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3D Printing Nosecones with RockSim

By Bruce Levison

Recently I purchased a 3D printer kit to have access to out-of-production plastic parts for the model rockets I build. There are many cool items you can make available as .stl files from Thingiverse.com, an internet repository for 3D printer files. The Thingiverse archive also contains numerous rocketry related files that can be downloaded for free; including designs for complete rockets and their associated parts like nosecones, fin-cans, tail-cones, and rail guides. This exercise provided me with a good introduction to the Ultimaker CURA slicing software (which I will refer to as CURA) that came with my printer. Slicing software like CURA generates a .gcode file which contains the specific set of instructions and parameters the 3D printer uses to print the 3D object layer by layer. These slicing software packages typically accept 3D CAD files with .stl or .obj extensions that are three-dimensional depictions of the object to be printed. The slicing software then generates a .gcode file from these 3D files based on the parameters you input for printing which are specific for filament type and the object i.e. whether a top or bottom layer is desired and the speed and fineness of the print.

For a more detailed introduction to 3D printing, I suggest viewing some of the numerous videos on the internet, I recommend Chris Taylor's Youtube channel T3DP, and another Youtube channel by Angus Deveson called "Maker's Muse." In addition to numerous tips and tricks on 3D printing and the nuances of the individual 3D printers themselves; these sites all describe a workflow for 3D printing which comprises:

1. Sketching out your idea for a 3D shape on paper,
2. Using CAD software to create a 3D drawing that generates a file with a .stl extension then,
3. Reading this file from a slicing software (like CURA) which controls the printer by generating a gcode file that contains all the parameters and instructions the printer uses for the 3D print,
4. Filament extrusion printing the desired object, and
5. Final finishing i.e. removing brims, rafts, and supports and then sanding or filing off seams and rough spots.

There is also an excellent article by Thomas Salverson titled "Custom 3D Printed Rockets" on page 31 in the May/June 2018 issue of Sport Rocketry nicely explains the workflow (or steps involved in the process) for creating 3D parts for model rocketry. A six-step workflow for 3D printing model rockets and parts is presented:

- Step 1: The Idea
- Step 2: Preliminary Simulation Design
- Step 3: CAD Modeling
- Step 4: 3D Printing
- Step: 5 Post Printing
- Step: 6 Final Stability Check and Assembly

For me, the slow step was going to be figuring out the CAD software needed to generate the 3D drawing of the object for the 3D print since I had no experience with these types of drawing programs.

So now that I had the 3D printer up and running, how to make the custom model rocket parts that I wanted? It seems most people master a CAD or 3D drawing program to create and duplicate the parts they want to produce. These programs allow you to draw and then dimension a shape in 3D. The shape is then meshed (defined into small triangles) which allows the design to be used by a slicing program for 3D printing. The issues I faced are: Which software should to choose, a freeware or a paid subscription? Which CAD software would be best for what I wanted to 3D print? Which CAD software had the shortest learning curve, best tutorials, and online support? This is not a trivial issue as there are numerous CAD programs available and some are even tailored to specific tasks like remodeling homes. The complexity of the CAD programs demands at least several weeks of training and probably months of practice to master.

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I couldn't help but notice my RockSim simulation files contain dimensioned parts and allow one to view model rocket designs in 3D. I also noticed the software allows you to export a 3D model of your work under the File drop-down menu **Figure 1**. I took one of my recent RockSim designs and deleted everything except the out of production Centuri #7 plastic nose cone that I needed and exported the 3D model (**Figure 2, Page 4**). The CURA slicing software (version 3.2.1) was able to use the file with the wavefront .mtl and .obj extension, the first format I tried! I tried all the others file formats available (.wrl, .rib, .iv, .oogl, .x3d, and .pov, and none of these files seemed useful and some were not even readable. Note: be sure to select "Open OBJ files with CURA" under the Choose Components menu (**Figure 3, Page 4**). I was also able to open some of these files with several CAD freeware programs; namely TinkerCAD and FreeCAD, but it was not straightforward what I could do with these 3D drawings in any of these software packages.

When I opened the .obj file in CURA the rendering of the nose cone in this file had a faceted or low-resolution appearance, **Figure 4**. RockSim allows you to adjust the resolution of these 3D exports in the preferences menu under the Edit tab. I changed the object resolution under 3D rendering from low-resolution **Figure 4** (**Page 5**) to high-resolution **Figure 5** (**Page 5**). This gave a much better rendering of the nose cone shape in CURA **Figure 6** (**Page 6**), but I was still not satisfied with the resolution of the 3D drawing, it still exhibited some faceting especially along the horizontal curve of the nose cone.

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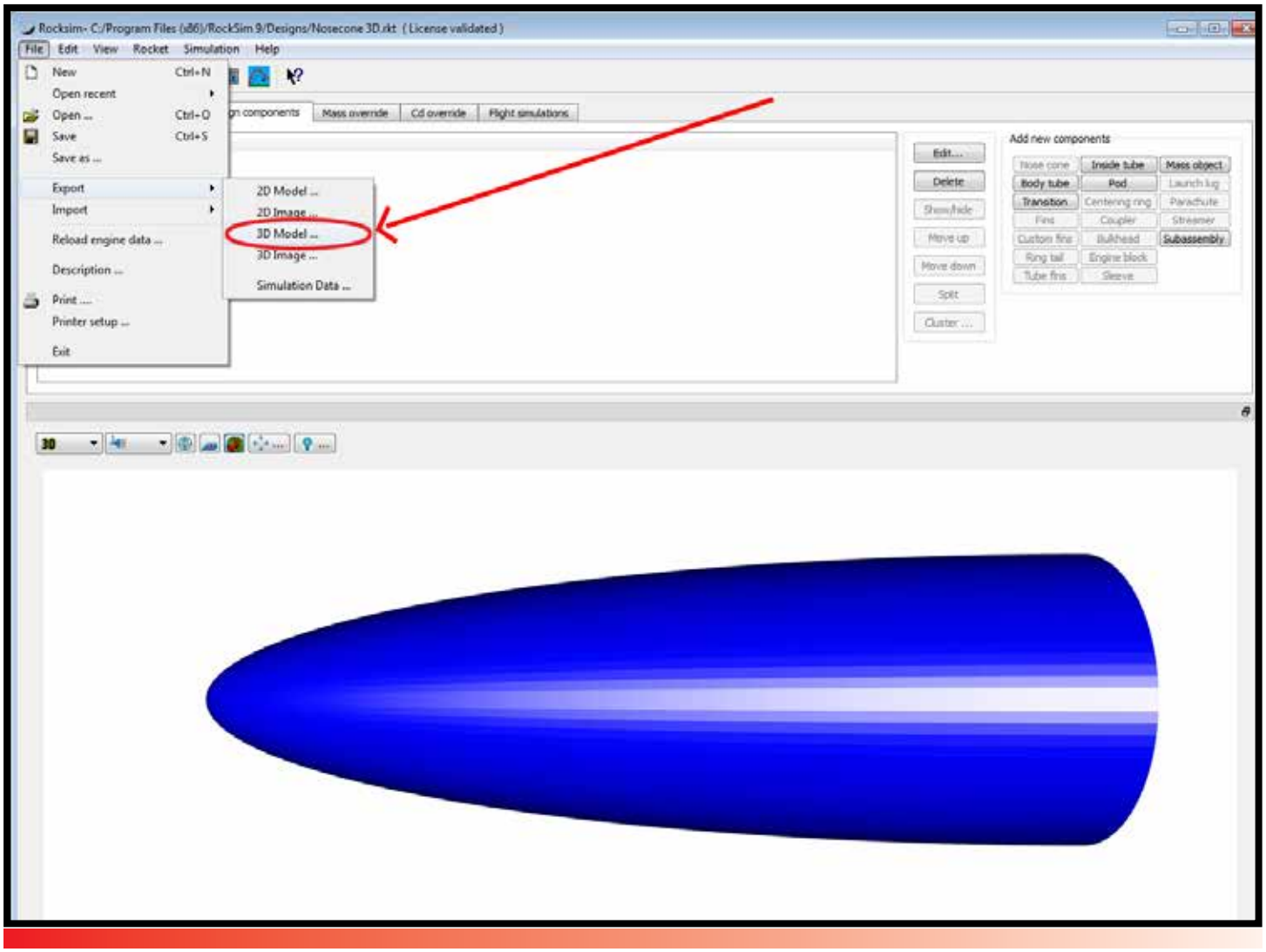

Figure 1: Export a 3D model of your work through RockSim.

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To fix this I changed the Curve and Filter extrusion settings to 180 and 90 respectively, **Figure 7** (**Page 6**). This created a nice smooth design in the RockSim software **Figure 8** (**Page 7**). Note; Increasing the Curve value [under "Preferences" in Edit menu, then under 3D Rendering tab for Extrusion (Nose Cones, Transitions, Etc.)] causes the resolution along the horizontal plane of the nose cone to be finer, i.e. an increase removes the flat areas near the tip of the nose cone. Increasing the Filter value [under Extrusion (Nose Cones, Transitions, Etc.)] causes the vertical resolution to increase; higher filter numbers remove more vertical faceting.

I have found that larger nosecones require higher Filter values to provide enough resolution to eliminate vertical faceting at the expense of a larger file size; for nose cones less than an inch diameter I found a Filter value of 90 to be sufficient, for nose cones up to 2 inches in diameter a Filter value of 180 works good and for 4 inch nose cone a value of 360 was used to eliminate vertical faceting. Note, I directly opened the .obj file directly with CURA and allowed it to do the slicing and generate the .gcode file and printed the nose cone. No CAD drawing program or experience needed!

I found the nose cone that I printed looked great it was fairly smooth and sturdy **Figure 9** (**Page 7**). I decided to sand it down as there were some minor bumps and raised imperfections (Z seam) on the surface mainly because I was still new at 3D printing and didn't have all the 3D printer parameters set correctly. The bumps were due to using too high of an extruder temperature on the 3D printer. When I started sanding the nosecones they cracked and separated at the joint at the shoulder of the nose cone. I found that the 3D print was quite thin at this junction point between the actual conical portion of the nose cone and its shoulder. To remedy this I redesigned the nose cone by first removing the existing shoulder and then replacing it with an inside tube with the same circumferential dimensions but about 1/8" longer than the real shoulder and buried the extra 1/8" length into the conical portion of the nose cone **Figure 10** (**Page 7**). The extra 1/8" of the inside tube overlaps into the inside of the nosecones conical portion. The nosecones I 3D printed from this RockSim simulation (with 3 layer thicknesses chosen in the printer settings) were much stronger and did not separate at the shoulder junction.

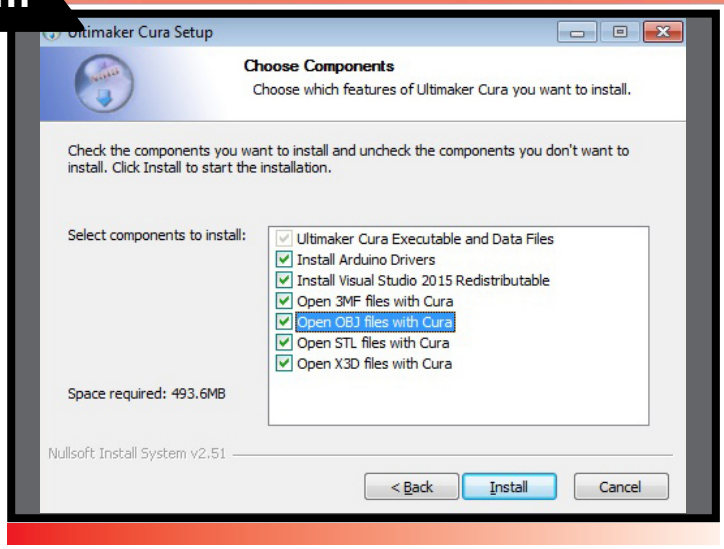

Figure 3: Make sure to select the "OPEN OBJ files with CURA" from the installation option pick list.

For the first 3D prints I used the default 3D printer settings and the PLA filament that shipped with the printer kit. Polylactic acid, PLA, is the cheapest and easiest filament to print with at a cost between $10 and $20 per kg (2.2lbs!) from suppliers like Amazon. Due to its lower price I chose to work with a white PLA filament for my first rocketry prints.

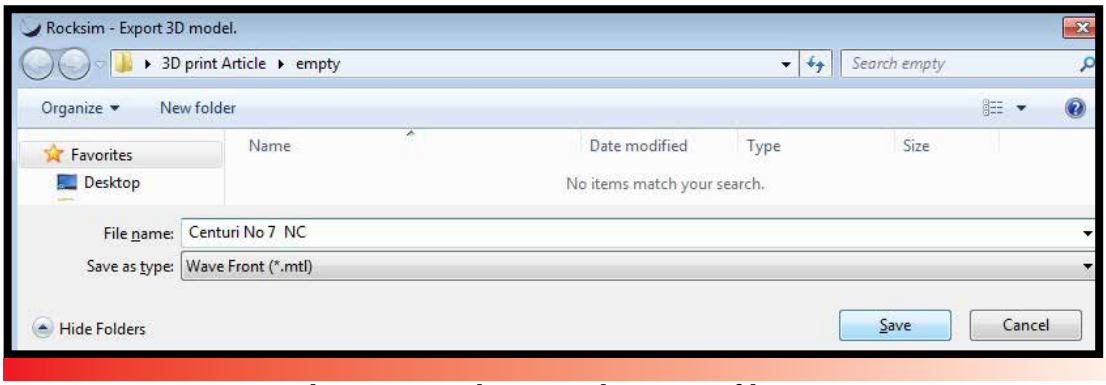

Figure 2: Centuri No 7 NC being exported as a ".mtl" 3D print file.

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For some practice with my printer, I downloaded the 3D print files for the Estes Orbis kit for free at the Estes Rockets website. These parts came out rather thin and fragile when I printed them as is using default 3D printer settings. The reason for this was they printed with only a 2 surface layer thickness. Turning up the number of surface layers to 3 provided nice sturdy prints of all 3 BT-20 nosecones. Since CURA uses metric settings by default when I opened these .stl files they appeared as very tiny objects (almost invisible) in the CURA software and had to be enlarged 2540 times on each axis to convert the English system units to millimeters. At 3 layer thickness, the fin can and launch lug won't fit over a BT-20 body tube nicely and the pin or bottom of the nose cone doesn't fit into the bottom of the nose cone if the nose cone is printed with 3 (or more) surface layers thickness. These ogive, tapered, and rounded nosecones should be good for a number of BT-20 (18mm) projects, the same goes for the 3 fin cans available (**Figure 11, Page 8**).

I recently started assembling an Estes Nike Apache kit and couldn't help but notice the complex transition that

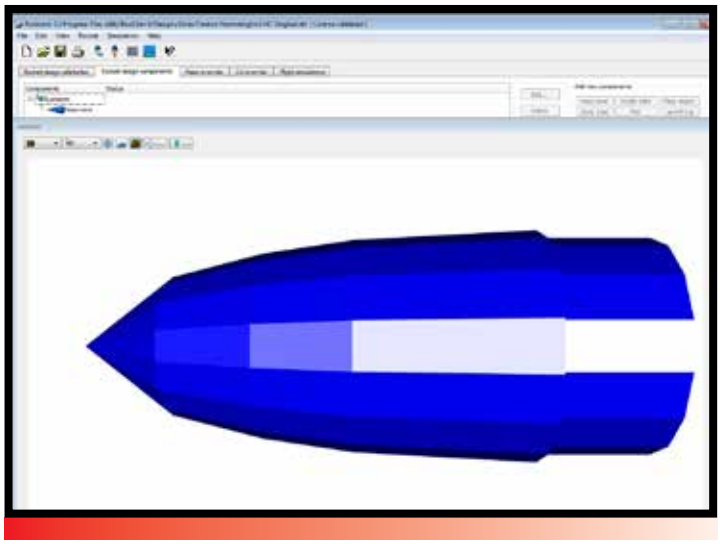

Figure 4: Nose cone view with low-resolution setting

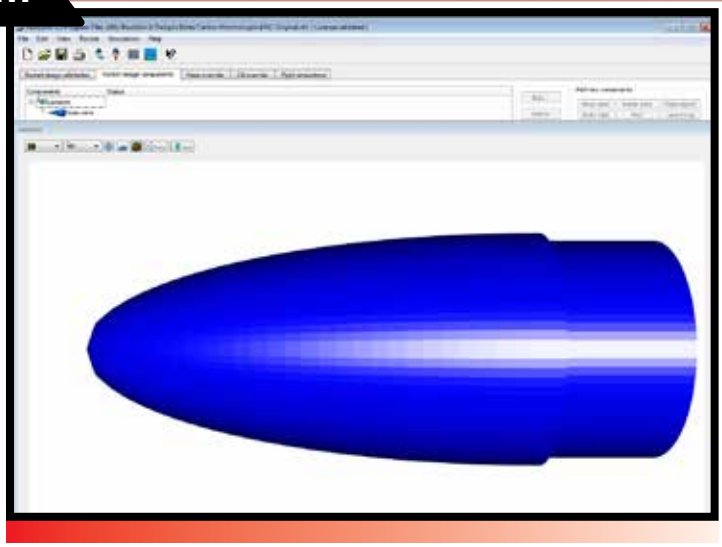

Figure 5: Nose cone view with high-resolution setting

came with the kit; this was the next object I attempted to 3D print. I measured the part from the unbuilt kit using an inexpensive digital caliper. The Transition had to be drawn as several transitions and tubes and I choose to draw the tip of the transition as a conical nose cone see **Figure 12** (**Page 8**). I was unable to include the 3 indentations (round bolt wells) in the edge of the upper part of the transition, perhaps as I learn more about CAD drawing programs I will figure out how to include this additional detail.

In the CAD programs, I have yet to figure out how to get from a drawing exported from RockSim to a solid figure that I can easily edit with a CAD program. As before with the nose cone I replaced the shoulders on the transition using inside tubes with the same circumferential dimensions but about 1/8" longer than on the real shoulders. Also as before, these inside tubes extend into the inside of the transition by 1/8" for strength. I then exported the 3D model out of RockSim using the higher resolution settings that I manually entered as mentioned above. I used CURA software to generate the .gcode file from the .obj file and printed the transition on a raft, the extra material visible around the base, in **Figure 13** (**Page 8**) with support for the conical bottom of the transition; these are

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columns of material extending down from the conical part of the transition's base. The part came out nice it fits both body tubes like the transition in the original kit. There is some roughness in the plastic wall where the support was attached to the lower conical part of the transition.

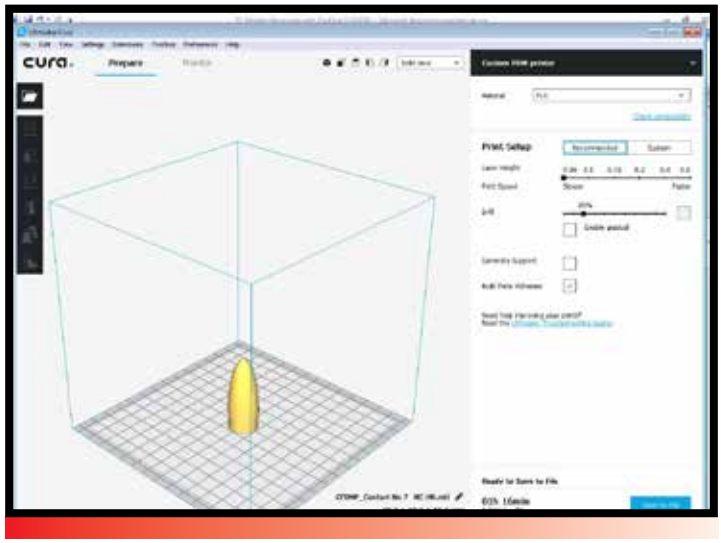

Figure 6: Clean rendering in CURA from resolution change in RockSim

Next, I tried printing a boat tail transition similar to the balsa tail cone on the out of production Estes V2 kit number K-22. I wanted a boat tail with a bore through the center to accept a motor tube like the solid balsa tail cone that came in the original kit. Again I deleted everything else from the V2, K-22 RockSim file except the balsa tail cone. As before with the nose cone and transition I replaced the forward shoulder on the tail cone using an inside tube with the same circumferential dimensions but about 1/8" longer than the real shoulder. Also as before, this inside tube extended into the inside of the tail cone by 1/8" for strength. I then exported the 3D model out of RockSim using the higher resolution settings that I as above. I printed the tail cone with the narrow end pointing up. I also attempted to include a through-hole in the boat tail for the spiral wound paper engine tube to fit into. In the RockSim file, I made sure the bore of the tail cone was wide enough by an extra 0.01 mm to accept the paper motor tube. When I attempted to print this 3D file the inner bore was printed too narrow and the internal structure was not securely attached to the rest of the boat tail. I tried several different settings in slicer software to correct this issue, but after several attempts, I was not able to get an acceptable print. For this part, I actually ended up using just the hollow printed boat tail **Figure 14, Page 8** (without the top and bottom layers) and used a cardboard motor tube with 2 centering rings.

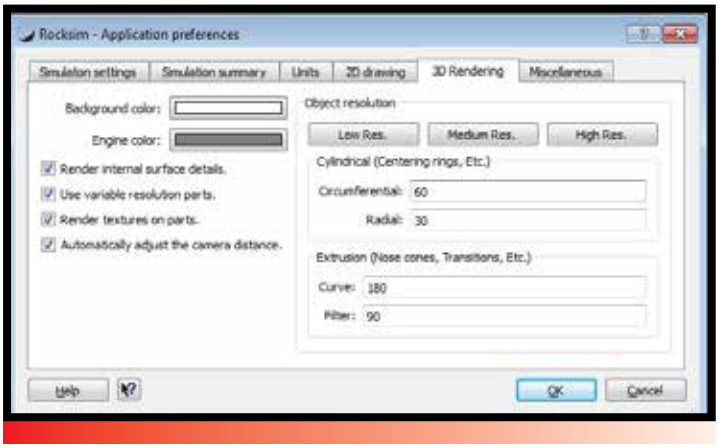

Figure 7: Adjust the resolution further in CURA by adjusting the curve and filter extrusion settings.

I had also desired to clone the complex nosecone from the Estes Python kit it which is 191 mm in length. To represent this complex shape in RockSim the nose cone was composed of one elliptical nose cone for the tip, 6 transitions of various diameters and cross sections and then an inside tube section for the nose cone shoulder **Figure 15, Page 9**. I selected to print 6 bottom layers to generate a closed end on this nosecone. The 3D prints using 3 wall layer thicknesses with PLA filament came out great for this design with a closed aft end. It is difficult to tell the 3D printed nose cone from the actual molded one that came in the original Estes kit **Figure 16, page 9**.

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I later tried to print this same nose cone design using similar settings (3 wall layers thicknesses) with acrylonitrile butadiene styrene (ABS) filament; however, these 3D prints were weak and easily came apart at all the seams between the different transitions. To remedy this issue I found I had to print the nose cone with more layers (5 or more wall layer thicknesses). This gave an acceptably strong nose cone with the sacrifice of some added weight.

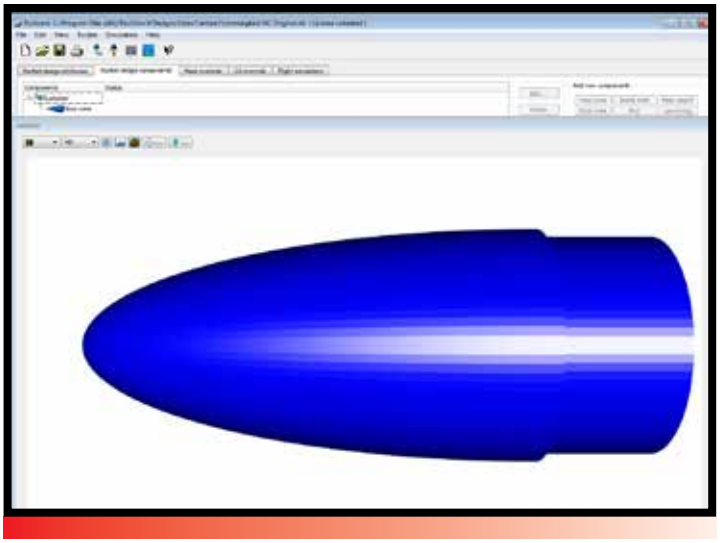

Figure 8: Completed adjustments create an even smoother rendering in RockSim

ABS filament is slightly more expensive than PLA, although sales are common to and can drop the price of ABS filament down to the $10 per kg range. ABS is lighter (less dense) than PLA and sands down much easier than the more crystalline PLA. ABS prints at higher temperatures than PLA typically 240°C versus 220°C respectively. ABS is more shatter resistant and less temperature sensitive than PLA. I had a large PLA nose cone break when I dropped it on the floor and I warped a PLA nose cone with boiling water just to see if the part would stand up to this treatment. Similar nosecones made from ABS did not shatter or warp under similar stresses. That said ABS is a more difficult polymer to print as it tends to warp on the printer platform (or bed) unless the platform is heated to around 110°C. I also noticed ABS requires more outer layers (5 layers typically) than PLA (which typically uses 3 layers).

Figure 9: First nose cone printed.

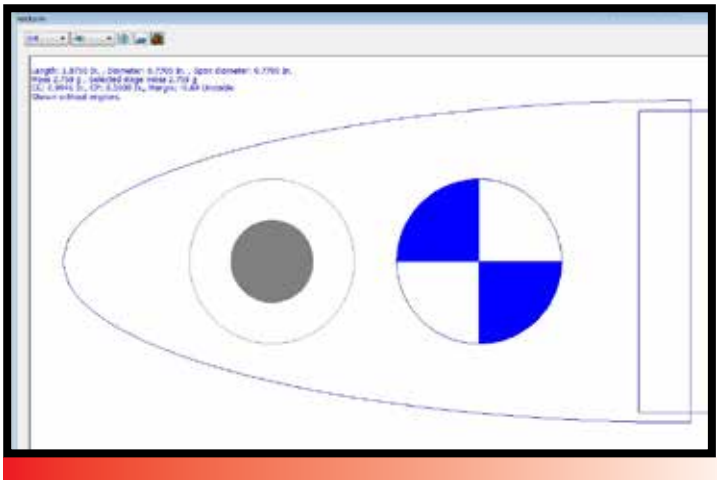

Figure 10: Nose cone adjustments made in RockSim to remove thin edges and prevent the nose cone from cracking.

I hope I have provided a useful description of how to use the number 1 model rocketry simulation software "RockSim" to generate 3D files that can be utilized by the slicing software that controls most 3D printers without learning or having access to CAD software.

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Figure 11: 3D prints from the Estes Orbis Kit Bulk Pack

About the Author

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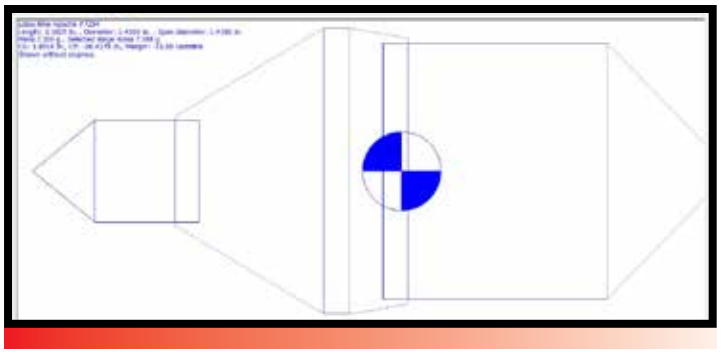

Figure 12: Estes Nike transition re-constructed in RockSim

Figure 13: 3D Nike transition printed on a raft

Figure 14: Hollow printed boattail

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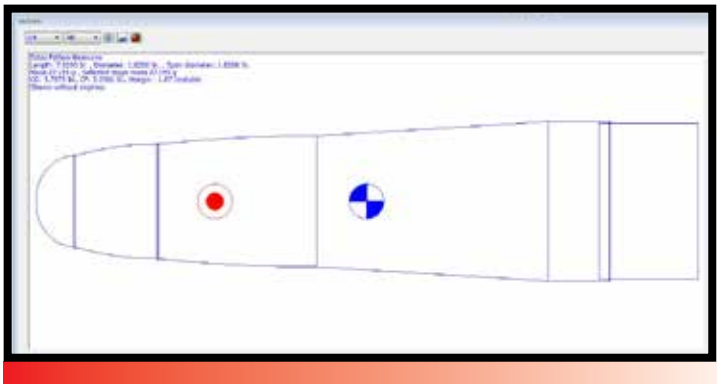

Figure 15: Estes Python nose cone re-constructed in RockSim

Figure 16: 3D Printed Python nose cone next to original mold

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