

6 Design and printing guidelines

Introduction

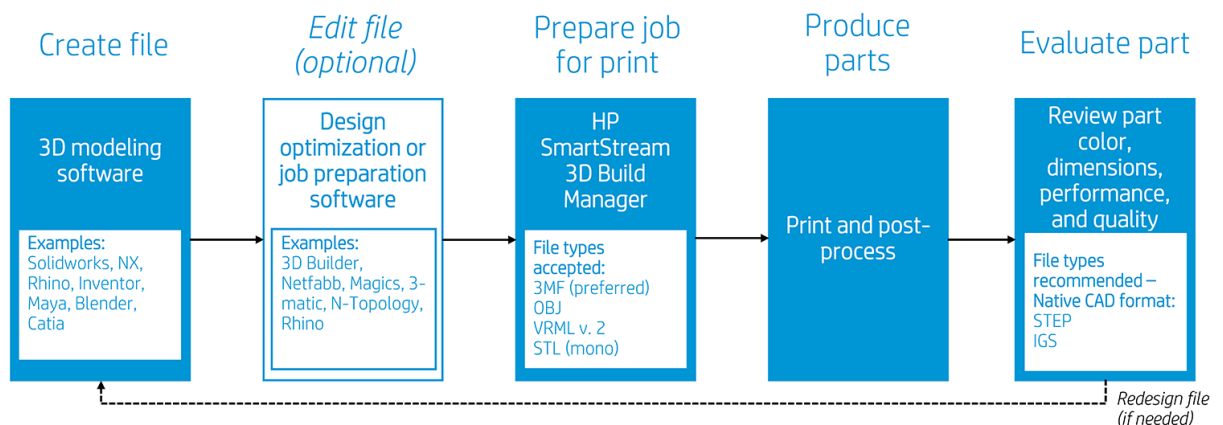
3D printing offers a much higher level of freedom in terms of design than any other traditional manufacturing technology. Designers and engineers can benefit from this, and use new geometries and concepts that were not feasible before. However, in order to optimize the design to be printed with MJF, you should be aware of some characteristics of the printing process and its capabilities, as this could help to get the best of the technology.

The design and printing guidelines offer an overview of the steps to follow before sending a job to print, from file preparation to the considerations that should be taken into account in the design of the parts and the orientation of them in the build chamber to optimize the final part quality and printing performance.

File preparation

File usage in the end-to-end workflow

In the end-to-end workflow of the printing process, the files pass through different software applications. For example, the first design may be done in a CAD program, while the job preparation will be handled in HP SmartStream 3D Build Manager. If required, the printed part can be scanned in 3D and compared with the original design.



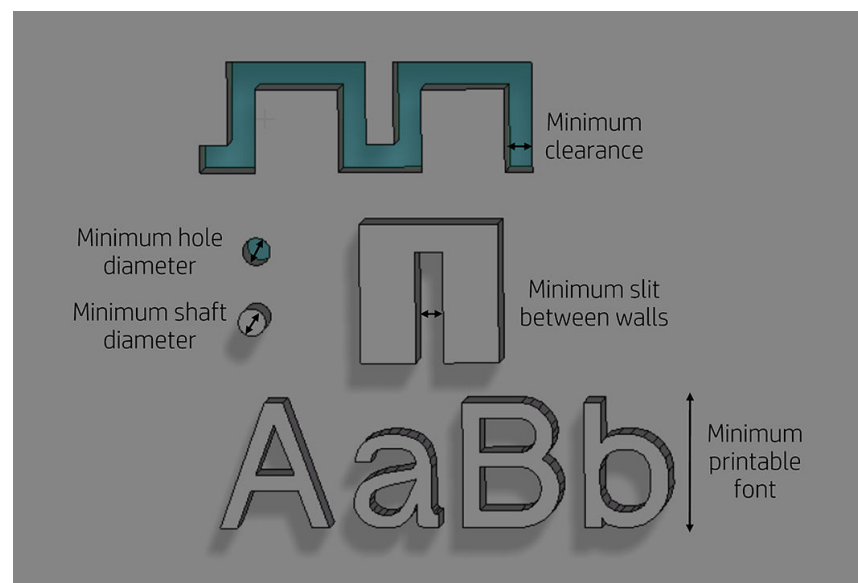
Minimum specification for parts

When designing parts in your 3D modeling software, HP recommends keeping this minimum specification in mind to avoid issues with parts and to achieve the best quality.

The minimum printable features in planes X, Y, and Z are as follows:

Table 6-1 Minimum printable

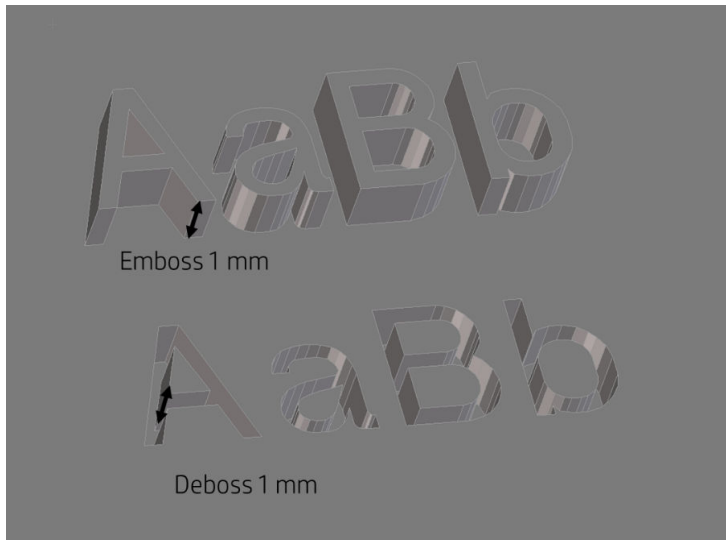
Specifications	Descriptions
Minimum hole diameter at 1 mm thickness	0.5 mm (0.02 in)
Minimum shaft diameter at 10 mm height (white parts)	0.5 mm (0.02 in)
Minimum shaft diameter at 10 mm height (color parts)	1 mm (0.04 in)
Minimum printable font size for embossed or debossed letters or numbers	6 pt (2.1 mm) (0.083 in)
Minimum clearance at 1 mm thickness	0.5 mm (0.02 in)
Minimum slit between walls	0.5 mm (0.02 in)



- **Engraving.** Multi Jet Fusion technology allows you to print letters and drawings with a very high resolution and definition.

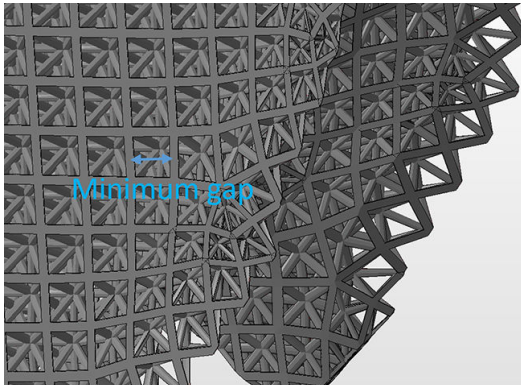
For the best possible output, any text, number, or drawing included in a part of the same color should have at least 1 mm of depth or height. When using contrasting colors, there is no minimum.

The best orientation for embossing and debossing letters is to place them upside down in the build chamber.

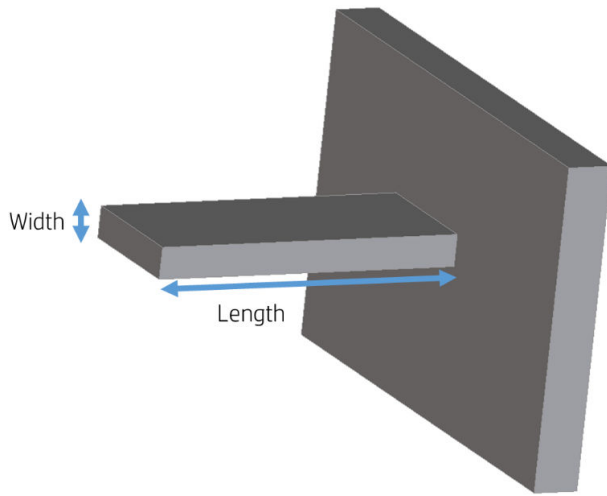


- **Solid part or structural fill.** Multi Jet Fusion allows you to print topology-optimized, generative designs or even small lattice structures. This kind of design helps to reduce the weight of the part and the quantity of material used, which not only reduces the cost of the part but also helps to reduce the operating cost in applications that are very weight-sensitive.

The minimum gap recommended in a lattice structure to ensure that all the material inside the part can be removed is 5 mm.



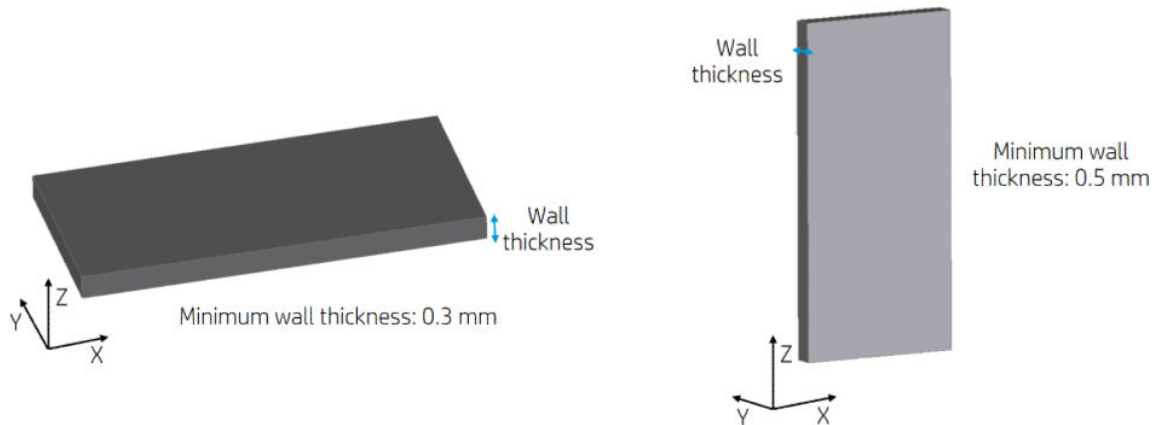
- When printing a **cantilever**, the minimum wall thickness depends on the aspect ratio, which is the length divided by the width.



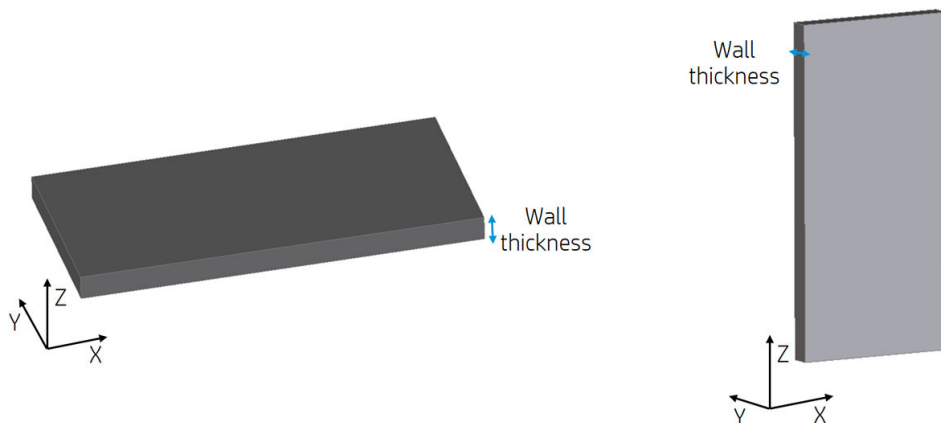
Aspect ratio = Length/Width

For a cantilever with a width less than 1 mm, the aspect ratio should be less than 1. For widths greater than 1 mm, parts with a high aspect ratio have a higher risk of warping (10:1 or greater).

- For white parts, in general, the minimum recommended **wall thickness** is 0.3 mm for short walls oriented in the XY plane, and 0.5 mm for short walls oriented in the Z plane.



For color parts, in general, the minimum recommended **wall thickness** is 0.5 mm for short walls oriented in the XY plane, and 1 mm for short walls oriented in the Z plane.



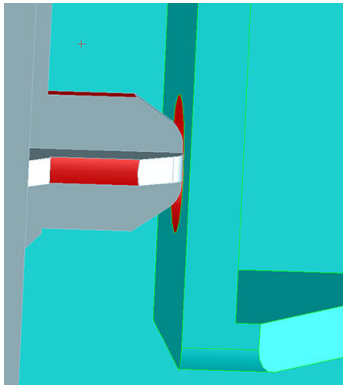
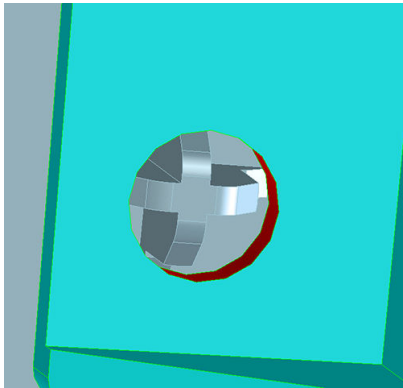
For parts with a high aspect ratio (>10:1), HP recommends increasing the wall thickness, or adding ribs or fillets to reinforce the part.

Very thick walls can accumulate heat and cause spot shrinkage in dense areas with an accumulation of material.

For best results, ribs should be no thicker than their base wall.

 **TIP:** Hollow out the part as much as possible, saving agent and material, and reducing sink marks.

- **Minimum gap** between parts to be assembled after printing. Sometimes a pair of printed parts need to fit together for the final application. In these cases, HP recommends gaps of at least 0.5 mm between the interface areas that should fit together, in order to ensure correct assembly.

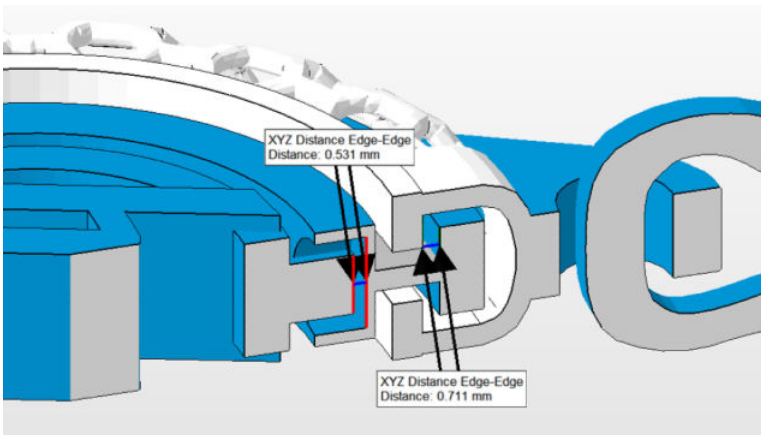
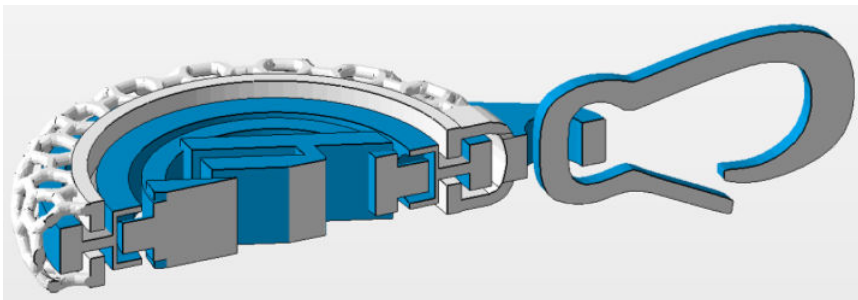


- **Minimum spacing and clearance** between parts printed as assemblies. Assembly parts that are printed together should have a minimum clearance of 0.7 mm. Parts with thick walls or large surface areas where the assembled features will fit together should have a larger gap to ensure sufficient material escape paths.

Consider this example using the HP Keychain part:



Here is a cross-section of said part:



- The inner circle with the HP logo will rotate freely after bead blasting although the clearance is quite low (less than 0.7 mm). This is because there is a small surface area of “contact” between the two surfaces that must freely move and an easy escape path for the unfused material to be removed during bead blasting.

- The outer circle contained in the white mesh cage typically requires more time bead blasting to remove all unfused material and more time “working” the rotating action by hand to work free any unfused material. Although there is at least 0.7 mm of clearance between the adjacent surfaces of the outer circle, the features that must rotate freely have a large amount of surface area, and there is no easy path for the unfused material between the two surfaces to escape during bead blasting. The large surface areas of fused material around the clearance also traps heat and could cause the material in the clearance area to fuse. This example highlights how, in order to design a successful assembly with components that move freely, there must be a clear escape path for the unfused material if small clearance sizes are required.
- Large surface area between faces with 0.711 mm clearance:



- Small surface area between faces with 0.531 mm clearance:

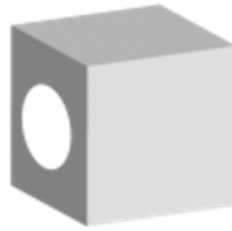


- **Hollow closed geometries.** Multi Jet Fusion is a process in which the parts are built by selectively fusing the desired areas of a material-based layer. If the parts printed are hollow, the unfused material can either be trapped inside the fused walls of the part or drain holes need to be added to the design to remove the material. The minimum recommended diameter of the holes is 5 mm; preferably larger, for ease of cleaning. HP recommends including at least two holes.



Two escape holes

Recommended



One escape hole

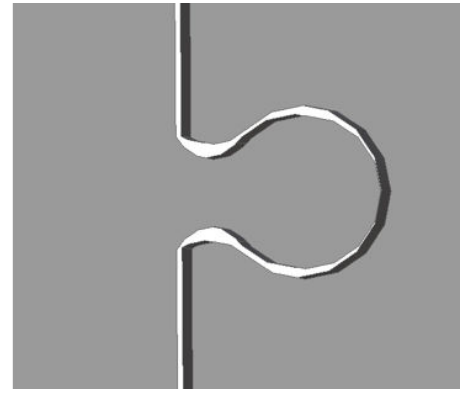
- Minimum recommended diameter of drain holes: 5 mm.
- Minimum recommended wall thickness: 2 mm.
- This method offers maximum part weight reduction.



No escape hole

- Unfused material will remain inside the part.
- Minimum recommended wall thickness is 2 mm.
- There is still a noticeable weight reduction compared to a solid part.
- **Glue lines.** Parts larger than the maximum build size can be printed with Multi Jet Fusion by splitting them into different parts. They can then be joined together by glueing, welding, or by pin inserts.

If you plan to glue parts together, HP recommends including interlocking features such as those shown in the pictures below: as a guide to position the parts, to help them to bond together, and to facilitate the glueing process. Remember to leave an additional space of 0.2 mm between parts for the glue, in addition to the minimum spacing between parts printed as assemblies (see above).



- **Ducts.** To remove material from narrow ducts, consider designing and printing a strip or a chain through the duct. When the parts have been printed, you can pull out the chain to dislodge most of the material. Any remaining material can be removed by the normal cleaning process.



Coloring parts

After creating your 3D model, it is recommended to color your model before bringing it into the HP SmartStream 3D Build Manager since coloring options are limited there. There are two primary ways of adding color to 3D models:

- **Color addition by part, face, or shell:** Commonly seen in CAD programs, this allows you to color specific areas of a part.

Figure 6-1 A model with the entire part colored

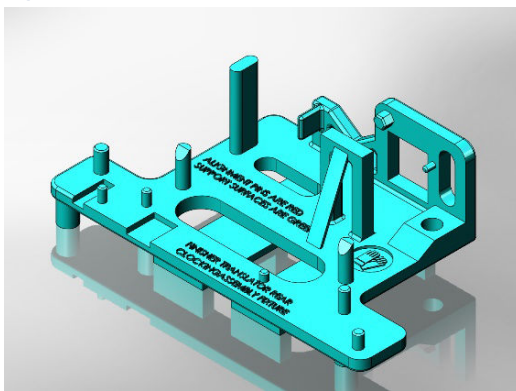
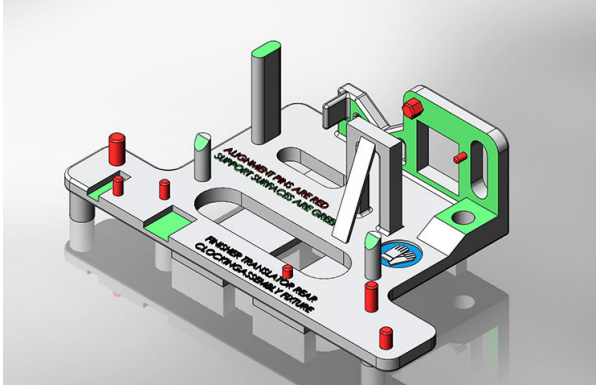


Figure 6-2 A model with the different colors on different faces



- **Texture mapping:** Commonly seen in graphic art programs, texture mapping takes an image and wraps it around a 3D object.

Figure 6-3 A model with a texture map



See your CAD or graphic arts software guidelines for how to use these features. You can also color previously uncolored models in a free program, such as Microsoft 3D Builder, which is free on all Windows systems. 3D Builder has easy-to-use color and texture map additions for beginners.

Saving and exporting files

After your files are designed and colored, your model needs to be tessellated, or converted into triangles, which are used by the printer to create layers. Tessellation occurs when you save or export your model file into specific file formats. The HP SmartStream 3D Build Manager accepts four different file formats:

- 3MF



NOTE: 3MF is the preferred file format for HP SmartStream 3D Build Manager.

However, defer to the recommended file export format chart below for color models.

- VRML 2 (.wrl)
- OBJ
- STL



NOTE: STL files do not carry color information. Use 3MF, VRML 2, or OBJ file formats for color models.

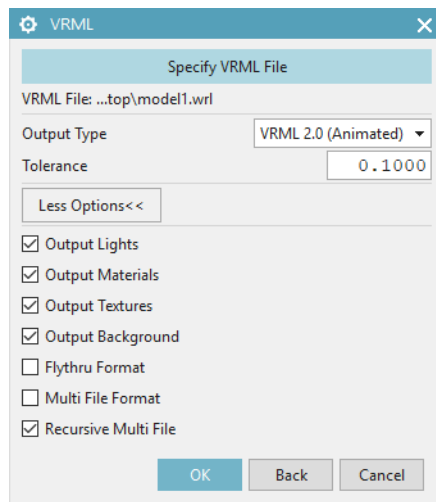
When saving or exporting your file, note that a normal file size for a model is about 1–200 MB, but the size depends on the type of software that created it, the number of triangles, the number and level of details, and so on. HP does not recommend working with files of more than 4 GB—beyond that size, the extra resolution in the file may have no effect on the printed part.

When exporting to STL, OBJ, or VRML 2 from a CAD package, you are often required to introduce some parameters such as angle tolerance and deviation chord height. These parameters define the resolution and file size of the part. The recommended parameters when exporting parts are an angle tolerance in the range 1–5 and a deviation chord height in the range 0.05–0.2. The angle tolerance should be reduced for parts with cylindrical or spherical shapes, and the chord height should be minimized for parts with fine details and small features.

Below, you will find some recommended export parameters/settings for common 3D modeling programs.

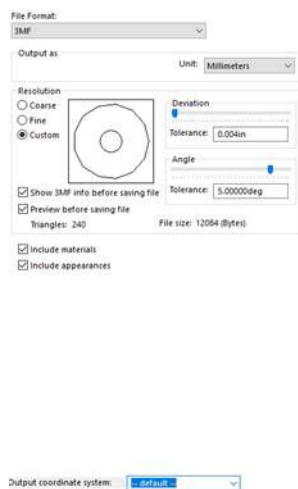
Siemens NX recommended export settings

Recommended export format: VRML (.wrl)



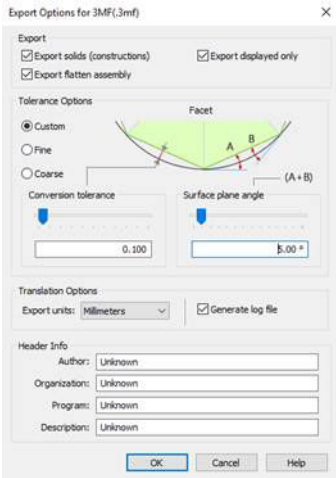
SolidWorks recommended export settings

Recommended export format: 3MF (.3mf)



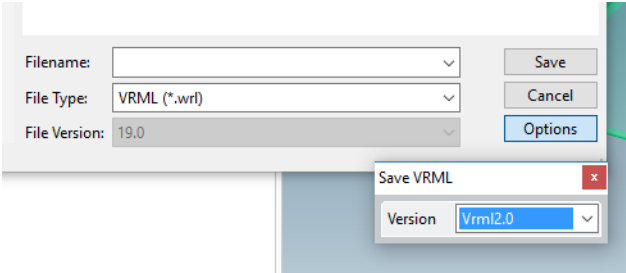
Solid Edge recommended export settings

Recommended export format: 3MF (.3mf)



Creo Elements recommended export settings

Recommended export format: VRML (.wrl)



Recommended file export formats for color models

In addition to having the correct export settings, HP recommends saving your color models in specific file formats, depending on which 3D modeling software program you use. Note that not all programs can export texture maps, even though texture mapping features may be available in the software. If this is the case, it is recommended to bring your uncolored model into a software that can export texture maps, and then add the texture map in that software. There are free software options, such as Microsoft 3D Builder and Blender, that allow you to do this.

Table 6-2 Recommended file export

Software	Recommended file export format	Can export texture?
3D Builder (16.1.651.0)	3MF	Yes
Adobe Photoshop (19.1.4)	VRML or OBJ	Yes
Autodesk 3ds Max (2019)	VRML	Yes
Autodesk Fusion 360 (2019)	STEP	No
Autodesk Inventor (2019)	OBJ	No
Autodesk Maya (2019)	OBJ	Yes

Table 6-2 Recommended file export (continued)

Software	Recommended file export format	Can export texture?
Autodesk Netfabb (2019.2)	3MF	Yes
Blender (2.79)	OBJ	Yes
Dassault CATIA (5)	VRML	Yes
Dassault SOLIDWORKS (2019)	3MF	Yes
Materialise Magics (21.0)	3MF	Yes
PTC Creo Elements (19)	VRML	No
PTC Creo Parametric (3.0)	OBJ	No
Rhino (6)	VRML	Yes
Siemens NX (12.0)	VRML	No
Siemens Solid Edge (ST10)	3MF	No



NOTE: If you are saving your color models in the recommended format and are still experiencing issues correctly opening your color models in HP SmartStream 3D Build Manager, see the printing tips and tricks document.

Tessellation problems

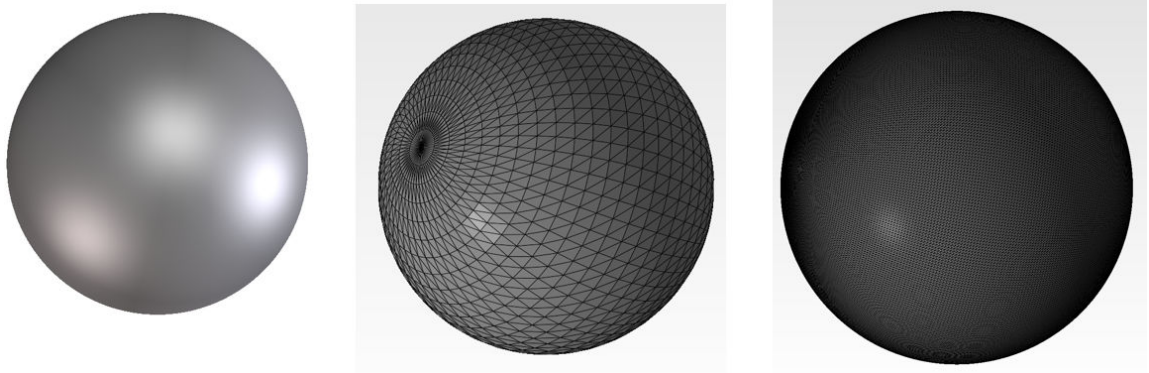
These are some common problems that you could experience during tessellation/exporting your files:

- Too many or too few triangles

Too many triangles are difficult to process and, when a certain size is reached, the extra triangles do not provide any further accuracy. For this reason, an excess of triangles could increase processing time for no benefit.

Triangulation of a surface causes faceting of the 3D model. The parameters used to output an STL model affect how much faceting occurs.

Figure 6-4 Example of tessellation



- Holes in triangles

STL models commonly suffer from surfaces that are not joined to their neighbors, and missing surfaces.

Repairing files

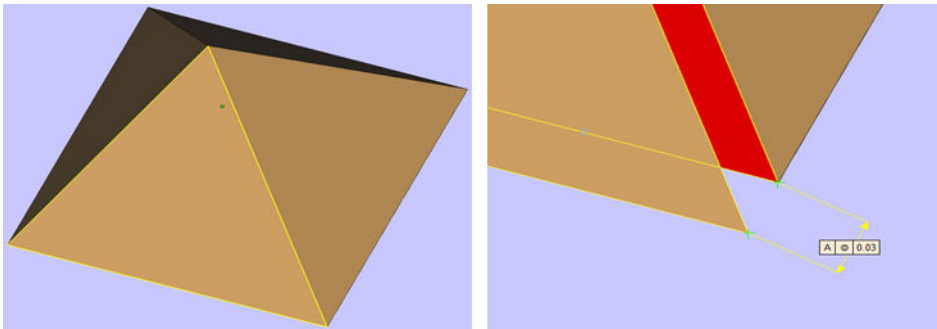
File-repairing software

- Magics – Materialise
- Autodesk Netfabb
- HP SmartStream 3D Build Manager

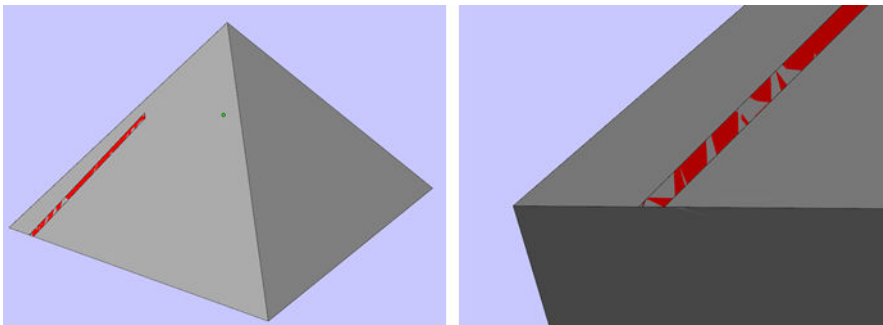
Common errors

Some common errors that cause part-quality-related issues are illustrated below. They can be fixed in the native CAD software; or, if that is not available, in Magics, Netfabb, or HP Smartstream 3D Build Manager. If these files are not fixed before attempting to build the design, either the software will not allow you to proceed due to poor file quality, or your part will not have good quality. Therefore, it is prudent to spend time at this stage to check that the CAD file designer produced a high-quality and printable design.

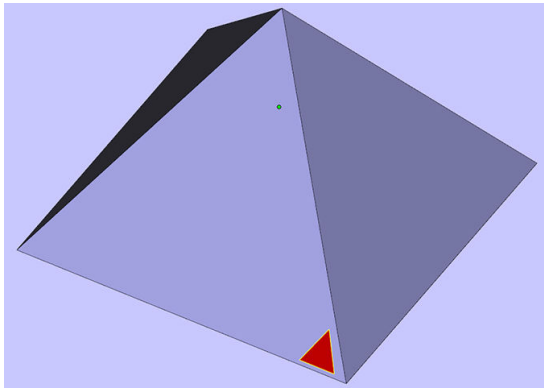
- Triangles not joined



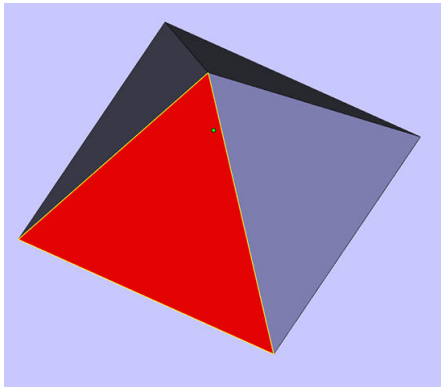
- Overlapping triangles



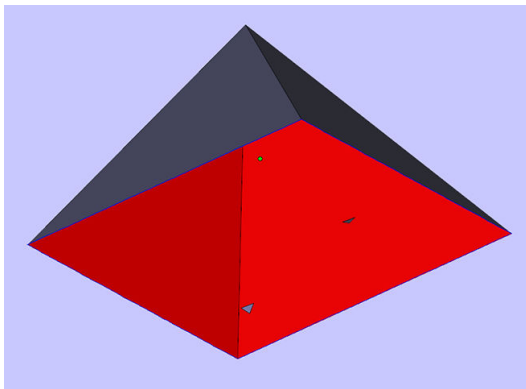
- Holes in parts



- Flipped-direction triangles



- Tiny shells



HP SmartStream 3D Build Manager

The HP SmartStream 3D Build Manager must be used to send jobs to print. Therefore, after files are exported, either from your CAD, graphic arts, or separate 3D build manager software, they must be brought into SmartStream 3D Build Manager.



NOTE: For optimal dimensional accuracy, export parts separately instead of grouping them within one file.

In HP SmartStream 3D Build Manager, you will be able to access some color editing features, including:

- The ability to color an entire part with one color of your choosing
- The ability to edit the hue, lightness, and saturation of existing colors
- The ability to display a print preview of the color part to be printed
- The ability to print a color set model to test colors

See the *HP SmartStream 3D Build Manager User Guide*

(<http://www.hp.com/go/SmartStream3DBuildManager/manuals>) for full descriptions of these features, or view this video: <https://www.youtube.com/watch?v=3IfpLMrJ4U&t=14s>.

The software preparation process may take from 15 minutes to 2 hours depending on the complexity of the job. It can be done while printing other jobs. Once ready, you can select the job to be printed from the job queue on the printer's front panel. If an error occurs while processing, a message appears on the front panel, and the printer cancels the job. To retry, you have to resubmit the job.