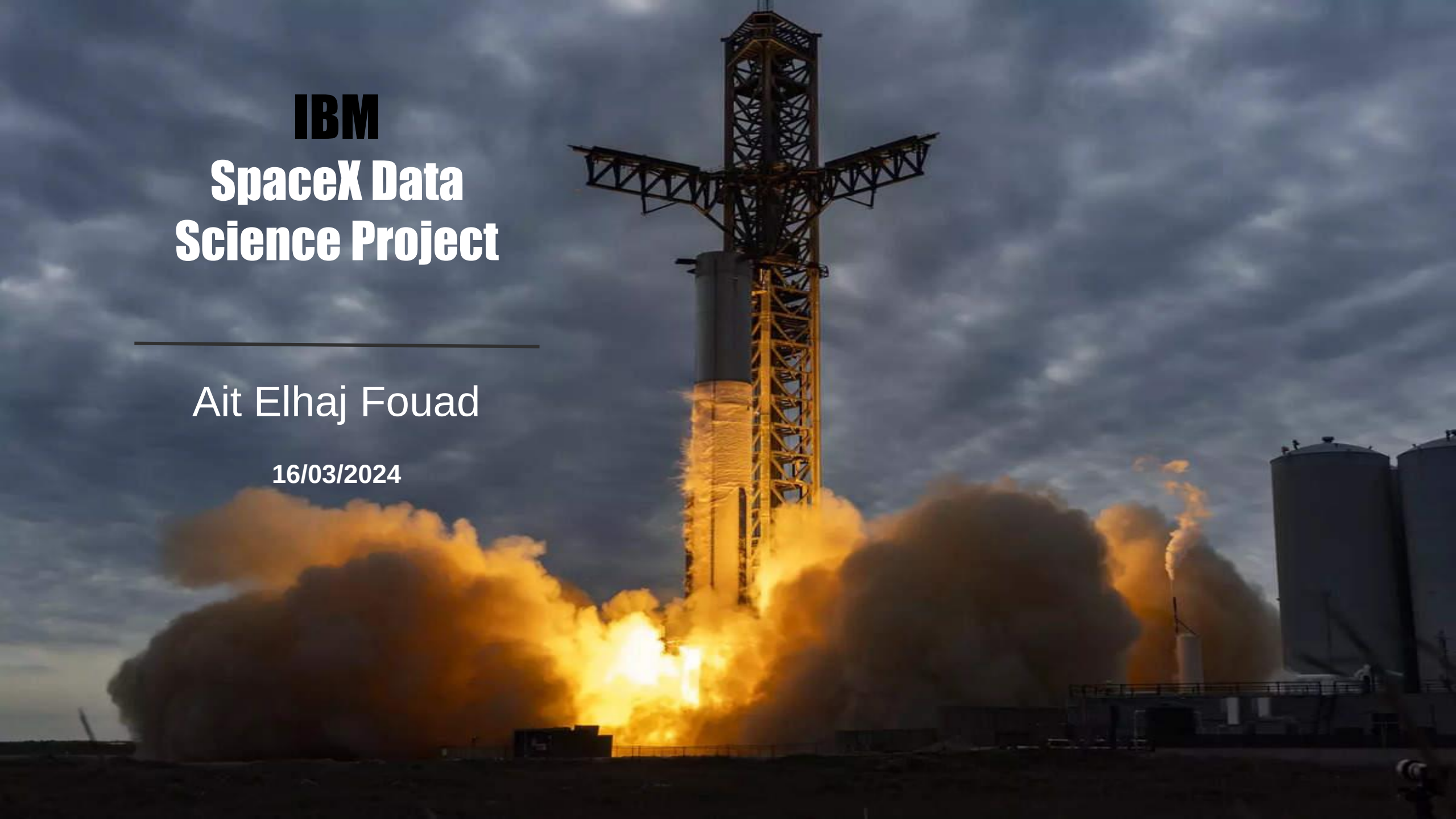


IBM SpaceX Data Science Project

Ait Elhaj Fouad

16/03/2024

Table of Content

Executive Summary

Summary of the methodologies:

- Data Collection with API and Web Scraping
- Data Wrangling
- Exploratory Data Analysis with SQL
- Exploratory Data Analysis with Data Visualization
- Interactive Maps with Folium
- Predictions with Machine Learning Algorithms

Summary of all results:

- Data Analysis along with Interactive Visualizations
- Best Model for Predictive Analysis

Introduction

Project context :

Within this study, our objective is to forecast the probability of successful landings for the Falcon 9 first stage. SpaceX notably markets Falcon 9 rocket launches at a significantly lower cost of 62 million dollars compared to other providers, whose prices can exceed 165 million dollars per launch. This cost efficiency stems largely from SpaceX's ability to reuse the first stage. Therefore, accurately predicting the first stage's landing outcome is crucial in estimating the overall launch cost. Such insights become valuable for potential competitors seeking to challenge SpaceX in bidding for rocket launch contracts.

Key Objectives :

- Identifying the determinants influencing the successful landing of the rocket.
- Investigating the correlation between various variables and their impact on the landing outcomes.
- Identifying optimal conditions conducive to achieving successful landings.

Section 1

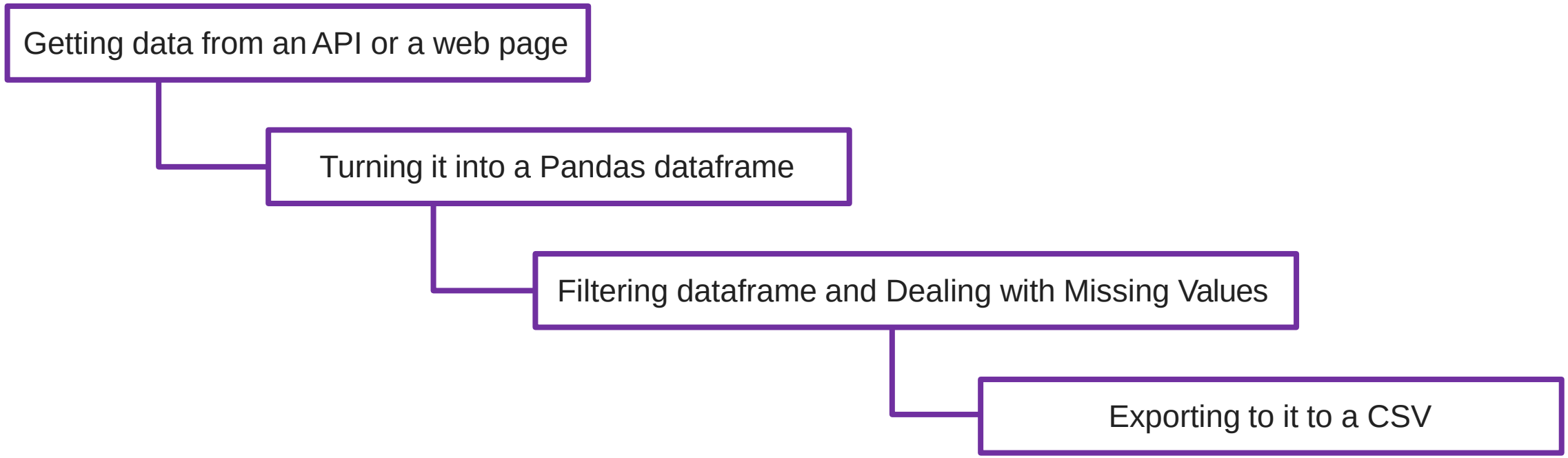
Methodology

Methodology

- Data collection methodology:
  - SpaceX API and web scraping from Wikipedia
- Perform data wrangling
  - One-hot encoding was used for categorical features
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - How to build, tune, evaluate classification models

Data Collection

Data collection involves gathering, measuring, and analyzing diverse information from relevant sources to address research inquiries, assess outcomes, and predict trends and probabilities. As previously noted, we utilized the SpaceX API and web scraping techniques to collect our data.



Data Collection - SpaceX API

- Get response from API
- Convert the response to a dataframe
- Apply custom function
- Clean and filter data
- Deal with the missing values(with mean)
- Export it to a CSV file

Repository Link

	FlightNumber	Date	BoosterVersion	PayloadMass	Orbit	LaunchSite	Outcome	Flights	GridFins	Reused	Legs
4	1	2010-06-04	Falcon 9	NaN	LEO	CCSFS SLC 40	None None	1	False	False	False
5	2	2012-05-22	Falcon 9	525.0	LEO	CCSFS SLC 40	None None	1	False	False	False
6	3	2013-03-01	Falcon 9	677.0	ISS	CCSFS SLC 40	None None	1	False	False	False
7	4	2013-09-29	Falcon 9	500.0	PO	VAFB SLC 4E	False Ocean	1	False	False	False
8	5	2013-12-03	Falcon 9	3170.0	GTO	CCSFS SLC 40	None None	1	False	False	False

```
spacex_url="https://api.spacexdata.com/v4/launches/past"
```

```
response = requests.get(spacex_url)
```

```
response = requests.get(static_json_url)
data = pd.json_normalize(response.json())
```

```
getBoosterVersion(data)
getLaunchSite(data)
getPayloadData(data)
getCoreData(data)
```

```
data_falcon9 = df.loc[df['BoosterVersion']!="Falcon 1"]
data_falcon9.loc[:,'FlightNumber'] = list(range(1, data_falcon9.shape[0]+1))
```

```
mean = data_falcon9['PayloadMass'].mean()
data_falcon9['PayloadMass'].fillna(mean, inplace=True)
```

```
data_falcon9.to_csv('dataset_part_1.csv', index=False)
```

Data Collection - Scraping

Getting response from Web page

Creating a BeautifulSoup object

Finding tables and getting the column names

Creating a dictionary and appending data to keys

Converting dictionary to a dataframe

Export it to a CSV file

Repository Link

```
static_url = "https://en.wikipedia.org/w/index.php?title=List_of_Falcon_9_and_Falcon_Heavy_launches&oldid=1027686922"
```

```
wiki_page = requests.get(static_url).text
```

```
soup = BeautifulSoup(wiki_page, 'html5lib')
```

```
html_tables = soup.find_all('table')
```

```
first_launch_table = html_tables[2]
```

```
column_names = []

for th in first_launch_table.find_all('th'):
    col_name = extract_column_from_header(th)
    if col_name is not None and len(col_name) > 0:
        column_names.append(col_name)
```

```
launch_dict= dict.fromkeys(column_names)
```

```
df = pd.DataFrame(launch_dict)
df.head()
```

	Flight No.	Launch site	Payload	Payload mass	Orbit	Customer	Launch outcome	Version Booster	Booster landing	Date	Time
0	1	CCAFS	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success\n	F9 v1.0B0003.1	Failure	4 June 2010	18:45
1	2	CCAFS	Dragon	0	LEO	NASA	Success	F9 v1.0B0004.1	Failure	8 December 2010	15:43
2	3	CCAFS	Dragon	525 kg	LEO	NASA	Success	F9 v1.0B0005.1	No attempt\n	22 May 2012	07:44
3	4	CCAFS	SpaceX CRS-1	4,700 kg	LEO	NASA	Success\n	F9 v1.0B0006.1	No attempt	8 October 2012	00:35
4	5	CCAFS	SpaceX CRS-2	4,877 kg	LEO	NASA	Success\n	F9 v1.0B0007.1	No attempt\n	1 March 2013	15:10

```
df.to_csv('spacex_web_scraped.csv', index=False)
```

Data Wrangling

Data wrangling is the process of cleaning and unifying messy and complex data sets for easy access and analysis.

1 Load Data
2Make a dataframe from it
3- Cleaning data
4Calculate number and occurence of mission outcome for per orbit type
5Create landing outcome label from Outcome column
6 Export it to a CSV file

Repository Link

```
df=pd.read_csv("https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/IBM-DS032
```

```
landing_outcomes = df["Outcome"].value_counts()
bad_outcomes=set(landing_outcomes.keys()[[1,3,5,6,7]])
```

```
landing_class = df["Outcome"].apply(lambda landing_class: 0 if landing_class in bad_outcomes else 1)
df['Class']=landing_class
```

	FlightNumber	Date	BoosterVersion	PayloadMass	Orbit	LaunchSite	Outcome	Flights	GridFins	Reused	Legs	Lanc
0	1	2010-06-04	Falcon 9	6104.959412	LEO	CCAFS SLC 40	None None	1	False	False	False	
1	2	2012-05-22	Falcon 9	525.000000	LEO	CCAFS SLC 40	None None	1	False	False	False	
2	3	2013-03-01	Falcon 9	677.000000	ISS	CCAFS SLC 40	None None	1	False	False	False	
3	4	2013-09-29	Falcon 9	500.000000	PO	VAFB SLC 4E	False Ocean	1	False	False	False	
4	5	2013-12-03	Falcon 9	3170.000000	GTO	CCAFS SLC 40	None None	1	False	False	False	

```
df.to_csv("dataset_part_2.csv", index=False)
```

EDA with Data Visualization

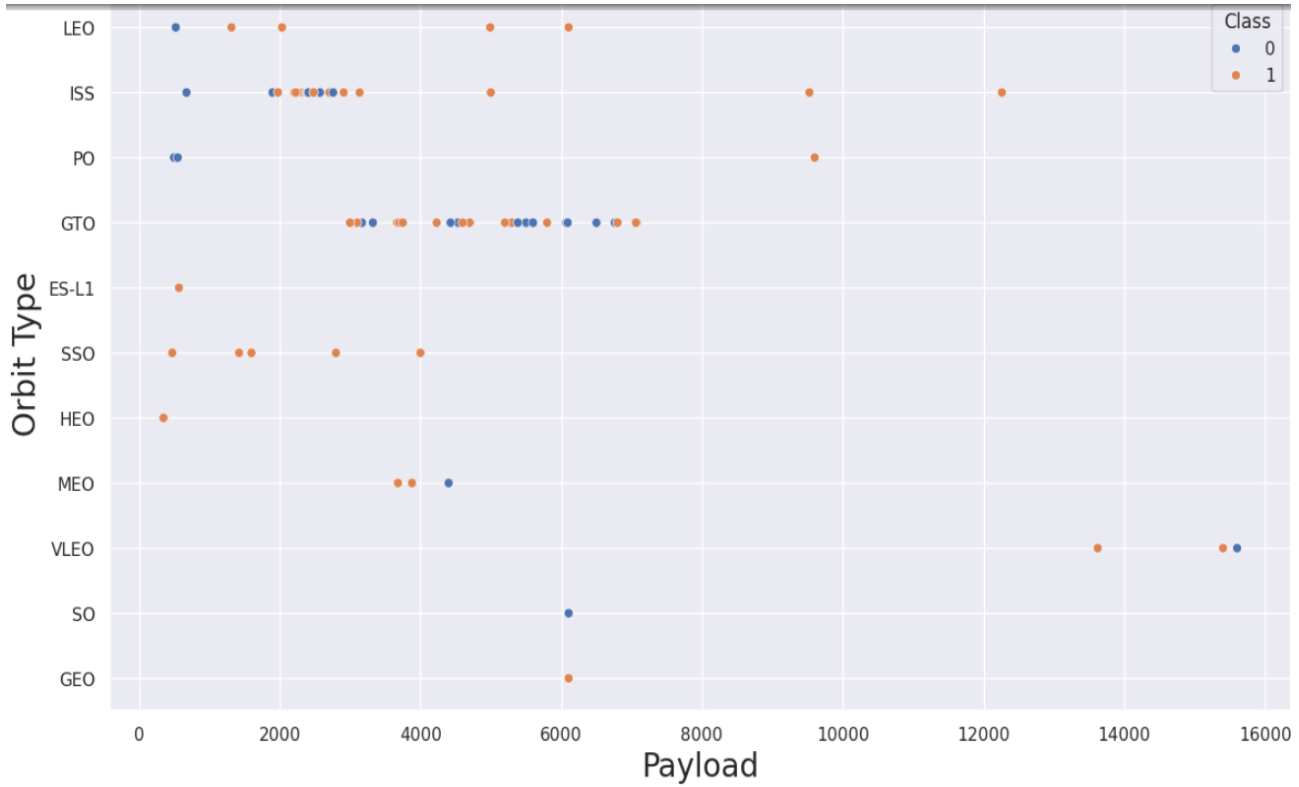
We first started with the scatter graph to find relationship between features;

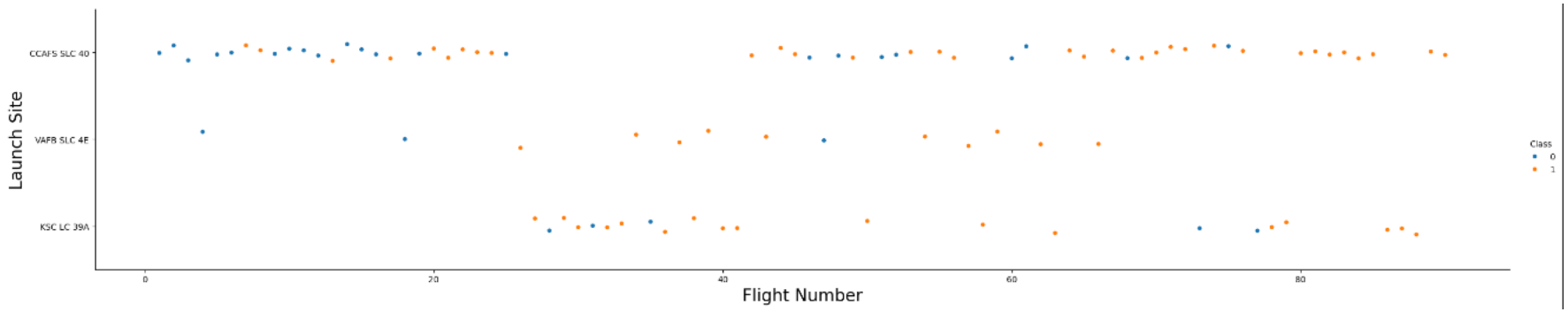
- Payload and Flight Number
- Flight Number and Launch Site
- Payload and Launch Site
- Payload and Orbit Type
- Flight Number and Orbit Type

With the scatter plot, we can easily observe the dependency of features with each other. And it gives us a sight to predict of which factors affect the successful landing.

Here is an example you can see the rest in the lab

Repository Link





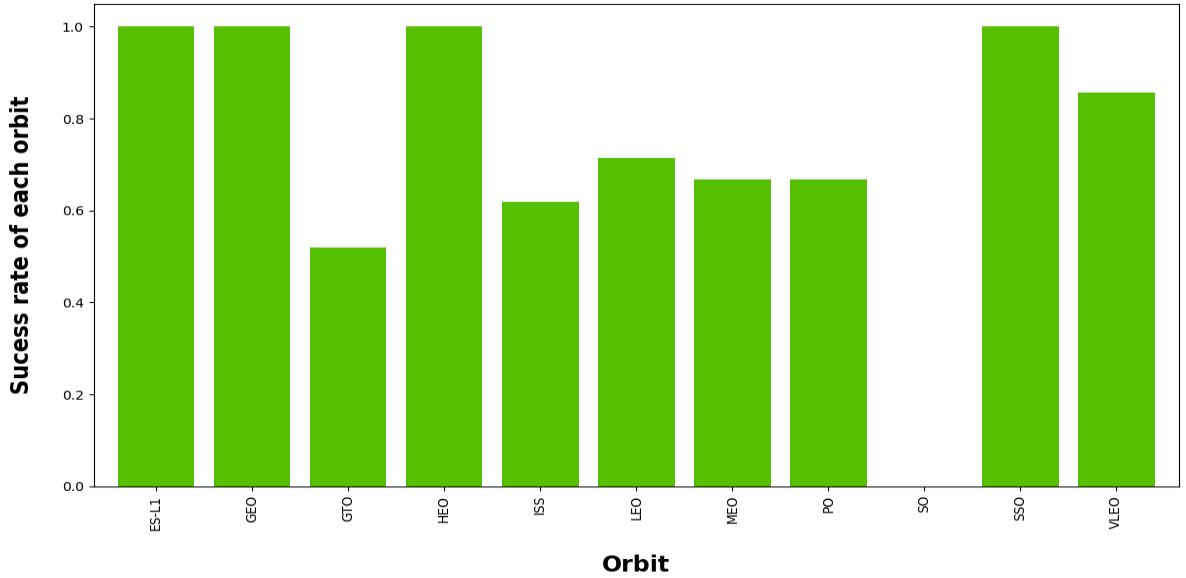
EDA with Data Visualization

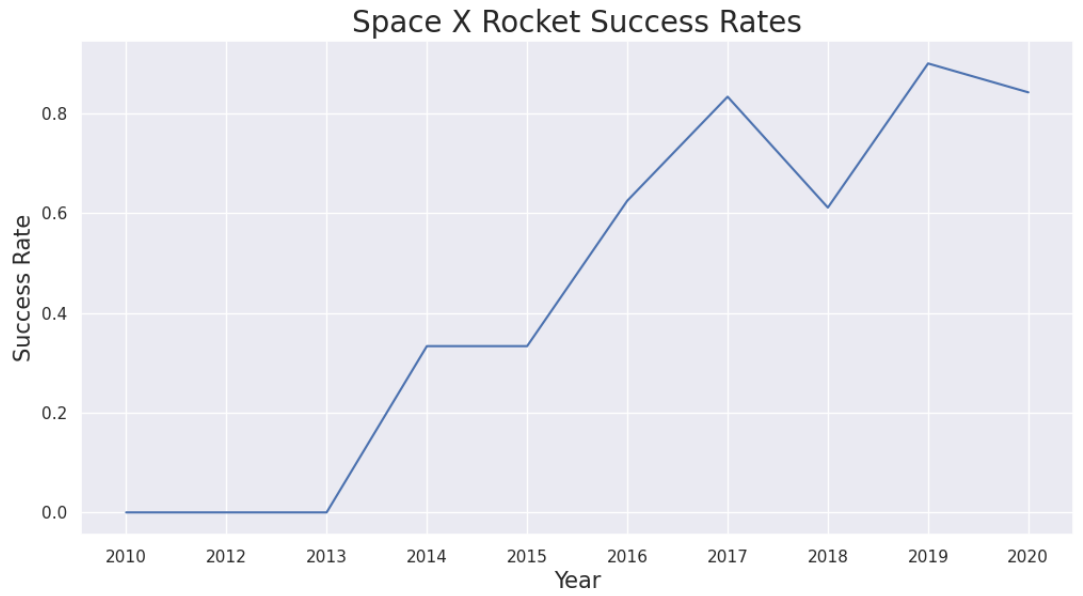
After the scatter plot, we used the bar graph and line plot for better understanding about data.

The bar graph is the easiest way to interpret the relationship between the features. We used the bar graph to observe the successful rates for each orbit. It helps us to determine which orbits have the highest probability for successful landing.

We used the line graph to see how the trends changes over time. It will help us to make predictions for the future.

Repository Link





EDA with SQL

We performed the SQL queries to gather information from given dataset:

- Display the names of the unique launch sites in the space mission
- Display 5 records where launch sites begin with the string 'CCA'
- Display the total payload mass carried by boosters launched by NASA (CRS)
- Display average payload mass carried by booster version F9 v1.1
- List the date when the first successful landing outcome in ground pad was achieved.
- List the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000
- List the total number of successful and failure mission outcomes
- List the names of the booster_versions which have carried the maximum payload mass. Use a subquery
- List the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015
- 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

Repository Link

Built an Interactive Map with Folium

Folium makes it easy to visualize data on an interactive leaflet map. We used the latitude and the longitude coordinates for each launch site with added the circle markers around the each launch site with the label of the name of the launch site.

We used the Red marker for failure landings (class 0) and Green marker for successful landings (class 1) on the map in Marker Cluster.

Map Marker	folium.map.Marker()	Map object to make a mark on map
Circle Marker	folium.Circle()	Create a circle where marker is being placed
Icon Marker	folium.Icon()	Create an icon on map
Marker Cluster	MarkerCluster()	It simplify a map containing many markers having the same coordinate.
PolyLine	folium.PolyLine()	Create a line between points

With those objects we can analyze the how close the launch sites with coastlines, highways, or cities.

Repository Link

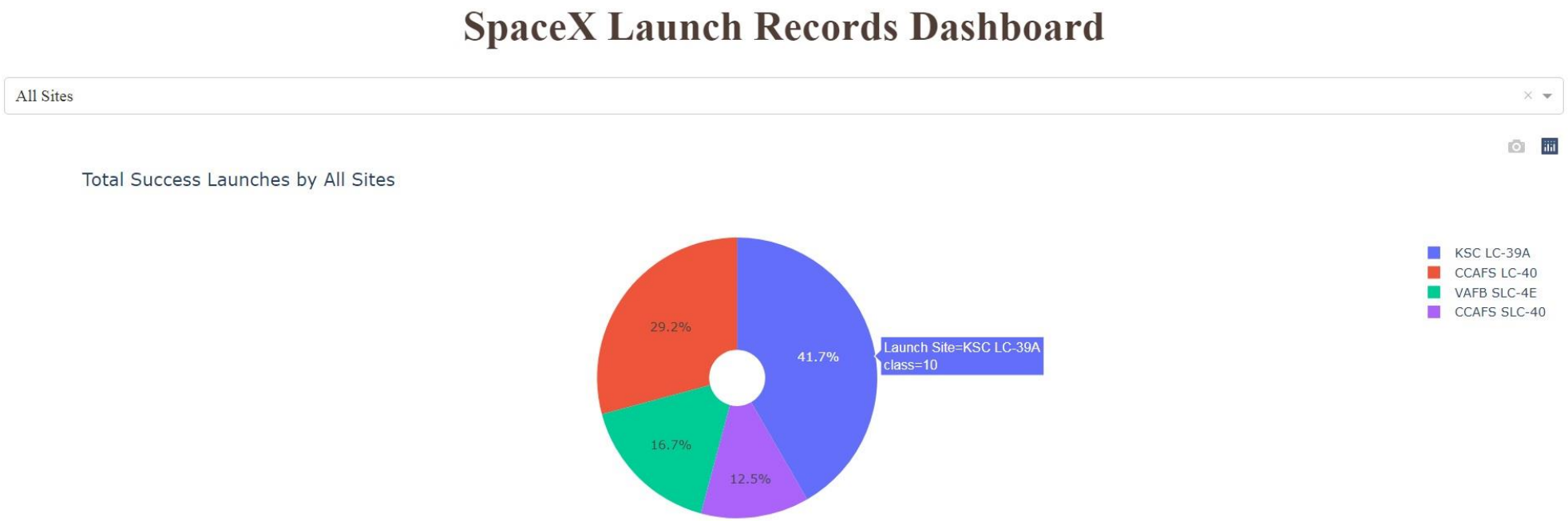
Built a Dashboard with Plotly Dash

We built an interactive dashboard with Plotly Dash, and added a pie chart and a scatter plot which providing the users to interact with the data as they wish.

The pie chart shows total success for all sites or by a certain launch site.

The scatter plot shows the relationship between the Outcome and Payload Mass(kg) for the different booster version.(see the repos code)

Repository Link



Predictive Analysis (Classification)

Building Model

- Load the data.
- Transform it as features (X) and target (y) data with Pandas and NumPy modules.
- Standardize data with StandardScaler() method.
- Split datas into training sets and test sets
- Create the object of Machine Learning Algorithm which will be used
- Set the parameters and use the GridSearchCV method to find the best parameters
- Fit the training set into the model

Evaluating Model

- Calculate the accuracy on the test data for each model
- Get the best parameters for each model
- Plot the Confusion Matrix

Repository Link

Finding the Best Model

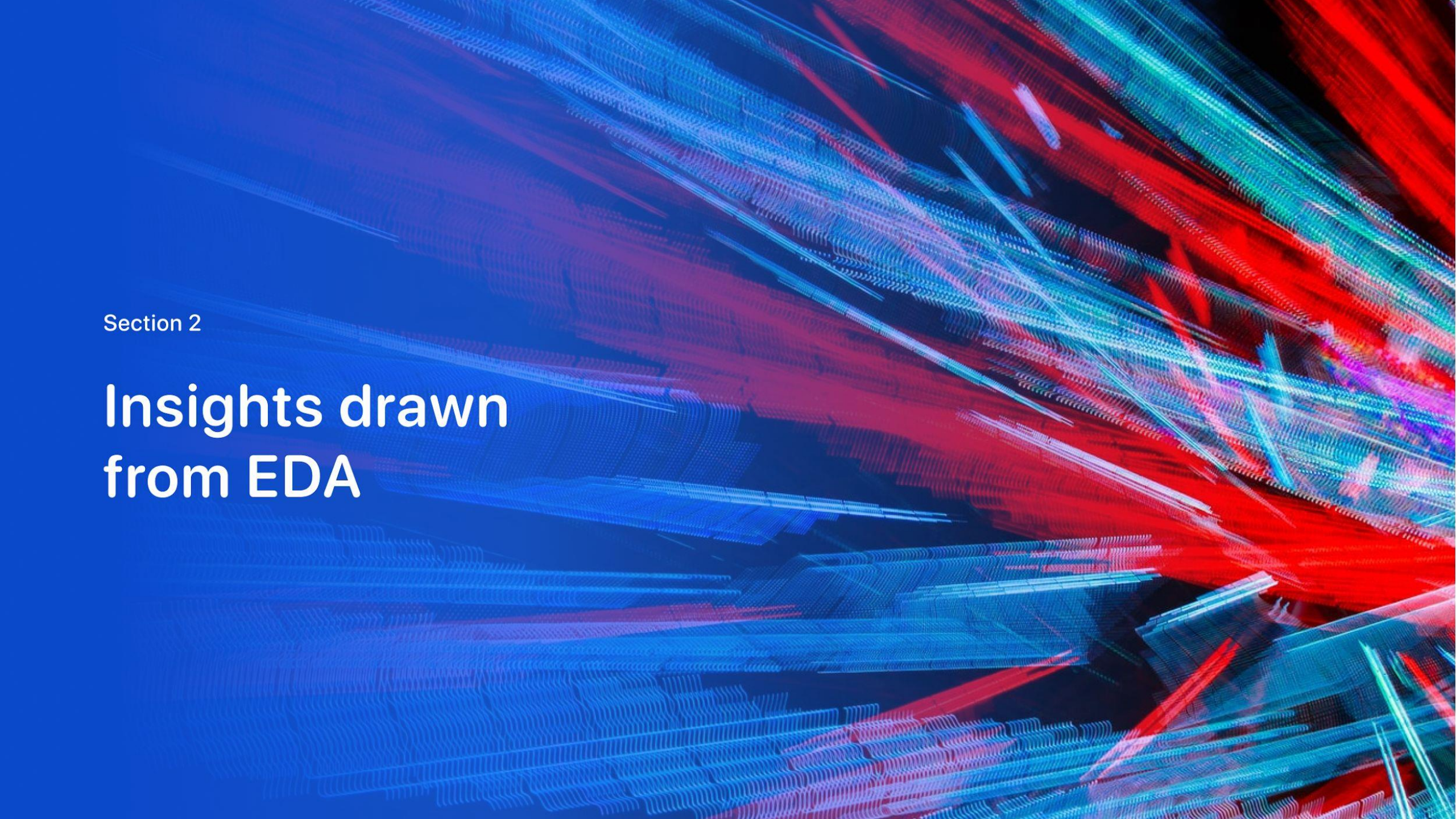
- The model which has the best accuracy score will be the Best Model to make predictions.

Results

Exploratory data analysis results

Interactive analytics demo in screenshots

Predictive analysis results

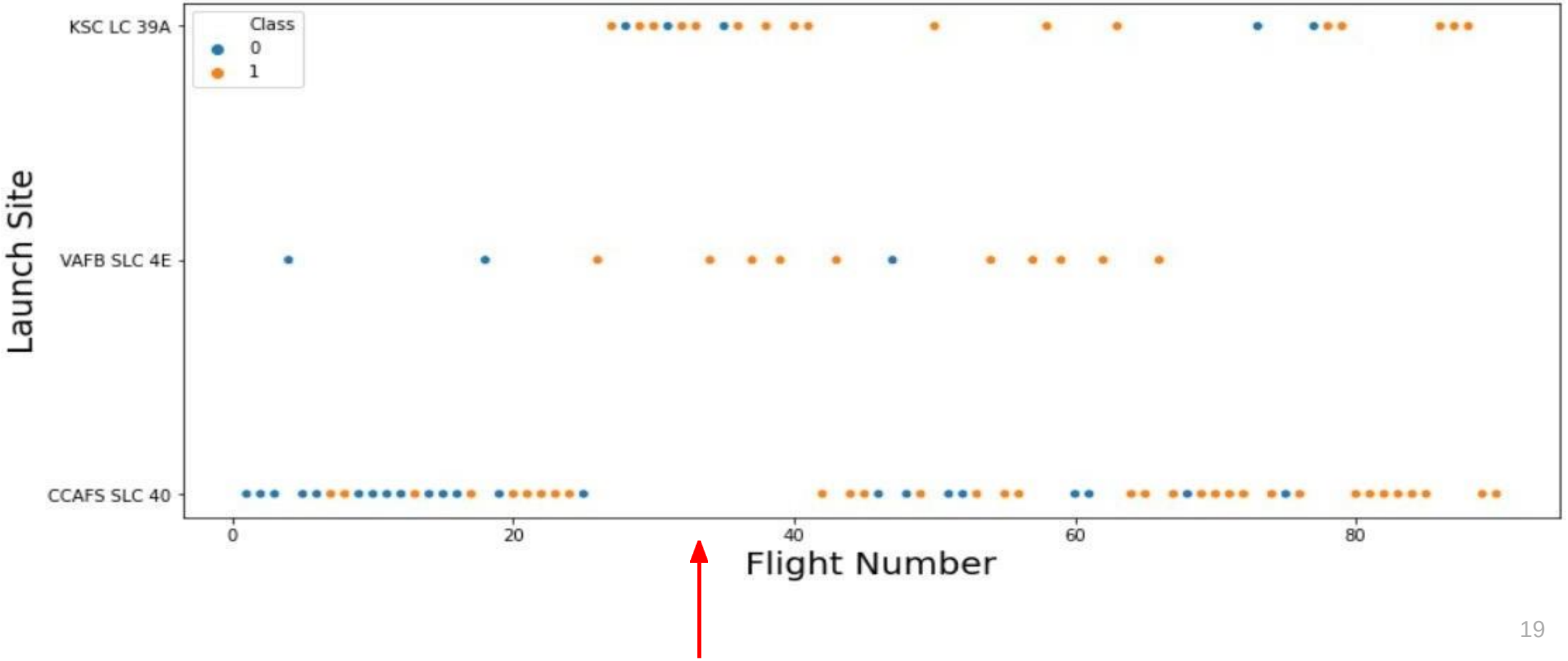


Section 2

Insights drawn from EDA

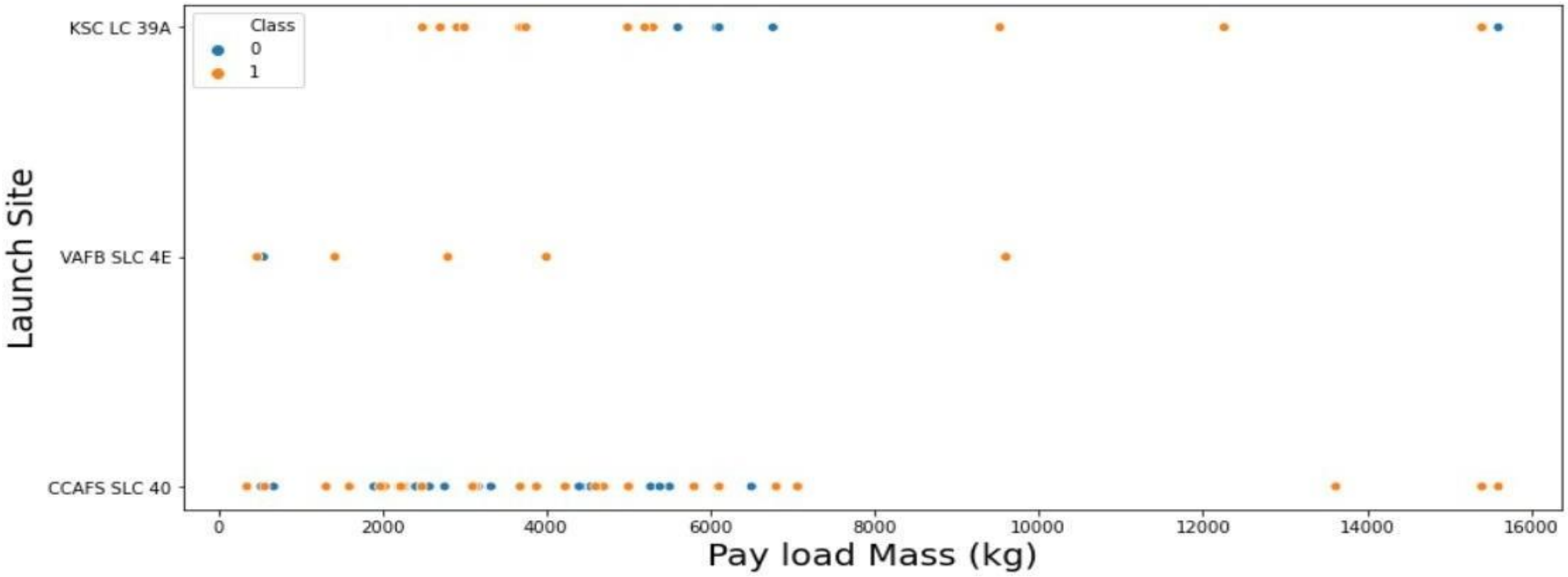
Flight Number vs. Launch Site

This scatter plot shows that with higher flight numbers the success rate is increasing.



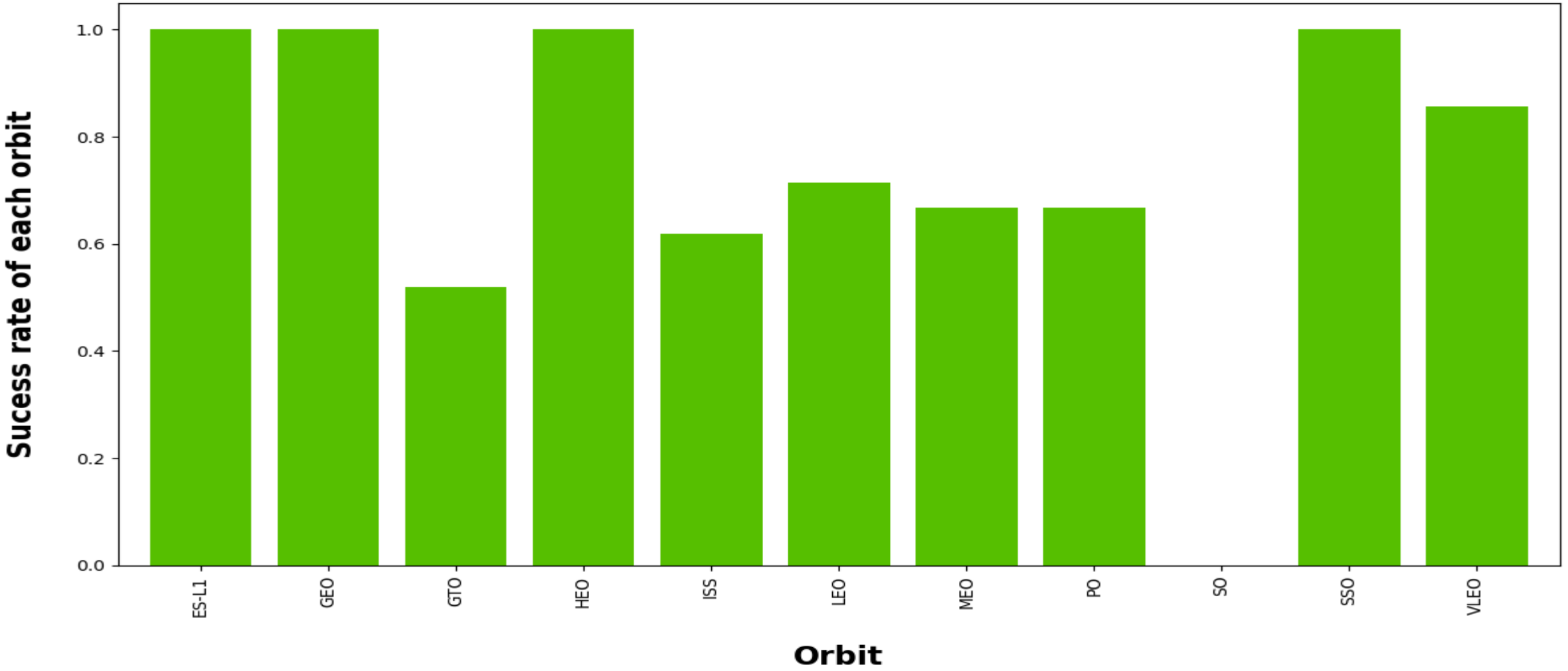
Payload vs. Launch Site

This scatter plot shows that there is no clear pattern between Launch site and Payload Mass for successful landing but we can observe that the VAFB-SLC launchsite there are no rockets launched for heavy payload mass(greater than 10000).



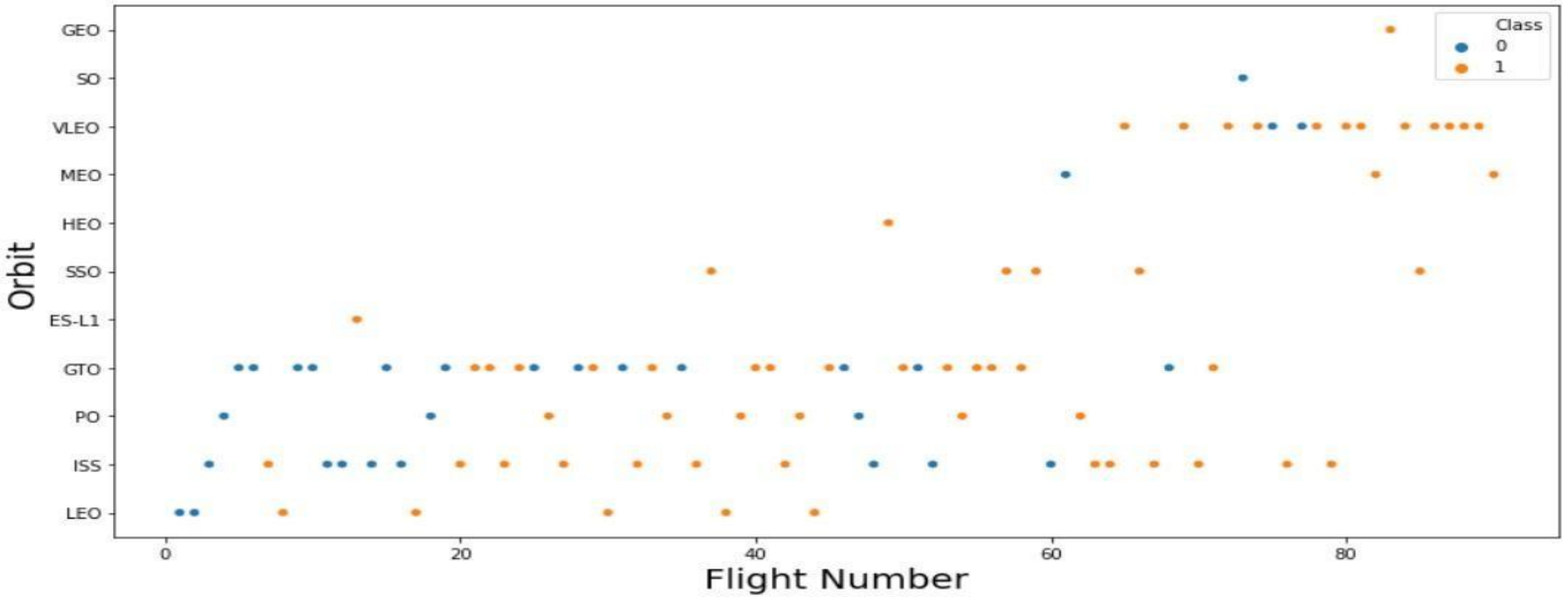
Success Rate vs. Orbit Type

With this bar plot, we can see that ES-L1, GEO,HEO and SSO have highest success rate and SO has no successful landing.



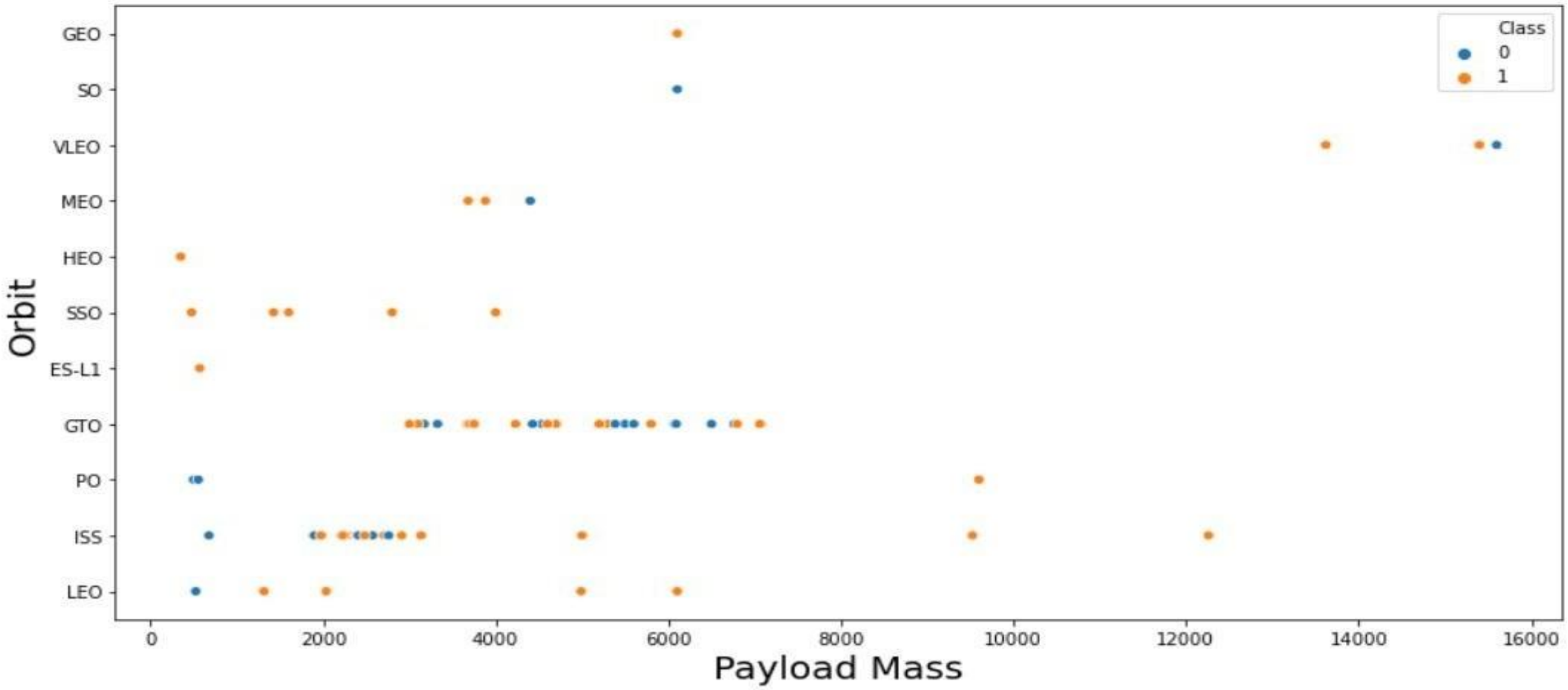
Flight Number vs. Orbit Type

This scatter plot shows that the larger flight number on each orbits, greater the success rate, such as LEO, except for GTO which indicates no relationship between these features.



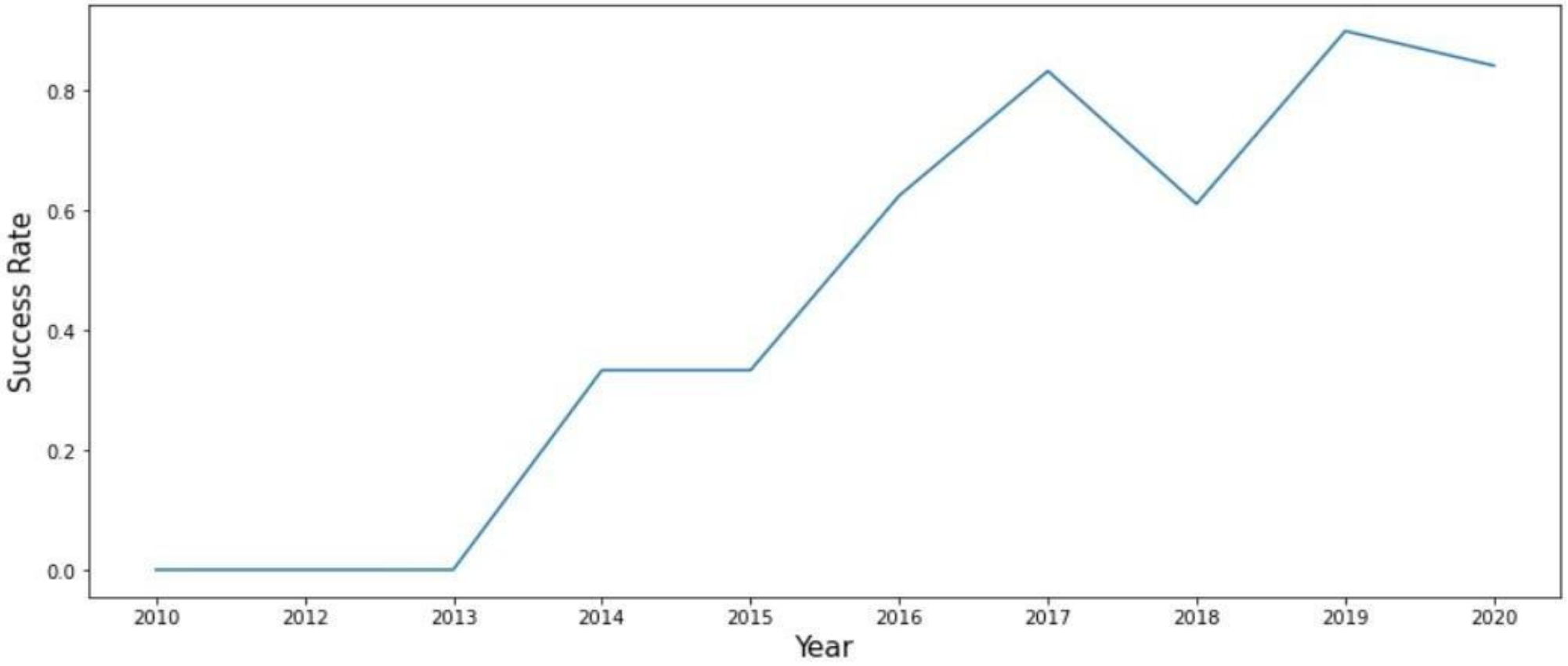
Payload vs. Orbit Type

This scatter plot shows that the heavier payloads have a positive influence on ISS, LEO and PO. On the other hand, it has negative influence on the MEO and VLEO. We can not see any relationship between the GTO and the payload mass.



Launch Success Yearly Trend

This chart shows that the successful rate is increasing relatively from the year 2013 until the 2020.



All Launch Site Names

SQL Query:

```
%sql SELECT DISTINCT LAUNCH_SITE as "Launch_Sites" FROM SPACEXTBL;
```

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

Description:

We used the DISTINCT function to find the all unique launch site names from Spacextbl with a launch_site column name.

Launch Site Names Begin with 'CCA'

SQL Query:

```
%%sql

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

Description:

We used the LIKE operator to find the records which begin with ‘CCA’ and LIMIT 5 operator to get 5 records.

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	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	00:35:00	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

SQL Query:

```
%%sql
SELECT SUM(PAYLOAD_MASS__KG_) AS "Total payload mass by NASA(CRS)" FROM SPACEXTBL
WHERE CUSTOMER = 'NASA (CRS)';
```

Description:

We used the SUM function to calculate the total payload carried by boosters from the NASA (CRS).

Total payload mass by NASA(CRS)
45596

Average Payload Mass by F9 v1.1

SQL Query:

```
%%sql
SELECT AVG(PAYLOAD_MASS__KG_) AS "Average Payload Mass by Booster Version F9 v1.1" FROM SPACEXTBL
WHERE BOOSTER_VERSION = 'F9 v1.1';
```

Description:

We used the AVG function to calculate the average payload carried by booster version F9 v1.1

Average Payload Mass by Booster Version F9 v1.1
2928

First Successful Ground Landing Date

SQL Query:

```
%%sql
SELECT MIN(DATE) AS "The first successful landing date" FROM SPACEXTBL
WHERE LANDING__OUTCOME = 'Success (ground pad)';
```

Description:

We used the MIN function to calculate the first successful landing outcome on ground pad

The first successful landing date
2015-12-22

Successful Drone Ship Landing with Payload Between 4000 and 6000

SQL Query:

```
%%sql
SELECT BOOSTER_VERSION FROM SPACEXTBL
WHERE LANDING__OUTCOME = 'Success (drone ship)' AND PAYLOAD_MASS__KG_ > 4000 AND PAYLOAD_MASS__KG_ < 6000;
```

Description:

We used the multiple where selection to find the names of boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 6000

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

Total Number of Successful and Failure Mission Outcomes

SQL Query:

```
%%sql
SELECT SUM(CASE WHEN MISSION_OUTCOME LIKE '%Success%' then 1 else 0 end) AS "Successful Mission",
SUM(CASE WHEN MISSION_OUTCOME LIKE '%Failure%' then 1 else 0 end) AS "Failure Mission"
FROM SPACEXTBL;
```

Description:

We used the CASE clause within the SUM functions to calculate the total number of successful and failure mission outcomes.

Successful Mission	Failure Mission
100	1

Boosters Carried Maximum Payload

SQL Query:

```
%%sql
SELECT BOOSTER_VERSION AS "Booster Versions which carried the maximum payload mass" FROM SPACEXTBL
WHERE PAYLOAD_MASS__KG_ = (SELECT MAX(PAYLOAD_MASS__KG_) FROM SPACEXTBL);
```

Description:

We used the sub-query with MAX function to find the names of the booster which have carried the maximum payload mass.

Booster Versions which carried the maximum payload mass
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

SQL Query:

```
%%sql
SELECT BOOSTER_VERSION, LAUNCH_SITE FROM SPACEXTBL
WHERE year(DATE) = '2015' AND LANDING__OUTCOME = 'Failure (drone ship)';
```

Description:

We used the year function to list the 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

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

SQL Query:

```
%%sql
SELECT LANDING__OUTCOME AS "Landing Outcome", COUNT(LANDING__OUTCOME) AS "Total Count" FROM SPACEXTBL
WHERE DATE BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY LANDING__OUTCOME
ORDER BY COUNT(LANDING__OUTCOME) DESC;
```

Description:

We used the COUNT function to calculate number of the failed landing_outcomes between the date 2020-06-04 and 2017-03-20 group by landing_outcome and ranked them in descending order.

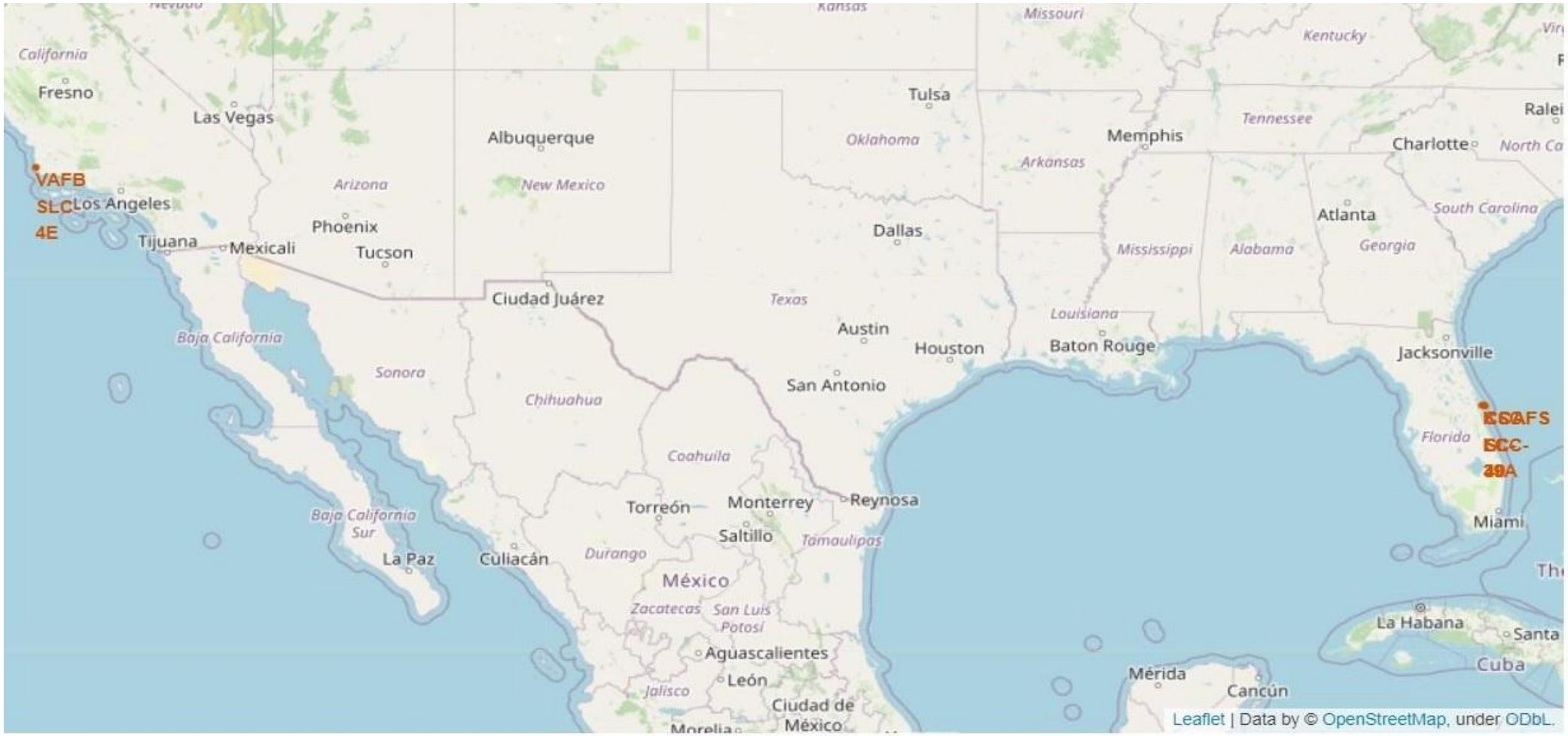
Landing Outcome	Total Count
No attempt	10
Failure (drone ship)	5
Success (drone ship)	5
Controlled (ocean)	3
Success (ground pad)	3
Failure (parachute)	2
Uncontrolled (ocean)	2
Precluded (drone ship)	1

Section 3

Launch Sites Proximities Analysis

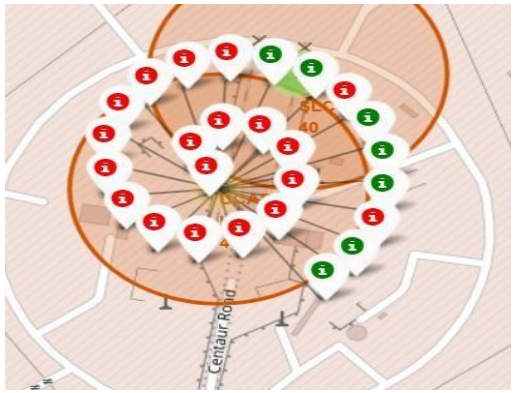
All Launch Sites on Folium Map

We can observe that all launch sites in very close proximity to the coast and they are located inside the United States of America.



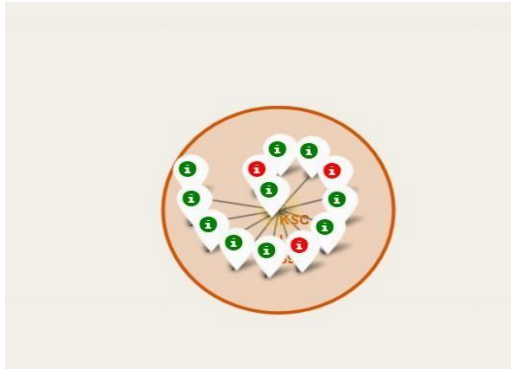
All Launch Sites on Folium Map

Green markers show the successful launches and Red markers show the failures.From these maps we can see that the KSC LC-39-A maximum probability of success

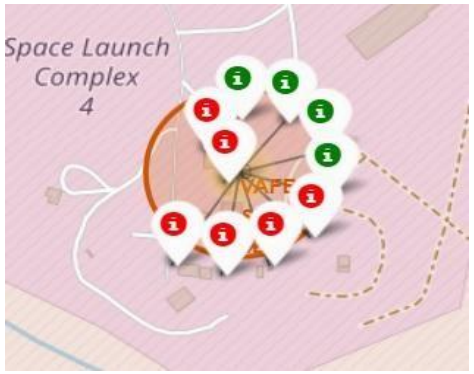


CCAFS LC-40

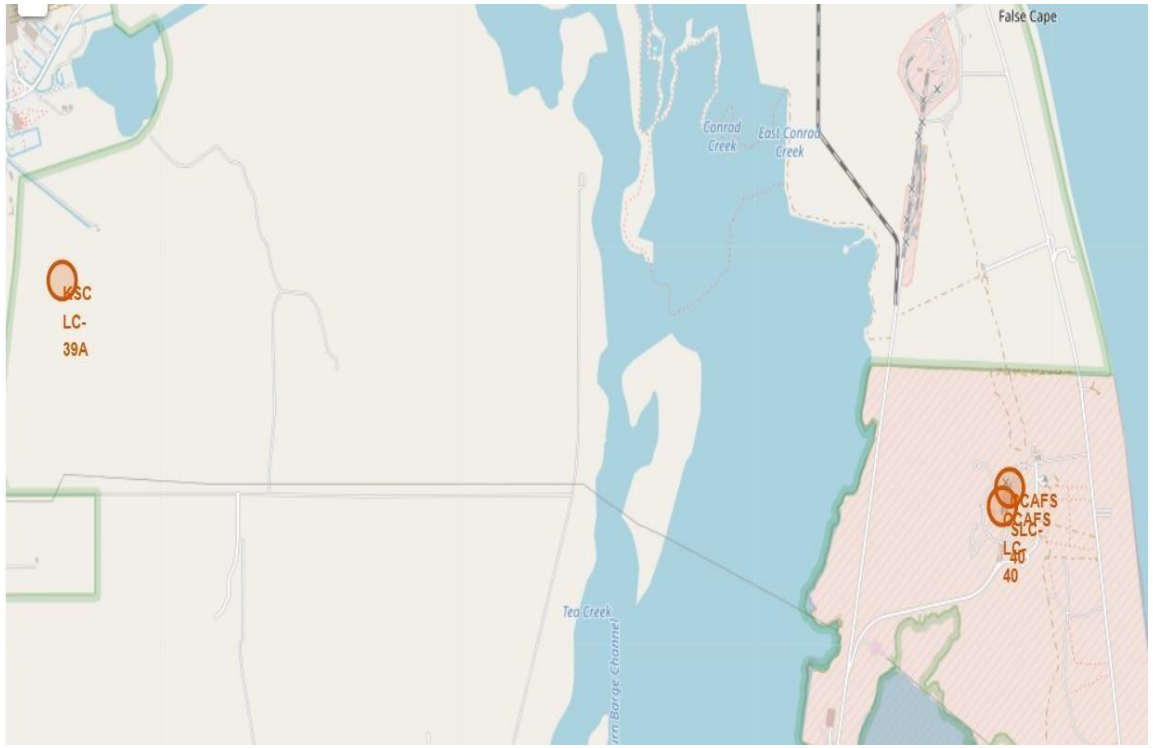
CCAFS SLC-40



KSC LC-39A

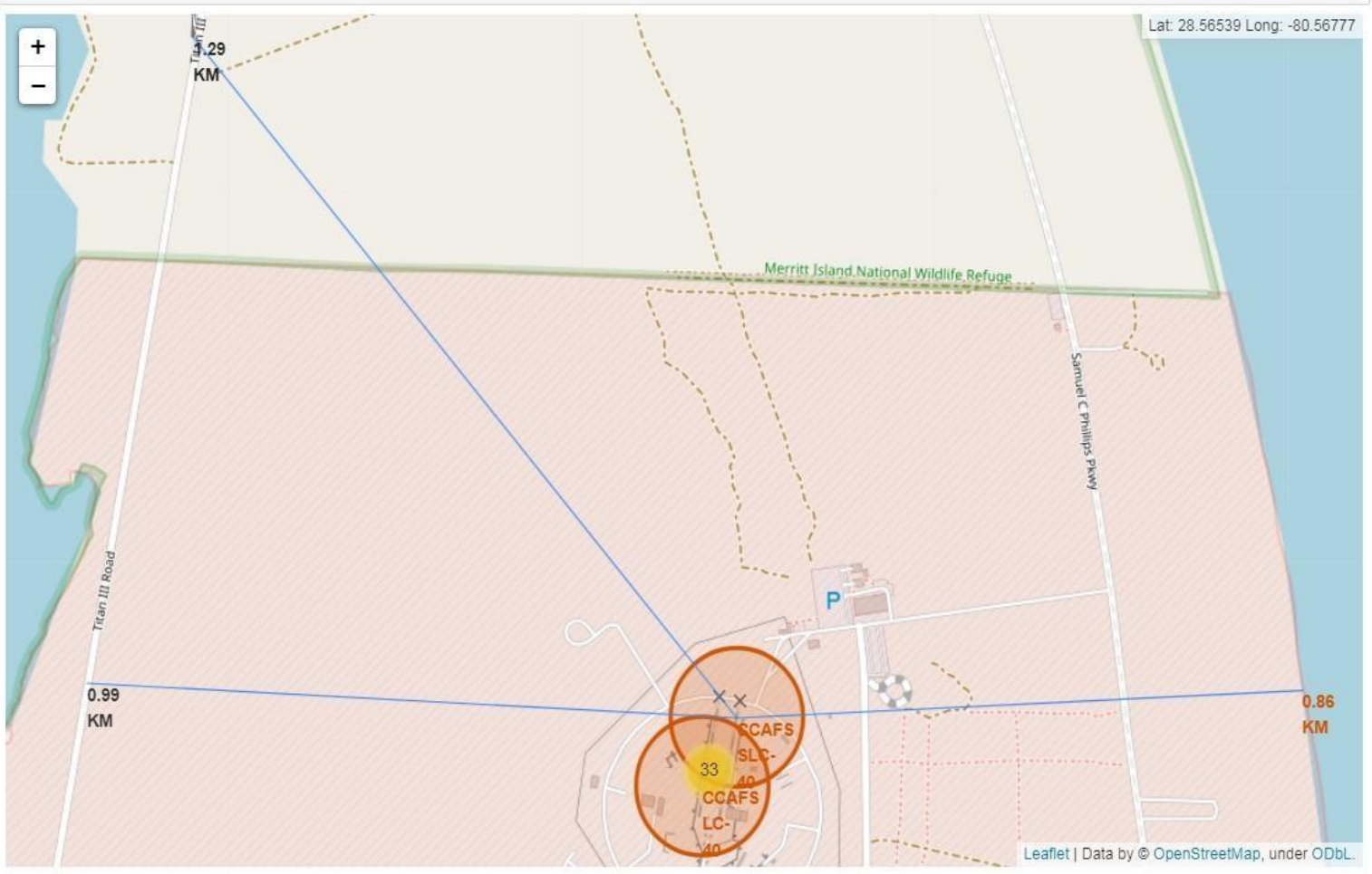


VAFB SLC-4E



The distances between launch sites to landmarks

We calculated the distances between launch sites to railway, highway, coastline, etc.



With these informations we can answer these questions:

- Are launch sites in close proximity to railways?

  Yes

- Are launch sites in close proximity to highways?

  No

- Are launch sites in close proximity to coastline?

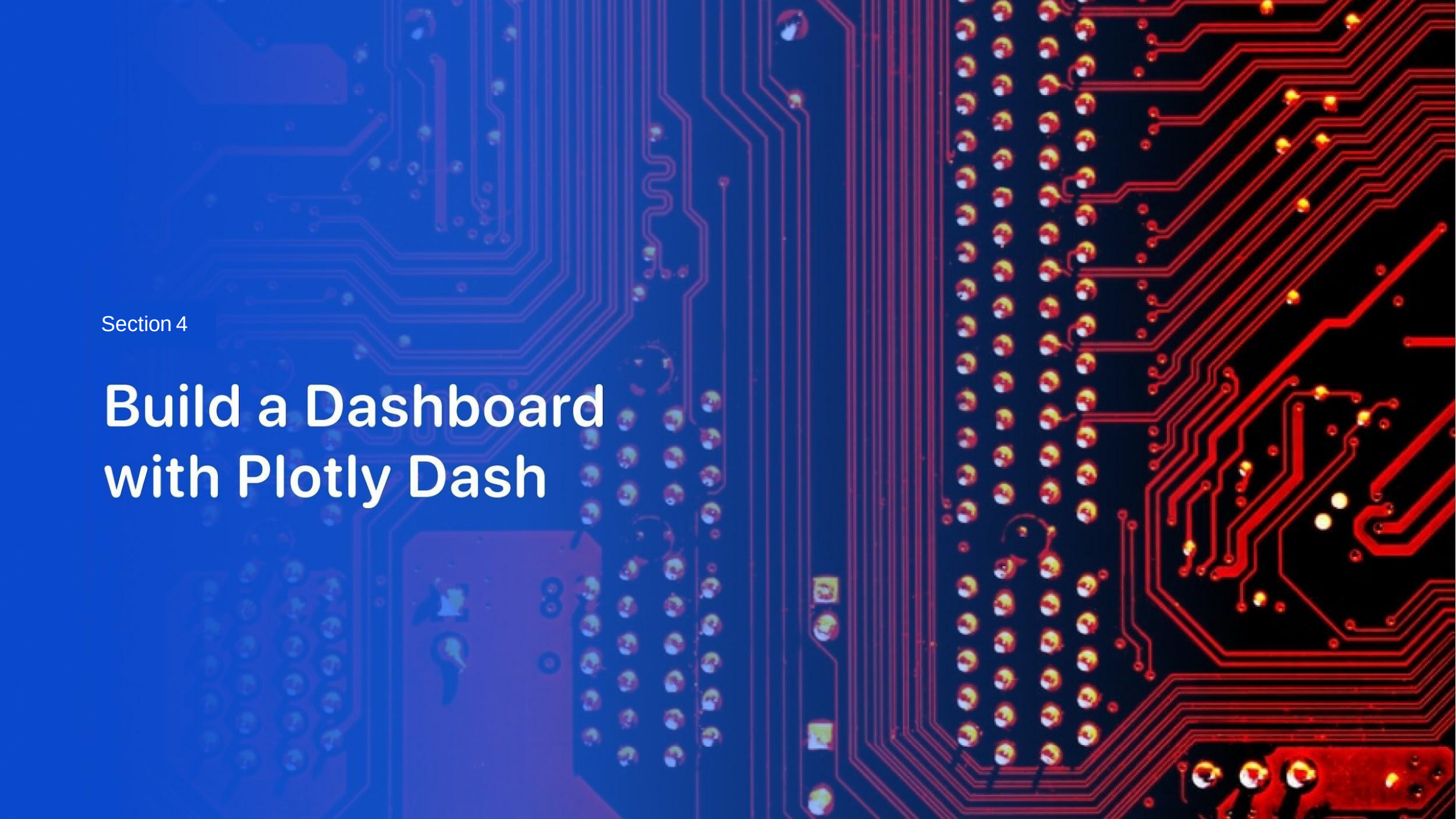
  Yes

- Do launch sites keep certain distance away from cities?

  Yes

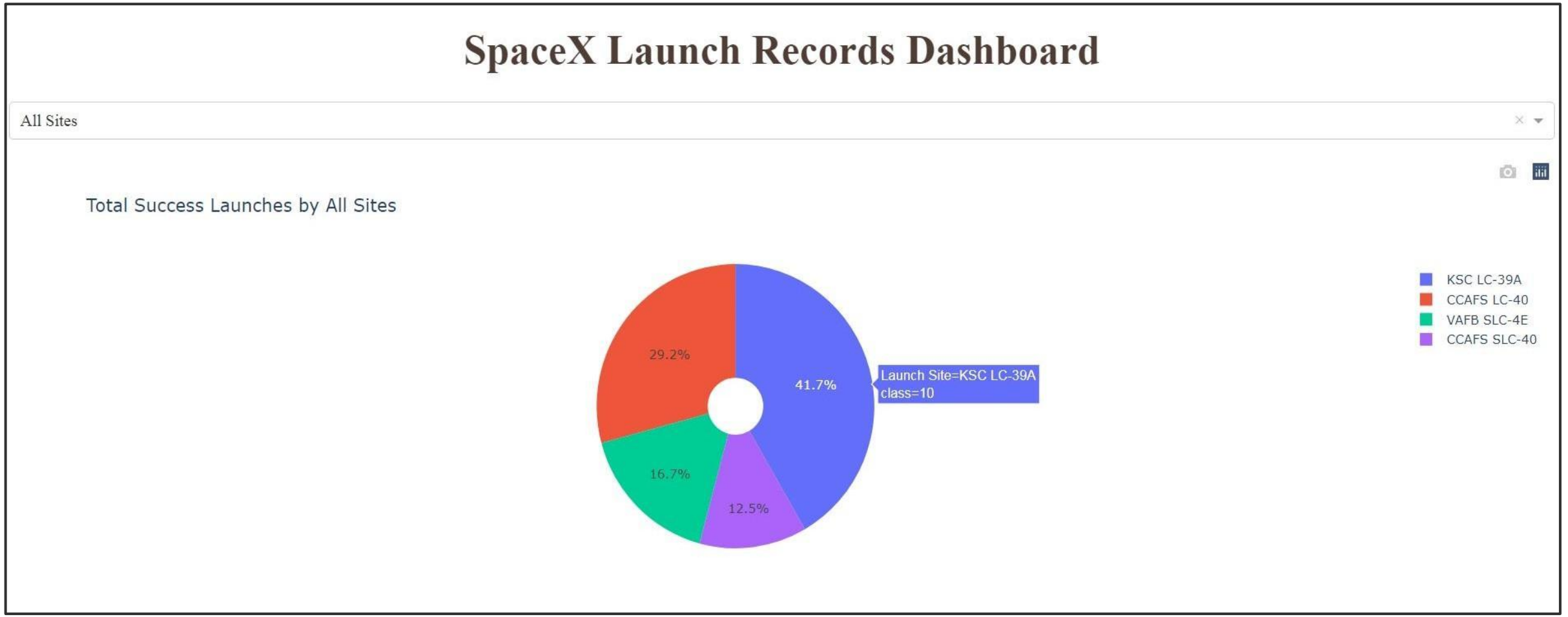
Section 4

Build a Dashboard with Plotly Dash



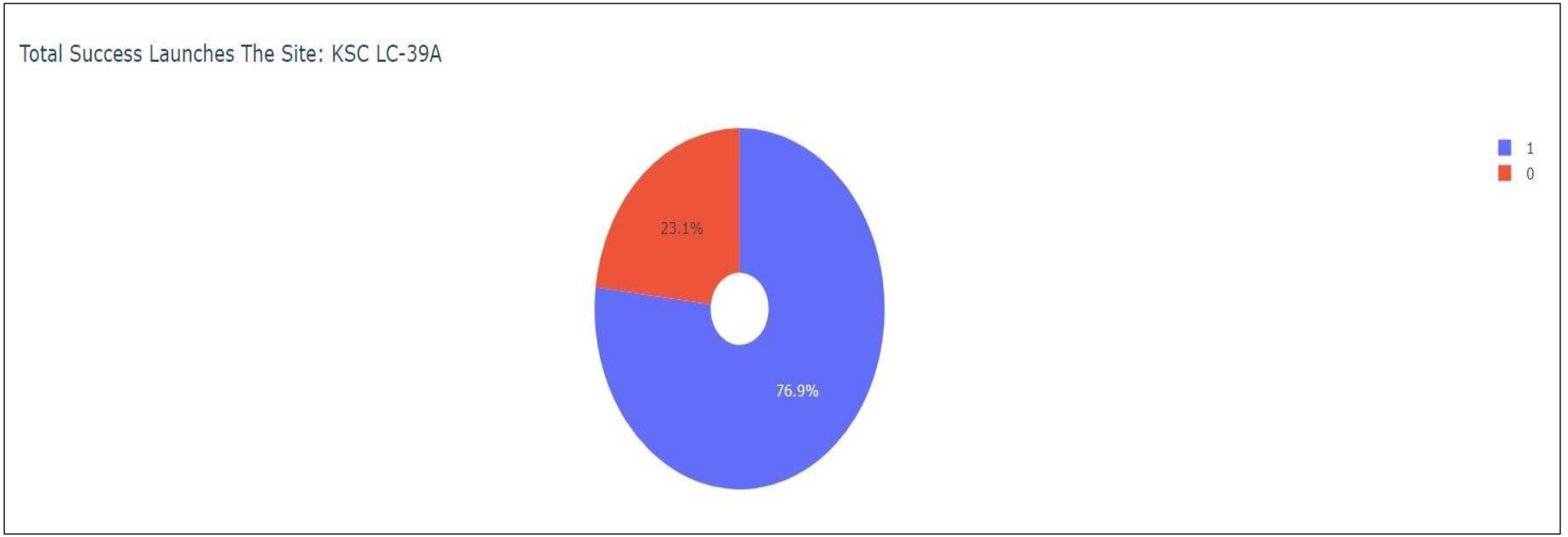
Launch Success Percentages by All Sites

We can easily see that KSC LC-39A has the most successful launches from all the sites

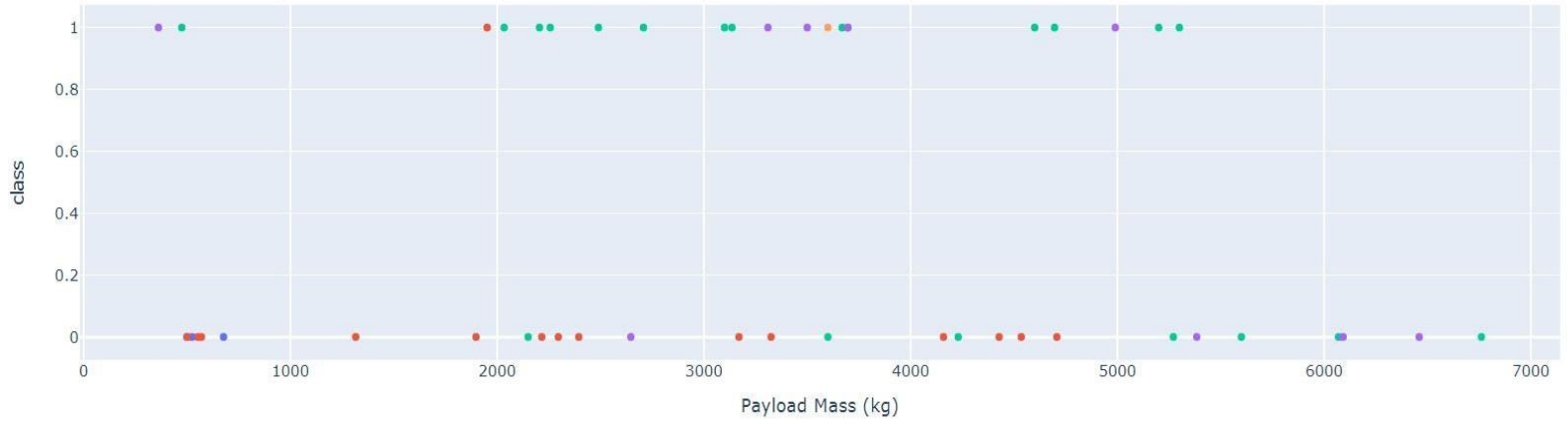


The Highest Launch Success: KSC LC-39A

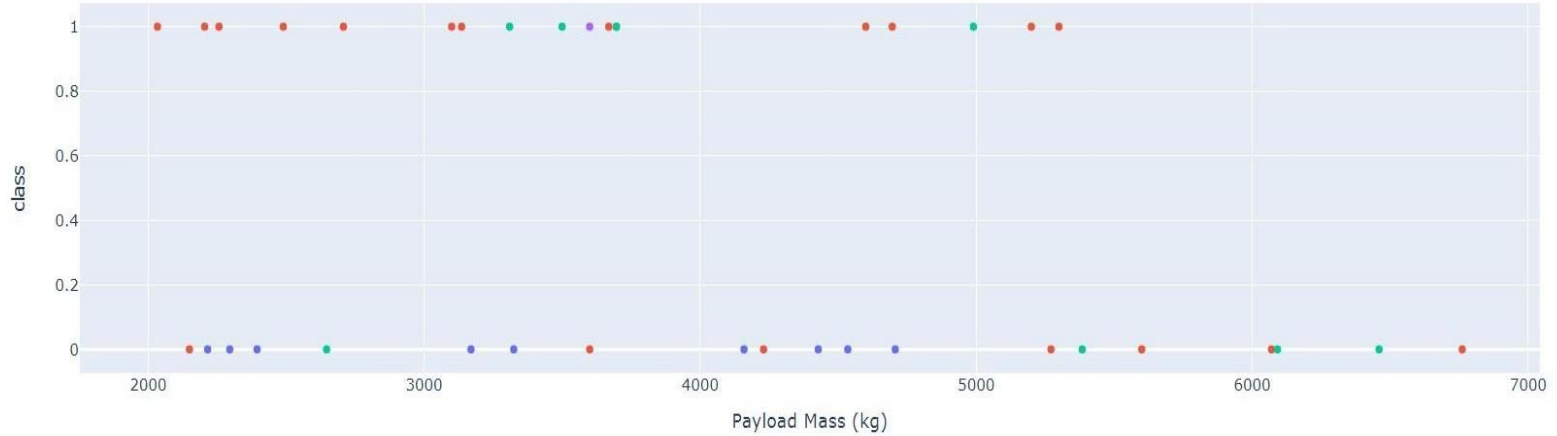
KSC LC-39A has a 76.9% success rate but getting a 23.1% failure rate.



The Payload vs. Launch Outcome Scatter Plot



Payload 0 kg - 7000 kg



Payload 2000 kg - 8000 kg

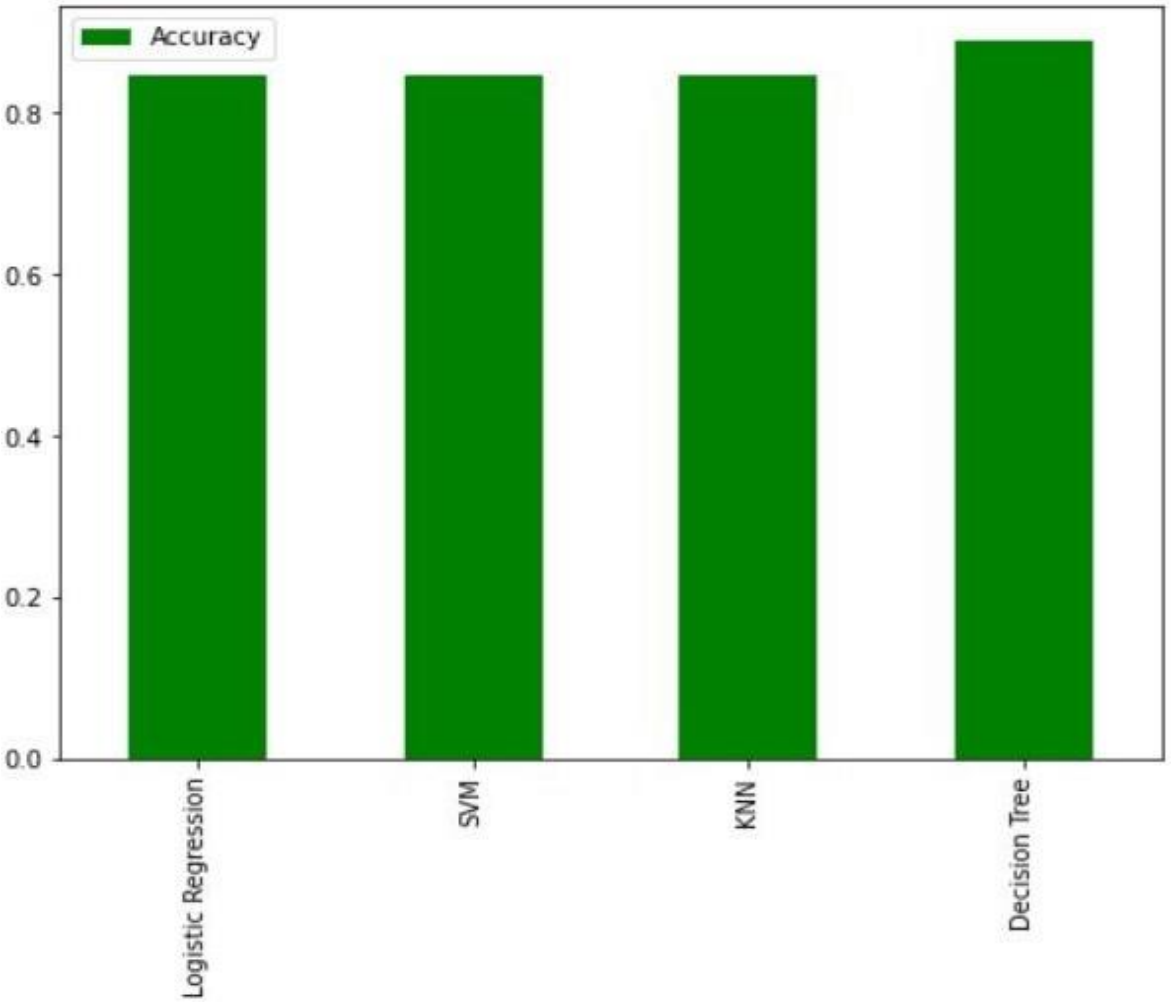
After using the dashboard, we can gain some insights about our data. With this dashboard we can observe these:

- The KSC LC-39A has the highest launch success rate
- The payload ranges between 2000kg - 10000kg has the highest launch success rate
- The FT booster version has the highest launch success rate

Section 5

Predictive Analysis (Classification)

Classification Accuracy



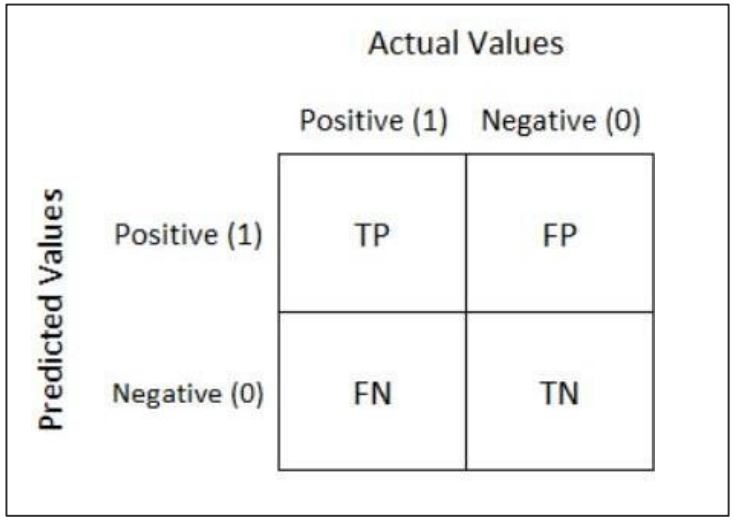
As you can see, the accuracy rates are really close to each other, but the **"Decision Tree"** model has the highest accuracy.

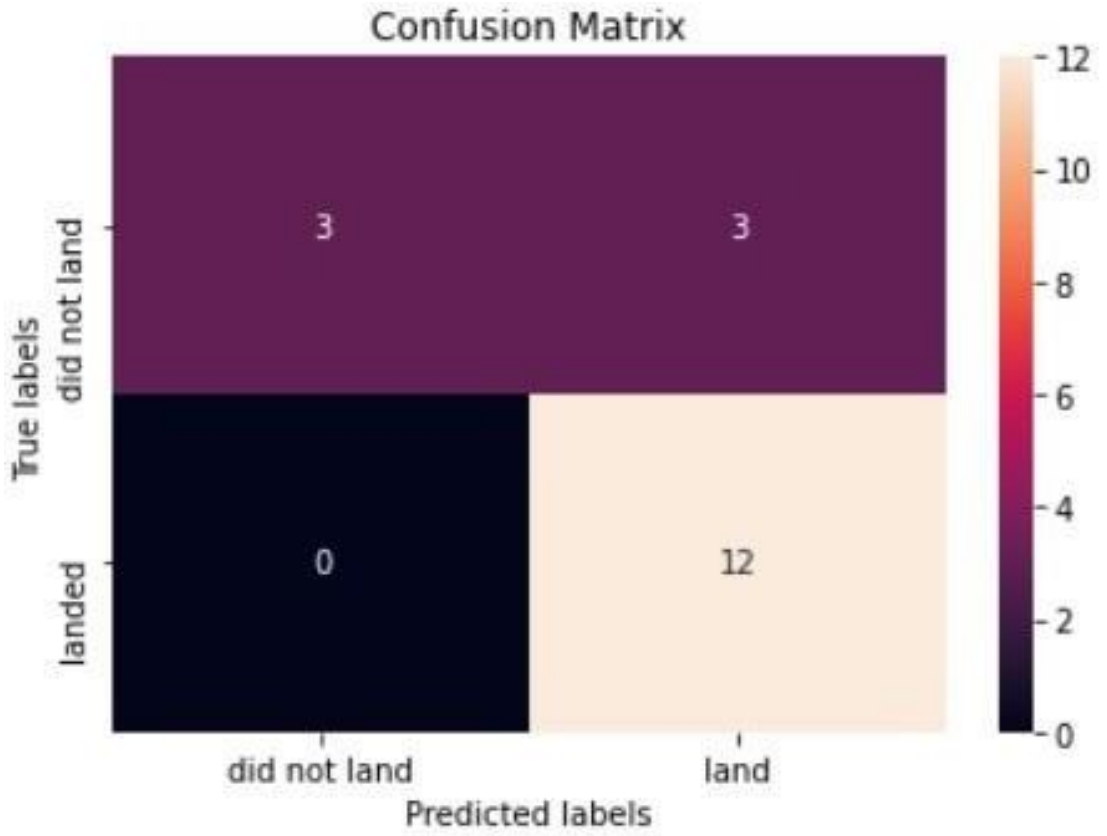
	Accuracy
Logistic Regression	0.846429
SVM	0.848214
Decision Tree	0.876786
KNN	0.848214

Confusion Matrix

A confusion matrix is a table that is used to define the performance of a classification algorithm. A confusion matrix visualizes and summarizes the performance of a classification algorithm.

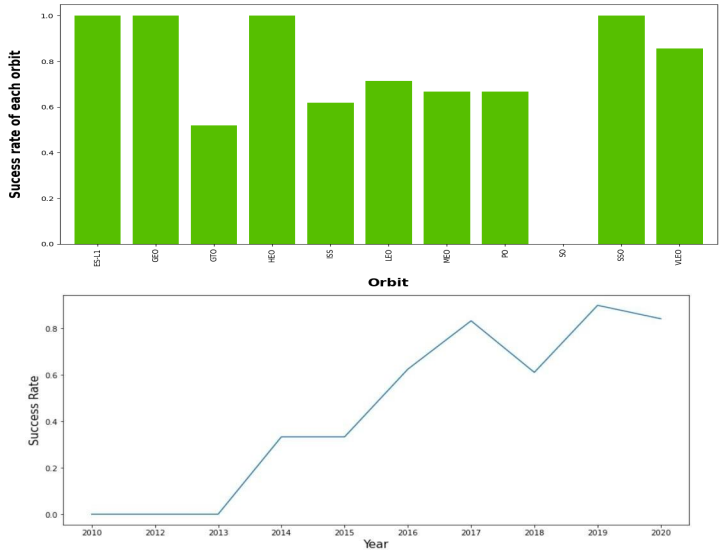
Unfortunately for all models, we found the same confusion matrix.

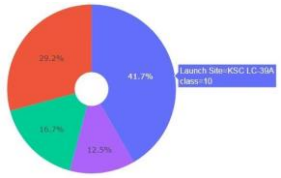


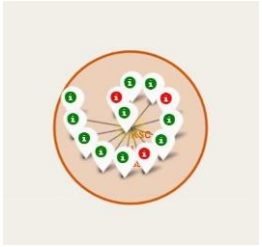


Conclusions

- ➔ The orbits ES-L1, GEO, HEO, SSO have the highest success rates.
- ➔ The success rates have been increasing by the time.
- ➔ KSC LC-39A has the most successful launches but increasing payload mass is affecting it negatively.
- ➔ The Decision Tree Classification is the best algorithm for this dataset.







	Accuracy
Logistic Regression	0.846429
SVM	0.848214
Decision Tree	0.876786
KNN	0.848214

LANDED SUCCESSFULLY AT THE END OF OUR JOURNEY

Thank you..