PEAK OF FLIGHT NEWSLETTER

ISSUE 591 / JAN 17TH 2023

IN THIS ISSUE

SHOCK CORD MATERIAL SELECTION
& MINOTAUR XL ROCKET PLAN

MINOTAUR XL

FREE PLAN

Available in This Issue!

https://www.apogeerockets.com/Peak-of-Flight-Rocket-Plans

www.ApogeeRockets.com
4960 Northpark Dr, Colorado Springs CO 80918
Ph# 719-535-9335

APOGEE COMPONENTS

PEAK OF FLIGHT

Shock Cord Material Selection

By Tim Van Milligan

This article will be an in depth review of the different materials that people have used for the shock cord of a model or high-power rocket.

A common question we get is which shock cord is "best." For those of you that know me, I abhor the word "best." If there was one that was best, then why would we even bother to sell all the other types of shock cords?

In reality, there is "optimal," but it depends on the situation you find yourself in. The result is that you'll find that there are several choices you'll have to make.

The Purpose of the Shock Cord

There is basically a single purpose why we use a shock cord. It is so that the entire rocket comes down together. The nose cone and the parachute stay attached to the body of the rocket.

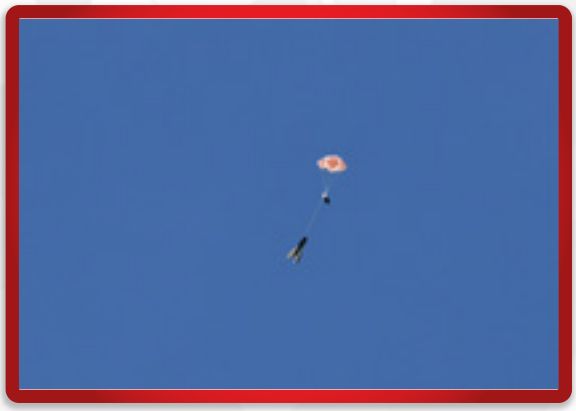


FIGURE 1 - THE SHOCK CORD ALLOWS ALL THE PARTS TO DESCEND AS ONE SET, SO YOU DON'T HAVE TO RETRIEVE MULTIPLE PIECES AFTER A LAUNCH.

We rocketeers like this, because it makes recovery much simpler. You only have to chase one group of parts rather than parts that come down separately and may have large distances between them where they land on the ground. The shock cord improves the odds that you'll have all the parts to your rocket, and nothing gets lost after the flight.

The reality is that if you don't mind chasing multiple pieces of your rocket, then you don't have to have a shock cord in the model. It is therefore an optional component of the rocket. But it is the rare person that wants to track multiple pieces of the rocket on descent, so pretty much every rocket will have a shock cord.

How Does It Work?

When the nose cone and parachute are pushed out of the rocket by the ejection charge of the rocket motor, they come out at a very high velocity. People exaggerate and say they come out as fast as a bullet. It isn't that fast, but you get the point. The separation speed is significant. As the nose travels outward from the rocket, it will eventually reach the end of the length of the cord that holds it to the rocket. But if it has momentum, it will often put a lot of stress on the cord and the attachment points on either end of the cord. The momentary force is called a "shock," and hence the name of the cord for model rockets. The "shock cord" must be able to handle that stress, or something will break in the rocket. Either the cord snaps, or the attachment points in the rocket fail. If there is a failure, then the rocket will come down in multiple pieces.

The bad part is that usually it is the heavy rear section of the rocket that comes down without a parachute. This is dangerous, because it could (and often does) streamline into the ground at a very high velocity. We obviously want to avoid that situation.

The purpose of this article is to offer up the different options you have to avoid the separation of the rocket due to shock cord failure.

Different Materials To Choose From

As you look at the Apogee website, you'll see there are a variety of different materials that are used for shock cords (https://www.apogeerockets.com/Building_Supplies/Parachutes_Recovery_Equipment/Shock_Cord). We sell Kevlar cord, elastic band, and Nylon webbing. There is also steel

Continued on page 3

About this Newsletter
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

Newsletter Staff
Writer and Cover: Tim Van Milligan
Plan: Martin Jay McKee
Layout and Proofreader: Michelle Mason

Shock Cord Material Selection

Continued from page 2

wire rope that is used in some model rocket kits as well.

Which material you choose to use is going to depend on how big of a rocket you're flying and what your preferences are.

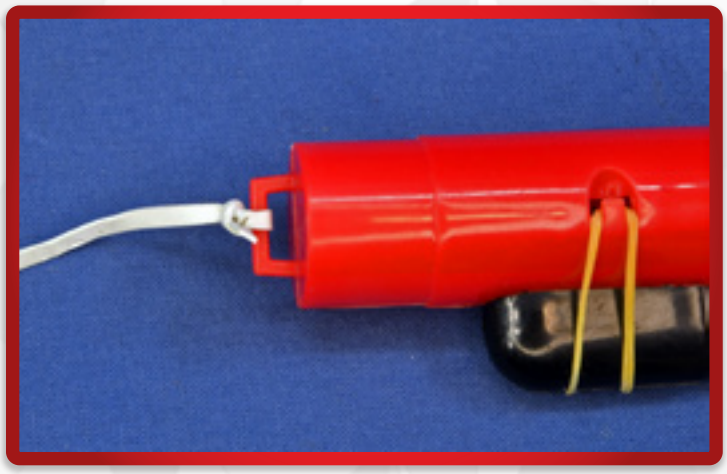


FIGURE 2 - THE RUBBER SHOCK CORD USED ON THE ESTES ASTRO-CAM ROCKET.

The most familiar shock cord that most new modelers are acquainted with is the flat rubber ribbon that Estes uses in most of their beginner level kits. The advantage of the rubber shock cord is that it stretches and it can absorb the energy of the ejection charge.

That is the original intent of the rubber shock cord. It lessens the forces applied to the attachment points. It is used so that there is a smaller likelihood that the rocket itself will be damaged from the shock of deployment.

However, it doesn't really absorb the energy; it actually temporarily stores it up as it stretches. The energy is released as the shock cord retracts back after stretching out.

This energy from the ejection charge has to be dissipated somehow. Most people don't consider this, but it is really crucial to a properly built system.

Most of the energy is dissipated by aerodynamic drag. When the nose and parachute come shooting out of the tube, they flow through the air, and drag is produced. If enough drag is produced, they will slow down sufficiently that there isn't a lot of stress on either the cord or the anchor points.

In the rubber shock cord, you actually have drag from the nose cone as it shoots outward, and aerodynamic drag as it moves back toward the rocket from the rubber ribbon as it recoils. It slows down in both directions, so it can be made shorter.

There are a couple of problems that people have noticed with rubber shock cords. First is that the recoil of the cord could snap the nose cone towards the body tube at a significant velocity. It's like a paddle-ball game you had as a young kid. The nose could whap into the tube really hard, and could dent the front end of the paper tube. People have termed this the "Estes Dent." Unfortunately, this damage is ugly and will have to be repaired.

The other problem with rubber or elastic shock cords is that they degrade over time. The rubber can get brittle with age or from the high heat of the ejection charge. So you don't know exactly when the rubber will "let go." But it eventually fails.

That is why you should always tug on each end of a

Continued on page 4

Shock Cord Material Selection

Continued from page 3

rubber shock cord before you fly it. You're testing the durability of the cord just before the flight to assure yourself that on this particular flight, it should work fine.

Elastic Shock Cords

The next most common shock cord material for small rockets is elastic. This is similar to the flat rubber ribbons that Estes uses, but it is actually a composite construction of rubber strings that are woven in with nylon strings. Think of the elastic that is on the waist of your underwear. It is essentially the same thing. Just a different width.

FIGURE 3 - ELASTIC COMES IN DIFFERENT SIZES.

The elastic ribbon functions similarly to the flat rubber shock cords Estes uses in their kits. But because they have non-strechy nylon strings woven in with the rubber strings, they don't stretch the same distance. So you'd have to use slightly longer shock cords if they are made from woven elastic ribbons.

The nylon does add a little bit of strength to the elastic shock cords. So that is an advantage.

However, they still retain the negative aspects of having rubber in them. The strength will be diminished over time as rubber in the cord gets old and brittle. Again, you have to do a test of the shock cord by pulling on it prior to each flight.

The other negative aspect of the elastic cord is that its surface is a little fuzzy and this fuzz is more susceptible to heat damage from the ejection charge. The fuzz is tiny wisps of nylon from the thread that is used during manufacturing. This fuzz, being so wispy, is easily melted and charred by the intense heat of the ejection charge. After you fly the rocket and inspect the elastic shock cord, you'll feel with your fingers that the surface texture is different. It feels rough. That is all the hairs on the threads that have melted

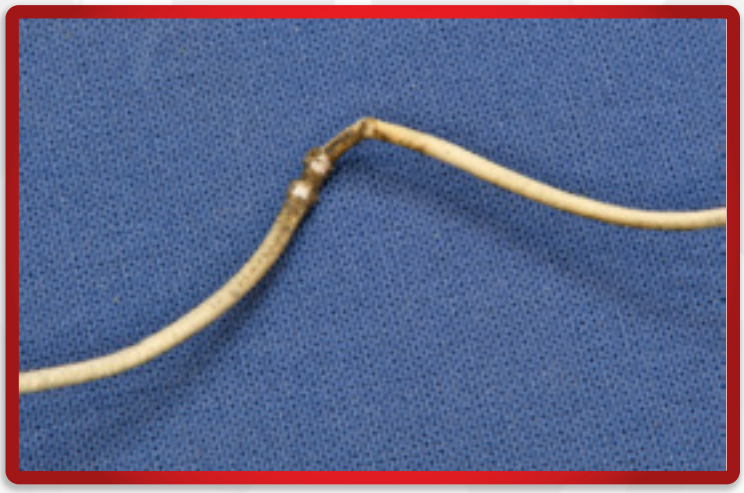


FIGURE 4 - HEAT DAMAGE ON AN ELASTIC SHOCK CORD. THE BRIGHT WHITE IS THE RUBBER INSIDE THE NYLON SHEATH.

Continued on page 5

Shock Cord Material Selection

Continued from page 4

and possibly burnt. After enough launches, you'll start to see some significant damage.

It was for this reason that Estes, having tried using elastic for a number of years, went back to a solid rubber ribbon as the shock cord on their low-level rockets. They found that the rubber shock cords lasted longer. Personally, I tend to agree with this decision.

Apogee does sell elastic shock cord (https://www.apogeerockets.com/Building_Supplies/Parachutes_Recovery_Equipment/Shock_Cord/Elastic_Shock_Cord) but it is a round cord instead of a flat ribbon. It is stronger than ordinary flat elastic. However, it still can get singed and degrade over time. Always give a tug on both ends of the shock cord to confirm the integrity of the cord for the launch.

FIGURE 5 - ELASTIC SHOCK CORD ON THE KLIMA ANDROMEDA ROCKET KIT.

Nylon Cord

When I first flew competition rockets in the 1980's, we used braided Nylon cord that is common in the fishing industry.

Nylon is a plastic material that feels soft and is very flexible. It is also fairly strong. All these characteristics are useful in rocketry, and therefore it can be used as a shock cord material.

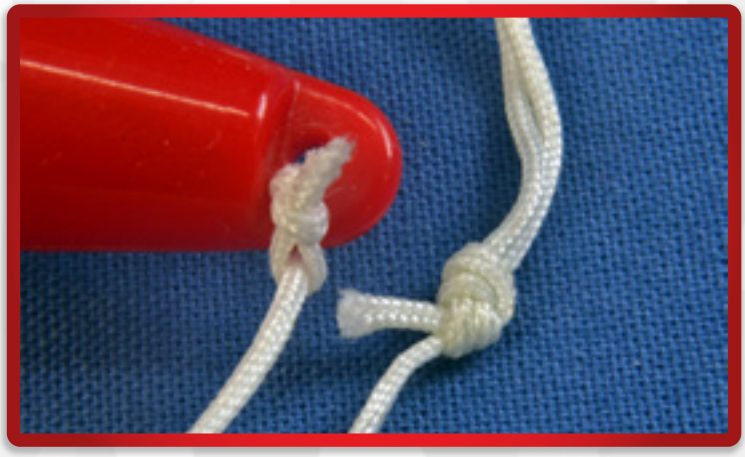


FIGURE 6 - NYLON SHOCK CORD USED ON THE ESTES ASTROCAM ROCKET. NOTICE HOW THE ENDS CAN LOOK FUZZY.

While nylon is strong, it is not as strong as Kevlar®. But it is a whole lot cheaper. So if you are on a budget, nylon can be a good choice.

There are a couple of disadvantages to nylon that should be pointed out. First, as mentioned previously in the elastic section, nylon is a plastic that can be melted or burned with high heat. So you need to inspect it carefully between flights. This is particularly true for thin nylon cords.

At Apogee Components, we sell a very heavy tubular

Continued on page 6

Shock Cord Material Selection

Continued from page 5

nylon shock cord (https://www.apogeerockets.com/Building-Supplies/Shock-Cord/1-2in-Nylon-Tubular-Webbing). Because this particular product has a lot of beefy mass, it is less susceptible to heat damage than thinner cords. But you should always inspect it between flights.

FIGURE 7 - THE HIGH-POWERED APOGEE KATANA ROCKET WITH ITS ORANGE COLORED NYLON SHOCK CORD.

There is a way to protect nylon cords pretty easily. That is to wrap something that is more heat resistant around the end of the shock cord where the heat is at its most intense. We sell shock cord protectors (https://www.apogeerockets.com/index.php?main_page=product_info&cpath=&products_id=258) for this very purpose. The protector is flame resistant, and encases the shock cord like a blanket to protect it from the heat of the ejection charge. If you're flying an expensive high-power rocket, you may want to consider adding a shock cord protector to the rocket.

Another cheap way of protecting the nylon shock cord is to wrap the heat exposed end with masking tape. The layer of paper tape isn't as heat proof as a fabric shock cord protector, but I've found that it works very well. The tape can get sooty, but it can be replaced after a few flights if you think the heat is getting through to the nylon shock cord.

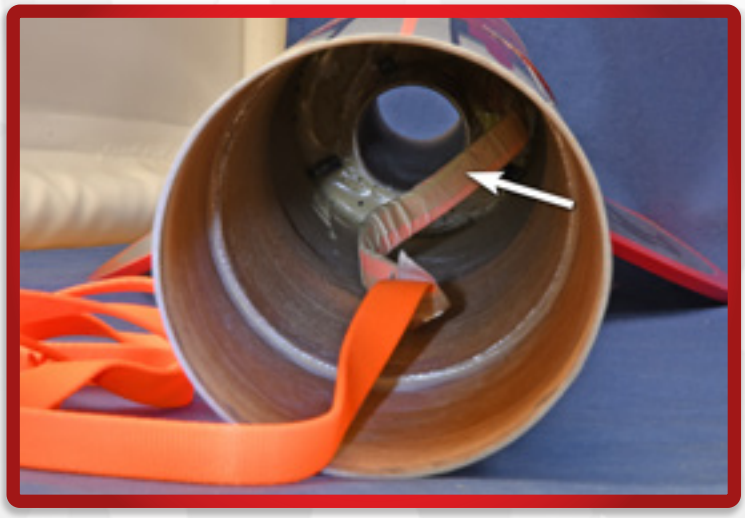


FIGURE 8 - MASKING TAPE LAYERED OVER THE NYLON SHOCK CORD CAN BE USED TO PROTECT IT FROM HEAT DAMAGE.

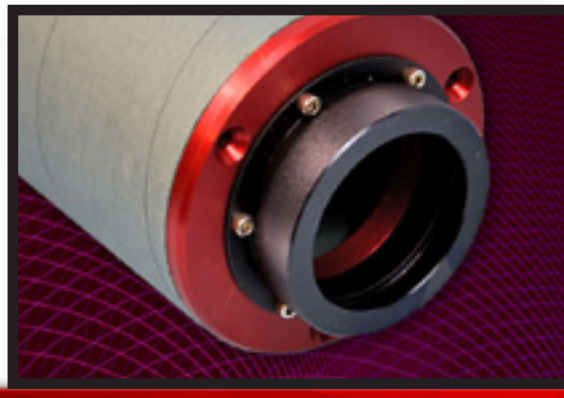
The main disadvantage of using tape is that it stiffens up the shock cord and makes it harder to fold inside the rocket. But for large diameter rockets, this isn't really too much of a concern.

Kevlar Shock Cords

Almost all of the rocket kits that Apogee Components produces use Kevlar® shock cords.

Kevlar is significantly stronger than nylon (it is 6 times

Continued on page 7



EXPERIENCED HPR BUILDERS USE THRUST PLATES

- Eliminates Shear Forces on Centering Rings
- Mates with AeroPacks Flanged Engine Retainers
- Fits Standard HPR Tubes, Blue Tubes, and Fiberglass Tubes
- Made from Aircraft Grade Aluminum

https://www.apogeerockets.com/Building_Supplies/Thrust_Plates

Shock Cord Material Selection

Continued from page 6

stronger than steel), is lighter in weight, is fire resistant, is relatively soft so that it can be easily coiled up, and it doesn't degrade over time. Other than being significantly more expensive, its physical characteristics make it a far superior material for shock cords than nylon.

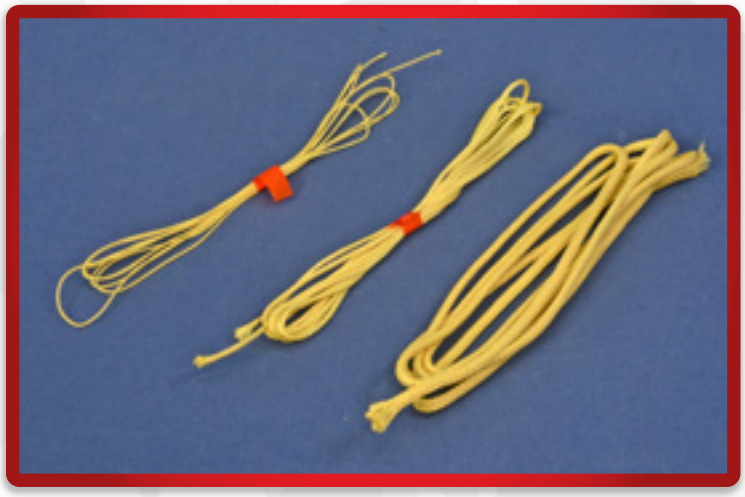


FIGURE 9 - BRAIDED KEVLAR CORD COMES IN A VARIETY OF SIZES.

You can put it in your rocket, and just about forget it is there. Although it doesn't hurt to tug on it like other shock cords to stay in the habit of inspecting everything between launches.

Kevlar is a man-made material (not organic), and comes in a variety of sizes. Here at Apogee, we have it available in diameters that relate to the tension strength of the cord. We have 100-pound, 300-pound, and 1,500-pound (https://www.apogeerockets.com/Building_Supplies/Parachutes_Recovery_Equipment/Shock_Cord).

The diameter you use would depend on the size of your rocket. Here is what we typically recommend:

100-pound Kevlar - for typical small rockets that use up to a "C" size rocket motor.

300-pound Kevlar - for mid-power rockets that use between "D" and "G" size rocket motors

1,500-pound Kevlar - for high power rockets that use "H" size rockets or larger.

Wire Rope Cords

While Apogee does not sell wire rope, we do have a few kits from other manufacturers that use this material as part of the shock cord systems that they use. In particular are the mid-power kits from North Coast Rocketry.

Wire rope (made from a collection of twisted steel wires) has one big advantage. It is flame proof. It won't burn when the ejection charge scorches it with intense heat and flame.

Another nice feature of it is that it is fairly slick. Where Kevlar is abrasive, the steel rope will slide over itself quite easily, so you don't have to worry about it wearing out or cutting through itself. So connecting two lengths of wire rope together, or attaching kevlar to wire rope is typically strong and durable.

However, it is significantly heavier than Kevlar. So for the same amount of strength, it is going to have more mass.

Also, unlike Kevlar, wire rope is stiff and doesn't fold easily. It sort of acts like a spring and wants to uncoil and

Continued on page 8

Shock Cord Material Selection

Continued from page 7

FIGURE 10 - WIRE ROPE IS USED INSIDE THE TUBE FOR ITS HIGH HEAT RESISTANCE.

stretch out inside the rocket. Packing wire rope and keeping it in place will be much more of a challenge than Kevlar. Additionally, it is nearly impossible to simply tie a knot in the wire rope because it is so stiff. So attaching the ends of the wire rope to the anchor points on the rocket is much more difficult. You'll need special rigging fittings (sleeves) to make attachment points in the rocket.

The Disadvantage of Non-Stretchy Shock Cords

The big disadvantage on non-stretchy shock cords like nylon, Kevlar or wire rope, is that they don't store up the energy of the deployment like an elastic cord does. So there is only one direction that the nose cone moves in as it ejects from the rocket - forward. It doesn't rebound back after it extends outward. So you only have one opportunity to slow the nose cone down before it reaches the full limit of the length of the cord.

What this means is that if you are using a non-stretchy shock cord in your rocket, it has to be long. In fact, it is my opinion that the longer the better!

A long shock cord allows the rocket and nose cone to slow down while the cord is being extended. You want each part, the nose and the body of the rocket, to be traveling as slowly as possible before the cord has fully extended. This will put the least amount of stress on the anchor points and the cord itself, and prevent damage to the rocket and keep it together during descent.

How long should your shock cord be?

My rule of thumb is to use a multiple of the diameter of the rocket. The multiple that I recommend is 40. So in other words, the shock cord should be at least 40 times the diameter of the rocket's tube. But you could make it longer than this, and that would be fine.

So if your rocket is 1 inch in diameter, the non-stretchy shock cord should be at least 40 inches long. If the rocket is 2 inches in diameter, the shock cord should be a minimum of 80 inches long. You get the idea.

A lot of people like to use a multiple of the "length" of the rocket. For example, I used to say at least three times the length. But I no longer give that recommendation, because short rockets end up having shock cords that are also very short. Think of something like the stubby Estes Big Daddy (https://www.apogeerockets.com/Model-Rocket-Kits/Skill-Level-3-Model-Rocket-Kits/Big-Daddy). It is 3 inches in diameter, and 19 inches long. If you used the 3x recommendation, the shock cord would be 57 inches long (less than 5 feet). But if you use the 40 times the diameter recommendation, the length would be 120 inches (10

Continued on page 9

Shock Cord Material Selection

Continued from page 8

feet long). For a heavy rocket like the Big Daddy, I'd much rather have a long cord to spool out. That gives it twice the amount of time to slow down before it reaches the end of the rope and puts stress on the places where it attaches to the rocket.

Zippering

A zippered tube is the big disadvantage people think of when considering Kelvar shock cords. Because it is so strong and doesn't have any stretch, it can easily cut through the end of a cardboard tube.

FIGURE 11 - A ZIPPERED BODY TUBE.

What makes kevlar more prone to cutting into the end of a tube is its small diameter size. The skinny diameter of kevlar concentrates the force onto a smaller point on the edge of the tube. So instead of crumpling the edge of a tube, it cuts into it. This cut is called a zipper.

The obvious way to overcome this is to spread out the force so it isn't concentrated on a tiny spot. You do this by weaving the cord into a flat ribbon instead of a round tube. This is why we chose a flat nylon shock cord over a round cord. It spreads out the force if the cord is draped over the edge of a tube.

FIGURE 12 - THE WIDER THE SHOCK CORD, THE LESS CHANCE OF A ZIPPER BECAUSE IT SPREADS THE FORCE OVER A LONGER SECTION OF THE TUBE PERIMETER.

Besides that, there are many other options to reduce the chances of zippering the tube. In the references at the end of this article are a few mechanical ways that people have used to reduce the possibility of zippering a tube.

Continued on page 10

JOIN TRIPOLI.ORG
Mention Apogee Components

CHECK OUT THE APOGEE YouTube PAGE
CLICK OR SUBSCRIBE HERE FOR OUR HELPFUL
AND INFORMATIVE HOW-TO VIDEOS
ON MODEL ROCKETRY
https://www.youtube.com/c/apogeerockets
APOGEE COMPONENTS

Shock Cord Material Selection

Continued from page 9

Be sure to check those out, as I won't repeat them in this article.

But if you understand where zippers happen most often, you can reduce the chances of damage without having to resort to mechanical means that increase the complexity of the rocket, or make it heavier.

The way to reduce the chances of having a zipper comes down to this: "proper motor selection and angling the launch rod (or rail)."

Zippers are most likely to occur when the rocket is pointing downward when the ejection charge goes off. You want to set up the launch conditions through motor ejection delay selection, and by properly angling the launch rod. This is totally in your control, but it does require making some wise decisions prior to pushing the launch button.

When the nose is pointed downward, you have the force of gravity working against you. The nose will come off fine, and will start to slow down due to drag. Additionally, the parachute will probably open pretty fast because there is a lot of air flowing over it as it falls downward. That part is fine.

But what most people forget about is the aft section of the rocket. Even with the nose cone off, the aft section is likely to be stable. Unfortunately, it is on a ballistic trajectory aimed at the ground. With gravity acting on it, that fin section is accelerating and gaining speed and momentum.

Do you get the idea here of what is going to happen? The nose cone essentially stops dead in its path because of the parachute slowing it down. But the aft section is going to scream past it as it hurls toward the ground. Now the shock cord is in the absolute worst orientation with respect to the tube. It is laying on the outside of the tube, draped over the front edge of the tube. It is positioned perfectly to zipper the tube. And that is exactly what happens.

To prevent the zipper, you want the rocket's orientation to be sideways, or at least traveling upward at a slow speed. Don't let it be pointed down when the ejection charge goes off.

You do this by selecting an ejection charge delay in the rocket motor that is "optimal", which means that it fires right when the rocket has reached its apogee point. I don't want to sound like an advertisement for RockSim, but that is what we use to figure out that optimal ejection charge delay.

With RockSim (or RockSim-Pro, and the Launch Visualizer at https://www.RockSim.com), you can quickly

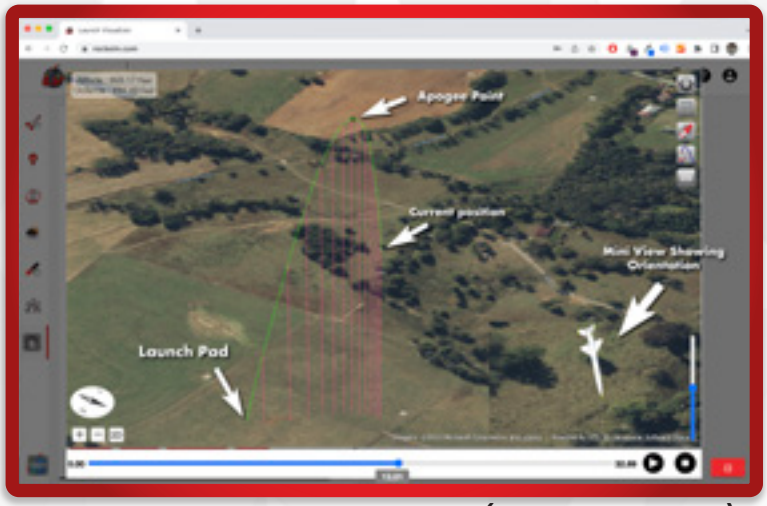
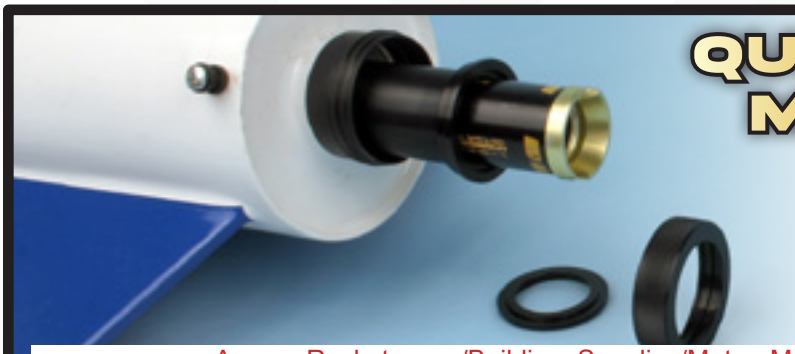


FIGURE 13: IN THE LAUNCH VISUALIZER (WWW.ROCKSIM.COM), YOU CAN SEE THE ORIENTATION OF THE ROCKET PRIOR TO PARACHUTE DEPLOYMENT. THIS ONE IS AIMED DOWNWARD.

Continued on page 11



QUICK-CHANGE MOTOR ADAPTERS

- Allows you to use smaller diameter motors in your rocket kits (adds versatility)
- Change out motors in seconds
- Works with all single-use and re-loadable motors
- Four sizes available

www.ApogeeRockets.com/Building_Supplies/Motor_Mount_Kits_Adapters/Ready-to-use_Motor_Adapters

Shock Cord Material Selection

Continued from page 10

see what the orientation of the rocket is when the ejection charge fires, and what is the optimal delay based on your wind conditions at launch. And it is sophisticated enough to allow you to angle the launch rod for liftoff.

People sometimes use overly long delays to get the rocket closer to the ground so that it doesn't drift far. But this is the exact situation that promotes a zippered tube. If you want to have a rocket that doesn't zipper, and that doesn't drift out of your launch range, then I highly recommend you use the Launch Visualizer. You can use it to adjust the placement of the launch pad and how to angle the launch rod to minimize the rocket drifting away.

Combination Shock Cords

Wouldn't it be great to combine the positive characteristics of the different materials together and at the same time diminish the negative aspects? The answer is "you can." You have to use a combination of materials in a shock cord system.

The first combination is to use the heat resistant materials inside the rocket, particularly deep in the tube where the ejection charge gasses are the hottest. For example, what a lot of people do is put a short Kevlar shock cord inside the tube, and then attach a rubber or elastic shock cord to the front end. The Kevlar provides a strong and heatproof anchor, and the elastic provides shock absorption to lessen the chances that the plastic loop on the nose cone would break.

If the kevlar is short enough, and doesn't extend past the open end of the tube, there is also a diminished chance of a zipper occurring. Why? The rubber or elastic cord is stretchy and doesn't dig into the paper tube the way that Kevlar or nylon would.

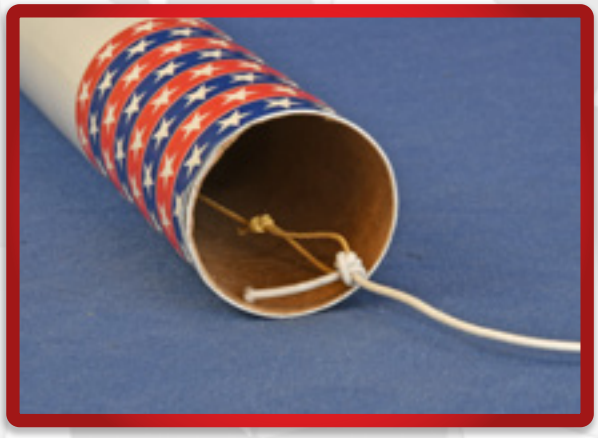


FIGURE 14 - ELASTIC TIED TO KEVLAR. NOTE THAT THE LOOP OF KEVLAR IS BELOW THE OPENING OF THE TUBE TO PREVENT IT FROM ZIPPERING THE TUBE.

You can do the same with a wire rope attached to the engine mount, which is what some manufacturers do with many of their kits. The purpose is to put the steel in a location that takes the hot gasses of the ejection charge, and attach something that isn't nearly as heat resistant, like nylon or elastic.

The other advantage to this, is that it makes it easy to replace the elastic or nylon cord that is attached between the lower shock cord, and the nose cone.

The weak link in this arrangement, where the two cords are tied together linearly, is elastic or nylon cord outside of the rocket. If something is going to snap, it will always be the weak cord like the elastic or rubber one.

Continued on page 12

Shock Cord Material Selection

Continued from page 11

To get around this weakness issue, instead of simply tying one cord to another, you can do two different cords in parallel to each other. For example, you can have a long kevlar cord for strength, and pair it with an elastic cord for shock absorption. Just remember to make the elastic cord about half of the length of the kevlar cord so that it can stretch out during deployment to absorb some of the shock forces.

This parallel chord arrangement is what North Coast Rocketry does in their mid-power kits. I like this arrangement, but it does have a couple of drawbacks. First, since you're using two cords in parallel, you've probably doubled the weight of the shock cord system. But unless you're really concerned about performance, it usually isn't a big issue.

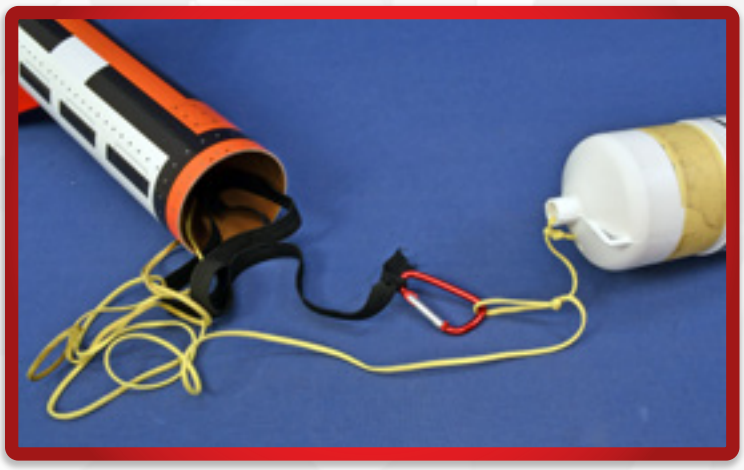


FIGURE 15 - PARALLEL SHOCK CORDS CAN PROVIDE BOTH ELASTICITY AND STRENGTH. THE LINK ALLOWS ONE CORD TO BE DETACHED SO THE TWISTS CAN BE EASILY REMOVED AFTER A FLIGHT.

The second drawback is that the cords wind themselves up during descent. The lower part of the rocket always spins as it descends under the parachute, and this will cause the two cords to twist together. You will find it to be a chore to unwind them after the rocket has landed. So what North Coast Rocketry does in their kits is to put a quick link on one end of the elastic cord. You just detach the chord after the landing so that it is much easier to untangle the shock cords in preparation of the next launch.

Conclusion

To answer the question: "which type of shock cord is the best?", I would say that "it depends." That is what engineers always say, right? Every type of material has advantages and disadvantages. You have to weigh the characteristics when you're making a decision on which type to use. I'm not going to say "never" use rubber, or whatever. They have their place in certain situations. And maybe you have a lot of experience using them and are comfortable with their characteristics. Your experience matters when making a decision.

As I mentioned, our philosophy here at Apogee Components is to use a single cord of Kevlar for ease of installation. But it is really long, so that it has less of a chance to cause a zipper. And we highly recommend using the right rocket motor and ejection charge delay for the flight. Avoid selecting a rocket motor or launching the rocket where it will be oriented downward when the ejection charge fires off and pushes the nose out. This is what really increases the chances of a zippered tube.

Continued on page 13

Shock Cord Material Selection

Continued from page 12

Additional Resources and Information about Shock Cords:

Replaceable Shock Cord System: https://www.apogeerockets.com/education/downloads/Newsletter338.pdf

What Length Should You Use for Elastic Shock Cords?: https://www.apogeerockets.com/education/downloads/Newsletter348.pdf

Anti-Zipper Harness system - https://www.apogeerockets.com/education/downloads/Newsletter282.pdf

Masking Tape Bumpers to Prevent Zippers - https://www.apogeerockets.com/education/downloads/Newsletter174.pdf

Strategies for Avoiding Zippered Tubes - https://www.apogeerockets.com/education/downloads/Newsletter290.pdf

Installing Shock Cords in rockets - https://www.apogeerockets.com/Peak-of-Flight/Newsletter573

External shock cord mount for competition rockets - https://www.apogeerockets.com/education/downloads/Newsletter278.pdf

Video: How to Attach a Shock Cord Anchor to a 13mm Tube - https://www.apogeerockets.com/Advanced_Construction_Videos/Rocketry_Video_312

Crochet your cord - https://www.apogeerockets.com/education/downloads/Newsletter253.pdf

Video: Preventing Long Shock Cords From Tangling ACV https://www.apogeerockets.com/Advanced_Construction_Videos/Rocketry_Video_31

Video: How to Replace a Shock Cord https://www.apogeerockets.com/Advanced_Construction_Videos/Rocketry_Video_314

Video: Simple Shock Cord Attachment Methods https://www.apogeerockets.com/Advanced_Construction_Videos/Rocketry_Video_87

Video: Anchor A Shock Cord to a Fiberglass nose cone - https://www.apogeerockets.com/Advanced_Construction_Videos/Rocketry_Video_57

Minotaur XL Plan

Download the ***RockSim*** design file for the Minotaur XL at:
https://www.apogeerockets.com/Peak-of-Flight-Rocket-Plans

Minotaur XL Parts List

10100 – (1) AT-24/18" Body Tube (BT-50) – 9" required
10164 – (1) AT-56/18" Body Tube (BT-70)
13037 – (1) CR-24/29 - 3 rings required
13057 – (1) 1/4"x3" Launch Lug - 1 launch lug required
14091 – (1) Basswood Sheet - 1/8" X 4" X 18"
15026 – (1) Centering Ring 24mm to 56mm (BT-70) - Cardstock
20070 – (1) PNC-56 (BT-70)
24049 – (1) E-Size Engine Hook - 1 hook required
29093 – (1) 24" Printed Nylon Parachute
30303 – (1) 2"x56" Mylar Streamer (12" for booster and 44" for sustainer)
29520 – (8 ft) 300# Kevlar
– Cardstock paper for rolled nozzle and wing fairings
– Printer paper for templates

Order parts at:
https://www.apogeerockets.com/Quick_Order

Recommended Motors
(Simulated at empty weight of 197g):
Estes D12-3 462' (141m)
Quest D22W-4 603' (184m)
Aerotech D15-4 610' (186m)
Estes E12-4 857' (261m)
Quest E35-5 1296' (395m)
Aerotech F12J-5 1432' (437m)

Minotaur XL *By Martin Jay McKee*

About the Design

The Minotaur XL is a mid-power rocket that was loosely based on air-launched orbital and suborbital vehicles such as the Pegasus. The Minotaur XL is a quick build, but has several interesting challenges and unique features including a rolled paper nozzle, inset wings, and hand folded fairings. It flies exceptionally well on high-thrust motors such as the Quest D22, Quest E26, and Aerotech E28. Taking care that sufficient nose weight is added for stability, it can even be flown on something like the Aerotech F35. The prototype used one of the printed nylon parachutes from Apogee and that is recommended here due to the slight added weight being beneficial in moving the CG of the rocket forward. Any other parachute of comparable size would work as well, however.

Continued on page 15

Minotaur XL Plan

Continued from page 14

Constructions Notes:

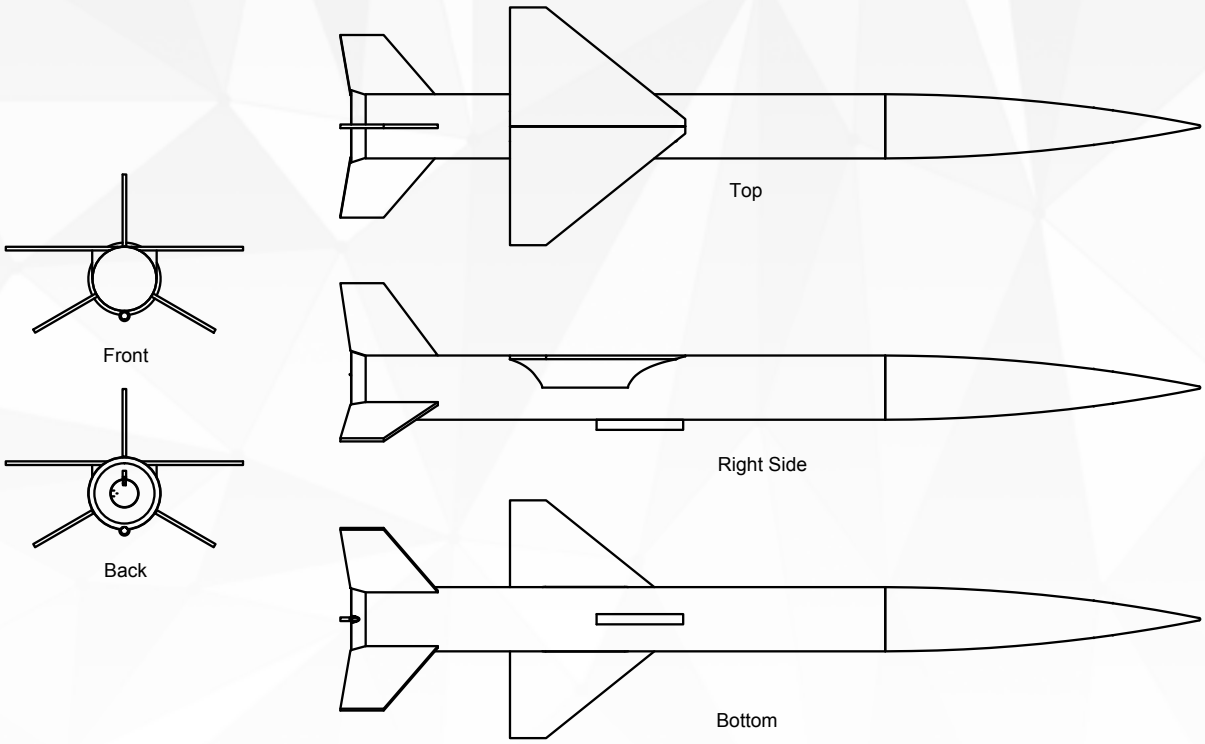
The first step in construction is to mark a full-length 18" BT-70 tube and cut the section out where the main wings will sit. Once that is done, the forward and middle centering rings can be temporarily placed in the tube (poking up through the slot) and marked so that they can be cut down. The aft centering ring also requires modification to add a slot for the motor hook. Once the centering rings are prepared, the motor mount should be constructed first, taking care to align the flats on the forward and middle rings, then the motor mount tube can be led in the rocket. Again, ensure that the flats are aligned and provide a flat saddle for the wings to sit on.

The wings should be glued flat at their root prior to installation. The wings are then installed. After the wings are in place, the construction order no longer really matters unless a fin alignment guide is being used to glue the main fins in place, as the rolled nozzle will interfere in removing the guide. In that case, the installation of the nozzle should wait until the final step.

THE MINOTAUR XL IS A MODERATELY SIZED ROCKET WITH A BIG PERSONALITY.

Construction of Cardstock Parts:

The cardstock parts on the Minotaur XL are actually fairly simple. There are three: two wing fairings, and the paper nozzle. The paper nozzle is a simple conical transition that has a notch removed as clearance for the launch rod. To make the nozzle easier to form, the notch should not be cut out until the nozzle has already been installed. A small pair of nail scissors or similar are ideal for cutting the notch out. The fairings have tabs that glue to the bottom surface of the wings and they simply glue directly to the surface of the tube. Rather than a sharp fold between the sections, they are designed for a smooth radius. If care is taken for forming and installation, there should only be minimal filling required.



Continued on page 16

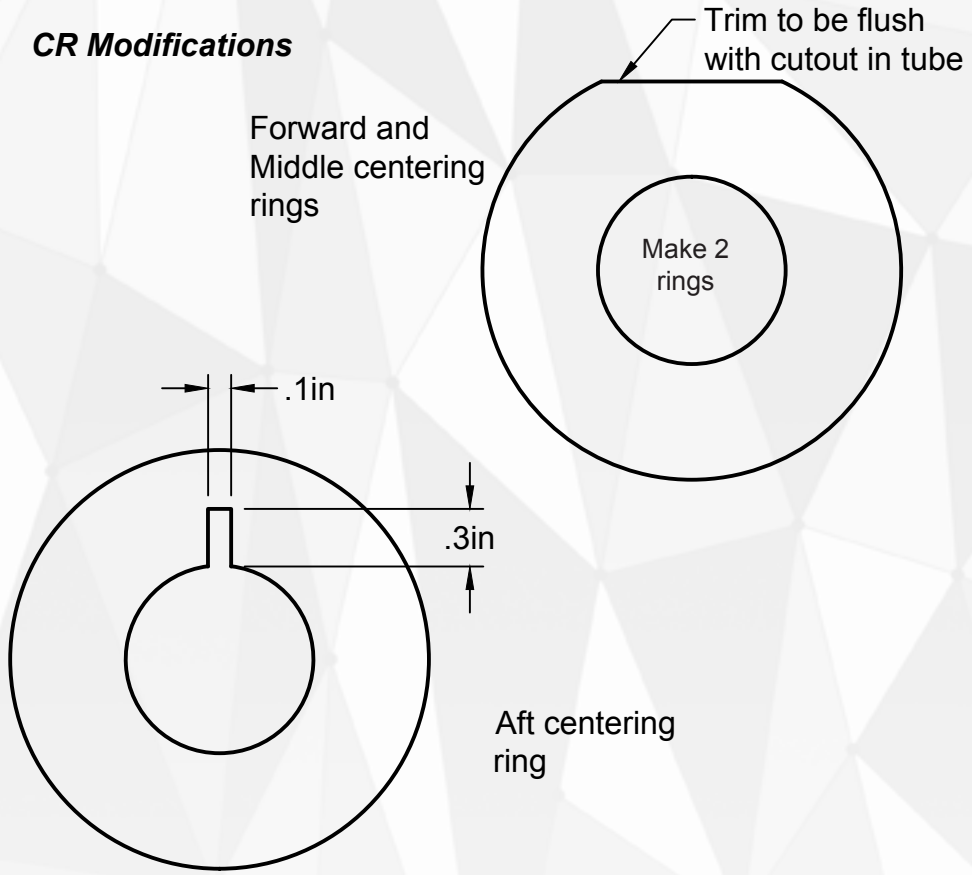
Minotaur XL Plan

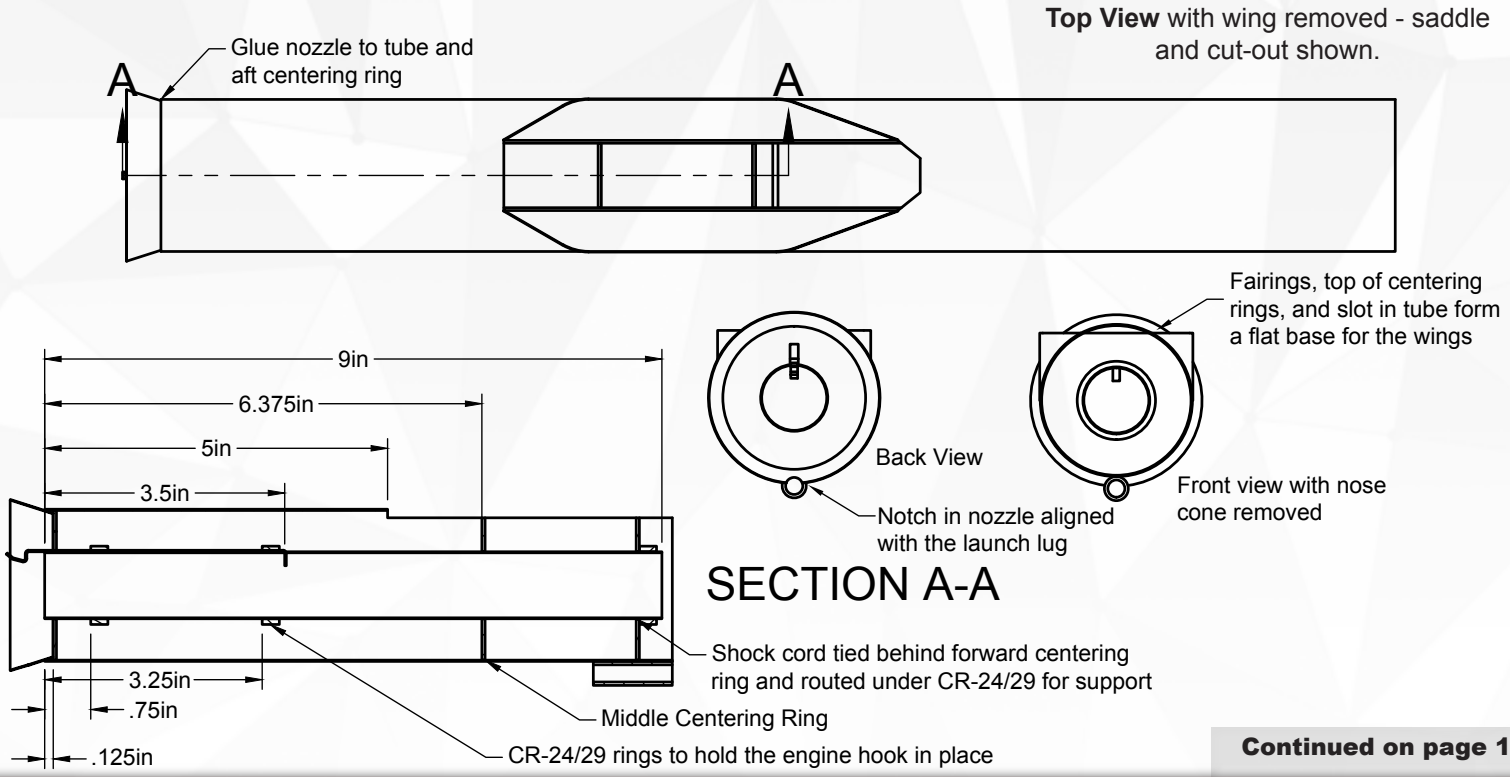
Continued from page 15

Stability Concerns:

The Minotaur XL is a stable rocket that flies well on D and E size motors. Given its rather squat appearance, its asymmetry, and the large main wing, it is worth checking the CP and CG before flying larger F size motors. As with the rest of the newsletter plans, a RockSim file is available to help predict the stability with different motors. In any case, the center of pressure (CP) is positioned 22.37" back from the tip of the nose cone. So, the flight center of gravity (CG) should be no more than 19.75" back from the tip of the nose cone for a 1 caliber stability margin (which should be considered the minimum for a stable rocket, for more information on stability, see Newsletter #462). Clay can be pressed into the nose cone to bring the CG forward if required.

CR Modifications





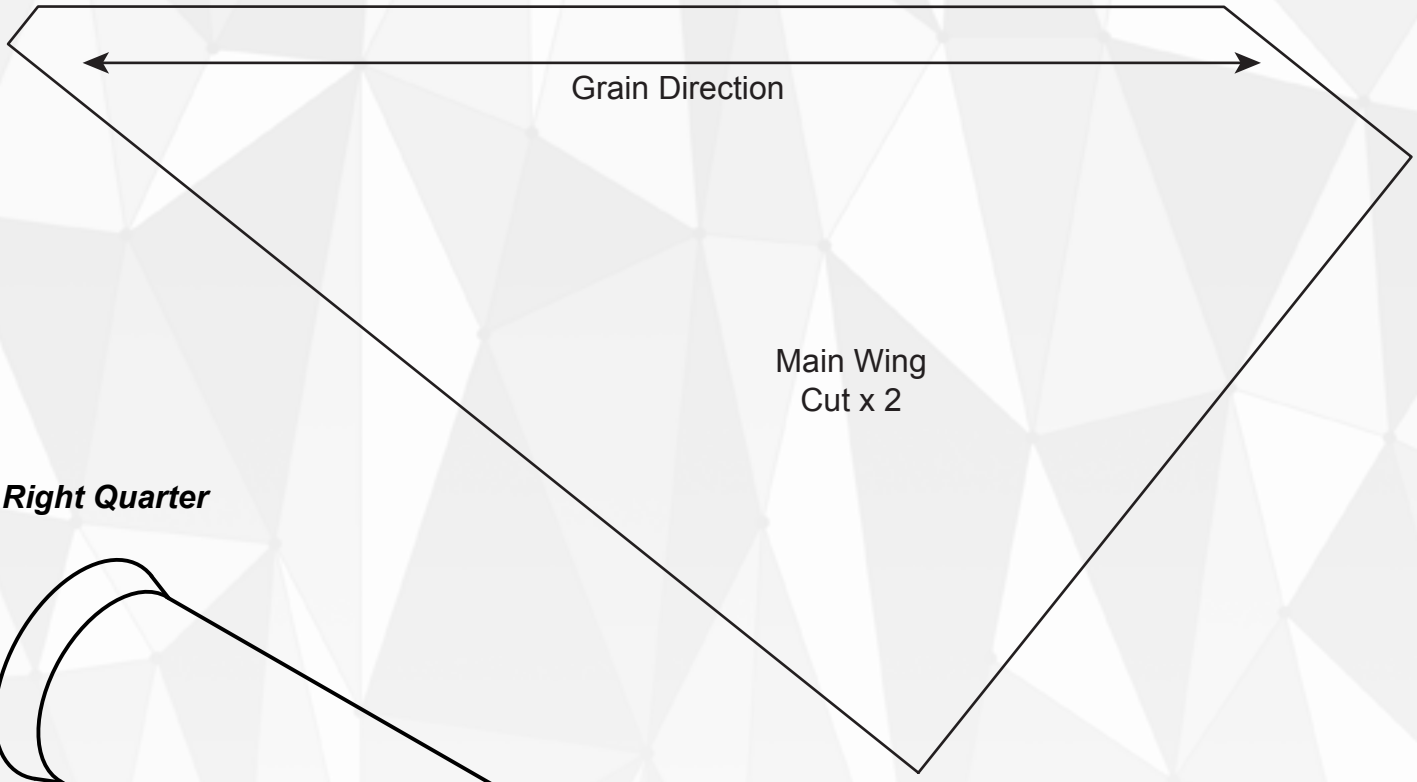
Continued on page 17

Minotaur XL Plan

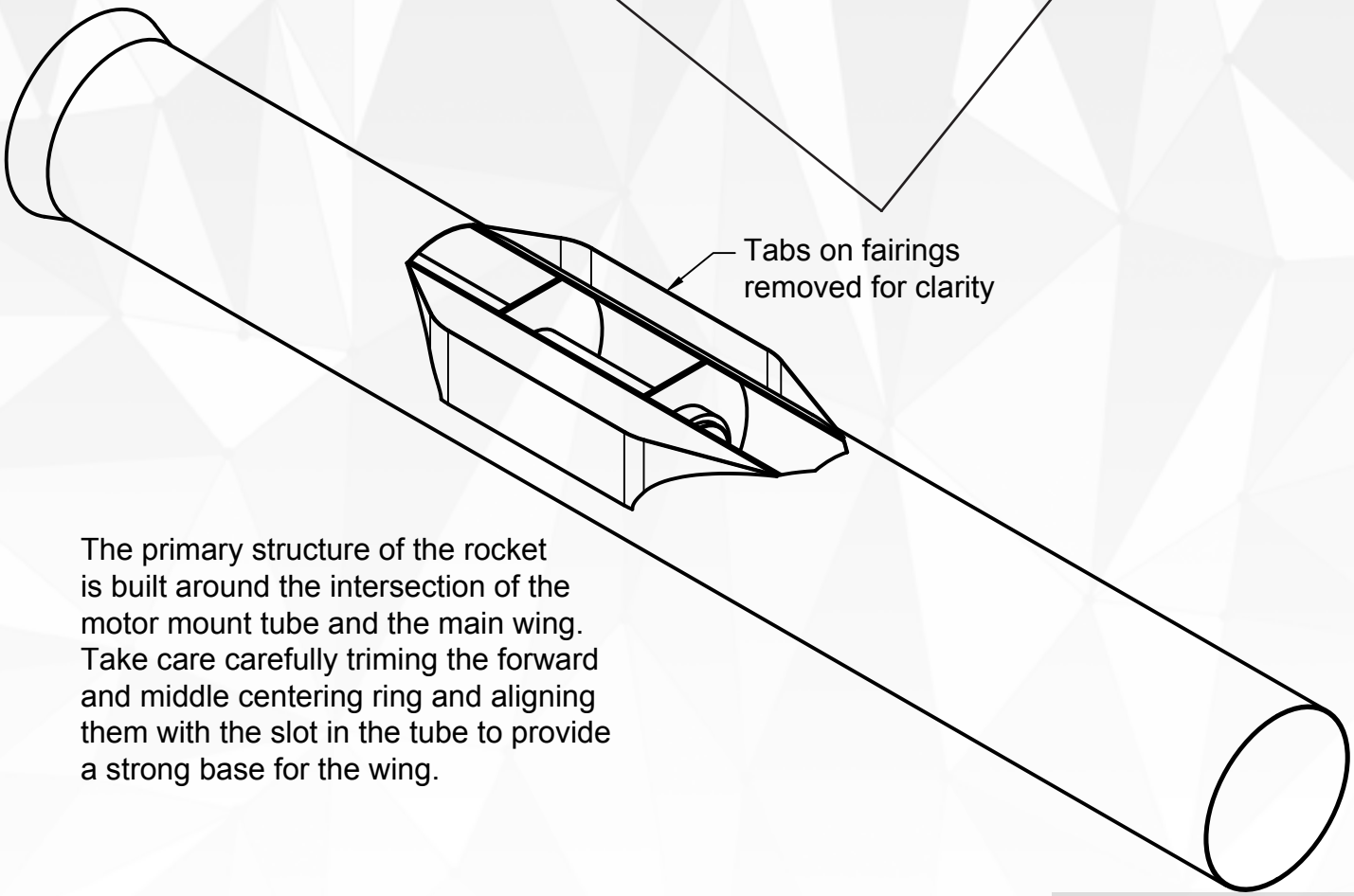
Continued from page 16

Template at 100% scale to cut the two main wing pieces from 1/8“ basswood (or balsa, if a lighter build is desired).

Main Wing Template



Upper Right Quarter

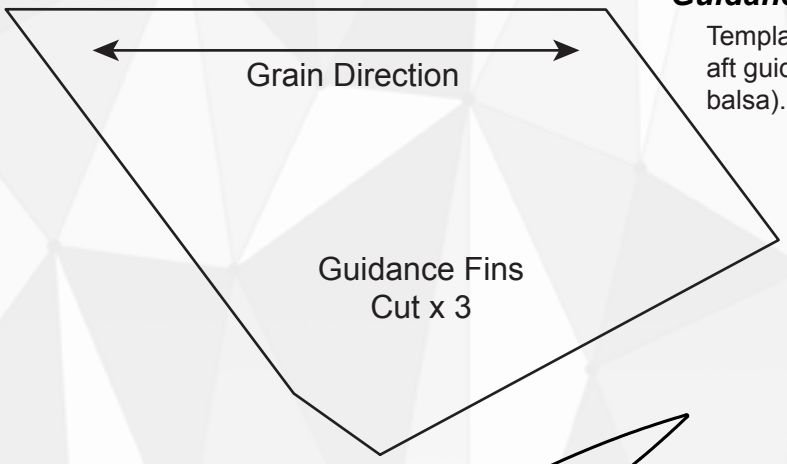


The primary structure of the rocket is built around the intersection of the motor mount tube and the main wing. Take care carefully triming the forward and middle centering ring and aligning them with the slot in the tube to provide a strong base for the wing.

Continued on page 18

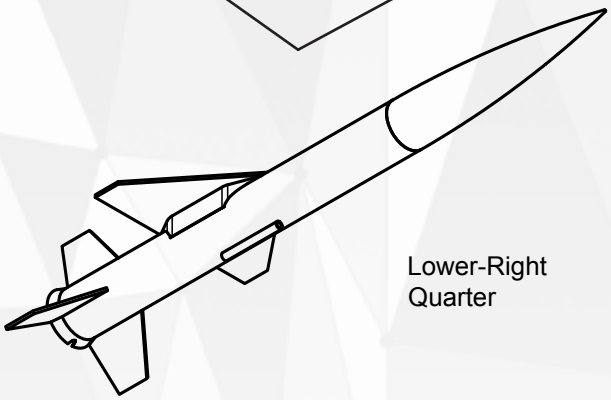
Minotaur XL Plan

Continued from page 17



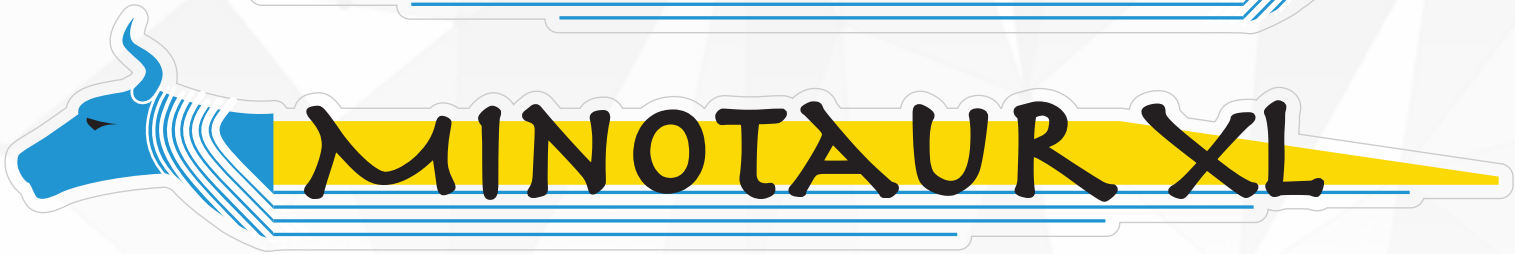
Guidance Fin Template

Template at 100% scale to cut the three aft guidance fins from 1/8“ basswood (or balsa).



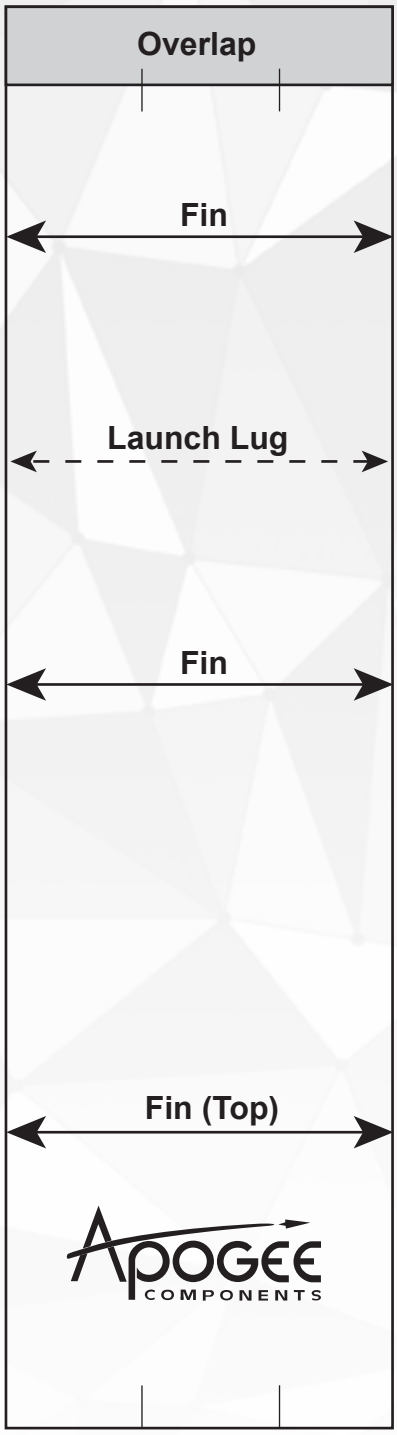
Decals

Decals at 100% scale.

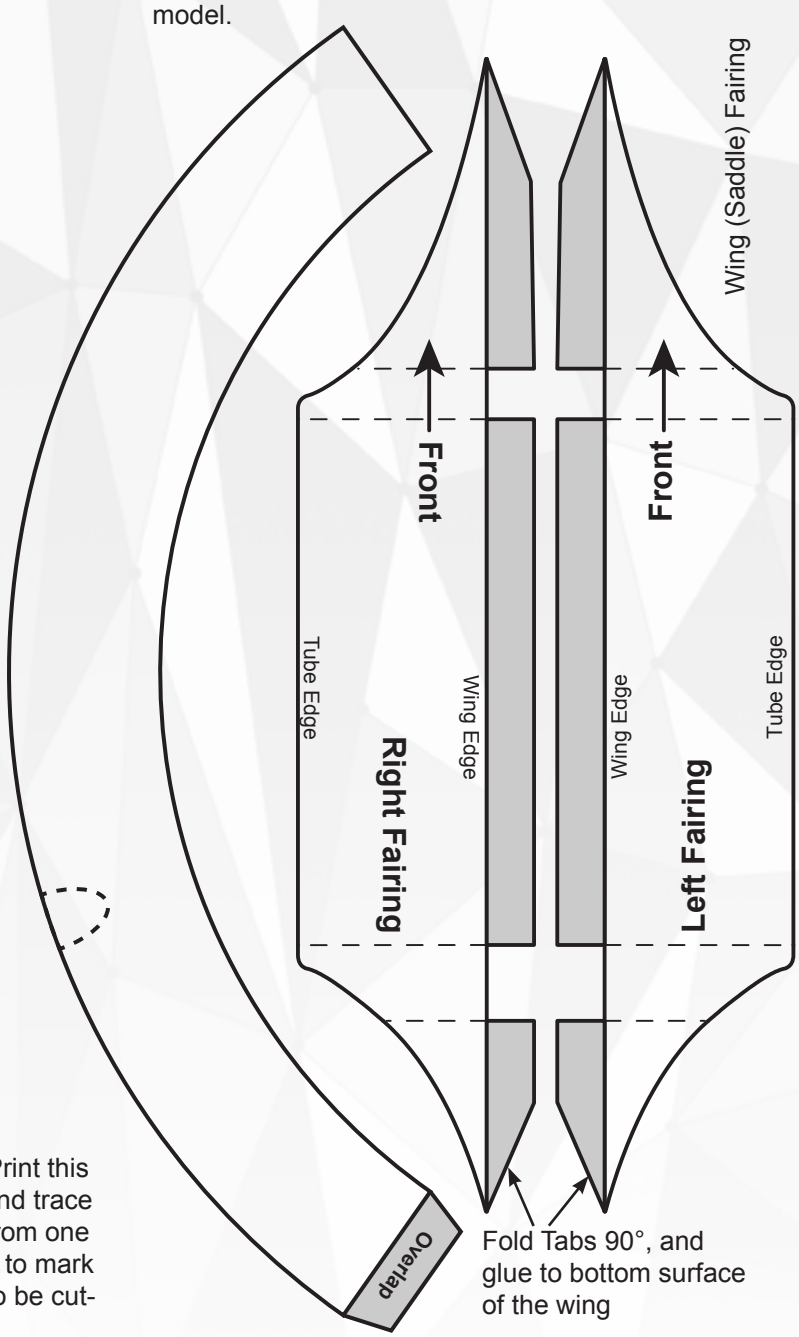


Minotaur XL Plan

Continued from page 18



Tube Marking Guide: Fin position marking guide at 100% scale. When marking the tube for cutting, the pattern should be aligned along the "top" line, opposite the launch lug.

Tube Cutout Pattern: Print this pattern at 100% scale and trace (with the flat side at 5" from one end) onto the body tube to mark the section that needs to be cut-out to mount the wing.

Cardstock Pattern: Cardstock parts at 100% scale. Print onto cardstock and then cutout for use on the model.