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The purpose of my REU project was to design, implement, and test a system that could measure the vibrations and movements of the CCAS (Center of Curvature Alignment Sensor) tower. This tower is used every night to align the individual 91 mirror segments of the HET (Hobby-Eberly Telescope), and because it stands 90 feet tall, the structure is prone to high wind events. The ultimate goal of this project is to find a solution that could mitigate the vibrations of the tower as to improve the accuracy of the calibration of the mirrors. My mentor for this project was Michael McMillan, the mechanical engineer at the HET facility.

We decided to employ accelerometers as our primary sensors. I had to study how the module works to gain an understanding as to how to use this sensor, which basically involves the use of piezoelectric materials inside it that emits a certain amount of voltage for a given amount of mechanical stress applied to it. The accelerometers we ordered measured acceleration in only one axis, so we used four total sensors; the CCAS tower consists of an inner and outer tower, and we wanted an x and y axis per tower.

Because we were not sure if we could collect enough relevant data on the accelerometers, we decided to go ahead and implement secondary sensors, strain gauges. I have not had any prior experience with such devices, so I spent some time learning the basics as to how it works, which is essentially the use of variations in the resistance of the gauge caused by the tension/compression forces, which translates to a voltage difference over the Wheatstone bridge setup. This approach was a bit more experimental, as it is mounted on the three guy wires that are anchored onto the CCAS tower, so a lot of improvisation had to be done. To create a flat and suitable mounting surface for the strain gauges, we had to carefully machine out aluminum sheet metal in the I-beam shape. The strain gauges were then super-glued onto the sheet metal, which were in turn attached to the guy wires via cable clamps.

As for data acquisition, we used the software/hardware from Windaq, which had recorded the data from all the channels together. I collected the data for several days, and then went through it to crop out the times where there were relatively high wind events. I converted the data to table form, and then used the Mathcad built in FFT (Fast Fourier Transform) function to calculate the relationship of the amplitudes of the different axis of vibrations versus the frequency. The main goal in analyzing the data is to find the resonant frequency, which is where the amplitude is at the maximum, and we found that the outer tower has its resonance at a range of 2.25 to 2.5 Hz and the inner tower at around 1.25 Hz.

Throughout the design, implement, and test phase, we have had some problems along the way. During the design, we had to decide as to which sensors and hardware to purchase for cost effectiveness, due to the wide variety of products online. As the strain gauges were being installed onto the guy wires, apparently one of the strain gauges either was damaged in the attachment process, or the connection in the soldering pads were too weak to read any resistance. I have also learned how to solder and fabricate all the wiring needed for my project, which aided me in fixing the poor connections we have received from the sensors due to the four to six wires that had to share a single port in the data logger box.

After looking at the data and researching the dynamics of tall building structures, I have come to the conclusion that the use of a tuned mass damper would be the most efficient way as to how to mitigate the vibrations on the CCAS tower. More specifically, the use of a pendulum mass damper would be appropriate in this situation, due to its simplicity and cost effectiveness. Because the pendulum's period is related to its arm length, the idea is to tune the arm length so that it equals the resonant frequency of the structure. Looking at the resonant frequencies of the inner and outer towers, the inner tower's arm length would be around 0.25 meters and the outer tower arm length would be around 0.05 meters, using the period equation of a pendulum and the frequency equation related to period. By attaching a beam that would connect two opposing ends of the outer tower, the pendulum could be dangled down the hollow shaft in the center of the tower. There will probably be a need for multiple pendulums to hold enough counterweights because of the very short arm length required by the CCAS tower; only about 100 lbs could be placed per pendulum.