IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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

Executive Summary

- Summary of methodologies
  - Data Collection using SpaceX API and web scraping
  - Exploratory Data Analysis (EDA), including data wrangling, data visualisation and interactive visual analytics
  - Machine Learning Prediction
- Summary of all results
  - It was possible to collect useful data from public sources.
  - EDA enabled us to determine which features best predict the success of launches.
  - Using all collected data, Machine Learning Prediction revealed the best model for predicting which characteristics are important to drive this opportunity.

Introduction

- Background
  - an alternate company wants to bid against SpaceX for a rocket launch
- Objectives
  - predict if the Falcon 9 first stage will land successfully
  - determine the cost of a launch
- Findings
  - the best place to make launches
  - the best method for estimating total launch costs by predicting successful first-stage rocket landings

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology
  - SpaceX data was obtained from two sources:
    - the Space X API (https://api.spacexdata.com/v4/rockets/)
    - web scraping (https://en.wikipedia.org/wiki/List of Falcon/ 9/ and Falcon Heavy launches/)
- Perform data wrangling
  - Performed some Exploratory Data Analysis (EDA) to find some patterns in the data and determined what would be the label for training supervised models

Methodology

Executive Summary

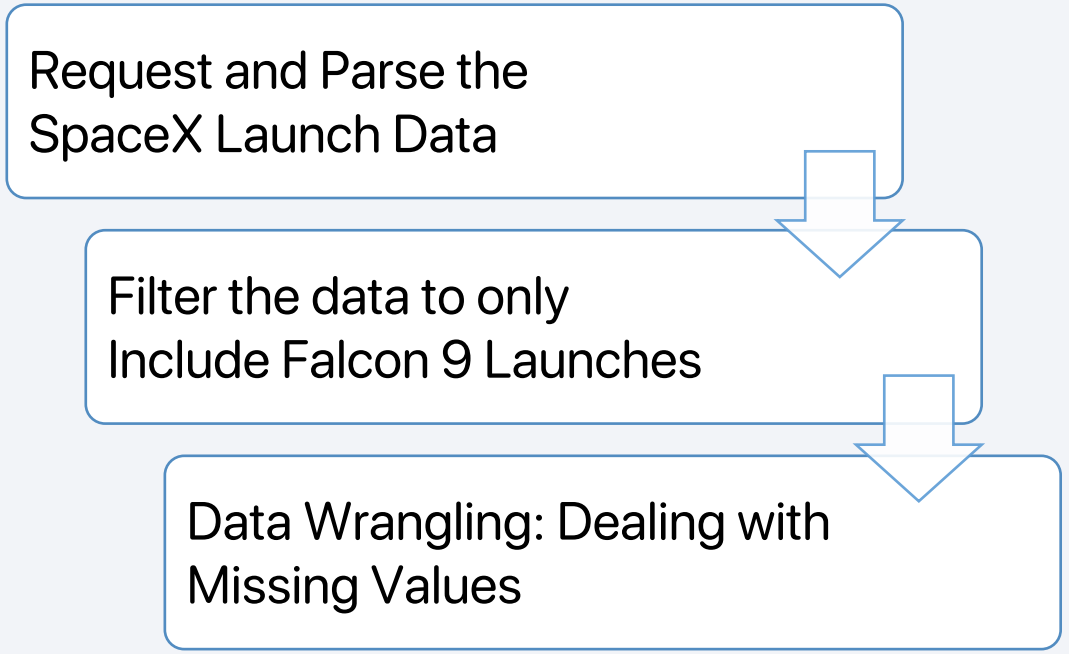
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - normalised the data collected up to this point
  - divided data into training and test sets
  - evaluated those data sets by four different classification models
  - evaluated the accuracy of each model using different parameter combinations

Data Collection

- SpaceX data was collected from two sources:
  - the Space X API (https://api.spacexdata.com/v4/rockets/)
  - web scraping (https://en.wikipedia.org/wiki/List of Falcon/ 9/ and Falcon Heavy launches/)

Data Collection – SpaceX API

1. Made a get request and parse the SpaceX launch data using the GET request
2. Filtered the data using the BoosterVersion column to only keep the Falcon 9 launches
3. Did some basic data wrangling and formatting as there are some missing values

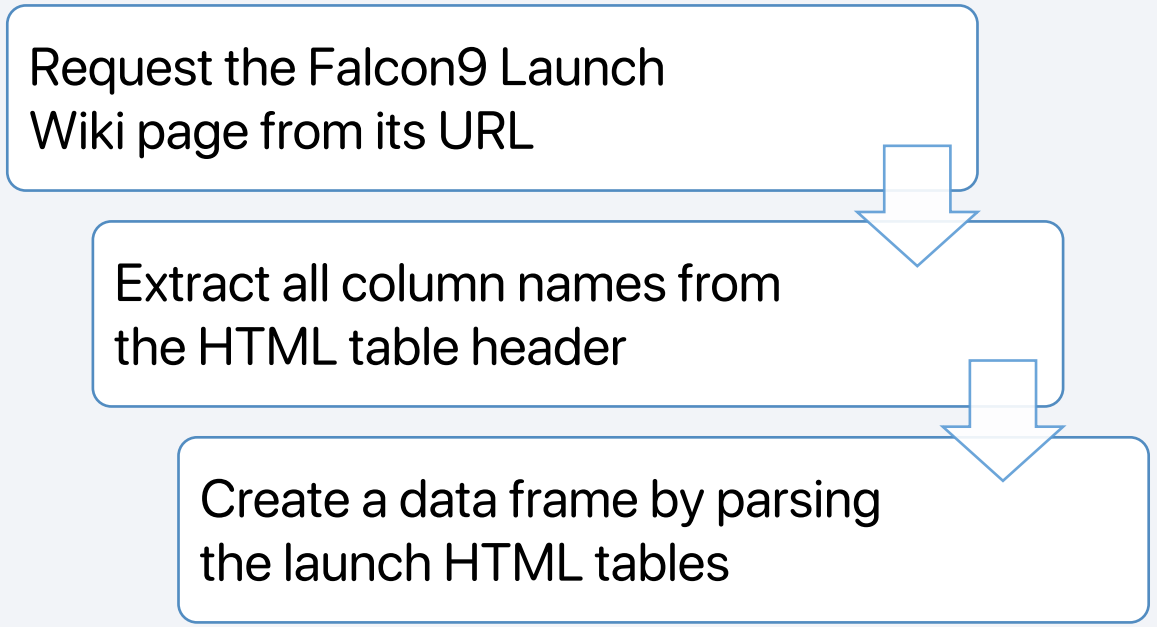


The SpaceX API Data Collection Process

HERE is the GitHub URL of the completed interactive map with Folium notebook, as an external reference.

Data Collection - Scraping

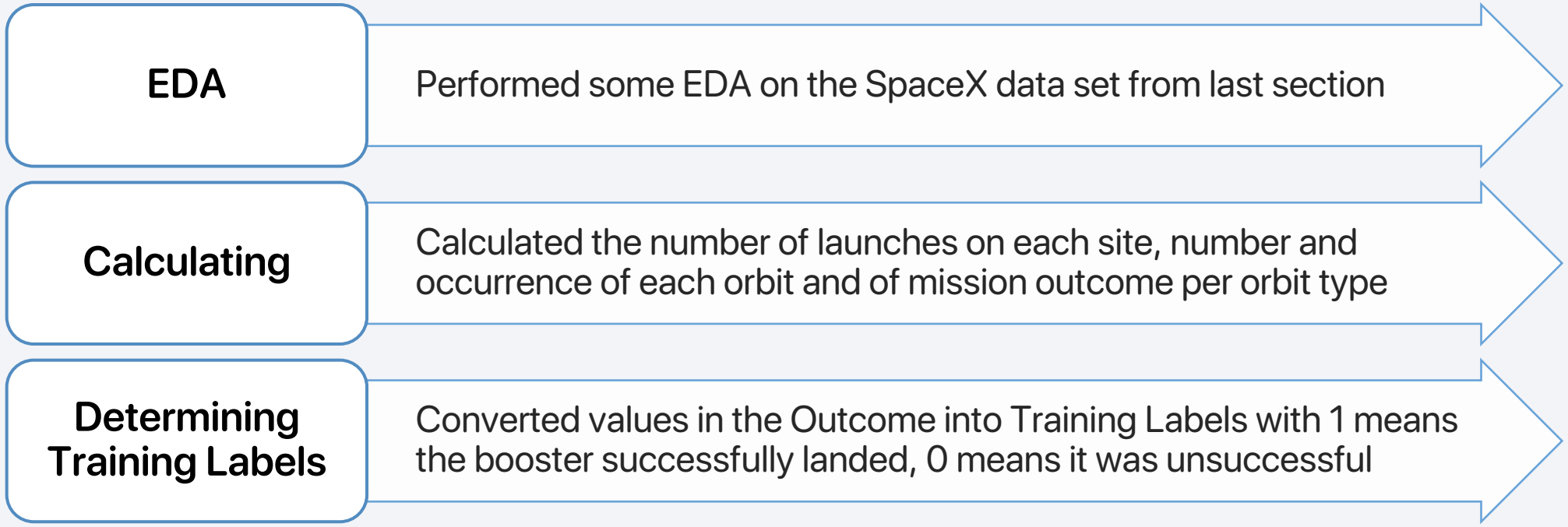
1. Perform an HTTP GET method to request the Falcon9 Launch HTML Wiki page, as an HTTP response
2. Extract all column/variable names from the HTML table header
3. Parsing the launch record values into a dictionary and create a data frame from it.



The Web Scraping Data Collection Process

HERE is the GitHub URL of the completed interactive map with Folium notebook, as an external reference.

Data Wrangling



The Data Wrangling Process

HERE is the GitHub URL of the completed interactive map with Folium notebook, as an external reference.

EDA with Data Visualization

- Scatter plots were used to visualise the correlation between numerical variables.
- Bar plot illustrates the relationship between numerical and categorical variables.
- Line graph was used to track changes over a short or long periods of time. It can also make prediction for unseen data.

- Scatter plots:
  - Flight Number and Launch Site
  - Payload and Launch Site
  - Flight Number and Orbit type
  - Payload and Orbit type
- Bar plot:
  - Success Rate of Each Orbit Type
- Line graph:
  - Launch Success Yearly Trend

HERE is the GitHub URL of the completed EDA with data visualisation notebook, as an external reference.

EDA with SQL

The following SQL queries were performed to gather and understand data:

- Displaying the names of the unique launch sites in the space mission
- Display 5 records where launch sites begin with the string 'CCA'
- Display the total payload mass carried by boosters launched by NASA (CRS)
- Display average payload mass carried by booster version F9 v1.1
- List the date when the first successful landing outcome in ground pad was achieved.
- List the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000
- List the total number of successful and failure mission outcomes
- List the names of the booster_versions which have carried the maximum payload mass
- List the records which will display the month names, failure landing_outcomes in drone ship, booster versions, launch site for the months in year 2015
- Rank the count of successful landing_outcomes between the date 2010-06-04 and 2017-03-20 in descending order

HERE is the GitHub URL of the completed EDA with SQL notebook, as an external reference.

Build an Interactive Map with Folium

Markers, circles, lines and marker clusters were created and added to the folium maps to better understand the problem and the data

- The red circles at several location display theirs coordinate, and the label show theirs name.
- The cluster of points demonstrate multiple and distinct information for the same coordinates
- Green markers represent the successful landings, whilst red markers represent the failed landings.
- The coloured lines indicate the distance between the launch site and key locations (railway, motorway, coastline, and city)

HERE is the GitHub URL of the completed interactive map with Folium notebook, as an external reference.

Build a Dashboard with Plotly Dash

The dashboard includes dropdown, pie chart, range slider, and scatter plot elements

- The Dropdown allows a user to select a specific launch site or all launch sites
- The pie chart shows both the total success and total failure for the launch site selected
- Range slider is used to select a payload mass in a fixed range
- Scatter chart illustrates the relationship between two variables, in particular Success vs Payload Mass

HERE is the GitHub URL and HERE are the screenshots of the completed Plotly Dash lab, as an external reference.

Predictive Analysis (Classification)

Data preparation

- Load data set
- Normalise and standardise data
- Split data into training and test sets

Model preparation

- Choose and set parameters for each of four machine algorithms (logistic, SVM, decision tree and KNN) to GridSearchCV
- Train each GridSearchCV model using the training set

Model evaluation

- Get best hyperparameters for each type of model
- Compute accuracy for each model using the test set
- Plot the confusion matrix

Model comparison

- Compare four models according to their accuracy
- Select the model with the highest accuracy score

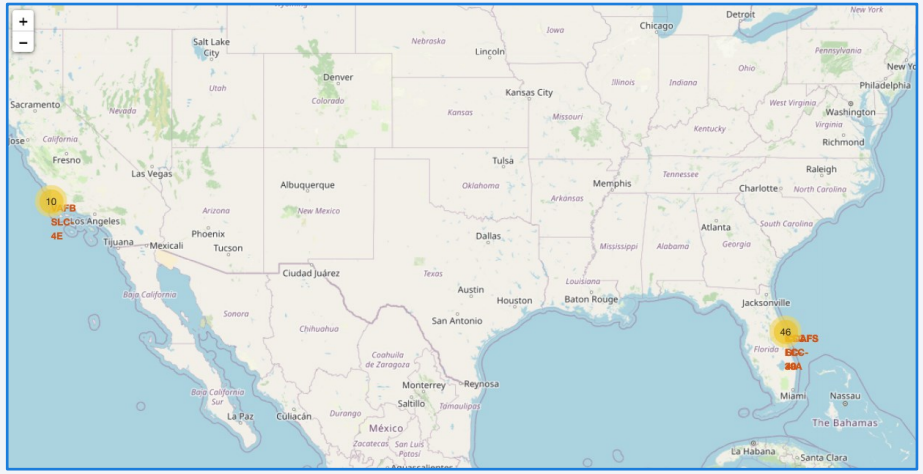
HERE is the GitHub URL of the completed interactive map with Folium notebook, as an external reference.

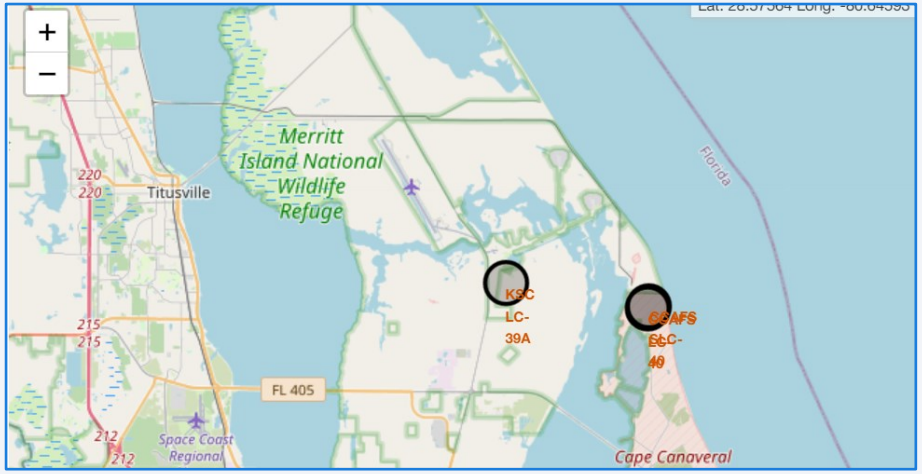
Results

- Exploratory data analysis results:
  - SpaceX launches from four different locations
  - The first launches were made by SpaceX and NASA
  - The average payload of F9 v1.1 booster is 2,928kg
  - The first successful landing occurred in 2015, five years after the first launch
  - Many Falcon 9 booster versions successfully landed in drone ships with payloads greater than the average
  - Almost 100% of mission outcomes were successful
  - In 2015, two booster versions failed to land on drone ships: F9 v1.1 B1012 and F9 v1.1 B1015
  - As time passed, the number of landing outcomes improved

Results

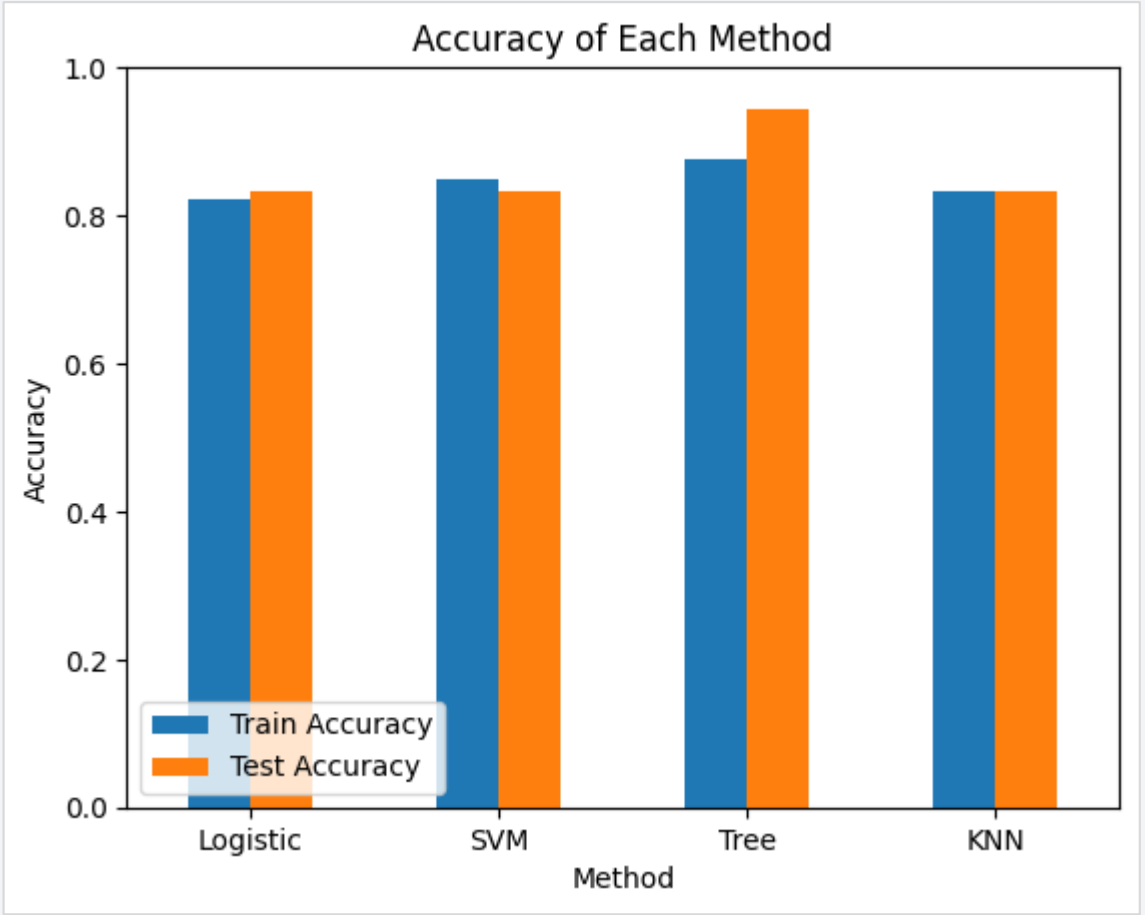
- Interactive analytics:
  - Using interactive analytics, it was possible to determine that launch sites used to be in safe areas, such as near the sea, and had a good logistics infrastructure nearby.
  - The majority of launches took place at east coast launch sites.





Results

- Predictive analysis
  - The final output shows that Decision Tree Classifier is the best model for predicting successful landings, with the highest accuracy of 87% and accuracy of over 94% for test data.

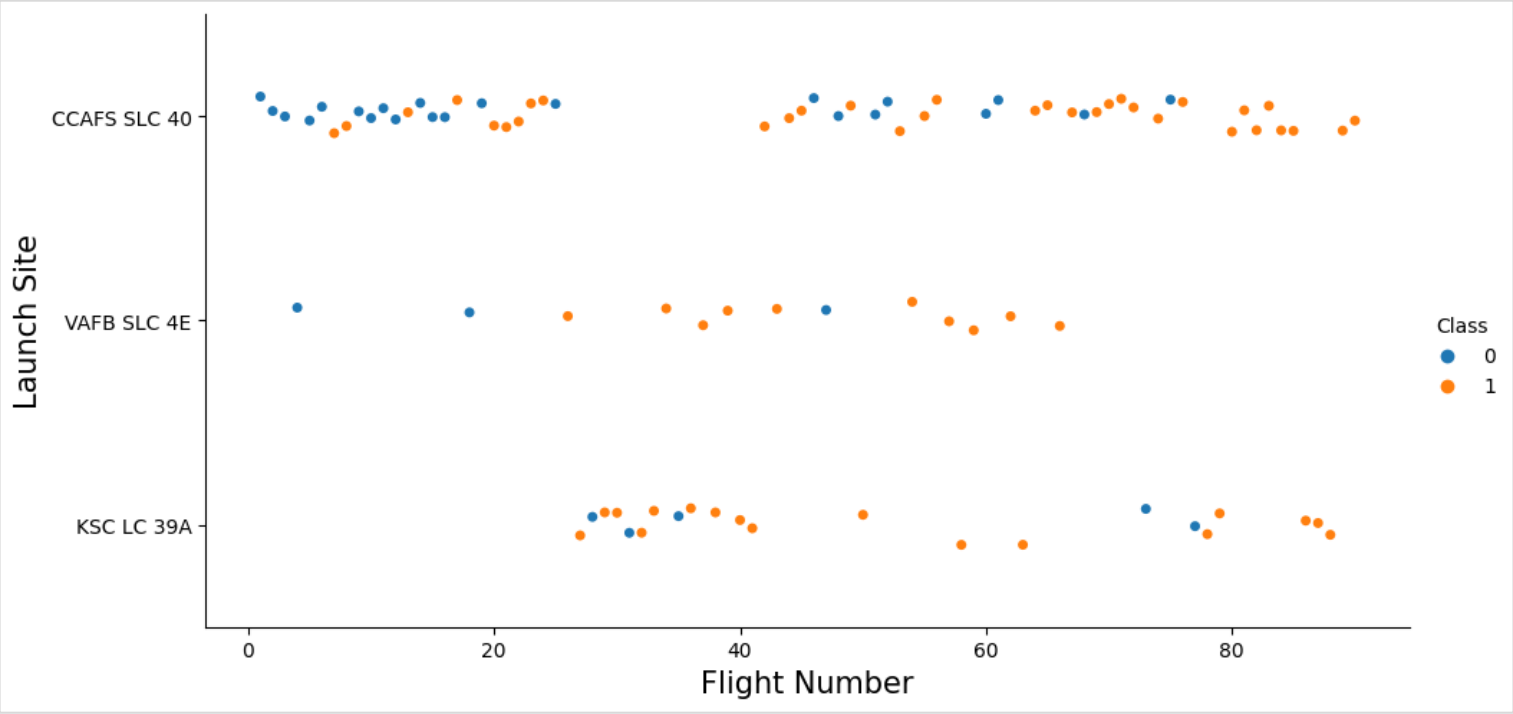


Section 2

Insights drawn from EDA

Flight Number vs Launch Site

The overall success rate has increased over time

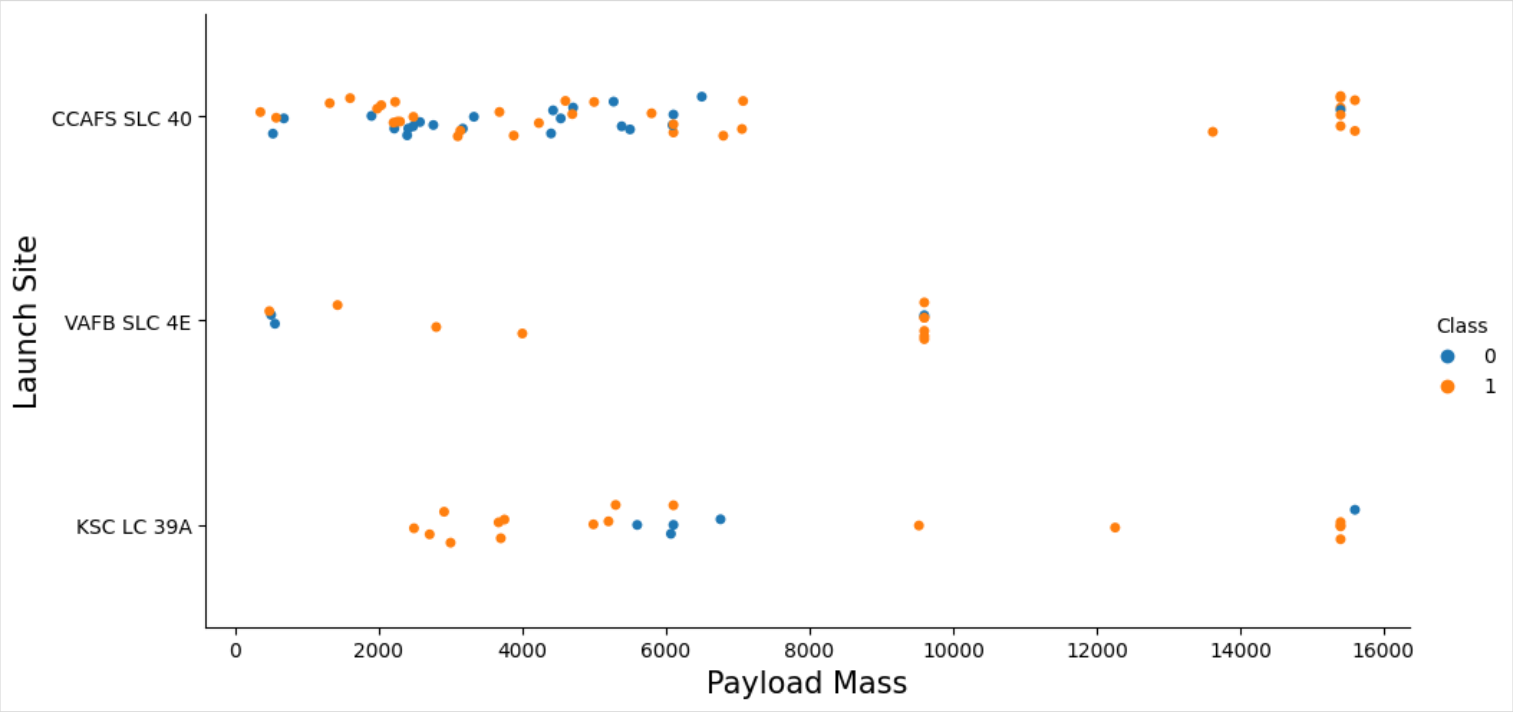


Scatter plot of Flight Number vs Launch Site

- The best launch site is CCAF5 SLC 40, where the most recent launches were successful.
- VAFB SLC 4E and KSC LC 39A are in second and third place, respectively.

Payload vs Launch Site

Depending on the launch site, a heavier payload may be necessary for a successful launch

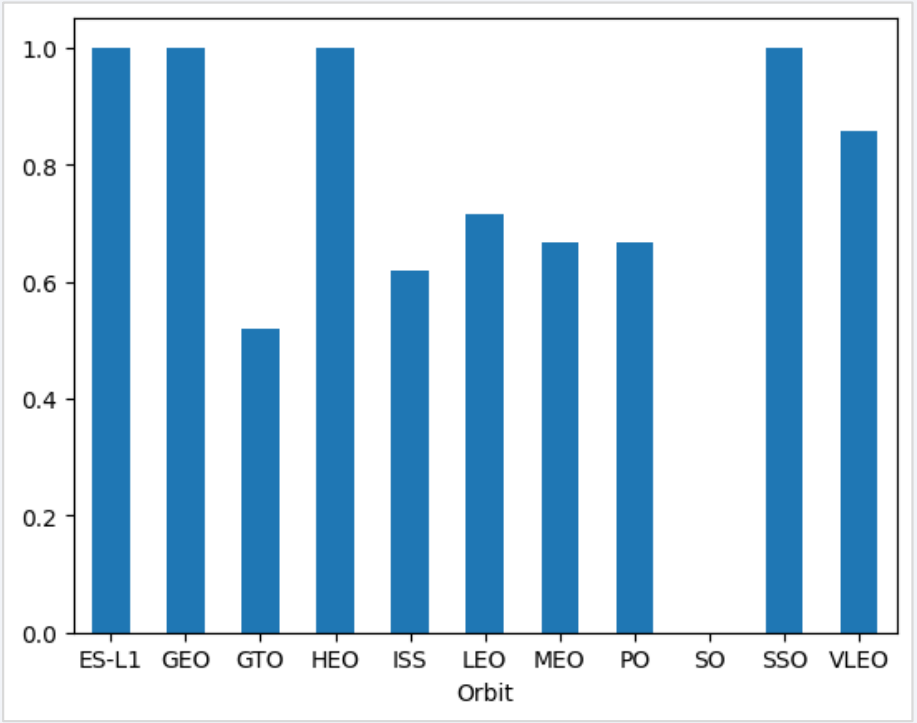


Scatter plot of Payload Mass vs Launch Site

- Payloads weighing more than 9,000kg have a high success rate.
- VAFB SLC 4E may be incapable of launching payloads weighing more than 12,000kg.

Success Rate vs Orbit Type

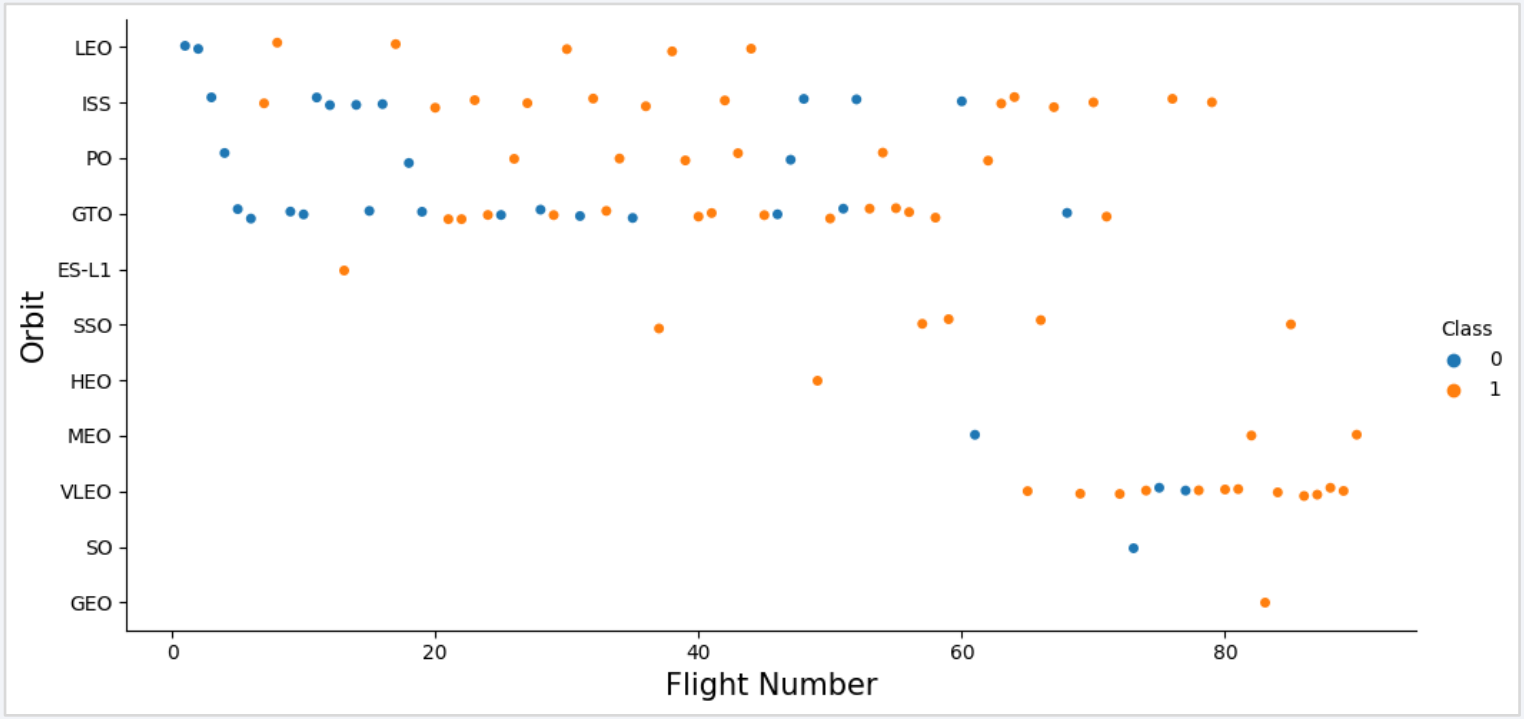
The ES-L1, GEO, HEO and SSO orbits have the highest success rate for launches, followed by VLEO (above 80%)



Bar chart for the success rate of each orbit

Flight Number vs Orbit Type

As the number of flights increased, so did the success rates in all orbits

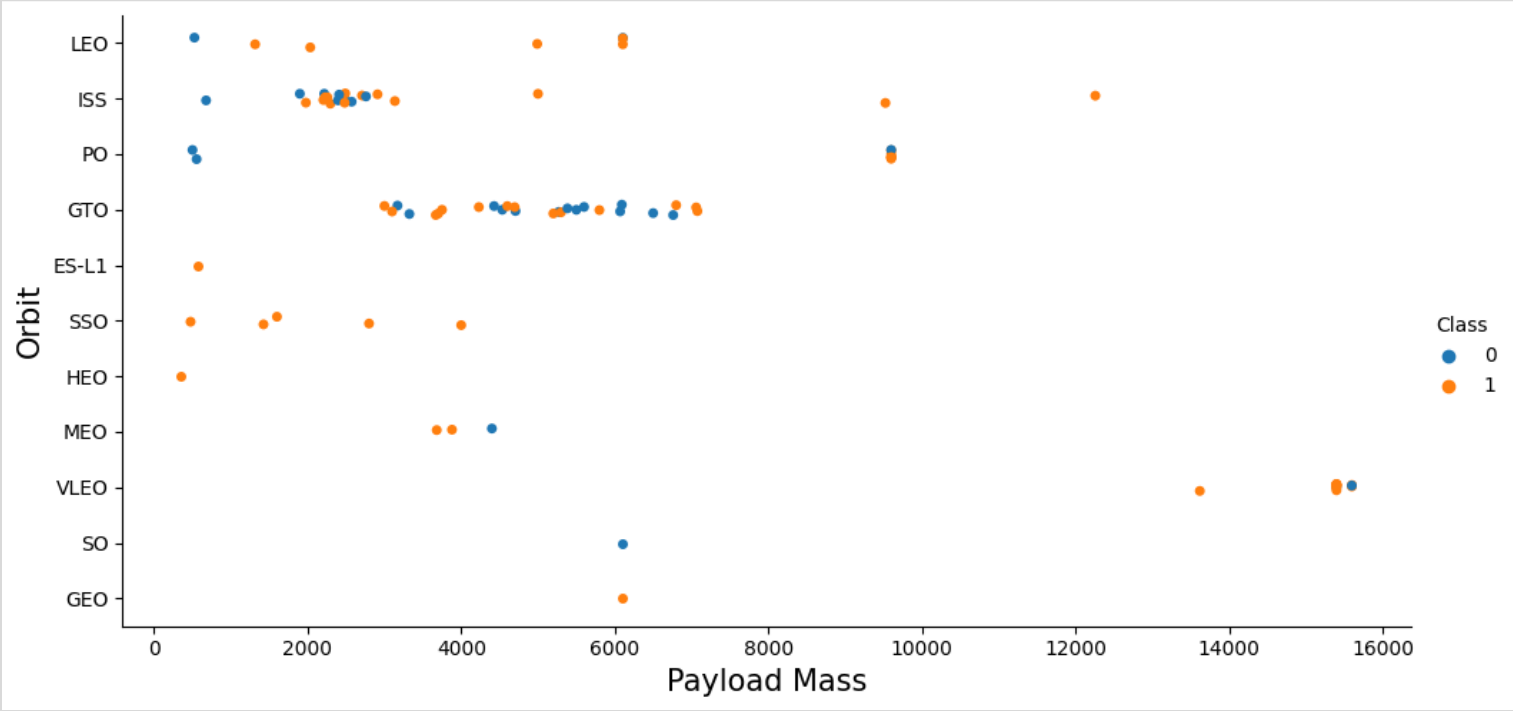


Scatter plot of Flight Number vs Orbit Type

- Because of the recent increase in frequency, VLEO orbit seems like a new business opportunity.
- We can assume that the high success rate of some orbits, such as SSO, is based on the knowledge gained from previous launches of other orbits.

Payload vs Orbit Type

The weight of payloads have a significant positive impact on the success rate of launches in specific orbits.

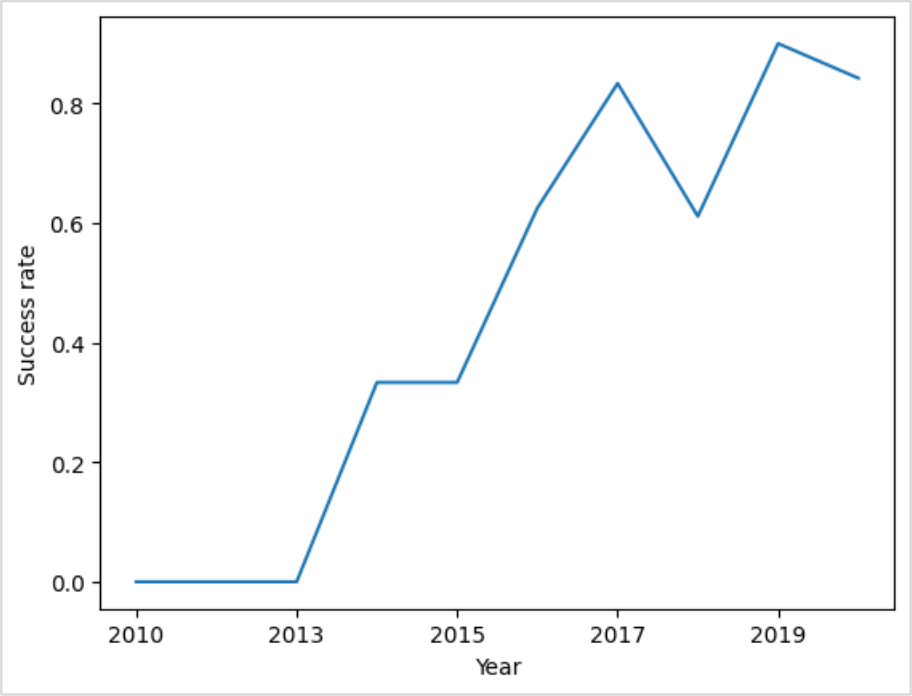


Scatter plot of Payload vs Orbit Type

- The higher the success rate for the LEO orbit, the heavier the payloads.
- There is no correlation between payload and GTO success rate.

Launch Success Yearly Trend

From 2013 to 2020, the SpaceX success rate has increased rapidly



There have been no changes in the first three years, it may be a period of adjustment and technological advancement

Line chart for the average launch success yearly trend

All Launch Site Names

Find the names of the unique launch sites

```
SELECT DISTINCT launch_site FROM spacex
```

The use of DISTINCT in the query was used to select the unique ‘launch_site’ names from the data set

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

Launch Site Names Begin with 'CCA'

Find 5 records where launch sites begin with ‘CCA’

```
SELECT * FROM spacex WHERE launch_site LIKE 'CCA%' LIMIT 5
```

The WHERE clause, followed by the LIKE clause, filtered out launch sites with the prefix ‘CCA’. LIMIT 5 displays the first 5 records from the filtered set.

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

Calculate the total payloads carried by booster from NASA (CRS)

```
SELECT SUM(payload_mass_kg_) as total_payload_mass FROM spacex
WHERE customer = 'NASA (CRS)'
```

total_payload_mass
45596

Average Payload Mass by F9 v1.1

Calculate the average payload mass carried by booster version F9 v1.1

```
SELECT AVG(payload_mass_kg_) FROM spacex
WHERE booster_version LIKE '%F9 v1.1%'
```

avg_payload
2534

This query returned the average of all payload masses where the booster version contains the substring ‘F9 v1.1’, which is 2534kg

First Successful Ground Landing Date

Find the dates of the first successful landing outcome on ground pad

```
SELECT MIN(DATE) FROM spacex WHERE landing_outcome = 'Success (ground pad)'
```

The WHERE clause filtered the data set in order to keep only records where landing on ground pad was successful.

The MIN function returned the record with the oldest date.

first_successful_date
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

List the names of boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 6000

```
SELECT booster_version, payload_mass_kg_ FROM spacex
WHERE payload_mass_kg_ BETWEEN 4000 AND 6000
AND landing_outcome = 'Success (drone ship)'
```

booster_version	payload_mass_kg_
F9 FT B1022	4696
F9 FT B1026	4600
F9 FT B1021.2	5300
F9 FT B1031.2	5200

Total Number of Successful and Failure Mission Outcomes

Calculate the total number of successful and failure mission outcomes

```
SELECT mission_outcome, COUNT(*) as occurences FROM spacex
GROUP BY mission_outcome
```

Grouping mission outcomes and counting records for each group led us to the summary below

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

Boosters Carried Maximum Payload

List the names of the booster which have carried the maximum payload mass

```
SELECT DISTINCT booster_version, payload_mass_kg_
FROM spacex
WHERE payload_mass_kg_ = (SELECT
                          MAX(payload_mass_kg_) FROM spacex)
```

The subquery filtered the data by returning only the heaviest payload mass with the MAX function. The main query used the subquery results and returned unique booster version (SELECT DISTINCT) with the heaviest payload mass

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

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

```
SELECT booster_version, launch_site,
landing_outcome FROM spacex
WHERE YEAR(DATE)=2015
AND landing_outcome = 'Failure (drone ship)'
```

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

This query returned booster versions and launch sites where landing was failed within 2015.

YEAR(DATE) extracted the year in DATE column.

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

```
SELECT landing_outcome, COUNT(*) as occurences
FROM spacex
WHERE "DATE" BETWEEN '2010-06-04' and '2017-03-20'
GROUP BY landing_outcome
ORDER BY occurences DESC
```

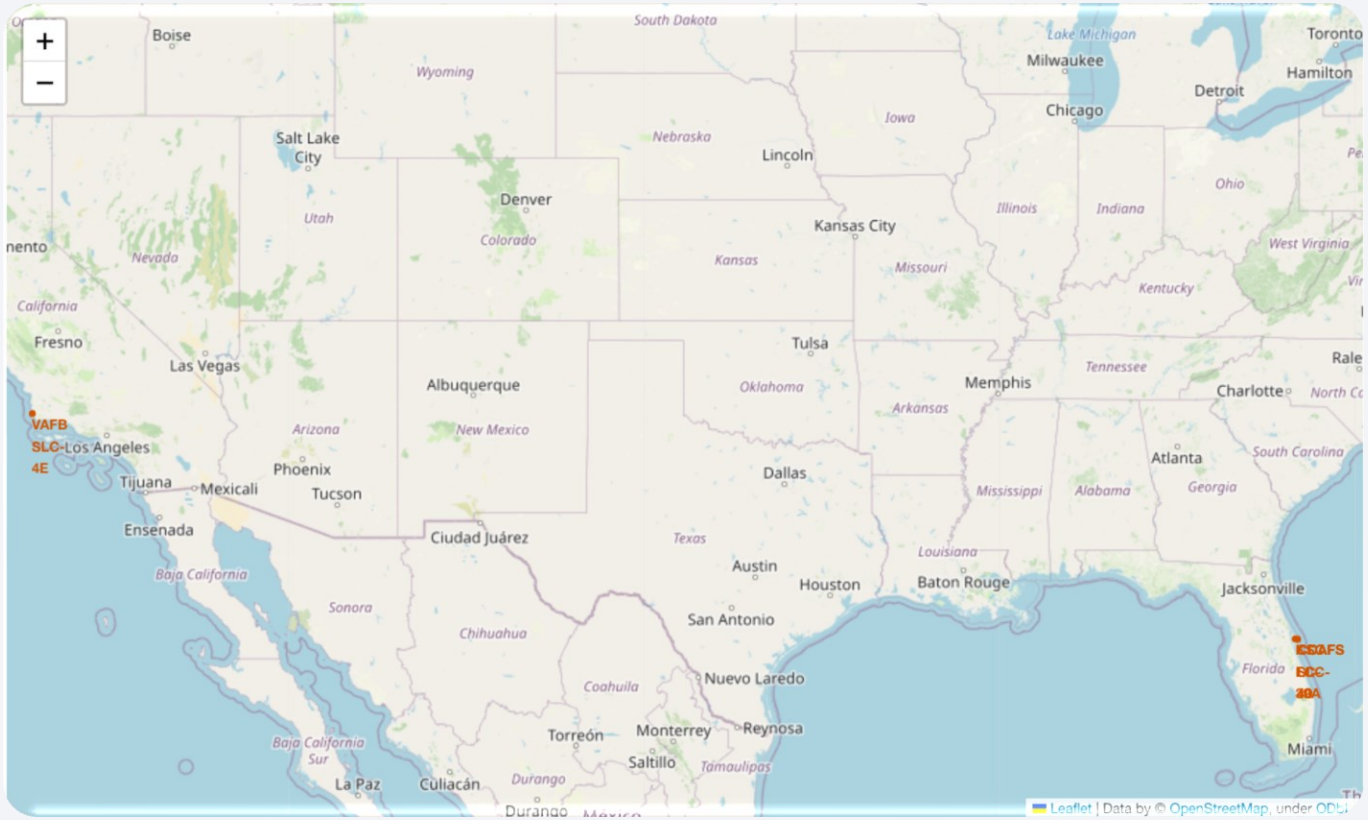
This query ranked landing outcomes by their number of occurrences from 4 Jun 2010 to 20 Mar 2017. The GROUP BY clause grouped the results by landing outcome and ORDER BY DESC displayed the results in descending order of occurrences.

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

Section 3

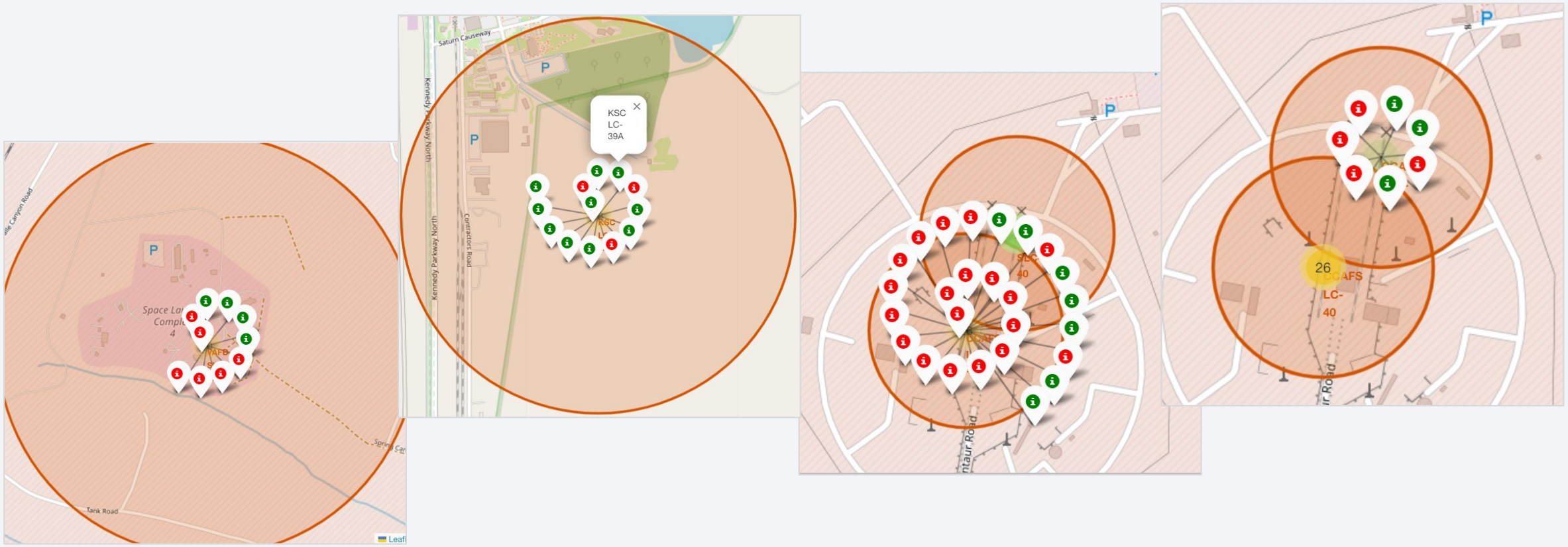
Launch Sites Proximities Analysis

All launch sites



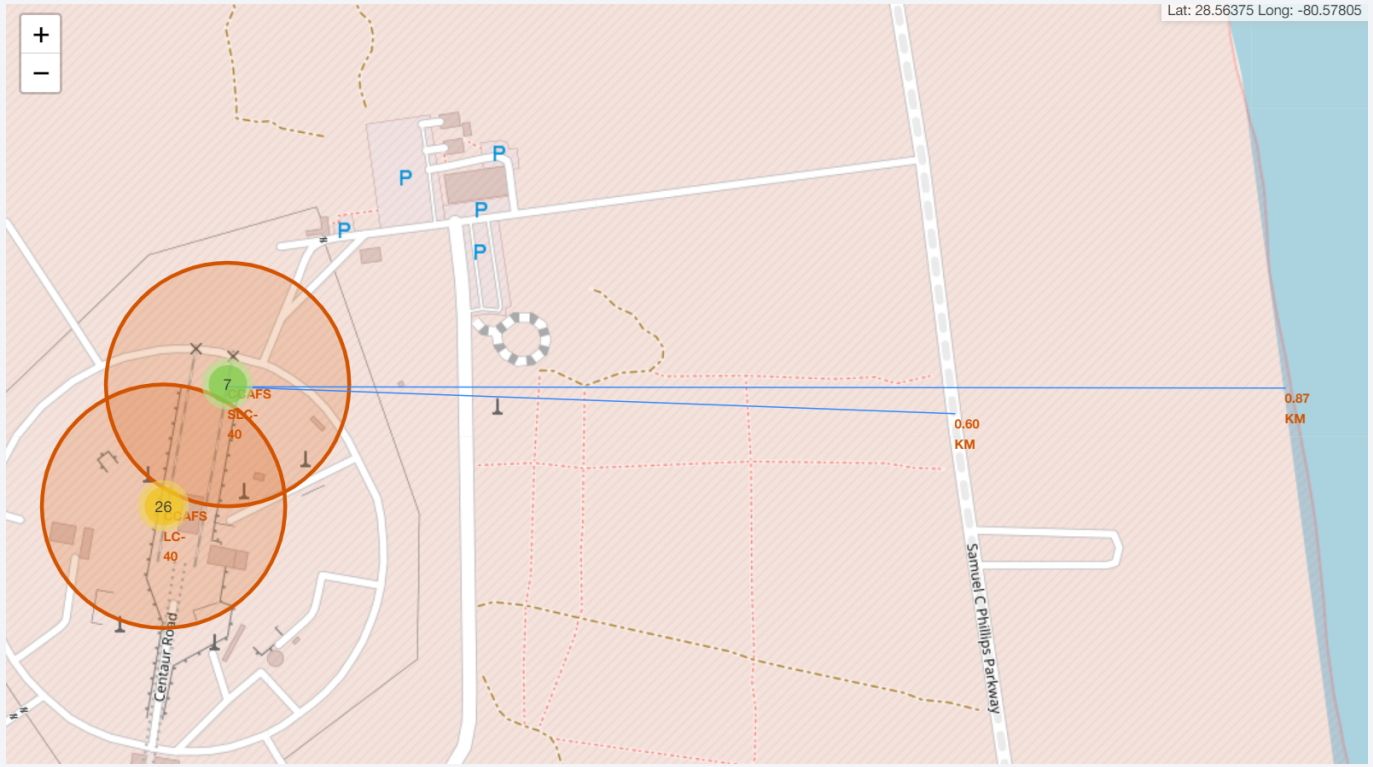
Launch sites are located on the coast of the United States, probably for safety, but not too far from roads and railways.

The colour-labelled launch site

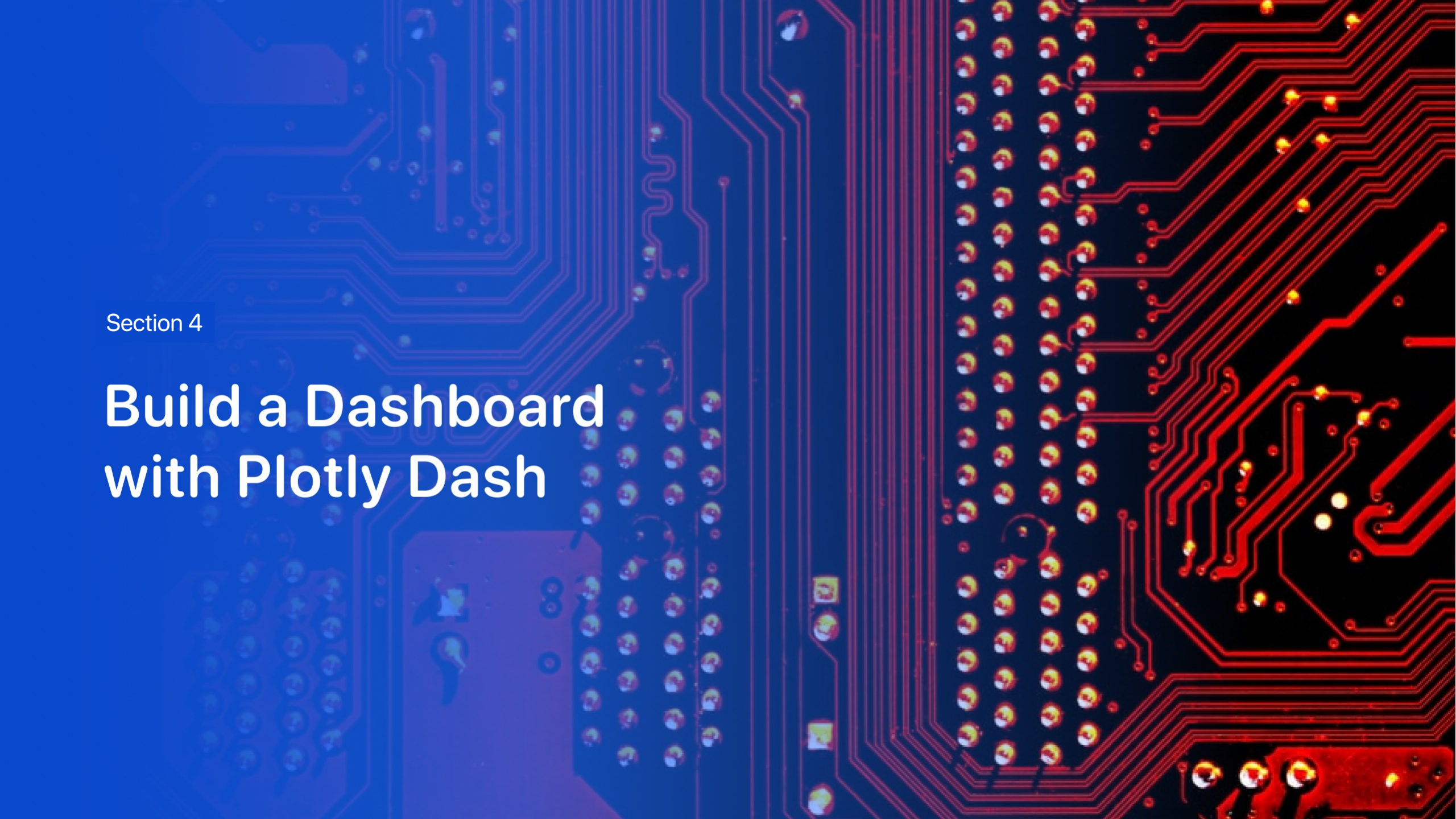


The green marker denotes successful launches. The red marker denotes failed launches. We notice that the KSC LC-39A has a higher success rate.

Logistics and Safety

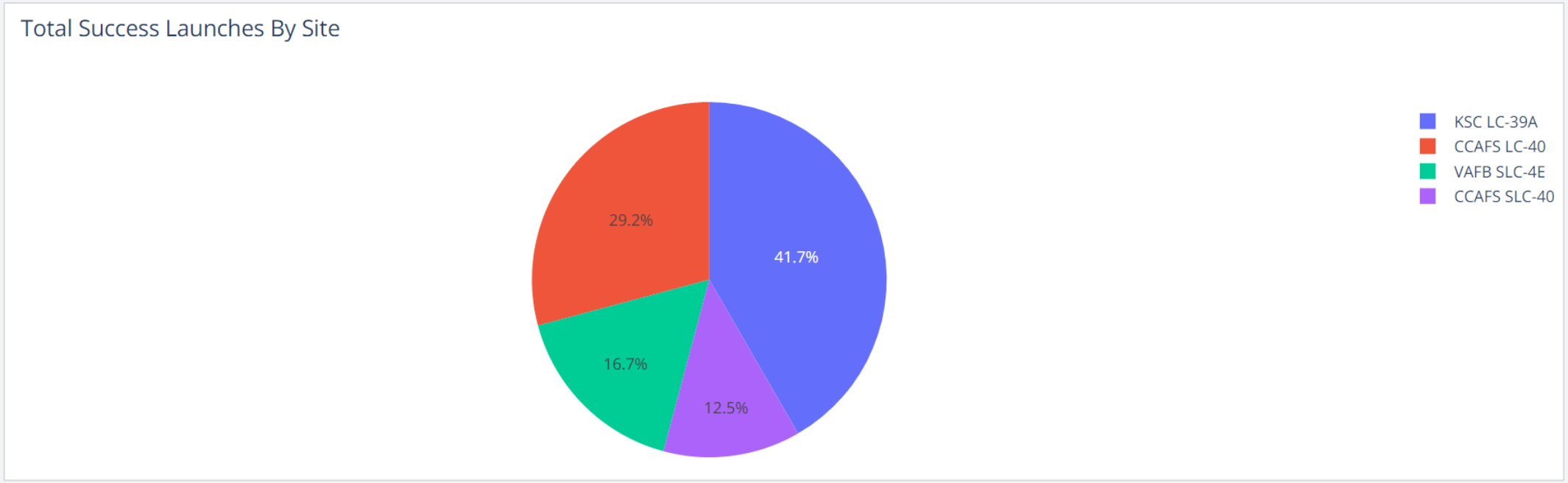


The launch site CCAFS SLC-40 has good logistics infrastructure, as it located in close proximity to railways, highways, coastline and relatively far from cities


Section 4
Build a Dashboard with Plotly Dash

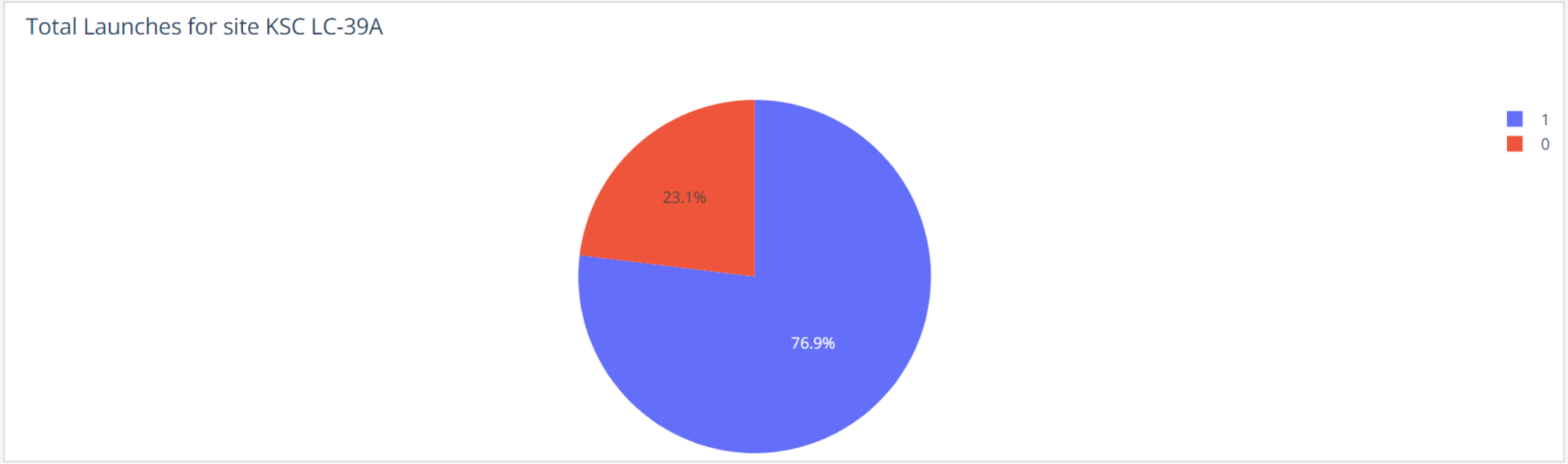
Total Successful Launches by Site

- Launch site appears to be an important factor of a successful mission
- KSC LC-39A stands out to be the best launch site with the success rate of 41.7%

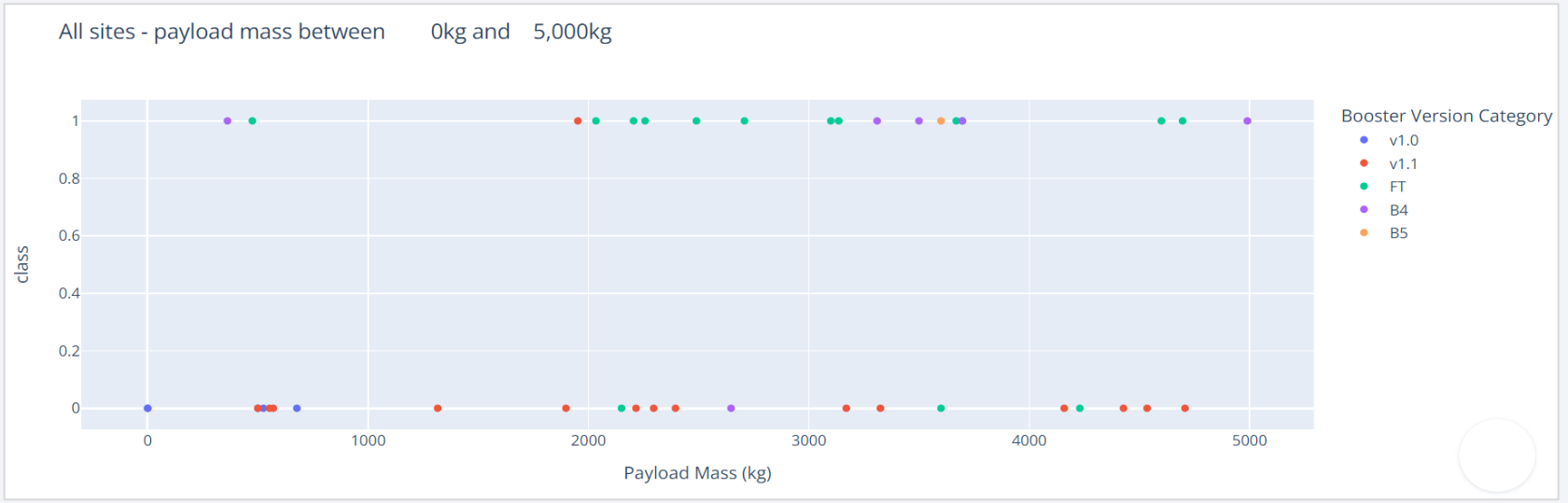


Launch Success Ratio for KSC LC-39A

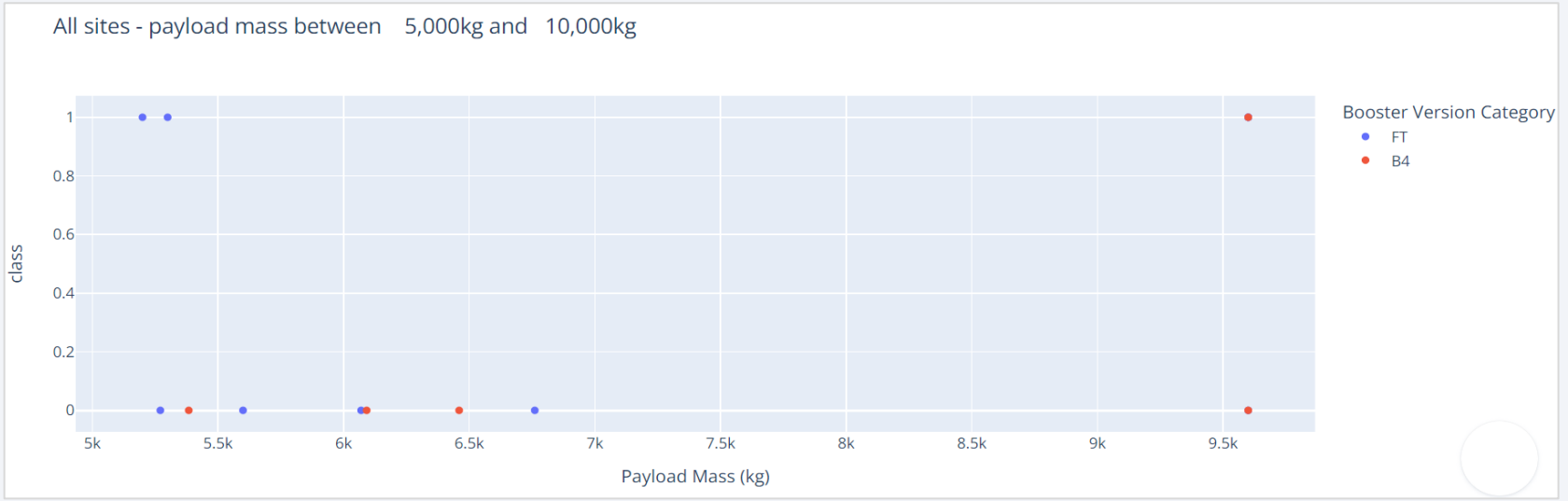
76.9% of launches are successful in the launch site KSC LC-39A



Payload Mass vs Outcome for all sites with different payload mass selected



Low weighted payloads have a higher success rate than heavy weighted payloads



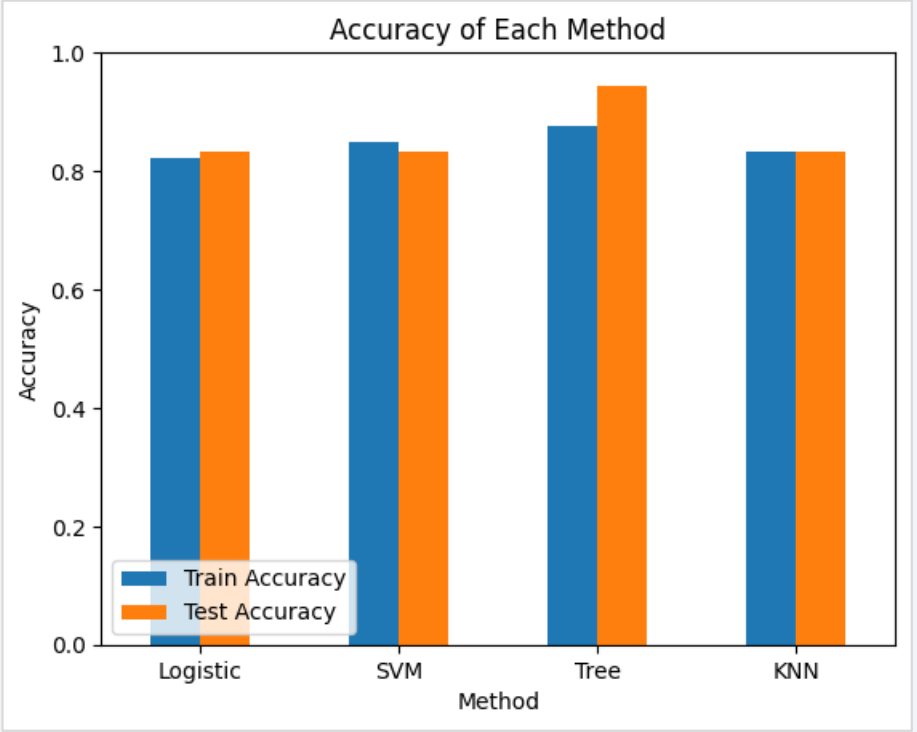
Not enough information to comment on payloads in range 7,000–9,500kg

Section 5

Predictive Analysis (Classification)

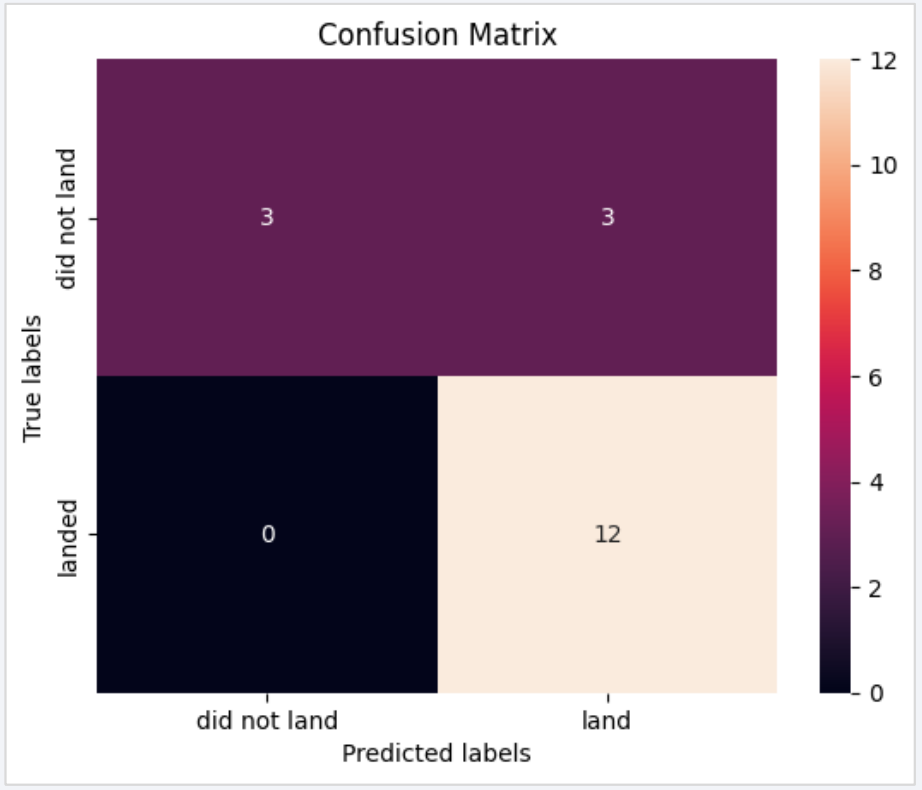
Classification Accuracy

- Four classification models were built, and their accuracies are shown in the accompanying figure.
- Both the train and test accuracy indices of the Decision Tree Classifier are above 87%, which are the highest values in the chart.



Confusion Matrix of Decision Tree Classifier

Confusion matrix of Decision Tree Classifier demonstrates its accuracy by displaying a large number of true positive and true negative results compared to false results.



Conclusions

- In this project, different data sets were analysed to refine conclusions.
- GEO, HEO, SSO and ES-L1 orbits have the highest success rates.
- KSC LC-39A is the best launch site.
- Depending on the orbits, payload mass can be a criterion to consider for the success of a mission. Some orbits required a light or heavy payload mass; however, low weighted payloads performed better than the heavy ones in general.
- Successful landing outcomes seem to improve over time, based on the evolution of engineering and technology.
- Decision Tree Classifier can be used to predict successful landings and increase profits because of its accuracy.

Appendix

All Python code, SQL queries, charts, Jupyter notebook and data sets that I have created during this project can be accessed from https://github.com/LeoThaiHuy/Applied-Data-Science-Capstone.git

Thank you!