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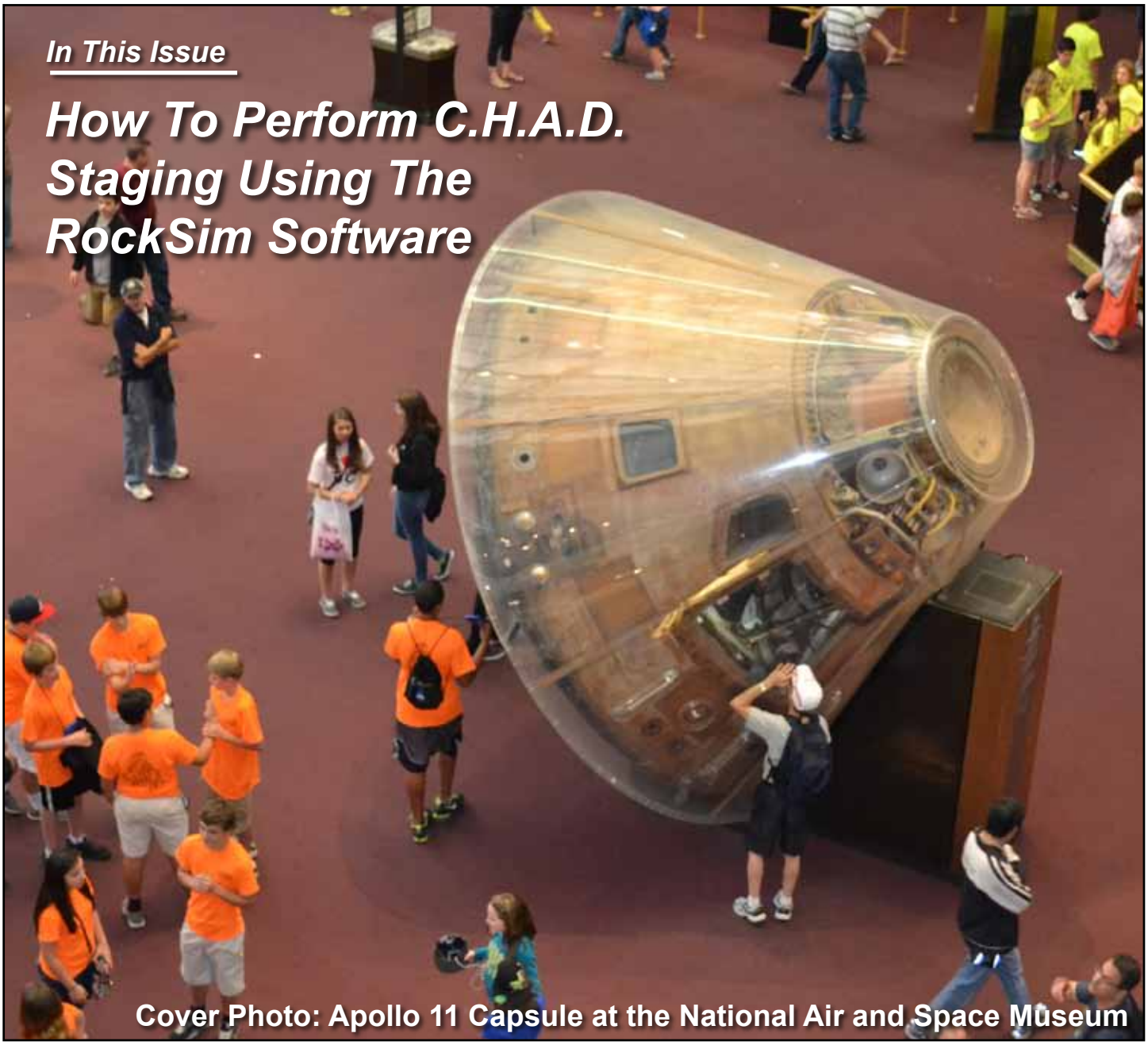

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How To Perform C.H.A.D. Staging Using The RockSim Software

Cover Photo: Apollo 11 Capsule at the National Air and Space Museum

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How To Perform C.H.A.D. Staging Using The RockSim Software

By Tim Van Milligan

The term C.H.A.D. Staging stands for CHeap And Dirty staging. Essentially, it implies that the booster stage motor is not held inside a separate finned stage. The booster motor is simply taped to the bottom of the sustainer stage.

This technique can only be used in specific circumstances:

1. Can only used with black powder propellant motors. The reason is that it requires direct-staging, where one motor ignites the second motor in the sequence. This is only possible with black powder motors, as composite propellant motors need a separate ignition system, like a staging timer to start the upper stage motor burning.

2. Can only be used on overly stable rockets. The reason for this, is that the CG of the rocket will shift rearward with the addition of the booster motor's mass. If the CG shifts too far back then the rocket could be unstable and therefore, unsafe.

This topic is covered in the book *Model Rocket Design and Construction* (www.ApogeeRockets.com/Rocket_Books_Videos/Books/Model_Rocket_Design_And_Construction), but I wanted to walk you through the steps of using RockSim to run simulations. By going through the process, I hope you'll also pick up some other rules of thumb that you can use with your other projects.

C.H.A.D. Staging Basics

Figure 1: The Estes Big Bertha is a good model to choose for your first experiments with C.H.A.D. staging.

Figure 2 shows the basic arrangement of the two motors. This is how the motors would look before you installed them into the rocket.

The booster motor is a specific type of rocket engine. It has a zero second ejection delay (such as a C6-0, C11-0, D12-0 or E12-0 . When the rocket reaches the end of the thrust phase, the hot gases inside burst forward and ignite the sustainer motor (the motor in the top stage).

The tape that is holding the two motors end-to-end is burnt away by the flame of the sustainer motor, and the booster stage motor falls away.

Now, having a tumbling motor drop to the ground is a safety hazard, so to slow it down and make it easier to see, one end of a streamer is taped to the casing, and the excess is rolled around the case. This streamer is held in place with a thin string, which is taped to the upper motor. The string, like the tape that is holding the motors together, also burns away; and this is what releases the streamer to unfurl. I never recommend having falling motors dropping from the sky without some sort of recovery device attached to them, unless they are mini motors. And even then, I try to be cognizant of where the motors spit out, just in case they should land in tall, dry grass that could easily catch fire. I believe that it is important to practice safe rocketry, even

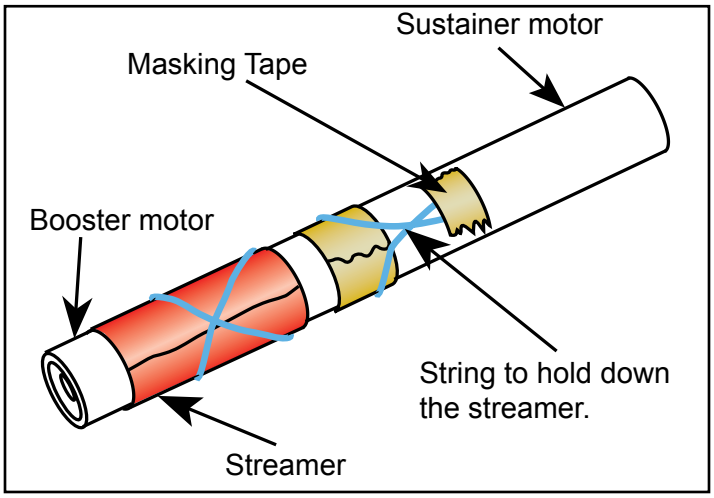

Figure 2: A streamer is attached to the booster motor to make sure it falls slowly and so that it can be retreived after the flight.

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when you are flying by yourself away from spectators.

Now that you have the basics down about how C.H.A.D. staging works, the next step is to look into RockSim (www.apogeerockets.com/RockSim/RockSim_Information) and see how the software can be used to simulate this two-stage situation.

In this example, I'm going to use the Estes Big Bertha kit as the prototype. Any rocket could be used, but I wanted one that I was sure was overstable and wouldn't require any modification (such as making the fins larger).

Step 1: Change The Number Of Stages

This is the simplest step of the process, but one that isn't self-evident. Because there are no parts in the booster stage, RockSim users don't always visualize that this is indeed a multi-stage rocket. But since it does use two motors fired in succession, it has to be created as a two-stage rocket design.

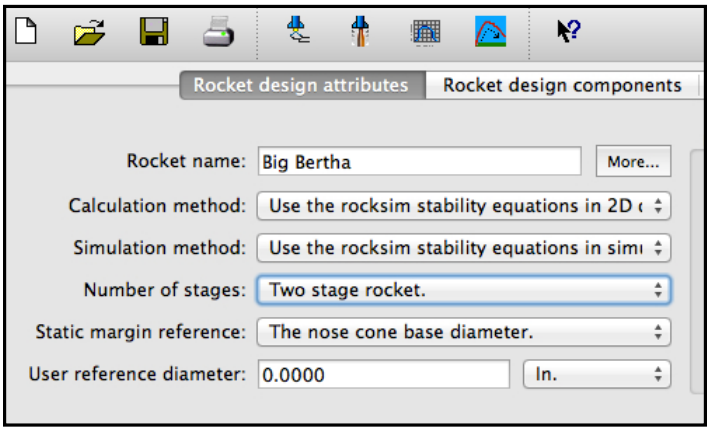

Figure 3: Change the rocket from a single stage to a "two stage rocket."

From the Rocket Design Attributes tab on the main screen of the software, simply go to the number of stages drop-down menu, and select "Two stage rocket" (See Figure 3). Even though the rocket is already completed as a design, you can always modify it to be one, two, or three stages.

Step 2: Create A Motor Mount Tube

In RockSim, you are required to put the rocket engines into a tube. Even though there won't be a tube in real life, you still have to do it in RockSim. This is the other thing that many users found hard to grasp. It does indeed put a crimp into the process. But we'll worry about

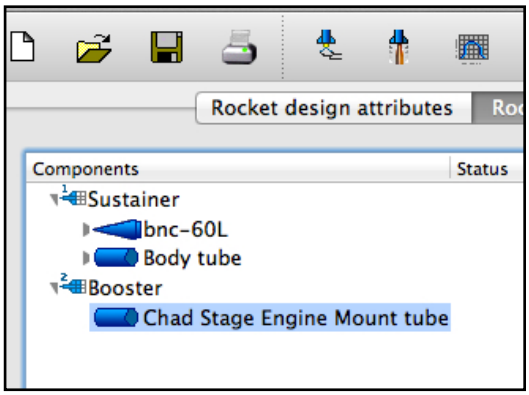

Figure 4: The booster stage has one single part: a motor tube.

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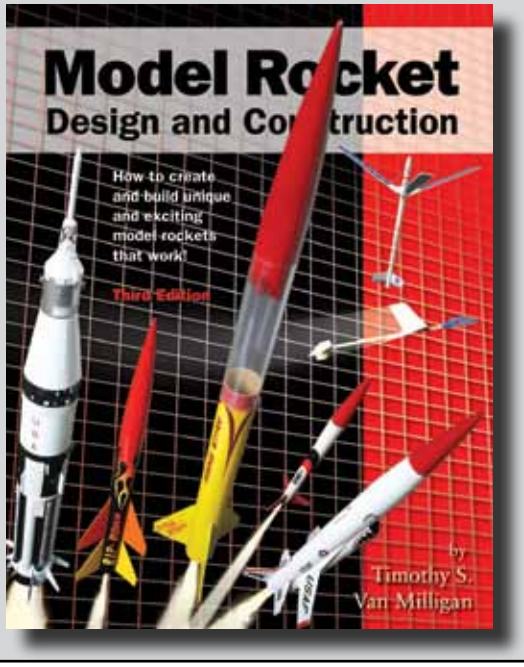

Model Rocket Design and Construction

By Timothy S. Van Milligan

The Expanded 3rd Edition

This massive, 328 page guidebook for serious rocket designers contains the most up-to-date information on creating unique and exciting models that really work. With 566 illustrations and 175 photos, it is the ultimate resource if you want to make rockets that will push the edge of the performance envelope. Because of the number of pictures, it is also a great gift to give to beginners to start them on their rocketry future.

For more information, and to order this hefty book, visit the Apogee web site at: www.ApogeeRockets.com

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the implications later. At this time, go ahead and create a motor mount tube that is the only part needed in the booster stage.

When you create the tube, the length is not important. In fact, you can make it just a whisker long to minimize the weight on the rocket.

This tube will stick out the back of the rocket, and might not be in the position you want it (see Figure 5). Because the tube isn't real, the position is not important. It is only there to let RockSim know where to put the motor.

And before you leave the screen where you input the dimensions of the tube, be sure to click the little check-box that says: "This is a motor mount" (see Figure 6). This is what tells RockSim that the tube is where the motor will go.

Actually, at this point in the process it's a good time to load up the motors in the design. As you can see in Figure 7, I've loaded up a C6-5 in the upper stage, and a D12-0 in the lower. This is a worst case scenario, as the D12 is heavy and is going to really move the CG back on the rocket.

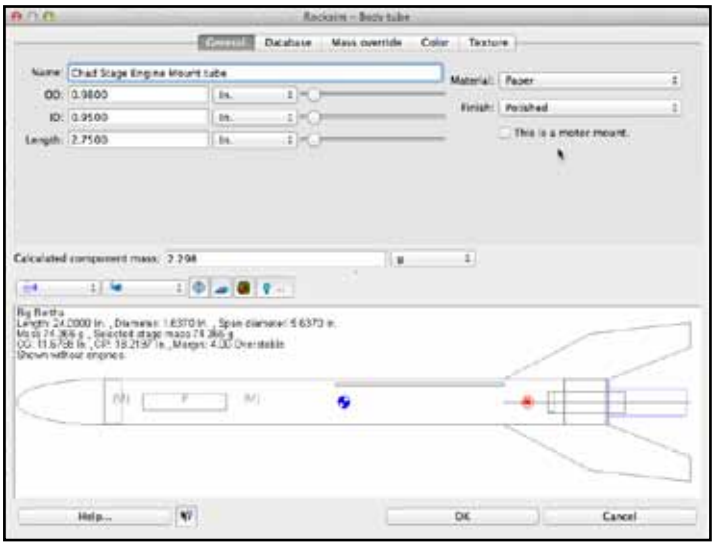

Figure 5: The engine mount tube will stick out the back of the rocket.

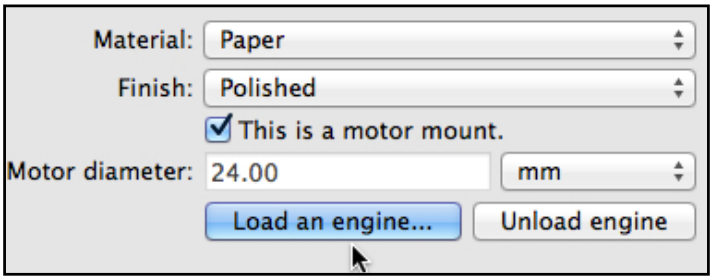

Figure 6: By checking "This is a motor mount," you can load motors to check the CG position.

Step 3: Check The Stability Of The Design

This is probably the most critical step for designers of any rocket. You must make sure the rocket is stable and therefore safe to launch. This is done by looking at the position of the CG relative to the position of the CP. The CG must be ahead of the CP for it to be stable.

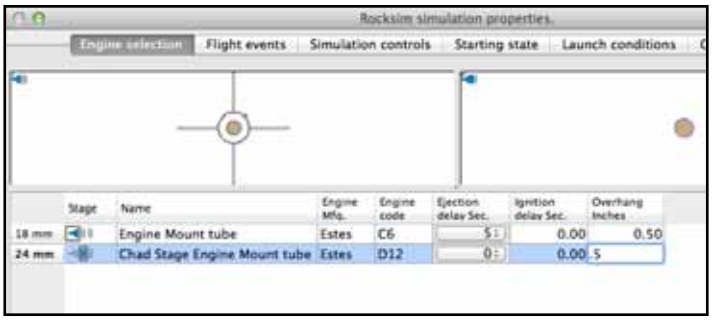

Figure 7: The motors are loaded into the design. The Engine Overhang field can be used to move the motor into the correct position .

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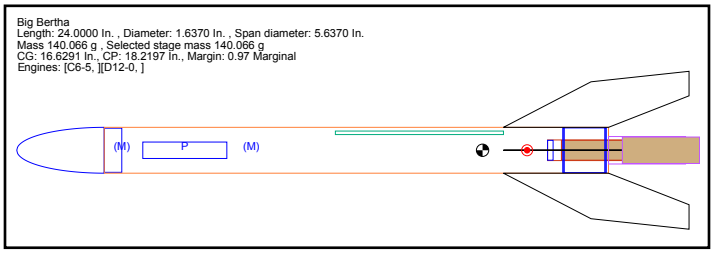

Figure 8: When the motors are installed, it is critical that the CG remain in front of the CP. Otherwise the rocket will need to be modified.

This is why you want to load the motors into the design, and get them in the right location where they will actually be for the flight. Therefore, in RockSim, use the engine overhang to position the motors into the correct spots. So even though the tube it is held in is not located properly, made sure the motor location is right. This will ensure that the CG location of the rocket is correct.

In Figure 8, the side-view of the rocket shows the locations of the CG and the CP. Since the CG is still forward of the CP, the rocket remains statically stable. This is what gives us the confidence that the rocket is safe to fly.

If it wasn't stable, we'd either have to scrap our plans to use this design for C.H.A.D. staging, or modify the rocket by putting on larger fins or adding nose weight to move the CG further forward.

Step 4: Make The Motor Tube Disappear

This step is optional, as it is really just an illusion to give the impression that the tube we used for the booster stage doesn't exist. Essentially, we'll camouflage it, which means it is still in the design–just harder to see.

This is done by changing the part color of the tube.

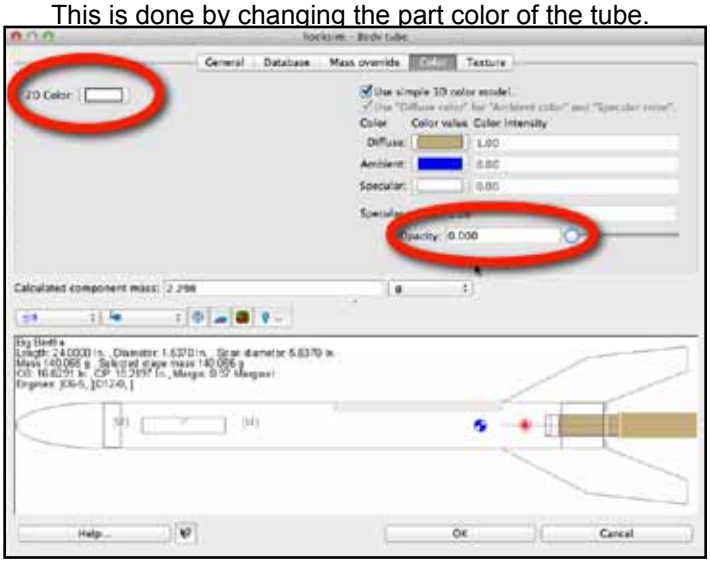

Figure 9: Adjusting the part color and the opacity can give the illusion that the tube isn't there.

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For the 2D viewing mode, you can change the part color to white. In the 3D mode, you can turn the opacity down to 0.00. That makes it completely see-through, so the part is invisible.

The only thing left to do is to get rid of the weight of the tube. This can be accomplished while you're still in the editor for the tube. Click on the "mass override" tab on the top of the screen, and then check the box that says "Use the mass and CG information below (Ignore the calculated mass and CG information). For the mass of the part, type in the number 0.001, and hit the tab key (see Figure 10).

The value here should be zero, but RockSim requires that it be greater than zero. The value of 0.001 is the smallest we can make it. And it is pretty close to zero in practical terms. To put this into perspective, my gram scale can only measure to the nearest 0.1 gram, so we're actually 1000 times lighter than that.

Making these value-judgments and assumptions is an important part of engineering. Unfortunately, it typically takes a bunch of past experience to know that it is OK to make these tweaks. In this case, the assumption is that

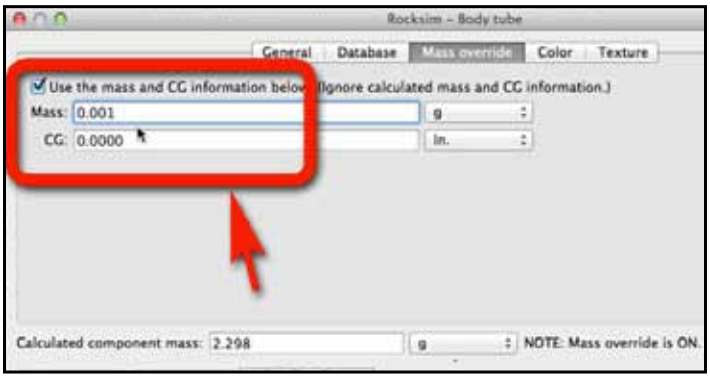

Figure 10: The mass of the engine mount tube can be minimized by using the 'mass override' feature.

the 'fake' tube we created that has a mass of 0.001 grams won't affect the simulations when we run them later. It is only through experience that you learn whether it works or not. I think that is why I get this question from users how to input a C.H.A.D. stage into RockSim. They just haven't had the experience yet.

Step 5: Add A Streamer

To finalize the weight of the rocket, you only need to add a streamer to that booster stage. That is pretty trivial. Remember, we want to be safe and have the motor visible as it falls to the ground.

Step 6: Run Flight Simulations

Running the flight simulations is the final step in the design process. And it is the results that you are looking for.

The one important part is to make sure the rocket

	Resul	Engines loaded	Max. altitude Feet	Velocity at launch guide departure Miles / Hour
1		[C6-5]	607.70	34.70
2		[D12-0] [C6-5]	1578.98	39.95
3		[C6-0] [C6-3]	1051.44	29.14

Figure 11: When running simulations, be sure to check the velocity of the rocket as it leaves the launch pad. If it is too slow, it will weathercock significantly on breezy days.

leaves the pad with sufficient speed. My rule-of-thumb is that the speed should be greater than 30 miles per hour by the time it reaches the end of the launch rod. You'll notice that in my example here, I had a D12-0 booster motor in the design, which is larger in diameter that the motor in the sustainer stager. The reason is shown in Figure 11. By looking at the simulation results, I saw that a C6-0 Booster wouldn't quite get the rocket moving fast enough coming off the pad

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(and these simulations were run using a longer launch rod – 48 inches long compared to a standard 36 inch rod).

The Big Bertha is a heavy and draggy rocket, and even a single C6 motor by itself will give a slow lift-off. Using an extra motor will slow it down even more coming off the launch rod, which is exactly what we see in Figure 11.

To compensate for this slower lift-off speed, the rocket needs more thrust. That is why I switched to the D12-0 booster motor for the design.

Note: If you want to learn more about picking motors, see the 2-part video I created at: www.ApogeeRockets.com/Advanced_Construction_Videos/Rocketry_Video_32

At this point the rocket design is complete. But there are some other considerations that need to be taken into account if you are doing C.H.A.D. staging of the Big Bertha and other rockets like it.

Engine Hook Interference

You may have noticed this too: as seen in Figure 12, an 18mm diameter motor slips easily into the casing of a 24mm motor (like the D12-0). This is a good thing, because it makes C.H.A.D. Staging relatively easy. You can still tape them together and have successful ignition of the C6 motor in the sustainer stage.

Figure 12: A C-size motor fits nicely inside the forward end of a D12-0 motor case.

The reality is that the kit I had already built had an engine hook installed. This complicates the situation, because the hook would directly interfere with the two motors mating to each other.

The way I chose to solve the problem was to make an adapter assembly out of two tubes and two centering rings.

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This would allow the motors to mate together for successful staging to occur.

Figure 13 below shows the construction of this simple adapter. The short green tube was custom made using the method described in Peak-of-Flight Newsletter #330 (www.ApogeeRockets.com/Education/Downloads/Newsletter330.pdf). The reason for the custom diameter tube is that it had to fit snuggly over the upper stage engine mount tube – with it's engine hook.

Because the tube is custom made, I had to also peel out some of the paper on the inside of the green centering rings so they would also fit over the green tube.

Figure 13: An adapter to allow the booster motor to mate with the upper stage.

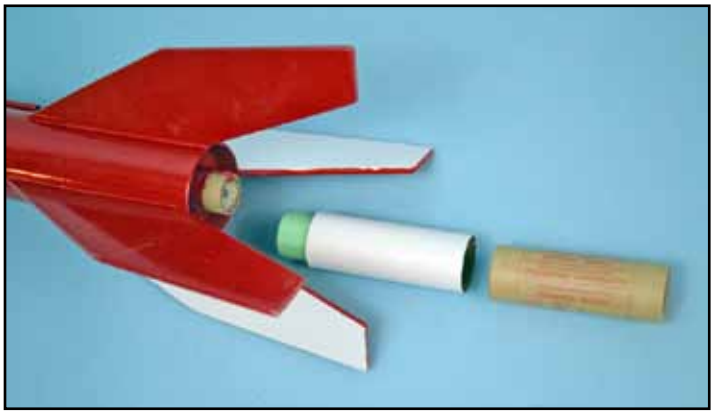

Figure 14 (top) and 15: The final mating of the booster stage to the sustainer using the adapter assembly.

Figure 14 and 15 show how the adapter tube is used to mate the D12-0 booster motor onto the base of the upper stage.

The only thing left to add is the streamer and the tie-down string that prevents the streamer from unravelling until the booster motor drops away (shown in Figure 16).

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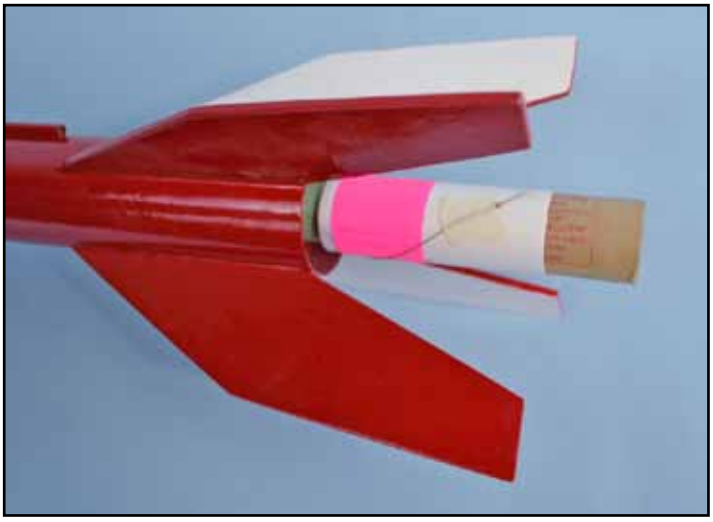

Figure 16: The streamer hold-down string, the forward end of which is tucked into the front end of the tube.

Since the rocket does require an adapter to mate the motors together, it is important to go back to RockSim and update the design to account for the extra mass of the adapter. But I'll leave that step up to you.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. 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 a 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 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 a FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site.
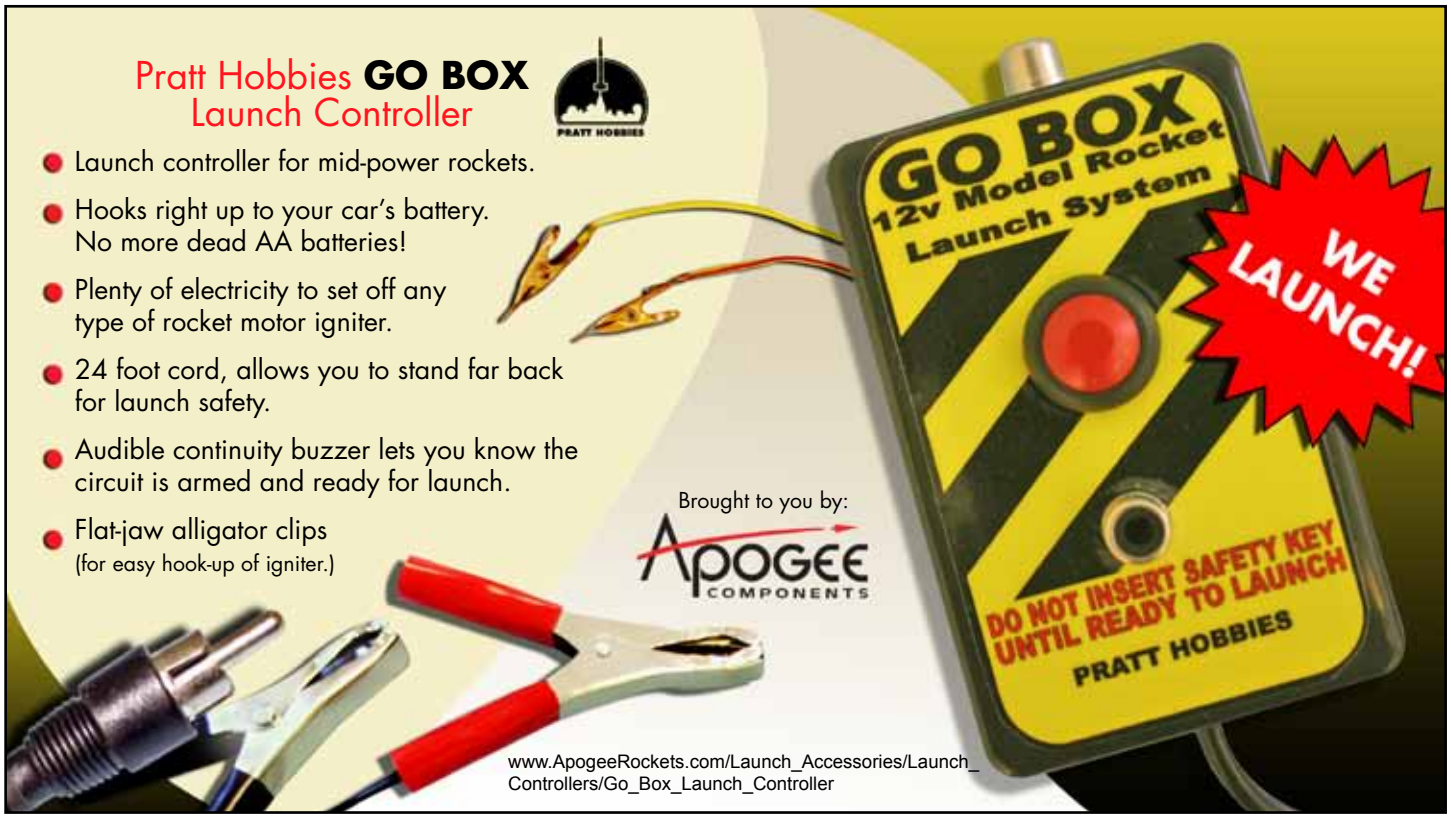
Figure 17: The Big Bertha rocket with a C.H.A.D. Stage.