IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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Executive Summary

Collected data from SpaceX API and Wikipedia page. Created labels column ‘class,’ which classifies successful landings. Explored data using SQL, visualization, folium maps, and dashboards. Gathered relevant columns to be used as features and changed all categorical variables to binary using one hot encoding. Standardized data and GridSearchCV were used to find the best parameters for machine learning models and finally visualize the accuracy score of all models.

Four machine learning models were used: Decision Tree Classifier, Logistic Regression, Support Vector Machine, and K Nearest Neighbors. All made similar results with an accuracy rate of about 83.3%.

Introduction

The objective is to evaluate the viability of the new company Space Y to compete with Space X.

What we are looking for:

1. The best way to estimate the total cost for launches, by predicting successful landings of the first stage of rockets;
2. Find the best locations for a possible launch that won't negatively affect the rocket's launch sequence and landing.

Section 1

Methodology

Methodology

1. Data collection methodology:
   - Combine data from SpaceX API and SpaceX Wikipedia page
2. Data wrangling:
   - Classify true landings as successful and unsuccessful otherwise
3. Exploratory data analysis (EDA) using visualization and SQL
4. Interactive visual analytics using Folium and Plotly Dash
5. Predictive analysis using classification models:
   - Tuned models using GridSearchCV

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Data Collection

1. To collect all the data, we needed about SpaceX launches, we pulled info from both the SpaceX API and Wikipedia. We used API requests from SpaceX's REST API (at https://api.spacexdata.com/v4/rockets/) to grab data points like Flight Number, Date, Booster Version, Payload Mass, Orbit, Launch Site, Outcome, and more.

2. To make sure we covered everything, we scraped some extra details from the SpaceX Wikipedia page (https://en.wikipedia.org/wiki/List_of_Falcon_9_and_Falcon_Heavy_launches). This allowed us to use data like Flight No., Launch site, Payload, Payload Mass, Orbit, Customer, Launch outcome, and more info to look at all the launches.

Data Collection – SpaceX API

1. SpaceX provides a public API that allows easy access to their launch data, which can then be processed and analyzed. Using this API, we followed a straightforward method to collect and clean the data.

2. The API request first pulls comprehensive information about all launches, after which we focus on filtering out only the Falcon 9 launches for a more specific analysis. Finally, we handle any missing values to ensure a complete dataset.

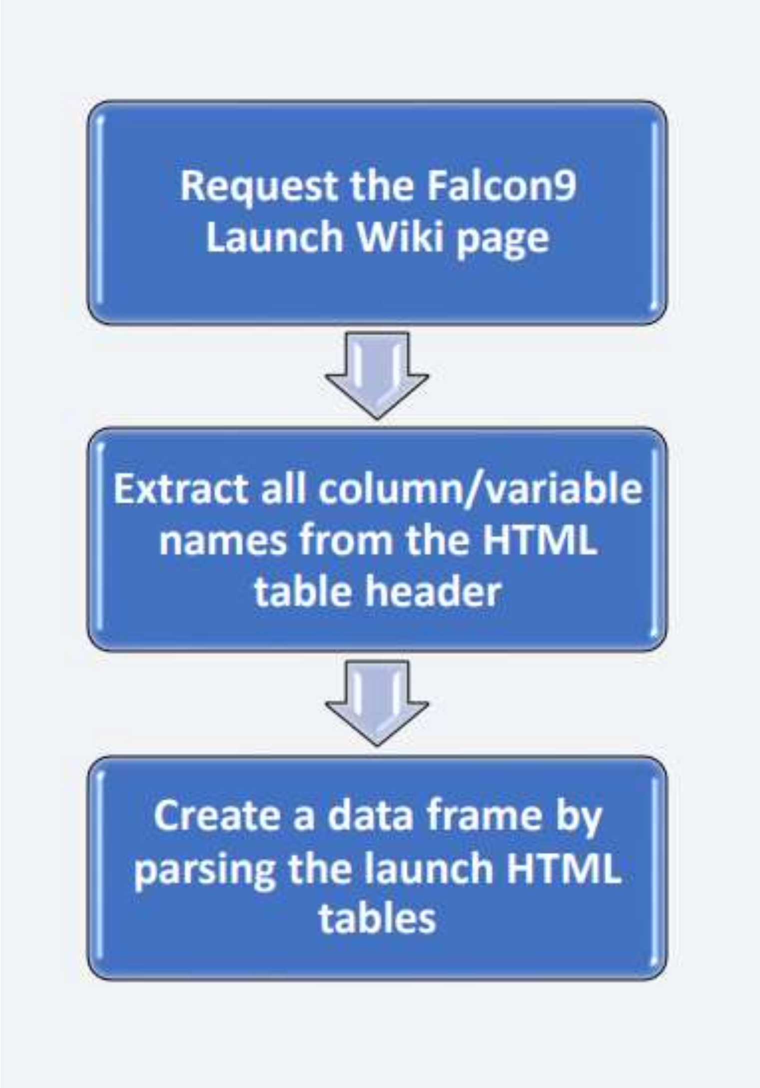
https://github.com/Cookie579/Coursera/blob/main/Data%20Collection%20API.ipynb

Data Collection - Scraping

1. In addition to the SpaceX API, extra launch data can be found by scraping the Wikipedia page for Falcon 9 launches. This page has detailed tables that show more data for each mission, such as payload, launch site, customer, and outcomes. By scraping this data, we can fill in additional variables that aren't available through the SpaceX API.

2. We begin by requesting the Wikipedia page, then parsing the HTML to extract all relevant column headers, followed by creating a structured data frame to hold the information. This data frame can then be saved for analysis.

https://github.com/Cookie579/Coursera/blob/main/Data%20Collection%20with%20Web%20Scraping.ipynb



Data Wrangling

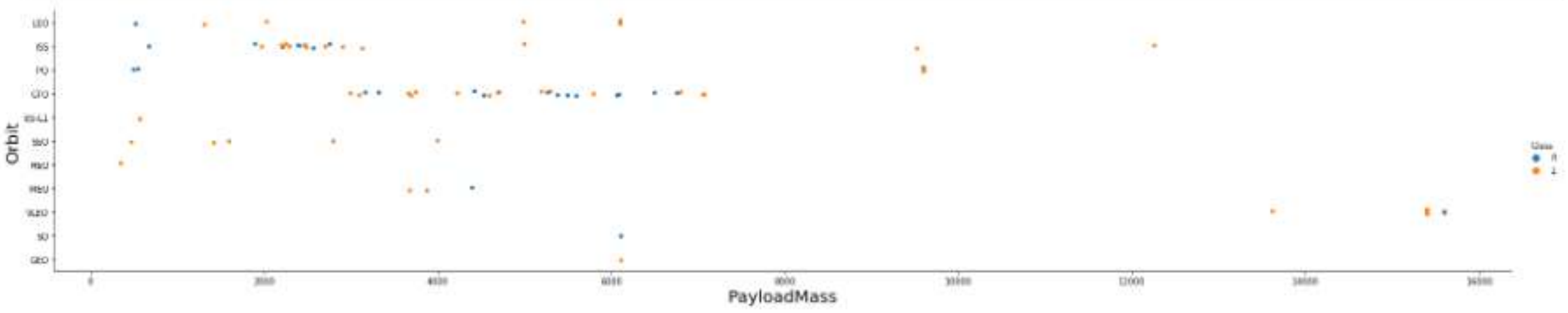
For this part, we need to create a classification label for each SpaceX launch, showing if the landing was successful or not. This will help us train a machine learning model to predict the success of future landings based on our certain launch parameters. We used a value of **1 for successful landings** and **0 for unsuccessful ones**.

Value Mapping:

The **Outcome** column contains two key components: **'Mission Outcome'** and **'Landing Location'**. Based on these, we can see the success or failure of each landing:

1. **True ASDS**: The booster successfully landed on an Autonomous Spaceport Drone Ship (ASDS). These landings are very challenging, as the ship is in the ocean to allow for a safe recovery of the rocket.
2. **True RTLS**: The booster successfully performed a **Return to Launch Site** (RTLS) landing, where it comes back to the launch site on land. This type of landing is used for lower-altitude missions, where the rocket can safely return.
3. **True Ocean**: In some cases, the rocket lands in the ocean without a platform. A **True Ocean** landing is a planned or successful splashdown without a platform.
4. **None**: None means there was no landing attempt made, or the mission didn't involve a landing. We consider this as unsuccessful, as it does not contribute to a proper recovery.
5. **False ASDS, False RTLS, False Ocean**: When the mission outcome is marked as **False** for any of the landing types, it means the landing attempt failed.

https://github.com/Cookie579/Coursera/blob/main/Data%20Collection%20API.ipynb



You should observe that Heavy payloads have a negative influence on GTO orbits and positive on GTO and Polar LEO (ISS) orbits.

EDA with Data Visualization

1. To explore the data, we used scatterplots and bar plots to visualize the relationship between the following relationships:
2. We plotted Payload Mass v. Flight Number, Launch Site v. Flight Number, Launch Site v. Payload Mass, Orbit v. Flight Number, Payload v. Orbit
3. Scatter plots in particular help show the relationships between variables; if a trend exists, it could be used in our machine learning model

https://github.com/Cookie579/Coursera/blob/main/EDA%20with%20Data%20Visualization.ipynb

EDA with SQL

We then loaded the dataset the IBM DB2 Database, and executed SQL queries with Python explore and analyze the data. We analyzed launch site names, mission outcomes, payload sizes, customer details, booster versions, and landing outcomes. SQL Queries:

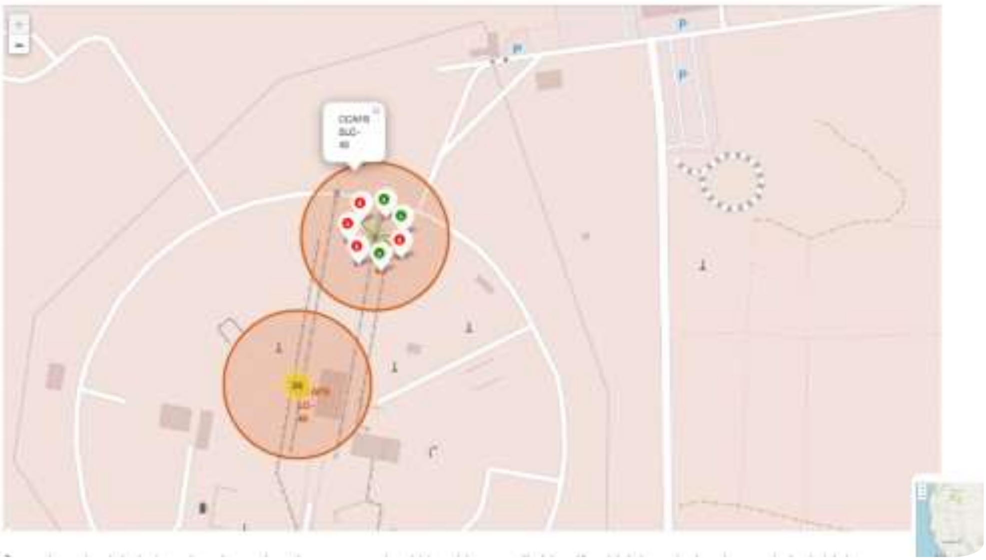
1. Displayed the unique names of launch sites involved in the space missions.
2. Retrieved 5 records where launch site names begin with 'CCA.'
3. Calculated the total payload mass for boosters launched by NASA (CRS).
4. Calculated the average payload mass carried by the booster version F9 v1.1.
5. Identified the date of the first successful ground pad landing.
6. Listed boosters that achieved successful drone ship landings with payloads between 4000 and 6000 kg.
7. Counted the total number of successful and failed mission outcomes.
8. Identified the booster versions that carried the maximum payload mass.
9. Listed failed drone ship landing outcomes with booster versions and launch site names for 2015.
10. Ranked landing outcomes, such as Failure (drone ship) or Success (ground pad), from 2010-06-04 to 2017-03-20 in descending order.

https://github.com/Cookie579/Coursera/blob/main/EDA%20with%20SQL.ipynb

Out[61]:

landing__outcome	COUNT
No attempt	10
Failure (drone ship)	5
Success (drone ship)	5
Controlled (ocean)	3
Success (ground pad)	3
Failure (parachute)	2
Uncontrolled (ocean)	2
Precluded (drone ship)	1

Build an Interactive Map with Folium



We then used Folium maps to mark all SpaceX launch sites, showing successful and unsuccessful landings, important regions, and infrastructure like railways, highways, the coast, and nearby cities. Markers were added with circles, popup labels, and text labels for each launch site, including the NASA Johnson Space Center.

Markers for Launch Sites: Displayed with circles and labeled with the launch site names, it allows easy identification of geographical locations and their proximity to the equator and coasts.

Colored Markers for Launch Outcomes: Successes are marked in green, while failures are marked in red, allowing for the visual comparison of success rates at each launch site using marker clusters.

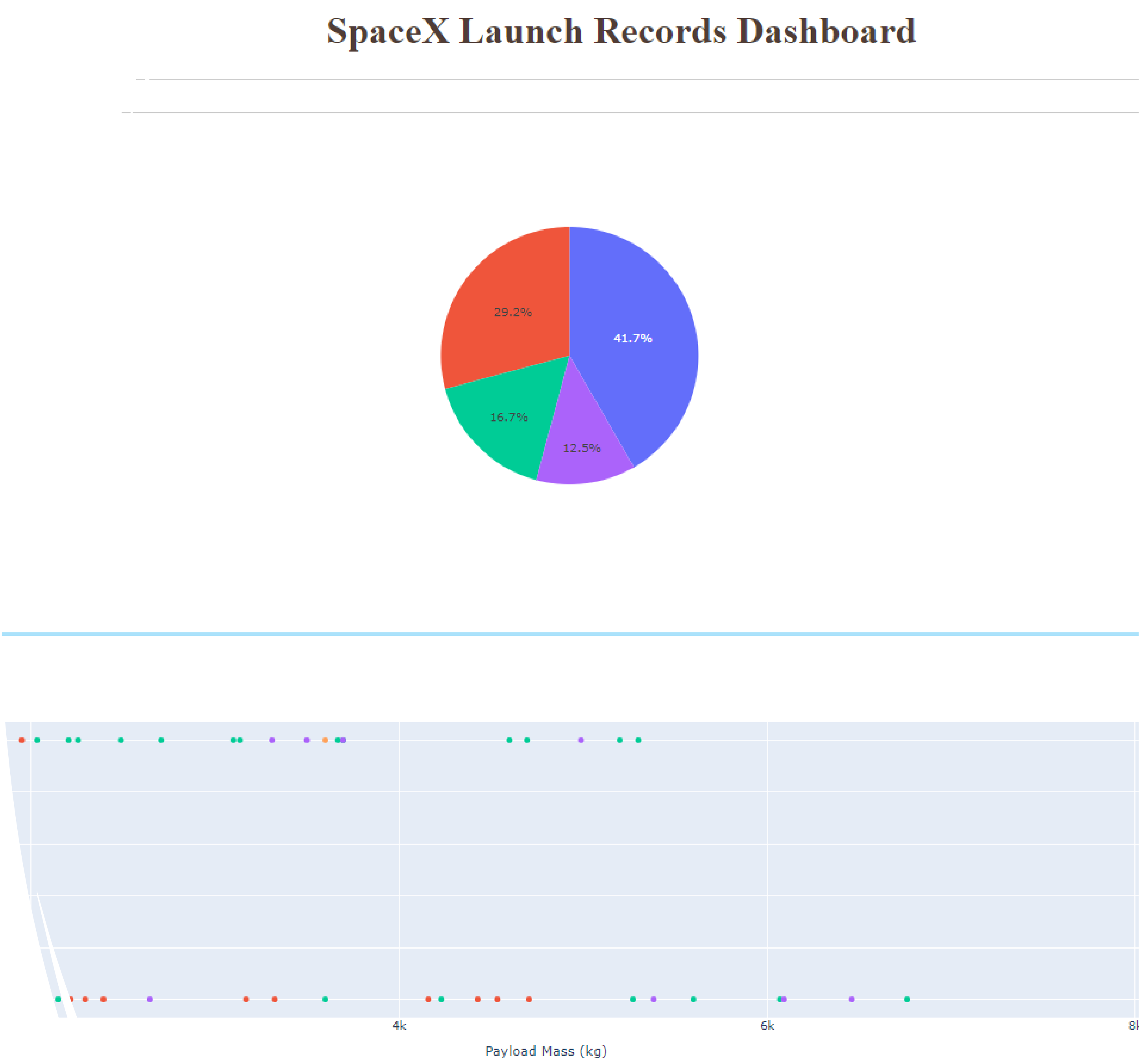
Distance Lines: We drew Lines from the KSC LC-39A launch site to nearby areas like the Railway, Highway, Coastline, and Closest City to give us a better understanding of why launch sites may be strategically located where they are and visualize a relationship between success and each location.

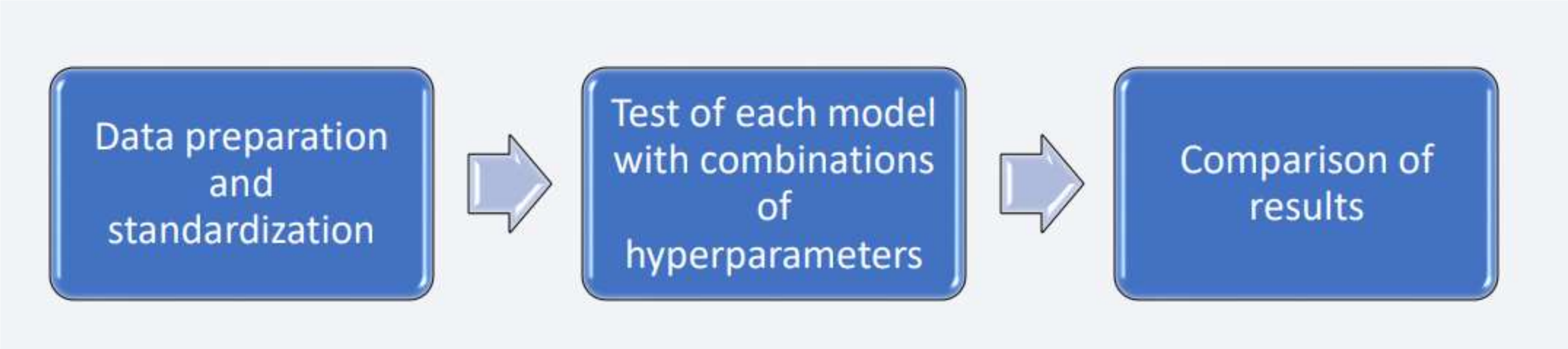
https://github.com/Cookie579/Coursera/blob/main/Interactive%20Visual%20Analytics%20with%20Folium%20lab%20(1).ipynb

Build a Dashboard with Plotly & Dash

1. Dashboard includes a pie chart and a scatter plot.
2. Pie chart can be selected to show distribution of successful landings across all launch sites and can be selected to show individual launch site success rates.
3. Scatter plot takes two inputs: All sites or individual site and payload mass on a slider between 0 and 10000 kg.
4. The pie chart is used to visualize launch site success rate.
5. The scatter plot can help us see how success varies across launch sites, payload mass, and booster version category.

https://github.com/Cookie579/Coursera/blob/main/spacex_dash_app%20(1).py





Predictive Analysis (Classification)

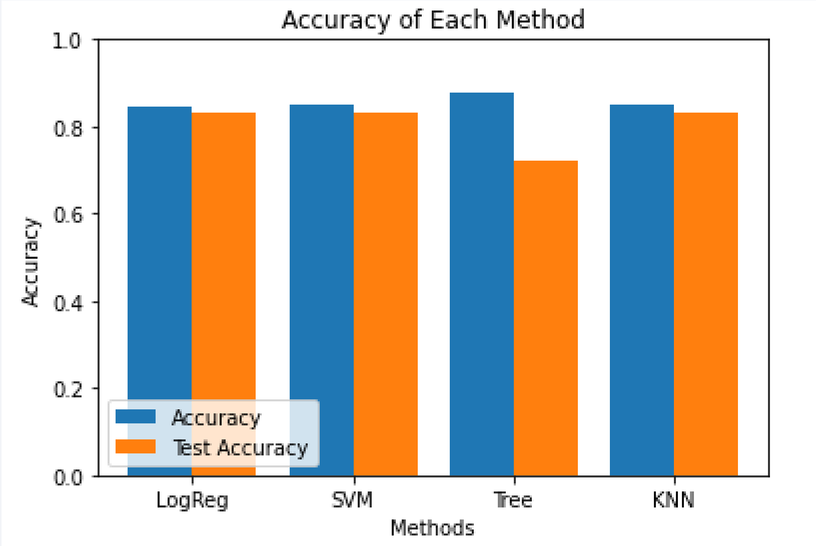
Four classification models were used:

1. Logistic Regression
2. Support Vector Machine
3. Decision Tree
4. K Nearest Neighbors (KNN).

https://github.com/Cookie579/Coursera/blob/main/Machine%20Learning%20Prediction.ipynb

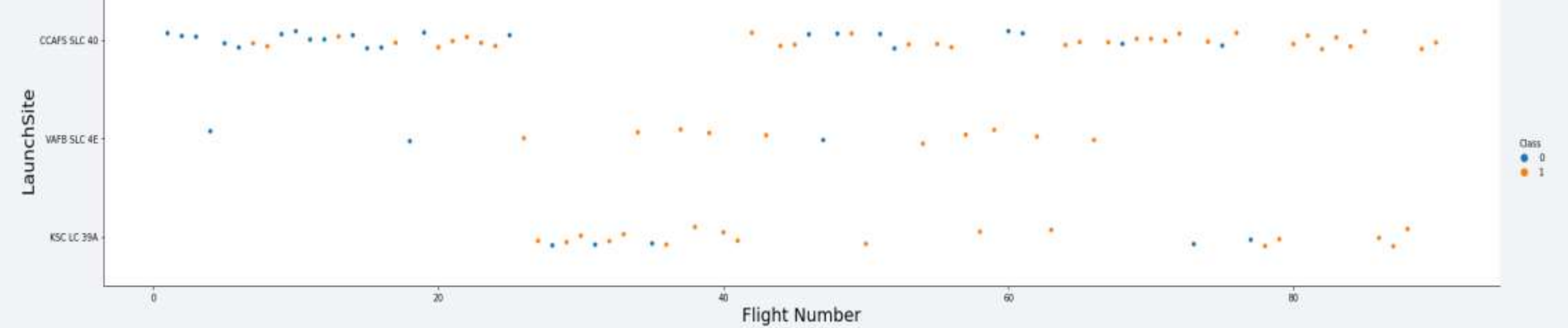
Results

1. Using interactive analytics, it is possible to identify that launch sites incorporate safety zones, are near the sea, have good logistic infrastructure etc...
2. We can see that most launches happen on the east cost launch sites.
3. Predictive Analysis showed that Decision Tree Classifier is the best model to predict successful landings, having an accuracy over 87% and for test data around 94%



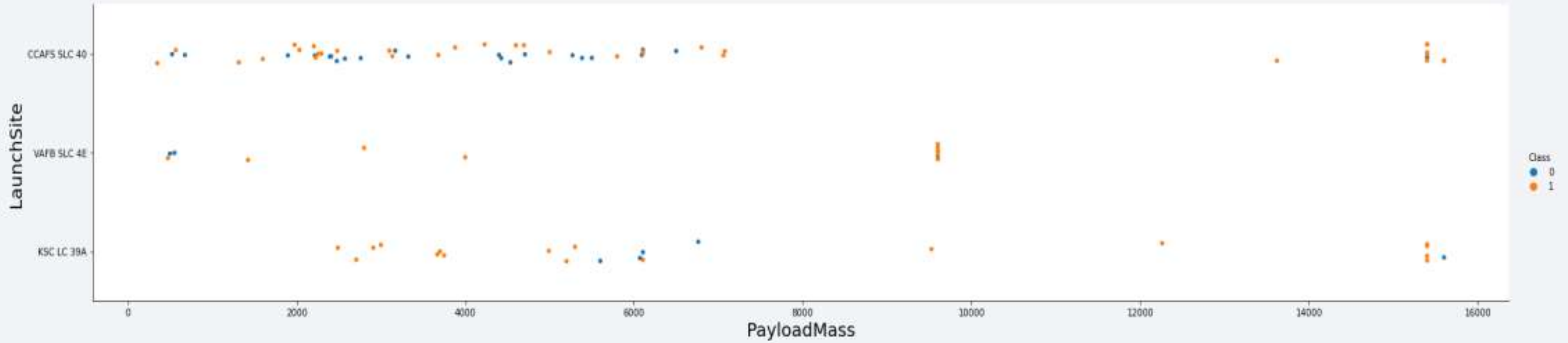
Section 2

Insights drawn from EDA



Flight Number vs. Launch Site

1. According to the plot above, it's possible to verify that the best launch site currently used is CCAF5 SLC 40, as that's where the most recent launches were successful
2. In second place is VAFB SLC 4E, third place is KSC LC 39A
3. We can also see that the general success rate improved over time.



Payload vs. Launch Site

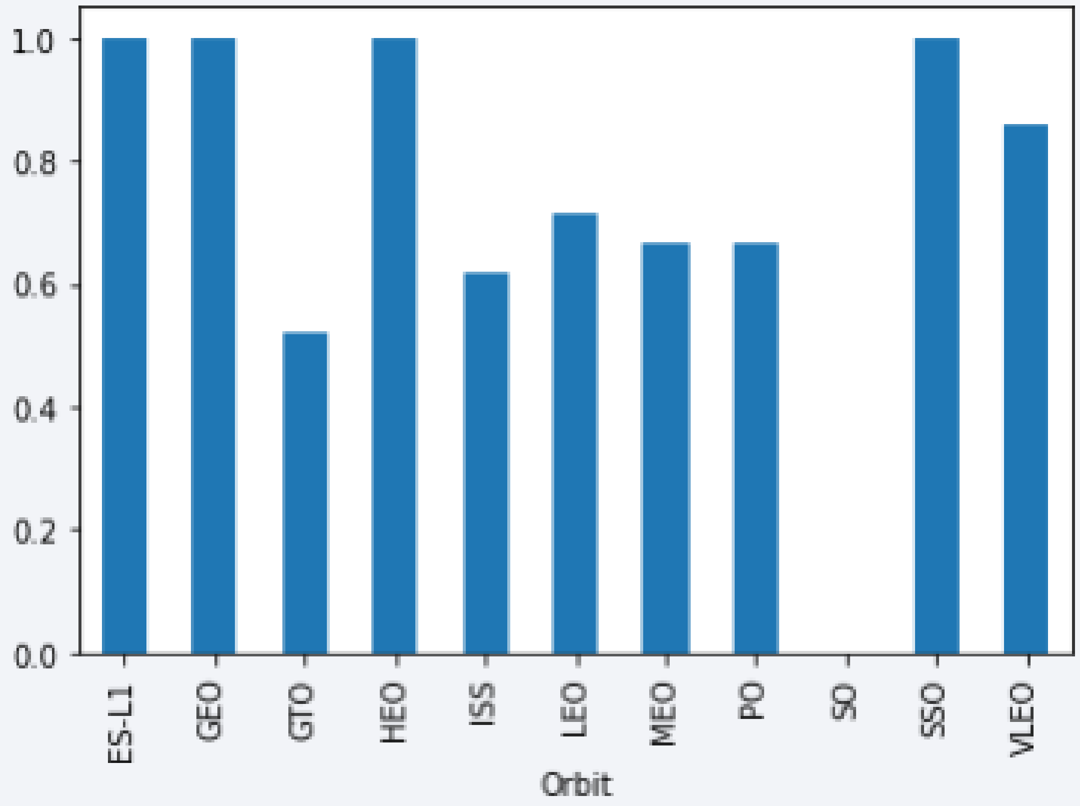
1. Payloads over 9,000kg have excellent success rate

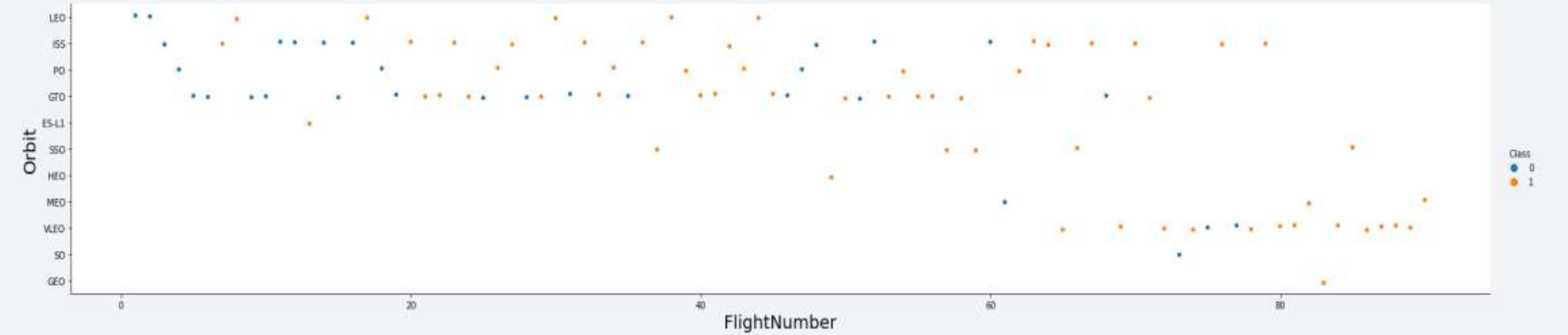
2. Payloads over 12,000kg seems to be possible only at CCAFS SLC 40 and KSC LC 39A launch sites.

Success Rate vs. Orbit Type

1. The biggest success rates happens in orbits:
    - ES-L1
    - GEO
    - HEO
    - SSO

2. Followed By:
    - VLEO (above 80%)
    - LFO (above 70%)

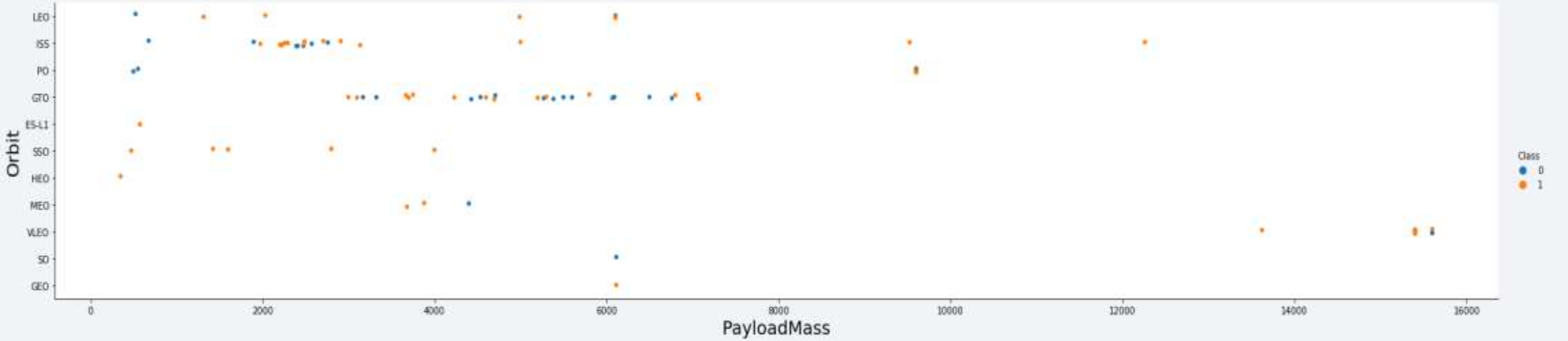




Flight Number vs. Orbit Type

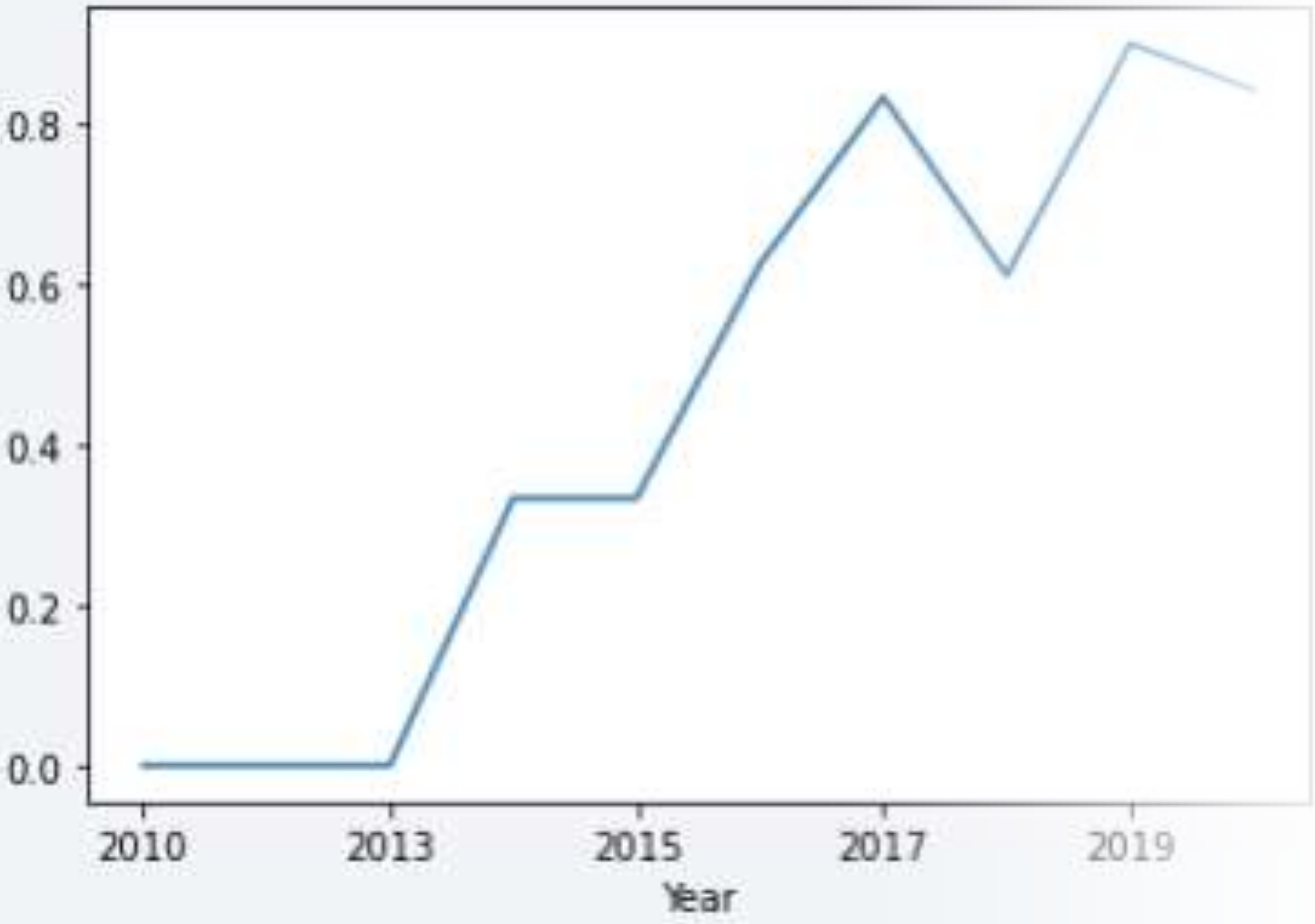
1. Clear improvement in success rate because of technological advancement

2. Looking at the sudden increase in VLEO orbits we can see it as a new business opportunity



Payload vs. Orbit Type

1. Looking at the data we can see there is no relation between payload and success rate to orbit GTO
2. ISS orbit has the widest range of payload and a decent rate of success
3. There are very few launches to the orbits SO and GEO.



Launch Success Yearly Trend

1. SpaceX continually improved from 2013 onward to 2020
2. The first three years were a period of adaptation and technological advanced

All Launch Site Names

1. According to data, there are four launch sites:

Launch Site
CCAFS LC-40
CCAFS SLC-40
KSC LC-39A
VAFB SLC-4E

2. They are obtained by selecting unique occurrences of “launch_site” values from the dataset.

Launch Site Names Begin with 'CCA'

1. 5 records where launch sites begin with “CCA”:

Date	Time UTC	Booster Version	Launch Site	Payload	Payload Mass kg	Orbit	Customer	Mission Outcome	Landing Outcome
2010-06-04	18:45:00	F9 v1.0 B0003	**CCA**FS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-12-08	15:43:00	F9 v1.0 B0004	**CCA**FS LC-40	Dragon demo flight C1, two CubeSats, barrel of Brouere cheese	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2012-05-22	07:44:00	F9 v1.0 B0005	**CCA**FS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	00:35:00	F9 v1.0 B0006	**CCA**FS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-03-01	15:10:00	F9 v1.0 B0007	**CCA**FS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attemp

2. Here we can see five samples of Cape Canaveral launches

Total NASA & Average F9 v1.1 Payload Mass

NASA

1. Total payload carried by boosters from NASA:

Total Payload (kg)
111.268

2. Total payload calculated above; by summing all payloads whose codes contain ‘CRS’, which corresponds to NASA.

F9 v1.1

1. Average payload mass carried by booster version F9 v1.1:

Avg Payload (kg)
2.928

2. Filtering data by the booster version above and calculating the average payload mass we obtained the value of 2,928 kg.

First Successful Ground Landing Date

1. First successful landing outcome on ground pad:

Min Date
2015-12-22

1. By filtering data by successful landing outcome on ground pad and getting the minimum value for date it's possible to identify the first occurrence, that happened on 12/22/2015.

Successful Drone Ship Landing with Payload between 4000 and 6000

1. Boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 6000

Booster Version
F9 FT B1021.2
F9 FT B1031.2
F9 FT B1022
F9 FT B1026

2. Selecting distinct booster versions according to the filters above, these 4 are the result.

Total Number of Successful and Failure Mission Outcomes

1. Number of successful and failure mission outcomes:

Mission Outcome	Occurrences
Success	99
Success (payload status unclear)	1
Failure (in flight)	1

2. Grouping mission outcomes and counting records for each group led us to the summary above. Total Number of Successful and Failure Mission Outcomes

Boosters Carried Maximum Payload

1. Boosters which have carried the maximum payload mass

Booster Version (...)
F9 B5 B1048.4
F9 B5 B1048.5
F9 B5 B1049.4
F9 B5 B1049.5
F9 B5 B1049.7
F9 B5 B1051.3

Booster Version
F9 B5 B1051.4
F9 B5 B1051.6
F9 B5 B1056.4
F9 B5 B1058.3
F9 B5 B1060.2
F9 B5 B1060.3

2. These are the boosters which have carried the maximum payload mass registered in the dataset.

2015 Launch Records

1. Failed landing outcomes in drone ship, their booster versions, and launch site names for in year 2015

Booster Version	Launch Site
F9 v1.1 B1012	CCAFS LC-40
F9 v1.1 B1015	CCAFS LC-40

2. The list above has the only two occurrences

Rank Landing Outcomes Between 2010-06-04 and 2017-03-20

1. Ranking of all landing outcomes between the date 2010-06-04 and 2017- 03-20:

Landing Outcome	Occurrences
No attempt	10
Failure (drone ship)	5
Success (drone ship)	5
Controlled (ocean)	3
Success (ground pad)	3
Failure (parachute)	2
Uncontrolled (ocean)	2
Precluded (drone ship)	1

2. This view of data shows us that “No attempt” outcomes must also be taken in account.

Section 3

Launch Sites Proximities Analysis

Launch Sites

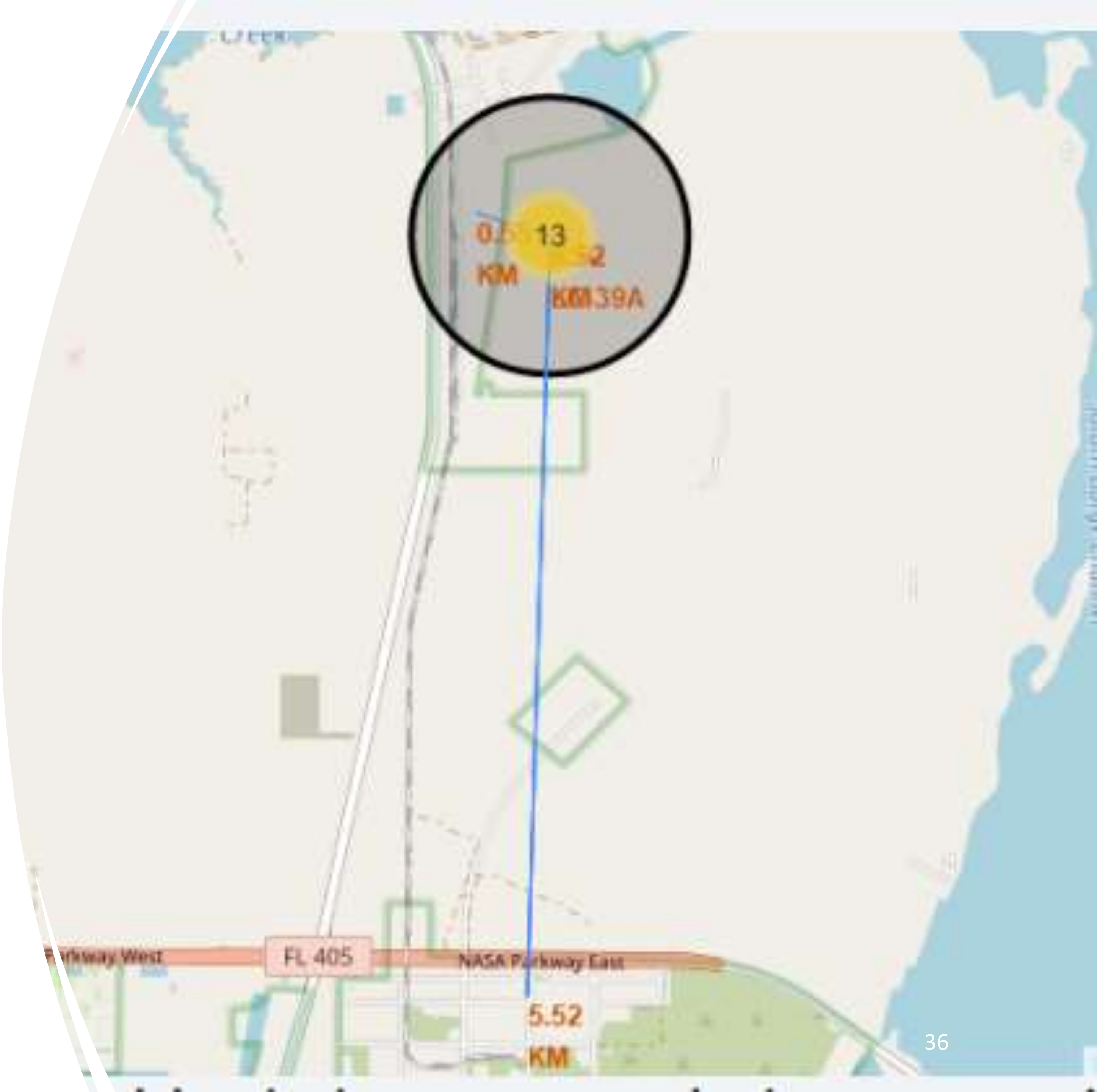
Launch sites are near to the sea for safety, but also stay close to necessary infrastructure like roads and railroads.

Launch Outcomes by Site

Green markers indicate successful launches and red ones indicate failed outcomes.

Logistics and Safety

Launch site KSC LC-39A has good logistics, being near railroad and road and relatively far from inhabited areas.

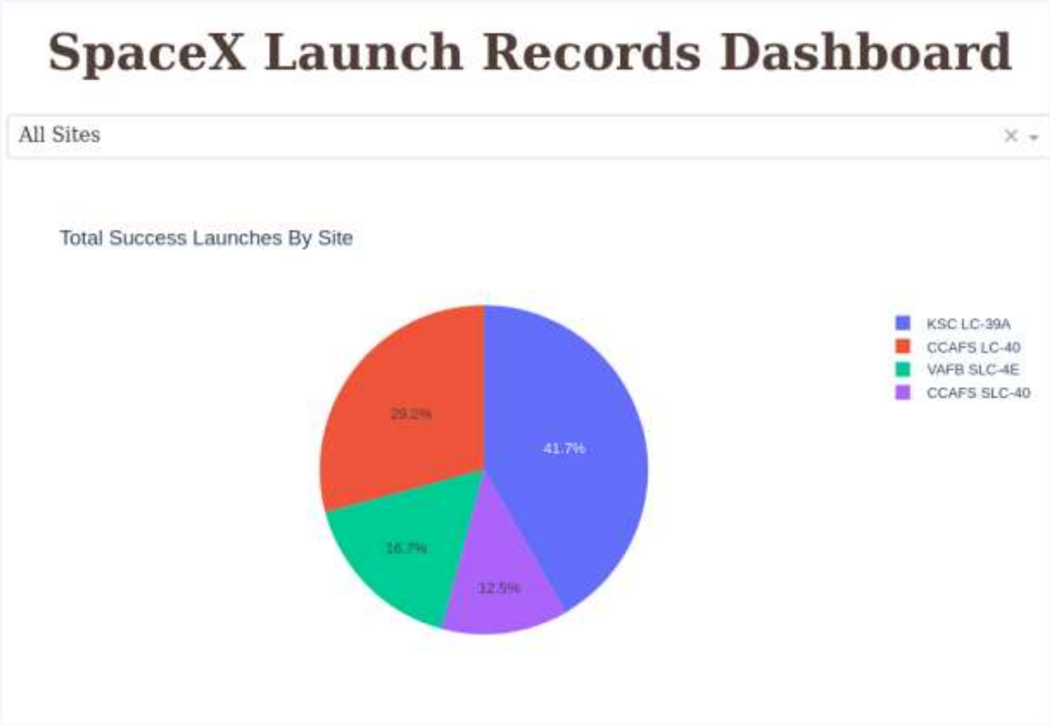


Section 4

Build a Dashboard with Plotly Dash

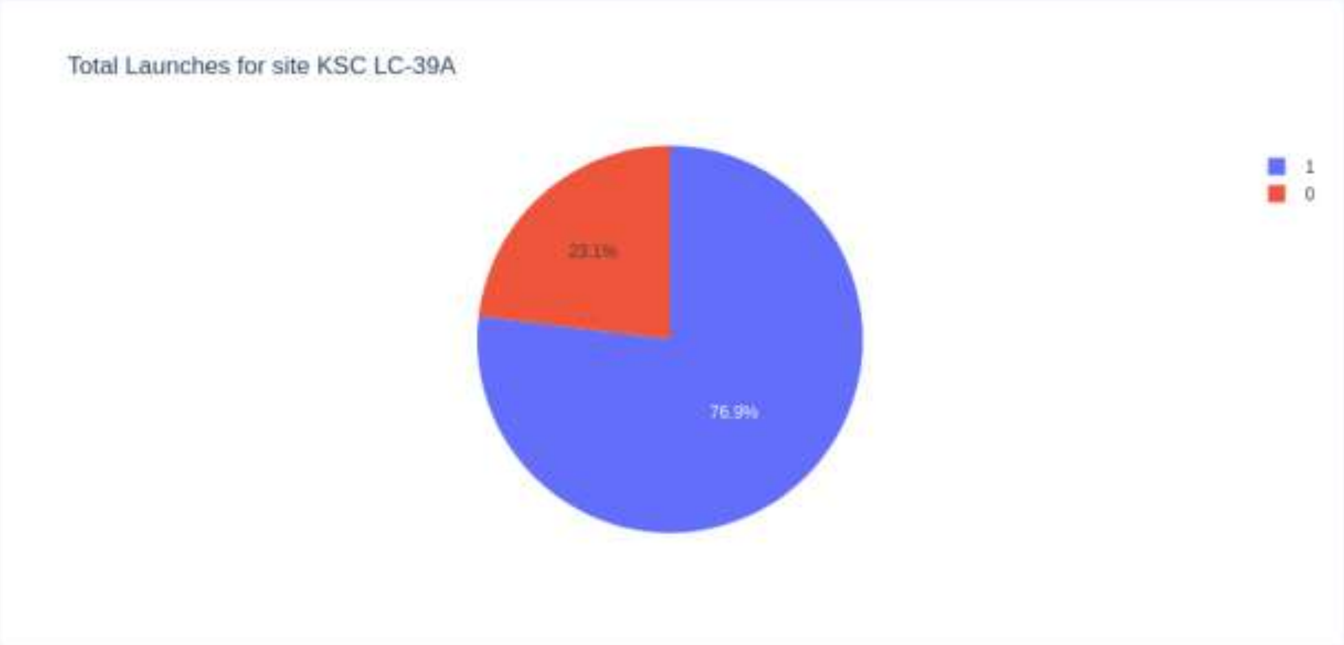
SpaceX Launch Records

We can see that launches are a critical factor in the success of a rocket launch



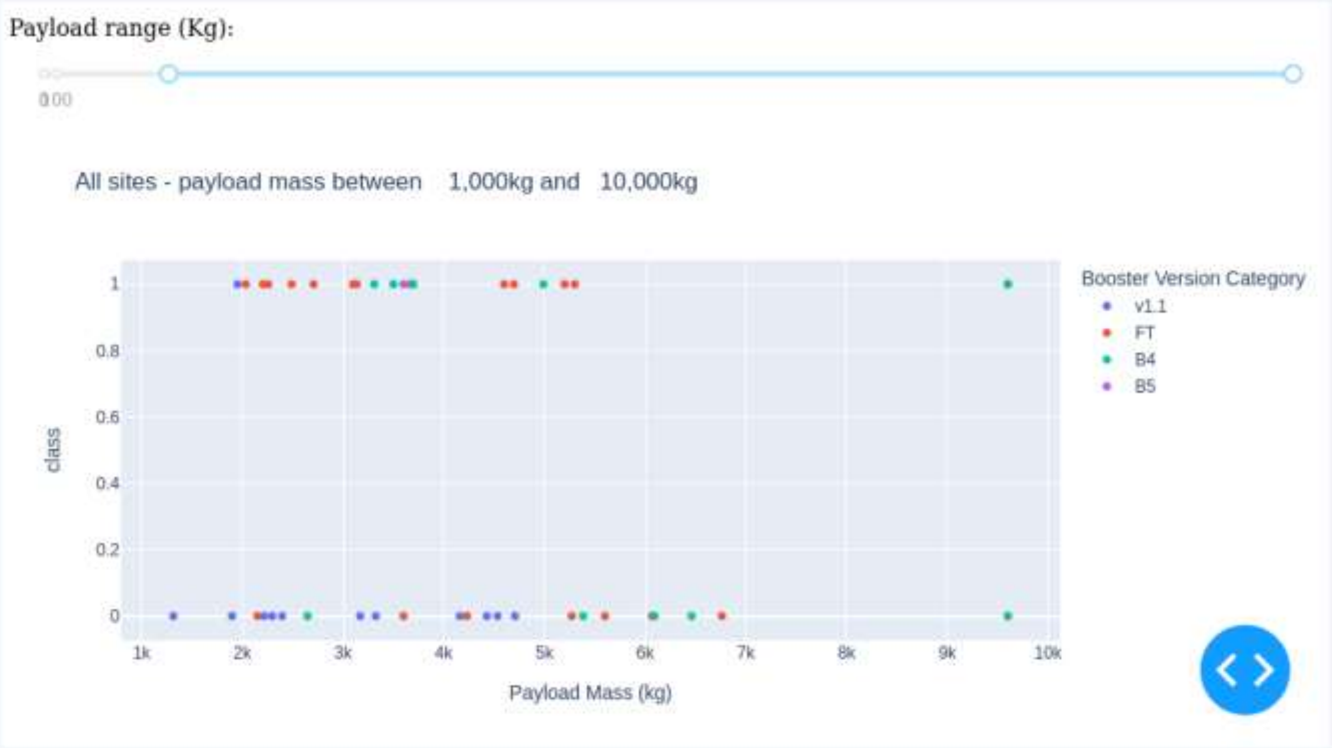
Launch Success Ratio for KSC LC-39A

76.9% of launches are successful at KSC LC-39A



Payload vs. Launch Outcome

Payloads under 6,000kg and FT boosters are the most successful combination.



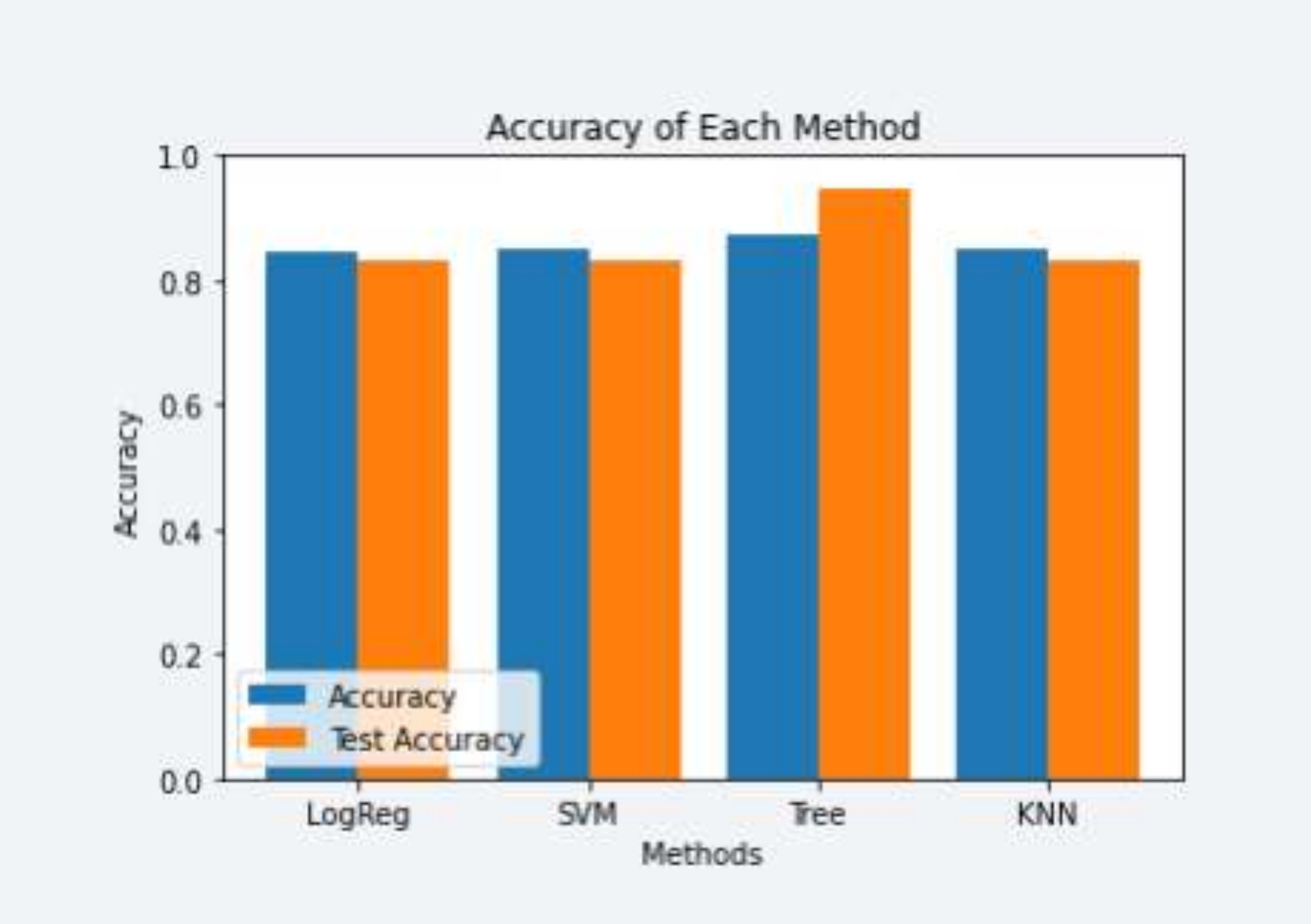
Section 5

Predictive Analysis (Classification)

Classification Accuracy

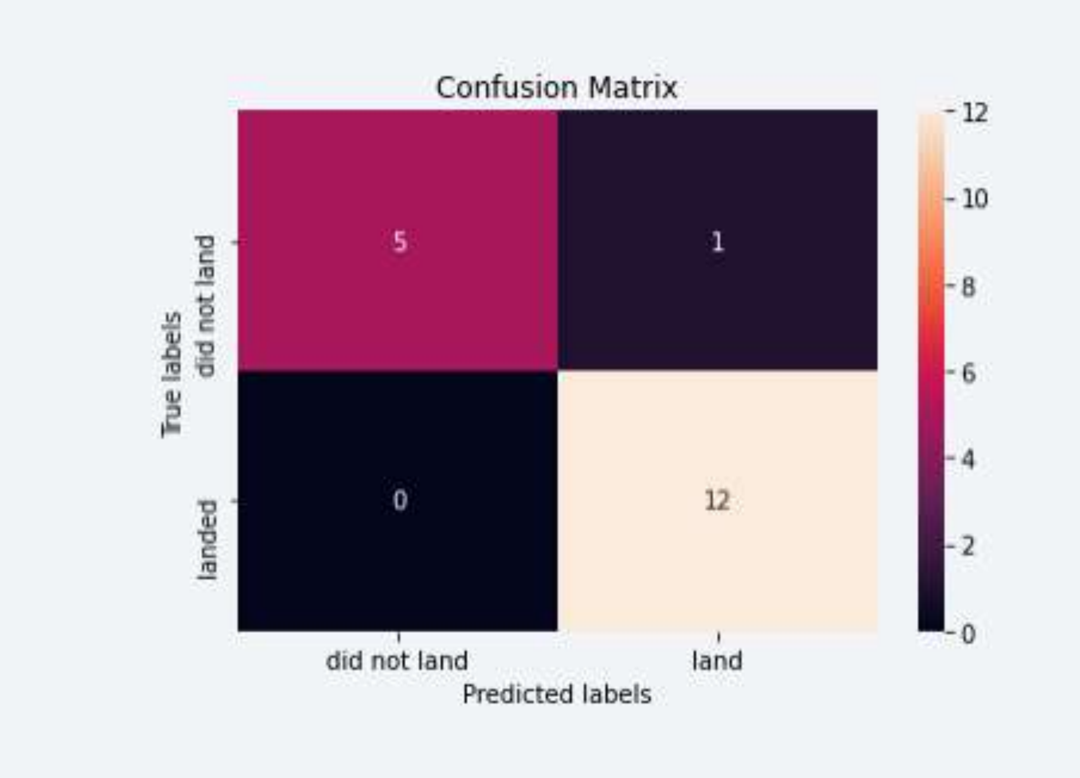
1. Four classification models were tested, and their accuracies are plotted beside. We tested all 4 methods the entire dataset to get a clearer picture

2. Looking at the graph we can see that the model with the highest classification accuracy is Decision Tree Classifier, which has accuracies over than 87%.



Confusion Matrix

Looking at the confusion matrix of Decision Tree Classifier we prove its accuracy by showing the big numbers of true positive and true negative compared to the false ones.



Conclusions

- The Decision Tree model clearly was the best for this dataset
- Launches with lighter payloads tend to have higher success rates compared to the heavier ones
- Most launch sites are close to the Equator, and all are near the coast
- The success rate of launches has improved over time reflection technological advancement
- The KSC LC-39A site has the highest success rate among all launch sites
- Orbits like ES-L1, GEO, HEO, and SSO all have 100% success rates

Thank you!

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