ERAU 1-Meter Attachment

Abstract - **Embry-Riddle Aeronautical University has a 1-meter telescope on campus that is used for observational astronomy research and is open to the public's use three times a semester. The goal of this project was to create an eye-piece attachment for the ERAU 1-Meter Telescope to allow for easier public use. The previous eye-piece did not allow for the public to view with ease and risked wires becoming tangled or falling out. We sketched a structural model for the whole eye-piece to be supported using research and input from Dr. Gillam and Dr. von Hippel. We designed the optical model using the software CODE V. Our eye-piece is designed to support collimated light and is to be 22 inches (558.8 mm) long plus another part connected with an elbow of 40 inches with a 30-degree slope. We anticipate our designed eye-piece to be used for future research in the astronomy field and aid in educating the public in the following years.**

I. INTRODUCTION

Embry-Riddle Aeronautical University (ERAU) was equipped with a 1-meter telescope by the manufacturing company DFM Engineering, Inc., in February 2014 [3]. The telescope is a Ritchey-Chrétien (RC) Cassegrain telescope. It has an effective focal ratio of F/8 and is composed of a primary and secondary mirror that were made with nearly zero expansion substrates. This means that the coefficient of thermal expansion is near zero and the mirrors will not expand much as temperature increases. The current eye-piece provided prior to the start of the project had a diameter of 2.7 inches (68.58 mm), an eye relief of 55 mm, and a 65 degree field of view (FOV) [10]. When the eye-piece is mounted to the diagonal on the telescope, it only extends out to $5\frac{3}{8}$ inches (136.525 mm). This causes difficulty when trying to view the sky as there are cables hanging in the way and when the telescope moves to point at an object, the eye-piece may become too high for people to reach. Therefore, an extended eyepiece is required for not only the ease of viewing but for safety reasons. As Embry-Riddle's 1-meter telescope is the largest in Florida, it is a major attraction. Having an eyepiece that accommodates everyone would be a great addition to this already popular telescope. We decided that a 3D printed eyepiece would be best for price purposes and for the function of what we want the eyepiece to do and the place it will reside in, a humid and compact area.

II. DESIGN PROCESS

To create the attachment for the 1-meter telescope, we had to figure out what angles everything would have to be placed for it to properly be used. This was conducted from taking physical measurements around the telescope, as well as coding the eyepiece and telescope on CODE V. We found out that we would need to have a L-shaped eyepiece for the convenience of the observers. The eyepiece would extend from a hole already in the telescope that has a diameter of 4 and 7/16 inches. This hole would be used to hold one side of our eyepiece, where the eyepiece would then extend in a horizontal direction from the telescope at a distance of 22 inches. This would not be useful if the eyepiece stopped here, so it would then need to have an elbow piece allowing for it to point to the ground at an angle of 25 degrees in the alpha direction and 30 degrees in the beta direction. The length of this second connected piece would be 40 inches with the diagonal we already have connected at the end holding our current lens. At this elbow bend we will need to have a mirror to capture the light from the telescope and direct it to the eyepiece. The importance of this length and angle of the eyepiece is due to the fact an observer of the telescope would need to be able to access the lens even when the telescope is parked at an angle that is not just pointing to zenith. This means the tip of the lens would originally be very far away from the observer, but with this size of the eyepiece the observer could view their celestial object at almost any angle the telescope is set at. Given the 3D material would be fairly light we would probably be able to have it hold itself up. If this were to not be the

case we would have to go back and figure out what type of beams or stable piece we could use to help hold the weight of the eyepiece.

III. MATERIAL PARAMETERS

When deciding what materials to use to create the connecting piece to the physical telescope itself, we considered a 3D printed piece. This brought up some questions on what types of material for the printed pieces we would use. After doing some research, we gathered it was best to use either PETG or TPU. These two were deemed the best from 3D Insider. The filament PETG would be good to use due to its humidity resistance, since it will be in the observatory which does suffer from high humidity within the dome at times. TPU would be viable as well as it's flexible, impact resistant, and has excellent vibration dampening. We would surprisingly not need an overabundance of the material to create the tube connecting the eyepiece to the telescope. One kilogram of PETG is about 111m worth of material you can work with. The overall amount of material we would need is 0.773 meters for the tube. One kilogram of PETG filament costs $20-25. This means we could order more filament than we needed in case something would mess up and we would have extra to use in its place for a low price. The TPU filament has 117m worth of material in 1kg of material, so our statement stands that we would order a lot more useful material than what we would need. One kilogram of TPU filament costs $65. Given the price difference of material, it would be financially best to use PETG filament to create the tube for our light to use to travel to the lens. The price of the mirror needed for the elbow of the eyepiece varies in price given it has to be custom made. However, looking at mirror and lens sellers such as Edmund Optics, it would be about $200 for the mirror.

IV. CODE V MODEL

The CODE V model of the telescope and eyepiece marks out the direction of each angle the attachment will make. On the CODE V application, it is quite difficult to adjust the "surface type" as there are set options and no place, from what we found, to make your own type. The 1-meter telescope is a Ritchey-Chrétien (RC) Cassegrain telescope as aforementioned. This means the shape of the mirrors are not just spherical or hyperbola or square, etc. After doing research and using "Bob May Astronomy", we found that there is an equation we can use to figure out the exact shape of the mirrors inside of the telescope. This equation solves for "K_p" and "K_s" respectively. K_p is the conic constant of the primary mirror and K_s is the conic constant of the secondary mirror. This is important within the equations: $K_p = \frac{-2*s}{m^3} - 1$ (1)

and $K_s = \frac{-4*m*(m-1)-2*(m+s)}{(m-1)^3} - 1$ (2).

Where s is the distance between the system focal plane and the secondary over the separation between the primary and the secondary. The other variable m is the distance between the system focal plane over the distance between the secondary to the focal point of the primary. After solving for the K_s and K_p we get -13.7137 inches and -1.2551 inches respectively. This implies the primary mirror would have a shape of a hyperbola with 1.25 times the correction and the secondary mirror would have the shape of a hyperbola with 13.71 times the correction. With this, we had assumed spherical mirrors in our CODE V design. This was due to the fact normal Cassegrain telescopes typically have spherical mirrors inside so it was easier to model it this way. For our eyepiece, we would have to have non-spherical mirrors as well, however, we designed them as spherical for our CODE V.

Figure 1: This is a 3D plot of the telescope with our eyepiece attached to it from CODE V.

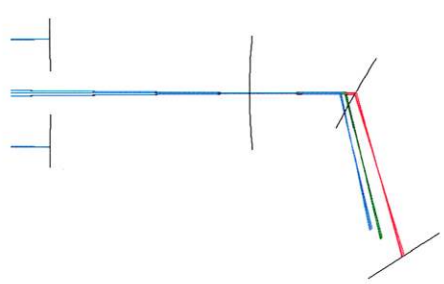

Figure 2: XZ plane of our eyepiece displayed in CODE V.

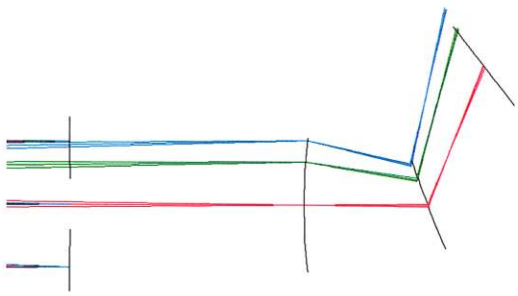

Figure 3: YZ plane of our eyepiece displayed in CODE V.

As displayed in the diagrams there is an extended side to the left and then an L-shaped bend where our eyepiece would reside. This extended side to the left is our telescope. We used the true measurements of the telescope to calculate the "y radius" and "thickness" for CODE V.

V. CONCLUSION

Principally, this project was to create an eye-piece attachment for the ERAU 1-Meter Telescope to allow for easier public use. We designed an eye-piece with the parameters of a total of 62 inches in length and used equation-based mirrors using CODE V. We also found that the most optimal material for the casing would be either PETG or TPU. PETG is best because of its resistance to humidity. TPU would also be a good choice because of its flexibility, impact strength, and resistance to vibration. Either would fit environmental conditions but PETG would be most economical pricing wise. The overall cost for the eye-piece would vary since the mirrors have to be custom made. Estimating, we would predict that the overall cost for the 3D printing materials would be at most $0.43 per meter. The mirror would cost under $200 to account for customization and labor prices [4]. Going forward, we hope for our designed eye-piece to be constructed and inputted for use on the university's telescope.

REFERENCES

[1] 3D printer material cost: An overview [Internet]. All3DP. 2022 [cited 2022Dec11]. Available from: https://all3dp.com/2/3d-printer-material-cost-the-real-cost-of-3d-printing-materials/#:~:text=A%20decent%20quality%20PETG%20filament,%2455%2C%20like%20MatterHackers%20Pro%20PETG

[2] CCT-40: Classical cassegrain 40' telescope [Internet]. CCT-40 | Classical Cassegrain 40' Telescope. [cited 2022Dec11]. Available from: https://www.dfmengineering.com/cct_40.html

[3] DFM News: Erau 40" Telescope installation [Internet]. DFM News | ERAU 40" Telescope Installation. [cited 2022Dec11]. Available from: https://www.dfmengineering.com/news_erau_install.html

[4] Edmund optics [Internet]. Edmund Optics Worldwide. [cited 2022Dec11]. Available from: https://www.edmundoptics.com/search/?criteria=custom+mirrors&Tab=Products

[5] Flynt J. The Pros and cons of every 3D printing filament material [Internet]. 3D Insider. 2020 [cited 2022Dec11]. Available from: https://3dinsider.com/pros-and-cons-3d-printing-filaments/

[6] French R, Huebner JL. The densities of all 3D printing materials [Internet]. Bitfab. 2020 [cited 2022Dec11]. Available from: https://bitfab.io/blog/3d-printing-materials-densities/

[7] How much does a 3D printer filament cost? | makeshaper [Internet]. [cited 2022Dec11]. Available from: https://www.makeshaper.com/3d-printer-filament-price-cost/

[8] Materials guide [Internet]. All-In-One 3D Printing Software. Simplify3D Software; 2019 [cited 2022Dec11]. Available from: https://www.simplify3d.com/support/materials-guide/

[9] Pros & Cons of 3D printing [Internet]. 3 Space. 2021 [cited 2022Dec11]. Available from: https://3space.com/pros-and-cons-of-3d-printing/

[10] Siebert H. [Internet]. Siebert optics - observatoy series. [cited 2022Dec11]. Available from: https://www.siebertoptics.com/SiebertOptics-eyepieces-observatory.html#This%2080mm%204%20eyepiece