SOURCE

August 2026, Issue 5
Rockets
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SOURCE:
a quarterly periodical that takes a look into interesting open source projects and applications. In this issue "Rockets!" we are going to step through how to design, and simulate the flight, of a rocket using the excellent open source OpenRocket application. We'll also, along the way, learn about the construction of small amateur or research rockets and explore how FreeCAD can help us make components for our build.

Welcome to SOURCE

Hello, I'm Jo, AKA Concretedog, and first of all, thank you for taking interest in SOURCE.

If you've looked through earlier issues of SOURCE, you'll know that SOURCE is my place for writing content that doesn't fit elsewhere in my paid writing work. It tends to be a little more in depth in it's tutorials whilst promoting opensource.

It's pay as you feel and I'd love to see some donations come in for my time as it's a pretty big undertaking getting this all together! That said, times are hard and if you aren't in a position to donate, I really hope you enjoy reading this, tell your friends about SOURCE, and much solidarity to you.

In this issue the theme is "Rockets". Rocketry, whether model or high power amateur, has been an excellent pastime and it really does have something for everyone. Whilst this issue looks at designing and scratchbuilding, I'd urge everyone to build and launch a model rocket from a kit at least once! Beyond rocket design it can lead you into other technical areas, parachute design, electronics and control systems, and much more!
I really hope you enjoy this issue, as ever do share this with people, you can host it, compress it and email people, put it in your USB dead drop, or just share links with people, let's spread opensource far and wide.

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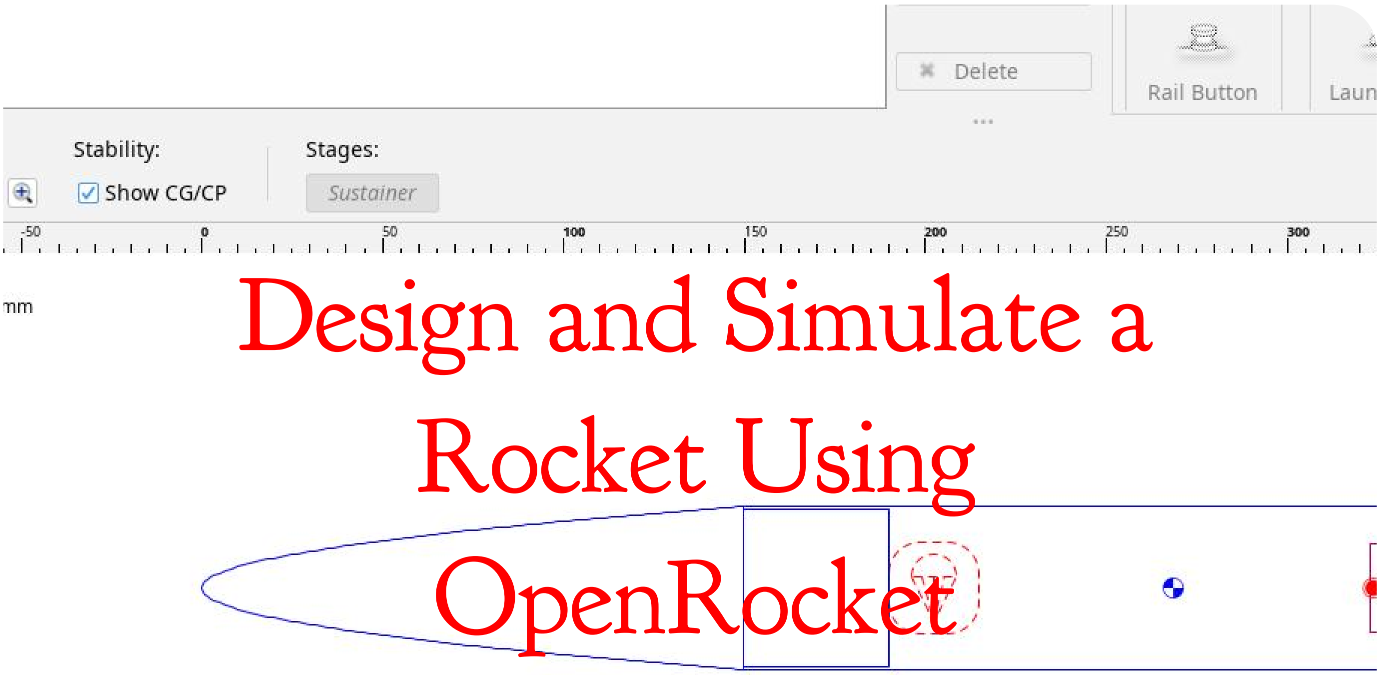


Design and Simulate a Rocket Using OpenRocket

Model and amateur and high power rocketry are all excellent pastimes. If you have any interest at all we urge you to buy a model rocket starter pack, read the instructions and safety guidance well, and then build and launch your model, it's incredible fun. Beyond that joining a rocketry club is an excellent next step along a rocketry journey. Another big step on this journey is designing and building your own rocket. Let's use open source tools to help us design, simulate and manufacture a rocket design.

We are primarily going to use two bits of open source software to help us do this. One is Open Rocket which will help us lay out a general design and allow us to simulate our model in flight and the second is FreeCAD with the add on Rocket Workbench installed which will help us create and modify CAD for parts of our design, allowing us to use 3D printing and more to create rocket components.

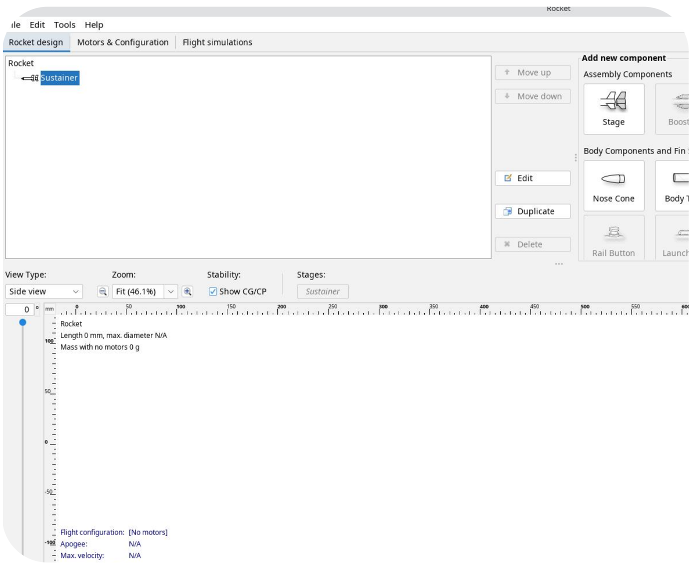
To begin though head over to https://openrocket.info/ and download and install the latest version of OpenRocket for your operating system. We are using version 24.12 using the x86-64 image on Debian.

Often the first part of designing a smaller rocket is to actually find a tube that you will base the rocket body on. Rocket body tubes are available from commercial vendors and might include cardboard tubes, phenolic tubes and even some types of plastic tubes. For lower power model rocketry a simple cardboard tube is often all that is needed. Postage tubes are often a target but you need to look for thin walled examples as often postal tubes are a little overbuilt and heavy for rocketry.

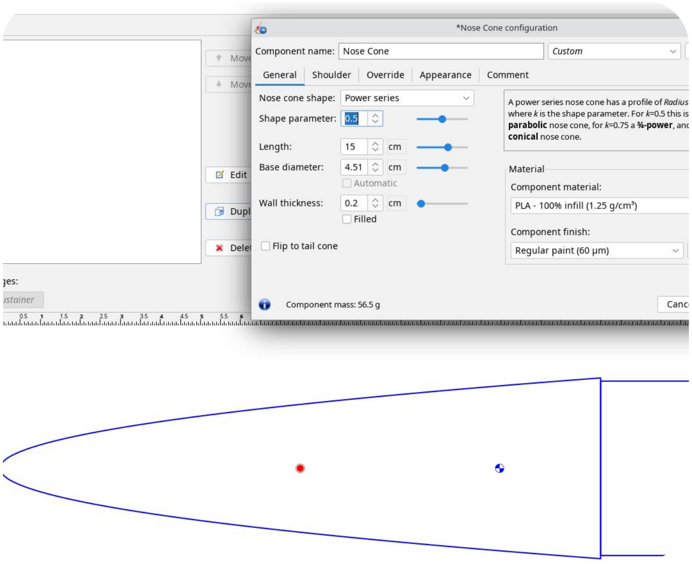
Our target tube is from the centre of some gift wrapping paper and we have a length of 66 cm we can use and the tube is thin walled and 45mm outside diameter (OD) and 43.4mm internal diameter (ID). If you are using a found tube just make sure it is nice and straight and not creased or folded as this can weaken the tube. We don't yet know how long we are going to build our rocket, so don't cut down your tube at this point.

Having identified your own tube grab a pair of calipers and make some careful measurements of the ID and OD. For the ID using a set of telescoping bore gauges can be more accurate if you have them, but calipers likely accurate enough for your first design.

With some knowledge of your tube dimensions we can dive straight into OpenRocket. Booting Openrocket for the first time we will see a welcome dialogue with release notes included telling us about the work that has gone into this latest release. We can close this window and can check the "Don't show this dialogue again" box so it doesn't show in subsequent boots.



You are now on the main "Rocket Design" page of Openrocket. The top half of the page has on the left hand side a component tree view which will build up a list of hierarchical components as we add them to our design. The upper right hand has an area "add new components" and we can see various buttons for various components we can add to our design. In the lower part of the page we can see the preview window which will show representations of our growing rocket design as we add components, as well as overlaying other calculated information such as the design mass, and stability margin values, more on those later.



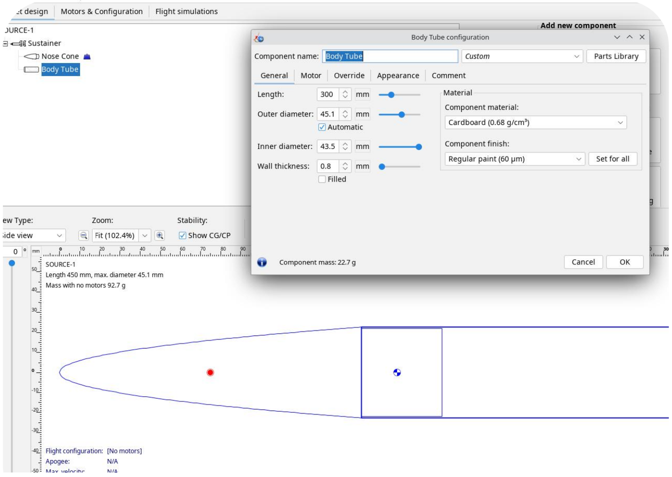
Let's begin by clicking the "Nose Cone" tool icon in the "Add new component" section in the upper right of the Rocket design page. You'll first see a popup window appear that contains a database of component presets. These are commercially available components from manufacturers. This is useful if you are designing using off the shelf components, or indeed you are creating a openrocket file for a commercial rocket design you already own (this can be great for simulating how your rocket will work with different motors for example).

As we are scratch building and plan to 3D print our nosecone, we will ignore the component preset database, and click close, additionally you can uncheck the "Always open this dialogue when creating a new Nose Cone" box so that the database doesn't automatically launch in the future (you can launch this database from any component parameter dialogue). Closing the component preset you should now see that you have a nose cone component outline in the preview area and a "Nose cone configuration" dialogue open. We can first play with the "Nose Cone Shape" dropdown menu. There are numerous options some of which are basic geometric descriptions so "Conical" "Ogive" Ellipsoid" etc but some are special rocket nosecone geometries, "Power series", "Haack Series" etc. This isn't the tutorial to explore deep dives into nosecone geometry for best aerodynamic performance for certain types of rockets, so for now you can play with these setting and simply chose on looks!

What is more important is that the size of the base of the nosecone matches the OD of our tube. So in the Nose cone configuration dialogue we changed the base diameter of our power series nosecone to 4.51cm. Note that wherever in openrocket you see a box containing a unit like "cm" you can click on that unit box and swap the unit to different imperial or metric units. For example we often prefer to input units as mm. Note also that you can globally change units by using the dropdown menu "Edit – Preferences" and then adjusting the "units" tab in the preferences dialogue.

Back on the Nose cone configuration for our nose cone we added the base value of 4.51 cm and set the length of the power series nosecone to 15cm, let's also set the "wall thickness" value to 0.8mm. In this case the "wall thickness" value doesn't matter too much for the nosecone but when we add a body tube later it should pick up on the 0.8mm wall thickness value and automatically our tube ID and OD will match the nosecone values. Nosecones in model rockets are often designed to eject from the body tube to release a parachute. This happens, in simple model rockets, via the motor. A commercial model rocket motor will, when ignited, burn for a certain period as a motor creating thrust. Then after burnout the motor will have a small timed fuse type area still burning and after a known delay this will ignite a small charge inside the rocket. This will push up through the rocket knocking out the nosecone and ejecting a parachute or other recovery system. As such the nosecone needs to have a "shoulder" which fits inside the body tube which holds the nosecone in place but acts like a piston to be pushed out at the correct time. To add a shoulder to our nosecone we can click the "Shoulder" tab in the "Nose Cone Configuration" dialogue. In the shoulder tab we added a shoulder with a Diameter of 43.5mm (matching the ID of our target tube) and a length of 40mm. We checked the "End capped" button as this means we, in essence create a solid nosecone rather than a hollow one with wall thicknesses.

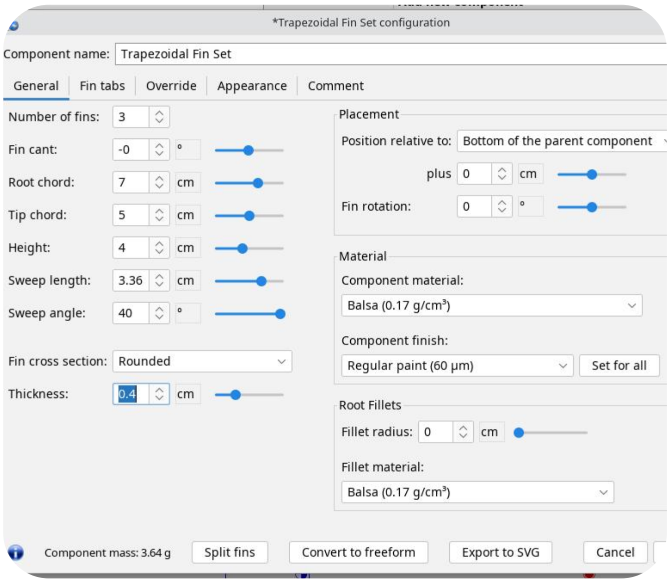
Clicking back to the "General" tab on the "Nose Cone Configuration" notice that we can also select different materials from the "component material" dropdown in the "material" section. Obviously materials effect the mass of the designed object so you can find one that matches how you plan to make your nosecone. However, also know for now, that you can use the "Override" tab on any component configuration dialogue to add a custom mass for the component. For now, we selected PLA 100% infill from the material list, but when we actually 3D print a nosecone we will weigh it and adjust the actual mass in the openrocket design. Note also you can set the component finish value, these obviously effect drag. So a highly polished and smoothed surface finish creates less drag than a rougher unfinished surface. We tend to stick with the "regular paint" value as we aren't excellent at creating a mirror finish paint job!



We can now close the nosecone component dialogue. Next let's add a length of body tube. With the nosecone component selected on the component tree click the "Body tube" tool icon in the "add new component" section. Again you will see the preset component database launch, close this window and the we can adjust the component parameters. Notice that it automatically has added a tube but that the tube OD, ID and wall thickness values match our real life tube and it has taken these parameters from our nose cone geometry. We aren't 100% sure again of how long a body tube we want in this design but we set it currently to 300mm long. Set the material to cardboard and the surface finish to regular paint.

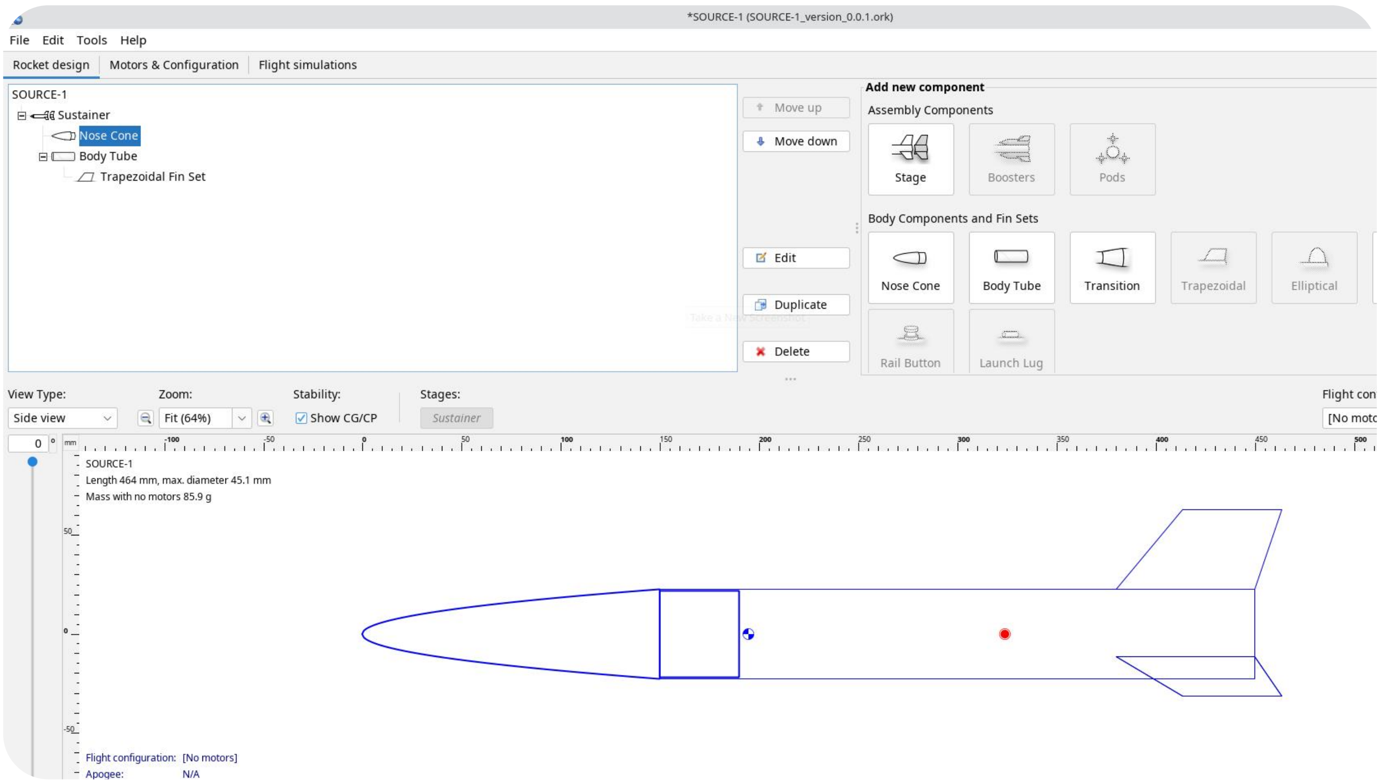
Note that at any point you can double click on an item in the model tree list and it will re-open that components dialogue and you can readjust any parameters you wish to.

Next with the "Body Tube" component highlighted in the component tree let's click the "Trapezoidal" tool icon to add a trapezoidal set of fins to our design. Note that there are numerous other fin tool types such as "elliptical" or "freeform", feel free to play with these. For our fins we have created a set of 3 fins with a "root chord" of 70mm. This is the length of the section where the fin joins the tube. We've made the "Tip chord" 50mm which is the outer edge of the fin. We set the fin height to 40mm and set a "Sweep angle" of 40 degrees, this should automatically then update the "Sweep length" to 33.6mm. We set the thickness of our fins to 1.5mm which is quite thin but we have some tough plywood in this thickness we are going to use, but feel free to add thicker 3mm fins.



You should now have something like the image at the bottom of this page where we can see the general layout of our rocket. Notice that we have 2 small icons on the rocket design, one blue and one red and that these have been moving as we added, or made changes to the components. These two icons, the cenre of gravity (blue) (CG) and the centre of pressure (red) (CP) will help us create a rocket design that should flight with stability in the correct direction!

Notice in the top right hand corner of the lower preview window we can see these icons again next to and under some numerical values. The first line reads "stability:" and in our design at this point reads "2.87cal/27.9%". These values show how far behind the centre of gravity the centre of pressure is moving from the fore/nosecone end towards the aft/fin end of the total rocket airframe. "2.87 cal" is where a single "cal" is the major diameter of the largest section, ie the body tube. With the body tube being around 45mm diameter we can sanity check this by seeing that underneath this line the CG and CP positions relative to the tip of the nosecone are around 130mm apart which matches roughly with 2.87 cal. The 27.9% value is another way of stating the stability margin and this is saying that the CP is 27.9% of the total length of the airframe behind the CG. We can again roughly check this as the total length of the airframe is listed as 464mm and if we multiply 464 by 0.279 (or 27.9%) we get roughly 130mm again.



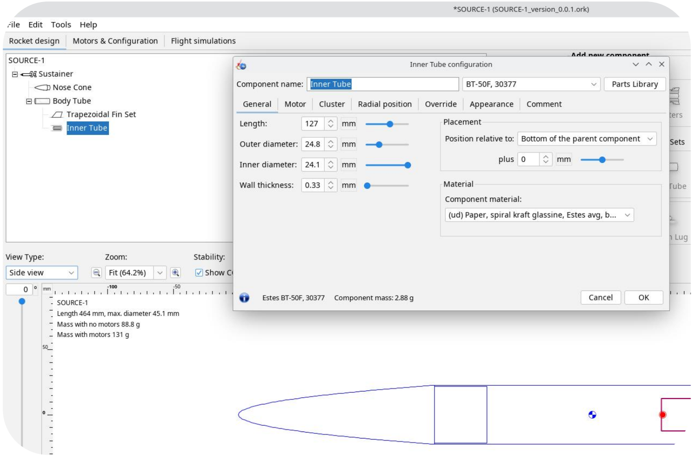
When you are making a simple rocket with just one major diameter of tube with no diameter changes it's often easier to think about stability in calibers or "cal". We are aiming to design a rocket so that when it has all its components and a full unburnt motor, ie as it would be when ready for launch, the stability is between 1 and 2 cal. If the rocket is less stable, say 0.3 cal or even a negative stability value, then there is a high chance that when launched it will spin dangerously in the air and not fly straight. However, it's also can be sub optimal if you make a rocket over stable.

The Centre of Gravity, or CG is the point around which a rocket will rotate or turn.

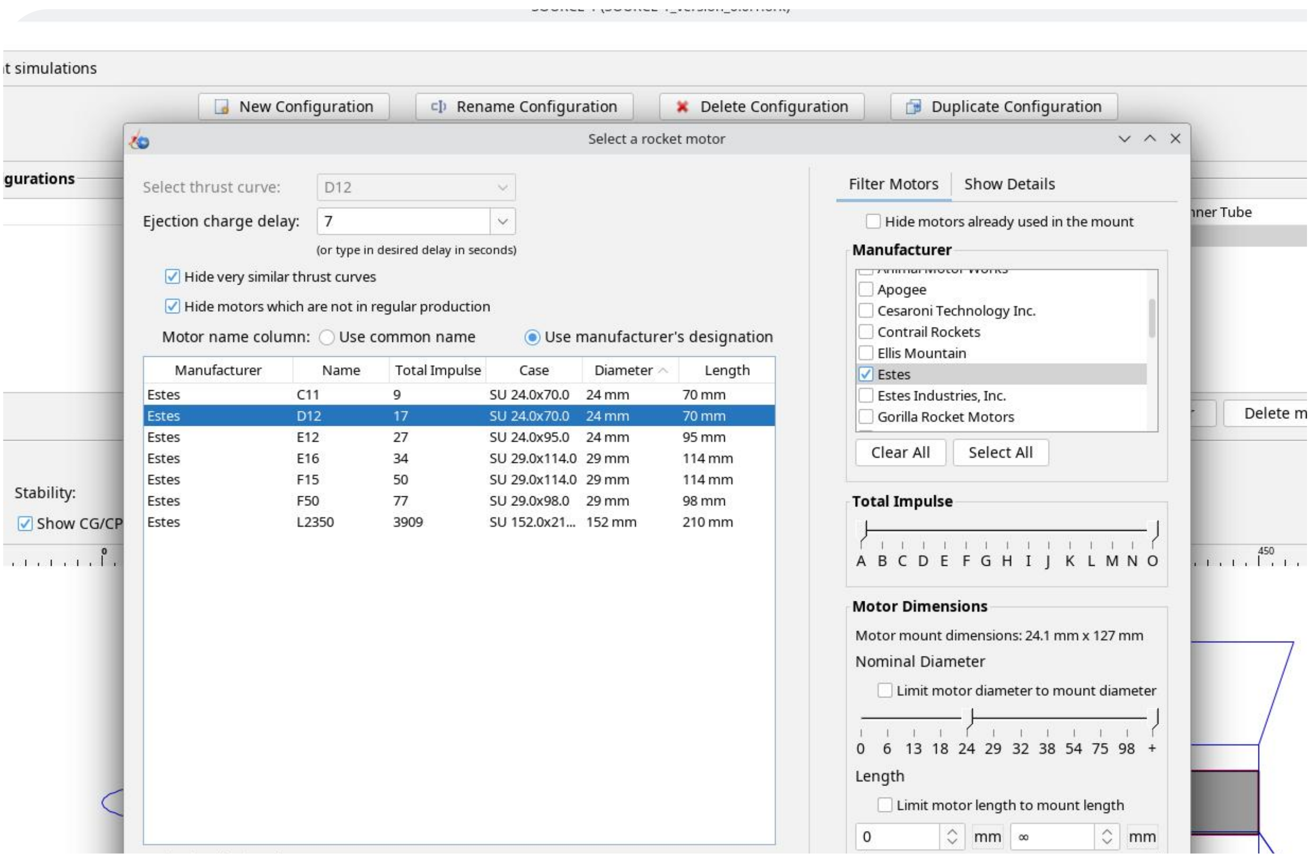
Say you design a rocket and the stability margin is high, say the CP is 6 cal behind the CG, then there is an issue where the rocket will turn into any tiny amount of side wind. You can imagine a line between CG and CP and consider this a lever, if the lever is very long and the wind pushes the lever even slighlty, then the rocket will turn into the wind, rotating around it's centre of gravity.

The Centre of Pressure or CP is the point where all the sum forces acting on a rocket meet.

The centre of gravity is obviously effected by adding mass to the rocket design. You might think that just adding more weight to the nosecone end is therefore the best solution, but, of course, generally speaking adding more mass means more weight to lift which potentially reduces altitudes reach etc. You can of course also effect the Centre of Pressure, increasing the fin size, or the number of fins, will move the CP towards the rear. Another technique to experiment with is lengthening the body tube. However the challenge is is that all these factors effect each other. One of the heaviest items to get added to a rocket is the motor. It can be a good idea at this stage, when we only have the nosecone, tube and fins, to add a motor to see roughly how the mass of the motor effects the CG-CP relationship. Eventually our design will have centering rings cut to fit inside the body tube to hold an internal tube into which the motors will be loaded. Model and amateur solid propellant rocket motors come in a range of fixed diameters so 13, 18, 24, 29, 38, 54mm and more are all classic motor diameters. We are going to design around a 24mm diameter motor mount tube as 24mm gives a good range of motors available suitable for some exciting flights for a rocket of this size.



With the body tube selected let's scroll down on the components window to find the "Inner components" section and then click "Inner Tube". Again you will see the parts library database dialogue with a large selection of commercially available tubes. As we plan to use a length of Estes BT50 tube we can select an Estes BT-50F from the list which inserts a 127mm length of BT tubing. We can then when building the rocket, cut a length of BT50 tubing to this size, or purchase a precut BT-50F tube. With the BT-50F selected we can close the part library dialogue and then we can see the "Inner Tube configuration" dilaogue. Before we close this we need to left click on the "Motor" tab in this window and then tick the box that is labelled "This component is a motor mount".
We are now ready to add a motor into our rocket. Motors are treated slightly differently than components in open rocket as they are added as a motor configuration, which, obviously, is important when it comes to simulating the flight of a potential design.

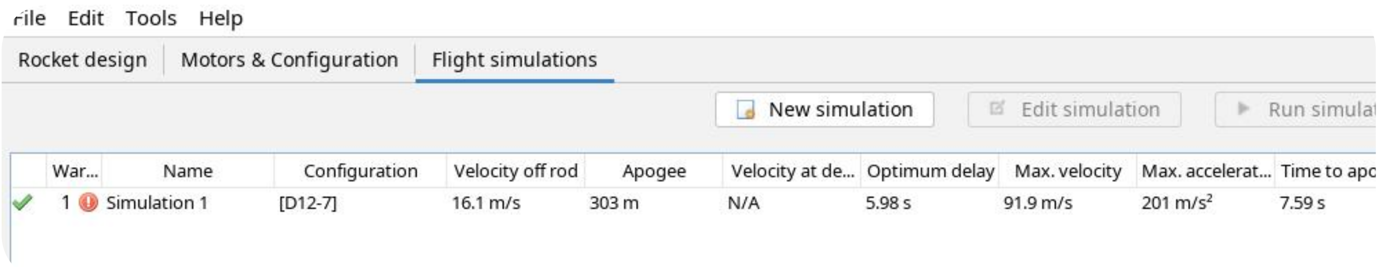


It also means that a single rocket design can have numerous motor configurations for simulation. This is excellent as we can look at the performance of a rocket using less or more powerful motors, and also react to what motors our rocket vendor may have in stock. We plan to first fly this rocket design with a classic Estes D12-7 motor.

In the upper left hand area of openrocket lets left click to switch onto the “Motors and Configuration” tab. Then let’s left click on “New Configuration”. This will launch the “Select A Rocket Motor” dialogue. This dialogue window contains a large database of commercially available model, amateur and high power rocket motors. There are numerous ways to narrow a search. You can check boxes to see only certain manufacturers, or there are sliders that limit the visible motor selection by power or impulse rating, or by the diameter of the motor. In our case we can scroll the motor manufacturer list and then check Estes, and then select the D12 motor from the shorter list of Estes Motors. It’s also fun to look at all the 24mm diameter motors and see what different powerful motors there might be available.

Smaller solid rocket propellant motors have an ejection charge that fires into the inside of the rocket after a predetermined delay. This delay is measured in seconds from the time the main thrust of the motor burns out. This ejection charge pushes out the parachute removing the nosecone. It’s important that we use motors with the correct ejection delay so that the parachute/recovery system is deployed at or near apogee when the rocket is moving slowly. If we eject too early the rocket may rip and tangle in the parachute, and we won’t achieve the maximum altitude, if we eject too late, well into the period where the rocket is falling the rocket may be travelling to fast so that the parachute rips on ejection. Many model scale motors, like the estes D12, are available with a reange of ejection delays. So for example the D12-5 has a 5 second delay and the D12-7 has a 7 second delay. As such, before we close the “Select a Rocket Motor” dialogue we need to select our preferred ejection delay let’s select 7 seconds from the “Ejection charge delay” dropdown menu.

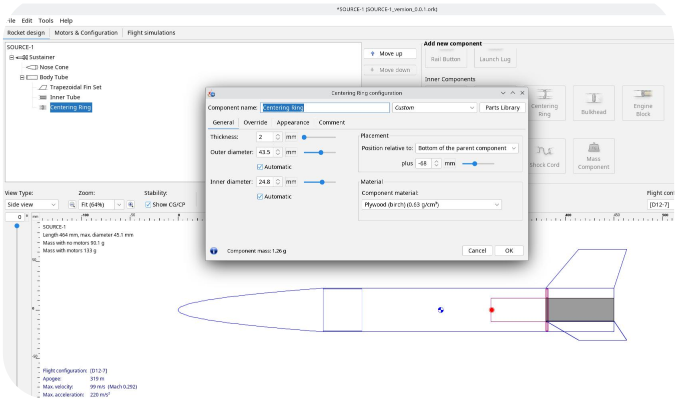
You’ll notice now that our rockets CG and CP have moved a reasonable amount as the weight of the D12-7 motor is added. We can see that our stability margin at this point is 1.19 calibers which is pretty decent. We know that there will be small amounts of mass added to the design, a parachute, centering rings and more but we are definitely in the correct ballpark.



As we are 3d printing the nosecone we can adjust the infill of the nosecone geometry making it lighter or heavier to adjust the CG. We can also now take a look at a preliminary flight simulation using the D12 motor. If we left click to select the "Flight Simulations" tab we should see a one line entry "simulation 1". In the left hand column there is a a warning that the rocket will fail due to there being no recovery device (no parachute or similar) but we can still see numerous details, including the suggested apogee of 303 metres. Which is pretty darn high!

Next lets add the centering rings that will, in real life, hold the motor mount tube in position. We plan to have 2 rings and we are going to use a custom 3d printed part to retain the motor. We aren't going to model the 3D printed retainer in OpenRocket, but we can add a centering ring and override it's mass to match the screw on threaded retainer we have previously made. This retainer is available to 3D print here. https://codeberg.org/concretedog/24mm_Threaded_Motor_Mount_Retainer/src/branch/main/

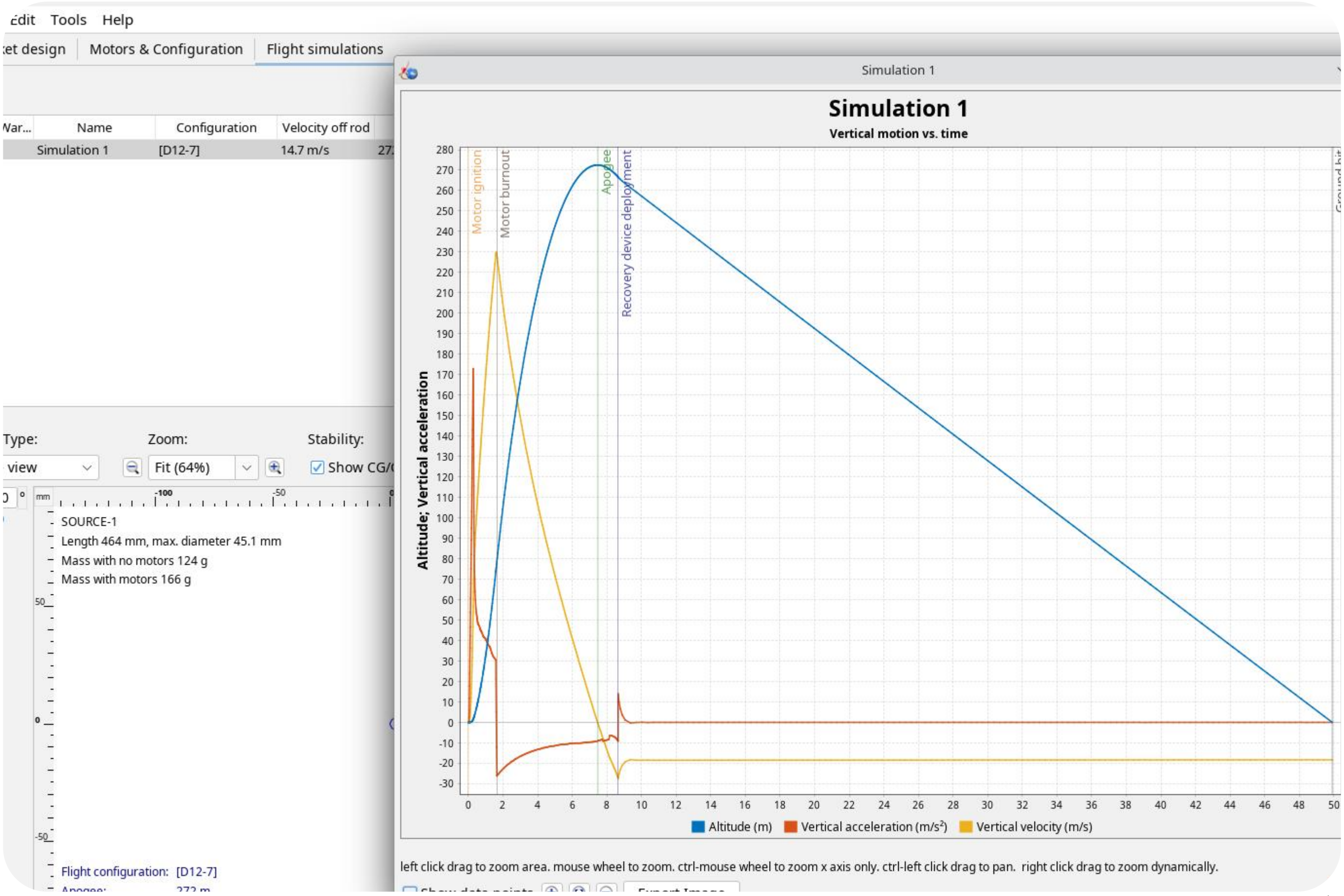
In openrocket highlight the main bodytube in the model tree and then click the "Centering Ring" component icon. This will add a centering ring at the very base of the rocket design but will automatically be placed around the motor mount tube. Close the component database and in the "Centering Ring Configuration" dialogue set the thickness to 2mm and set the material to "plywood (birch)". We can make this the forward centering ring by adjusting the "Placement" value. We like to have a centering ring at the upper edge of the fin roots as this then forms a strong fin area. As such we moved the position, relative to the bottom of the parent component, a value of -68mm. We clicked OK to apply the change.



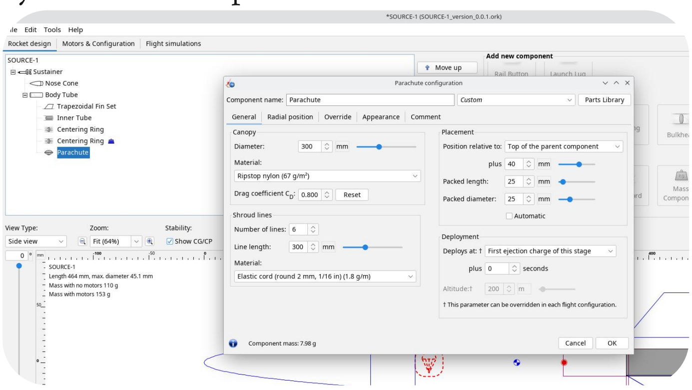
We are going to repeat the above process and place a second centering ring in the base of the rocket body tube. Whilst this isn't how the rocket will actually look or be constructed, if we override the mass of the centering ring it gives a close enough approximation to make the simulation somewhat accurate. Weighing our rear centering ring and the 3D printed motor retainer they weigh 12.3 grams .

So we once again highlighted the body tube and added a centering ring. As the motor retainer part is around 16mm tall we placed the centering ring at -8mm into the body tube and then, in the "Centering Ring Configuration" dialogue we switched to the "Override" tab and over rode the mass to 12.3 grams.

You can use the "Override" tab in any component dialogue to adjust the mass of the real world item. As you make components it's worth weighing them and returning to input the data into your rocket design.



Next we added a parachute component as a recovery system. We highlighted the body tube and then clicked to add a parachute. We didn't deviate from the the default parachute which is 300mm diameter and made from fine ripstop nylon. We moved the component back in the bodytube 40mm using the Placement section of the Parachute Configuration dialogue. Hopefully you'll see by now that most components can be moved and also can have overrides applied to dial in your real life data as you make or add parts.



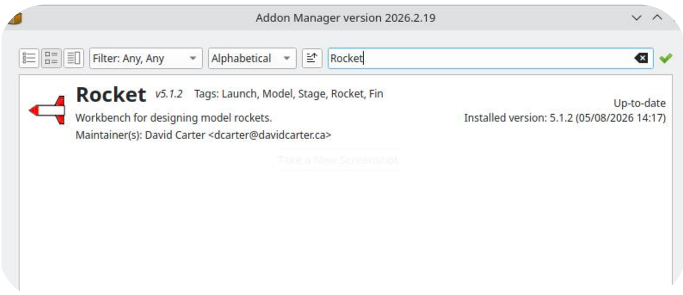
At this point our design is currently around 0.944 calibres stable. This is pretty good and will certainly become over 1.0 calibres when we actually 3D print the nosecone. One advantage of 3D printing is that we can adjust the infill amount when we slice our design which can adjust the final mass of the component. Also many slicers will give an estimate weight of a sliced object prior to printing. We printed this nosecone at a very dense 40% infill and it actually weighed 97 grams. We think that we can target the infill to still create a strong nosecone and have it weight perhaps 70 grams. As an experiment if we override the nosecone mass and set it to 70 grams our stability margin changes to a healthy 1.23 calibres.

Before we leave openrocket we can quickly run the simulations again with our D12-7 motor. Move to the "Flight Simulations" tab and click the "Run Simulations" button to ensure the simulation is up to date. Then, with the simulation highlighted left click on the Plot/Export button. Leave the "Edit Simulation" dialogue as it is and click the "Plot" button. You should now see a graphical output with all the flight simulation data plotted. Notice that our ejection charge is deploying the parachute just shortly after the apogee. This is great in that we are definitely attaining the maximum altitude whilst not delaying so much that the rocket is travelling to fast back to ground potentially causing the parachute to shred!

From OpenRocket to FreeCAD Rocket Workbench

Having designed and simulated our rocket in Openrocket, it's useful to know that we can pretty quickly recreate our geometry in FreeCAD using the Rocket Workbench addon.

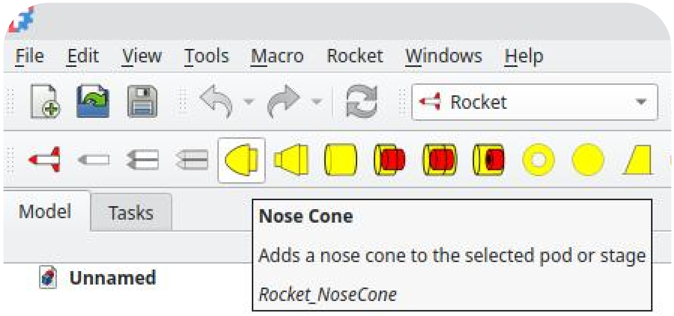
If you haven't ever installed an addon workbench in FreeCAD it's really straightforward. From anywhere in FreeCAD click the "tools" dropdown menu and then click "Addon manager". In the addon manager dialogue type "rocket" into the search bar and you should find the listing for the Rocket workbench.



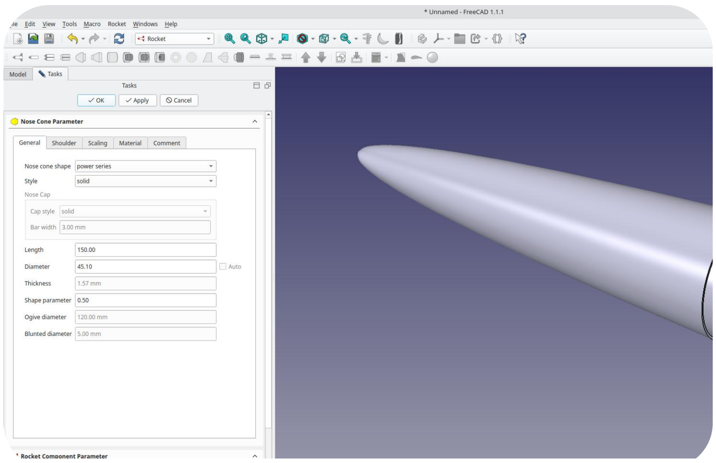
Left click on the listing and you can then read the information about the workbench before clicking "install". Once installed FreeCAD will request a restart and then, once restarted you will see the rocket workbench in the workbench dropdown menu.

We aren't going to fully explore the ROcket workbench in this article, but it's worth a quick look as the FreeCAD Rocket Workbench has been designed to mimic some parts of the OpenRocket workflow.

On the Rocket workbench you'll see a collection of yellow tool icons that are reasonably intuitive, there is a nosecone icon, a tube tool icon, a fin tool icon and more. Let's click the nosecone icon to add a nosecone.



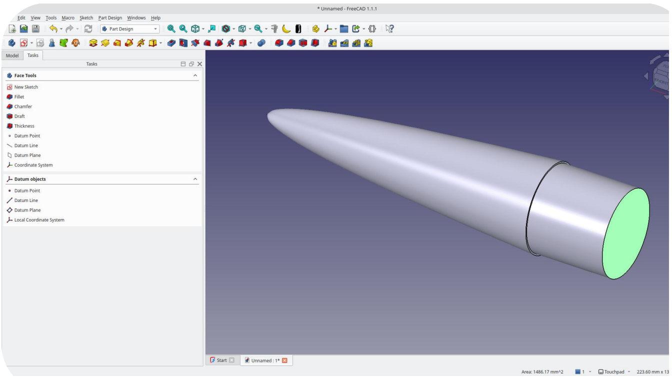
You should notice immediately some similarities with Openrocket. In the "Nose Cone Parameter" dialogue we can simply input the same values as our openrocket design. So in this case we set the nose cone shape to "power series" set the length to 150mm, the diameter to 45.1mm and the shape parameter to 0.5. We then can click the "Shoulder" tab in the dialogue and we can add the length of 40mm and the diameter of 43.5. We can then see in the preview window this has created the exact same geometry as our nosecone in our Openrocket design.



Clicking OK, our nosecone object is created and appears in the preview window and in the model tree view as does any other item in FreeCAD. If we required we can now highlight the Nosecone item in the model tree, then left click the main "File" menu dropdown and select "Export" and export as an STL.

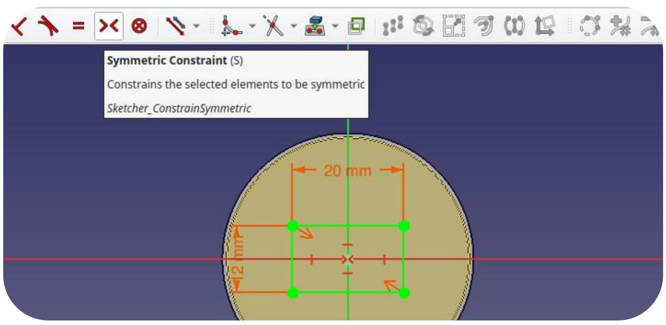
However! Of course having created this nosecone in FreeCAD we can do much more to the nosecone geometry using the more regular CAD tools and approaches outside the Rocket Workbench. As a quick example let's add some geometry where we can connect the rocket recovery system too (the harness that connects the nosecone, main tube and parachute together when the nosecone is released and the parachute pushed out.

First let's use the dropdown menu to move to the "Part Design" workbench. Then, in the preview window, let's left click to highlight the base of the shoulder as shown in the image below.

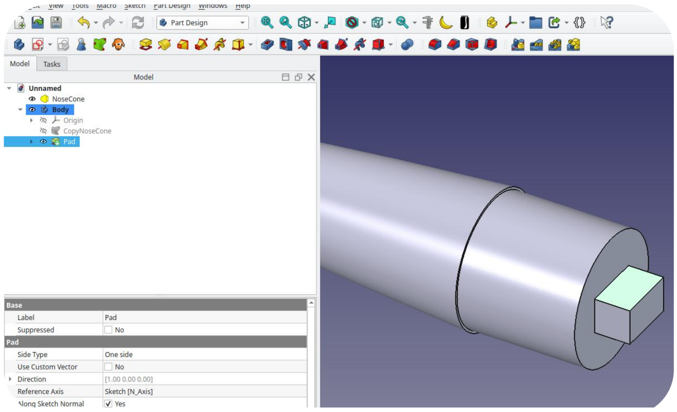


With that face highlighted then click the "New Sketch" tool icon. A dialogue will appear warning that an "Active Body is Required". It will offer to "Create New Body" and can simply click "OK" and then click "cross reference" as the type of copy.

This will then switch us to the Sketcher workbench. Let's create a first sketch on the base of our nosecone. Click to select the "Rectangle" tool and begin to draw a rectangle over the centre point of our nosecone base. Using the live inputs set the width to 20mm and the height to 12mm. Then click "enter" to finish the rectangle drawing. Next left click first the upper left hand corner of the rectangle then the lower right hand corner and finally click the centre origin point of the sketch. With those 3 points selected in that order, then click the "Symetric Constraint" tool icon. This will fully constrain the rectangle around the origin point centering it in our design.

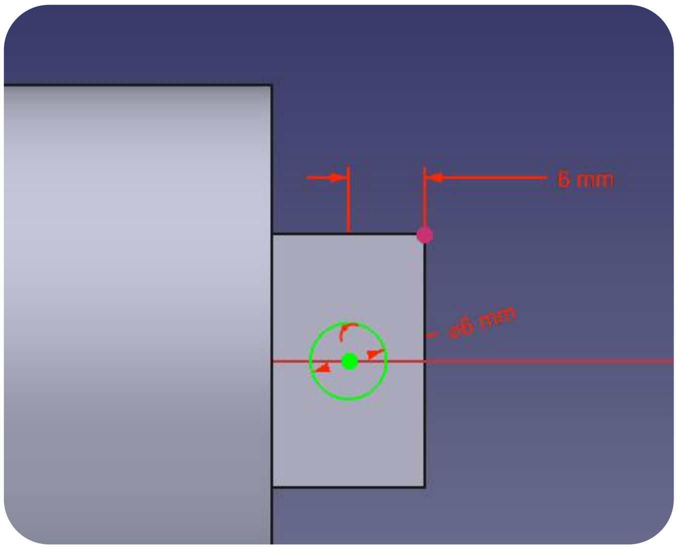


We can now left click "close" to close the sketch and we will be returned to the Part Design workbench. Our sketch we just created should be highlighted in the model tree view so we can straight away left click on the "Pad" tool icon to pad the sketch. We set our pad length to be 12mm and then clicked "OK".

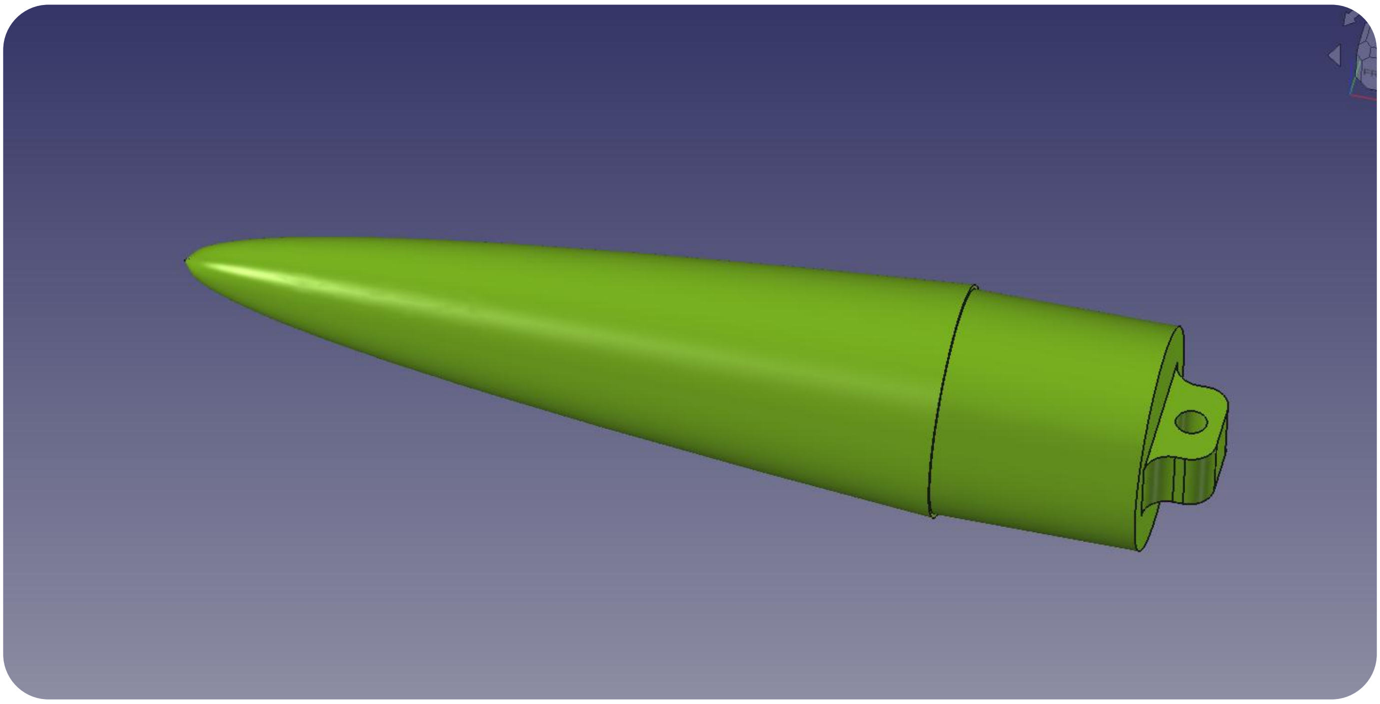


Next, let's create another sketch highlighting one of the longer sides of the pad we just made (as shown above). Click the face of the pad and click the "New Sketch" tool icon.

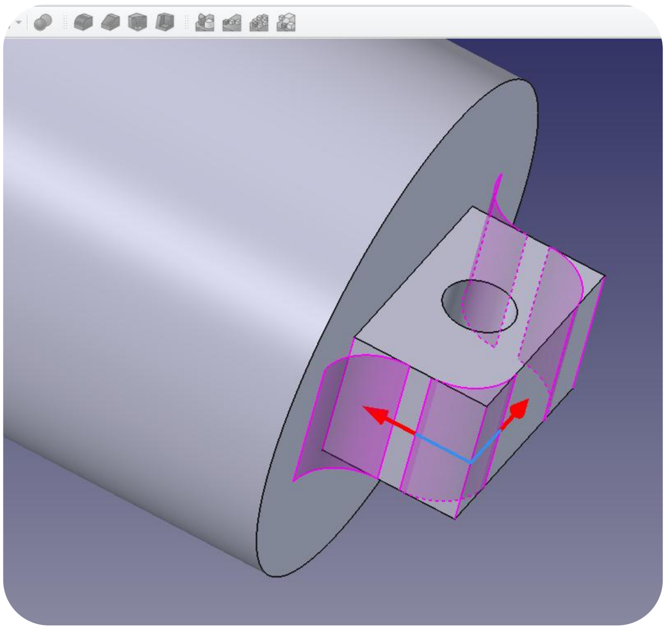
In this new sketch we first used the circle tool to draw a 6mm diameter circle attached to the X axis line. We then used the "External Projection" tool icon to click to create selectable reference geometry for one corner of our 12mm long pad. We could then set a distance constraint between the corner of the pad and the centre of the circle to constrain the circle to the centre of the pad.



Again we can now click to close the sketch, and with this sketch highlighted in the model tree we can click the "Pocket" tool icon on the Part Design workbench to create a hole through the pad section with our sketch.



With the major parts of our attachment point complete we can finish the little design by adding some fillets to the pad. In the preview window select one of the edges that we want to add a fillet too. With that edge highlighted then click the "Fillet" tool. We set the fillet radius to 5mm then clicked the "select" button in the Fillet dialogue panel and in turn selected the other edges to apply the internal and external fillets too.



With the fillet edges selected we can then click to apply the fillet and close the dialogue. We could then, with the last operation "Fillet" highlighted in the model tree click "File" and then select export in the drop down menu to export the nosecone we just created as an number of filetypes, stl, 3mf, obj etc, ready for slicing and 3D printing.

Of course you are only limited by your imagination and effort. We could certainly create more complex and better designs, and indeed there is little limit to the types of rocket parts, or geometries you add onto or into parts created in the Rocket workbench. It's a superb tool and entriely developed by one person Dave Carter, who is a fabulous advocate for both rocketry and FreeCAD.

Thanks for Reading!

Thanks so much for reading the very overdue SOURCE issue 5. Obviously this is a one person operation and sometimes life get's in the way! I am superkeen to continue though and I'm planning issue 6 already, which amongst a few new ideas for SOURCE is definitely going to contain an article on the excellent Open Flexure Microscope which is a project I've built recently and been excited to share more widely.

Take good care in these tricky times everyone.
Jo AKA Concretedog.

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