PEAK OF FLIGHT NEWSLETTER

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HOW TO BUILD A SCALE ROCKET MODEL FROM A 3D MODEL

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PEAK OF FLIGHT

How to Build a Scale Model Rocket From a 3D Model

By Samer Najia

Objective

I have always built scale models, but as a model rocketeer, I have also always enjoyed building and flying models of real rockets that have flown. Part of the fun, for me anyway, is to see if I can 'reverse engineer' a design just from some design files and get it in the air. This article details some of my experiences, and while I have not always been successful, I have come up with a few methods that might prove useful to you.

Pitfalls

Sometimes, our ambitions get the best of us and we really cannot scale down something without major design work. I usually realize this far too late in the process after expending a lot of time and effort trying to give my idea life. Don't think of this as a failure, but rather as a learning experience. If anything, I have adopted a maxim from a ski instructor I had when I was younger that asked me if I had fallen on any given day – if I had not, she would respond with: "then you have not learned anything new today." Needless to say, I fell often.

Sources of Information

There is no shortage of places you can go to gather your initial data. Sometimes all I have are a few photographs. Other times I have design files, and still other times, I find someone has come up with a design I can adjust to my purposes.

NASA: One of the best sources out there for popular rockets, NASA has published a series of 3D models in a file format with the extension .3DS. Those can be converted to STL or StereoLithography files that are suitable as 3D models of various systems, rockets and vehicles in its inventory. I usually go to MakeXYZ's website for this (https://www.makexyz.com/convert/3ds-to-stl). Even if you don't have a computer aided design background, or don't want to get into it, you can see using a simple STL viewer (3D Builder comes with Windows 10 for example) what all the dimensions are, and as you scale the entire model up or down you can then see the dimensions of every part. From there you are retrofitting an engine mount and coming up with a recovery system. NASA's models can all be found at https://nasa3d.arc.nasa.gov/models.

Published Plans: There are a lot of drawings out there. One source that should be available to everyone reading this are the NAR Journals. Many of these have some great drawings in them of various subjects that will undoubtedly interest you. You can even acquire a drawing as a print or poster. If you go out and get one, you can then use a ruler to get dimensions for everything so long as you treat every part in relation to the overall design. For example, a 10 foot tall rocket scaled down to 2 feet would mean being scaled down to 1/5th. That means every part has to be reduced to 1/5th its current size. So take out that ruler, measure everything on the drawing and divide by 5. So long as I have 2 dimensional drawings, I can replicate most things to an excellent level of detail.

Thingiverse: Thingiverse (and YouMagine, among others) is a website (www.thingiverse.com) where designers publish their designs for download. A large (if not most) of the designs can be printed by a 3D printer. However, you are not limited to this medium and the design files are useful for viewing and figuring out the dimensions of all the parts. One of the things I like most about Thingiverse is that if someone has designed a complicated part and published it as an STL (like a complex nose cone), I can build the rocket fuselage and fins, but get the nosecone printed (either on my printers or through a service), achieving the sort of realism I might not otherwise.

Basic Scaling

The way I have had to do this in the past is to pick an "anchor" object and use its dimensions to govern how I scale a model. Because my intention is to ultimately build the model out of as many standard parts as possible, for rockets that is almost always the body tube. I will scale a model down to accommodate the size of a standard body tube (my favorite is the BT-80, but you can use whatever you like). Of course, the size (length) of the rocket is also going to be a factor, since it is unlikely I am going to get a 15 foot long model rocket built out of paper tubes, I also scale the rocket down to a size that allows me to use one up to no more than three body

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tubes. That is not to say you can't build bigger and with other materials. There is certainly nothing stopping you from building a "giant scale" model, but I prefer model rockets I can fit in my car. One day, I dream of building my own high altitude rocket and launching it at a dry lakebed, but for now, standard materials, engines and recovery systems are the norm.

Once I have scaled the rocket tube to a known length and diameter, I now have the start of my inventory as well: the body tubes and the couplers. From there, it should be straightforward to define the size of the fins, and then depending on how big the rocket is and how powerful an engine I will use, I can decide on materials (e.g. plywood or balsa) and construction method (surface mount or through-the-tube). The remaining elements are any body-tube surface details, decals and of course the nose cone. For most projects I will select a nose cone that is as close to the original as possible that fits in the body tube size I have selected. If that is not possible, I will either hand fabricate one by modifying an existing product or 3D print one. A note on 3D Printing nosecones: print them hollow and "cut" the design so that as little support material is needed as possible (and preferably none at all). This means nose cone parts that do not have radically sharp turns in them. A good mainstay for those who do not want to print anything is to modify a balsa nosecone and add paper and plastic parts to enhance the realism.

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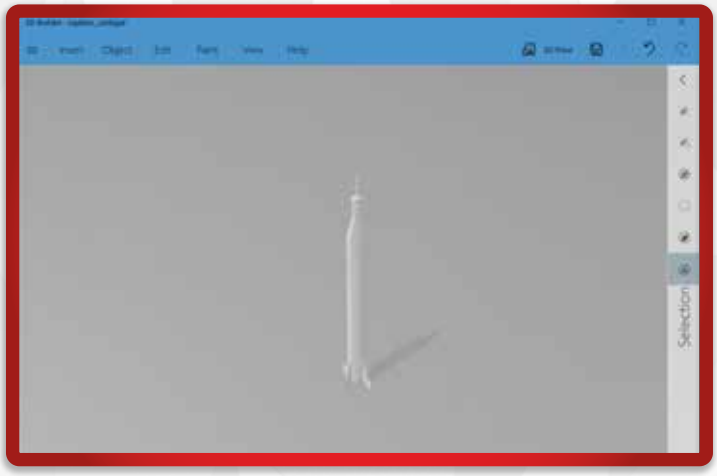
If you are operating from a 3D Drawing, you can import the drawing into 3D Builder or TinkerCAD (a free, browser based Computer Aided Design, or CAD, application). One of my projects is the Jupiter C rocket published by NASA (https://nasa3d.arc.nasa.gov/detail/jupiterc-c). The nosecone on this rocket is pretty simple and can be a modified standard nosecone with the tip chopped off and 2 different diameter dowels mounted on top. Here is a picture from NASA's website:

And here is a screenshot of the model in 3D Builder:



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Depending on how it is converted, you might find yourself now scaling the model up instead of down. This is because the drawing, in being converted, has units embedded in it and whoever published the drawing had set a scaled down size. In this case, the drawing comes up around 50mm tall. I would have to scale the whole thing up to a reasonable size to get it flying, of course.

Simulation

Once you have the dimensions figured out, you should be able to now model your rocket in RockSim (https://www.apogeerockets.com/RockSim/RockSim_Information) or any other model rocket simulator software. Try to approximate the nosecone as much as you can if you are unable to model it in RockSim. You should be able to:

•Come up with an inventory of some standard parts (e.g. engine mount, centering rings, body tubes, fins).

•Simulate the performance of the rocket based on different engines and if you choose to have them, payloads. Optimize the rocket for the ideal flight based on the mission.

•This also means you will know the approximate lift-off weight and can select an appropriate parachute (if you are using this method for recovery).

Experiment with your design and try it out using B, C and larger engines. You might also find that your design has been scaled down too far and you really need a D, E or F motor and have to scale back up accordingly. Another fun exercise is to design the same rocket for both smaller and larger motors. If the real rocket flies on multiple engines, can your design do the same? Maybe a rocket that flies badly on 1 D motor might do spectacularly on 3 C motors. I encourage you to try all the permutations you can.

Keep in mind that clustered motor rockets need some special treatment (line of thrust, simultaneous ignition of all engines, ejection gas volume). My forays into this arena have taught me to get an airframe in the air successfully first using one or two engines at most before I start to add more complex clustering schemes in updated designs of the same rocket. Once you have finalized the design, it's time to select materials and build your final inventory of components.

Material Selection

As my projects have become more complex, I have found that I cannot reliably scale a model down too small. What is "too small"? Anything that flies on less than a B Class motor might be too small. For me, this has been because the scale model is "draggy" or does not really have sufficient fin area at smaller scales, and adding that fin area departs from the original attention to the original design (it's not that I don't like clear plastic fins, it's just knowing that they are there bothers me). My Jupiter C model had all it needed to get in the air at about 13" tall, but the result was too heavy for a B

engine, for example. If your design would only reliably fly on larger engines, use high power model rocket materials and techniques such as plywood fins and centering rings, and through-the-tube construction. Use epoxy instead of super glue or white glue, and use thicker or stronger body tubes. Visually speaking, a larger model will look and photograph better the bigger it is.

The computer simulation should be able to give you an all-up weight, but you should also be able to determine the weight of each component (fins, nose cone, any additional parts, engine mount, parachute, etc.) based on the materials available. If plywood is too heavy, can you use paper laminated balsa instead, or laminate fins by gluing material so that the grain of each layer is

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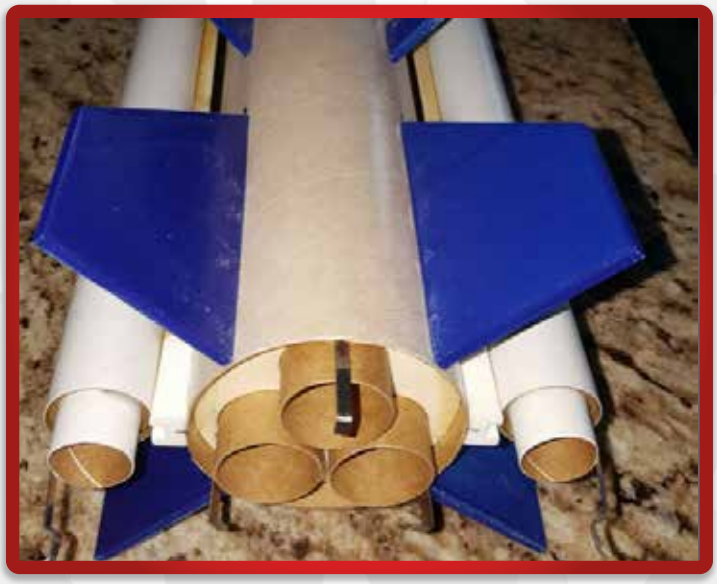
perpendicular to the one adjacent to it? How about using sheet styrene, or fiberglass fins? I have a small kitchen scale I use to weigh sheet material based on size, especially when I have no idea what the weight of the material is based on area (for a given thickness of the material). There are a lot of variables, but ultimately your objective is to get as close to the weight depicted in the simulation as possible. If you are over or under that threshold, go back to the simulation and add a weight to the rocket (in the nose, at the fins, in the payload bay) to see what the effect will be on the center of gravity and it's location relative to the center of pressure. Will your rocket still fly and be stable with the same engine? Do you need to revisit the design in any way? This part of the design process is iterative but the benefit will be a solid and stable rocket that you can not only fly again and again, but also build and rebuild again and again.

Custom Component Development and Construction Notes

As much as I can, I prefer to use as many standard parts as possible. This includes body tubes, engine mounts, centering rings, nose cones and parachutes. Some rockets that have auxiliary boosters are trickier to design and build. With breakaway boosters, I prefer to use standard parts as well here, but this also means I am introducing another "anchor" for my scale design. Apogee, for example, offers a strap on booster kit (https://www.apogeerockets.com/Rocket-Kits/Skill-Level-2-Model-Rocket-Kits/Strap-on-Booster-Pods) that I have used before, and because that kit is a certain size, then I must scale the main rocket section to fall in line with those boosters. Sometimes, it's a better idea to just not make those boosters anything more than decorative.



CUSTOM ROCKET WITH APOGEE BOOSTERS INSTALLED

THE SAME ROCKET BEING PREPPED FOR WEIGHING

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Nosecones are another customization target. My Jupiter C requires a custom nose cone, but it is easily built up. I do highly recommend you also limit any protrusions on the body tube. There is a lot you can do with decals (see my Apogee E-Zine article on custom decals for more on this topic: https://www.apogeerockets.com/education/downloads/Newsletter480.pdf) that will be far easier to render on a body tube than gluing on additional parts.

Initial Flight

In your simulation you should have identified multiple potential engine possibilities. Your first flight should use the engine that keeps your rocket at the lowest possible altitude and still be safely recovered. You are at this point stress testing your design – the airframe overall, the materials you have selected and of course your selected build technique. After a successful first flight, go ahead and move up the list of engines and put in the more powerful ones. One thing I try to factor into each rocket is a payload bay to house a camera. A view looking down will help me see how stable the flight is. I like to use cheap keychain cameras (https://www.apogeerockets.com/Electronics-Payloads/Cameras/808-Keychain-Camera) for this that I don't mind losing if the rocket disappears. But assuming some semblance of recovery, I will have a flight video I can look at and learn from for my next effort. It's not always possible, but I try to incorporate something like this in every rocket I custom build.

Learning from Past Mistakes

As you have seen in this article, there is no shortage of places where a variable may bite and result in a failure. However, always consider your project to be a journey and an opportunity to master one or more aspects of your build. If your rocket did not fly well or at all, did you learn more about design and perhaps about rocketry in general? Maybe you developed your own construction technique for future models, or discovered a new use for some material. I don't always succeed, but I learn something new every time.

Ongoing Development and Extending the Methodology

Whatever the outcome of your build, you should be able to extend this process to more than just custom builds. I have built scaled down versions of many real life missiles and rockets that do not exist in kit form anywhere using this approach, and I have also applied the same ideas to my own designs, some more outlandish than others. Use this opportunity to exercise your creativity and blast off!

About the Author

Samer has been building and flying models, including rockets for as long as he can remember and a NAR member for just as long (on and off). You will find him posting articles

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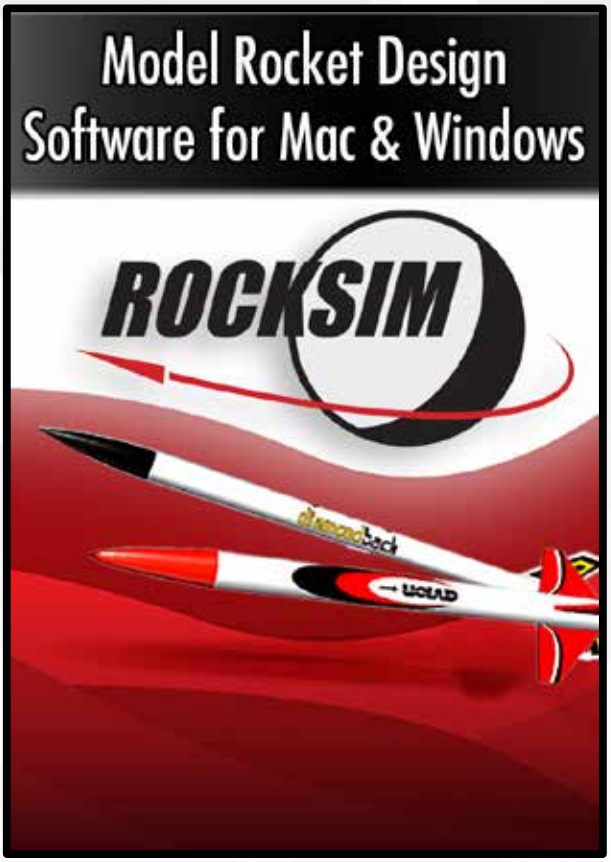
on building rockets, airplanes, 3D printers, tracked vehicles and other things online. He is a firm believer in DIY and using and re-using whatever he can get his hands on to complete his projects, no matter how long it takes. Look for Samer's projects online and on Google+ as well as on MAKE Magazine's web sites. His most recent 'big' project is a homebuilt flight simulator.



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