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NEWSLETTER

Feature Article:

How to Pick The Correct Size Streamer

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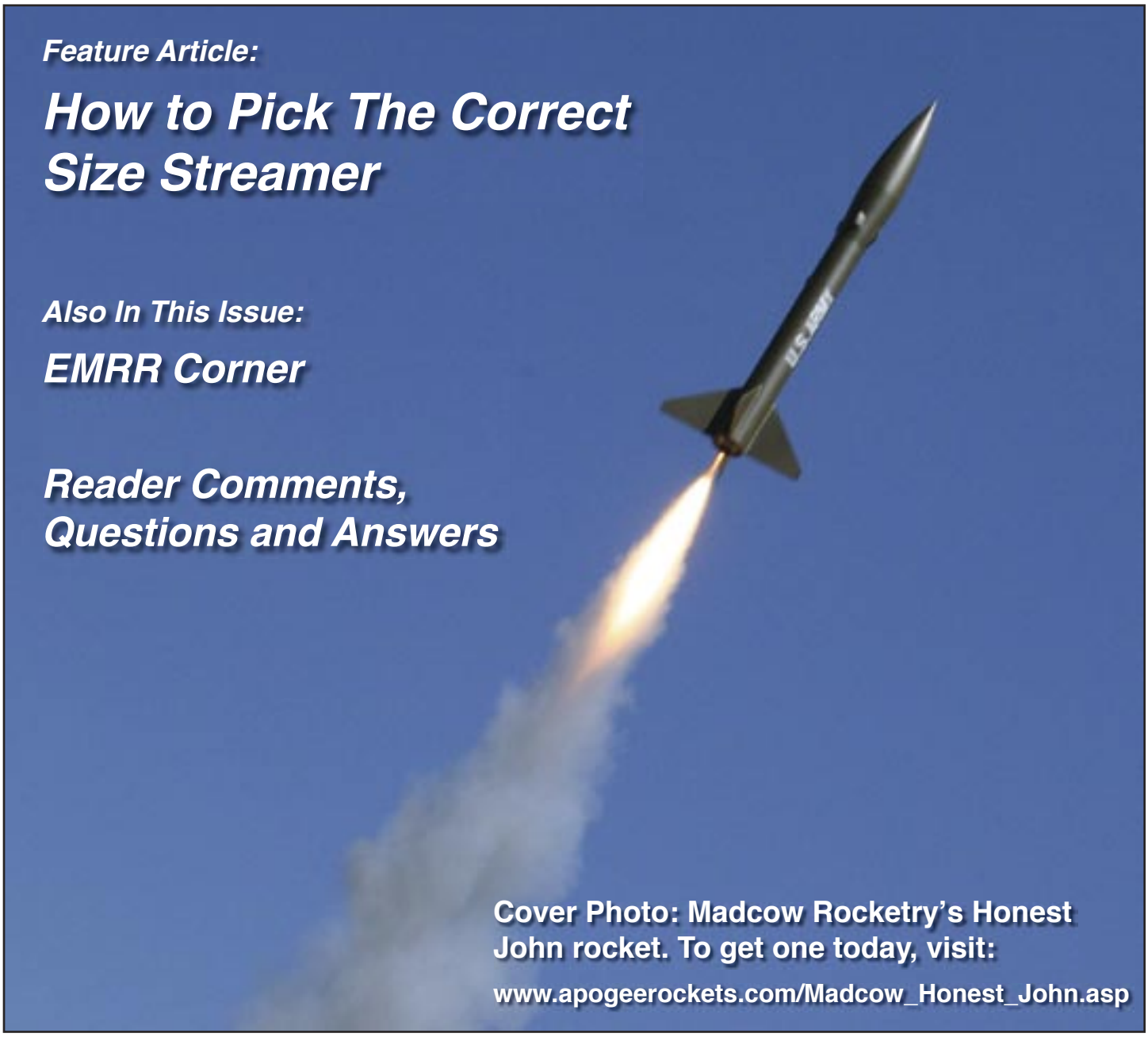
Reader Comments, Questions and Answers



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www.apogeerockets.com/Madcow_Honest_John.asp

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ISSUE 244 SEPTEMBER 22, 2009

How To Pick The Correct Size Descent Streamer

Written By Tim Van Milligan

The TARC contest gets more challenging every year, mainly because the competitors get more studious and focused and build better rockets. I think this is awesome! This year's TARC contest has a tasty little twist to it that adds some extra difficulty. Not only do the contestants have to launch to exactly 825 feet and return the egg to the ground unbroken within a time range of 40 to 45 seconds, but the portion of the model containing the egg must return using streamer recovery.

I really like this new additional challenge, as I've been lobbying for something like this. My reason is that I've been concerned that the models in the past were being built heavy like tanks, which goes against general aviation principles to keep the rocket light weight. By putting this one criterion on the rocket design, it forces the students to concentrate on reducing the mass of their rockets.

In real-life engineering as it concerns rockets, "weight" is a constant enemy. The higher the weight of the rocket, the less payload mass the rocket can boost in the air. If you review the history of the Apollo program, you'll read about the competition in the Grumman assembly plant to reduce the mass of the Lunar Lander. They took some pretty dramatic risks to trim the weight of the LEM. Every ounce that they took off meant that an additional ounce of moon rock could be returned to the earth for scientific study. The same should hold true for model rockets too.

Also, in model rocketry you have to keep an eye towards safety; and here again, weight can be an enemy. A lightweight rocket has a lower risk of causing serious damage compared to a heavy one.

With the requirement to use a streamer for the recovery of the egg capsule, the obvious question becomes: "What size streamer should I use?"

I'll tell you up front that finding the correct size streamer is a lot more difficult than sizing a parachute. The reason is that parachutes are more consistent from one flight to the next. A streamer can behave much differently from flight to flight.

To get an understanding on the procedure we'll need to follow in sizing the streamer, we need to understand how a streamer works.

Figure 1: A streamer attached to an egg capsule.

Essentially, like a parachute, a streamer creates a force called "drag" that hinders or impedes the motion of the falling rocket. Without drag, the rocket would continue to gain speed as it plummets to the earth. The drag force reduces this speed at which the rocket falls.

So the question becomes, how fast will the rocket fall? That is a good question. Even with the streamer (or parachute), the rocket will accelerate faster and faster as it falls. It stops accelerating and achieves a constant descent speed when the drag force produced by the recovery device, equals the force of gravity pulling the rocket down. Why is this? It is an outcome of Newton's Second Law of Motion, where $F=m \cdot a$. If there is an unbalanced force, you must have an increase in acceleration on the other side of the equation. If you need help understanding this, please ask your science teacher…

What this means is that the Force of Drag will eventually equal the force of gravity pulling down on the rocket. And when it does, the rocket will now fall at a constant speed. This point is called the rocket's final or "terminal velocity".

How do we determine that terminal velocity? That is

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About this Newsletter

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How To Pick The Correct Size Streamer

what this exercise is all about. Once we find out the rate of descent, we can find out how long it takes the rocket to fall from a height of 825 feet. Then we can make adjustments to make it fall faster or slower to get the optimum descent time of 40 to 45 seconds.

At this point, we know that when the rocket reaches terminal velocity, the drag force will equal the force of gravity.

Drag = Force of Gravity = m•a

We can easily calculate out the force of gravity, because we know the mass of the falling object and the term "a" has a value of approximately 9.8m/s^2.

The Drag force on the left side of the equation is a bit more complicated. It's formula is:

$$\text{Drag Force} = \frac{1}{2}\rho A C_d V^2 \qquad \text{(Eq. 1)}$$

Where the terms are defined as:

ρ = density of air (1225 g/m^3 at sea level)
A = the surface area of the streamer. This is the term we are trying to find.
C_d = Coefficient of drag of the streamer
V = the terminal velocity of the falling streamer.

We actually know what our terminal velocity should be by dividing our peak altitude of 825 feet by 40 seconds. This gives us a starting point from which to work. Our target descent speed should be in the range of 18-19 feet/sec (5.48 to 5.79 m/s). Note: actually the speed will be higher than this because we haven't subtracted out the time it takes the rocket to ascend to 825 feet. But you can figure that out later…

Remember, our goal here is to find the size of the streamer for the TARC event.

Setting the two forces equal, the equation becomes:

$$m\,a = \frac{1}{2}\rho A C_d V^2 \qquad \text{(Eq. 2)}$$

Rearranging and solving for the surface area of the streamer, the equation becomes:

$$A = \frac{2\,m\,a}{\rho C_d V^2} \qquad \text{(Eq. 3)}$$

At this point, we really know everything except the Coefficient of Drag of the streamer.

Here's where it gets complicated...

Finding or estimating the coefficient of drag for a streamer is much more complicated than finding the value if the recovery device was a parachute.

Your first inclination will be to use the RockSim software to help guide you. And that hunch would be the correct one to make. It will throw a number out at you.

But how accurate is this Coefficient of Drag value? That is the great unknown. It is certainly better than starting off with nothing. But you will have to confirm it is accurate.

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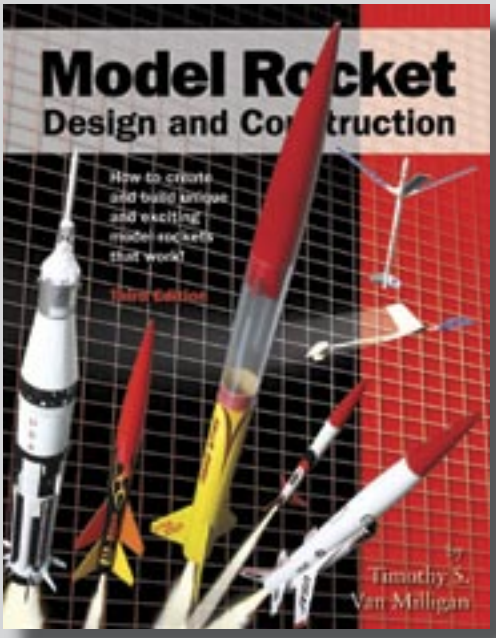

Model Rocket Design and Construction

By Timothy S. Van Milligan

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APOGEE COMPONENTS

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How To Pick The Correct Size Streamer

It is difficult to estimate the Cd value of a streamer because of a number of reasons. For example, streamers operate by slipping through the air, so the surface finish is going to play a huge factor in their effectiveness. A slippery streamer made from Mylar® (Mylar is the registered trademark name for polyester plastic made by Dupont) is going to have a lower C_d value than a rough one made from a material like crepe paper.

Another little known fact is that a long streamer (as defined by its length to width ratio) is going to have a lower C_d value than a shorter streamer. You better read and understand that statement again. This means that a wide and short streamer will have a higher value and will slow down the falling object better.

This actually confuses things.

If you look at the formula (Eq. 3), when you make your streamer area larger, it would indicate that it should fall slower. But when you make it longer, you're actually affecting two variables, the velocity, and the coefficient of drag.

Both these variables go down when you make the streamer longer. But because the Coefficient of Drag is going down too, you've just reduced the amount that the velocity is reduced.

In other words, you might have thought that you could have reduced the velocity of the falling streamer by 5 feet per second by making the streamer 20 inches longer. But in actuality, you might have only reduced the velocity by 1 foot per second because the drag coefficient also dropped.

Here's a tip that you'll eventually figure out sooner or later: make your streamer wider if you need to lower the velocity of the falling model. It is much more effective than making the streamer longer.

Why is it that a wide streamer has a higher drag coefficient? The reason is because of the whipping factor. This is hard to predict, but modelers have found out over the years that shorter streamers whip around more as they descend than longer streamers. This whipping increases the drag on the streamer, which in the case of our formula means that the streamer has a higher coefficient of drag.

But you can't make it too short and wide. The reason is that the contest rules say that the streamer must be at a minimum of five times longer than it is wide.

Another way to induce whipping of the streamer is to fold it strategically. That is what a lot, if not all, the competitors will do. And that is a very smart thing to do. But the streamer must be stiff enough to hold the creases in

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How To Pick The Correct Size Streamer

the material. If the streamer stretches out and essentially becomes a flat ribbon, then you will reduce the amount of whipping around it will do while it descends. If it doesn't whip around enough, you may not be getting enough drag from it.

What kind of material works well? A thick mylar film that is at least 1mil thick. And if your design can tolerate the extra weight, 2mil thick is even better.

If you want some ideas on types of folds that have been tried in competition rocketry over the years, see Apogee Technical Publication #4 (www.apogeerockets.com/technical_publications.asp).

Back To The Drawing Board

By now you've designed your rocket in RockSim and you're at the step where you have to put in the streamer. You go to the streamer design page, and you get a starting Cd for the streamer based on the size you've selected. It is at this point where you notice that RockSim doesn't give you a predicted descent rate like it does if your designing a parachute.

ARRRGH!

We know about this inconsistency with RockSim, and

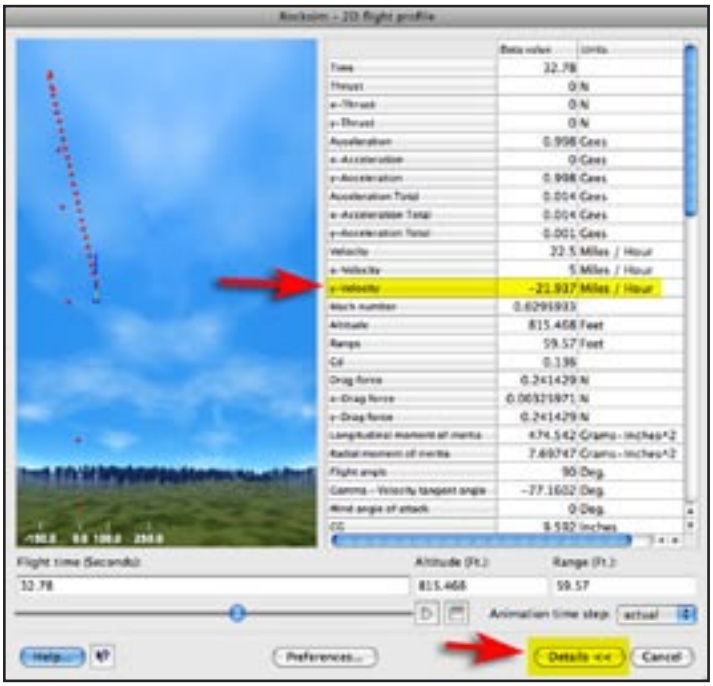

Figure 2: The descent rate as shown in the 2D flight profile details screen.

we'll work to fix it in a future update.

The RockSim does generate the descent rate data, but

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How To Pick The Correct Size Streamer

you'll have to run a launch simulation first to get it.

After you run the simulation, you can actually find the descent rate information from a multitude of sources: the details in the 2D flight Profile screen, the Detail Simulation results, or the simulation plot. When using the plot or the 2D flight profile, make sure to look at the Y-velocity, and not just the "velocity." The "velocity" is a sum of both the vertical

Figure 3: Descent rate as listed in Simulation Details.

velocity (as the rocket descends) and its horizontal velocity which happens if it is being blown sideways by the wind.

Once you have your descent rate from the simulation, you'll probably have to go back to the streamer design screen to tweak things a bit, such as the size of the streamer.

The Coefficient of Drag Revisited

As you dial things in with your design, you're really

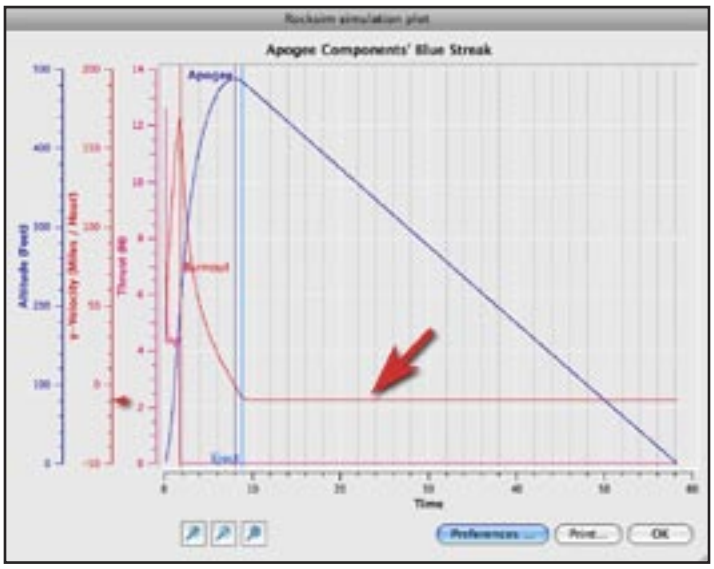

Figure 4: The descent rate can also be graphed on the Simulation Plot screen.

going to need to know how accurate the drag coefficient is. RockSim is estimating it. But you're going to have to confirm that value is accurate for your particular streamer design.

How do you do that? The simple answer is doing a lot of drop tests.

A drop test is where you take your streamer up to a high place, drop it to the ground, and record how long it takes to land. With the time known, you figure out its

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REVIEW CORNER EMRR

A Family Photo Opportunity

How many fat boys would a fat boy build if a fat boy could build fat boys? (Or something like that)

EMRR has been holding a photo contest that celebrates those that like to build the same kind of rocket. It is well known that rocketeers have favorites and end up building a so-called "family" of rockets.

For instance:

Series up up/down scales
Same type (gliders, stubby, etc)
Same theme (Goonies, Star Wars, etc.)
Same paint theme
Same rocket w/ different configurations

That's the contest that is going on over at Essence's Model Rocketry Reviews!

Check it out and get your entry in because the contest ends on 10/1!

* it is a riddle, not an insult

Brought to you by Essence's Model Rocketry Reviews & Resourses - www.rocketreviews.com

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How To Pick The Correct Size Streamer

terminal velocity. You can do that, because you also know how high you were when you dropped it to the ground. Just divide the height by the time it took to reach the ground.

Note that the higher up you are when you drop the streamer, the more accurate and repeatable your results will be.

Once you know the descent rate, you just go back to the terminal velocity equation (Eq. 2), and solve for the coefficient of drag.

Then take this coefficient of drag and plug it into RockSim so you can re-run your simulations.

It is going to take a little bit of extra work this year than it was when you used a parachute for the recovery device. But I think you'll learn a lot more about the scientific method of research.

Please also remember to send me your drop test results. This information will allow us to make RockSim more accurate in the future. There isn't a lot of information available on the drop rates of different streamers and how they are folded. So you'll actually be doing a lot of scientific research at the same time.

Multiple Streamers

If you study the rules, you'll see that you actually are allowed to use multiple streamers attached to the design. You may think that this throws a wrench in things as far as RockSim goes. But actually, the procedure for RockSim is identical to what I've listed above. The only exception is that you don't add a second streamer to the rocket design. You just tweak the dimensions (to account for the extra weight) and the Cd of the first streamer!

By the way, are two or more streamers the way to go in this event? That is a great question. And I don't really know

Figure 5: Two streamers attached to a rocket.

the answer to that question. Traditionally, competitors use just a single streamer attached to their rockets. I don't know if that is because of convenience, or if the multiple streamers just wind up around each other and make it like a single streamer anyway. If you are interested in using multiple streamers, I think you'll have a bit more experimenting to do.

It should be interesting to see the results. Again, send me the results. I won't share them with any other team until after the event is over next year.

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How To Pick The Correct Size Streamer

Other tips for this competition

1. Separate the egg capsule from the bottom portion of the rocket as shown in Figure 1. You're probably aware of this strategy already. The reason is to reduce the weight of the part of the rocket that the streamer has to slow down. The less weight, the slower it descends.

The way to do this in RockSim is to make the rocket a two stage design. I've gone ahead and redone the video instructions that show this technique in RockSim. They are listed as TARC Tutorial 3 at: www.apogeerockets.com/RockSim_tutorials.asp

2. Don't forget about the lower section of the rocket. It must be safely recovered too, or you'll be disqualified.

3. Make sure your rocket flies straight when it comes off the launch pad. A longer launcher is better, because it allows the rocket to leave the pad with a higher speed. The higher the lift-off speed, the less the rocket is affected by the wind that may be blowing on launch day.

In the Peak-of-Flight Newsletter 243, I talked about using a very long launch rail. I recommend you consider something like this. www.ApogeeRockets.com/education/downloads/Newsletter243.pdf

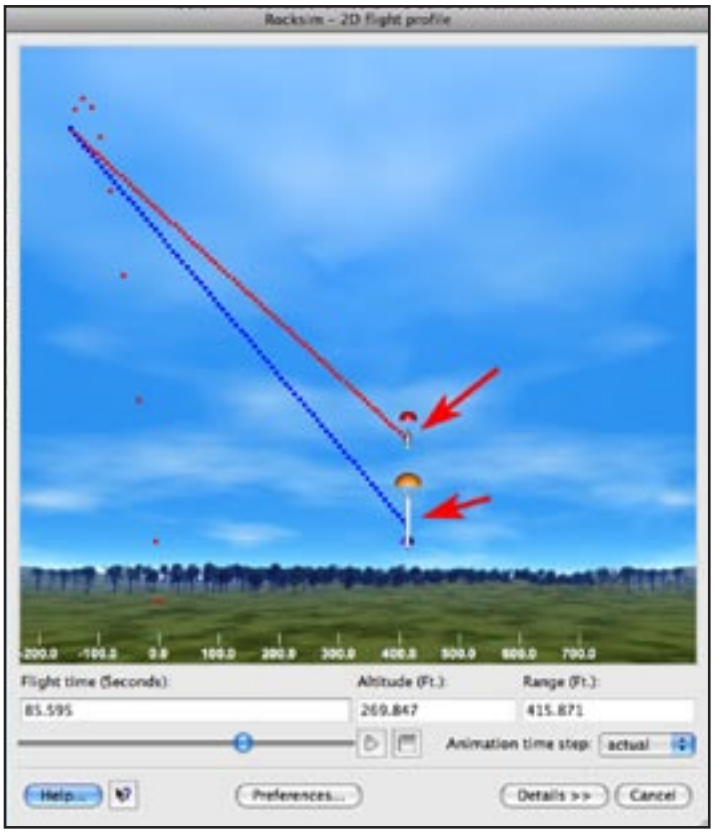

Figure 6: In RockSim v9, you can have the nose cone come down separate from the engine section.

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How To Pick The Correct Size Streamer

Conclusion

Figuring out the correct size streamer for your design is a bit more complicated than finding the right size parachute. It will take a lot of drop tests to dial things in and get good estimation of descent rates. The more time you spend on streamer design, the more consistent your results will be. And in this competition, "consistency" is the key to winning.

Other Relevant Information:

Newsletter 184 – sizing your parachute www.ApogeeRockets.com/education/downloads/Newsletter184.pdf.

10" Wide Mylar Streamers – These are now available from Apogee Components. You may not need the 10 inches of width, but it is a lot easier to cut it down and make it skinnier than trying to make a skinny streamer wider. www.apogeerockets.com/Streamers.asp

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.

Reader Questions and Answers

Responses By Tim Van Milligan

Fly-Away Rail Guides Revisited

In Peak-of-Flight Newsletter 243 (www.ApogeeRockets.com/education/downloads/Newsletter243.pdf), we talked about Fly-Away Rail Guides. Here are a couple of responses that I got back about that topic.

Paul Wolaver writes: *"Very cool, Tim... Think about taking this one step further, replacing launch lugs for model rockets that use launch rods. Where your design has the formed hooks that go inside the launch rail, extend this idea a bit further so that semi-circle hooks on the end of the music wire overlaps, and make a circle that will enclose the launch rod. Same principle, as soon as it leaves the rod, the rod will no longer hold together the loop/circle/hooks - and fly away.*

"I am going to start using rails/buttons because the 1/4" rods are always too busy, but these fly away rail guides might be a good "field expedient" supplement - just use them instead of the normal lug, when the rods are real busy. This would be for a sport rocket, where the drag of the permanently mounted, but unused launch lug would not be that big of a deal, and altitude isn't everything.

Thanks for the idea!!!"

Bill Colburn writes: *"Though I have never seen a fly-apart launch lug made of wire, the concept has been used for many years, back to launches in the 60's at Wallops. There is a picture of it at: www.rocketryonline.com/how-to/astrobee/ad_forwardlug.html. Good to get it out to the many though, thanks for that."*

I knew I couldn't have been the first person to think of this. In a way I'm glad someone else thought of it first, otherwise I would have doubts to the "smarts" of the rocket community. It is a relief to be proved that rocketeers are a bunch of smart dudes. I guess it "does take a rocket scientist."

Loading and then Storing A Reloadable Motor

Mark DiBois asks: *"How far in advance of a launch can you load reloadable motors? If I put the O rings in and lubricate them and seal them up, do they have a limited shelf life or what? Talking a few weeks not years or months."*

Great question. I asked Gary Rosenfield at Aerotech, and he said something that I didn't even consider. The answer he gave is that a few weeks is OK. The problem is not the O-ring. They will last a long long time.

The issue is that the O-ring must remain in contact with the surface of the propellant to provide a good seal. The problem is that the propellant is not as resilient as the O-ring. So while the propellant is rubbery and will seal well for a while, over time it will yield and dent. At that point, it can allow the hot gases to get around the O-ring. So a few weeks is probably fine, but you don't want to extend that to months.

TARC Questions and Answers

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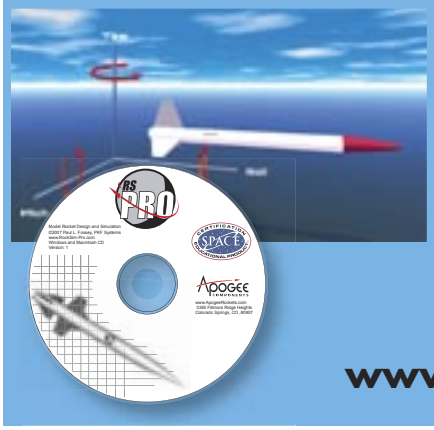
Sim Your Rockets With The Confidence of 6-Degrees-of-Freedom

RS-PRO is a 6-degree-of-freedom rocket simulator to find the behavior of high-performance rockets. It picks up where RockSim leaves off:



- Speeds up to Mach 10
- Altitudes up to 392.7 miles
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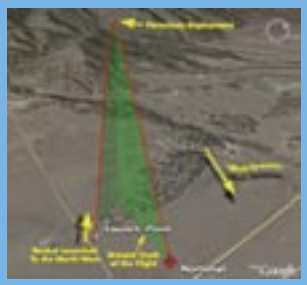

www.ApogeeRockets.com/RS-PRO.asp

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Reader Questions and Answers

William Mullooly wrote with several good questions concerning this year's TARC contest. He writes:

"I am mentoring a TARC team at Redlands High School, Redlands CA. I have a few questions that I have not been able to find in the Help menus, the Apogee Newsletters, or the RockSim manual.

1. When adding a streamer, what does RockSim use to calculate the recommended dimensions of the streamer? Specifically, how does it address the mass of the engine selected and does it subtract the propellant mass?"

Yes. It does subtract the mass of the propellant to find the descent weight of the model. This is not shown on the streamer design screen, like it is for the parachute design screen, but the end-result is the same. RockSim does remove the mass of the motor for descent rate calculations. You can confirm this by plotting out a mass versus time curve for a launch simulation.

"2. How does RockSim consider payload and booster drag during descent? One of the techniques to slow descent when using streamers (the required payload recovery device for TARC 2010) is to attach the streamer externally at the center of gravity of the booster so that it descends horizontally, thus increasing drag. Is there a way to simulate this descent orientation with RockSim?"

RockSim does not consider the rocket portion during descent. It just considers it as a point mass. So hanging it horizontal from the streamer does not affect RockSim's calculations. You will have to bump up the value of the streamer's coefficient of drag.

"3. Or conversly, is there a way to have separate drag coefficients--one for ascent, and a different one for descent that would simulate the increased drag of a horizontal booster descent?"

RockSim does separate the boost portion from the descent portion. It basically switches CD's and reference areas once the recovery device is deployed.

"4. One of the configurations we would like to model would be one which has separate recovery systems for the payload and booster for a single stage rocket. (i.e. have the [lighter] payload descend on its own using a streamer thus giving better control of the payload descent time. Is there a way to simulate this configuration in RockSim for a single stage rocket? Or, is there a way to simulate the configuration with a multi stage rocket with the payload taking the place of the upper stage. (no upper stage motor)?"

Yes. See TARC video 3 at: www.apogeerockets.com/RockSim_tutorials.asp