Kit Contents

Tools:

- Single edge Razor blade (1)
- Push Pins (6 ea)
- Ball Point Pins (4 ea)
- Emery Board (Fingernail board 1 ea)
- Plans
- Glue applicator
- CD containing plans, instructions, miscellaneous articles on rubber powered flight

Materials

- 1/16" X 1/16" X 12" Balsa (9 pcs) for rotor spars, bump posts and ribs
- 3/32" X 3/32" X 6" Balsa (7 pcs) for practice cutting & gluing
- 3/16" X 1/4" X 10" Balsa (2 pcs) Motor stick
- 3/32" X 3/32" X 12" Balsa (9 pcs) rotor spars, rotor hubs and bracing posts
- 1/16" X 1/4" X 1" Predrilled Plywood (4pcs) thrust bearing mount
- 1/8" X .73" diameter discs (2 pcs) for top rotor
- Wire Rotor shaft with plastic thrust bearing (4 pcs)
- Clay ballast
- Rubber (1 pc) 1/8" X 9.5 feet

Items needed to build helicopter

- Waxed Paper (1 piece 12" X 16")
- Building Board (approximately 5" X 13" A piece of flat material that will accept pins. Acoustic ceiling tile is perfect but foam or a cork board will be fine.)
- Non-corrugated cardboard or very thick and stiff paper (approximately 3" X 8")
- Glue stick
- Masking Tape
- Cellophane or clear packing tape
- Thread (2 pieces approximately 3 ft long)
- Covering material (kitchen plastic wrap, wrapping tissue, balloon Mylar® or similar.)
- Glue (acetone based; Dubro or Quick Grip , white glue;; Elmer's, wood glue; Tite-Bond or thick CA)
- Ruler or scale
- Scissors
- Patience & Practice

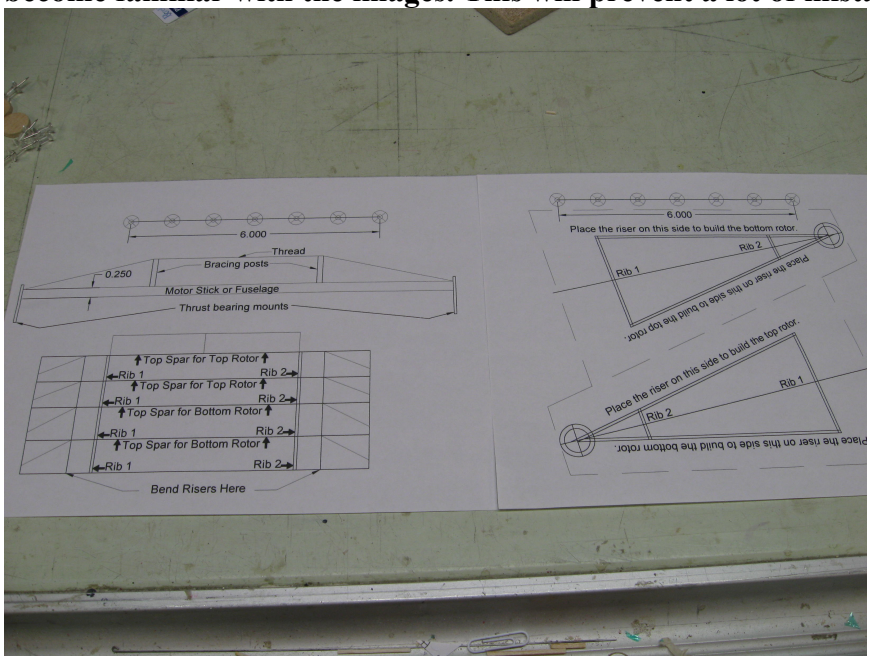
Items needed to fly the Helicopter well

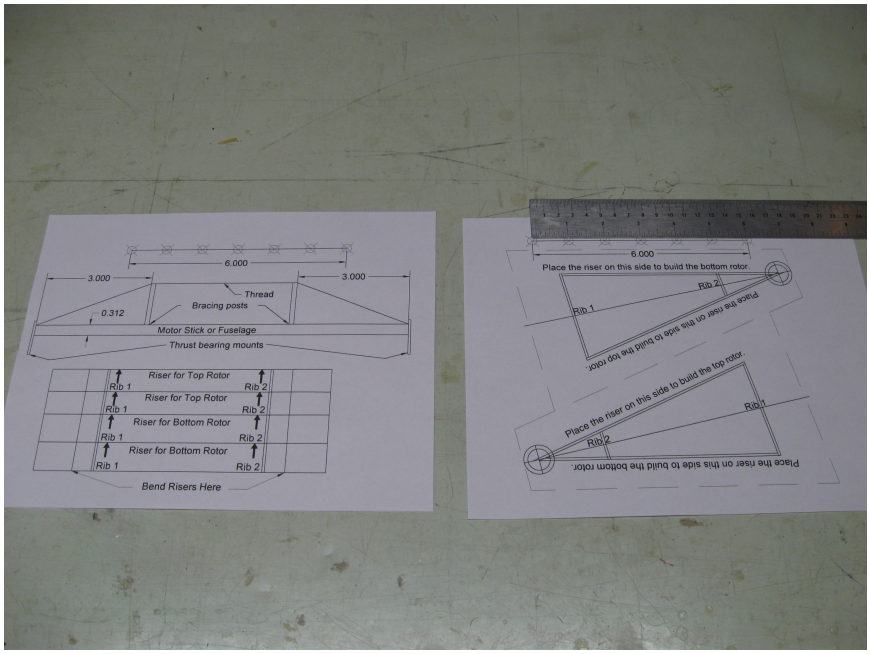
- Access to a balance that can measure 3.0 grams.
- 15:1 Ratio Rubber Winder (a 5:1 ratio winder is acceptable)
- Rubber Lube (Armor All®)
- A box or container in which to transport the helicopter
- Patience & Practice

Overview

Two rotors (think propellers but Helicopters have rotors) will be built. Please note the pitch (angles of the surfaces) of the top and bottom rotors are opposite of each other. Both rotors will be spun by the rubber motor but in opposite directions hence the need to

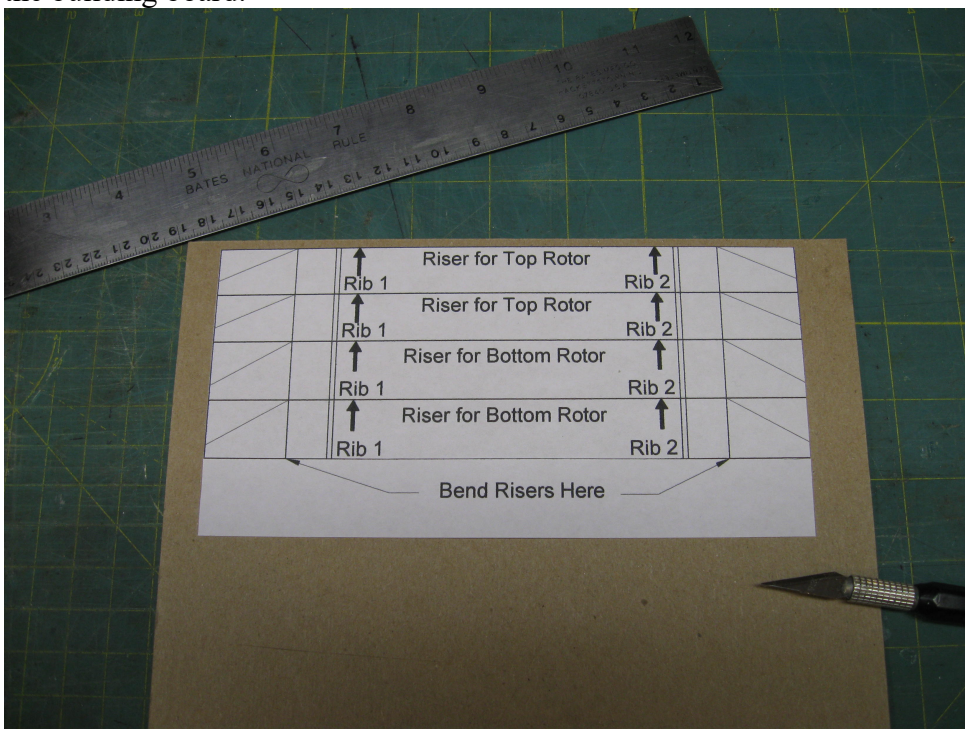
reverse the direction of their pitches. The motor stick will be braced with two posts and a length of thread running from each end over the posts.
PLEASE NOTE: When printing the .pdf files using Adobe you must set the “Page Scaling” to NONE or the drawings will not be full size.
Please note that some of the images used are from previous years and may show rotors with as many as 10 ribs. The 2013 rules specify the smallest diameter rotors and lightest helicopter to date so the number of ribs have been reduced from previous years.
Before you start please, please, please read completely through the instructions and become familiar with the images. This will prevent a lot of mistakes.





Step 1 Making the Risers

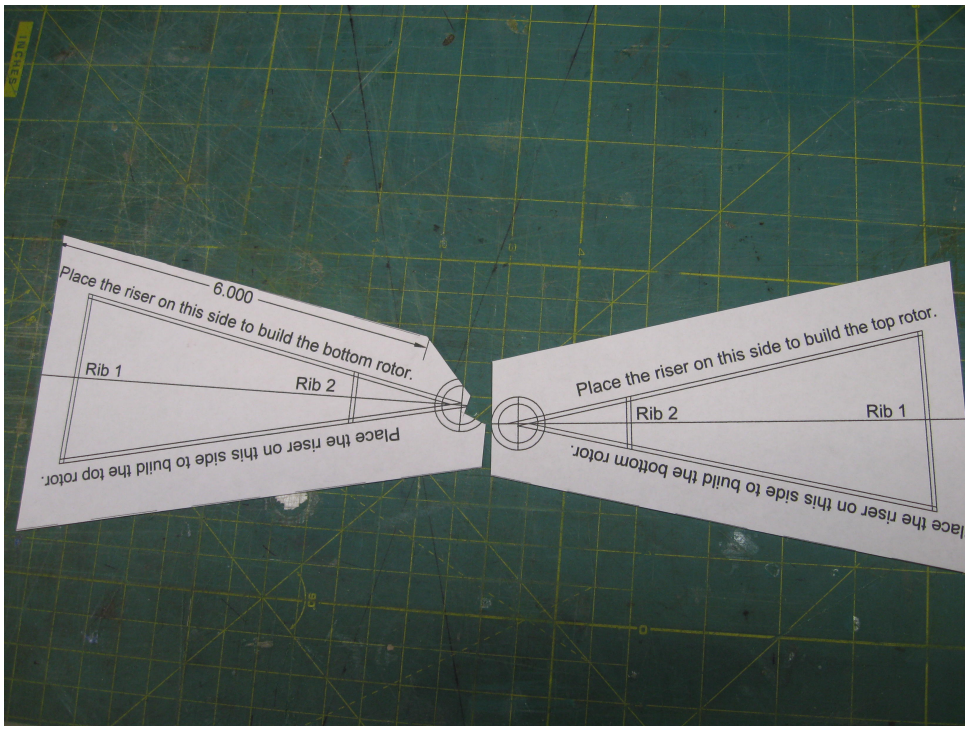
Cut around the four risers in the plans so you have one piece of paper containing all four. Glue this piece of paper to the thin cardboard. While the glue is drying you can start on the building board.



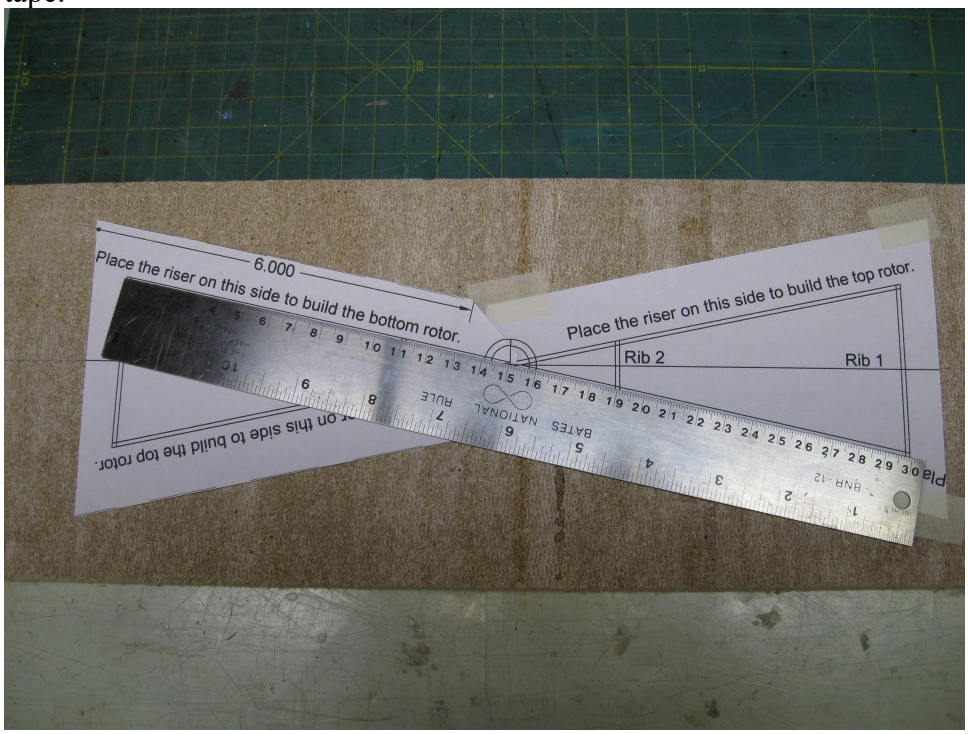
Step 2 Preparing the Building Board.

Find a flat surface where you can place the building board. A kitchen table generally works nicely. Any piece of flat material that will accept pins can be used as a building board. Draw a line lengthwise down the center of the building board.

Cut the rotor plans along the dashed lines to yield two pie shaped pieces. Cut approximately half of the circle at the small end of one of the plans.

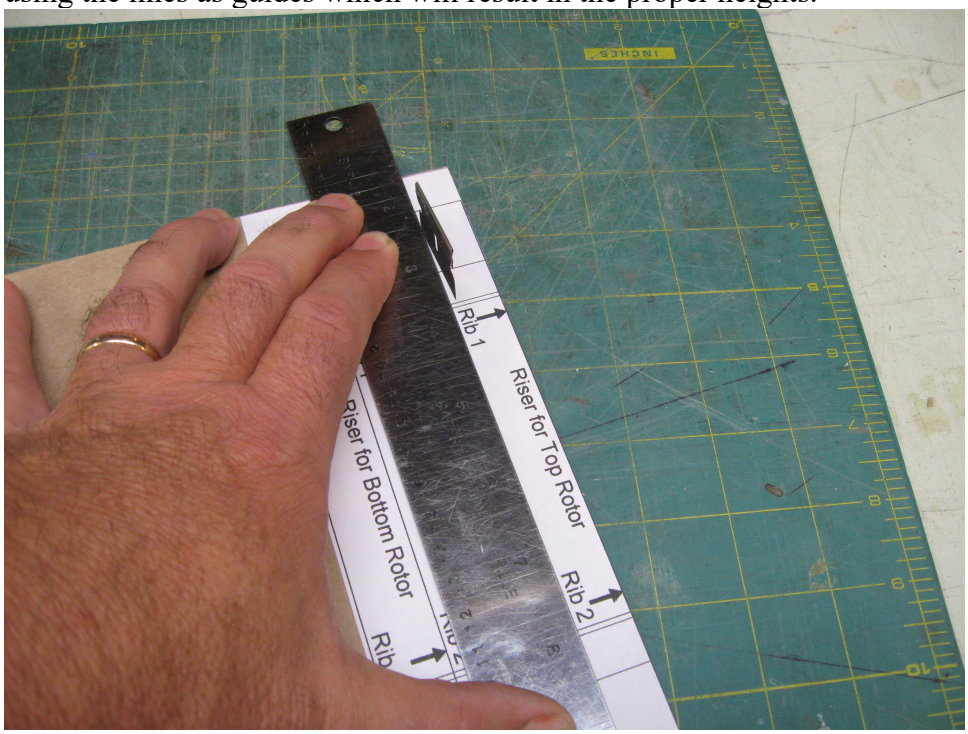


Place the piece with the complete circle on the building board with the small end near the center of the board. The center line on the plan should be directly over the line drawn on the board. Once you are satisfied with its position, tape it in place using 4 small pieces of tape.



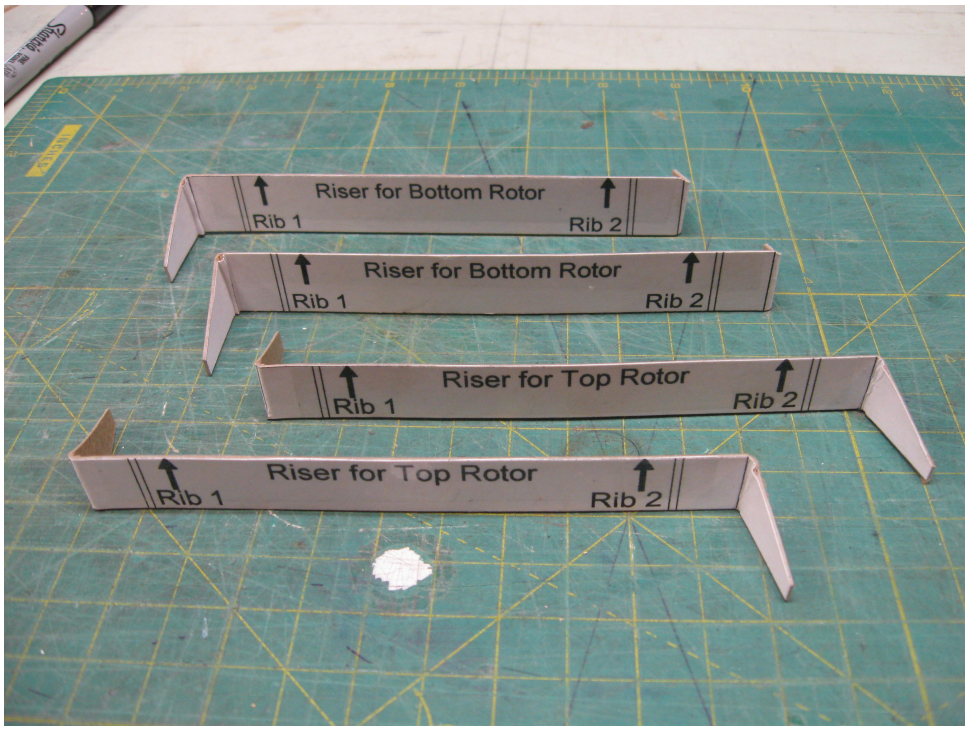
Place the other plan on the building board aligning the circles at the small end with the circles on the other plan and the centerline on the line drawn on the building board. Once it is properly positioned tape this in place.
Because paper shrinks and stretches, measure the overall length of the rotor spars (not the centerline). They should be about 29.9 centimeters. Making the rotor slightly smaller than the allowable maximum is intentional. If the rotor does not turn exactly about its center, the diameter swept by the longer of the two "halves" can be greater than the 30.0 cm limit which is not good.
Cover the building board with a piece of waxed paper and tape it in place. This will prevent the parts from becoming glued to the plans and board. Both the top and bottom rotors will be built using this one plan. If need be place weights on the board to flatten it to the table. You do not want the board to be bowed.

Step 3 Back to the Risers
Once the glue attaching the risers print to the card board has dried the four risers can be cut to size. Use a straight edge and the single edge razor to carefully cut the rises apart using the lines as guides which will result in the proper heights.



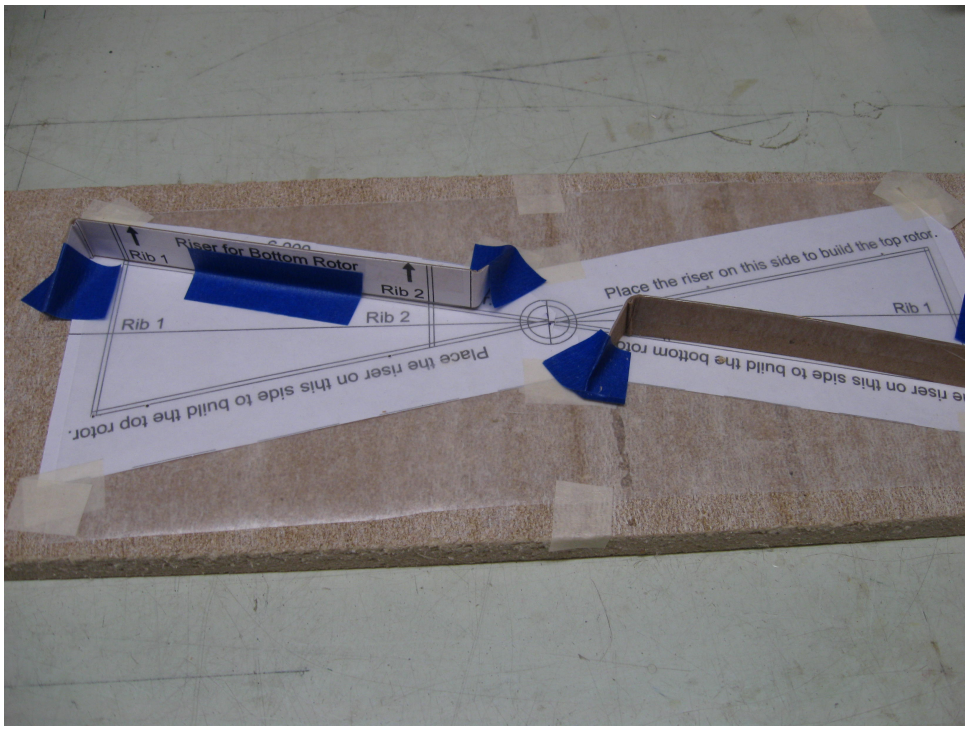
Once the risers are cut apart cover the top edge (were the arrows point) with cellophane or packing tape. This will prevent the glue from bonding the top spar and ribs to the risers. Once this is done you can use scissors to trim the risers to length and make the angled cuts on each end. (The angle cuts make it easier to tape them to the building board.)
Look closely at the directions of the bends shown in the figure below. If the legs are bent the wrong way you will not be able to place the bottom spar on the building board. This is not a disaster but your work getting the risers attached properly will have to be redone after bending the legs in the proper directions. When you bend the legs their bottom

surfaces should be flush with the bottom surface of the riser. If not, the riser will not be vertical.



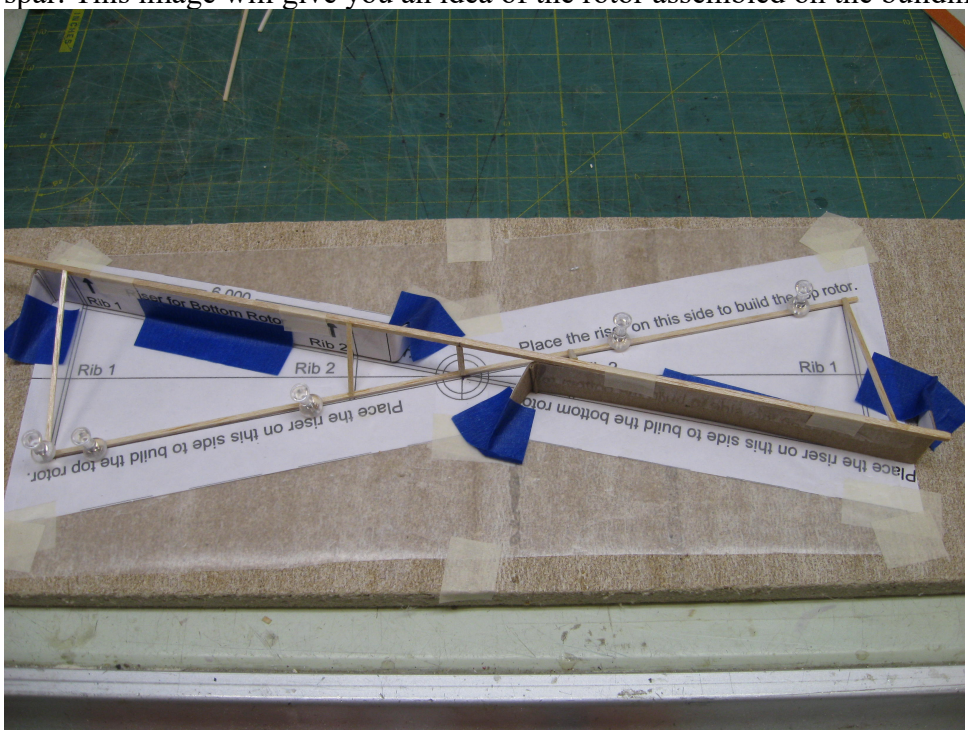
Step 4 Placing the risers on the building board.

Take two risers, either bottom or top (do not mix them) and place them over the appropriate location on the building board. Align the vertical double lines for Rib 1 on the double lines identified as Rib 1 on the rotor plan. There will probably be a mismatch at Rib 2 of ½ to 1 millimeter (remember about paper shrinking and stretching?). This mismatch will not create a problem because the exact location of this rib is not critical. Use three pieces of tape for each riser. One piece in the middle to keep the riser from sliding up or down the spar outline and a piece of tape on each leg.

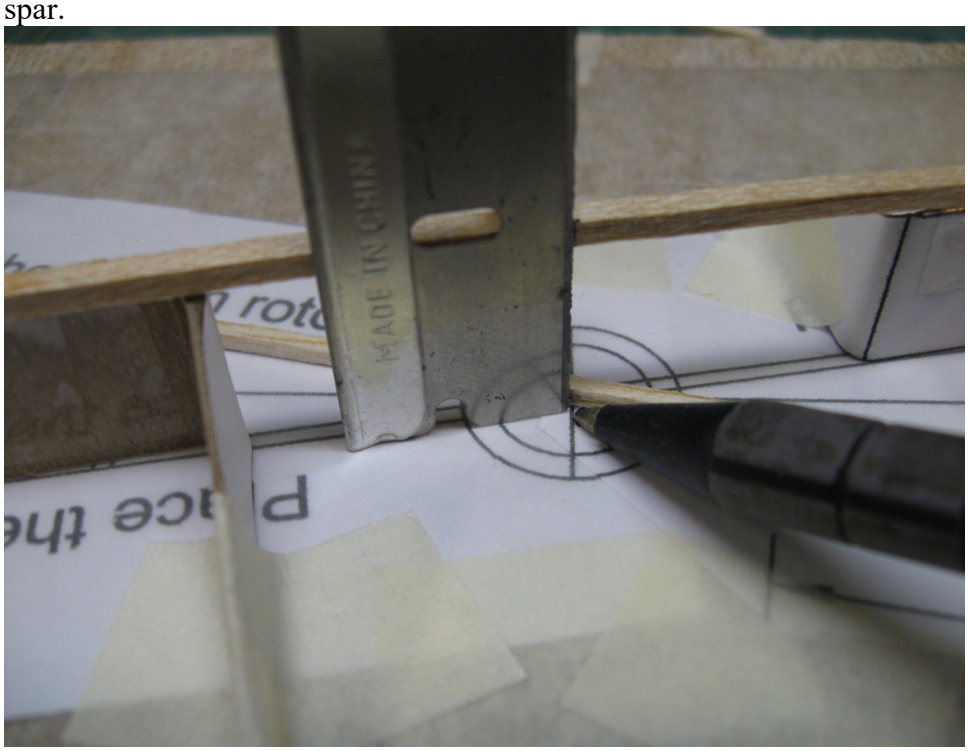


Step 5 Rotor Spars

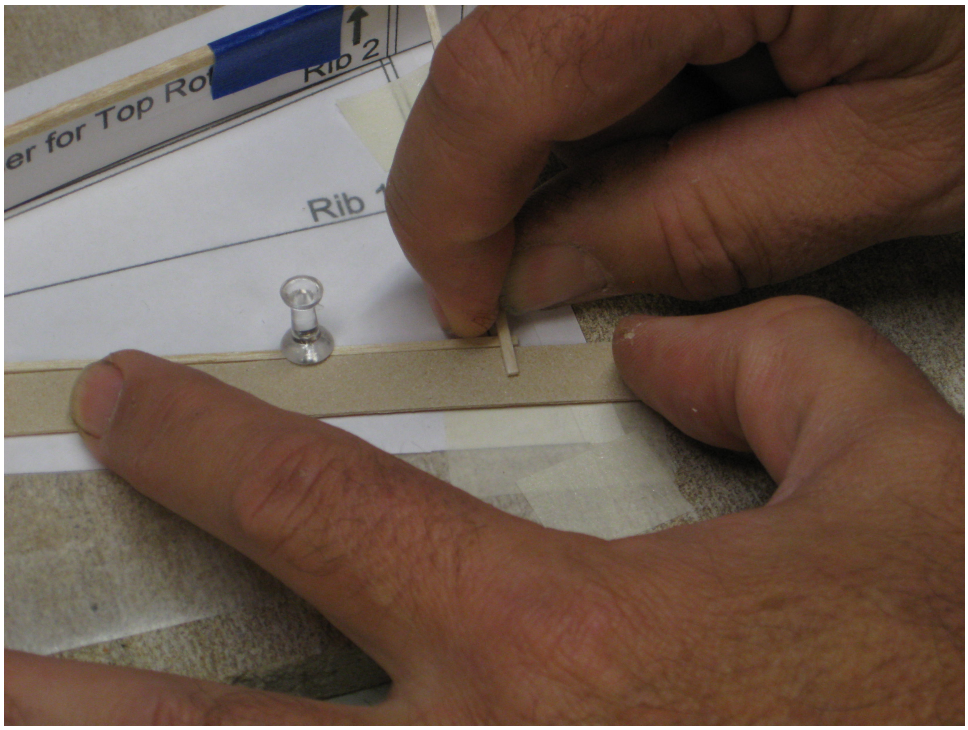
Place a piece of 1/16" X 1/16" X 12" balsa directly on the wax paper covering the outline of the rotor spar. Align it so both ends of the spar extend past the outline on the plan. Once it is aligned, use push pins to hold it in place. You will need to use the bottom of the plastic head to hold the balsa stationary. The pins should not be located where the outlines of the ribs join the spars. Allow room to glue the ribs on the top surface of this spar. This image will give you an idea of the rotor assembled on the building board.



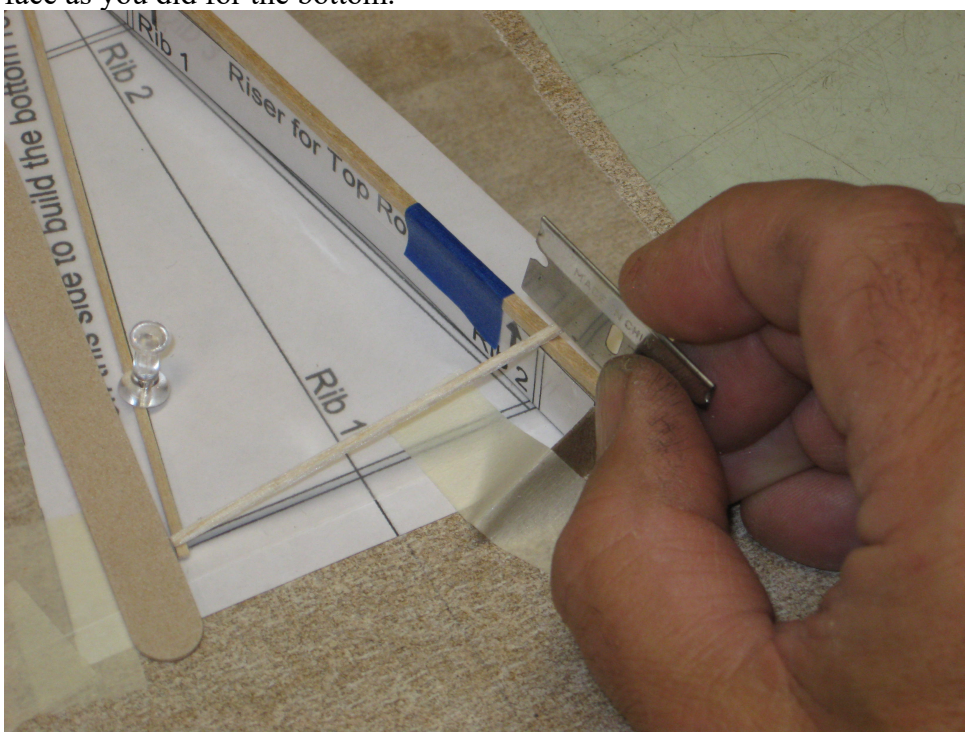
A gentle touch is needed when installing the pins. Do not apply so much pressure that you crush the wood and never push the pin through the balsa. Have 4 pieces of masking tape about ½" X ¾" ready. Place a piece of 3/32" X 3/32" X 12" balsa on the top of the risers. (To build a lighter AND MORE FRAGILE helicopter 1/16" X 1/16" wood can be used for both top and bottom spars.) Again, both ends of the spar need to extend past the outline of rib 1. Attach the spar onto the riser using two pieces of tape on each riser. Do not put tape where the ribs will be glued. Do not trim the ends of the spars. We will do that later.
With a pen place a mark the sides of the spar at the center of the plan. You can use a credit card, business card or the razor blade as a straight to get the vertical line on the top spar.



Step 6 Cutting & Sanding Ribs.
This step might take a bit of practice before you get the results you want so be patient.
It is important to say a few words about cutting balsa.
First: Supplied in the kit is a single edge razor blade. Razor blades are very SHARP. Handle them carefully and only by the reinforced edge where the metal is folded over.
Second: Even though the razor is sharp you must slice the wood not try to chop it. As you apply downward pressure on the razor blade, push or pull it forward or backward to slice the wood. If you just push down with the razor blade, to cut the wood, you might get a good cut once in a while but most of the time the wood will crush.
Use some of the short pieces to practice with.
Here are some techniques that you may find helpful:
Position a piece of 1/16" X 1/16" wood over the Rib 1 location with one end extending past the lower spar. Using the nail board gently sand the bottom of the 1/16" X 1/16" wood to get the correct angle.



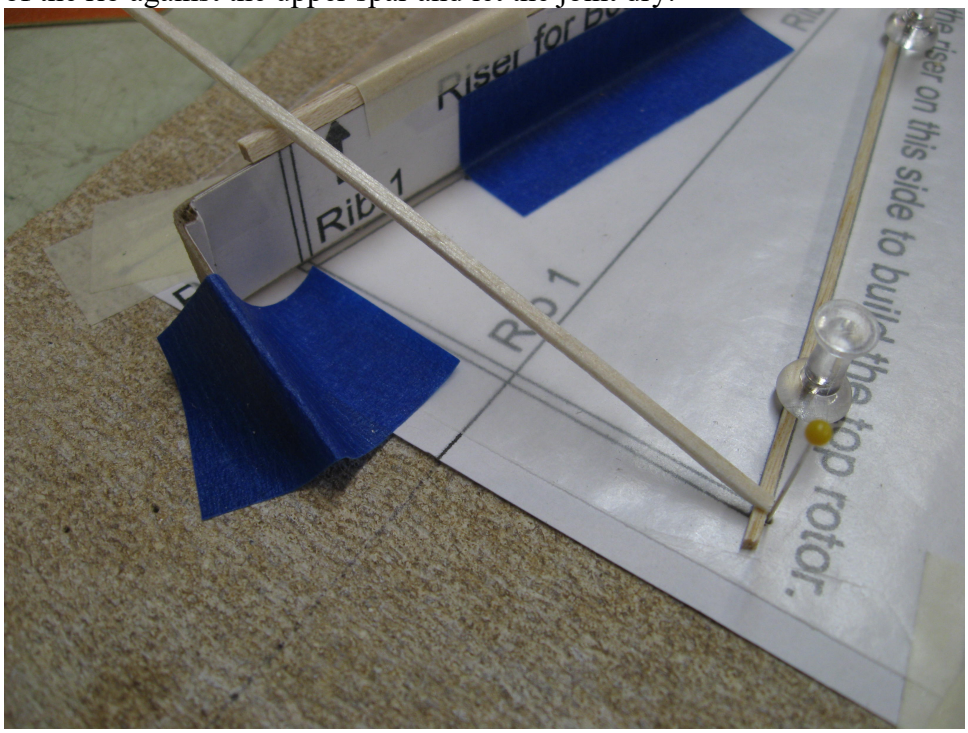
With the bottom of the rib sanded to the proper angle it is time to cut the rib to length with the proper angles. This can be done by aligning the razor blade with the top spare and cutting down vertically. This takes practice to achieve good results. Another approach is to cut the rib about a 1/16” too long and use the nail board to sand the top face as you did for the bottom.



Step 7 Gluing the Ribs to the Spars

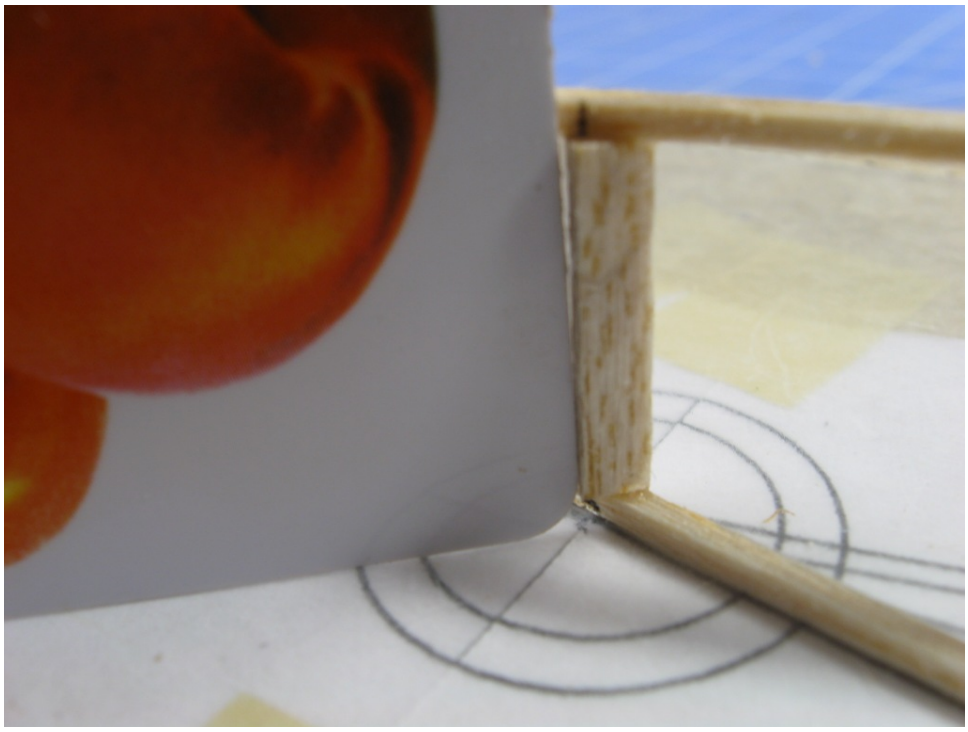
I recommend placing one of the short (1") Ball Point pins on the outside of the spar that is pinned to the building where the rib will be glued. Before applying any glue test fit the rib by placing one end against the pin and the other against the spar taped on the riser.

If you are using an acetone based glue (Duco or Ambroid), white or wood glue you need to use a technique called double gluing. (All of these glues should be thinned before use. The wood glues can usually be thinned with water while acetone, nail polish remover, is used to thin Duco and Ambroid.) Apply a VERY SMALL amount (about a quarter of a drop) of glue to ends of each rib and to where they will be glued to the spars. Allow this glue to completely dry. (If you use too much glue the drying time will take a many minutes.) Apply a small amount of glue to the appropriate locations on the bottom spar. Place the rib on the spar and slide it against the 1" Ball Point pin. Just rest the other end of the rib against the upper spar and let the joint dry.



Continue gluing the remaining 3 ribs in this manner. Once the glue has dried raise the unglued end of a rib away from the spar to create a space about 1/8". Apply a small amount of glue to the rib and gently push it back into contact with the spar. Do this for the remaining 2 ribs and allow the glue to dry. Once the glue is dry, use a piece of 1/16"X1/16" Balsa and gently push against each ribs' glue joints. If any are loose, glue the joint again. The ribs must be firmly attached to the spars or the rotor will disassemble while spinning and ruin your day.

Take the a piece of the 3/32" X 3/32" Balsa and cut it to fit between the top and bottom spars. This will be the Rotor Hub. Glue it between the upper spar (taped to the riser) and the lower spar (the one pinned to the building board) exactly in the center of the rotor. The marks you made earlier on the sides of the lower spar will help locate the center of the rotor. Use something square (a credit or ID card will work) to make sure the Rotor Hub is vertical. Each end should be in the center of the rotor.



Note the gap at the top of the hub. While it would be nice if it was not there, this will give an idea how much error can be acceptable,

Step 8 Removing the rotors from the Building Board

First gently remove the 4 pieces of tape that hold the top spar to the risers. (The spar will most likely be glued to the riser. We'll take care of that shortly.)

Some of the 1" Ball Point Pins will be glued to the ribs and lower spar.

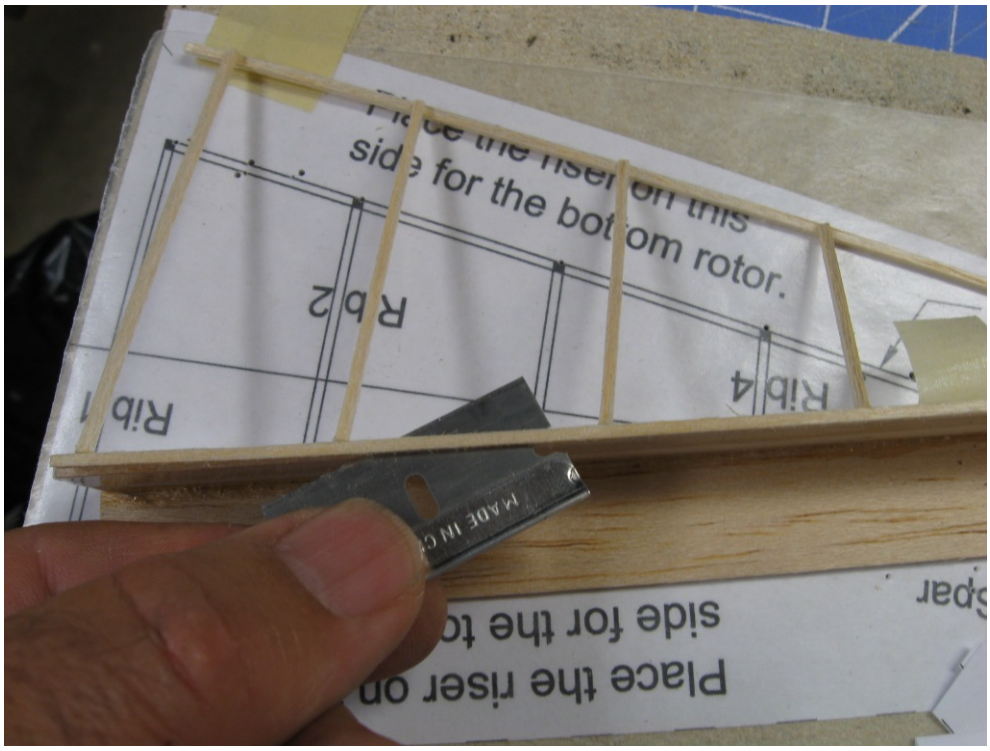
DO NOT PULL THE PINS OUT! ROTATE the 1" Ball Point Pins **BEFORE** you pull them out of the Building Board. Once they rotate freely then you can pull them out gently. If the spar lifts off the waxed paper make sure the pins rotate and hold the lower spar down as you remove the pins.

Remove the push pins that held the lower spar in place.

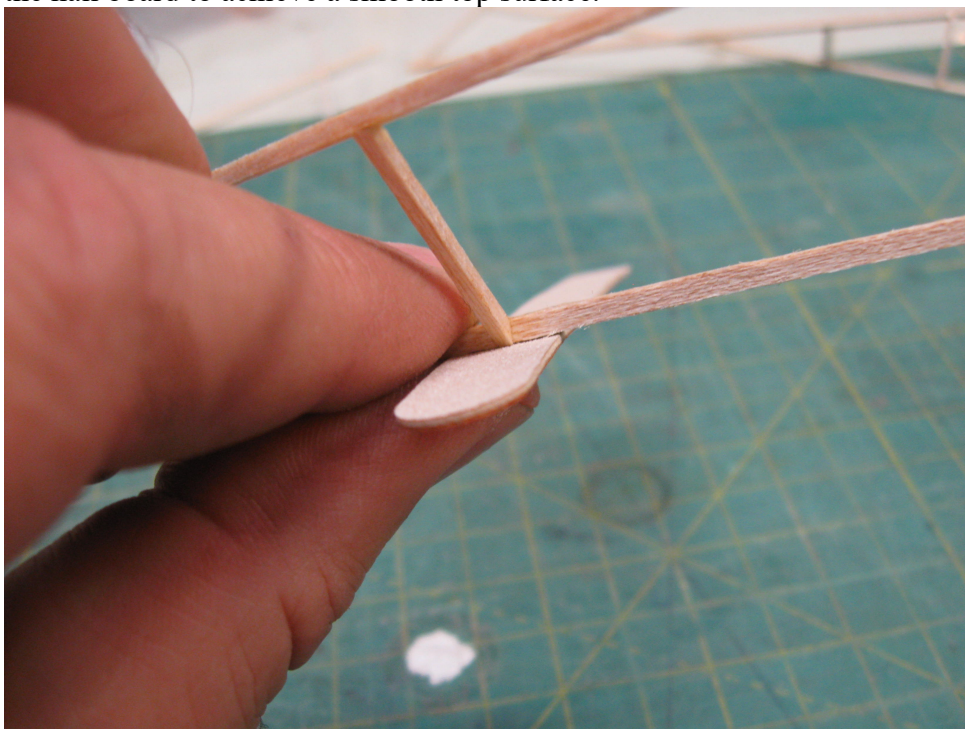
Remove the pins (or weights) that hold the risers in place.

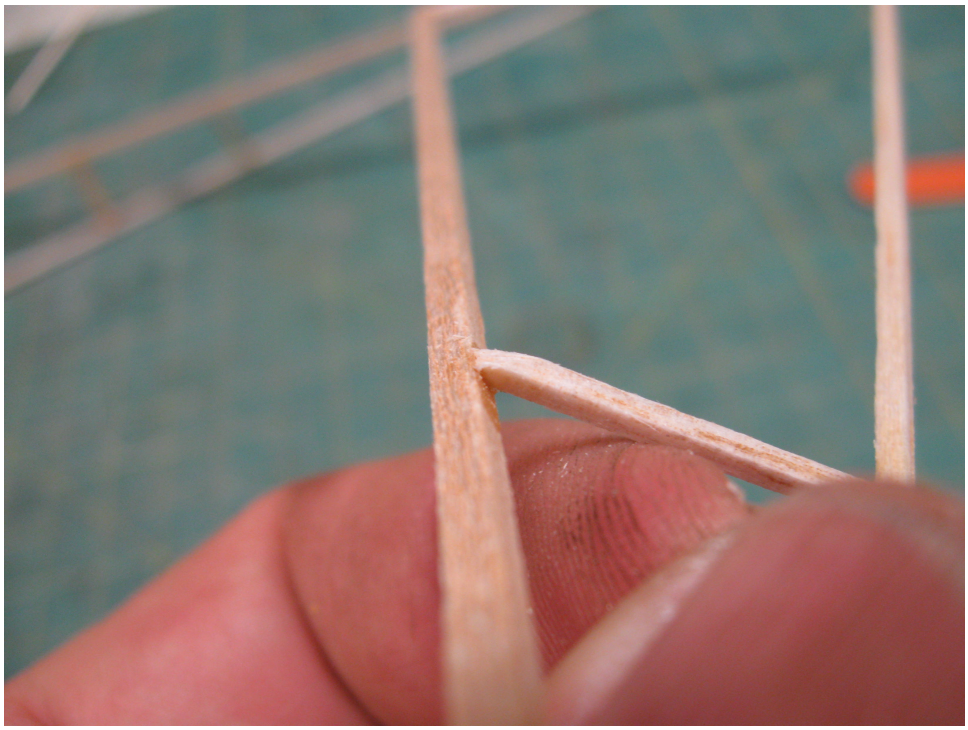
DO NOT MOVE THE ROTOR YET!.

Slide the corner of a thin piece of stiff paper or plastic (business card, credit card, driver's license) under the lower spar between any two ribs. Gently slide it to each end and center of each side of the rotor. This will break loose any glue that has attached the spar to the waxed paper. Now that the lower spar is loose you can check to see where the ribs on the upper spar are attached to the risers. Carefully break the glue loose from the risers until the rotor is free. Look at the picture below. The razor blade was inserted between ribs 2 & 3 and is being pushed from left to right to break the glue loose at the ribs.



Step 9 Trimming and sanding the rotors.
No matter how careful you were attaching the ribs to the spars there will be some bumps and bits of glue that need to be removed before the rotor is covered with plastic film. Use the nail board to achieve a smooth top surface.





Now is the time to trim the ends of the spars flush with the ribs. Be sure to support the spars as you cut the excess off. Once this is completed take the nail file and smooth any raised pieces and sharp corners that might tear the film. As when you sanded the ends of the ribs use a gentle touch.

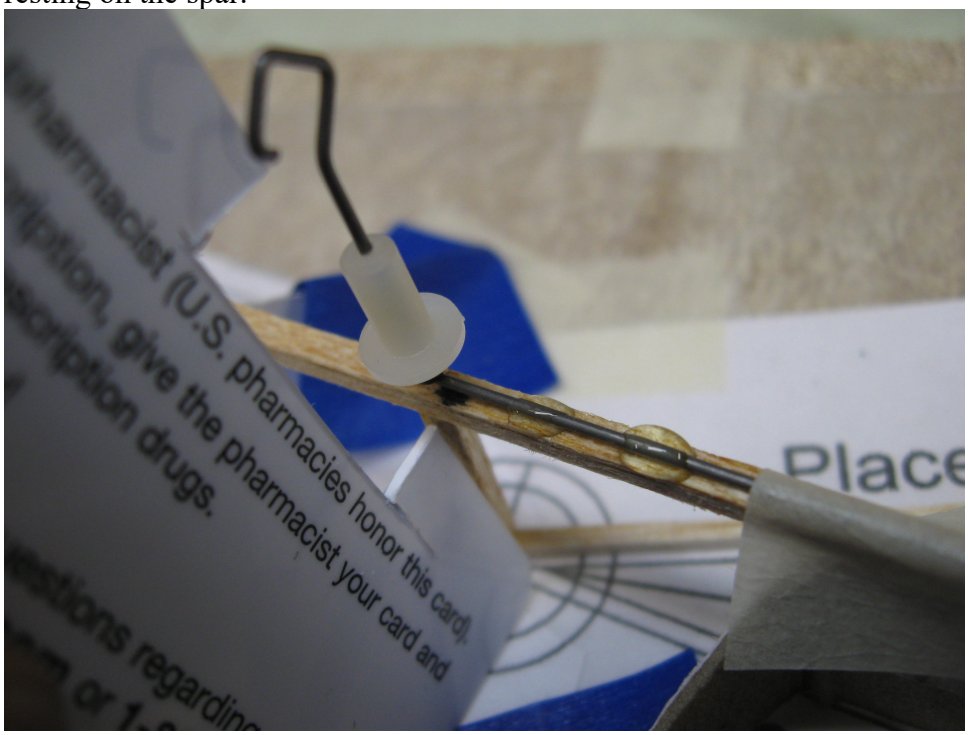
Step 10 Attaching the Rotor Shaft to the Top Rotor.

It is VERY IMPORTANT to take your time to get this right.

Locate the Top Rotor and its lower spar. The lower spar should have the center marks you made to help locate the rotor hub. These marks will now be used to locate the rotor shaft. Take a piece of stiff paper about 2” X 2” and cut out a rectangle about ¼” X ½” in the middle of one edge.

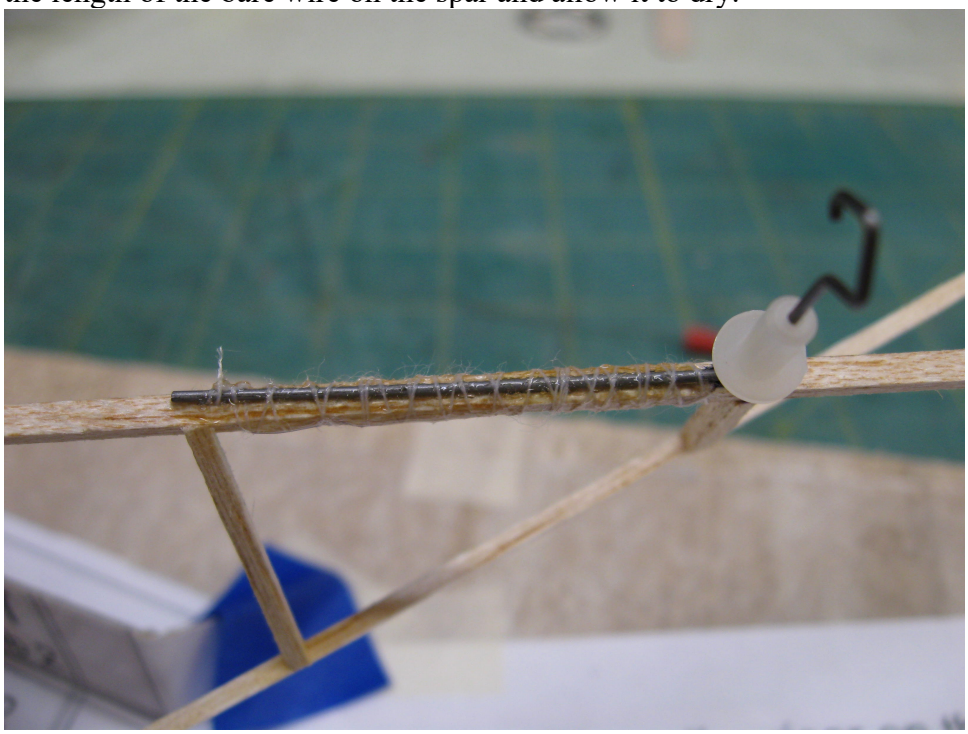
Hold the top rotor turned upside down. Place the rotor shaft on the spar so the 90° bend is at the center mark on the spar. The bare leg should be centered in the width of the spar. While holding the shaft on the spar, use your other hand to place the paper along the hub and shaft. (The cutout in the paper will allow for clearance for the hardware.) Make the rotor shaft parallel to the edge of the paper.

Have your other team member place a SMALL piece of tape on the wire to attach it to the spar. Double check the alignment then place two drops of glue on the leg of the shaft resting on the spar.



Do not get glue on the black glass bead, the Teflon washer, the white nylon thrust bearing or your fingers. Allow the glue to dry while ensuring the shaft remains in position. Once the glue is dry recheck to ensure it is parallel to the hub. Once satisfied with the

alignment wrap the wire and spar with a piece of thread and apply a coating of glue along the length of the bare wire on the spar and allow it to dry.



Step 11 Attaching the Rotor Shaft to the Bottom Rotor.
The process is the exact same as for the top rotor with

ONE IMPORTANT EXCEPTION.

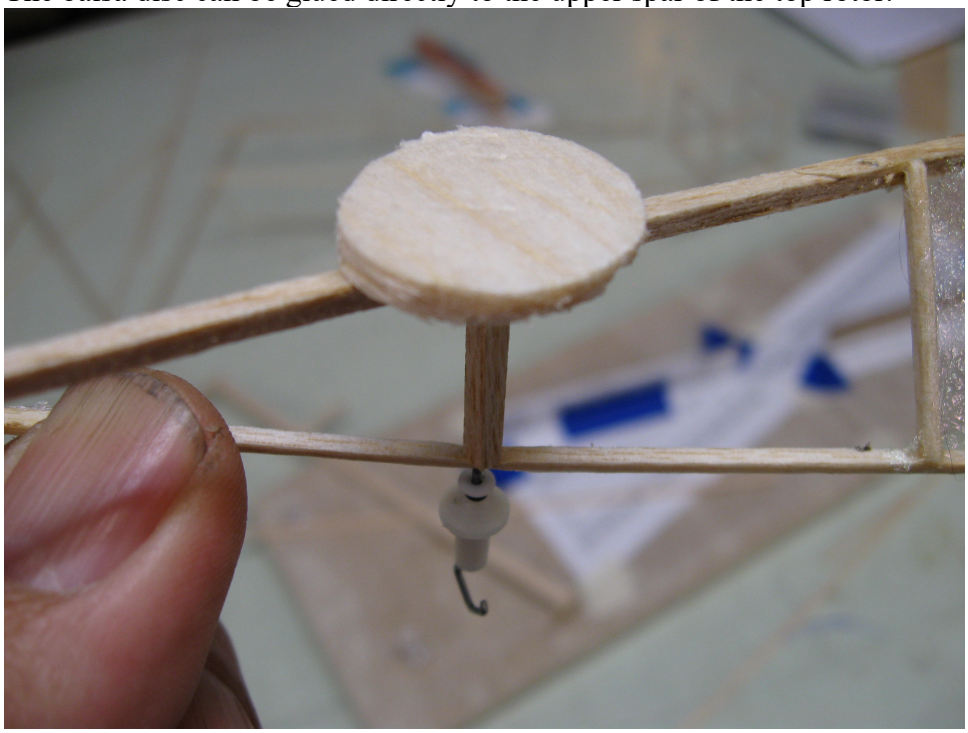
The rotor shaft for the bottom rotor is attached to the top spar.

Remember both rotors will be driven by one rubber motor and will rotate in opposite directions.

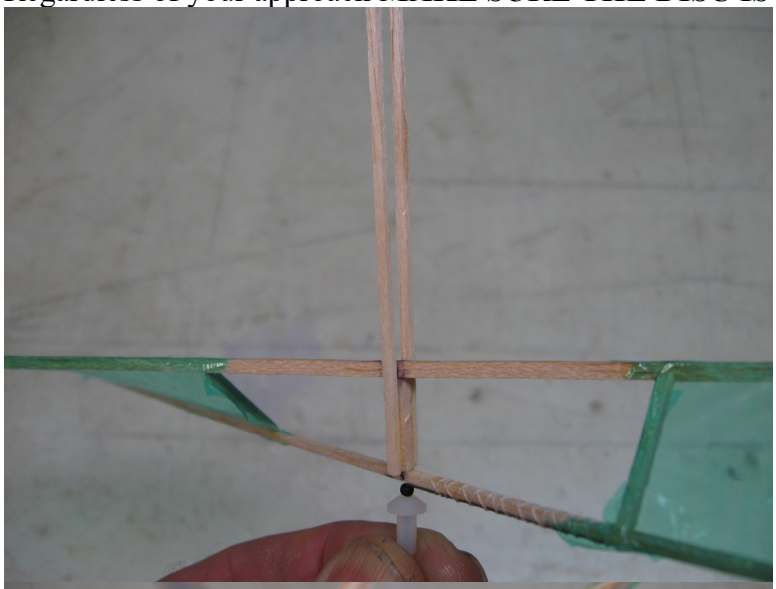
Step 12 Covering the rotor using a glue stick
Included with this information pack is an article on how to cover with film using a spray adhesive such as 3M® 77. I prefer to use a glue stick because the film can be repositioned (correct a mistake) unlike some of the sprays.
Cut a piece of kitchen plastic wrap about 18” long. Cut this into 4 pieces approximately 6” X 9”.
Take one of the pieces and smooth it out on a flat surface with one of the 6” edges at the edge of the flat surface.
Before applying adhesive to the rotor, practice placing the rotor on the film and rotating it so the upper spar is the only piece contacting the film. Next, practice rolling or rotating the rotor so Rib#1 contacts the film, then the lower spar. Do this a few times because once the film is stuck to the wood, removing it is not fun and you stand a chance of breaking the rotor.
Apply the adhesive to the top surface of the spars, rib #1 and rib #5 on one side of the rotor. (You marked these surfaces in Step 4 so they are now easy to identify.)
Place the rotor onto the film so the upper spar only contacts the film. Gently press the back side of the spar to the film.

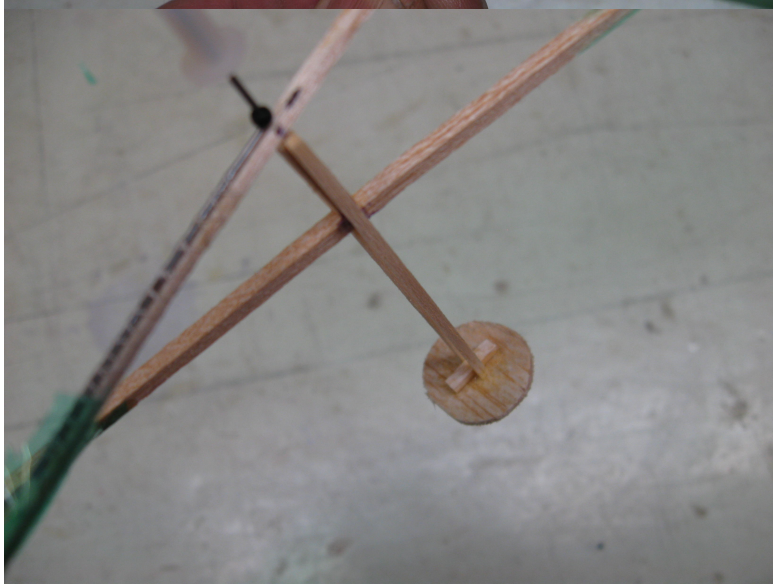
Now rotate the rotor so rib #1(the first spar should still be on the flat surface) is in contact with the film and press this to the film.
Rotate the rotor so the lower spar contacts the film. (The film has lifted off the table where it is attached to the other spar and rib #1.) Press the spar to the film.
Lift the rotor off the table and attach the film to rib #5 by squeezing the rib between your finger and thumb.
Since this is harder to describe than it is to do, there is a short video on the CD that shows the covering being attached to the rotor.
Hold the rotor so the excess film falls away from a spar. Apply adhesive to the exposed surface and then attach the film. Do this for the other spar and ribs 1 & 5. Trim the excess film from the rotor using a razor blade.
Repeat this for the other side of the rotor and the other rotor.

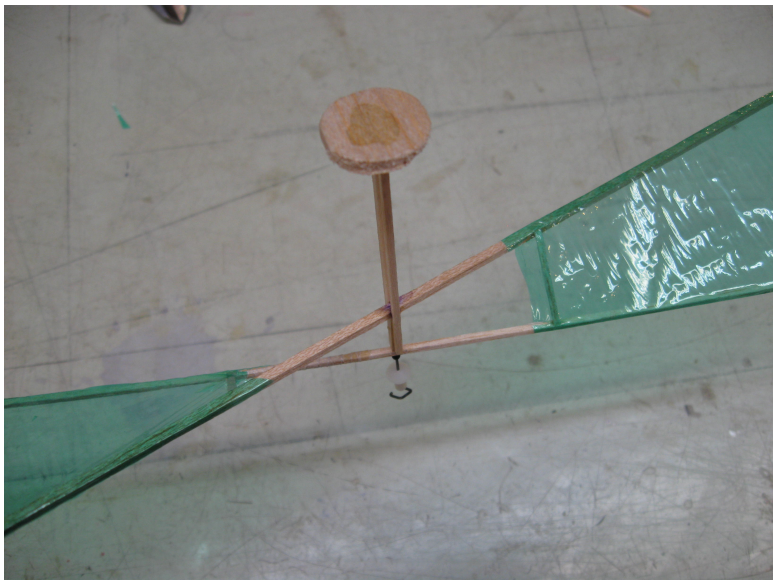
Step 12 Applying the Dime size disc to the Top Rotor
I would like to give my thoughts on why this is a requirement. Helicopters designed for national and international indoor competitions have a post on their top rotor commonly referred to as a "Bump Stick". This Bump Stick is at the center of the rotor and is the first thing to contact the ceiling when the helicopter reaches maximum height that is the ceiling. Often the helicopter will remain in place against the ceiling whirling away for what seems to be an eternity until it starts to descend.
I can only guess that someone has assumed if the Bump stick is sufficiently pointed and the helicopter climbs fast enough and the ceiling material is soft enough, the bump stick can impale the ceiling, stick there and get an advantage in flight time. I do not understand the premise. If this should happen the top rotor will stop spinning if the Bump stick skewers the ceiling and the flight time should stop, but as the saying goes, "Those the rules".
The balsa disc can be glued directly to the upper spar of the top rotor.



This approach will meet the intent of the rule but will not provide the benefit of a Bump stick unless the helicopter is perfectly stable. (I have not seen any rubber powered free-flight helicopter fly like this.)
I suggest adding an extension to the top rotor's upper spar and attaching the disc to the extension. Below are images that show one approach.
Please remember if the disc detaches during a flight the time will stop at that moment.
Regardless of your approach **MAKE SURE THE DISC IS ATTACHED SECURELY**







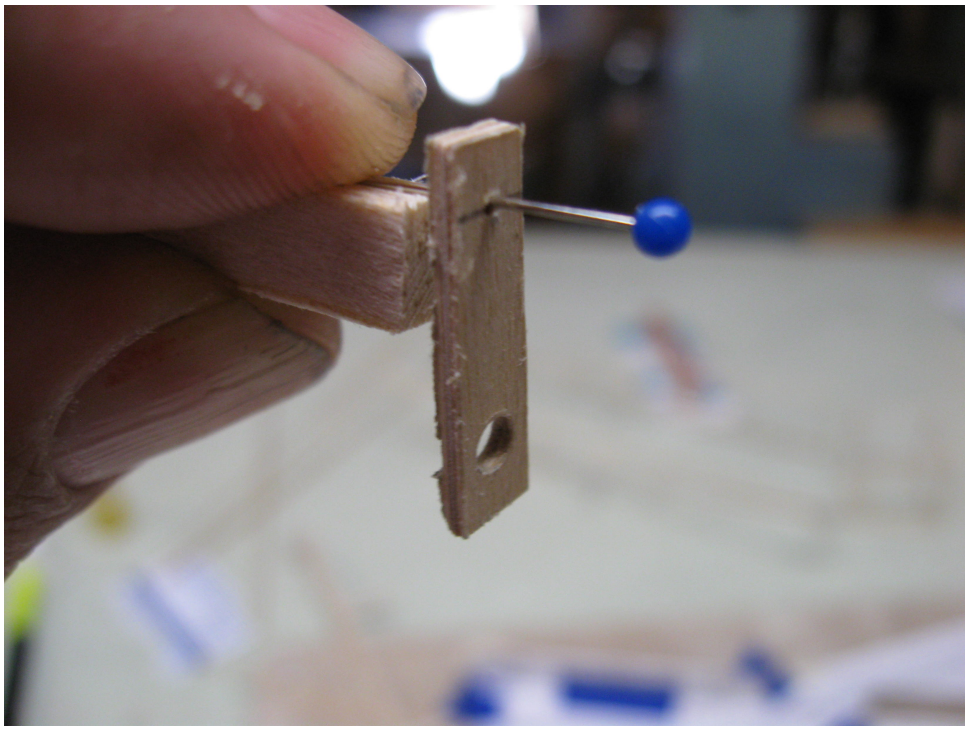
Step 13 Balancing the rotors

Hold the rotor by the white plastic thrust bearing and you will notice one blade always goes to the bottom. The rotor is out of balance and the bottom blade is heavier than the top blade. Cut a piece of masking tape about 1" long. Press the adhesive side to your shirt or pants to reduce the strength of the adhesive. You want this to just barely stick to the top blade. Hopefully this amount of tape will make the rotor rotate and the blade with the tape is now on the bottom. If it does not rotate add another piece of tape. If it rotates with the first piece of tape, use scissors and start to cut off small pieces of tape until it rotates again. Do not be surprised if it only rotates 90 degrees and is horizontal. Cut a new piece of tape the size of the one that rotated the blade. Attach it to rib #1 on the light blade. Fold the tape over so it is on both sides on the blade. If more than one piece of tape was needed, use a scale to get the weight of the tape. Depending on how much weight is needed you can glue a small piece of ballast (wood, plastic, wire or etc.) to the inside of rib #1.

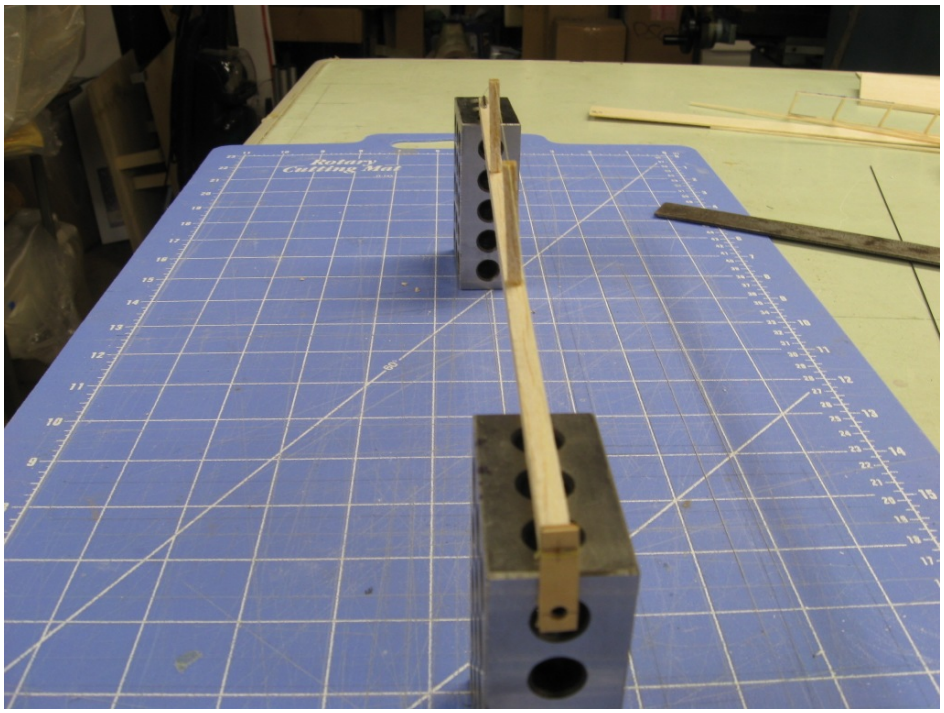
Step 14 Assembling the Motor Stick

Locate the 3/16" X 1/4" X 10" stick and the 1/16" X 1/4" X 1" Predrilled Plywood Thrust bearing mounts.

The thrust bearing mounts are glued to each end of the motor stick. Place a Ball Point pin through the small hole in the mount. Hold the pin on the 3/16" wide side of the stick. Securely glue the mount to the stick.



Glue the second thrust bearing mount on the opposite end making sure they are oriented the same way.
Cut two pieces of 3/32” X 3/32” to approximately ¾” to make the bracing posts. Look at the plans and glue them on the proper side and locations. Place a little glue on the tops of both bracing posts so the thread will not cut into them. It is more important that they are vertical and in line with each other than where they are located.
Tie a piece of thread to one of the thrust bearing mount (feeding it through the small hole makes this easy.) and glue it to the thrust bearing mount. Once the glue is dry, pass the end of the thread through the small hole in the other thrust bearing mount. Set the thread on the tops of both bracing posts and pull it taught enough that the motor stick just barely begins to bend. Make a couple of loops around the thrust bearing mount and glue the thread to the thrust bearing mount while keeping tension on it. Once the glue is dry, apply glue to the tops of both bracing posts. This thread will counteract the force of the rubber motor. Without the string, the motor stick will at least distort and at worst break from the force of the rubber.



Step 15 Final adjustments

Insert the top rotor into the thrust bearing mount by carefully threading the wire rotor shaft through the hole.

While every effort has been made to insure the wire rotor shaft was bent at a 90 degree angle it is possible the angle is not as precise as it should be. The top rotor should spin freely and perpendicular to the motor stick. If it is not perpendicular due to the bend in the wire rotor shaft adjust the bend by holding the spar and wire between your fingers with one hand and the white thrust bearing in the other hand. VERY CAREFULLY bend it in the direction required. Small pliers can also be used but hold both legs of the wire. If you don't hold both while trying to bend the wire, either the spar or thrust bearing mount will break.

Do the same for the bottom rotor.

Place the completed assembly on a scale that you know is accurate. (If you are in doubt ask some one to help you calibrate the scale with a set of test weights.) Ideally the assembled helicopter WITHOUT the motor will be just less than 3.0 grams. Do not be disappointed if your first helicopter weighs 4 or more grams. As you develop skill in building and are able to use more sophisticated materials and techniques the weight will come down.

Once you achieve a sub 3.0 gram helicopter, add clay ballast to the bottom of the motor stick until you reach 3.05 grams.

It will be very difficult to wind the rubber motor with the propeller. It is impossible to generate the number of turns with the motor attached to both rotors. I really suggest using a rubber winder and wind the rubber off of the helicopter.

Many articles have been written about winding rubber motors so I will not address the topic with these instructions but I cannot stress the importance of becoming familiar with this information. With the CD are a couple of articles which specifically address winding rubber and adjusting motors.

Step 13 Flying

Before you transport your helicopter outside, you will need a box of some type in which to carry it. If it is windy or raining the helicopter can be ruined by the elements in seconds. A pizza box with raised sides and a lid can do the job.

When you pack the helicopter to go to a flying sight also pack a tool/repair kit. This should contain a couple of pieces of wood, plastic covering, glue, tape, clay ballast, a couple of paper towels and any other items you might need to perform a "field repair" so you can keep flying. Along with this tool/repair kit you should have your winder, rubber lubricant, spare rubber motors, flight log and pen or pencil. Make a check list for these items so you can be sure you have everything you need.

Once the motor is wound and attached to the rotor shaft and rear rubber hook you are ready to launch your helicopter. **DO NOT THROW IT INTO THE AIR!**

Hold the top rotor with one hand and the bottom rotor with the other. Release the top rotor and allow it to start spinning. After a second or two the top rotor will reach its maximum rotation speed and you can release the bottom rotor.

Trimming

With this design there are limited options for trimming at the flying site.

First, verify the pitch of each blade of the top rotor is the same and the pitch of each blade of the bottom rotor is the same. If you used an acetone based glue the bond between the wire and spar can be softened, adjusted and allowed to harden.

To obtain different pitch blades, new rotors will need to be made. The same plan can be used with different height risers. The top rotor should have less pitch than the bottom rotor so it can "pull" the helicopter up.

For those who want to experiment, the original AutoCAD® .dwg file is included with the CD and a link to free CAD software that can be used to edit the drawing is included. I do not recommend this approach. I believe designs from other sources, will be a better investment of time.

Second, the rotors should revolve in a plane perpendicular to the motor shaft as discussed in Step 15.

Last, the motor stick should not bend or distort due to the tension of the rubber motor. This is addressed by the tension of the thread. If the thread is slack the stick will bend, causing the rotors to not be coaxial at the beginning of the flight and the helicopter will behave very erratically.

Improving Flight Times

The main method to optimize flight times is to build a helicopter at the minimum mass. Achieving a helicopter weighing 3.0 grams takes a number of attempts and creative thinking.

The next step is through adjusting the rubber motor. Ideally the helicopter should land just as the rubber completely unwinds. The longer the motor, the more turns but more

weight and less torque. If there are still turns left the motor should be shortened. If it runs out of turns while at altitude the length can be increased. The wider the motor, the more torque (faster climb) but the less turns per inch of length (less duration).
It is **VERY IMPORTANT** to lubricate the motor. Armor All is a favorite. Spray it on the motor before you wind it.

We anticipate commercially produced kits will soon be available from a number of sources.
Additional sources for information.
www.indoorduration.com
http://www.indoorfreeflight.com/
http://freeflight.org/Community/links.htm
http://www.aeroaces.com/
http://www.3ds.com/products/draftsight/#vid1 free software to edit the .dwg drawing

Information is often updated on Maryland Science Olympiad web site so please take a look at it periodically.