IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

- Executive Summary
- Introduction
- Methodology
- Results
- Conclusion
- Appendix

Executive Summary

- **Summary of methodologies**

Data Collection: Collected data using SpaceX API and web scraping.

Data Wrangling: Cleaned and processed the collected data.

Exploratory Data Analysis (EDA): Conducted EDA using visualization tools and SQL.

Predictive Analysis: Built, tuned, and evaluated classification models to predict the success of Falcon 9 first-stage landings.

- **Summary of all results**

The SVM model provided the highest accuracy for predicting landing success.

Identified key factors influencing landing success, including launch site and payload mass.

Introduction

- **<u>Project background and context</u>**

The commercial space age is being driven by companies like SpaceX, which has revolutionized space travel with reusable rockets. The ability to reuse the first stage of the Falcon 9 rocket significantly reduces launch costs, making SpaceX a leader in the industry.

The main objective of this project was to predict whether the Falcon 9 first stage would successfully land, which directly affects the cost-efficiency of space missions.

- **<u>Problems you want to find answers</u>**

Which launch sites have the highest success rates for first-stage landings?

How does payload mass affect the success of the landings?

What machine learning model best predicts the success of Falcon 9 first-stage landings?

Section 1

Methodology

Methodology

Executive Summary

- **<u>Data collection methodology:</u>**

Data was gathered using the SpaceX REST API and web scraping techniques. The API provided information on all Falcon 9 launches, including details about launch sites, payloads, and outcomes.

- **<u>Perform data wrangling</u>**

The collected data was cleaned and processed. This involved handling missing values, correcting data types, and transforming the data into a usable format for analysis.

Methodology

Executive Summary

- **Perform exploratory data analysis (EDA) using visualization and SQL**

Visualizations and SQL queries were employed to explore the data and identify key patterns. This included analyzing launch success rates across different sites and payloads.

- **Perform interactive visual analytics using Folium and Plotly Dash**

Tools like Folium and Plotly Dash were used to create interactive maps and dashboards for deeper insights.

- **Perform predictive analysis using classification models**

Classification models, including Logistic Regression, SVM, Decision Trees, and K-Nearest Neighbors (KNN), were built, tuned, and evaluated to predict the success of Falcon 9 first-stage landings.

Data Collection

- **<u>Describe how data sets were collected.</u>**

Data collection involved two main methods: using the SpaceX REST API to gather detailed records of Falcon 9 launches and using web scraping techniques to collect additional contextual information about launch sites.

The API provided data such as launch dates, sites, payloads, and landing outcomes. Web scraping was employed to gather supplementary data, like geographic information related to the launch sites.

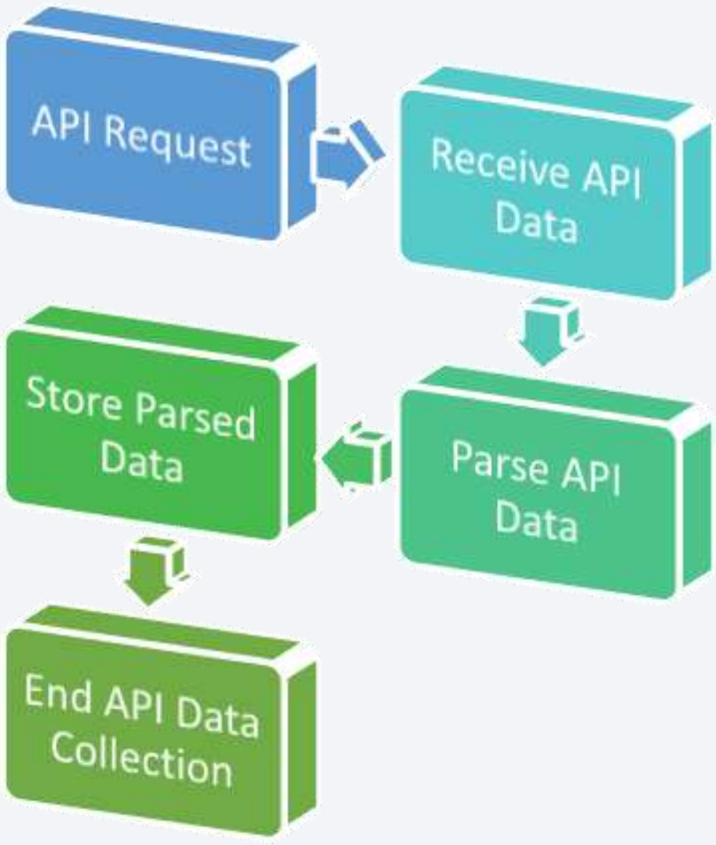
- You need to present your data collection process use key phrases and flowcharts

Data Collection – SpaceX API

- Present your data collection with SpaceX REST calls using key phrases and flowcharts

- Add the GitHub URL of the completed SpaceX API calls notebook (must include completed code cell and outcome cell), as an external reference and peer-review purpose

- https://github.com/GianE04/SpaceY/blob/main/jupyter-labs-spacex-data-collection-api.ipynb



Data Collection - Scraping

- Present your web scraping process using key phrases and flowcharts

- Add the GitHub URL of the completed web scraping notebook, as an external reference and peer-review purpose

- https://github.com/GianE04/SpaceY/blob/main/jupyter-labs-webscraping.ipynb

Data Wrangling

- **Describe how data were processed**

Handling Missing Values: Missing values were identified and addressed by either filling them with appropriate values (e.g., mean, median) or removing rows/columns with excessive missing data.

Data Type Correction: Data types were standardized to ensure consistency across the dataset. For example, date fields were converted to datetime objects, and numeric fields were ensured to be in the correct numeric format.

Feature Engineering: New features were created from existing data to enhance the predictive power of the models. This could include categorizing payload masses or converting categorical variables into numerical ones through one-hot encoding.

Data Wrangling

- **Describe how data were processed**

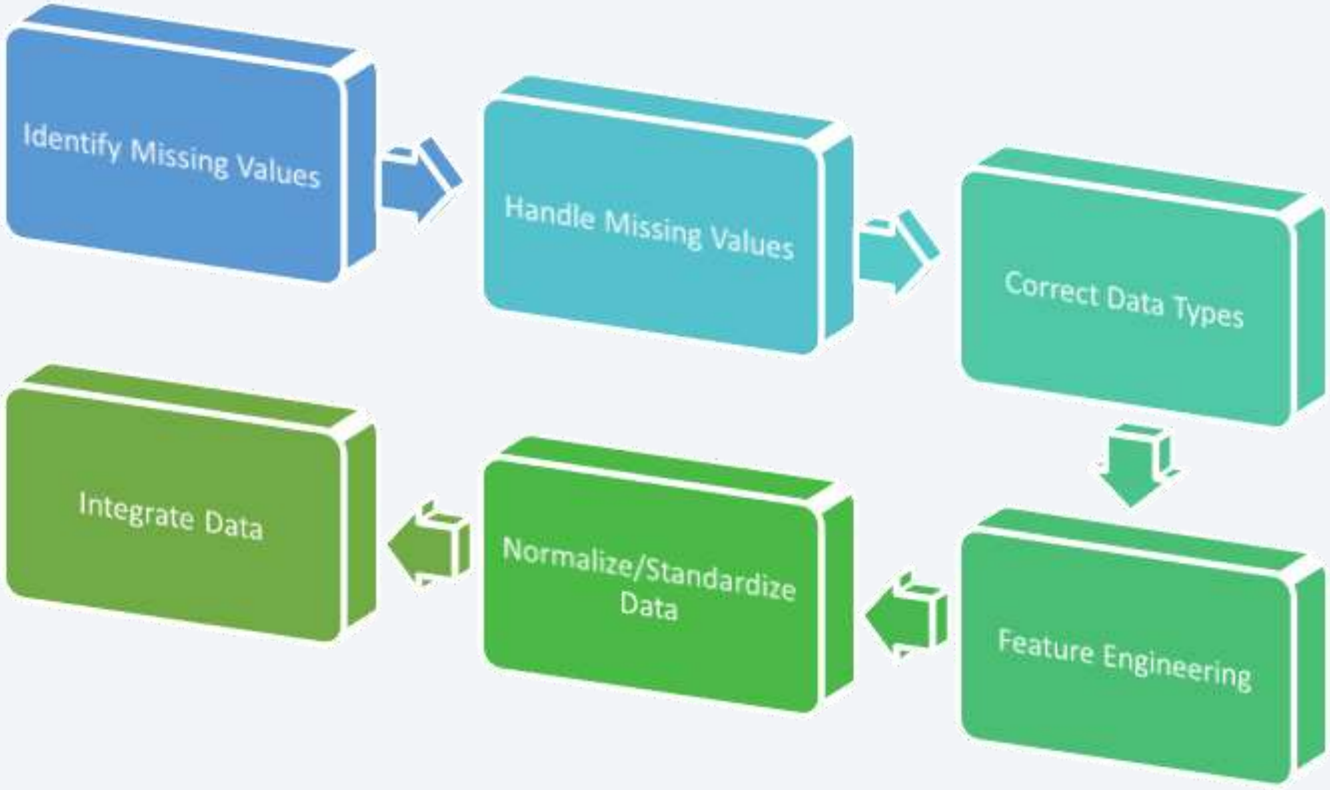
Normalization/Standardization: Continuous variables were normalized or standardized to ensure that all features contributed equally to the analysis and modeling.

Data Integration: Data from different sources (API and web scraping) was integrated into a single, cohesive dataset, ensuring that all relevant information was included.

- Add the GitHub URL of your completed data wrangling related notebooks, as an external reference and peer-review purpose
- https://github.com/GianE04/SpaceY/blob/main/labs-jupyter-spacex-Data%20wrangling.ipynb

Data Wrangling

- You need to present your data wrangling process using key phrases and flowcharts



EDA with Data Visualization

- **Summarize what charts were plotted and why you used those charts**

Scatter Plot: Flight Number vs. Launch Site: To examine the relationship between the number of flights and the success rates across different launch sites. This helps in understanding how experience (as indicated by the flight number) and location impact the success of the Falcon 9 landings.

Scatter Plot: Payload vs. Launch Site: To explore the relationship between payload mass and launch outcomes at different sites. This visualization helps identify which sites are more successful at handling heavier payloads.

Bar Chart: Success Rate vs. Orbit Type: To analyze the success rates across different orbit types. This chart helps to determine which orbit types are more likely to result in successful landings.

EDA with Data Visualization

- **Summarize what charts were plotted and why you used those charts**

Scatter Plot: Flight Number vs. Orbit Type: To see how the number of flights correlates with success in different orbit types. This helps in understanding if experience impacts success across different orbits.

Scatter Plot: Payload vs. Orbit Type: To investigate the relationship between payload mass and success in different orbit types. This can highlight whether certain orbits are more challenging for heavier payloads.

Line Chart: Launch Success Yearly Trend: To visualize the trend in launch success rates over time. This chart helps identify whether SpaceX's success rate has improved over the years.

- Add the GitHub URL of your completed EDA with data visualization notebook, as an external reference and peer-review purpose

https://github.com/GianE04/SpaceY/blob/main/jupyter-labs-eda-dataviz.ipynb

EDA with SQL

- Using bullet point format, summarize the SQL queries you performed
- Query 1: SELECT DISTINCT LaunchSite FROM SPACEXTBL;
- Query 2: SELECT * FROM SPACEXTBL WHERE LaunchSite LIKE 'CCA%’;
- Query 3: SELECT SUM(PayloadMass) FROM SPACEXTBL WHERE Customer = 'NASA (CRS)’;
- Query 4: SELECT AVG(PayloadMass) FROM SPACEXTBL WHERE BoosterVersion = 'F9 v1.1’;
- Query 5: SELECT MIN(Date) FROM SPACEXTBL WHERE LandingOutcome = 'Success (ground pad)';
- Add the GitHub URL of your completed EDA with SQL notebook, as an external reference and peer-review purpose
- https://github.com/GianE04/SpaceY/blob/main/jupyter-labs-eda-sql-coursera_sqllite.ipynb

Build an Interactive Map with Folium

- Summarize what map objects such as markers, circles, lines, etc. you created and added to a folium map
- Explain why you added those objects

Markers: Added markers to the map for each launch site to indicate their locations. These markers help visualize the geographic distribution of the launch sites.

Circles: Created circles around each launch site to represent a radius of interest, helping to identify proximity to important features like cities, coastlines, and highways.

Lines (Polylines): Drew lines between the launch sites and the nearest cities, railways, or coastlines to measure and display the distance between them. This helps analyze the strategic positioning of the launch sites.

Color-Coded Markers: Used color-coded markers to indicate the outcome of each launch (e.g., green for success, red for failure). This allows for a quick visual assessment of success rates across different sites.

- Add the GitHub URL of your completed interactive map with Folium map, as an external reference and peer-review purpose
- https://github.com/GianE04/SpaceY/blob/main/lab_jupyter_launch_site_location.ipynb

Build a Dashboard with Plotly Dash

- **Summarize what plots/graphs and interactions you have added to a dashboard**

Total Successful Launches by Site (Pie Chart): A pie chart was created to display the total number of successful launches for each launch site. This helps in quickly visualizing which sites have the most successful launches.

Success vs. Failed Launches for Highest Success Ratio Site (Pie Chart): A pie chart was used to show the success vs. failed launches specifically for the site with the highest success ratio. This gives insight into the reliability of that particular site.

Payload vs. Launch Outcome Scatter Plot: A scatter plot was created to show the relationship between payload mass and the outcome of the launch. This was interactive, allowing users to filter the results based on payload ranges and view the corresponding outcomes.

Build a Dashboard with Plotly Dash

- **Explain why you added those plots and interactions**

Dropdown Menu: Added a dropdown menu to allow users to select different launch sites. This interaction updates the pie chart and scatter plot to show data specific to the selected site.

Range Slider: Included a range slider to filter payload mass ranges in the scatter plot. This interaction helps users see how different payload masses affect launch outcomes across various sites.

- Add the GitHub URL of your completed Plotly Dash lab, as an external reference and peer-review purpose
- https://github.com/GianE04/SpaceY/blob/main/Build_a_Dashboard_Application_with_Plotly_Dash.pdf

Predictive Analysis (Classification)

- **Summarize how you built, evaluated, improved, and found the best performing classification model**

Model Selection: Multiple classification models were considered, including Logistic Regression, Support Vector Machines (SVM), Decision Trees, and K-Nearest Neighbors (KNN).

Data Splitting: The dataset was split into training and testing sets, with 80% of the data used for training and 20% for testing. This ensures that the model can be evaluated on unseen data.

Hyperparameter Tuning: GridSearchCV was used to perform hyperparameter tuning for each model. This involved testing different combinations of parameters to find the best settings that maximize model performance.

Model Evaluation: Each model was evaluated using cross-validation to ensure that the results were robust. Accuracy, precision, recall, and F1-score were calculated for each model to assess performance.

Predictive Analysis (Classification)

- **Summarize how you built, evaluated, improved, and found the best performing classification model**

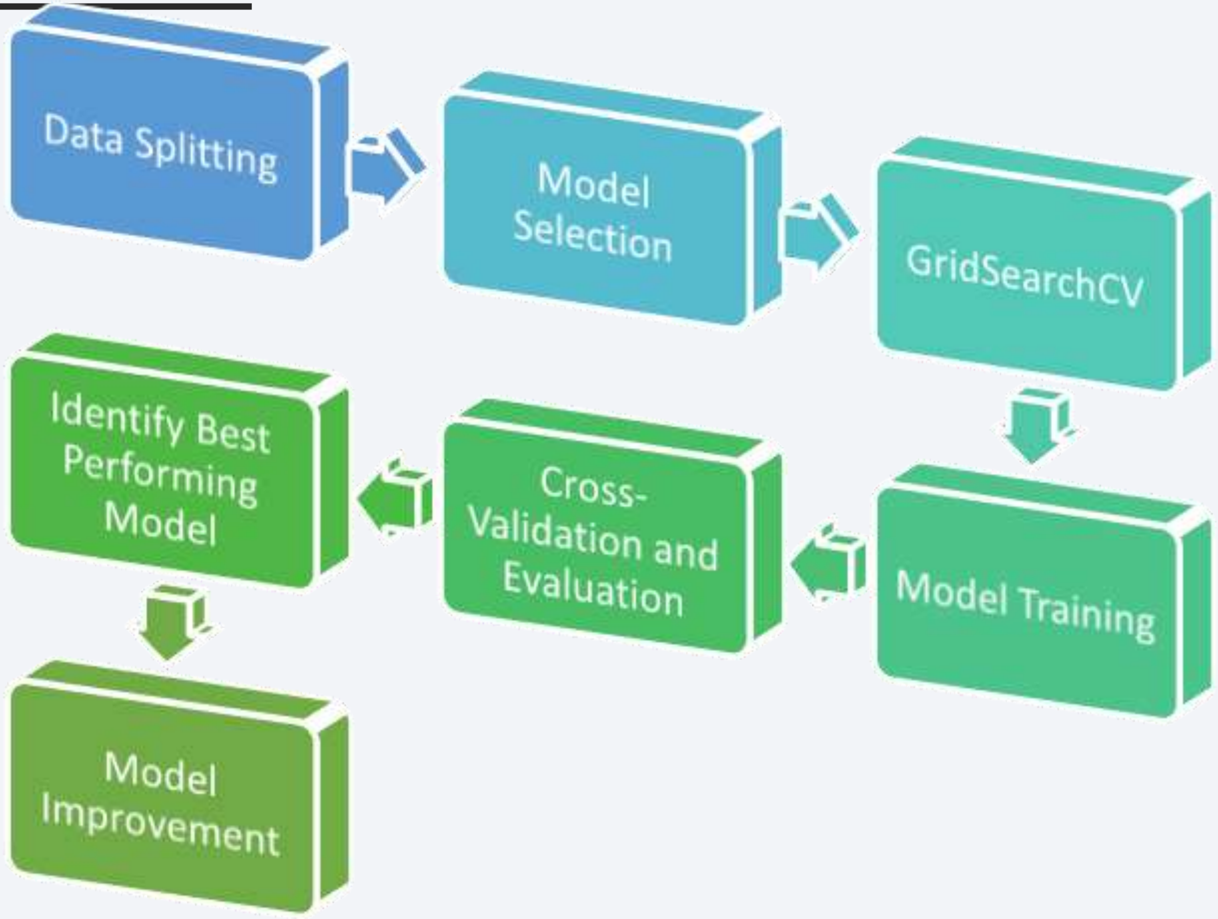
Best Performing Model: After evaluation, the Support Vector Machine (SVM) model with the RBF kernel was identified as the best-performing model, achieving the highest accuracy on the test data.

Model Improvement: Feature selection and scaling were applied to improve model performance. Redundant features were removed, and continuous variables were standardized to ensure that all features contributed equally to the model.

- Add the GitHub URL of your completed predictive analysis lab, as an external reference and peer-review purpose
- https://github.com/GianE04/SpaceY/blob/main/SpaceX_Machine_Learning_Prediction_Part_5.jupyterlite.ipynb

Predictive Analysis (Classification)

- **<u>You need present your model development process using key phrases and flowchart</u>**



Results

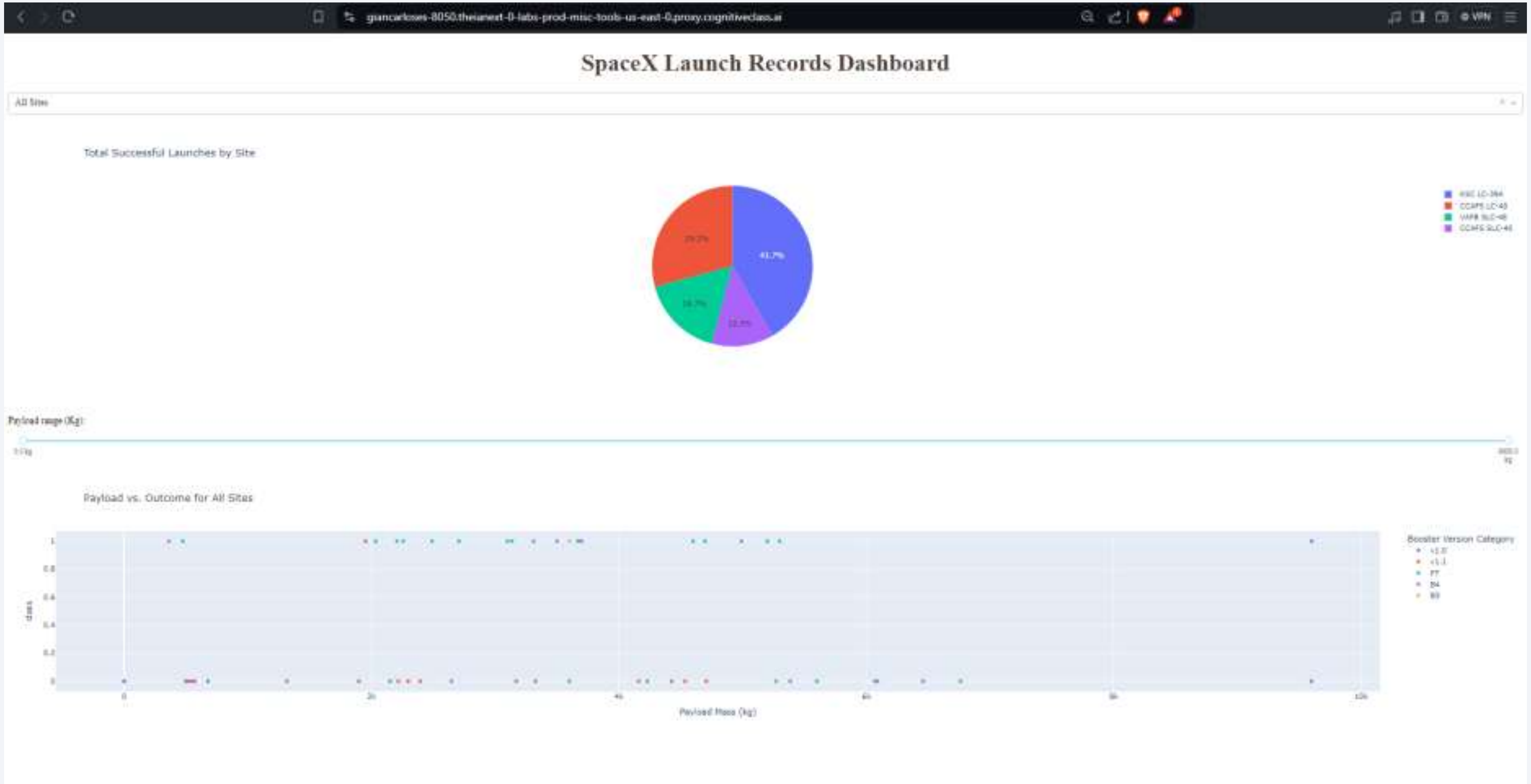
- **Exploratory data analysis results**

The EDA revealed that certain launch sites consistently achieved higher success rates, particularly those located closer to the coastlines.

Payload mass was identified as a significant factor influencing the success of the Falcon 9 landings, with certain payload ranges showing higher success rates.

Results

- **<u>Interactive analytics demo in screenshots</u>**



Results

- <u>**Predictive analysis results**</u>

The Support Vector Machine (SVM) model with the RBF kernel was found to be the most accurate in predicting landing success, achieving an accuracy of 88% on the test data.

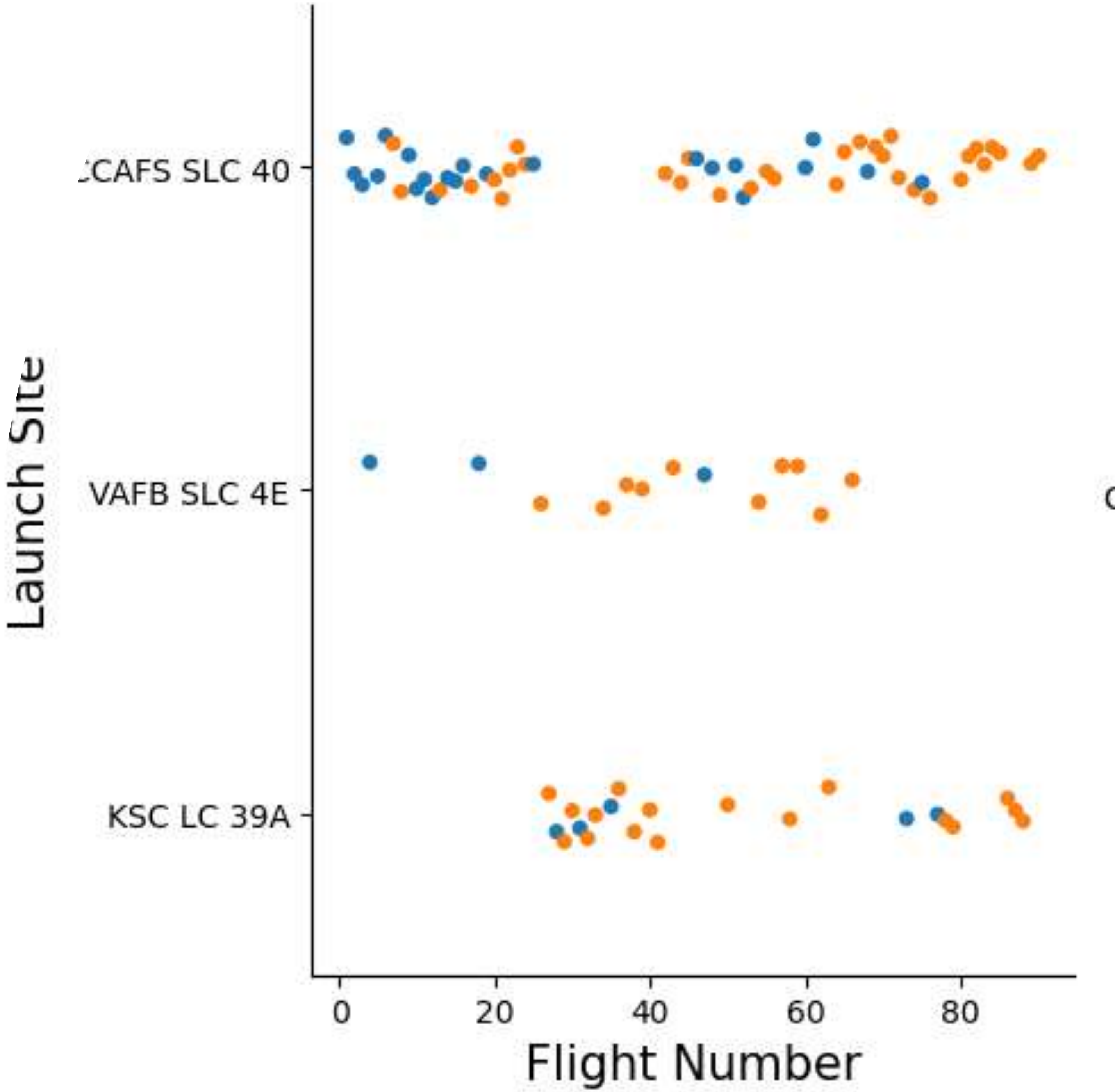
The model's performance was further validated using cross-validation techniques, confirming its robustness and reliability.

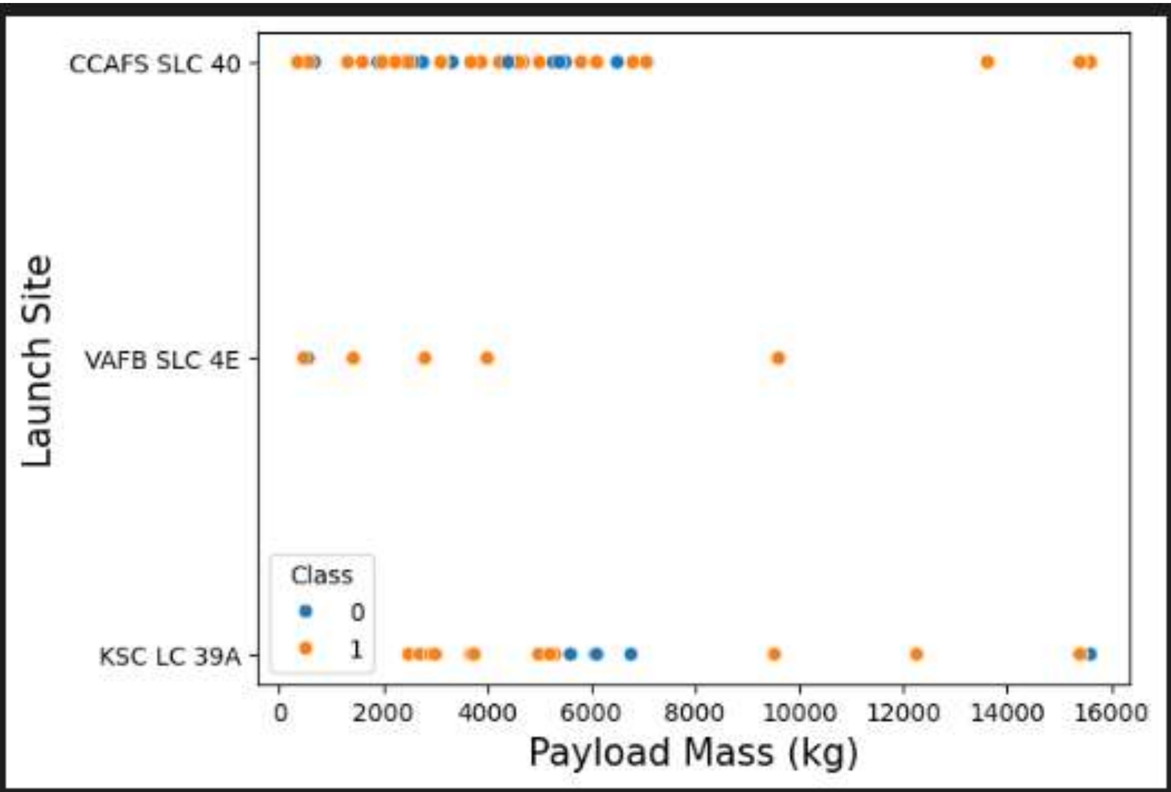
Section 2

Insights drawn from EDA

Flight Number vs. Launch Site

- Show a scatter plot of Flight Number vs. Launch Site
- Show the screenshot of the scatter plot with explanations
- The scatter plot reveals that SpaceX's success rates improved over time as their technology matured and their operations became more refined. The choice of launch site also appears to have evolved, with certain sites like KSC LC 39A being favored for later, likely more critical missions, where success was more common.

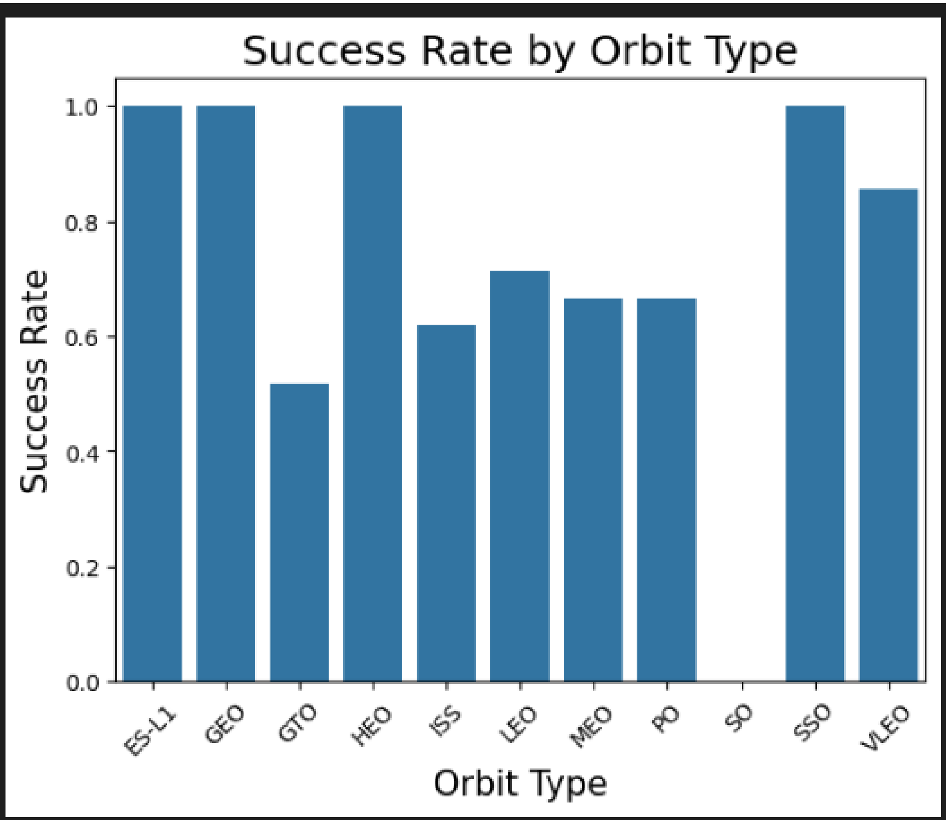




Now if you observe Payload Vs. Launch Site scatter point chart you will find for the VAFB-SLC launchsite there are no rockets launched for heavypayload mass(greater than 10000).

Payload vs. Launch Site

- Show a scatter plot of Payload vs. Launch Site
- Show the screenshot of the scatter plot with explanations

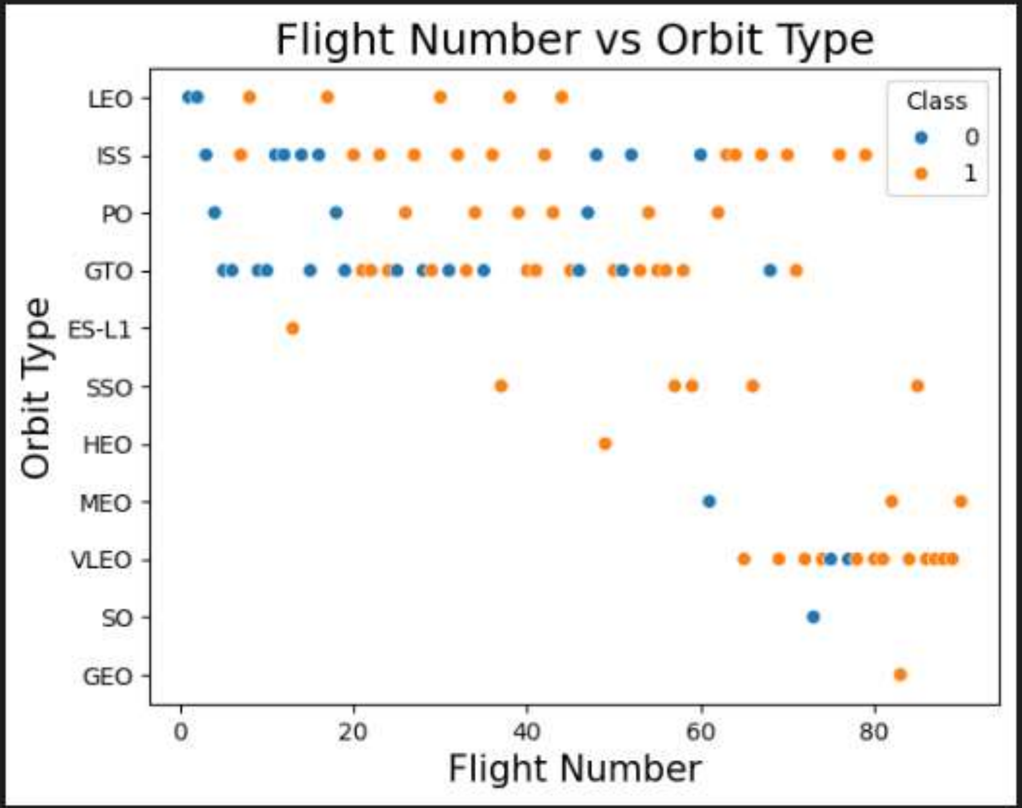


Analyze the ploted bar chart try to find which orbits have high sucess rate.

ES-L1, GEO, HEO, and SSO: These orbits show a 100% success rate, indicating that launches to these orbits have consistently resulted in successful landings.

Success Rate vs. Orbit Type

- Show a bar chart for the success rate of each orbit type
- Show the screenshot of the scatter plot with explanations

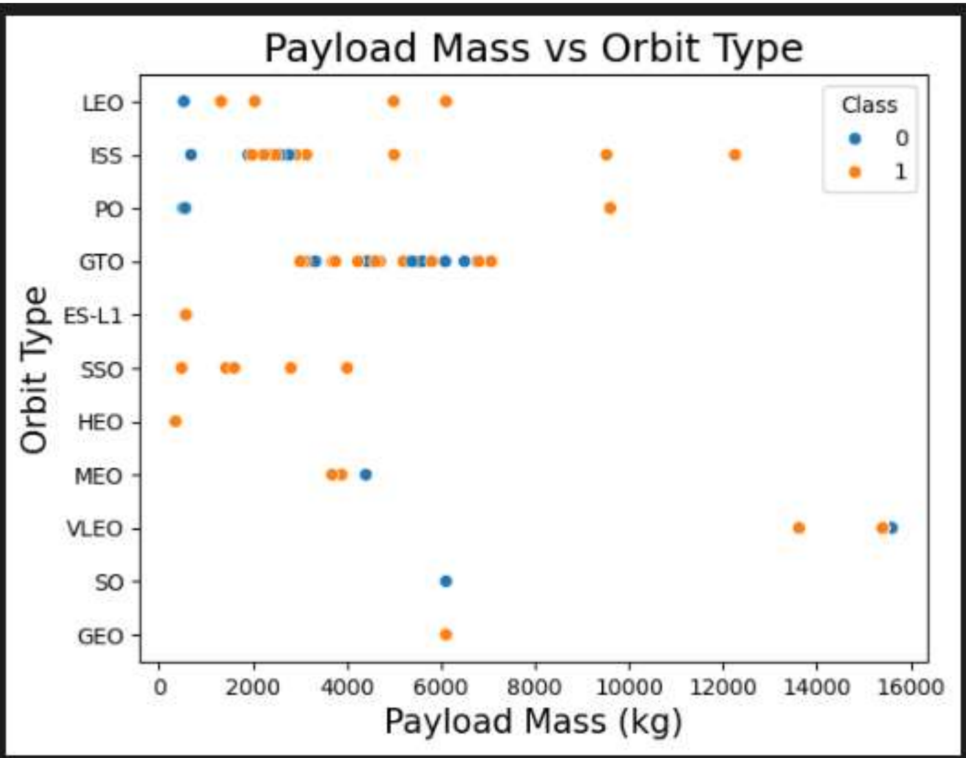


You should see that in the LEO orbit the Success appears related to the number of flights; on the other hand, there seems to be no relationship between flight number when in GTO orbit.

Flight Number vs. Orbit Type

- Show a scatter point of Flight number vs. Orbit type

- Show the screenshot of the scatter plot with explanations



With heavy payloads the successful landing or positive landing rate are more for Polar,LEO and ISS.

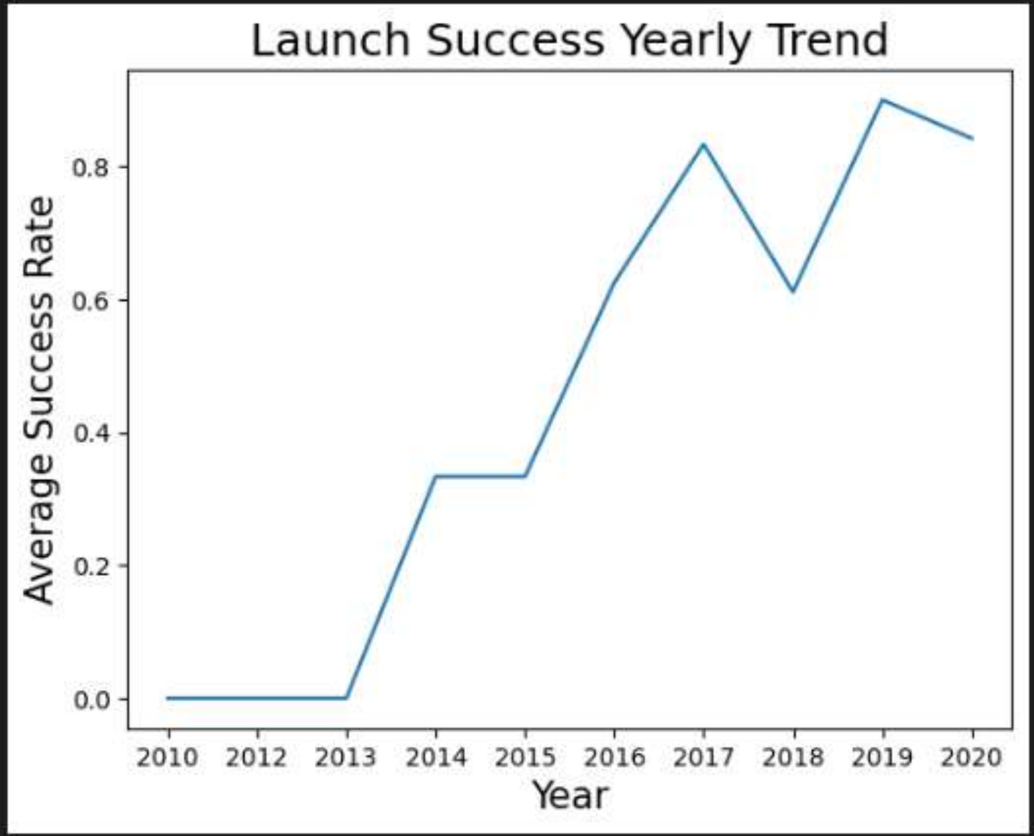
However for GTO we cannot distinguish this well as both positive landing rate and negative landing(unsuccessful mission) are both there here.

Payload vs. Orbit Type

- Show a scatter point of payload vs. orbit type
- Show the screenshot of the scatter plot with explanations

Launch Success Yearly Trend

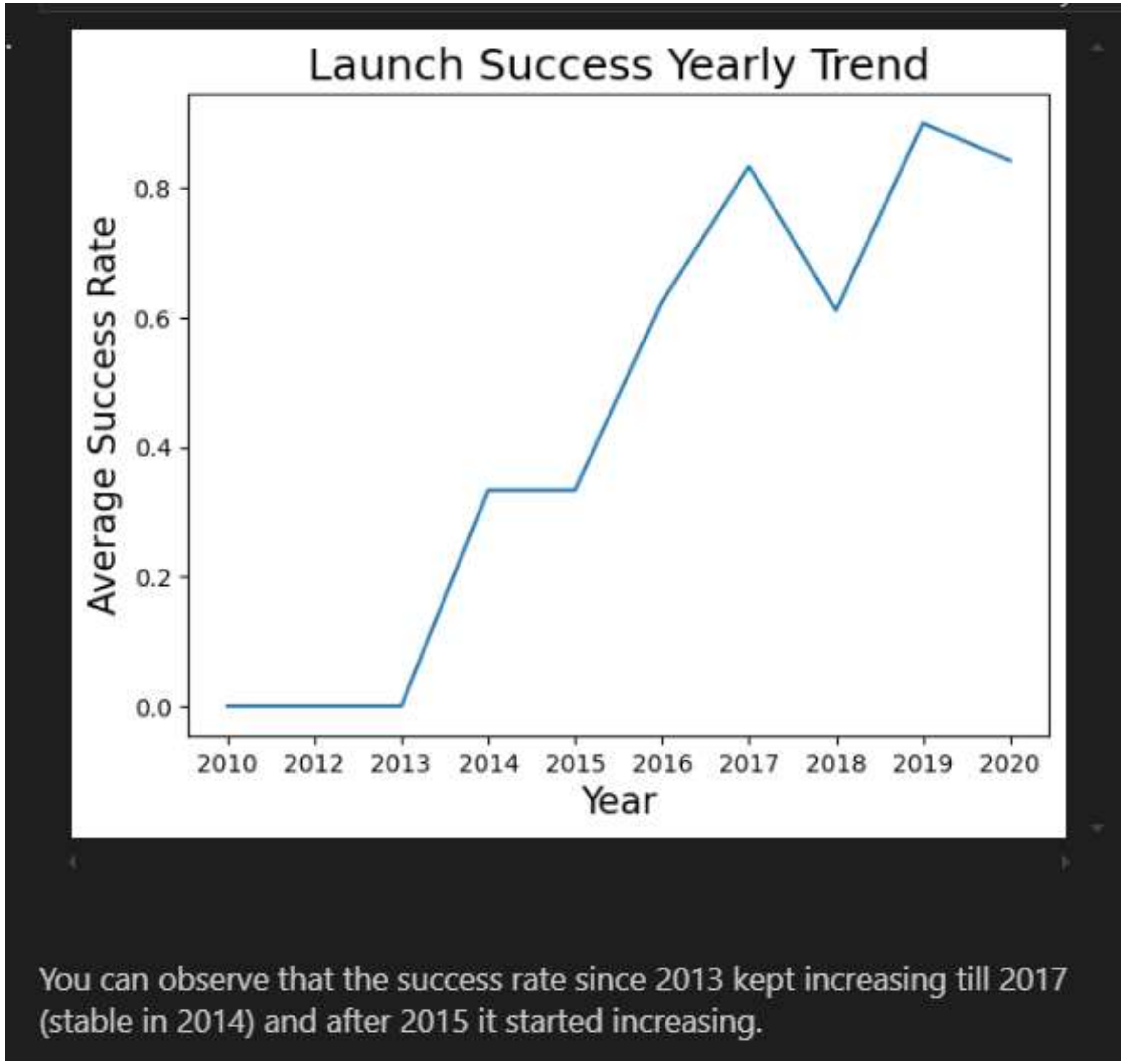
- Show a line chart of yearly average success rate
- Show the screenshot of the scatter plot with explanations



You can observe that the success rate since 2013 kept increasing till 2017 (stable in 2014) and after 2015 it started increasing.

All Launch Site Names

- Find the names of the unique launch sites
- Present your query result with a short explanation here



Launch Site Names Begin with 'CCA'

Date	Time (UTC)	Booster_Version	Launch_Site
2010-06-04	18:45:00	F9 v1.0 B0003	CCAFS LC-40
2010-12-08	15:43:00	F9 v1.0 B0004	CCAFS LC-40
2012-05-22	7:44:00	F9 v1.0 B0005	CCAFS LC-40
2012-10-08	0:35:00	F9 v1.0 B0006	CCAFS LC-40
2013-03-01	15:10:00	F9 v1.0 B0007	CCAFS LC-40

- Find 5 records where launch sites begin with `CCA`

- <u>Present your query result with a short explanation here</u>

SELECT * FROM SPACEXTBL WHERE LaunchSite LIKE 'CCA%' LIMIT 5;

Total Payload Mass

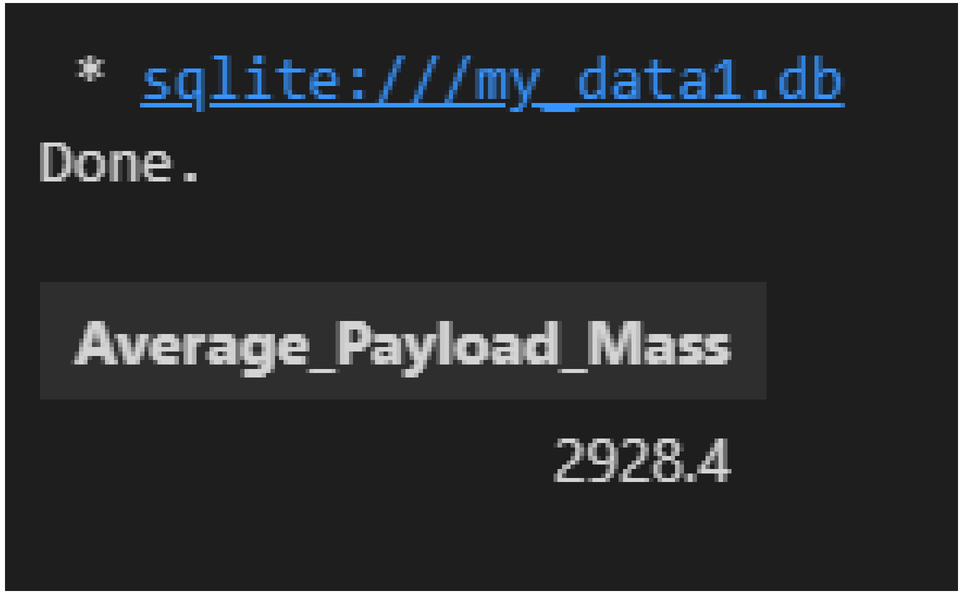
```
* sqlite:///my_data1.db
Done.
```

Total_Payload_Mass
48213

- Calculate the total payload carried by boosters from NASA
- Present your query result with a short explanation here

%sql SELECT SUM(PAYLOAD_MASS__KG_) AS Total_Payload_Mass \ FROM SPACEXTABLE \ WHERE Customer LIKE '%NASA (CRS)%';

Average Payload Mass by F9 v1.1


* sqlite:///my_data1.db
Done.

Average_Payload_Mass
2928.4

- Calculate the average payload mass carried by booster version F9 v1.1
- Present your query result with a short explanation here

%sql SELECT AVG(PAYLOAD_MASS__KG_) AS Average_Payload_Mass \

FROM SPACEXTABLE \

WHERE "Booster_Version" = 'F9 v1.1';

First Successful Ground Landing Date

- Find the dates of the first successful landing outcome on ground pad
- Present your query result with a short explanation here

```
%sql SELECT MIN(Date) AS First_Successful_Landing_Date \

FROM SPACEXTABLE \

WHERE "Landing_Outcome" = 'Success (ground pad)';
```

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

First_Successful_Landing_Date
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

- List the names of boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 6000

- Present your query result with a short explanation here

```
%sql SELECT "Booster_Version" \

FROM SPACEXTABLE \

WHERE "Landing_Outcome" = '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

- Calculate the total number of successful and failure mission outcomes
- Present your query result with a short explanation here

%sql SELECT "Mission_Outcome", COUNT(*) AS Total_Count \

FROM SPACEXTABLE \

GROUP BY "Mission_Outcome";

* sqlite:///my_data1.db

Done.

Mission_Outcome	Total_Count
Failure (in flight)	1
Success	98
Success	1
Success (payload status unclear)	1

Boosters Carried Maximum Payload

- List the names of the booster which have carried the maximum payload mass
- Present your query result with a short explanation here

%sql SELECT "Booster_Version" \

FROM SPACEXTABLE \

WHERE "PAYLOAD_MASS__KG_" = (SELECT MAX("PAYLOAD_MASS__KG_") FROM SPACEXTABLE);

* 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

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

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

- List the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015

- Present your query result with a short explanation here

```
%sql SELECT substr(Date, 6, 2) AS Month, \

"Landing_Outcome", "Booster_Version", "Launch_Site" \

FROM SPACEXTABLE \

WHERE "Landing_Outcome" = 'Failure (drone ship)' \

AND substr(Date, 0, 5) = '2015';
```

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

- Rank the count of landing outcomes (such as Failure (drone ship) or Success (ground pad)) between the date 2010-06-04 and 2017-03-20, in descending order

- Present your query result with a short explanation here

```
%sql SELECT "Landing_Outcome", COUNT(*) AS Outcome_Count \
FROM SPACEXTABLE \
WHERE Date >= '2010-06-04' AND Date <= '2017-03-20' \
GROUP BY "Landing_Outcome" \
ORDER BY Outcome_Count DESC;
```

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

Landing_Outcome	Outcome_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

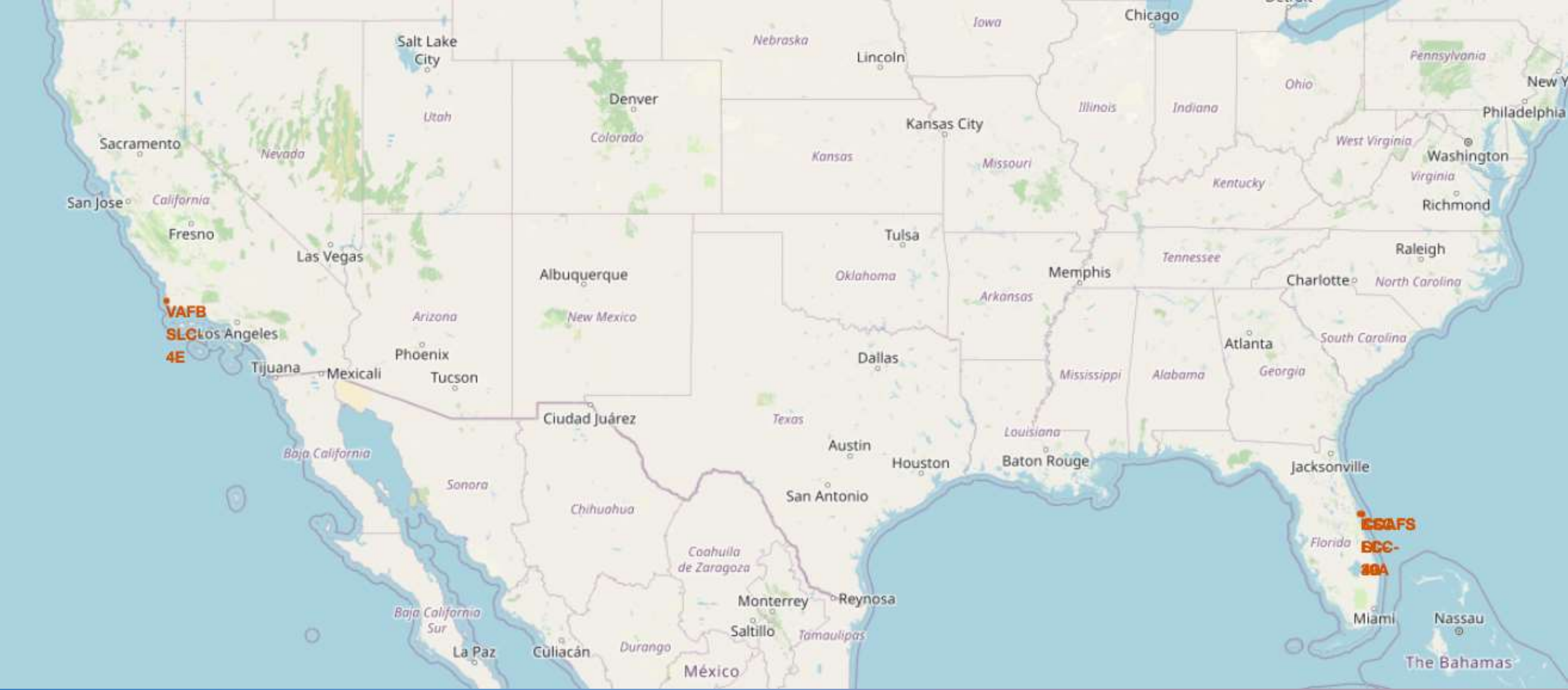
Launch Sites Proximities Analysis

Interactive Map: Launch Sites

- Replace <Folium map screenshot 1> title with an appropriate title

- Explore the generated folium map and make a proper screenshot to include all launch sites' location markers on a global map

- Explain the important elements and findings on the screenshot



Interactive Map: Launch Sites

Interactive Map: Launch Sites

- **<u>Explain the important elements and findings on the screenshot</u>**

Geographical Distribution: the launch sites are distributed geographically, particularly focusing on their proximity to coastlines. This is a strategic choice to minimize risk and maximize safety during launches.

Coastline Proximity: Point out that most SpaceX launch sites are located close to coastlines. This is crucial for safe rocket launches, as it minimizes the risk of debris falling overpopulated areas.

Proximity to Major Cities: While the sites are near coastlines, they are also strategically placed away from major cities to ensure safety and security during launches.

Launch Outcomes: Color-Coded Markers on the Map

- Replace <Folium map screenshot 2> title with an appropriate title
- Explore the folium map and make a proper screenshot to show the color-labeled launch outcomes on the map
- Explain the important elements and findings on the screenshot

Launch Outcomes: Color-Coded Markers on the Map

Launch Outcomes: Color-Coded Markers on the Map

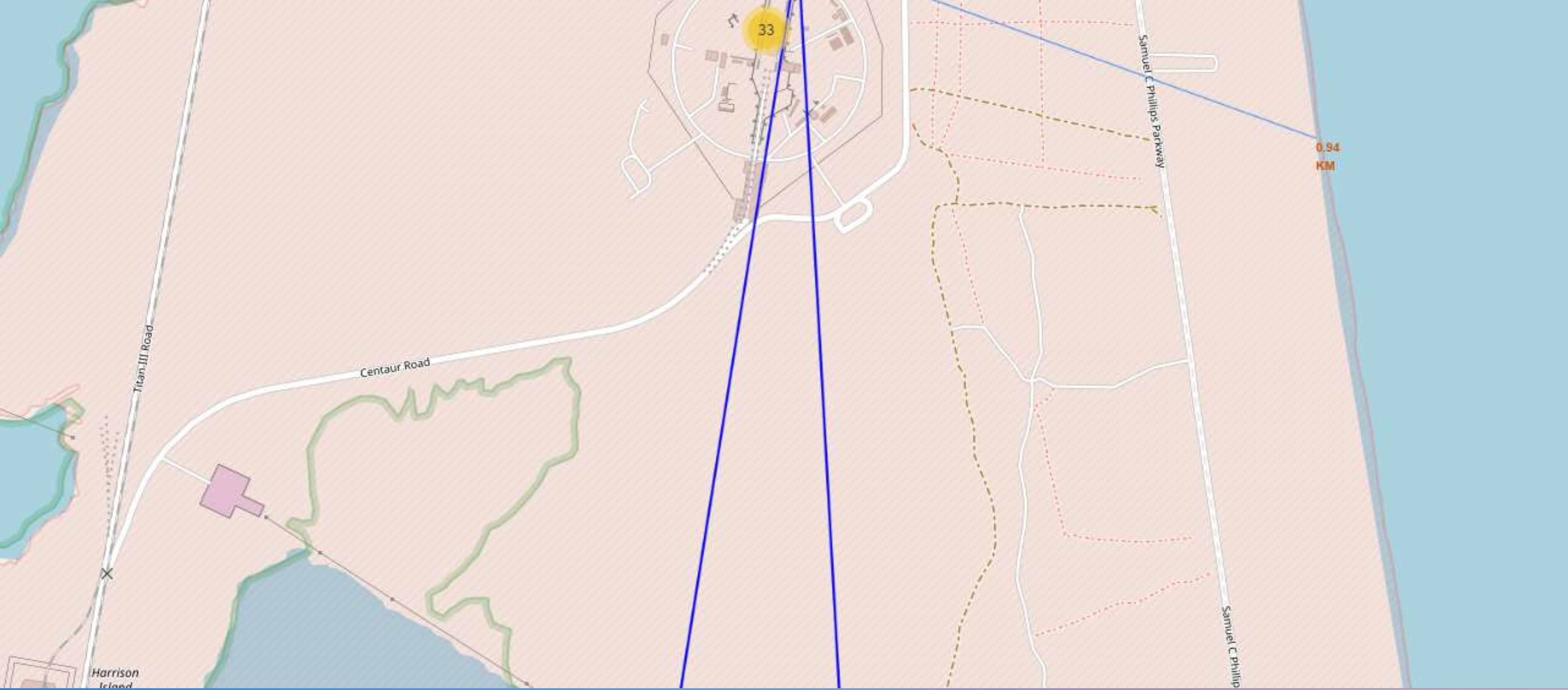
- **<u>Explain the important elements and findings on the screenshot</u>**
- The map uses color-coded markers to differentiate between successful and unsuccessful launches. Typically, green markers indicate successful landings, while red markers indicate failures.
- This visual analysis could inform decisions about future launches, potentially choosing sites with a higher historical success rate.

Proximity Analysis: Launch Site to Key Infrastructure

- Replace <Folium map screenshot 3> title with an appropriate title

- Explore the generated folium map and show the screenshot of a selected launch site to its proximities such as railway, highway, coastline, with distance calculated and displayed

- Explain the important elements and findings on the screenshot



Proximity Analysis: Launch Site to Key Infrastructure

Proximity Analysis: Launch Site to Key Infrastructure

- **Explain the important elements and findings on the screenshot**

The lines connecting the launch site to nearby infrastructure such as railways, highways, and coastlines. Discuss the calculated distances displayed on the map.

The proximity to infrastructure like railways and highways is crucial for logistical reasons, such as transporting rockets and equipment. Proximity to coastlines is important for safety reasons during launches.

Section 4

Build a Dashboard with Plotly Dash

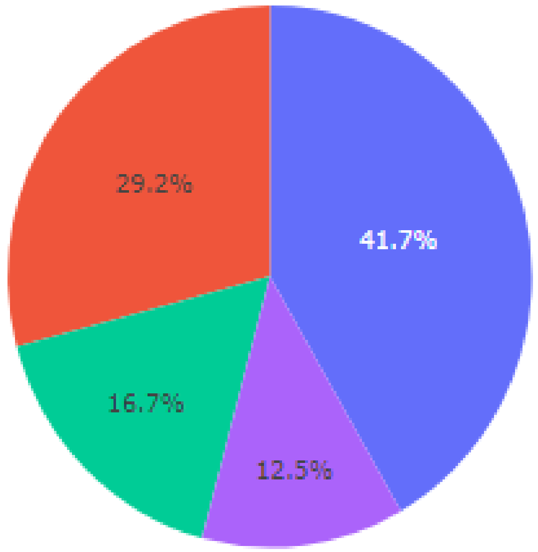
Launch Success Count by Site: Pie Chart Visualization

- Replace <Dashboard screenshot 1> title with an appropriate title

- Show the screenshot of launch success count for all sites, in a piechart

- Explain the important elements and findings on the screenshot

SpaceX Launch Records Dashboard



Launch Success Count by Site: Pie Chart Visualization

Launch Success Count by Site: Pie Chart Visualization

- **Explain the important elements and findings on the screenshot**

The pie chart visually represents the proportion of successful launches at each site. Highlight which site has the largest share of successful launches.

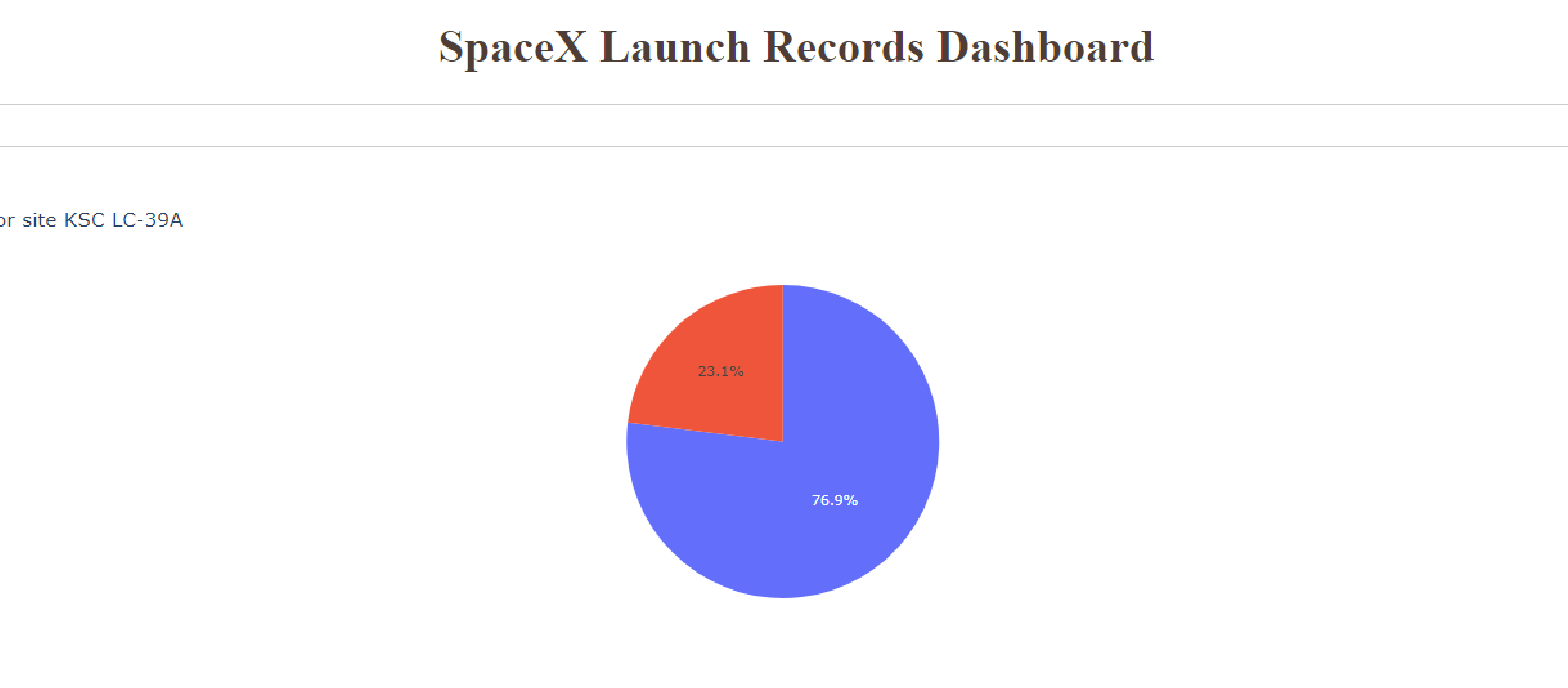
The pie chart makes it easy to see the relative performance of different launch sites in terms of success rate.

Launch Success Ratio: Pie Chart for Top Performing Site

- Replace <Dashboard screenshot 2> title with an appropriate title

- Show the screenshot of the piechart for the launch site with highest launch success ratio

- Explain the important elements and findings on the screenshot



Launch Success Ratio: Pie Chart for Top Performing Site

Launch Success Ratio: Pie Chart for Top Performing Site

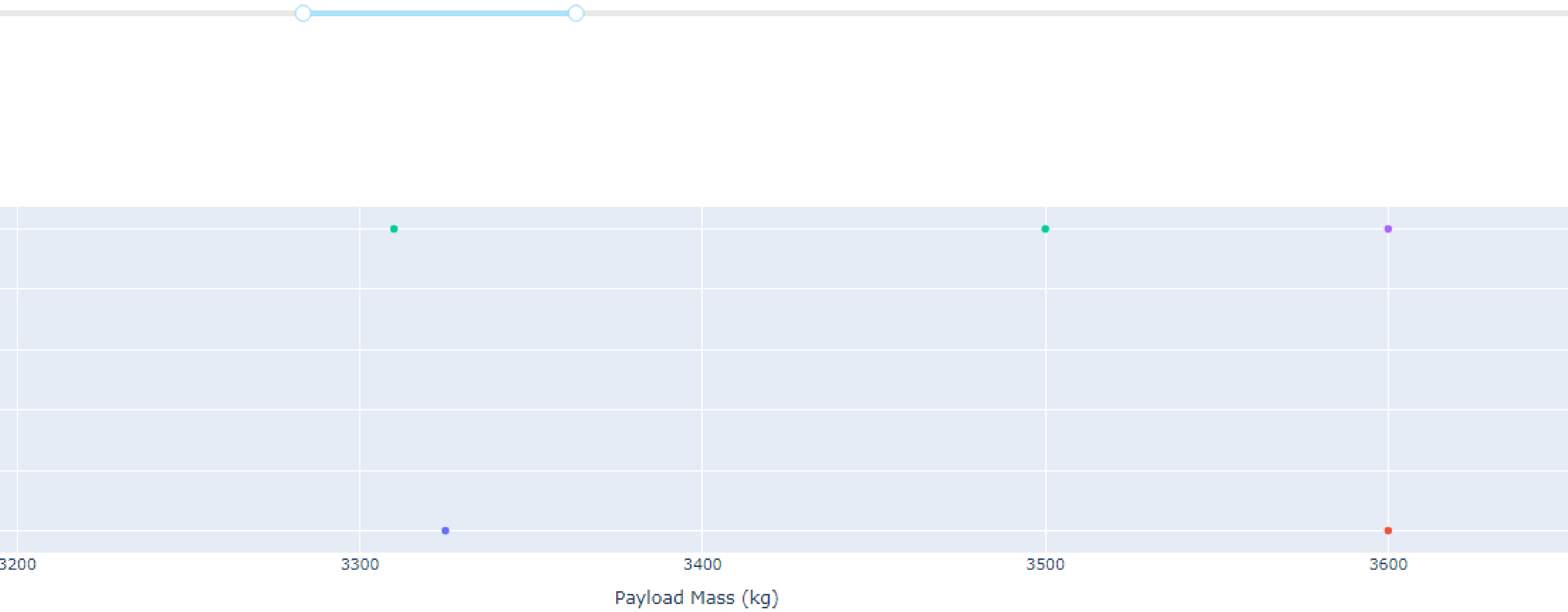
- **Explain the important elements and findings on the screenshot**

The pie chart shows that the "KSC LC-39A" launch site has a high success rate, with 76.9% of launches being successful. This indicates that most launches from this site achieve their objectives without issues.

However, 23.1% of the launches from this site have failed, which is a substantial portion. This suggests that while the site is generally successful, there is still a notable risk of failure.

Payload vs. Launch Outcome: Scatter Plot Analysis Across All Sites

- Replace <Dashboard screenshot 3> title with an appropriate title
- Show screenshots of Payload vs. Launch Outcome scatter plot for all sites, with different payload selected in the range slider
- Explain the important elements and findings on the screenshot, such as which payload range or booster version have the largest success rate, etc.



Payload vs. Launch Outcome: Scatter Plot Analysis Across All Sites

Payload vs. Launch Outcome: Scatter Plot Analysis Across All Sites

- **Explain the important elements and findings on the screenshot, such as which payload range or booster version have the largest success rate, etc.**

The range slider at the top indicates that the selected payload range is between approximately 3100 kg and 3700 kg. This specific range is used to filter the data points displayed in the scatter plot.

The legend on the right side of the plot indicates the different booster versions used for the launches. The data points are color-coded according to the booster version category (e.g., v1.1, FT, B4, B5).From the plot, it’s evident that different booster versions are associated with varying payload masses and outcomes.

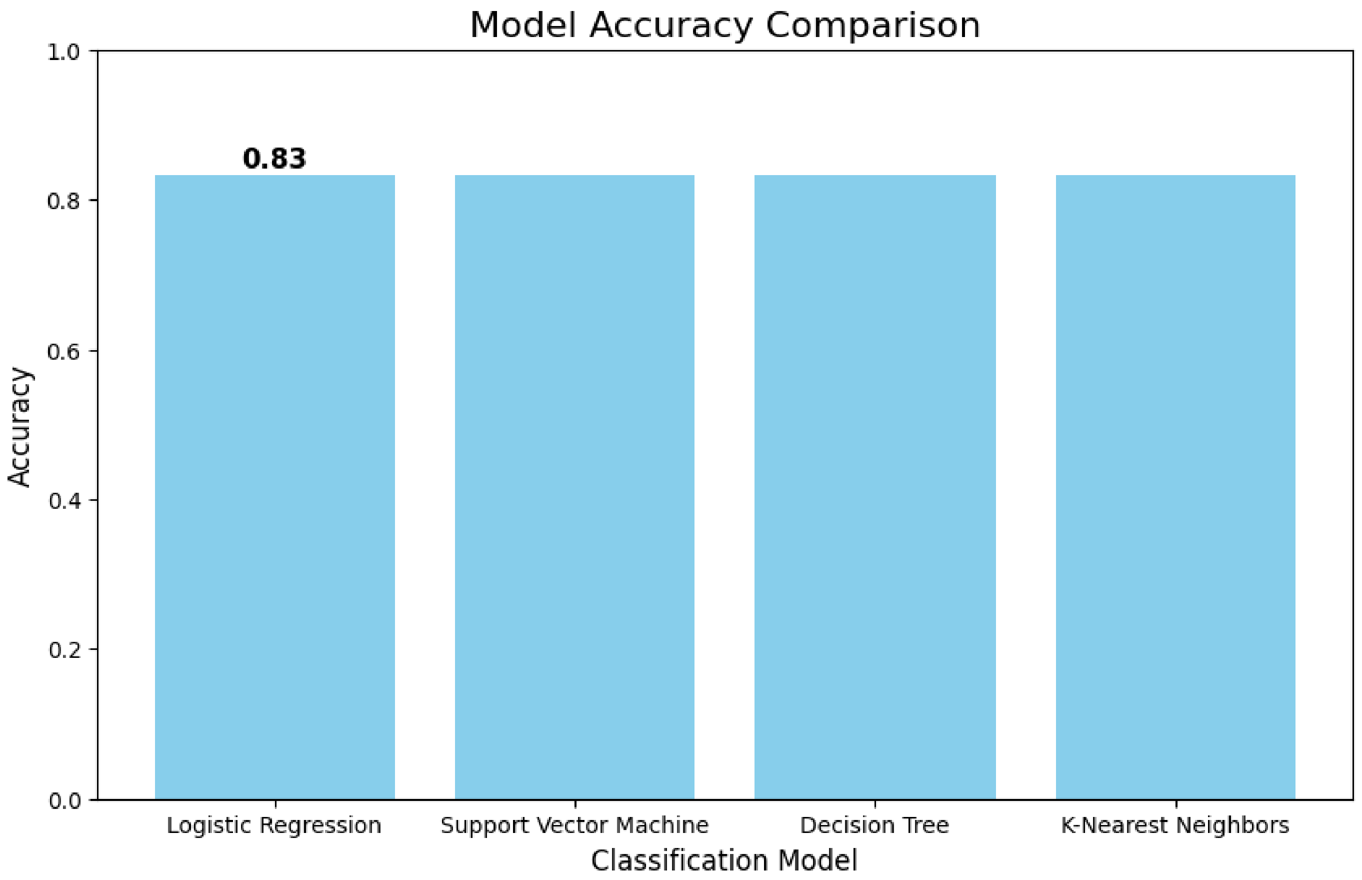
Section 5

Predictive Analysis (Classification)

Classification Accuracy

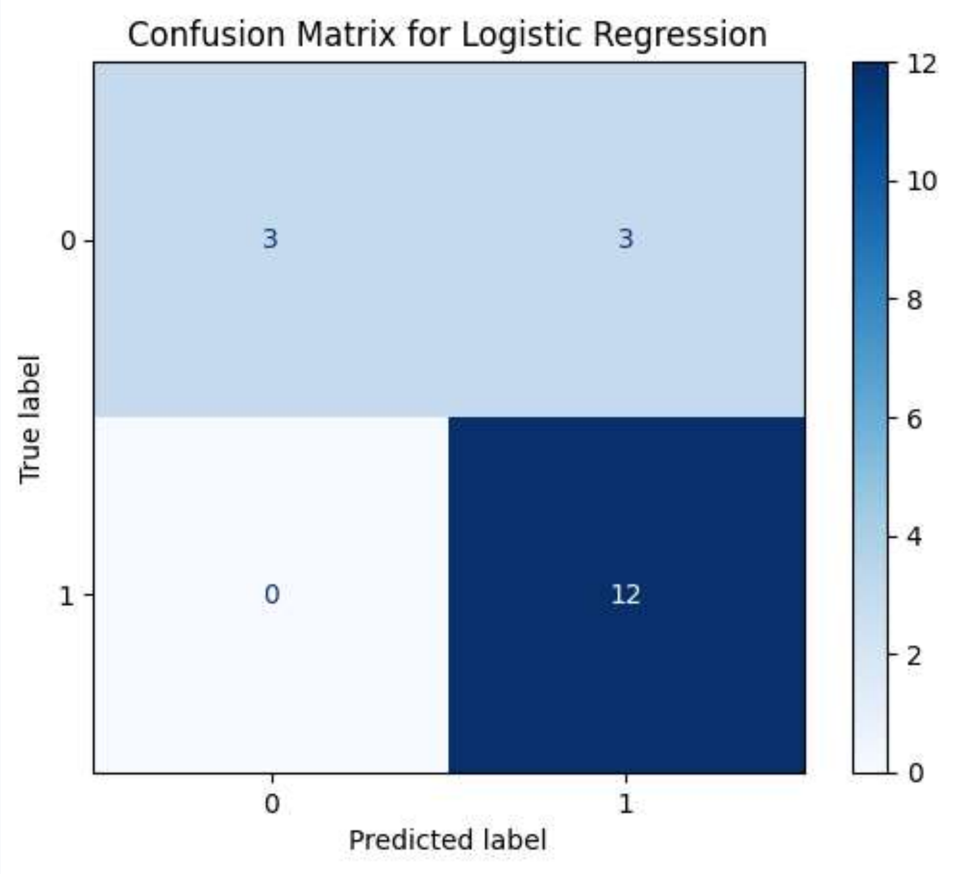
- Visualize the built model accuracy for all built classification models, in a bar chart

- Find which model has the highest classification accuracy



Confusion Matrix

- Show the confusion matrix of the best performing model with an explanation



Conclusions

Model Performance:

- All four models (Logistic Regression, Support Vector Machine, Decision Tree, K-Nearest Neighbors) achieved a test accuracy of 83.33%.
- Logistic Regression was identified as the best-performing model based on its predictive accuracy and simplicity.

Insights from the Analysis:

- Launch Sites: The analysis highlighted that the KSC LC-39A site had the highest success ratio, making it a critical site for successful launches.
- Payload Impact: The scatter plots revealed that payload mass does influence the success rate, particularly for certain orbits and booster versions.

Conclusions

Importance of Predictive Analysis:

- Predictive analysis is crucial for SpaceX (or any other space company) to optimize costs by accurately predicting the likelihood of first-stage landings, thereby increasing the chances of reusing rockets and reducing overall mission costs.

Application of Findings:

- The models developed can assist in making informed decisions about launch schedules, payload capacities, and launch site selections to maximize success rates.
- The dashboard and interactive maps provide valuable tools for real-time decision-making and planning.

Conclusions

Future Work:

- Further data collection and model refinement could improve prediction accuracy.
- Exploration of additional factors (e.g., weather conditions, precise timing) could provide deeper insights into successful landings.

Appendix

- Include any relevant assets like Python code snippets, SQL queries, charts, Notebook outputs, or data sets that you may have created during this project

Thank you!