ISSUE 97 - JAN. 31, 2003

APOGEE

PEAK OF FLIGHT

NEWSLETTER

How To Design Tumble Recovery Booster Stages - Part 2

Motor Retention Techniques For Minimum Diameter Rockets - Part 3

Quest Gamma-Ray ii Now Available From Apogee Components
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Answers To Your Team America Design Questions: What Size and Arrangement of Fins?

A reader writes:

Every multi-stage kit I've seen has larger fins on the booster. Besides stability concerns (keeping CP/CG relationship proper) is there another reason for this?

Response: That is the right reason. Always keep the CP/CG relationship correct.

A Team America team asks me this about their rocket they've designed on Rocksim and for simplicity sake they want to make the booster and sustainer fins identical in size. With a static stability margin of between 7 and 10 calibers would there be any other reason why not to recommend that it's alright? (their rocket is 2.1" by between 5.2' and 6', they're still not final on electronics bay length and depending on motor weights)

Response: These particular models are going to be very -- very nose heavy...

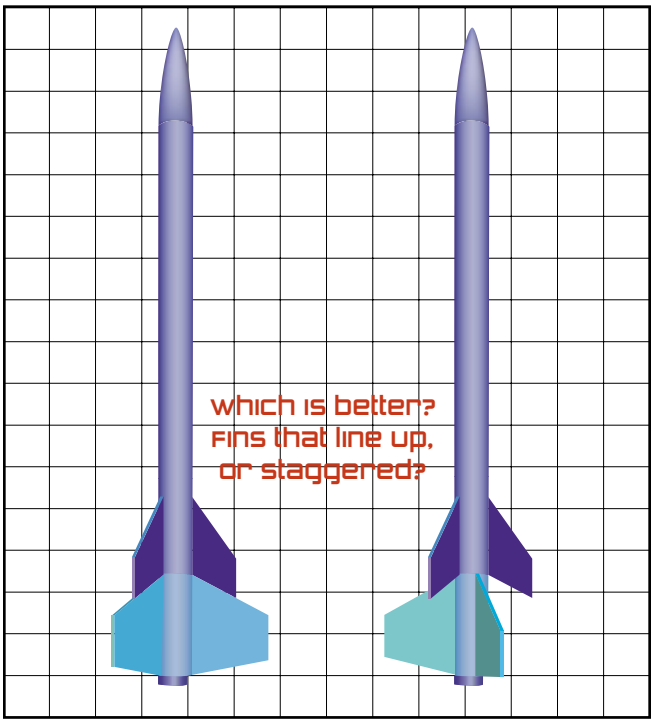
The CG is going to be extremely far forward, so the students are going to think that they can decrease the fin size to reduce the static margin. I don't think this is a good idea, as the rockets are going to take off really slow. That is going to mean a lot of non-vertical flights.

If you have the AeroCFD software, you can double check the CP location at low flight speeds. That really is the only way to find out how small you can make the fins.

If they do reduce the fin size, make sure they use a longer launch rod. You can also cant the fins to make the model spin: see e-zine # 90 (http://www.ApogeeRockets.com/education/downloads/newsletter90.pdf)

These flights really need to go vertical to increase the chances of winning. If they start arcing, you're going to deploy below the 1500 feet.

Stine's book recommends for dynamic stability sake on multistaged models to "interdigitate" booster & sustainer fins. i.e. for a 3 fin/stage design, looking end view you'ld see six fins. Reasons given seem logical - avoid downwash area of preceeding fins, 6 fins verses 3 acting to keep zero angle of attack, etc. But in my limited experience I've only seen kits picturing in-line booster/sustainer fin arrangements. What's your take on this?

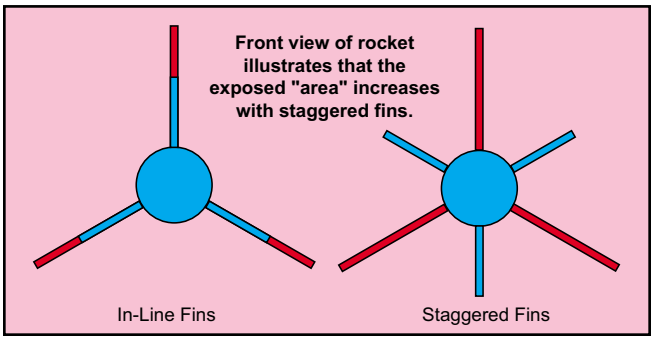


Response: It depends on how big the fins are.

My opinion (this is just an opinion) is that the fins are nearly always in turbulent air. That reduces their effectiveness. So staggering the booster fins is a good idea. (I agree with G. Harry Stine).

But if the fins have a large span, they may stick out into clean laminar flow air. In that case, you can align the booster fins with the upper stage fins to reduce the overall drag of the rocket. The drag is reduced, because the frontal area of the rocket is reduced, as shown in the illustration below.

So... Both methods are acceptible for use.



How To Design Tumbling Booster Stages

Part 2

By Tim Van Milligan

In the e-zine #96, (http://www.apogeerockets.com/education/downloads/newsletter96.pdf) we started a discussion about how to design tumbling booster stages. If you recall, we started the discussion about how to get the stage to tumble. Basically, it is much like designing any model rocket; where you manipulate the positions of the Center-of-Gravity (CG) and the Center-of-Pressure (CP).

Where we left off in the e-zine #96 is with the question: "Will the booster stage fall slow enough?" Basically, the answer to this question will help us determine how big we can make tumbling booster stages.

Finding the answer to this question is going to be tougher than finding whether or not the booster will tumble. We'll have to pull out all our available design tools, including some geometry, math, RockSim, and AeroCFD.

The Terminal Velocity Equation

The final descent speed of any falling object can be found from the "terminal velocity equation." We use this all the time to find the speed of a falling parachute. We'll go ahead and derive it, just so that you know how for future reference.

When a falling rocket reaches a final descent speed, the rocket is no longer accelerating. That means that the forces trying to accelerate the rocket downward are equal to the forces retarding its descent. In other words, the gravity force is balanced by the drag force:

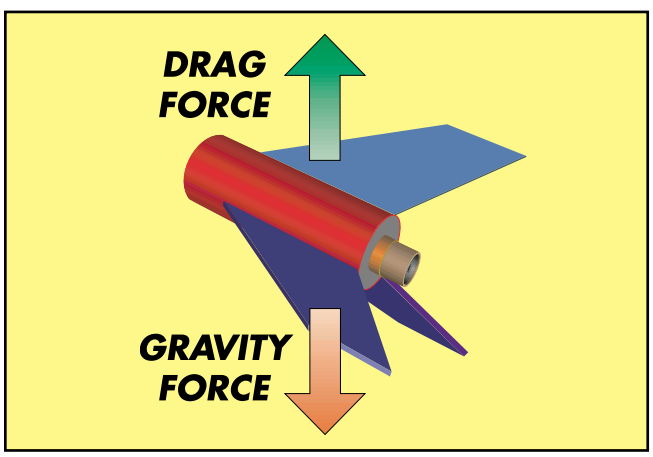


Figure 1: To find the falling velocity of a booster stage, we first start with a balanced vector diagram.

$F_{(down)} = F_{(up)}$

$F_{(gravity)} = F_{(drag)}$

$F_{(gravity)}$ = mass X acceleration due to gravity

$F_{(gravity)} = m\,g$ Equation #1

Where m is the mass of the falling rocket, measured in grams, and g is the acceleration due to gravity, which has a sea level value of 9.81 m/s^2.

$F_{(drag)} = 1/2\ \rho\ V^2\ S\ C_d$ Equation #2

Where ρ is the density of air (1225 g/m^3 at sea level), V is the velocity of the falling velocity of the rocket in m/s, S is the reference area (see figure 2), and finally, C_d is the drag coefficient.

Since the rocket is not accelerating, we'll set Equation #1 equal to Equation #2. Then, we'll solve for the velocity.

$$V = \sqrt{\frac{2 \times g \times m}{\rho \times C_d \times S}} \qquad \text{Equation \#3}$$

While we know the mass, and we can measure the reference area, we don't know the C_d of the tumbling rocket. Without that, we can't determine the velocity of the falling rocket.

But before we talk about the Cd, first let's find the mass and the reference area of the booster stage.

The mass is the easiest part to find. Since you're using RockSim to design your booster stage (see Part #1 of this article in e-zine Issue #96), you can quickly find the descent mass of the rocket.

In Rocksim, run your simulation as described in Part #1, and select 2-D Flight Profile from the simulation menu. Then click the Flight Profile Details button. Finally, scroll down on the list to find the final mass of the rocket. To get the units in grams, you simple go to the to the application settings and switch the mass to display in grams.

The reference area and the C_d go hand-in-hand. This means, that if you use one reference area, you'll use a specific C^d value. If you change and use a different reference area, the C_d value will be completely different too. In rocketry, we typically use the area at the base of the nose cone as the reference

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Tumbling Booster Stages

(Continued from page 3)

area. But this doesn't seem to make much sense for tumbling boosters, because the side area of the fin is going to cause the most drag. So for the reference area, we're going to use the lateral area, as shown in figure 2. We want to know the side area.

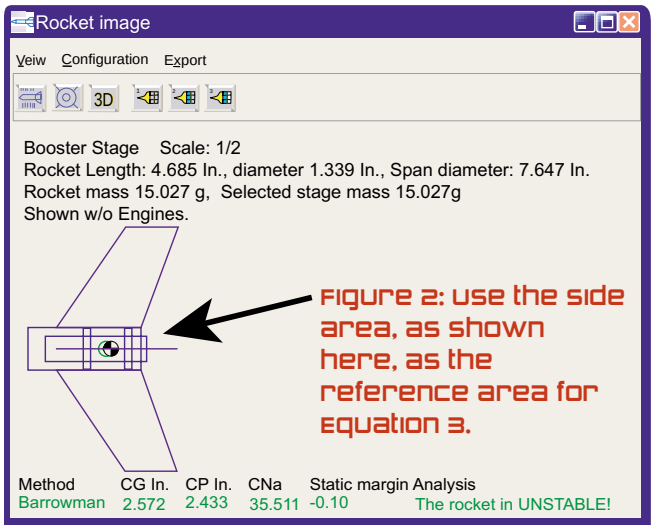

Figure 2: Use the side area, as shown here, as the reference area for equation 3.

This is where you have to do a little bit of geometry to figure out the actual area. It isn't hard, but it is a little bit tedious. The drawing below shows how you would go about finding the side area of the rocket. Basically, you break it up into sections. You don't have to be exact at this point, but try to be reasonably close. Also, make sure that after you're done, you convert the area to m^2 so that the equation #3 will work.

What C_d value do we use?

We now come to the difficult part—finding the C_d of the tumbling booster. This is difficult, because the rotating booster is constantly changing its orientation to the airflow as it falls. This is imporatant, because it is the orientation that determines the C_d; and also the reference area. For example, if the front end of the tube is pointed downward, the stage will have a lower drag than if the side of the stage is parallel to the ground.

The C_d is constantly changing as the booster stage tumbles to the ground. It would be easy to determine the final descent velocity if the C_d stayed the same, but it is never a static number. The best we can hope for is an average value.

It is because the C_d is constantly changing that I don't worry about getting an exact value for the reference area (see the illustration below). An approximate area is going to be good enough for your calculations.

So which C_d should be used?

I was able to have a friend into performing a simple experiment for me. Basically, he took a booster stage from an Estes CCExpress rocket, and dropped it from a known height. He simply timed the fall using a stopwatch. From that, we found that the booster fell at an average speed of 5.108 m/s.

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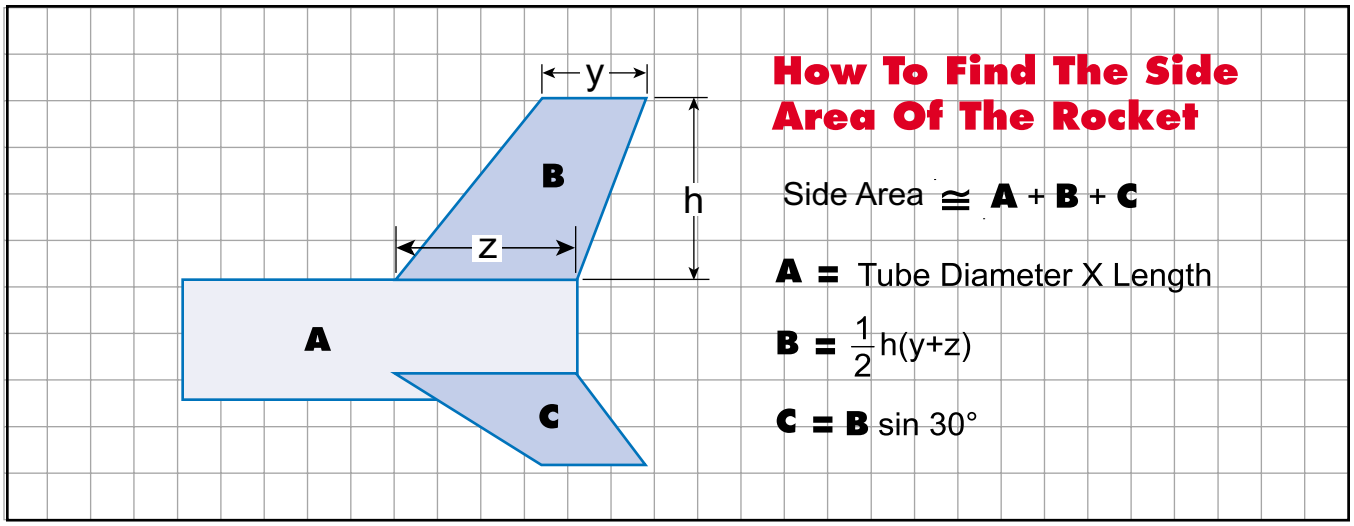
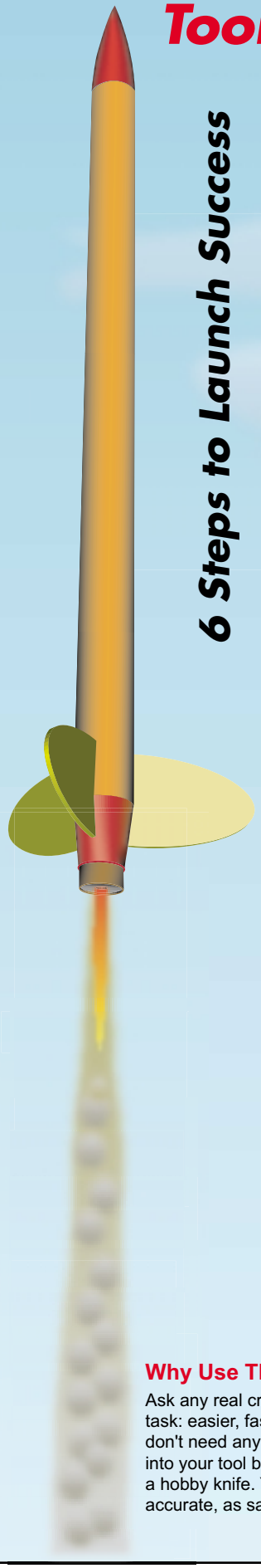


Archives of this Newsletter
All the articles that have appeared in this newsletter are archived at
http://www.apogeerockets.com/education/newsletter_archive.asp

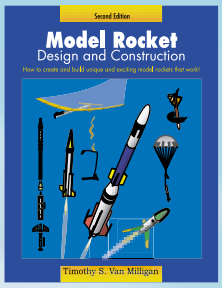
Tools to Turn Dreams Into Reality!



6 Steps to Launch Success

Step 1: Dream

It all starts with an idea. Somewhere in your mind, an dream is brewing, ready to jump from your subconscious mind to your frontal lobe. You can force it to the forefront by seeing how other people have solved similar design challenges. That is where the book Model Rocket Design & Construction comes in. Within its pages, you'll find hundreds of unique ideas for new rockets; and how to make them succeed in the physical world.



Step 2: Design

Sketch out your dream rocket on a piece of paper. Then, flush out the details by using the RockSim design software.

Step 3: Refine

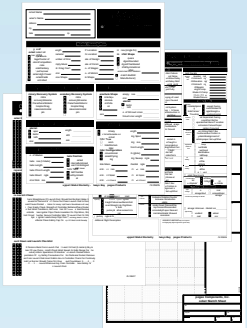
Start running launch simulations in RockSim. Find the best motor combination that yeilds a safe and satisfying lift-off. Now start tweaking the design by testing the configuration in AeroCFD, HyperCFD, and FinSim. These programs will help you gain confidence in your design by telling you more details about the flight qualities of the rocket, and if the design is structurally sound.

Step 4: Build

Gather up your building materials and construction supplies. Now is the time to physically assemble your dream machine. Do you need supplies? Be sure to visit the Apogee Components' web site for parts, tools, and motors. Also watch the video book: Building Skill Level 1 Model Rockets. It will show you the proper techniques for making your rocket quickly and strong

Step 5: Test Fly

Test flights are an important part of any new rocket design. Basically, you need to collect data about the flying characteristics of your rocket. The Apogee Data Sheet Collection helps you record the physical qualities of the launch, and helps you track down those problems that may have caused the rocket to go astray.



Step 6: Receive Applause

You did it! Your new rocket is ready to be presented to the world. Get ready to receive the applause that you deserve for the worthy spacecraft you've created.

Why Use These Tools?

Ask any real craftsman, and he'll tell you that having the right tools makes any task: easier, faster, safer, more accurate, and more enjoyable. To be honest, you don't need any of these tools to design and build rockets. To prove my point, go into your tool box and throw out all your tools except a bottle of glue, a ruler, and a hobby knife. You can still build rockets, but would it be as fun, as fast, as accurate, as safe, or as enjoyable? *Get the right tools... it makes a lot of sense.*

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Tumbling Booster Stages

(Continued from page 4)

Once you know the average speed, you can rearrange the terminal velocity equation to solve for the C_d:

$$C_d = \frac{2 \times g \times m}{\rho \times V^2 \times S} \qquad \text{Equation \#4}$$

Solving this equation using the known values, it was found that this particular booster stage had C_d value of 1.41.

This value gives us a starting point for new booster stage designs, and we can plug it into equation #3.

The next question we need to ask it what range of descent speeds should we design the stage. As a starting point try for 12 to 19 ft/s (3.6 to 5.7 m/s). The lower the number, the slower the booster stage will descent.

Refining the Design for Bigger Engines

Once we know the descent speed, we can refine the design. This is where we'll find out how big we can make the booster stage—particularly if we want to use larger and more powerful rocket engines.

For example, say we have completed a preliminary design, and we have a descent speed of 5.1. Can we upscale it for bigger rockets? Obviously, we'd like it to use tumble recovery to keep things simple. There are two things we need to consider.

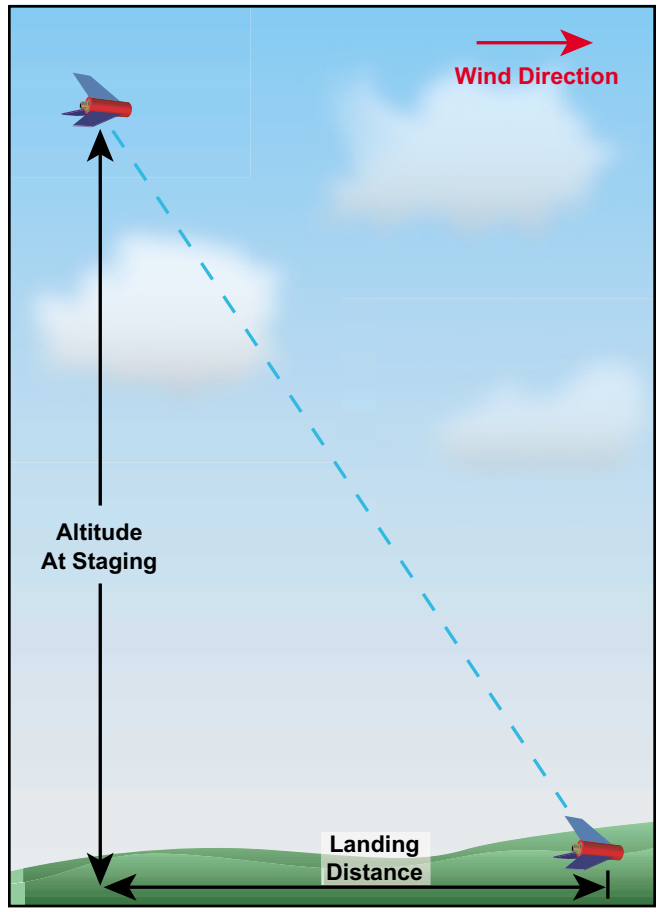
First, even if the rocket falls slow, you may not want to fly it because it is too heavy. For example, if a 50 Kg weight was dropped from 1 meter high, I still wouldn't want it landing on my foot. It is just too heavy.

How heavy can you make the booster? I guess it comes down to how much weight you'd feel comfortable with. A rule of thumb you can use is: how much weight could you tolerate if it landed on your head? Personally, anything over 1 pound, (453 grams) and I'd start to consider putting an alternative recovery device on the booster. A streamer or parachute is fairly easy to attach. You can get some ideas in the book: "Model Rocket Design & Construction."
http://www.apogeerockets.com/design_book.asp

The second thing to consider in how big can you make the booster stage is landing damage. The bigger the fins (which you'd need to slow down a heavy booster stage) the more susceptible they are to cracking off when the stage touches down. To make the fins stronger, we usually end up adding more weight, which makes the problem worse.

Where Will the Booster Stage Land?

Determining where the booster stage will land is fairly easy to figure out. At this point, you should know the descent velocity of the stage; and from RockSim, you can get the altitude where the booster stage drops off the rocket. From this, you simply divide the altitude by the descent rate (remember to watch your units). This will give you the time in seconds that it takes the stage to fall to the ground.



Finally, the approximate distance away the stage will land is simply found by multiplying the wind speed to the time it takes to fall. It's that simple.

About the Author

Tim Van Milligan is the owner of Apogee Components (http://www.apogeerockets.com) and the new 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 this e-zine at the Apogee Components web site, or sending any message to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject of the message.

Motor Retention for Minimum Diameter Rockets - Addendum

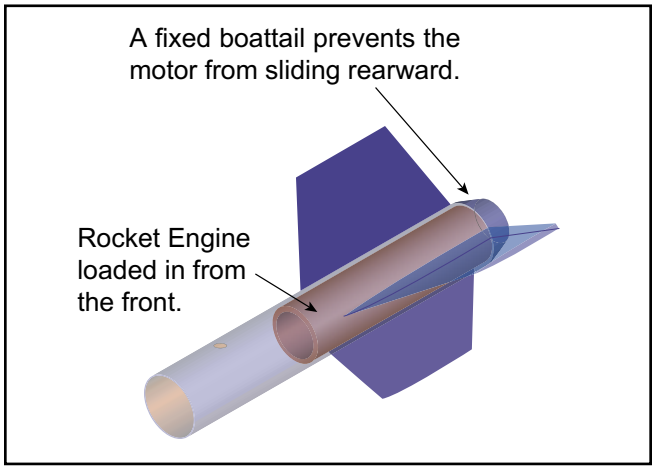
(Continued from Newsletter #96)

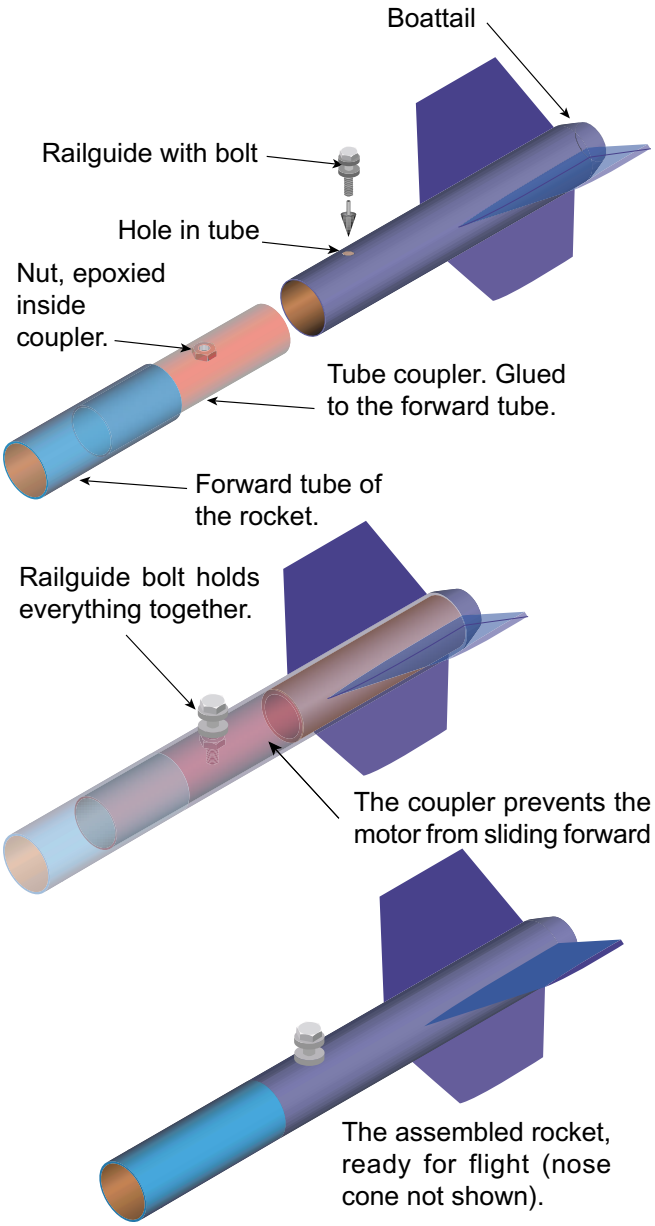
By Tim Van Milligan

In e-zine issue #95, http://www.apogeerockets.com/education/downloads/newsletter95.pdf we started a discussion about how to restrain motors in minimum diameter rockets. Since then, readers have been writing in to me suggesting other alternatives. Last issue, we showed one from Norm Diedzic, and in this issue, I got a new method from Germany's Oliver Amend. He writes:

"Reading your newsletter I came up with another idea for a min. diam. engine mount, which does not alter the surface of the rocket.

You have a regular rear section of body tube. This extends forward of the fins or the engine, whichever lies more forward, at least so that one can mount a rail guide and have a good coupler joint. A boat-tail is glued into the end of the rocket, which will keep the engine from falling out or being ejected (and improved aerodynamics ;-).



The forward section of the body tube includes a coupler that extends back to the engine. On different lengths of engines in the 29 mm area or greater, one could use adapter tubes. This coupler has a small hole that coincides with a hole in the rear body tube, which in turn is in the place where the forward rail guide is supposed to be.

On the inside of the coupler tube, a nut is glued where the hole is. Now one can use a screw to tighten the rail guide to the body and join the forward and rear sections. The screw "only" has to hold the inertial and drag forces acting on the rear section, thrust is directly taken over by the coupler. For high power models, which have heavy rear sections, one could use more than one screw, where all but the rail guide screws are countersunk into the outer body tube and distributed evenly around the circumference. The only problem is the thrust rings on RMS engines."