An Introduction to
3D Printing
for Mac Admins

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I run a couple of educational labs. All Mac. No major help desk duties outside of the Labs.

But we’re also a printing service bureau.
- And an equipment rental service.

So my boss says, “The Faculty is buying a $40K 3D printer. You get to run it.”
“Oh, and it only works with Windows.”

Whether it happens this or some other way, the powers that be are going to look for the nearest tech-savvy person when they get the idea that they should buy 3D printer. What are the odds that this will be you? Or maybe this technology excites you, or you are interested in the Maker community. Regardless, I'm here to share my 30 months of experience with you to make any implementation that much smoother.

What I’ve Learned

- The Output
- The Hardware
- The Software
- Models

I’ll divide this up into four topics.
Software will include free software and services to help you survive.

The Output

In order to build something, we need materials.

Materials

With 3D printing, you either *build* with resin or filament (PLA, ABS) or you carve or etch out of a solid piece of material (like wood).

While I was preparing this presentation, Studio Neat, who you might be familiar with for their Glif iPhone stand & tripod mount, released a $12 stand for the new AppleTV remote. • It's this part that interested me: they used an open source CNC machine to mill their product. This is a great example of that kind of 3D creation. Having said this, this is the last we will speak of milling and other subtractive methods in this presentation, because…

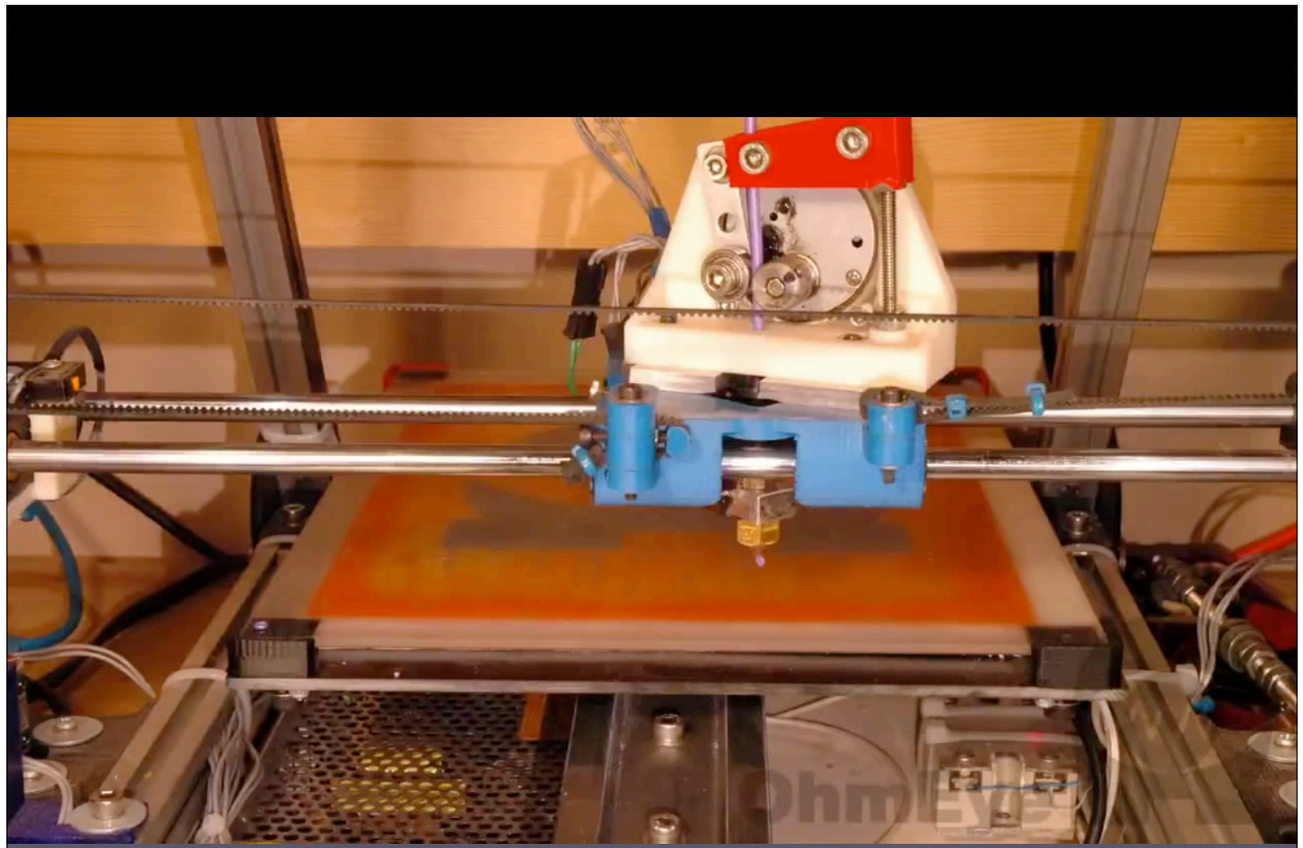
Additive Manufacturing

- Fused Deposition Modelling / Fused Filament Fabrication
- Layers of resin under UV lamp

The kind of printing I deal with is where you add material. There are a couple of common kinds.
FDM is the trademarked term used by Stratasys, but their patent has expired; FFF is the generic term — think of how a glue gun works; really, we're melting the filament, mixing it with glue, and forming it. The printer I administer works more like an inkjet printer, laying layers of resin on a printing build tray from bottom to top.

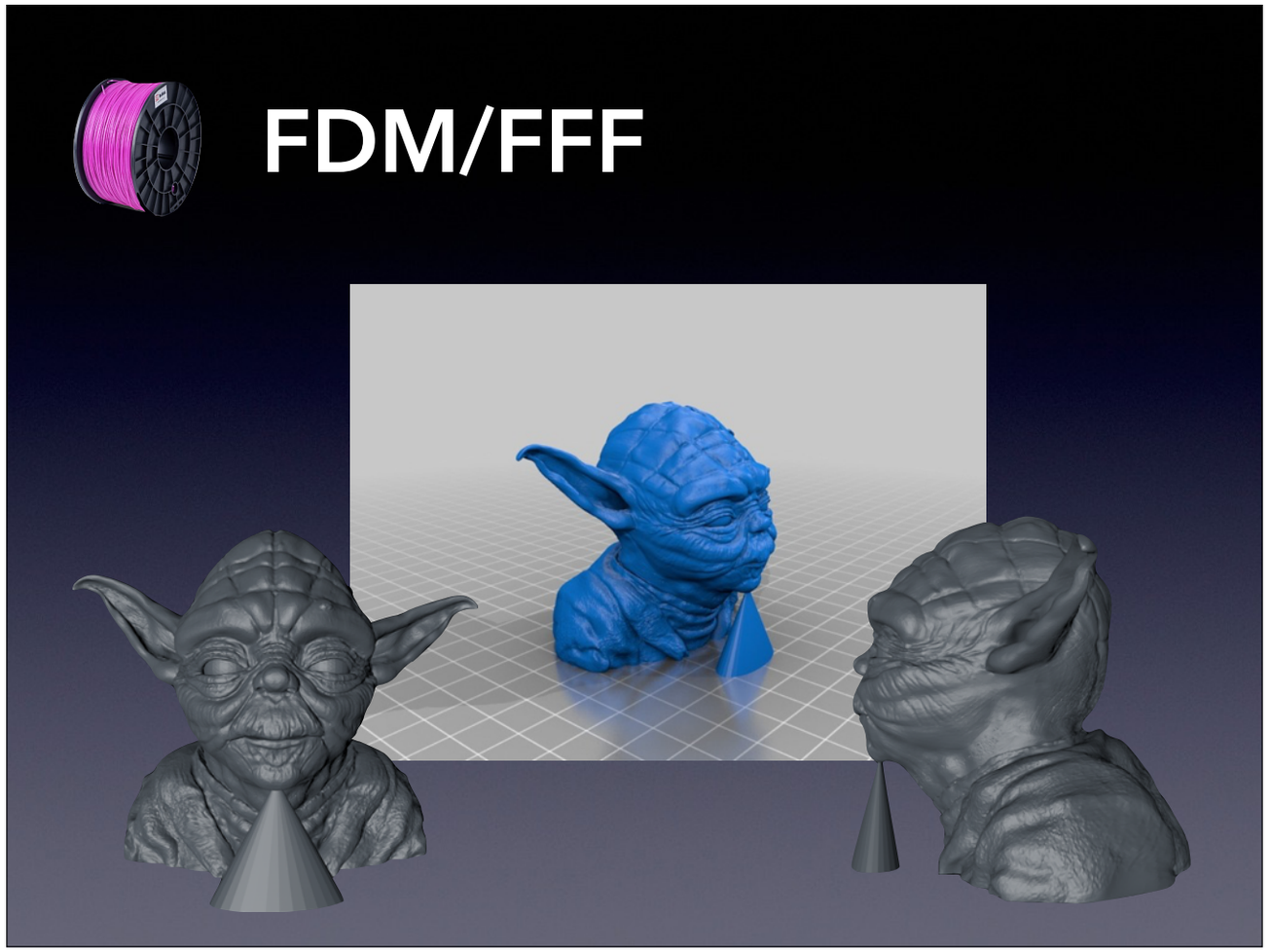
Credit: OhmEye (Creative Commons License)
https://youtu.be/1213kMys6e8

Let’s start with a timelapse video of a filament-based printer.
Hyperboloid print

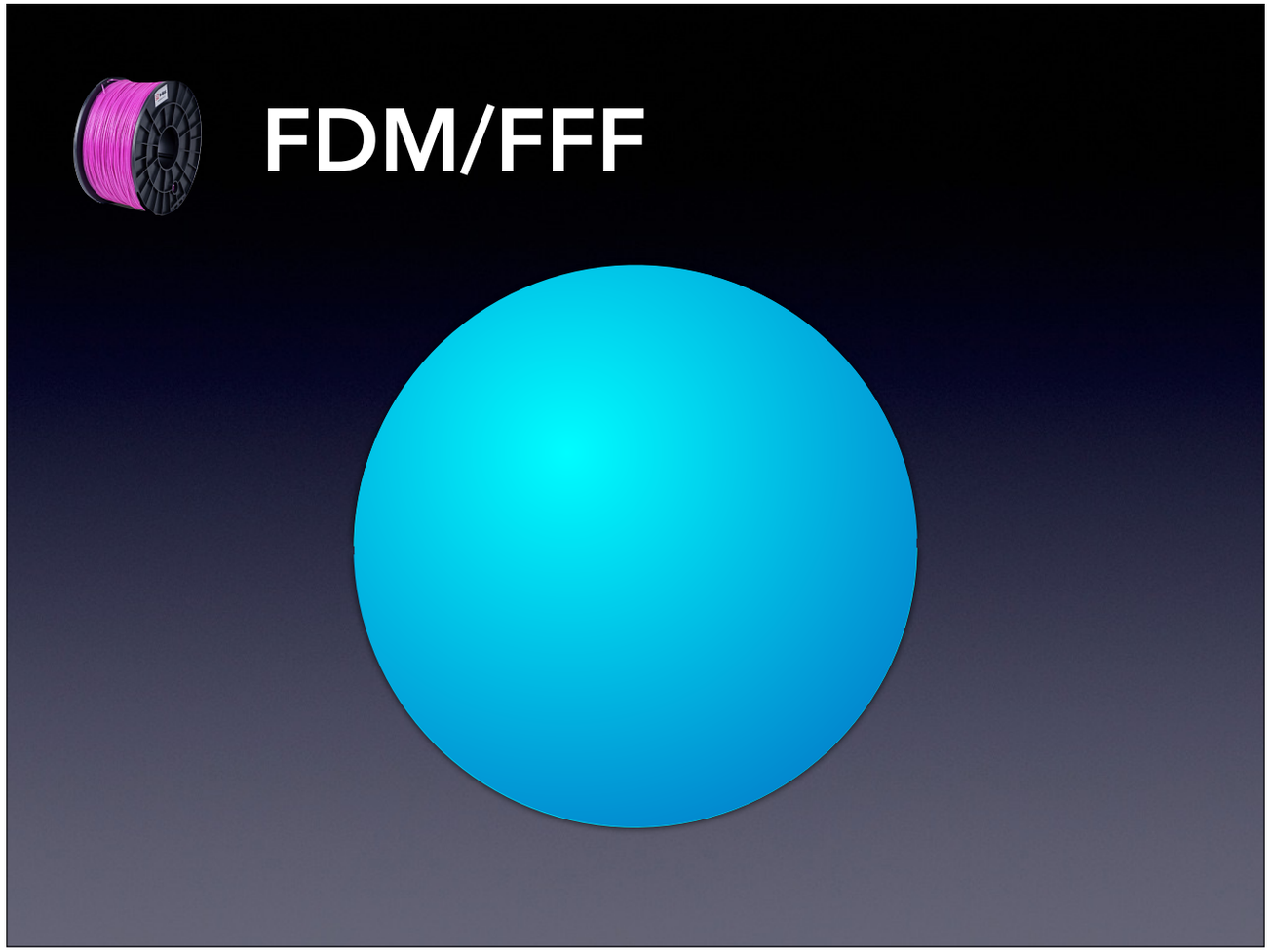


Credit: OhmEye (Creative Commons License)
https://youtu.be/NzQF7SRU_1E

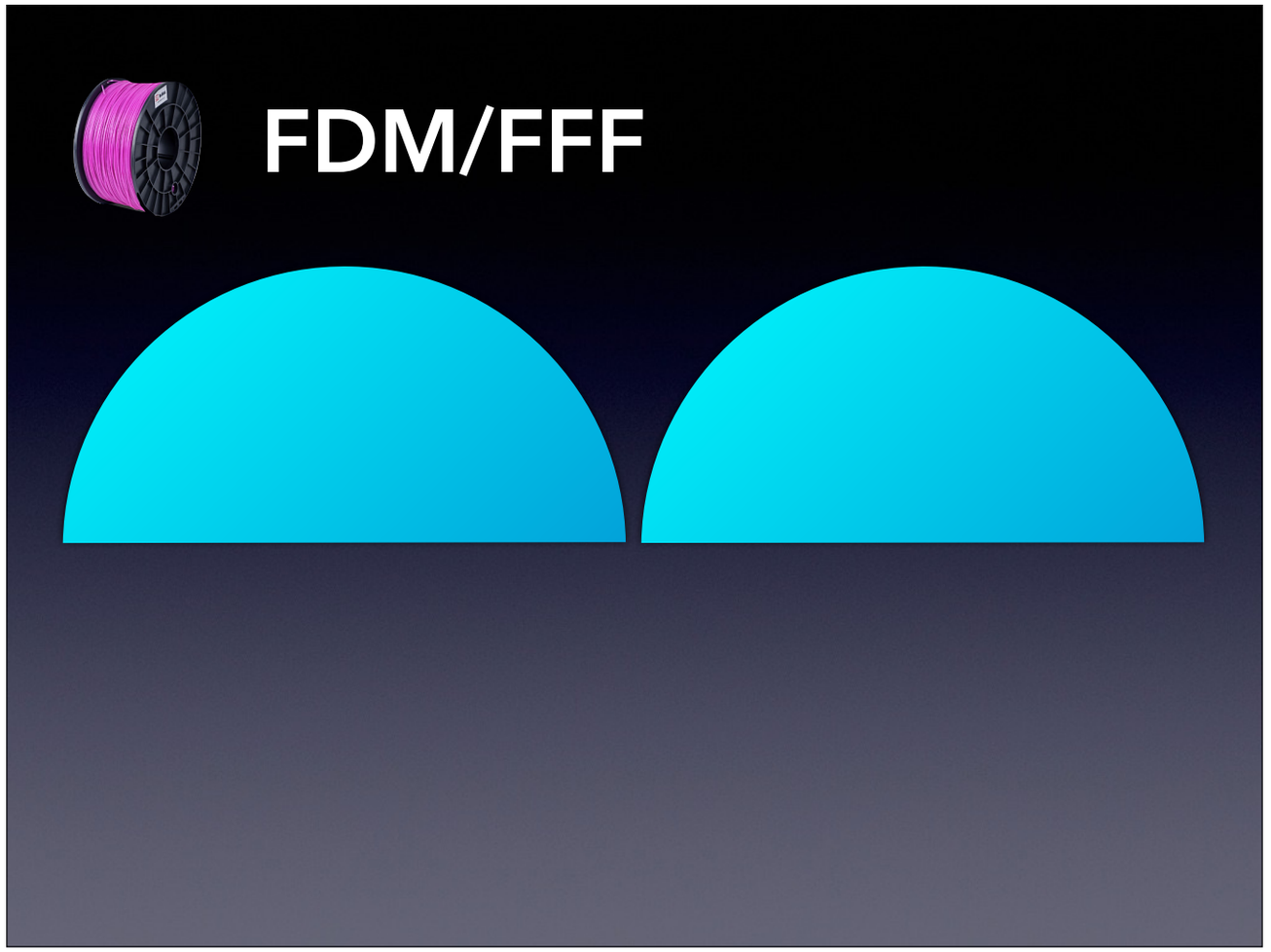
I want you to notice the angles in play here. Also, this print would have taken hours and hours to make. Don’t let the time lapse fool you.



One of the key limitations with filament-based printers is angle. The Yoda model is a standard of sorts to give you an indication of what is possible. Notice that with a strong base, Yoda's ears quite angled they are. But the person who remixed this version, one Nick R Brewer, felt that the chin was too much of an overhang and would not produce clean results. So he added a chin support, which you would break off after printing.



Let’s look at another example: a simple sphere. A filament-based printer can’t handle the sharp angle at the base •



your best bet might be to cut the sphere in half, print the two halves with the flat side down and then glue the two printed halves together.

FDM/FFF

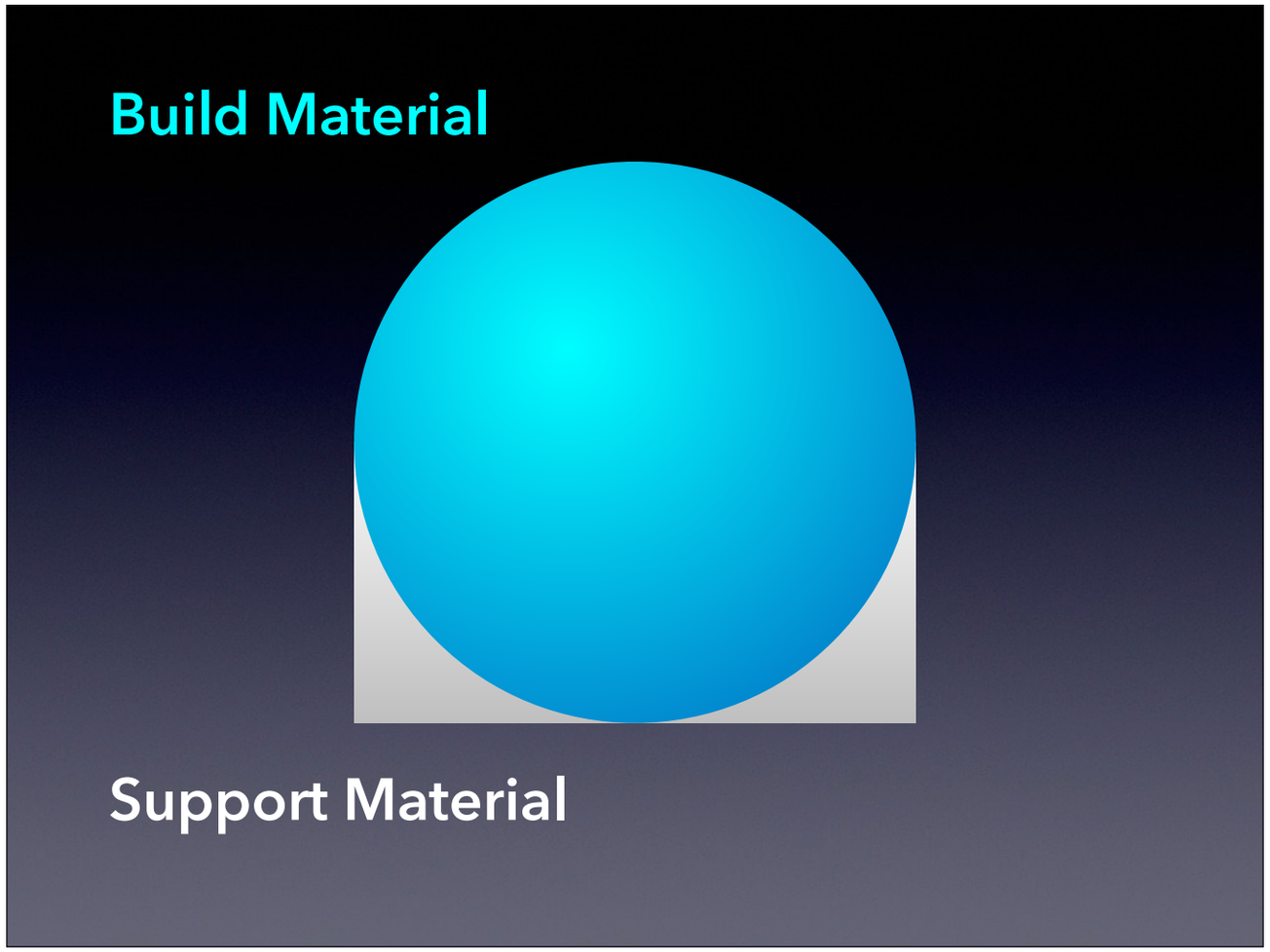
- Less expensive printers & materials
  - *Often print hollow*
- Variety of materials & colours
  - *PLA, ABS, Nylon, Wood*
- Printing angle a consideration
- Some designs can’t be printed
- 100 µm (0.1 mm) minimum thickness (250 µm typical)

Less than $500 for some printers; filament at US$25 to $30 / kg
Something like a celtic knot can’t be printed
A printer like the 5th Generation Makerbot Replicator that can print at 100 µm goes for ~$3000.

Resin

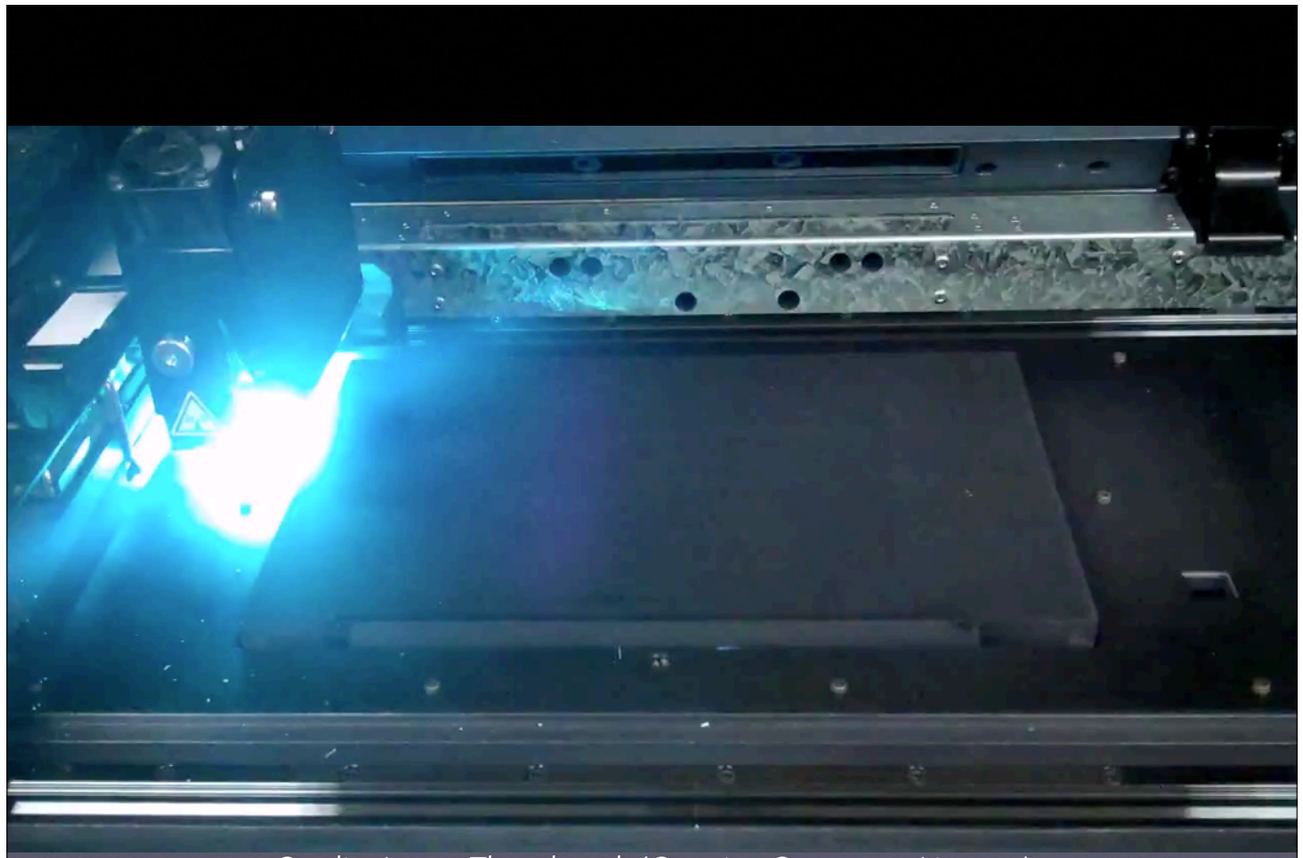
- Build Material
- Support Material

What I operate is a resin-based printer. As I mentioned before, it is more like layered inkjet printing with two inks, or in this case, resins. Support material is meant to be removed after printing.



Let’s go back to that sphere I just showed you. With a resin-based printer, • you use support material to defy gravity. Note that the support material would go entirely around the base; this is kind of a cross-section view.

Credit: James Thornburgh (Creative Commons License)
https://youtu.be/AKca08-ggX0



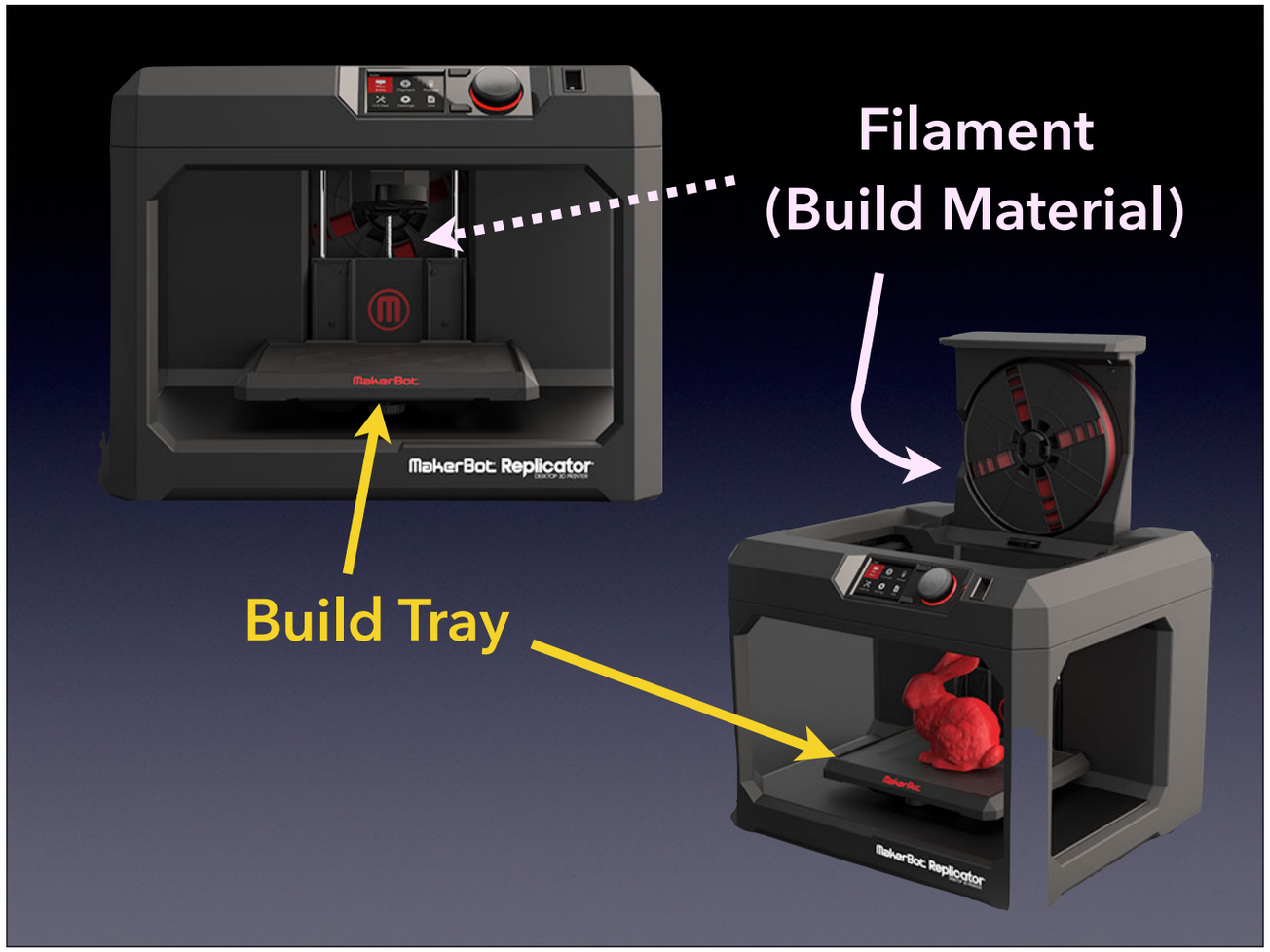
Credit: James Thornburgh (Creative Commons License)
https://youtu.be/-rJnVPey_5Q

Resin

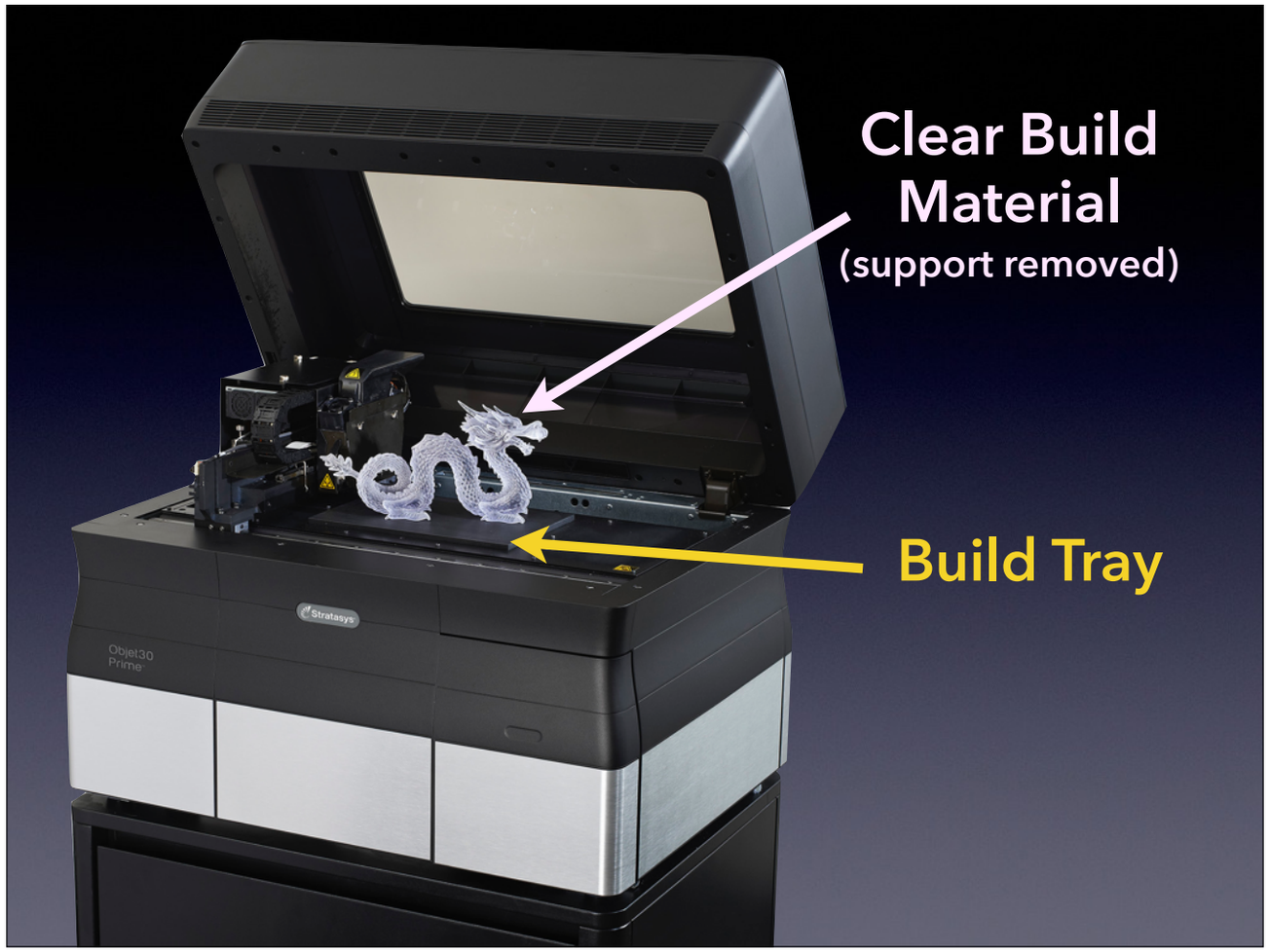
- More expensive – proprietary
- Material variety increases with cost of printer
- No angle restrictions
  - *Solid objects*
- 28 µm typical (0.028 mm)
- Hazardous waste
- Model cleaning required

Printer is worth $20K and up; build materials are $250–350 / kg
At the base level, you get 1 colour: white; spend $30K and you get 2 whites, blue, black, and clear; go into the $60K range and you can get rubber and mixed colours

The Hardware



Here’s that $3000 printer I spoke of, the 5th Gen MakerBot Replicator.



On this printer, the tray moves up and down. On many filament-based printers, the tray stays still and the head moves up and down.

Setup & Operating Considerations

• Levelling of less expensive printers is an art. Even the 5-figure models do not operate reliably if they are not level. This will be a serious area of concern for you on setup. Make sure the desk or table you put the printer on is sturdy as well.

Setup & Operating Considerations

These things stink. Think about it: melting plastic, adding glue. Resin-based are no better — Stratasys recommends that your ventilation system completely replace the air 4x/h. Do not even think about putting it near where you work unless you are willing to vacate that space for hours at a time. And you don’t want a direct breeze on a filament-based printer, as it could affect the print.

Setup & Operating Considerations

Noise is less of an issue, but they are not silent, particularly the 5-figure ones.

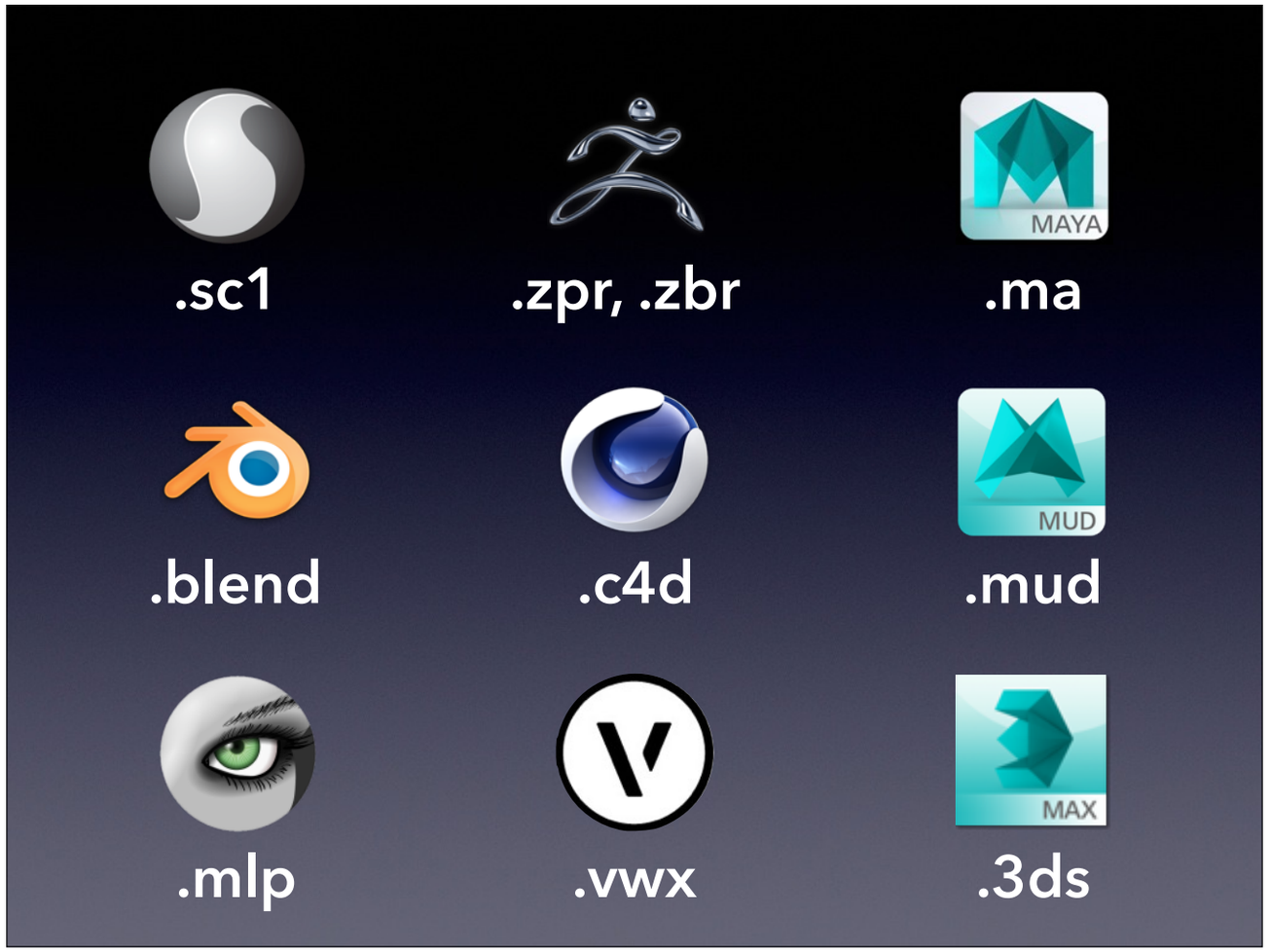
Setup & Operating Considerations

The cheaper the printer, the more mechanically inclined you need to be.
These printers are finicky. If you _are_ mechanically inclined, this should be OK, even fun perhaps.
If you’re more of a software person like me, it can be a challenge. With the 5-figure printers which come with 4-figure annual service contracts, it is more manageable.

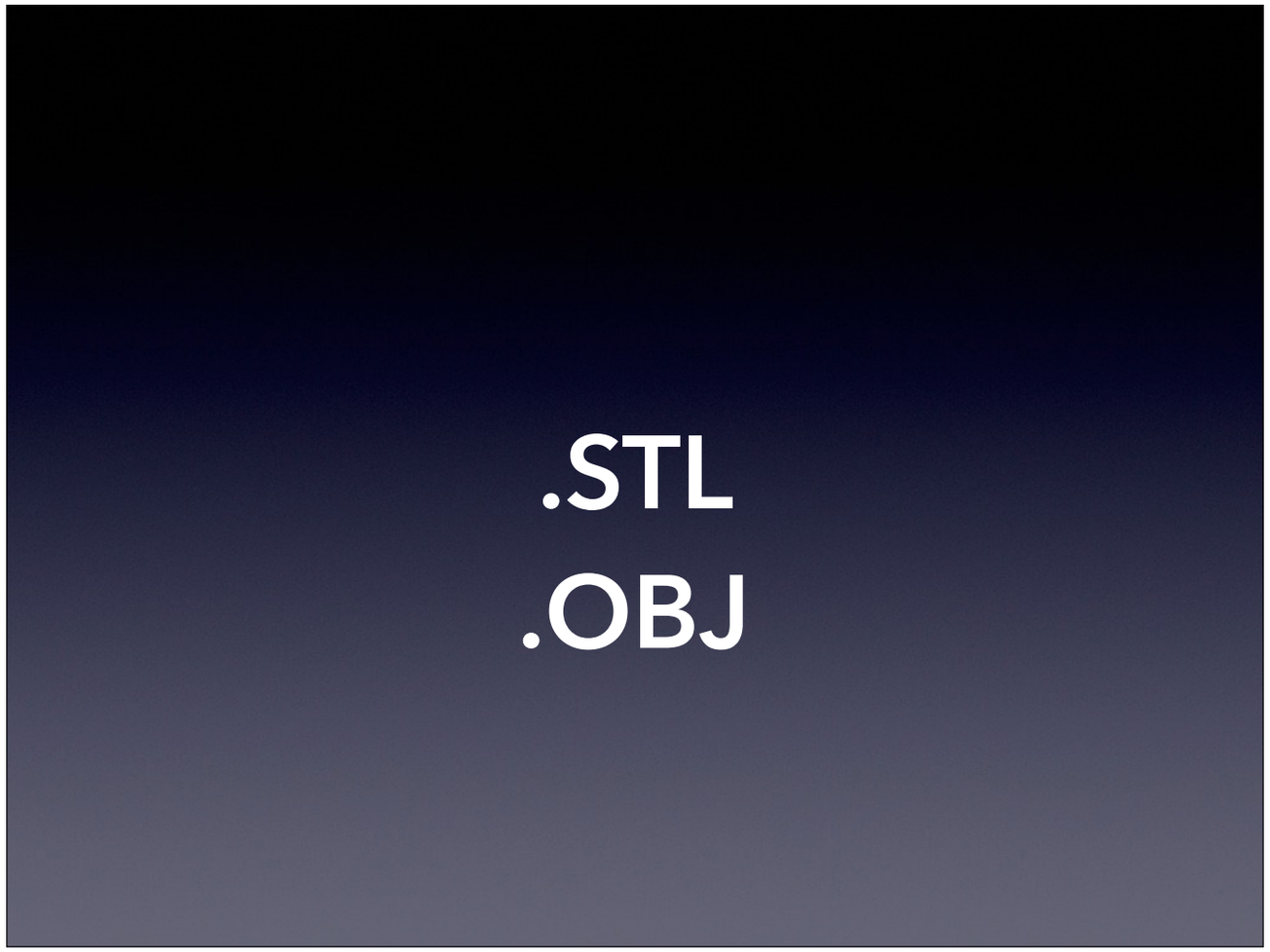
Setup & Operating Considerations

Time. This is nothing like running a laser printer, even though the powers that be think it must be. The manufacturer of my printer says you should at least do a small test print or a nozzle check every 7 days. If you're going to leave it for longer than a week, you should consider flushing the system, flushing $100-200 worth of materials with it when you include the flush and the refill. And when you wake the printer up (mine only gets powered down when it has been flushed), it takes a while for the heads to warm up. My weekly maintenance takes me a minimum 30 minutes each time — longer if I actually print something useful. For the cheaper printers, the time factor is dealing with their finicky-ness. We had our campus computer store and our main library setup a 3D printing service using the $3000 printers one generation back. They were in service for less than 6 months before they broke down.

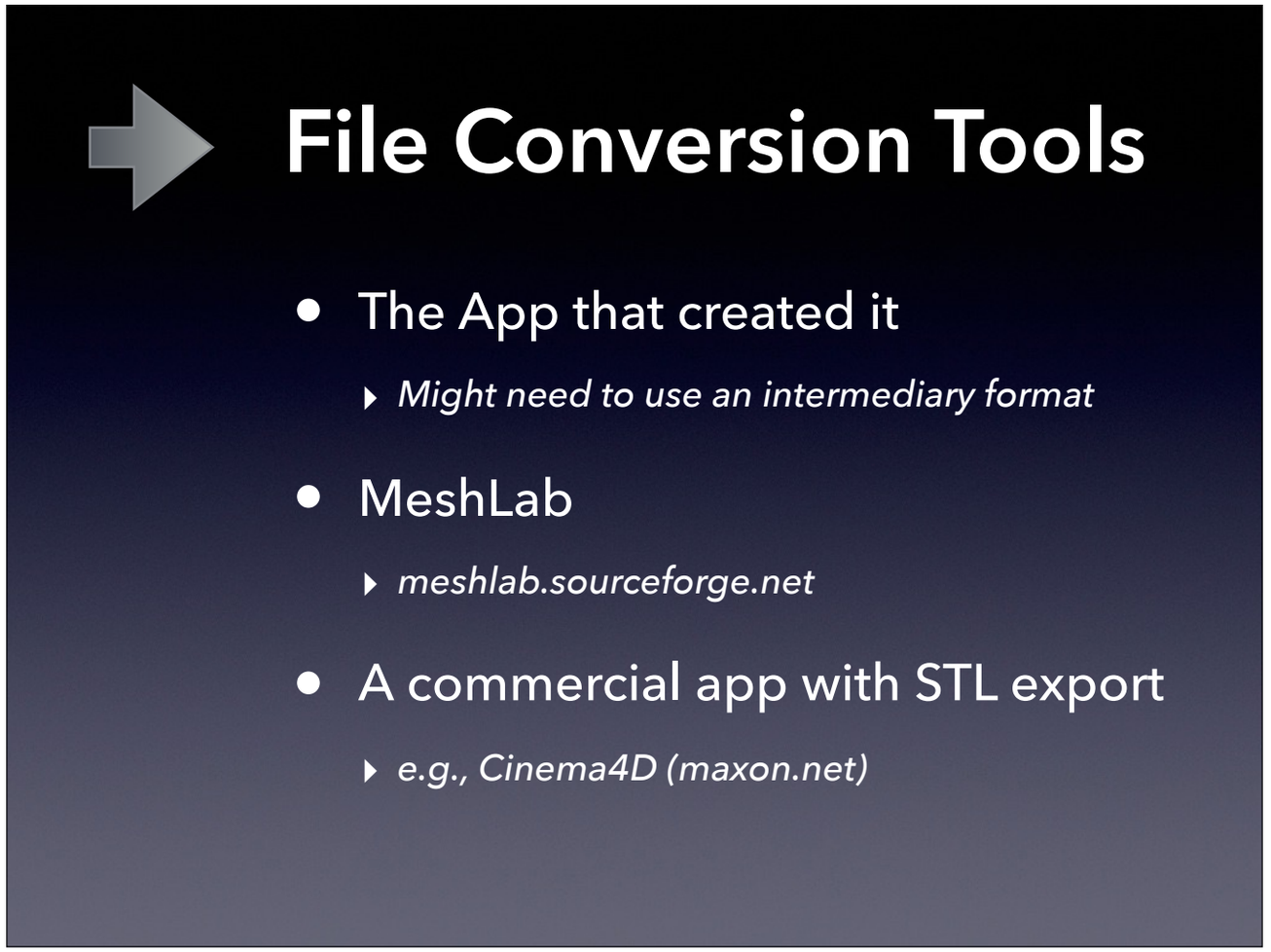
The Software



There are literally dozens of apps on multiple platforms to create 3D models. Some focus on CAD, some on animation, some on modelling or sculpting. Some try to do more than one. • They all have their own file formats as well. This becomes a problem, because my printer wants one format:



Stereo Lithography or .stl files. Such files just describe the geometry of the model, which makes it ideal for printing with a single build material. Some apps can save out as STL files, but others can’t. • On MakerBots, you can also use .obj files, which end up being a good intermediary format to get to STL if your printer requires that.

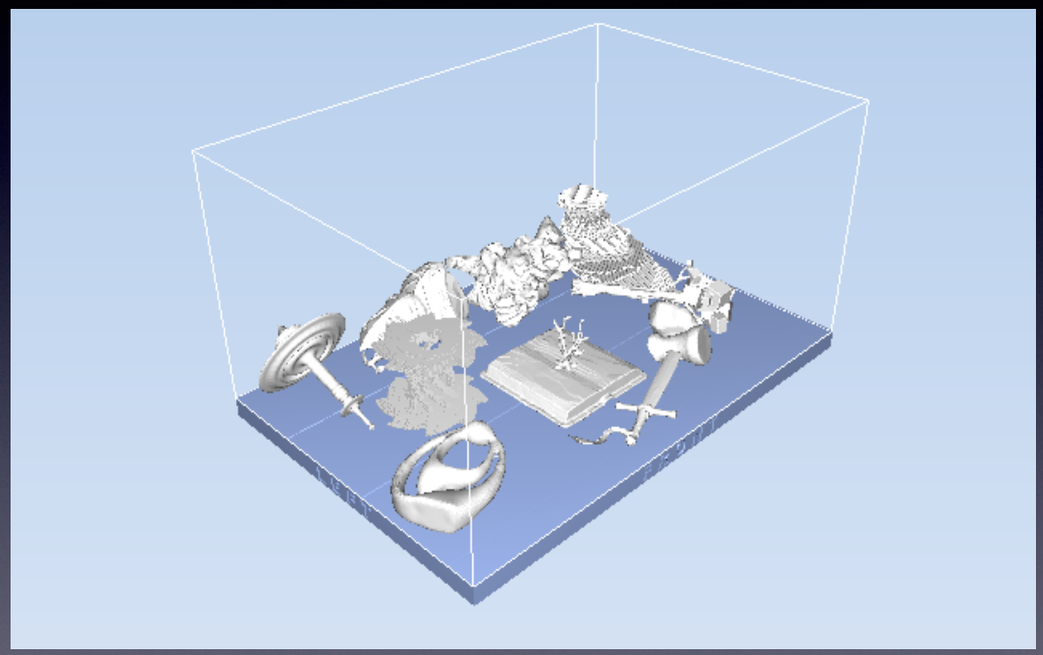


MeshLab reads 22 formats and outputs 16, including STL and OBJ, the latter being the most common export format. (Proprietary —> obj —> stl is probably the most you will have to do.)

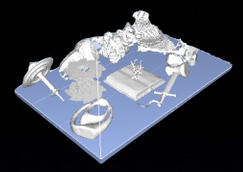
Software & Services

Your printer manufacturer will determine what software you use to drive the printer. • On mine, they use their own in-house software (common), but since the OS inside the printer is Windows XP, their software is Windows only. Up until we got this printer, I had been able to avoid touching any Windows computers. There will be plenty of people running Windows who will want to use the printer, regardless of what OS the printer demands, so you may have to up your game in that regard.

Making a Tray



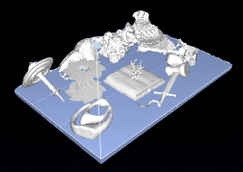
So after I got over the horror of Windows, I learned that when we print, we don’t print a file, we print a tray, which can have one or more objects on it. Here are the steps I follow to prepare a tray:



Making a Tray

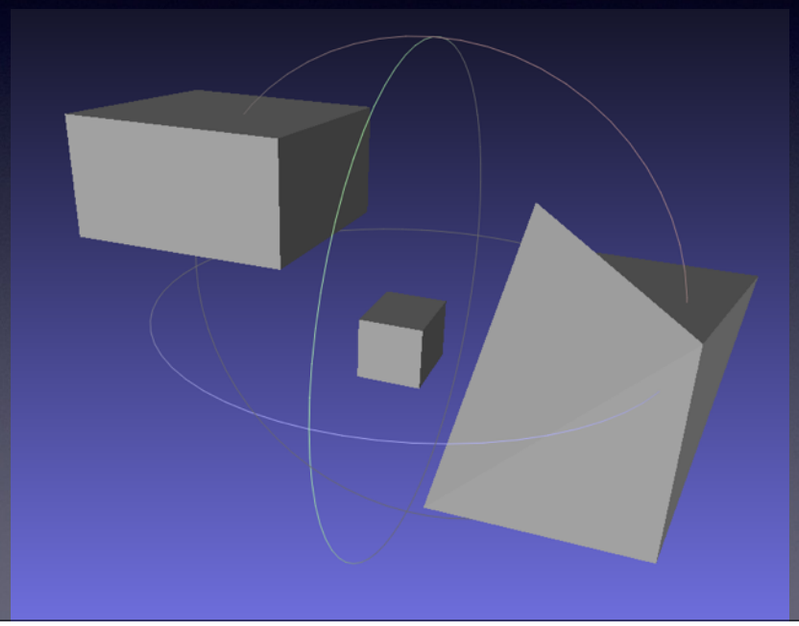
1. Collect your STL model(s)
2. Open the software (VM is OK)
3. Import each model, specifying scale units (mm or inch)
4. Adjust placement (auto or manual)
5. Verify tray
6. Estimate materials & Save Tray

[details on each step]
…fairly simple, right? Well, I have some Pro Tips for common issues surrounding trays.

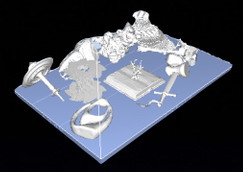


Making a Tray – Issues

2+ models in 1 STL file



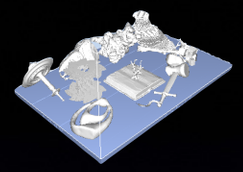
There’s no manner in which I can orient this STL file where I don’t have to suspend models with support material and take up a lot of space on the tray. We want to have maximum flexibility.



Making a Tray – Issues

2+ models in 1 STL file

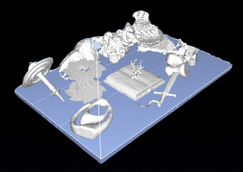
- User exports models separately
- Split with an app:
  NetFabb Basic (Free)
  - *www.netfabb.com/downloadcenter.php?basic=1*



Making a Tray – Issues

Unclosed contours, vertices, other defects

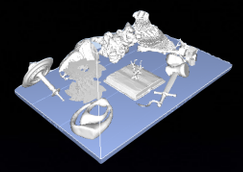
When you go to verify your tray, it will check to see if it can decipher the models. On my printer, it basically says “yes” or “no” and mentions the type of defect it found. Other printers may flag errors but let you try to print it.



Making a Tray – Issues

Unclosed contours, vertices, other defects

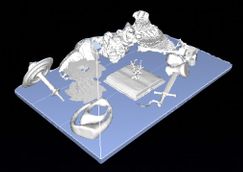
- NetFabb Basic
- MeshLab
- NetFabb online (“cloud”) service
  - *https://netfabb.azurewebsites.net/*
  - *Requires (free) Microsoft account*
- NetFabb Private (“personal”)
  - *US$300*
- NetFabb Professional ($$$$)



Making a Tray – Issues

Model too large

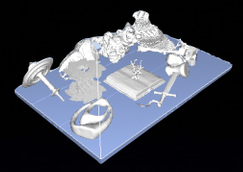
Build trays are surprisingly small. Our expensive printer can go no larger than 150 x 200 x 300 mm or a little under 6 x 8 x 12”. As well, that “too large” can also be subjective. I deal with artists, who are not rolling in dough. Frequently, they would send me a model, I would use the printer software to estimate the cost, and the feedback I got was that they couldn’t afford that and could I make it smaller so that it would only cost $X.



Making a Tray – Issues

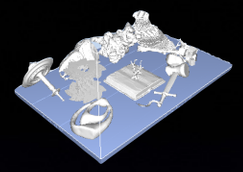
Model too large

- Scale the model
  - *printer software*
  - *any design software*
- Split the Model
  - *NetFabb Basic*
- Resin: re-orient the model



Making a Tray – Issues

Speed of Printing



Making a Tray – Issues

Speed of Printing

- Resin: Z-axis is slowest
  e.g., 25×50×100 mm (1×2×4"):
  - *9h when z=100 mm*
  - *5h when z=50 mm*
  - *3h when z=25 mm*
- Fill the tray
  - *6h for 4 copies on 1 tray when z=25 mm*

In the end, find out what works for your printer. Yes, even read the documentation.

Models

Since this talk is directed at people who would administer these printers, I've left the creation of models to the end.

There are really three sources of models: first are the ones that people design themselves.
Here's the slide from earlier. While some of these specialize in animation or CAD,• the three on the left can make models for free.

Making Models

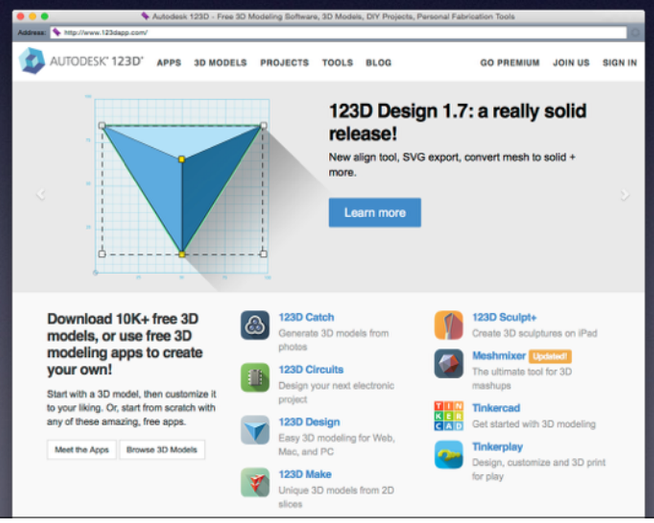
- Sculptris (Pixologic)
  - *pixologic.com/sculptris/*

- Blender
  - *www.blender.org*

- MeshLab
  - *meshlab.sourceforge.net*

Making Models

- Autodesk 123D
  - *www.123dapp.com*

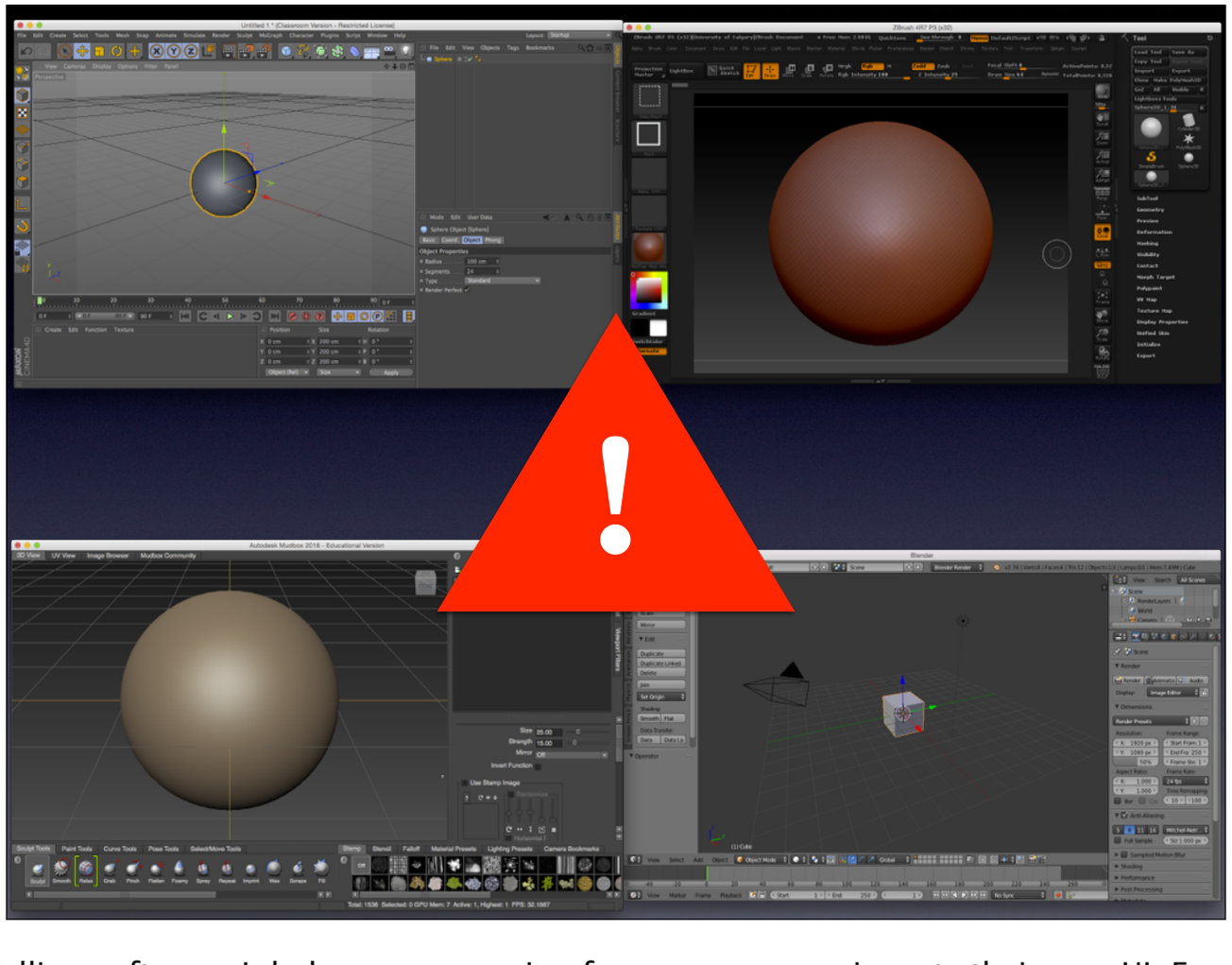


In addition to all the commercial software Autodesk has (like Maya, Mudbox, and 3DS Max), they also have some gateway drug software that they make available for free. Some even work on iPad.

Making Models

- SketchUp Make
  (Trimble Navigation)
  - *www.sketchup.com*
  - *Ruby API*
  - *SDK*

Yes, SketchUp was a Google product, but Trimble now owns it and offers a free version for “personal projects” or “any educational purpose” and a paid Pro version at $700 (less for education).



If you have not seen or used 3D modelling software, I do have one warning for you: everyone invents their own UI. Everyone.

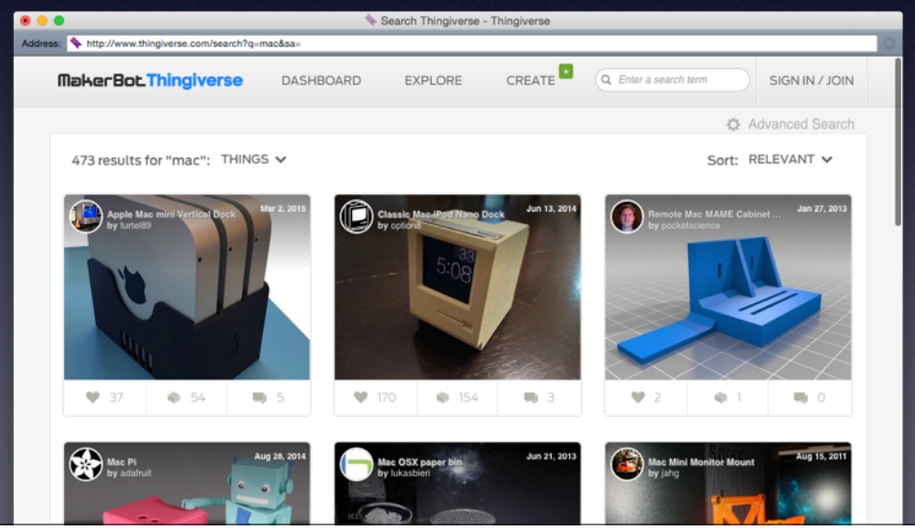
3D Scanning

- Different Kinds, Different Sizes
- Notorious for needing model cleanup

The second way you might get models is 3D Scanning.

Community

- Thingiverse (Makerbot)
  - *www.thingiverse.com*



Thingiverse is a great place to get a model for printing or mashing up for any 3D printer. Since it is driven by users of MakerBot printers, the models are generally sturdy and easy to print.

Community

- 3D Warehouse (SketchUp)
  - *3dwarehouse.sketchup.com*
- TurboSquid
  - *www.turbosquid.com/Search/3D-Models/free*
  - *Paid royalty-free models as well*

These ones are not printing-specific. They usually require one or two conversions to get to printable, plus perhaps a repair. Consider these to be secondary sources.

Many Thanks

- MacTech Conference
  - *Ed Marczak*
- Rob Furr
  - *Instructor, Dept. of Art, University of Calgary*
- Natasha Shevchenko
  - *Student Tech, IAML, University of Calgary*

ucalgary.ca/iaml/help/pro/3dprint

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