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NEWSLETTER

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ISSUE 214 JULY 29, 2008

Find the Maximum Recommended Lift-Off Weight

By Tim Van Milligan

A couple of weeks ago, we received the new Quest D5-P rocket engine. As I was putting it up on the Apogee website so that you could purchase it, I came to the column called "maximum lift-off weight." I looked through all the literature on the new engine, including the official NAR certification paperwork. I couldn't find it listed anywhere.

Finding the *Maximum Recommended Lift-Off Weight* (MRLOW) seems to be a mystery to people, maybe because there isn't a step-by-step procedure written down. So that is the purpose of this article.

The procedure that I prefer is based on the apogee point in flight, which was described in Peak-of-Flight Newsletter #35 (www.ApogeeRockets.com/education/downloads/Newsletter35.pdf). I'll call it the *Barber MRLOW Procedure*, after it's creator, Mr.Trip Barber.

Most maximum lift-off procedures are based on zero-wind conditions. This isn't true in real life, as there is almost always wind when you are launching rockets. Without wind, you're really still just guessing. And because you're guessing, you have to figure in a factor-of-safety to compensate for the uncertainty you've introduced into the procedure. This factor-of-safety is going to lower the maximum lift-off weight that you calculate. Wouldn't it be better to have a procedure to give you the most weight?

What happens at launch when the rocket gets heavy?

That is an important question, because the answer is the reason why we have to watch the weight of the rocket. What happens is that the rocket leaves the pad slower. The heavier the rocket, the slower flies as it leaves the launch rod. Slow lift-offs are bad. But why?

As we found out in the discussion about dynamic stability (see Newsletters #192 - #198 at www.apogeerockets.com/education/newsletter_archive.asp) is that slow rockets are more susceptible to weathercocking as they leave the launch rod. In effect, they turn horizontal instead of traveling in an upward direction. From a safety standpoint, a horizontally-travelling rocket is more dangerous and should be avoided.

The BarberMRLOW Procedure gives us the criteria for how much weathercocking is too much. Based on this, we can load up the rocket with weight and find the point where it exceeds the "too much weathercocking" criteria. At that point, we can accurately predict the maximum lift-off weight the rocket can handle. In simple terms, the Barber MRLOW Procedure looks at the trajectory of the rocket as it leaves the launch pad.

Before getting into the procedure, I hope you can grasp that the maximum lift-off weight for the motor is going to depend on the size and configuration of the rocket, and the weather conditions on the day of the launch. The reason is that these variables also affect the trajectory of the rocket. Anything that affects the trajectory of the rocket will affect the maximum lift-off weight of the motor.

This is important, because there is not a single "maximum recommended lift-off weight" that can be used for all sizes of rockets. This may be contrary to what you've been used to for all your rocketry career. That MRLOW number you see published on the manufacture's web site is only good for a very narrow set of conditions. You really have to generate the number yourself based on the design of the rocket you've created.

Fortunately, with RockSim, it is relatively easy to find the maximum liftoff weight for the motor in your particular design. I'll walk you through the process using the example of the new Quest D5-P rocket engine. Here is the step-by-step procedure.

Step 1. Locate or create the rocket engine data file, and get it into RockSim.

Before you start creating the engine file, you should check to see if it is already available. The place to look is www.thrustcurve.org.

Fortunately, this file does already exist, and you can download it directly to your computer. If it did not exist, you would have to create it from scratch. You will find a video tutorial on how to do this at: www.apogeerockets.com/RockSim_tutorials.asp. Look for videos #13 and #14, as they will walk you through the most common issues you'll

Continued on page 3

About this Newsletter

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Continued from page 2

Find an Engine's MRLOW

encounter as you create motor files.

Before you go on, you'll have to store the file in the correct place on your hard drive so that RockSim can find it easily. The place that all the other motor files are stored is the "data" folder of RockSim. The default path to it is: c:/program files/Rocksim 8/data/

If you have problems doing this, see the aforementioned videos. They will walk you through the steps to get the motor file into RockSim.

Step 2: Create the rocket design file for RockSim.

This is also pretty straight forward. The only hitch is that the Quest D5-P motor is an odd diameter at 20 mm. So if you design around that size engine, you'll do OK. I've created a sample design file for you to try as you read through this article. You'll find it at: http://www.ApogeeRockets.com/Education/downloads/Quest_D5_design.zip. This file also contains the engine data file for your convenience.

Step 3: Set up the initial launch conditions. For this, you'll want to launch straight up, and have a constant 10mph wind speed. To make a constant wind, set the "Wind conditions" to "Custom speed range". You'll then enter 10 mph for both the "Low wind speed" and "High wind speed".

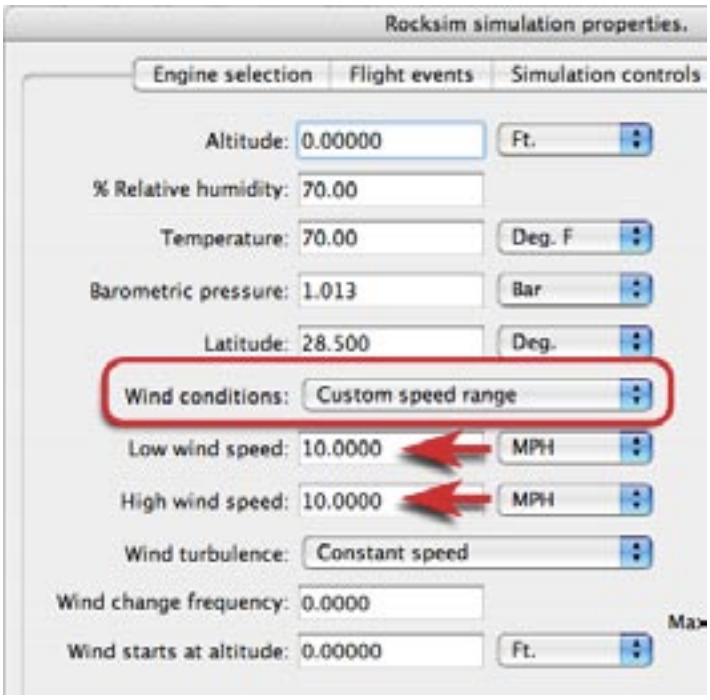

Figure 1: To set up a steady wind, you have to use the Custom Speed Range option.

Also, since the Quest D5 does not contain an ejection charge, we'll use a Flight Event to deploy the parachute.

Continued on page 4

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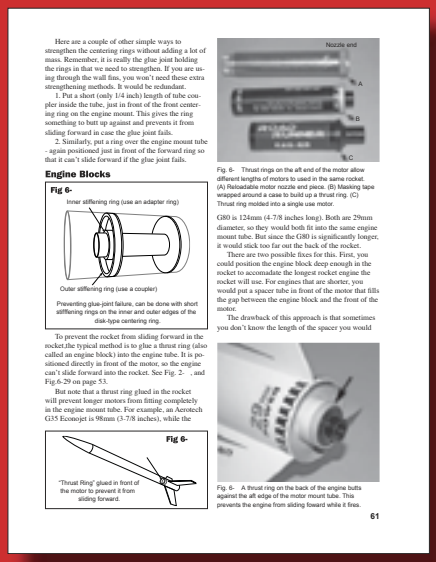

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Continued from page 3

Find an Engine's MRLOW

Set the parachute to deploy at apogee. Finally, we don't really care about the descent phase of the rocket, so under the Simulation Controls tab, choose "End simulation when the first recovery device is deployed."

Step 4A: Run the launch simulation

For the first launch, go ahead and display the 2D flight profile. This is where we have to determine if the weathercocking is acceptable. If it is too much, then the rocket is too heavy and we will have to reduce its weight.

According to the Barber Procedure, rockets that weathercock to an apogee elevation angle below 70 degrees (as measured from the horizontal) in a 10 mph wind, or rockets that "prang" prior to ejection in a 20 mph wind have a maximum recommended lift-off weight that is too high.

We can make a visual of this as shown in the Figure 2. What I did was overlay in red the criteria of acceptable weathercocking on top of the 2D flight profile that is generated by RockSim.

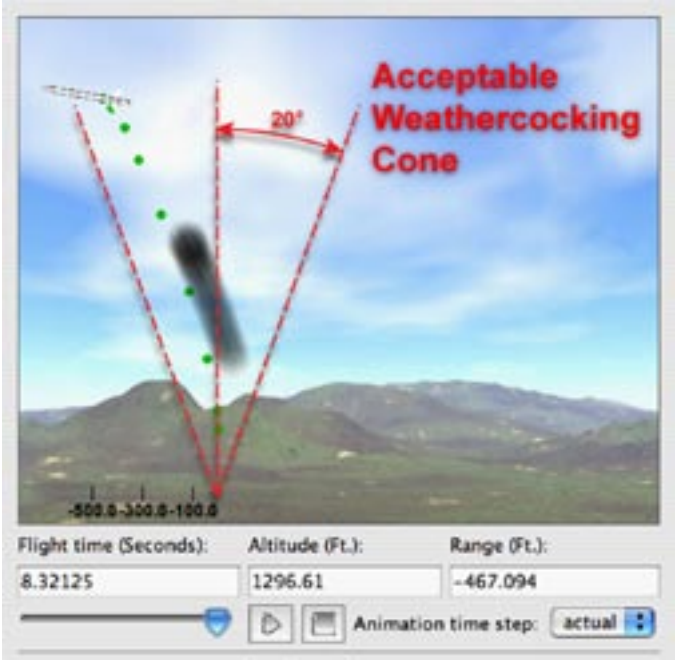


Figure 2: Definition of acceptable weathercocking.

Essentially, the criteria describes an inverted cone with a half-angle of 20 degrees, where the tip of the cone is at the launch location. If the rocket's apogee point is within this cone, then the weathercocking is acceptable. If it lies outside the cone, then the rocket is too heavy for the motor.

For this particular case, the rocket is still within the cone, so the weathercocking is OK.

Ideally, it would be cool if RockSim gave us this visual image. That is one thing that I'd like to see in the next version of RockSim, since it would tell us quickly if the trajectory is within a criteria defined as "safe." Unfortunately, we're not there yet.

But you can still make the determination of "acceptable" from the information on the screen. Notice that we have both the altitude and range at deployment. With a little trigonometry, we can easily calculate the angle from vertical to determine how far the rocket weathercocked.

The equation to do this is:

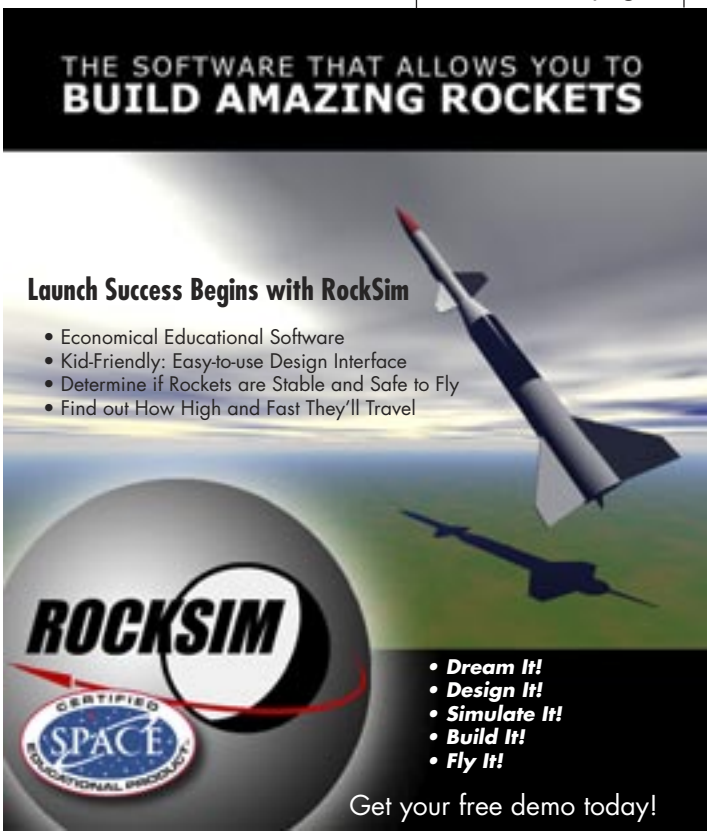
Elevation Angle = arctan (range ÷ altitude) – Measured from vertical to the apogee point.

In this example from Figure 2, the range is -467.094 feet and the altitude is 1296.61 feet. Doing the trig, we find that the elevation angle is 19.8 degrees (measured from the vertical).

This is about as far as we would allow in weight for acceptable weathercocking.

Please note that you actually have to use the absolute value of the range, so that you aren't working with a negative number. In other words, drop the negative sign in front

Continued on page 5



Continued from page 4

Find an Engine's MRLOW

of the range when you do these calculations.

Step 4B: We can actually simplify the procedure of Step 4a. We don't have to go to the flight profile screen every time we run a simulation. We can get it from the detailed flight report. Just double-click on the simulation number, and the detailed flight report will come up. Just scroll down to the section called "Recovery system data" to find the altitude and range at deployment as shown in Figure 3.

More good news: you don't actually have to take the

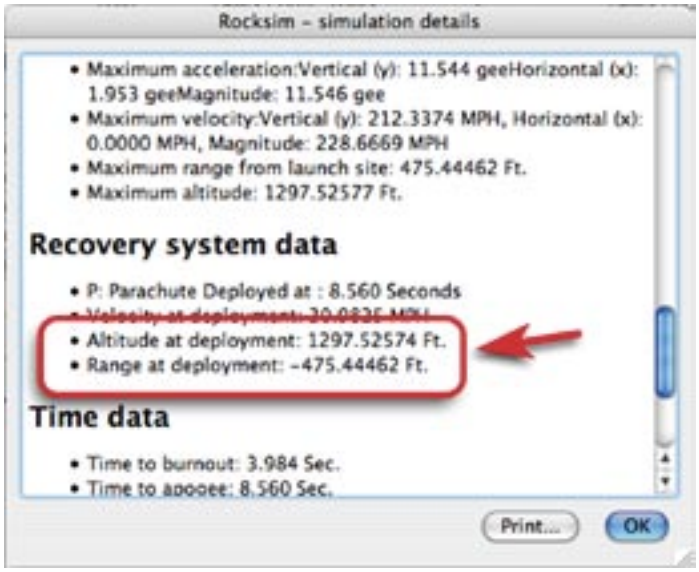


Figure 3: Find the deployment position from the simulation details report.

arc-tangent of the number when you divide the range by the altitude. We can find the arc-tangent of 20 degrees which is 0.36397 and compare to that.

In simplifies to this: ***If the range divided by the altitude is less than 0.36397, the weathercocking is acceptable.***

Anyone can easily make this comparison with a simple calculator!

If the weathercocking is acceptable, you can go back to your RockSim design and add more weight to the rocket and then rerun the simulation again. I suggest putting a mass object located at the rocket's current center of gravity location. You will keep adding mass until the rocket weathercocks outside of the cone, which will give you a number greater than 0.36397.

It should be noted that this value is only for a zero second delay. In this case, the Quest D5 is a plugged motor, so this is the value that I would use. I simply remove the engine from the design, and read off the rocket's current mass; which is 56.205 grams. This is the value I list on the Apogee web site as the MRLOW for the D5-P motor which is at: www.apogeerockets.com/quest_motors.asp

If the motor has a delay, the number is going to be a bit less. How much less? Just go on to the next step to find out.

Step 5: There is a second criteria in the Barber MRLOW Procedure that we can look at:

Continued on page 6

EMRR CORNER REVIEW

Rocket Contests Add to the Excitement

There are many activities that can add and enhance the model rocketry experience. One such activity is getting involved in model rocketry contests (we are referring to those outside of NAR competitive flying).

The internet has opened up the opportunity for rocketeers to participate in many, many different contests. There are design contests, photo contest and video contests (just to name a few).

We would like to encourage you to participate in one or more contests, just to add to the excitement of model rocketry. You may even win some cool rocketry prizes:

Look at some of these winning entries from past contests!

Steve Kristal's - Flight of the Snitch (Winning Rocket Video) Rocket Video Contest 2008 is currently active on EMRR!

Ray King's - Neutron (Winning Design this Spaceship) Design this Spaceship 2008 is currently active on EMRR!

Todd Mullin's - Y-Wing Fighter (EMRR Challenge 2007) Made from Recyled Parts See the 2008 EMRR Challenge

Chan Steven's - The Forum (NASROC Virtual Rocket Contest) All entries are in RockSIM Watch for future contests

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Continued from page 5

Find an Engine's MRLOW

"Rockets which go 'over the top' and fall to below about 50% of apogee or 10 meters (32.808 feet) of altitude – which ever is lower – before ejecting are too heavy for the motor/delay combination used."

What does this mean?

You're looking at the distance between the apogee point and the deployment point and seeing if it is less than 32.808 feet. I use the 32.808 feet criteria, because it is the one you would use for any rocket that flies higher than 65.6 feet – which is about ALL real rockets.

Let's do an example. While the Quest D5 really doesn't have any delay combinations, lets say that a 7 second delay was available. What would be the maximum recommended lift-off weight of the rocket/motor combination?

Using the same rocket as before, we'll make a few adjustments in the simulation prep screen.

First, change the delay value for the motor to seven seconds. Just TYPE the number in the delay field, and hit the TAB key (Enter key on the MAC). This forces RockSim to accept the new delay value.

Next, go to the flight events and set the parachute to deploy at maximum engine ejection. Finally, confirm that the simulation end point (under the Simulation controls tab) is still set to "End the simulation when the first recovery device is deployed."

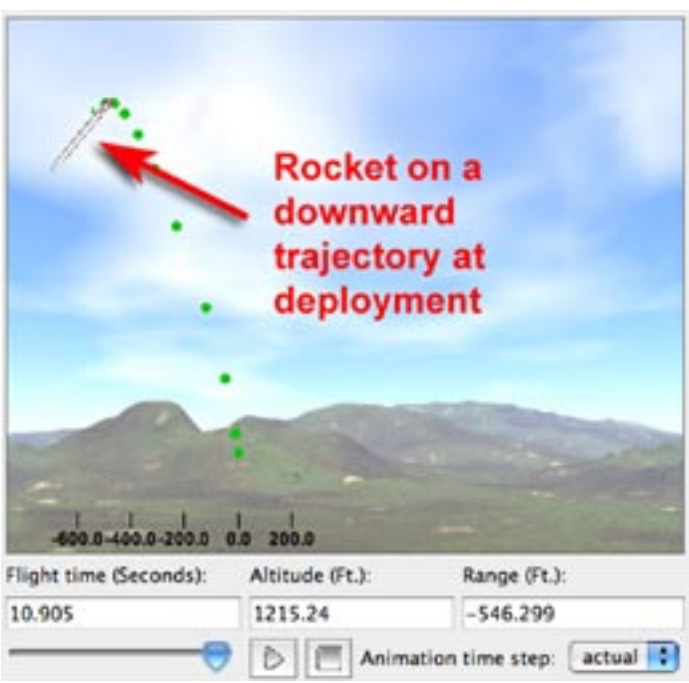

Figure 4: Rocket on a downward trajectory.

Now run your simulation and display the 2D flight profile.

What you see in the 2D flight profile (Figure 4) is that the rocket did indeed travel 'over the top' and was headed in a downward direction when the parachute is deployed.

Now bring up the simulation details screen by double-clicking on the simulation number on the main screen of RockSim.

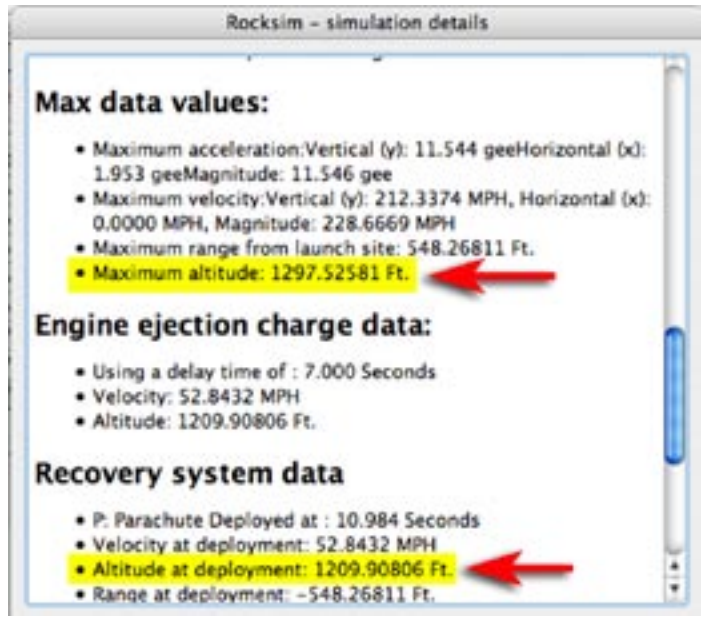

Figure 5: Compare peak to the deployment altitude.

Here, we want to compare the maximum altitude and the altitude at deployment. If the difference is greater than 32.8 feet, then the rocket is too heavy for the delay and we'll have to remove some weight.

The value for maximum altitude is 1297.52 feet, and the deployment altitude is 1209.90 feet. The difference is 87.62 feet, which is greater that the allowable 32.8 feet.

Based on this, we will have to back off the rocket's weight and do the simulation again.

When you lower the rocket's weight, it is going to fly higher, and the trajectory is going to be straighter. And the altitude at deployment is going to be higher. Because of all this, you will find yourself doing a number of simulations to dial in to the result that gives the deployment altitude that is within 32.8 feet of the peak altitude.

The purpose of the 10 meter difference between the peak and the deployment altitude is to reduce the deployment speed to a manageable velocity. You don't want your parachute to shred from opening at a high rate of speed

Continued on page 7

Continued from page 6

Find an Engine's MRLOW

if you were setting this scenario up in the SMARTSim software (www.ApogeeRockets.com/smartsim.asp), you'd probably dial in on the deployment speed as the optimum value. That would have the same effect. For starters, I'd try to keep your deployment speed to around 40 mph, to limit the stresses that will try to rip the parachute to shreds.

Conclusion

There could be some debate over the criteria in the Barber Procedure for finding the MRLOW of a motor. I personally like the aspect of a definition of acceptable weather-cocking. The part that may be debatable is how far a rocket can go over the top before the parachute is deployed. But does it really matter in the grand scheme of things?

I say that, because it is very rare that you'll ever have to find the MRLOW of a motor if you use Rocksim. Besides, do you really want to fly at such a high weight that the rocket is on the verge of being under powered? Really the only reason that I can think of is to get the slowest lift-off speed to make it easier to take pictures of your rocket as it takes off. Other than that, you're giving up a lot of performance and you're reducing your safety margins.

The only practical reason to have a MRLOW is to give you a quick evaluation as to whether or not a motor can be used as a starting point for a specific rocket project. But that really doesn't eliminate the motor entirely. If you read through Technical Publication #28: Selecting Rocket Motors: A Step-by-Step Procedure (www.ApogeeRockets.com/technical_publications.asp), you will see that there are a host factors that go into picking what motors will work with your rocket design. The motor you pick as starting point in the process will speed up the selection process, but if you pick wrong, the process will still loop back and help you get the others that will work.

The beauty of RockSim is that it opens up more choices for you than if you only looked at factors such as the Maximum Recommended Lift-Off Weight. It is a guideline that I wish people wouldn't put so much emphasis on.

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 or by sending an e-mail to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.

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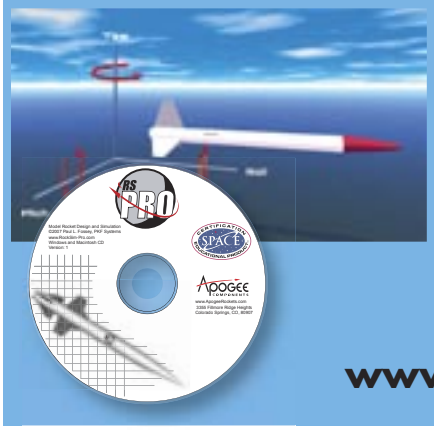

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Reader Responses

Applying Decals in RockSim v8 - More Example files

By Tim Van Milligan

"This is in response to an article in Newsletter 211 (www.ApogeeRockets.com/education/downloads/Newsletter211.pdf) about putting decals on a rocket using Rocksim. In the beginning I had some trouble fitting the texture maps, and the instructions in the help file were terse, to say the least. After a while the light went on, I thought of making the maps 1:1, actual size. This way worked almost perfectly. Then I tried to place textures across part boundaries. After measuring I resized the maps to individual parts.

One of the problems I encountered was the bleed through on the fins. Solved that by making the fins two parts and separating them by a distance more than 0.000, again if you look at the V2 files you will see the "58" white on one side and black on the other. The business of the internal shoulder took me a while to work out. Just as you show in your article, turn off internal parts, and the maps work fine. If you look at the textures included you can see how I developed the various maps to the rocket.

I was also experimenting with the Redstone missile I modeled, including textures on it. Making long parts out of paper, strong enough to stand up to a launch. But that's another story. The Redstone was the first tactical nuclear weapon fielded by the Army. Considering the rockets that were based on the design, Jupiter-C and Mercury-Redstone, it was a negelected (unglamorous) design, put together by Werner Von Braun and his Space Rangers, as they were called back then." -- M. Gerstman

Figure 1: Top to bottom: V2 in camoflag pattern, Jupiter C, and Mercury Redstone rocket. RockSim decal files for these rockets are available from the Apogee web site.

You can download these three rockets from the Apogee web site. All the decal files are there. The Mercury Redstone rocket, which looks the most complicated, is actually the easiest one to apply decals to.

V2 in Camo colors: www.ApogeeRockets.com/education/downloads/A4_camo.zip

Jupiter C Rocket: www.ApogeeRockets.com/education/downloads/Estes_Jupiter_C-2.zip

Mercury Redstone Rocket: www.ApogeeRockets.com/education/downloads/Estes_MR-2.rkt.zip