcpy                 break
2929 gcpy     print(numlinesfound)

```

---

Once the initial parameters are parsed, the stock may be set up:

---

```

2931 gcpy         self.setupcuttingarea(sizeX, sizeY, sizeZ, extentleft,
                                         extentfb, extentd)
2932 gcpy
2933 gcpy         commands = []
2934 gcpy         for line in gcfilecontents:
2935 gcpy             Xc = 0
2936 gcpy             Yc = 0
2937 gcpy             Zc = 0
2938 gcpy             Fc = 0
2939 gcpy             Xp = 0.0
2940 gcpy             Yp = 0.0
2941 gcpy             Zp = 0.0
2942 gcpy             if line == "G53G0Z-5.000\n":
2943 gcpy                 self.movetosafeZ()
2944 gcpy             if line[:3] == "M6T":
2945 gcpy                 tool = int(line[3:])
2946 gcpy                 self.toolchange(tool)

```

---

Processing tool changes will require examining lines such as:

```
;TOOL/MILL, Diameter, Corner radius, Height, Taper Angle
;TOOL/CRMILL, Diameter1, Diameter2, Radius, Height, Length
;TOOL/CHAMFER, Diameter, Point Angle, Height
```

which once parsed will be passed to a command which uses them to set the variables necessary to effect the toolchange:

```
if line[:11] == "(TOOL/MILL,"
    subdivisions = line.split()
    diameter = float(subdivisions[1][-3])
    cornerradius = float(subdivisions[2][-3])
    height = float(subdivisions[3][-3])
    taperangle = float(subdivisions[4][-3])
    self.settoolparameters("mill", diameter, cornerradius, height, taperangle)

if line[:14] == "(TOOL/CHAMFER,"
    subdivisions = line.split()
    tipdiameter = float(subdivisions[1][-3])
    diameter = float(subdivisions[2][-3])
    radius = float(subdivisions[3][-3])
    height = float(subdivisions[4][-3])
    length = float(subdivisions[4][-3])
    self.settoolparameters("chamfer", tipdiameter, diameter, radius, height, length)
```

---

```
2947 gcpy           if line[:2] == "G0":
2948 gcpy           machinestate = "rapid"
2949 gcpy           if line[:2] == "G1":
2950 gcpy           machinestate = "cutline"
2951 gcpy           if line[:2] == "G0" or line[:2] == "G1" or line[:1] ==
2952 gcpy           "X" or line[:1] == "Y" or line[:1] == "Z":
2953 gcpy           if "F" in line:
2954 gcpy           Fplus = line.split("F")
2955 gcpy           Fc = 1
2956 gcpy           fr = float(Fplus[1])
2957 gcpy           line = Fplus[0]
2958 gcpy           if "Z" in line:
2959 gcpy           Zplus = line.split("Z")
2960 gcpy           Zc = 1
2961 gcpy           Zp = float(Zplus[1])
2962 gcpy           line = Zplus[0]
2963 gcpy           if "Y" in line:
2964 gcpy           Yplus = line.split("Y")
2965 gcpy           Yc = 1
2966 gcpy           Yp = float(Yplus[1])
2967 gcpy           line = Yplus[0]
2968 gcpy           if "X" in line:
2969 gcpy           Xplus = line.split("X")
2970 gcpy           Xc = 1
2971 gcpy           Xp = float(Xplus[1])
2972 gcpy           if Zc == 1:
2973 gcpy           if Yc == 1:
2974 gcpy           if machinestate == "rapid":
2975 gcpy           command = "rapidXYZ(" + str(Xp) + "
2976 gcpy           ",_u" + str(Yp) + ",_u" + str(Zp) +
2977 gcpy           ")"
2978 gcpy           self.rapidXYZ(Xp, Yp, Zp)
2979 gcpy           else:
2980 gcpy           command = "cutlineXYZ(" + str(Xp) +
2981 gcpy           ",_u" + str(Yp) + ",_u" + str(Zp) +
2982 gcpy           ")"
2983 gcpy           self.cutlineXYZ(Xp, Yp, Zp)
2984 gcpy           else:
2985 gcpy           if machinestate == "rapid":
2986 gcpy           command = "rapidYZ(" + str(Yp) + ",

```

```

2987 gcpy
2988 gcpy
2989 gcpy
2990 gcpy
2991 gcpy
2992 gcpy
2993 gcpy
2994 gcpy
2995 gcpy
2996 gcpy
2997 gcpy
2998 gcpy
2999 gcpy
3000 gcpy
3001 gcpy
3002 gcpy
3003 gcpy
3004 gcpy
3005 gcpy
3006 gcpy
3007 gcpy
3008 gcpy
3009 gcpy
3010 gcpy
3011 gcpy
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3018 gcpy
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3020 gcpy
3021 gcpy
3022 gcpy
3023 gcpy
3024 gcpy
3025 gcpy
3026 gcpy
3027 gcpy #
3028 gcpy #
3029 gcpy #
3030 gcpy #
3031 gcpy #
3032 gcpy
3033 gcpy #
3034 gcpy #
3035 gcpy
3036 gcpy #
3037 gcpy

    else:
        if Xc == 1:
            if machinestate == "rapid":
                command = "rapidXZ(" + str(Xp) + ", "
                " " + str(Zp) + ")"
                self.rapidXZ(Xp, Zp)
            else:
                command = "cutlineXZ(" + str(Xp) +
                ", " + str(Zp) + ")"
                self.cutlineXZ(Xp, Zp)
        else:
            if machinestate == "rapid":
                command = "rapidZ(" + str(Zp) + ")"
                self.rapidZ(Zp)
            else:
                command = "cutlineZ(" + str(Zp) + " "
                ")"
                self.cutlineZ(Zp)

    else:
        if Yc == 1:
            if Xc == 1:
                if machinestate == "rapid":
                    command = "rapidXY(" + str(Xp) + ", "
                    " " + str(Yp) + ")"
                    self.rapidXY(Xp, Yp)
                else:
                    command = "cutlineXY(" + str(Xp) +
                    ", " + str(Yp) + ")"
                    self.cutlineXY(Xp, Yp)
            else:
                if machinestate == "rapid":
                    command = "rapidY(" + str(Yp) + ")"
                    self.rapidY(Yp)
                else:
                    command = "cutlineY(" + str(Yp) + " "
                    ")"
                    self.cutlineY(Yp)

    else:
        if Xc == 1:
            if machinestate == "rapid":
                command = "rapidX(" + str(Xp) + ")"
                self.rapidX(Xp)
            else:
                command = "cutlineX(" + str(Xp) + " "
                ")"
                self.cutlineX(Xp)
        commands.append(command)
        print(line)
        print(command)
        print(machinestate, Xc, Yc, Zc)
        print(Xp, Yp, Zp)
        print("/n")

for command in commands:
    print(command)
show(self.stockandtoolpaths())
self.stockandtoolpaths()

```

---

## 4 Notes

### 4.1 Other Resources

#### 4.1.1 Coding Style

A notable influence on the coding style in this project is John Ousterhout's *A Philosophy of Software Design*[SoftwareDesign]. Complexity is managed by the overall design and structure of the code, structuring it so that each component may be worked with on an individual basis, hiding the maximum information, and exposing the maximum functionality, with names selected so as to express their functionality/usage.

Red Flags to avoid include:

- Shallow Module
- Information Leakage
- Temporal Decomposition

- Overexposure
- Pass-Through Method
- Repetition
- Special-General Mixture
- Conjoined Methods
- Comment Repeats Code
- Implementation Documentation Contaminates Interface
- Vague Name
- Hard to Pick Name
- Hard to Describe
- Nonobvious Code

#### 4.1.2 Coding References

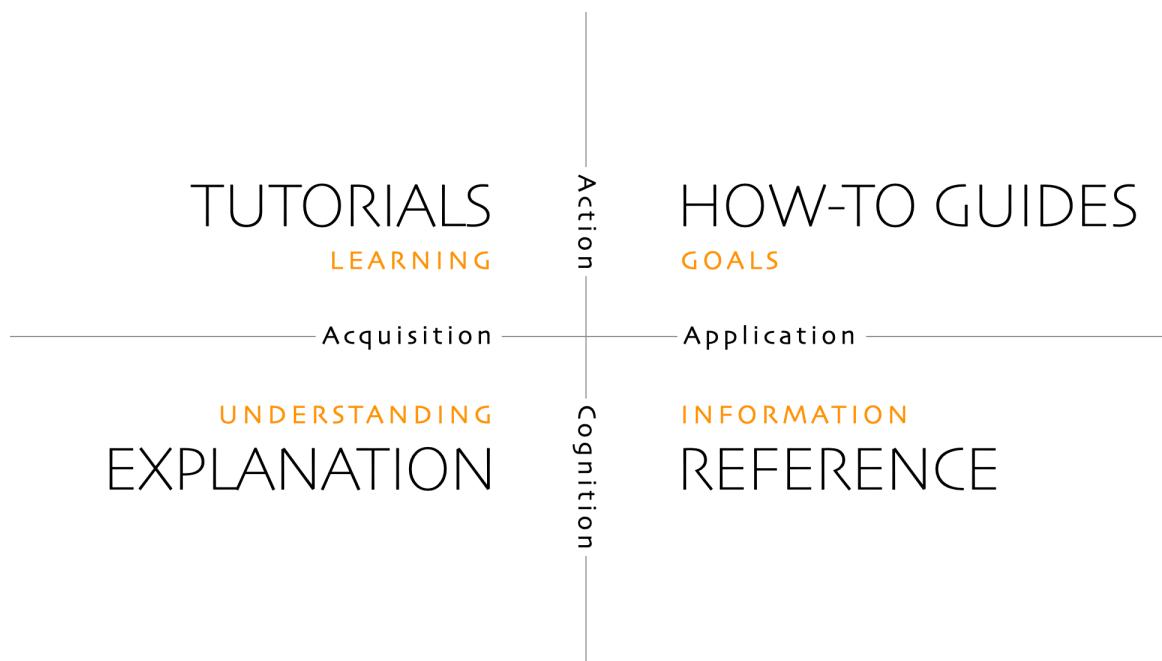
<https://thewhitetulip.gitbook.io/py/06-file-handling>

#### 4.1.3 Documentation Style

<https://diataxis.fr/> (originally developed at: <https://docs.divio.com/documentation-system/>)  
— divides documentation along two axes:

- Action (Practical) vs. Cognition (Theoretical)
- Acquisition (Studying) vs. Application (Working)

resulting in a matrix of:



where:

1. `readme.md` — (Overview) Explanation (understanding-oriented)
2. Templates — Tutorials (learning-oriented)
3. `gcodepreview` — How-to Guides (problem-oriented)
4. Index — Reference (information-oriented)

Straddling the boundary between coding and documentation are docstrings and general coding style with the latter discussed at: <https://peps.python.org/pep-0008/>

#### Holidays

Holidays are from <https://nationaltoday.com/>

#### DXFs

<http://www.paulbourke.net/dataformats/dxf/>  
<https://paulbourke.net/dataformats/dxf/min3d.html>

## 4.2 Future

### 4.2.1 Images

Would it be helpful to re-create code algorithms/sections using OpenSCAD Graph Editor so as to represent/illustrate the program?

### 4.2.2 Bézier curves in 2 dimensions

Take a Bézier curve definition and approximate it as arcs and write them into a DXF?

<https://pomax.github.io/bezierinfo/>  
<https://ciechanow.ski/curves-and-surfaces/>  
<https://www.youtube.com/watch?v=aVwxzDHniEw>  
c.f., <https://linuxcnc.org/docs/html/gcode/g-code.html#gcode:g5>

### 4.2.3 Bézier curves in 3 dimensions

One question is how many Bézier curves would it be necessary to have to define a surface in 3 dimensions. Attributes for this which are desirable/necessary:

- concise — a given Bézier curve should be represented by just the point coordinates, so two on-curve points, two off-curve points, each with a pair of coordinates
- For a given shape/region it will need to be possible to have a matching definition exactly match up with it so that one could piece together a larger more complex shape from smaller/simpler regions
- similarly it will be necessary for it to be possible to sub-divide a defined region — for example it should be possible if one had 4 adjacent regions, then the four quadrants at the intersection of the four regions could be used to construct a new region — is it possible to derive a new Bézier curve from half of two other curves?

For the three planes:

- XY
- XZ
- ZY

it should be possible to have three Bézier curves (left-most/right-most or front-back or top/bottom for two, and a mid-line for the third), so a region which can be so represented would be definable by:

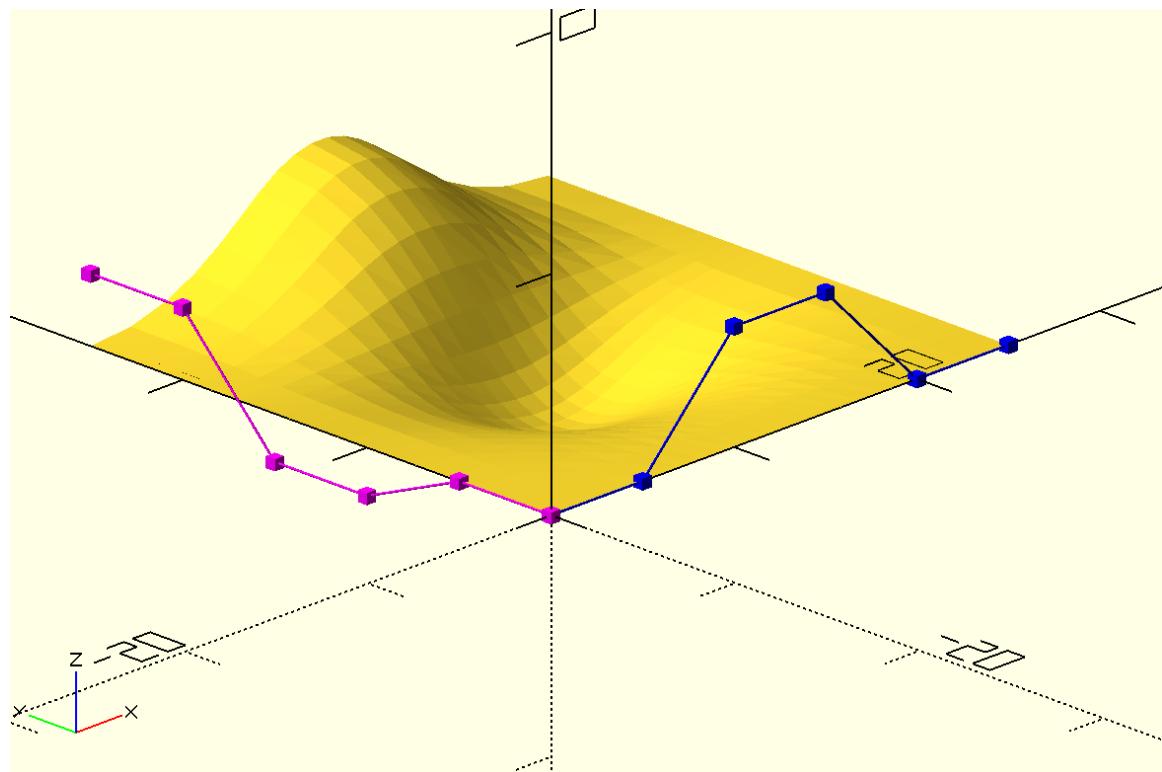
3 planes \* 3 Béziers \* (2 on-curve + 2 off-curve points) == 36 coordinate pairs

which is a marked contrast to representations such as:

<https://github.com/DavidPhillip0ster/Teapot>

and regions which could not be so represented could be sub-divided until the representation is workable.

Or, it may be that fewer (only two?) curves are needed:



<https://pages.mtu.edu/~shene/COURSES/cs3621/NOTES/notes.html>  
c.f., <https://github.com/BelfrySCAD/BOSL2/wiki/nurbs.scad> and [https://old.reddit.com/r/OpenPythonSCAD/comments/1gjcz4z/pythonscad\\_will\\_get\\_a\\_new\\_spline\\_function/](https://old.reddit.com/r/OpenPythonSCAD/comments/1gjcz4z/pythonscad_will_get_a_new_spline_function/)

#### 4.2.4 Mathematics

<https://elementsofprogramming.com/>

## References

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## Command Glossary

. [25](#)

**setupstock** setupstock(200, 100, 8.35, "Top", "Lower-left", 8.35). [23](#)

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