

# 3D Printing Scale Replica's How It's Done

Presented by CatzPaw Innovations, LLC



*Link to Presentation Handout: [www.catzpaw.com](http://www.catzpaw.com)  
Click "3D Printing Scale Replicas Presentation Handout"  
located in the lower right hand corner under "Gallery."*

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## Introduction to CatzPaw

- CatzPaw is a small woman owned business dedicated to designing and 3D printing scale model replica's of just about anything.
- We are a creative and technology savvy duo, with over 40+ years of experience in the technology industry and 10+ years of hands-on experience in 3D printing.
- We do it all: design, create, 3D print, package, ship, and more.
- We are located in Locust Grove, GA; USA.



We participated in our first NMRA Model Train show in March of 2014. It was sponsored by the Piedmont Division.

We gave our first presentation on 3D printing to the Piedmont Division of the NMRA the same year.

May 2015 we did our second presentation to a group of GA Tech professors.

## Things That We 3D Print

Scenic Details

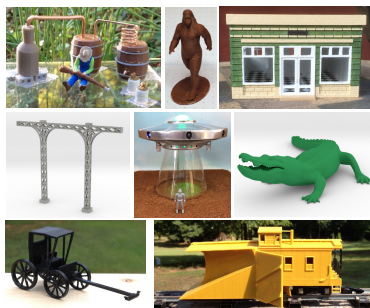
Animals & Birds

Figures

Small Buildings

Vehicles

And more...



**Flickering**

- Campfires
- Burn Barrels
- BBQ Grills



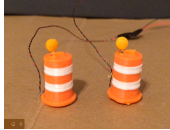
**Illuminated**

- Gas Pumps
- Ghosts
- Buildings



**Flashing**

- Traffic Barrels
- UFO's



**Animated - the InvisaTrax System**

*Coming Soon*



InvisaTrax stems from multiple requests from customers to have Big Foot move through the woods. The system will support all types of objects to be animated on a layout.

## Where Things We Make Are Found

Model Railroad layouts

Farm Toy displays

Slot car layouts

Die cast dioramas

Historical dioramas

School projects

Any place a scale model is needed



Don Bizzozero's Model Railroad



Jason Young's Die cast Diorama



American Flyer Circus Train  
Stop Motion Video by Tom Barker



Model Railroad Layout  
by Pete Silcox



Model Railroad Layout  
by Jimmie Walters



Award Winning Farm Display  
by Christopher Steeb



"Life along the Verde River" Vignettes by Mainenti Miniatures  
River of Time Museum in Fountain Hills, AZ



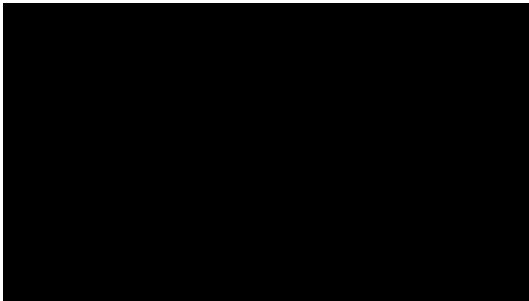
Cuthbert Georgia Civil War Diorama by Jimmy Bradley  
Randolph County Welcome Center in Cuthbert, GA



Cuthbert is located in southwest GA near the Alabama, Florida state lines.

## Importance of Scale Replica's

Courtesy of Jimmy Bradley; Civil War Diorama Cuthbert, GA



## Benefits of 3D Printing

A multitude of unique products becoming available.



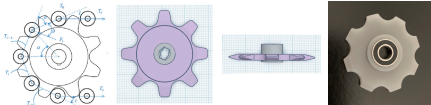
Custom items can be made according to individual needs.



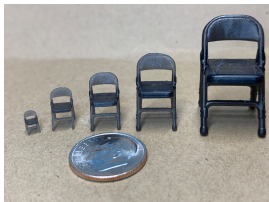
The ability to create and print replacement parts for broken or missing pieces for out-of-production models.



Prototypes, for testing, can be created quickly and cost effectively.



Scalability - Items designed in one scale (S - 1:64) can be reduced or enlarged to other scales: Z - 220, N - 1:160, HO - 1:87, O - 1:48, & G - 1:22.5, or any size in between.



- Unlimited creativity: some say “if it can be drawn in a 3D computer program, it can be 3D printed.”
- 3D printing is a tool-less process that reduces costs and lead times. Whereas milling and mold making both require specialized tools and die making before a part can be manufactured.
- Complex objects can be designed as a single piece or multiple pieces that can be assembled later.
- The use of ABS, nylon, and carbon infused filaments can yield lighter and stronger objects versus traditional resin castings which are heavy and fragile.
- Use of specialized UV resins can meet specific needs for strength, durability, and flexibility of an object.



## 3D Printing Technology



### What is 3D Printing?

3D printing, or additive manufacturing, is a process of making three dimensional objects from a digital file.

The 3D printing process creates an item by laying down layer upon layer of material until the object is completed. Each of these layers can be seen as a thinly sliced cross-section of the object.



## Types of 3D Printers

**Fused Deposition Modeling (FDM)** - filament based 3D printers that typically print at 0.2 mm (200 microns) and can go as low as 0.1mm (100 micron) layer thickness. The average cost is \$200 - \$3,000.

**Digital Light Projection (DLP)** - resin based 3D printers that print at 0.05 mm (50 microns) and can go as low as at a 0.01mm (10 micron) layer thickness. The average cost is \$200 - \$2,000.

**Material Jet, PolyJet, Select Laser Sintering (SLS), Stereolithography (SLA)**- are just a few industrial grade printers used by 3D printing services. The cost of these printers start around \$45,000 and go up from there.

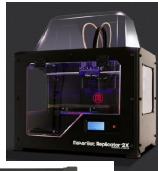


For this presentation we will focus on the consumer level resin and filament 3D printer technology.

## Filament Based Printers Used by CatzPaw

Fused Deposition Modeling  
(FDM - Filament) Printers

- MakerBot Replicator Dual & Replicator 2x (x2)
- Wanhao Duplicator 4S
- All four have dual print heads; providing the ability to print objects in two colors.
- Build area: 9.7" (246mm) X 6.4" (152mm) X 6.1" (155mm)
- AnyCubic Chiron
- Build area: 15.75" (400mm) X 15.75" (400mm) X 17.72" (450mm)



## Filament Based Printers Used by CatzPaw

Filaments

- ABS Plastic in multiple colors.
- Other Filaments include: PLA, HIPS, PETG, Nylon, and a host of others.
- We source our filaments from US based manufactures. Most notably 3DXTech ([3DXTech.com](http://3DXTech.com))

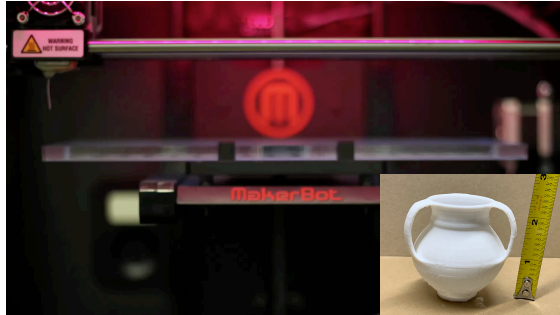
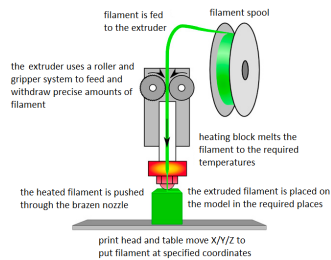


## How FDM Printing Works

The FDM 3D printing process works by melting plastic filament which is deposited a layer at a time through a heated extruder onto a movable build platform.

Each layer hardens as it is deposited and bonds to the previous layer.

For complex shapes, support material is added to overhangs and must be removed during post-processing.



This object took 2.5 hours to print and used 21 grams of filament.

Object Height (59.6mm) ÷ Print Layer Height (0.2mm) = Number of Layers (298)  
Print Time = (Travel Distance x Travel Time per layer) x Number of Layers

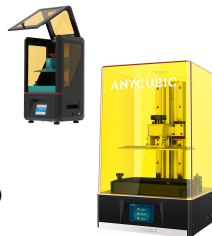


This same vase printed in resin took 3 hours 47 minutes to print and used 18 grams of resin. It had 1172 layers.

## Resin Based Printers Used by CatzPaw

Digital Light Projection  
(DLP - Resin) Printers

- AnyCubic Photon (x4)
  - Build area: 4.52" (115mm) X 2.56" (6.5mm) X 6.1" (155mm)
- AnyCubic Photon Mono X
  - Build area: 7.5" (192mm) X 4.72" (120mm) X 9.84" (245mm)



# Resin Based Printers Used by CatzPaw

## Resins

- HERO Tough in 10+ various colors.
- Standard, Fast+, and Hard resins
- BLUEprint ENG, and Gasket resins.
- We source our resin from US based resin manufacturer 3D Resin Solutions, Inc. ([3dresinsolutions.com](http://3dresinsolutions.com))

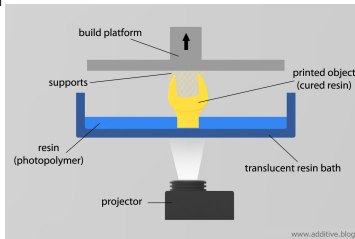


## How DLP Resin Printing Works

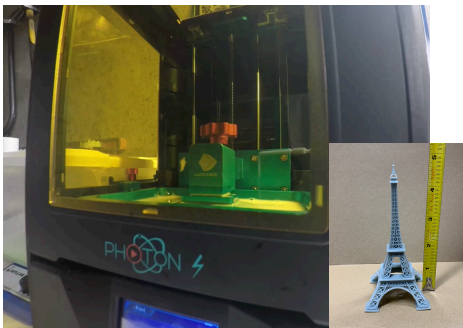
The DLP Resin printing process works by exposing a thin layer of resin to UV light. Each layer of resin hardens as it is exposed by UV light and bonds to the previous layer.

The build plate is raised and lowered in and out of the vat of resin during the process.

For complex shapes, support material is added to overhangs and islands (areas that aren't attached to the model yet) which must be removed during post-processing.



[www.additive.blog](http://www.additive.blog)



This object took 7 hrs 45 min to print and used 11grams of resin.

Object Height (120.9mm) ÷ Print Layer Height (0.05mm) = Number of Layers (2418)  
Print Time = (Exposure Time + Lift Time + Retract Time per layer) x Number of Layers





## 3D Printing Pen

### 3D Printing Pen

- Utilizes FDM technology
- Plastic Filament (same as used in the FDM printers)
- Cost of a 3D Printing Pen: \$50 - \$150

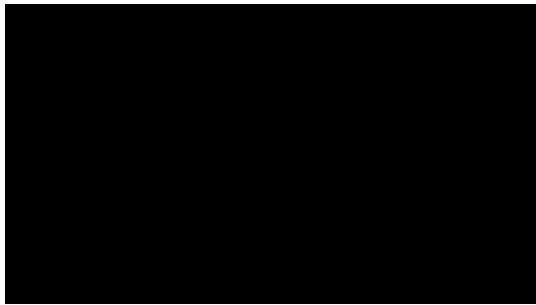


## How 3D Pen Printing Works

3D Pen Printers work like FDM printers extruding filament through a heated nozzle. However, they are controlled neither by a computer nor software but guided instead by your hand. Most 3D printing pens are powered by batteries.

The filament is inserted into the pen, where it's heated to the point of melting and extruded.

As the molten filament leaves the pen, it's rapidly cooled by the air around it. You can draw desired objects on any surface or in thin air. If you're familiar with hot glue guns, 3D pen printers work in a similar way.

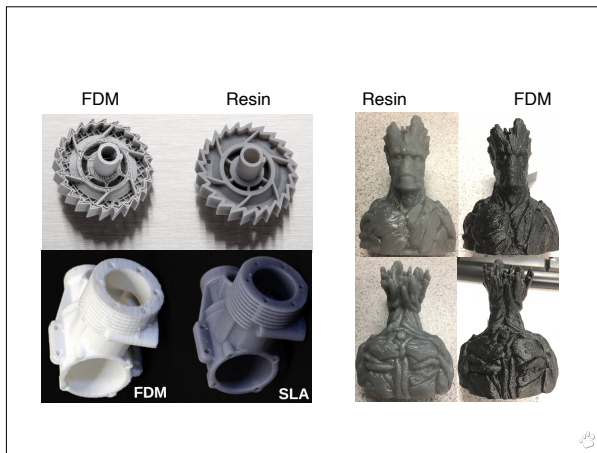


Video courtesy of MakeAnything.



## FDM and Resin Prints Compared

	FDM Printer	Resin Printer
<b>Resolution</b>		
<b>Accuracy Dimensional</b>		
<b>Accuracy Detail</b>		
<b>Surface Finish</b>		
<b>Part Strength</b>		
<b>Complex Design</b>		
<b>Ease of Use</b>		
<b>Applications</b>	Large light weight items with minimal detail, proof of concept	Small detail items, molds for casting, jewelry, dental, functional prototype
<b>Material Costs</b>	\$20 - 50 per 1 kg roll	\$20 - 60 per 1 kg bottle
<b>Environment</b>	Temperature regulated, humidity control, ventilated	Temperature regulated, humidity control, ventilated, UV light blocked
<b>Ancillary Equipment</b>	Support removal, finishing tools	Wash & cure stations, support removal, finishing tools
<b>Pros</b>	Fast, Low Cost Machines & Materials	Great Detail, Smooth Surface Finish, Low Cost Machines
<b>Cons</b>	Low Accuracy, Low Details, Rough Surface	Extra clean-up required, sensitive to UV light exposure



## The Cost of 3D Printing

**Cost of Printing = Material Costs** (*resin/filament, consumables [gloves, masks, rags, acetone, FEP, IPA, kapton tape]*) + **Manpower Costs** (*print preparation, printer operation, post processing*) + **3D Printer Operation and Upkeep Costs** (*electricity, cost of printer, cost of printer parts [nozzles, belts, build platforms, vats, screens], print time*) + **Post-Processing Operation Costs** (*tools/machines to clean a print, smooth a print, and glues/adhesives to assemble a print*)

Print times are based on the layer thickness selected, the height of the model, as well as travel speed and distance. For resin printers the exposure time per layer used and lift and retraction times also play a factor.

FDM printers take longer to print when multiple items are on the build plate.

Resin printers can print one or multiple items in the same amount of time.

**Most print services base their pricing on:** Material selected, Finish selected, Model Volume, Machine Space, Support Structure, Parts Bounds Volume, Part Count, and Post Processing.

- This is the cost to print only.
- If you are designing a new object that you want to sell, you also need to include time to research the object, time for generating initial drawings, time for researching licensing/copyrights/trademarks, and the time to design the 3D object.
- These costs do not include the cost of any software needed to design, repair, and slice a file.

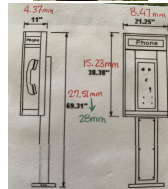
# From Concept To Print

**First** - the spark of inspiration: an idea we have or a request from a customer.

**Second** - research: obtain as many details/measurements/photos/drawings as possible. Our items are true to scale and as realistic as possible.

During this stage we verify that our new product will be unique and not infringe on anyone else's copyright or trademark.

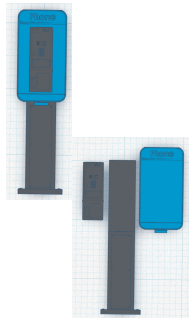
**Third** - the original item's measurements are scaled and if necessary, traditional mechanical drawings are created.



**Fourth** - the prototype design: the object is recreated in a 3D computer aided design (CAD) program.

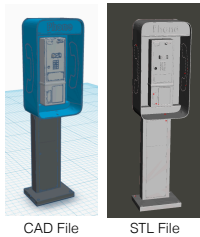
Once the object is created in the 3D program, it needs to be refined and made printable.

- For two or more colors in a print, the object is separated into multiple objects, one for each color. Each separate 3D file is printed in the desired color.



**Fifth** - file conversion: the file is converted from the CAD program's native file format (obj, 3ds, etc.) to a format that the slicing and printer software understands an STL file.

- STL - Standard Tessellation Language
- An STL file describes only the surface geometry of a three-dimensional object without any representation of color, texture or any other attributes.



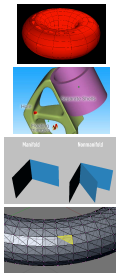
CAD File

STL File

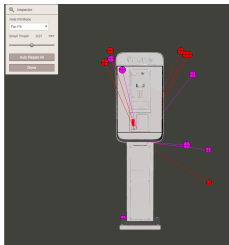


**Sixth** - checking for printability: not all STL files are printable; even if they look good in the CAD program and the STL viewer. To be printable, a model must be:

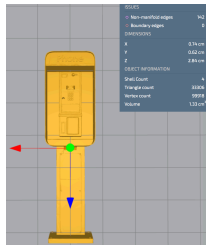
- Watertight - have no holes in the mesh; if you poured water into it, none would leak out.
- Solid - the model must be one solid piece with no surface intersections or separate shells.
- Manifold - each edge must connect to exactly two faces (non-manifold edges connect to three or more).
- Made from Front-Facing Polygons - the normals (fronts) must face out, cannot overlap or have overlapping vertices.



The STL file is opened in a utility program that is capable of checking for issues and correcting those issues, either automatically or manually.



MeshMixer

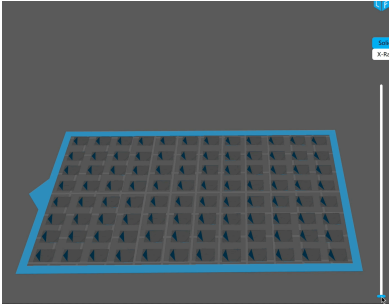


MakePrintable



**Seventh** - slicing: once we know the STL file is printable, it then needs to be sliced into the layers that will be printed.

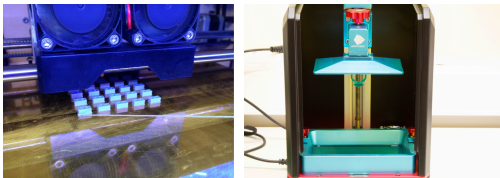
- For FDM prints we use 0.2mm layer thickness.
- For resin prints we use 0.05mm layer thickness.
- The thinner the layer the greater the detail and the longer the print time.
- The quality of a print is also determined by the material used and the software that performs the slicing. There are several slicing programs available, each having their own strengths and weaknesses.
- Supports are typically added during this phase.



Slicing creates the instruction set to be used by the printer, whether FDM or resin, to create each layer of the object. This file is referred to as machine code or gcode and is specific to each printer.



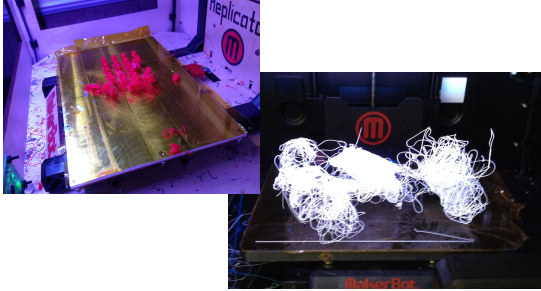
## Finally We Print the Object



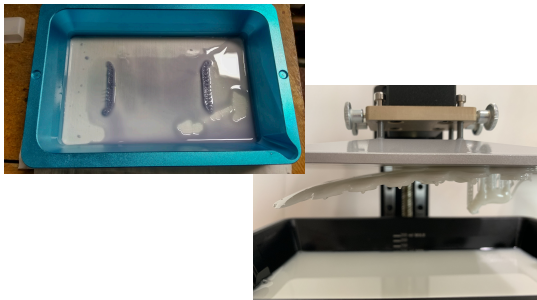
Unfortunately the process does not end here. It is rare that an object prints successfully the first time.



## Sometimes no matter what we do, we get this...



## And also this...



## Which Means...

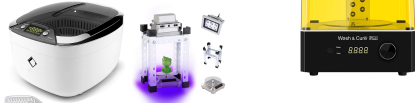
1. We check the printer for potential mechanical issues and perform normal maintenance routines (tram the build plate, check FEP, check cables, remix resin, dry filament, etc.). We also check for environmental issues (humidity, temperature).
2. We may go back to the original 3D CAD file and tweak the design of the object itself to make it more printer friendly. We split the file as necessary creating separate objects and files to be printed.
3. We export and convert the CAD file(s) to STL files; which are then checked for errors and repaired as necessary.
4. We add/adjust supports (one of the most common reasons for a failure next to bed adhesion issues), slice the new file, and print.

*We repeat this process until we successfully print an item. We then print at least five (5) iterations of each item to make sure it is stable and reproducible. Just because it prints once, doesn't mean it will print successfully a second, or third time.*

## Post-Processing

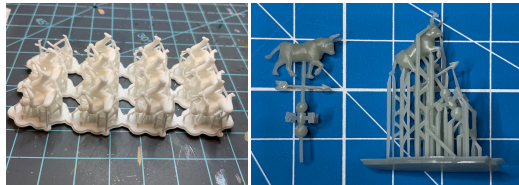
Resin prints require additional post-processing steps that include uncured resin removal. Typically Isopropyl Alcohol (IPA) is used. However, different resins can use other solvents. Once the print is cleaned it is then cured under 405nm UV Light.

There are Wash & Cure stations available or you can use your own combination of UltraSonic Cleaner and UV Lights.



**Support Removal:** building an object by layers requires support structures for overhanging geometries and islands. This is true whether printing with filament or resin.

Supports are removed manually by snapping and/or cutting them off the part. Resin prints should have the supports removed before the final curing process.



For resin prints, heating the object with a blow dryer, heat gun, or placing in warm facilitates easier support removal.

Some objects need extra finishing steps. Whether filling gaps, fixing scarring caused by support removal, layer line smoothing, glueing multipart objects together, or painting.

- **Filling Gaps:** use a 3D printing pen, ABS slurry (ABS filament dissolved in Acetone), resin cured with a UV flashlight.
- **Cutting:** sprue cutters or other diagonal cutters, hobby knife, scalpel, jeweler's saw, hot knife.

- **Sanding:** hand sand with a fine grain sand paper or use an electric sander. Be sure to wear a face mask!



MicroLux® Micro Sander  
<https://www.micromark.com/MicroLux-Micro-Sander>

- **Smoothing:** melting with a Hot Knife or 3D Print Finishing Tool, ABS Slurry, thin layer of resin cured with UV flashlight.



<http://www.modify3dpro.com>

- **Glueing:** Super glue, also referred to as cyanoacrylate glue, or CA glue, works on a variety of materials, including ABS, PLA, PETG filaments and most resins.

Resin can also be used to bind printed parts together, again using a UV flashlight to cure the resin. When working with resin be sure to use nitrile gloves.

- **Painting:** most 3D printed items work best with acrylic based paints. Models can be painted with or without a primer coat. Once the model is painted it can also be sealed with a clear top coat.



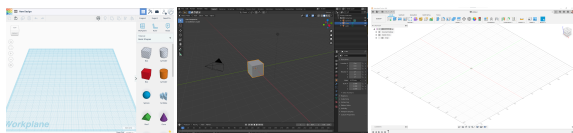
## Software Used and Useful Links

### Mechanical Design

TinkerCad (<https://www.tinkercad.com>)

Blender (<https://www.blender.org>)

Fusion360 (<https://www.autodesk.com/products/fusion-360/free-trial>)





## Organic Design

Daz3D (<https://www.daz3d.com>)

ZBrush (<http://zbrushcore.com>)

Blender (<https://www.blender.org>)



## Other Design Software

SketchUp (<https://www.sketchup.com>)

Rhino 3D (<https://www.rhino3d.com>)

Solidworks (<https://www.solidworks.com/product/solidworks-3d-cad>)

FreeCad (<https://www.freecadweb.org>)

OpenScad (<https://openscad.org>)

Maya (<https://www.autodesk.com/products/maya/overview>)

3DS Max (<https://www.autodesk.com/products/maya/overview>)

Cinema 4D (<https://www.maxon.net/en/cinema-4d>)

MakeHuman (<https://github.com/makehumancommunity/makehuman>)

SculptGL (<https://stephaneginier.com/sculptgl/>)

And a host of others!

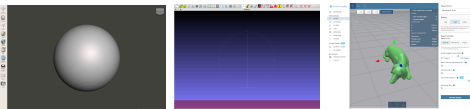
## Modifying & Repairing

Meshmixer (<https://www.meshmixer.com>)

Meshlab (<https://www.meshlab.net>)

Netfabb Online - *has been merged with Fusion360; see details here*  
(<https://help.autodesk.com/view/fusion360/ENU/courses/AP-MESH-REPAIR>)

MakePrintable (<https://makeprintable.com/dashboard>)



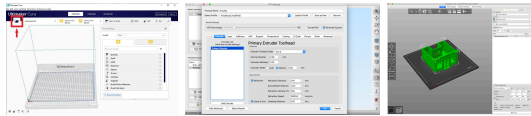
In addition, some slicers can perform basic repairs on imported files.

## Slicing FDM

Cura 3D (<https://ultimaker.com/software/ultimaker-cura>)

Simplify3D (<https://www.simplify3d.com>)

PrusaSlicer ([https://www.prusa3d.com/page/prusaslicer\\_424/](https://www.prusa3d.com/page/prusaslicer_424/))



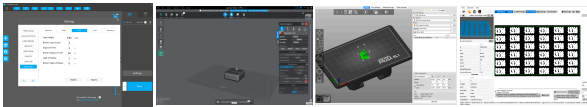
## Slicing Resin

ChituBox (<https://www.chitubox.com/en>)

Lychee (<https://mango3d.io/downloads/>)

Prusa Slicer (<https://www.prusa3d.com/prusaslicer/>)

UV Tools (<https://github.com/sn4k3/UVtools>)  
*Is used to find issues and repair sliced files.*



## Other Slicers

Slic3r (<https://slic3r.org>)

Repetier (<https://www.repetier.com>)

KISSlicer (<https://www.kisslicer.com>)

ideaMaker (<https://www.raise3d.com/ideamaker/>)

OctoPrint (<https://octoprint.org>)

3DPrinterOS (<https://www.3dprinter-os.com>)

MatterControl (<https://www.matterhackers.com/store//mattercontrol/sk/MKZGTDW6>)

And there are a host of others!



## What if I Can't Draw?

Most Popular Sites to Download Files to Print

<https://www.thingiverse.com>

<https://cults3d.com>

<https://www.myminifactory.com>

<https://www.cgtrader.com>

<https://www.turbosquid.com>

<https://www.shapeways.com>

For creating fantasy figures:  
<https://www.heroforge.com>  
<https://titancraft.com>

Note: you may still need to repair files that have been downloaded; they are not necessarily printable.



There is also a search engine for 3D print files called [yeggi.com](http://yeggi.com)

Pre-supported files that have been downloaded may need additional supports added. One support structure does not work for all. Every printer and resin has specific requirements that need to be taken into account.

There are also a host of artists who have a “Patreon” site (<https://www.patreon.com>) where you can subscribe and download models of items they have created.

## Can I sell 3D prints of the files I have downloaded?

The short answer is: **No**.

Most all creations published and shared on websites are exclusively reserved for private and personal use. That means you can not sell the model or any derivative of the model for economic or financial gain. For example, you cannot sell the digital model, a derivative or adaptation of that model, nor can you sell prints of the model or make trade of it.

There are exceptions, 3D models with a *Creative Commons License* stating *Commercial Use* are allowed for resale.

The best thing to do if you want to sell a printed version of a 3D file is to ask the designer directly to see if they will give you permission. Be sure to get that permission in writing.



## I don't have a printer.

But I designed an item, where can I get it printed?

Most Popular 3D Printing Service Providers

<https://www.shapeways.com>

<https://i.materialise.com/en>

<https://www.sculpteo.com/en/>

<https://www.xometry.com>

<https://www.hubs.com>

Also check your local library, schools, and Maker Space as most have 3D printers for the public/students to use.





Q: What is the best software: CAD, repair, slicer?

A: The one you take the time to learn and use.

Q: Can we ask you more questions?

A: Yes. You can email questions to [info164@catzpaw.com](mailto:info164@catzpaw.com)

You can also follow us on FaceBook, look for CatzPaw164 or use this link: <https://www.facebook.com/Catzpaw64>

Q: Do you do custom work?

A: Yes, sometimes. Contact us with your project and we will let you know if it something we can do for you.



Q: What does your (CatzPaw) setup look like?

A: An organized mess. But seriously, it is easier to show you. The following video is a brief overview and walk-through of our setup.

## CatzPaw's Workspace

May 2022



## NMRA Partnership Program

Discount Code: NMRA2019



[www.catzpaw.com](http://www.catzpaw.com) • [info164@catzpaw.com](mailto:info164@catzpaw.com)



## Addendum - Items Missed in Video



**Digital Caliper** - can be purchased at local hardware store or online. (<https://www.micromark.com/Digital-Caliper-with-Standard-Numerals-6-Inch-Capacity>)

**Model Railroaders Ruler** (<https://www.micromark.com/Model-Rr-Rule>)  
Has scale graduations in HO, O, S and N gauge, plus inch and millimeter calibrations. Decimal equivalent chart and reference table on the opposite side. 1 inch wide x 12 inches long. Stainless steel.



**Infrared Thermometer** to check temperatures of build plates, resin, filament, heated chambers, etc. These can be purchased from Home Depot, Lowes, Ace Hardware, or Amazon.

## Addendum - Items Missed in Video



**Nitrile gloves** in glove holder with paper towels and blue shop towels in holders. Glove holder was purchased from Amazon. These are located right above the cleaning area and close to the printer. Both need to be accessible and within arms reach.

Lots of empty plastic shopping bags to dispose of contaminated gloves, shop towels, supports that have been removed, and failed prints. These also need to be easily accessible and close at hand, so I have mine hanging from hooks underneath the printer stand.

Once the bag is full, it is closed and placed outside in the sun for natural curing of the resin.

Large disposable plastic containers. I use these to dispose of IPA that can no longer be filtered. The IPA is poured in the container and once the container is full it is placed outside in the sun for natural curing of the resin and natural evaporation of the IPA. When done only cured resin will be left in the bottom of the container. I get these extra large ones from a local store that sells infused oils and vinegars. You can also use empty milk containers or whatever you can find. You can also use empty glass jars as well. I break things, so I use plastic when possible.

Once resin is cured it is not longer considered hazardous waste and can be placed in the trash for pickup.

NOTE: uncured resin and IPA are considered hazardous waste and must be handled and disposed of according to local regulations.



## MicroMark Items Mentioned in the Video

MicroMark is also a member of the NMRA Partnership Program.

Be sure to use the NRMA discount code if you place an order.

**MicroLux® Micro Sander** (<https://www.micromark.com/MicroLux-Micro-Sander>)

A reciprocating Micro Power Sander with 8 different interchangeable sanding shapes that snap into the working end with just a twist. Works on wood, metal or plastic.

**Pic-N-Stick** (<https://www.micromark.com/Pic-n-Stick>)

Pick-n-Stick is a 2-1/2 inch long plastic stick with a waxy adhesive on one end. To use, just press the adhesive end against the part you need to hold. To remove, just twist. Adhesive grips tightly, but won't transfer to the part.

**Microbrushes** (<https://www.micromark.com/Microbrushes>)

Use to apply a tiny amount of liquid adhesive, paint or lubricant (as little as one-eighth of a drop!). Microbrush tips are non-linting and non-absorbent, and feature bendable handles

