Slide 1

3D Printing
(which I consider to be a legitimate form of Computer Graphics display…)

Oregon State University

Mike Bailey

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3dPrinting.pptx

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Slide 2

In the Beginning, All Manufacturing was "Subtractive"

1. The whirling drill bit follows a 3D path around a block of metal, wax, or wood
2. Chips fly
3. A block of metal becomes a part
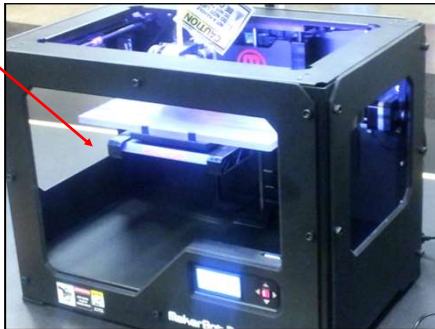
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Slide 3

Today's 3D Printing Process

"3D Printing" is generally considered to be some sort of **"Additive"** process in which layers of material get deposited on previous layers. (Additive manufacturing is also sometimes called *Stereolithography*.)

The current frenzy in 3D Printing consists mostly of desktop systems that deposit layers of molten plastic, like this one. But there are many others.
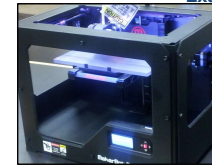
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Slide 4

Examples of 3D Printing using a Variety of Materials

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Slide 5

Portland's Laika uses Color 3D Printing to Make Faces for Stop-motion Movies 5

From *Kubo and the Two Strings*

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Slide 6

The 3D Printing Geometry File 6

3D Printers are fed a file called an "STL File", which lists all the triangles in the object. All 3D CAD-ish 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
```

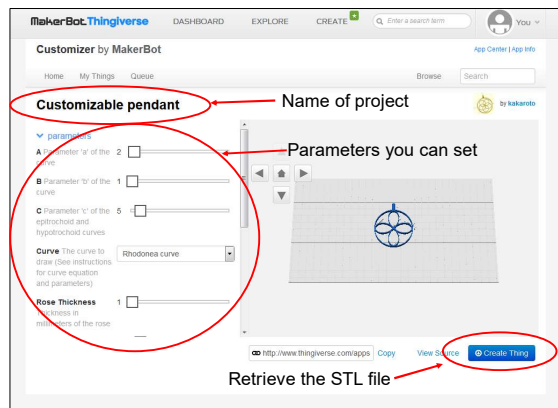In this particular file, these coordinates were in units of inches.

Some 3D Printers still use **inches**, but most now seem to use **millimeters**.
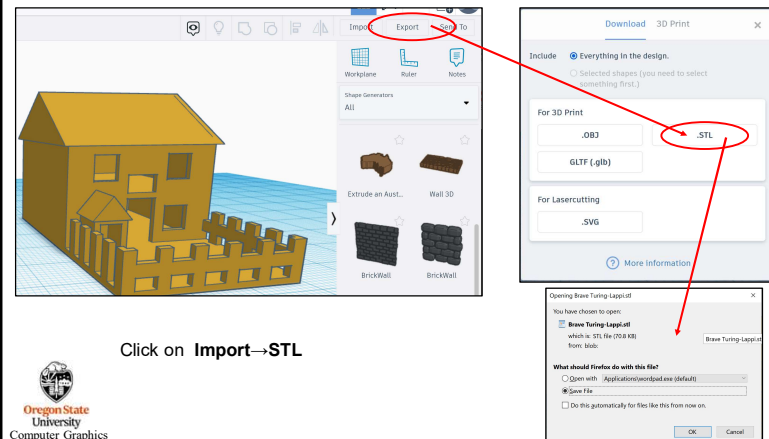
Check! It matters!

Note: there are 25.4 mm/inch

If you sent this file to a millimeter-based 3D printer, the part would come out very, very tiny! ☺

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Slide 7

thingiverse.com 7

Name of project

Parameters you can set

Retrieve the STL file

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Slide 8

TinkerCad 8

Click on **Import→STL**

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Slide 9

Object Rules for 3D Printing 9

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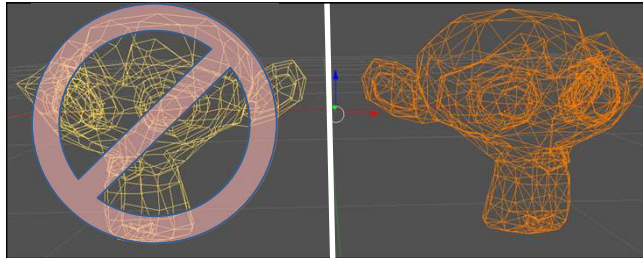
Quads and triangles   **Triangles only**

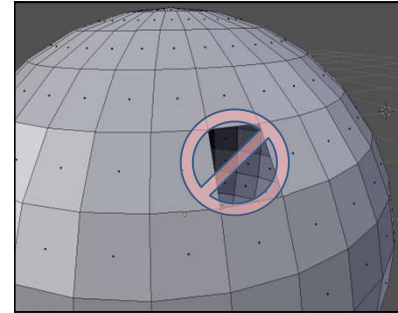**In Blender:** Modifiers → Add Modifier → Triangulate

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Slide 10

Object Rules for 3D Printing 10

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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Slide 11

Object Modeling Rules for 3D Printing 11

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, legal object.
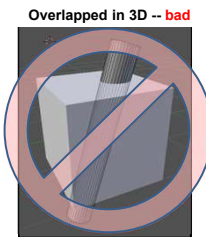
Overlapped in 3D -- bad   **Boolean union -- good**

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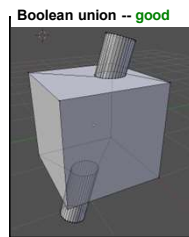
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Slide 12

Object Rules for 3D Printing 12

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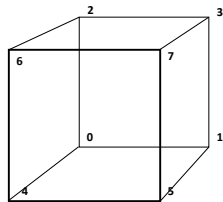

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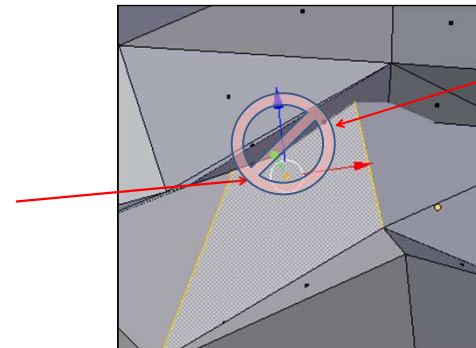
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The Simplified Euler's Formula* for Legal Solids

$$F - E + V = 2$$

F	Faces
E	Edges
V	Vertices

For a cube: 6 – 12 + 8 = 2

*sometimes called the Euler-Poincaré formula

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The Full Euler's Formula* for Legal Solids

$$F - E + V - L = 2(B - G)$$
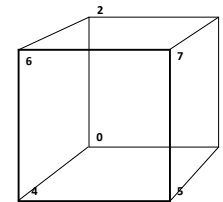
F	Faces
E	Edges
V	Vertices
L	Inner Edge Loops (within faces)
B	Bodies
G	Genus (number of through-holes)

For a cube: 6 – 12 + 8 – 0 = 2(1 – 0)

*sometimes called the Euler-Poincaré formula

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Advice on 3D Printing

Don't make the part too big to start – it will take a long time to 3D print. It's nice if you can fit several models in a single run.

Try to rotate the part so the smallest dimension is vertical. It's stronger that way, and it builds faster.

The 3D Printer will like it better if the part gets smaller as it goes up, not the other way around.

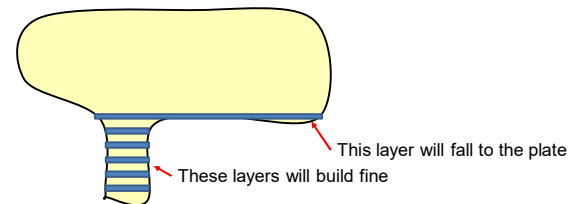Don't design the part with long, thin edges. They will snap right off.
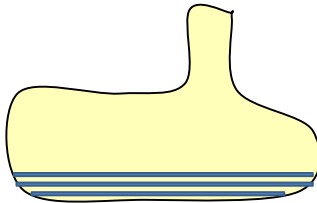
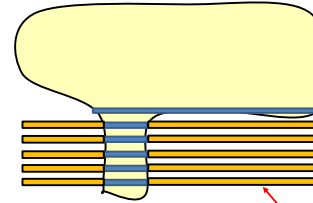Don't make walls too thin – they will break.

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Watch Out for Overhangs!

This layer will fall to the plate

These layers will build fine

16
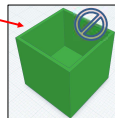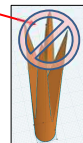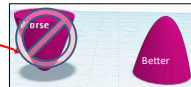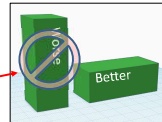
Note that, if you build this object upside-down, it will probably be fine
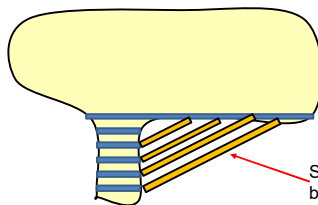
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Watch Out for Overhangs!

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

Watch Out for Overhangs!

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Some 3D printers handle overhangs by using software to add "support structures" to the overhangs
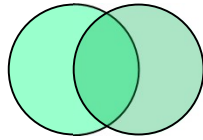
Some 3D printers handle this better than others…

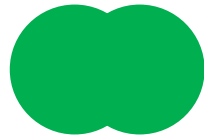**What Happens if You Don't Follow the Rules?**

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

Slide 21

How Can You Guarantee That You Are Modeling With Legal Solids? Remember the "3D Venn Diagrams"
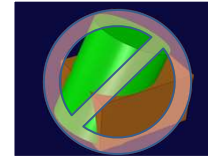

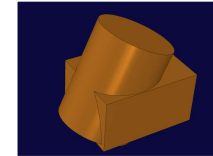Two Overlapping Shapes — Union — Intersection — Difference
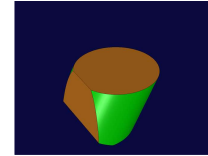
Slide 22

How Can You Guarantee That You Are Modeling With Legal Solids? Remember the "3D Venn Diagrams"

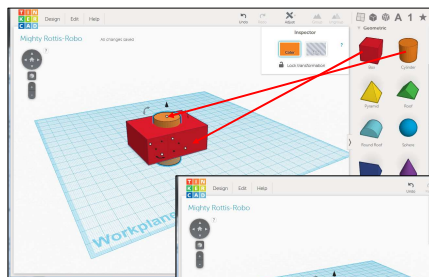Two Overlapping Solids — Union — Intersection — Difference
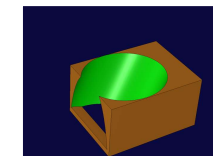
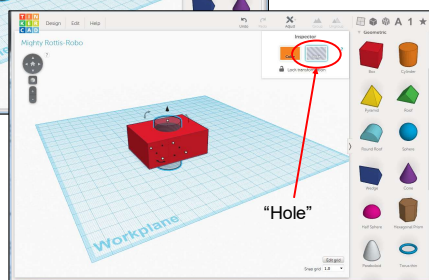**This is often called Constructive Solid Geometry (CSG)**

Slide 23

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.
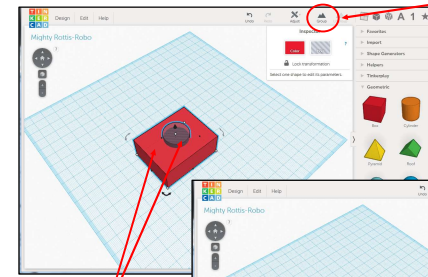
"Hole"

Slide 24

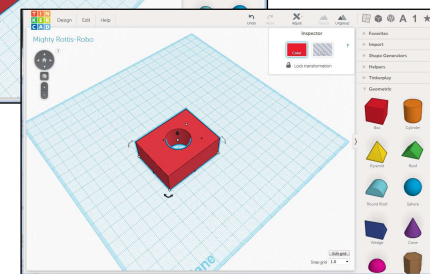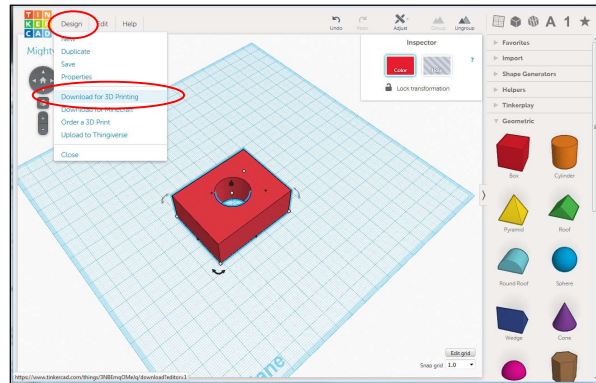### TinkerCad

2. "Group"

1. Select both (Shift-left click)

TinkerCad
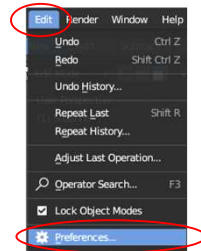

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Procedural CSG Using TinkerCad/Codeblocks

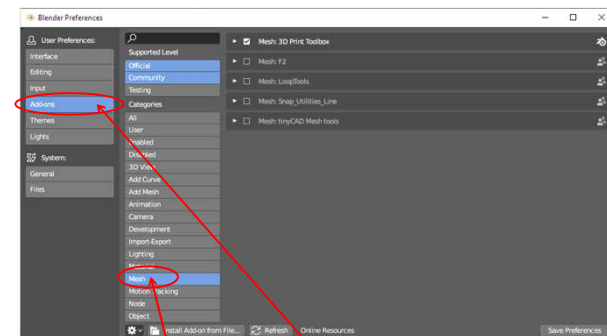

26
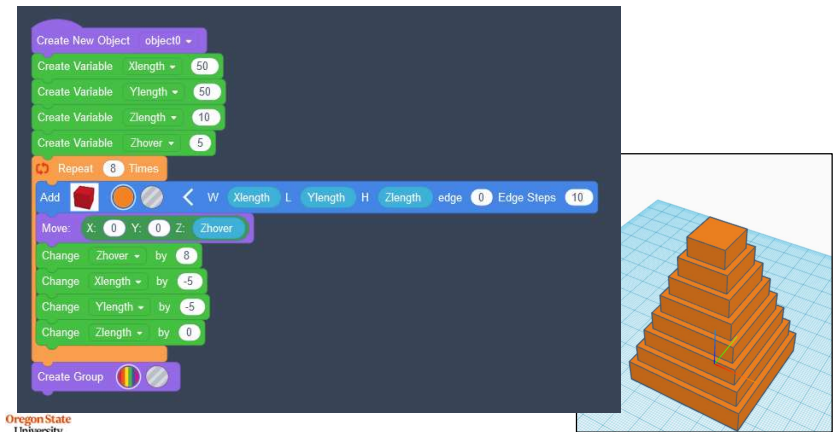
Blender's 3D Printing Utility isn't there by Default

By default, Blender doesn't let you see its 3D Printing utility. You need to tell Blender to turn it on.

1. Click **Edit → Preferences**

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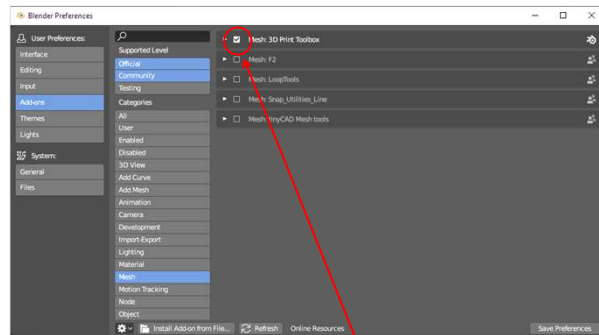## Blender's 3D Printing Options aren't there by Default

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

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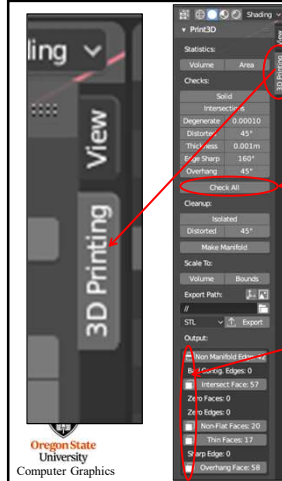## Slide 29 — Blender's 3D Printing Options aren't there by Default

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

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Slide 30 — Blender Options for 3D Printing

3D Printing now shows up in your Properties Region (hit the 'n' key if you're not seeing it)

Objects destined for 3D Printing must be "legal solids". Clicking on object and then on **Check All** will try to determine that
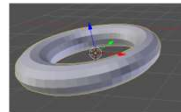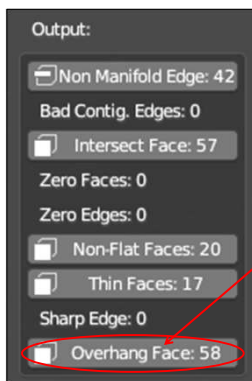
Tab over to Edit Mode. Clicking on any of these will highlight where they are on your object.

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Slide 31 — Blender Options for 3D Printing

Output:
- Non Manifold Edge: 42
- Bad Contig. Edges: 0
- Intersect Face: 57
- Zero Faces: 0
- Zero Edges: 0
- Non-Flat Faces: 20
- Thin Faces: 17
- Sharp Edge: 0
- Overhang Face: 58

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

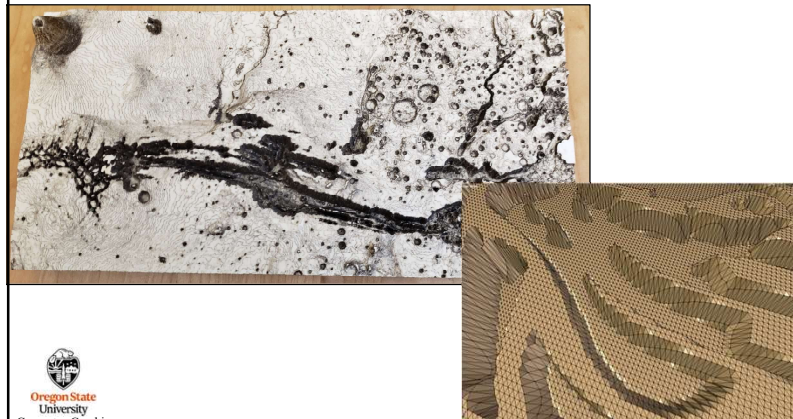However, overhang faces that are not the bottom of the part could be a problem.

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Slide 32 — Heightmap Files are Straightforward to use with 3D Printing

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A Very Special Heightmap 3D Printing Model (mmm...)

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A Very Special Heightmap 3D Printing Model (mmm...)

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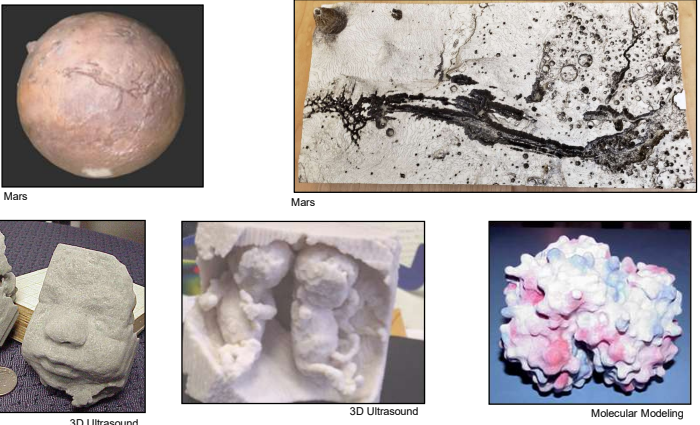## Most Any *Data* Can be Turned into a 3D-Printable Model

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Mars

Mars

3D Ultrasound

3D Ultrasound

Molecular Modeling

Most Any *Data* Can be Turned into a 3D-Printable Model

36

Oregon

Grand Canyon

Dinosaur Egg

MRI Scan

Earth

33

34

35
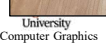
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The OSU Library Has Four 3D Printers for Student Use 37

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

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

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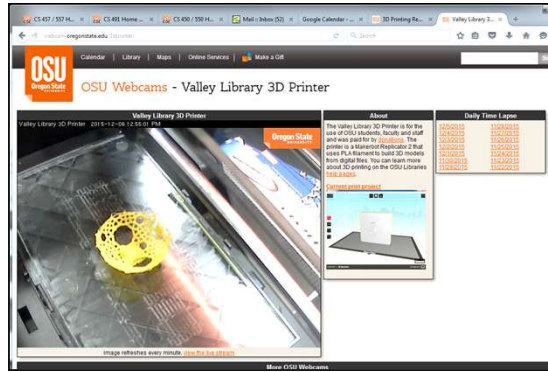
The OSU Library Has Four 3D Printers for Student Use 38

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

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

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