

3D Printing



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In the Beginning, Manufacturing was “Subtractive”

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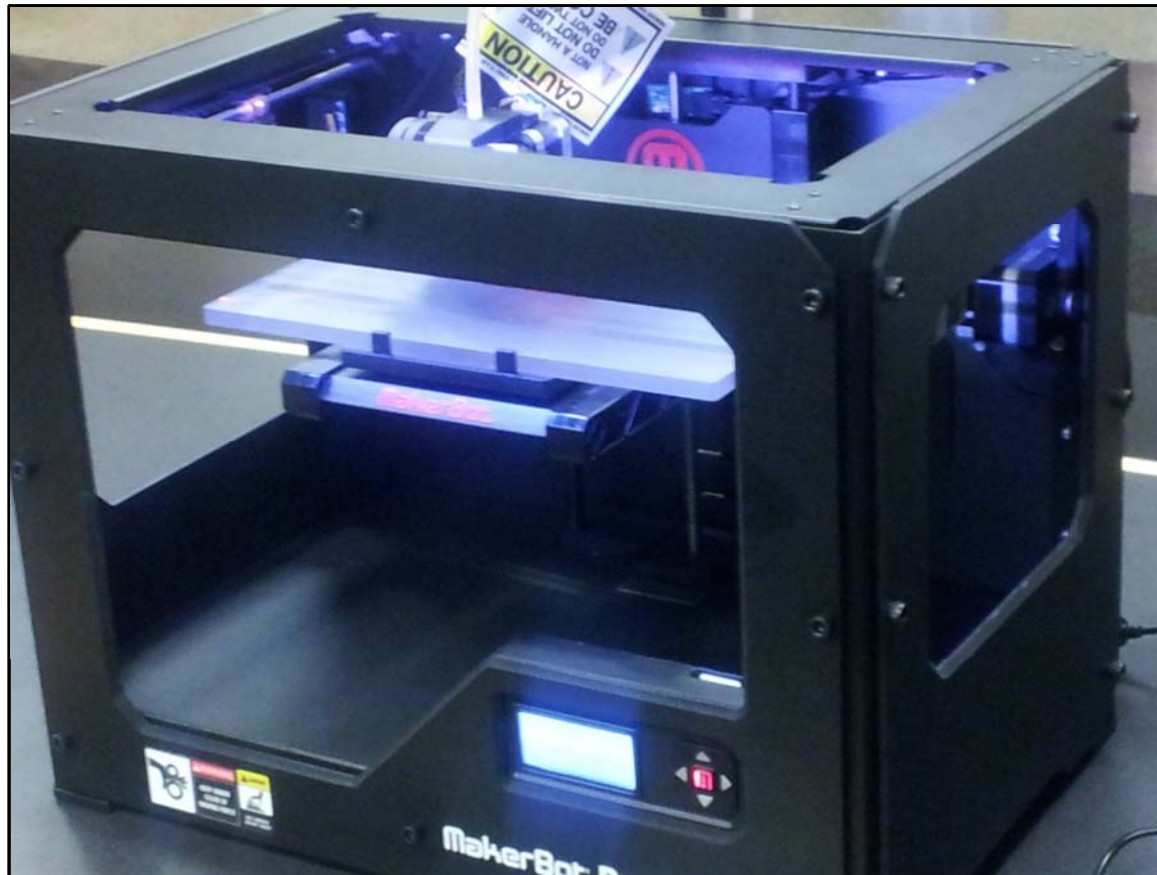


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Today's 3D Printing Process

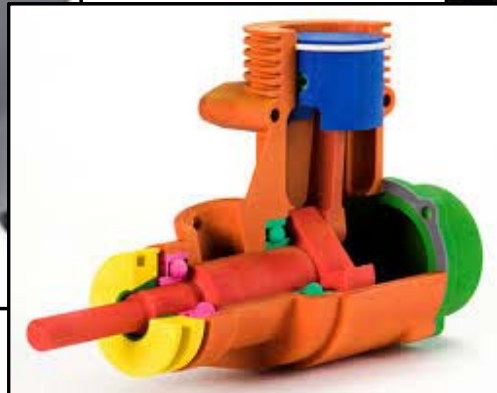
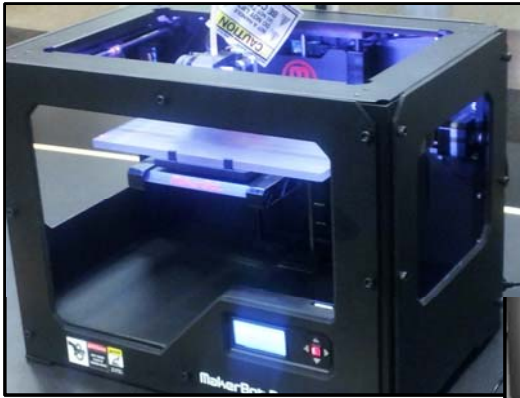
“3D Printing” is defined as some sort of “**additive**” process. (Additive manufacturing is also sometimes called Stereolithography.) The current frenzy in 3D Printing consists mostly of desktop systems that deposit layers of molten plastic:



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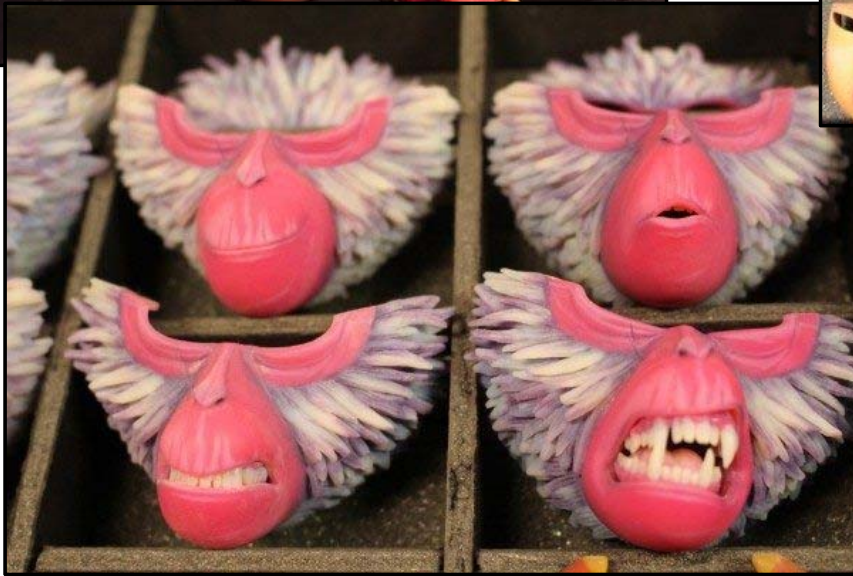
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Examples of 3D Printing



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

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Kibo and the Two Strings



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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



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MakerBot Thingiverse DASHBOARD EXPLORE CREATE You

Customizer by MakerBot App Center | App Info

Home My Things Queue Browse

Customizable pendant Name of project

Parameters you can set

parameters

- A** Parameter 'a' of the curve 2
- B** Parameter 'b' of the curve 1
- C** Parameter 'c' of the epitrochoid and hypotrochoid curves 5
- Curve** The curve to draw (See instructions for curve equation and parameters) Rhodonea curve
- Rose Thickness** Thickness in millimeters of the rose 1

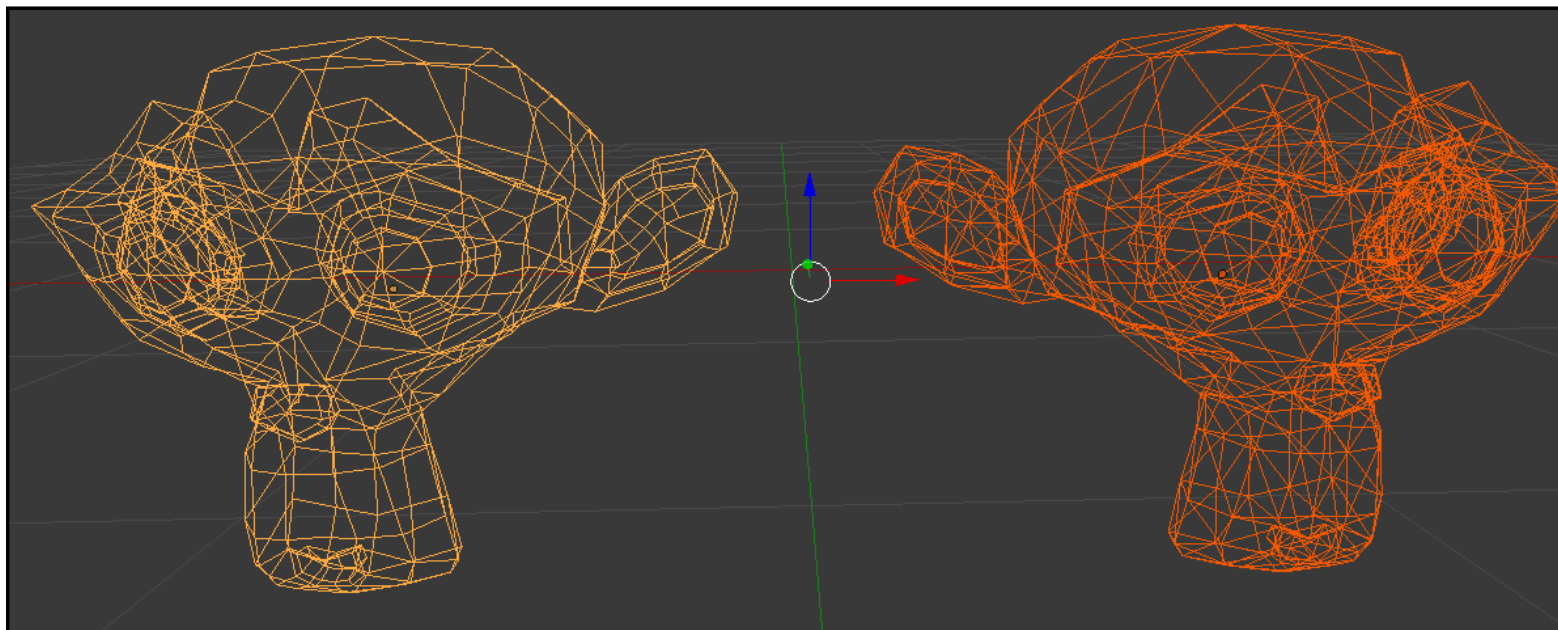
<http://www.thingiverse.com/apps> Copy View Source **Create Thing**

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



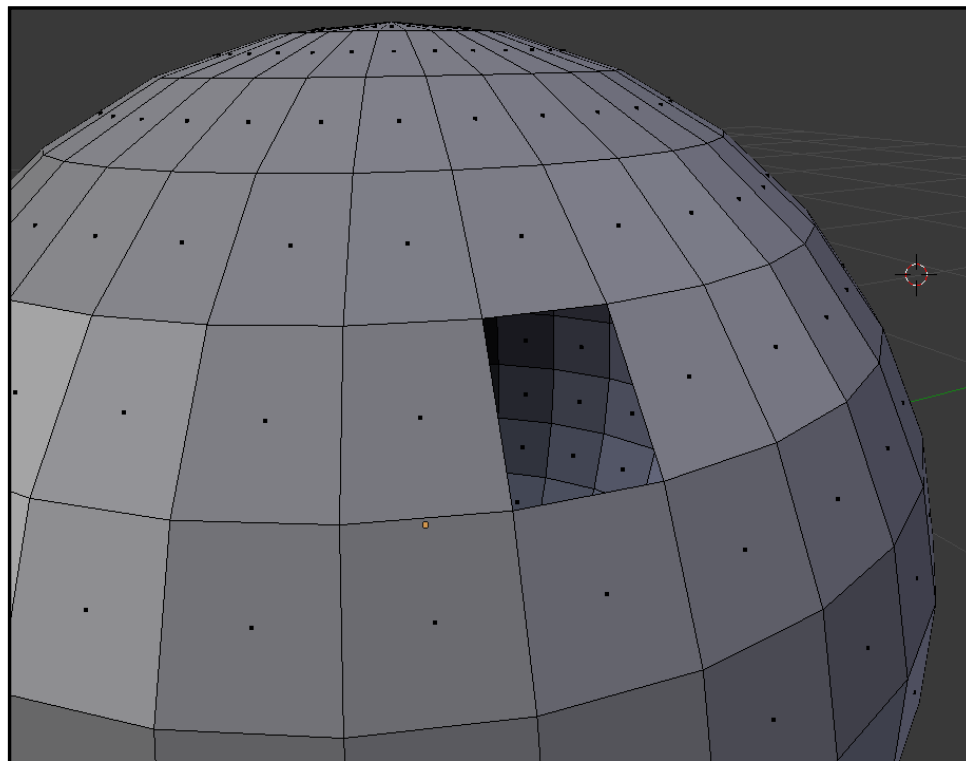
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In Blender: Modifiers → Add Modifier → Triangulate

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.



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



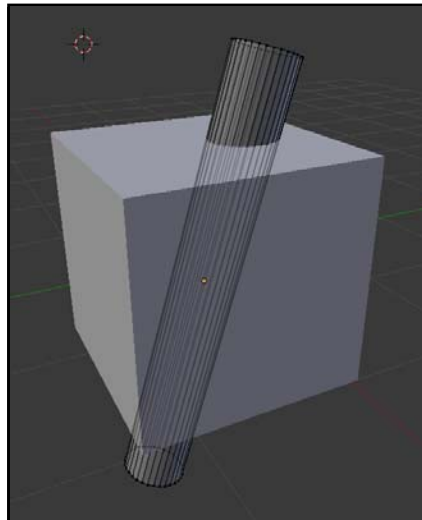
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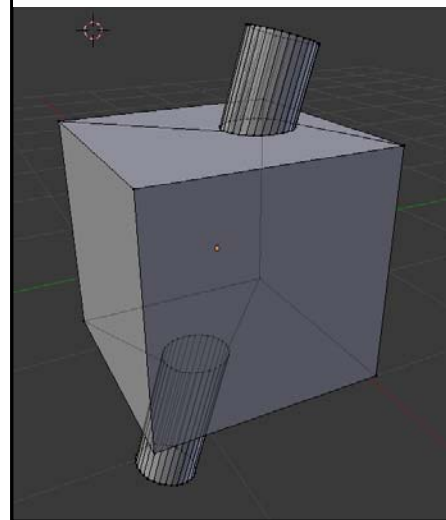
Object Modeling Rules for 3D Printing

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**

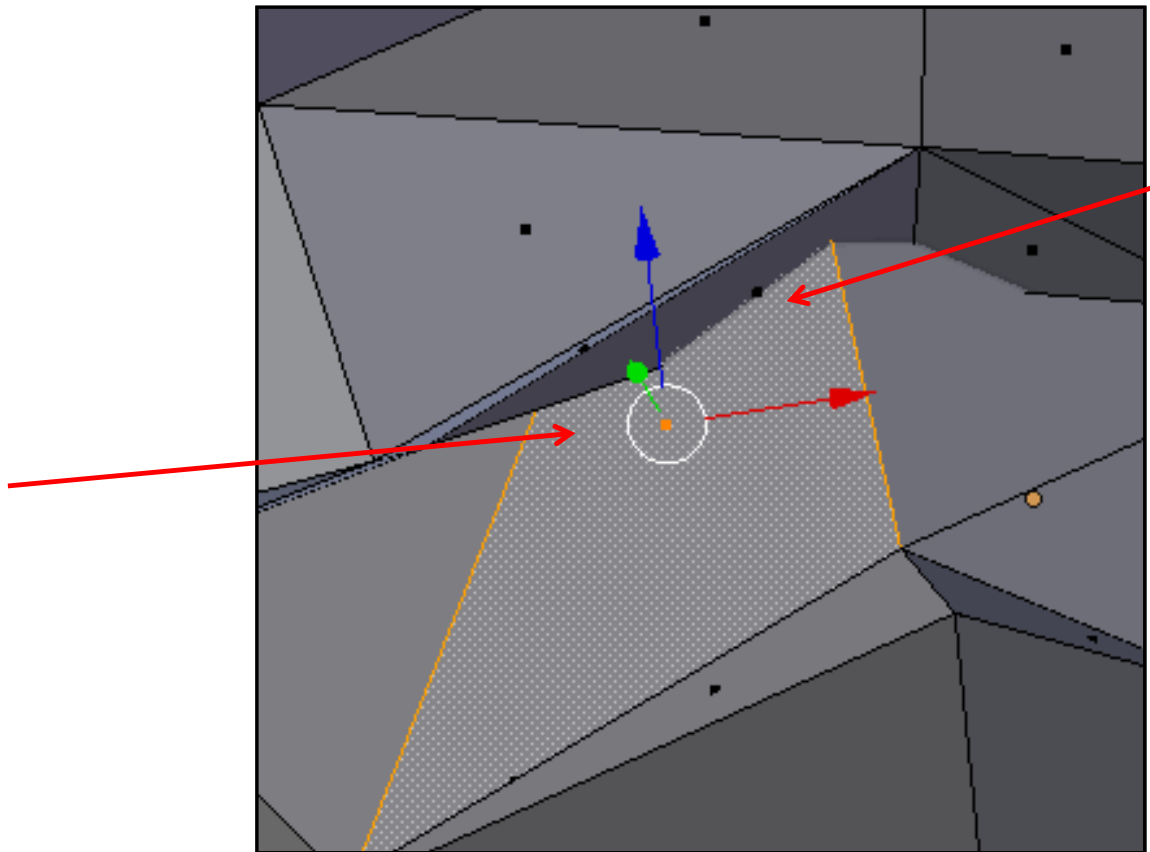


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Object Rules for 3D Printing

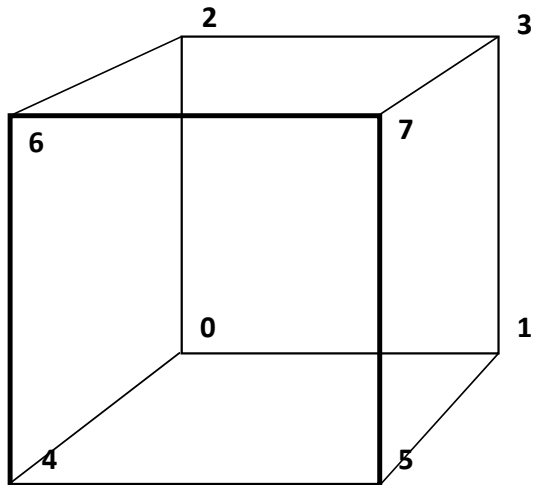
4. Each edge in the mesh must bound 2 and only 2 triangles (this is known as the **Vertex-to-Vertex Rule**)



The Simplified Euler's Formula* for Legal Solids

$$F - E + V = 2$$

F	Faces
E	Edges
V	Vertices



$$6 - 12 + 8 = 2$$

*sometimes called the Euler-Poincaré formula

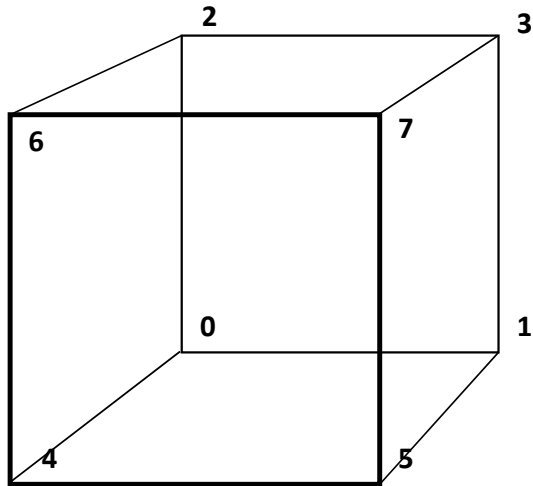


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The Full Euler's Formula* for Legal Solids

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



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

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

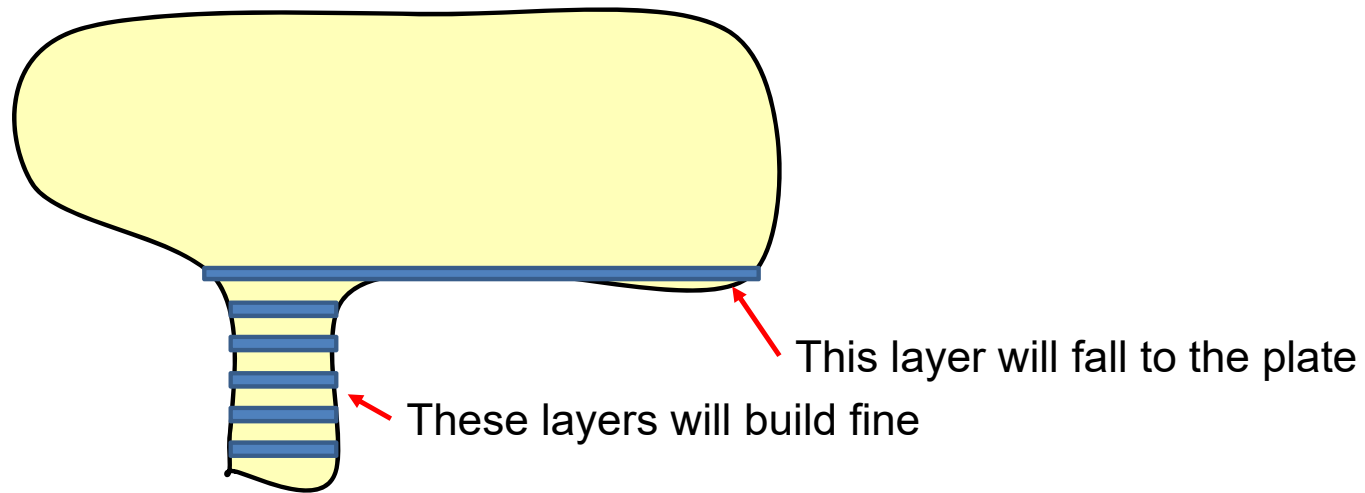
*sometimes called the Euler-Poincaré formula



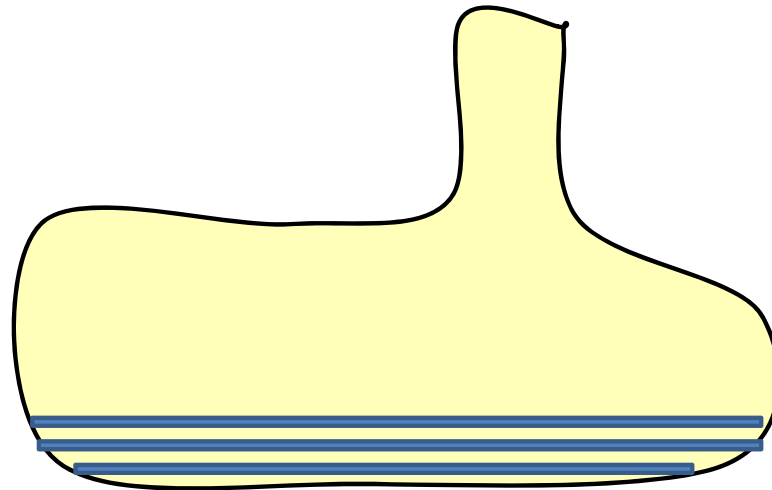
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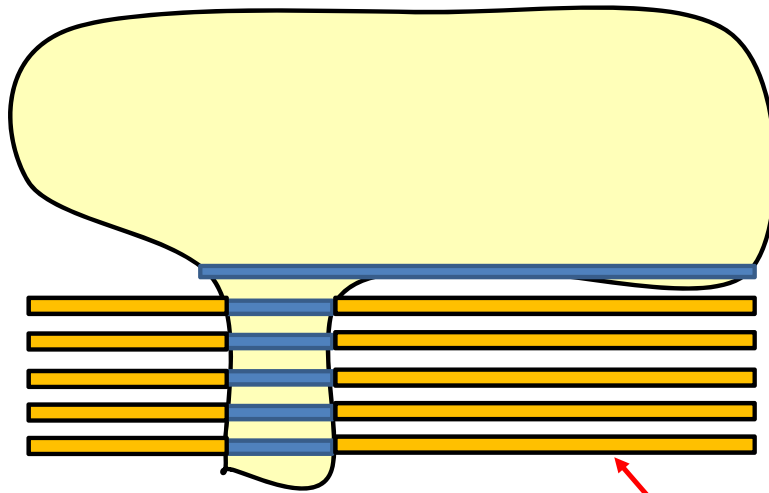
Watch Out for Overhangs!



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



Watch Out for Overhangs!



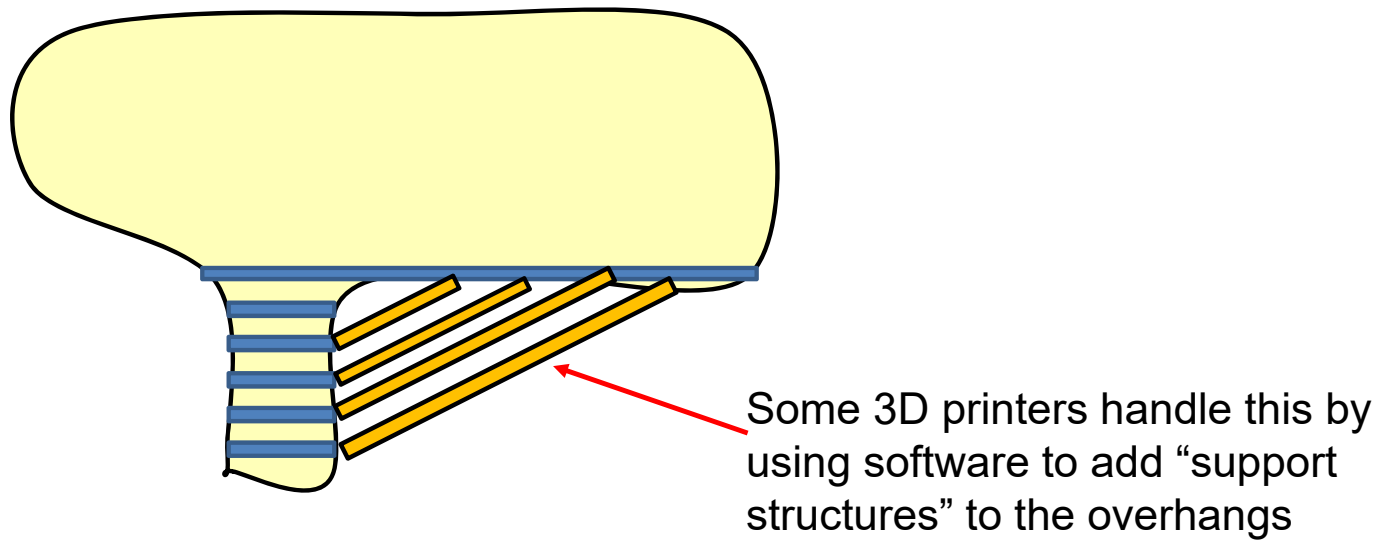
Some 3D printers handle this by leaving unused material in place to support the overhangs



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Watch Out for Overhangs!



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



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What Happens if You Don't Follow the Rules?

Check here:

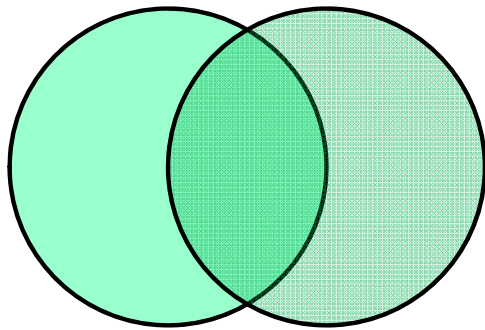
<http://twistedifter.com/2013/08/when-3d-printing-goes-wrong/>



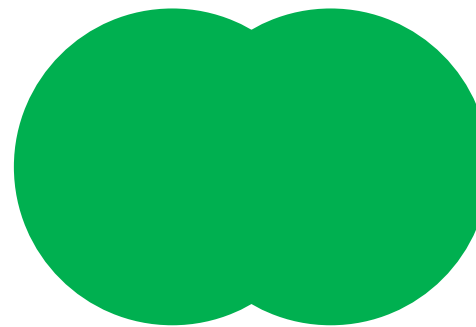
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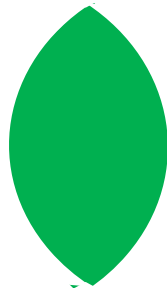
**Another way to Model:
Remember Venn Diagrams (2D Boolean Operators) from High School?**



Two Overlapping Shapes



Union



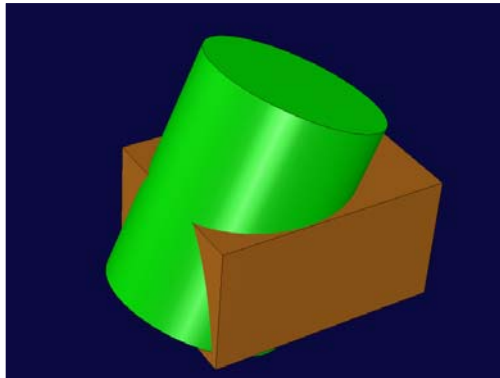
Intersection



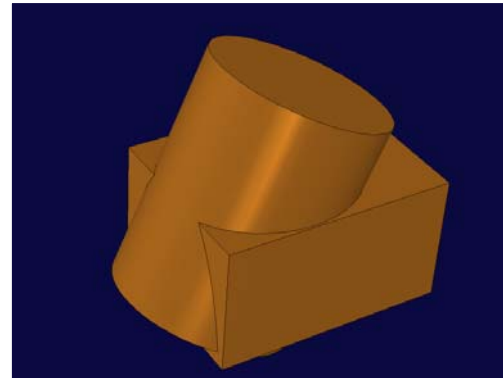
Difference



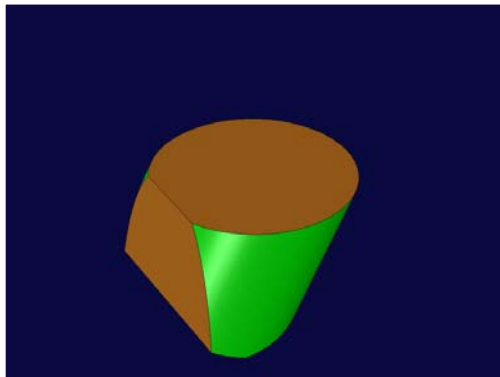
Solid Modeling Using 3D Boolean Operators



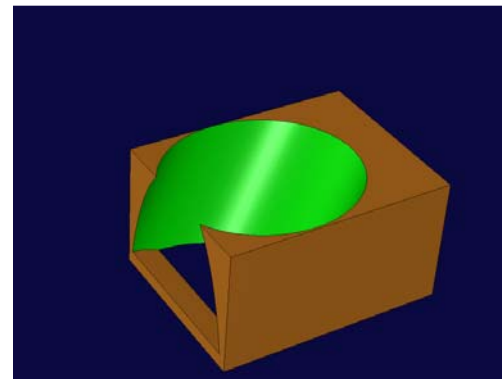
Two Overlapping Solids



Union



Intersection



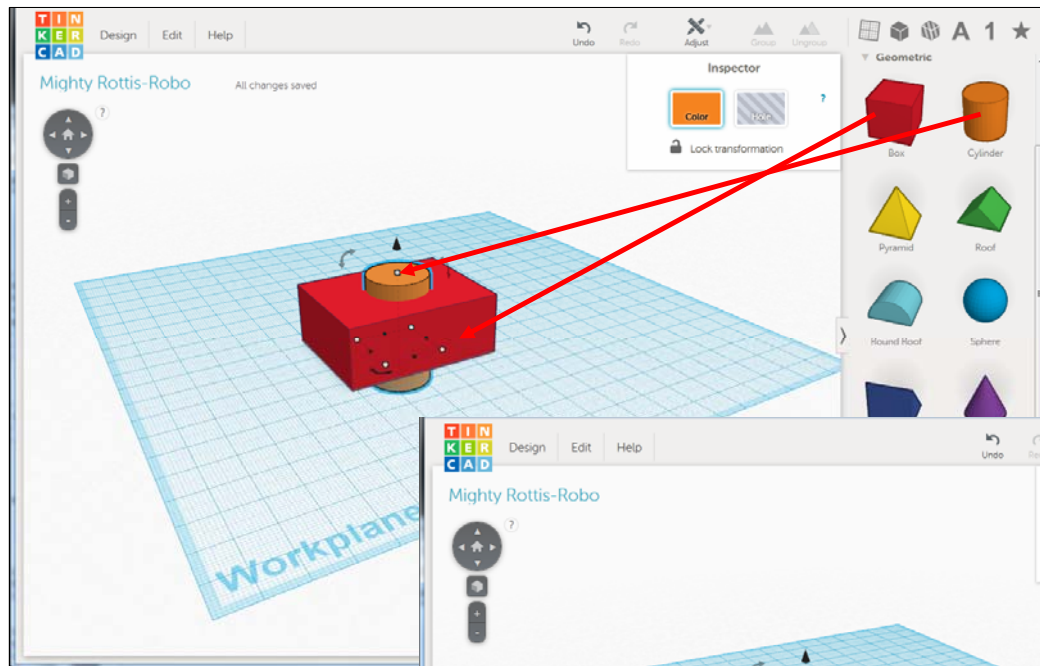
Difference

This is often called Constructive Solid Geometry (CSG)

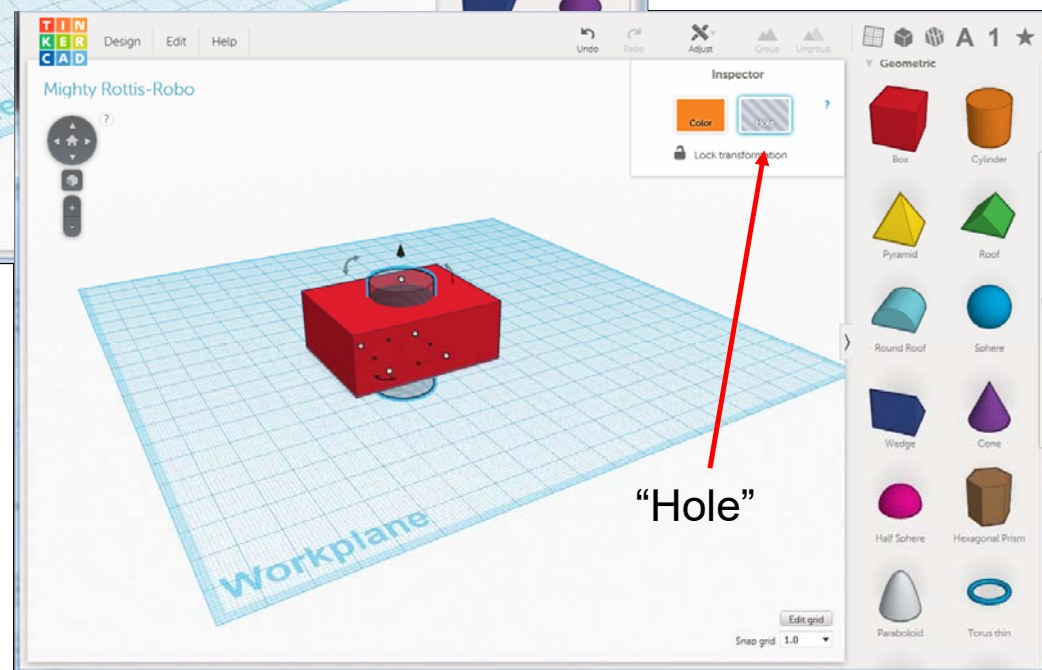


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Like many CAD systems, TinkerCAD uses 3D Boolean operators (3D Venn diagrams). This guarantees a legal solid for 3D Printing.



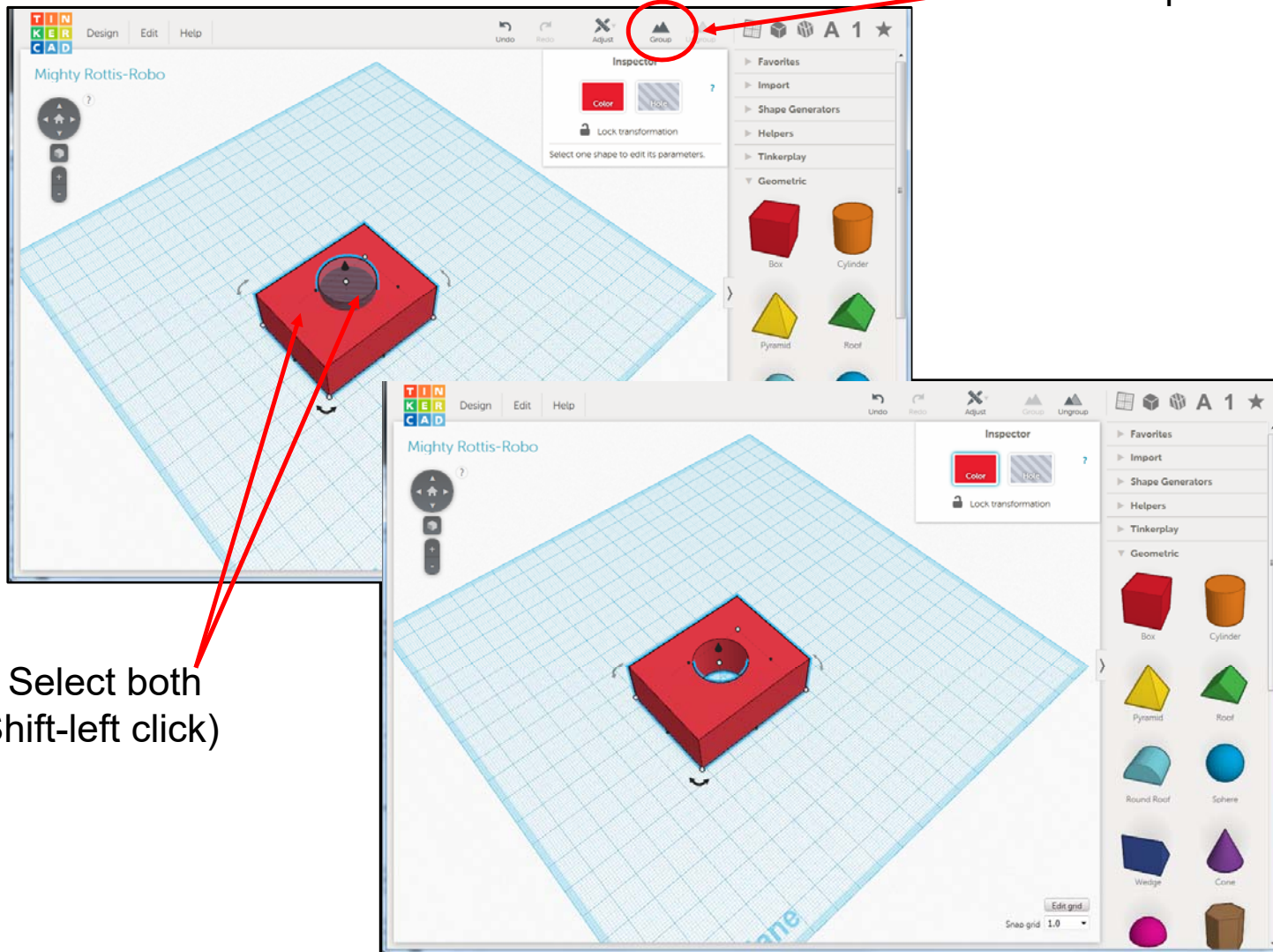
“Hole”



TinkerCAD

2. "Group"

1. Select both
(Shift-left click)

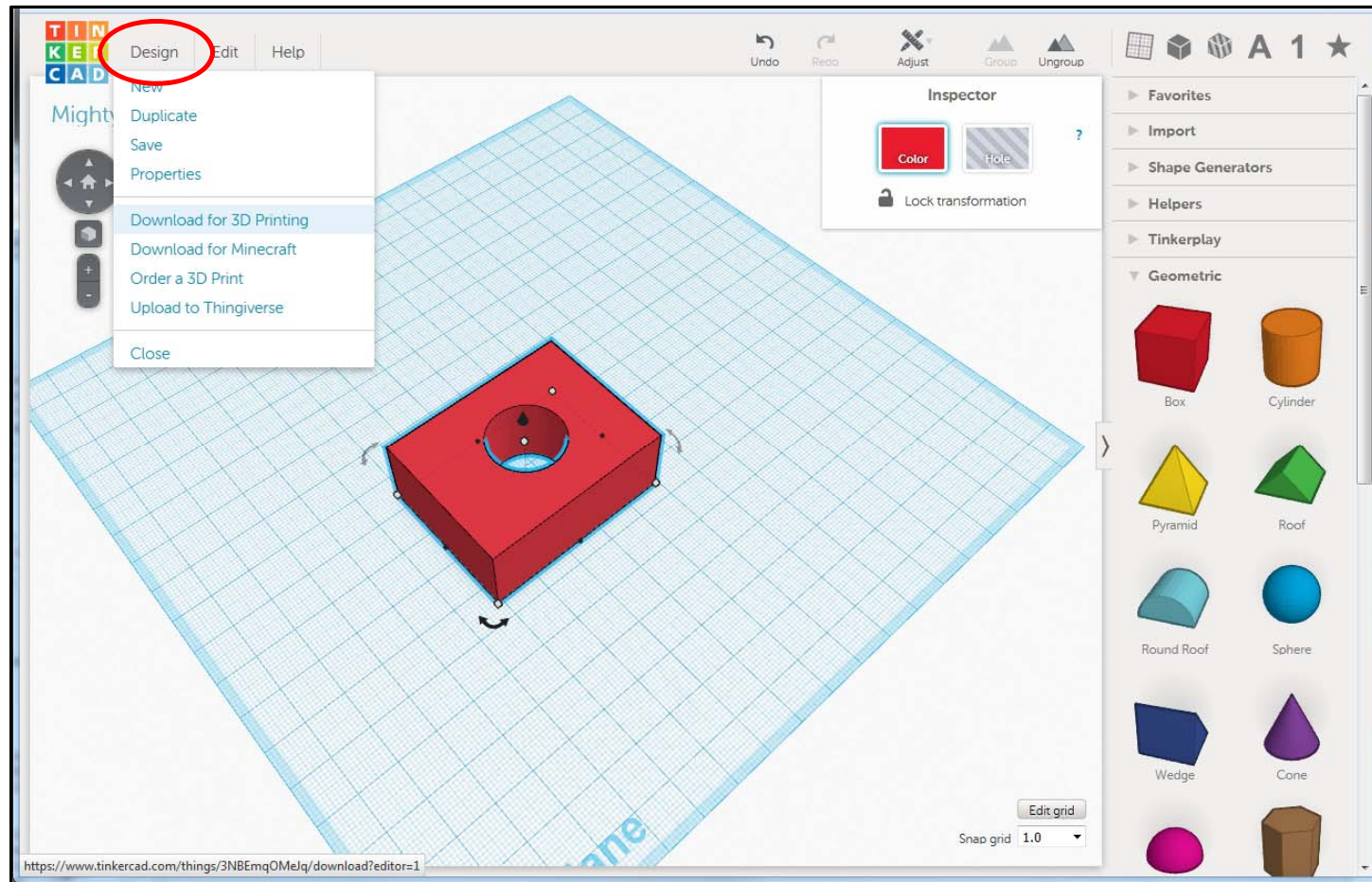


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Tinkercad

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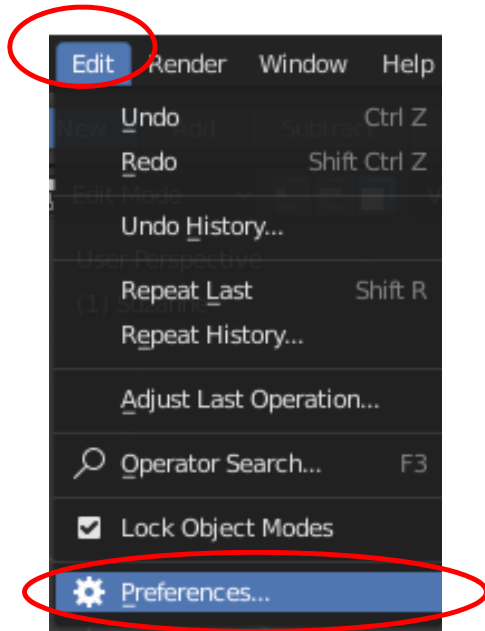


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Blender's 3D Printing Options aren't there by Default

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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.

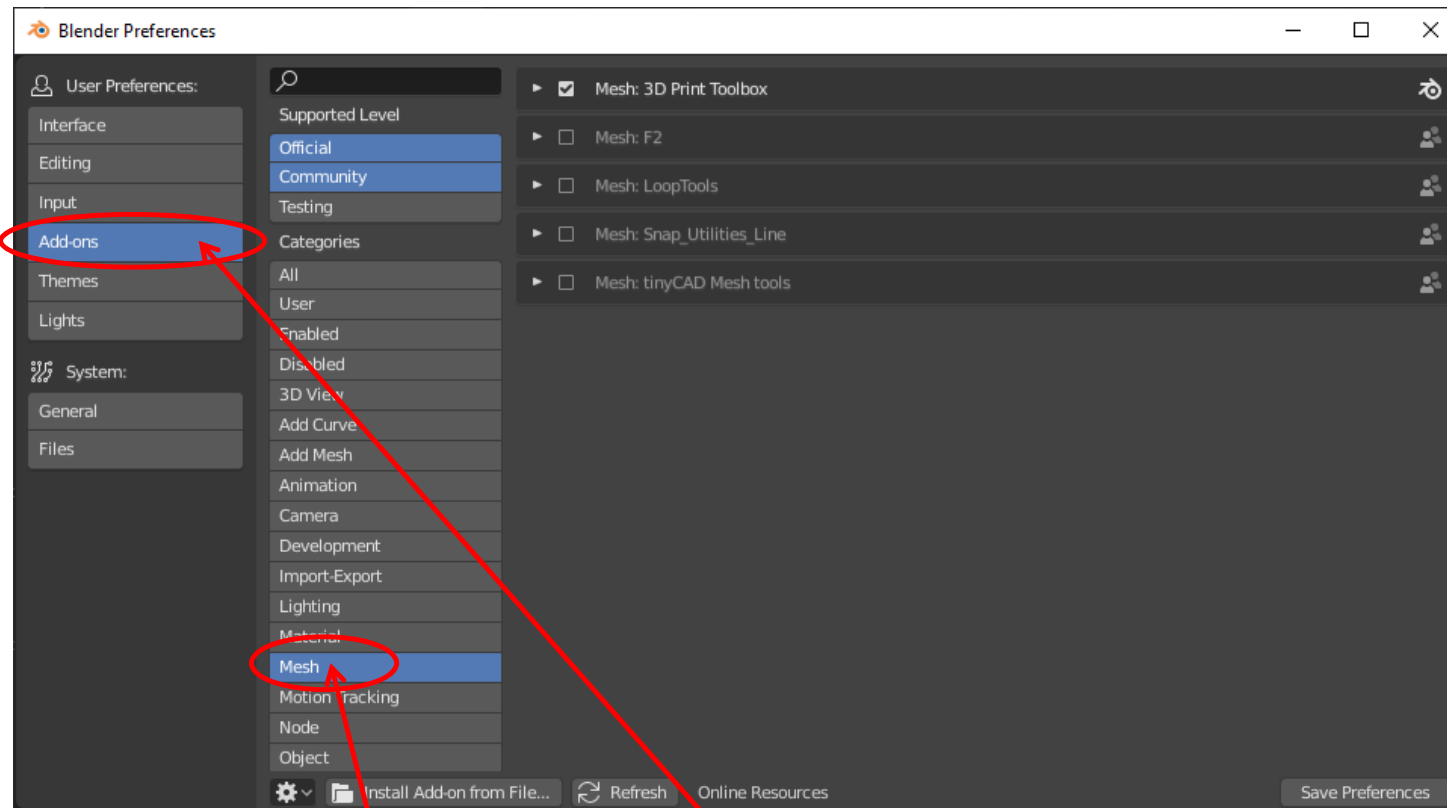
1. Click **Edit** → **Preferences**



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



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

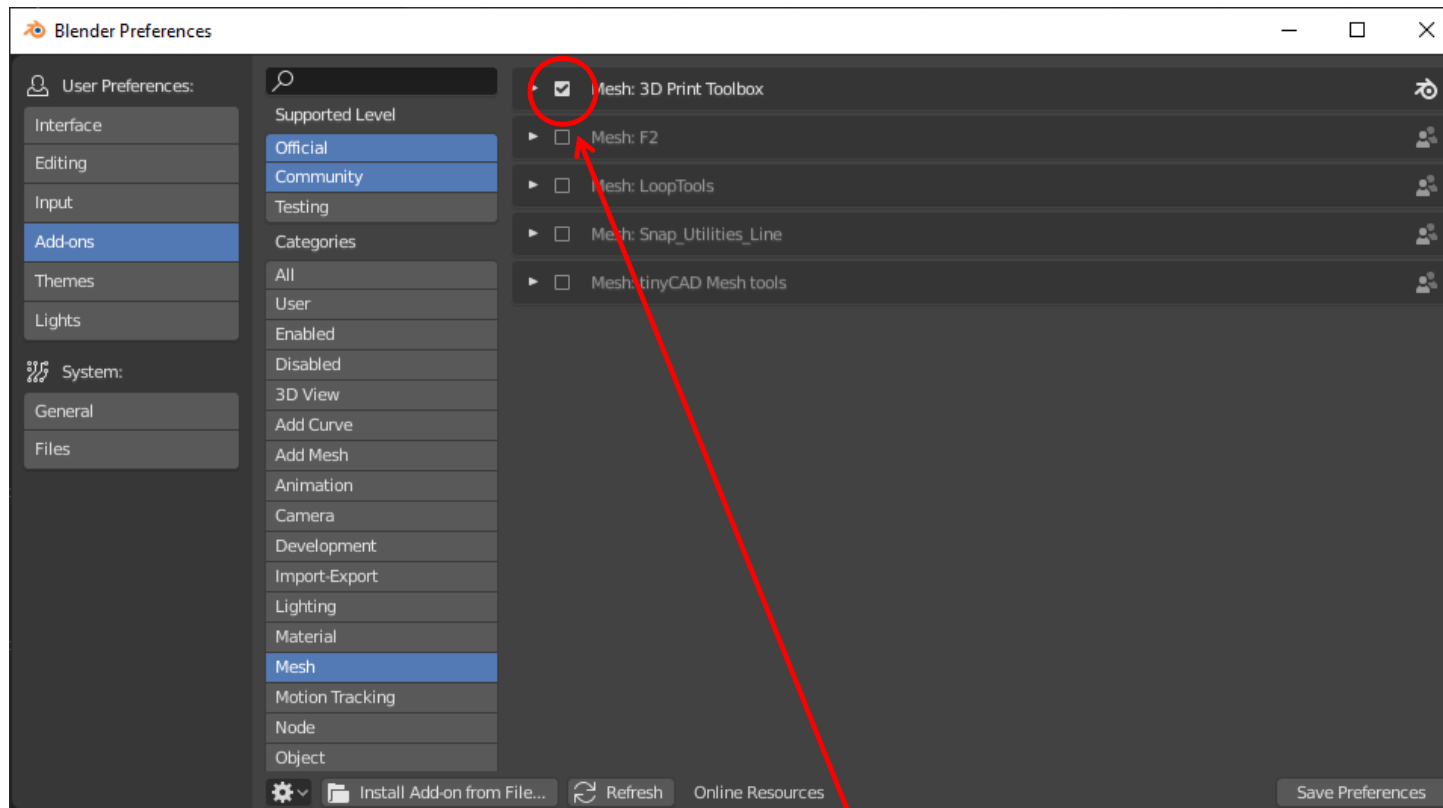


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Blender's 3D Printing Options aren't there by Default

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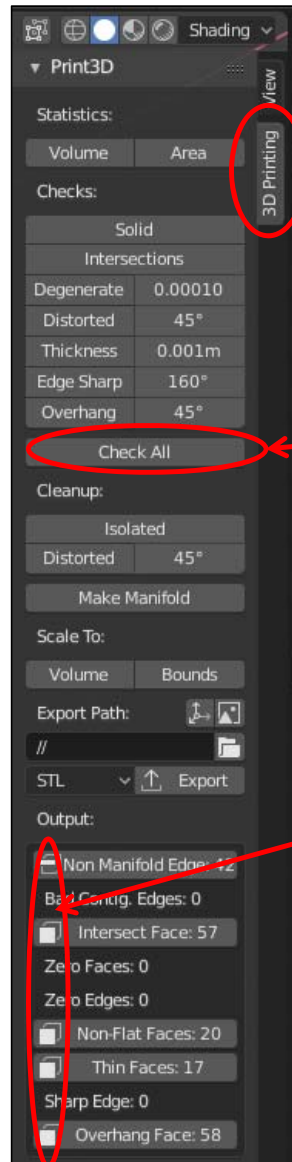
4. Click the **Mesh: 3D Print Toolbox**



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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.

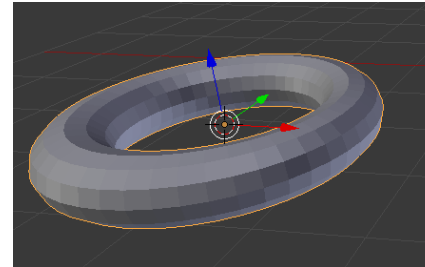
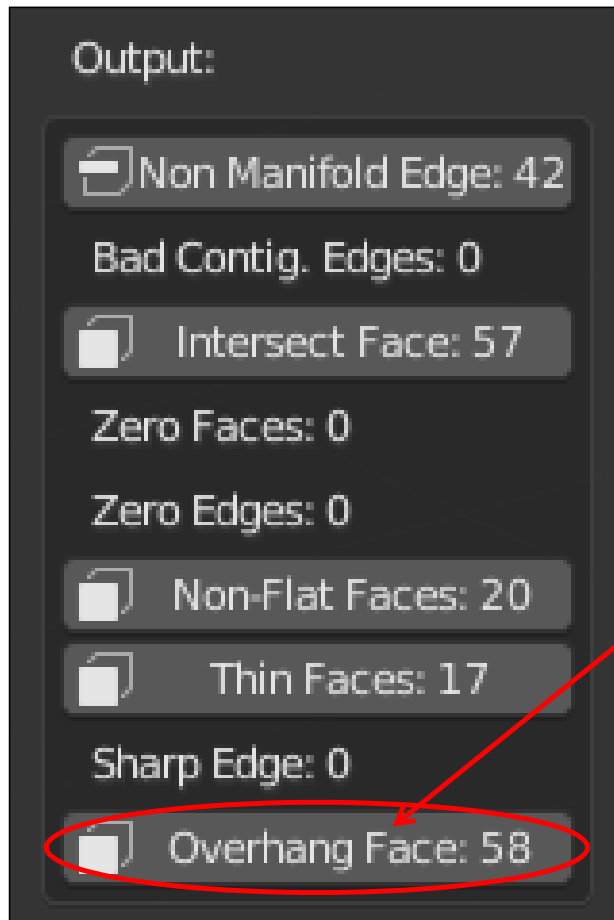


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Blender Options for 3D Printing

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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.

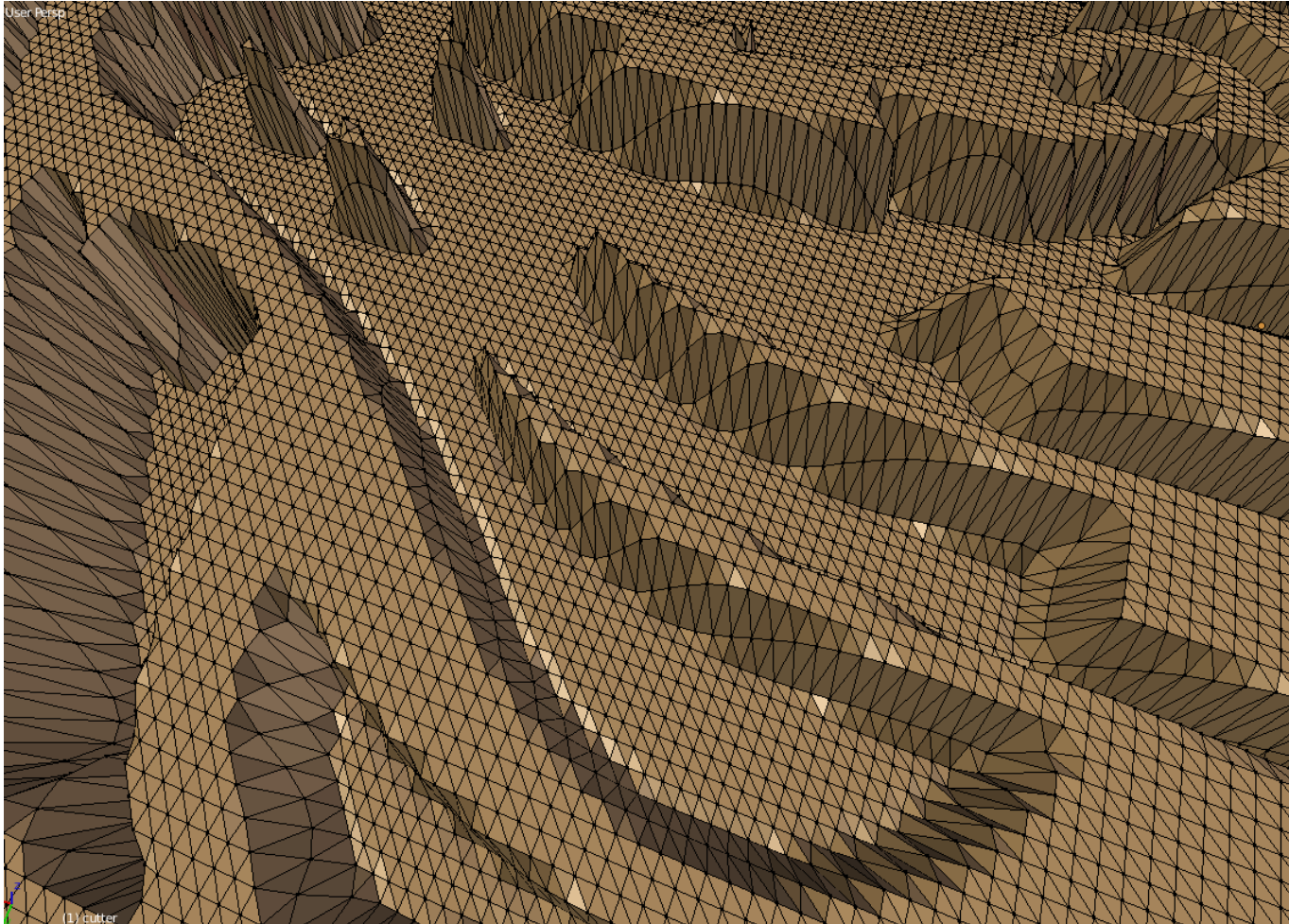


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Heightmap Files are Straightforward to use with 3D Printing

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A Very Special Heightmap 3D Printing Model

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A Very Special Heightmap 3D Printing Model

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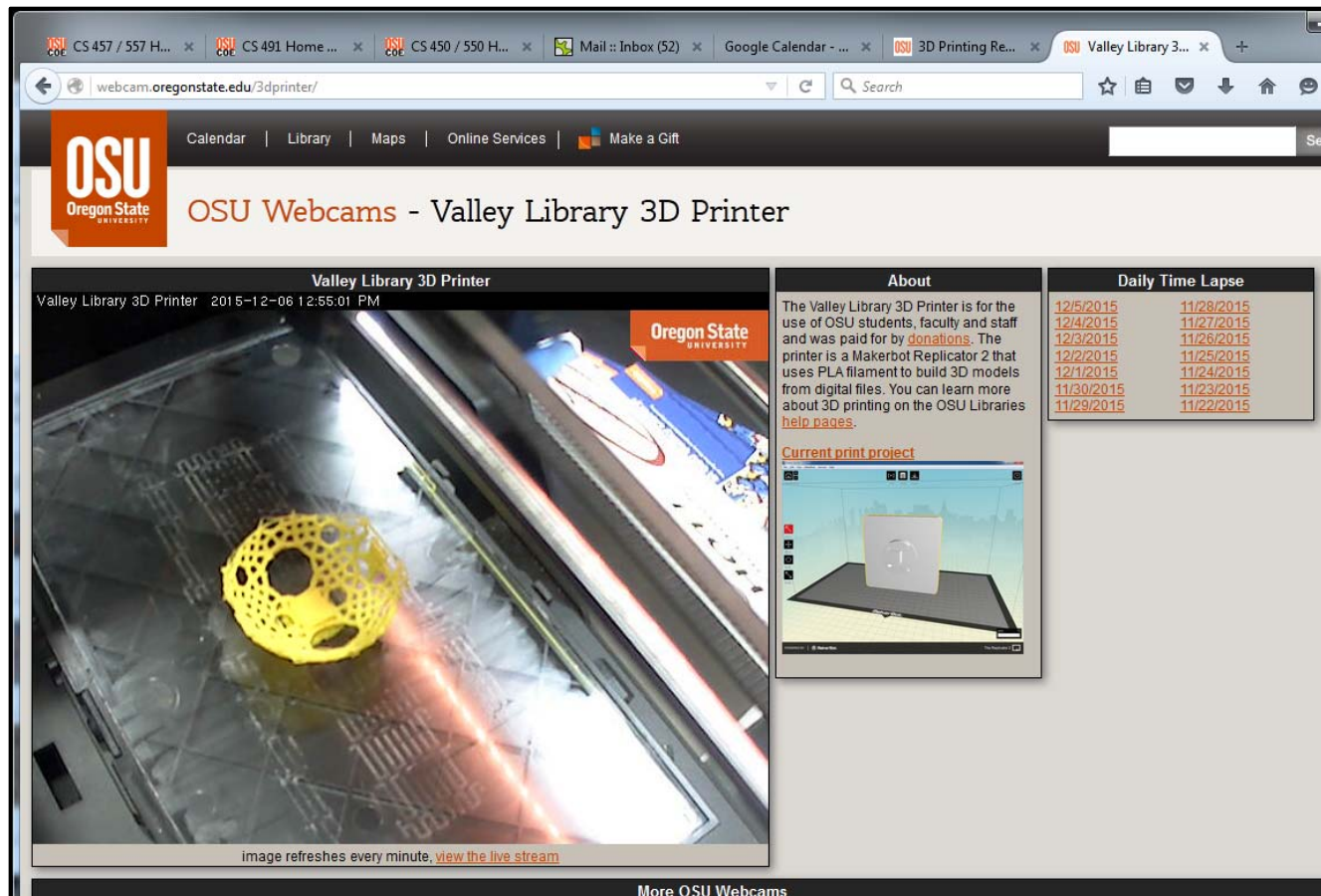
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The OSU Library's 3D Printers

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

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



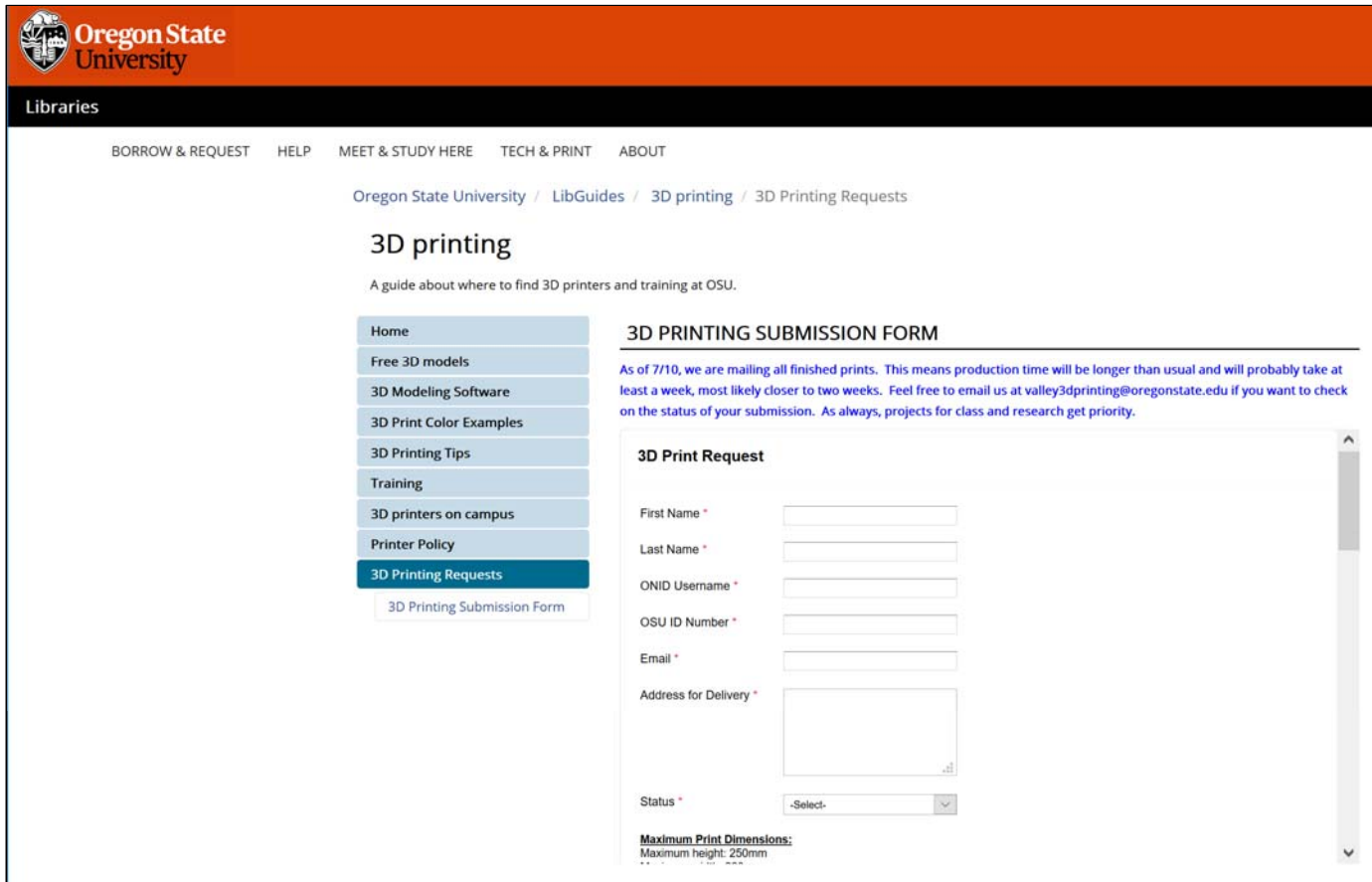
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The OSU Library's 3D Printers

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

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



The screenshot shows the Oregon State University LibGuides website. The header is orange with the OSU logo and name. Below the header is a black bar with the word "Libraries". A navigation menu includes "BORROW & REQUEST", "HELP", "MEET & STUDY HERE", "TECH & PRINT", and "ABOUT". The breadcrumb trail reads "Oregon State University / LibGuides / 3D printing / 3D Printing Requests". The main heading is "3D printing" with a subtext "A guide about where to find 3D printers and training at OSU." On the left is a sidebar with a list of links: Home, Free 3D models, 3D Modeling Software, 3D Print Color Examples, 3D Printing Tips, Training, 3D printers on campus, Printer Policy, 3D Printing Requests (highlighted), and 3D Printing Submission Form. The main content area is titled "3D PRINTING SUBMISSION FORM". It contains a notice: "As of 7/10, we are mailing all finished prints. This means production time will be longer than usual and will probably take at least a week, most likely closer to two weeks. Feel free to email us at valley3dprinting@oregonstate.edu if you want to check on the status of your submission. As always, projects for class and research get priority." Below the notice is the "3D Print Request" form with the following fields: First Name *, Last Name *, ONID Username *, OSU ID Number *, Email *, Address for Delivery *, and Status *. The Status dropdown menu is currently set to "-Select-". At the bottom of the form, it states "Maximum Print Dimensions: Maximum height: 250mm".



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mjb – August 13, 2020