CIRES Lab Adapts Fe-Doppler LiDAR for NASA Rocket Campaign

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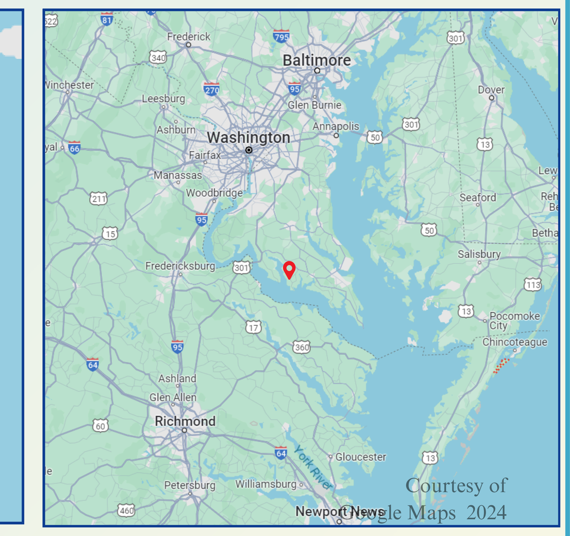
1) Abstract:

CU Boulder's CIRES lab has been long-established and involved in the scientific community through its research at McMurdo Station in Antarctica. Now the group faces a new objective, establishing LiDAR setup in Wallops Island Flight Facility in Virginia to aid in a NASA-funded Rocket Campaign. Its challenge in this endeavor is to adapt the already existing Fe-Doppler LiDAR techniques, pioneered by Dr. Xinzhao Chu's lab, to best provide experimental data needed for NASA aerospace applications. To adequately surmise this project, the students must engineer a set-up capable of enabling the LiDAR devices to take data with high attitude repeatability, precision, and low-elevation pointing range in order to provide accurate flight conditions regarding the instability in the mesosphere and lower thermosphere. Over the past year, the team has been successfully establishing a new testing site in Golden, Colorado intending to enable CU students to perform LiDAR experimentation and analysis. The testing facility is equipped with all the technology necessary to complete these projects, and the undergraduate students are modeling and implementing supplemental devices to best optimize and practicalize the reliability, range, and repeatability of the resulting data obtained from the telescopes. With the implementation of the Fe Doppler-free spectroscopy method, the students will be able to record and analyze the physics and chemistry of the atmosphere at Wallops Island for local aerospace and atmospheric science applications with NASA.

2) Scientific Motivations:

Understanding the local atmospheric environment for future rocket launches at Wallops Island.



Virginia's Wallops Island Flight Facility is used for many aerospace applications including high altitude balloons, rockets, and aircraft for a wide variety of commercial, scholarly, and governmental justifications. Understanding the local launch conditions and properties (temperature, air velocity, density, etc) is important for the launches of rockets present at Wallops Island. Understanding these conditions fully would help the scientific community more appropriately design and correct the launches and data acquisition relevant to the site. Through the high precision LiDAR methods of Dr. Xinzhao Chu, the flight facility will be able to collect data of the precise launch conditions of the facility to an unprecedented level of accuracy. This application of these ambitious methods will not only benefit NASA, but the many groups that use Wallops Island for their launches, thus, making this project have hopeful implications of improvement for the US military, aerospace industry, and global scientific community.

3) Adapting the Previous Design

The main goal was to adapt the current telescope in Golden, Colorado used in previous projects to enable same Fe-Doppler LiDAR method but to adapt it to the needs of the rocket campaign in Virginia. This was accomplished by adapting the previous telescope container to be able to achieve a high amount of repeatability, quantitative positional accuracy, and a wider range of movement.

3.1) Previous Telescope Aiming System

Proceeding system was repeatable, but only went to about 35 degrees off zenith (maximum inclination shown in figure above). Needed to cover a wider range of angles and have more modes in between, while adapting to the current telescope holder and connected sled. Also needed to withstand new swamp conditions prevalent in new local climate.

3.2) Adaptions

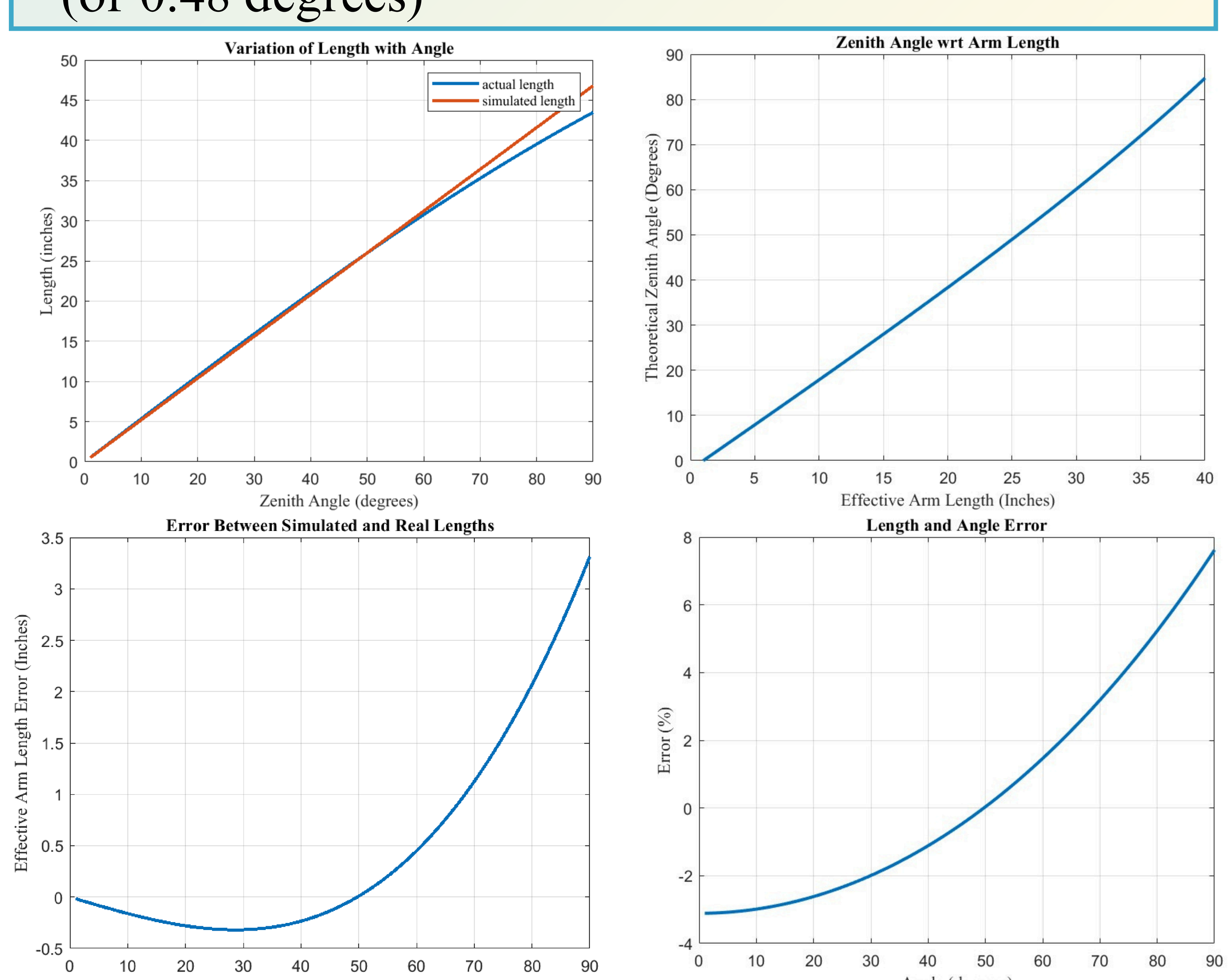
- Bar elongated to allow for wider array of angles up to 56 degrees, gaining a total of 21 degrees of tilt over the previous system.
- Arm made out of aluminum and plunger made out of steel to accommodate climate and strength specifications needed to move 400 pound telescope system.
- Plunger design added that varies in radius and screws into the modal arm to ensure repeatability of system
- Holes or "modes" added with precision to comply with the dimensions of the plunger
    - Plunger designed optimized for ease of use while also ensuring that arm would not slide through during any foreseeable maneuver

4) Results

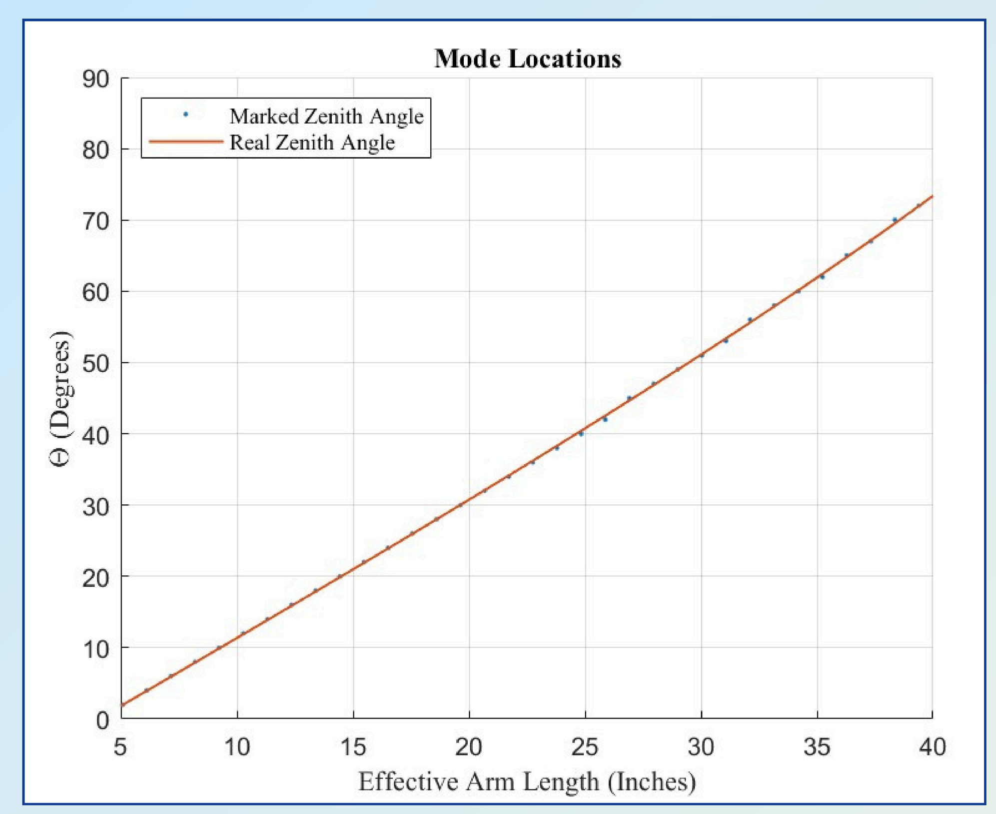
$$\theta = \cos^{-1}\left(\frac{-d^2}{1860.5} + 1\right)$$

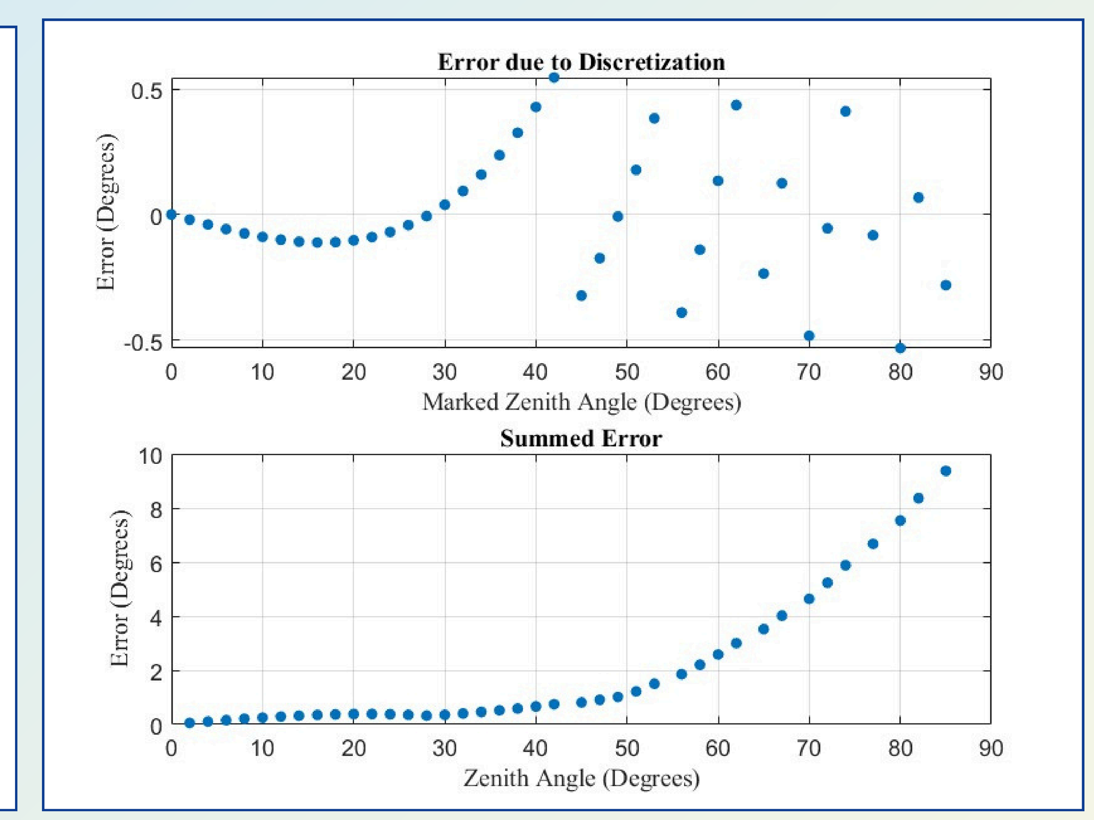
* *where θ represents the angle from zenith to the view of the telescope in degrees and d is the effective arm length*

- Error percentage increases with angle. At 90 degrees, the error is approximately 7.61%.
- Minimum absolute error in arm length and zenith angle occurs when θ is around 50 degrees and 0 degrees from zenith
- Absolute error of zenith angle exactly proportional to that of length, with bounds of -0.6 to 6.4 degrees.
- Error of zenith angle at 56 degrees is about 0.86% (or 0.48 degrees)

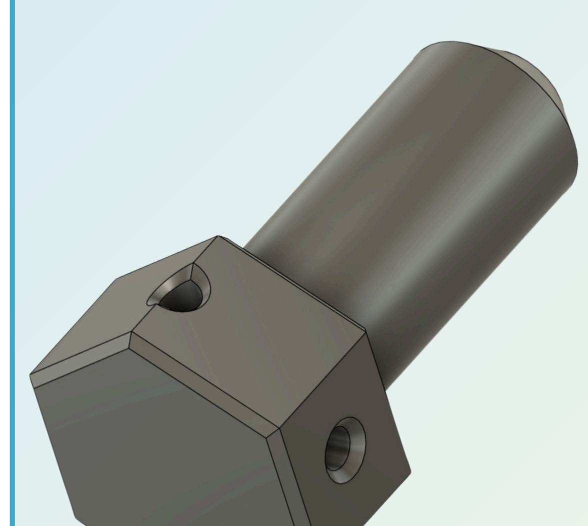


5) Final Product and Conclusions





Plunger:



- Arm angles discretized and modified to avoid areas of high discretization error.
- Summing the area, it can be shown that the device can reach up to 56 degrees zenith while staying under an error of 2 degrees.
- Prototype installed and tested and deemed structurally sound for telescope's weight.
- Linearization contributes the most to error of any source presently accounted for.

Arm

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