PEAK OF FLIGHT NEWSLETTER

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DIY ALUMINUM THRUST PLATE FABRICATION

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PEAK OF FLIGHT

DIY Aluminum Thrust Plate Fabrication

By Josh Frizzell

1: Introduction – What is a Thrust Plate?

Typically, one would construct a model rocket motor mount by starting with a motor mount tube just large enough in diameter for the motor to slide into, attach centering rings with some form of adhesive, then further glue the centering rings into the rocket's body tube (Figure 1). The result is concentric tubes secured to each other with the adhesive providing the physical link between the motor and the body tube. In that case, thrust force from the motor is transmitted through the adhesive bond to the outside of the motor tube and the inside of the body tube, and that force acts in a direction parallel to the tube surfaces. Certainly, there are exceptions such as the minimum diameter rocket design, but the centering ring/motor tube design is ubiquitous in low power, mid power, and well into high power rocketry. That's perfectly adequate in most model rocketry applications, but when high thrust motors are added to the equation, the thrust generated could be enough to overcome the adhesive bonds to the tube surfaces and centering rings, resulting in a motor mount failure.

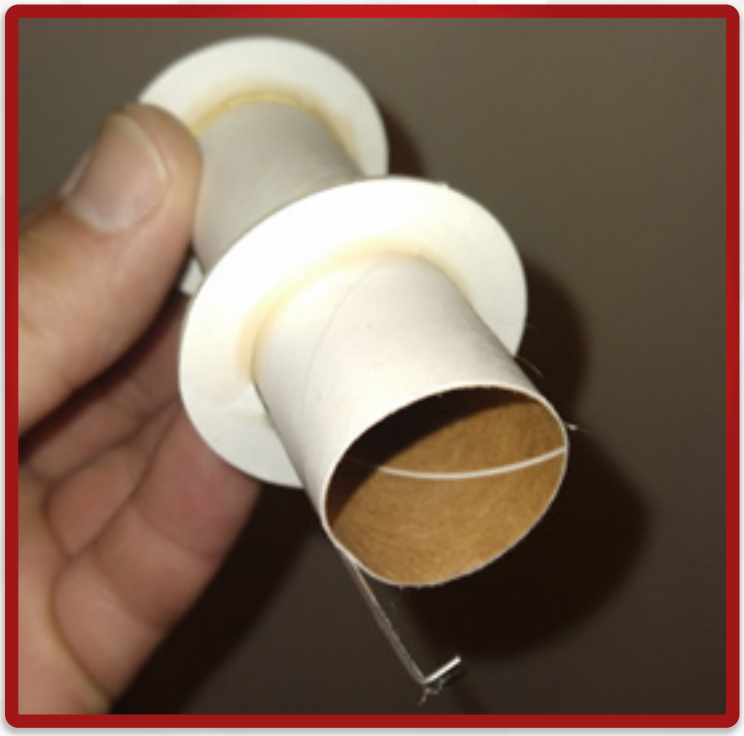

FIGURE 1: CONVENTIONAL LOW POWER MOTOR MOUNT WITH CENTERING RINGS.

The solution? Enter the thrust plate. Instead of transmitting thrust force through adhesive bonds attached to surfaces parallel to the thrust force direction, we can transmit thrust force normal (perpendicular) to the rocket body tube aft end, thereby eliminating the shearing forces that occur with a traditional centering ring-based design. The motor pushes the rocket from the back, rather than from the inside.

Thrust plates are available commercially, pre-machined for common airframe diameters and drilled for commercially available flanged aluminum motor retainers (https://www.apogeerockets.com/Building_Supplies/Thrust_Plates). Those thrust plates offer out-of-the-box installation readiness and a tidy, professional look to the aft end of a rocket. However, we can also produce our own custom thrust plates with common tools and easily obtained materials. By investing some time and elbow grease we can create aluminum thrust plates of practically any diameter, configured for any motor diameter or retainer option, that are visually appealing and come with the satisfaction of a DIY project and likely some cost savings.

2: Fabrication

For this example, I'll be creating a custom thrust plate for an 8.25-inch outer diameter fiberglass over cardboard airframe with a 75-millimeter motor mount, but the steps involved can be adapted to other motor mount and airframe sizes or airframe materials.

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You can subscribe to receive this e-zine FREE at the Apogee Components website www.ApogeeComponents.com, or by clicking the link here Newsletter Sign-Up

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2.1: Pre-Build Considerations

For this thrust plate construction technique, I will be using threaded tee nuts to secure the thrust plate to the airframe. The tee nuts will be installed on the inner side of the aft centering ring, so the tee nuts will need to be added before the aft centering ring is epoxied in place. In this case I used ½ inch thick plywood for the centering ring, so I selected pronged tee nuts. The sharp tee nut prongs are hammered into the plywood to keep the tee nut in place, and I also added some epoxy to each tee nut to make sure it stays securely in place. For other centering ring materials (e.g., fiberglass), non-pronged tee nuts can be epoxied in place with the threads facing inward (forward).

2.2: Materials

I created the example thrust plate from a 2 millimeter thick, 10-inch diameter aluminum plate disc purchased on eBay for around 12 dollars (Figure 2). The 2mm thickness provides a balance of strength and weight for the project at hand, but a thicker plate could also be used for additional strength.

For this project I secured the thrust plate to the aft centering ring using eight size 10-24 tee nuts and bolts. I also provided motor retention using an Aeropack flanged 75mm motor retainer (https://www.apogeerockets.com/Building_Supplies/Motor_Retainers_Hooks/Screw-On_Retainers/75mm_AeroPack_Retainer_Flanged). Since the retainer contacts the rear of the thrust plate, its design is consistent with the goal of applying thrust force to the rear of the rocket rather than internal components. An alternative to the Aeropack retainer could be to cut the motor hole in the thrust plate large enough to accept the motor but small enough to engage with the motor's thrust ring. This approach, although likely more economical, would require a precision center hole cut and some other form of motor retention (e.g., a threaded rod with a nut and washer). Both approaches require that the aft end of the motor mount tube is installed flush with the aft end of the airframe tube.

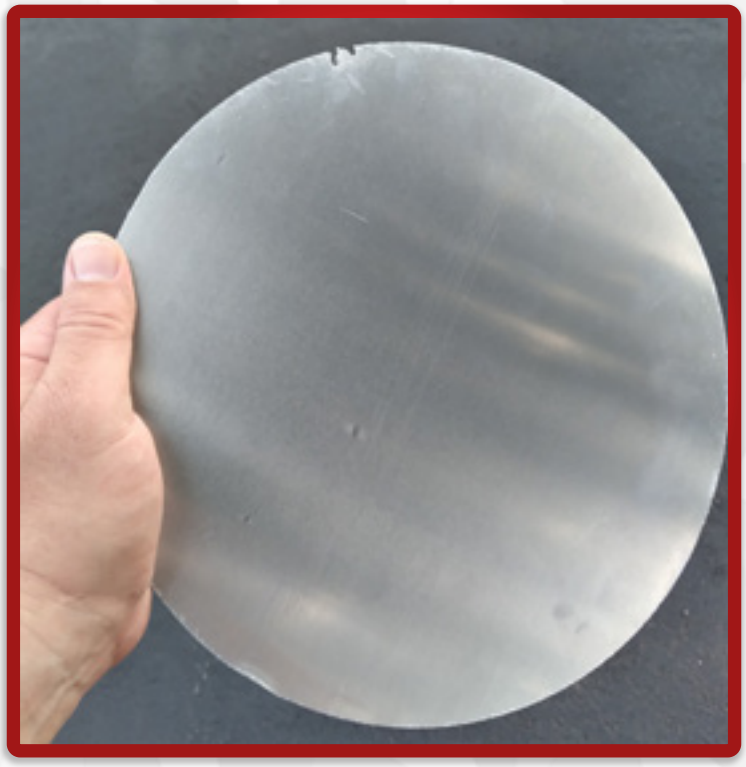

FIGURE 2: 10-INCH DIAMETER SHEET ALUMINUM BLANK.

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FIGURE 3: FINE-TOOTHED METAL CUTTING JIG SAW BLADE.

FIGURE 4: ELECTRIC DRILL WITH STEP DRILL BIT.

2.3: Tools

Since aluminum is a relatively soft metal, we can get away with using common, non-specialized tools to fabricate our thrust plate. To cut the thrust plate to size and shape I used an electric jig saw with a fine-toothed metal cutting blade (Figure 3). Holes for mounting the thrust plate to the rocket and for mounting the motor retainer body were drilled using a hand-held electric drill with a 1/8” to 1/2” sized step drill bit (Figure 4). Flapwheels for the electric drill are also useful for finalizing the shape of the thrust plate and arriving at smooth edges. I found a 40 grit flapwheel ideal for moderate shaping and an 80 grit flapwheel good for sneaking up on the final inner and outer dimensions (Figure 5). A center punch or a hammer with a sharp nail are also important to ensure precision placement for drill holes. We’ll also need a compass to lay out some circles, a protractor to measure the angles between drill holes, and ideally an ultra-fine point Sharpie permanent marker. Handy but not required is an angle grinder with an abrasive conical flapwheel (Figure 6). The angle grinder will allow for rapid material removal from the outer diameter of the thrust plate if needed. However, careful attention to detail in the cutting phase should eliminate the need for the angle grinder.

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FIGURE 5: ABRASIVE FLAP WHEEL FOR AN ELECTRIC DRILL.

FIGURE 6: ANGLE GRINDER WITH ABRASIVE CONICAL FLAP WHEEL.

3: *Cutting Pattern*

To establish the correct shape and dimensions for the thrust plate, I began by tracing the outer diameter of my airframe tube onto my aluminum disc with a Sharpie, demarcating the outer diameter of the outer cut in the aluminum (Figure 7). Keep in mind that the outer diameter of the thrust plate must overlap the aft end of the body tube to serve its purpose, but for aesthetic and aerodynamic drag considerations should ideally not extend beyond the outer diameter of the body tube. For some fiberglass airframes that might mean dimensional tolerances of one mm or less. With that in mind I used a fresh, ultra-fine point Sharpie to create a precision line to guide the cut for the outer diameter of the thrust plate.

To correctly place the center hole for the motor we'll need to locate the center of the circle we created to mark out the thrust plate's outer diameter. I traced the outer

FIGURE 7: BODY TUBE OUTER DIAMETER TRACED ONTO ALUMINUM BLANK.

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diameter of the airframe tube onto a piece of paper, cut it out, and folded it in half. Lining up the half circle of paper inside the outer diameter circle drawn on the aluminum from two directions and tracing along the straight edge of the paper marks the center where the lines cross (Figure 8). Repeating from a third direction confirms it (Figure 9).

After locating the center of the thrust plate, I made a small indentation at the center point using a sharp nail and a light blow from a hammer. A compass set at the radius of the hole needed for the motor to pass through the center of the thrust plate (37.5mm in this case). My compass only accommodates pencil, so I carefully traced over the compass line with ultra-fine tip Sharpie to make the mark more visible during cutting. If using the Aeropack flanged retainer it is best to err slightly too large for this hole since the flange will still have plenty of surface to contact with the thrust plate, but any error on the too small diameter side will prevent the motor from being inserted through the center hole. If not using a commercially made retainer, a high degree of precision will be necessary to make sure the motor's thrust ring will be in contact with the thrust plate. I recommend verifying the final inner circle dimension using a motor casing (and thrust ring, if applicable) and retainer before proceeding to cutting steps to ensure the center hole will be large enough for the motor to fit through but small enough to leave plenty of material for the retainer to butt up against.

Before cutting I also marked holes that would need to be drilled to mount the thrust plate to the aft centering ring with size 10-24 bolts. First, I traced out a circle demarcating the distance from the center of the thrust plate to the bolt holes using the compass. Then, using the protractor, I marked out eight evenly spaced marks for each bolt hole.

FIGURE 8: MARKING CIRCLE CENTER ON THE ALUMINUM BLANK.

FIGURE 9: VERIFIED CIRCLE CENTER ON THE ALUMINUM BLANK.

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4: Making the Cut(s)

A jigsaw fitted with a fine-tooth metal cutting blade easily cuts 2mm thick aluminum plate. Slow and steady with the goal of high precision is worth the time spent. Keep in mind, for the outer diameter cut, we want to be close to the outer diameter of the airframe but can't error on the too-small side of our target diameter. If the outer diameter is too small the thrust plate won't press up against the back of the airframe and its purpose will be defeated. If the thrust plate outer diameter is too large, we can reduce the diameter with other tools (e.g., abrasive tools such as a flapwheel-equipped drill or grinder), but a careful initial cut will reduce refinement work later. For very thin-walled airframe materials such as thin-walled fiberglass it may be wise to slightly overshoot the target outer diameter and sneak up on the outer diameter of the airframe using abrasive tools to avoid scrapping a piece of aluminum that ends up too small. Also keep in mind that the blade will remove a kerf, so the edge of the blade should move along the outer edge of the outer diameter mark line.

The inner hole for the motor can also be cut with the jigsaw (Figure 10). The entry hole for the blade can be drilled using the stepped drill bit. This is also a good practice opportunity with the stepped drill bit. Once established at the first diameter the bit will very easily and surprisingly quickly advance to the next step larger diameter. This is fine for creating a starter hole for the jigsaw blade since the center piece will be discarded but drilled holes for the mounting bolts and screws (described below) can't end up oversized.

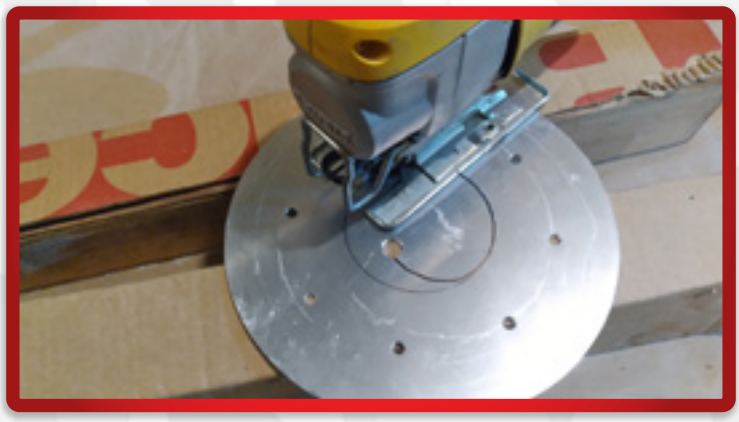

FIGURE 10: CUTTING THE MOTOR HOLE WITH A JIG SAW.

5: Drilling Holes

We'll need holes for mounting bolts to secure the thrust plate to the aft centering ring and, if using a flanged retainer, holes for the retainer mounting screws. Both tasks can be easily completed using a stepped drill bit. Drilling the holes for the thrust plate mounting bolts first will make it easier to mark out and correctly align the holes for the retainer mounting screws because the bolts will allow the thrust plate to be temporarily installed correctly centered over the motor mount tube. For each thrust plate mount bolt hole, I made a small indentation at the hole location using a nail with a light tap from a hammer. This prevents the drill bit from "walking" away from the intended hole location. Then we can carefully advance the stepped drill bit into the aluminum. The first step will take more effort to get started than the successively diameter steps, so use caution not to press the drill into the workpiece excessively or risk ending up with an oversized hole.

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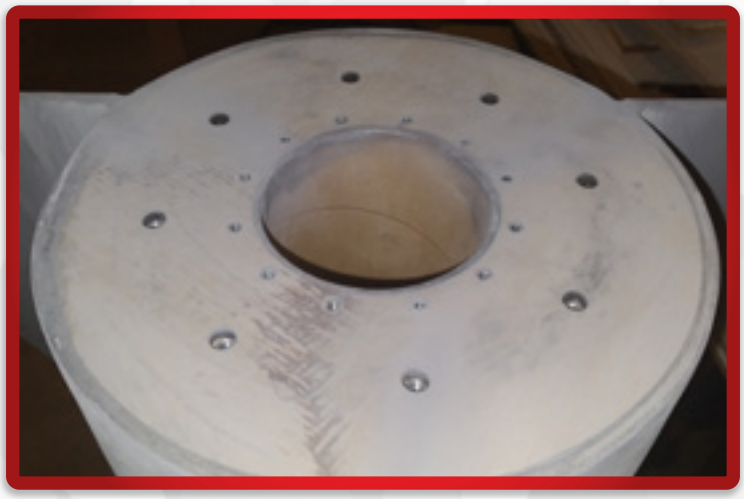

FIGURE 11: AFT CENTERING RING WITH TEE NUTS FOR SECURING THE THRUST PLATE AND THREADED INSERTS FOR THE MOTOR RETAINER INSTALLED WITH EPOXY.

6: Pre-Installation

Before permanently installing the aft centering ring I added size 10-24 tee nuts to the holes previously created in the centering ring. With the tee nuts in place, I installed the aft centering ring loosely with no epoxy and used the tee nuts to bolt the thrust plate temporarily in place. I placed the Aeropack retainer over the center hole of the thrust plate and used an unloaded motor casing to align it with the hole for the motor. With the retainer centered I used a fine point Sharpie to mark the 12 holes needed for the threaded inserts that secure the retainer to the aft centering ring using the holes in the retainer as a guide. As with the thrust plate mounting bolt holes, I used the point of a sharp nail with a light hammer tap to create an indentation in the aluminum to prevent the drill bit from walking away from center. After drilling the holes for the threaded inserts, I removed the thrust plate and retainer and installed the threaded inserts. After completing a dry fit check, it's time to permanently install the aft centering ring with epoxy (Figure 11). Ensure that the bolt holes don't line up with the fins so the bolts extending through the centering ring don't conflict with fin tabs inside the airframe.

7: Finishing

With the thrust plate cut to shape and all necessary holes prepared, it's time to give the thrust plate a professional-looking shine. Since aluminum is a relatively soft metal, we can use sanding techniques like what we might use for other common rocket materials such as plywood. Sanding will create aluminum dust, so where possible I prefer to use the wet sanding method to maintain dust control. Dipping wet/dry sandpaper in water will help keep the sandpaper from clogging and create a slurry that prevents creating a dusty aluminum mess.

I started by sanding the edges of the thrust plate using a 40 grit flapwheel on an electric drill to remove jigsaw tool marks and complete any final shaping to match the shape of the airframe. This step is not conducive to wet sanding if using the flapwheel since the flapwheel would wildly fling aluminum slurry if water was thrown into the mix. Instead, I donned a particulate dust mask and used dry sanding. Of course, regular sandpaper with hand sanding could be an alternative if wet sanding is preferred. I followed up with an 80 grit flapwheel to help smooth the edges and hand sanded with wet sanding using progressively finer grit sandpaper until I was happy with the finish.

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For the flat surface of the thrust plate, I began wet sanding using 220 grit sandpaper to remove scratches left by the jig saw while cutting the initial shape. I found the seemingly most effective way to remove material while sanding aluminum is to sand in a straight-line pattern for several strokes, then change direction and sand in a perpendicular direction with subsequent alternating back and forth between sanding directions. This approach seemed to be more effective than sanding in a swirling pattern.

Once I had removed the scratches from initial fabrication, I began wet sanding using progressively finer sandpaper (Figure 12). I progressed from 220 grit to grits of 320, 400, 600, and 1000. After sanding with 1000 grit sandpaper, I was happy with the result. Certainly, one could go finer if desired, using grits of 2000 or even finer for a high-shine polished result. Figure 13 shows the sanding in progress, with obvious scratching left by the 220-grit sandpaper on the left and sanding completed through 600 grit on the far right of the thrust plate.

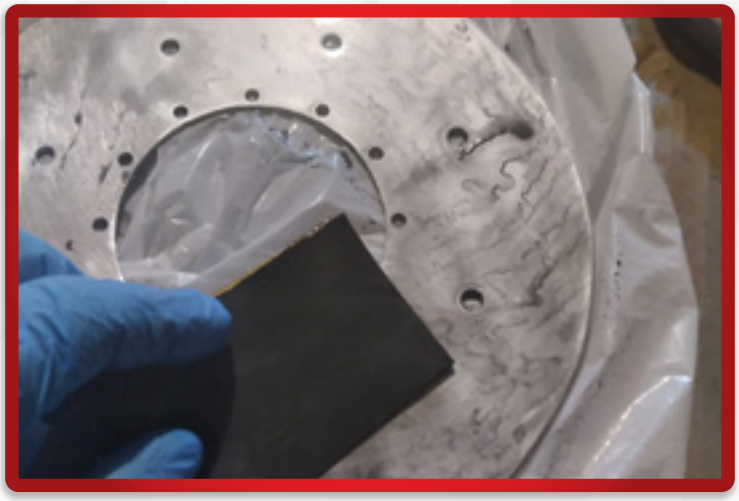

FIGURE 12: WET SANDING WITH PROGRESSIVELY FINER SAND-PAPER.

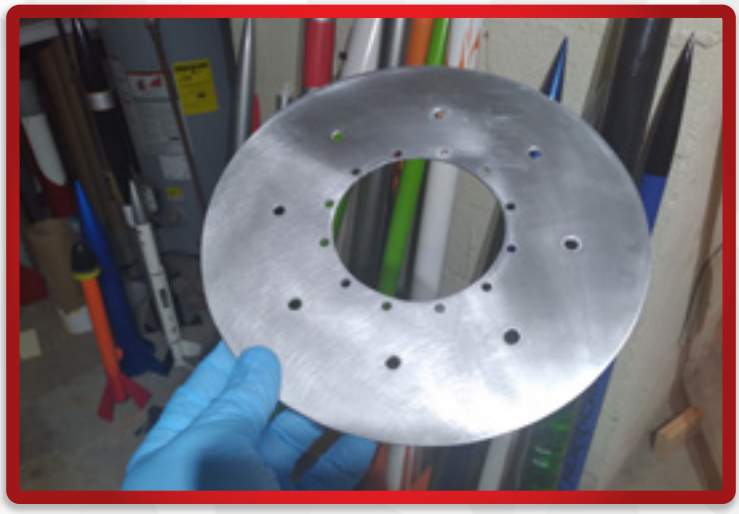

FIGURE 13: COSMETIC SURFACE SANDING IN PROGRESS WITH 220 GRIT SANDING COMPLETED ON THE LEFT AND 600 GRIT SANDING COMPLETED ON THE RIGHT PART OF THE THRUST PLATE.

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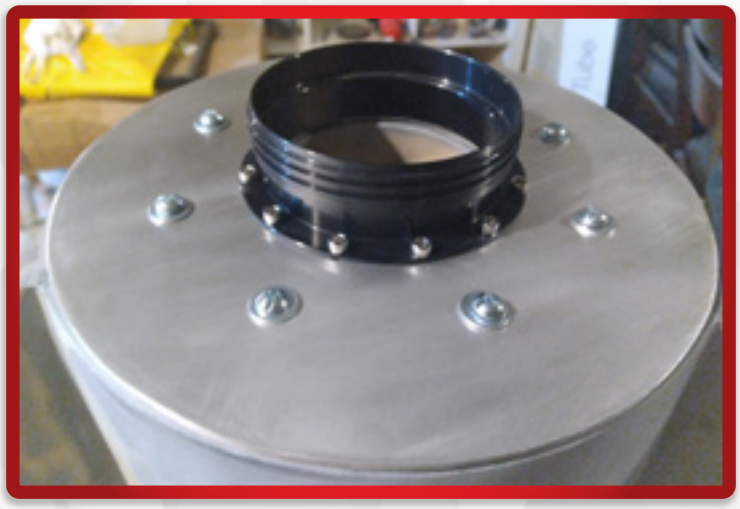

FIGURE 14: FINAL INSTALLATION OF THE THRUST PLATE AND MOTOR RETAINER.

8: Completion

With final tweaks to the outer diameter of the thrust plate and cosmetic finishing completed, it's time to perform final installation of the thrust plate and motor retainer. Since we have equipped the aft centering ring with tee nuts and threaded inserts, we only need to align the bolt holes, install the bolts, and do the same for the retainer and retainer screws (Figure 14). I applied a bit of blue Loctite to help ensure all the hardware stays in place.

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9: Conclusion

Thrust plates can not only help relieve shearing forces that might otherwise break free centering rings or motor mount tubes when subjected to high-thrust motors, but cap off the aft end of a rocket with a sharp, metallic look. Admittedly, thrust plates fabricated as described in this article don't quite have the sexy fit and finish of commercially produced machined aluminum counterparts (e.g., those made by SC Precision, see www.apogeerockets.com/Building_Supplies/Thrust_Plates). However, attractive, effective DIY thrust plates can be produced economically and for any custom size of airframe and motor mount, not to mention leaving you with the satisfaction of having done it yourself.

Author Bio:

Josh Frizzell has been building and flying rockets since his childhood in the 1980's. Josh is NAR Level 2 High Power Rocketry Certified and is also a NAR certified "Rocket Science Teacher."

Reader Submitted Photos Detailing the Flying Machine

From Eric Becher

PHOTO 1: HALF PEARLS FROM AMAZON

PHOTO 2: APPLICATORS

PHOTO 3: APPLYING THE HALF PEARLS TO THE FINS

PHOTO 4: ASSEMBLED

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Reader Submitted Photos Detailing the Flying Machine

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PHOTO 5: WOOD FINISHED

PHOTO 6: STAND

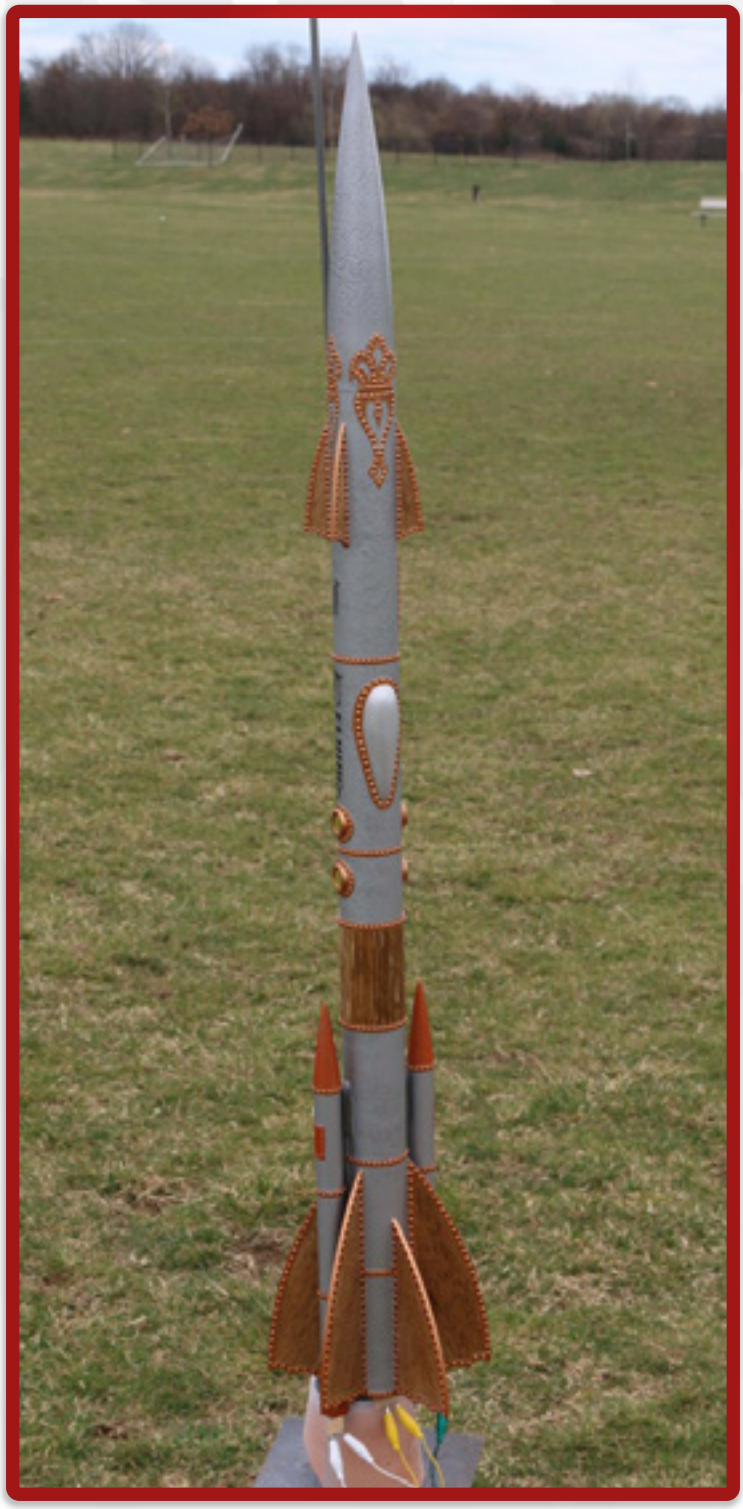

PHOTO 7: STAND

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Reader Submitted Photos Detailing the Flying Machine

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PHOTO 8: FLYING MACHINE

PHOTO 9: FRONT LEFT SIDE

PHOTO 10: TAKEOFF

PHOTO 11: SEPARATION