

Winning Space Race with Data Science

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ExecutiveSummary

- Summaryof methodologies
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Introduction

SpaceX is a revolutionary company who has disrupted the space industry by offering rocket launches specifically Falcon 9 as low as 62 million dollars; while other providers cost upward of 165 million dollars each. Most of this saving thanks to SpaceX's astounding idea to reuse the first stage of the launch by re-landing the rocket to be used on the next mission. Repeating this process will make the price even lower. As a data scientist of a startup rivaling SpaceX, the goal of this project is to create the machine learning pipeline to predict the landing outcome of the first stage in the future. This project is crucial in identifying the right price to bid against SpaceX for a rocket launch.

The problems included:

- Identifying all factors that influence the landing outcome.
- The relationship between each variables and how it is affecting the outcome.

Section 1

Methodology

Methodology

ExecutiveSummary

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

Data Collection

Data collection is the process of gathering and measuring information on targeted variables in an established system, which then enables one to answer relevant questions and evaluate outcomes. As mentioned, the dataset was collected by REST API and Web Scrapping from Wikipedia

For REST API, its started by using the get request. Then, we decoded the response content as Json and turn it into a pandas dataframe using `json_normalize()`. We then cleaned the data, checked for missing values and fill with whatever needed.

For web scrapping, we will use the BeautifulSoup to extract the launch records as HTML table, parse the table and convert it to a pandas dataframe for further analysis

Data Collection- SpaceXAPI

Get request for rocket launch data using API

Use json_normalize method to convert json result to dataframe

Performed data cleaning and filling the missing value

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

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

```
# Use json_normalize meethod to convert the json result into a dataframe
data = pd.json_normalize(response.json())
```

```
# Lets take a subset of our dataframe keeping only the features we want and the flight number, and date_utc.
data = data[['rocket', 'payloads', 'launchpad', 'cores', 'flight_number', 'date_utc']]
```

```
# We will remove rows with multiple cores because those are falcon rockets with 2 extra rocket boosters and rows that have multiple payloads in a single rocket.
```

```
data = data[data['cores'].map(len)==1]
data = data[data['payloads'].map(len)==1]
```

```
# Since payloads and cores are lists of size 1 we will also extract the single value in the list and replace the feature.
```

```
data['cores'] = data['cores'].map(lambda x : x[0])
data['payloads'] = data['payloads'].map(lambda x : x[0])
```

```
# We also want to convert the date_utc to a datetime datatype and then extracting the date leaving the time
data['date'] = pd.to_datetime(data['date_utc']).dt.date
```

```
# Using the date we will restrict the dates of the launches
data = data[data['date'] <= datetime.date(2020, 11, 13)]
```

Data Collection- Scraping

Request the Falcon9
Launch Wiki page from url

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

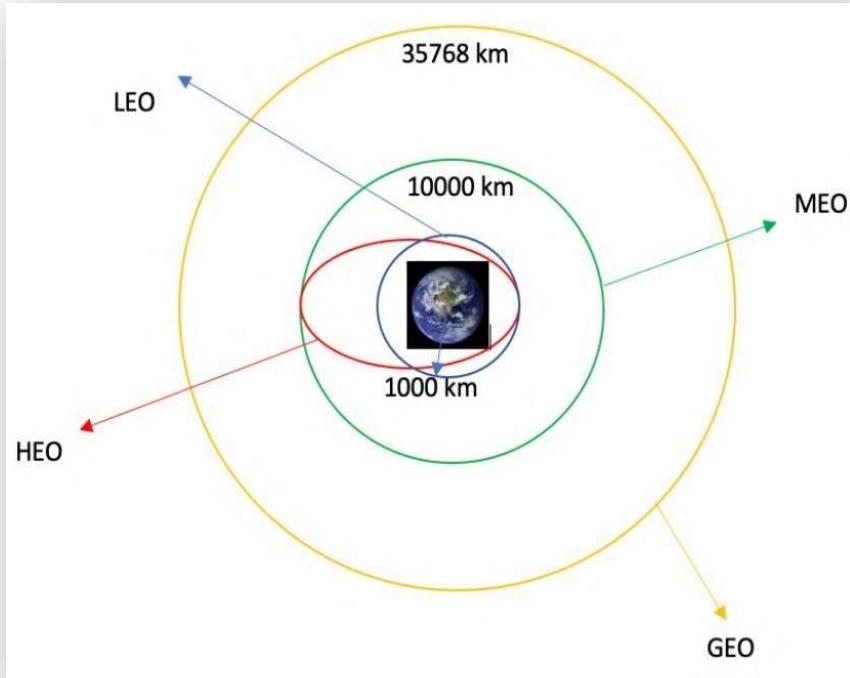
Create a BeautifulSoup
from the HTML response

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

Extract all column/variable
names from the HTML
header

```
extracted_row = 0
#Extract each table
for table_number,table in enumerate(soup.find_all('table',"wikitable plai
nrowheaders collapsible")):
    # get table row
    for rows in table.find_all("tr"):
        #check to see if first table heading is as number corresponding t
o launch a number
        if rows.th:
            if rows.th.string:
                flight_number=rows.th.string.strip()
                flag=flight_number.isdigit()
        else:
            flag=False
```

Data Wrangling

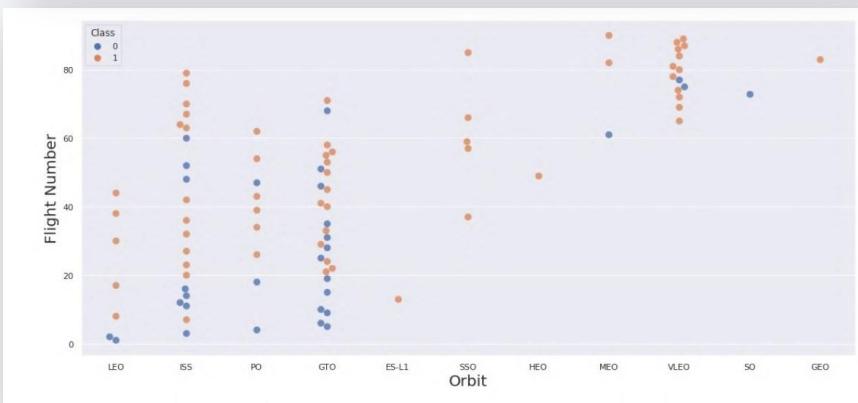
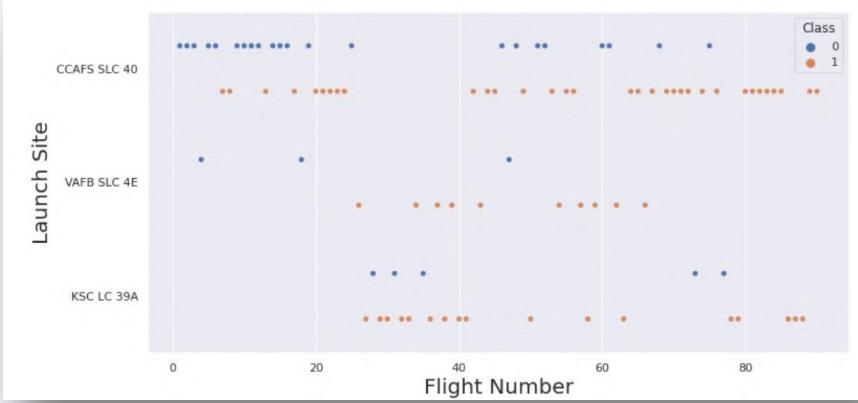


Data Wrangling is the process of cleaning and unifying messy and complex data sets for easy access and Exploratory Data Analysis(EDA).

We will first calculate the number of launches on each site, then calculate the number and occurrence of mission outcome per orbit type.

We then create a landing outcome label from the outcome column. This will make it easier for further analysis, visualization, and ML. Lastly, we will export the result to a CSV

EDA with Data Visualization

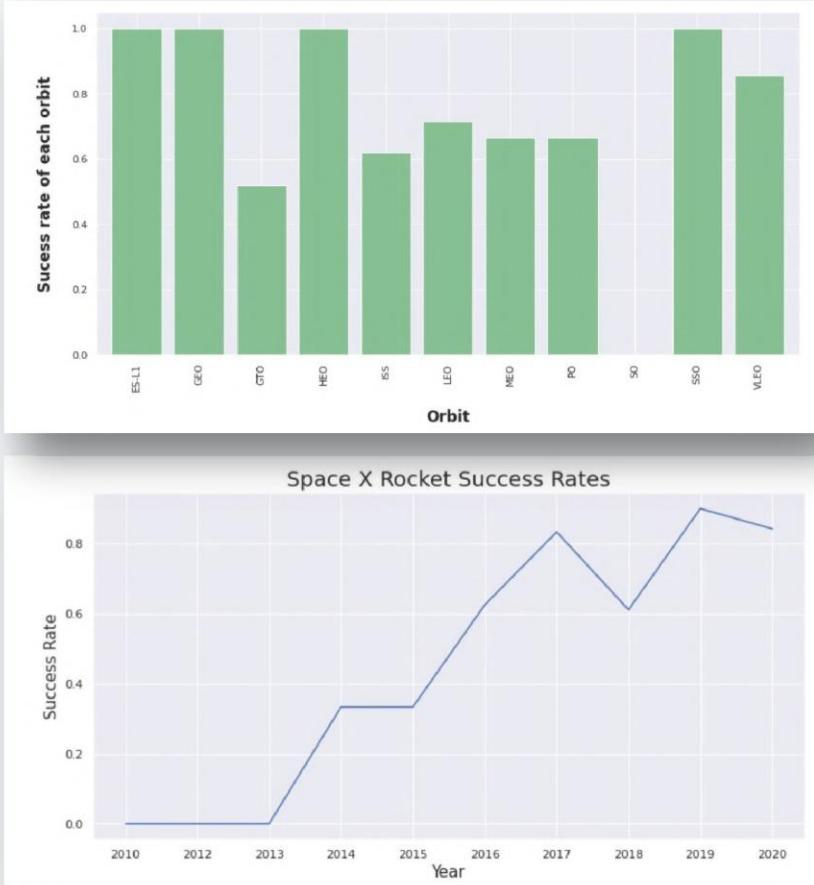


We first started by using scatter graph to find the relationship between the attributes such as between:

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

Scatter plots show dependency of attributes on each other. Once a pattern is determined from the graphs. It's very easy to see which factors affecting the most to the success of the landing outcomes.

EDA with Data Visualization



Once we get a hint of the relationships using scatter plot. We will then use further visualization tools such as bar graph and line plots graph for further analysis.

Bar graphs is one of the easiest way to interpret the relationship between the attributes. In this case, we will use the bar graph to determine which orbits have the highest probability of success.

We then use the line graph to show a trends or pattern of the attribute over time which in this case, is used for see the launch success yearly trend.

We then use Feature Engineering to be used in success prediction in the future module by created the dummy variables to categorical columns.

EDA with SQL

Using SQL, we had performed many queries to get better understanding of the dataset,

Ex:

- Displaying the names of the launch sites.
- Displaying 5 records where launch sites begin with the string ‘CCA’.
- Displaying the total payload mass carried by booster launched by NASA (CRS).
- Displaying the average payload mass carried by booster version F9 v1.1.
- Listing the date when the first successful landing outcome in ground pad was achieved.
- Listing the names of the boosters which have success in drone ship 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.

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 then assigned the dataframe `launch_outcomes(failure,success)` to classes 0 and 1 with **Red** and **Green** markers on the map in `MarkerCluster()`.

We then used the Haversine's formula to calculated the distance of the launch sites to various landmark to find answer to the questions of:

- How close the launch sites with railways, highways and coastlines?
- How close the launch sites with nearby cities?

Build a Dashboardwith Plotly Dash

- We built an interactive dashboard with Plotly dash which allowing the user to play around with the data as they need.
- We plotted pie charts showing the total launchesby a certain sites.
- We then plotted scatter graph showing the relationship with Outcome and Payload Mass (Kg) for the different booster version.

Predictive Analysis(Classification)

Building the Model

- Load the dataset into NumPy and Pandas
- Transform the data and then split into training and test datasets
- Decide which type of ML to use
- set the parameters and algorithms to GridSearchCV and fit it to dataset.

Evaluating the Model

- Check the accuracy for each model
- Get tuned hyperparameters for each type of algorithms.
- plot the confusion matrix.

Improving the Model

- Use Feature Engineering and Algorithm Tuning

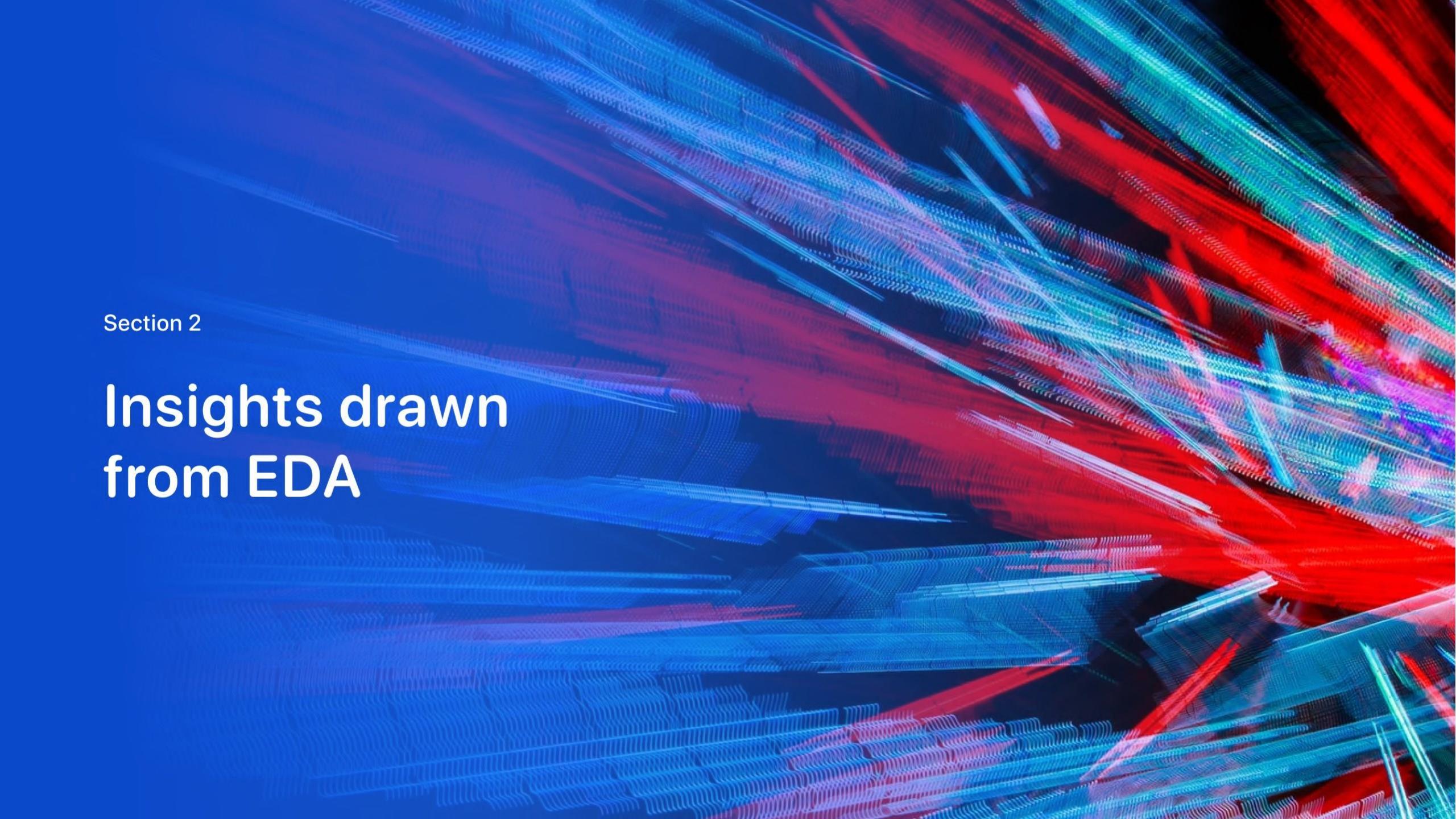
Find the Best Model

- The model with the best accuracy score will be the best performing model.

Results

The results will be categorized to 3 main results which is:

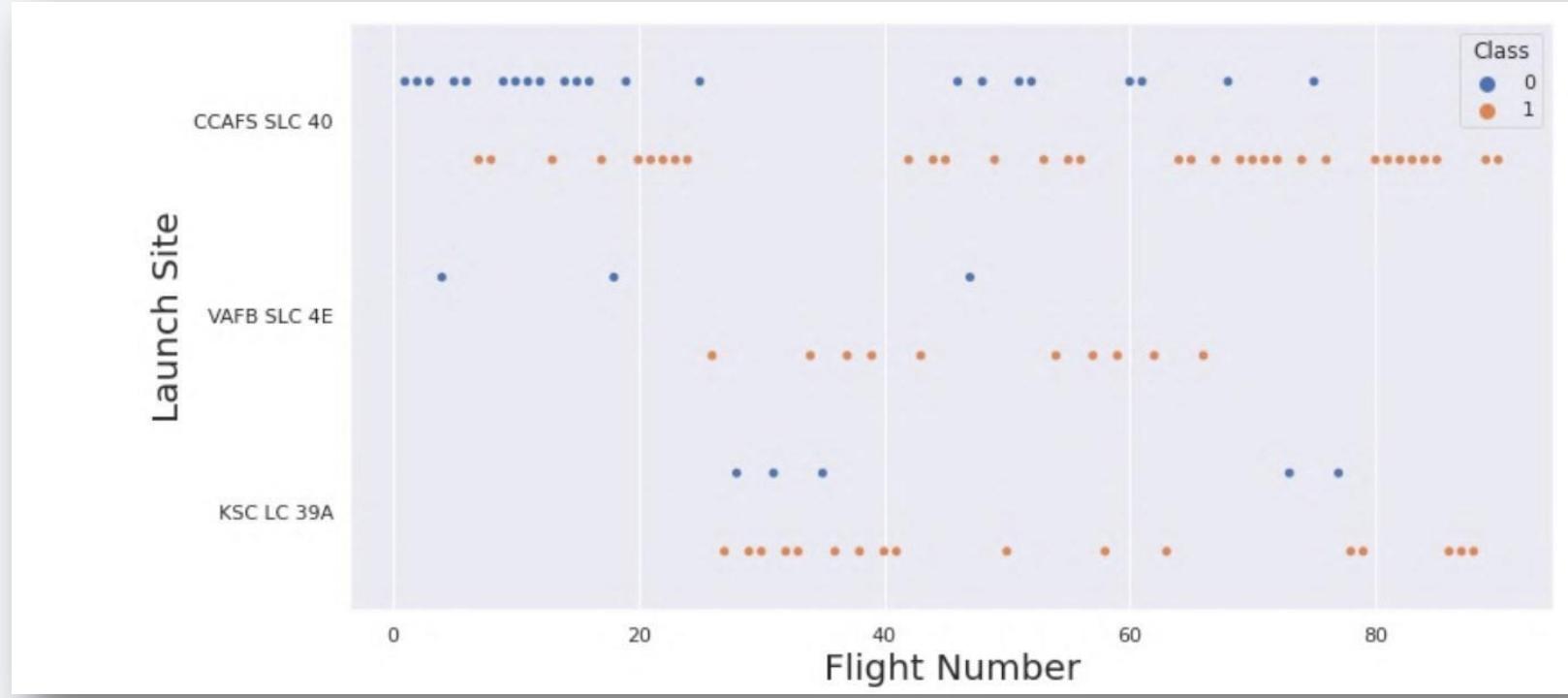
- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

The background of the slide features a complex, abstract pattern of glowing lines. These lines are primarily blue and red, creating a sense of depth and motion. They appear to be composed of numerous small, individual light points that form a continuous, flowing structure across the entire frame. The overall effect is reminiscent of a digital or quantum landscape.

Section 2

Insights drawn from EDA

Flight Number vs. Launch Site



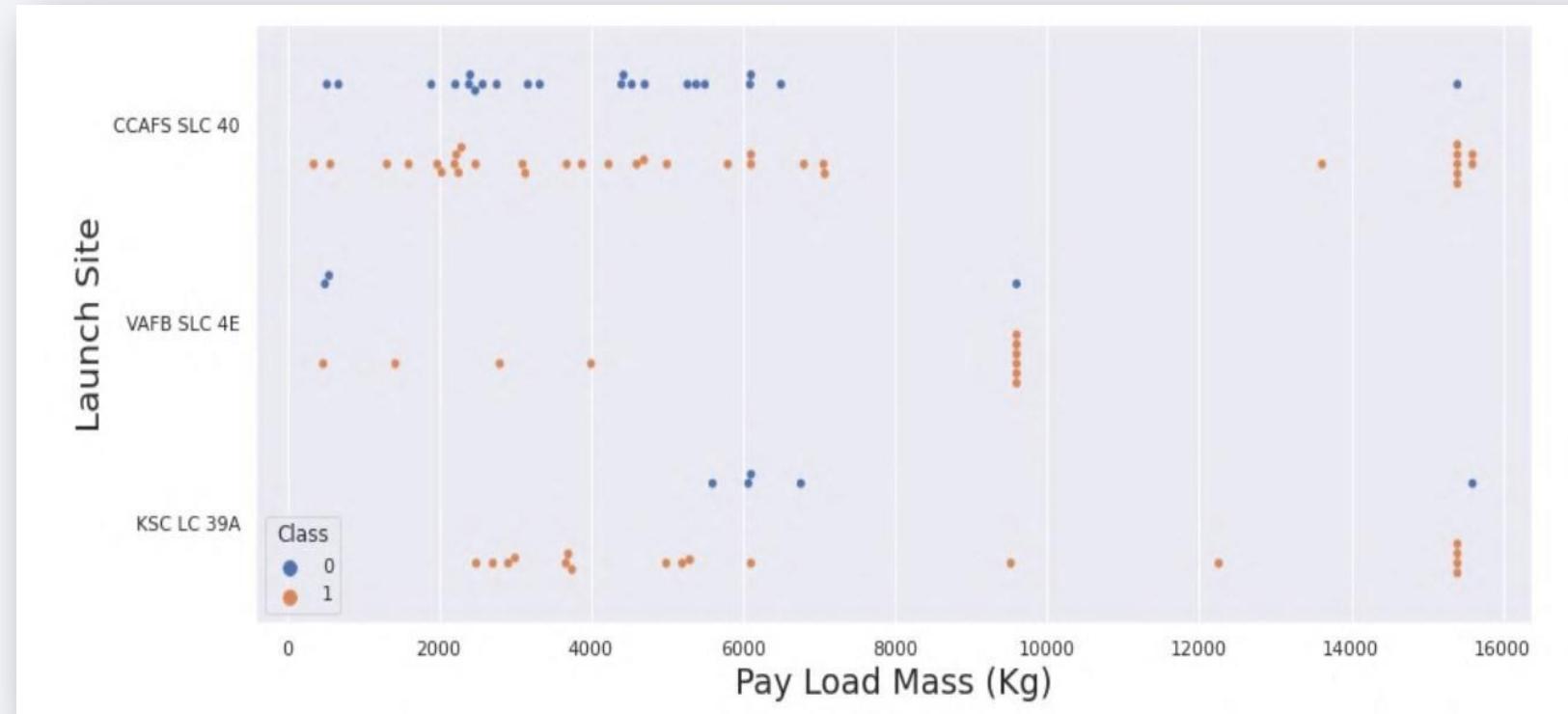
This scatter plot shows that the larger the flights amount of the launch site, the greater the success rate will be.

However, site CCAFS SLC40 shows the least pattern of this.

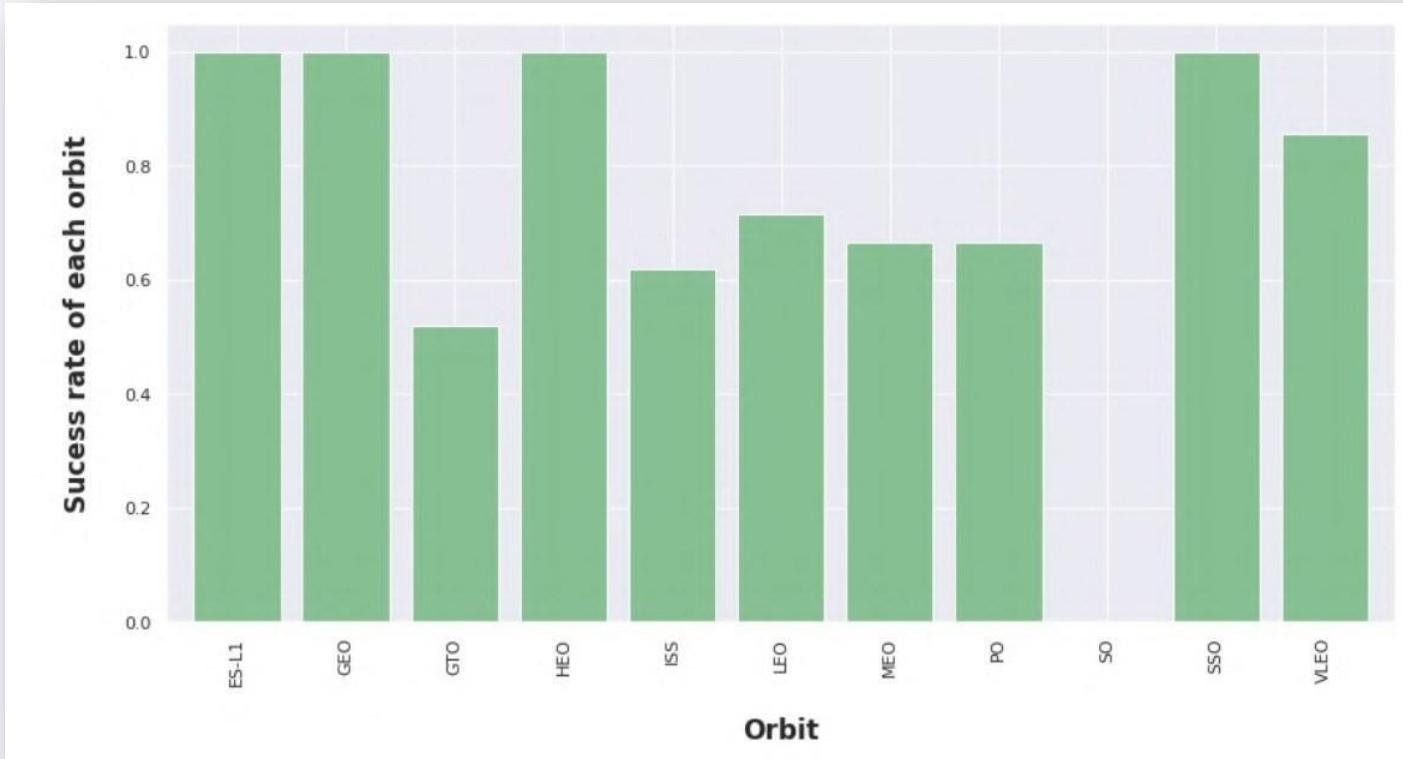
Payload vs. Launch Site

This scatter plot shows once the pay load mass is greater than 7000kg, the probability of the success rate will be highly increased.

However, there is no clear pattern to say the launch site is dependent to the pay load mass for the success rate.



Success Rate vs. Orbit Type



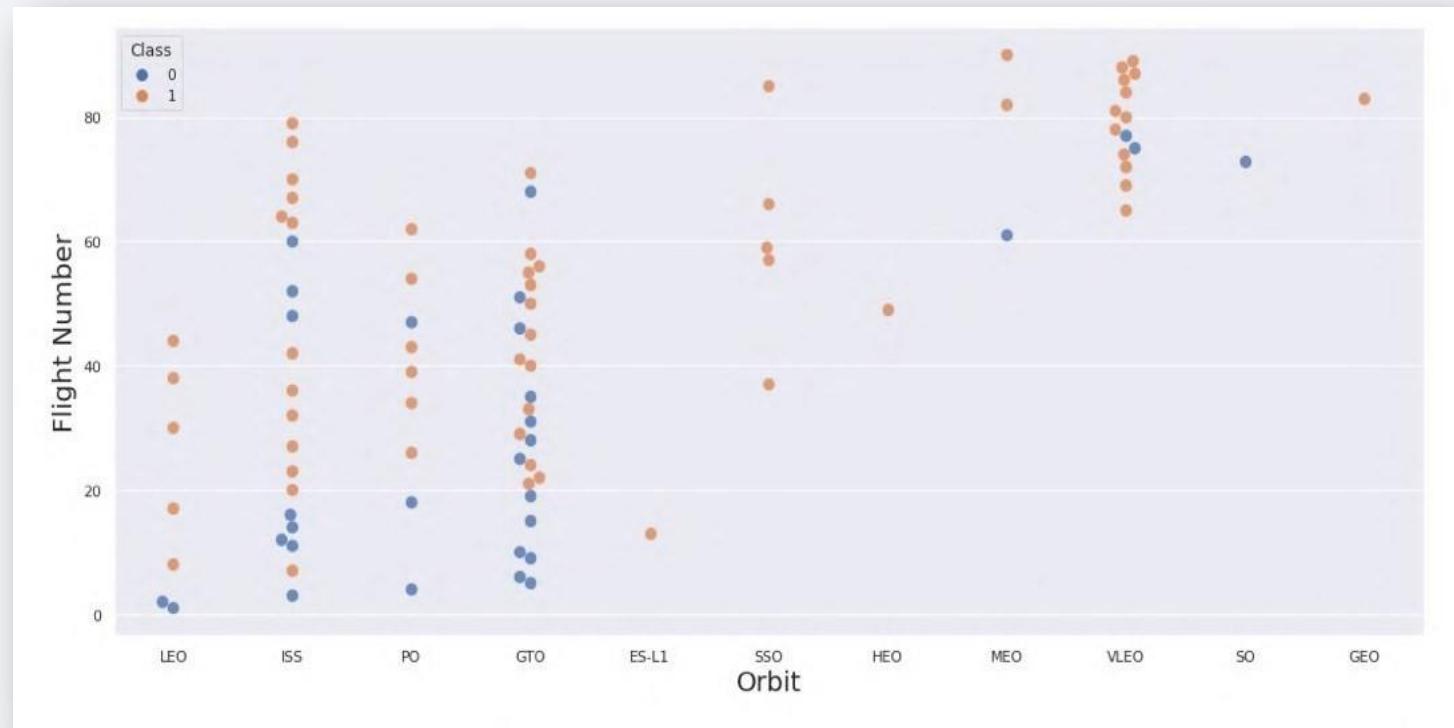
This figure depicted the possibility of the orbits to influences the landing outcomes as some orbits has 100% success rate such as SSO, HEO, GEO AND ES-L1 while SO orbit produced 0% rate of success.

However, deeper analysis show that some of this orbits has only 1 occurrence such as GEO, SO, HEO and ES-L1 which mean this data need more dataset to see pattern or trend before we draw any conclusion.

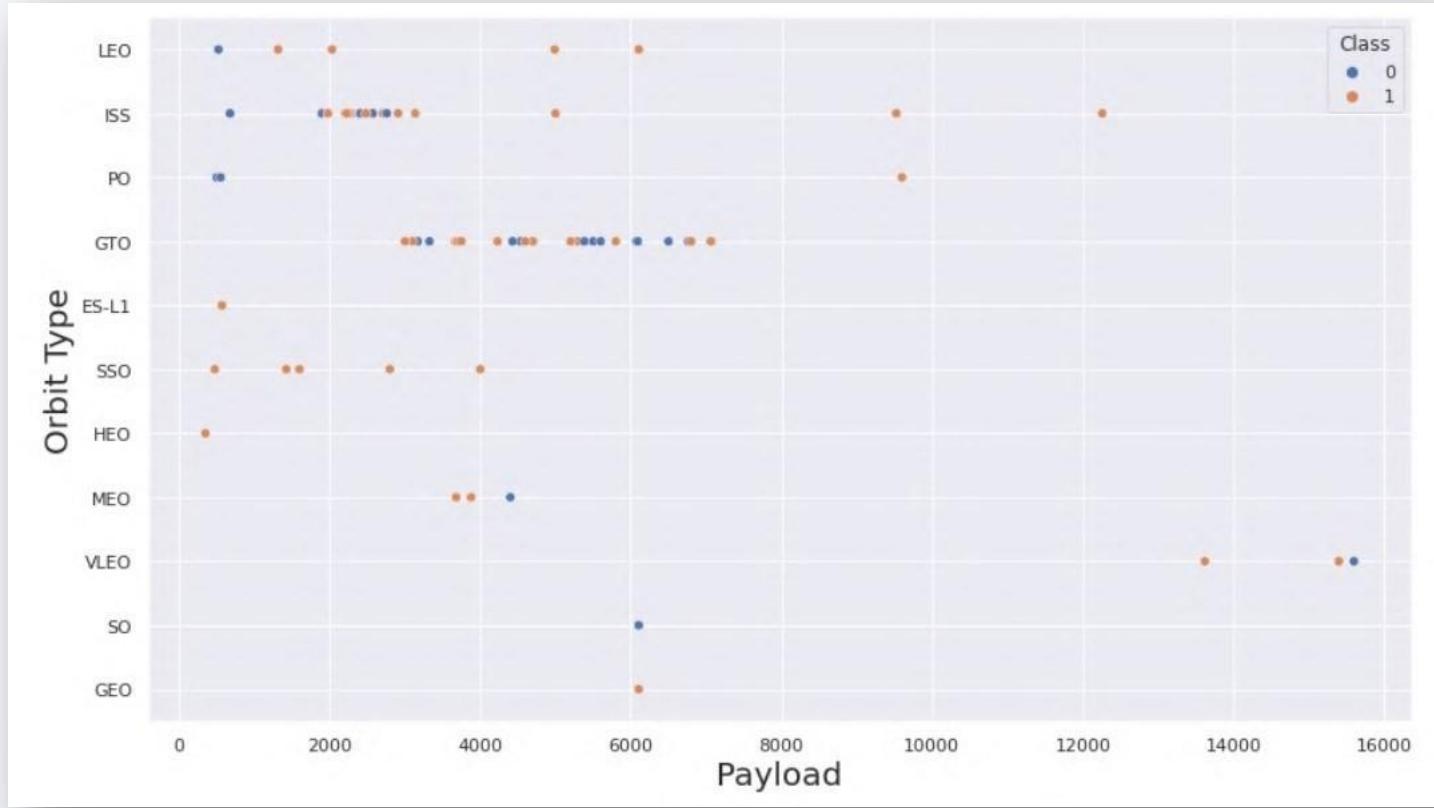
Flight Number vs. Orbit Type

This scatter plot shows that generally, the larger the flight number on each orbits, the greater the success rate (especially LEO orbit) except for GTO orbit which depicts no relationship between both attributes.

Orbit that only has 1 occurrence should also be excluded from above statement as it's needed more dataset.



Payload vs. Orbit Type



Heavier payload has positive impact on LEO, ISS and P0 orbit. However, it has negative impact on MEO and VLEO orbit.

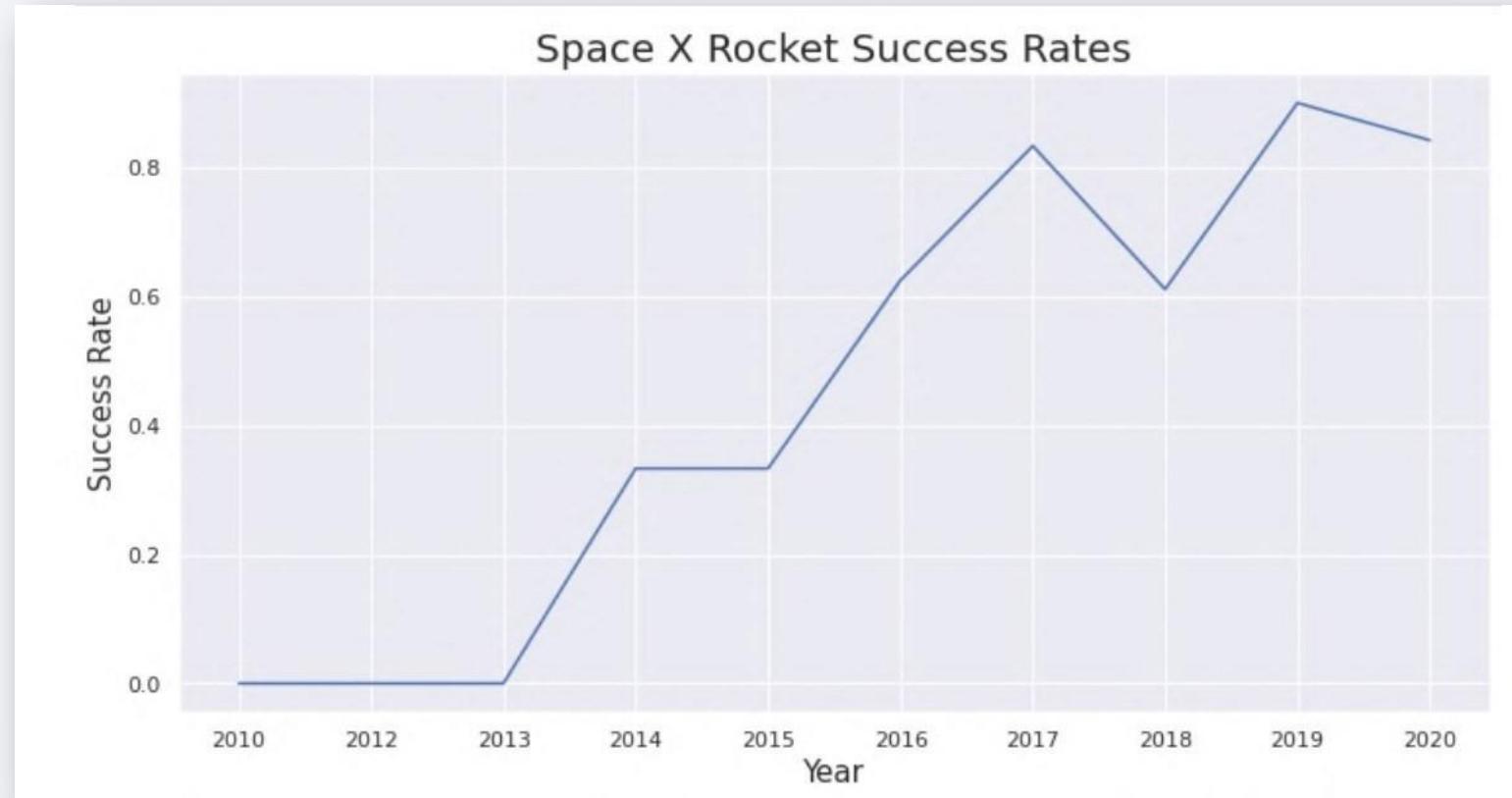
GTO orbit seems to depict no relation between the attributes.

Meanwhile, again, SO, GEO and HEO orbit need more dataset to see any pattern or trend.

Launch Success Yearly Trend

This figures clearly depicted and increasing trend from the year 2013 until 2020.

If this trend continue for the next year onward. The success rate will steadily increase until reaching 1/100% success rate.



All LaunchSite Names

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

In [5]:

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

* ibm_db_sa://zpw86771:***@fdb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3
sd0tgtu0lqde00.databases.appdomain.cloud:32731/bludb
Done.

Out[5]: [Launch_Sites](#)

CCAFS LC-40

CCAFS SLC-40

KSC LC-39A

VAFB SLC-4E

LaunchSite Names Begin with 'CCA'

We used the query above to display 5 records where launch sites 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 |

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)

```
%sql SELECT SUM(PAYLOAD_MASS__KG_) AS "Total Payload Mass by NASA (CRS)
```

```
* ibm_db_sa://zpw86771:***@fbdb88901-ebdb-4a4f-a32e-9822b9fb237b.c1ogj3  
sd0tgtu0lqde00.databases.appdomain.cloud:32731/bludb  
Done.
```

Total Payload Mass by NASA (CRS)

45596

Average Payload Mass by F9 v1.1

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

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

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

```
* ibm_db_sa://zpw86771:***@fb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3  
sd0tgtu0lqde00.databases.appdomain.cloud:32731/bludb  
Done.
```

Average Payload Mass by Booster Version F9 v1.1

2928

First Successful Ground Landing Date

We use the min() function to find the result

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

```
%sql SELECT MIN(DATE) AS "First Successful Landing Outcome in Ground Pad"
WHERE LANDING_OUTCOME = 'Success (ground pad)';
```

```
* ibm_db_sa://zpw86771:****@fbd88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3
sd0tgtu0lqde00.databases.appdomain.cloud:32731/bludb
Done.
```

First Successful Landing Outcome in Ground Pad

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 SPACEX WHERE LANDING_OUTCOME = 'Success (drone ship)' \
AND PAYLOAD_MASS_KG_ > 4000 AND PAYLOAD_MASS_KG_ < 6000;

* ibm_db_sa://zpw86771:***@fdb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3sd0tgtu0lqde00.datab
ases.appdomain.cloud:32731/bludb
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 MissionOutcome was a successor a failure.

List the total number of successful and failure mission outcomes

```
%sql SELECT COUNT(MISSION_OUTCOME) AS "Successful Mission" FROM SPACEX WHERE MISSION_OUTCOME LIKE 'Success%';
```

```
* ibm_db_sa://zpw86771:***@fb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3sd0tgtu0lqde00.databases.appdomain.cloud:32731/bludb
Done.
```

Successful Mission

100

```
%sql SELECT COUNT(MISSION_OUTCOME) AS "Failure Mission" FROM SPACEX WHERE MISSION_OUTCOME LIKE 'Failure%';
```

```
* ibm_db_sa://zpw86771:***@fb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3sd0tgtu0lqde00.databases.appdomain.cloud:32731/bludb
Done.
```

Failure Mission

1

Boosters Carried Maximum Payload

```
%sql SELECT DISTINCT BOOSTER_VERSION AS "Booster Versions which carried the Maximum Payload Mass" FROM SPACEX  
WHERE PAYLOAD_MASS_KG_ =(SELECT MAX(PAYLOAD_MASS_KG_) FROM SPACEX);  
  
* ibm_db_sa://zpw86771:***@fdb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3sd0tgtu0lgde00.databases.appdomain.cloud:32731/bludb  
Done.  
  
Booster Versions which carried the Maximum Payload Mass  
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
```

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

2015 Launch Records

We used a combination 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 BOOSTER_VERSION, LAUNCH_SITE FROM SPACEX WHERE DATE LIKE '2015-%' AND \
LANDING_OUTCOME = 'Failure (drone ship)';

* ibm_db_sa://zpw86771:***@fbdb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3sd0tgtu0lqde00.
databases.appdomain.cloud:32731/bludb
Done.

booster_version    launch_site
-----  -----
F9 v1.1 B1012    CCAFS LC-40
F9 v1.1 B1015    CCAFS LC-40
```

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

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

```
* ibm_db_sa://zpw86771:***@fb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3sd0tgtu01qde00.databases.appdomain.cloud:32731/bludb
Done.
```

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

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.

The background of the slide is a photograph taken from space at night. It shows the curvature of the Earth against the dark void of space. City lights are visible as numerous glowing yellow and white spots, primarily concentrated in the lower right quadrant where the United States appears. The atmosphere is visible as a thin blue layer, and there are wispy white clouds scattered across the dark blue surface of the planet.

Section 4

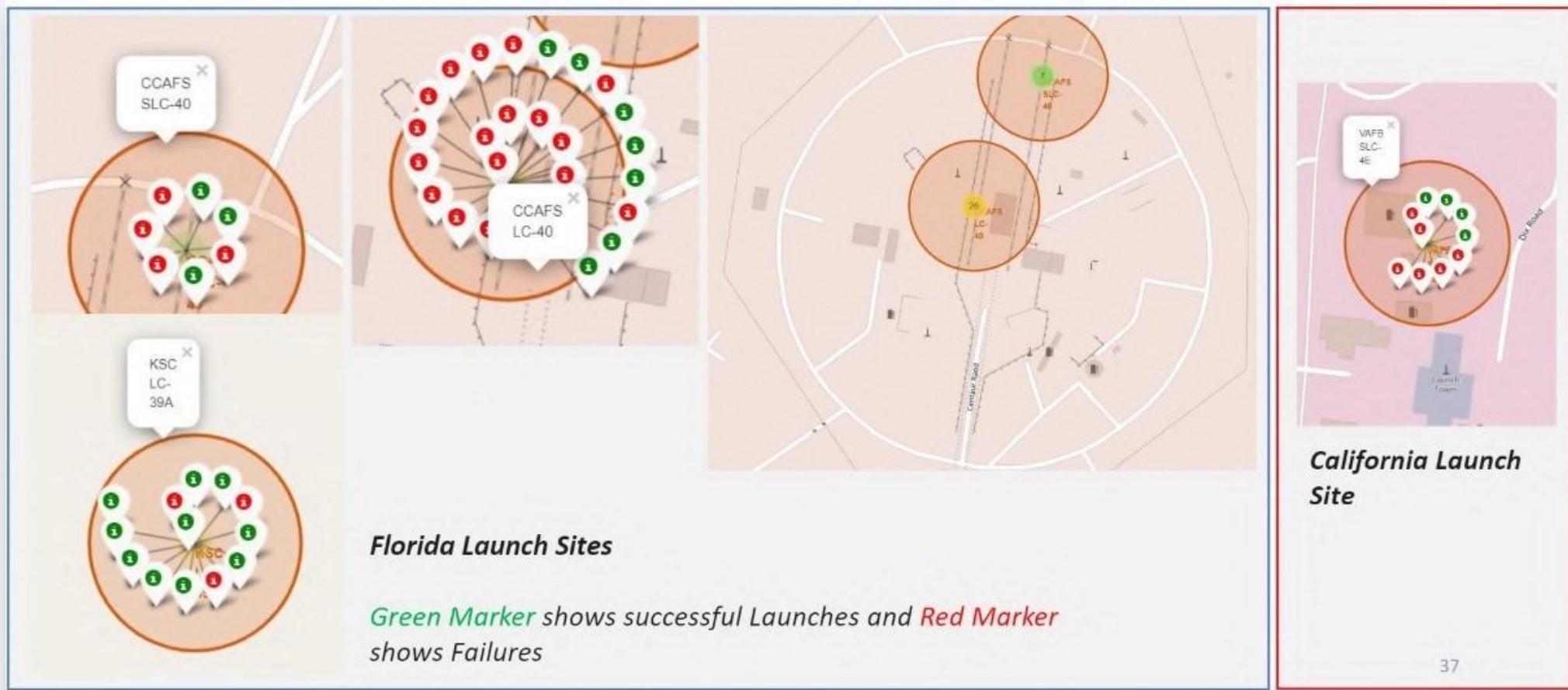
Launch Sites Proximities Analysis

Location of all the Launch Sites

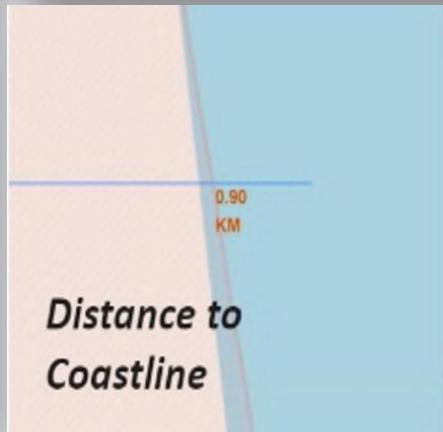
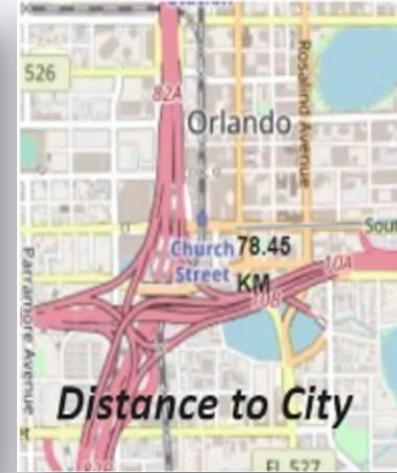


We can see that all the SpaceX launch sites are located inside the United States

Markers showing launch sites with color labels



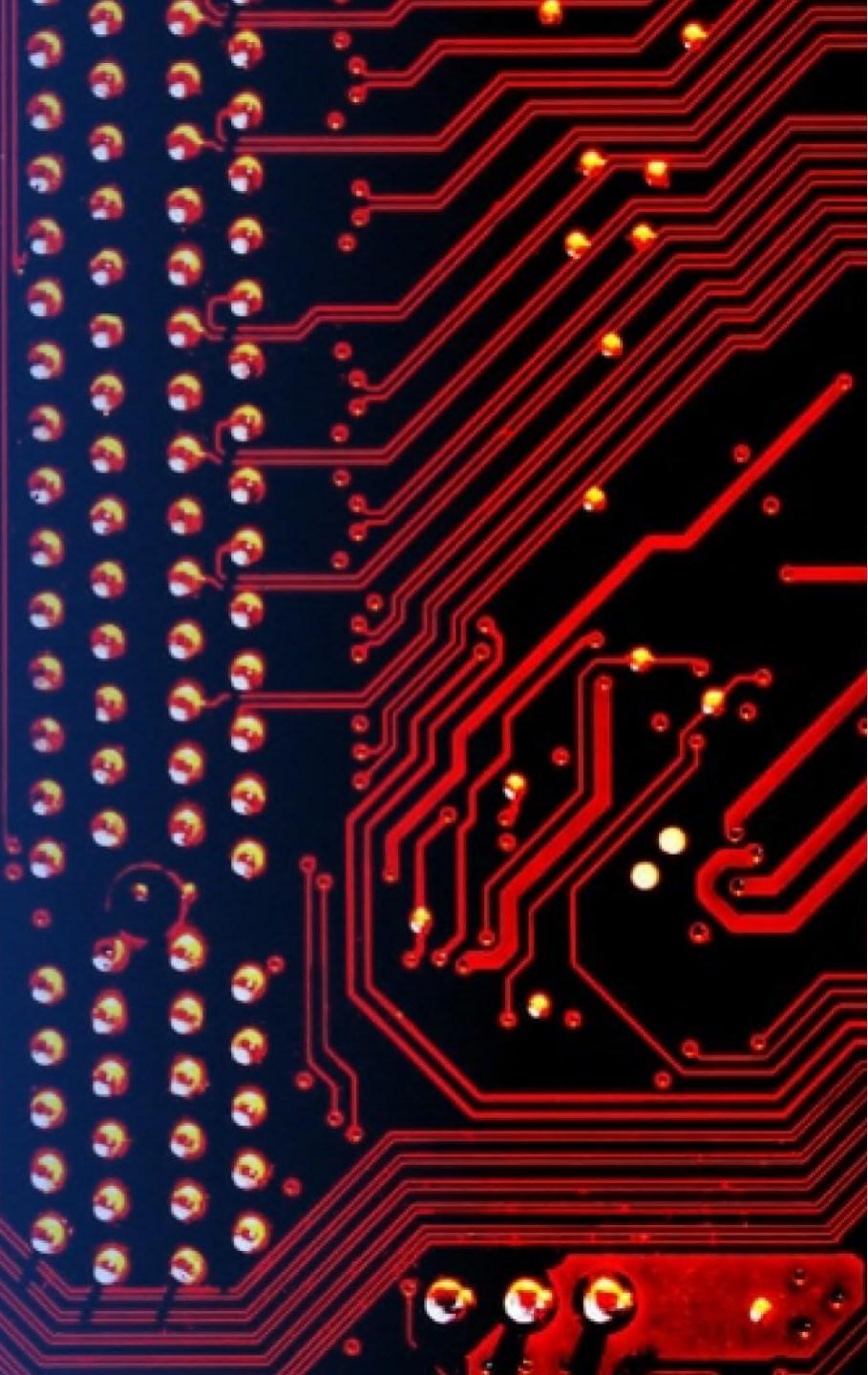
Launch Sites Distance to Landmarks



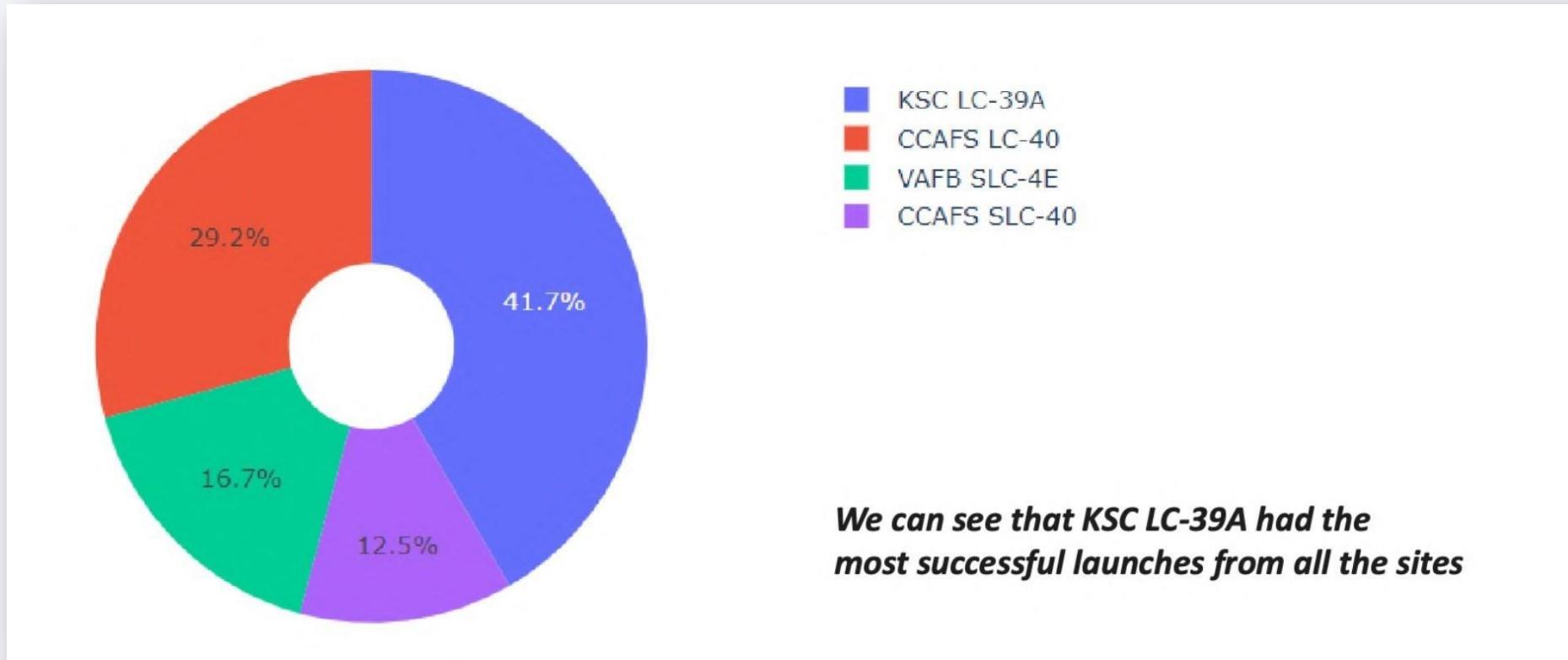
- Are launch sites in close proximity to railways? No
- Are launch sites in close proximity to highways? No
- Are launch sites in close proximity to coastline? Yes
- Do launch sites keep certain distance away from cities? Yes

Section 5

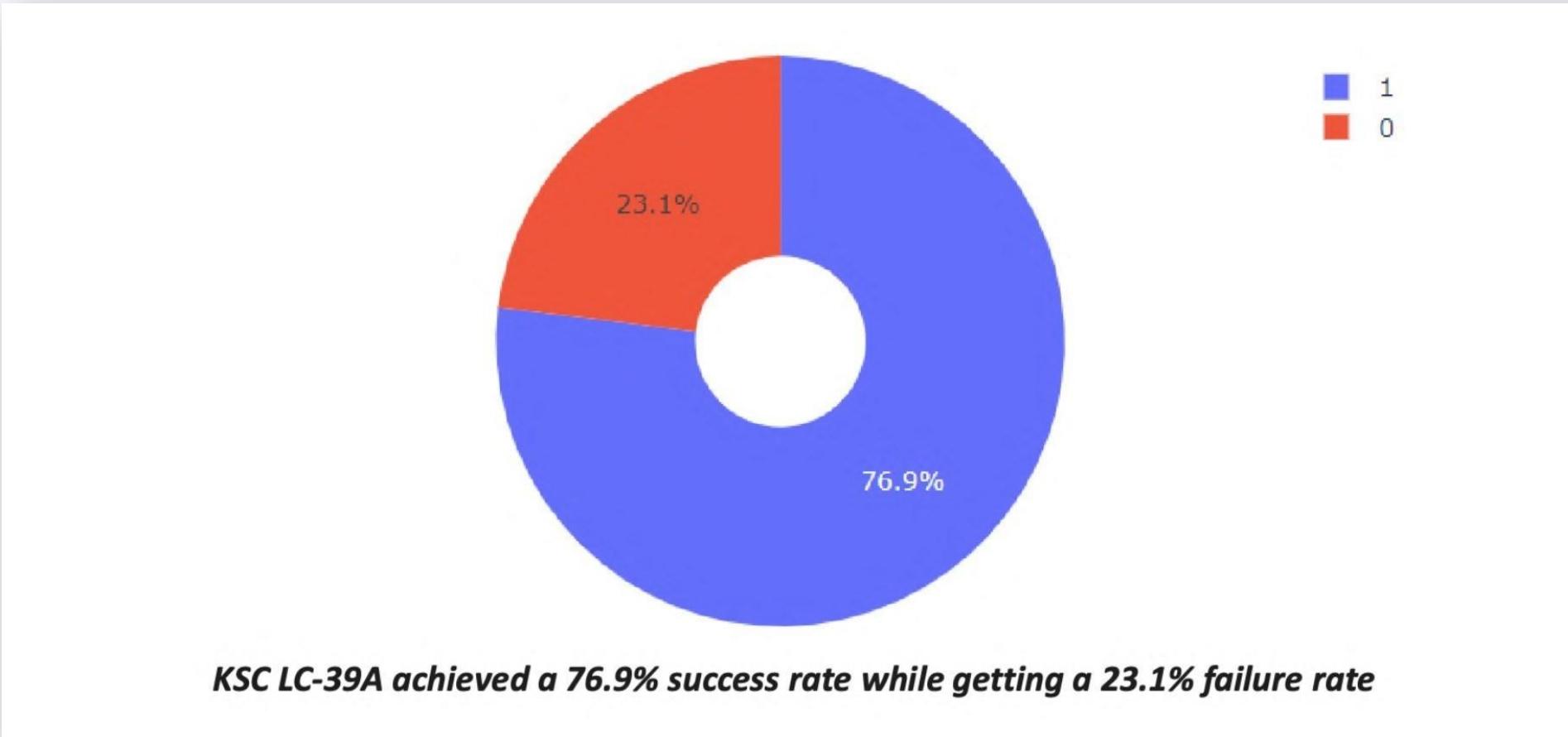
Build a Dashboard with Plotly Dash



The success percentage by each sites.

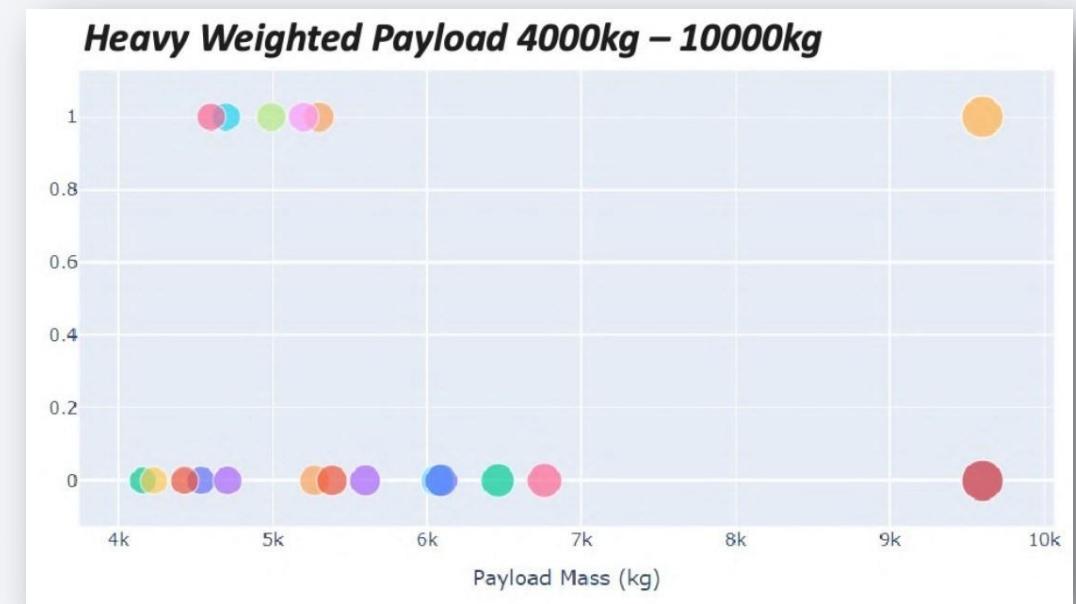
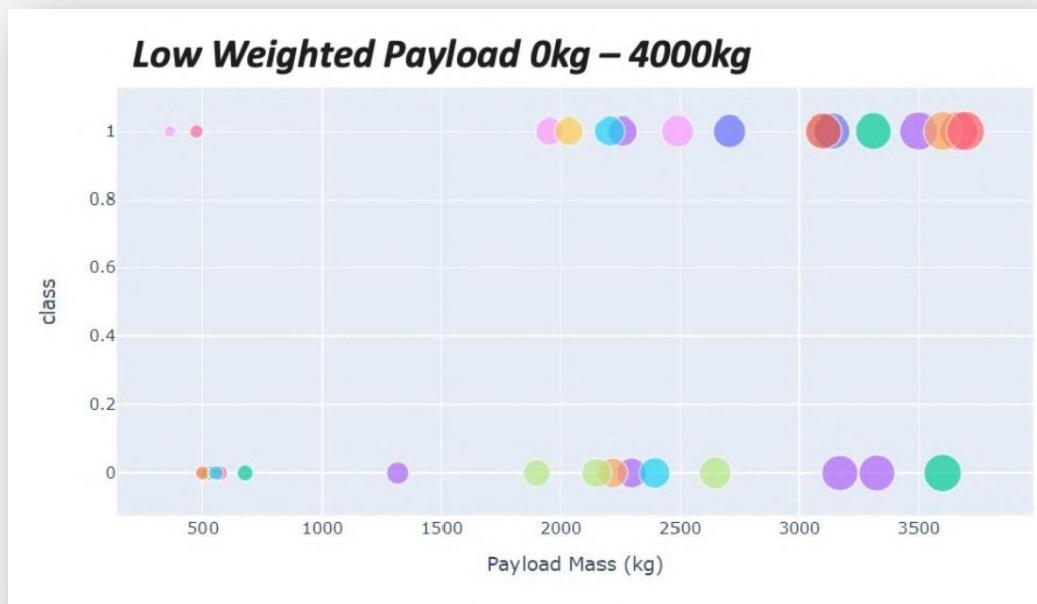


The highest launch-success ratio: KSCLC-39A



Payload vs Launch Outcome Scatter Plot

We can see that all the success rate for low weighted payload is higher than heavy weighted payload



Section 6

Predictive Analysis (Classification)

Classification Accuracy

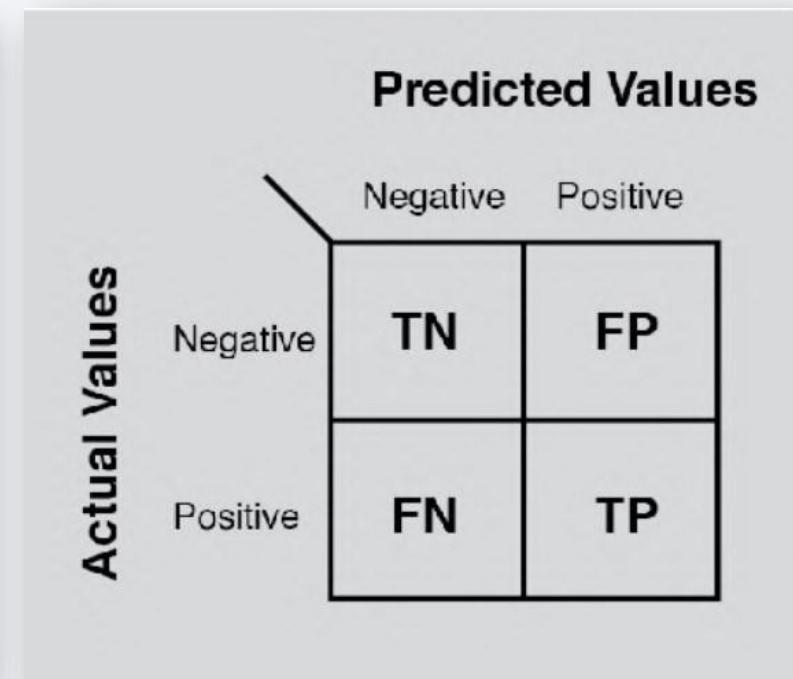
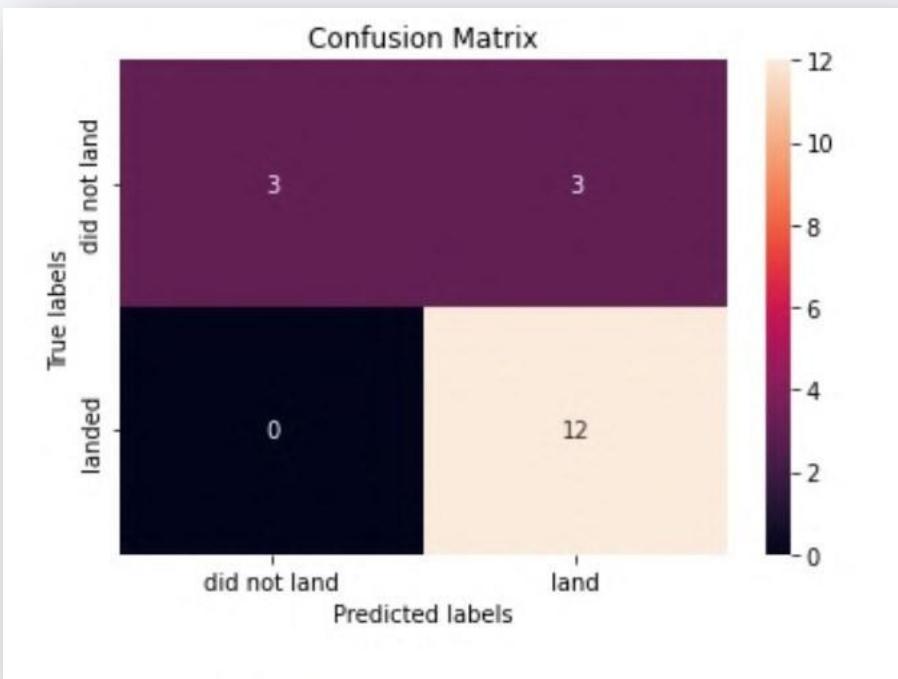
As we can see, by using the code as below: we could identify that the best algorithm to be the TreeAlgorithm which have the highest classification accuracy.

```
algorithms = {'KNN':knn_cv.best_score_,'Tree':tree_cv.best_score_, 'LogisticRegression':logreg_cv.best_score_}
bestalgorithm = max(algorithms, key=algorithms.get)
print('Best Algorithm is',bestalgorithm,'with a score of',algorithms[bestalgorithm])
if bestalgorithm == 'Tree':
    print('Best Params is :',tree_cv.best_params_)
if bestalgorithm == 'KNN':
    print('Best Params is :',knn_cv.best_params_)
if bestalgorithm == 'LogisticRegression':
    print('Best Params is :',logreg_cv.best_params_)
```

```
Best Algorithm is Tree with a score of 0.9017857142857142
Best Params is : {'criterion': 'entropy', 'max_depth': 10, 'max_features': 'auto', 'min_samples_leaf': 2, 'min_samples_split': 10, 'splitter': 'random'}
```

Confusion Matrix

The confusion matrix for the decision tree classifiers 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 TreeClassifierAlgorithm is the best MachineLearning approach for this dataset.
- The low weighted payloads (which define as 4000 kg and below) performed better than the heavy weighted payloads.
- Starting from the year 2013, the success rate for SpaceX launches increased, directly proportional time in years to 2020, which it will eventually perfect the launches in the future.
- KSCLC-39A have the most successful launches of any sites; 76.9%
- SSOorbit have the most success rate; 100 % and more than 1 occurrence.

Appendix

This project has made use of the following softwares and libraries:

Programing: Python. SQL

Numpy and Scipy libraries

Sci-kit learn

Folium

Matplotlib, Plotly and Seaborn

Thank you!

