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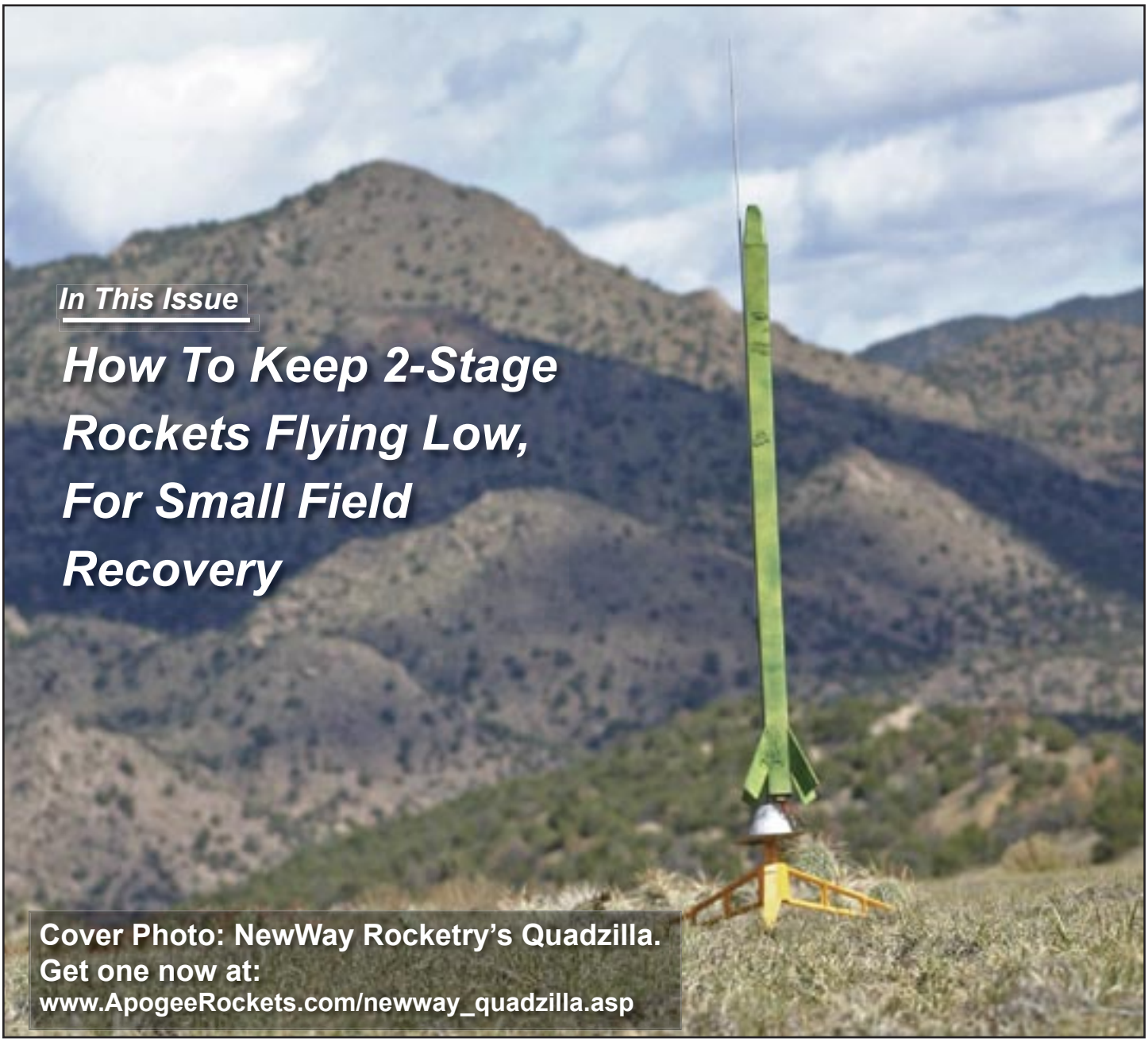
NEWSLETTER



In This Issue

How To Keep 2-Stage Rockets Flying Low, For Small Field Recovery

Cover Photo: NewWay Rocketry's Quadzilla. Get one now at: www.ApogeeRockets.com/newway_quadzilla.asp

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How To Keep 2-Stage Rockets Flying Low

By Tim Van Milligan

Mike Freidberg wrote to me a while back with this question: *"I've been building rockets kits since I was a boy; I'm now building them with my own sons. One of the rockets I would love to experiment with is a multi-stage rocket. But I live on the densely wooded East Coast, and I have lost enough single-stage rockets in the trees around the high school playing field that I don't want to risk building one that goes even higher. Thanks for any suggestions you have."*

For starters, I feel your pain. I've been flying model rockets since I was in the 6th grade, and I've probably lost more rockets than most people have even built. And I know there are a lot of readers that are teachers and are flying off of small athletic fields too. This is a common problem that many people face.

Two-stage rockets are awesome. I understand why you want to experiment more with them. Because they carry two motors, they are a bit heavier at lift-off from the pad and they seem to take off slower. But when the booster stage drops away and the upper stage ignites, you definitely see a speed change in the rocket. Right before staging, the rocket is going pretty fast; but then it seems to kick into warp speed when the top stage ignites. I understand the excitement this kind of flight creates. You ain't seen "FAST" until you've witnessed a two-stage flight!

But there is a downside to this, if you fly from a field like the one Mike describes. The model goes so high that even a little bit of wind is going to cause it to drift for long distances. And that greatly increases the likelihood that the model will get lost.

Now it is possible to make a 2-stage rocket with a lot of frontal surface area that flies low and slow. And a lot of people do that with things shaped like UFO's or with Spool rockets (rockets made from cardboard spools that had wire or rope wrapped around them). But that takes away from the visual effect of a speed change that you get with a conventional configuration rocket.

In this article, I will give you some techniques that you can use to help you keep the conventional 2-stage rocket flying lower. That way you still get the thrill of the two-stage rocket, but minimize the chances of losing the upper stage.

First, here is the ground rule – the model must be safe. Obviously, this is a given. But when people start modifying rockets, they often make changes that could make the rocket unsafe.

For example, the first idea that pops into your head is to add weight to the rocket. We all know that a heavier rocket is going to fly lower, because the engine has to waste energy pushing that extra mass against gravity. That is obvious.

But this does have a downside. The rocket also travels slower, especially at lift-off. If we allow it to fly too slow, the fins on the model rocket will not be as effective in keeping it going on a straight trajectory. This is dangerous.

Also, a heavy mass going up means a heavy mass coming down. And should something go wrong, like the recovery device fail to deploy, that heavier mass coming down could cause more damage.

Adding additional mass to the rocket is something I'd suggest only as a last resort. And if you have to add mass, start by using tracking powder. The benefit is that it creates a big puff-cloud in the sky helping you to spot it more easily. And the powder will disperse and will not come down in a manner that would be a safety issue.

Motor Selection

The motors you choose in the rocket are going to have the biggest impact on the height attained. So that is where you should start.

As you know, when you increase from one letter to the next, the power of the motor doubles. And this effectively increases the altitude of the rocket by approximately twice as much. A "C-size" motor will go twice as high as a "B-size" rocket motor, even though the motors share the same case size.

So you want to drop down in motor power as your first step. And this includes both stages in the rocket. You want to make them as small as possible.

Don't discount dropping down to a different diameter motor too. At Apogee, we have motor mount adapters that

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allow smaller diameter motors to be used in mounts designed for bigger motors. You'll find them at: www.ApogeeRockets.com/motor_mount.asp

Figure 1: Engine mount adapters, like these plastic ones from Estes, allow you to use smaller diameter motors in bigger rockets.

The limiting factor is flight speed, which we said before. We must always keep the speed of the rocket to a minimum level at lift-off. That speed is the minimum lift-off velocity, which I recommend as 30 miles per hour as the rocket leaves the top of the launch rod. Without an active guidance system, this is the speed at which the fins become effective at keeping the rocket going in the intended direction. By the way, active guidance is described in the article "Why Aren't There Fins on The Ares 1-X Rocket?" in *Peak-of-Flight Newsletter 248* (www.ApogeeRockets.com/Education/Newsletter248.pdf).

One way to cheat is by using a smaller motor, and the way to still get to the minimum lift-off speed is to use a longer launch rod. This gives the rocket more time to build up speed before it starts its free-flight.

The one big problem with rockets that fly at low speeds is that they weathercock more. That means that the wind causes them to turn and go horizontal.

Weathercocking has all kinds of problems, but the most serious for a two-stage rocket is the upper stage igniting while the rocket is going horizontal. This could mean the rocket crashing hard way upwind.

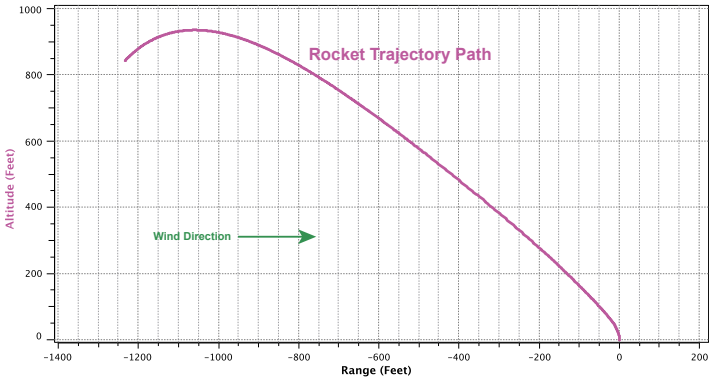

Figure 2: RockSim will allow you to predict the amount of weathercocking a rocket will experience.

How do you predict weathercocking if you don't have a lot of experience with rocketry? You'll need to use the RockSim software. It will give you a pretty good estimate of the trajectory of the rocket throughout the entire flight. And more importantly, it will tell you if your rocket accelerates fast enough to reach that minimum lift-off speed.

Finally, RockSim is an indispensable tool for finding where the rocket will land too. It will predict how far the rocket might drift in the wind, so you can determine if your launch site is big enough to fly a two-stage rocket.

Add Drag

After reducing the size of the rocket motors, my next favorite technique to keep rockets flying low is to add to the drag of the rocket.

Drag is a force that acts opposite the direction that the rocket is traveling at. You can look at the Drag formula to see which variables you can change to increase the Drag force.

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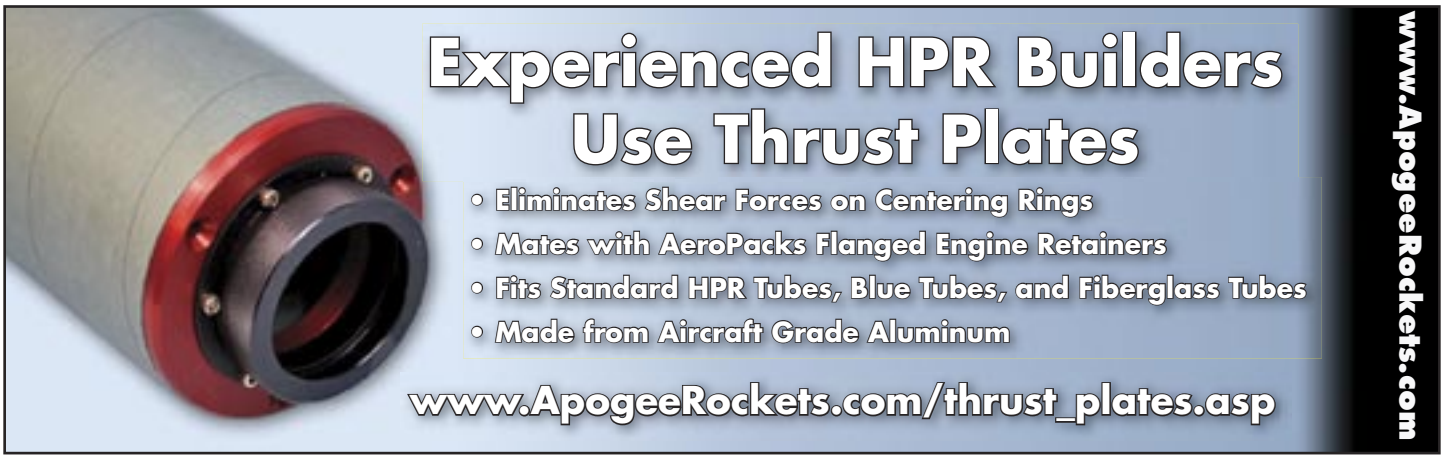

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$$D = 1/2\ \rho\ V^2\ S\ C_d$$

Where D is the Drag force, ρ is the density of air, V is the velocity of the rocket, S is the reference area (typically the cross sectional area of the largest diameter body tube in the rocket), and C_d is a dimensionless number called the Coefficient of Drag. This number is a catch-all bucket that takes into account the profile of the rocket (its shape), and its surface friction.

Looking at the Drag formula, we can toss out changing the density of air. The only time you can change that is by picking the day you fly your rocket. Air is denser on a dry, cold day, like in the dead of winter.

The velocity is controlled by the rocket motor we use. The higher the velocity, the higher the drag. In fact, the drag goes up by the square of the velocity. That means if you double the velocity of the rocket, the drag goes up by a factor of 4.

You actually can control the velocity of the rocket by the selection of the rocket motor you use. It is controlled by the average thrust of the motor. You can tell this by the first number following the letter in the motor designation. The higher the number, the faster the speed that the rocket will fly. And as we just said, the faster the speed, the more drag on the rocket, and therefore it won't go as high.

For example, if you had a choice between the C11-0 booster motor and the C6-0 booster motor, you should choose the C11-0. It won't go as high because it makes the rocket travel faster (for the same amount of propellant).

The next variable is the reference area. By making the area of the rocket larger, such as making the rocket bigger, you'll increase the drag force proportionally.

This may not help you, since you've probably already had a rocket kit in mind for your two-stage flight. And if you make the rocket bigger, you might have to bump up the size of the motors to compensate for the extra weight.

But, you can cheat a little bit. You can swap out your thin fins for thicker ones, right?

The final variable is the Coefficient of Drag. How do you increase this number?

First, you can increase the skin friction of the rocket.

My daughter did her 5th grade science fair project on the effect that changing the surface finish of the rocket had on maximum altitude. It was a great little project, and simple too. To make the surface rough, she painted on glue over the surface of the rocket, and dipped it in sand. It was

Figure 3: A rough surface finish, like this extreme one coated with sand and then painted, will greatly increase the drag on the rocket.

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Wanted: Your Rocket Products

If you're a manufacturer of rocketry products, like kits, electronic payloads, parts, construction tools, motors, launch equipment, or something totally cool, we're interested in talking to you. We're always looking for new products to sell.

So why have Apogee sell your products?

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Figure 4: Surface details, like vacuum-form wraps add skin friction drag and help slow down the rocket.

very rough, and it didn't fly nearly as high.

You can change the Coefficient-of-Drag by changing the shape of the rocket. Making the fins have square edges instead of airfoiling them will create a significant increase in drag.

You can also add "texture" to the rocket, which is what I call the stuff you might glue to the side of the rocket to make it look cooler.

The vacuum-form wraps (www.ApogeeRockets.com/vac-form_wraps.asp) are great for this, and can even be added to a rocket kit that is already constructed. It adds a bit of drag, and also makes the rocket even better looking. See also: www.ApogeeRockets.com/Rocketry_Videos/Rocketry_Video_37.asp

Other bits and details glued to the outside of the rocket also do the same thing. You might add extra fins and pods as details too.

But before you fly a rocket with extra fins and pods on it, be sure to check if it remains stable in RockSim.

Spin the Rocket

Spin can be induced into the rocket by canting the fins at an angle, or by putting a spin tab on the trailing edge of each fin. You can see the technique of adding canted fins in our how-to construction video at: www.ApogeeRockets.com/motor_mount.asp

Spinning the rocket does two things. First, it makes the

Figure 5: Spin tabs on the trailing edge of each fin will cause the rocket to spin and increase the drag.

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Figure 6: The Corkscrew (www.ApogeeRockets.com/oddl_corkscrew_flic.asp) is a high-drag rocket because it is designed to wobble into the sky.

rocket fly straighter – like rifling a bullet. It can be used to cancel out a lot of the weathercocking of the rocket if it is flying slow. This is a really good thing!

And second thing spinning does is to increase the drag force and therefore the rocket doesn't fly as high. The reason is that it takes energy to cause the rotation, and that energy comes from the speed of the rocket. The faster the spin, the lower the final altitude of the rocket.

Variable Drag devices

It isn't too common, but using a variable drag device

Figure 7: Crepe-Paper streamers can be attached to the fins of the rocket to limit the altitude. This design by Jim Flis, called the St. Louis Arch, takes it to the extreme. Photo courtesy of Chris Taylor. www.naramlive.com/naramlive-2011/naramlive/05tuesday/day5-02.html

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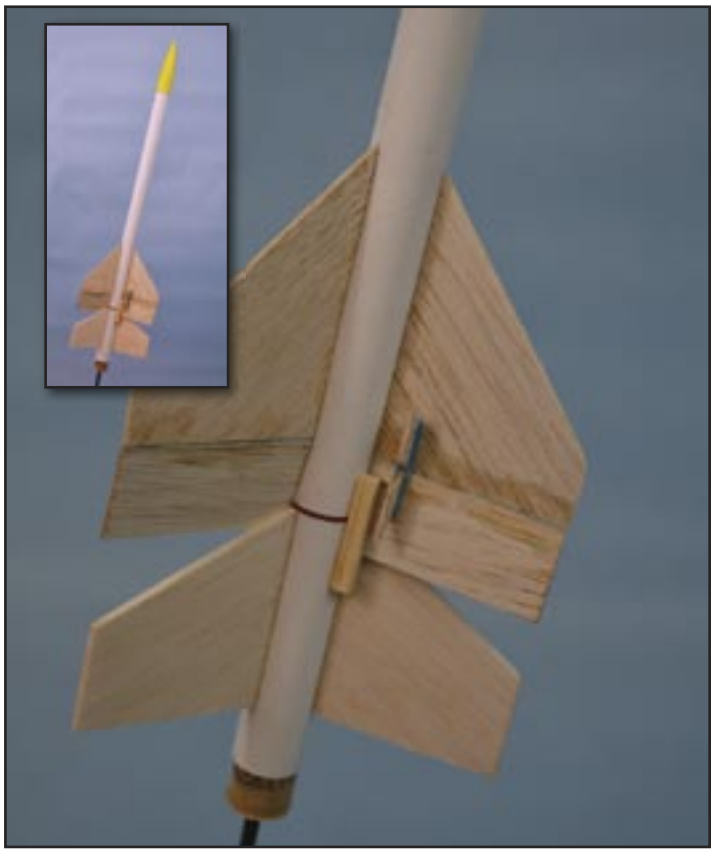

Figure 8: A variable-geometry two stage rocket in the launch configuration. The sticks (attached to the lower stage), extend forward, and lock down the spin tabs on the upper stage during boost.

on the rocket is another alternative to keeping the 2-stage rocket from flying too high.

What this means is to have some sort of actuator on the rocket to transform its shape mid-flight (see www.ApogeeRockets.com/Rocketry_Videos/Rocketry_Video_56.asp). You could go from a low-drag rocket, to a high-drag rocket once it stages.

The advantage of this is that the rocket would come off the pad fairly fast, because it has low drag initially. But then when it stages, the upper stage would transform into a high drag vehicle and slow down quickly after motor burnout. It gives a great visual effect and keeps the rocket from going too high.

What strategies might be used to accomplish this?

First, it might be as simple as short streamers tied to the base of the upper stage of the rocket. During the initial boost, the streamers could be housed in pods strapped to the outside of the booster stage. After the stages separate, the streamers would be pulled out and create a lot of drag.

Another way would be to have canting spin tabs on the upper stage fins. Think of the Texas Twister rocket kit (www.ApogeeRockets.com/texas_twister.asp) mounted on top of a small booster stage. Initially, the spin tabs are in-line with the fins on the upper stage. But after staging, they cant over and cause the upper stage to spin. That creates a lot of drag, as we said before, and slows the speed of the top stage. The cool thing is that the rocket could arc over

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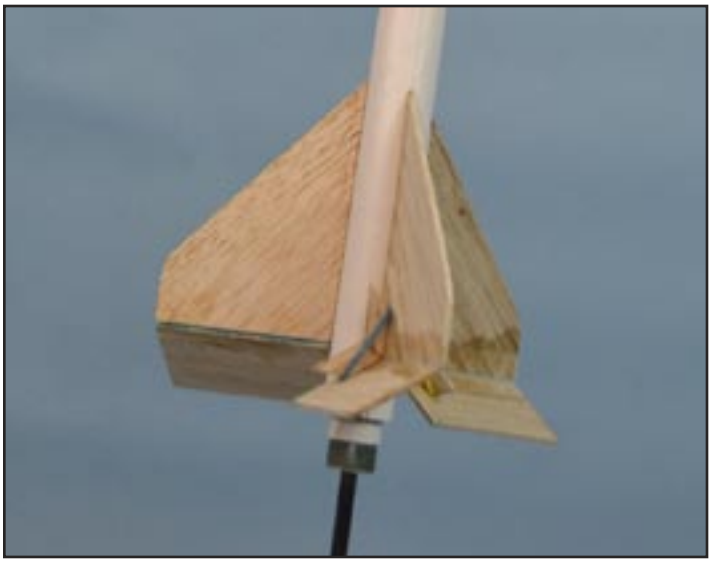

Figure 9: Once the stages separate, the spin tabs kick over, and the rocket begins to spin and slow the rocket.

and spin all the way down to the ground like the typical recovery of the Texas Twister. Without a deployable recovery device, the rocket wouldn't drift nearly as far downwind.

There are a lot of possibilities in this regard for variable geometry two-stage rockets. In fact, I'd like to challenge you to come up with a design. I'd love to publish it here in this newsletter.

Fly High – But Drift Not

Another strategy you can use on smaller fields is to attempt to minimize the drift of the rocket. Fly high, but come down as close to the pad as possible.

If you're thinking dual-deployment, you've got the basic idea. If it is a high-power rocket, or if you have the room for the electronics to control a dual-deployment system, then go for it.

Otherwise, you'll need to use other techniques to get your rocket to land inside the perimeter of your launch site. The obvious way is to reduce the size of your parachute, or cut a spill hole into it. You can also use a gradual parachute deployment device (see Peak-of-Flight Newsletter 143 at www.ApogeeRockets.com/education/downloads/newsletter143.pdf). Finally, and probably the most common method is to swap out the parachute for a streamer that will allow it to fall faster. For information on calculating the size of the streamer, see Peak-of-Flight Newsletter 244 at www.ApogeeRockets.com/education/downloads/newsletter244.pdf.

Yet another flight strategy to get your rocket to land in a small field is to use a longer delay in the rocket engine. That way the rocket will arc over and be heading down a bit before the deployment takes place.

This is riskiest of all, because the stresses on the rocket in this kind of deployment are quite significant. I'm sure that you've seen your fair share of chutes and streamers being ripped off the rocket or the nose completely separating from the body. If you employ this strategy, make sure to build your recovery system extra strong. You'll find tips on the Apogee web site at: www.ApogeeRockets.com/Rocketry_Videos/Rocketry_Video_44.asp

Tracking Down Your Lost Rockets

To make this article complete, I'll also mention a couple of ways to help you track down those lost rockets that did make it to the tree line.

GPS – The TeleMetrum system is the gold-standard of GPS based systems. Here, the rocket transmits its location so you can find it. You can find more information at: www.ApogeeRockets.com/Altus_Metrum_GPS.asp

Beepers – A less expensive alternative to the GPS is

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an audible beeper system. As long as you are within earshot of the rocket, there is a good chance that you'll be able recover it (assuming it isn't high up in a tree). At Apogee Components, we carry the BeepX (www.ApogeeRockets.com/BeepX.asp), and the Pratt MicroBeacon (www.ApogeeRockets.com/Pratt_MicroBeacon.asp).

If you plan ahead, you can also create some simple tracking scopes that work well at aiding you in locating lost rockets. See the system in *Peak-of-Flight Newsletters* #222 and #223 (www.ApogeeRockets.com/education/newsletter_archive.asp).

I used these tracking scopes with my daughter's fifth grade class, and it was remarkable how well they worked. If you're interested in using this in a school setting, see www.ApogeeRockets.com/classroom_rocketry.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.