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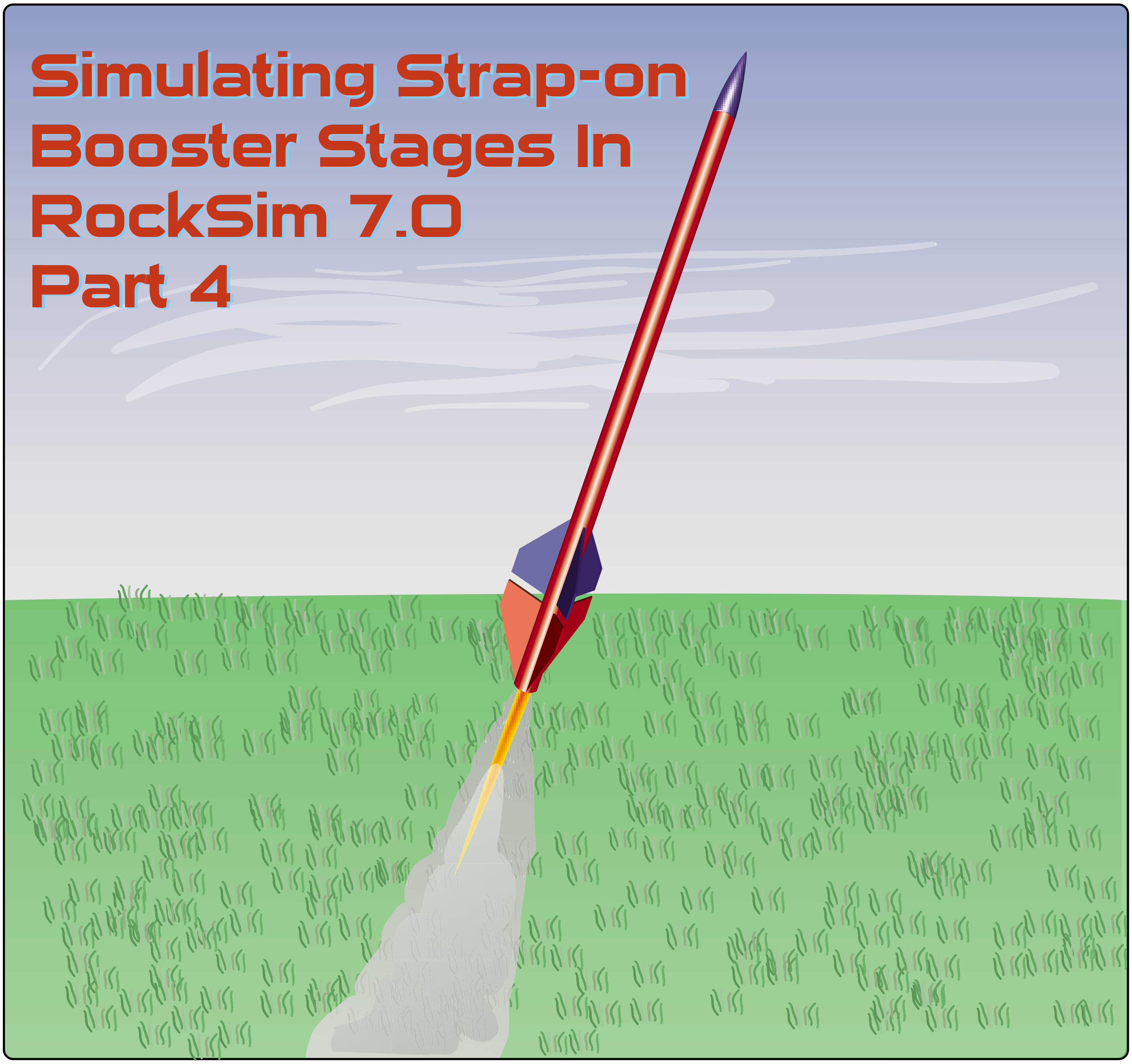
NEWSLETTER

Simulating Strap-on Booster Stages In RockSim 7.0 Part 4



Apogee Components
1130 Elkton Drive, Suite A
Colorado Springs, CO 80907 USA
www.ApogeeRockets.com
orders @ApogeeRockets.com
phone 719-535-9335 fax 719-534-9050

Using RockSim To Simulate Strap-on Booster Stages - Part 4

By Tim Van Milligan

{ed. We're now nearing the end of our series of articles on how to create parallel staged models in RockSim 7.0. In the last issue, we went through the design process step-by-step, and created a fake motors files in the Engine Edit program. In this issue, we'll run our three simulations and see if our results match our preditions.

This article will conclude the series of articles on how to add strap-on boosters in RockSim 7.0. If you want to see the entire four-part series, see the advertisement on page 7; which includes the detailed step-by-step videos that show you how to set the whole thing up in RockSim 7.0. It not only teaches you to add strap-on boosters, but also gives you a lot of insight in using RockSim to simulate complex models.}

Let's Run Some Simulations

To run our simulations, we must first install the rocket motors, and select the flight events.

Enter the simulation prep screen, which will display a screen like shown in Figure 21.

If you recall, I said that Case #2 is easier to sim than Case #1. In Case #2, the core vehicle is going to be ignited just as the strap-on motors fall off.

To simulate this, we'll put two identical C6-0 motors in the strap-on pods. The central engine in the booster stage cluster (our fake tube) doesn't need any motor.

In the core vehicle part of the rocket, we'll load a standard C6-7 motor.

Note that for this particular simulation, we don't need any special or trick motors. Everything is "standard," right out of the Rocksim motor database.

When we launch the rocket, we get an altitude of approximately 1,987 feet. This is shown in as "sim # 0" on the image shown in Figure 19.

With that first simulation complete, lets check the results of the graphs, and compare them to our initial expectations, which were shown in Figure 6 on page 4. Plotting out the graphs of Thrust, C_d, and Mass, we get Figure 20.

The results look pretty good when the comparison is made. This shows we are on the right track. Now, lets load up the rocket, and run Case Study #1.

Case Study #1 is a bit more complicated because we are going to use the two trick motors we made earlier. The hard part is remembering which trick motor goes where.

Figure 21 shows all the motors loaded in the rocket. The two trick motors are the 1/16A on the top of the list, and the C6F on the bottom. The two other booster motors are stan-

Continued on page 3

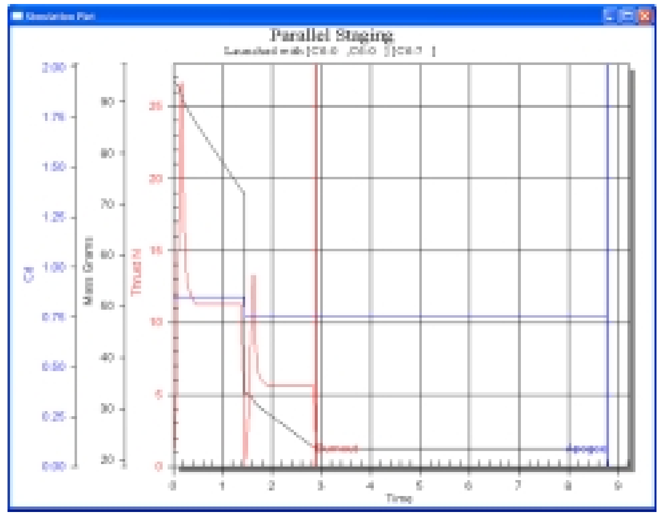


Figure 20: Graph of RockSim's results when running Case Study #1. Compare this with Figure 6 on page 4.

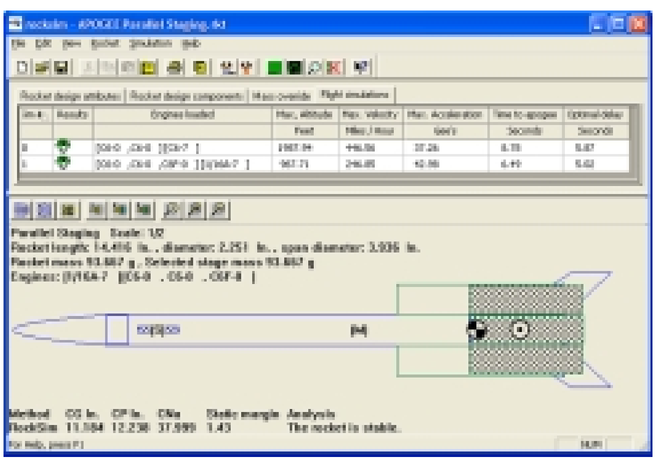


Figure 19: Simulation results of our two case studies. Sim #0, is our Case Study #2 - which is the core vehicle is ignited when the strap-on pods drop off. Sim#1 is our Case Study #1 (where all the motors are ignited on the ground when the button is pushed.)

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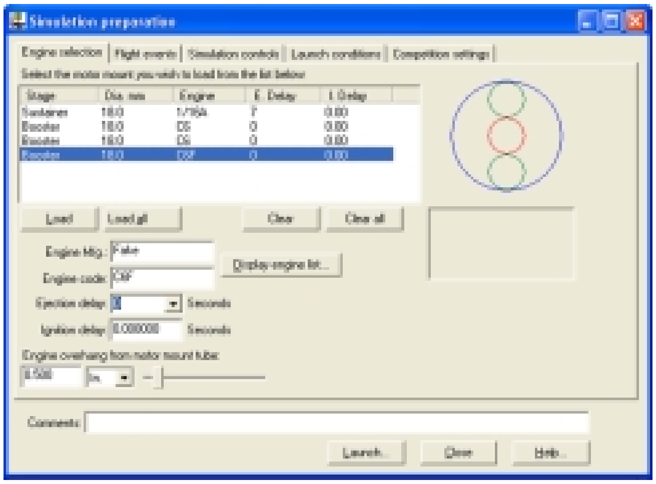

Figure 21: In Case Study #1, we are loading up the rocket with two standard motors, and two "trick" motors we created in EngEdit.

dard Estes C6 motors from the RockSim database.

If you forgot which motor goes in which engine mount, you can take a look at the Engine Selection screen to give you some hints (See Figure 22).

If you recall, the bottom fake motor was going to have thrust, but no case mass. If it has thrust, then it should have a "Total Impulse" that will match the Estes C6. So if we look at the list of available motors, we can see that the C6F has a Total Impulse number that matches the Estes C6. So that is the motor we want in the bottom stage.

The motor in our core vehicle (the sustainer in RockSim), is a phantom motor. Its purpose is to simulate the empty case weight of the motor. But is should have near-zero thrust. In the Engine Selection screen, this is the 1/16A motor that we created.

I just wanted to illustrate that when you are making trick motors that you give them names that are easier to remember. In the next simulation, I'll do a better job picking names for the motors I make.

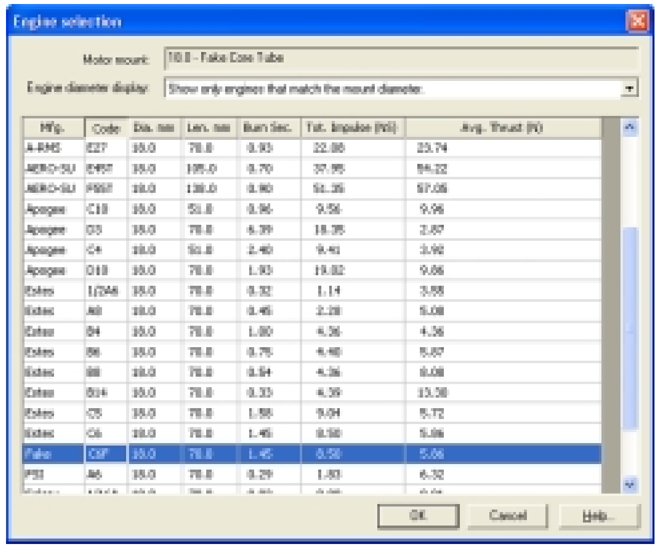

Figure 22: The engine selection screen will give you some hints if you forgot the name of your two trick motors.

Once the engines are loaded, we'll click the launch button. The result of Case #1 is also shown in Figure 19 (as Sim #1). This time, the rocket flew to an altitude of 967 feet.

While that sounds reasonable based on my own personal experiences, I do want to double check the graphs and make a comparison against our expectations.

Figure 23 shows the thrust, C_d, and the mass curves for Case Study #1. When compared to our expectations (Figures 3, 4, & 5), the shapes of the curves match up pretty good. I think we're on to something here!

Case Study #3 - The complicated one...

On page 6 of this report, we started talking about the situation where all motors start firing on the launch pad (similar to Case Study #1). But now, the core vehicle has a longer burning motor than the strap-on engines. We want the strap-on engines to fall away, while the core vehicle continues on burning. What do we do here to simulate this condition?

Like before, to make things feel familiar to you, let's say that for this example, we have two Estes B6-0 motors in the strap-on pods, and a single C6-7 motor in the core vehicle. I

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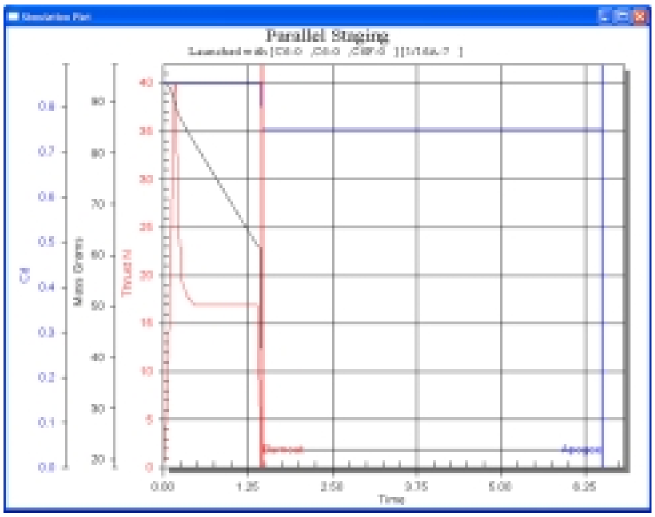

Figure 23: Results of Case Study #1. Compare the shapes of the graph to Figures 3, 4, and 5.

selected this, because the thrust curves have such a simlar shape. The main difference between the shapes of the B6 and C6 is that the C6 burns twice as long.

Let us do the same thing we did before at the beginning of this article. We have to analyze the situation in our heads, and come up with some predictions of what the different graphs will look like.

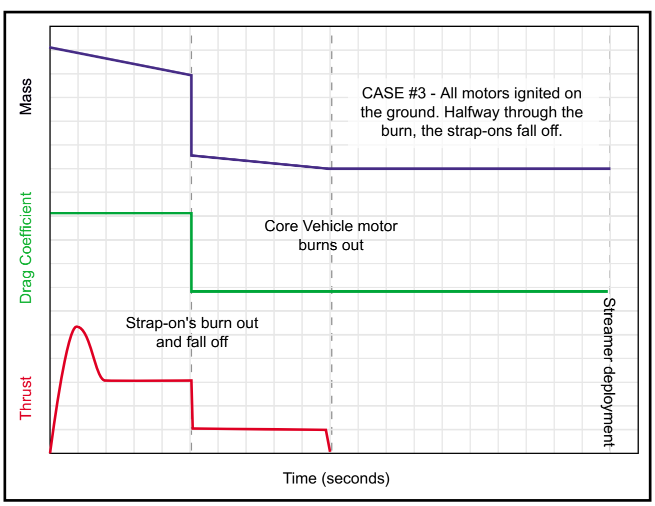

Figure 24: This shows our expectations for Case #3, where the strap-ons fall off during the middle of the core vehicles burn.

When thinking about Case Study #3, we should expect something similar to the graphs in Figure 24.

You could have selected any motor combination for your simulations. But I just wanted to make the graphs easy to distinguish.

The shapes of the thrust curves of the C6 and B6 are very similar. They have the same spike shape, and the level of the sustaining thrust should be the same. The only difference is that the burn time of the B6 is shorter than the C6. So if you clustered them all together in the same rocket, you'd get the what is shown in Figure 24.

If you think about this a little bit, the only way to tell that these three curves weren't made by a cluster model is the top two curves. I've created a set of curves for a simple one-stage cluster model of two B6 and a single C6 motor shown in Figure 25. It is the Drag Coefficient curve that really gives it away.

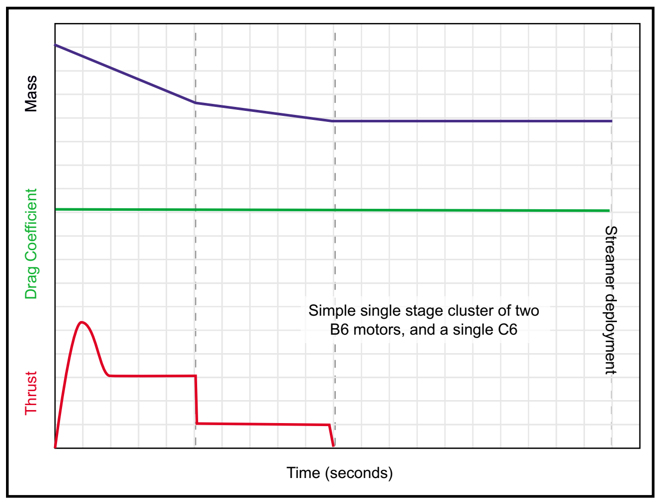

Figure 25: The thrust curve in this example is identical to figure 24. But this set of curves was made by a single stage cluster, not by a rocket that has strap-on boosters.

The mass curve gives a slight indication that some event happened, but you might not make the connection that the two B6 motors burned out.

The point I want to make here is that without coming up with reasonable expectations before we create our simulations, we could end up with garbage.

Creating Motor Files For Case #3

When I first started playing around with strap-on boosters, I thought I could use the "ignition delay" setting shown in in the Simulation Preparation screen (Figure 21 on page 13).

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If this worked, it would be real simple to run complex simulations. Unfortunately, it doesn't work. I tried a lot of different simulations before I came to the realization that I'd have to create "trick' motor files like we did for Case #1.

One thing that becomes readily apparent is that you have to plan ahead when you are considering which motor combinations you are going to use in your simulations. If you have to make trick motors for every combination, you are in for a lot of work. Like I said at the beginning of this article, running these simulations would be a lot of effort. Until we have a new version of RockSim that is specifically designed to allow strap-on boosters, you'll have to go through this process.

Most people that ask me about how to design strap-on rockets are already good planners. So I don't worry about them being able to figure out which motors they want to use in their rockets. I'll just go through the steps and show you how to take the motors you want to use, and create the fake files to make it all work in RockSim.

In my simulation, I've decided to use two B6 motors in the strap-ons, and one C6 motor in the core vehicle. To make this work, we'll need two fake motors. One will be placed in the cluster stage with our two B6 motors. The other fake motor will be placed in the core vehicle (the sustainer stage).

When we made trick motors before, we put all the thrust and the propellant mass in the bottom motor. The top motor had only the case mass, and a negligible amount of thrust.

This time, we need to split both the thrust and the mass of the real motor between our two fake ones.

Deciding where to split is the easy part. The "Time" will be the burnout location of the B6 motors. So first open up the B6 motor file and note the burn time.

The bottom stage motor will now have the beginning portion of the C6 thrust curve, but it will end at the burn time of the B6.

The top motor will have the remainer of the C6 burn time, and the thrust cuve that is the last part of the curve.

Figure 26 shows what this should look like.

Once we have decide where the core motor will be split, we'll go ahead and create it in EngEdit. But before we do that, I've created a little worksheet to help you figure out what are the important parameters to enter as you create the new motor files. You will find this worksheet on the next page. You can print this page out to help you when you are making your own motor files to simulate strap-on motors.

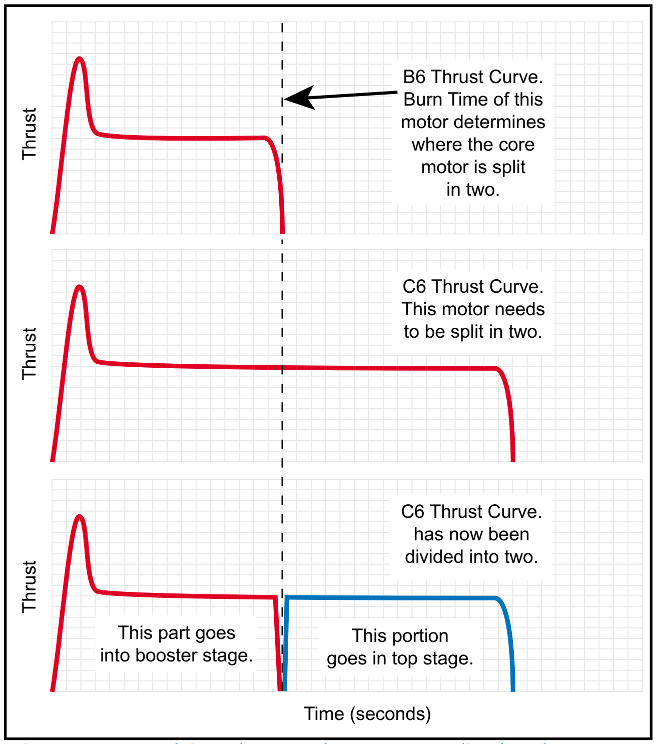

Figure 26: This shows how to split the long burn motor to create two seperate engine files.

In Figure 27, I've gone ahead and filled it out for the Case Study #3 using the Estes B6 and Estes C6 motors.

The basic proceedure is as follows. First open up the motor file of the engine you plan on using in the strap-on boosters. Get the burn time of this motor.

Now, open up the motor file for the engine you plan on splitting in two. While you have it open, write down the data in the worksheet.

What I did next was to choose "Save As" from the file menu in EngEdit. I changed then name of the file to Estes_modified.eng. I did this so that I wouldn't accidentally screw up my regular Estes files.

Now, I deleted all the individual thrust curve entries except the C6 motor. This was done so I didn't have duplicate Estes engine files in RockSim, like two Estes B4, D12, etc. All I want is to add my two fake engine files.

I decided to click the "Duplicate Engine File" button on the top menu bar. Now I'll have two identical C6 motors in the Estes_modified.eng file. The reason I did this is so I keep the basic thrust curve shape. It is easier to delete points than to enter them when you are trying to duplicate things exactly.

At this point, I'm going to finish up the rest of the

Continued on page 6

"Special Motor" Worksheet

Use this to help create the special engine files to simulate strap-on boosters

Strap-on Booster Motor:

Burn Time = ______ A

Unmodified Core Motor (This is the motor data before we split it in two parts)

Initial Mass = ______ B

Propellant Mass = ______ C

Casing Mass = ______ D (= B - C)

Total Impulse = ______ E

Burn Time = ______ F

Fake Core Motor (to be placed in "Booster Stage" of the Rocket)

Manufacturer Name Chosen = ______ G

Engine Code Chosen = ______ H

Initial Mass = ______ I* (< C)

Propellant Mass = ______ J (= I)

Total Impulse = ______ K

Burn Time = ______ L (= A)

Fake Core Motor (to be placed in "Sustainer Stage" of the Rocket)

Manufacturer Name Chosen = ______ M

Engine Code Chosen = ______ N

Initial Mass = ______ O (= D + P)

Propellant Mass = ______ P (= C - J)

Total Impulse = ______ Q (= E - K)

Burn Time = ______ R (= F - L)

*** Make a good guess. It is better to underestimate this number, than making it too large.**

☐ *Total Impulse is determined by the shape of the thrust curve.*

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worksheet so that I can modify the two engines.

The worksheet should be straight-forward to fill out. There are two things that I should note. First, the Initial Mass of the booster stage motor requires you to make a guess. As long as the number is less than the propellant mass of the real motor, you should be OK. But I'd err on the side of caution, and make it low rather than high. What this will do is make the upper stage less stable when it ignites during the simulation. As long as the model doesn't go unstable, you'll be OK. We just want to make sure we use a worse-case situation when designing that upper stage so that it will always be stable.

Second, the Total Impulse numbers are calculated by EngEdit. You don't get the option of entering them into the software. The only way to modify them is by changing the shape of the thrust curve.

Make the bottom (Booster stage) motor first. Since you'll be truncating the thrust curve, it is the easier motor to create. After your done modifying the curve, write down the Total Impulse (letter K in the worksheet).

From this, figure out what the Total Impulse of the

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Continued from page 7

"Special Motor" Worksheet

Use this to help create the special engine files to simulate strap-on boosters

Strap-on Booster Motor:

Burn Time = .70 sec A Note: From the Estes B6 Motor file

Unmodified Core Motor (This is the motor data before we split it in two parts)

Initial Mass = .0222 kg B Total Impulse = 8.50 N-s E

Propellant Mass = .0108 kg C Burn Time = 1.45 sec F

Casing Mass = .0114 kg D (= B - C) Note: This Data from the Estes C6 Motor file

Fake Core Motor (to be placed in "Booster Stage" of the Rocket)

Manufacturer Name Chosen = Fake G

Engine Code Chosen = C6BOT H

Initial Mass = .006 kg I* (< C) Total Impulse = 4.404 N-s K

Propellant Mass = .006 kg J (= I) Burn Time = .70 sec L (= A)

Fake Core Motor (to be placed in "Sustainer Stage" of the Rocket)

Manufacturer Name Chosen = Fake M

Engine Code Chosen = C6TOP N

Initial Mass = .0162 kg O (= D + P) Total Impulse = 4.181 N-s Q (= E - K)

Propellant Mass = .0048 kg P (= C - J) Burn Time = .75 sec R (= F - L)

I* ~ Make a good guess. It is better to underestimate this number, than making it too large.

Total Impulse is determined by the shape of the thrust curve.

Figure 27: This is the worksheet filled out using data from the Estes B6 and Estes C6 motors.

Sustainer motor should be (Letter Q in the worksheet). This is our target number we should try to get when we make the thrust curve for the sustainer motor.

To achieve the target, you'll have to tweak the position of the points on the thrust curve of the sustainer motor. It is easy to see, because as you drag the points around on the screen, the Total Impulse number is constantly changing. This is probably the last thing you'll do prior to saving the engine data file to disk.

Figure 28 and 29 show the screen shots of the two fake motors I create for this simulation.

Once the motors have been created, we'll again run the engine database compiler program (CompEng). This takes the data, and formats it specificallly for RockSim. If you don't get any errors when you compile the data files, you're ready to run your simulation in Rocksim.

RockSim Simulations

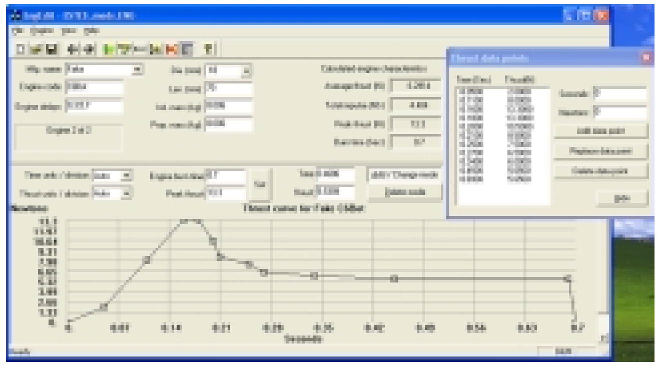

Figure 28: The C6BOT motor created for our simulation. Basically, this is a regular C6 motor that has been shortened to the burn time of a B6 motor.

We don't need to modify the .rkt file that we've already created. We'll just load our new motors into the design, and run our simulation.

Loading the motors should be easier this time, because I made a better choice of names. C6Top goes into the sustainer portion of the rocket. The strap-on pods both get B6-0 motors. The remaining tube in the booster stage is loaded with the C6BOT motor file.

After launching the rocket, we get the results shown in Figure 30 - 1369 feet.

So far, everything looks good. But's lets double check the results by looking at the graphs of the Thrust, C_d, and mass. These are shown in Figure 31.

Comparing them to our expectations in Figure 24 shows that things look real good.

The only thing that is really noticible is the sliver of missing thrust when the rocket stages at .74 seconds. This is a result of the limitations of the WRASP file format. If it didn't

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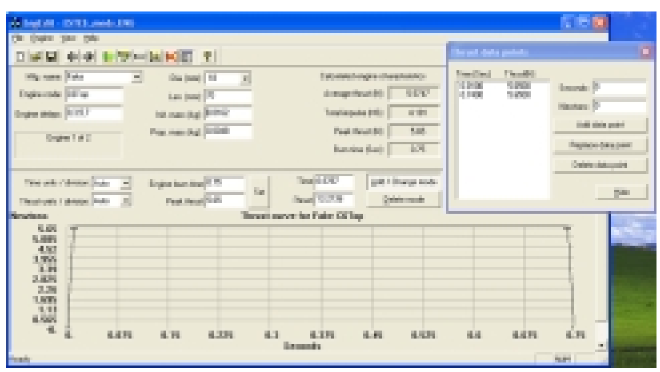

Figure 29: The fake sustainer motor, which is the aft portion of the C6 thrust curve.

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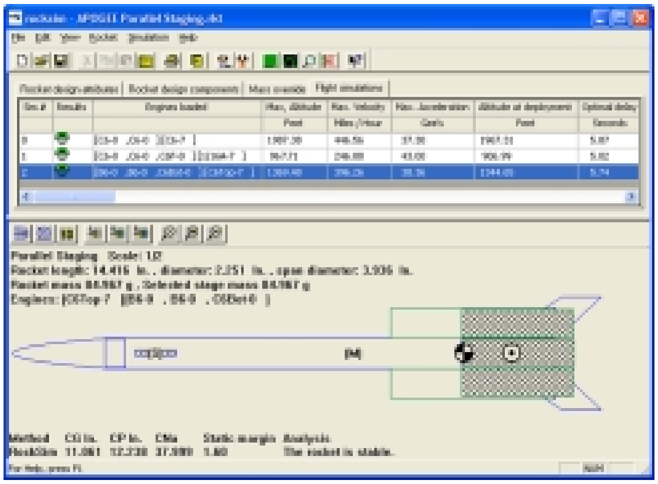

Figure 30: Our final simulation - where the booster stages drop off while the core motor continues to burn.

limit us to just two digits after the decimal point, we could squeeze that little notch even tighter together.

Conclusion

This article had many purposes. The biggest one, probably from your personal standpoint is finding a way to simulate strap-on booster stages in RockSim. While the proceedure is fairly long, and somewhat complex, it isn't insurmountable. You should be able to do it for your own designs if you follow the steps outlined here.

Eventually, we'll be adding a "Strap-on" feature into RockSim, so that it will go faster and be less complex. But I don't know when that will be yet. So give this method a try. I think you'll learn a lot about RockSim and rocketry.

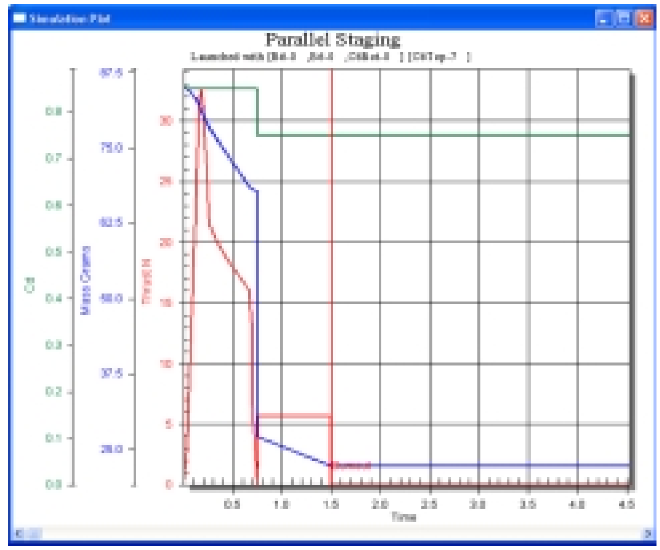

Figure 31: Graphs of our simulated parallel staging rocket. Compare these curves against the ones in Figure 24 on page 14.

About the Author:

Tim Van Milligan is the owner of Apogee Components (http://www.apogeerockets.com) and the curator of the rocketry education web site: http://www.apogeerockets.com/education. He is also the author of the books: *"Model Rocket Design and Construction," "69 Simple Science Fair Projects with Model Rockets: Aeronautics"* and publisher of the FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site, or sending an email to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.