<Zack David Ruiz>
<November 9, 2024>

Outline

Executive Summary

Methodologies

- **Data Loading & Inspection**: Loaded datasets, checked initial structure, and data types.
- **Missing Values**: Identified and filled NaN values using column means.
- **Data Cleaning**: Removed irrelevant columns, standardized data types.
- **Statistical Summary**: Generated descriptive stats (mean, median, etc.) for key insights.
- **Verification**: Rechecked data integrity after transformations.
- EDA with data visualization
- EDA with SQL

Key Results

- **Improved Data Quality**: Eliminated missing values and irrelevant columns.
- **Insights via Stats**: Highlighted data patterns, trends, and potential outliers.
- **Reliable Data**: Verified transformations to ensure accurate analysis-ready data.

Introduction

Project Background and Context

- This project aimed to predict the likelihood of a successful landing for the Falcon 9's reusable first stage. SpaceX markets Falcon 9 launches at a cost of $62 million, significantly lower than other providers, who charge upwards of $165 million. This cost advantage largely stems from SpaceX's ability to reuse the first stage. By accurately predicting if the first stage will land, we can assess the potential costs for a launch. This analysis could be valuable for other companies considering competitive bids against SpaceX.

Key Problems Addressed

- Identifying the factors that influence the success of a rocket landing.
- Understanding how each variable impacts the likelihood of a successful landing.
- Determining the conditions SpaceX needs to optimize to achieve the highest success rate for rocket landings.

Section 1

Methodology

Executive Summary

Data Collection and Preparation

- Data was collected using the SpaceX REST API and web scraping from Wikipedia.
- Data wrangling techniques were applied to prepare the data for machine learning.
- Irrelevant columns were removed, and data fields were one-hot encoded for machine learning compatibility.

Exploratory Data Analysis (EDA)

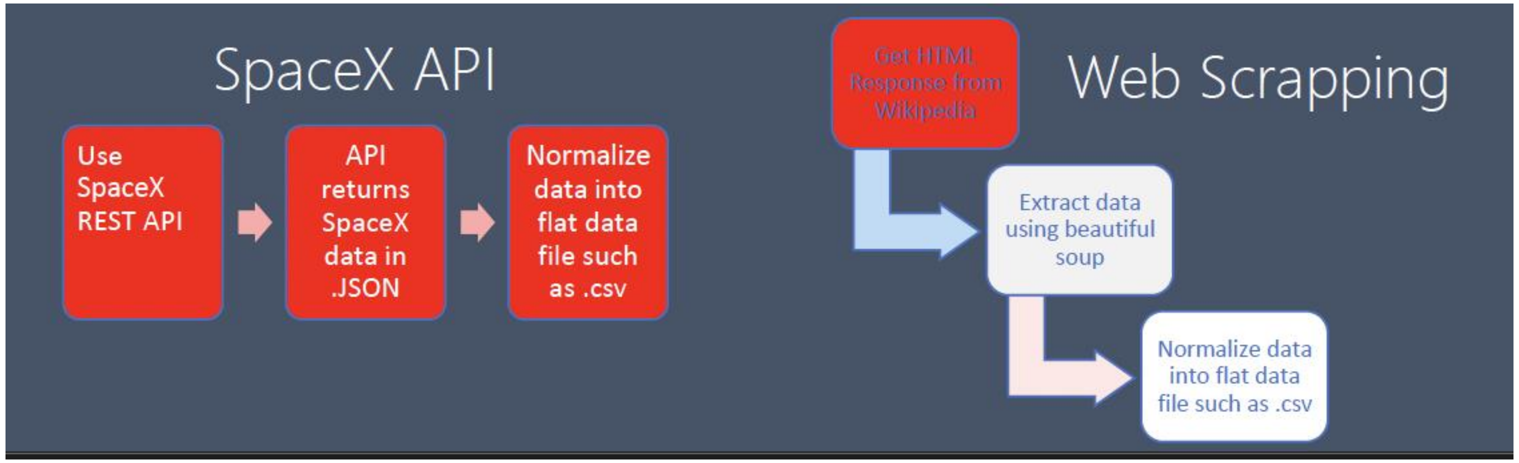
- Conducted EDA using visualization tools and SQL.
- Created scatter plots and bar graphs to illustrate relationships and patterns in the data.

Interactive and Predictive Analysis

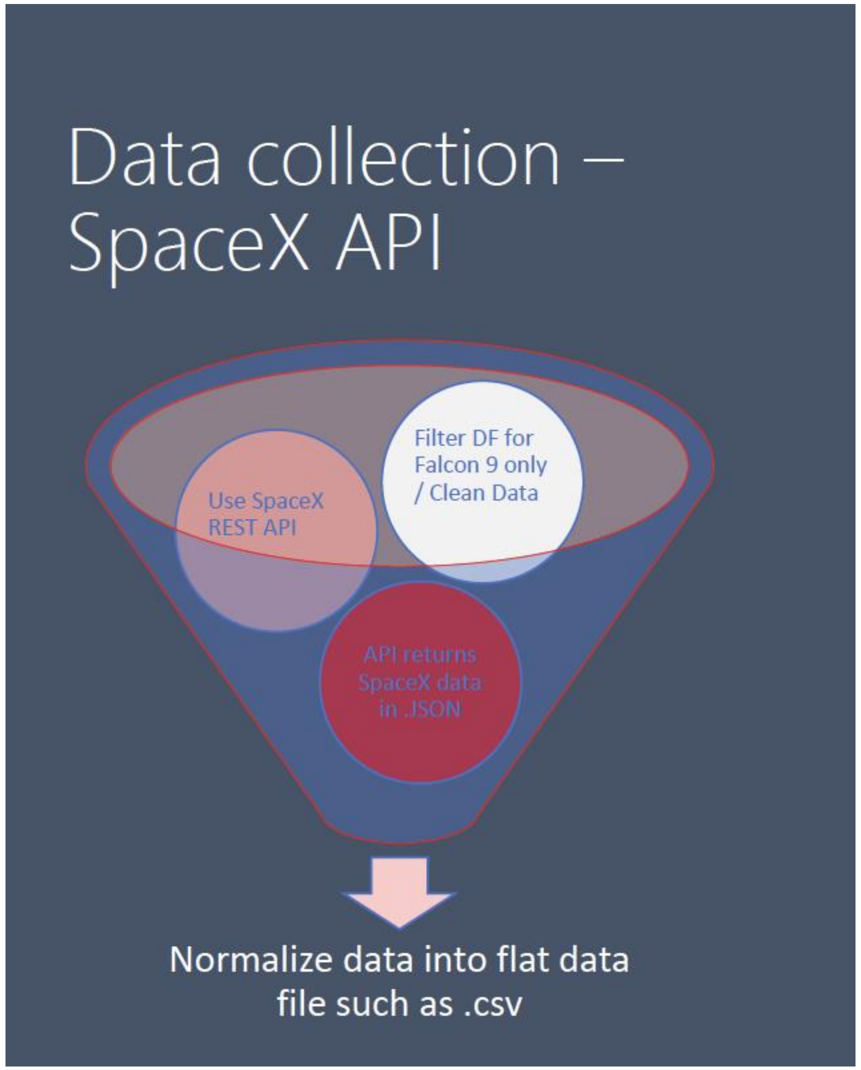
- Used Folium and Plotly Dash for interactive visual analytics.
- Built, tuned, and evaluated classification models for predictive analysis.

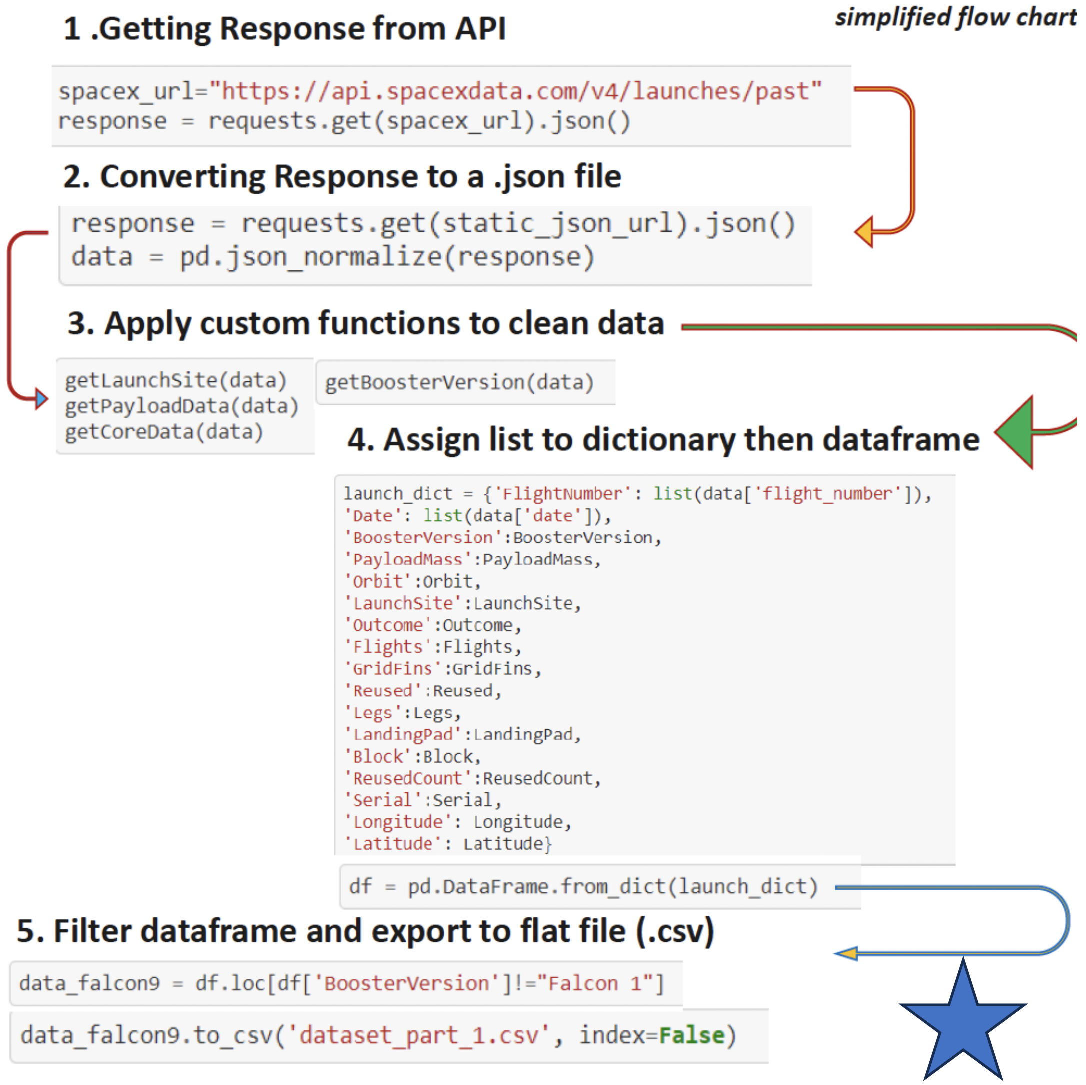
Data Collection

- **Data Collection Overview**
- We gathered SpaceX launch data through the SpaceX REST API, which provides detailed information on each launch, including rocket specifications, payload details, launch and landing specifications, and landing outcomes.
- Our objective was to use this data to predict whether SpaceX will attempt to land a rocket.
- The SpaceX REST API endpoints are accessible via api.spacexdata.com/v4/.
- Additionally, we used web scraping with BeautifulSoup to gather supplementary Falcon 9 launch data from Wikipedia.


SpaceX API
Use SpaceX REST API
API returns SpaceX data in .JSON
Normalize data into flat data file such as .csv
Get HTML Response from Wikipedia
Web Scrapping
Extract data using beautiful soup
Normalize data into flat data file such as .csv

Data Collection – SpaceX API


Data collection – SpaceX API
Use SpaceX REST API
Filter DF for Falcon 9 only / Clean Data
API returns SpaceX data in JSON
Normalize data into flat data file such as .csv


simplified flow chart

1 .Getting Response from API

```
spacex_url="https://api.spacexdata.com/v4/launches/past"
response = requests.get(spacex_url).json()
```

2. Converting Response to a .json file

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

3. Apply custom functions to clean data

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

```
getBoosterVersion(data)
```

4. Assign list to dictionary then dataframe

```
launch_dict = {'FlightNumber': list(data['flight_number']),
'Date': list(data['date']),
'BoosterVersion':BoosterVersion,
'PayloadMass':PayloadMass,
'Orbit':Orbit,
'LaunchSite':LaunchSite,
'Outcome':Outcome,
'Flights':Flights,
'GridFins':GridFins,
'Reused':Reused,
'Legs':Legs,
'LandingPad':LandingPad,
'Block':Block,
'ReusedCount':ReusedCount,
'Serial':Serial,
'Longitude': Longitude,
'Latitude': Latitude}
```

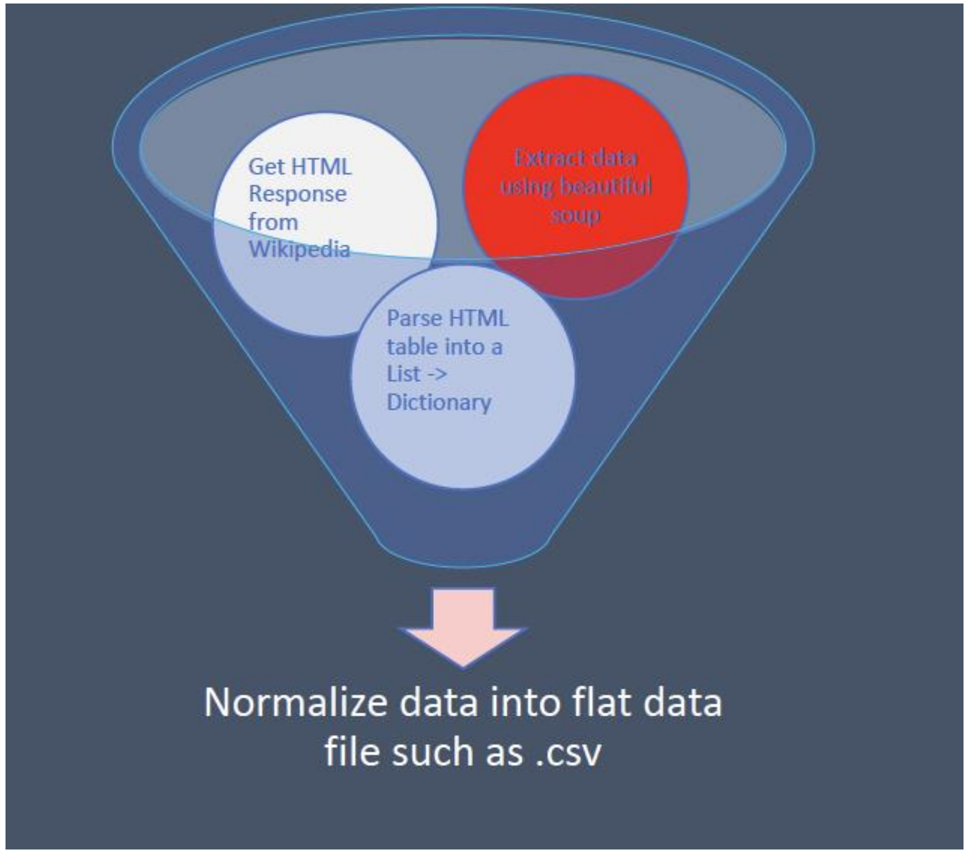
```
df = pd.DataFrame.from_dict(launch_dict)
```

5. Filter dataframe and export to flat file (.csv)

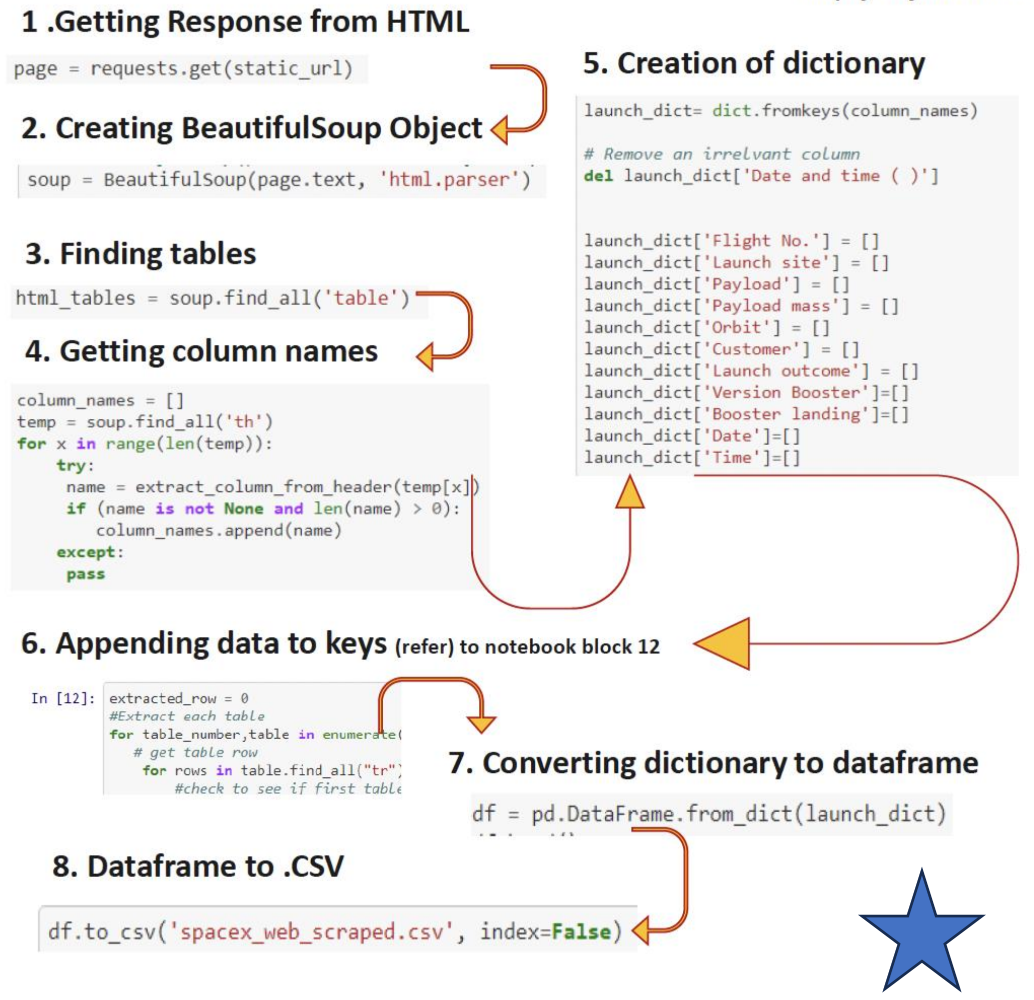
```
data_falcon9 = df.loc[df['BoosterVersion']!="Falcon 1"]
```

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

Data Collection - Scraping


Get HTML Response from Wikipedia
Extract data using beautiful soup
Parse HTML table into a List -> Dictionary
Normalize data into flat data file such as .csv

simplified flow chart



1 .Getting Response from HTML

```
page = requests.get(static_url)
```

2. Creating BeautifulSoup Object

```
soup = BeautifulSoup(page.text, 'html.parser')
```

3. Finding tables

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

4. Getting column names

```
column_names = []
temp = soup.find_all('th')
for x in range(len(temp)):
    try:
     name = extract_column_from_header(temp[x])
     if (name is not None and len(name) > 0):
        column_names.append(name)
    except:
     pass
```

5. Creation of dictionary

```
launch_dict= dict.fromkeys(column_names)

# Remove an irrelvant column
del launch_dict['Date and time ( )']


launch_dict['Flight No.'] = []
launch_dict['Launch site'] = []
launch_dict['Payload'] = []
launch_dict['Payload mass'] = []
launch_dict['Orbit'] = []
launch_dict['Customer'] = []
launch_dict['Launch outcome'] = []
launch_dict['Version Booster']=[]
launch_dict['Booster landing']=[]
launch_dict['Date']=[]
launch_dict['Time']=[]
```

6. Appending data to keys (refer) to notebook block 12

```
In [12]: extracted_row = 0
         #Extract each table
         for table_number,table in enumerate(
            # get table row
             for rows in table.find_all("tr")
                 #check to see if first table
```

7. Converting dictionary to dataframe

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

8. Dataframe to .CSV

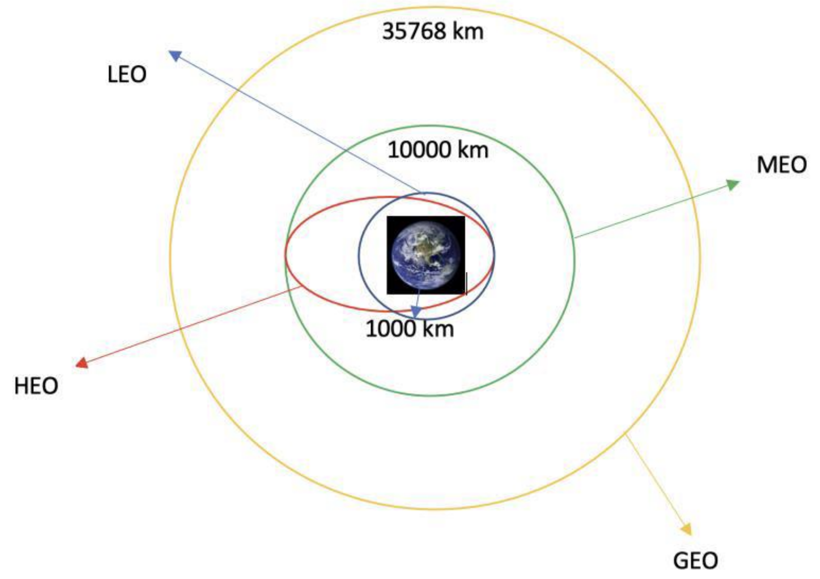
```
df.to_csv('spacex_web_scraped.csv', index=False)
```

Data Wrangling

In the dataset, there are several instances where the booster did not land successfully. Sometimes a landing was attempted but failed due to an accident. For example:

- **True Ocean** indicates a successful landing in a specific ocean region, while **False Ocean** indicates an unsuccessful landing in that region.
- **True RTLS** means the booster successfully landed on a ground pad, whereas **False RTLS** means it landed unsuccessfully on the ground pad.
- **True ASDS** represents a successful landing on a drone ship, while **False ASDS** indicates an unsuccessful landing on a drone ship.

These outcomes are converted into training labels: 1 for a successful landing and 0 for an unsuccessful one.



EDA with Data Visualization

Bar Graph being drawn:

Mean VS. Orbit

A bar diagram makes it easy to compare sets of data between different groups at a glance. The graph represents categories on one axis and a discrete value in the other. The goal is to show the relationship between the two axes. Bar charts can also show big changes in data over time.

Line Graph being drawn:

Success Rate VS. Year

Line graphs are useful in that they show data variables and trends very clearly and can help to make predictions about the results of data not yet recorded

Scatter Graphs being drawn:

- Flight Number VS. Payload Mass
- Flight Number VS. Launch Site
- Payload VS. Launch Site
- Orbit VS. Flight Number
- Payload VS. Orbit Type
- Orbit VS. Payload Mass

EDA with SQL

Performed SQL queries to gather information about the dataset.

For example of some questions we were asked about the data we needed information about. Which we are using SQL queries to get the answers in the dataset :

- Displaying the names of the unique launch sites in the space mission
- Displaying 5 records where launch sites begin with the string 'KSC'
- Displaying the total payload mass carried by boosters launched by NASA (CRS)
- Displaying average payload mass carried by booster version F9 v1.1
- Listing the date where the successful landing outcome in drone ship was achieved.
- Listing the names of the boosters which have success in ground pad and have payload mass greater than 4000 but less than 6000
- Listing the total number of successful and failure mission outcomes
- Listing the names of the booster versions which have carried the maximum payload mass.
- Listing the records which will display the month names, successful landing outcomes in ground pad ,booster versions, launch s ite for the months in year 2017
- Ranking the count of successful landing outcomes between the date 2010-06-04 and 2017-03-20 in descending order.

Build an Interactive Map with Folium

To visualize the Launch Data into an interactive map. We took the Latitude and Longitude Coordinates at each launch site and added a *Circle Marker around each launch site with a label of the name of the launch site.*

We assigned the dataframe launch_outcomes(failures, successes) to *classes 0 and 1* with Green and Red markers on the map in a MarkerCluster()

Using Haversine's formula we calculated the distance from the Launch Site to various landmarks to find various trends about what is around the Launch Site to measure patterns. **Lines** are drawn on the map to measure distance to landmarks

Example of some trends in which the Launch Site is situated in.

```
•Are launch sites in close proximity to railways? No
•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
```

Build a Dashboard with Plotly Dash

Used Python Anywhere to host the website live 24/7 so your can play around with the data and view the data

- **The dashboard is built with Flask and Dash web framework.**

Graphs

- **Pie Chart showing the total launches by a certain site/all sites**

  - *display relative proportions of multiple classes of data.*
  - *size of the circle can be made proportional to the total quantity it represents.*

[URL Link to live website]

[GitHub Link to source code]

Scatter Graph showing the relationship with Outcome and Payload Mass (Kg) for the different Booster Versions

- It shows the relationship between two variables.
- It is the best method to show you a non-linear pattern.
- The range of data flow, i.e. maximum and minimum value, can be determined.
- Observation and reading are straightforward.

Predictive Analysis (Classification)

BUILDING MODEL

- Load our dataset into NumPy and Pandas
- Transform Data
- Split our data into training and test data sets
- Check how many test samples we have
- Decide which type of machine learning algorithms we want to use
- Set our parameters and algorithms to GridSearchCV
- Fit our datasets into the GridSearchCV objects and train our dataset.

EVALUATING MODEL

- Check accuracy for each model
- Get tuned hyperparameters for each type of algorithms
- Plot Confusion Matrix

IMPROVING MODEL

- Feature Engineering
- Algorithm Tuning

FINDING THE BEST PERFORMING CLASSIFICATION MODEL

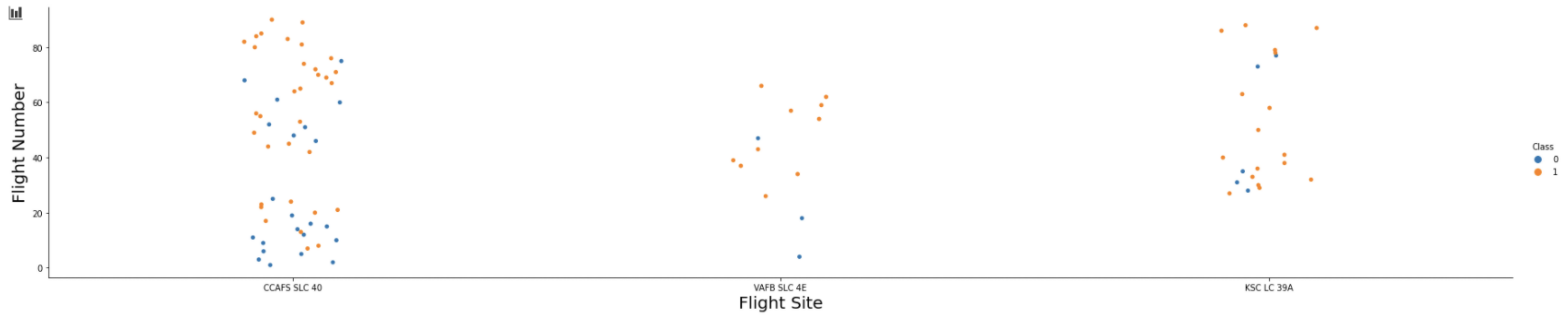
- The model with the best accuracy score wins the best performing model
- In the notebook there is a dictionary of algorithms with scores at the bottom of the notebook.

Results

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

Section 2

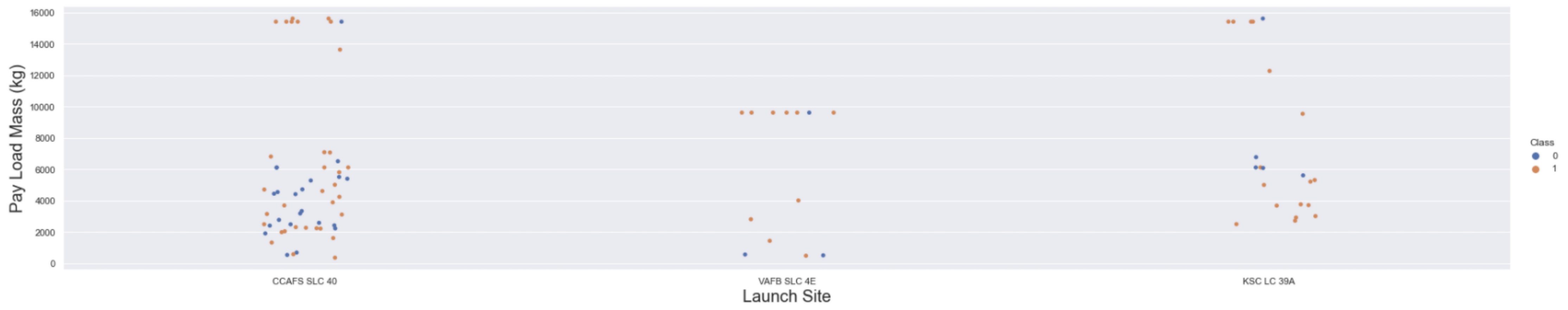
Flight Number vs. Launch Site



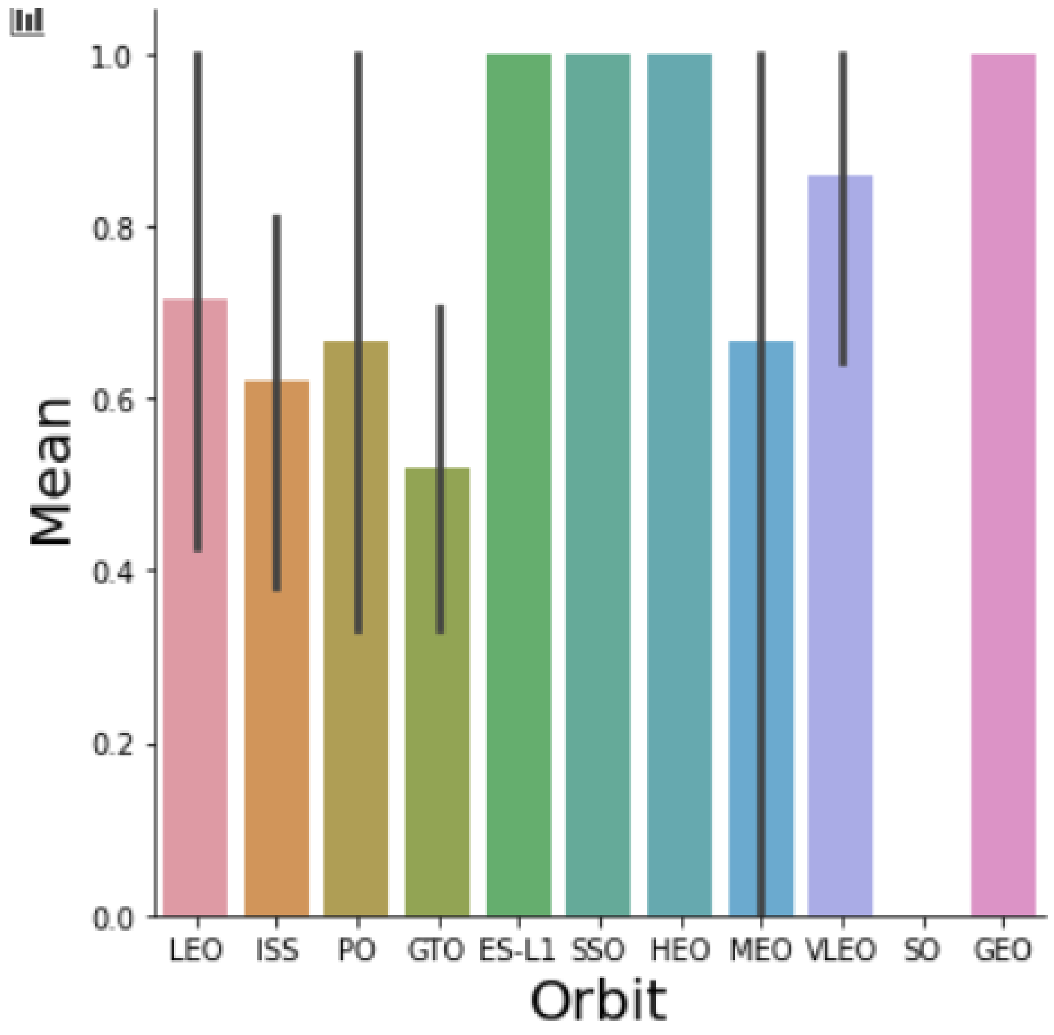
The more amount of flights at a launch site the greater the success rate at a launch site.

Payload vs. Launch Site

The greater the payload mass for Launch Site CCAFS SLC 40 the higher the success rate for the Rocket. There is not quite a clear pattern to be found using this visualization to make a decision if the Launch Site is dependent on Pay Load Mass for a success launch.

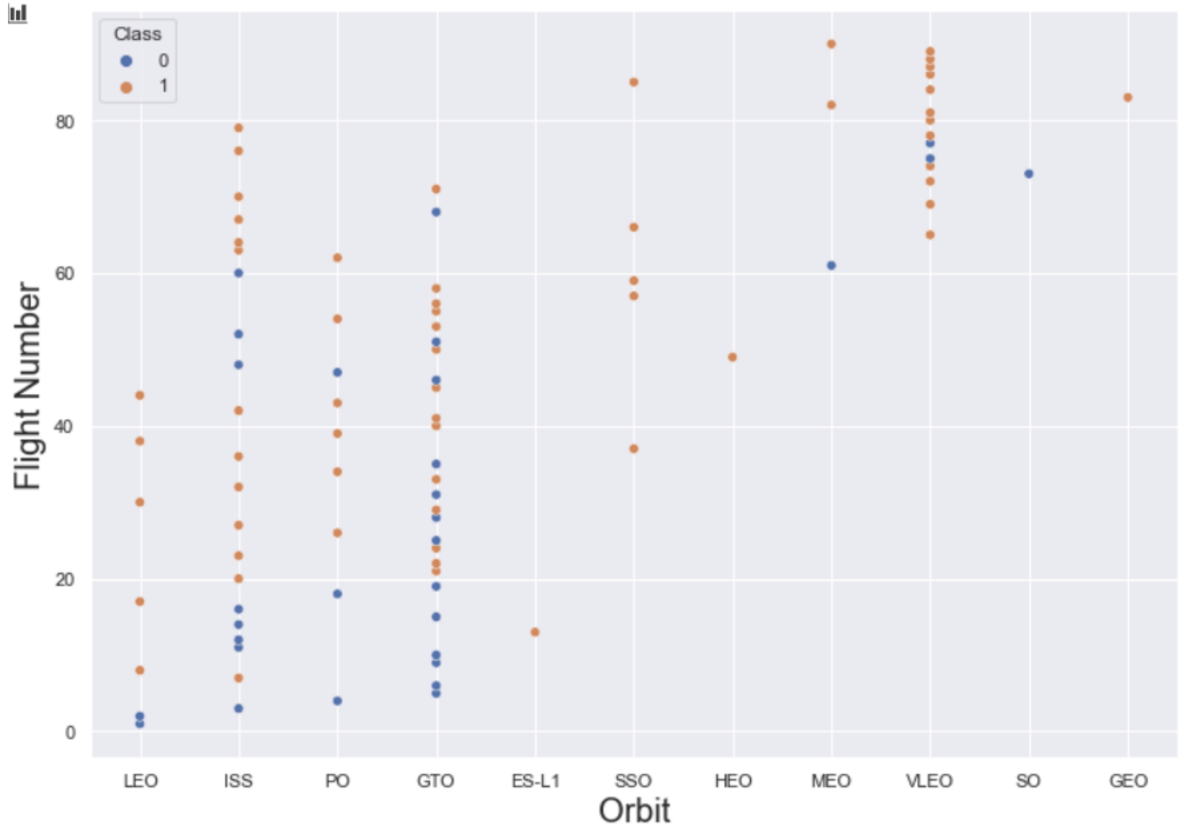


Success Rate vs. Orbit Type



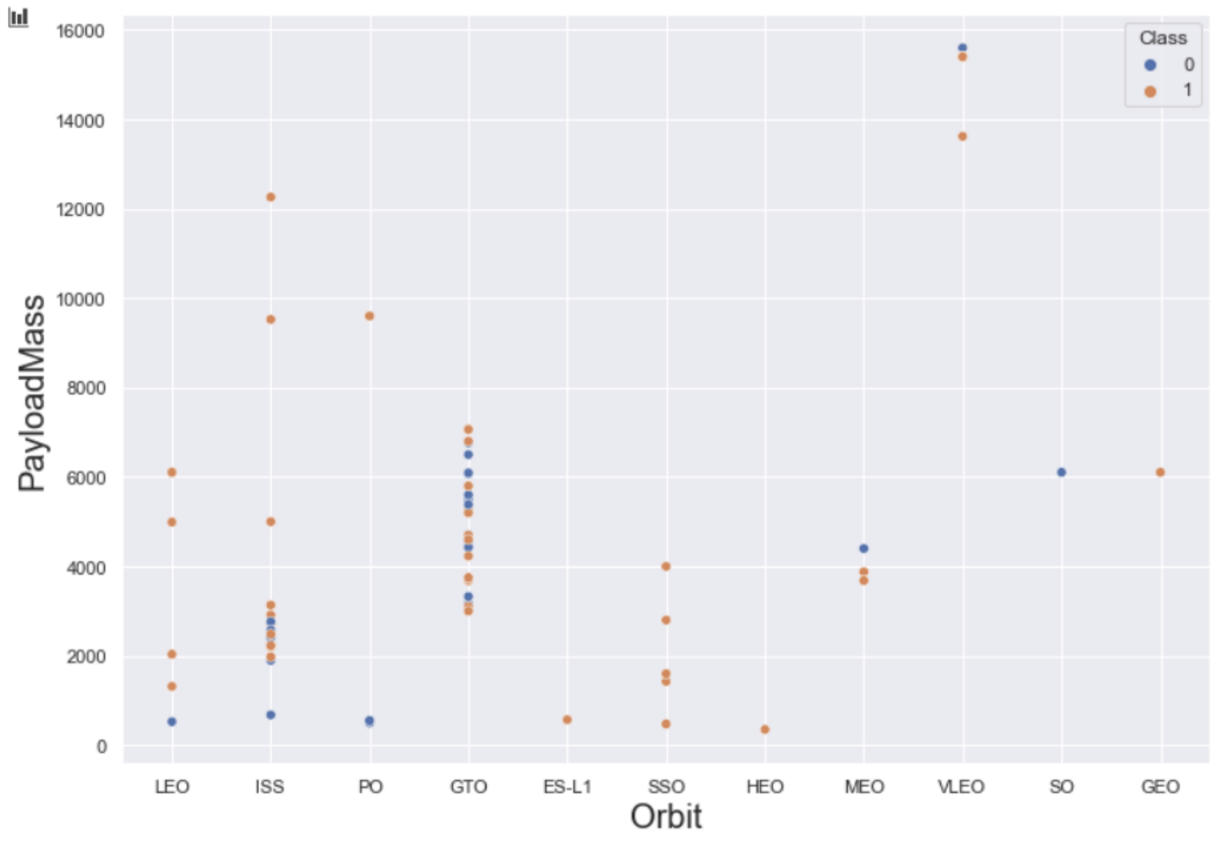
Orbit GEO,HEO,SSO,ES-L1 had the best Success Rate

Flight Number vs. Orbit Type

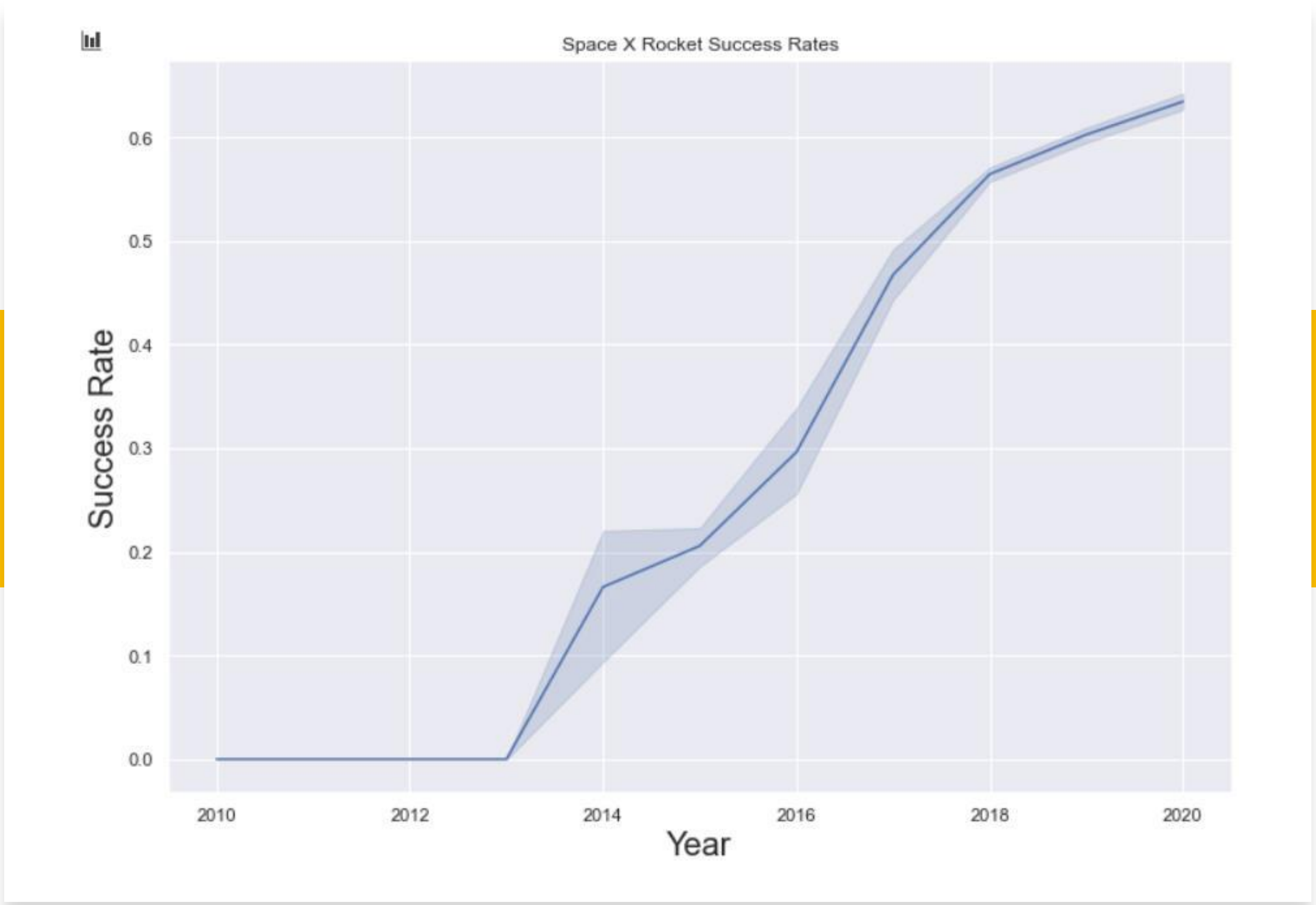


You should see that in the LEO orbit the Success appears related to the number of flights; on the other hand, there seems to be no relationship between flight number when in GTO orbit.

Payload vs. Orbit Type



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

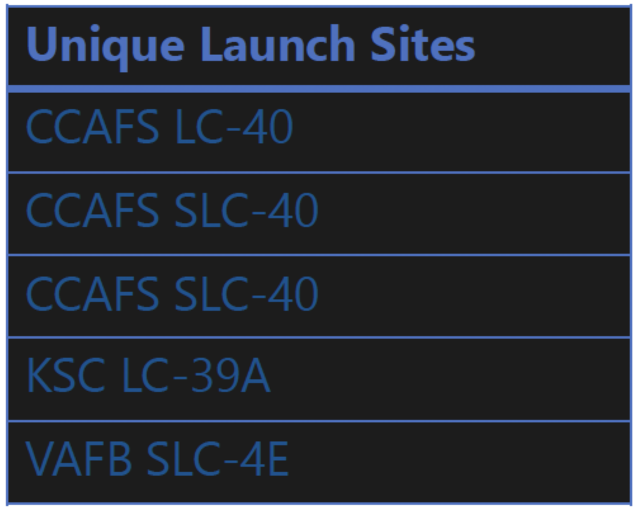


Launch Success Yearly Trend

All Launch Site Names

SQL QUERY

```
select DISTINCT Launch_Site
from tblSpaceX
```



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

QUERY EXPLAINATION

Using the word ***DISTINCT*** in the query means that it will only show Unique values in the ***Launch_Site*** column from ***tblSpaceX***

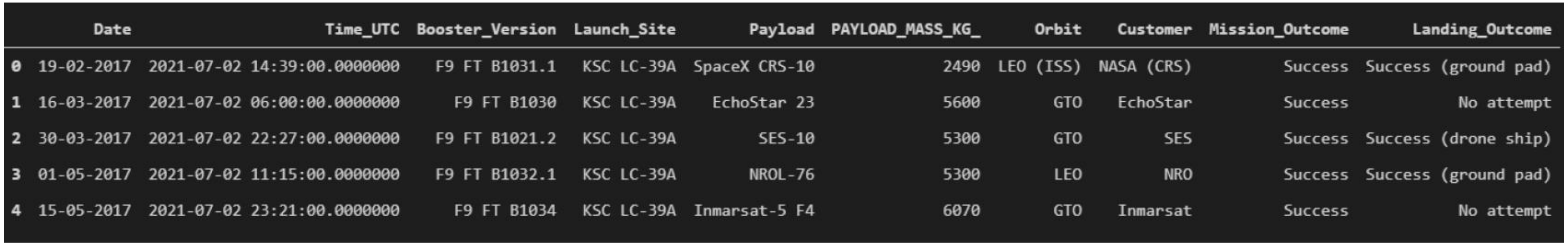
Launch Site Names Begin with 'CCA'

SQL QUERY

```
select TOP 5 * from tblSpaceX
WHERE Launch_Site LIKE 'KSC%'
```

QUERY EXPLAINATION

Using the word ***TOP 5*** in the query means that it will only show 5 records from ***tblSpaceX*** and ***LIKE*** keyword has a wild card with the words ***'KSC%'*** the percentage in the end suggests that the Launch_Site name must start with KSC.

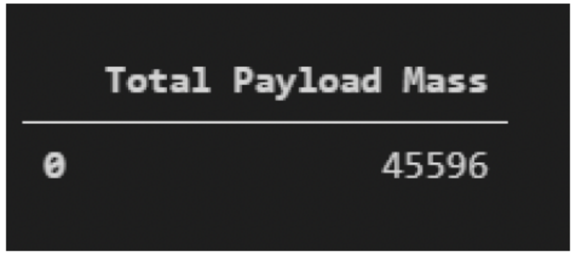


```
         Date                 Time_UTC  Booster_Version  Launch_Site         Payload  PAYLOAD_MASS_KG_     Orbit     Customer  Mission_Outcome       Landing_Outcome
0  19-02-2017  2021-07-02 14:39:00.0000000    F9 FT B1031.1  KSC LC-39A  SpaceX CRS-10              2490  LEO (ISS)  NASA (CRS)          Success  Success (ground pad)
1  16-03-2017  2021-07-02 06:00:00.0000000      F9 FT B1030  KSC LC-39A    EchoStar 23              5600        GTO    EchoStar          Success            No attempt
2  30-03-2017  2021-07-02 22:27:00.0000000    F9 FT B1021.2  KSC LC-39A          SES-10              5300        GTO         SES          Success  Success (drone ship)
3  01-05-2017  2021-07-02 11:15:00.0000000    F9 FT B1032.1  KSC LC-39A         NROL-76              5300        LEO         NRO          Success  Success (ground pad)
4  15-05-2017  2021-07-02 23:21:00.0000000      F9 FT B1034  KSC LC-39A  Inmarsat-5 F4              6070        GTO    Inmarsat          Success            No attempt
```

SQL QUERY

select SUM(PAYLOAD_MASS_KG_) TotalPayloadMass from tblSpaceX
where Customer = 'NASA (CRS)'",'TotalPayloadMass

Total Payload Mass



```
     Total Payload Mass
0                 45596
```

QUERY EXPLAINATION

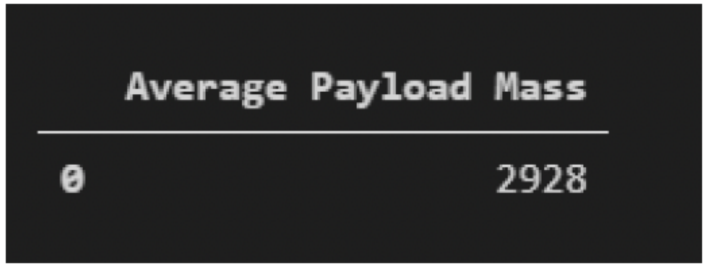
Using the function ***SUM*** summates the total in the column ***PAYLOAD_MASS_KG_***

The ***WHERE*** clause filters the dataset to only perform calculations on ***Customer NASA (CRS)***

Average Payload Mass by F9 v1.1

SQL QUERY

```
select AVG(PAYLOAD_MASS_KG_) AveragePayloadMass from tblSpaceX
where Booster_Version = 'F9 v1.1'
```



```
   Average Payload Mass
0                  2928
```

QUERY EXPLAINATION

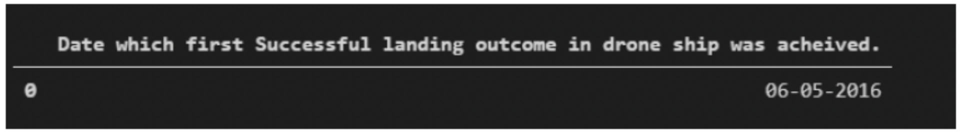
Using the function ***AVG*** works out the average in the column ***PAYLOAD_MASS_KG_***

The ***WHERE*** clause filters the dataset to only perform calculations on ***Booster_version F9 v1.1***

First Successful Ground Landing Date

SQL QUERY

select MIN(Date) SLO from tblSpaceX where Landing_Outcome = "Success (drone ship)"



```
   Date which first Successful landing outcome in drone ship was acheived.
0                                                              06-05-2016
```

QUERY EXPLAINATION

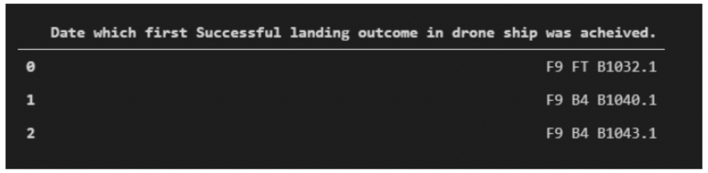
Using the function ***MIN*** works out the minimum date in the column ***Date***

The ***WHERE*** clause filters the dataset to only perform calculations on ***Landing_Outcome Success (drone ship)***

Successful Drone Ship Landing with Payload between 4000 and 6000

SQL QUERY

select Booster_Version from tblSpaceX where Landing_Outcome = ‘Success (ground pad)’ AND Payload_MASS_KG_ > 4000 AND Payload_MASS_KG_ < 6000



```
   Date which first Successful landing outcome in drone ship was acheived.
0                                                            F9 FT B1032.1
1                                                            F9 B4 B1040.1
2                                                            F9 B4 B1043.1
```

QUERY EXPLAINATION

Selecting only ***Booster_Version***

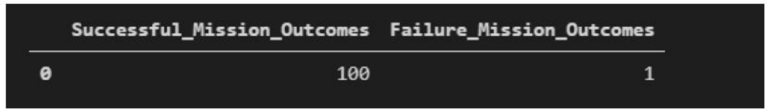
The ***WHERE*** clause filters the dataset to ***Landing_Outcome = Success (drone ship)***

The ***AND*** clause specifies additional filter conditions ***Payload_MASS_KG_*** > 4000 AND ***Payload_MASS_KG_ < 6000***

Total Number of Successful and Failure Mission Outcomes

SQL QUERY

```
SELECT(SELECT Count(Mission_Outcome) from tblSpaceX where Mission_Outcome
LIKE '%Success%’) as Successful_Mission_Outcomes,
(SELECT Count(Mission_Outcome) from tblSpaceX where Mission_Outcome
LIKE '%Failure%’) as Failure_Mission_Coutcomes
```



```
   Successful_Mission_Outcomes  Failure_Mission_Outcomes
0                          100                         1
```

QUERY EXPLAINATION

a much harder query I must say, we used subqueries here to produce the results. The ***LIKE ‘%foo%’*** wildcard shows that in the record the ***foo*** phrase is in any part of the string in the records for example.

PHRASE “(Drone Ship was a Success)”
LIKE ‘%Success%’
Word ‘Success’ is in the phrase the filter will include it in the dataset

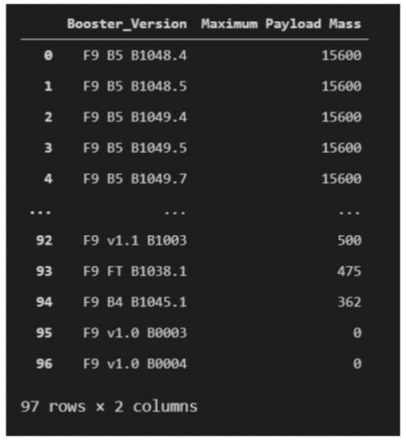
Boosters Carried Maximum Payload

SQL QUERY

```
SELECT DISTINCT Booster_Version, MAX(PAYLOAD_MASS
_KG_) AS [Maximum Payload Mass]
FROM tblSpaceX GROUP BY Booster_Version
ORDER BY [Maximum Payload Mass] DESC
```

QUERY EXPLAINATION

Using the word ***DISTINCT*** in the query means that it will only show Unique values in the ***Booster_Version*** column from ***tblSpaceX***
GROUP BY puts the list in order set to a certain condition.
DESC means its arranging the dataset into descending order



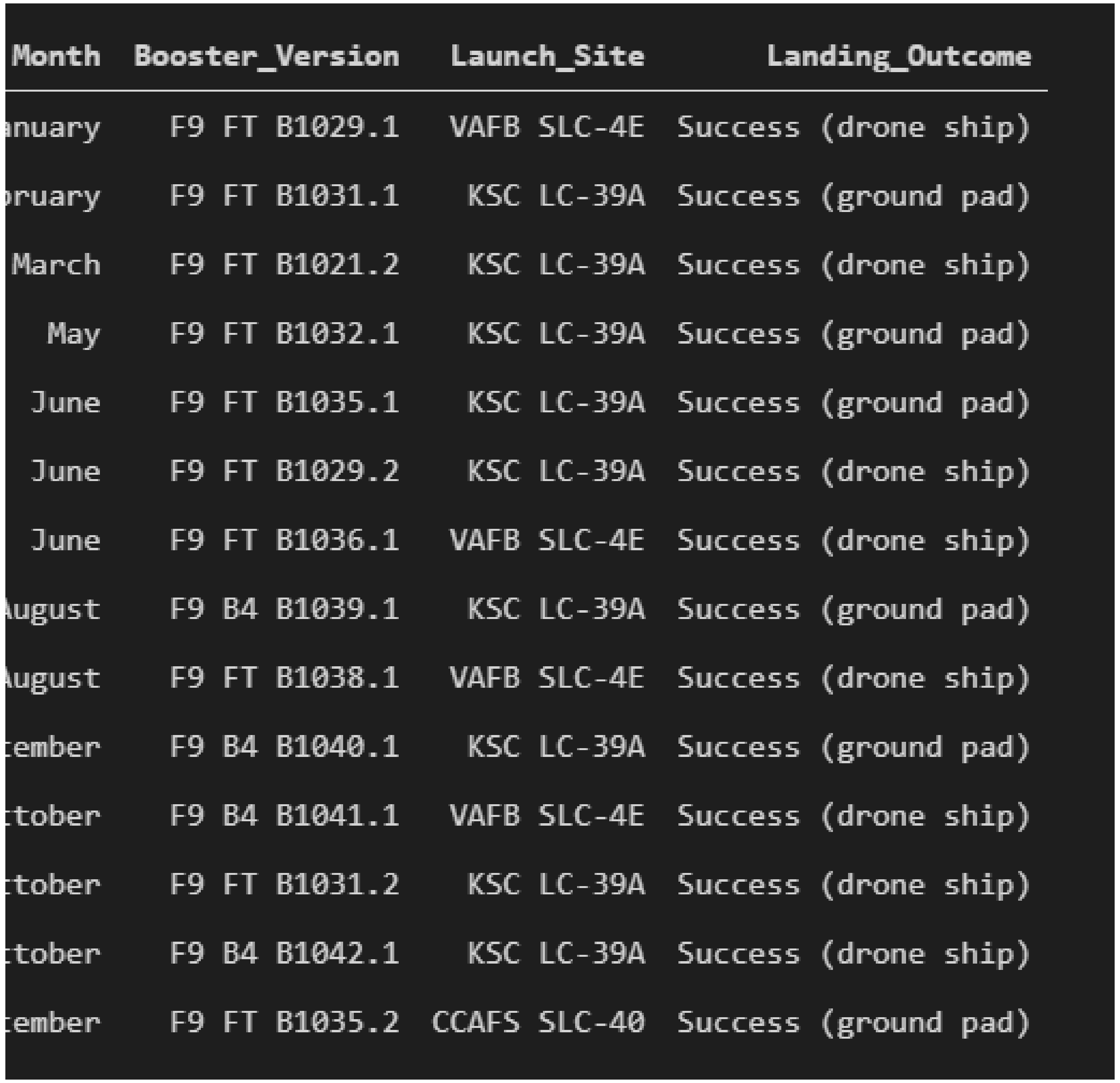
```
     Booster_Version  Maximum Payload Mass
0    F9 B5 B1048.4                   15600
1    F9 B5 B1048.5                   15600
2    F9 B5 B1049.4                   15600
3    F9 B5 B1049.5                   15600
4    F9 B5 B1049.7                   15600
...            ...                     ...
92   F9 v1.1 B1003                     500
93   F9 FT B1038.1                     475
94   F9 B4 B1045.1                     362
95   F9 v1.0 B0003                       0
96   F9 v1.0 B0004                       0

97 rows × 2 columns
```

2015 Launch Records

- SQL QUERY
- SELECT DATENAME(month, DATEADD(month, MONTH(CONVERT(date, Date, 105)), 0) -1) AS Month, Booster_Version, Launch_Site, Landing_Outcome
- FROM tblSpaceX WHERE (Landing_Outcome LIKE N'%Success%') AND (YEAR(CONVERT(date, Date, 105)) = ‘2015')

- QUERY EXPLAINATION
- a much more complex query as I had my Date fields in SQL Server stored as NVARCHAR the MONTH function returns name month. The function CONVERT converts NVARCHAR to Date.
- WHERE clause filters Year to be 2015



```
Month  Booster_Version  Launch_Site       Landing_Outcome
anuary    F9 FT B1029.1  VAFB SLC-4E  Success (drone ship)
bruary    F9 FT B1031.1   KSC LC-39A  Success (ground pad)
 March    F9 FT B1021.2   KSC LC-39A  Success (drone ship)
   May    F9 FT B1032.1   KSC LC-39A  Success (ground pad)
  June    F9 FT B1035.1   KSC LC-39A  Success (ground pad)
  June    F9 FT B1029.2   KSC LC-39A  Success (drone ship)
  June    F9 FT B1036.1  VAFB SLC-4E  Success (drone ship)
ugust     F9 B4 B1039.1   KSC LC-39A  Success (ground pad)
ugust     F9 FT B1038.1  VAFB SLC-4E  Success (drone ship)
ember     F9 B4 B1040.1   KSC LC-39A  Success (ground pad)
tober     F9 B4 B1041.1  VAFB SLC-4E  Success (drone ship)
tober     F9 FT B1031.2   KSC LC-39A  Success (drone ship)
tober     F9 B4 B1042.1   KSC LC-39A  Success (drone ship)
ember     F9 FT B1035.2 CCAFS SLC-40  Success (ground pad)
```

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

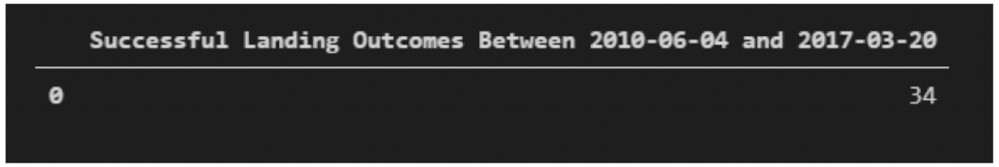
SQL QUERY

```
SELECT COUNT(Landing_Outcome)
FROM     tblSpaceX
WHERE  (Landing_Outcome LIKE '%Success%')
AND (Date > '04-06-2010')
AND (Date < '20-03-2017')
```

QUERY EXPLAINATION

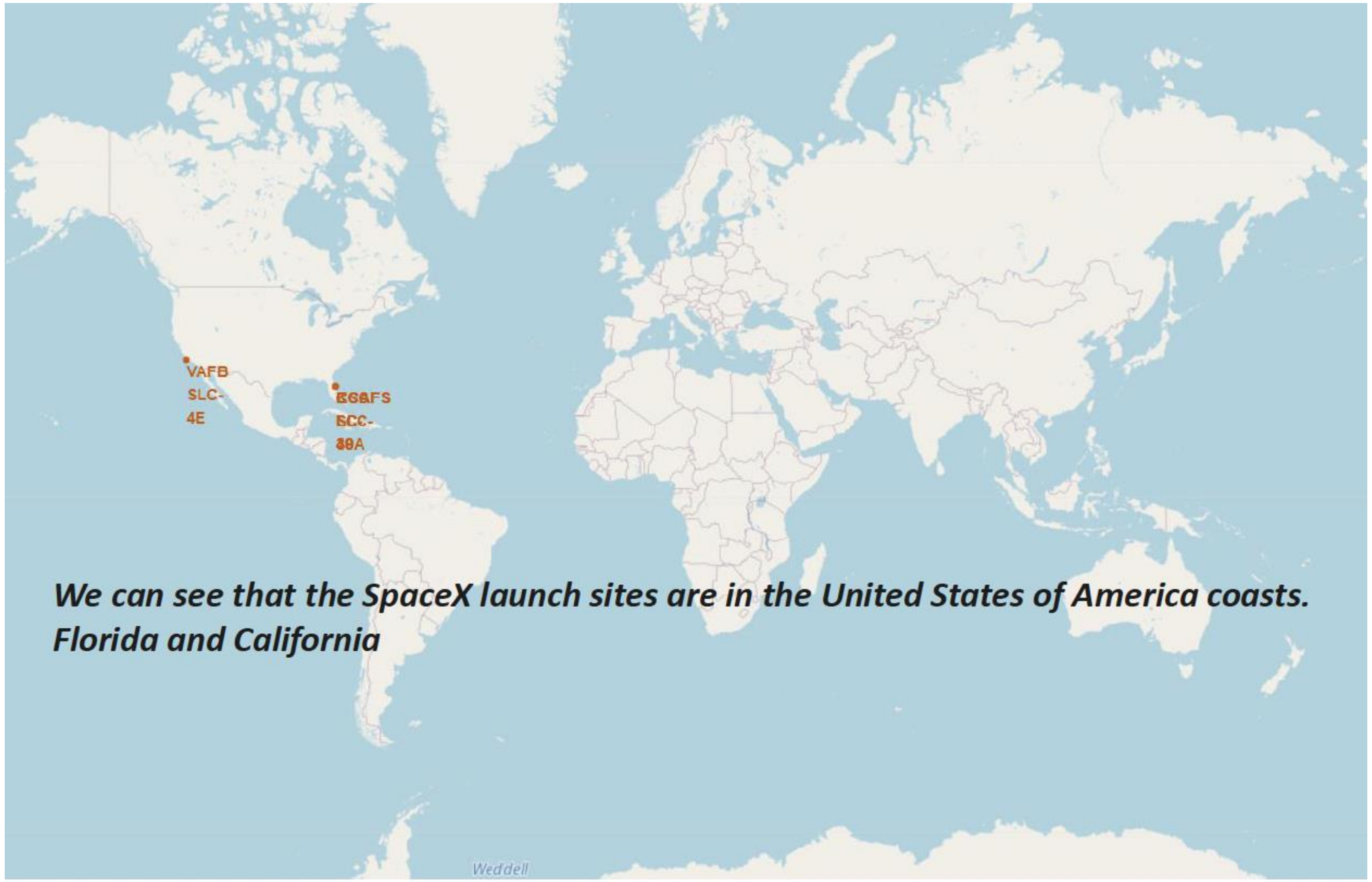
Function ***COUNT*** counts records in column
WHERE filters data

LIKE (wildcard)
AND (conditions)
AND (conditions)



```
   Successful Landing Outcomes Between 2010-06-04 and 2017-03-20
0                                                              34
```

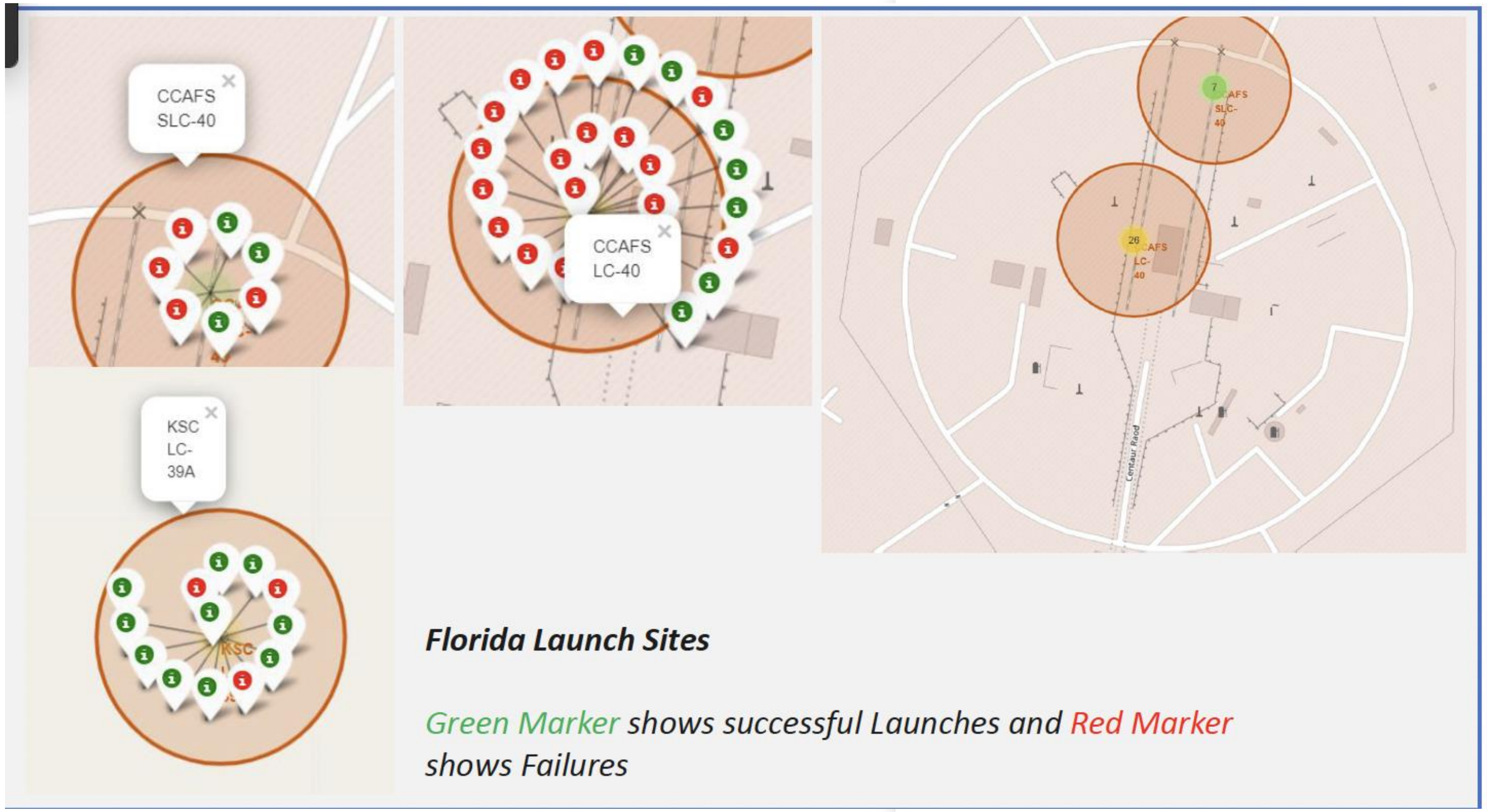
Section 3



We can see that the SpaceX launch sites are in the United States of America coasts. Florida and California

<Folium Map Screenshot 1>

<Folium Map Screenshot 2>

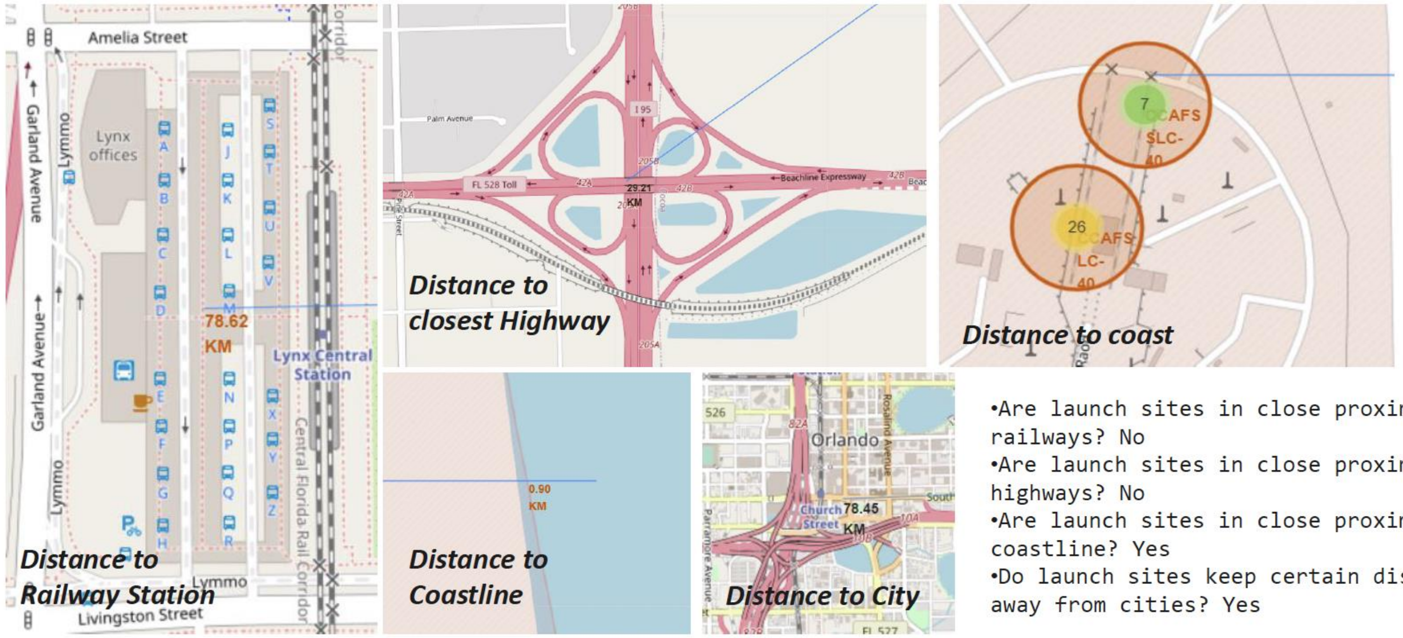


Florida Launch Sites

Green Marker shows successful Launches and Red Marker shows Failures

VAFB SLC-4E
Launch Tower

California Launch Site

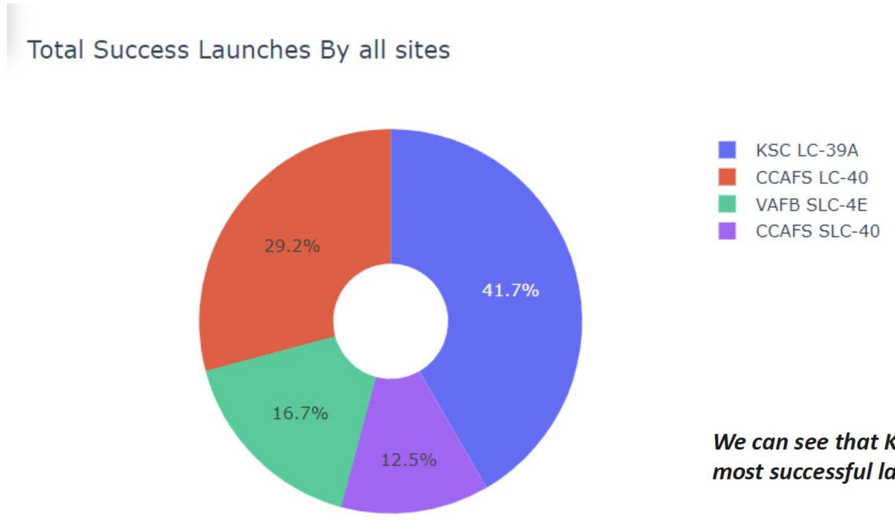


•Are launch sites in close proximity to railways? No
•Are launch sites in close proximity to highways? No
•Are launch sites in close proximity to coastline? Yes
•Do launch sites keep certain distance away from cities? Yes

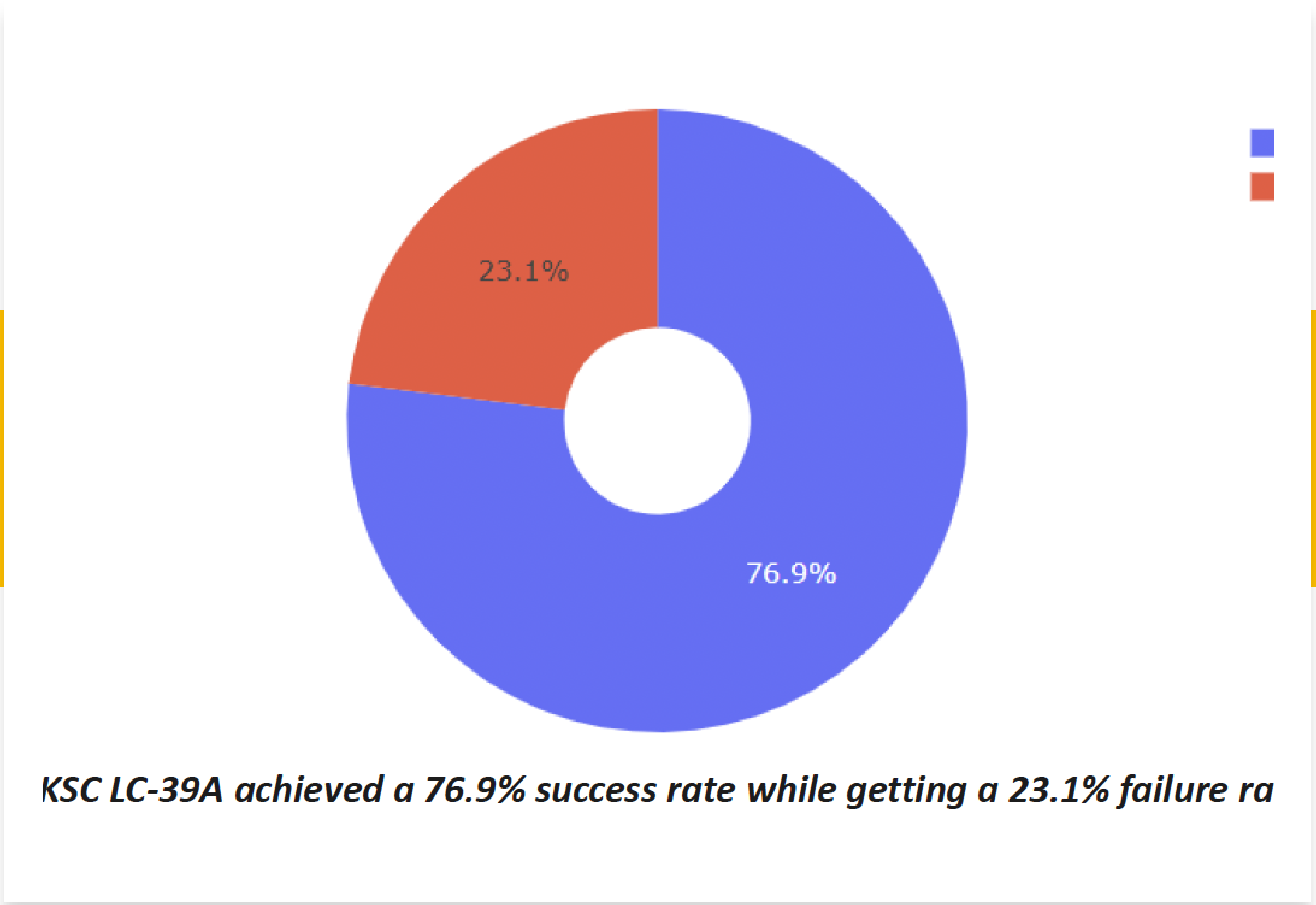
<Folium Map Screenshot 3>

Section 4

<Dashboard Screenshot 1>



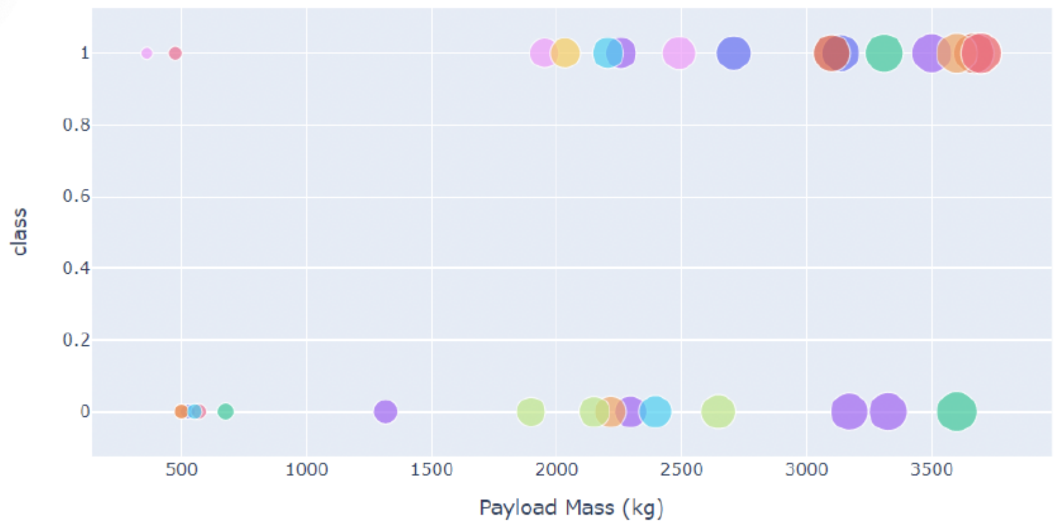
We can see that KSC LC-39A had the most successful launches from all the sites



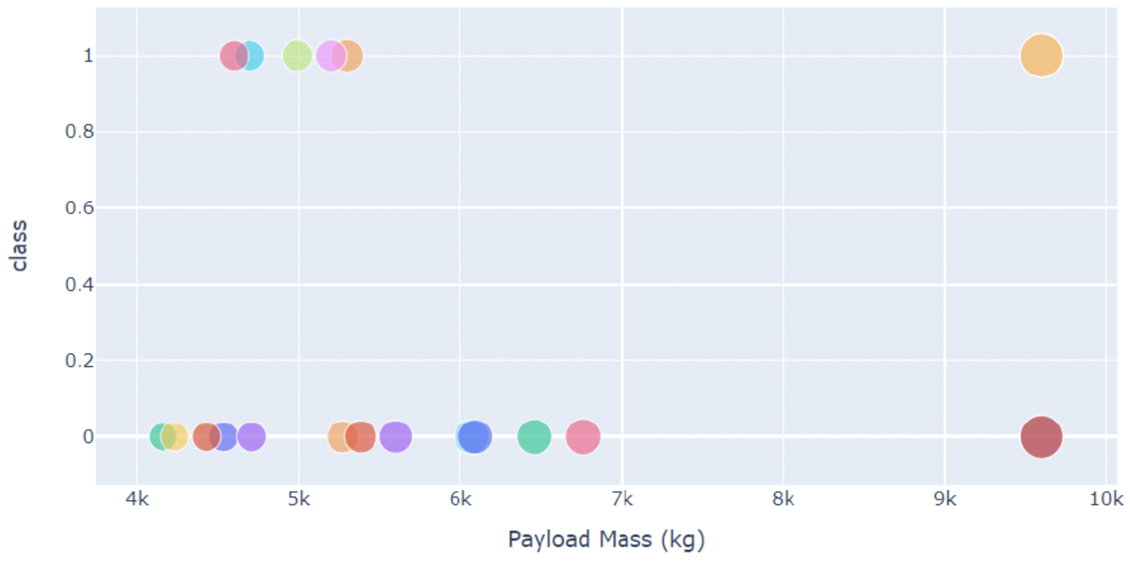
KSC LC-39A achieved a 76.9% success rate while getting a 23.1% failure ra

<Dashboard Screenshot 2>

Low Weighted Payload 0kg – 4000kg



Heavy Weighted Payload 4000kg – 10000kg



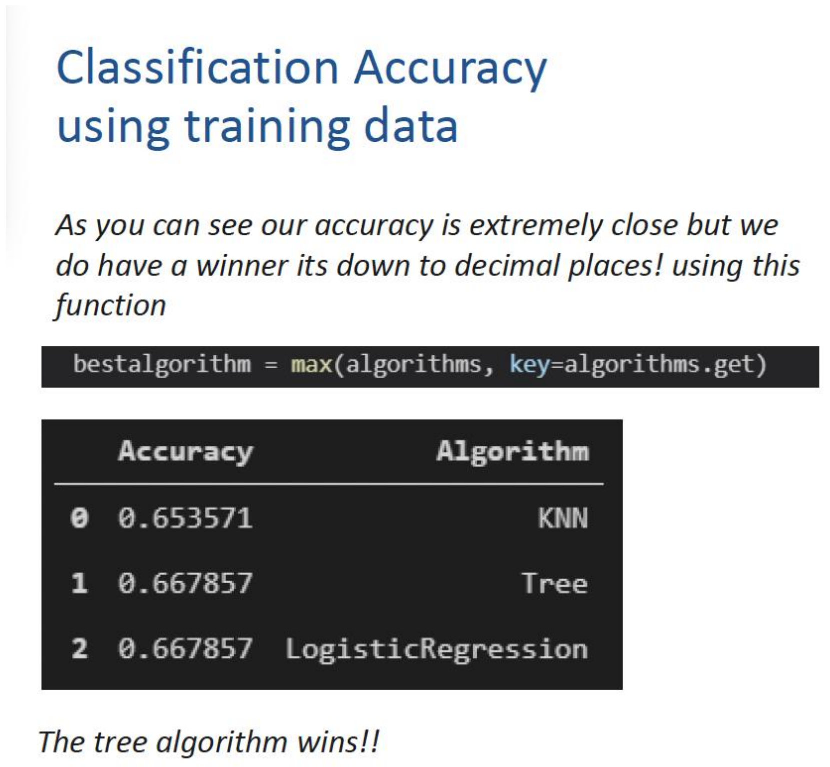
We can see the success rates for low weighted payloads is higher than the heavy weighted payloads

<Dashboard Screenshot 3>

Section 5

Classification Accuracy

After selecting the best hyperparameters for the decision tree classifier using the validation data, we achieved 83.33% accuracy on the test data.



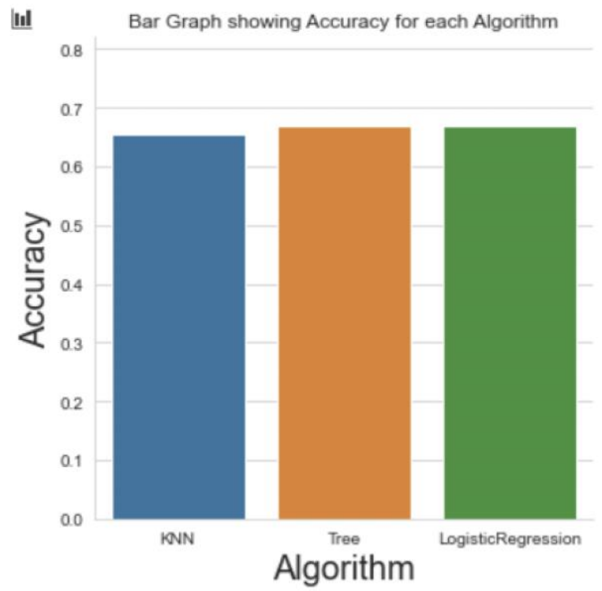
Classification Accuracy using training data

As you can see our accuracy is extremely close but we do have a winner its down to decimal places! using this function

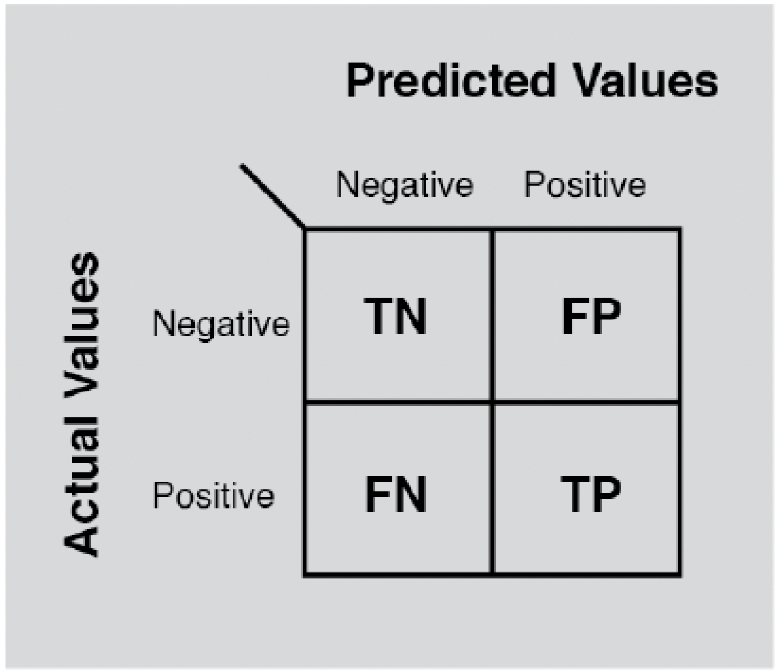
```
bestalgorithm = max(algorithms, key=algorithms.get)
```

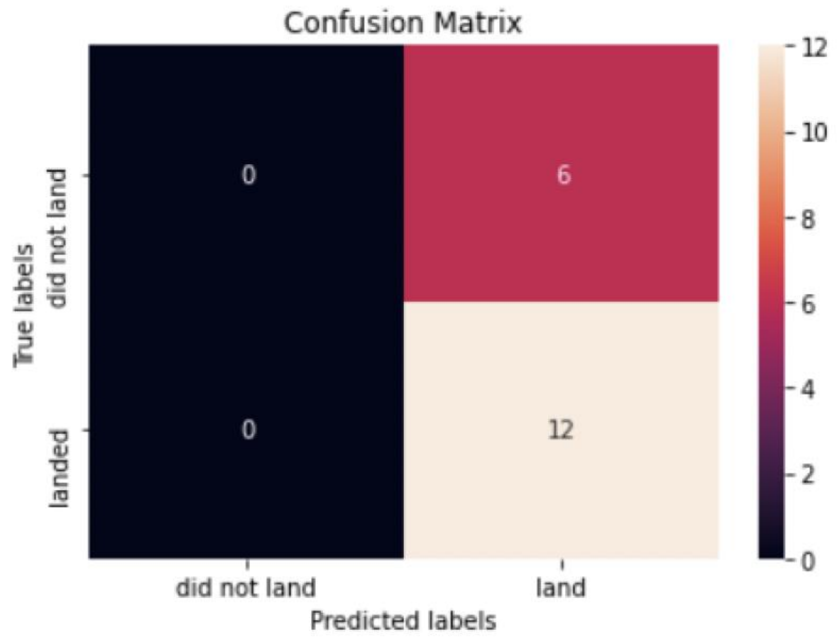
	Accuracy	Algorithm
0	0.653571	KNN
1	0.667857	Tree
2	0.667857	LogisticRegression

The tree algorithm wins!!



```
Best Algorithm is Tree with a score of 0.6678571428571429
Best Params is : {'criterion': 'gini', 'max_depth': 2, 'max_features': 'auto', 'min_samples_leaf': 1, 'min_samples_split': 2, 'splitter': 'best'}
```





Confusion Matrix

Confusion Matrix for the Tree

Examining the confusion matrix, we see that Tree can distinguish between the different classes. We see that the major problem is false positives.

Conclusions

- The **Decision Tree Classifier** algorithm is the most effective for machine learning with this dataset.
- **Lighter payloads** achieve higher success rates than heavier payloads.
- **Success rates** for SpaceX launches increase over time, suggesting they will continue to improve as years go by.
- The **KSC LC 39A launch site** has recorded the highest number of successful launches among all sites.
- **Orbits GEO, HEO, SSO, and ES L1** have the highest success rates.

Appendix

- In this project, various assets were created to analyze the data effectively:
- 1. **Python Code Snippets**:
- • Used pandas, numpy, and matplotlib for data loading, cleaning, and visualization.
- • Implemented a **Decision Tree Classifier** to predict landing success, revealing trends in payload weight performance and model accuracy.
- 2. **SQL Queries**:
- • Ran SQL queries to filter and aggregate launch data by factors like launch site, orbit type, and success outcomes, enabling deeper insights.
- 3. **Visualizations**:
- • Created line plots and bar charts to show trends, including:
- • Yearly fluctuations in launch success.
- • Success rates by payload weight and launch site, highlighting KSC LC 39A as the most successful.
- • Orbits with the highest success rates, such as GEO, HEO, and SSO.
- 4. **Notebook Outputs**:
- • Documented each analysis step in Jupyter Notebooks, with outputs showing model results, data transformations, and statistical insights, like SpaceX's increasing success over time.
- 5. **Data Sets**:
- • Refined data for analysis, focusing on launch site performance, orbit success, and payload weight.