

The gcodepreview PythonSCAD library*

Author: William F. Adams
willadams at aol dot com

2025/11/30

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.

Contents

1	readme.md	4
2	Usage and Templates	8
2.1	gcpdxf.py	8
2.2	gcpcutdxf.py	12
2.3	gcodepreviewtemplate.py	14
2.4	gcodepreviewtemplate.scad	19
2.5	gpcthreadp.py	23
2.6	gcodepreviewtemplate.txt	24
3	gcodepreview	24
3.1	Cutviewer	25
3.1.1	Stock size and placement	25
3.1.2	Tool Shapes	25
3.2	Module Naming Convention	27
3.2.1	Parameters and Default Values	29
3.3	Implementation files and gcodepreview class	29
3.3.1	init	31
3.3.2	Position and Variables	33
3.3.3	Initial Modules	34
3.3.4	Adjustments and Additions	37
3.4	Tools and Shapes and Changes	37
3.4.1	Numbering for Tools	38
3.4.2	Laser support	51
3.5	Shapes and tool movement	52
3.5.1	Tooling for Undercutting Toolpaths	52
3.5.2	Generalized commands and cuts	52
3.5.3	Movement and color	52
3.5.4	tooldiameter	68
3.5.5	Feeds and Speeds	69
3.5.6	3D Printing	69
3.6	Difference of Stock, Rapids, and Toolpaths	80
3.7	Output files	81
3.7.1	Python and OpenSCAD File Handling	81
3.7.2	DXF Overview	84
3.7.3	G-code Overview	91
3.8	Cutting shapes and expansion	94
3.8.1	Building blocks	94
3.9	(Reading) G-code Files	113
4	Notes	116
4.1	Other Resources	116
4.1.1	Coding Style	116
4.1.2	Coding References	117
4.1.3	Documentation Style	117
4.2	Future	118
4.2.1	Images	118
4.2.2	Bézier curves in 2 dimensions	118
4.2.3	Bézier curves in 3 dimensions	118
4.2.4	Mathematics	119
	Index	122
	Routines	123
	Variables	124

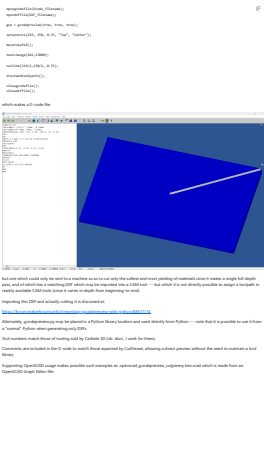
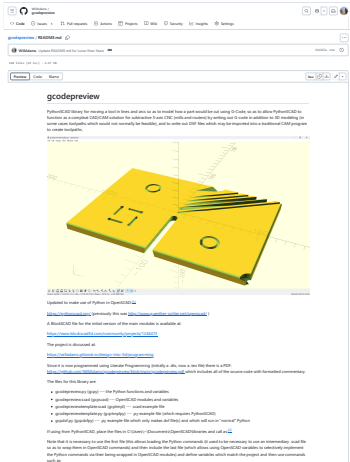
*This file (gcodepreview) has version number v0.93, last revised 2025/11/30.

Contents

1	readme.md	4
2	Usage and Templates	8
2.1	gcpdxf.py	8
2.2	gcpcutdxf.py	12
2.3	gcodepreviewtemplate.py	14
2.4	gcodepreviewtemplate.scad	19
2.5	gpcthreadp.py	23
2.6	gcodepreviewtemplate.txt	24
3	gcodepreview	24
3.1	Cutviewer	25
3.1.1	Stock size and placement	25
3.1.2	Tool Shapes	25
3.1.2.1	Tool/Mill (Square, radiused, ball-nose, and tapered-ball)	26
3.1.2.2	Corner Rounding, (roundover)	26
3.1.2.3	V shaped tooling (and variations)	27
3.2	Module Naming Convention	27
3.2.1	Parameters and Default Values	29
3.3	Implementation files and gcodepreview class	29
3.3.1	init	31
3.3.2	Position and Variables	33
3.3.3	Initial Modules	34
3.3.3.1	setupstock	34
3.3.3.2	setupcuttingarea	36
3.3.3.3	debug	36
3.3.4	Adjustments and Additions	37
3.4	Tools and Shapes and Changes	37
3.4.1	Numbering for Tools	38
3.4.1.1	toolchange	41
3.4.1.1.1	settoolparameters	41
3.4.1.1.2	toolchange	42
3.4.1.1.3	Square (including O-flute)	42
3.4.1.1.4	Ball-nose (including tapered-ball)	44
3.4.1.1.5	V	45
3.4.1.1.6	Keyhole	46
3.4.1.1.7	Bowl	47
3.4.1.1.8	Tapered ball nose	48
3.4.1.1.9	Roundover (cove tooling)	49
3.4.1.1.10	Dovetails	50
3.4.1.1.11	closing G-code	51
3.4.2	Laser support	51
3.5	Shapes and tool movement	52
3.5.1	Tooling for Undercutting Toolpaths	52
3.5.2	Generalized commands and cuts	52
3.5.3	Movement and color	52
3.5.3.1	toolmovement	53
3.5.3.1.1	Square (including O-flute)	54
3.5.3.1.2	Ball nose (including tapered ball nose)	54
3.5.3.1.3	bowl	54
3.5.3.1.4	V	54
3.5.3.1.5	Keyhole	55
3.5.3.1.6	Tapered ball nose	55
3.5.3.1.7	Dovetails	55
3.5.3.2	Concave toolshapes	56
3.5.3.2.1	Roundover tooling	56
3.5.3.3	shaftmovement	56
3.5.3.4	tool outlines	56
3.5.3.4.1	defineshaft	57
3.5.3.4.2	Square (including O-flute)	58
3.5.3.4.3	Ball-nose (including tapered-ball)	58
3.5.3.4.4	V tool outline	58
3.5.3.4.5	Keyhole outline	59
3.5.3.4.6	Bowl outline	59
3.5.3.4.7	Tapered ball nose	59
3.5.3.4.8	Roundover (cove tooling)	59
3.5.3.5	rapid and cut (lines)	60
3.5.3.6	Arcs	62
3.5.4	tooldiameter	68
3.5.5	Feeds and Speeds	69

3.5.6	3D Printing	69
3.5.6.1	Sample 3D printing file	70
3.5.6.2	Feed and Speed ratio	73
3.5.6.3	Time and Firmware for 3D printers	73
3.6	Difference of Stock, Rapids, and Toolpaths	80
3.7	Output files	81
3.7.1	Python and OpenSCAD File Handling	81
3.7.2	DXF Overview	84
3.7.2.1	Writing to DXF files	84
3.7.2.1.1	DXF Lines and Arcs	85
3.7.3	G-code Overview	91
3.7.3.1	Closings	93
3.8	Cutting shapes and expansion	94
3.8.1	Building blocks	94
3.8.1.1	List of shapes	94
3.8.1.1.1	circles	96
3.8.1.1.2	rectangles	96
3.8.1.1.3	Keyhole toolpath and undercut tooling	99
3.8.1.1.4	Dovetail joinery and tooling	106
3.8.1.1.5	Full-blind box joints	108
3.9	(Reading) G-code Files	113
4	Notes	116
4.1	Other Resources	116
4.1.1	Coding Style	116
4.1.2	Coding References	117
4.1.3	Documentation Style	117
4.2	Future	118
4.2.1	Images	118
4.2.2	Bézier curves in 2 dimensions	118
4.2.3	Bézier curves in 3 dimensions	118
4.2.4	Mathematics	119
	Index	122
	Routines	123
	Variables	124

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    .opendxf(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     closedxf();
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, dxfrectangle
           |
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

```

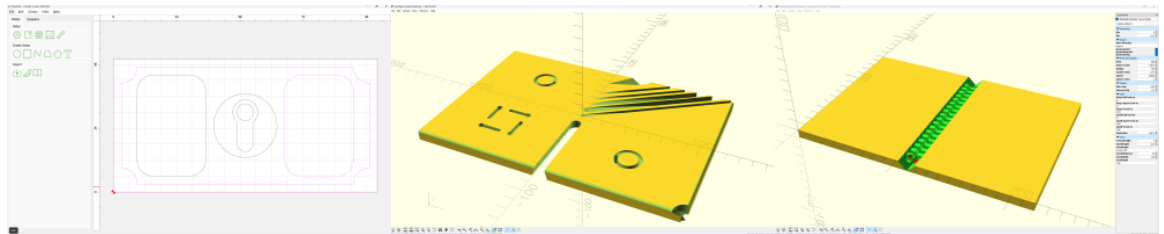
```
        use for stock, or possibly preserve the state after one cut and
        then rotate the cut stock/part)
113 rdme - support for additional tooling shapes (lollipop cutters)
114 rdme - create a single line font for use where text is wanted
115 rdme - Support for METAPOST and Bézier curves (latter 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/DXFs 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 allows 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/
3               gcodepreview/refs/heads/main/gcodepreview.py")
4 gcpdxfpy from gcodepreview import *
5 gcpdxfpy
6 gcpdxfpy gcp = gcodepreview("no_preview", # "cut" or "print"
7               False, # generategcode
8               True  # generatedxf
9               )
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.dxfrectangle(large_square_tool_num, 0, 0, stockXwidth,
50                           stockYheight)
51 gcpdxfpy
52 gcpdxfpy gcp.setdxfcolor("Red")
53 gcpdxfpy
54 gcpdxfpy gcp.dxfarc(large_square_tool_num, inset, inset, radius, 0, 90)
55 gcpdxfpy gcp.dxfarc(large_square_tool_num, stockXwidth - inset, inset,
56                     radius, 90, 180)
57 gcpdxfpy gcp.dxfarc(large_square_tool_num, stockXwidth - inset, stockYheight
58                     - inset, radius, 180, 270)
59 gcpdxfpy gcp.dxfarc(large_square_tool_num, inset, stockYheight - inset,
60                     radius, 270, 360)
61 gcpdxfpy
62 gcpdxfpy gcp.dxfline(large_square_tool_num, inset, inset + radius, inset,
63                     stockYheight - (inset + radius))
64 gcpdxfpy gcp.dxfline(large_square_tool_num, inset + radius, inset,
65                     stockXwidth - (inset + radius), inset)
66 gcpdxfpy gcp.dxfline(large_square_tool_num, stockXwidth - inset, inset +
67                     radius, stockXwidth - inset, stockYheight - (inset + radius))
68 gcpdxfpy gcp.dxfline(large_square_tool_num, inset + radius, stockYheight -
69                     inset, stockXwidth - (inset + radius), stockYheight - inset)
70 gcpdxfpy
71 gcpdxfpy gcp.setdxfcolor("Blue")
72 gcpdxfpy
73 gcpdxfpy gcp.dxfrectangle(large_square_tool_num, radius + inset, radius,
74                           stockXwidth/2 - (radius * 4), stockYheight - (radius * 2),
75                           cornerstyle, radius)
76 gcpdxfpy gcp.dxfrectangle(large_square_tool_num, stockXwidth/2 + (radius *
77                           2) + inset, radius, stockXwidth/2 - (radius * 4), stockYheight -

```

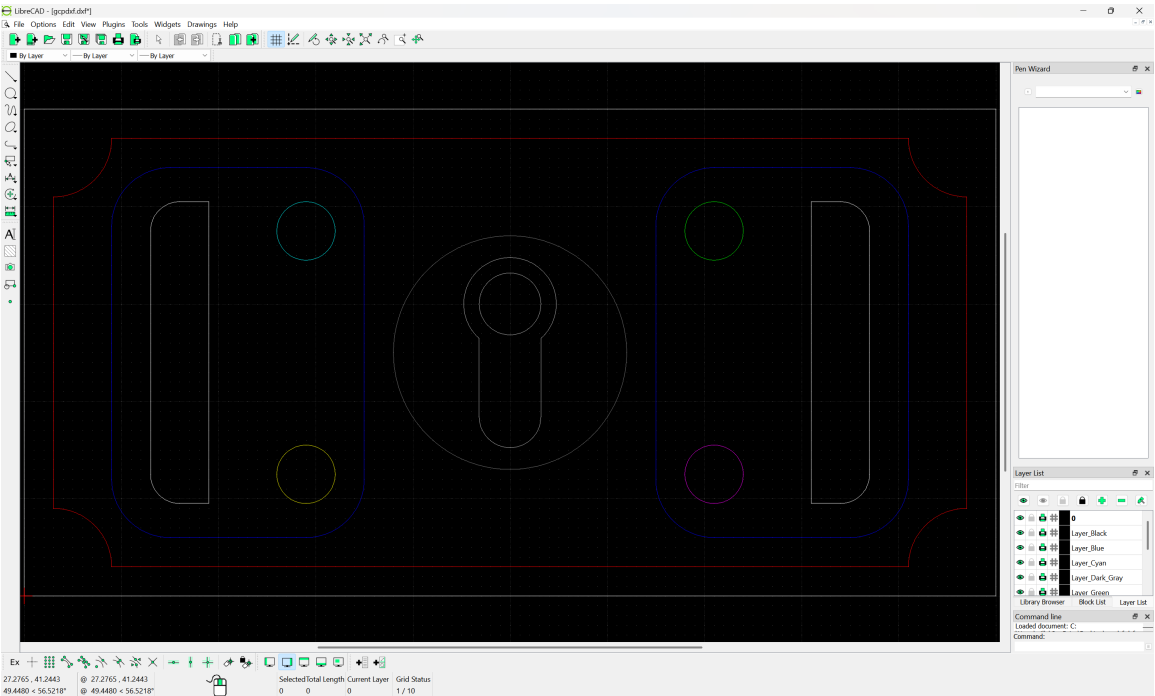
```

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

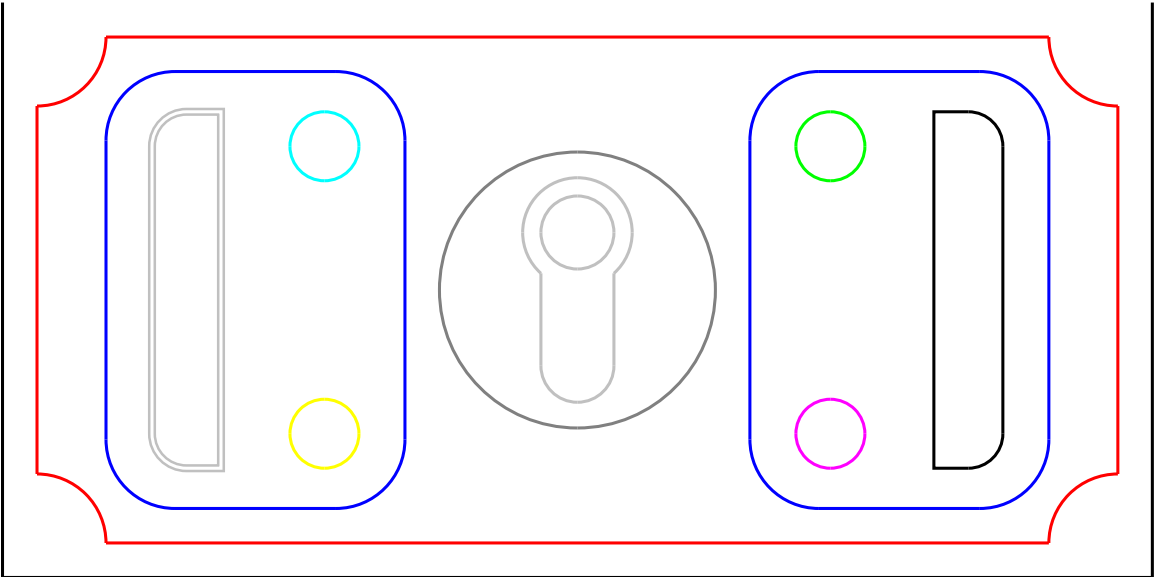
```

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

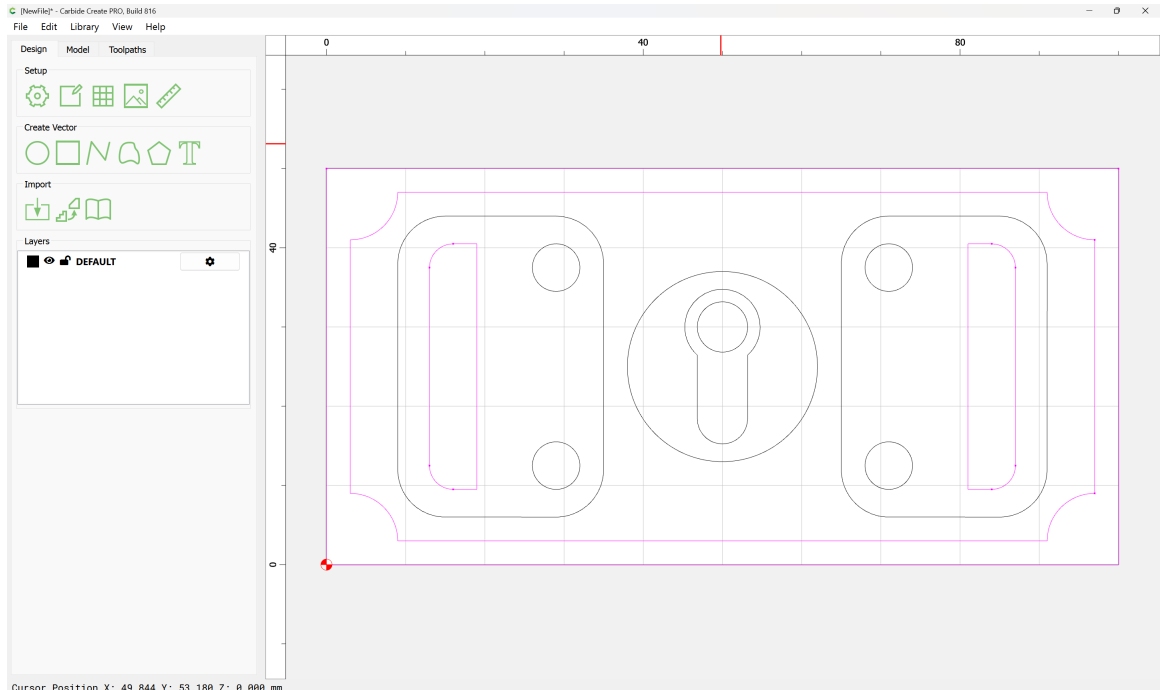
which creates a .dxf file which may be imported into any CAD program:



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)
- `dxfarc` (specifying arc center, radius, and beginning/ending angles)
- `dxfKH` (specifying origin, depth, angle, distance)

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

```

```

27 gcpcutdxfp Base_filename = "gcpdxf"
28 gcpcutdxfp
29 gcpcutdxfp
30 gcpcutdxfp # [CAM] */
31 gcpcutdxfp large_square_tool_num = 112
32 gcpcutdxfp # [CAM] */
33 gcpcutdxfp small_square_tool_num = 0
34 gcpcutdxfp # [CAM] */
35 gcpcutdxfp large_ball_tool_num = 111
36 gcpcutdxfp # [CAM] */
37 gcpcutdxfp small_ball_tool_num = 0
38 gcpcutdxfp # [CAM] */
39 gcpcutdxfp large_V_tool_num = 0
40 gcpcutdxfp # [CAM] */
41 gcpcutdxfp small_V_tool_num = 0
42 gcpcutdxfp # [CAM] */
43 gcpcutdxfp DT_tool_num = 374
44 gcpcutdxfp # [CAM] */
45 gcpcutdxfp KH_tool_num = 0
46 gcpcutdxfp # [CAM] */
47 gcpcutdxfp Roundover_tool_num = 0
48 gcpcutdxfp # [CAM] */
49 gcpcutdxfp MISC_tool_num = 0
50 gcpcutdxfp
51 gcpcutdxfp # [Design] */
52 gcpcutdxfp inset = 3
53 gcpcutdxfp # [Design] */
54 gcpcutdxfp radius = 6
55 gcpcutdxfp # [Design] */
56 gcpcutdxfp cornerstyle = "Fillet" # "Chamfer", "Flipped Fillet"
57 gcpcutdxfp
58 gcpcutdxfp gcp.opendxf(Base_filename)
59 gcpcutdxfp
60 gcpcutdxfp gcp.setupstock(stockXwidth, stockYheight, stockZthickness,
    zeroheight, stockzero, retractheight)
61 gcpcutdxfp
62 gcpcutdxfp gcp.toolchange(large_square_tool_num)
63 gcpcutdxfp
64 gcpcutdxfp gcp.setdxfc("Red")
65 gcpcutdxfp
66 gcpcutdxfp gcp.cutrectangl(xf, large_square_tool_num, 0, 0, 0, stockXwidth,
    stockYheight, stockZthickness)
67 gcpcutdxfp
68 gcpcutdxfp gcp.toolchange(large_ball_tool_num)
69 gcpcutdxfp
70 gcpcutdxfp gcp.setdxfc("Gray")
71 gcpcutdxfp
72 gcpcutdxfp gcp.rapid(inset + radius, inset, 0, "laser")
73 gcpcutdxfp
74 gcpcutdxfp gcp.cutlinedxf(inset + radius, inset, -stockZthickness/2)
75 gcpcutdxfp gcp.cutquarterCCNEdxf(inset, inset + radius, -stockZthickness/2,
    radius)
76 gcpcutdxfp
77 gcpcutdxfp gcp.cutlinedxf(inset, stockYheight - (inset + radius), -
    stockZthickness/2)
78 gcpcutdxfp
79 gcpcutdxfp gcp.cutquarterCCSEdxf(inset + radius, stockYheight - inset, -
    stockZthickness/2, radius)
80 gcpcutdxfp
81 gcpcutdxfp gcp.cutlinedxf(stockXwidth - (inset + radius), stockYheight - inset
    , -stockZthickness/2)
82 gcpcutdxfp
83 gcpcutdxfp gcp.cutquarterCCSWdxf(stockXwidth - inset, stockYheight - (inset +
    radius), -stockZthickness/2, radius)
84 gcpcutdxfp
85 gcpcutdxfp gcp.cutlinedxf(stockXwidth - (inset), (inset + radius), -
    stockZthickness/2)
86 gcpcutdxfp
87 gcpcutdxfp gcp.cutquarterCCNWdxf(stockXwidth - (inset + radius), inset, -
    stockZthickness/2, radius)
88 gcpcutdxfp
89 gcpcutdxfp gcp.cutlinedxf((inset + radius), inset, -stockZthickness/2)
90 gcpcutdxfp
91 gcpcutdxfp gcp.setdxfc("Blue")
92 gcpcutdxfp
93 gcpcutdxfp gcp.rapid(radius + inset + radius, radius, 0, "laser")
94 gcpcutdxfp
95 gcpcutdxfp gcp.cutrectanglerounddxf(large_square_tool_num, radius +inset,

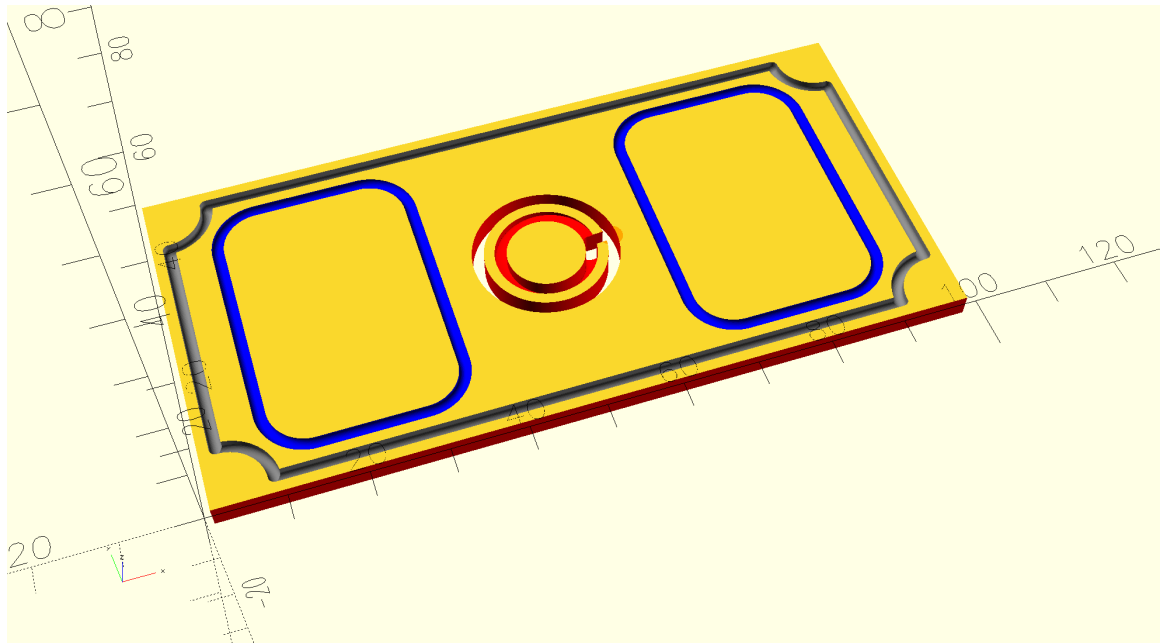
```

```

        radius, 0, stockXwidth/2 - (radius * 4), stockYheight - (radius
        * 2), -stockZthickness/4, radius)
96 gcpcutdxfp
97 gcpcutdxfp gcp.rapid(stockXwidth/2 + (radius * 2) + inset + radius, radius, 0,
        "laser")
98 gcpcutdxfp
99 gcpcutdxfp gcp.cutrectanglerounddx(
        large_square_tool_num, stockXwidth/2 + (
        radius * 2) + inset, radius, 0, stockXwidth/2 - (radius * 4),
        stockYheight - (radius * 2), -stockZthickness/4, radius)
100 gcpcutdxfp
101 gcpcutdxfp gcp.setdxfc("Red")
102 gcpcutdxfp
103 gcpcutdxfp gcp.rapid(stockXwidth/2 + radius, stockYheight/2, 0, "laser")
104 gcpcutdxfp
105 gcpcutdxfp gcp.toolchange(large_square_tool_num)
106 gcpcutdxfp
107 gcpcutdxfp gcp.cutcircleCC(stockXwidth/2, stockYheight/2, 0, -stockZthickness,
        radius)
108 gcpcutdxfp
109 gcpcutdxfp gcp.cutcircleCC(stockXwidth/2, stockYheight/2, -stockZthickness, -
        stockZthickness, radius*1.5)
110 gcpcutdxfp
111 gcpcutdxfp gcp.closedxfile()
112 gcpcutdxfp
113 gcpcutdxfp 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 DXFs 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", 3.6ř
61 gcptmplpy #304 tapered ball nose 0.1250", 0.2500", 1.50", 2.4ř
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/
    /B0CPJPTMP
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 R0_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.opendxf( Base_filename)
104 gcptmplpy
105 gcptmplpy gcp.setupstock(stockXwidth, stockYheight, stockZthickness,
106 gcptmplpy             zeroheight, stockzero, retractheight)
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             )
139 gcptmplpy gcp.rapidZ(retractheight)
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(),
151 gcptmplpy             stockYheight/16, -stockZthickness/4)
152 gcptmplpy #gcp.cutarcCC(90, 180, gcp.xpos(), gcp.ypos()-stockYheight/16,
153 gcptmplpy             stockYheight/16, -stockZthickness/4)
154 gcptmplpy #gcp.cutarcCC(180, 270, gcp.xpos()+stockYheight/16, gcp.ypos(),
155 gcptmplpy             stockYheight/16, -stockZthickness/4)
156 gcptmplpy #gcp.cutarcCC(270, 360, gcp.xpos(), gcp.ypos()+stockYheight/16,
157 gcptmplpy             stockYheight/16, -stockZthickness/4)
158 gcptmplpy gcp.cutquarterCCNEdxf(gcp.xpos() - stockYheight/8, gcp.ypos() +
159 gcptmplpy             stockYheight/8, -stockZthickness/4, stockYheight/8)
160 gcptmplpy gcp.cutquarterCCNWdxf(gcp.xpos() - stockYheight/8, gcp.ypos() -
161 gcptmplpy             stockYheight/8, -stockZthickness/2, stockYheight/8)
162 gcptmplpy gcp.cutquarterCCSWdxf(gcp.xpos() + stockYheight/8, gcp.ypos() -

```



```

        stockYheight/8, -stockZthickness * 0.75, stockYheight/8)
157 gcptmplpy gcp.cutquarterCCSEdxf(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)

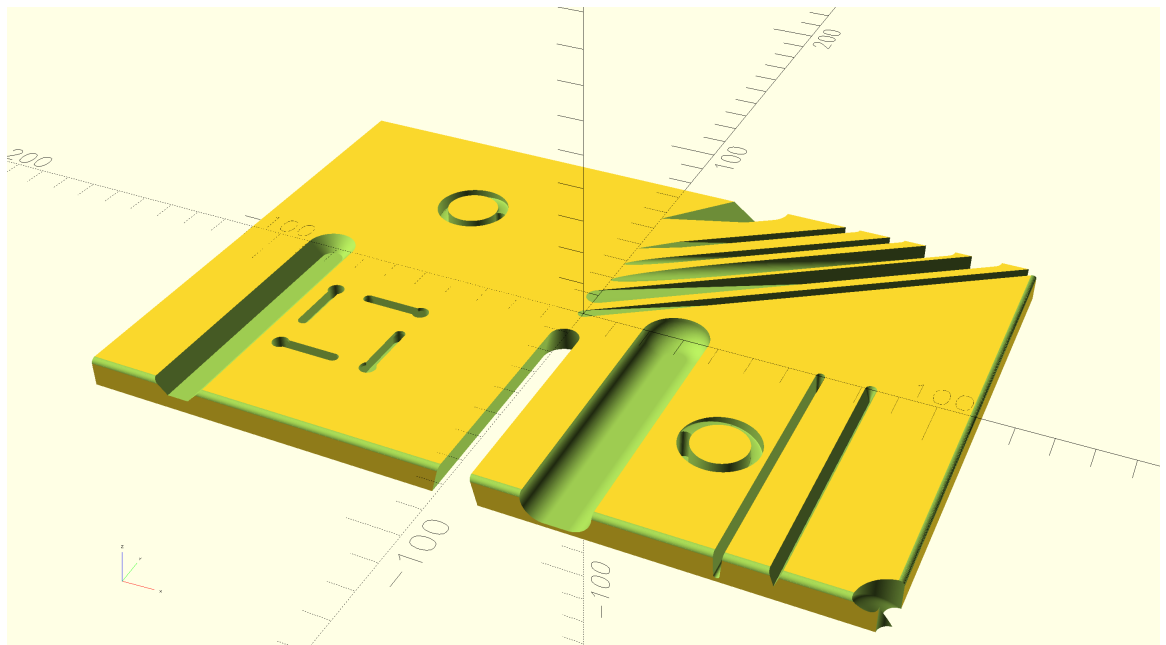
```

```

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.closedxfile()

```

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 outline(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 cutquarterCCNEdx(xpos() - stockYheight/8, ypos() + stockYheight/8,
        -stockZthickness/4, stockYheight/8);
167 gcptmplscad cutquarterCCNWdx(xpos() - stockYheight/8, ypos() - stockYheight/8,
        -stockZthickness/2, stockYheight/8);
168 gcptmplscad cutquarterCCSWdx(xpos() + stockYheight/8, ypos() - stockYheight/8,
        -stockZthickness * 0.75, stockYheight/8);
169 gcptmplscad //cutquarterCCSEdx(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));

```

```

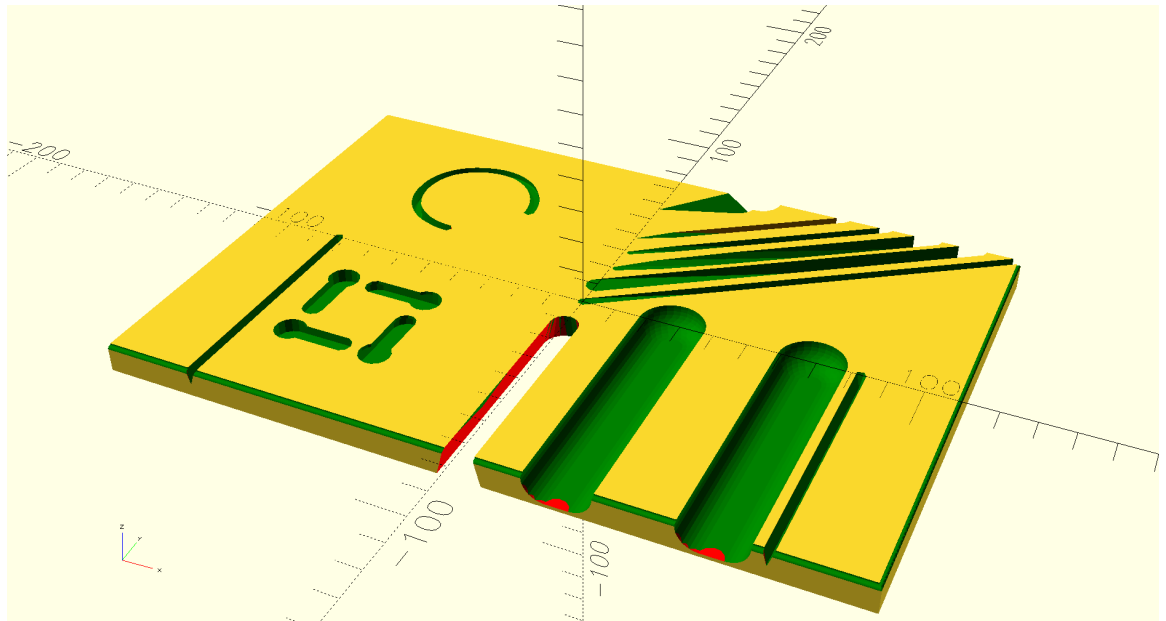
251 gcptmplscad
252 gcptmplscad rapidZ(retractheight);
253 gcptmplscad toolchange(502, 10000);
254 gcptmplscad rapidXY(stockXwidth*0.375, 0);
255 gcptmplscad cutline(gcp.xpos(), gcp.ypos(), -4.24);
256 gcptmplscad cutlinedxfgc(gcp.xpos(), -stockYheight/2, -4.24);
257 gcptmplscad
258 gcptmplscad rapidZ(retractheight);
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 cutlineZgcfed(-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 cutlineZgcfed(-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 closedxfxfile();

```

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



2.5 gpcthreadp.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 Ordbot Quantum

```

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

```

2.6 gcodepreviewtemplate.txt

Throughout this document, examples of commands will be shown and then collected in `gcodepreviewtemplate.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 gcodepreview

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 4th 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 `output(<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

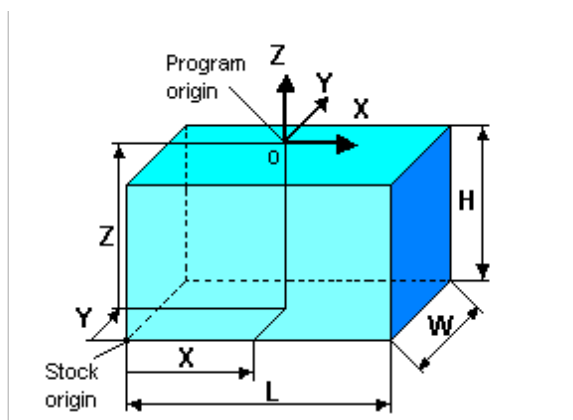
This problem space, showing the result of cutting stock using tooling in 3D has a number of tools addressing it, Camotics (formerly OpenSCAM) is an opensource option. Many tools simply create a wireframe preview such as <https://ncviewer.com/>. Cutviewer is a notable commercial program which has a unique 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:

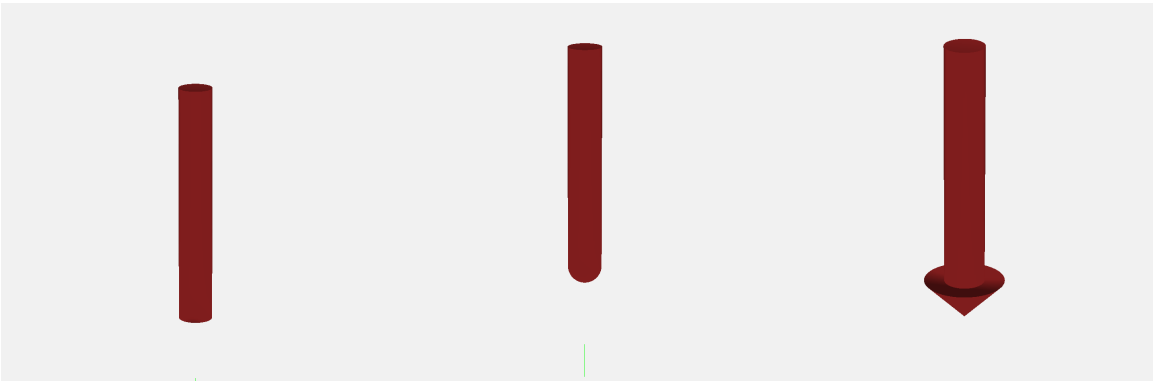
```
(STOCK/BLOCK, Length, Width, Height, Origin X, Origin Y, Origin Z)
```



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:

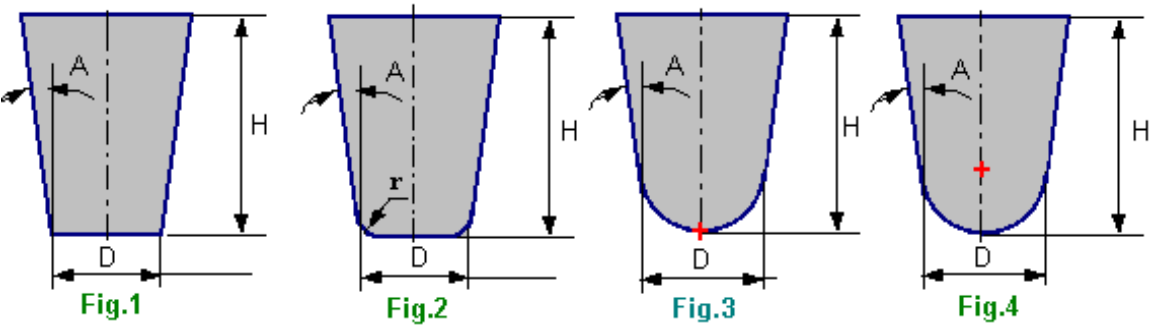


- Square (#201 and 102) — able to cut a flat bottom, perpendicular side and right angle, their simple and easily understood geometry makes them a standard choice
- Ballnose (#202 and 101) — rounded, they are the standard choice for concave and organic shapes
- V tooling (#301, 302, 311 and 312) — pointed 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, radiused, ball-nose, and tapered-ball) The CutViewer values include:

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

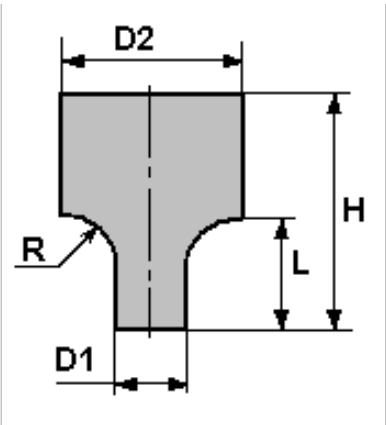


Note that it is possible to use these definitions for a wide variety of tooling, e.g., a Carbide 3D #301 V tool being represented as:

(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, D1, A1, L, D2, A2, 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 complete 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
 - `dx` (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	dx	gcode	cut	dx	gcode
cut	cutline		cutlinegc	cutarc		cutarcgc
dx	cutlinedx	dxline		cutarcdx	dxarc	
gcode	cutlinegc		linegc	cutarcgc		arcgc
	cutlinedxfgc			cutarcdxfgc		

Note that certain commands (`dxlinegc`, `dxarcgc`, `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 `dx` columns and the matter of having specific commands which encompass those file types is tied up in having the internal variables `generategcode`, `generatedx` and `generatecut` if...then structures using those variables. The addition of a `generatecut` variable adds the necessary 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(ing)`, `dx`, `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 `dx` 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 (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 vo.8)
- Programming in Python and calling OpenSCAD — 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=\thegcpscad}
\begin{writecode}{a}{gcodepreview.scad}{scad}
module FOOBAR(...) {
    oFOOBAR(...);
}

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

```

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                 cutorprint = "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         cutorprint      : string
39 gcpy                        Enables creation of 3D model for cutting or
                                printing.
40 gcpy         generategcode : boolean
41 gcpy                        Enables writing out G-code.
42 gcpy         generatedxf   : boolean
43 gcpy                        Enables writing out DXF file(s).
44 gcpy
45 gcpy         Returns
46 gcpy         -----
47 gcpy         object
48 gcpy         The initialized gcodepreview object.
49 gcpy         """
50 gcpy         if cutorprint == "print":
```

```

51 gcpy             self.generatecut = False
52 gcpy             self.generateprint = True
53 gcpy             self.gcodefileext = ".gcode"
54 gcpy             elif cutorprint == "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
        False
78 gcpy             self.generateddxfs = False
79 gcpy # set up 3D previewing parameters
80 gcpy             fa = gcpfa
81 gcpy             fs = gcpfs
82 gcpy             self.steps = steps
83 gcpy # initialize the machine state
84 gcpy             self.mc = "Initialized"
85 gcpy             self.mpx = float(0)
86 gcpy             self.mpy = float(0)
87 gcpy             self.mpz = float(0)
88 gcpy             self.tpz = float(0)
89 gcpy # initialize the toolpath state
90 gcpy             self.retractheight = 5
91 gcpy # initialize the DEFAULT tool
92 gcpy             self.currenttoolnum = 102
93 gcpy             self.endmilltype = "square"
94 gcpy             self.diameter = 3.175
95 gcpy             self.flute = 12.7
96 gcpy             self.shaftdiameter = 3.175
97 gcpy             self.shaftheight = 12.7
98 gcpy             self.shaftlength = 19.5
99 gcpy             self.toolnumber = "100036"
100 gcpy            self.cutcolor = "green"
101 gcpy            self.rapidcolor = "orange"
102 gcpy            self.shaftcolor = "red"
103 gcpy # the command definesquaretool(3.175, 12.7, 20) is used in the
        toolchange command
104 gcpy            self.tooloutline = polygon( points
        =[[0,0],[3.175,0],[3.175,12.7],[0,12.7]] )
105 gcpy            self.toolprofile = polygon( points
        =[[0,0],[1.5875,0],[1.5875,12.7],[0,12.7]] )
106 gcpy            self.shaftoutline = polygon( points
        =[[0,12.7],[3.175,12.7],[3.175,25.4],[0,25.4]] )
107 gcpy            self.shaftprofile = polygon( points
        =[[0,12.7],[1.5875,12.7],[1.5875,25.4],[0,25.4]] )
108 gcpy            self.currenttoolshape = cylinder(h = self.flute, r = self.
        shaftdiameter/2)
109 gcpy            sh = cylinder(h = self.flute, r = self.shaftdiameter/2)
110 gcpy            self.currenttoolshaft = sh.translate([0,0,self.flute])
111 gcpy # debug mode requires a variable to track if it is on or off
112 gcpy            self.debugenable = False
113 gcpy # the variables for holding 3D models must be initialized as empty
        lists so as to ensure that only append or extend commands are
        used with them
114 gcpy            self.rapids = []
115 gcpy            self.toolpaths = []
116 gcpy            print("gcodepreview class initialized")
117 gcpy
118 gcpy # def myfunc(self, var):
119 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 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.

toolmovement

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 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

ypos

zpos

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

```
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 gcpscad function xpos() = gcp.xpos();
31 gcpscad
32 gcpscad function ypos() = gcp.ypos();
33 gcpscad
34 gcpscad function zpos() = gcp.zpos();
```

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

setxpos

setypos

setzpos

```
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.

toolmovementThe 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.

tipThere 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 interac- toolpaths tion with the stock at rapid speed it will be obvious. A similar method should be implemented for the shafts of tooling.

gcodepreview3.3.3.1 setupstockThe first such setup subroutine is gcodepreview setupstock which is setupstock 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.setupstockSince 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
                             be positive or negative
174 gcpy      stockzero : string
175 gcpy                      Lower-Left, Center-Left, Top-Left, Center,
                             determines XY position of stock
176 gcpy      retractheight : float
177 gcpy                      Distance which tool retracts above surface
                             of stock.
178 gcpy
179 gcpy      Returns
180 gcpy      -----
181 gcpy      none
182 gcpy      """
183 gcpy      self.stockXwidth = stockXwidth
184 gcpy      self.stockYheight = stockYheight
185 gcpy      self.stockZthickness = stockZthickness
186 gcpy      self.zeroheight = zeroheight
187 gcpy      self.stockzero = stockzero
188 gcpy      self.retractheight = retractheight
189 gcpy      self.stock = cube([stockXwidth, stockYheight,
                             stockZthickness])
```



```
224 gcpy          self.stock = self.stock.translate([0, -self.
                    stockYheight / 2, 0])
225 gcpy          if self.generategcode == True:
226 gcpy              self.writetc("(stockMin:0.00mm,␣-", str(self.
                    stockYheight/2), "mm,␣0.00mm)")
227 gcpy              self.writetc("(stockMax:", str(self.stockXwidth
                    ), "mm,␣", str(self.stockYheight/2), "mm,␣-",
                    , str(self.stockZthickness), "mm)")
228 gcpy              self.writetc("(STOCK/BLOCK,␣", str(self.
                    stockXwidth), "␣", str(self.stockYheight),
                    "␣", str(self.stockZthickness), "␣0.00,␣",
                    str(self.stockYheight/2), "␣0.00mm)");
229 gcpy          if self.stockzero == "Top-Left":
230 gcpy              self.stock = self.stock.translate([0, -self.
                    stockYheight, 0])
231 gcpy          if self.generategcode == True:
232 gcpy              self.writetc("(stockMin:0.00mm,␣-", str(self.
                    stockYheight), "mm,␣0.00mm)")
233 gcpy              self.writetc("(stockMax:", str(self.stockXwidth
                    ), "mm,␣0.00mm,␣", str(self.stockZthickness)
                    , "mm)")
234 gcpy              self.writetc("(STOCK/BLOCK,␣", str(self.
                    stockXwidth), "␣", str(self.stockYheight),
                    "␣", str(self.stockZthickness), "␣0.00,␣",
                    str(self.stockYheight), "␣0.00)")
235 gcpy          if self.stockzero == "Center":
236 gcpy              self.stock = self.stock.translate([-self.
                    stockXwidth / 2, -self.stockYheight / 2, 0])
237 gcpy          if self.generategcode == True:
238 gcpy              self.writetc("(stockMin:␣-", str(self.
                    stockXwidth/2), "␣-", str(self.stockYheight
                    /2), "mm,␣0.00mm)")
239 gcpy              self.writetc("(stockMax:", str(self.stockXwidth
                    /2), "mm,␣", str(self.stockYheight/2), "mm,␣
                    ", str(self.stockZthickness), "mm)")
240 gcpy              self.writetc("(STOCK/BLOCK,␣", str(self.
                    stockXwidth), "␣", str(self.stockYheight),
                    "␣", str(self.stockZthickness), "␣", str(
                    self.stockXwidth/2), "␣", str(self.
                    stockYheight/2), "␣0.00)")
241 gcpy          if self.generategcode == True:
242 gcpy              self.writetc("G90");
243 gcpy              self.writetc("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 gcpscad module setupstock(stockXwidth, stockYheight, stockZthickness,
                             zeroheight, stockzero, retractheight) {
37 gcpscad     gcp.setupstock(stockXwidth, stockYheight, stockZthickness,
                             zeroheight, stockzero, retractheight);
38 gcpscad }
```

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,
                    extentfb, extentd):
246 gcpy          #          self.initializemachinestate()
247 gcpy          c=cube([sizeX,sizeY,sizeZ])
248 gcpy          c = c.translate([extentleft,extentfb,extentd])
249 gcpy          self.stock = c
250 gcpy          self.toolpaths = []
251 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_kwargs) -> None:
254 gcpy      """
255 gcpy      Print debug output if enabled.
256 gcpy
257 gcpy      Accepts the same arguments as built-in print (except file
              is supported via print_kwargs).
258 gcpy      """
259 gcpy      if not self.debugenable:
260 gcpy          return
261 gcpy      # Build the message and print under a lock to avoid
              interleaving in multithreaded apps
262 gcpy      self.prefix = "DEBUG:␣"
263 gcpy      msg = self.prefix + sep.join(map(str, args))
264 gcpy      with self._lock:
265 gcpy          print(msg, end=end, **print_kwargs)
```

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 gcpscad module shiftstock(shiftX, shiftY, shiftZ) {
41 gcpscad     gcp.shiftstock(shiftX, shiftY, shiftZ);
42 gcpscad }
```

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

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

the OpenSCAD module is a descriptor as expected:

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

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 variables (rapids, toolpaths) as lists processed/created using a command toolmovement which will subsume all tool related functionality. As other routines need access to information about the 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:

rapids
toolpaths
toolmovement

- 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 expressible.

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

1	2-3	4-5	6
┌──────────┐	┌──────────┐	┌──────────────────────────┐	┌──────────┐
endmill type	radius/angle cutting	diameter(and tip radius for tapered ball nose)	cutting flute length

- 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 - 1/32nd
 - 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 pa-
toolchange rameters. 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 pre-viewing 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.

settoolparameters There are two separate commands for handling a tool being changed, the first sets the param-
toolchange eters which describe the tool and may be used to effect the change of a tool either in a G-code file 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
283 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

3.4.1.1.2 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")
```

3.4.1.1.3 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,
                                     self.shaftlength)
355 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                                   self.flute, 0, self.shaftlength)
356 gcpy          self.toolnumber = 10003
357 gcpy          elif (tool_number == 201) or (tool_number == 100047): #
201/251/322 (Amana 46202-K) == 100047
358 gcpy          self.writetc("T00L/MILL,␣6.35,␣0.00,␣0.00,␣0.00)")
359 gcpy          self.endmilltype = "square"
360 gcpy          self.diameter = 6.35
361 gcpy          self.flute = 19.05
362 gcpy          self.shaftdiameter = 6.35
363 gcpy          self.shaftheight = 19.05
364 gcpy          self.shaftlength = 20.0
365 gcpy          self.definesquaretool(self.diameter, self.shaftheight,
                                     self.shaftlength)
366 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                                   self.flute, 0, self.shaftlength)
367 gcpy          self.toolnumber = "100047"
368 gcpy          elif (tool_number == 112) or (tool_number == 100024): #112
== 100024
369 gcpy          self.writetc("T00L/MILL,␣1.5875,␣0.00,␣0.00,␣0.00)")
370 gcpy          self.endmilltype = "square"
371 gcpy          self.diameter = 1.5875
372 gcpy          self.flute = 6.35
373 gcpy          self.shaftdiameter = 3.175
374 gcpy          self.shaftheight = 6.35
375 gcpy          self.shaftlength = 12.0
376 gcpy          self.definesquaretool(self.diameter, self.shaftheight,
                                     self.shaftlength, (self.shaftdiameter - self.
diameter)/2)
377 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                                   self.flute, 0, self.shaftlength)
378 gcpy          self.toolnumber = "100024"
379 gcpy          elif (tool_number == 122) or (tool_number == 100012): #122
== 100012
380 gcpy          self.writetc("T00L/MILL,␣0.79375,␣0.00,␣0.00,␣0.00)")
381 gcpy          self.endmilltype = "square"
382 gcpy          self.diameter = 0.79375
383 gcpy          self.flute = 1.5875
384 gcpy          self.shaftdiameter = 3.175
385 gcpy          self.shaftheight = 1.5875
386 gcpy          self.shaftlength = 12.0
387 gcpy          self.definesquaretool(self.diameter, self.shaftheight,
                                     self.shaftlength, (self.shaftdiameter - self.
diameter)/2)
388 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                                   self.flute, 0, self.shaftlength)
389 gcpy          self.toolnumber = "100012"
390 gcpy          elif (tool_number == 324): #324 (Amana 46170-K) == 100048
391 gcpy          self.writetc("T00L/MILL,␣6.35,␣0.00,␣0.00,␣0.00)")
392 gcpy          self.endmilltype = "square"
393 gcpy          self.diameter = 6.35
394 gcpy          self.flute = 22.225
395 gcpy          self.shaftdiameter = 6.35
396 gcpy          self.shaftheight = 22.225
397 gcpy          self.shaftlength = 20.0
398 gcpy          self.definesquaretool(self.diameter, self.shaftheight,
                                     self.shaftlength)
399 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                                   self.flute, 0, self.shaftlength)
400 gcpy          self.toolnumber = "100048"
401 gcpy          elif (tool_number == 205) or (tool_number == 100048): #205
== 100048
402 gcpy          self.writetc("T00L/MILL,␣6.35,␣0.00,␣0.00,␣0.00)")
403 gcpy          self.endmilltype = "square"
404 gcpy          self.diameter = 6.35
405 gcpy          self.flute = 25.4

```

```
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,
                                     self.shaftlength)
410 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                                     self.flute, 0, self.shaftlength)
411 gcpy          defineKeyholetool(self.diameter, self.flute, self.
                                     shaftdiameter, self.shaftheight, self.shaftdiameter,
                                     self.shaftlength)
412 gcpy          self.toolnumber = "100048"
413 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
                                     == 000204
415 gcpy          self.writegc("(T00L/MILL,□2.0,□0.00,□0.00,□0.00)")
416 gcpy          self.endmilltype = "O-flute"
417 gcpy          self.diameter = 2.0
418 gcpy          self.flute = 6.35
419 gcpy          self.shaftdiameter = 6.35
420 gcpy          self.shaftheight = 6.35
421 gcpy          self.shaftlength = 12.0
422 gcpy          self.definesquaretool(self.diameter, self.shaftheight,
                                     self.shaftlength, (self.shaftdiameter - self.
                                     diameter)/2)
423 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                                     self.flute, 0, self.shaftlength)
424 gcpy          self.toolnumber = "100204"
425 gcpy          elif (tool_number == 274) or (tool_number == 100036): #274
                                     == 000036
426 gcpy          self.writegc("(T00L/MILL,□3.175,□0.00,□0.00,□0.00)")
427 gcpy          self.endmilltype = "O-flute"
428 gcpy          self.diameter = 3.175
429 gcpy          self.flute = 12.7
430 gcpy          self.shaftdiameter = 3.175
431 gcpy          self.shaftheight = 12.7
432 gcpy          self.shaftlength = 20.0
433 gcpy          self.definesquaretool(self.diameter, self.shaftheight,
                                     self.shaftlength)
434 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                                     self.flute, 0, self.shaftlength)
435 gcpy          self.toolnumber = "100036"
436 gcpy          elif (tool_number == 278) or (tool_number == 100047): #278
                                     == 000047
437 gcpy          self.writegc("(T00L/MILL,□6.35,□0.00,□0.00,□0.00)")
438 gcpy          self.endmilltype = "O-flute"
439 gcpy          self.diameter = 6.35
440 gcpy          self.flute = 19.05
441 gcpy          self.shaftdiameter = 3.175
442 gcpy          self.shaftheight = 19.05
443 gcpy          self.shaftlength = 20.0
444 gcpy          self.definesquaretool(self.diameter, self.shaftheight,
                                     self.shaftlength)
445 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                                     self.flute, 0, self.shaftlength)
446 gcpy          self.toolnumber = "100047"
447 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
                                     == 204047
449 gcpy          self.writegc("(T00L/MILL,□6.35,□3.175,□0.00,□0.00)")
450 gcpy          self.endmilltype = "ball"
451 gcpy          self.diameter = 6.35
452 gcpy          self.flute = 19.05
453 gcpy          self.shaftdiameter = 6.35
454 gcpy          self.shaftheight = 19.05
455 gcpy          self.shaftlength = 20.0
```

```
456 gcpy          self.defineballnosetool(self.diameter, self.flute, self
                    .shaftlength)
457 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                    self.flute, 0, self.shaftlength)
458 gcpy          self.toolnumber = "204047"
459 gcpy          elif (tool_number == 101) or (tool_number == 203036): #101
                    == 203036
460 gcpy          self.writegc("(TOOL/MILL,□3.175,□1.5875,□0.00,□0.00)")
461 gcpy          self.endmilltype = "ball"
462 gcpy          self.diameter = 3.175
463 gcpy          self.flute = 12.7
464 gcpy          self.shaftdiameter = 3.175
465 gcpy          self.shaftheight = 12.7
466 gcpy          self.shaftlength = 20.0
467 gcpy          self.defineballnosetool(self.diameter, self.flute, self
                    .shaftlength)
468 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                    self.flute, 0, self.shaftlength)
469 gcpy          self.toolnumber = "203036"
470 gcpy          elif (tool_number == 111) or (tool_number == 202024): #111
                    == 202024
471 gcpy          self.writegc("(TOOL/MILL,□1.5875,□0.79375,□0.00,□0.00)"
                    )
472 gcpy          self.endmilltype = "ball"
473 gcpy          self.diameter = 1.5875
474 gcpy          self.flute = 6.35
475 gcpy          self.shaftdiameter = 3.175
476 gcpy          self.shaftheight = 6.35
477 gcpy          self.shaftlength = 20.0
478 gcpy          self.defineballnosetool(self.diameter, self.flute, self
                    .shaftlength, (self.shaftdiameter - self.diameter)
                    /2)
479 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                    self.flute, 0, self.shaftlength)
480 gcpy          self.toolnumber = "202024"
481 gcpy          elif (tool_number == 121) or (tool_number == 201012): #121
                    == 201012
482 gcpy          self.writegc("(TOOL/MILL,□3.175,□0.79375,□0.00,□0.00)")
483 gcpy          self.endmilltype = "ball"
484 gcpy          self.diameter = 0.79375
485 gcpy          self.flute = 1.5875
486 gcpy          self.shaftdiameter = 3.175
487 gcpy          self.shaftheight = 1.5875
488 gcpy          self.shaftlength = 20.0
489 gcpy          self.defineballnosetool(self.diameter, self.flute, self
                    .shaftlength, (self.shaftdiameter - self.diameter)
                    /2)
490 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                    self.flute, 0, self.shaftlength)
491 gcpy          self.toolnumber = "201012"
492 gcpy          elif (tool_number == 325) or (tool_number == 204048): #325
                    (Amana 46376-K) == 204048
493 gcpy          self.writegc("(TOOL/MILL,□6.35,□3.175,□0.00,□0.00)")
494 gcpy          self.endmilltype = "ball"
495 gcpy          self.diameter = 6.35
496 gcpy          self.flute = 25.4
497 gcpy          self.shaftdiameter = 6.35
498 gcpy          self.shaftheight = 25.4
499 gcpy          self.shaftlength = 20.0
500 gcpy          self.defineballnosetool(self.diameter, self.flute, self
                    .shaftlength, (self.shaftdiameter - self.diameter)
                    /2)
501 gcpy          self.defineshaft(self.diameter, self.shaftdiameter,
                    self.flute, 0, self.shaftlength)
502 gcpy          self.toolnumber = "204048"
503 gcpy          #
```

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          elif (tool_number == 301) or (tool_number == 390074): #301
                    == 390074
505 gcpy          self.writegc("(TOOL/MILL,□0.10,□0.05,□6.35,□45.00)")
506 gcpy          self.endmilltype = "V"
507 gcpy          self.diameter = 12.7
```

```
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
                    == 906053
572 gcpy          self.writegc("(T00L/MILL,␣9.53,␣0.00,␣3.17,␣0.00)")
573 gcpy          self.endmilltype = "keyhole"
574 gcpy          self.diameter = 9.525
575 gcpy          self.flute = 3.175
576 gcpy          self.radius = 8
577 gcpy          self.shaftdiameter = 6.35
578 gcpy          self.shaftheight = 3.175
579 gcpy          self.shaftlength = 20.0
580 gcpy          self.defineKeyholetool(self.diameter, self.flute, self.
                    shaftdiameter, self.shaftheight, self.shaftdiameter,
                    self.shaftlength)
581 gcpy          self.toolnumber = "906053"
582 gcpy          elif (tool_number == 376) or (tool_number == 907040): #376
                    == 907040
583 gcpy          self.writegc("(T00L/MILL,␣12.7,␣0.00,␣4.77,␣0.00)")
584 gcpy          self.endmilltype = "keyhole"
585 gcpy          self.diameter = 12.7
586 gcpy          self.flute = 4.7625
587 gcpy          self.radius = 6.35
588 gcpy          self.shaftdiameter = 6.35
589 gcpy          self.shaftheight = 4.7625
590 gcpy          self.shaftlength = 20.0
591 gcpy          self.defineKeyholetool(self.diameter, self.flute, self.
                    shaftdiameter, self.shaftheight, self.shaftdiameter,
                    self.shaftlength)
592 gcpy          self.toolnumber = "907040"
593 gcpy          elif (tool_number == 378) or (tool_number == 907050): #378
                    == 907050
594 gcpy          self.writegc("(T00L/MILL,␣12.7,␣0.00,␣4.77,␣0.00)")
595 gcpy          self.endmilltype = "keyhole"
596 gcpy          self.diameter = 12.7
597 gcpy          self.flute = 4.7625
598 gcpy          self.radius = 8
599 gcpy          self.shaftdiameter = 6.35
600 gcpy          self.shaftheight = 4.7625
601 gcpy          self.shaftlength = 20.0
602 gcpy          self.defineKeyholetool(self.diameter, self.flute, self.
                    shaftdiameter, self.shaftheight, self.shaftdiameter,
                    self.shaftlength)
603 gcpy          self.toolnumber = "907050"
604 gcpy #
```

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
                    Inch Shank
607 gcpy          self.writegc("(T00L/MILL,0.03,␣0.00,␣10.00,␣30.00)")
608 gcpy          self.writegc("(T00L/MILL,␣15.875,␣6.35,␣19.05,␣0.00)")
609 gcpy          self.endmilltype = "bowl"
610 gcpy          self.diameter = 12.7
611 gcpy          self.flute = 12.7
612 gcpy          self.radius = 3.175
613 gcpy          self.shaftdiameter = 6.35
614 gcpy          self.shaftheight = 12.7
615 gcpy          self.shaftlength = 20.0
616 gcpy          self.definebowltool(self.diameter, self.flute, self.
                    radius, self.shaftdiameter, self.shaftlength)
617 gcpy          self.toolnumber = "445981"
618 gcpy          elif (tool_number == 45982):#0.507/2, 4.509
619 gcpy          self.writegc("(T00L/MILL,␣15.875,␣6.35,␣19.05,␣0.00)")
620 gcpy          self.endmilltype = "bowl"
621 gcpy          self.diameter = 19.05
622 gcpy          self.flute = 15.875
623 gcpy          self.radius = 6.35
624 gcpy          self.shaftdiameter = 6.35
625 gcpy          self.shaftheight = 15.875
626 gcpy          self.shaftlength = 20.0
627 gcpy          self.definebowltool(self.diameter, self.flute, self.
                    radius, self.shaftdiameter, self.shaftlength)
628 gcpy          self.toolnumber = "445982"
629 gcpy          elif (tool_number == 1370): #1370 == 401370
630 gcpy #Whiteside Bowl & Tray Bit 1/4"SH, 1/8"R, 7/16"CD (5/16" cutting
                    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,
6.35, 38.1, 3.6)
684 gcpy #         elif (tool_number == 304):#
685 gcpy #             self.writegc("(")
686 gcpy #             self.currenttoolshape = self.tapered_ball(3.175, 6.35,
38.1, 2.4)
687 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):#
0.508/2, 1.531 56125 == 603042
689 gcpy         self.writegc("(TOOL/CRMILL,□0.508,□6.35,□3.175,□7.9375,
□3.175)")
690 gcpy         self.endmilltype = "roundover"
691 gcpy         self.tipdiameter = 0.508
692 gcpy         self.diameter = 6.35 - self.tipdiameter
693 gcpy         self.flute = 8 - self.tipdiameter
694 gcpy         self.radius = 3.175 - self.tipdiameter/2
695 gcpy         self.shaftdiameter = 6.35
696 gcpy         self.shaftheight = 8
697 gcpy         self.shaftlength = 10.0
698 gcpy         self.defineRoundovertool(self.diameter, self.
tipdiameter, self.flute, self.radius, self.
shaftdiameter, self.shaftlength)
699 gcpy         self.toolnumber = "603042"
700 gcpy         elif (tool_number == 56142) or (tool_number == 602032):#
0.508/2, 2.921 56142 == 602032
701 gcpy         self.writegc("(TOOL/CRMILL,□0.508,□3.571875,□1.5875,□
5.55625,□1.5875)")
702 gcpy         self.endmilltype = "roundover"
703 gcpy         self.tip = 0.508
704 gcpy         self.diameter = 3.175 - self.tip
705 gcpy         self.flute = 4.7625 - self.tip
706 gcpy         self.radius = 1.5875 - self.tip/2
707 gcpy         self.shaftdiameter = 3.175
708 gcpy         self.shaftheight = 4.7625
709 gcpy         self.shaftlength = 10.0
710 gcpy         self.toolnumber = "602032"
711 gcpy #         elif (tool_number == 312):#1.524/2, 3.175
712 gcpy #             self.writegc("(TOOL/CRMILL, Diameter1, Diameter2,
Radius, Height, Length)")
713 gcpy #         elif (tool_number == 1568):#0.507/2, 4.509 1568 == 603032
714 gcpy ##FIX             self.writegc("(TOOL/CRMILL, 0.17018, 9.525,
4.7625, 12.7, 4.7625)")
715 gcpy ##             self.currenttoolshape = self.toolshapes("roundover",
3.175, 6.35, 3.175, 0.396875)
716 gcpy #             self.endmilltype = "roundover"
717 gcpy #             self.diameter = 3.175
718 gcpy #             self.flute = 6.35
719 gcpy #             self.radius = 3.175
720 gcpy #             self.tip = 0.396875
721 gcpy #             self.toolnumber = "603032"
722 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
723 gcpy #             elif (tool_number == 1570):#0.507/2, 4.509 1570 == 600002
?!?
724 gcpy #             self.writegc("(TOOL/CRMILL, 0.17018, 9.525, 4.7625,
12.7, 4.7625)")
725 gcpy ##             self.currenttoolshape = self.toolshapes("roundover",
4.7625, 9.525, 4.7625, 0.396875)
726 gcpy #             self.endmilltype = "roundover"
727 gcpy #             self.diameter = 4.7625
728 gcpy #             self.flute = 9.525
729 gcpy #             self.radius = 4.7625
730 gcpy #             self.tip = 0.396875
731 gcpy #             self.toolnumber = "600002"
732 gcpy #         elif (tool_number == 1572): #1572 = 604042
733 gcpy ##FIX             self.writegc("(TOOL/CRMILL, 0.17018, 9.525,
4.7625, 12.7, 4.7625)")
734 gcpy ##             self.currenttoolshape = self.toolshapes("roundover",
6.35, 12.7, 6.35, 0.396875)
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" 14ř 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.)

3.4.1.1.11 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://lasergribl.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 3D model of the tool, or a cross-section of it for both `cut...` and `rapid...` operations.

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 G0 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

The first command which must be defined is `toolmovement` which is used as the core of the other 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), 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)

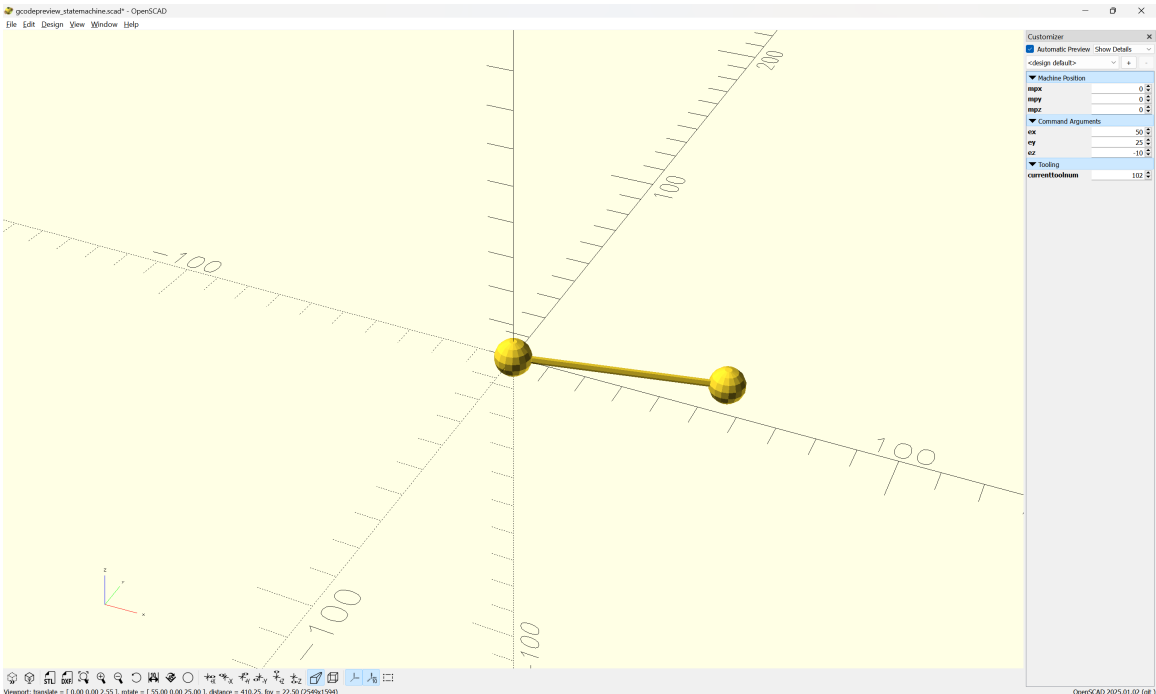
Most tools are easily implemented with concise 3D descriptions which may be connected with a simple hull operation. Note that extending the normal case to a pair of such operations, one for the shaft, the other for the cutting shape will markedly simplify the code, and will make it possible to color-code 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, X0, Y0, Z0, 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 square3.5.3.1.1 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              return tslist
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          return tslist
804 gcpy      #
```

ballnose3.5.3.1.2 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              return tslist
810 gcpy      #
```

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

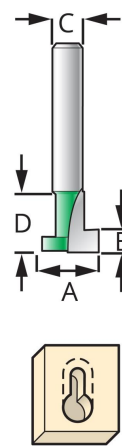
```
809 gcpy          if self.endmilltype == "bowl":
810 gcpy              inner = cylinder(r1 = self.diameter/2 - self.radius, r2
811 gcpy                  = self.diameter/2 - self.radius, h = self.flute)
812 gcpy              outer = cylinder(r1 = self.diameter/2, r2 = self.
813 gcpy                  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.
821 gcpy                          diameter / 2 - self.radius + self.radius * Sin(i
822 gcpy                              +self.steps), h = self.radius/90, center=False)
823 gcpy                  slices = hull(slices, slice.translate([0, 0, self.
824 gcpy                      radius - self.radius * Cos(i+self.steps)]))
825 gcpy              tslist.append(hull(slices.translate([bx, by, bz]),
826 gcpy                  slices.translate([ex, ey, ez])))
827 gcpy              return tslist
828 gcpy      #
```

endmill v3.5.3.1.4 VThe 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.



Keyhole Router Bits

#	A	B	C	D
374	3/8"	1/8"	1/4"	3/8"
375	9.525mm	3.175mm	8mm	9.525mm
376	1/2"	3/16"	1/4"	1/2"
378	12.7mm	4.7625mm	8mm	12.7mm

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

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.
                        shaftdiameter / 2), h=self.shaftlength, center = False)
873 gcpy             ts = ts.translate([0, 0, self.shaftheight])
874 gcpy             tslist.append(hull(ts.translate([bx, by, bz]), ts.translate
                        ([ex, ey, ez])))
875 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,
                transition, shaft):
878 gcpy      if shaftdiameter == 0:
879 gcpy          self.shaftoutline = polygon(points=[[0, flute], [
                diameter, flute], [diameter, shaft], [0, shaft]])
880 gcpy      self.shaftprofile = polygon(points=[[0, flute], [
                diameter/2 ,flute], [diameter/2, shaft], [0, shaft
                ]])
881 gcpy      sh = cylinder(h = shaft, r = diameter/2)
882 gcpy      self.currenttoolshaft = sh.translate([0,0,flute])
883 gcpy      if shaftdiameter > 0:
884 gcpy          self.shaftoutline = polygon(points=[
885 gcpy              [shaftdiameter / 2 - toolingdiameter / 2, flute],
886 gcpy              [0, flute + transition],
887 gcpy              [0, flute + transition + shaft],
888 gcpy              [shaftdiameter, flute + transition + shaft],
889 gcpy              [shaftdiameter, flute + transition],
890 gcpy              [shaftdiameter / 2 + toolingdiameter / 2, flute],
891 gcpy              ] )
892 gcpy      self.shaftprofile = polygon( points= [
893 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 + offset,0],[diameter + offset,flute],[0 +
                    offset,flute]] )
903 gcpy          self.toolprofile = polygon( points=[[0,0],[diameter/2,0],[
                    diameter/2,flute],[0,flute]] )
904 gcpy          self.currenttoolshape = cylinder(h = flute, r = diameter/2)
905 gcpy          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 =
0):
908 gcpy          s = square([diameter,flute - diameter/2])
909 gcpy          sh = s.translate([0 + offset, diameter/2])
910 gcpy          c = circle(d=diameter)
911 gcpy          b = c.translate([diameter/2 + offset, diameter/2])
912 gcpy          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 #          bns = bn.translate([0, diameter/2])
920 gcpy          thein = square([diameter/2,flute])
921 gcpy #          theins = thein.translate([diameter/2, 0])
922 gcpy          self.toolprofile = intersection(thein, bn)
923 gcpy #
924 gcpy          self.shaftprofile = polygon( points=[[0,flute],[diameter/2,
                    flute],[diameter/2,shaft],[0,shaft]] )
925 gcpy #
926 gcpy #          b = self.toolprofile
927 gcpy #          bn = b.translate([-diameter/2, 0])
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 =
0):
933 gcpy          self.tooloutline = polygon([[diameter/2, 0], [diameter,
                    flute], [0, flute]])
934 gcpy #
935 gcpy
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], [
              diameter, flute], [diameter/2 + narrowdiameter/2, flute
              ], [diameter/2 + narrowdiameter/2, flute + narrowflute],
              [diameter/2 - narrowdiameter/2, flute + narrowflute], [
              diameter/2 - narrowdiameter/2, flute], [0, flute]])
951 gcpy #
952 gcpy
953 gcpy          self.toolprofile = polygon([[0, 0], [diameter/2, 0], [
              diameter/2, flute], [narrowdiameter/2, flute], [
              narrowdiameter/2, flute + narrowflute], [0, flute +
              narrowflute]])
954 gcpy #
955 gcpy          self.shaftprofile = polygon([[0, flute + narrowflute], [
              narrowdiameter/2, flute + narrowflute], [shaftdiameter
              /2, flute + narrowflute + shaftlength], [0, flute +
              narrowflute + shaftlength]])
956 gcpy
957 gcpy #
958 gcpy          self.currenttoolshape = rotate_extrude(self.toolprofile)
959 gcpy #
960 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 #          self.tooloutline =
965 gcpy          self.toolprofile = polygon([[0,0], [diameter/2, 0, radius],
              [diameter/2, radius], [diameter/2, flute], [0, flute]])
966 gcpy #
967 gcpy          self.shaftprofile = polygon([[0,flute], [shaftdiameter/2,
              flute], [shaftdiameter/2, flute + shaftlength], [0,
              flute + shaftlength]])
968 gcpy #
969 gcpy          self.currenttoolshape = rotate_extrude(self.toolprofile)
970 gcpy #
971 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 #          print(diameter)
983 gcpy #          print(tipdiameter)
984 gcpy #          print(flute)
985 gcpy #          print(radius)
986 gcpy #          print(shaftdiameter)
987 gcpy #          print(shaftlength)
988 gcpy #          self.tooloutline =
```

```
988 gcpy #
989 gcpy     self.toolprofile = polygon([[0,0], [tipdiameter/2, 0], [
        diameter/2, flute], [0, flute]])

990 gcpy #
991 gcpy     self.shaftprofile = polygon([[0,flute], [shaftdiameter/2,
        flute], [shaftdiameter/2, flute + shaftlength], [0,
        flute + shaftlength]])

992 gcpy #
993 gcpy     self.currenttoolshape = rotate_extrude(self.toolprofile)
994 gcpy #
995 gcpy     self.currenttoolshaft = rotate_extrude(self.shaftprofile)
```

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.
                zpos(), ex, ey, ez)
1003 gcpy             tm = color(tm, self.shaftcolor)
1004 gcpy             ts = self.shaftmovement(self.xpos(), self.ypos(), self.
                zpos(), ex, ey, ez)
1005 gcpy             ts = color(ts, self.rapidcolor)
1006 gcpy             self.toolpaths.extend([tm, ts])
1007 gcpy             self.setxpos(ex)
1008 gcpy             self.setypos(ey)
1009 gcpy             self.setzpos(ez)
1010 gcpy
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
            (), ex, ey, ez)
1015 gcpy         tm = color(tm, self.cutcolor)
1016 gcpy         ts = self.shaftmovement(self.xpos(), self.ypos(), self.zpos
            (), ex, ey, ez)
1017 gcpy         ts = color(ts, self.rapidcolor)
1018 gcpy         self.setxpos(ex)
1019 gcpy         self.setypos(ey)
1020 gcpy         self.setzpos(ez)
1021 gcpy         if self.generatecut == True:
1022 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.
            retractheight)
1026 gcpy #         if self.generatepaths == True:
1027 gcpy #             rapid = self.rapid(self.xpos(), self.ypos(), self.
            retractheight)
1028 gcpy #             self.rapids = self.rapids.union(rapid)
1029 gcpy #         else:
1030 gcpy #             if (generategcode == true) {
1031 gcpy #                 // writecomment("PREPOSITION FOR RAPID PLUNGE");Z25.650
1032 gcpy #                 //G1Z24.663F381.0, "F", str(plunge)
1033 gcpy #                 if self.generatepaths == False:
1034 gcpy #                     return rapid
1035 gcpy #                 else:
1036 gcpy #                     return cube([0.001, 0.001, 0.001])
1037 gcpy             return rapid
1038 gcpy
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 #         else:
1049 gcpy #             if self.generatepaths == False:
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 #         else:
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 gcpscad module movetosafeZ(){
53 gcpscad     gcp.rapid(gcp.xpos(), gcp.ypos(), retractheight);
54 gcpscad }
55 gcpscad
56 gcpscad module rapid(ex, ey, ez) {
57 gcpscad     gcp.rapid(ex, ey, ez);
58 gcpscad }
59 gcpscad
60 gcpscad module rapidXY(ex, ey) {
61 gcpscad     gcp.rapid(ex, ey, gcp.zpos());
62 gcpscad }
63 gcpscad
64 gcpscad module rapidXZ(ex, ez) {
65 gcpscad     gcp.rapid(ex, gcp.zpos(), ez);
66 gcpscad }
67 gcpscad
68 gcpscad module rapidZ(ez) {
69 gcpscad     gcp.rapid(gcp.xpos(), gcp.ypos(), ez);
70 gcpscad }
```

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_X", str(ex), "Y", str(ey), "Z", str(ez)
1082 gcpy             , "F", 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.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.
                    ypos(), ex, ey)
1091 gcpy          self.writegc("G01_X", str(ex), "Y", str(ey), "Z", str(ez)
                    )
                    self.cutline(ex, ey, ez)
1092 gcpy
1093 gcpy
1094 gcpy      def cutvertexdxf(self, ex, ey, ez):
1095 gcpy          self.addvertex(self.currenttoolnumber(), ex, ey)
1096 gcpy          self.writegc("G01_X", str(ex), "Y", str(ey), "Z", str(ez)
                    )
                    self.cutline(ex, ey, ez)
1097 gcpy
1098 gcpy
1099 gcpy      def cutlineXYZwithfeed(self, ex, ey, ez, feed):
1100 gcpy          return self.cutline(ex, ey, ez)
1101 gcpy
1102 gcpy      def cutlineXYZ(self, ex, ey, ez):
1103 gcpy          return self.cutline(ex, ey, ez)
1104 gcpy
1105 gcpy      def cutlineXYwithfeed(self, ex, ey, feed):
1106 gcpy          return self.cutline(ex, ey, self.zpos())
1107 gcpy
1108 gcpy      def cutlineXY(self, ex, ey):
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_Z", 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 gcpscad module cutline(ex, ey, ez){
73 gcpscad     gcp.cutline(ex, ey, ez);
74 gcpscad }
75 gcpscad
76 gcpscad module cutlinedxfgc(ex, ey, ez){
77 gcpscad     gcp.cutlinedxfgc(ex, ey, ez);
78 gcpscad }
79 gcpscad
80 gcpscad module cutlineZgcfed(ez, feed){
81 gcpscad     gcp.cutlineZgcfed(ez, feed);
82 gcpscad }
```

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`
- `cutcircleCCdxf`
- `cutcircleCWdxf`

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 (I and J), rather than the radius parameter (K) G2/3 ...
- DXF — `dxffarc(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:

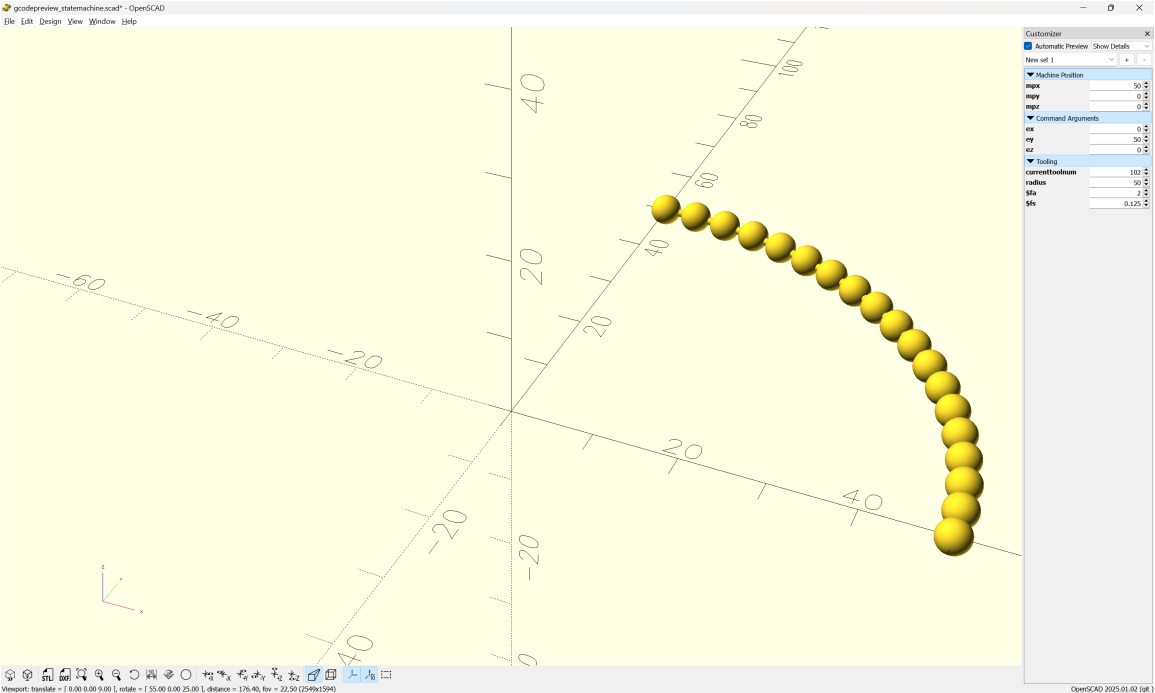
- `ex` — note that the matching origins (`bx`, `by`, `bz`) as well as the (current) toolnumber are accessed using the appropriate commands for machine position
- `ey`
- `ez` — allowing a different Z position will make possible threading and similar helical tool-paths
- `xcenter` — the center position 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)
cutarcCC 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 #          self.setxpos(xcenter + radius * Cos(earc))
1149 gcpy #          self.setypos(ycenter + radius * Sin(earc))
1150 gcpy
1151 gcpy      def cutarcCW(self, barc, earc, xcenter, ycenter, radius,
                        tpzreldim, stepsizearc=1):
1152 gcpy #          print(str(self.zpos()))
1153 gcpy #          print(str(ez))
1154 gcpy #          print(str(barc - earc))
1155 gcpy #          tpzinc = ez - self.zpos() / (barc - earc)
1156 gcpy #          print(str(tpzinc))
1157 gcpy #          global toolpath
1158 gcpy #          print("Entering n toolpath")
1159 gcpy          tpzinc = tpzreldim / (barc - earc)
1160 gcpy #          cts = self.currenttoolshape
1161 gcpy #          toolpath = cts
1162 gcpy #          toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])
1163 gcpy #          toolpath = []
1164 gcpy          i = barc
1165 gcpy          while i > earc:
1166 gcpy              self.cutline(xcenter + radius * Cos(i), ycenter +
                        radius * Sin(i), self.zpos()+tpzinc)
1167 gcpy #          self.setxpos(xcenter + radius * Cos(i))
1168 gcpy #          self.setypos(ycenter + radius * Sin(i))
1169 gcpy #          print(str(self.xpos()), str(self.ypos()), str(self.zpos
1170 gcpy #          ())))
1171 gcpy          self.setzpos(self.zpos()+tpzinc)
1172 gcpy          i += abs(stepsizearc) * -1
1173 gcpy #          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
radius, barc, earc)
1174 gcpy #          if self.generatepaths == True:
1175 gcpy #              print("Unioning n toolpath")
1176 gcpy #              self.toolpaths = self.toolpaths.union(toolpath)
1177 gcpy #          else:
1178 gcpy              self.setxpos(xcenter + radius * Cos(earc))
1179 gcpy              self.setypos(ycenter + radius * Sin(earc))
1180 gcpy #          self.toolpaths.extend(toolpath)
1181 gcpy #          if self.generatepaths == False:
1182 gcpy #              return toolpath
1183 gcpy #          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:

```
1199 gcpy      def cutarcCWdxf(self, barc, earc, xcenter, ycenter, radius,
1200 gcpy          tpzreldim, stepsizearc=1):
1201 gcpy          self.cutarcCW(barc, earc, xcenter, ycenter, radius,
1202 gcpy          tpzreldim, stepsizearc=1)
1203 gcpy          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
1204 gcpy          radius, earc, barc)
1205 gcpy          if self.generatepaths == False:
1206 gcpy          return toolpath
1207 gcpy          else:
1208 gcpy          return cube([0.01, 0.01, 0.01])
1209 gcpy
1210 gcpy      def cutarcCCdxf(self, barc, earc, xcenter, ycenter, radius,
1211 gcpy          tpzreldim, stepsizearc=1):
1212 gcpy          self.cutarcCC(barc, earc, xcenter, ycenter, radius,
1213 gcpy          tpzreldim, stepsizearc=1)
1214 gcpy          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
1215 gcpy          radius, barc, earc)
```

Matching OpenSCAD modules are easily made:

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

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
1223 gcpy      def cutquarterCCNW(self, ex, ey, ez, radius):
1224 gcpy          if self.zpos() == ez:
1225 gcpy              tpzinc = 0
1226 gcpy          else:
1227 gcpy              tpzinc = (ez - self.zpos()) / 90
1228 gcpy              tpzinc = (self.zpos() + ez) / 90
1229 gcpy          self.debug("tpzinc_", tpzinc)
1230 gcpy          i = 91
```

```

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

```

```

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

```

```
118 gpcscad }
119 gpcscad
120 gpcscad module cutquarterCCSEdxf(self, ex, ey, ez, radius){
121 gpcscad     gcp.cutquarterCCSEdxf(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 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 E0 ;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 E0

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_S0")
1367 gcpy	
1368 gcpy	def setfanspeed(self, fan, speed):
1369 gcpy	self.writegc("M106_P", fan, "_S", speed)
1370 gcpy	
1371 gcpy	def pauseforclearbuffer(self):
1372 gcpy	self.writegc("M400_;_wait_for_buffer_to_clear")

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_S", feedratio)
1376 gcpy	self.feedratio = feedratio
1377 gcpy	
1378 gcpy	def setspeedratio(self, speedratio):
1379 gcpy	self.writegc("M221_S", 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	<i>#Set extruder temperature: M104 [T<index>] [S<temperature>]</i>
-----------	--

```
1383 gcpy      def setextrudertemperature(self, temperature):
1384 gcpy          self.writegc("M104 S" + 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 S" + str(temperature) + "; set
          temperature and wait for it to be reached")
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 S" + 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 S" + 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 ; set units to millimeters")
1410 gcpy          self.writegc("G90")
1411 gcpy          self.writegc("M82 ; use absolute distances for extrusion")
1412 gcpy          self.writegc("G28 ; home")
1413 gcpy          self.writegc("M729 ; Clean Nozzle")
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 Z5 F" + str(liftfeed) + " ; lift nozzle")
1422 gcpy          self.writegc("G92 E0")
1423 gcpy          self.writegc("G1 E-2 F" + str(extrusionfeed))
1424 gcpy          self.writegc("G92 E0")
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 S", 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 P", percent)
1434 gcpy          self.percent = percent
```

The program 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 / toolchar

```

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 mm³/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 gcpy          l = k.translate([ew/2-lh/2,0,0])
1453 gcpy          m = union(l, square([ew/2-lh/2, lh]))
1454 gcpy          c = rotate_extrude(m)
1455 gcpy          c = c.translate([0,0,-self.layerheight])
1456 gcpy          tslist = hull(c.translate([self.xpos(), self.ypos(),self.
              zpos()]), c.translate([ex, ey, ez]))
1457 gcpy          self.toolpaths.append(tslist)
1458 gcpy          #volume = ∫ r^2 ∫ length
1459 gcpy          #          + extrusionwidth-layerheight ∫ layerheight ∫
              length
1460 gcpy          distance = math.dist([self.xpos(), self.ypos(), self.zpos()
              ], [ex, ey, ez])
1461 gcpy          print("Distance_=", distance)
1462 gcpy          v = self.extrusionwidth-self.layerheight * self.layerheight
              * distance + 3.14159 * self.layerheight/2 * self.
              layerheight/2 * distance
1463 gcpy          print("Volume_=",v)
1464 gcpy          el = self.extrusion_normal_length * v
1465 gcpy          print("Extrusion_length_=",el)
1466 gcpy          self.writegc("G01_X" + str(ex) + "_Y" + str(ey) + "_Z_" +
              str(ez) + "_E" + str(el) + "_F" + str(self.feedrate))

```

The system Fullcontrolcode <https://fullcontrolgcode.com/> affords a complete 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/ 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

writeln 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.generateddxf == 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.generateddxfs == 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.generateddxfs == True:
1524 gcpy              if (self.large_square_tool_num == toolnumber):
1525 gcpy                  self.dxf_lgsq.write(line_to_write)
1526 gcpy                  self.dxf_lgsq.write("\n")
1527 gcpy              if (self.small_square_tool_num == toolnumber):
1528 gcpy                  self.dxf_ssq.write(line_to_write)
1529 gcpy                  self.dxf_ssq.write("\n")
1530 gcpy              if (self.large_ball_tool_num == toolnumber):
1531 gcpy                  self.dxf_lgb.write(line_to_write)
1532 gcpy                  self.dxf_lgb.write("\n")
1533 gcpy              if (self.small_ball_tool_num == toolnumber):
1534 gcpy                  self.dxf_smb.write(line_to_write)
1535 gcpy                  self.dxf_smb.write("\n")
1536 gcpy              if (self.large_V_tool_num == toolnumber):
1537 gcpy                  self.dxf_lgv.write(line_to_write)
1538 gcpy                  self.dxf_lgv.write("\n")
1539 gcpy              if (self.small_V_tool_num == toolnumber):
1540 gcpy                  self.dxf_svm.write(line_to_write)
1541 gcpy                  self.dxf_svm.write("\n")
1542 gcpy              if (self.DT_tool_num == toolnumber):
1543 gcpy                  self.dxf_DT.write(line_to_write)
1544 gcpy                  self.dxf_DT.write("\n")
1545 gcpy              if (self.KH_tool_num == toolnumber):
1546 gcpy                  self.dxf_KH.write(line_to_write)
1547 gcpy                  self.dxf_KH.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 opendxfile 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,
    small_square_tool_num, large_ball_tool_num, small_ball_tool_num,
    large_V_tool_num, small_V_tool_num, DT_tool_num, KH_tool_num,
    Roundover_tool_num, MISC_tool_num) {
135 gpcscad     gcp.opendxfiles(Base_filename, large_square_tool_num,
    small_square_tool_num, large_ball_tool_num,
    small_ball_tool_num, large_V_tool_num, small_V_tool_num,
    DT_tool_num, KH_tool_num, Roundover_tool_num, MISC_tool_num)
    ;
136 gpcscad }
```

opengcodefile With matching OpenSCAD commands: opengcodefile for OpenSCAD:

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

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.gcodefilename = basefilename + self.gcodefilext
1570 gcpy             self.gc = open(self.gcodefilename, "w")
1571 gcpy             self.writegc("(Design_File:_" + self.basefilename + ")")
1572 gcpy
1573 gcpy     def opendxfile(self, basefilename = "export"):
1574 gcpy         self.basefilename = basefilename
1575 gcpy         # global generatedxfs
1576 gcpy         # global dxfclosed
1577 gcpy         self.dxfclosed = False
1578 gcpy         self.dxfcolor = "Black"
1579 gcpy         if self.generatedxif == True:
1580 gcpy             self.generatedxfs = 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                                large_square_tool_num = 0,
1587 gcpy                                small_square_tool_num = 0,
1588 gcpy                                large_ball_tool_num = 0,
1589 gcpy                                small_ball_tool_num = 0,
1590 gcpy                                large_V_tool_num = 0,
1591 gcpy                                small_V_tool_num = 0,
1592 gcpy                                DT_tool_num = 0,
1593 gcpy                                KH_tool_num = 0,
1594 gcpy                                Roundover_tool_num = 0,
1595 gcpy                                MISC_tool_num = 0):
1596 gcpy #                                global generatedxfs
1597 gcpy                                self.basefilename = basefilename
1598 gcpy                                self.generatedxfs = True
1599 gcpy                                self.large_square_tool_num = large_square_tool_num
1600 gcpy                                self.small_square_tool_num = small_square_tool_num
1601 gcpy                                self.large_ball_tool_num = large_ball_tool_num
1602 gcpy                                self.small_ball_tool_num = small_ball_tool_num
1603 gcpy                                self.large_V_tool_num = large_V_tool_num
1604 gcpy                                self.small_V_tool_num = small_V_tool_num
1605 gcpy                                self.DT_tool_num = DT_tool_num
1606 gcpy                                self.KH_tool_num = KH_tool_num
1607 gcpy                                self.Roundover_tool_num = Roundover_tool_num
1608 gcpy                                self.MISC_tool_num = MISC_tool_num
1609 gcpy                                if self.generatedxfs == True:
1610 gcpy                                    if (large_square_tool_num > 0):
1611 gcpy                                        self.dxf_lsqfilename = basefilename + str(
                                                large_square_tool_num) + ".dxf"
1612 gcpy #                                        print("Opening ", str(self.dxf_lsqfilename))
1613 gcpy                                        self.dxf_lsq = open(self.dxf_lsqfilename, "w")
1614 gcpy                                if (small_square_tool_num > 0):
1615 gcpy #                                    print("Opening small square")
1616 gcpy                                        self.dxf_ssqfilename = basefilename + str(
                                                small_square_tool_num) + ".dxf"
1617 gcpy                                        self.dxf_ssq = open(self.dxf_ssqfilename, "w")
1618 gcpy                                if (large_ball_tool_num > 0):
1619 gcpy #                                    print("Opening large ball")
1620 gcpy                                        self.dxf_lgbfilename = basefilename + str(
                                                large_ball_tool_num) + ".dxf"
1621 gcpy                                        self.dxf_lgb = open(self.dxf_lgbfilename, "w")
1622 gcpy                                if (small_ball_tool_num > 0):
1623 gcpy #                                    print("Opening small ball")
1624 gcpy                                        self.dxf_smbfilename = basefilename + str(
                                                small_ball_tool_num) + ".dxf"
1625 gcpy                                        self.dxf_smb = open(self.dxf_smbfilename, "w")
1626 gcpy                                if (large_V_tool_num > 0):
1627 gcpy #                                    print("Opening large V")
1628 gcpy                                        self.dxf_lvgfilename = basefilename + str(
                                                large_V_tool_num) + ".dxf"
1629 gcpy                                        self.dxf_lvg = open(self.dxf_lvgfilename, "w")
1630 gcpy                                if (small_V_tool_num > 0):
1631 gcpy #                                    print("Opening small V")
1632 gcpy                                        self.dxf_svgfilename = basefilename + str(
                                                small_V_tool_num) + ".dxf"
1633 gcpy                                        self.dxf_svg = open(self.dxf_svgfilename, "w")
1634 gcpy                                if (DT_tool_num > 0):
1635 gcpy #                                    print("Opening DT")
1636 gcpy                                        self.dxfDTfilename = basefilename + str(DT_tool_num
                                                ) + ".dxf"
1637 gcpy                                        self.dxfDT = open(self.dxfDTfilename, "w")
1638 gcpy                                if (KH_tool_num > 0):
1639 gcpy #                                    print("Opening KH")
1640 gcpy                                        self.dxfKHfilename = basefilename + str(KH_tool_num
                                                ) + ".dxf"
1641 gcpy                                        self.dxfKH = open(self.dxfKHfilename, "w")
1642 gcpy                                if (Roundover_tool_num > 0):
1643 gcpy #                                    print("Opening Rt")
1644 gcpy                                        self.dxfRtfilename = basefilename + str(
                                                Roundover_tool_num) + ".dxf"
1645 gcpy                                        self.dxfRt = open(self.dxfRtfilename, "w")
1646 gcpy                                if (MISC_tool_num > 0):
1647 gcpy #                                    print("Opening Mt")
1648 gcpy                                        self.dxfMtfilename = basefilename + str(
                                                MISC_tool_num) + ".dxf"
1649 gcpy                                        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

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:

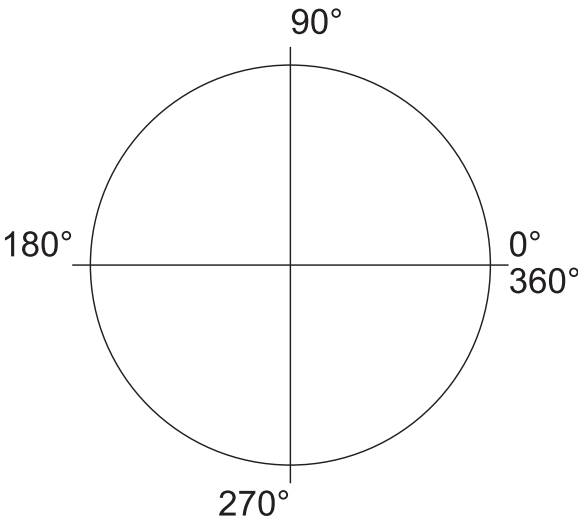
writedxflgbl	• Ball nose, large (lgbl) writedxflgbl
writedxfsmb1	• Ball nose, small (smb1) writedxfsmb1
writedxflgsq	• Square, large (lgsq) writedxflgsq
writedxfsmsq	• Square, small (smsq) writedxfsmsq
writedxflgV	• V, large (lgV) writedxflgV
writedxfsmV	• V, small (smV) writedxfsmV
writedxfKH	• Keyhole (KH) writedxfKH
writedxfDT	• Dovetail (DT) 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	• arc dxfarc
dxfarc	• circle — a notable option would be for the arc to close on itself, creating a circle dxfcircle
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 == "Dark_Gray"):
1701 gcpy              self.writedxf(tn, "Layer_Dark_Gray")
1702 gcpy          if (self.dxfcolor == "Light_Gray"):
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 == "Dark_Gray"):
1723 gcpy              self.writedxf(tn, "8")
1724 gcpy          if (self.dxfcolor == "Light_Gray"):
1725 gcpy              self.writedxf(tn, "9")
1726 gcpy
1727 gcpy
1728 gcpy
1729 gcpy
1730 gcpy
1731 gcpy
1732 gcpy
1733 gcpy
1734 gcpy
1735 gcpy
1736 gcpy
1737 gcpy
1738 gcpy
1739 gcpy
1740 gcpy
1741 gcpy
1742 gcpy      module setdxfcOLOR(color){
1743 gpcscad          gcp.setdxfcOLOR(color);
1744 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 dxfarf(self, tn, xcenter, ycenter, radius, anglebegin,
                endangle):
1784 gcpy          if (self.generatedxf == True):
1785 gcpy              self.writedxf(tn, "0")
1786 gcpy              self.writedxf(tn, "ARC")
1787 gcpy #
1788 gcpy          self.writedxfcolor(tn)
1789 gcpy #
1790 gcpy          self.writedxf(tn, "10")
1791 gcpy          self.writedxf(tn, str(xcenter))
1792 gcpy          self.writedxf(tn, "20")
1793 gcpy          self.writedxf(tn, str(ycenter))
1794 gcpy          self.writedxf(tn, "40")
1795 gcpy          self.writedxf(tn, str(radius))
1796 gcpy          self.writedxf(tn, "50")
1797 gcpy          self.writedxf(tn, str(anglebegin))
1798 gcpy          self.writedxf(tn, "51")
1799 gcpy          self.writedxf(tn, str(endangle))
1800 gcpy
1801 gcpy      def gcodearc(self, tn, xcenter, ycenter, radius, anglebegin,
                endangle):
1802 gcpy          if (self.generategcode == True):
1803 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 cutarcNECCdxf(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(),
self.zpos()])
1809 gcpy          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                radius, 0, 90)
1810 gcpy          if (self.zpos == ez):
1811 gcpy              self.settzpos(0)
1812 gcpy          else:
1813 gcpy              self.settzpos((self.zpos()-ez)/90)
1814 gcpy #          self.setxpos(ex)
1815 gcpy #          self.setypos(ey)
1816 gcpy #          self.setzpos(ez)
1817 gcpy #          if self.generatepaths == True:
1818 gcpy #              print("Unioning cutarcNECCdxf toolpath")
1819 gcpy          self.arcloop(1, 90, xcenter, ycenter, radius)
1820 gcpy #          self.toolpaths = self.toolpaths.union(toolpath)
1821 gcpy #          else:
1822 gcpy #              toolpath = self.arcloop(1, 90, xcenter, ycenter,
radius)
1823 gcpy #          print("Returning cutarcNECCdxf toolpath")
1824 gcpy          return toolpath
1825 gcpy
1826 gcpy      def cutarcNWCCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1827 gcpy #          global toolpath
1828 gcpy #          toolpath = self.currenttool()
1829 gcpy #          toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])
1830 gcpy          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                radius, 90, 180)
1831 gcpy          if (self.zpos == ez):
1832 gcpy              self.settzpos(0)
1833 gcpy          else:
1834 gcpy              self.settzpos((self.zpos()-ez)/90)
1835 gcpy #          self.setxpos(ex)
1836 gcpy #          self.setypos(ey)
1837 gcpy #          self.setzpos(ez)
1838 gcpy #          if self.generatepaths == True:
1839 gcpy #              self.arcloop(91, 180, xcenter, ycenter, radius)
1840 gcpy #              self.toolpaths = self.toolpaths.union(toolpath)
1841 gcpy #          else:
1842 gcpy          toolpath = self.arcloop(91, 180, xcenter, ycenter, radius)
1843 gcpy          return toolpath
1844 gcpy
1845 gcpy      def cutarcSWCCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1846 gcpy #          global toolpath
1847 gcpy #          toolpath = self.currenttool()
1848 gcpy #          toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])

```



```

1849 gcpy          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 180, 270)
1850 gcpy          if (self.zpos == ez):
1851 gcpy              self.settzpos(0)
1852 gcpy          else:
1853 gcpy              self.settzpos((self.zpos()-ez)/90)
1854 gcpy #          self.setxpos(ex)
1855 gcpy #          self.setypos(ey)
1856 gcpy #          self.setzpos(ez)
1857 gcpy          if self.generatepaths == True:
1858 gcpy              self.arcloop(181, 270, xcenter, ycenter, radius)
1859 gcpy #          self.toolpaths = self.toolpaths.union(toolpath)
1860 gcpy          else:
1861 gcpy              toolpath = self.arcloop(181, 270, xcenter, ycenter,
                        radius)
1862 gcpy              return toolpath
1863 gcpy
1864 gcpy          def cutarcSECCdx(self, ex, ey, ez, xcenter, ycenter, radius):
1865 gcpy #              global toolpath
1866 gcpy #              toolpath = self.currenttool()
1867 gcpy #              toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])
1868 gcpy          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 270, 360)
1869 gcpy          if (self.zpos == ez):
1870 gcpy              self.settzpos(0)
1871 gcpy          else:
1872 gcpy              self.settzpos((self.zpos()-ez)/90)
1873 gcpy #          self.setxpos(ex)
1874 gcpy #          self.setypos(ey)
1875 gcpy #          self.setzpos(ez)
1876 gcpy          if self.generatepaths == True:
1877 gcpy              self.arcloop(271, 360, xcenter, ycenter, radius)
1878 gcpy #          self.toolpaths = self.toolpaths.union(toolpath)
1879 gcpy          else:
1880 gcpy              toolpath = self.arcloop(271, 360, xcenter, ycenter,
                        radius)
1881 gcpy              return toolpath
1882 gcpy
1883 gcpy          def cutarcNECWdx(self, ex, ey, ez, xcenter, ycenter, radius):
1884 gcpy #              global toolpath
1885 gcpy #              toolpath = self.currenttool()
1886 gcpy #              toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])
1887 gcpy          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 0, 90)
1888 gcpy          if (self.zpos == ez):
1889 gcpy              self.settzpos(0)
1890 gcpy          else:
1891 gcpy              self.settzpos((self.zpos()-ez)/90)
1892 gcpy #          self.setxpos(ex)
1893 gcpy #          self.setypos(ey)
1894 gcpy #          self.setzpos(ez)
1895 gcpy          if self.generatepaths == True:
1896 gcpy              self.narcloop(89, 0, xcenter, ycenter, radius)
1897 gcpy #          self.toolpaths = self.toolpaths.union(toolpath)
1898 gcpy          else:
1899 gcpy              toolpath = self.narcloop(89, 0, xcenter, ycenter,
                        radius)
1900 gcpy              return toolpath
1901 gcpy
1902 gcpy          def cutarcSECWdx(self, ex, ey, ez, xcenter, ycenter, radius):
1903 gcpy #              global toolpath
1904 gcpy #              toolpath = self.currenttool()
1905 gcpy #              toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])
1906 gcpy          self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 270, 360)
1907 gcpy          if (self.zpos == ez):
1908 gcpy              self.settzpos(0)
1909 gcpy          else:
1910 gcpy              self.settzpos((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 cutarcSWCWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1922 gcpy              global toolpath
1923 gcpy              toolpath = self.currentttool()
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.settzpos(0)
1930 gcpy              else:
1931 gcpy                  self.settzpos((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 cutarcNWCWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1943 gcpy              global toolpath
1944 gcpy              toolpath = self.currentttool()
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.settzpos(0)
1951 gcpy              else:
1952 gcpy                  self.settzpos((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:

cutarcNECCdxf(-(stockXwidth/4, stockYheight/4+stockYheight/16, -stockZthickness, -stockXwidth/4, stockYh
cutarcNWCCdxf(-(stockXwidth/4+stockYheight/16), stockYheight/4, -stockZthickness, -stockXwidth/4, stock
cutarcSWCCdxf(-(stockXwidth/4, stockYheight/4-stockYheight/16, -stockZthickness, -stockXwidth/4, stockYh
cutarcSECCdxf(-(stockXwidth/4-stockYheight/16), stockYheight/4, -stockZthickness, -stockXwidth/4, stock

```
1959 gcpy          def arcCCgc(self, ex, ey, ez, xcenter, ycenter, radius):
1960 gcpy              self.writegc("G03_X", str(ex), "Y", str(ey), "Z", str(ez)
1961 gcpy                , "R", str(radius))
1962 gcpy          def arcCWgc(self, ex, ey, ez, xcenter, ycenter, radius):
1963 gcpy              self.writegc("G02_X", str(ex), "Y", str(ey), "Z", str(ez)
1964 gcpy                , "R", 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.cutarcNECCdxf(ex, ey, ez, xcenter, ycenter, radius
1970 gcpy                    )
1971 gcpy              else:
1972 gcpy                  return self.cutarcNECCdxf(ex, ey, ez, xcenter, ycenter,
1973 gcpy                    radius)
```

```
1972 gcpy      def cutarcNWCCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                :
1973 gcpy      self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1974 gcpy      if self.generatepaths == False:
1975 gcpy          return self.cutarcNWCCdxfc(ex, ey, ez, xcenter, ycenter,
                radius)

1976 gcpy
1977 gcpy      def cutarcSWCCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                :
1978 gcpy      self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1979 gcpy      if self.generatepaths == False:
1980 gcpy          return self.cutarcSWCCdxfc(ex, ey, ez, xcenter, ycenter,
                radius)

1981 gcpy
1982 gcpy      def cutarcSECCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                :
1983 gcpy      self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1984 gcpy      if self.generatepaths == False:
1985 gcpy          return self.cutarcSECCdxfc(ex, ey, ez, xcenter, ycenter,
                radius)

1986 gcpy
1987 gcpy      def cutarcNECWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                :
1988 gcpy      self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1989 gcpy      if self.generatepaths == False:
1990 gcpy          return self.cutarcNECWdxfc(ex, ey, ez, xcenter, ycenter,
                radius)

1991 gcpy
1992 gcpy      def cutarcSECWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                :
1993 gcpy      self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1994 gcpy      if self.generatepaths == False:
1995 gcpy          return self.cutarcSECWdxfc(ex, ey, ez, xcenter, ycenter,
                radius)

1996 gcpy
1997 gcpy      def cutarcSWCWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                :
1998 gcpy      self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1999 gcpy      if self.generatepaths == False:
2000 gcpy          return self.cutarcSWCWdxfc(ex, ey, ez, xcenter, ycenter,
                radius)

2001 gcpy
2002 gcpy      def cutarcNWCWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                :
2003 gcpy      self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
2004 gcpy      if self.generatepaths == False:
2005 gcpy          return self.cutarcNWCWdxfc(ex, ey, ez, xcenter, ycenter,
                radius)

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

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) GOX0Y0 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) GOX0.000Y-152.400 Z0.250	writecomment(...) 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 dxfpostamble(self, tn):
2008 gcpy #          self.writedxf(tn, str(tn))
2009 gcpy          self.writedxf(tn, "0")
2010 gcpy          self.writedxf(tn, "ENDSEC")
2011 gcpy          self.writedxf(tn, "0")
2012 gcpy          self.writedxf(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_E0")
2021 gcpy              self.writegc("M107_;;_turn_off_cooling_fans")
2022 gcpy              self.writegc("M104_S0_;;_turn_off_temperature")
2023 gcpy              self.writegc("G28_X0_;;_home_X_axis")
2024 gcpy              self.writegc("M84_;;_disable_motors")
```

`dxfpostamble` It will be necessary to call the `dxfpostamble` (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.generatedxfile == True:
2033 gcpy #              global dxfclose
2034 gcpy              self.dxfpostamble(-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.dxfpostamble(self.large_square_tool_num)
2042 gcpy              if (self.small_square_tool_num > 0):
2043 gcpy                  self.dxfpostamble(self.small_square_tool_num)
2044 gcpy              if (self.large_ball_tool_num > 0):
2045 gcpy                  self.dxfpostamble(self.large_ball_tool_num)
2046 gcpy              if (self.small_ball_tool_num > 0):
2047 gcpy                  self.dxfpostamble(self.small_ball_tool_num)
2048 gcpy              if (self.large_V_tool_num > 0):
2049 gcpy                  self.dxfpostamble(self.large_V_tool_num)
2050 gcpy              if (self.small_V_tool_num > 0):
2051 gcpy                  self.dxfpostamble(self.small_V_tool_num)
2052 gcpy              if (self.DT_tool_num > 0):
2053 gcpy                  self.dxfpostamble(self.DT_tool_num)
2054 gcpy              if (self.KH_tool_num > 0):
2055 gcpy                  self.dxfpostamble(self.KH_tool_num)
2056 gcpy              if (self.Roundover_tool_num > 0):
2057 gcpy                  self.dxfpostamble(self.Roundover_tool_num)
2058 gcpy              if (self.MISC_tool_num > 0):
2059 gcpy                  self.dxfpostamble(self.MISC_tool_num)
2060 gcpy
2061 gcpy              if (self.large_square_tool_num > 0):
2062 gcpy                  self.dxfclose()
2063 gcpy              if (self.small_square_tool_num > 0):
2064 gcpy                  self.dxfclose()
2065 gcpy              if (self.large_ball_tool_num > 0):
2066 gcpy                  self.dxfclose()
2067 gcpy              if (self.small_ball_tool_num > 0):
2068 gcpy                  self.dxfclose()
2069 gcpy              if (self.large_V_tool_num > 0):
2070 gcpy                  self.dxfclose()
2071 gcpy              if (self.small_V_tool_num > 0):
2072 gcpy                  self.dxfclose()
2073 gcpy              if (self.DT_tool_num > 0):
2074 gcpy                  self.dxfclose()
```

```
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()
```

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

```
162 gpcscad module closecodefile(){
163 gpcscad     gcp.closecodefile();
164 gpcscad }
165 gpcscad
166 gpcscad module closedxfiles(){
167 gpcscad     gcp.closedxfiles();
168 gpcscad }
169 gpcscad
170 gpcscad module closedxfile(){
171 gpcscad     gcp.closedxfile();
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 be 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 — dxflines
- arcs — dxfarcs

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°)
 - * sextants (60°)
 - * octants (45°)
 - 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 sector¹
 - 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:

¹en.wikipedia.org/wiki/Hyperbolic_sector and 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 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)
2091 gcpy          self.cutquarterCCNW(xcenter - radius, ycenter, self.zpos()
2092 gcpy              + ez/4, radius)
2092 gcpy          self.cutquarterCCSW(xcenter, ycenter - radius, self.zpos()
2093 gcpy              + ez/4, radius)
2093 gcpy          self.cutquarterCCSE(xcenter + radius, ycenter, self.zpos()
2094 gcpy              + ez/4, radius)
2094 gcpy
2095 gcpy      def cutcircleCCdxf(self, xcenter, ycenter, bz, ez, radius):
2096 gcpy          self.cutcircleCC(self, xcenter, ycenter, bz, ez, radius)
2097 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)
2102 gcpy              self.dxfline(tool_num, xorigin + xwidth, yorigin,
2103 gcpy                  xorigin + xwidth, yorigin + yheight)
2103 gcpy              self.dxfline(tool_num, xorigin + xwidth, yorigin +
2104 gcpy                  yheight, xorigin, yorigin + yheight)
2104 gcpy              self.dxfline(tool_num, xorigin, yorigin + yheight,
2105 gcpy                  xorigin, yorigin)
2105 gcpy          elif corners == "Fillet":
2106 gcpy              self.dxfrectangleround(tool_num, xorigin, yorigin,
2107 gcpy                  xwidth, yheight, radius)
2107 gcpy          elif corners == "Chamfer":
2108 gcpy              self.dxfrectanglechamfer(tool_num, xorigin, yorigin,
2109 gcpy                  xwidth, yheight, radius)
2109 gcpy          elif corners == "Flipped_Fillet":
2110 gcpy              self.dxfrectangleflippedfillet(tool_num, xorigin,
2111 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):
2113 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 dxfrectanglechamfer(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              xorigin + xwidth, yorigin + radius)
```

Flipped Fillet:

```
2204 gcpy      def dxfrectangleflippedfillet(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              zdepth)
2227 gcpy          self.dxfrectangle(tool_num, bx, by, xwidth, yheight, "
```

The rounded forms instantiate a radius:

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

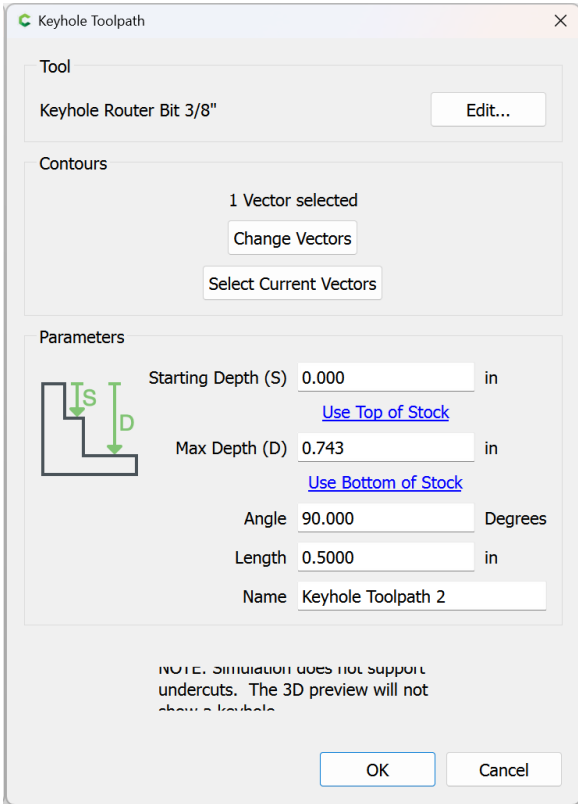
```

yheight, zdepth, radius):
2228 gcpy #     self.rapid(bx + radius, by, bz)
2229 gcpy     self.cutline(bx + radius, by, bz + zdepth)
2230 gcpy     self.cutline(bx + xwidth - radius, by, bz + zdepth)
2231 gcpy     self.cutquarterCCSE(bx + xwidth, by + radius, bz + zdepth,
                                radius)
2232 gcpy     self.cutline(bx + xwidth, by + yheight - radius, bz +
                                zdepth)
2233 gcpy     self.cutquarterCCNE(bx + xwidth - radius, by + yheight, bz
                                + zdepth, radius)
2234 gcpy     self.cutline(bx + radius, by + yheight, bz + zdepth)
2235 gcpy     self.cutquarterCCNW(bx, by + yheight - radius, bz + zdepth,
                                radius)
2236 gcpy     self.cutline(bx, by + radius, bz + zdepth)
2237 gcpy     self.cutquarterCCSW(bx + radius, by, bz + zdepth, radius)
2238 gcpy
2239 gcpy     def cutrectanglerounddx(self, tool_num, bx, by, bz, xwidth,
yheight, zdepth, radius):
2240 gcpy         self.cutrectangleround(tool_num, bx, by, bz, xwidth,
yheight, zdepth, radius)
2241 gcpy         self.dxfrectangleround(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 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 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,
	kh_max_depth, kht_direction, kh_distance):
2244 gcpy	if (kht_direction == "N"):
2245 gcpy	toolpath = self.cutKHgcdxf(kh_tool_num, kh_start_depth,
	kh_max_depth, 90, kh_distance)
2246 gcpy	elif (kht_direction == "S"):
2247 gcpy	toolpath = self.cutKHgcdxf(kh_tool_num, kh_start_depth,
	kh_max_depth, 270, kh_distance)
2248 gcpy	elif (kht_direction == "E"):
2249 gcpy	toolpath = self.cutKHgcdxf(kh_tool_num, kh_start_depth,
	kh_max_depth, 0, kh_distance)
2250 gcpy	elif (kht_direction == "W"):
2251 gcpy	toolpath = self.cutKHgcdxf(kh_tool_num, kh_start_depth,
	kh_max_depth, 180, kh_distance)
2252 gcpy #	if self.generatepaths == True:
2253 gcpy #	self.toolpaths = union([self.toolpaths, toolpath])
2254 gcpy	return toolpath
2255 gcpy #	else :
2256 gcpy #	return cube([0.01, 0.01, 0.01])
<hr/>	
174 gcpscad	module cutkeyholegcdxf(kh_tool_num, kh_start_depth, kh_max_depth,
	kht_direction, kh_distance){
175 gcpscad	gcp.cutkeyholegcdxf(kh_tool_num, kh_start_depth, kh_max_depth,
	kht_direction, kh_distance);
176 gcpscad	}

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,
	kh_angle, kh_distance):
2259 gcpy	oXpos = self.xpos()
2260 gcpy	oYpos = self.ypos()
2261 gcpy	self.dxfKH(kh_tool_num, self.xpos(), self.ypos(),
	kh_start_depth, kh_max_depth, kh_angle, kh_distance)
2262 gcpy	toolpath = self.cutline(self.xpos(), self.ypos(), -
	kh_max_depth)
2263 gcpy	self.setxpos(oXpos)
2264 gcpy	self.setypos(oYpos)
2265 gcpy #	if self.generatepaths == False:
2266 gcpy	return toolpath
2267 gcpy #	else :
2268 gcpy #	return cube([0.001, 0.001, 0.001])
<hr/>	
2270 gcpy	def dxfKH(self, kh_tool_num, oXpos, oYpos, kh_start_depth,
	kh_max_depth, kh_angle, kh_distance):
2271 gcpy #	oXpos = self.xpos()
2272 gcpy #	oYpos = self.ypos()
2273 gcpy	<i>#Circle at entry hole</i>
2274 gcpy	self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius(
	kh_tool_num, 7), 0, 90)
2275 gcpy	self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius(
	kh_tool_num, 7), 90, 180)
2276 gcpy	self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius(
	kh_tool_num, 7), 180, 270)
2277 gcpy	self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius(
	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 #         print(r)
2281 gcpy         rt = self.tool_radius(kh_tool_num, 1)
2282 gcpy #         print(rt)
2283 gcpy         ro = math.sqrt((self.tool_radius(kh_tool_num, 1))**2-(self.
                tool_radius(kh_tool_num, 7))**2)
2284 gcpy #         print(ro)
2285 gcpy         angle = math.degrees(math.acos(ro/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
                .tool_radius(kh_tool_num, 1), 180, 270)
2290 gcpy #Upper left of entry hole
2291 gcpy             self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), self
                .tool_radius(kh_tool_num, 1), 90, 180)
2292 gcpy #Upper right of entry hole
2293 gcpy #             self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
                41.810, 90)
2294 gcpy             self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
                angle, 90)
2295 gcpy #Lower right of entry hole
2296 gcpy             self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
                270, 360-angle)
2297 gcpy #             self.dxfarc(kh_tool_num, self.xpos(), self.ypos(),
                self.tool_radius(kh_tool_num, 1), 270, 270+math.acos(self.
                tool_diameter(kh_tool_num, 5)/self.tool_diameter(kh_tool_num, 1)
                ))
2298 gcpy #Actual line of cut
2299 gcpy #             self.dxfline(kh_tool_num, self.xpos(), self.ypos(),
                self.xpos()+kh_distance, self.ypos())
2300 gcpy #upper right of end of slot (kh_max_depth+4.36))/2
2301 gcpy             self.dxfarc(kh_tool_num, self.xpos()+kh_distance, self.
                ypos(), self.tool_diameter(kh_tool_num, (
                kh_max_depth+4.36))/2, 0, 90)
2302 gcpy #lower right of end of slot
2303 gcpy             self.dxfarc(kh_tool_num, self.xpos()+kh_distance, self.
                ypos(), self.tool_diameter(kh_tool_num, (
                kh_max_depth+4.36))/2, 270, 360)
2304 gcpy #upper right slot
2305 gcpy             self.dxfline(kh_tool_num, self.xpos()+ro, self.ypos()-(
                self.tool_diameter(kh_tool_num, 7)/2), self.xpos()+
                kh_distance, self.ypos()-(self.tool_diameter(
                kh_tool_num, 7)/2))
2306 gcpy #             self.dxfline(kh_tool_num, self.xpos()+(math.sqrt((self
                .tool_diameter(kh_tool_num, 1)^2)-(self.tool_diameter(
                kh_tool_num, 5)^2))/2), self.ypos()+self.tool_diameter(
                kh_tool_num, (kh_max_depth))/2, ((kh_max_depth-6.34))/2)^2-(
                self.tool_diameter(kh_tool_num, (kh_max_depth-6.34))/2)^2, self.
                xpos()+kh_distance, self.ypos()+self.tool_diameter(kh_tool_num,
                (kh_max_depth))/2, kh_tool_num)
2307 gcpy #end position at top of slot
2308 gcpy #lower right slot
2309 gcpy             self.dxfline(kh_tool_num, self.xpos()+ro, self.ypos()+(
                self.tool_diameter(kh_tool_num, 7)/2), self.xpos()+
                kh_distance, self.ypos()+(self.tool_diameter(
                kh_tool_num, 7)/2))
2310 gcpy #             dxfline(kh_tool_num, self.xpos()+(math.sqrt((self.
                tool_diameter(kh_tool_num, 1)^2)-(self.tool_diameter(kh_tool_num
                , 5)^2))/2), self.ypos()-self.tool_diameter(kh_tool_num, (
                kh_max_depth))/2, ((kh_max_depth-6.34))/2)^2-(self.
                tool_diameter(kh_tool_num, (kh_max_depth-6.34))/2)^2, self.xpos
                ()+kh_distance, self.ypos()-self.tool_diameter(kh_tool_num, (
                kh_max_depth))/2, KH_tool_num)
2311 gcpy #end position at top of slot
2312 gcpy #             hull(){
2313 gcpy #                 translate([xpos(), ypos(), zpos()]){
2314 gcpy #                     keyhole_shaft(6.35, 9.525);
2315 gcpy #                 }
2316 gcpy #                 translate([xpos(), ypos(), zpos()-kh_max_depth]){
2317 gcpy #                     keyhole_shaft(6.35, 9.525);
2318 gcpy #                 }
2319 gcpy #             }
2320 gcpy #             hull(){
2321 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,
                feed);
2330 gcpy #         setxpos(getxpos()-kh_distance);
2331 gcpy #     } else if (kh_angle > 0 && kh_angle < 90) {
2332 gcpy # //echo(kh_angle);
2333 gcpy #     dxfarc(getxpos(), getypos(), tool_diameter(KH_tool_num, (
                kh_max_depth))/2, 90+kh_angle, 180+kh_angle, KH_tool_num);
2334 gcpy #     dxfarc(getxpos(), getypos(), tool_diameter(KH_tool_num, (
                kh_max_depth))/2, 180+kh_angle, 270+kh_angle, KH_tool_num);
2335 gcpy # dxfarc(getxpos(), getypos(), tool_diameter(KH_tool_num, (
                kh_max_depth))/2, kh_angle+asin((tool_diameter(KH_tool_num, (
                kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_num, (kh_max_depth
                ))/2)), 90+kh_angle, KH_tool_num);
2336 gcpy # dxfarc(getxpos(), getypos(), tool_diameter(KH_tool_num, (
                kh_max_depth))/2, 270+kh_angle, 360+kh_angle-asin((tool_diameter
                (KH_tool_num, (kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_num
                , (kh_max_depth))/2)), KH_tool_num);
2337 gcpy # dxfarc(getxpos()+(kh_distance*cos(kh_angle)),
2338 gcpy #     getypos()+(kh_distance*sin(kh_angle)), tool_diameter(KH_tool_num
                , (kh_max_depth+4.36))/2, 0+kh_angle, 90+kh_angle, KH_tool_num);
2339 gcpy # dxfarc(getxpos()+(kh_distance*cos(kh_angle)), getypos()+(
                kh_distance*sin(kh_angle)), tool_diameter(KH_tool_num, (
                kh_max_depth+4.36))/2, 270+kh_angle, 360+kh_angle, KH_tool_num);
2340 gcpy # dxflines( getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2*
                cos(kh_angle+asin((tool_diameter(KH_tool_num, (kh_max_depth
                +4.36))/2)/(tool_diameter(KH_tool_num, (kh_max_depth))/2))),
2341 gcpy #     getypos()+tool_diameter(KH_tool_num, (kh_max_depth))/2*sin(
                kh_angle+asin((tool_diameter(KH_tool_num, (kh_max_depth+4.36))
                /2)/(tool_diameter(KH_tool_num, (kh_max_depth))/2))),
2342 gcpy #     getxpos()+(kh_distance*cos(kh_angle))-((tool_diameter(KH_tool_num
                , (kh_max_depth+4.36))/2)*sin(kh_angle)),
2343 gcpy #     getypos()+(kh_distance*sin(kh_angle))+((tool_diameter(KH_tool_num
                , (kh_max_depth+4.36))/2)*cos(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
                +4.36))/2)/(tool_diameter(KH_tool_num, (kh_max_depth))/2)));
2347 gcpy # //echo(kh_angle);
2348 gcpy #     cutwithfeed(getxpos()+(kh_distance*cos(kh_angle)), getypos()+(
                kh_distance*sin(kh_angle)), -kh_max_depth, feed);
2349 gcpy #         toolpath = toolpath.union(self.cutline(self.xpos()+
                kh_distance, self.ypos(), -kh_max_depth))
2350 gcpy         elif (kh_angle == 90):
2351 gcpy #Lower left of entry hole
2352 gcpy         self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius
                (kh_tool_num, 1), 180, 270)
2353 gcpy #Lower right of entry hole
2354 gcpy         self.dxfarc(kh_tool_num, oXpos, oYpos, self.tool_radius
                (kh_tool_num, 1), 270, 360)
2355 gcpy #left slot
2356 gcpy         self.dxfline(kh_tool_num, oXpos-r, oYpos+ro, oXpos-r,
                oYpos+kh_distance)
2357 gcpy #right slot
2358 gcpy         self.dxfline(kh_tool_num, oXpos+r, oYpos+ro, oXpos+r,
                oYpos+kh_distance)
2359 gcpy #upper left of end of slot
2360 gcpy         self.dxfarc(kh_tool_num, oXpos, oYpos+kh_distance, r,
                90, 180)
2361 gcpy #upper right of end of slot
2362 gcpy         self.dxfarc(kh_tool_num, oXpos, oYpos+kh_distance, r,
                0, 90)
2363 gcpy #Upper right of entry hole
2364 gcpy         self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 0, 90-angle)
2365 gcpy #Upper left of entry hole
2366 gcpy         self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 90+angle,
                180)
2367 gcpy #         toolpath = toolpath.union(self.cutline(oXpos, oYpos+
                kh_distance, -kh_max_depth))
2368 gcpy         elif (kh_angle == 180):
2369 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(

```

```

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

```



```

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 #     }
2501 gcpy #     cutwithfeed(getxpos(), getypos(), -kh_max_depth, feed);
2502 gcpy #     cutwithfeed(getxpos()-kh_distance, getypos(), -kh_max_depth,
2503 gcpy #     feed);
2504 gcpy #     setxpos(getxpos()+kh_distance);
2505 gcpy # } else if (kh_angle == 270) {
2506 gcpy # //Upper right of entry hole
2507 gcpy # dxfarc(getxpos(), getypos(), 9.525/2, 0, 90, KH_tool_num);
2508 gcpy # //Upper left of entry hole
2509 gcpy # dxfarc(getxpos(), getypos(), 9.525/2, 90, 180, KH_tool_num);
2510 gcpy # //lower right of slot
2511 gcpy # dxfarc(getxpos(), getypos()-kh_distance, tool_diameter(
2512 gcpy # KH_tool_num, (kh_max_depth+4.36))/2, 270, 360, KH_tool_num);
2513 gcpy # //lower left of slot
2514 gcpy # dxfarc(getxpos(), getypos()-kh_distance, tool_diameter(
2515 gcpy # KH_tool_num, (kh_max_depth+4.36))/2, 180, 270, KH_tool_num);
2516 gcpy # //Actual line of cut
2517 gcpy # dxfline(getxpos(), getypos(), getxpos(), getypos()-kh_distance
2518 gcpy # );
2519 gcpy # //right of slot
2520 gcpy # dxfline(
2521 gcpy #     getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
2522 gcpy #     getypos()-(math.sqrt((tool_diameter(KH_tool_num, 1)^2)-(
2523 gcpy #     tool_diameter(KH_tool_num, 5)^2))/2), //( (kh_max_depth-6.34)
2524 gcpy #     /2)^2-(tool_diameter(KH_tool_num, (kh_max_depth-6.34))/2)^2,
2525 gcpy #     getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
2526 gcpy # //end position at top of slot
2527 gcpy #     getypos()-kh_distance,
2528 gcpy #     KH_tool_num);
2529 gcpy # //left of slot
2530 gcpy # dxfline(
2531 gcpy #     getxpos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
2532 gcpy #     getypos()-(math.sqrt((tool_diameter(KH_tool_num, 1)^2)-(
2533 gcpy #     tool_diameter(KH_tool_num, 5)^2))/2), //( (kh_max_depth-6.34)
2534 gcpy #     /2)^2-(tool_diameter(KH_tool_num, (kh_max_depth-6.34))/2)^2,
2535 gcpy #     getxpos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
2536 gcpy # //end position at top of slot
2537 gcpy #     getypos()-kh_distance,
2538 gcpy #     KH_tool_num);
2539 gcpy # //Lower right of entry hole
2540 gcpy # dxfarc(getxpos(), getypos(), 9.525/2, 360-acos(tool_diameter(
2541 gcpy # KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), 360, KH_tool_num
2542 gcpy # );
2543 gcpy # //Lower left of entry hole
2544 gcpy # dxfarc(getxpos(), getypos(), 9.525/2, 180, 180+acos(
2545 gcpy # tool_diameter(KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)),
2546 gcpy # KH_tool_num);
2547 gcpy #     hull(){
2548 gcpy #         translate([xpos(), ypos(), zpos()]){
2549 gcpy #             keyhole_shaft(6.35, 9.525);
2550 gcpy #         }
2551 gcpy #         translate([xpos(), ypos(), zpos()-kh_max_depth]){
2552 gcpy #             keyhole_shaft(6.35, 9.525);
2553 gcpy #         }
2554 gcpy #     }
2555 gcpy #     hull(){
2556 gcpy #         translate([xpos(), ypos(), zpos()-kh_max_depth]){
2557 gcpy #             keyhole_shaft(6.35, 9.525);
2558 gcpy #         }
2559 gcpy #     }

```

```
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,
      feed);
2552 gcpy #      setypos(getypos()+kh_distance);
2553 gcpy #  }
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.blocks3d.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,
      Number_of_Dovetails, Spacing, Proportion, DTT_diameter,
      DTT_angle):
2557 gcpy          DTO = Tan(DTT_angle) * (stockZthickness * Proportion)
2558 gcpy          DTR = DTT_diameter/2 - DTO
2559 gcpy          cpr = self.rapidXY(0, stockZthickness + Spacing/2)
2560 gcpy          ctp = self.cutlinedxfgc(self.xpos(), self.ypos(), -
      stockZthickness * Proportion)
2561 gcpy #          ctp = ctp.union(self.cutlinedxfgc(Joint_Width / (
      Number_of_Dovetails * 2), self.ypos(), -stockZthickness *
      Proportion))
2562 gcpy          i = 1
2563 gcpy          while i < Number_of_Dovetails * 2:
2564 gcpy #              print(i)
2565 gcpy              ctp = ctp.union(self.cutlinedxfgc(i * (Joint_Width / (
      Number_of_Dovetails * 2)), self.ypos(), -
      stockZthickness * Proportion))
2566 gcpy              ctp = ctp.union(self.cutlinedxfgc(i * (Joint_Width / (
      Number_of_Dovetails * 2)), (stockZthickness +
      Spacing) + (stockZthickness * Proportion) - (
      DTT_diameter/2), -(stockZthickness * Proportion)))
2567 gcpy              ctp = ctp.union(self.cutlinedxfgc(i * (Joint_Width / (
      Number_of_Dovetails * 2)), stockZthickness + Spacing
      /2, -(stockZthickness * Proportion)))
2568 gcpy              ctp = ctp.union(self.cutlinedxfgc((i + 1) * (
      Joint_Width / (Number_of_Dovetails * 2)),
      stockZthickness + Spacing/2, -(stockZthickness *
      Proportion)))
2569 gcpy              self.dxfrectangleround(self.currenttoolnumber(),
      i * (Joint_Width / (Number_of_Dovetails * 2))-DTR,
2570 gcpy              stockZthickness + (Spacing/2) - DTR,
2571 gcpy              DTR * 2,
2572 gcpy              (stockZthickness * Proportion) + Spacing/2 + DTR *
      2 - (DTT_diameter/2),
2573 gcpy              DTR)
2574 gcpy              i += 2
2575 gcpy          self.rapidZ(0)
2576 gcpy          return ctp
2577 gcpy
```

and

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

```

2583 gcpy          ctp = self.cutlinedxfgc(self.xpos(), self.ypos(), -
                    stockZthickness * Proportion)
2584 gcpy          ctp = ctp.union(self.cutlinedxfgc(
2585 gcpy              Joint_Width / (Number_of_Dovetails * 2) - (DTT_diameter
                    - DT0),
2586 gcpy              self.ypos(),
2587 gcpy              -stockZthickness * Proportion))
2588 gcpy          i = 1
2589 gcpy          while i < Number_of_Dovetails * 2:
2590 gcpy              ctp = ctp.union(self.cutlinedxfgc(
2591 gcpy                  i * (Joint_Width / (Number_of_Dovetails * 2)) - (
                        DTT_diameter - DT0),
2592 gcpy                  stockZthickness * Proportion - DTT_diameter / 2,
2593 gcpy                  -(stockZthickness * Proportion)))
2594 gcpy              ctp = ctp.union(self.cutarcCWdxf(180, 90,
2595 gcpy                  i * (Joint_Width / (Number_of_Dovetails * 2)),
2596 gcpy                  stockZthickness * Proportion - DTT_diameter / 2,
2597 gcpy                  self.ypos(),
2598 gcpy                  DTT_diameter - DT0, 0, 1))
2599 gcpy              ctp = ctp.union(self.cutarcCWdxf(90, 0,
2600 gcpy                  i * (Joint_Width / (Number_of_Dovetails * 2)),
2601 gcpy                  stockZthickness * Proportion - DTT_diameter / 2,
2602 gcpy                  DTT_diameter - DT0, 0, 1))
2603 gcpy              ctp = ctp.union(self.cutlinedxfgc(
2604 gcpy                  i * (Joint_Width / (Number_of_Dovetails * 2)) + (
                        DTT_diameter - DT0),
2605 gcpy                  0,
2606 gcpy                  -(stockZthickness * Proportion)))
2607 gcpy              ctp = ctp.union(self.cutlinedxfgc(
2608 gcpy                  (i + 2) * (Joint_Width / (Number_of_Dovetails * 2))
                        - (DTT_diameter - DT0),
2609 gcpy                  0,
2610 gcpy                  -(stockZthickness * Proportion)))
2611 gcpy              i += 2
2612 gcpy          self.rapidZ(0)
2613 gcpy          self.rapidXY(0, 0)
2614 gcpy          ctp = ctp.union(self.cutlinedxfgc(self.xpos(), self.ypos(),
                    -stockZthickness * Proportion))
2615 gcpy          self.dxfarc(self.currenttoolnumber(), 0, 0, DTR, 180, 270)
2616 gcpy          self.dxfline(self.currenttoolnumber(), -DTR, 0, -DTR,
                    stockZthickness + DTR)
2617 gcpy          self.dxfarc(self.currenttoolnumber(), 0, stockZthickness +
                    DTR, DTR, 90, 180)
2618 gcpy          self.dxfline(self.currenttoolnumber(), 0, stockZthickness +
                    DTR * 2, Joint_Width, stockZthickness + DTR * 2)
2619 gcpy          i = 0
2620 gcpy          while i < Number_of_Dovetails * 2:
2621 gcpy              ctp = ctp.union(self.cutline(i * (Joint_Width / (
                    Number_of_Dovetails * 2)), stockZthickness + DT0, -(
                        stockZthickness * Proportion)))
2622 gcpy              ctp = ctp.union(self.cutline((i+2) * (Joint_Width / (
                    Number_of_Dovetails * 2)), stockZthickness + DT0, -(
                        stockZthickness * Proportion)))
2623 gcpy              ctp = ctp.union(self.cutline((i+2) * (Joint_Width / (
                    Number_of_Dovetails * 2)), 0, -(stockZthickness *
                        Proportion)))
2624 gcpy              self.dxfarc(self.currenttoolnumber(), i * (Joint_Width
                    / (Number_of_Dovetails * 2)), 0, DTR, 270, 360)
2625 gcpy              self.dxfline(self.currenttoolnumber(),
2626 gcpy                  i * (Joint_Width / (Number_of_Dovetails * 2)) + DTR
                    ,
2627 gcpy                  0,
2628 gcpy                  i * (Joint_Width / (Number_of_Dovetails * 2)) + DTR
                    , stockZthickness * Proportion - DTT_diameter /
                        2)
2629 gcpy              self.dxfarc(self.currenttoolnumber(), (i + 1) * (
                    Joint_Width / (Number_of_Dovetails * 2)),
                    stockZthickness * Proportion - DTT_diameter / 2, (
                        Joint_Width / (Number_of_Dovetails * 2)) - DTR, 90,
                        180)
2630 gcpy              self.dxfarc(self.currenttoolnumber(), (i + 1) * (
                    Joint_Width / (Number_of_Dovetails * 2)),
                    stockZthickness * Proportion - DTT_diameter / 2, (
                        Joint_Width / (Number_of_Dovetails * 2)) - DTR, 0,
                        90)
2631 gcpy              self.dxfline(self.currenttoolnumber(),
2632 gcpy                  (i + 2) * (Joint_Width / (Number_of_Dovetails * 2))
                        - 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_diameter)
toolpaths.append(gcp.cut_tails(stockXwidth, stockZthickness, Number_of_Dovetails, Spacing, Proportion, DTT_diameter))
```

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,
                    side, width, thickness, Number_of_Pins, largeVdiameter,
                    smallDiameter, normalormirror = "Default"):
2643 gcpy          # Joint_Orientation = "Horizontal" "Even" == "Lower", "Odd" ==
                    "Upper"
2644 gcpy          # Joint_Orientation = "Vertical" "Even" == "Left", "Odd" == "
                    Right"
2645 gcpy          if (orientation == "Vertical"):
2646 gcpy              if (normalormirror == "Default" and side != "Both"):
2647 gcpy                  if (side == "Left"):
2648 gcpy                      normalormirror = "Even"
2649 gcpy                  if (side == "Right"):
2650 gcpy                      normalormirror = "Odd"
2651 gcpy          if (orientation == "Horizontal"):
2652 gcpy              if (normalormirror == "Default" and side != "Both"):
2653 gcpy                  if (side == "Lower"):
2654 gcpy                      normalormirror = "Even"
2655 gcpy                  if (side == "Upper"):
2656 gcpy                      normalormirror = "Odd"
2657 gcpy          Finger_Width = ((Number_of_Pins * 2) - 1) * smallDiameter *
                    1.1
2658 gcpy          Finger-Origin = width/2 - Finger_Width/2
2659 gcpy          rapid = self.rapidZ(0)
2660 gcpy          self.setdxfcolor("Cyan")
2661 gcpy          rapid = rapid.union(self.rapidXY(bx, by))
2662 gcpy          toolpath = (self.Finger_Joint_square(bx, by, orientation,
                    side, width, thickness, Number_of_Pins, Finger-Origin,
                    smallDiameter))
2663 gcpy          if (orientation == "Vertical"):
2664 gcpy              if (side == "Both"):
2665 gcpy                  toolpath = self.cutrectanglerounddxf(self.
                    currenttoolnum, bx - (thickness - smallDiameter
                    /2), by-smallDiameter/2, 0, (thickness * 2) -
                    smallDiameter, width+smallDiameter, (
                    smallDiameter / 2) / Tan(45), smallDiameter/2)
```

```

2666 gcpy          if (side == "Left"):
2667 gcpy              toolpath = self.cutrectanglerounddx(
                    self.currenttoolnum, bx - (smallDiameter/2), by -
                    smallDiameter/2, 0, thickness, width +
                    smallDiameter, ((smallDiameter / 2) / Tan(45)),
                    smallDiameter/2)
2668 gcpy          if (side == "Right"):
2669 gcpy              toolpath = self.cutrectanglerounddx(
                    self.currenttoolnum, bx - (thickness - smallDiameter
                    /2), by - smallDiameter/2, 0, thickness, width +
                    smallDiameter, ((smallDiameter / 2) / Tan(45)),
                    smallDiameter/2)
2670 gcpy          toolpath = toolpath.union(self.Finger_Joint_square(bx, by,
                    orientation, side, width, thickness, Number_of_Pins,
                    Finger_Origin, smallDiameter))
2671 gcpy          if (orientation == "Horizontal"):
2672 gcpy              if (side == "Both"):
2673 gcpy                  toolpath = self.cutrectanglerounddx(
                    self.currenttoolnum,
                    bx - smallDiameter/2,
                    by - (thickness - smallDiameter/2),
                    0,
                    width + smallDiameter,
                    (thickness * 2) - smallDiameter,
                    (smallDiameter / 2) / Tan(45),
                    smallDiameter/2)
2674 gcpy
2675 gcpy
2676 gcpy
2677 gcpy
2678 gcpy
2679 gcpy
2680 gcpy
2681 gcpy
2682 gcpy          if (side == "Lower"):
2683 gcpy              toolpath = self.cutrectanglerounddx(
                    self.currenttoolnum,
                    bx - (smallDiameter/2),
                    by - smallDiameter/2,
                    0,
                    width + smallDiameter,
                    thickness,
                    ((smallDiameter / 2) / Tan(45)),
                    smallDiameter/2)
2684 gcpy
2685 gcpy
2686 gcpy
2687 gcpy
2688 gcpy
2689 gcpy
2690 gcpy
2691 gcpy
2692 gcpy          if (side == "Upper"):
2693 gcpy              toolpath = self.cutrectanglerounddx(
                    self.currenttoolnum,
                    bx - smallDiameter/2,
                    by - (thickness - smallDiameter/2),
                    0,
                    width + smallDiameter,
                    thickness,
                    ((smallDiameter / 2) / Tan(45)),
                    smallDiameter/2)
2694 gcpy
2695 gcpy
2696 gcpy
2697 gcpy
2698 gcpy
2699 gcpy
2700 gcpy
2701 gcpy
2702 gcpy          toolpath = toolpath.union(self.Finger_Joint_square(bx, by,
                    orientation, side, width, thickness, Number_of_Pins,
                    Finger_Origin, smallDiameter))
2703 gcpy          return toolpath
2704 gcpy
2705 gcpy          def Finger_Joint_square(self, bx, by, orientation, side, width,
                    thickness, Number_of_Pins, Finger_Origin, smallDiameter,
                    normalormirror = "Default"):
2706 gcpy              jointdepth = -(thickness - (smallDiameter / 2) / Tan(45))
2707 gcpy              # Joint_Orientation = "Horizontal" "Even" == "Lower", "Odd" ==
                    "Upper"
2708 gcpy              # Joint_Orientation = "Vertical" "Even" == "Left", "Odd" == "
                    Right"
2709 gcpy              if (orientation == "Vertical"):
2710 gcpy                  if (normalormirror == "Default" and side != "Both"):
2711 gcpy                      if (side == "Left"):
2712 gcpy                          normalormirror = "Even"
2713 gcpy                      if (side == "Right"):
2714 gcpy                          normalormirror = "Odd"
2715 gcpy              if (orientation == "Horizontal"):
2716 gcpy                  if (normalormirror == "Default" and side != "Both"):
2717 gcpy                      if (side == "Lower"):
2718 gcpy                          normalormirror = "Even"
2719 gcpy                      if (side == "Upper"):
2720 gcpy                          normalormirror = "Odd"
2721 gcpy              radius = smallDiameter/2
2722 gcpy              jointwidth = thickness - smallDiameter
2723 gcpy              toolpath = self.currenttool()
2724 gcpy              rapid = self.rapidZ(0)
2725 gcpy              self.setdxcolor("Blue")
2726 gcpy              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              self.addvertex(self.currenttoolnumber(), self.xpos(),
                self.ypos())
2731 gcpy              toolpath = toolpath.union(self.cutlineZgcfeed(
                jointdepth,1000))
2732 gcpy              i = 0
2733 gcpy              while i <= Number_of_Pins - 1:
2734 gcpy                  if (side == "Right"):
2735 gcpy                      toolpath = toolpath.union(self.cutvertexdx(
                        self.xpos(), self.ypos() + smallDiameter +
                        radius/5, jointdepth))
2736 gcpy                  if (side == "Left" or side == "Both"):
2737 gcpy                      toolpath = toolpath.union(self.cutvertexdx(
                        self.xpos(), self.ypos() + radius,
                        jointdepth))
2738 gcpy                      toolpath = toolpath.union(self.cutvertexdx(
                        self.xpos() + jointwidth, self.ypos(),
                        jointdepth))
2739 gcpy                      toolpath = toolpath.union(self.cutvertexdx(
                        self.xpos(), self.ypos() + radius/5,
                        jointdepth))
2740 gcpy                      toolpath = toolpath.union(self.cutvertexdx(
                        self.xpos() - jointwidth, self.ypos(),
                        jointdepth))
2741 gcpy                      toolpath = toolpath.union(self.cutvertexdx(
                        self.xpos(), self.ypos() + radius,
                        jointdepth))
2742 gcpy                  if (side == "Left"):
2743 gcpy                      toolpath = toolpath.union(self.cutvertexdx(
                        self.xpos(), self.ypos() + smallDiameter +
                        radius/5, jointdepth))
2744 gcpy                  if (side == "Right" or side == "Both"):
2745 gcpy                      if (i < (Number_of_Pins - 1)):
2746 gcpy                          # print(i)
2747 gcpy                          toolpath = toolpath.union(self.cutvertexdx(
                                self.xpos(), self.ypos() + radius,
                                jointdepth))
2748 gcpy                          toolpath = toolpath.union(self.cutvertexdx(
                                self.xpos() - jointwidth, self.ypos(),
                                jointdepth))
2749 gcpy                          toolpath = toolpath.union(self.cutvertexdx(
                                self.xpos(), self.ypos() + radius/5,
                                jointdepth))
2750 gcpy                          toolpath = toolpath.union(self.cutvertexdx(
                                self.xpos() + jointwidth, self.ypos(),
                                jointdepth))
2751 gcpy                          toolpath = toolpath.union(self.cutvertexdx(
                                self.xpos(), self.ypos() + radius,
                                jointdepth))
2752 gcpy                      i += 1
2753 gcpy                  # Joint_Orientation = "Horizontal" "Even" == "Lower", "Odd" ==
                    "Upper"
2754 gcpy                  if (orientation == "Horizontal"):
2755 gcpy                      rapid = rapid.union(self.rapidXY(bx + Finger_Origin, by
                        ))
2756 gcpy                      self.addvertex(self.currenttoolnumber(), self.xpos(),
                        self.ypos())
2757 gcpy                      toolpath = toolpath.union(self.cutlineZgcfeed(
                        jointdepth,1000))
2758 gcpy                      i = 0
2759 gcpy                      while i <= Number_of_Pins - 1:
2760 gcpy                          if (side == "Upper"):
2761 gcpy                              toolpath = toolpath.union(self.cutvertexdx(
                                    self.xpos() + smallDiameter + radius/5, self
                                    .ypos(), jointdepth))
2762 gcpy                          if (side == "Lower" or side == "Both"):
2763 gcpy                              toolpath = toolpath.union(self.cutvertexdx(
                                    self.xpos() + radius, self.ypos(),
                                    jointdepth))
2764 gcpy                              toolpath = toolpath.union(self.cutvertexdx(
                                    self.xpos(), self.ypos() + jointwidth,
                                    jointdepth))
2765 gcpy                              toolpath = toolpath.union(self.cutvertexdx(
                                    self.xpos() + radius/5, self.ypos(),
                                    jointdepth))

```

```

2766 gcpy                toolpath = toolpath.union(self.cutvertexdxf(
                        self.xpos(), self.ypos() - jointwidth,
                        jointdepth))
2767 gcpy                toolpath = toolpath.union(self.cutvertexdxf(
                        self.xpos() + radius, self.ypos(),
                        jointdepth))
2768 gcpy                if (side == "Lower"):
2769 gcpy                    toolpath = toolpath.union(self.cutvertexdxf(
                        self.xpos() + smallDiameter + radius/5, self
                        .ypos(), jointdepth))
2770 gcpy                if (side == "Upper" or side == "Both"):
2771 gcpy                    if (i < (Number_of_Pins - 1)):
2772 gcpy                        # print(i)
2773 gcpy                    toolpath = toolpath.union(self.cutvertexdxf
                        (self.xpos() + radius, self.ypos(),
                        jointdepth))
2774 gcpy                toolpath = toolpath.union(self.cutvertexdxf
                        (self.xpos(), self.ypos() - jointwidth,
                        jointdepth))
2775 gcpy                toolpath = toolpath.union(self.cutvertexdxf
                        (self.xpos() + radius/5, self.ypos(),
                        jointdepth))
2776 gcpy                toolpath = toolpath.union(self.cutvertexdxf
                        (self.xpos(), self.ypos() + jointwidth,
                        jointdepth))
2777 gcpy                toolpath = toolpath.union(self.cutvertexdxf
                        (self.xpos() + radius, self.ypos(),
                        jointdepth))

2778 gcpy                i += 1
2779 gcpy                self.closepolyline(self.currenttoolnumber())
2780 gcpy                return toolpath
2781 gcpy
2782 gcpy                def Full_Blind_Finger_Joint_smallV(self, bx, by, orientation,
                        side, width, thickness, Number_of_Pins, largeVdiameter,
                        smallDiameter):
2783 gcpy                    rapid = self.rapidZ(0)
2784 gcpy                    # rapid = rapid.union(self.rapidXY(bx, by))
2785 gcpy                    self.setdxfcolor("Red")
2786 gcpy                    if (orientation == "Vertical"):
2787 gcpy                        rapid = rapid.union(self.rapidXY(bx, by - smallDiameter
                        /6))
2788 gcpy                        toolpath = self.cutlineZgcfeed(-thickness,1000)
2789 gcpy                        toolpath = self.cutlinedxfgc(bx, by + width +
                        smallDiameter/6, - thickness)
2790 gcpy                    if (orientation == "Horizontal"):
2791 gcpy                        rapid = rapid.union(self.rapidXY(bx - smallDiameter/6,
                        by))
2792 gcpy                        toolpath = self.cutlineZgcfeed(-thickness,1000)
2793 gcpy                        toolpath = self.cutlinedxfgc(bx + width + smallDiameter
                        /6, by, -thickness)
2794 gcpy                    # rapid = self.rapidZ(0)
2795 gcpy
2796 gcpy                    return toolpath
2797 gcpy
2798 gcpy                def Full_Blind_Finger_Joint_largeV(self, bx, by, orientation,
                        side, width, thickness, Number_of_Pins, largeVdiameter,
                        smallDiameter):
2799 gcpy                    radius = smallDiameter/2
2800 gcpy                    rapid = self.rapidZ(0)
2801 gcpy                    Finger_Width = ((Number_of_Pins * 2) - 1) * smallDiameter *
                        1.1
2802 gcpy                    Finger-Origin = width/2 - Finger_Width/2
2803 gcpy                    # rapid = rapid.union(self.rapidXY(bx, by))
2804 gcpy                    # Joint_Orientation = "Horizontal" "Even" == "Lower", "Odd" ==
                        "Upper"
2805 gcpy                    # Joint_Orientation = "Vertical" "Even" == "Left", "Odd" == "
                        Right"
2806 gcpy                    if (orientation == "Vertical"):
2807 gcpy                        rapid = rapid.union(self.rapidXY(bx, by))
2808 gcpy                        toolpath = self.cutlineZgcfeed(-thickness,1000)
2809 gcpy                        toolpath = toolpath.union(self.cutlinedxfgc(bx, by +
                        Finger-Origin, -thickness))
2810 gcpy                    rapid = self.rapidZ(0)
2811 gcpy                    rapid = rapid.union(self.rapidXY(bx, by + width -
                        Finger-Origin))
2812 gcpy                    self.setdxfcolor("Blue")
2813 gcpy                    toolpath = toolpath.union(self.cutlineZgcfeed(-
                        thickness,1000))

```

```

2814 gcpy      toolpath = toolpath.union(self.cutlinedxfgc(bx, by +
                width, -thickness))
2815 gcpy      if (side == "Left" or side == "Both"):
2816 gcpy          rapid = self.rapidZ(0)
2817 gcpy          self.setdxfc("Dark_Gray")
2818 gcpy          rapid = rapid.union(self.rapidXY(bx+thickness-(
                smallDiameter / 2) / Tan(45), by - radius/2))
2819 gcpy      toolpath = toolpath.union(self.cutlineZgcfeed(-(
                smallDiameter / 2) / Tan(45),10000))
2820 gcpy      toolpath = toolpath.union(self.cutlinedxfgc(bx+
                thickness-(smallDiameter / 2) / Tan(45), by +
                width + radius/2, -(smallDiameter / 2) / Tan(45)
                ))
2821 gcpy      rapid = self.rapidZ(0)
2822 gcpy      self.setdxfc("Green")
2823 gcpy      rapid = rapid.union(self.rapidXY(bx+thickness/2, by
                +width))
2824 gcpy      toolpath = toolpath.union(self.cutlineZgcfeed(-
                thickness/2,1000))
2825 gcpy      toolpath = toolpath.union(self.cutlinedxfgc(bx+
                thickness/2, by + width -thickness, -thickness
                /2))
2826 gcpy      rapid = self.rapidZ(0)
2827 gcpy      rapid = rapid.union(self.rapidXY(bx+thickness/2, by
                ))
2828 gcpy      toolpath = toolpath.union(self.cutlineZgcfeed(-
                thickness/2,1000))
2829 gcpy      toolpath = toolpath.union(self.cutlinedxfgc(bx+
                thickness/2, by +thickness, -thickness/2))
2830 gcpy      if (side == "Right" or side == "Both"):
2831 gcpy          rapid = self.rapidZ(0)
2832 gcpy          self.setdxfc("Dark_Gray")
2833 gcpy          rapid = rapid.union(self.rapidXY(bx-(thickness-(
                smallDiameter / 2) / Tan(45)), by - radius/2))
2834 gcpy      toolpath = toolpath.union(self.cutlineZgcfeed(-(
                smallDiameter / 2) / Tan(45),10000))
2835 gcpy      toolpath = toolpath.union(self.cutlinedxfgc(bx-(
                thickness-(smallDiameter / 2) / Tan(45)), by +
                width + radius/2, -(smallDiameter / 2) / Tan(45)
                ))
2836 gcpy      rapid = self.rapidZ(0)
2837 gcpy      self.setdxfc("Green")
2838 gcpy      rapid = rapid.union(self.rapidXY(bx-thickness/2, by
                +width))
2839 gcpy      toolpath = toolpath.union(self.cutlineZgcfeed(-
                thickness/2,1000))
2840 gcpy      toolpath = toolpath.union(self.cutlinedxfgc(bx-
                thickness/2, by + width -thickness, -thickness
                /2))
2841 gcpy      rapid = self.rapidZ(0)
2842 gcpy      rapid = rapid.union(self.rapidXY(bx-thickness/2, by
                ))
2843 gcpy      toolpath = toolpath.union(self.cutlineZgcfeed(-
                thickness/2,1000))
2844 gcpy      toolpath = toolpath.union(self.cutlinedxfgc(bx-
                thickness/2, by +thickness, -thickness/2))
2845 gcpy      # Joint_Orientation = "Horizontal" "Even" == "Lower", "Odd" ==
                "Upper"
2846 gcpy      if (orientation == "Horizontal"):
2847 gcpy          rapid = rapid.union(self.rapidXY(bx, by))
2848 gcpy          self.setdxfc("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.setdxfc("Dark_Gray")
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 +
                    width + radius, by+thickness-(smallDiameter / 2)
                    / Tan(45), -(smallDiameter / 2) / Tan(45)))
2861 gcpy          rapid = self.rapidZ(0)
2862 gcpy          self.setdxfc("Green")
2863 gcpy          rapid = rapid.union(self.rapidXY(bx+width, by+
                    thickness/2))
2864 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-
                    thickness/2,1000))
2865 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx +
                    width -thickness, by+thickness/2, -thickness/2))
2866 gcpy          rapid = self.rapidZ(0)
2867 gcpy          rapid = rapid.union(self.rapidXY(bx, by+thickness
                    /2))
2868 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-
                    thickness/2,1000))
2869 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx +
                    thickness, by+thickness/2, -thickness/2))
2870 gcpy          if (side == "Upper" or side == "Both"):
2871 gcpy              rapid = self.rapidZ(0)
2872 gcpy              self.setdxfc("Dark_Gray")
2873 gcpy              rapid = rapid.union(self.rapidXY(bx - radius, by-(
                    thickness-(smallDiameter / 2) / Tan(45))))
2874 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-(
                    smallDiameter / 2) / Tan(45),1000))
2875 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx +
                    width + radius, by-(thickness-(smallDiameter /
                    2) / Tan(45)), -(smallDiameter / 2) / Tan(45)))
2876 gcpy          rapid = self.rapidZ(0)
2877 gcpy          self.setdxfc("Green")
2878 gcpy          rapid = rapid.union(self.rapidXY(bx+width, by-
                    thickness/2))
2879 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-
                    thickness/2,1000))
2880 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx +
                    width -thickness, by-thickness/2, -thickness/2))
2881 gcpy          rapid = self.rapidZ(0)
2882 gcpy          rapid = rapid.union(self.rapidXY(bx, by-thickness
                    /2))
2883 gcpy          toolpath = toolpath.union(self.cutlineZgcfeed(-
                    thickness/2,1000))
2884 gcpy          toolpath = toolpath.union(self.cutlinedxfgc(bx +
                    thickness, by-thickness/2, -thickness/2))
2885 gcpy          rapid = self.rapidZ(0)
2886 gcpy          return toolpath
2887 gcpy
2888 gcpy          def Full_Blind_Finger_Joint(self, bx, by, orientation, side,
                    width, thickness, largeVdiameter, smallDiameter,
                    normalormirror = "Default", squaretool = 102, smallV = 390,
                    largeV = 301):
2889 gcpy              Number_of_Pins = int(((width - thickness * 2) / (
                    smallDiameter * 2.2) / 2) + 0.0) * 2 + 1
2890 gcpy              # print("Number of Pins: ",Number_of_Pins)
2891 gcpy              self.movetosafeZ()
2892 gcpy              self.toolchange(squaretool, 17000)
2893 gcpy              toolpath = self.Full_Blind_Finger_Joint_square(bx, by,
                    orientation, side, width, thickness, Number_of_Pins,
                    largeVdiameter, smallDiameter)
2894 gcpy              self.movetosafeZ()
2895 gcpy              self.toolchange(smallV, 17000)
2896 gcpy              toolpath = toolpath.union(self.
                    Full_Blind_Finger_Joint_smallV(bx, by, orientation, side
                    , width, thickness, Number_of_Pins, largeVdiameter,
                    smallDiameter))
2897 gcpy              self.toolchange(largeV, 17000)
2898 gcpy              toolpath = toolpath.union(self.
                    Full_Blind_Finger_Joint_largeV(bx, by, orientation, side
                    , width, thickness, Number_of_Pins, largeVdiameter,
                    smallDiameter))
2899 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.gcodefilext"
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\\will\\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          gcfilerecontents = []
2904 gcpy          with gc_file as file:
2905 gcpy              for line in file:
2906 gcpy                  command = line
2907 gcpy                  gcfilerecontents.append(line)
2908 gcpy
2909 gcpy          numlinesfound = 0
2910 gcpy          for line in gcfilerecontents:
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 gcfilerecontents:
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] ==
                    "X" or line[:1] == "Y" or line[:1] == "Z":
2952 gcpy              if "F" in line:
2953 gcpy                  Fplus = line.split("F")
2954 gcpy                  Fc = 1
2955 gcpy                  fr = float(Fplus[1])
2956 gcpy                  line = Fplus[0]
2957 gcpy              if "Z" in line:
2958 gcpy                  Zplus = line.split("Z")
2959 gcpy                  Zc = 1
2960 gcpy                  Zp = float(Zplus[1])
2961 gcpy                  line = Zplus[0]
2962 gcpy              if "Y" in line:
2963 gcpy                  Yplus = line.split("Y")
2964 gcpy                  Yc = 1
2965 gcpy                  Yp = float(Yplus[1])
2966 gcpy                  line = Yplus[0]
2967 gcpy              if "X" in line:
2968 gcpy                  Xplus = line.split("X")
2969 gcpy                  Xc = 1
2970 gcpy                  Xp = float(Xplus[1])
2971 gcpy              if Zc == 1:
2972 gcpy                  if Yc == 1:
2973 gcpy                      if Xc == 1:
2974 gcpy                          if machinestate == "rapid":
2975 gcpy                              command = "rapidXYZ(" + str(Xp) + "
                                          ,\u" + str(Yp) + ",\u" + str(Zp) +
                                          ")"
2976 gcpy                              self.rapidXYZ(Xp, Yp, Zp)
2977 gcpy                          else:
2978 gcpy                              command = "cutlineXYZ(" + str(Xp) +
                                          ",\u" + str(Yp) + ",\u" + str(Zp)
                                          + ")"
2979 gcpy                              self.cutlineXYZ(Xp, Yp, Zp)
2980 gcpy                      else:
2981 gcpy                          if machinestate == "rapid":
2982 gcpy                              command = "rapidYZ(" + str(Yp) + ",
                                          \u" + str(Zp) + ")"
2983 gcpy                              self.rapidYZ(Yp, Zp)
2984 gcpy                          else:
2985 gcpy                              command = "cutlineYZ(" + str(Yp) +
                                          ",\u" + str(Zp) + ")"
2986 gcpy                              self.cutlineYZ(Yp, Zp)
```

```
2987 gcpy                                     else:
2988 gcpy                                     if Xc == 1:
2989 gcpy                                         if machinestate == "rapid":
2990 gcpy                                             command = "rapidXZ(" + str(Xp) + ",
                                                    _" + str(Zp) + ")"
                                                    self.rapidXZ(Xp, Zp)
2991 gcpy                                         else:
2992 gcpy                                             command = "cutlineXZ(" + str(Xp) +
2993 gcpy                                                 ",_" + str(Zp) + ")"
                                                    self.cutlineXZ(Xp, Zp)
2994 gcpy
2995 gcpy                                     else:
2996 gcpy                                         if machinestate == "rapid":
2997 gcpy                                             command = "rapidZ(" + str(Zp) + ")"
2998 gcpy                                             self.rapidZ(Zp)
2999 gcpy                                         else:
3000 gcpy                                             command = "cutlineZ(" + str(Zp) + "
                                                    )"
                                                    self.cutlineZ(Zp)
3001 gcpy
3002 gcpy                                     else:
3003 gcpy                                         if Yc == 1:
3004 gcpy                                             if Xc == 1:
3005 gcpy                                                 if machinestate == "rapid":
3006 gcpy                                                     command = "rapidXY(" + str(Xp) + ",
                                                            _" + str(Yp) + ")"
                                                            self.rapidXY(Xp, Yp)
3007 gcpy                                                 else:
3008 gcpy                                                     command = "cutlineXY(" + str(Xp) +
3009 gcpy                                                         ",_" + str(Yp) + ")"
                                                            self.cutlineXY(Xp, Yp)
3010 gcpy                                         else:
3011 gcpy                                             if machinestate == "rapid":
3012 gcpy                                                 command = "rapidY(" + str(Yp) + ")"
3013 gcpy                                                 self.rapidY(Yp)
3014 gcpy                                             else:
3015 gcpy                                                 command = "cutlineY(" + str(Yp) + "
3016 gcpy                                                     )"
                                                            self.cutlineY(Yp)
3017 gcpy
3018 gcpy                                     else:
3019 gcpy                                         if Xc == 1:
3020 gcpy                                             if machinestate == "rapid":
3021 gcpy                                                 command = "rapidX(" + str(Xp) + ")"
3022 gcpy                                                 self.rapidX(Xp)
3023 gcpy                                             else:
3024 gcpy                                                 command = "cutlineX(" + str(Xp) + "
                                                            )"
                                                            self.cutlineX(Xp)
3025 gcpy                                     commands.append(command)
3026 gcpy                                     print(line)
3027 gcpy #                                     print(command)
3028 gcpy #                                     print(machinestate, Xc, Yc, Zc)
3029 gcpy #                                     print(Xp, Yp, Zp)
3030 gcpy #                                     print("/n")
3031 gcpy #
3032 gcpy
3033 gcpy #                                     for command in commands:
3034 gcpy #                                         print(command)
3035 gcpy
3036 gcpy #                                     show(self.stockandtoolpaths())
3037 gcpy                                     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

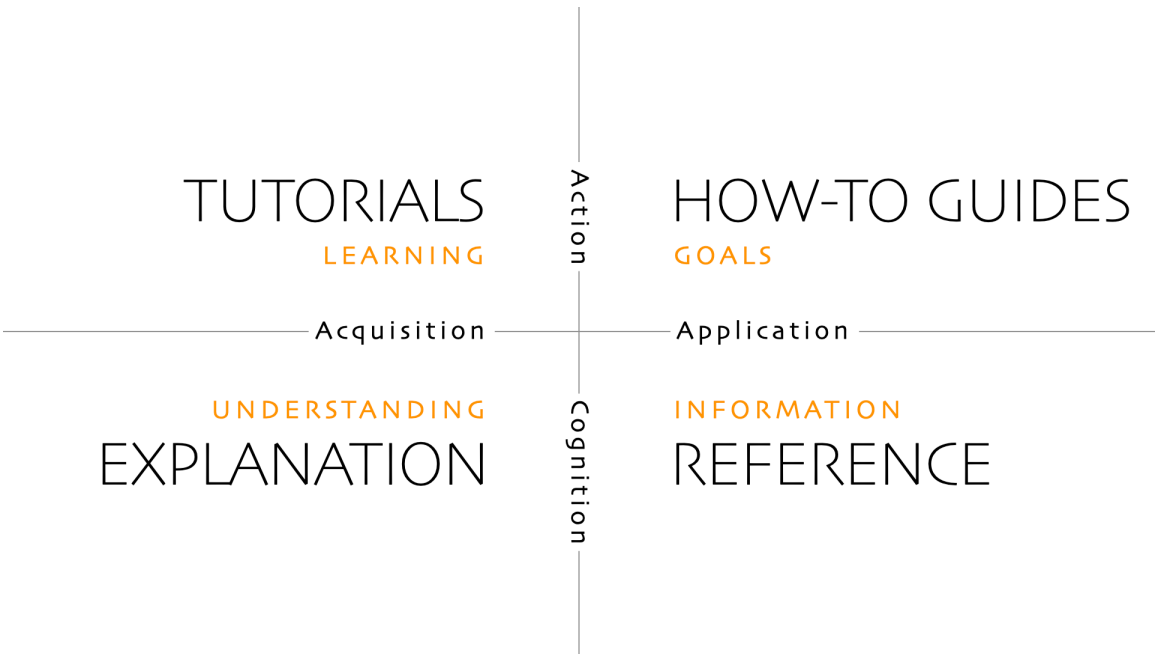
<https://thewhitetulip.gitbook.io/py/06-file-handling>

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:

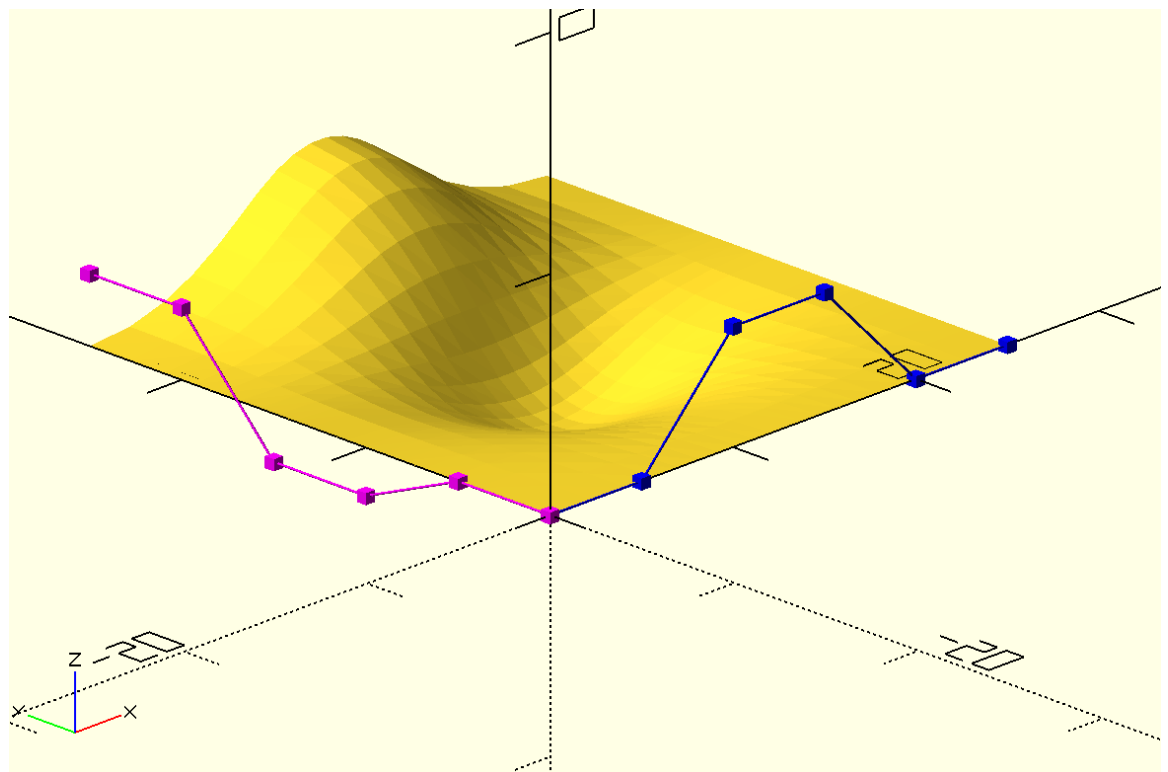
3 planes * 3 Béziers * (2 on-curve + 2 off-curve points) == 36 coordinate pairs

which is a marked contrast to representations such as:

<https://github.com/DavidPhillipOster/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/

4.2.4 Mathematics

<https://elementsofprogramming.com/>

References

[ConstGeom] Walmsley, Brian. *Construction Geometry*. 2d ed., Centennial College Press, 1981.

[MkCalc] Horvath, Joan, and Rich Cameron. *Make: Calculus: Build models to learn, visualize, and explore*. First edition., Make: Community LLC, 2022.

[MkGeom] Horvath, Joan, and Rich Cameron. *Make: Geometry: Learn by 3D Printing, Coding and Exploring*. First edition., Make: Community LLC, 2021.

[MkTrig] Horvath, Joan, and Rich Cameron. *Make: Trigonometry: Build your way from triangles to analytic geometry*. First edition., Make: Community LLC, 2023.

[PractShopMath] Begnal, Tom. *Practical Shop Math: Simple Solutions to Workshop Fractions, Formulas + Geometric Shapes*. Updated edition, Spring House Press, 2018.

[RS274] Thomas R. Kramer, Frederick M. Proctor, Elena R. Messina.
https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=823374
<https://www.nist.gov/publications/nist-rs274ngc-interpreter-version-3>

[SoftwareDesign] Ousterhout, John K. *A Philosophy of Software Design*. First Edition., Yaknyam Press, Palo Alto, Ca., 2018

Command Glossary

. 25

setupstock setupstock(200, 100, 8.35, "Top", "Lower-left", 8.35). 23

Index

- addvertex, 85
- ballnose, 54
- beginpolyline, 85
- closedxfile, 93, 94
- closegcodefile, 93, 94
- closepolyline, 85
- currenttool, 33
- currenttoolnum, 33
- cut..., 52, 61
- cutarcCC, 64
- cutarcCW, 64
- cutkeyhole toolpath, 99
- cutKHgcdxf, 100
- cutline, 61
- cutrectangle, 98
- diameter, 34
- dovetail, 55
- dxfarc, 85
- dxfcircle, 85
- dxfline, 85
- dxfpreamble, 93, 94
- dxfpreamble, 85
- dxfwrite, 85
- endmill square, 54
- endmill v, 54
- endmilltype, 34
- feed, 69
- flute, 34
- gcodepreview, 31
 - writeln, 81
- gcp.setupstock, 34
- generatecut, 28
- generatedxf, 28
- generategcode, 28
- init, 31
- mpx, 33
- mpy, 33
- mpz, 33
- opendxfile, 82
- opengcodefile, 82
- plunge, 69
- previewgcodefile, 114
- ra, 34
- rapid, 60
- rapid..., 52
- rapids, 34, 37
- roundover, 56
- settoolparameters, 41
- setupstock, 34
 - gcodepreview, 34
- setxpos, 33
- setypos, 33
- setzpos, 33
- shaftmovement, 52, 56
- speed, 69
- stockzero, 35
- subroutine
 - gcodepreview, 34
 - writeln, 81
- tip, 34
- tool diameter, 68
- tool number, 41
- tool radius, 69
- toolchange, 41, 42
- toolmovement, 33, 34, 37, 42, 52
- toolpaths, 34, 37
- tpzinc, 33
- writedxfileDT, 85
- writedxfileKH, 85
- writedxfilegbl, 85
- writedxfilegsq, 85
- writedxfileV, 85
- writedxfilesmbl, 85
- writedxfilesmq, 85
- writedxfilesmV, 85
- xpos, 33
- ypos, 33
- zeroheight, 35
- zpos, 33

Routines

- addvertex, 85
- ballnose, 54
- beginpolyline, 85
- closedxfile, 93, 94
- closegcodefile, 93, 94
- closepolyline, 85
- cut..., 52, 61
- cutarcCC, 64
- cutarcCW, 64
- cutkeyhole toolpath, 99
- cutKHgcdxf, 100
- cutline, 61
- cutrectangle, 98
- dovetail, 55
- dxfar, 85
- dxfcircle, 85
- dxfline, 85
- dxfpreamble, 93, 94
- dxfpreamble, 85
- dxfwrite, 85
- endmill square, 54
- endmill v, 54
- gcodepreview, 31, 34
- gcp.setupstock, 34
- init, 31
- opendxfile, 82
- opengcodefile, 82
- previewgcodefile, 114
- rapid, 60
- rapid..., 52
- roundover, 56
- setupstock, 34
- setxpos, 33
- setypos, 33
- setzpos, 33
- shaftmovement, 52, 56
- tool diameter, 68
- tool radius, 69
- toolchange, 41, 42
- toolmovement, 33, 34, 37, 42, 52
- writedxDT, 85
- writedxKH, 85
- writedxflgbl, 85
- writedxflgsq, 85
- writedxflgV, 85
- writedxsmbl, 85
- writedxsmV, 85
- writedxsmV, 85
- writeln, 81
- xpos, 33
- ypos, 33
- zpos, 33

Variables

currenttool, 33	plunge, 69
currenttoolnum, 33	ra, 34
diameter, 34	rapids, 34, 37
endmilltype, 34	settoolparameters, 41
feed, 69	speed, 69
flute, 34	stockzero, 35
generatecut, 28	tip, 34
generatedxf, 28	tool number, 41
generategcode, 28	toolchange, 41
mpx, 33	toolpaths, 34, 37
mpy, 33	tpzinc, 33
mpz, 33	zeroheight, 35