DIRECT MANUFACTURING

Become a 3D printing expert: Insider design advice

Guide to rapid prototyping

Today, the pace of innovation in the manufacturing industry is faster than ever before, but at the same time engineers are under increased pressure to get concepts to market quickly. Development teams must make fast and accurate decisions during the conceptual stage of design. These decisions can inform numerous cost factors, such as manufacturing methods and material selection, making fast conceptual and functional prototyping essential to the development stage of the product lifecycle.

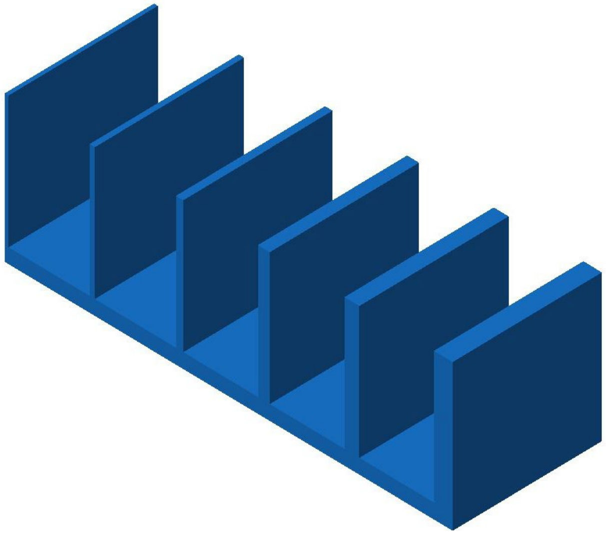
Rapid prototyping with 3D printing gives designers the ability to fail fast, produce multiple design iterations quickly and change a product design overnight to meet deadlines. But with a plethora of 3D printing technologies and materials to choose from, variation from one machine to the next, and unique process specifications, it may feel safer to take the traveled road than to pave the way for new technology and innovation—especially when your reputation is on the line.

The future of your industry involves 3D printing, so if you don't get up to speed, you risk being at a disadvantage. Luckily, we have a roadmap to help you navigate adoption quickly.

Start with your design—you know it better than anyone and are the expert in your product and industry. Then turn to the 3D printing experts. Stratasys Direct Manufacturing knows 3D printing technologies and materials better than anyone else. Making your prototype its best requires more than a great machine. It takes tried and true practices and deep industry knowledge and expertise to make a complicated process straightforward and successful.

Key design considerations

3D printing frees you from manufacturability constraints of conventional manufacturing methods that many have followed for decades and gives you the opportunity to think differently about design and prototyping.



CAD illustration comparing thin walls to thick walls.

3D printing allows you to create parts solely for the desired form, fit and function by eliminating tooling, machining, casting and fabrication, so that parts can flow, twist and contort into organic shapes with astonishing strength-to-weight ratios.

At the same time, there are design considerations unique to 3D printing and each 3D printing technology that ensure your design is optimized for the process and development delays are minimized.

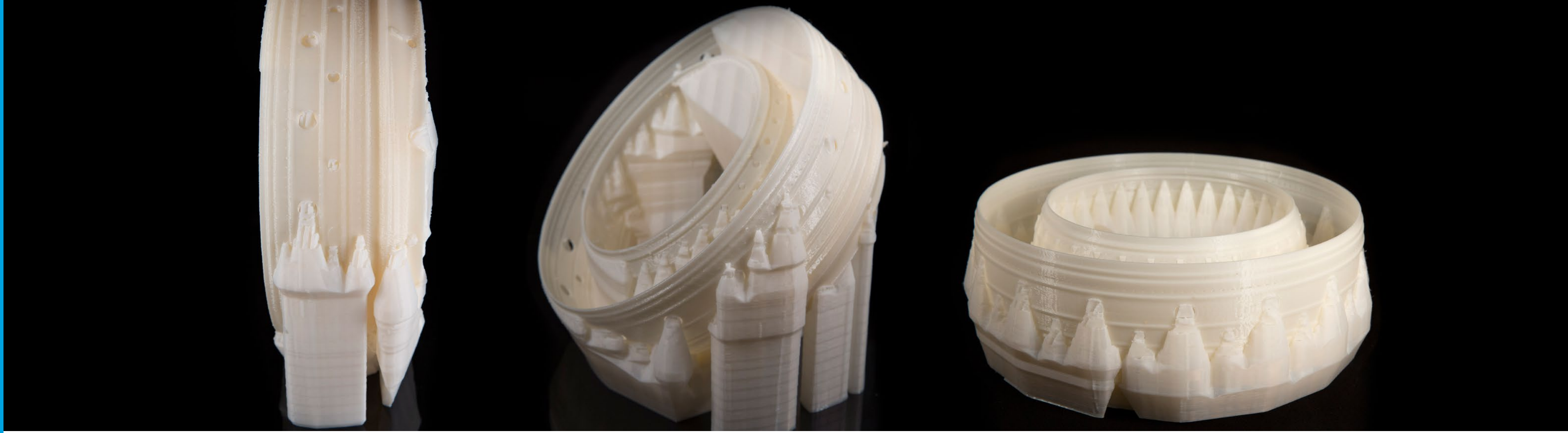
Across 3D printing technologies

File format

3D printers use .STL format files for build setup and part production. While native CAD can usually be converted to .STL format outside of the native software, issues may arise, causing build failures or missing features. Sending your CAD file in .STL format to a service provider reduces the chance for errors.

Wall thickness

Each 3D printing technology has its own limitations in terms of the minimum wall thickness to ensure an accurate prototype. Wall thickness can be geometry and application dependent, but a good rule of thumb is to 3D print walls greater than 0.020” for photopolymer processes and 0.030” to 0.040” for thermoplastic processes.



Combustion liner prototype build at three different orientations.

Overhangs

When working with material jetting and material extrusion 3D printing technologies, remember that the machine cannot extrude material onto open air, so support structures must be added to the design before printing. The support material acts as scaffolding on overhangs, such as windows, holes, undercuts, cutouts, etc., until the model is complete, and then must be dissolved in a water tank (when using soluble support material), manually removed or machined off. Additional support material can cause increased lead times and cost. Keep overhangs over 45 degrees, so they won't require support material; this will reduce material usage and build time.

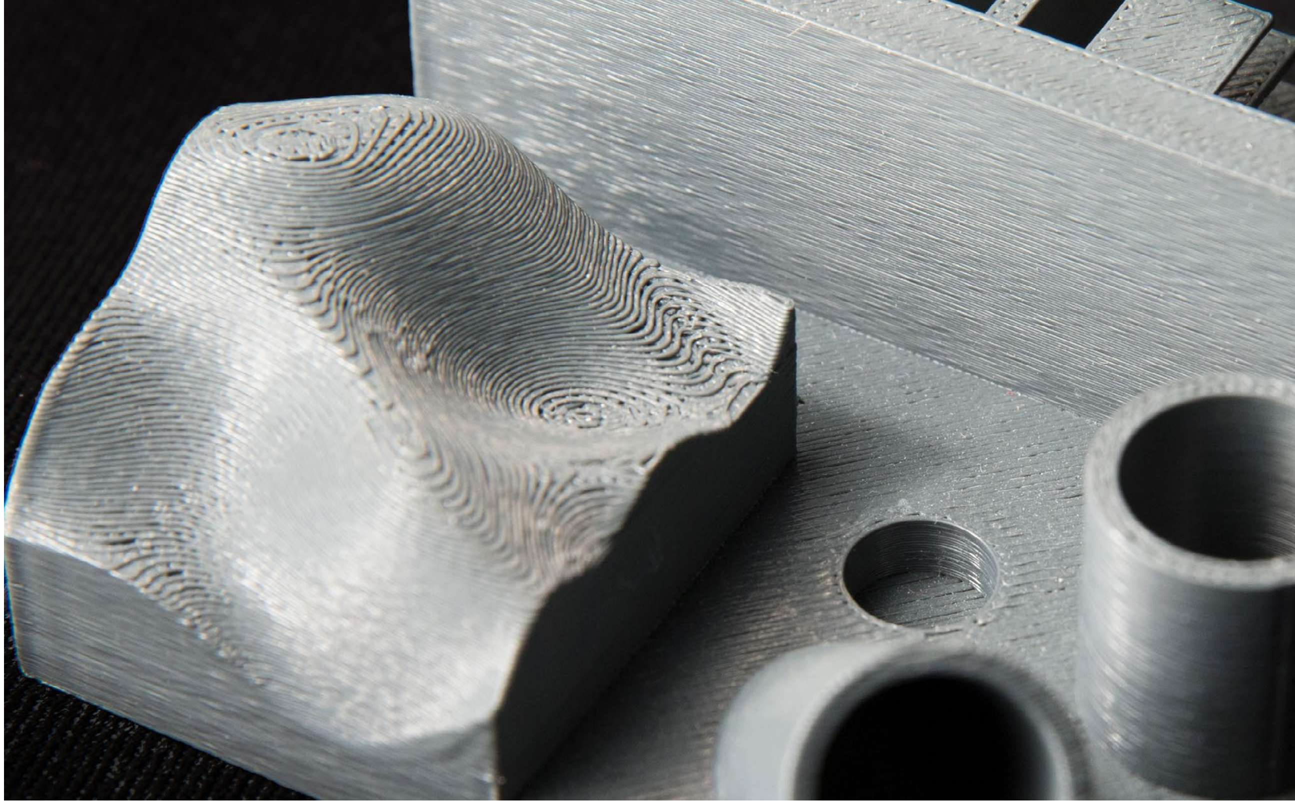
Build orientation

Part orientation, or the axis on which you build the model (X, Y, or Z), can significantly impact a prototype's aesthetic or functionality. In particular, it can affect geometric dimension and tolerance errors, the energy expended and the extent of support structures needed—all contributing to the overall cost of the part. The best orientation depends on the prototype's intended use and purpose and what technology you're using. If you're creating a concept model, for example, you may choose an orientation to reduce build layer lines and create a smooth surface. If functionality is critical to your prototyping use case, reducing support material and space between layers to increase strength will dictate orientation.

Warping and shrinking

During a thermal 3D printing process, materials are heated, melted and cured. There are often hot and cold spots in the build chamber that cause contracting and shrinking throughout the process. Differential cooling, particularly with material extrusion and powder bed fusion technologies, can cause walls to warp or distort, if they aren't properly designed. To avoid any potential warping, add ribs to thin walls (as you would with an injection molding process) and avoid large, flat surfaces. Parts can also shrink as they cool after the build, so your service provider must factor shrink into the design.

Layer resolution is the thickness of each slice laid out during the build of a 3D printed prototype.



Stair-stepping effect inherent to thicker layer heights.

Curling

Curling most often occurs with laser-based 3D printing processes, such as LS and SL. Individual layers are prone to shrink during the build process as they're exposed to light. As one layer shrinks on top of the other, the edges begin to curl. Your service provider can add proper anchors and optimize orientation to minimize curl, but also avoid large, flat surfaces within your designs.

Tolerance variance

3D printing technologies are primarily free-form production systems and thus have lesser tolerance control than traditional manufacturing methods, like CNC machining and injection molding. 3D printing is still accurate within thousands of an inch, but certain designs (i.e. interference fits/ line-to-line designs) need to account for slight dimensional variance.

Resolution

Layer resolution is the thickness of each slice laid out during the build of a 3D printed prototype. A thinner layer height can reduce the inherent stair-stepping effect or visible ridges that appear on the surface of a part post-build, creating a finer resolution. The thinner the layer lines, the more detailed and smooth the surface of the part is, but the build time will be longer and more costly.

Size

Each technology has an optimal build volume. Parts bigger than the available build volume of any given technology need to be sectioned in CAD and bonded together post-build. The size of a part also impacts the amount of time it will take to build and the minimum feature size possible. Moreover, a bigger part will take longer to build and require more material, adding to the overall cost of the part.

Mating parts

Prevent mating components of a prototype, such as connectors, hinges or box lids, from fusing together by designing in proper clearances. Use at least a 0.2mm offset for designs requiring a tight fit.

Multiple shells or unshared edges

Good .STL files typically contain only one shell and should never have unshared edges. Multiple shells and unshared edges usually signal uneven topography, meaning surfaces may overlap or disconnect from one another. If multiple shells and unshared edges are left in the file, it may not build as intended, causing missing features or separate pieces.

There are some instances when you may need multiple shells for specific designs. Sometimes there are joined pieces like chain links that need to be separate. When printing in multiple durometers or multiple colors on a PolyJet system, you need separate shells aligned perfectly. Consult with a design engineer in these instances.

Designing for **the technology**

Each 3D printing technology has its unique nuances and design limitations (tolerance, feature definition, material properties, etc.). These unique technology and material characteristics should be considered when designing your prototype part so that offsets, variances, and modifications can be implemented into the CAD model(s).

Figure 1 [and Figure 2 - see following page] contains the basic specifications you should be aware of, but always make sure to look at the comprehensive design guidelines and consult your 3D printing service provider on its particular equipment, material limitations and design guidelines. Download Stratasys Direct's design guidelines at *stratasysdirect.com*

TECHNOLOGY	MAXIMUM BUILD VOLUME	MINIMUM LAYER THICKNESS	MINIMUM WALL THICKNESS	MAXIMUM RESOLUTION	TOLERANCES
PolyJet	19.3" x 15.35" x 7.9"	0.00106"	0.028"	1,800 dpi	±0.005" or ±0.001" /", whichever is greater
Stereolithography	23.6" x 15.75" x 2.95"	0.00394"	0.00394"	—	±0.020" or ±0.004" /", whichever is greater
Fused Deposition	36" x 24" x 36"	0.007"	0.028"	—	±0.0035" or ±0.0015" /", whichever is greater
Laser Sintering	26" x 13.5" x 20"	0.004"	0.04"	—	±0.020" or ±0.003" /", whichever is greater
Multi Jet Fusion	16" x 12" x 16"	0.003"	0.02"	1,200 dpi	±0.010" or ±0.001" /", whichever is greater
Direct Metal Laser Sintering	9.5" x 9.5" x 10.5"	0.012"	0.012"	—	±0.005" for the first inch and ± 0.002" /", thereafter

Figure 1

Performance scale

PolyJet

LAYER RESOLUTION	THIN WALLS	SURFACE FINISH
OUTSTANDING	OUTSTANDING	OUTSTANDING

Support: Soluble, water jet

⊕ Realism, versatility, easy support removal, office friendly operation.

⊖ UV-sensitivity

Stereolithography

LAYER RESOLUTION	THIN WALLS	SURFACE FINISH
VERY GOOD	OUTSTANDING	OUTSTANDING

Support: Breakaway

⊕ Precision, surface smoothness

⊖ UV-sensitivity, extra post-curing steps

Fused Deposition

LAYER RESOLUTION	THIN WALLS	SURFACE FINISH
OK	OK	GOOD

Support: Soluble, breakaway

⊕ Durability, reliability, familiar materials, easy support removal, office-friendly operation.

⊖ Visible layer lines, anisotropic strength (weaker along layer lines)

Laser Sintering

LAYER RESOLUTION	THIN WALLS	SURFACE FINISH
GOOD	GOOD	VERY GOOD

Support: None

⊕ Tough materials, isotropic properties (equally strong in all directions)

⊖ Limited material options, complex operation, extra steps to change materials and post-process parts, not office friendly

Multi Jet Fusion

LAYER RESOLUTION	THIN WALLS	SURFACE FINISH
GOOD	GOOD	VERY GOOD

Support: None

⊕ Tough materials, isotropic properties (equally strong in all directions)

⊖ Limited material options, complex operation, extra steps to change materials and post-process parts, not office friendly

Direct Metal Laser Sintering

LAYER RESOLUTION	THIN WALLS	SURFACE FINISH
VERY GOOD	GOOD	GOOD

Support: Metal

⊕ Compared with machining, MPBF produces complex parts more cost-efficiently, creates less waste, and consumes less energy.

⊖ Requires a production environment with specialized equipment and skilled labor for support removal and finishing

Figure 2

Conclusion

The pace of product development isn't slowing down any time soon. It's an exciting and challenging time to be a design engineer.

Those who embrace and understand new technology and techniques will have a competitive advantage. But learning new technologies doesn't happen overnight. That's why it's our job to work with you on your ideas and champion them into real products and parts by identifying ways 3D printing can bring them to life faster and easier.

About Stratasys Direct Manufacturing

You want quality parts, fast – and for a fair price. We have that covered. But building parts demands more than acing the basics. It requires specialized know-how of the materials and technologies. With our problem-solving experts working tirelessly to match to designs and specs, Stratasys Direct Manufacturing is your partner in making that happen. When it comes to 3D printing or other custom manufacturing services, our responsive team isn't satisfied until you are.

With decades of experience and an insatiable appetite for collaboration, we know firsthand the challenges you face – and won't stop until we overcome them, together.

Supported by Stratasys' strong commitments to R&D and innovation, we regularly push processes and materials to their limits. And with ISO 9001 and AS9100 certifications, we ensure your parts meet the standards for any industry, including aerospace, automotive, medical and consumer.

Learn more about rapid prototyping with 3D printing »

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