3D Printing
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 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 Thingiverse and Blender) can produce this type of file for you.

<table>
<thead>
<tr>
<th>solid</th>
</tr>
</thead>
<tbody>
<tr>
<td>facet normal 0.00 0.00 -1.00</td>
</tr>
<tr>
<td>outer loop</td>
</tr>
<tr>
<td>vertex -2.000000 -2.000000 0.250000</td>
</tr>
<tr>
<td>vertex -1.980000 -1.980000 0.250000</td>
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<tr>
<td>vertex -1.980000 -2.000000 0.250000</td>
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<tr>
<td>endloop</td>
</tr>
<tr>
<td>endfacet</td>
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<td>facet normal 0.00 0.00 -1.00</td>
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</table>

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

Customizable pendant

Parameters you can set

Retrieve the STL file
Object Rules for 3D Printing

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

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.
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** \( \text{Faces} \)
- **E** \( \text{Edges} \)
- **V** \( \text{Vertices} \)

\[ 6 - 12 + 8 = 2 \]

*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!

These layers will build fine

This layer will fall to the plate
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)
Like many CAD systems, TinkerCAD uses 3D Boolean operators (3D Venn diagrams). This guarantees a legal solid for 3D Printing.
**TinkerCAD**

1. Select both (Shift-left click)

2. “Group”
TinkerCAD
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

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

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

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

http://wiki.blender.org/index.php/Extensions:2.6/Py/Scripts/Modeling/PrintToolbox
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.
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.
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.
Heightmap Files are Straightforward to use with 3D Printing
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