

3D Printing

Mike Bailey

mjb@cs.oregonstate.edu

Oregon State University



This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](#)



Oregon State University
Computer Graphics

In the Beginning, Manufacturing was “Subtractive”

2

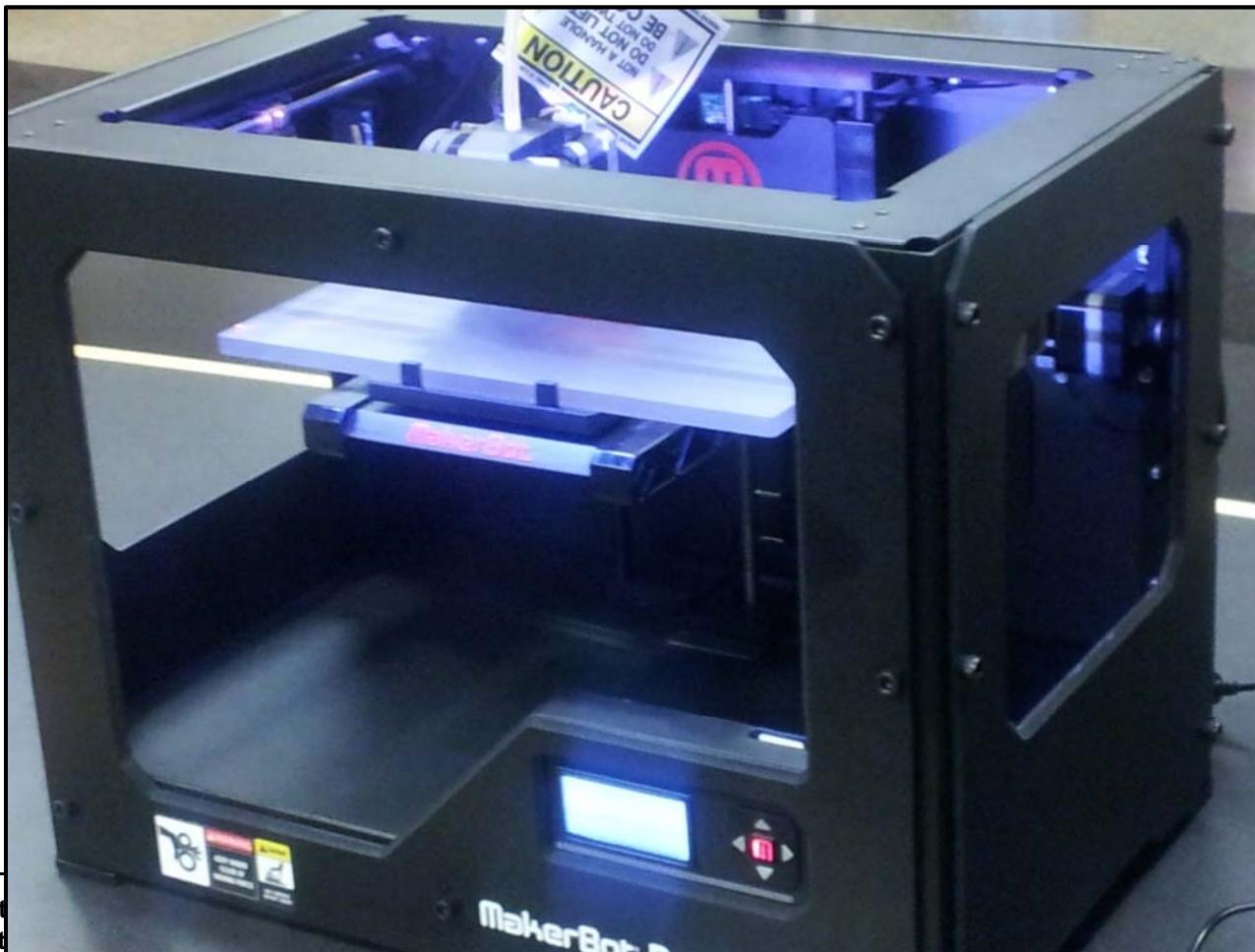


Oregon State University
Computer Graphics

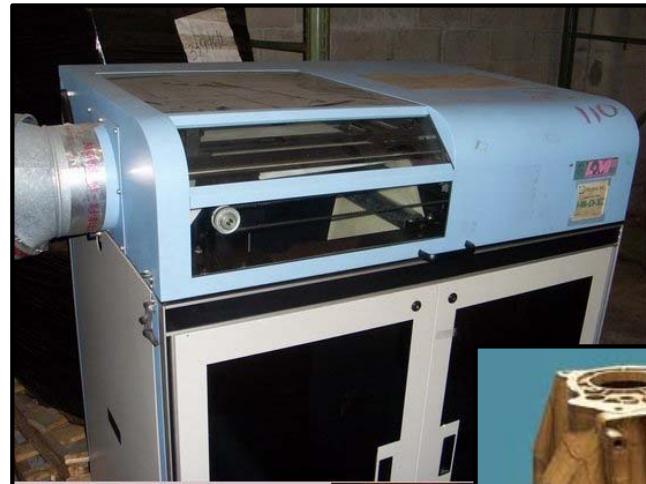
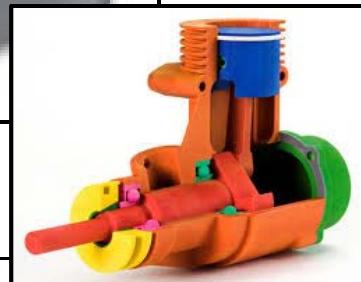
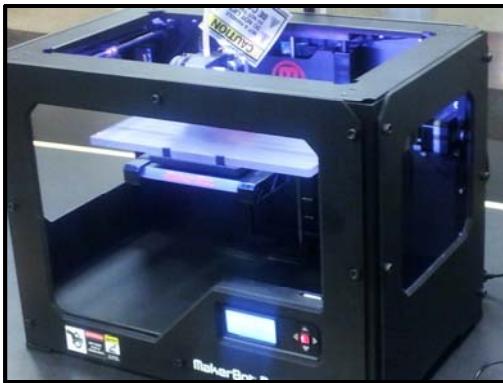
mjb – September 2, 2016

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



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 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**, many now use **millimeters**.

Check! It matters!

Note: there are 25.4 mm/inch

thingiverse.com

The screenshot shows the MakerBot Thingiverse Customizer interface for a "Customizable pendant". The interface includes a navigation bar with links to DASHBOARD, EXPLORE, CREATE, a search bar, and user account information. Below the navigation is a section titled "Customizer by MakerBot" with links to Home, My Things, Queue, and a "Browse" dropdown.

A red circle highlights the "Customizable pendant" title and the "parameters" section. Inside this circle, three parameters are labeled:

- A Parameter 'a' of the 2 drive**: A slider set to 2.
- B Parameter 'b' of the 1 curve**: A slider set to 1.
- C Parameter 'c' of the 5 epitrochoid and hypotrochoid curves**: A slider set to 5.

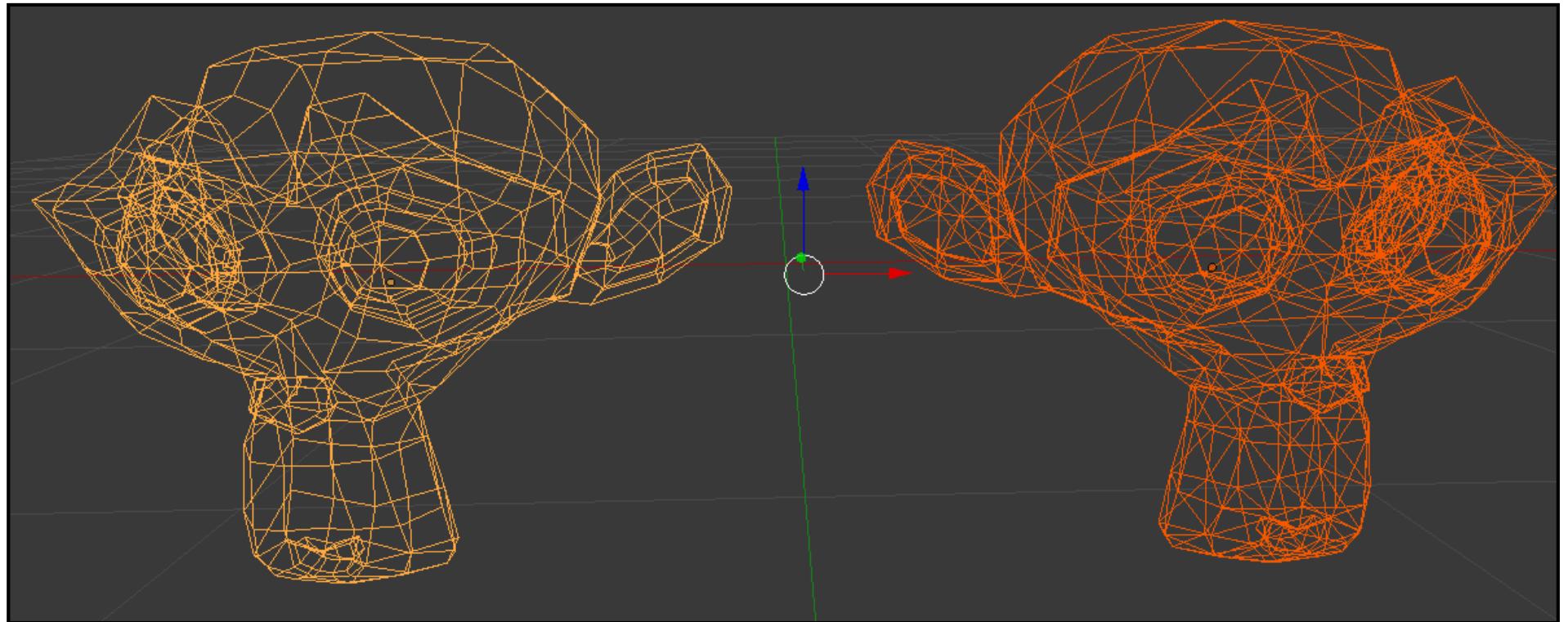
The "Curve" dropdown is set to "Rhodonea curve". The "Rose Thickness" slider is set to 1. To the right of the parameters is a preview window showing a blue Rhodonea curve design on a grid. Below the preview are links to "http://www.thingiverse.com/apps", "Copy", "View Source", and a prominent blue "Create Thing" button.

Annotations with arrows point to specific elements:

- An arrow points from the text "Name of project" to the "Create Thing" button.
- An arrow points from the text "Parameters you can set" to the parameter sliders.
- An arrow points from the text "Retrieve the STL file" to the "Create Thing" button.

Object Rules for 3D Printing

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



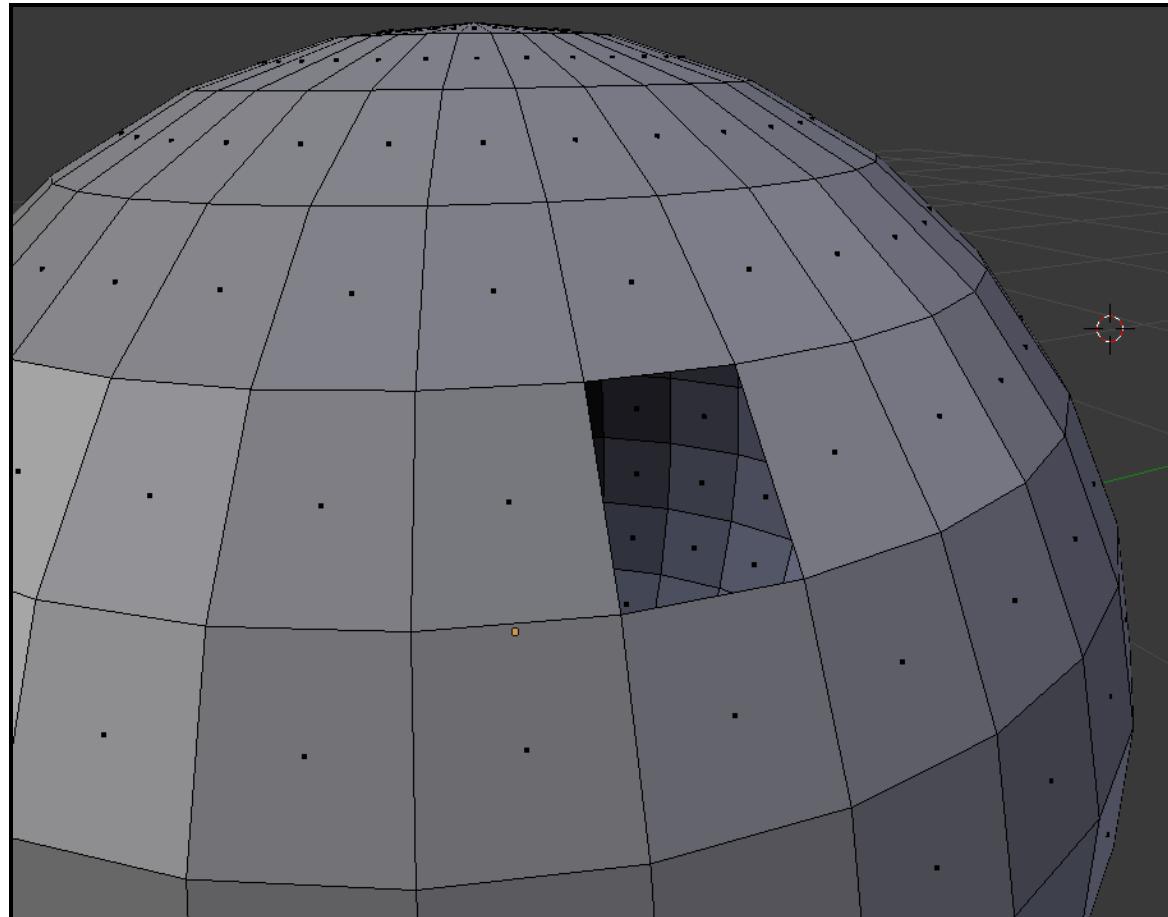
Quads and triangles

Triangles only

In Blender: Modifiers → Add Modifier → Triangulate

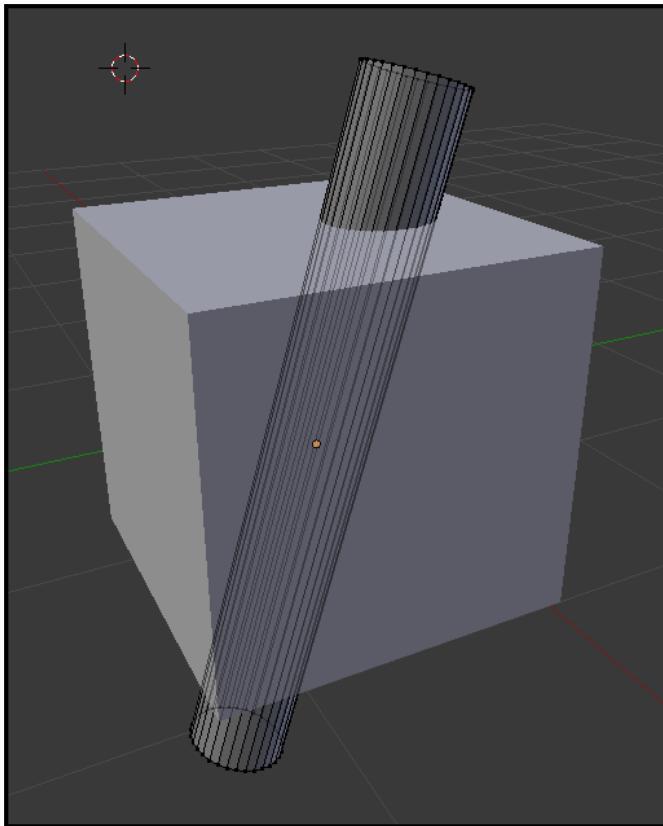
Object Rules for 3D Printing

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.

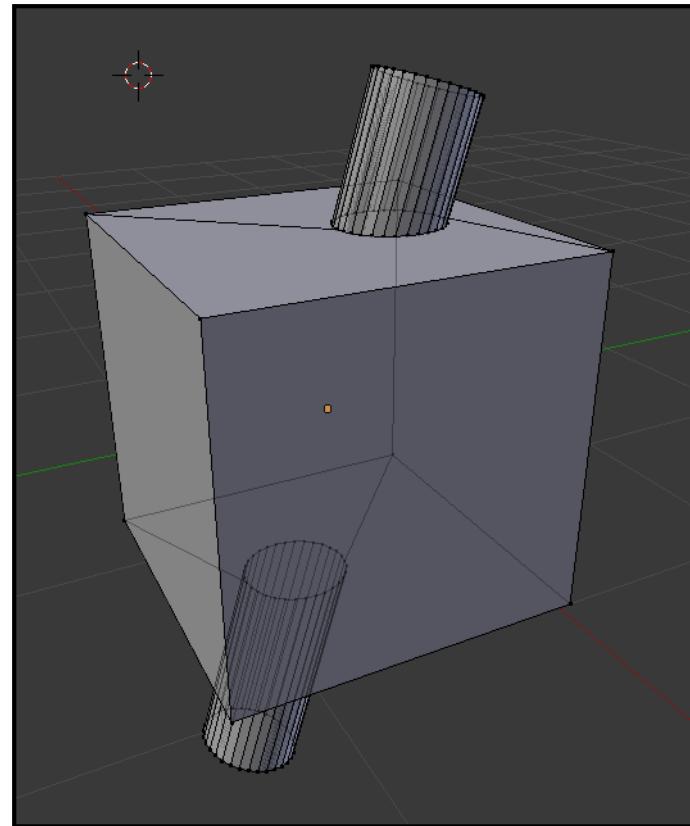


Object Rules for 3D Printing

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.



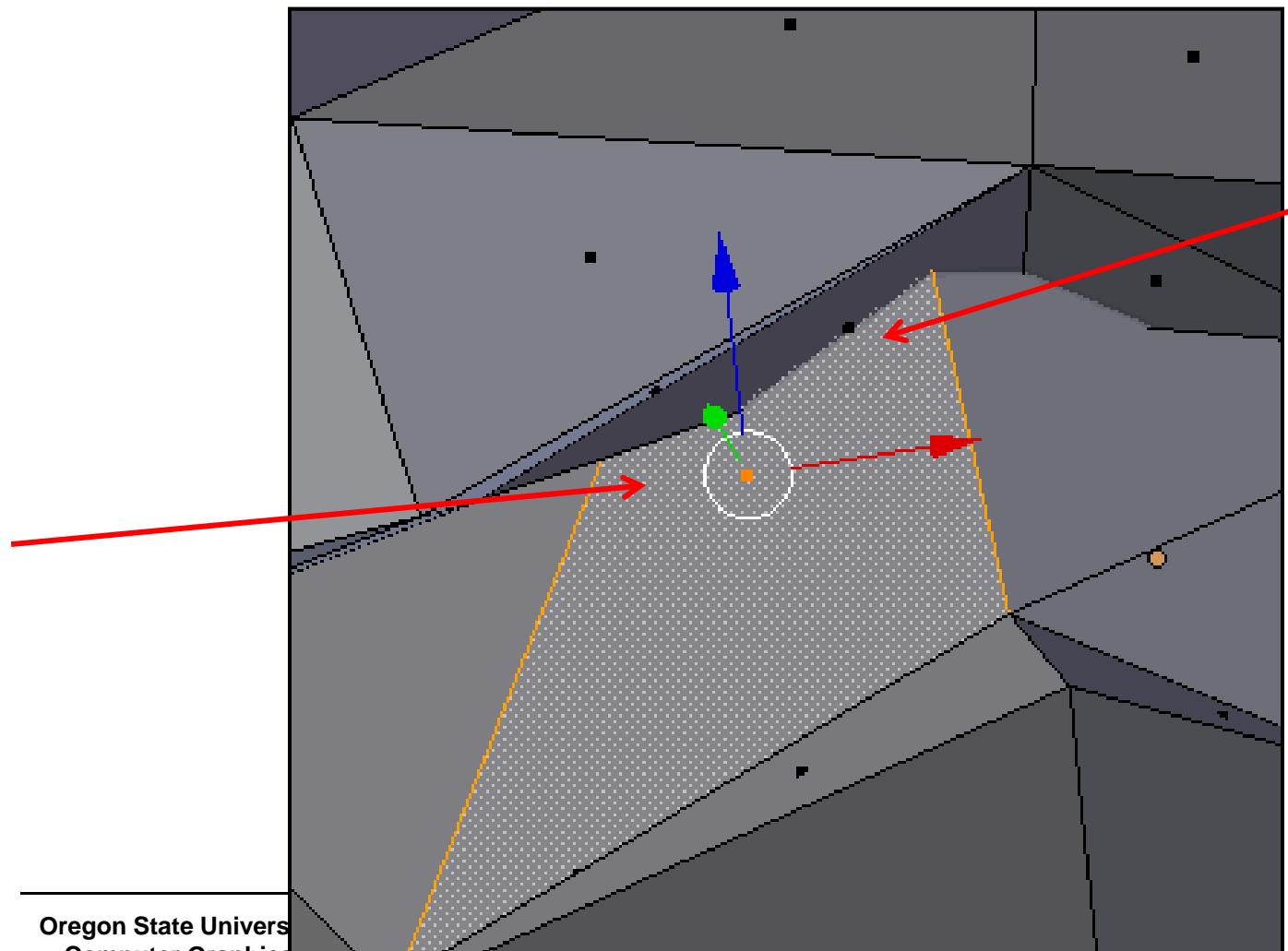
Overlapped in 3D -- **bad**



Boolean union -- **good**

Object Rules for 3D Printing

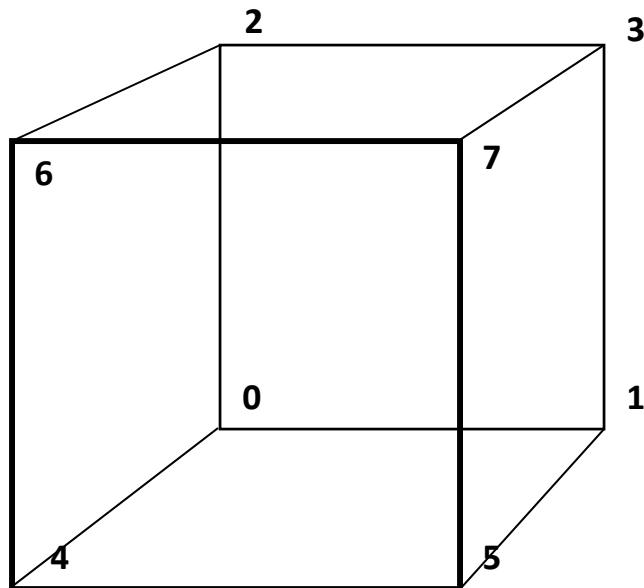
4. Each edge in the mesh must bound 2 and only 2 triangles
(this is known as the **Vertex-to-Vertex Rule**)



The Simplified Euler's Formula* for Legal Solids

11

$$F - E + V = 2$$



F	Faces
E	Edges
V	Vertices

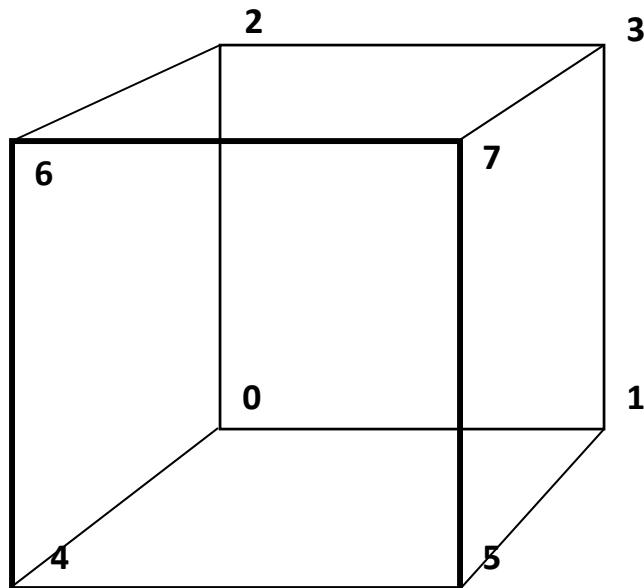
$$6 - 12 + 8 = 2$$

*sometimes called the Euler-Poincaré formula

The Full Euler's Formula* for Legal Solids

12

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

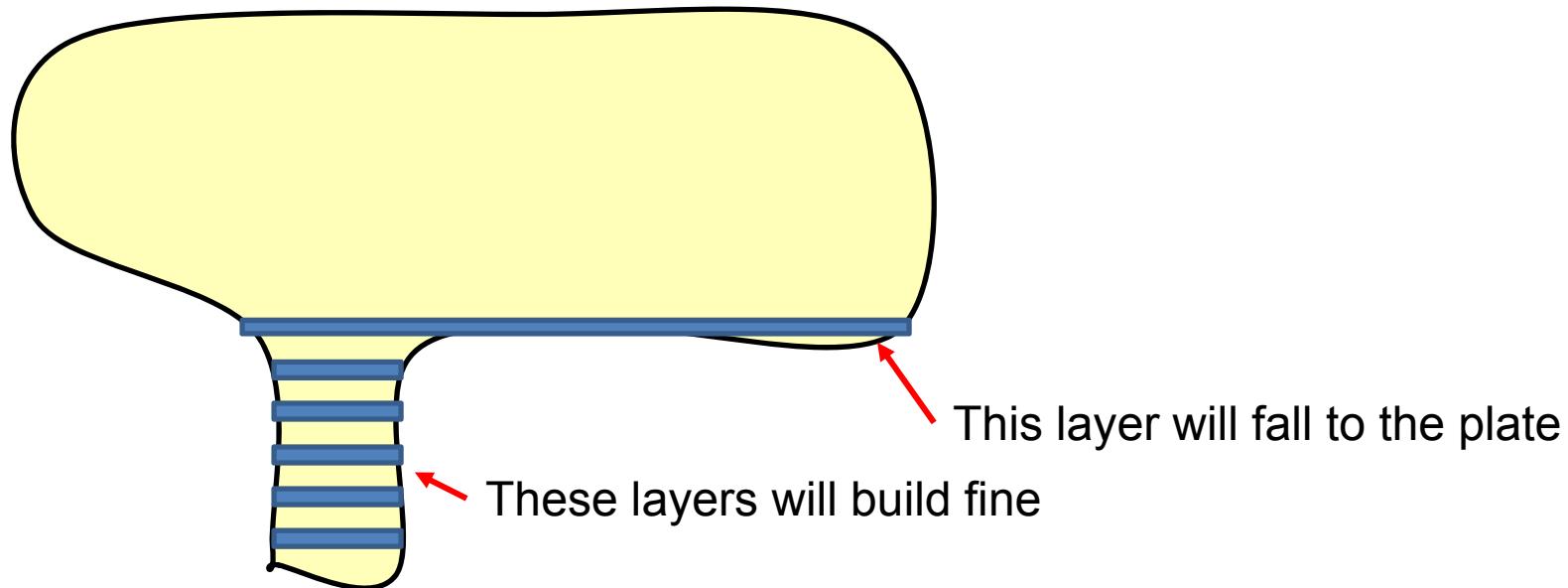


F	Faces
E	Edges
V	Vertices
L	Inner Loops (within faces)
B	Bodies
G	Genus (number of through-holes)

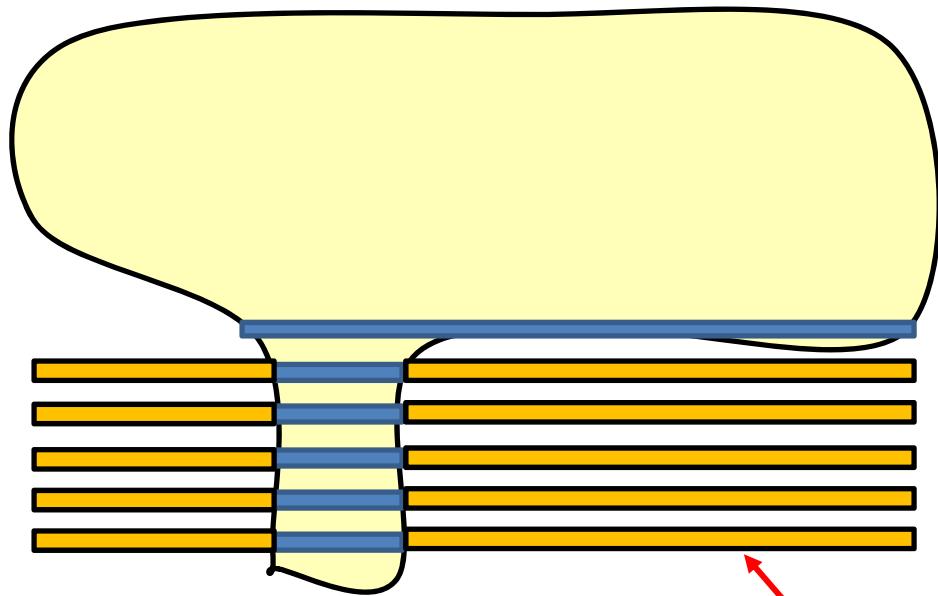
$$6 - 12 + 8 - 0 = 2(1 - 0)$$

*sometimes called the Euler-Poincaré formula

Watch Out for Overhangs!



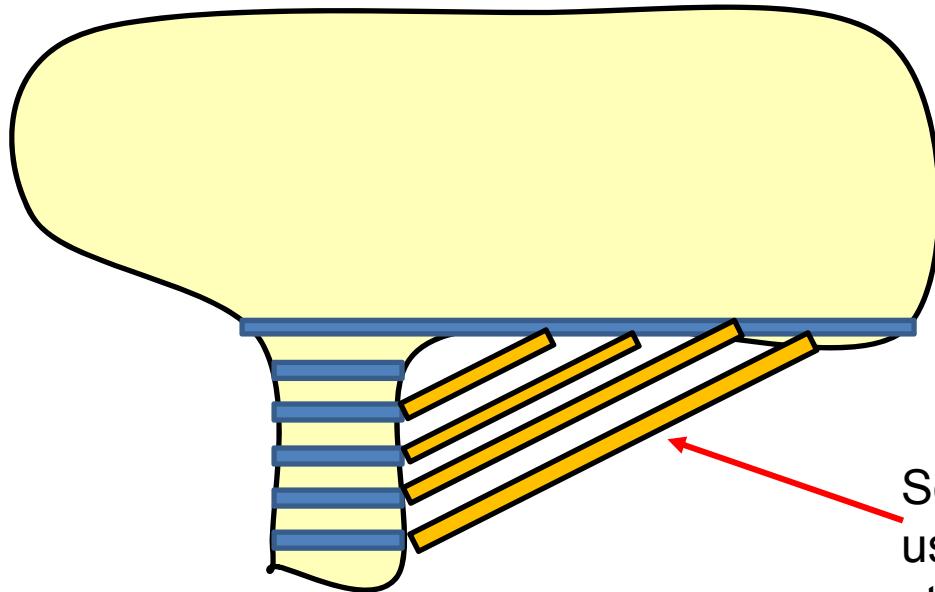
Watch Out for Overhangs!



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

Watch Out for Overhangs!

15



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

Some 3D printers handle this better than others...

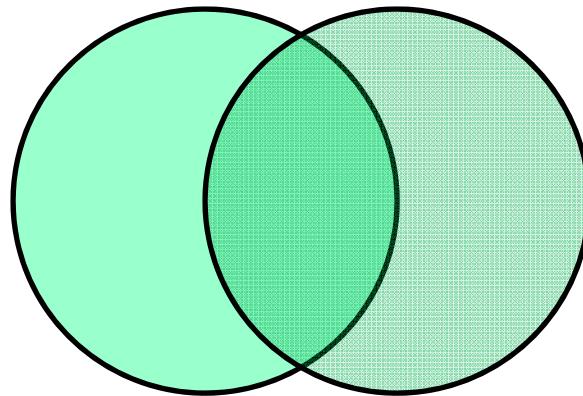
What Happens if You Don't Follow the Rules?

Check here:

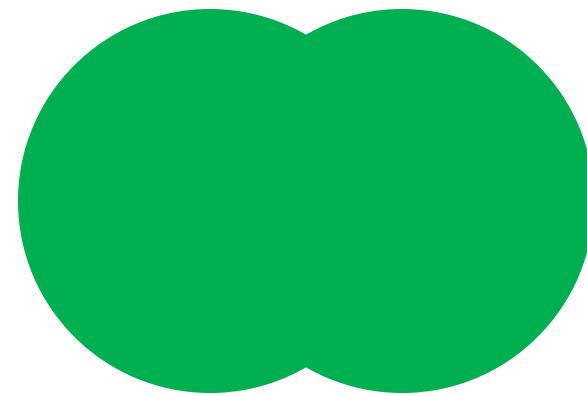
<http://twistedsifter.com/2013/08/when-3d-printing-goes-wrong/>



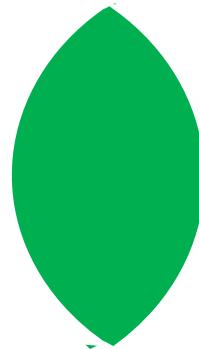
Another way to Model:
Remember Venn Diagrams (2D Boolean Operators) from High School?



Two Overlapping Shapes



Union

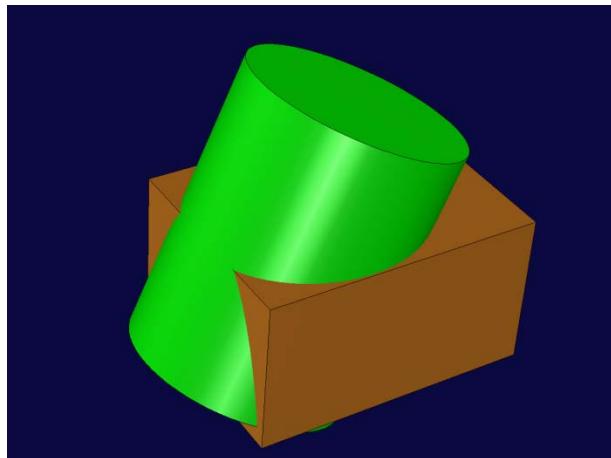


Intersection

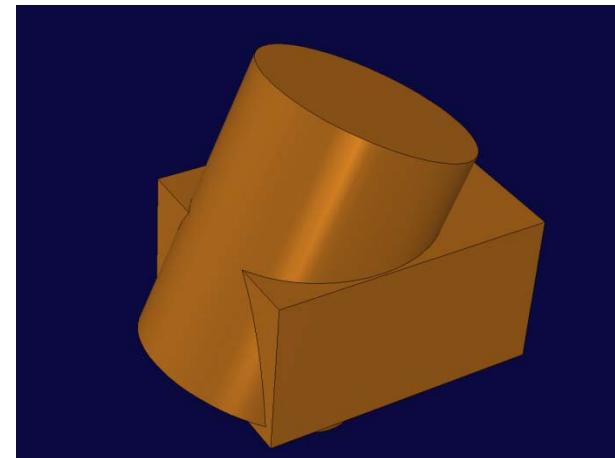


Difference

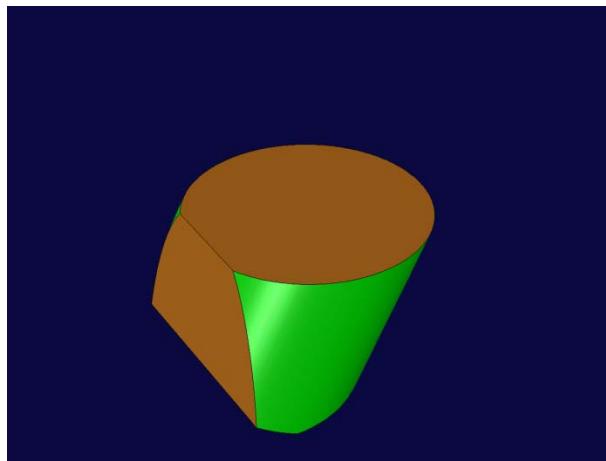
Solid Modeling Using 3D Boolean Operators



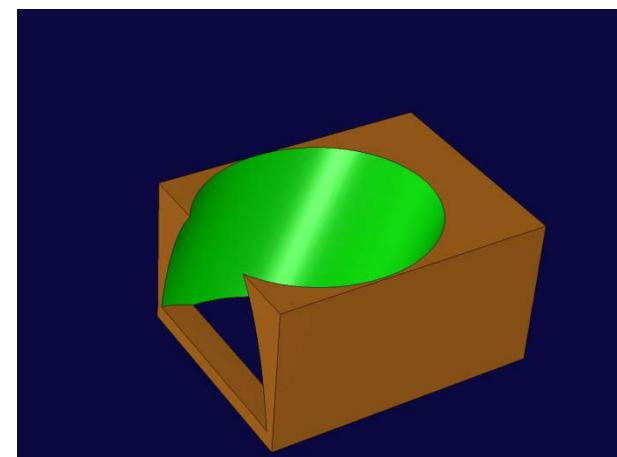
Two Overlapping Solids



Union



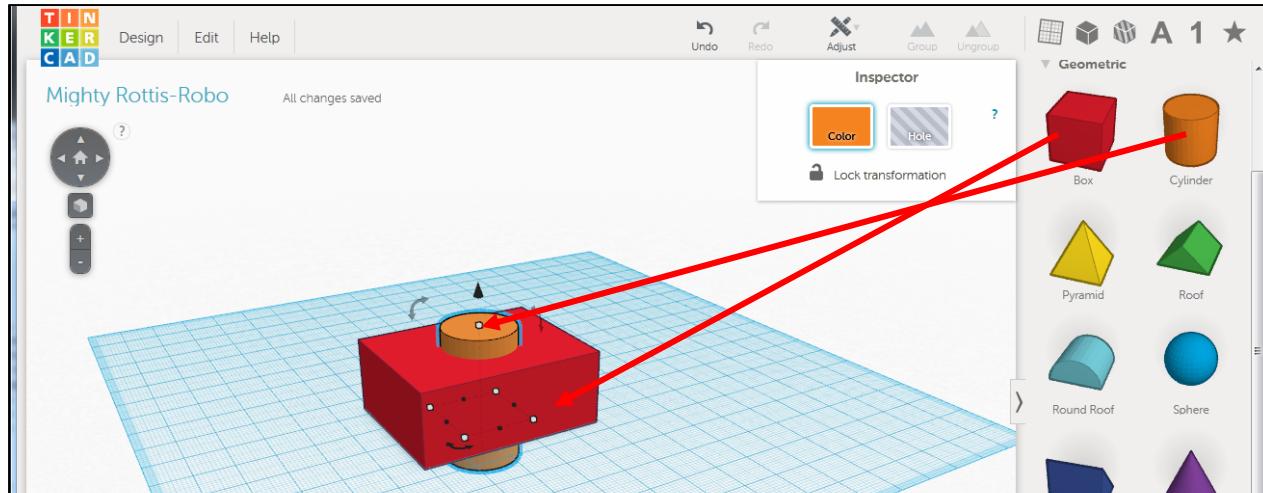
Intersection



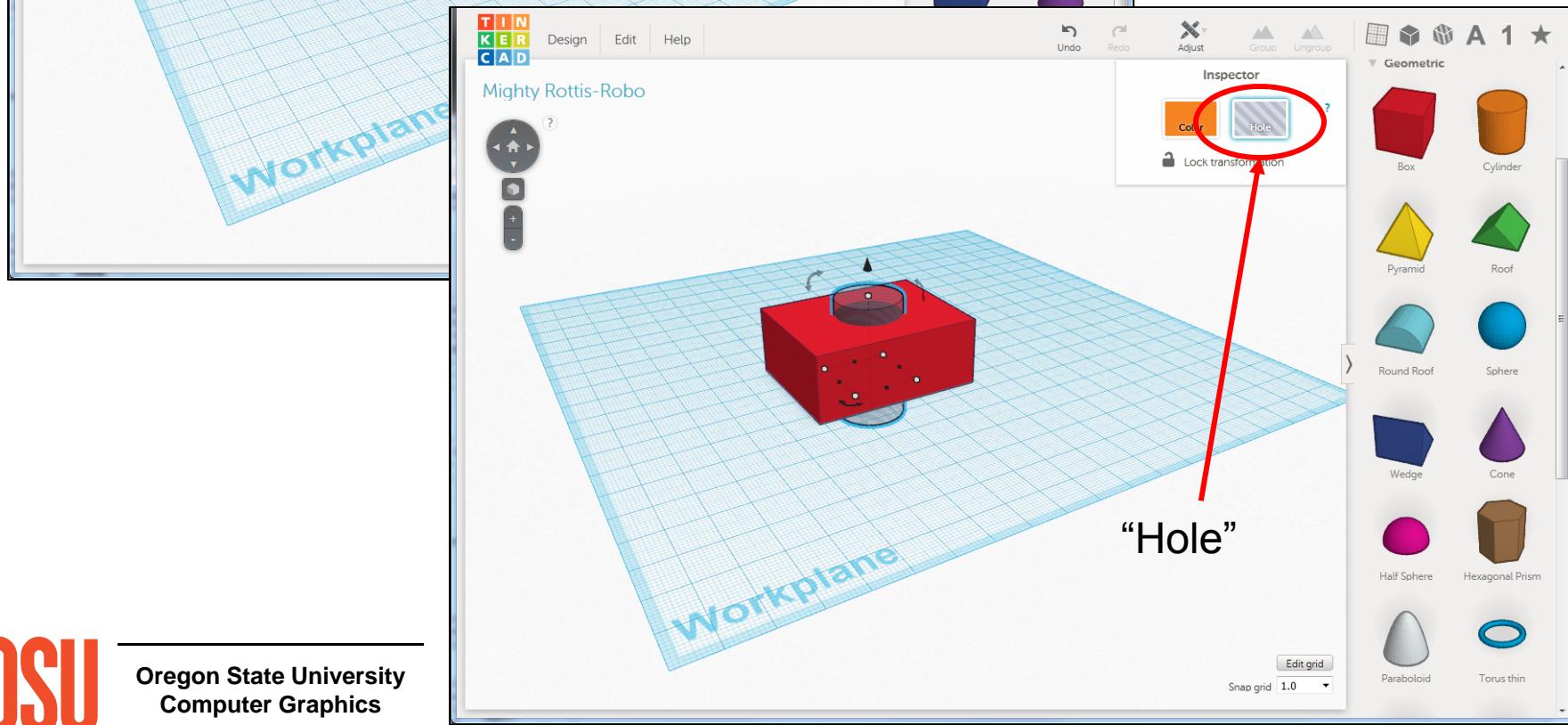
Difference

TinkerCAD: <http://www.tinkercad.com>

19



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



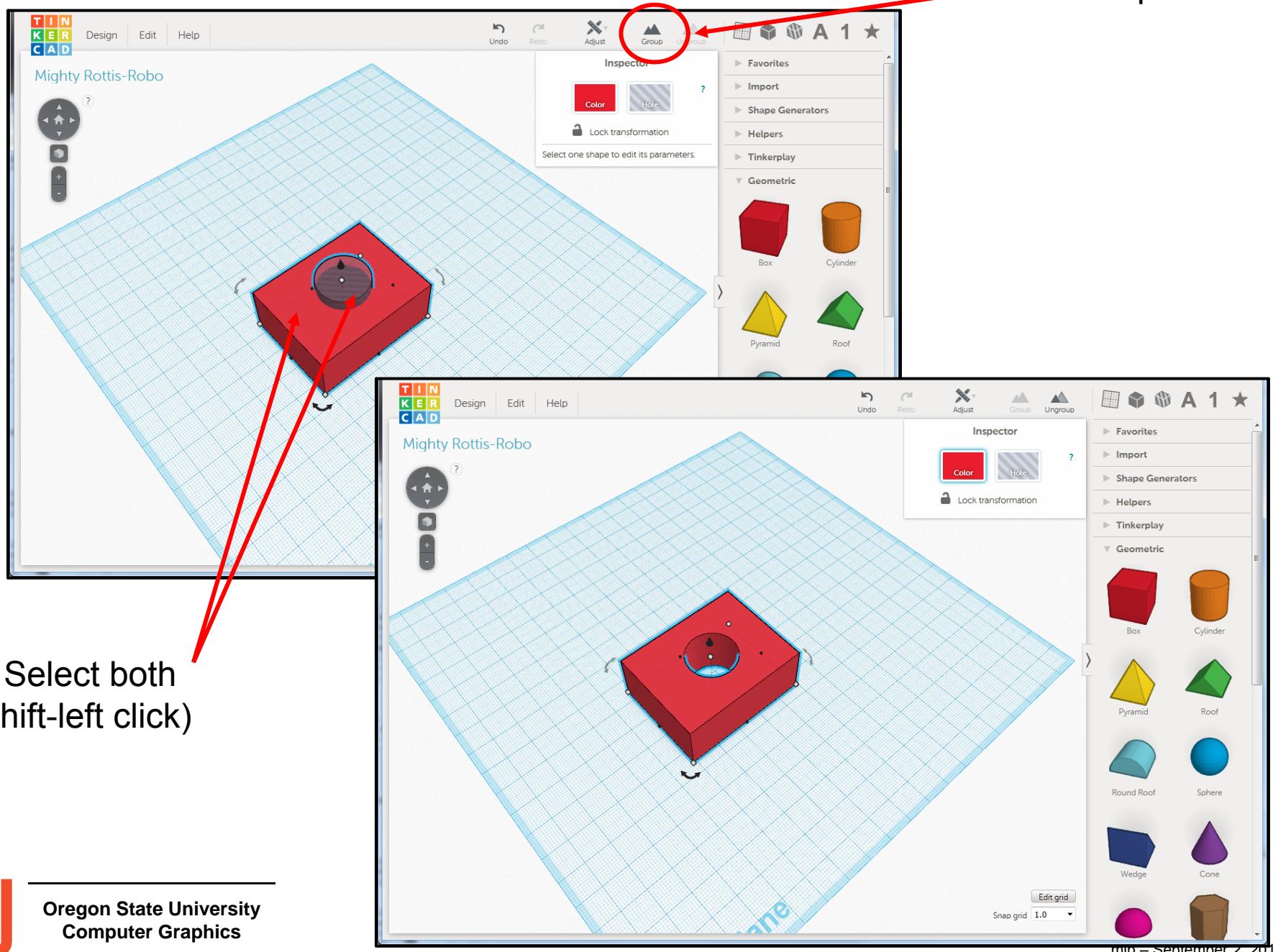
“Hole”



Oregon State University
Computer Graphics

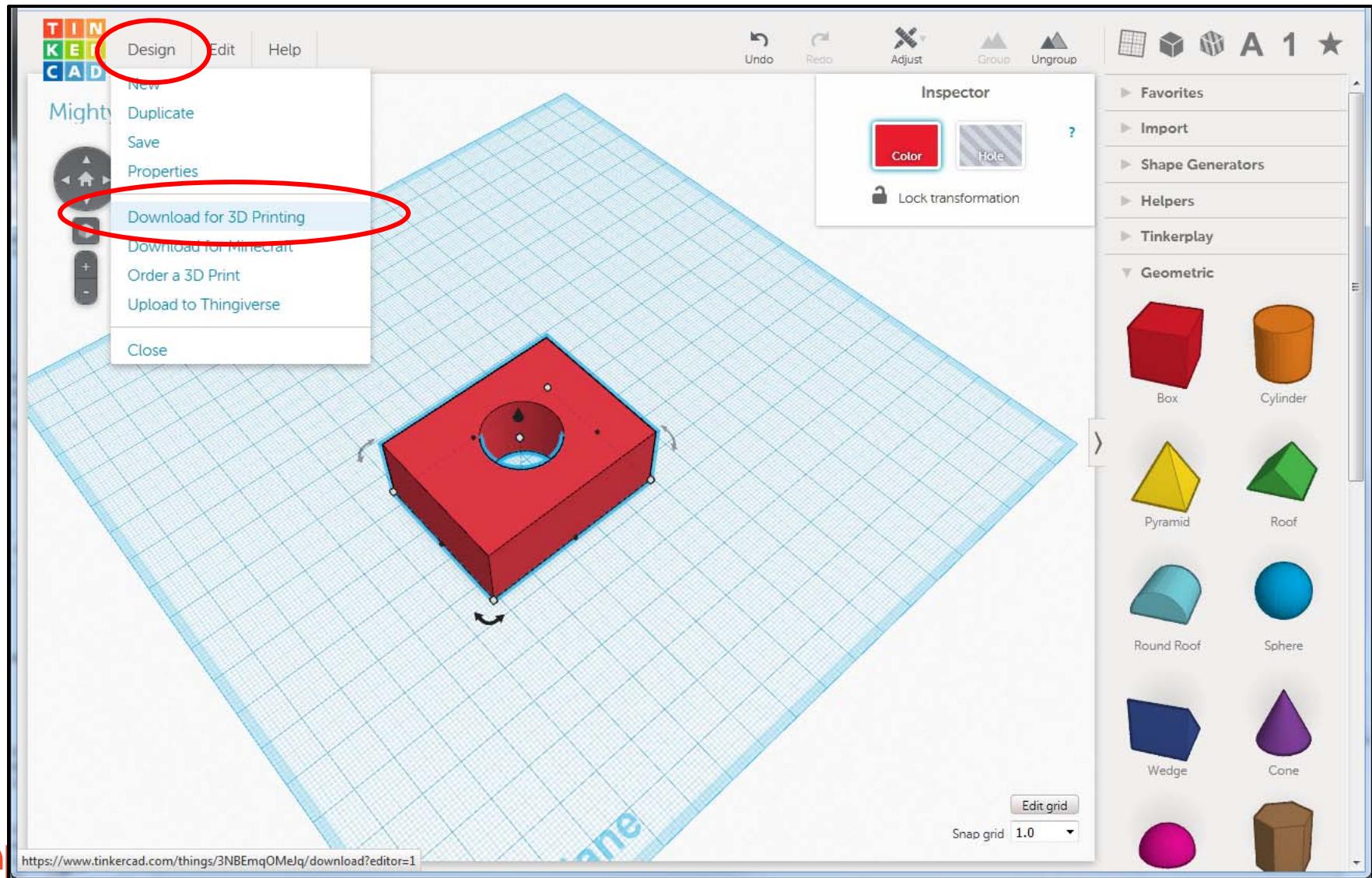
mjp – September 2, 2016

TinkerCAD



TinkerCAD

21



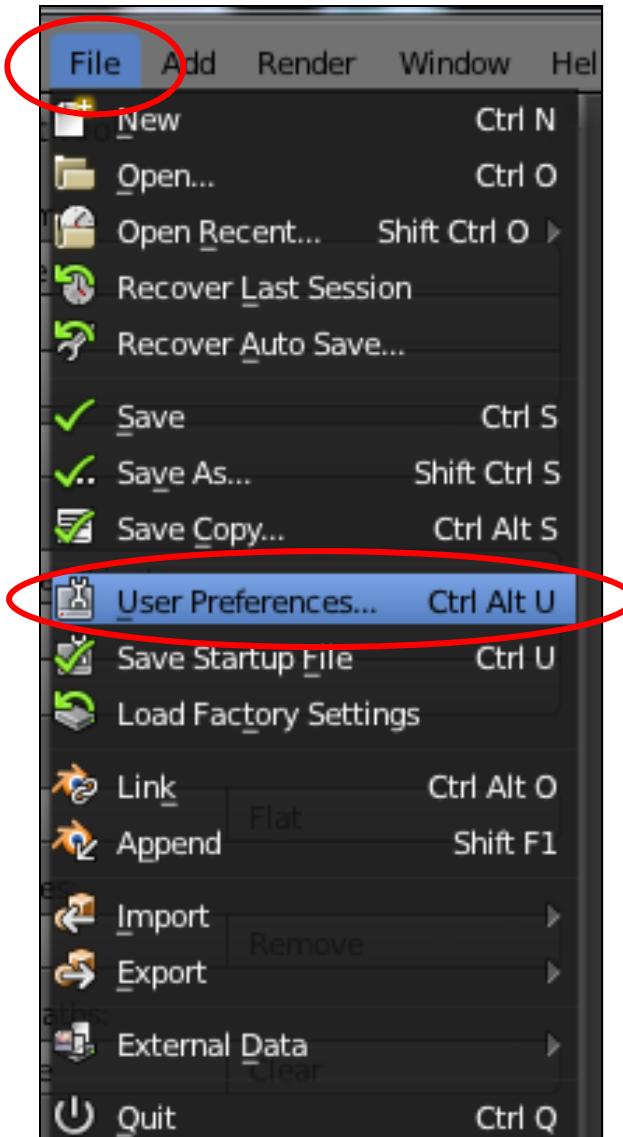
Starting with Version 2.70, Blender's 3D Printing Options show up as a Tab in the Toolshelf



. . .but only if it's installed properly . . .

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

23



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

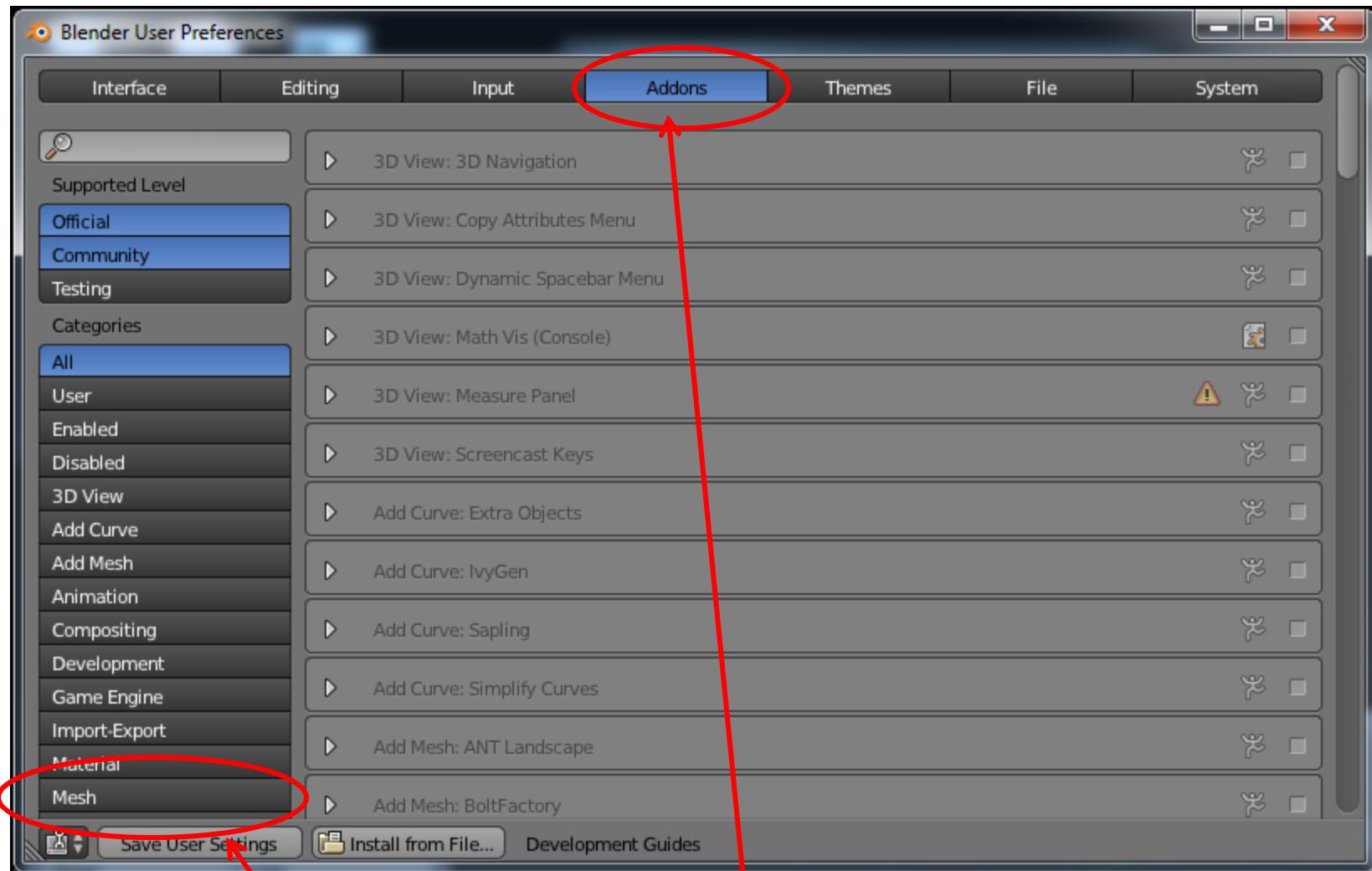
The versions of Blender in the **OSU CGEL** have already had this done to it.

If you are on a system that doesn't show a "3D Printing" option in the toolshelf tabs, do this:

1. Click File → User Preferences

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

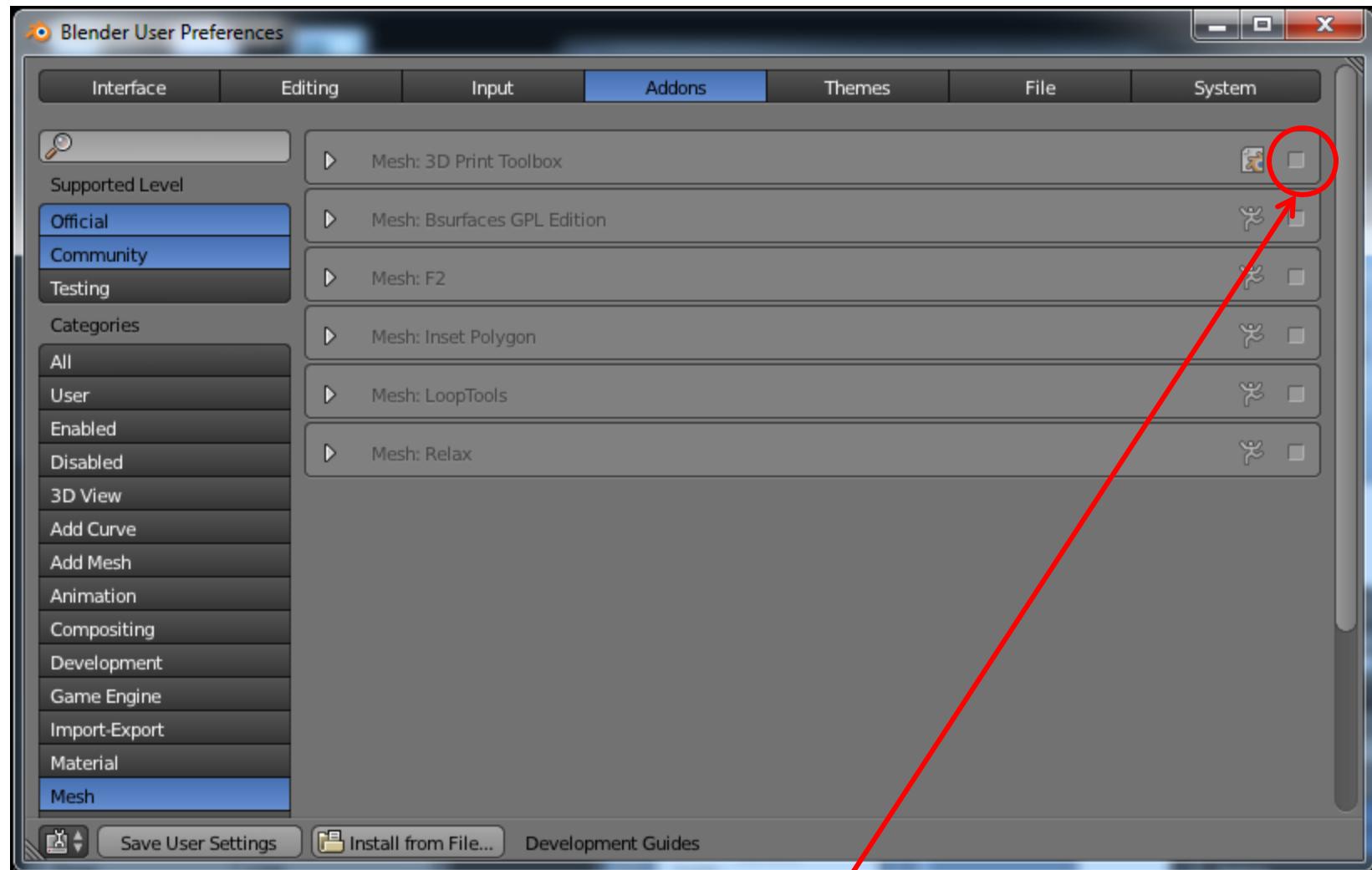
24



2. Click on the Addons tab
3. Scroll down to the Mesh Addons, or click on Mesh

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

25



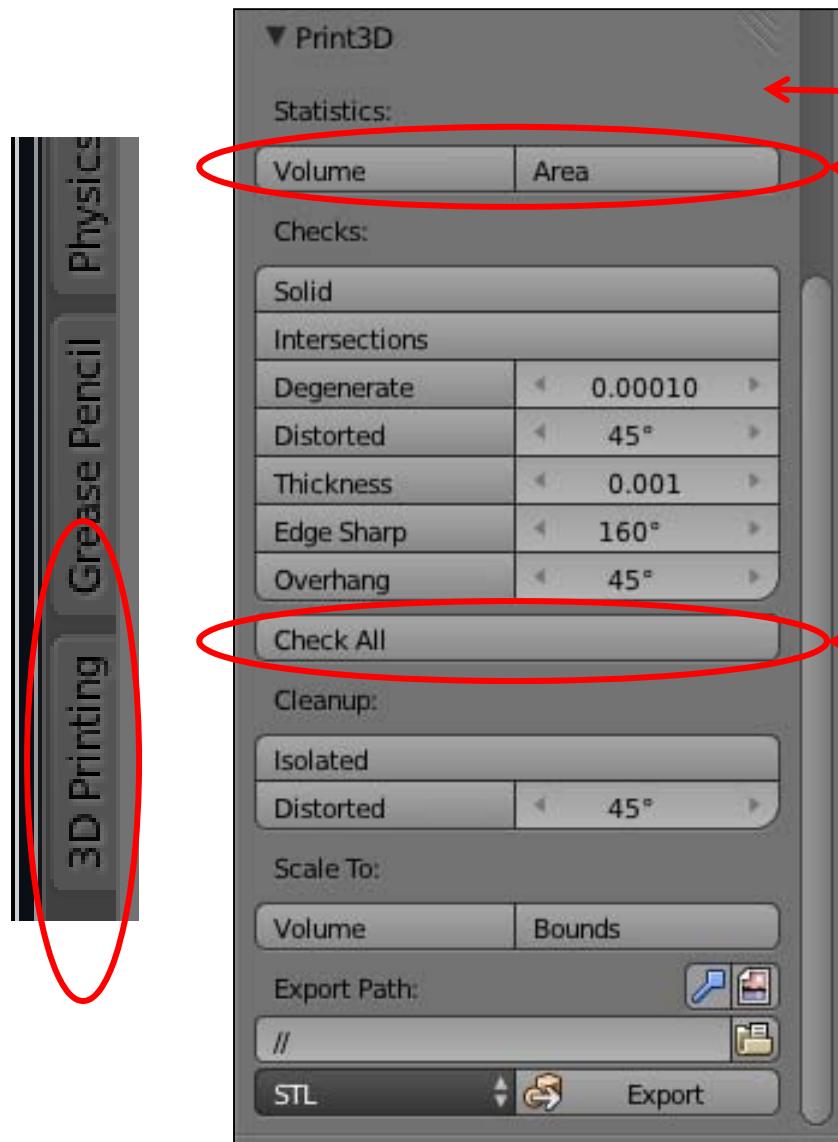
4. Click the **Mesh: 3D Print Toolbox**



Ore
c <http://wiki.blender.org/index.php/Extensions:2.6/Py/Scripts/Modeling/PrintToolbox>

mjb – September 2, 2016

Options for 3D Printing

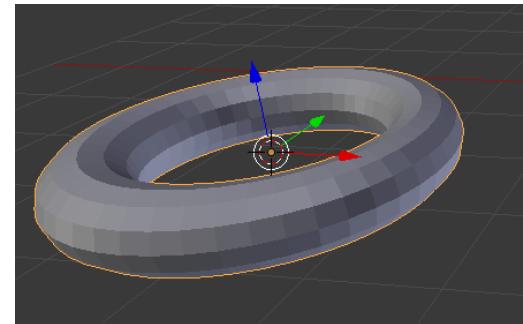
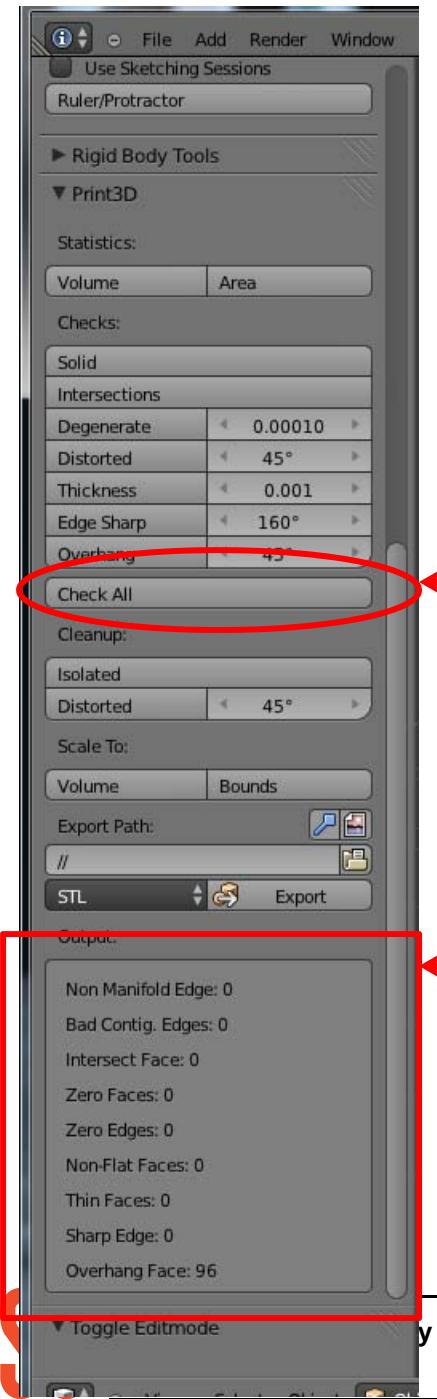


This now shows up in your Toolshelf

These are fun to click on. They will show you your object's volume and surface area (listed below).

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

Options for 3D Printing

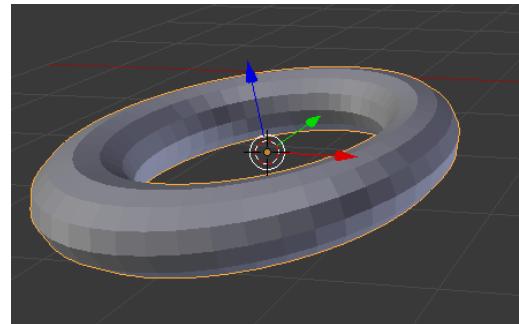


Objects destined for 3D Printing must be “legal solids”.
Clicking on **Check All** will try to determine that

The **Check All** output is here. You might have to scroll down to see it.

Options for 3D Printing

28



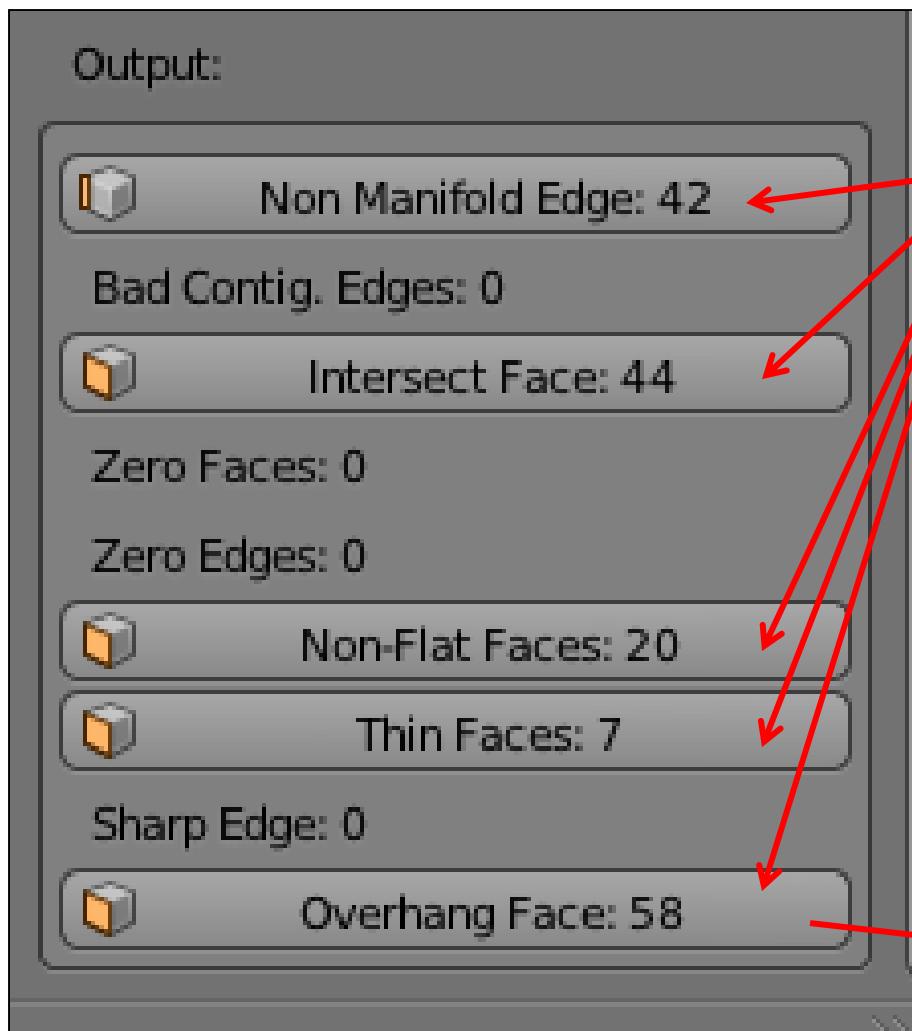
Output:	
Non Manifold Edge:	0
Bad Contig. Edges:	0
Intersect Face:	0
Zero Faces:	0
Zero Edges:	0
Non-Flat Faces:	0
Thin Faces:	0
Sharp Edge:	0
Overhang Face:	96

The fact that all of these are zero is good. Any of them being non-zero would probably mean that your object cannot be 3D printed.

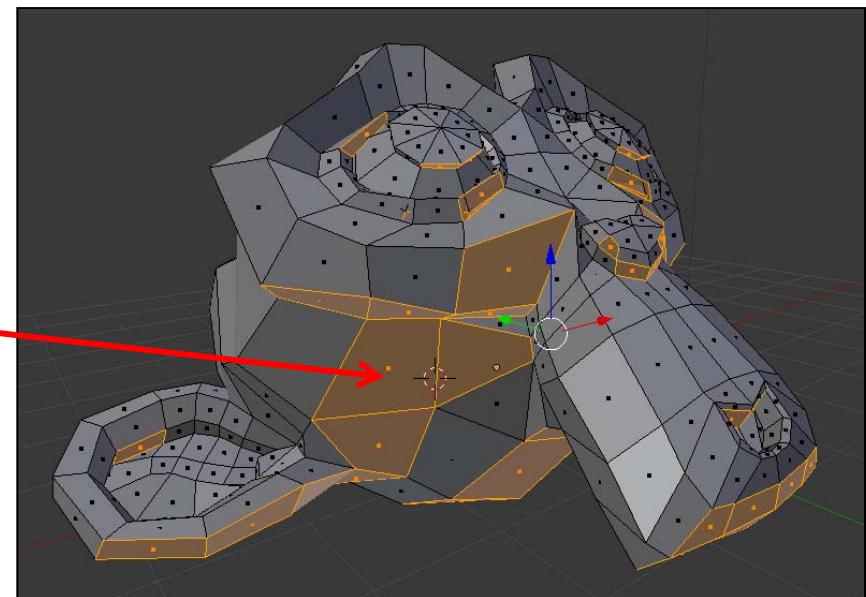
An overhang face is not necessarily a bad thing. The entire bottom of the part will consist of, by necessity, overhang faces.

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

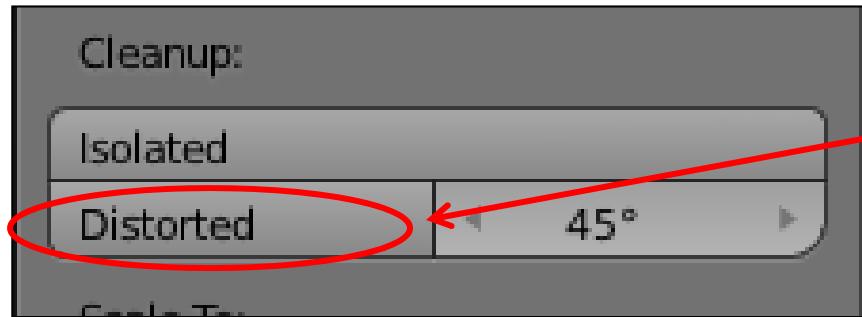
Options for 3D Printing



If you do get some values that are non-zero, Tab into Edit Mode and click on them. Blender will show you where they are located.



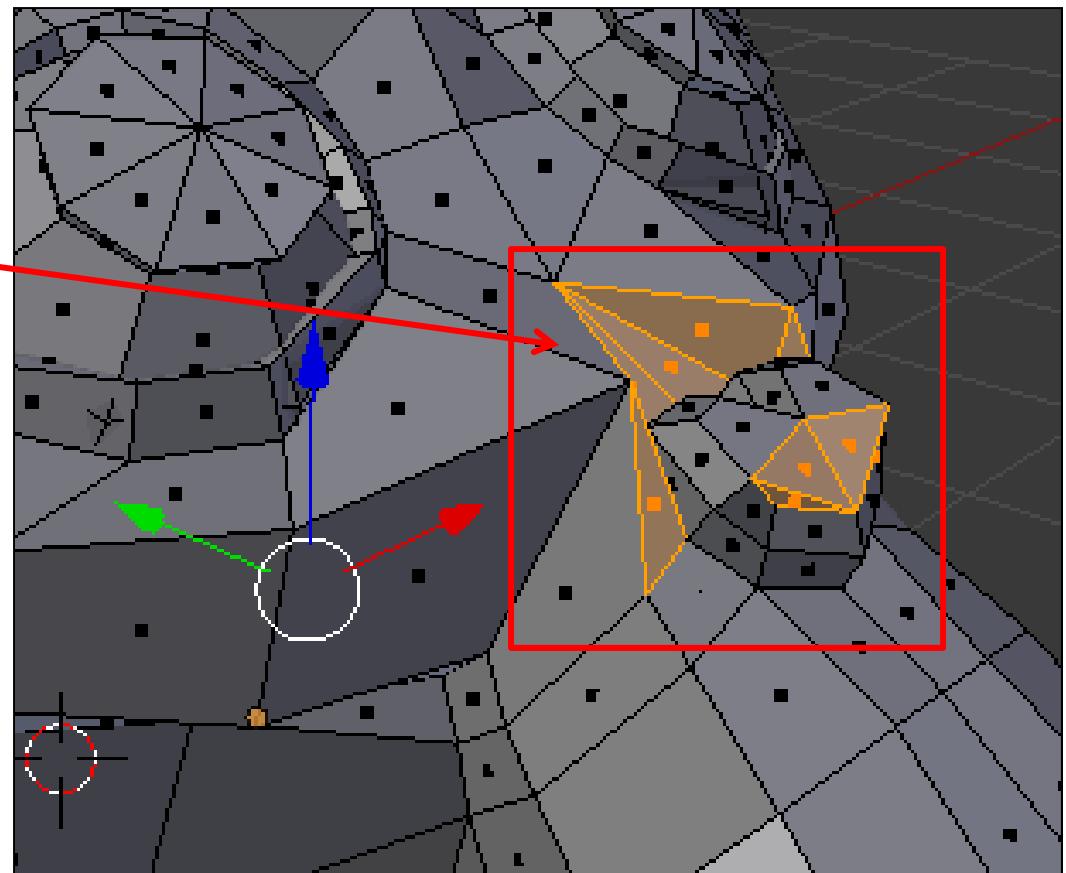
Options for 3D Printing



Non-planar faces can be fixed by clicking here

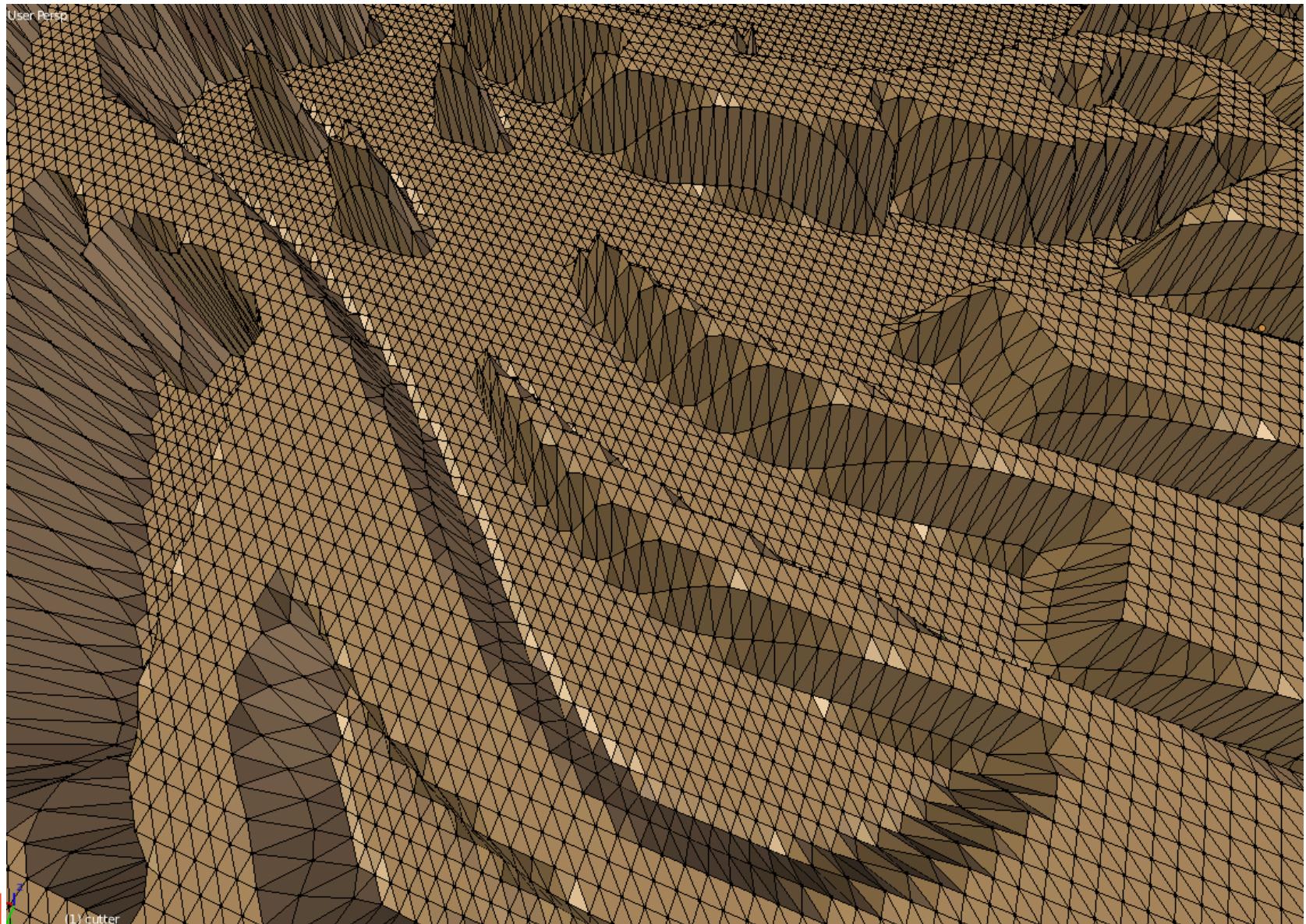
Blender then turns those non-planar quadrilaterals into triangles

You can click on **Check All** to confirm this.



mjb – September 2, 2016

Heightmap Files are Straightforward to use with 3D Printing ³¹



A Very Special Heightmap 3D Printing Model

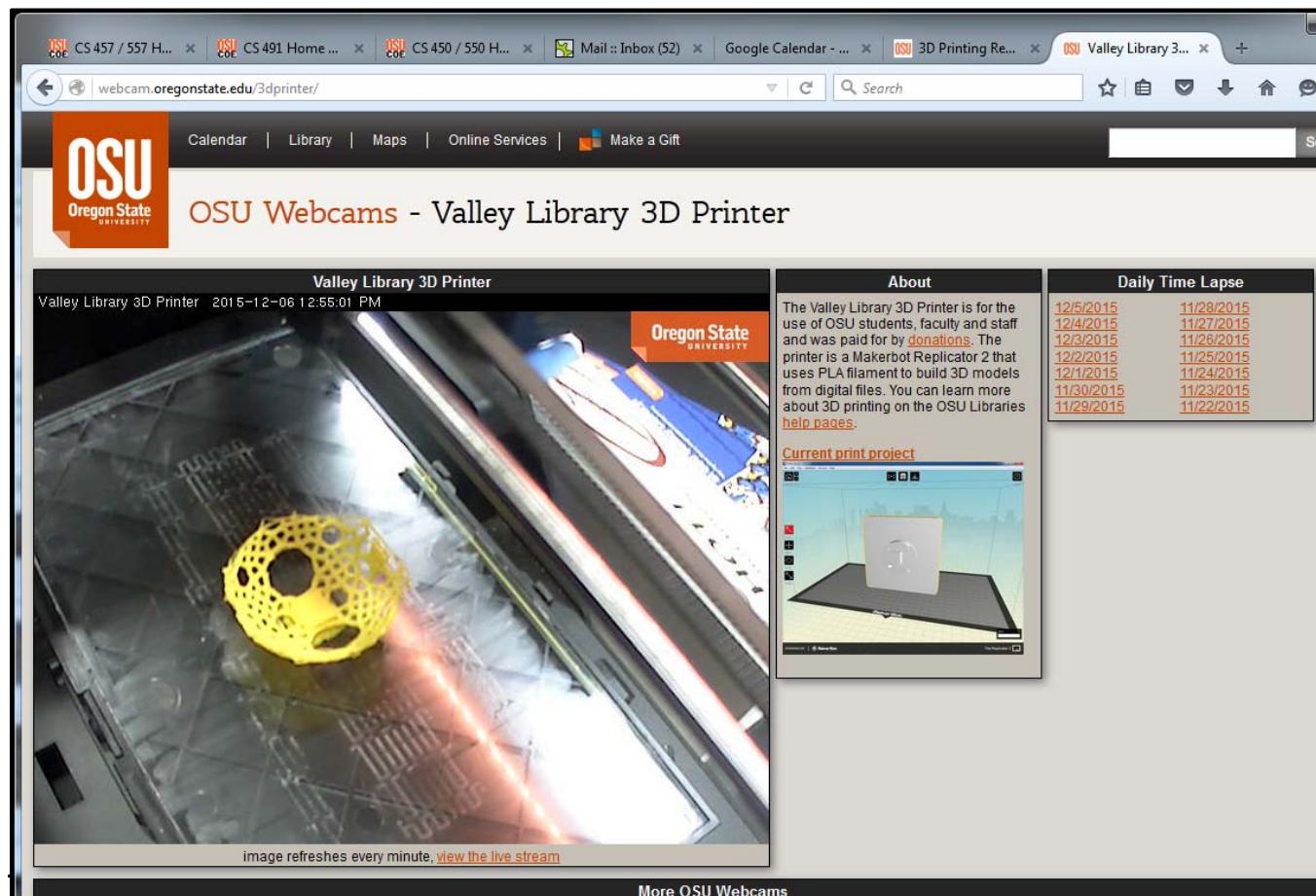
32



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>

guide about where to find 3D printers and training at OSU.

3D Printing Submission Form

Only ".stl" (Stereo Lithography Type) files are accepted. File size must be less than 5 MB. If your file is larger than 5 MB, please email valley3Dprinting@oregonstate.edu

Attach ".stl" file No file selected.

- If you want to know the cost of printing your model before we begin, select "Notify me" in the menu below, and we will contact you with the cost and wait for your approval to start printing.
- If you prefer to cut down on wait time, select a price limit from the menu, and we will print as soon as possible, unless the cost will exceed the limit you indicated.
- If charging to a department index, choose that from the drop down and provide the index & authorization in the comment field.

Charge approval *

-Select-

-Select-\$5.00 or less-\$15.00 or less-\$30.00 or less-Notify me-Departmental Index

Reset

