Newtonian 17.5-inch Optical Tube Assembly

Kevin Phung[1], Jacob Hass[1], Victor Chen[2], Kevin Thompson[1], and Russell Genet[1, 3]

1. California Polytechnic State University, San Luis Obispo, CA
2. University of California Irvine, CA
3. Cuesta College, San Luis Obispo, CA

Abstract The optical tube assembly design is composed of three aluminum boxes connected by steel conduits. After modeling the design, an equation was derived to determine where the center of mass of the telescope was. This determined where the center box would be placed and how long the trusses would be. Collimation was achieved using a laser collimating tool. For testing, the telescope was tilted toward Polaris because of the convenience of the star being fixated on the celestial sphere. Stars were observed and were able to be brought to focus during the field testing of the telescope.

Introduction

Before the invention of the Newtonian reflector in 1668 by Isaac Newton, astronomers worked with refractor telescopes (Wilson 2004, p.9). Refractor telescopes utilize an objective lens located in the front of the aperture in order to direct and focus light into an eyepiece. Unfortunately, refractor telescopes run into the issue of chromatic aberration. Chromatic aberration is the phenomena in which different wavelengths of light diffract at different angles when traversing through a medium, in this case, the telescope's lens. This causes images produced to be blurry when viewed because the different wavelengths are focused at different points.

To contrast, the Newtonian reflector, seen in Figure 1, relies on mirrors to direct incoming light instead of lenses, causing chromatic aberration to cease to be a problem. Parallel light rays enter through the aperture and are reflected off of a primary concave mirror located at the very end of the optical tube assembly. The light is reflected back to a secondary diagonal located a focal length away along the centerline of the primary. The secondary then directs the light to the eyepiece and the focuser to the observer.

Figure 1. A replica of Newton's reflector telescope.

Design

Optical Layout

The optical layout determines the parameters in the optical tube assembly's construction. From the optical layout seen in Figure 2, the distance between the secondary and primary mirror is 62.5" and the distance between the secondary to the eyepiece is 16.125". The secondary mirror has to be offset by 0.25" from the centerline in order to direct all of the light into the eyepiece.

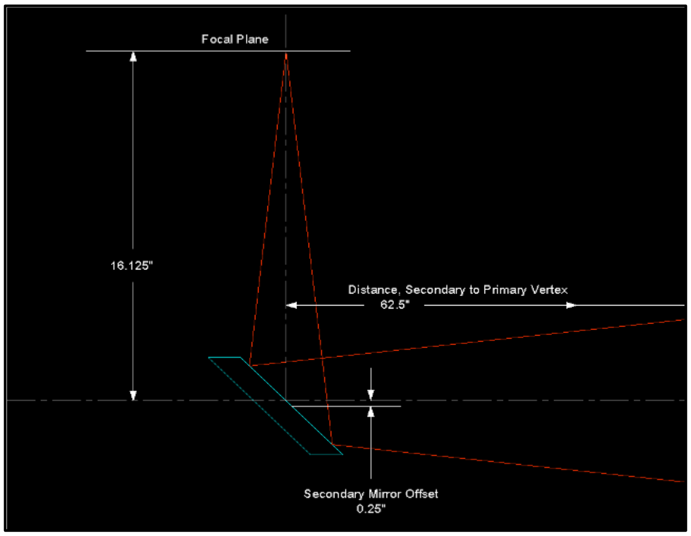

Figure 2. Optical layout of the OTA.

Structure

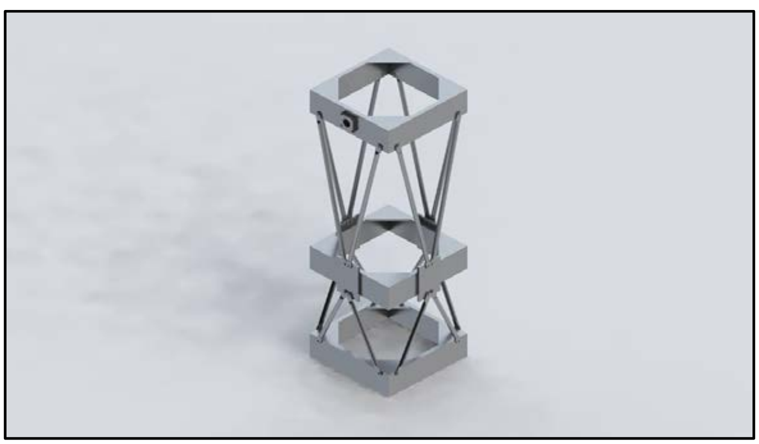

Figure 3. SolidWorks diagram of OTA.

The optical tube assembly, seen in Figure 3, consists primarily of three aluminum boxes of size 22" x 22" x 6". The bottom box contains the 17.5" primary mirror and the mirror cell. The top box contains the secondary mirror that is held in place by a spider manufactured by Astrosystems. Steel conduits connect the middle box to both the top and bottom boxes. Covers on the top and the bottom of the box protect the mirror from the environment. The covers are made of aluminum composite sheets consisting of a polyethylene core in between 0.3mm aluminum outer layers. The bottom cover is 20.5” x 22” and slides right in between two z-bars that act like rails screwed underneath the bottom box. The top cover is 21” x 21” and slides into place with between two z-bars.

Mirror Cell

The mirror cell was custom-made by Aurora Precision. The frame of the cell is composed of welded 1” x 1” square steel tubing that is .09” thick and coated in black. The cell is fixated in the aluminum box by two aluminum cradles, called a whippletree, on one end and a hinge that allows detachment on the other end (Aurora Precision). Two brass knobs located on the bottom of the mirror cell allow tilting for collimation, seen from the side view in Figure 4. The mirror is held down by four clips and is supported by six .14” thick stainless steel triangular supports creating 18 points of floatation seen in the top view of Figure 4.

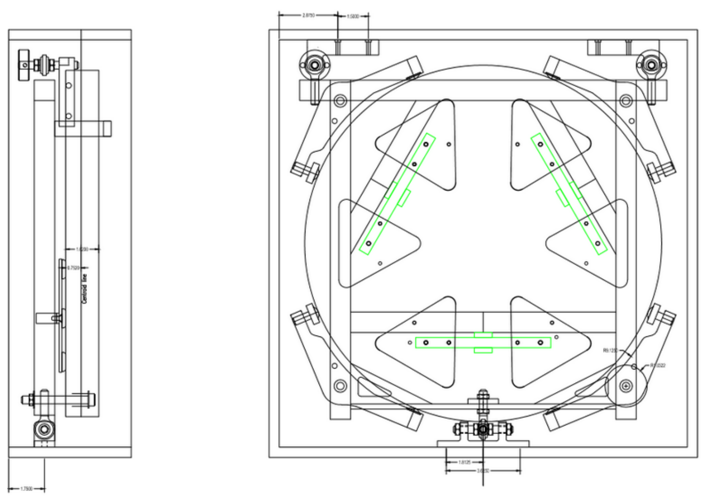

Figure 4. Side view, left, and top view, right, of mirror cell.

Secondary Mirror

The secondary mirror and spider support system were manufactured by AstroSystems. The secondary mirror, whose dimensions are in Table 1, is held in place by the spider. The spider is 2.5” wide at its center body, having a maximum length of 26” with four 0.029” thick vanes (AstroSystems). At the end of each vane protrudes two fasteners that are threaded into aluminum angles, which are bolted down onto the gussets on the top side of the top aluminum box. A side view of the spider can be seen in Figure 5 along with its dimensions shown in Table 1.

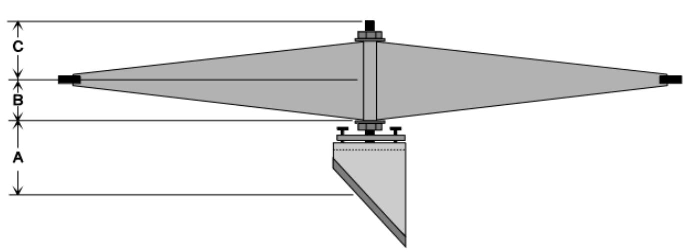

Figure 5. Diagram of the spider and secondary support system.

Mirror Minor Axis	Mirror Major Axis	A	B	C
4.25”	6.01”	5.65”	1.50”	2.75”

Table 1. Dimensions corresponding to parts of Figure 5. Each dimension is represented in inches.

Construction

To determine the overall height of the OTA, the primary mirror was placed 3” from the bottom of the bottom box in order to allow room for collimation by tilting the mirror cell using the brass knobs. The secondary mirror was placed a focal length, approximately 62.5”, away from the primary mirror. This caused the overall height of the OTA to be 70.125”.

Determining the position of the center of mass of the structure determined where the middle box is placed in relation to the top and bottom boxes. Placing the middle box at the center of mass would balance the telescope. The center of mass was found using Equation 1.

$$W_1 X_{in} + W_{T1}\left(\frac{X_{in}}{2}\right) = W_2(D - X_{in}) + W_{T2}\left(\frac{D - X_{in}}{2}\right) \qquad \textit{Eq. 1}$$

D is the distance between the center of the bottom box to the center of the top box in centimeters. W_1 is the weight of the bottom box and its interior components; likewise, W_2 is the weight of the top box with the weight of potential instrumentation accounted for. W_{T1} and W_{T2} are the weights of the steel conduits that are connected to the bottom and top boxes, respectively. X_{in} is the distance between the bottom box and the middle box; therefore, it is effectively the center of mass of the telescope. Using D = 64.125” and the values from Table 2, the value of X_{in} was determined to be 23”. Therefore the middle box was placed 23” from the center of the bottom box.

Variable	Weight (Pounds)
W_1	62.15
W_2	28.85
W_{T1}	8.95
W_{T2}	16.78

Table 2. Weights of different components of the OTA.

Once the positions of the boxes were found, the length of the steel conduits were determined to be 19.05” and 36.30” by using simple trigonometry. The steel conduits were then cut to the required lengths using a bandsaw. Originally circular, the ends of the conduits were flattened with a vice and ground down with a grinder. Holes were drilled on the flattened ends of the conduits using a drill press so the conduits could be bolted to the aluminum boxes.

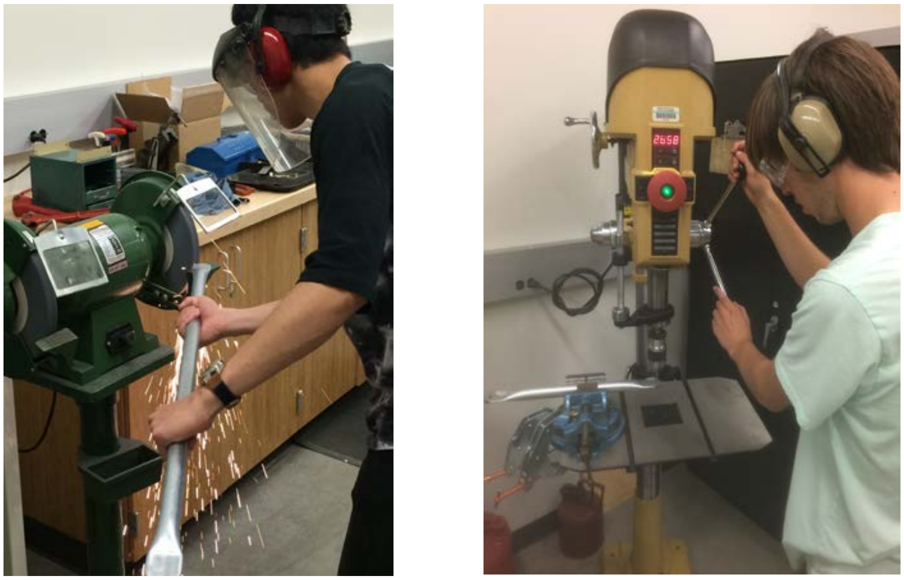

Figure 6. Kevin Phung, left, and Jacob Hass, right, work on grinding and drilling the steel conduits.

Alignment

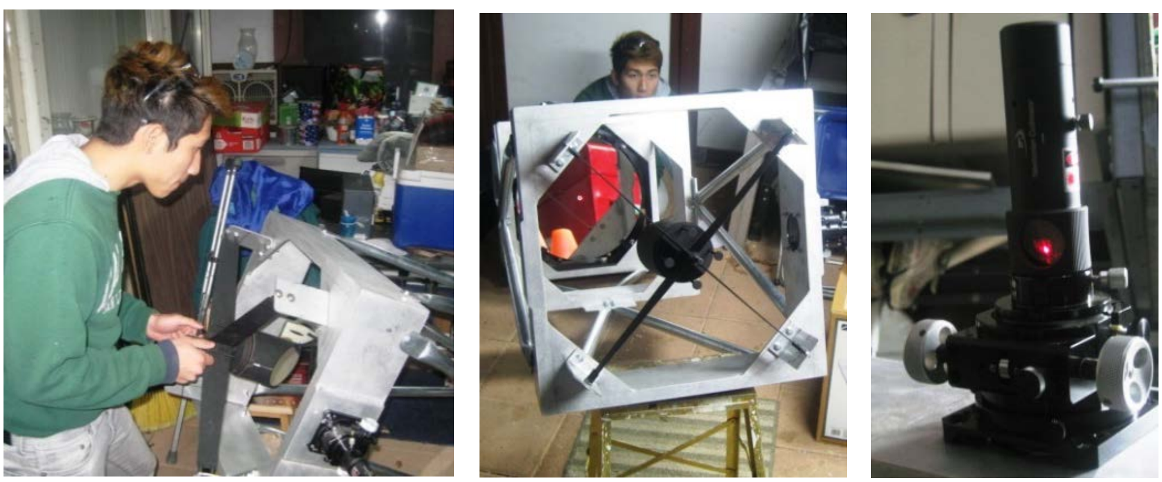

Figure 7. Collimation of primary and secondary mirrors, left and center, using the laser collimating tool, right.

The first step to collimate the telescope was to direct the laser into the center of the primary mirror by adjusting the actuators on the back of the spider. Next, the actuators on the back of the mirror cell were adjusted so that the laser was reflected back up the diagonal and into the eyepiece. A screen with crosshairs located on the collimating tool gave a reading on how centered the laser beam was. The ideal was to center it on the crosshairs for perfect alignment.

Testing

Figure 8. Installment of CCD camera, left, and image of drift captured, right.

To test the optical tube assembly, stars were observed at the zenith and were focused with an eyepiece with a focal length of 25mm. After installing an SBIG ST-402 CCD camera into the focuser, stars drifting across the zenith were captured as seen in Figure 8.

Conclusion

By deriving a solution to the center of mass of the OTA with the constraint of the focal length of the primary mirror, the length of the trusses that connect the pieces of the telescope were determined. The OTA was constructed in the machine shops located at California Polytechnic University and brought back to the Orion Observatory. During the field test, stars drifting past zenith were observed with an eyepiece and captured using a CCD camera. This deemed the construction a success.

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