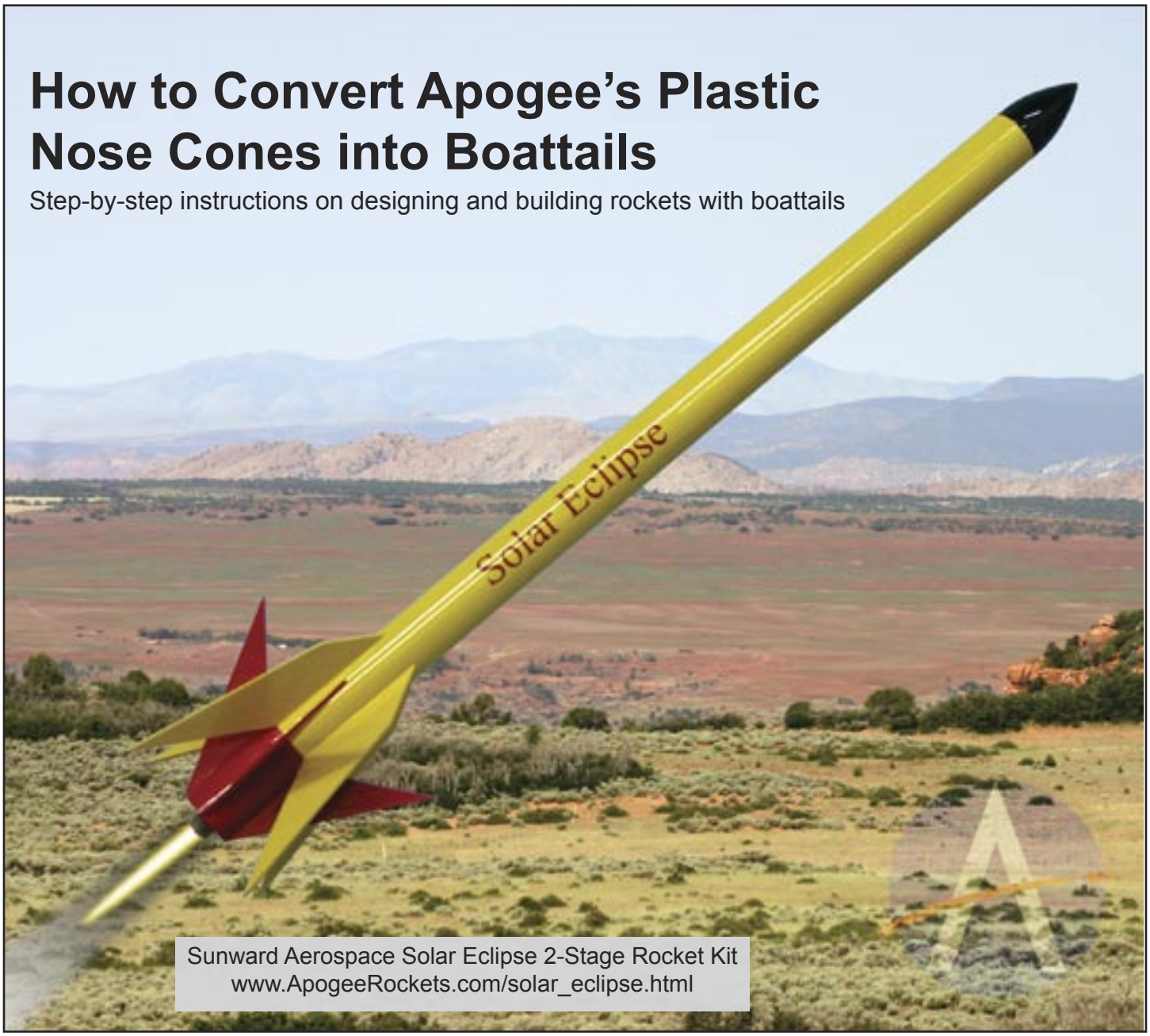
Apogee Components

PEAK OF FLIGHT

NEWSLETTER

How to Convert Apogee's Plastic Nose Cones into Boattails

Step-by-step instructions on designing and building rockets with boattails



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How to Turn a Plastic Nosecone Into a Boattail

By Tim Van Milligan

"Hi Tim and crew! Thanks again for the newsletter. I appreciate the time you take to pass on your knowledge to the rest of us. Something I've been interested in is how to best utilise your fantastic BT-70 (P/N 20070) & BT-80 (P/N 20080) nose cones as boattails.

What is the best way to cut them? How can I make accurate fin slots? What about motor retention? What sort of glue works on the polystyrene for bonding and fillets? What is the best way to mount the motor tube?

Thanks and regards." -- Matt Small

You're in luck! I just happen to be working on the instructions for a new DynaStar kit that uses one of our nose cones as a boattail. This new kit, due out in a couple of months was designed by Shrox and will be called the Lexx-Jet. So I'll borrow from the instructions and show you how to take one of our nose cones and turn it into a drag-reducing boattail.

First off, in case you're wondering, you can find these two nose cones from the Apogee Components web site at:

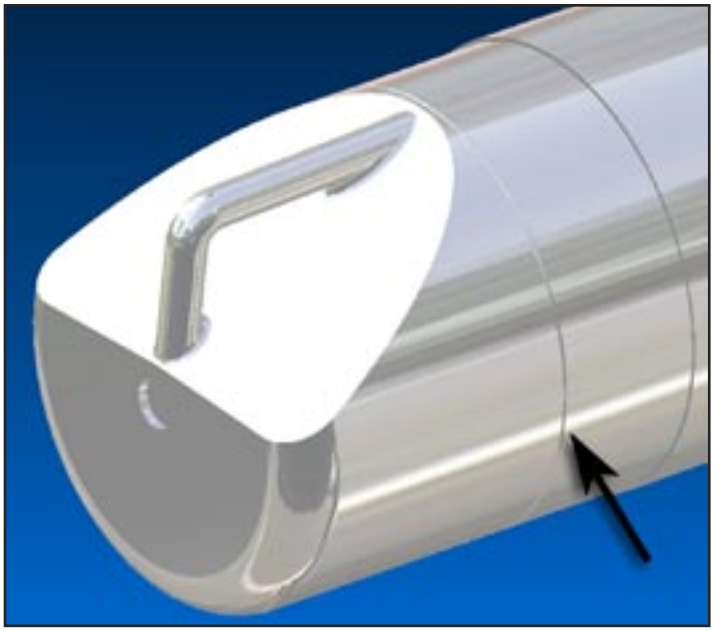

Figure 2: The V-groove on the shoulder makes it easy to cut off the rear end of the nose.

Figure 1: Rocket designer "Shrox" holding a prototype of the new Dynastar Lexx-Jet rocket.

http://www.ApogeeRockets.com/nose_cones.asp.

What makes the two Apogee nose cones special is that they were designed to be easily converted to boattails. I don't know of any other manufacturer that has created nose cones like ours. We think ahead and try to make our parts extra useful and as easy to work with as possible.

The features that makes them unique is we've included the cut lines on the tip and on the shoulder to make it easier to cut them.

On the rear end of the nose cone is a V-groove that you simply run a hobby knife along. You only need to score the plastic, and it with a little flexing it will snap off.

The other feature on the nose cones are two little raised beads near the tip. We put these on the nose cone

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Newsletter Staff

Writer: Tim Van Milligan
Layout / Cover Artist: Tim Van Milligan
Proofreader: Michelle Mason

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Turn a Plastic Nosecone Into a Boattail

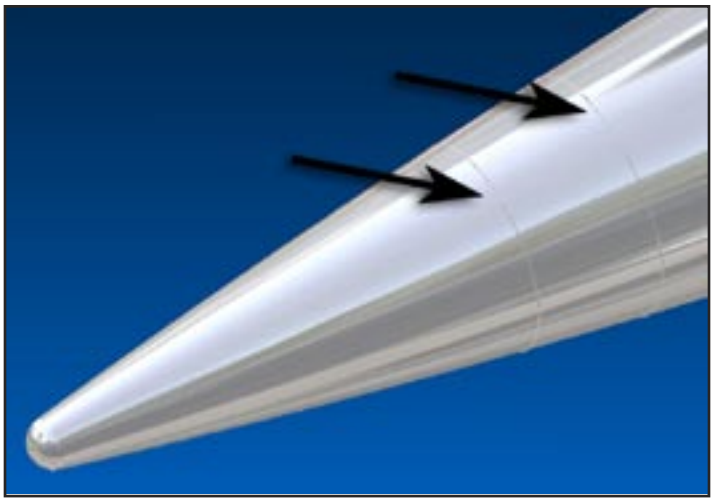

Figure 3: Raised beads on the tip of the nose make it easier to cut off the correct length for both 24mm and 29mm tubes.

to make it easier to cut off the correct amount so that the hole left will be sized to allow the engine mount tube to slide through with a nice slip fit. The bead near the tip is used as the cutting guide if you want to use a 24mm (BT-50) size tube, and the further aft bead is a cutting guide if you want to use a 29mm diameter engine mount tube.

Why did we use a raised bead instead of a "V-groove" like we did on the rear shoulder? That is a great question. The V-groove definitely makes it easier to cut the plastic. But what if you don't want to cut the plastic? Now you have a groove in the nose cone that has to be filled prior to painting. That can be time consuming if you want a sleek-looking nose cone.

By making the cut line a raised bead, it is really easy to sand off if you want the smooth surface. It is much easier to sand it smooth than it would be to try to fill a groove line. Makes sense, doesn't it?

Creating the boattail

I'll give you the main steps in creating the boattail in this article. Since every rocket is unique, your particular design might be configured differently than what is shown here.

Step 1: Cut off the tip using a razor saw.

Because of the way blow-mold nose cones are made, the plastic is much thicker at the tip of the cone than at the bottom. Normally, this is a good thing. It puts more weight near the top of the rocket and also makes the nose cone stronger so it can survive hard landings.

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But the extra plastic near the tip makes is much harder to cut the tip off. It is possible to use a hobby knife, but the plastic is so thick that it would take a long time and you'd have a good chance of snapping off the tip of the knife blade. That is why I recommend using a razor saw to cut off the tip. The teeth on the razor saw will quickly cut through the plastic, and you'll have the tip off in about 30 seconds.

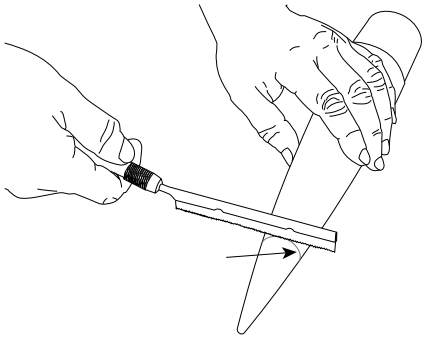

Figure 4: Keep the blade on the forward side of the plastic ridge.

The only caution is to make the cut on the nose-tip side of the raised plastic bead. The goal is to create a hole that is just big enough for your engine mount tube to slide through with a nice slip fit. Because of this, you want the hole to be slightly small after the initial cutting process. Then you can come back and either shorten the length of the boattail, which opens up the hole bigger, or you can sand out the inside of the plastic.

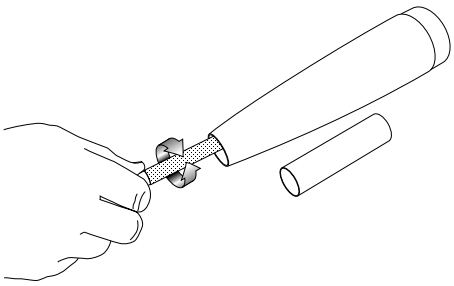

Figure 5: Sand the inside edge to create a slip-fit for the engine tube.

Because the plastic is so thick near the tip, sanding out the inside edge of the boattail is what I prefer and recommend. Just wrap some sandpaper around a dowel (1/2" to 3/4" dia) and work the inside edges as shown in figure 5.

The wall thickness of the plastic will not be uniform because of the way the nose cone is manufacturered. So sanding out the inside edge is a good way to control the thickness and insure that the engine mount tube will be concentric inside the boattail.

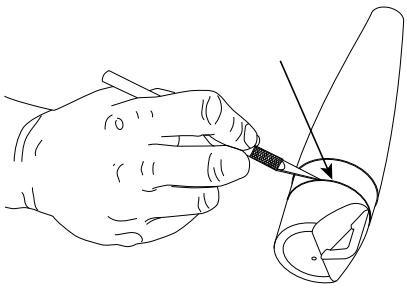

Figure 6: You can cut off the aft shoulder using a hobby knife.

Step 2: Cut off the shoulder end.

As stated previously, there is a "V-groove" on the shoulder of the nose cone, just forward of the parachute attachment loop. Cutting this end is much easier. All you have to do is deeply score the plastic in the bottom of the groove with a hobby knife. Then flex the plastic by gently squeezing the shoulder. This flexing will open up the crack, and eventually the end of the shoulder will separate from the part.

Step 3: Build your engine mount.

Because the nose cones are very long, there are a couple of options when it comes to designing and installing the engine mount. You an either have a short engine mount tube, or a long one.

I prefer the longer engine mount tube in the boattail because I want to make sure that it is centered concentrically with the outside body tube. As I mentioned previously, the manufacturing method used to make blow-molded nose cones has a drawback that the wall thickness of the part is not perfectly uniform. Because of this, it is possible that

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the engine mount might be cocked slightly in the tube. This would result in canted thrust from the engine which might

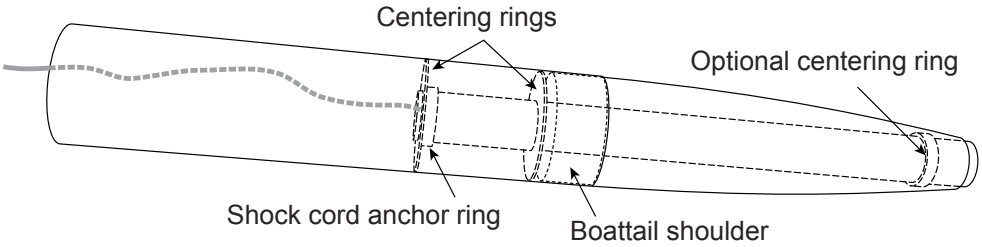


Figure 7: It is preferred that a long engine mount tube be used just to make sure the engine mount tube is straight and concentric.

possibly cause the rocket to go unstable.

The long engine mount tube alleviates this problem. The engine mount tube is made long enough so that you will have two centering rings inside the big tube that will hold the engine mount tube perfectly concentric (see Figure 7). After that assembly is glued into the big tube, the plastic boattail is slid on and glued in place.

Just one small caution; make sure the centering rings are deep enough in the tube so that they don't interfere with the shoulder of the plastic boattail.

If space inside the rocket is limited, and you need more room to house the parachute, then you can make the engine mount shorter. This is the case in the Dynastar Lexx-Jet kit that I'm working on right now.

Making the short engine mount will mean that the forward centering ring will be much larger in diameter than the aft ring (sorry to state the obvious). You can see a picture of what the engine mount will look like in Figure 8.

The engine mount is a critical part of the rocket, so I would test fit everything a couple of times before applying any glue.

You'll notice that in both in Figures 7 and 8 that I use a second ring right behind the most forward centering ring. This is the ring that anchors the Kevlar® shock cord. I found that you need the extra gluing surface area to prevent the shock

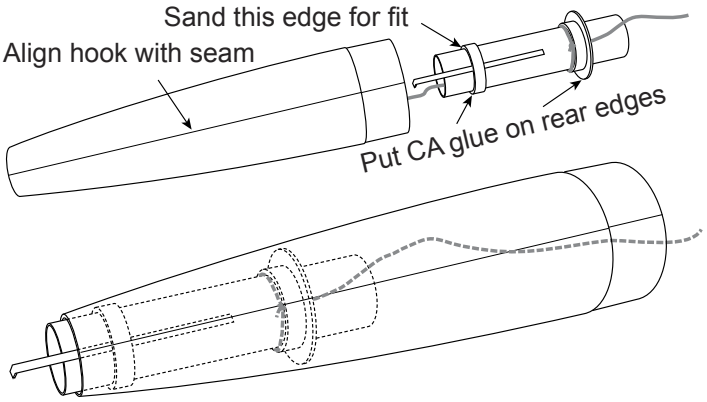
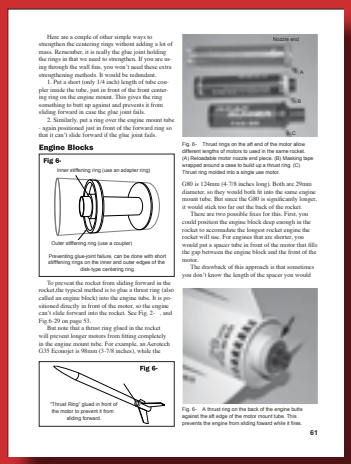


Figure 8: Anatomy of a short engine mount tube in the plastic boattail.

Model Rocket Design And Construction



Here are a couple of other simple ways to strengthen the centering rings without adding a lot of mass. Remember, it is really the glue joint holding the rings in that we need to strengthen. If you are using through the wall fins, you won't need these extra strengthening methods. It would be redundant.

1. Put a short (only 1/4 inch) length of tube coupler inside the tube, just in front of the front centering ring on the engine mount. This gives the ring something to butt up against and prevents it from sliding forward in case the glue joint fails.

2. Similarly, put a ring over the engine mount tube - again positioned just in front of the forward ring so that it can't slide forward if the glue joint fails.

Engine Blocks

Fig 6-

Inner stiffening ring (use an adapter ring)

Outer stiffening ring (use a coupler)

Preventing glue-joint failure, can be done with short stiffening rings on the inner and outer edges of the slab-type centering ring.

To prevent the rocket from sliding forward in the rocket,the typical method is to glue a thrust ring (also called an engine block) into the engine tube. It is positioned directly in front of the motor, so the engine can't slide forward into the rocket. See Fig. 2- , and Fig.6-29 on page 53.

But note that a thrust ring glued in the rocket will prevent longer motors from fitting completely in the engine mount tube. For example, an Aerotech G38 Econojet is 96mm (3-7/8 inches), while the

Fig 6-

"Thrust Ring" glued in front of the motor to prevent it from sliding forward.

Nozzle end

Fig. 6- Thrust rings on the aft end of the motor allow different lengths of motors to used in the same rocket. (A) Reloadable motor nozzle end piece. (B) Masking tape wrapped around a case to build up a thrust ring. (C) Thrust ring molded into a single use motor

G80 is 124mm (4-7/8 inches long). Both are 29mm diameter, so they would both fit into the same engine mount tube. But since the G80 is significantly longer, it would stick too far out the back of the rocket.

There are two possible fixes for this. First, you could position the engine block deep enough in the rocket to accomodate the longest rocket engine the rocket will use. For engines that are shorter, you would put a spacer tube in front of the motor that fills the gap between the engine block and the front of the motor.

The drawback of this approach is that sometimes you don't know the length of the spacer you would

Fig. 6- A thrust ring on the back of the engine butts against the aft edge of the motor mount tube. This prevents the engine from sliding toward while it fires.

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cord from pulling through the front centering ring. One word of caution here about this shock cord anchor ring. Use only wood glue to assemble it. I had a customer that thought that CA glue would be better. But the CA made the shock cord stiff and brittle, and it cracked and failed on the first flight. Wood glue is more plyable and allows the shock cord to flex without making the fibers brittle.

Because you will be using wood glue, make sure everything is bone-dry before gluing the mount inside the plastic boattail. Once the assembly is inside the plastic boattail, air cannot get to the rings to dry the wood glue. So you need to let it dry completely before gluing it in.

The glue to use when putting the engine mount into the plastic boattail is thick (gap-filling) CA. The CA will harden inside, and the thick viscosity adhesive will help to center everything up nicely.

Engine Restraint

There are a number of different methods of engine restraint you might consider when using a boattail. My favorite is to extend the motor mount tube out the back of the boattail by 1/2 inch (12.7mm). The motor sticks out of this tube 1/2 inch, and you simply wrap masking tape over the motor and the tube that extends past the boattail as shown in Figure 9.

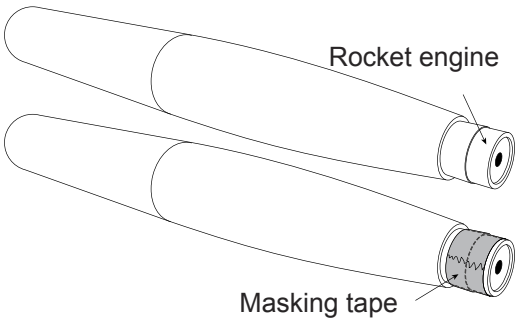

Figure 9: The simpliest engine retention method for boattail rockets.

You'll notice that in Figure 8, there is an aft centering ring inside the boattail. This ring serves a double purpose. Not only does it center up the mount in the boattail, but it also holds down the metal engine hook.

From personal experience, I've found that the hole on the back end of the boattail is never perfectly circular and is always a little big. So there will probably be room for the metal engine hook to fit through the opening along with the engine tube. If there isn't, you can use a hobby knife and carefully cut a notch for the hook.

If your engine mount includes a metal engine hook, I would try to orient the hook so that it aligns with one of the

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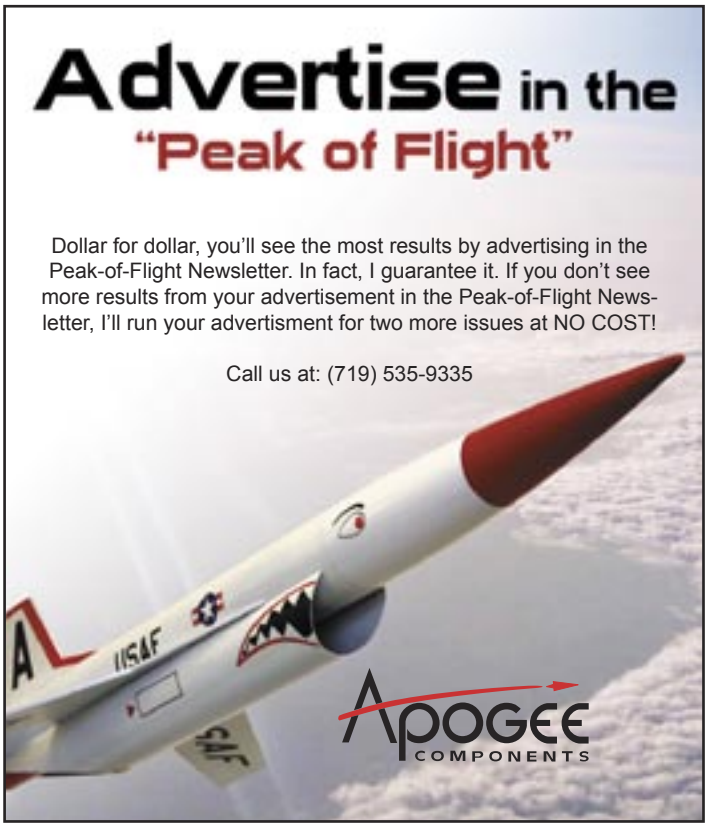

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seams on the outside of the boattail. This is only for aesthetic reasons, but you'll see why later on.

At the end of this article, under *additional information,* you'll find a link to another article I wrote on engine retention in boattails. It is a little more complicated, but it can be used to give you an even more aerodynamic boattail.

Step 4: Glue the boattail on to the body tube.

This is a pretty simple step, but I just wanted to point out that you need to use that thick (gap-filling) CA adhesive. The reason is that wood glue won't stick to the plastic of the boattail.

I also recommend orienting the seam line on the boattail with a fin line on the tube (if you've already drawn them on the tube). This will make attaching the fins easier.

Step 5: Mark the body tube and then the boattail for correct fin spacing.

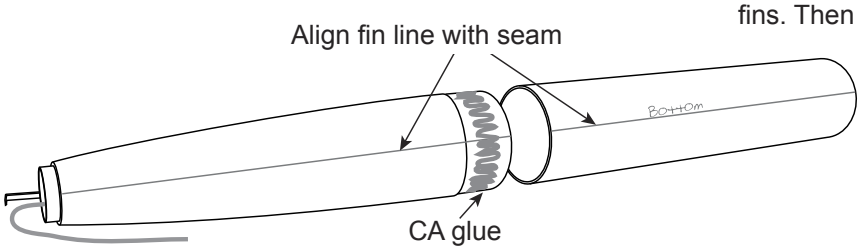

Figure 10: Use thick CA glue to attach the bottail to the tube. Thread the shock cord out the back temporarily so it doesn't get glue on it.

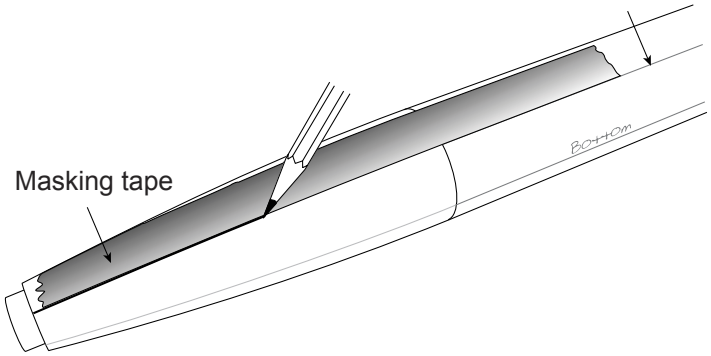

Figure 11: Use masking tape pressed down on the boattail as your straight edge for marking fin lines.

Drawing straight lines on a boattail is very difficult. In fact, I consider it in the range of a Skill Level 3 technnique.

To make the process easier, I recommend marking fin locations the body tube first, and then extending the lines onto the boattail. And use the seam lines on the plastic boattail as much as possible. If your rocket has four fins, you can use the seam lines as two of the locations for the fins. Then you only need to draw lines for the other two fins.

I have yet to find a fixture that is good for drawing lines straight down a curved boattail. I've tried using an aluminum angle as a guide along with a mechanical pencil with the graphite sticking out really far. But no matter what I tried, the pencil line curved to the side as it got close to the small end of the boattail. If you

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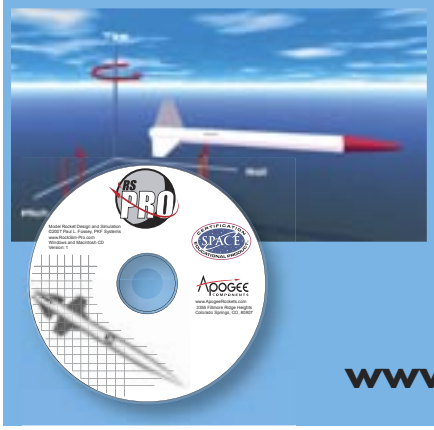

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have a good way please let me know.

The only technique that gives acceptible results is to use a very long strip of masking tape. Position one edge along the fin line on the body tube, and then press that edge of the tape down the length of the body tube.You do have to sight along the tube to make sure the tape went down straight. But once you've confirmed that, you can draw the pencil line for the fin line.

Step 6: Design your fins in RockSim

Why RockSim (www.Apogeerockets.com/rocksim.asp) to design the fins? It makes getting the exact curature on the root-edge of the fin very simple to do. Without it, you'll probably have to go through an extensive trial-and-error process of drawing the curvature and then cutting out a template to see if it matches the curvature of the plastic boattail.

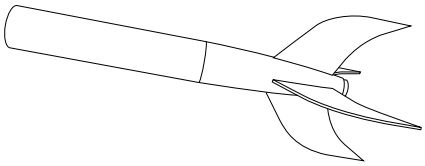

Figure 12: Use RockSim to design the fins, so the root edge matches the curvature of the plastic boattail.

RockSim makes the process much easier because it is so accurate. But before you can start, you need to measure the exposed length of the boattail, and the small diameter at the base (you already know the big diameter, because it is a standard size tube). With these numbers, you can quickly create a design in RockSim to draw the boattail. Then it is just a matter of designing the fins onto the boattail. Another nice feature is that by using Rocksim, you can add those fin tabs if you want them.

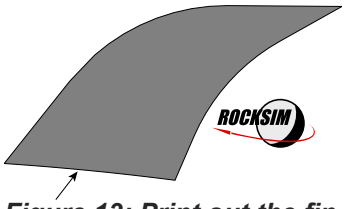

Figure 13: Print out the fin template using RockSim.

Once you design your fins, it is just a trivial task to print the template so you can start cutting wood. The result is a fin that nicely matches the curature of the boattail.

Step 7: Attach the fins to the boattail

Since wood glue will not stick to the plastic, you'll need to use CA adhesive or epoxy. I recommend that you use the CA adhesive. With epoxy, you would have to hold the fins in place for a long time for them to grab. And it is harder to attach fins to a curved boattail, so you might as well use the quicker setting CA adhesive.

Use the thick (gap-filling) variety of CA glue for this

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task. There may be small gaps under the fin root, and the thicker variety will fill them easier.

The original question from Matt Small also asked how to cut slots for through-the-wall fin tabs. I will skip that answer for now, because this article is already long and that is a much harder task to accomplish. But it can be done, although it requires a lot of skill and patience.

A nice alternative to through-the-wall fin tabs is to use the Fix-It epoxy clay (www.apogeerockets.com/epoxy-clay.asp) and create nice fin fillets around the joint where the fin attaches to the boattail. Not only will you fill any remaining gaps along the joint line, but the Fix-It epoxy will really make the attachment strong. I don't recall when any fin popped off a rocket if it had a fillet made from Fix-It epoxy clay. Usually the fin will break somewhere else further out from the tube.

Conclusion

I tried to show in this article the simple steps needed to convert the PNC-56 (BT-70 size) and the PNC-66 (BT-80 size) nose cones into drag-reducing boattails. I say "simple" because the nose cones were designed from the beginning to be easily converted. They differ from other nose cones in that they have V-grooves and raised ridges that can be used to guide the cutting process. They are also made from polystyrene plastic, which can be easily glued and painted.

About the only other advice I can give you in designing the boattail is to sit down and really give some thought into the layout of the parts. You have to decide where the internal centering rings will go. You can't just slap things together, or you will probably find that the parts don't fit properly. It is highly recommened that you use the RockSim software as a design aid. It allows you to see the general layout of the parts before you start the process of building. It doesn't do fit-checking, but I believe that it will help things go together better and faster.

Let me know how your designs turn out. Send me a photo and a note saying what you might have done differently. I'm sure our other readers would love to see it.

Additional Information:

Peak-of-Flight Newsletter #203: Learn how to build a engine restraint system inside a boattail that eliminates that ugly metal engine hook sticking out the back end of the rocket. www.ApogeeRockets.com/education/downloads/Newsletter203.pdf

Peak-of-Flight Newsletter #126: Learn how to make your own disk-type centering rings. www.ApogeeRockets.com/education/downloads/Newsletter126.pdf

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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.

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