IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

Executive Summary

- **Summary of Methodologies:**
  - Data was collected using a RESTful API and web scraping techniques.
  - Preprocessing and data cleaning were performed to prepare the dataset.
  - Exploratory Data Analysis (EDA) was conducted to identify patterns and insights.
  - Machine learning models (Logistic Regression, SVM, Decision Trees, KNN) were applied to predict the Falcon 9 first-stage landing success.

- **Summary of All Results:**
  - All models (Logistic Regression, SVM, KNN, Decision Trees) achieved an accuracy of 0.83, indicating equal performance across all models.
  - No single model outperformed the others, meaning the dataset does not favor a specific approach.
  - Further analysis or feature engineering may be needed to differentiate model performance.

Introduction

- This project aims to predict the success of Falcon 9's first-stage landing.
- SpaceX offers Falcon 9 rockets at a cost of $62 million, while other companies charge upwards of $165 million for each launch.
- A significant portion of SpaceX's savings comes from the ability to reuse the first stage, allowing them to offer much lower prices compared to competitors.

Problems You Want to Find Answers:

- Can we predict the success of the Falcon 9 first-stage landing?
- What factors influence the success of the first-stage landing?
- How can this prediction be used to improve pricing strategies for competing companies?

Section 1

Methodology

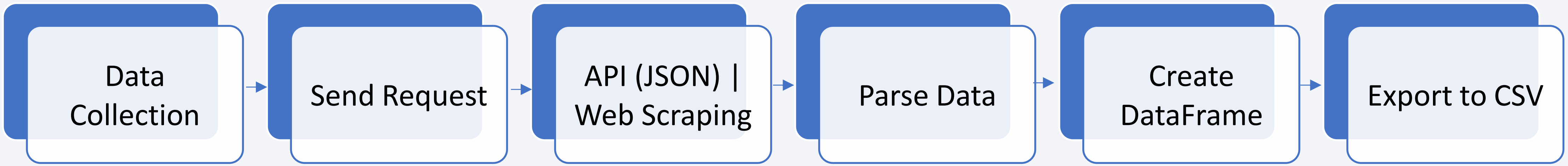
Methodology

Executive Summary

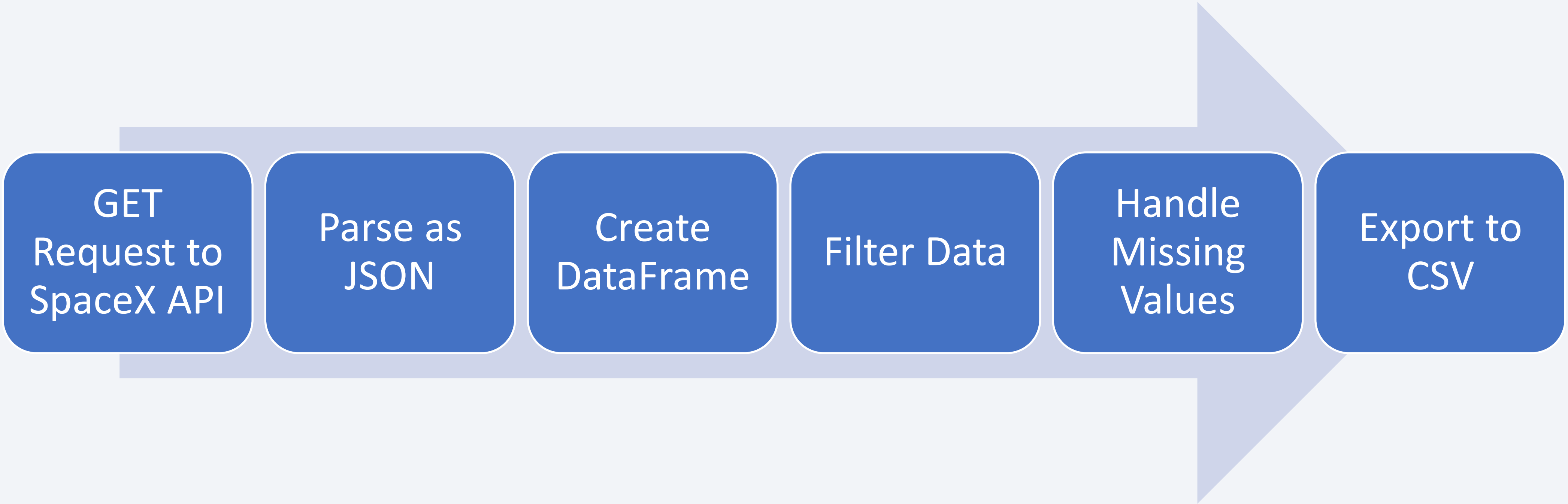
- Data collection methodology:
  - Fetched Falcon 9 and Falcon Heavy launch data using web scraping and SpaceX API.
- Perform data wrangling
  - Perform exploratory data analysis (EDA) and determine appropriate training labels.
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - Tune hyperparameters for SVM, KNN, Decision Trees and Logistic Regression.
  - Evaluate and identify the best model using test data.

Data Collection

In this step, we collect data on Falcon 9 rocket launches using two methods: the **SpaceX API** and **Web Scraping**. The API provides launch data in JSON format, while Web Scraping allows us to extract structured data from HTML tables on relevant web pages for further analysis.

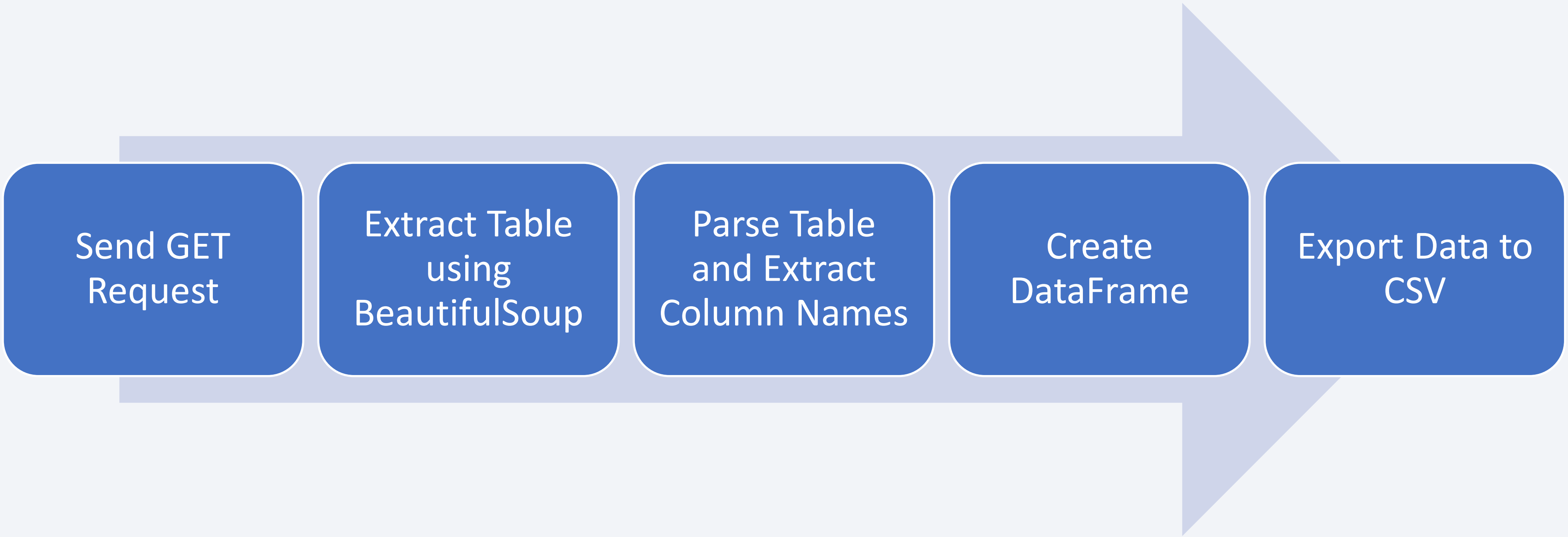


Data Collection – SpaceX API



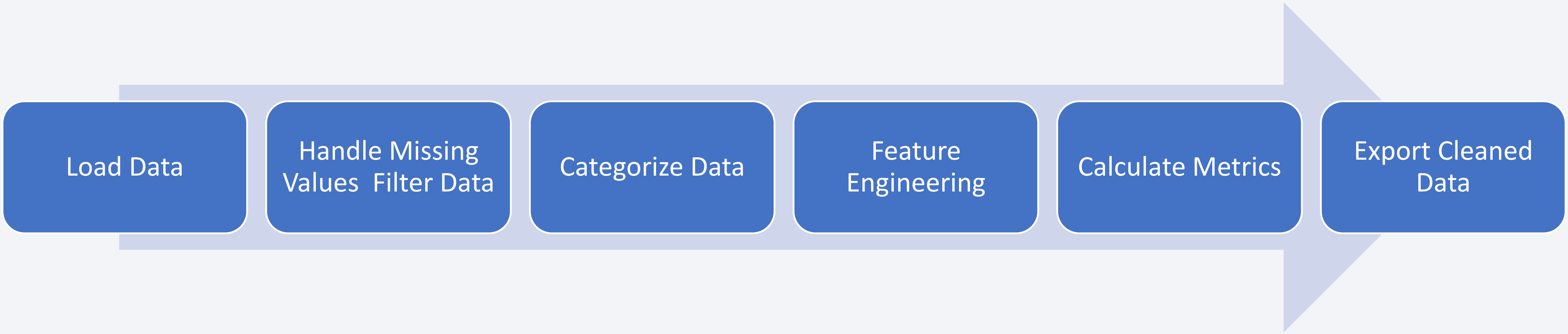
GitHub Link for the Notebooks:(SpaceX-Falcon9-Landing-Prediction/01_spacex-data-collection-api.ipynb at main · Haila-Abdullah/SpaceX-Falcon9-Landing-Prediction)

Data Collection - Scraping



GitHub Link for the Notebooks: (SpaceX-Falcon9-Landing-Prediction/02_spacex-web-scraping.ipynb at main · Haila-Abdullah/SpaceX-Falcon9-Landing-Prediction)

Data Wrangling



GitHub Link for the Notebooks: [SpaceX-Falcon9-Landing-Prediction/03_spacex_data_wrangling.ipynb at main · Haila-Abdullah/SpaceX-Falcon9-Landing-Prediction]

EDA with Data Visualization

- **Flight Number vs. Launch Site (Scatter Plot):**
  - Purpose: To explore the distribution of launches across different launch sites.
- **Payload Mass vs. Launch Site (Scatter Plot):**
  - Purpose: To analyze how payload mass correlates with launch sites.
- **Success Rate by Orbit Type (Bar Chart):**
  - Purpose: To compare success rates across different orbit types.
- **Flight Number vs. Orbit Type (Scatter Plot):**
  - Purpose: To examine the relationship between flight experience and success rates in different orbits.
- **Payload Mass vs. Orbit Type (Scatter Plot):**
  - Purpose: To understand the impact of payload mass on launch success by orbit type.
- **Yearly Launch Success Trend (Line Chart):**
  - Purpose: To track the success trend of launches over the years.

GitHub Link for the Notebooks: (SpaceX-Falcon9-Landing-Prediction/02_spacex-web-scraping.ipynb at main · Haila-Abdullah/SpaceX-Falcon9-Landing-Prediction)

EDA with SQL

- **Unique Launch Sites:** Find names of unique launch sites.
- **Launch Sites Starting with 'CCA':** Retrieve 5 records where launch sites begin with 'CCA'.
- **Payload by NASA Boosters:** Calculate total payload carried by NASA boosters.
- **Payload for F9 v1.1:** Calculate average payload mass for F9 v1.1 booster version.
- **First Successful Landing Date:** List date of the first successful landing on ground pad.
- **Boosters Landing on Drone Ship:** List boosters that successfully landed on drone ship with payload between 4000 and 6000 kg.

EDA with SQL (Continued)

- **Mission Outcomes Count:** Count total successful and failed mission outcomes.
- **Max Payload Booster Versions:** List booster versions with maximum payload mass.
- **Failure Landing Outcomes in 2015:** Retrieve records of failed drone ship landings in 2015.
- **Landing Outcomes Ranking (2010-06-04 to 2017-03-20):** Rank landing outcomes within the specified date range.

GitHub Link for the Notebooks: https://github.com/Haila-Abdullah/SpaceX-Falcon9-Landing-Prediction/blob/05792915e7b1ddea76938aa19149998b462e98f8/04_spacex-eda-sql-sqllite.ipynb

Build an Interactive Map with Folium

- **Markers:** Accurately identify launch site locations, helping to visualize their geographical positions.
- **Circles:** Show the influence areas around the sites, highlighting nearby infrastructure like coastlines and highways.
- **Lines:** Display the distances between launch sites and key proximities, making spatial relationships clearer.
- **Popups:** Provide additional information on launch success or failure, enhancing interactivity with the data.

GitHub Link for the Notebooks:[SpaceX-Falcon9-Landing-Prediction/06_launch-site-location.ipynb at main · Haila-Abdullah/SpaceX-Falcon9-Landing-Prediction]

Build a Dashboard with Plotly Dash

📊 **Pie Chart:** Displays the launch success rate for each site to compare performance.

📉 **Scatter Plot:** Analyzes the relationship between payload and launch success rate.

🔽 **Dropdown List:** Allows selecting a launch site for individual analysis.

📏 **Range Slider:** Enables selecting a payload range to study its impact on success.

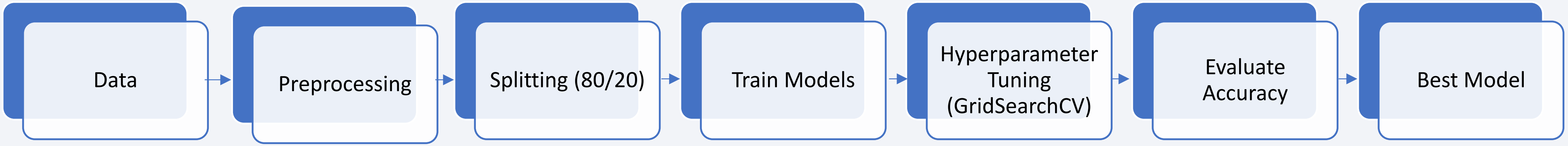
Importance of These Interactions:

- Identify the most successful launch sites.
- Analyze the impact of payload on success.
- Evaluate Falcon 9 booster performance.
- Provide a flexible and interactive analysis experience.

GitHub Link for the Notebooks:[SpaceX-Falcon9-Landing-Prediction/07_spacex-dashboard.py at main · Haila-Abdullah/SpaceX-Falcon9-Landing-Prediction]()

Predictive Analysis (Classification)

The process began with data preprocessing, which involved creating a class label column and standardizing the features. The dataset was split into 80% for training and 20% for testing. Multiple models, including SVM, KNN, Classification Trees, and Logistic Regression, were trained. Hyperparameters were tuned using GridSearchCV. Upon evaluation, all models achieved similar performance, with an accuracy of 0.83.



GitHub Link for the Notebooks:[SpaceX-Falcon9-Landing-Prediction/08_spacex-machine-learning-prediction.ipynb at main · Haila-Abdullah/SpaceX-Falcon9-Landing-Prediction]

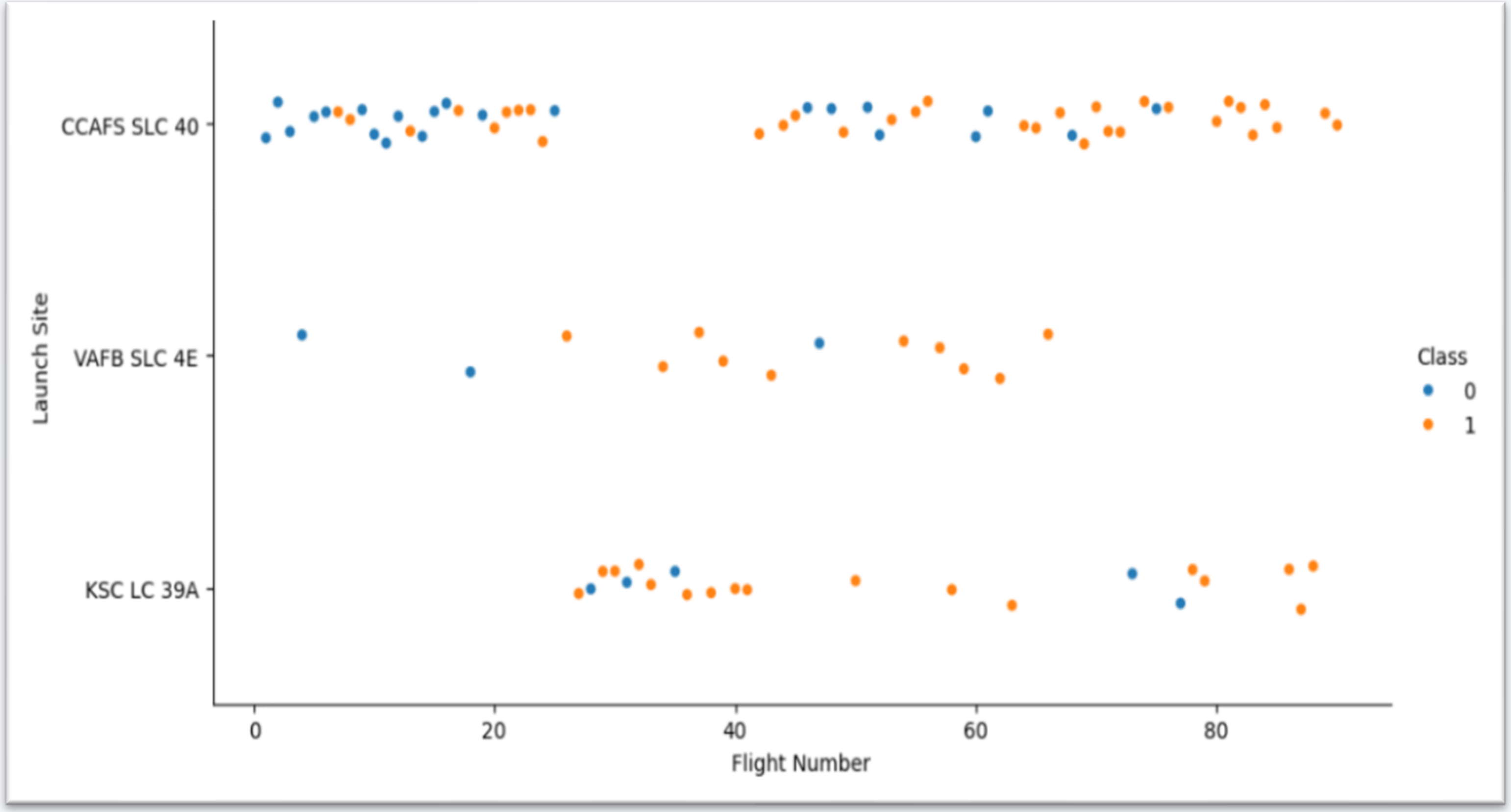
Results

- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

Section 2

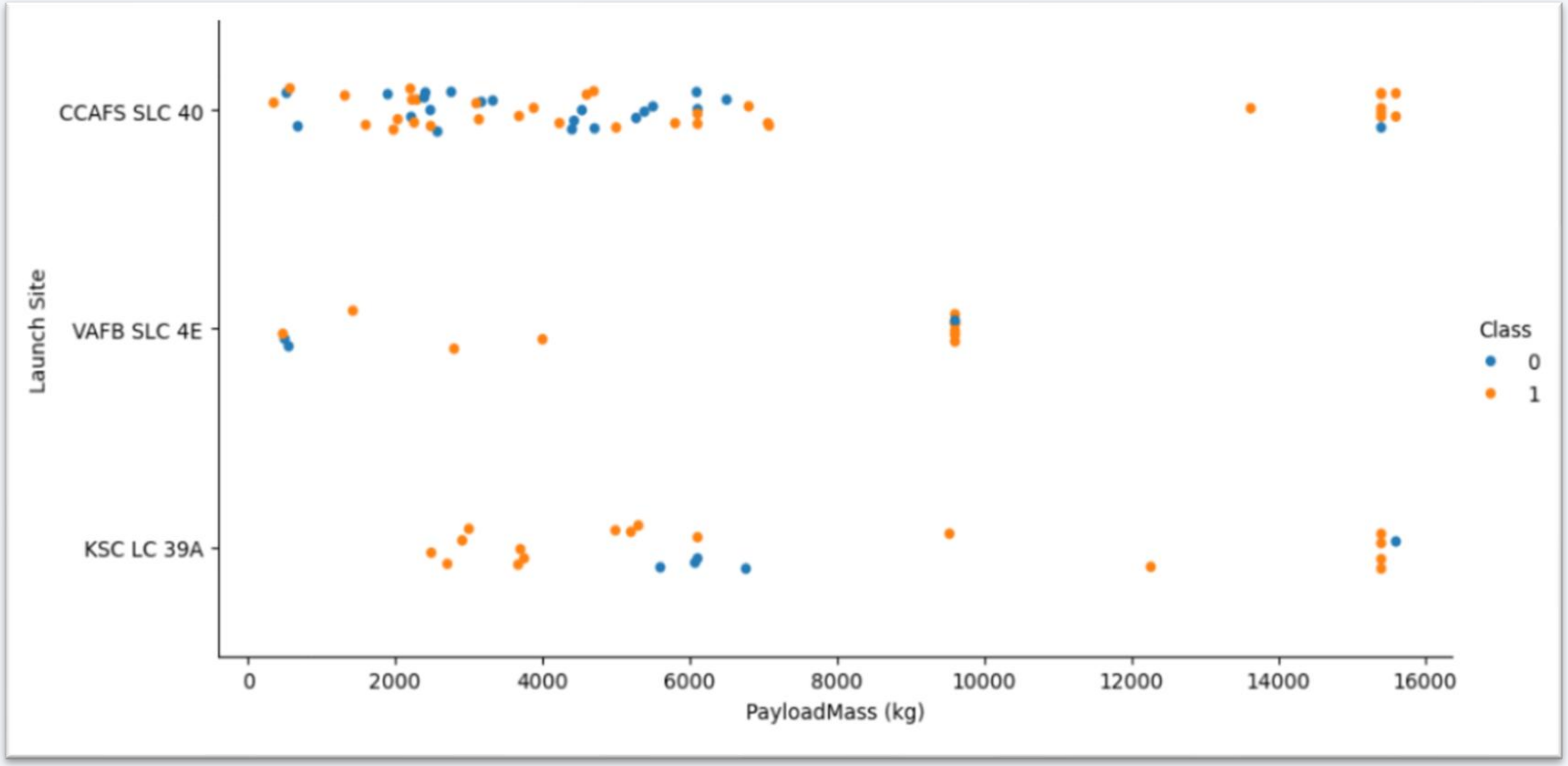
Insights drawn from EDA

Flight Number vs. Launch Site



The scatter plot shows that **CCAFS SLC 40** has the highest launch frequency with varying success rates, while **KSC LC 39A** shows a higher success rate. **VAFB SLC 4E** has fewer launches, and success rates improve as flight numbers increase.

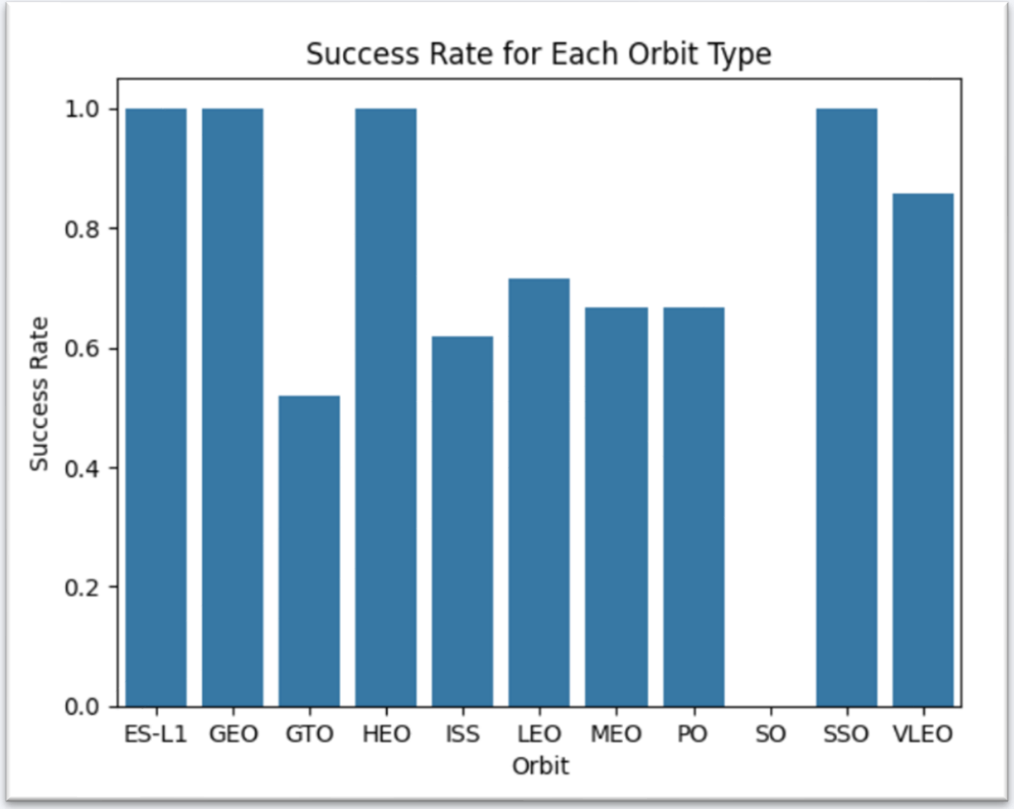
Payload vs. Launch Site



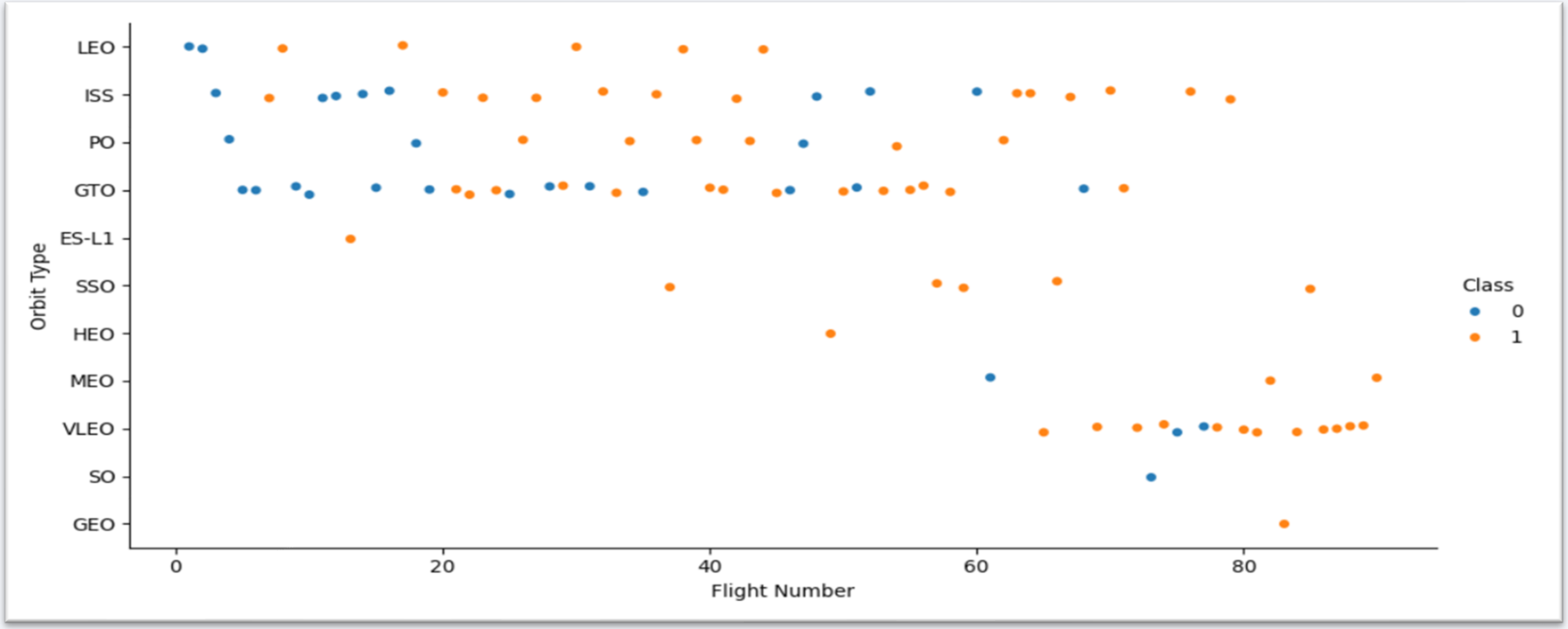
The scatter plot shows that no rockets with a heavy payload mass (greater than 10,000 kg) were launched from the **VAFB-SLC 40** launch site.

Success Rate vs. Orbit Type

The bar chart shows that the **ES-L1, GEO, HEO,** and **SSO** orbits have the highest success rates in launches, indicating a correlation between the orbit type and launch success.

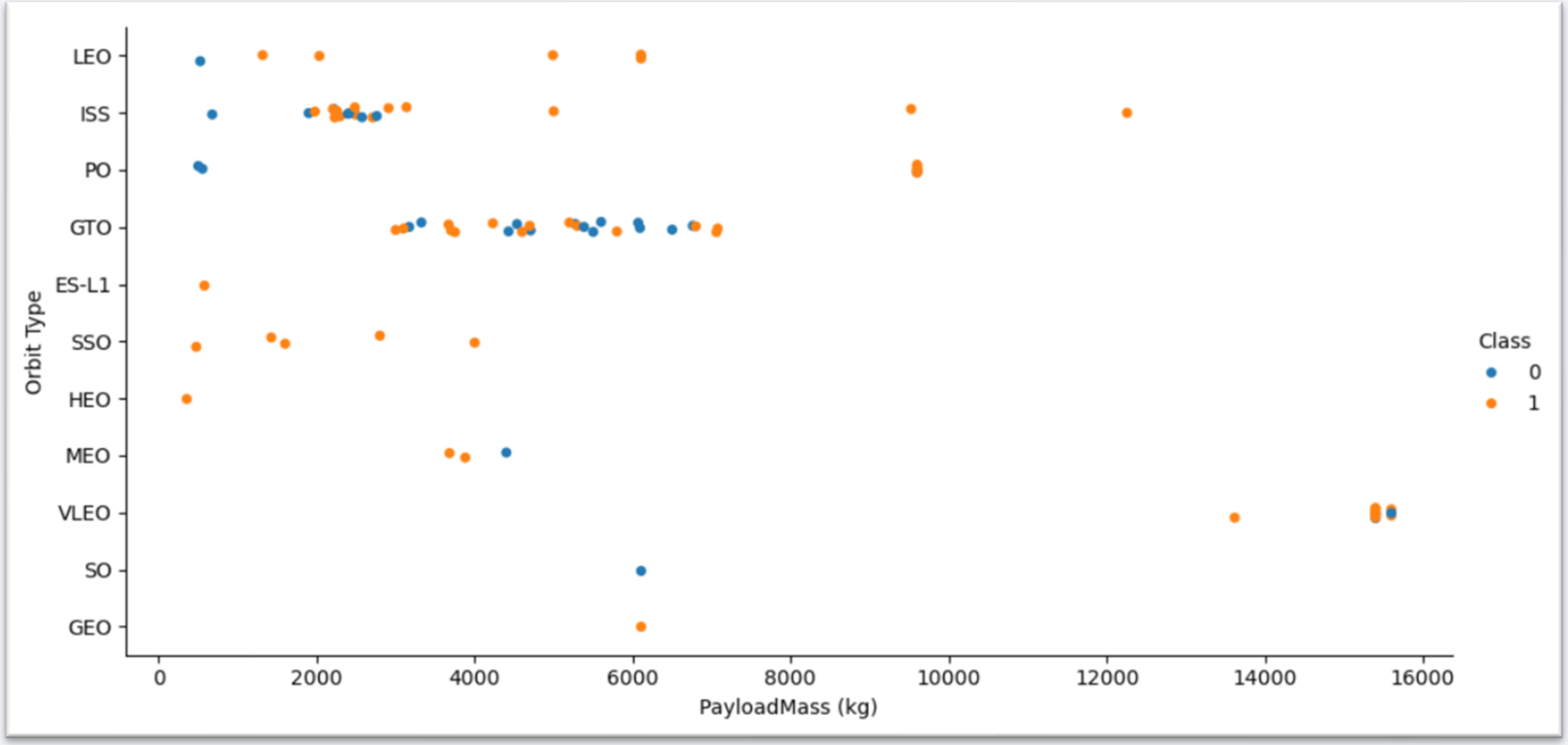


Flight Number vs. Orbit Type



Scatter plot showing the relationship between flight number and orbit type. In the **LEO orbit**, success appears to be linked with the number of flights, whereas in the **GTO orbit**, no clear relationship is observed between flight number and success.

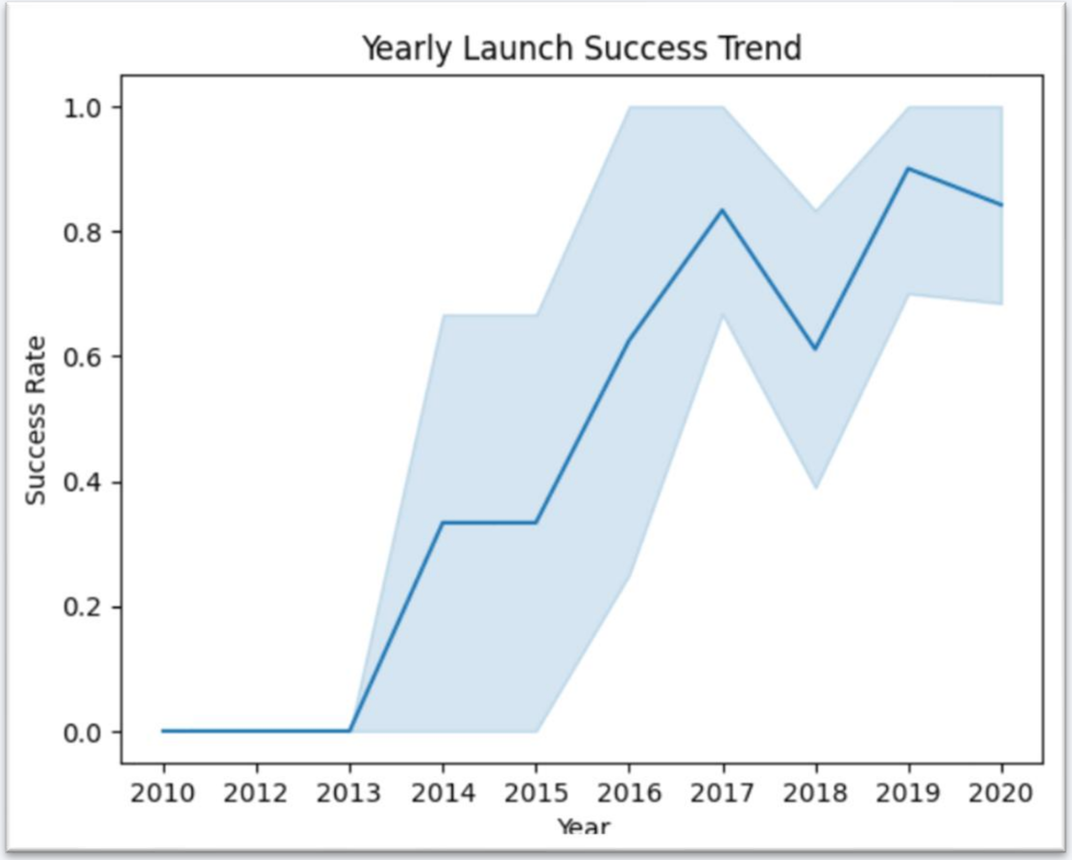
Payload vs. Orbit Type



This scatter plot illustrates the relationship between payload weight and landing success across various orbits. It shows that heavy payloads tend to have a higher success rate for landings in the **Polar**, **LEO**, and **ISS** orbits. In contrast, the **GTO** orbit does not show a clear pattern, as both successful and unsuccessful landings are present.

Launch Success Yearly Trend

The line chart shows a continuous increase in the **success rate** from 2013 to 2020, reflecting a noticeable improvement in launch performance over time.



All Launch Site Names

This SQL query retrieves the **unique launch site names** from the SPACEXTBL table and displays all the launch sites used by SpaceX for rocket launches.

```
%sql select distinct LAUNCH_SITE from SPACEXTBL;
```

```
 * sqlite:///my_data1.db
Done.
```

Launch_Site
CCAFS LC-40
VAFB SLC-4E
KSC LC-39A
CCAFS SLC-40

Launch Site Names Begin with 'CCA'

This SQL query retrieves 5 records from the SPACEXTBL table where the launch sites begin with **'CCA'**. The **'LIKE'** operator is used with the **'CCA%'** pattern to filter the records, and the **'LIMIT 5'** clause ensures only 5 results are shown.

```
%sql select * from SPACEXTBL where LAUNCH_SITE like 'CCA%' limit 5;
```

```
 * sqlite:///my_data1.db
Done.
```

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	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-12-08	15:43:00	F9 v1.0 B0004	CCAFS LC-40	Dragon demo flight C1, two CubeSats, barrel of Brouere cheese	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2012-05-22	7:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	0:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-03-01	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

Total Payload Mass

This SQL query calculates the **total** payload mass carried by boosters from NASA. The SUM function is used to sum up the PAYLOAD_MASS__KG_ values for all records where the CUSTOMER field contains **'NASA'** and **'CRS'**. The result provides the total payload mass in kg.

```
%sql select SUM(PAYLOAD_MASS__KG_) from SPACEXTBL where CUSTOMER like 'NASA%CRS%';
```

```
 * sqlite:///my_data1.db
Done.
```

SUM(PAYLOAD_MASS__KG_)
48213

Average Payload Mass by F9 v1.1

This SQL query calculates the **average** payload mass for the F9 v1.1 booster by using the AVG function on the PAYLOAD_MASS__KG_ column, filtering for rows where the BOOSTER_VERSION is **'F9 v1.1'**. The result is 2928.4 kg.

```
%sql select AVG(PAYLOAD_MASS__KG_) from SPACEXTBL where BOOSTER_VERSION ='F9 v1.1';
```

```
 * sqlite:///my_data1.db
Done.
```

AVG(PAYLOAD_MASS__KG_)
2928.4

First Successful Ground Landing Date

This SQL query retrieves the earliest date when a successful landing outcome on the ground pad was achieved by using the MIN function on the DATE column, filtered by the LANDING_OUTCOME field for **'Success (ground pad)'.** The result shows the first successful landing date for this outcome.

```
%sql select MIN(DATE) from SPACEXTBL where LANDING_OUTCOME ='Success (ground pad)';
```

```
 * sqlite:///my_data1.db
Done.
```

MIN(DATE)
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

This SQL query retrieves the names of boosters that successfully landed on a drone ship with a payload mass between 4000 and 6000 kilograms. It filters for **LANDING_OUTCOME = "Success (drone ship)"** and **PAYLOAD_MASS__KG_** within the specified range, then displays the matching booster versions.

```
[ ] %sql select BOOSTER_VERSION from SPACEXTBL where LANDING_OUTCOME is 'Success (drone ship)' and PAYLOAD_MASS__KG_>4000 and PAYLOAD_MASS__KG_<6000;
```

```
 * sqlite:///my_data1.db
Done.
```

Booster_Version
F9 FT B1022
F9 FT B1026
F9 FT B1021.2
F9 FT B1031.2

Total Number of Successful and Failure Mission Outcomes

This SQL query calculates the total number of successful and failed missions from the **SPACEXTBL** table. It counts successful missions by filtering the **MISSION_OUTCOME** column for 'Success' and failed missions by excluding 'Success'.

```
%sql select count(MISSION_OUTCOME) as Success from SPACEXTBL where MISSION_OUTCOME = 'Success';
```

```
 * sqlite:///my_data1.db
Done.
```

Success
98

```
%sql select count(MISSION_OUTCOME) as Failure from SPACEXTBL where MISSION_OUTCOME != 'Success';
```

```
 * sqlite:///my_data1.db
Done.
```

Failure
3

Boosters Carried Maximum Payload

This SQL query lists the names of the booster versions that carried the **maximum** payload mass. It uses a subquery to first find the maximum payload mass (MAX(PAYLOAD_MASS__KG_)) and then selects the booster versions that match this maximum payload mass.

```
%sql select BOOSTER_VERSION from SPACEXTBL where PAYLOAD_MASS__KG_ = (select MAX(PAYLOAD_MASS__KG_) from SPACEXTBL);
```

```
 * sqlite:///my_data1.db
Done.
```

Booster_Version
F9 B5 B1048.4
F9 B5 B1049.4
F9 B5 B1051.3
F9 B5 B1056.4
F9 B5 B1048.5
F9 B5 B1051.4
F9 B5 B1049.5
F9 B5 B1060.2
F9 B5 B1058.3
F9 B5 B1051.6
F9 B5 B1060.3
F9 B5 B1049.7

2015 Launch Records

This SQL query retrieves records showing the month, booster version, launch site, and landing outcome for 2015 drone ship failures. The **substr(DATE, 6, 2)** function extracts the month, and **substr(DATE, 0, 5) = '2015'** filters for the year. It then filters the records to show only failures on the drone ship.

```
%sql select substr(DATE, 6, 2) as Month, BOOSTER_VERSION, LAUNCH_SITE, LANDING_OUTCOME
from SPACEXTBL
where substr(DATE, 0, 5) = '2015'
and LANDING_OUTCOME = 'Failure (drone ship)';
```

```
 * sqlite:///my_data1.db
Done.
```

Month	Booster_Version	Launch_Site	Landing_Outcome
01	F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)
04	F9 v1.1 B1015	CCAFS LC-40	Failure (drone ship)

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

This SQL query ranks landing outcomes (e.g., 'Failure (drone ship)', 'Success (ground pad)') between 2010-06-04 and 2017-03-20. It groups records by **LANDING_OUTCOME**, counts occurrences, and sorts the results in descending order by count (**Event_Count**).

```
%%sql select LANDING_OUTCOME, count(LANDING_OUTCOME) as Event_Count from SPACEXTBL
where DATE between '2010-06-04' and '2017-03-20'
group by LANDING_OUTCOME
order by Event_Count desc;
```

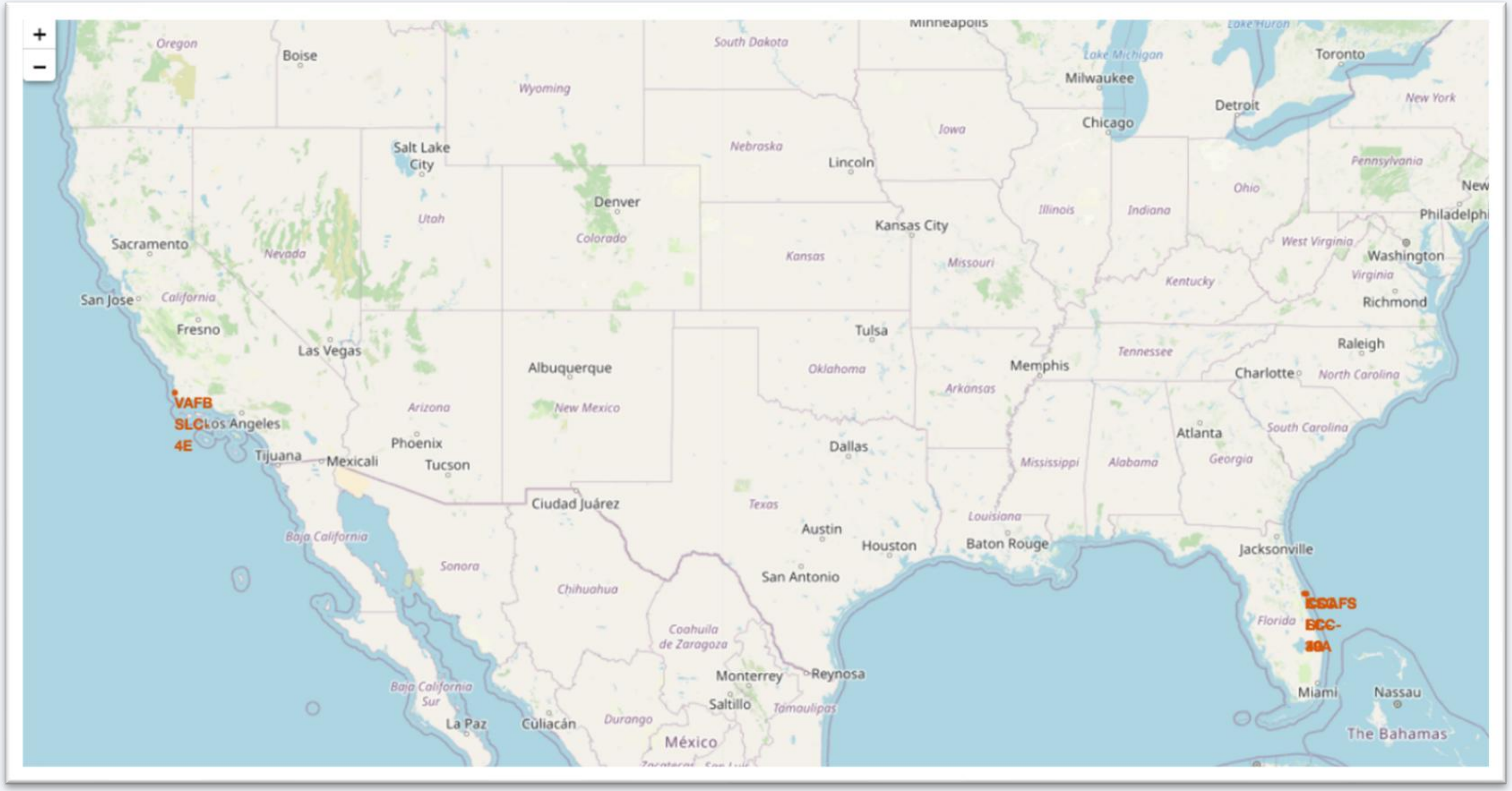
```
 * sqlite:///my_data1.db
Done.
```

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

Section 3

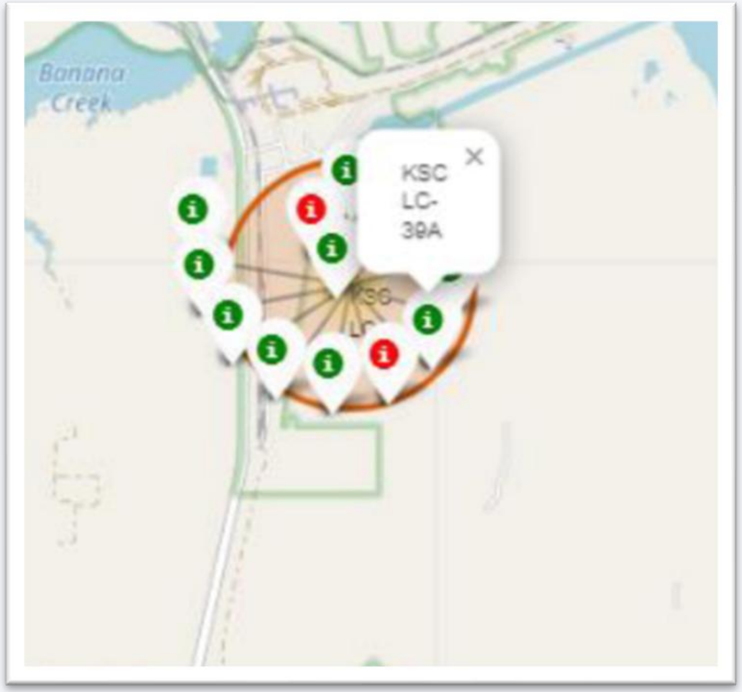
Launch Sites Proximities Analysis

Launch Sites Locations



The launch sites are strategically positioned **near the equator and coastlines,** optimizing the efficiency of launches while ensuring safety in case of failure. This geographic distribution is crucial for maximizing launch performance and minimizing risks.

Launch Outcomes: Success vs Failure



KSCLC-39A shows the highest success rate, while CCAFS SLC-40 has a relatively lower success rate, as indicated by the color-coded markers on the map.

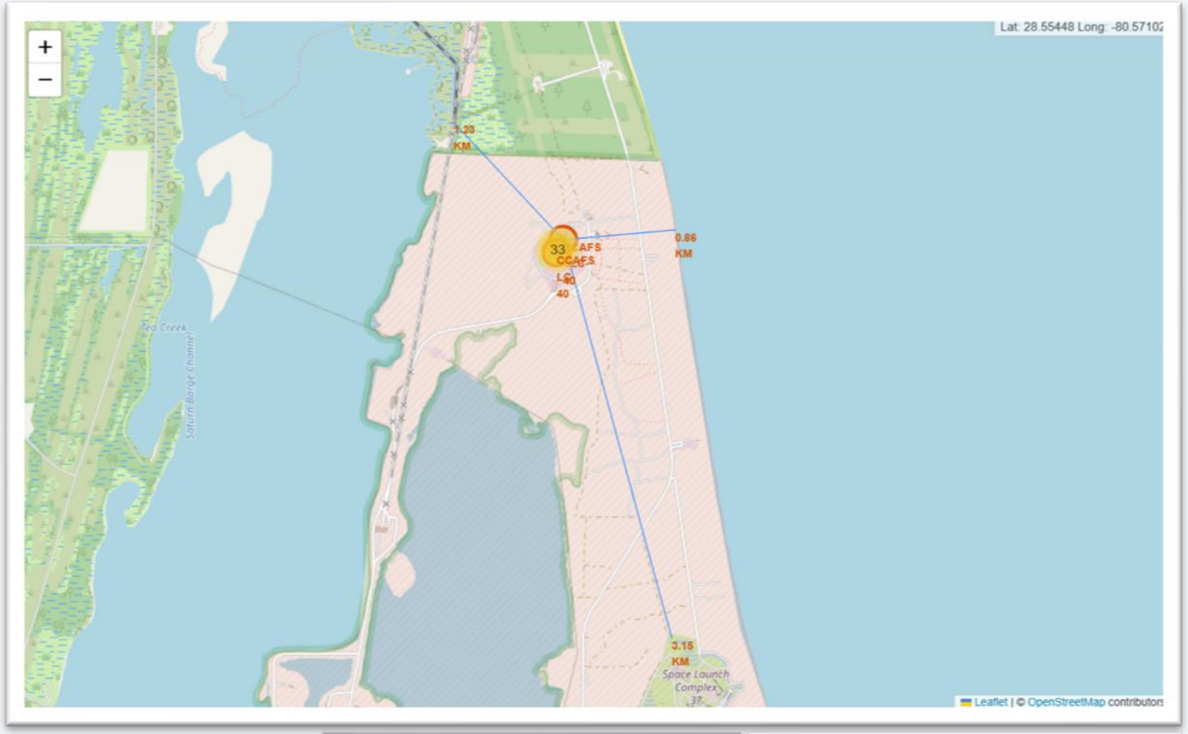
Launch Site Proximity Distances

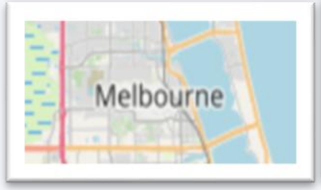
Proximity Analysis of Launch Sites

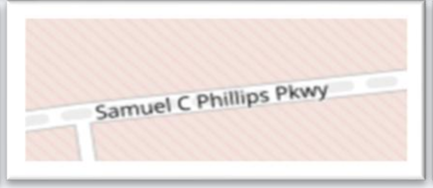
- Distance to Closest Coastline: 0.856 km
- Distance to Space Launch Complex 37: 3.15 km
- Distance to NASA Railroad: 1.23 km

Key Insights

- Launch Sites: Located near coastlines to ensure optimal launch trajectories.
- Distance from Cities: Strategically distanced from cities and control centers for safety.
- Railways/Highways: Likely private, designed for transporting mission-related materials.



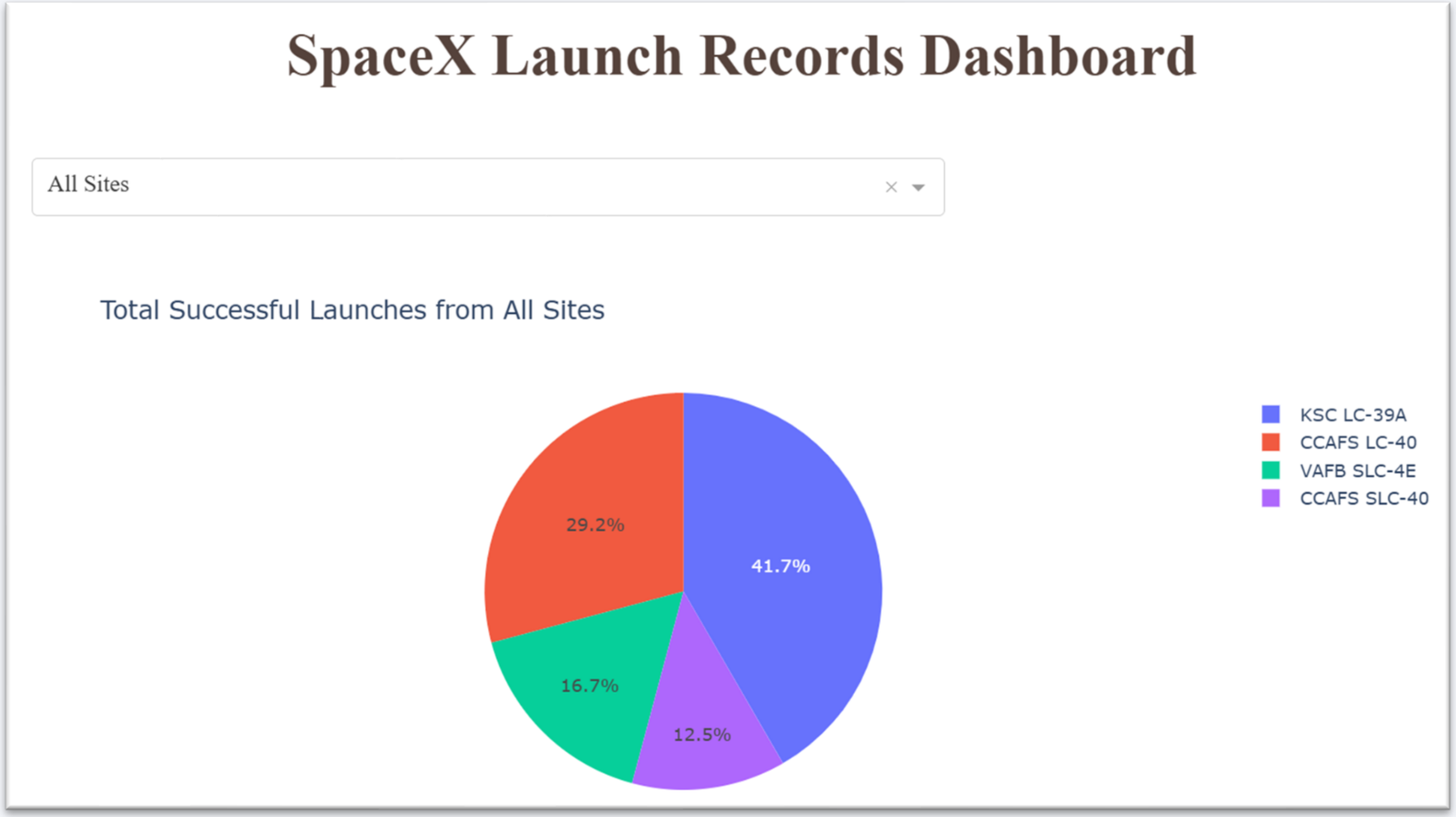




Section 4

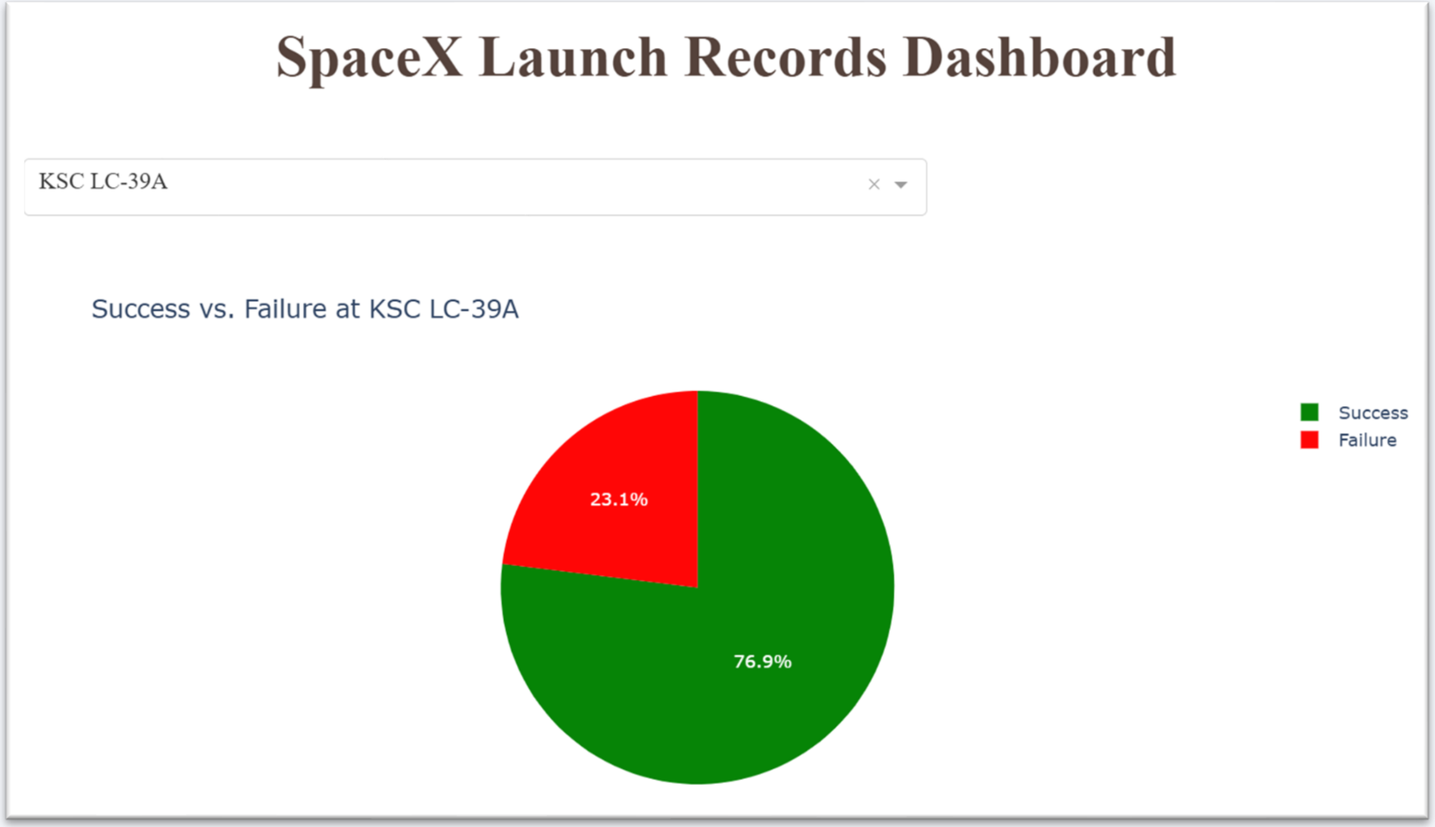
Build a Dashboard with Plotly Dash

Pie Chart for Launch Success Count for All Sites



The pie chart analysis indicates that **KSC LC-39A** achieved the highest number of successful launches among all launch sites.

Pie Chart for Launch Site with Highest Launch Success Ratio



The pie chart analysis indicates that **KSC LC-39A** achieved a success rate of **76.9%** and a failure rate of **23.1%**, making it the site with the highest launch success ratio among all sites.

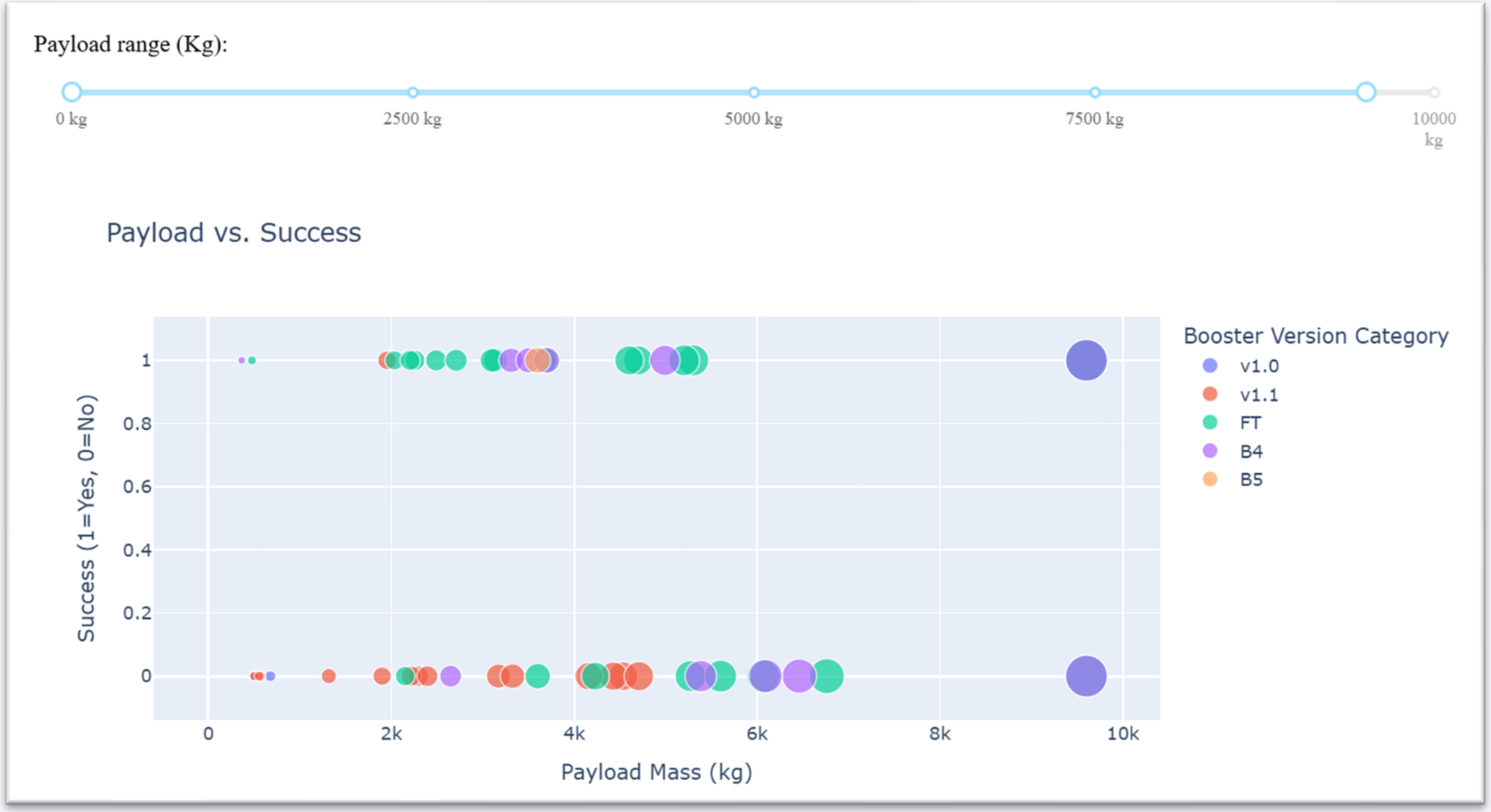
Payload vs. Launch Outcome Scatter Plot for All Sites

- **Highest Success Rates:**

  FT and B4 are the most successful in launches.

- **Payload Success:**
  - **2000-6000 kg:** Highest success rates.
  - **Less than 2000 kg:** Higher failure rates with older boosters.
  - **More than 6000 kg:** Newer boosters achieve higher success.

- **Key Insight:**
  - **FT and B4** are the most reliable for launching medium and heavy payloads.

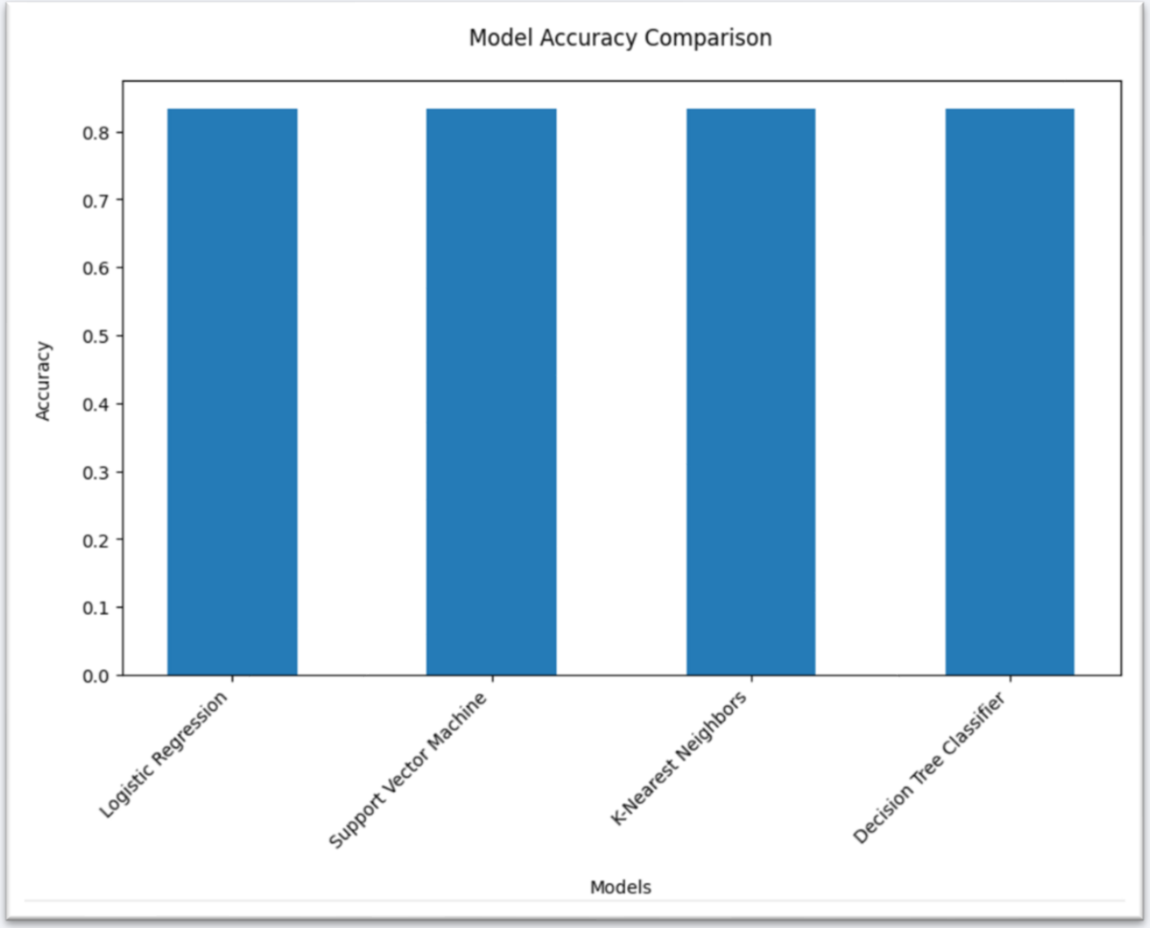


Section 5

Predictive Analysis (Classification)

Classification Accuracy

- The bar chart shows the accuracy of four models: Logistic Regression, SVM, KNN, and Decision Tree Classifier.
- All models achieved the same accuracy of **0.83**, which was rounded to 0.8 in the chart, indicating no significant difference in performance.

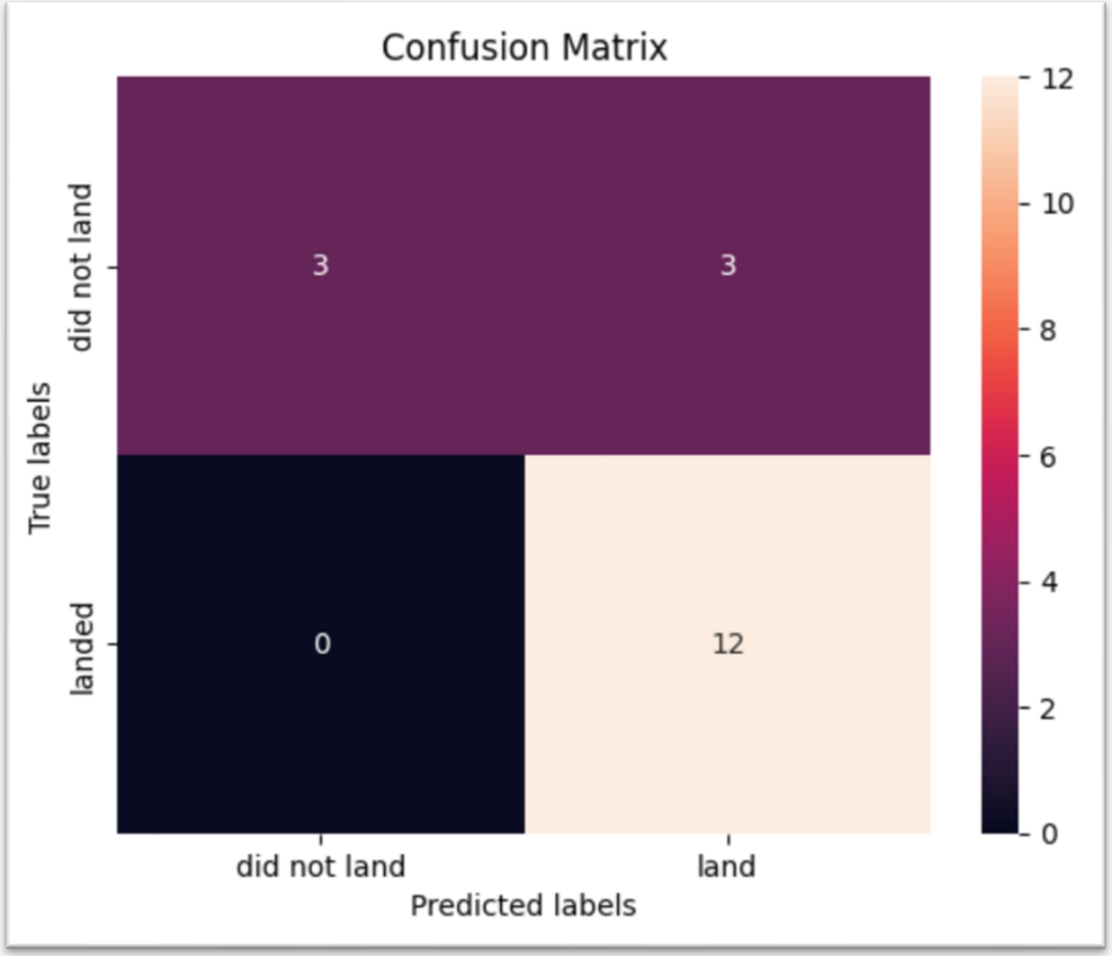


Confusion Matrix

After examining the confusion matrix, it is clear that the models effectively distinguish between the classes. However, the main issue identified is **false positives**.

- **True Positives (12):** Correct predictions of "landed."
- **False Positives (3):** Incorrect predictions of "landed" when the true label is "not landed."

Overall, the performance is good, but the focus should be on reducing **false positives** for further model improvement.



Conclusions

- **Models Used & Accuracy:**
  - Logistic Regression, SVM, Random Forest, and KNN were used to predict the successful landing of the first stage of the Falcon 9 rocket.
  - All models achieved an accuracy of 0.83, showing equal performance.
- **Factors Influencing Success:**
  - Location: KSC LC-39A showed the highest success rate (76.9%).
  - Payload Weight: Payloads between 2000 and 6000 kg showed higher success rates, particularly with FT and B4 rockets.
  - Rocket Type: FT and B4 rockets had higher success rates with certain payloads.

Conclusions (Continued)

- **Importance of Results:**
  - These findings are crucial for developing pricing strategies for competing space companies and reducing costs.
  - Future Improvements:
  - Models can be enhanced through further analysis or feature engineering.
- **Final Outcome:**
  - Successfully predicting the landing can improve operational efficiency, reduce risks, lower costs, and enhance competitiveness in the space market.

Appendix

- **Python Code Snippets**: Available in the GitHub repository.
- **SQL Queries**: Available in the GitHub repository.
- **Charts and Plots**: Available in the GitHub repository.
- You can access all the assets in my GitHub repository[Haila-Abdullah/SpaceX-Falcon9-Landing-Prediction]

Thank you!