

*Feature Article:*

## ***Experiments with Dynamic Stability Analysis***

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## ***Rocketry Tips You Can Use***



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# PEAK OF FLIGHT

## Experimenting With Dynamic Flight Analysis

By Bernard Herman

I sat down to do some work on RockSim ([www.ApogeeRockets.com/rocksim.asp](http://www.ApogeeRockets.com/rocksim.asp)) on one of my designs. I wanted to make sure it was a really stable design to cope with the winds of Northeast Ohio where I live. RockSim showed my static stability at 1.8 calibers with the motor I had chosen, but I wanted to make sure it wouldn't be disturbed in flight by a gust of wind and end up in a tree somewhere. So I opened up my archives of this *Peak of Flight* newsletter and copied the issues containing Tim Van Milligan's series on the Basics of Dynamic Flight Analysis in issues 192, 193, and 195 thru 198 (download them at: [www.ApogeeRockets.com/education/newsletter\\_archive.asp](http://www.ApogeeRockets.com/education/newsletter_archive.asp)). The articles cover a lot of information, but they are arranged and written in a way that make it easy to understand the rocket science, and with RockSim it's easy to get the data.

I wanted to share some of the tricks I learned for getting the data, something I learned you should be careful with, and the versatility of the RockSim program. Also I wanted to share some information regarding rocket design- ing I picked up.

Going through the steps to optimize the rocket in Part 6 of the series (written in issue 198), I came to the step on natural frequency optimization. I looked at Part 4 on Natural Frequency in issue 196. Tim had written to plot out a graph of the Velocity in meters/ second and the Nat. Freq. at Zero Roll Rate (rad/s), and to pick out one point on the line to read off the values. I was hoping to be a little more precise in my numbers, so I looked for a way to get the actual numbers RockSim uses to create the graph. This isn't hard; all I had to do was export the data from the graph to a spreadsheet program like Excel, and open the file and the numbers are all there. Picking two sets of data, I divided to come up with a value and a check. There was a minor variation in the hundredths place, so I set up the excel spreadsheet to compute each set of data and then give an average of all the products.

I found my rocket had a value of 1.08V, which was over the higher end of the range given in the article. This meant my rocket design was more susceptible to winds, which is exactly what I didn't want. I never would have known this if

it wasn't for these articles and RockSim. The article stated that I needed to adjust the Longitudinal Moment of Inertia or the Corrective Moment. I went back to Part 1 on Longitudinal Moment of Inertia in Issue 192. This is where things really got fun and interesting.

I was reading about the experiments that Tim had done on the Estes Alpha with stretching one to change the Longitudinal Moment of Inertia. I noted with interest that by stretching the Alpha, not only did you increase the moment, you decreased the altitude by 6.7% using the numbers Tim had come up with. Tim had mentioned that this was caused by the increased drag caused by the stretched rocket staying at an angle of attack for a longer period of time. I wondered, could the stretching have caused an increase in the coefficient of drag on that model thereby decreasing the altitude? And if so, just how much difference in altitude did increasing the Longitudinal Moment of Inertia really create? This was a job for RockSim!

In the article, it mentioned that not only could the Longitudinal Moment of Inertia be increased by lengthening the body tube, but also by moving mass away from the center of gravity. I had a way of answering my question. Tim had made each of his rockets equal in mass by reducing the mass in the nose cone of the stretched version by

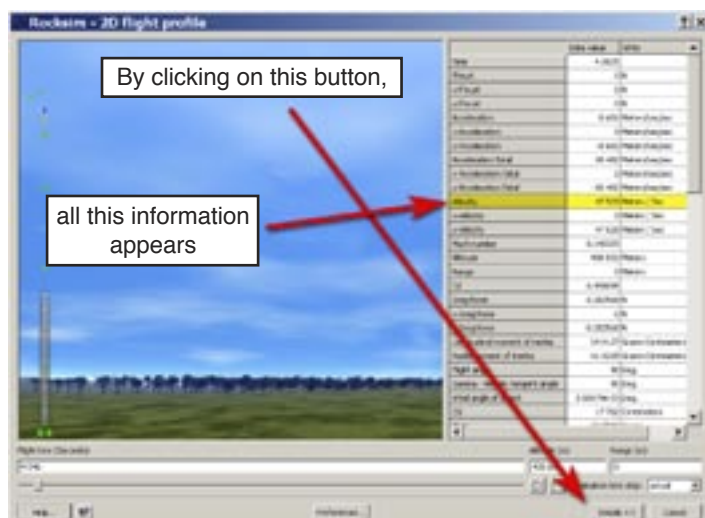


Figure 1: 2D flight profile screen with details

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## Experimenting with Dynamic Analysis

the amount of weight the extra body tube had created. I decided to create three copies of the Alpha file. The first would have the body tube stretched so that it was 5 cm longer than the original. The second would be the original design with a mass object added weighing the difference between the original and the stretched version and with the mass object located forward enough to create a Longitudinal Moment of Inertia equal to that of the stretched version. The third would be the original design with the same mass object as design 2, but having it located at the center of gravity. This design would be the control rocket.

The mass object ended up weighing 1.524 grams. Through trial and error I tried to get the correct placement for the mass object. This was a bit time consuming since I had to plot the graph, then export the data, then open the file and read the data. . I found an easier way though. Select the flight that has the data you need in it and open the 2-D Flight Profile. On the screen of the Flight Profile is a button in the lower right hand corner marked "Details". Click

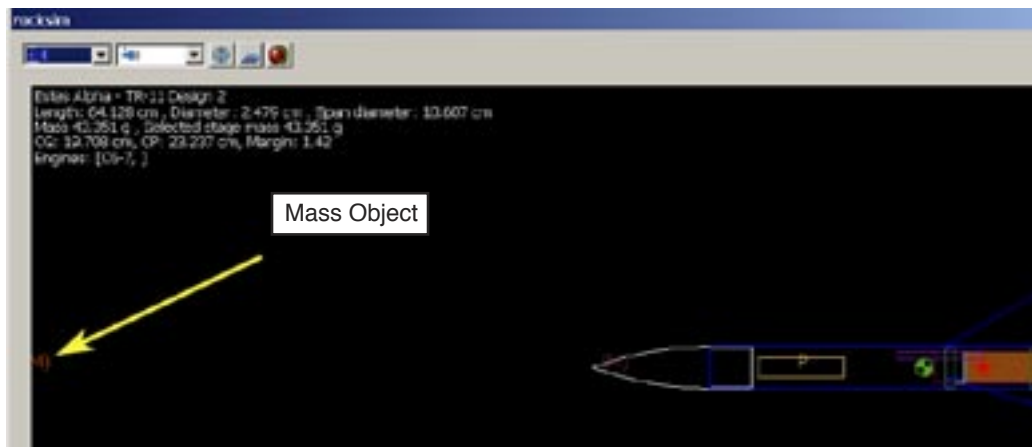
on that button and the right half of the Flight Profile Screen becomes filled with all the data on the flight. The data changes as the flight is running, so just stop the simulation at an appropriate time and read the data you need (see Figure 1). This speeded things up considerably. With the Longitudinal Moment of Inertia remaining constant after the burnout of the motor, I could stop the flight profile anytime after burnout and just read the data right on the screen.

Eventually, I ended up with a point about 34 cm ahead of the nosecone where the moment for design 2 equaled the moment for design 1 (see Figure 2). I started running my simulations.

Something weird came up on the first set of simulations I ran with no wind. The control rocket (design 3) did fly higher than the stretched version (design 1), but the forward placed mass rocket (design 2) flew higher than both. I was confused and wondered what was happening? Design 2 and design 3 having everything else equal except their longitudinal moments should have flown to the same altitude in a no wind scenario. I started hearing an old boss's statement in my head. "Don't always accept it as

fact just because a computer told you, use your brain and think." So I fully engaged my brain.

I didn't have far to search for the answer. After checking the 2D Flight Profile to see if there were any major differences in the flights, I concluded that the only way for design 2 to go higher would be for the coefficient of drag ( $C_d$ ) for that rocket to be lower. Using the  $C_d$  Analysis in the Rocket pull down menu, I



**Figure 2: Rocket Design showing mass object out front. This was added to attain equal Moment-of-Inertia as in Design 1.**

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## Experimenting with Dynamic Analysis

quickly confirmed that the  $C_d$  for design 2 was lower than design 3 (see Figure 3). But why?

$C_d$ @ 100m/s	Predicted $C_d$	Nose & Body $C_d$	Base $C_d$	Fins $C_d$
Design 1	0.445	0.1931	0.06599	0.1637
Design 2	0.404	0.1416	0.07707	0.1637
Design 3	0.423	0.1669	0.07099	0.1637

**Table 1:  $C_d$  analysis of designs**

The  $C_d$  for both design 2 and design 3 should have been the same (see Table 1). They weren't though. For some reason the  $C_d$  in design 2 was less than that of design 3. With the only difference between the two designs being the placement of the mass object itself, I began to play with it. This is when I found something you have to be careful with in RockSim.

Apparently if you move a mass object within other objects (a body tube or a nose cone), even if it's not the owning part, there is no problem. But if you move it outside of the parts like I did to theoretically adjust a parameter, it creates an object outside of the rocket that can influence your  $C_d$ . The mass object that I had moved forward and outside the design body of the rocket was creating a slipstream for my rocket, I assume, and therefore lowering its  $C_d$ .

My next thought was to use the  $C_d$  override tab and preset each  $C_d$  to the appropriate value. This has a problem with it.  $C_d$  is not a static number, meaning it changes with the velocity of the rocket. By overriding the number, RockSim would no longer be computing

what it should be at each point in the flight and therefore I would not be getting the data in a way I could use.

To keep the mass object within the body of the design, I revamped all the designs. The first thing I did was to add a five-gram mass object to each design. In design one, I made the body tube longer again, but this time by only one centimeter. I also subtracted the additional weight from the 5 gram mass object and located it at the center of gravity. In design two, I moved the 5-gram mass object forward until the moment of inertia again equaled that of design one. This time with the larger weight, it was about 2.5 cm inside the nose cone. And in design 3, I just placed the five-gram mass object at the center of gravity.

My results surprised me. The rocket with the larger longitudinal moment of inertia and shorter body tube (design 2) did fly higher than the other two in the wind. It wasn't by much, compared to the control (design 3). Less than a quarter meter in a flight of over three hundred meters (see Table 2).

## Conclusions and Observations

From the data obtained in this experiment, we can

	Design 1	Design 2	Design 3
Static Stability	3.48	3.71	3.33
L. Moment of Inertia	17495.19 g-cm <sup>2</sup>	17495.19 g-cm <sup>2</sup>	6896.05 g-cm <sup>2</sup>
Alt. no wind	402.13m	404.03m	404.03m
Max. vel. No wind	108.37 m/s	108.53 m/s	108.53 m/s
Alt. w/ 32kph wind	339.45m	340.70m	340.53m
Max. vel. w/ wind	107.8130 m/s	107.9730 m/s	107.9650 m/s
Range	210.68m	213.01m	213.31m

**Table 2: Results for RockSim Experiment. Flights used Estes C6-7 motors.**

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## Experimenting with Dynamic Analysis

conclude that it is not the increased longitudinal moment of inertia causing the loss in altitude; it is the additional drag of the stretched body tube. On the contrary, increasing the longitudinal moment of inertia without stretching the body

believe this is a result of saved energy from less oscillation of the design 2 rocket. Indeed upon examination of the wind angle of attack data, design 2 has its last noticeable oscillation in the data at 2.450 seconds into the flight. Design 3 is, almost a tenth of a second later at 2.545 seconds

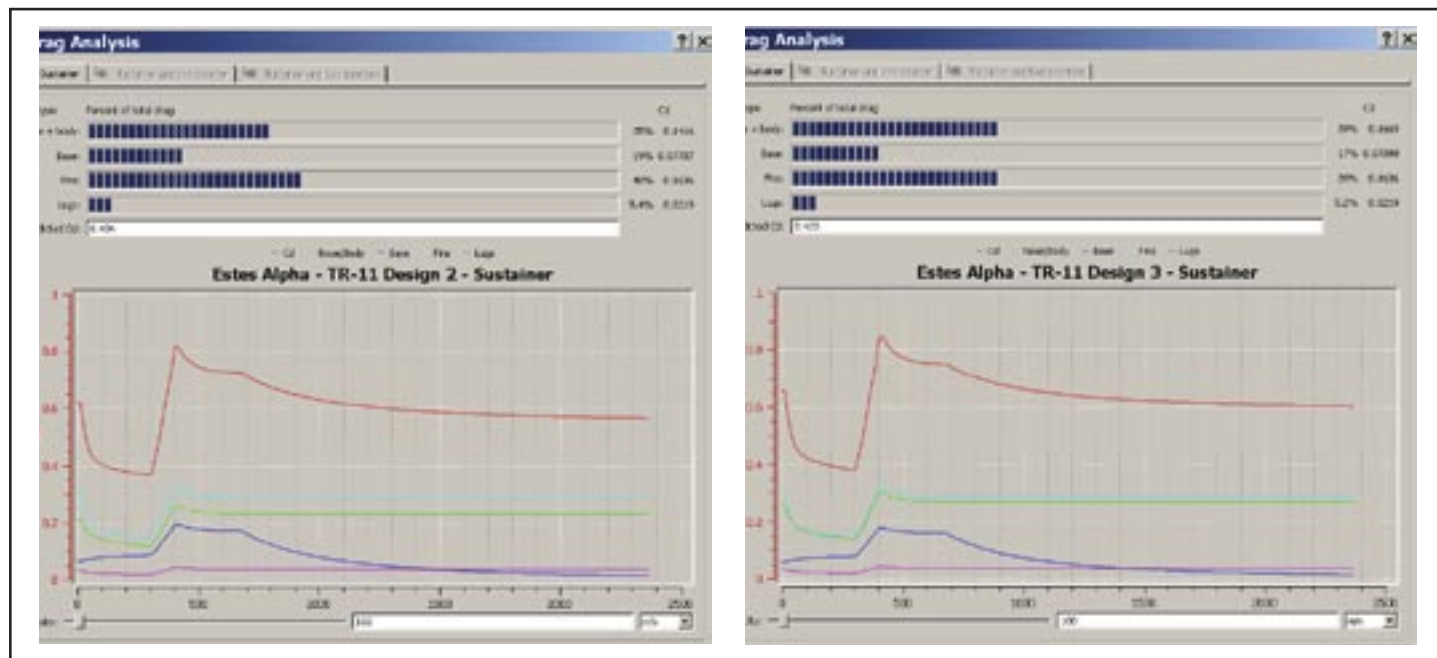


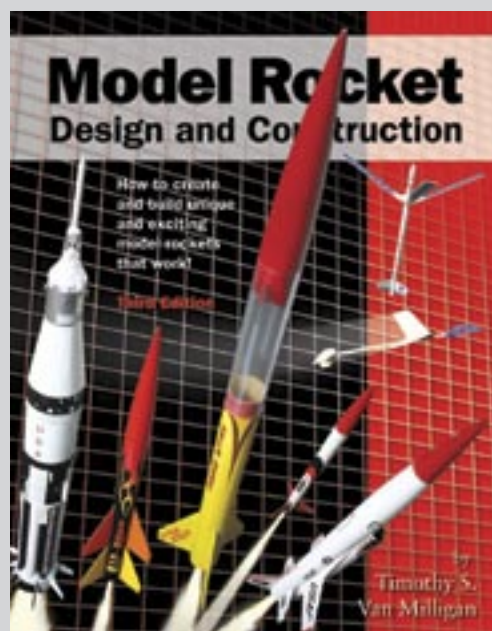
Figure 3: Showing the Cd of Design 2 and Design 3 at 100 m/s.

tube seems to create a small increase in altitude on flights where there is some wind. If you note the maximum velocities of design 2 and 3, you will see an 8mm difference. I

into the flight.

I do have to mention that this experiment was limited to

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## Model Rocket Design and Construction

By Timothy S. Van Milligan

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# PEAK OF FLIGHT

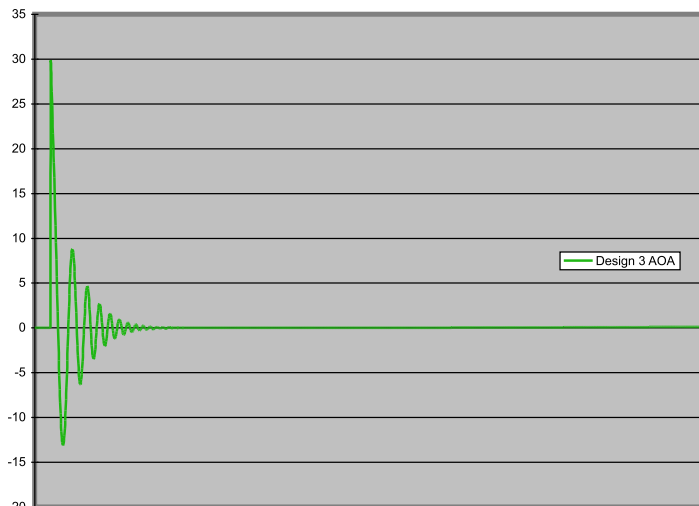
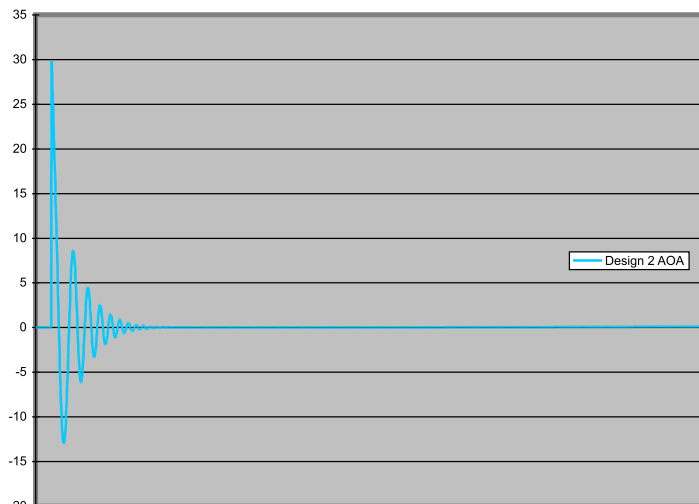
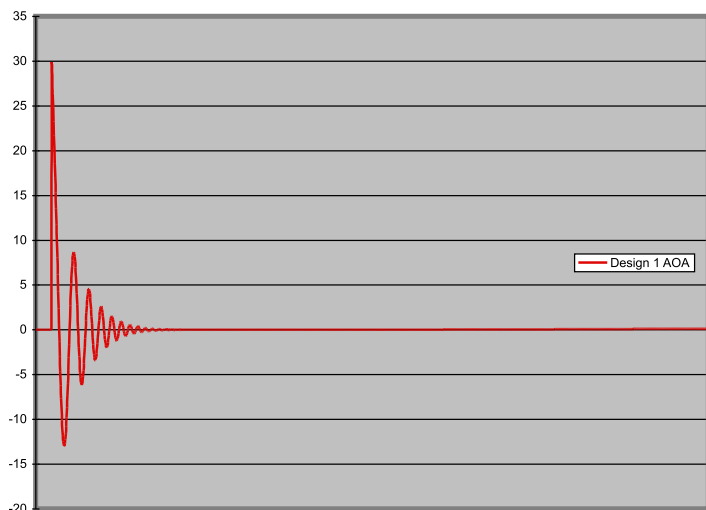
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## Experimenting with Dynamic Analysis

just determining if the drag on the rocket was the cause of lost altitude and was done using an extreme wind (32kph which is approximately 20mph, the highest wind the rocket code allows us to launch in). I would assume that at lower wind speeds the difference in altitudes would be less, but I did not test to find the degree of the changes.

It is interesting to note that such a small length increase (1cm) in the body tube was equal to a mass of 5 grams being moved about 12.5 cm. For someone needing the extra stability and not as concerned about the altitude reached,

**Figure 4: Oscillation data created by RockSim for the three different rocket designs.**



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## Experimenting with Dynamic Analysis

increasing the rocket's length looks to be the best choice. On the other hand, if we are looking for extra altitude, especially with a payload (egg lofting?), it might be more advantageous to move mass to the extents (farthest ends) of the rocket to peek out just a bit more. Of course this is only relevant if there is a wind during the launch, but how many times have you ever launched when it has been perfectly calm? Always check to make sure that the rocket's stability is not too negatively affected by any changes, especially when moving mass towards the rear of the rocket.

With this one experiment I only looked at one small part of the much larger area of dynamic stability. If I could learn so much from such a little experiment using the RockSim program, I wonder how much more there is to learn, such as, at what point does increasing the weight of the mass object in design 2 stop increasing the altitude gained on a windy day? In other words, is there an optimum mass for flights on windy days? Is there an optimum location? I think with the help of the RockSim program we can explore more of these questions and further our knowledge of rocketry.

### About the Author:

Bernard Herman is a land surveyor in the state of Ohio who has been building model rockets since the early 1970's. He has written two previous articles (Newsletters [#164](#) and [#230](#)) concerning the accuracy of altitude measurements using tracking instruments. He is considering going to college to pursue an aerospace engineering and/or

teaching degree.

He has been married for over twenty years and is the father of five children, two of which are in college. Although none of the children share his extreme passion for model rocketry, they have always enjoyed launching rockets with him.

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## Rocket Tips That You Can Use

By Tim Van Milligan

Flying rockets in cold weather requires a bit more preparation than does flying during the summer months. Plastic parachutes are one area of concern as they can get stiff and take a set when folded. That means that when it is ejected out of the rocket, the parachute doesn't want to pop open quickly. Even though the plastic doesn't melt and fuse together, the chute can often come down in that "plastic-wad-recovery" configuration.

One way to encourage the parachute to open properly is to dust it with talcum powder before you fold it. The traditional method is to lay the parachute flat on a table, and squeeze some powder out of the container onto the plastic and then start spreading it around with your fingers. You'll often squeeze out too much and then have to dump the remainder.

One way to limit the amount of powder is to use an old sock as a dispenser. You can pour your powder into the sock, and then tie off the end so the powder doesn't dump out. To apply the powder to the plastic parachute, you just gently tamp the powder bag against the plastic chute and use the bag to spread it around. It puts just enough powder on the chute without wasting any, and it is much easier to spread it around on the canopy.



**Figure 1:** A powder bag allows you to dispense the correct amount of powder without making a big mess.

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## Rocket Tips That You Can Use

When you are done dusting the chute, you can store your powder bag in a plastic ziplock baggie, and put that in your range box.

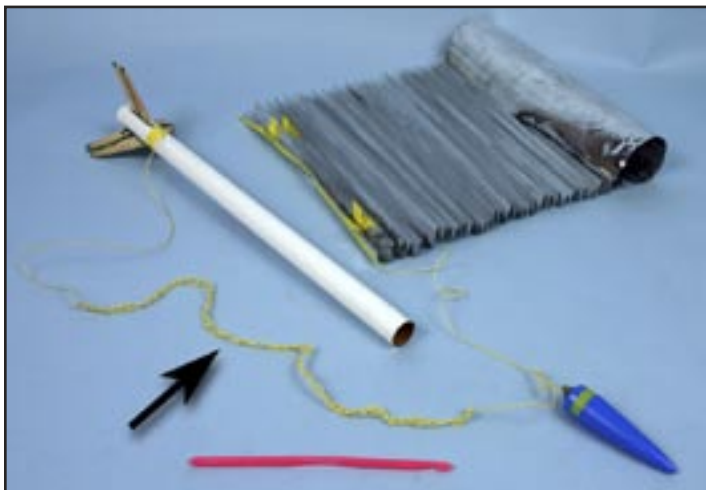
And don't forget, you do need to powder both sides of the plastic parachute before you fold it in your rocket. For my fool-proof folding technique, see Peak-of-Flight Newsletter #199 ([www.ApogeeRockets.com/education/downloads/newsletter199.pdf](http://www.ApogeeRockets.com/education/downloads/newsletter199.pdf)).

## Preventing Shock Cord Tangles

I often get emails from people that ask me how long to make a shock cord. You can find out that information in the book *Model Rocket Design and Construction* ([www.ApogeeRockets.com/design\\_book.asp](http://www.ApogeeRockets.com/design_book.asp)). You start with that minimum length, but longer is better.

The only problem with a long Kevlar® shock cord ([www.ApogeeRockets.com/shock\\_cord.asp](http://www.ApogeeRockets.com/shock_cord.asp)) is that it becomes tiresome to stuff the long cord into the body tube of the rocket. You can wind it around a dowel and slide it into the tube, which works well about 80% of the time. But all too often, the cord can become tangled. When this happens, it shortens the effective length of the cord. Then bad things happen, like zippering the tube, or snapping the loop off the back end of the nose cone. I speak from experience; been there, done that, repeated it again...

One solution that I found that seems to work is to crochet the cord before stuffing it into the tube. Yes, you read that right. I mean to crochet the cord, like my mother does when she makes a blanket from yarn. The only special tool it requires is a hooked needle that you can get from a craft store that sells yarn.



**Figure 2: A long shock cord that has been crocheted and ready to insert in the tube.**



**Figure 3: Close-up of the crochet loops in the shock-cord. Arrow points to the end closest to the nose.**

Doing this shortens the length of cord that you have to insert in the tube, making it less prone to tangle. And it is easier to insert into the rocket because the cord seems thicker and easier to shove into the tube with your fingers.

The cool thing about it is that the crochet loops pull apart without any effort. So when the nose cone pops off, it extends to the full length without much resistance. What little resistance there is is actually a good thing too.

Look for a future video on the Apogee web site that shows the proper technique. It will be found at: [www.ApogeeRockets.com/Rocketry\\_Video\\_tips.asp](http://www.ApogeeRockets.com/Rocketry_Video_tips.asp).

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