Monitoring Height Changes of Small Satellites
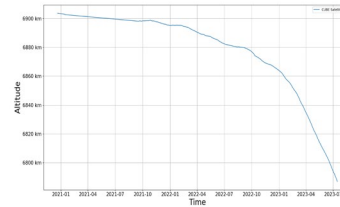
Shujia Zhang

Mentors: Guojun Gu
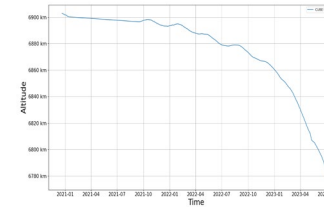
Objectives

- Quantify the decline of SPIRE's small satellites' height over time
- Test the reliability of open source software RTKLIB for positional tracking
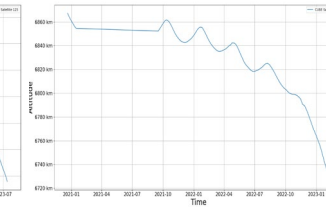- Assess the relationship between atmospheric drag and small satellites' height

CUBESat 124 **CUBESat 125** **CUBESat 102**

$$r = \sqrt{x^2 + y^2 + z^2}$$

r = distance from earth's center
x, y and z are coordinates in ECF (Earth's Centered Framework)
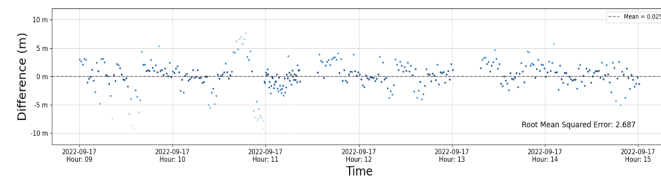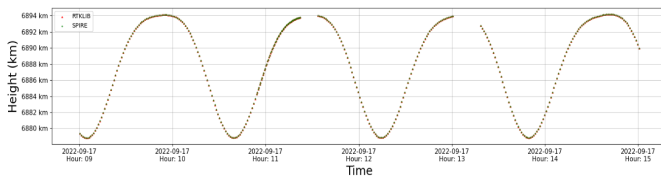
- In recent years SPIRE has launched many LEO satellites
- LEO satellites experience orbital decay and a decline in height over time
- CUBESat 124 drops 116km over a two and a half year period, Satellite 125 drops approximately 128 km over a two and a half year period, and Satellite 102 drops approximately 142 km over a two year period.

RTKLIB vs SPIRE (Lemur 2 Oscalator)
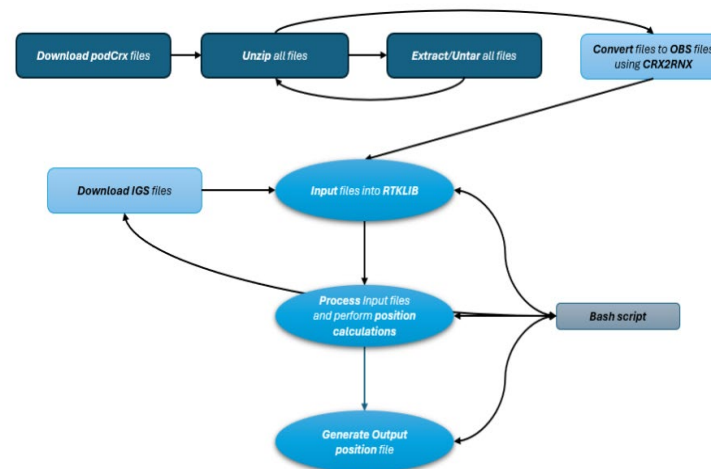
Root Mean Squared Error: 2.687

- The Graphs above are generated by SPIRE's commercial software, which leverage more advanced algorithms
- RTKLIB is an open-source software which can perform similar tasks and can be a viable alternative
- By correctly configuring podCRX files and retrieving IGS files, we can use RTKLIB to process Output positional data and analyze its measurement discrepancies between the original SP3 files generated by commercial software.

Methodology for RTKLIB

Download podCrx files → Unzip all files → Extract/Untar all files → Convert files to OBS files using CRX2RNX

Download IGS files → Input files into RTKLIB

Process Input files and perform position calculations ↔ Bash script

Generate Output position file

Mean	RMSE	Range
.025	2.687	-9 to 7 meters

File Format	SP3	CRX	RNX	GPS Broadcast Ephemeris file
Description	contains high precision positional data	Compressed RINEX files, more efficient	stores and exchanges satellite data	Combination of navigation files

CISESS — Cooperative Institute for Satellite Earth System Studies

Methodology
- ❖ Requested TLE files covering the period from December 1st, 2020 to January 1st, 2024 (for CUBESAT 124)
- ❖ Extracted BSTAR Drag Term and corresponding times from 2LE files

The BSTAR (B) Drag Term is not a direct representation of atmospheric drag, but rather a simplified representation of the effects

- ❖ All Earth-Orbiting Objects in the atmosphere experience atmospheric drag
- ❖ The graphs portray that over time, as the height of the satellite decreases the BSTAR value increases
- ❖ A positive feedback effect occurs, resulting in accelerated orbital decay

*Why do satellites decline in height over time?*

Lower altitude → Increased Density → Increased Drag → Deceleration
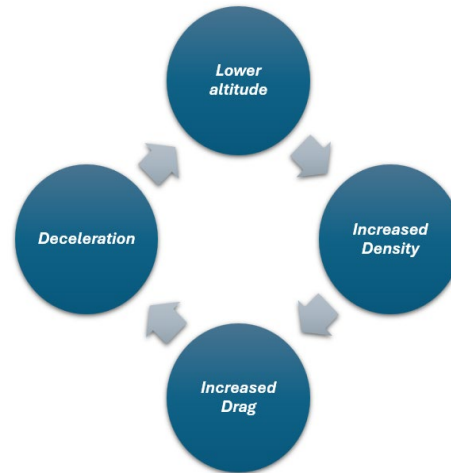
2LE (two line element)

a data format encoding a list of orbital elements of an Earth-Orbiting Object for a given point in time.

BSTAR Drag Term over time
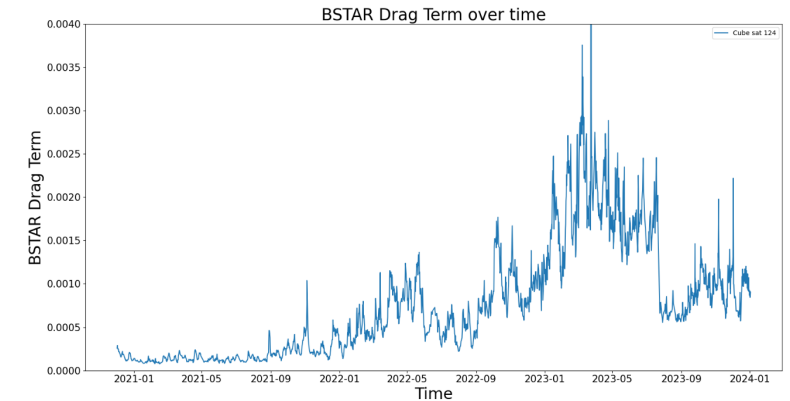
The decrease in atmospheric drag from June 2023 to January 2024 can be attributed to faulty data

Altitude vs BSTAR Drag Term
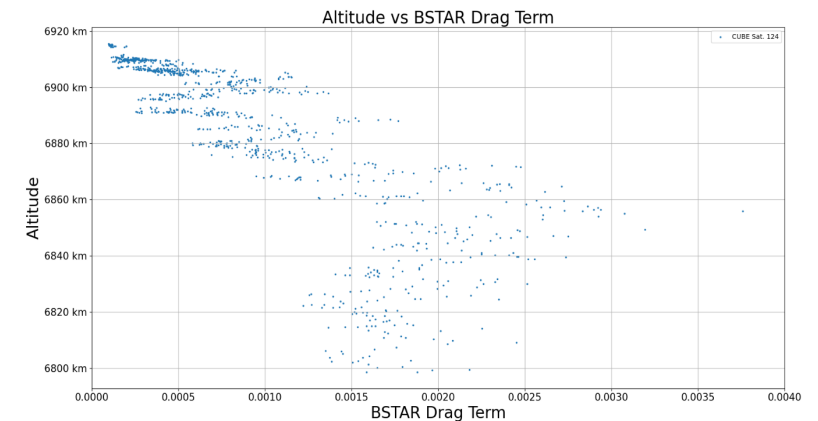
❖ Results/Conclusions

    ➢ A basic use of RTKLIB can be a great alternative for commercial softwares and for monitoring tasks that aren't position critical but not for the contrary

    ➢ The results confirmed that atmospheric drag causes accelerated orbital decay

❖ Future Work:

    ➢ Assess the impact altitude changes have on the quality of measurements of Atmospheric Water Vapor (Radio Occultation) and Ocean surface winds (GNSS - R)

    ➢ Consider antennae position of satellite's and calculate the mass center of the satellite and utilize more advanced algorithms alongside RTKLIB