Introduction to 3D Printing

HAMFEST March 18th 2023

By
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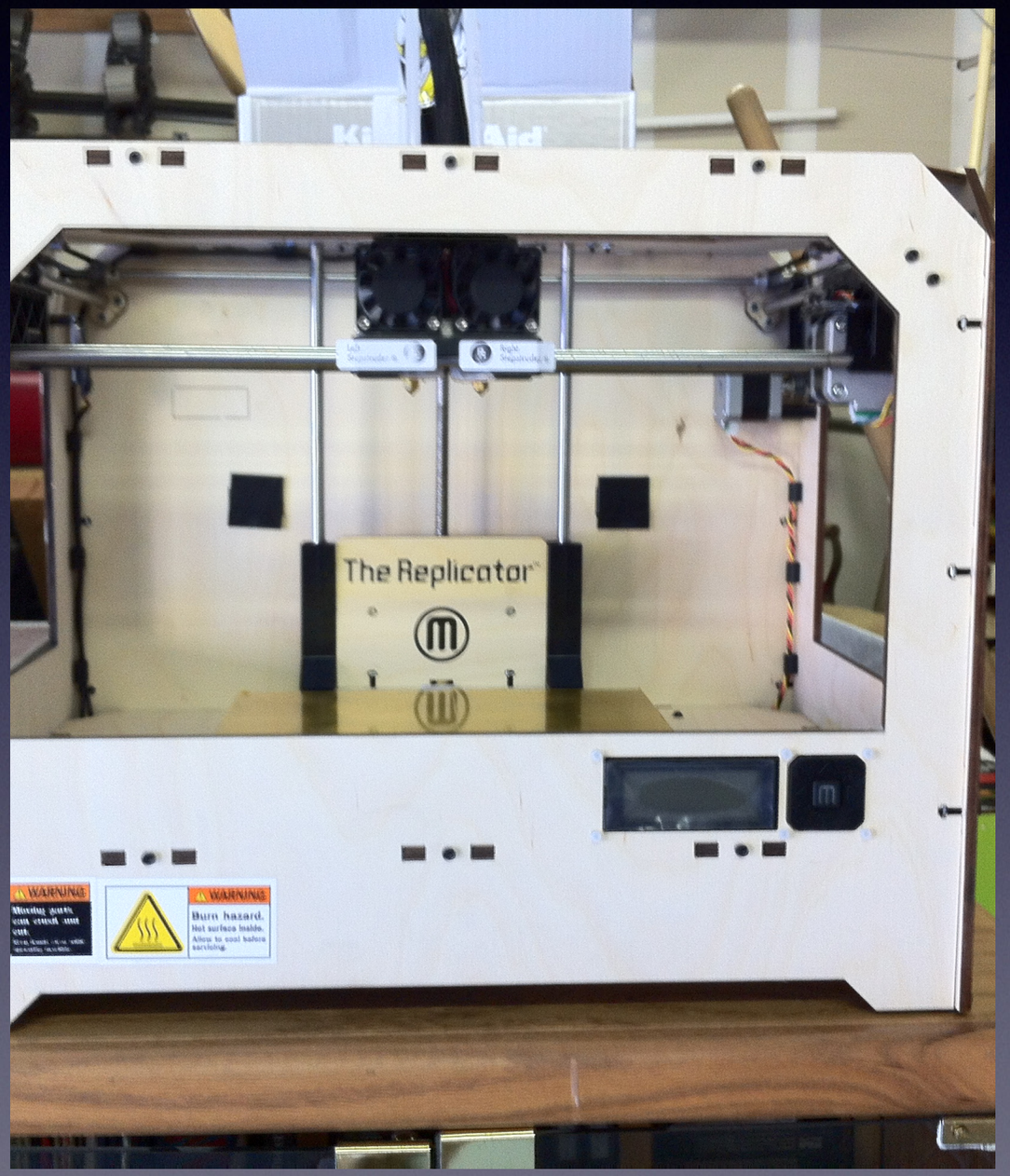
Any sufficiently advanced technology is indistinguishable from magic.

- Arthur C. Clarke

Introduction to the technology

- What is 3D printing?
- What was 2D printing?



3D Printing in the World

- 3D printed houses, cars, planes, bicycles, cakes & decorations, antennas (using dielectric resin), things that go bang!
- Armed forces using them to print parts
- ISS has one
- Print organs - human liver - eliminates rejection on transplants
- Featured in Sci-fi movies, books, not just the StarTrek Replicator, Lost in Space, The Peripheral..
- Parts for prototype, molds, test fixtures
- Prosthetic limbs

What's available

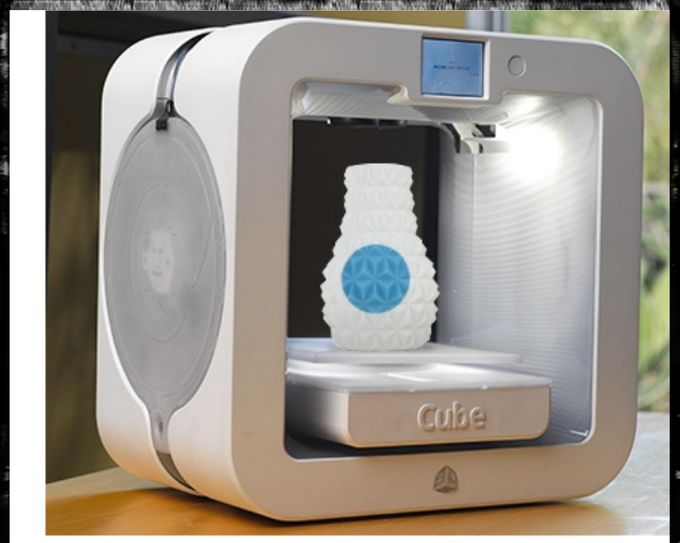
- Printers vary from kits you can build to fully assembled models
- Vary in price (<$300 to >$3000), size (4inch build area 10+ inch build area) and functionality (dual extruders, heated beds, LCD panels.)
- B&H Photo (NY) listed over 25 printers from $200-$2000
- Most now come with software but…

3D Printers

Play (4x4x5) (3)

Simple (6x6x6) (4)

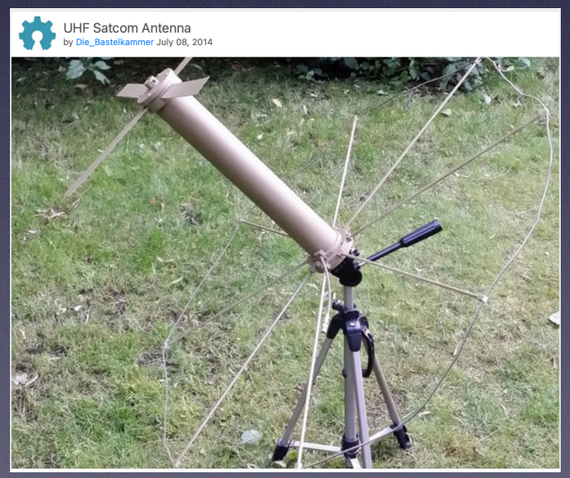
Plus (10x10x10) (2)



What can I print at home?

- Toys for your Grandkids
- New tools or adapters for existing tools
- Replacement parts for broken stuff…
- Christmas/Easter/Halloween Ornaments
- Signs
- iPhone/iPad stands
- Prosthetic hands for children (e-NABLE).
- Food chocolate, marzipan and potato puree Hors d’oeuvres!
- **Whatever you can image…..**

Ham 3D Prints



What is 3D Printing?

- Simply put, it's the ability to print a real object that you can hold, play with, attach, paint, glue, wear, or use that object to create more objects…*
- Where did it come from?
- So how does it work?

* *My definition*

What was 2D printing?

- What was 2D printing? *Did I miss it?*
- 2D printing prints in 2 directions or dimensions which we will call X, Y! (First technical terms!)
- For example the printer head in your printer moves in the X direction (left to right) and the paper moves in the Y direction (front to back).

Demo

This is an example of 2D printing. The text came across left to right (X)

Then the text moved up (Y).

Remember typewriters or XY Plotters?

2D to 3D Printing

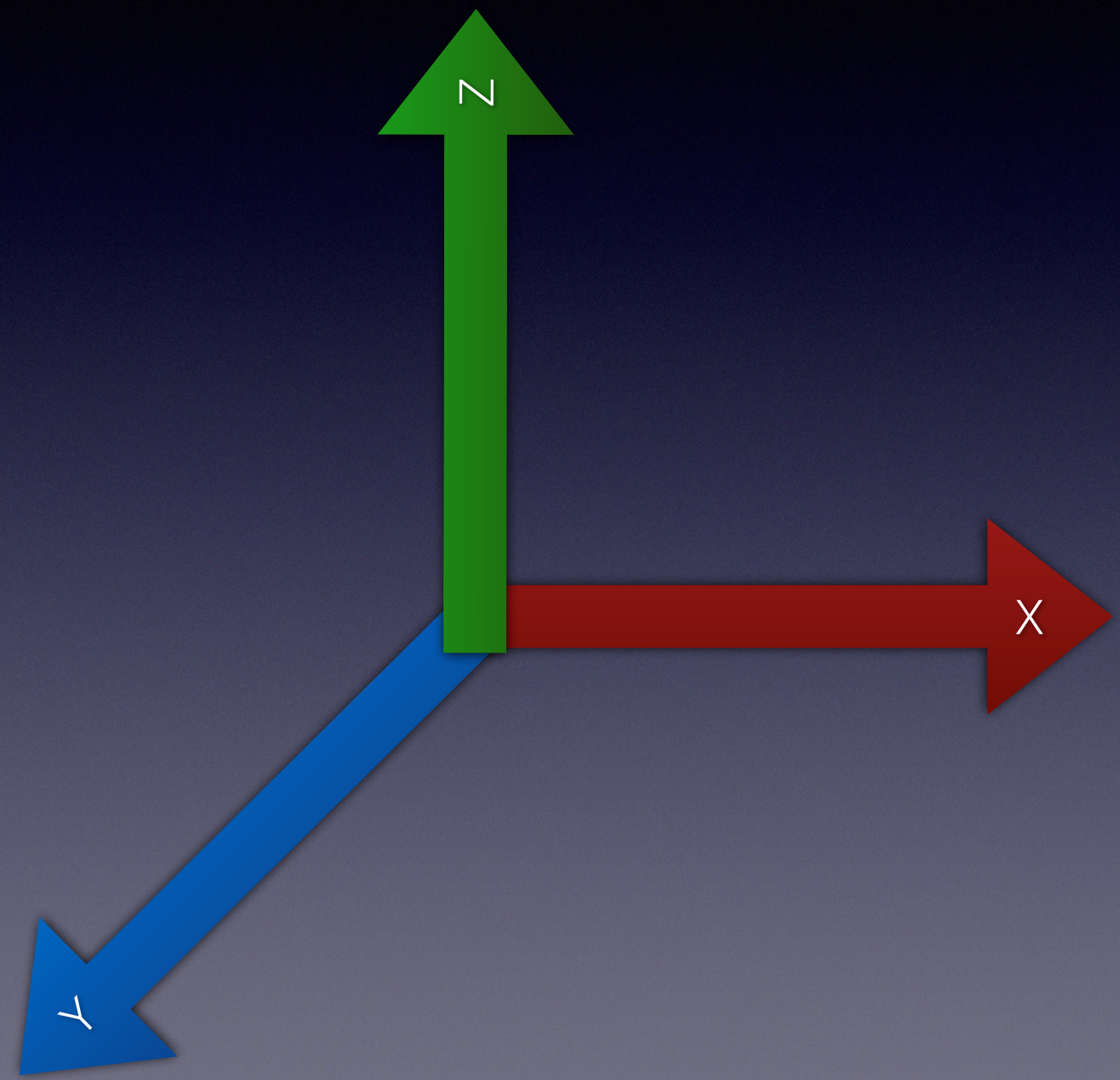
- So if we can print in 2 dimensions (X & Y) how can we print in 3 dimensions - Z? (Next technical term!)

- The print head in a 3D printer moves up/down in the Z dimension. (Your model of printer may vary on the Z direction)

3D terms

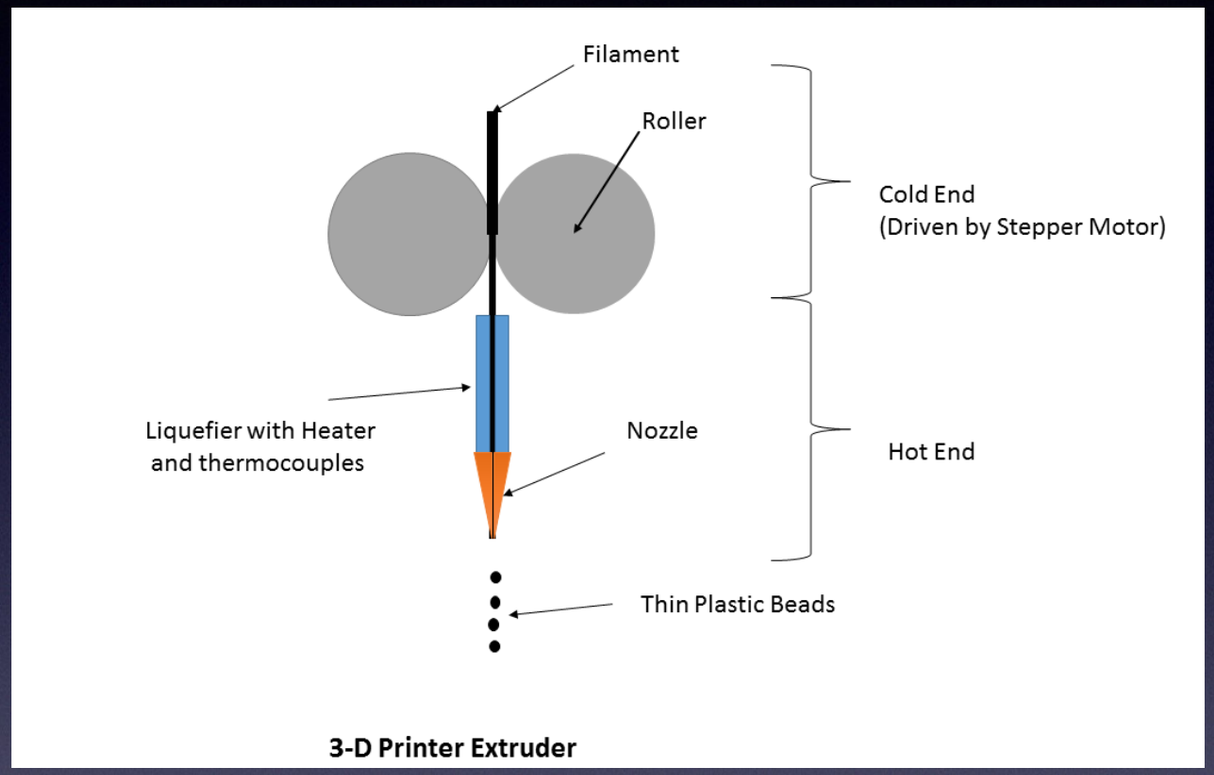
- What does X, Y and Z axis mean?
- What is an extruder?
- Heated Bed
- Bed leveling
- What is FDM, or SLA? (FDM uses filament; SLA uses resin.)
- What is filament?
- What is additive versus extractive manufacturing techniques?
- G-Code

X,Y and Z



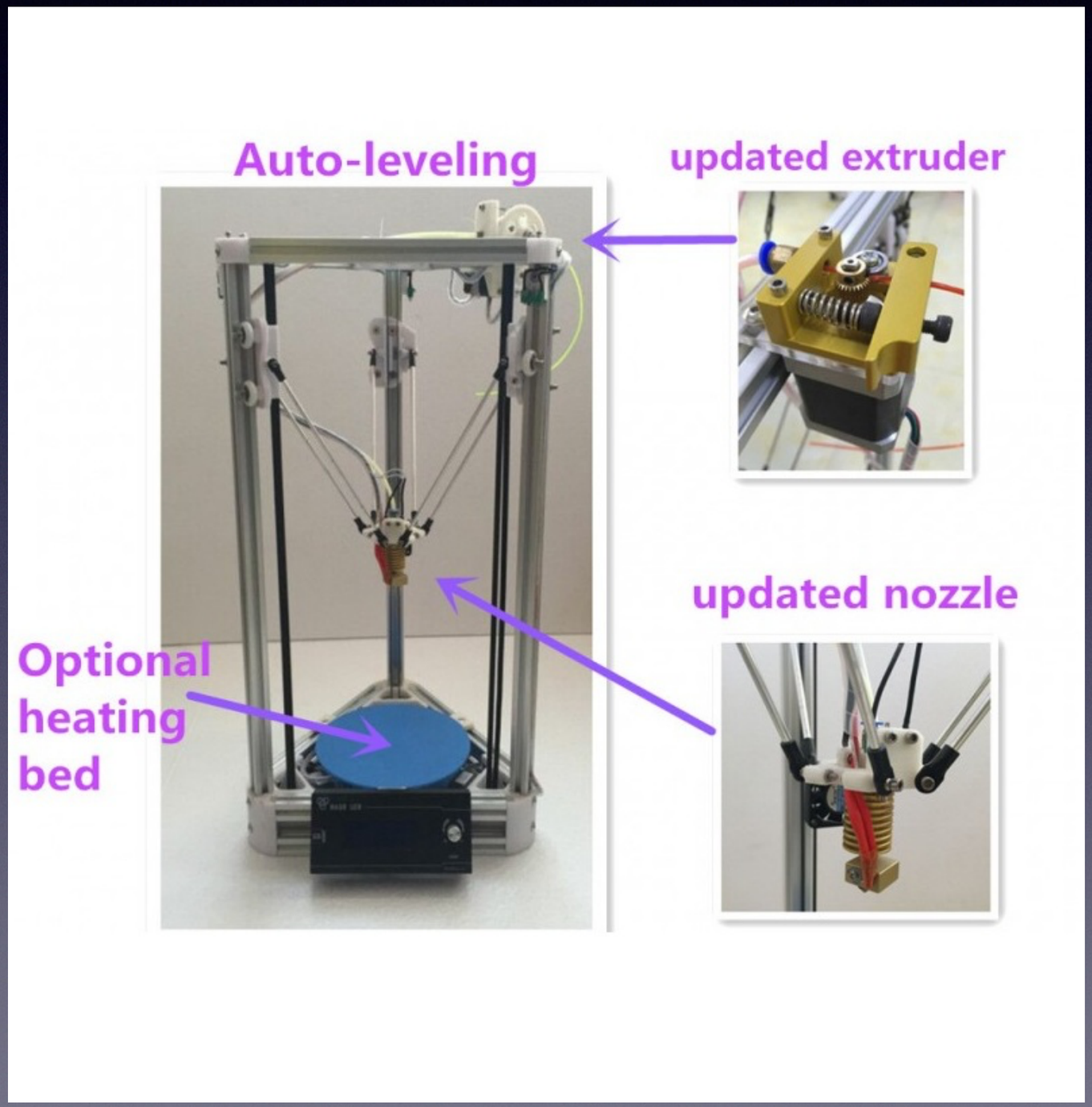
Extruder

- Sometime called the Hot End.
- Comprised of:
  - A heater
  - Temperature sensor
  - Gear mechanism to push the plastic through
- Some extruder have heater/motor/gears in one module.
- Others just the heater to cut down on mass for more accurate movement.



3-D Printer Extruder

Delta Printer



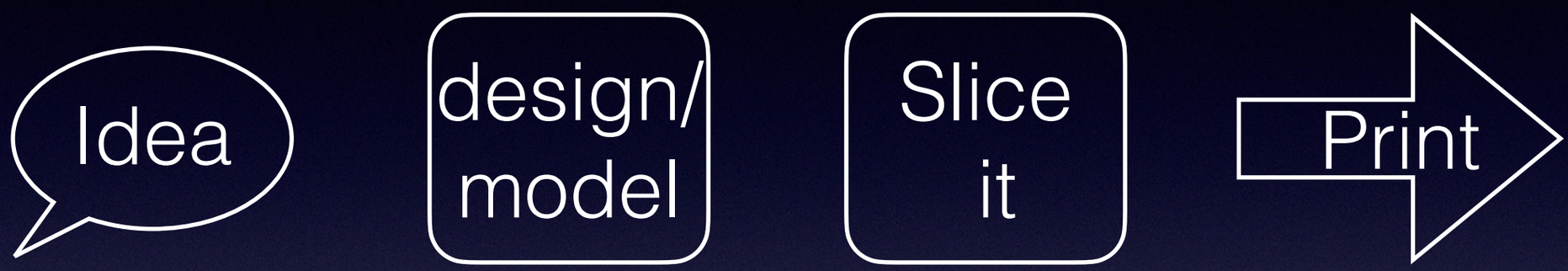
Filament

- ABS
- PLA
- Carbon Fibre
- Wood texture - bamboo
- Nina flex - makes flexible prints
- Glass
- Metal powder
- Marzipan, Potato puree,

More Terms

- CNC/CAD/CAM
- G-Code
- STL
- Brim, raft, support
- Infill percentage
- Shells
- Water tight model
- Slicing
- Profiles (or .ini files)
- OpenSource versus Propriety

3D Printing Process



Start from scratch | CAD Software | Slicer software | Print Software

Search the web | Download from Web | Slicer & Print software

Design or download - Slicer - send to printer

Different Software Programs you may need to use.

G-Code

```
23  ;Layer count: 1198
24  ;LAYER:0
25  M107
26  G0 F3000 X50.458 Y50.997 Z0.300
27  ;TYPE:SKIRT
28  G1 F2100 X51.194 Y50.261 E0.05193
29  G1 X52.083 Y49.439 E0.11234
30  G1 X52.141 Y49.401 E0.11579
31  G1 X52.673 Y48.906 E0.15205
32  G1 X52.818 Y48.832 E0.16017
33  G1 X53.340 Y48.365 E0.19511
```

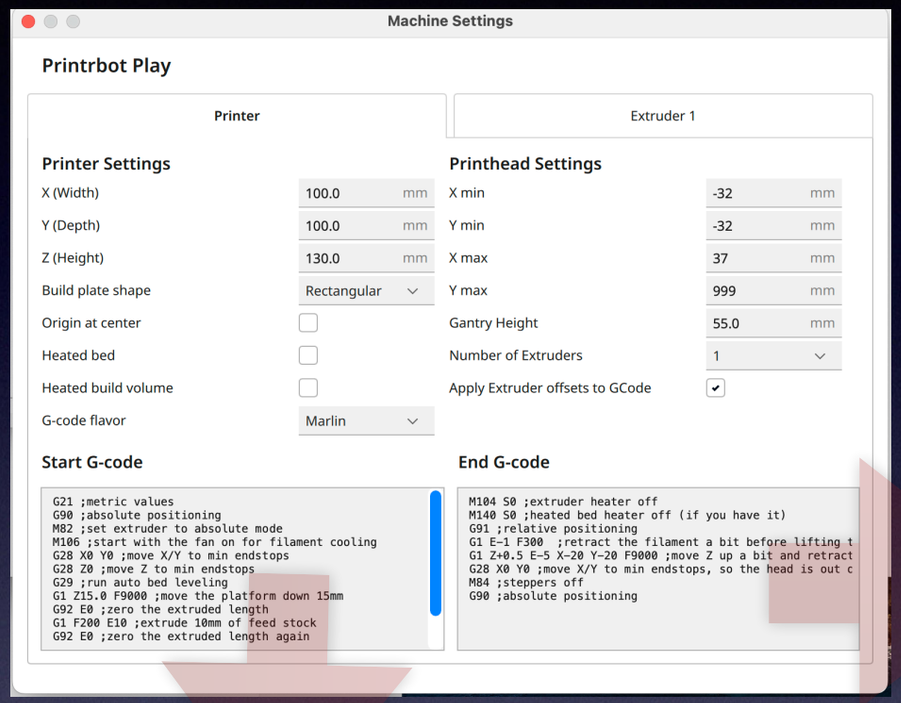
← X, Y and Z positions

← X, Y position and Extrude command

```
11333  G0 F3000 X59.367 Y95.289
11334  G1 F2100 X54.714 Y90.635 E466.75338
11335  ;LAYER:1
11336  M106 S127
11337  G0 F3000 X54.826 Y90.919 Z0.400
11338  ;TYPE:WALL-INNER
11339  G1 F2460 X54.639 Y90.681 E466.75841
```

For Reference: http://reprap.org/wiki/G-code

Printer setup G-Code




```
2806  G1 F2700 E436.15909
2807  M107
2808  M104 S0 ;extruder heater off
2809  M140 S0 ;heated bed heater off (if you have it)
2810  G91 ;relative positioning
2811  G1 E-1 F300  ;retract the filament a bit before lifting the nozzle, to release some of the pressure
2812  G1 Z+0.5 E-5 X-20 Y-20 F9000 ;move Z up a bit and retract filament even more
2813  G28 X0 Y0 ;move X/Y to min endstops, so the head is out of the way
2814  M84 ;steppers off
2815  G90 ;absolute positioning
2816  M82 ;absolute extrusion mode
2817  M104 S0
2818  ;End of Gcode
2819  ;SETTING_3 {"global_quality": "[general]\\nversion = 4\\nname = Fine #2\\ndefini
2820  ;SETTING_3 tion = printrbot_play\\n\\n[metadata]\\ntype = quality_changes\\nqual
2821  ;SETTING_3 ity_type = normal\\nsetting_version = 21\\n\\n[values]\\nadhesion_typ
2822  ;SETTING_3 e = brim\\nsupport_enable = False\\nsupport_type = buildplate\\n\\n",
2823  ;SETTING_3  "extruder_quality": ["[general]\\nversion = 4\\nname = Fine #2\\ndef
2824  ;SETTING_3 inition = printrbot_play\\n\\n[metadata]\\ntype = quality_changes\\nq
2825  ;SETTING_3 uality_type = normal\\nsetting_version = 21\\nposition = 0\\n\\n[valu
2826  ;SETTING_3 es]\\ninfill_pattern = gyroid\\ninfill_sparse_density = 10.0\\n\\n"]}
2827
```

```
1   ;FLAVOR:Marlin
2   ;TIME:470
3   ;Filament used: 0.436859m
4   ;Layer height: 0.2
5   ;MINX:32.2
6   ;MINY:32.2
7   ;MINZ:0.3
8   ;MAXX:67.8
9   ;MAXY:67.8
10  ;MAXZ:2.9
11  ;Generated with Cura_SteamEngine 5.3.0
12  M104 S200
13  M105
14  M109 S200
15  M82 ;absolute extrusion mode
16  G21 ;metric values
17  G90 ;absolute positioning
18  M82 ;set extruder to absolute mode
19  M106 ;start with the fan on for filament cooling
20  G28 X0 Y0 ;move X/Y to min endstops
21  G28 Z0 ;move Z to min endstops
22  G29 ;run auto bed leveling
23  G1 Z15.0 F9000 ;move the platform down 15mm
24  G92 E0 ;zero the extruded length
25  G1 F200 E10 ;extrude 10mm of feed stock
26  G92 E0 ;zero the extruded length again
27  G1 F9000
28  ;Put printing message on LCD screen
29  M117 Printing...
```

G-code for 3mm Square Model Sliced and printed by Cura.

Notice:

1) The start/end G-code
2) The line number count.

Words of Caution!

- You are melting plastic - ~210 C
- You may have a heated bed - ~120 C
- There are moving parts
- It uses electricity

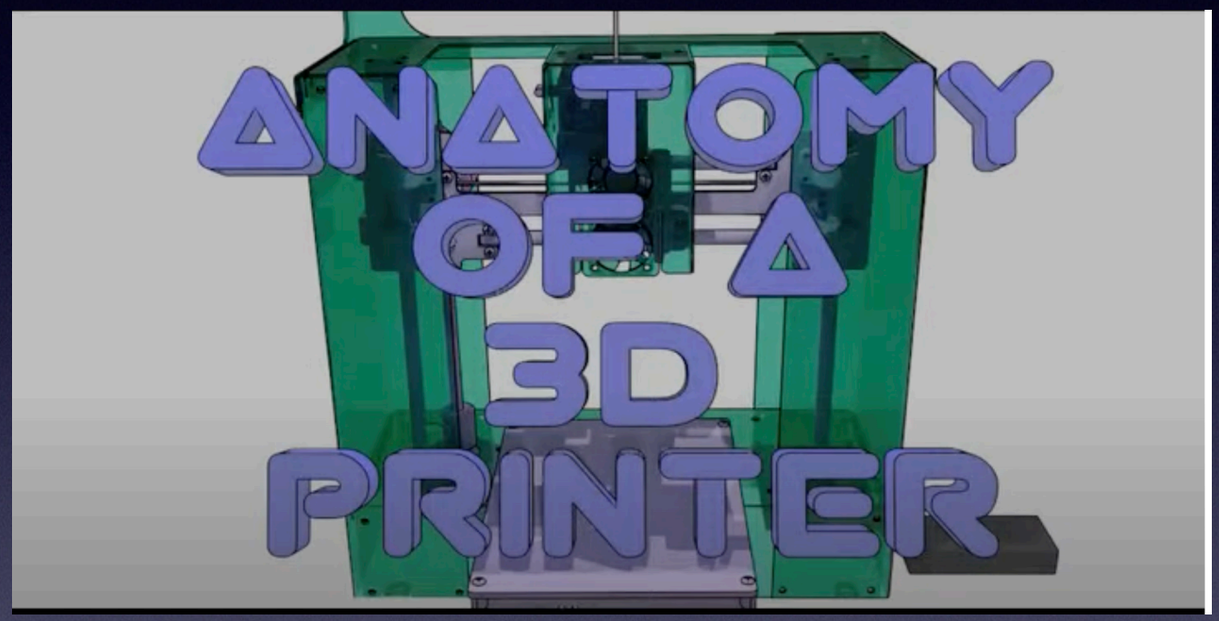
Use common sense

Words of Caution!

- The process heats up and melts plastic - it will smell.
  - ABS is quite strong
  - PLA is not quite as strong
- Medical studies are underway to tell you how bad for your help 3D Plastic printing is.

Anatomy of a 3D Printer

- X Axis for left to right movement
- Y axis for back and front movement
- Z axis for up or down movement
- Extruder = motor which pushes plastic through a heated tube



Copy link for animation
https://youtu.be/xuEENIHbbrA

Anatomy cont…

- Power supply
- Controller board
- USB socket
- SD card reader
- Sometimes an LCD screen and buttons. Wifi connect is available on some newer models.

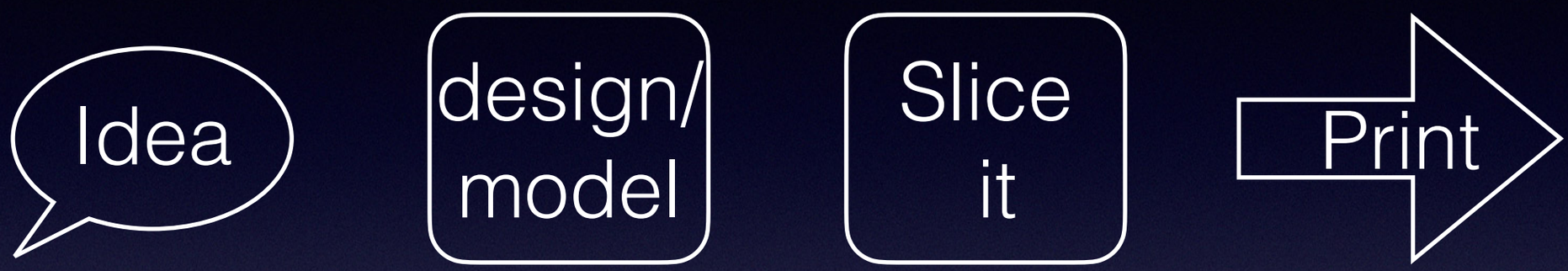
Getting started

- It all depends what you want to do…
  - Add to an existing hobby - Ham Radio,model planes, trains, cars..
  - Jewelry - mockups, molds
  - Prototypes - cases, holders, adapters, fasteners
  - Props for theaters or Cosplay.. Horns, claws, space guns, old telephones..
  - Make replacement parts - Roomba, aquarium pumps
  - e-NABLE volunteer making prosthetics hands…
  - Hobby income by joining 3d Hubs or printing for friends.

Getting started

- To buy or not to buy?
- What else will I need beside the printer?
  - Supplies
    - Filament
    - Tape (painters or Kapton)
  - Tools
    - Calipers
    - Scrapers (for removal of models)
    - Hex set, screwdrivers
- Build your own:
  - Kit
  - From scratch

3D Printing Process



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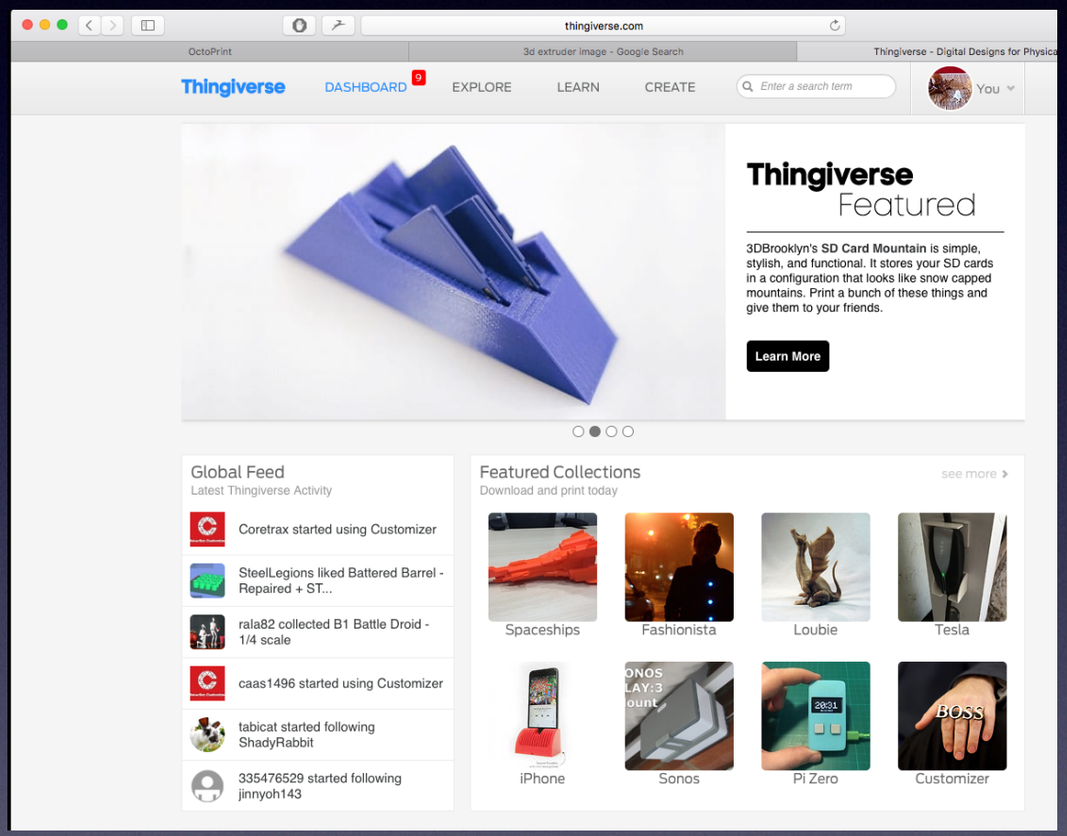
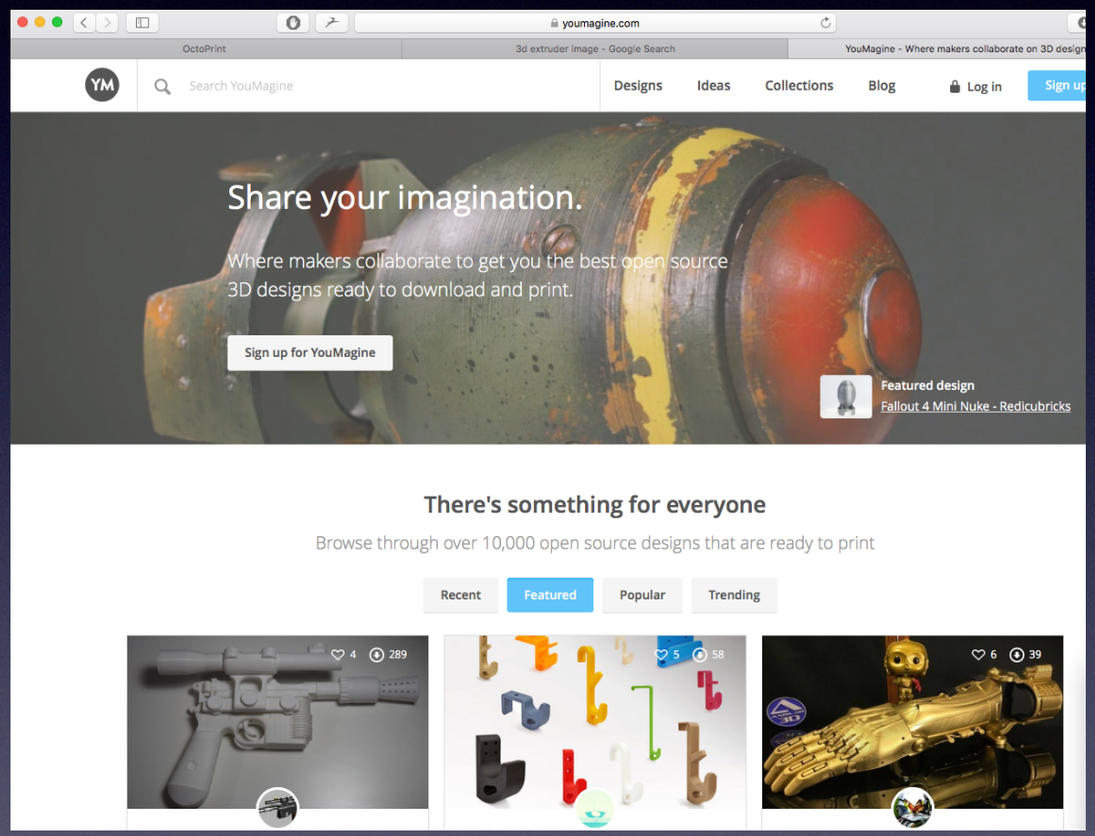
Search the web | Download from Web | Slicer & Print software

Design or download - Slicer - send to printer

Different Software Programs you may need to use.

Where can you find stuff to print?



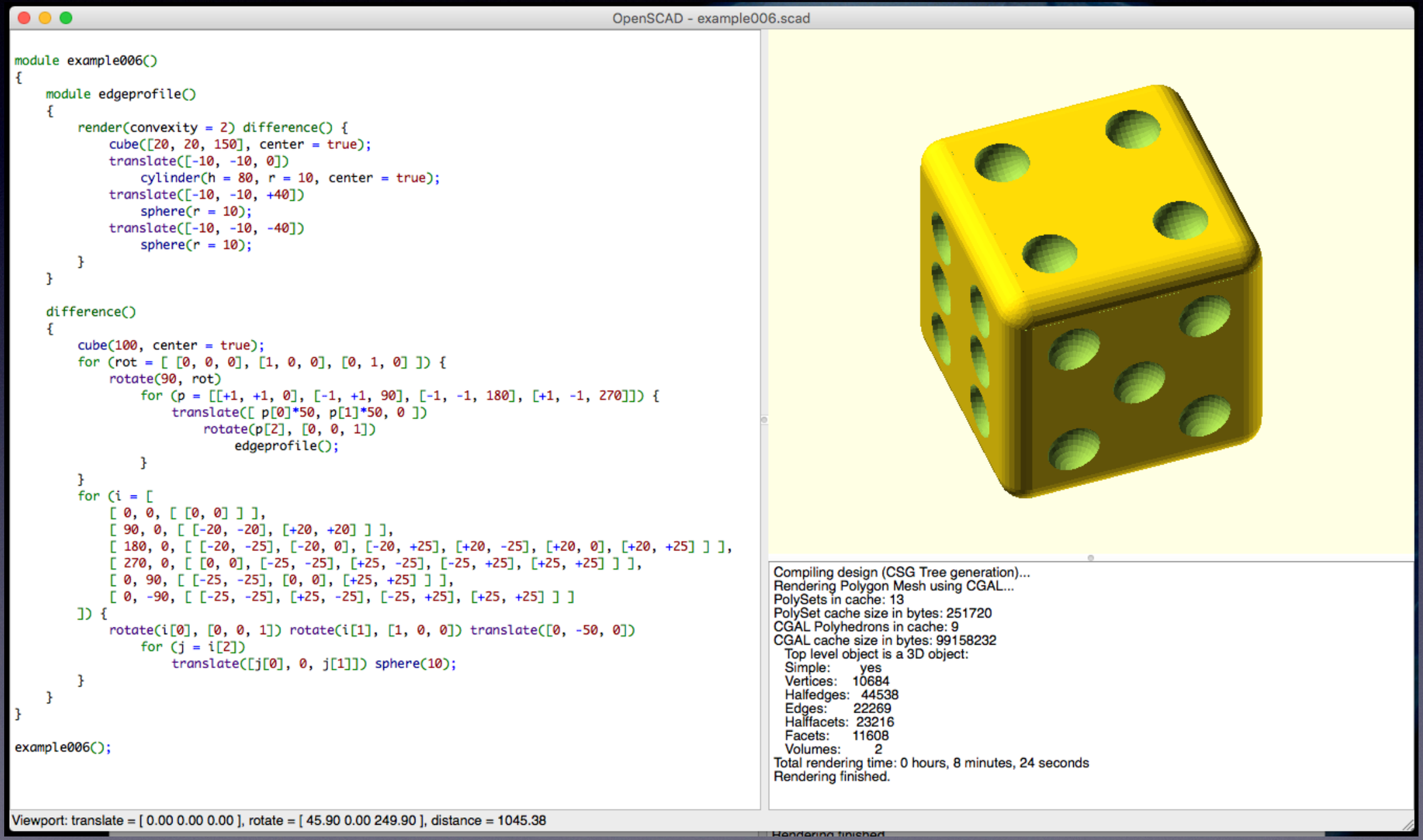


- Two Popular sites - but use the web…
- Use your smartphone as a 3D Scanner (123D Catch)

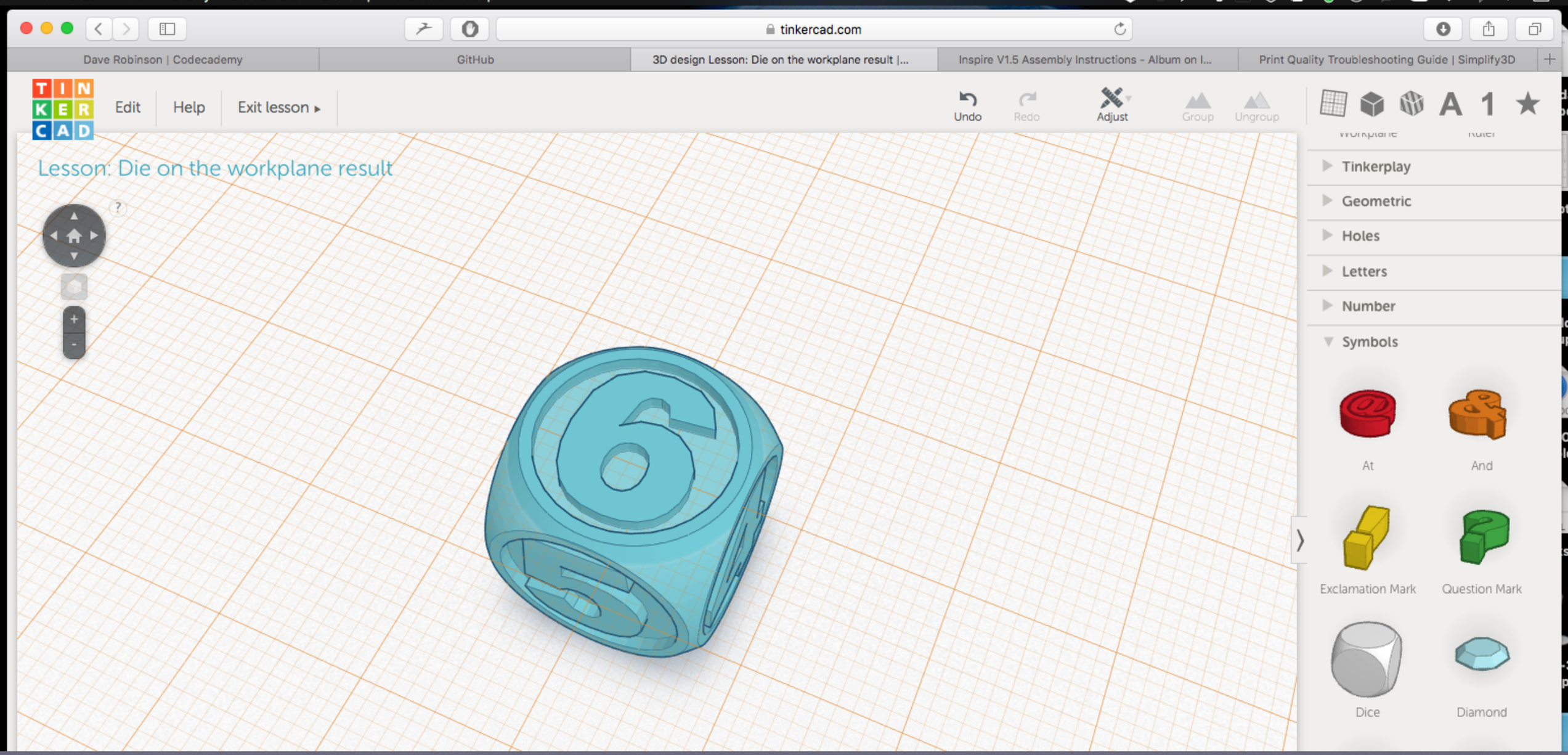
Software

- Usually you will need some kind of software to make your designs/models
- Prices and features vary
  - Free to expensive license based
  - Easy to very complex
  - Text based to graphical based

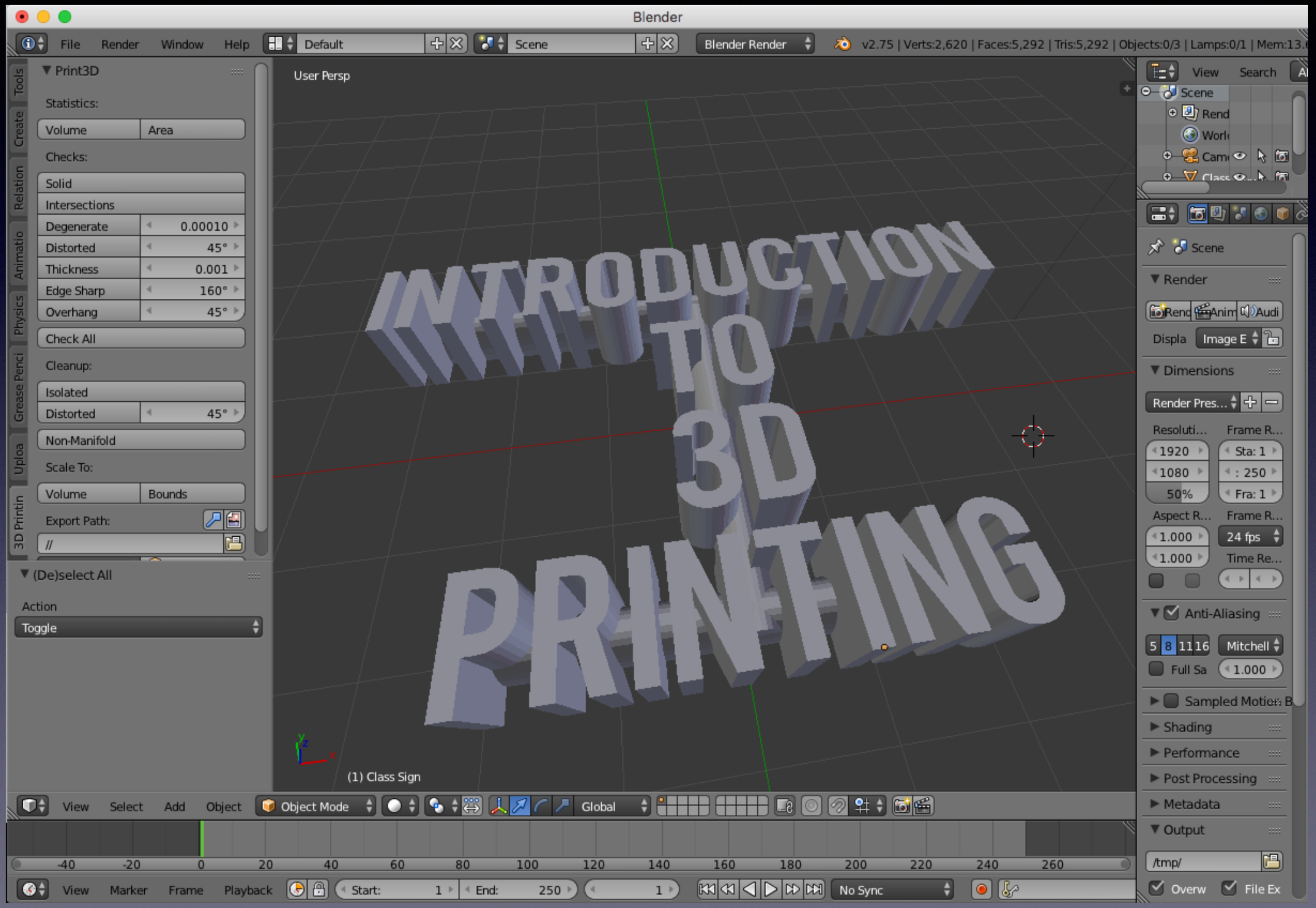
Text based - scientific modeling style - OpenSCAD



Graphical Online based

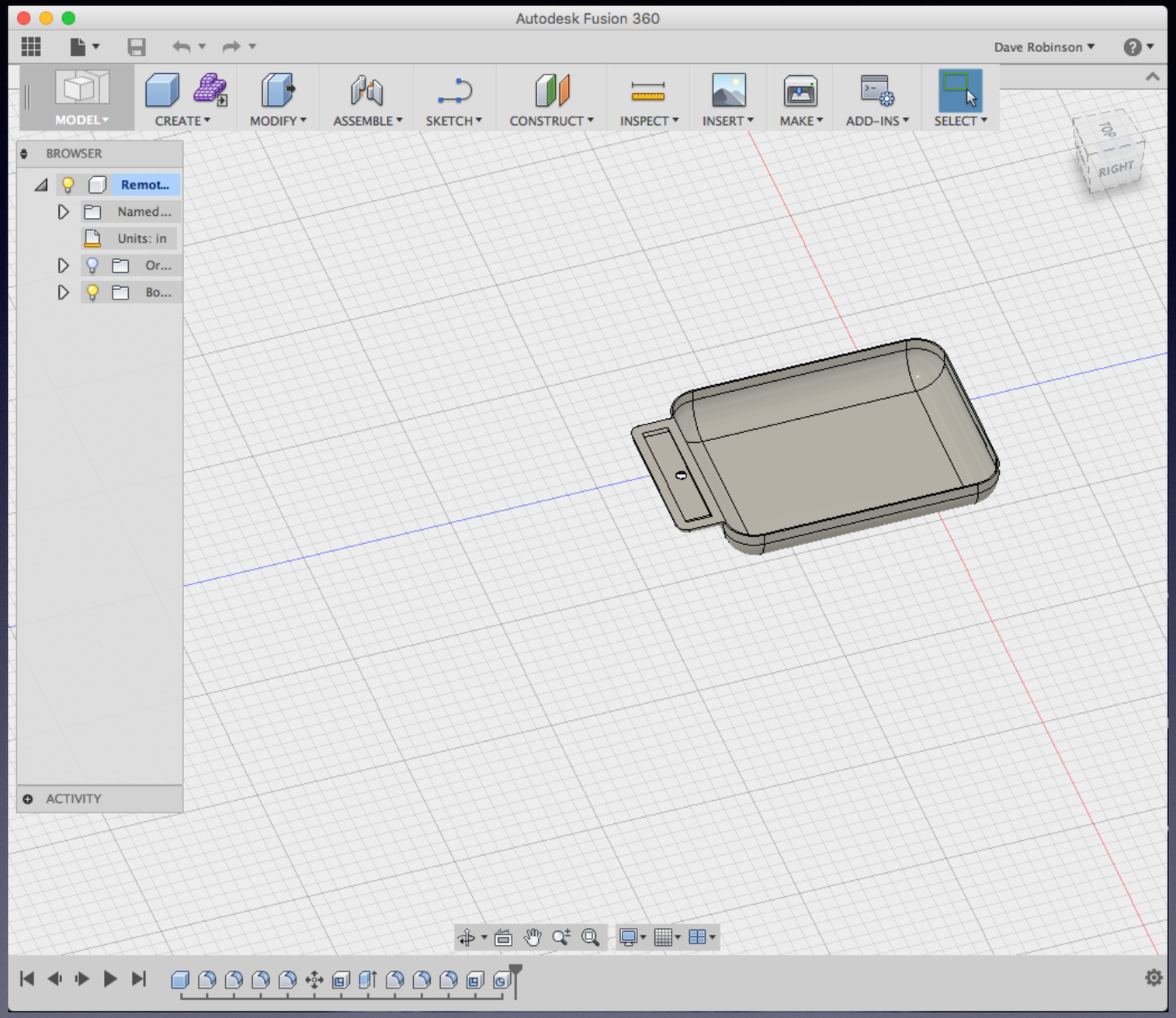


Blender



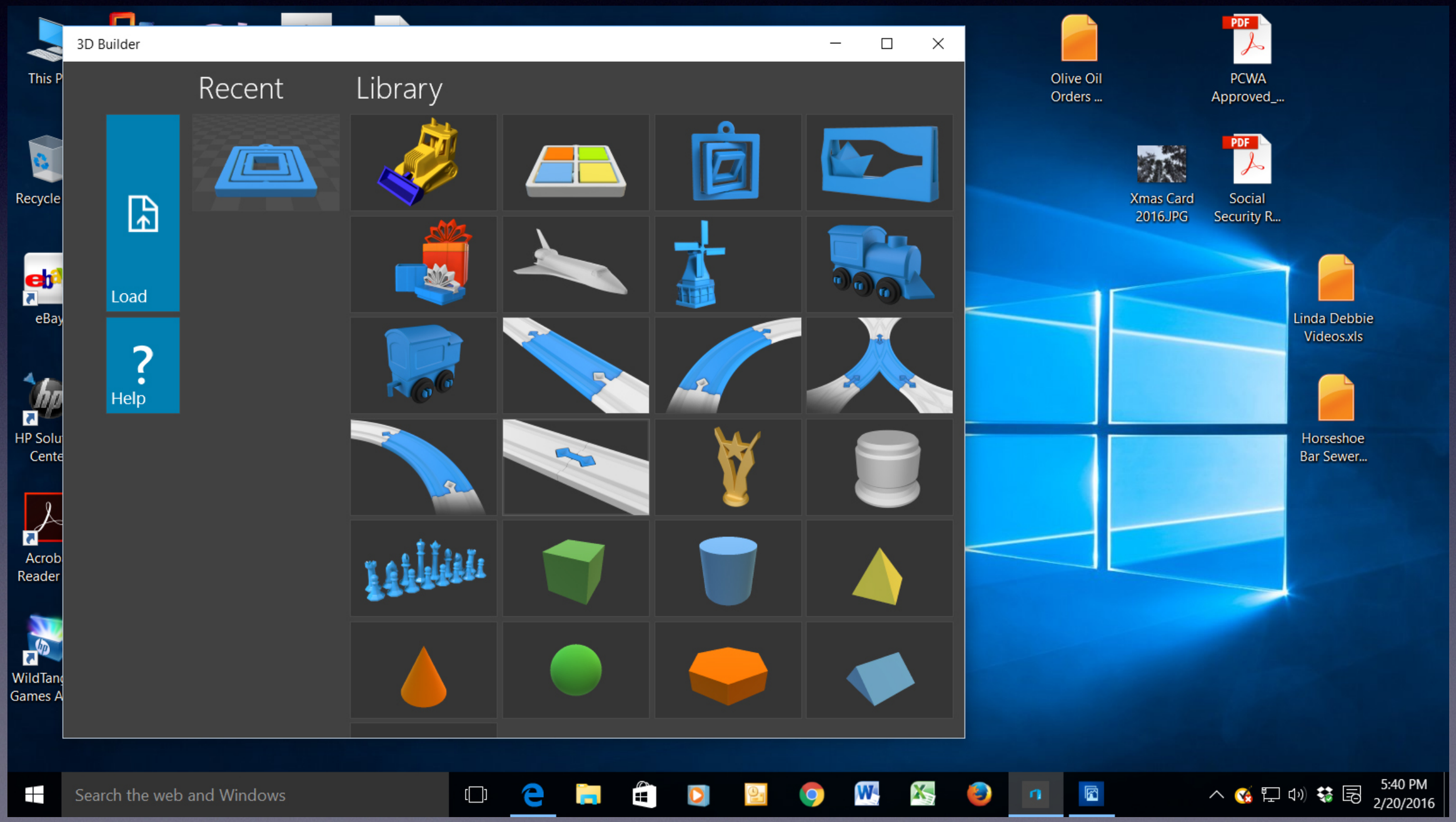
A very powerful 3D Animation package

AutoDesk-Fusion 360

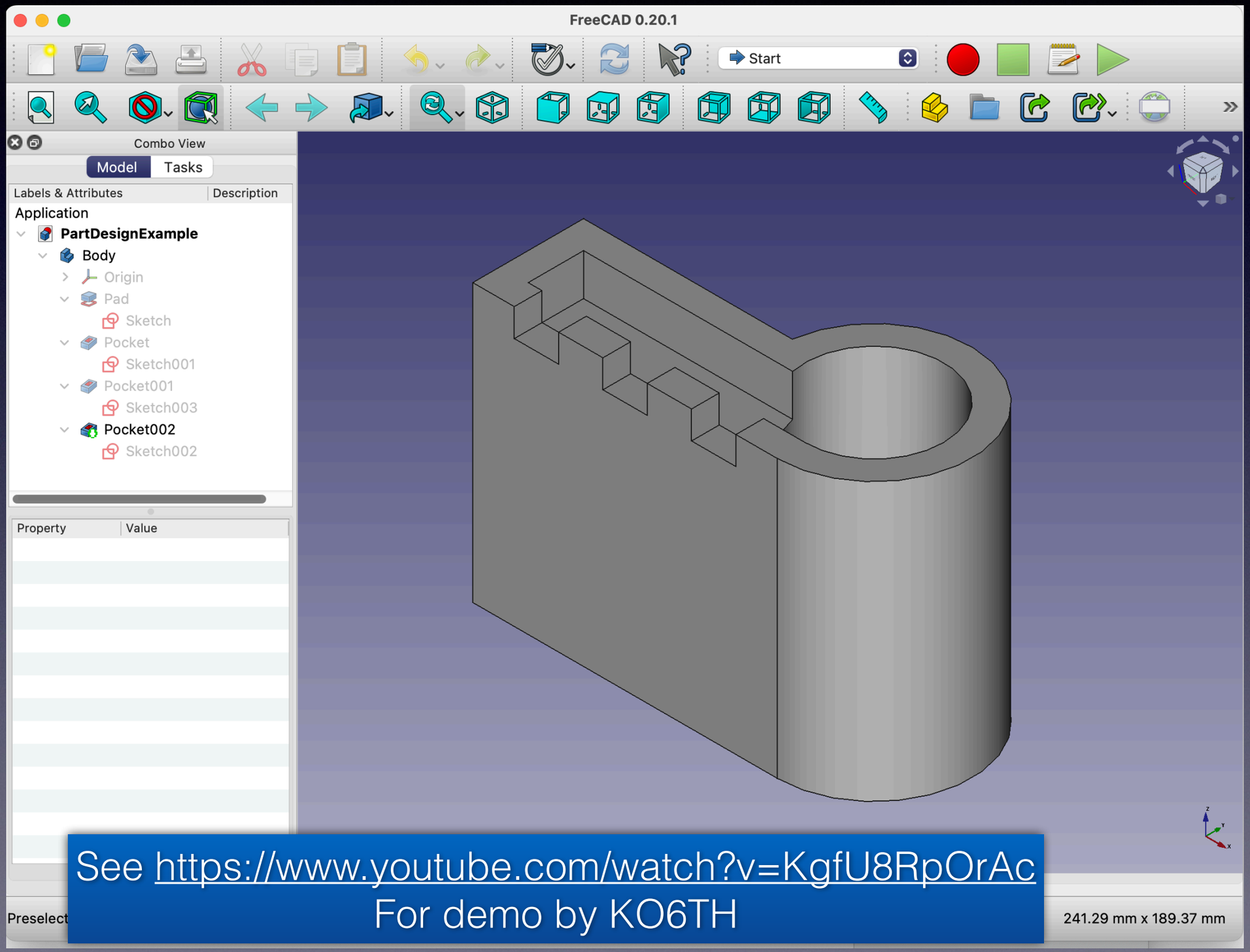


Very powerful CAD system - can be got free and can export to 3D Printers.

Microsoft 3D Builder



FreeCAD



See https://www.youtube.com/watch?v=KgfU8RpOrAc
For demo by KO6TH

Ideas on Modeling

- Parts fit together…
- Print as one part..
- Parts glue together…
- Screw threads for fixing or mounting holes…
- Embedding nuts in to the model (g-code pause)
- Overhangs
- Solid versus hollow
- Multi-colored models - swap filament, use marker dye…
- Scaling - will effect things like openings, screw thread sizes

Component Models!

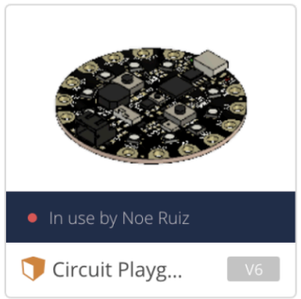
- Companies such as McMaster-Carr, Adafruit are posting 3D models of their components/ products.

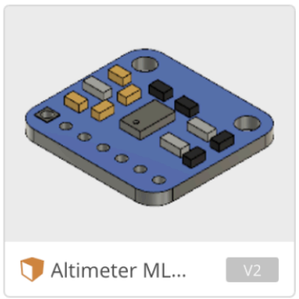
- Nuts, bolts, LEDs, circuit boards, Motors etc..

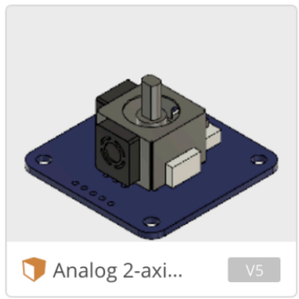
Adafruit

JULY 5, 2018 AT 2:30 PM

3D Models of Adafruit Parts on Github







1048 1.2in 8x8 Matrix Backpack	1.2in 8x8 LED Matrix backpack
1054 Laser Diode	PyGamer and laser diode
1092 Tactile On Off Switch	Big commit!
1119 Tactile Switch 12mm (B3F-40...	1119 Tactile Switch
1143 Micro Servo - High Torque Me...	updating mounting hole
1145 16mm button	Moar parts!
1185 Massive Arcade Button 100mm	Big commit!
1214 PermaProto Small Mint	Adding PermaProto Small Minty
1221 Adafruit 2020 Extrusion	Big commit!
1253 Aluminum Timing Pulley	Big commit!
1304 MicroLipo Charger	Adding 1304 MicroLipo Charger V2
1313 Speaker 3in 8Ohm 1W	Big commit!
1317 150mAh Lipo Battery	Adding 1317 150mAh Lipo Battery
1321 Battery 9V	Big commit!
1374 Capacitive Touch Breakout AT...	Adding Capacitive Touch Breakout ATA42QT1010
1376 NeoPixel Strip	Big commit!
1400 Push Button Power Switch	Adding Push Button Power Switch
1426 8x NeoPixel Stick	Big commit!
1438 Adafruit MotorShield	Big commit!
1455 LED driver TLC59711	Adding LED Driver TCL59711

McMaster-Carr

Alloy Steel Socket Head Screws

Fully Threaded

Partially Threaded

With a tensile strength of 170,000 psi, these alloy steel screws are stronger than Grade 8 steel screws. Length is measured from under the head.

Black-oxide steel screws are mildly corrosion resistant in dry environments. **Zinc-plated** steel screws resist corrosion in wet environments. The screws with a **blue-dyed** finish are easy to distinguish. **Zinc-flake-coated** steel screws are 20 times as corrosion resistant as zinc-plated screws and comparable to Dacromet-coated screws.

Coarse threads are the industry standard; choose these screws if you don't know the pitch or threads per inch. **Fine** and **extra-fine** threads are closely spaced to prevent loosening from vibration; the finer the thread, the better the resistance. They are not compatible with coarse threads.

Screws that meet **ASTM A574**, **ASTM A574M**, and **ISO 898-1** comply with specifications and testing requirements for material quality. Screws that meet **ASME B18.3**, **ASME B18.3.1M**, **ISO 21269**, and **ISO 4762** (formerly DIN 912) comply with specifications for dimensional standards.

CAD For technical drawings and 3-D models, click on a part number.

Lg.	Threading	Min. Thread Lg.	Thread Spacing	Head Dia.	Head Ht.	Drive Size	Tensile Strength, psi	Specifications Met	Pkg. Qty.		Pkg.
0-80											
Black-Oxide Alloy Steel											
1/16"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	ASTM A574	50	**91251A051**	$16.94
3/32"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		31	9.14
1/8"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		52	4.26
5/32"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		45	15.24
3/16"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		54	4.40
1/4"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		55	4.43
5/16"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		02	9.93
3/8"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		03	8.88
7/16"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		47	10.16
1/2"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		59	8.55
9/16"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		49	12.70
5/8"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		78	5.79
3/4"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		72	6.30
7/8"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	AS		57	15.24
1"	Fully Threaded	—	Fine	0.096"	0.06"	0.050"	170,000	ASTM A574	10	91251A777	9.26

Black-Oxide Alloy Steel Socket Head Screw, 0-80 Thread Size, 1/16" Long

Packs of 50

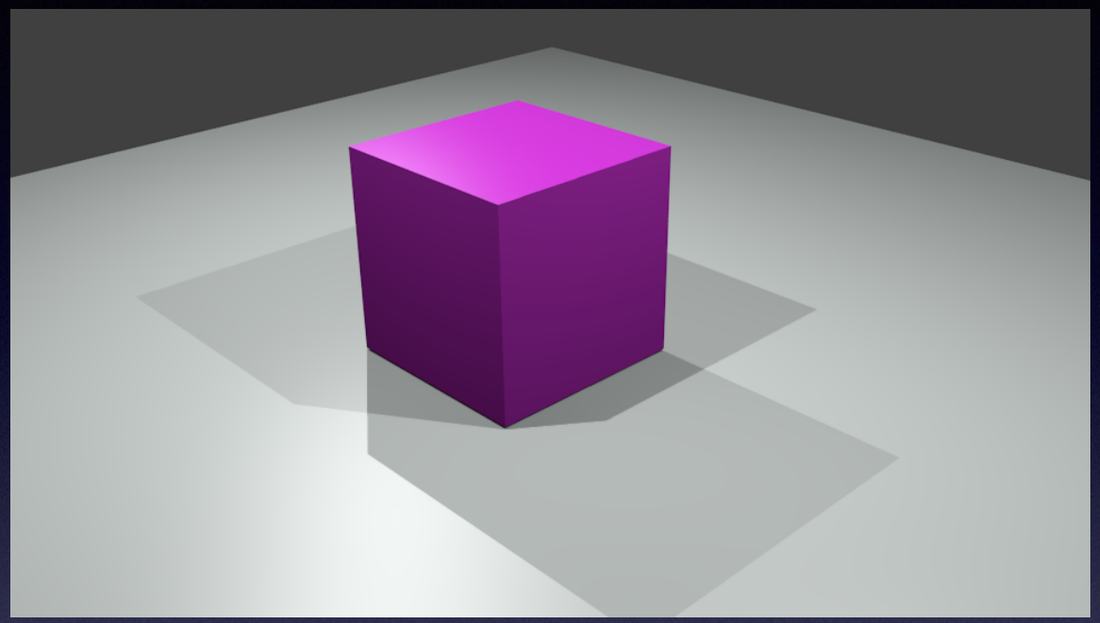
ADD TO ORDER

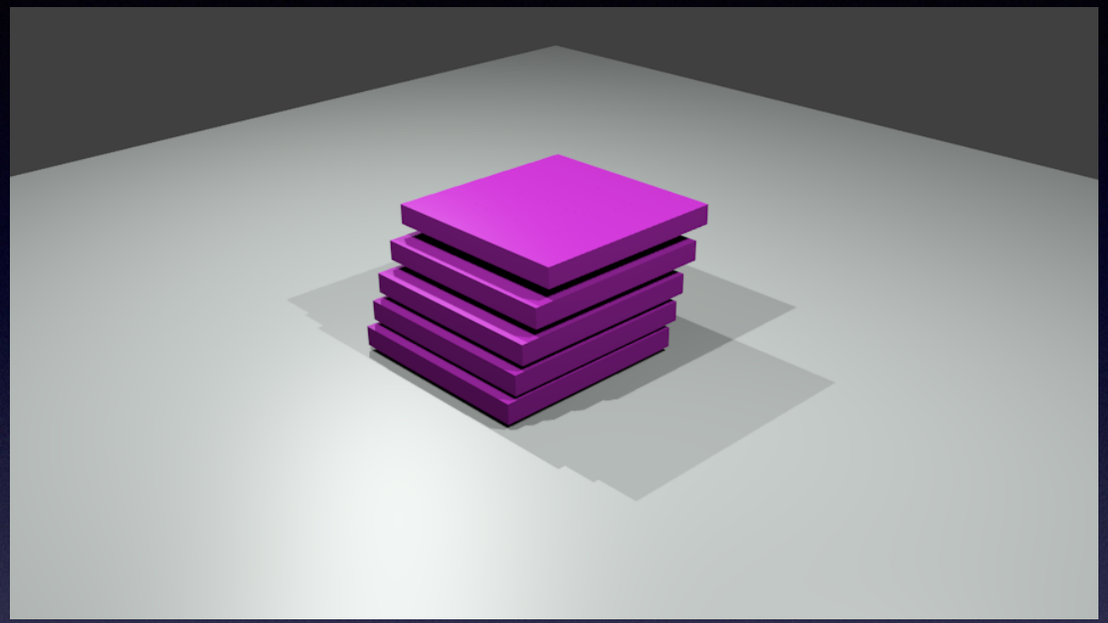
In stock

Product Detail | CAD | 3-D Solidworks | Download

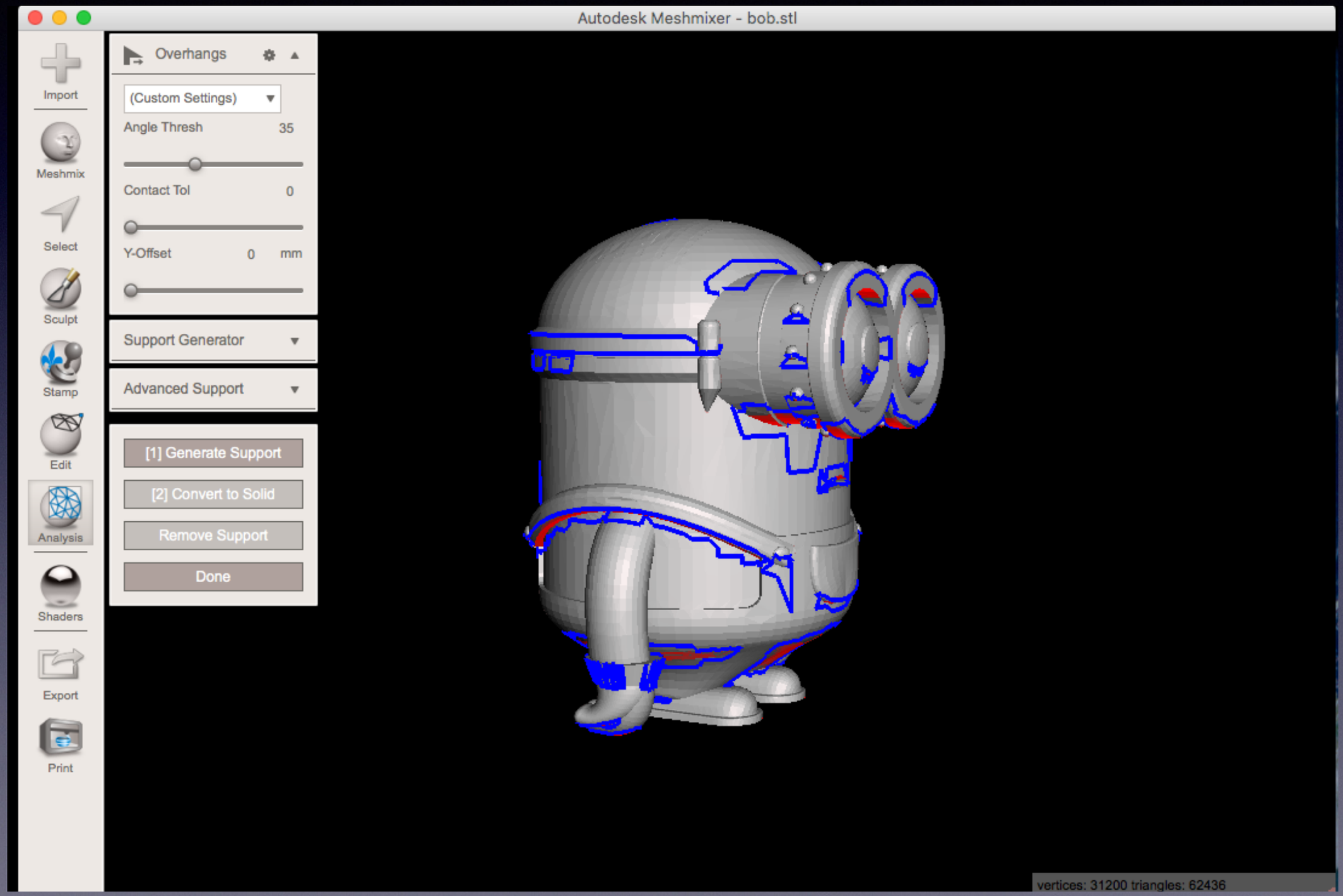
- 3D Models
  - 3-D EDRW
  - 3-D IGES
  - 3-D PDF
  - 3-D SAT
  - ✓ **3-D Solidworks**
  - 3-D STEP
  - 3-D STEP no threads
- 2D Drawings
  - 2-D DWG
  - 2-D DXF
  - 2-D PDF
  - 2-D Solidworks

Slicing

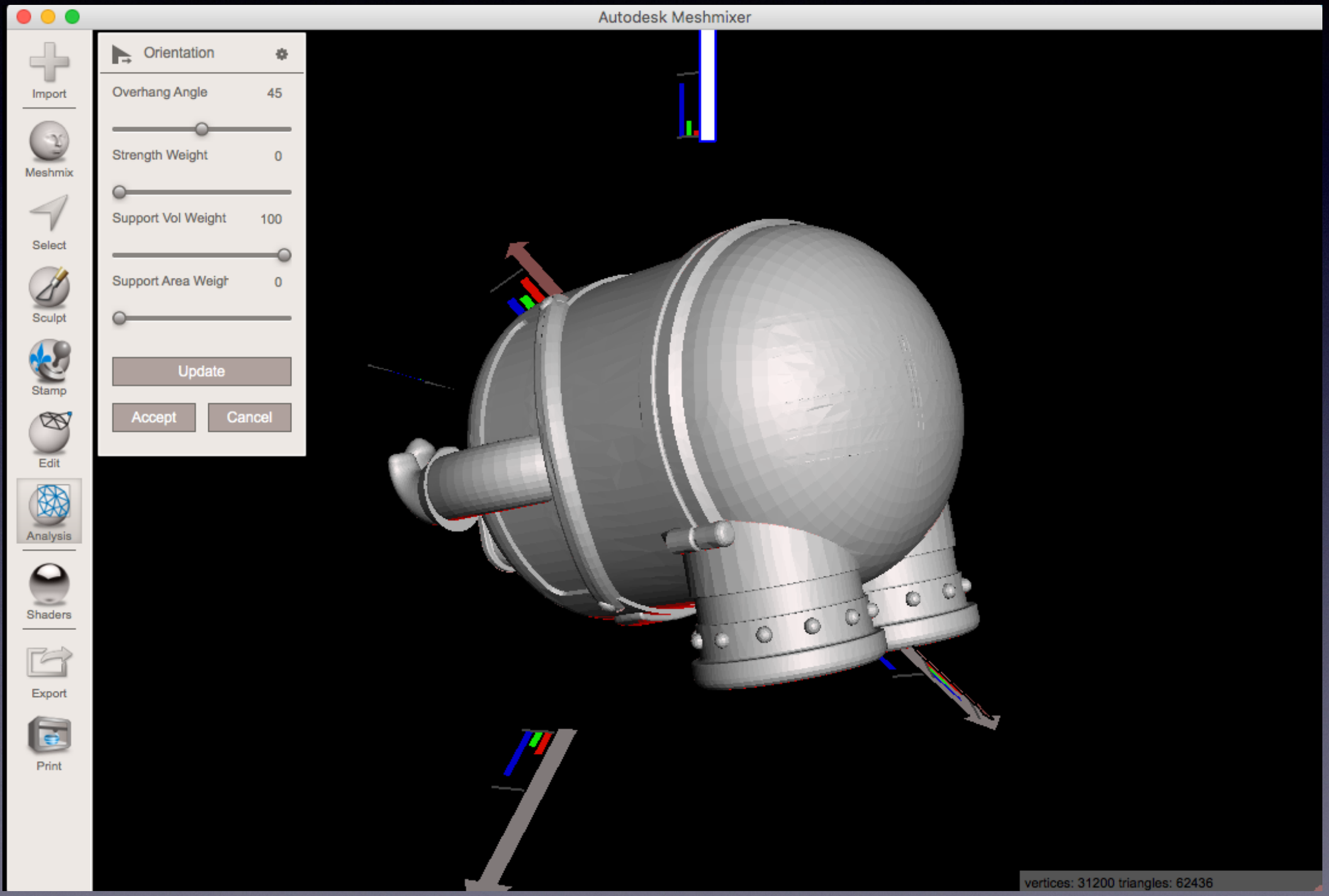




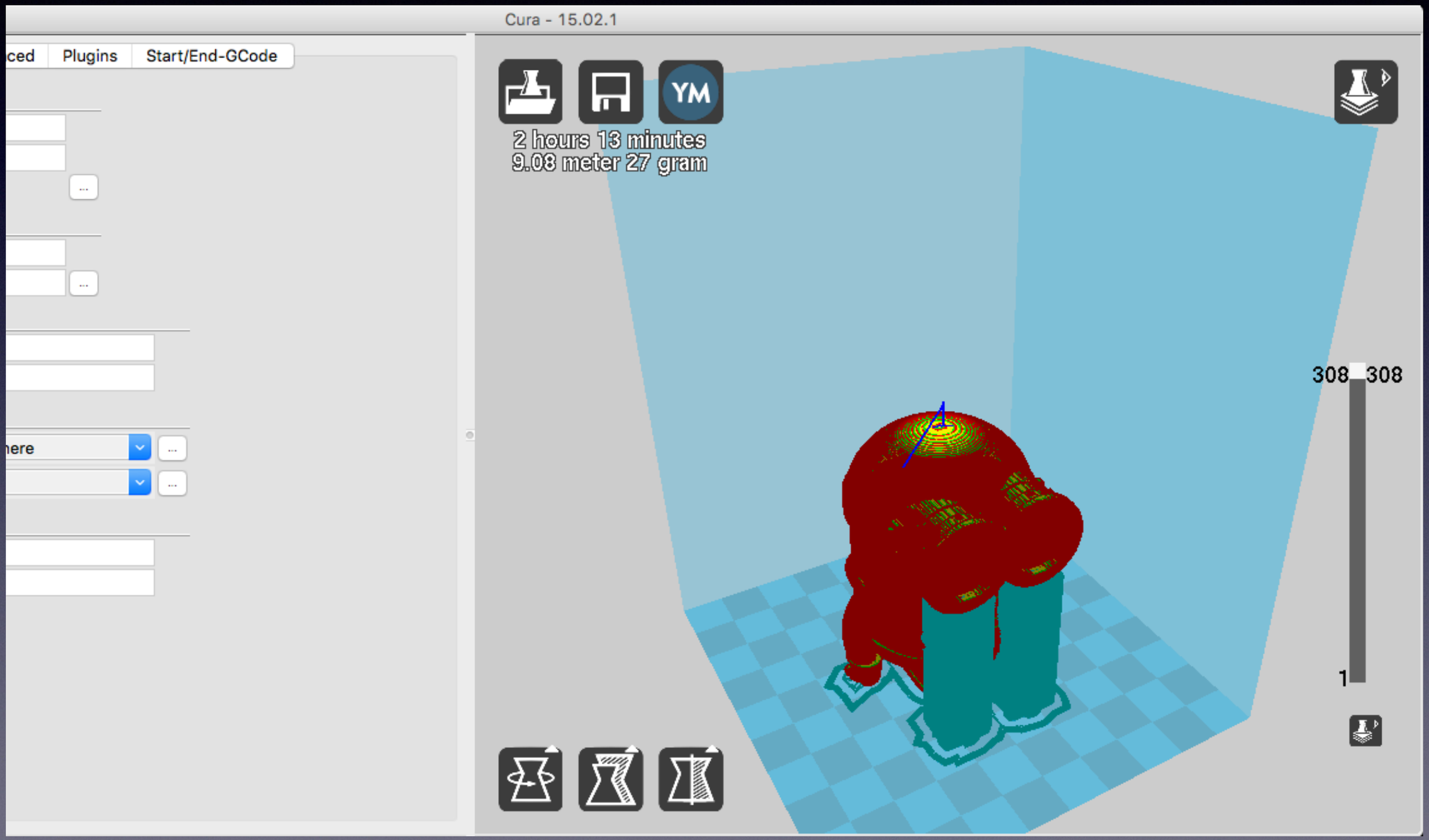
Overhangs


Autodesk Meshmixer - bob.stl
Import
Meshmix
Select
Sculpt
Stamp
Edit
Analysis
Shaders
Export
Print
Overhangs
(Custom Settings)
Angle Thresh 35
Contact Tol 0
Y-Offset 0 mm
Support Generator
Advanced Support
[1] Generate Support
[2] Convert to Solid
Remove Support
Done
vertices: 31200 triangles: 62436

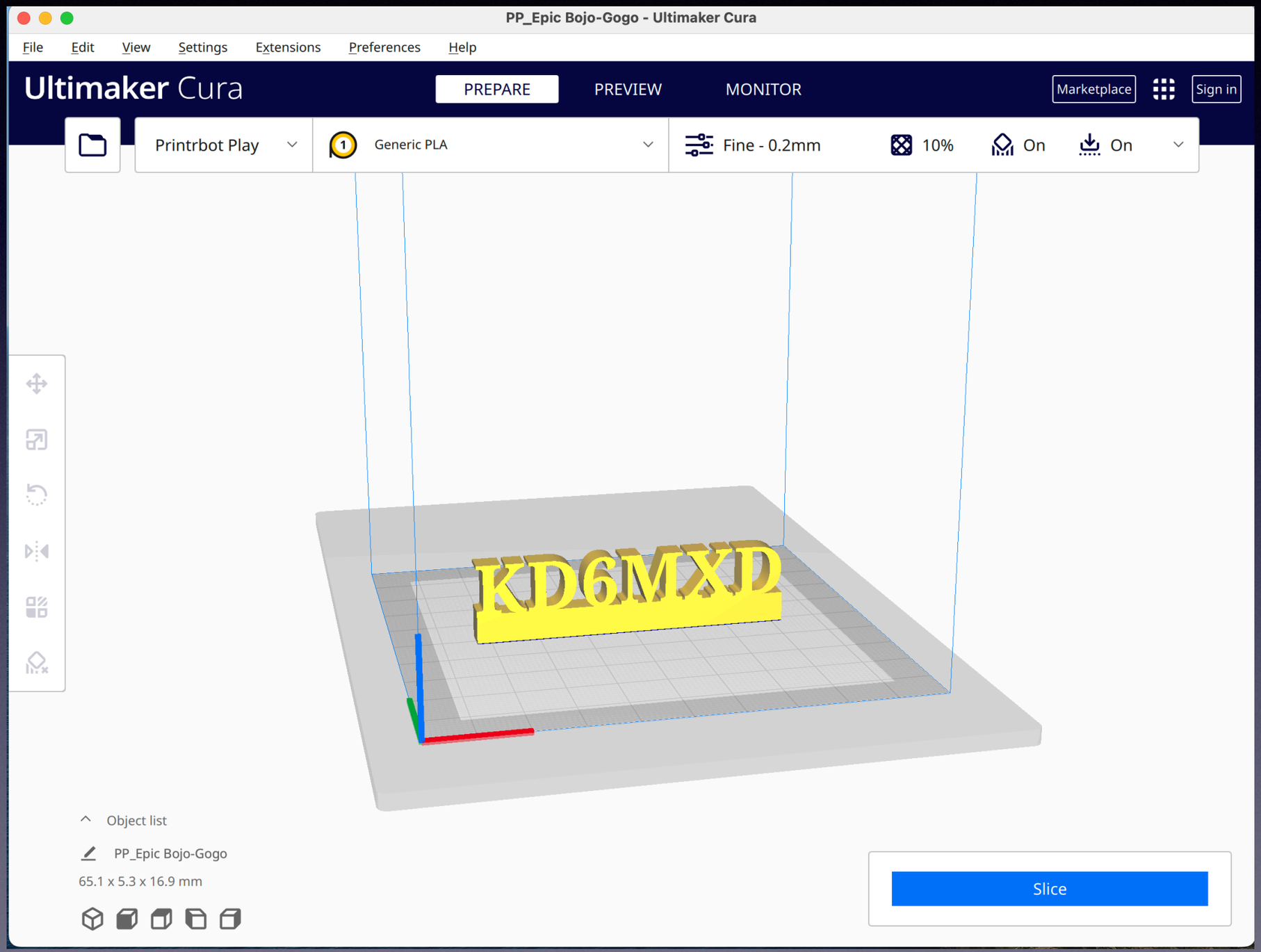
Overhangs…


Autodesk Meshmixer
Import
Meshmix
Select
Sculpt
Stamp
Edit
Analysis
Shaders
Export
Print
Orientation
Overhang Angle
45
Strength Weight
0
Support Vol Weight
100
Support Area Weigh
0
Update
Accept
Cancel
vertices: 31200 triangles: 62436

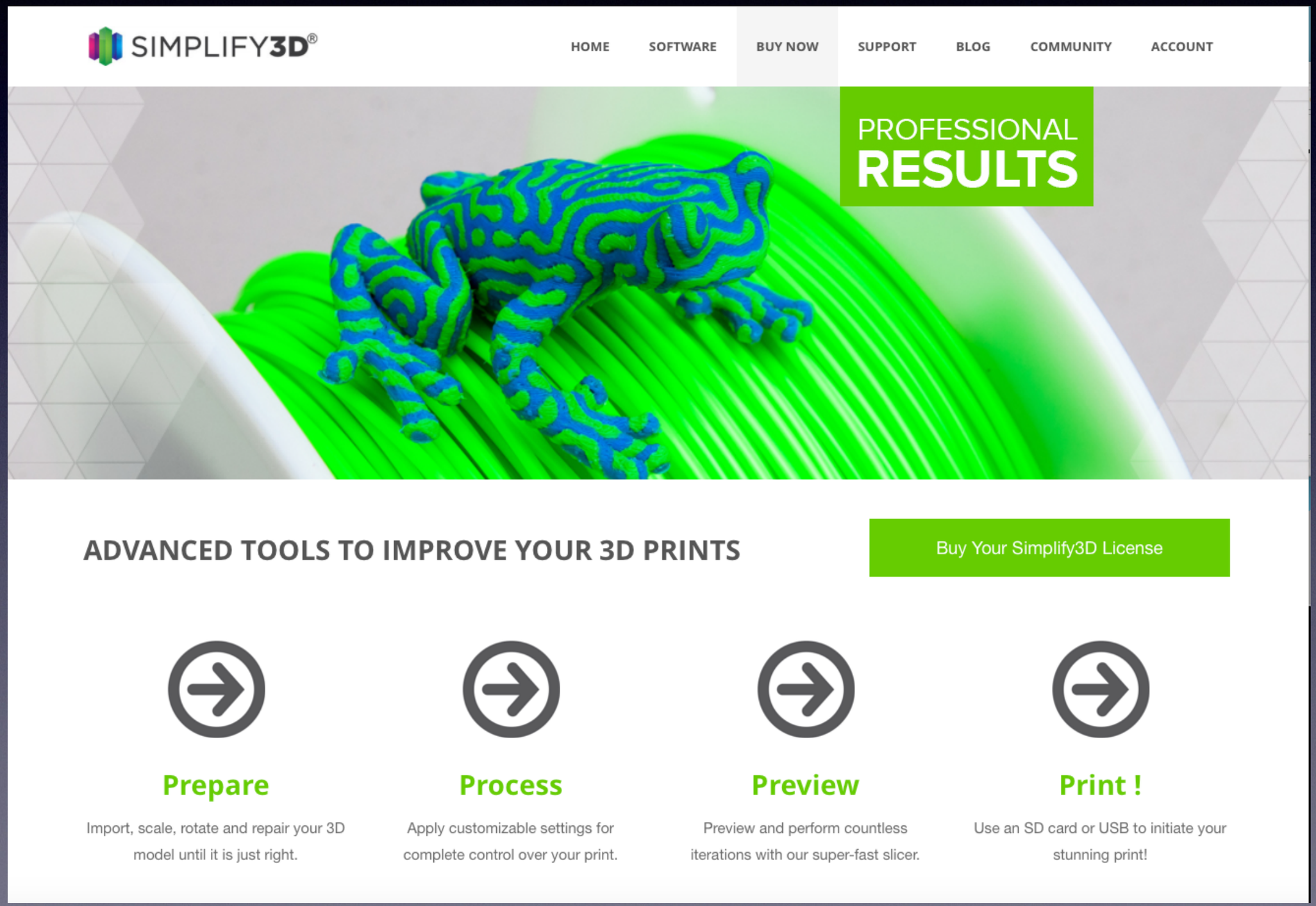
Cura Software Supports



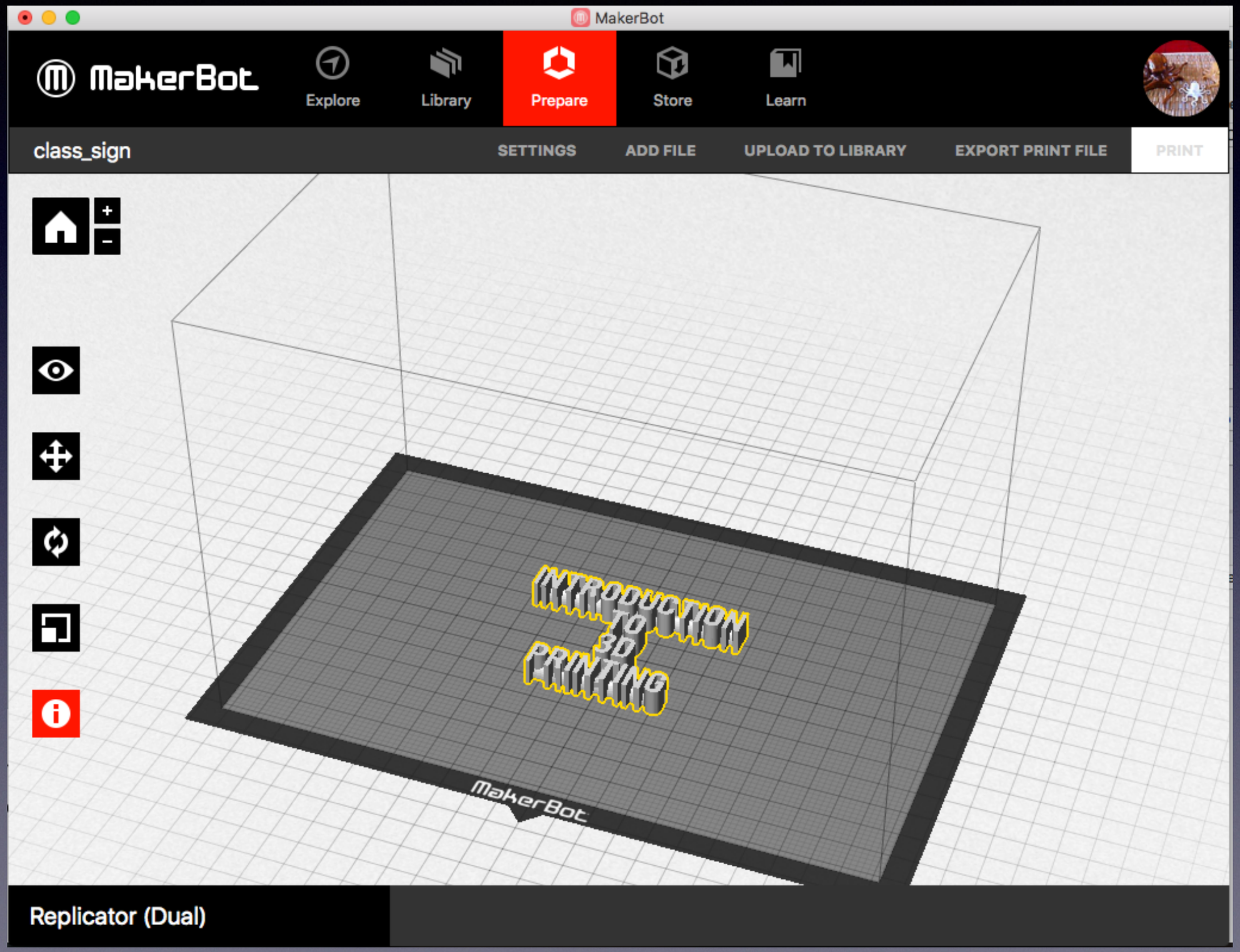
Printer Software-Cura



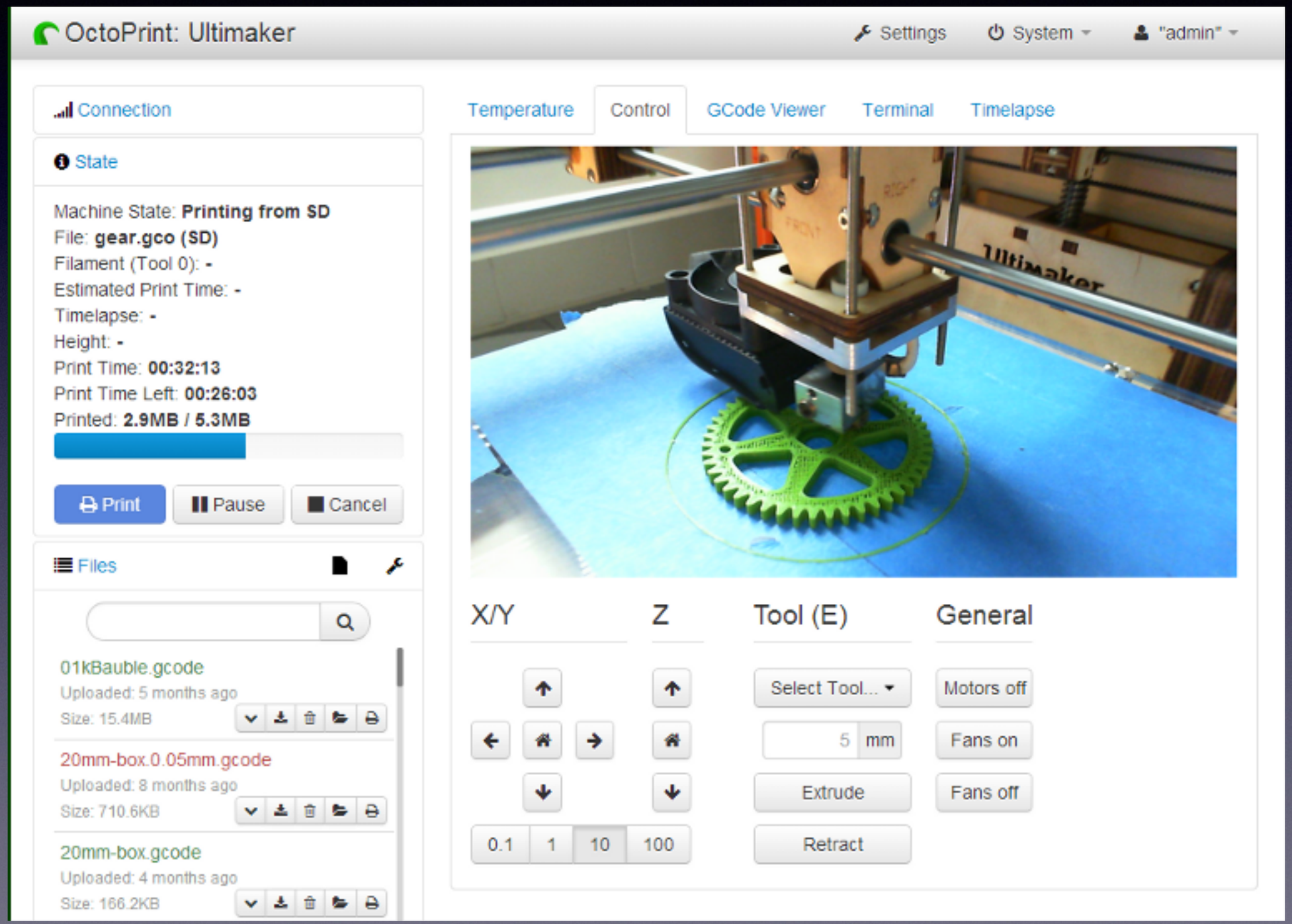
Printer Software-Simplify3D



Printer Software MakerBot



OctoPrint

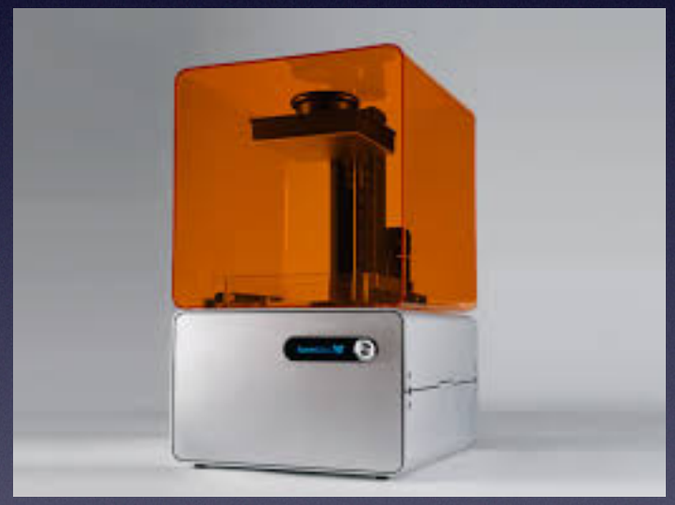

OctoPrint: Ultimaker
Settings
System
"admin"
Connection
State
Machine State: Printing from SD
File: gear.gco (SD)
Filament (Tool 0): -
Estimated Print Time: -
Timelapse: -
Height: -
Print Time: 00:32:13
Print Time Left: 00:26:03
Printed: 2.9MB / 5.3MB
Print
Pause
Cancel
Files
01kBauble.gcode
Uploaded: 5 months ago
Size: 15.4MB
20mm-box.0.05mm.gcode
Uploaded: 8 months ago
Size: 710.6KB
20mm-box.gcode
Uploaded: 4 months ago
Size: 166.2KB
Temperature
Control
GCode Viewer
Terminal
Timelapse
X/Y
Z
Tool (E)
General
Select Tool...
Motors off
5
mm
Fans on
Extrude
Fans off
0.1
1
10
100
Retract

Finishing Prints

- ABS can use acetone to produce a smooth finish
- Sandpaper
- Model paint
- Other model making techniques

Hardware

- Printers vary from kits you can build to fully assembled models
- Vary in price (<$300 to >$3000), size (4inch build area 10+ inch build area) and functionality (dual extruders, heated beds, LCD panels.)
- B&H Photo (NY) listed over 25 printers from $200-$2000
- Most now come with software but…



Printing without the Computer

- Usually the printers come with an SD card slot.
- Download the final g-code (after slicing) to the card and then print.
- If your printer has an LCD screen use the menu to select file and print.

- Some printers use a special file name and select that file when they power up.

How to 3D print without a 3D printer.

- 3D Hubs
- The UPS Store (Nearest- Mountain View, Pleasanton, Campbell)
- Shapeways/ Ponoko
- Hacker Labs (If they are still open)
- Libraries are starting to get them… (Sac is closed at the moment)

Things to consider Using a Service

- Most services will check your model can be printed, but…
- You pay by material used so make models hollow where possible. (SLA printed models)

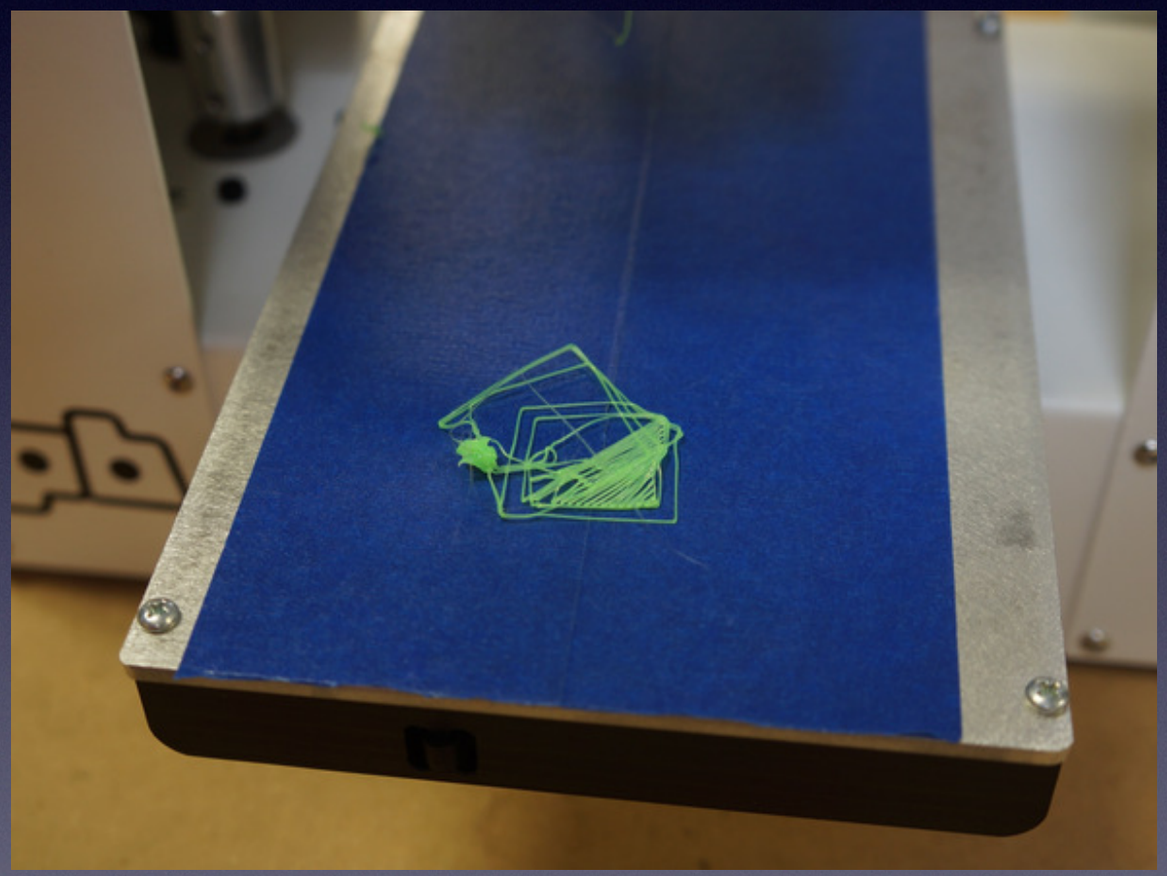
Love/Hate Relationship

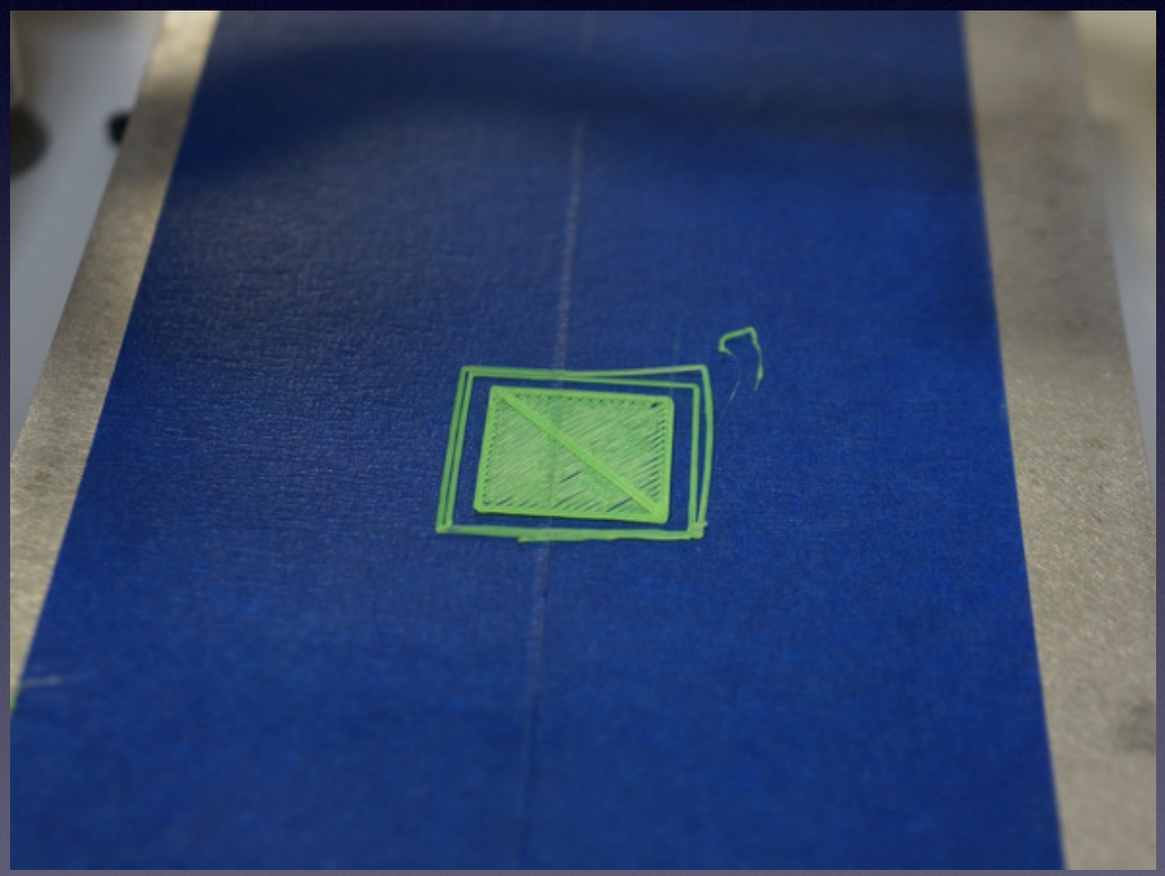
Modelling	Software	Hardware
Overhangs with no support	Incorrect profile for your printer	Power fluctuations during printing.
Model not water tight	Sliced wrong - wrong filament/nozzle size	Cables snagging on moving parts
	Computer gets hung up during printing	Mechanical failure -Z motor coupling
		Running out of filament or breaking!
		Using a laptop on battery power!

Problems You Will Encounter

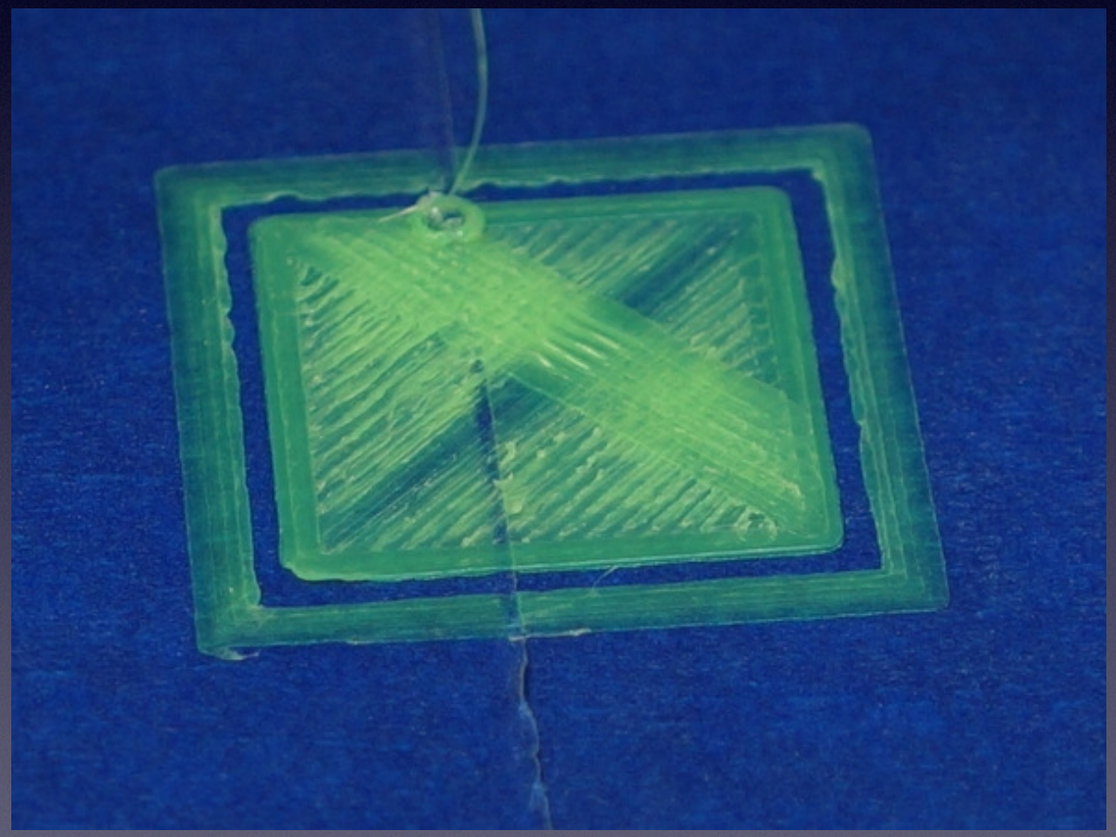
- Stiction - or lack off
  - The first layer of the print fails to stick to the surface.
  - ABS - heated bed not hot enough
  - Extruder too high
  - Can use raft to alleviate the issue
  - Air currents - drafts -
- Jammed/Clogged Extruder
  - Can be caused by “dirty” or damp filament.
  - Head too close during printing.

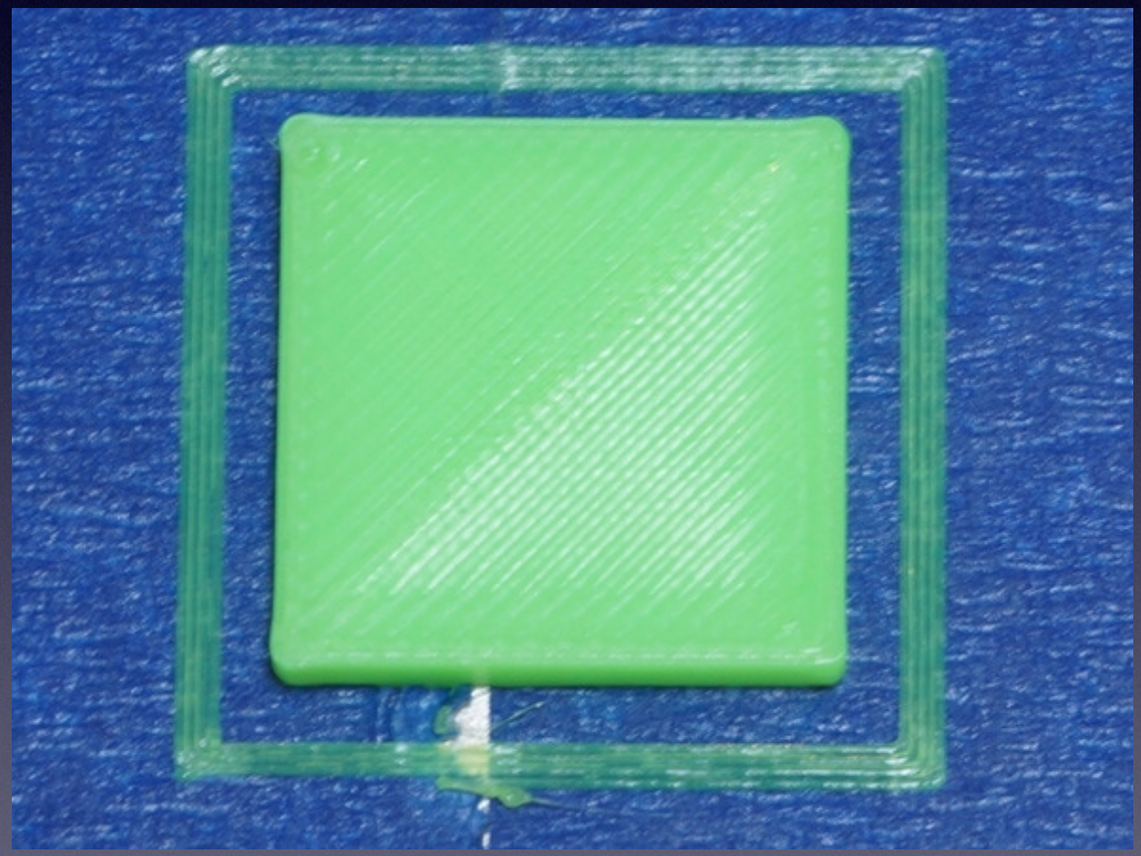
First Layer Issue





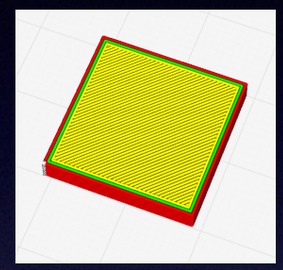
First Layer Issues

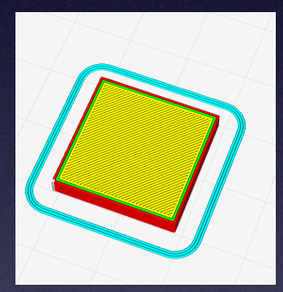


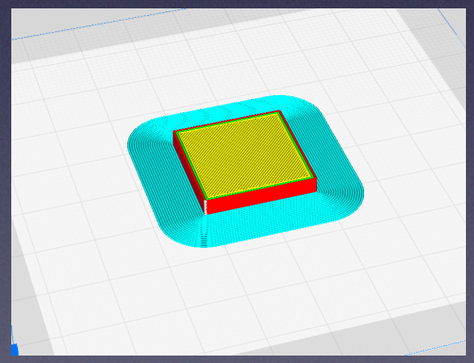


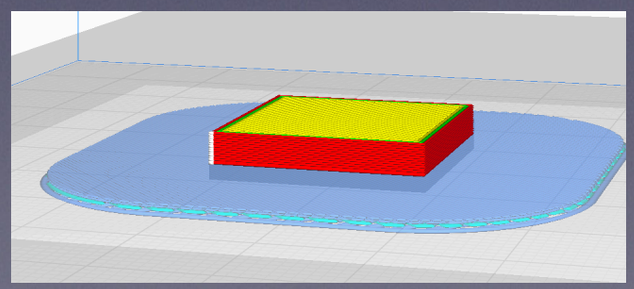
First Layer Solutions

- None
- Skirt
- Brim
- Raft





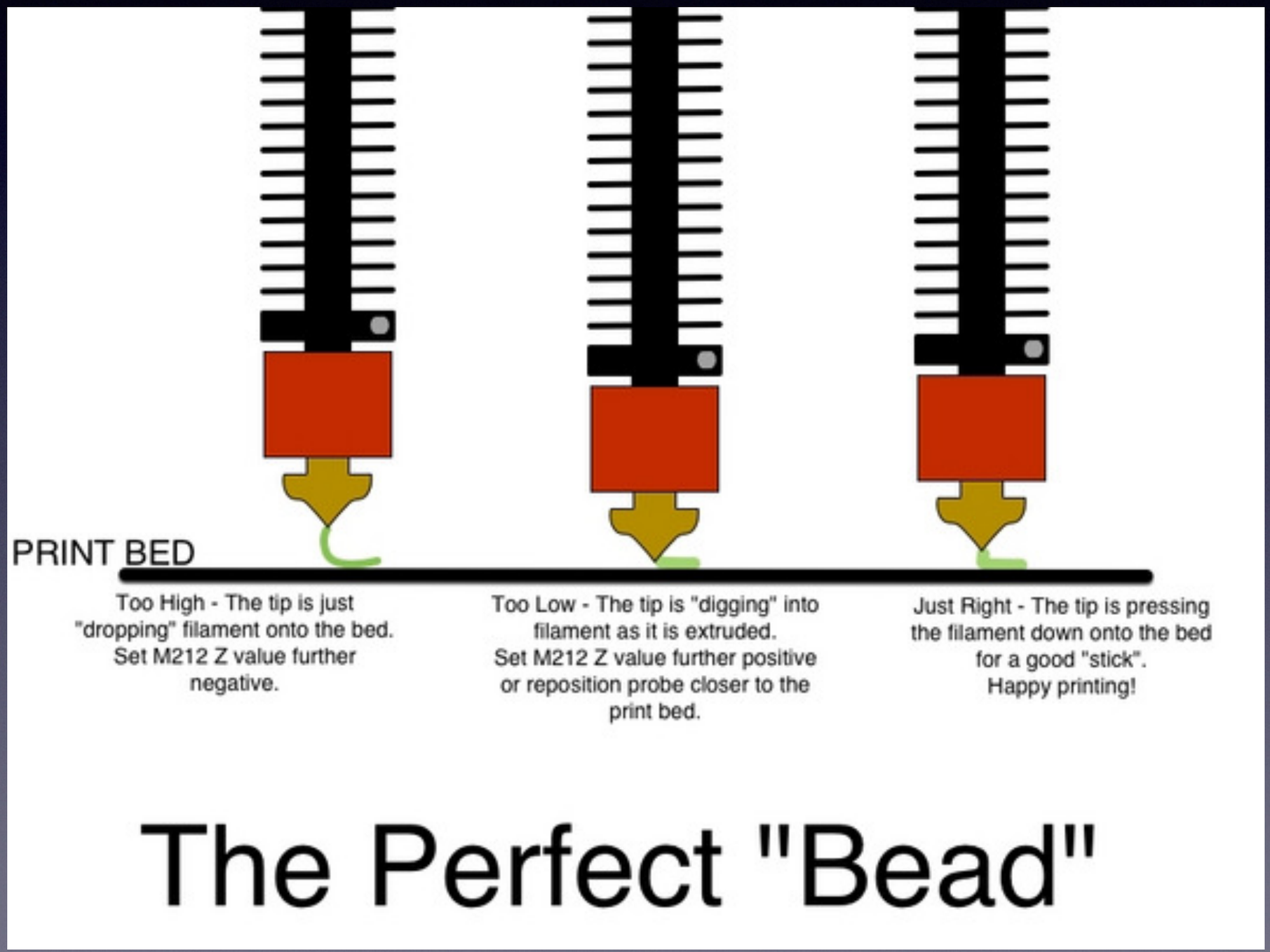




First Solutions

- Vendor “Glue”
- ABS Solution Glue
- Special Tape

Goldilocks!!


PRINT BED
Too High - The tip is just "dropping" filament onto the bed. Set M212 Z value further negative.
Too Low - The tip is "digging" into filament as it is extruded. Set M212 Z value further positive or reposition probe closer to the print bed.
Just Right - The tip is pressing the filament down onto the bed for a good "stick". Happy printing!
The Perfect "Bead"

Available Resources

- The Internet (you may have heard of it!)
  - http://3dprint.com
  - https://learn.adafruit.com/category/3d-printing
- Definitions:
  - http://reprap.org/wiki/Glossary
  - http://www.3dgeni.us/jargon-buster/
- Print Issues: https://www.simplify3d.com/support/print-quality-troubleshooting/#holes-and-gaps-in-the-top-layers…
- Books…