3D Printing

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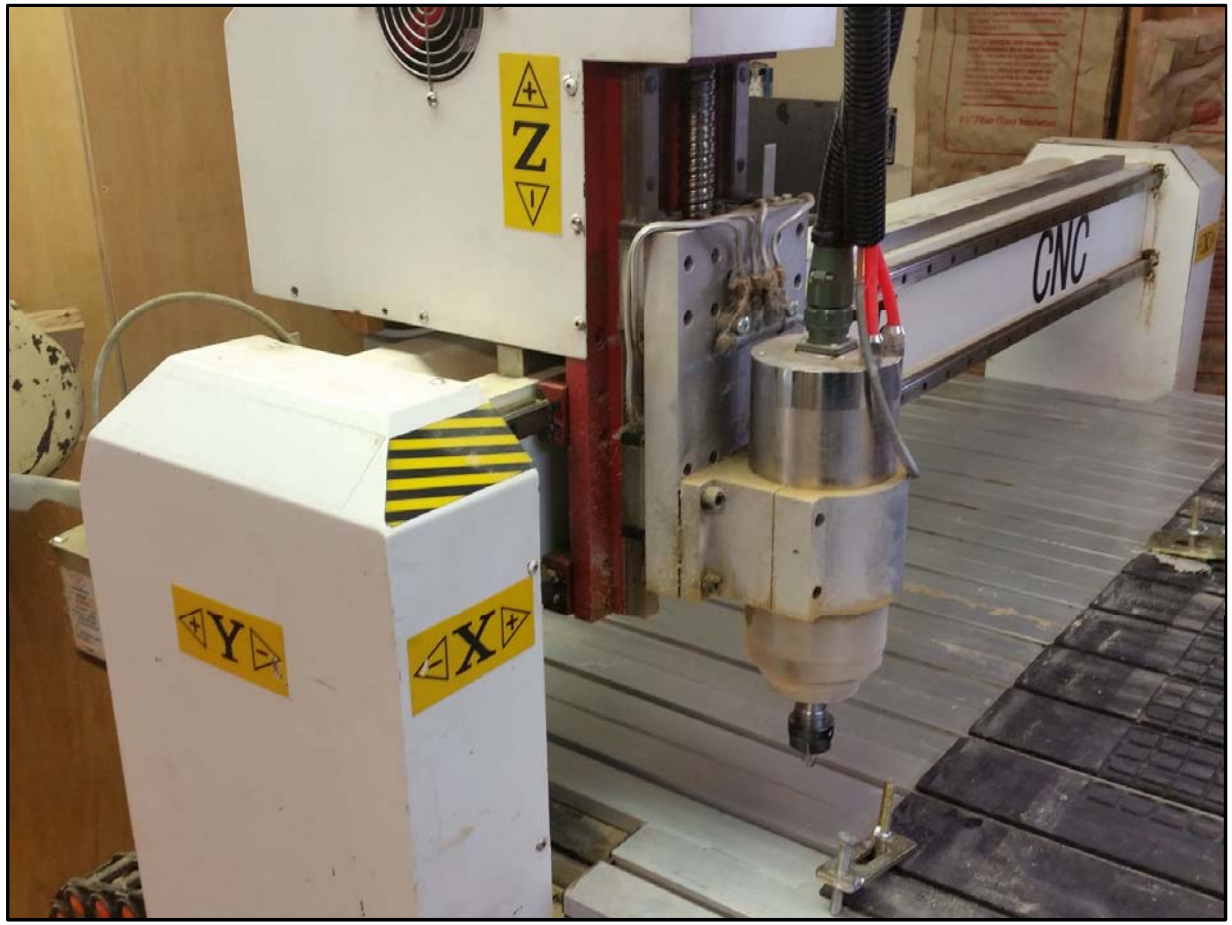
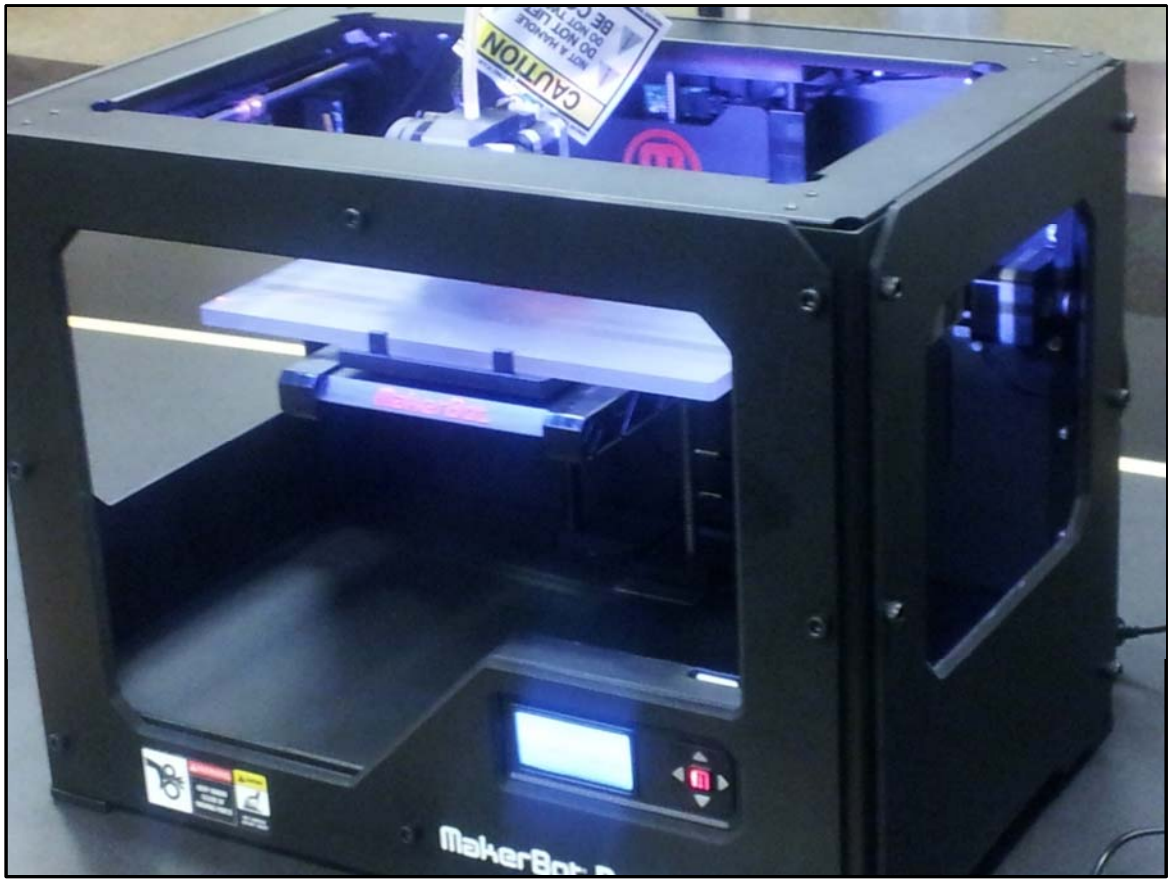
Oregon State University
Computer Graphics

In the Beginning, Manufacturing was "Subtractive"

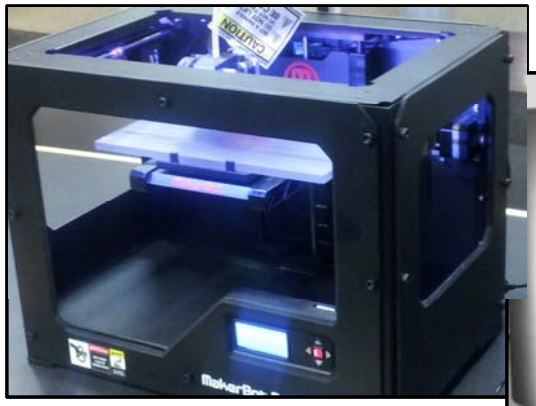


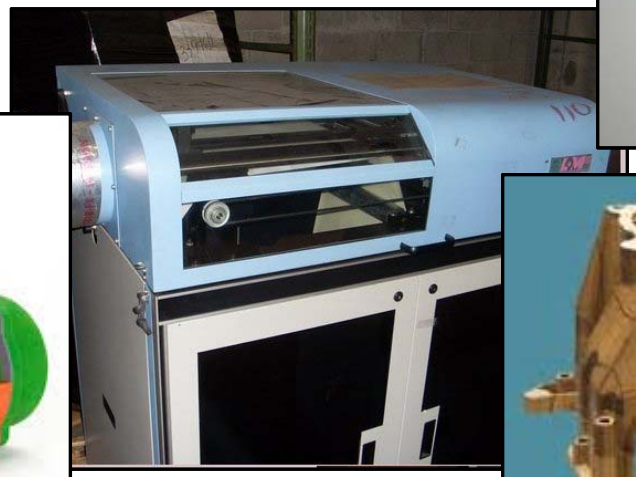
Today's 3D Printing Process

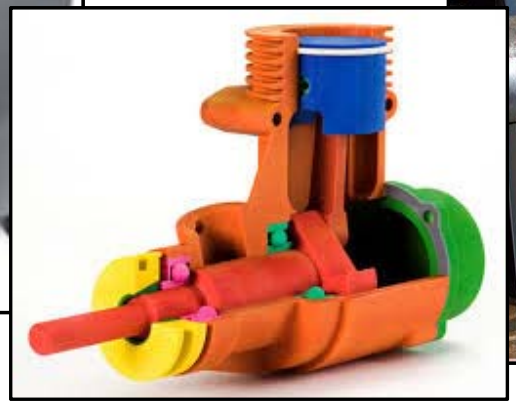
"3D Printing" is defined as some sort of **"additive**" process. (Additive manufacturing is also sometimes called Stereolithography.) The current frenzy in 3D Printing consists mostly of desktop systems that deposit layers of molten plastic:



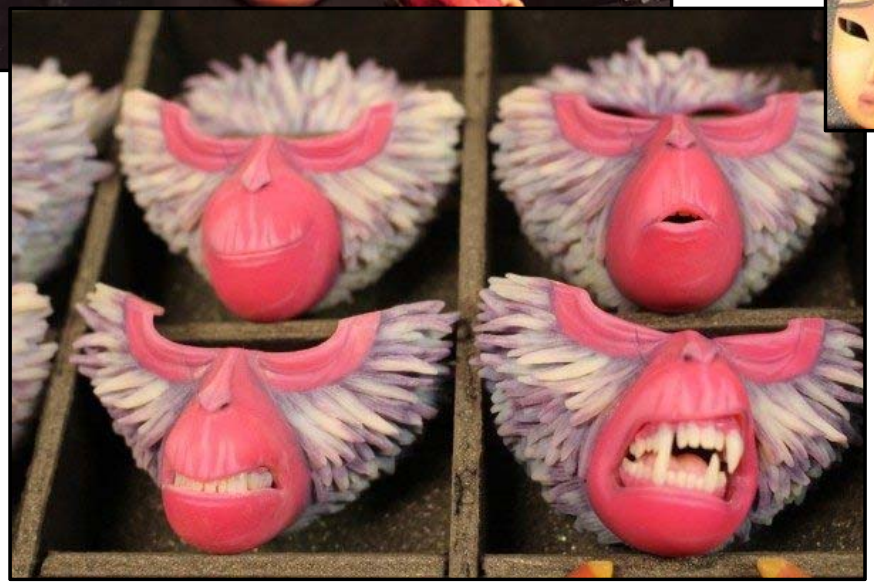
Examples of 3D Printing







Portland's Laika uses Color 3D Printing for Stop-motion Movies



Kubo and the Two Strings

The 3D Printing Geometry File

3D Printers are fed a file called an "STL File", which lists all the triangles in the object. All 3D CAD systems (as well as TinkerCad, Thingiverse, and Blender) can produce this type of file for you.

```
solid

 facet normal   0.00  0.00   -1.00
  outer loop
    vertex   -2.000000   -2.000000   0.250000
    vertex   -1.980000   -1.980000   0.250000
    vertex   -1.980000   -2.000000   0.250000
  endloop
 endfacet

 facet normal   0.00  0.00   -1.00
  outer loop
    vertex   -2.000000   -2.000000   0.250000
    vertex   -2.000000   -1.980000   0.250000
    vertex   -1.980000   -1.980000   0.250000
  endloop
 endfacet

       . . .

endsolid
```

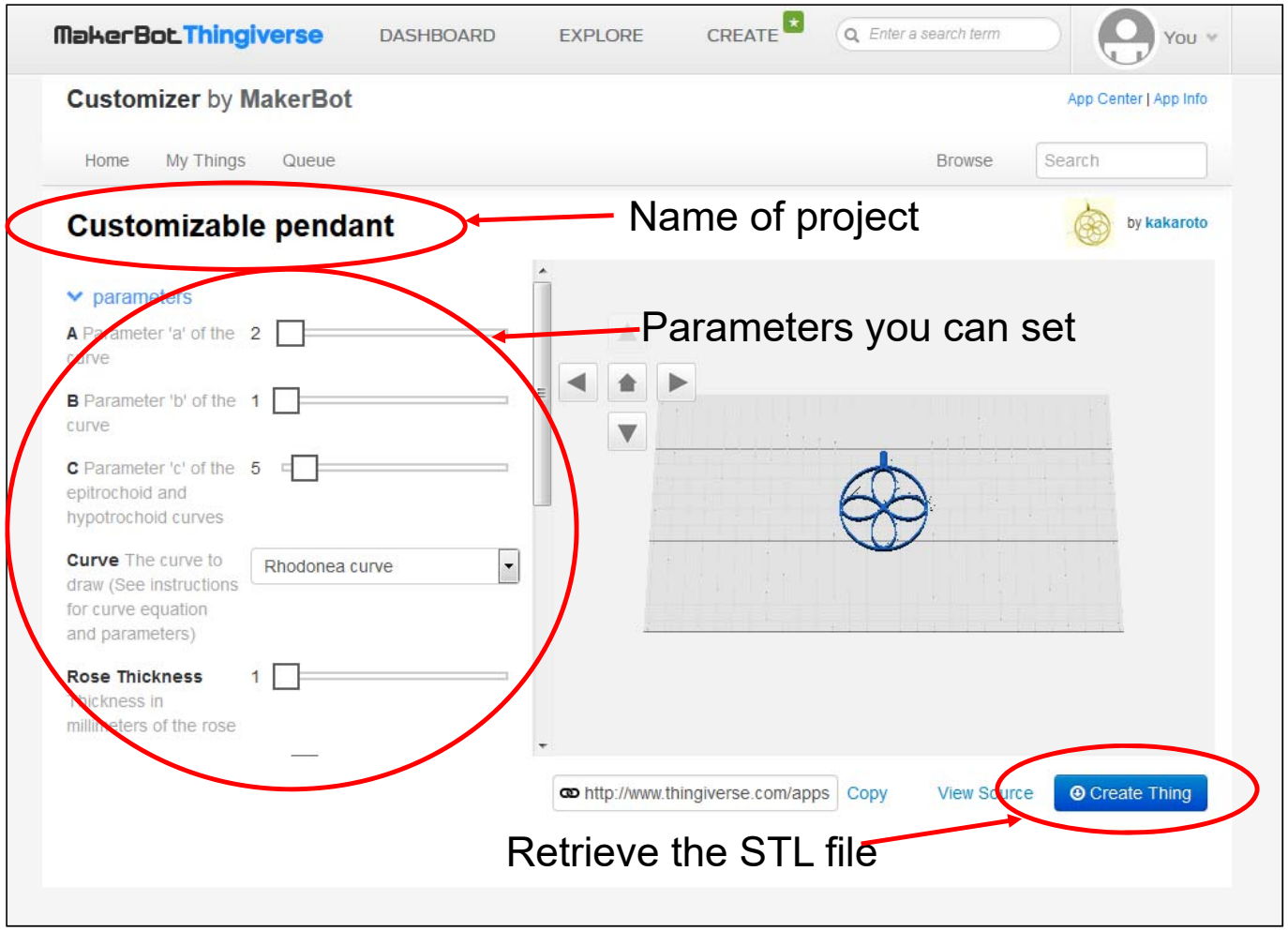
In this particular file, these coordinates are in units of inches.

Some 3D Printers use **inches**, most now seem to use **millimeters**.

Check! It matters!

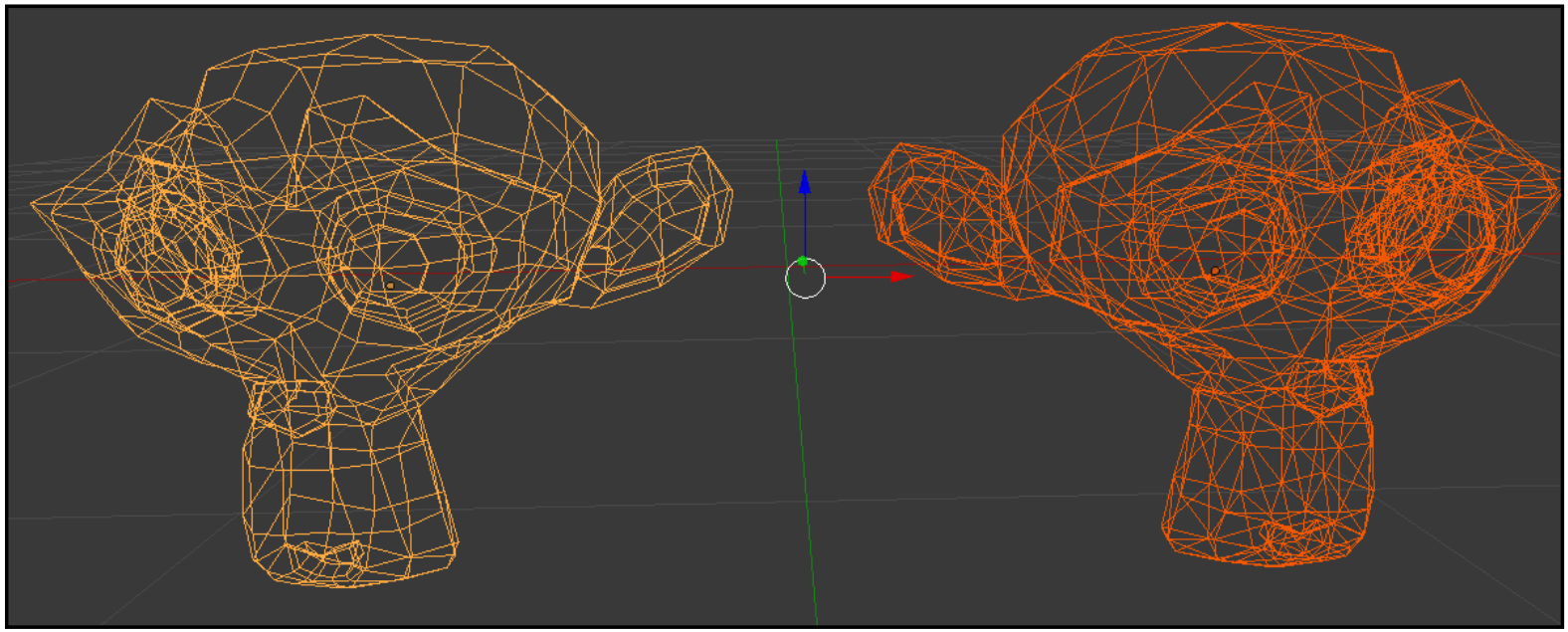
Note: there are 25.4 mm/inch

thingiverse.com



Object Rules for 3D Printing

1. The object must be a mesh and ***consist only of triangles***.



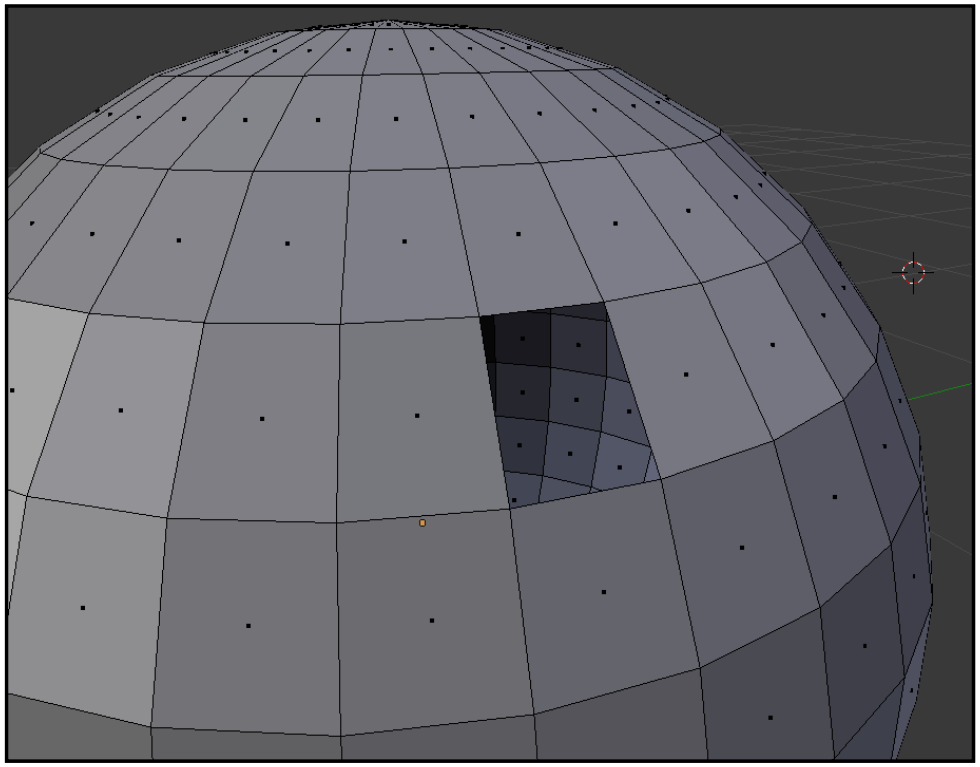
Quads and triangles

Triangles only

In Blender: Modifiers → Add Modifier → Triangulate

Object Rules for 3D Printing

2. The object must be a legal solid. It *must* have a definite inside and a definite outside. It can't have any missing face pieces.

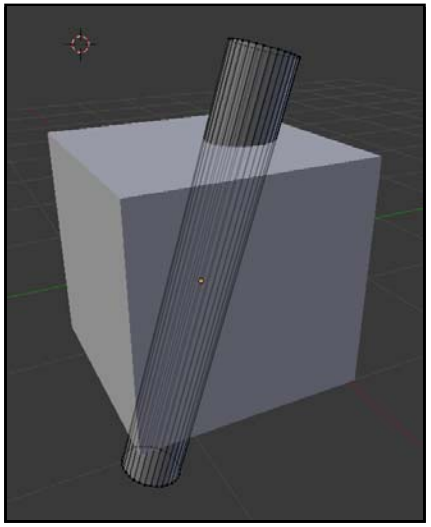


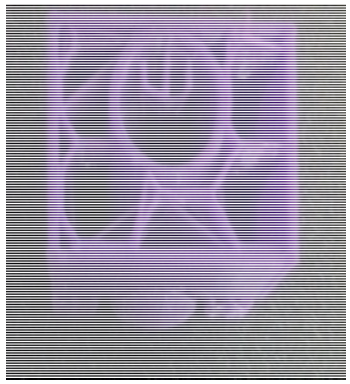
"Definite inside and outside" is sometimes called "Two-manifold" or "Watertight"

Object Modeling Rules for 3D Printing

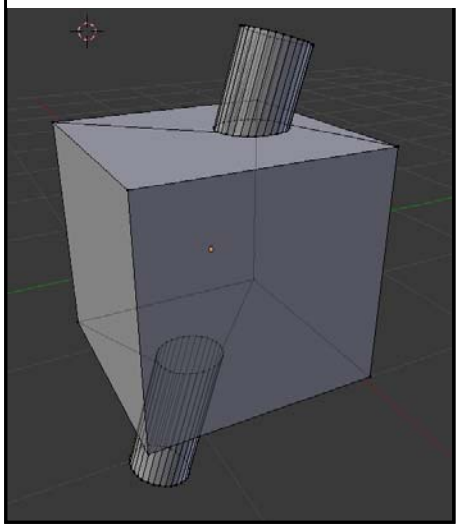
3. You can't make a compound object by simply overlapping two objects in 3D. If you want both shapes together, do a Boolean union on them so that they become one complete object.

Overlapped in 3D -- bad



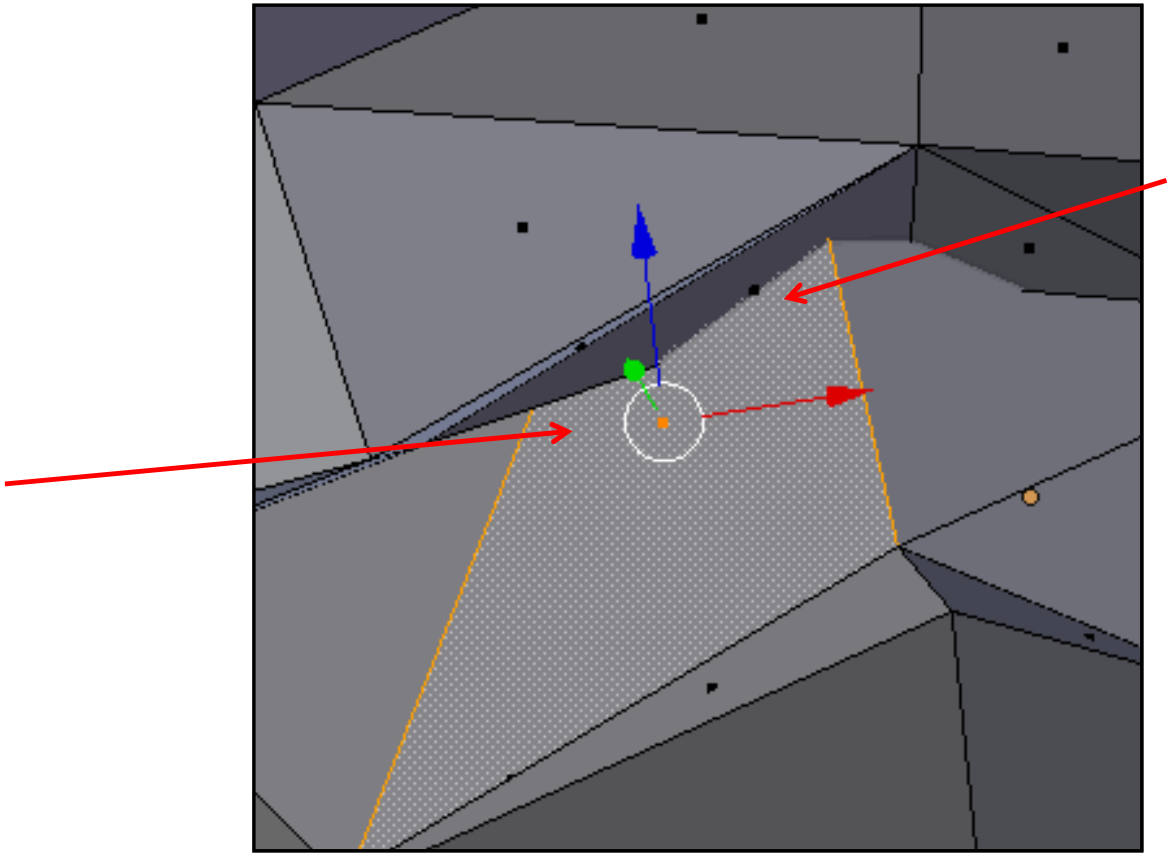


Boolean union -- good



Object Rules for 3D Printing

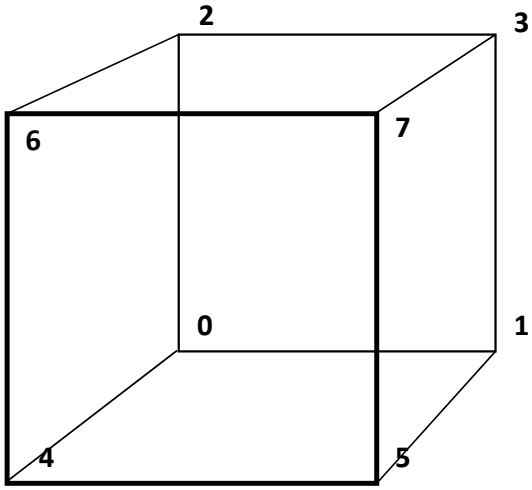
4. Each edge in the mesh must bound 2 and only 2 triangles (this is known as the **Vertex-to-Vertex Rule**)



The Simplified Euler's Formula* for Legal Solids

$$F - E + V = 2$$

F	Faces
E	Edges
V	Vertices

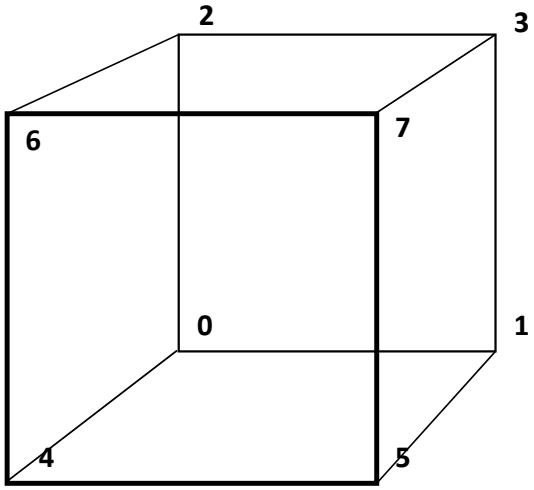


$$6 - 12 + 8 = 2$$

*sometimes called the Euler-Poincaré formula

The Full Euler's Formula* for Legal Solids

$$F - E + V - L = 2(B - G)$$

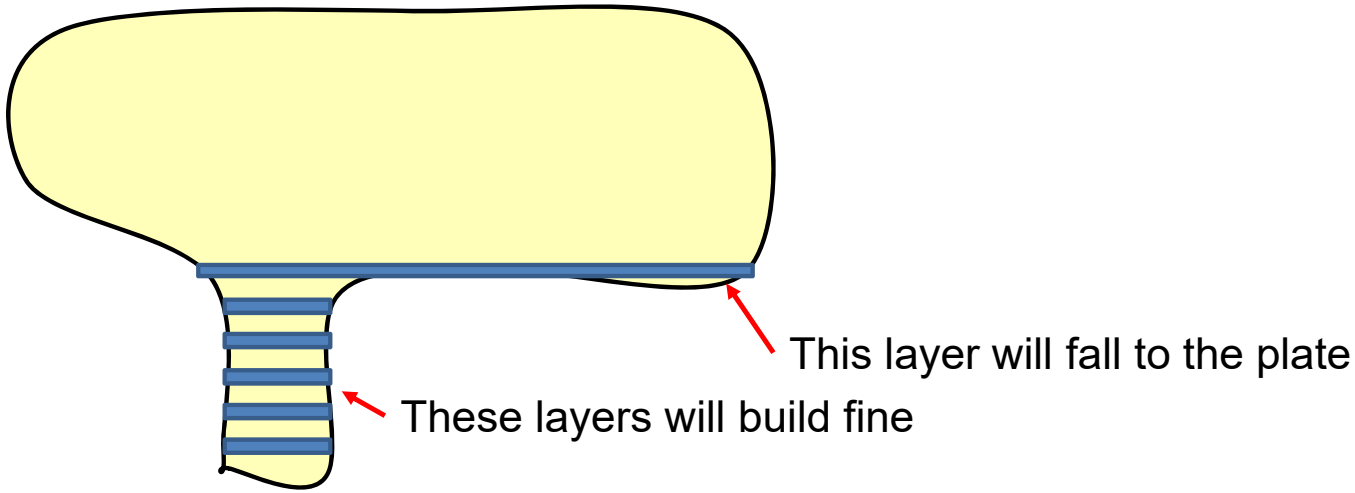


F	Faces
E	Edges
V	Vertices
L	Inner Edge Loops (within faces)
B	Bodies
G	Genus (number of through-holes)

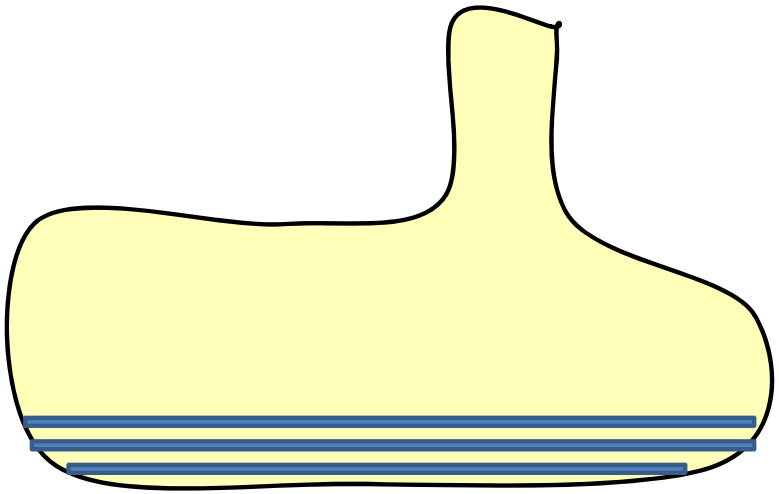
$$6 - 12 + 8 - 0 = 2(1 - 0)$$

*sometimes called the Euler-Poincaré formula

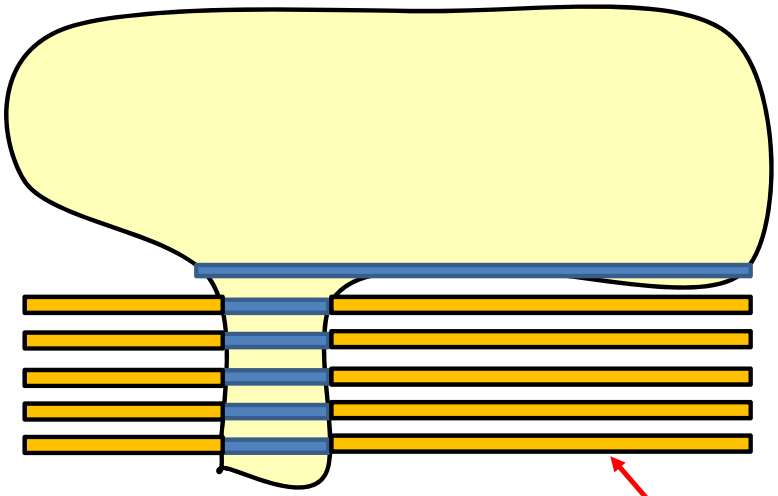
Watch Out for Overhangs!



Note that, if you build this object upside-down, it will probably be fine

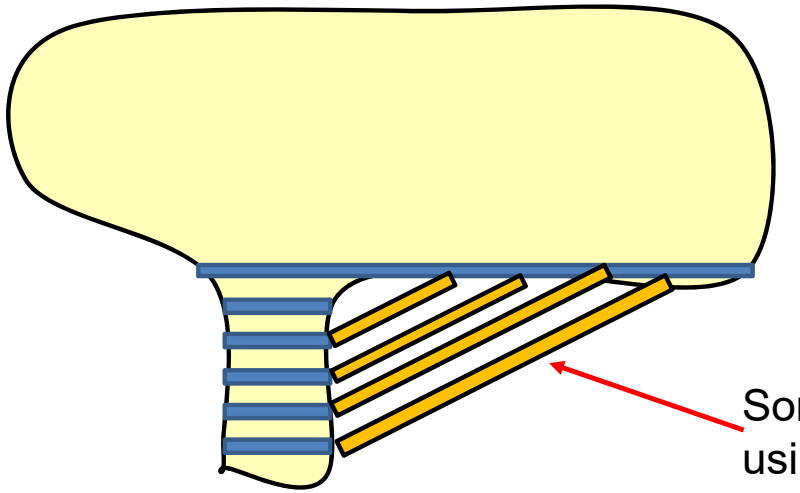


Watch Out for Overhangs!



Some 3D printers handle this by leaving unused material in place to support the overhangs

Watch Out for Overhangs!



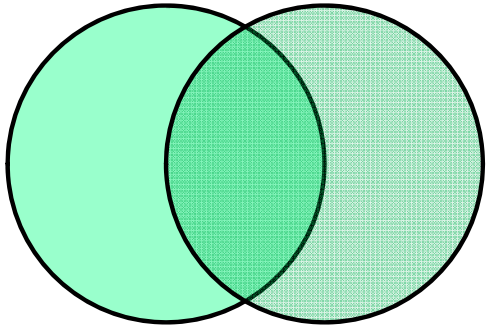
Some 3D printers handle this by using software to add “support structures” to the overhangs

Some 3D printers handle this better than others…

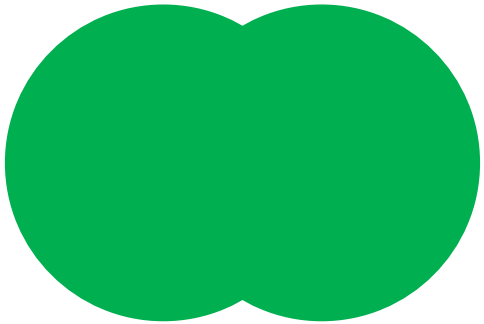
What Happens if You Don't Follow the Rules?

Check here:
http://twistedsifter.com/2013/08/when-3d-printing-goes-wrong/

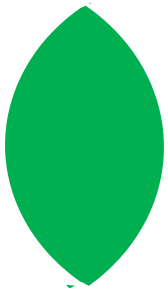
Another way to Model:
Remember Venn Diagrams (2D Boolean Operators) from High School?



Two Overlapping Shapes



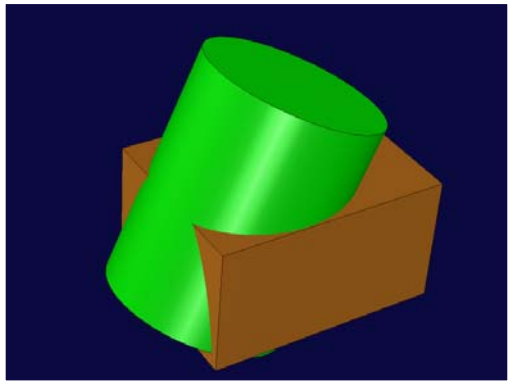
Union



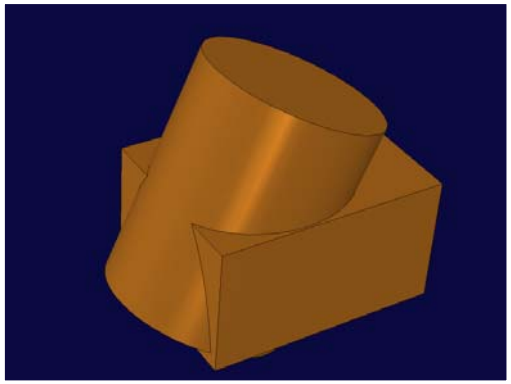
Intersection

Difference

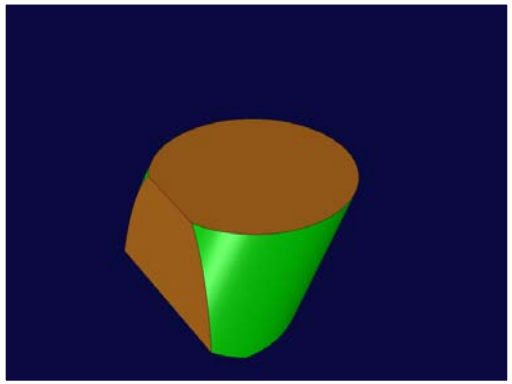
Solid Modeling Using 3D Boolean Operators



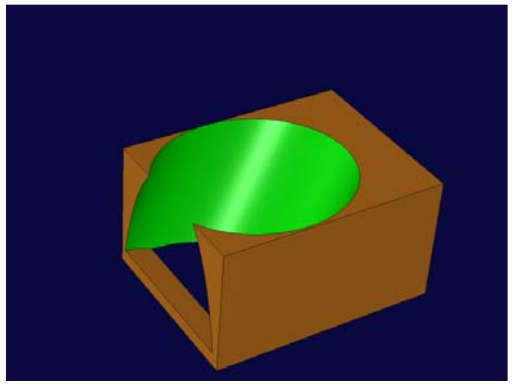
Two Overlapping Solids



Union



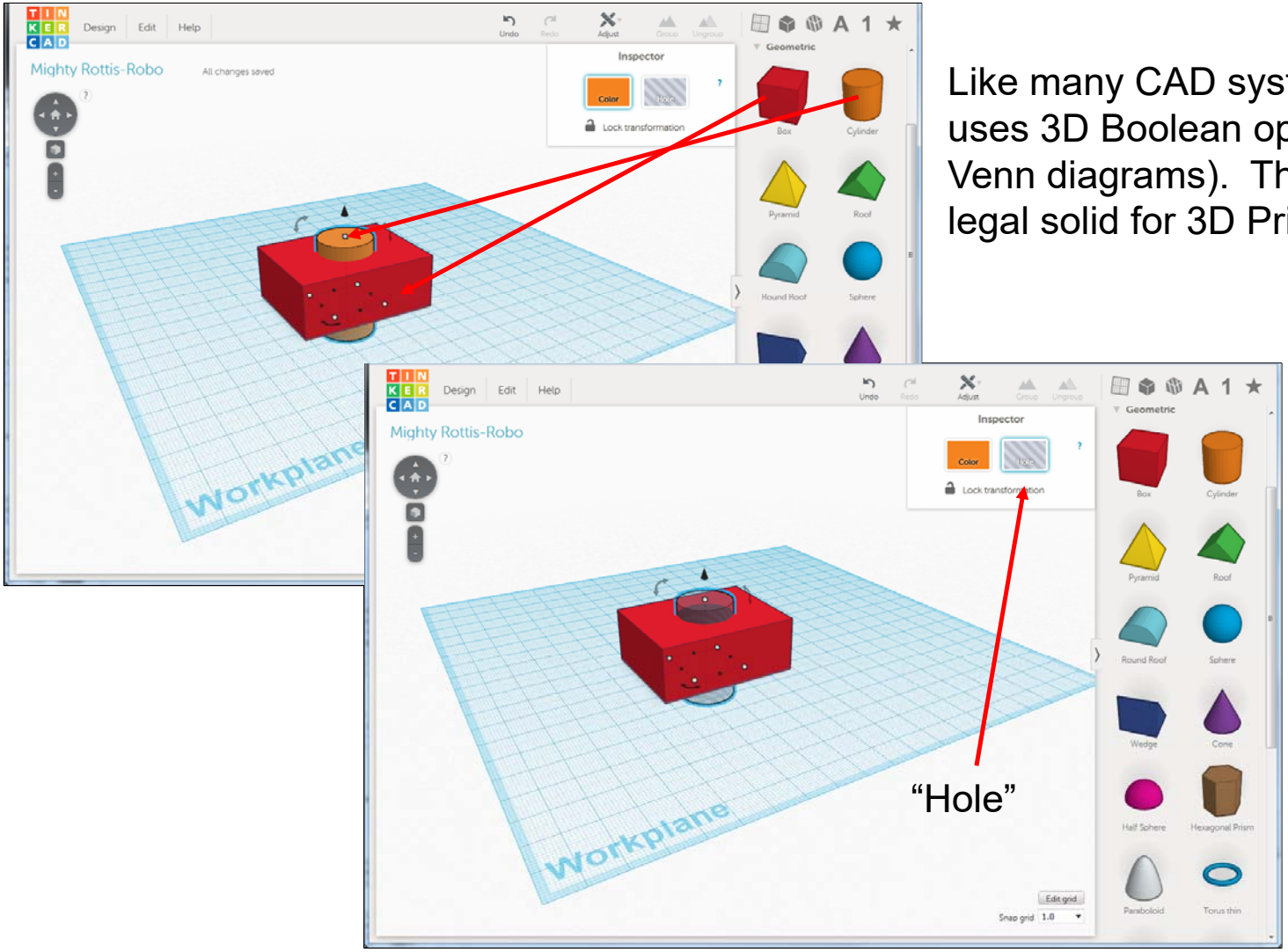
Intersection



Difference

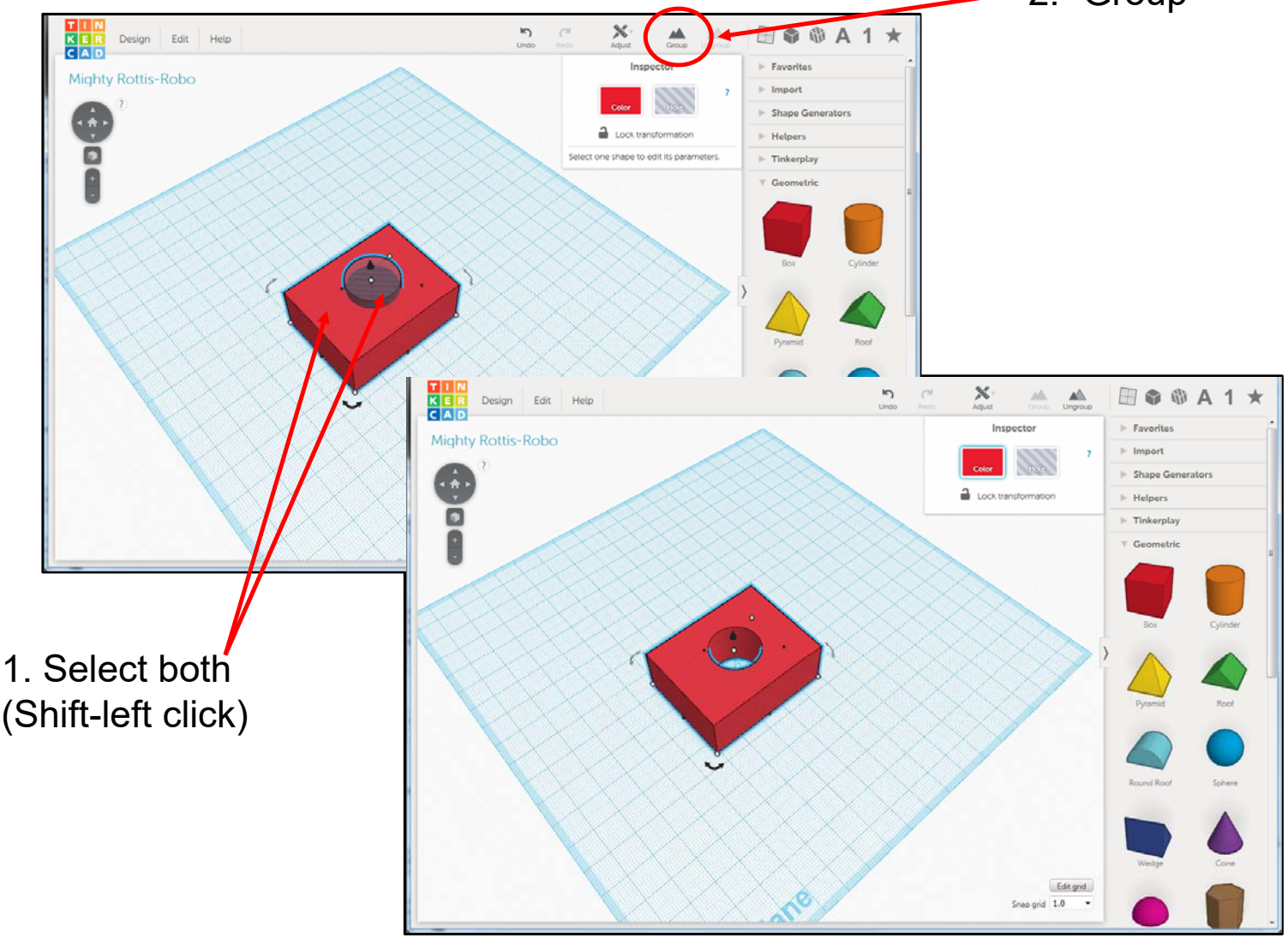
This is often called Constructive Solid Geometry (CSG)

TinkerCAD: http://www.tinkercad.com

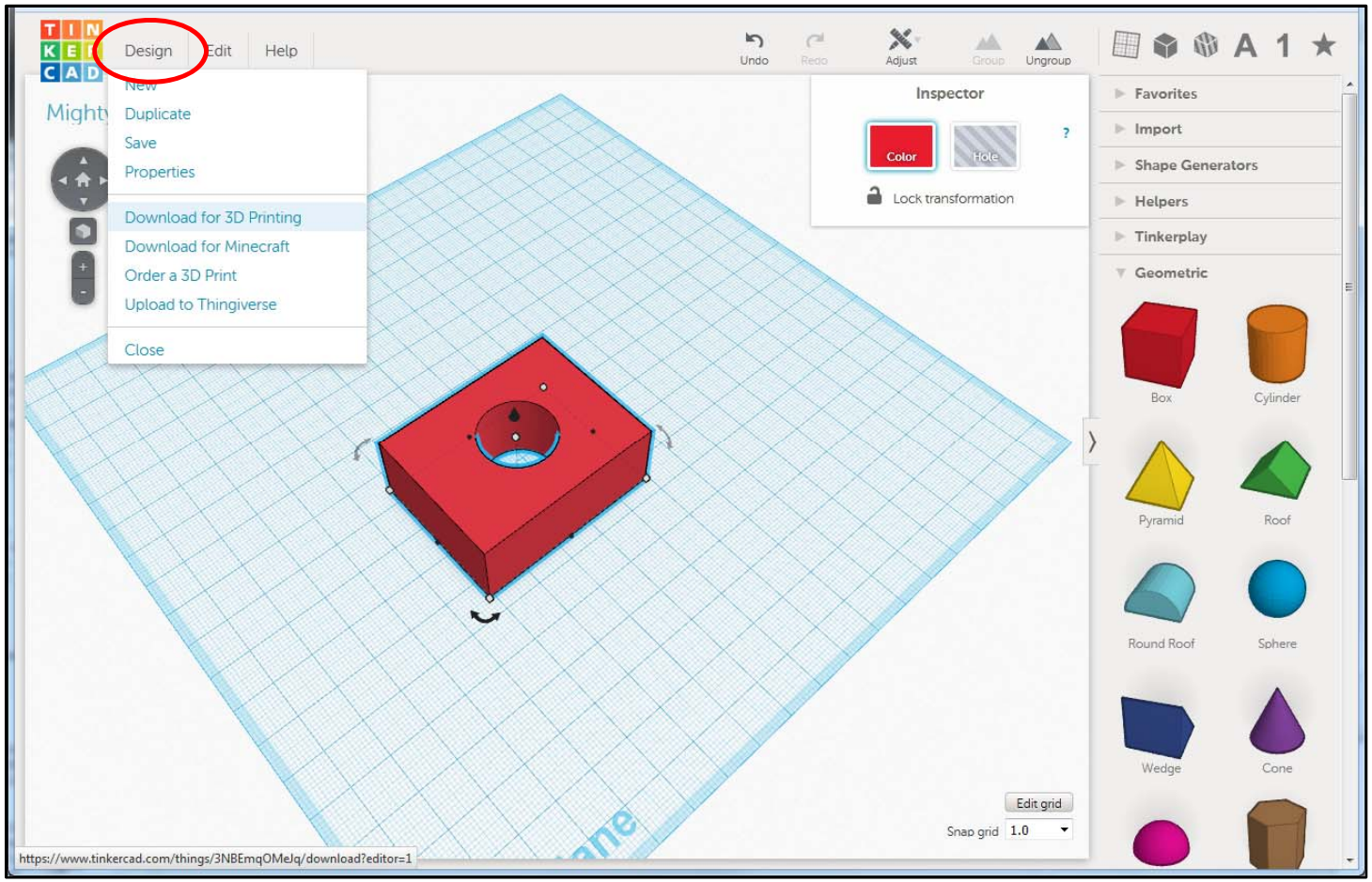


Like many CAD systems, TinkerCAD uses 3D Boolean operators (3D Venn diagrams). This guarantees a legal solid for 3D Printing.

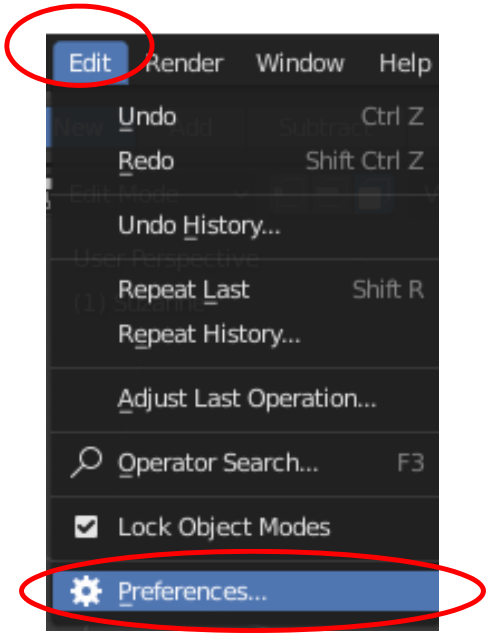
TinkerCAD


2. “Group”
1. Select both
(Shift-left click)
Design
Edit
Help
Mighty Rottis-Robo
Inspector
Color
Hole
Lock transformation
Select one shape to edit its parameters.
Favorites
Import
Shape Generators
Helpers
Tinkerplay
Geometric
Box
Cylinder
Pyramid
Roof
Round Roof
Sphere
Wedge
Cone
Edit grid
Snap grid 1.0

TinkerCAD


Design
Edit
Help
Undo
Redo
Adjust
Group
Ungroup
New
Duplicate
Save
Properties
Download for 3D Printing
Download for Minecraft
Order a 3D Print
Upload to Thingiverse
Close
Inspector
Color
Hole
Lock transformation
Favorites
Import
Shape Generators
Helpers
Tinkerplay
Geometric
Box
Cylinder
Pyramid
Roof
Round Roof
Sphere
Wedge
Cone
Edit grid
Snap grid
1.0
https://www.tinkercad.com/things/3NBEmqOMeJq/download?editor=1

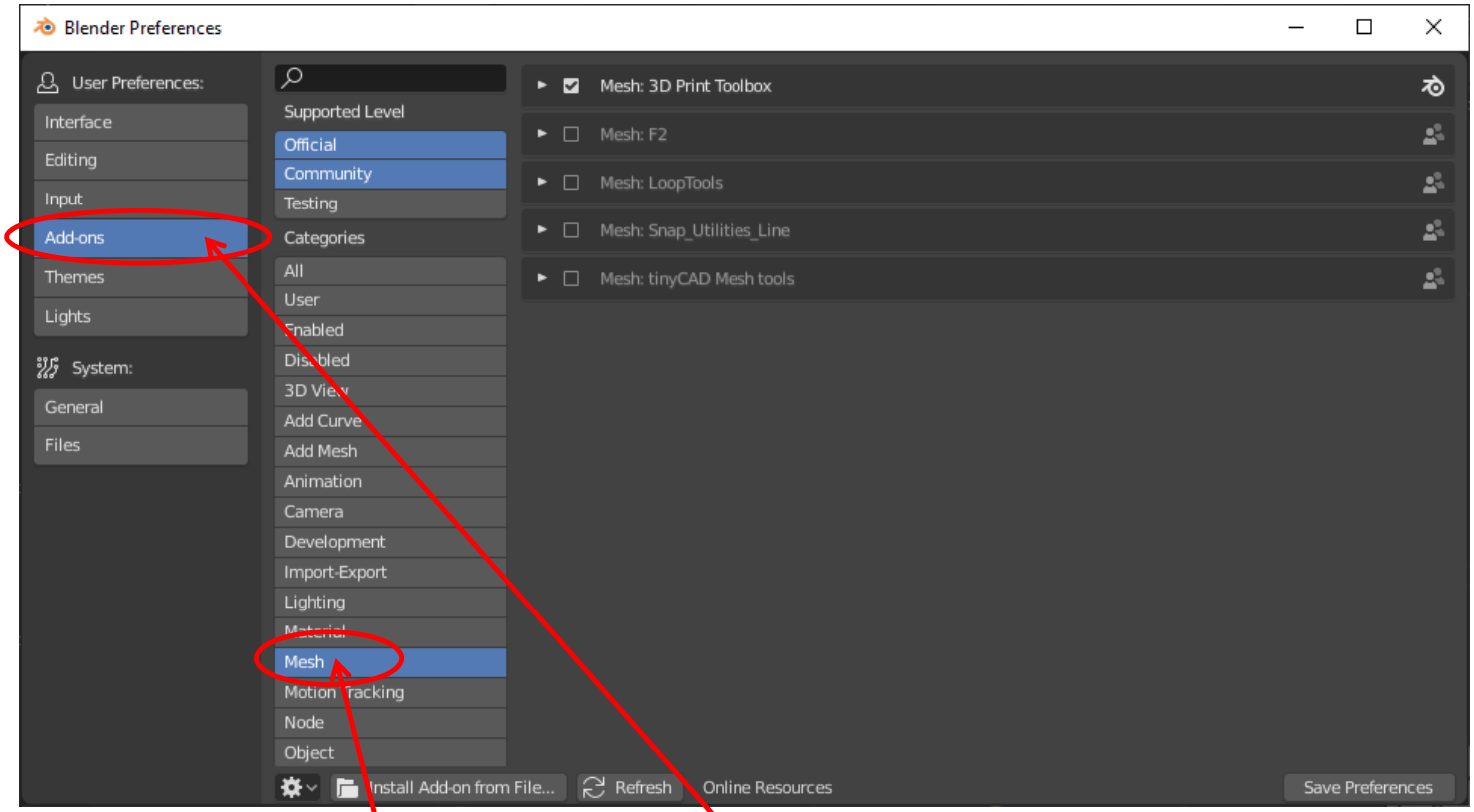
Blender's 3D Printing Options aren't there by Default



But, by default, Blender doesn't let you see its 3D Printing options. You need to tell Blender to turn these on.

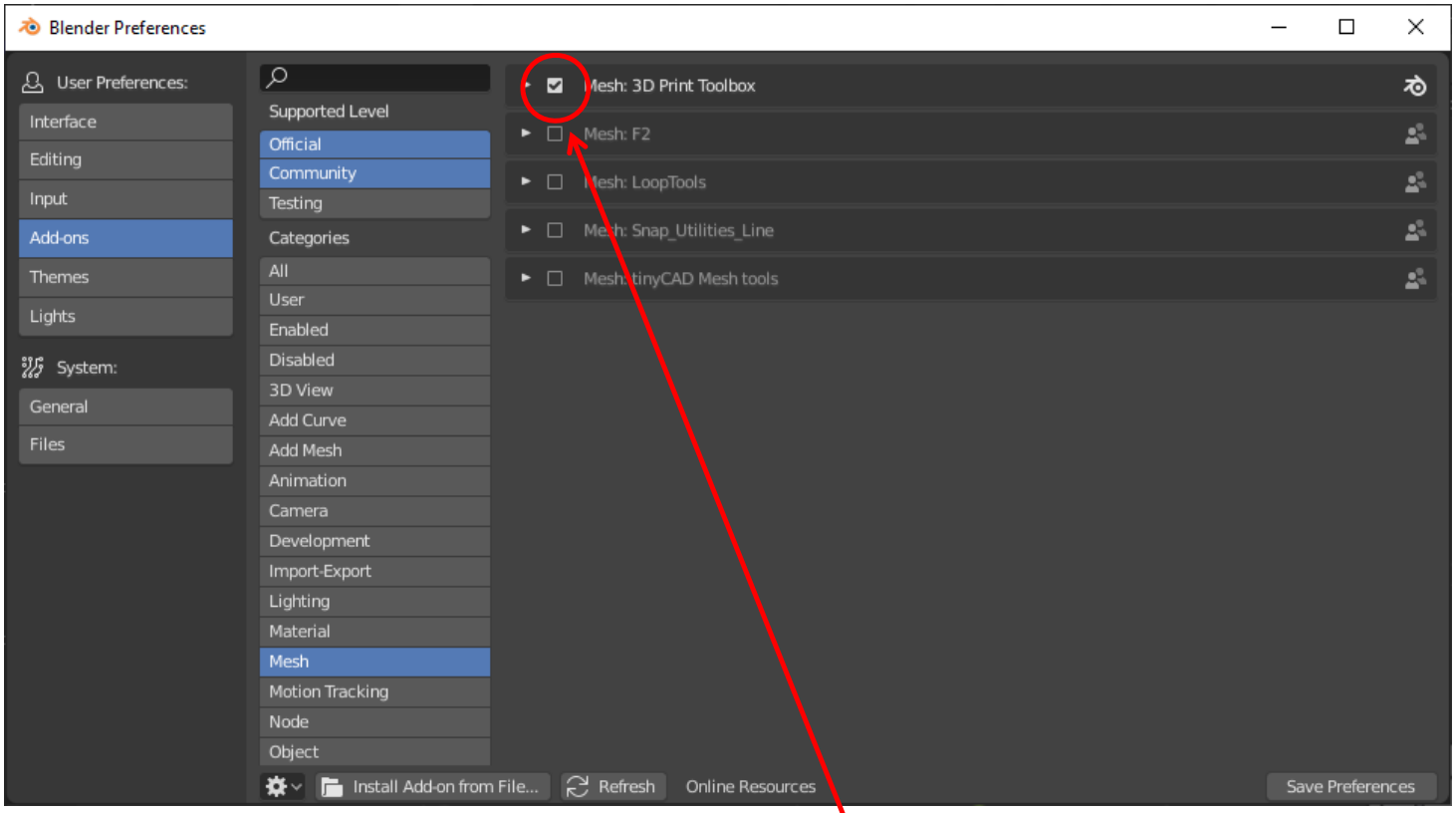
1. Click **Edit → Preferences**

Blender's 3D Printing Options aren't there by Default



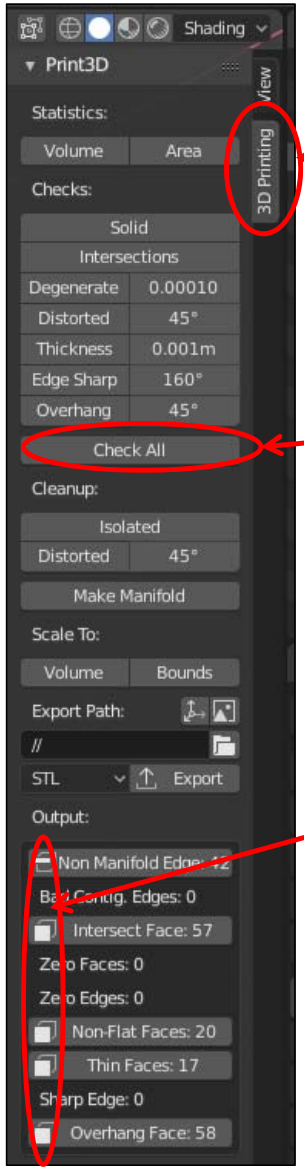
2. Click on the **Addons** tab
3. Click on **Mesh**

Blender's 3D Printing Options aren't there by Default



4. Click the **Mesh: 3D Print Toolbox**

Blender Options for 3D Printing

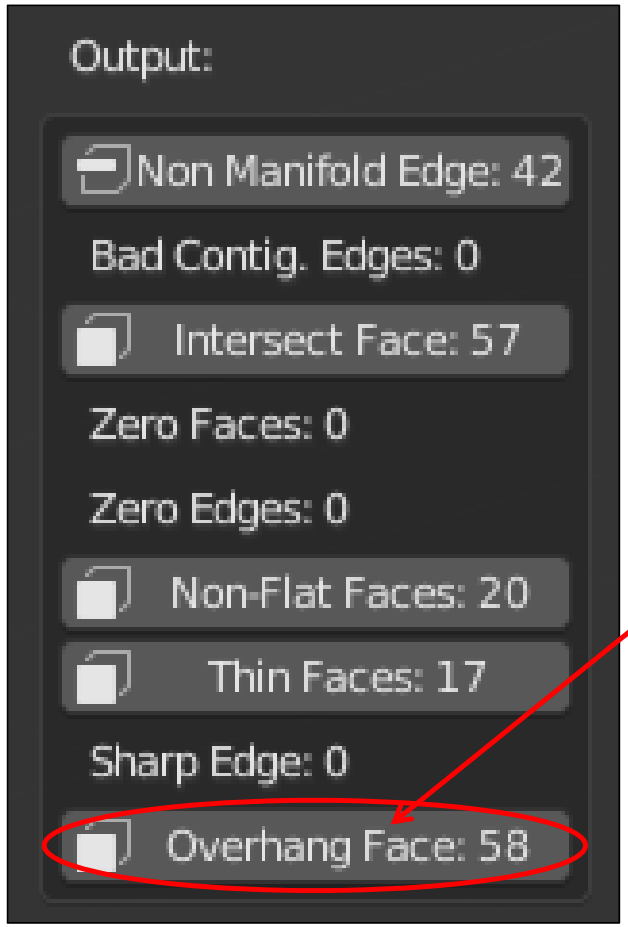


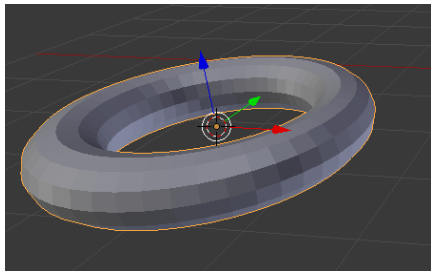
This now shows up in your Properties Region (hit the 'n' key to turn it on)

Objects destined for 3D Printing must be "legal solids". Clicking on **Check All** will try to determine that

Tab over to Edit Mode. Clicking on any of these will highlight where they are on your object.

Blender Options for 3D Printing

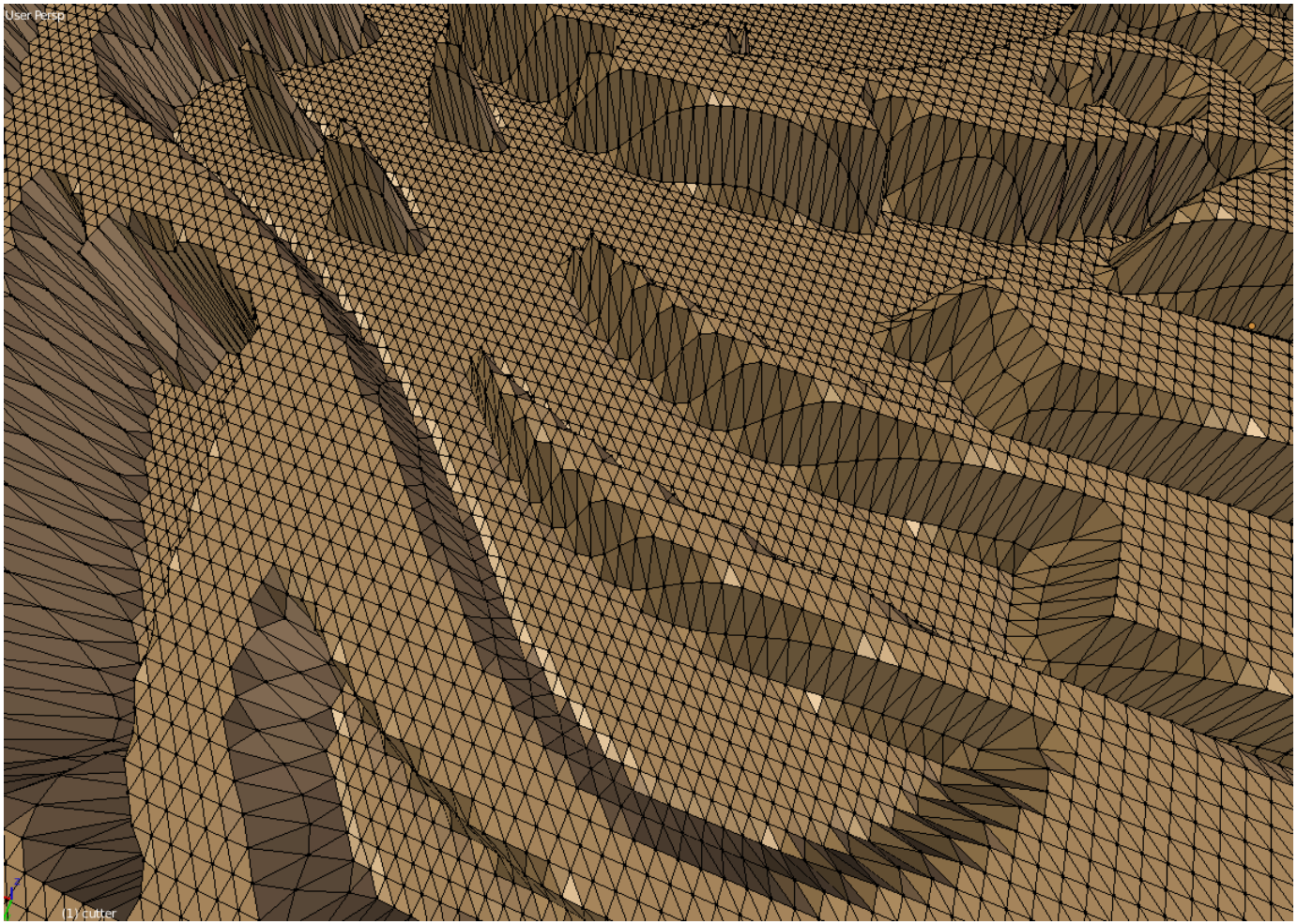




An overhang face is not necessarily a bad thing. The entire bottom of the part will consist of, by necessity, overhang faces.

However, overhang faces that are not the bottom of the part could be a problem.

Heightmap Files are Straightforward to use with 3D Printing



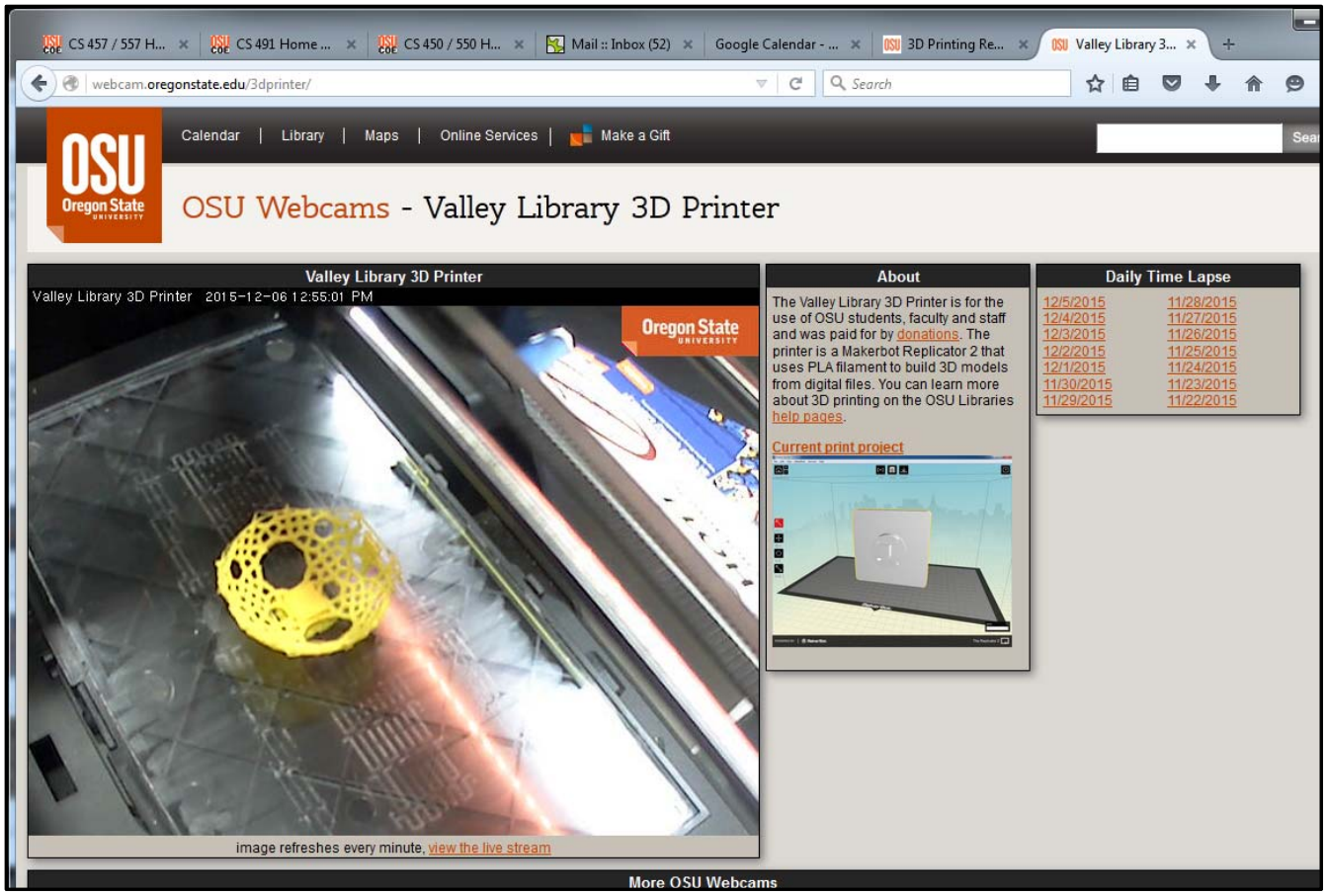
A Very Special Heightmap 3D Printing Model

A Very Special Heightmap 3D Printing Model

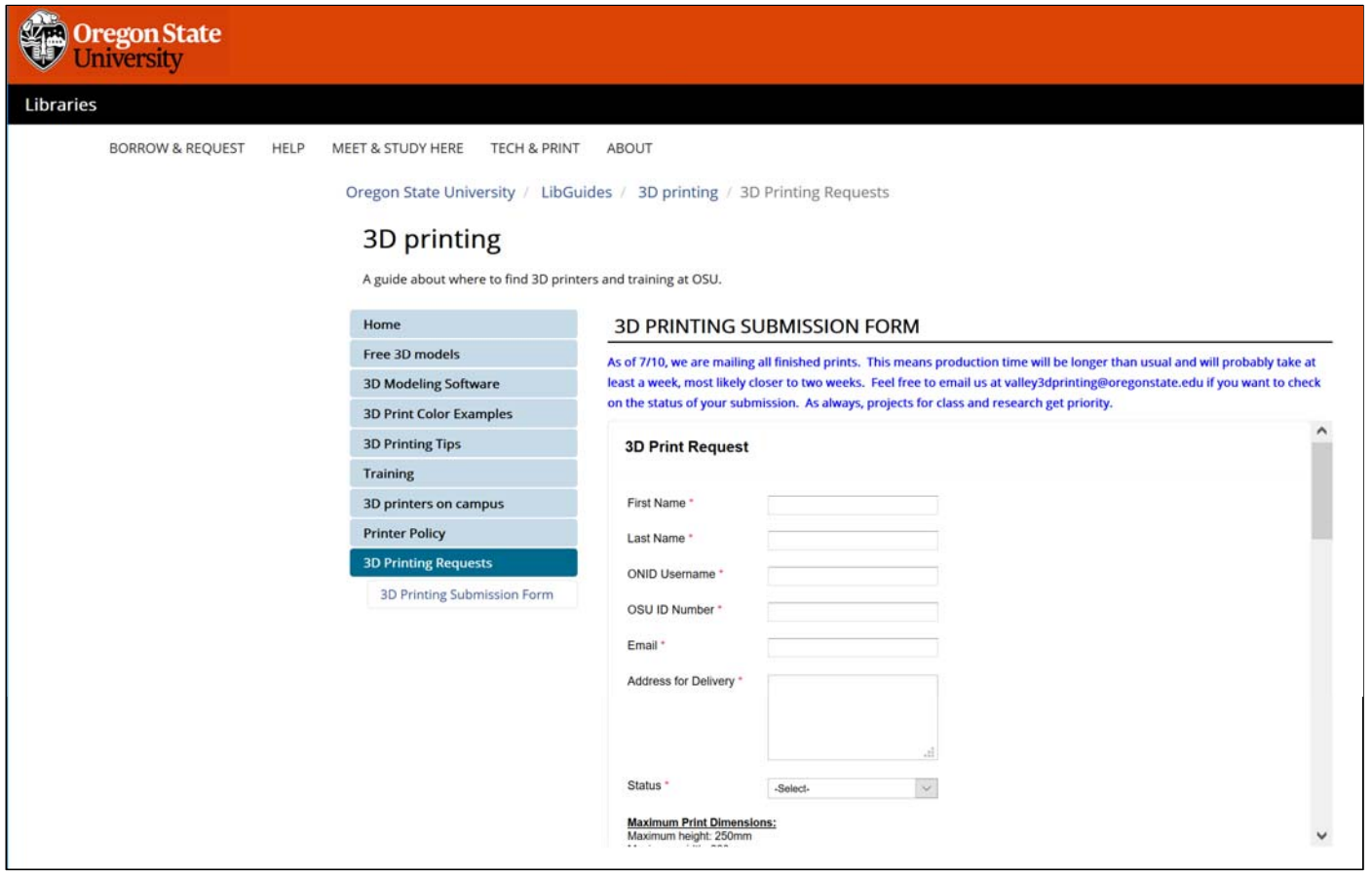
The OSU Library's 3D Printers

To watch one of the OSU Library's 3D Printers, go to:

http://webcam.oregonstate.edu/3dprinter/



The OSU Library's 3D Printers

To send an STL model to the OSU Library's 3D Printers, go to:

http://guides.library.oregonstate.edu/3Dprinting/3Dprintform