

How to Build a Dobsonian Telescope



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This document shows specifically how to make a 6" f/8 Dobsonian telescope, a Newtonian reflector with an altazimuth mount, but you should be able to make any other reasonable size by making some obvious modifications.

1 Before You Begin

A few words before you start building your telescope:

My telescope making came across because of an astronomy class at my high school. We had to make a final project to get an A in the class, and I decided to make mine a telescope. I enlisted the aid of my friend Galen, and began looking up ways to build one. I eventually ran across a site from the Sidewalk Astronomers of San Francisco, detailing the construction of Dobsonian telescopes. The method that I am using in here basically follows the plans that they had, with a few modifications. With these instructions I am trying to be a little more explicit than they were, and at the same time provide more explanations, so that you understand what you are doing, and not just mindlessly following directions. If any part of my plans seem incomplete, you can go to their site and see what they did there, because chances are I did something similar. If this happens, please email me and tell me about the problem, so that I can fix it.

A word of warning: NEVER use the telescope outside in the daytime or to look at the sun. In addition, when you are handling the mirror, try to do it inside, or, if you must do it outside, when it is darker out.

Some of you may be wondering how much this is going to cost. I ordered all of my parts from Orion. If you get your parts from there, the prices should be basically the same, though this was all done several years ago at this point. I can't say anything about other companies, but chances are they'll all be in about the same range. My primary mirror cost a little over \$110. My secondary mirror was about \$15. My eyepiece is an Orion Plössl, and it cost about \$50. My focuser and a 5 power finder cost about \$15 each. If you add all this together, you'll get about \$200 - and that's without buying the plywood, sonotube, and other supplies. This is *more* than you will spend if you just purchase a Newtonian reflector from a company selling telescopes. Something must be prompting you to desire to build one on your own. I personally recommend it because not only does it give you a better idea of how the things work, but it's also more fun. Plus, it's nice to show off your scope, and watch your friends be amazed.

One final note: Because I am trying to give precise instructions, and because I am trying to explain things as I go along, there is quite a bit of text. If it appears that the plans are going too slowly, this is why. Don't be intimidated by the number of words, as it's not really all that much once you get down to it; my explanations take the most time.

I think that's about it. Have fun, and happy building.

2 Materials

Here is a list of the materials that you will need. Except for the first five items, most of them can be found at your local hardware store. If you can't find all of the items, that's not necessarily a problem. You don't need the exact same parts for most of the items, you

just need something that is functionally equivalent. I recommend reading through the rest of the plans before you buy everything, so that you can get an idea of what else you could substitute in.

Telescope Objective Mirror (1) You will need to purchase a primary mirror. I ordered mine from Orion, but you can get it from somewhere else if you are so inclined. The mirror should be 6" diameter, with an f/8 focal length. There are other sizes, of course, so if you want a bigger one you can use that, but then all the measurements that I am going to give will be different than the ones you should use, and you might have better luck with other instructions.

Telescope Diagonal Mirror (1) This is a much smaller and cheaper mirror. I ordered this from Orion as well. It is 1.22" across the major axis.

Eyepiece (As many as you want) You can order many eyepieces of many sizes. My advice would be to start with one and move on from there, as you figure out what you want - you might want different eyepieces for looking at a wide swath of the sky and the rings of Jupiter

Focuser (1) The plans I read didn't call for a commercial focuser, but I decided I wanted one because otherwise I'd just be stuck with a cardboard tube. A simple rack and pinion focuser works okay, and you can get these from Orion as well.

Finder (1, optional) This is an optional piece to attach to your telescope. It is used to help point the tube in the right direction. I used a 5 power finder, but a 1-power will work also - and if you don't get one at all, you can just sight along the tube.

Cardboard Tube ("Sonotube") (1) Construction stores, specifically concrete construction supply houses, usually carry these tubes, which are used for forming concrete. I was able to find one at a hardware store near me. We want the tube to be wide enough to fit the mirror in, so get it 8" in diameter, and at least 48 inches long. If you can get it longer than that, you are better off. You can cut the excess off later, and it give you a little extra room.

Exterior Grade Plywood (4' x 8' x 3/4") A plan to show you how to cut this is shown in Figure 1. You can probably get your hardware store to make the vertical cuts when you buy it, saving you the trouble. Make sure that these pieces are exactly (er, as close to exactly as possible) the sizes shown; remember that the saw blade has a width, so if you just mark it at the places shown you will lose some room - cut one piece and *then* mark the next one to the right size.

Paint, painting supplies You need flat black for the inside of the tube, but any color will work for the outside, if you choose to paint it. White is not recommended though, because it takes longer for a white tube to cool to ambient temperature - in winter you might see some distortions for a while. If you do not paint it, you might want to do what we did and use polyurethane on the outside - you don't want your telescope to warp!

Nails (lots), Screws (lots)

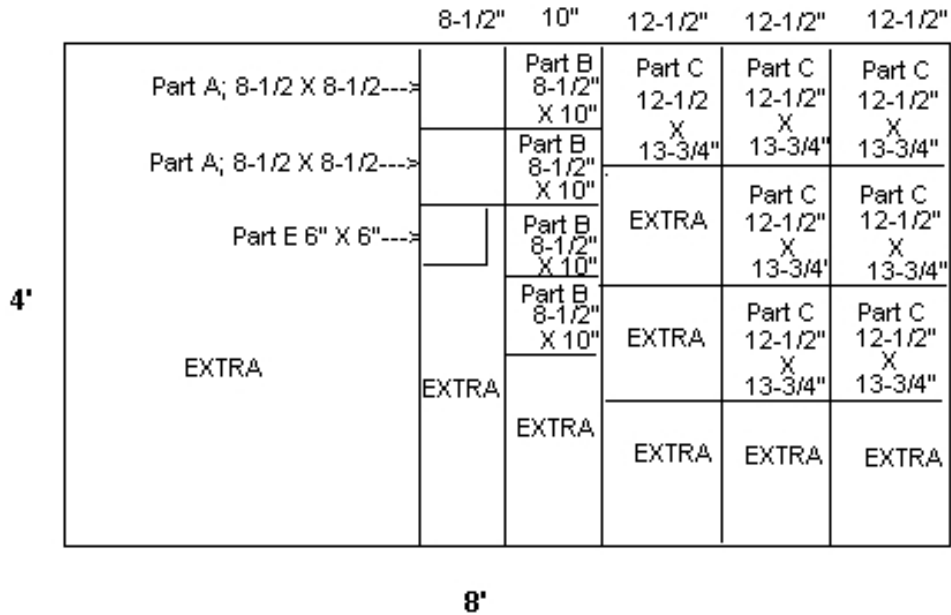


Figure 1: Cut plan for the plywood

Machine Bolts (3) Each should be 1" long, 3/8" in diameter.

Lag screw with matching washer (1) Make it 3" long, 1/2" in diameter.

Record (1) A phonograph record. 33 1/3 LP rpm size. You might want to make this an old one; you won't be getting it back.

Cedar Shim Shingles (3) About 1-1/2" to 2" wide. You only need three of them, but they break pretty easily (I speak from experience here) so you will probably want more. I got mine in a pack of 20, and that worked just fine.

Wooden Dowel (1) One piece, longer than four inches. You will eventually cut it down, but you will want room to spare. The plans I used called for 1-3/4" diameter, but I couldn't find one that big, so I just used the largest one I could find.

Thumbtacks (a few)

Leather Scrap (3 small pieces)

Sticker or Decal (1) About 1/2" in diameter. Mine was a little smaller, the size you get from using a hole punch. In fact, I just took a post-it note and used a hole punch to get a small circle with the sticky part.

Masonite You will need only *need* three small pieces of this, about 1/2" x 1/2", and 1/8" thick, but I used a lot of extra in order to get things to fit tighter, so I'd recommend getting a whole sheet of it. If you can't find 1/8", 1/4" will work also.

Teflon You will need 7 pieces, each a little smaller than 1" x 1", and 1/4" thick. Well, the directions I had called for 1/4" thick, but I couldn't find any so I just used 1/8". If you can't find this at a hardware store, try an electronics surplus house; I got mine from my neighbor, but not all of us can be this lucky.

Furniture Glides (4) Well, my plans called for "Furring nails" or "Rubber furniture glides" but no one I talked to knew what those were, so after much searching I just got regular furniture glides. Make sure that they are not too big and can fit on a 3/4" wide surface without hanging. In truth, hanging over won't really hurt all that much, but it looks prettier if it doesn't.

Glue White wood glue works fine for most things. The plans I had called for 100% black silicone glue for some parts, but I couldn't find that so I just used epoxy on parts I *really* needed to stick.

Something circular (2) Make sure they are the same size. I used film canisters, provided by my neighbor (the same on with the Teflon pads). Whatever they are, make them about 5-6" in diameter, and make sure that they are *round*. You will be using these to tilt the telescope up and down when it is in the mount, so you want it to run smoothly.

You will also want basic tools such as hammers, screwdrivers, saws, drills, a compass, a tape measurer, crescent wrenches, awls, and a T-square to help make things a lot more exact.

You will also need some of the spare wood to cut a few small parts later on, so keep it around.

3 The Spider

The spider is the piece that goes into the tube and has the diagonal mirror on it. It takes light reflected from the primary mirror in the base of the telescope, and redirects it to the eyepiece. When finished, it should look something like Figure 2, but painted black:

To begin with, you need to get your dowel rod out. You are going to have to cut it so that one face is at a 45 degree angle. To find a 45 degree angle, it is easier to make one on a flat piece of paper, rather than the curved dowel. Make two 45 degree cuts in the paper so that they come together at a point, and then wrap the paper around the dowel, where you can use the edge of the paper as a guide. Once you have cut it, you will need to cut three grooves down the side of the dowel, running from the flat end to the face cut at an angle. Before you do this, you can shorten it to about three inches long at the shortest point, so you won't have to cut as much. The grooves need to be 120 degrees apart, each a third of the way around the circumference of the dowel. One way to get the grooves exactly 120 degrees apart, is to wrap a string around the dowel, then cut it off so that the string is the same length as the circumference. Divide the string into three parts of equal length, and



Figure 2: A view of the unpainted spider from the top



Figure 3: A picture of the spider in the clamp

mark them at each part. Once you do that, you can wrap it back around the end of the dowel, and make a line by where each of your marks were. There is probably a much easier way to do this, but I didn't think of it. The easiest way I found to cut the grooves is to stick it in a clamp horizontally and *slowly* run the saw up and down the lines you marked.

Once that is done, you need to take three cedar shingles and stick them into the grooves, narrow end in, wide end out. Position them so they form a plane with the flat face of the dowel, and glue them in.

The next step is to cut the shingles so that they will fit in the tube. It is sort of hard to measure exactly where to cut, so hold them up to the tube when you mark where to cut, making sure the dowel is as close to the exact center of the tube as you can. It is better to make the shingles too long than too short, because as I learned, much to my dismay, when the shingles are too short it's a pain getting the spider to stay in the tube when you try to install it. You want them to be just long enough so that you can stick the spider in the tube and it will not fall when you take your hand away, but not so tight that you can't move it.

After that, you need to paint your spider flat black. Do this on every part of the spider except the part of the dowel you cut slanted earlier. It may help to put tape over the slanted



Figure 4: The spider with one fin (left) and all fins (right) attached

end so that you do not paint it accidentally, and stuff does not drip onto it. Once the paint is done drying, you are ready to stick the secondary mirror on. We do not want to stick the mirror directly on the wood, so we are going to put leather scrap between them to soften it. Cut three small pieces of leather (I took mine from an old belt) so that they will all fit on the slanted end of the dowel at the same time, each about a third of the way around. Liberally coat these in glue, and stick them on. Once they have stuck, you can coat them with glue again and stick the secondary mirror on them.

4 The Tailgate

The tailgate will eventually be stuck into the back of the tube. The primary mirror rests on it, and bolts are stuck through it so that you can adjust the primary.

To start with, get the square piece of wood (Part E on the cut plans in Figure 1) out. First, you need to find the center of the piece. You can do this easily by drawing diagonal lines from one corner to the opposite, and using the place where they intersect as the center. Mark this clearly.

As it is, this piece of wood will not fit into the end of the tube, because the corners get in the way. To remedy this, you need to cut the corners off, and then sand it so that it will fit into the tube, but will not fall or even wobble if you take your hand away. You can get an accurate estimate of where to cut by using a compass to draw a circle of the same radius as that of the inside of the tube. When you cut though, remember that too big is easier to fix than too small, so leave an extra bit of wood that you can sand off to fit exactly later. If you get the corners smoothed out so that they are curved, like the side of the tubes, it will work much better.

Once you have that done, you need to draw another circle on the wood, this one smaller, with a diameter of 4" (2" smaller than the diameter of the primary mirror). This circle will be used to place the tailgate bolts. Mark off three points on the circumference of this circle, each 120 degrees away from the others. The plans I used called for 6 of them 60 degrees apart, but I never used the other three, so I don't see much point in them. When you do this, try to get one mark pointed right in the center of the edges, and the other two



Figure 5: A view of tailgate from the back, with the bolts screwed in

pointing sort of (but not exactly, they will each be about 15 degrees off) at the opposite two corners.

Use a drill to place pilot holes on those three spaces you marked. Each hole should be $1/16$ " smaller than the bolts (or about $5/16$ "), so that the bolts will have to be threaded into the wood and will fit very tightly. Loose bolts are no good to anyone. After you've put the holes in, go ahead and screw in the bolts. They should be snug and difficult to turn. Do not screw them in all the way, halfway should be good for now.

We are going to rest the primary mirror on the other side of the tailgate (the side that the tips of the bolts should be pointing through). However, we don't want to put the mirror right on the ends of the bolts - we need something to cushion it. To do this, begin by cutting a triangle of cardboard big enough so that the corners will cover the ends of the bolts, and extend a little bit past them (but obviously *not* so big that it extends off the edge of the wood). The cardboard should not be heavy duty; the side of a cereal box works fine. It will have to bend easily, so that the primary mirror can be aligned by turning the bolts. After you have cut it out, attach it. We don't want the cardboard to be glued to the bolts themselves though. Just place a glob of glue in the *center* of the cardboard triangle, and place that in the center of the tailgate, so that the corners cover the bolts. Of course, cardboard by itself will not protect the mirror, it is only something to stick the real protection on. After the glue has finished drying, you need to glue masonite squares (about 1" x 1", but you've got a little leeway here - just make sure that they are bigger than the bolts) to the corners, right over the spots where the bolts protrude. Apply glue to the corners of the triangle, over the bolts, and place the masonite squares over that. The bolts should be completely covered, with the masonite centered over them. You need to let this dry, as well. It is best to place something hard, flat, and heavy over it, like a textbook or a piece of spare wood.

Once this is done drying, take two thumbtacks and use them to fix the cardboard in place by sticking them in the center, near where you glued. (Before you do this, double check that the masonite completely covers the bolts).



Figure 6: A view of finished tailgate from front. Sorry about the glare.

5 The Mount

The mount takes up the majority of the wood you cut earlier, as well as quite a bit of time. There are four (well, three, sort of) main components. We have

1. The tube box, which the tube will slide into
2. The ground board, which serves as the bottom base of everything
3. The rocker box, the biggest part, which will be let free to rotate on the ground board
4. The side boards, which will hold the tube box, and eventually get stuck to the side of the rocker box (which is why I hesitated to call them a separate component)

Note: When I say "attach" in reference to putting wood together, I mean using nails and glue to stick together, and then I recommend clamping the pieces together and letting it dry for a while. Not only does it look better if all of the pieces are flush against each other, but it also might make the telescope more stable.

5.1 The tube box

First off, make the tube box. Take four pieces of wood (Two of part A and two of part B) and fasten them together to make a square. The two of part B are longer than the part A's, so when you put them together, they will be outside the A's, as shown in Figure 7. In regards to the side bearings, wait until you have measured the side boards before attaching them, because it will make measuring them (the side boards) much easier. The side bearings are two circles, either of wood or something else (I used two of those metal film canisters), but you want it as close to a perfect circle as possible. You will need to fit these into the center of the two part B's (Actually, you can do it on the A's as well, as long as they're opposite. Or, if you prefer, you can put four side bearings on, one on each side, in case you want to rotate your scope 90 degrees for easier viewing in some cases). Make sure that these are in the exact center, because if they are off kilter with each other, even by just a little, the tube will end up sitting crooked. This is bad.



Figure 7: The tube box with no side bearings



Figure 8: Pictures of the tube box with side bearings.



Figure 9: A view of the completed bottom board

5.2 The ground board

Next we get to make the ground board. This is the base of the telescope. It will be thick and rest on three feet set into the bottom for stability. The rocker box will go on top of it, with the LP record in between the two, so that it will swivel easily. The record will rest on pieces of Teflon attached to the ground board, so that it will rotate smoothly. To begin, take two part C's and fasten them together, so that they line up like one thick board. This is to help support the telescope, lowering the center of mass and giving a solid base. Now you need to flip the board upside down (Well, you don't really have a top yet, so I suppose upside down is relative) and stick the feet on. The feet are three blocks of wood cut from the extra plywood you have laying around, about $1\text{-}1/2''$ by $1\text{-}1/2''$. One of them is placed along one of the longer edges, in the center of the side. The other two are placed in the corners opposite that, so that the three feet form an isosceles (*not* equilateral) triangle, with the two in the corners as the vertices of the base. The next trick is to drill the hole in the board that the rocker box will pivot on. This will NOT go in the center of the board, it will go in the center of the triangle formed by the feet. You can find this by drawing two medians (lines from one foot to the center of the opposite side of the triangle) and marking the place where they intersect. Do this on the *top* of the ground board, because you will need that point to draw a circle. Use a compass to draw a circle centered at the point you just marked, big enough that you have a bit more than an inch or so extra space on the closest side. After doing that, you can use a drill to place a $5/16''$ hole in the ground board at the point you marked. Next attach the Teflon. This is used to help the LP record slide easier. The Teflon pieces will be placed on the circle you just drew, each of the three pieces 120 degrees from each other. You can use a protractor to mark these places out. The Teflon pieces should be about $1'' \times 1''$ each. Place them on the spots marked, and nail them in with finishing nails (nails with really small heads). Then sink the nails so that the heads are below the surface of the Teflon. You can do this by taking a nail set, or a dull, thick nail, and placing the point on the head of the nail you hammered in, then banging the end of that, driving the first nail in deep.



Figure 10: Views of the rocker box, from front and back

5.3 The rocker box

Now for the rocker box. The bottom of this will also be two part C's, but do not nail them together just yet, because that will make it hard to stick on the sides. The sides of the rocker box do *not* go exactly on the edges of the bottom board. You will have to move them in just far enough so that when you attach the side boards, the tube box will fit in. To calculate how far in you need to put them, you will need to account for the thickness of the various parts. You have a tube box, which is 10". You need to add 3/4" for each of the side boards, plus 1/8" on each side for extra clearance. This means that the distance between the side boards must be 11-3/4". Subtract this from the length of the bottom board, divide that by two, and you will get the distance from the ends of the bottom board you will need to attach the sides. Attach them so that they are "short side up," that is, so that when they are attached they will go higher into the air than the other way. Attach both of the sides on like that, making sure to get them straight. One edge of each side should be lined up with one edge of the bottom board, so that you can attach another piece of wood over all three parts. You can look at Figure 10 to help you visualize all of this. You can nail them in from the bottom of the ground board, so that the heads are on the bottom. After that, you can nail the other part C onto the bottom board, so that you have a double thickness bottom. Finally, you will need to attach the front board. Do this by sticking it "long side up" on the front of the boards on the sides - there will be nothing under this, it will stick out from the bottom board. Make the front board low enough so that it covers the front of the bottom board as well. After that, you need to drill the pivot hole in there. Using the ground board as a guide, mark the spot on the bottom board which coincides with the hole in the ground board. Both sets of double thickness boards should line up corner to corner. Now take the ground board away and drill a 1/2" hole in the bottom board (Yes, this is wider than the one you drilled in the ground board, this is so that bolt we will use to pivot it will have a place to go in to). While you have the 1/2" bit out, use it to drill a hole in the center of the LP record as well. Be careful when you do this, the record will want to ride up the bit, making it hard to drill - it will help to have someone hold it in place.

You can attach the bottom board to the rocker box by simply placing the record on the ground board, and the rocker box on the record, making sure the holes line up. Then take

the lag screw and screw it in from the top, making sure that you don't make it do tight that it does not rotate at all, and smashes the record. Keep it loose enough so that it will swivel freely. However, you might not want to do this just yet because it will be hard to stick the side boards on correctly. It will be best to leave the parts unattached until the end, when you have successfully nailed the side boards in the right place, a task that will have to wait for a while.

5.4 The side boards

Now for the side boards. These parts must be as close to exactly the same as possible, or else you will be forced to go to great lengths to avoid letting the tube wobble from side to side. The side boards will be used to hold the side bearings on the side of the rocker box, and allow them to rotate the tube box up and down. This will control the altitude that the telescope points. The simplest way to do this is to cut a V shape in the side boards that the side bearings can rest in. You could also try to cut a semicircle for aesthetic reasons, but that would be a lot harder, and I'm not going to get into that here. To cut the V shape, find the exact center of each of the two remaining part B's. From there, make a 60 degree angle towards one of the shorter sides, and cut away. The point of the V should be 60 degrees, and the vertices of the V should be in a little bit from the corners. Cut out this V. Repeat on the other side board, trying to get them as close to exactly aligned as possible. Precision really counts here! The next step is to attach the Teflon pads. You will stick two on each board, one on each side of the V. These pads will help the side bearings rotate easier. To make sure that you have it lined up correctly, take one of the side bearings (this is why I suggested that you not attach them earlier) and two Teflon pieces, then set them up inside the V so that it fits the best, with the side bearings touching the Teflon squarely (the Teflon should be tangent to the bearings), and the V not at all. When that is done, nail the Teflon into place, and sink the heads as done earlier with the ground board. Now do the same for the other side. Ideally, the placement of the pads should match exactly, but this will probably not happen because it is hard to measure things exactly, and the two boards are probably different despite your best efforts to the contrary. It is more important that the side bearing fits into this side the same way it does to the other than it is to have the Teflon pads in the same spot, though in a perfect world these two goals would coincide. You can always tilt one of the side boards when you nail it in so that it lines up with the other. Once you have nailed the Teflon in to this side, you are done with the side boards for now. You will not attach them to the sides of the rocker box yet; that will come later. For know, just be thankful that this part is done.

6 The Tube

All right, now to stick the stuff together so it really looks like a telescope.

6.1 Preparing the Tube

Take out that sonotube we've ignored up to this point - it's time to use it. The first thing you have to do is paint the inside of the tube flat black, so that light doesn't start reflecting

off of the walls as well as the mirrors. This can get a bit messy, as you will probably have trouble reaching down all the way into the tube. The plans I used recommended attaching a paint brush to the end of a broom, and using that to extend your reach. I opted just to get messy, so I put on an old shirt, dipped a sponge in the paint, and used that to coat the inside liberally. When I got as far as I could reach, I flipped the tube over and did it from the other end. You might want to use a few layers. A few words of warning: paint drips. Make sure you have an old newspaper or something under the tube, and don't spin it around too fast when you go to paint the other side. Also, the drippings will cause the paint to be thicker at the end of the tube, making it harder to get the spider and tailgate in. You might want to get this excess off, using a razor or something, and then going back later and painting a thin coat over any part that you accidentally cut too much paint off of.

After that, you will probably want to coat the outside of the tube with some kind of sealant, so that if you take it out on a wet night, nothing will warp. You can opt to paint it if you want, but my partner and I decided to polyurethane it instead. Whatever floats your boat.

6.2 Focuser and Finder

Next we are going to install the focuser and any finder you may have chosen to purchase. To install the focuser in the correct spot, first you will need to find the true focal length of the mirror. It *should* be 48", but it could end up being a few inches off. See Appendix A to find where to put the focuser. When you have found it, cut out a hole big enough for the focuser to fit in, and screw it in. If you can, save the part that you cut out in case you have to patch it up later. Before you put on the finder, you might want to decide what angle you want the eyepiece to be at. You can put it at the top, of course, but that might make looking at it hard sometimes. I chose to stick it on the side, at about 45 degrees from the top (see Figure 11). This will determine where you put the finder. About 90 degrees away from the eyepiece is where I went, because it looks pretty, but it doesn't really matter as long as it is in a convenient spot, preferably on the top half of the scope. Install that too; mine just screwed right in like my focuser, but different finders might go in different ways. I suppose that goes for focusers as well, actually.

6.3 The tailgate

Now on to the tailgate. This is going to go on the other end of the tube from which you attached your focuser and finder. The mirror is not actually going to attach to the tailgate, it is going to rest on it. Unfortunately, in this case if you tilt the tube upside down or bang it by accident, the mirror could end up falling right out the other end. To fix this, we are going to first install four mounting blocks on the inside of the tube to stop the mirror if it starts to fall.

To create the blocks, you are going to have to cut four more pieces out of the extra plywood. Each of these should be 4" long and 1" wide. With the thickness of the plywood being 3/4", the dimensions of each piece will be 4" x 1" x 3/4". These mounting blocks are NOT going to go into the tube with the same orientation. All of them will go in with the 4" end going further down the tube, but the ones you will put on the bottom will be "taller" than the ones on the top. You can do this by making the 1" part go up and down,



Figure 11: Telescope with focuser (left) and finder (right). Note that the telescope is tilted, the finder is not actually directly on the top of the tube.



Figure 12: The installed tailgate, viewed from down the tube. You can see the mounting blocks holding it in place.

and the $3/4$ " be the width. For the ones on the top, just rotate the block 90 degrees so that it is wider, but less tall. The wood alone will not stop the mirror from falling (actually, the mirror is going to rest on the wood), so you need something else to stop it. For this we will use the furniture glides. To determine where on the tube you will need to stick these, you need to find out how thick the mirror is. Measure this, add $3/4$ " for clearance, and then stick the glides so that they leave that much room on one end. Unless you for some reason have an uncommonly thick mirror, the glides should not be centered on the block. When you do this, remember that two of the blocks will need to have the glide on a different face than the other two. Figure 12 is actually a picture of the installed tailgate as a whole, but you can see the mounting blocks there too.

Once you have finished putting the furniture glides on the mounting blocks, it is time to stick them in the tube. You will screw them in on the inside, so that the screw goes into the part of the mounting block behind the furniture glide. If the glide divided the block into two pieces, this should be the longer piece. Screw the mounting blocks into the tube

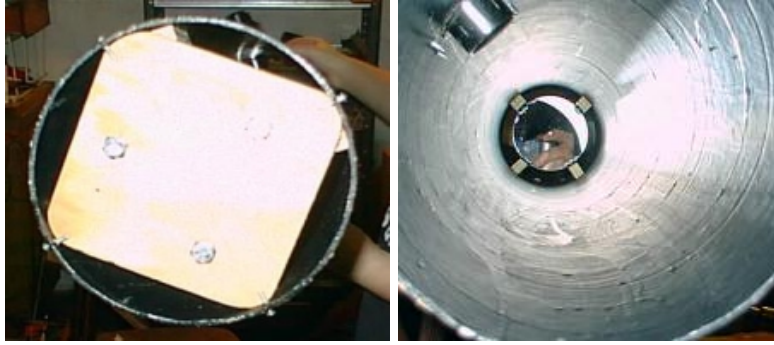


Figure 13: The tube with the mirror and tailgate installed, from behind the tube (left), and down the tube (right).

so that they are each 90 degrees away from each other ($1/4$ of the way around the tube) in such a way that the two taller ones are on the bottom, and the two shorter ones are on the top. None of the blocks should be directly on the top or directly on the bottom, you should place them so that they are bottom-right, bottom-left, top-right, and top-left. You will need to put each of the blocks a very little bit more than $3/4$ " in, maybe $1/16$ " more or so. This is so the tailgate will have some place to go behind them. When you finally screw them in, make sure that they are all the same distance down the length, because otherwise the tailgate will end up crooked.

Now to actually put the tailgate in. Just stick it in the end so that the cardboard triangle is facing away from you, and put a screw in each corner that actually touches the tube to hold it in place. I lined mine up so that one bolt was directly up, and the other two were going down to the sides, but I suppose it doesn't really matter. Don't get too happy once you've stuck it in though, now you get to take it out again. You are going to put in the primary mirror. Before you do this, you need to put a small sticker or decal in the center of the mirror to assist with the alignment later. This will not affect the image - you will not need to remove it later. I used a hole punch to get part of the sticky end of a post-it note, and used that for a sticker. To find the exact center, traced the mirror on a piece of paper, and cut it out to get a circle. I folded it in half two ways, so that it had two creases in it. Where they intersect is the center. I used a hole punch to make a hole there, and placed the paper on the mirror. I then put the sticky part I had punched out and placed it in the hole in the paper. Now it is in the exact center of the mirror.

Remove the tailgate and put the primary mirror in to the tube, so that it rests on the wooden mounting blocks. You should not have to force this mirror in, but on the other hand, it shouldn't have extra space between the mirror and the blocks. It should fit snugly, just not overly so. After you have put the mirror in so that it is at the closest ends out the mounting blocks, stick the tailgate in once more. The masonite squares on the tailgate should be touching the mirror. That way, you can turn the bolts from the outside, and this will adjust the alignment of the mirror by pushing it one way or another with the bolts. See Figure 13 for a picture of this.

From now on, when you leave your telescope out, it is a good idea to put a bag over the open end so that dust will not fly in and contaminate your mirror.

6.4 The spider

For now, just stick the spider in the tube, don't glue it in place or anything. we're going to align it in the next section.

Wasn't that part easy?

That's all for the tube, now you get to align everything. What fun!

7 Alignment

Okay, now for the fun part - balancing everything. This part is extremely frustrating because it seems like you're *almost* done, but it still takes a long time to get everything just right.

What you need to do first is get the tube itself balanced. The plans I used said to use a broomstick to do this. If you can figure out how to do this, let me know, because I sure couldn't. What I ended up doing instead was getting a spare 2"x4" and laying it on a flat surface, with the long narrow end up. I stuck all of the parts on the tube that I would need (focuser, spider, finder, tailgate, mirrors) and put the tube in the tube box. Putting the center of the tube box directly over the 2"x4", I slid the telescope along the tube box until I found where it balanced. Once that was done, I glued masonite into the tube box to tighten the fit so that the tube wouldn't slide around.

Once that is done, you need to get the side boards onto the mount. In order to do this, you need to find out how far it is from the tube box to the bottom of your tube, as you have to be able to stand your tube upright in the box - you want the side boards to be high enough so that they don't let the tube hit the bottom of the mount when you swing it up. It was really annoying to line this up correctly, but you should be able to determine where they should go. If you clamp the side boards on firmly where you think they should go, you can stick the tube (in the rocker box) onto the sideboards and try out the fit. If it isn't quite right, loosen one of the clamps and move that board around a bit, then tighten it again. Once that is done, you can take the tube out and nail or screw the side boards in place. Make sure when you are doing all of this that the centers of the side boards are over the pivot hole you drilled in the bottom earlier, and that they are on the *inside*, not the outside, of the box.

After you finish putting the side boards on, you can finally stick the mount onto the ground board. You already have all the holes drilled and everything, so just take the big lag screw and stick it down through the mount, record, and ground board. Don't tighten it so much that you smash the record into the Teflon pads, you want the mount to be able to turn from side to side.

Now for the most nerve-wracking part: sticking the spider in position. All you have to do is glue it into place, but remember - once it's glued, it's glued. So, align it right the first time. I used epoxy to stick mine in, and I suppose if you do that and screw up, you could try carefully putting acetone over the parts you epoxied, and see if that makes it come off. Best of luck, if that happens. First, you have to find a tube about half a foot long and stick it in the focuser so that the end is 6 inches away from the tube. A metal or brass tube is the best, because it won't bend, but I used a piece of rolled up paper. Stick the spider in a position such that when you look through the focuser, you can see the primary mirror. When you look through the focuser (there is no eyepiece in it yet, just the tube) you should

be able to see two circles formed by the ends of the tube. You should also be able to see the reflection of the spider in the primary mirror, as well as the dot you stuck in the center of the mirror. For now, ignore the spider's reflection, and just concentrate on the dot and the circles formed by the tube. Wiggle the spider around until the circles are concentric, centered around the dot. You should be able to see the *entire* primary mirror as well. If only part of it is showing, keep adjusting the spider until it's right. One frustrating aspect of this is that when you move your eye around, the reflection moves around too, so even if it is lined up correctly, you can move your head and it will appear unaligned. All I can say to this is try to keep your eye to the center of the tube. When you have the picture perfect, with the concentric circles with a dot in the middle, and the full primary mirror showing, glue the spider in place. I put globs of epoxy on either side of the cedar fins in the corners where they meet with the tube.

After that, all that is left is to align the primary. This isn't nearly as bad as the spider part, because if you screw up, it doesn't really matter - it's designed to be adjustable. It helps if you get another person to help you here. You look through the focuser, and tell the other person to loosen or tighten the bolts as needed to adjust it. Apparently it is conventional to call the bolts "yours", "mine" and "ours" to refer to the ones close to your friend, close to you, and on the top, respectively. This seemed to work pretty well. The goal here is to get the dot on the primary right over the eye that you see in the reflection in the spider's mirror. So, line up the dot with the eye, and you're set.

After that, you're all aligned! Wait for everything to dry, then go out and look at the stars.

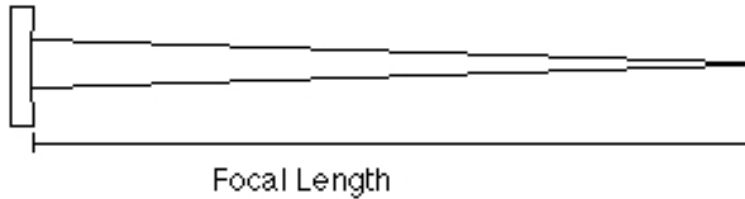


Figure 14: This is a rough image of what is happening. The parabolic primary mirror is on the far left, and directs the light to a “point” as shown. The distance from the mirror to the point is the focal length. For our telescope to work best, we need to have the eyepiece right where that point is.

A Finding the Focal Length

The mirror we are using is a 6” f/8. Thus to find the focal length, we can multiply $6 \times 8 = 48$ ” (If we were using a 6” f/6, the focal length would be 36”). However, just because you ordered a mirror of a certain size doesn’t mean that it is *exactly* that size. You probably want to find the focal length manually before determining where to put your focuser, because it could be off by a couple of inches in either direction.

To find the true focal length, you will need a blank white piece of paper, a tape measurer, a flashlight, your mirror, and a long hallway. Prop the mirror up vertically at one end of the hallway so that it is not tilted. What we are trying to do is find out where the light will be reflected into a ”point” (see Figure 14). However, this would be hard to do, so we are going to let the light continue out until we get something the size of the original image, only upside down (extend the lines from the mirror below, past where they intersect until they are as far apart as they originally were). This means that what we are looking for here is *twice* the focal length. So, will need to run the tape measure out to a bit more that 96” ($48 \times 2 = 96$). Starting at about 96” (because the true focal length will be around there), shine the flashlight at the mirror, and hold the paper next to the flashlight, so that they are the same distance from the mirror. Move the paper/flashlight system a little toward and away from the mirror until you can see the image of the flashlight clearly on the paper. There should be no doubt when this actually happens; you will be able to see the filaments in the flashlight quite clearly, and the image will not be just a hazy circle of light. When you have found this position, look at the tape measure to determine how far away from the mirror you are. Divide this by 2 to get your true focal length in inches.

The secondary mirror on the spider will deflect the light at a 45 degree angle as shown in Figure 15. This will not change the focal length, it just redirects where the focal point is. So, the distance from the primary mirror to the secondary mirror plus the distance from your secondary mirror to your eyepiece must be the focal length. Thus, to determine the distance from the end of the tube with the mirror in it to the place on the tube where you will put your focuser you must do the following:

1. Start with your true focal length.
2. Add the thickness of the mirror.
3. Subtract the radius of your tube.

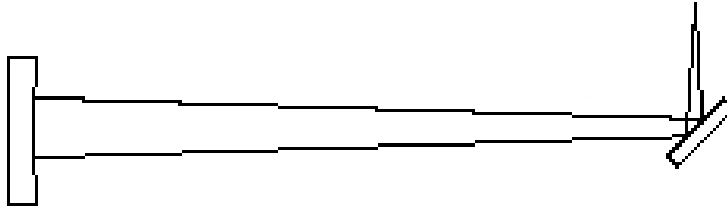


Figure 15: The spider redirects the light at a 45 degree angle into the eyepiece on the side of the tube. When you turn the focuser, you make minute adjustments in the distance the eyepiece is along the path of the light, in order to try to get it right where the light comes to a point

4. Subtract the racked-in length of your focuser.

See how that works? The number you have is the number of inches from the back to put your focuser.

For example, let's say that you have a $3/4$ " thick mirror with a true focal length of $46-1/2$ ", and a focuser with a racked-in height of 3 ". We are using an 8 " tube, so the radius is 4 ". So, you must put the focuser $46-1/2+3/4-4-3=40-1/4$ ".

The purpose of the focuser is to let you minutely adjust the distance from the mirror to the eyepiece, in order to get rid of any slight inaccuracies. By moving the eyepiece up and down, you are moving it away from or closer to the mirror.

When I did this, I screwed up the measurement, and put my focuser in the wrong spot (I suspect that I subtracted the mirror thickness instead of adding it). If this happens to you, check out Appendix B to see how I fixed it.

B Troubleshooting

This section has solutions to various problems you might come across. Either I had these problems and figured out how to fix them, or I anticipated having these problems and thought of a way to fix them.

I drilled the hole for my focuser in the wrong spot. What do I do? You have a couple options here. If you caught your mistake and noticed this before you glued the spider in place, you're a little better off. Take the piece you cut out of the tube and tape it back in place. Black electrical tape works well. If you don't have this piece, you can take either a thick piece of cardboard (the best is extra sonotube material) or thin wood and cut it to the size of the hole and use that to patch it. Or, take a hunk of a sonotube that has the same diameter as your tube, and just put it over the hole (Because the curvature is the same, it will just rest over the tope without letting much extra light in, like a flat patch would) If your spider *is* glued in, you have a bit more of a problem. You can't move the focuser or replace it, because that would mess up the alignment of the focuser. If your focuser is too far down the tube, what you can do is take the mounting blocks and attach them further down the tube too, to compensate. If you didn't put it far enough down, you need to extend the distance to

the eyepiece from the spider. Putting a block of wood under the focuser will not work, because it is really hard to get it to line up correctly again. What I ended up doing is taking a metal tube that is 1.25" wide, and then a bit wider at one end (I think it's from a vacuum cleaner) and sticking that in the focuser instead of the eyepiece. Then I drilled a hole in the wider end, got a flat ended screw, and used that to make the eyepiece stay in the tube.

The fins on the spider are too short, it won't stay in the tube. Take another shingle, a little longer than one of the ones you have on now, and glue this shingle onto the side of the other one. Paint it black, and viola.

I put the spider in the wrong place! Well, again you have a few options, but be warned, I haven't actually tried any of them. If you have epoxied it in, use acetone to try to get rid of the epoxy and pull the spider out. You could also try to cut the fins along where they are attached to the tube, then sand the stubs where it was attached off, elongate the fins on the spider (see the above solution) and then attach it again. Make sure if you do this that the primary mirror is out of the tube so it doesn't get covered in sawdust. Yet another option is to move the focuser over the spider and then use the solution above which explains what to do if you put the focuser in the wrong place to fix it. I think this last one would be quite difficult, however, and I'd recommend the other two first.

If you have any more problems or questions that I forgot or didn't think of, email me and I'll try to find a solution.