

3D Printing



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In the Beginning, Manufacturing was “Subtractive”

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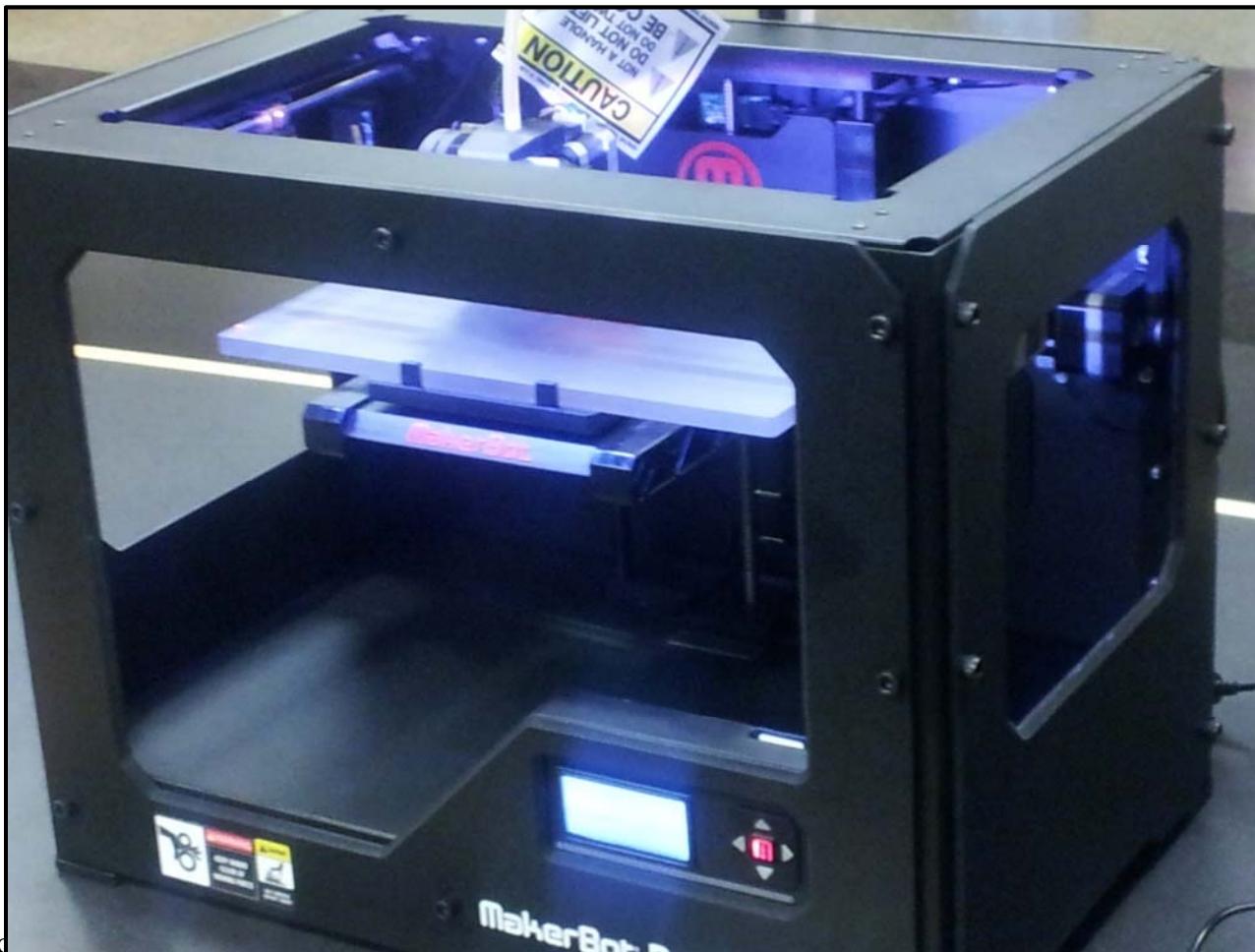
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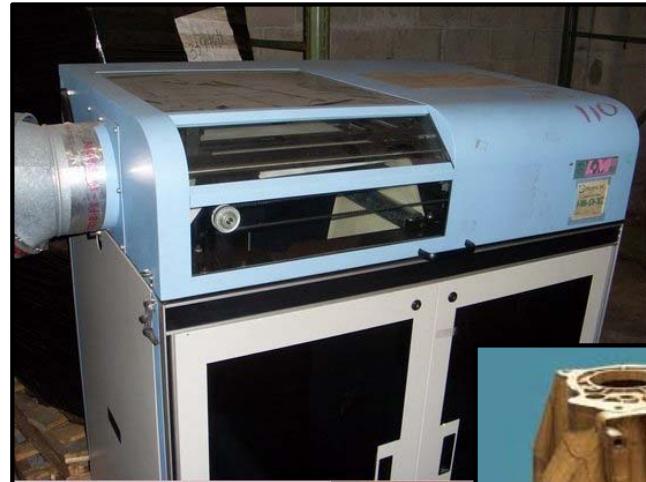
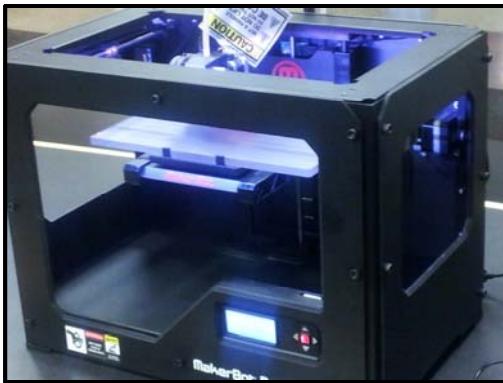
mjb – October 21, 2017

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 3D Printing for Stop-motion Movies 5



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 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. At the top, there's a navigation bar with links for DASHBOARD, EXPLORE, CREATE, a search bar, and a user profile icon. Below the navigation is a section titled "Customizer by MakerBot". The main area features a title "Customizable pendant" and a preview image of a blue rose-like curve on a grid. On the left, there's a sidebar with a "parameters" section containing three sliders labeled A, B, and C, and a dropdown menu set to "Rhodonea curve". Below this is a "Rose Thickness" slider set to 1. At the bottom right of the main area are links for "View Source" and a prominent blue "Create Thing" button. Red annotations highlight several elements: a red circle encloses the "Customizable pendant" title and the parameter sliders; an arrow points from the text "Name of project" to the user profile icon; another arrow points from the text "Parameters you can set" to the sliders; and a final arrow points from the text "Retrieve the STL file" to the "Create Thing" button.

Customizable pendant

Name of project

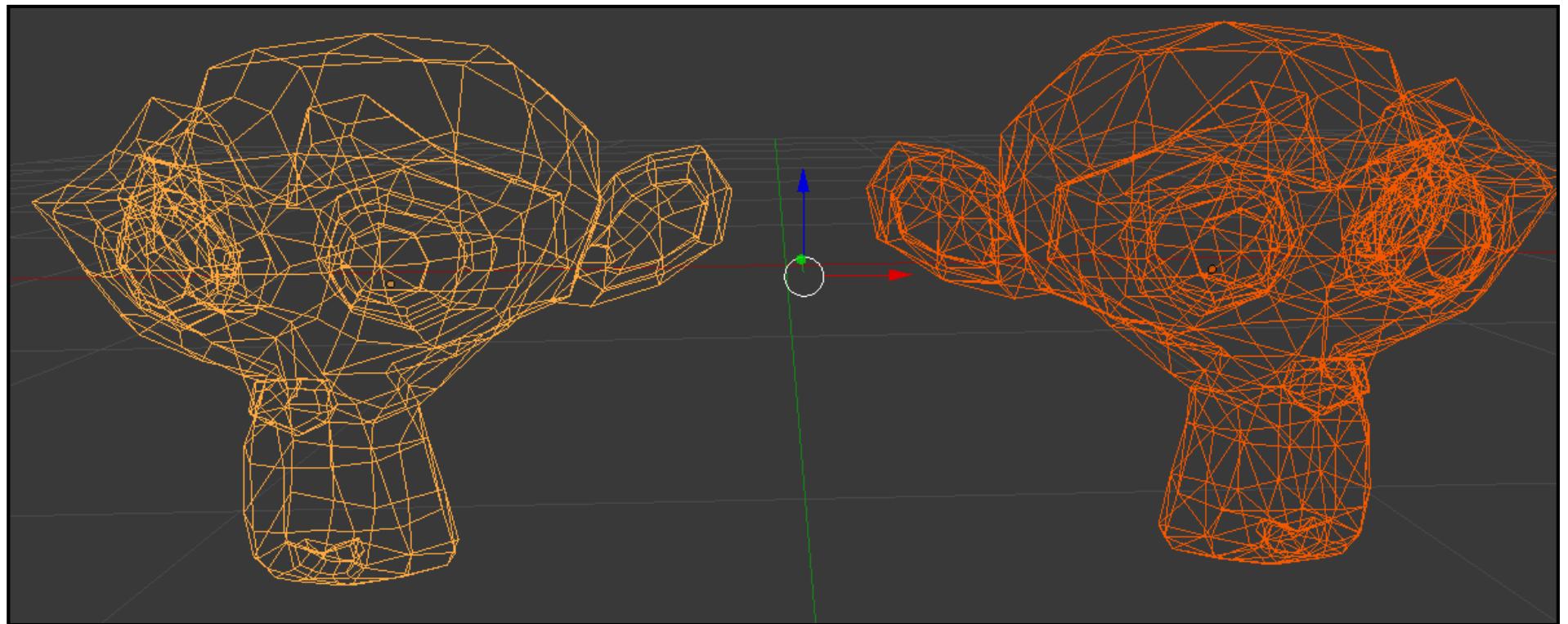
Parameters you can set

Create Thing

Retrieve the STL file

Object Rules for 3D Printing

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



Quads and triangles

Triangles only

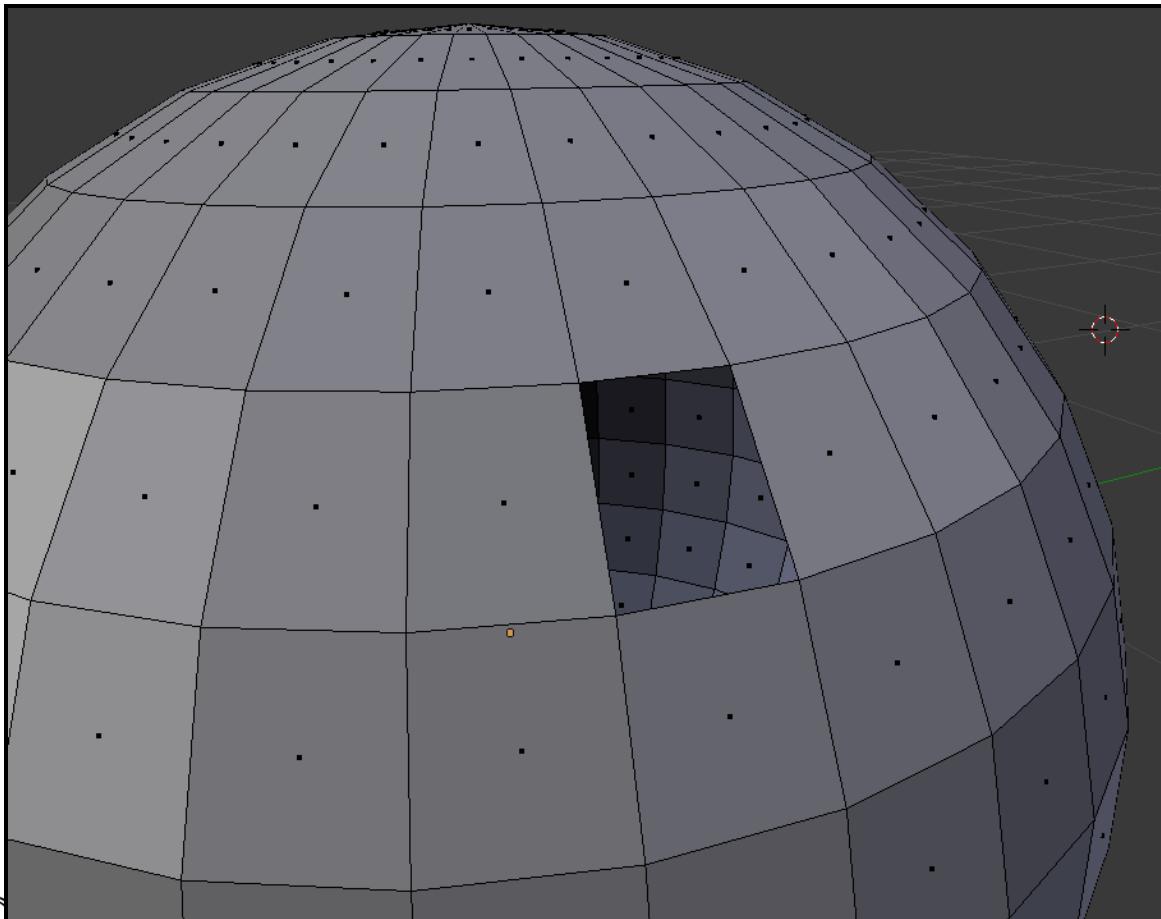


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In Blender: Modifiers → Add Modifier → Triangulate

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.



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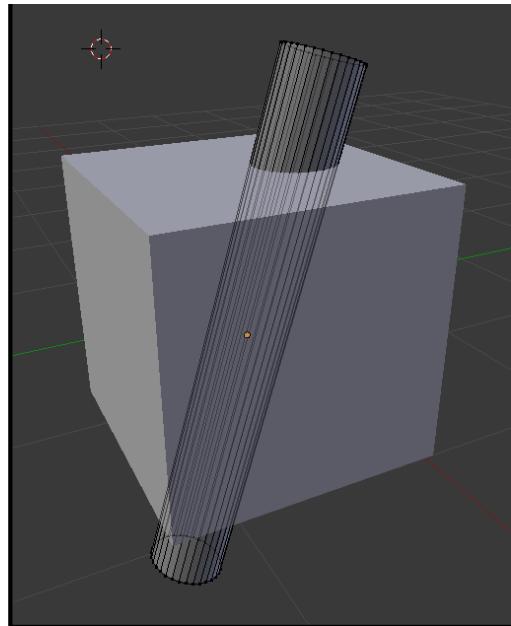
“Definite inside and outside” is sometimes called “Two-manifold” or “Watertight”

Object Modeling Rules for 3D Printing

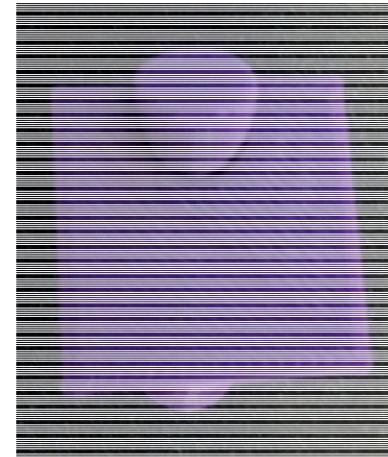
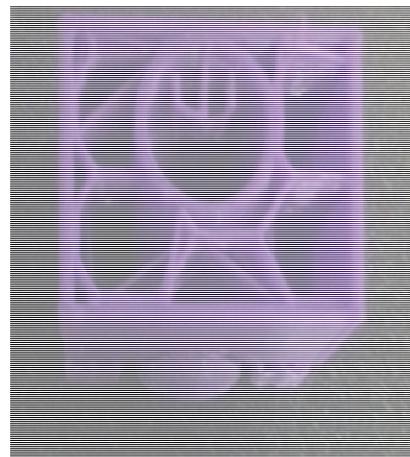
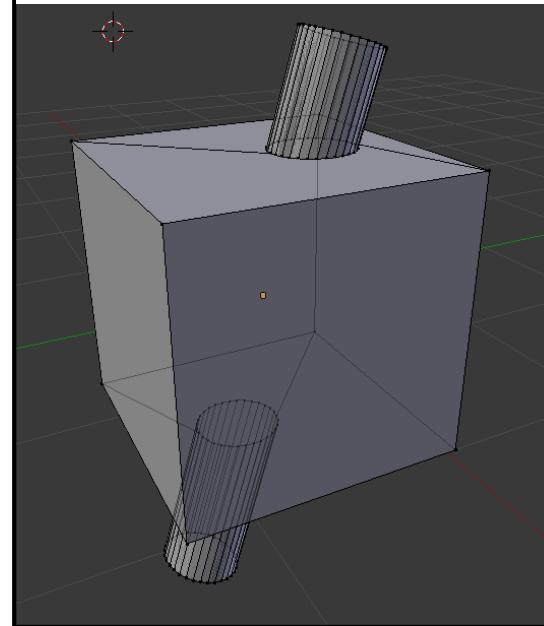
10

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**



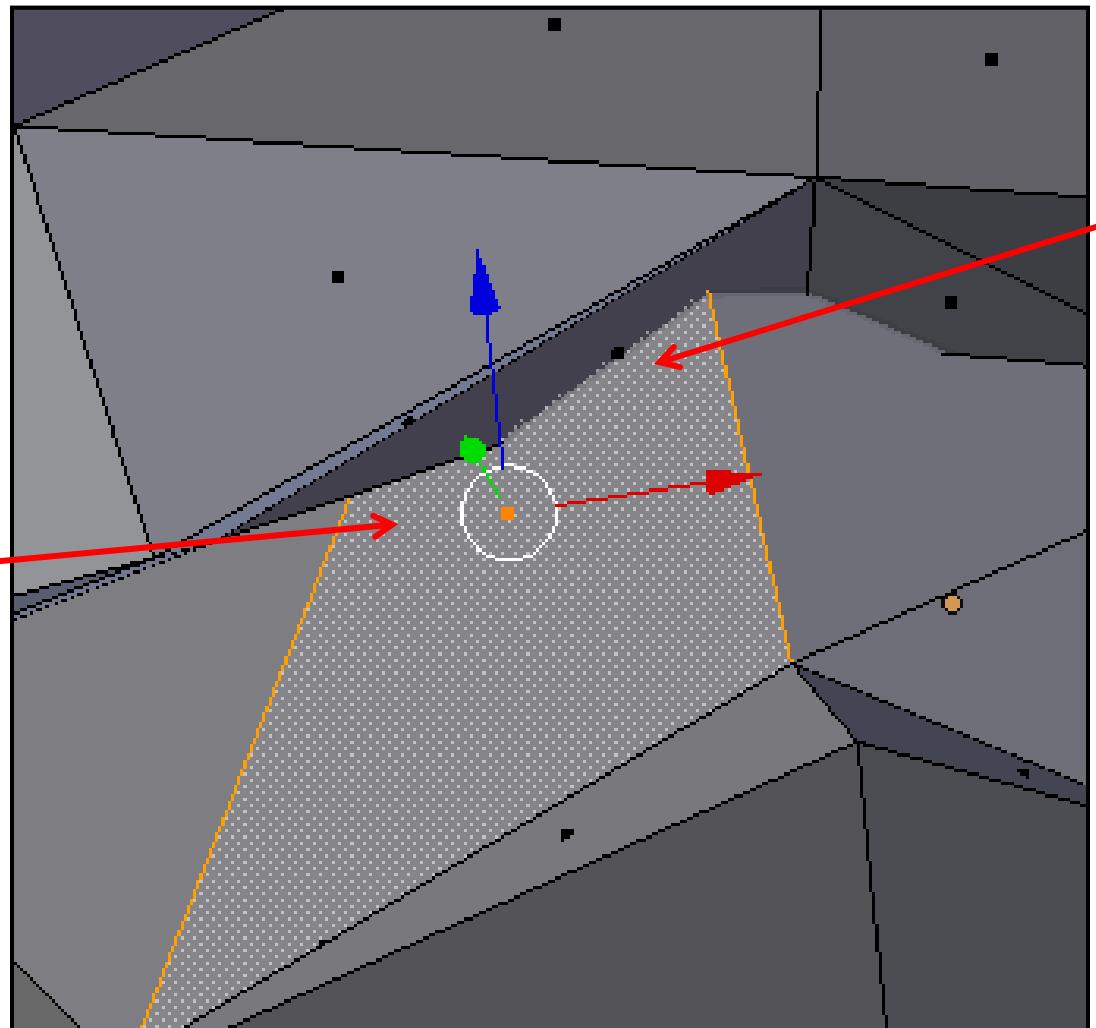
Boolean union -- **good**



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Object Rules for 3D Printing

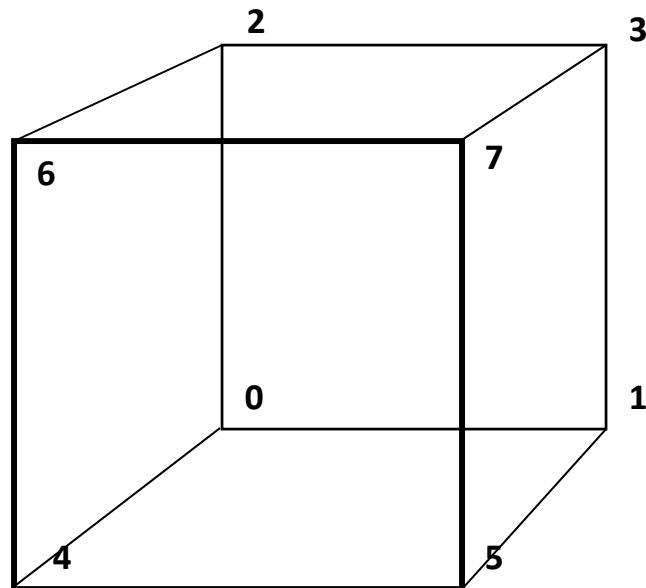
4. Each edge in the mesh must bound 2 and only 2 triangles
(this is known as the **Vertex-to-Vertex Rule**)



The Simplified Euler's Formula* for Legal Solids

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$$F - E + V = 2$$



F	Faces
E	Edges
V	Vertices

$$6 - 12 + 8 = 2$$



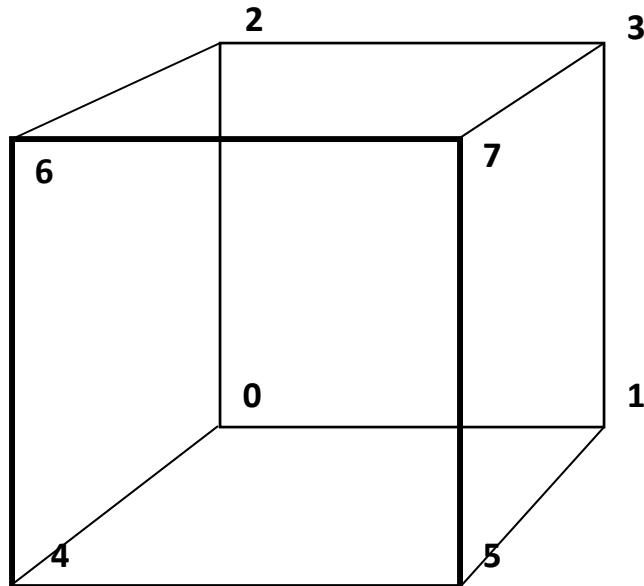
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*sometimes called the Euler-Poincaré formula

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The Full Euler's Formula* for Legal Solids

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

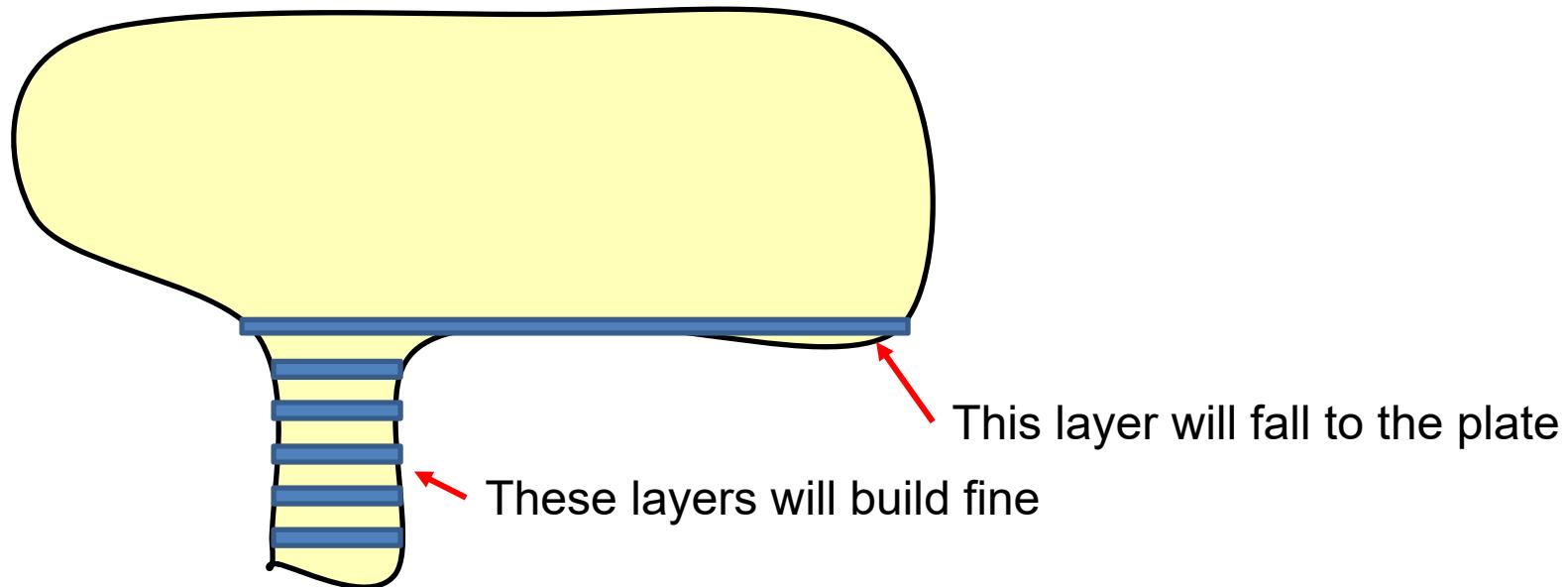


F	Faces
E	Edges
V	Vertices
L	Inner Edge Loops (within faces)
B	Bodies
G	Genus (number of through-holes)

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



Watch Out for Overhangs!

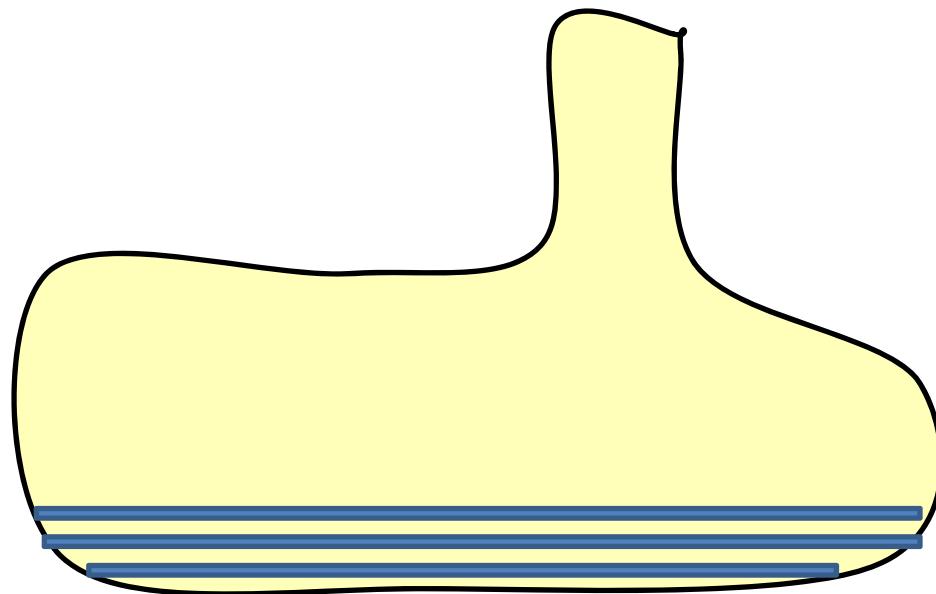


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Note that, if you build it upside-down,
it will probably be fine

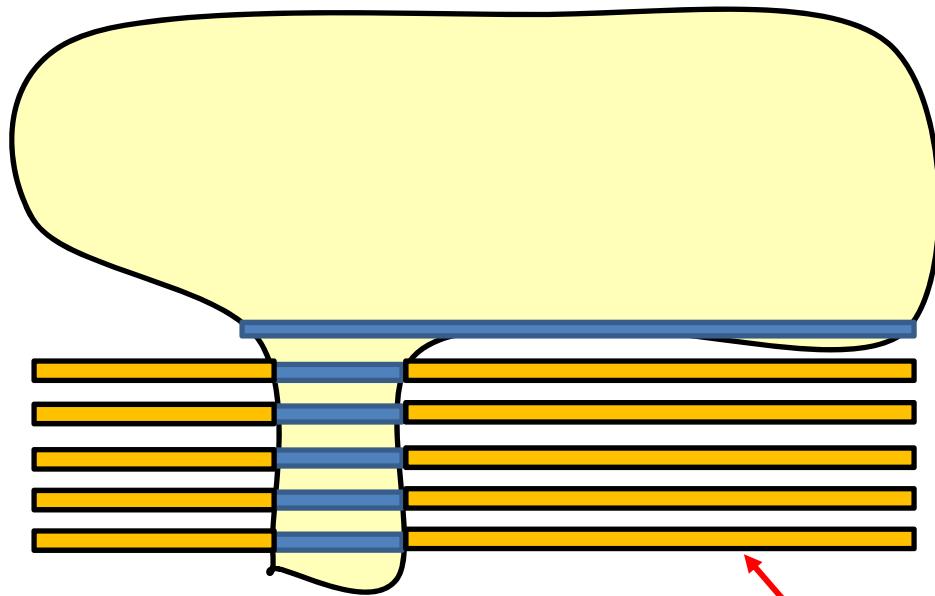


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Watch Out for Overhangs!



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

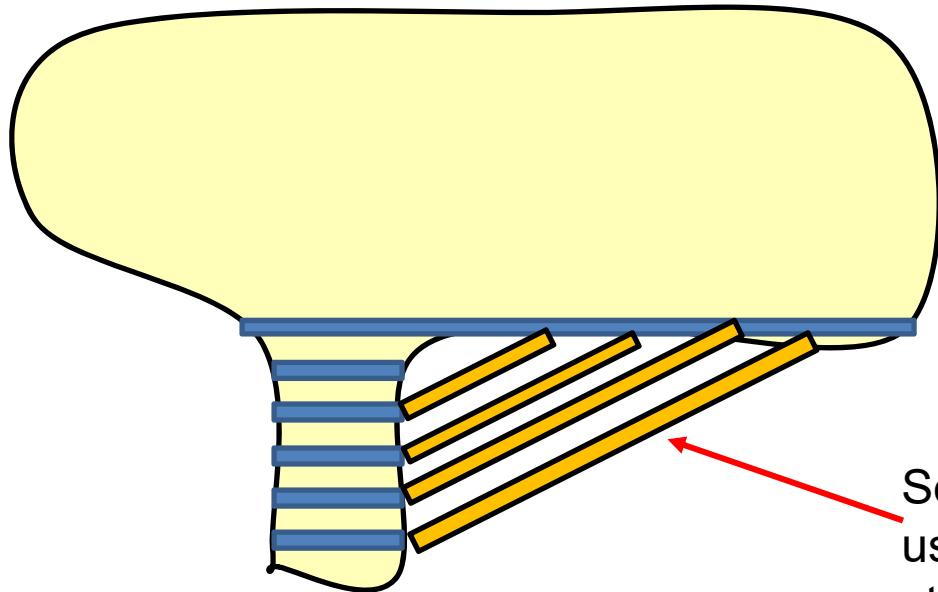


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Watch Out for Overhangs!



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

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



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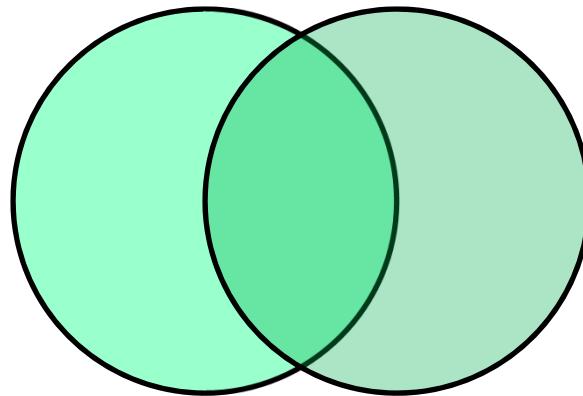
What Happens if You Don't Follow the Rules?

Check here:

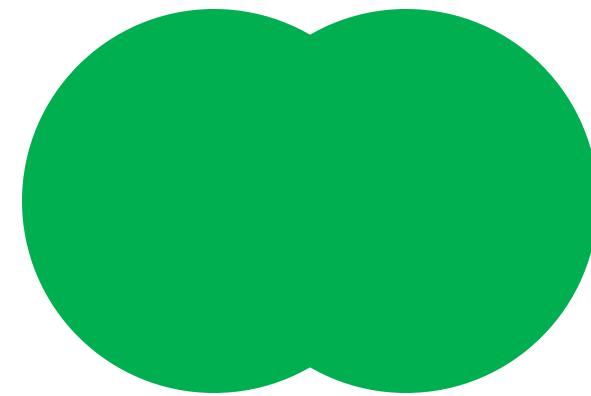
<http://twistedsifter.com/2013/08/when-3d-printing-goes-wrong/>



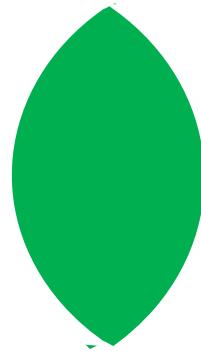
Another way to Model:
Remember Venn Diagrams (2D Boolean Operators) from High School?



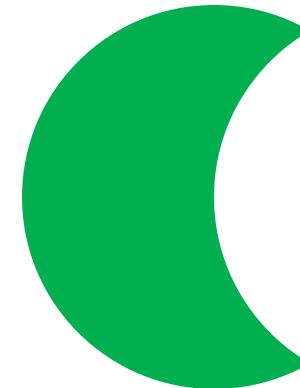
Two Overlapping Shapes



Union



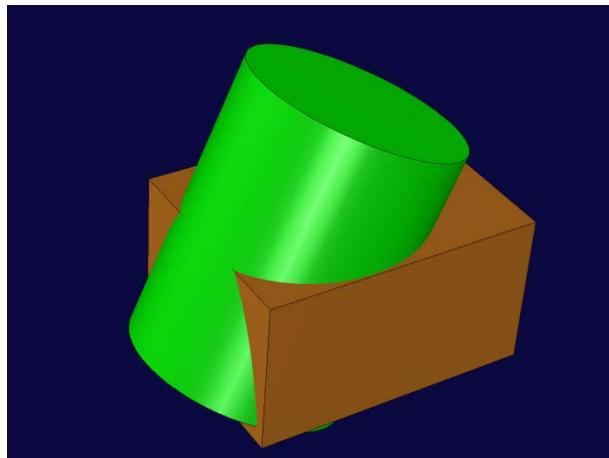
Intersection



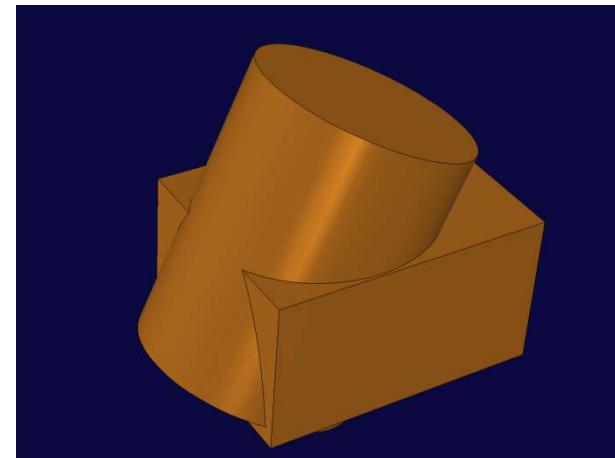
Difference



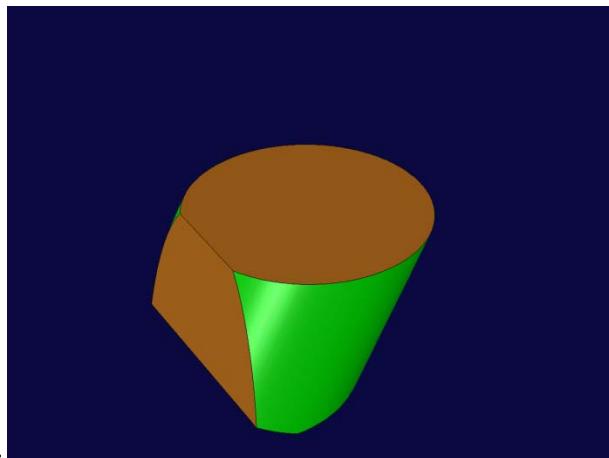
Solid Modeling Using 3D Boolean Operators



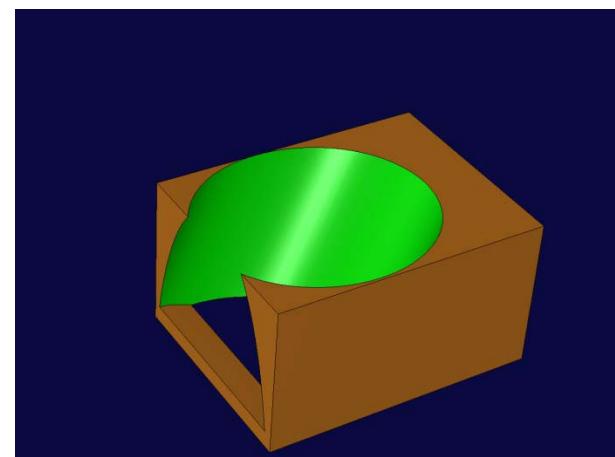
Two Overlapping Solids



Union



Intersection

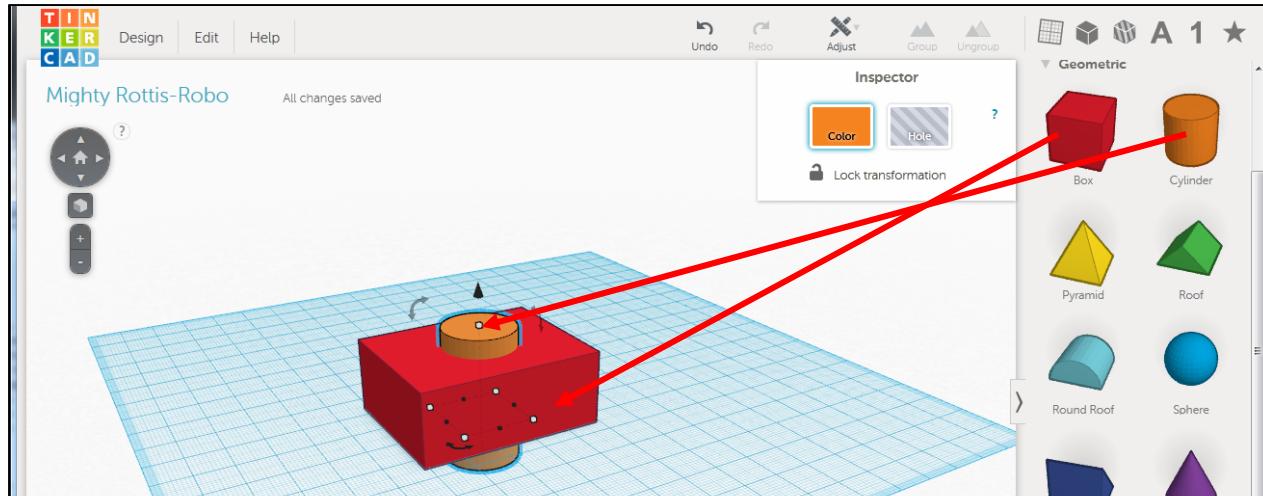


Difference

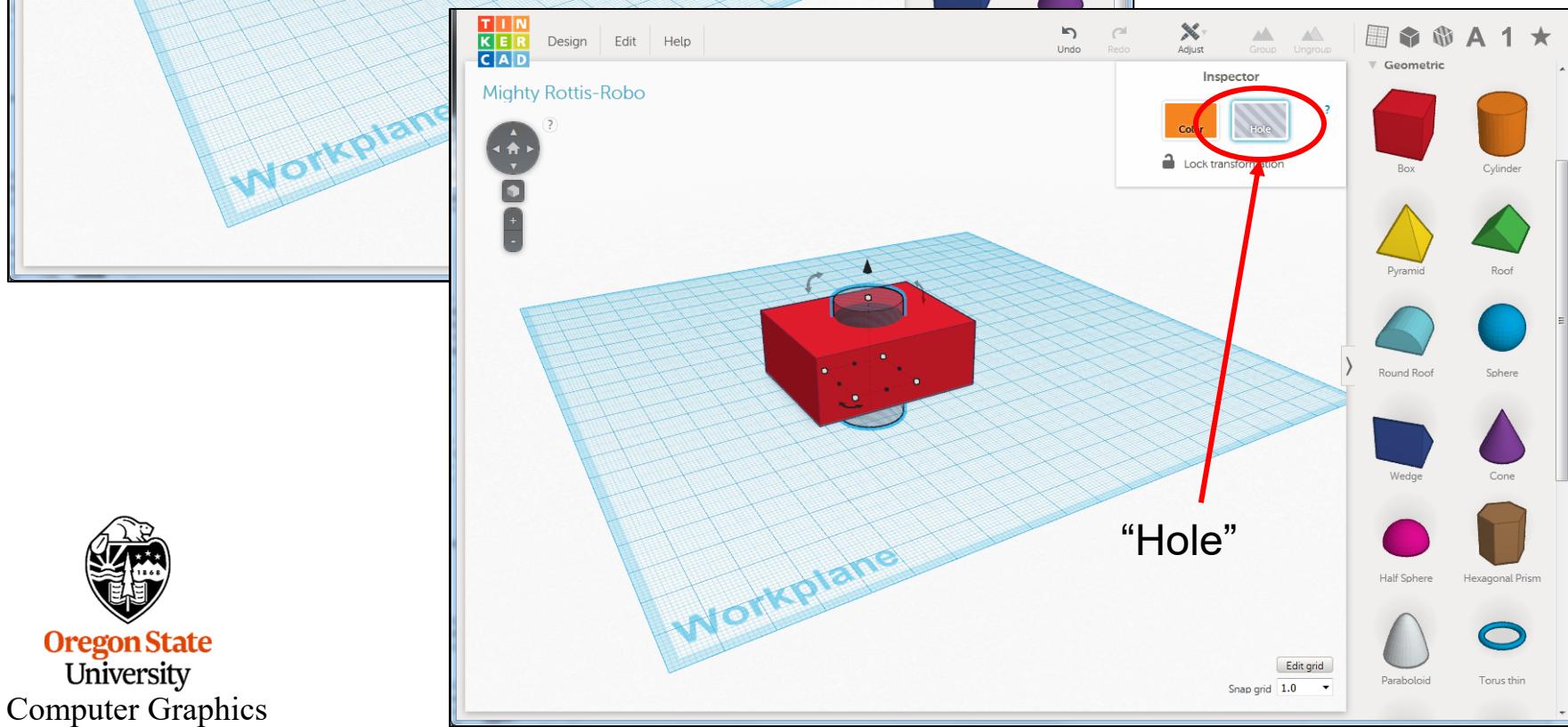
This is often called Constructive Solid Geometry (CSG)

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

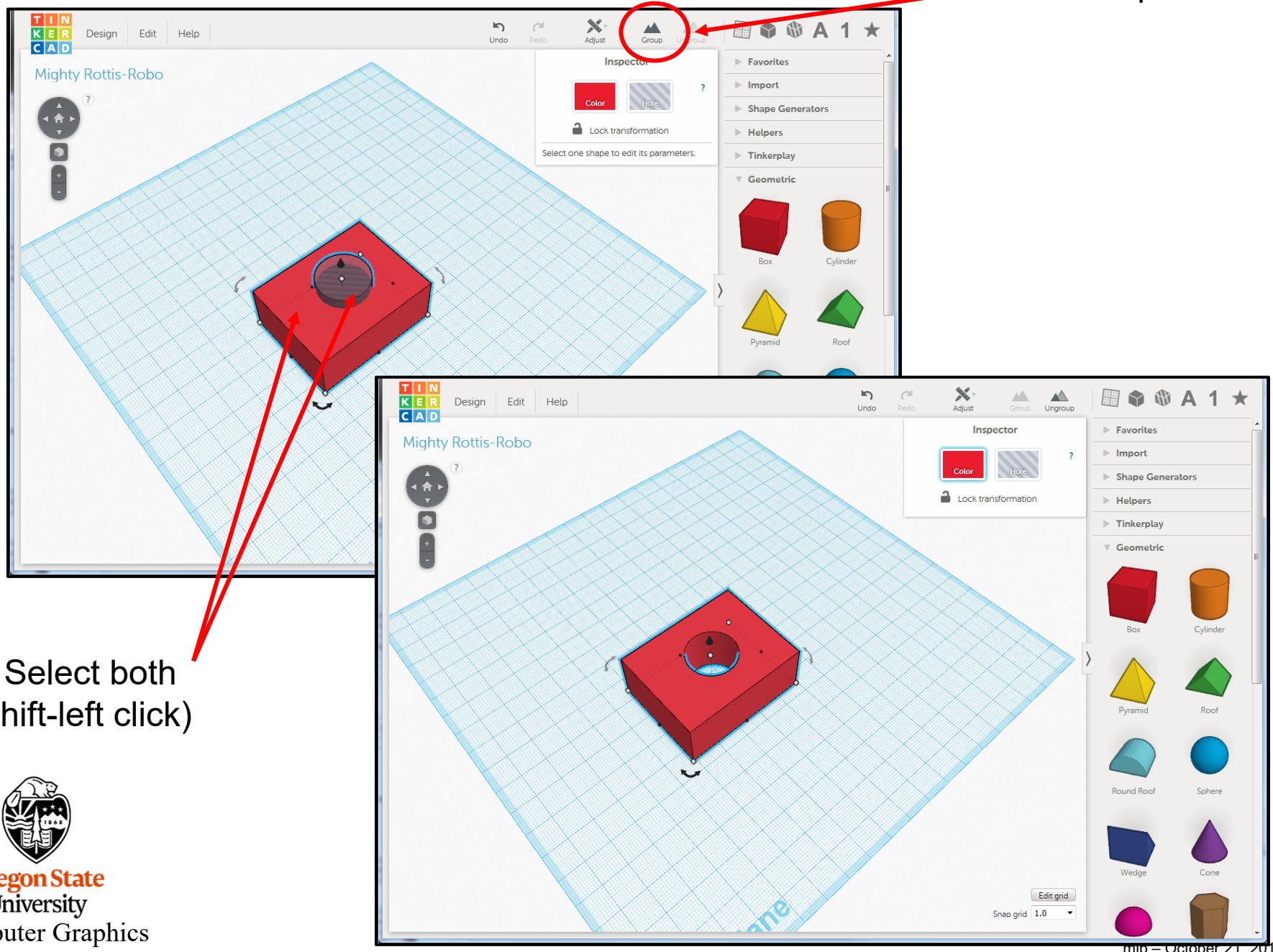
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Like many CAD systems, TinkerCAD uses 3D Boolean operators (3D Venn diagrams). This guarantees a legal solid for 3D Printing.

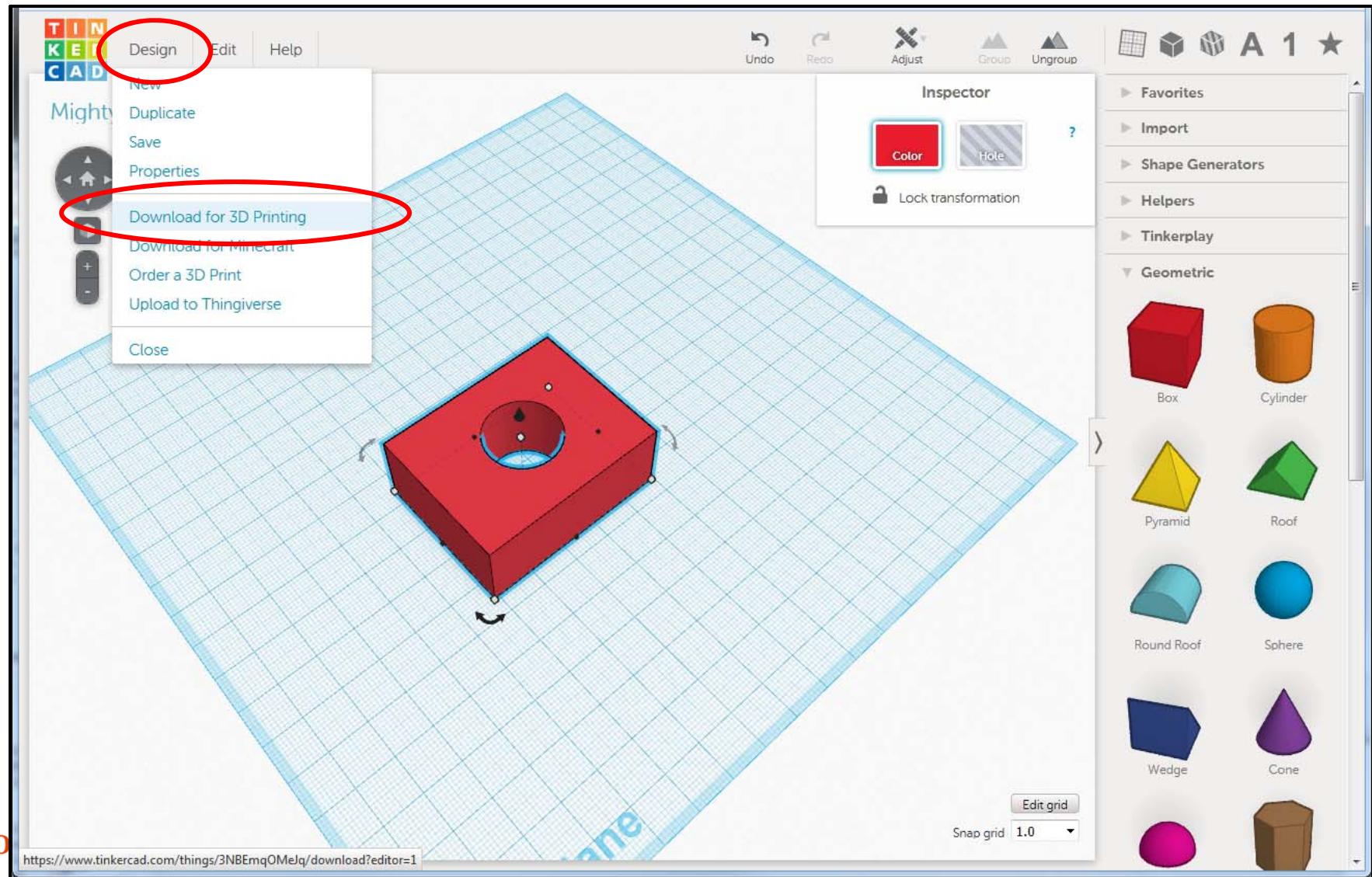


TinkerCAD



TinkerCAD

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

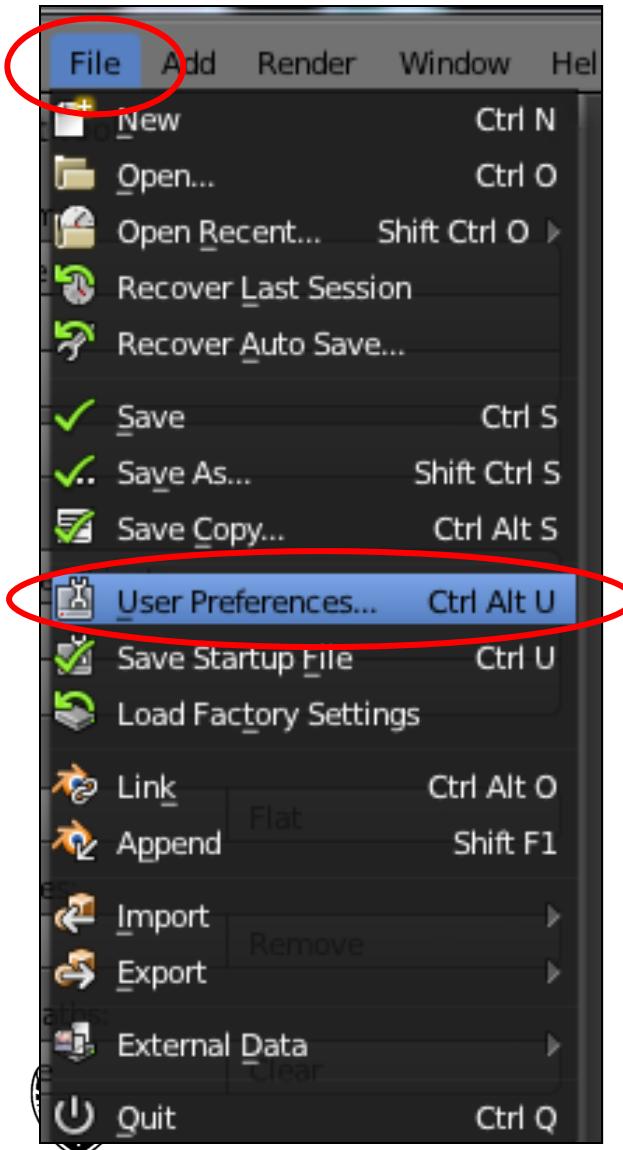


. . .but only if it's installed properly . . .



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

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

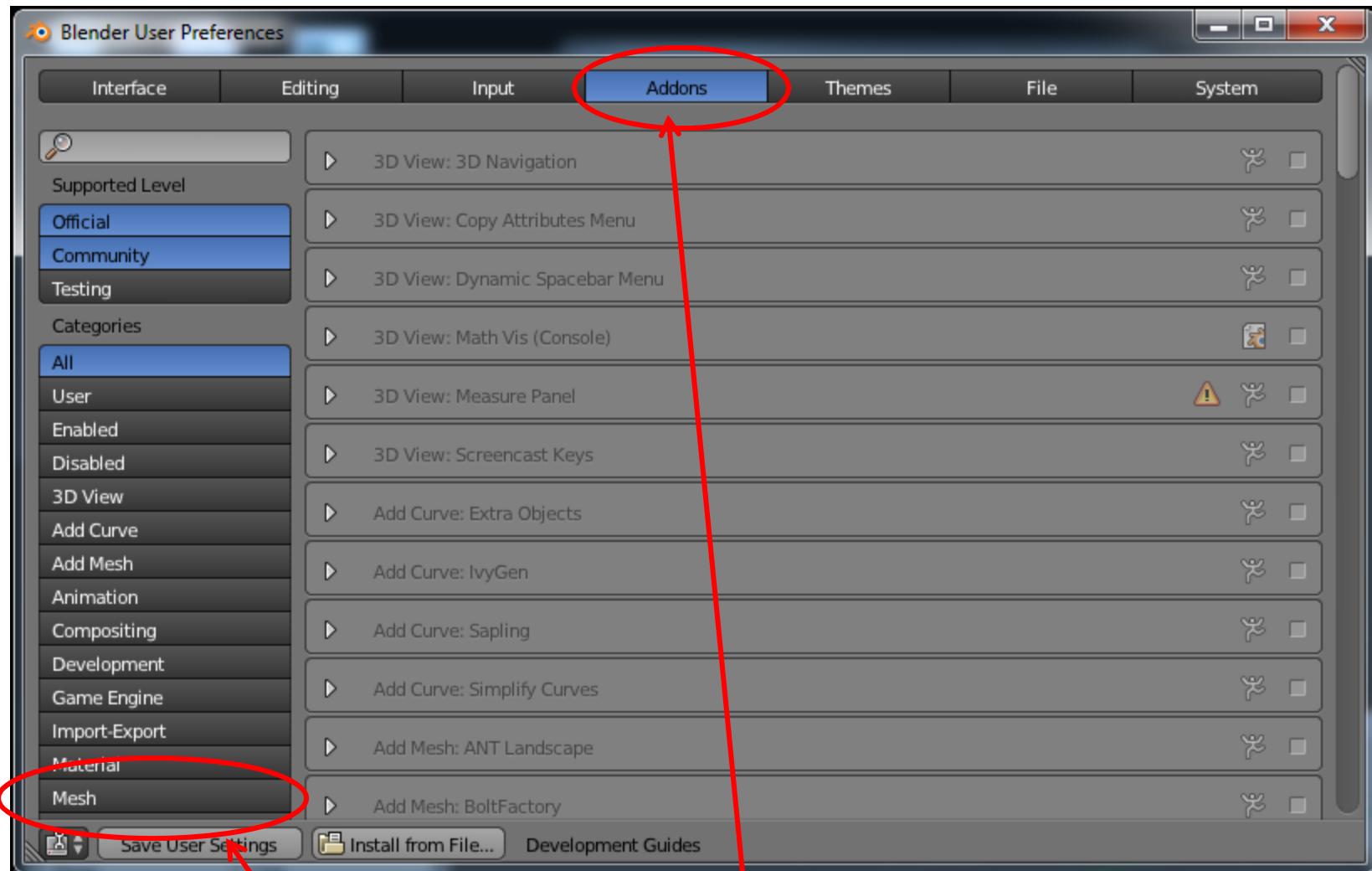
The versions of Blender in the **OSU CGEL** have already had this done to it.

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

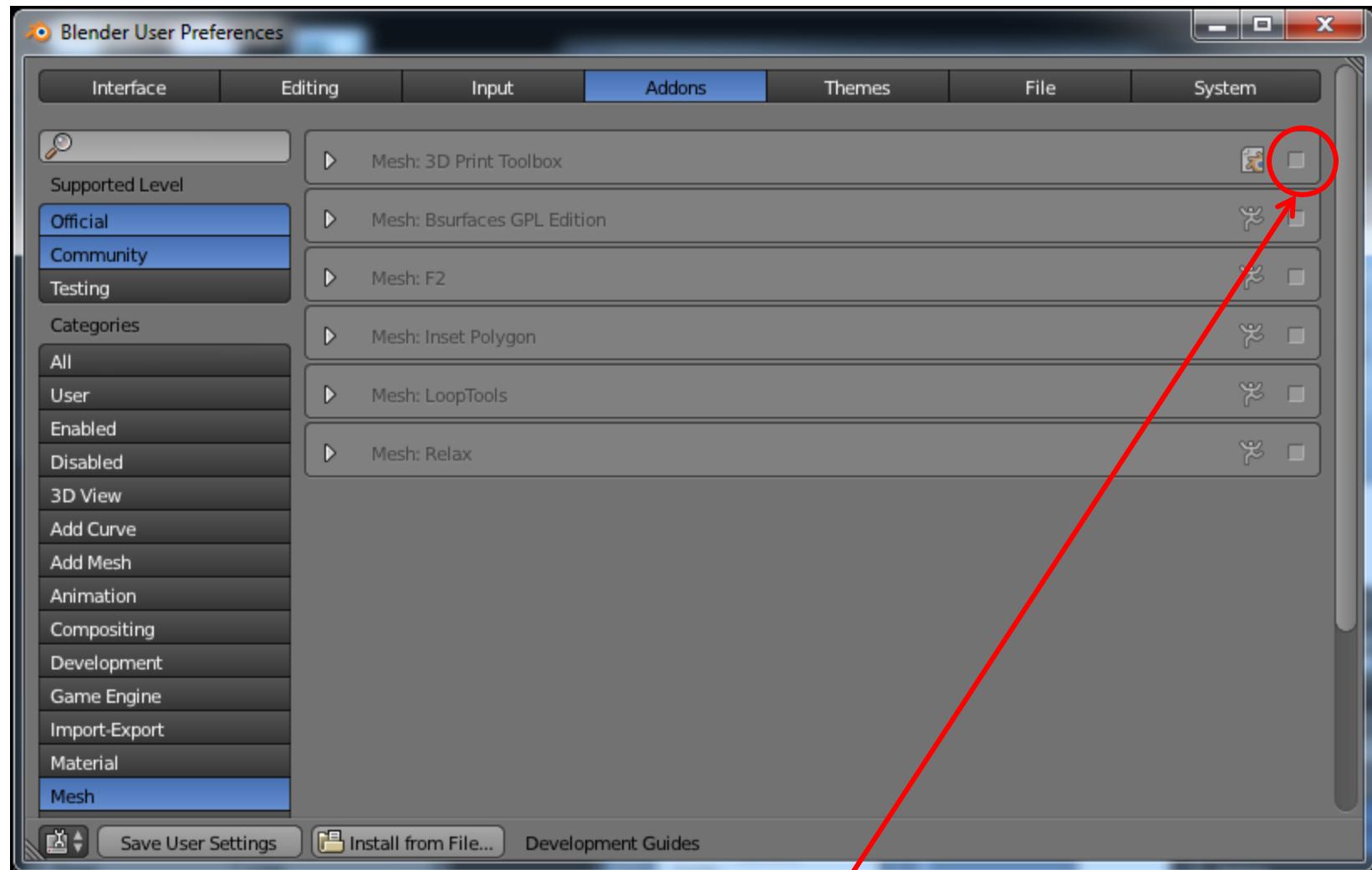
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2. Click on the Addons tab
3. Scroll down to the Mesh Addons, or click on Mesh

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

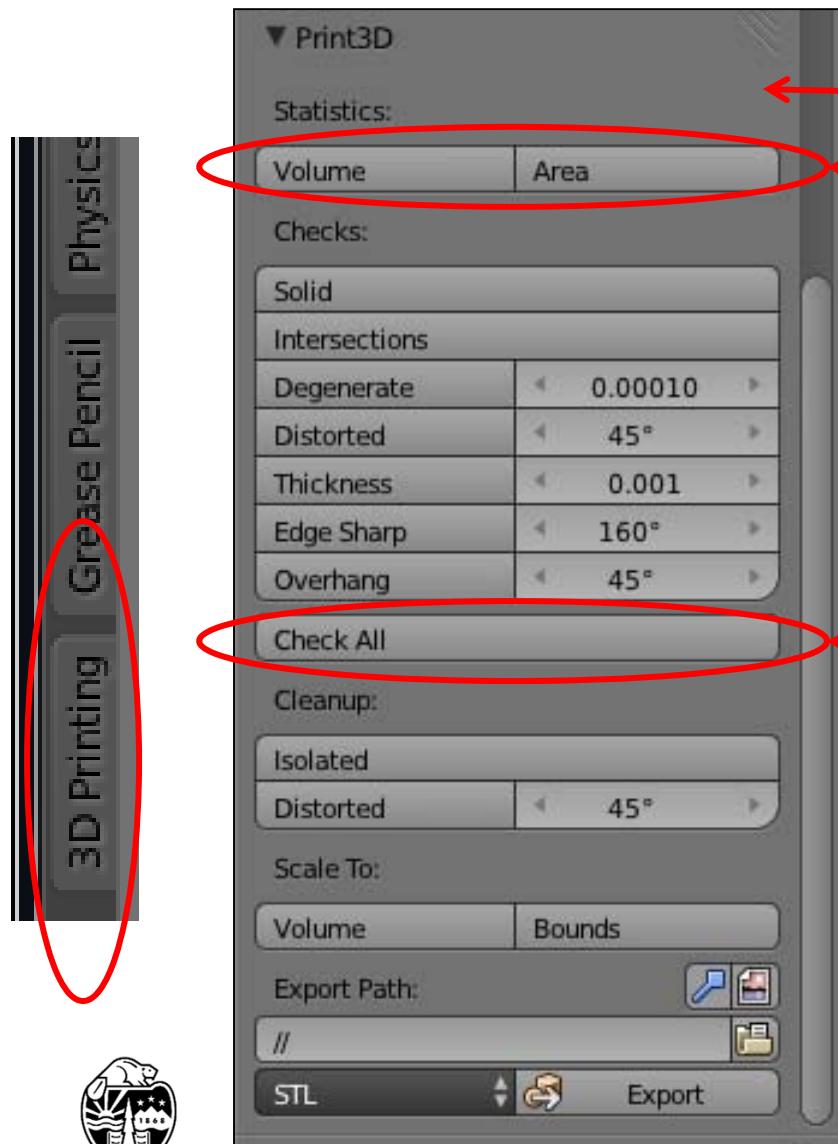
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4. Click the **Mesh: 3D Print Toolbox**



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).

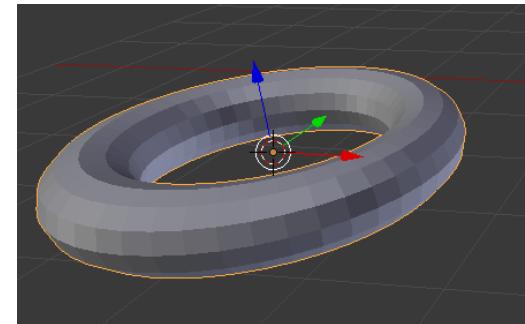
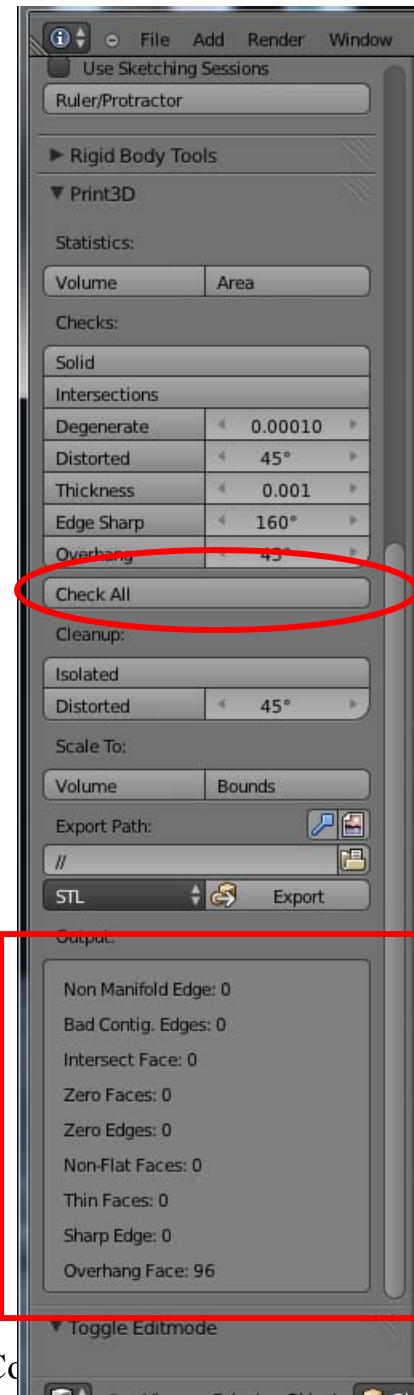
Objects destined for 3D Printing must be “legal solids”.
Clicking on **Check All** will try to determine that



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Options for 3D Printing

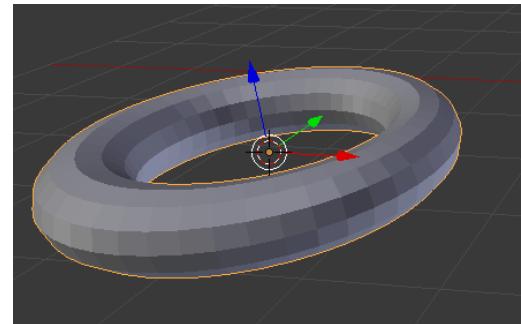


Objects destined for 3D Printing must be “legal solids”.
Clicking on **Check All** will try to determine that

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

Options for 3D Printing

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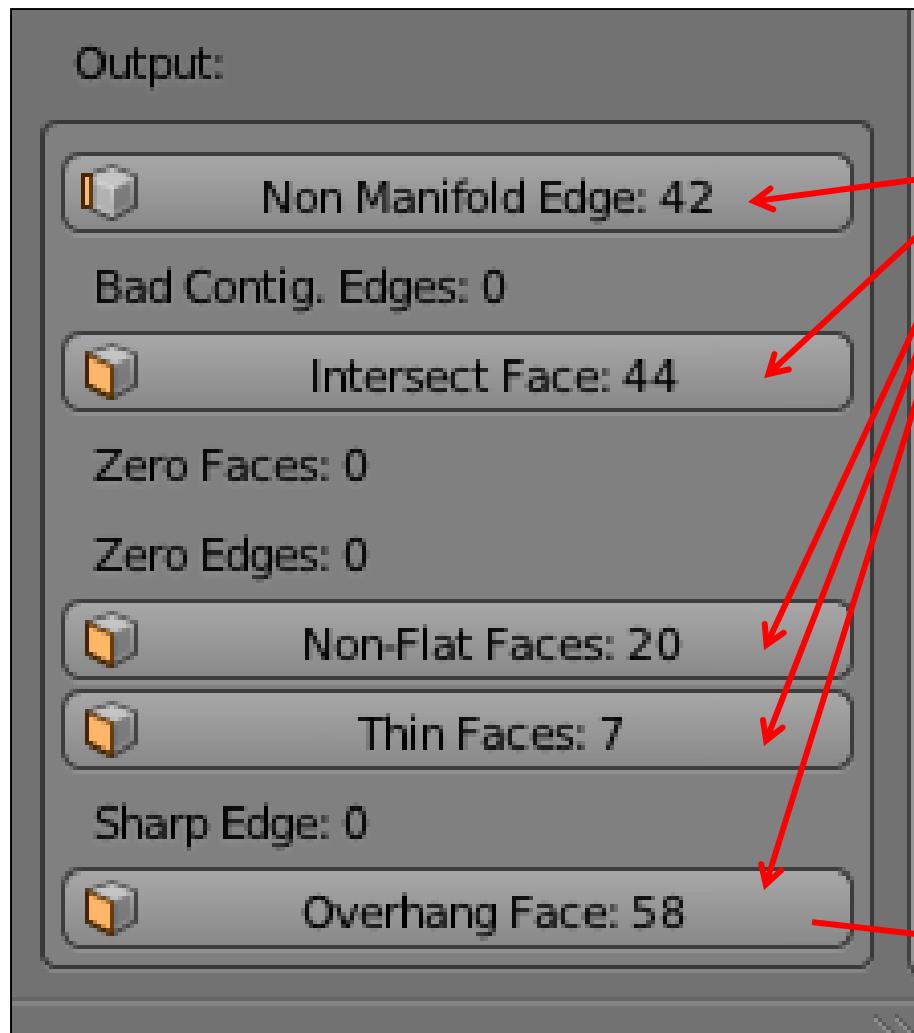
Output:	
Non Manifold Edge:	0
Bad Contig. Edges:	0
Intersect Face:	0
Zero Faces:	0
Zero Edges:	0
Non-Flat Faces:	0
Thin Faces:	0
Sharp Edge:	0
Overhang Face:	96

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.

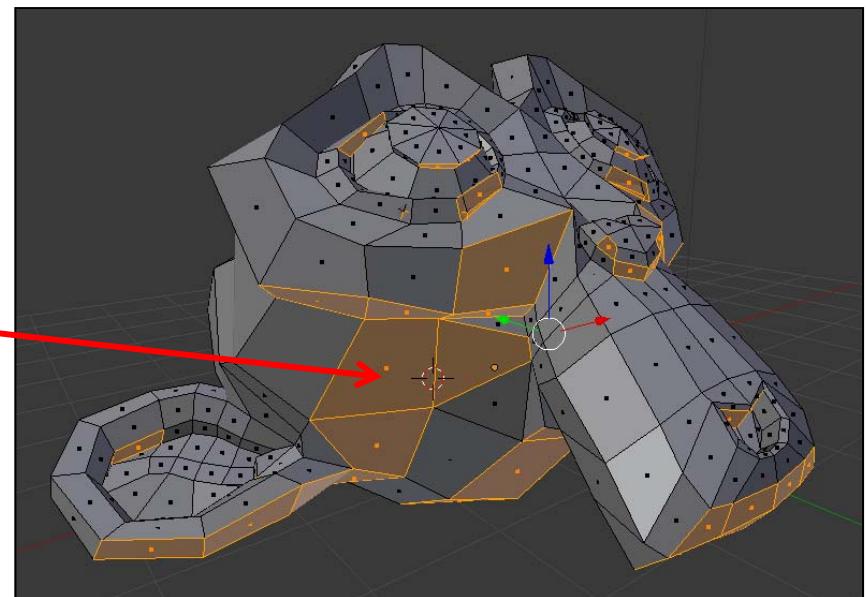
An overhang face is not necessarily a bad thing. The entire bottom of the part will consist of, by necessity, overhang faces.

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

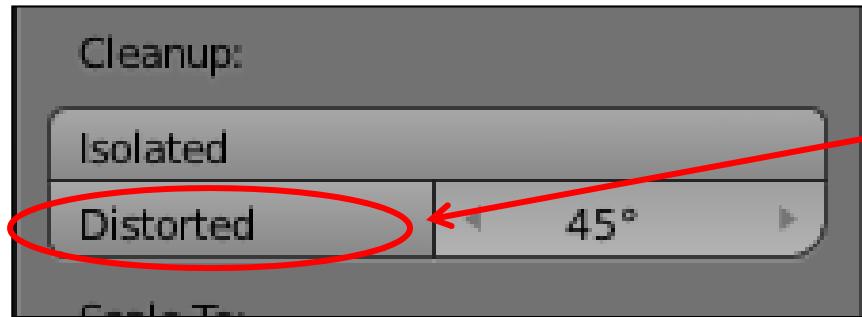
Options for 3D Printing



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.



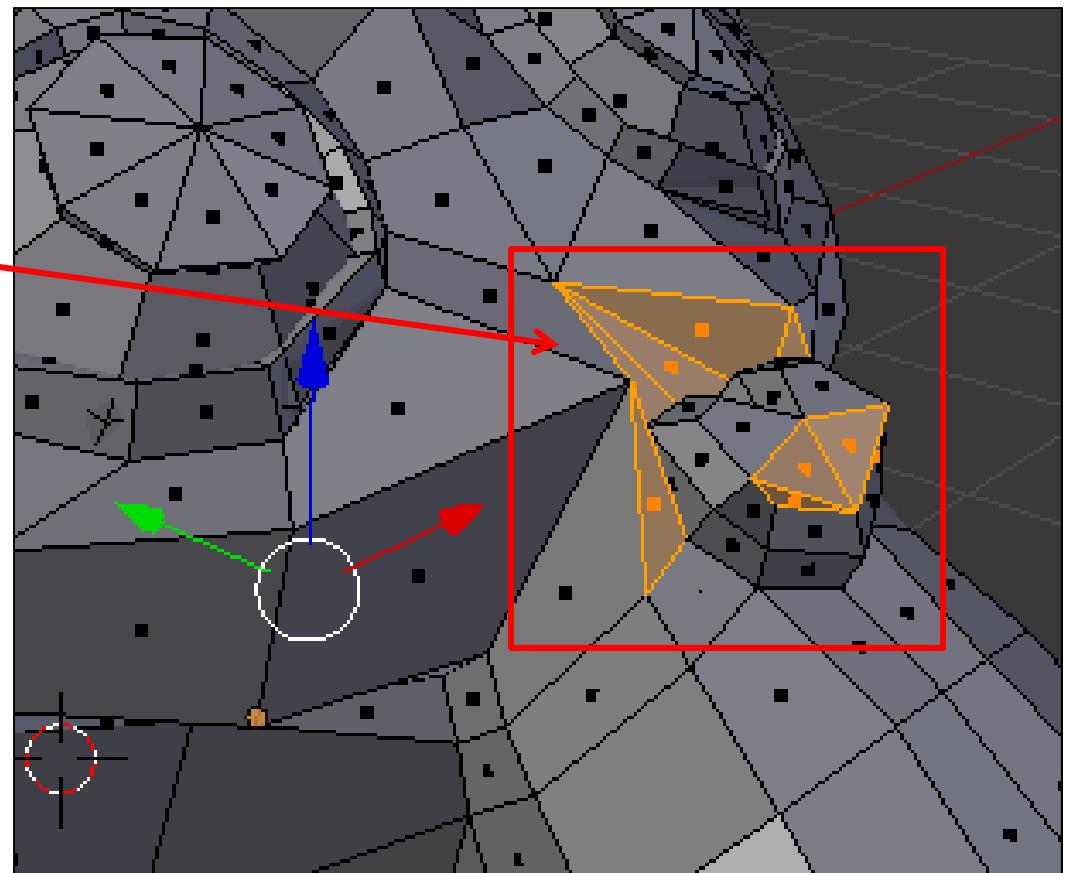
Options for 3D Printing



Non-planar faces can be fixed by clicking here

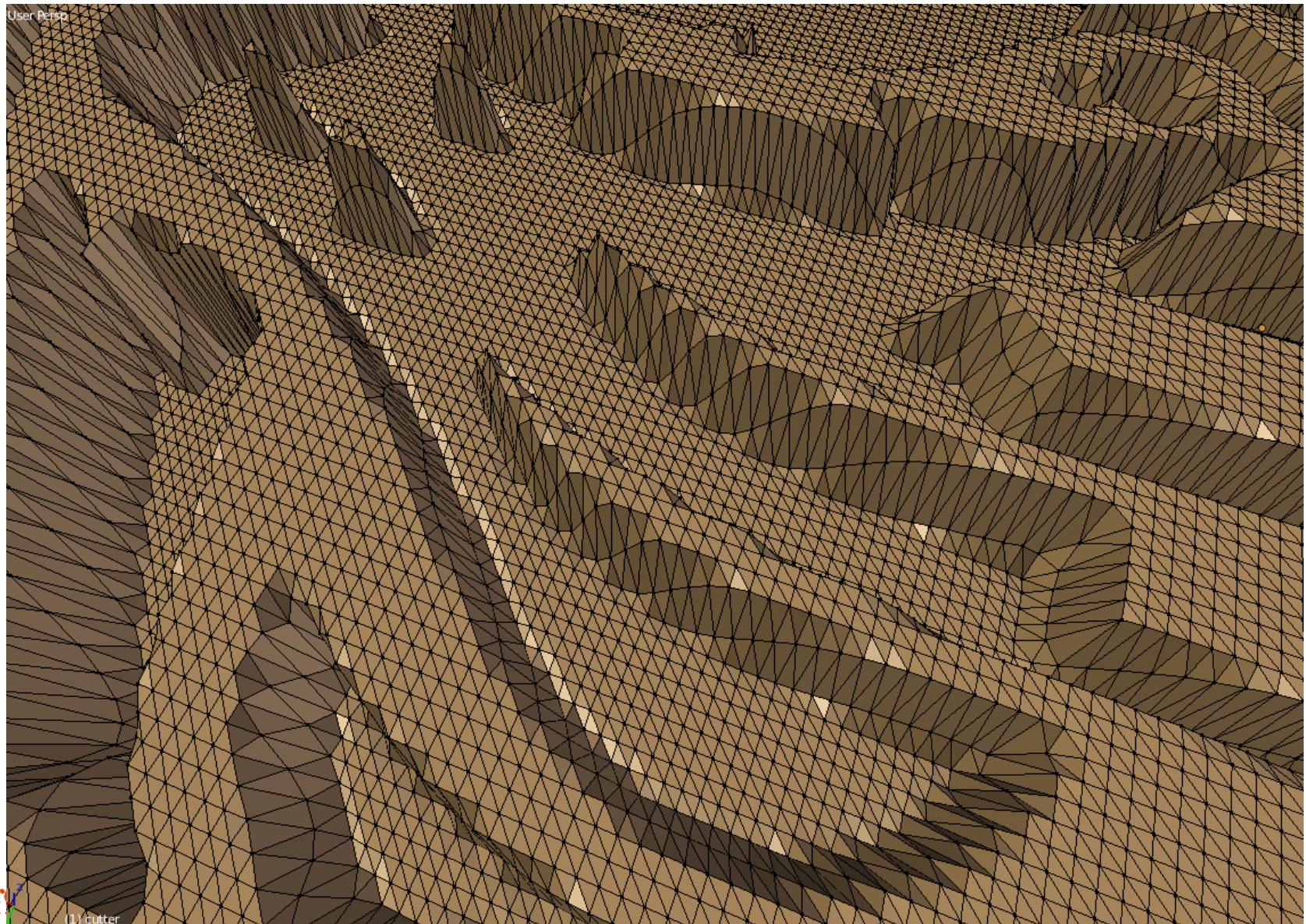
Blender then turns those non-planar quadrilaterals into triangles

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



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Heightmap Files are Straightforward to use with 3D Printing ³³



A Very Special Heightmap 3D Printing Model

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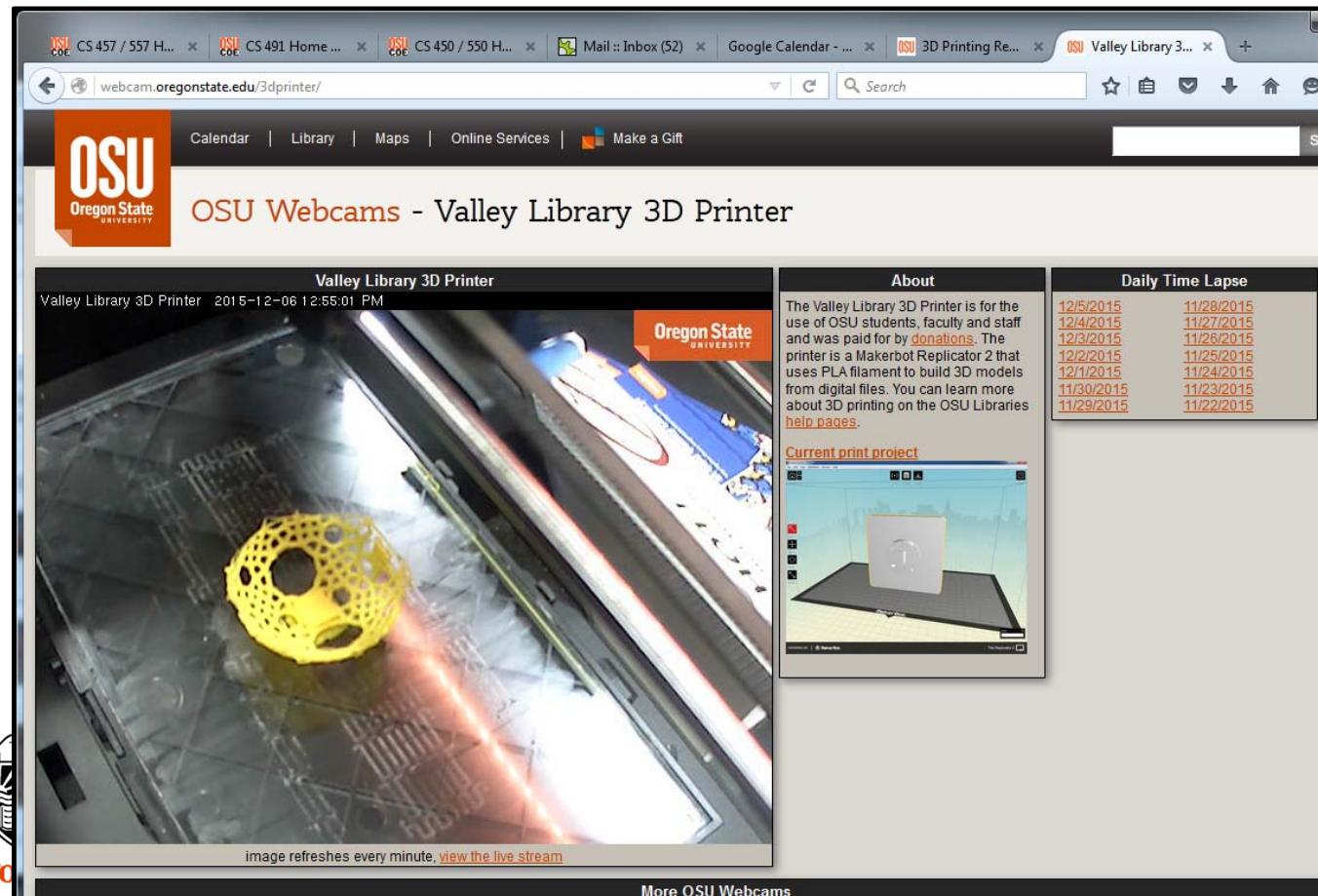


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The OSU Library's 3D Printers

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.

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[3D Printing Tips](#)
[Printer Policy](#)
[Training](#)
[3D printers on campus](#)
[3D Printing Requests](#)
[3D Printing Submission Form](#)

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 lessNotify meDepartmental Index

Reset