

# SKETCHUP AND RAPID PROTOTYPING

Jack Burgess © 2014

## My Experience

- You can see the parts that I have designed to date at:  
[www.shapeways.com/designer/jack1939](http://www.shapeways.com/designer/jack1939)

## Information

This handout covers the use of the free SketchUp computer program for drawing a part, the free computer program netfabb to get the 3D drawing file ready to be uploaded to be “printed” (the process of producing the part using rapid prototyping technology), and Shapeways, a firm which will actually print the part and mail it to you.

## Getting Started

- A good reference book for using SketchUp is *Google SketchUp - The Missing Manual* by Chris Grover. It is available from Amazon and other book stores.
- There is free SketchUp version and a Pro version for \$495; the free version will do everything you need. Download the free version of SketchUp at :

[www.SketchUp.com/](http://www.SketchUp.com/)

Note that there are offers to download a trial version of the Pro Version on some SketchUp download sites; you want the free version. (Google developed Sketchup but it was sold in 2012 to Trimble.)

- There are literally thousands of YouTube videos illustrating how to use various tools and solve common drafting challenges. If you get stuck, Google search for “SketchUp Push-Pull tool” or a similar search.
- SketchUp files have a .skp extension. However, Shapeways needs a .stl file. To avoid confusion, I set up a main SketchUp folder with subfolders for each part that I draw based on the name of the part (*Fairmont T27 Engine*, etc.) Under each “part” subfolder, I create another subfolder entitled *Other Files*. SketchUp files are in this *Other Files* subfolder. The final file which will be uploaded to be printed (which will be a .stl file) will be in the main folder. I do this because the .skp and .stl file extensions are easily confused.
- For more complex projects, I do a **Save As** often with file names such as *Tank A.skp* and *Tank B.skp*. Even though SketchUp has a multiple **Undo** command, using the **Save As** allows me to go back to a previous version of the file if I need to nearly start over.
- Parts can be 3D printed in a number of materials. However, for model parts, always specify Frosted Ultra Detail (FUD). The material you use will impact the minimum size of portions of the part.
- Shapeways, one of the companies which prints 3D parts, lists the minimum and maximum dimensions for parts. These design guidelines for Frosted Ultra Detail are at:

[www.shapeways.com/materials/frosted-detail-design-guidelines](http://www.shapeways.com/materials/frosted-detail-design-guidelines)

Note that Ultra Frosted Detail design guidelines are on the right. Below that table are explanations of the design standards and tips about avoiding warping, etc.

- All dimensions in these guidelines are listed in millimeters (rather than inches). An online conversion website such as

[www.onlineconversion.com/length\\_common.htm](http://www.onlineconversion.com/length_common.htm)

can be used convert inches to millimeters (mm). Woodland Scenics also has a free app for smart phones, tablets, computers, etc. called Model Scaler which can also be used. It can be used directly from the Woodland Scenics website or downloaded to a device. Search for “Model Scaler App” on the Woodland Scenics website to get the link. To use this app, choose your scale and, in the following screen, select inches (in) for the Actual and millimeters (mm) for the model. Input the minimum design standard (in millimeters) in the box for the Model and touch “return”. The actual minimum thickness will be displayed in the Actual box.

- The following table provides the most important design elements for printing a part using Frosted Ultra Detail for both HO and O scales. For example, a wall supported by walls on all four sides must be at least 0.3mm thick which is equal to slightly more than 1” thick (1.03”) in HO or about 5/8” thick (0.566”) in O scale:

Design Standard	Millimeter (mm)	HO Prototype Inches	O Prototype Inches
Min Wall Supported (1)	0.3 mm	1.03 inches	.566 inches
Min Wall Free (2)	0.6 mm	2.05 inches	1.13 inches
Min Wire Supported (3)	0.6 mm	2.05 inches	1.13 inches
Min Wire Free (4)	0.8 mm	2.74 inches	1.51 inches
Min Wire Free (5)	1.0 mm	3.42 inches	1.89 inches
Min Embossed Detail (6)	0.1 mm	0.34 inches	0.19 inches

(1) This is the minimum wall thickness where the wall is supported on all four sides

(2) This is the minimum thickness for an unsupported wall

(3) This is the minimum thickness of a “wire” which doesn’t bear any weight but is supported on both ends.

(4) This is the minimum thickness of a “wire” which extends out from a part without support.

(5) This is the minimum thickness of a sprue connecting parts

(6) This is the minimum width of a groove embossed or “engraved” into the surface of the part

- Shapeways also has a minimum size for the “box”, which virtually encloses the parts, as follows:

Minimum Total of Height+Width+Length in millimeters for the finished part	Minimum Size of Box HO Prototype Inches	Minimum Size of Box O Prototype Inches
7.5 millimeters total	25-13/16” total	14-1/4” total

For simple parts, just add together the height, width, and length of the part. Or, after processing a part through the netfabb program (as discussed later) including scaling it for your particular scale, netfabb will list the height, width, and length of the part in millimeters. You can add these numbers together—they need to equal or be larger than 7.5 millimeters. You can also use the above information during design. For example, say that you are designing a square part for which the prototype dimensions are 8” high by 6” wide by 6” long. That would total 20” total. That size part would meet the standards if you are modeling in O scale but would be too small in HO. However, there are tricks to still accommodate this standard if you are modeling in HO. You could add a simple “sprue” to one side of the part and make it long enough to meet the design standard and just cut it off after receiving the finished part. If you choose this option, make sure that the “sacrificial” part is equal to the minimum diameter for a “supported wire” as discussed above. The challenge is to meet the minimum design standards while minimizing total volume (which affects the cost of the part).

### SketchUp

- Always draw in full size (at the start of SketchUp, select “Choose Template” and then select “Simple Template - Feet and Inches” and then “Start using SketchUp”). This means that you can input accurate measurements with inches and feet abbreviations (“and ’). Dimensions can be entered in either even feet (4’) or inches (2 3/8) or a combination (4’ 2 3/8”). If you don’t add a foot or inch symbol, SketchUp will assume you are entering inches.
- SketchUp is very intuitive. For example, click on a drawing tool, hold the cursor on the edge of a circle, and then move toward the center of the circle and the cursor will lock to the center.
- SketchUp models circles as straight-line segments. After drawing a circle, use the Select tool (the arrow at the upper left corner of the Large Tool Set) and click the outside of the circle and then right click and choose “Entity Info”. Change the Segments from 24 to 96 to increase accuracy and smoothing. You can also use this dialogue box to change the radius of the circle if needed.

### Exporting a .stl File

- Once you have finished building a 3D model in SketchUp, you will need to export it as a .stl file (SketchUp files are .skp files) as the first step in uploading the file to be 3D printed. You can download a SketchUp extension to do this directly from SketchUp. In SketchUp (you need to be connected to the Internet at the time), click on **Window/Extension Warehouse** and then click on **SketchUp Team** under the list for **Top Developers**. Then scroll

down to “SketchUp STL by SketchUp Team - Import and Export STL files for 3D printing”. Download this extension which will install itself under the File menu.

- Once a part is finished (or I want to upload it to test the results to date), I export it using **File/Export STL**. I will save the resulting .stl file in the root project folder to separate it from the SketchUp files. I save that file with the same name as the most recent SketchUp project .stl file. When you choose the menu **Export STL** option, you may get a message “No objects selected. Export entire model?”. If so, select “Yes” and then select the “Inches and Binary” option.

### netfabb Download

- One more step is needed prior to uploading a .stl file to Shapeways for printing. That process involves 1) converting the part from full-size inches to full-size millimeters; and 2) rescaling the part to your modeling scale; and 3) checking your model for errors and fixing any problems. This can be accomplished using a free program called netfabb (with a lower case “n”). Go to Shapeways and the download for this program at [www.shapeways.com/tutorials/how\\_to\\_use\\_meshlab\\_and\\_netfabb](http://www.shapeways.com/tutorials/how_to_use_meshlab_and_netfabb) and click on the download. (You do not need to download meshlab since SketchUp can create the .stl file.) This program does a lot of things but we only need to do the steps listed below. There are two methods to use this program to fix any rescale the part and fix any errors.

### netfabb tips - Simple Projects

- The following process has worked for me for all of my projects, which for the most part, have been simple projects. (Note: I have used this simpler/quicker process even when the netfabb program finds a problem with a project and displays a red warning triangle. However, I have also had problems with parts uploaded to Shapeways after they seemed fine in netfabb. If you upload a part to Shapeways and it appears corrupted, you might run the same .skp file through the set of instructions for more complex projects (next section).
  - Open the SketchUp .skp file in netfabb.
  - From the drop down menu, select **Part/Convert Units** and then choose the **Inches to mm (scale up by 25.4)** menu item to convert the part from inches to millimeters.
  - From the drop down menu, select **Part/Scale** command and use the *Scale Factor* based on the desired final scale (you only need to input it in one of the X/Y/Z input boxes.) Input the scale as a decimal; the number to be inputted is equal to 1 divided by your scale factor (1/87 for HO, 1/48 for O, etc.) For N scale input 0.00635, for HO input 0.01149, for S scale input 0.01563, and for O scale input 0.02083. Input the scale factor in one of the input boxes and select **Scale**.
  - From the drop down menu, select the **Part/Export part/As STL** command.
  - If it says you have errors, click the **Repair** button and then click on the **Export** button after the problems have been repaired.
  - I save that .stl file with the name that I want it to appear in Shapeways, i.e., the final project name.
  - When closing the program, it asks whether I want to save the project. That is the part under the name I opened it so I simply choose “No”.

### netfabb tips - Complex Projects

- For more complex projects and if the file has the red warning triangle in the lower corner, use this process:
  - Open the SketchUp .skp file in netfabb. There may be a red warning triangle in the lower corner but ignore it for now.
  - From the drop down menu, select **Part/Convert Units** and then choose the **Inches to mm (scale up by 25.4)** menu item to convert the part from inches to millimeters.
  - From the main drop down menu, select the **Part/Scale** command and input the *Scale Factor* based on the desired final modeling scale (you only need to input it in one of the X/Y/Z input boxes.) Input the scale as a decimal; the number to input is equal to 1 divided by your scale factor (1/87 for HO, 1/48 for O, etc.) Therefore, for N scale input 0.00635, for HO input 0.01149, for S scale input 0.01563, and for O scale input 0.02083. Input the scale factor in one of the input boxes and click on **Scale**.
  - Click on the Red Cross on the main/top menu to **Repair** it.



- Click on **Automatic Repair** at the bottom of the column along the right side of the screen.
- Then select **Simple Repair** and then click on **Execute**.
- When it has finished, select **Apply Repair** from the bottom of the column along the right side of the screen.
- When it says **Remove Old Part**, click on **Yes**.
- The red warning triangle should now be gone. From the main drop down menu, select **Part/Export part/As STL** command. If netfabb still finds a few things to fix on the Export, click the **Repair** button.
- Then click on the **Export** button after any problems have been repaired.
- I always save that .stl file with the name that I want it to appear in Shapeways, i.e., the final part name.

### Shapeways Tips

- There are a number of other firms which provide rapid prototyping services. But so far, I have been satisfied with Shapeways (<http://www.shapeways.com/>) since they are totally committed to small designers with no minimum purchases and the built-in ability to also sell the parts you design if you choose.
- To use Shapeways, you will first need to establish an account. Click on **Join** to set up an account where you can upload projects and order parts.
- The Shapeways website isn't that intuitive. Once you have an account, log in and then click on the "smiley face" on the extreme right of the menu. That menu will let you access to your "My Models" and to your "Orders". Clicking on "My Models" lets up upload new parts or edit parts you have already unloaded. If you want to order one of your parts, be sure to click on the down arrow menu item for the part to select the Frosted Ultra Detail material before you order the part. (If you don't do this and order a part and later realize that you didn't specify the FUD material, you can cancel the order through the "Orders" menu item as long as you don't wait too long...don't ask how I know this trick.) After you have placed an order, you will receive an e-mail confirming the order along with e-mails when it is being placed into production, etc. You can click on Orders under your login anytime and then click on the "Order", the "Invoice", or "Tracking" to see when it will arrive in your mailbox.
- When you are first getting started using SketchUp, I'd suggest exporting the part often as a .stl file. Then process it through netfabb and upload it to SketchUp. You can then carefully examine it for flaws; you can right click your mouse and hold the button down to rotate the part in all directions. When I first started using SketchUp, I discovered a number of times that a part which looked fine in SketchUp and even exported fine from netfabb, had flaws once it was uploaded to SketchUp. If you find a problem and used the simple method to run the part through netfabb, go back and run the original .skl file through netfabb using the second method. If you used that method, go back to SketchUp and fix it. You can then use **Edit Model** in Shapeways to upload the repaired file. For some parts, I uploaded the part, found a problem, fixed it and continued to draw the part only to find another problem. Upload often!
- Once you are successful (it will be easier to reach that stage with experience using SketchUp), you can also fill in information about the part (under **Edit Details**) and choose whether or not to offer it for sale. At a minimum, you can click on the box for **Display to the public** so that you can send your friends a link to your parts (otherwise, they won't be able to see them).
- Cost is based on the volume of the part and the selected material. Shapeways suggests that you minimize the volume whenever possible by adding holes in the bottom of larger parts where they won't show or affect the part.