Calculation of Launch Occultation Geometry into the Polar Night

Savannah Church[1] , David Encarnacion[2] , Sowmya Muthurangan[2] , Aklima Khatun[2] , Scott Bailey[2] , Justin N. Carstens[2] , Samantha Kenyon[3], Bill McClintock[4]

[1] Virginia Tech, Department of Physics, [2] Virginia Tech, Department of Electrical and Computer Engineering, [3] Virginia Tech, Department of Aerospace Engineering, [4] University of Colorado, Boulder, Laboratory for Atmospheric and Space Physics

Introduction

- A sounding rocket will be launched into the polar night this winter to study the Nitric Oxide (NO) in the atmosphere.
- The **PolarNOx 2026** mission utilizes stellar occultation, which observes the star's irradiance outside the desired atmospheric layer and measures the light's attenuation as the sounding rocket passes through the lower layers.
- Light from the star Algenib (γ-Pegasi) is attenuated through the lower atmosphere to observe the resulting NO emission spectrum.
- The star selection was made based on the required wavelength and the general position in the sky that would be best for launch.
- The altitude of this launch is lower than the last launch with an apogee of 245km, established based on historical NO densities relative to altitude, such that the sounding rocket reaches above the NO and falls back through on its way down.

Date	Time (Local)	UTC	Zenith Angle	Altitude (Deg)	Moon Location Above Horizon
1/26/26	4:41	14:41	99.54	-9.54	-2.36
1/27/26	4:37	13:37	99.54	-9.54	5.61
1/28/26	4:33	13:33	99.54	-9.54	13.43
1/29/26	4:29	13:29	99.54	-9.54	20.64
1/30/26	4:25	13:25	99.54	-9.54	26.75
1/31/26	4:21	13:21	99.54	-9.54	31.18
2/1/26	4:17	13:17	99.54	-9.54	33.44

Table 1: Depicts the top 7 launch dates based on zenith angle and moon location relative to the view at apogee, found using historical data.

Methodology

- Python and the astropy library were utilized to write a script that utilizes historical data to plot the movement of the Sun, Moon, Earth, and the star of interest for different periods.
- Object positions were calculated during a period of NO abundance (Jan 17th - Feb 8th) during polar night just above the launch site in Poker Flat, AK.
- Many launch times were found in which, at apogee, the sounding rocket would achieve a ~100° zenith angle relative to the star based on geometric calculations.
- The desired angle between the Moon and the star, from the sounding rocket's point of view, must be greater than 90 degrees such that moonlight does not interfere with the data collection.
- The Sun is also considered, as it must be either in a similar position away from the star or well below the horizon to reduce the risk of stray light.
- Under the above constraints, two windows of best launch were found:
  - Jan 17th - 21st
  - Jan 26th -Feb 1st
- With this information, the best date and time for launch is Jan 30th at 13:25:00 UTC.

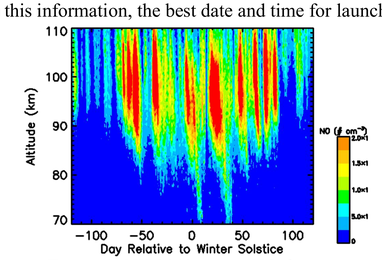

Figure 1: NH 2011 winter NO density

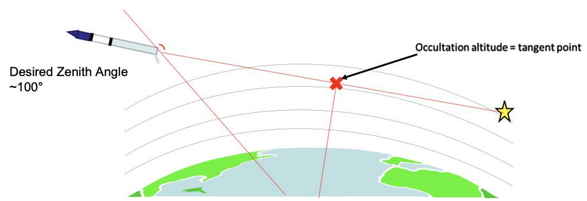

Figure 2: A general diagram showcasing Stellar Occultation

Research Objective

- Find the optimal launch window for observing NO in the polar night.
- Generate a program capable of finding such a launch window.
- In addition to the **PolarNOx** mission-specific launch characteristics, allow for conditions such as location, star, and time to be modified for any number of launch configurations.
- Include possible interfering objects, such as the moon and the sun, to consider windows that minimize their effects.
- Compare results to results found in different coding platforms to help determine correctness.

Conclusion & Future

- The optimal launch time is calculated to be 01/30/2026 at 13:25:00 UTC with a nominal apogee of 245km and a zenith angle of 99.54°.
- This result will be used for the 2026 launch date, and these calculation methods will be employed for future launch preparations.
- Consider deploying similar instruments and measurement techniques in a satellite for continuous data collection.

Stellar Occultation Geometry

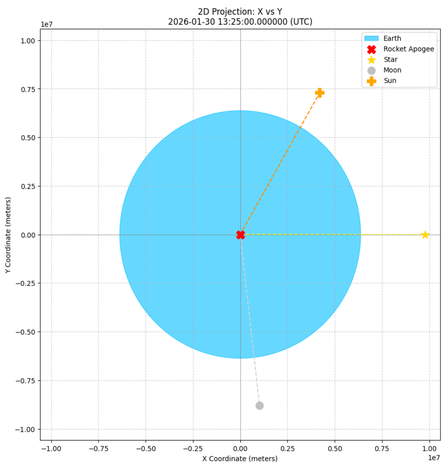

Figure 3: Graph of Earth, Sounding Rocket, Moon, Star, and Sun from directly above Poker Flat

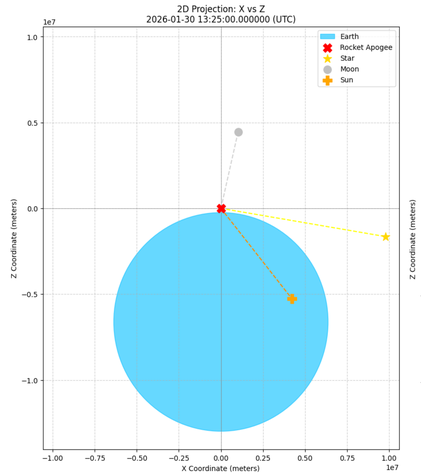

Figure 4: Graph of Earth, Sounding Rocket, Moon, Star, and Sun from the side where Poker Flat is at the northernmost point

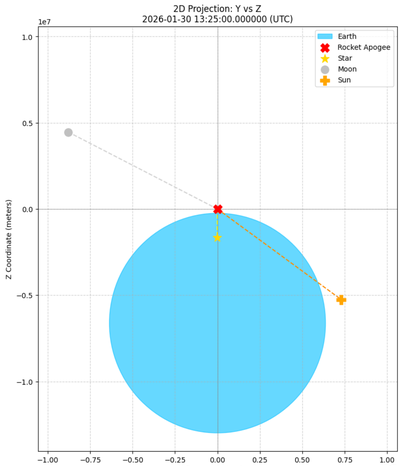

Figure 5: Graph of Earth, Sounding Rocket, Moon, Star, and Sun from the side where Poker Flat is at the northernmost point

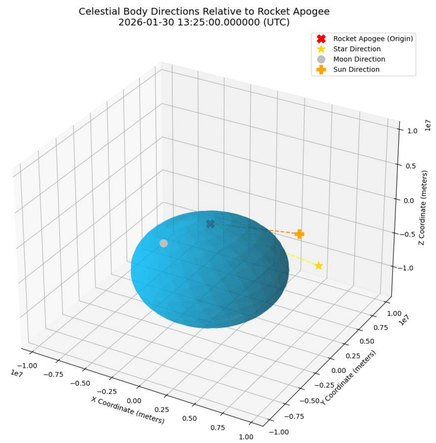

Figure 6: 3D graph of Earth, Sounding Rocket, Moon, Star, and Sun from the side where Poker Flat is at the northernmost point

- Concerning the above plots, the location of Poker Flats was used, referencing its latitude and longitude of 65.1298 N 147.4833 W, with an elevation of 213m above sea level.
- The star Algenib can be characterized with a right ascension of 00h 13m 14s and a declination of +15° 11' 00", referenced to the Julian epoch 2000.0 (J2000).
- Using the data found in *Table 1*, the best date and time for launch were found assuming a perfectly vertical launch; however, considering an edge case of a +5° change in latitude, the star remains visible, and all interfering objects do not significantly change position.
- This day was also graphed on 2D and 3D plots to visualize the accuracy of the calculation, where the red symbol depicts the sounding rocket at apogee, the yellow represents the star, the orange represents the sun, and the grey represents the moon.
- *Figures 3-6* show the placement and line of sight between the Earth, sounding rocket, Star, Moon, and Sun.
- Figure 3 showcases the angles at which the Sun and Moon are separated from the star.
- Figures 4 and 5 help to understand the placement of the sun and moon relative to the angle of observation. The Moon is positioned well above apogee, while the sun is under the horizon around the time of data collection.

References

Bailey, Scott M., et al. "Sounding rocket observation of nitric oxide in the polar night." Journal of Geophysical Research: Space Physics 127.6 (2022): e2021JA030257

Thirukoveluri, P. (2011). Planning and simulating observations for a sounding rocket experiment to measure polar night nitric oxide in the lower thermosphere by stellar occultation (Master's thesis, Virginia Tech).Virginia Tech Electronic Theses and Dissertations. http://scholar.lib.vt.edu/theses/available/etd-05182011-163321/