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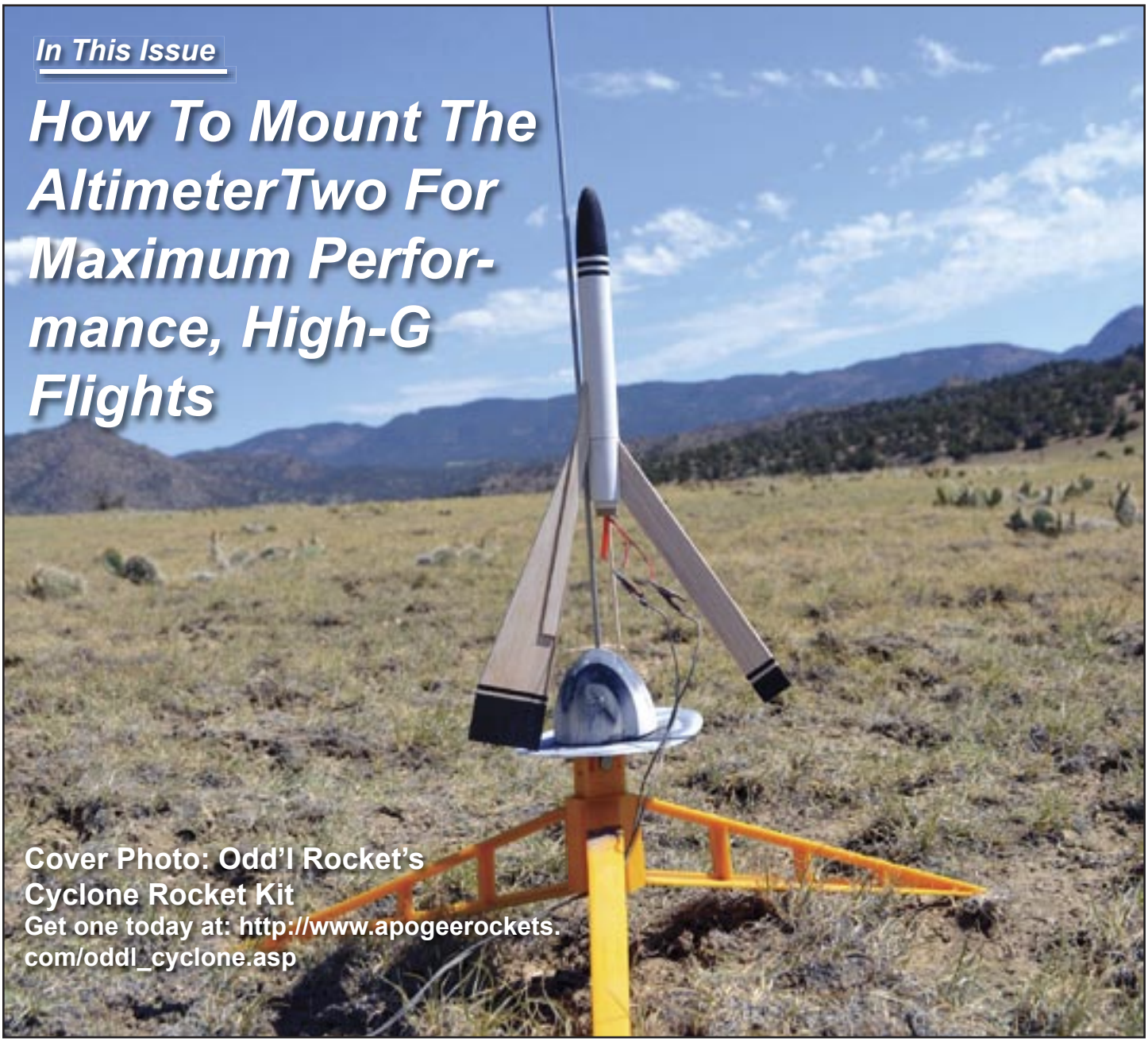
PEAK OF FLIGHT

NEWSLETTER



In This Issue

How To Mount The AltimeterTwo For Maximum Performance, High-G Flights

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How To Mount The AltimeterTwo For Maximum Performance, High-G Flights

By Steven Collins

Overview

The Jolly Logic AltimeterTwo (www.ApogeeRockets.com/AltimeterTwo.asp) is awesome in that it can accurately compute the peak speed of a rocket at lift-off by measuring its lift-off acceleration forces. It does this using a three-axis accelerometer capable of measuring up to 24 Gs in each axis. The typical installation, such as hanging the AltimeterTwo on the parachute loop of the nose cone, results in one axis of the accelerometer being aligned with the thrust axis of the rocket. This limits the AltimeterTwo to measuring only 23 Gs, after accounting for the Earth's gravitational field. At 23 G's, it takes about 1.5 seconds for a rocket to reach the speed of sound (roughly 700 mph). For most rockets, this acceleration-limit is sufficient for the AltimeterTwo to capture the maximum speed of the rocket at lift-off. As an example, the Apogee Apprentice rocket (www.ApogeeRockets.com/Apprentice.asp) on a B6 motor will hit around 21 Gs at lift-off.

But for lightweight rockets with high-thrust motors, this limit of 23 G's can easily be exceeded. What this means is that the maximum speed shown on the AltimeterTwo after the flight will be too low. Note: The altitude of the rocket is measured independantly by a pressure sensor, so it is not affected by the acceleration limit of the 3-axis accelerometer. That means the altitude measurement will be accurate regardless of the speed of the model.

The instruction manual that comes with the AltimeterTwo states that if the device is mounted in a '"one corner" highest' configuration, it is capable of measuring in excess of 40 Gs of acceleration due to thrust. How is this possible? It is possible because it is the magnitude of adding the three acceleration vectors together. According to the Pythagorean Theorem, the magnitude of the resultant vector is equal to the square root of ($24^2 + 24^2 + 24^2$). This is 41.56 Gs. Subtract the one gee due to gravity, and you get 40.56 G's.

This is really cool, because at 40 Gs, it takes about 0.87 seconds for the rocket to reach the speed of sound. This means that there is a way to capture that peak speed more accurately if we reorient the AltimeterTwo inside the rocket instead of simply hanging it from the nose cone.

This article examines how to determine what this "one corner" highest configuration looks like and how to implement a mount to hold the altimeter in the optimal orientation within the rocket.

Before You Begin

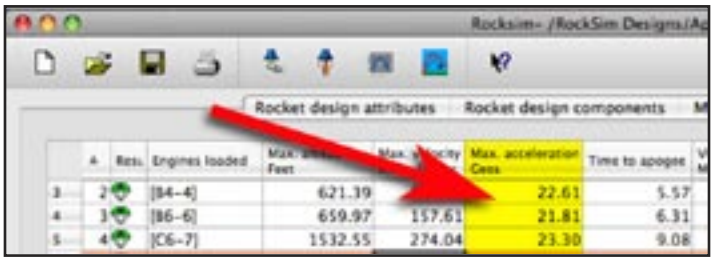

Figure 1: Using RockSim, you can get a good estimate of the maximum Gs on the rocket.

Mounting the AltimeterTwo for high-G flights does take some effort. And as mentioned previously, not every rocket needs this extra sophistication. So before you begin, I recommend that you put your rocket design into the RockSim software and run a simulation with the motor you intend to fly. RockSim will calculate the maximum G's of the flight, and then you can determine if it is worth the time and effort to hard-mount the AltimeterTwo in the rocket. If it exceeds 23 Gs, then you might want to do the mounting.

One last thing to consider - Don't fret too much if your AltimeterTwo is not at the optimum angle described here in this article - it will still work! The optimum angle is for *maximum* G-load. Even at an "off-optimum" angle, you will still get better than the minimum of 23 Gs that you get by orienting the AltimeterTwo long-ways in the rocket. Remember, you may not need the maximum; which is why you're checking RockSim first.

Analysis

The easiest way to see the "one corner" highest configuration is to take a rectangular box, measure equi-

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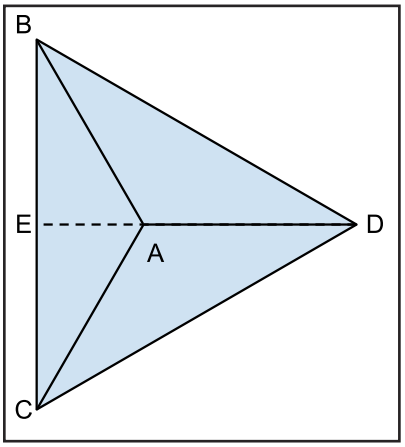

Figure 2: Top view of pyramid.

distant down each of the three edges from a common corner, draw lines connecting each of the measured points to the other two points, and cut the corner off along the three lines. The result is a three-faced pyramid with an equilateral triangle for a base and three isosceles right triangles for faces. Figure 2 shows a top down view of this pyramid. The apex has been labeled "A", and the three corners of the base are labeled "B", "C", and "D". The mid-point of the line between points B and C is labeled "E". If the pyramid is mounted inside a rocket, attaching the AltimeterTwo to a face with two edges of the altimeter aligned to the edges leading to the apex of the pyramid places the altimeter in the correct orientation. The pyramid is not an ideal shape for mounting inside an airframe, so it should be used as a guide to build a mount that fits better. To design this mount you need to know the slope of the face of the pyramid.

To determine the requisite slope, find the relative lengths of various edges of the triangles that comprise the pyramid. Assign an arbitrary value to one edge of the structure and compute the remaining sides. Figure 3 shows the ΔABC face of the pyramid. The face is divided into two smaller isosceles right triangles by extending a line from A to E. The sides of the smaller triangles are all the same length and are labeled "*a*", while the hypotenuses of the two triangles are also equal and labeled as "*b*". If *a* is defined to be $\sqrt{3}$ then you may use the Pythagorean Theorem to determine that *b* is $\sqrt{6}$. Note that the edge between points A and D is the same length as the edge between A and B and thus is also $\sqrt{6}$.

To visualize the slope of the face of the pyramid, take a cross-section of the pyramid that passes through the points A, D, and E. Figure 4 shows this cross-section. Note that the cross-section is another right triangle and that

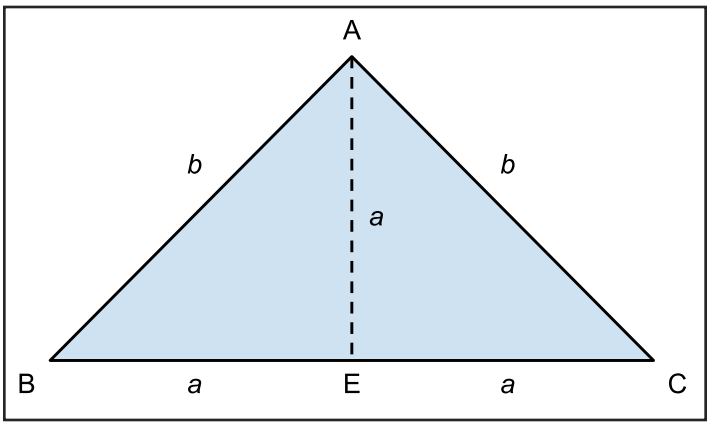

Figure 3: Face ABC of the pyramid

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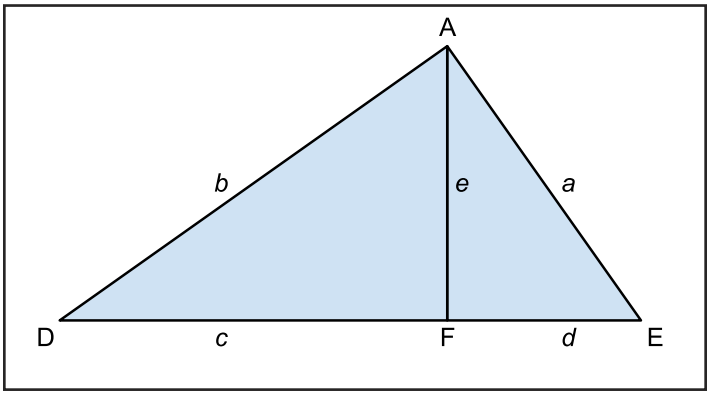

Figure 4: A cross-section of Pyramid from points ADE.

the lengths of the two sides of the right angle are already known. Apply the Pythagorean Theorem again to determine that distance between the points D and E is 3. Divide ΔADE into two smaller right triangles by dropping a line straight down from A to the point F and labeling the edges of the new triangles "*c*", "*d*", and "*e*" as shown in the illustration. Remember that the face of the pyramid is represented by the line AE. To determine the slope of this line you need to determine the lengths of *d* and *e*. Because the three triangles ΔADE, ΔFDA, and ΔFAE all have the same angles they are similar triangles and their sides are proportional to each other, thus you can use the known sides of ΔADE to find the lengths of the sides of the other two triangles.

$$\frac{e}{b} = \frac{a}{c+d}$$

$$\frac{e}{\sqrt{6}} = \frac{\sqrt{3}}{3}$$

$$e = \frac{3\sqrt{2}}{3} = \sqrt{2}$$

Using the Pythagorean Theorem one more time reveals that *d* is 1. Since *c* + *d* is 3 it is obvious that *c* is 2. So the slope of the face of the pyramid is $\frac{e}{d}$ or $\frac{\sqrt{2}}{1}$ or $\sqrt{2}$. In laymen's terms, it is 54.735° as measured off the horizontal axis.

Design

The basis of the mount design is a cylinder (a tube of the proper diameter to fit inside the rocket). Slice through the tube with a plane having a slope of $\sqrt{2}$, attach a flat surface to the cut face of the cylinder, and mount the altimeter at the appropriate angle across the face of the flat surface. How do you find the correct angle to mount the altimeter? Figure 5 shows the proposed cylinder superimposed over the pyramid. The illustration defines the *x* and *y* axes. It also shows a polar coordinate system with 0 along the positive *x* axis. Use the plane defined by the ABC face of the pyramid as the plane that slices through the cylinder and the AB edge as the edge to mount the altimeter. This places the highest point of the sliced tube at 0° and the lowest at 180°. Since the base of the pyramid, BCD, is an equilateral triangle, each of the angles of that triangle are 60° and the edges are at

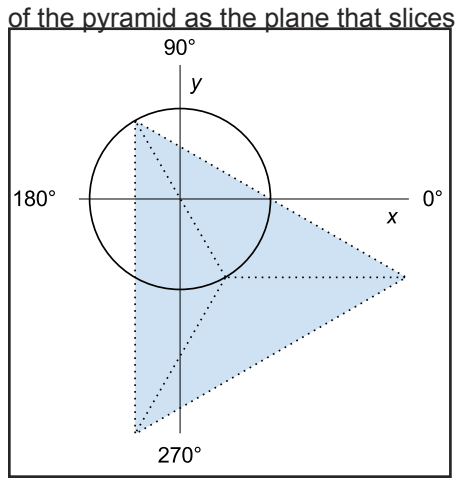

Figure 5: A cylinder cutting through the pyramid.

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30° with respect to the base. This means the edge that the altimeter is mounted along passes through the 120° and 300° positions on the cylinder as shown in the illustration.

To implement this design you need to create a template to apply to the cylinder that will guide the cutting of the tube and the mounting of the flat surface. The height of the plane slicing through the cylinder is a function of the distance along the *x* axis. The distance along this axis as a function of the angle θ around the cylinder is defined as *r cos* θ, where *r* is the radius of the cylinder, so the height of the cylinder as you move around the perimeter is given by the equation $\sqrt{2}\, r \cos\theta$.

Construction

Tube Selection

The first step is to select a tube of an appropriate diameter to fit inside the intended mounting location in the rocket. The tube selection influences the overall height of the mount, so you need to know the maximum height of the mount. The maximum height of the tube is $\sqrt{2}d + m$, where *d* is the diameter of the tube and *m* is the minimum height of the mount. The minimum height of the mount is the lowest point where the plane slices through the tube. You should plan to have some material below this lowest point in order to provide strength to the mount during construction.

Another factor influencing tube selection is that the tube must be big enough to mount the AltimeterTwo without it overhanging the mount. The minimum diameter to meet this requirement is approximately 48mm, so this mount will only work in 54mm rockets and up.

Template Generation

There are three means of creating a template — either printing or drawing one by hand, or using Tim Van Milligan's method shown in Peak-of-Flight Newsletter #121 (www.ApogeeRockets.com/Education/Downloads/Newsletter121.pdf). However, the easiest way is to print the template.

Printing a Template

In order to help you create a template, I have constructed a web site capable of generating a template in the Hewlett-Packard, PCL5 printer control language. If you have access to a printer capable of rendering a PCL5 file, such as an HP LaserJet printer, use this method. The file must be sent to the printer as a "binary" file. Because there are numerous operating systems and each has its own means of printing a binary file this article does not attempt to explain how to print such a file. Refer to the documentation for your particular operating system for printing a "raw" or "binary" file. Sometimes such files use a ".prn" extension, so you may want to search for how to print a file with this extension. Failure to send the template to the printer as a binary file will result in the print using a large amount of paper, which will be mostly blank or with only a few characters.

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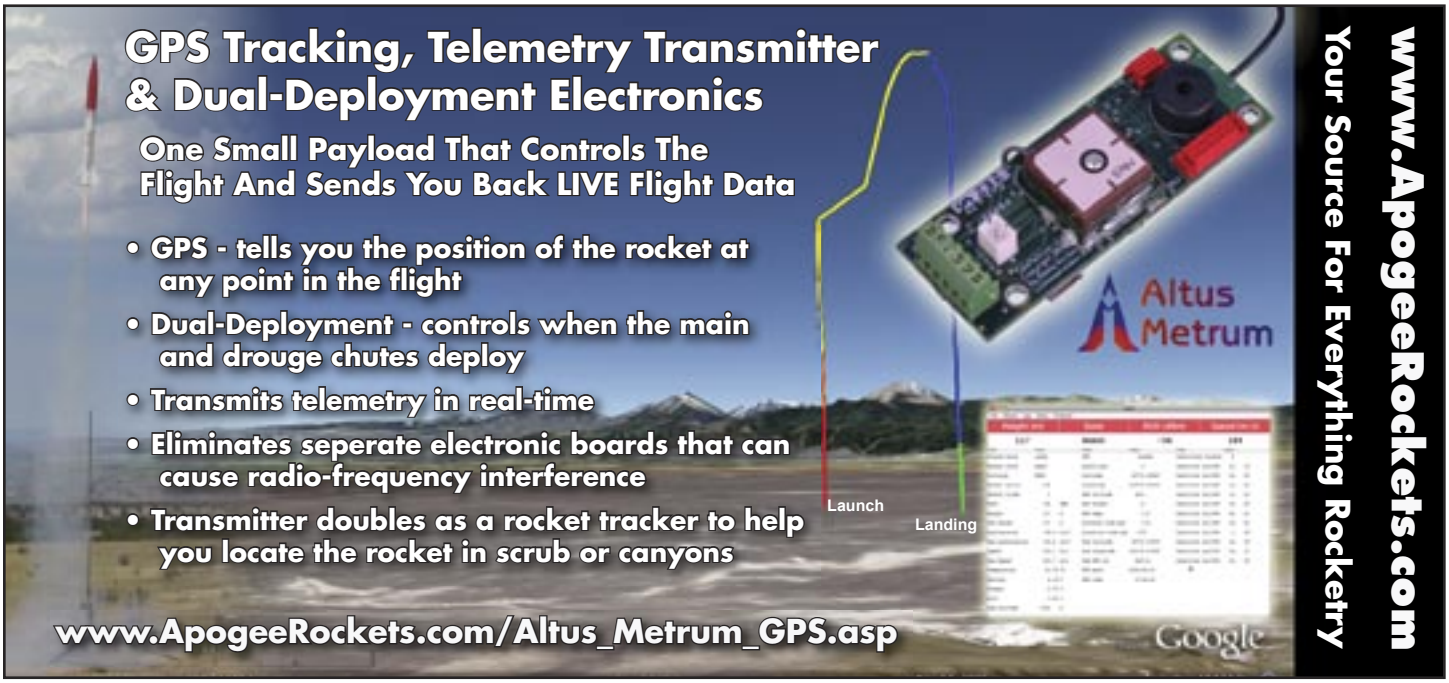

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Visit http://idrocketeer.horizon-host.com/ to generate a template for printing. Input the outer diameter and inner diameter of the tube being used to construct the mount. Enter the minimum height for the mount which is how high you want the mount to be at the lowest point where the plane slices through the tube. After the data is entered, click "Generate Template" to generate and download the template to your computer. You can specify the location where to download the template. Next, send the template file to the printer.

Hand Drawing a Template

Use a sheet of graph paper to draw a template by hand. The largest tube that can be accommodated on a standard 8x11" piece of paper is just under 89mm in diameter. Use the following procedure to draw the template. In the equations that appear in the following steps these variables are used:

r - the exterior radius of the tube, 1⁄2 of the outer diameter.

m - the minimum height of the mount.

Follow these steps:

1. Place a sheet of graph paper in landscape orientation and draw a line across the page near the bottom edge. The line needs to be at least as long as the outer circumference of the mount tube. This line marks the base of the mount.
2. Find the horizontal center of the graph paper and select the nearest line on the graph paper to be the center line of the template.
3. Measure up along the center line from the base line to a distance of $\sqrt{2}r + m$. Mark a horizontal line at this point. This line is the reference line from which you will measure the points that define the intersection of the plane with the tube. We will refer to this line as the *mid line* since it represents the middle between the minimum and maximum points where the plane slices through the tube.

As you compute the height of the cut with respect to the mid line, some values will be negative and some will be positive. Negative values are measured down from the mid line, towards the base line, while positive values are measured up from the mid line.

When locating the mid line it is convenient to adjust the minimum height to align the mid line with one of the printed lines on the graph paper. If you reduce the minimum height make sure you are leaving sufficient material at the bottom of your tube. If you increase the minimum height make sure doing so will not cause the mount to exceed the physical limits of the space where you intend to mount it.

4. Measure one half of the circumference of the tube from

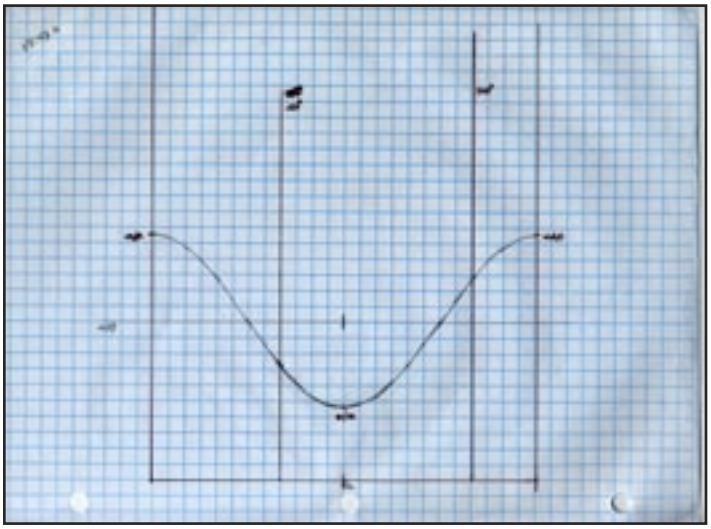

Photo 1: A hand-drawn template on graph paper.

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the center line along the base line drawn in step 1. Draw a vertical line at this point that is at least as high as the maximum height of the mount. Measure from the mid line up the vertical line and mark the maximum height ($\sqrt{2}r$).

5. Repeat step 4, measuring in the opposite direction from the center line along the base line. The two vertical lines mark the left and right edges of the template and should meet when the template is wrapped around the tube. The left-hand edge corresponds to the 0° mark in Figure 4, with degrees around the circumference of the tube increasing as you proceed to the right.
6. Measure 1⁄3 of the circumference to the right from the left edge of the template and draw a vertical line. This is the 120° mark, which will be used to align the altimeter in the finished mount.
7. Measure 1⁄2 of the circumference to the right from the 120° mark and draw another vertical line. This is the 300° mark, which will also be used to align the altimeter.
8. Starting at the center line compute the height from the mid line for each vertical line on the graph paper. The height is a function of the distance from the center line. If we call this distance *D*, the equation for the height (*h*) is:

$$h = \sqrt{2}r\ \cos\left(\frac{D}{r} + \pi\right)$$

Note that the template is symmetric about the center line, so you may duplicate the height measurement equidistant about the center line.

9. You may connect the points along the graph, but keep in mind as you use the template that it is the measured points that count.

Creating A Template On Your Computer

If you search back to Peak-of-Flight Newsletter #121,

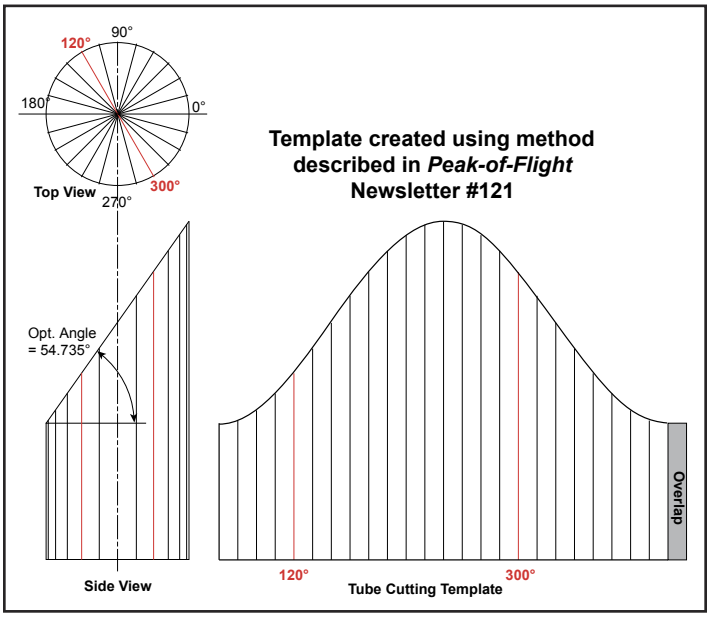

Figure 6: You can also make a template on your computer using instructions from Newsletter #121.

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there is a complete description on how to make a diagonal tube cutting guide. This is exactly what were doing here. The optimum angle for the cut is 54.735° as shown in Figure 6. Since the instructions were given there, we'll now go on to cutting out and using your template.

Cutting the Tube

Cut out the template along the two side lines and the base line. It is not necessary to attempt to cut to the curving line across the top of the template. Wrap the template ***tightly*** around the tube. The fit should be very snug to get the edges together. If the template does not fit tightly or

Photo 2: The template wrapped around the tube.

cannot be made to close around the tube, double check the measurements and create a new template. Once the template fits properly on the tube, use a spray adhesive on the back of the template to adhere the template to the tube. Follow the instructions for the adhesive to give a temporary bond so the template may be removed later. You may find it necessary to place adhesive tape across the two edges to ensure they stay against the tube. Photo 2 shows an example of a tube with a template applied.

Photo 3: The rough-cut of the tube.

Use an appropriate tool to cut the tube near the cut line on the template. Don't attempt to cut directly on the line as you will likely remove more material than intended, particularly along the lower half of the curve. Photo 3 shows a rough cut tube.

Photo 4: The tube sealed after sanding.

Finish trimming the tube to the guide line on the template by using a sanding block and sand paper. Photo 4 shows a tube with sanding nearly complete. If a cardboard tube is used, as shown in the example, it is recommended that a thin layer of CA glue be applied to the edge prior to sanding, and at regular intervals during the sanding process. This will harden the edge, yielding a better finish. It also tends to anchor the template during sanding, minimizing the chance of damaging the template.

Mounting the Plate

The next step is to attach a flat surface to the tube for mounting the altimeter. This surface needs to be aligned to the 120° and 300° marks on the template so the AltimeterTwo may be mounted at the correct angle. An electronics prototyping board is ideal for this purpose, with its predrilled holes providing an easy means of aligning the board to the mount tube.

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Regardless of what type of board is used to make the plate, it needs to have a line drawn on each side, with both lines being the same distance from a common edge. Photo 5 shows the example tube sitting on a prototyping board that has been marked as indicated. Note how the 300° mark is sitting on the line on the board. The 120° mark, on the opposite side of the tube, is also sitting on the line on the board.

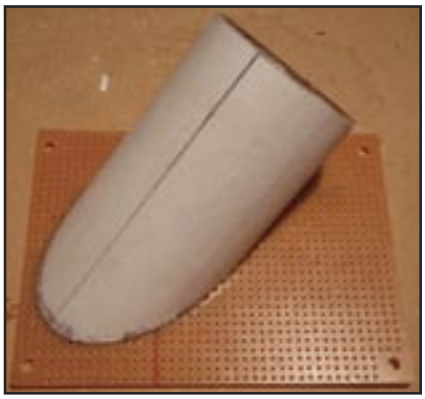

Photo 5: The board is attached to the tube.

With the mount tube resting on the board and the alignment marks aligned to the guide line on the board, tack the mount tube in place with CA glue applied at multiple places around the joint. Carefully trim excess plate material around the mount tube. Do not cut too close to the mount tube. Photo 6 shows the plate after rough trimming has been completed.

Photo 6: The prototyping board trimmed close to the tube.

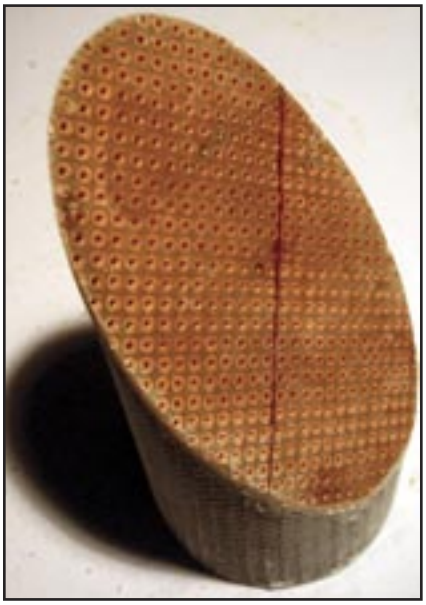

Photo 7: Prototyping board sanded smooth.

Remove the template from the mount tube. Use a sanding block or sander to remove excess plate material by sanding parallel to the surface of the mount tube until the plate is flush with the side of the tube. Photo 7 shows the example mount after the plate has been sanded as described. Note the line on the face of the board that corresponds to the line on the opposite side of the board that was used to align the board to the tube.

Attaching the AltimeterTwo to the Mount

Align the altimeter to the guide line on the face of the plate. Make sure the altimeter is not overhanging the sides of the mount by sighting straight down both sides of the

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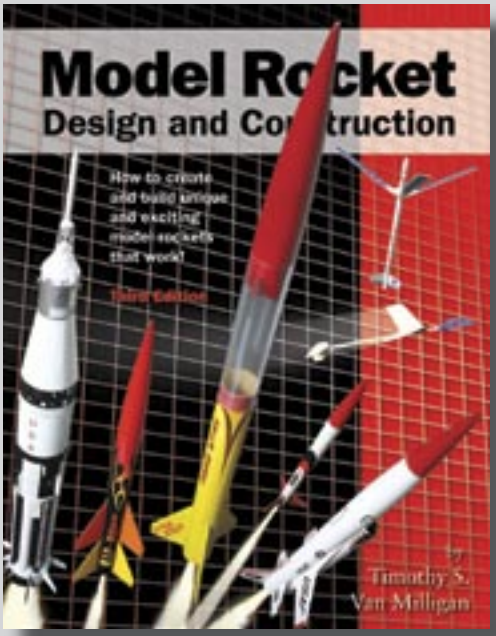

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mount. There are two methods to secure the altimeter to the plate, which are a wire bail mount and a USB socket mount.

The Wire Bail Mount

In small diameter mounts there isn't any space to allow for extending the length of the altimeter as would occur if attempting to use a USB socket mount. In this situation the altimeter may be secured to the board using a stiff wire bail and a #4 screw. Photo 8 shows an example of this mounting scheme. A heavy gauge wire is bent to conform to the width of the altimeter to form the wire bail. With the altimeter aligned to the guide line on the plate, determine where to locate the bail wire and mark where the wire needs to pass through the board. Holes are drilled through the plate just large enough to allow the bail wire to pass through. Pass the ends of the bail wire through the holes, place the altimeter under the bail to set the height for the bail, then tack the bail in place with CA glue. Be careful to not glue the altimeter to the board during this operation. While holding the altimeter in its mounting location on the plate, place a mark on the plate aligned with the mounting hole of the AltimeterTwo. Drill a 1⁄8" hole at this location in the plate. Place a nut on a #4 screw and pass the screw through the hole and attach another nut. Refer to photo 8 for the placement of the screw.

This placement allows easy access to the back side of the plate for attaching the nut. Tighten the nuts to securely hold the nut in the hole, make sure the nut on the face of the mount is aligned such that it does not interfere with the AltimeterTwo sitting flat on the board, then tack both nuts in place with CA glue. Be careful to not glue the screw into the nuts. Once the CA glue has set, remove the screw from the nuts. Using epoxy apply a fillet to the inside of the mount between the plate and the edge of the tube. Also epoxy the

Photo 8: The AltimeterTwo mounted to the board with a screw and a stiff piece of wire.

bail wire and the nut, being careful to not get any epoxy inside the nut. Once the epoxy has cured carefully apply epoxy to the nut on the face of the mount. Do not place epoxy where it would interfere with placement of the altimeter.

I personally used a 5/32 x .014 aluminum tube, obtained from the local hobby shop, to fashion a stand-off

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Photo 9: Instead of a wire loop shown in Photo 7, you could use a USB socket mounted to the board to hold the AltimeterTwo in place.

that was then epoxied to the nut on the face of the mount. The purpose of this stand-off is to prevent damage to the AltimeterTwo due to accidental over-tightening of the mount screw.

Here's a cool idea: using a USB extension cable it is possible to recharge the altimeter without removing it from the mount!

The USB Socket Mount

In larger diameter mounts it may be convenient to use a USB socket and a mounting screw to secure the AltimeterTwo to the mount. Photo 9 shows a close-up of an example of this configuration. Due to the thickness of the AltimeterTwo case it is necessary to solder the connector on to a small section of prototyping board and then epoxy this board to the face of the mount. The mounting screw is affixed in the manner described in the previous section, but excludes the front nut and standoff.

Photo 10: The "corner-up" mount installed in a rocket. Note the rod on the top that is used to help pull the mount out of the rocket so the AltimeterTwo can be read after the flight.

Ensuring a clean, straight insertion into the socket requires these be omitted, so care should be taken to not over-tighten the mounting screw during installation of the altimeter. If the socket is wired it would even be possible to recharge the altimeter without removing it from the mount, but this would of course require extra weight in the rocket.

Conclusion

This article has described how to design and construct a mount for an AltimeterTwo to optimize its performance in higher thrust rockets that would normally exceed its capabilities. When mounted in this configuration and secured inside a rocket the AltimeterTwo can measure up to 40Gs. The analysis provided should allow the design of alternative styles of mounts that provide the same capability.

One modification to the design is to truncate the mount above the altimeter in larger diameter rockets, since the height of the design shown is proportional to the diameter of the tube used for the mount, this would likely be a desirable enhancement. Also note that no attempt has been made to explain how to secure the mount inside the rocket. It is the view of the author that such details are best left to the user to determine for his or her individual rocket.

Photo 10 shows the finished example installed in the coupler tube of the author's 54mm rocket which is constructed from LOC/Precision tubes. The coupler tube has a single layer of fiberglass on the inside to strengthen it. The example mount was constructed from the shipping tube from a Cesaroni 38mm reload with a single layer of fiberglass applied to slightly increase its diameter and strengthen it during the construction process. A small piece of wood has been added to the inside of the mount and a counter sunk screw passes through the wall of the coupler and the mount to anchor in the wood.

About the Author:

Steven Collins holds a B.S. in Computer Science and is employed as a Firmware Engineer. He is a Tripoli Level 2 and flies with Tripoli Idaho Rocketry. He maintains a blog at http://idrocketeer.blogspot.com, which serves as a gateway to his additional web resources, such as his YouTube videos and sites about his rockets.