IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

Mohammad Meysam Arjomand
15.01.2025

Outline

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

Executive Summary

- This project aimed to analyze and predict the success of SpaceX Falcon 9 first-stage landings using historical launch data. Data was collected from the public SpaceX API and Wikipedia, including details on rocket types, launch sites, payloads, and landing outcomes. A new column, ‘class’, was created to classify landing success.
- The data underwent cleaning and processing, including exploratory data analysis (EDA) to identify patterns like success rates for different orbit types and correlations between launch sites and payload mass. Categorical variables were converted to binary using one-hot encoding, and the data was standardized for machine learning model training.
- Four machine learning models—Logistic Regression, Support Vector Machine (SVM), Decision Tree Classifier, and K-Nearest Neighbors (KNN)—were developed and evaluated. All models achieved a similar accuracy of **83.33%**, with a tendency to over-predict successful landings. GridSearchCV was used to optimize hyperparameters, and further data collection is needed for improved accuracy.
- Additionally, an interactive dashboard was created using **Plotly Dash** and **Folium**, allowing real-time exploration of launch data and trends, including interactive maps of launch site locations. The findings offer valuable insights into SpaceX's launch operations, helping to refine strategies and decision-making for future missions.

Introduction

- **Project Background and Problem Statement**
- SpaceX leads the commercial space industry with cost-effective launches ($62 million vs. $165 million) thanks to its ability to recover the first stage of rockets. SpaceY aims to compete by predicting Falcon 9's first-stage landing success.
- The goal is to build a machine learning model that predicts landing success based on historical data, including mission conditions, rocket parameters, and launch sites. The key question is: **Can we predict landing success or failure using available data?**

SpaceX Falcon 9 Rocket –TheVerge

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology
- Perform data wrangling
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models

Data Collection

1. Space-X REST API:

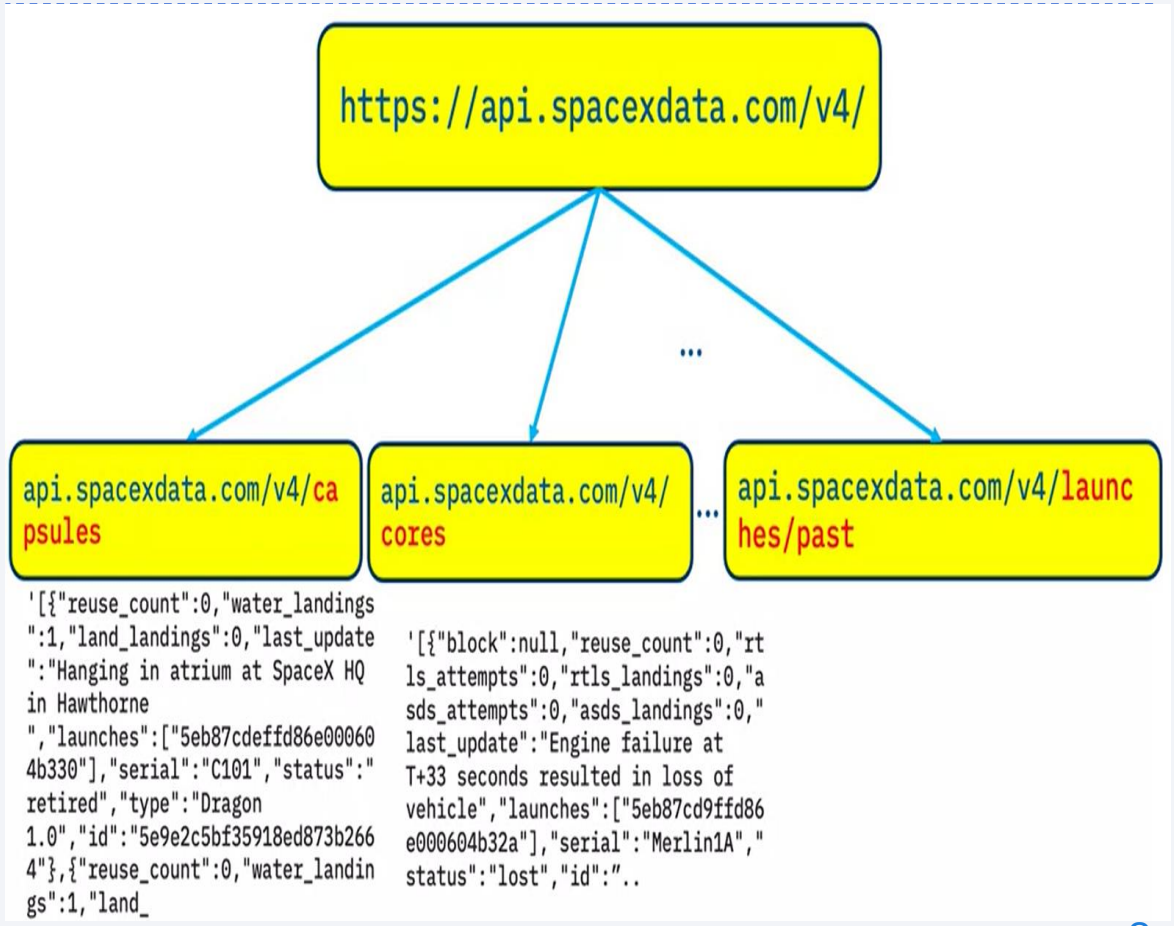
- Data on past rocket launches was retrieved from the endpoint **api.spacexdata.com/v4/launches/past**
- The JSON data includes information about rockets, launch and landing parameters, as well as results.

2. Web-Scraping

- Using **BeautifulSoup**, HTML tables of Falcon 9 launches were extracted and stored in a **Dataframe**.

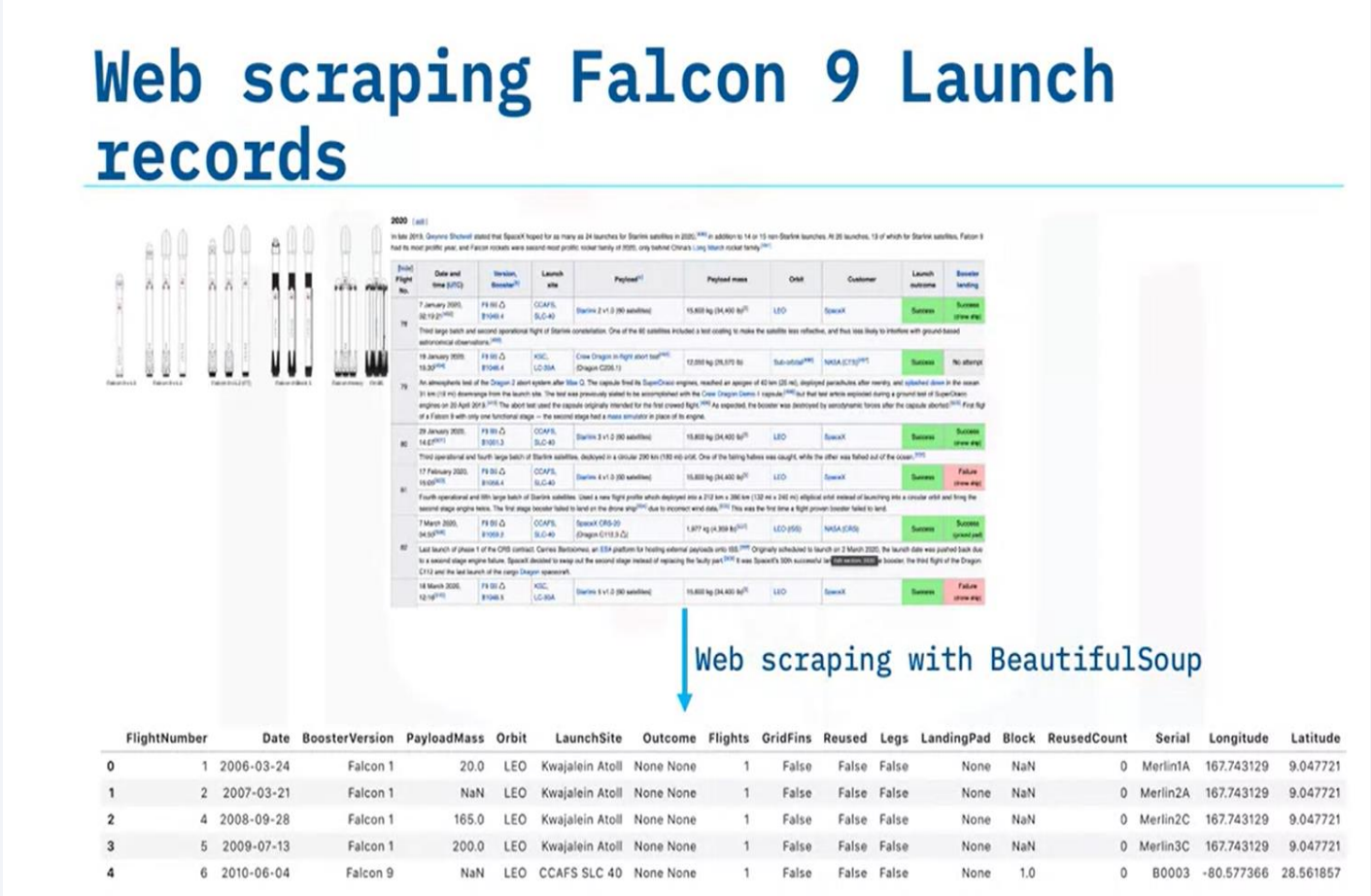
Data Collection – SpaceX API

- This API will provide us with data about launches, including information about the rocket used, launch specifications, landing specifications, and the landing outcome.
- There are various endpoint APIs; we will work with **api.spacexdata.com/v4/launches/past**.
- LINK



Data Collection – Scraping Process

- Extracted Falcon 9 launch records from Wikipedia using BeautifulSoup.
- Parsed the HTML table to retrieve rows and columns.
- Converted the extracted data into Validated ana Pandas DataFrame.
- Validated and cleaned the data for further analysis.
- LINK



	FlightNumber	Date	BoosterVersion	PayloadMass	Orbit	LaunchSite	Outcome	Flights	GridFins	Reused	Legs	LandingPad	Block	ReusedCount	Serial	Longitude	Latitude
0	1	2006-03-24	Falcon 1	20.0	LEO	Kwajalein Atoll	None None	1	False	False	False	None	NaN	0	Merlin1A	167.743129	9.047721
1	2	2007-03-21	Falcon 1	NaN	LEO	Kwajalein Atoll	None None	1	False	False	False	None	NaN	0	Merlin2A	167.743129	9.047721
2	4	2008-09-28	Falcon 1	165.0	LEO	Kwajalein Atoll	None None	1	False	False	False	None	NaN	0	Merlin2C	167.743129	9.047721
3	5	2009-07-13	Falcon 1	200.0	LEO	Kwajalein Atoll	None None	1	False	False	False	None	NaN	0	Merlin3C	167.743129	9.047721
4	6	2010-06-04	Falcon 9	NaN	LEO	CCAFS SLC 40	None None	1	False	False	False	None	1.0	0	B0003	-80.577366	28.561857

Data Wrangling

- To create the training labels, we defined a new column called **'class'** based on the **Mission Outcome** and **Landing Location**. A value of **1** was assigned for successful landings, which includes outcomes like **True ASDS**, **True RTLS**, and **True Ocean**. A value of **0** was assigned for failures, including outcomes like **False ASDS**, **False RTLS**, **None ASDS**, and **None Ocean**.
- Performed exploratory data analysis to identify patterns and determine the labels for training supervised models
- Handling of Null Values:

  Null values were identified and handled to ensure data quality.
- LINK

EDA with Data Visualization

- Exploratory Data Analysis performed on variables Flight Number, Payload Mass, Launch Site, Orbit, Class andYear.
- PlotsUsed:
- Flight Number vs. Payload Mass, Flight Number vs. Launch Site, Payload Mass vs. Launch Site, Orbit vs. Success Rate, Flight Number vs. Orbit, Payload vs Orbit, and Success YearlyTrend
- Scatter plots, line charts, and bar plots were used to compare relationships between variablesto
- decide if a relationship exists so that they could be used in training the machine learningmodel
- LINK

EDA with SQL

- Loaded data set into IBM DB2Database.
- Queried using SQL Pythonintegration.
- Queries were made to get a better understanding of thedataset.
- Queried information about launch site names, mission outcomes, various pay load sizes of customers and booster versions, and landingoutcomes

- LINK

Build an Interactive Map with Folium

- Folium maps mark Launch Sites, successful and unsuccessful landings, and a proximity example to key locations: Railway, Highway, Coast, andCity.
- This allows us to understand why launch sites may be located where they are. Also visualizes successful landings relative tolocation.
- Reason for Adding These Objects:
  These objects enhance the map's interactivity and provide a clear, visual representation of spatial relationships and patterns, aiding in the exploration of optimal launch site locations.
- LINK

Build a Dashboard with Plotly Dash

- Dashboard includes a pie chart and a scatterplot.
- Pie chart can be selected to show distribution of successful landings across all launch sites and can be selected to show individual launch site successrates.
- Scatter plot takes two inputs: All sites or individual site and payload mass on a slider between 0 and 10000kg.
- The pie chart is used to visualize launch site successrate.
- The scatter plot can help us see how success varies across launch sites, payload mass,and
- booster versioncategory.

Predictive Analysis (Classification)

1.Data Preparation:

- Split the dataset into training and testing sets to evaluate model performance.

2.Model Building:

- Built and trained four different classification models:

Logistic Regression, Support Vector Machine (SVM), Decision Tree Classifier, K-Nearest Neighbors (K-NN)

3.Model Evaluation:

- Used a Confusion Matrix to evaluate the accuracy and performance of each model.
- LINK

Results

1.Exploratory data analysis results :

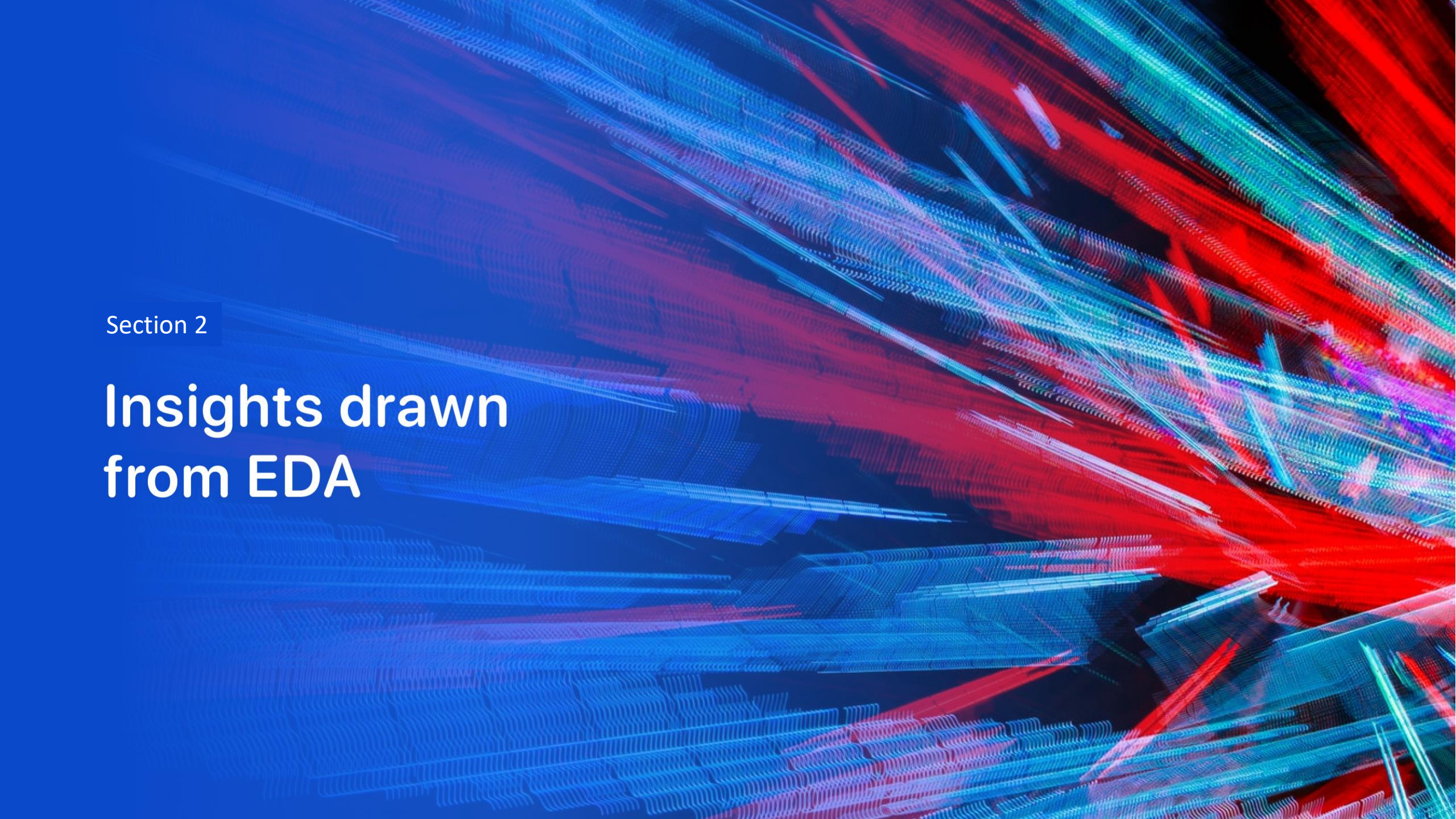
- Bar chart: Success rate by orbit type.
- Scatter plot: Launch site vs. payload mass.
- Line chart: Yearly launch success trends.

2.Interactive analysis results :

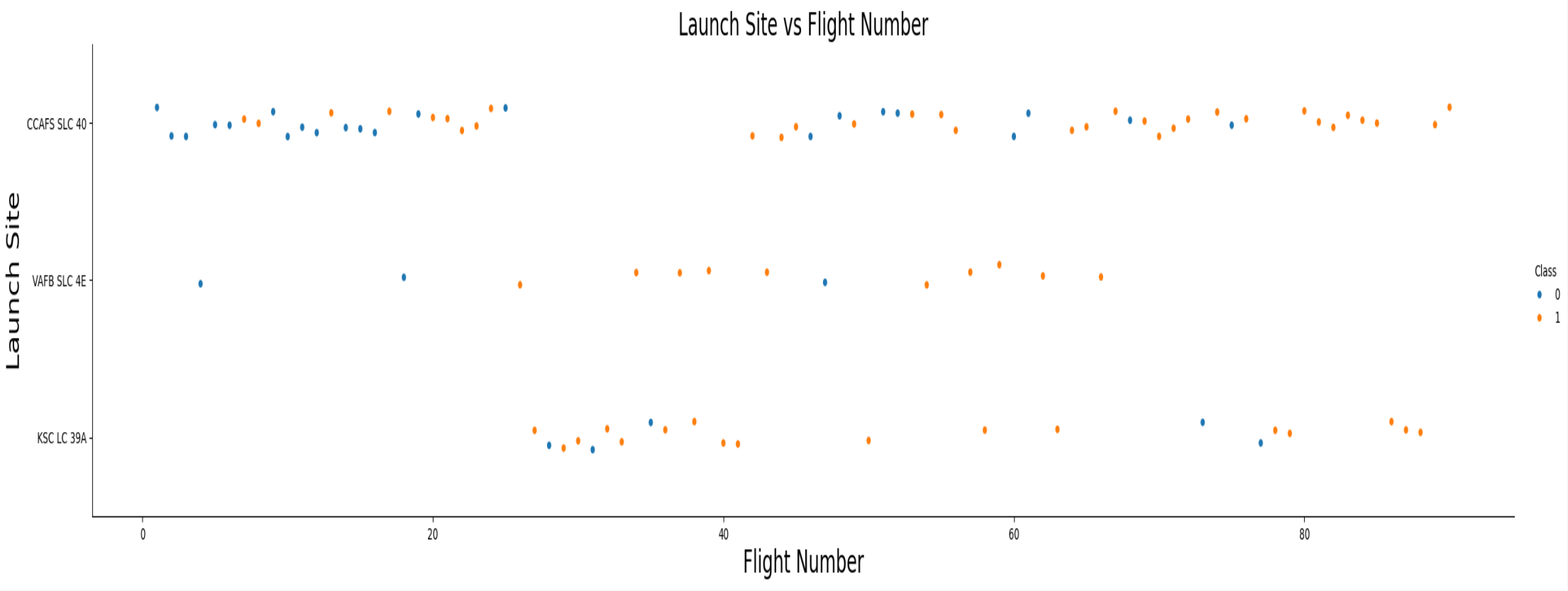
- Dashboard: Interactive maps and real-time data exploration with Folium and Plotly Dash.

3.Predictive analysis results :

- All models (Logistic Regression, Decision Tree, KNN, SVM) achieved an accuracy of **83.33%**.


Section 2
Insights drawn from EDA

Flight Number vs. Launch Site

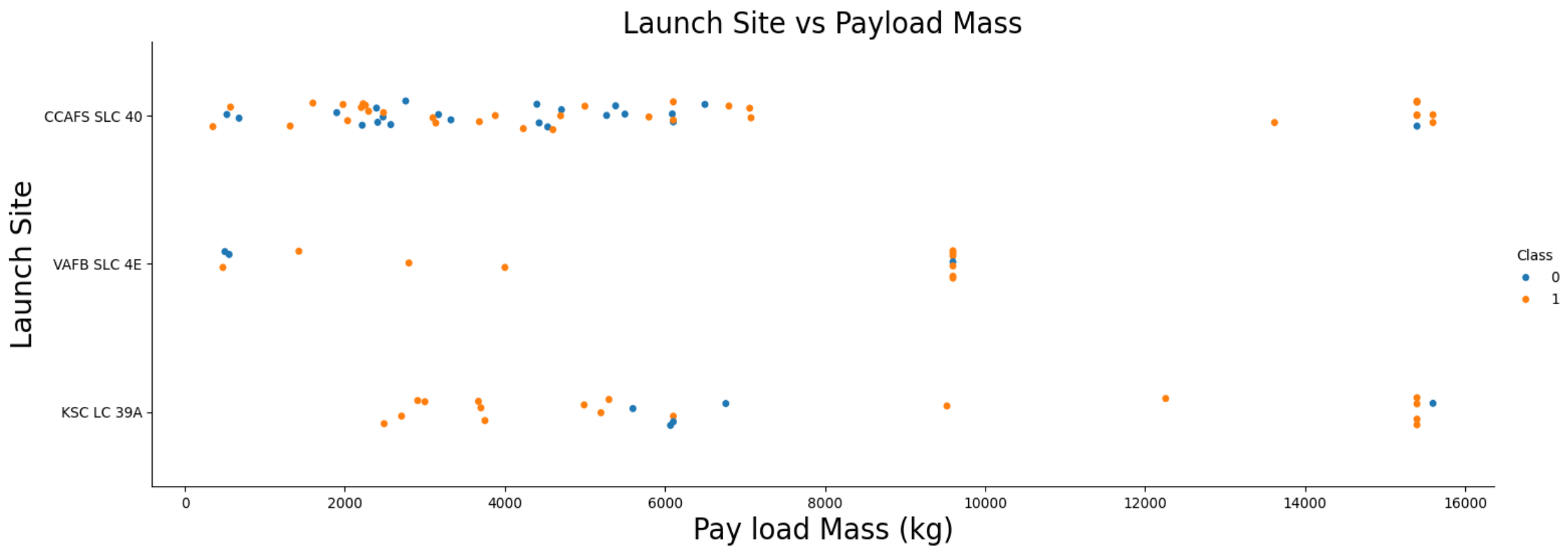


Relationship between flight number and launch site

Class 0 = Unsuccessful landing of the Falcon 9 first stage.

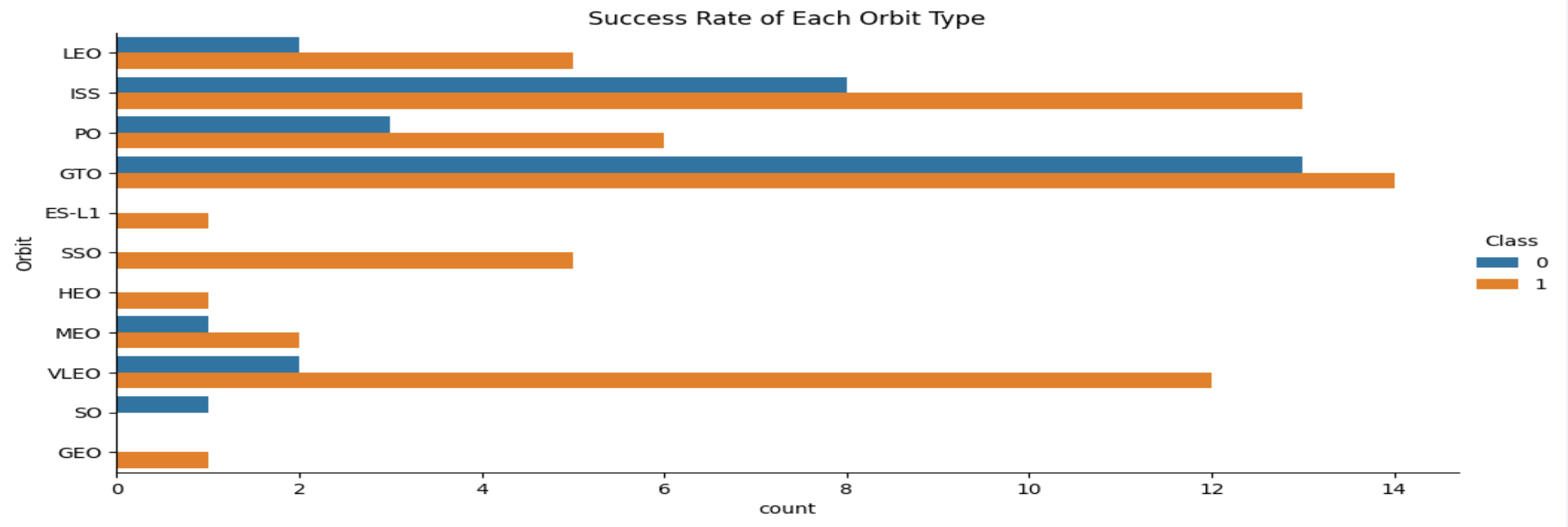
Class 1 = Successful landing of the Falcon 9 first stage.

Payload vs. Launch Site



Payload mass appears to fall mostly between 0 6000 kg. Different launch sites also seem to use different payload mass.

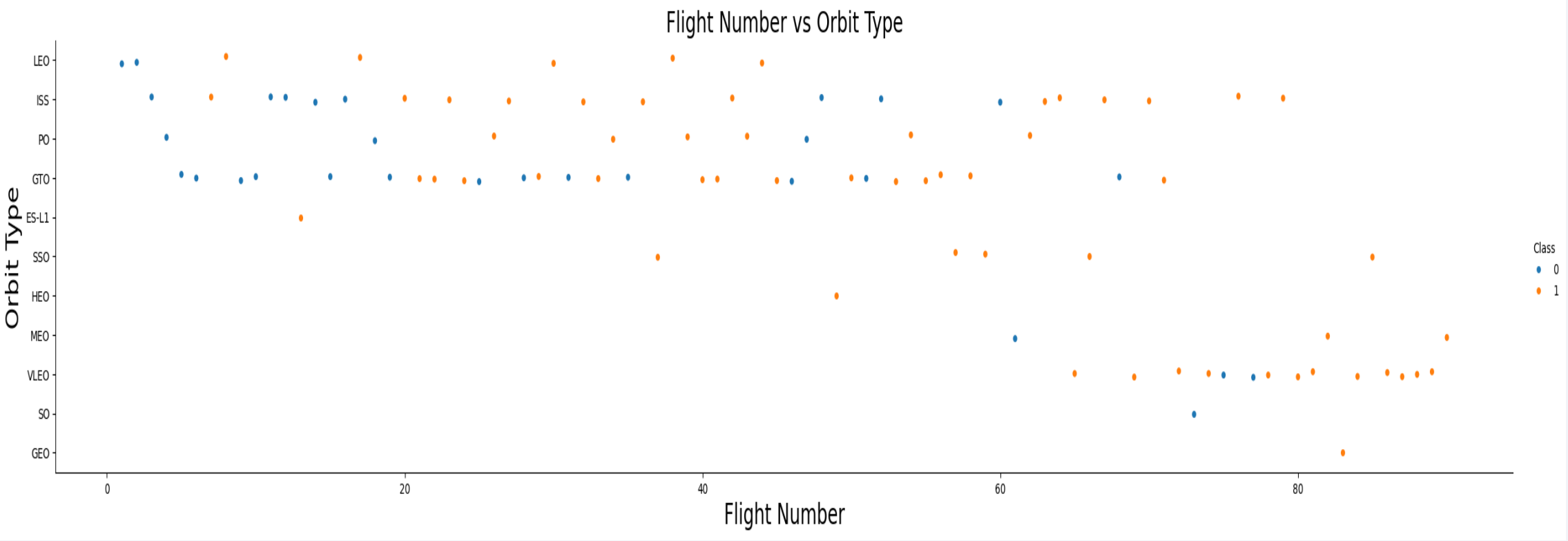
Success Rate vs. Orbit Type



- Most failures occurred in GTO

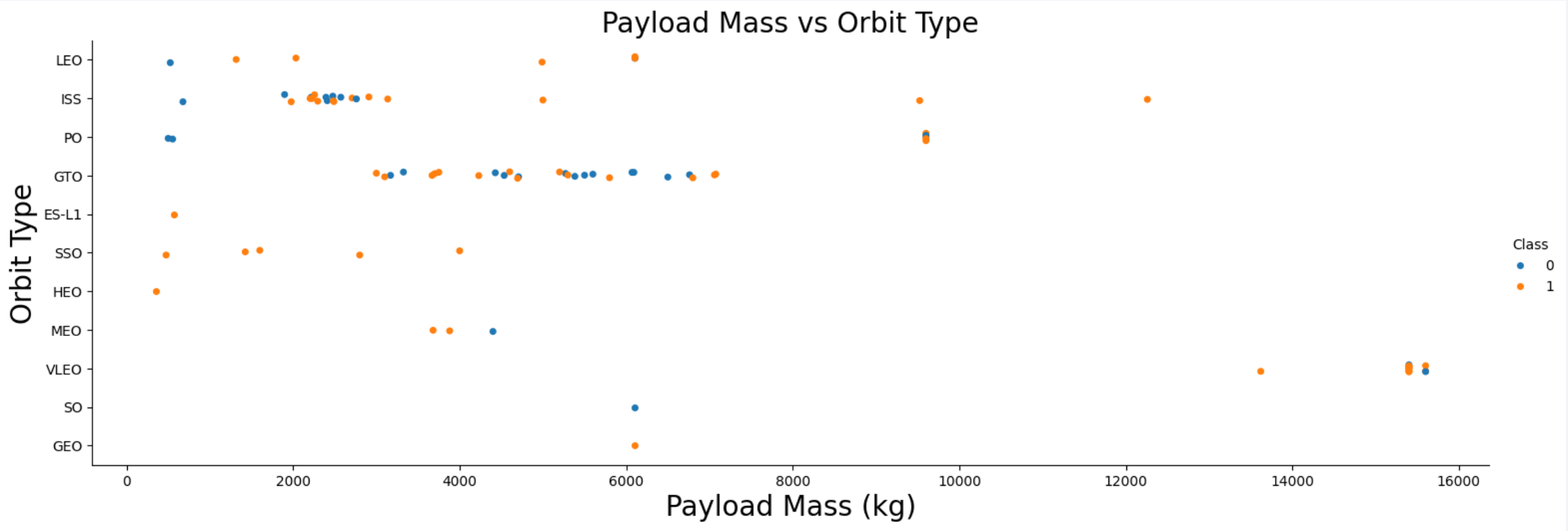
GEO,ES-L1, SSO, and HEO, all attempts were successful.

Flight Number vs. Orbit Type



- Launch Orbit preferences changed over Flight Number. Launch Outcome seems to correlate with thispreference.
- SpaceX started with LEO orbits which saw moderate success LEO and returned to VLEO in recent launches SpaceX appears to perform better in lower orbits or Sun-synchronousorbits

Payload vs. Orbit Type



Payload mass seems to correlate withorbit

LEO and SSO seem to have relatively low payloadmass

The other most successful orbit VLEO only has payload mass values in the higher end of therange

Launch Success Yearly Trend

Success generally increases over time since 2013 with a slight dip in2018 Success in recent years at around80%

EDA with SQL

- The names of the unique launch sites

```
[10]
# Display the name of unique launch sites in the space mission
%sql select distinct(Launch_Site) from SPACEXTABLE;
```

```
 * 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'

First five entries in database with Launch Site name beginning with CCA.

```
#Display 5 records where launch sites begin with the string 'CCA'
%sql select * from SPACEXTABLE where Launch_Site like 'CCA%' limit 5;
```

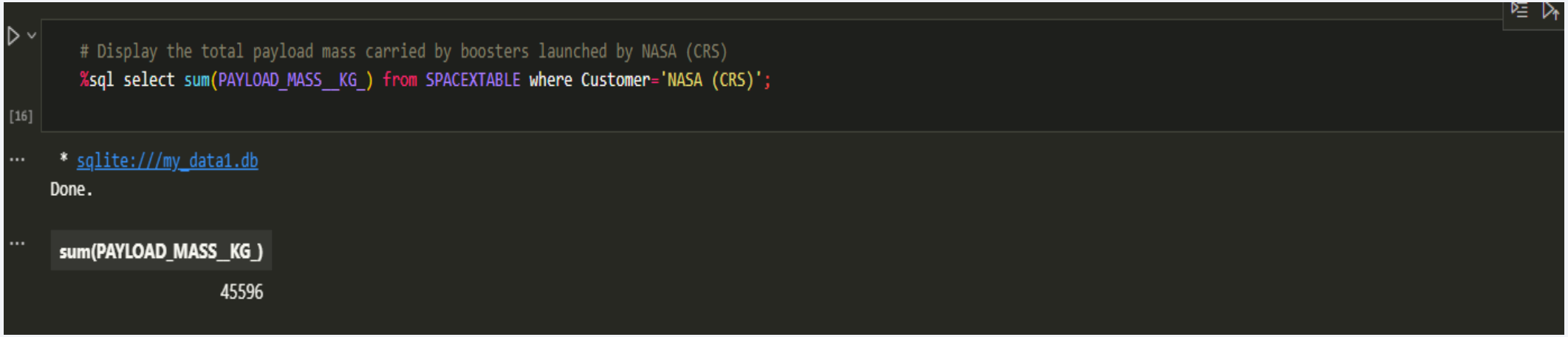
```
14]
```

```
 * 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 query sums the total payload mass in kg where NASA was the customer.



Average Payload Mass by F9 v1.1

This query calculates the average payload mass or launches which used booster version F9v1.1

```
# Display average payload mass carried by booster version F9 v1.1
%sql select avg(PAYLOAD_MASS__KG_) from SPACEXTABLE where Booster_Version='F9 v1.1';
```

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

avg(PAYLOAD_MASS__KG_)
2928.4

First Successful Ground Landing Date

- The dates of the first successful landing outcome on ground pad

```
# List the date when the first successful landing outcome in ground pad was achieved
%sql select min(Date) from SPACEXTABLE 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

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

```
%sql select Booster_Version from SPACEXTABLE where Landing_Outcome='Success (drone ship)' and PAYLOAD_MASS__KG_ between 4000 and 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

- The total number of successful mission outcomes

```
[24]  %sql select count(Mission_Outcome) from SPACEXTABLE where Mission_Outcome='Success';

 * sqlite:///my_data1.db
Done.

count(Mission_Outcome)
                    98
```

Boosters Carried Maximum Payload

- List the names of the booster which have carried the maximum payload mass

```
%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

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

```
%sql select strftime('%m',Date) as Month,Landing_Outcome,Booster_Version,Launch_Site from SPACEXTABLE where strftime('%Y',Date)='2015' and Landing_Outcome='Failure (drone ship)';
```

```
 * 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

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

```
%sql select Landing_Outcome, count(Landing_Outcome) as Count from SPACEXTABLE where Date between '2010-06-04' and '2017-03-20' group by Landing_Outcome order by Count desc;
```

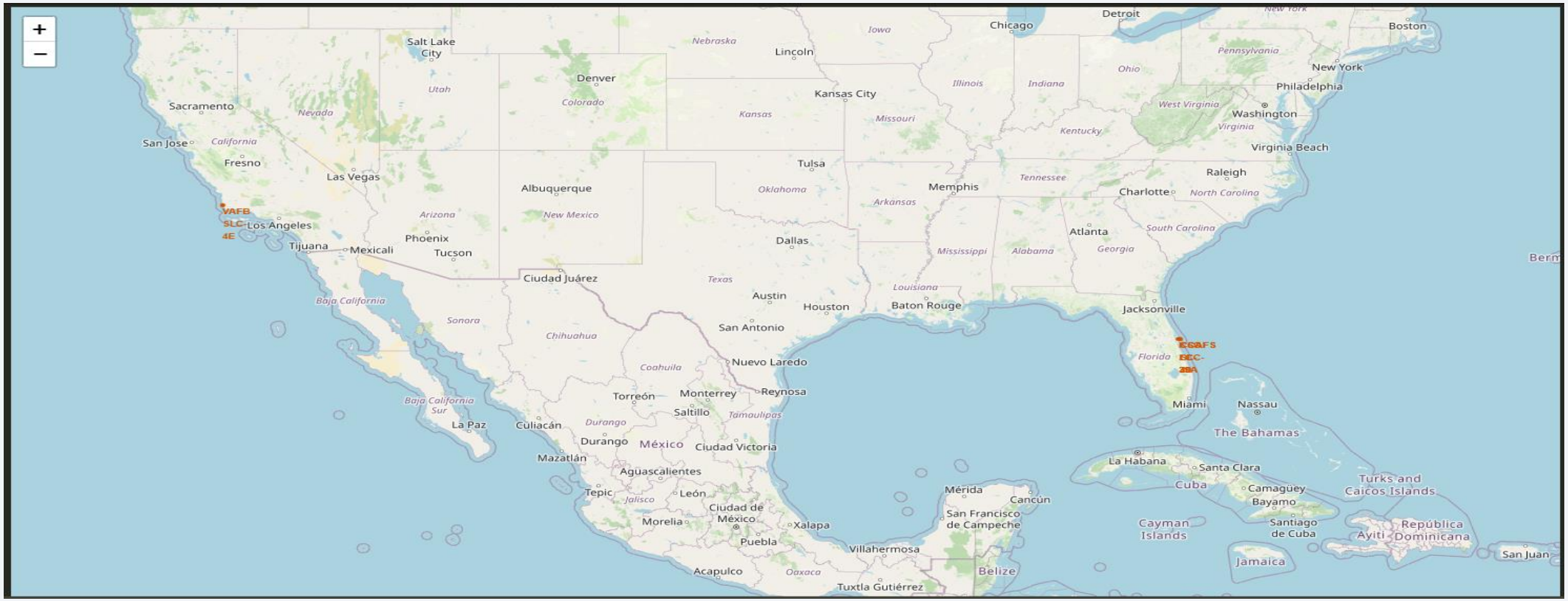
```
 * sqlite:///my_data1.db
Done.
```

Landing_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

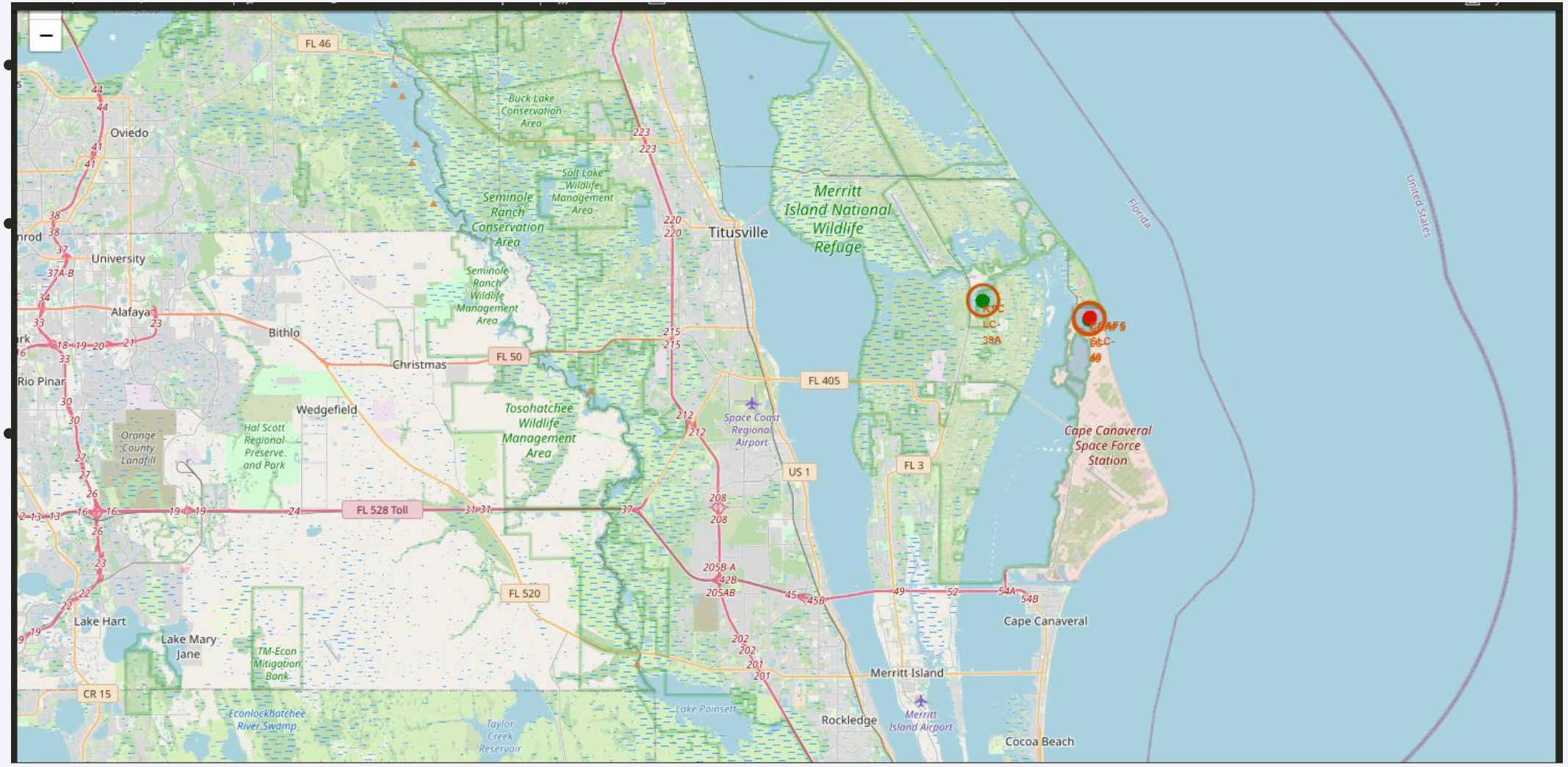
Launch Sites Proximities Analysis

Interactive Visual Analytics with Folium

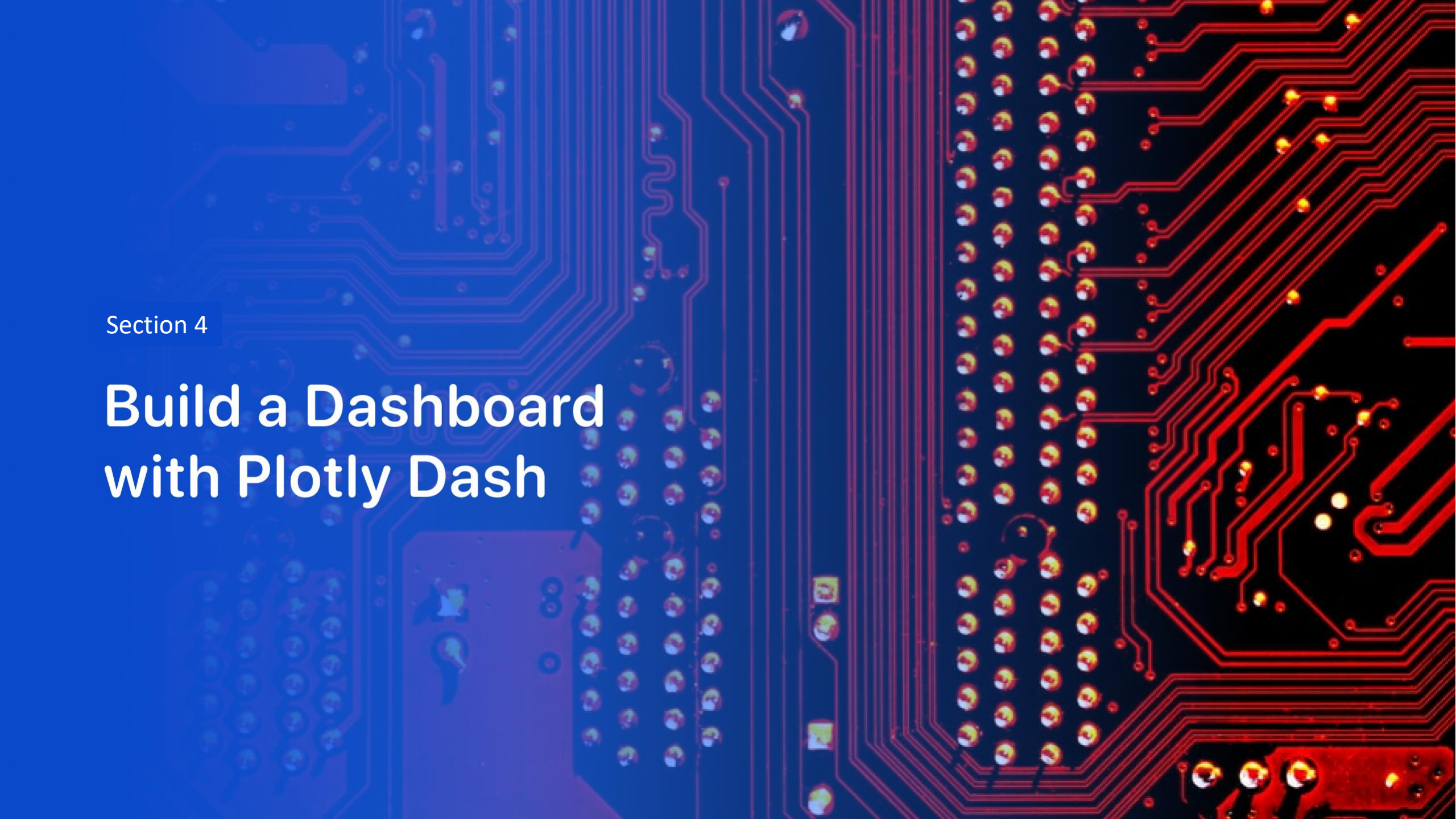


- The map shows all launch sites relative US map.

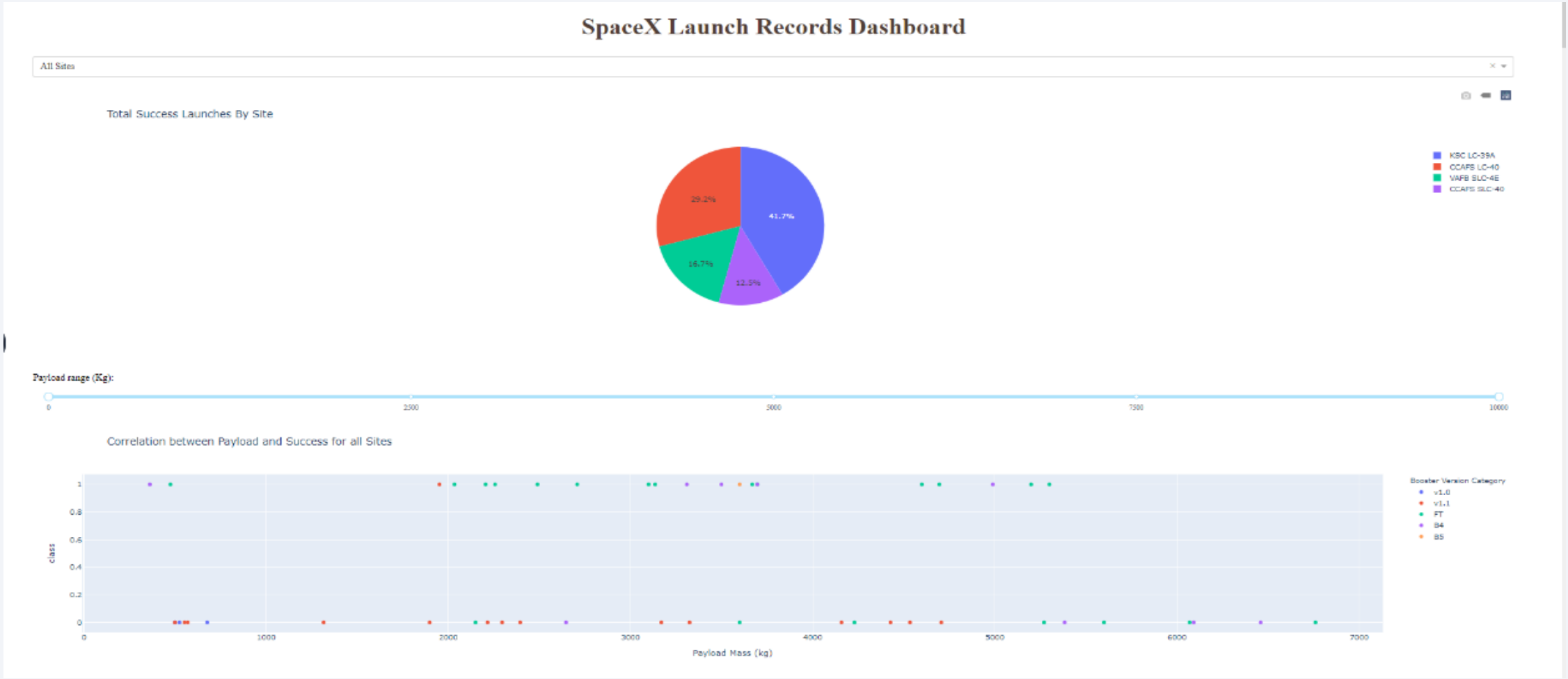
Success/failed launches for each site on the map



The distances between a launch site to its proximities


Section 4
Build a Dashboard with Plotly Dash

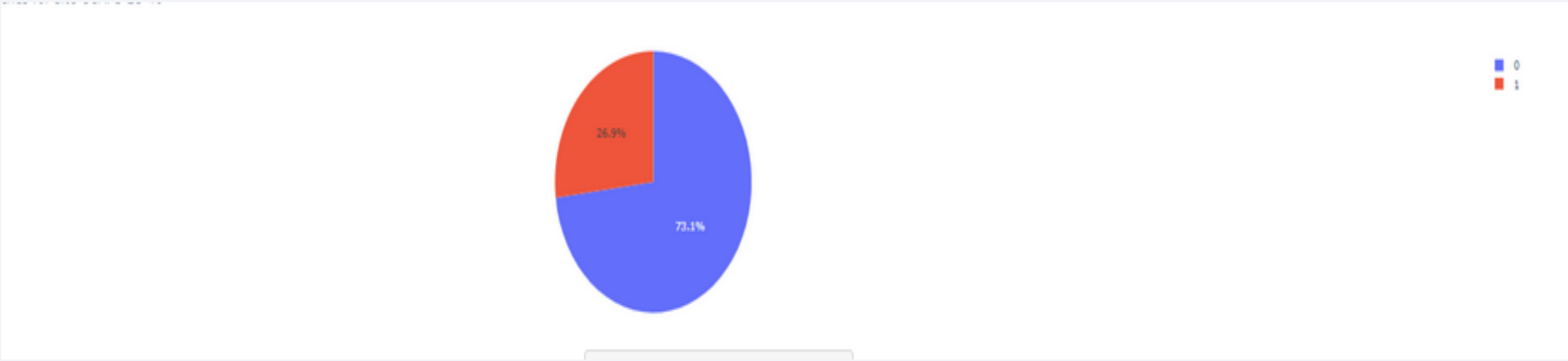
Interactive Dashboard with Ploty-Dash



This dashboard application contains input components such as a dropdown list and a range slider to interact with a pie chart and a scatter point chart.

Total Success Launches for site CCAFS LC-40

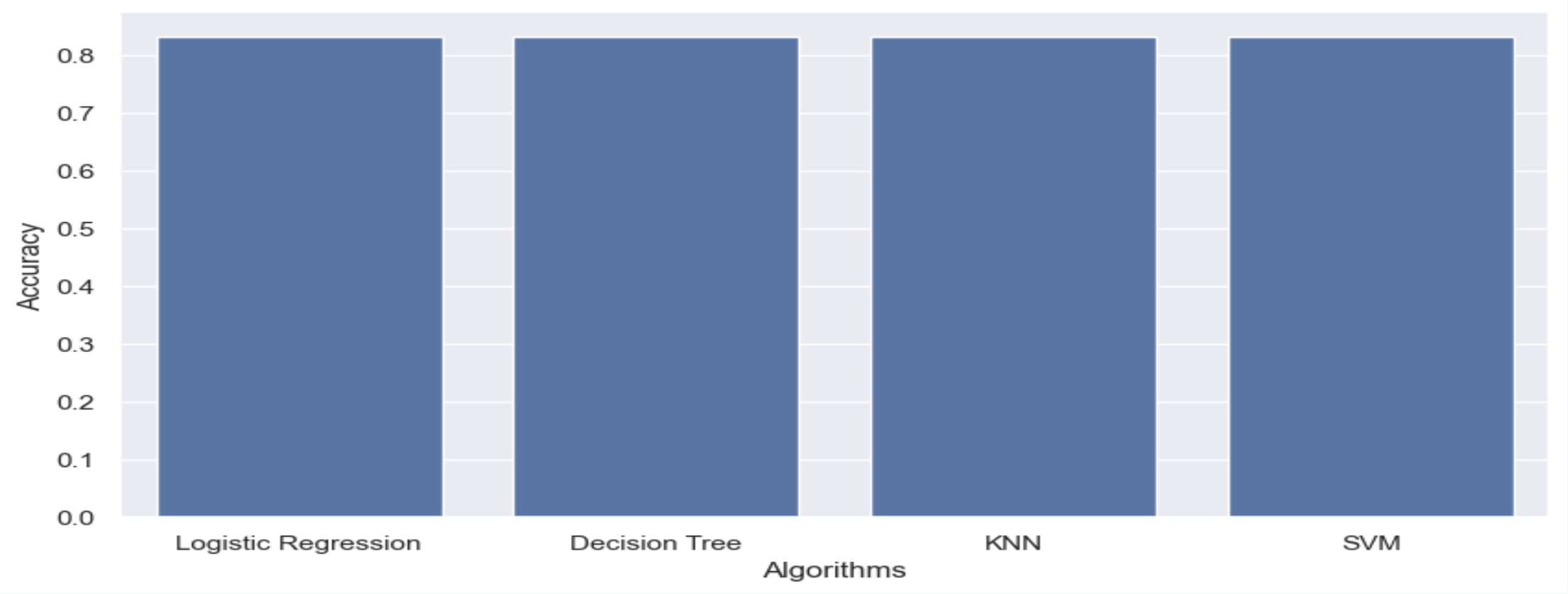
- The pie-chart for the launch site with highest launch success ratio



Section 5

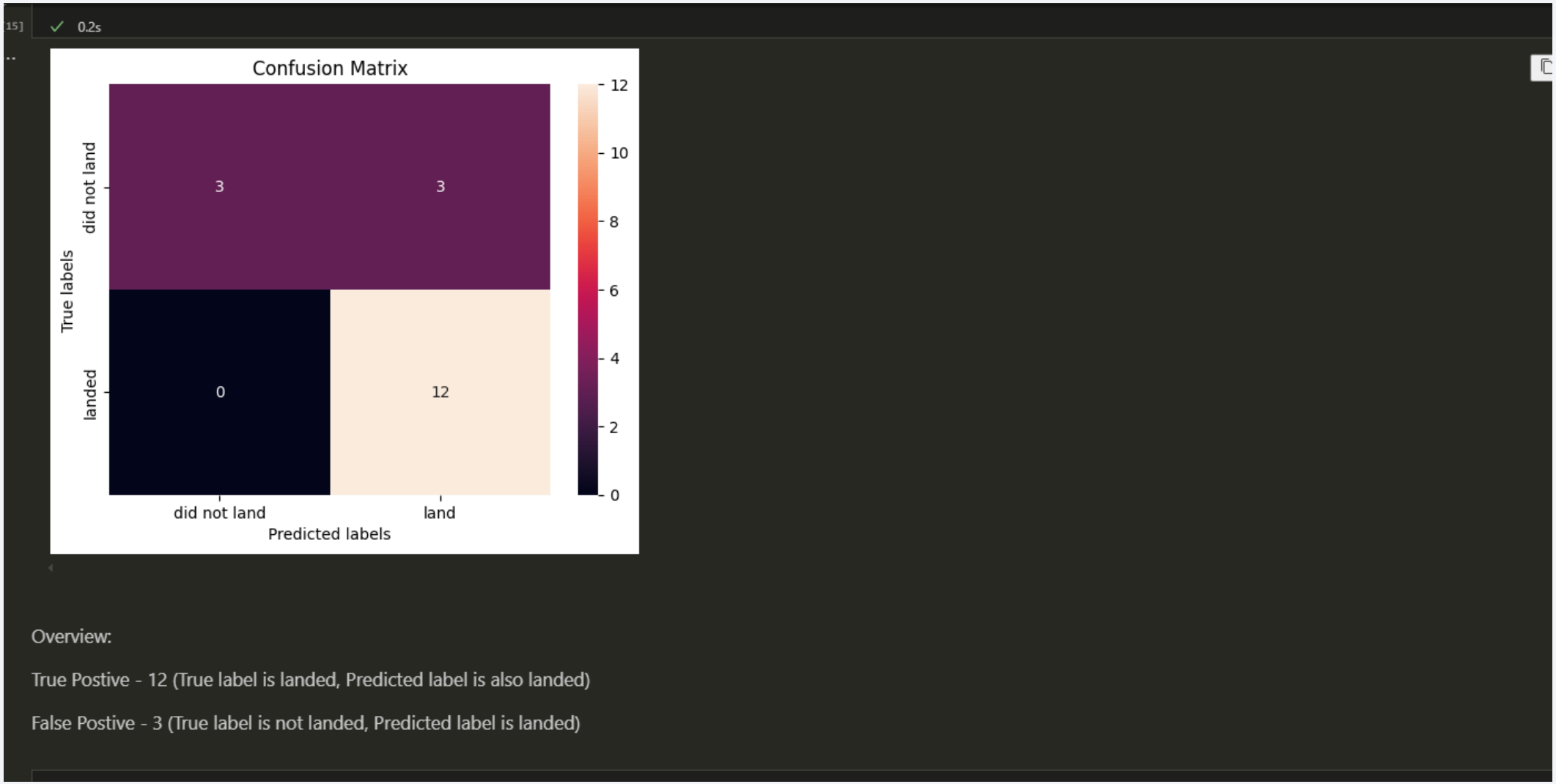
Predictive Analysis (Classification)

Classification Accuracy



- All models had virtually the same accuracy on the test set at 83.33% accuracy. It should be noted that test size is small at only sample size of18.

Confusion Matrix

- 

Conclusions

- The analysis provided valuable insights into the success rates of SpaceX launches across different orbit types and launch sites.
- Interactive dashboards enabled real-time exploration of data, enhancing the understanding of patterns and trends.
- Predictive models (Logistic Regression, Decision Tree, KNN, SVM) demonstrated similar performance with an accuracy of 83.33%.
- The findings can help optimize launch site selection and improve future landing predictions for Falcon 9.

Appendix

- API – LINK
- Web Scraping – LINK
- Data Wrangling – LINK
- Data-Set, SQL queries – LINK
- Exploring and Preparing Data - LINK
- Interactive Visual Analytics with Folium – LINK
- Machine Learning Prediction - LINK

Thank you!