FINAL PROJECT ABSTRACT

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ATMS 305: Computing and Data Analysis
Final Project

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***N*omenclature**
LASSI · Laboratory for Advanced Space Systems at Illinois
LEO · Low Earth Orbit
GEO · Geosynchronous Equatorial Orbit
MEO · Medium Earth Orbit
HEO · Highly Elliptical Orbit
CSV · Comma-Separated Values

1 Introduction

My capstone research project for ATMS 305: Computing and Data Analysis relates to my curriculum as an aerospace engineering major and my growing interest in data analysis in the atmospheric sciences realm. For this final project, I wanted to use the skills I've learned throughout this semester to explore an engineering concept that I'm passionate about and will pursue in graduate school and industry.

As Program Manager at the Laboratory of Advanced Space Systems at Illinois, I oversee and manage our five active cubesat missions in preparation for their respective launches [2]. Through a payload trade study I conducted with the Future Systems team of the Satellite Development Organization, I was able to identify trends in various satellite missions and payload purposes [3]. For my final project, I plan on diving deeper into these correlations and trends as satellites become increasingly important for scientific research and deep-space exploration.

2 Dataset Overview

The dataset I've selected for my final project is "Active Satellites in Orbit Around Earth" found on Kaggle as a comma-separated values (CSV) file and updated quarterly, dating back to 1974 [1]. For my data analysis purposes, I opted to upload this dataset to my Google Drive and then mount the directory in my notebook.

The data in my dataset covers a wide range of topics in association with each launched mission. The dataset contains reported data for official satellites launched by countries or organizations of the United Nations registry since 1974. It includes the mission's owner or operator, as well as the country of production. Each mission is detailed with the purpose and the targeted user audience. It also includes orbit information, such as class, type, longitude of geosynchronous orbit, perigee, apogee, eccentricity, inclination, and period. Other physical parameters are also featured in the dataset, such as mass, power, and expected lifetime. The date of launch is appended at the end with the respective launch site and launch vehicle.

The database includes basic information about the satellites and their orbits, but does not contain the detailed information enabling viewers to locate individual satellites. The information included in the database is publicly accessible, free, and collected from corporate, scientific, government, military, non-governmental, and academic websites available to the public [1].

A unique characteristic about the data is how it correlates with the undergraduate aerospace engineering curriculum. As discovered in my preliminary findings, the data provides all information necessary to visualize the orbit paths of individual satellites, which was fun to explore and calculate.

There are some limitations to my dataset, as I've discovered early on. Skimming the data, some entries seem to have data values missing. Due to the magnitude of the dataset itself, I don't believe this potential issue impacted my research. I'm confident that working with this dataset has allowed me to highlight my knowledge of Python and its various packages available to users.

3 Preliminary Findings

As I began more deeply exploring my dataset, I started out with some preliminary findings that could help direct me into forming a generated hypothesis. As shown in the below figures, I created different plots to look at the overall composition and trends of different axes of the dataframe, including orbit classes, launch frequency trends, and payload purposes.

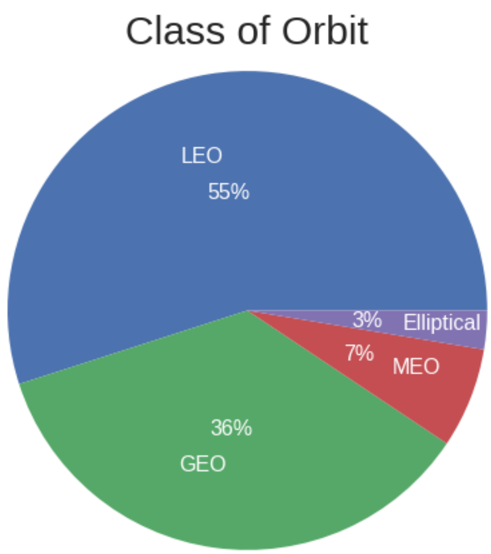

Figure 1: Pie chart showing class of orbit proportions

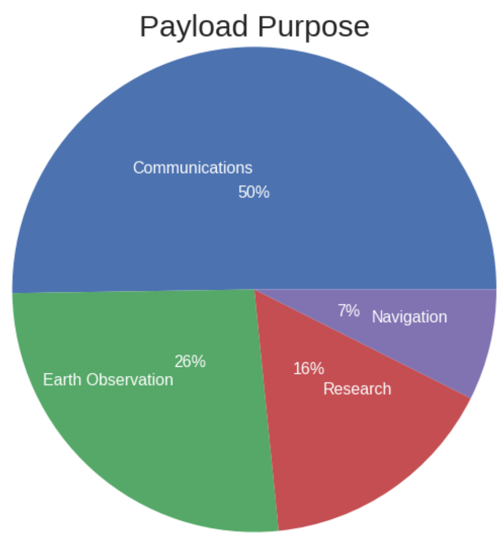

Figure 2: Pie chart showing payload purpose proportions

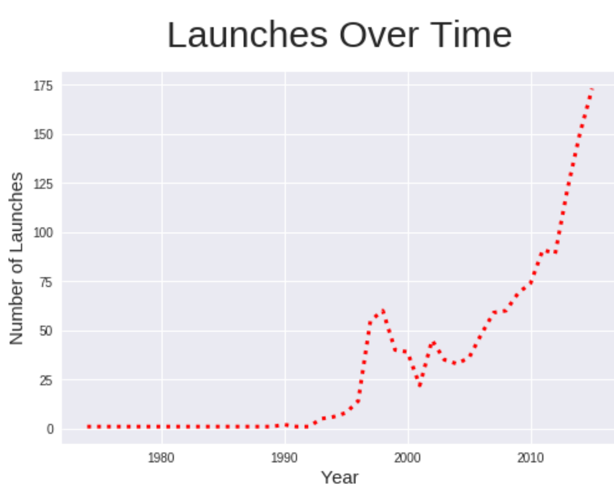

Figure 3: Line graph showing an increase in launches over time

As shown in Figure 4, I also generated a map to visualize launch site frequencies and locations.

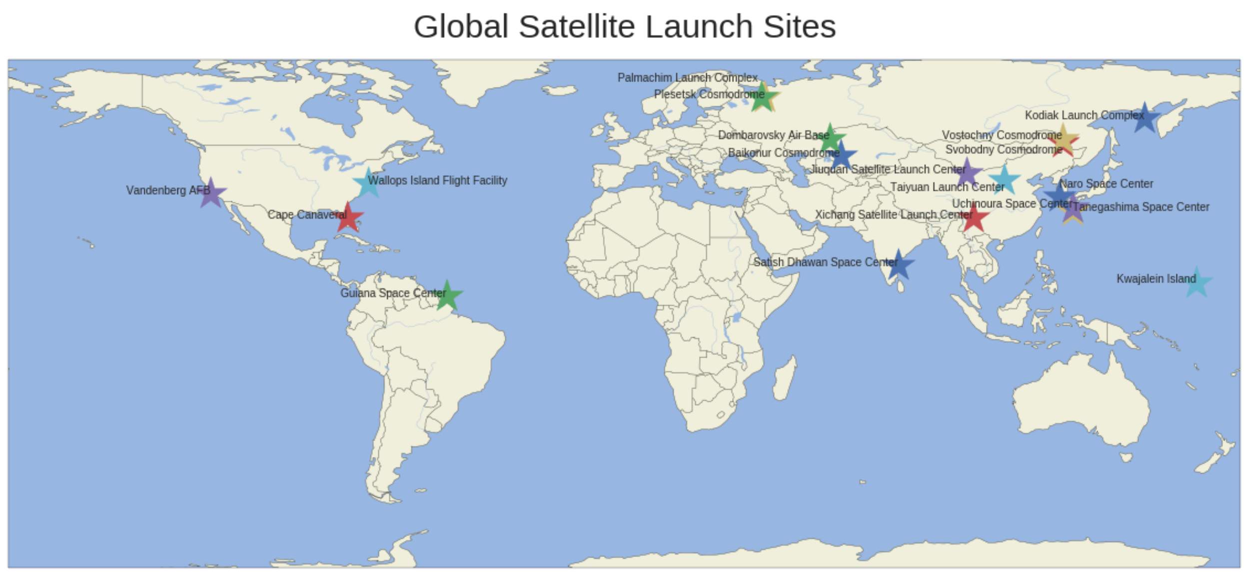

Figure 4: Mapped projection of featured launch sites

Arguably the most interesting part of my preliminary research included plotting the individual orbit paths, grouped by GEO, HEO, LEO, and MEO classes, with figures below.

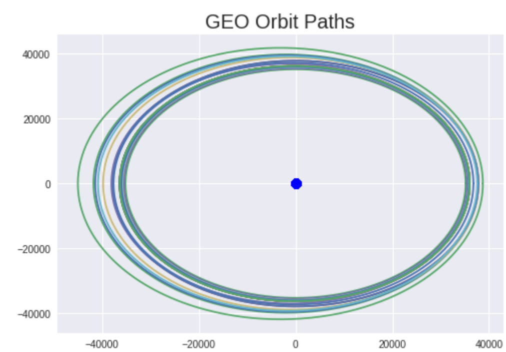

Figure 5: Geosynchronous Earth/Geostationary orbit paths

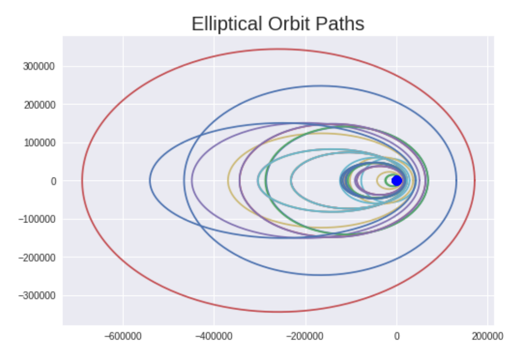

Figure 6: Elliptical orbit paths

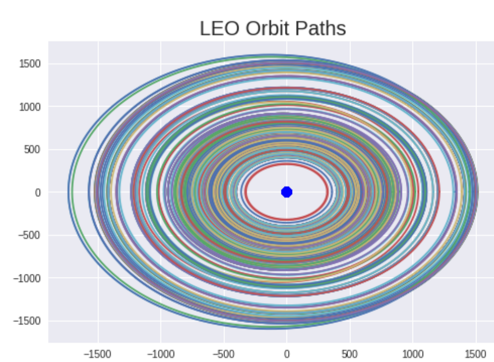

Figure 7: Low Earth orbit paths

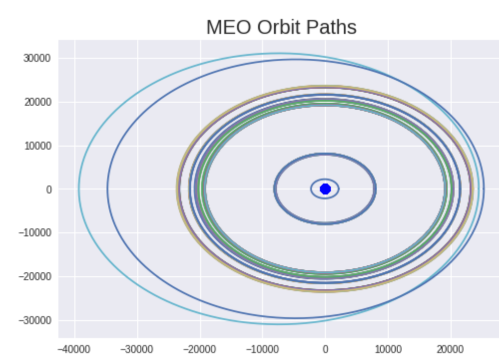

Figure 8: Medium Earth orbit paths

Overall, my preliminary findings in initially exploring the dataframe highlighted how all the different facets of a successful mission impact the different subsystems through intricate connections. For example, the amount of power a payload needs to function will affect the orbit semimajor axis the overall satellite is capable of handling. Similarly, the location of the launch can impact the level of experience of the ground systems team and the resources available on the day of launch and throughout the duration of the mission. I decided to look more into a correlation inspired by these realizations in the form of a hypothesis test.

4 Scientific Question

My hypothesis test was generated to allow me to conclude if there is a statistically significant correlation between power used in Watts and total mission lifetime in years. The null hypothesis is that the population correlation coefficient is not significantly different from zero. In other words, there is not a statistically significant correlation between the two variables. The research hypothesis is that the population correlation coefficient is significantly different from zero. In other words, there is a statistically significant correlation between the two variables. I carried out this statistical analysis test to see if the correlation coefficient is statistically significant at the 95% confidence level.

5 Analytical Technique

I used a correlation calculation, similar to what we did in ATMS 305, to find the p-value in relation to my hypothesis test. I also ran a linear regression model to get the slope and y-intercept for the line of best fit and created a scatter plot to visualize if a linear relationship seems plausible, shown below in Figure 9.

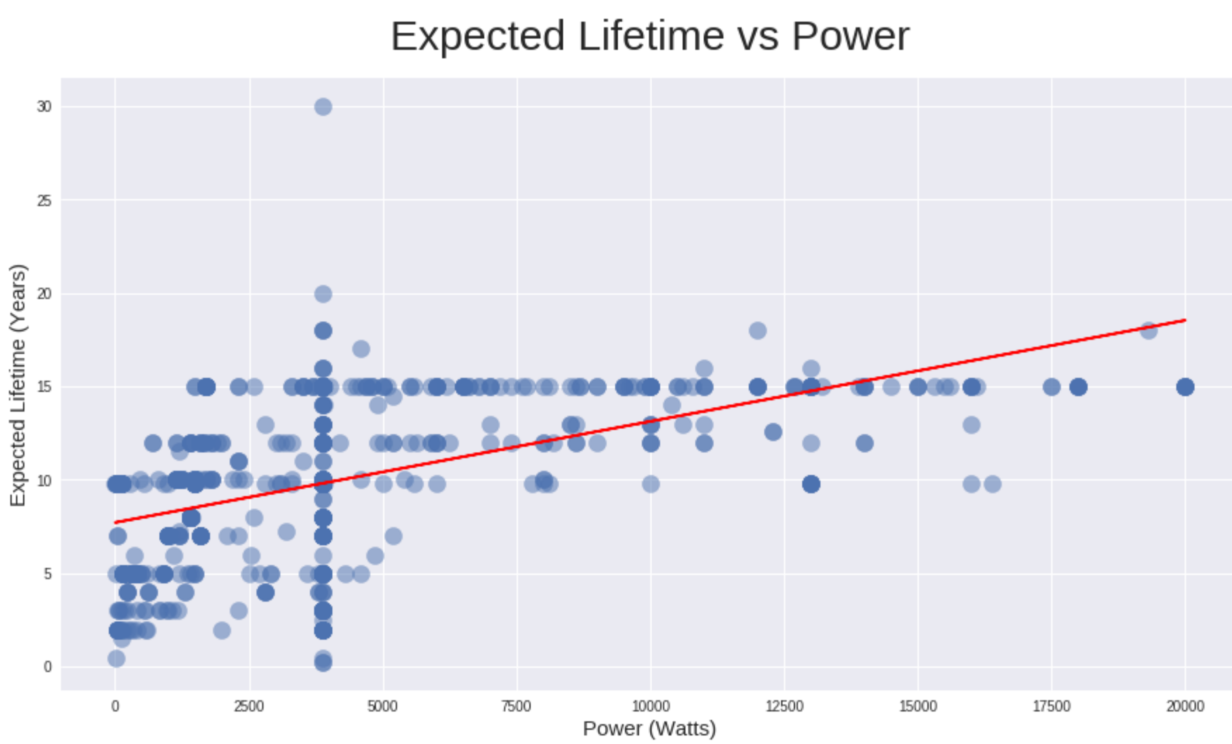

Figure 9: Expected lifetime in years plotted against power used by the satellite in Watts

6 Results and Conclusions

The conducted correlation test yielded a p-value of $5.2985026405101416 \times 10^{-80}$. Since the p-value is less than the significance level of 0.05, we are able to reject the null hypothesis at the 95% confidence level. There is sufficient evidence to conclude there is a significant linear relationship between power and expected lifetime because the correlation coefficient is significantly different from zero.

This finding is both robust and relevant. It makes sense that you would have a more powerful source to supply a mission in order for its lifetime to be optimized. On the other hand, if the mission is shorter, or in a lower orbit, not as much power would be demanded to support it for the duration of its flight.

This test shows the connections between the different subsystems of a satellite that enable a mission to continue for the duration of its desired lifetime. Throughout the various data analyses conducted throughout this project, I was able to apply what I'm learning in the aerospace engineering curriculum to a deeper statistical understanding with data science. I took each concept covered throughout ATMS 305 and used it in some capacity to learn more about my chosen dataset. A consolidated list of all the concepts used throughout this project include, but are not limited to, Cartopy, matplotlib, hypothesis testing, linear regression, and an abundance of built-in Python and Pandas functions and packages.

References

[1] Grimwood, T., "Active Satellites in Orbit Around Earth," Union of Concerned Scientists, https://www.kaggle.com/ucsusa/active-satellites.

[2] "Laboratory for Advanced Space Systems at Illinois," Department of Aerospace Engineering, https://aerospace.illinois.edu/research/research-facilities/laboratory-advanced-space-systems-illinois-lassi.

[3] "Satellite Development Organization at the University of Illinois at Urbana-Champaign," http://satdev.ae.illinois.edu/.