Maker Culture in CMU SCS
Part II: 3D Printing

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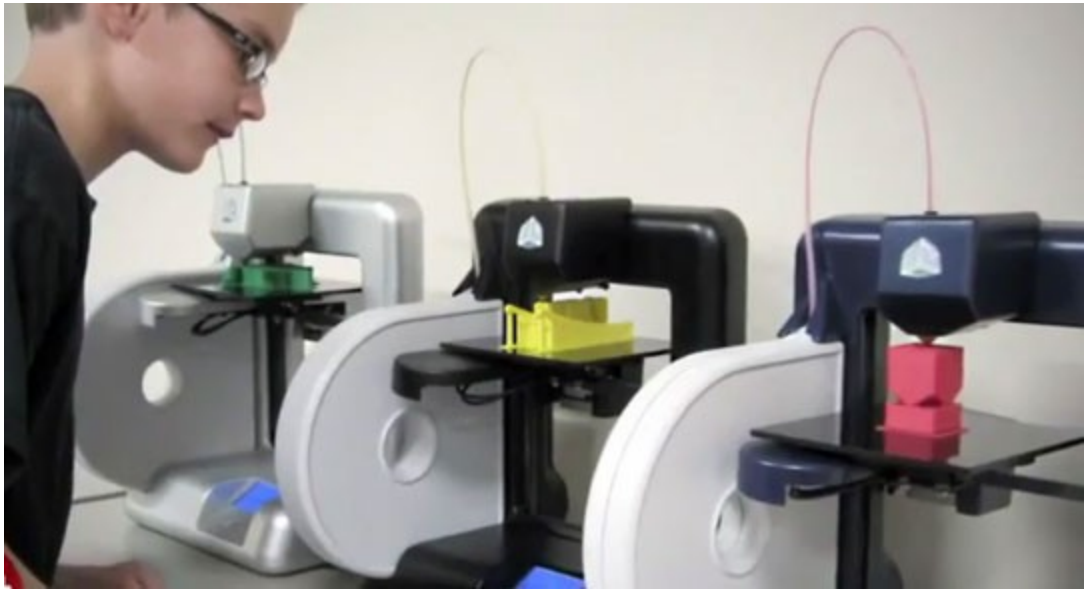
http://www.cs.cmu.edu/~dst/Maker

3D Printing vs. Laser Cutter

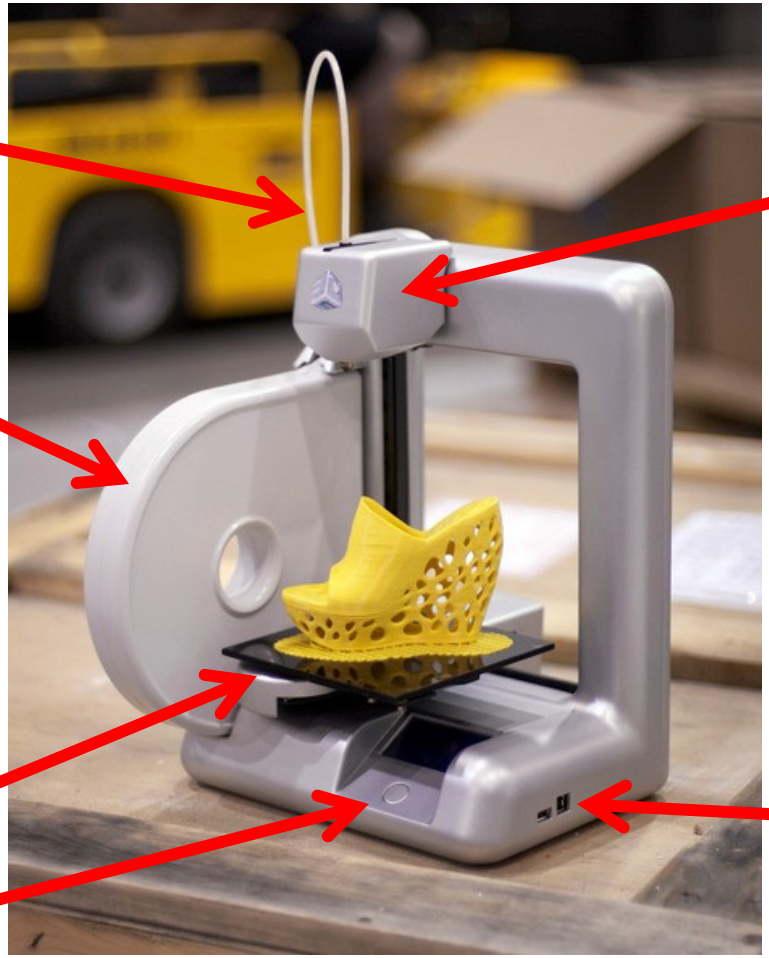
- x Slower
- x Less precise
- x More expensive
- x Limited materials
- x Support material may be required
- ✓ Complex 3D structures!



Low Cost 3D Printers

- RepRap: 2005 onward
  - Adrian Bowyer, University of Bath (UK)
  - Goal: open source 3D printer that can replicate itself
  - 4 generations: Darwin, Mendel, Prusa Mendel, Huxley
  - Spawned many start-ups
- Makerbot
  - Evolved from RepRap; initially was open source
  - Cupcake, Thing-o-Matic, Makerbot2, Replicator
- Solidoodle ($500)
- Cube
- Many, many more…

Cube Components



2nd Generation Cube

- Prints ABS (acrylonitrile butadiene styrene) or PLA (polylactic acid).
- Faster than original cube.
- Better precision (200 microns vs. 250 for original model.)
- No heated bed: saves time.
- Can print “hollow” or “solid” objects.
- Same cost as the original: $1300.
- Buy it at Staples, or at Cubify.com.

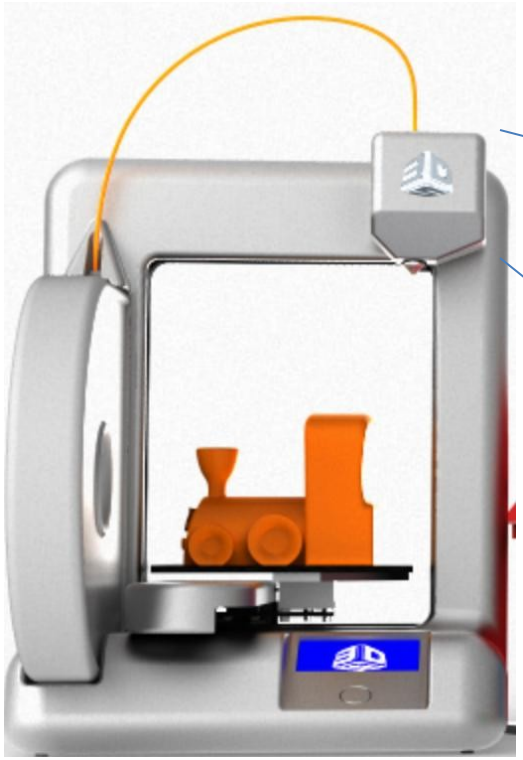
Inside the Cartridge

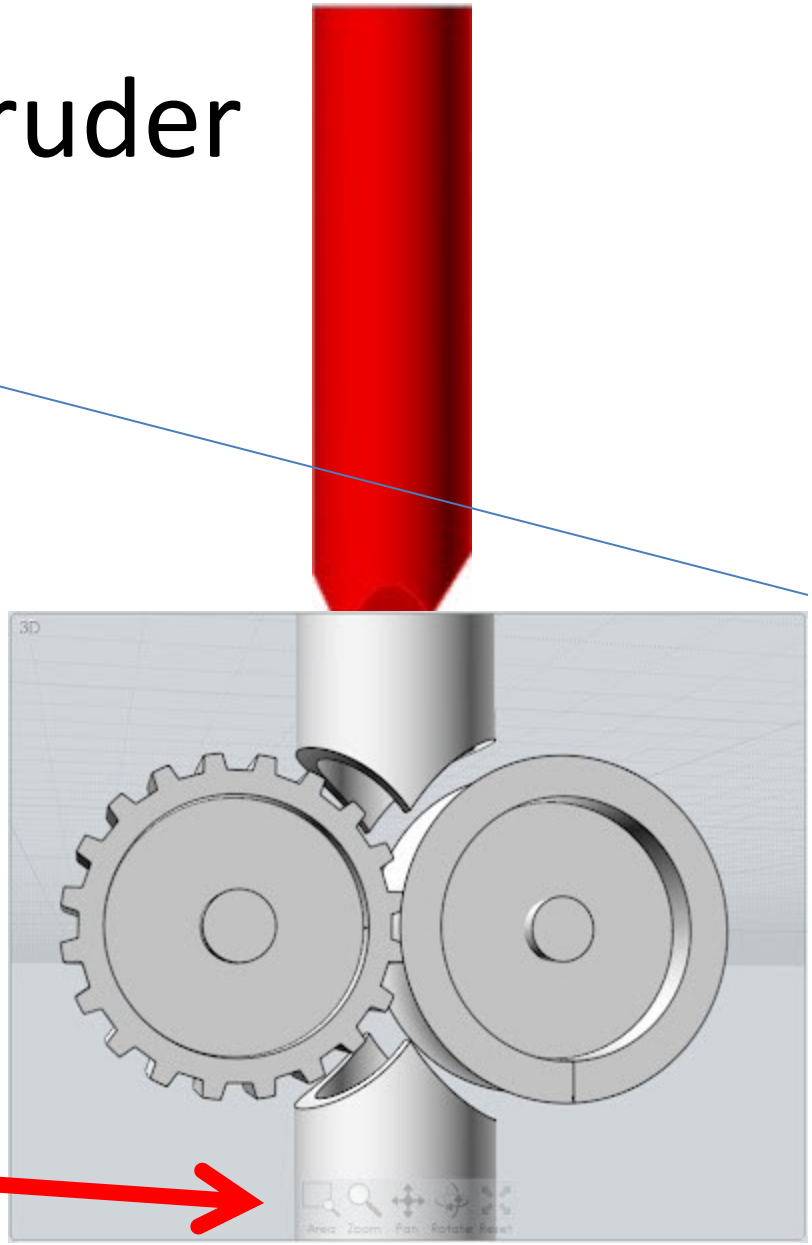
- Chip in cartridge tracks how much material used.
- No actual sensing.

Changing Cartridges

- Takes several minutes for the extruder to heat.
- Never yank filament out of the extruder!
  - Can damage the mechanism.
  - If a piece breaks off, the extruder will clog.
  - Once it heats up, the filament comes out easily.
- Always reinstall the thumbscrew to protect the cartridge.

The Cube Extruder





Heated section

Image from cubifyfans.blogspot.com

Cutting the Filament

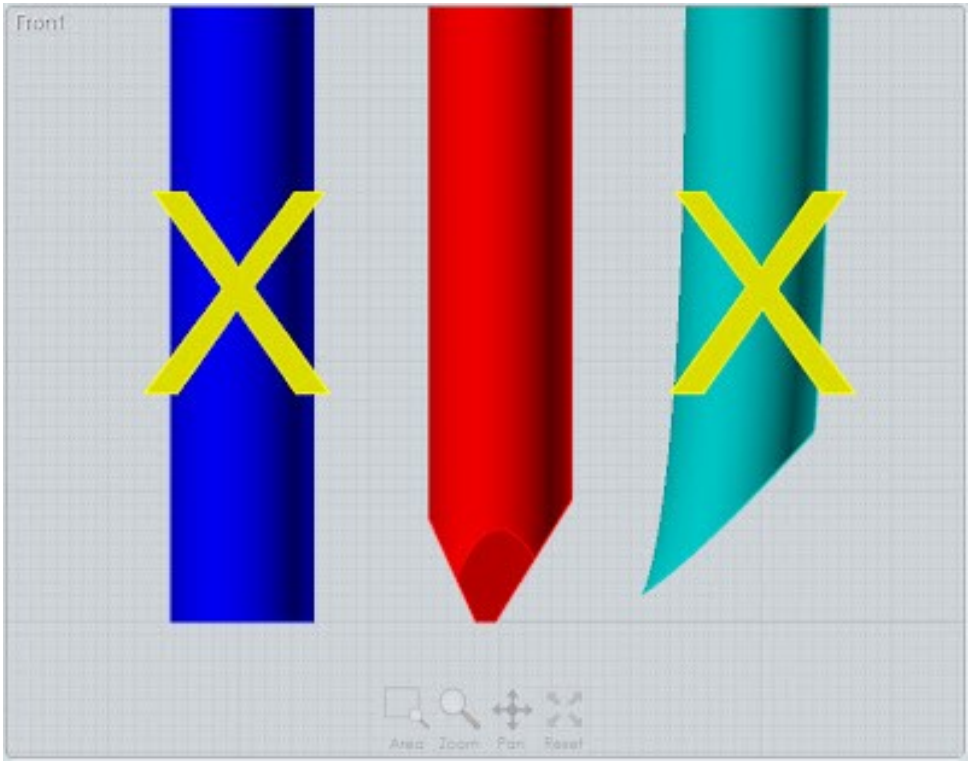


Image from cubifyfans.blogspot.com

A simple 45^{o} cut will help to prevent jams in the extruder.

Preparing to Print

- Check the extruder gap?

- Coat the print pad with the “cube stick”.
  - Not too thick a layer, but aim for uniformity.
  - Keeps the object from shifting or warping.

- Insert flash drive with your Cubify Print file.
  - Flash drive must be FAT32 (Windows95) format.

- Select your file using the Print menu.

- If print bed doesn’t rise within 30 seconds, cancel and start again (software glitch).

- 5 minute warm-up before printing starts.
  - Extruder becomes very hot!

After Printing

- Brief cool-down period for the extruder.
  - 20 minute cooldown on 1st generation (heated bed).
- Your object needs to cool as well.
- Printer will announce when cool-down done.
- Object might not come easily off the bed.
  - Soak in water to dissolve the glue.
- Run the bed under the faucet in the kitchen sink to get all the glue off.
- Dry the bed and reinstall on the printer.

Post-Processing Steps

- Wash any residual glue off the object.
- Snap off any supports or raft.
  - Cutting tools are in the cabinet.
- Use a hot knife to remove stray material and retouch plastic that turned white.
- Sanding or filing might also be helpful.
- Machining? Painting? Gluing? Fake fur?
  - It's up to you!

Designing for the Cube

Symmetry and Precision

- Dimension tool
- Sketch relations
- Centerlines

Production Steps for Cube

1. Design in SolidWorks or some other tool.
2. Export an STL file.
3. Load the STL file into the Cubify Client program.
4. Set print parameters:
   a) Orientation and scale.
   b) Material: ABS or PLA?
   c) Do you want supports?
   d) Do you want a raft?
5. Click “Build” to produce a Cubify Print file.
6. Check the print file for reasonableness.
7. Save to flash drive and send to the printer.

Designing 3D Shapes In SolidWorks

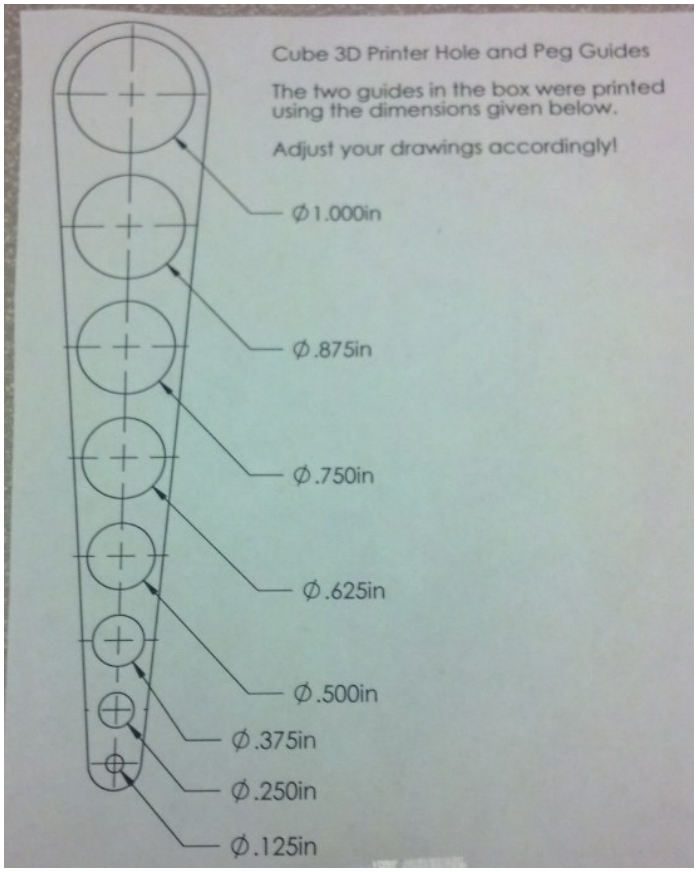
- Extruded base (from previous session)
- Extruded cut
- Make a chalice:
  - Revolved base
  - Filleting
- Swept base
  - Planes
  - Profile sketch, guide sketch
- Make a hammer (SolidWorks tutorial):
  - Planes
  - Lofts
  - Flex

Design Rules

- Shafts will be slightly **thicker** than intended.
- Holes will be **narrower** than intended.
- Do you want a 2.5 mm hole? On a 1st generation Cube:
  - Use 3.0 mm for a horizontal hole.
  - Use 3.7 mm for a vertical hole.
- Minimum widths for walls?

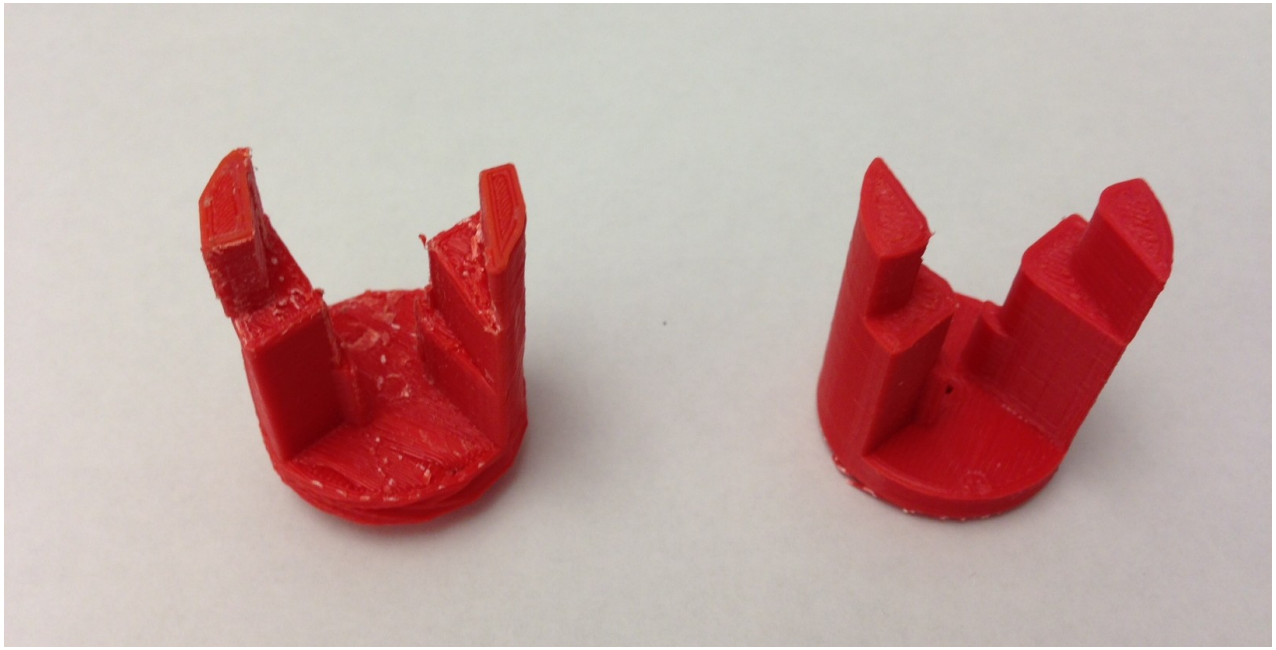
Test Object (Mike Taylor)

- Compare requested size vs. actual.



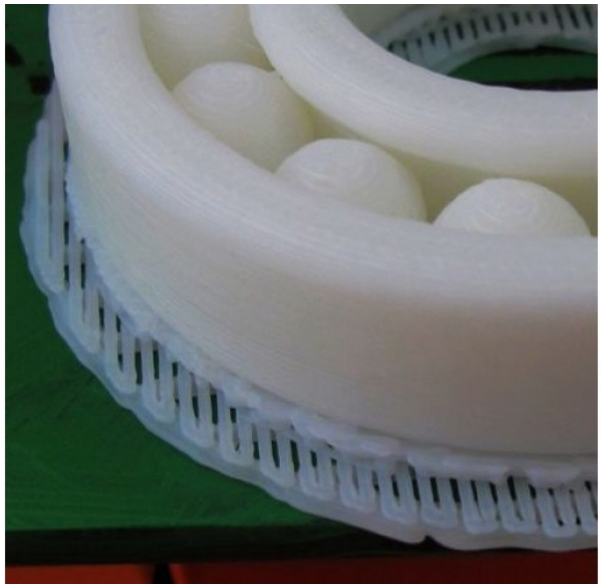
Coarse vs. Fine STL Triangulation

- Too coarse can lose detail, but too fine can also cause features to be lost.
  - SolidWorks “fine” seems to be okay, but don’t go to “custom” and crank up resolution to the max.



Use of a Raft

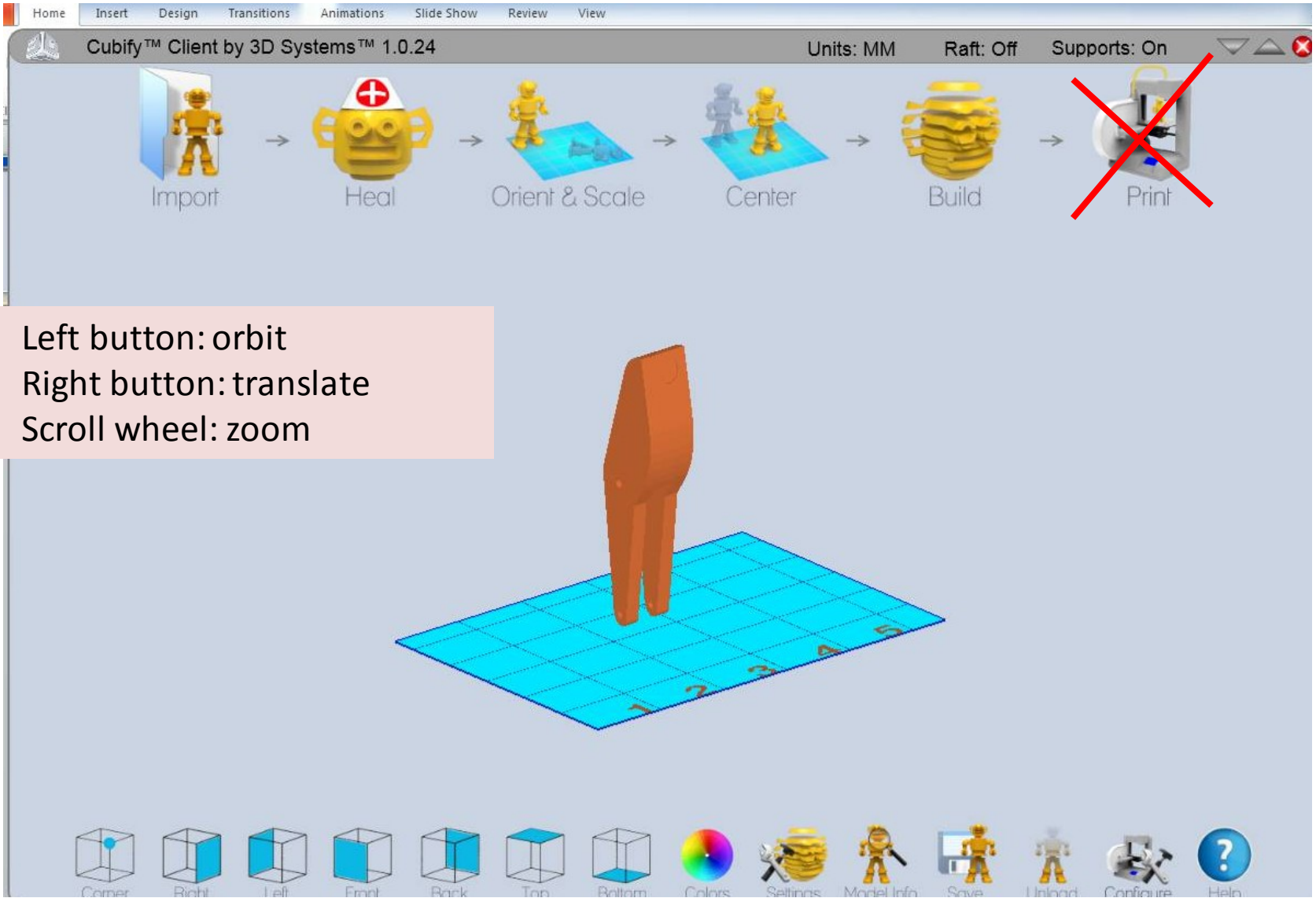
- Why use a raft?
  - Stable base of support for tall, skinny parts.
  - Prevents warping of big smooth parts (like cases) by reducing surface contact with heated bed (1st gen. Cubes only).
- Why avoid a raft?
  - Ruins the part finish (get out your sandpaper).
  - Takes more time and more plastic to print.



Cubify Client Program

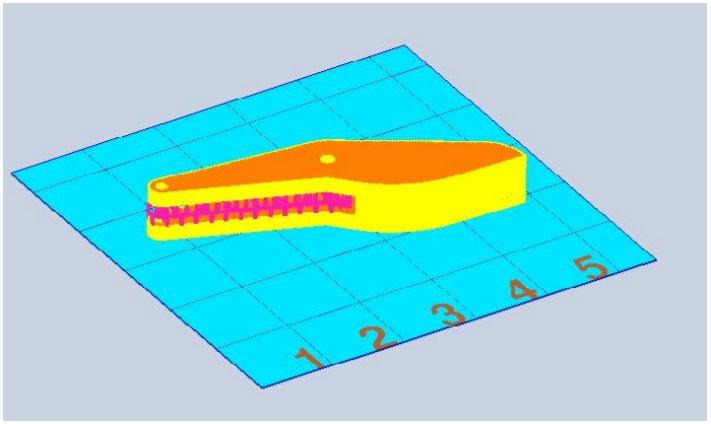
- Windows or Mac; you can install it yourself
- Turns STL files into Cube Print files
- Workflow:
  Import→ Heal → Orient/Scale → Center → Build
- Settings:
  - ABS or PLA
  - Strong/Hollow/Solid
  - 2nd Generation (not Original cube)
  - Support on/off
  - Raft on/off
- Import the Cube Print file to check supports.

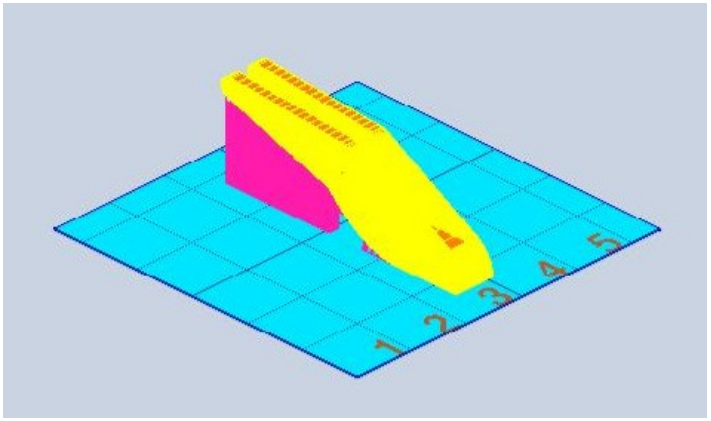
Cubify Client



Part Orientation

- Choose your part orientation to avoid the need for supports if possible.
- Don’t put supports where they will be difficult to remove.





- Remember: supports leave a rough surface.

Hollow, Strong, and Solid Modes

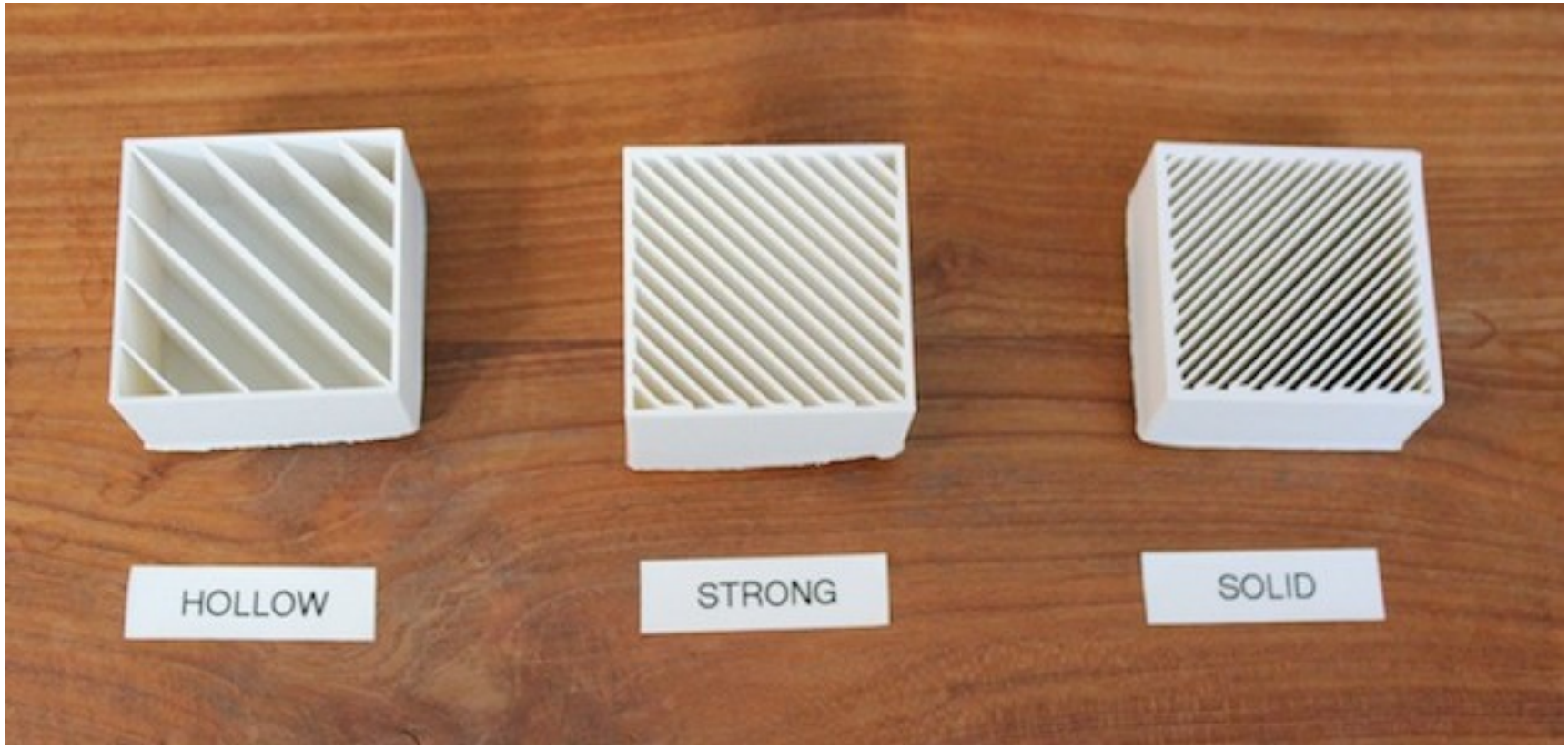
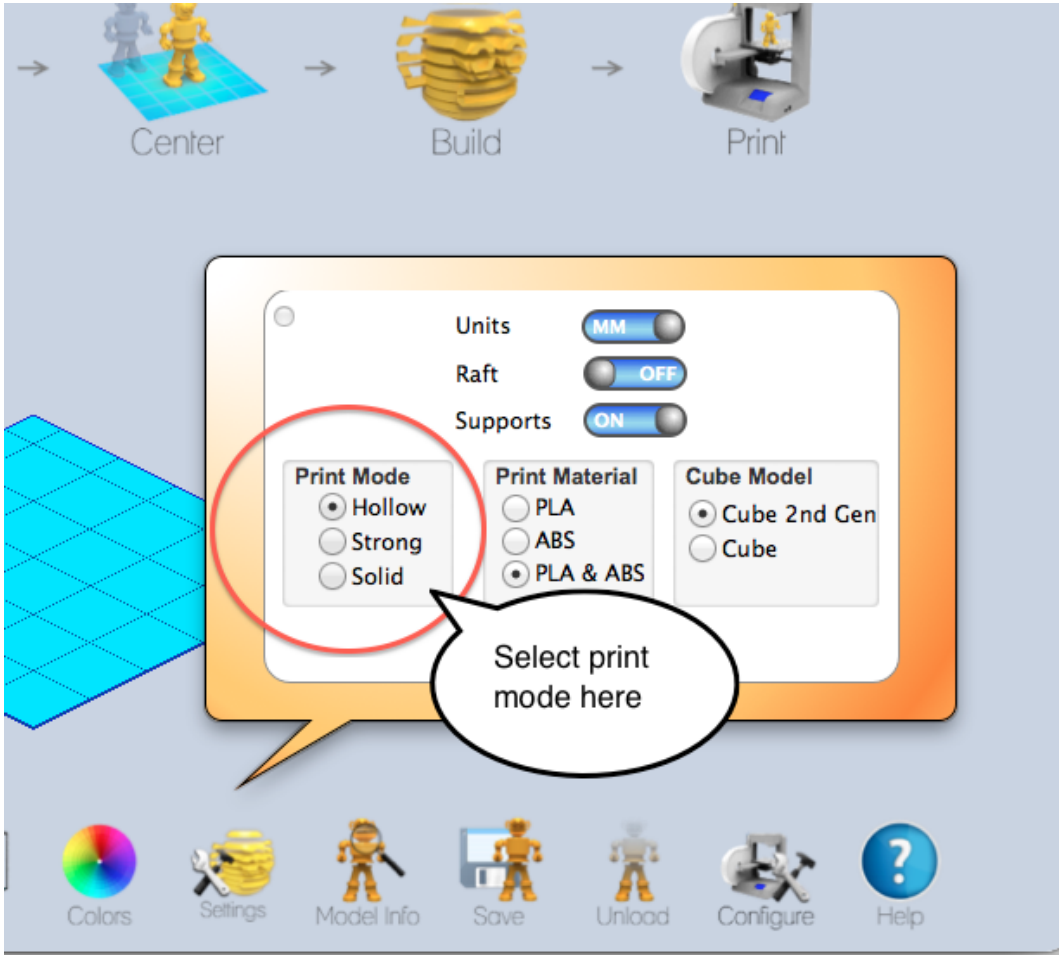
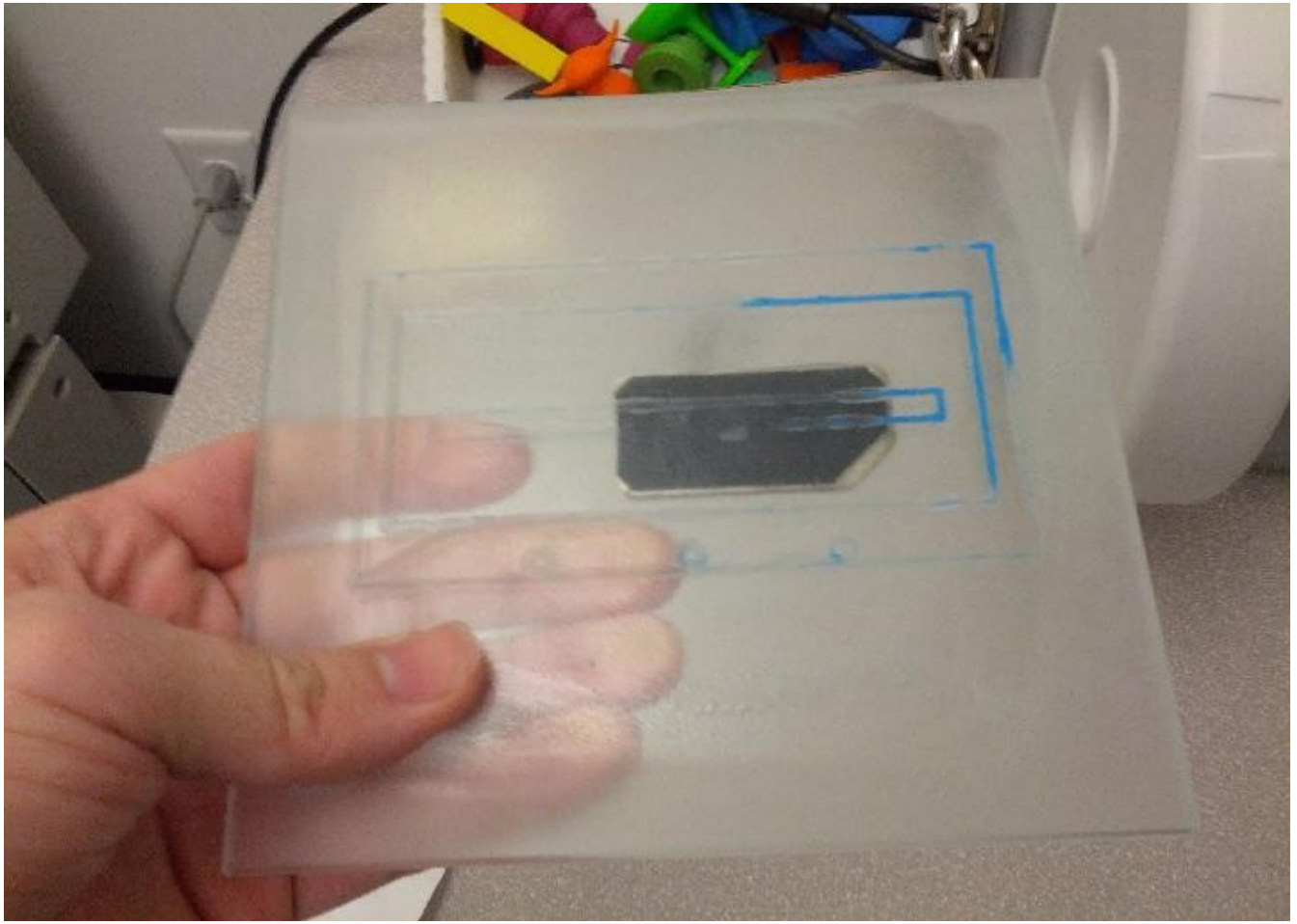


Image from cubify.com

Setting Print Mode



When the Bed Isn’t Perfectly Level



Cubify Client Annoyances

- Needs write access to its own directory, so you must fix the directory permissions if not running as Administrator.
  - C:\Program Files (x86)\3D Systems Corporation\Cubify
- Tells Windows that all STL files are “Cubify 3D Model” files.
- Creates a bunch of auxiliary files with every Cubify Print file.
  - VMF file has triangulation information

When Things Go Wrong

CubeX

- Up to three print heads.
- Can use PLA as dissolvable support material to make complex ABS parts.
- Faster, better precision than Cube
- $4400 for three-headed version; $1450 for ultrasonic tank.
- Released in 2013; still needs some fine tuning.

Where to Learn More

- Cubify.com to learn about Cube and CubeX
- cubifyfans.blogspot.com has lots of useful info about these printers.
- User's Guide, Cubify Client software, and demo objects can be downloaded from:
  www.cs.cmu.edu/~dst/Maker/Cube
  (only visible to CMU IP addresses)

Alternative CAD Software Choices

- Google SketchUp
  - Fast drawing/dragging/moving.
  - Requires plug-in to export STL files.
- Cubify Invent
  - Built on Alibre; similar to SolidWorks; $49
- Sculptris: 3D sculpting
- Sketch It/Make It (CMU spinoff)
  - Quick designs for laser cutter
  - Requires a WACOM tablet.
  - Looking for beta testers.

Alternative Printing Choices

- Objet printer in Larry Hayhurst's shop.
  - Finer resolution, smoother finish.
  - Can print dissolvable support material.
  - Pay by the cubic centimeter.
- TechShop in Bakery Square
  - Makerbot Replicator and Replicator II (dual head)
  - Multiple laser cutters, and a water jet machine.
- Shapeways
  - High end 3D printing service; many materials.
  - Library of models and applications.
  - 8 day turn-around; fast shipping.