PEAK OF FLIGHT
NEWSLETTER

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Cover Photo: Quasar One's U.S. Army XR-7930 model rocket kit. Get your's today at:
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Construct Functional Strap-on Booster Pods

By Annette Sostarich

As a so-called Born-Again Rocketeer, I became once again familiar with all the basic principles of model rocketry, built some kits, learned about high power rocketry, built some kits, and rather quickly became a bit bored with many of the kits available out there.

I discovered that designing and building from scratch isn't that hard – It's not Rocket Sci... Okay, it IS, but, at least in the smaller scales we usually work with, it's not hard to produce an original design that's safe and fun, especially with the aid of simulation programs like Rocksim. It just requires a little creative thought.

I began wanting my designs to do more. My first really unusual design was a semi-scale model of Spaceship One on a very small scale that had a functional pivoting wing for featherweight recovery. The wing was spring-loaded with a pair of rubber bands and held in a horizontal position during boost by a clip attached to the motor mount. The motor mount was ejected at apogee, releasing the wing to pivot 90 degrees for a "Shuttlecock" recovery.

Having read articles about other people's projects, I decided to see if I could build a simple, inexpensive, 18mm powered rocket that mimicked the behavior of vehicles such as the Titan IV, with boosters that actually drop off at some point in the flight. I've never seen this done before on this small a scale. Sure, people build scale models of space launchers that do all kinds of interesting things, but I don't have the time or the budget for that kind of thing (or the space!)

I had built several boost-gliders and seen the many ways the motor ejection charge could be used to change the configuration of the vehicle. That is the basis of this design as shown in Figure 1.

The overall height of this rocket with a balsa nose cone is about 25 inches, and uses standard size model rocket tubes and components. The main body is a BT-55 tube (1.325") transitioning upward to a BT-70 tube (2.217"). The boosters are about 10" tall including the nose cones and are made from BT-50 (.976"). The transition was made from scratch using centering rings and a paper cone. All motor mounts are 18 mm.

It is loosely based on the (sadly, cancelled) NASA Constellation project, with a recognizable crew capsule as the nose cone. The real Constellation crew module would have been launched on a modified Space Shuttle solid booster, without strap-ons. If something like this model had been built for real, it probably would have had the capability to send 6 astronauts into Lunar orbit.

A full sized vehicle of this sort will typically have 2 solid boosters with a lot of short-term thrust to get the vehicle up to speed quickly (like the Space Shuttle, the solid boosters only burn for about 2 minutes). The liquid-fuel sustainer engine burns much longer (again, like the Space Shuttle, the main liquid-fuel engines burn for about 8 minutes). This is technically known as a 1-1/2 stage vehicle.

Note that this model is not really a 1-1/2 stage vehicle. If you use simulation software, simulate it as a cluster, because all 3 motors ignite on the launch pad. The dropping of the boosters happens after all the motors burn out, so the only difference between simulation and reality is your core vehicle may coast a little higher after it's free of the drag and weight of the boosters.

This design should scale up nicely, at least to mid-power. It's possible to design such a ve-

Figure 1: The rocket with strap-on booster pods.

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hicle with a very long burning sustainer motor such as the Apogee Medalist E6, with a burn time of 7.2 seconds. This would be a true 1-1/2 stage rocket, with the boosters separating while the sustainer is still going full blast. I have not found a way to simulate dropping boosters in Rocksim v7 for a 1-1/2 stage design, so such a rocket will probably go a lot higher than Rocksim says it will. Tim at Apogee Components tells me that it is possible to simulate the dropping of the booster pods in the newer RockSim v9.

Building the core vehicle

The core vehicle, or sustainer, has straightforward construction, and can fly on its own if one so chooses. I won't go into details of the parachute recovery system, fins, or motor mount here, because they are identical to any other rocket of the same general size. You wouldn't be reading this article if you didn't already know some of the basics. The only important design consideration here is that the core have 4 fins, because the boosters have to go between the fins. I'm not out to have you build an exact copy of my design, although you can if you want. Instead, I'd rather share the general principles I learned so you can apply them to your own design. I do highly recommend, however, that you get some kind of simulation software to aid in design, because designs such as this one have somewhat critical motor requirements.

One design criterion to keep in mind when choosing tube diameters for both the core and boosters is to keep them as small as you can, because this is a 3- motor cluster. You don't want those 2 outboard motors to be too far from the vehicle's center line in the event of an ignition failure. The only reason I used larger than necessary tube for the core was to leave more room between the boosters and the fins, to ensure smooth separation.

Neither the core nor the boosters can be minimum diameter, however. The diameter of the core must allow for a "lip" that the rear retaining clip for the booster can attach to, and the boosters must be large enough to accommodate a recovery system wrapped around the motor mount as seen in Figure 2.

The motor retainer hook on the core should be 90 degrees from the booster mount points, to avoid too much

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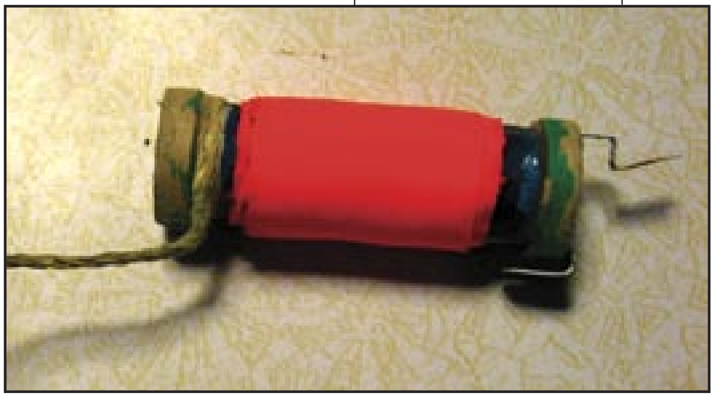

Figure 2: The engine mount of the strap-on booster uses rear-ejection with the recovery device wrapped around the motor tube.

clutter between motors. I used a Kevlar lower shock cord and an elastic upper shock cord. I also used an ejection charge baffle in the lower tube because I'm not too fond of wadding, Kevlar chute shields, or pistons.

The core vehicle and the boosters must both be constructed before the attachment system can be built, because the fit of these parts is so critical, I couldn't figure out how to do it by measurement, so I did it by actual fit.

Building the boosters

Booster construction is the key to this design. The boosters use a rear ejection motor mount that does two things: It deploys the booster's streamer recovery system, and it also releases the booster from the core vehicle. The booster motor mount is tethered to the inside of the booster with 4 feet of Kevlar shock cord. The nose cone is glued in place. The motor mount has the recovery streamer wrapped around it between the two centering rings, which are sanded as necessary to make a smooth slip fit inside the booster's body tube. A centering ring is used as a thrust block glued inside the booster to stop forward motion of the motor mount during boost. The thrust block must be hollow so the shock cord has someplace to go. A standard motor hook is used for motor retention.

The aft centering ring on the booster motor mount is notched on its inner diameter to permit the mounting of the U-shaped brass clip that holds the booster to the core during powered flight. It is also notched 180 degrees from the clip to accommodate the motor hook. Because the clip is attached to the booster motor mount, the assembly will not separate under thrust. See Figure 3.

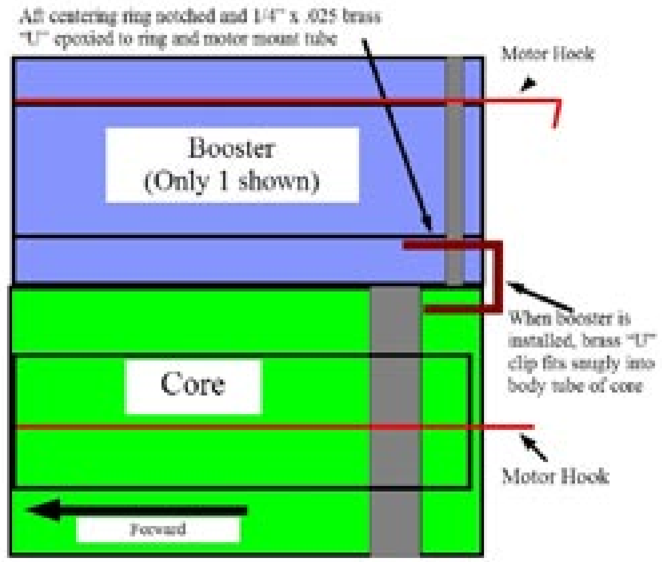

Figure 3: The hook on the booster pod latches to the bottom of the core, keeping everything together.

The "U" shaped clip should be adjusted so that, when the booster is installed, it grips the inside of the core body tube.

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The forward centering ring on the booster motor mount has a notch in its outer diameter to accommodate the shock cord. It's very important that you only use Kevlar for the shock cord in the boosters, because these shock cords are exposed directly to the hot ejection charge. Make them a generous length because you won't be able to use elastic, either. See Figure 4 for the details of the motor mount construction.

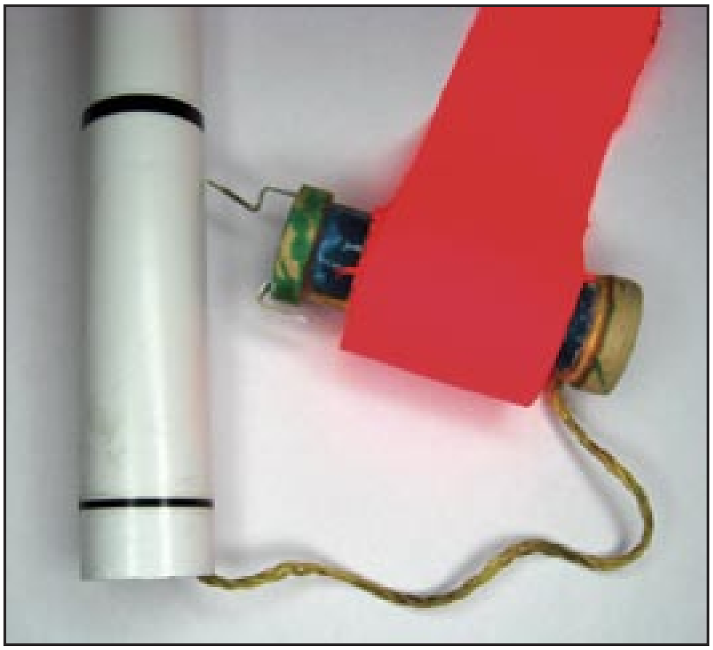

Figure 4: The engine mount on the pod is ejected from the rear, so make it strong!

Putting it together

The only truly demanding part of the entire project is constructing the forward booster mounts, because they must line up exactly in order to ensure easy separation as seen in Figure 5. The way I found to do this is as follows: after constructing the core and the boosters, mark the booster position on the core vehicle, and then temporarily hold the booster to the core vehicle in the correct position using masking tape. Be absolutely sure that the booster is parallel to the sustainer!

Figure 5: The forward booster mounts consist of dowels that engage in tubes on the central core vehicle.

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I used 2, 1-1/2" pieces of 1/8" launch lug per booster mount. After temporarily taping the booster in its correct position on the core vehicle, place one launch lug just behind the booster nosecone, and touching both booster and core. (See Figure 6 for the correct relationship).

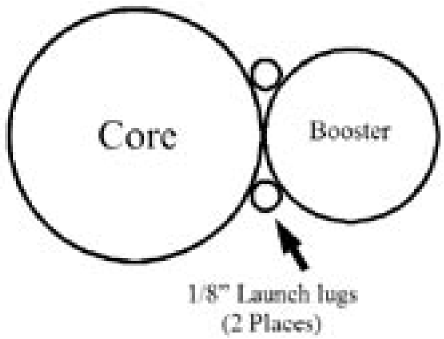

Figure 6: Two forward lugs are used to prevent the tube from swaying side-to-side on the rocket.

Very carefully, without changing the position of the booster on the core, tack the launch lug to the core (not the booster!) with a drop of superglue. Repeat for the other lug, checking to be sure booster, core, and both launch lugs are in intimate contact with each other, then remove booster and firmly glue down both launch lugs with white glue or epoxy. Repeat everything for the other booster.

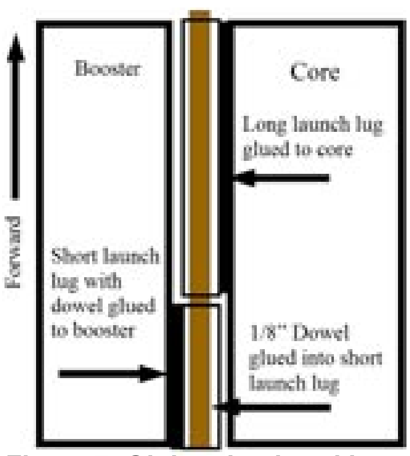

Figure 7: Gluing the dowel in the lug helps keep the alignment correct.

Now you can make the booster side of the forward attachment point. Cut 4 pieces of 1/8" dowel approximately 1/2" longer than the launch lugs you just installed. Cut 4 pieces of 1/8" launch lug about 1/2" long. Glue each dowel inside each loose launch lug so the end of the lug is even with one end of the dowel. This is to allow for the thickness of the launch lug that the dowel is going into on the core vehicle (see Figure 7).

Round the end of each dowel. The dowels are longer than maybe they need to be, but I left them that length to help ensure that the boosters slide straight back upon separation, to avoid fin damage.

Now again, temporarily tape the booster to the core vehicle. It should fit perfectly between the two launch lugs you already attached to the core. Now, from the bottom, slide one of your 1/8 inch dowel assemblies into one of the launch lugs you glued to the core vehicle. It should be a loose fit. When you're satisfied with the fit, apply a drop of super glue to the joint between the launch lug (not the dowel!) and the booster. Repeat for the other side, than repeat for the other booster. You should now have a mounting assembly that looks like Figure 5 on page 5.

Remove the motor mount from the booster and test the fit of the forward mounts. They should be loose enough so that the booster will fall off by its own weight when the assembly is held upright. If the fit is satisfactory, you can now fillet all the launch lug joints on boosters and core. Do not paint the dowels (they can be masked with scraps of launch lug). After painting, do a final test, and if the dowels are too tight, as they were on my prototype, sand the dowels till the fit is correct. Remember, this assembly is going to be pushed tighter together when under thrust, so make sure it won't stick when you push it together. My boosters wound up very slightly different from each other, just enough so that they won't interchange on the core. I had to mark them 1 and 2 so they would always go on the same side of the

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core, otherwise they stick.

If this is done correctly the boosters will be snug against the side of the core vehicle until separation, but come off very easily when the motor mount separates.

What can go wrong?

As the size of the vehicle goes up, the consequences of a sloppy separation do too. Full-size launch vehicles have carefully timed separations, usually involving lots of pyrotechnics, as well as small separation motors that ensure there is no collision between booster and vehicle during separation. However, on this scale at least, having the boosters slide straight backwards will be adequate. The worst that can happen is a dinged fin, or a failure to separate, neither of which will cause the rocket's loss.

Choosing motors

Most full size strap-on booster systems such as the space shuttle and the Titan IV light the sustainer engine as well as the booster engines at lift off. That's the way this system works also. This means that we should choose high thrust but short duration motors for the boosters, and a longer duration motor for the sustainer. With 18 mm motors, there is no combination that will separate during thrust, but you do want them to separate before apogee. My first flight on this vehicle was made using 2 A8-3 motors for the boosters, and a C6-5 for the sustainer. It performed as designed, attaining an altitude of several hundred feet. The sustainer motor should always have a longer delay than the booster motors, and in the case of my motor selection, the thrust time of the C6-5 is about twice that of an A8-3. Just make sure the right motor goes in the center mount!

According to Rocksim, this rocket can attain almost 1100 feet with 3 C6 motors: 2 C6-3s for the boosters, and 1 C6-7 for the core. I haven't tried flying it that high yet, because I don't like picking my rockets out of trees, and in my home state of Arizona, the trees have Big Thorns!

Clustering

This was also my first cluster rocket, and I was quite nervous about making sure I had simultaneous ignition, although black powder motors are easier to ignite than composite motors. All of the black powder motor igniters are better than they were when I was a kid. Back then, they were just a bent piece of Nichrome wire with no pyrogen! I can't remember ever having a modern Estes igniter fail me.

For clustering, however, I discovered that Quest makes igniters with long insulated leads and more durable heads that won't flake and break the way the Estes ones do. The long leads eliminate the need to fabricate a "clip whip" because they are long enough to twist together on their own. Be sure to wire igniters correctly. Twist one wire from each igniter together, then twist the other wire from each igniter together. Be sure that you're using an ignition system that can handle the high current of three igniters. I have been launching with a club that uses a 12 Volt system. This is very reliable with small igniters.

Flight preparation

Flight prep on the core vehicle is going to be the same as any other parachute recovered small rocket. Since I'm using a baffle, I don't use wadding, although sometimes I'll use one piece wrapped around the parachute as extra "insurance."

To prep the boosters, start by stuffing most of the Kevlar shock cord up inside the booster, getting it past the thrust block. You may need to work at this a bit with a long finger or a stick to get the shock cord past the thrust block,

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otherwise the motor mount won't go in all the way.

Wrap the recovery streamer around the motor mount, then stuff the rest of the shock cord inside the booster, route the shock cord through the notch in the forward centering ring, and insert the motor mount all the way into the booster, making sure that the brass "U" clip is exactly centered between the 2 forward mounting dowels, and that the motor mount assembly is not too tight in the booster. It should be somewhat looser than the nose cone on a regular rocket, because the clip holding it to the aft end of the core will create some additional friction. You should be able to pull the motor mount assembly out easily with two fingers.

Figure 8: Booster clip is engaged in the core tube.

Slip the 2 dowels on the booster into their mating launch lugs on the core. Ensure that the "U" clip goes into the base of the core vehicle (as seen in Figure 8). The assembly should feel solid and show no tendency to come apart easily. Install the motors and igniters, connect them together as described above, and you are ready to launch.

Going further

What else can be done with this sort of design? I'm planning to mount a tiny video camera on mine to record launch and booster separation. Could the boosters use Zero-Delay booster motors? Could this idea be used on, say, a scale Delta? That's an awful lot of boosters to be chasing after! How far up can it be scaled before it becomes unworkable or unsafe? Could rails instead of launch lugs be used on larger designs? (Put the rails on the boosters, and the buttons on the core.) What can be used on a larger design when friction fit is no longer reliable? Someone else out there has probably answered a lot of these questions, but more can be done.

About the name of the rocket

This is an experimental design which is still being tested as I write this. The design came long before the name, but as I was trying to think up a good name, a book by former astronaut Mike Mullane came to mind. He was a member of NASA at the time of the Challenger disaster, and he lost seven good friends that day. After Challenger, he flew one more time before he retired. When asked

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before the flight, what his future plans were, he replied, “I have no plans past MECO!” (Main engine cut-off), so the name of the rocket became “No Plans Past MECO”. It’s not that I don’t have faith in my own designs, but it’s been said that the chance of a failure goes up as the approximate square of the number of engines. We do everything NASA does, only on a smaller scale, including occasional spectacular failures. That’s why they call it Rocket Science!

If you would like to download the RockSim v9 file for this rocket, visit: www.apogeerockets.com/strap-on_Boosters_Design.asp

Alternate Way To Make Strap-On Booster Pods And Secure Them To The Core Rocket

Ed: *{Before Annette first sent me this article, I was skeptical. I have seen a lot of strap-on booster designs that were downright dangerous, because they didn’t constrain the pod in case it failed to ignite. This design is acceptible, but in my opinion, it is good only for lightwight rockets with up to a D size motor in the pods. On a heavier rocket, the inertia of the rocket motor in the pod might make the engine mount slide rearward and out of the rocket if the engine fails to ignite. Make sure that you get a good friction fit on the U-clip on the bottom of the pod where it attaches to the core.*

For high power motors, I recommend you switch to a more secure method of attaching the pods to the rocket. This is shown with a number of images in the book: “Model Rocket Design and Construction.” This book is available at: www.ApogeeRockets.com/Design_book.asp.*}*

About the Author

Ever since she can remember, Annette Sostarich has been fascinated with two subjects - electronics and aviation. From watching planes take off as a kid on Saturday mornings to over 450 parachute jumps, designing and building numerous kites, volunteer work at Tucson, Arizona’s Pima Air & Space Museum in their restoration hangar, and now designing unusual rockets, there have been a lot of adventures.

Her electronics background began with picking up a soldering iron by the wrong end at the age of 12, and has since been parlayed into a part-time computer repair business. She is just beginning to apply electronics to rocketry with subcompact video cameras as payloads. She met her husband of 28 years while skydiving, and they jumped into their own wedding. Her husband is an aircraft mechanic who is currently building an airplane in their garage.