15-294 Rapid Prototyping Technologies:

Molecule Exercise and Cube Intro

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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, Cube 2, Cube 3, CubeX, ...
- Many, many more...

Cube 3D Printers

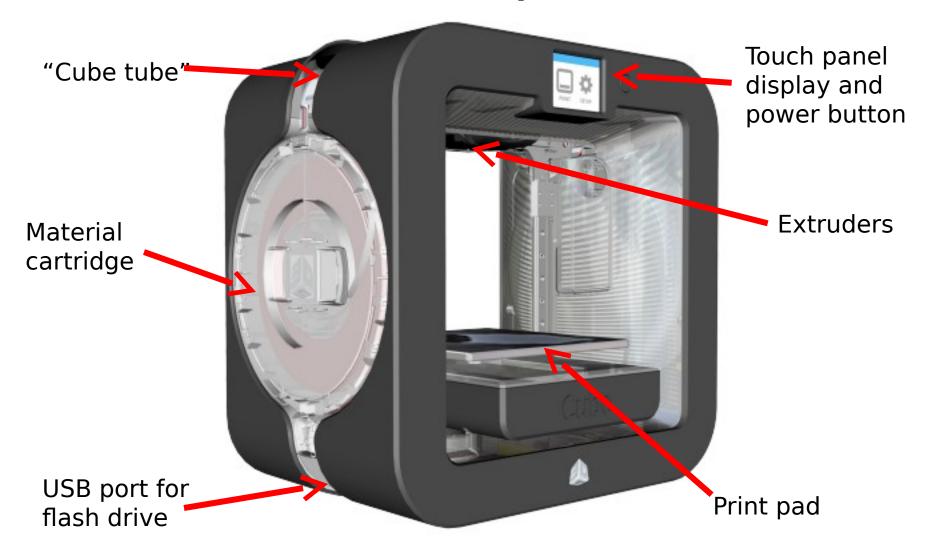


Cube 2nd generation



Cube 3rd generation

Cube Components



3rd Generation Cube

- Prints ABS (acrylonitrile butadiene styrene) or PLA (polylactic acid).
- Faster than original and 2nd generation cubes.
- Better precision (70 microns vs. 200 microns for 2nd gen vs. 250 for original model.)
- No heated bed: saves time.
- Can print "hollow" or "solid" objects.
- Less cost than the original: \$1000 vs \$1300.
- Buy it at Staples, or at Cubify.com.

Inside the Cartridge



 Chip in the cartridge tracks how much material used.

Changing Cartridges

- Takes several minutes for the extruder to heat.
- Easy to unlock cartridge for release.
- Auto-Level and Gap after installing!
 - Prevents clogged cartridges.
 - Keeps print head in appropriate position.

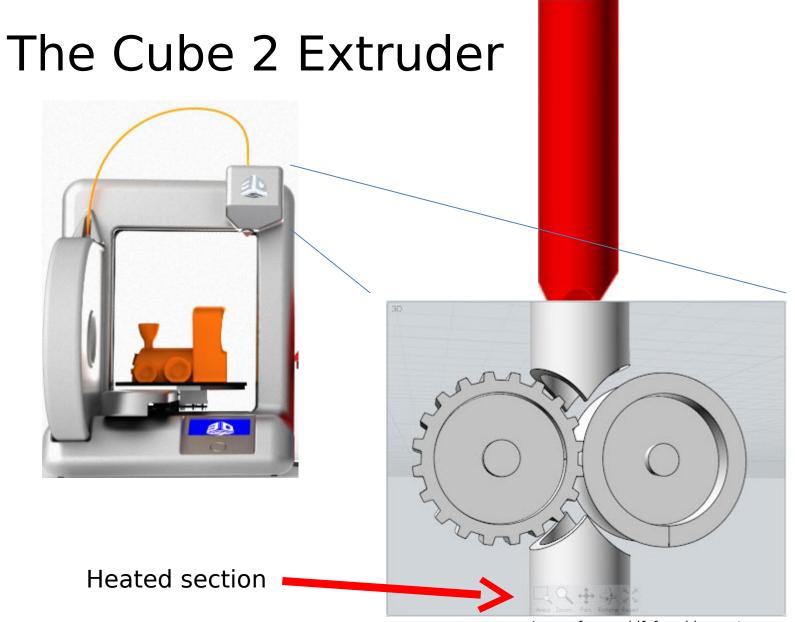
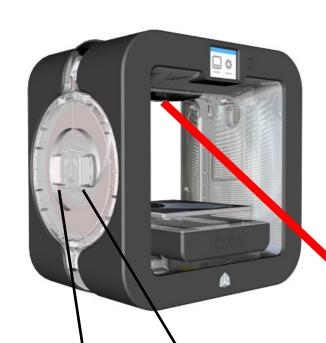


Image from cubifyfans.blogspot.com

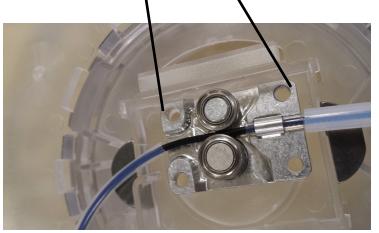
The Cube 3 Extruder







Extruder Bottom





Heated Section

Preparing to Print

- No longer need to auto-level and auto-gap when loading a cartridge; IdeATe staff have dobe that.
- 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.
- 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 on the table next to the Cubes.
- 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!

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.

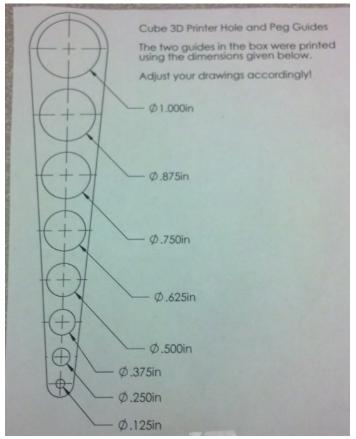
Design Rules

- 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)

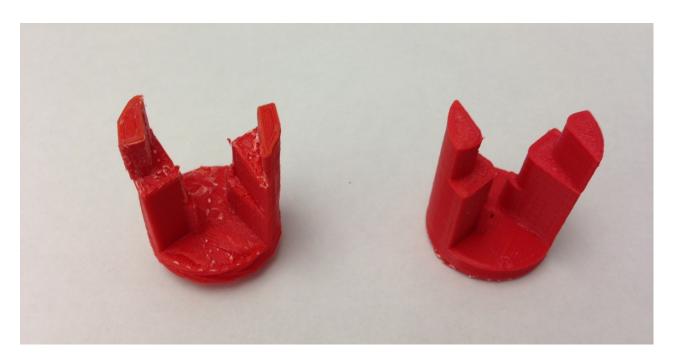
Compare requested size vs. actual.





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.

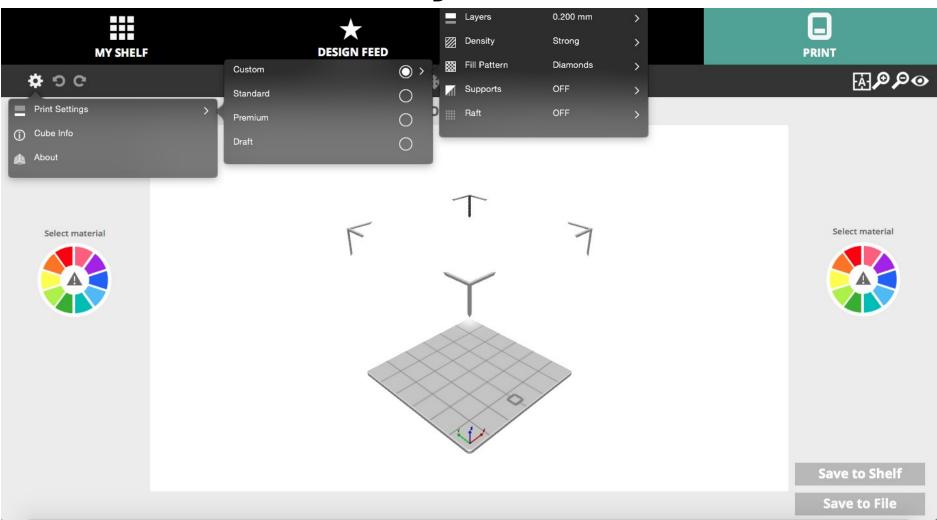




Cubify Client Program

- Windows or Mac; you can install it yourself
- Turns STL files into Cube Print files
- Workflow:
 Import → 'Print Now' → Orient/Scale/Position → Color → Save
- Settings:
 - ABS or PLA with various colors
 - Strong/Hollow/Solid
 - Support on/off
 - Raft on/off

Cubify Client

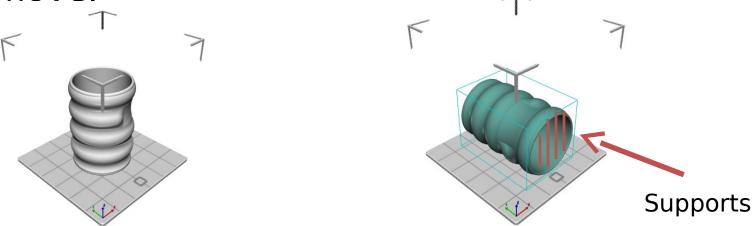


Part Orientation

 Choose your part orientation to avoid the need for supports if possible.

Don't put supports where they will be difficult

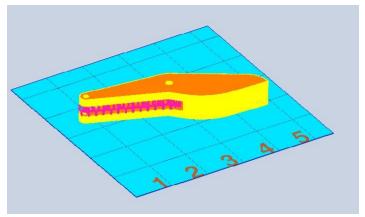
to remove.

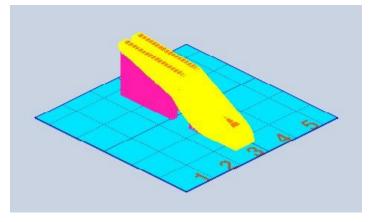


Remember: supports leave a rough surface.

Part Orientation

- Sometimes the use of support material is unavoidable.
- Don't put supports where they will be difficult to remove.





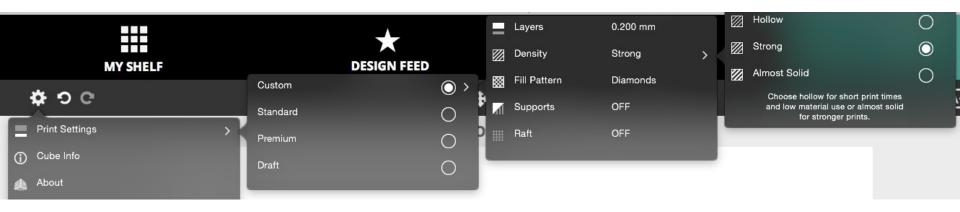
Remember: supports leave a rough surface.

Hollow, Strong, and Solid Modes

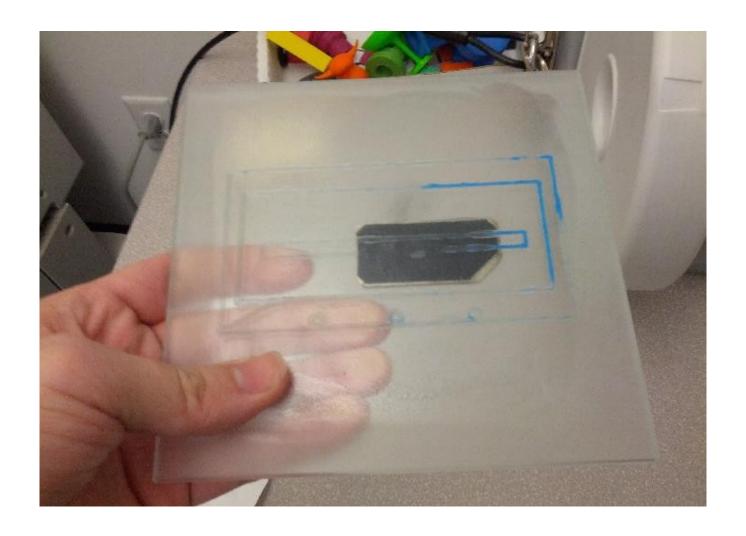


Image from cubify.com

Setting Print Density



When the Bed Isn't Perfectly Level



Cubify Client Annoyances

- Coloring a part is not user-friendly
- Color palette sides actually matter!
- Tells Windows that all STL files are "Cubify 3D Model" files.
- Often buggy/slow when loading.

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 Printing Choices

- Form 1+ and Stratasys Dimension printers at IDeATe.
- 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
 - printrbot open source printers (used to have Makerbots).
- Shapeways
 - High end 3D printing service; many materials. e.g., ceramics.
 - Library of models and applications.
 - 8 day turn-around; fast shipping.