Winning Space Race with Data Science

<Jiapei Lei>
<5/31/2025>

Outline

- Executive Summary
- Introduction
- Methodology
- Results
- Conclusion
- Appendix

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
  - SpaceX offers Falcon 9 rocket launches at a cost of $62 million, whereas other providers charge upwards of $165 million per launch. A major contributor to this cost advantage is SpaceX's ability to reuse the rocket's first stage.
  - Accurately predicting the success of first-stage landings is crucial for estimating launch costs. Such insights could empower competing companies to make informed bids against SpaceX in the commercial launch market.
- Problems you want to find answers
  - Which factors most influence the success of a rocket's first-stage landing?
  - How do these factors interact to impact the landing outcome?
  - What operational conditions are necessary to ensure consistent and successful landings?

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

- **API Access**

Launch data was retrieved by sending GET requests to the SpaceX API. The response content was decoded in JSON format using the .json() function and then converted into a pandas DataFrame using json_normalize().

- **Data Cleaning**

The resulting dataset was cleaned by checking for and handling missing values appropriately.

- **Web Scraping**

Additional launch records were obtained by scraping Wikipedia using BeautifulSoup. The Falcon 9 launch table was extracted from the HTML content, parsed, and converted into a pandas DataFrame for further 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.
- GitHub URL: https://github.com/JQY8/Applied-Data-Science-Capstone/blob/main/Data%20Collection%20API%20Lab.ipynb

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

```
static_json_url='https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/IBM-DS0321EN-SkillsNetwork/datasets/API_call_spacex_api.json'
```

We should see that the request was successfull with the 200 status response code

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

```
response.status_code
```

```
200
```

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

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

Using the dataframe `data` print the first 5 rows

```
# Get the head of the dataframe
print(data.head())
```

```
       static_fire_date_utc  static_fire_date_unix    tbd    net  window  \
0  2006-03-17T00:00:00.000Z           1.142554e+09  False  False     0.0
1                      None                    NaN  False  False     0.0
2                      None                    NaN  False  False     0.0
3  2008-09-20T00:00:00.000Z           1.221869e+09  False  False     0.0
4                      None                    NaN  False  False     0.0

                     rocket  success  \
0  5e9d0d95eda69955f709d1eb    False
1  5e9d0d95eda69955f709d1eb    False
2  5e9d0d95eda69955f709d1eb    False
3  5e9d0d95eda69955f709d1eb     True
4  5e9d0d95eda69955f709d1eb     True
```

Data Collection - Scraping

- Web scraping was applied using BeautifulSoup to extract Falcon 9 launch records from Wikipedia, with the launch table parsed and converted into a pandas DataFrame for analysis.
- GitHub URL: https://github.com/JQY8/Applied-Data-Science-Capstone/blob/main/Data%20Collection%20with%20Web%20Scraping%20lab.ipynb

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
r = requests.get(static_url)
# assign the response to a object
data = r.text
```

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

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

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

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

TASK 2: Extract all column/variable names from the HTML table header

Next, we want to collect all relevant column names from the HTML table header

Let's try to find all tables on the wiki page first. If you need to refresh your memory about `BeautifulSoup`, please check the external reference link towards the end of this lab

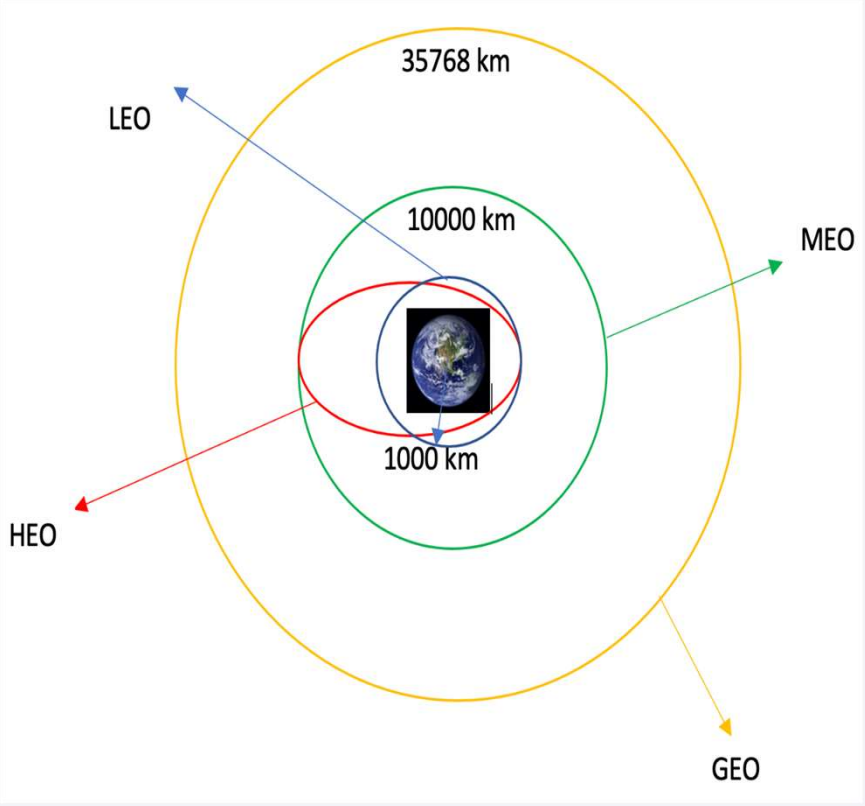
```
# Use the find_all function in the BeautifulSoup object, with element type `table`
# Assign the result to a list called `html_tables`
html_tables = soup.find_all('table')
```

Starting from the third table is our target table contains the actual launch records.

```
# Let's print the third table and check its content
first_launch_table = html_tables[2]
print(first_launch_table)
```

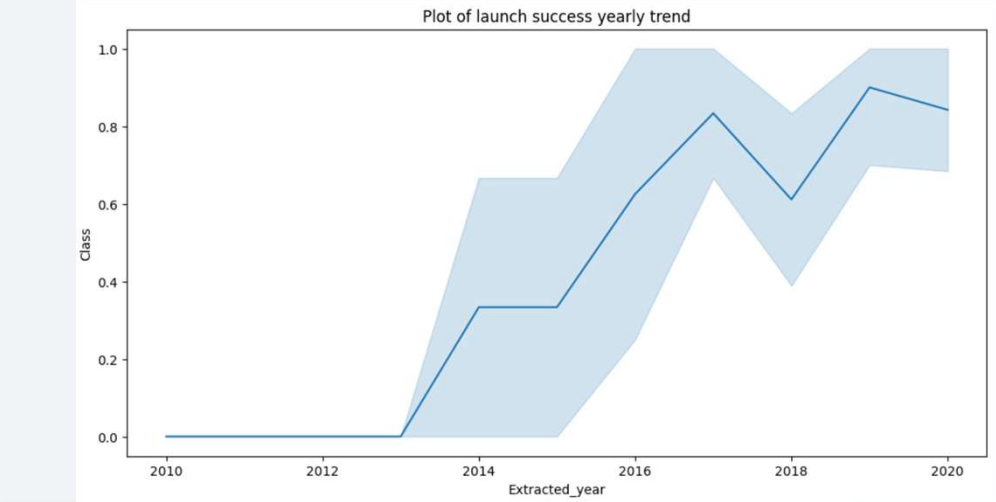
Data Wrangling

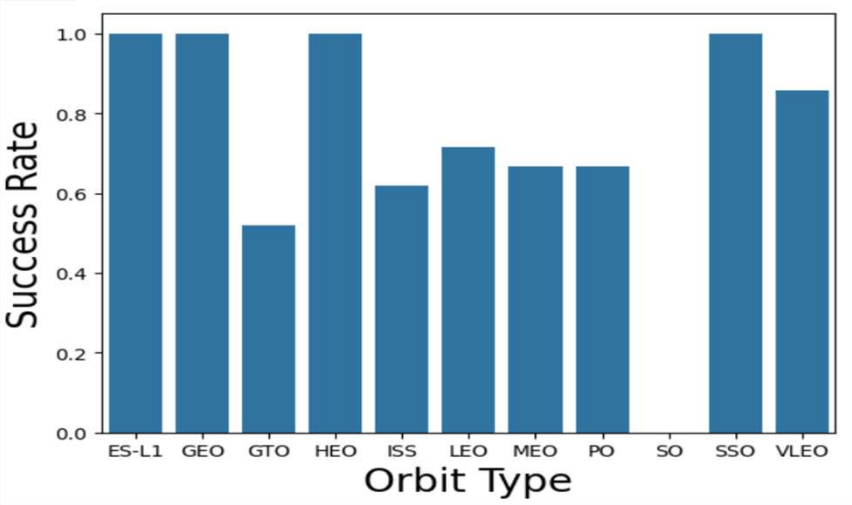
- Data were collected using GET requests from the SpaceX API and web scraping from Wikipedia with BeautifulSoup. The raw data were then converted into pandas DataFrames, cleaned for missing values and inconsistencies, and merged into a single dataset for analysis.
- Data Collection (API + Web Scraping)
  -> Data Conversion (JSON + HTML -> DataFrames)
  -> Data Cleaning (Missing values, type correction)
  -> Data Integration (Merge, align keys)
  -> Feature Engineering (Derived variables)
- GitHub URL: https://github.com/JQY8/Applied-Data-Science-Capstone/blob/main/Data%20Wrangling.ipynb



EDA with Data Visualization

- The data was explored through a series of visualizations, including: the relationship between flight number and launch site; the correlation between payload and launch site; the success rate by orbit type; the interaction between flight number and orbit type; and the yearly trend in launch success.
- GitHub URL: https://github.com/JQY8/Applied-Data-Science-Capstone/blob/main/EDA%20with%20Visualization%20Lab.ipynb

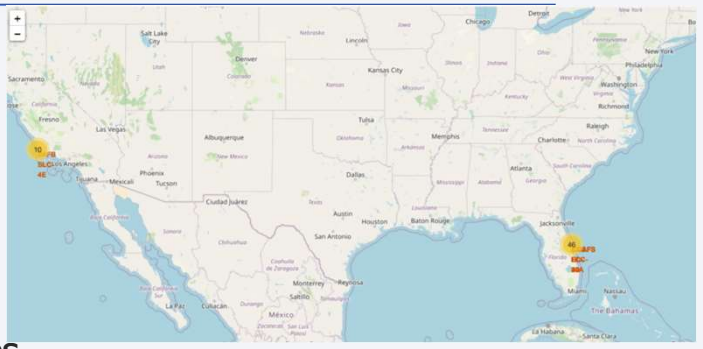




EDA with SQL

- Loaded the SpaceX dataset into a PostgreSQL database directly from within the Jupyter Notebook environment.
- Performed exploratory data analysis (EDA) using SQL to derive insights from the dataset.
- Executed queries to identify:
  - Unique launch site names involved in the space missions.
  - Total payload mass transported by boosters launched under NASA (CRS) missions.
  - Average payload mass carried by the F9 v1.1 booster version.
  - Total number of missions categorized as successful or failed.
  - Failed drone ship landing outcomes, including their associated booster versions and launch site names.
- GitHub URL: https://github.com/JQY8/Applied-Data-Science-Capstone/blob/main/EDA%20with%20SQL.ipynb

Build an Interactive Map with Folium

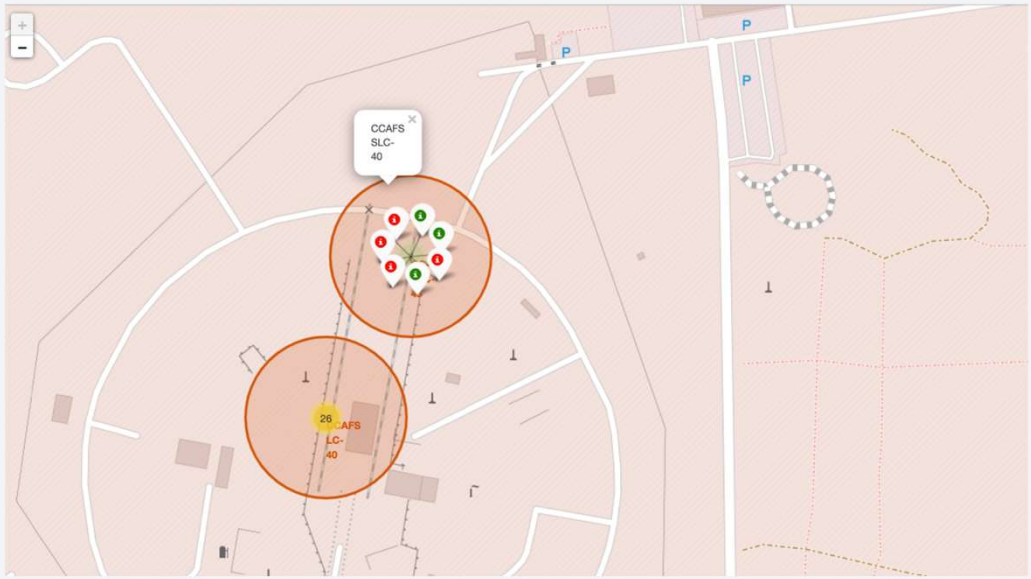


- Map Objects Added to Folium
  - Launch Site Marker
    Pinpointed the exact coordinates of the launch site for spatial reference
  - Proximity Markers
    Identified nearby features such as cities, highways, railways, and coastlines
  - Distance Lines (PolyLine)
    Connected the launch site to each nearby feature to visualize direct distances
  - Optional Circles (Buffer Zones)
    Represented radius-based proximity to assess spatial influence or safety zones
- Purpose of Map Elements
  - Visualize spatial relationships between launch sites and surrounding infrastructure
  - Assess proximity to key features for logistical and safety considerations
- GitHub URL: https://github.com/JQY8/Applied-Data-Science-Capstone/blob/main/Interactive%20Visual%20Analytics%20with%20Folium%20lab.ipynb

Build a Dashboard with Plotly Dash

Dashboard Components & Purpose

- Dropdown Menu (Launch Site)
  - Filters data by site or shows all launches
  - Enables comparison of site performance
- Pie Chart (Launch Success)
  - Shows success distribution by site
  - Displays success vs. failure for selected site
- Payload Range Slider
  - Filters launches by payload mass
  - Helps explore payload impact on success



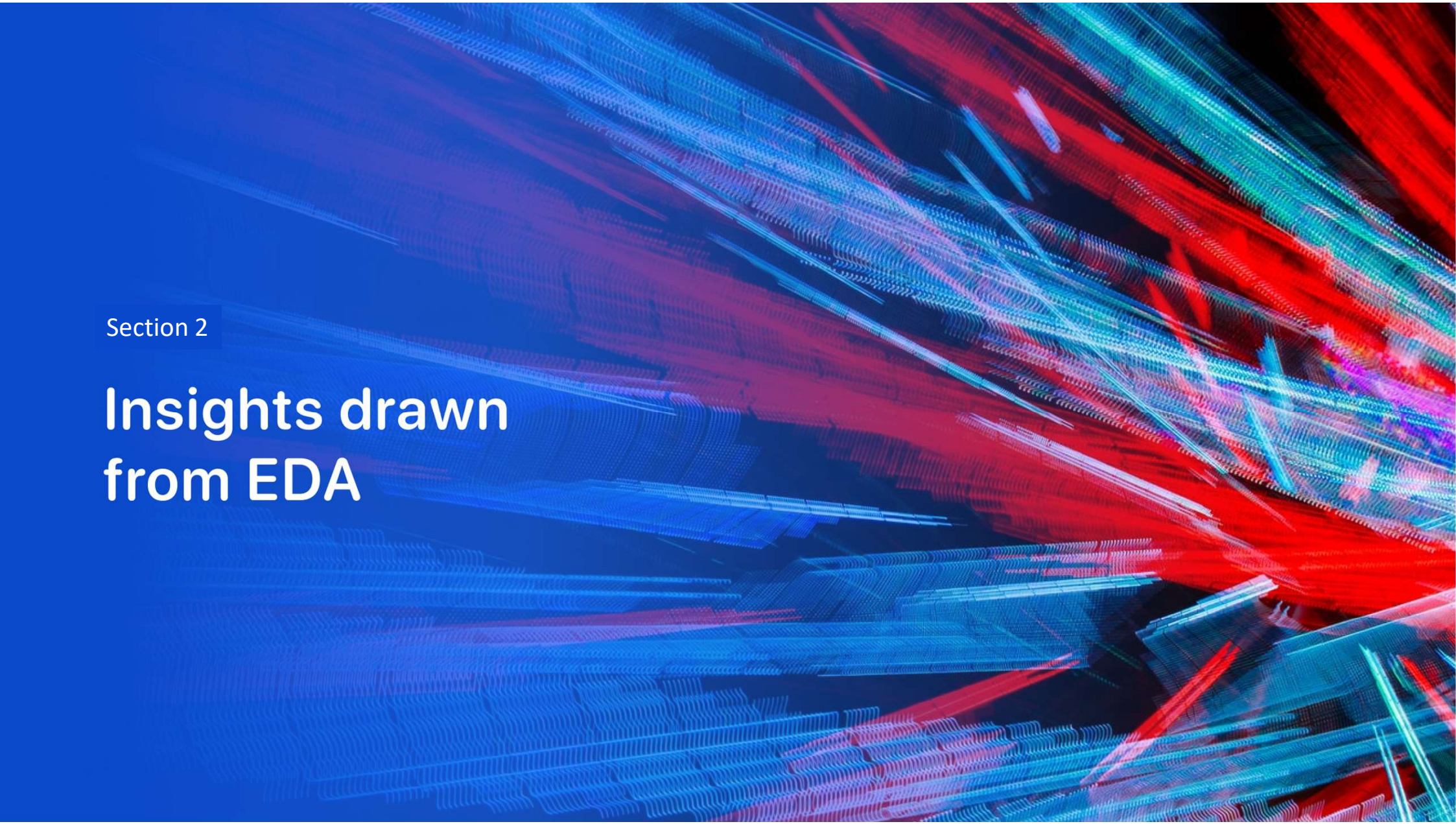
- Scatter Plot (Payload vs. Success)
  - Shows correlation between payload and launch outcome
  - Colored by booster version for deeper insights
- GitHub URL: https://github.com/JQY8/Applied-Data-Science-Capstone/blob/main/Build%20an%20Interactive%20Dashboard%20with%20Ploty%20Dash.ipynb

Predictive Analysis (Classification)

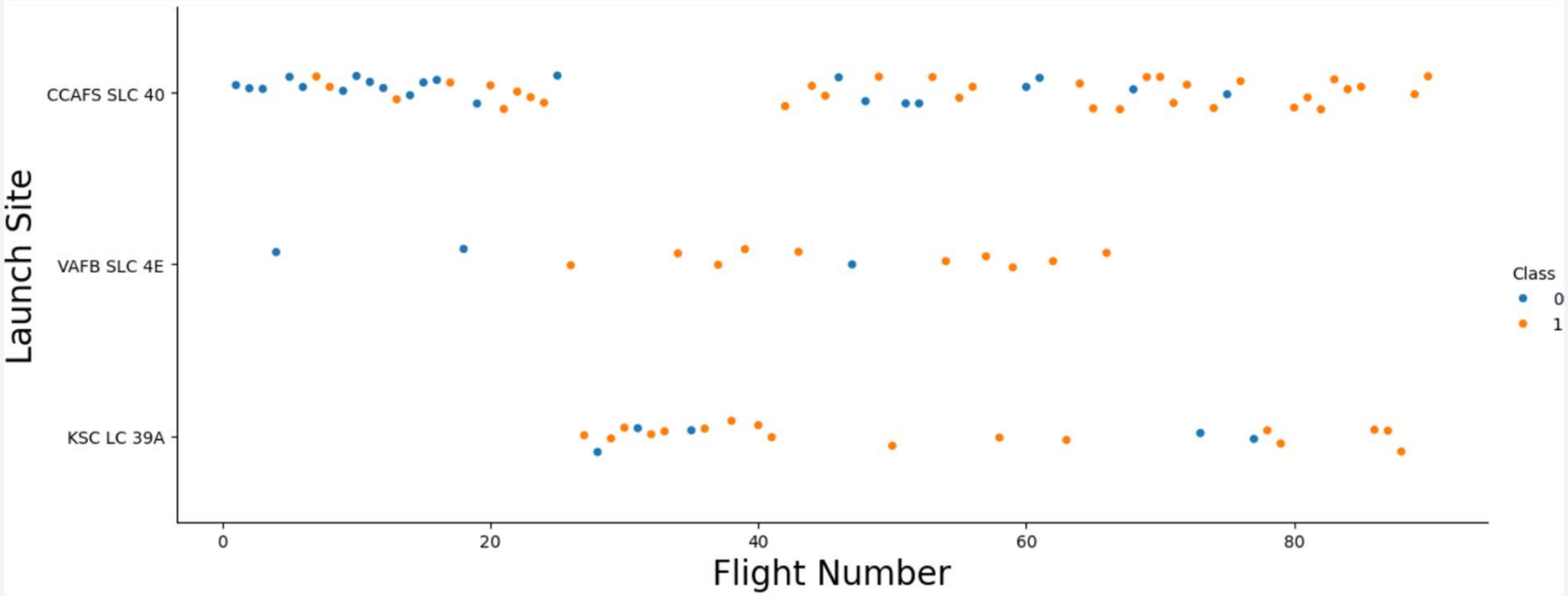
- Data Preparation
  - Extracted target (Class), dropped from features, standardized features with StandardScaler
- Train/Test Split
  - 80/20 split, random_state=2, 18 samples in test set
- Model Selection & Hyperparameter Tuning
- Model Evaluation
  - KNN performed the best with a score of 0.8482142857142858
  - All models showed low false negatives according to the confusion matrixes
- GitHub URL: https://github.com/JQY8/Applied-Data-Science-Capstone/blob/main/Machine%20Learning%20Prediction%20lab.ipynb

Results

- Exploratory data analysis results
  - The larger the flight amount at a launch site, the greater the success rate at a launch site.
- Interactive analytics demo in screenshots
  - Visualize spatial relationships between launch sites and surrounding infrastructure
- Predictive analysis results
  - The k nearest neighbors classifier is the best machine learning algorithm for this task.

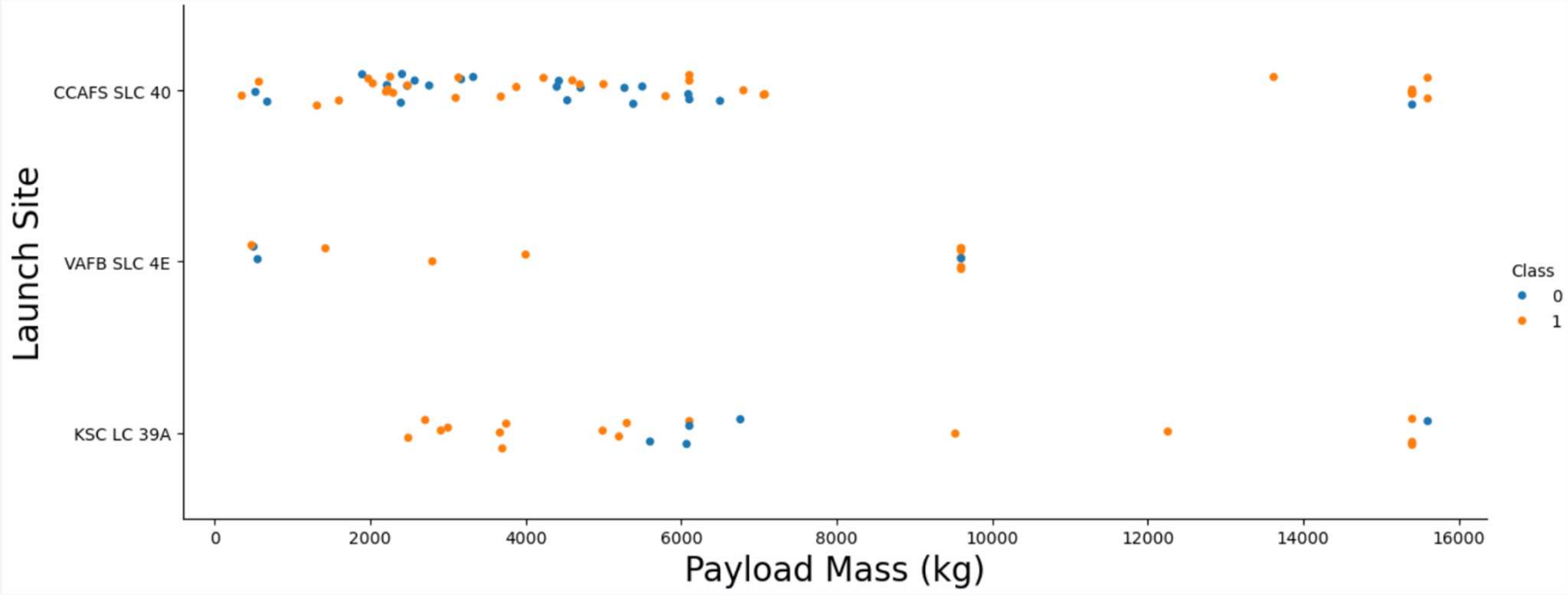

Section 2
Insights drawn
from EDA

Flight Number vs. Launch Site



- The scatter plot shows that for each launch site, a higher number of flights is associated with a higher success rate, indicating that increased launch experience at a site contributes to improved reliability.

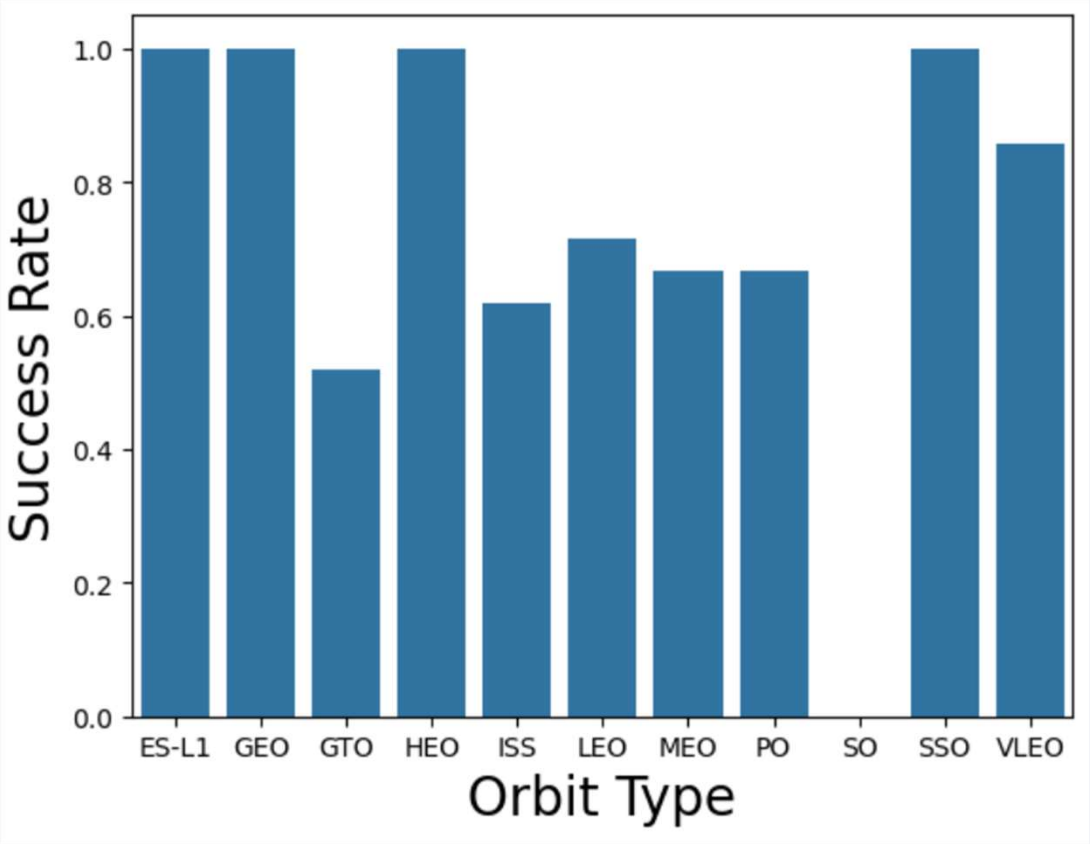
Payload vs. Launch Site



- For the VAFB-SLC launchsite there are no rockets launched for heavy payload mass (greater than 10000).

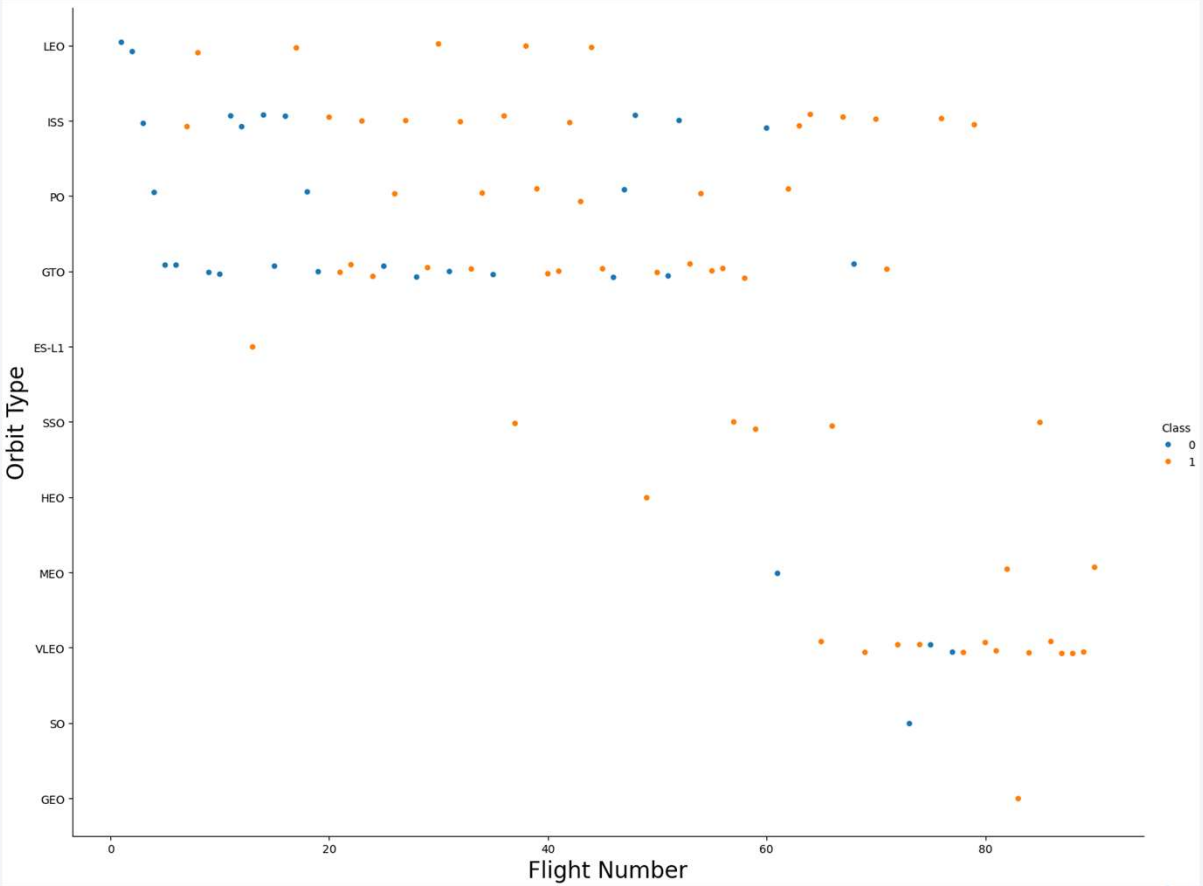
Success Rate vs. Orbit Type

- The ES-L1, GEO, HEO, and SSO have the highest success rate.
- The SO has the lowest success rate.

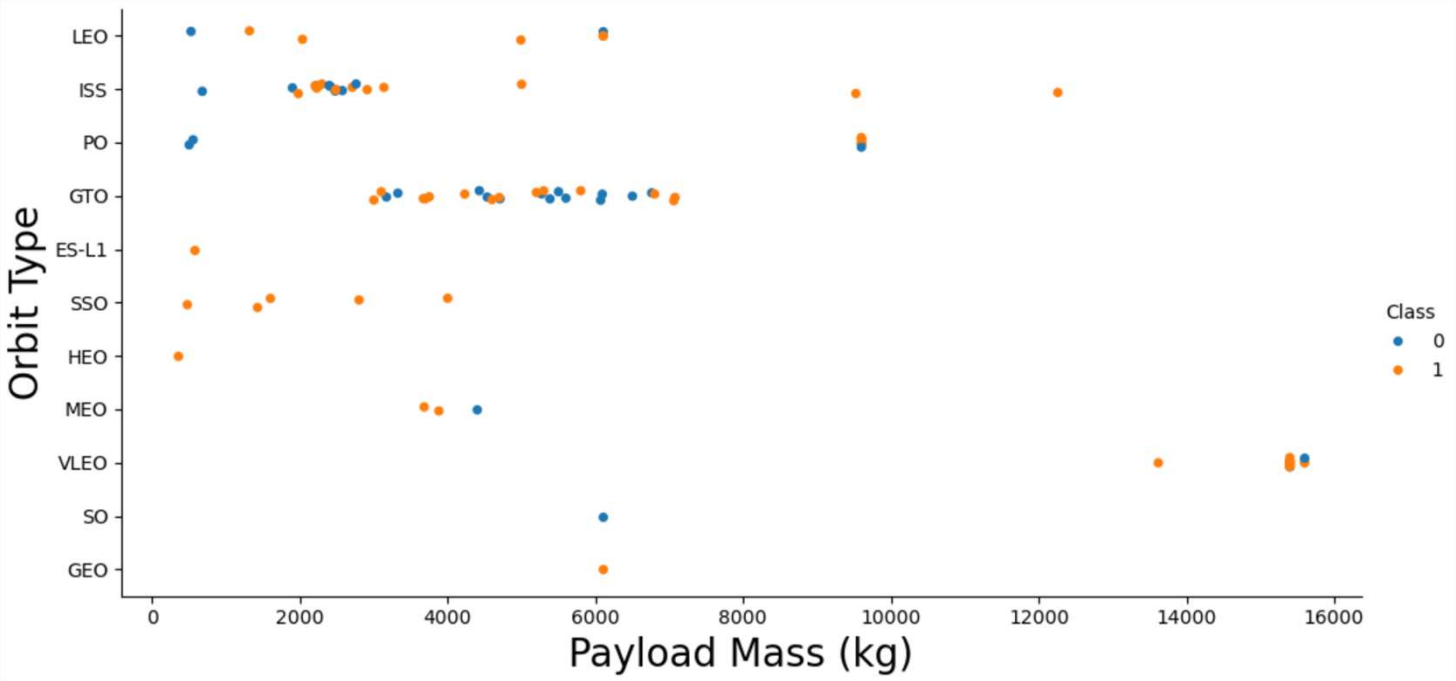


Flight Number vs. Orbit Type

- In the LEO orbit, success seems to be related to the number of flights.
- Conversely, in the GTO orbit, there appears to be no relationship between flight number and success.

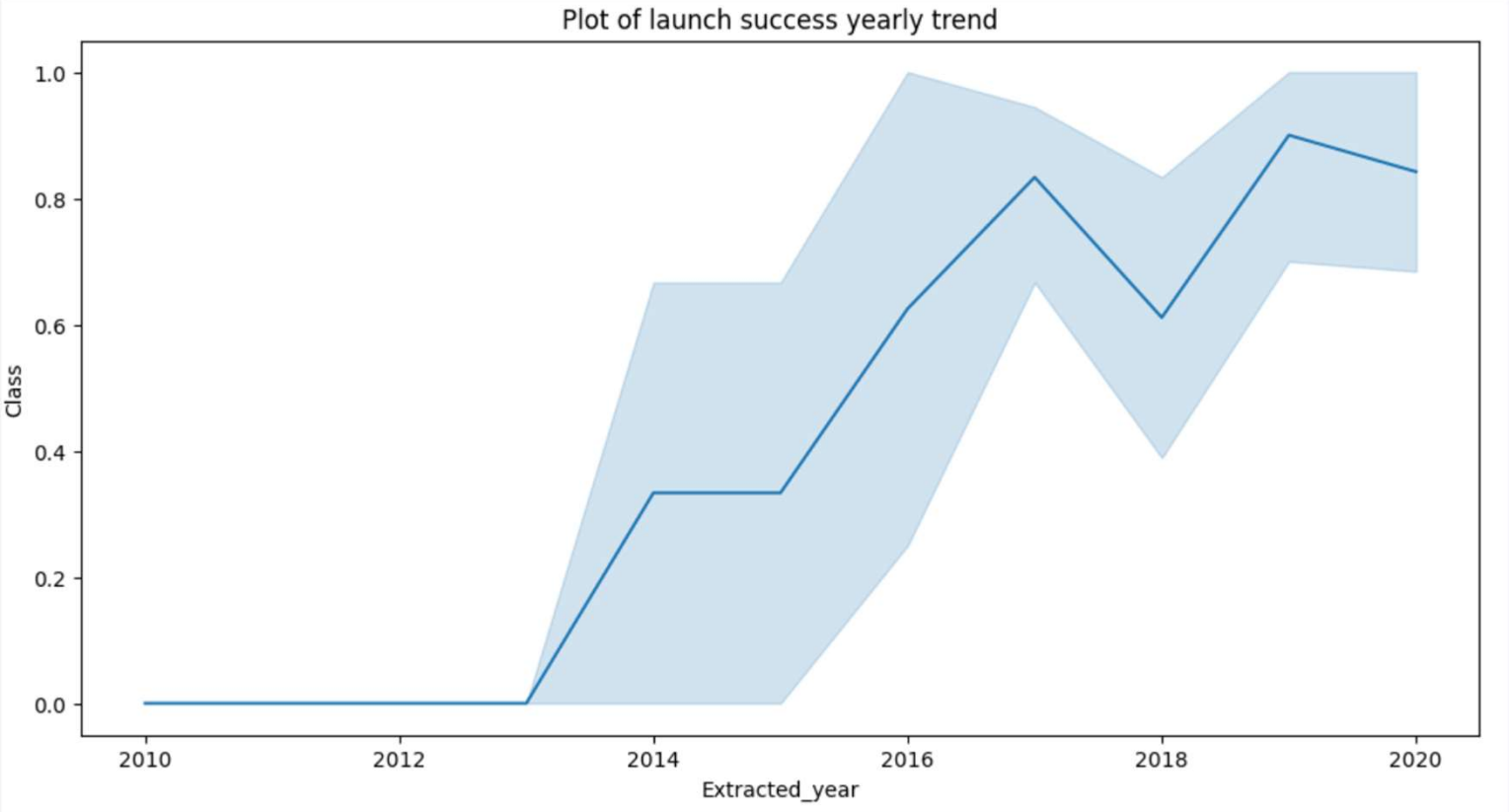


Payload vs. Orbit Type



- With heavy payloads the successful landing or positive landing rate are more for Polar,LEO and ISS.
- However, for GTO, it's difficult to distinguish between successful and unsuccessful landings as both outcomes are present.

Launch Success Yearly Trend



- The success rate since 2013 kept increasing till 2020

All Launch Site Names

- Used the key word DISTINCT to show only unique launch sites from the SpaceX data.

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

Launch Site Names Begin with 'CCA'

	index	Date	Time_(UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing_Outcome
0	0	None	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
1	1	None	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	2	None	7:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
3	3	None	0:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
4	4	None	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

```
SELECT *
FROM SpaceX
WHERE LaunchSite LIKE 'CCA%'
LIMIT 5
```

Total Payload Mass

```
SELECT SUM(PayloadMassKG) AS Total_PayloadMass
FROM SpaceX
WHERE Customer LIKE 'NASA (CRS)'
```

	sum(PAYLOAD_MASS__KG_)
0	45596

Average Payload Mass by F9 v1.1

```
SELECT AVG(PayloadMassKG) AS Avg_PayloadMass
FROM SpaceX
WHERE BoosterVersion = 'F9 v1.1'
```

	avg(PAYLOAD_MASS__KG_)
0	2928.4

First Successful Ground Landing Date

```
SELECT MIN(Date) AS FirstSuccessfull_landing_date
FROM SpaceX
WHERE LandingOutcome LIKE 'Success (ground pad)'
```

	firstsuccessfull_landing_date
0	2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

```
SELECT BoosterVersion
FROM SpaceX
WHERE LandingOutcome = 'Success (drone ship)'
        AND PayloadMassKG > 4000
        AND PayloadMassKG < 6000
```

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

Total Number of Successful and Failure Mission Outcomes

```
SELECT COUNT(MissionOutcome) AS SuccessOutcome
FROM SpaceX
WHERE MissionOutcome LIKE 'Success%'

SELECT COUNT(MissionOutcome) AS FailureOutcome
FROM SpaceX
WHERE MissionOutcome LIKE 'Failure%'
```

	Mission_Outcome	count(*)
0	Failure	1
1	Success	100

Boosters Carried Maximum Payload

```
SELECT BoosterVersion, PayloadMassKG
FROM SpaceX
WHERE PayloadMassKG = (
                    SELECT MAX(PayloadMassKG)
                    FROM SpaceX
                    )
ORDER BY BoosterVersion
```

	Booster_Version
0	F9 B5 B1048.4
1	F9 B5 B1049.4
2	F9 B5 B1051.3
3	F9 B5 B1056.4
4	F9 B5 B1048.5
5	F9 B5 B1051.4
6	F9 B5 B1049.5
7	F9 B5 B1060.2
8	F9 B5 B1058.3
9	F9 B5 B1051.6
10	F9 B5 B1060.3
11	F9 B5 B1049.7

2015 Launch Records

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

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

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

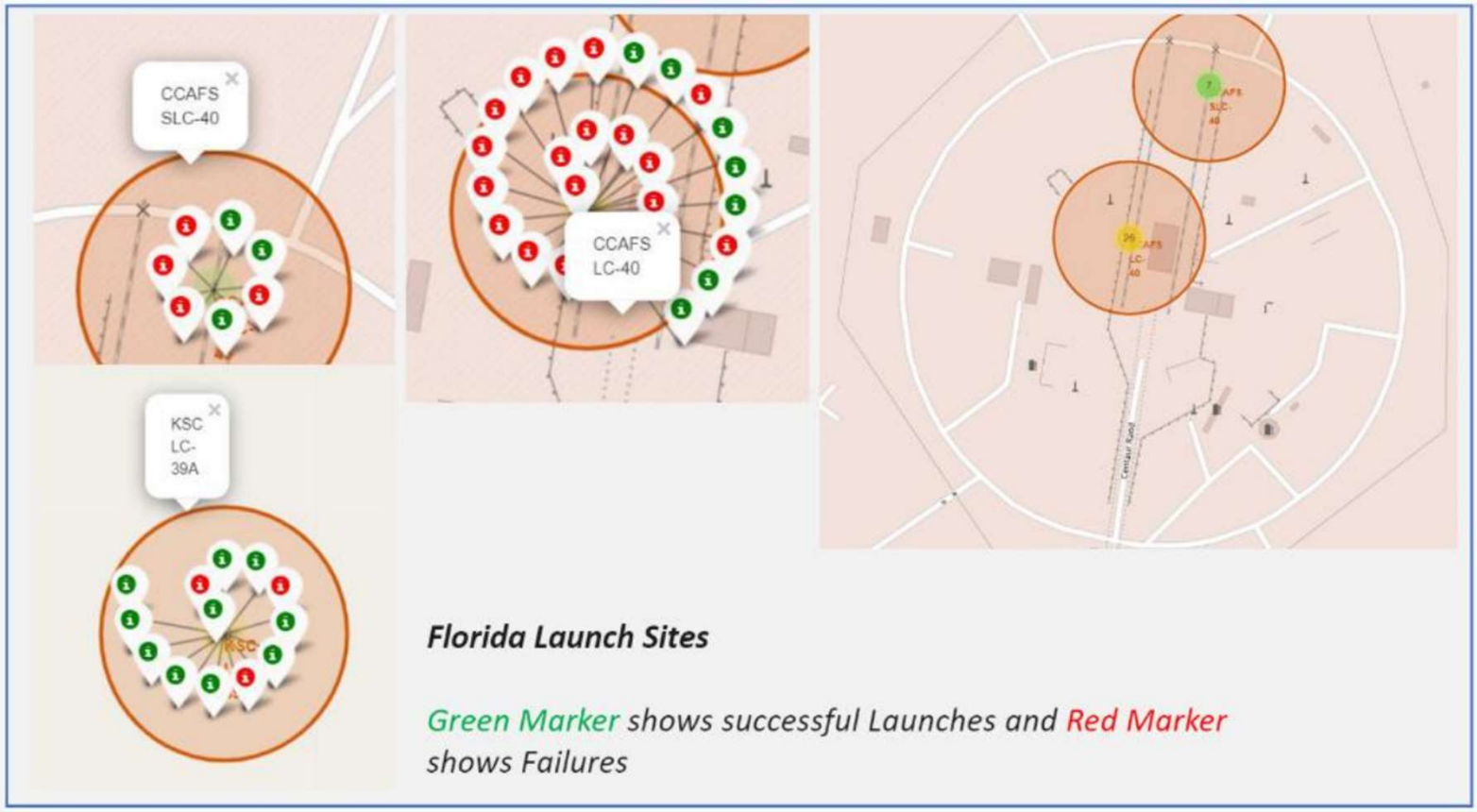
```
SELECT LandingOutcome, COUNT(LandingOutcome)
FROM SpaceX
WHERE DATE BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY LandingOutcome
ORDER BY COUNT(LandingOutcome) DESC
```

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

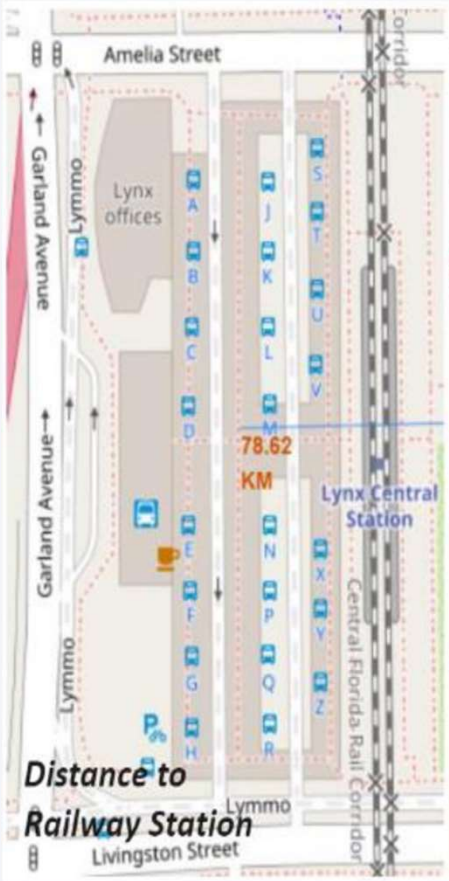

Section 3
Launch Sites
Proximities Analysis

All launch sites global map markers

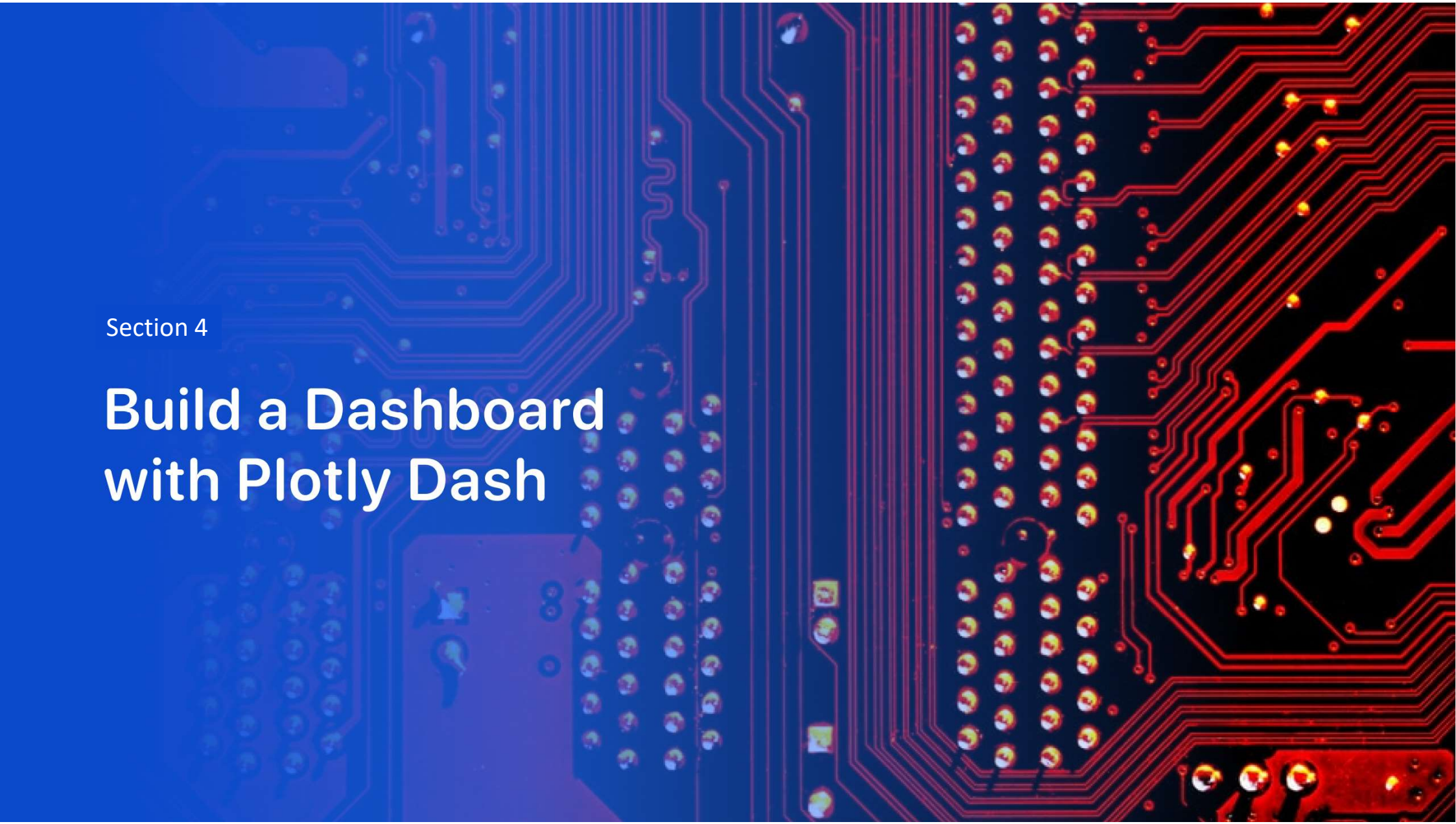
Markers showing launch sites with color labels



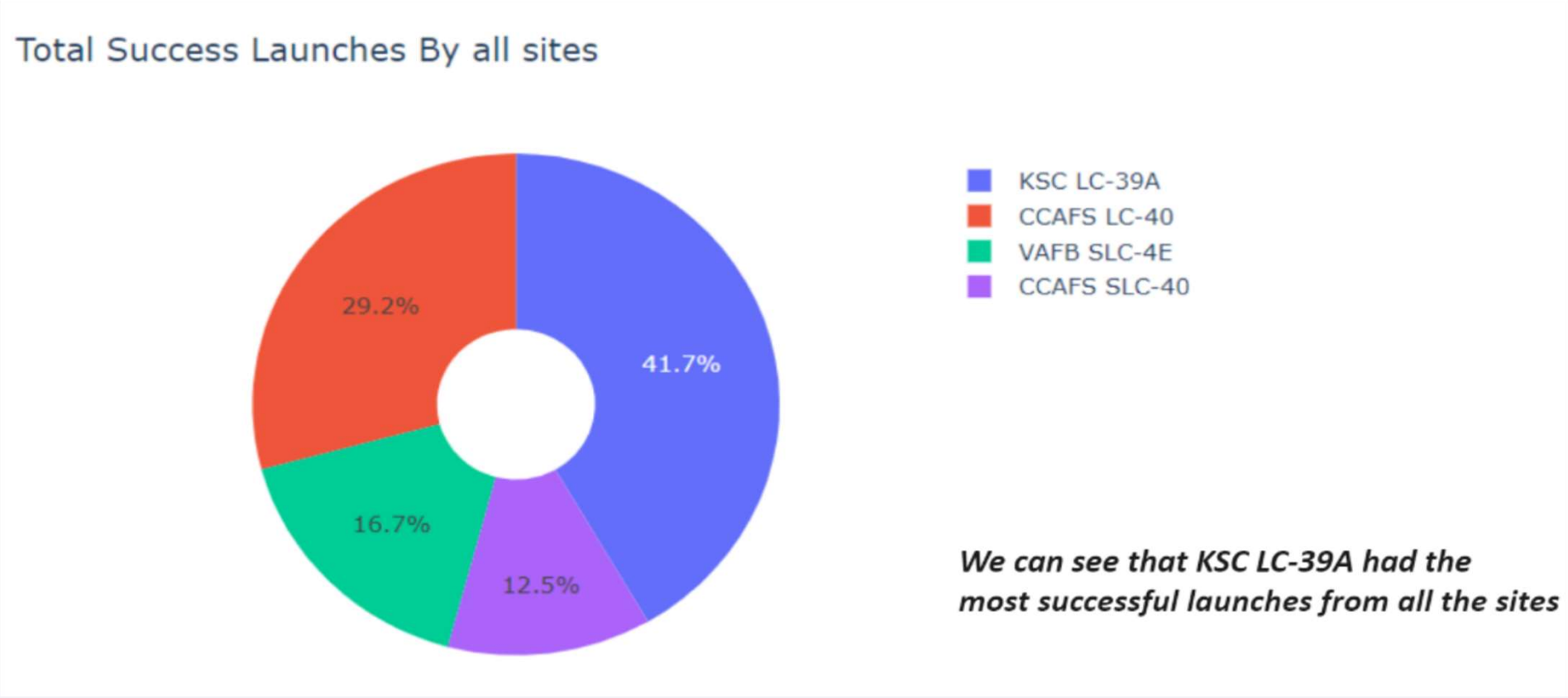
Launch Site distance to landmarks



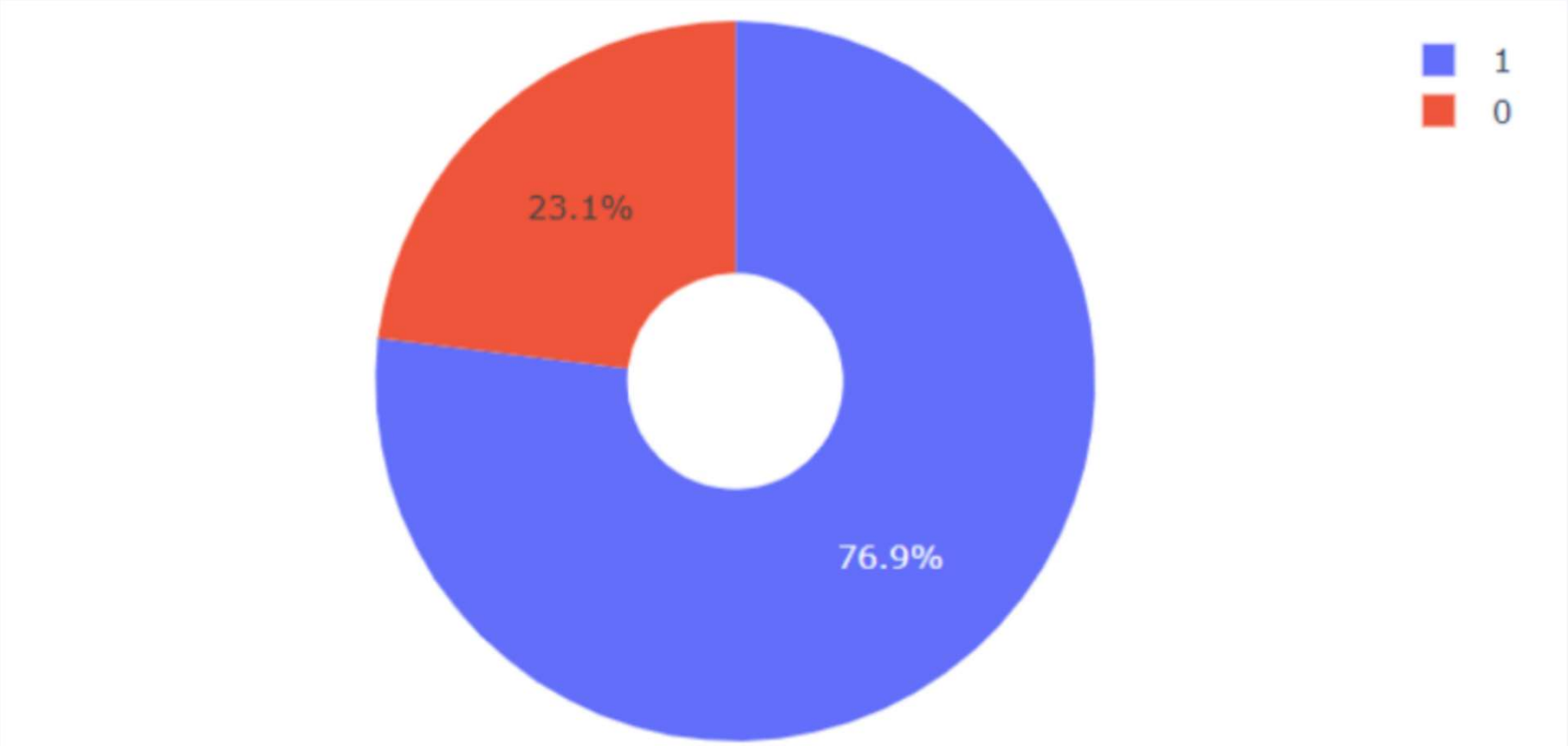
- Are launch sites in close proximity to railways? No
- Are launch sites in close proximity to highways? No
- Are launch sites in close proximity to coastline? Yes
- Do launch sites keep certain distance away from cities? Yes


Section 4
Build a Dashboard with Plotly Dash

Pie chart showing the success percentage achieved by each launch site

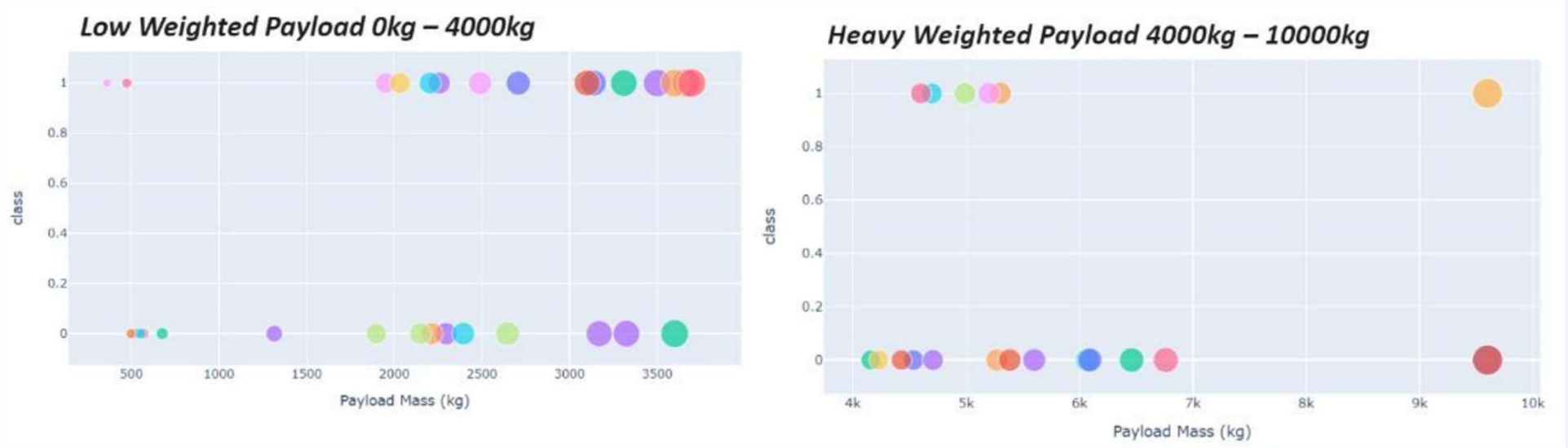


Pie chart showing the Launch site with the highest launch success ratio



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



- The success rate for light weighted payloads is higher than the success rate for heavy weighted payloads.

Section 5

Predictive Analysis (Classification)

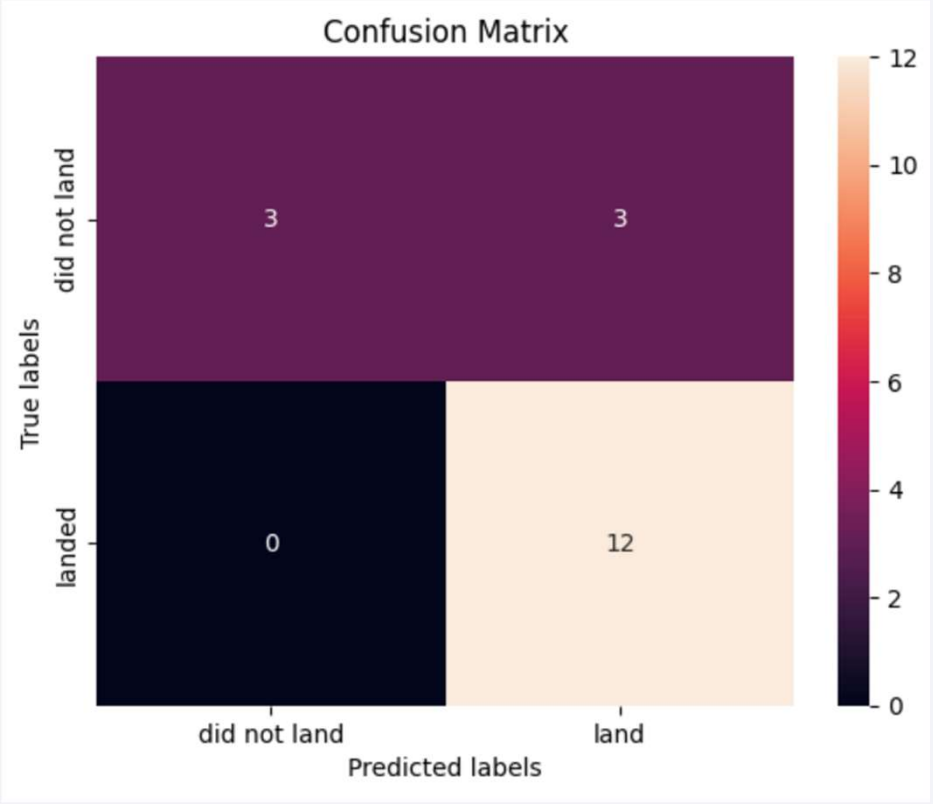
Classification Accuracy

Model	Validation Data Accuracy	Test Accuracy
Logistic Regression	0.846	0.833
SVM	0.848	0.833
Decision Tree	0.836	0.778
KNN	0.848	0.833

- Best model is KNN with a score of 0.8482142857142858
- Best params is : {'algorithm': 'auto', 'n_neighbors': 10, 'p': 1}

Confusion Matrix

- The classifier can distinguish between the different classes.
- The major problem is the false positives e.g., unsuccessful landing marked as successful landing by the classifier.



Conclusions

- 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 k nearest neighbors classifier is the best machine learning algorithm for this task.

Thank you!