Introduction

It has been nearly twenty years since Wisconsin dentist Dave Kriege gave us the Obsession telescope model, followed by his book with Richard Berry. At the time the Obsession was a revolutionary design advance. His design changed the Dobsonian design emphasis from low cost to high performance. The key feature was replacing heavy sonotube construction with a variant Serrurier truss design and minimizing the size of wood panels in the mount. His design was not the first to move in this direction, but was certainly the most influential. A 24” scope went from something that was transported on a flatbed truck to something that could fit in a small car. The Obsession model has been wildly popular and copied by virtually all builders, amateur and commercial.

Telescope makers have taken the ball from there in refining and extending the Obsession design to the UltraLight movement. Perhaps it's time to apply some critical thinking to the end result. I say that the design while popular, is seriously flawed. Allow me to explain how I came to this result.

Two years ago I started construction on my 12.5" f/6 Dob using the Obsession model. One of the central tenets of the model is a mirror box as low to the ground as possible for enhanced stability. Like everyone else I slavishly followed the model and think I may have achieved Obsession perfection: a balance point for my new scope only 14-3/4" high, a distance exactly equal to the radius of the altitude bearings. The scope moved wonderfully.

But there was a dark side. The result was a mirror box that weighed 46.5 pounds to balance properly. Granted if I had chosen the common f/5 focal ratio things would have been better - but not by much. The mirror box was at best inconvenient to carry over any appreciable distance. One can readily see the risk of carrying such a heavy component over uneven ground in the dark while fatigued. It’s probably the single biggest risk we Dob owners take with our precious optics.

I’ll bet your first reaction is “he made the upper end too heavy”. But look at that photo carefully - the cage struts, truss tubes, and light shield were carbon fiber, with the rest of the construction being 1/2” baltic birch. While the actual weight ended up two pounds heavier than the planned weight, it was still a relatively light assembly (5.2 pounds to be exact). What went wrong? I was so myopically focused on the Obsession model that I lost sight of some very fundamental truths about weights, arms, and moments.

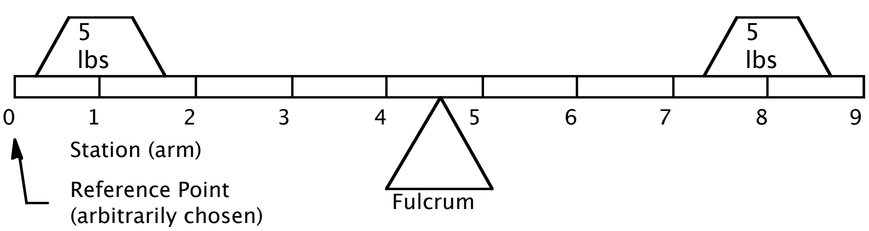
Weight & Balance 101

The balance point of a telescope (or center of gravity, hereafter cg) can be calculated with good accuracy. All that is required is to measure the weights and arms of each component. The arm (or station) is simply distance from a reference point of measurement. The reference point can be any point the builder wishes to select. For consistency I use the rearmost end of the mirror box (or optical tube for a solid-tubed scope).

The resulting product of weight and arm is called a moment. When the moments of all components are summed and divided by the total weight of the components, the result is the cg of the system.

It is readily apparent that this system is in balance. And since we desire telescopes that are statically stable, we make the altitude rotation point (fulcrum) as close to the balance point as possible.

Example 1
Balanced System
Center of Rotation (cr) = Center of Gravity (cg)



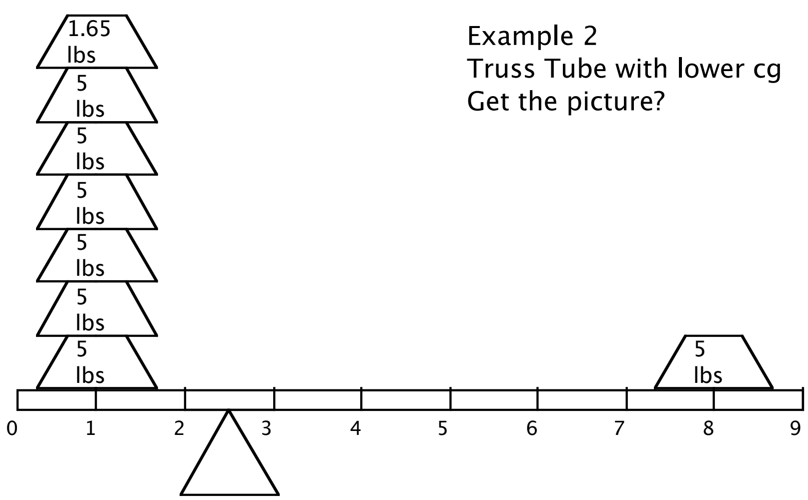
Item	Weight	Arm	Moment
Left weight	5	1	5
Right weight	5	8	40
Beam	10	4.5	45
Totals	20	n/a	90
cg =		4.5	

You may have noticed that Example 1 looks very similar to a solid tube Newtonian. On one end there is a primary mirror and cell. On the other end a focuser, eyepiece, and diagonal assembly. The fulcrum represents the center of our altitude bearing. On most solid tube telescopes the resulting balance is somewhat close to the physical center of the tube, depending upon the weights of installed equipment.

But few of us are interested in solid tube Newtonians these days. We want larger portable scopes. We want trusses. And with the Obsession model, we want a low cg to make for a short rocker box.

Let's say we want to move the cg of our design above from station 4.5 to station 2.5. Instinctively we know that we will need more weight in the lower end. When you do the math, the amount of weight required is rather shocking:

Item	Weight	Arm	Moment
Left weight	**31.65**	1	31.65
Right weight	5	8	40
Beam	10	4.5	45
Totals	46.65	n/a	116.65
cg		2.5	



Example 2
Truss Tube with lower cg
Get the picture?

Am I the only telescope maker to look at this and see something seriously wrong? Perhaps so, because Example 2 has become accepted as "normal". Some people are even putting wheelbarrow handles on medium sized telescopes! While that is a clever engineering solution, there is an even cleverer one.

The Tried Solutions

One may quickly point out that a set of truss tubes (the beam in the examples I have used) don't weigh ten pounds. Actual weights for 1" diameter tubing will run 3 ounces per foot, per tube, plus connector and clamp weight. For larger scopes utilizing eight tubes, ten pounds may not be too far off the mark! And all of that weight is **forward** of the cg and therefore detrimental.

The typical ATM attacks this problem by building a minimalist upper cage, allowing for weight reductions in the mirror box. Hence the birth of the "Ultra-Light" movement. Incidentally, Obsession offers a highly regarded Ultra-light.

But there are practical limits as to how lightweight we can make the upper end of a telescope. Soon the builder is scraping to save not ounces but grams, and making bad trade-offs to do so. And the upper end weight still adds up quickly. Getting back to my 12.5" f/6:

		Planned				Actual		
Item		Weight	Arm	Moment		Weight	Arm	Moment
Upper Cage		3.29	71.25	234.41		5.20	70.00	364.00
Eyepiece (median)		1.40	71.25	99.75		1.40	70.00	98.00
Finder		1.56	66.00	102.96		1.75	62.88	110.04
QuickPoint		0.38	64.00	24.32		0.20	62.38	12.48
Tubes (carbon fiber)		0.55	35.88	19.73		1.40	35.00	49.00
Mirror Box		45.79	2.98	136.31		46.50	3.88	180.42
Totals		52.97		617.48		56.45		813.94
CG			11.66				14.42	

The spacings of our major components are determined by the dimensions of the optics set we choose. Effectively there is just **one** spacing option for the primary mirror, diagonal, focuser, and eyepiece. We can move finders and Telrads around to a small extent (on the upper cage no less), but that's it. Beyond this we need non-functional weight (ballast) to make a telescope balance in the desired location. Almost universally this ballast is needed in the mirror box.

Stepping back to see the Big Picture we can see that the Obsession model naturally forces a builder into the following compromises:

1) Minimalist upper cages that are ridiculously undersized. A small oval of Kydex behind the secondary mirror is not up to the task of controlling stray light and reducing

veiling glare. No self-respecting refractor owner would *ever* accept a refractor with equivalent baffle shielding. As a reflector owner, why should you?

2) Limited options for finders placement and weight. Cramped upper cages lead to poor ergonomics. The only place to mount my Stellar Vue F-50 finder was on top of the upper cage, or slightly underneath. The over-the-top position resulted in a sore back from leaning over the tube. In the underneath position the finder eyepiece poked my girlfriend in the chest when she used the scope. (The humor of that situation faded rather quickly.)
3) Increased balance sensitivity. The resulting long moment arm of the focuser makes the scope more sensitive to changes in eyepiece weight loads. Most of us have both the heavy wide fields and lightweight planetary eyepieces in our cases. As any long-time CloudyNights reader knows, eyepiece balance problems are a recurring theme.
4) Mirror boxes that are *far* heavier than structural requirements. Even with heavy wood construction and welded **steel** tailgates, addition of ballast is commonly required! For most f/5 Obsession designs 4 to 5 pounds of mirror box weight is required for every pound of upper end weight. Weight that has to be carried from storage to car, car to observing site, and back again every session. Not much fun when you are rested, let alone cold and tired at 3:00 AM.

After crunching the numbers it dawned on me that the only real place for dramatic weight savings is in the mirror box, not the upper cage. By accepting a cg only 4" higher I could reduce the weight of my mirror box by around 15 pounds. But with the Obsession model, raising the cg means increasing the length of the mirror box (because we need a place to attach the altitude bearings) while simultaneously reducing its weight. Quite a conundrum.

As telescope makers isn't the real answer to minimize mirror boxes, build comfortable upper cages, and build better rocker boxes and accept a small height increase?

The Answer - The Double Truss Design

It occurred to me that the only way to effectively raise my cg and minimize the mirror box structure was to go with the design employed by large professional scopes - the original Serrurier Truss. While the Serrurier Truss is commonly thought of in connection

with the Obsession design, it's origins are actually with the Hale 200" telescope. The Big Idea was that by suspending each end of the telescope from a center pivot, flexure of the tube sections would be equal under the influence of gravity and collimation would be maintained.

What the Obsession model does is eliminate the center section of that idea. On large scopes this is certainly better than sonotube, but it **guarantees** that our scopes will flex **unequally** as we slew in altitude. The mirror box (and primary mirror) has a direct load path to the ground. In terms of flexure, it isn't going anywhere. The upper cage (and diagonal mirror) is suspended on the end of the truss tubes. Even though the tubes form triangles, bending loads are experienced and the trusses do indeed deflect a small amount.

While the double truss also utilizes triangles, the geometry is substantially different. In doing the research I found the rigidity for a triangle under compression is $R = Y * S * (W^2 / L^3)$ where

R = Rigidity;
Y = Young Modulus;
S = Section;
W = Triangle width or base; and
L = Triangle length or height.

One can immediately see that the key to the triangular truss is the ratio of base to height. Forgetting the material differences between my single and double truss scopes and just comparing the geometry:

	Base	Height	Ratio (higher is better)
Single Truss	14	52	0.0010
Double Truss Upper Section	12.875	26	0.0094
Double Truss Lower Section	12.875	14	0.0604

Next time you see a large structure utilizing triangles in the framework, notice whether the triangles are short or long. To me it makes a lot of sense to copy concepts engineers use rather than concepts they avoid. The short squat triangles afforded by the double truss offer much higher rigidity compared to to the long narrow triangles typical of the Obsession single truss approach. And of course 26” truss tubes are much easier to stow in the car.

How much deflection can be tolerated? The Amateur Astronomy Handbook by J.B. Sidwick puts forth a rule of thumb based on when a stars Airy Disk becomes noticeably effected: 0.000143” time the cube of the focal ratio. For my f/6 scope, the total flexure allowable is .03”. This sounds rather generous, but remember there may be more sources of movement in a scope other than the truss tubes. The situation for the more common f/5 scope becomes much more restrictive: 0.018”. Perhaps that fancy autocollimator may be more useful to you as a chart paperweight. For a more comprehensive look at telescope structures, Sky & Telescope has published several relevant articles. See the June 1976, January 1989, and February 1994 issues for these.

Getting back to weights and balance let’s see the weight and balance of the same 12.5” f/6 optic optic set reincarnated as a double truss design:

		Planned				**Actual**		
Item		Weight	Arm	Moment		Weight	Arm	Moment
Upper Cage		10.00	71.25	712.50		9.95	70.63	702.72
Eyepiece (median weig		1.40	71.25	99.75		1.40	70.38	98.53
Upper Tubes		2.38	48.00	114.14		2.38	48.00	114.24
Upper Connectors		0.40	59.75	23.90		0.40	59.75	23.90
Lower Tubes		1.40	13.18	18.45		1.20	13.88	16.65
Lower Connectors		0.40	6.88	2.75		0.40	6.88	2.75
Mirror Box		21.85	2.98	65.04		21.85	3.75	81.94
Ballast		0.00	0.00	0.00		0.00	0.50	0.00
		37.83		1036.54		37.58		1040.72
CG			27.40				27.69	

The biggest thing that jumps out is that the mirror box structure was reduced *by almost 25 pounds!* The new structure weighs just 22 pounds, and 16 pounds of that is **glass**. The structure itself is very open to promote airflow and mirror cooling. The wood supports between the upper and lower rings serve as handles. On the single truss version the mirror box was bulky and heavy. And the carry position was in front of the body such that I could not see where my next foot step would be. On the double version the mirror box is easily carried single handed and to the side of my body, like a briefcase.

The dramatic reduction in mirror box weight alone is reason enough to say Mission Accomplished. However, the benefits of the design just keep coming.

While cutting the weight of the mirror box in half, I was able to double the weight of the upper cage with no penalty. What I did with my extra weight was to lengthen that section to provide a better light box to kill stray reflections and reduce veiling glare. It is also sturdier to allow for better mounting of the spider assembly. As a personal preference, I was able to replace the Rigel Quickpoint with the heavier Telrad unit, and move it further away from the focuser (and my head). And while I still had adequate (and comfortable) room to mount my StellarVue F-50 on the upper cage, a far better option presented itself, discussed below.

In terms of eyepiece balance sensitivity, the focuser is 42-1/4” from the cg. On the single truss version the focuser was 55-1/4” from the cg. This means that all of my eyepieces exert significantly (23%) less torque on the altitude bearings. Switching from a 31 Nagler to a lightweight eyepiece presents no balance issues. The method I have used in the past to deal with imbalance is enlarged altitude bearings. Compared to the single truss version the altitude bearings could be reduced in size, but I like the larger sizes for other considerations.

Some might argue I have just shifted weight from the mirror box to a new location. This is true. However, the weight of my heaviest component is reduced by more than 50% (remember that when you are searching for your wheelbarrow handles). The new center component can be easily carried with one hand (it weighs 19 pounds). Also keep in mind this is my first iteration of this design, should I rebuild I am confident I could shave a few more pounds off the entire system.

Double Truss Disadvantages

It is said that all designs are a series of trades-offs, which would imply that there are some disadvantages to this approach. Thus far I have identified three minor ones:

1. Doubling your trusses requires twice the number of blocks and connectors. This is primarily an issue of money (or labor if you fabricate your own connectors). For my six tube design, I needed six extra Moonlight connectors at an approximate cost of $150. This is somewhat offset by going from six long tubes to twelve shorter tubes, less tubing is used due to more efficient cuts and less waste.
2. Raising the cg requires a somewhat taller rocker box, which must be made stiffer. Fortunately, this is rather easily accomplished by thickening the upright sections of the rocker box and using hollow-core construction to keep the weight down.
3. Set-up time requires an extra 2-5 minutes. Well, we all need something to do while the optics cool, don’t we?

The Double Truss Under the Stars

While the numbers sound good, how is actual performance? In a word, silk. Everything functions better than expectations, and this is with the initial teflon pad spacing. Normally I spend several sessions fine-tuning the mount motion for the best balance of light forces and stability, but I am tempted just to leave well enough alone!

During my daylight testing, I could look at a nearby mountaintop with a high power lightweight eyepiece, and then switch to a 2.2 pound 31 Nagler and experience no detectable drift after five minutes - and this is with the tube pointing at a relatively low elevation where eyepieces exert the most torque on the altitude bearing. Further usage has shown that I can use a 2” barlow with the 31 Nagler and still not suffer uncommanded movement.

One of the nice benefits of the double truss design is that the center section can serve as a mounting deck for a finderscope. Since this location has only a small influence on bal-

ance, I decided to upgrade from a F-50 to a TMB Signature Series 80 mm Triplet. Fitted with a 2” Amici diagonal and a 27 mm Panoptic, this becomes a 19x80 RACI finder with a 3-1/2 degree field. Being mounted so close to the center of altitude rotation the eyepiece is nearly stationary. The new finder and mounting equipment tip the scales at 11 pounds (try that on an Obsession-style design), so I placed an attachment point under the center box for a counterweight.

I can use this finder from a folding chair, with my chart table at my side for the ultimate in star hopping convenience. But it gets better: By placing the dovetail mounting plate on top of the center section (vs. the side), the field of view clears the top of the upper cage. Therefore two people can observe at once: one at the APO, and one on the Newtonian! And of course, the telescope can be steered from either location.

Where Does the Double Truss Fit for the ATM?

With so many advantages, is every scope layout suitable for double-truss? In a word, no. Some applications may be better suited to solid tubes or single truss. The determining factor is overall focal **length**.

With my 12.5” f/6 scope (75 inches of focal length), I may be pushing the lower limit. It works well, but the tube lengths on the lower section are already very short and the angles very sharp. I could have centralized the center of gravity more by making the upper end heavier. However, this would just be adding extraneous weight. The lower end can’t get too much lighter, the mirror already is 73% of total lower end weight. However, the enterprising ATM may be able to successfully shrink the length of the center box, relaxing the lower truss angles and making the design more desirable for even shorter focal lengths.

One area I think could see great application is a revival for longer focal ratio mirrors. If you lust after the standard of “refractor-like”, you need f/8 or longer. Smooth mirrors, flat fields, imperceptible coma, and loads of contrast without the need to resort to filters. And of course lightweight easy-to-balance four element eyepieces are great performers at the slower f-ratios.

Long focus mirrors are not in vogue for the obvious reason - single trusses don’t do a good job in those applications and solid tubes are ponderous. But the double truss offers three compact assemblies for the slow mirror and the truss tubes can fit in the interior of a car. A small car. And of course, the geometry of squat trusses is more robust.

Sounds like heresy, right? Newtonian users are all abuzz now about ultra-fast f/3 (and faster) mirrors. But one needs to keep perspective on why this is being done - eliminating the need for ladders on large scopes. Improved optical quality is not the driver here.

The last possibility I will offer is the return of the Equatorial Newtonian. The center section of the double truss is a natural attachment point to a large equatorial mount. Robert F. Royce has the plans on his website for a rotating center section. All the builder must do is keep the length of the rotating section the same length as the center section of the Dobsonian version. He would then have capability of using his optics in Dobsonian or Equatorial configuration.

Addendum - The Other Stuff You May Have Noticed

I view each new scope project as a test bed of ideas, some borrowed and some original. Some work well in a particular application, some not so much. I’ll point out a few of the non-standard ideas in this project, and my ideas for Double Truss version 2.0. From the ground up:

Rocker Boxes

If a Dobsonian mount has springiness or damping issues, the problem is often located in the rocker box. This is no place to skimp, and a re-examination of this structure is in order. As in K/B, I like double thickness bases as a starting place. The weight penalty is about 2.6 pounds per square foot of area, and worth every ounce.

A rocker box experiences two forces in use. The first is compression from the weight it supports. Since most common ATM materials are very strong in compression and the supported weight is relatively light, compression is a non-issue. The second force is torsion, or twisting force. This comes into play whenever the scope is moved is azimuth, and can create problems.

The contact point of the OTA and the rocker box is the formica bearings on the teflon pads. When pushed, the tube will actually want to rotate on top of the pads until some part of the tube structure comes into physical contact with the rocker box to accelerate it around the azimuth pivot. This creates a small amount of play or rebound. In extreme cases, the optical tube can actually jump the tracks! I had this happen to me one evening while observing Omega Centauri. The tube was pointing near the horizon, and the entire telescope was sitting on an equatorial platform. The platform was tipping about 15 degrees and the scope literally slid off the mount sideways. That scope used a conventional mirror and sling cell, you can guess the rest.

Since that time I have always constructed raised edges on the my rocker box to serve as both safeties and guides. These are are the mahogany strips you see. They catch on the altitude bearings and accelerate the rocker box in azimuth. The amount of play is quite small because I make the tolerance tight.

Another basic flaw in the rocker box is that it tends to be an open structure. From an engineering perspective, this means that it is ill-suited to resist twisting forces (torsion). The structure will flex by some amount, and then rebound when force is no longer applied. In contrast, a closed structure will be more resistant to torsion. You can demonstrate this with an empty shoebox. First, take the lid off the shoebox and grasp it by each end. Twist the ends in opposite directions. The shoebox deforms easily. Now replace the lid and repeat the twisting motion. Notice the stiffness of the shoebox is dramatically increased with only a minimal weight penalty.

If you now stand over the rocker box and look down at the pivot bolt, you can see that it is some form of open structure: Usually two uprights with a connecting board in the front forming a three-sided box. This is an open structure, and that connecting board is not doing much for you. And the taller you make the rocker uprights, the more susceptible to deformation they will be. (Which is the underlying reason the Obsession model stresses low to the ground construction.)

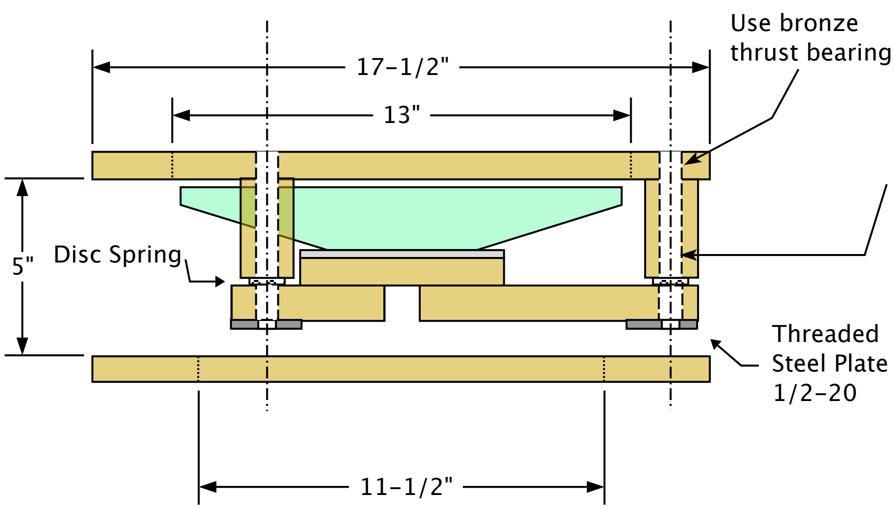
As mentioned earlier, the key is to thicken those rocker uprights to increase the stiffness. This could be done as a solid slab of wood, but does not need to be. Hollow structures offer very nearly the same rigidity as a solid structure of the same shape at substantially reduced weight. (This is why our truss tubes are hollow and not solid aluminum rods.)

To construct hollow uprights, I make two frames of 3/4” baltic birch and glue them together. Then I add a 1/4” skin to each side to enclose the structure. These halves are then glued together to produce a single finished upright. When attached to the bottom board the result is an extremely rigid tall rocker box where no connecting piece is required. Or desired. Each upright is 1-3/4” thick, yet only weighs eight pounds - slightly less than an equivalent height solid sheet of 3/4” baltic birch.

Mirror Box

One of the nuisances of Newtonian telescopes is having to get on your knees for collimation due to the location of the collimation bolts. For ergonomics I wanted top-mounted bolts. A very nice improvement.

The collimation bolts are also increased in size for increased rigidity to 1/2-20. Bronze flange and sleeve bearings are used so that the bolts do not bear directly against the wood. Instead of traditional compression springs, spring washers are used. This is a Bob Royce idea on his Dall-Kirkham line of planetary scopes. He claims they hold collimation better than traditional springs. So far they are holding up well, and are quite strong. The range of travel of an individual spring washer is small, so I needed to stack them.



Of course the biggest departure is the wood structure itself. The conical mirror lends itself to open designs, and this is about as open as I care to make it. Mirror ventilation is not an issue.

For Double Truss 2.0, I would want to reduce the size and weight of the scope, and the mirror box is the key. I made the first version overly wide (17-1/2”). By minimizing this dimension the rocker arms can be brought closer together and the bottom board reduced in length and width.

Center Box

This is the central piece of the structure, so one needs to be circumspect about skimping here so in the original construction I opted for 3/4” wood. The finished part was rather heavy and I suspected overbuilt, so produced another version in 1/2” wood. This has proven satisfactory and is about six pounds lighter than the original.

One caution I would offer to builders - a not-so-apparent function of the center box is to provide support to the altitude bearings, particularly at the ends. Therefore, I have enlarged the dimensions of this part in both length and height. Additionally, I have used 1” thickness altitude bearings.

In a single or double truss scope unsupported ends convert the altitude bearings and whatever they attach to into an open structure that resembles a large tuning fork, subject to low frequency vibrations (the worst kind). There are of course other ways to support the ends and close the structure. For example, I have used cross bars in the past.

Truss Tubes

The single truss version utilized carbon fiber tubes with custom Moonlight connectors. This was done as a weight saving measure. Since the time of construction, carbon fiber prices have approximately doubled. Aside from cost, there was another compelling reason to switch back to standard aluminum: the double truss strategy is not nearly as weight sensitive as a single truss scope, and extreme weight reduction measures are not needed.

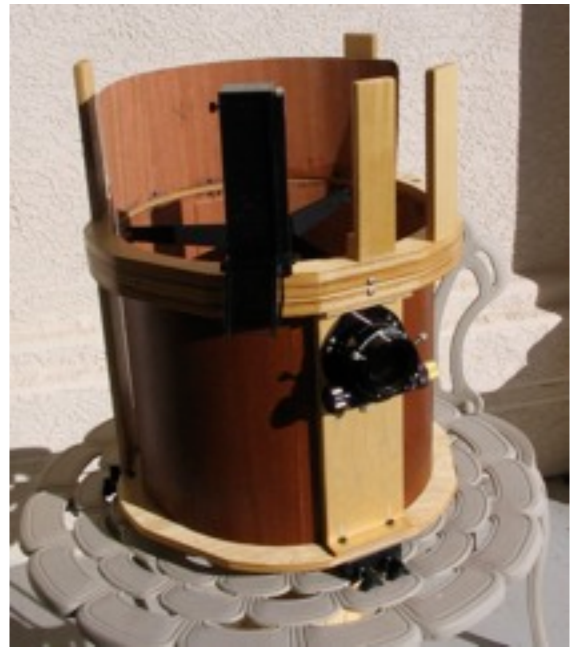
As readers will notice, the tube angles between the primary mirror section and the center box are rather large. In fact, too large for standard Moonlight ball and socket connectors. I would like to give a special mention to Ron Newman at Moonlight. He was very accommodating and worked with me to arrive at a solution. Charges for CNC set-up were

quite reasonable with fast turnaround times. Several iterations were required, but we arrived at combination of bevelled tube inserts combined with removing the inside corners of each socket block. I would like to point out that the final corner removal on the truss blocks was my router handiwork, hence the rough appearance. Ron Newman's modifications are very professional in appearance. The Moonlight connectors work extremely well - easy and fast to set-up with repeatable alignment at each assembly. Only minimal collimation adjustments are required.

Upper Cage

What I like best about this structure is that it is "full length" for shrouding. Decades ago the old rule-of-thumb was to extend the upper end of the scope by a distance equal to the diameter of the primary mirror. This was done for protection both from dew and stray light. With the minimalist design you lose both of these. And for what, to save perhaps a pound of weight? I believe the Old Guys were onto something here. Fortunately, the double-truss design doesn't force one into these bad trade-offs. And, there are more comfortable locations to mount finders.

The most unusual feature of the upper cage is the detachable extension. It occurred to me as a method to, on a temporary basis, use very heavy accessories such as binoviewers. By removing the extension, balance would be easier to maintain. It is held on by a single 3/8" dowel pin and eight neobyium magnets. The prongs on the extension serve two functions, to protect the light shield and serve as finder mounting points. I added a few more than needed since I was not certain as to which position would prove most comfortable for viewing. In hindsight, I would probably not do this again and just build a monolithic upper cage unit to my desired length.



In place of the standard Kydex or other thermoplastic, I utilized 1/16" mahogany plywood from Aircraft Spruce. It is flexible enough to be shaped into a cylinder, and takes a finish well. Ironically, it actually weighs a bit less than Kydex before blackening the inside surface. For this I used ProtoStar flocking paper. Overall weight is now slightly more than equivalent area of Kydex, but, the weight constraints are not very restrictive compared to the Obsession style. More important, flocking paper is significantly less reflective than Kydex.

Another departure from standard practice is the spider mounting ring. Aluminum tubes are meant to be loaded in compression. Mounting a spider to them and tightening the lugs puts a slight bending moment on the cage tubes. Enough to matter, or increase vibrations? I don't know. But since I had a generous weight budget, I decided to make a structure that would allow me to tighten the spider as much as I liked. Inasmuch as the ProtoStar diagonal mount that I am using features two lugs per vane, I had to make the upper ring wide enough to accommodate this.

You may also be wondering why I chose a hexagonal pattern for my upper and lower assemblies. This idea came from the last scope I built. With only the upper rings left to cut, I made the unpleasant discovery that the last piece of plywood was just a little narrower than the design plan for the rings. So I made lemonade from lemons: the resulting flat spot on the rings made installing a focuser board perfectly square to the tube quite easy. On this scope I just made the flat spots symmetrical purely for looks. Since focusers with leveling screws are common now, it was really unnecessary and added to construction time.

I hope that my latest project provides ideas to the ATM community, and the concept is advanced beyond my initial offering. For those of you starting out, reading is a fine way to learn, but building is a much more effective teacher. Good luck and clear skies.