IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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Executive Summary

- Today, SpaceX is considered on of the best companies over the world in terms of space rockets launches, due to the rocket science advancements that achieved in making space missions more affordable and practical, generally space rockets companies offer a rocket launch with a cost of 165 million dollars, whereas SpaceX offers by the same service for only 62 million dollars which considered a huge savings led organizations such NASA to sign contracts with SpaceX.

- In this report, I am taking the role of a data scientist working for a new rocket company, called SpaceY that would like to compete with SpaceX founded by Billionaire industrialist Allon Musk. my job is to use data science instead of rocket science to discover the possibility of competing with SpaceX. I am doing this by gathering information about SpaceX, performing data analytics, modeling ML algorithms and creating dashboards for my team.

Introduction

- Since 1957, the countries around the world are competing to expand beyond Earth, whether through satellites launches or space exploration, these missions require huge amounts of money where a launch of one space rocket costs in average 165 million dollars, a company like Space X changes the equation by reducing this amount of money massively to only 60 million dollars due to its unique and advanced technologies in returning the first stage of rocket structure.

- As mentioned above one of the key factor of SpaceX's success in the space race is the first stage of rockets return through a safe landing, from this point we will discover together what are the main attributes or variables that control these successful landings, through asking questions about the nature of the launch process , the payload mass of rocket, launch location, rocket orbit, and more by analyzing and visualizing these information through the data science methodology provided by IBM.

Section 1

Methodology

Methodology

1- Data collection Methodology:

The data was collected using SpaceX rest API in addition of using data web scraping on Wikipedia webpages.

2- Perform data wrangling:

The data was preprocessed using Panadas and NumPy, some of main technique are used: OneHot encoding, unnecessary columns removal, data normalization and standardization.

3- Perform exploratory data analysis (EDA)

Using libraries such as seaborn and matplotlib for visualization and SQL for data quires.

4- Perform interactive visual analytics

Using the following libraries Folium and Plotly Dash

5- Perform predictive analysis using classification models

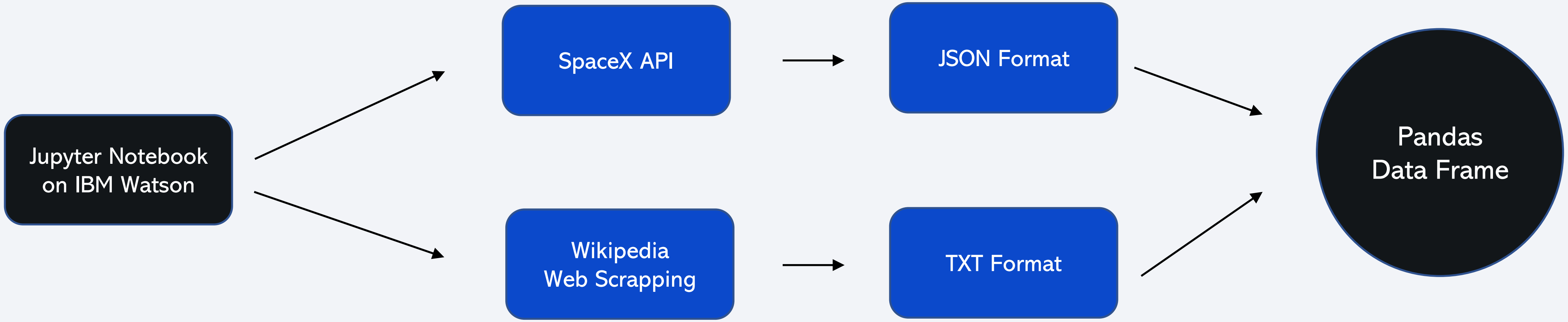
- Starting with splitting the data into train and test sets
- Identifying the best algorithm and parameters through hyperparameters tuning using Grid Search
- Adopting the best algorithm and parameters for the purpose of model deployment.

Data Collection

<u>We have collected the data from two main sources:</u>

- SpaceX API: Open Source REST API for launch, rocket, core, capsule, starlink, launchpad, and landing pad data.
- Wikipedia: is a free online encyclopedia, created and edited by volunteers around the world and hosted by the Wikimedia Foundation

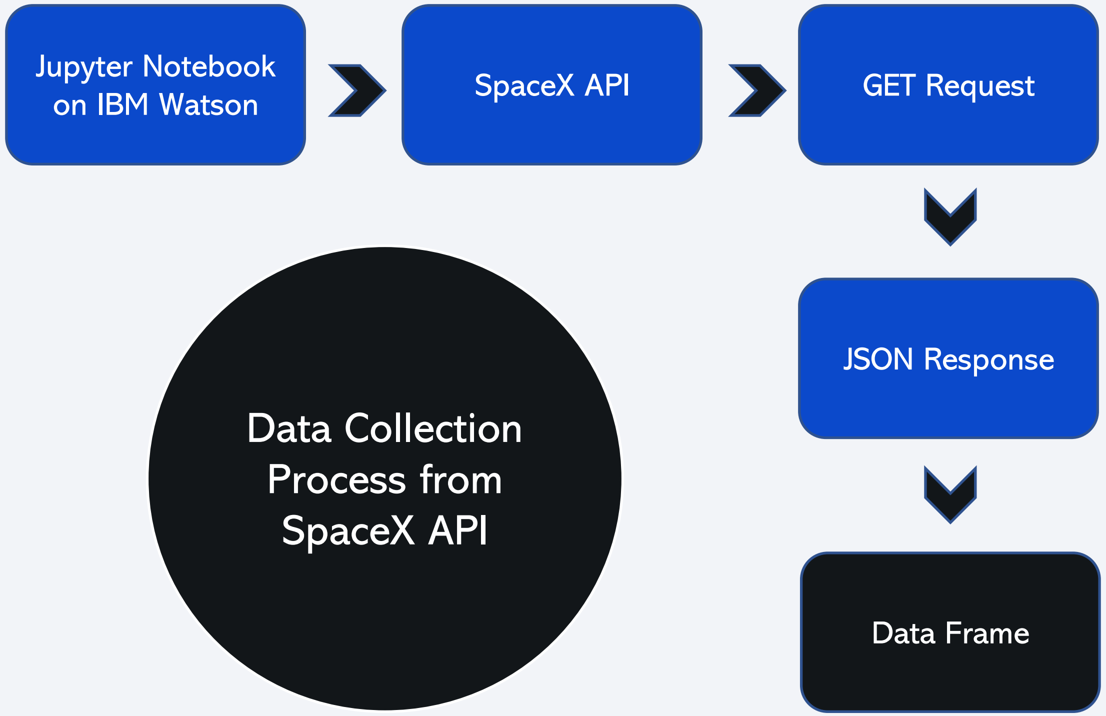
<u>The Process of data collection:</u>



Data Collection – SpaceX API

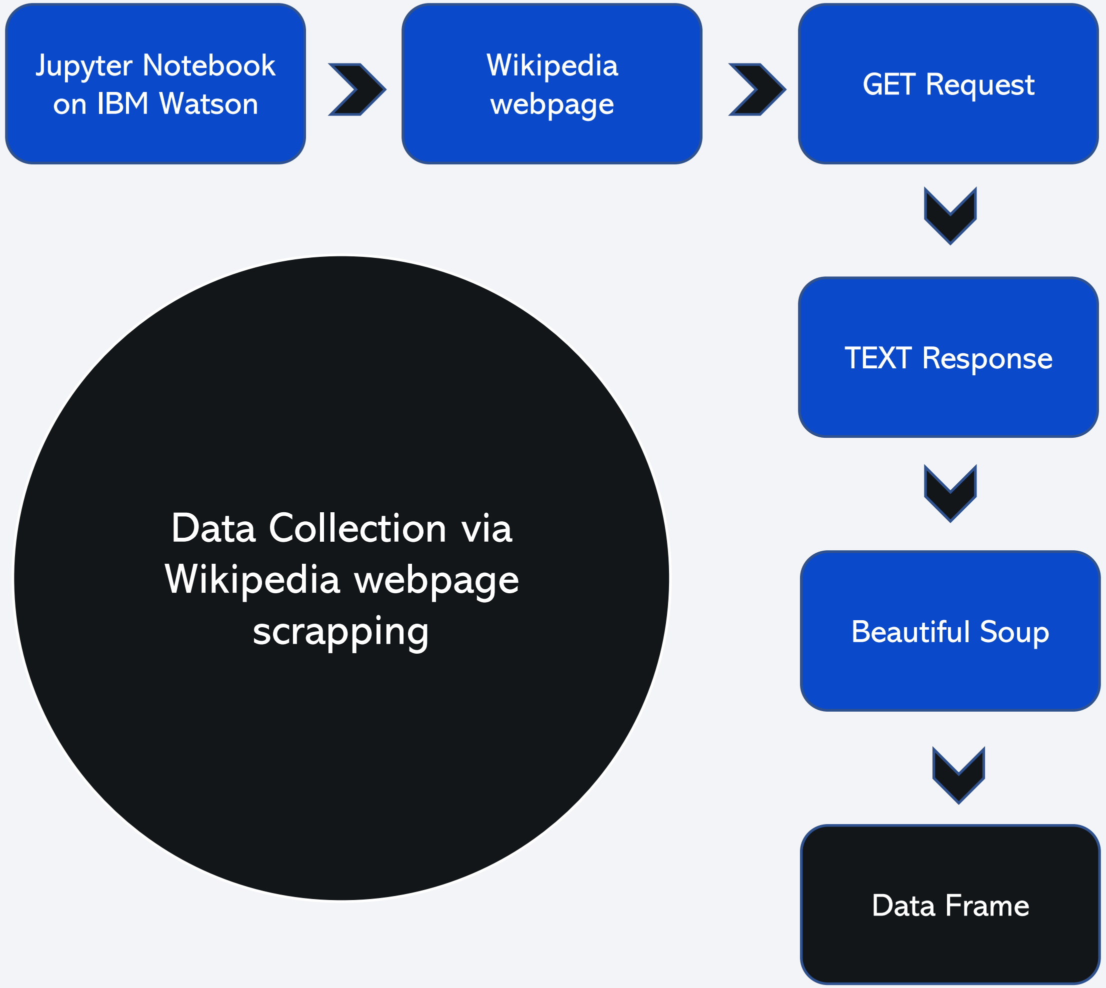
- We started the data collection from SpcaeX API by importing the required libraries such as pandas, NumPy and Request, then we established a URL GET request, this request is raised as JSON file to be finally converted to a data frame through choosing the required information like the geospatial info, rocket type, orbit, flight number and more.

- GitHub URL of the completed SpaceX API calls notebook [Click Here]



Data Collection - Scraping

- As we have done before we start by importing the required Python libraries beautiful soup and request to perform our task, and this time, we have used a webpage on Wikipedia called “Space X Falcon 9 First Stage Landing Prediction” as a data source, then we initialized an HTTP Get Request and the response was as a text format, then we used the beautiful soup library to extract the tables and columns effectively from the text response to be converted later to a pandas' data frame.
- GitHub URL of the completed web scrapping task notebook [Click Here]



Data Wrangling

- In this stage we started by importing pandas and NumPy, loading our collected data in the previous stage to perform our exploratory data analysis which aimed to clean the data and choose the valid features for training a machine learning model.

- GitHub URL of the completed Data wrangling notebook [Click Here]

Data Wrangling stages

1- Loading the collected dataset.

2- Identifying and calculating the percentage of the missing values in each attribute

3- Identifying which columns are numerical and categorical:

4- Calculating the number of launches on each site

5- Calculating the number and occurrence of each orbit

6- Creating a landing outcome label from Outcome column

7- determining the success rate of returning the first stage of the rocket

EDA with Data Visualization

- In this stage we completed our EDA process through finding the correlation between the features and the target using different visualization tools via seaborn and matplotlib furthermore we have performed feature engineering by converting categorical features into dummy values.

- GitHub URL of the completed EDA with data visualization notebook, [Click Here]

EDA with Data Visualization Stages

- Visualize the relationship between Flight Number and Launch Site
- Visualize the relationship between success rate of each orbit type
- Visualize the relationship between Payload and Launch Site
- Visualize the relationship between Flight Number and Orbit type
- Visualize the relationship between Payload and Orbit type
- Visualize the launch success yearly trend

EDA with SQL

- In this stage we used SQL quires as shown on the right to complete our EDA on our collected dataset

- GitHub URL of the completed EDA with SQL notebook, [Click Here]

SQL Quires

• 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).

• 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 the 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.

Build an Interactive Map with Folium

- In this stage we used folium library to represent our work as geospatial data by drawing markers circles and lines on an interactive map.

- GitHub URL of the completed interactive map with Folium map notebook, Click Here

Building an Interactive Map with Folium

- We started our interactive map by drawing 4 circles on 4 different sites belongs to Falcon 9 rockets lunches have the following information:

Launch Site	Lat	Long
CCAFS LC-40	28.562302	-80.577356
CCAFS SLC-40	28.563197	-80.576820
KSC LC-39A	28.573255	-80.646895
VAFB SLC-4E	34.632834	-120.610746

- We put markers to on the same sites to represent the successful/failed first stage of rockets return using marker objects :

- Finally, we calculated the distances between the launch site (CCAFS LC-40) to its proximities 1-the closest city, 2-coastline, and 3-highway. Then we drew polylines to represent these distances using PolyLine object.

Build a Dashboard with Plotly Dash

Building an Interactive Dashboard with Plotly Dash

1- We added a dropdown list to enable Launch Site selection including the following options:

All Sites, CCAFS LC-40, CCAFS SLC-40, VAFB SLC-4E, KSC LC-39A

2- we added a pie chart to show the total successful launches count for all sites

3- we added a slider to select payload which ranges from 0 -10000

4- finally we added a scatter chart to show the correlation between payload and launch success

GitHub URL of the completed Building an Interactive Dashboard with Plotly Dash notebook, Click Here

Predictive Analysis (Classification)

Machine Learning Stages:

1- Importing the required libraries.

2- Loading the cleaned data.

3- Standardizing the data to prevent the bias.

4- splitting the data into 20% for testing data and 80% training data.

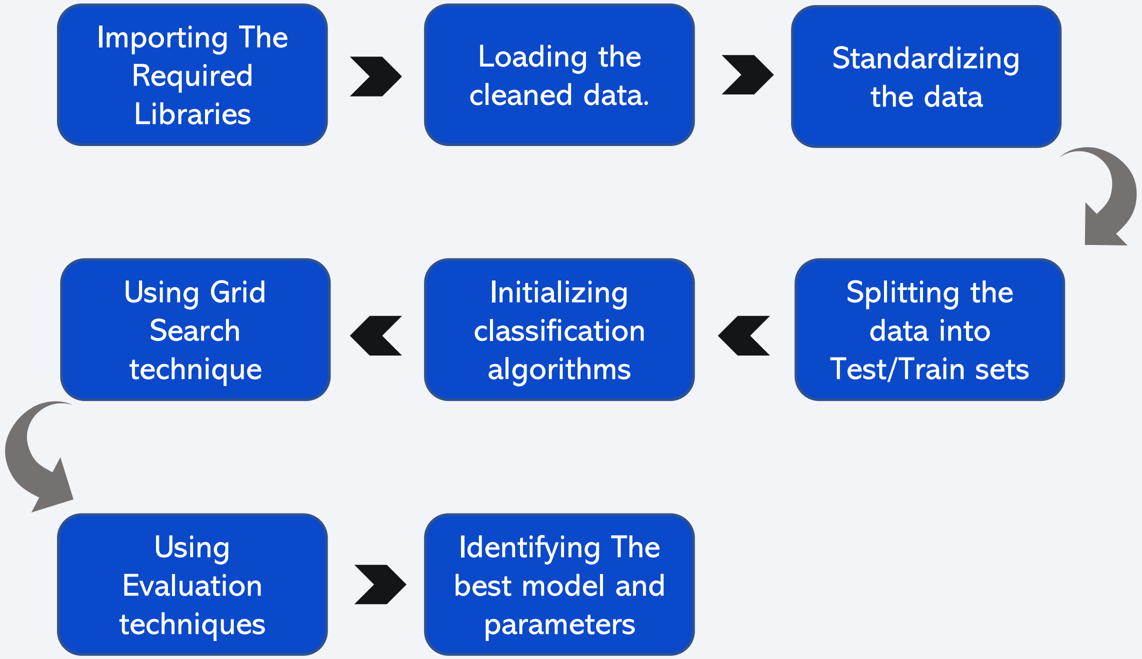
5- Initializing 4 different classification algorithms:

- Logistic Regression (LR)
- Support Vector Machine (SVM)
- Decision Tree (DT)
- K nearest neighbors (KNN)

6- Using Grid Search technique to find the best parameters

7- Using Evaluation techniques including, Confusion matrix , F1 score, Jaccard Score for the purpose of using the best model among the algorithms above.

Machine Learning Pipelines



Results

Exploratory data analysis results

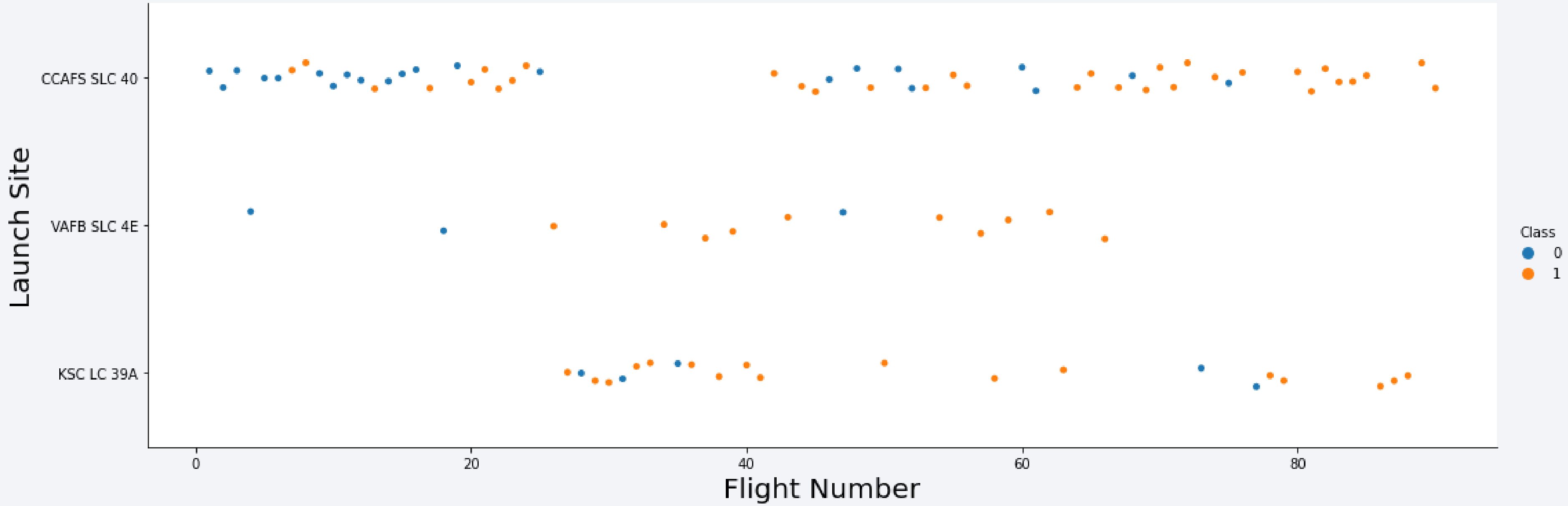
Interactive analytics demo in screenshots

Predictive analysis results

Section 2

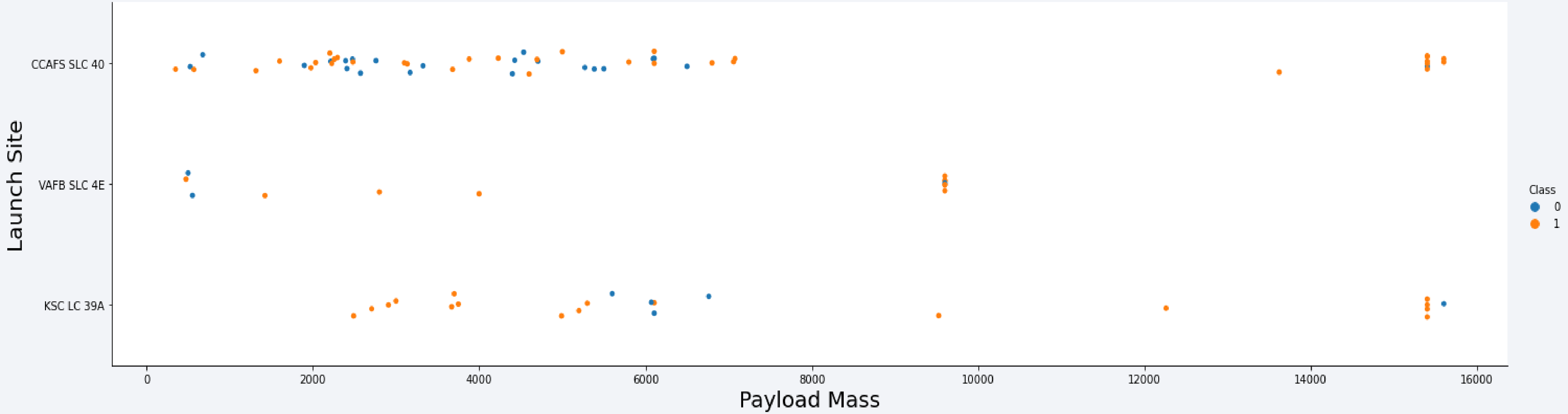
Insights drawn from EDA

Flight Number vs. Launch Site



1- CCAFS SLC 40 : is the most usable site for launching SpaceX's rockets and it has 55 trials, 33 of them are successful and 22 of them are failed # 60% success rate
2- VAFB SLC 4E : is the least usable site for launching SpaceX's rockets and it has 13 trials, 10 of them are successful and 03 of them are failed # 77% success rate
3- VAFB SLC 4E : is a moderate site in terms of launching SpaceX's rockets and it has 22 trials, 17 of them are successful and 05 of them are failed # 77% success rate

Payload vs. Launch Site



According to the plot above:
there is no strong relationship between the payload mass and the success of first stage return since there are approximately equivalent numbers of failed and successful trials.

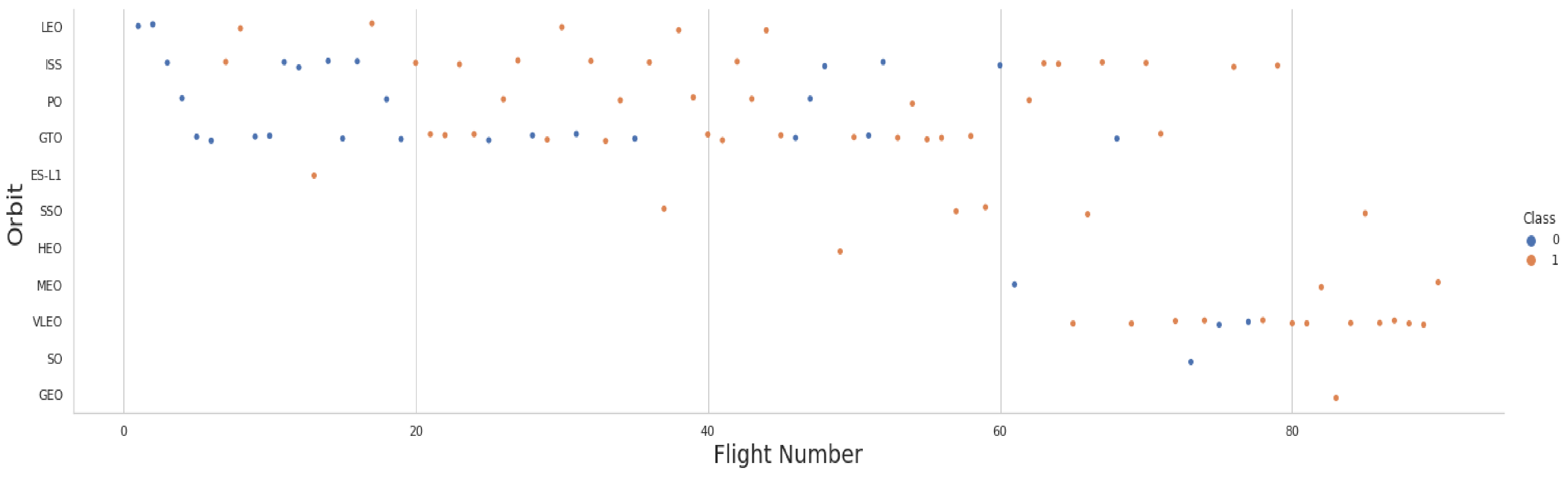
Success Rate vs. Orbit Type

According to the bar plot :

The best orbits in terms of successful first stage returns are ['ES-L1', 'GEO', HEO, SSO]

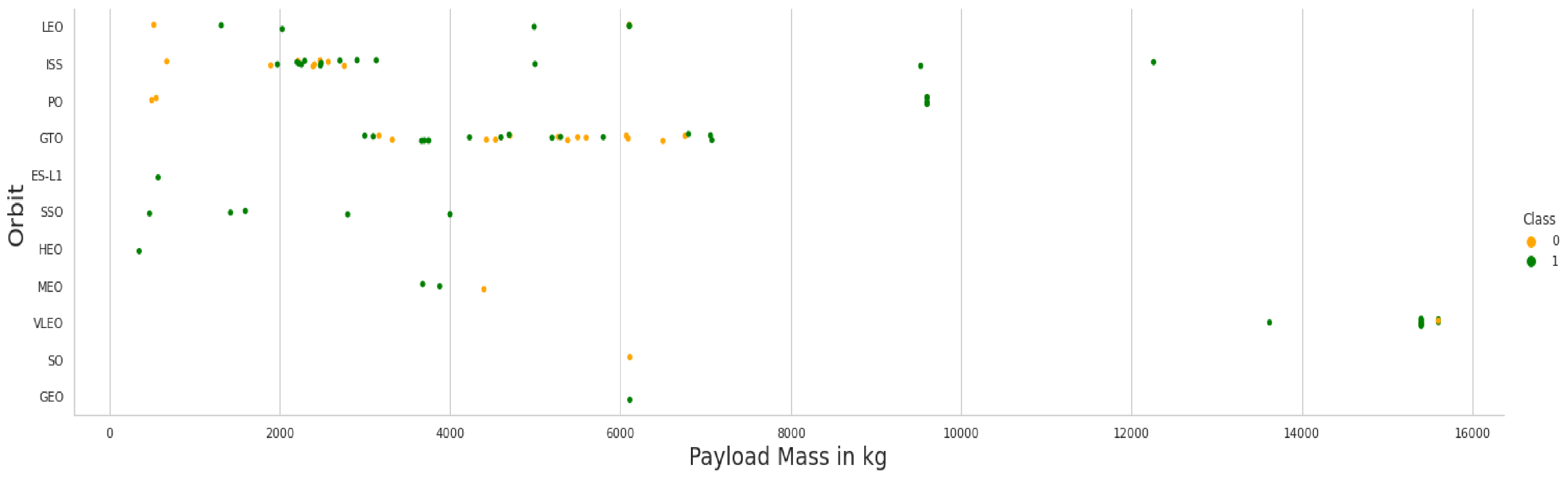
Where the worst orbit is 'GTO’ , therefore we need to understand why it is the worst to avoid the failure of first stage return.

Flight Number vs. Orbit Type



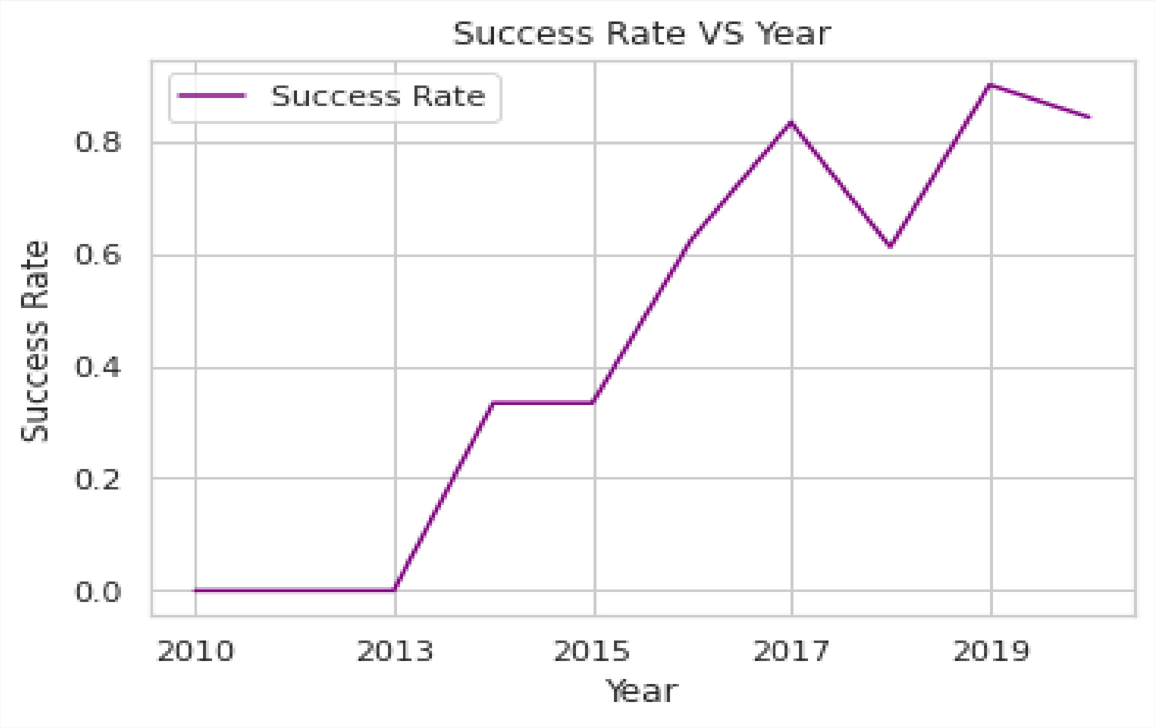
We can see that in the LEO orbit the Success appears related to the number of flights; on the other hand, there seems to be no relationship between flight number when in GTO orbit.

Payload vs. Orbit Type



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

Launch Success Yearly Trend



We can observe that the success rate since 2013 kept increasing till 2020

All Launch Site Names

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

```
%sql select distinct launch_site from SPACEXTBL
```

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

As shown above we have 4 distinct sites for rockets launches listed in the Table above.

Launch Site Names Begin with 'CCA'

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

```
%sql select * from SPACEXTBL where launch_site like 'CCA%' limit 5;
```

DATE	time__utc_	booster_version	launch_site	payload	payload_mass__kg_	orbit	customer	mission_outcome	landing__outcom
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

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

```
%sql select sum(payload_mass__kg_) from SPACEXTBL where customer = 'NASA (CRS)';
```

1
45596

The total amount of payload that moved to the outer space by NASA through SpaceX rockets equals to 45596 Kg which is equal to 50.261 Us ton.

Average Payload Mass by F9 v1.1

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

```
%sql select avg(payload_mass__kg_) as avg_mass_F9 from SPACEXTBL where booster_version = 'F9 v1.1'
```

avg_mass_f9
2928

The average payload mass carried by booster version F9 v1.1 is 2928 kg

First Successful Ground Landing Date

List the date when the first successful landing outcome in ground pad was acheived.

Hint:Use min function

```
%sql select min(DATE) from SPACEXTBL where landing__outcome = 'Success (ground pad)'
```

1
2015-12-22

Date of the first successful landing outcome on ground pad was in 22-12-2015

Successful Drone Ship Landing with Payload between 4000 and 6000

List the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000

```
%sql select booster_version from SPACEXTBL\
where (landing__outcome = 'Success (drone ship)' and (payload_mass__kg_ > 4000 and  payload_mass__kg_ > 6000));
```

booster_version
F9 FT B1029.1
F9 FT B1036.1
F9 B4 B1041.1

The boosters which have success in drone ship landing with payload between 4000 and 6000 kg are :

- F9 FT B1029.1
- F9 FT B1036.1
- F9 B4 B1041.1

Total Number of Successful and Failure Mission Outcomes

List the total number of successful and failure mission outcomes

```
%sql select mission_outcome, count(mission_outcome) as counts from SPACEXTBL GROUP BY mission_outcome
```

mission_outcome	counts
Failure (in flight)	1
Success	99
Success (payload status unclear)	1

We can see clearly that the success rate of mission outcomes is the most dominant we have only 1 failed mission while we have 99 successful ones.

Boosters Carried Maximum Payload

List the names of the booster_versions which have carried the maximum payload mass. Use a subquery

```
%sql select distinct booster_version from SPACEXTBL\
where payload_mass__kg_ in (select max(payload_mass__kg_) from SPACEXTBL);
```

booster_version
F9 B5 B1048.4
F9 B5 B1048.5
F9 B5 B1049.4
F9 B5 B1049.5
F9 B5 B1049.7
F9 B5 B1051.3
F9 B5 B1051.4
F9 B5 B1051.6
F9 B5 B1056.4
F9 B5 B1058.3
F9 B5 B1060.2
F9 B5 B1060.3

The booster versions that carry the maximum payload starts with F9 B5 and ranges from B1048 up to B1060

2015 Launch Records

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

```
%sql select landing__outcome, booster_version, launch_site from SPACEXTBL\
where (landing__outcome = 'Failure (drone ship)' and date like '2015%')
```

landing__outcome	booster_version	launch_site
Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40

We have two failed landing in 2015 on a drone ship which both in the same site, CCAFS LC-40 and with same booster version F9 v1.1

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

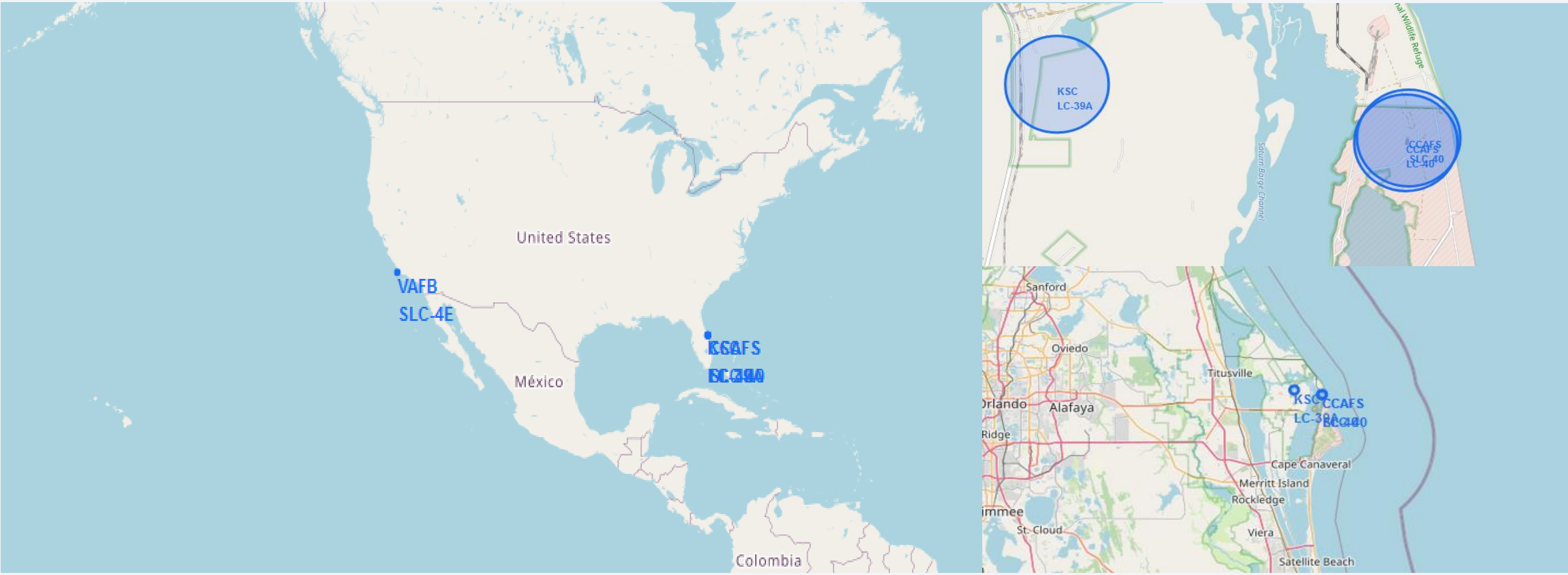
```
%sql select landing__outcome, count(*) as counts_of_landing_outcomes from SPACEXTBL\
where DATE between '2010-06-04' and  '2017-03-20' group by landing__outcome\
order by count(landing__outcome) desc
```

landing__outcome	counts_of_landing_outcomes
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 4

Launch Sites Proximities Analysis

Folium Map: Launch Sites.



All site locations are near the coast and Equator line, SpaceX focuses on locations that are close to water and the zeroth latitude for the purpose of avoiding any undesired accidents.
The launch sites are distributed in two states California and Florida

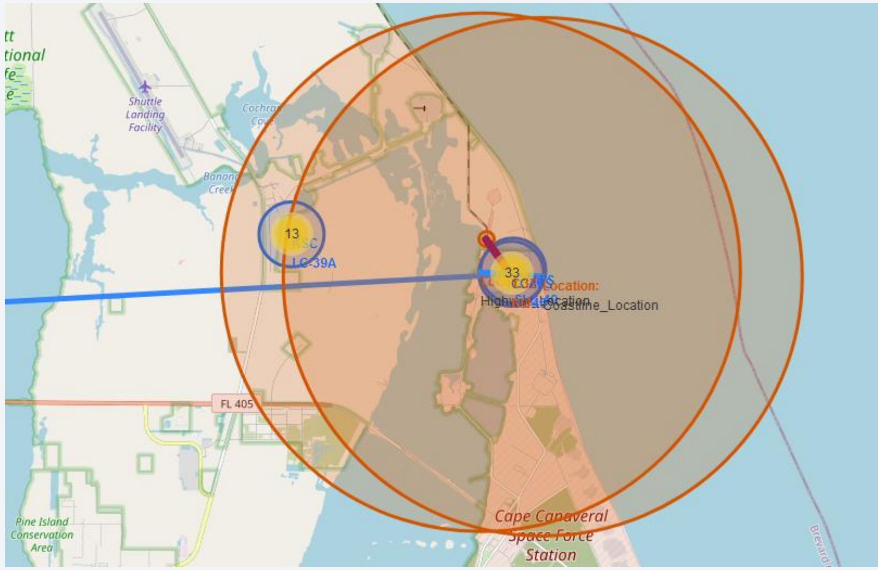
Folium Map: Success rate for each launch location

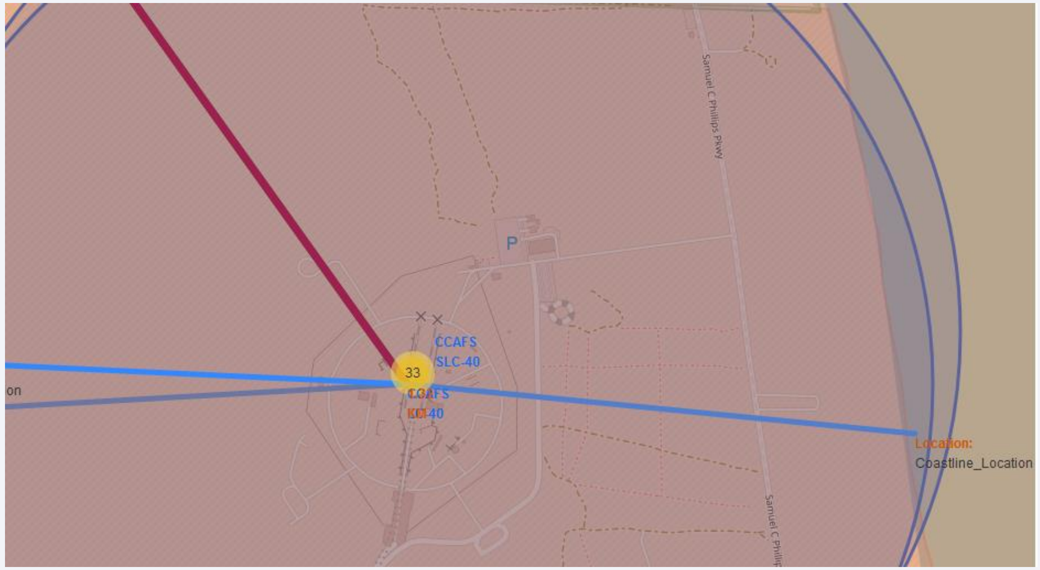
From the color-labeled markers in marker clusters, we can easily identify which launch sites have relatively high success rates.

Green Marker = Successful Return

Red Marker = Failed Return

Folium Map: Closest Proximities to CCAFS LC-40





Proximities Cordinates

	Location	Lat	Long
0	Orlando_Location	28.52300	-81.38260
1	Coastline_Location	28.56146	-80.56746
2	Highway_Location	28.56270	-80.58703

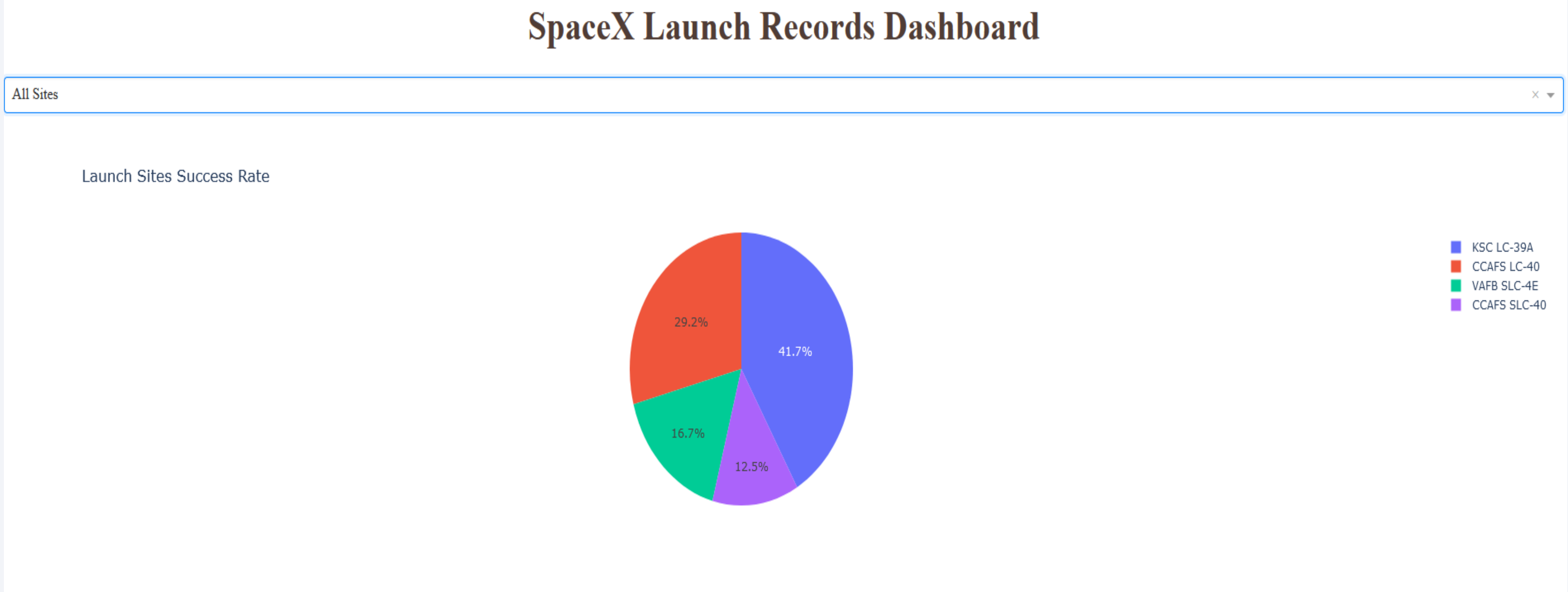
we calculated the distances between the launch site (CCAFS LC-40) to its proximities

Orlando City Distance ≈ 78.8 Km,
Coastline Distance ≈ 0.97 Km,
Highway Distance ≈ 0.95Km

Section 5

Build a Dashboard with Plotly Dash

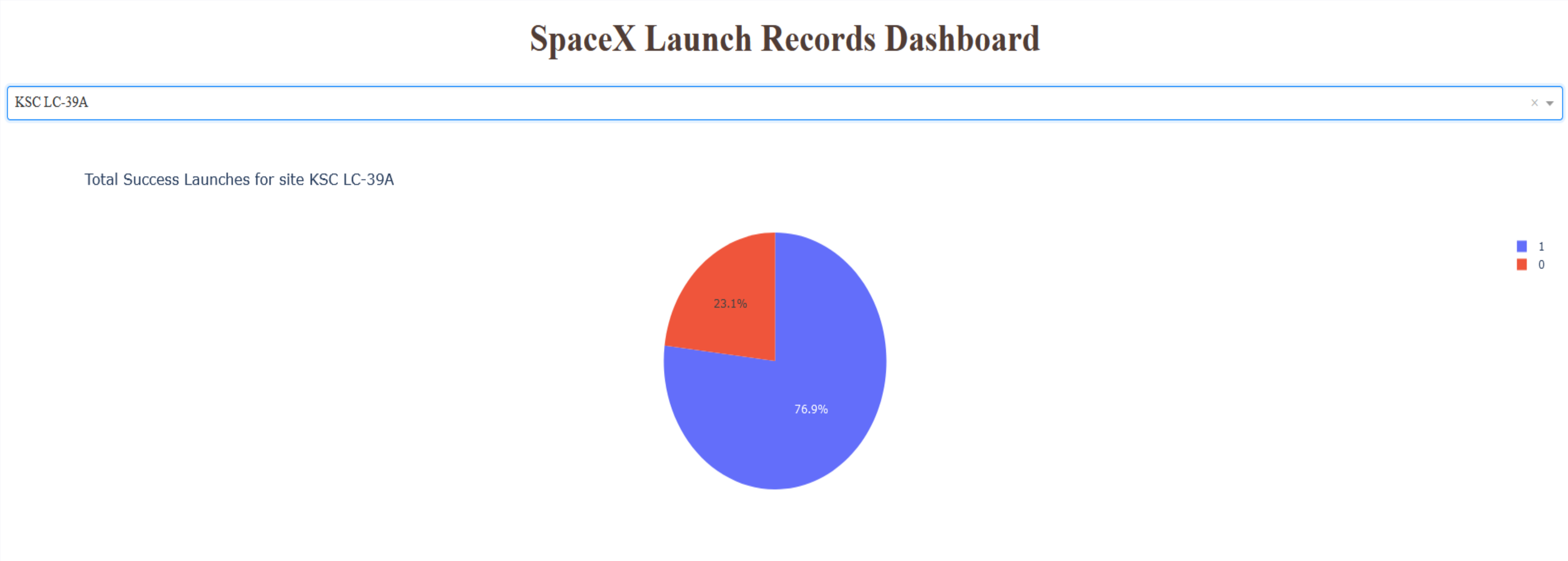
Dashboard: Launch success count for all sites



The graph shows the success percentage for every single site in terms of first stage return:

- The best site is KSC LC-39A with 41.7%. of total successful rocket launch among all sites
- The least site for successful rocket launch: CCAFS SLC-40 with only12.5%.

Dashboard: Launch success for KSC LC 39A



Total Success Launches for site KSC LC-39

- KSC LC-39A with 76.9% successful missions
- KSC LC-39A with 23.1% Failed missions

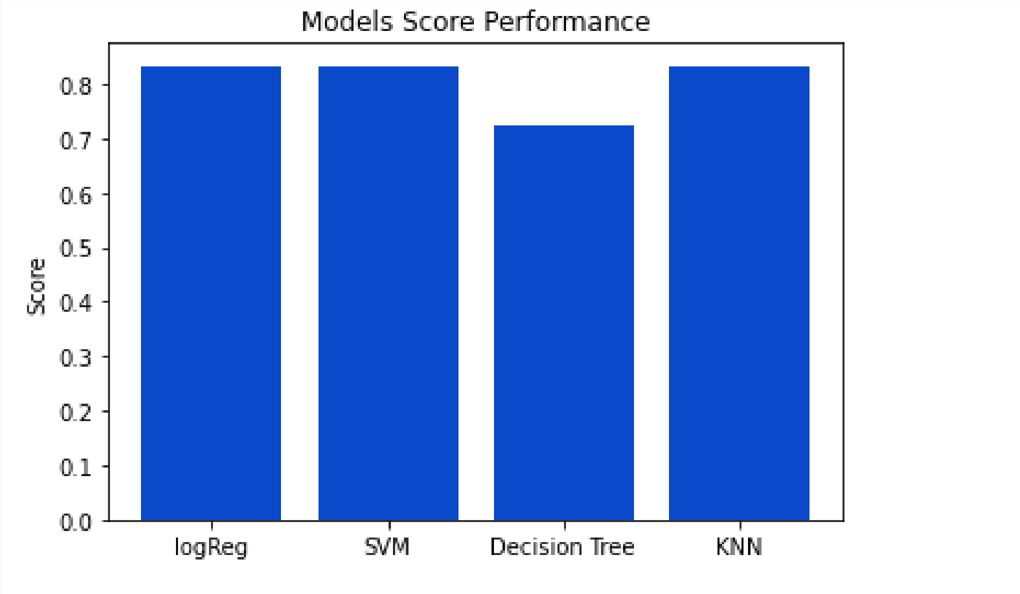
<Dashboard Screenshot 3>

This interactive scatter plot shows the launch outcome based on the relationship between the payload mass and the final outcomes as we can infer that the success rate per booster version for example, the payload mass < 4000 kg more likely to be successful.

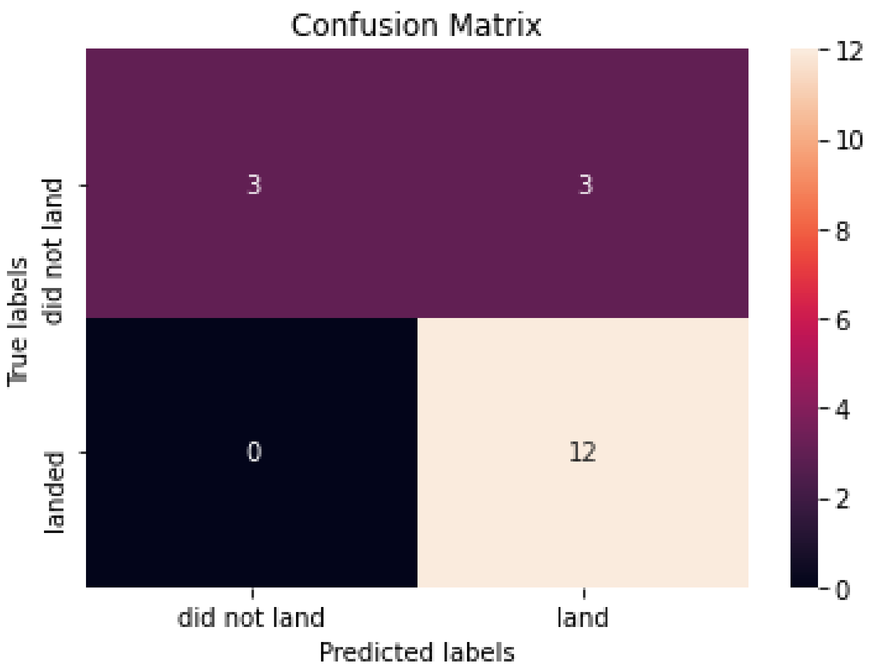
Section 6

Predictive Analysis (Classification)

Classification Accuracy



Logistic Regression , SVM and KNN has the same performance where the Jaccard Score is same : 0.8
Where Decision Tree has the worst performance compared to other models.




```
Logistic Regression:
Jaccard Score of = 0.8
F1 Score = 0.7777777777777778
========================================
SVM:
Jaccard Score of = 0.8
F1 Score = 0.7777777777777778
========================================
Decision Tree:
Jaccard Score of = 0.6666666666666666
F1 Score = 0.6727272727272727
========================================
KNN:
Jaccard Score of = 0.8
F1 Score = 0.7777777777777778
========================================
```

Confusion Matrix

Logistic Regression , SVM and KNN have the same confusion matrix and results:

- True Positive = 12
- False Positive = 0
- True Negative = 3
- False Negative = 3

Conclusions

a successful first stage return, leads to huge savings in terms of rockets lunches cost

A wide range of attributes affects the possibility of a successful first stage return. In our model there were 83 attributes were taken into consideration.

SpaceX Falcon9 launch sites were all close to a highway, railway, and coastline proximities, which aimed in transportation cost-reduction

insight requires further investigation. SpaceX success rate increased with years, KSC LC – 39A site is the highest in success rate.

Orbit and booster version affect success rate.

Appendix

- SpaceX API URL ”Click Here“
- SpaceX Static Wikipedia URL ”Click Here“
- SpaceX data used in ML training “Click Here”

Thank you!