IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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- Introduction
- Methodology
- Results
- Conclusion
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Executive Summary

- Summary of methodologies
  - Data Collection through API
  - Data Collection with Web Scraping
  - Data Wrangling
  - Exploratory Data Analysis with SQL
  - Exploratory Data Analysis with Data Visualization
  - Interactive Visual Analytics with Folium
  - Machine Learning Prediction
- Summary of all results
  - Exploratory Data Analysis result
  - Interactive analytics in screenshots
  - Predictive Analytics result

Introduction

- Project background and context

Space X advertises Falcon 9 rocket launches on its website with a cost of 62 million dollars; other providers cost upward of 165 million dollars each, much of the savings is because Space X can reuse the first stage. Therefore, if we can determine if the first stage will land, we can determine the cost of a launch. This information can be used if an alternate company wants to bid against space X for a rocket launch. This goal of the project is to create a machine learning pipeline to predict if the first stage will land successfully.

- Problems you want to find answers
  - What factors determine if the rocket will land successfully?
  - The interaction amongst various features that determine the success rate of a successful landing.
  - What operating conditions needs to be in place to ensure a successful landing program.

Section 1

Methodology

Methodology

Executive Summary

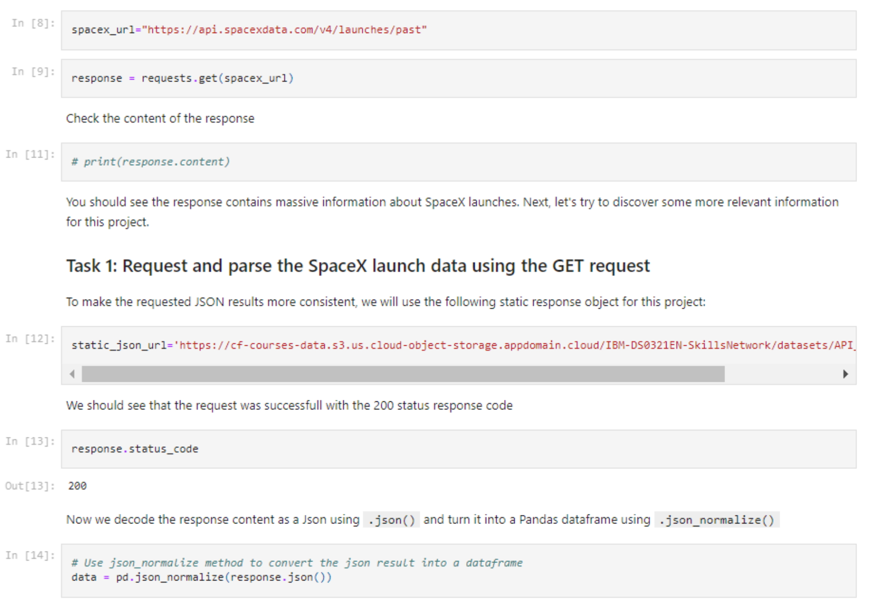
- Data collection methodology:
  - Describe how data was collected
- Perform data wrangling
  - Describe how data was processed
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - How to build, tune, evaluate classification models

Data Collection

- The data was collected using various methods:
  - Data collection was done using get request to the SpaceX API.
  - Next, we decoded the response content as a Json using .json() function call and turn it into a pandas dataframe using .json_normalize().
  - We then cleaned the data, checked for missing values and fill in missing values where necessary.
  - In addition, we performed web scraping from Wikipedia for Falcon 9 launch records with BeautifulSoup.
  - The objective was to extract the launch records as HTML table, parse the table and convert it to a pandas dataframe for future analysis.

Data Collection – SpaceX API

- We used the get request to the SpaceX API to collect data, clean the requested data and did some basic data wrangling and formatting.
- https://github.com/Ahmad-Su01/IBM-Data_Science_Capstone_SpaceX/blob/4630cf4c0cce6359f74b4b878a12222df8c0d67e/IBM/Applied%20Data%20Science%20Capstone/Capstone%20Introduction%20and%20Understanding%20the%20Datasets/jupyter-labs-spacex-data-collection-api.ipynb


In [8]:
```
spacex_url="https://api.spacexdata.com/v4/launches/past"
```
In [9]:
```
response = requests.get(spacex_url)
```
Check the content of the response

In [11]:
```
# print(response.content)
```
You should see the response contains massive information about SpaceX launches. Next, let's try to discover some more relevant information for this project.

Task 1: Request and parse the SpaceX launch data using the GET request

To make the requested JSON results more consistent, we will use the following static response object for this project:

In [12]:
```
static_json_url='https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/IBM-DS0321EN-SkillsNetwork/datasets/API_
```
We should see that the request was successfull with the 200 status response code

In [13]:
```
response.status_code
```
Out[13]: 200

Now we decode the response content as a Json using `.json()` and turn it into a Pandas dataframe using `.json_normalize()`

In [14]:
```
# Use json_normalize method to convert the json result into a dataframe
data = pd.json_normalize(response.json())
```

Data Collection - Scraping

- We applied web scrapping to webscrap Falcon 9 launch records with BeautifulSoup
- We parsed the table and converted it into a pandas dataframe.
- https://github.com/Ahmad-Su01/IBM-Data_Science_Capstone_SpaceX/blob/4630cf4c0cce6359f74b4b878a12222df8c0d67e/IBM/Applied%20Data%20Science%20Capstone/Capstone%20Introduction%20and%20Understanding%20the%20Datasets/jupyter-labs-webscraping.ipynb

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

Next, request the HTML page from the above URL and get a `response` object

TASK 1: Request the Falcon9 Launch Wiki page from its URL

First, let's perform an HTTP GET method to request the Falcon9 Launch HTML page, as an HTTP response.

```
# use requests.get() method with the provided static_url
# assign the response to a object
response = requests.get(static_url)
```

Create a `BeautifulSoup` object from the HTML `response`

```
# Use BeautifulSoup() to create a BeautifulSoup object from a response text content
soup = BeautifulSoup(response.text, 'html.parser')
```

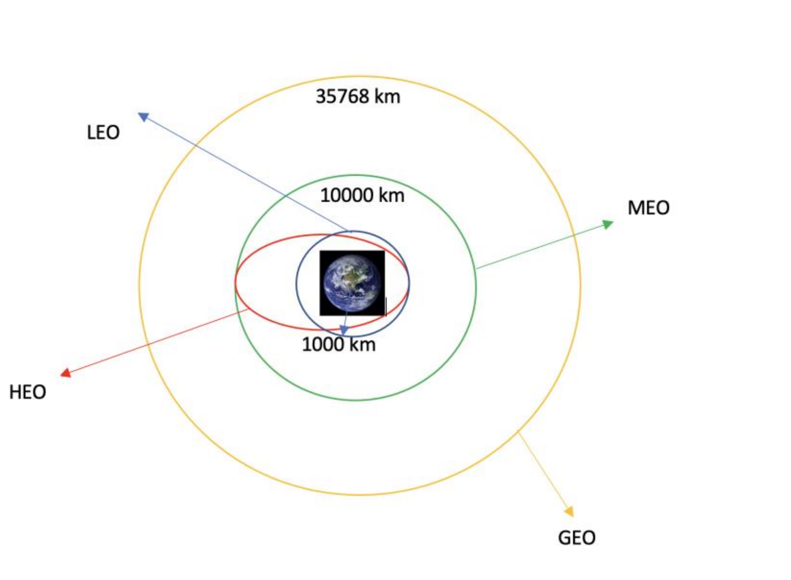
Print the page title to verify if the `BeautifulSoup` object was created properly

```
# Use soup.title attribute
# print(soup.prettify())
print(soup.title)
```

```
<title>List of Falcon 9 and Falcon Heavy launches - Wikipedia</title>
```

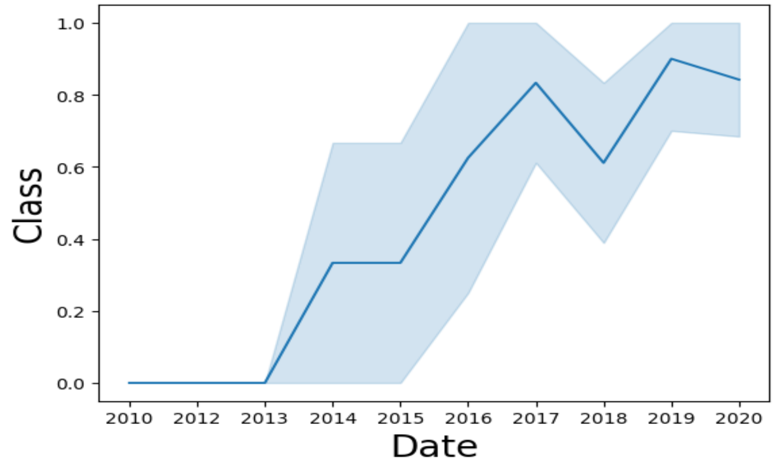
Data Wrangling

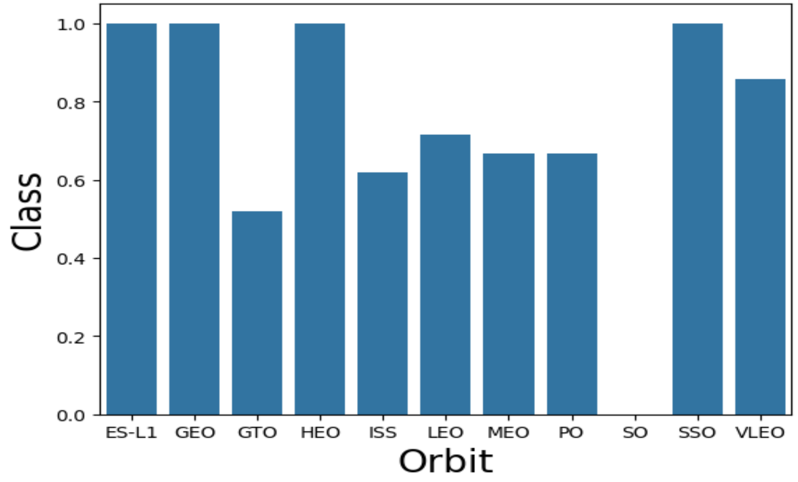
- We performed exploratory data analysis and determined the training labels.
- We calculated the number of launches at each site, and the number and occurrence of each orbits.
- We created landing outcome label from outcome column and exported the results to csv.
- https://github.com/Ahmad-Su01/IBM-Data_Science_Capstone_SpaceX/blob/5e30f67783535440201bb48da6653638149cb3fe/IBM/Applied%20Data%20Science%20Capstone/Capstone%20Introduction%20and%20Understanding%20the%20Datasets/labs-jupyter-spacex-Data%20wrangling.ipynb



EDA with Data Visualization

- We explored the data by visualizing the relationship between flight number and launch Site, payload and launch site, success rate of each orbit type, flight number and orbit type, the launch success yearly trend.



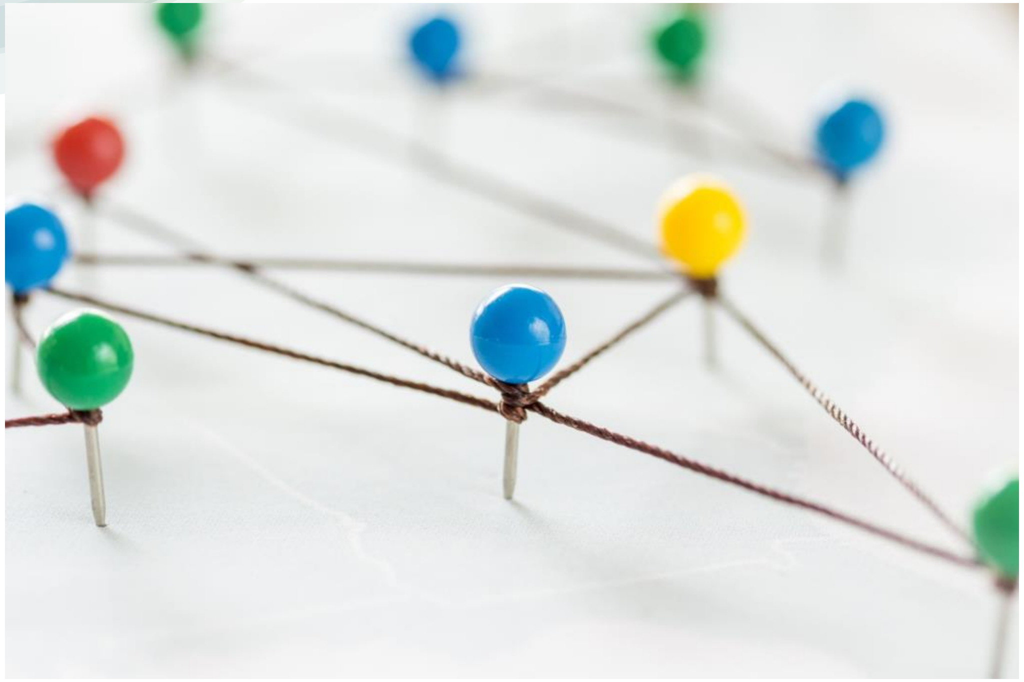


https://github.com/Ahmad-Su01/IBM-Data_Science_Capstone_SpaceX/blob/5e30f67783535440201bb48da6653638149cb3fe/IBM/Applied%20Data%20Science%20Capstone/Explanotary%20Data%20Analysis%20(EDA)/edadataviz.ipynb

EDA with SQL

- We loaded the SpaceX dataset into a sqlite3 database without leaving the jupyter notebook.
- We applied EDA with SQL to get insight from the data. We wrote queries to find out for instance:
  - The names of unique launch sites in the space mission.
  - The total payload mass carried by boosters launched by NASA (CRS).
  - The average payload mass carried by booster version F9 v1.1
  - The total number of successful and failure mission outcomes.
  - The failed landing outcomes in drone ship, their booster version and launch site names.
- https://github.com/Ahmad-Su01/IBM-Data_Science_Capstone_SpaceX/blob/4630cf4c0cce6359f74b4b878a12222df8c0d67e/IBM/Applied%20Data%20Science%20Capstone/Explanotary%20Data%20Analysis%20(EDA)/jupyter-labs-eda-sql-coursera_sqllite.ipynb

Build an Interactive Map with Folium



- We marked all launch sites, and added map objects such as markers, circles, lines to mark the success or failure of launches for each site on the folium map.
- We assigned the feature launch outcomes (failure or success) to class 0 and 1.i.e., 0 for failure, and 1 for success.
- Using the color-labeled marker clusters, we identified which launch sites have relatively high success rate.
- We calculated the distances between a launch site to its proximities. We answered some question for instance:
    - Are launch sites near railways, highways and coastlines.
    - Do launch sites keep certain distance away from cities.
- https://github.com/Ahmad-Su01/IBM-Data_Science_Capstone_SpaceX/blob/4630cf4c0cce6359f74b4b878a12222df8c0d67e/IBM/Applied%20Data%20Science%20Capstone/Interactive%20Visual%20Analytics%20and%20Dashboard/lab_jupyter_launch_site_location.ipynb

Build a Dashboard with Plotly Dash

- We built an interactive dashboard with Plotly dash.
- We plotted pie charts showing the total launches by a certain sites.
- We plotted scatter graph showing the relationship with Outcome and Payload Mass (Kg) for the different booster version.
- https://github.com/Ahmad-Su01/IBM-Data_Science_Capstone_SpaceX/blob/4630cf4c0cce6359f74b4b878a12222df8c0d67e/IBM/Applied%20Data%20Science%20Capstone/Interactive%20Visual%20Analytics%20and%20Dashboard/spacex_dash_app.py

Predictive Analysis (Classification)

- We loaded the data using numpy and pandas, transformed the data, split our data into training and testing.
- We built different machine learning models and tune different hyperparameters using GridSearchCV.
- We used accuracy as the metric for our model, improved the model using feature engineering and algorithm tuning.
- We found the best performing classification model.
- https://github.com/Ahmad-Su01/IBM-Data_Science_Capstone_SpaceX/blob/4630cf4c0cce6359f74b4b878a12222df8c0d67e/IBM/Applied%20Data%20Science%20Capstone/Predictive%20Analysis%20(Classification)/SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb

Results

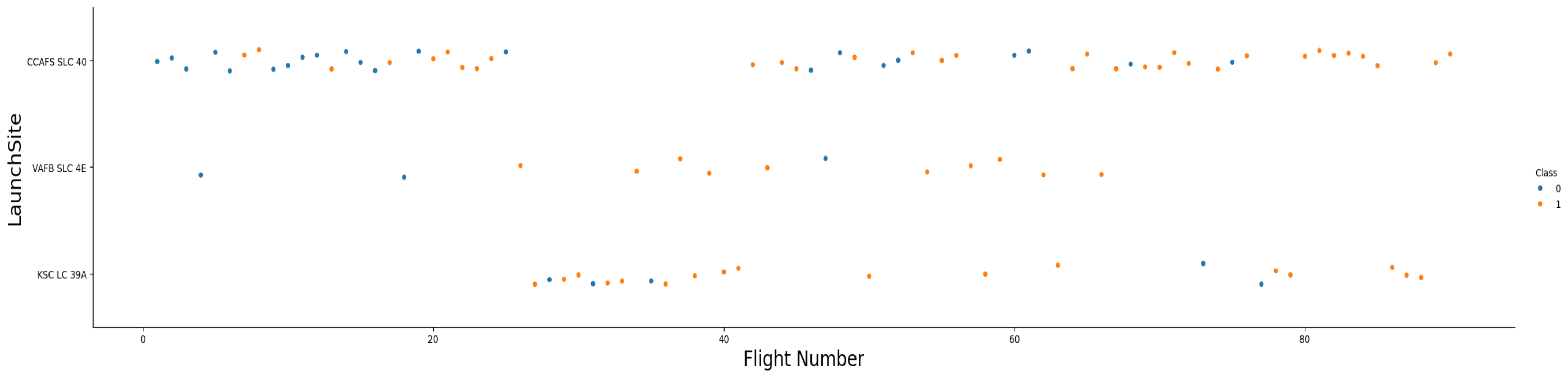
- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

Section 2

Insights drawn from EDA

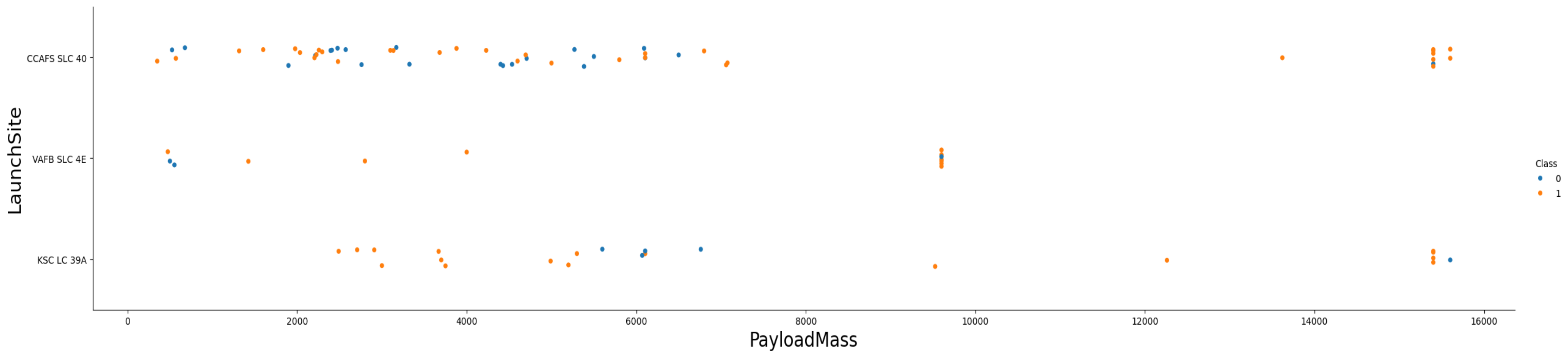
Flight Number vs. Launch Site

- From the plot, we found that the larger the flight amount at a launch site, the greater the success rate at a launch site.



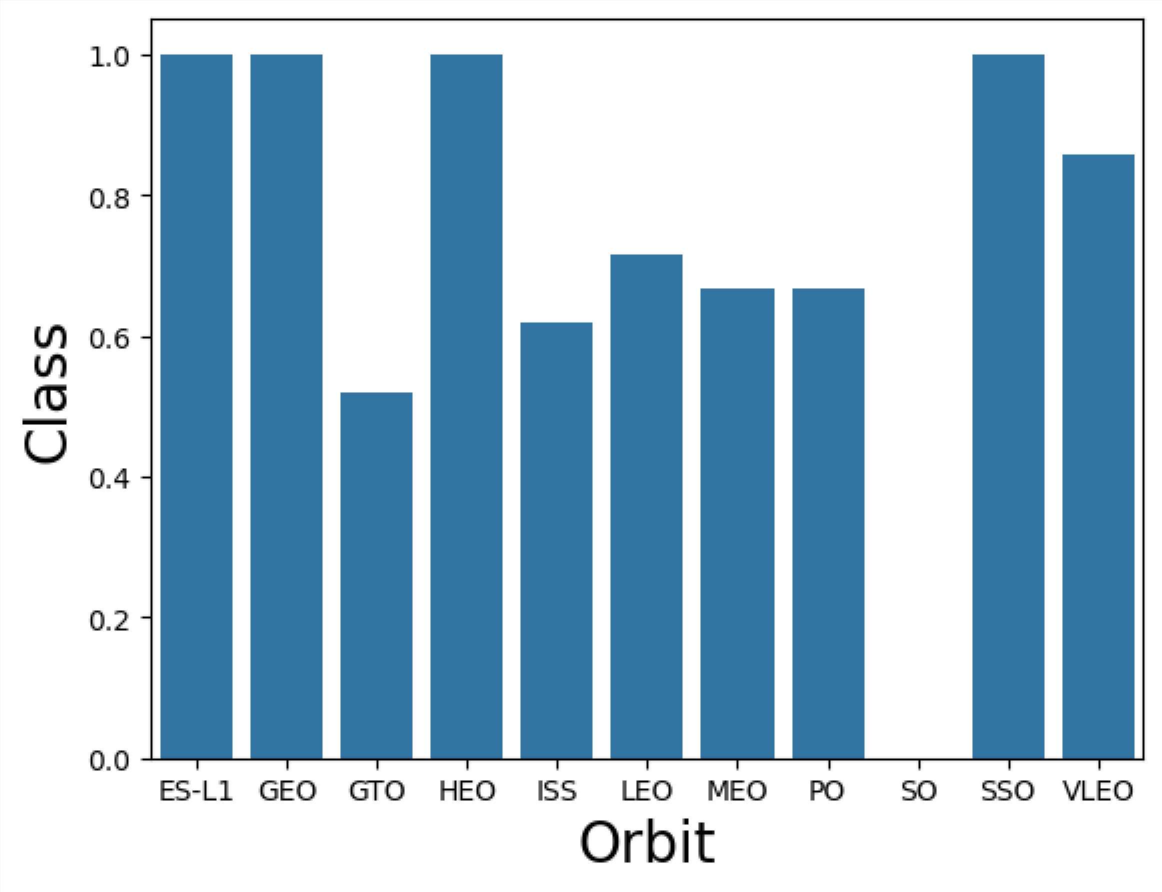
Payload vs. Launch Site

- The greater the payload mass for launch site CCAFS SLC 40 the higher the success rate for the rocket.



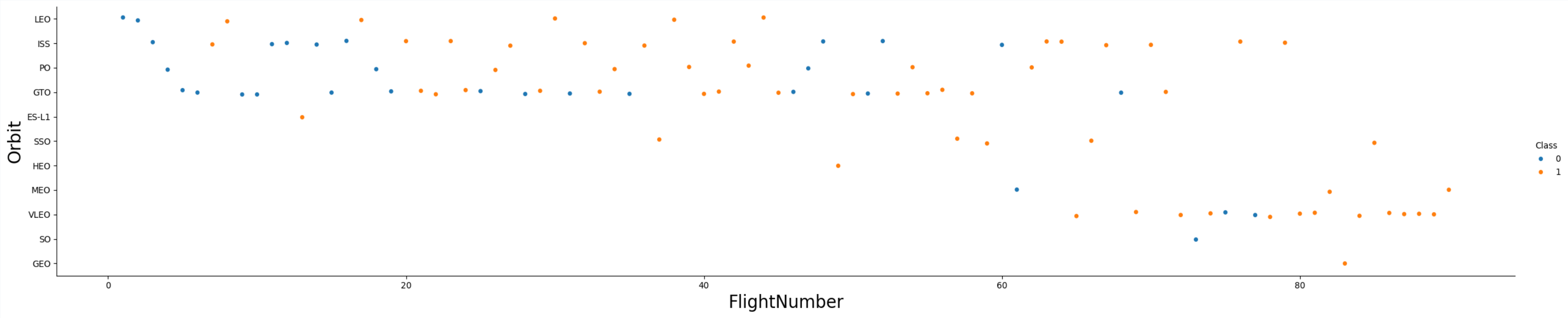
Success Rate vs. Orbit Type

- From the plot, we can see that ES-L1, GEO, HEO, SSO, VLEO had the most success rate.



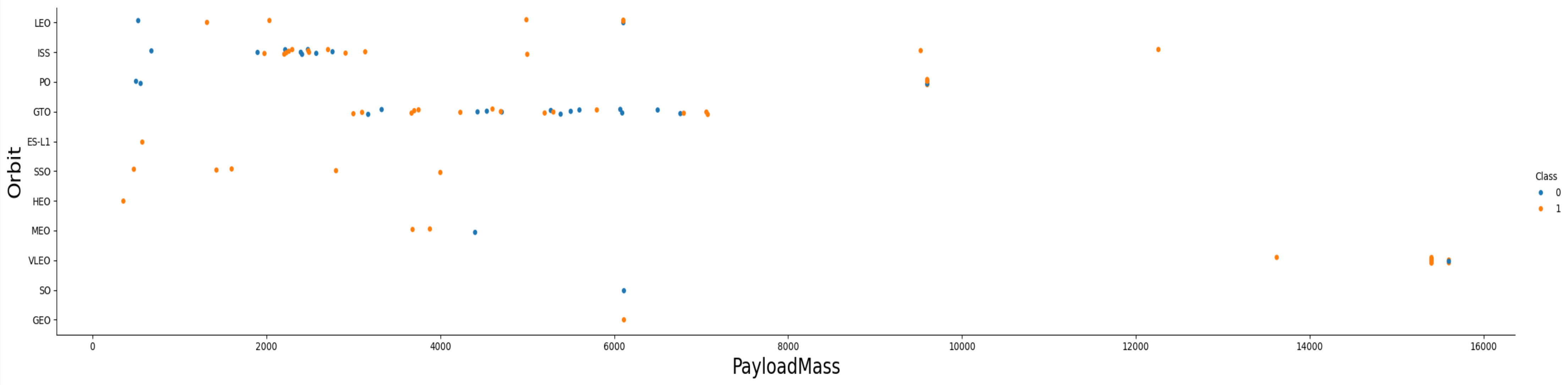
Flight Number vs. Orbit Type

- The plot below shows the Flight Number vs. Orbit type. We observe that in the LEO orbit, success is related to the number of flights whereas in the GTO orbit, there is no relationship between flight number and the orbit.



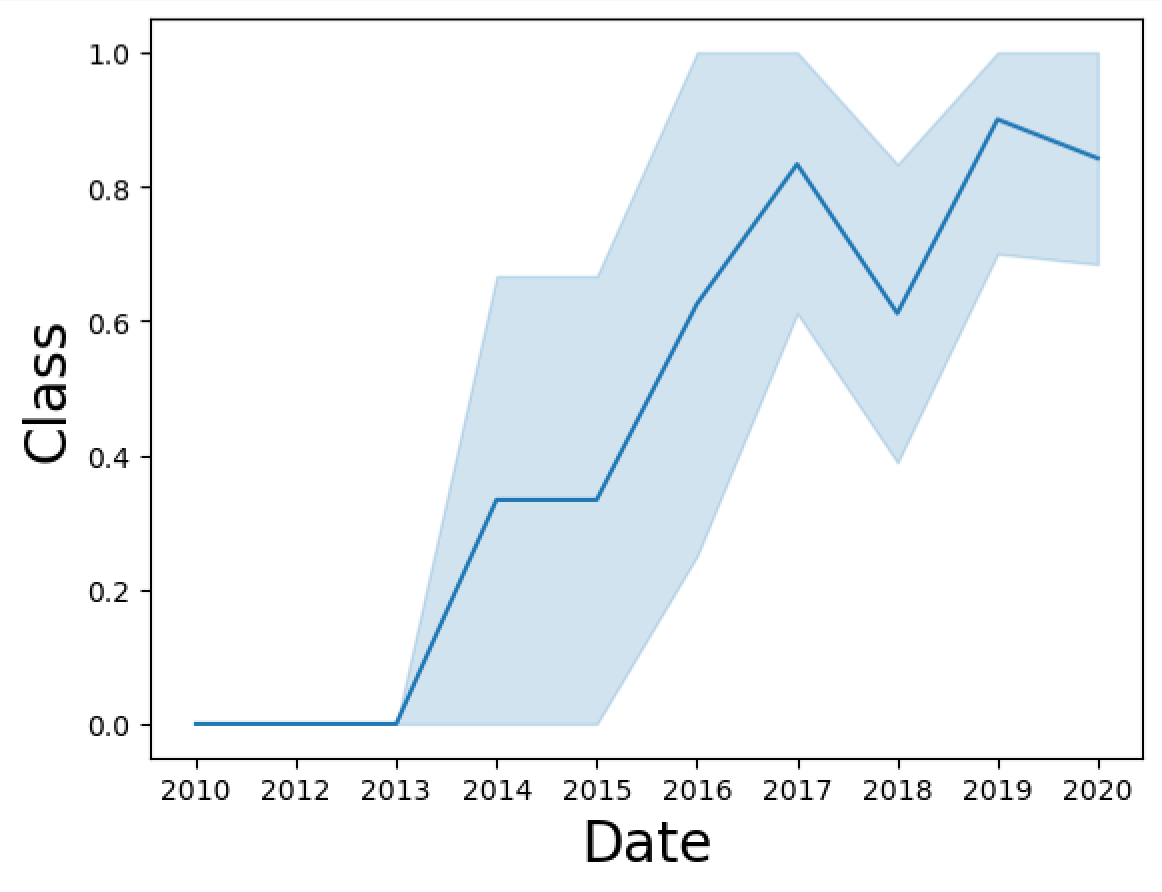
Payload vs. Orbit Type

- We can observe that with heavy payloads, the successful landing are more for PO, LEO and ISS orbits.



Launch Success Yearly Trend

- From the plot, we can observe that success rate since 2013 kept on increasing till 2020.



All Launch Site Names

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

```
%sql select DISTINCT Launch_Site from spacextbl;
```

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

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

Launch Site Names Begin with 'CCA'

- We used the query below to display 5 records where launch sites begin with `CCA`

```
%sql select * from spacextbl where Launch_Site like 'CCA%' limit 5;
```

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

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing_Outcome
2010-06-04	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-12-08	15:43:00	F9 v1.0 B0004	CCAFS LC-40	Dragon demo flight C1, two CubeSats, barrel of Brouere cheese	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2012-05-22	7:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	0:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-03-01	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

Total Payload Mass

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

```
%sql Select sum(PAYLOAD_MASS__KG_) from spacextbl where Customer == 'NASA (CRS)'
```

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

sum(PAYLOAD_MASS__KG_)
45596

Average Payload Mass by F9 v1.1

- We calculated the average payload mass carried by booster version F9 v1.1 as 2928.4

```
%sql select avg(PAYLOAD_MASS__KG_) from spacextbl where Booster_Version == 'F9 v1.1';
```

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

avg(PAYLOAD_MASS__KG_)
2928.4

First Successful Ground Landing Date

- We observed that the dates of the first successful landing outcome on ground pad was 22nd December 2015

```
%sql Select min(Date) from spacextbl where Landing_Outcome == 'Success (ground pad)';
```

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

min(Date)
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

- We used the **WHERE** clause to filter for boosters which have **successfully landed on drone ship** and applied the **AND** condition to determine **successful landing** with **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_ between 4000 and 6000;
```

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

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

Total Number of Successful and Failure Mission Outcomes

- We used wildcard like **'%'** to filter for **WHERE Mission_Outcome** was a **success** or a **failure** by using **group by** clause.

```
%sql select Mission_Outcome, COUNT(*) AS total_count
from spacextbl group by Mission_Outcome;
```

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

Mission_Outcome	total_count
Failure (in flight)	1
Success	98
Success	1
Success (payload status unclear)	1

Boosters Carried Maximum Payload

- We determined the booster that have carried the **maximum payload** using a subquery in the **WHERE** clause and the **MAX()** function.

```
%sql select Booster_Version from spacextbl
where PAYLOAD_MASS__KG_=(select max(PAYLOAD_MASS__KG_) from spacextbl)
```

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

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

2015 Launch Records

- 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**.

```
%sql select substr(Date, 6, 2) as 'Month Name', landing_outcome as 'Failure',
Booster_Version as 'Version', launch_site as 'launch' from spacextbl
where landing_outcome == 'Failure (drone ship)' and substr(Date, 0, 5) = '2015';
```

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

Month Name	Failure	Version	launch
01	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
04	Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40

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

- We selected Landing outcomes and the COUNT of landing outcomes from the data and used the WHERE clause to filter for landing outcomes BETWEEN 2010-06-04 to 2010-03-20.
- We applied the GROUP BY clause to group the landing outcomes and the ORDER BY clause to order the grouped landing outcome in descending order.

```
%sql select landing_outcome, count(*) as 'Outcome' from spacextbl
where Date between '2010-06-04' and '2017-03-20'
GROUP BY landing_outcome ORDER BY count(Landing_Outcome) DESC;
```

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

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

Section 3

Launch Sites Proximities Analysis

All launch sites global map markers

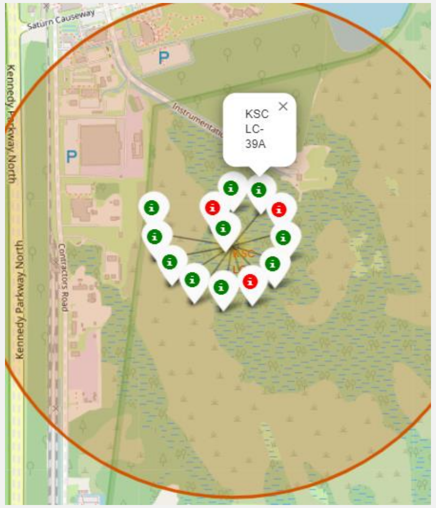
- All the launches are in the United States of America. Exactly in Florida and California.

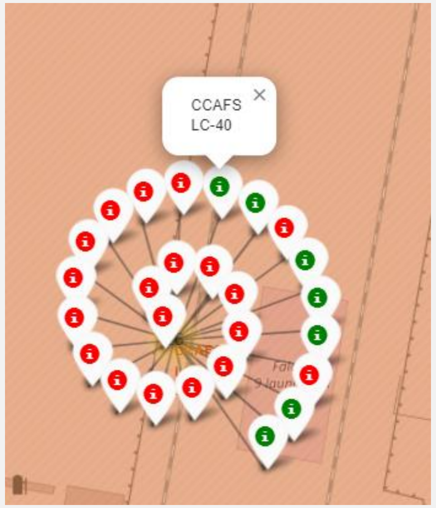
Markers showing launch sites with color labels

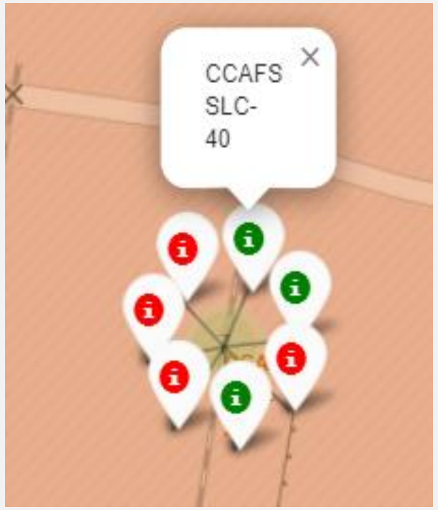
Florida Lauch Site

Green marker represents a successful launch.

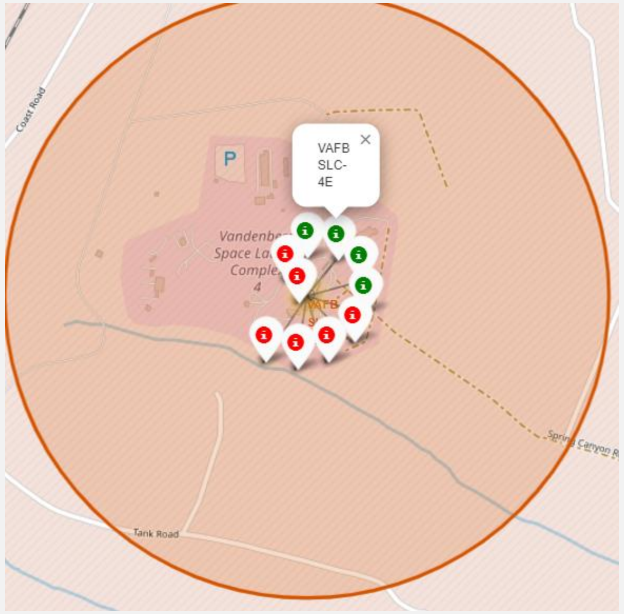
Red marker represents unsuccessful launch.



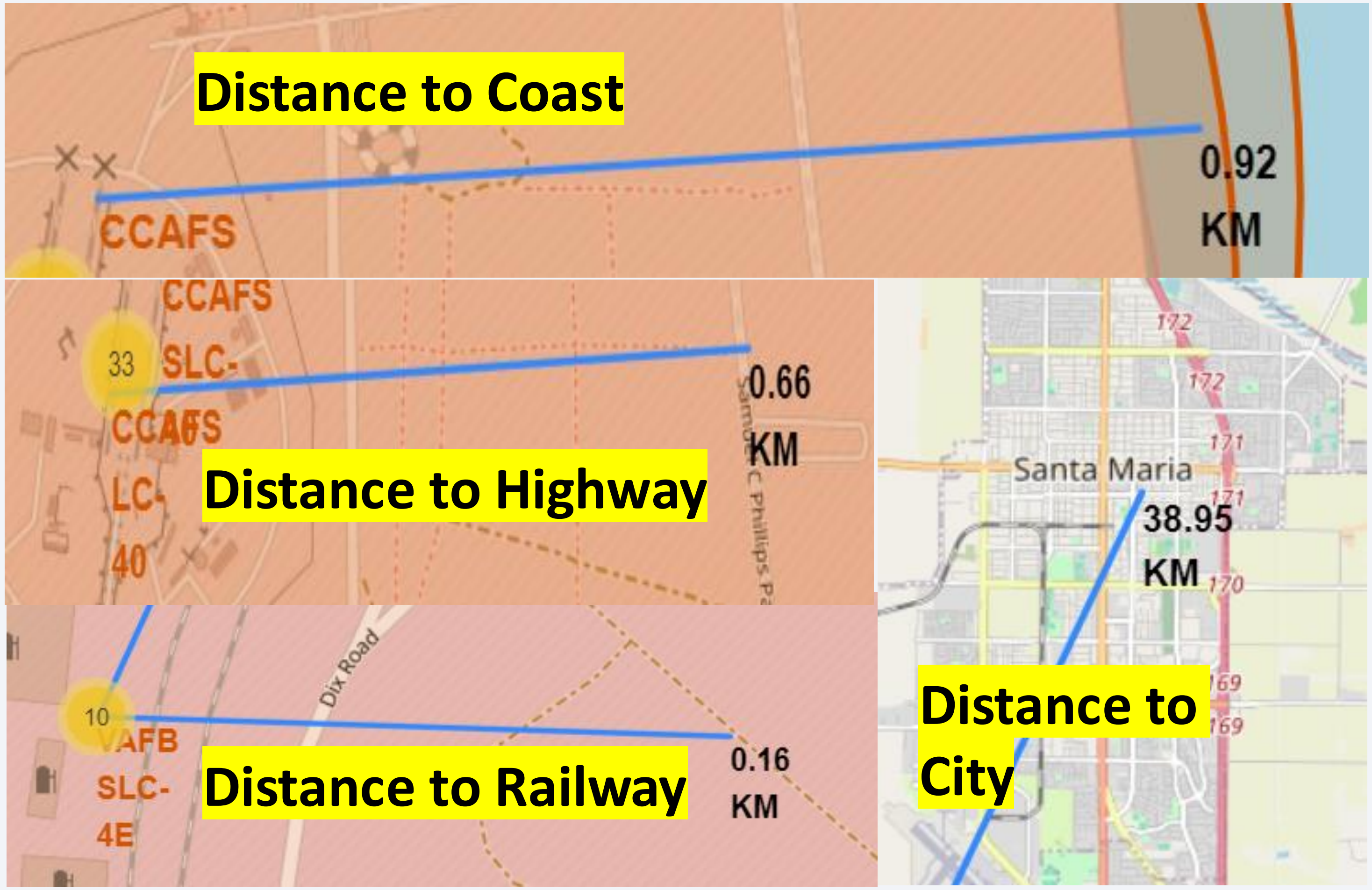




California Launch Site



Launch Site distance 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

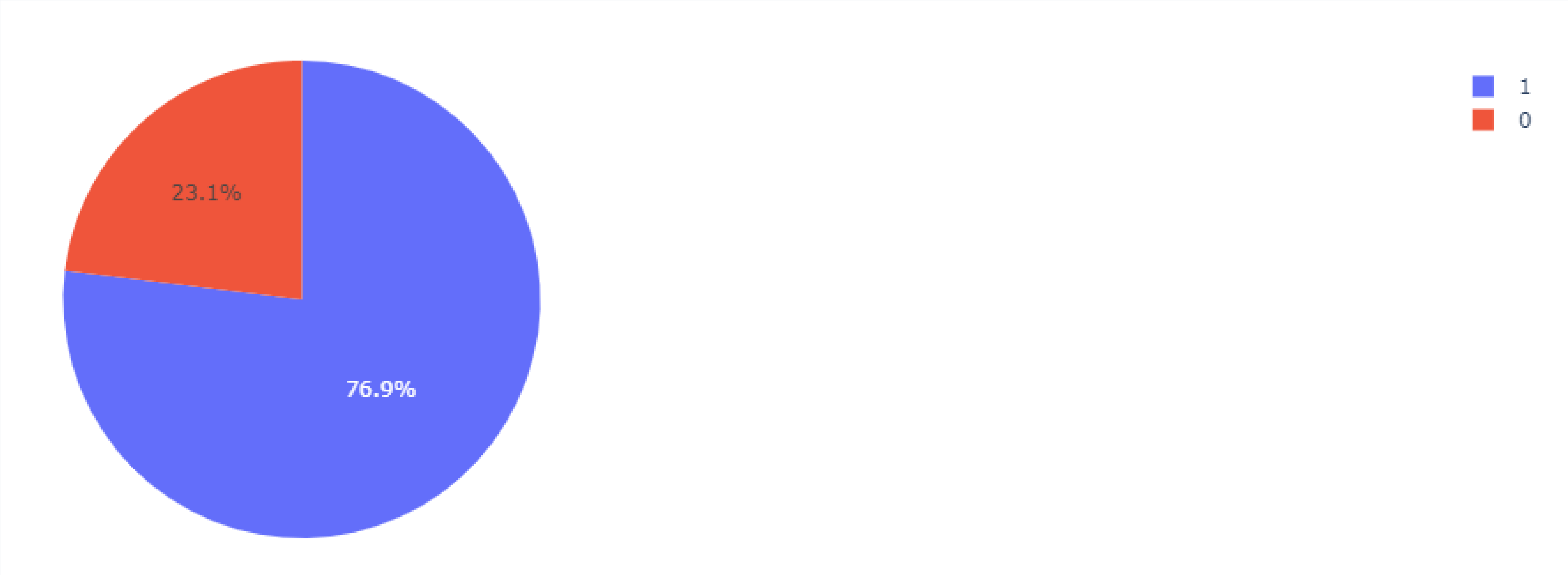
Section 4

Build a Dashboard with Plotly Dash

Pie chart showing the success percentage 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

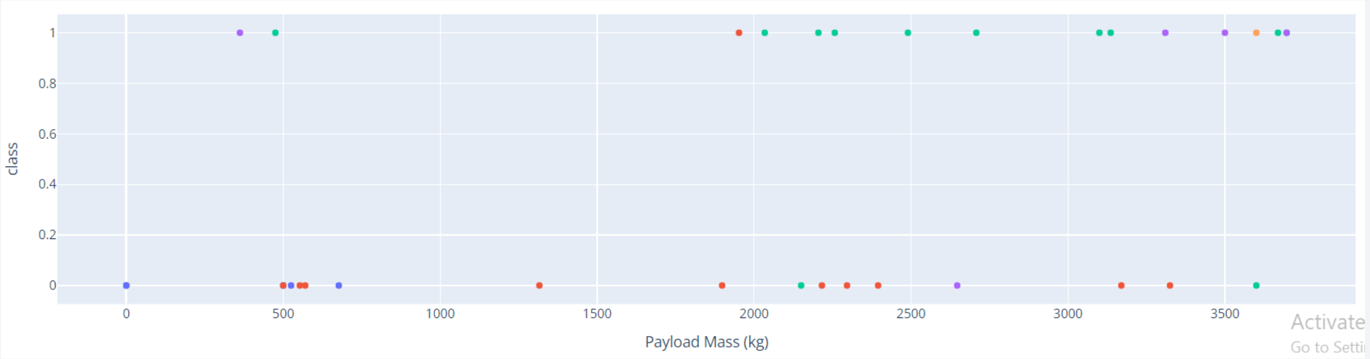


- KSC LC-39A achieved a 76.9% success rate while getting a 23.1% failure rate.

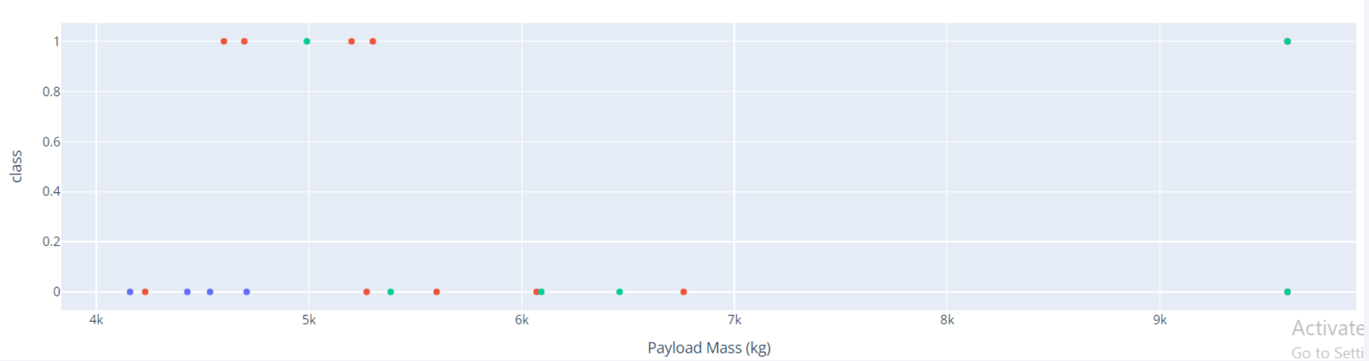
Scatter plot of Payload vs Launch Outcome for all sites, with different payload selected in the range slider

Successful rates for low weighted payload is heavier than the heavy weighted payload.

Low weighted payload 0kg - 4000kg



High weighted payload 4000kg - 10000kg

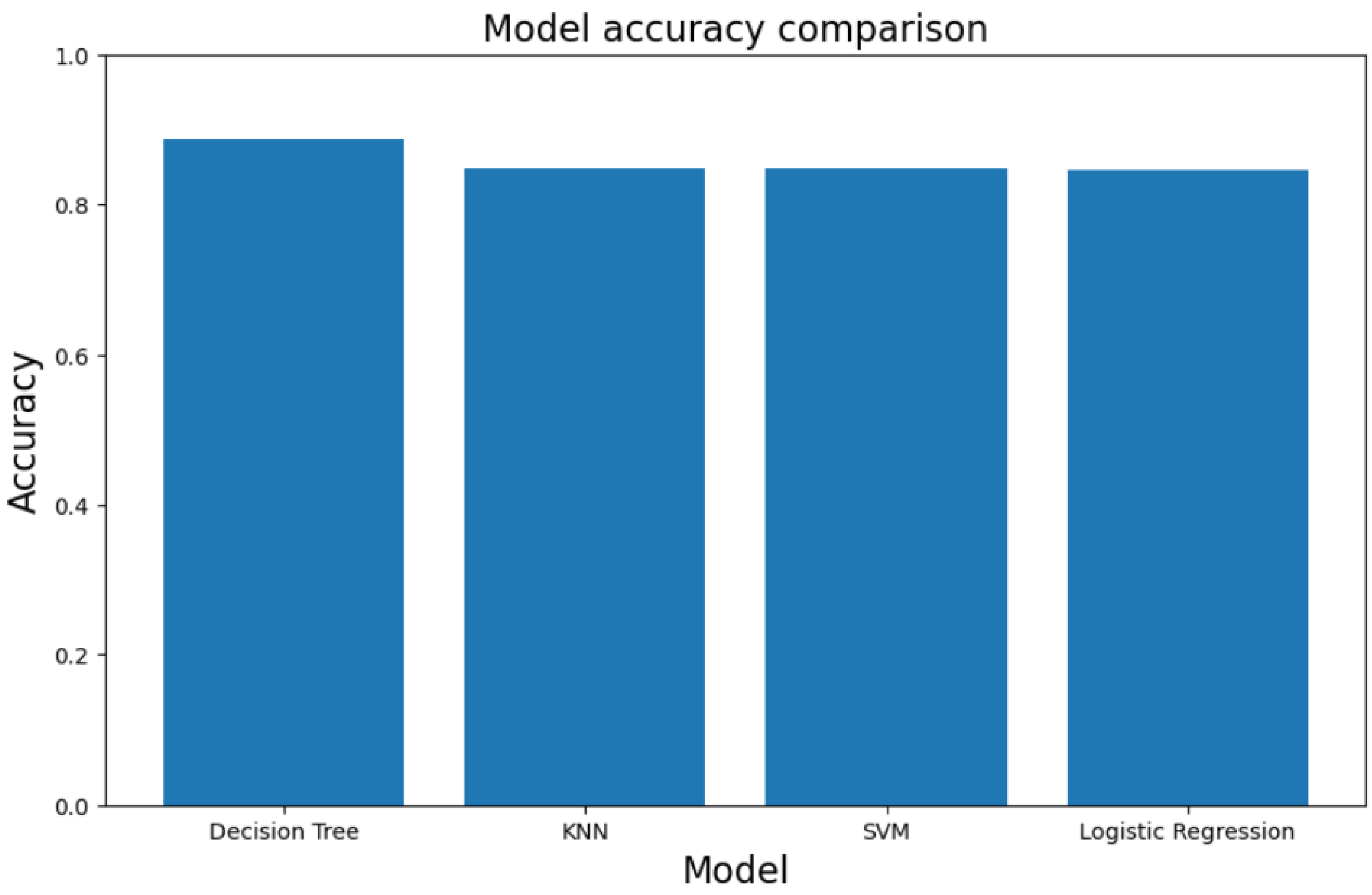


Section 5

Predictive Analysis (Classification)

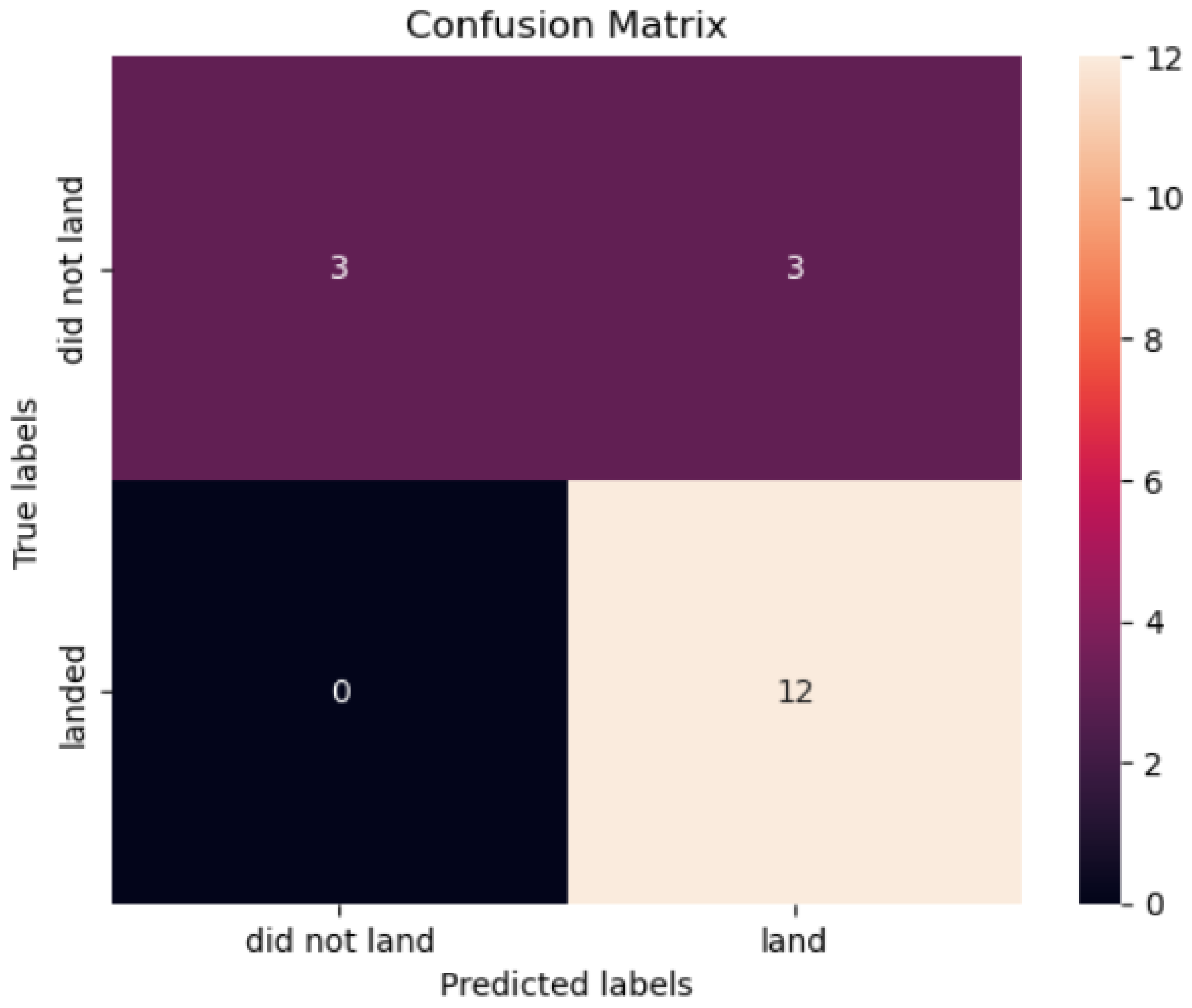
Classification Accuracy

- From the bar chart provided we can deduct that Decision Tree contains the highest accuracy among the models.



Confusion Matrix

The confusion matrix for the decision tree 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 landing by the classifier.



Conclusions

- We can conclude that:
  - The larger the flight amount at a launch site, the greater the success rate at a launch site.
  - 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 Decision tree classifier is the best machine learning algorithm for this task.

Thank you!