

## **1. Introduction**

The project design develops an adjustable refracting telescope with the capabilities of zooming and focusing by altering the spacing between its lenses. The challenge here is to develop a simple but functioning optical system with a relationship between focal length, magnification, and clarity of image, yet keeping the structure mechanically stable. Most introductory telescopes face problems such as vibration, loose sliding mechanisms, and noticeable deflection under extension of the tube.

This design tries to solve those issues by developing a smooth, controlled sliding system for the lens adjustment and a rigid support structure that minimizes motion under load. Something new in this project is the incorporation of a sliding optical tube assembly, a custom lens housing, and material layout designed to reduce vibration during manual focusing. Instead of using fixed-length tubes or low-tolerance plastic components this group is developing a more engineering-oriented prototype that illustrates how mechanical design decisions directly impact optical performance. Our group has come up with a preliminary engineering design for the telescope that includes a rough drawing showing how the sliding mechanism, the lens housing, and the supporting structure fit together. The drawing isn't fully dimensioned yet, but it does map out the layout of the optical tube, the amount of travel needed for focusing and zooming, and the overall shape of the telescope.

Based on the selection of materials previously discussed, our group selected the material for the main tube to be aluminum due to its high stiffness and low weight, brass for the lens cell to keep the optics aligned, and PTFE pads to help the sliding parts glide smoothly. The mount design also uses stainless-steel fasteners, hinge pieces, and small rubber components to help dampen vibration. All of these choices support the goal of creating an adjustable telescope with stability

while its optics move. The work that has been done so far sets a basic foundation for the adjustable mechanism of focusing and gives a clear starting point for the next steps. Moving on from here, the group will finalize dimensions, assemble the sliding tube, and begin testing how well the design holds up mechanically.

We pursued this design because users care deeply about stability, portability, and reliability in field telescopes, especially students, amateur astronomers, and educational programs where durability and simplicity often matter more than raw optical power. A tripod that flexes or a tube that loses focus with temperature changes can render a telescope unusable. Our design aims to create a robust, user-friendly instrument that remains stable on uneven ground, tolerates temperature variation, and can be manufactured using accessible machining methods. A well-designed mount and tripod significantly improve the viewing experience and enable functionality of the optics they support.

This work builds on prior research and engineering practice in optical instrument design, including the established use of brass for precision threading, aluminum alloys for lightweight structural tubes, and PTFE interfaces for low-friction bearing surfaces. Tripod configuration and buckling behavior follow classical structural mechanics and precedented design approaches used in surveyor tripods and precision camera mounts. Thermal behavior considerations reflect known constraints in refracting telescopes, where aluminum optical tubes experience expansion-induced focus drift that must be managed through mechanical design. Considering these established principles in new design choices tailored to our project goals, we produced a functional, manufacturable telescope system.

## **2. Methods/Experimental Design**

### **2.1. Tools and Knowledge Used in Design:**

In developing our telescope and tripod system, we relied on several tools and areas of engineering knowledge to guide our decisions and validate the design. First, we used SolidWorks CAD modeling to create accurate 3D representations of every component and to ensure that all parts fit together correctly. Engineering drawings and dimensioning were used to establish manufacturable geometry and proper tolerances. We applied statics and free-body diagram analysis to understand how forces travel through the tripod legs and hinge assembly, and we used trigonometry to calculate load components based on the leg angle.

Our load calculations were based on material property data, especially the mechanical characteristics of Aluminum 6061-T6. We also used Euler buckling theory to evaluate the stability of the tripod legs under compression and determine an appropriate safety factor. Knowledge of mechanical joints and hinge behavior helped us design the pivoting mechanism and understand the importance of rigid connections. We incorporated principles of friction and contact mechanics when selecting rubber feet and PTFE pads to reduce slipping and improve hinge motion. Finally, we used manufacturing considerations such as threading, tolerances, and assembly constraints to ensure the telescope could be produced and assembled realistically. Together, these tools and concepts allowed us to design a functional, stable, and manufacturable telescope system.

## **2.2. Simplifications Made to Solve the Physical Problems:**

For this project, we made a few practical simplifications to keep the structural analysis clear and manageable. We treated each tripod leg as a perfectly straight and uniform aluminum column, even though real parts always have small imperfections. We also assumed that the weight of the telescope is shared evenly by all three legs during normal use, which let us calculate the forces

more easily. The hinge assembly and the central hub were treated as completely rigid so we did not have to account for small deformations or friction inside the joints. Our analysis focused only on steady, static forces such as the weight of the telescope or a user pressing on it, and we did not include vibrations from wind, footsteps or adjustments because those effects are more complex to model. We ignored the weight of very small components like screws, rubber feet and brass rings since they do not noticeably affect the overall loading. We also assumed that the material properties of the aluminum stay constant everywhere and did not include thermal expansion in the load calculations. In addition, we treated the tripod feet as if they are always in perfect contact with the ground without slipping or sinking. Finally, we considered the optical tube to be completely rigid and used simple trigonometric relationships to estimate the horizontal forces at the hinge. These assumptions let us focus on the main structural behavior while keeping the calculations straightforward.

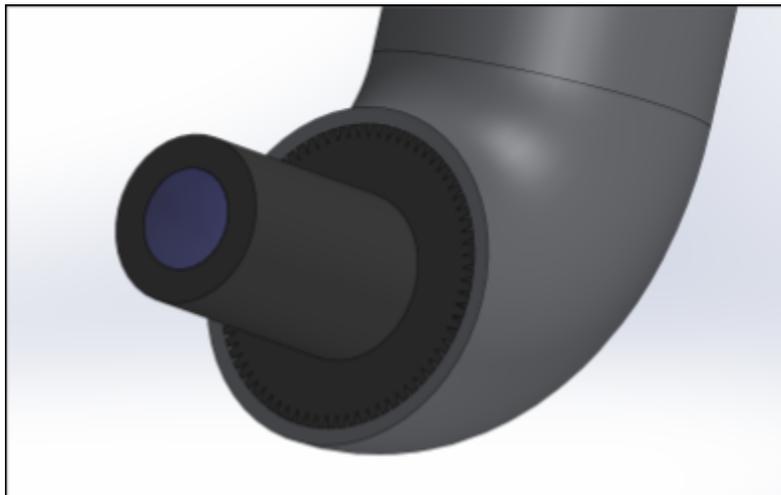
### 2.3. Geometry:



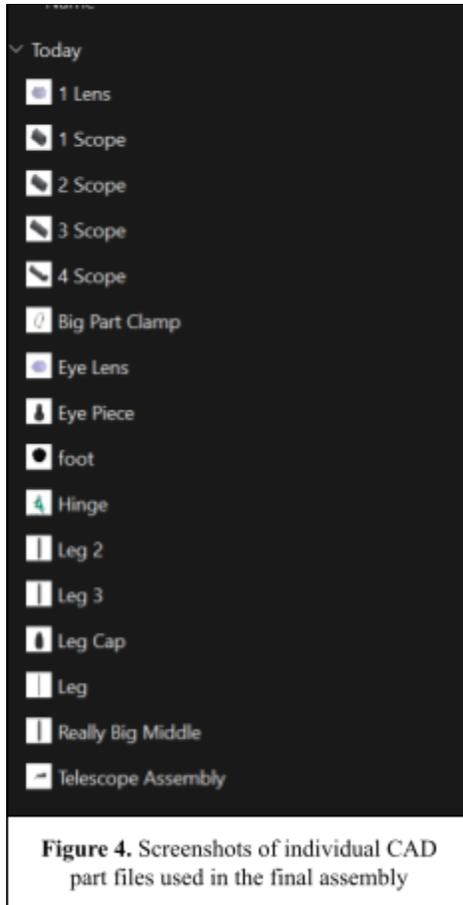
**Figure 1.** Complete telescope assembly with tripod showing full design geometry and proportions.



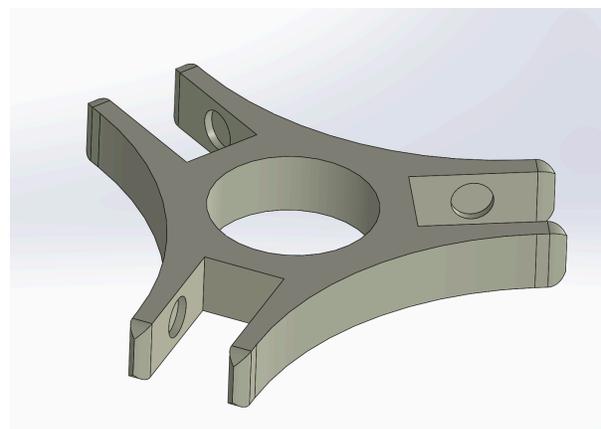
**Figure 2.** Tripod close up showing telescoping leg sections and hinge joints for adjustment.



**Figure 3.** Eyepiece and curved lens housing for user comfort and image alignment.



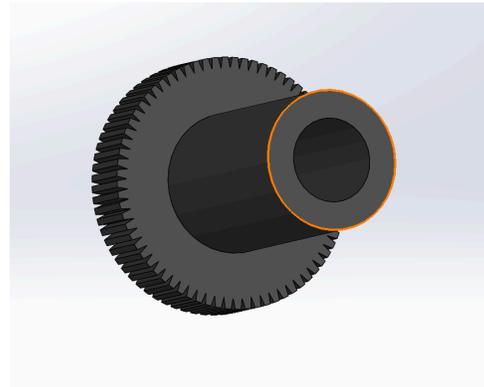
**Hinge Assembly** - The hinge component connects the three tripod legs to the central base. It allows each leg to pivot and lock at a fixed angle to ensure stability on uneven surfaces.



**Leg Cap** - The leg cap is attached to the bottom of each telescoping leg to provide grip and prevent slipping.

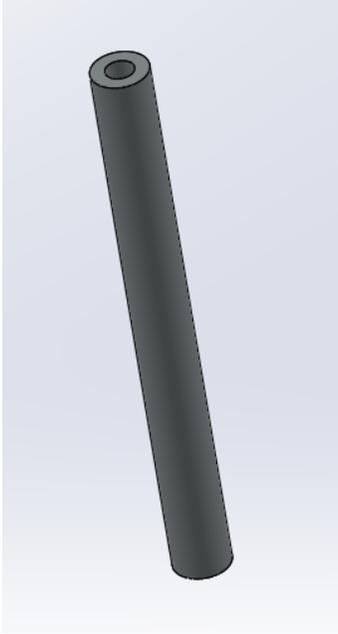
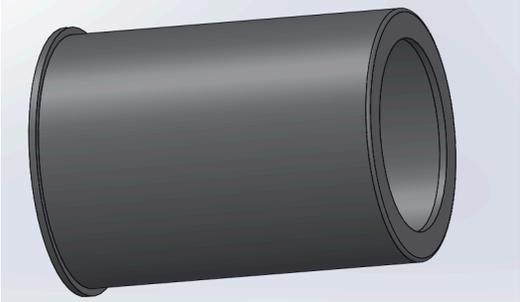


**Eye piece** - The eyepiece is threaded to accept various lenses and is designed for easy attachment and removal.



**Curved eye lens** - The curved lens holder allows for angled viewing. It houses a mirror that redirects light into the eyepiece, improving comfort for the user.



<p><b>Base of foot</b> - This part provides the main lower support for each tripod leg. It is reinforced to withstand axial loads transmitted from the telescope.</p>	
<p><b>The Largest Scope</b> - The main optical tube holds the primary lens assembly and serves as the structural core of the telescope.</p>	

The completed CAD design shows that all telescope components fit together correctly and maintain proper proportions for both function and stability. The hinge and leg assemblies ensure even weight distribution and a secure stance on various surfaces, while the curved eyepiece design provides comfortable viewing without repositioning the telescope body.

Each individual part was modeled with attention to real world assembly and manufacturability.

The design allows for telescoping leg adjustments, smooth hinge motion, and reliable alignment

between the optical tube and the eyepiece. The CAD model also confirmed that the telescope can be fully collapsed for portability without compromising structural strength.

Overall, the CAD modeling phase validated the geometric accuracy of our design and helped refine details such as leg angle, hinge placement, and optical tube diameter. These refinements make the telescope more practical for production and ensure that it meets all functional and stability requirements.

#### **2.4. Quantitative Load Case Analysis and Calculations:**

The analytical calculations developed in Progress Report #2 were refined and used as the foundation for our structural evaluation. These load cases define the strength and stability requirements of the tripod and mount, ensuring that the telescope remains secure under realistic operating conditions.

We have assumed that the user will most likely apply no more than 50 lbf on the telescope at any given time. This is reasonable since a user will never apply their full body weight to the telescope. The telescope tube assembly itself is assumed to weigh 15 lbs.

Number of legs(n): 3

Leg length at full extension(L): 4 ft (48 in)

Leg angle from vertical ( $\theta$ ): 40°

Material: 6061 T6 Aluminum (E = 10,000 ksi)

Factor of safety Buckling (FoS): 2.0

Load Case:	Calculations:
<p><b>Load Case 1: Peak Load</b> (Telescope + User Push)</p>	<p><u>Load in each Tripod Leg:</u></p> $3F\cos(\theta) = W$ $F = \frac{W}{3\cos(\theta)}$ $F = \frac{50 + 15}{3\cos(40)}$ $F = 28.28 \text{ lbf per leg}$ <p><u>Horizontal component of the joint where all 3 legs connect:</u></p> $V = F\sin(\theta)$ $V = 28.28\sin(40)$ $V = 18.18 \text{ lbf per leg}$ <p>(need this for designing the joint and fasteners to hold the legs and makes sure it doesn't spread or break apart at the hinges)</p> <p><u>Buckling Requirement:</u></p> $P = FoS(F)$ $P = 2.0(28.28)$ $P = 56.57 \text{ lbf}$
<p><b>Load Case 2: Telescope only</b></p>	<p><u>Load in each Tripod Leg:</u></p> $F = \frac{15}{3\cos(40)}$ $F = 6.53 \text{ lbf per leg}$

	<p><u>Horizontal component of the joint where all 3 legs connect:</u></p> $V = 6.53\sin(40)$ $V = 4.20 \text{ lbf per leg}$ <p><u>Buckling Requirement:</u></p> $P = 2.0(4.20)$ $P = 13.06 \text{ lbf}$
<p><b>Load Case 3:</b> Uneven ground/off center load</p>	<p>Assume <math>W = 65 \text{ lbf}</math> and 40% on one leg and 30% on each of the other two (worst leg carriers 40%)</p> <p><u>Vertical on worst leg:</u> <math>0.40(65) = 26 \text{ lbf}</math></p> $F = \frac{26}{\cos(40)}$ $F = 33.96 \text{ lbf}$ <p><u>Vertical on other legs:</u> <math>0.30(65) = 19.5</math></p> $F = 25.48 \text{ lbf}$

These analytical results confirm that the tripod legs can safely support operational and off axis loading with a conservative buckling safety factor of 2.0. The data guided refinement of the leg diameter, hinge placement, and mounting hub geometry in the CAD model to ensure rigidity and balance.

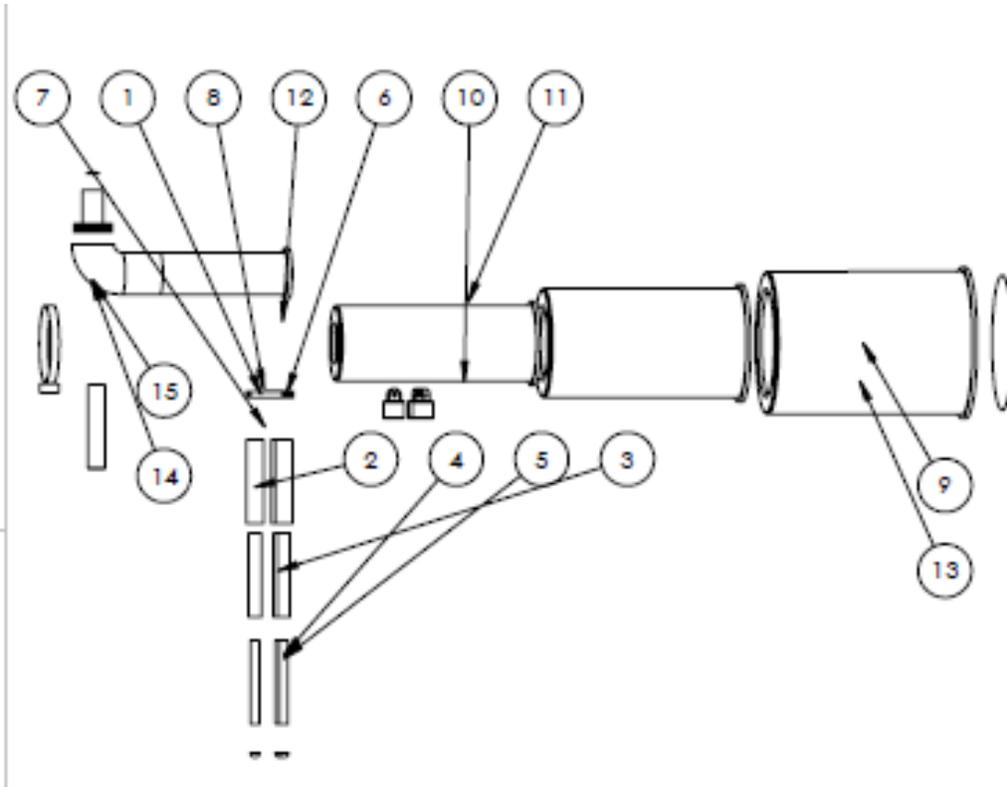
## **Material Selection:**

The telescope and tripod components were designed using materials that balance strength, manufacturability, and weight. Aluminum 6061-T6 was selected for the main structural elements such as the tripod legs, hinge assembly, and optical tube. This alloy offers a strong combination of stiffness, durability, and low weight, making it ideal for portable equipment that must also remain stable under load. Its good machinability and corrosion resistance also make it practical for both manufacturing and long-term outdoor use.

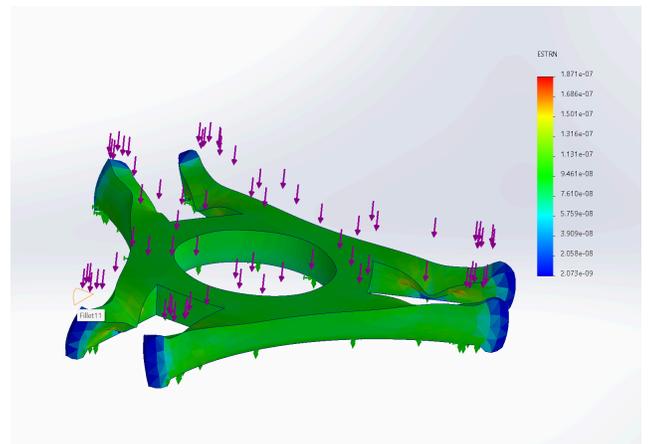
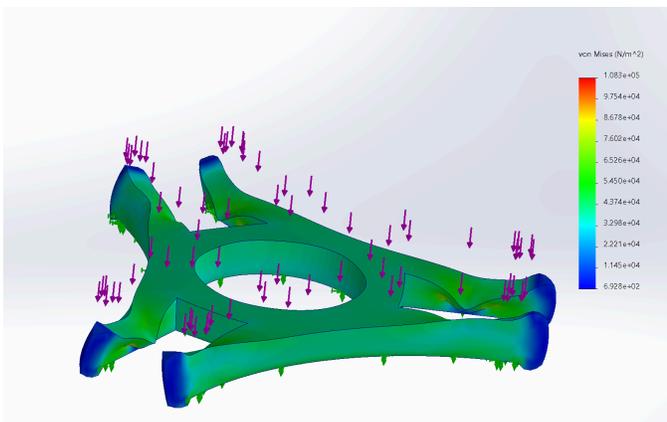
Rubber and PTFE were selected for several non-structural but functionally important areas. Rubber feet were added to improve ground grip and prevent slipping on smooth surfaces. PTFE pads were used in the hinge to reduce friction and ensure smooth pivoting motion without sticking. These materials not only enhance ergonomics and functionality, but also help reduce small vibrations that could affect viewing stability. Brass was chosen for the lens holder and threaded eyepiece components. Brass provides a smooth, precise threading action and resists galling, which is important for parts that will be repeatedly assembled and removed. It also adds durability and helps maintain alignment in the optical path.

Overall, the material selections were made to ensure the telescope is lightweight, stable, comfortable to use, and manufacturable while meeting the structural demands identified in the load case analysis.

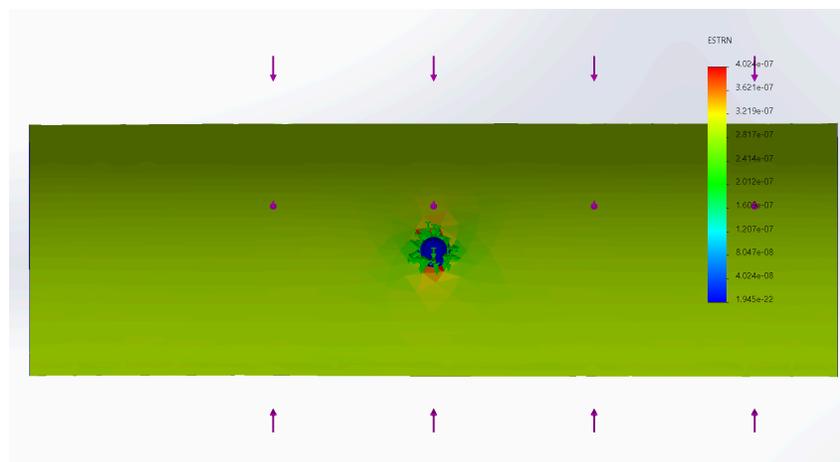
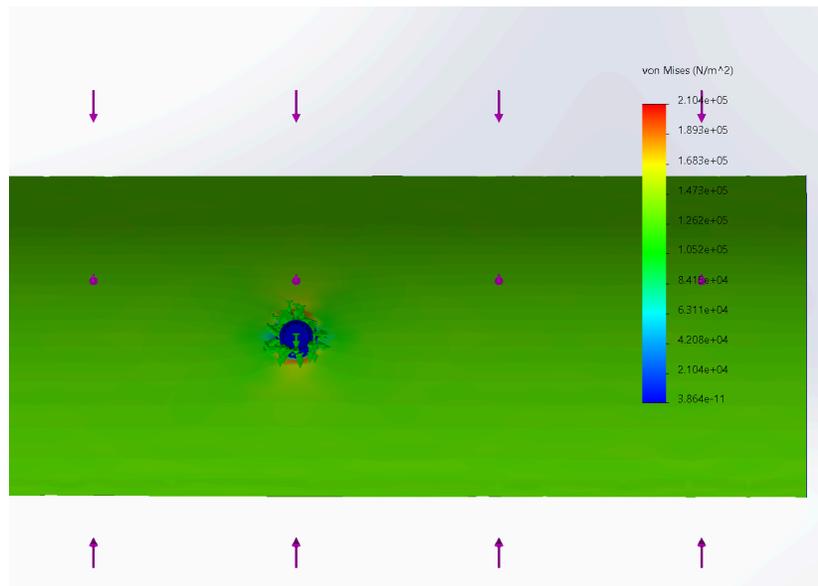
## **3. Results and Discussion**



As shown above, our engineering drawing depicts the 15 parts necessary for the creation of the telescope design. We have employed our expertise in SolidWorks to create the full model image of the telescope as well as all of the relevant finite element analysis studies necessary to ensure a safe and functional product.



Depicted above are the stress and strain results on the middle hinging component of the telescope. We applied a very high force downward onto the hinge to depict the user pressing down. A 45 lbf was applied and has shown the hinge compressing downward—especially on the portions where the legs will connect to the mechanism. In a redesign, we may opt to further structure the hinge mechanism, but as far as safety is concerned, the product performed well. The strain image, on the right, shows that there is the most strain right around those points where the legs connect, which is expected, as these are free hanging components that do not get supported by anything else.



A 115lbf was applied to the middle scope of the telescope to simulate intense pressure that the telescope will feel under the user. Shown are the stress and strain graphs, respectively. While this is an unrealistic amount of force, it was crucial for us to understand how the screw would be affected by the pressure. As was expected, the screw experienced the highest amount of stress exhibited was  $2.10E5 \text{ N/m}^2$ . The highest amount of stress was shown at the screw point in which was expected, since the screw was defined as fixed. However, we observed little to no buckling on the telescope itself, proving that it was a successfully built part of the telescope.

#### **4. Conclusions**

The CAD modeling phase confirmed that all telescope components fit together correctly and maintain proper proportions for function and stability. Key design features, such as the tripod's telescoping leg sections, hinge joints for adjustment, and the curved lens housing for comfortable viewing, were confirmed. The telescope design also was able to show that the telescope can be fully collapsed without compromising its structural strength. We chose material that balanced our needs of stiffness, weight, manufacturability, thermal behavior, and strength. Our project was able to successfully apply the engineering principles that we learned from the lecture including stress, buckling (using Euler's equation), and material properties, to design a sturdy and functional telescope. Challenges, such as maintaining a lightweight yet stable tube and managing thermal expansion differences between aluminum and brass, were addressed through material selection, wall thickness adjustments, and the addition of ventilation gaps. In the future we can work on development and optimizing structural and functional aspects of the design, including performing and refining Finite Element Analysis (FEA). The design philosophy embraces systems thinking, balancing mechanical, optical, and ergonomic

considerations, while maintaining a focus on improving the material used and finding alternatives with less cost and waste.

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