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Feature Article

Designing A Parachute Compartment Into A Booster Stage.

APOGEE COMPONENTS
1130 Elkton Drive, Suite A
Colorado Springs, Colorado 80907 USA
www.ApogeeRockets.com email: orders@ApogeeRockets.com
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Designing a Parachute Compartment Into A Booster Stage

By Tim Van Milligan

In the past three years, many students in the Team America Rocketry Championship have asked a very common question: "how do I put a parachute into a booster stage?" The purpose of this article is to give you a few different design arrangements to think about.

Before we jump into some designs, let's ask and answer another question: when is it necessary to put a recovery device into a booster stage?

The first case might be for the rocket that flies so high that we want to make it easier to find. But this is very rare in regards to booster stages. Usually burnout for the booster stage occurs close to the ground, and the stage is easy to find as it falls.

The second case for using a parachute in the booster is whenever it is falling too fast, and is likely to cause damage upon landing. But how fast is too fast? And can it be made to fall slower without using a parachute? Both of these questions were discussed previously in *Peak-of-Flight newsletters* issues #96 and #97 (see http://www.apogeerockets.com/education/newsletter_archive.asp). So I'll leave it up to you to go back and review that material. For the rest of this article, I'll assume you've made the decision that the stage is too heavy, too stable (not tumbling), or is just falling too fast to be safe.

What Flavor Rocket Do You Have?

The different designs we might use for putting a parachute into the booster section depend on what kind of rocket engines are being used in the stages. Are you using black powder motors in the booster stage, or a composite propellant motor? Same question for the top stage...

I have to ask these questions, because we need to know how the motors are staged (ignited). Most people, including Team America participants would prefer the simplicity of direct staging of the motors. This requires black powder motors in both the lower and the upper stages. For information on how direct staging works, see *Apogee Peak-of-Flight newsletters* #98 and #99 (see http://www.apogeerockets.com/education/newsletter_archive.asp).

Because of the simplicity of direct staging, a common question is: "why can't you use direct staging with composite propellant staging?" That would make it really easy to send heavy rockets skyward using multiples stages.

The major problem is that composites are ignited differently than black powder propellant motors. They have to be ignited from the top of the propellant, not the bottom like a black powder motor. Therefore, they always need to be ignited with an igniter. In other words, they require an onboard launch controller contained within the rocket to fire off the top stage.

This means staging a rocket with composite motors in it is more complex than when using black powder motors. Fortunately, I've covered this subject in a previous newsletter, and you can read how to do it in *Peak-of-Flight newsletter* issue #91 (see http://www.apogeerockets.com/education/newsletter_archive.asp).

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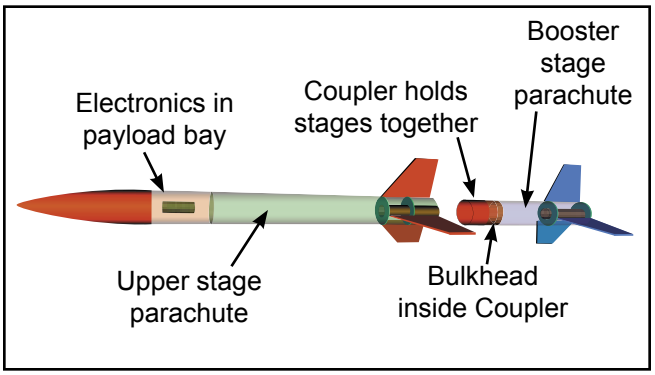

Figure 1: General layout of a two stage rocket with an on-board ignition system for the motor in the top-stage.

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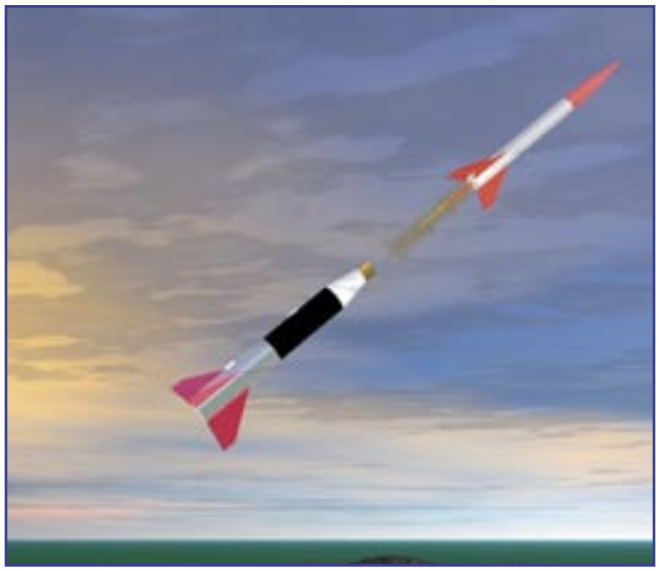

Figure 2: With electronics onboard to ignite the upper stage, the booster stage can use regular delay motors. In this scene, the transition will pop off to allow the chute to be ejected.

Designs for Composite Motors

While it is more complex to actually stage composite motors, they actually make it easier to incorporate a parachute into the lower stage of the model. In this case, you can design the booster stage to operate like a single stage model. This is because you don't have to allow the for the gases of the booster motor to pass through the rocket and ignite the upper stage rocket.

So the booster stage will probably look like the ones shown in Figure 1 through Figure 4.

How does it work? The upper stage is ignited by its own onboard electronics. So we don't have to worry about the staging process. As soon as the upper stage ignites, it will pull away from the booster stage. At that point, the booster stage will free fall toward the ground. The parachute (or streamer) is then ejected by the built-in ejection charge in the motor installed in the booster stage. It is very simple. For example, the booster stage motor would have a delay, like a E30-5 motor, where 5 seconds after the motor burns out, the parachute would be ejected from the booster stage.

While it is simple to design a parachute into the booster stage of a composite propellant lofted rocket, there are a couple of things you have to keep in the back of your mind.

Figure 3: The parachute is pulled out by the coupler section at the front of the booster stage.

The first is that there be a solid bulkhead at the base of the booster's coupler section. This is needed so the ejection charge has something to push against so that the parachute is ejected properly (similar to the base of a nose cone).

The solid bulkhead also prevents the exhaust gases of the upper stage motor from burning the parachute installed in the booster section. You obviously don't want that to get charred, do you?

The other thing has to do with where the electronics that ignite the upper stage are positioned. In Newsletter #91, I gave one possible location for the electronics to be placed in the booster stage itself. But you should use this location with caution. Why? Because if the upper stage should happen to coast upward and off the booster stage prematurely, it will yank out the igniter in the upper stage. You really have to have a tight fit on the stages to prevent this from occurring. That is possible, but it could cause other problems; such as tip off. This means the top stage might suddenly change directions and may not be pointed vertically when the motor does finally ignite. This should be vigorously tested.

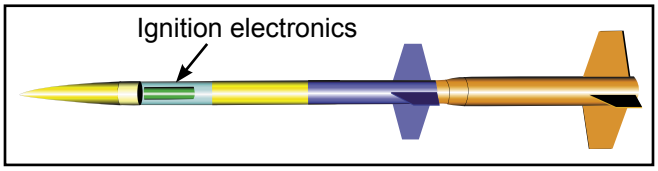

Figure 4: Put ignition electronics in the top stage to prevent wires from being yanked out early.

I now recommend putting the electronics in the upper stage, so you don't have to worry about the igniter being pulled out prematurely in case the stages come apart a split second early. It means the upper stage is a bit more complex, but it is safer.

Direct Staging Design

If you are trying to put a parachute in the booster section of a rocket that utilizes direct staging with black powder motors, it is far more complicated.

However, if the rocket has only one rocket engine in

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the bottom stage (such as a single D12-0, or a C6-0), then I recommend that you utilize tumble recovery. Such single-engine rockets are fairly lightweight, and can be designed to tumble so that they fall slow enough to be safe. This is the most common configuration for two stage rockets.

Clustering motors in the bottom stage means the booster section is heavier, and may require a parachute to slow it down to be safe. This is why so many similar questions come from Team America contestants, because they are more likely to cluster several D12-0 or C11-0 motors in the booster section.

Fortunately, having more than one motor in the booster stage does give us some options. For example: where is it written that all the motors in the booster stage have to be D12-0? Why can't you use one D12-0 to ignite the upper stage using traditional direct staging, and use a D12-3 to pop out the parachute after the booster stage has dropped off? Think about that for a second. Doesn't it solve a few problems? For one, you don't have to worry about the parachute getting in the way of the hot gases being used to ignite the upper stage motor. And the booster stage is free and clear of the upper stage, so it is less likely to cause tip-off problems.

This mixing of motors is what I'd recommend doing. Both motors, the D12-0 and the D12-3 burn identically. So you don't have a one motor making more thrust than the other, which would cause the rocket to turn in flight. The only difference is that one motor ejects much later than the other.

However, there is still the problem of where do you put the parachute, right? For staging to be successful, ideally you'd like a straight tube from the D12-0 (or whatever particular booster you use), and the motor in the upper stage.

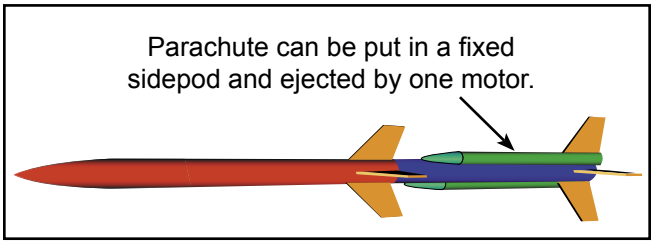

Figure 5: Some cluster arrangements make it easy to add a parachute pod.

A cluster of two motors is tricky, and we'll come back to it later. But if you use a cluster of three motors in the booster stage, you can use a straight-line arrangement of the tubes to allow a single straight tube from the middle motor up to the sustainer motor so you can utilize direct staging.

If you go this route, the simplest arrangement would be to use strap-on pods on the outside of the booster stage to house the parachute compartment. Basically, it is like a self-contained rocket attached to the outside of the stage. One that has a nose cone on it, and ejects a parachute, just like a traditional rocket (see Figure 5).

When the motors are all inside the rocket, it is a bit trickier. Why?

Because the hole in the top of the stage means the hot gases coming down from the upper stage motor as it ignites will melt the parachute into a plastic wad. You have to protect the parachute from that heat, or what is the point of even having it in the booster stage?

One way is to run a long tube from one of the three motor tubes and plug it with a solid bulkhead (a nose cone would work). Essentially, you've just moved the strap-on tube to the

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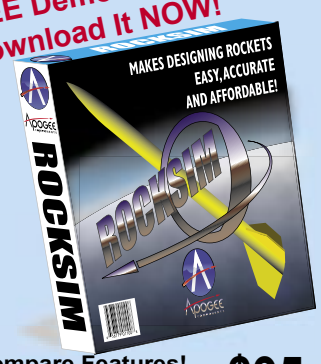

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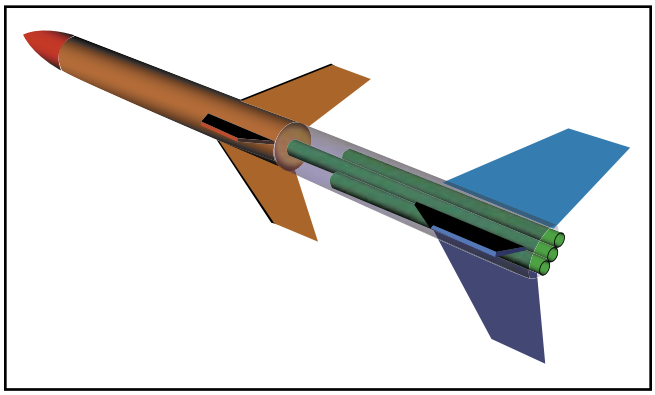

Figure 6: You can also move the sidepods to the inside of the model. A layer of wadding to cover the shorter tubes protects the parachutes from the heat of the upper stage motor when it fires.

inside of the booster stage. It may not be elegant, but it works (see figure 6).

Two Motors In The Cluster?

Two motors in the cluster poses a problem. It is no longer easy to get a straight tube from the booster motor up to the sustainer motor in the top stage. You could mount the second motor outside the body in a strap-on configuration, but that leads to an asymmetric arrangement. You'll have an offset thrustline, which will cause the rocket to rotate and go unstable.

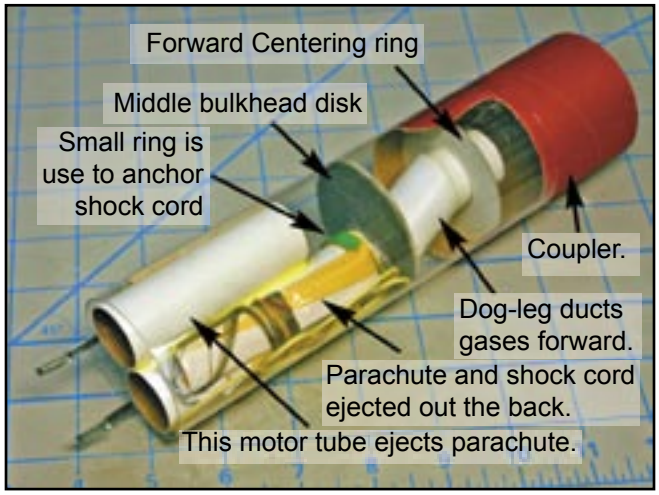

Figure 7: Anatomy of a booster stage designed to eject the parachute out the rear end.

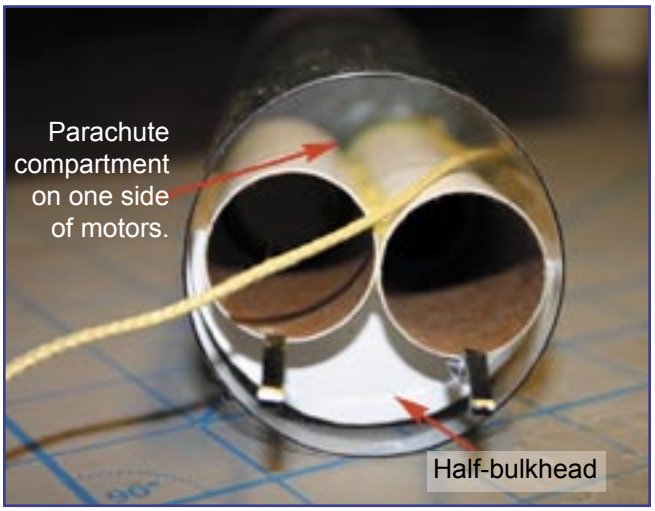

Figure 8: Rear view of engine mount. One side is open, so parachute can be installed. The other side is plugged with a half-bulkhead, so that all ejection gases are forced to exit the open side.

It would be better to have the motors together, so that they keep the thrustline parallel and concentric with the body of the top stage. What is required is a tube that has a dog-leg configuration. In other words, one tube is bent so that its ejection charge gases are directed at the base of the upper stage motor (see Figure 9). Yes, this does work! Why? Because it is the "heat," not the burning particles that ignite the upper stage motor.

That solves igniting the upper stage motor using direct staging techniques, but how do you protect and eject the parachute? Great question! The answer is to use "Rear Ejection."

Rear ejection is not very common, but it isn't too hard to do. Instead of popping the chute out the top of the stage, we'll eject it out the bottom. Figure 7 shows how this booster stage might be configured.

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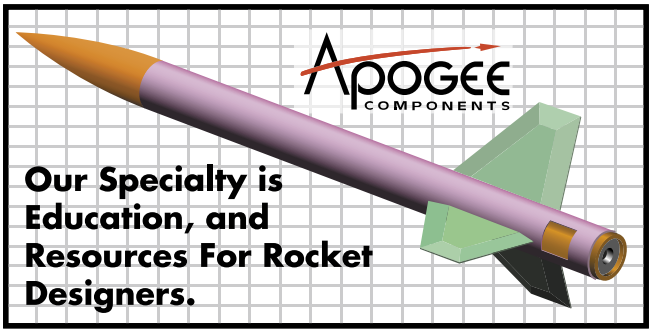

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Note that the one engine tube is shorter, and the ejection charge gases hit a fire-wall (covered with a thin layer of epoxy-clay) directly in front of the tube. They don't have any choice but turn around and flow out the bottom of the stage – where it ejects the parachute. It is a simple arrangement, although it is a bit tricky to build.

Making the dog-leg tube is the most challenging aspect. I build one using the techniques for cutting angled tubes shown in *Peak-of-Flight newsletter* #121 (see http://www.apogeerockets.com/education/newsletter_archive.asp). The result is shown in the photo below.

One problem though, did you see it? In the drawing shown in Figure 9, we have a tube with an oval cross-section that is mated with a tube with a circular opening. They won't match up, will they?

However, I found that if I cut the middle section at the correct angle, the tube with the circular ends will slide inside the oval ends. All I had to do was compress the tube slightly, and it fit right in. That makes assembly much easier. If you are interested in getting my cutting template, you can order it as a set of plans in *Technical Publication #29* (http://www.apogeerockets.com/technical_publications.asp).

I know you have one more question. How do you keep the parachute from falling out the bottom of the rocket?

All it takes is a piece of paper tape over the opening. The paper holds the chute inside the rocket, but when the ejection charge fires, it is blown aside without any effort. Cool, huh?

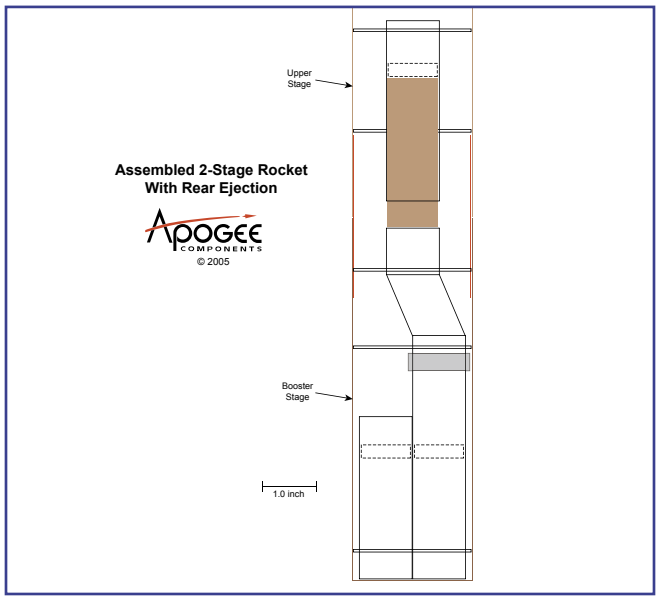

Figure 9: Drawing of a 2-engine cluster with rear ejection. From Apogee Tech Publication #29.

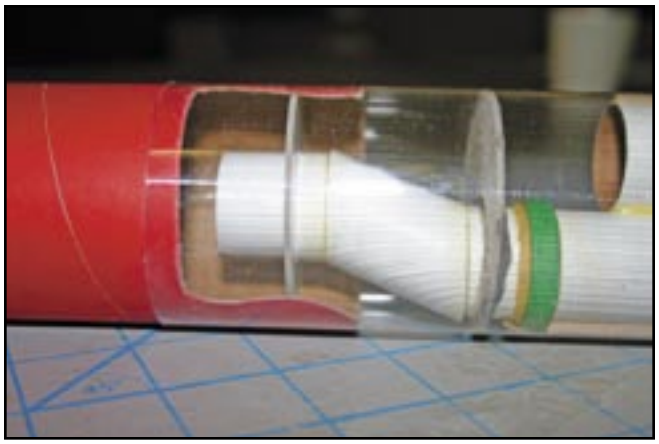

Figure 10: The dog-leg in one tube allows direct staging of the upper stage motor. The red tube coupler holds the stages together.

Conclusion

In this article I gave you several options for installing a parachute into the booster stage of a two-stage rocket. The method you decide upon using will depend on whether you are using direct or indirect staging, and by the number of motors in the booster stage.

If you have any other options that I haven't considered, please let me know. I'd be happy to share them with other readers of this newsletter.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who looks forward to 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 around the earth. 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 the FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site, or sending an email to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.