



PolyJet Design Guide



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DIRECT MANUFACTURING



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Material Selection, Design Tips & Color Application

At the center of any great 3D printed model is thoughtful planning and a solid design. While the 3D printing industry offers several methods for printing 3D models, PolyJet technology presents a range of possibilities unlike any other.

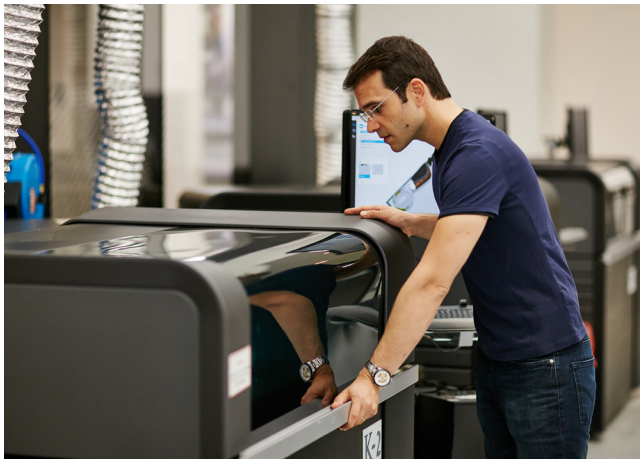
In a nutshell, the PolyJet process begins with your design in the form of 3D CAD data. You then need to convert your CAD file into an STL file which slices it into multiple 2D cross-sections. From there you can upload it into Stratasys Direct's quoting engine.

The print head jets and cures photopolymer material simultaneously, cross-section by cross-section with ultraviolet (UV) light. The machine adds support structures using specially formulated

material to support free-floating features. After each cross-section, the build platform lowers and the process repeats until the full part is formed.

Once we remove the completed parts from the build platform, we use water and manually break away supports, apply any finishing procedures, pack and ship the part to you.

Beyond the basics of how PolyJet technology works, this guide will help you decide when to use it, show you how to select materials for the process, prepare your design files for printing and explain the nuances of designing for the process to ensure a flawless design that is ready for print.



Benefits and Applications

The first step of this process is understanding the main benefits of PolyJet technology and determining if it's the best fit for your application. Consider the following features before getting started.

Multi-Color and Multi-Material 3D Printing

PolyJet incorporates multiple material properties and full color into a single model, produced in one build process (no secondary operations). PolyJet is capable of printing more than 500,000 distinct colors bringing designs to life in vivid color and full feature detail that convey final product aesthetics. These capabilities make PolyJet the ideal solution for fast and realistic parts for conceptual modeling and functional prototyping.

Speed

PolyJet helps bring products to market quickly by both conceptualizing and forming designs early on in the product development cycle. The process is extremely fast compared to other 3D printing technologies, but exact turnaround time depends on the size of the part and desired resolution. Typically, Stratasys Direct is able to ship PolyJet parts within two to three days after receiving an order.

High Resolution

PolyJet is considered one of the most dimensionally accurate 3D printing technologies because it uses high-resolution ink-jet technology to produce parts quickly and economically. PolyJet photopolymers and the ability to print in thin layers—as thin as 27 microns—allow designers to produce highly realistic, accurate and functional 3D models with precision. Since this process does not involve heat, warping and shrinking are unlikely to occur.



Considerations for Material Selection

The next step is to carefully select materials for your application. PolyJet uses photopolymer thermosets that start as liquid then are cured with UV light. There are several base resins that can be blended together to create a variety of material properties and colors. These hybrid materials simulate thermoplastics and elastomers used in production applications.

It's critical to carefully examine each material's mechanical properties in order to ensure they meet your specifications before you start the design process. Refer to our [PolyJet material spec sheets](#) for mechanical properties.

1.0 Base Resins

Base resins refer to the unblended material that comes straight from the material cartridge. Stratasys Direct offers several base resins that may be used alone or blended to create composite Digital Materials. These base materials are ideal for presentation and display models, form and fit prototypes, patterns and simulating products during functional testing for early performance evaluations.

2.0 Transparent/Translucent

Stratasys Direct offers translucent Vero (Rigid) Clear material, a clear, rigid material that enables light to pass through. Vero (Rigid) can be used to evaluate form and fit of assemblies in order to visualize the placement and interface of internal components and features. Other applications include modeling for artistic expression, substituting for cutaway demonstration samples, and models that provide a visual analysis of fluid flow through a product.

Transparent PolyJet parts can be polished to simulate commercial thermoplastics. It demonstrates strength, stiffness, elongation and impact resistance similar to that of polymethyl methacrylate (PMMA) commonly known as Plexiglass. Use VeroClear as an alternative to glass for lenses, clear covers, dispensers and light pipes.

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Simulated Polypropylene

Stratasys Direct offers a PolyJet material that simulates the characteristics of polypropylene. The material is Rigur, a semi-rigid, strong and tough material with almost twice the flexibility and impact resistance, as well as three times the elongation of Vero materials.

The materials often used to prototype containers, packaging, toys, battery cases, laboratory equipment, loudspeakers and automotive components. It's also helpful when prototypes include flexible features.

Rigur has been formulated to demonstrate improved dimensional and visual characteristics. It is also bright white in color and displays better surface finishes than other PolyJet materials.

For this reason, it's a good option for visual applications. Additionally, higher temperature resistance and increased strength make it the better choice for form, fit and light functional testing when prototyping polypropylene parts.

Rubber-Like

Agilus is a rubber-like material that emulates thermoplastic elastomer and is ideal for visual, tactile and functional applications. This includes non-slip surfaces, soft-touch and sealing faces, rubber surrounds, overmolding, buttons, knobs, grips, gaskets and hose assemblies.

Integrating rubber-like material in your next prototype will allow you to match the flexibility of production elastomers or run tests on a variety of slightly different options to determine the right feel.

Engineering Plastic

Stratasys Direct offers two PolyJet materials that can be used to simulate engineering plastics- Digital ABS Plus and Rigur. These materials have higher thermal resistance properties and toughness.

Because Digital ABS Plus retains its rigidity and toughness in thin-walled parts, it presents an ideal solution for consumer goods prototyping including electronics and small appliances. Digital ABS Plus can be used for functional prototypes, prototype tooling for injection molding and manufacturing aids, such as jigs fixtures and gauges.

Multi-Color

Another advantage of PolyJet is the extensive color palette. The wide array of color options ensure product realism. [See page 13](#) of this guide for instructions on applying color to your model in various software programs and file formats.





Prepare Your STL File

Standard Triangulation Language (STL) is a file format used in rapid prototyping. The process consists of approximating CAD surfaces with triangles. Every 3D form is made up of several polygons that are defined as flat shapes bounded by closed circuits. Each polygon contains n number of sides and can be represented using n-2 triangles.

For example, imagine a box that has six sides, each one of them is a polygon. Each side

is a square, meaning the structure can be represented using 12 triangles. Each triangle has a direction within a three-dimensional shape.

The direction is expressed by the normal of the triangle (the outward direction is represented by the normal). The two triangles illustrated here, though they are identical, are facing in opposite directions. Your CAD file must be converted to an STL file in order to print.

Common Errors in CAD to STL Conversion

While CAD software allows for the creation of STL files, the process doesn't always yield a printable output.

There are four common errors in CAD to STL conversion to be aware of. If you run into these issues, they will need to be fixed so that the design model can be printed successfully.

1.0 Inverted Normals

Inverted normals arise when the surface direction is inconsistent. Occasionally, the interpretation of the surface between CAD and STL results in an inverted normal.

2.0 Zero Thickness

In order to be fabricated, 3D models must have a volume larger than zero or a positive thickness. Sometimes, a model is represented in CAD using 2D, which has no volume, and therefore no thickness. For the file to be printable, you need the measurements to hold volume.

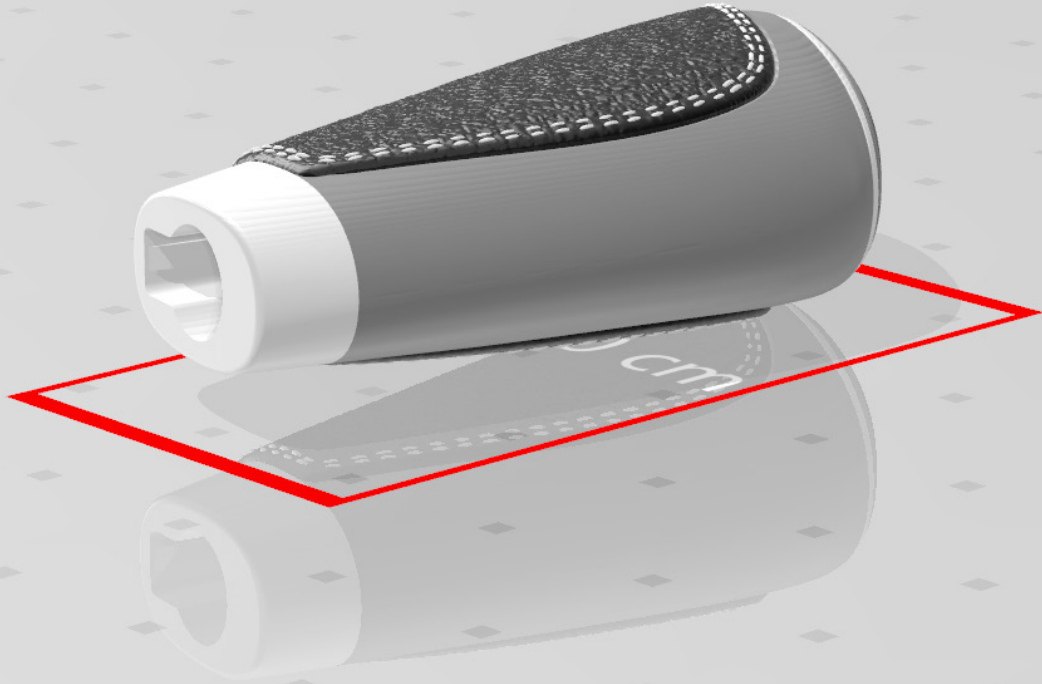
3.0 Bad Edges

The third common error is bad edges or gaps occurring between triangles. There are two types of bad edges: near bad and real bad. Near bad edges have a neighbor triangle that surpasses the set threshold for closeness, whereas real bad edges typically enclose a hole in the shape.

While the former is automatically detected and closed by software solutions, the latter is more complex and may cause a fault due to zero thickness. To solve this problem, you can add triangles to close the hole or create thickness and make the part printable.

4.0 Non-Manifold

The final error that we commonly see in STL files is non-manifold objects—where an edge touches more than two faces. These errors can be mitigated by inserting space between boxes to make sure the model has two distinct shells.



Common STL Manipulation Actions

STL manipulation software solutions can be used to convert your design into a 3D-printable format and make files editable outside of the CAD software. Here are some manipulation techniques that can help ensure the Stratasys Direct team can adjust and prepare your design files for printing.

Cutting

Cutting can be used to divide one large design in to smaller parts that can each be printed separately and then assembled in post-processing.

Cutting can also be used to contour the design or divide it into multiple different sections. Consult the documentation of your CAD software suite for more details.

Labeling

Labeling various parts of your design with text or an image will help us identify and track the different parts on the same job. When it comes to creating a design that will include multiple materials, create the label on a separate file or shell to indicate any differences or special instructions.

Boolean Operations

A Boolean tool can add, subtract and intersect space between two objects. If the Boolean option is not used, it is possible that overlapping parts will be assigned a random color, or areas with space between walls may generate supports and separate during handling.

Designing for PolyJet: Key Considerations

Building an understanding of the mechanics and best practices for PolyJet photopolymers and corresponding 3D printing platforms is key to ensuring optimal success. Each 3D printing technology comes with unique nuances and design limitations in terms of tolerance, feature, definition, material properties and more.

Be sure to take these considerations into account so that offsets, variances and modifications can be integrated with your CAD model(s). Consult your project engineer on the particular equipment, material limitations and design guidelines early on.

Design Considerations	Specification
Minimum feature size	0.020"
Featured edge	0.020"
Font (raised or recessed)	0.012"
Minimum wall	0.030"
Layer thickness	27 microns (0.00106")
Resolution	X-axis 600 dpi; Y-axis 600 dpi; Z-axis 1,800 dpi
Tolerance	+/- .005" or +/- .001 inch over inch, whichever is greater

Feature Size

Stratasys Direct recommends a minimum feature size of 0.020". Although PolyJet can achieve a feature size of 0.012", 0.020" will apply for a majority of designs. Note that ultra-small features are more likely to withstand the finishing process with flexible materials, versus those produced with rigid materials.

Wall Thickness

In terms of wall thickness, Stratasys Direct recommends .030-.040 despite the fact that the technology is capable of as little as .010".

Remember, the design feature needs to not only be printable, but it also has to survive the support removal process. It will also need to be able to survive packaging and shipping. That's why we recommend .030-.040.

- The best practice for models that will be created with rigid PolyJet materials is a minimum wall thickness of 0.040". At .040" and thicker, rigid models are far more likely to survive the finishing process
- The best practice for models that will be created with flexible PolyJet materials is a minimum wall thickness of .030". At .030" and thicker, flexible models are far more likely to survive the finishing process.

Bosses

In order for embossed and engraved details to appear visible, the designs should be at least 0.20" above or below the surface of the part.

Holes and Channels

Holes and channels should measure greater than 0.020" in width. Holes should be vertically oriented to maximize the feature's circularity. Also note, channels with a depth-to-width ratio of 2:1 are particularly difficult to clean between uses.

Pins

Stratasys Direct recommends a 0.020" minimum pin diameter, unless they are required to be functional, in which case they should be closer to 0.080". An alternative option could be to insert an off the shelf pin into the drilled hole.

Joints

Joints should have a clearance of 0.008" around all sides, which should also be accessible to allow cleaning or removal of support materials build up in the gap.

Living Hinges

When designing living hinges for PolyJet, select a low durometer material for the hinge. We also recommend printing the hinge with the same materials as the two rigid pieces it connects. These structures are commonly used for caps, closures, clips and clamps.

Orientation

With PolyJet, support removal does not impact surfaces to an extreme degree, so part orientation isn't as critical as it is with other 3D printing processes.

Keep in mind PolyJet support material tends to be more expensive. Visual surface designs could be orientated to limit support usage, or so that the surface faces upward to ensure a smooth surface finish.



Overmolded parts can simulate grips and rubber-like surfaces on prototypes

Designing Overmolded Parts

Overmolding is the process of manufacturing a component with flexible and rigid elements in a single model produced in one build process (no secondary operations).

Overmolding enables you to incorporate multiple durometers and textures into one component which helps enhance feel, appearance and durability.

To manufacture a PolyJet overmold model, we utilize the rubber-like Agilus material to create the flexible (overmold) component of your design. Choose from a wide range of durometer (Shore A hardness) values.

To build the substrate (rigid) aspect of your model, we utilize VeroWhite Plus.

This solution is much less costly and time consuming than the alternatives, such as injection and RTV molding for overmolded prototypes.

Appropriate Substrate (Rigid) Material

The substrate is the rigid element of the overmold design. Refer to the VeroWhite Plus specification sheet at www.stratasysdirect.com.

Appropriate Overmold (Flexible) Material

The overmold is the flexible element of the overmold design. The flexible Agilus Black material has excellent tear resistance and elongation at break properties. Refer to the specification sheet at www.stratasysdirect.com to choose the best Agilus Black Shore A value for your application.

Designing Multi-color Parts

PolyJet (Rigid) Multi-Color allows you to print models with gradients, textures, transparent and opaque components.

There are three file formats or workflows that multi-color PolyJet machines can read: Shell-Based File Format (Multiple .STLs), VRML File Format and GrabCad Print. These file formats have different requirements and color application methods.

Shell-Based File Format (Multiple .STLs)

If the model you wish to print is separated into shells (different parts for one assembly), you can use a shell-based file format that allows you to assign different colors and textures per shell.

With this format you are free to choose the colors and level of transparency.

Make sure that each of the file names are appended with the associated RGB color code from the RGB Color Calculator (stratasysdirect.com/rgb-calculator).

Once the RGB color code for an .STL shell is determined, it should be added to the file name.

The shell-based file format is best for designs that incorporate Vero and those that include distinct colored sections as opposed to gradients or blending.



VRML File Format

Virtual Reality Modeling Language (VRML) is another standard file format (with the extension .wrl) for representing 3D interactive graphics. It provides the capability to apply colors and texture to a model, enabling it to be 3D printed with those textures.

External modeling software, such as Photoshop or CATIA are needed to design a VRML file. With this software you can either create the model or import it from other CAD software, and then apply the textures and colors before uploading the file to Stratasys Direct Manufacturing to print.

Texture Mapped Files

When ordering a texture-mapped model, you will need two files: a VRML (.wrl) file and an image file with the texture or images included. The image file resolution should be at least 600 DPI. Lower resolutions reduce print quality and higher resolutions will automatically be lowered to 600 DPI by PolyJet Studio.

Texture-mapped models are essentially “wrapped” with the texture in a process called UV mapping. For good printing resolution, make sure the UV mapping size matches the model size.

Designating Color in a VRML

There are four different ways you can assign color in a VRML file:

1. Color per object, mesh or shell:

The first is color per object, mesh or shell, in which you assign each component of an assembly with a solid color (usually referred to as diffuse color or material color).

2. Color per face:

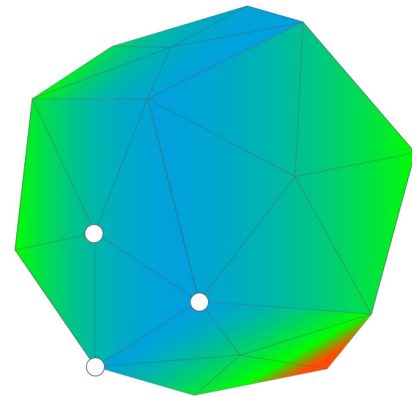
Next is color per face, in which you assign each triangle or face of the model a distinct color. A face can be anything from one triangle in a mesh to as many polygons as you select.

3. Color per vertex:

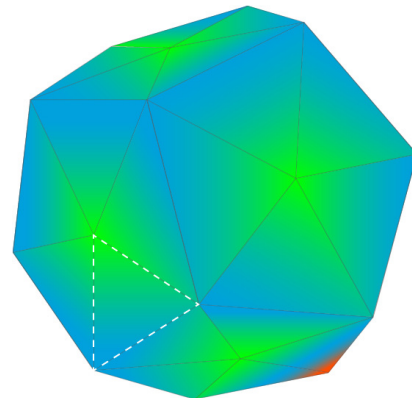
The third way you can designate a color is by assigning a different color to every vertex of every triangle in the design file. Each color value gets interpolated across the mesh. Note, the quality of the color is a result of the model resolution.

4. Color by texture / UV mapping:

Finally, you may also assign color by texture, or UV mapping. This is the process of adding an image or graphics to a 3D geometry. Color information is stored in a 2D image file, which is related to the coordinates of the mesh. This type of file shows the most detailed color information.



Color by Vertex: Each vertex (points) of a triangle has color value



Color by Face: Each face (triangle) is assigned a color value

Design Software Considerations

SOLIDWORKS, Adobe Photoshop and Rhinoceros 3D are the three types of software that can export files for PolyJet Multi-Color 3D printing. Follow the instructions for applying colors in each platform below.

SOLIDWORKS

In SOLIDWORKS you can apply different colors to each part of an assembly and save them separately. In addition, you can apply different colors to different faces of a model and save all of them together.

Even though it's possible to apply color textures to models, SOLIDWORKS doesn't export them—you will need a separate application to export.

To save the model:

1. From the **File** menu, click **Save As**. The **Save As** dialog box opens.
2. From the **Save As** drop-down menu, select **VRML (*.wrl)**.
3. Choose the location to save the file.
4. Click on the **Options** button.
5. Change the VRML version to **VRML 97**.
6. Click **OK**.
7. In the **Save As** dialog box, click **Save**.

Adobe Photoshop

Adobe Photoshop allows you to apply colors and textures to your model in different ways and export all of them into a VRML file.

1. From the **3D** menu, click **Export 3D Layer**. The **Export Properties** dialog box opens.
2. From the **3D File Format** drop-down menu, select **Virtual Reality Modeling Language – VRML**.
3. From the **Texture Format** drop-down menu, select **BMP** (best fit to the VRML format).
4. Click **OK**.
5. Choose the location to save the file.
6. Click **Save**.
7. Choose **Windows** file format and **24 Bit**.
8. Click **OK**.

If your model is an assembly, or if it has multiple textures, you can combine all the parts and color textures into one VRML file using the following steps.

9. From the **3D** menu, click **Unify Scene for 3D Printing**. This will combine all the parts of the assembly into one mesh.
10. From the **3D** menu, click **Generate UVs**. This will combine all the textures into one.
11. In the window that appears on the screen, click **OK**.
12. To make the color texture resolution as high as possible, change the value in the drop-down menu to **4096x4096**, then click **OK**.

Rhinoceros

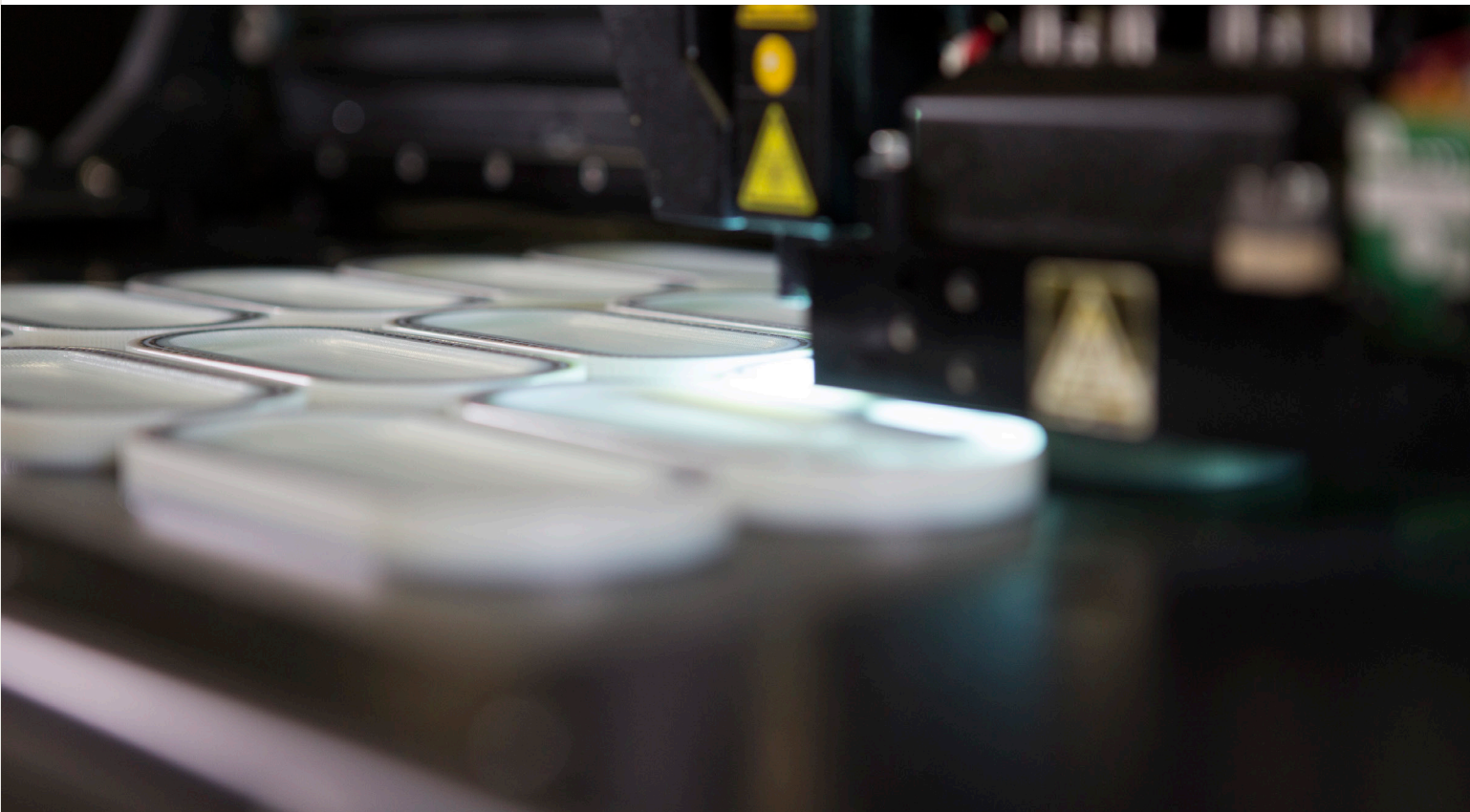
In Rhinoceros 3D, you are able to apply different colors and colored textures to create VRML files. There are two ways of saving a VRML file: saving all parts of the models or saving specific components of the models.

Saving all parts of the models:

1. From the **File** tab, click **Save As**.
The **Save As** dialog box opens.
2. From the **Save As** drop-down menu, select **VRML (*.wrl)**.
3. Choose the location to save the file.
4. In the **Save As** dialog box, click **Save**.
5. After pressing the **Save** button, a new window opens.
6. Verify that version 2.0 is selected and if textures were applied to the model, mark the **Texture Coordinates** as well.
7. Click **OK**.

Saving specific parts from the models:

1. Select the relevant part you wish to export from the model.
2. From the **File** tab, click **Export Selected**.
3. From the **Save As** drop-down menu, select **VRML (*.wrl)**.
4. Choose the location to save the file.
5. In the **Save As** dialog box, click **Save**.
6. After pressing the **Save** button, a new window opens.
7. Verify that version 2.0 is selected and if textures were applied to the model, mark the **Texture Coordinates** as well.
8. Click **OK**.



GrabCAD Print

GrabCAD Print (.print) is another tool and file format that can be utilized to incorporate color into the model design. Since GrabCAD Print is the operating software that powers PolyJet 3D printers, it is the most streamlined method for conveying your color design to Stratasys Direct Manufacturing and starting the print process.

The first step is to download GrabCAD Print (grabcad.com/print). After the download is complete, the designer can import .STL shells (“Add STLs as assembly”) and assign RGB values. Alternatively, the designer may elect to utilize VRML within GrabCAD Print.

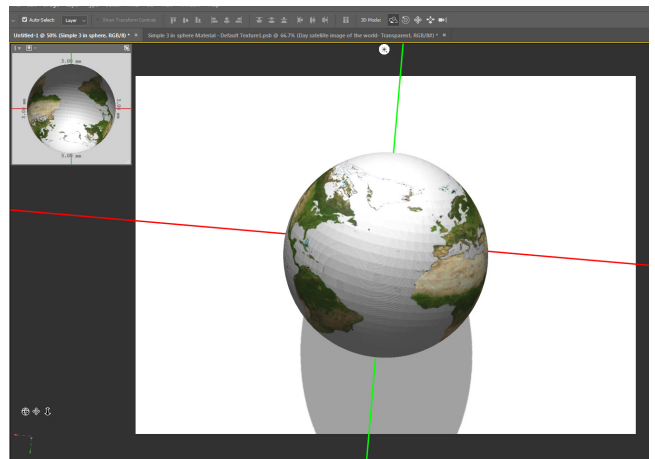
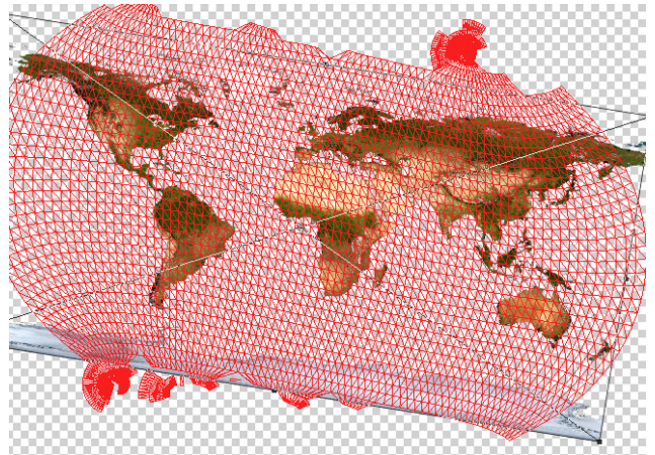
For more information concerning best practices for color design using GrabCAD Print, reference the user-friendly tutorial at grabcad.com/tutorials/selecting-color-in-solidworks-and-grabcad-print

For a more detailed, thorough 3-part series on color design, check out the following:

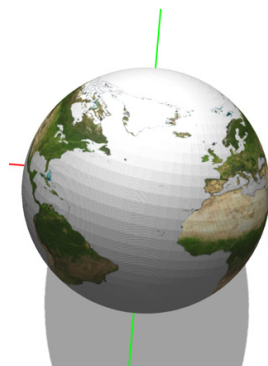
- [How to 3D Print in Full Color \(Part 1\)](#)
- [How to 3D Print in Full Color \(Part 2\): Repairing and Checking VRMLs](#)
- [How to 3D Print in Full Color \(Part 3\): Clear + Texture Together](#)

Actual color results may vary. Colors may appear different and will vary due to many variations in monitors, device screens, browsers and will deviate from actual plastic and photocured resin. Computer monitors, mobile device and tablet screens (“Devices”) are not all calibrated equally. Color tones will vary when viewed on such Devices via the Internet and may not be precise or an accurate representation of actual results of a 3D printed model. Stratasys Direct Manufacturing does not guarantee that colors selected on such Devices will accurately represent or match the color of the actual 3D printed model purchased. The representation of colors, pigments, finishes and/or textures vary by technology, geometry, size and material and may even vary from one 3D printed model to another. Therefore, color accuracy and match is not guaranteed and the color samples displayed should be used only as a guide. For specific questions regarding color selection please contact us at info@stratasysdirect.com or 1-888-311-1017.

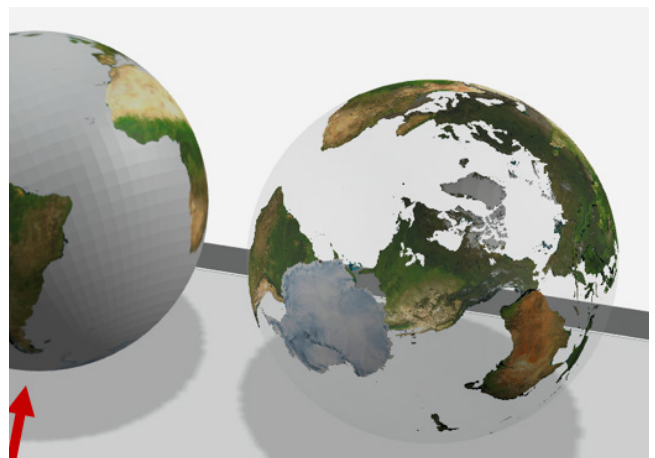
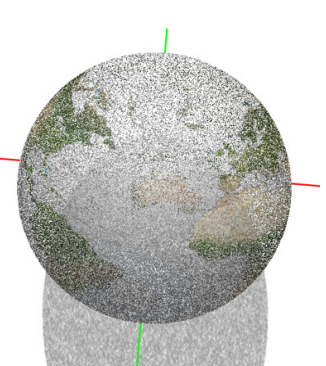
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100% Opacity



50% Opacity



Conclusion

PolyJet technology makes product realism possible before a product launch. The versatile 3D printing solution lets you see, touch, feel, test, analyze and use new products that have thermoplastic or elastomer characteristics. Since the technology offers a wide range of material possibilities and color options, you can design models for a wide range of industries and a diverse set of requirements in design, engineering, manufacturing, anatomical and artistic applications.

While only one step in the product development lifecycle, these design considerations can help save you time and money—ultimately getting your product to market faster. Once you've taken these guidelines into account and have a design ready for production, Stratasys Direct will work with you to make any additional tweaks to further ensure it's ready to be built. Request a quote today at rq.stratasysdirect.com.



