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## **TROUBLESHOOTING AND CLEANUP TECHNIQUES FOR 3D PRINTING**

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## AGENDA

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- Understanding the 3D Printing Technologies
- Choosing a Material
- Working with Color?
- Choosing a File Format
- Getting Quality Results

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Most materials are printer specific. And within each printing technology there are specific available options.

Only certain printers can print texture or offer specific color options. If your project needs color, and more specifically textured color, then that will be a critical factor on choosing a 3D Printing Technology for production.

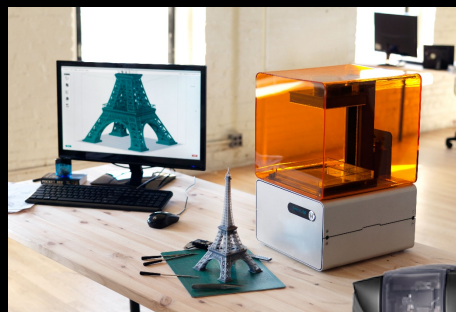
# SOME IMPORTANT THINGS TO REMEMBER...



- Regardless of software, every model is getting reduced to a triangulated mesh object.
- The printer is performing small several-micron-thick Boolean slices of your model in order to divide the model into an X and Y.
  - If your model is failing to Boolean in the modeling software, it will fail in the print software.
- Gravity is your friend and your enemy.
  - The same force keeping the print material adhering to the plate is working relentlessly to topple the whole object over.

## CATEGORIES OF 3D PRINTING TECHNOLOGIES

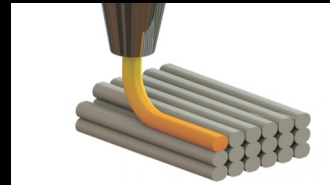
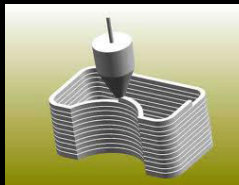
- Each printer lays out material in slices in terms of X and Y axis
- Each successive slice forms the Z axis
- The differences between technologies relate to how the material is applied and cured.
- Each technology carries with it specific considerations, limits, and advantages in terms of part stage arrangement.



## FUSED DEPOSITION MODELING (FDM)



- Heated material squirted onto a model in successive layers from a nozzle.
- Like a hot glue gun with precision.
- Can support some LIMITED overhang without support material.
- Most common printer technology
- Affordable
- Multiple materials, colors, temperatures, and flexibility
- Cleanup:
  - Some support removal
  - Cutting and sanding may be required
  - Epoxy coating for waterproofing
- Examples:
  - Makerbot, Replicator
  - Stratatsys, uPrint and Dimension



## FDM WITH CONCRETE

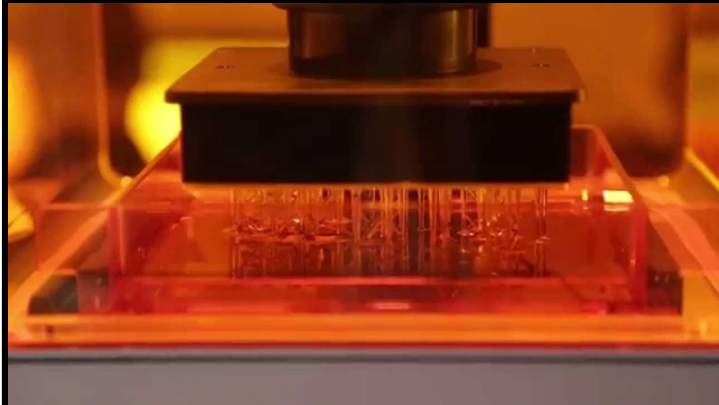
- Large scale
- Architecture, landscape, and other applications

Any material that could be ejected as a liquid and fused to an existing surface could probably be FDM



## STEREOLITHOGRAPHY (SLA)

- “Photopolymerization”
- Laser heats liquid resin, causing the top-most layer of resin to solidify.
- Table then lowers into the tank allowing another layer of resin liquid to form over the solid.
- Modern evolutions of the SLA technology have inverted this process.
  - Resin tanks with a transparent bottom.
  - Lasers cure the material from below.
  - Parts are grown suspended from a platform above the resin tank.



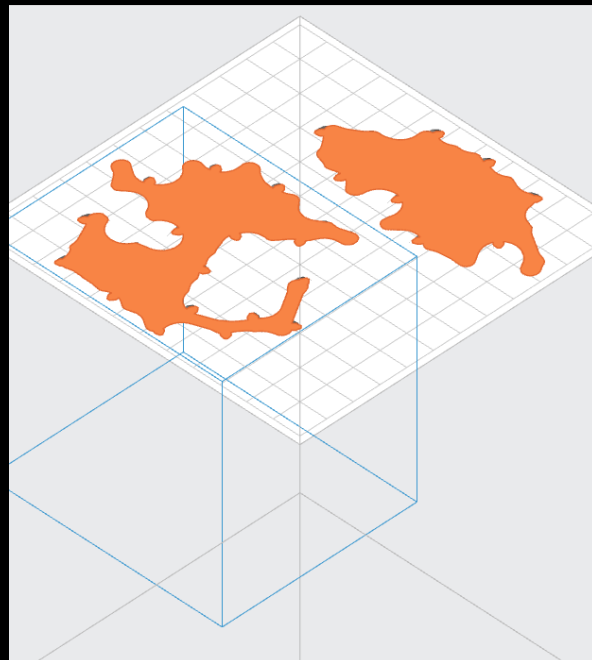
- Examples:
  - Formlabs Form 1, Form 1+, and Form 2
  - EnvisionTEC Micro, Perfactory

## SLA PRINT PROCESS

1. Printer begins by laying down a supporting layer. Each layer represents a slice of the part in X and Y axis

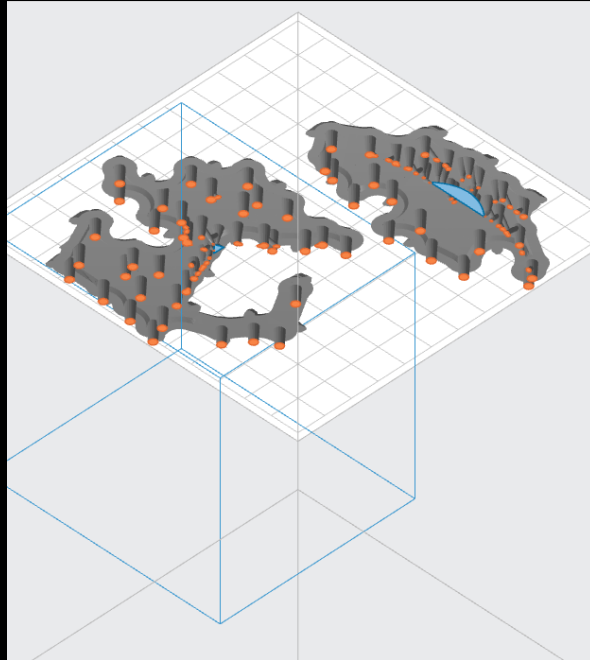
### Note:

The process detailed here is for a Stereolithography (SLA) printing process such as found on Formlabs Form printers.



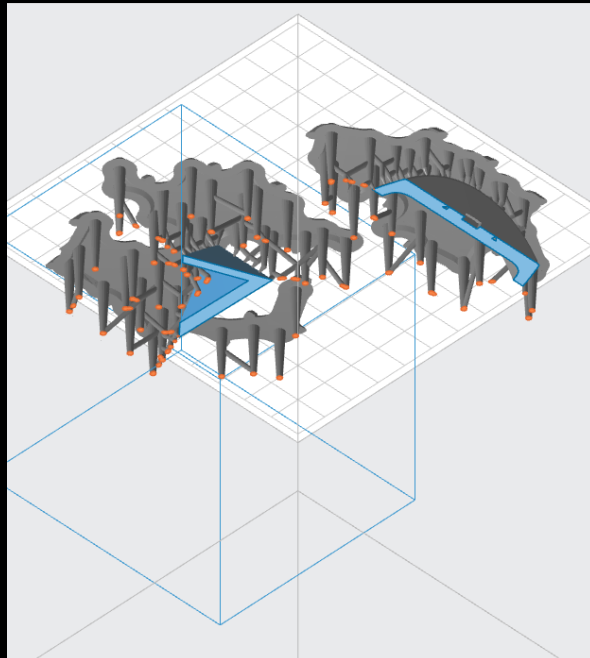
## SLA PRINT PROCESS

2. Printer peels each successive X and Y layer. Successive layers add up to form the Z axis.
3. Once the foundation is solidly built, supports will be extended from the foundation to the parts as they are built.



## SLA PRINT PROCESS

... The parts are built up with each successive layer

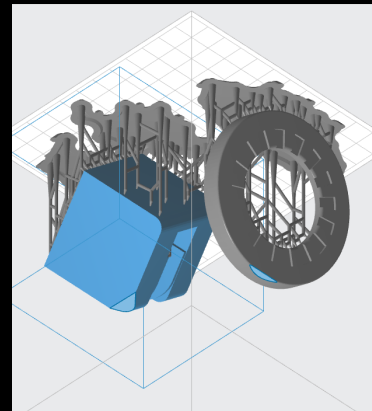
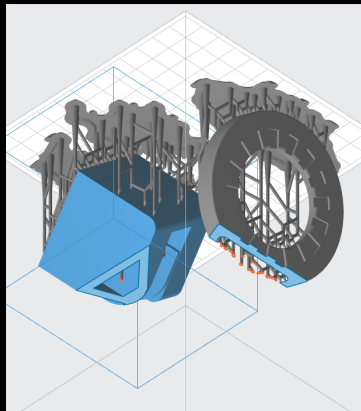
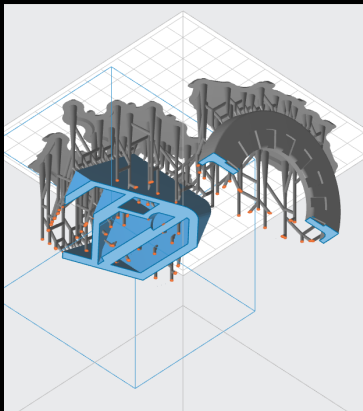


# SLA PRINT PROCESS

... Layer after layer

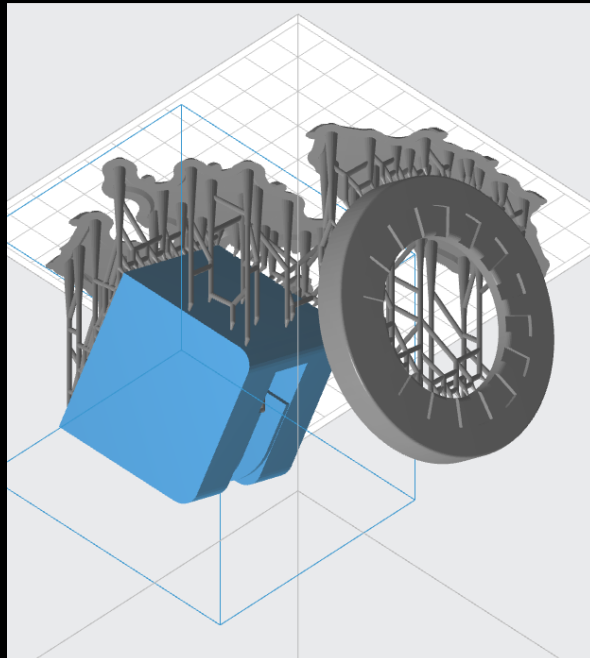
## Continuous Liquid Interface Production (CLIP)

- Also called Continuous Pull 3D Printing
- Instead of a laser point curing each layer between separate peels, in the CLIP process a projector cures each layer instantly and the peel is constant.
- This emerging evolution of SLA print technology promises vast speed increases.



# SLA PRINT PROCESS

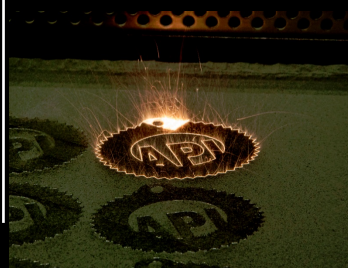
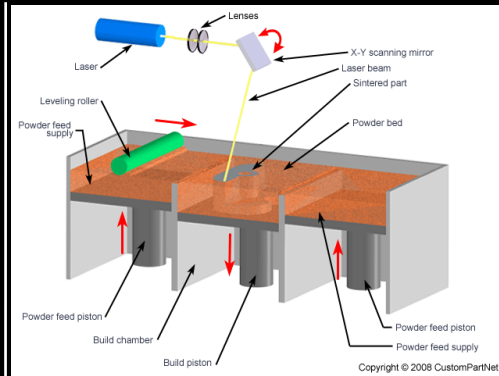
4. Once complete the parts are finally extracted from the print tray for cleaning and finish.





## LASER SINTERING (SLS)

- “Granular materials binding”
- Lasers melting engineered powdered material
- Material powder rolled over surface.
- Laser heats and melts material.
- Direct Metal Laser Sintering (DMLS)
  - SLS with metal material dust
  - Higher power laser
- Electron Beam Melting (EBM)
  - SLS in a vacuum
  - Medical implants
  - Materials that have an affinity for oxygen



## POLYJET

- Works similar to ink jet printing
- Instead of jetting ink, a PolyJet printer jets a curable liquid that is instantly cured using UV light.
- A water soluble support material surrounds the part during printing and provides support for areas standing off of the build platform.
- Cleanup:
  - Requires post-printing support removal by hand or with water in a solution bath.
- Example: Object 30





## LAMINATED OBJECT MANUFACTURING

- Thin sheets of paper, plastic, or metal are cut using lasers, blades, cutters, water, or other devices.
- Subsequent layers are laminated together using an adhesive.
- Some printers (especially paper based) provide low cost options.
- Cleanup:
  - Waste paper or material removal.
  - Sanding for smoothing
  - Sealant or coating for water resistance or finishing
- Example:  
MCOR Iris (right)



## DEMYSTIFYING PRINTER SPECIFICATIONS



- Learn the specifications of the 3D printer being used.
- Learn the specifications of the material being used to print.
- Work with your vendor to insure your design meets the printer's capabilities
- Where printer, material, and design do not work to achieve the desired result:
  1. Amend the design as necessary to meet the printer and material specifications.
  2. Choose a different printer, technology, and material that meets the needs of the design.

Formlabs <https://formlabs.com/3d-printers/tech-specs/>

Modeling Specs: <https://support.formlabs.com/hc/en-us/articles/115000024504-Design-Specs>

Shapeways: <https://www.shapeways.com/materials>

Each material and process that Shapeways supports has its own material specific listing

Example material: Frosted Detail <https://www.shapeways.com/materials/frosted-detail-plastic>

## DECIPHERING THE TERMINOLOGY



- Most print manufacturers or service providers will reference these common attributes:
  - Minimum supported wall Long walls that are supported on one single length or on two or more lengths. Unsupported are always weakest and most critical.
  - Minimum unsupported wall
  - Minimum supported wires Thin wire like structures that interface at only one end or at both ends. Unsupported are always weakest and most critical.
  - Minimum unsupported wires
  - Minimum embossed detail Detail such as text that projects out from the surface or into the surface. Prevents detail from being obscured or bonded over.
  - Minimum engraved detail
  - Minimum hole diameter
  - Minimum drain / escape hole diameter Some processes require escape holes to allow trapped material or gas to be evacuated. Prevents embolisms and bonding across any holes.
  - Minimum Clearance How much distance must be provided to keep material from bonding across the separation between components or details.
  - Interlocking and enclosed parts
  - Multiple parts per model file
  - Minimum unsupported overhang length or angle, if any.
- Other specific details may be required depending upon the print technology, process being desired, or the vendor's specific pipeline. Do your research!

## CHOOSING A MATERIAL



- Standard Materials
- Specialized Materials
- Materials Requiring Post-Print Treatment
- Deciphering Material Specifications

## WORKING WITH COLOR

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- Which printing technologies can print color?
- Which file formats support color?
- Pipelines for projects using color and textures

## PRINTING COLOR

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- For FDM printers, color is added based on Filament.
  - For most Objet / Stratasys printers color is applied in the Objet software on a per shell basis.
  - For SLA printers, color is added based on which resin is used in the tank.
  - For MCor printers, color is applied by actually printing ink via a bubble jet printer onto each successive paper layer.
- 
- Graphics will be added soon.
  - Supporting Illustrations will be added to all subsequent slides.

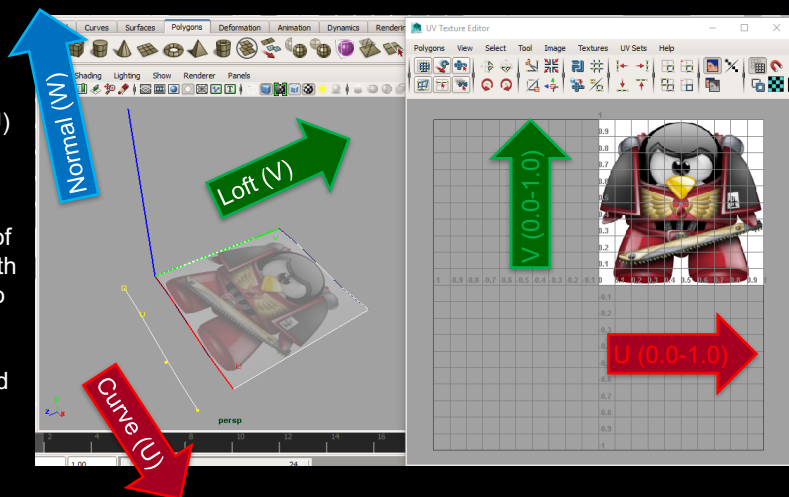
# PRINTING TEXTURED COLOR

- Overview of UV Coordinates
  - UV Unwrapping for texturing
  - NURBS is made of U and V coordinates and is automatically unwrapped when converted to polygon.
  - VRML or OBJ files
- 
- Graphics will be added soon.
  - Supporting Illustrations will be added to all subsequent slides.

## TEXTURE (NURBS)

NURBS and UV coordinates:

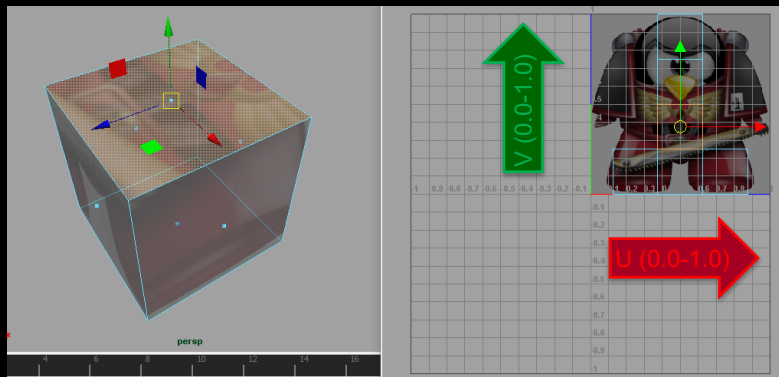
- A curve is an infinite number of points projected along a path (U) ranging in value from 0.0 to 1.0 (0-100%)
- A surface is an infinite number of curves (U) projected along a path (V) ranging in value from 0.0 to 1.0 (0-100%)
- Texture coordinates are mapped from 0.0 to 1.0 (0-100%) in UV.
- NURBS Surfaces are automatically UV unwrapped



# TEXTURE (POLYGONS)

Polygons:

- Polygons are not inherently linked to UV coordinates at a surface level like NURBS.
- In polygons each vertex can store a U and V coordinate for each face it contributes to.
- If a vertex contributes to three faces it can store three different coordinates, so each face can project into different regions of the UV aperture.
- When a vertex stores the same value for multiple faces that it contributes to we call those edges “sewn”



# FILE FORMATS FOR COLOR 3D PRINTING

- OBJ format
- VRML format (Virtual Reality Modeling Language)
- AMF (Additive Manufacturing File Format)
- X3D
- 3DS
- Color STL (Careful, most STL files do not contain color)
- Consult with the print vendor for specific format and submission requirements. Most vendors will provide support information, like the company here:

• <http://www.lgm3d.com/blog/exporting-a-model-with-color-and-or-texture-maps>

# COLOR 3D PRINTING SPECIFICS



- When including File Formats with Textures:
  - The texture needs to be sourced from the same folder as the geometry file.
  - Most companies require these files to be compressed together into a ZIP archive.
- Shapeways, Designing for color 3D printing in sandstone tutorial:

• <https://www.shapeways.com/tutorials/designing-for-better-colors-in-full-color-sandstone>

# 3D PRINTING SPECIFICS - OBJ



- OBJ:
  - Warning: the OBJ format can include polygon quads.
  - Quads need to be absolutely planar. Any non-planar quads need to be tessellated into triangles prior to export!
  - From Maya, export with the Materials option checked but all other options off.

## 3D PRINTING SPECIFICS - VRML



- VRML:
  - From within the 3DS Max or the Maya 2015 VRML plug-in be sure to generate “Color per Vertex”.
  - Maya-specific issues:
    - Autodesk has retired VRML export as of Maya 2016!
    - According to Autodesk, “the source code can be found in the Maya 2015 devkit under the path: obsolete /devkit/obsolete/games/vrml2Export”.
    - Maya 2015 does include a VFML2 export plug-in, available from the plug-in manager.
    - Some aspects of the Maya VRML2 exporter may not export for print properly:
      - One alternate pipeline would be to export to OBJ and then use a tool like Meshlab (<http://meshlab.sourceforge.net/>) to convert to VRML.
      - Another alternate pipeline would be to use Direct Connect from Maya to 3DS Max and then convert to VRML via 3DS Max.
  - Shapeways, 3DS Max to VRML tutorial:  
[https://www.shapeways.com/tutorials/full\\_color\\_3d\\_printing\\_from\\_3ds\\_max](https://www.shapeways.com/tutorials/full_color_3d_printing_from_3ds_max)

## COLOR WITH STRATASYS



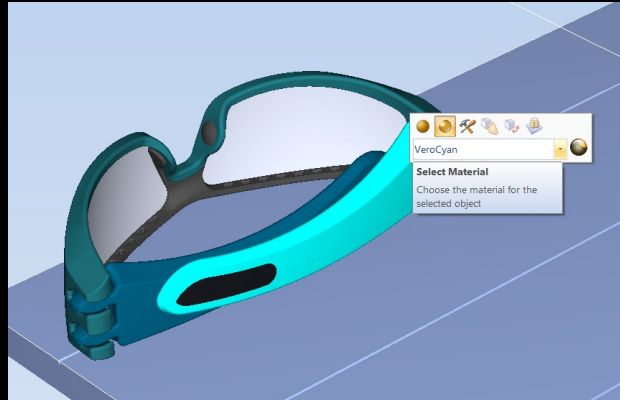
- Objet / Stratasys Digital Materials and Color FAQ's:
  - <https://www.manualslib.com/manual/1156232/Stratasys-J750.html?page=1>
  - <http://www.d2m-solutions.com/faq-stratasys-j750-3d-printer/>
- Stratasys uses VRML for Color:
  - “vertices and edges for a 3D polygon can be specified along with the surface color, UV mapped textures, shininess, transparency, etc.”



## DIGITAL MATERIALS WITH STRATASYS



- Digital Materials are selected within the Polyjet Studio software and proprietary to each specific Stratasys 3D printer
- Digital Materials are assigned per-shell.
- The Objet printing process naturally bonds materials which are zero distant from each other.
- So objects that have been broken up into individual adjacent manifold shells can have different digital material and percentage assignments and due to the zero distance between them, they will be bonded during curing into a uniform final printed part.



<https://www.cati.com/blog/wp-content/uploads/2016/08/SOLIDWORKS-1472240669595-1.jpg>

## CHOOSING A FILE FORMAT



- The STL Format
- Others...

## GETTING GOOD RESULTS

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- What is “Clean”?
- Best Practices
- Working with Vendors
- Common Problems
- Uncommon Problems
- Staging a Model on the Printer
- Where the science ends and the craft begins...