Engineering Lightweight Dobsonian Telescopes

Part 1 of 4

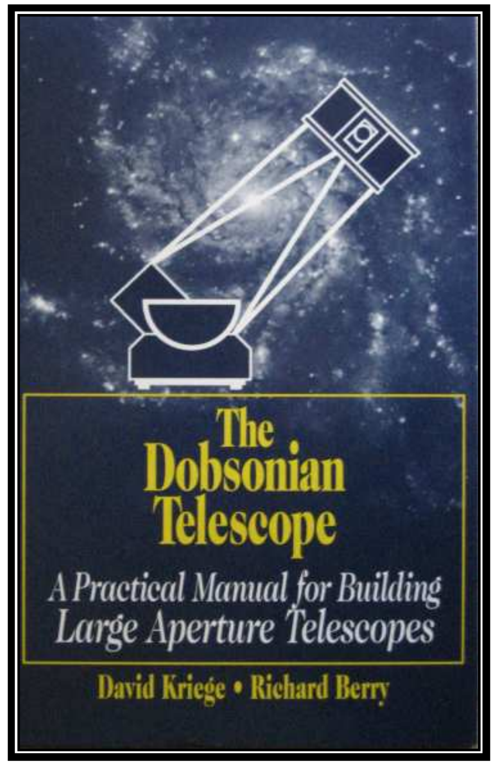
by Lonnie Robinson

Updated 2013

ATM Connection

INTRODUCTION

John Dobson really started something with his ***Dobsonian "Dob"*** telescope design. He enabled the average Amateur Telescope Maker "ATM" to create a large and very stable telescope with common workshop tools. Since then Dob's have evolved from a heavy boxy structure to elegant lightweight designs with truly excellent optics. The Dob design performs best with the wide fields of lower magnifications, where nudging the scope for tracking is minimal. This design is very stable for high power viewing, but adding a motorized tracking system, like Servo Cat or Sedereal Technology, greatly enhances the observing experience.

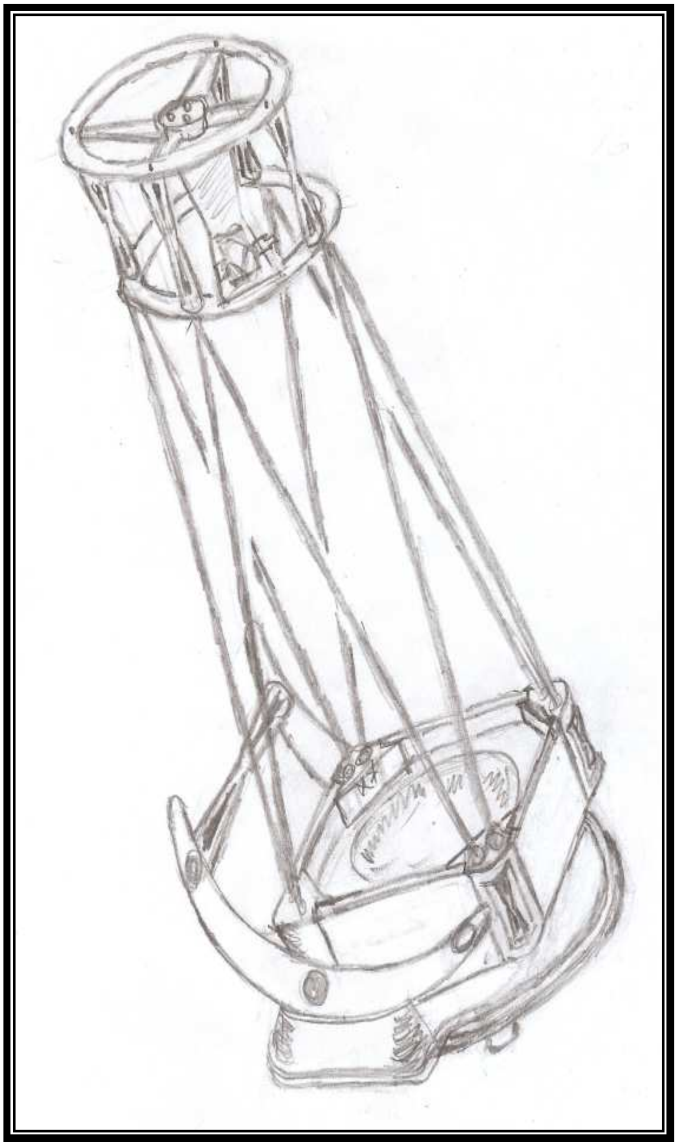


If there's one "must read" and "must own" book on building a Dob, its ***The Dobsonian Telescope by David Kriege & Richard Berry***. This book will expertly guide you through every step of design, construction, and mirror making. Building your own scope presents the opportunity to continually upgrade and customize over time.

I would like to share my personal thought process and my lightweight Dob building adventure with you, hopefully adding some additional fresh ideas to help inspire your new Dob telescope project.

WHAT SIZE IS BEST?

Let's begin with what size Dob fits your needs. If you enjoy quickly setting up your scope at home (in the city) for short viewing sessions, then a six to ten inch could be the best size. This size range is very portable and is usually built with a one piece tube or trusses that can be left assembled for easy storage. Viewing conditions under city light pollution limits the effectiveness of scopes over ten inches. As you progress to higher and clearer viewing locations, the range of twelve to twenty four inches is doable. ***Bigger is definitely better***. My personal requirements involved the largest scope I could afford, one I could lift in and out of a car by myself, and one with a reasonable eyepiece height. It's a huge effort to build your own scope, so I suggest choosing one large enough to cure your aperture fever for many years. You will also save a lot more money building a larger scope. The Dob book says "my observing friends and I agree that we could live the rest of our lives observing with a 16" without the slightest regret". For me 16" $f/5$ was the maximum comfortable, usable, and affordable size.



DRAW YOUR DESIGN

Now that the issue of size is decided, let's consider some basic design parameters and make a rough pencil drawing of your new Dob. I spent a lot of time researching scope design on the internet. The ultra light trend, in my opinion, borderlines being too fragile and open to keep the optics properly aligned and protected. The heaver box like designs seemed too large for easy storage, transport, and setup. I really liked the style and graceful lines of the large altitude bearings used on ultra lights, so I decided to design a middle weight Dob incorporating the best of both worlds.

Some designs use only six trusses instead of the usual eight, but they should probably remain at eight with a medium weight cage and the longer lengths required for a lightweight design. Besides, six trusses make for a very difficult mounting sequence at the base. My friend asked a question after I had finished roughing out my scope, "will those longer poles fit in the trunk of your car?" I hadn't considered that, and in a mild panic I was immediately motivated to check the fit. Yes, they just barley fit!

My upper cage design is only as tall as necessary, with enough area to block most stray light, and protect the optics. The medium size ensures plenty of room and support for any accessory, yet it's still small enough for easy storage.

Large diameter removable altitude bearings add style, grace, and function. They allow designing a very short, compact, and strong mirror box, that's very easy to carry and store. The extra large bearings produce higher surface speeds, which enhances Teflon's buttery smoothness and speed regulation qualities. Stiction, resistance to initial movement, is nearly zero after applying a touch of silicone wax. Designing the altitude and azimuth bearings with nearly the same diameter, equalizes the force required to move the scope in either direction. The large altitude bearings spread the Teflon pads wide and low in the short sided rocker box, making the scope exceptionally stable, lightweight, and very strong. The collimation bolts make excellent feet to set the mirror box on during assembly, so the bottom of the altitude bearings should not extend below the collimation bolts. There's a lot to like with these stylish, removable, large altitude bearings!

Don't worry too much about designing in balance, since it can easily be achieved later by changing the radius of the altitude bearings. The lower edge of the altitude bearing surface is locked in position just below the mirror box, so by changing the radius it will raise or lower the optical tubes center of gravity.

Truss tube placement and truss connector styles are very difficult choices. Kriege & Berry like the trusses mounted on the outside of the mirror box for added stability, but that interferes with clean lines and design possibilities. Integrating the truss mounting holes in the wooden mirror box corners permits locating them just inside the box edge for more than adequate stability and good looks. I'll discuss the truss connectors in detail a bit later.

I have a book on router techniques, and it describes how to make decorative spindles and longitudinal decorative groves. That inspired my idea for the wooden ***hourglass*** shaped cage struts, mirror box handles, altitude bearing support bar, and the telescope name. To me, hourglass implies looking back in time with a glass optic. I carried the theme throughout the best I could. You can do the same with the many available wood turning design ideas.

After considering all these design goals, they inspired my first rough drawing. I would be pleased if you should decide to copy it. Have fun and let yourself go with the design of your choice.

WHERE TO START

First ***acquire all the optical parts***; the main mirror, focuser, eyepieces, secondary mirror, and the secondary spider. You will need them to establish focal length, fit, and balance. However, you could use dummy weights until the parts arrive.

Let's talk about ***choosing the perfect main mirror***. Since we are building a large Dob for deep space objects, you probably desire the *brighter images from a large mirror, and wide field views from low magnification*. After choosing the biggest mirror you and your budget can handle, the first part of the image brightness equation is locked in. The second part, low magnification, then directly relates to the f/ ratio & focal length. Magnification changes only with focal length (*"f"=focal length, "F"=focal point*), and the two parameters that set the focal length (magnification) are the mirrors fixed focal length, and eyepieces (barlows included). **We will assume the mirror size remains fixed for the following discussion.**

The **f/ratio** (the focal length divided by the objective diameter) is used to describe a telescope , and somewhere along the way the f/ ratio incorrectly became the benchmark of how bright the visual image will be as in faster lower f/ratios will have brighter images. This is simply not the case unless it relates to photography, cameras vary the objective diameter (brightness) and not the focal length (magnification and field of view) to change the exposure and f/ ratio. In our example with a selected fixed objective size, the focal length and f/ratio are proportional and relative to each other, so both can be used to describe the magnification range characteristics of a telescope.

Brighter Images are a direct result of lower magnification (with a fixed objective size). Using different f/ length eyepieces allows you to control how the available light is spread out. Two mirrors of equal diameter, with different f/ ratios, will display the exact same "visual" brightness if different f/ length eyepieces are used to equalize the magnification (focal length).

Wide Field Views (related to the objective and not eyepiece design) are a direct result of lower magnification and not the objectives size. Bigger mirrors usually have a longer focal lengths, because of practical f/ ratio-f length limitations. That means, in general, much bigger mirrors will produce higher magnification, narrower fields of view, but produce brighter images.

Are there other reasons to choose a specific f/ratio? Absolutely!   **Eyepiece height** is real concern, and if the objective is very large (18" and up), a very low *f*/ ratio-f length may be necessary to keep the viewing ladder reasonably short. You also want to use **common eyepiece sizes**, so mid f/ ratios are a good fit. If your f/ ratio is too low, the view at the eyepiece will display coma (blurring at the edge of the field). This may require an expensive light robbing **coma corrector**. Eyepiece diameter, field stop, and designed-in field of view, combined with the telescope mirror, ultimately determine the actual ***true field*** of your telescope.

Bright images and wide fields, are best accomplished with an f/ ratio at or below f/5. The magnification range will be relatively low producing brighter images, but the secondary mirror must be larger to encompass the steeper and wider light cone. Eyepiece height is lower because of the shorter focal length.

For ***all purpose viewing***, *f/* 5 to *f/* 6 seems the best compromise. I decided on a 16" *f/* 5 for the best all around viewing without using coma correctors, great high power planetary views, low power wide field performance, with a reasonable secondary size and eyepiece height.

High power Planetary viewing is best accomplished with a smaller mirror (6"to 10") with a longer focal ratio of f/8 to f/15 and over. Most planets are very bright, lowering the light gathering requirements. However, larger mirrors would provide greater contrast and resolution to highlight surface detail. A smaller mirror will have a shorter focal length for a given f/ number, and provide a reasonable eyepiece height. High *f/* ratios provide a higher magnification range, long in-focus travel, narrower field of view, require a smaller secondary with less light obstruction, and provide clear high contrast images. Longer-focal-length eyepieces can be used with their increased eye relief.

Should you decide to ***make your own mirror***, *f/* 5 and higher presents the best chance of making a really good mirror. Between *f/* 4 and *f/* 5 the in-focus range is extra sensitive, and the steeply angled light cone requires highly accurate figuring. Coma is two times worse in *f/* 4 than *f/* 5! Don't' forget as the f/ratio gets lower, it requires an ever larger secondary mirror with more light obstruction and resulting loss of contrast. The higher the *f/* ratio, the easier your mirror is to figure.

Polish and figure your mirror first so you can measure the final focal length to set the truss length, assemble the scope, and star test on Polaris before aluminizing. Polaris works because it moves very little, and the optical tube assembly can be propped up on the ground in a fixed position. You can get some really great views of bright objects without the aluminum! The total uncoated light grasp is about 4%, making an uncoated 16" about equal to an aluminized 3.2" (20% of the diameter) but with a 16"s resolution. My 16" showed amazing detail on the moon without a filter, and Saturn was tack sharp.

The Dob book divides mirror makers and telescope makers, saying it is difficult to do both. They even indicate if you make mirrors you may never observe again. I did both, and even though it took a lot of time, the rewards are awesome. Viewing a celestial object with your own mirror is very satisfying, and in many cases you can make a better mirror than a professional simply by spending more time to perfect it. However, there are many great commercial mirrors available.

The ***focuser*** is a fun choice. I really like the 2” Feather Touch and Moonlight crayford units, with a nod to the Feather Touch. Moonlite offers some great colors. Feather Touch has taken the crayford design to the next level. They use dovetail like stainless steel rails to run the upper ball bearings on, resulting in a very durable, smooth, and tight system. They both have an excellent gear reduction knob for fine focus, and cant adjustment screws in the base for aligning the focuser on the optical axis. They both have motorized focus available. I highly recommend a compression ring for holding eyepieces and equipment. The ring holds securely, centers, and doesn’t mar your eyepieces. It really helps when using heavy eyepieces, binoviewers, cameras, and aligning with laser collimators. There is a complaint that the new recessed security groves on newer eyepieces catches on the compression ring, but I haven’t experienced a problem with it. Be sure and choose a fairly low profile focuser with at lease a 2” range of focus. If it is too tall, it could necessitate an increased secondary mirror size. Focusers have come a long way in recent years relating to smoothness, accuracy, toughness, and good looks.

Secondary mirror size is a difficult choice. What you want overall is the smallest secondary you can get away with to catch all the available light from the main mirror, a minimum light obstruction, and adequate eyepiece illumination. The diameter and focal length of the eyepieces you want to use, and their field of view, will affect the required secondary size. Your largest diameter, widest field, and lowest power eyepiece needs the largest illumination area, so use that eyepiece as a basis to decide the secondary size. High power 1-1/4” eyepieces can use a slightly smaller secondary. Eyepieces with very large fields of view, like 80 degree Naglers, require a slightly larger secondary mirror. Check out the Dob book for details on eyepiece illumination, but it should have a fully illuminated image diameter between ½” and ¾”. Try to keep the secondary mirrors maximum obstruction to 19% or less on a liner basis (opposed to area). Lower than 19% achieves very little visual improvement, and higher gradually degrades the image resolution and contrast. Cassegrain obstruction can approach 34% linier, so you can see how much wiggle room there is! My experience is that smaller is not necessarily better, since a little extra obstruction is pretty much undetectable visually. There is a series of standard secondary sizes available. I found my exact choice to be in-between standard sizes, so I simply opted for the next larger size (3.1”) making sure not to waste any precious light from the primary mirror. The larger size fully illuminates a 3/4" field for my favorite, 65 deg, 2", 32mm, wide field Tele Vue eyepiece. Planetary views at 300X are amazing even with a 19% obstruction!

I have come to really appreciate the ***secondary spider*** from Proto Star. It has a nylon center mount bolt that stretches, applying constant spring like pressure on the collimation screws as you adjust the mirror. This allows each collimation screw to be adjusted independently, without affecting the other two adjustment screws. It also keeps things snugly locked in place after adjusting. I crafted my own version of Bob's Knobs from three stainless steel 10-24 threaded rods and small knobs secured with Loctite. Optical alignment literally takes seconds with a laser collimator, Proto Star spider, and these knobs. It couldn't be easier! Well perhaps having your significant other set it up for you would help.

OK, we have completed Part 1 with our drawing and have acquired all the optical components.

Next we will discuss:

Part 2- Mirror Cell & Mirror Box - Upper Cage

Part 3- Truss Poles & Truss Connectors - Optical Tube Balance - Rocker Box – Ground Board & Pivot Bolt – Powered Ground Board - Encoders

Part 4- Altitude Bearing Design & Installation - Wood Finishing - Final Assembly, Collimation & Star Testing

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Part 2 of 4
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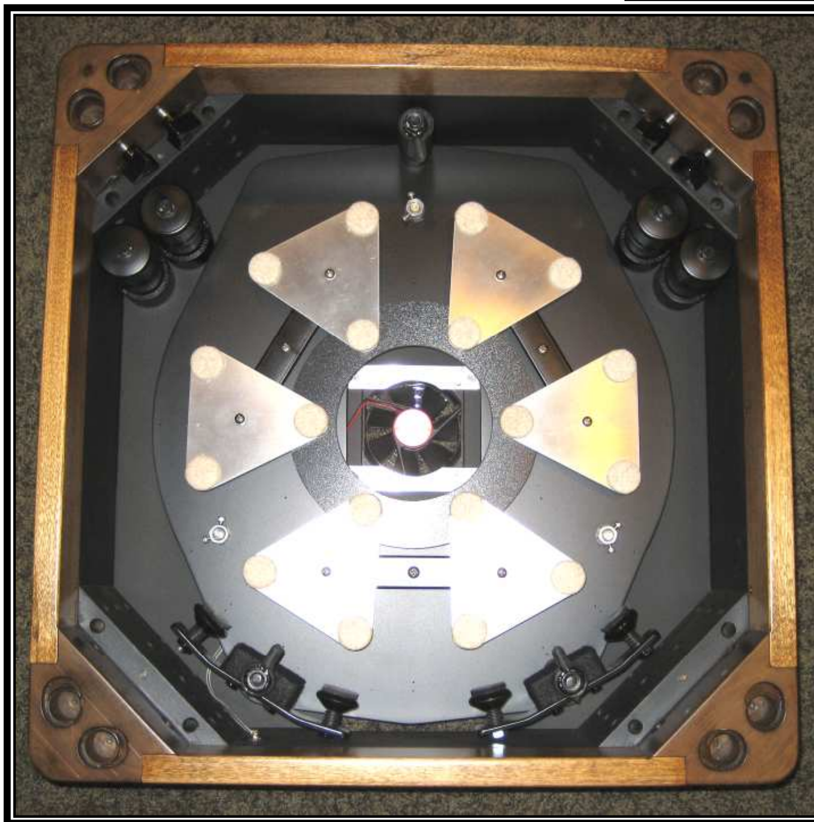
MIRROR CELL & MIRROR BOX

The Dobsonian Telescope book suggests building a steel frame to support the ***mirror cell*** and give the mirror box rigidity. The frame is left open to promote air flow around the mirror for temperature stabilization. It's my opinion the open bottom presents a physical risk to the mirror during setup and storage. I also don't care for closely positioned collimation bolts mounted to the cell pivot bars. Being closer to the center, they offer less mirror support to maintain alignment, move the mirror more per turn resulting in coarser collimation adjustments, and have a tipsy support base when used as legs to stand the mirror box on. I used 3/8" round head carriage bolts with 16 threads per inch for the collimation bolts. After rounding the square drive under the head, I drilled a hole in a large plastic knob and secured it with a 3/8" jam nut and washer underneath. Very tough and great looking adjusters! They are threaded into inch long brass inserts installed in the base. With just a touch of silicon applied to the threads, the collimation bolts feel velvety smooth when adjusting. It was difficult to install 3/8" locknuts for the slip turn mounting in the mirror cell plate, so I drilled and tapped two holes in each of six standard 3/8" nuts for setscrews. The local hardware store had some great nylon spacers and nylon washers that act as bearings under the nuts and around the bolts in the cell plate. Adjust the nuts with just enough space to allow the mirror cell plate to tilt a bit, and tighten the setscrews. You might consider permanently locking one of the collimation bolts to maintain the mirrors exact height along the optical axis, and keep the adjustment travel centered. Only two adjusters are required to set collimation. Cell excellence!

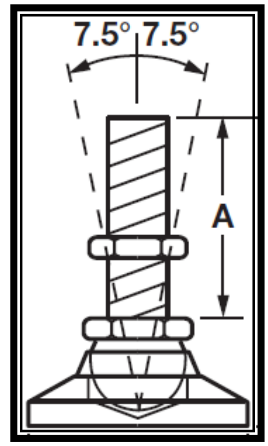
I'm not convinced, when using a fan, an open box bottom design makes for faster ***mirror cool down***. Installing a fan in the bottom without directing the airflow around the mirror accomplishes very little. My mirror box is enclosed, and the airflow is directed up through a large center hole in the cell, across the mirrors bottom surface, then outward and upward around the edge. The short sided mirror box design promotes airflow to quickly escape out the top. I'll never forget meeting John Dobson. A great inspirational man and one of his many comments was that open truss designs are really bad for air currents. Well, "really bad" was not quite his actual quote. I didn't argue with him, but quietly thought it over. ***Tube currents*** are mainly

Lonnie, John Dobson, Doug, & Cary. 2005



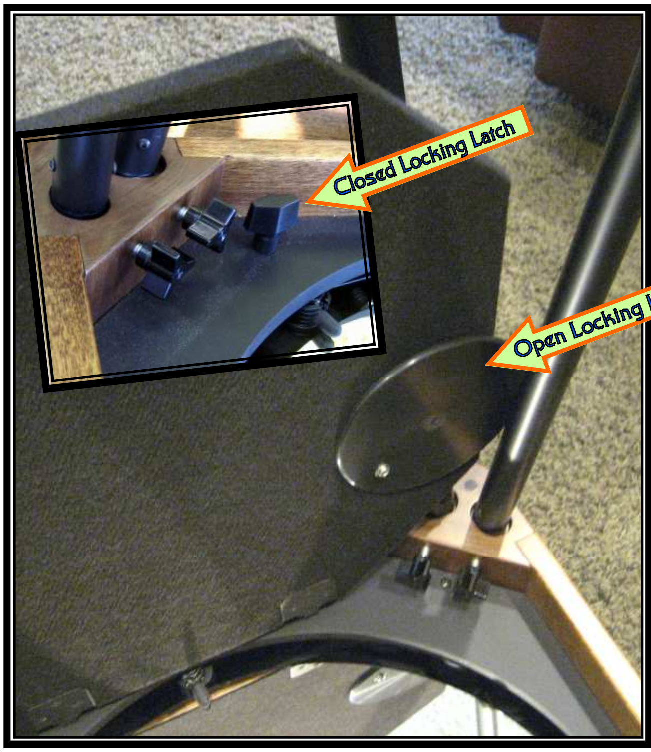
caused by entrapped heat that is trying to dissipate. It seems obvious to me, that the open truss design promotes equalizing temperatures, and therefore has fewer potential air currents? However, any external air movement like a good sneeze, a breeze, or body heat will upset the balance. A great solution is a nylon spandex shroud over the trusses that doesn't retain heat, breathes while restricting airflow, and blocks stray light. At dark sites with no wind the shroud can be successfully left off, but be careful not to drop anything on the mirror! My mirror box design allows the use of a strong 1" thick wooden base board with the collimation bolts widely positioned for finer adjustments, better mirror support to retain collimation, wider stance for feet to sit the box down on, directed air flow from the fan, no loss of stiffness, and great mirror protection. Works for me.

A sling ***mirror edge support*** excels at supporting a mirror without applying any local pressure to distort the optical figure. However, how stable is it for repeating and holding collimation setup after setup? The mirror probably moves around a bit while observing, and definitely during transport. I decided to make a mirror cell implementing the unique edge support system used by Night Sky Telescopes, and followed the Dob book guidelines for a floating 18 point mirror cell at the rear. The mirror edge wiffle tree supports consist of two swivel bars, each incorporating two vinyl covered appliance leveling bolts with felt pads added to the ends. I recently discovered a great swivel leveling mount, for mirror edge supports, with a 1" nylon head from McMaster Carr part #6111K72. They should equalize the forces at the mirrors edge nicely. My supports are equally spaced 30 degrees apart (30+30+30) across the bottom edge of the mirror. However, recent research indicates a 45 degree spacing (45+45+45) offers much better support rivaling a sling. Check out Cruxis.com for further details. Each of the four support pads carries about 7.5 pounds of mirror weight on my 16". The adjustable pads enable precise mirror centering on the optical centerline, (very important for encoders) and move with the mirror cell plate to maintain alignment. It's the same style edge support that Pegasus Optics and John Lightholder use on their mirror test stands. I used a solid ¼ inch thick aluminum plate for the cell base with a cooling hole in the center. More holes could be added if you are depending on convection air cooling. This design has proven very successful each time I set up. I haven't noticed any large collimation changes during setup and observing, and haven't visually detected any distortion from improper edge support or slow mirror cool down. The cell also has a very low profile. The best of all worlds. Can you tell I like this mirror cell design?



The main consideration with the ***mirror box is stiffness***. The box must not twist or the movement will transmit to the truss poles and misalign the optics. Movement would also create havoc with encoder alignment. A strong base board is the key. I used a 1" thick laminated birch plywood piece, and didn't worry too much about weight. You'll need it here since it takes about 5 pounds to counter balance 1 pound of weight at the upper cage. I decided to incorporate the truss pole sockets and lifting handles into the mirror boxes wood corner pieces. The truss ball socket locking bolt holes are drilled and tapped in the wood. Hard wood will take a great thread, and the threads are very durable and strong. Keep the threads coarse (1/4x20), seal with thinned urethane, and add a little wax for lubrication. The handles have proven indispensable for transport and assembly, and the ball truss sockets located near the outer mirror box edge are adequately spread out for great stability and good looks. I decided to make the mirror box side panels from ¾" solid Birch. Half inch ply didn't seem like enough to hold the thread inserts, and prevent the altitude bearing mounts from flexing. Make the mirror mask id 1" larger than the mirror. All the spacing measurements are tight, and a lot of planning went into keeping the box dimensions minimal. The end result is a great looking mirror box that stores and transports easily.

I designed a terrific ***hinged mirror cover***, with a latch, that keeps things clean and safe during storage and transport. With a short sided mirror box, a



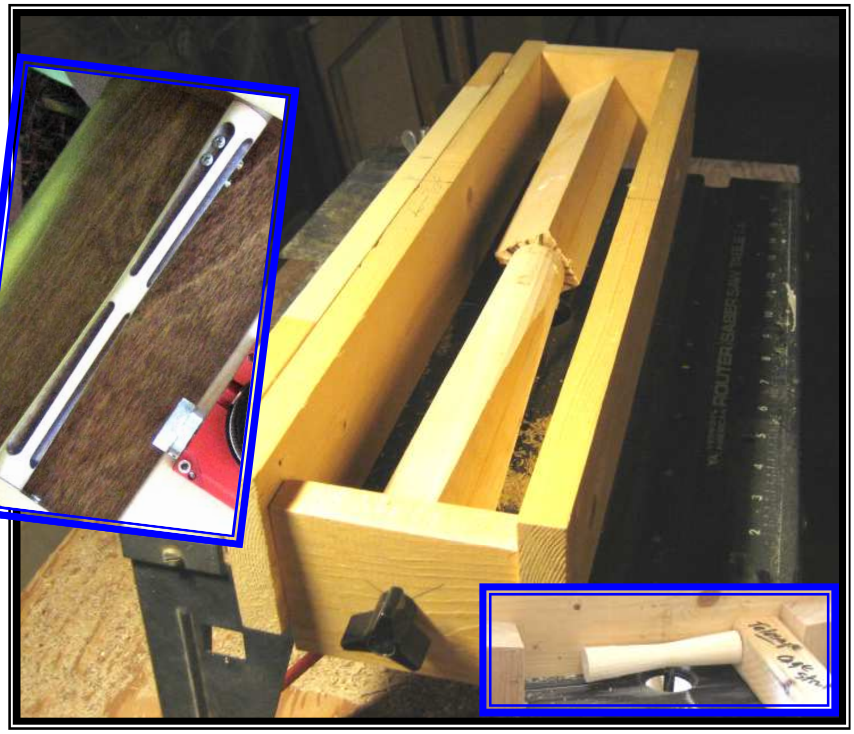
loose cover could be accidentally dropped on the mirror. Because it's attached, it's always handy to close keeping out dust and those curious little fingers. The lid can be supported slightly open by rotating the closed locking latch under it, allowing cooling airflow while protecting the mirror. Latching the cover open is accomplished with an eccentric rotating plastic plate, mounted under the lid, and catching on a truss pole. With the open truss design, the open lid provides some protection over the mirror from dew, dust, small meteors, and falling stuff. As it turns out the lid also helps counterbalance the large altitude bearings.

An **unexpected *balance problem*** came up because of the weight of the large altitude bearings extending out over the back side. When pointing at the Zenith, the scope would ever so slowly move by itself because of the overhanging bearing weight! The mirror lid is hinged at the top edge, and when open it offers some ballast to the opposite side. An adjustable weight track could be added on the lid, but I opted to install small weights inside the top corners of the mirror box. For the weights, I used 1" PVC plastic pipe with end caps and filled with buckshot. It looked much like I was making pipe bombs in my garage, which I was glad to finish and get installed out of sight. A bolt is inserted all the way down through the center with a loose locknut under the top lid to hold it in place. Then it's threaded into the wood base plate for a secure mount. The buckshot allows for future weight adjustments.

UPPER CAGE

The upper cage *w*as a fun project. Overall size and weight must be kept to a minimum, so with that in mind I decided on the dimensions and materials to use. The cage height measurement was based on adding 3" past the bottom of the secondary mirror, and ½" inch over the spider center bolt. My cage figured in at 11" high. Add one inch to the main mirror size for the inside ring diameters, and they are 1.5" wide. The

Dob book will guide you on these dimensions for different sized mirrors. A local hardwood supplier caries 1/8" aircraft birch ply which proved excellent for the secondary baffle material, and I used ½" birch ply for the cage rings. The 1/8" was easy to work with, and it conformed nicely to the cage rings after several days moistened with water and tightly rolled up. Kerf cuts on the back of the baffling would help with tighter bends for smaller cages. When routing the rings and focuser board, rabbit cut an extra notch to accommodate the 1/8" baffle paneling. After carefully cutting the baffle to the exact size, it should snap in place under its own tension. This wood has beautiful grain and has proven to be very strong. It adds great stiffness to the whole cage assembly with very little weight, and the sun won't warp the wood like it does Kidex plastic.



I designed ***hardwood cage struts*** instead of using left over aluminum truss pieces. The aluminum starts to get very heavy with the required nut inserts and bolts. I used my router and a jig to make the round hourglass shaped struts, but a lathe would be a better choice. The truss piece was mounted higher on one end to create the angle, and the whole jig was slid side to side and the piece rotated after each cut. The decorative groves were made with the piece mounted level, causing the cutter to make deeper and wider groves toward the tapered ends. The same procedure was used for the mirror box handles and altitude bearing cross support. These struts are great looking, lightweight, and very strong. A decision came up about where to locate the cage struts. Should they be located over the truss tube connections or in between? My answer was over the trusses for obvious strength reasons and good looks. Looks sometimes plays a major role in decisions, and luckily I picked a spot that works with my yet to be chosen focuser location. Long lightweight stainless Phillips screws were used to mount the struts to the cage rings.

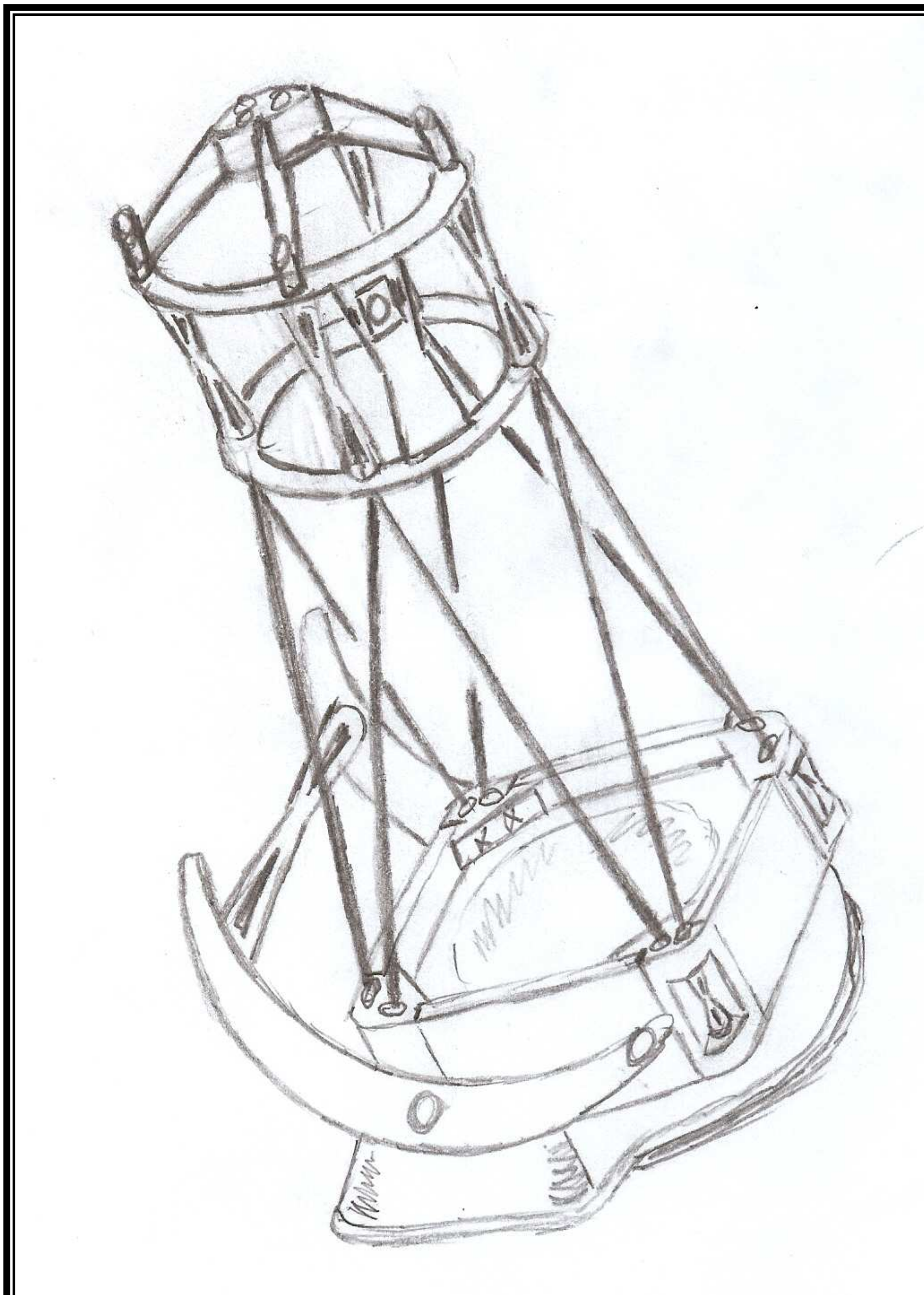
Left or right side focuser position is a very tough decision? I didn't realize there were so many possible positions and reasons why. Running a survey on focuser locations of several telescope makers proved inconclusive with almost equal results for left and right sides! If you use a ladder or stool, do you want your scope to move away or toward you when tracking an object? Objects move further and faster in the eyepiece near the celestial equator, which is more toward the south here in the US. Are you right or left eye dominant? With your arm extended point your finger out, and with both eyes open align it on a distant target. Close one eye at a time and note which eye is still aligned on target? Which hand do you want to use moving the scope? The right hand would probably do a more coordinated job of steering the scope, but it's needed to conveniently do other things. I occasionally find myself using my right hand on the lower cage ring to help position the scope. I elected to install a small handheld PC next to the focuser, using the Pocket Sky, and connected to a B-Box with encoders. That involves using my right hand to input info with the stylus. A lot of conditions! For me, the obvious choice was to position the focuser on the left side looking from the bottom end of the telescope. I use my left hand to guide, and my right hand for focusing and PC operation. The scope should move away from your ladder or stool while tracking most objects. Hopefully, you won't fall off the stool when it moves too far! I am right eye dominant so it is far more convenient positioning my eye on the focuser and especially the finder scope. The left side is the answer unless you live in the southern hemisphere, you are left handed, and or left eye dominate!!! Are we having fun yet?

Where is the focuser located on the cage? By locating it on the side, the eyepiece would be easier to look through until the scope is pointed down towards the horizon. I find myself viewing more stuff nearer the horizon as the night evolves because I get lazier. At lower positions it would be convenient to have it positioned toward the top or back of the cage making it much easier to look into the eyepiece. A compromise is the solution! I located it towards the back just enough not to interfere with vertical convenience, and to help with the horizon position. I really like it there! There are no optical issues wherever you decide to locate it, only to avoid strut locations. One of the cage struts could be replaced with the focuser board.

The ***location of the focus knob*** is optional too. Which rotation is best, Right, top, or bottom? Being right handed dictates the most convenient knob location to be on the right with the bottom a close second. Moving the scope towards the horizon rotates the right side focuser knob to the top or the bottom location to the right.

One more important variable would be the addition of a Servo Cat drive system. The scope tracking should be mostly away from the stool especially during coffee breaks!

I came up with a great idea of designing the cage so it could optionally be installed upside down with a another set of duplicate truss connectors attached to a second set of short 36" truss poles. The lower ball connectors would easily facilitate the different truss pole angles. Then attach a third ***5" round tertiary mirror*** to the top mounting with the existing upside down truss connectors. I could comfortably view sitting down at a 16" f5 scope, with an eyepiece height of about 47"! Cool observing for an old lazy guy. The secondary obstruction would be about 31%, still less than a cassegrains 34%, and it could excel at viewing faint fuzzes near the zenith. In retrospect, I should have located the focuser exactly half way between the side and the back so when inverting the cage it would be in the same location. The end result would be two telescopes in one, one more suitable for planetary viewing and the other for deep sky.



I told you this was going to be fun. The upper cage presents a smorgasbord of tantalizing gourmet tidbits to mull over in your mind.

More to come in parts 3 and 4!

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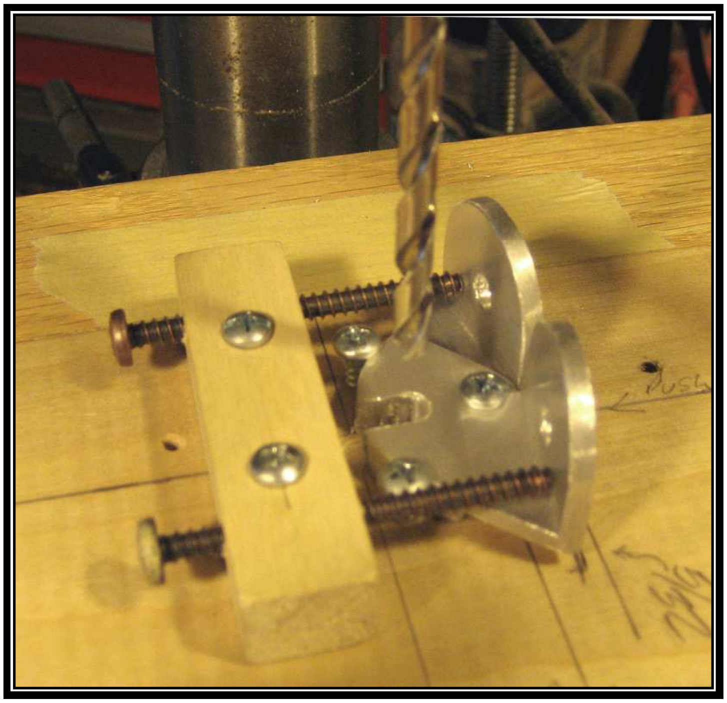
TRUSS POLES & TRUSS CONNECTORS

Truss connectors were one of my biggest challenges. There are so many different great ideas and several are covered in the Dob book. Moonlite Telescope Accessories offer some really great truss ball connectors as well as top of the line focusers. The ball connectors easily and securely maintain any angle, making truss pole installation a breeze. Moonlite also offers truss pole end plugs for mounting your own connectors, and they will sell the ball connectors without the sockets. I decided to use the ball connectors for the bottom ends. After searching the web I finally found a hinged, ultra compact, upper truss connector I liked designed by Stathis Kafalis. I liked it so much that I copied it almost exactly, just turned it inside out. I hope he doesn't mind? The connector hinges two poles together for a single knob attachment at the upper cage, greatly simplifying assembly and storage. He used bicycle seat lever clamps, but I opted to use a knob instead with the connector mounted inside out for better knob access clearance and a cleaner appearance. A router table with a jigsaw mounted underneath made cutting the aluminum pieces easy. My radial arm saw with an old carbide blade worked really well cutting the square parts. Make sure to wear eye protection in case a carbide tip comes loose, or something grabs and gets your attention. Please be careful and fully support the piece to be cut, go slowly with small cutting increments, and by all means keep the fingers safe. You can tell I really need a band saw! The radial arm saw is perfect for accurately cutting very small amounts off the truss poles too! A tube cutter leaves a ridge inside the tube, will only cut ¼" increments or larger, and will probably leave marks on the outer surface. When the lower pole ends are spread for insertion in the mirror box sockets, a slot in the upper truss connector hinges open for the cage



attachment bolt to drop into. I made a simple jig for cutting the slot at just the right angle. Attach two poles to a semi finished connector, spread open the bottom ends of the poles to the mirror box dimension, and the resulting angle is correct for the slot. Then adjust the jig to hold the piece, without the poles, while a drill press cuts the slot. I used 10x32 knobs for a secure connection. The upper cage bracket is drilled and taped for a 10x32 round Allen head truss connector bolt, eliminating the need for a nut by allowing the bolts head to be jammed securely angst the brackets backside. The mirror box truss ball sockets are recessed a bit extra, creating a ridge that supports the poles in the correct upright position while attaching the upper cage. It makes assembling the upper cage as easy as dropping it in the slots. The cage rests patiently and securely in the slots until you tighten the knobs. The ball connectors are very stylish, small, very lightweight, easy to align, and quite secure. I promise you will really like these connectors.

I like Moonlites offering of black ***truss poles***. They have proven very durable as long as reasonable care is taken to avoid scratches. The black surface reduces stray reflected light from the poles located inside the optical shroud, without using bulky foam covers or black tape. I stumbled across a great idea for setting the truss pole length, which saves making a mistake with your expensive aluminum trusses. It just happens that the truss ball assemblies fit snugly inside ¾" thin walled white plastic sprinkler pipe. Use plastic electrical tape to secure the truss connectors to the plastic pipe and proceeded to gradually cut them to length. I cut the poles so my par focal eyepieces would focus at about half of my 1.75" (.87") total focuser travel, instead of the usual suggested 1/2", leaving a bit for future adjustments. Some variation may be necessary depending on different eyepieces and accessories. Be sure to focus on infinity when cutting the pole length, and don't forget to center the overall travel of the main mirrors collimation bolts. Also make sure the secondary mirror is in it's final offset position (see collimation later in this article). It was surprising how well the plastic pipes held optical alignment even when looking at the horizon, and even though I could see them flexing.

My dear wife Jan sewed a ***truss pole storage bag*** with separate pockets that keeps them from getting scratched, and rolls into a compact unit for transport. She also put together a great black spandex light shroud for the assembled open trusses. Thank you Jan! Now if I could only train her to set up my scope, serve coffee and doughnuts at least hourly, and perhaps occasionally clean my glasses. That could be the title of a future article, "How to get a quick and easy divorce".

OPTICAL TUBE BALANCE

Once the optical assembly is roughed out and assembled, it can be picked up to ***find the balance point***. It's important to mount everything on the upper cage that you will be using during an observing session, including your heaviest eyepiece. I added an extra pound and a half for future equipment changes. It takes a lot less weight to adjust the balance at the upper cage than at the mirror box end. I installed a ***weight rail*** on the cage that will hold any assortment of screw on round movable weights from ½ lb to perhaps a total of 6 lbs. I ordered some very inexpensive 2" round steel ½ lb and 1 lb blanks and a sliding track, from McMaster Carr. I ordered enough extra weights and a rail long enough to make a balance system for my 8" Mead cassgrain too. Drilling and tapping a ¼" hole in the weights enabled me to screw in a stud, with a jam nut, for chucking in my drill press. It was fun sanding the spinning weights and polishing them with Scotchbrite. Mounting the weights on a ¼" bolt inserted in the rail, with a nylon washer in-between, allows smooth sliding adjustments with a secure twist lockdown. The weights could even be double stacked on top of each other. Someday soon I would like to purchase an inexpensive powder coater from Harbor Freight. I could have the only red weights in existence to mach my red focuser. It's really a treat to balance the light secondary cage and not the mirror box. With all the accessories and extra weight attached, mark the optical tube assembly's balance point. Measure from that point to the mirror box bottom and add ½" overhang to get the radius of the altitude bearings. Mine measured in at a 17" radius. I'll discuss altitude bearing design and installation after completing the rocker box and ground board.

ROCKER BOX

A *wide low profile rocker box* with generous altitude bearing spacing is extremely strong and stable, easy to store, and transport. Make every effort to keep the space between the mirror box and rocker bottom at a minimum. There should be about a ½" space when rotated down in altitude. It's necessary to cut a slot in the mirror box to accommodate an azimuth encoder housing. If you never want to use encoders, the mirror box lower edge can be cut back at an angle for more clearance and additional eyepiece height. Don't forget to design in

side thrust bearings to control the side to side motion of the altitude bearings. I incorporated a ridge, in the rocker box cradle boards, to mount the Teflon side thrust bearings. Four thrust bearings instead of two should track more accurately for encoder applications. With larger mirror boxes and smaller altitude bearings, the thrust bearings could be mounted inside between the rocker box and mirror box.

The ***rocker box cradle boards*** are 1-1/2" thick and only about 5" high, eliminating the need to reinforce with an end panel. They stand by themselves, resulting in a great looking low profile rocker box. There is one issue. With no rocker box end panel, there is nothing to stop the scope when it reaches the Zenith. I came up with a neat ***adjustable stop***, with a locknut, mounted on the base of the rocker box under the front of the mirror box. Center it on the board so the encoder cutout will provide clearance. It's small and easy to adjust at the Zenith for setting up the required zero wobble motion for encoders and a computer system.

Where can we ***mount the electronics***? A sliding drawer works well for compact storage. The component box is wired and fused to supply 5, 9, and 12volts for the b-box, pocket pc, laptop or tablet pc, and the cooling fan. I wired in a DB9 serial computer connector with a null modem switch, to easily swap between a pocket pc or a laptop. The B-Box is mounted inside, with the RJ11 encoder sockets in the back panel. It would be fairly simple to add a short vertical strut mounted to the rocker cradle bottom, designed to support a laptop 18" to 24" off the ground. No loose wires to get tangled! Even better, add a wireless LAN or Blue Tooth adapter. Then your computer could be located away from the scope on a separate table. Whichever device you choose, it will probably need to be tethered to a long term power supply.

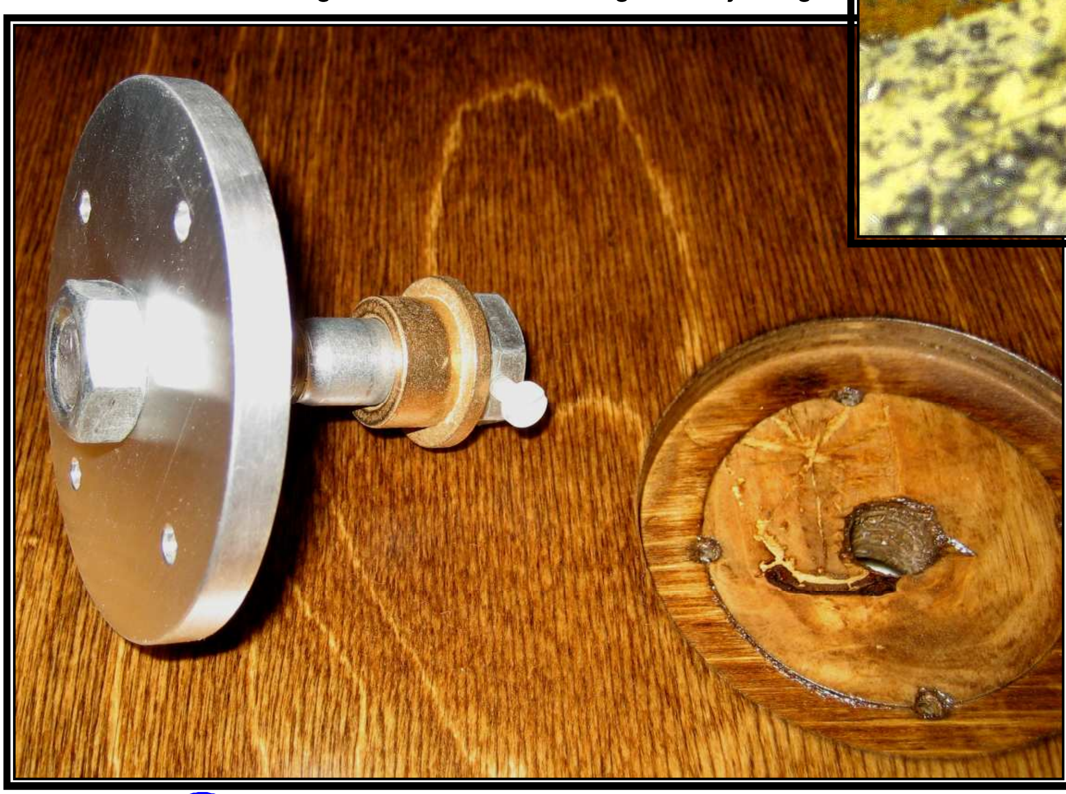
My electronic component box is the same size as the ***Servo Cat*** controller, and there is sufficient space to mount the servo motor and gearbox. This preparation, along with a powered ground board, should make a future Servo Cat addition easy. The Servo Cat can be operated with a pocket pc, laptop, the newer tablet pc's, and even smart phones.

GROUND BOARD & PIVOT BOLT

The large size of the ground board is important for placing the feet and Teflon bearings as wide apart as possible for the best overall telescope support. Be sure to mount the Teflon directly over the feet. The accurately cut round ground board should be nearly as large as the rocker base board, and close enough for the Servo Cat drive shaft to engage.

For the ***ground board feet*** I used three round rubber door stops, like the ones used on a wall for doorknob contact, and sawed them off to about 1/2" inch high. My thinking is that they perform much like the anti-vibration pads sold for tripods. Hopefully the fairly stiff rubber will dampen some of the vibration and cancel it out quickly, and indeed it seems to work. If you have encoders, the rubber feet effectively stick to the ground, making it difficult to accidentally knock everything out of alignment.

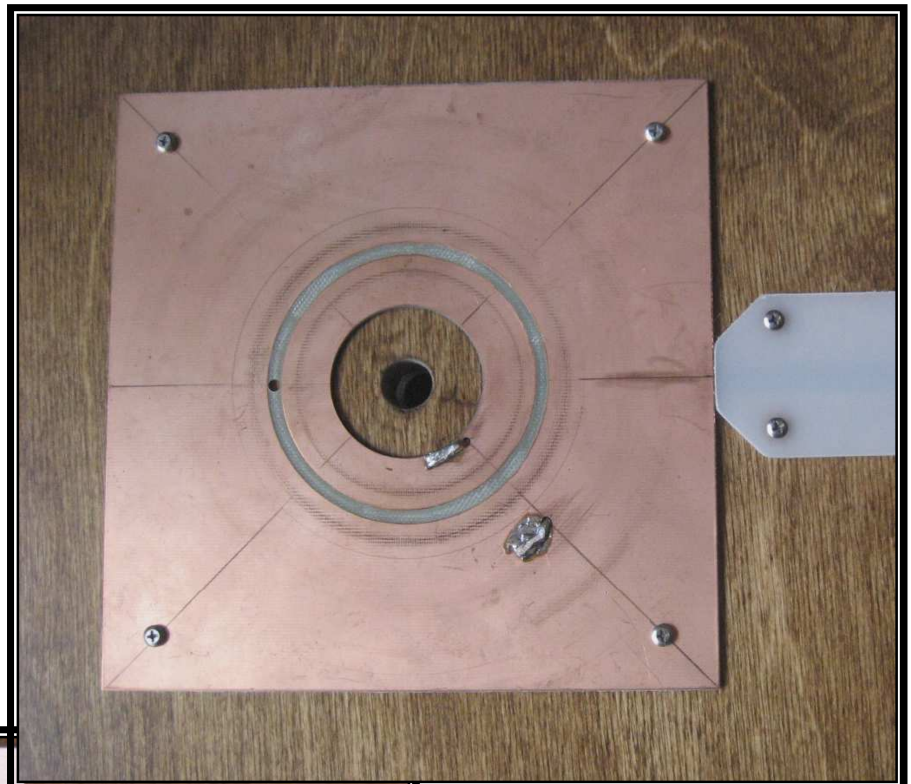
The Dob book suggests finding a friend with a metal lathe to machine a perfectly centered hole in the ***pivot bolt*** for the azimuth encoder shaft, but a drill press worked quite nicely. First, clamp a board to the drill press table, and drill a ½" hole through it. Remove the ½" bit and Insert the ½" pivot bolt in the hole. Then chuck up a ¼" bit and drill a perfectly centered ¼" hole, in the restrained and centered pivot, bolt for the azimuth encoder. A little 3 in 1 oil helps here. It was easy to drill and tap a small setscrew hole in side of the bolt head for securing the encoder shaft. Visit the local hardware store for a ½" ID brass bearing, with a top shoulder, for the azimuth bearing. Most pivot bolt designs utilize a large blind nut on the bottom, but finding a ½" one locally proved difficult. I decided to use a ¼" thick piece of aluminum, cut it to a 3" circle with my router, and drilled and taped the center hole for ½" x 16 threads. Next, drill four mounting screw holes to secure the plate in a recessed cut out in the bottom of the ground board. Installing and adjusting the pivot bolt tension is easy, and a thin jam nut on the bottom locked the bolt in position. Homemade pivot bolts are super inexpensive and very functional.



When cutting the Teflon bearing pads, make an extra doughnut shaped one for the center bearing. When installed it will carry some of the scopes weight, reducing the outer bearing resistance. Simply shim the bearing until the motion feels right. It would be very cool to have an external adjusting screw, through the aluminum pivot bolt plate, that could put variable pressure on the center Teflon bearing.

The ground board is fairly simple and straight forward. On some Ultra Lights without encoders, it's simply a triangle piece just big enough to hold the Teflon bearings, pivot bolt or roller bearings, and feet.

POWERED GROUND BOARD

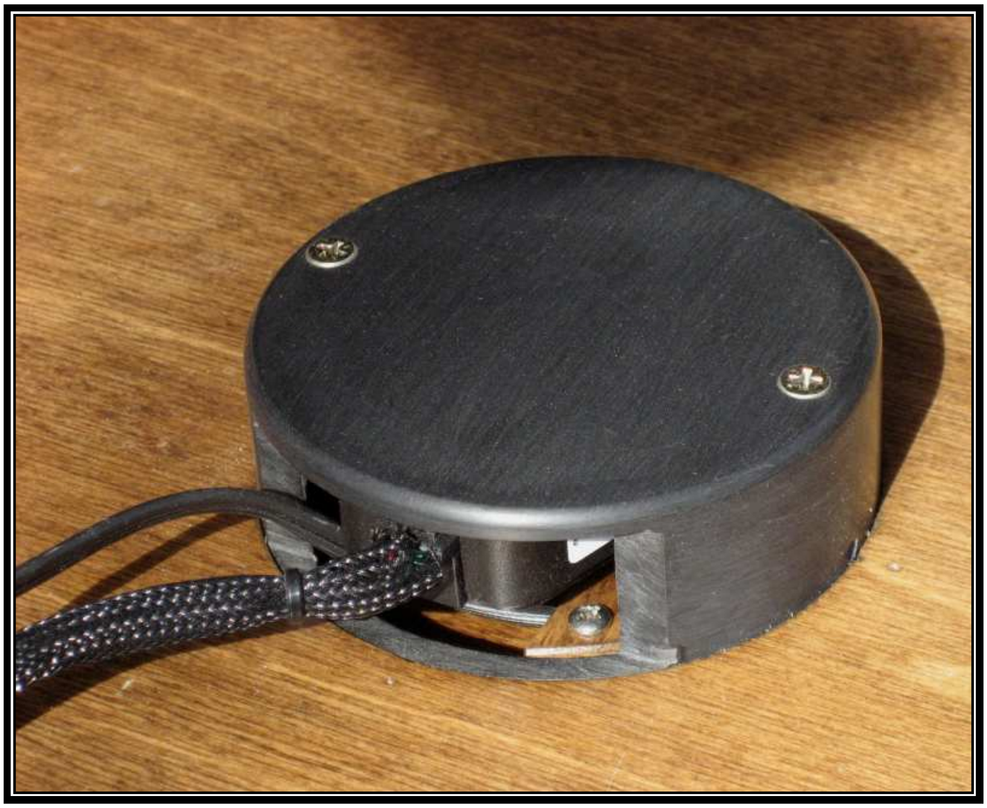


This was another fun project. I didn't want a bunch of wires winding up around my feet and the telescope while observing, so If elected to make a powered ground board. Mounting a 12v battery on board would take up a lot of space and there wasn't a great place to put it. This way there is only one wire going to the base board from a remote battery, up through the brushes, and connecting to the system. I bought a small circuit board at Fry's Electronics, drilled a center hole, and set up my router to cut shallow circular groves for separating the circuits and to provide a brass running surface for the brushes. The board goes on top of an off center jig with the router underneath, and then the circuit board was rotated to cut the groves. Round electric motor brushes work perfect with two plastic sleeves acting as brush holders. There isn't any heat build up in the brushes like in a motor, so plastic sleeves work well. (Note: After using the carbon brushes and plastic sleeves, I discovered a lot of voltage resistance through them. I have since replaced the carbon brushes with 1/4" solid brass and the plastic sleeves with brass shoulder bushings. It improved the connectivity and current capacity greatly! The next improvement will be replacing the circuit board with aluminum slip rings for greater wear potential.) The large hole in the center of the

board circuit is for the donut shaped Teflon bearing. Fabricate a wooden top cap to hold the wiring and compress the brush springs. Now the scope can spin without the cords tangling. It's also ready for a future Servo Cat System. The cooling fan, handheld computer, and servo drive systems can run all night on a large 12 volt battery.

ENCODERS

US Digital S6 large encoders are preferred and have a new plug in connector in the encoder housing. 8192 ticks offer high enough resolution for most applications. Higher than 8192 ticks may require special interface hardware to handle the increased encoder information. Scrounging around the plumbing department at our local home improvement store, I found a 4" black ABS pipe end cap that was fairly flat on top. This end cap would become the azimuth encoder housing. I routed a recessed hole in the base board just the right size for the cap, cut an opening in the cap making it look like a World War II machine gun bunker. Hmm, pipe bombs and machine gun bunker analogies, hope no one gets the wrong impression? A short aluminum arm is all that's needed on the azimuth encoder. I used a ¼" nylon encoder positioning bolt threaded into the baseboard. It allows a zero snug fit in the encoder arm slot that can slip with any longitudinal movement. The altitude encoder is very straight foreword. Simply mount on a long aluminum arm and route the wire around and in the open end of the rocker box. I wired RJ11 phone connectors to both encoder wires for easy attachment to the control box.



Stay tuned for part 4, the final edition.

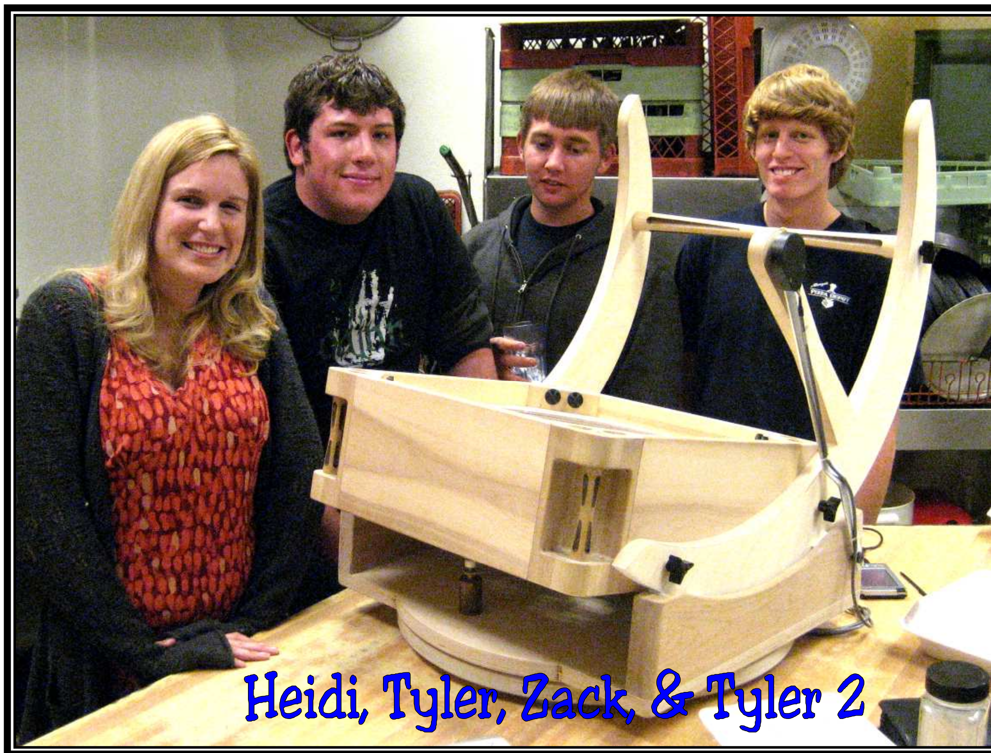
No cheering please!

Engineering Lightweight Dobsonian Telescopes

Part 4 of 4
by Lonnie Robinson

ATM Connection

ALTITUDE BEARING DESIGN & INSTALLATION

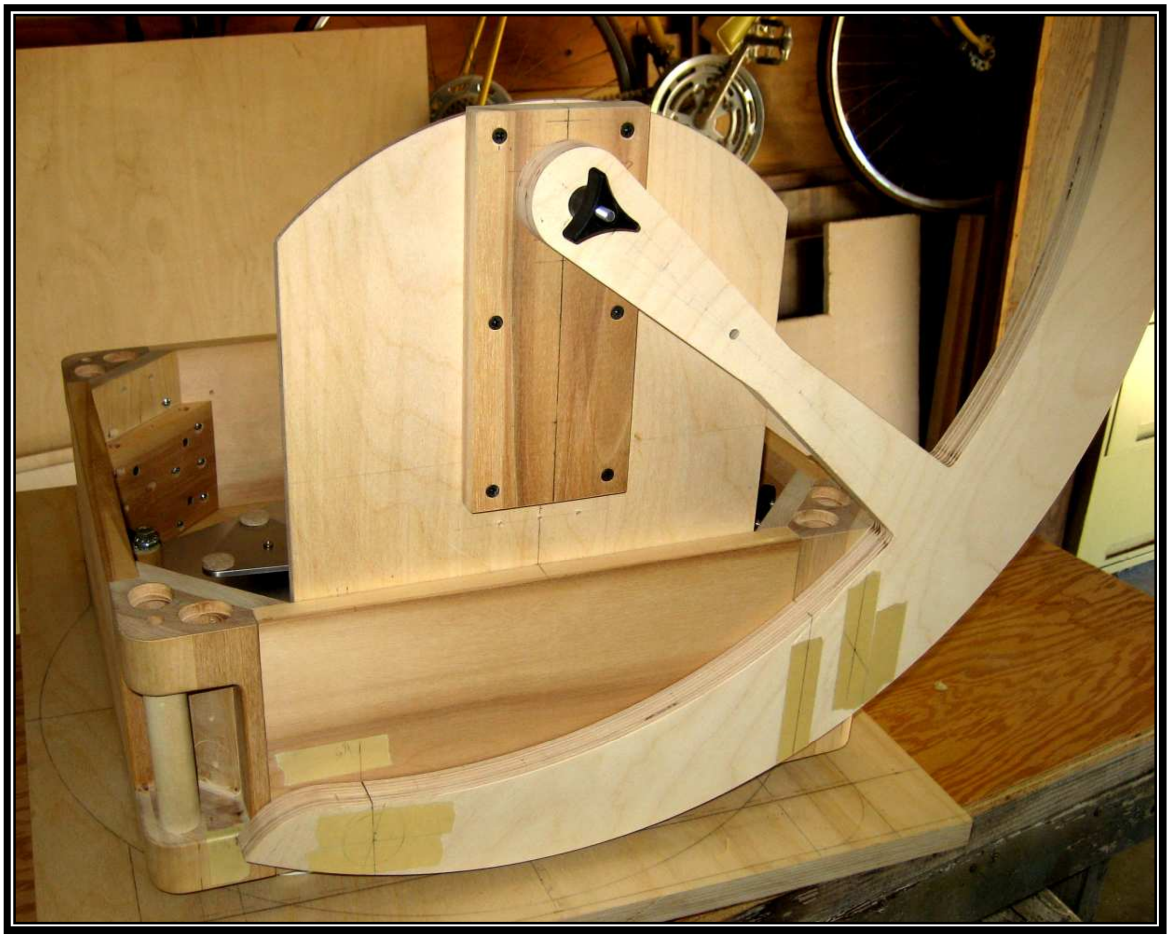


Heidi, Tyler, Zack, & Tyler 2

The altitude bearing design is left up to your imagination. I was concerned my design would be too fragile, giving up strength for style. I measured the distance across the altitude bearing tips with the scope pointing at the zenith and then at the horizon. The 1” thick bearings flexed 1/32”. However, it hasn’t presented a problem with the encoders. The solution would be to pre-stress them 1/32” inward and then cut the outside radius just like they did at Mt. Palomar. When the telescope weight flexes the bearings, they would flex back to a perfect radius. There is always the possibility of reinforcing the bearing sides with a layer of aluminum or Formica. You could design the bearings with support structures built in if you like. I really liked the low, slim, and graceful look of my design, so I’m willing to put up with some very minor flexing.

Now that the rocker box and base board are finished, you can establish the ***altitude bearing length***. Cut the outside radius first, and clamp the unfinished altitude bearings to the mirror box base. Use some temporary plastic milk bottle pieces, with double backed tape, for bearings. With the scope pointed at the zenith, the front end of the altitude bearing should just stop over the bearing in the cradle. Swinging the optical tube to the floor will give the top end measurement. My bearing length turned out much less than a half circle. Now you can finish cutting out the altitude bearings.

One of my bearings has an arm incorporated on it for the altitude encoder. The encoder hole is exactly located at the bearings center radius, and a hole is drilled and tapped in the wood to secure the encoder shaft with a nylon bolt. This one center hole is necessary to establish the exact location to drill and mount the bearings to the mirror box. A simple jig temporarily mounted inside the mirror box establishes the exact center pivot location. Use the bearing, with the encoder arm, to drill the holes in the mirror box, and then move it and the jig to the other side of the mirror box to drill those mounting holes. Use the holes in the encoder bearing as a template to drill the other altitude bearing mounting holes. Make two wooden support blocks, to temporally insert between the rocker base and rear of the mirror box. The front of the box will sit on the altitude stop. By supporting the mirror box slightly high with these blocks, it makes bolt alignment simple when installing and removing the altitude bearings. Then remove the blocks after tightening the bolts. It also helped to grind a point on the bolts which guides them into the threaded inserts. Good stuff!



A good choice for a large Dobs ***bearing surfaces*** is fiberglass reinforced panel (FRP). It has worked out well instead of Ebony Star Formica against the Teflon, and is much less expensive. FRP has a rougher surface than Ebony Star, and requires less telescope weight per square inch on the Teflon. The roughness isn't a factor in big scopes because the larger diameter bearings produce faster bearing surface speeds and carry more weight, evening out the irregular surface. I purchased my virgin Teflon in a .187 x 12" x 12" piece for less than $30 from Interstate Plastics. I have plenty left over for a couple more scopes. The altitude and azimuth bearing resistance is set by the Teflon bearing surface area (weight per square inch) and the angular separation distance. The Dob book recommends 65 to 75 degrees separation for the altitude bearings, further apart makes for more resistance. My altitude bearing separation ended up a little closer resulting in slightly reduced drag. Since the altitude bearings are bigger around than the azimuth ground board, the closer spacing helped make the resistance more equal. There should be no loss of stability, since the large bearing footprint is so wide to begin with. An additional adjustable center altitude bearing could help in reducing the friction? A very important note on laminating Formica or FRP; long experience making restaurant counter tops has revealed that a sealer coat of oil based urethane on the wood, before applying any glue, will make the bond a ton stronger. It seems bare unsealed wood absorbs the glue, weakens the bond, and causes early separation. Do not use water based contact cement, and make double sure there isn't an open flame anywhere near your work or even in the same building. This stuff is really flammable!!

WOOD FINISHING

Appling stain seems like a simple task, but lots of ***things can and did go wrong***. My first challenge was the decorative groves in the hourglass shaped truss pieces. I planned on a coat of varnish before cutting the groves so the stain would only color the grove. It was almost successful. Almost, because the stain decided to siphon into the lengthwise wood pores under the varnish, and ruined the piece. I was using an oil based stain, and after some experimenting found that a water based stain wouldn't penetrate or bleed nearly as much producing excellent results.

Minwax Provincial is my favorite oil based stain, and getting it to evenly cover different grain directions was very challenging. ***End grain*** would stain almost black while horizontal grain was the correct color. Pre-stain didn't seem to help. By mixing stain 1 to 1 with oil based polyurethane, I was able to control the absorption of the end grains for a more normal color saturation. After first staining and sealing the end grains with my mixture, I used regular strength stain everywhere else. This mixture might have prevented the bleeding in the decorative groves of the cage struts? I decided to leave the cage ring edges a natural wood color. That required staining everything,

applying a coat of varnish for a sealer, and then applying the natural wood veneer edges last. After the edges were applied with a hot iron, the parts were ready for the final finish coats. Be sure to stain before gluing any parts together, because any accidental glue overflow will resist the stain absorption and cause uneven coloration.

There are many different ***varnish choices***. Indoor, outdoor, water based, oil based, urethane, spar, lacquer, etc. I have been a big fan of oil based polyurethane for many years. It's very long lasting and durable, but it has one serious problem that of yellowing over time. Yellowing looks OK over medium to dark stains, but on natural light woods it looks terrible. With this in mind, I searched for a new finish. Exterior varnishes dry much softer to allow for thermo expansion, making them, in my opinion, too soft for telescope use. Lacquer was a good choice, but I found a new water based satin polyurethane, by Minwax, that looked very interesting. Its promise was that it would dry very quickly, crystal clear, and would never yellow. The downside is that it isn't as durable as its oil based cousin, but it dries harder than exterior varnishes. Applying it with a spray gun at about 15lbs pressure was super easy, very low overspray, dried quickly with little tendency to run, and very convenient water clean up. I was sold, and decided that a slightly less tough finish was worth all these advantages. It sprayed on hazy and milky looking at first, then it dried crystal clear and super smooth in about ten minutes! There are some unique problems with the water based clear finish. The water in the finish lifts the wood grain and must be lightly sanded for a mandatory second coat. Oil based urethane brought out the natural wood grains of unstained wood, the water based wouldn't. I decided to ***use oil based urethane like a rub on oil finish***, wiping it on with a rag and polishing it off before it could dry. It left the enhanced grain and hopefully not enough varnish to yellow. After allowing ample drying time, I applied the final coats of water based satin urethane. Another problem surfaced when I bolted the altitude bearings on a day after applying the finish. They stuck to the mirror box after leaving them assembled for a very short time. Lesson learned, if I had allowed more drying time it wouldn't have happened. Other finishes would have probably done the same thing? Several years later Minwax water based interior satin urethane has lived up to its promise of a non yellowing, crystal clear, and a relatively tough finish. It's truly beautiful and quite durable.

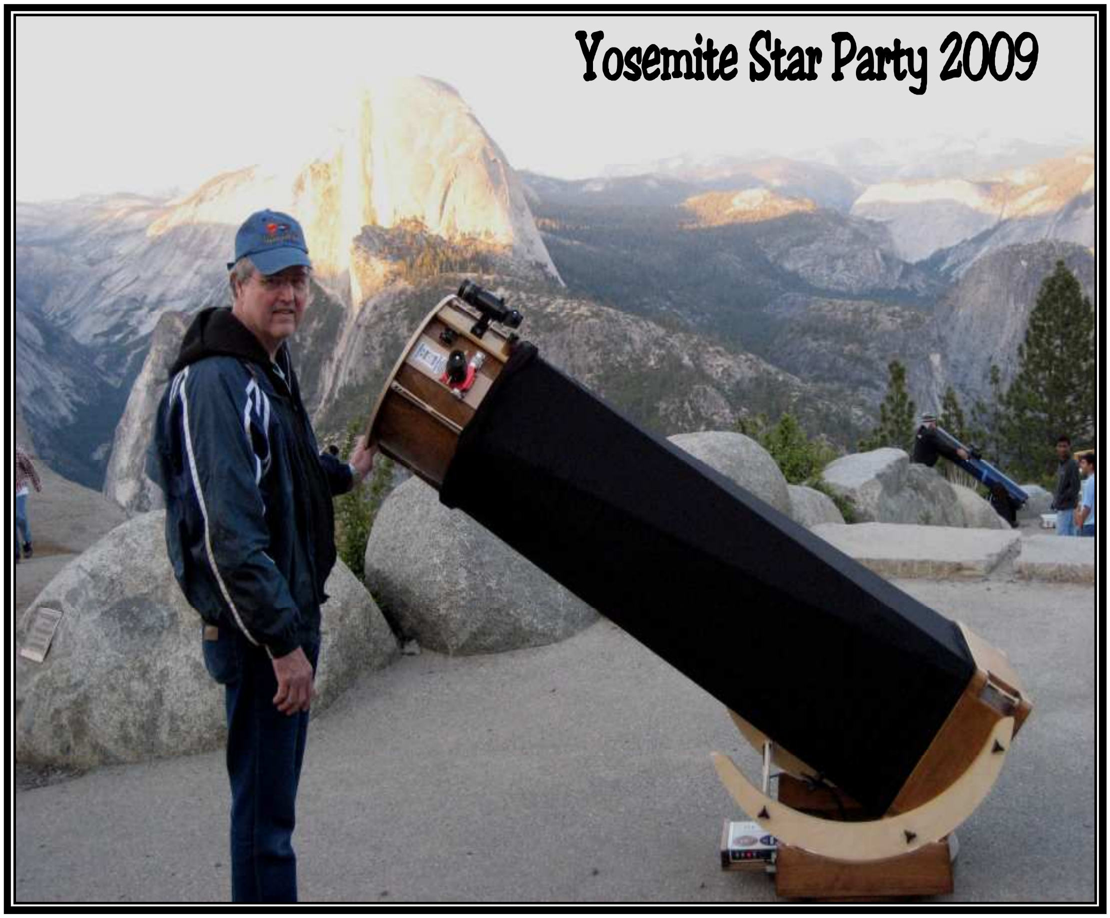
FINAL ASSEMBLY, COLLIMATION, & STAR TESTING

It seemed like final assembly would never arrive. It's really satisfying to put all the parts together for the last time. All the different colored parts needed to be finished separately. It's best not to spray the whole scope at once, because it would be difficult to take apart for future upgrades. Adding the logos and various stickers were great finishing touches.

A rear view ***laser collimator*** is almost a necessity for a large Newtonian. The return light beam can be watched, on the angled open eyepiece target, from the back of the mirror box while making final adjustments to the main mirror. There are several companies that make quality side target collimators. Now is the time to verify the accuracy of your laser collimator. Simply rotate it in the focuser, firmly held down, and observe the laser point on the center spot of your primary mirror. Any laser wobble indicates it needs alignment. I installed my Orion collimator in an old 2”eyepiece adapter after drilling six set screw adjustment holes in the parameter. The set screws allowed very precise laser alignment. There should also be adjustment screws in the collimator itself. The 2” adapter, with a top shoulder ring, gave it badly needed positive support in the 2” focuser.

Also check out a new collimator by Hotech. Turning the central ring compresses and expands the rubber rings to fit tightly in the focuser, eliminating all movement and making setup very stable and repeatable. They manufacture their own lasers, which can be left on for extended periods without damage. An extra large photo cell battery is used for long lasting power, and the on off switch is the rotating top cap which prevents accidental startups. The 2” model separates for use in 1.25” focusers. It has become my hands down favorite.

Collimation starts at the focuser, so let's get it aligned properly during installation. Remove the secondary mirror temporarily. Using a yardstick and some masking tape, mark a point on the upper cage ring exactly opposite from the focuser. Then come down the inside of the cage using a square, and put a permanent white mark on the inner shroud the exact same distance down as the center line of the focuser. Insert a laser collimator, target your mark on the opposite baffle, and adjust the focuser tilt (cant)to align. This aligns the focuser exactly centered on and perpendicular to the optical axis. Next use a ½” wooden dowel rod inserted in the spiders center hole with a couple wraps of masking tape to prevent it from falling through. Draw an X dead center on the top end to facilitate centering the secondary mirror side to side and measuring the offset away form the focuser. The laser should hit the dowel on center when finished. There are two dimensions for a ***full offset,*** the first is towards the main mirror and the second is an equal amount away from the focuser. A the third measurement is from the secondary mirrors center line to the offset alignment mark on the mirror surface. Refer to the DOB book for the math and a template to carefully mark the secondary mirror offset with a fine point Sharpie. Then apply a tiny speck of permanent black paint. Install and center the secondary mirror by adjusting its height and rotation until the laser hits the black mark. Next, use the laser to rotate the secondary mirror perpendicular to the focuser. Adjust the secondary collimation screws to position the laser beam on the main mirror an inch or so out from it's center mark, towards the focuser side. Then loosen the mounting bolt and rotate the secondary mirror left and right while observing the laser pattern on the main mirror. Align the secondary reflected laser on the focusers optical centerline. Tighten the secondary mounting bolt and realign to the main mirror with the secondary collimation screws. Confirm the laser is still on the secondary offset mark. Then adjust the main mirror collimation bolts, aiming the laser back at the secondary offset mark and on to the laser target in the focuser. Success! A ***Cheshire eyepiece*** will give a very accurate confirmation of your laser setup, but the secondary image outline will be slightly off center, towards the main mirror, when you incorporate a full offset. An important note; aligning the laser to the secondary offset dot as described, "will not" move the optical tubes center axis and upset encoder alignment! You have moved the secondary mirror by the offset amount but not the optical center axis as marked by the mathematically determined spot on the secondary. The final last word on collimation is the star test. Perhaps a small tweak is all that is needed. If there is an error after star testing, you can incorporate it each time you use the laser. Once the laser collimation is verified by the star test, repeating accurate collimation, especially in the dark, is a simple fast routine involving only slight primary adjustments with an occasional tweak of the secondary.



Thank you for sharing my DOB telescope building adventure, its issues, and celebrated results. There were mixed emotions upon completion, elation that my telescope was finished and a certain a sadness because a very enjoyable project had ended. I reminded myself that it was just the beginning, because continuing refinements are the always in the works. I'm looking foreword to installing the Servo Cat, and engineering a compact tertiary system. Upon finishing this article, it is my sincere wish that you will come away inspired to build your own large Dobsonian Telescope.

All the best, *Lonnie Robinson*

Suppliers:

New Port Glassworks- 16” f5 pre generated Pyrex mirror blank.

Proto Star- Spider, secondary mirror.

Moonlite Telescopes- Focuser, black truss poles, truss ball connectors.

Scope Stuff- Dovetail brackets, green laser pointer, and hardware.

Orion Telescopes- 9X50 finder, red dot finder, laser pointer bracket, dovetail brackets, and deluxe laser collimator.

Interstate Plastics- Virgin Teflon.

McMaster Carr- knobs, nuts, bolts, threaded inserts, rails and weights.

Rockler Woodworkers Supply- 1-9/16” wide real wood edge trim.

Hughes Hardwoods, Sacramento, CA. ½”Solid core birch plywood, 1/8” aircraft birch ply.

C&H Metals, Sacramento, CA. Scrap aluminum.

Blue Collar Supply, Sacramento, CA. Aluminum, truss poles?

US Digital- S6 encoders, cables, and connectors.

JMI- B-Box.

Software Bisque- The Sky for Pocket PC.

Servo Cat- Servo motor gearboxes, drive controllers.

Argo Navis- Required computer interface for the Servo Cat go-to function

Index