# Automated Optical Telescope Mount


**B.Sc. (Honours) in Industrial Physics**

**Department of Physical Sciences**

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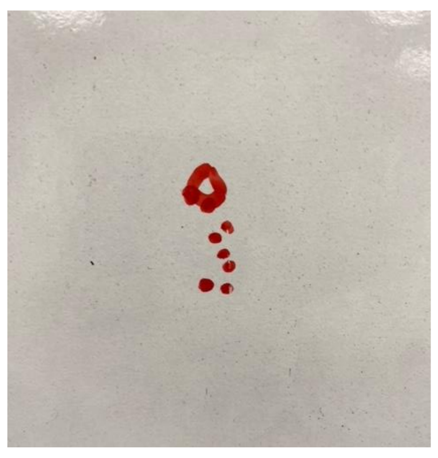
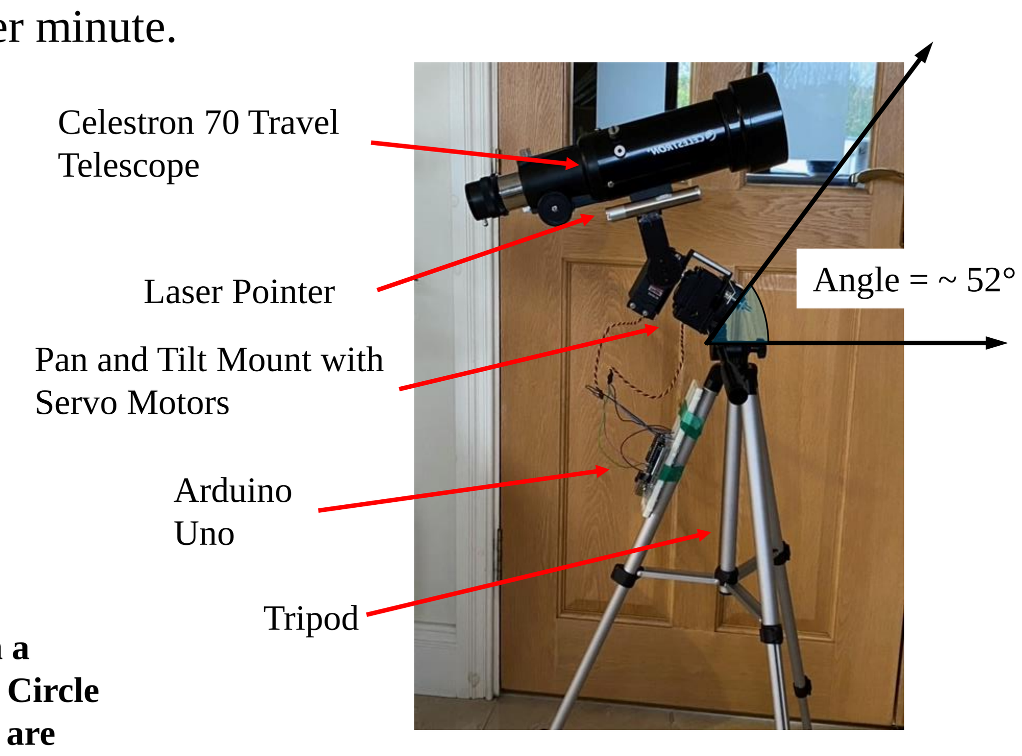
## Introduction

- This project involves building a basic mechanical telescope mount that can securely hold the optical telescope and allow the telescope to be moved and pointed with precision at an object of interest in the sky.
- The mount should be motorised to allow the telescope to point at specific coordinates and rotate with the night sky to track an object with precision for a period.
- There are many advantages of using a motorised mount rather than a manual mount. A motorised mount will be more accurate and can be calibrated, it can be set to automatically track the current object by rotating along with the apparent movement of the object across the sky, take pictures and videos of the objects at set intervals.
- The mount is controlled using an Arduino Uno which drives the servo motors to point the mount at the desired coordinates.
- The tracking of the mount should match the apparent movement of the sky which is 15 degrees per hour or 0.25 degrees per minute.



**Testing the Accuracy of the Mount on a Whiteboard Using a Laser Pointer: Large Circle is Original Position and Smaller Points are Position of Laser After Pointing Repeatedly at the Coordinates**




**Assembled Mount at 52 Degrees to Match the Latitude**

### Testing the Accuracy of the Mount

By facing the mount towards a blank wall and attaching a laser pointer to it the exact position on the wall the mount is pointing at was known and marked. By selecting certain points that will lie on the same tracking path, i.e. points with the same declination angle, and having the mount repeatedly point at these coordinates and running the tracking sequence to see how well the mount passed through these points the accuracy was determined.

To test the accuracy on the night sky, the mount would be positioned due south and inputting coordinates for a known celestial object and determining how the position of the object differs from the direction the mount is facing. Adjustments could be made to increase the accuracy in the Arduino code. The tracking could be tested by centering the scope on a bright celestial object and seeing how well the mount follows the object over a few hours.

## Coordinate System

### Equatorial Coordinates

- The equatorial coordinate system (RA/Dec) is a projection of the latitude and longitude coordinate system onto the celestial sphere.
- The latitude lines become declination (Dec) which is measured in degrees, arcminutes and arcseconds. This indicates how far north or south of the celestial equator the body is. The longitude lines become right-ascension (RA) and is measured in hours, minutes, and seconds east of where the celestial equator intersects the vernal equinox.
- Equatorial coordinates are used in most modern star maps as they describe the sky as seen from the Solar System.
- The advantage of equatorial coordinates is that they do not change with time and only one axis needs to be rotated to track an object once it is locked onto it, the right ascension axis.
- In order for the mount to use equatorial the mount itself will have to be at an angle matching the latitude of the location on Earth, for Cork, Ireland this angle is 51.8985 degrees.

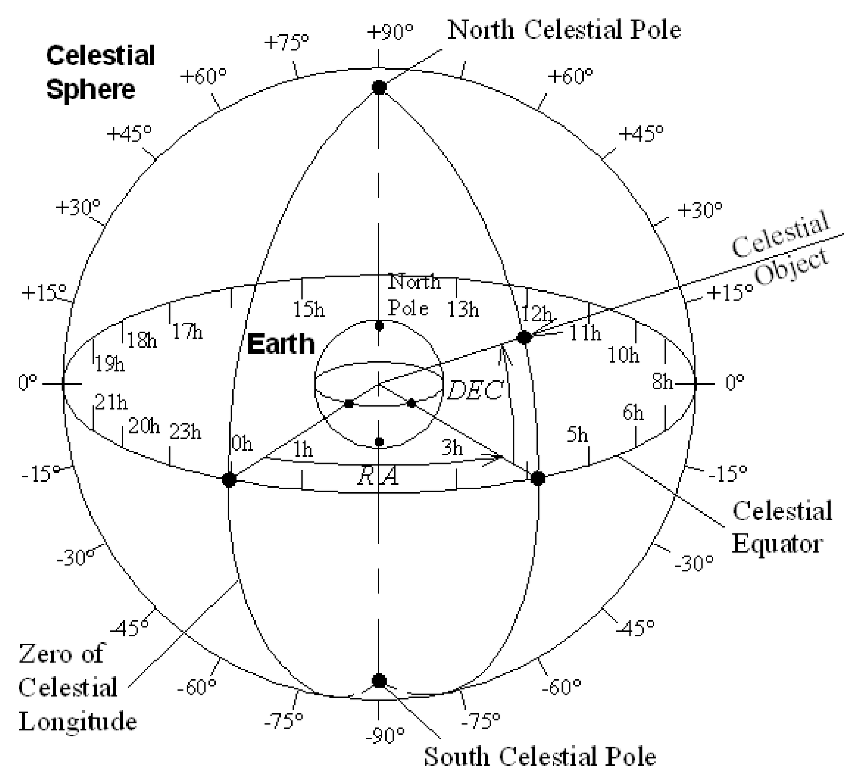
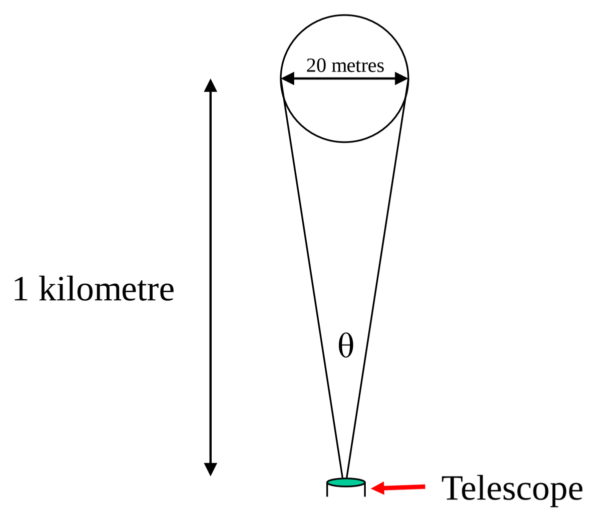



**Diagram Showing How Equatorial Coordinates Work**




**Linear Field Width of Telescope with 10mm Eyepiece in metres per kilometre**

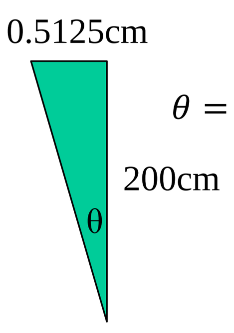
**Close up Image of the Moon Taken With MikrOkular Camera at 1280x720 Resolution**

## Results and Accuracy

### Accuracy

The results from testing the mount 2 meters away from a whiteboard and marking the points each time the mount pointed at specified coordinates showed that the mount was on average 0.5125cm off from the previous point in various directions.

This equates to 0.0026 radians away from the specified equatorial coordinates or 0.15 degrees. This can be compared to the angular size of the moon which is 0.52 degrees as viewed from Earth.




$$\theta = \tan^{-1}\frac{0.5125}{200} = 0.1468° = 0.00256\,rad$$

### Observations

- The higher the delay, which determines how quickly the servo motors rotate the mount, the more accurate the points became.
- This is due to the telescope not causing the mount to shake as much and the jitter from the servos was reduced as they rotate slower.
- Causing the mount to shake too much or move too quickly greatly decreases the accuracy and repeatability of the mount.
- The tripod should be kept as still as possible to prevent moving from its original position

### Field of View

$$Magnification = \frac{Focal\ Length\ of\ Telescope}{Focal\ Length\ of\ Eyepiece}$$

$$True\ Angular\ Field = \frac{Apparent\ Field\ of\ Eyepiece}{Magnification}$$

20mm Eyepiece: 20x Magnification, 50° Apparent FOV

Linear Field Width of 40 meters at 1 kilometre

10mm Eyepiece: 40x Magnification, 50° Apparent FOV

Linear Field Width of 20 meters at 1 kilometre

The MikrOkular HD telescope camera which has a resolution of 1920x1080 pixels, the field of view is calculated to be 0.82°x0.465°

### Range of Motion

- The range of motion for both of the servo motors used in the mount is 195 degrees when using an Arduino to control them. Servo motors are either continuous rotation or positional. With positional motors the angle the servo is facing can be set, so a suitable range must be selected.
- For the right ascension axis 180 degrees will be used and this gives a range of 12 hour angles, with this range an object could theoretically be tracked for 11 hours and 58 minutes.
- For the declination axis only 90 degrees will be used. This is due to any negative values would be below the horizon and would not be visible. 195 degree servo motors are suitable for both of these axes.

## References


"Equatorial Coordinate System COSMOS", Astronomy.swin.edu.au, 2022. [Online]. Available: https://astronomy.swin.edu.au/cosmos/e/equatorial+coordinate+system#:~:text=The%20equatorial%20coordinate%20system%20is,Earth%2C%20onto%20the%20celestial%20sphere.&text=The%20equator%20becomes%20the%20celestial,and%20south%20celestial%20poles%20respectively. [Accessed: 10- Feb- 2022].

"LCAS - Equatorial Vs Altazimuth Mountings", Lcas-astronomy.org, 2022. [Online]. Available: https://www.lcas-astronomy.org/articles/display.php?filename=equatorial_vs_altazimuth_mountings&category=telescopes#:~:text=Movement%3A%20With%20an%20equatorial%2C%20you,or%2Ddown%20(altitude).