PEAK OF FLIGHT NEWSLETTER

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Making Model Rockets From Rigid Foam Sheets

By Thomas Stuart

I have always been impressed with the shapes of foam radio control aircraft and decided to see if it was applicable to model rocketry. The obvious advantage here is that the foam could be shaped to provide surface detail for scale rockets or curvy outer shape for fanciful ones. I also postulated that if the technique were viable enough, rocket designs could be made with fin cans that followed area rule for better performance in supersonic flight.

I wanted to determine that the foam could be used as a structural member of the rocket design and not a simple overlay on a structurally complete airframe to this end, the fins and later the nose itself would be connected to the inner body tube only through the foam.

It should be noted here that at the start of this project, I had very little knowledge of the state of the art in rocket building, having been out of the hobby for a while, and only possessed basic hand tools, with the exception of a drill press and band saw both of which proved to be luxury rather than necessity in airframe construction. Having said that, construction is fairly easy. That is not to say that I built this project particularly well, I was learning as I went. I believe that you first learn to make ugly shapes that work then learn to make working parts look good. That said, I always did the math to assure myself that this project would work correctly, I simulated worst-case conditions to establish and stay above minimum requirements.

About the Rocket

The rocket described in this project is the Wildcat Mark 3. The first two airframes built in this series were non-flyable, Mark 1 being a simple design exercise lacking internal structure for flight and the Mark 2 proving to be too heavy to fly under model rocket rules. The term “Wildcat” refers to the fin shape, originally based on a foreshortened wing of the F4F Wildcat fighter of WWII.

As you can see in **Figure 1**, this is a big rocket, and it surprises most people that the weight is under 1500 grams and it can fly on F motor power.

The rocket itself is made from three, 18” thin wall BT-55 tubes on to which are glued a series of rings made from 2” thick, UL listed foam board. I mention that the foam is UL listed for the reason that listed foam meets a standard for density and will also self-extinguish in the case that it catches on fire. The only other thing directly connected to the inner tube is the 29mm motor mount at the tail, which extends an inch past the last foam ring. Even the shock cord mount ends in the foam, though it penetrates through the tube on its way to the foam. The top tube would extend 3” into the nose cone, holding it in place during flight.

Figure 1:The Wildcat Mark 3 is large but not very heavy.

In essence, the rocket is one big stuffer tube to which all the aerodynamic bits are attached. The concern here was if the foam was strong enough to hold together while under the pressures and G loading of flight as there would be no outer skin on the rocket other than a thin coat of paint, but that what this series of rockets is here to test.

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Figure 2 shows a typical body ring, with 4 lightening holes surrounding a central hole for the body tube to be fit to. This is what the majority of the rocket is built from, with the exception being the nose cone and tail section containing the fins. These were made by; first cutting 6x6" blocks of foam, marking two lines from corner to corner, which form an X in the center of the block, marking the halfway point from center to corner on those lines. What I did next was to drill a 3/16" center hole in the middle of each block, this allowed me to slide the foam block on to a 1/4" rod on a jig I made for my band saw. This held the foam tightly, 3" from the blade of the saw. The foam was then rotated cutting a circle around the center hole.

Figure 2: Foam body ring with lightening holes.

At this point, I want to point out that any machine work on foam generates quite a bit of flying dust. At the very least, a dust mask should be worn during any machine work on foam. I usually rig some sort of mount for a shop vac hose to collect flying dust as well.

What is unseen in **Figure 2** is the collection system mounted below the drill press, pulling the foam dust away from below.

Once the circle cutting was done, the center hole and four lightening holes were drilled using a 1 1/8" hole saw. As you can see, there was enough room to drill twice as many lightening holes. I didn't do that on this airframe because I was planning on mounting the fins directly to the foam. There is plenty of room to make these sections lighter! Also, note that the standard 1-1/8" hole saw you see in the picture makes a hole that is too small for a BT-55 tube. I wanted a tight fit, these rings are going to stiffen the inner tube and the inner tube must be able to transfer quite a bit of force to the foam. I was also worried that the hole saw, being designed for wood, would leave far too rough a surface for the foam to attach to. These problems were all solved by wrapping the hole saw with 100 grit sandpaper and running it through the hole again. I ended up with beautifully finished holes that were nicely tight on the body tubes.

The only exceptions to this method were the bottom three rings making up the boat tail and the top seven which are part of the nose cone. Those were all cut at an angle and did not get the extra lightening holes. The nose cone foam did not even get a center hole. I just cut an increasing angle for the nose, marking the top of one sections circle onto whatever scrap was available then cutting that circle freehand on the bandsaw. The boat tail was cut at a consistent 15-degree angle, which I believe gives decent aerodynamics. I could have cut a final, fourth section for the boat tail, but I was concerned about heat from the motor and decided to leave the last 2" of body tube exposed.

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As seen in **Figure 3**, that leaves me with rings ready to be stacked on body tubes. The lowest section was already completed in that picture (there is a hole in my workbench that the last bit of body tube is sticking down through). The fin slots you see in the picture were cut on each individual ring with the band saw after making a fin pattern using a piece of thin cardboard to keep them consistent from ring to ring. That actually worked out rather well.

Figure 3: Completed cut foam rings with fin slots.

Each ring would slide down the body tube on to the previous ring after applying wood glue to the lower ring and body tube area. I kept the glue layer thin so that it would grip and hold after only a few seconds of pressure.

As I came to the end of a tube, I coupled on the next section of tubing and continued the build. Since the nose did not have a tube to use for alignment, I clamped the slanted circle cuts together in eighths, and fourths, then finally the two halves together. Once the body sections were together, I sanded the entire assembly and shaped the nose.

When I build the next rocket in the Wildcat series, I will use Gorilla Glue at least around the edges (because it will expand a bit and fill gaps). I might also rig up some sort of jig to keep weight on the stack. This is all because gaps appear between the ring segments if the two surfaces are not perfect. That does not hurt the structure, but it does look bad. Also, I may use a 50/50 mixture of white glue and water to adhere a newspaper layer to the surface of the nose cone. That would add some much-needed surface toughness (the current nose cone is starting to look like a golf ball).

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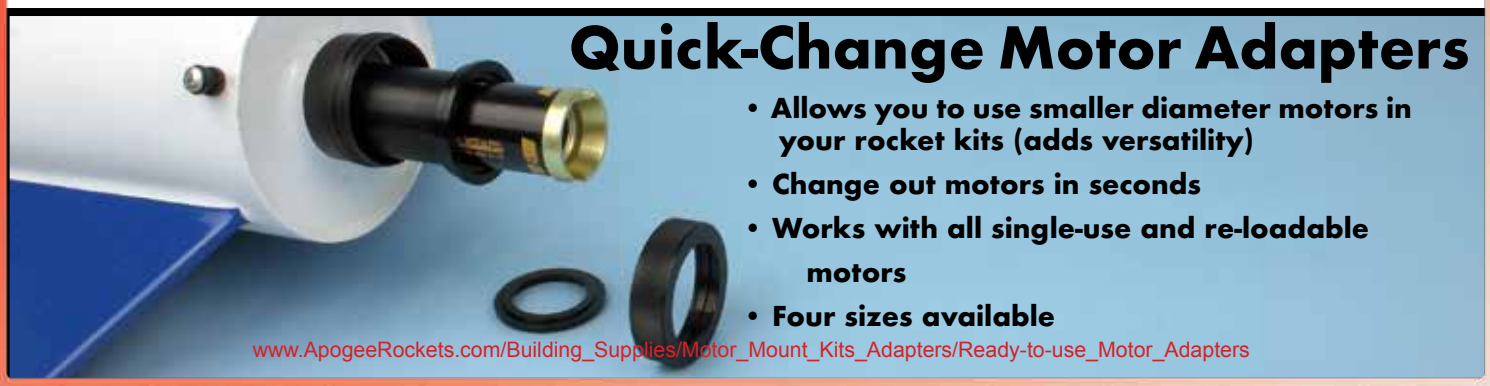

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The fins (**Figure 4**) are foam core poster board cut to shape and glued into the slots in the foam. They look weak, but the attachment area is around 14 square inches per fin! In fact, even after several launches using G78 motors and using the original oversize fins, I could find no evidence of weakness in the attachment. Foam core board worked great in every way except for the edges. I have not found a good way to finish the leading and trailing edges. In the end, I simply chamfered the leading edges a little then covered them with colored vinyl tape. The trailing edges were tapered down some but ended up looking bad. I painted the exposed trailing edge foam with white glue and told myself that they needed to be draggy to test the attachments.

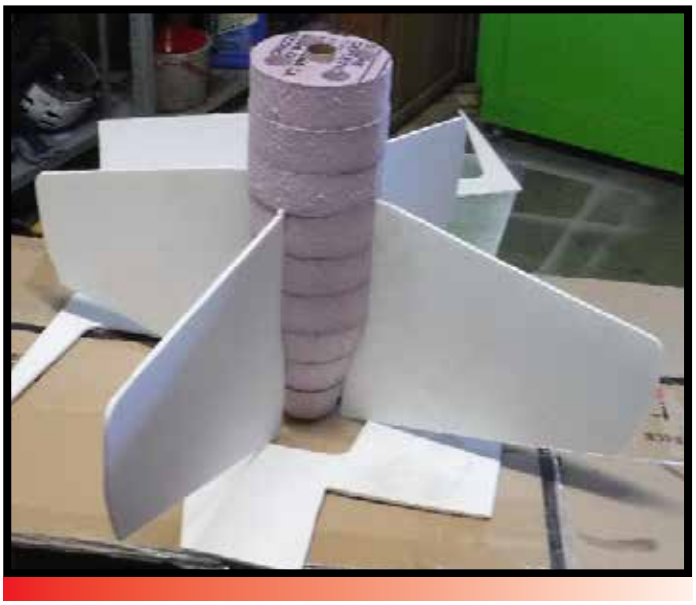

Figure 4: The fin can with the fins temporarily put in place.

I made a 30" parachute for it that was calculated to bring it down easy, This proved to be a mistake, but I was on the large side, not the small. More on that later. Shock cord was run through the inner tube and foam to one of the lightening holes where it got a nylon washer then was knotted and glued. Tests with this method proved it good to 20 pounds of straight pull, which I thought was adequate. You can imagine my surprise when I found that mid-power rockets were using steel hardware and 500-pound test shock cords!

The surface of the rocket originally was very rough, it took a lot of sanding to get it right, which brings us to the next part, finishing. I cannot overemphasize how much foam hates solvents. Everything that adheres to the foam for finishing was water based. For the body section, I found some latex, sandable primer which I brushed on and sanded with 220 grit paper for final smoothness. The nose cone was brushed with a 50/50 mixture of white glue and water then primed then sanded smooth. There were a couple of spots that I sanded too thin and those had to be repainted with water based primer to protect them from the solvent based spray paint I used for final finishing. In the end, there were two places that had pinholes in the finish that allowed the spray paint to eat ugly little holes in the surface of the airframe. They were not a structural problem, merely unappealing. The color scheme was neon orange and chartreuse to make it easier to find on the frozen lake it would launch from.

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Calculations put the center of pressure for the rocket just above the tops of the fins with the measured center of mass (with motor) 12" above that. Simulations showed that a G-74 would get it off a seven-foot launch rod with a little speed to spare. Apogee would be a moderate 300-400 feet on a 4 second delay time.

Figure 5: First launch

The first launch (**Figure 5**) was on a clear subzero day with no wind. Performance during the powered flight was perfect. The rocket rose straight with no noticeable spin whatsoever. It coasted into a nice, small arc, the ejection charge fired when the body was horizontal and then the motor retainer failed.

The motor casing ejected out the rear when the parachute was still one inch from being completely clear of the inner tube. The ejected nose cone was drawn backward along the body, folding the chute tight against the portion of the inner tube that had extended into the nose cone to keep it in place. At this point, the rocket returned to earth in what looked to be the slowest ballistic trajectory ever. Even with it landing right on the hard ice there was only minor cracking in the upper two rings. Its performance seemed comparable to the Nerf dart that it looked like.

The fault was mine for using a black powder engine hook with a composite motor. This was aggravated by it having to push a 36" parachute out of a five-foot-long BT-55 tube. A wrap of electrical tape would solve the motor retention problem, but that would not mean that the chute would come out! There was a load of friction in that system and I wanted it gone. That meant a redesign of the upper portion of the rocket adding more room for the recovery system.

Once the damage was assessed, I replaced the two rings damaged on landing and replaced them with three rings of body diameter and ¾" thickness. The new "parachute bay" section added to the top of the airframe would now allow plenty of room for recovery gear to come out without friction. The floor of this bay was covered with a thin cardboard layer leaving an opening in the center for the ejection gasses to pass through. The nose had a thin, wide cardboard ring attached that would slide into the new, larger opening afforded by the redesigned parachute bay and hold the nose cone in place during flight. The nose cone ring was easy to add. I simply slit a circle 1 inch deep into the base of the nose cone, then slid the cardboard into the slit with some glue added.

Having a large bay with a flat floor for the recovery gear worked far better than expected. The chute does not even have to be carefully folded

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now. As long as it is not actually tangled when it is put back in the bay, it comes out fine.

Even though the existing fins were very light, I was sure that they were extremely draggy. I ran some simulations to see how much fin I could lose and remain stable. It turned out that I could remove two-thirds of the fin span and still retain over one caliber of stability.

Subsequent flights in the new "mod IV" configuration worked flawlessly with the only other modification being the removal of the motor hook and taping the motors in for launch.

Final Modification

With the newly expanded parachute bay up top, it now needed a place to put electronics. This is where the foam body makes things easy. I bent corrugated cardboard to the curve of the body for a cover, then I milled a corresponding rebate into the side of the airframe. Once the cover was fitting nice and flush with the rocket surface, the inner foam was milled away and a plastic frame was glued to the foam to give cover screws something to bite into (**Figure 6**). The frame was just a plastic baby food container that would work as the bay interior.

All this "milling" was done on a drill press, by simply locking the spindle in place, with a Dremel milling bit in the chuck, then rotating or sliding the rocket body around on the table under it. None of this was super accurate work. If I got it to within a 1/16 or so, that was fine

Forming simple curves in corrugated cardboard is easy. Simply wet one side then hold that side down against a round form till dry. The wet side will want to expand and bend the opposite direction, but the wet cardboard will easily take the new shape. I found that ace bandages work well for clamping wet cardboard against a round surface (using the rocket for a form) while the cardboard to dries. Once dry, I added a new layer of heavy paper to the compressed side of the cardboard with wood glue to retain the strength of cardboard, then pressed the piece to the form again till the glue dried.

Figure 6: Electronics bay installation

Final Thoughts

This is a great project for rocketeers too young for high power, but who are ready for bigger rockets. It also makes an excellent demonstration rocket as it is quite visible throughout the whole flight and does put on a good show. As it uses model rocket motors and has a super squishy body, the spectators do not have to be very far away.

The rocket has stood up to a great deal of abuse and many flights, so obviously it is still too heavy. The experiment with the parachute bay has shown that much more material can be removed from the foam rings while still producing a strong airframe

The blue board worked well, but there are lighter fire resistance foams out there. Type I EPS board should allow mid power airframes up to five inches diameter and ten feet long if the foam proves to be as structurally sound as the denser foams seem to be.

When dealing with large diameter airframes that are so lightweight, you are going to have very short coast times. Slower burning, longer thrust motors work well here. It also has a very "soft" apogee, meaning that a 4-second delay may be optimal for certain motors, but it won't be going down very fast even after 7 seconds and can still deploy a parachute without damage.

Obviously, the surface finish needs to be addressed, but as light, as the body is, it benefits from a large cross-section and the strength it provides. A super lightweight fiberglass coating as an outer layer could make the airframe stronger still. This would also allow for a much smoother finish.

About the Author

Tom Stuart is a former F-14 and UH-60 airframe and hydraulics mechanic trained as a mechanical engineer, however he decided to work as an industrial electrician on Alaska's North Slope for 20 years before Underwriters Laboratories made an honest engineer out of him. He now inspects and tests products and equipment for safety all over the United States. He enjoys building a working rocket out of whatever he can (even trash) if no better materials present themselves.

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