PEAK OF FLIGHT NEWSLETTER

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PERFECTING COMPETITION ROCKETS IN ROCKSIM

https://www.apogeerockets.com/Rocket-Kits/Skill-Level-3-Model-Rocket-Kits/SR-72-Darkbird

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APOGEE COMPONENTS

PEAK OF FLIGHT

Perfecting Competition Rockets in RockSim

By Bobby Potter

RockSim has a lot more going on than people often see at first glance. A casual user or average hobbyist can use RockSim to design rockets and acquire a whole bunch of data and insights about that rocket before they even begin building it. An experienced RockSim user would be able to take that rocket file and through a series of tests, create a rocket file that would produce the necessary data to allow you to make on-the-fly adjustments to your rocket. A more accurate rocket file means you can use RockSim to more accurately predict a rocket's performance in different weather conditions, with alternative payloads, and provide the insights you might need to better hit your objectives. This process is essential for competition environments and for those looking to leave their stamp on the field.

If you are looking to really level up your TARC team, you should be familiar with this process. It's the key to achieving consistent success under competition conditions.

For many of these competitions, you are often tasked with reaching a very specific altitude, and are penalized for going above or below it. Hitting that specific altitude consistently can be an incredibly challenging problem, as there are a ton of variables that can affect your flight. Often the ability to account for these variables can make or break a TARC team.

Step 1 - From the competition rules, design your rocket.

This is a bit of an obvious first step, but we need something to work with. With any competition requirements, it's important to design your rocket to meet the given rules.

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Make sure it is capable of any payloads you need to carry aloft, make sure it has the right dimensions, and that the mass is acceptable (with some wiggle room, which we will need later).

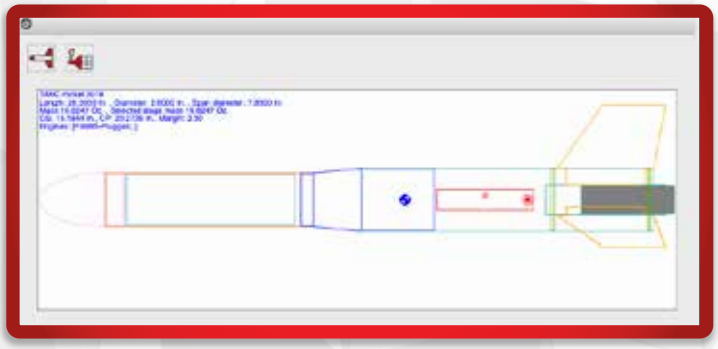

FIGURE 1: A TARC ROCKET DESIGN FILE MEETING THE COMPETITION GUIDELINES FROM 2018.

Competitions like TARC will also require specific engine retainers (no tape or friction fits), minimum stability margins and specific recovery systems. Make sure these are also accounted for in your rocket. Making any major changes to your rocket in later stages could result in your team starting this process all over.

Apart from meeting the rules of the competition, the only thing we really care about in this step is the stability. TARC requires your static stability margin to be at least 1.5 diameters. This means the distance between the center-of-gravity and the center-of-pressure is at least one and a half times as long as the diameter of the largest body tube.

A final note here - it's important to consider what is doable. You can hop in RockSim, custom design a nose cone perfect for your objectives, but if that style of nose cone isn't available at any retailers (which it likely wouldn't be if it was custom) then you would be forced to fabricate it yourself. For some people, that's doable, but even then this is going to add a lot of work and cost to your rocket.

If you want to fabricate a component, this video might be a good place to start: https://www.apogeerockets.com/Advanced_Construction_videos/Rocketry_Video_305

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About this Newsletter
You can subscribe to receive this e-zine FREE at the Apogee Components website www.ApogeeComponents.com, or by clicking the link here Newsletter Sign-Up

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However, it's better to stick with parts that are readily available, so do your shopping while you are designing. Find the nose cone that works for your rocket, put it in your rocket file, and write that part number down. That way when you get ready to build it, you'll have an easy time sourcing the components you need.

When you have completed your rocket design, it's time to move on to testing and optimization.

Step 2 - Simulations and Dynamic Stability

Dynamic stability is an evaluation of the rocket's stability over time. As a rocket motor burns, it burns off a lot of mass. As the mass changes in the rocket, its stability also changes. Wind also causes the rocket to wobble as it flies, and that wobble not only affects how high you can get, but it also greatly affects the consistency of your rocket's performance. For competition conditions, you want to know exactly how high your rocket is going to fly, so getting a consistent performance out of your rocket is critical.

To get consistent flights from your rocket, the best approach is to reduce the amount of variables that can affect it. Weather conditions account for a vast majority of these variables. Fortunately, before we even start building the rocket, we can greatly reduce their impact on the flight.

Simulation	Engines loaded	Max. altitude Feet	Max. velocity Miles / Hour	Max. acceleration Feet/sec/sec	Time to apogee	Velocity at deployment Miles / Hour	Weather
1	[F27R-4]	673.39	159.48	224.52	6.33	n/a	Unsafe
0	[F27R-4]	737.88	160.03	225.30	6.63	5.74	Safe

FIGURE 2: COMPARE THE ALTITUDE ACHIEVED BY THESE 2 SIMULATIONS. THE ONLY DIFFERENCE BETWEEN THESE SIMULATIONS WERE THE WEATHER CONDITIONS, AND YET IT HAD A MASSIVE IMPACT ON THE POTENTIAL ALTITUDE.

Unfortunately, dynamic stability (how we can reduce the impact of weather) is just too large a topic to fully cover in a single article - but we've got a whole series on optimizing for dynamic stability. Here are the resources you would need to understand this process.

Peak-of-Flight #193 - Basics of Dynamic Flight Analysis, the Corrective Moment Coefficient
https://www.apogeerockets.com/education/downloads/Newsletter193.pdf

Peak-of-Flight #195 - Basics of Dynamic Flight Analysis, Damping Moment Coefficient
https://www.apogeerockets.com/education/downloads/Newsletter195.pdf

Peak-of-Flight #196 - Basics of Dynamic Flight Analysis, Radial Moment of Inertia and the Natural Frequency
https://www.apogeerockets.com/education/downloads/Newsletter196.pdf

Peak-of-Flight #197 - Basics of Dynamic Flight Analysis, Damping Ratio
https://www.apogeerockets.com/education/downloads/Newsletter197.pdf

Peak-of-Flight #198 - Basics of Dynamic Flight Analysis, Optimizing for Altitude
https://www.apogeerockets.com/education/downloads/Newsletter198.pdf

Peak-of-Flight #200 - Tips on Finding Optimum Mass
https://www.apogeerockets.com/education/downloads/Newsletter200.pdf

Peak-of-Flight #253 - Experiment with Dynamic Flight Analysis
https://www.apogeerockets.com/education/downloads/Newsletter253.pdf

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Step 3 - Build Phase

Once you are satisfied with the rocket file, it's time to get building. Take that list of part numbers and start sourcing your components.

Prior to building your rocket, weigh each of these components individually. Take those component weights and compare them to the weights listed in your rocket file. Make any adjustments you need in RockSim by doing a mass override on the individual components. This will give you the best accuracy in your simulation results. Remember that when you use the mass override, you also need to enter the CG location of the component too. Where the mass is concentrated also affects the trajectory of the rocket, which is why it is important to measure the CG position of any part too.

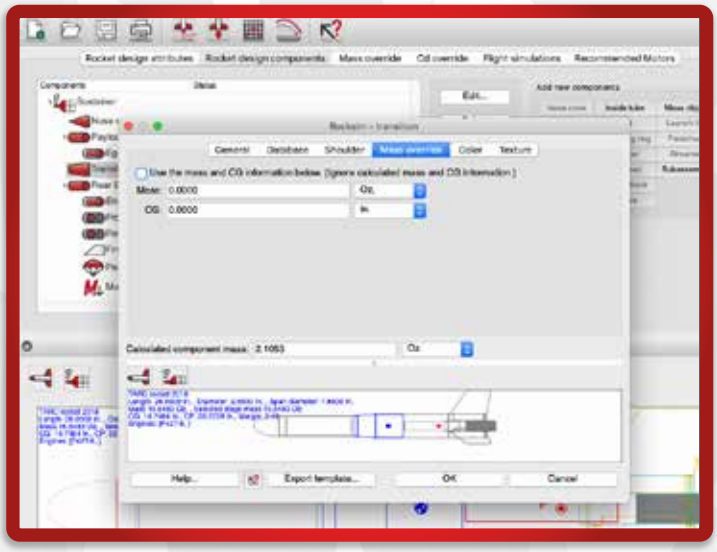

FIGURE 3: TO CHANGE THE MASS OF A SINGLE COMPONENT, HIGHLIGHT THE COMPONENT IN THE "ROCKET DESIGN COMPONENTS" TAB AND CLICK EDIT. SELECT THE MASS OVERRIDE TAB

Even though we will weigh the completed rocket after building (as things like epoxy and paint will alter the mass), we weigh each component individually to make sure we have the mass distributed correctly throughout the rocket. If the calculated mass of your components comes in quite a bit different than the actual mass of the components, you may want to consider re-running a few of your dynamic stability tests to make sure your rocket has remained optimized.

After weighing the individual components, the mass of the built rocket should match up pretty close to the weight listed in RockSim. If it differs, first verify the individual component weight is listed correctly. Then, balance the rocket

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on your finger and compare that point to the center-of-gravity listed in your RockSim file. If everything lines up, the mass difference is likely due to excess paint or epoxy. After eliminating the individual component mass as the reason for the difference, complete a simple mass and CG override of the entire rocket to account for the paint and epoxy. The mass override input into RockSim should be the same as the actual weight of the fully built rocket.

Step 4 - Testing and Optimization

This stage is all about getting the rocket simulation to behave exactly as the rocket would under any given conditions. This will take time and many flights, but with each you should get closer and closer to the actual performance of your rocket.

Take your rocket to the launch site. You'll need an altimeter as well as a way to check or measure atmospheric conditions. This can be done with some margin of error by just using local weather apps, however those who are really serious should consider measuring that themselves, as it can vary from area to area. For that, I'd recommend one of the Kestrel Weather Meters.

For each test launch, you'll want to track:

Temperature
Humidity
Barometric Pressure
Wind Speeds

After measuring your weather data, input those into the "launch conditions" in RockSim. Launch the simulation and record your predicted altitude.

Depending on the altimeter you are using, you can get a lot of data from these flights. All these figures can be compared to your simulation to better identify the differences between your rocket file and the actual rocket you are flying. Our best tool here is going to be the flight graphs that show each stage of the rocket's flight.

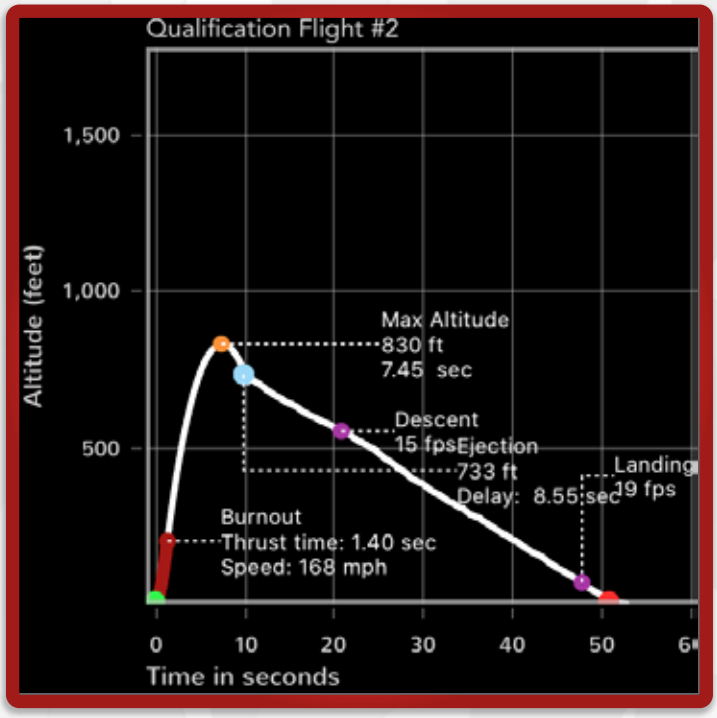

FIGURE 4: A STANDARD FLIGHT GRAPH FOR OUR 2018 TARC ROCKET PRODUCED BY AN ALTIMETERTHREE.

Compare the results of your flight with the projected results of your simulation. In altitude, how close were the RockSim estimations? Did apogee occur at the same time? Was the descent rate for your recovery system accurate?

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If you take the altimeter data and compare it to the graphs produced by RockSim, you should get all these answers. For an at-a-glance approach, we can create a similar graph in RockSim by highlighting the simulation and clicking the "plot graph" icon.

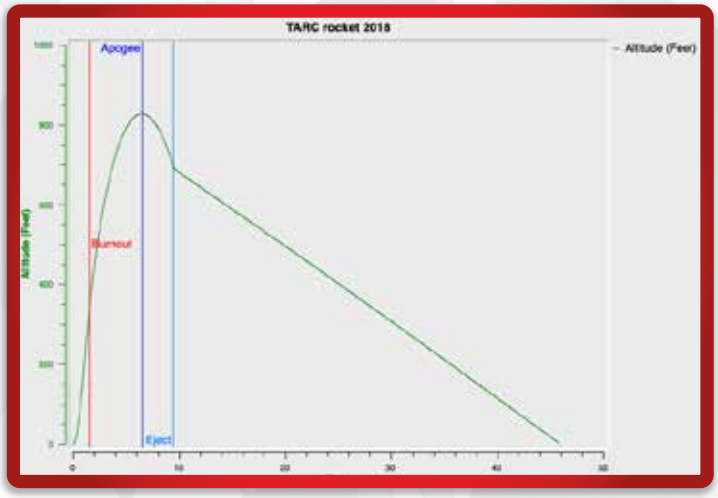

FIGURE 5: AN ALTITUDE X TIME GRAPH PRODUCED BY ROCKSIM

As you can see, our altimeter graph and the graph produced by our simulation line up pretty well. Apogee occurs at about the same time, the projected altitude is the same, our ejection charge fires at the same time, etc. The biggest difference is from the parachute, where the simulation touches the ground a full 5 seconds before the actual flight data suggests it should. This could be due to thermals, but our graph indicates a fairly steady descent, so it is more likely that we need to adjust the coefficient of drag on the parachute.

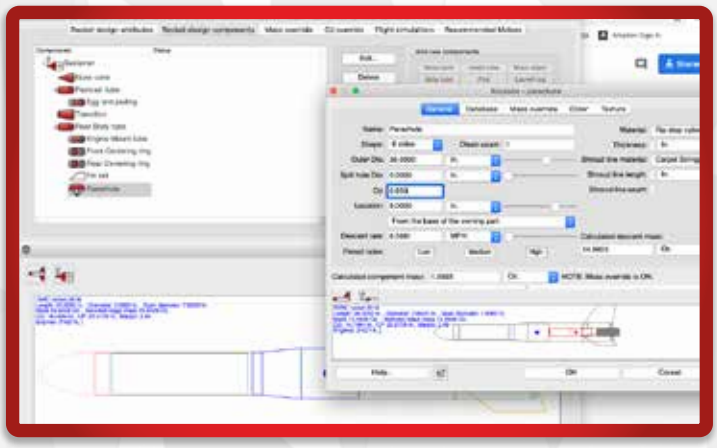

FIGURE 6: ADJUST THE PARACHUTE'S COEFFICIENT OF DRAG BY HIGHLIGHTING THE PARACHUTE IN THE "ROCKET COMPONENTS" TAB AND CLICKING EDIT.

Note that this is just an altitude over time comparison. You should be comparing every possible data point at your disposal. For instance, the AltimeterTwo and AltimeterThree also provide data points on acceleration, velocity, descent rates and more. Each of these figures can be compared to your simulation.

Thrust time	1.4	secs
Max speed	167.7	mph
Peak accel	6.9	Gs
Average accel	5.4	Gs
Ejection delay	8.6	secs
Coast-Apogee	6.1	Gs
Apogee-Eject	2.5	Gs
Ejection altitude	733.0	ft
Initial descent	15.5	fps
Landing speed	18.9	fps
Location		
Longitude	-104.8088	
Latitude	38.15586	
Map Link	Click Here	
Ground Pressure	82847	Pa

FIGURE 7: ADDITIONAL FLIGHT DATA PROVIDED BY THE ALTIMETER TWO

There are a ton of things to look for when trying to troubleshoot your simulation, so this step is going to take some trial and error. If your simulation was off from the actual results, there are a few things you could try.

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Launch your rocket again, on the same day, with the same weather conditions and the same motor. How close was this altitude to your first launch? If these flights are very different, then little gusts of wind are likely having a large impact on the flight profile of your rocket. Take another look at your dynamic stability.

If repeated flights are getting you the same or very similar results, your dynamic stability is likely calibrated well. This could indicate the problem is a difference in your coefficient of drag (Cd). RockSim generates a value for you, but you can overwrite it manually. Try adjusting the Cd in RockSim and see if you can get the simulations to mirror the actual results of your rocket.

After you have calibrated for the basic rocket, it's time to make sure the rocket still behaves correctly under different conditions. Repeat your tests on different days in different weather conditions and continue to adjust your rocket file to match the actual results achieved. Continue to repeat this process until RockSim is correctly predicting your rocket's behavior in any weather conditions.

Once RockSim can accurately predict the altitude in all variety of weather conditions, it's time to eliminate another important variable: Mass.

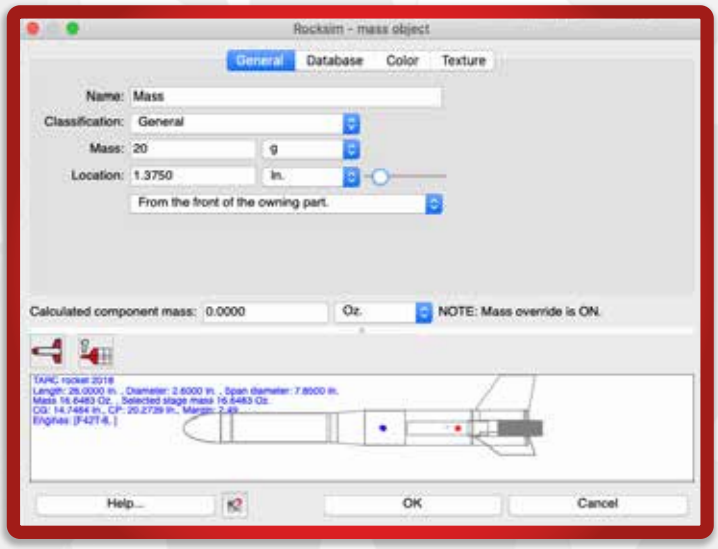

FIGURE 8: ADD A MASS OBJECT BY HIGHLIGHTING YOUR BODY TUBE IN THE "ROCKET COMPONENTS" TAB AND SELECTING "ADD MASS OBJECT" FROM THE RIGHT. BE SURE TO SET THE LOCATION AT YOUR CENTER-OF-GRAVITY (IF THE MASS ISN'T PLACED AT THE CENTER OF GRAVITY, IT WILL AFFECT STABILITY).

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Take your rocket out again. Input all the weather data, and insert a mass object like clay into the rocket at the center of gravity. Input that mass object into RockSim and run the simulation. Launch your rocket and compare the results.

FIGURE 9: A BALLAST POD

Continue to manipulate the Cd until your rocket matches the simulations. Repeat the test without the mass added to make sure it still aligns with your original results.

This entire process should also be done with your parachute and steamer to verify the descent rates are also accurate. Have a variety of parachutes and streamers that meet your competition conditions all tested and behaving the same in real life as they are in the simulations.

This will take a long time. Continue to test and adjust your rocket file until it matches the results of the actual rocket in any weather conditions, with any mass added, and with any motor files. There will always be some margin of error as it is impossible to account for every possible variable, but if you have good dynamic stability, you should be able to get these results to be incredibly accurate.

Step 5 - Competition Day

Now that all the hard work is behind us, launch day should be easy and less stressful. We know that our RockSim file behaves exactly as our rocket does, so we can just make small adjustments to our rocket on launch day.

Take your weather instruments and RockSim to the launch field with you. Measure the weather conditions, and plug that information into RockSim. Run a simulation under those conditions. Add the mass object in RockSim to the center-of-gravity and continue to add weight until the altitude predictions meet your goals for the competition. Verify the descent rate of your recovery system is where you would like it to be and if it isn't, adjust your recovery system (the length of the streamer, the size of the spill hole in the parachute, etc.).

Once you have a simulation that achieves your mission goals, add that same mass in clay at your center of gravity. Make any adjustments you need to make to your recovery system.

Once the simulation is behaving the way you want, and any adjustments are mirrored on your rocket, you are free to launch and you can feel confident that your rocket is going to perform exactly as you wanted it to.