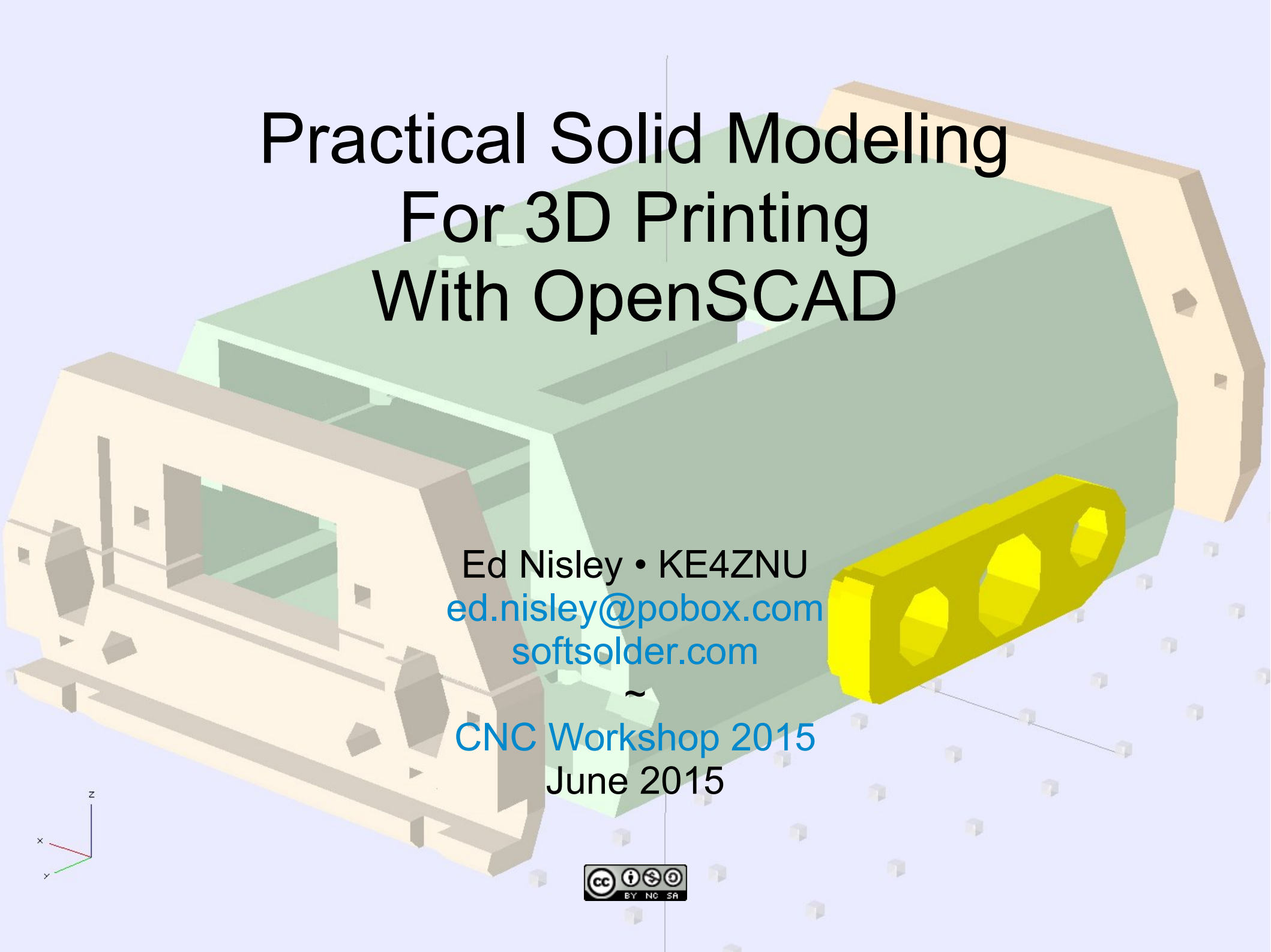
Practical Solid Modeling For 3D Printing With OpenSCAD



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ed.nisley@pobox.com
softsolder.com

~

CNC Workshop 2015
June 2015

Upcoming Events

- Defining the Terms
  - Practical · Solid Modeling · 3D Printing · OpenSCAD
- Constructive Solid Geometry
  - CSG Solids · Operations · Transformations
  - OpenSCAD “Debugging” · Iterators · Conditionals
- Modeling Printable Objects
  - Geometric & Process Constraints
  - Hole Calibration & Compensation
  - Bridging · Overhang · Support Structures
- Other Fancy Stuff

Defining the Terms

Practical

prac·ti·cal

adjective /ˈpraktikəl/

Of or concerned with

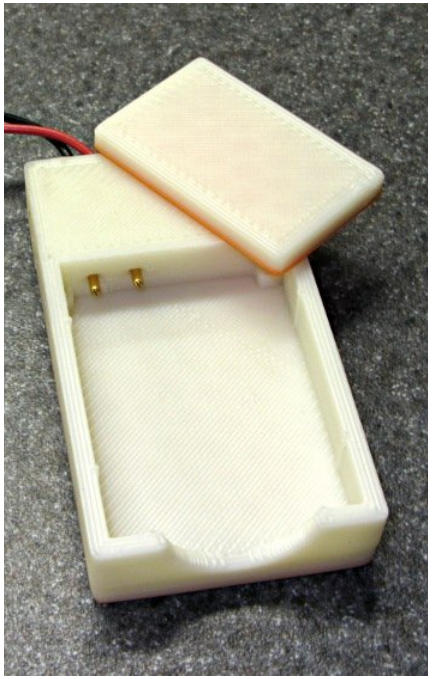
the actual doing or use of something

rather than with theory and ideas

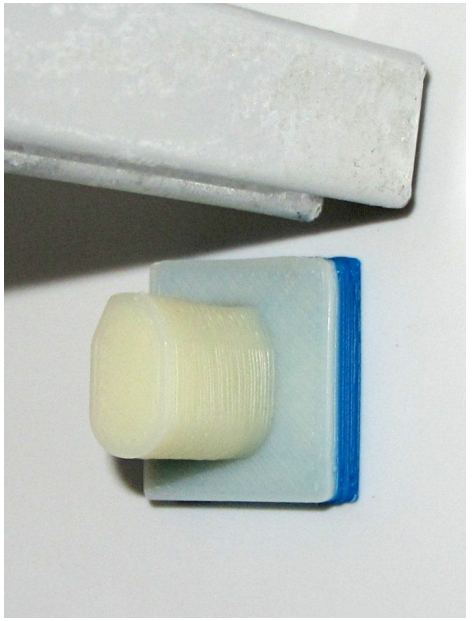
Thus sayeth Google

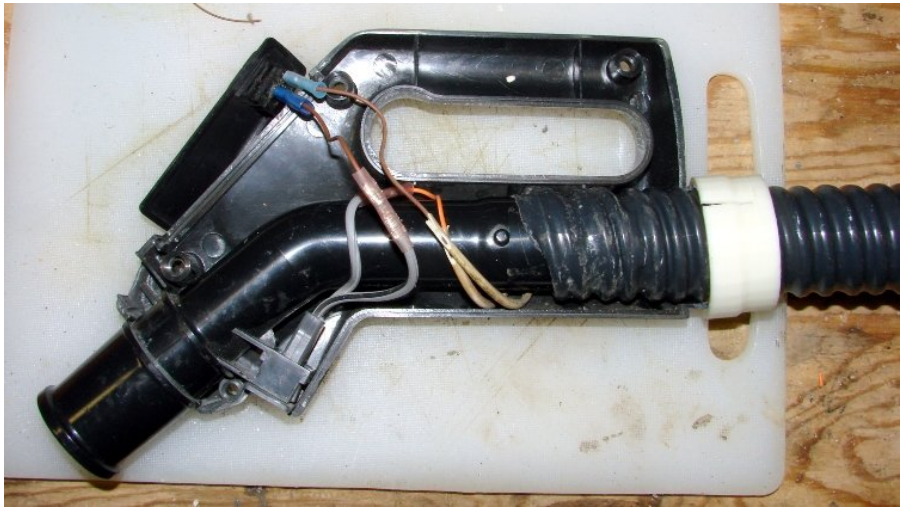
`define: practical`

Custom Devices

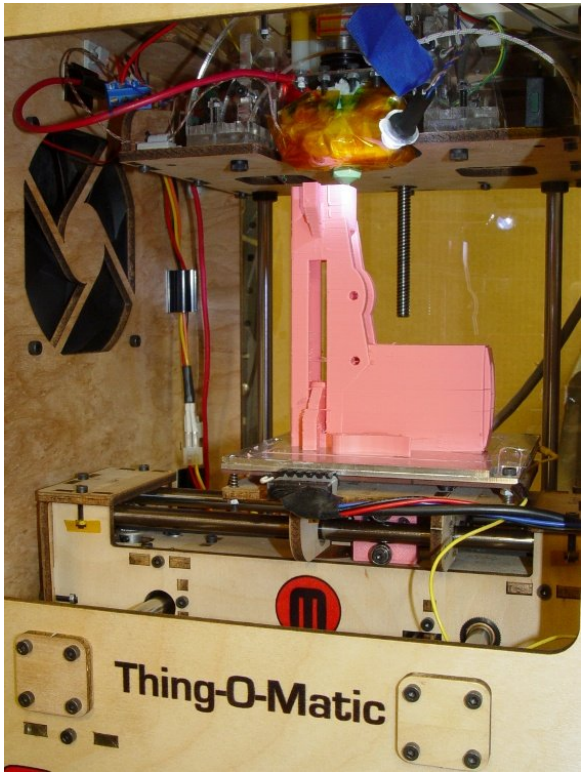


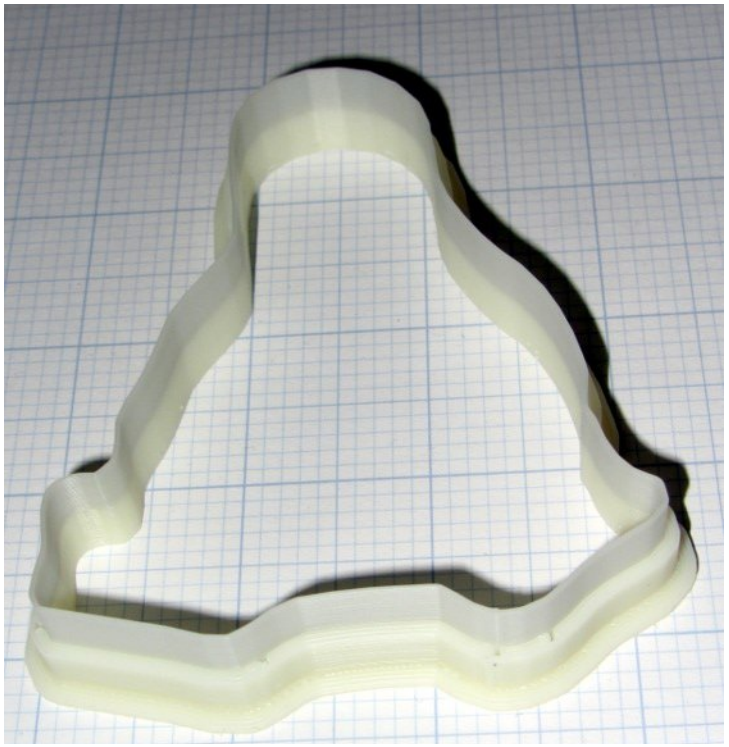
Repair Parts

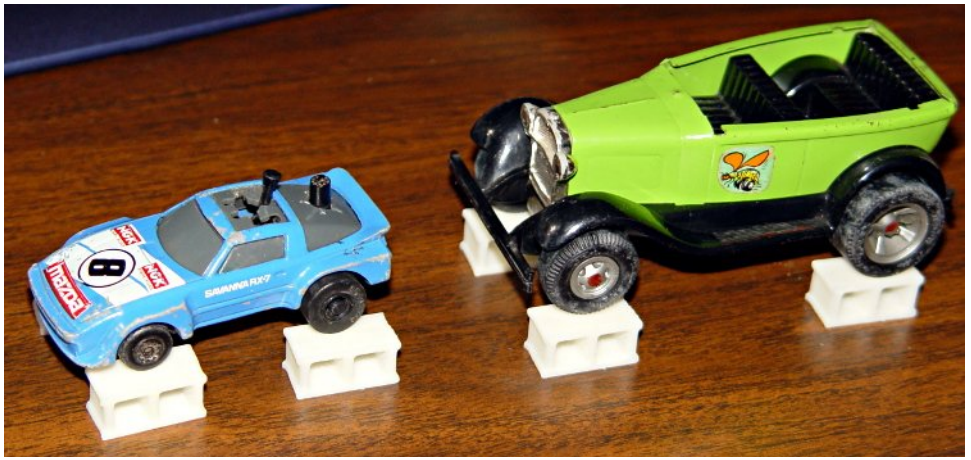


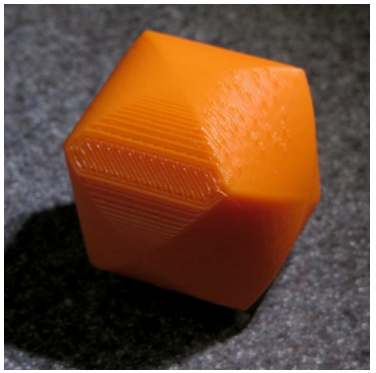


Fun Stuff

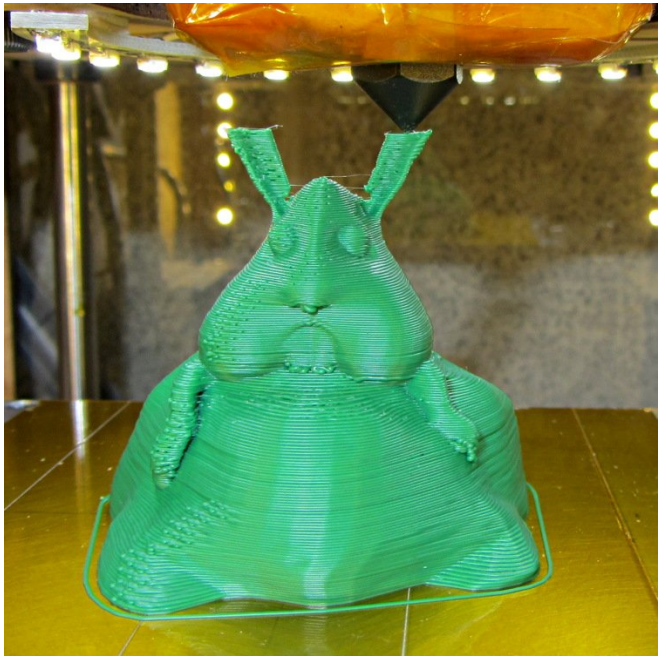


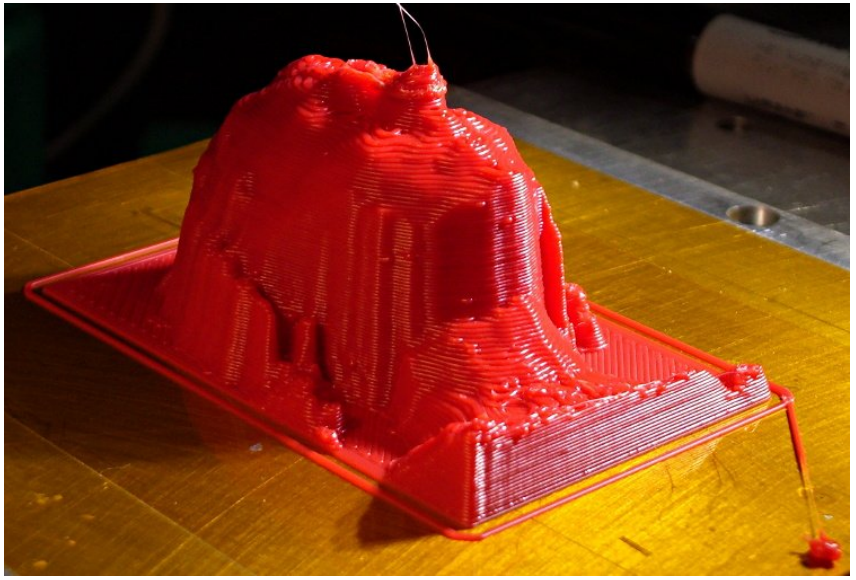






Other People's (Im)practical Stuff





Project Details

Custom Parts

- Propane QD wrench
- Photodiode fixture
- Helmet mirror
- Microscope ring light
- Microscope camera
- Camera macro lens
- Amateur radio GPS
- Battery fixture

Repair Parts

- Caliper thumbwheel
- Freezer shelf bracket
- Broom handle
- Vacuum hose clamp
- Bar clamp handle

Project Details

Fun Stuff

- Nerf Pistol
- CO2 Capsule Fins
- Tux Cookie Cutter
- Concrete Blocks
- Triple Cylinder Thing
- Quilting Pin Caps

Other Peoples' Stuff

- Dr. Who Cutter/Press
- Knot
- Fat Bunbun
- Chalk people
- Companion Cube
- Stanford Bunny
- Octopus
- 3D Portrait

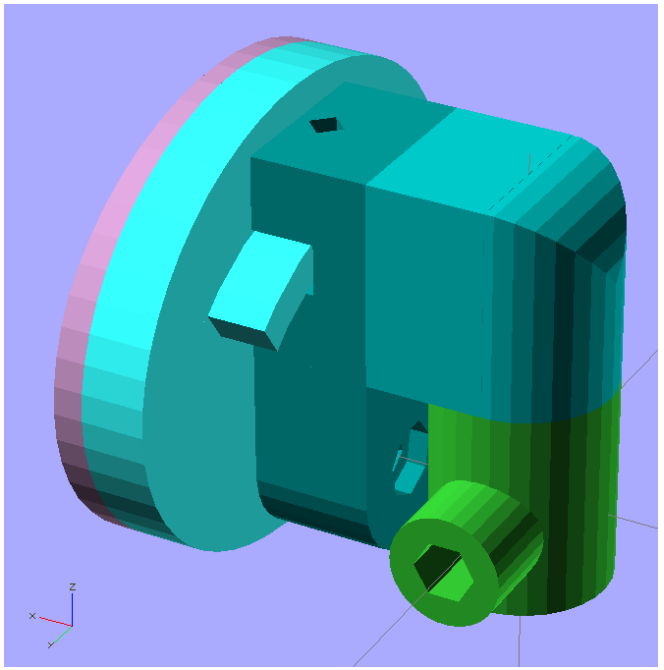
Solid Modeling

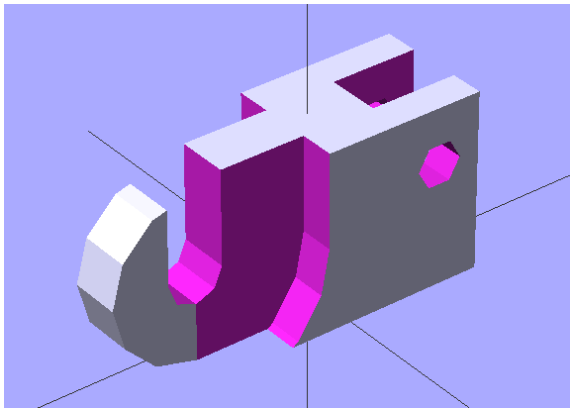
... is a consistent set of principles
for mathematical and computer modeling of
three-dimensional solids.

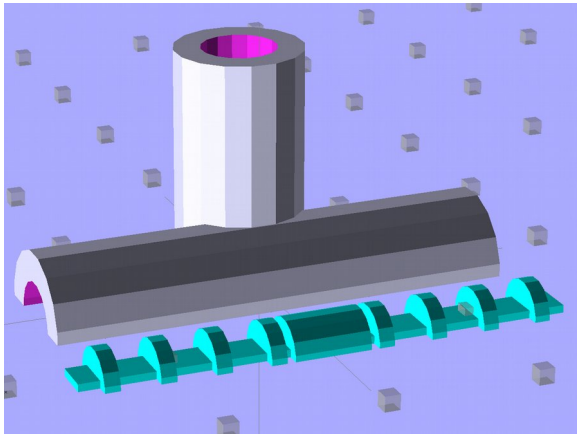
Solid modeling is distinguished
from related areas of geometric modeling and
computer graphics by
its emphasis on physical fidelity.

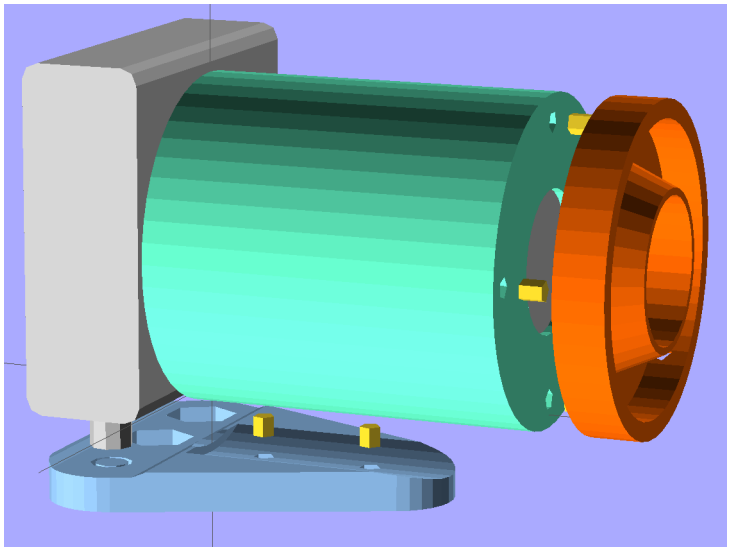
Thus sayeth Google
`define: "solid modeling"`

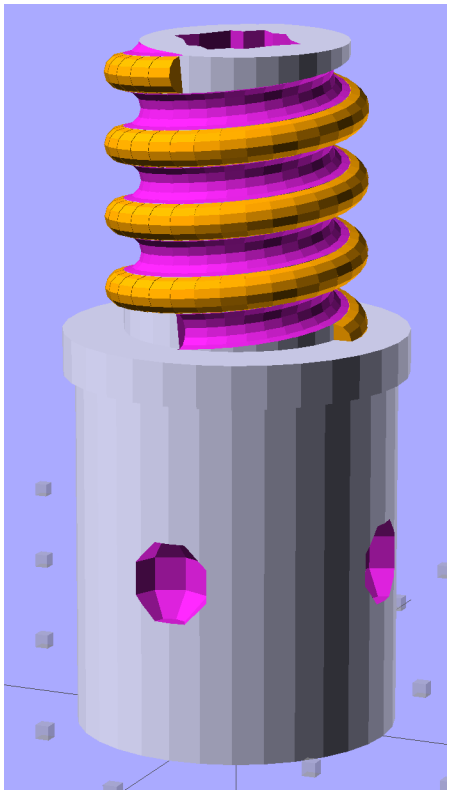
Three Dimensional Solid Models

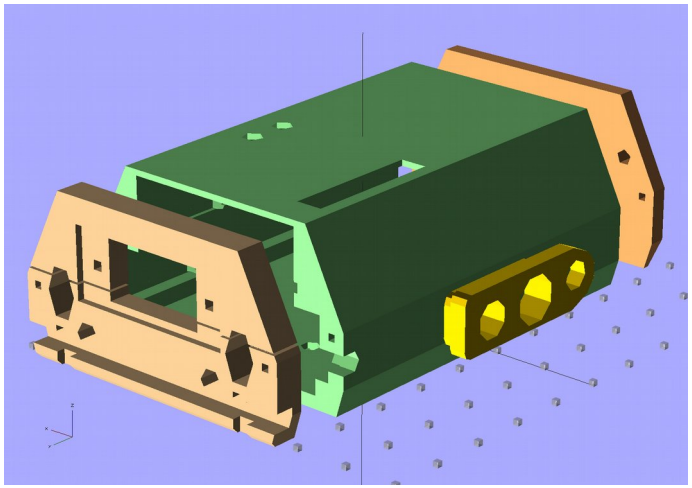




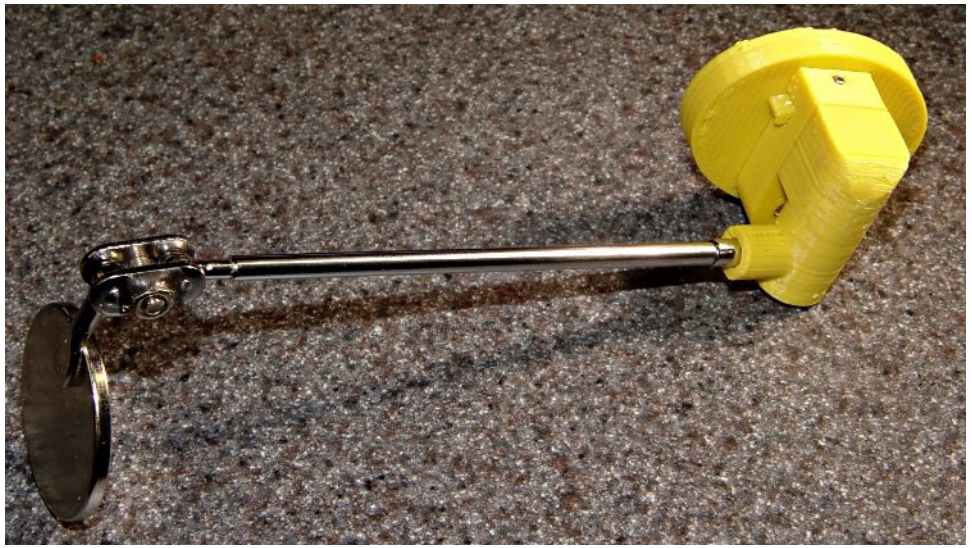


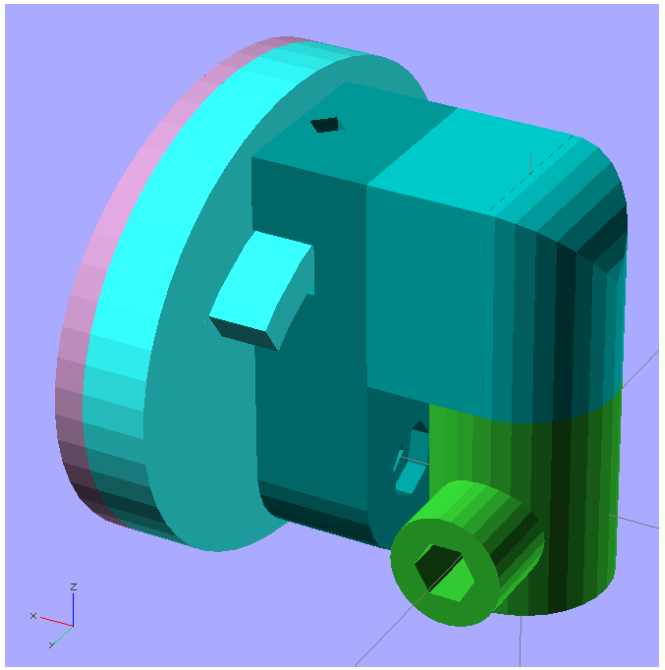


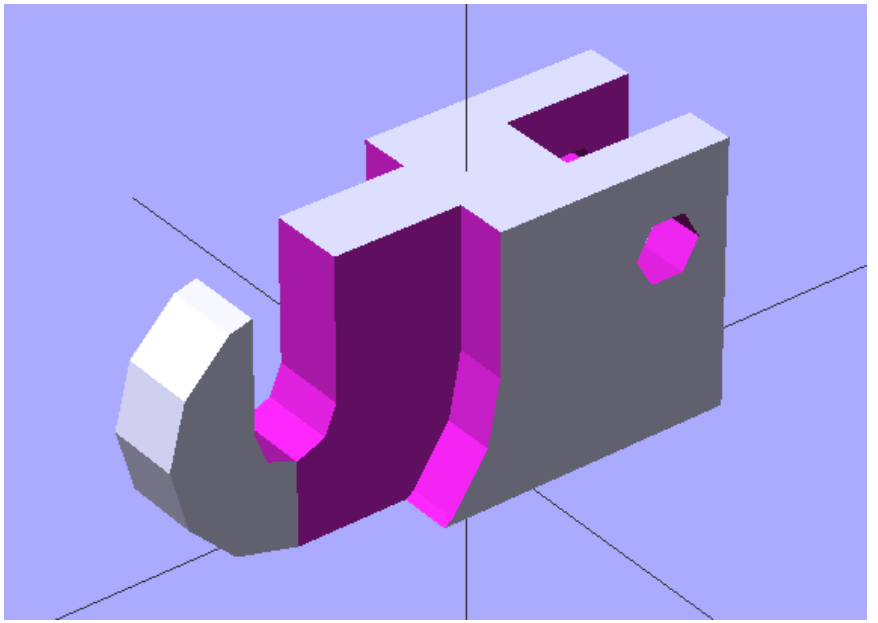




Emphasis on Physical Fidelity







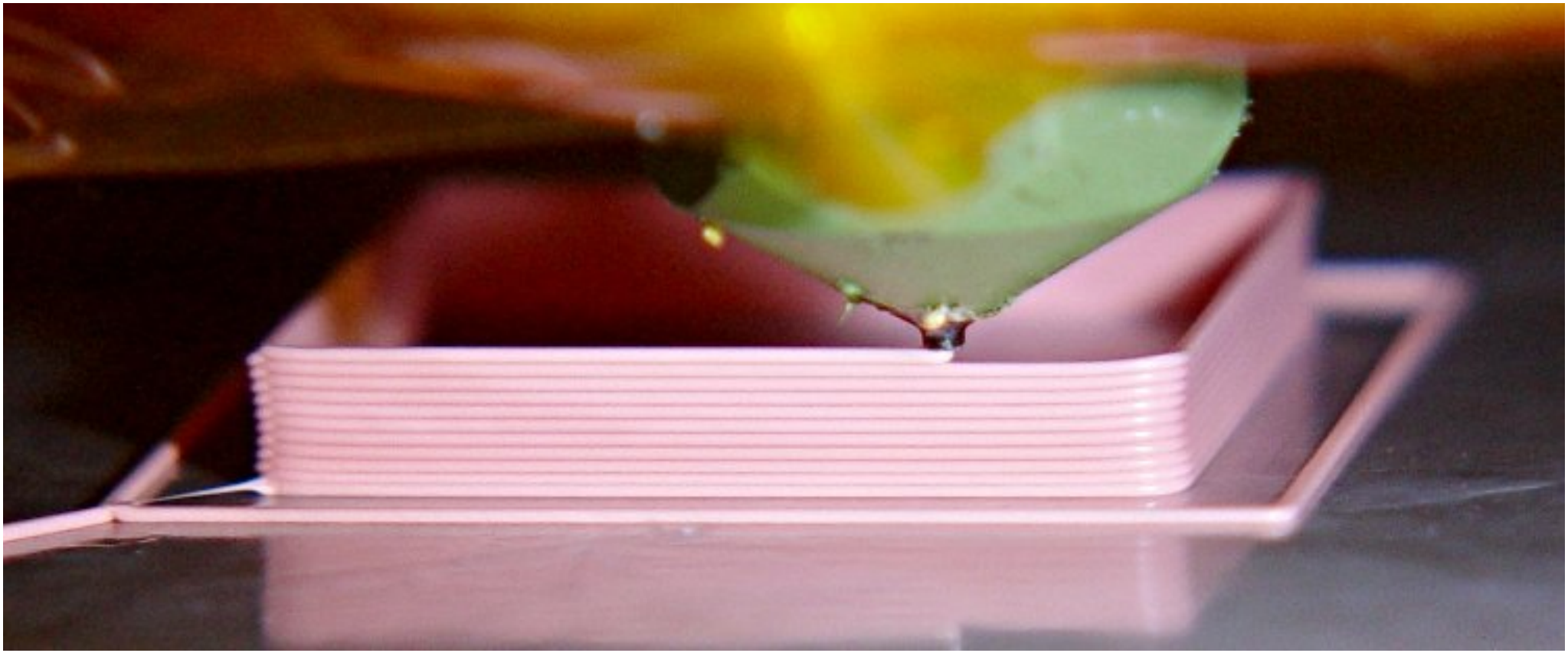
3D Printing

Additive manufacturing or 3D printing is a process of making a three-dimensional solid object of virtually any shape from a digital model.

3D printing is achieved using an additive process, where successive layers of material are laid down in different shapes.

Thus sayeth Wikipedia
http://en.wikipedia.org/wiki/3D_printing

“Fused Deposition” 3D Printing



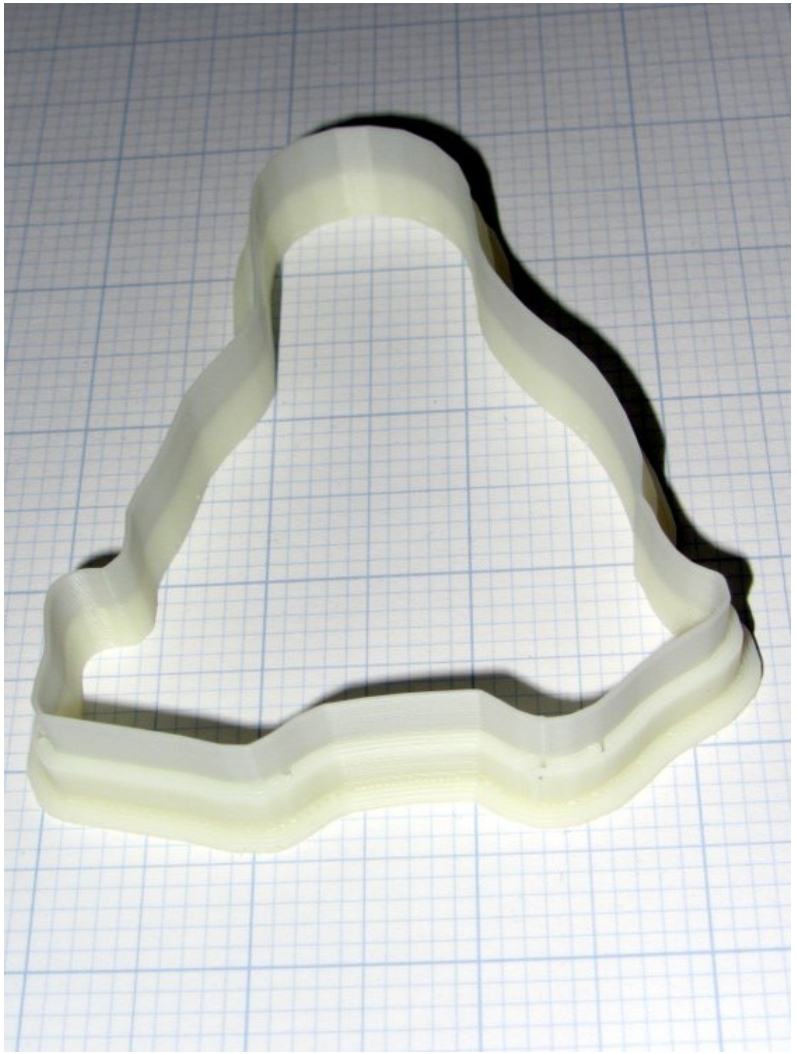
- Fused Filament Fabrication
- Glorified Glue Gun Technology …
- Beware the trademark & IP minefield

3D Printing Up Close

Tux Cookie Cutter

~

The Movie



http://softsolder.com/2011/09/07/tux-cookie-cutter/

OpenSCAD

OpenSCAD is a software for
creating solid 3D CAD models.

~

It is ... a 3D-compiler that
reads in a script file describing the object
and
renders the 3D model

Thus sayeth OpenSCAD
www.openscad.org

OpenSCAD

Thus it might be
the application you are looking for
when you are planning to
create 3D models of machine parts

~

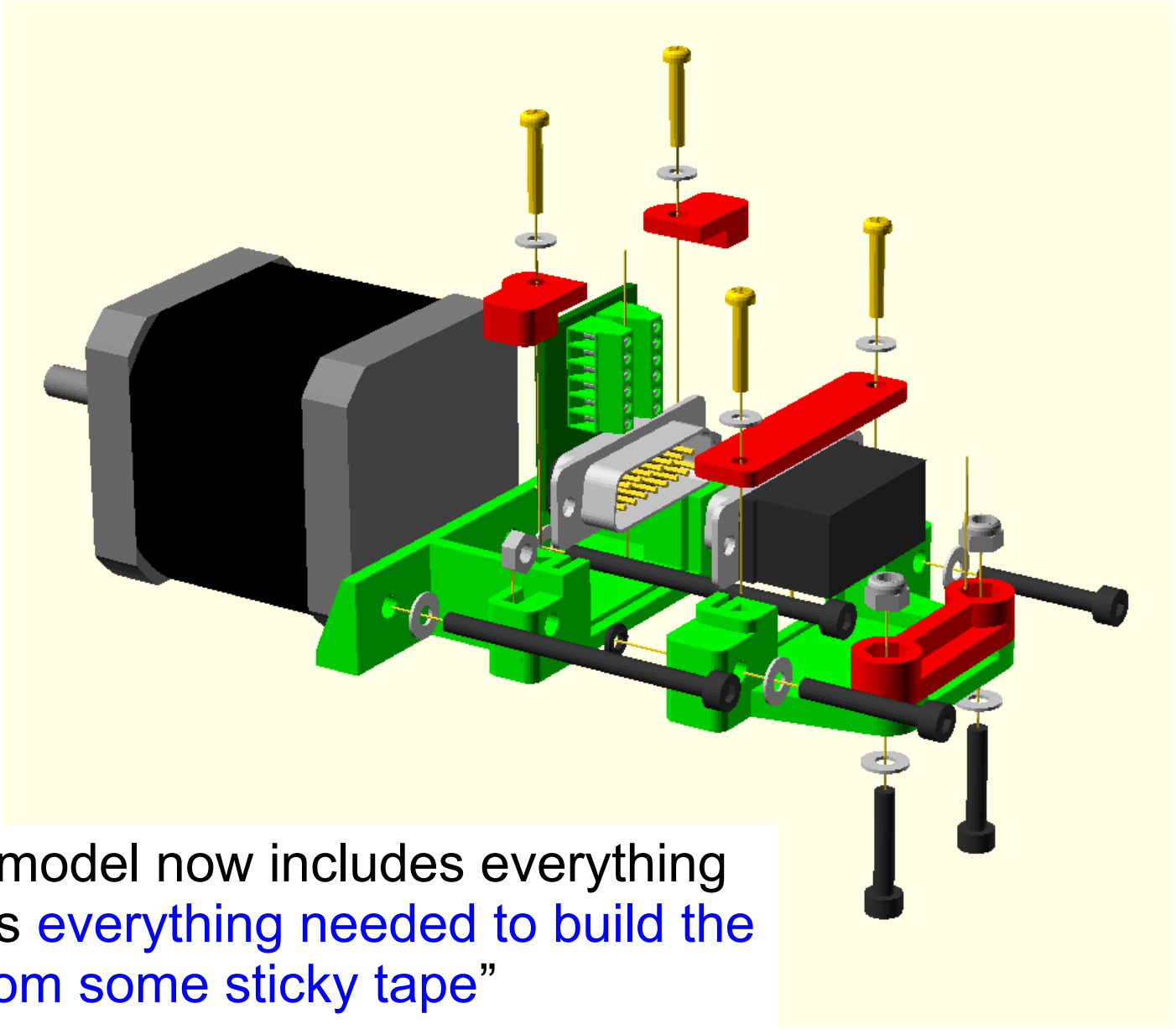
but pretty sure [it] is not ... for
creating computer-animated movies.

Thus sayeth OpenSCAD
www.openscad.org/about.html

OpenSCAD Machine Models

Mendel90

by nophead



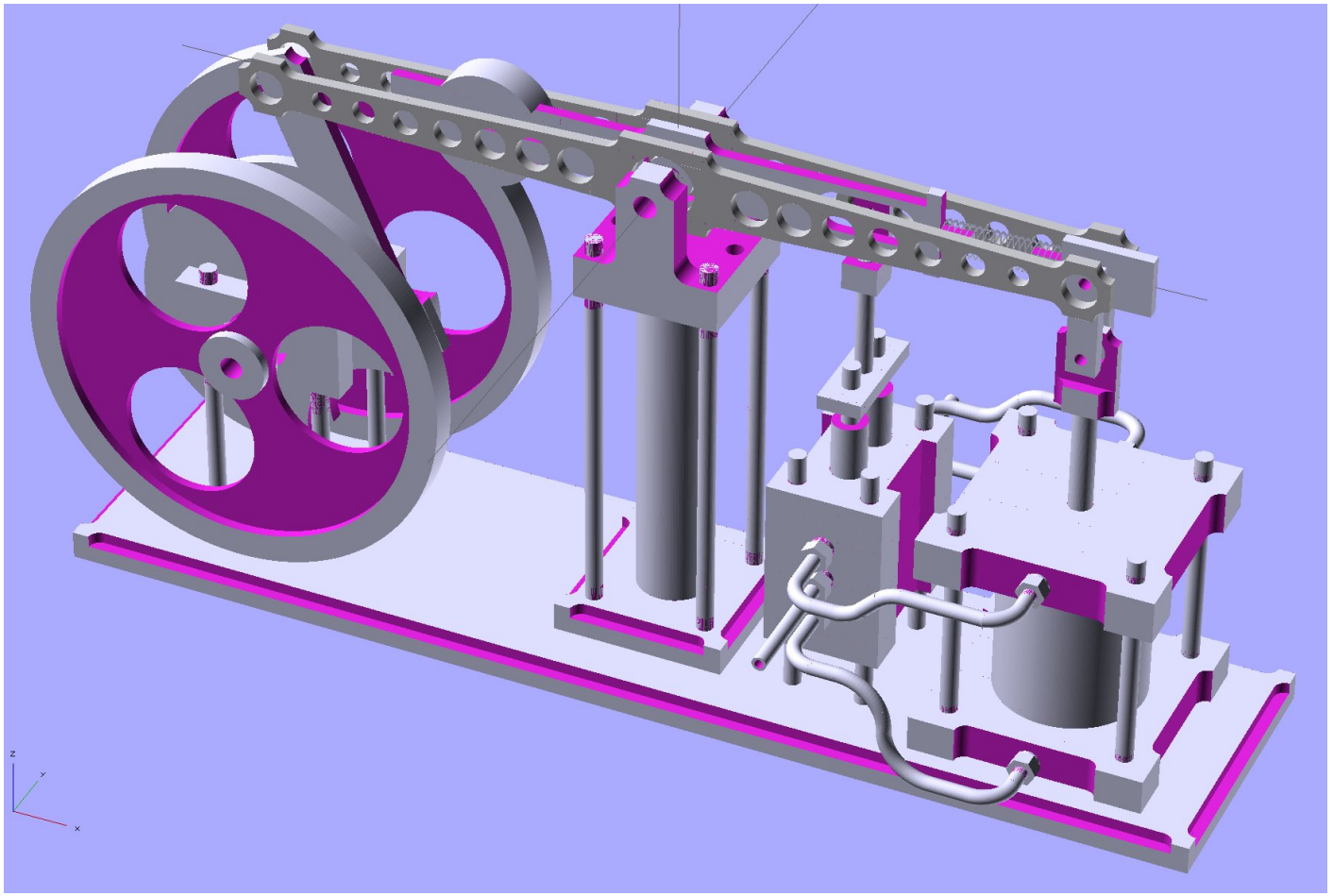
"The OpenScad model now includes everything in the kit, which is everything needed to build the machine apart from some sticky tape"

OpenSCAD Machine Models

Beam engine solid model

by David Powell

“it’s just a mockup and not intended for 3d printing”



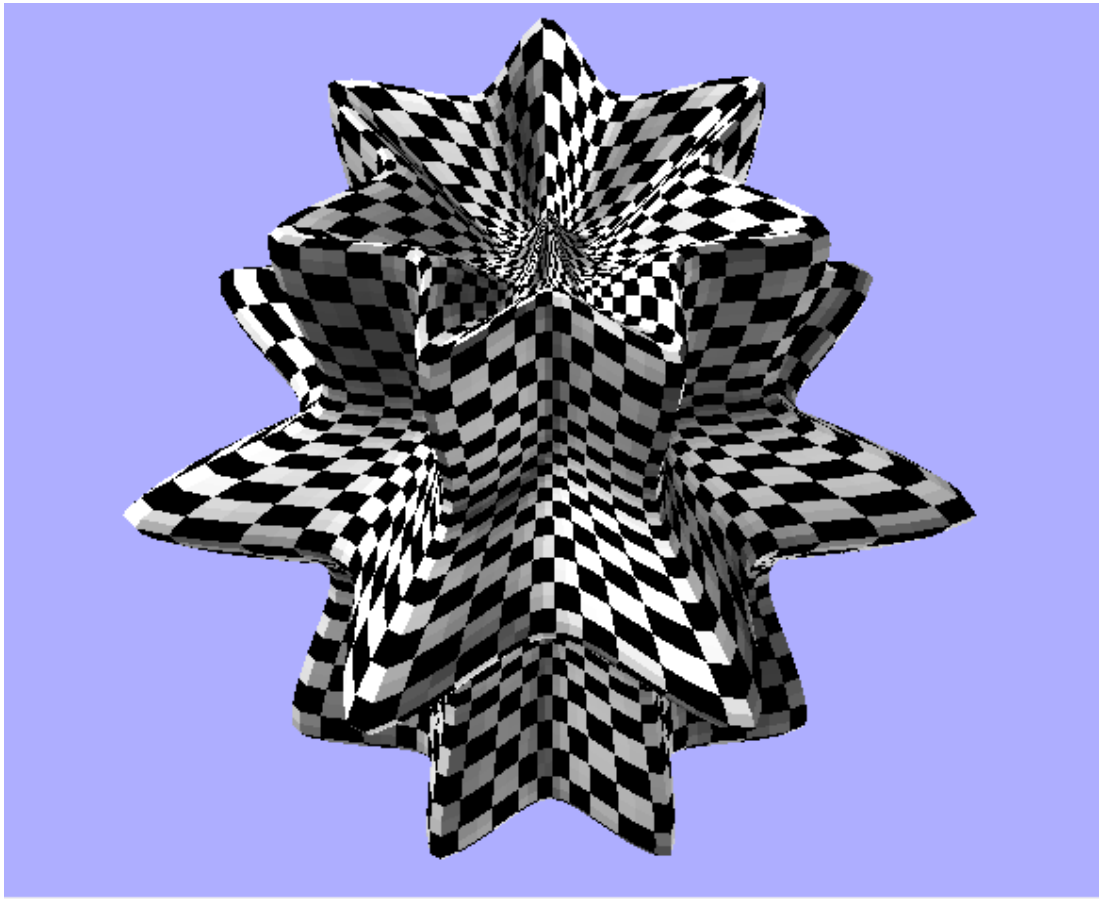
OpenSCAD (Im)Practical Models

SuperShapes

by WilliamAAdams

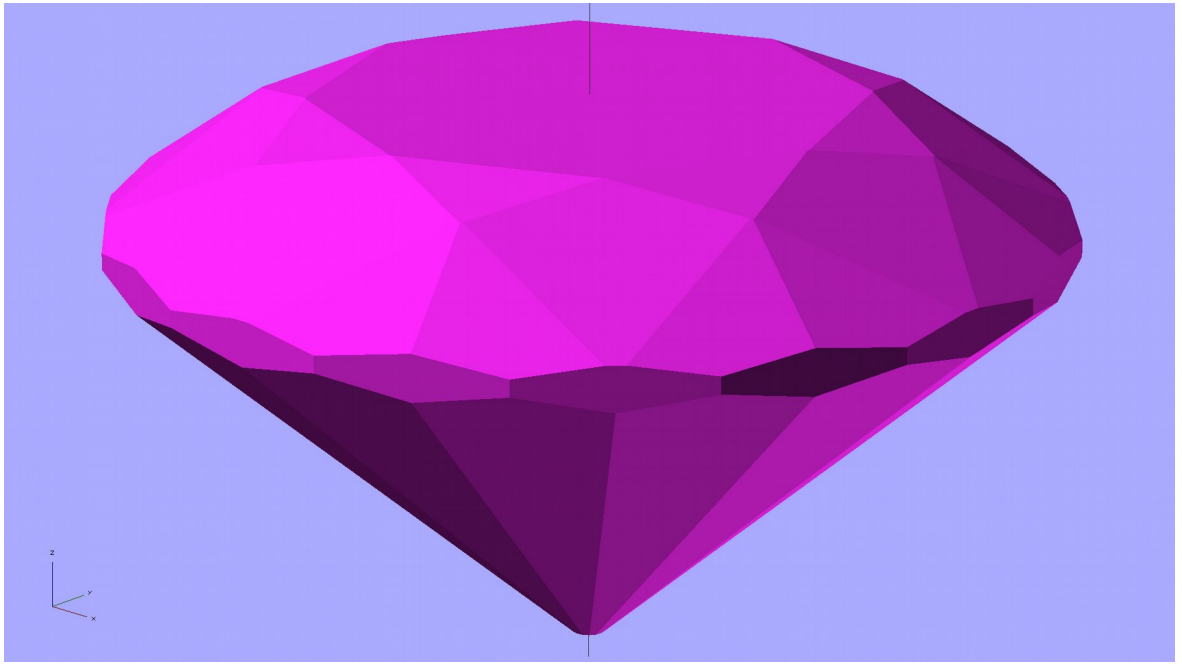
“You also get the procedural texture mapping checkerboard pattern, thrown in for free.”

He also does very practical stuff...



OpenSCAD Techniques

“I made grind() a recursive module that just removes one facet at a time and passes the stone so far to the recursion.”



A problem posed on the OpenSCAD mailing list.
Design by kitwallace: difference of union()
Modified by nophead: recursive difference()

http://forum.openscad.org/union-problem-tp7111.html

Constructive Solid Geometry

“CSG”

Constructive Solid Geometry

… an object is constructed from primitives

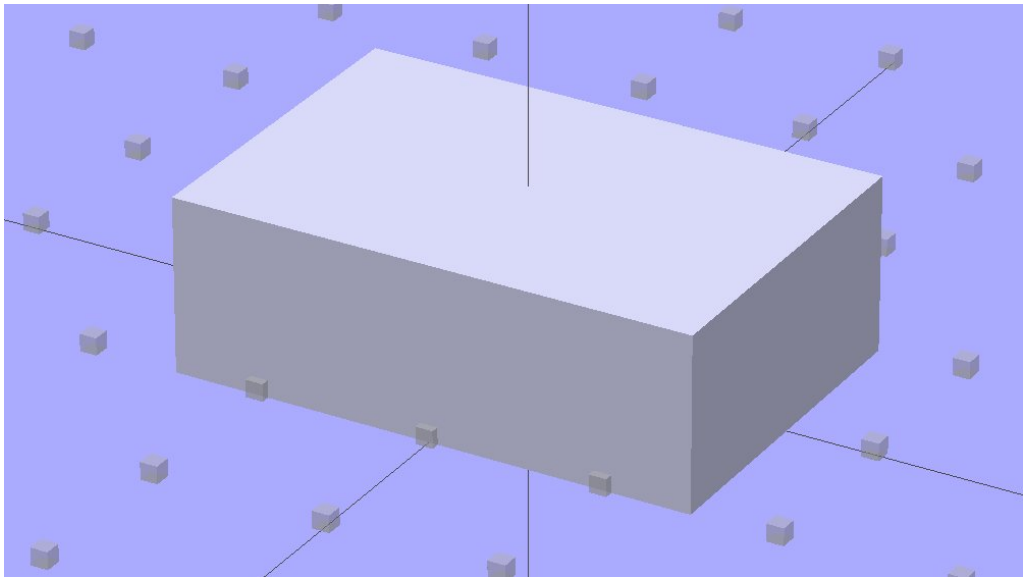
by means of allowable operations,

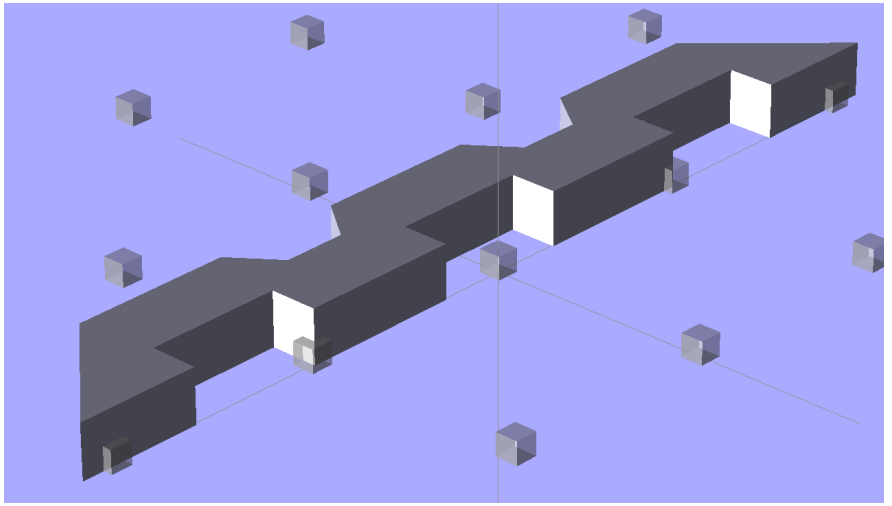
which are ... Boolean operations on sets:

union, intersection and difference.

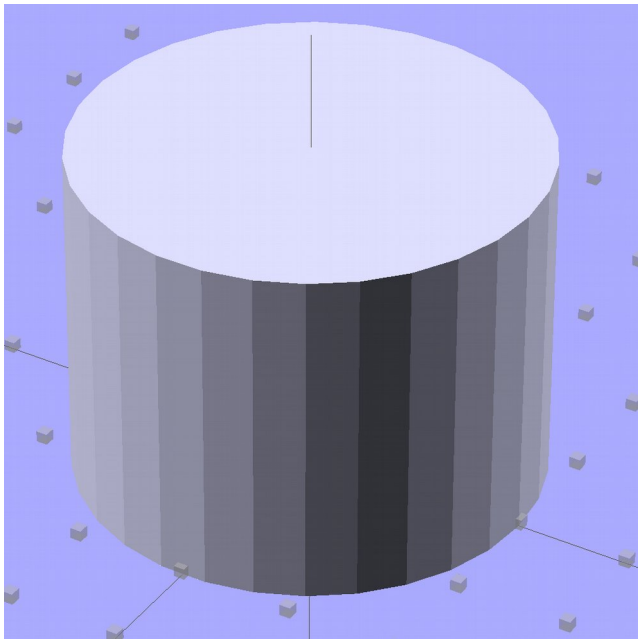
Thus sayeth Wikipedia
http://en.wikipedia.org/wiki/Constructive_solid_geometry

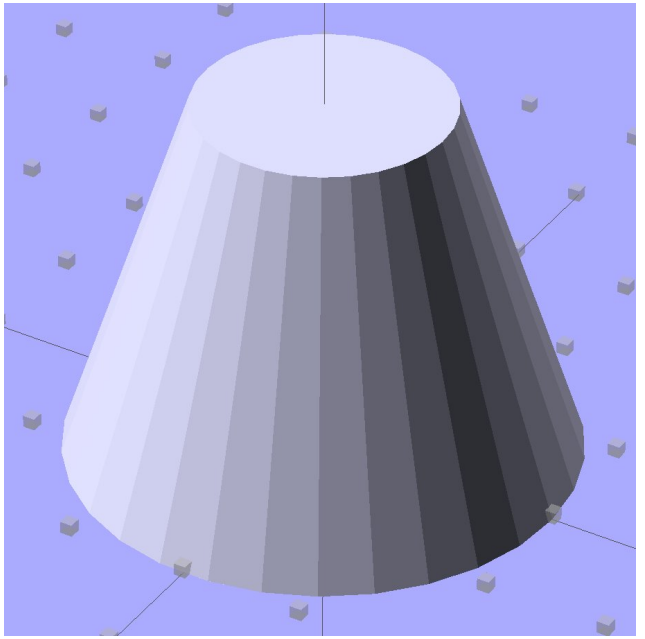
CSG Primitives

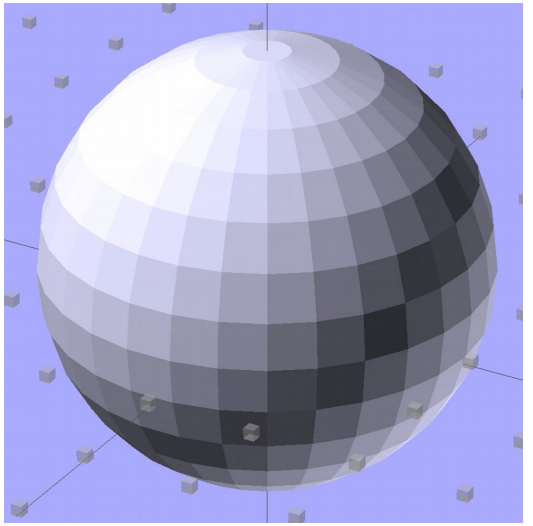




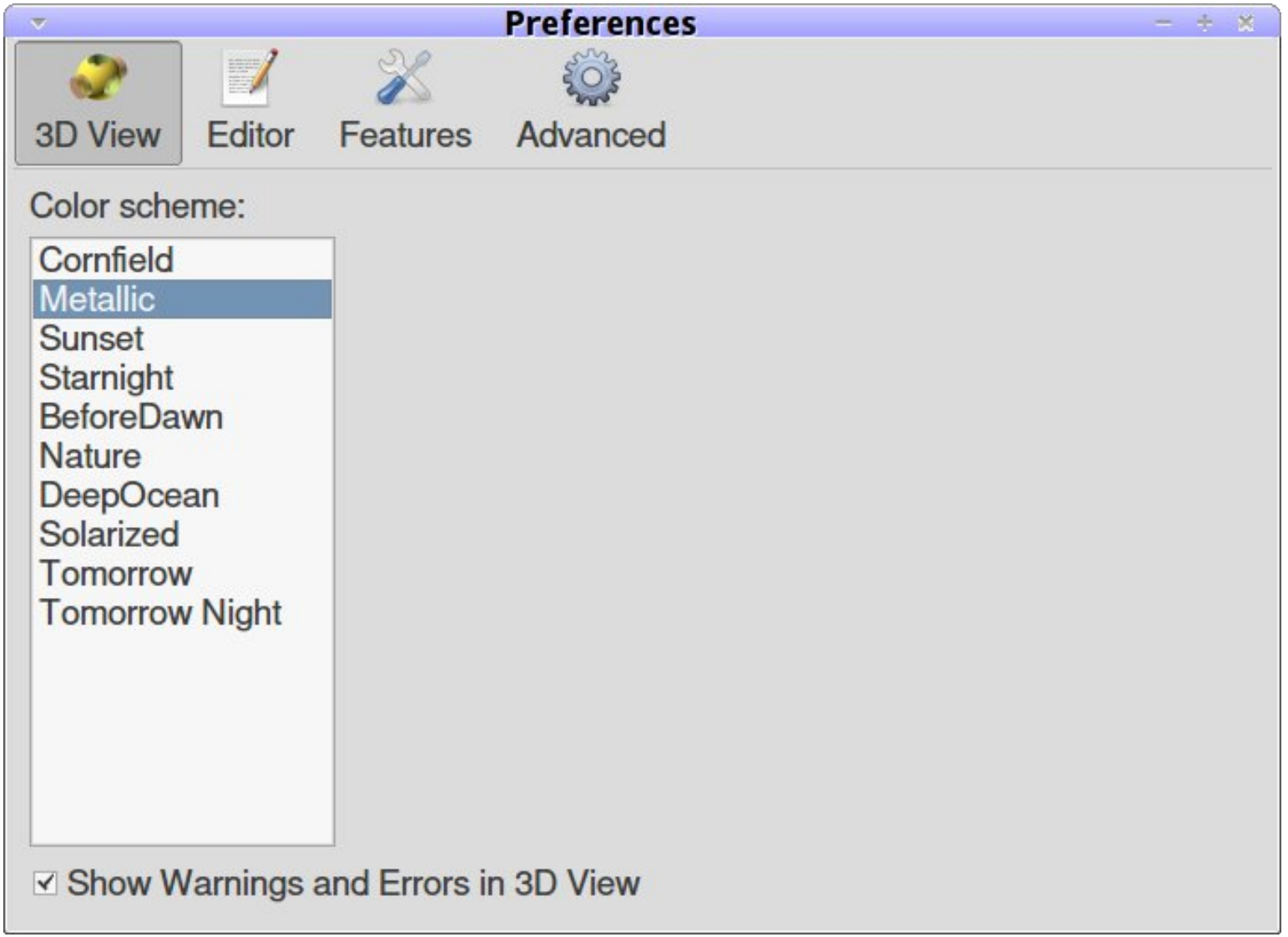
OpenSCAD: cube cylinder sphere



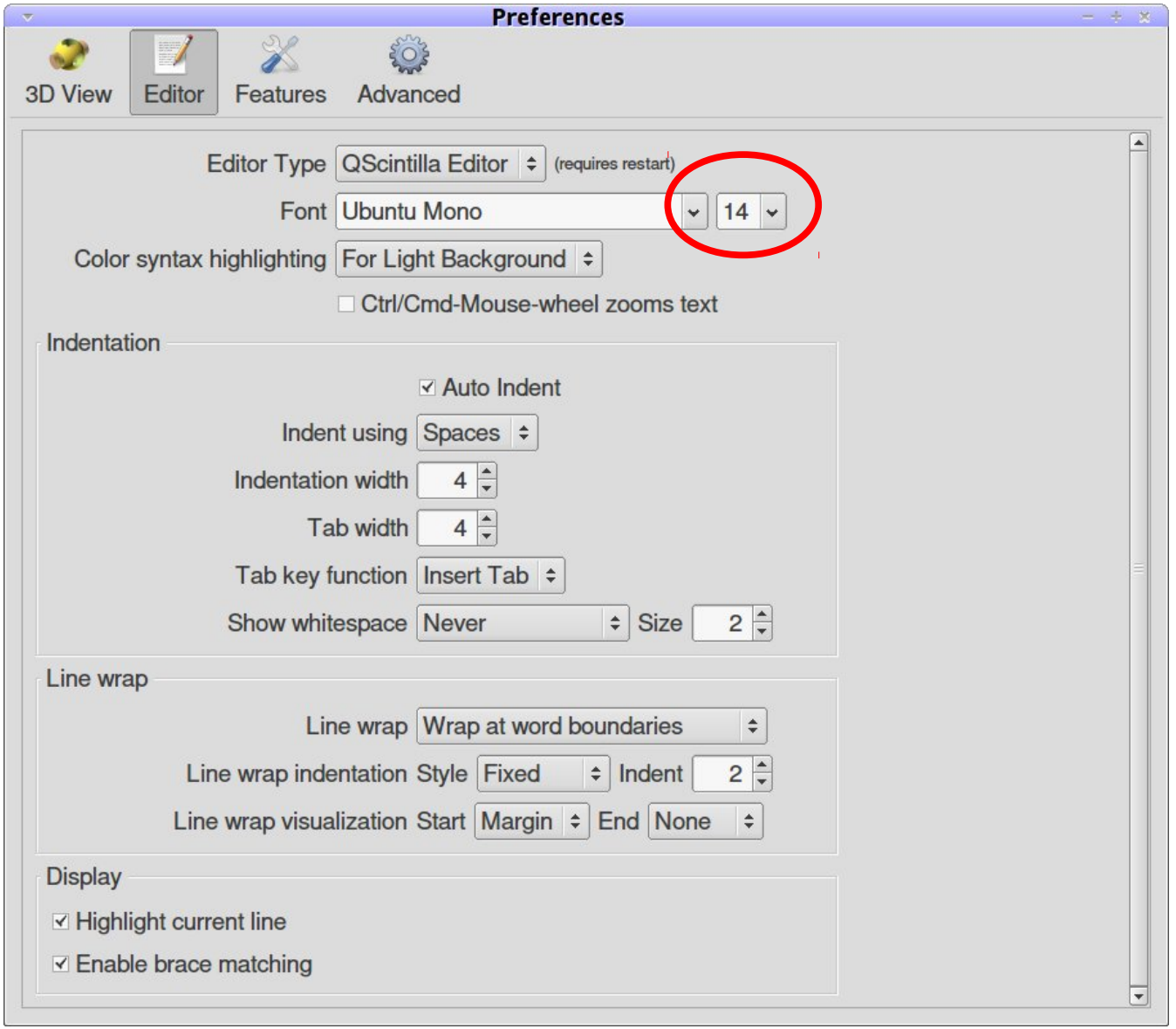




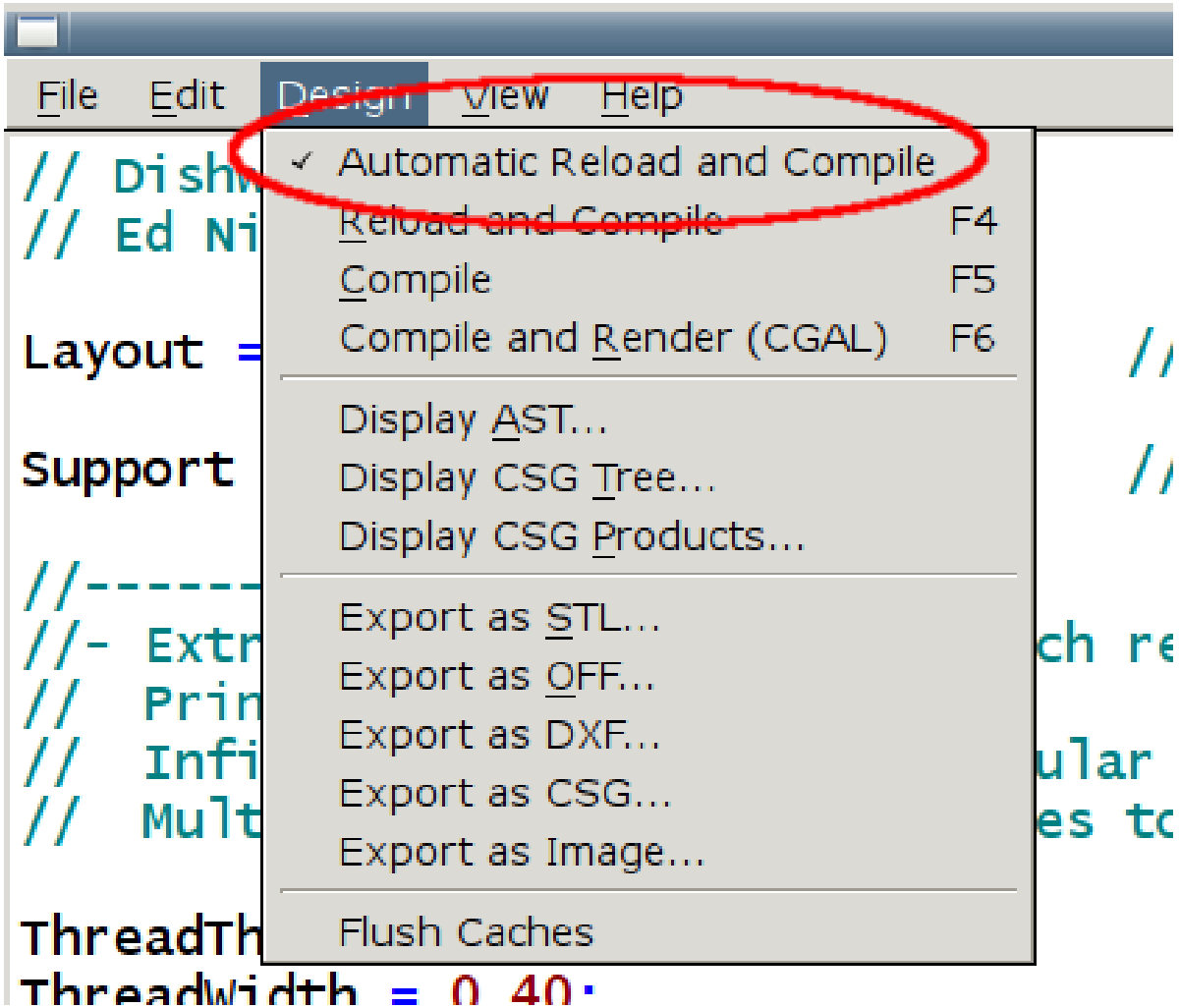
OpenSCAD Color Scheme



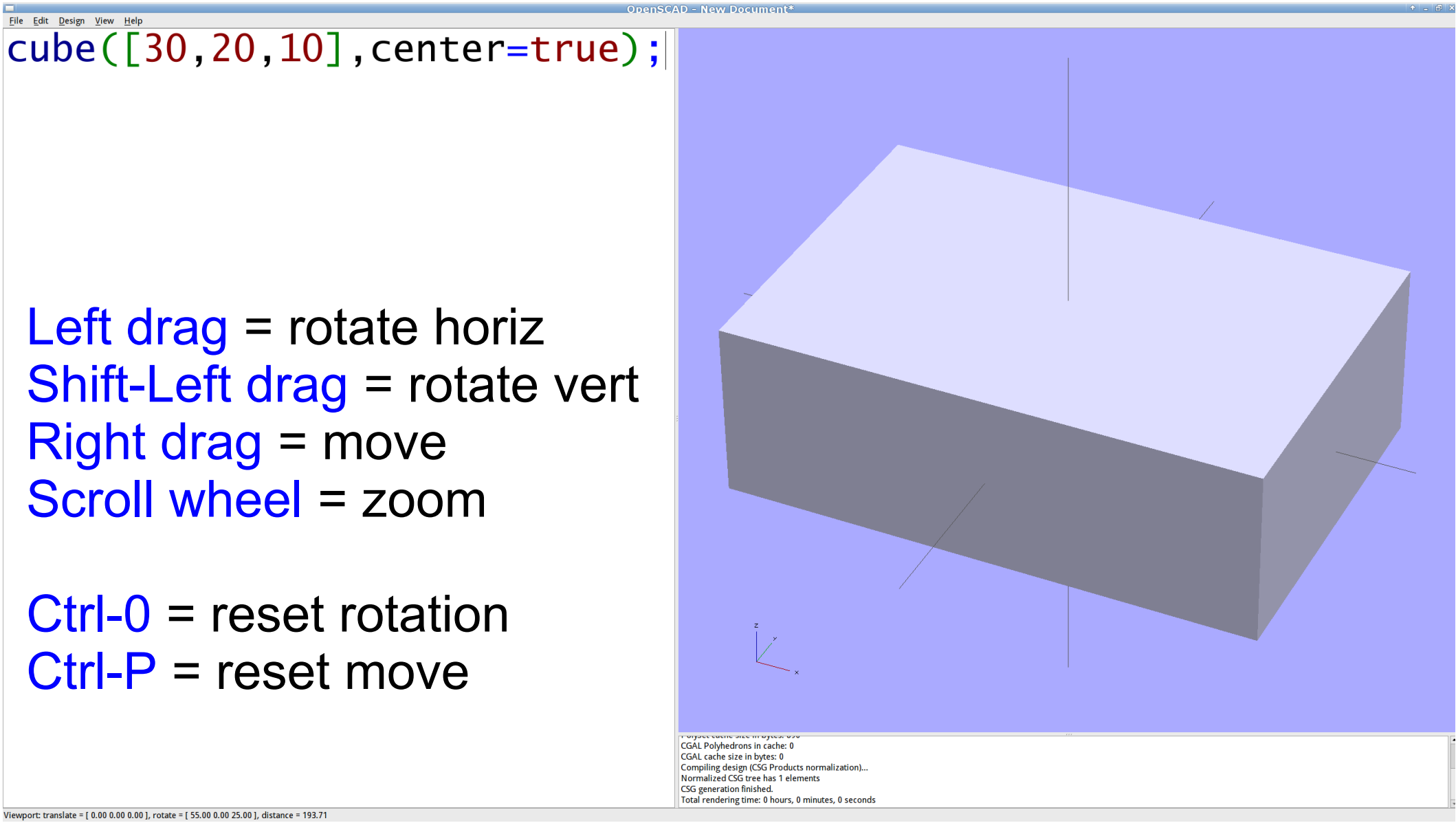
OpenSCAD Editor Preferences



OpenSCAD Design Option



CSG Primitive: Cube



Left drag = rotate horiz
Shift-Left drag = rotate vert
Right drag = move
Scroll wheel = zoom

Ctrl-0 = reset rotation
Ctrl-P = reset move

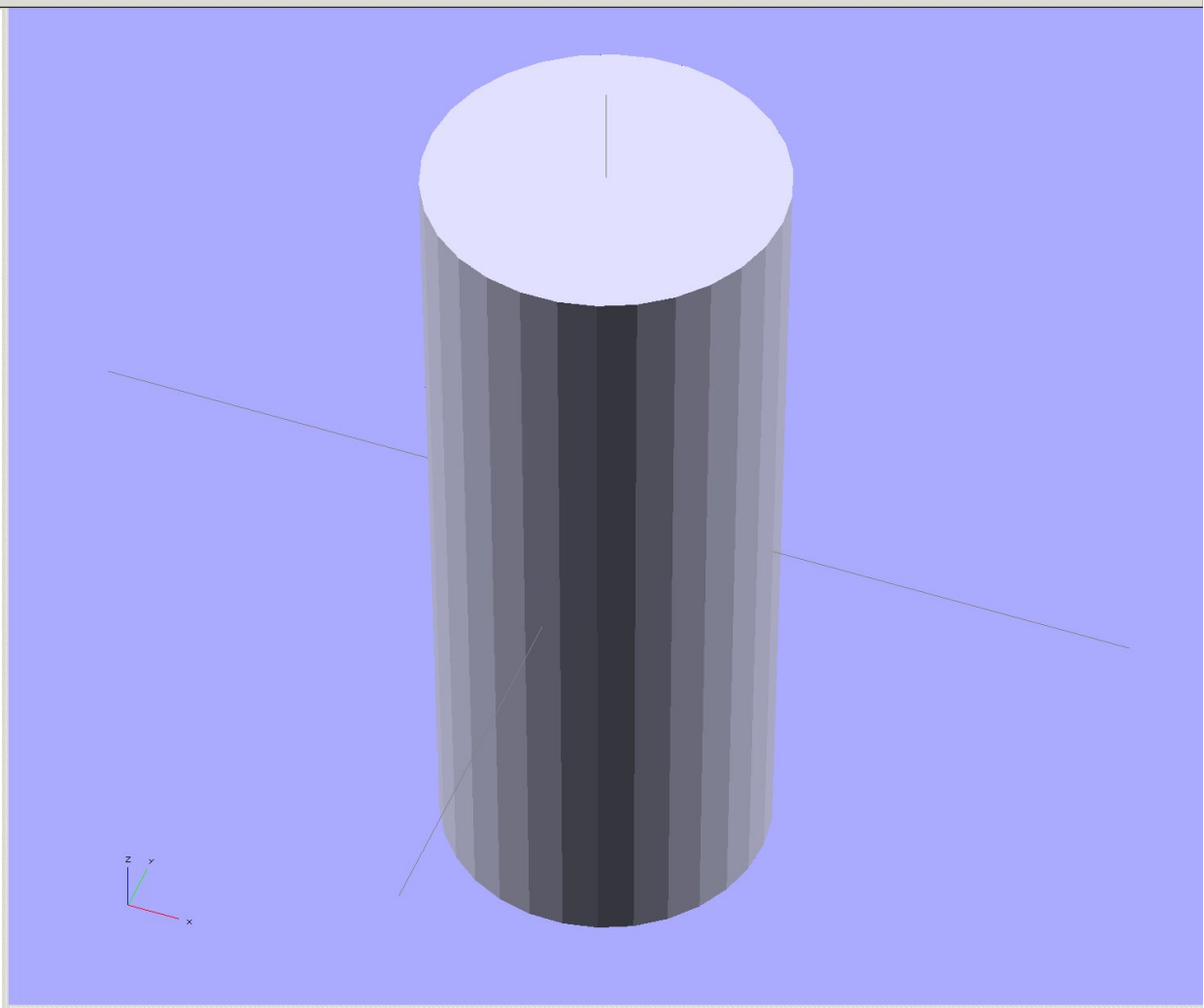
CSG Primitive: Cylinder

OpenSCAD - New Document*

File Edit Design View Help

```
cylinder(r=20,h=100,
         center=true);
```

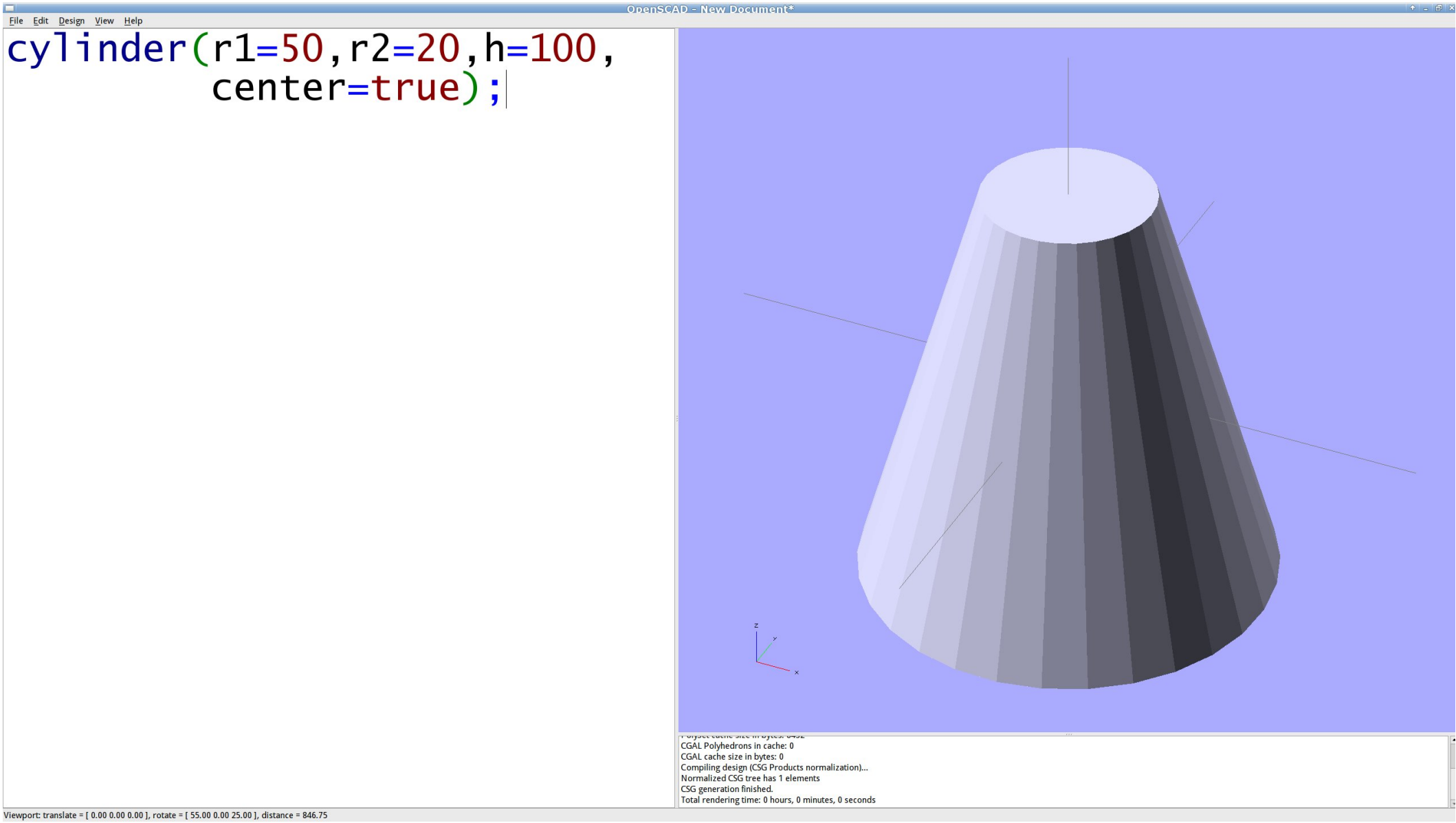
Define number of sides:
$fn=3 → triangular
$fn=6 → hexagonal (nuts!)
$fn=8 → octagonal



PolySet cache size in bytes: 6992
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 1 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

Viewport: translate = [0.00 0.00 0.00], rotate = [44.50 0.00 20.80], distance = 617.28

CSG Primitive: Cylinder



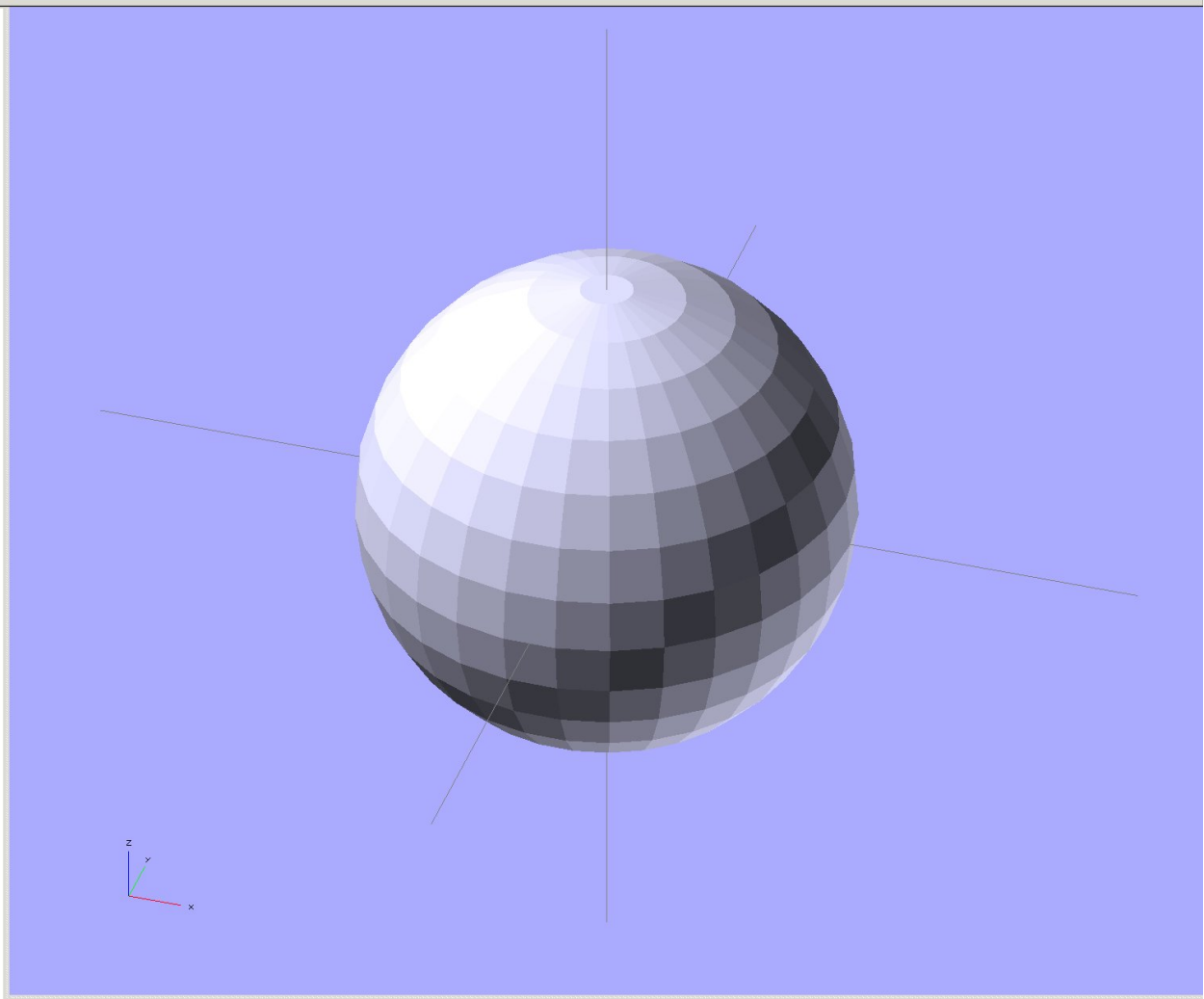
CSG Primitive: Sphere

OpenSCAD - New Document*

File Edit Design View Help

```
sphere(10);
```

Control facets at equator:
$fa = minimum angle
$fs = minimum size
$fn = actual number



PolySet cache size in bytes: 1131128
CGAL Polyhedrons in cache: 389
CGAL cache size in bytes: 7579996
Compiling design (CSG Products normalization)...
Normalized CSG tree has 1 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

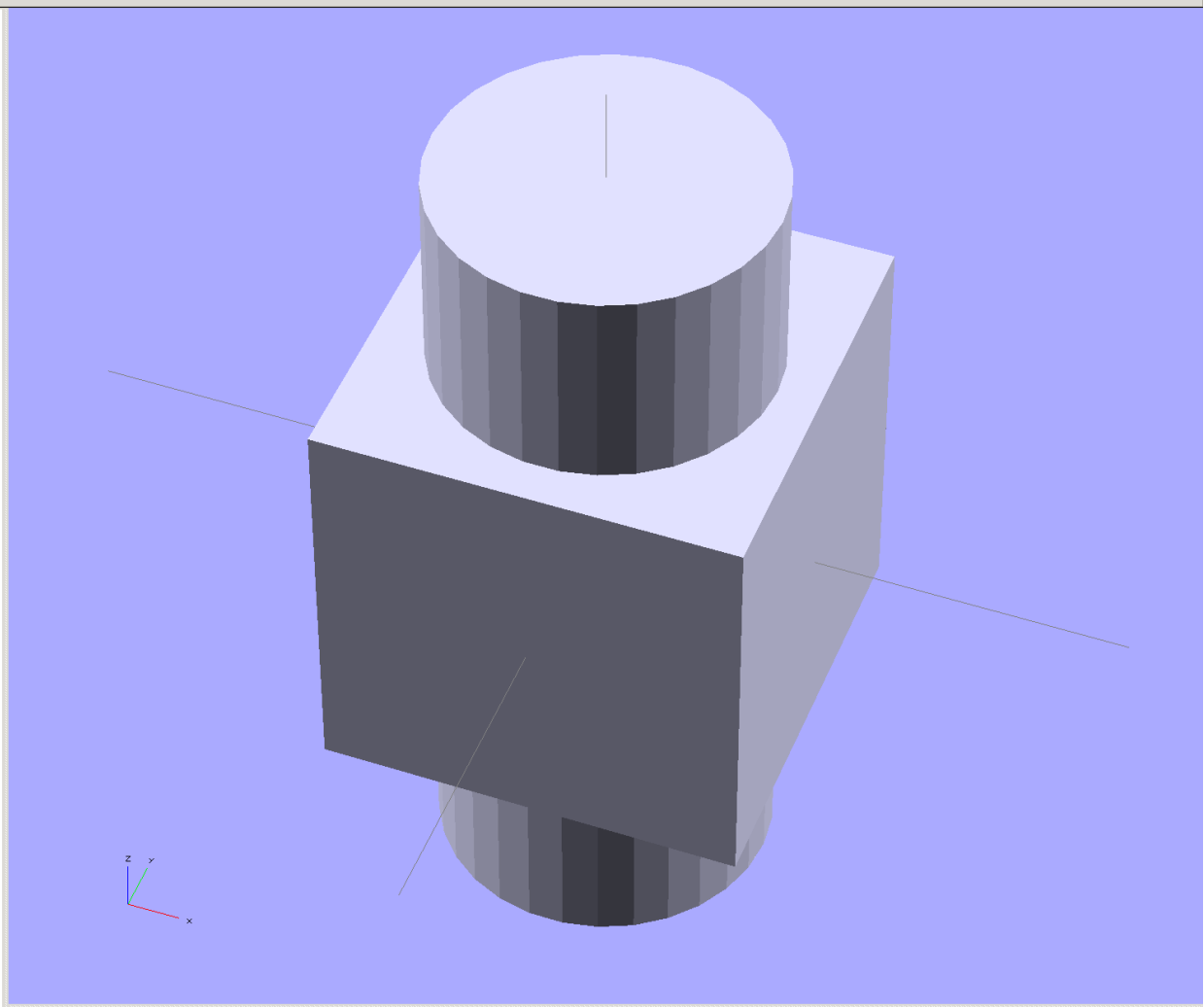
Viewport: translate = [0.00 0.00 0.00], rotate = [55.00 0.00 17.30], distance = 215.23

CSG Operation: Union

OpenSCAD - New Document*

File Edit Design View Help

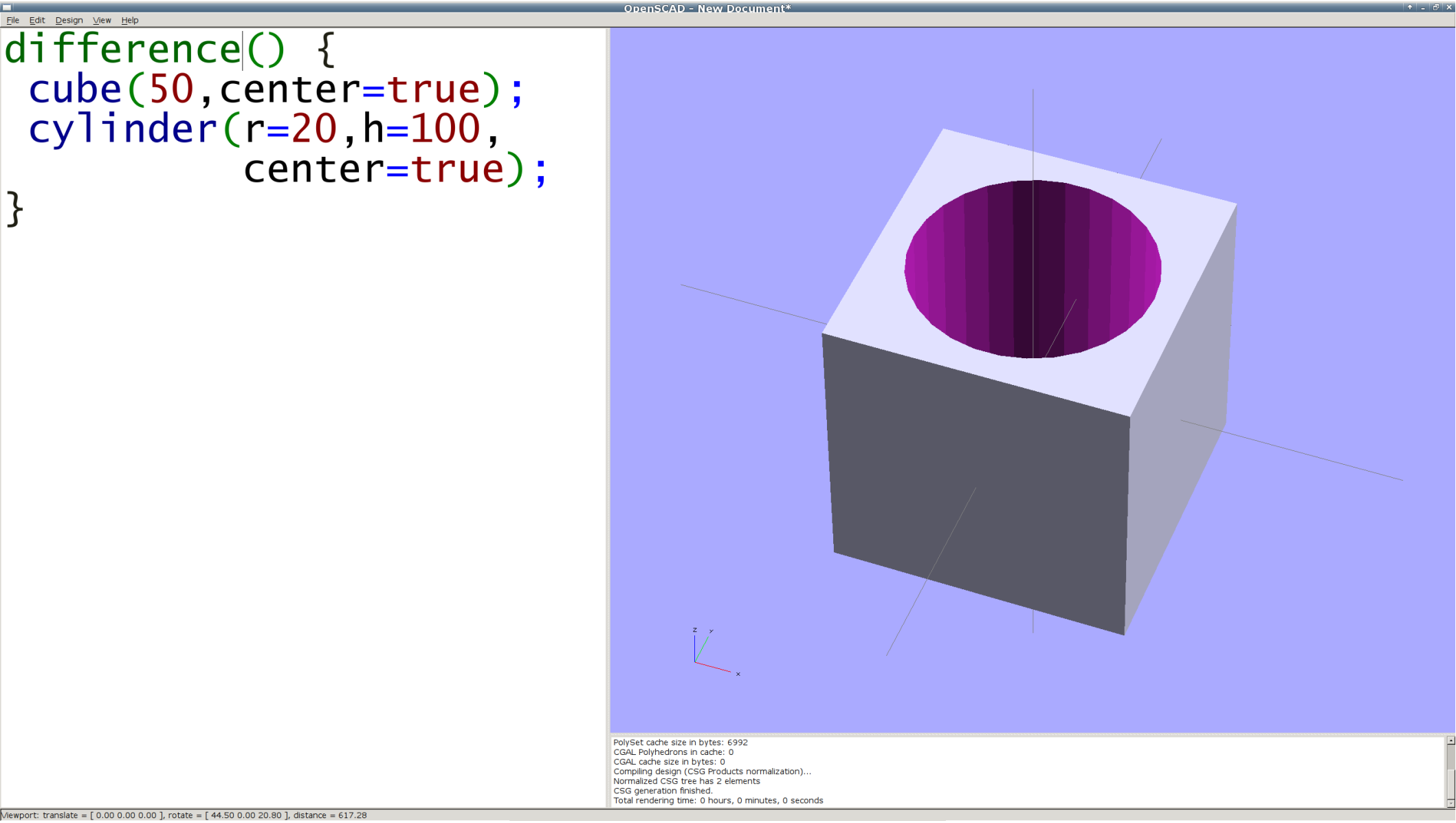
```
union() {
  cube(50,center=true);
  cylinder(r=20,h=100,
           center=true);
}
```



PolySet cache size in bytes: 6992
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 2 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

Viewport: translate = [0.00 0.00 0.00], rotate = [44.50 0.00 20.80], distance = 617.28

CSG Operation: Difference

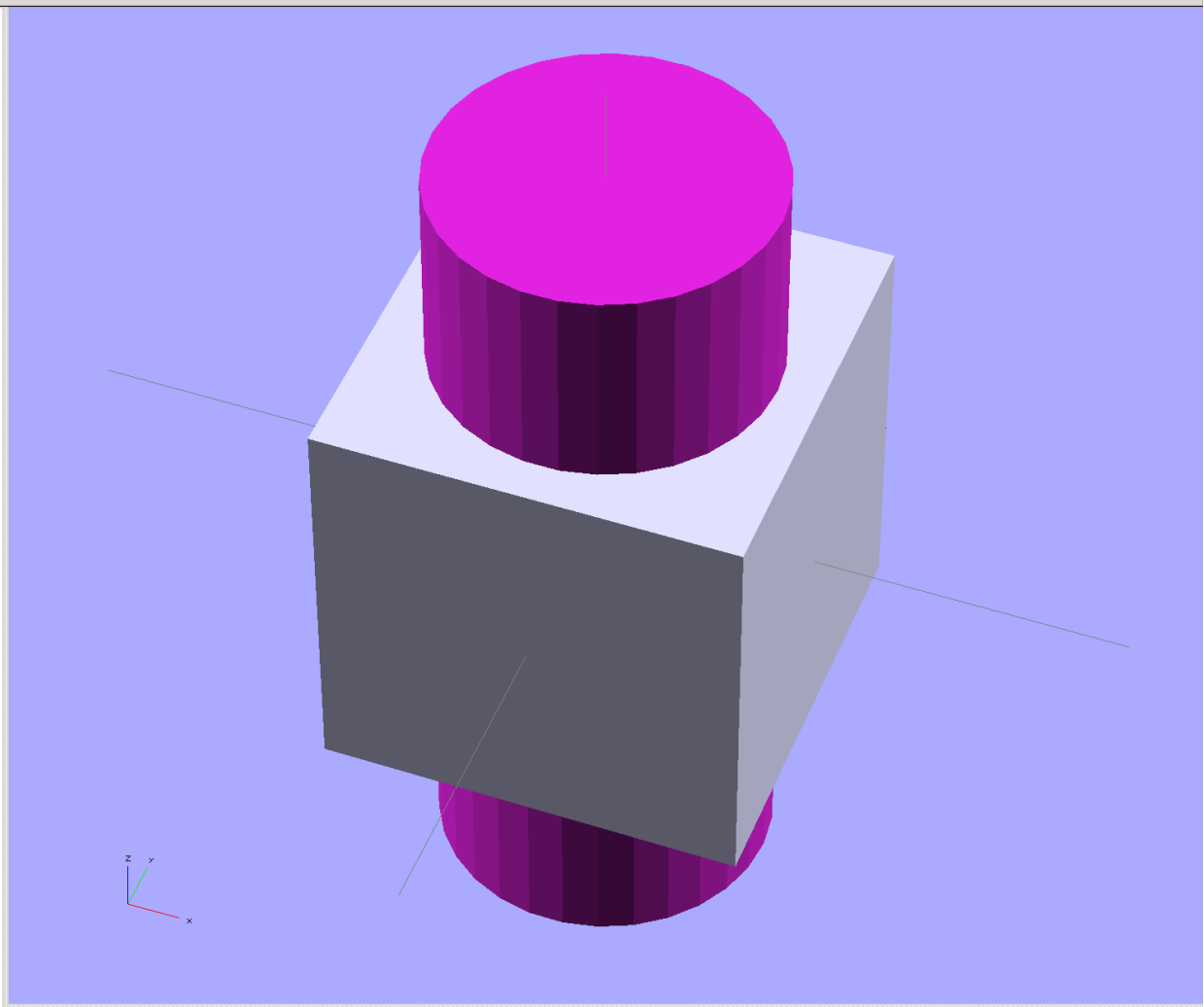


CSG Operation: Difference

OpenSCAD - New Document*

File Edit Design View Help

```
difference() {
  cube(50,center=true);
  cylinder(r=20,h=100,
           center=true);
}
```



PolySet cache size in bytes: 6992
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 2 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

Viewport: translate = [0.00 0.00 0.00], rotate = [44.50 0.00 20.80], distance = 617.28

F9 = OpenCSG view

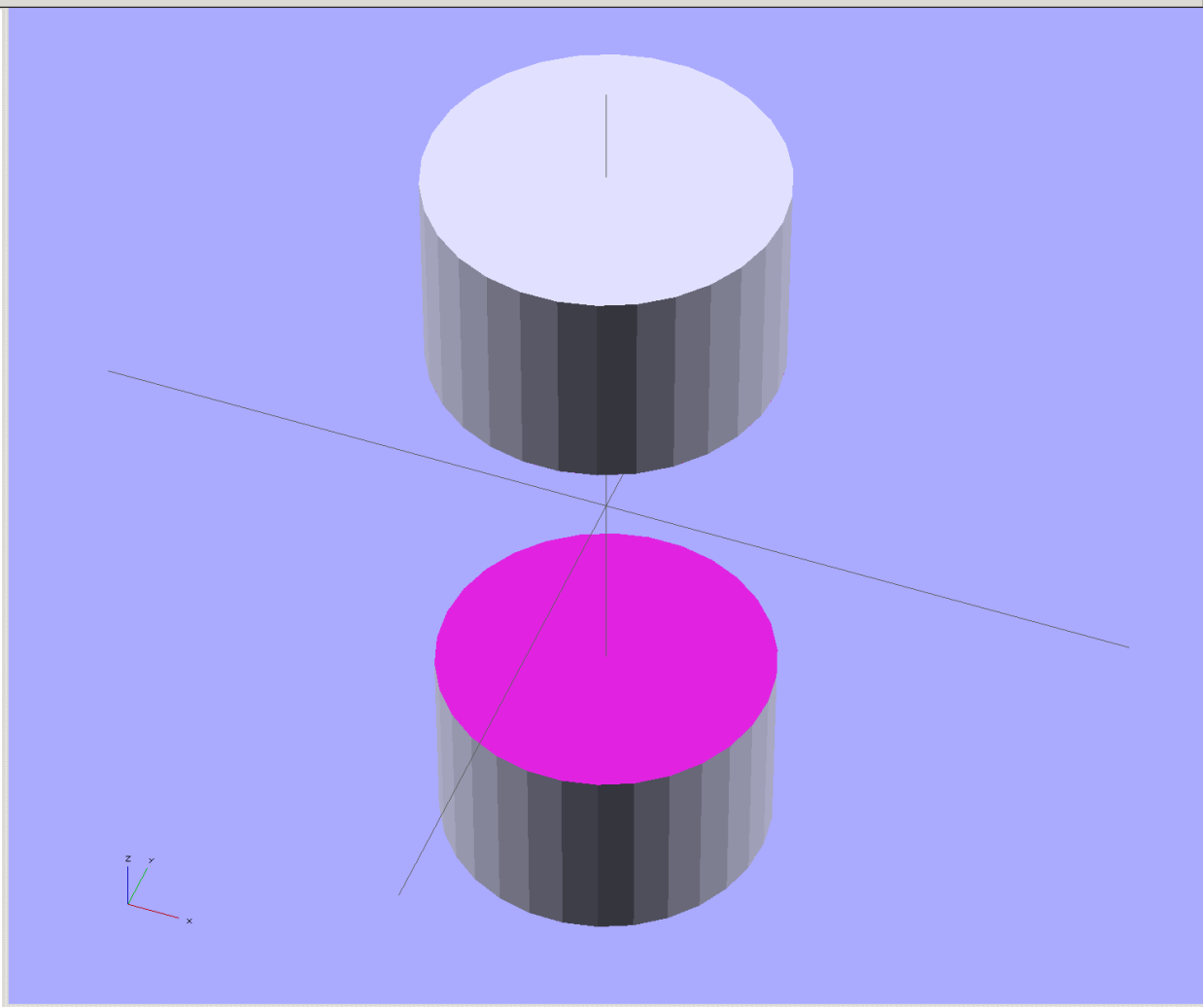
F12 = “Thrown Together”

CSG Operation: Difference

OpenSCAD - New Document*

File Edit Design View Help

```
difference() {
  cylinder(r=20,h=100,
           center=true);
  cube(50,center=true);
}
```



PolySet cache size in bytes: 6992
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 2 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

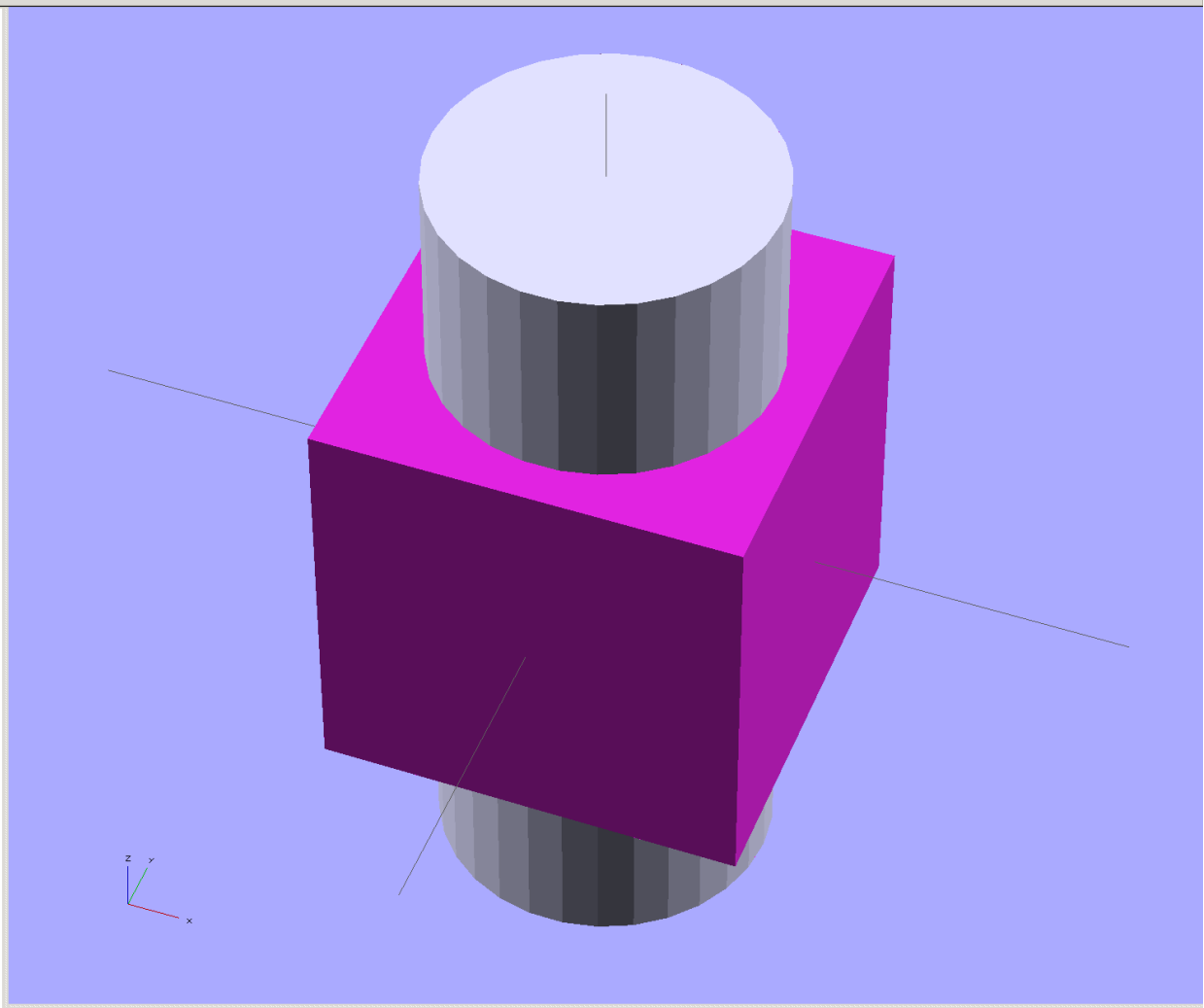
Viewport: translate = [0.00 0.00 0.00], rotate = [44.50 0.00 20.80], distance = 617.28

CSG Operation: Difference

OpenSCAD - New Document*

File Edit Design View Help

```
difference() {
 cylinder(r=20,h=100,
          center=true);
 cube(50,center=true);
}
```



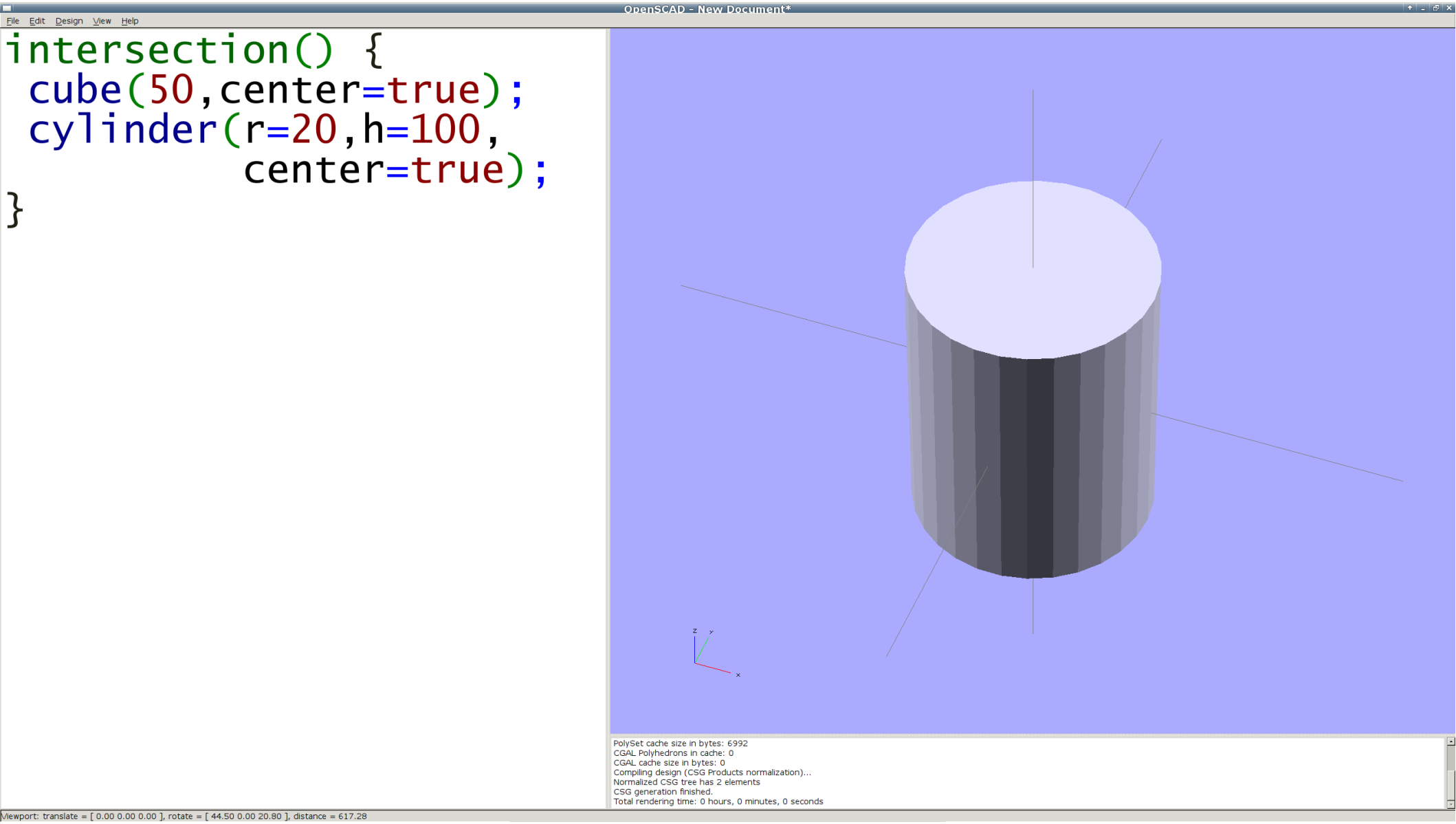
F9 = OpenCSG view

F12 = “Thrown Together”

```
PolySet cache size in bytes: 6992
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 2 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [0.00 0.00 0.00], rotate = [44.50 0.00 20.80], distance = 617.28

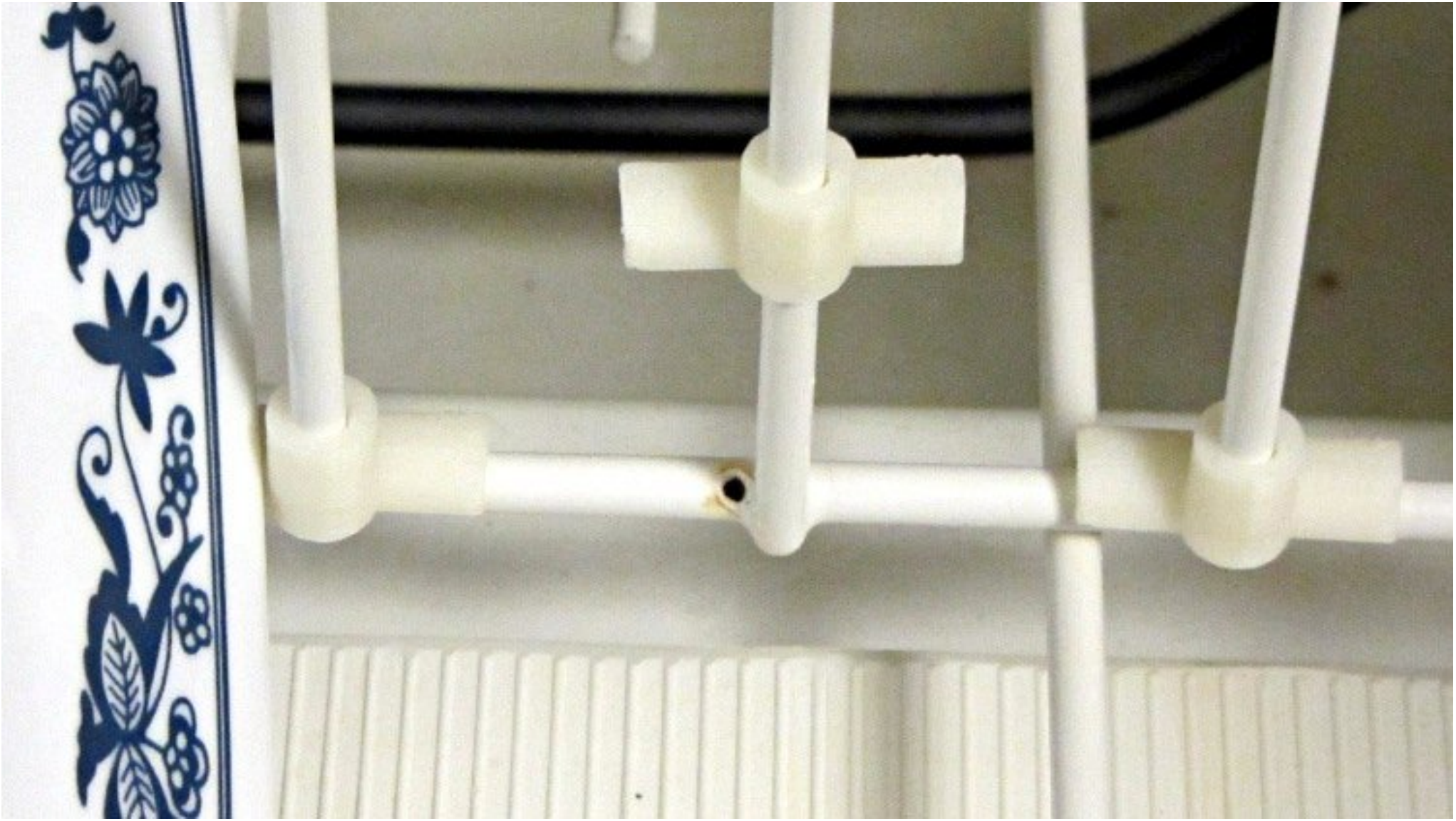
CSG Operation: Intersection



Essential Transformations

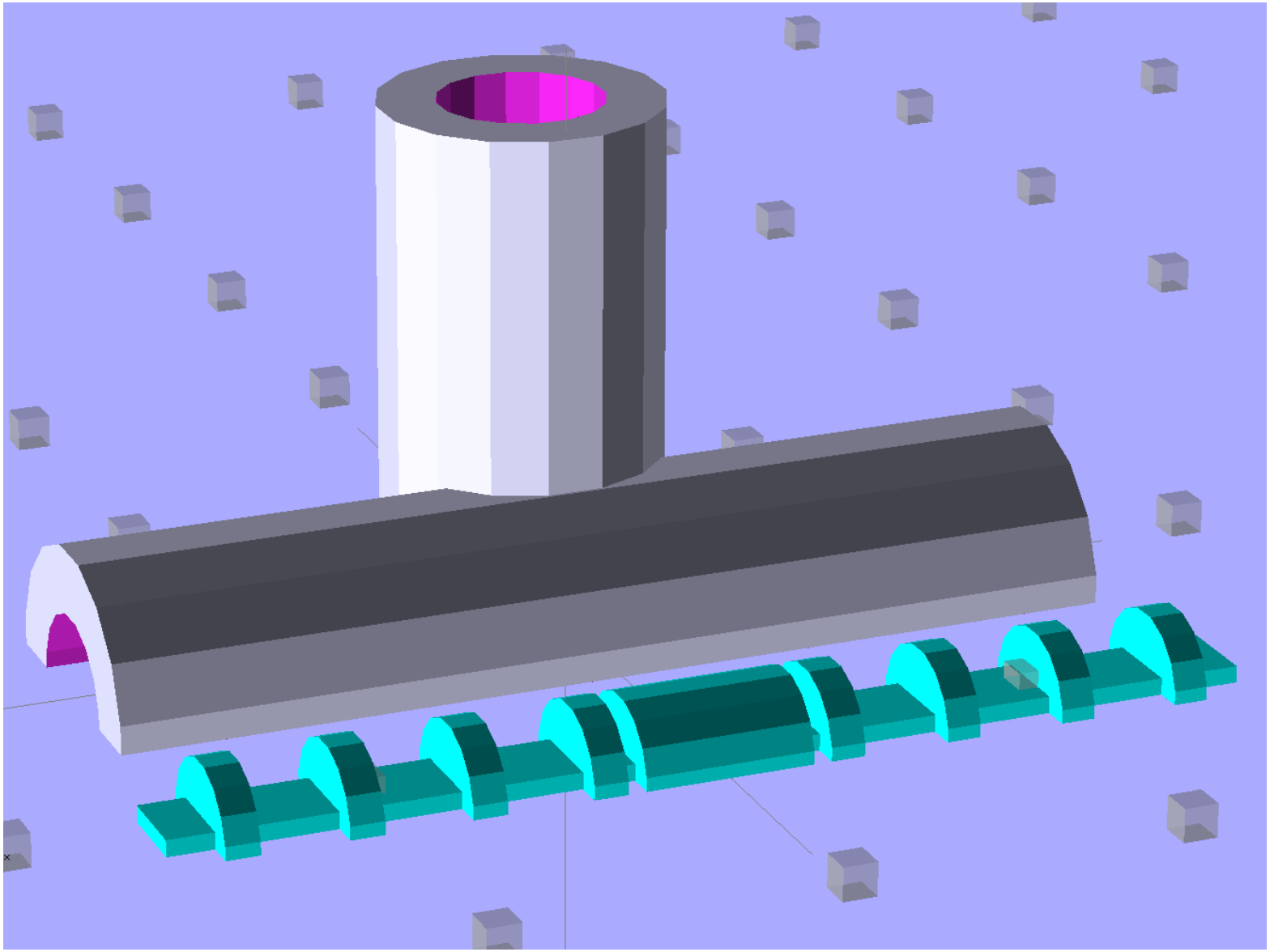
- translate([x,y,z])
- rotate([x,y,z]) with angles in degrees
  - Rotate(angle) around Z axis
- color (“name”) or color(“name”,alpha)
  - “name” *not* case sensitive!
- mirror([x,y,z])
  - [x,y,z] = normal of mirror plane through origin
- scale([x,y,z]) and resize([x,y,z])

Dishwasher Rack Protector



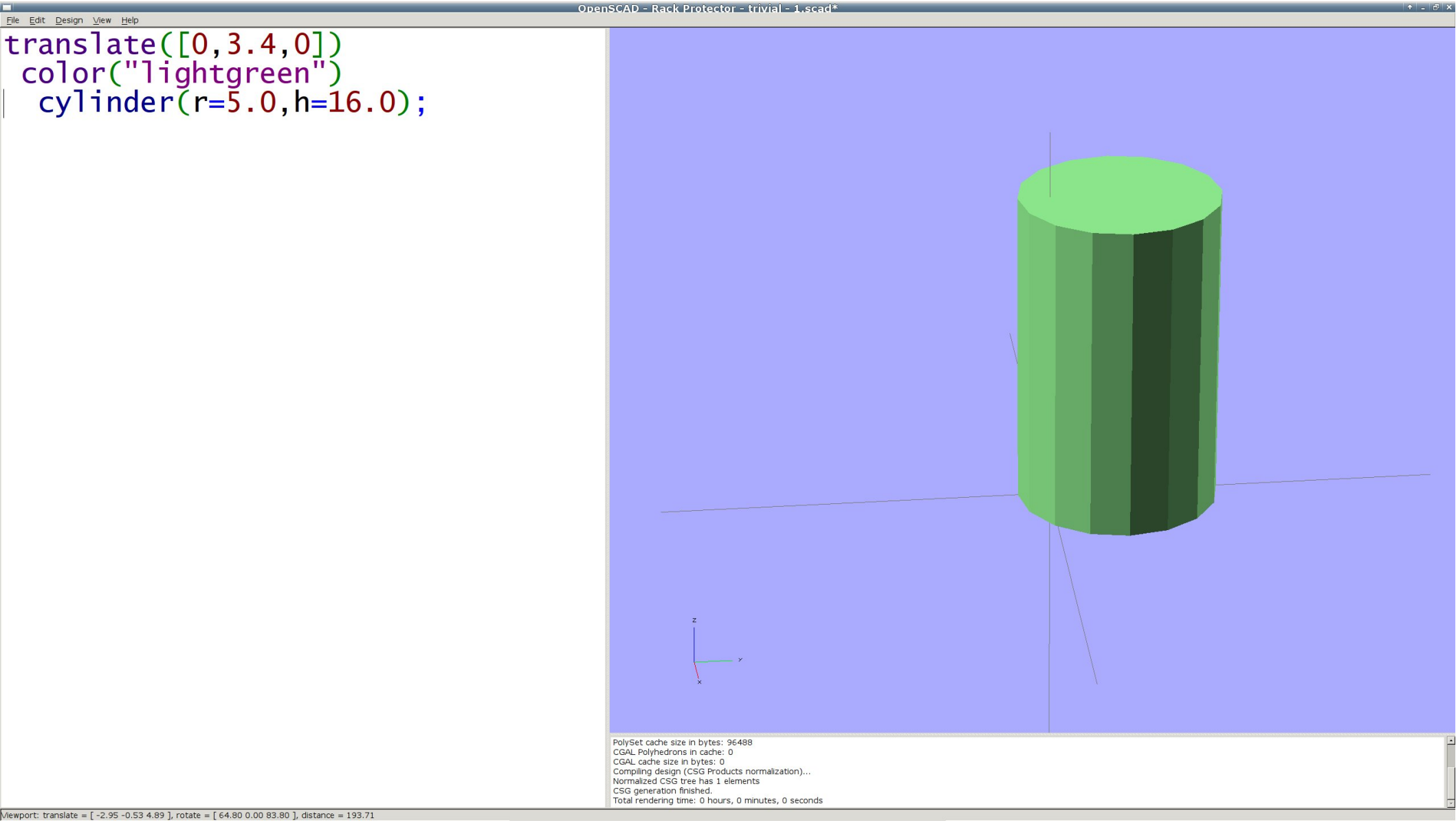
http://softsolder.com/2013/02/04/dishwasher-rack-protectors-into-the-maw/

Dishwasher Rack Protector



http://softsolder.com/2013/02/04/dishwasher-rack-protectors-into-the-maw/

Translate([x,y,z])

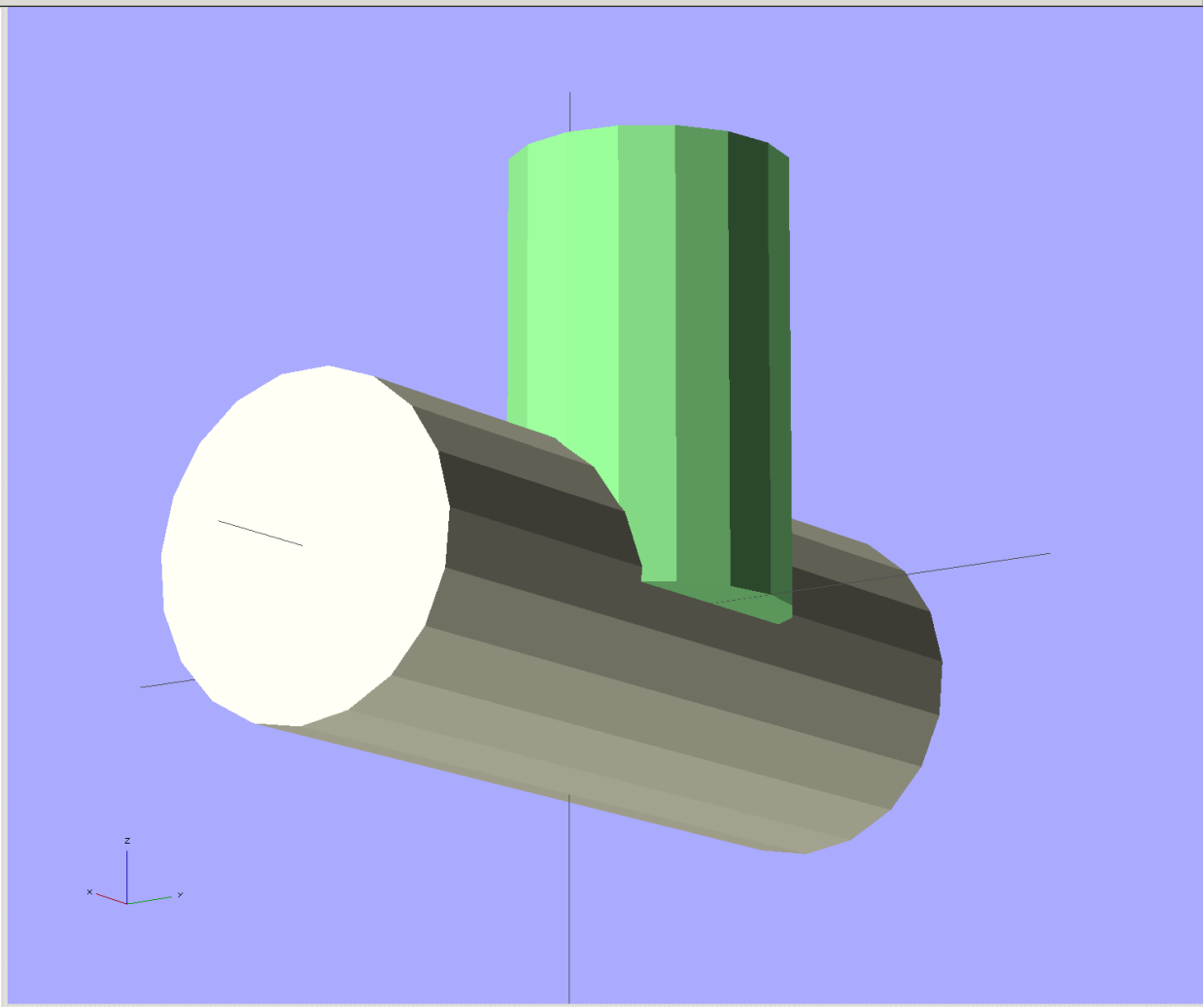


Rotate([x,y,z])

OpenSCAD - Rack Protector - trivial - 1.scad*

File Edit Design View Help

```
translate([0,3.4,0])
 color("lightgreen")
  cylinder(r=5.0,h=16.0);

translate([-15.0,0,0])
 rotate([0,90,0])
  color("lightyellow")
   cylinder(r=6.0,h=30.0);
```



CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 2 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
Loaded design '/mnt/bulkdata/Project Files/Practical Solid Modeling with OpenSCAD/Solid Models/Rack Protector - trivial - 1.scad'.

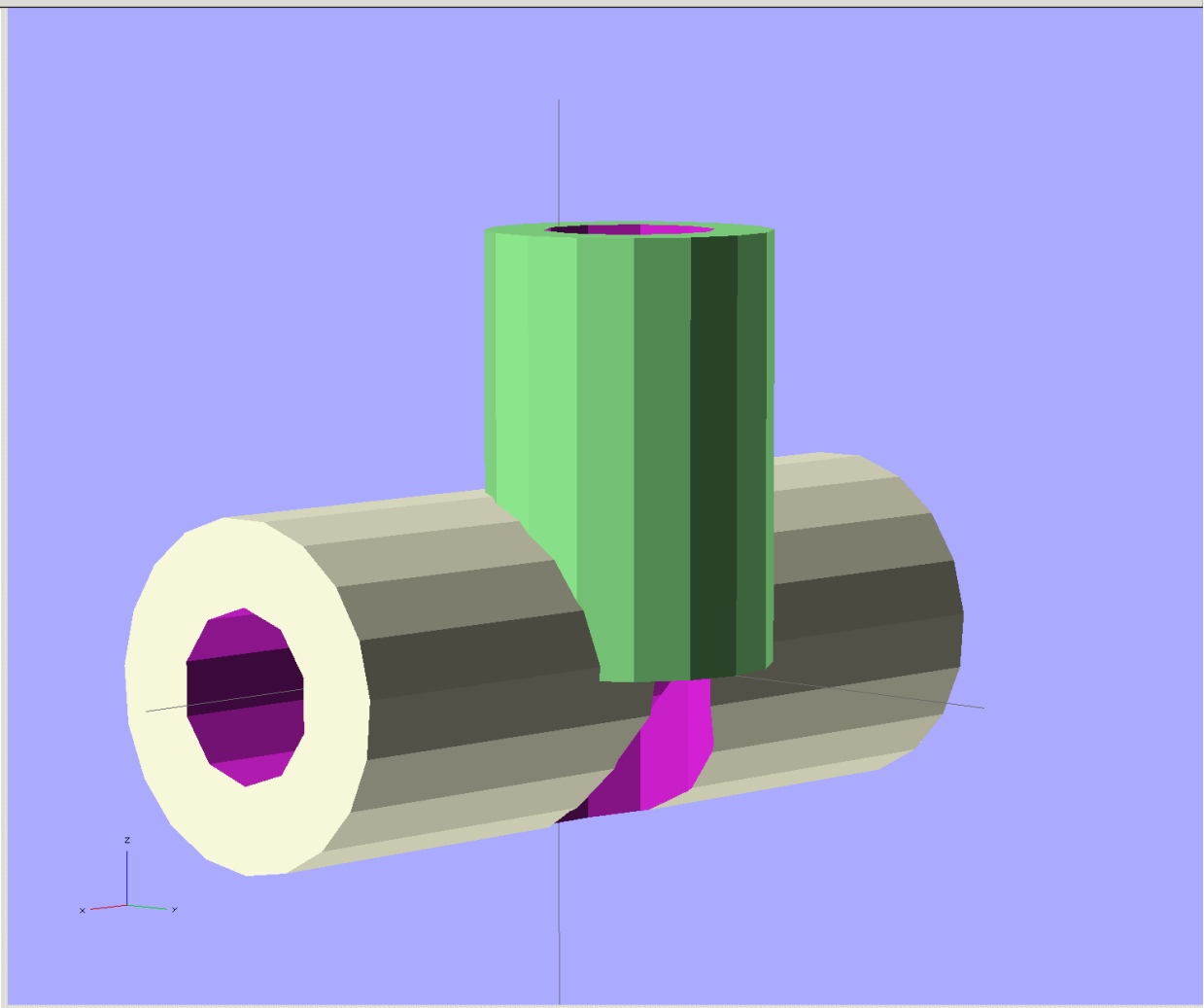
Viewport: translate = [-2.95 -0.53 4.89], rotate = [103.30 0.00 125.10], distance = 193.71

Difference: F9 View

OpenSCAD - Rack Protector - trivial - 2.scad

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);
}
```



PolySet cache size in bytes: 104872
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 6 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

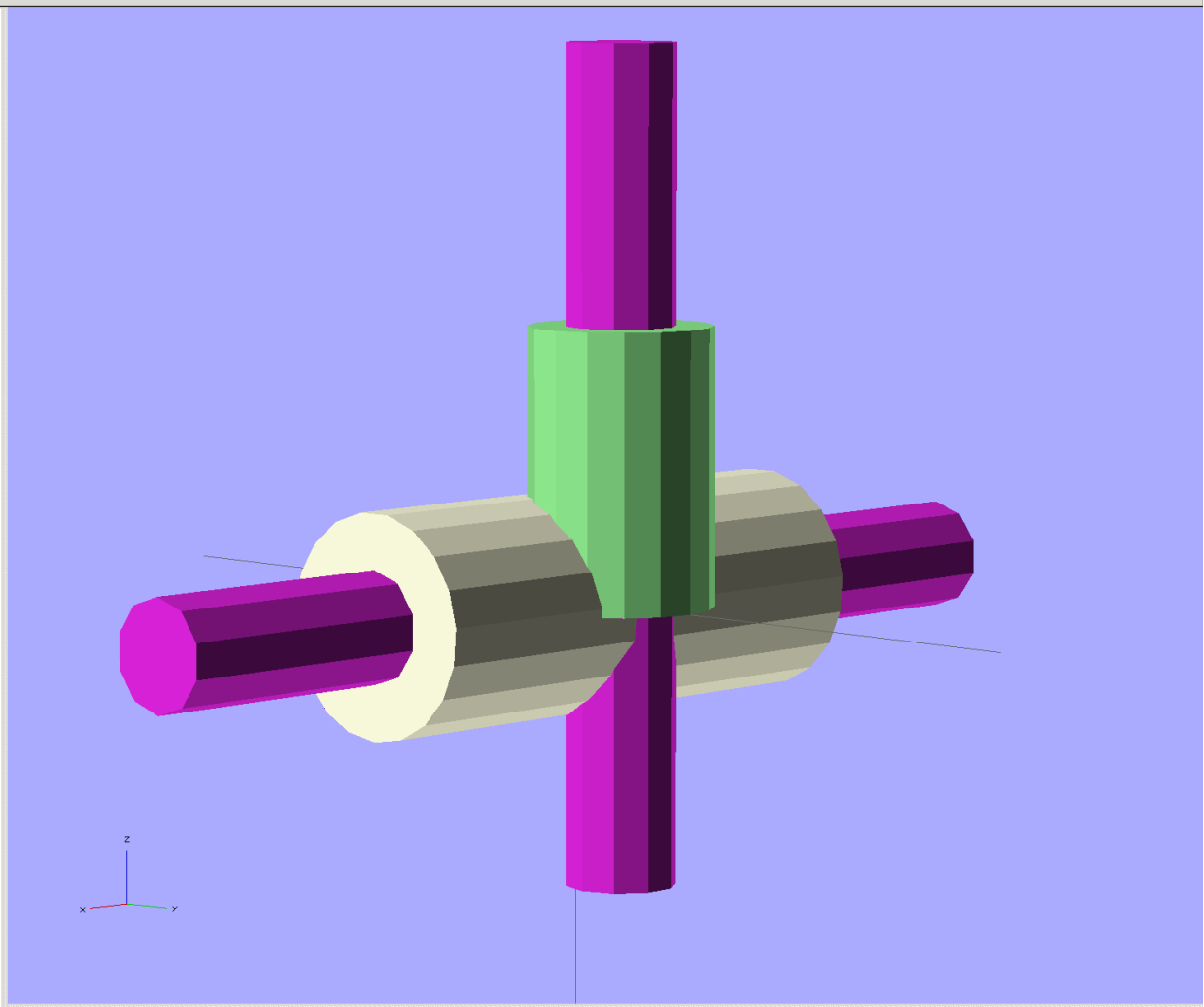
Viewport: translate = [-2.95 -0.53 4.89], rotate = [83.70 0.00 133.50], distance = 193.71

Difference: F12 View

OpenSCAD - Rack Protector - trivial - 2.scad

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);
}
```



PolySet cache size in bytes: 104872
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 6 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

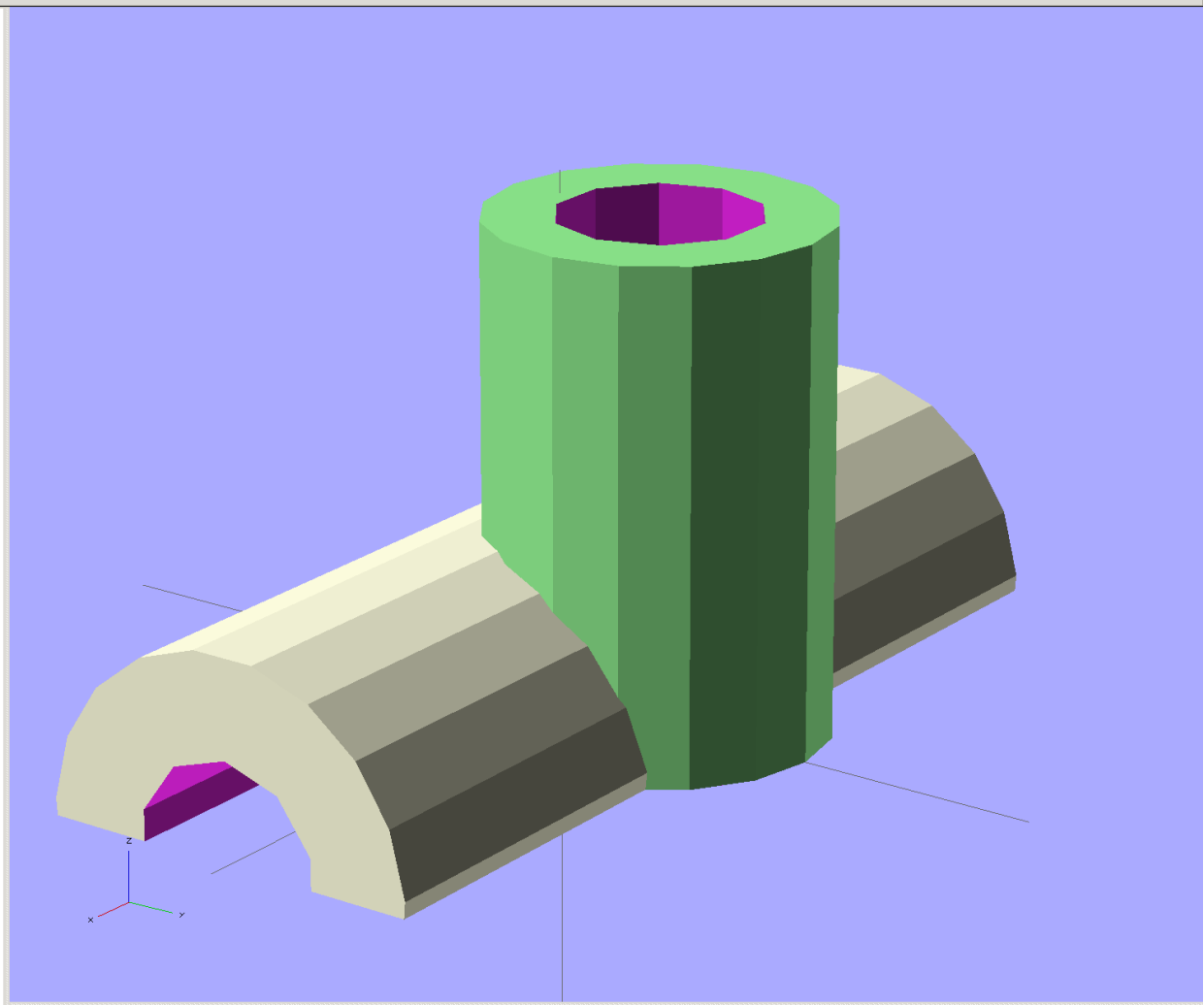
Viewport: translate = [-2.95 -0.53 4.89], rotate = [83.70 0.00 133.50], distance = 295.25

Difference: F9 View

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

 translate([0,0,-5.0])
  cube([50,50,10.0],center=true);
}
```



```
PolySet cache size in bytes: 106664
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 8 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

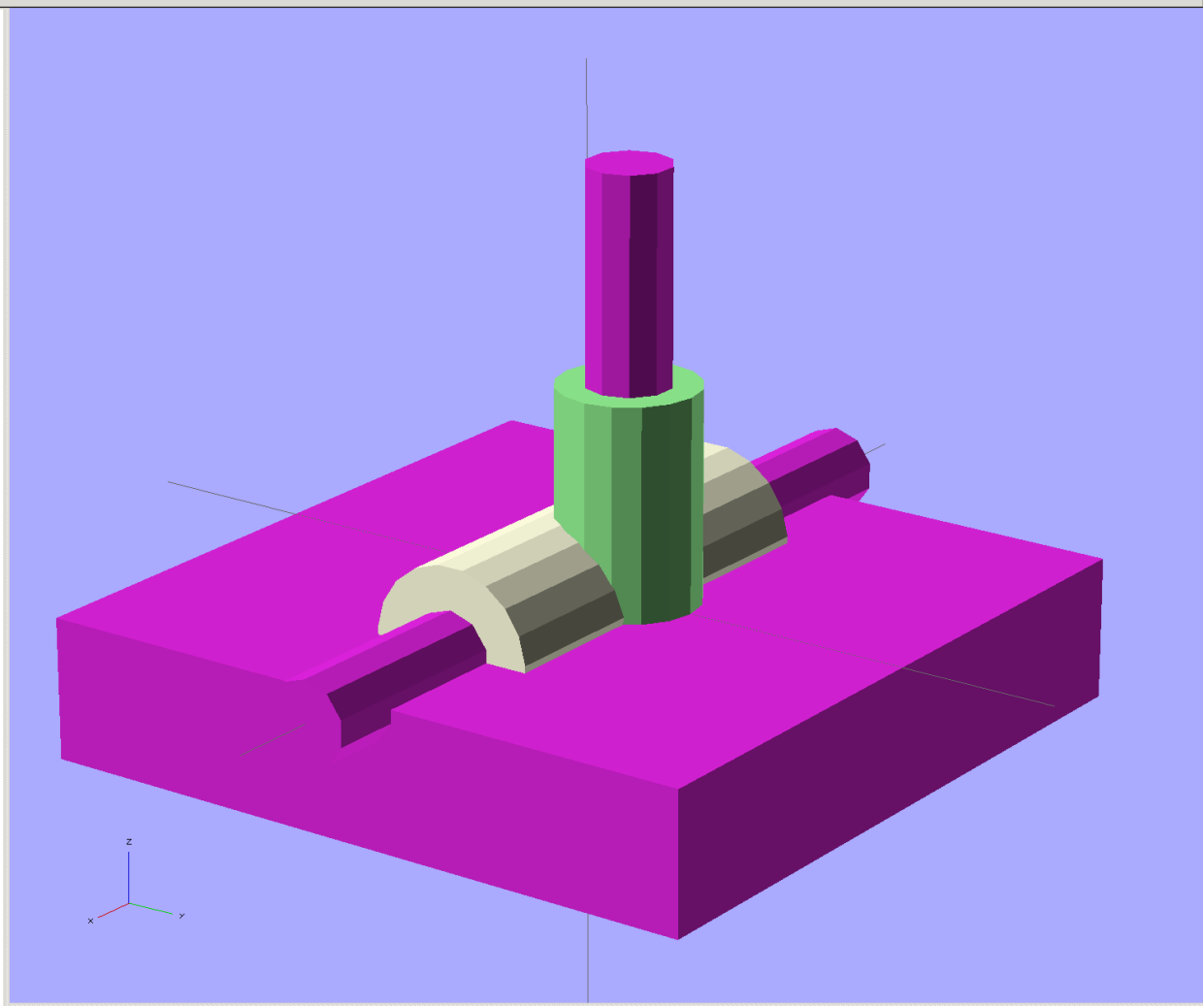
Viewport: translate = [-2.95 -0.53 4.89], rotate = [70.40 0.00 125.80], distance = 156.91

Difference: F12 View

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

 translate([0,0,-5.0])
  cube([50,50,10.0],center=true);
}
```

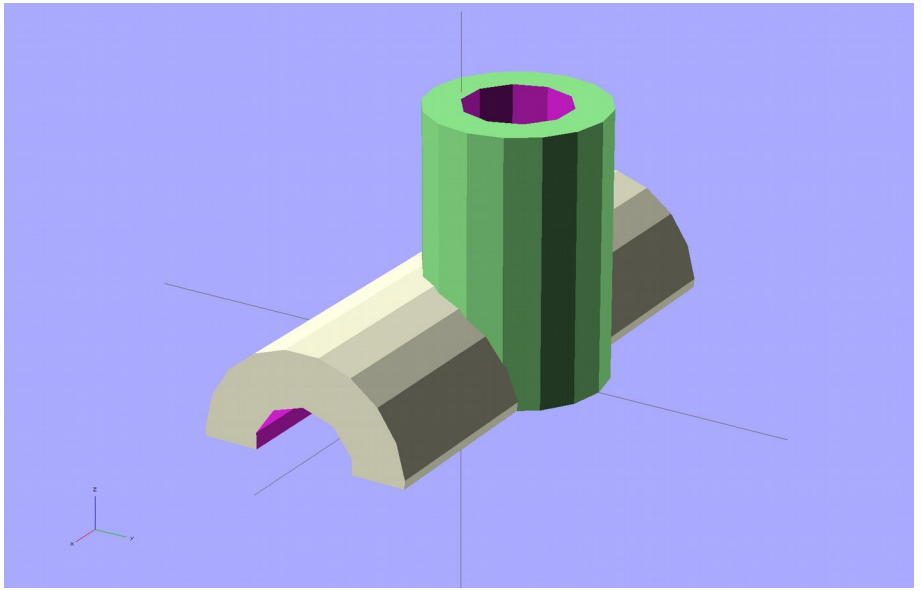


PolySet cache size in bytes: 106664
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 8 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

Viewport: translate = [-2.95 -0.53 4.89], rotate = [70.40 0.00 125.80], distance = 364.50

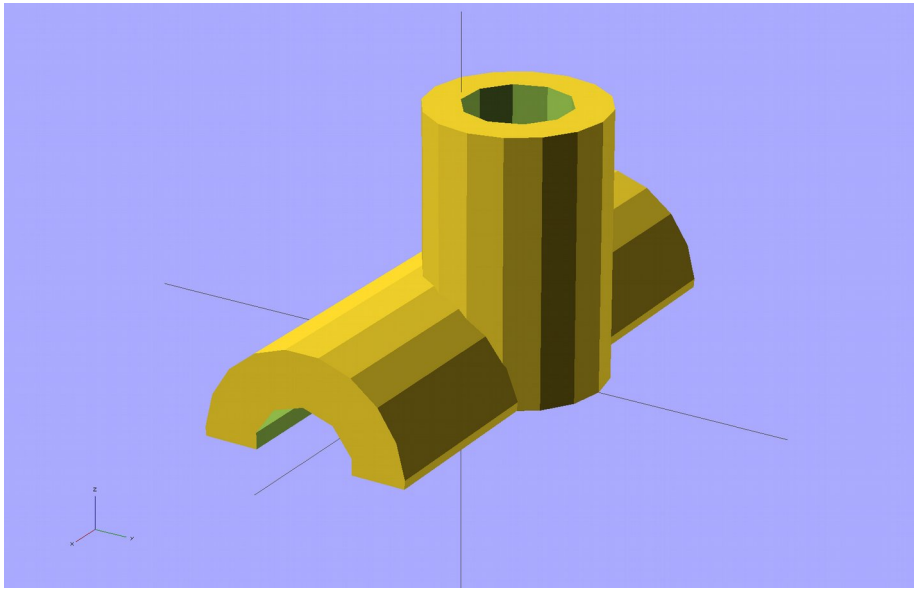
(Re)Compile: F5

- Fast preview mode
  - Simple depth buffer
  - No actual 3D model
  - Colors as expected
- Not exportable!



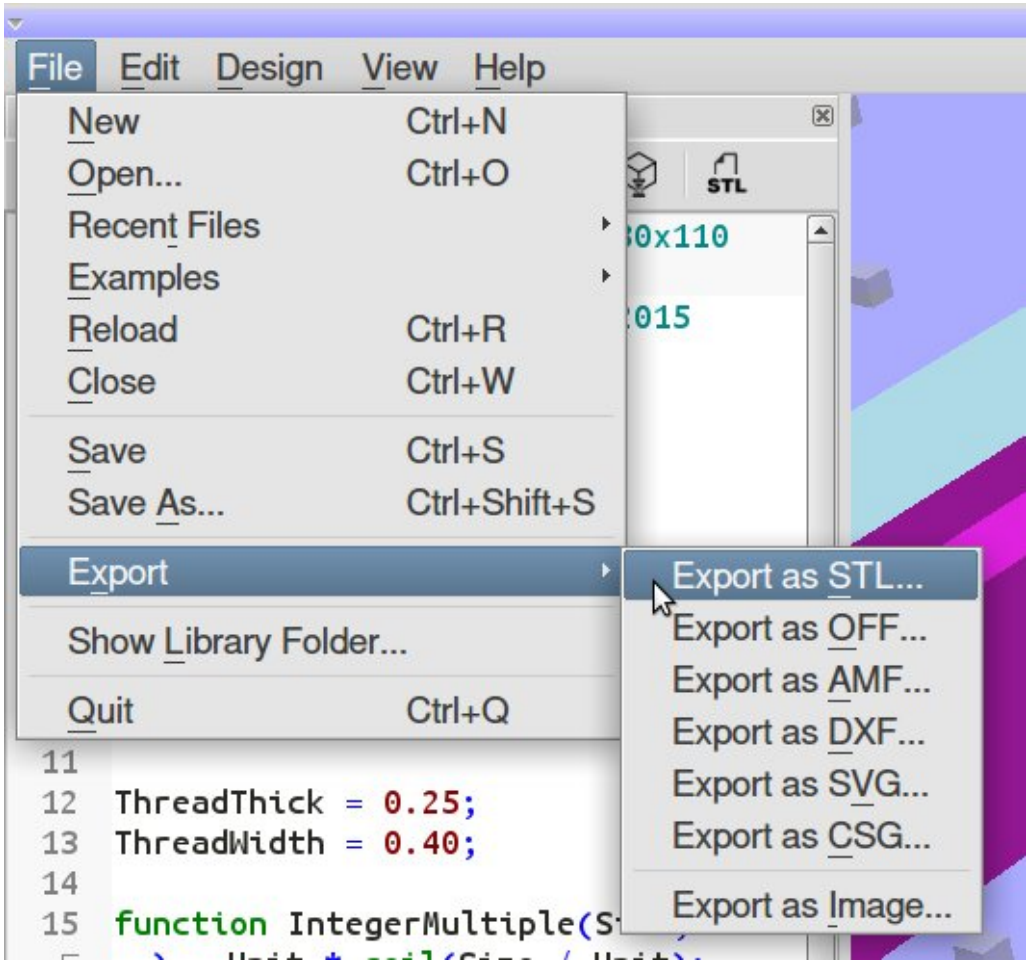
Compile & Render: F6

- Solid Model Generation
  - Full 3D rendering
  - All geometry resolved
  - Single color
- May not be manifold
  - If you screwed up
- Exportable!



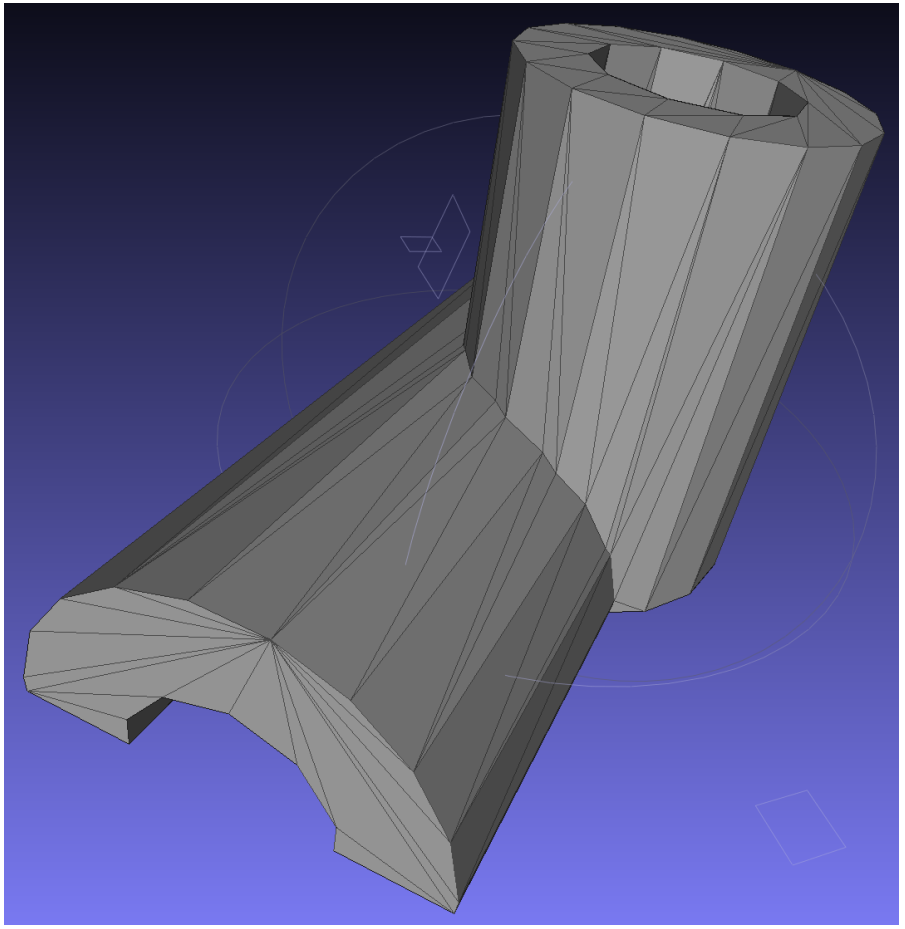
STL File Generation

- ASCII file format
  - Huge files
- That's all it takes



STL File Contents

- Triangle tessellation
  - No curves!
  - No “model” content
  - No smarts
- Surface normals
  - For each triangle
  - You have no control



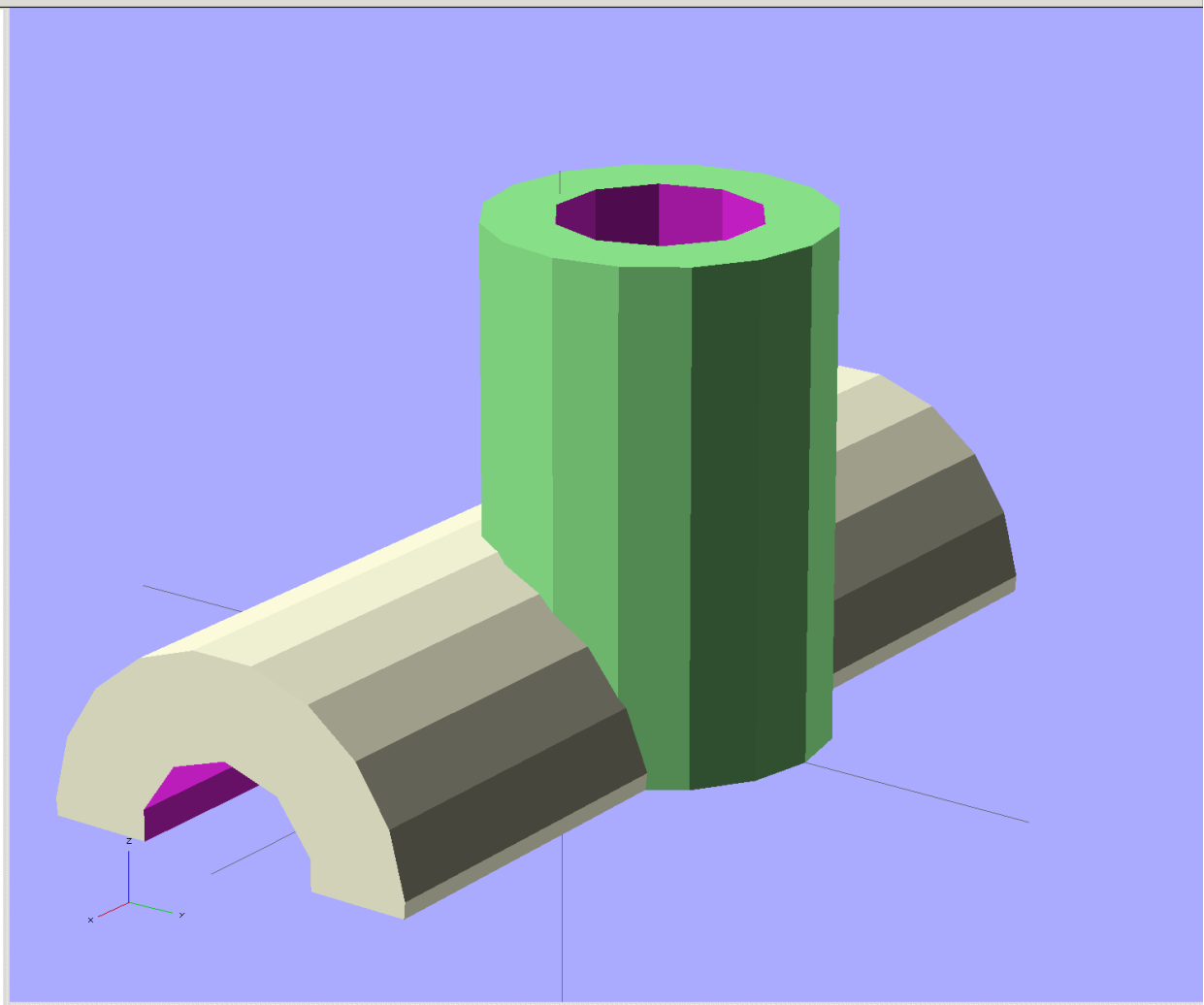
OpenSCAD
CSG “Debugging”

Ordinary F9 View

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

 translate([0,0,-5.0])
  cube([50,50,10.0],center=true);
}
```



```
PolySet cache size in bytes: 106664
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 8 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

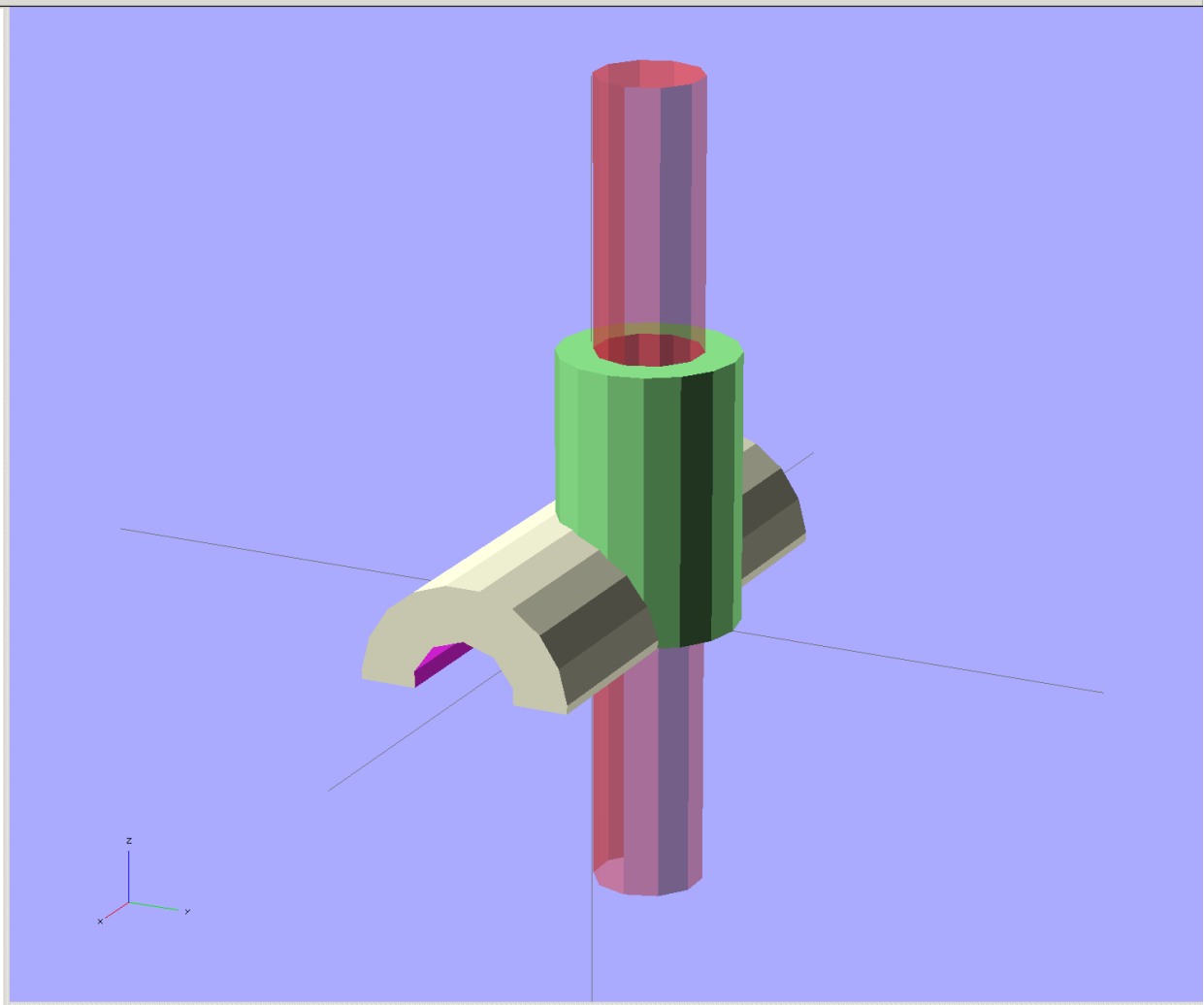
Viewport: translate = [-2.95 -0.53 4.89], rotate = [70.40 0.00 125.80], distance = 156.91

Highlighting an Object:

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

#  translate([0,3.4,-15.0])
   cylinder(r=3.0,h=3*15.0);

  translate([-30.0,0,0])
   rotate([0,90,0])
    cylinder(r=3.0,h=2*30.0);

  translate([0,0,-5.0])
   cube([50,50,10.0],center=true);
}
```



CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Compiling highlights (1 CSG Trees)...
Normalized CSG tree has 8 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

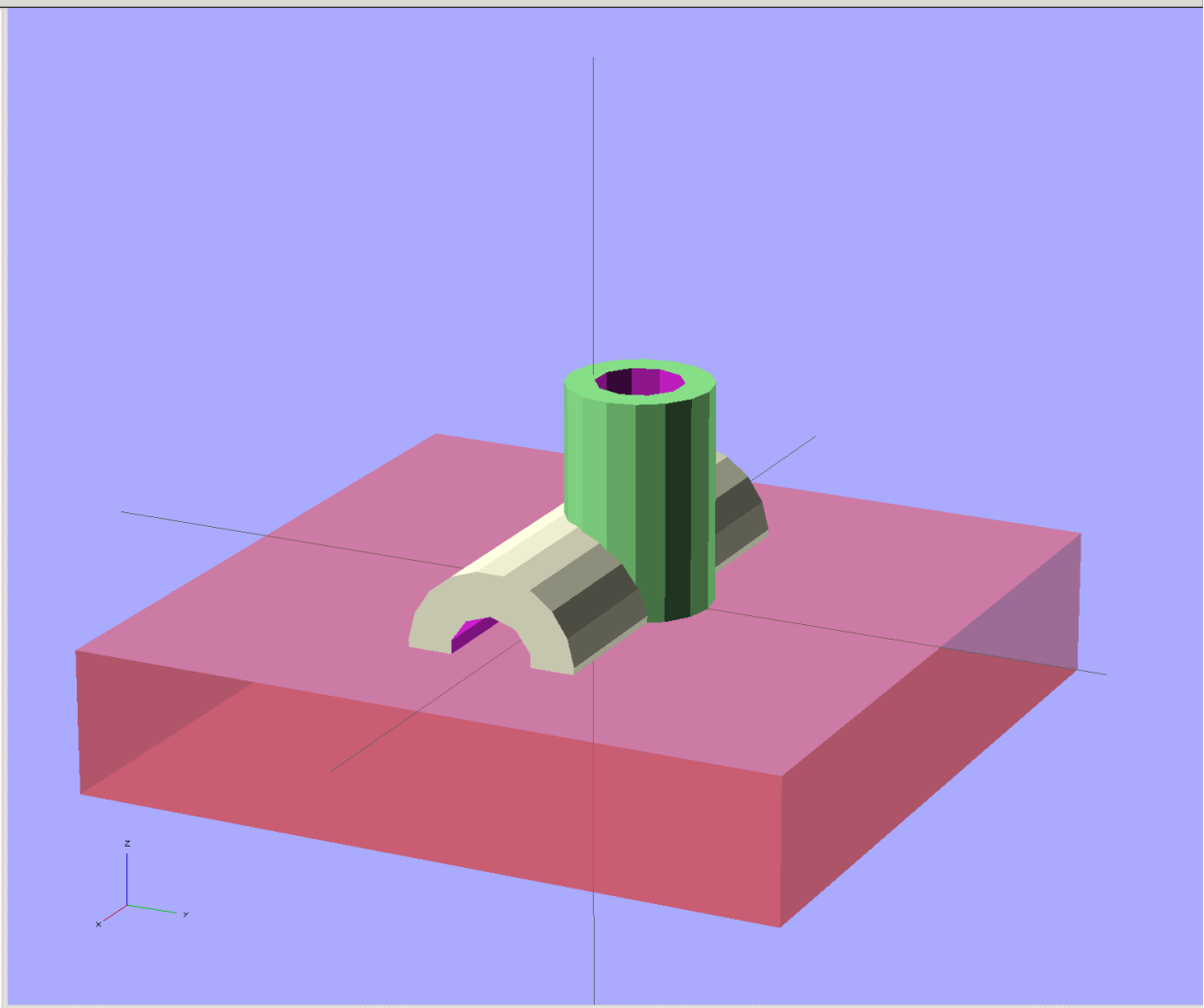
Viewport: translate = [-2.95 -0.53 4.89], rotate = [71.10 0.00 116.00], distance = 295.25

Highlighting an Object: # in F9

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

#  translate([0,0,-5.0])
   cube([50,50,10.0],center=true);
}
```



CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Compiling highlights (1 CSG Trees)...
Normalized CSG tree has 8 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

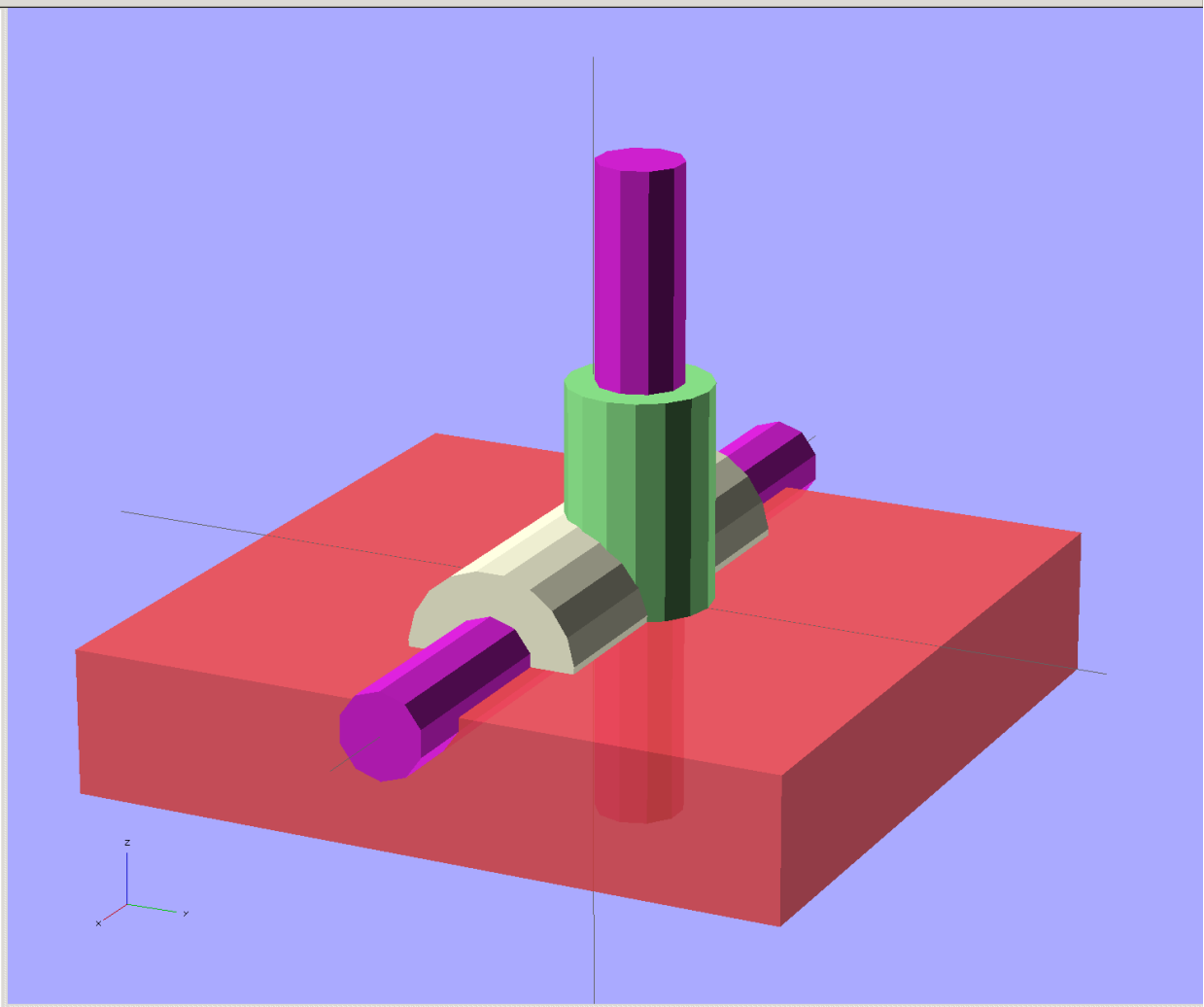
Viewport: translate = [-2.95 -0.53 4.89], rotate = [71.10 0.00 116.00], distance = 364.50

Highlighting: # in F12

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

#  translate([0,0,-5.0])
   cube([50,50,10.0],center=true);
}
```



```
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Compiling highlights (1 CSG Trees)...
Normalized CSG tree has 8 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

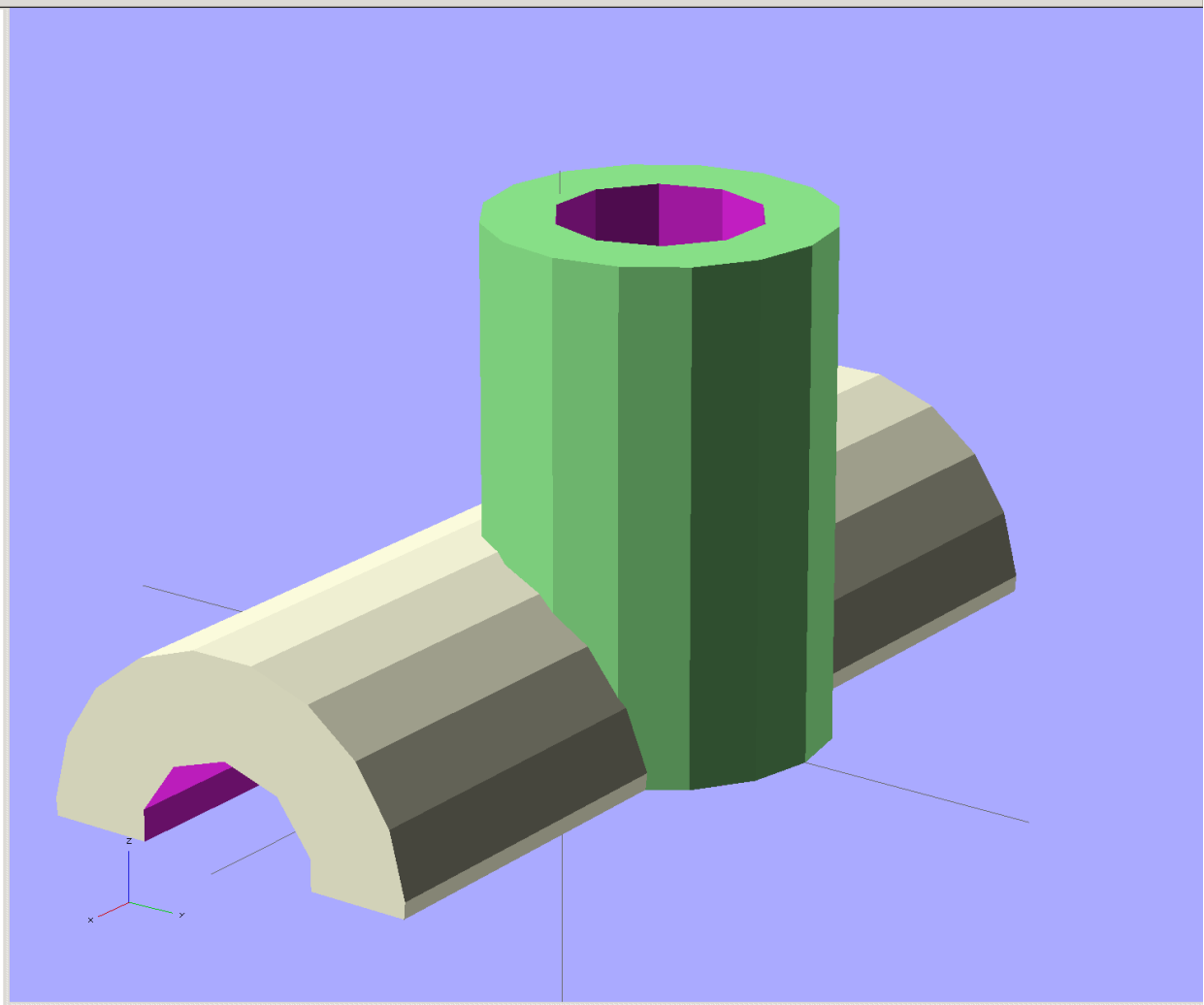
Viewport: translate = [-2.95 -0.53 4.89], rotate = [71.10 0.00 116.00], distance = 364.50

What You Expected

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

 translate([0,0,-5.0])
  cube([50,50,10.0],center=true);
}
```



PolySet cache size in bytes: 106664
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 8 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

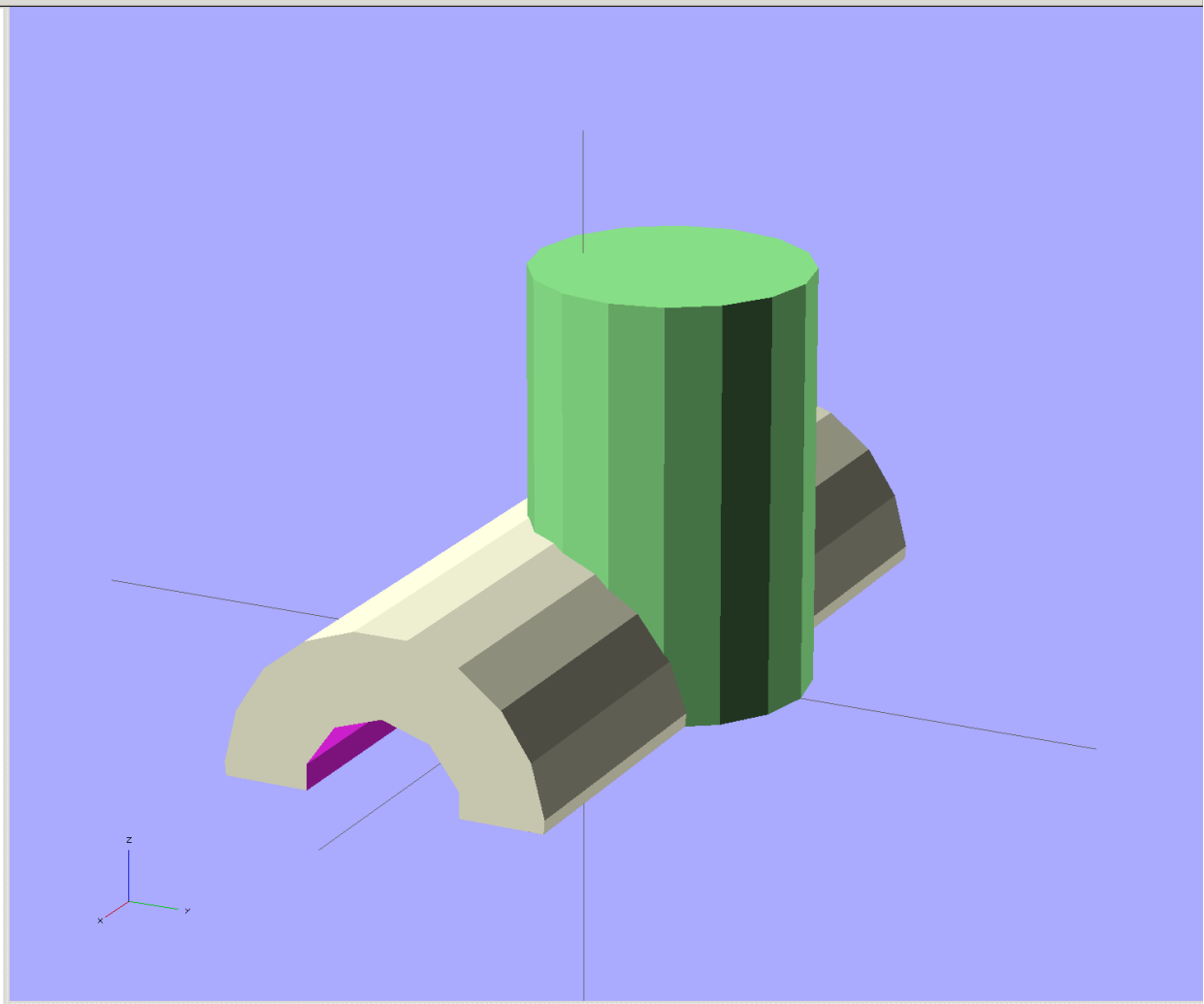
Viewport: translate = [-2.95 -0.53 4.89], rotate = [70.40 0.00 125.80], distance = 156.91

What You Got

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,34,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

 translate([0,0,-5.0])
  cube([50,50,10.0],center=true);
}
```



PolySet cache size in bytes: 109352
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 6 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

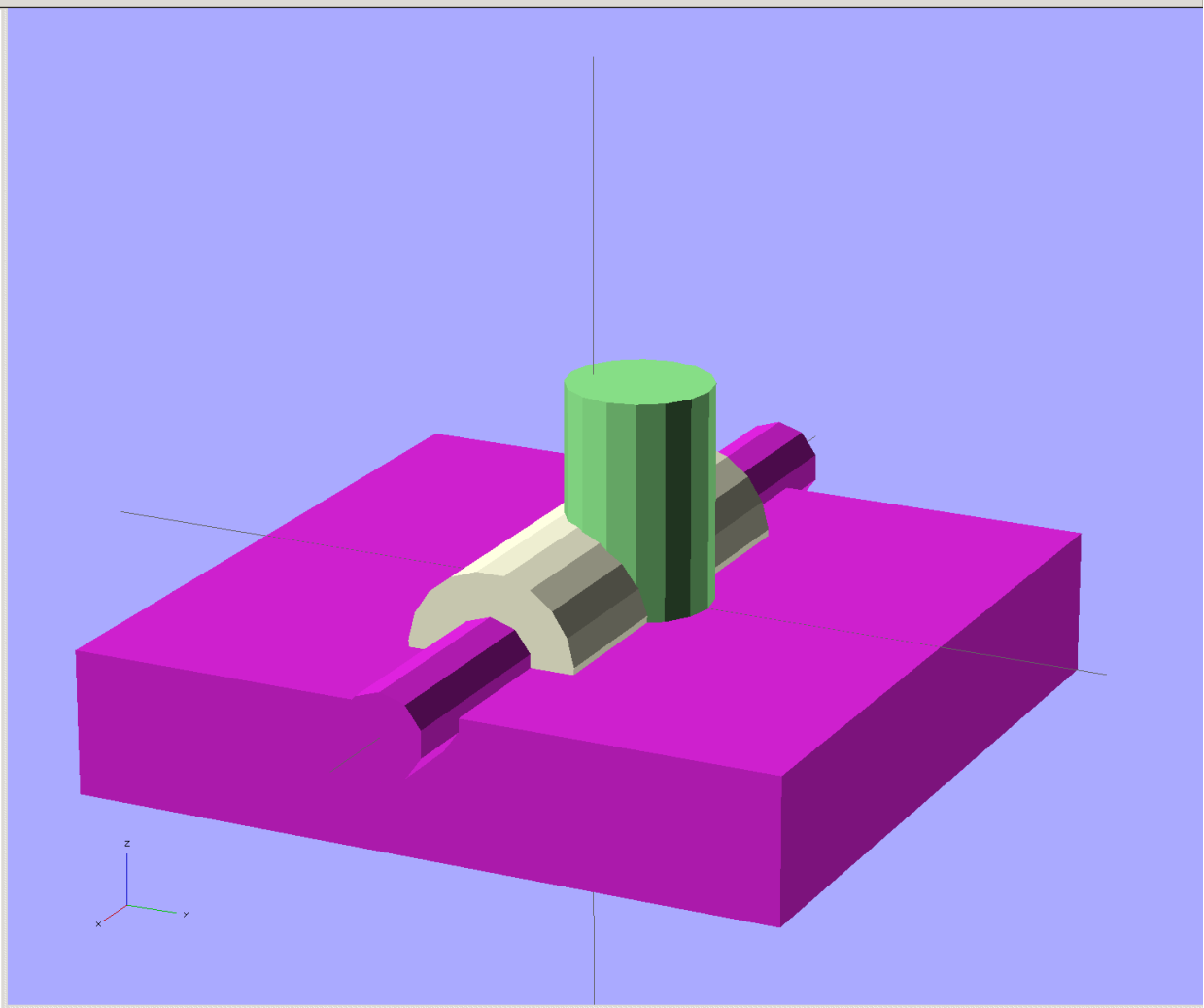
Viewport: translate = [-2.95 -0.53 4.89], rotate = [71.10 0.00 116.00], distance = 193.71

Where's the Missing Hole in F12?

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,34,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

 translate([0,0,-5.0])
  cube([50,50,10.0],center=true);
}
```



PolySet cache size in bytes: 109352
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 6 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

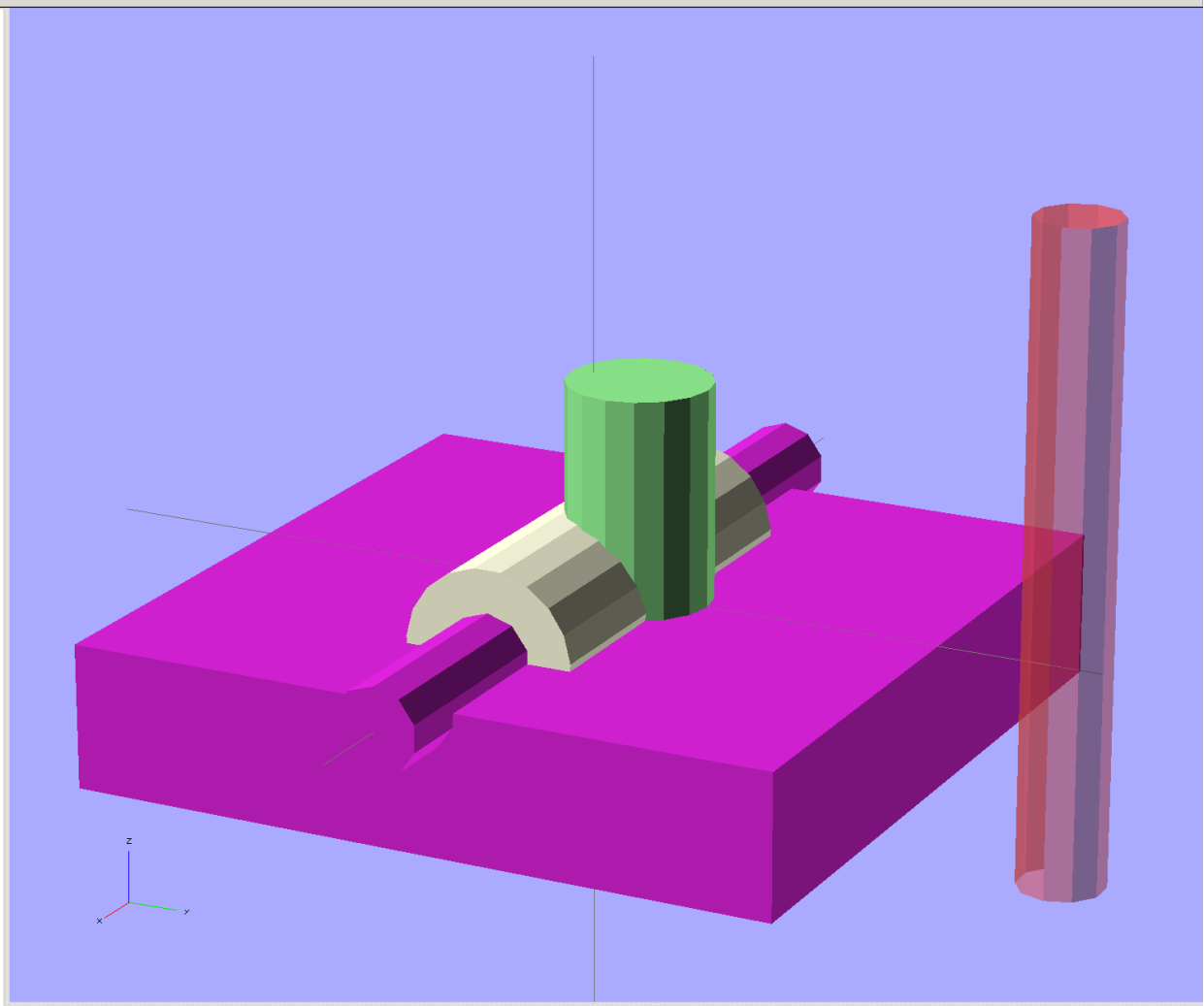
Viewport: translate = [-2.95 -0.53 4.89], rotate = [71.10 0.00 116.00], distance = 364.50

Highlighting: # in F12

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

#  translate([0,34,-15.0])
   cylinder(r=3.0,h=3*15.0);

  translate([-30.0,0,0])
   rotate([0,90,0])
    cylinder(r=3.0,h=2*30.0);

  translate([0,0,-5.0])
   cube([50,50,10.0],center=true);
}
```



CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Compiling highlights (1 CSG Trees)...
Normalized CSG tree has 6 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

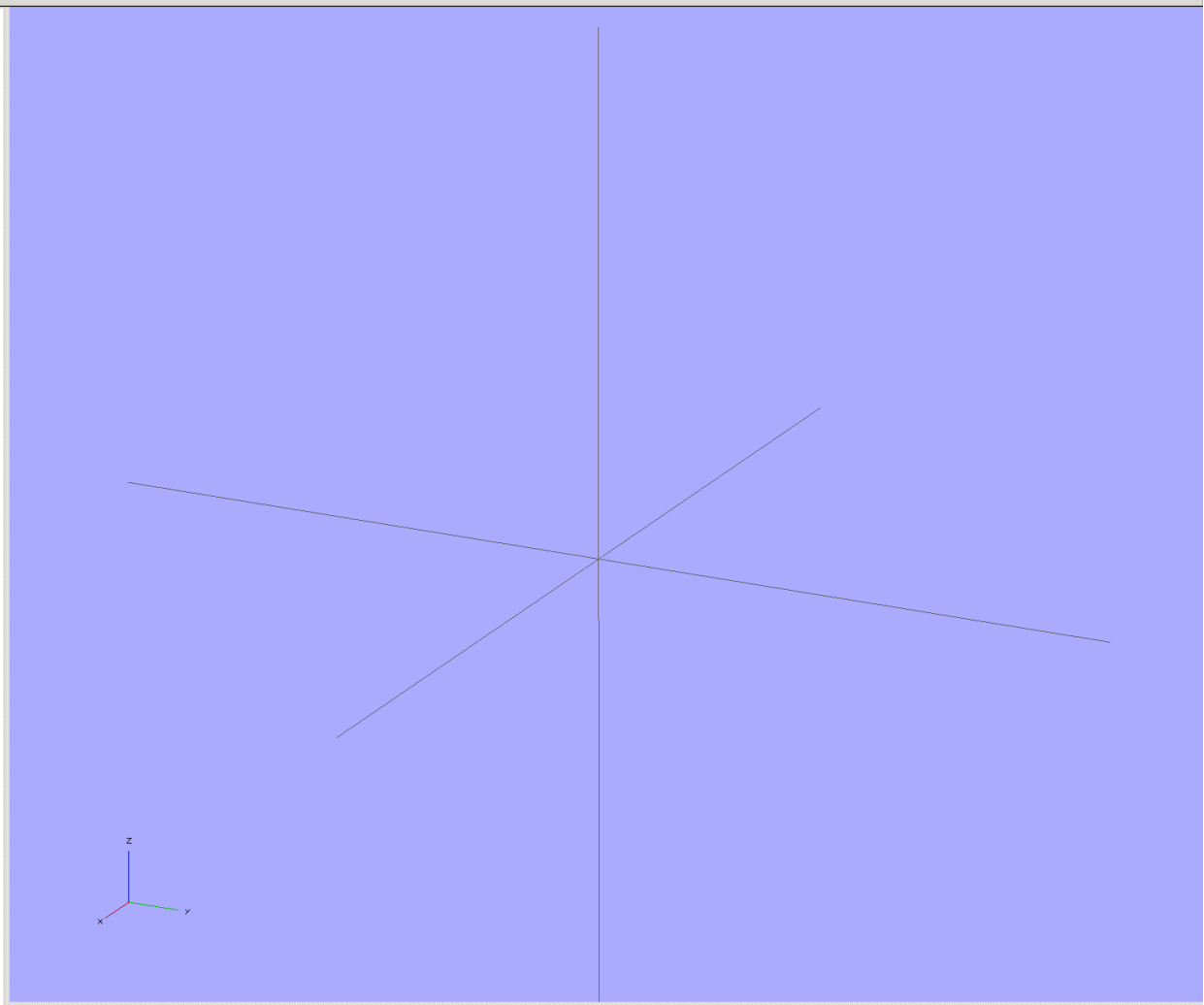
Viewport: translate = [-2.95 -0.53 4.89], rotate = [71.40 0.00 116.90], distance = 364.50

Where Did Everything Go?

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

 translate([0,0,-00.0])
  cube([50,50,60.0],center=true);
}
```



PolySet cache size in bytes: 109352
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 8 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

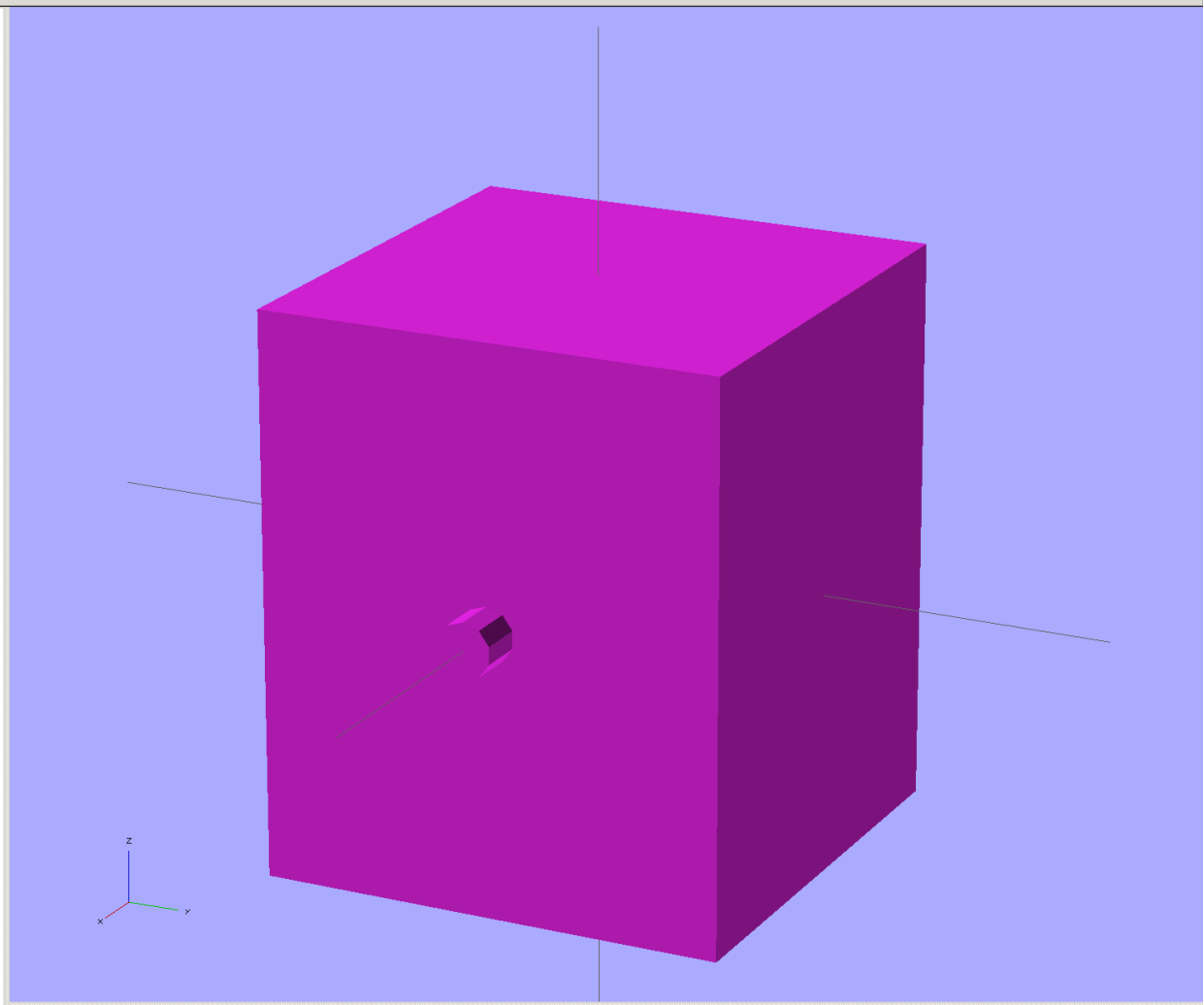
Viewport: translate = [-2.95 -0.53 4.89], rotate = [71.10 0.00 116.00], distance = 555.56

Everything in F12 View

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

 translate([0,0,-00.0])
  cube([50,50,60.0],center=true);
}
```



PolySet cache size in bytes: 109352
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 8 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

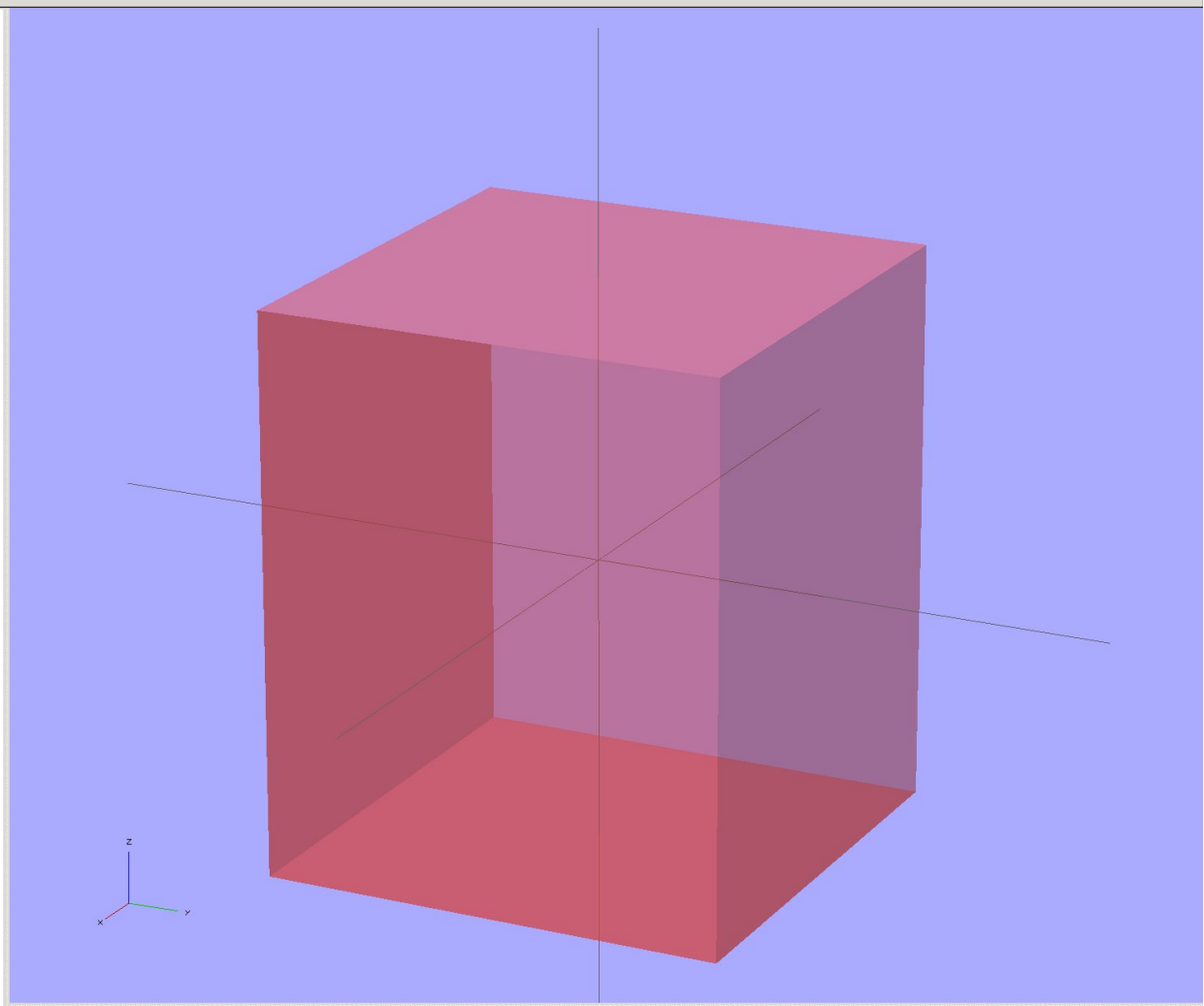
Viewport: translate = [-2.95 -0.53 4.89], rotate = [71.10 0.00 116.00], distance = 555.56

Everything Highlighted Cube: F9

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

#  translate([0,0,-00.0])
   cube([50,50,60.0],center=true);
}
```



CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Compiling highlights (1 CSG Trees)...
Normalized CSG tree has 8 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

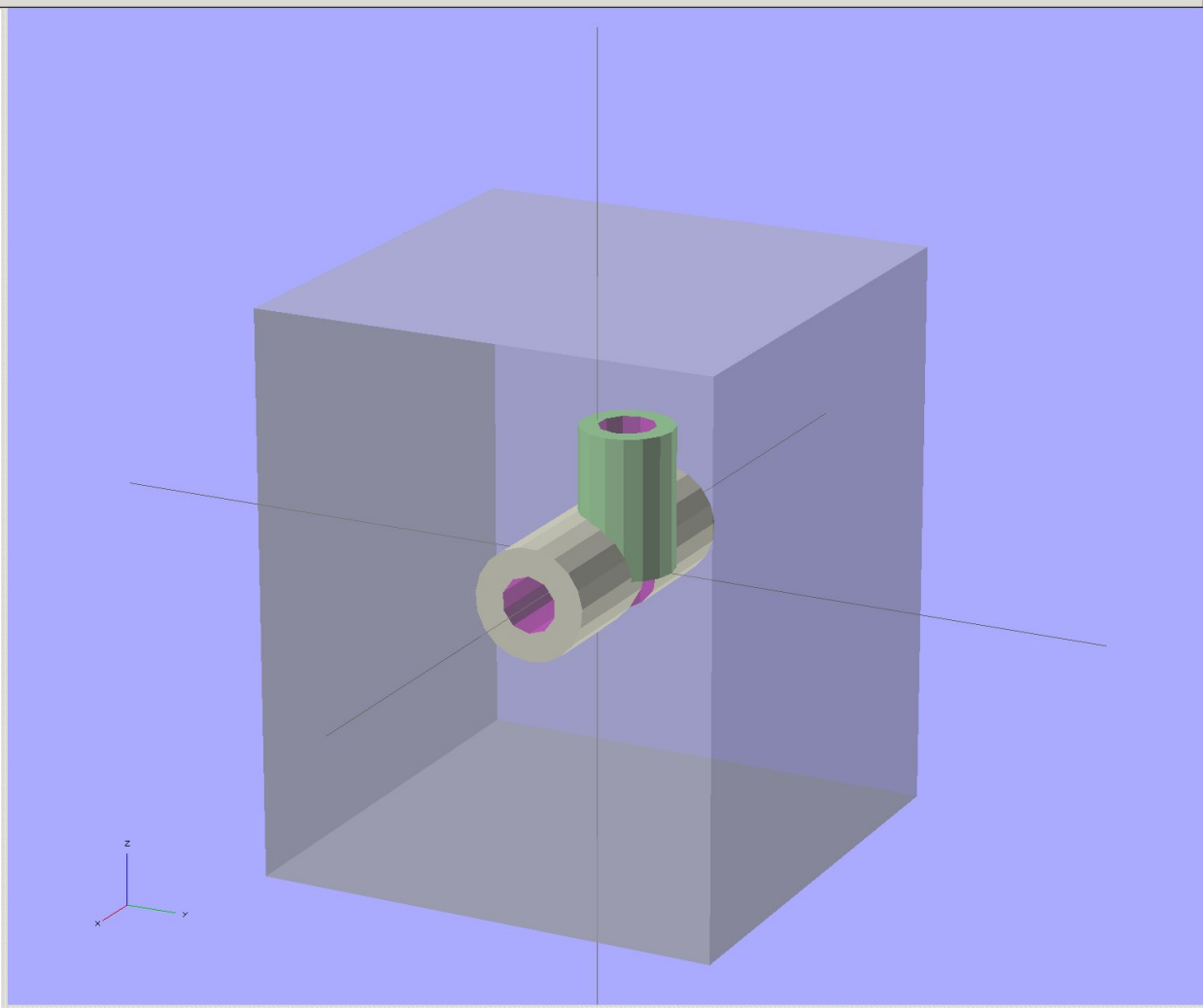
Viewport: translate = [-2.95 -0.53 4.89], rotate = [71.10 0.00 116.00], distance = 555.56

Debug Modifier: % in F9

OpenSCAD - Rack Protector - trivial - 3.scad*

File Edit Design View Help

```
difference() {
 union() {
  translate([0,3.4,0])
   color("lightgreen")
    cylinder(r=5,h=15);
  translate([-15.0,0,0])
   rotate([0,90,0])
    color("lightyellow")
     cylinder(r=6.0,h=30.0);
 }

 translate([0,3.4,-15.0])
  cylinder(r=3.0,h=3*15.0);

 translate([-30.0,0,0])
  rotate([0,90,0])
   cylinder(r=3.0,h=2*30.0);

%  translate([0,0,-00.0])
   cube([50,50,60.0],center=true);
}
```



CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Compiling background (1 CSG Trees)...
Normalized CSG tree has 6 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

Viewport: translate = [-2.95 -0.53 4.89], rotate = [71.40 0.00 116.90], distance = 555.56

OpenSCAD Non-Bugging

- Use an external editor!
  - Hide the OpenSCAD editor pane
- Add / change one tiny little thing at a time
  - Editor's Undo function will be your BFF
- Use what meager assistance you have
  - F12: Thrown Together view
  - Modifier characters: % and #
  - echo(str("This: ",name)) shows computed values
- Keep it simple and make it obvious

OpenSCAD
Is
Not
C

OpenSCAD. Is. Not. C.

- Similar syntax, *vastly* different semantics
  - Declarative, not procedural
  - Describes geometry, not process
- Lacks many “high level” features
  - *This is not a bug*
- Probably a write-only language
  - Not easy to visualize the effects
  - Modules not easily re-usable due to geometry
  - Global / local variables vs. parameters

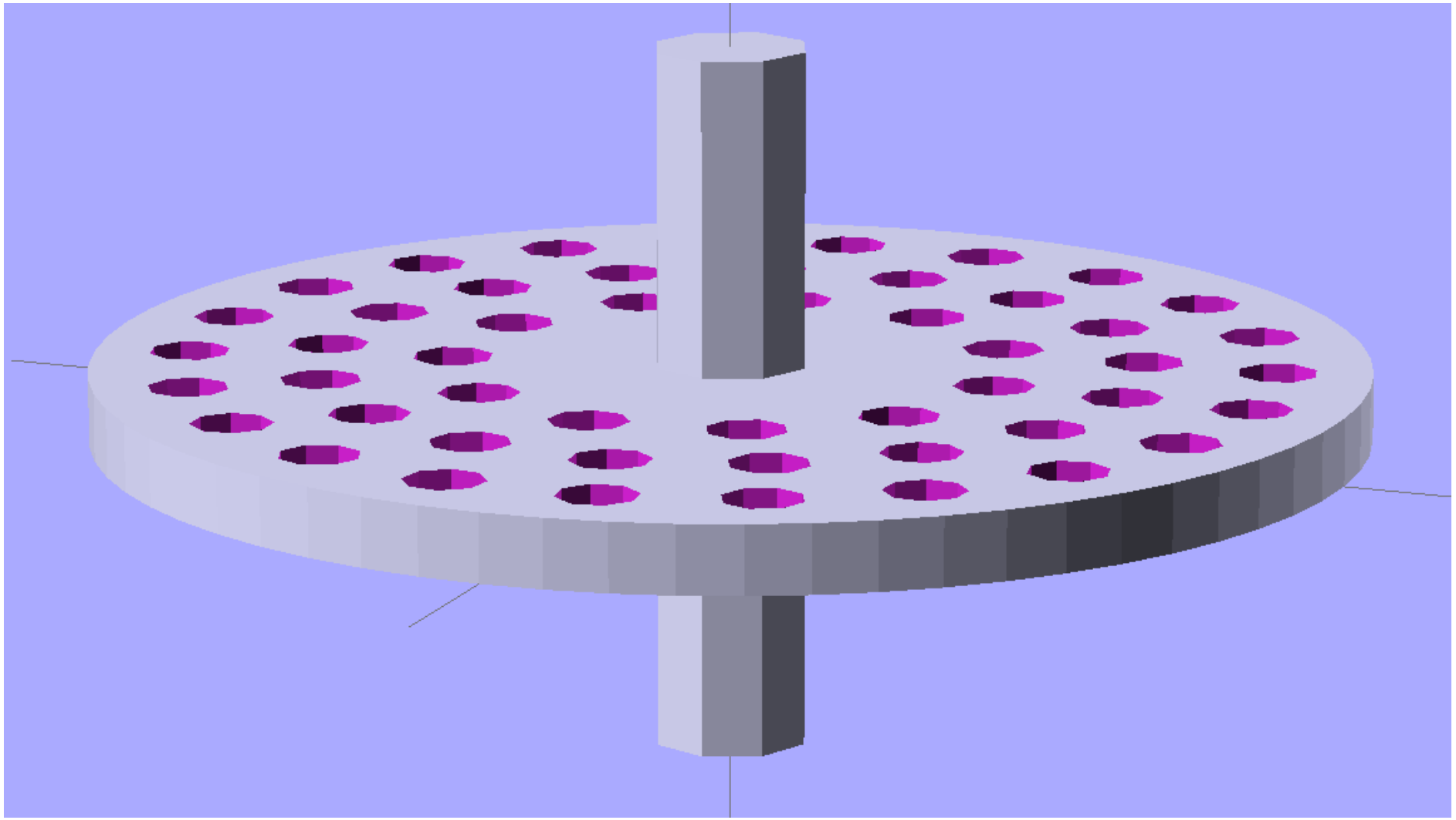
The better you are
at C / C++ / Java / whatever
~
The more trouble
you are about to have
with OpenSCAD

Iteration

- for (i = [start:increment:end])
  - Don’t get clever with increment value
  - Use integers, compute floats in loop
- for (i = [list, of, many, values, in, a, vector])
  - Don’t get clever with nested vectors = arrays
- Implicit union() of all objects within loop
  - Use intersection_for() for intersections...

Sink Strainer

Sink Strainer

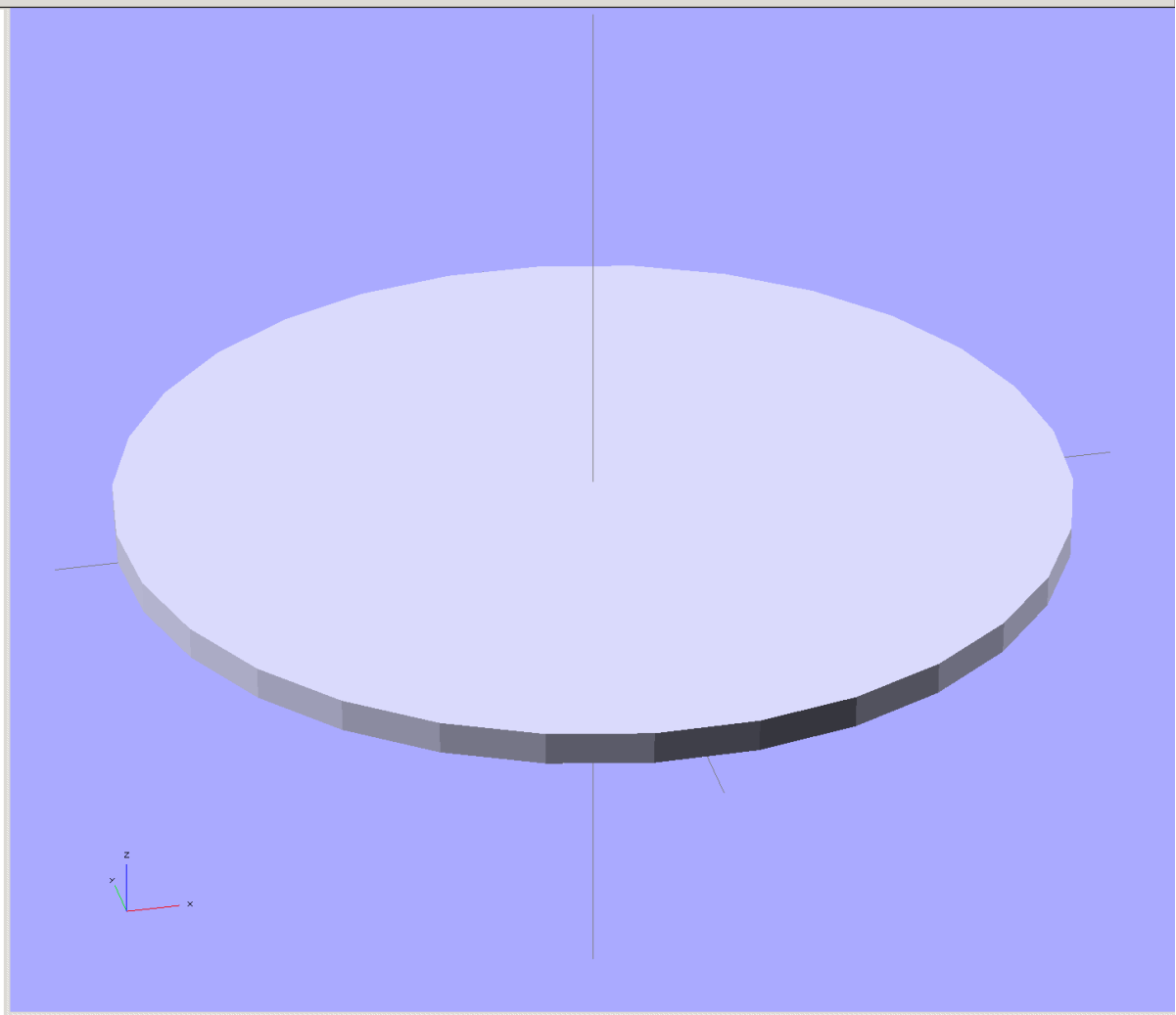


Define the Measurements!

OpenSCAD - Strainer Plate - simple - 1.scad

File Edit Design View Help

```
Protrusion = 0.1;

PlateOD = 150.0;
PlateThick = 5.0;
HoleOD = 6.0;

NumRings = 4;
RingMinDia = 20.0;
RingStep = 30.0;


 cylinder(r=PlateOD/2,h=PlateThick);
```



PolySet cache size in bytes: 18280
CGAL Polyhedrons in cache: 84
CGAL cache size in bytes: 5576208
Compiling design (CSG Products normalization)...
Normalized CSG tree has 1 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

Viewport: translate = [0.00 0.00 0.00], rotate = [60.60 0.00 347.20], distance = 846.75

Code should have only the standard magic constants

… 0, 1, and 2

… 90, 180, 360

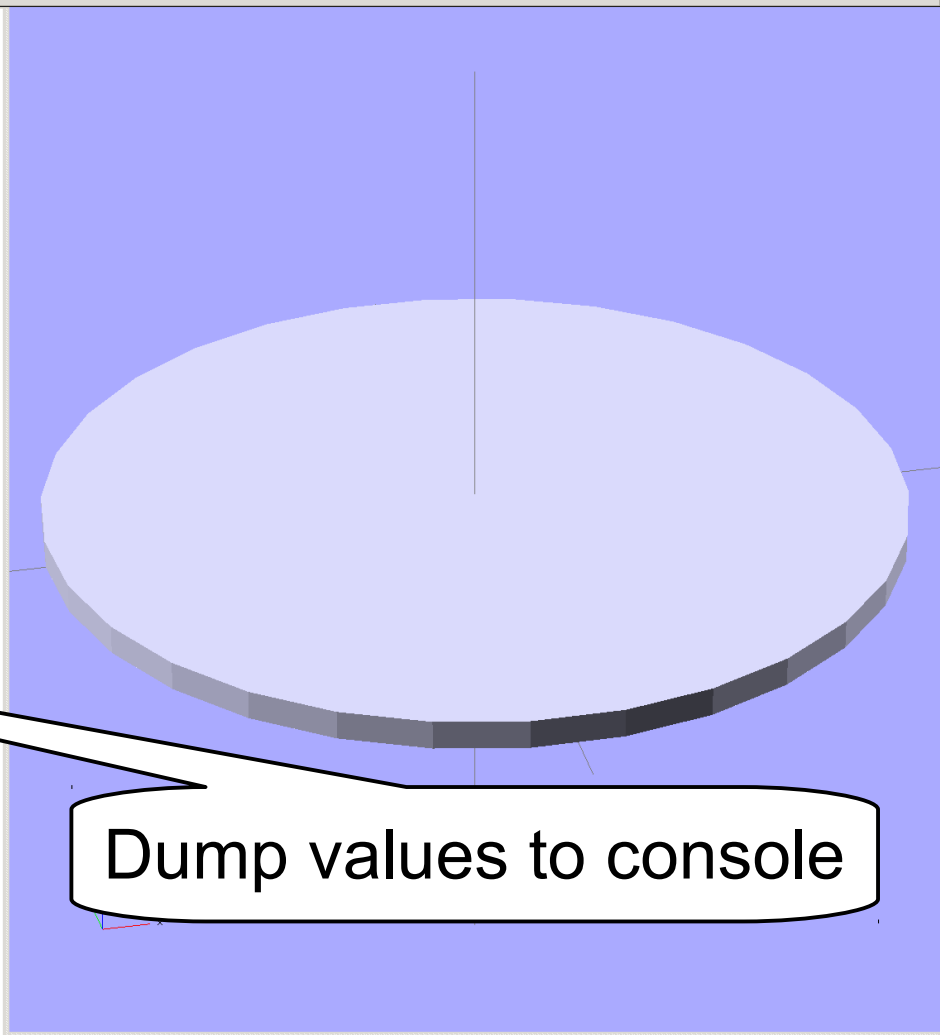
… *maybe* sqrt(2)

Create a Module

OpenSCAD - Strainer Plate - simple - 2.scad*

File Edit Design View Help

```
Protrusion = 0.1;

PlateOD = 150.0;
PlateThick = 5.0;
HoleOD = 6.0;

NumRings = 4;
RingMinDia = 20.0;
RingStep = 30.0;

module RingHoles(RingDia,HoleDia,Thickness) {

  Num = floor(90/asin(HoleDia/RingDia));
  echo("Dia: ",RingDia," holes: ",Num);

  for(n=[0:(Num-1)]) {
   rotate([0,0,n*360/Num])
    translate([RingDia/2,0,-Protrusion])
     cylinder(r=HoleDia/2,
              h=(Thickness + 2*Protrusion));
  }

}

 cylinder(r=PlateOD/2,h=PlateThick);
```



Dump values to console

```
PolySet cache size in bytes: 18280
CGAL Polyhedrons in cache: 84
CGAL cache size in bytes: 5576208
Compiling design (CSG Products normalization)...
Normalized CSG tree has 1 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [0.00 0.00 0.00], rotate = [60.60 0.00 347.20], distance = 846.75

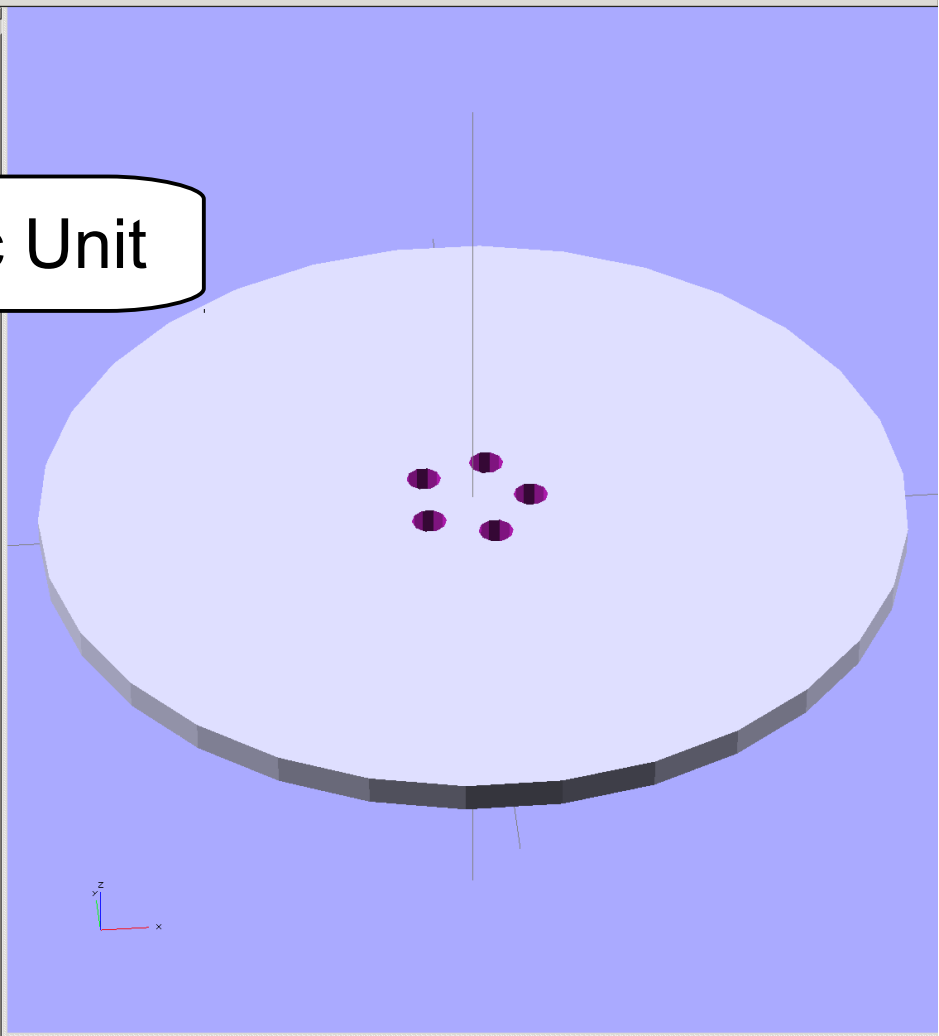
Try a Simple Case

OpenSCAD - Strainer Plate - simple - 2.scad*

File Edit Design View Help

```
Protrusion = 0.1;

PlateOD = 150.0;
PlateThick = 5.0;
HoleOD = 6.0;

NumRings = 4;
RingMinDia = 20.0;
RingStep = 30.0;

module RingHoles(RingDia,HoleDia,Thickness) {

  Num = floor(90/asin(HoleDia/RingDia));
  echo("Dia: ",RingDia," holes: ",Num);

  for(n=[0:(Num-1)]) {
   rotate([0,0,n*360/Num])
    translate([RingDia/2,0,-Protrusion])
     cylinder(r=HoleDia/2,
              h=(Thickness + 2*Protrusion));
  }
}

difference() {
 cylinder(r=PlateOD/2,h=PlateThick);
 RingHoles(RingMinDia,HoleOD,PlateThick);
}
```

Geometric Unit



```
PolySet cache size in bytes: 18280
CGAL Polyhedrons in cache: 84
CGAL cache size in bytes: 5576208
Compiling design (CSG Products normalization)...
Normalized CSG tree has 6 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [0.00 0.00 0.00], rotate = [51.50 0.00 354.90], distance = 846.75

Dump Values to “Console”

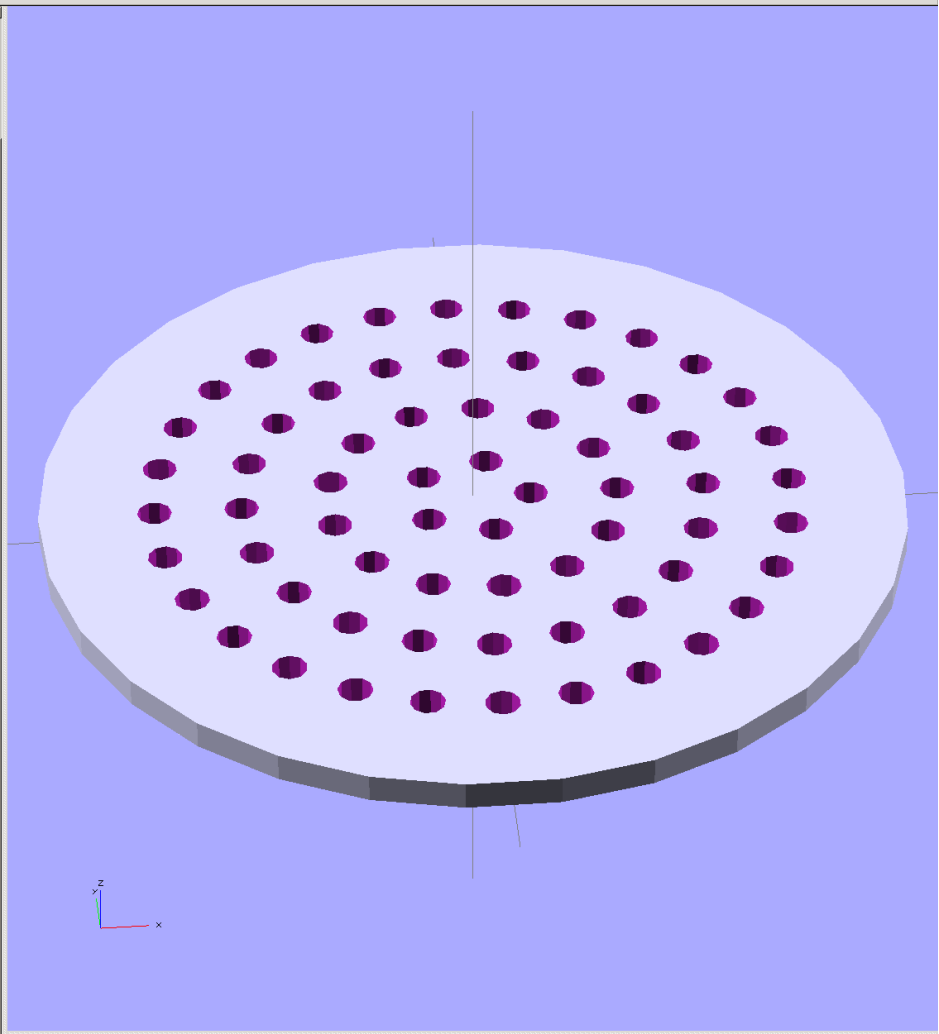
```
Module cache size: 0 modules
Compiling design (CSG Tree generation)...
ECHO: "Dia: ", 20, " holes: ", 5
Compiling design (CSG Products generation)...
PolySetCache hit:
cylinder($fn=0,$fa=12,$fs=2,h=5,r1=75,r2
PolySetCache hit:
cylinder($fn=0,$fa=12,$fs=2,h=5.2,r1=3,r
… snippage ...
```

Iterate Over All Rings

OpenSCAD - Strainer Plate - simple - 2.scad*

File Edit Design View Help

```
PlateThick = 5.0;
HoleOD = 6.0;

NumRings = 4;
RingMinDia = 20.0;
RingStep = 30.0;

module RingHoles(RingDia,HoleDia,Thickness) {

  Num = floor(90/asin(HoleDia/RingDia));
  echo("Dia: ",RingDia," holes: ",Num);

  for(n=[0:(Num-1)]) {
   rotate([0,0,n*360/Num])
    translate([RingDia/2,0,-Protrusion])
     cylinder(r=HoleDia/2,
              h=(Thickness + 2*Protrusion));
  }
}

difference() {
 cylinder(r=PlateOD/2,h=PlateThick);
 for (RingID = [0:NumRings-1]) {
  RingHoles((RingMinDia + RingID*RingStep),
            HoleOD,PlateThick);
 }
}
```



```
PolySet cache size in bytes: 18280
CGAL Polyhedrons in cache: 86
CGAL cache size in bytes: 5792232
Compiling design (CSG Products normalization)...
Normalized CSG tree has 67 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [0.00 0.00 0.00], rotate = [51.50 0.00 354.90], distance = 846.75

Conditionals

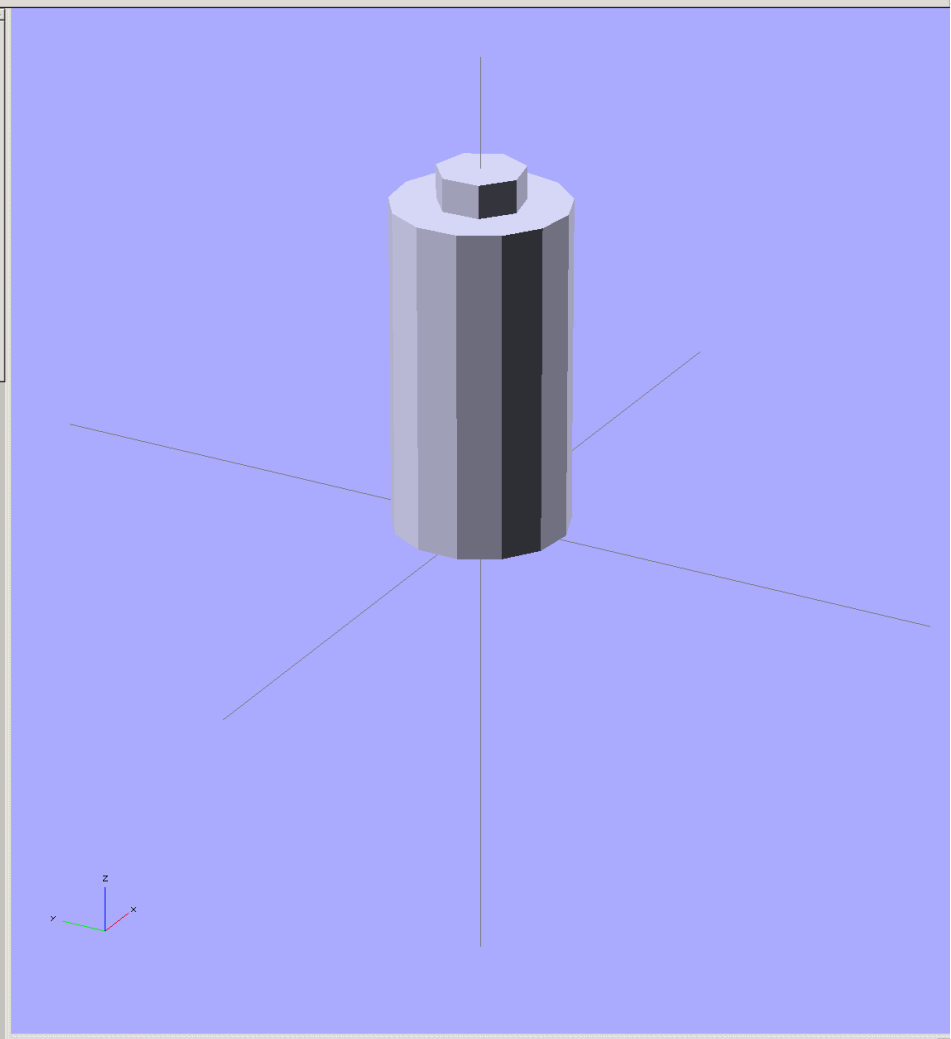
- if (this operator that)
  - As in C: double-equal == equality operator
  - Use to select objects, not values
- if (this == “string value”)
  - Case matters
- value = (this operator that) ? if_true : if_false
  - Use to select values, not objects
  - Remember: There Are No Variables!

Construct a Handle

OpenSCAD - Strainer Plate - simple - 4.scad

File Edit Design View Help

```
Layout = "Handle";

Protrusion = 0.1;

PlateOD = 150.0;
PlateThick = 5.0;

HoleOD = 6.0;

NumRings = 4;
RingMinDia = 20.0;
RingStep = 30.0;

HandleOD = 8.0;
HandleLength = 15.0;
HandlePegOD = HandleOD/2;
HandlePegLength = 1.5;

module Handle() {

 cylinder(r=HandleOD/2,
          h=HandleLength);
 cylinder(r=HandlePegOD/2,
          h=(HandleLength + HandlePegLength));

}
```



```
PolySet cache size in bytes: 32448
CGAL Polyhedrons in cache: 86
CGAL cache size in bytes: 5792232
Compiling design (CSG Products normalization)...
Normalized CSG tree has 2 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [0.00 0.00 0.00], rotate = [64.80 0.00 298.90], distance = 215.23

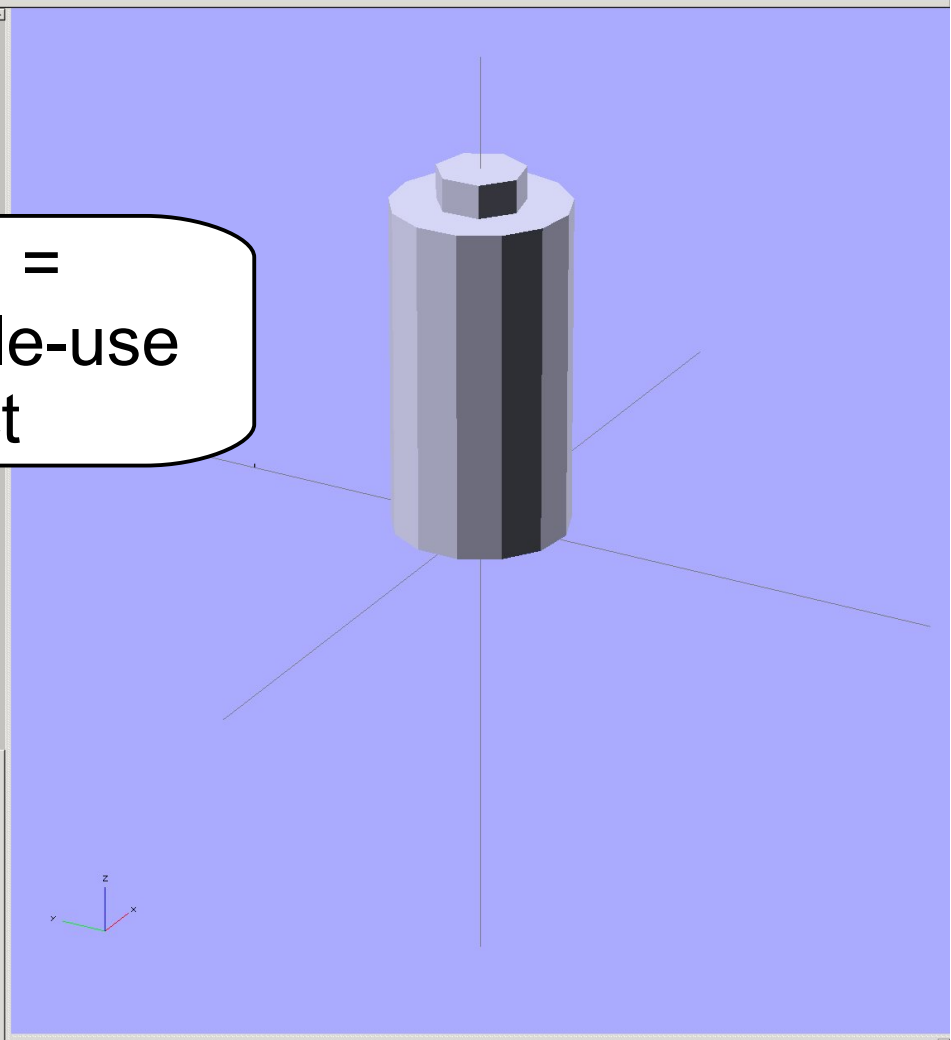
Conditional Object Instances

OpenSCAD - Strainer Plate - simple - 4.scad*

File Edit Design View Help

```
            center=true);
  }
}

//-- Build it!

if (Layout == "Plate")
 StrainerPlate();

if (Layout == "Handle")
 Handle();

if (Layout == "Build") {
 StrainerPlate();
 translate([PlateOD/2,PlateOD/2,0])
  Handle();
 translate([-PlateOD/2,PlateOD/2,0])
  Handle();
 }

if (Layout == "Show") {
 color("LightYellow")
  StrainerPlate();
 color("LightGreen") {
  translate([0,0,-HandleLength])
   Handle();
  translate([0,0,(PlateThick + HandleLength)])
```

Module = any multiple-use object



```
PolySet cache size in bytes: 32448
CGAL Polyhedrons in cache: 86
CGAL cache size in bytes: 5792232
Compiling design (CSG Products normalization)...
Normalized CSG tree has 2 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

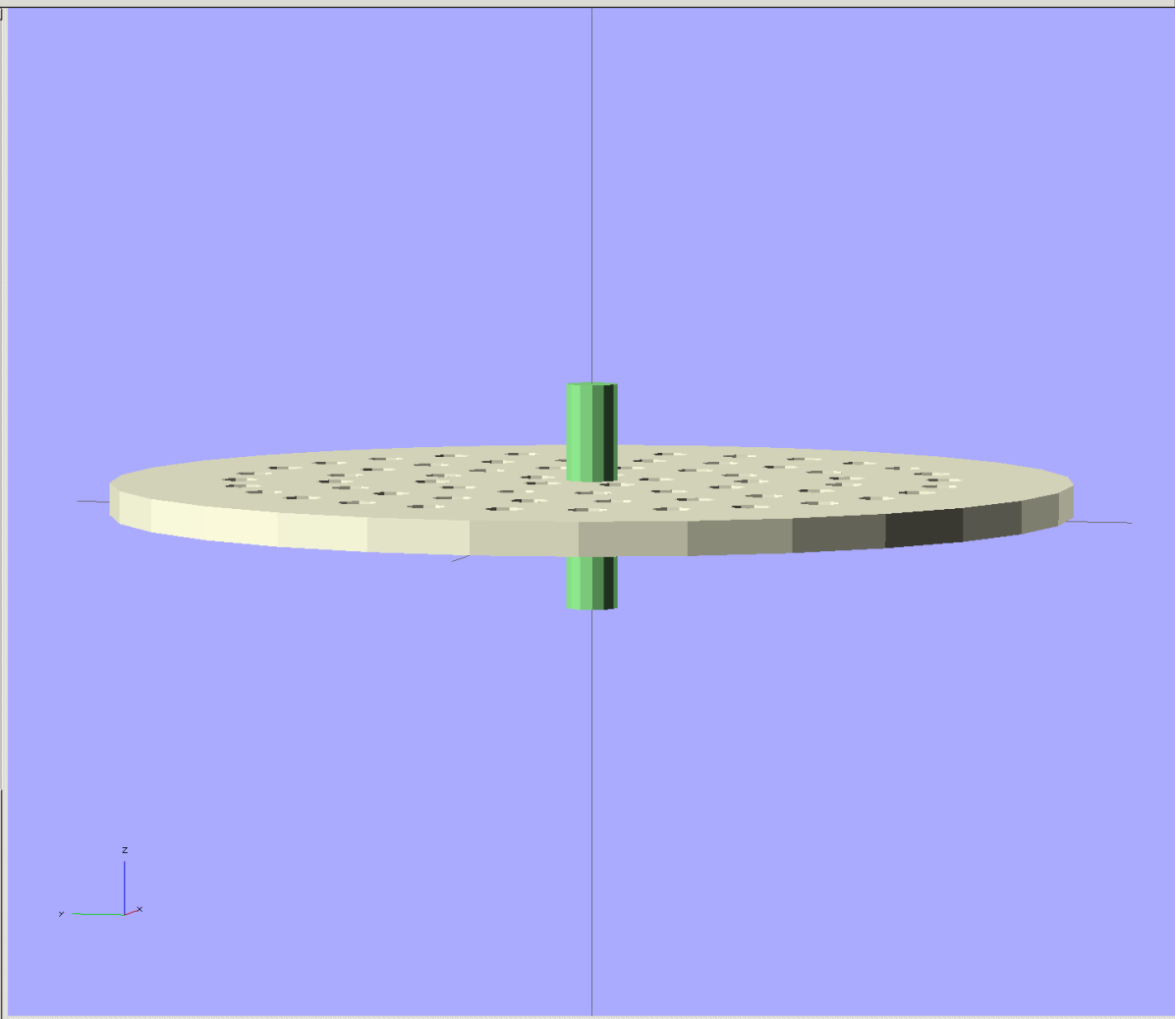
Viewport: translate = [0.00 0.00 0.00], rotate = [64.80 0.00 298.90], distance = 215.23

Layout = “Show”

OpenSCAD - Strainer Plate - simple - 4.scad*

File Edit Design View Help

```
if (Layout == "Plate")
 StrainerPlate();

if (Layout == "Handle")
 Handle();

if (Layout == "Build") {
 StrainerPlate();
 translate([PlateOD/2,PlateOD/2,0])
  Handle();
 translate([-PlateOD/2,PlateOD/2,0])
  Handle();
 }

if (Layout == "Show") {
 color("LightYellow")
  StrainerPlate();
 color("LightGreen") {
  translate([0,0,-HandleLength])
   Handle();
  translate([0,0,
      (PlateThick + HandleLength)])
   rotate([180,0,0])
   Handle();
 }

}
```



```
PolySet cache size in bytes: 32448
CGAL Polyhedrons in cache: 86
CGAL cache size in bytes: 5792232
Compiling design (CSG Products normalization)...
Normalized CSG tree has 72 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

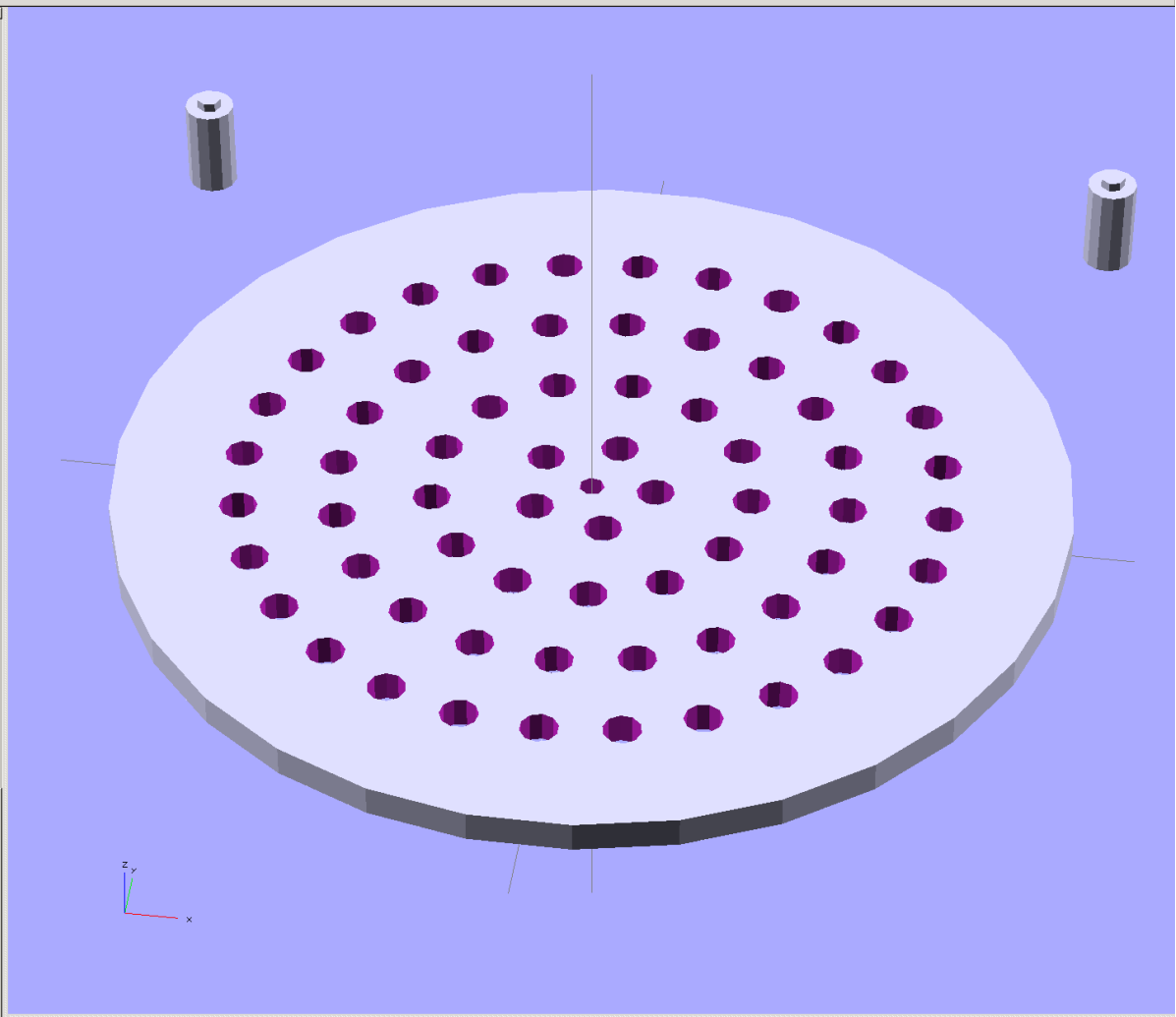
Viewport: translate = [0.00 0.00 0.00], rotate = [85.10 0.00 283.50], distance = 846.75

Layout = “Build”

OpenSCAD - Strainer Plate - simple - 4.scad*

File Edit Design View Help

```
if (Layout == "Plate")
 StrainerPlate();

if (Layout == "Handle")
 Handle();

if (Layout == "Build") {
 StrainerPlate();
 translate([PlateOD/2,PlateOD/2,0])
  Handle();
 translate([-PlateOD/2,PlateOD/2,0])
  Handle();
 }

if (Layout == "Show") {
 color("LightYellow")
  StrainerPlate();
 color("LightGreen") {
  translate([0,0,-HandleLength])
   Handle();
  translate([0,0,
      (PlateThick + HandleLength)])
   rotate([180,0,0])
   Handle();
 }

}
```



PolySet cache size in bytes: 32448
CGAL Polyhedrons in cache: 86
CGAL cache size in bytes: 5792232
Compiling design (CSG Products normalization)...
Normalized CSG tree has 72 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

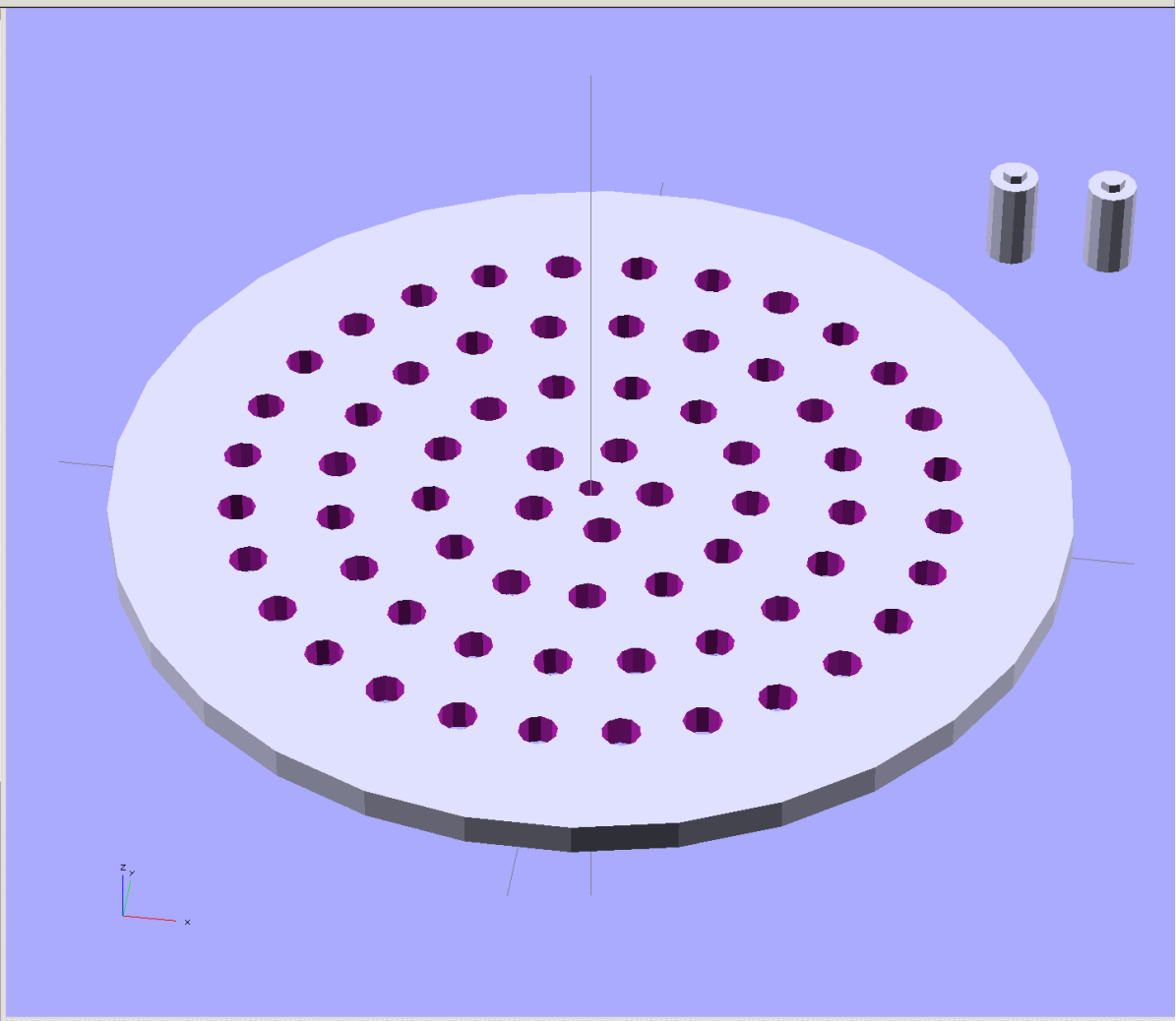
Viewport: translate = [0.00 0.00 0.00], rotate = [48.70 0.00 8.20], distance = 846.75

Optimize Build Platform Layout

OpenSCAD - Strainer Plate - simple - 4.scad*

File Edit Design View Help

```
if (Layout == "Plate")
 StrainerPlate();

if (Layout == "Handle")
 Handle();

if (Layout == "Build") {
 StrainerPlate();
 translate([PlateOD/2,PlateOD/2,0])
  Handle();
 translate([(PlateOD/2 - 2*HandleOD)
,PlateOD/2,0])
  Handle();
 }

if (Layout == "Show") {
 color("LightYellow")
  StrainerPlate();
 color("LightGreen") {
  translate([0,0,-HandleLength])
   Handle();
  translate([0,0,
      (PlateThick + HandleLength)])
   rotate([180,0,0])
   Handle();
 }
```



```
PolySet cache size in bytes: 32448
CGAL Polyhedrons in cache: 86
CGAL cache size in bytes: 5792232
Compiling design (CSG Products normalization)...
Normalized CSG tree has 72 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [0.00 0.00 0.00], rotate = [48.70 0.00 8.20], distance = 846.75

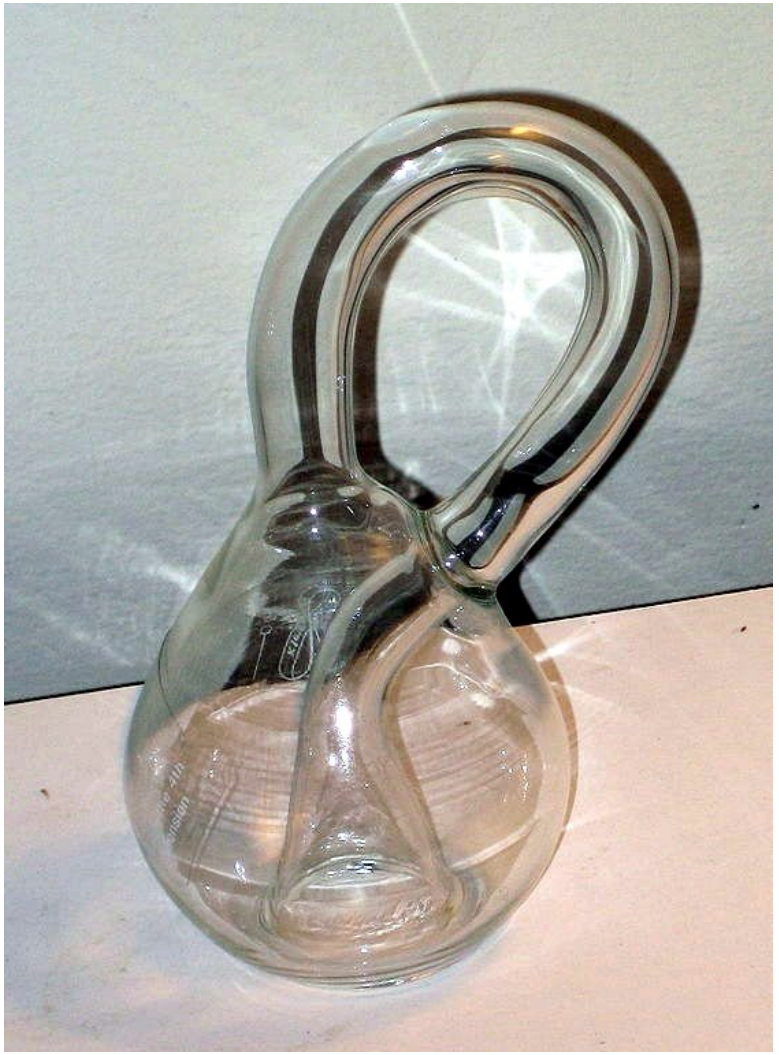
My “Best Practices”

- OpenSCAD is not a programming language
- Don’t Be Clever
  - If you must be clever, preprocess in Python, et. al.
- There Are No Variables
  - Only defined constants with global scope
  - Get over it
- Have a conditional layout for every module
  - Think of it as a unit test harness
- Proceed in tiny steps

Modeling Printable Objects

Geometric Requirements

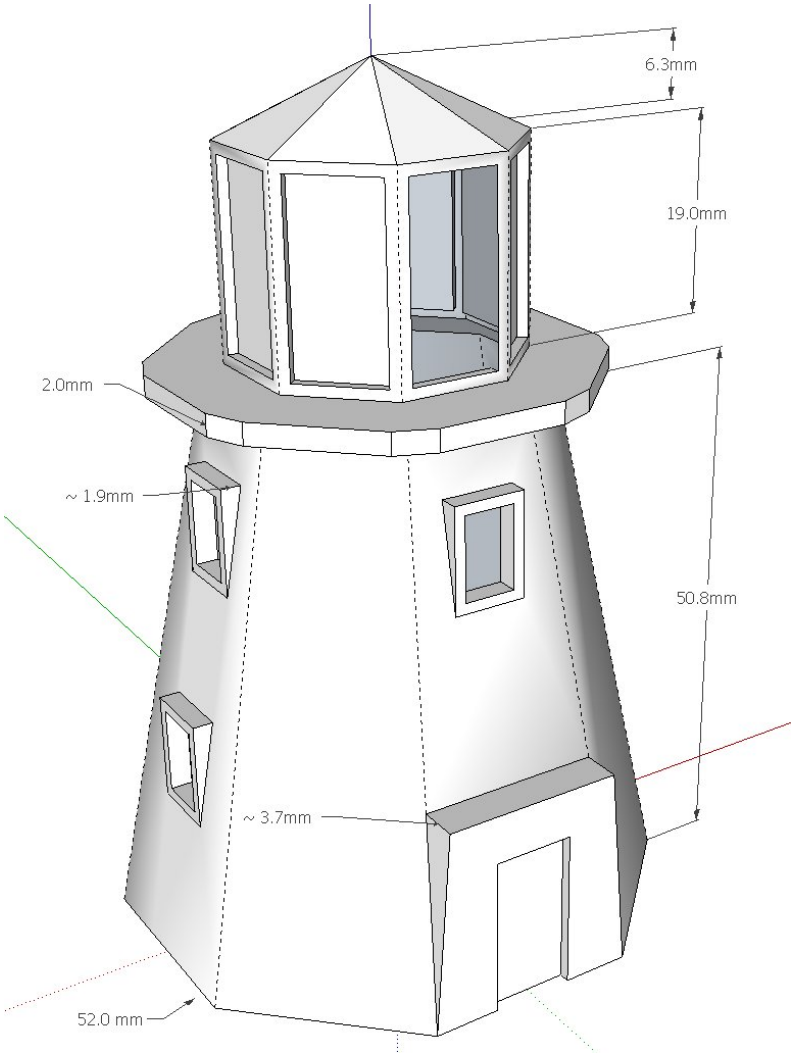
- Closed surface
  - “Watertight” objects
- Consistent Normals
  - All aimed outward
- 2-Manifold
  - Exactly 2 faces / edge
    - No coincident faces



http://reprap.org/wiki/Separate_page_on_the_question
https://en.wikipedia.org/wiki/File:Acme_klein_bottle.jpg

What's Wrong With This Picture?

- Not a closed surface
  - Not "watertight"
- Inconsistent normals
- Easy to see?
  - Maybe in *this* model...
  - Book version is OK
- CSG = 3D volumes
- Mesh = 2D surfaces



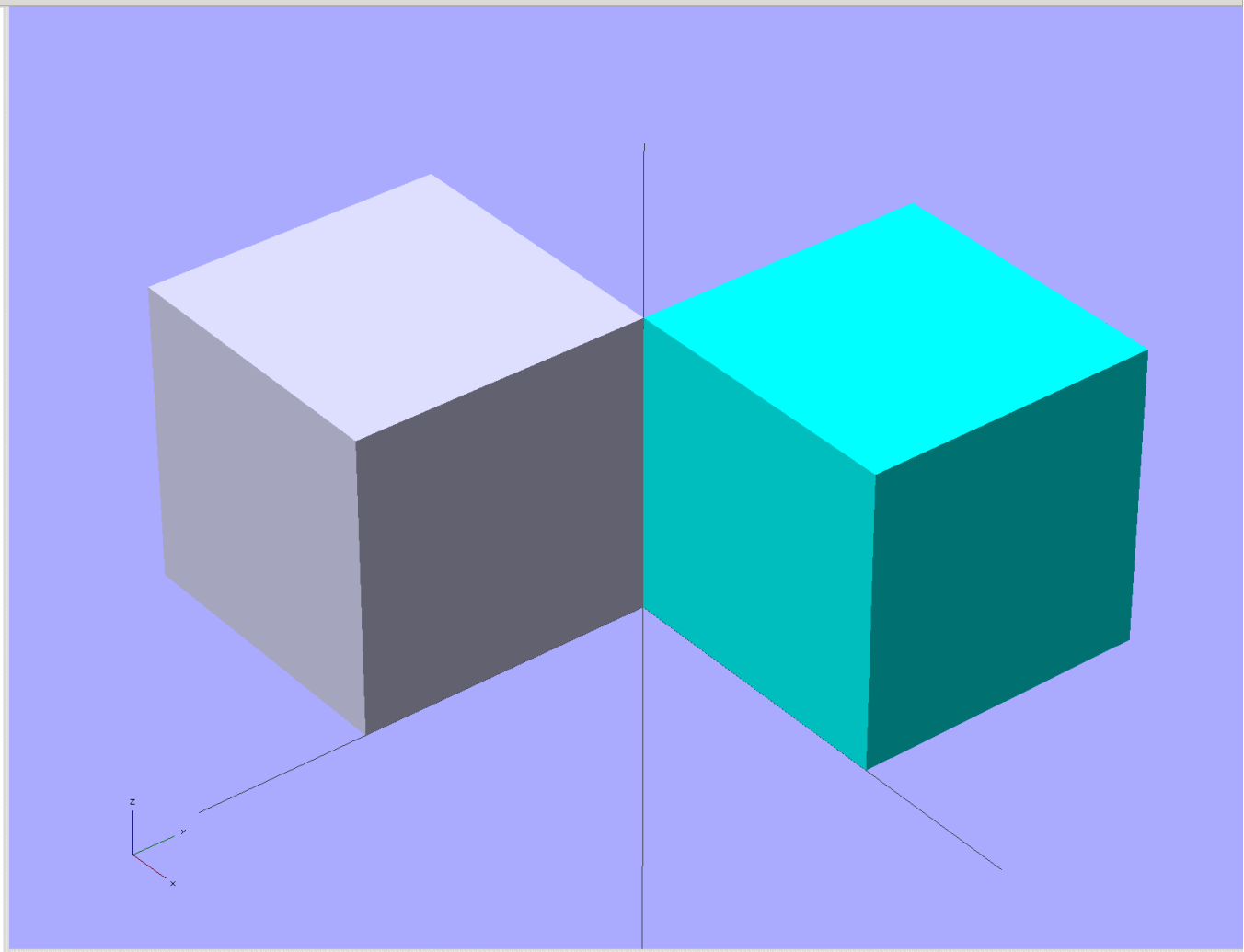
Beginning Google SketchUp for 3D Printing http://www.apress.com/9781430233619
http://reprap.org/wiki/Sketchup_Modeling_for_3d_Printing
http://reprap.org/wiki/Art_of_illusion

Not 2-Manifold: 4 Sides/Edge

OpenSCAD - New Document*

File Edit Design View Help

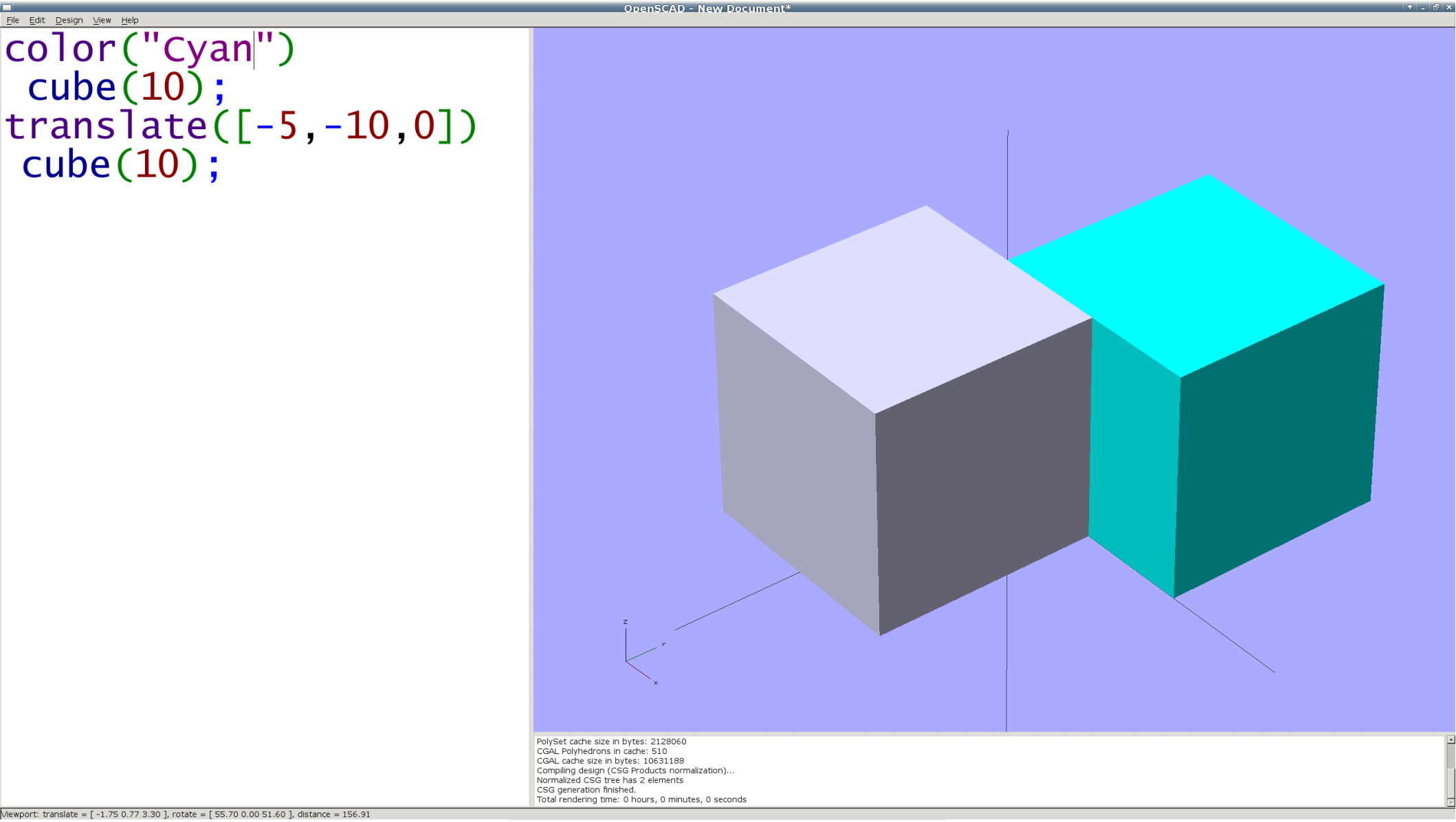
```
color("Cyan")
 cube(10);
rotate(180)
 cube(10);
```



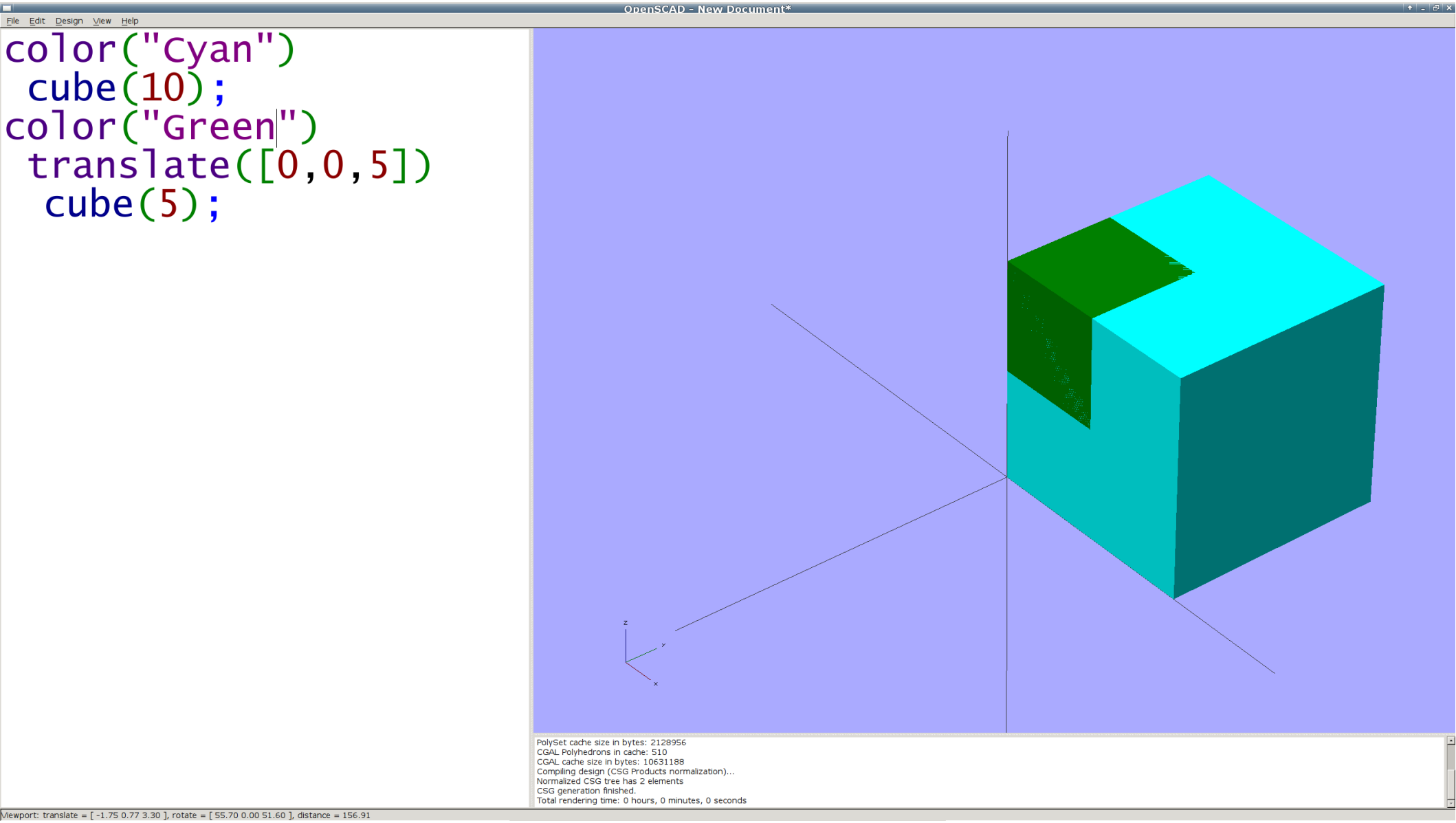
PolySet cache size in bytes: 2128060
CGAL Polyhedrons in cache: 510
CGAL cache size in bytes: 10631188
Compiling design (CSG Products normalization)...
Normalized CSG tree has 2 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds

Viewport: translate = [-1.75 0.77 3.30], rotate = [55.70 0.00 51.60], distance = 156.91

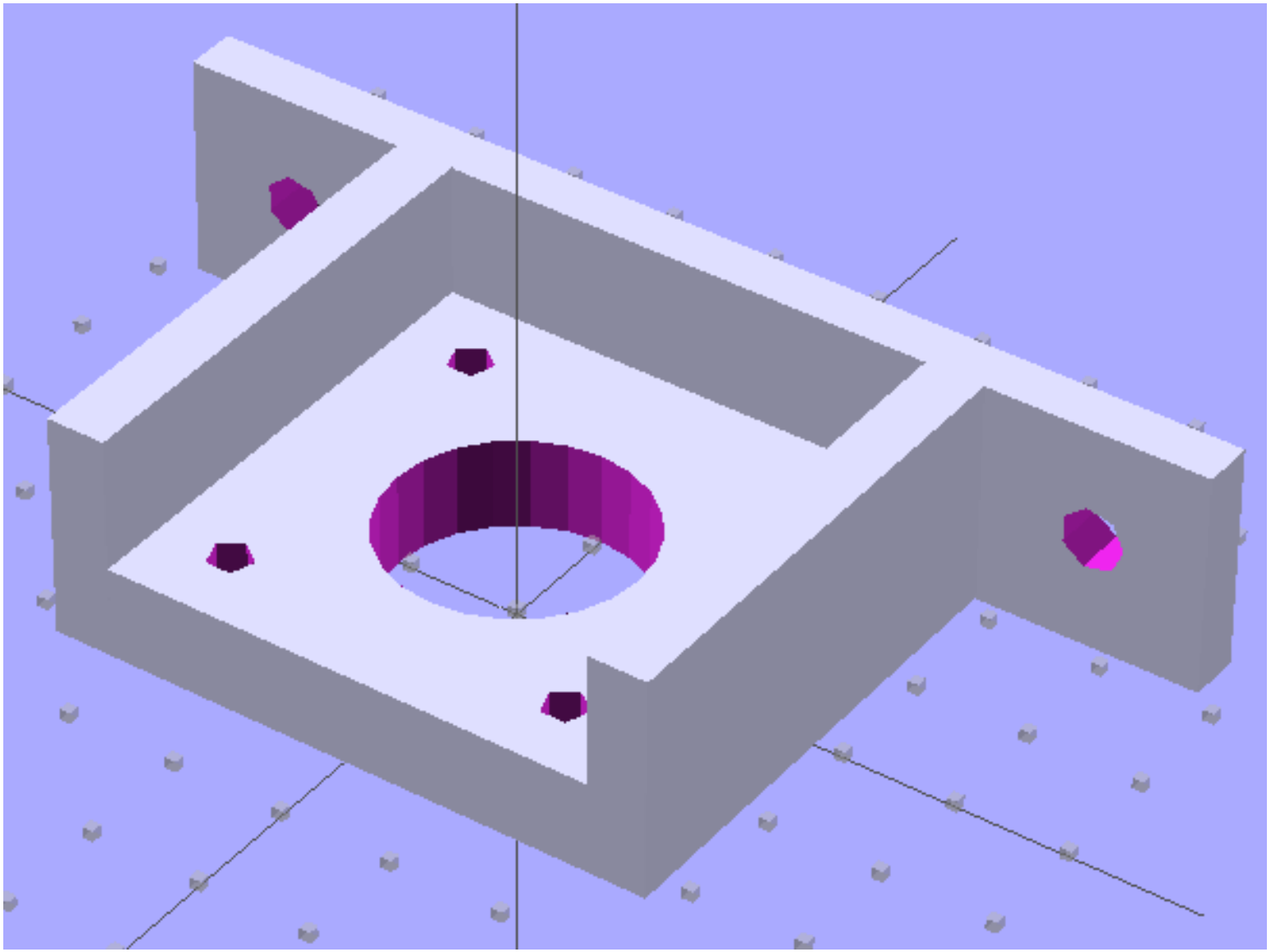
Not 2-Manifold: Coincident Faces



Not 2-Manifold: Coincident Faces

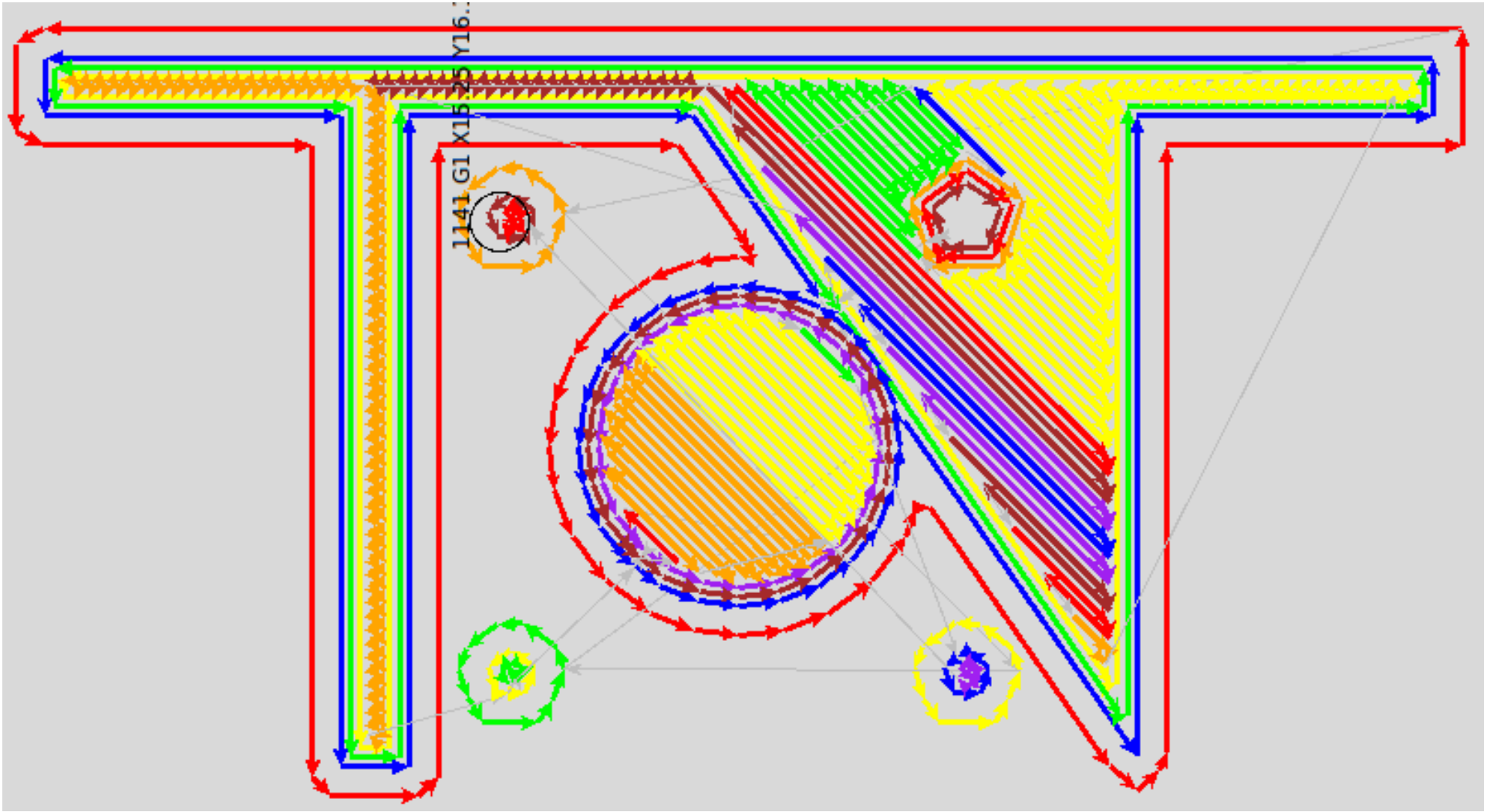


What's Wrong With This Picture?



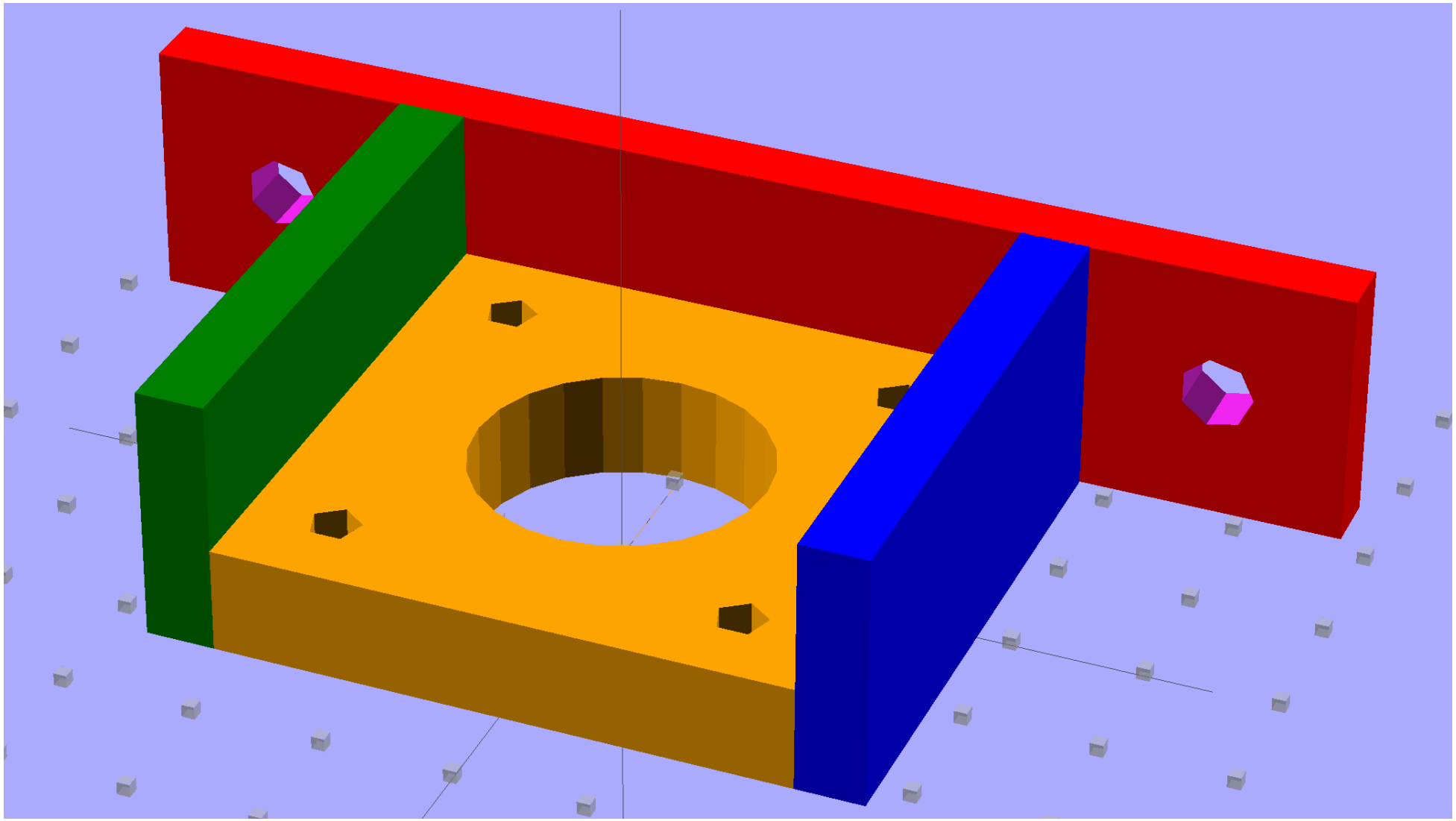
http://softsolder.com/2011/08/23/nema-17-stepper-motor-mount

Solid Model → G-Code



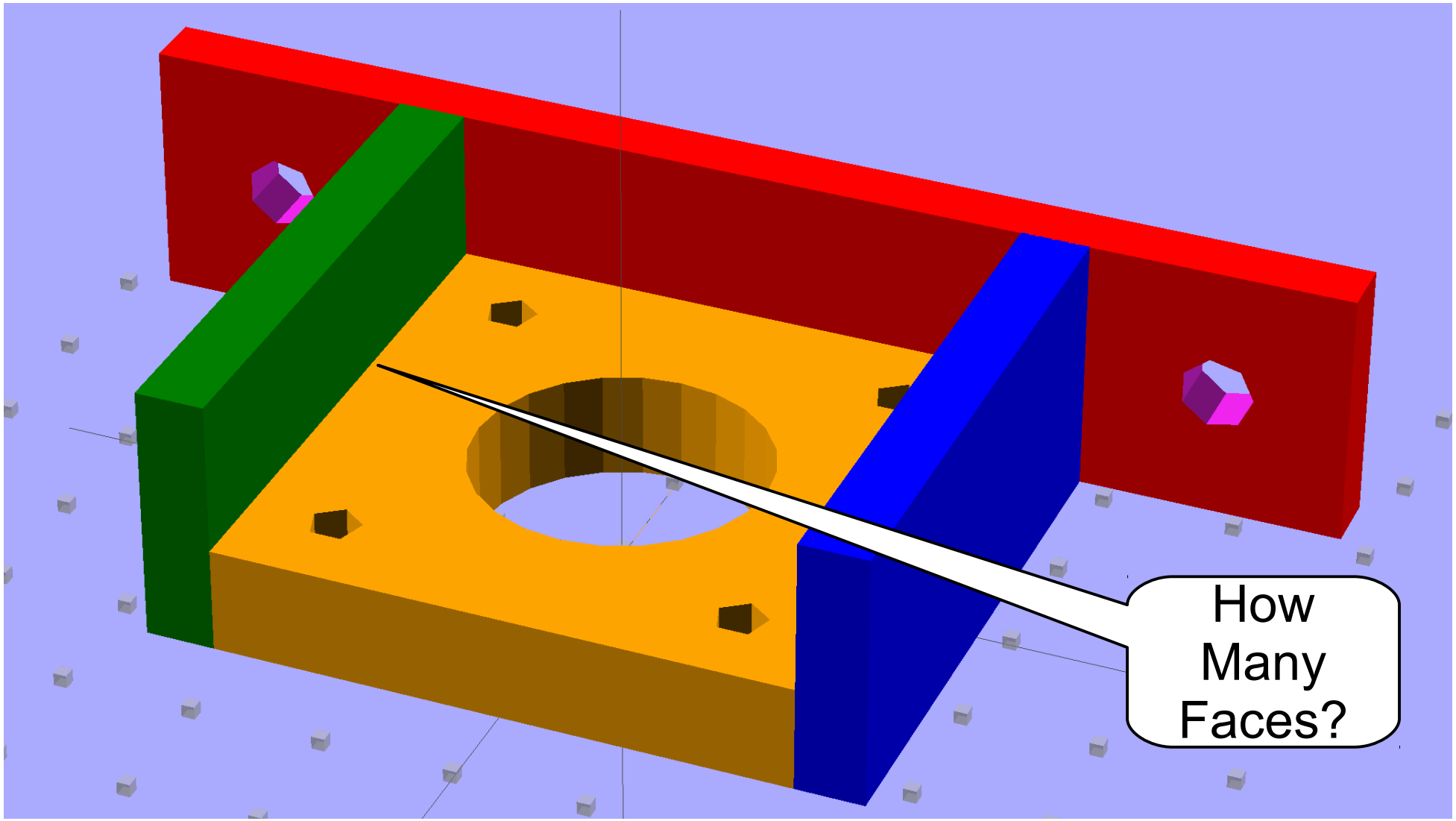
http://fabmetheus.crsndoo.com/wiki/index.php/Skeinforge_Skeinlayer
http://softsolder.com/2011/09/05/openscad-vs-skeinforge-40-bogus-g-code/

What's Wrong With This Picture?



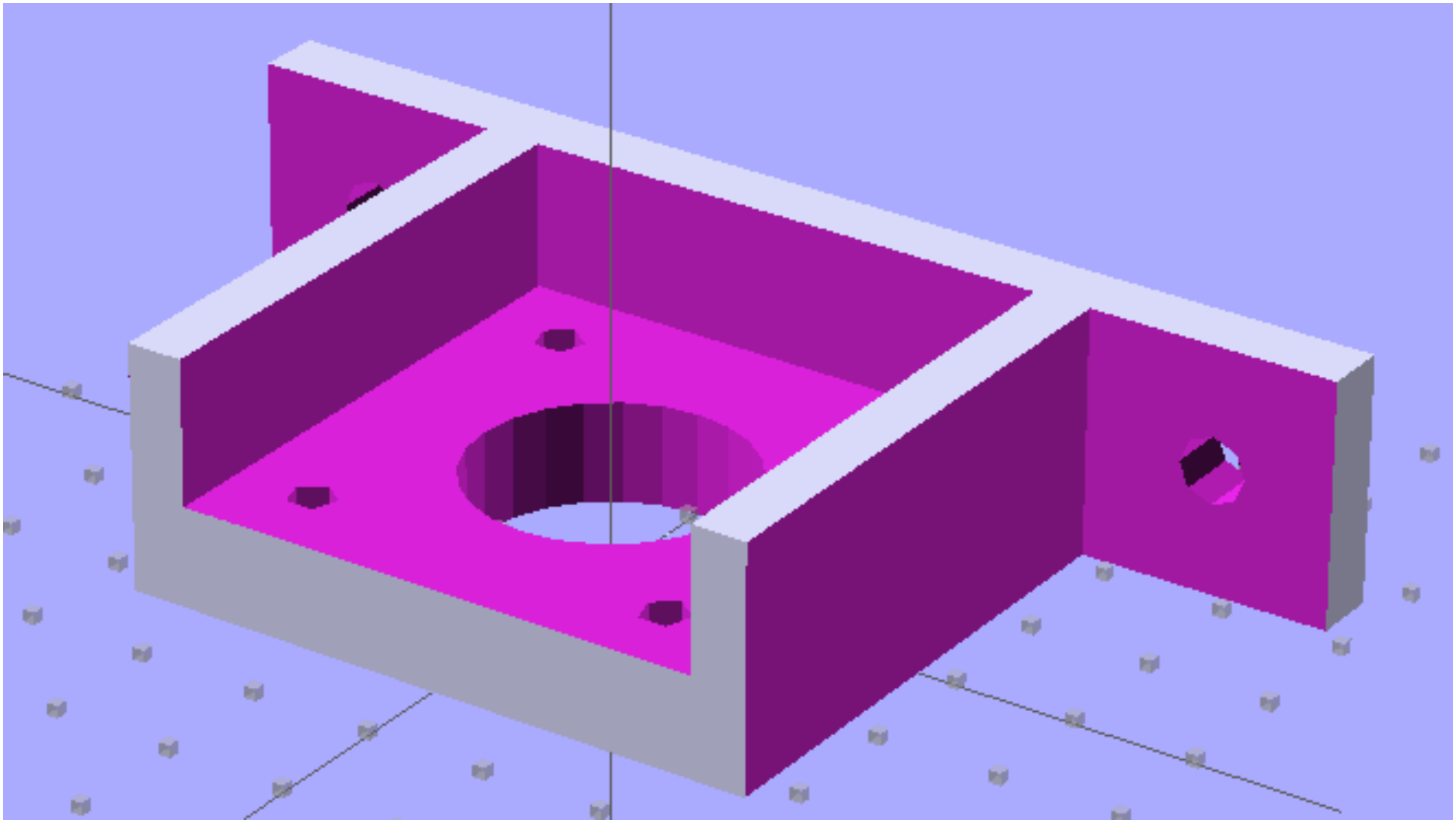
http://softsolder.com/2011/08/23/nema-17-stepper-motor-mount

What's Wrong With This Picture?



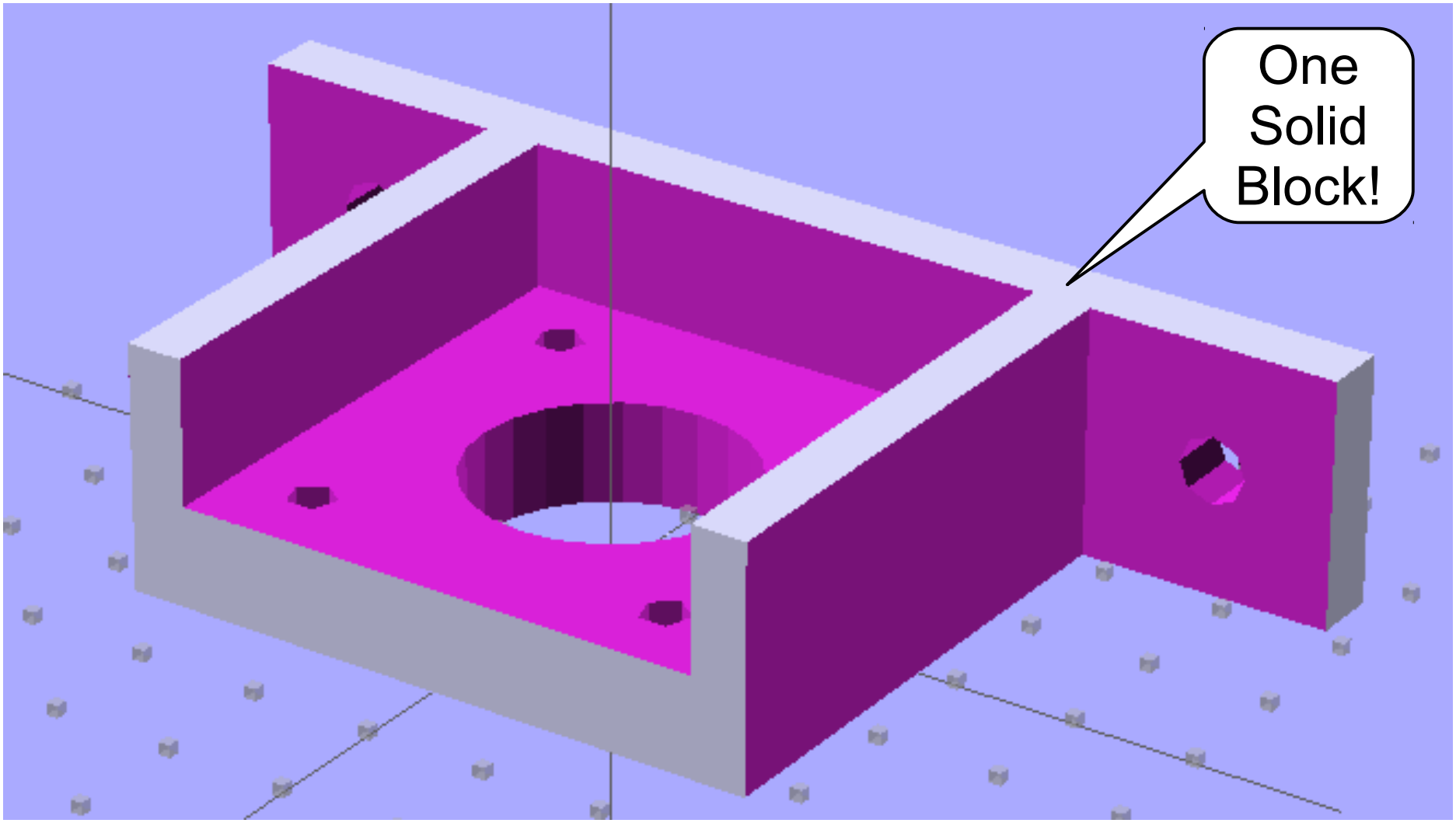
http://softsolder.com/2011/08/23/nema-17-stepper-motor-mount

What's *Right* With This Picture?



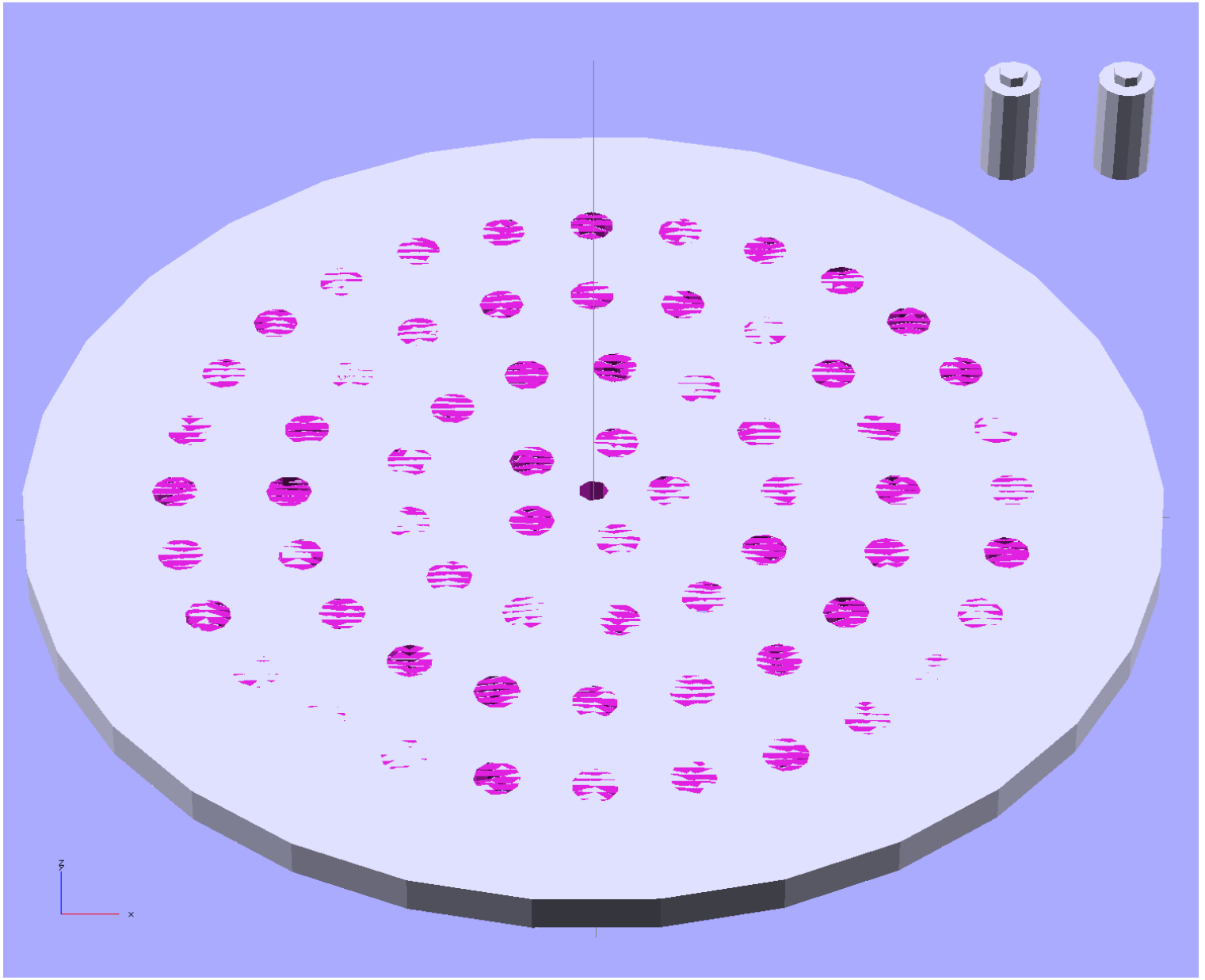
http://softsolder.com/2011/08/23/nema-17-stepper-motor-mount

What's *Right* With This Picture?

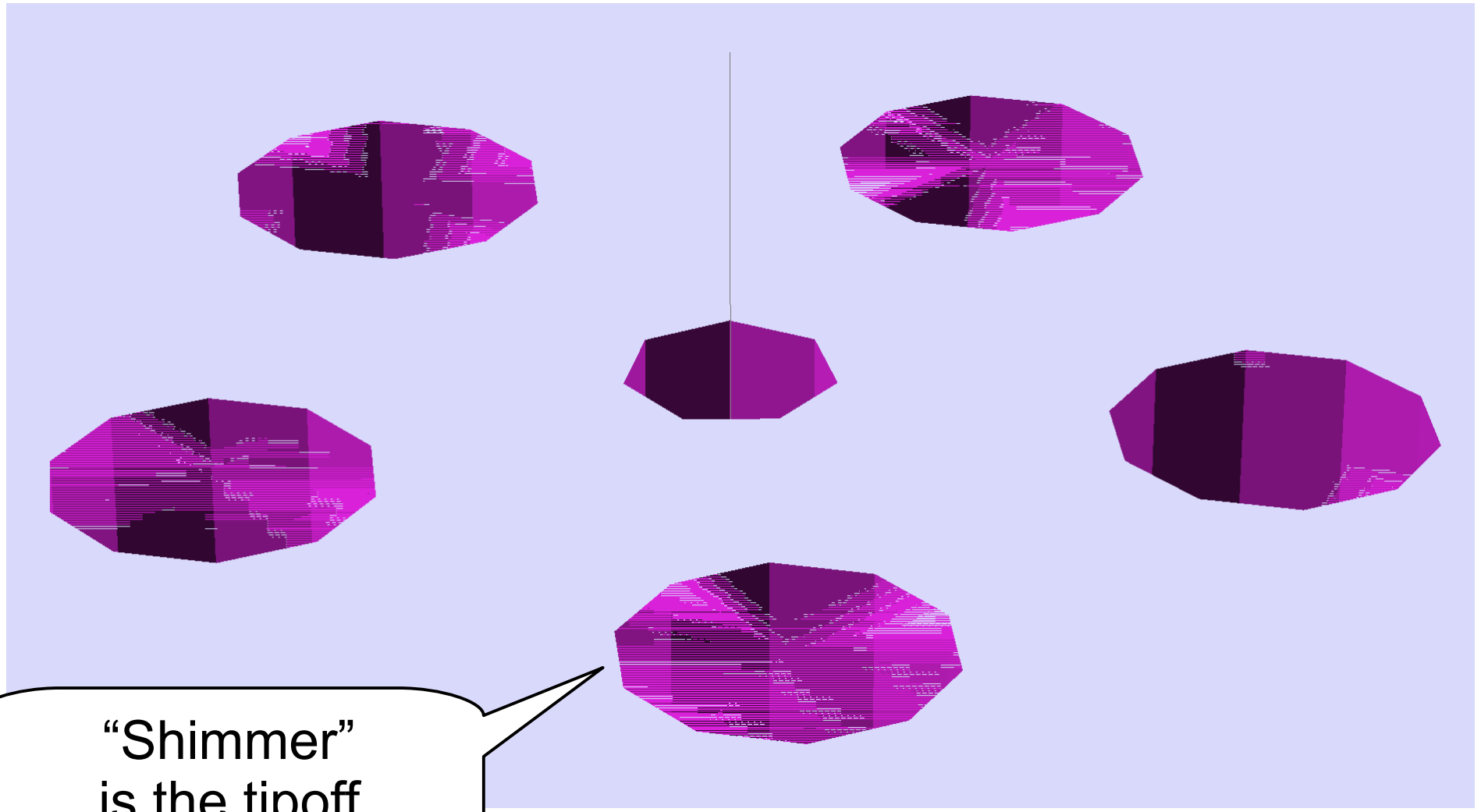


http://softsolder.com/2011/08/23/nema-17-stepper-motor-mount

What's Wrong With This Picture?

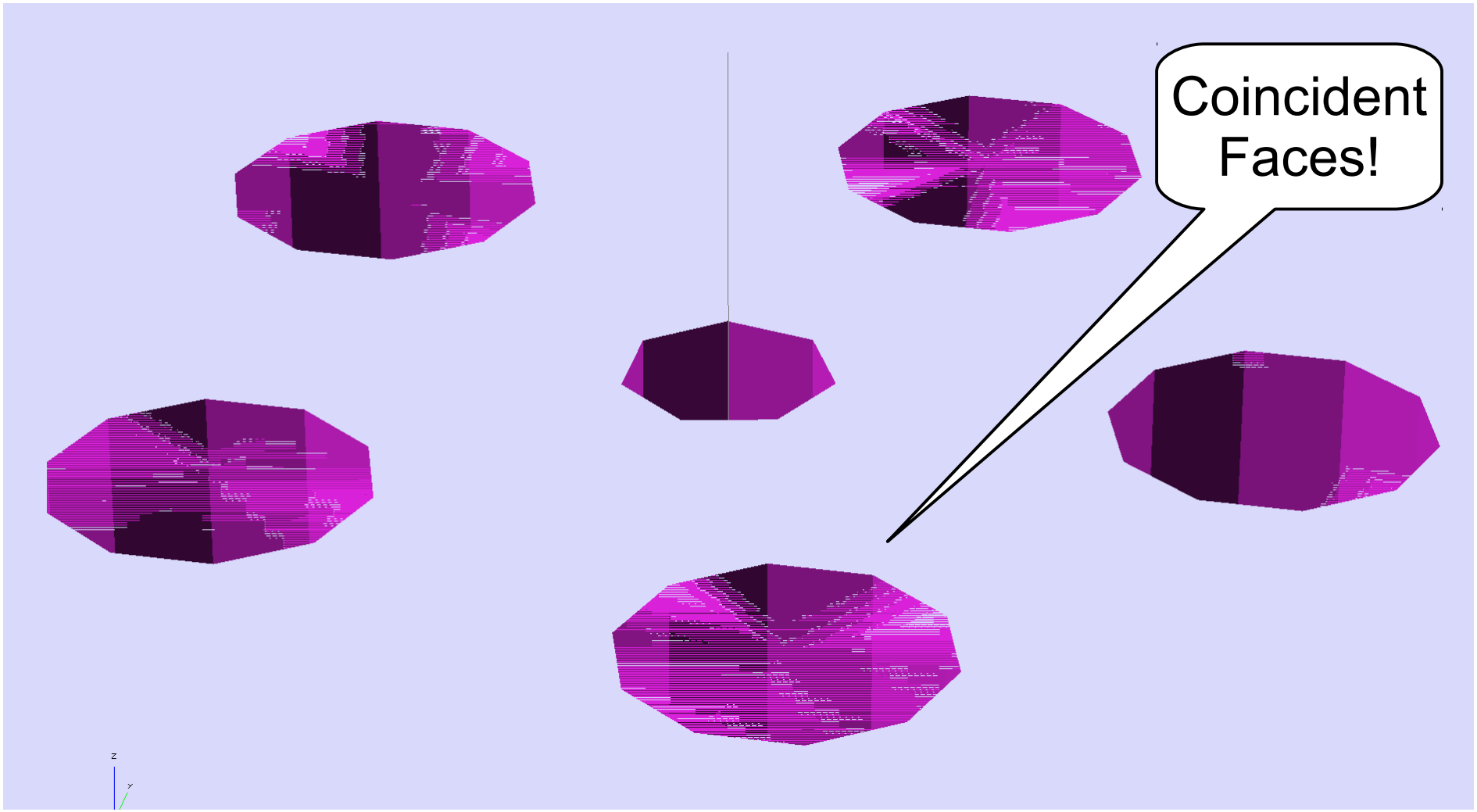


What's Wrong With This Picture?

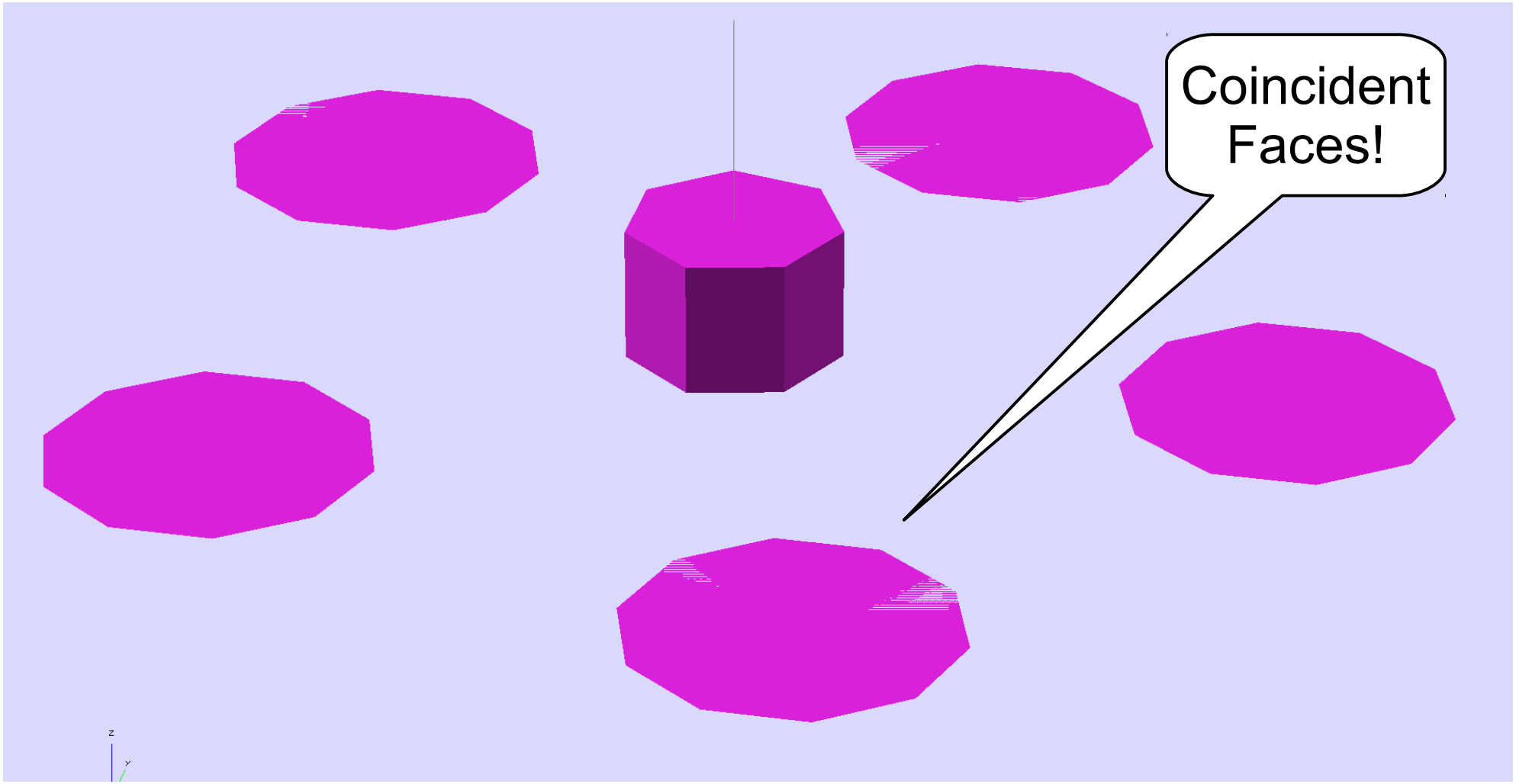


"Shimmer"
is the tipoff

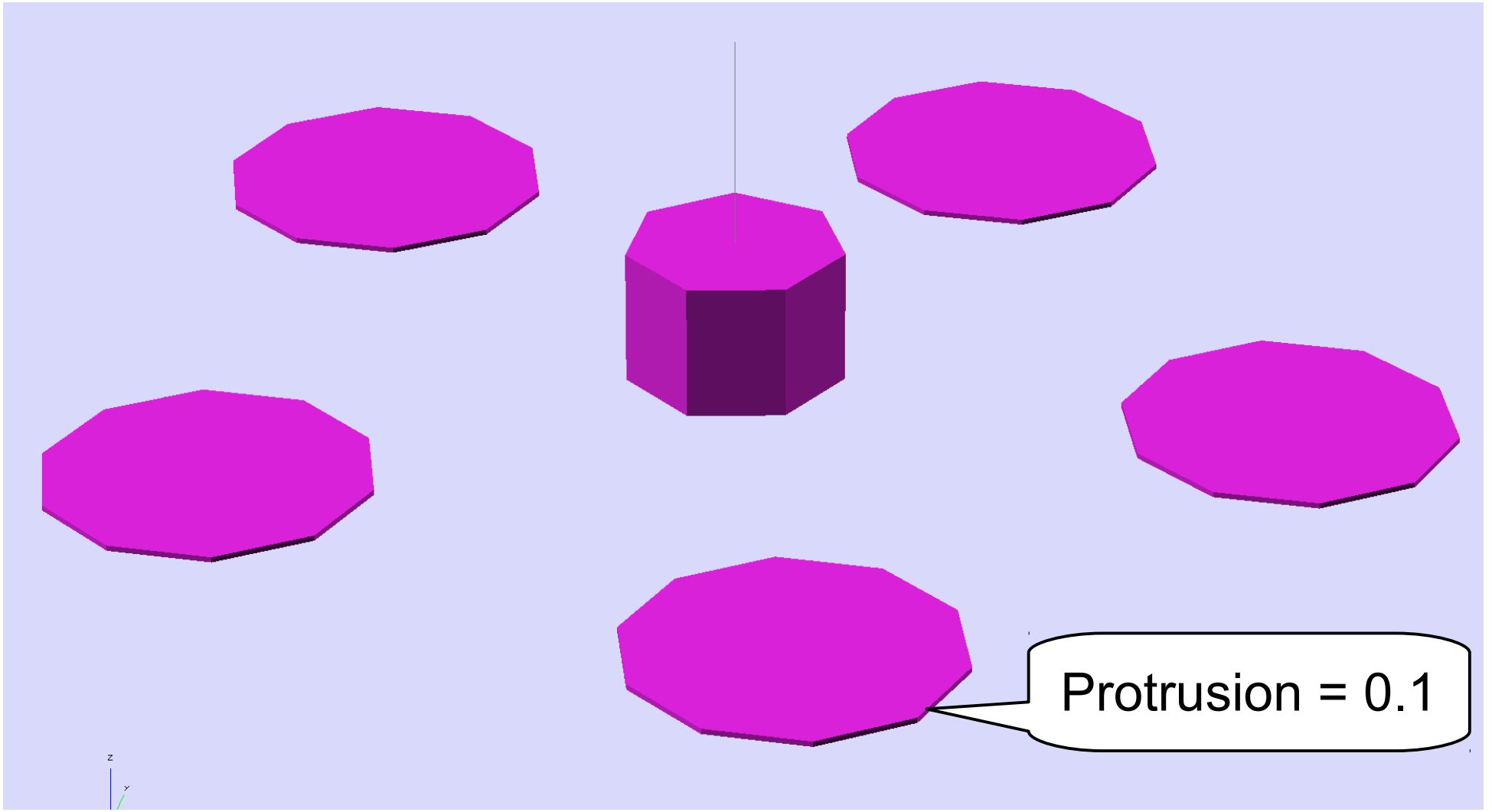
What's Wrong With This Picture?



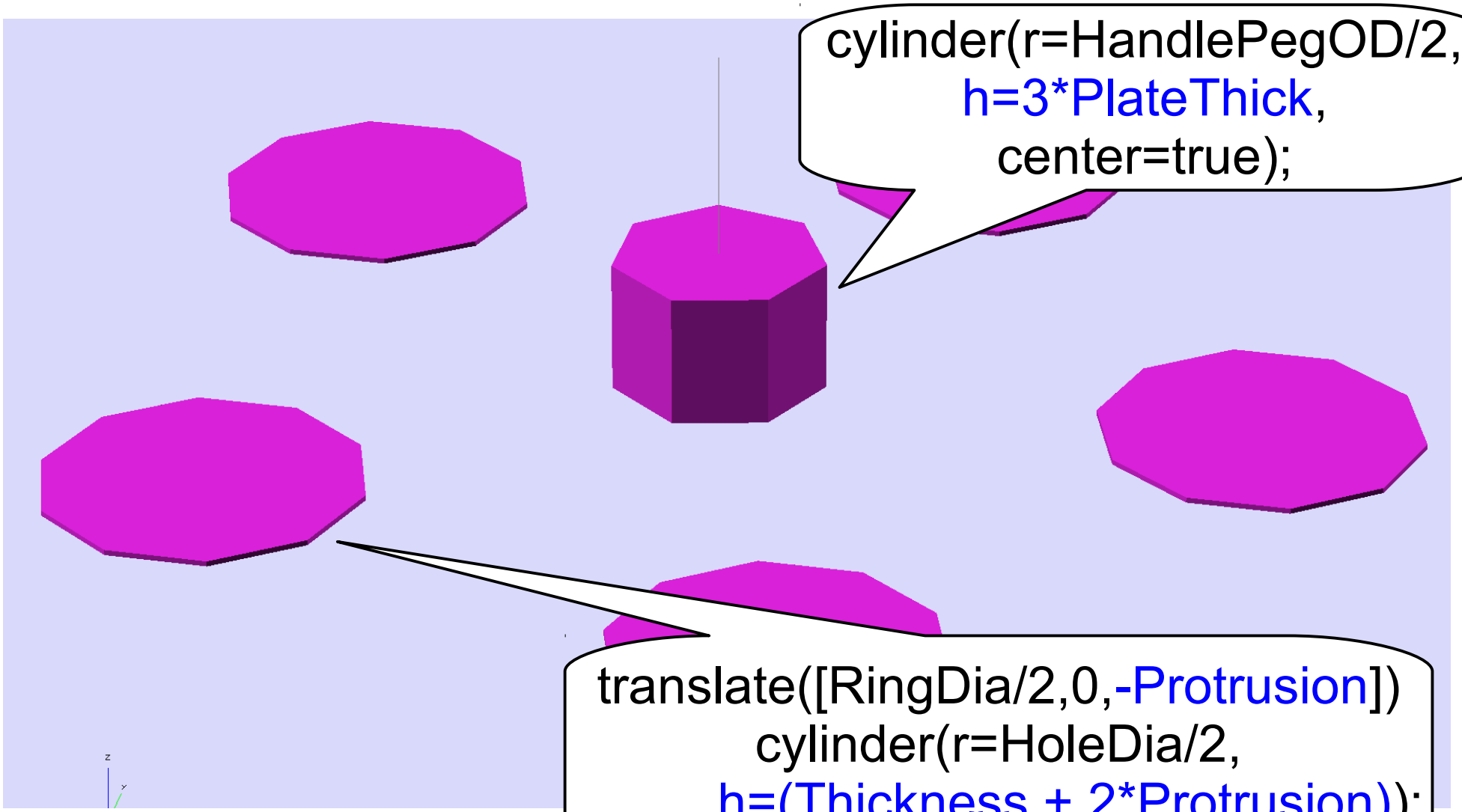
F12 View



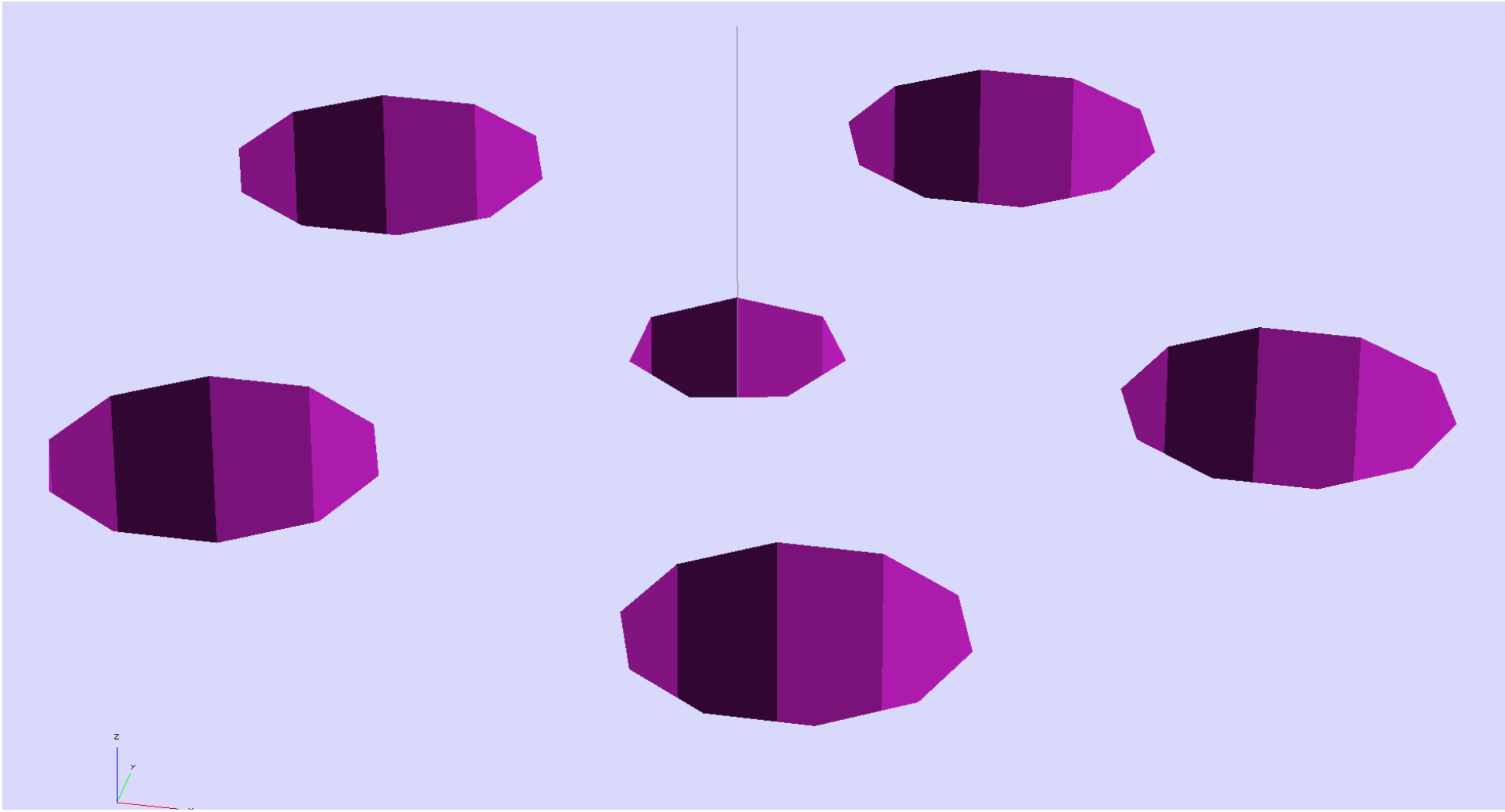
What's Right With This Picture?



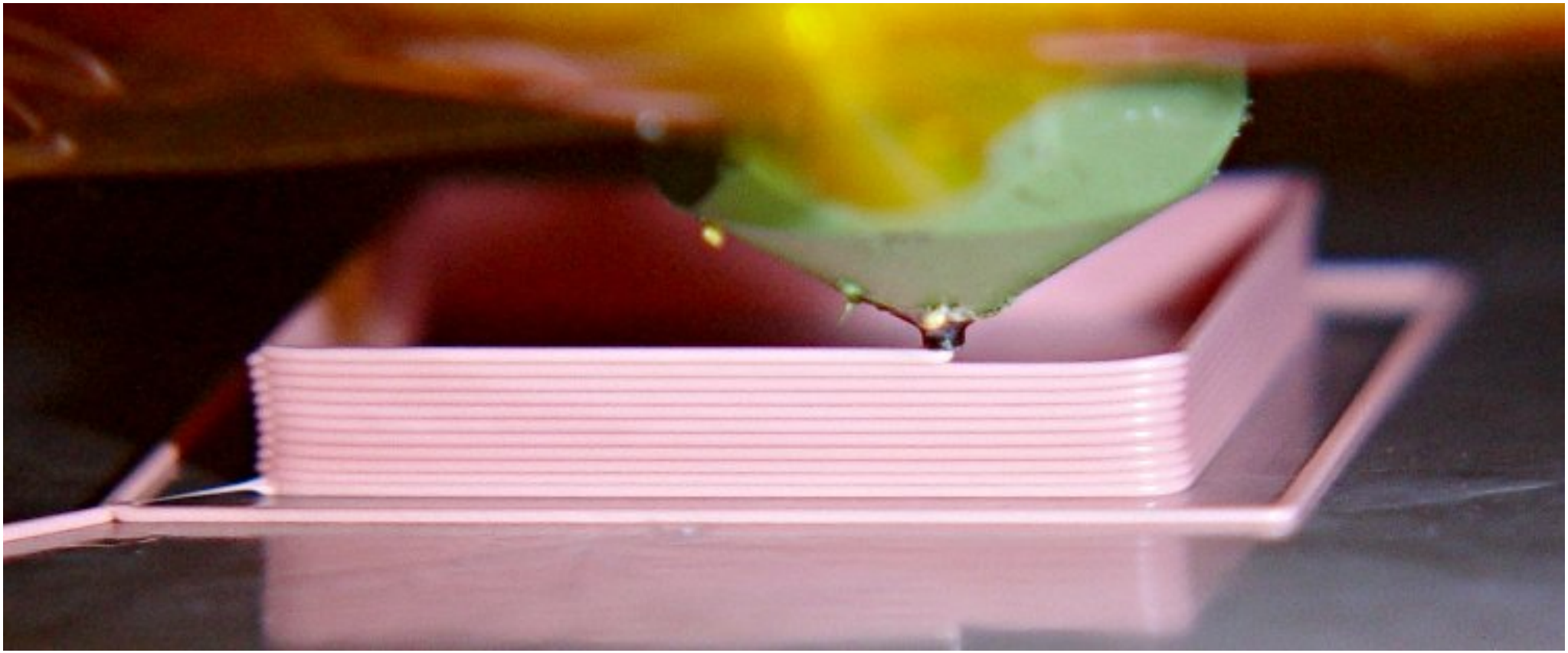
What Does It Take To Be Right?



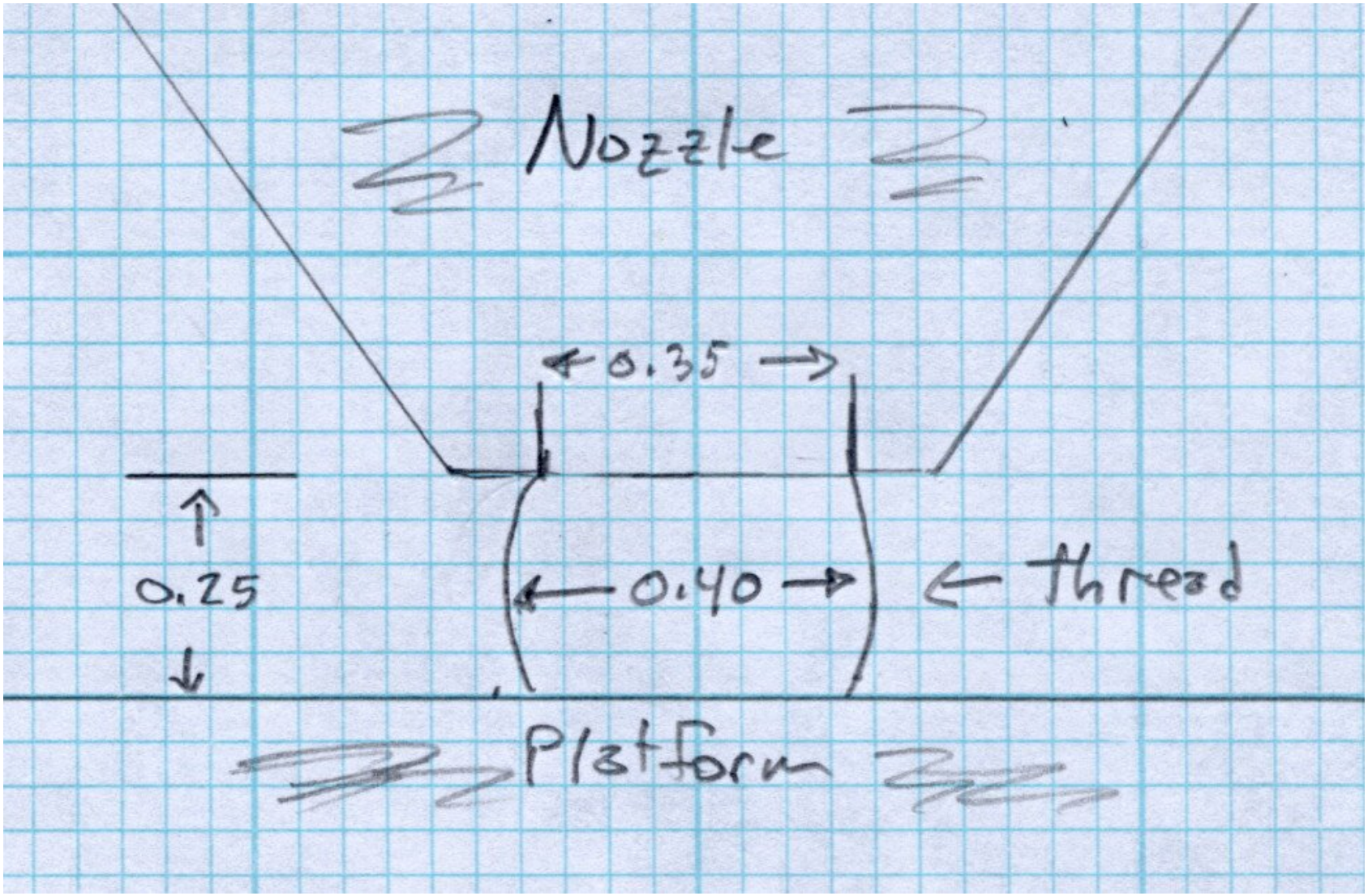
What's Right With This Picture?



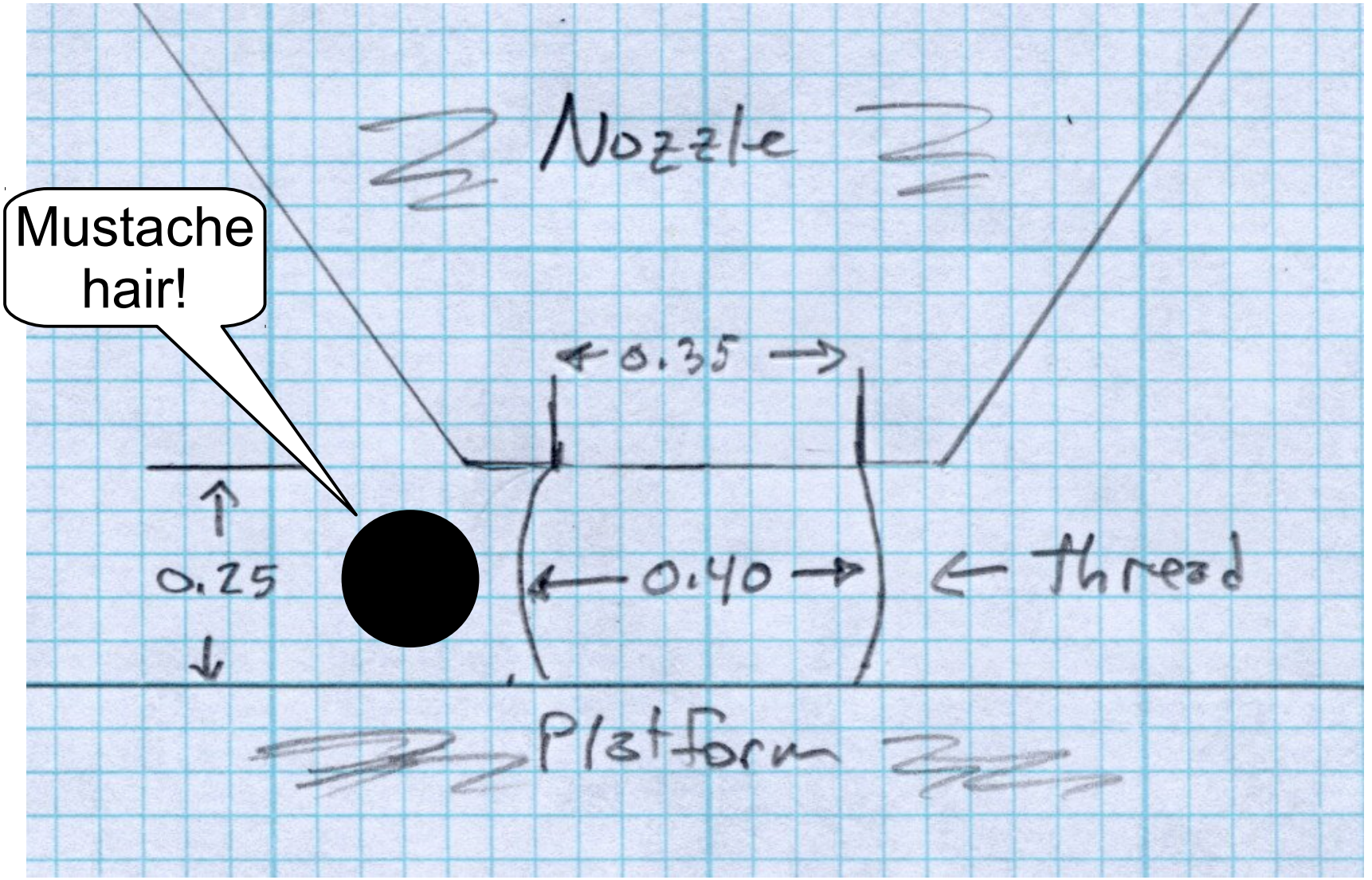
Process Limitations



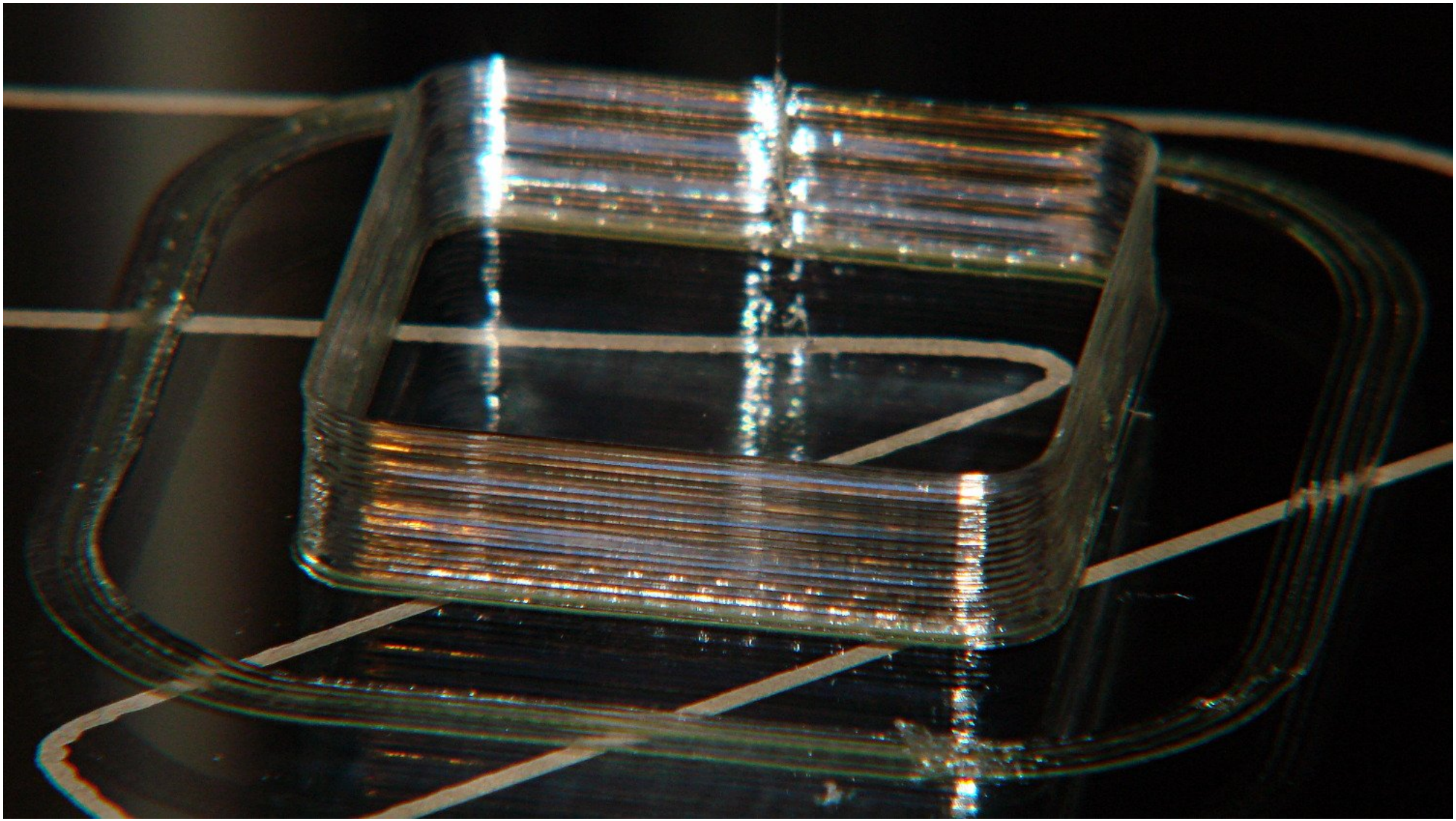
Fundamental Sizes



Fundamental Sizes



Extruder Calibration

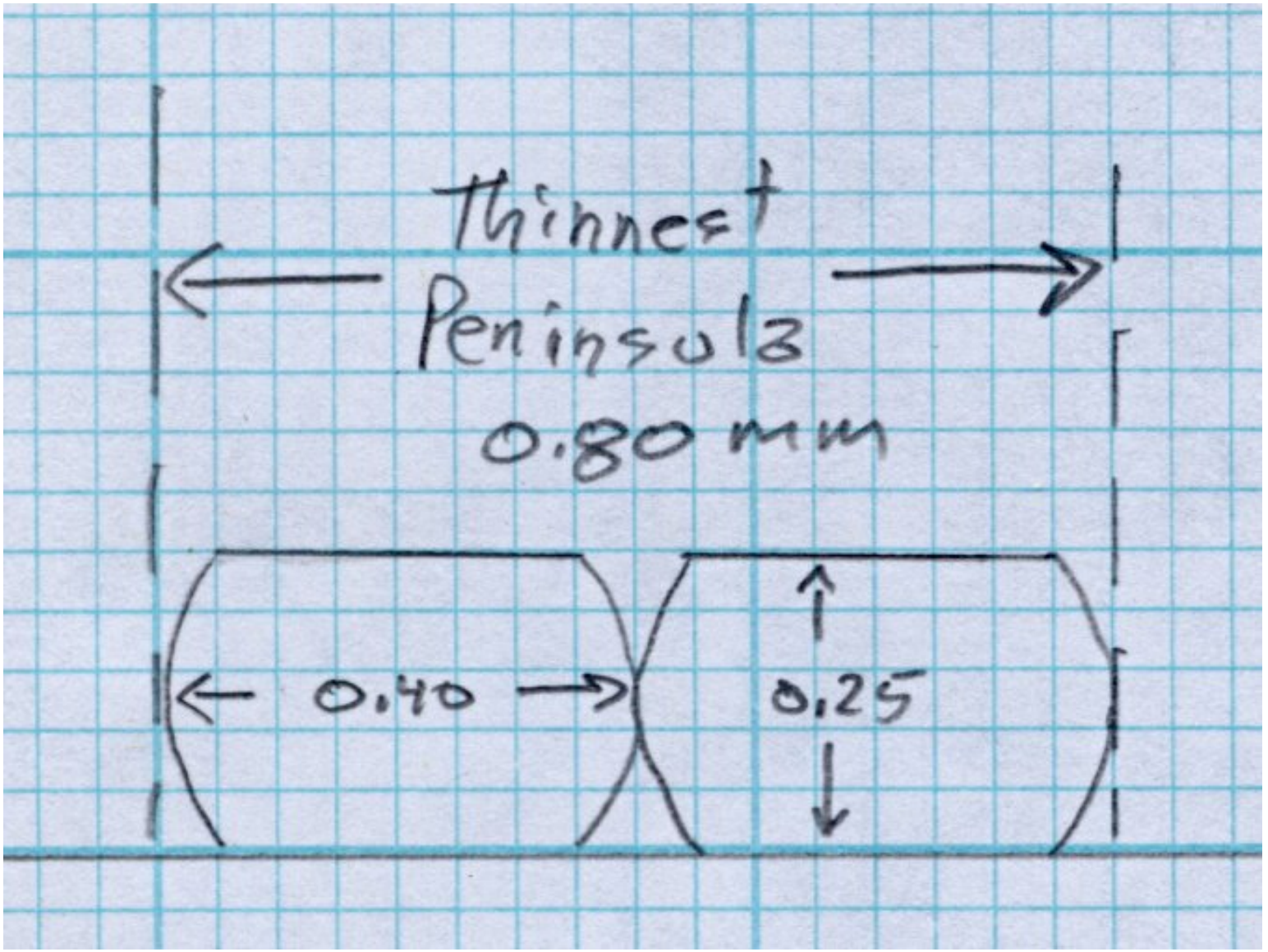


http://softsolder.com/2013/04/16/makergear-m2-fundamental-test-object/

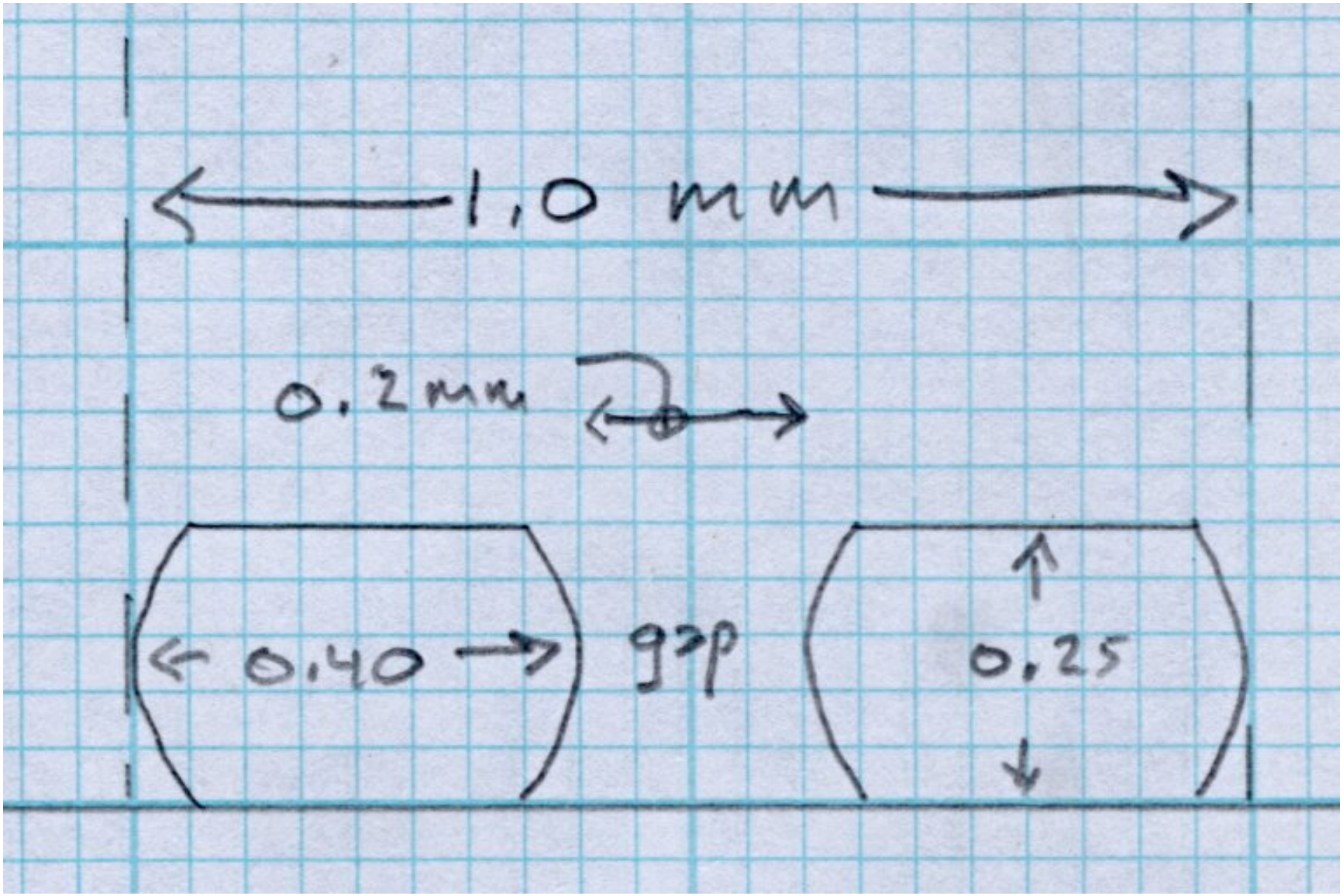
Extruder Calibration

http://softsolder.com/2013/04/16/makergear-m2-fundamental-test-object/

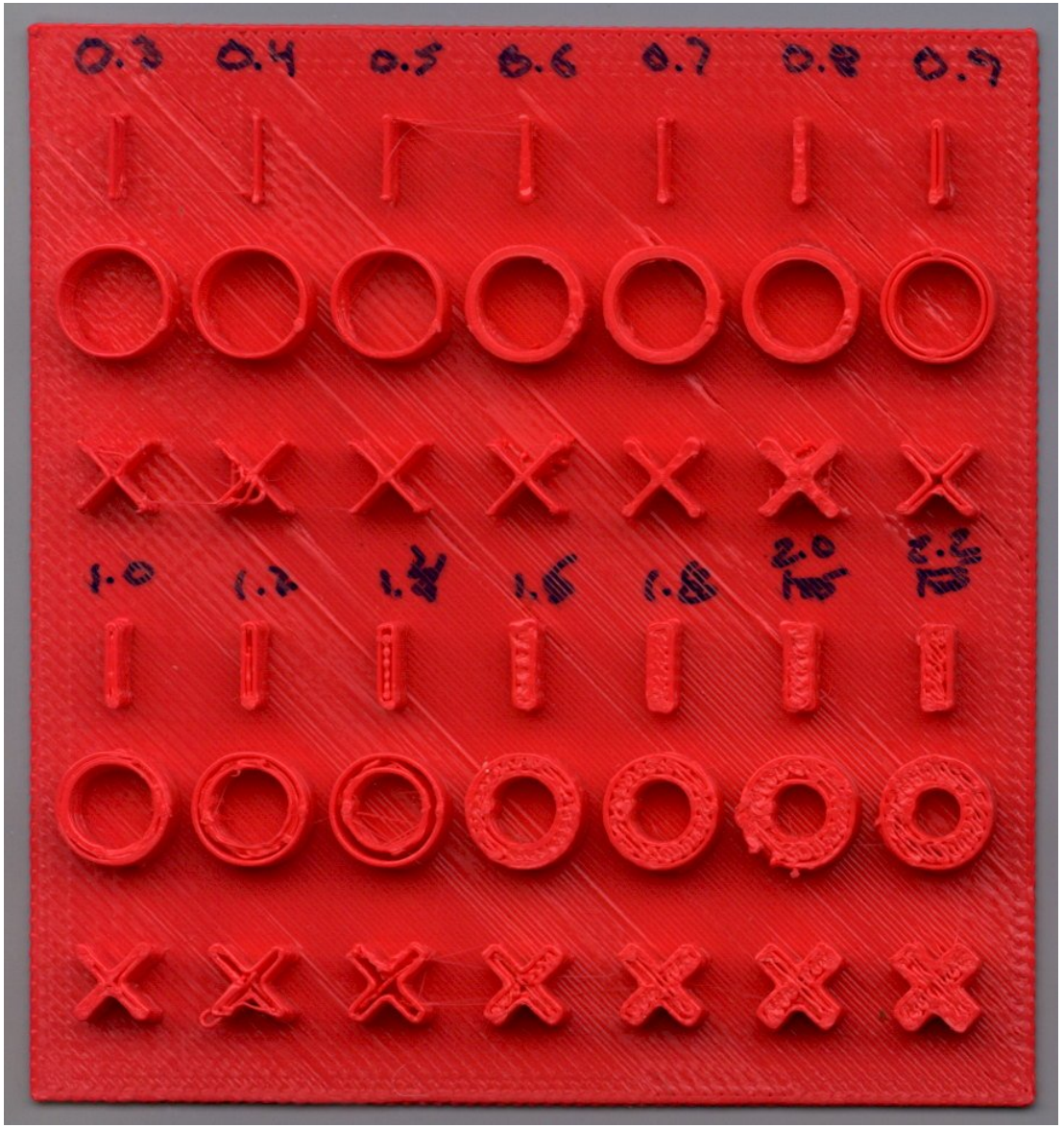
Smallest Possible Feature



Unavoidable Gap!

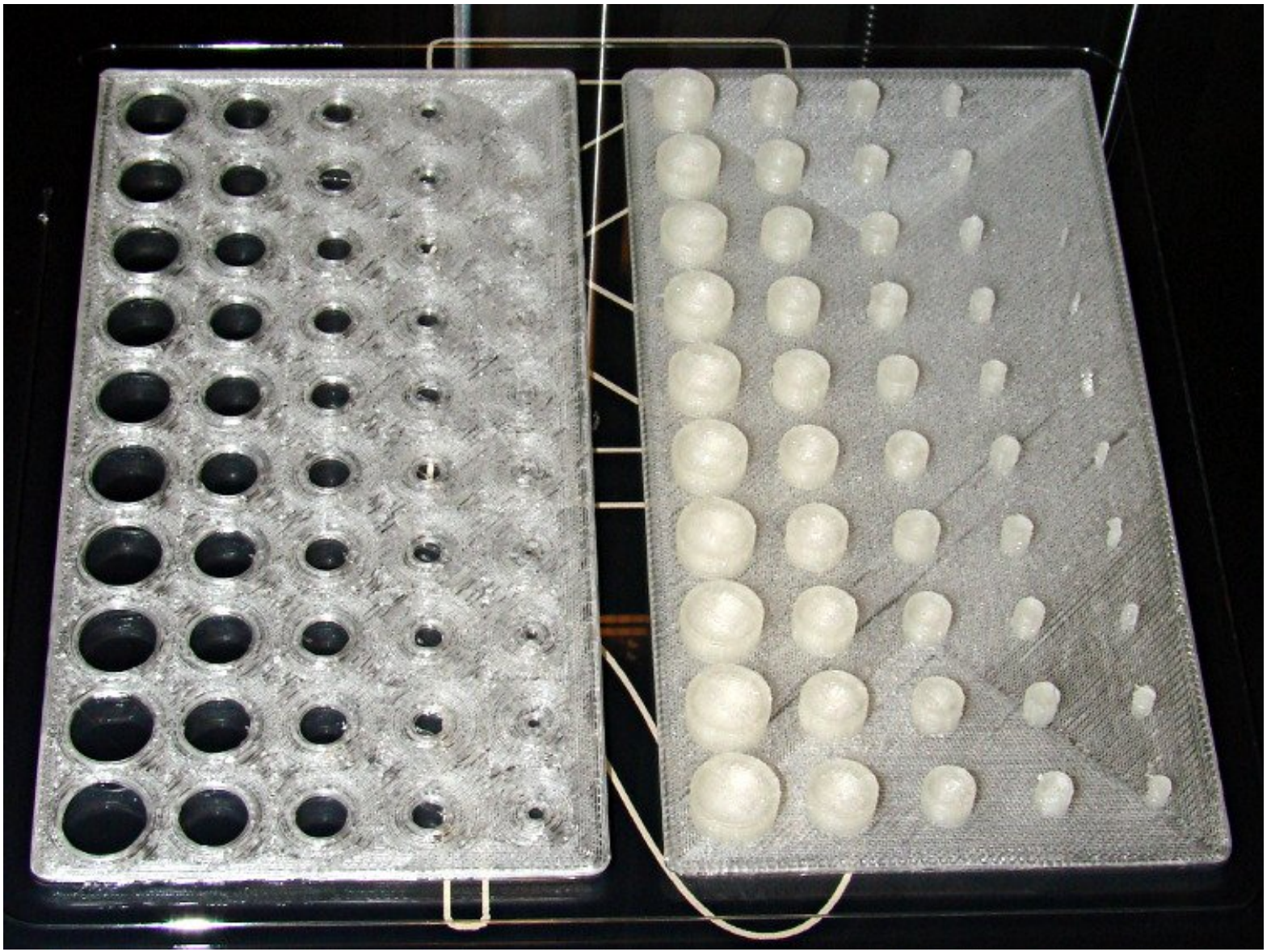


Wall Width Test Piece



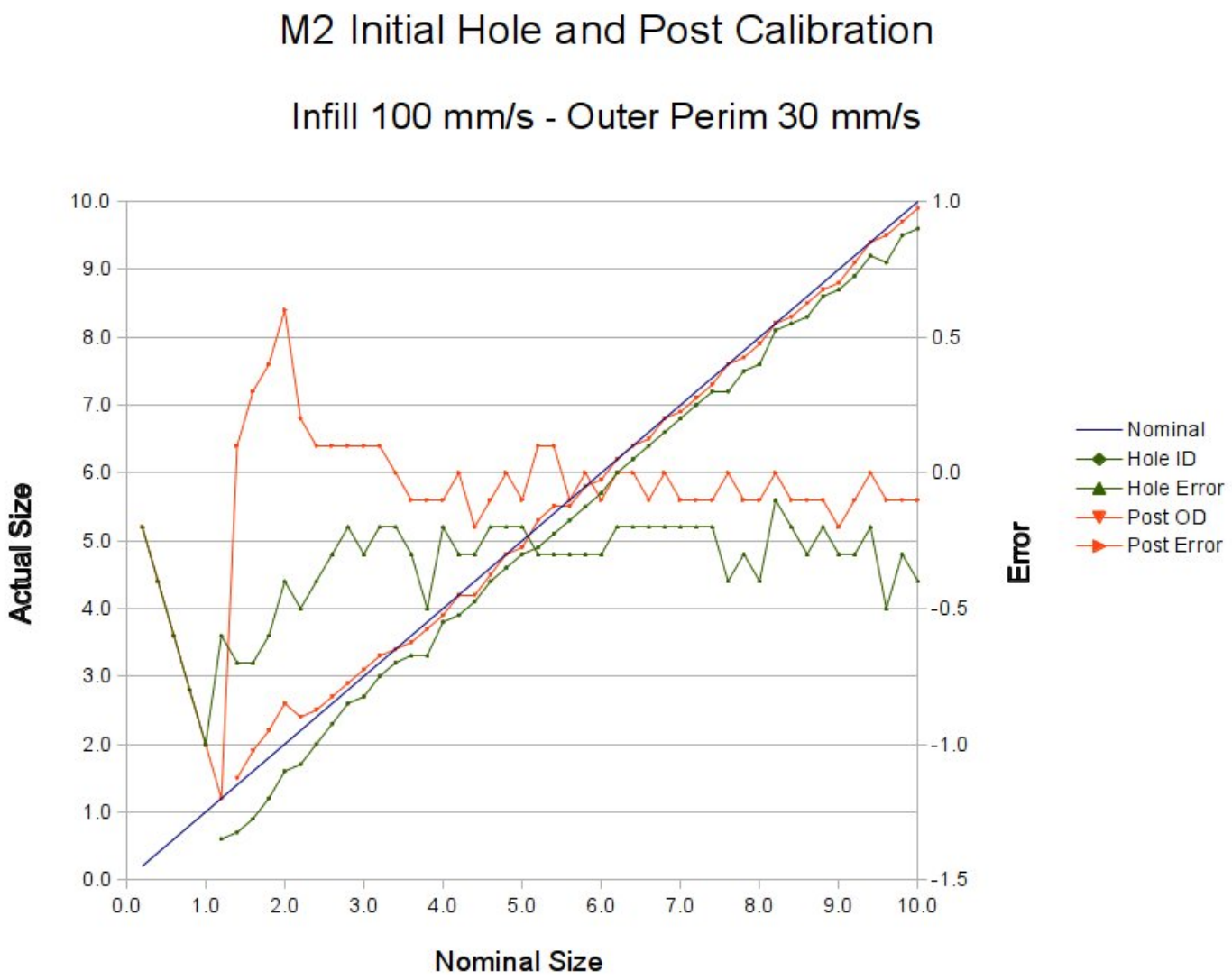
http://www.thingiverse.com/thing:8859

Hole & Pillar Tests



http://www.thingiverse.com/thing:42800

Hole & Pillar Calibration



http://softsolder.com/2013/04/21/makergear-m2-post-and-hole-calibration-test-objects/

Hole Size Compensation

```
HoleWindage = 0.2;


module PolyCyl(Dia,Height,ForceSides=0) {
  Sides = (ForceSides != 0) ?
            ForceSides : (ceil(Dia) + 2);
  FixDia = Dia / cos(180/Sides);
  cylinder(r=(FixDia + HoleWindage)/2,
            h=Height,$fn=Sides);
}
```

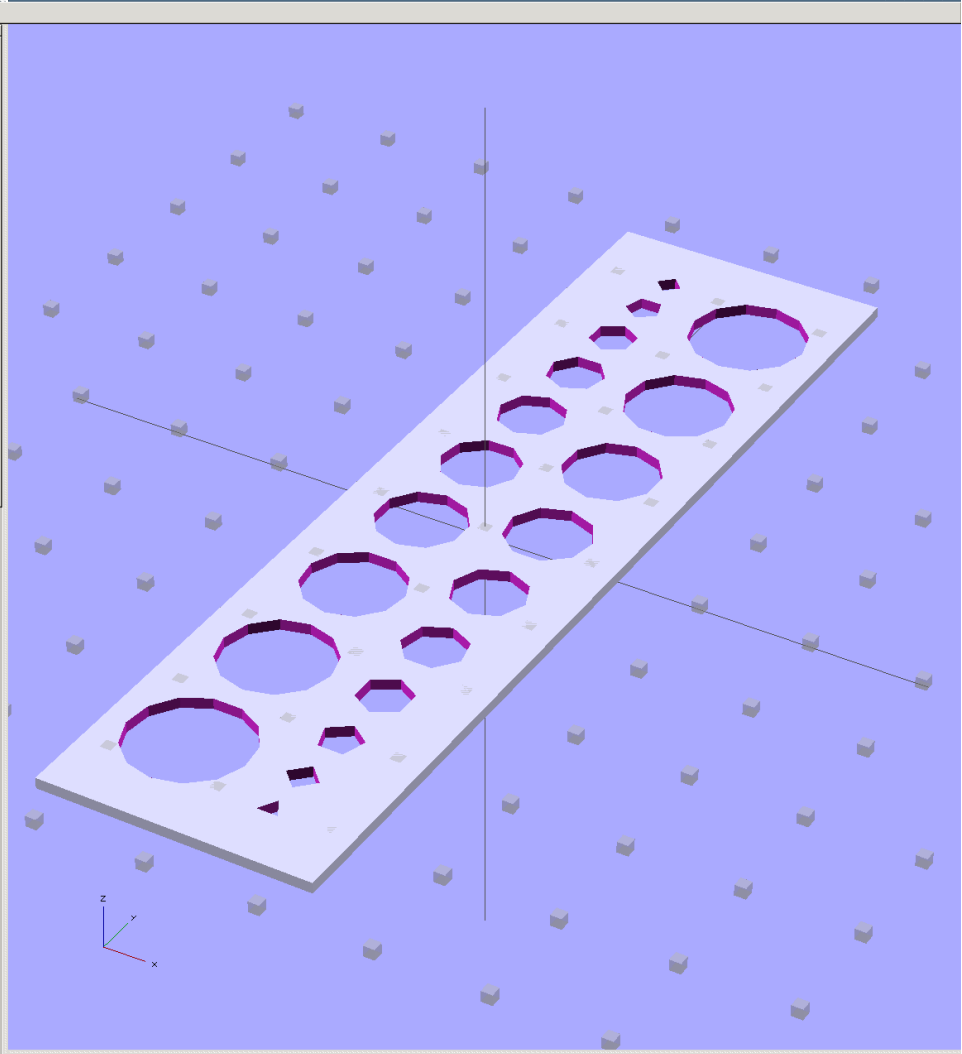
Based on Nophead's Polygonal Holes
http://hydraraptor.blogspot.com/2011/02/polyholes.html

Hole Size Test Piece

OpenSCAD - Small Circle Cal.scad*

File Edit Design View Help

```
// Small circle diameter calibration
// Adapted from Nophead's polyholes testpiece
// Ed Nisley - KE4ZNU - Nov 2011

//-------
//- Extrusion parameters must match reality!
//  Print with +1 shells, 3 solid layers

ThreadThick = 0.25;
ThreadWidth = 2.0 * ThreadThick;

HoleFinagle = 0.20;
HoleFudge = 1.00;

function HoleAdjust(Diameter) = HoleFudge*Diameter + HoleFinagle;

Protrusion = 0.1;    // make holes end cleanly

function IntegerMultiple(Size,Unit) = Unit * ceil(Size / Unit);

//-------
// Dimensions

DiaStep = 1.0;

NumHoles = 10;

Border = 5*ThreadWidth;

AllHoleLength = DiaStep*(NumHoles*(NumHoles + 1)/2) + // total hole
dia
      (NumHoles + 1)*Border +       // total border size
      DiaStep*NumHoles/2;         // radius of largest hole

BlockLength = AllHoleLength + 2*Border;
BlockWidth = 2*NumHoles*DiaStep + 2*Border;
BlockThick = IntegerMultiple(1.0,ThreadThick);

echo("Length: ",BlockLength);
```

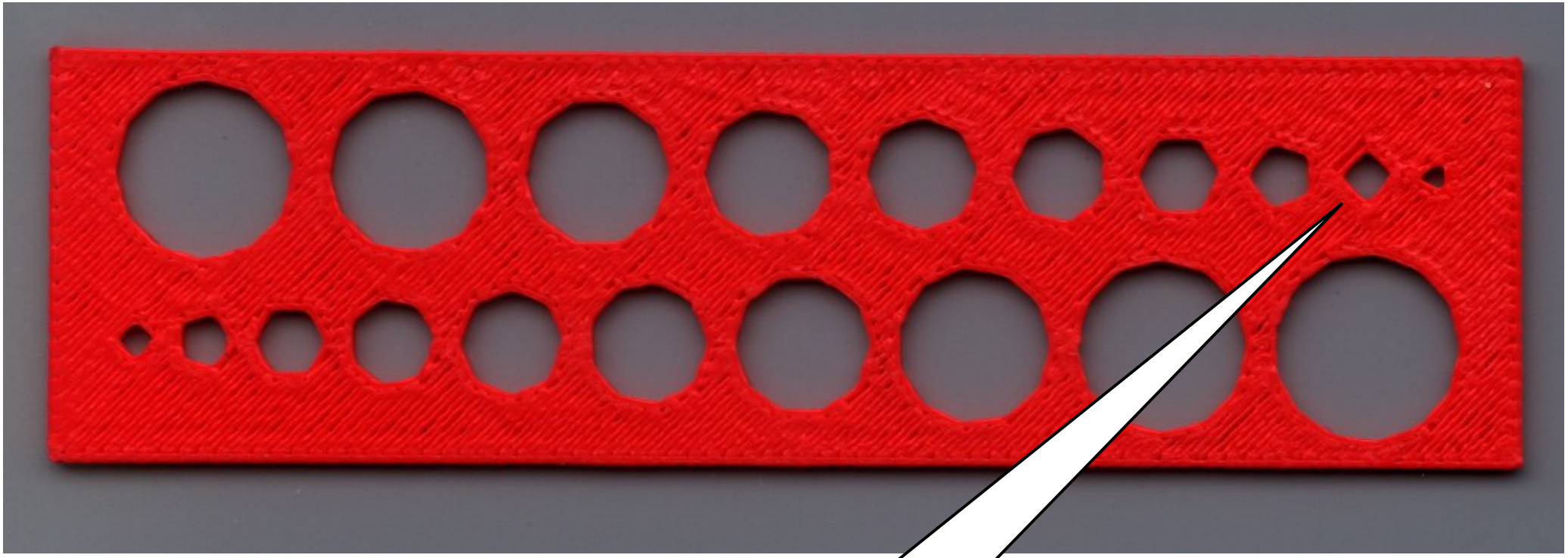


```
CGAL Polyhedrons in cache: 389
CGAL cache size in bytes: 7579996
Compiling design (CSG Products normalization)...
Compiling background (121 CSG Trees)...
Normalized CSG tree has 21 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [0.00 0.00 0.00], rotate = [55.00 0.00 30.60], distance = 405.00

http://softsolder.com/2011/11/25/thing-o-matic-small-hole-calibration/

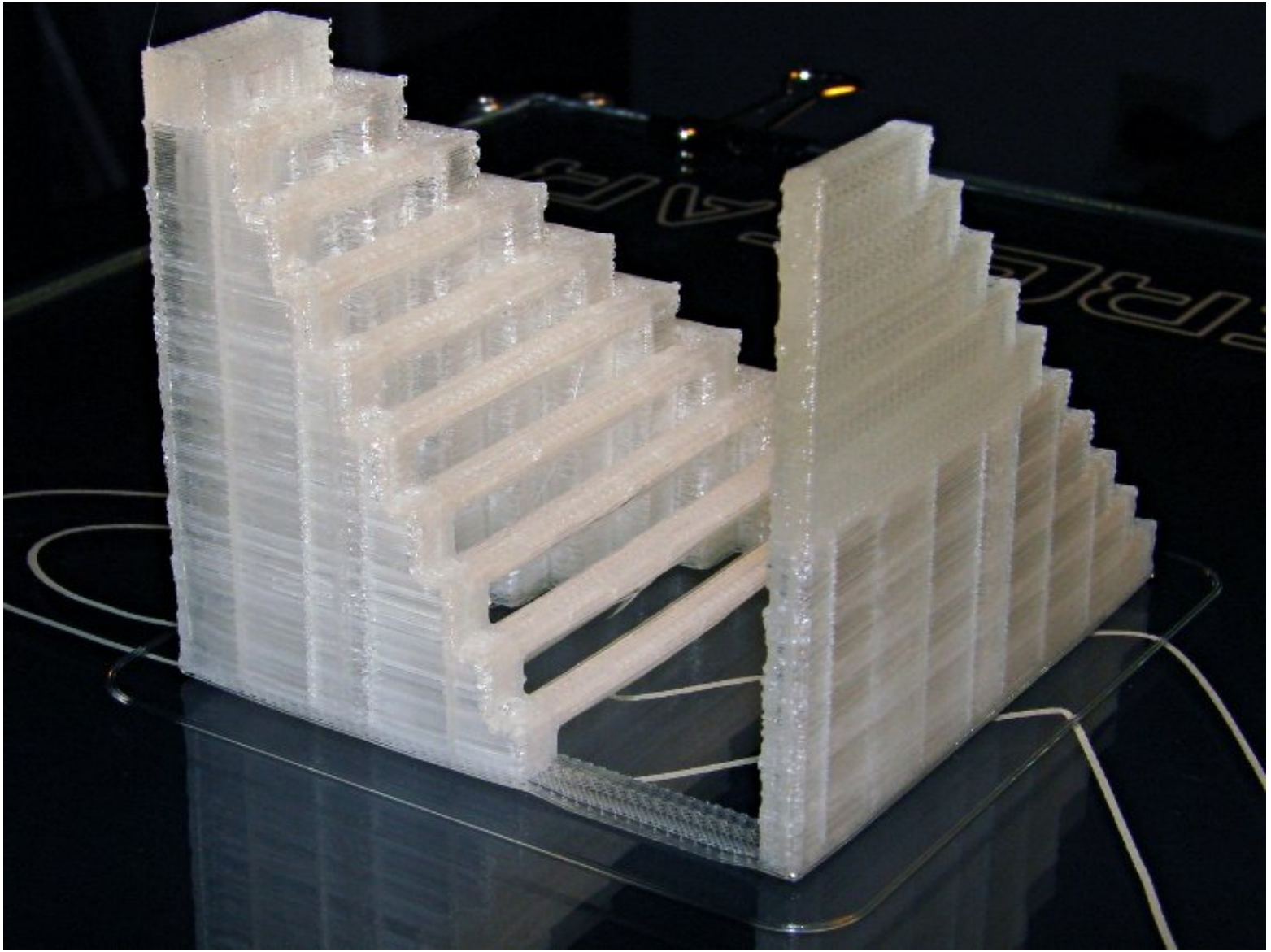
Hole Size Test Piece



Circumscribes
original diameter

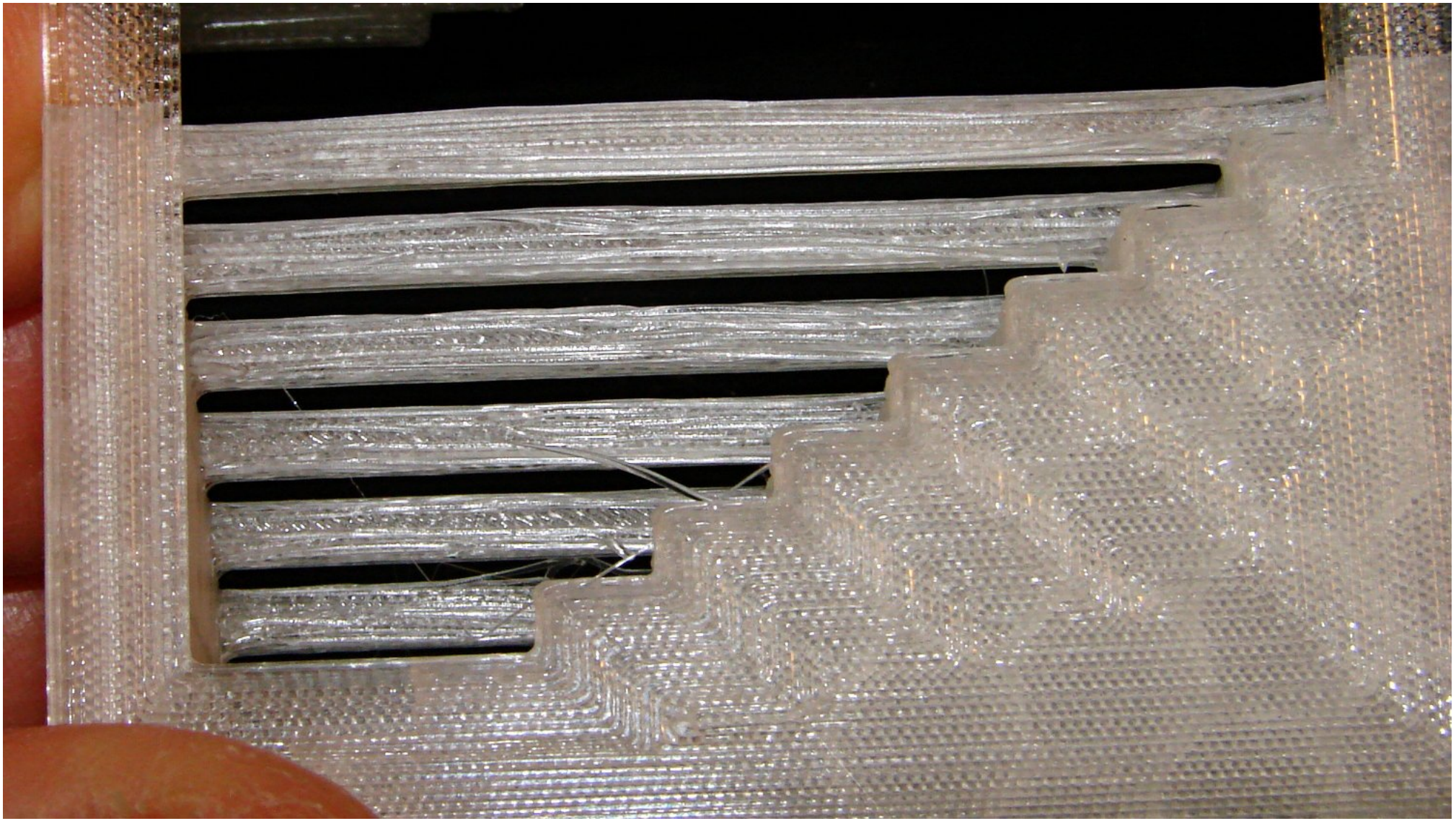
http://softsolder.com/2011/11/25/thing-o-matic-small-hole-calibration/

Bridge Test Piece



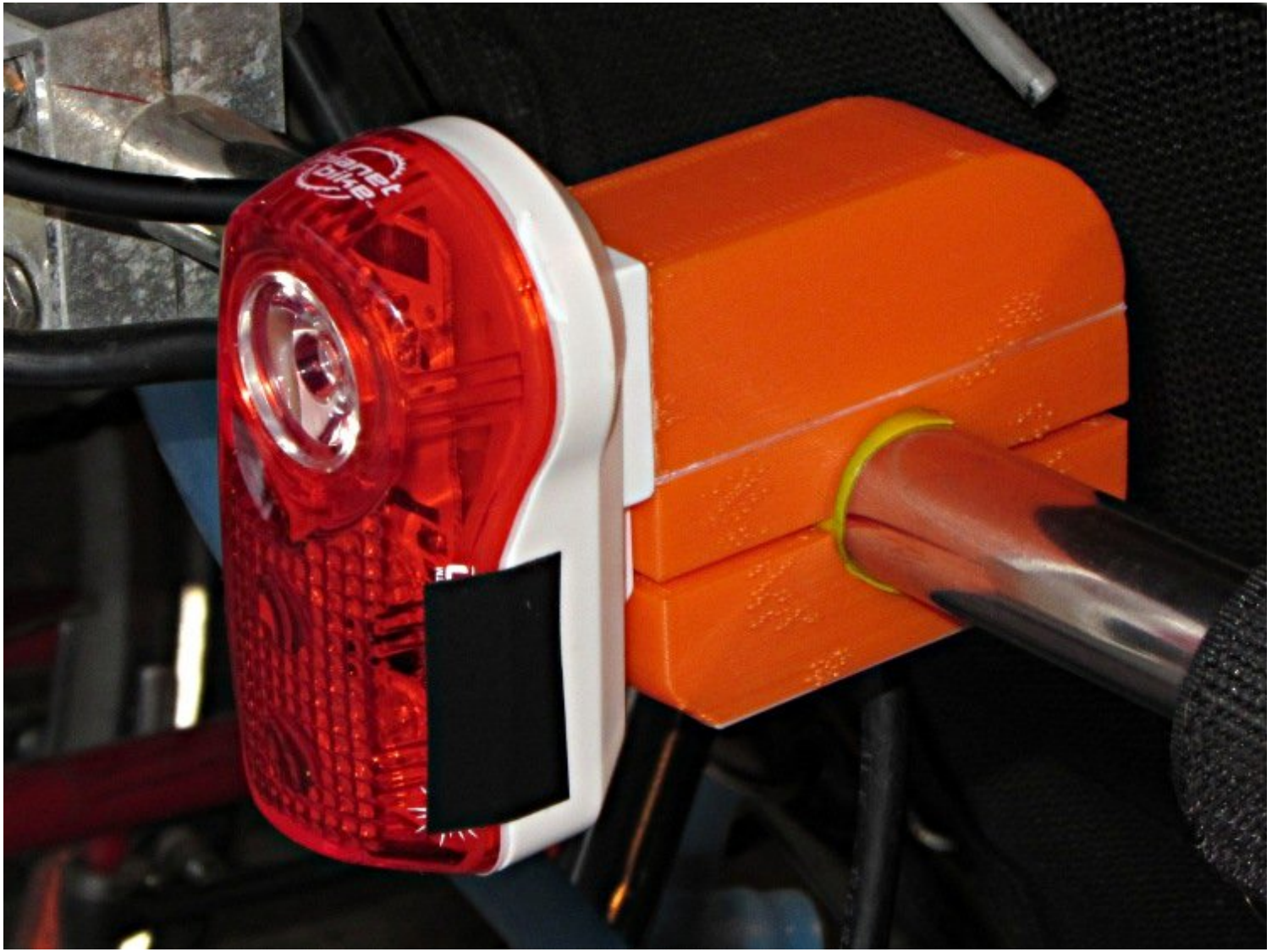
http://www.thingiverse.com/thing:9804

Bridge Test



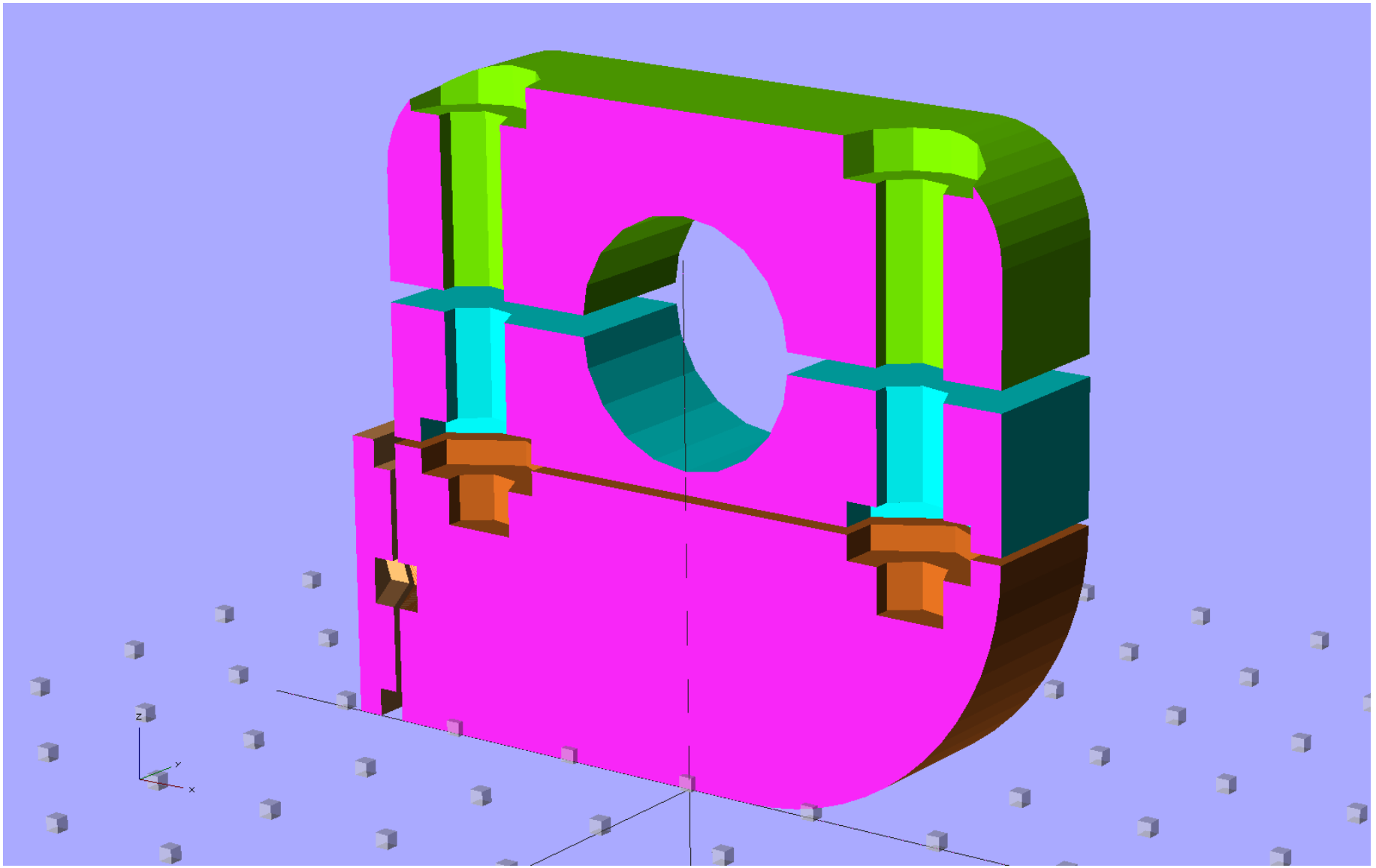
http://www.thingiverse.com/thing:9804

Overhang



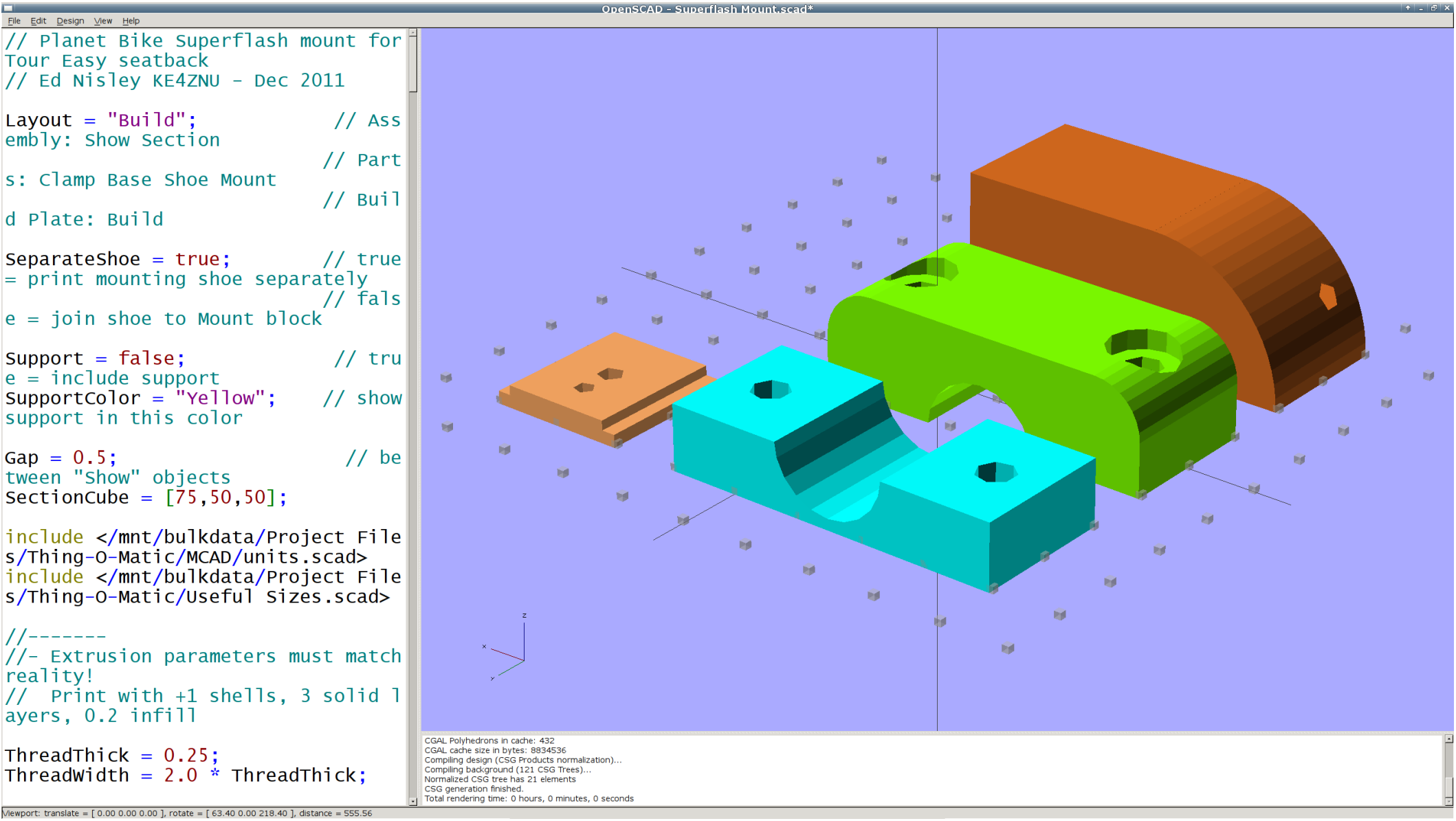
http://softsolder.com/2012/01/03/planet-bike-superflash-tour-easy-mount/

Overhang vs. Bridging



http://softsolder.com/2012/01/03/planet-bike-superflash-tour-easy-mount/

Overhang and Bridging



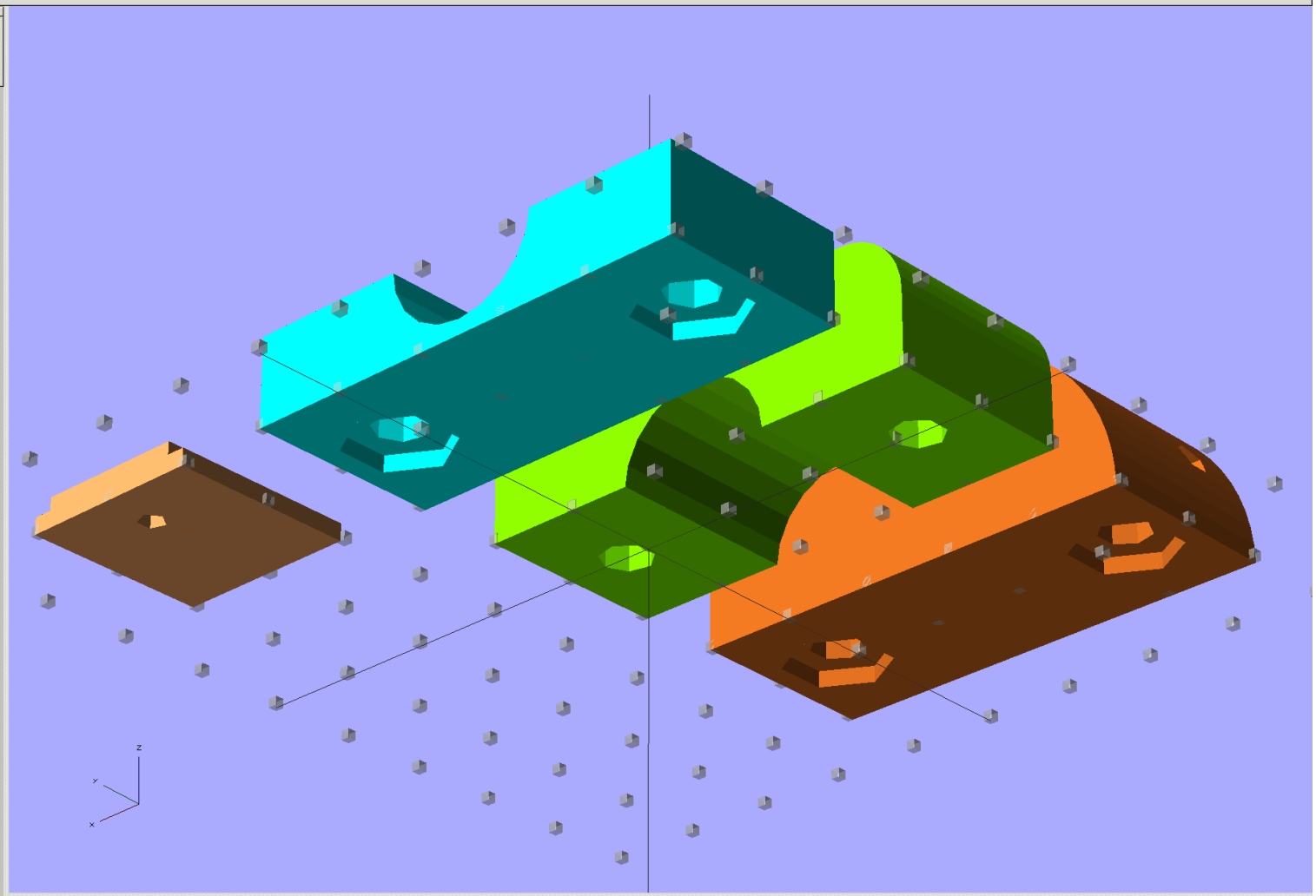
http://softsolder.com/2012/01/03/planet-bike-superflash-tour-easy-mount/

Overhang and Bridging

OpenSCAD - Superflash Mount.scad*

File Edit Design View Help

```
// Planet Bike Superflash mount for
Tour Easy seatback
// Ed Nisley KE4ZNU - Dec 2011

Layout = "Build";              // Ass
embly: Show Section
                               // Part
s: Clamp Base Shoe Mount
                               // Buil
d Plate: Build

SeparateShoe = true;           // true
= print mounting shoe separately
                               // fals
e = join shoe to Mount block

Support = false;               // tru
e = include support
SupportColor = "Yellow";       // show
support in this color

Gap = 0.5;                      // be
tween "Show" objects
SectionCube = [75,50,50];

include </mnt/bulkdata/Project File
s/Thing-O-Matic/MCAD/units.scad>
include </mnt/bulkdata/Project File
s/Thing-O-Matic/Useful Sizes.scad>

//-------
//- Extrusion parameters must match
reality!
//  Print with +1 shells, 3 solid l
ayers, 0.2 infill

ThreadThick = 0.25;
ThreadWidth = 2.0 * ThreadThick;
```



```
CGAL Polyhedrons in cache: 432
CGAL cache size in bytes: 8834536
Compiling design (CSG Products normalization)...
Compiling background (121 CSG Trees)...
Normalized CSG tree has 21 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [-4.11 2.83 7.90], rotate = [118.70 0.00 222.60], distance = 500.00

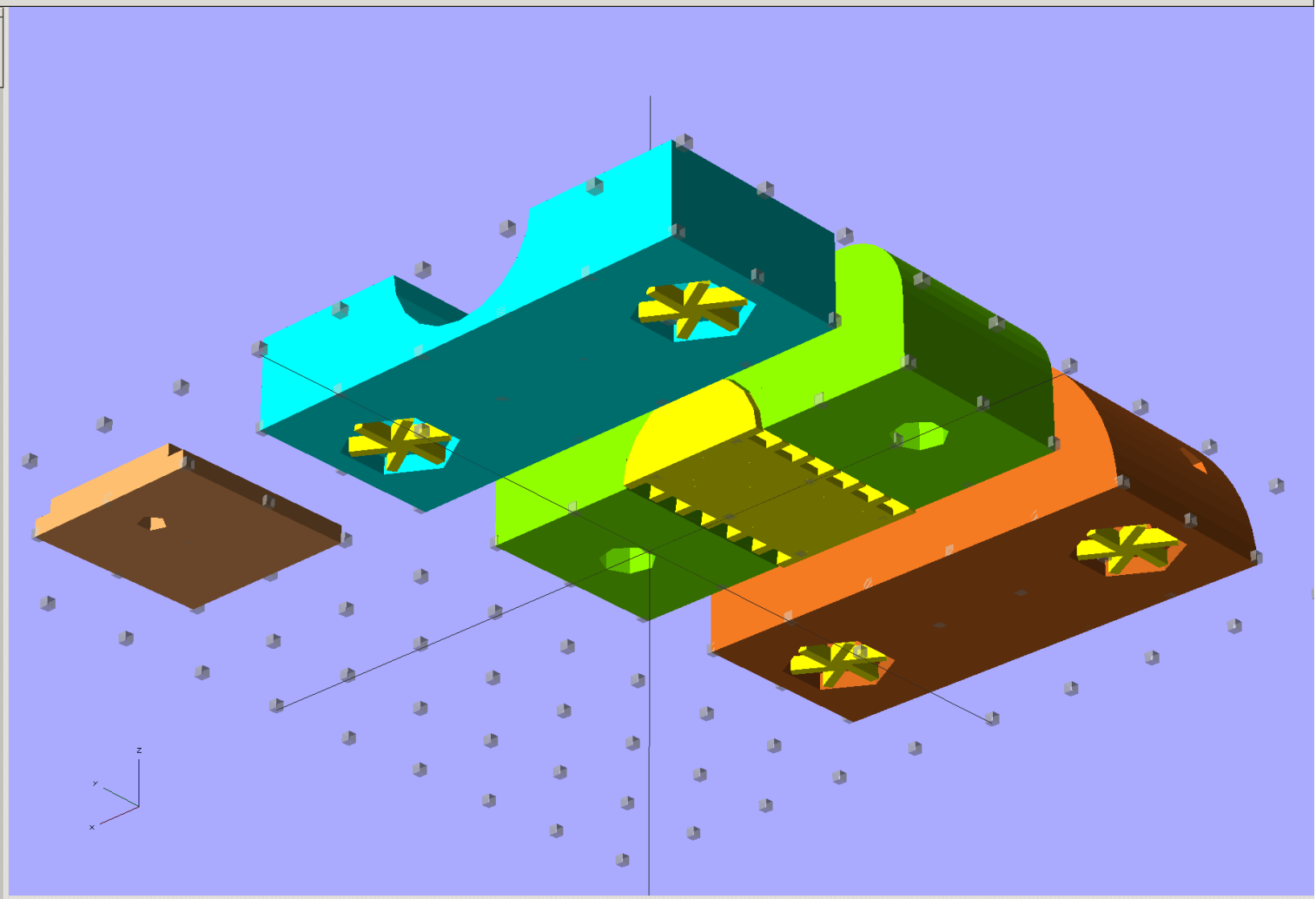
http://softsolder.com/2012/01/03/planet-bike-superflash-tour-easy-mount/

Support Structures!

OpenSCAD - Superflash Mount.scad*

File Edit Design View Help

```
// Planet Bike Superflash mount for
Tour Easy seatback
// Ed Nisley KE4ZNU - Dec 2011

Layout = "Build";              // Ass
embly: Show Section
                               // Part
s: Clamp Base Shoe Mount
                               // Buil
d Plate: Build

SeparateShoe = true;           // true
= print mounting shoe separately
                               // fals
e = join shoe to Mount block

Support = true;                // true
= include support
SupportColor = "Yellow";       // show
support in this color

Gap = 0.5;                      // be
tween "Show" objects
SectionCube = [75,50,50];

include </mnt/bulkdata/Project File
s/Thing-O-Matic/MCAD/units.scad>
include </mnt/bulkdata/Project File
s/Thing-O-Matic/Useful Sizes.scad>

//-------
//- Extrusion parameters must match
reality!
//  Print with +1 shells, 3 solid l
ayers, 0.2 infill

ThreadThick = 0.25;
ThreadWidth = 2.0 * ThreadThick;
```



```
CGAL Polyhedrons in cache: 432
CGAL cache size in bytes: 8834536
Compiling design (CSG Products normalization)...
Compiling background (121 CSG Trees)...
Normalized CSG tree has 60 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [-4.11 2.83 7.90], rotate = [118.70 0.00 222.60], distance = 500.00

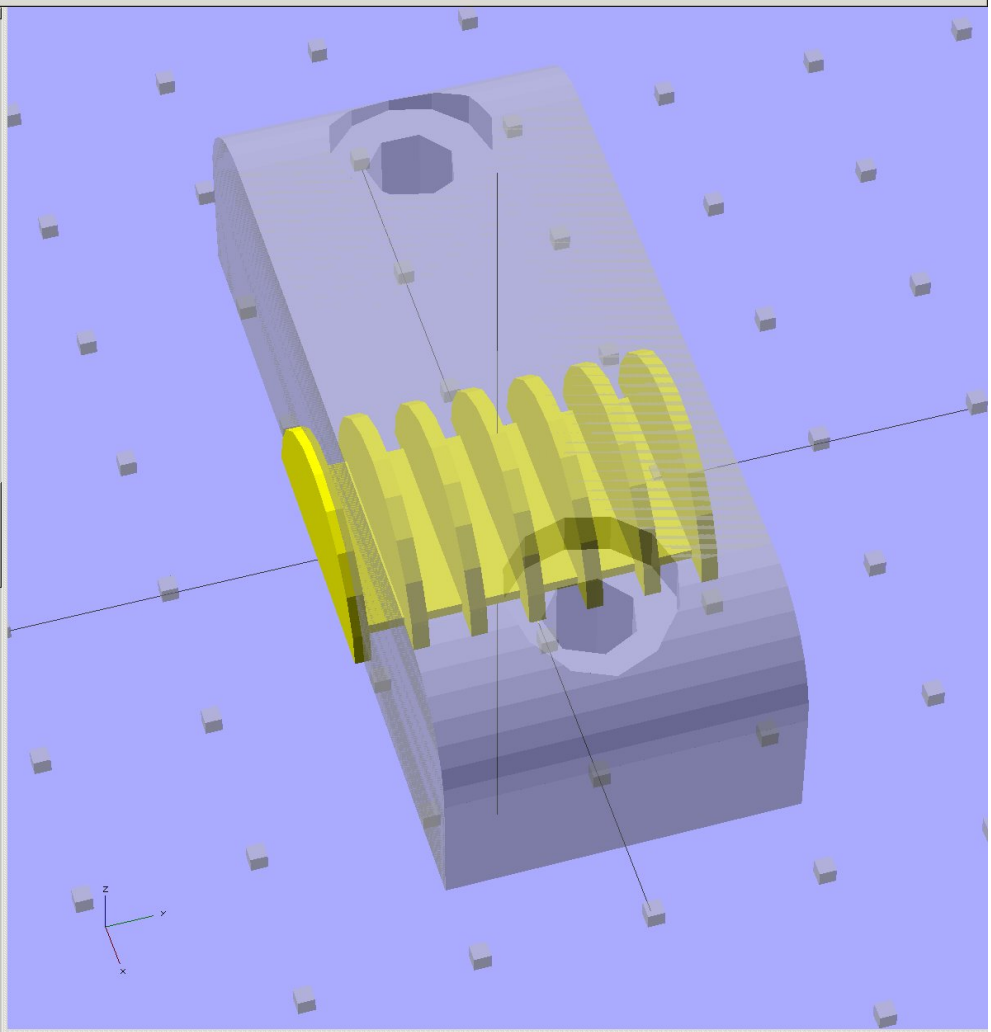
http://softsolder.com/2012/01/03/planet-bike-superflash-tour-easy-mount/

Bridge (?) Support Structure

OpenSCAD - Superflash Mount.scad*

File Edit Design View Help

```
  }

  if (Support)
  color(SupportColor)
  union() {
    translate([0,0,1.5*ThreadThick])
    cube([0.75*HoleDia,(MountWidth + 2*ThreadWidth),3*ThreadThick],
         center=true);
    intersection() {
    for (Index=[-3:3])
      translate([0,Index*(MountWidth/6),-TightSpace/2])
      rotate([90,0,0])
        cylinder(r=(HoleRad - 0.25*ThreadThick),
           h=2*ThreadWidth,center=true,$fn=HoleSides);
    translate([-HoleRad,-0.6*MountWidth,0])
      cube([HoleDia,1.2*MountWidth,HoleRad]);
    }
  }
}

//-------
// Lower clamp half = base

module Base() {

  color("Cyan")
  difference() {
    translate([0,0,-TightSpace/2])
      difference() {
        translate([0,0,BaseHeight/2])
          cube([MountLength,MountWidth,BaseHeight],center=true);
        translate([0,(MountWidth/2 + Protrusion)])
          rotate([90,0,0])
            PolyCyl(HoleDia,(MountWidth + 2*Protrusion),HoleSides)
;
        for (Index=[-1,1])
          translate([(Index*BoltOffset),0,0]) {
            translate([0,0,-Protrusion])
              PolyCyl(BoltClear,(BaseHeight + Protrusion));
```

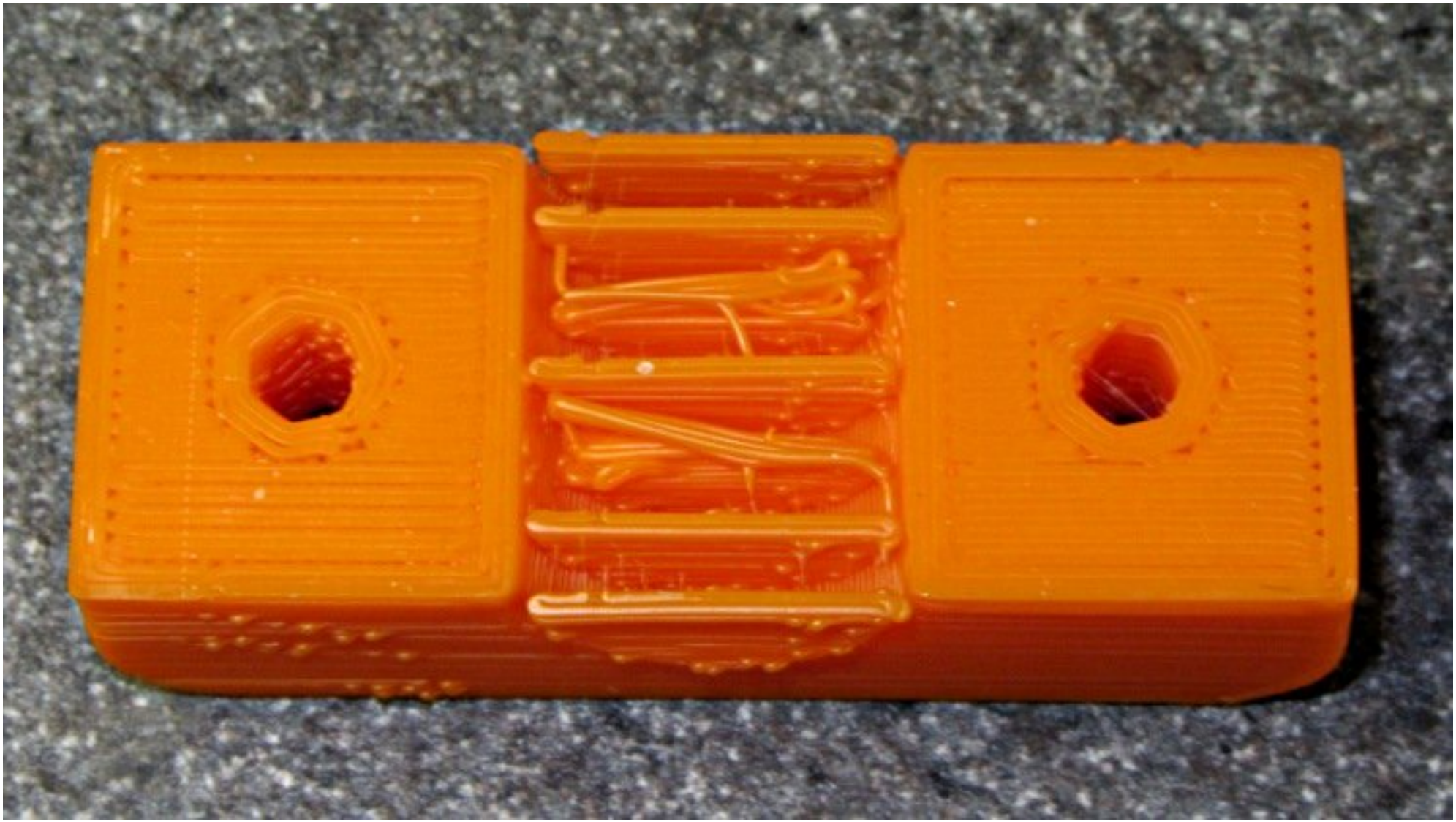


```
CGAL Polyhedrons in cache: 432
CGAL cache size in bytes: 8834536
Compiling design (CSG Products normalization)...
Compiling background (122 CSG Trees)...
Normalized CSG tree has 15 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [0.00 0.00 0.00], rotate = [39.60 0.00 73.30], distance = 295.25

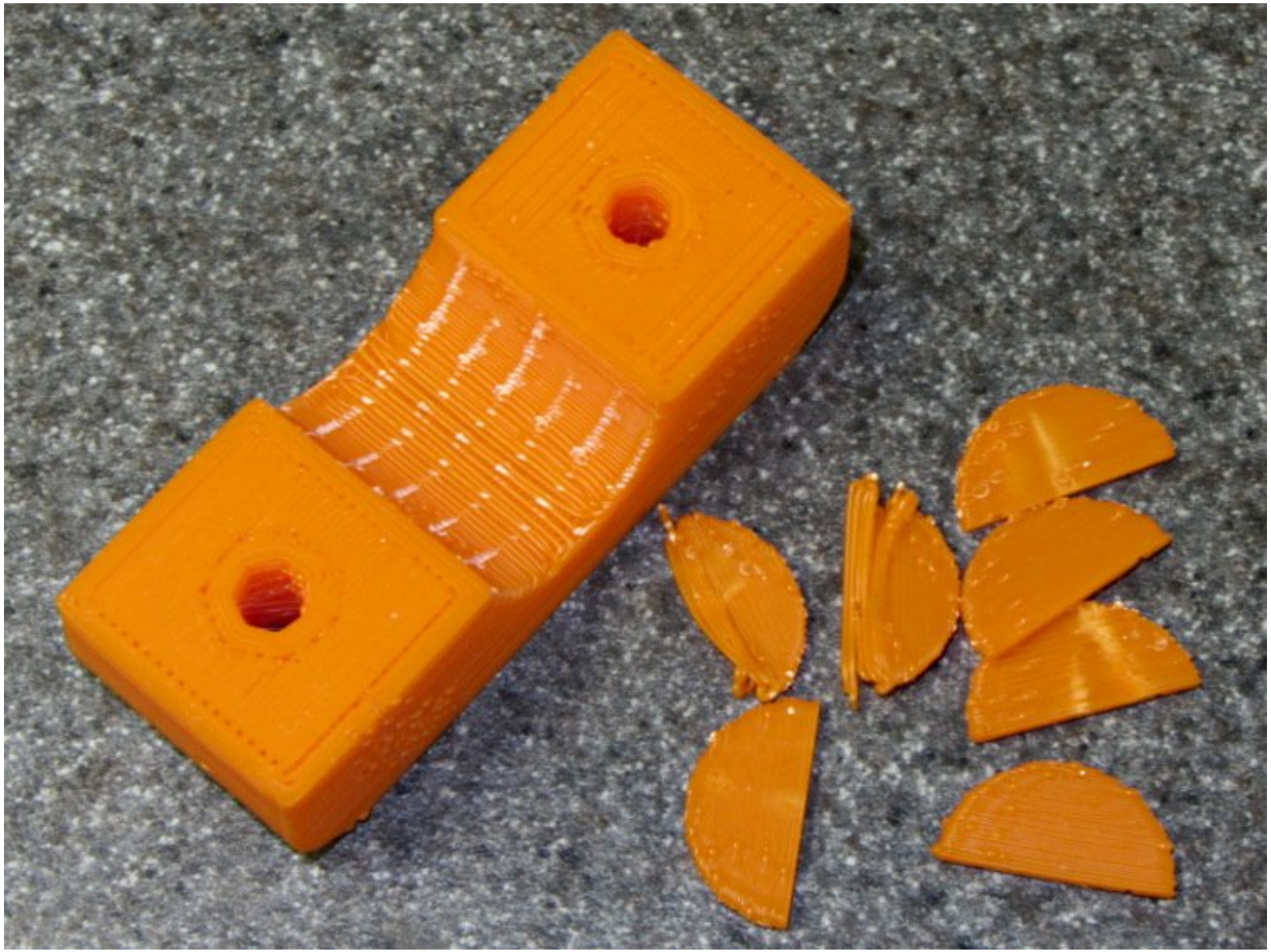
http://softsolder.com/2012/01/03/planet-bike-superflash-tour-easy-mount/

Support Structure: Oops



http://softsolder.com/2012/01/03/planet-bike-superflash-tour-easy-mount/

Support Structure



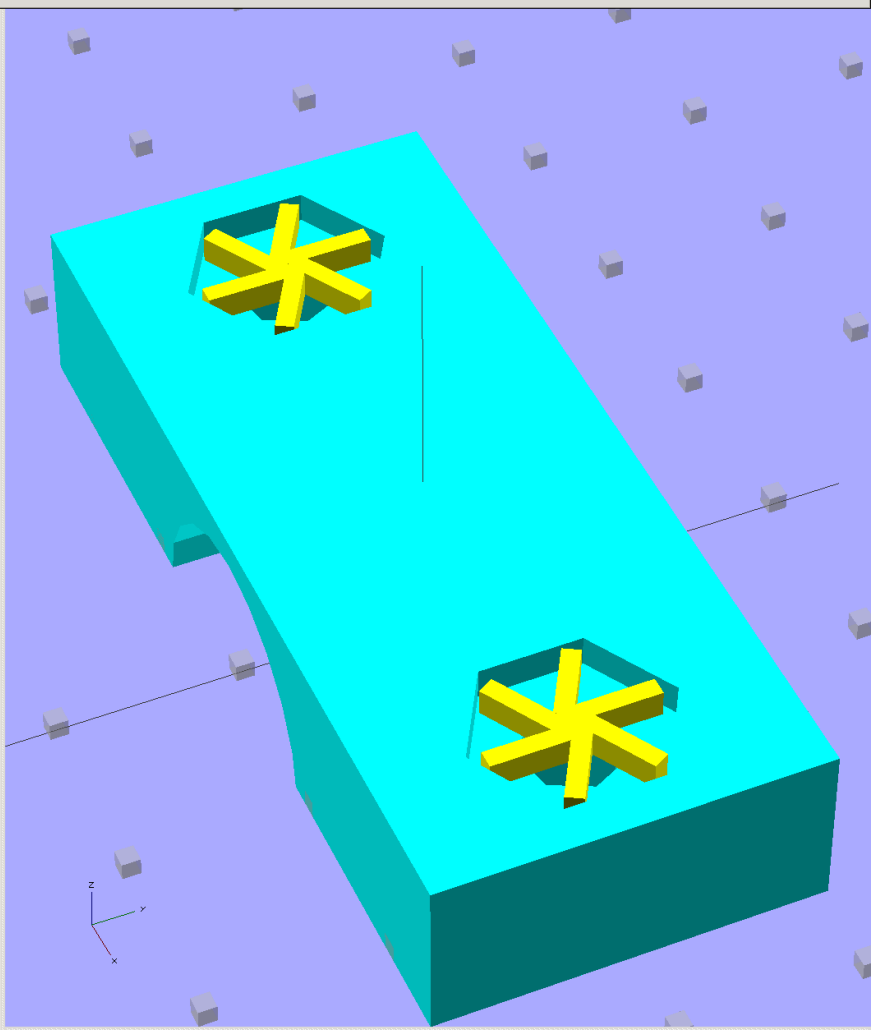
http://softsolder.com/2012/01/03/planet-bike-superflash-tour-easy-mount/

Overhang Support Structure

OpenSCAD - Superflash Mount.scad*

File Edit Design View Help

```
  if (Support)
    color(SupportColor)
    for (Index=[-1,1])
      translate([(Index*BoltOffset),
                 0,
                 (BaseHeight - (NutPart - ThreadThick) - TightSpace/2)]) {
        translate([0,0,0])
          for (Seg=[0:5]) {
            rotate(30 + 360*Seg/6)
              cube([NutDia/2,2*ThreadWidth,NutPart - ThreadThick],
                   center=false);
          }
      }


}

//-------
// Superflash mounting shoe
// Offset by -ShoeOffset/2 in Y to align on Mount (half of total offset o
n each side)

module Shoe() {

  color("SandyBrown")
  difference() {
 translate([-ShoeThick/2,-ShoeOffset/2,PlateWidth/2])
    if (SeparateShoe)
   cube([ShoeThick,PlateLength,PlateWidth],center=true);
    else
   cube([(ShoeThick + Protrusion),PlateLength,PlateWidth],center=true);


 translate([-(FlangeThick - Protrusion),
      -(PlateLength/2 + ShoeOffset/2 + Protrusion),
      (MountHeight - FlangeWidth)])
   cube([FlangeThick,(PlateLength + 2*Protrusion),(FlangeWidth + Protrus
ion)]);
```

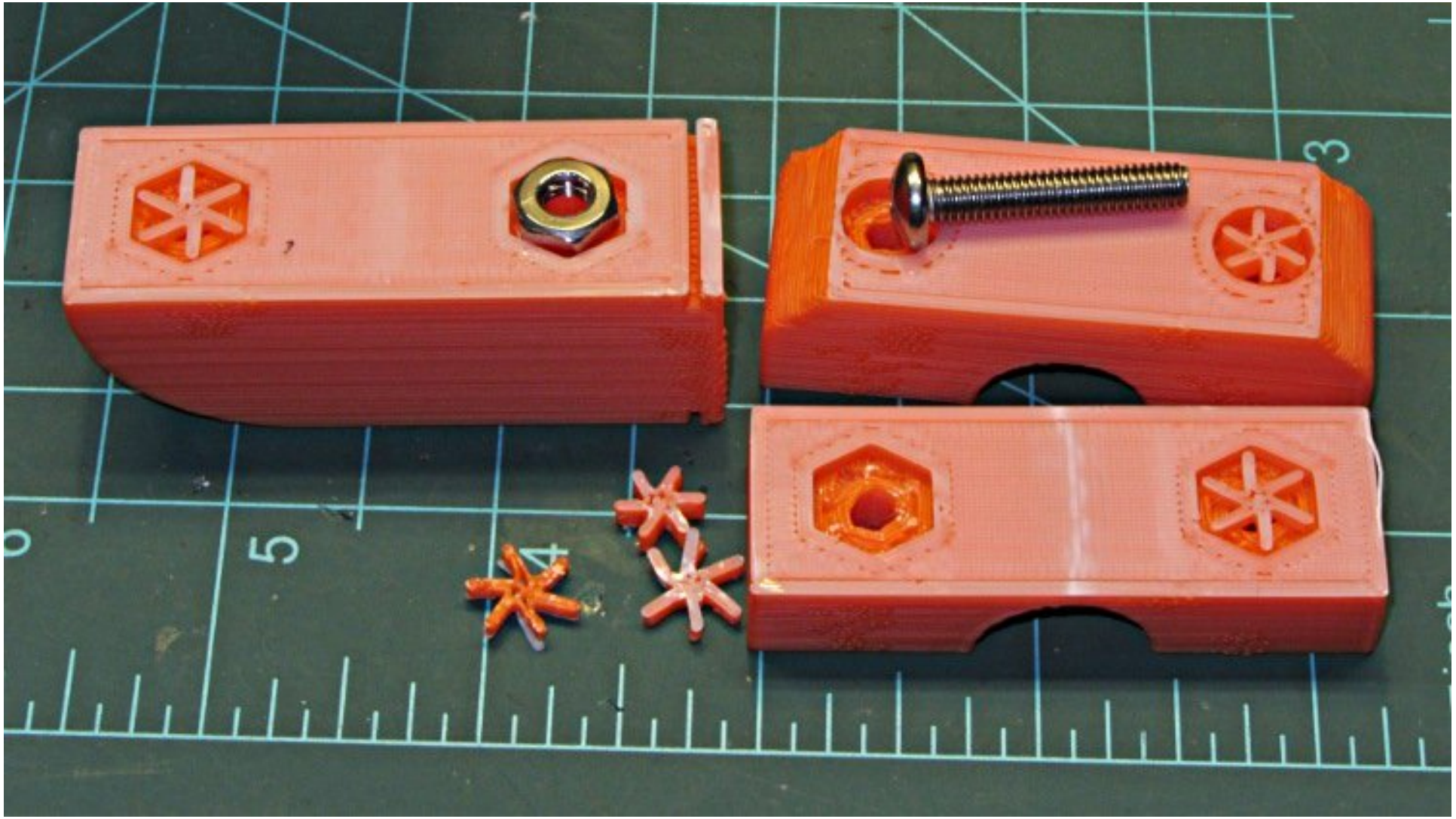


```
CGAL Polyhedrons in cache: 432
CGAL cache size in bytes: 8834536
Compiling design (CSG Products normalization)...
Compiling background (121 CSG Trees)...
Normalized CSG tree has 19 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [-2.14 1.76 4.33], rotate = [45.20 0.00 66.30], distance = 239.15

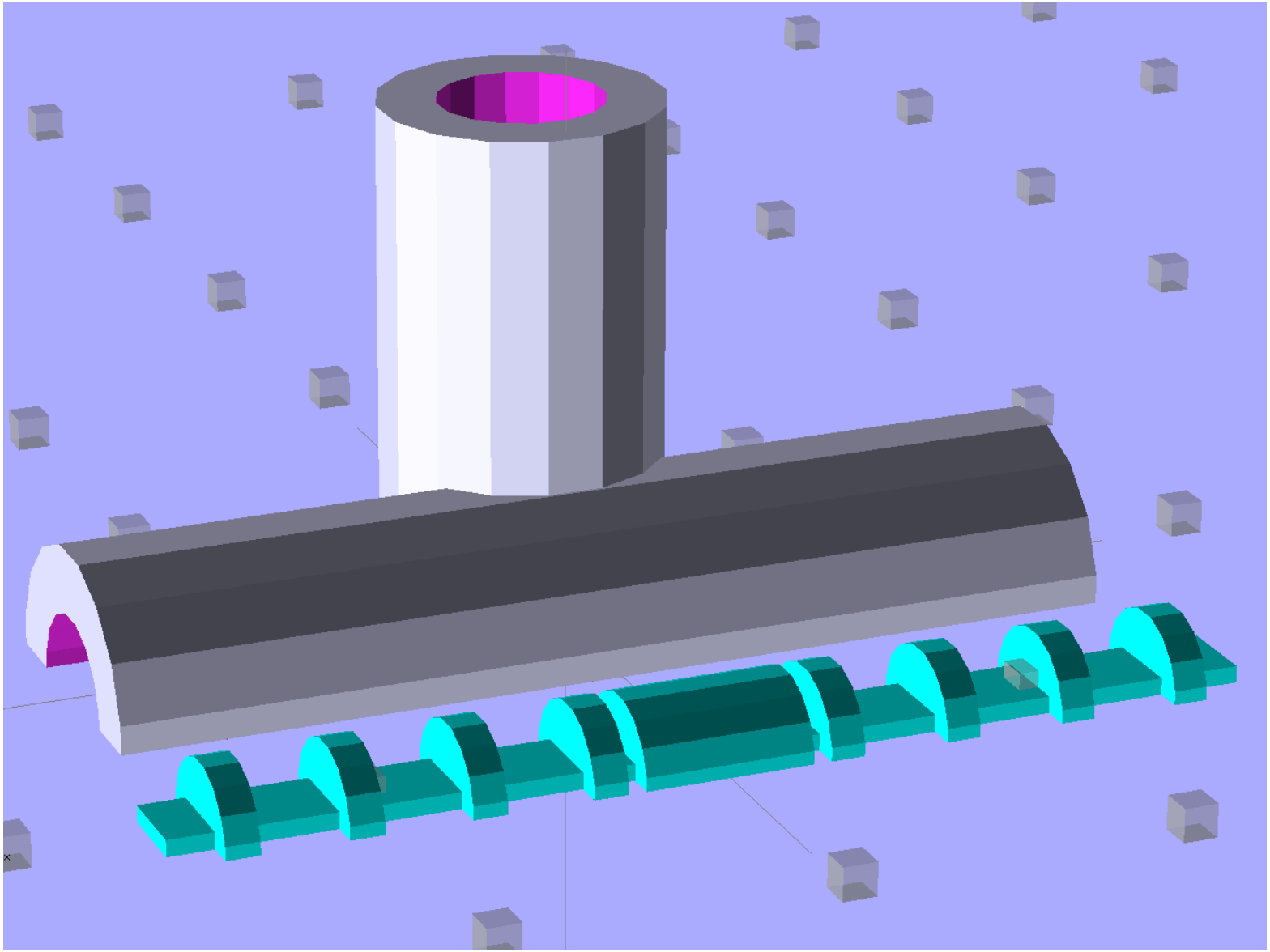
http://softsolder.com/2012/01/03/planet-bike-superflash-tour-easy-mount/

Support Structures!



http://softsolder.com/2012/01/03/planet-bike-superflash-tour-easy-mount/

Bridge (?) Support Structure



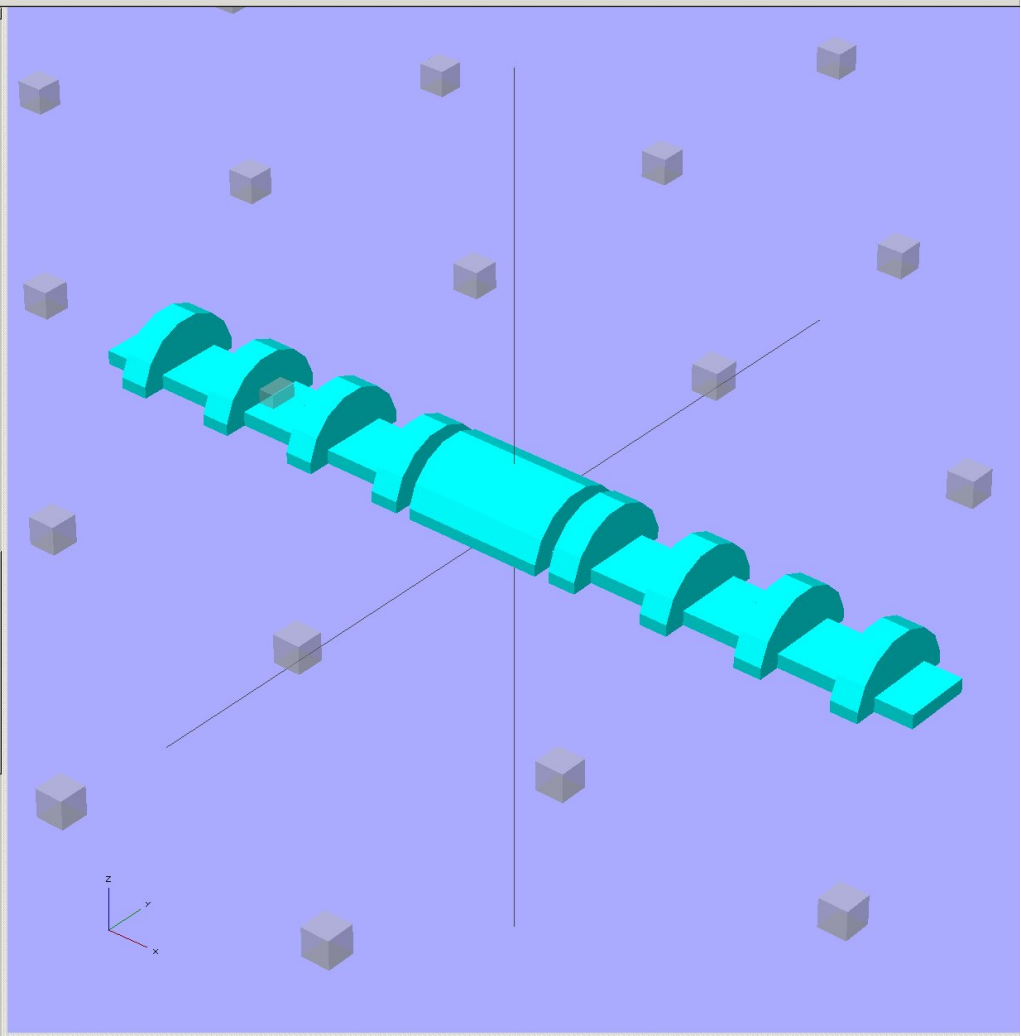
http://softsolder.com/2013/02/04/dishwasher-rack-protectors-into-the-maw/

Support Structure

OpenSCAD - Rack Protector.scad*

File Edit Design View Help

```
module SupportStructure() {

  color("cyan")
  difference() {
    union() {
      for (Index=[-4:4])
        translate([Index*(BarTubeLength/8.5),0,0])
          rotate([0,90,0])
            rotate(180/TubeSides)
              cylinder(r=SupportClear*BarRadius,
                       h=2*ThreadWidth,
                       center=true);

      rotate([0,90,0])
        rotate(180/TubeSides)
          cylinder(r=SupportClear*BarRadius,
                   h=10*ThreadWidth,
                   center=true);

      translate([0,0,ThreadThick])
        cube([(BarTubeLength + 4*ThreadWidth),
              BarRadius,
              2*ThreadThick],
             center=true);
    }

    translate([0,0,-(BarRadius + Protrusion)/2])
      cube([(BarTubeLength + 2*Protrusion),
          BarDia,
          (BarRadius + Protrusion)],center=true);

  }

}

//-------
```



```
CGAL Polyhedrons in cache: 432
CGAL cache size in bytes: 8834536
Compiling design (CSG Products normalization)...
Compiling background (121 CSG Trees)...
Normalized CSG tree has 21 elements
CSG generation finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
```

Viewport: translate = [0.00 0.00 0.00], rotate = [57.10 0.00 39.70], distance = 156.91

http://softsolder.com/2013/02/04/dishwasher-rack-protectors-into-the-maw/

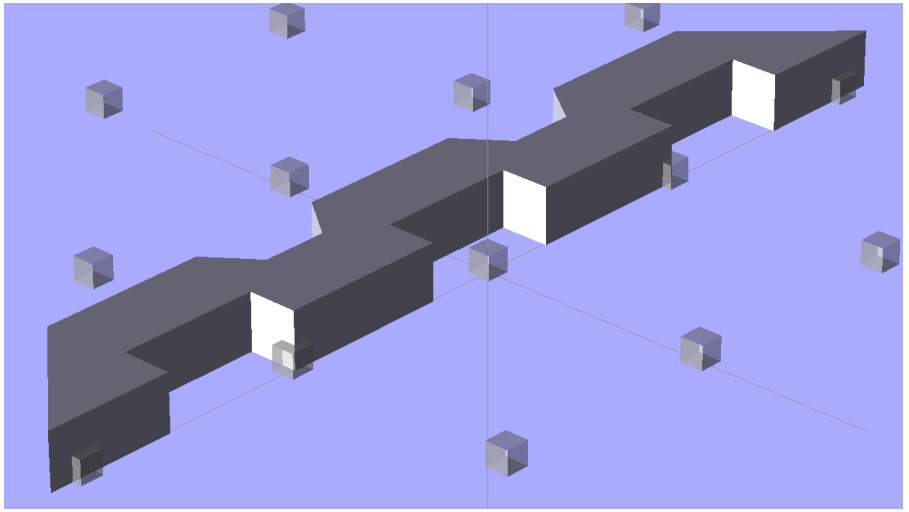
Removing Support Structures

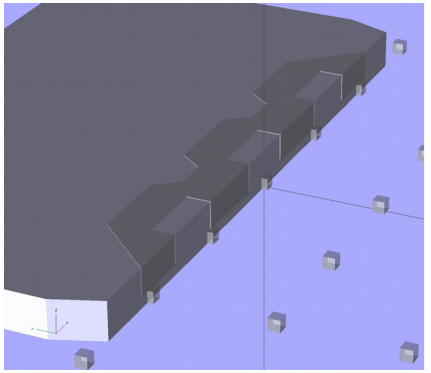
http://softsolder.com/2013/02/04/dishwasher-rack-protectors-into-the-maw/

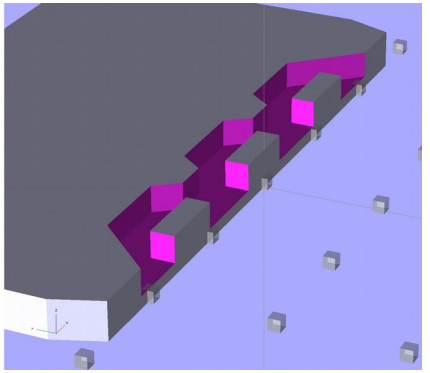
Other Fancy Stuff

Polygons and Polyhedrons

- polygon(…)
  - List of points
  - linear_extrude(...)
- polyhedron(…)
  - List of points
  - List of *faces*
- Calculate the points!
  - Internal precision
  - Direct measurement?



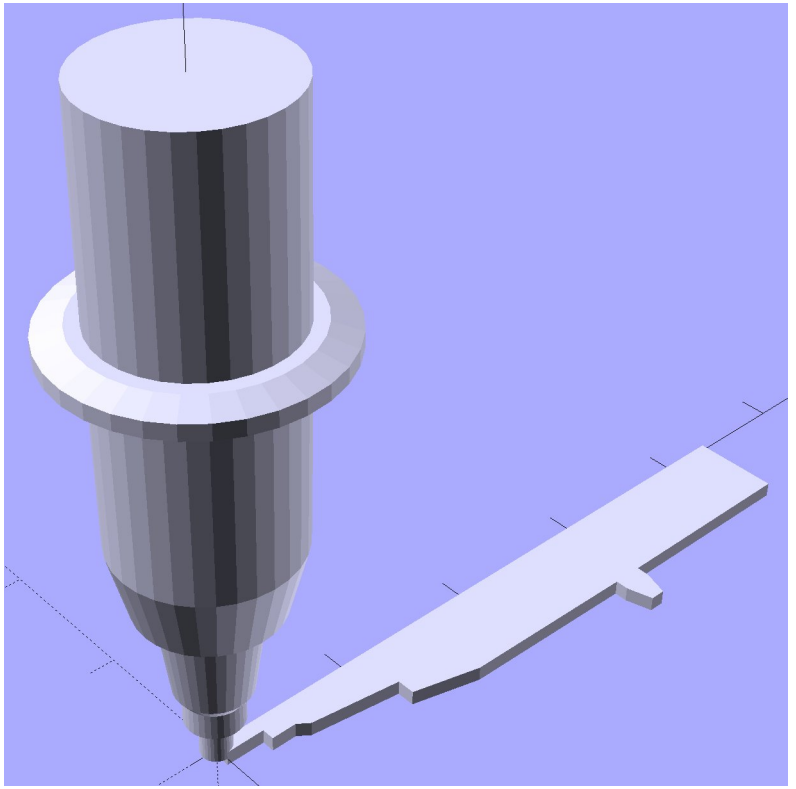




http://softsolder.com/2012/04/05/kg-uv3d-gpsvoice-battery-pack-alignment-lugs/

Rotary Extrusion

- polygon(…)
  - X must be ≥ 0
  - Measured coordinates?
  - Or any other 2D shape
- rotate_extrude(...)
  - Symmetric around Z axis
  - $fn = number of sides



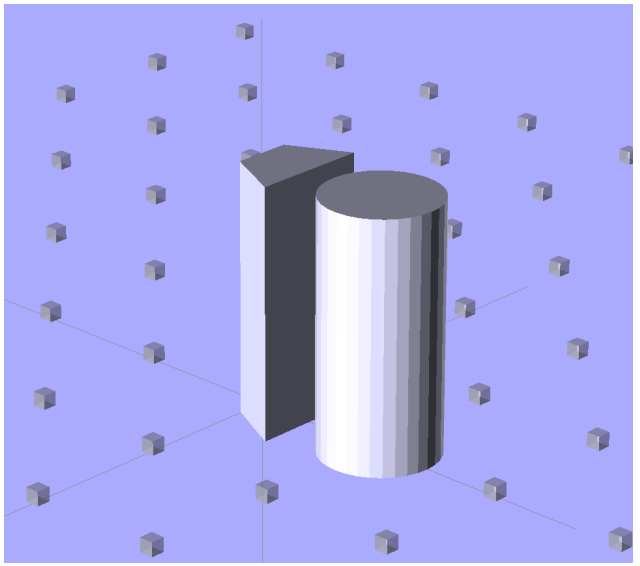
http://softsolder.com/2015/04/21/hp-7475a-plotter-oem-pen-body-model/

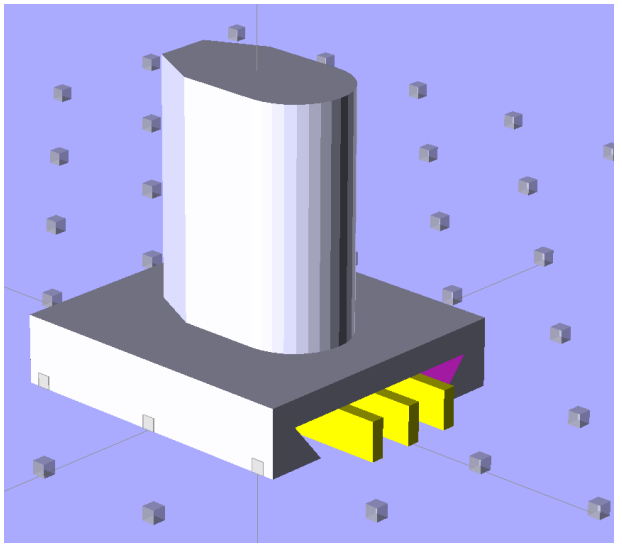
DXF Import & Export

- import() and projection()
- In theory: you can import complex diagrams
- In practice: it's *very* fussy about content
- Good luck...

hull(...)

- 2D figures on XY plane
  - polygon()
  - circle(), square()
  - Then use linear_extrude(…)
- 3D figures in XYZ
  - Shrinkwrap objects

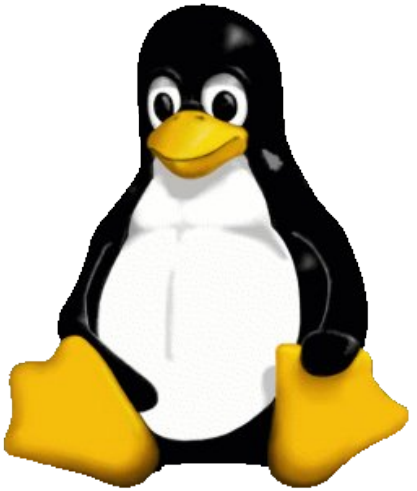


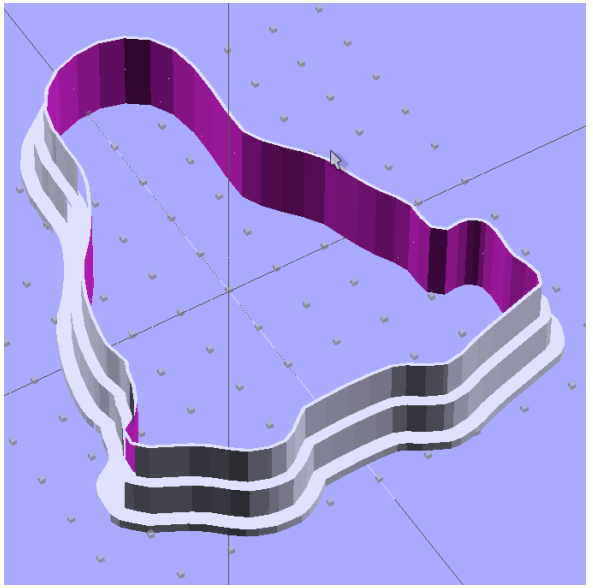


http://softsolder.com/2012/11/02/whirlpool-refrigerator-replacement-freezer-shelf-bracket/

Outlines From Drawings

- Perimeter → Shape
  - Start from EPS
  - Limited resolution
  - Maintain chirality
- A simple matter of software
  - Imagemagick FTW!
  - minkowski() sum

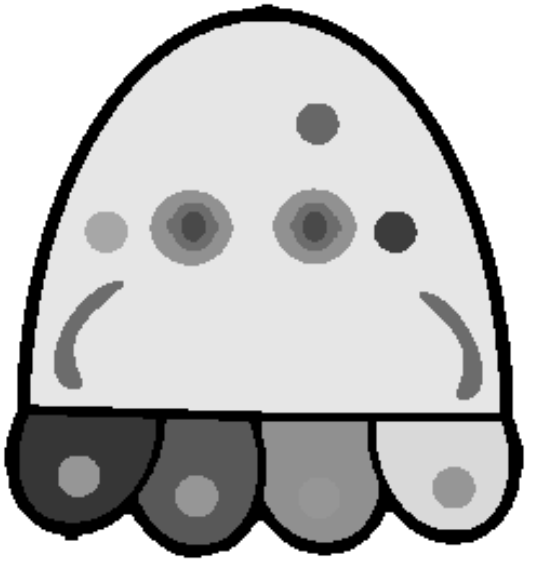




http://softsolder.com/2011/09/07/tux-cookie-cutter/

Surface Height Maps

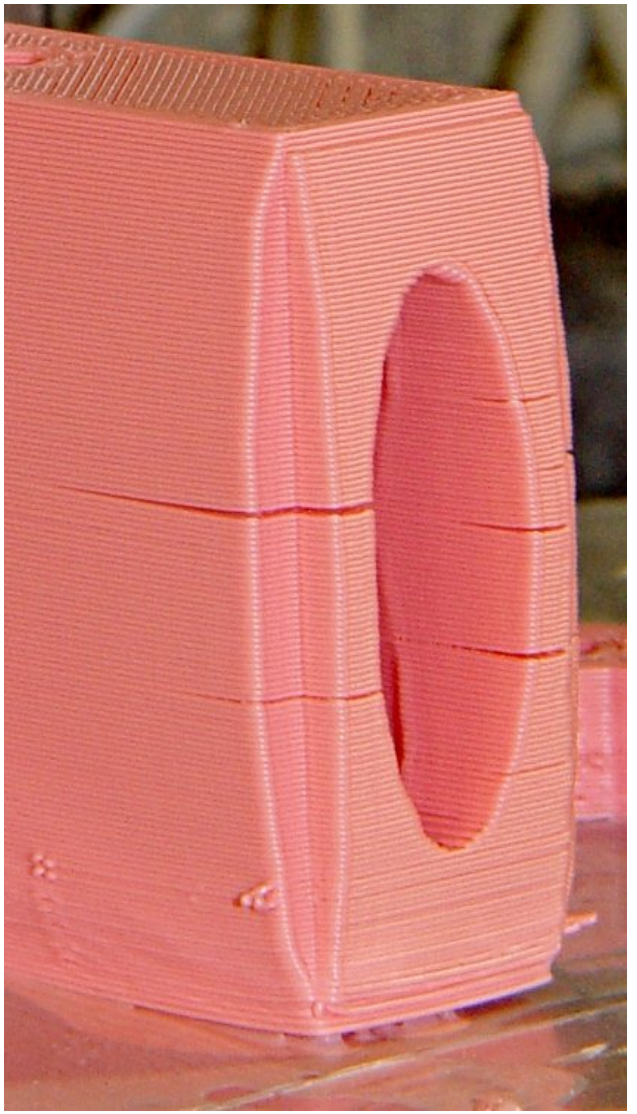
- surface(file=...)
  - Very specific file format
- 8 bit grayscale → Z height
  - Yes, 256 Shades of Grey...
- A simple matter of software
  - Imagemagick FTW!
  - Bash scripting
  - XY resolution limit



http://softsolder.com/2012/11/09/automated-cookie-cutters-putting-it-all-together/

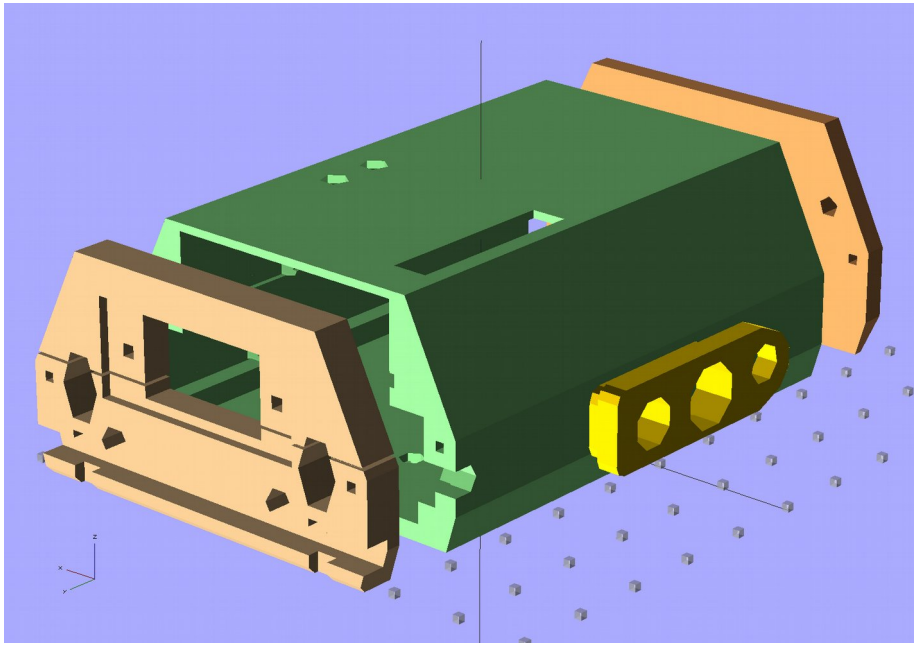
More To Learn ...

- Design for Printability
  - Material properties
  - Platform adhesion
  - Aspect ratios
- Slicing Parameters
  - Infill pattern & density
  - Perimeter control
  - The Need for Speed?
- And. Much. More.



Finally ...

- Start simple
  - Keep it simple
- Math is your friend
  - Measurements!
  - Calculate *everything*
- Slice & Verify G-Code
  - That's another talk...
  - *Always* verify before printing
- Build Stuff You Need!



More Info

reprap.org
www.openscad.org

My *Along the G-Code Way* column
In Digital Machinist magazine

And, of course...
softsolder.com

Copyright-ish Stuff

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[whatever that is]

The rest is my own work

•

Ed Nisley

Say “NISS-lee”, although we're on the half-essed branch of the tree

Engineer (ex PE), Hardware Hacker, Programmer, Author

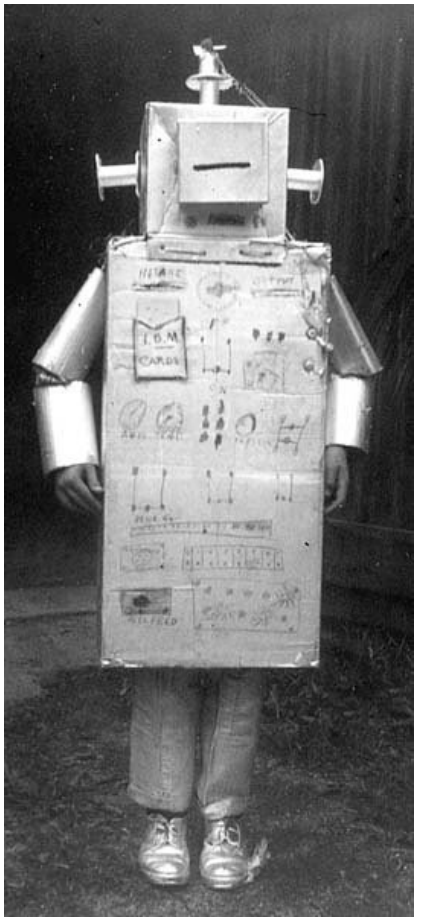
The Embedded PC's ISA Bus: Firmware, Gadgets, Practical Tricks

Circuit Cellar www.circuitcellar.com
- Firmware Furnace (1988-1996) - Nasty, grubby hardware bashing
- Above the Ground Plane (2001 ...) - Analog and RF stuff

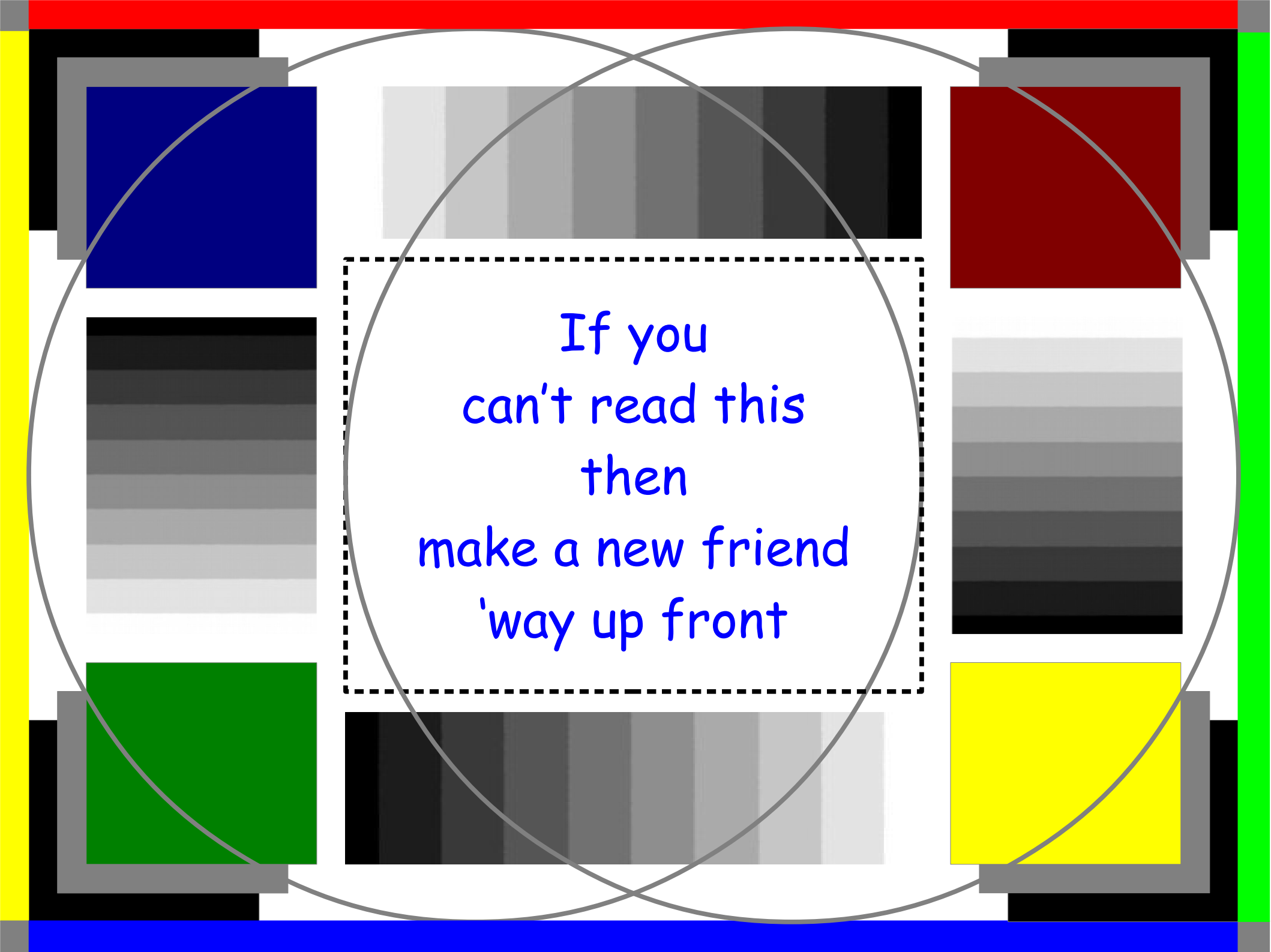
Digital Machinist www.homeshopmachinist.net
- Along the G-Code Way (2008 ...) - G-Code, math, 3D printing

Dr. Dobb’s Journal www.ddj.com
- Embedded Space (2001-2006) - All things embedded
- Nisley’s Notebook (2006-2007) - Hardware & software collisions

My Blog: The Smell of Molten Projects in the Morning
softsolder.com



September 1962


If you
can't read this
then
make a new friend
'way up front