

IBM

Applied Data Science

Capstone project

Falcon 9 spaceX landing prediction



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Agenda

- 01** Executive summary
- 02** Introduction
- 03** Methodology
- 04** Results
- 05** Conclusion



01 EXECUTIVE SUMMARY

METHODOLOGY

1. Data Collection through API
2. Data Collection with Web Scrapping
3. Data Wrangling
4. EDA with SQL
5. EDA with Data Visualization
6. Interactive Visual Analytics with Folium
7. Machine Learning Prediction

RESULTS

1. Exploratory Data Analysis result
2. Interactive analytics in screenshots
3. Predictive Analytics result from Machine Learning Lab



02 INTRODUCTION

In this capstone, we will predict if the Falcon 9 first stage will land successfully. SpaceX 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 SpaceX 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 SpaceX for a rocket launch.

The problems included:

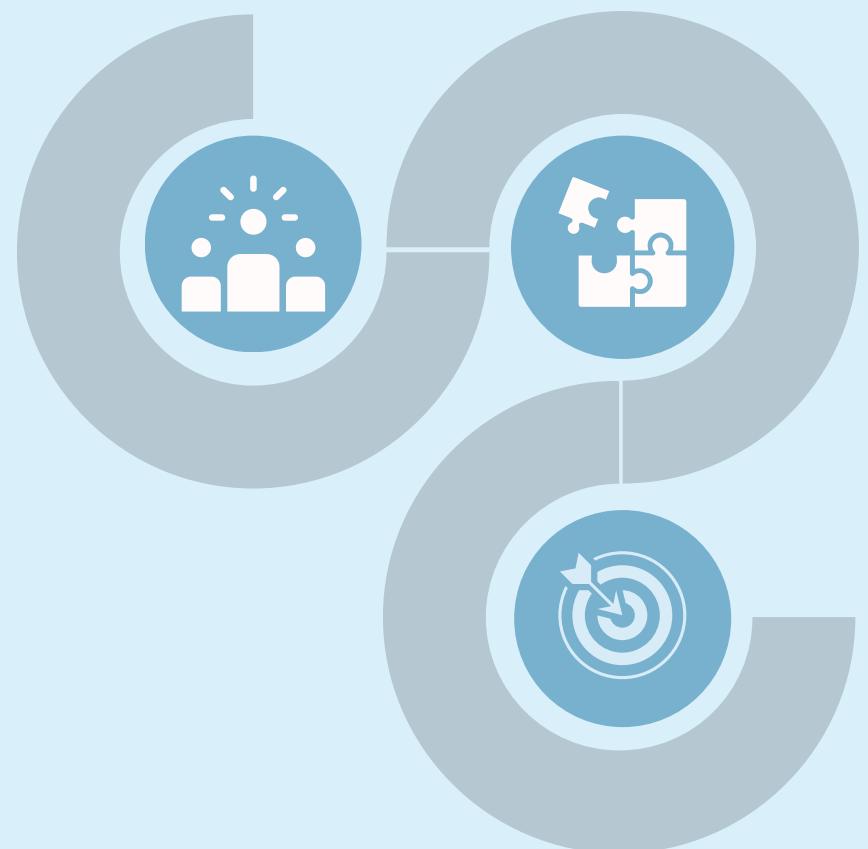
1. Identifying all factors that influence the landing outcome.
2. The relationship between each variables and how it is affecting the outcome.
3. The best condition needed to increase the probability of successful landing.



03 METHODOLOGY

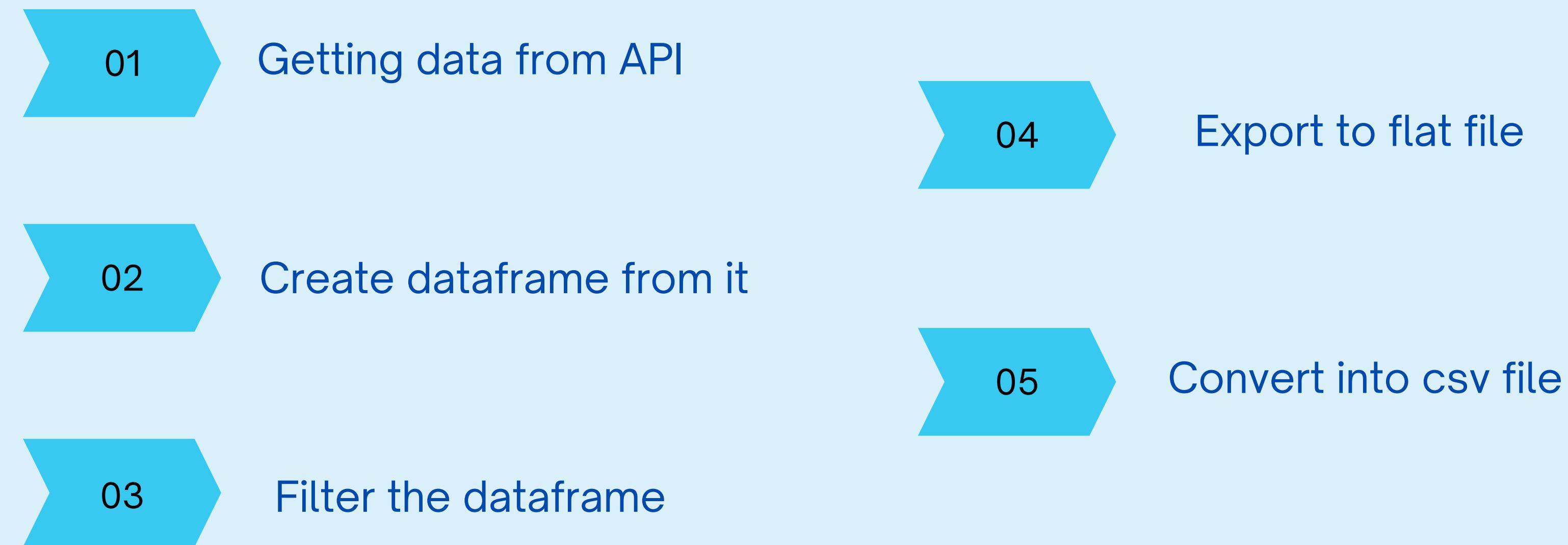
EXECUTIVE SUMMARY

- **Data collection :**
SpaceX REST API and web scrapping from Wikipedia
- **Data wrangling :**
Using one-hot encoding for categorical features
- **Exploratory data analysis (EDA):**
Using visualization and SQL
- **Interactive visual analytics:**
Using Folium and Plotly Dash
- **Predictive analysis:**
Using classification models
- **To build, tune, evaluate classification models**



Data collection

Data collection is a process of gathering and measuring information on targeted variables in an established system, which then enables one to answer relevant questions and evaluate outcomes



Data Collection via SpaceX API

1

Get request for rocket launch data using API

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

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

2

Use json_normalize method to convert json result to dataframe

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

3

Performed data cleaning and filling the missing value

```
# 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 via webscraping

1

Getting response
from HTML

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

2

Creating a beautifulsoup
object

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

3

Extracting the columns
and creating a dataframe
to csv file

```
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
```

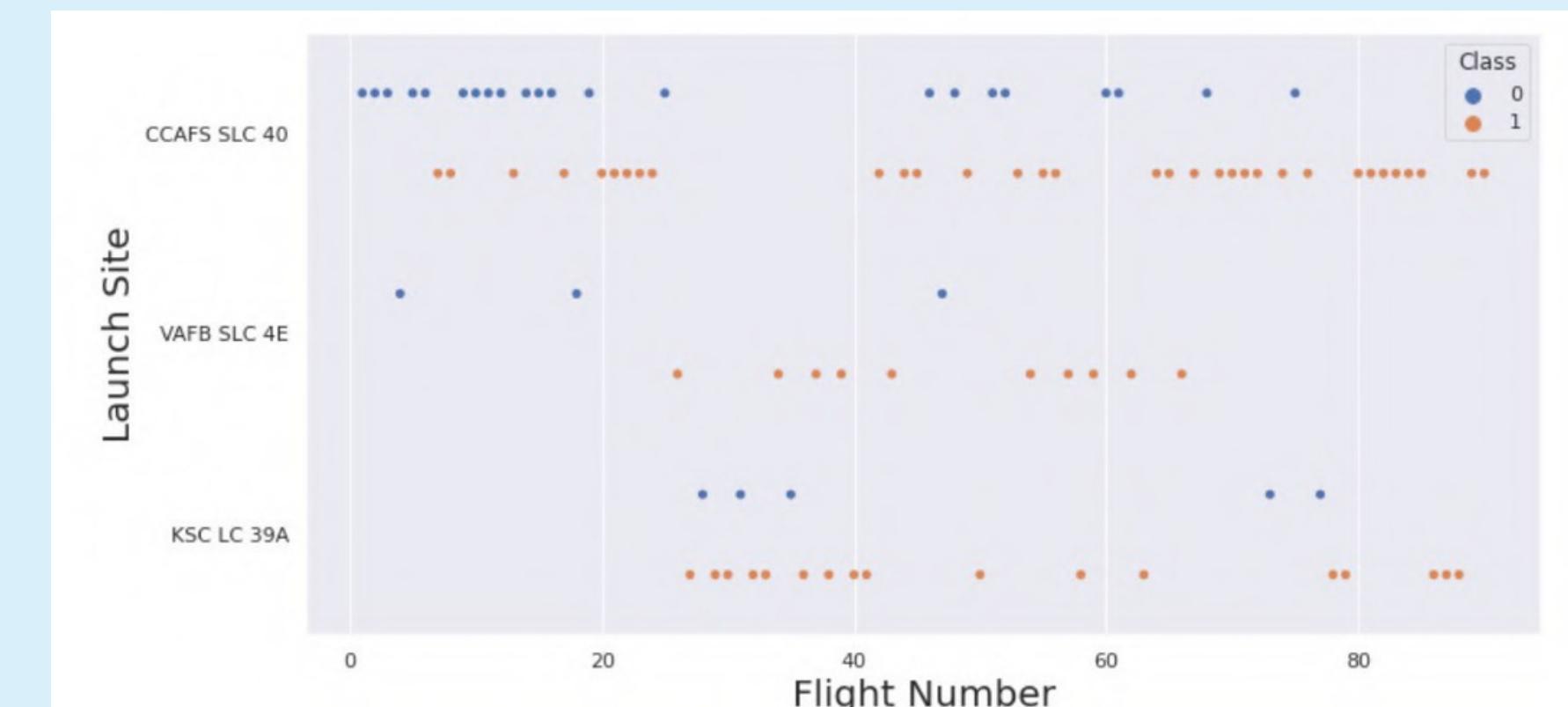
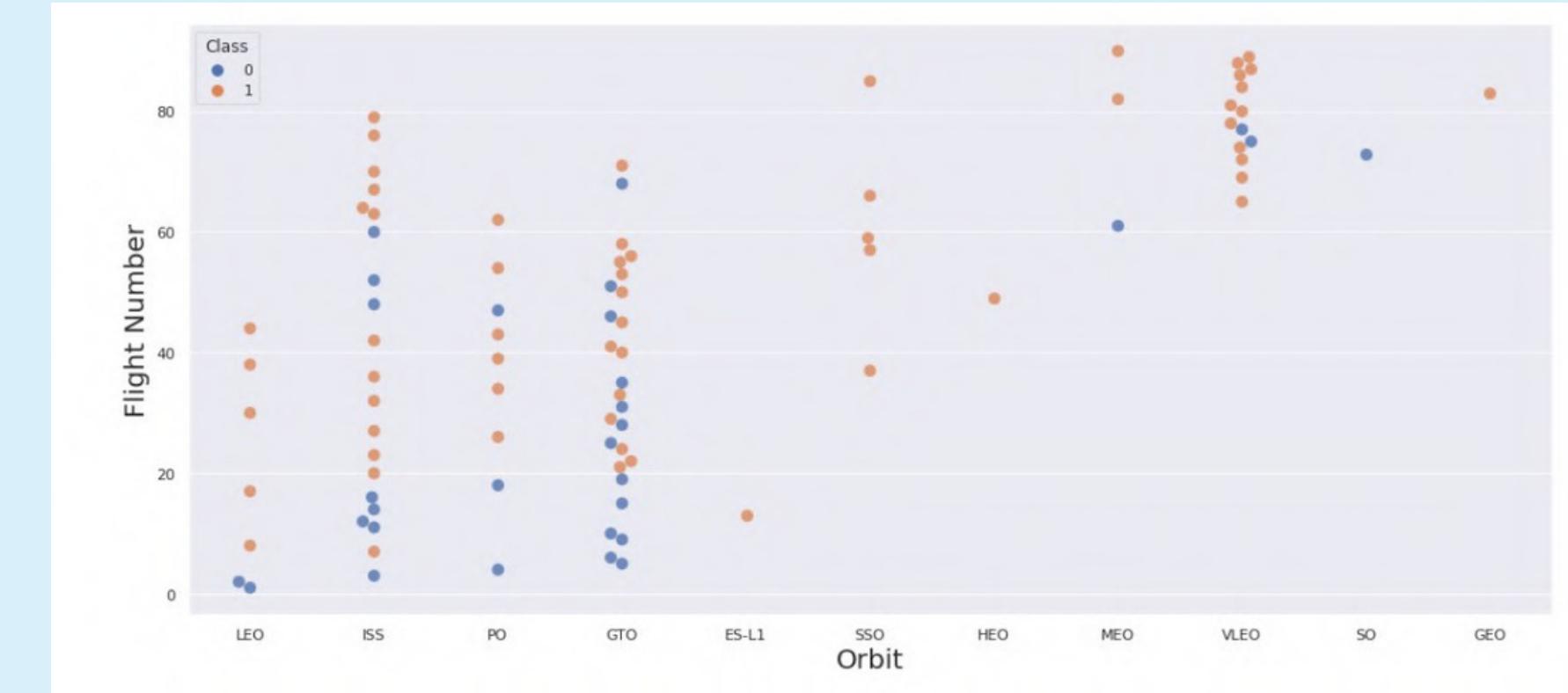
Data wrangling

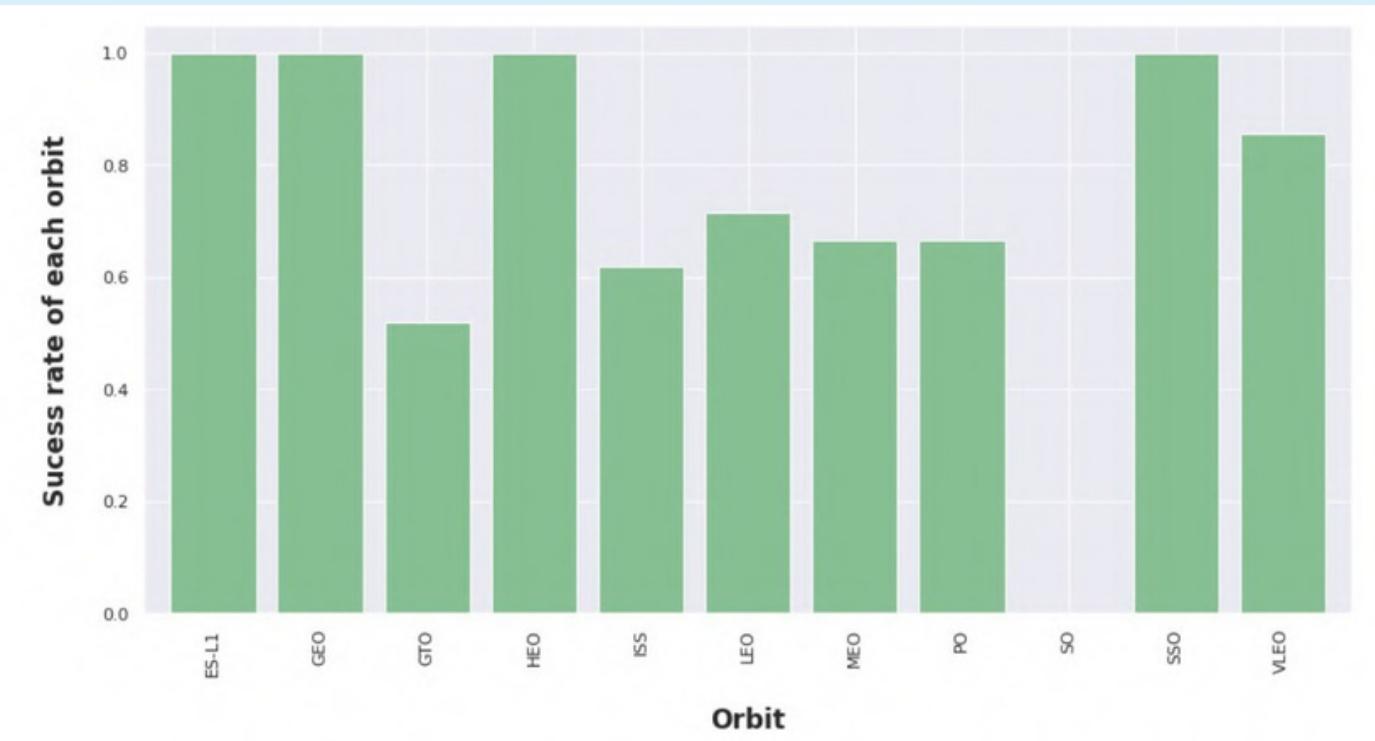
- Data Wrangling is the process of cleaning and unifying messy and complex data sets for easy access and Exploratory Data Analysis (EDA).
- We will first calculate the number of launches on each site, then calculate the number and occurrence of mission outcome per orbit type.
- We then create a landing 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 Matplotlib

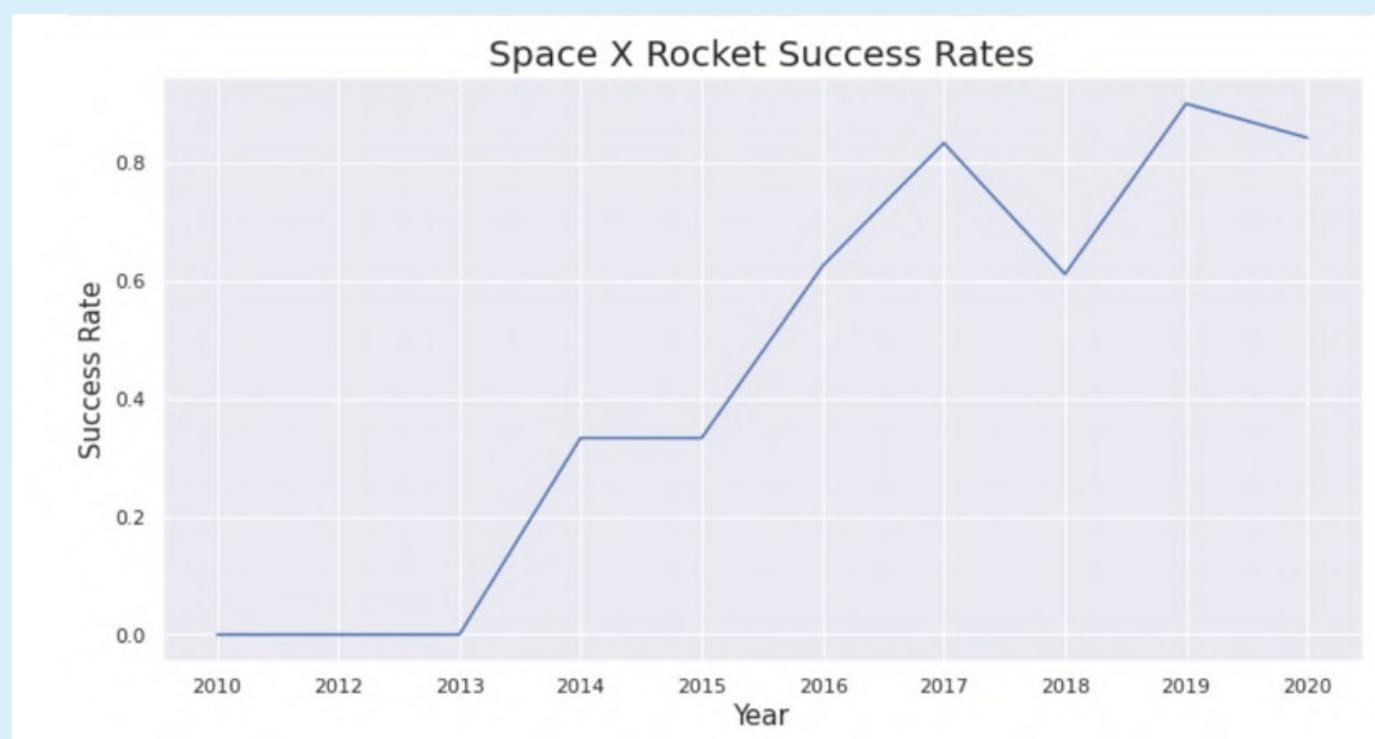
Using scatter graph to find the relationship between the attributes such as between:

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





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.

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.
- Listing the failed landing_outcomes in drone ship, their booster versions, and launch sites names for in year 2015.
- Rank the count of landing outcomes or success between the date 2010-06-04 and 2017-03-20, in descending order.

INTERACTIVE DASHBOARD

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()`.

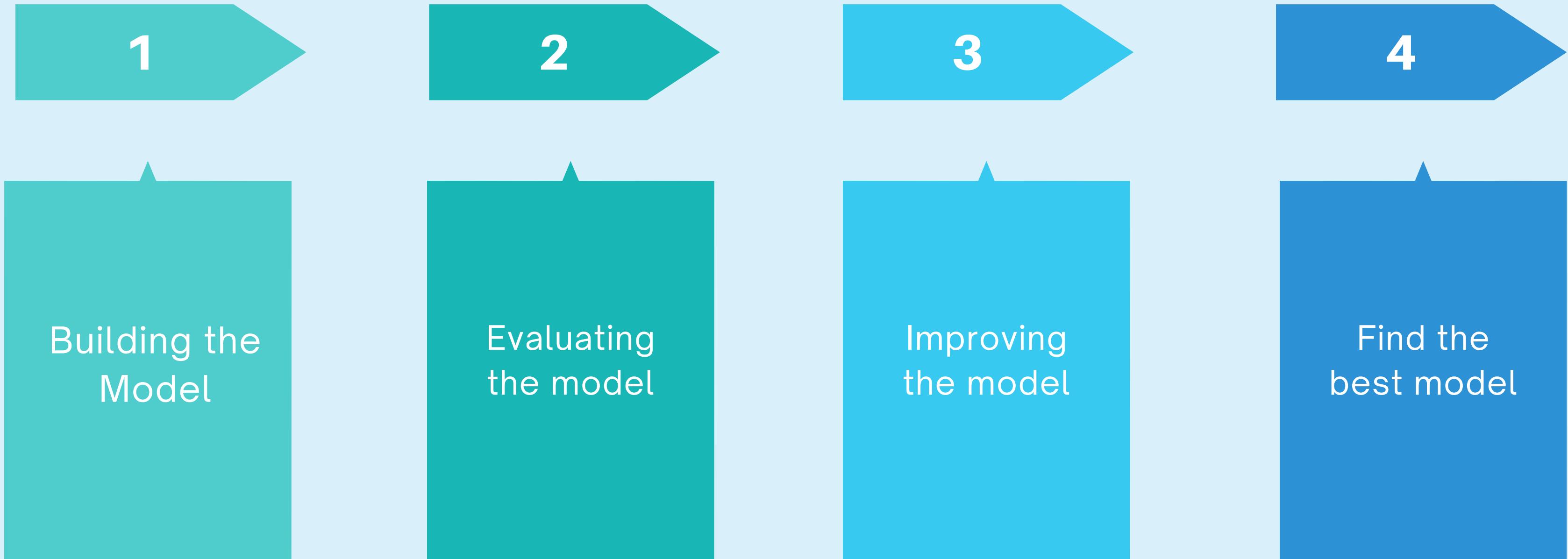
We then used the Haversine's formula to calculated the distance of the launch sites to various landmark to find answer to the questions of:

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

Build a Dashboard with 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 launches by a certain sites.
- We then plotted scatter graph showing the relationship with Outcome and Payload Mass (Kg) for the different booster version.

Predictive Analysis



Result

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

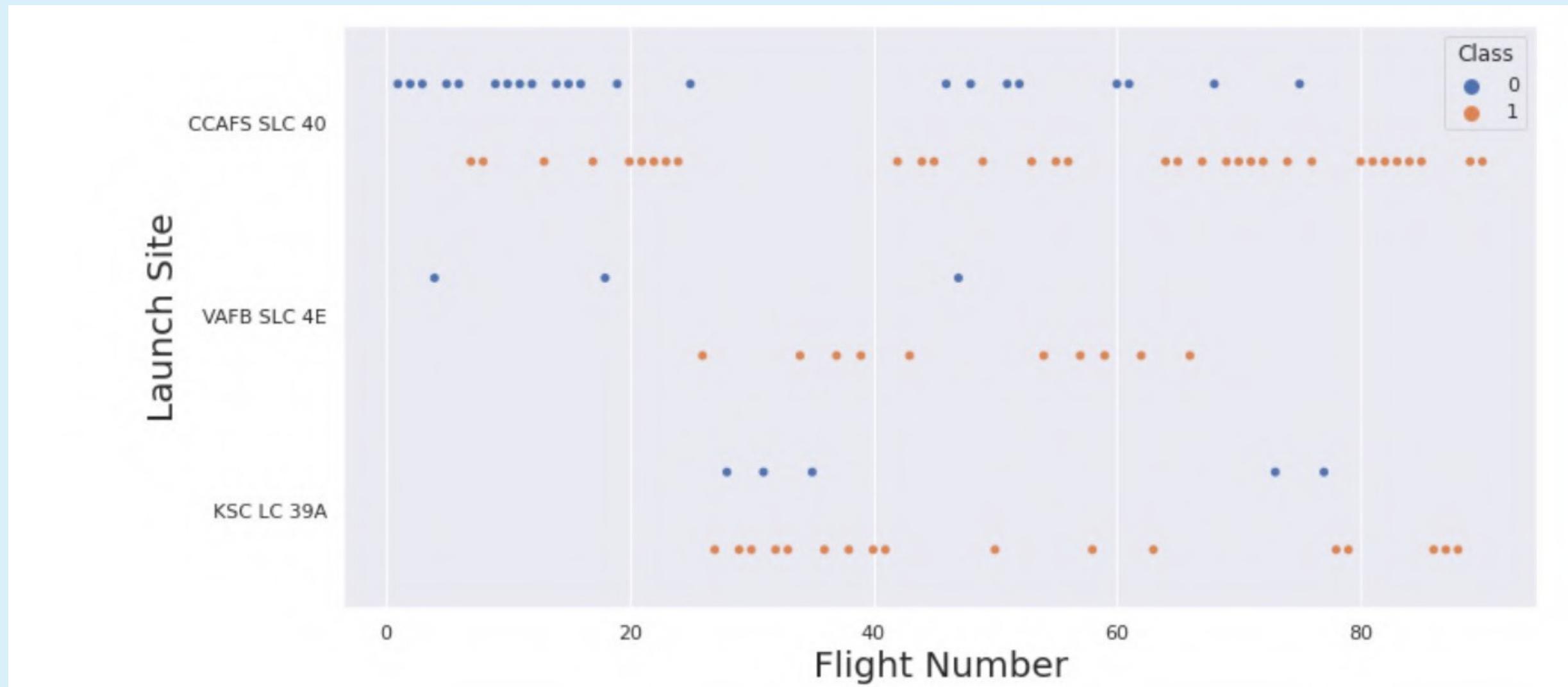
- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results





INSIGHTS DRAWN FROM EDA

Flight Number vs. Launch Site

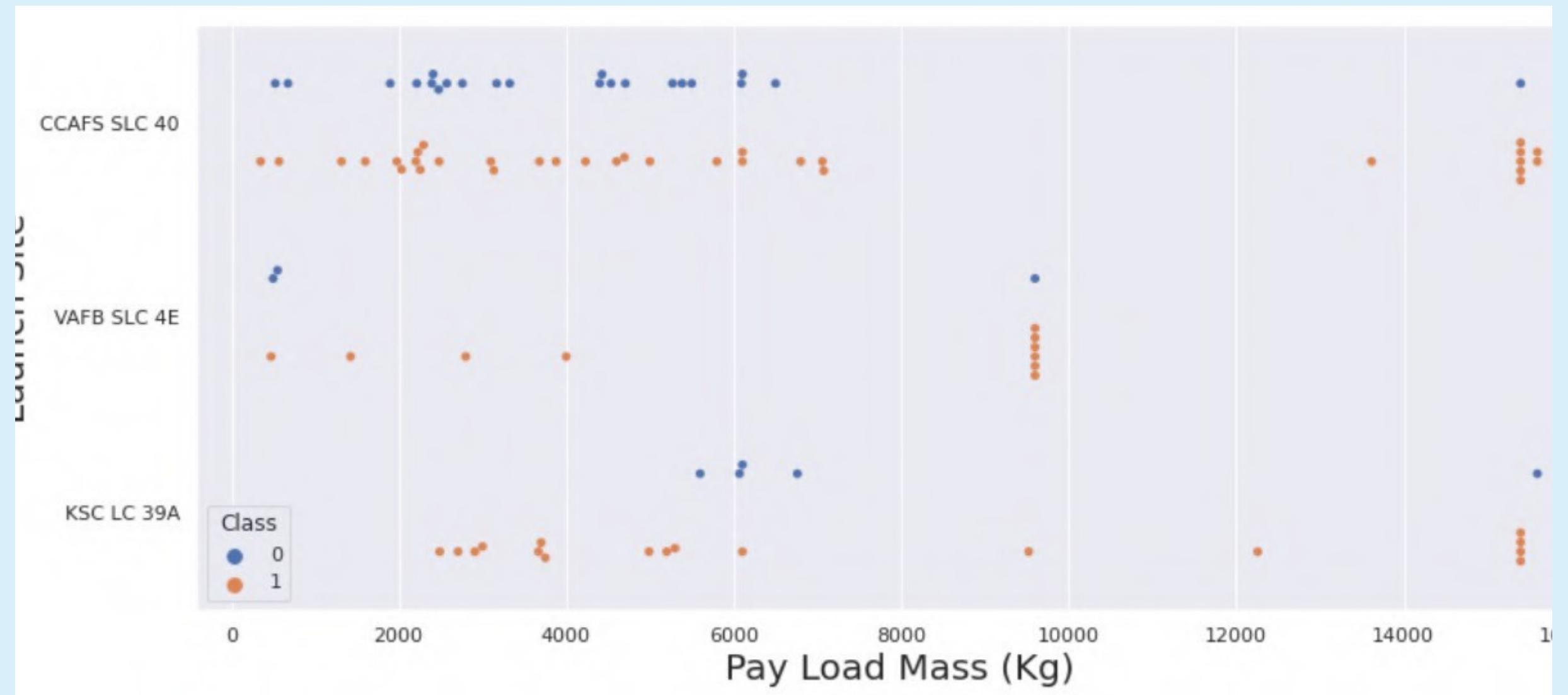


This scatter plot shows that the larger amount of the launch site, the greater the success rate will be. However, site CCAFS SLC40 shows the least pattern of this.

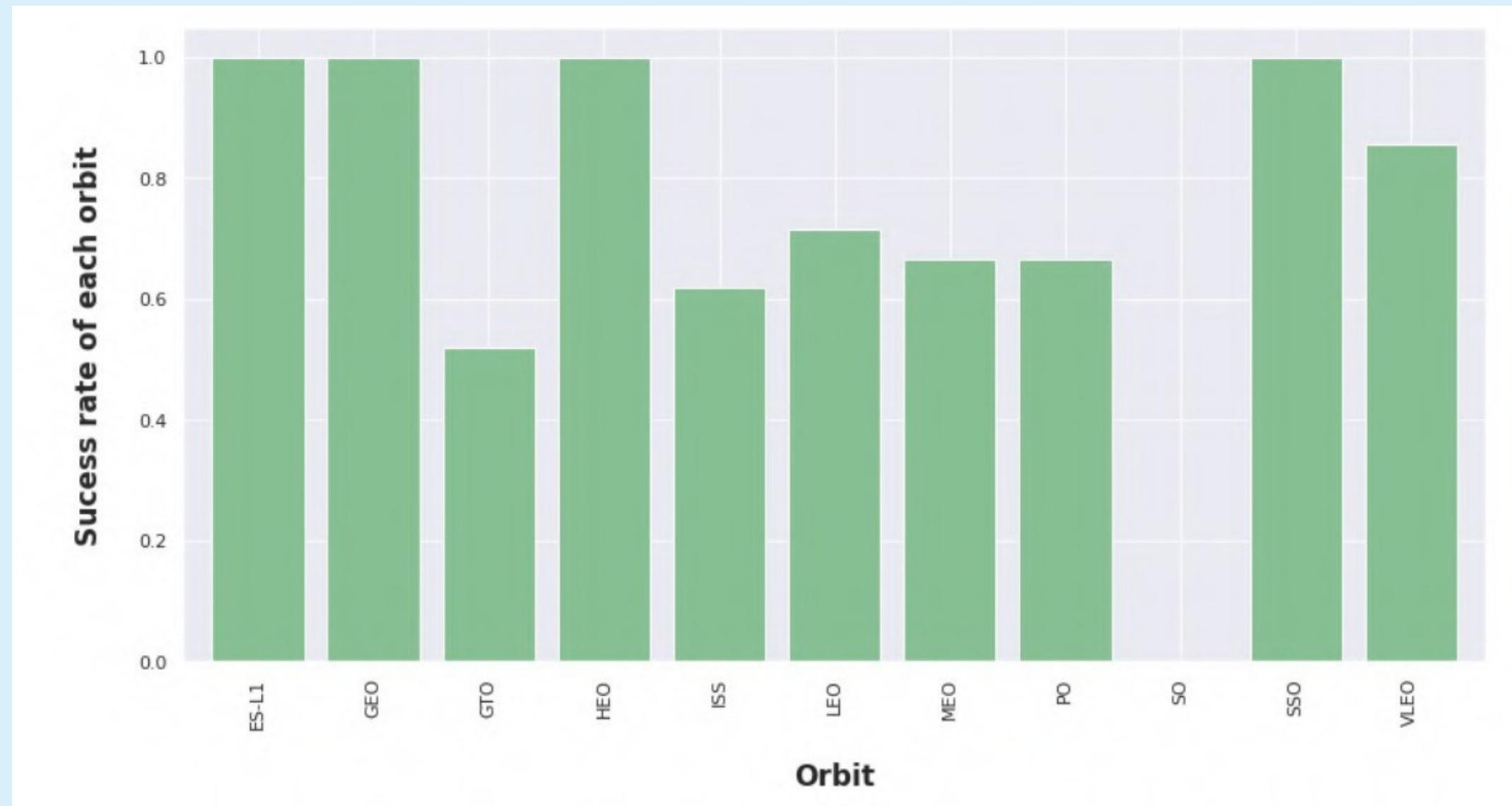
Payload vs. Launch Site

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

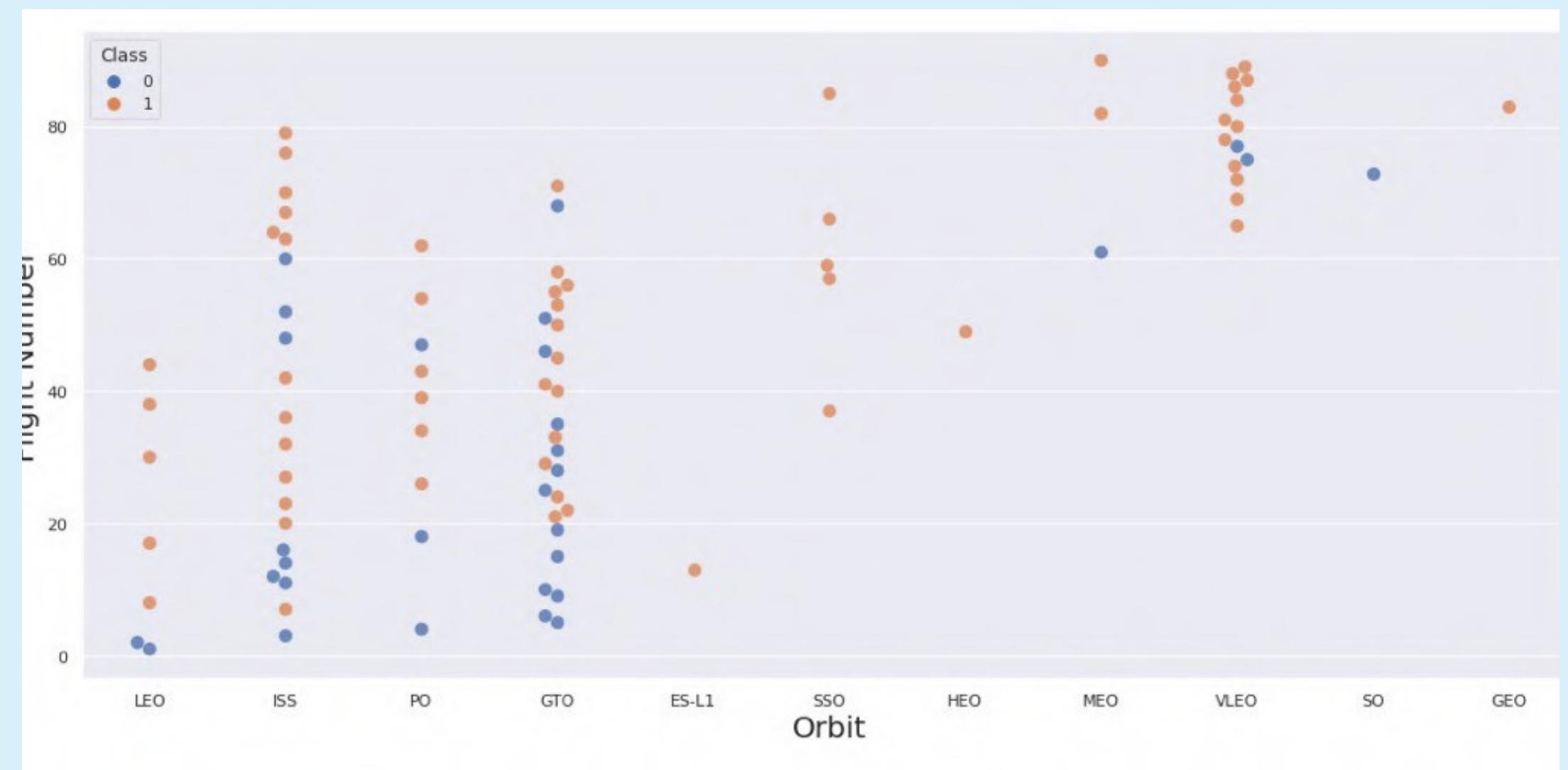


This figure depicted the possibility of the orbits to influences the landing outcomes as some orbits has 100% success rate such as SSO, HEO, GEO AND ES-L1 while SO orbit produced 0% rate of success. However, deeper analysis show that some of this orbits has only 1 occurrence such as GEO, SO, HEO and ES-L1 which mean this data need more dataset to see pattern or trend before we draw any conclusion.

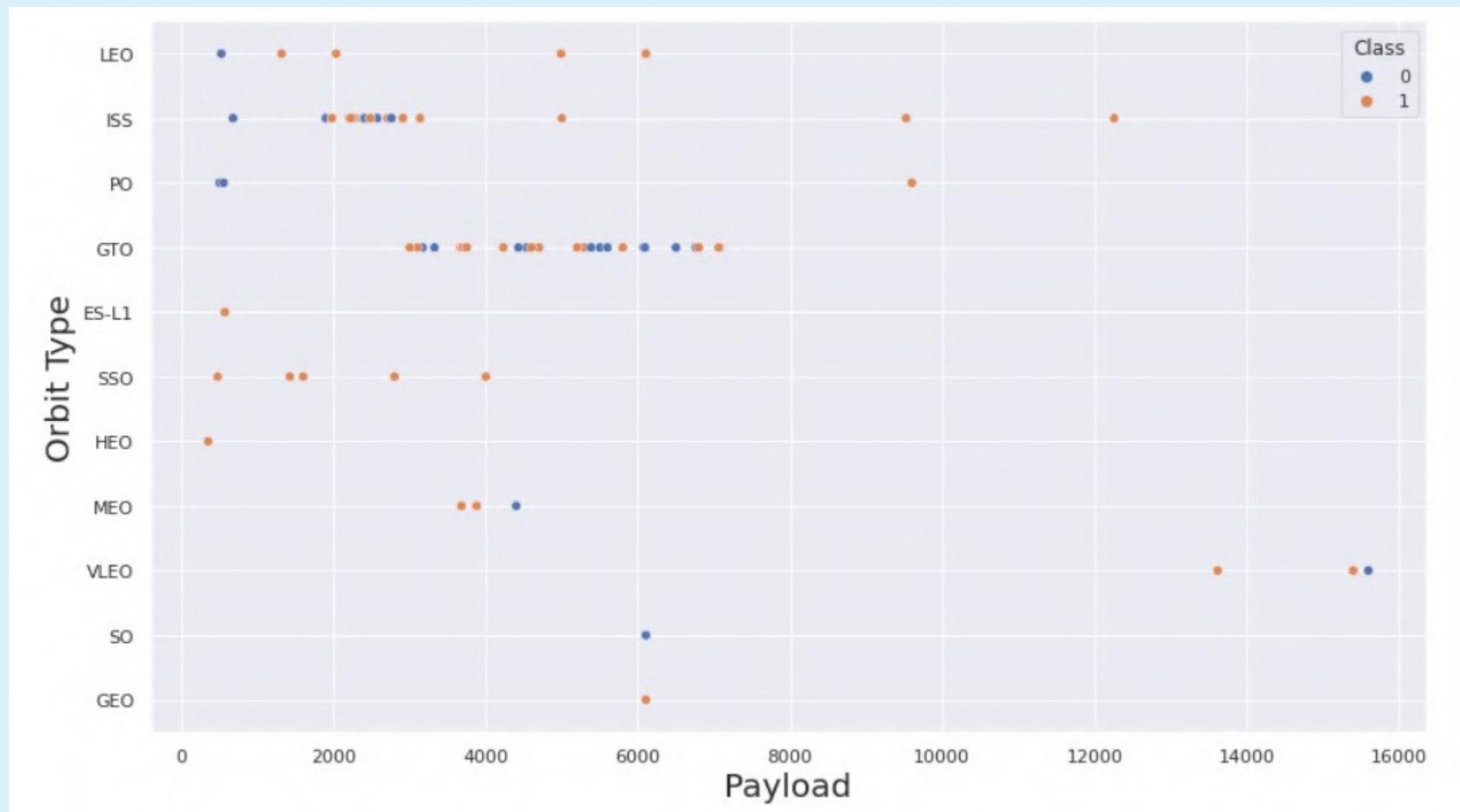
Flight Number vs. Orbit Type

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



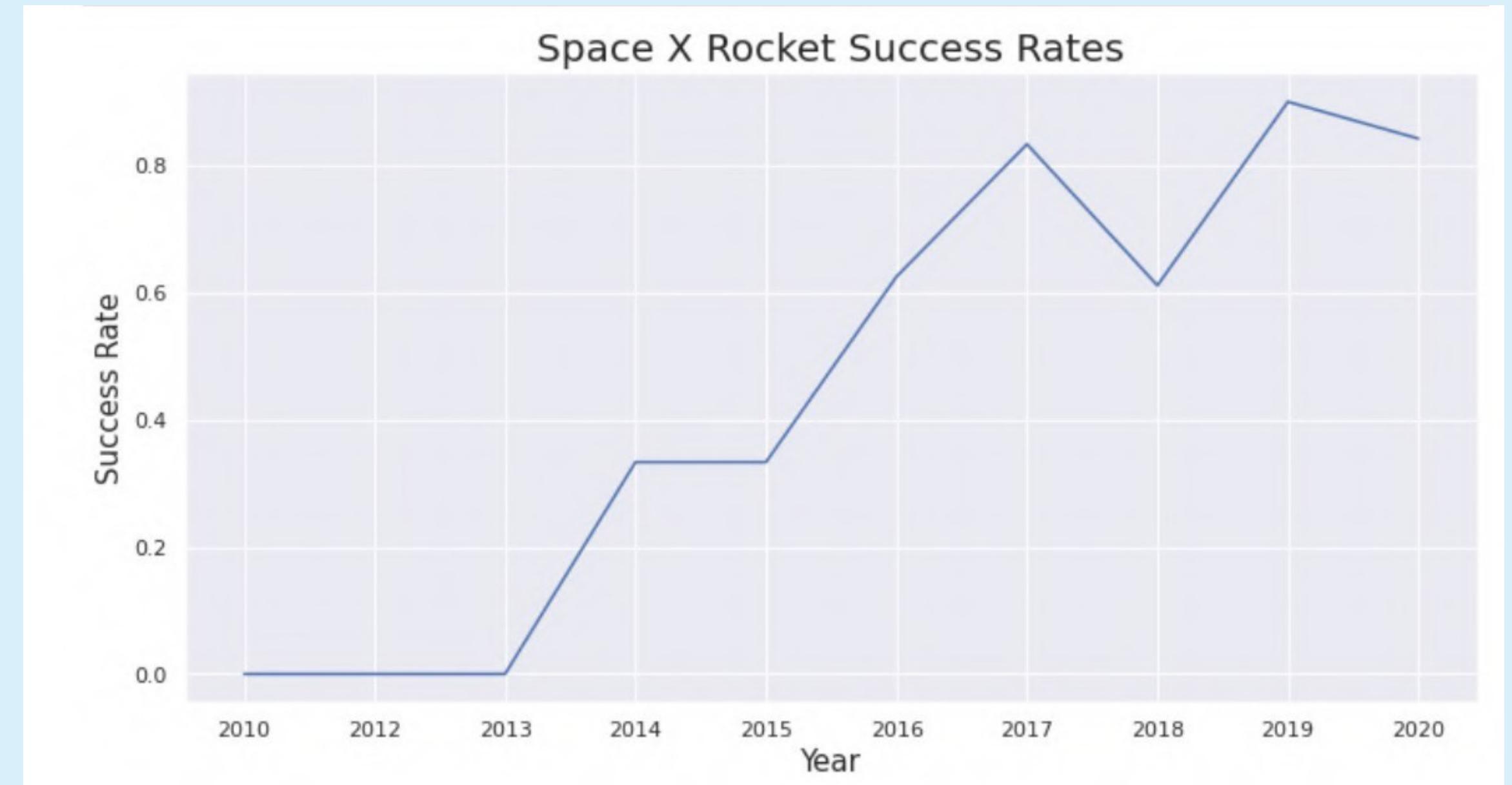
Heavier payload has positive impact on LEO, ISS and P0 orbit. However, it has negative impact on MEO and VLEO orbit.

GTO orbit seem 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 figure clearly depicted an increasing trend from the year 2013 until 2020. If this trend continues for the next year onward, the success rate will steadily increase until reaching 100% success rate.



All Launch Site 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:***@fbdb88901-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

Launch Site Names Begin with 'CCA'

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

```
In [11]:  
task_2 = '''  
SELECT *  
FROM SpaceX  
WHERE LaunchSite LIKE 'CCA%'  
LIMIT 5  
'''  
create_pandas_df(task_2, database=conn)
```

	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	2013-01-22	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.clogj3
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 Sucessful Landing Outcome in Ground Pad  
WHERE LANDING__OUTCOME = 'Success (ground pad)';
```

```
* ibm_db_sa://zpw86771:***@fbdb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3  
sd0tgtu0lqde00.databases.appdomain.cloud:32731/bludb  
Done.
```

First Sucessful 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:***@fbdb88901-ebdb-4a4f-a32e-9822b9fb237b.c1ogj3sd0tgtu0lqde00.databases.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 success or 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:***@fbdb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3sd0tgtu01qde00.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:***@fbdb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3sd0tgtu01qde00.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.clogj3sd0tgtu0lqde00.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 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 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:***@fbdb88901-ebdb-4a4f-a32e-9822b9fb237b.clogj3sd0tgtu0lgde00.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.



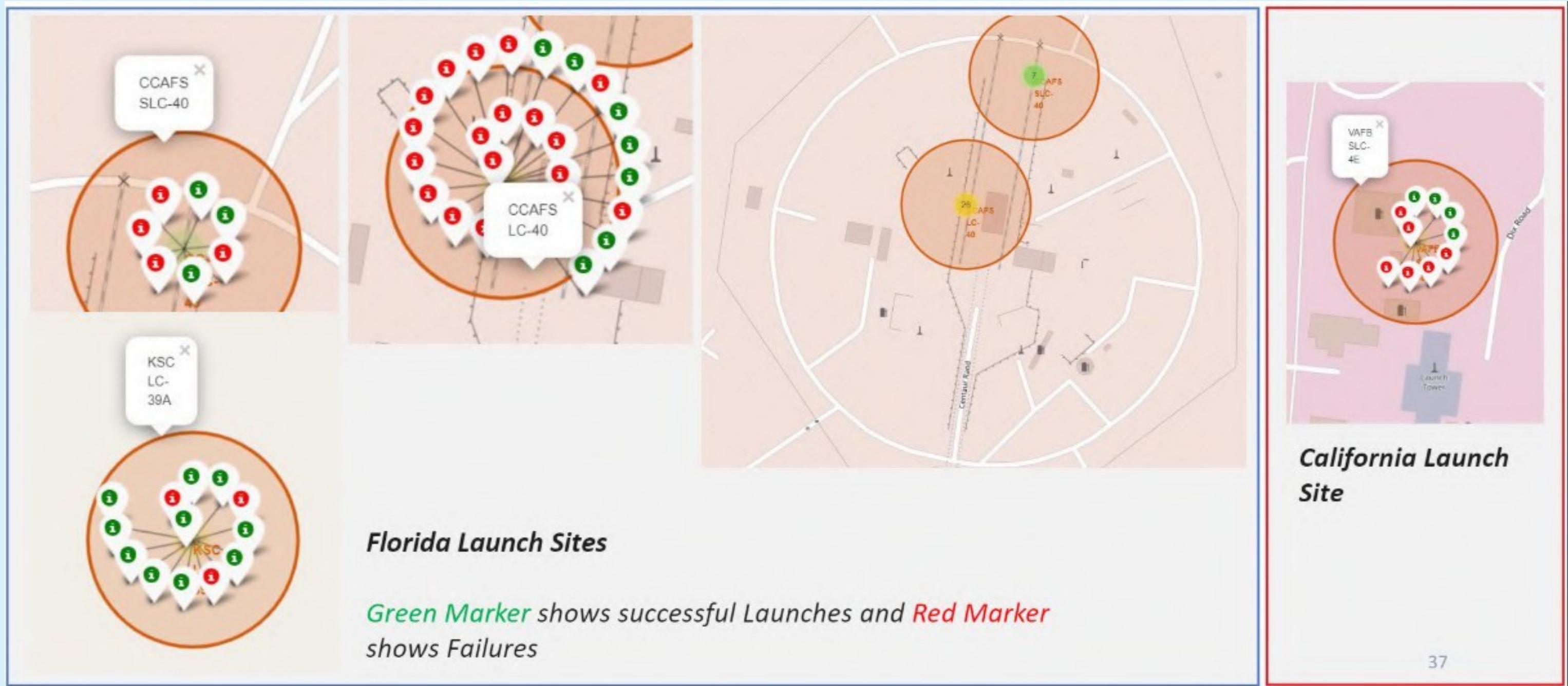
LAUNCH SITES PROXIMITIES ANALYSIS

Location of all the Launch Sites

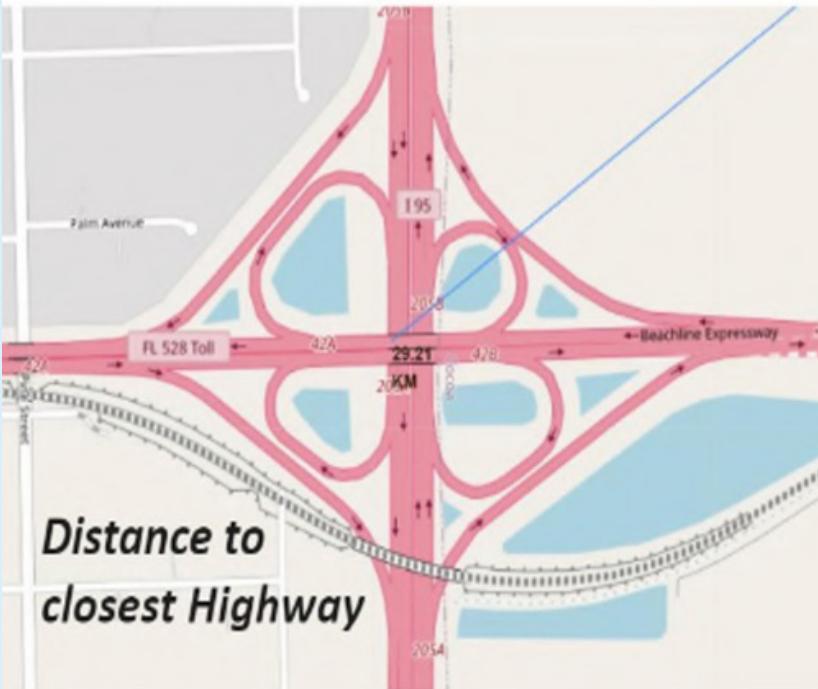


We can see that all the SpaceX launch sites are located inside the United States

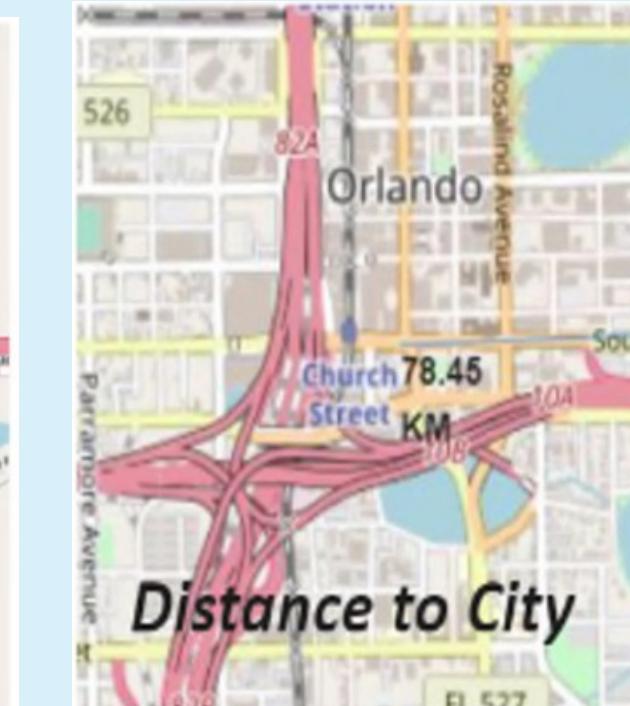
Markers showing launch sites with color labels



Launch Sites Distance to Landmarks



Distance to Coastline



Distance to City



Distance to coast

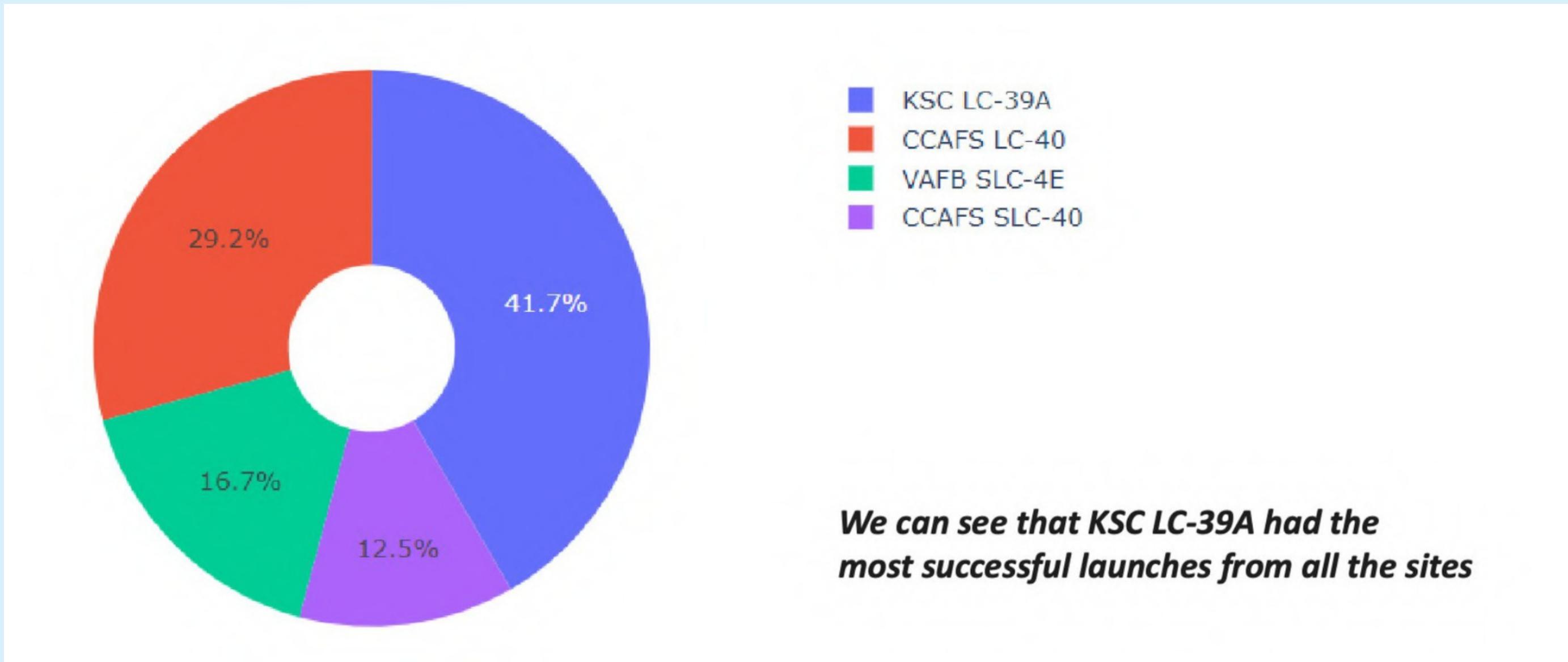
railways? No

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

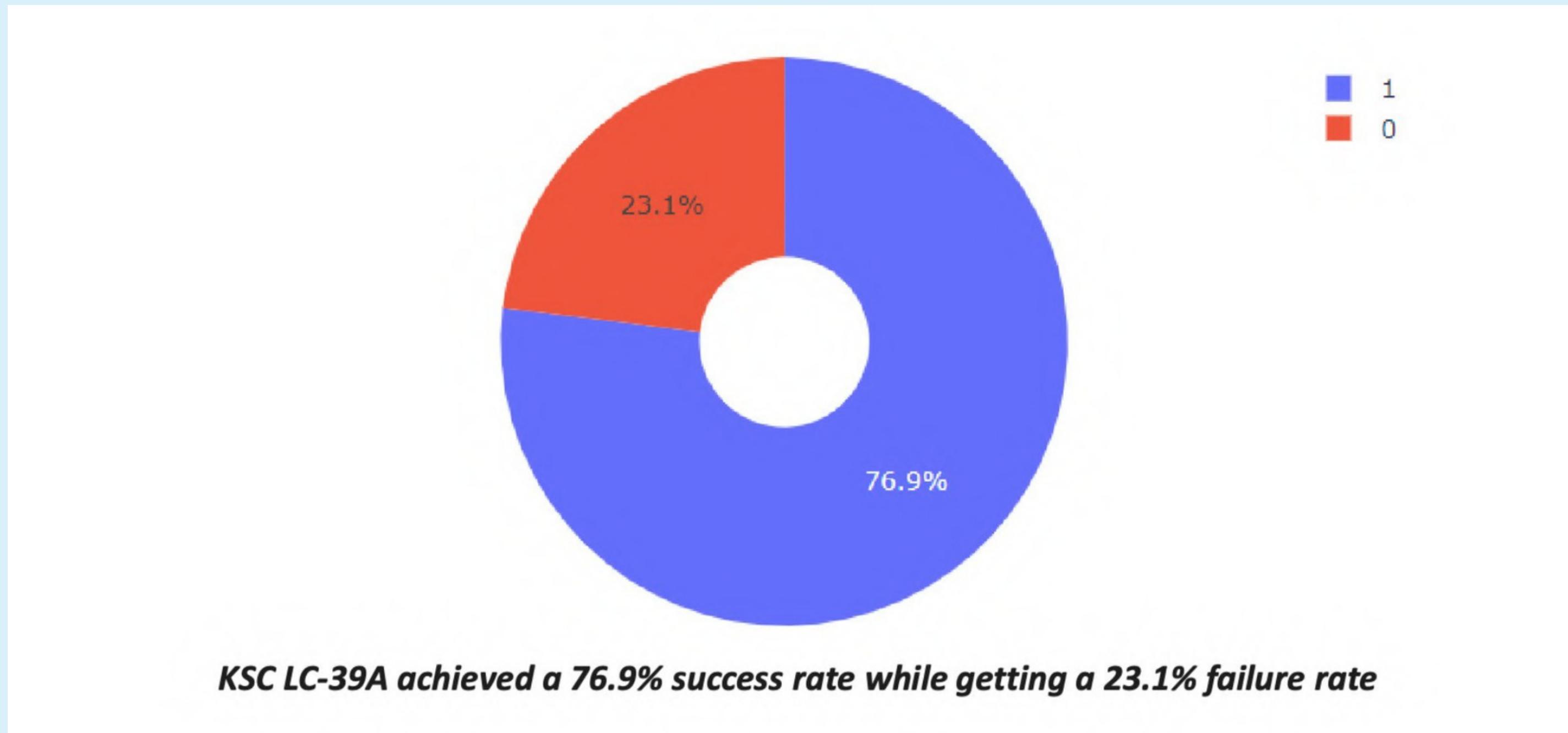


BUILD A DASHBOARD WITH PLOTLY DASH

The success percentage by each sites.

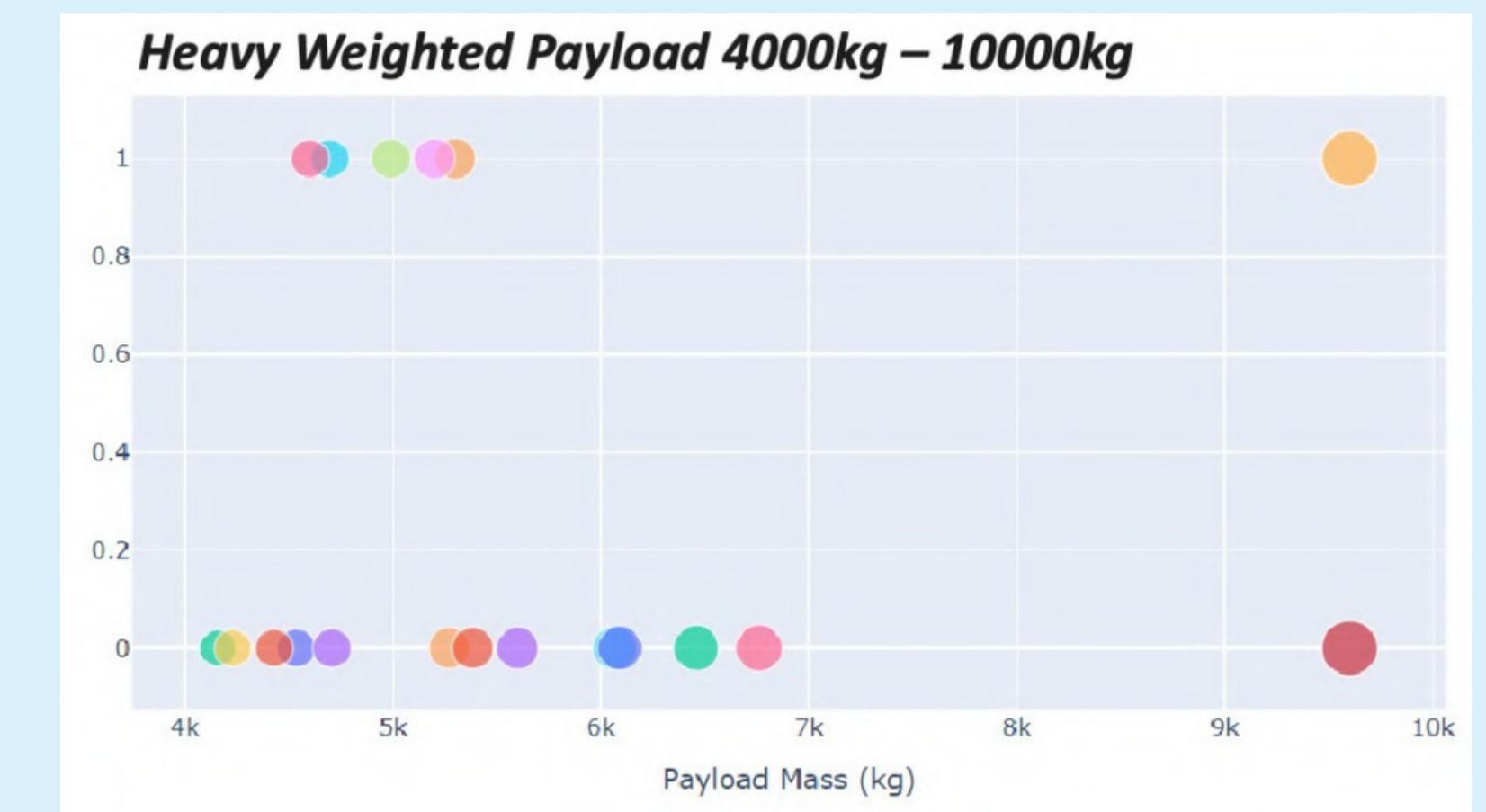
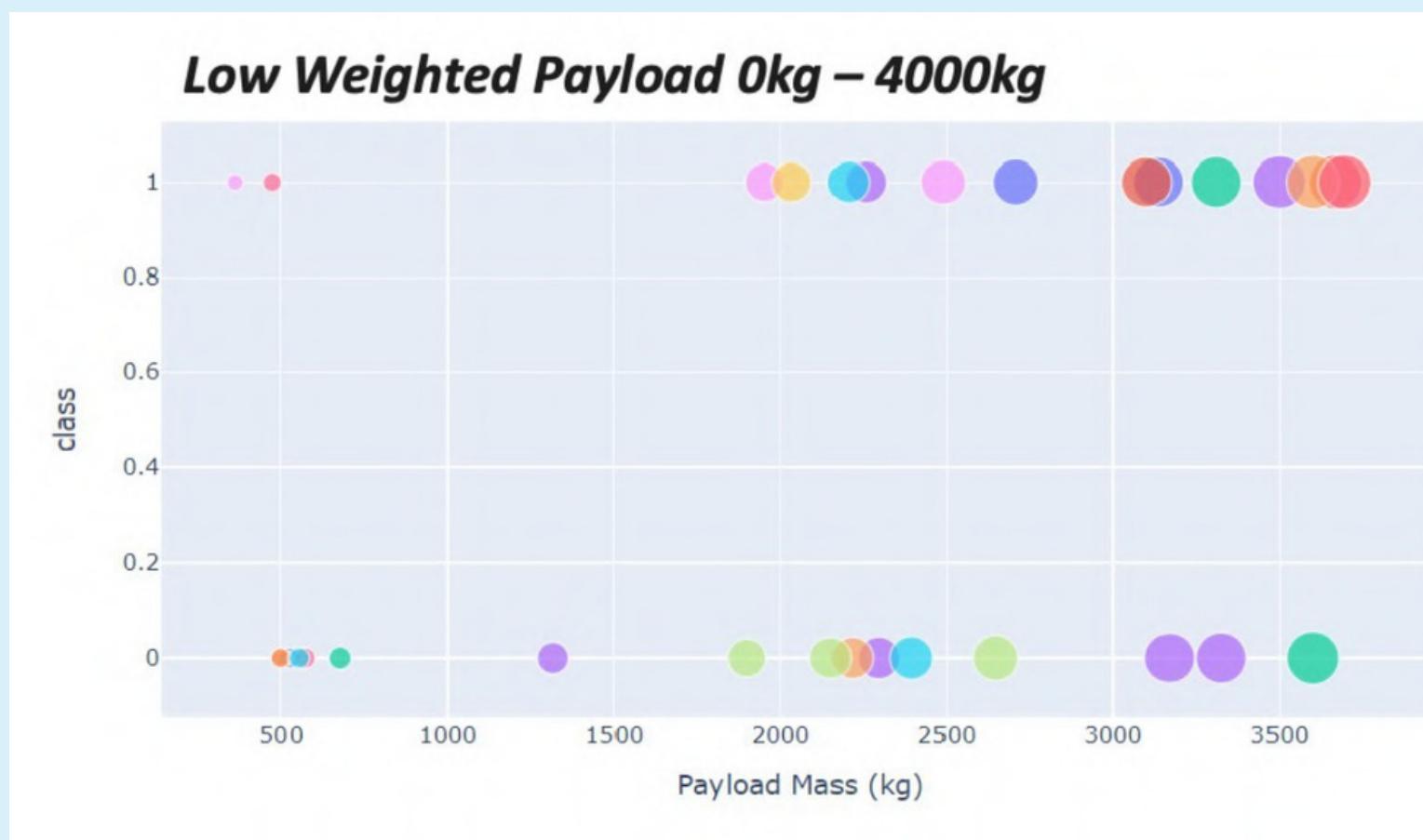


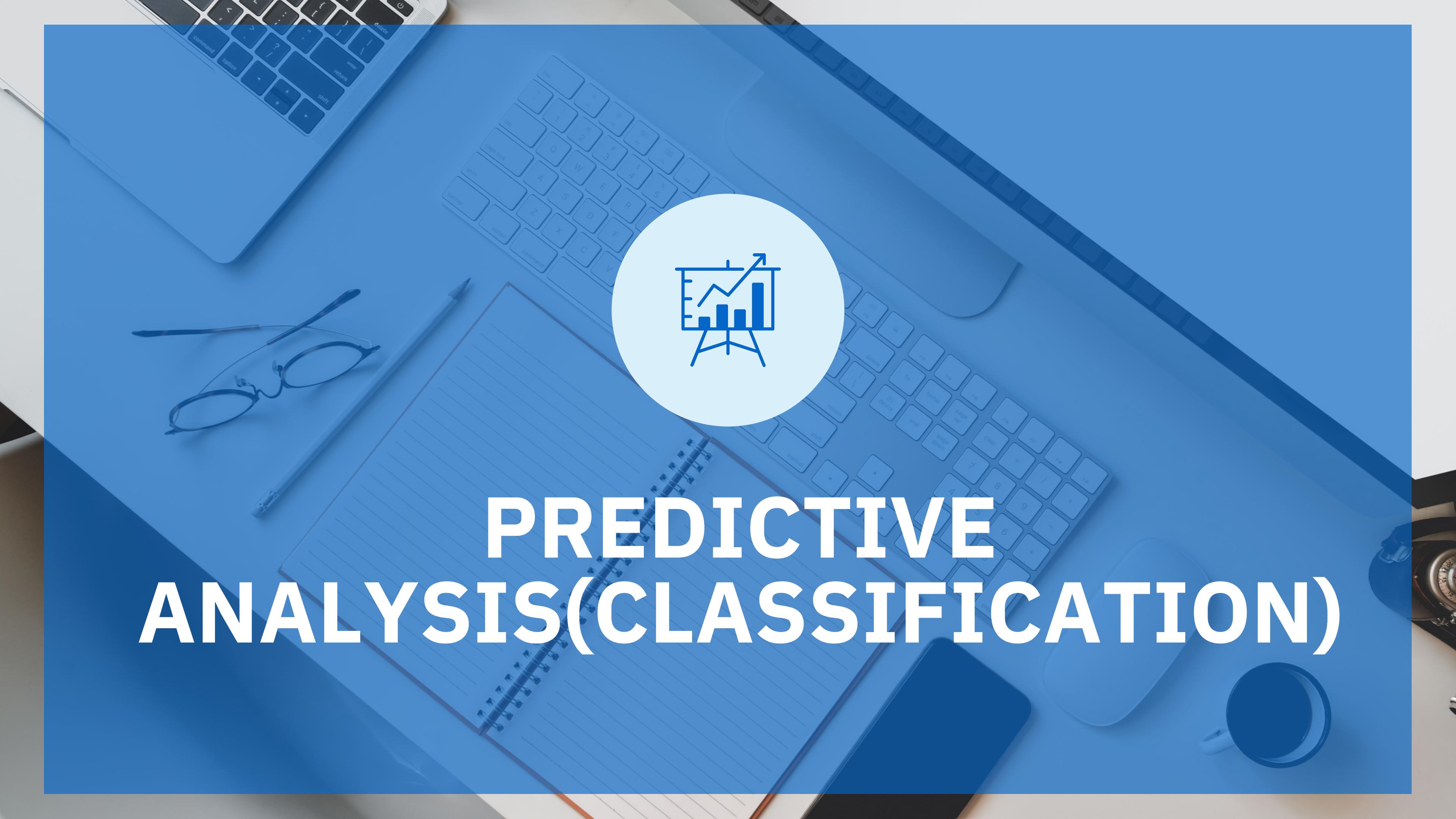
The highest launch-success ratio: KSC LC-39A



Payload vs Launch Outcome Scatter Plot

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





PREDICTIVE ANALYSIS(CLASSIFICATION)



Classification Accuracy

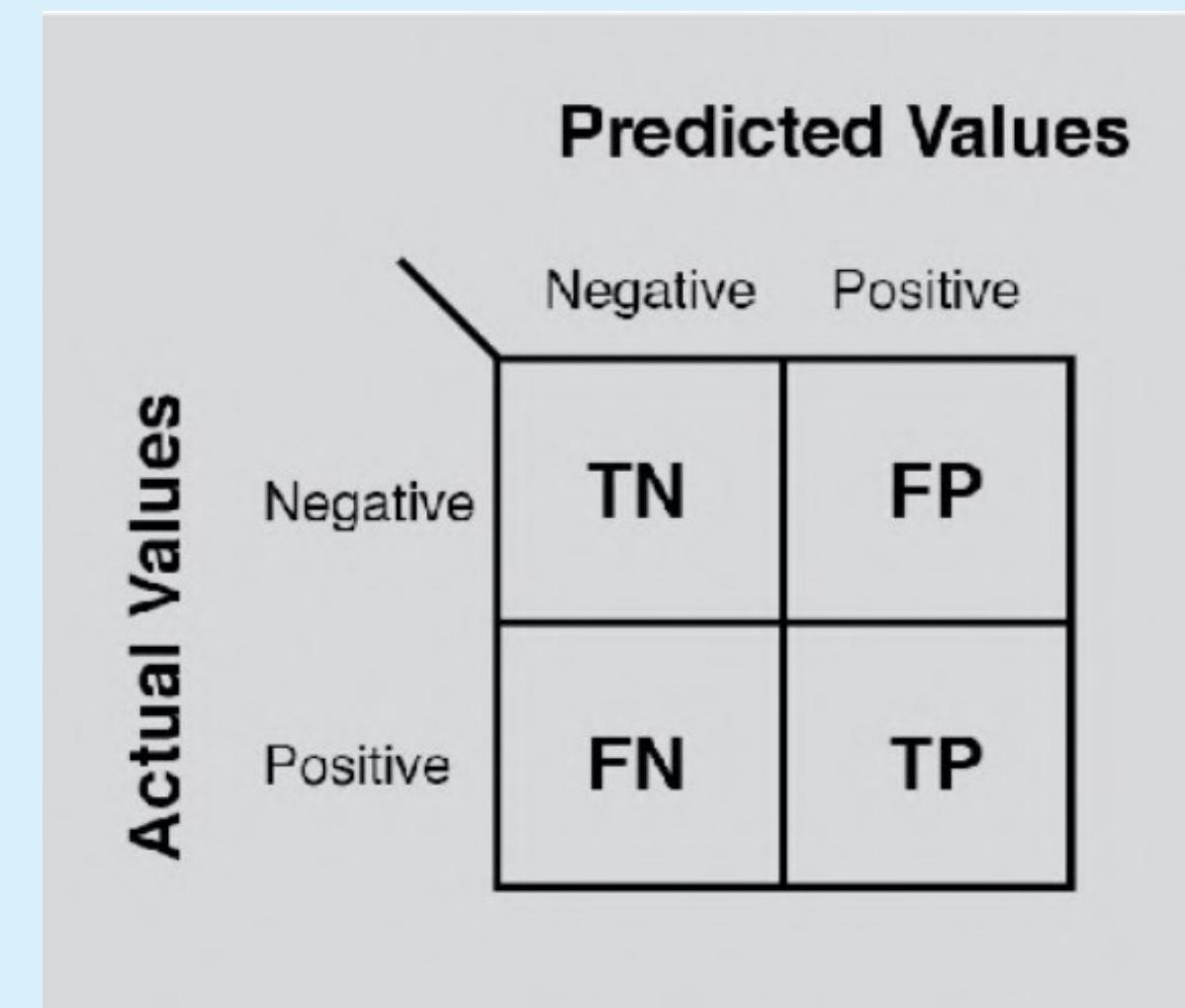
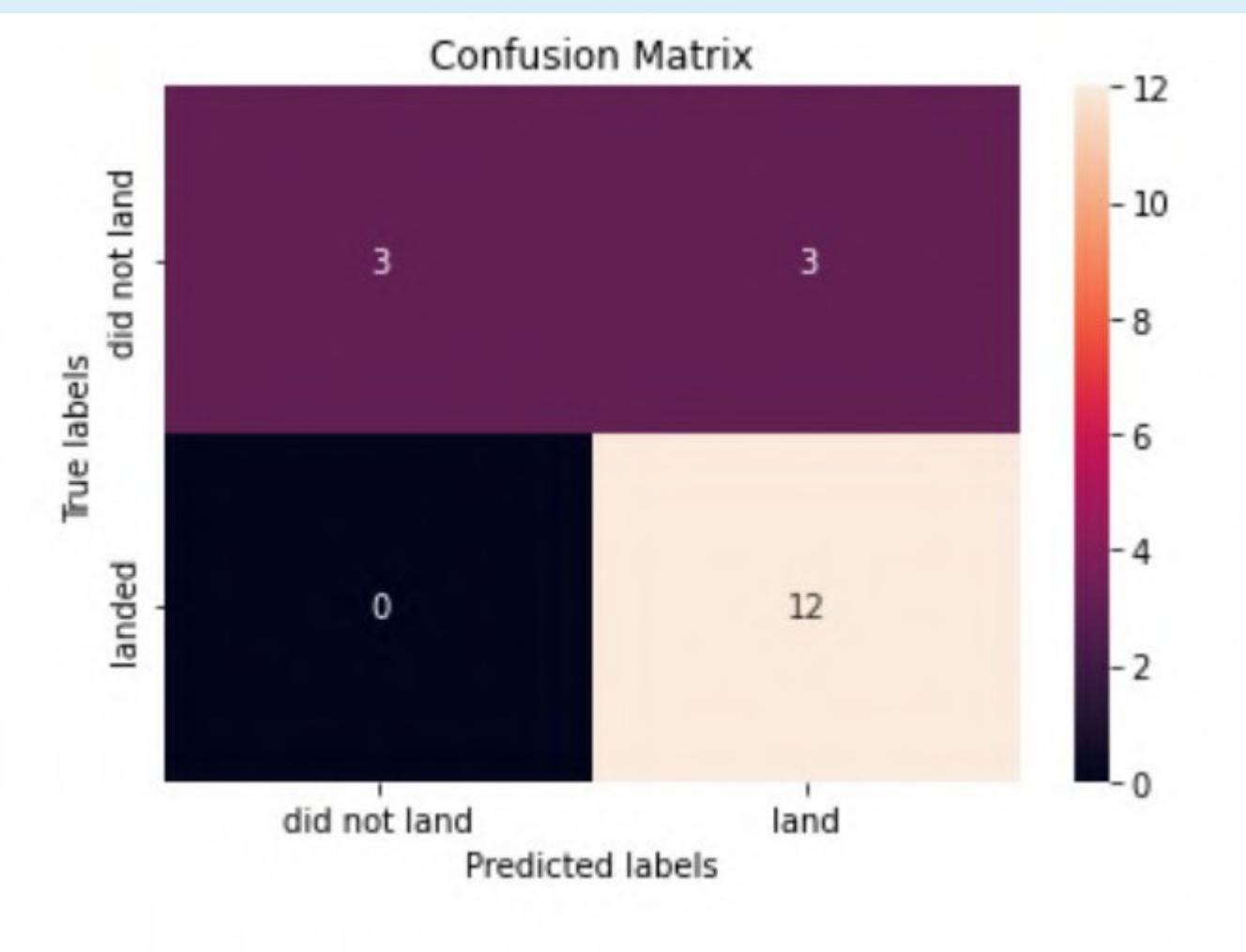
As we can see, by using the code as below: we could identify that the best algorithm to be the Tree Algorithm which have the highest classification accuracy.

```
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 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.



Conclusion:

We can conclude that:

- The Tree Classifier Algorithm is the best Machine Learning approach for this dataset.
- The low weighted payloads (which define as 4000kg and below) performed better than the heavy weighted payloads.
- Starting from the year 2013, the success rate for SpaceX launches is increased, directly proportional time in years to 2020, which it will eventually perfect the launches in the future.
- KSC LC-39A have the most successful launches of any sites; 76.9%
- SSO orbit have the most success rate; 100% and more than 1 occurrence.

THANK YOU!

