Winning Space Race with Data Science

Abdul Azeez

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Outline

- Executive Summary
- Introduction
- Methodology
- Results
- Conclusion

Executive Summary

Summary of methodologies

In this capstone project, we will predict if the SpaceX Falcon 9 first stage will land successfully using several machine learning classification algorithms.

The main steps in this project include:

- Data collection, wrangling, and formatting
- Exploratory data analysis
- Interactive data visualization
- Machine learning prediction

Summary of all results

Our graphs show that some features of the rocket launches have a correlation with the outcome of the launches, i.e., success or failure.

It is also concluded that decision tree may be the best machine learning algorithm to predict if the Falcon 9 first stage will land successfully

Introduction

- Project background and context
  - SpaceX, A leader in the space industry strives to make space travel affordable for everyone. It's accomplishments include sending spacecraft to the International Space Station, launching a satellite constellation that provides Internet access and sending manned missions to space. SpaceX can do this because the rocket launches are relatively inexpensive ($62 million per launch) due to its novel reuse of the first stage of its Falcon 9 rocket other providers which are not able to reuse the first stage cost upwards of $165 million each. By determining if the first stage will land, we can determine the price of the launch. To do this, we can use public data and machine learning models to predict whether SpaceX - or a competing company - can reuse the first stage.
- Problems you want to find answers
  - How payload mass, launch site, number of flights, and orbits abstract first stage landing success
  - Rate of successful landings overtime
  - Best predictive model for successful landing (binary classification]

Section 1

Methodology

Methodology

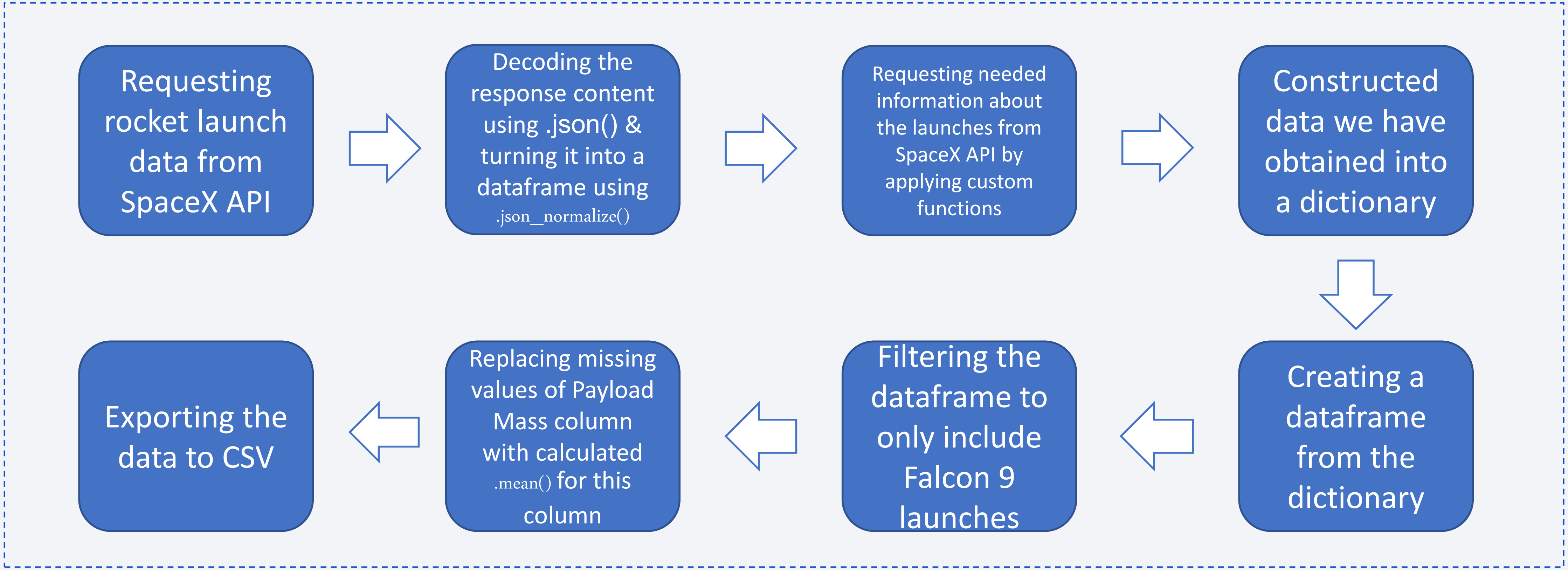
Executive Summary

- Data collection methodology:
  - Using SpaceX REST API
  - Using web scrapping from Wikipedia
- Perform data wrangling
  - Filtering the data
  - Dealing with missing values
  - Using One Hot Encoding to prepare the data to a binary classification
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - Building, tuning and evaluation of classification models to ensure the best results

Data Collection

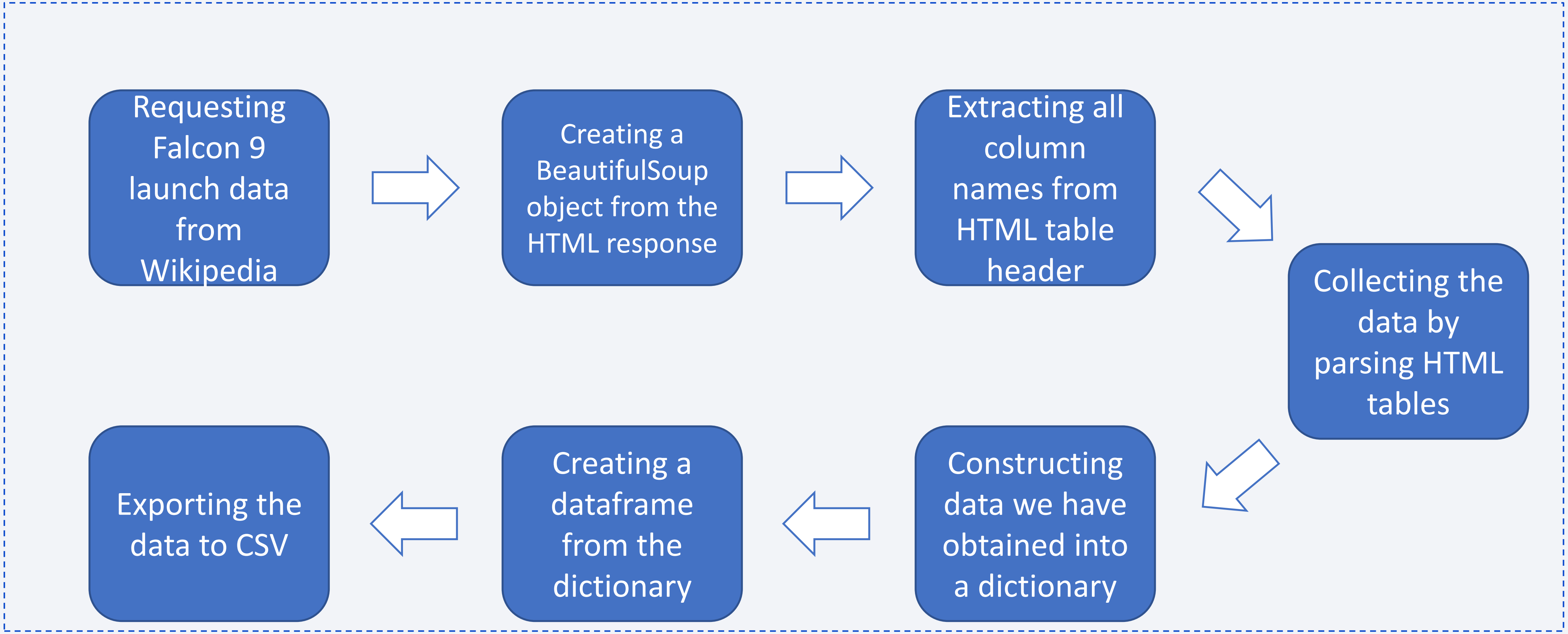
- Describe how data sets were collected.
  - Data Collection process involved a combination of API requests from SpaceX REST API and Web Scraping data from a table in SpaceX's Wikipedia entry.
  - We had to use both of these data collection method in order to get complete information about the launches for a more detailed analysis.
- Data Columns are obtained by using SpaceX REST API:
  - FlightNumber, Date, BoosterVersion, PayloadMass, Orbit, LaunchSite, Outcome, Flight, GridFins Reused, Legs, LandingPad, Block, ReusedCount, Serial, Longitude, Latitude.
- Data Columns Auto obtained by using Wikipedia Web Scraping:
  - Flight No., Launch site, Payload, PayloadMass, Orbit, Customer, Launch outcome, Version Booster, Booster Landing, Date, Time.

Data Collection – SpaceX API



- 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

Data Collection - Scraping



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

Data Wrangling

- Describe how data were processed
  - Initially some Exploratory Data Analysis was performed on the dataset
  - Then the summaries launches per site, occurrences of each orbit and occurrences of mission outcome per orbit type were calculated.
  - Finally, the landing outcome label was created from Outcome column.

- Add the GitHub URL of your completed data wrangling related notebooks, as an external reference and peer-review purpose

EDA with Data Visualization

- Summarize what charts were plotted and why you used those charts
  - Flight Number vs. Payload Mass, Flight Number vs. Launch Site, Payload Mass vs. Launch Site, Orbit Type vs. Success Rate, Flight Number vs. Orbit Type, Payload Mass vs. Orbit Type and Success Rate Yearly Trend.
  - Scatter plots show the relationship between variables. If a relationship exists, they could be used in machine learning model.
  - Bar charts show comparisons among discrete categories. The goal is to show the relationship between the specific categories being compared and a measured value.
  - Line charts show trends in data over time [time series].
- Add the GitHub URL of your completed EDA with data visualization notebook, as an external reference and peer-review purpose

EDA with SQL

- Using bullet point format, summarize the SQL queries you performed
    - Displaying name of the unique launch files in the space mission.
    - Displaying file records where launch sites begin with the string 'CCA'.
    - Displaying total payload mass carried by boosters launched by NASA (CRS).
    - Displaying average payload mass carried by booster version F9 v1.1.
    - Listing the day when the first successful landing outcome in ground pad was achieved.
    - Listing names of boosters which have success in drone ship & have payload mass > 4000 but < 6000.
    - Listing total number of successful and failure mission outcomes.
    - Listing names of booster versions which have carried maximum payload mass.
    - Listing failed landing outcomes in drone ship, their booster versions & launch site names for months in 2015.
    - Ranking the count of landing outcomes [such as Failure [drone ship] or Success [Ground pad]] between the date 2010-06-04 & 2017-03-20 in descending order.

- Add the GitHub URL of your completed EDA with SQL note in the space mission. book, as an external reference and peer-review purpose

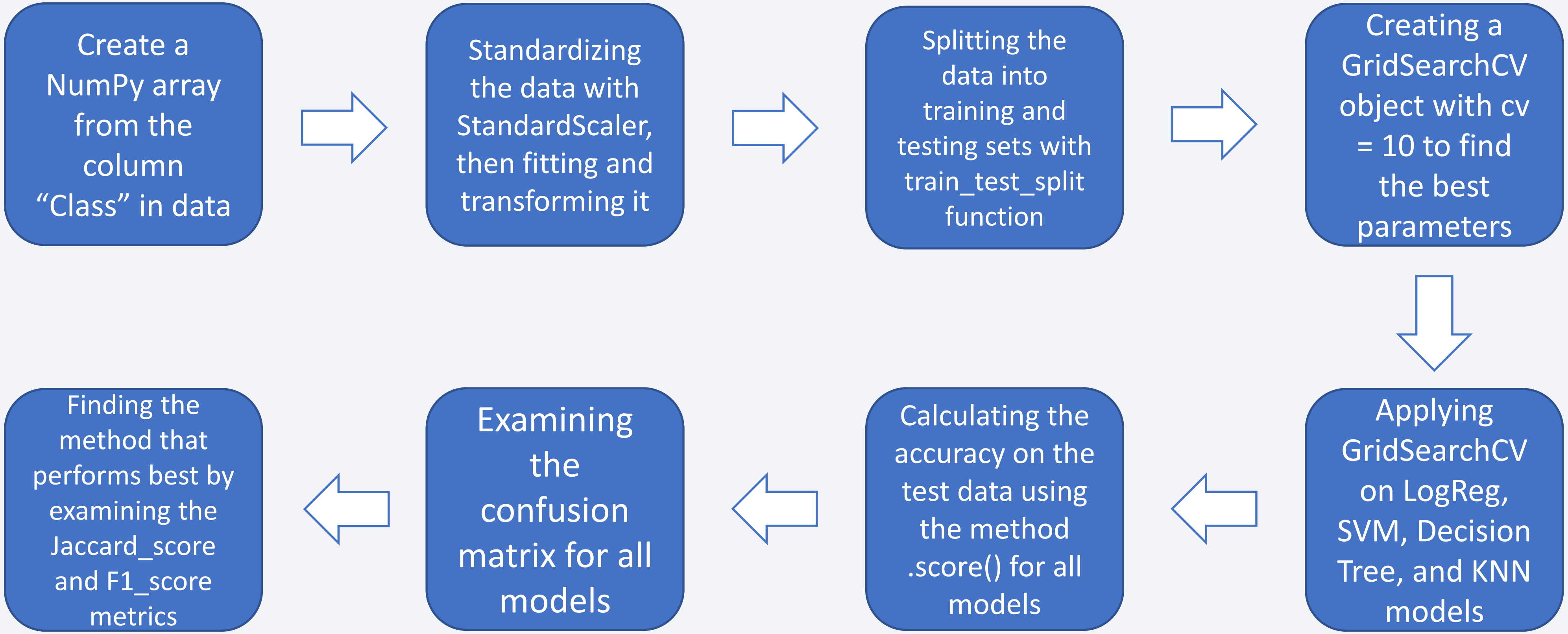
Build an Interactive Map with Folium

- Markers Indicating Launch Sites
  - Added Blue Circle at NASA Johnson Space Center's coordinate with a pop up label showing its name using its latitude and longitude coordinates.
  - Added Red Circles at all launch sites coordinates with a pop up label showing its name using its latitude and longitude coordinates.
- Colored Markers of Launch Outcomes
  - Added colored markers of successful [green] and unsuccessful [red] launches at each launch site to show which launch sites have high success rates.
- Distances between a Launch Site to Proximities
  - Added colored lines to show distance between launch site CCAFS SLC – 40 and its proximity to the nearest coastline, railway, highway, and city.
- Add the GitHub URL of your completed interactive map with Folium map, as an external reference and peer-review purpose

Build a Dashboard with Plotly Dash

- Launch Sites Dropdown List:
  - Added a dropdown list to enable Launch Site selection.
- Pie Chart showing Success launches (All Sites/Certain Site):
  - Added a pie chart to show the total successful launches count for all sites and the Success vs. Failed counts for the site, if a specific Launch Site was selected.
- Slider of Payload Mass Range:
  - Added a slider to select Payload range.
- Scatter Chart of Payload Mass vs. Success Rate for the different Booster Versions:
  - Added a scatter chart to show the correlation between Payload and Launch Success
- Add the GitHub URL of your completed Plotly Dash lab, as an external reference and peer-review purpose

Predictive Analysis (Classification)



- Add the GitHub URL of your completed predictive analysis lab, as an external reference and peer-review purpose

Results

- Exploratory data analysis results
  - Launch success has improved over time.
  - KSC LC-39A has the highest success rate among landing sites.
  - Orbits ES-L1, GEO, HEO and SSO have a 100% success rate.

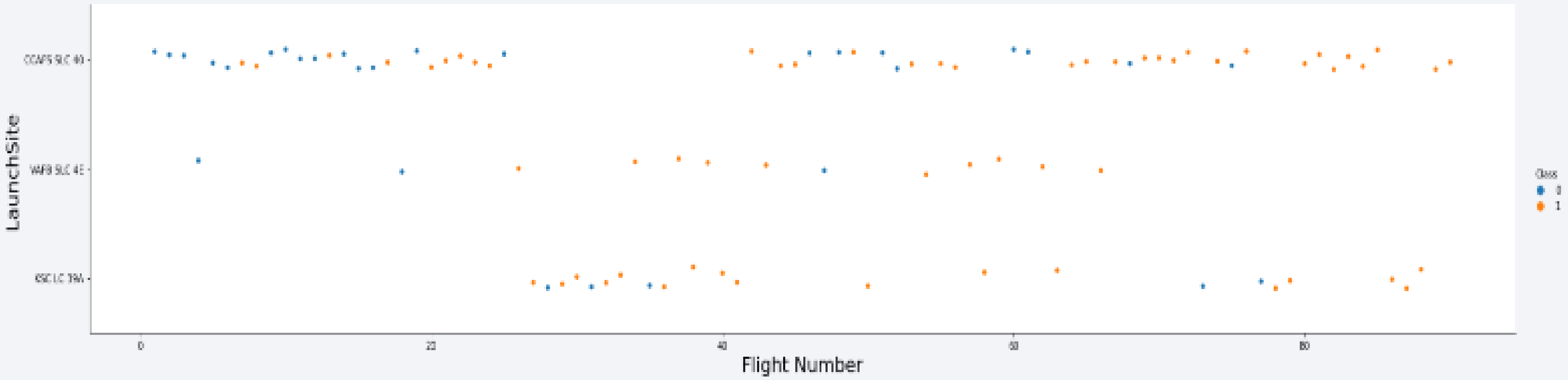
- Interactive analytics demo in screenshots

- Predictive analysis results
  - Decision Tree model is the best predictive model for the dataset.

Section 2

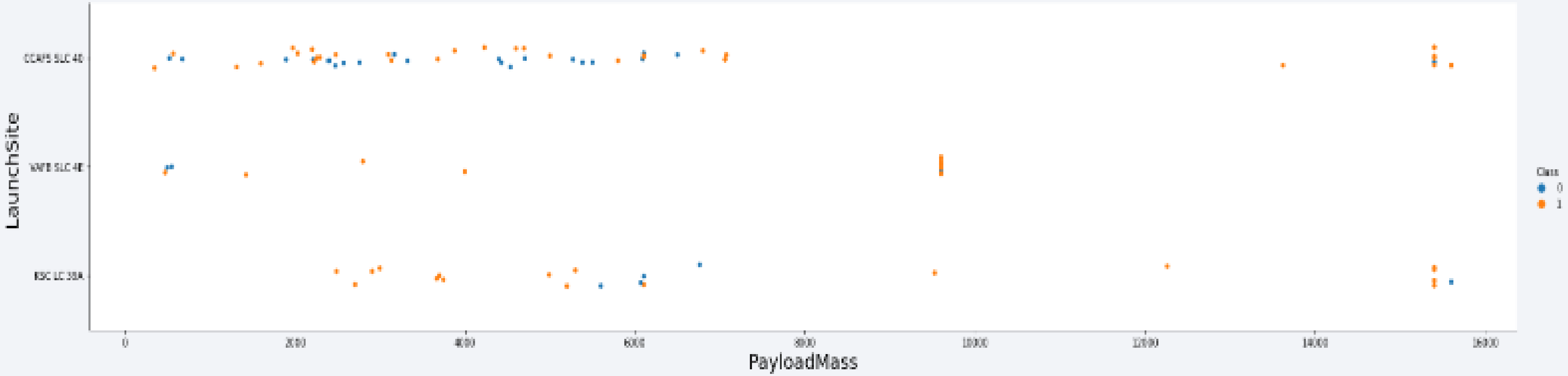
Insights drawn from EDA

Flight Number vs. Launch Site



- According to the plot above, it's possible to verify that the best launch site nowadays is CCAF5 SLC 40, where most of recent launches were successful;
- In second place VAFB SLC 4E and third place KSC LC 39A;
- It's also possible to see that the general success rate improved over time.

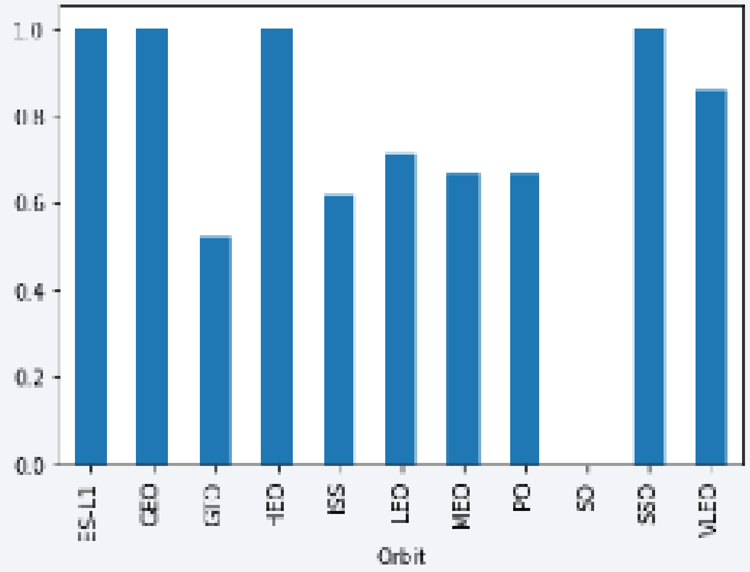
Payload vs. Launch Site



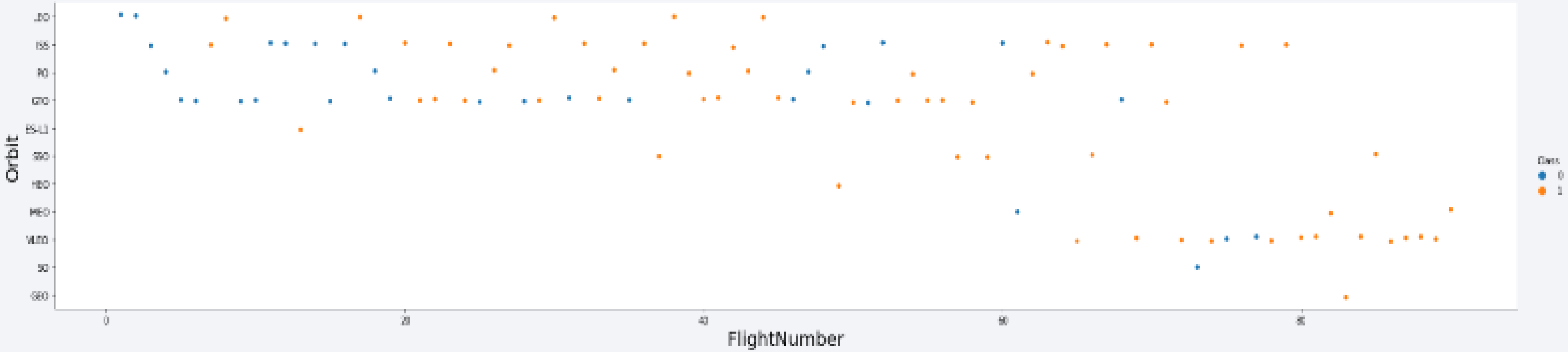
- Payloads over 9,000kg (about the weight of a school bus) have excellent success rate;
- Payloads over 12,000kg seems to be possible only on CCAFS SLC 40 and KSC LC 39A launch sites.

Success Rate vs. Orbit Type

- The biggest success rates happens to orbits:
  - ES-L1;
  - GEO;
  - HEO; and
  - SSO.
- Followed by:
  - VLEO (above 80%); and
  - LFO (above 70%).

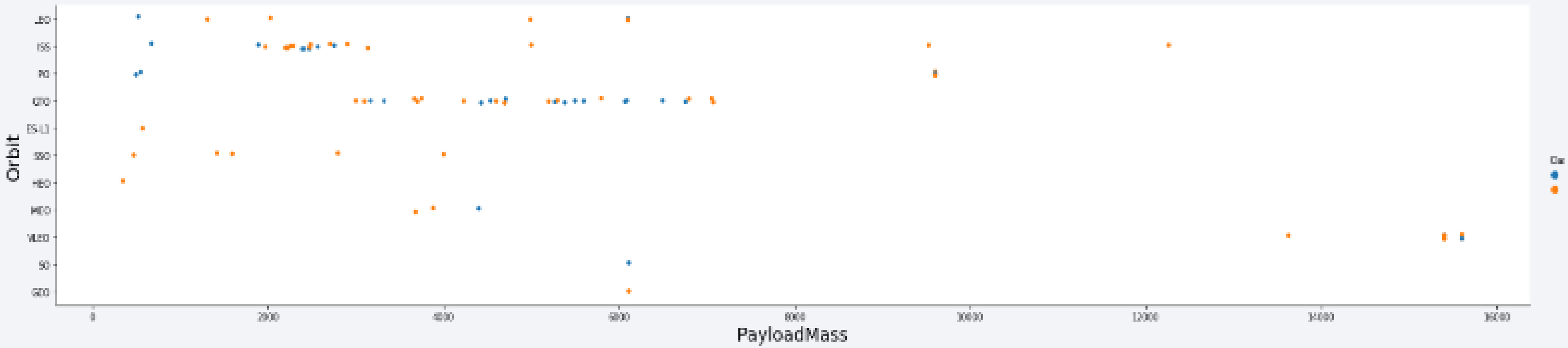


Flight Number vs. Orbit Type



- Apparently, success rate improved over time to all orbits;
- VLEO orbit seems a new business opportunity, due to recent increase of its frequency.

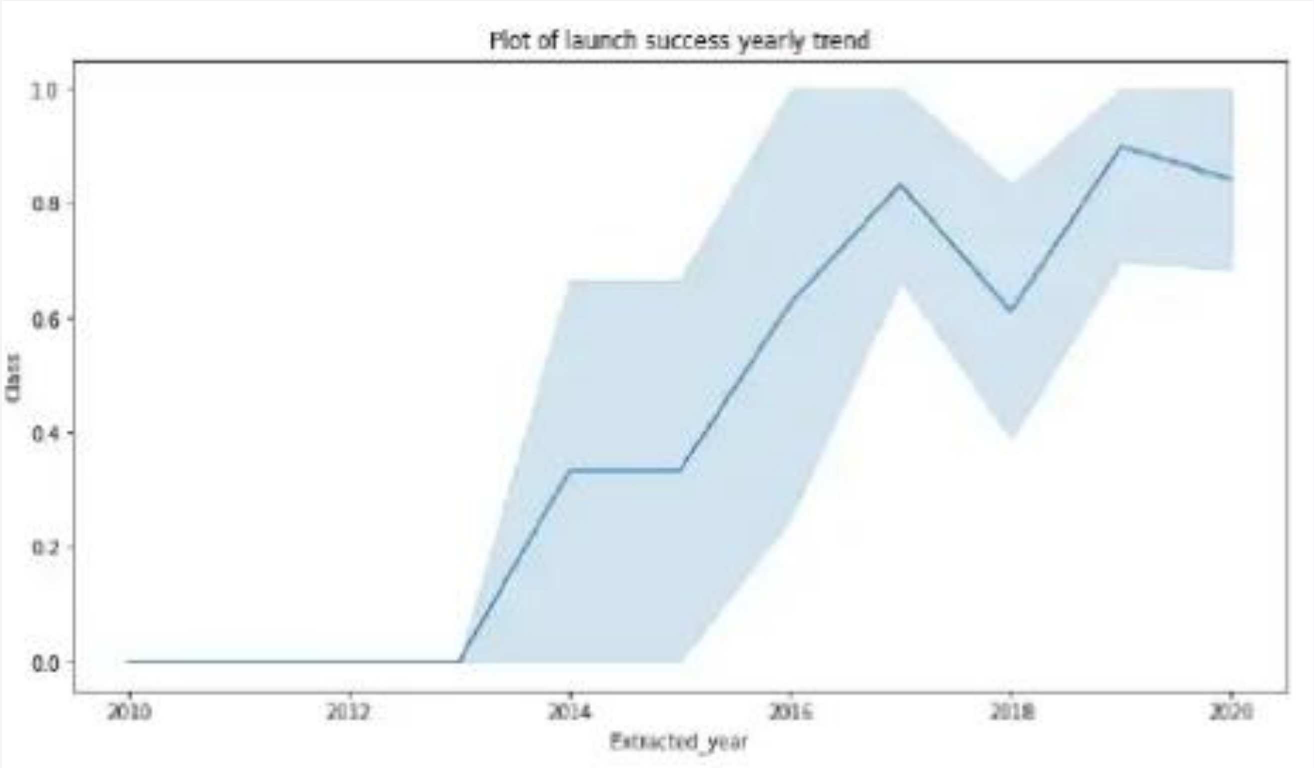
Payload vs. Orbit Type



- Apparently, there is no relation between payload and success rate to orbit GTO;
- ISS orbit has the widest range of payload and a good rate of success;
- There are few launches to the orbits SO and GEO.

Launch Success Yearly Trend

- Show a line chart of yearly average success rate
  - From this plot we can observe that success rate since 2013 kept on increasing till 2020.



All Launch Site Names

- Find the names of the unique launch sites
  - We used the key word DISTINCT to show only unique launch sites from the SpaceX data.

Display the names of the unique launch sites in the space mission

In [10]:

```
task_1 = '''
        SELECT DISTINCT LaunchSite
        FROM SpaceX
'''
create_pandas_df(task_1, database=conn)
```

Out[10]:

	launchsite
0	KSC LC-39A
1	CCAFS LC-40
2	CCAFS SLC-40
3	VAFB SLC-4E

Launch Site Names Begin with 'CCA'

Display 5 records where launch sites begin with the string 'CCA'

In [11]:

```
task_2 = '''
        SELECT *
        FROM SpaceX
        WHERE LaunchSite LIKE 'CCA%'
        LIMIT 5
        '''
create_pandas_df(task_2, database=conn)
```

Out[11]:

	date	time	boosterversion	launchsite	payload	payloadmasskg	orbit	customer	missionoutcome	landingoutcome
0	2010-04-06	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
1	2010-08-12	15:43:00	F9 v1.0 B0004	CCAFS LC-40	Dragon demo flight C1, two CubeSats, barrel of...	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2	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
3	2012-08-10	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
4	2013-01-03	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

- We used the above query to display 5 records where launch sites begin with 'CCA'.

Total Payload Mass

- We calculated the total payload carried by boosters from NASA as 45596 using the query below

Display the total payload mass carried by boosters launched by NASA (CRS)

In [12]:
```
task_3 = '''
        SELECT SUM(PayloadMassKG) AS Total_PayloadMass
        FROM SpaceX
        WHERE Customer LIKE 'NASA (CRS)'
        '''
create_pandas_df(task_3, database=conn)
```

Out[12]:

	total_payloadmass
0	45596

Average Payload Mass by F9 v1.1

- We calculated the average payload mass carried by booster version F9 v1.1

Display average payload mass carried by booster version F9 v1.1

In [13]:

```
task_4 = '''
        SELECT AVG(PayloadMassKG) AS Avg_PayloadMass
        FROM SpaceX
        WHERE BoosterVersion = 'F9 v1.1'
        '''
create_pandas_df(task_4, database=conn)
```

Out[13]:

	avg_payloadmass
0	2928.4

First Successful Ground Landing Date

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

In [14]:
```
task_5 = '''
        SELECT MIN(Date) AS FirstSuccessfull_landing_date
        FROM SpaceX
        WHERE LandingOutcome LIKE 'Success (ground pad)'
        '''
create_pandas_df(task_5, database=conn)
```

Out[14]:

	firstsuccessfull_landing_date
0	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

In [15]:
```
task_6 = '''
        SELECT BoosterVersion
        FROM SpaceX
        WHERE LandingOutcome = 'Success (drone ship)'
            AND PayloadMassKG > 4000
            AND PayloadMassKG < 6000
        '''
create_pandas_df(task_6, database=conn)
```

Out[15]:

	boosterversion
0	F9 FT B1022
1	F9 FT B1026
2	F9 FT B1021.2
3	F9 FT B1031.2

Total Number of Successful and Failure Mission Outcomes

- Calculate the total number of successful and failure mission outcomes

In [16]:
```
task_7a = '''
        SELECT COUNT(MissionOutcome) AS SuccessOutcome
        FROM SpaceX
        WHERE MissionOutcome LIKE 'Success%'
        '''

task_7b = '''
        SELECT COUNT(MissionOutcome) AS FailureOutcome
        FROM SpaceX
        WHERE MissionOutcome LIKE 'Failure%'
        '''
print('The total number of successful mission outcome is:')
display(create_pandas_df(task_7a, database=conn))
print()
print('The total number of failed mission outcome is:')
create_pandas_df(task_7b, database=conn)
```

The total number of successful mission outcome is:

	successoutcome
0	100

The total number of failed mission outcome is:

Out[16]:

	failureoutcome
0	1

Boosters Carried Maximum Payload

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

In [17]:
```
task_8 = '''
        SELECT BoosterVersion, PayloadMassKG
        FROM SpaceX
        WHERE PayloadMassKG = (
                                SELECT MAX(PayloadMassKG)
                                FROM SpaceX
                                )
        ORDER BY BoosterVersion
        '''
create_pandas_df(task_8, database=conn)
```

Out[17]:

	boosterversion	payloadmasskg
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
5	F9 B5 B1051.3	15600
6	F9 B5 B1051.4	15600
7	F9 B5 B1051.6	15600
8	F9 B5 B1056.4	15600
9	F9 B5 B1058.3	15600
10	F9 B5 B1060.2	15600
11	F9 B5 B1060.3	15600

2015 Launch Records

- List the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015
- We used a combinations of the **WHERE** clause, **LIKE**, **AND**, and **BETWEEN** conditions to filter for failed landing outcomes in drone ship, their booster versions, and launch site names for year 2015

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

In [18]:

```
task_9 = '''
        SELECT BoosterVersion, LaunchSite, LandingOutcome
        FROM SpaceX
        WHERE LandingOutcome LIKE 'Failure (drone ship)'
            AND Date BETWEEN '2015-01-01' AND '2015-12-31'
        '''
create_pandas_df(task_9, database=conn)
```

Out[18]:

	boosterversion	launchsite	landingoutcome
0	F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)
1	F9 v1.1 B1015	CCAFS LC-40	Failure (drone ship)

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

In [19]:
```
task_10 = '''
        SELECT LandingOutcome, COUNT(LandingOutcome)
        FROM SpaceX
        WHERE DATE BETWEEN '2010-06-04' AND '2017-03-20'
        GROUP BY LandingOutcome
        ORDER BY COUNT(LandingOutcome) DESC
        '''
create_pandas_df(task_10, database=conn)
```

Out[19]:

	landingoutcome	count
0	No attempt	10
1	Success (drone ship)	6
2	Failure (drone ship)	5
3	Success (ground pad)	5
4	Controlled (ocean)	3
5	Uncontrolled (ocean)	2
6	Precluded (drone ship)	1
7	Failure (parachute)	1

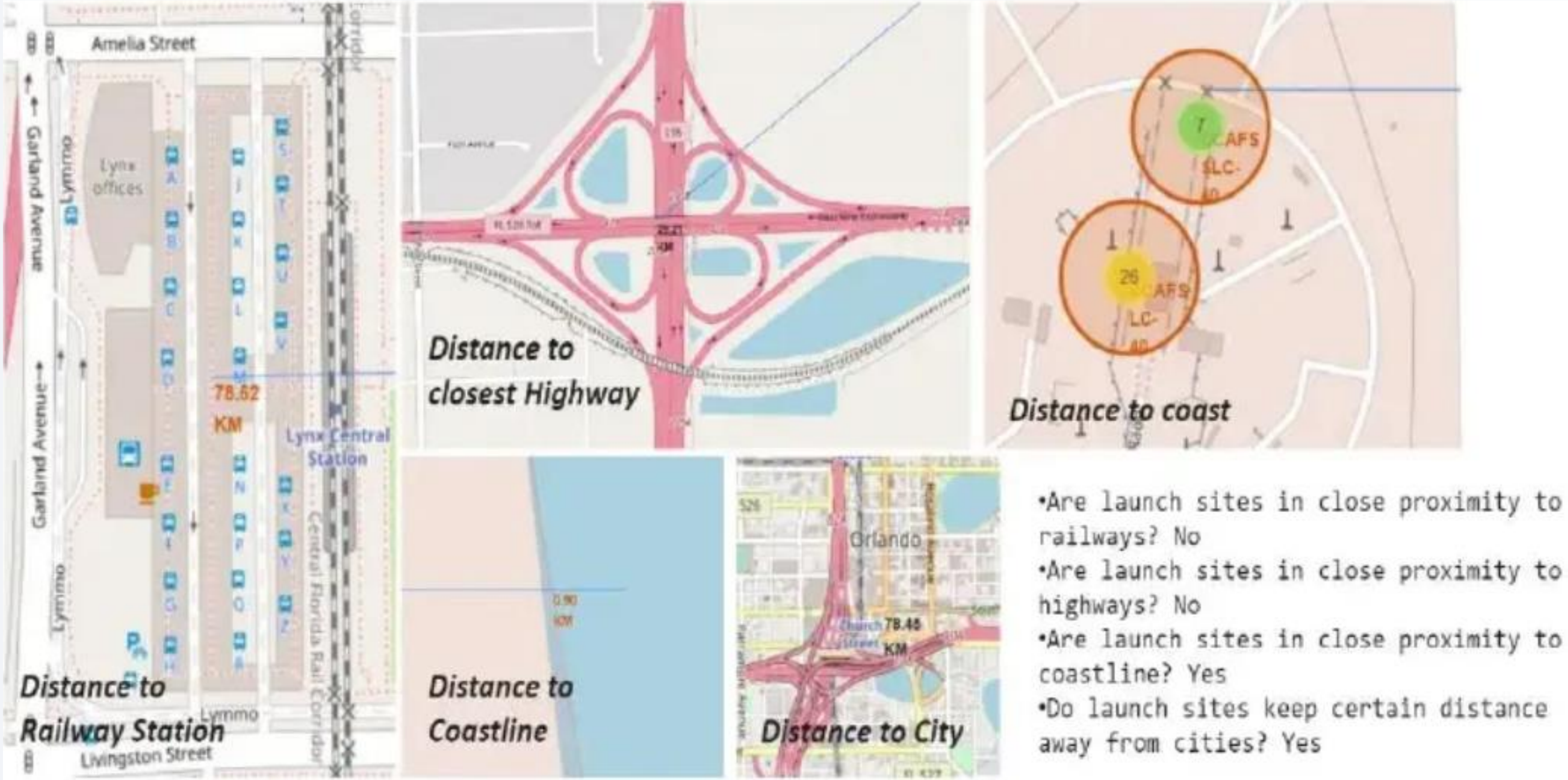
Section 3

Launch Sites Proximities Analysis

All Launch Sites global map markets

Markers showing Launch Sites with color labels

Launch Site distances to Landmarks

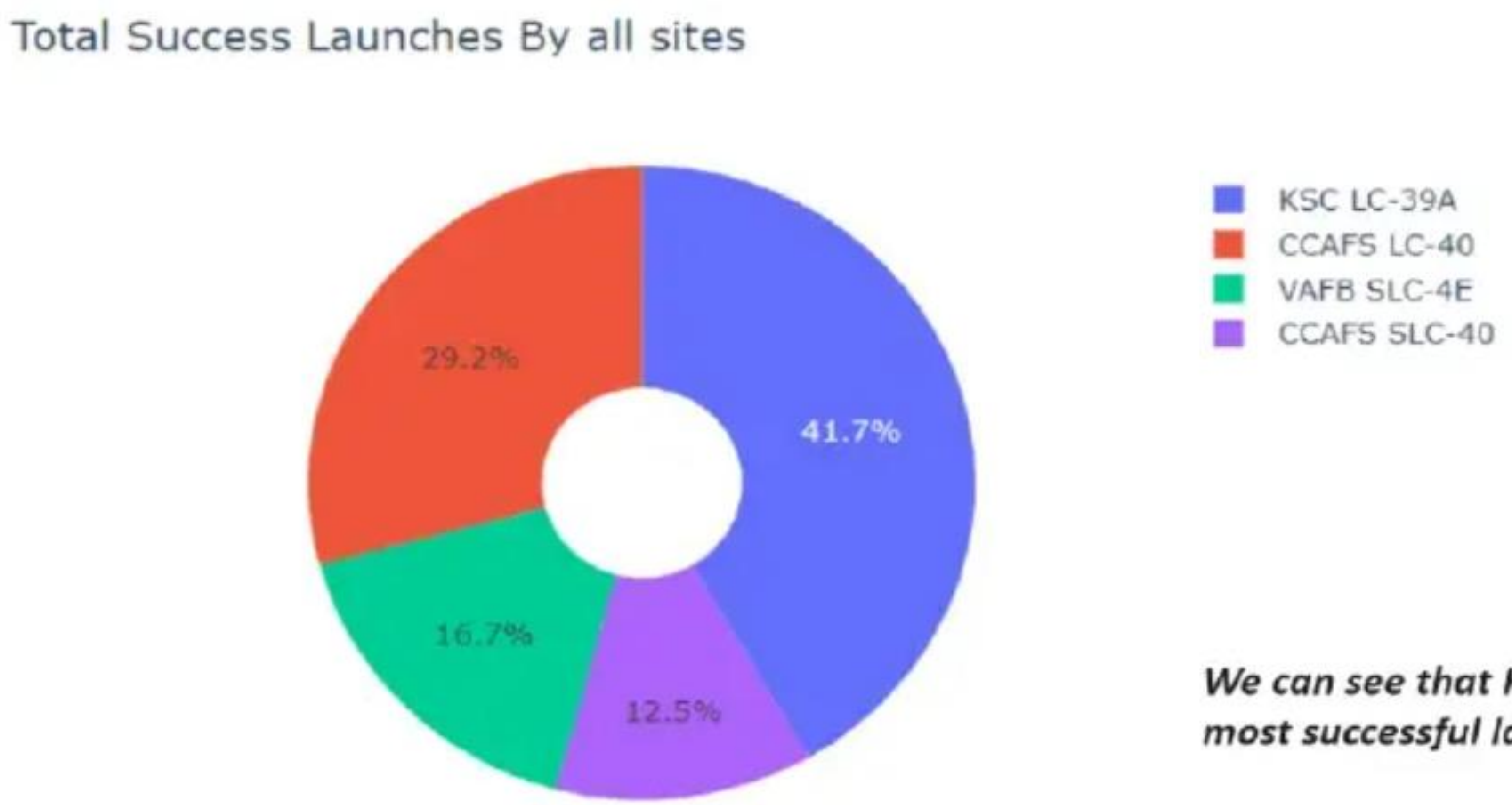


- Are launch sites in close proximity to railways? No
- Are launch sites in close proximity to highways? No
- Are launch sites in close proximity to coastline? Yes
- Do launch sites keep certain distance away from cities? Yes

Section 4

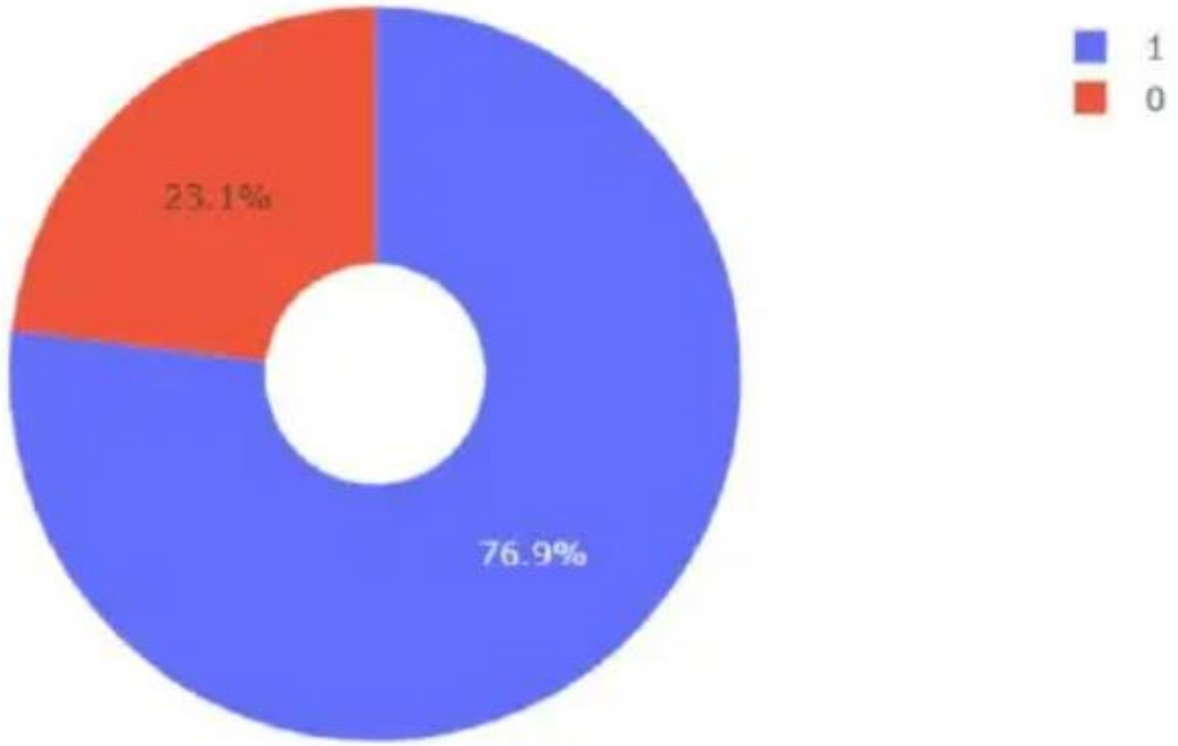
Build a Dashboard with Plotly Dash

Pie Chart showing success rate achieved by each Launch Site



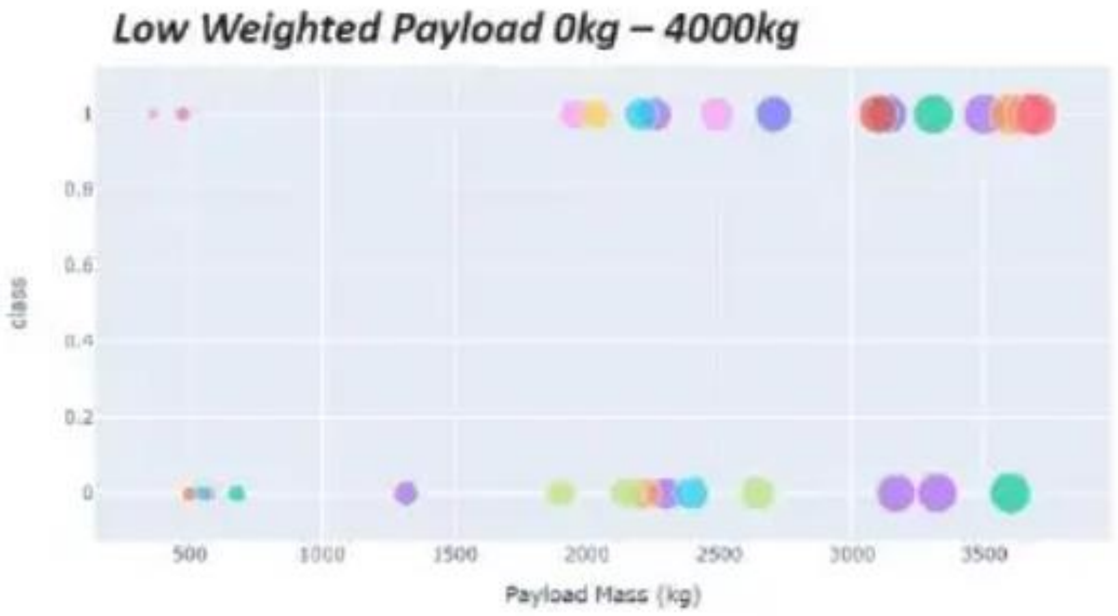
We can see that KSC LC-39A had the most successful launches from all the sites

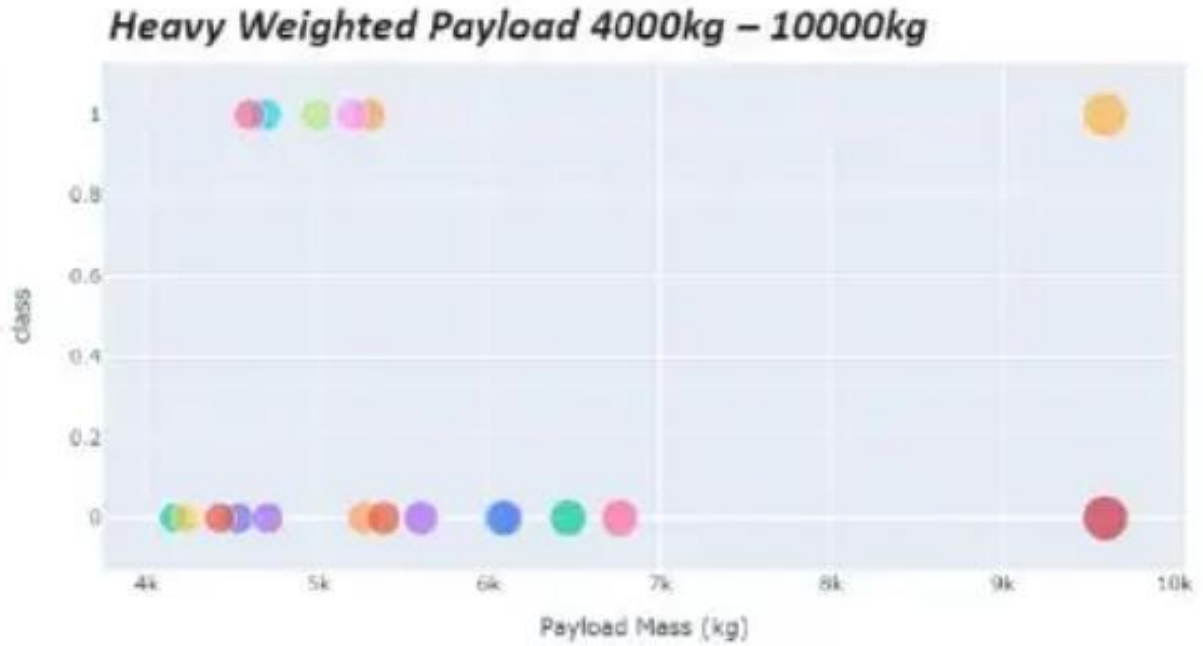
Pie Chart showing the Launch Site with the highest launch success ratio



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

Scatter Plot of PayLoad vs Launch Outcome for all sites with different payload selected by range slider





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

Section 5

Predictive Analysis (Classification)

Classification Accuracy

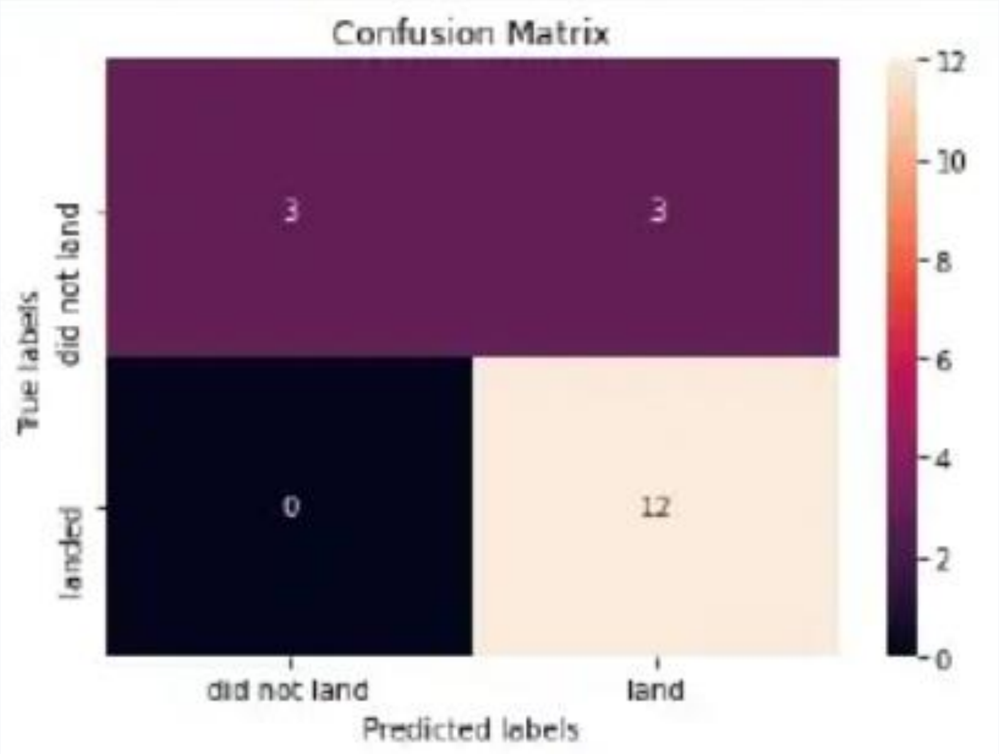
```
models = {'KNeighbors':knn_cv.best_score_,
              'DecisionTree':tree_cv.best_score_,
              'LogisticRegression':logreg_cv.best_score_,
              'SupportVector': svm_cv.best_score_}

bestalgorithm = max(models, key=models.get)
print('Best model is', bestalgorithm,'with a score of', models[bestalgorithm])
if bestalgorithm == 'DecisionTree':
    print('Best params is :', tree_cv.best_params_)
if bestalgorithm == 'KNeighbors':
    print('Best params is :', knn_cv.best_params_)
if bestalgorithm == 'LogisticRegression':
    print('Best params is :', logreg_cv.best_params_)
if bestalgorithm == 'SupportVector':
    print('Best params is :', svm_cv.best_params_)
```

```
Best model is DecisionTree with a score of 0.8732142857142856
Best params is : {'criterion': 'gini', 'max_depth': 6, 'max_features': 'auto', 'min_samples_leaf': 2, 'min_samples_split': 5, 'splitter': 'random'}
```

- The DecisionTree classifier is the model with the highest classification accuracy

Confusion Matrix

- The confusion matrix of the best performing model with an explanation
  - The confusion matrix for the DecisionTree classifier shows that the classifier can distinguish between the different classes. The major problem is the false positives .i.e., unsuccessful landing marked as successful as the classifier.



Conclusions

We can conclude that

- The larger the flight amount at a launch site, he greater the success rate at a lunch sie.
- Launch success rate started to increase in 2013 till 2020.
- Orbits ES-L1, GEO, HEO, SSO, VLEO had the most success rate.
- KSC LC-39A had the most successful launches of any sites.
- The DecisionTree classifier is the best machine learning algorithm for the task

Thank you!