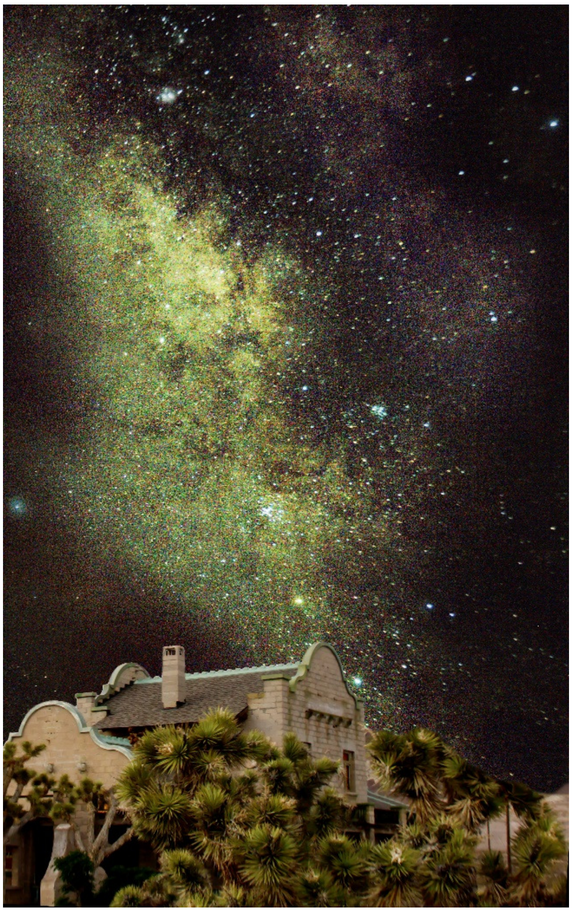
A Homemade Observatory Project

by Stephen Charnock

How to Begin

What does one do over the long summer days when waiting for the long evenings to pass before you get a chance to see a fleeting glance of the stars? Naturally some form of astronomical project is required so why not build an observatory – it can't be that difficult and surely must cost less than buying one. This article follows such a project that I undertook this summer culminating in my observatory seeing first light on the 1st September. It was probably either the joy or the sudden change in stress levels that ultimately led to me having a heart-attack (literally) on the 2nd September.

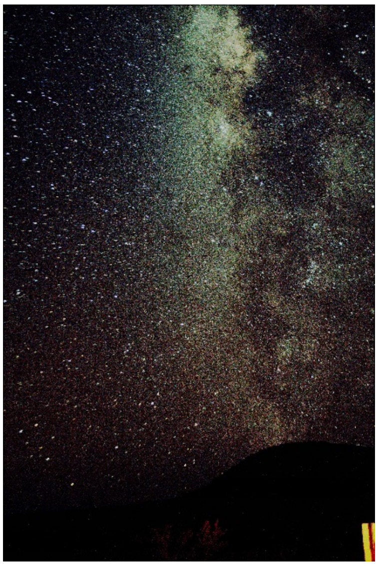
Usually sometime after taking an interest in astronomy you get around to looking at purchasing your own telescope. On asking for advice on what type of telescope to buy, putting to one side for now what your main astronomy interests are, you invariable get the answer "a telescope with as large an objective as you can afford" followed pretty rapidly by "but it needs to be one that you will use – size has a cost besides financial". Both are equally important!



I initially got interested in astronomy when serving in America in Las Vegas where I was stationed for 6 years. I started out buying a small 90mm Orion Apex Maksutov-Cassegrain telescope on an EQ1 unguided mount to see whether my interest would last. Being a small device it was pretty easy to pack up and move around on my travels including regular visits to Death Valley and its plentiful ghost towns.

Ryholite Ghost Town on the edge of Death Valley National Park and a Total Annular Eclipse captured from Cedar Breaks NP

The dark skies gave me the bug to concentrate on astrophotography and over the last two years I was in the States I managed to capture a whole raft of interesting astronomical events including the total annular eclipse of the Sun in May 2012 (which passed just 200 miles NE of Las Vegas) and the Venus Transit in Jun 2012 which I captured from the balcony of a cruise ship while travelling up Glacier Bay in Alaska.



Just before we left the US we visited Hawaii and on a trip to the Observatories on Mauna Kei I managed to capture some shots of the Milky Way using my DLSR Camera (Canon 60D) on relatively short 20sec exposures – it helps when you have truly dark skies.

During the last year in the US I also picked up for $100 a 127mm Newtonian that I used to do some more ambitious deep space object astrophotography, however, I eventually decided I needed something bigger that I could use as a firm foundation for developing my astrophotography hobby. I opted to purchase a 10” (254mm) Orion Astrograph (essentially a Newtonian but with a very fast focal nos F3.9 and modified to overcome the usual problems of limited back focus that can present a problem when attaching cameras and other accessories). I also bought as part of the same package an Atlas EQ-G (EQ6) Go-To mount which cost me a combined sum of $1500 (£900).

But here the second part of the maxim I stated above – “what should I buy” came well and truly home with a vengeance. The combination of telescope and mount were simply too large to move around easily. Getting them out of the patio doors became a big issue even after buying a trolley to try and make it more manageable. However at over 110 lbs the mount, counterweights and telescope were simply too big to use regularly and eventually I resorted to using the other two telescopes mounted on the Atlas mount instead and left the Astrograph in its packing box.

The Initial Idea

On returning to the UK in early 2013 and formally retiring from the RAF in May 2013 I decided I needed to look again at how best to utilise all the astronomy equipment I had collected over the last 3 years. It became apparent pretty quickly that I needed to have some form of permanent setup if I was going to use my 10” Astrograph - so what form should this setup take and where would I site it.

Initially I looked at simply siting a pier in the garden but unless I could attach the telescope to it permanently I felt I was going to have the same problems as before. If I could fix the telescope I would then have a problem with security and so I felt that this simple solution wasn’t really practical. I then investigated a whole range of options available on the open market from modified slide back roof sheds, to half opening clamshell domes and rotating aperture slit domes. So which type to use and what are their pro and cons? This largely draws down to personal preference but each type does have specific advantages and disadvantages.

Firstly the slide back roof shed. These are generally the cheapest type of observatory on the market. Although you can modify your own shed you can pick up customised sheds (7'x7') for around £700. However, the footprint of this type of observatory when the roof is pushed back can almost end up double the closed footprint. This was likely to be a problem with where I wanted to site my observatory (more later) at least with my better half. When open these observatories provide some shelter from the elements but not much protection or shielding from light pollution.

The clamshell style observatory (as typified by SkyShed's POD and sold through Altair Astro in the UK) range in cost between £2300 and £2800 for a 2.4m (8') dome and base depending on what additional storage pods you want to have fitted around the basic structure. These domes generally take up a smaller footprint in operation than the roll-off shed and provide greater protection from the elements and light pollution primarily because only half the dome folds back and the remaining half can be rotated round to provide you with the coverage you want.

Finally, the rotating slit opening dome construction. The most popular design appears to be that from Pulsar who offer 2.2m domes and bases from £3000 or £2000 for the dome only. These domes offer a reduced footprint over the roll off shed, and good protection from light pollution and the elements. However, from an astrophotography perspective for long exposure times you have the physical problem or either automating the dome rotation or being present to do it yourself as the star/planet or deep space object (DSO) moves out of the field of view of the slit. Depending on the altitude of the astronomical object being studied this can be surprisingly quickly.

Off course with all of the above there are a number of other costs to be considered. Unless you want to assembly the shed/dome yourself there is usually an installation fee. You also need to have prepared and constructed a large concrete base on which to position the dome and base and a base for the telescope pier which is ideally isolated from the dome's concrete base. Most of the constructions do not include the installation of electrics or any form of automation although these can be purchased as additional (somewhat costly) add-ons. You may also want to consider access to the internet (either wirelessly, or through Ethernet or Bluetooth) and finally how are you going to protect your investment in terms of security and insurance cover.

What to Choose

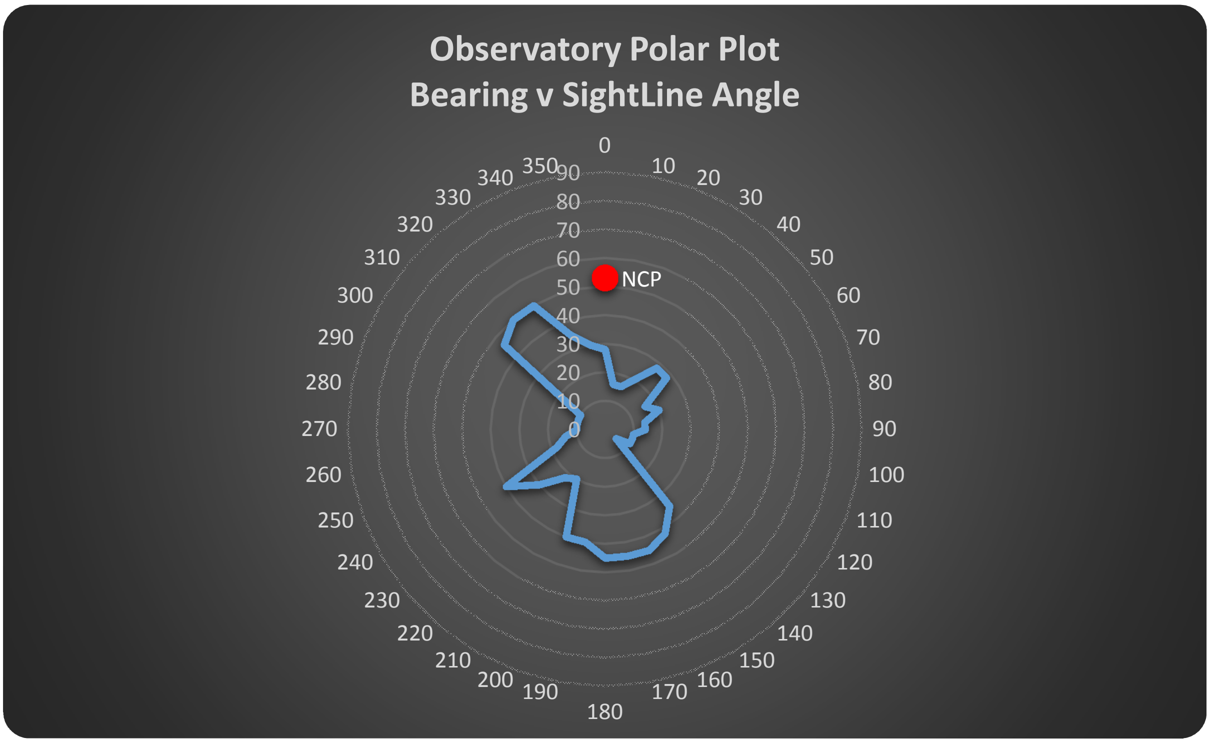
Looking through the options I knew that if cost was no factor then I would want to go for a rotating slit dome. However, having just retired, I really didn't feel that I could afford or probably more importantly justify spending over £3000 for such a dome. Additionally, when I looked at the size of my mount and the Orion Astrograph I felt that Pulsars 2.2m dome was going to be a tight squeeze and that maybe I would have to go for the next size up at 2.7m. This however was going to cost £4500 or in kit form £2800.

At this point I started to think that surely I could make one myself at a considerably cheaper cost. Although the construction of the dome itself might not be straightforward I was confident that plans must exist on the internet and that my wood-working skills would suffice. My confidence was boosted by the fact that my next door neighbour was keen to help and was himself a retired builder and joiner.

Eventually I found some plans on-line for an 8 foot dome constructed on top of a hexagonal base. The whole construction other than the covering of the dome was made out of basic softwood timber and plywood and although the structure on the slit needed to be amended to make it a fully sliding construct rather than a fold down design these plans formed the basis of what we decided to move forward with.

Location Location Location

Few gardens have open views in all directions and most have some restrictions to some extent. Ours is no different and in fact there were very few places where I could place an Observatory which had a reasonable range of views and one where ideally I could also have sight of the North Celestial Pole. Boundaries always appear to be in the wrong position but eventually I found a location which gave me sight of the NCP (albeit above the house) and had reasonable but restricted views of the North through to the South East and then from the South West through North West.



So now with the style and location set the only thing left to do was build it.

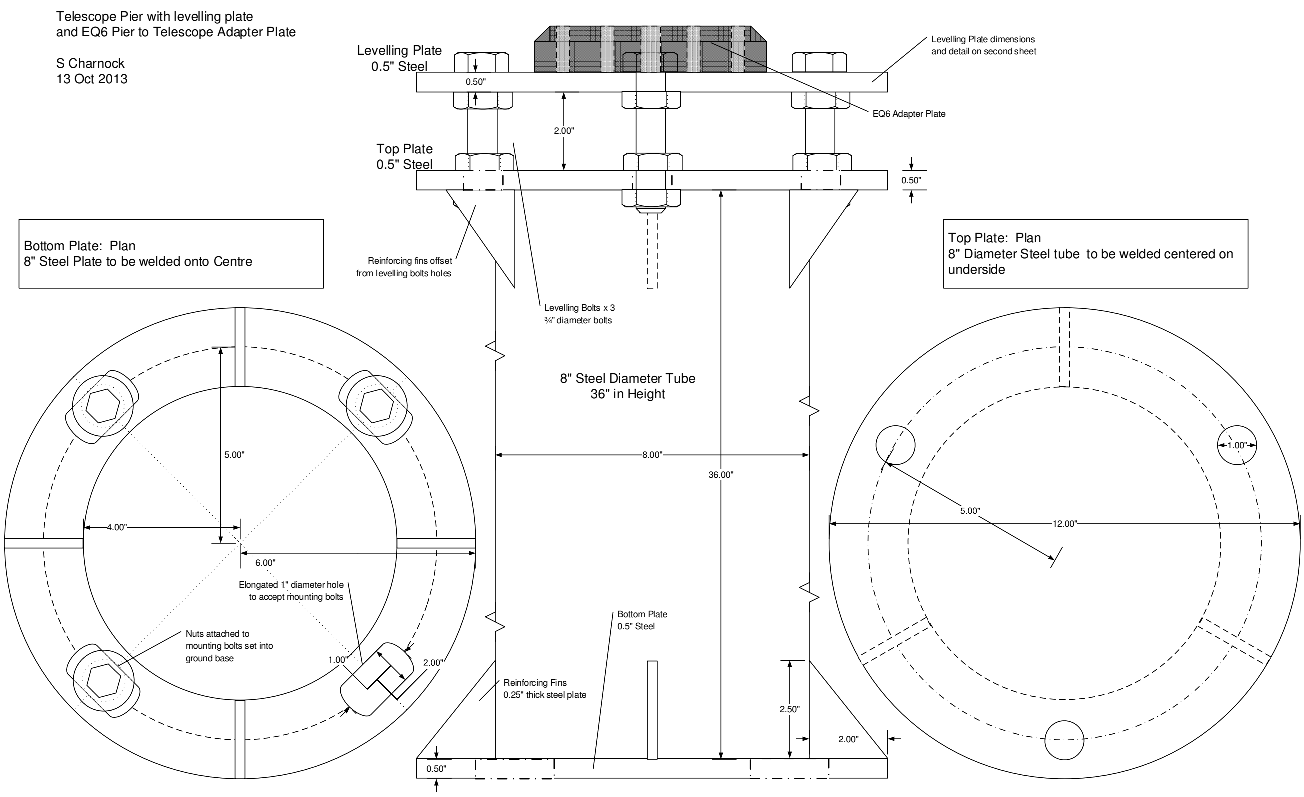
The Build

The build consisted of a number of discrete parts many of which are completely independent on each other. The major elements were:

a. The construction of the Telescope Pier Base
b. The construction of the Dome Concrete Base
c. Design and Manufacture of the Telescope Pier
d. Manufacture of the Upper Dome Structure
e. Manufacture of the Dome Base Structure on Concrete Base
f. Installation of the Telescope Pier on its Base
g. Installation of the Upper Dome Structure atop of Dome base

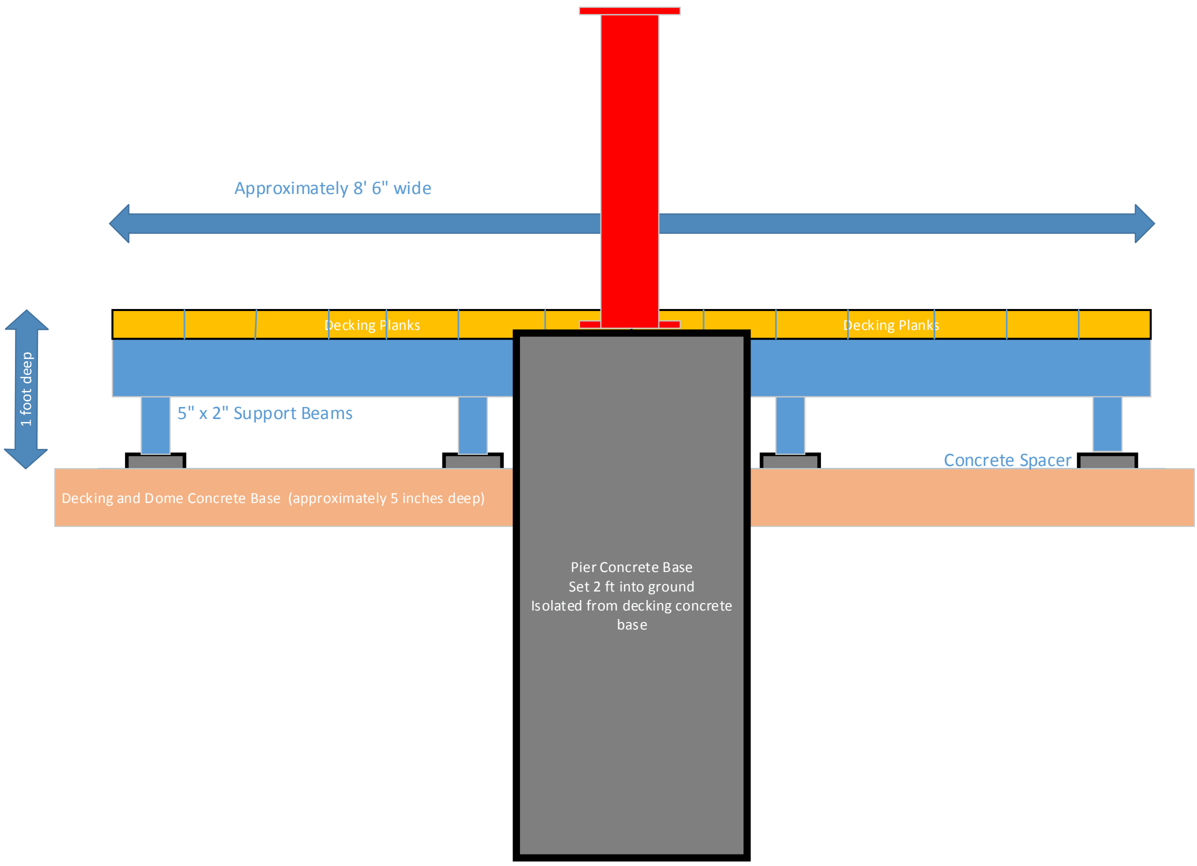
Telescope Pier Design

Although you can buy a telescope pier on-line they tend to be pretty pricey for what they are. For instance Altair Astro offers an 8 inch diameter pier for just under £500. Although it offers some additional functionality over that of a simpler design in most cases this extra functionality is of very limited value. In essence all that is required is a substantial steel pier generally 7 to 8 inches in diameter with flanges at top and bottom and another plate to fit above the top flange to enable the pier to be accurately levelled and also to which your mount is attached through an adapter. My design is shown below. The fillets on the top and bottom flanges are not required for strength but provide some degree of vibration damping. Some people suggest that the pier should be filled with sand to further dampen vibration although to date I have not found this to be a problem. I managed to find a local engineering firm happy to construct the pier for £200.



Telescope Pier Base

As mentioned earlier the Telescope Pier's concrete base ideally needs to be isolated from the concrete being used as a base for the rest of the dome. This is especially important if you intend to conduct astrophotography as movement on the dome concrete base would be transferred to the pier resulting in vibration and consequent camera shake if the pier is not isolated. Many designs on-line for the concrete base of the pier suggest inserting a metal cage into the base with bolts extending beyond the base of the concrete onto which the pier is attached. Personally I do not believe that this is necessary as the range of concrete fixings available today make it relatively simple to attach the pier to the concrete once the concrete has set. The pier design discussed earlier consisted of a 12 inch diameter base section. Having a concrete base extending at least 3 inches from the rim of the pier is adequate to ensure that when the concrete is drilled into it does not crack, however, the larger the better within reason. In my design the pier concrete base was 2 ft square. The concrete needs to extend at least 2ft below ground to ensure that it does not move or heave with frost. My design also extended one foot above ground to take into account that the dome was to sit on some decking whose total height above ground came to approximately one inch above the height of the pier concrete base. The pier was attached to the base by drilling holes into the concrete and fixing in rawlplugs to align with the slots cut in the base of the pier. It is important to make sure that the pier is aligned to within a few degrees azimuth of the NCP when bolting down the pier. Although the pier base has elongated slots these will not compensate if you are seriously off with your alignment.

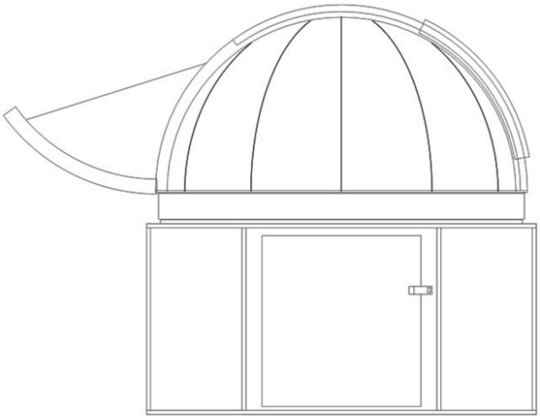


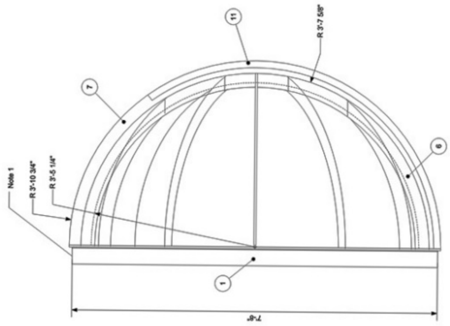
Decking Concrete Base

The concrete base for the dome and/or base needs to be approximately 4 to 5 inches thick and if being used to directly support the dome needs to be as near to level as possible. To ensure that it is isolated from the concrete pier base I put some rubber insulating material around the pier when pouring the dome concrete base. (The green cable in the pictures below happens to be the VIrginMedia internet cable that just happened to run through this area).

Manufacture of the Observatory

The construction of the observatory consisted of two elements – the construction of the dome and the construction of the base. A semi-complete set of plans is available although the construction we undertook made some significant changes on the hoof including replacement of the fold down slit door with a fully sliding up and over door. However the overall construction is shown below.





The first part of the dome construction consisted of building 4 rings of the same diameter of the required dome joined together in pairs. Each ring was made out of ½ inch ply making each combined pair one inch thick. These rings were then combined together with 5 inch spacers to make a strong base ring structure onto which the rib structure could be erected. The original design called for each of the rings to be made out of 60 degrees segments which when overlapped would create a double ring. However, using an 8 x 4 ft sheet of ply it is possible to cut out the rings in just 2 halves rather than as 60 degree segments.

This ring structure sits on top of the base structure and rotates on a bearing framework. We modified the design so that the ring in fact was screwed to a steel ring and it was this steel ring that rotated on the bearings. If I made another dome I would have the steel ring manufactured first and use this as a template to help make the plywood rings and ensure that the ring structure was perfectly flat. The steel ring is shown below and was manufactured in 2 parts for £200 along with the bearing structure it was to rotate on.

After making the ring structure, it is best to cut out and attach the 2 primary hemispherical ribs that form the main slot structure. This again was made from double thickness ½ in ply. This slot structure needs to be aligned accurately as all the ribs that provide the dome its strength are attached to both this structure and the ring.

The ribs are also made from double thickness ply and form the overall dome structure and shape. Although seemingly complicated the shape of each rib is essentially the same and matches the diameter of the ring structure and simply needs to be cut to the lengths specified in the plans. Therefore the templates created to manufacture the base ring ease the manufacture of the ribs.

Possibly the most awkward part of the construction and certainly one where more than one set of hands is useful is fitting the skin to the dome structure. In the plans this is done using a material (effectively waterproof hardboard) which is not available in the UK. Instead we used 1/8 inch ply. By clamping suitably cut down sheets of ply over the top of the ribs, the shape of the ply can be marked out in pencil from inside the dome structure. Adding on half the thickness of each rib onto the shape pencilled out enables the cut out shape to be nailed into the one inch thick ribs. The ring structure at the bottom of the dome was also covered in 1/8 in ply. The bottom edge of these sections extended ¼ inch below the rings so as to provide a drip edge on the dome.


Once the skin was completed we started to modify the door slit structure. We wanted to create a door structure that enabled the door to be slide back so that it opened beyond the directly overhead position. This required the overall slit door structure to be made up of three different parts. The rear section was simply fixed in place. The middle section was the primary sliding section and slide


back over the top of the dome, passed over the fixed section and finished, when pushed fully back, with its top edge level with bottom edge of the dome rim. The third section formed a small removable section at the front of the slot. This was needed as it was not possible to have a one

piece sliding section that extended beyond the directly overhead section and did not knock into the dome base structure. An added bonus of this configuration was that it helped reduce light pollution even further by allowing the opening to be customised. In reality I usually leave the bottom removable section of the slit opening in place as I only need to remove it if I am looking at targets below 30 degrees elevation. The photos shows the front removable and rear fixed sections in place. The edge structure of the moveable middle section can also be seen and demonstrate how the

sections were designed to run on the outer edge of the slot structure. The sections were internally lined with 1/8 inch ply to provide a more professional finish and hide the section support structure. This photo shows the metal right angle stretcher supports which not only were used throughout the design but also provided the sliding edge on which the section would run (these also had metal strips added shown on a later photo).

Although the dome looked pretty nice in its raw plywood finish it wasn’t really suitable to withstand the elements. There are a number of weatherproof remedies but to reduce repeated maintenance we decided that the best solution was to fibreglass the construction. Covering the dome with 80g fibreglass mat and finishing it with a dyed top coat cost just over £120. The top coat provided a much smoother finish. The bottom edge of the dome structure was then levelled off so that it had an 1/8 inch overhang – anymore and it was likely that the dome would catch on the base structure. Metal strips were then fitted over the dome slit rim edges to help reduce the drag on sliding the slit sections along the rim edges.

We finished the dome structure by attaching a 4mm thick steel ring of 4 inch width to the underside of the ring structure of the dome. As mentioned earlier if we were doing this again we would do this as the first stage in constructing the ring. You need to make sure that the steel is attached to the ring structure off-centre as the bearings on which the dome rotates should run through the centre-line of the steel ring.

That essentially finished the construction of the dome and we could turn to constructing the hexagonal base. This was in comparison a relatively simple exercise. Each of the 6 sides was made from 4 x 4 feet ½ inch ply reinforced along each of its edges with 3 x 2 inch timber. The timber on the edges of each of the panels were shaped to ensure a stronger edge. The panel edges can then be screwed together. Although it sounds pretty simple it is essential that the base forms a perfect hexagon and is perfectly level as the dome has to fit neatly and symmetrically over the top of the

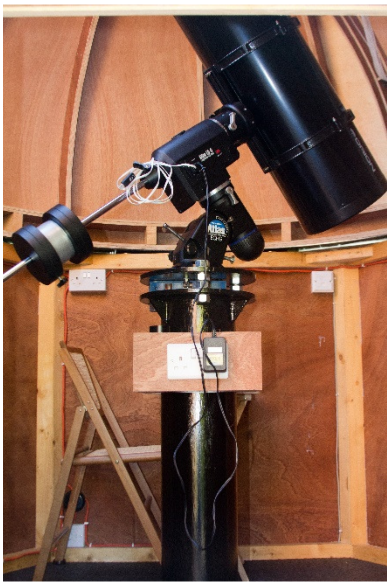
base. Screwing the panels together as well as screwing the panels to the deck floor provides a very secure base.

We found constantly measuring every corner from the centre of the pier helped ensure that everything was symmetrical. You can see the system we used using a spare piece of timber which could be rotated around the pier – a supporting piece of timber of the correct height ensured that there was no droop in the measurement stick. The pictures also show the arrangement of the timber decking and how it passes over the top of the pier's concrete base ensuring no transfer of vibration.

This picture shows the steel ring floating on top of the bearings that were embedded into the top timber frame of each panel. A total of 12 bearings were used (2 for each panel) situated where the dome structure crossed over each panel. The bearings – ball transfer units (BTU) each were capable of supporting 120 kg and cost just £3 each. As the BTUs enable free movement in all X/Y directions we needed to come up with some system to stop the dome when fitted from sliding off the base structure. We settled on roller pins that form part of up and over garage construction. You can see one we trialled out in the photo. The roller pins were place at the centre point of each panel and were positioned vertically so that the nylon wheel would run along the inside of the bottom ring on the dome structure. The pins were fitted after the dome had been placed on the base structure.

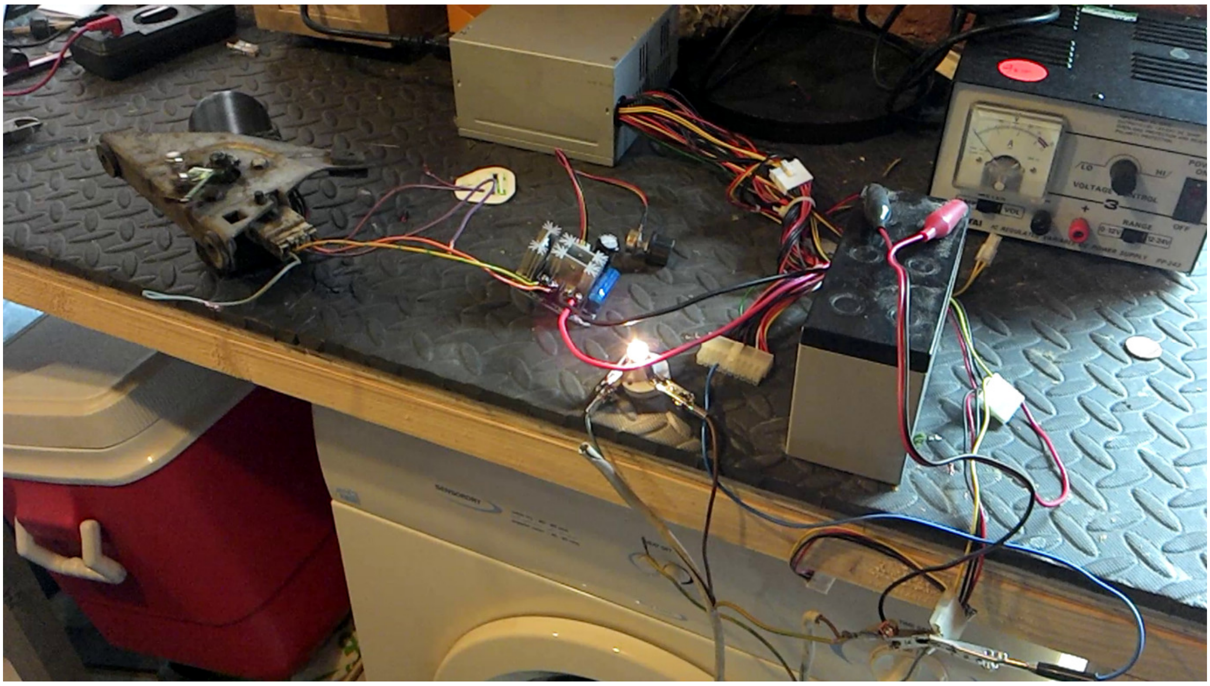
Moving the dome from where it was manufactured (under the car port) and placing the dome on top of the base structure needed a bit of extra help. Jacksons Timber in Newark kindly offered to help move the dome for a small contribution to their Christmas fund. Due to the garden geometry the dome had to be loaded onto a truck driven down the drive through the village and into a field that bordered our garden and then lifted over the boundary hedge and positioned on top of the base.

Over the following few weeks I then kitted out the dome with power (electric sockets and lighting), internet access, security alarm and other accessories including a block and tackle system to help with loading and unloading my astrograph as well as a padded floor. Finally I arranged a Battle of Britain fly past to officially commemorate the observatory's first light.



What's next

As mentioned earlier one of the problems with this design from an astrophotography perspective is the need to constantly rotate the dome. Motorising the dome seems to a logical first step in overcoming this problem and I am currently working on using a second hand windscreen wiper motor coupled to a modified PC ATX power supply that can deliver an impressive 17A at 12V. The ATX power supply also provides numerous outputs at 12V, 5V and 3.5V and can be used to recharge a large 12V battery.



For those interested in attempting something similar I can provide a more comprehensive set of plans along with a lot more photographs showing the build in various stages and a bill of materials listing. In all the basic cost of building the dome including making the observatory and telescope pier concrete base but excluding the pier itself came to about £1500. But first maybe I should actually get on and take some photos. Below is my first check out of the Andromeda Galaxy pretty low on the NE horizon.

Canon30D Ha Modded: Stackx20 30s 1600iso