PEAK OF FLIGHT NEWSLETTER

Issue 611 / October 24th 2023

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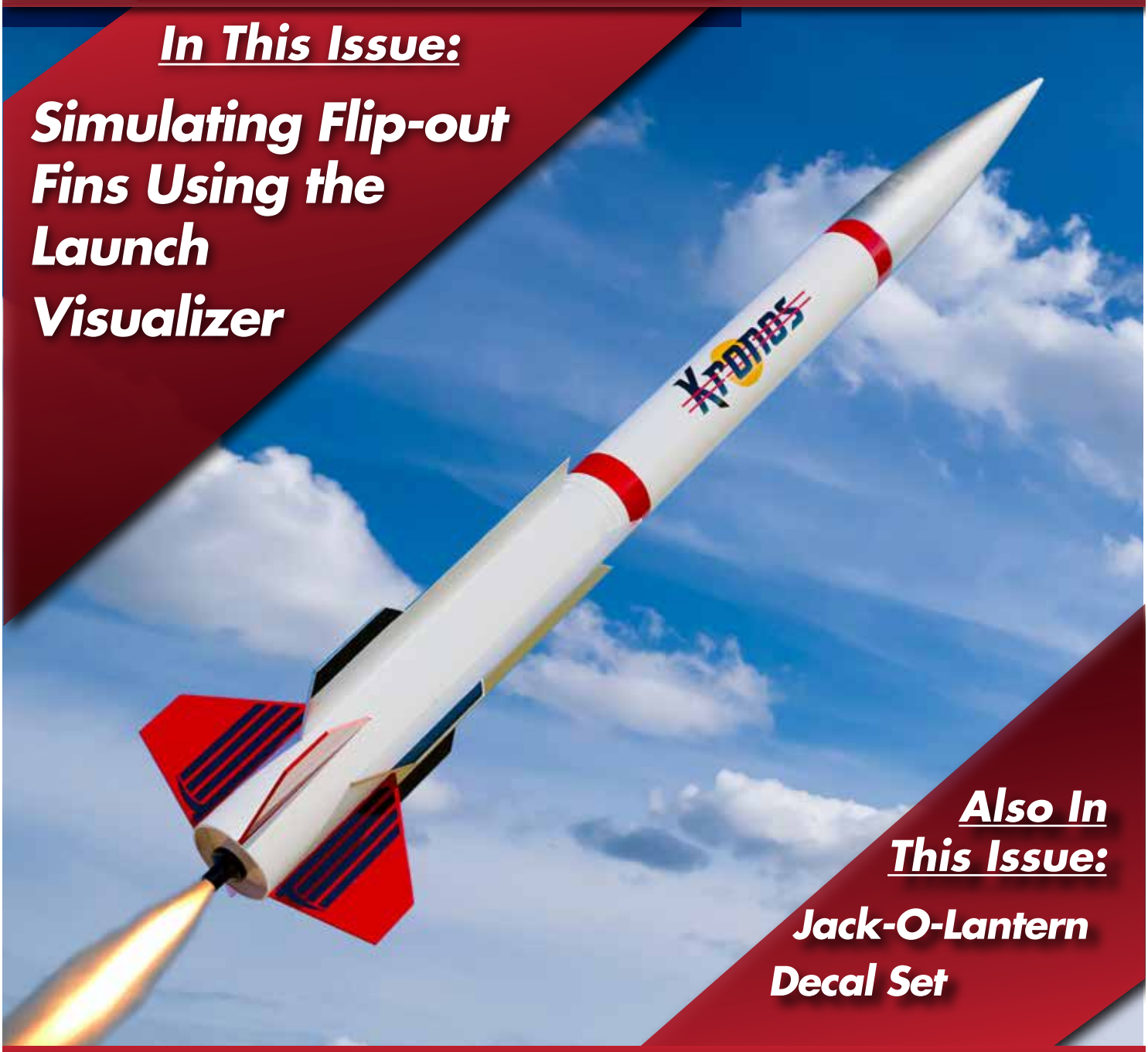
Simulating Flip-out Fins Using the Launch Visualizer



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Simulating Flip-Out Fins Using the Launch Visualizer

By Tim Van Milligan

How do you run a complicated launch simulation of a multistage rocket that has flip-out fins? This is difficult to do, because with flip-out fins, the actual configuration of the rocket changes during the flight. At launch, the fins of the upper stage are stowed inside the rocket and don't contribute to the stability or the drag to the rocket, since air is not flowing over them. But when the booster stage drops away, they flip out and then they do provide stability to the model.

How do you account for this in your simulations? That is what I'm going to cover in this article. I'll give you a step-by-step process for accomplishing this advanced simulation.

Background

In 2014, my daughter Allison and I were modifying one of the Apogee 1/70th scale Saturn 1B (**https://www.apogeerockets.com/Rocket-Kits/Skill-Level-5-Model-Rocket-Kits/Saturn-1B-1-70th-Scale**) rockets for her to use at the World Space Modeling Championships which were held in Bulgaria. The project was an extensive modification of the basic kit, because we wanted it to actually be a 3-stage rocket. The stock Apogee kit is still a single-stage design, using a single 29mm motor for the launch.

We highly modified the rocket to use 8 motors in the booster stage (four C6-0 and four A10-3T), a single 24mm diameter C11-0 in the middle stage, and an A10-3T in the upper stage. Since my daughter was only 14 years old at the time, we decided to try to simplify the launch preparation and only use direct staging. There were no electronics involved. All my daughter had to do in regards to launch preparation was put the motors in the rocket and install the parachutes in their compartments. There was of course twisting 8 sets of igniter wires together on the booster stage, but she was competent enough at 14 years old to do that without any help.

You can read about the actual flight in Peak-of-Flight Newsletter 373 (**https://www.apogeerockets.com/education/downloads/Newsletter373.pdf**).

The real problem was to have both sets of the upper stage fins housed internally inside the rocket and then pop out when the lower stages dropped away.

Figure 1: Allison Van Milligan along with Ellis Langford showing off the flip-out fins on the middle stage of the modified Saturn 1B rocket.

This article is not about modifying the kit. That is something that is beyond the scope of this discussion. What I want to explain is how to run simulations in RockSim so you can predict how high the rocket goes.

This modified Saturn 1B is not a simple 3-stage rocket that you can just simulate in one push of the launch button. The reason is those flip-out fins actually change the configuration of the model during flight. If it was a normal RockSim simulation, you would have to simulate the rocket with all the fins deployed, such as shown in Figure 2. This is the only way a 3-stage rocket can be assembled in RockSim, because the fins have to be fixed. Unfortunately, there isn't an option yet to change the configuration of the rocket in flight by stowing or deploying the fins.

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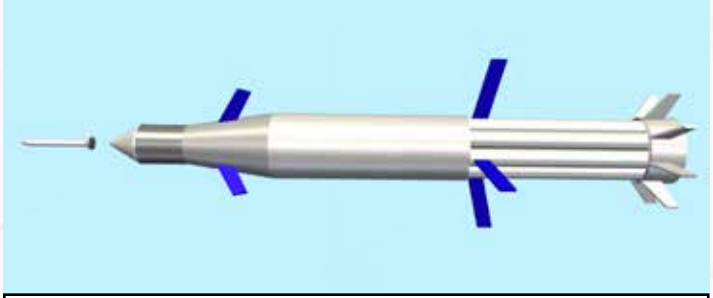


Figure 2: Having the upper stage fins deployed is the only way RockSim can simulate a 3-stage rocket.

The problem of trying to simulate this in RockSim is that the CG/CP relationship and the aerodynamics are dramatically different compared to the situation where the fins are stowed during flight.

To simulate rockets with flip-out fins, you will actually need to break the rocket up into separate configurations, and look at each of those independently. First we'll check the stability of the rocket. Then, we'll need to add the simulations together to see how high it actually flies.

Finding The Stability of the Rocket

Figure 3 shows the stability calculations of the rocket with the fins deployed. This is the worst case situation, and the rocket would never be launched this way.

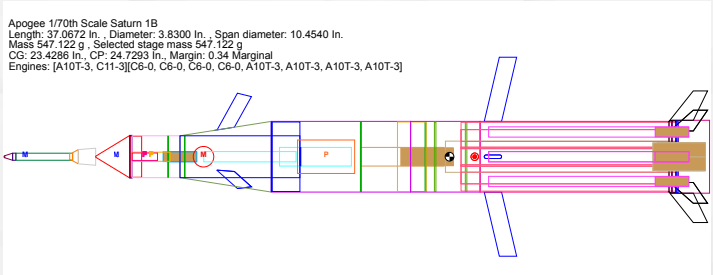


Figure 3: The traditional way a three stage rocket would look in RockSim where the fins on each stage are fixed.

In figure 4, I've created three separate files to show the rocket in the launch configuration of the stage when it fires.

Comparing the rocket from Figure 3 to the bottom rocket in Figure 4, you can see that the big change is that the CP moves much further back when the flip-out fins are stowed for flight. The CP location goes from 24 inches to 27 inches as measured from the tip of the escape tower. This makes the rocket much more stable, and is why we want to simulate the lift-off of the rocket in this configuration.

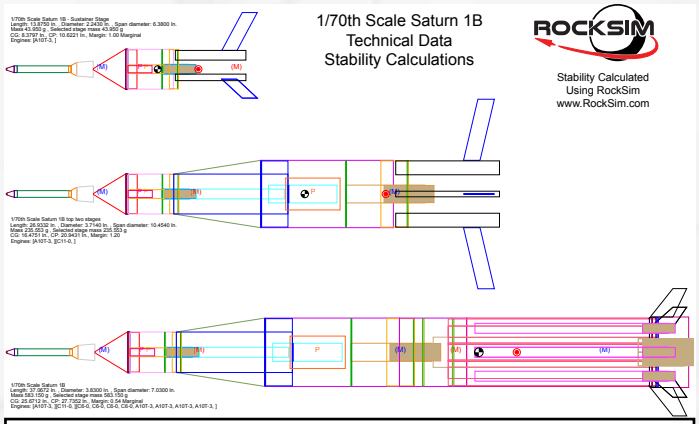


Figure 4: The three configurations of the rocket. Each is a separate .rkt design file that is saved independently.

You're probably wondering what I did with the stowed fins in the bottom two stages in figure 4. Since fins can only be put on the outside of the rocket in RockSim, what I had to do was delete them from the rocket, but actually account for them by adding a mass object. That way, the weight of the stowed fins is accounted for in the rocket.

Looking at each of the three stages of the rocket in Figure 3, I'm confident that each stage is stable to fly. Putting the fins on posts that extend down from the base of the rocket is a great position from a stability standpoint. The further aft you can get the fins, the more stable the rocket will be because it moves the CP aft. I've also designed the fins so that they sweep aft as well, which again helps to move the CP as far back as possible.

How Would You Create a Design File?

The original RockSim files that I used for the Saturn 1B from 2014 somehow got lost. So for this article, I'll show you how I'd simulate a simpler two stage design, as seen in Figures 5 and 6.

In figure 6, you see the upper stage of the rocket with the fins hanging off the back of the tube. I only included the green struts to which the fins are attached just to show you how it might look in real life. You don't actually need to include these struts as a physical object in the RockSim design like I did, because they don't contribute to the stability of the rocket like a fin would. You could just account for them as a mass

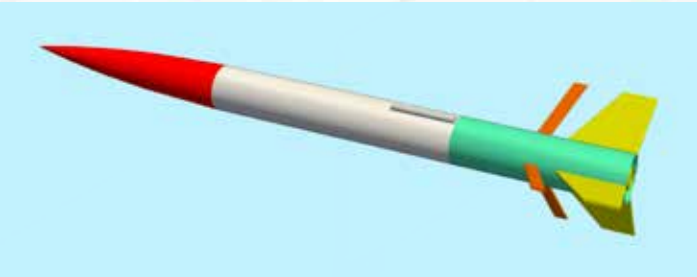


Figure 5: A simple two stage rocket. The orange fins would be folded forward and stowed inside the green booster stage for launch.

Figure 6: The upper stage with the fins deployed. The green struts are how the fins might be attached to the upper stage.

object, because they don't contribute to the drag or the stability of the rocket. I recommend you leave them off, just to make your RockSim file simpler.

At this point, we would have two separate RockSim files. One for the upper stage alone, like shown in Figure 6, and a second RockSim file for the lift-off configuration. In the lift-off configuration, the fins of the upper stage are folded forward, and are slid into the bottom stage. This is shown in Figure 7. Since the fins are internal, they are actually removed from the RockSim file, and are replaced by a single mass object.

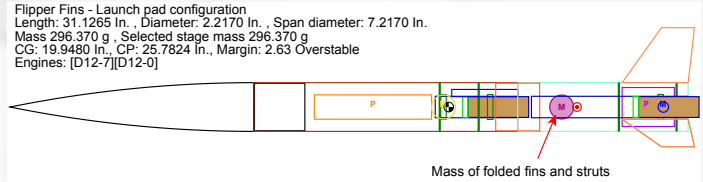


Figure 7 - The launch configuration of the two stage rocket with flip-out fins.

The RockSim files are available for download, so that you can follow along and perform the simulations as I did them here. See the references at the conclusion of this article for the links.

How to Run the Simulations

The game plan at this point is to run each RockSim file separately, and then we'll add the results together. In other words, the second simulation will start where the first one stops.

In essence, this is how RockSim normally runs all simulations. It breaks the flight up into separate phases, and runs each phase separately. The typical phases are:

1. From lift-off to motor burn out
2. The coast phase, which is from motor burnout to parachute deployment,
3. The recovery phase, which is measured from deployment of the parachute until the rocket touches back down to the ground.

RockSim is capable of stringing these together, particularly from phase 1 to 2, because the rocket doesn't change configuration. But in our case, the rocket does change. We literally have two different rockets. As of today, RockSim can't

automatically merge and splice the two configurations together into a single simulation. So we have to do it manually.

However, there is a problem with running our launch simulations for this two-stage configuration using RockSim. Whenever we start a simulation, each stage would start its journey with zero velocity, and at ground level. That doesn't work for the upper stage, which is the rocket with flip-out fins. When the stages separate and the fins flip out, the upper stage is neither starting out with zero velocity nor launched from the ground. It is already high in the sky, and the rocket is moving with some velocity.

RockSim does not allow for a rocket starting out with a non-zero velocity. But RockSim-Pro and the Launch Visualizer (www.RockSim.com) do. So to run these simulations, we'll need to use one of those programs. I'll use the Launch Visualizer here, since it costs less for users, and in this case might be a little easier to use (because it uses simplified flight events compared to RockSim-Pro).

The next step is to upload the two RockSim design files into your account in the Launch Visualizer. This takes about 30 seconds, because you can upload them in succession without running any simulations.

Once uploaded, I loaded in the first stage design and got the simulation set up. I just used a Estes D12-0 in the booster stage, and a D12-5 in the upper stage.

I already know that for this particular rocket, when the upper stage ignites, the stage will go unstable because this first design doesn't have any fins on the upper stage. I don't care what happens after the stages separate in this simulation. What is important is to capture the information about speed, location, altitude, and orientation of the rocket right at burnout of the booster stage. I want to capture this information because it will be used as the initial condition of the second simulation when we load in the upper stage portion design file.

For my launch, I picked a picturesque launch site in western Colorado, and had the wind blowing at 5 mph from due west. The rocket was launched straight up, with no angling of the rod.

Figure 8 shows the Flight events for the simulation as seen in the Launch Visualizer.

Figure 8: The flight events from the launch Visualizer.

The flight events are configured to have staging occur at the Maximum Ejection delay of the booster stage motor. Since this is a D12-0, this will occur at zero seconds after engine burnout. This is the important point in the launch, where we have to capture the information about the orientation and speed of the rocket.

What is that point? The time to engine burnout can be found in the motor selection screen when we install the motors in the rocket. You can see from Figure 9 that the burn time of the D12 motor is 1.65 seconds.

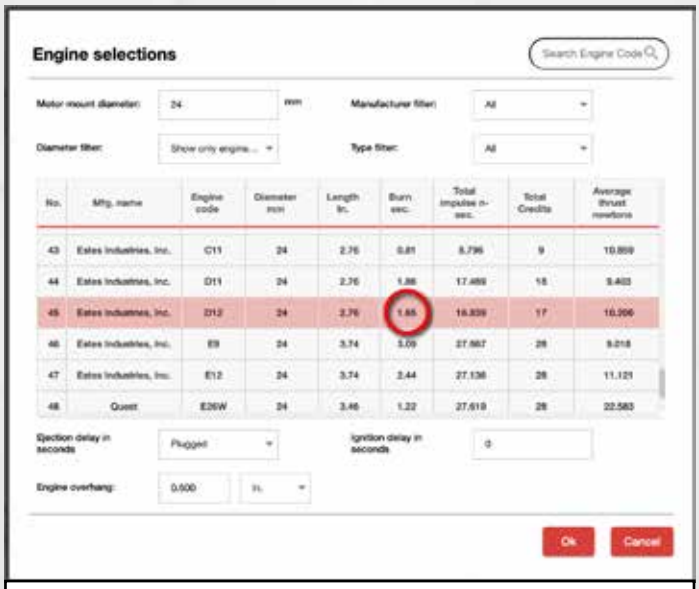


Figure 9 - The burn time of the D12 in the engine selection chart.

Next, we simply start the simulation and take a look at the 3D simulation of the rocket (see my simulation at: https://rocksim.com/apis/Y3_cTGrnd?img=LVgifs-4.gif).

In figure 10, I paused the simulation to grab a screenshot. Since the two stages are still together in this image, you can surmise correctly that we're less than 1.65 seconds into the flight. If you let the simulation run all the way, you'll see separation and staging, and then watch the upper stage go completely unstable.

Figure 10: The rocket takes off and zooms skyward in the Launch Visualizer simulation.

On the right side of the screen, there are a set of buttons. The second one is the property table. We want to click on that button to open it up and display the flight information.

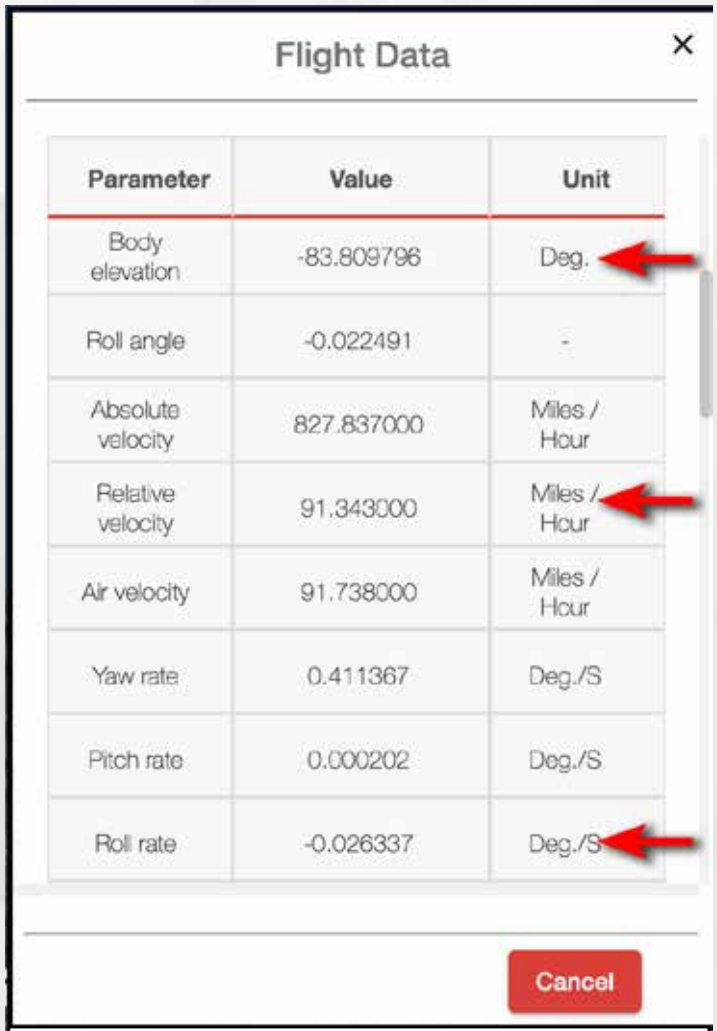
Figure 11: The property table will display the flight information about the rocket.

Now we want to use the time scrub bar at the bottom of the screen to get right to the point of stage separation. From Figure 9, we found that the burnout time of the D12-0 motor will occur at 1.65 seconds into the flight. So move the time slider to as close as you can get. In figure 11, you can see I have it at 1.66 seconds.

But in the Property Table, it is showing the exact time at 1.655779 seconds. That's as close as we can get.

Now we have to get out a piece of paper and start taking down some information. First we want to note the new latitude and longitude of the rocket. Because the rocket arced into the wind, it will no longer be directly over the launch pad location. That is why we want to jot these numbers down.

Next, note the "Alt AGL." This is the rocket's altitude above ground level. I chose this number rather than Altitude ASL (above sea level) because it will be easier to input later.



Flight Data

Parameter	Value	Unit
Body elevation	-83.809796	Deg.
Roll angle	-0.022491	-
Absolute velocity	827.837000	Miles / Hour
Relative velocity	91.343000	Miles / Hour
Air velocity	91.738000	Miles / Hour
Yaw rate	0.411367	Deg./S
Pitch rate	0.000202	Deg./S
Roll rate	-0.026337	Deg./S

Cancel

Figure 12: Additional flight data from the Property Table

After that, we want to write down the "Body Azimuth" angle. This is the compass direction that the nose is pointing at this point in the flight. In our case, the rocket is pointing to 268.290403° - which is nearly to the west. This makes sense, as the rocket is weathercocking into the wind, which is coming out of the west.

Now we need to scroll down through the table to get some other numbers. Note the "Body Elevation" angle. Looking at it, you'll think that this seems to be a weird number, at -83.809796° as seen in Figure 12. The software is thinking in reverse than what you are. An angle of 0° would mean the rocket is pointing down to the center of the earth. And an angle of 90° means the rocket is parallel to the surface of the earth. Going further, an angle of -90° means the rocket is pointed straight up, directly opposite from the center of the earth.

In our case, an angle of -83.809796° means the rocket is almost pointed straight up. If you subtract the number from -90°, you find that the rocket is 6.1902024° from pointing straight up. We'll use this number in the second simulation as the launch rod tilt angle (in Figure 15, you'll see it is actually called "Launch angle from vertical").

Next, we want the "relative velocity" of the rocket. This is the speed of the rocket with respect to the spinning earth. We'll use this number as the initial velocity of the rocket when we run the second simulation of the upper stage.

Finally, we want the "Roll rate" of the rocket. The rocket at this point is rolling very slightly because of the way the wind is blowing over the fins. We can enter this roll rate into the second simulation too.

Once we have all these numbers written down, we can close the first stage simulation by loading in the 2nd stage design.

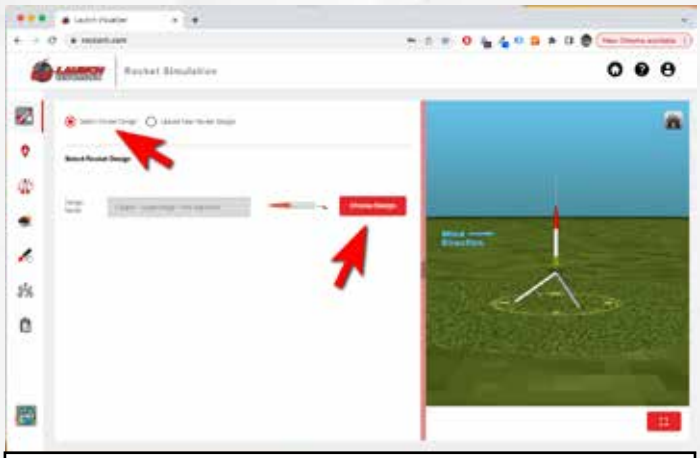


Figure 13 - The upper stage loaded. We'll go through the tabs on the left column to set up the simulation.

Once the 2nd stage file is loaded, go to the first tab, which is the launch site location (Figure 14). This is where we'll enter the new Latitude, Longitude, and the altitude above ground level.

If you noticed that your rocket has traveled a long distance, the altitude at the ground coordinates and the Landing zone altitude might be different. You may need to reset those if the terrain where you're flying is hilly. In my case, the rocket really didn't travel too far from the original launch site. But my rocket is in the mountains, so just to be safe, I'll reset the values for the altitudes of the ground above sea level.

In the Launch Visualizer, you can simply double-click on the satellite view map, and then click the "Confirm Launch Site" button below the map, and it will automatically grab the altitude of the ground at that location. So after you've entered the Latitude and Longitude, zoom in on the map, and double-click at a position that is very close to the current

location of the red dot. Then click on “confirm the launch site” below the satellite view screen.

However, when you do that, the latitude and longitude will reset to a new value, and you’ll have to enter them again. But now the altitudes will be correct.

Figure 14: The launch site specifications.

There is one last thing to enter on this screen. That is the “Launch altitude (AGL).” This is from flight data we recorded earlier. The 2nd stage is up in the air, and by putting in the launch altitude, what you’re doing is moving the launch pad into the sky (like it was hanging below a balloon). In our case, the launch pad is 132.63 feet in the sky.

Then we’ll go to the Starting State tab and enter the Launch Angle from vertical (6.1902024°) and the launch guide length, which will be zero. The reason we’ll use zero is because there is no rod to keep the rocket oriented on the path. At this point, the rocket is free flying in the sky.

We’ll leave the “Launch guide placement” as being “fixed to earth.” The alternative is that it drifts with the wind, which means it would have some initial horizontal velocity from the west. We don’t want that for our simulation.

Next, we’ll enter the “Launch guide azimuth angle” which in our case is the “Body Azimuth” angle from Figure 11. The rocket’s “Starting velocity” is the “Relative velocity” value we saw in Figure 12, which was 91.343 mph.

We’re going to ignore the “Starting roll orientation” because we have a symmetrical rocket - where the fins are placed evenly around the outside of the tube. If we had something like an airplane, then the roll orientation would be important, but in our case, it isn’t.

Finally, we’ll enter the “Starting roll rate” which we also recorded earlier (see figure 12). Our roll rate is very small, but it doesn’t hurt to enter it. The negative sign just tells us the direction it is rolling.

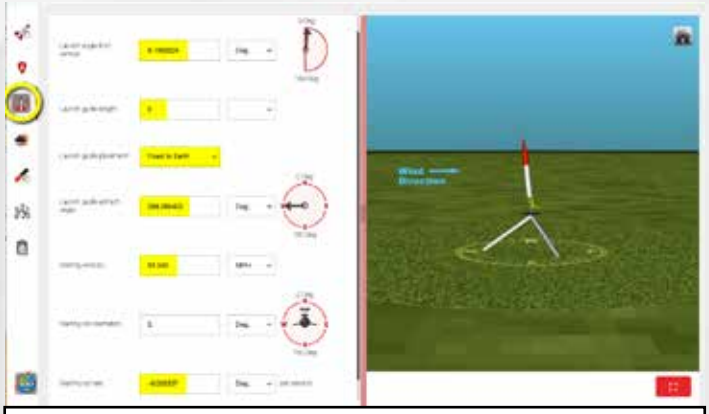


Figure 15 - the starting state for the 2nd stage of the rocket. The image on the right just shows you how it would look if it was sitting on a launch pad.

On the Launch Conditions tab, we shouldn't have to do anything. The simulation is still set to have a 5mph wind coming out of the west (270° direction).

Now we just load the rocket motor into the vehicle. Again, this is going to be a D12-5 motor from Estes. At this point, we can click the Launch Button. You'll probably get a warning message to confirm the launch site, which you should do. Since we updated the latitude and longitude to new values, the software needs to use those instead of where we double-clicked to get the altitude values.

After it computes the flight, it will show you the 3D scene. This is where it gets interesting, because the rocket will be sitting on a launch pad, and it is suspended in the sky as shown in figure 16.

Figure 16: The rocket is up in the sky, because we moved the pad above the ground for launch.

The launch pad itself is not really there. It is just to draw in the scene to show where the rocket is launched from. It can be ignored.

When you play the animation, you'll see the flight of the second stage. It has some initial velocity, so it moves quickly at the beginning. It also takes longer to descend to the ground because it started higher up above the ground. If you would like to see an animation of my simulation, you'll find it here: **https://rocksim.com/apis/-om4KhSN5?img=LVgifs-7.gif**

Figure 17: The trajectory of the 2nd stage of the rocket.

After you close the full screen mode of the 3D visualizer, you'll come back to the summary screen showing the flight data. This is the final data we wanted to get, as seen in Figure 18.

The only thing that I noticed that I might change would be to change the delay time of the motor to a 7-second delay because it had ejected the parachute just a little early. It

No.	Results	Engines loaded	Max. altitude FL	Max. velocity MPH	Optimal delay	Velocity at launch guide departure MPH	Velocity at deployment MPH
3		[D12-6]	1180.73	205.07	9.27	91.02	25.80

Figure 18 - Final results of our simulation.

wasn't bad, but if you want to get more altitude, you'll need a longer coast period of the rocket.

But overall, we hit an altitude of 1180 feet, which is pretty good for this design.

Conclusion

I wish that we had a way to change the configuration of the rocket in the middle of the upward trajectory, as it would make simulating rockets with flip-out fins much easier. But until then, there is a work-around that you can do using the Launch Visualizer or RockSim-Pro. As you saw in this article, it involves breaking the rocket into two designs, and simulating them separately. The second simulation is configured to start by using the parameters from the first simulation where the configuration of the rocket changes.

If this had been a three stage model, like the Saturn 1B model shown at the beginning, we would have had to break the rocket up into three files and run three simulations. It is the same process, just a bit more involved.

This process does involve a little work, but it is a fun and excellent learning experience on how an engineer would approach the situation where a single simulation isn't possible. If you'd like to recreate this combined simulation, you can download the RockSim files that are listed at the end of this article. Then upload them to the Launch Visualizer under your account and have fun playing around.

References

RockSim files for the two stage rocket are available for download at:

Entire Rocket for use at Liftoff from the ground - https://www.ApogeeRockets.com/downloads/rocksim_files/Flipper-Full-Stack-without-fins.rkt

2nd Stage Configuration with the flip-out fins deployed - https://www.ApogeeRockets.com/downloads/rocksim_files/Flipper-upper-stage-fins-deployed.rkt

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward an M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and also the author of the books: Model Rocket Design and Construction, 69 Simple Science Fair Projects with Model Rockets: Aeronautics and publisher of the "Peak-of-Flight" newsletter, a FREE e-zine newsletter about model rockets. You can email him by using the contact form at https://www.apogeerockets.com/Contact.

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Jack-O-Lantern Decal Set

By Ryan M. Conway

Introducing the "Jack-O-Lantern," a set of Halloween-themed decals that promise to take your spooky celebrations to new heights. The Jack-O-Lantern will launch your Halloween celebrations into the stratosphere of excitement and wonder. Get ready to unleash your inner witch/wizard. This is a ghoulishly delightful way to light up the night on All Hallows' Eve!

These Halloween-themed decals are intended for Apogee Components' Atomizer rocket kit. Print these at 100% and apply to exterior of rocket.

https://www.apogeerockets.com/Model-Rocket-Kits/Skill-Level-2-Model-Rocket-Kits/Atomizer