Winning Space Race with Data Science

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Outline

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Executive Summary

The project of capstone deals with the prediction whether the SpaceX Falcon 9's first stage will be landing successfully or not. If the first stage will land successfully, it will allow as to estimate the cost of a launch. This can be achieved by using different machine learning classification algorithms. The methodology of this project involves data collection, data wrangling and processing, exploratory data analysis, data visualization and machine learning prediction. The result of my analysis indicates that some features of rocket launches have a correlation with the success of failure launches. To sum up, the decision trees allowed me to decide the best machine learning algorithm for this project.

Introduction

The aim of the capstone project is to predict whether the Falcon 9 first stage will land successfully or not. It is clearly shown how SpaceX is so proud of itself for being able to reuse the first stage of a rocket launch, where it advertise on SpaceX's website the cost of rocket launch (~$62 million) to compare itself with others, who is rocket launches cost $165 million. This saving came as a result of the first stage's reusability.

Determining if the first stage will land, will allow us to determine the cost of any launch in which other companies can use this information to compete with SpaceX in term of rocket launching.

So, with the given data about Falcon 9's features, will we be able to answer this question or not? And will the Falcon 9 first stage will land successfully?

Section 1

Methodology

Methodology

Executive Summary

I used two methods to collect data:

requesting data from the SpaceX API.

Web Scraping Launch Data (Wikipedia Webpage).

Following this, I perform data wrangling to transform and clean the data using Python's pandas library.

The result of the data wrangling approach, the exploratory data analysis (EDA) was performed using visualization tools such as Python's matplotlib and seaborn libraries, as well as answering questions using SQL queries.

Using python’s interactive visualization packages to answer some analytical questions. Folium was used for creating maps while Plotly Dash was used to create interactive data visualizations.

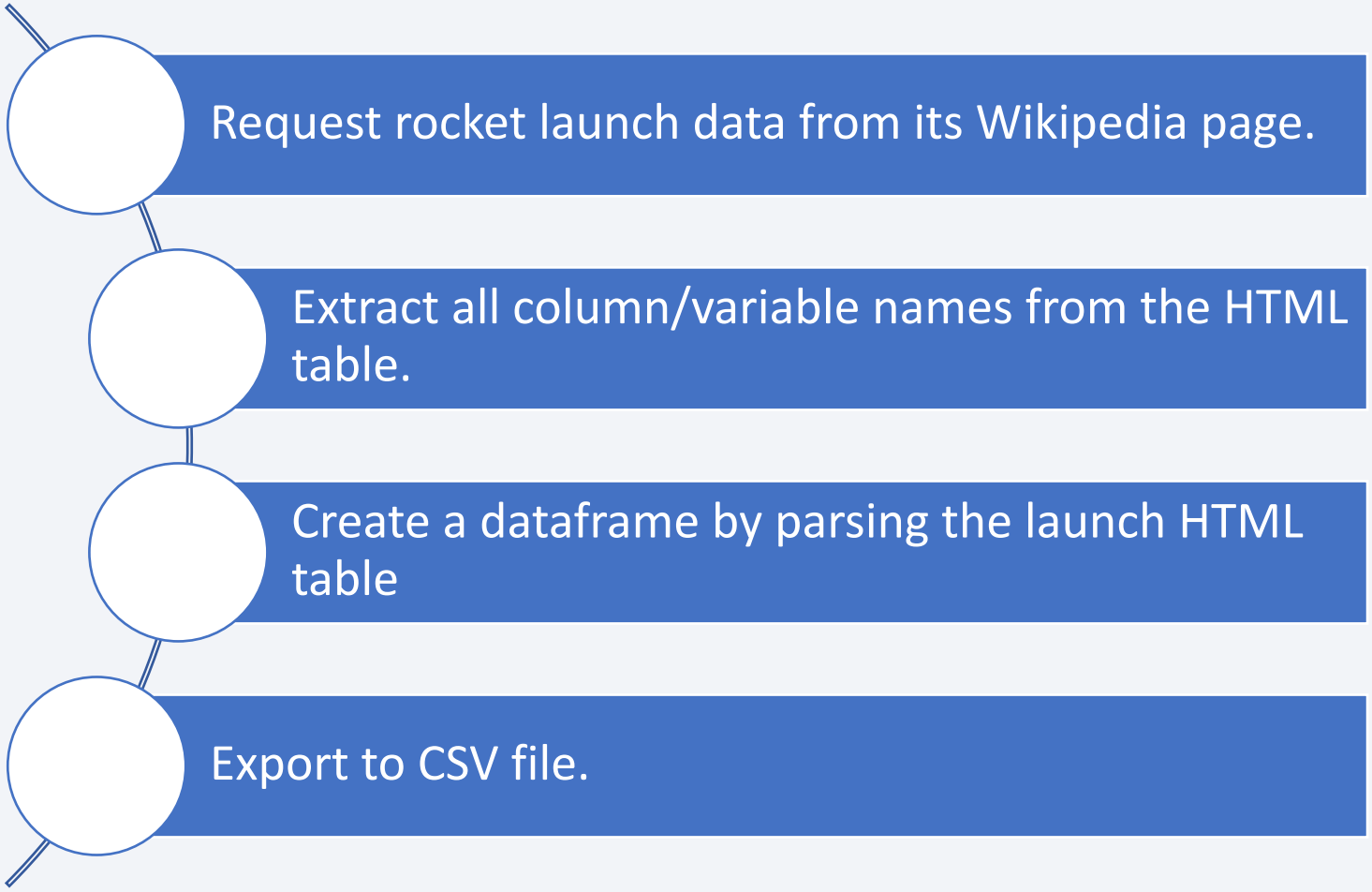
In case of machine learning, four different machine learning classification model were used for predictive analysis. These models include logistic regression, support vector machines, k-nearest neighbour and decision tree classifier. Each model was trained, tuned and evaluated to find the best one.

Data Collection

- Request and parse SpaceX launch data using the GET request.
- Normalize JSON response into a dataframe.
- Extract only useful columns using auxiliary functions.
- Create a new pandas dataframe from dictionary.
- Filter dataframe to only include Falcon 9 launches.
- Handle missing values.
- Export data to CSV file.

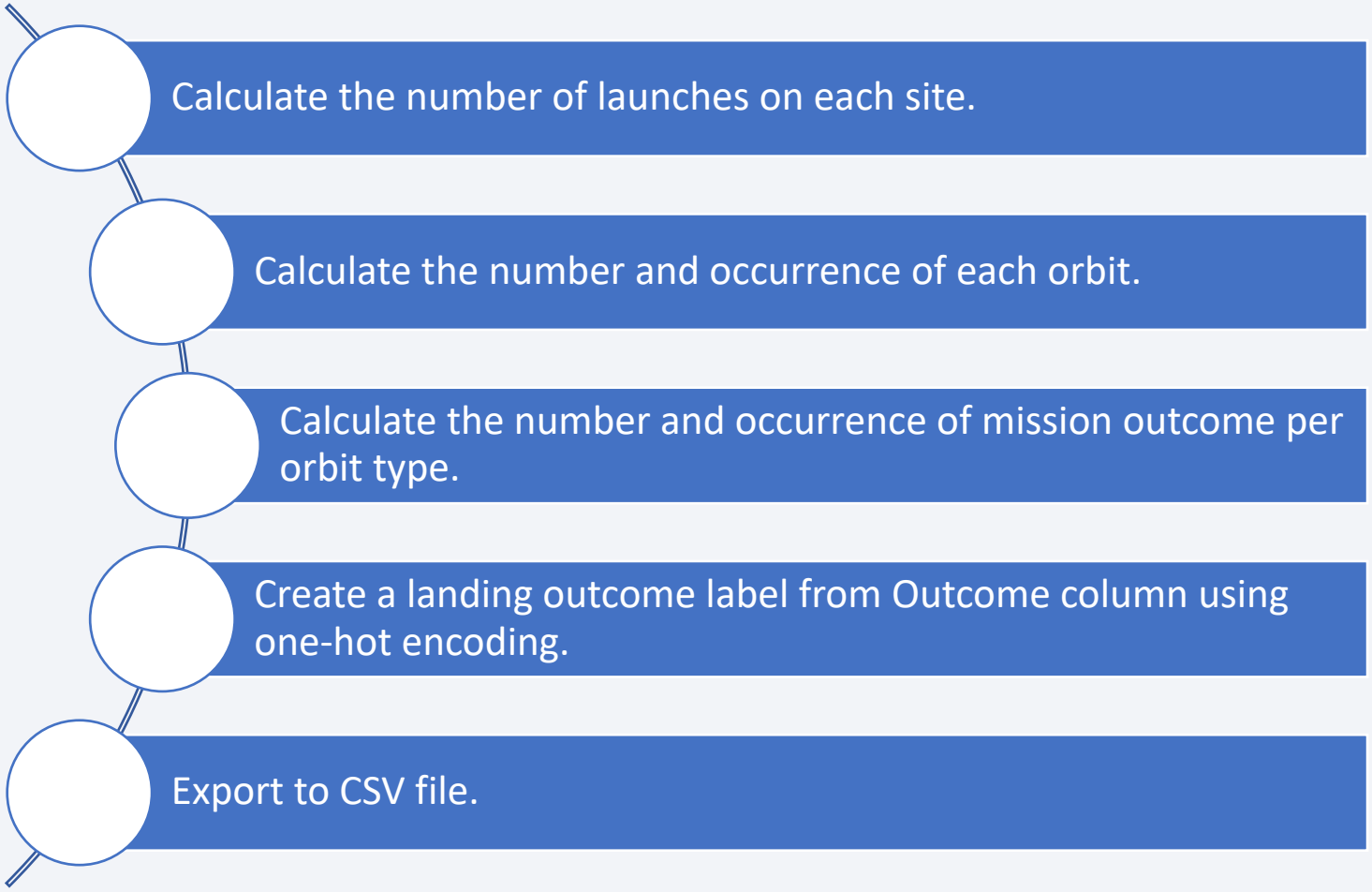
GitHub: Data Collection with API

Data Collection - Scraping



GitHub: Data Collection with Web Scraping

Data Wrangling



GitHub: Exploratory Data Analysis

EDA with Data Visualization

GitHub: EDA with Data Visualization

- I used three plots to represent the relationship between two variables:
  - Scatter plots: used different sets of features: *Flight Number vs. Launch Site, Payload vs. Launch Site, Flight Number vs. Orbit Type and Payload vs. Orbit Type.*
  - Bar charts: used to simplify and compare values between multiple groups. X-axis represents a category, and Y-axis represents a discrete values. I compared the *Success Rate* for different *Orbit Types*.
  - Line charts: were used for showing data trends over time. *Success Rate* over a certain number of *Years*.

EDA with SQL

GitHub: EDA with SQL

A list of some of the SQL queries performed on the dataset is listed below:

- Displaying the names of the unique launch sites in the space mission --- Displaying 5 records where launch sites begin with the string
  - 'CCA' --- Displaying the total payload mass carried by boosters launched by NASA
  - (CRS) --- Displaying 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 site names for in year 2015
  - Ranking the count of landing outcomes between the date 2010-06-04 and 2017-03-20, in descending order.

Build an Interactive Map with Folium

- Objects were created and added to a Folium map. Marker objects were used to show all launch sites on a map as well as the successful/failed launches for each site on the map. Line objects were used to calculate the distances between a launch site to its proximities
- By adding these objects, following geographical patterns about launch sites are found:
  - Are launch sites in close proximity to railways? Yes
  - Are launch sites in close proximity to highways? Yes
  - Are launch sites in close proximity to coastline? Yes
  - Do launch sites keep certain distance away from cities? Yes

GitHub: Interactive Visual Analytics with Folium

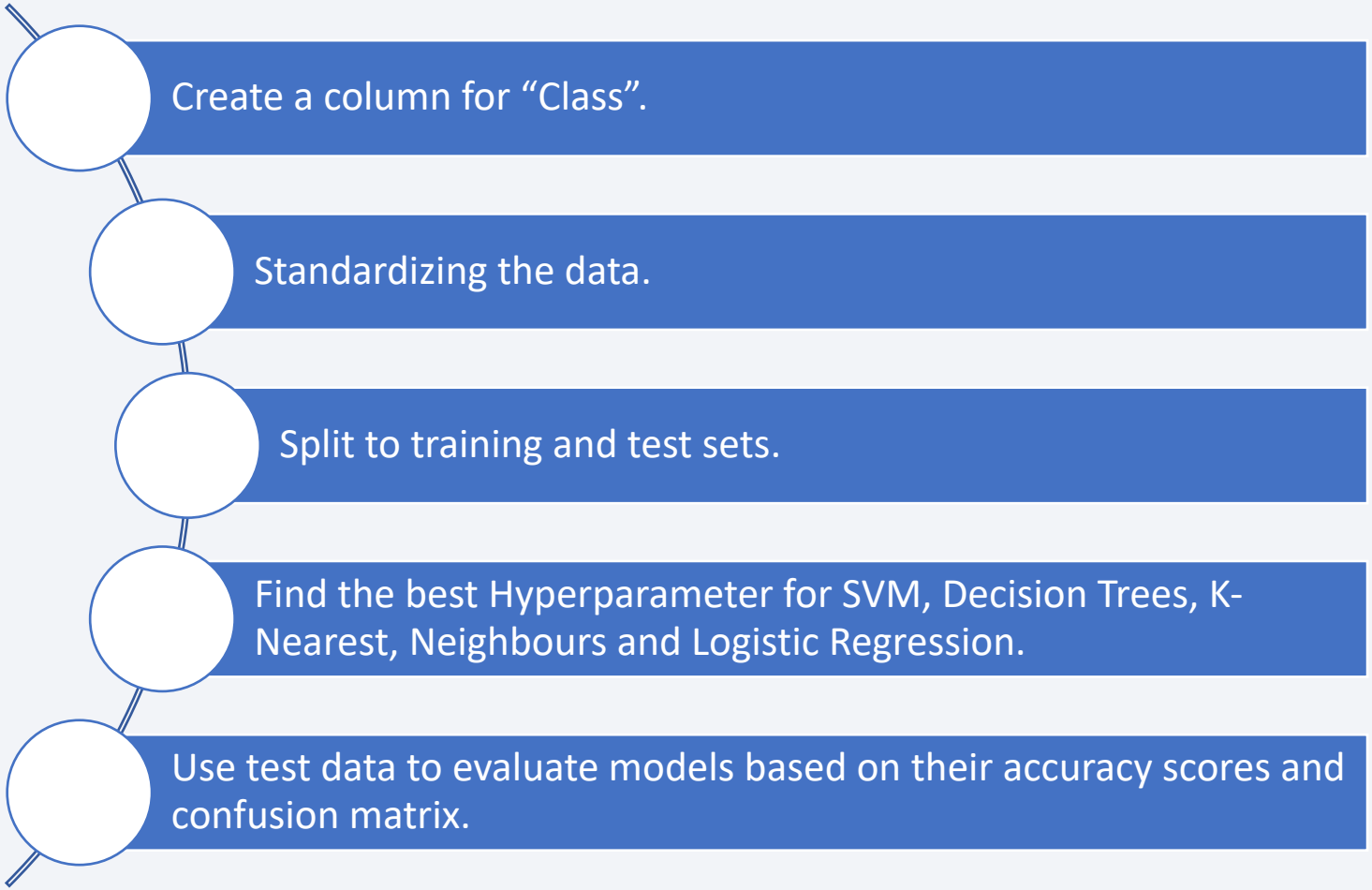
Build a Dashboard with Plotly Dash

The dashboard application contains two charts:

- A pie chart that shows the successful launch by each site. This chart is useful as you can visualize the distribution of landing outcomes across all launch sites or show the success rate of launches on individual sites.
- A scatter chart that shows the relationship between landing outcomes the payload mass of different boosters. The dashboard takes two inputs, namely the site(s) and payload mass. This chart is useful as you can visualize how different variables affect the landing outcomes,

GitHub: SpaceX Dashboard

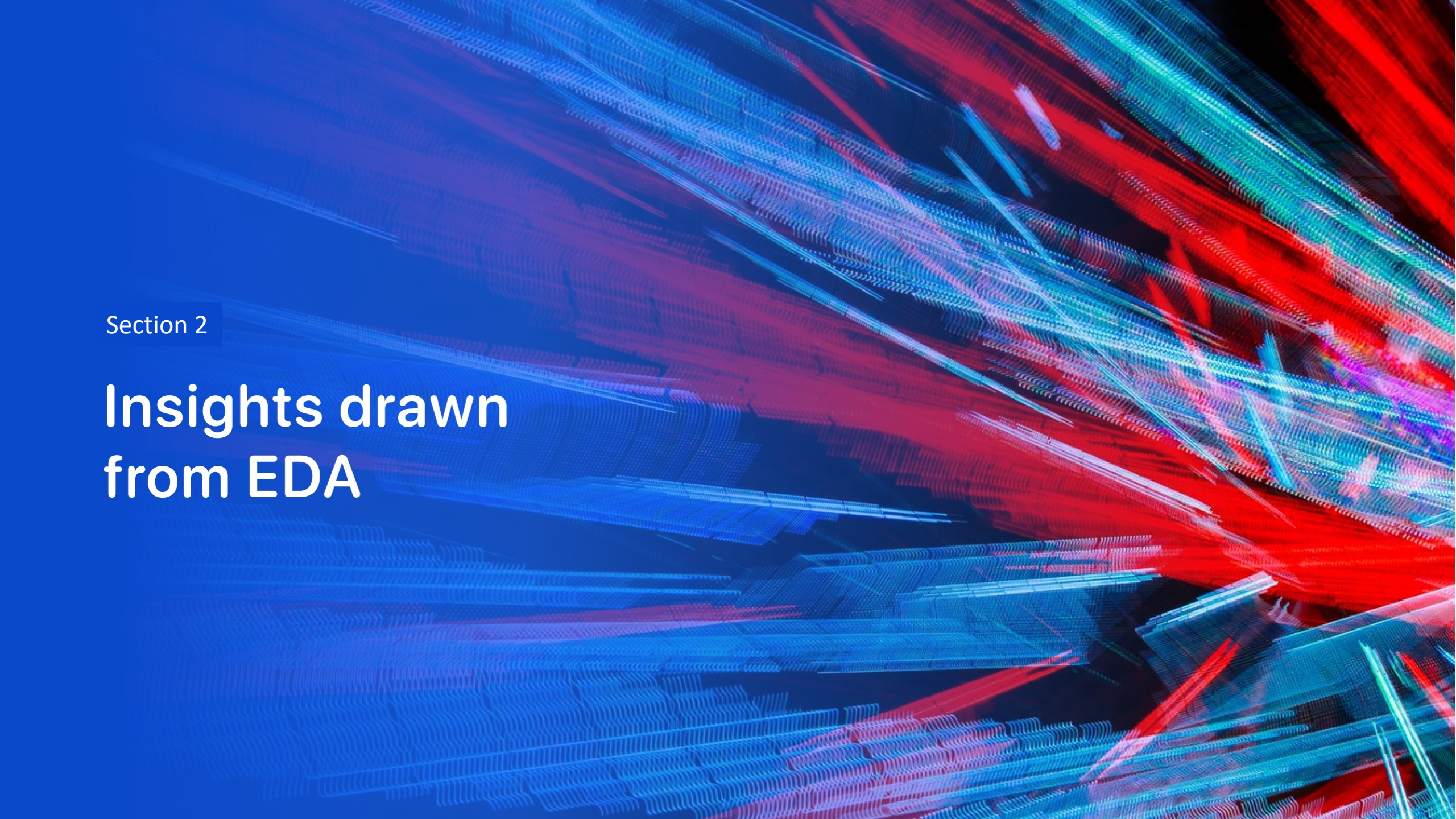
Predictive Analysis (Classification)



GitHub: SpaceX Machine Learning Predition

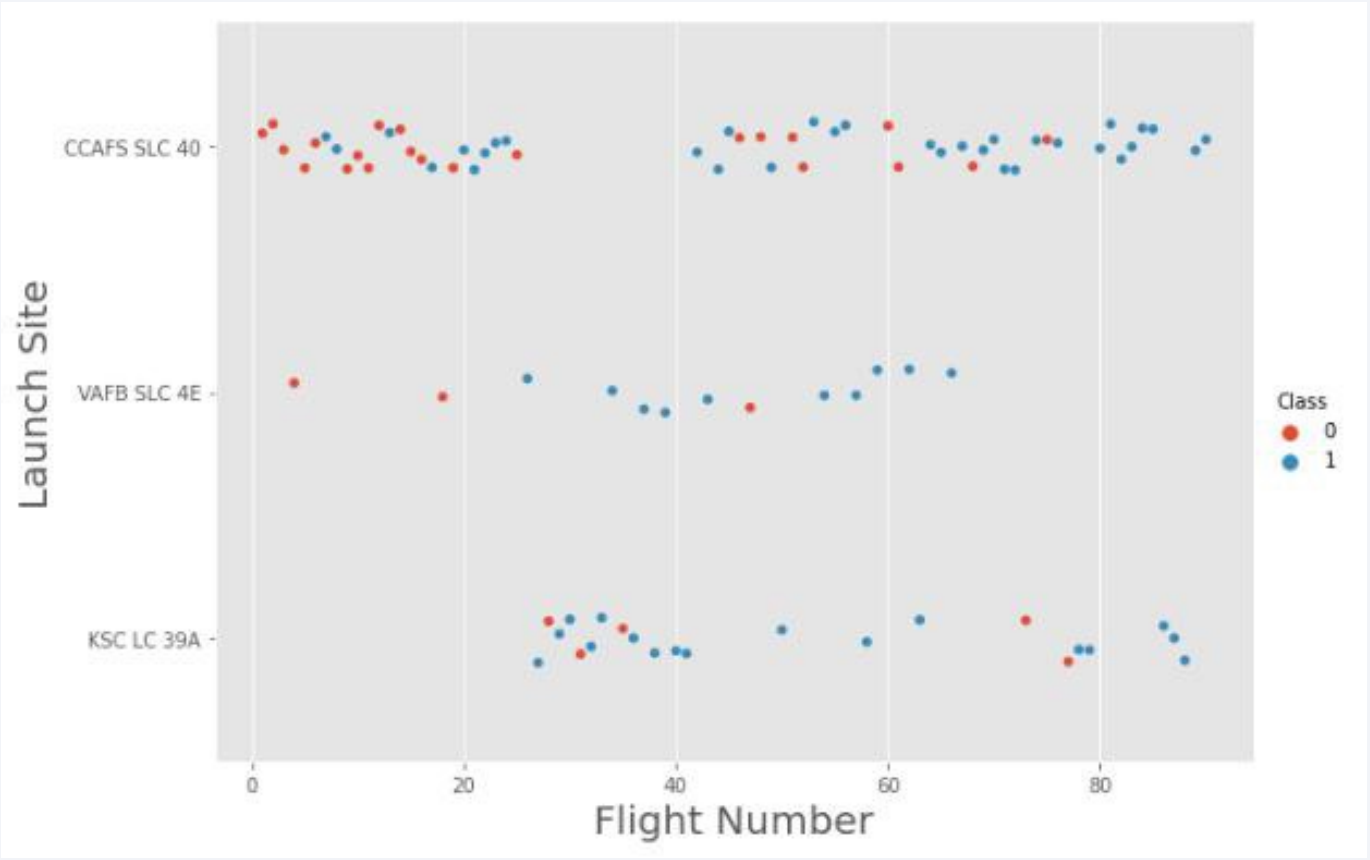
Results

- The results of the exploratory data analysis revealed that the success rate of the Falcon 9 landings was 66.66%.
- The predictive analysis results showed that the Decision Tree algorithm was the best classification method with an accuracy of 94%.


Section 2
Insights drawn from EDA

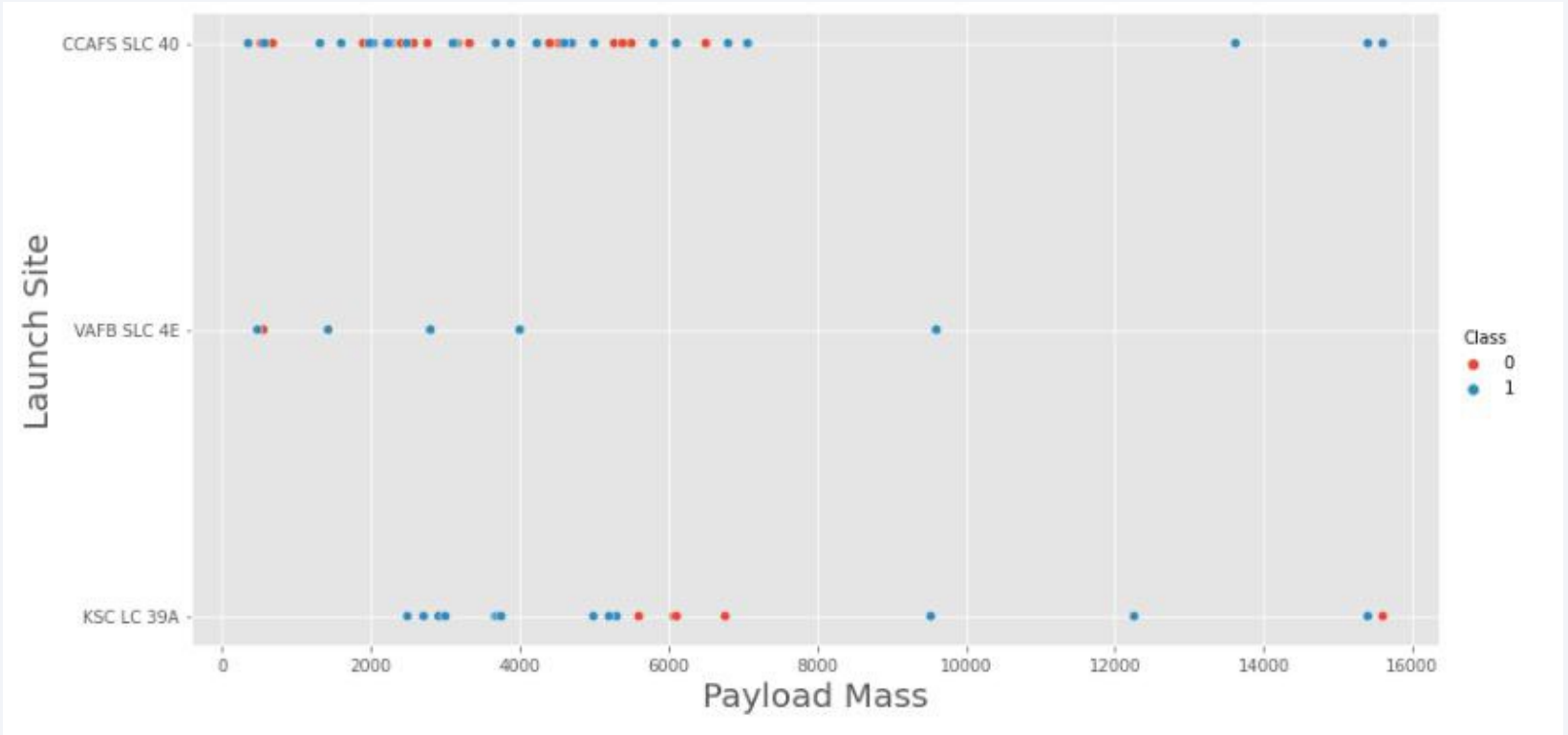
Flight Number vs. Launch Site

- This figure shows that the success rate increased as the number of flights increased.
- The blue dots represent the successful launches while the red dot represent unsuccessful luanches.
- There seems to be an increase in successful flights after the 40th launch.

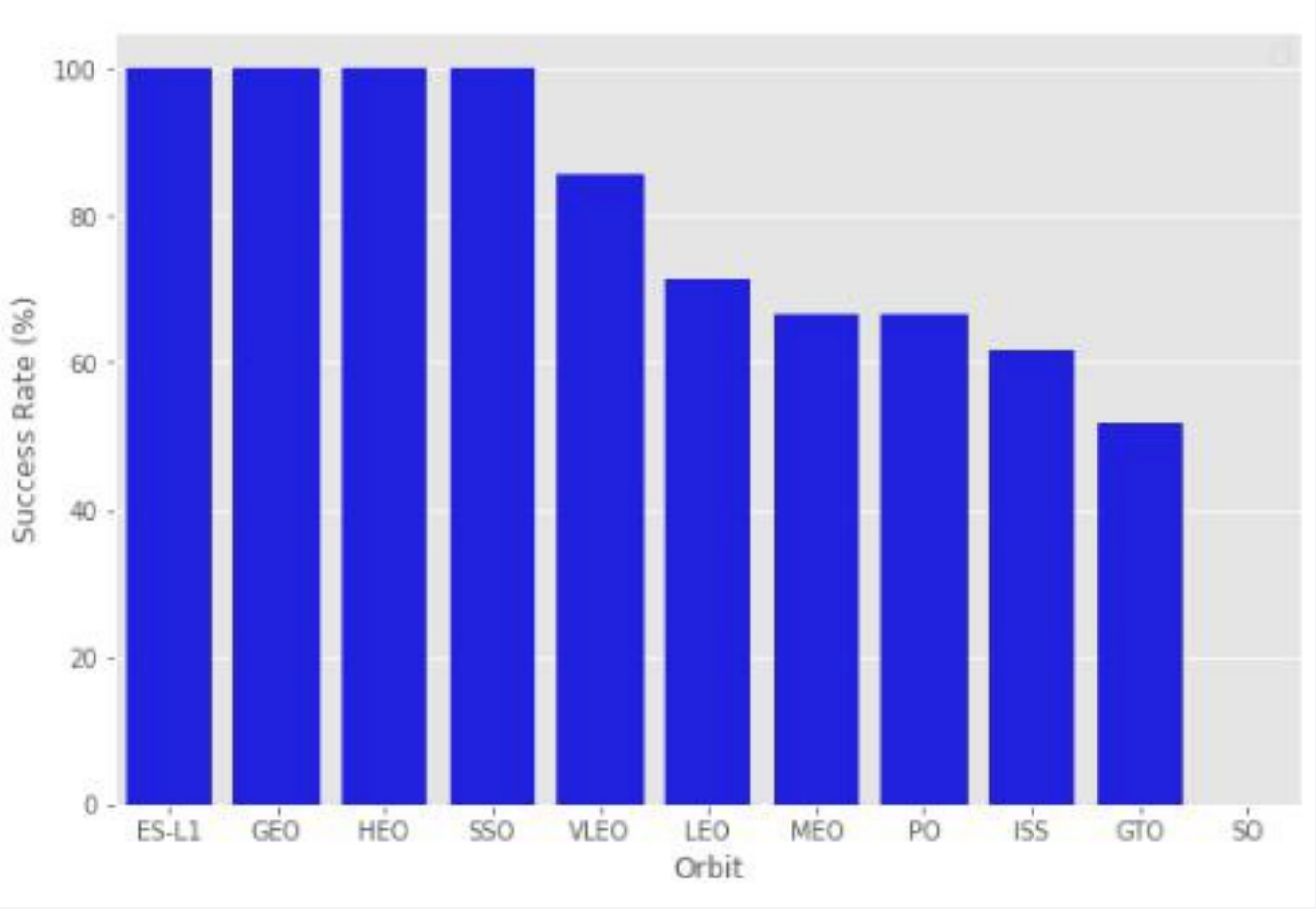


Payload vs. Launch Site

- The blue dots represent the successful launches while the red dots represent unsuccessful launches.
- For the VAFB-SLC launchsite there are no rockets launched for heavy payload mass
- There seems to be a weak correlation between Payload and Launch Site and therefore decisions cannot be made using this metric.



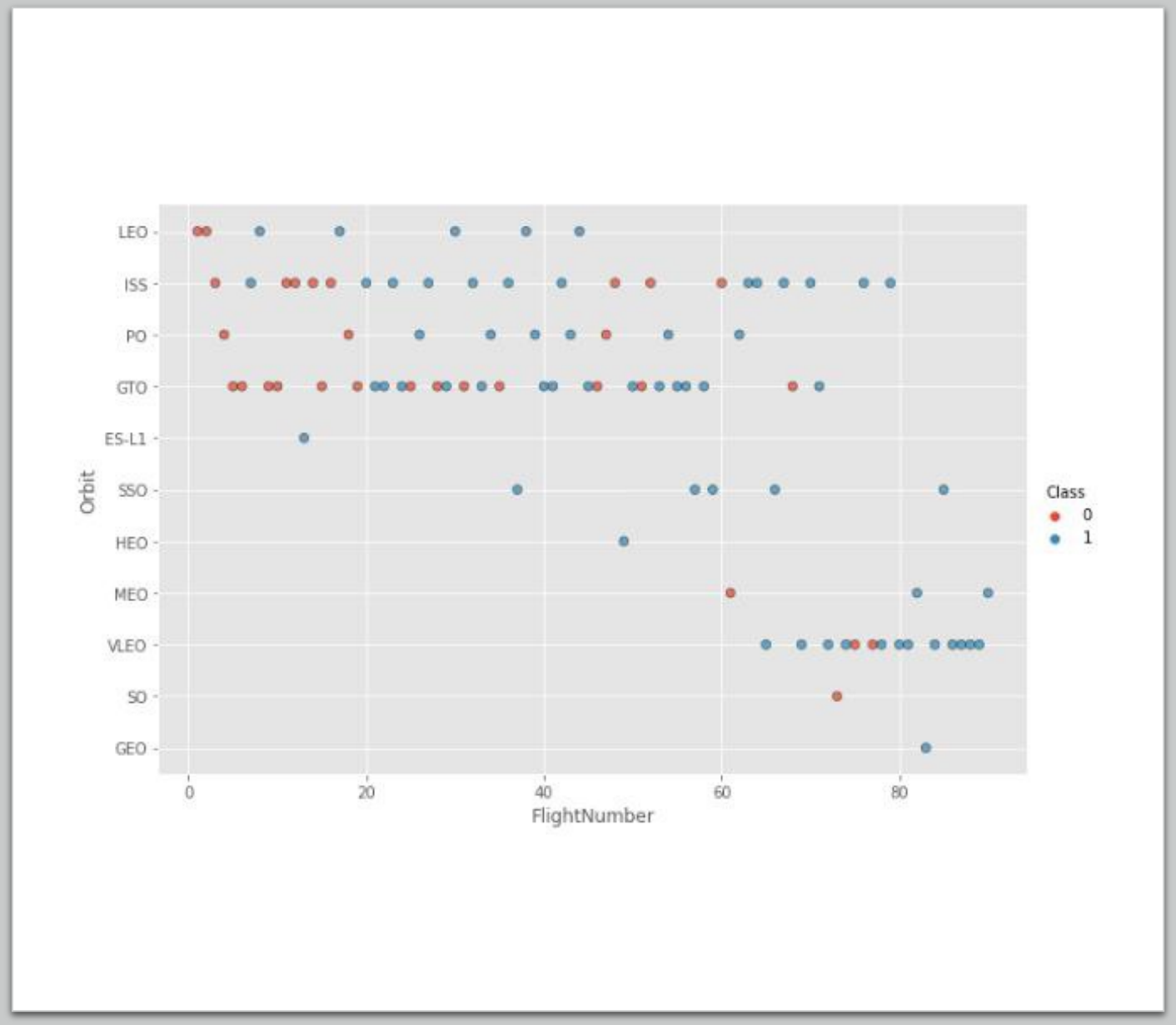
Success Rate vs. Orbit Type



- Orbits SSO, HEO, GEO, and ES-L1 have 100% success rates.
- SO orbit did not have any successful launches with a 0% success rate.

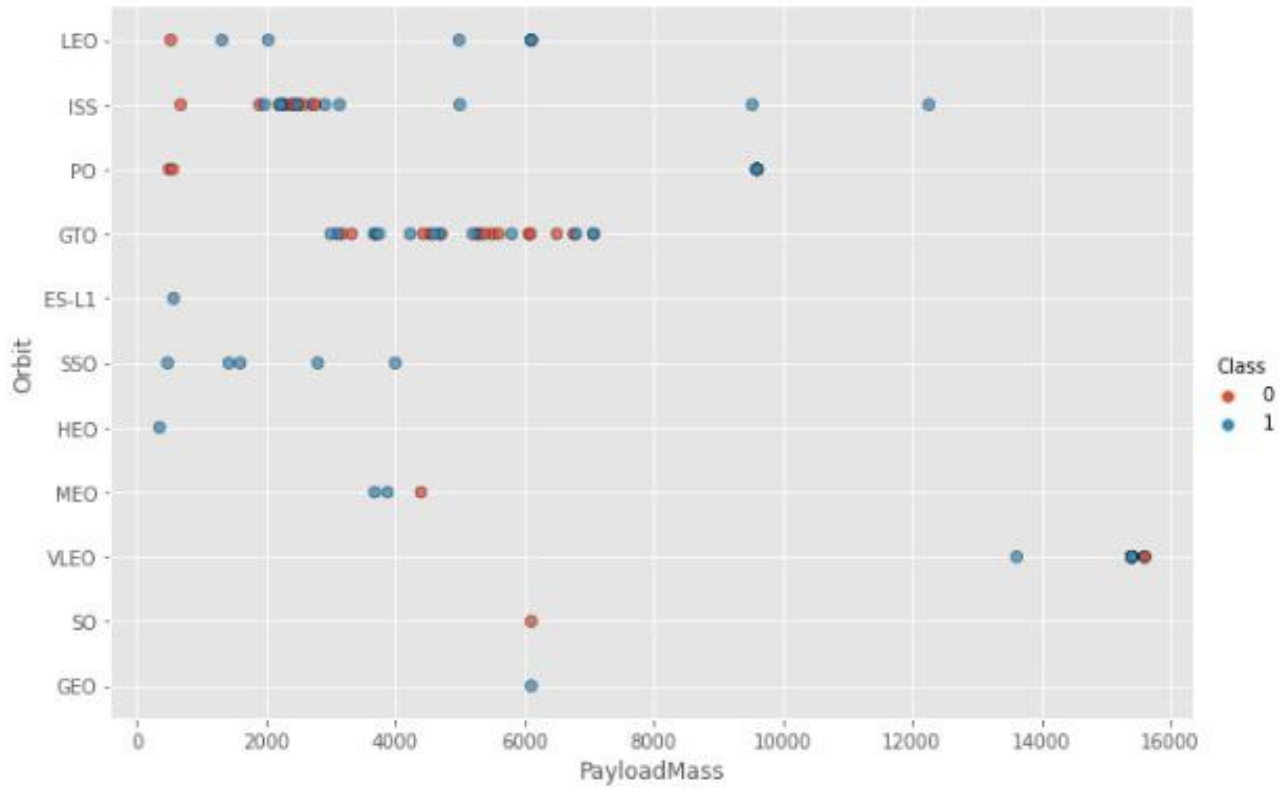
Flight Number vs. Orbit Type

- In the LEO orbit, the success is positively correlated to the the number of flights.
- There seems to be no relationship between flight number in the GTO orbit.
- The SSO orbit has a 100% success rate however with fewer flights than the other orbits
- Flights numbers greater than 40 have a higher success rate than flight numbers between 0-40.

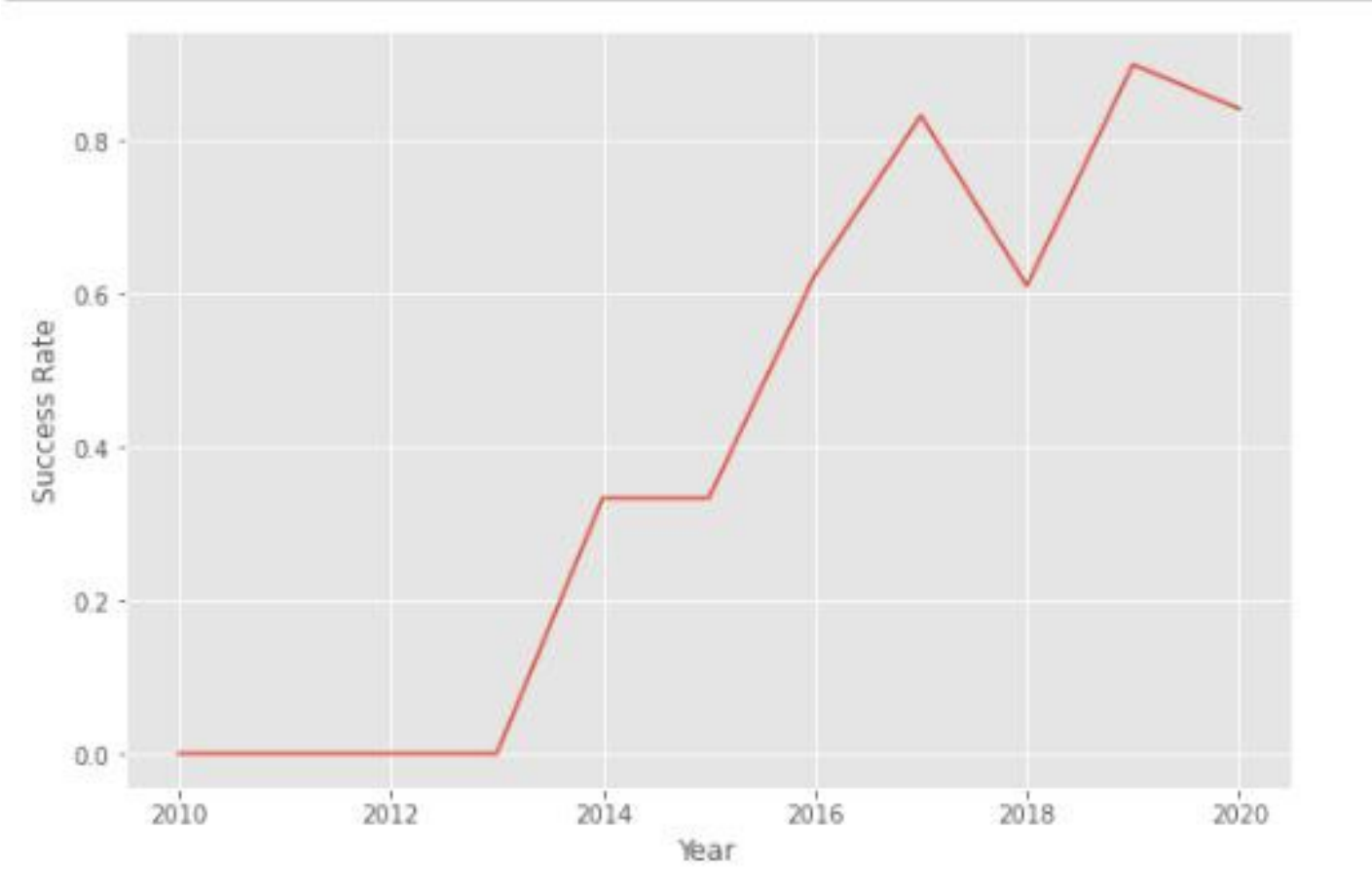


Payload vs. Orbit Type

- As the payloads get heavier, the success rate increases in the PO, SSO, LEO and ISS orbits.
- There seems to be no direct correlation between obrit type and payload mass for GTO orbit as both successful and failed launches are eually present



Launch Success Yearly Trend



- The general trend of the chart shows an increase in landing success rate as the years pass. There is however a dip in 2018 as well as in 2020.

All Launch Site Names

- The DISTINCT clause was used to return only the unique rows from the launch_site column.
- The names of the launch sites are CCAFS LC-40, CCAFS SLC-40, KSC LC-39A, VAFB SLC-4E .

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

Launch Site Names Begin with 'KSC'

- The LIMIT and LIKE clauses were used to display only the top five results where the launch_site name starts with 'CCA'

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	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	00:35:00	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

- The SUM() function was used to the calculate the total payload carried by boosters from NASA from the payload_mass__kg column.

total_payload_mass_kg
45596

Average Payload Mass by F9 v1.1

- The AVG() function was used to the calculate the average payload the average payload mass carried by booster version F9 v1.1
- The WHERE clause was used to filter results so that the calculations were only performed on booster_versions only if they were named “F9 v1.1”

avg_payload_mass_kg
2928

First Successful Ground Landing Date

- The MIN(DATE) function was used to find the date of the first successful landing outcome on ground pad
- The WHERE clause ensured that the results were filtered to match only when the 'landing_outcome’ column is 'Success (ground pad)'

first_successful_landing_date
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

- The BETWEEN clause was used to retrieve only those results of payload mass greater than 4000 but less than 6000. The WHERE clause filtered the results to include only boosters which successfully landed on drone ship.

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

Total Number of Successful and Failure Mission Outcomes

- The COUNT() function is used to count the number of occurences of different mission outcomes with the help of the GROUPBY clause applied to the 'mission_outcome' column. A list of the total number of successful and failure mission outcomes os returned.
- There have been 99 successful mission outcomes out of 101 missions.

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

Boosters Carried Maximum Payload

- The MAX() function was used in a subquery to retrieve a list of boosters which have carried the maximum payload mass

booster_version	payload_mass__kg_
F9 B5 B1048.4	15600
F9 B5 B1048.5	15600
F9 B5 B1049.4	15600
F9 B5 B1049.5	15600
F9 B5 B1049.7	15600
F9 B5 B1051.3	15600
F9 B5 B1051.4	15600
F9 B5 B1051.6	15600
F9 B5 B1056.4	15600
F9 B5 B1058.3	15600
F9 B5 B1060.2	15600
F9 B5 B1060.3	15600

2015 Launch Records

- The SELECT statement was used to retrieve multiple columns from the table. The YEAR(DATE) function was used to retrieve only those rows with a 2015 launch date.

landing__outcome	booster_version	launch_site
Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40

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

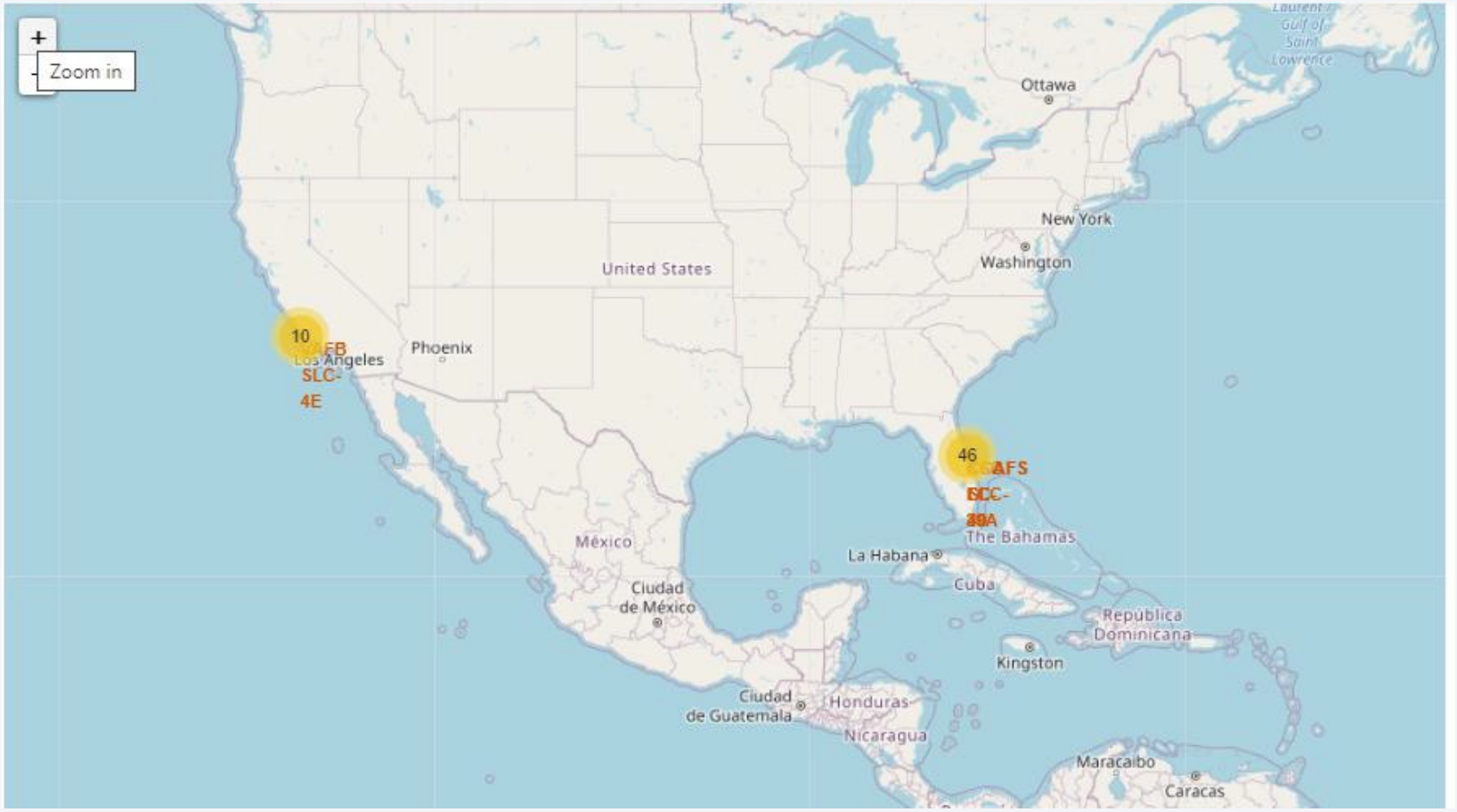
- COUNT() function was used to count the different landing outcomes. The WHERE and BETWEEN clauses filtered the results to only include results between 2010-06-04 and 2017-03-20. The GROUPBY clause ensure that the counts were grouped by their outcome. The ORDERBY and DESC clauses were used to sort the results by descending order.

landing__outcome	total_number
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

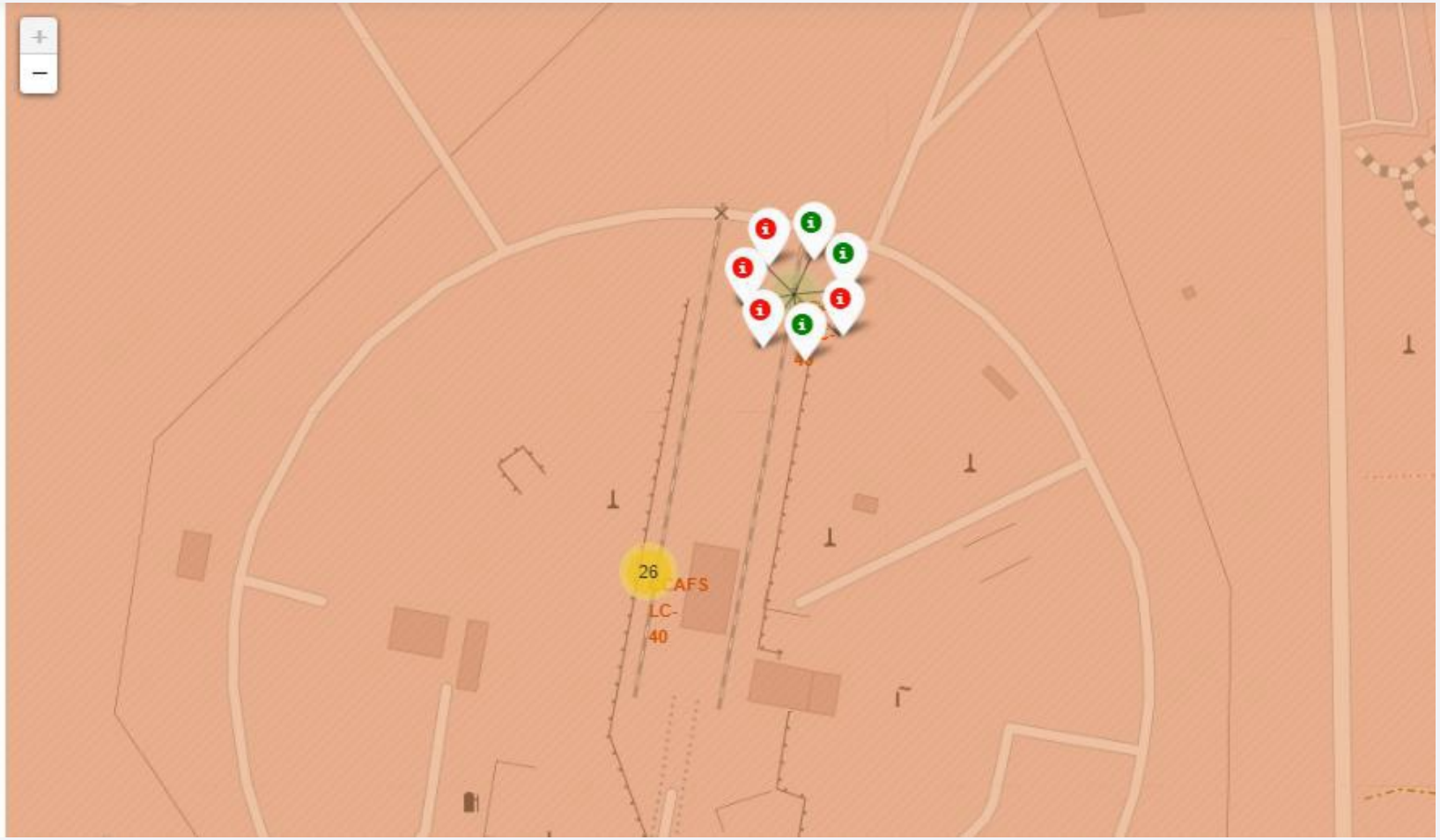
<Folium Map Screenshot 1>

- The yellow markers are indicators of where the locations of all the SpaceX launch sites are situated in the US.
- The launch sites have been strategically placed near the coast



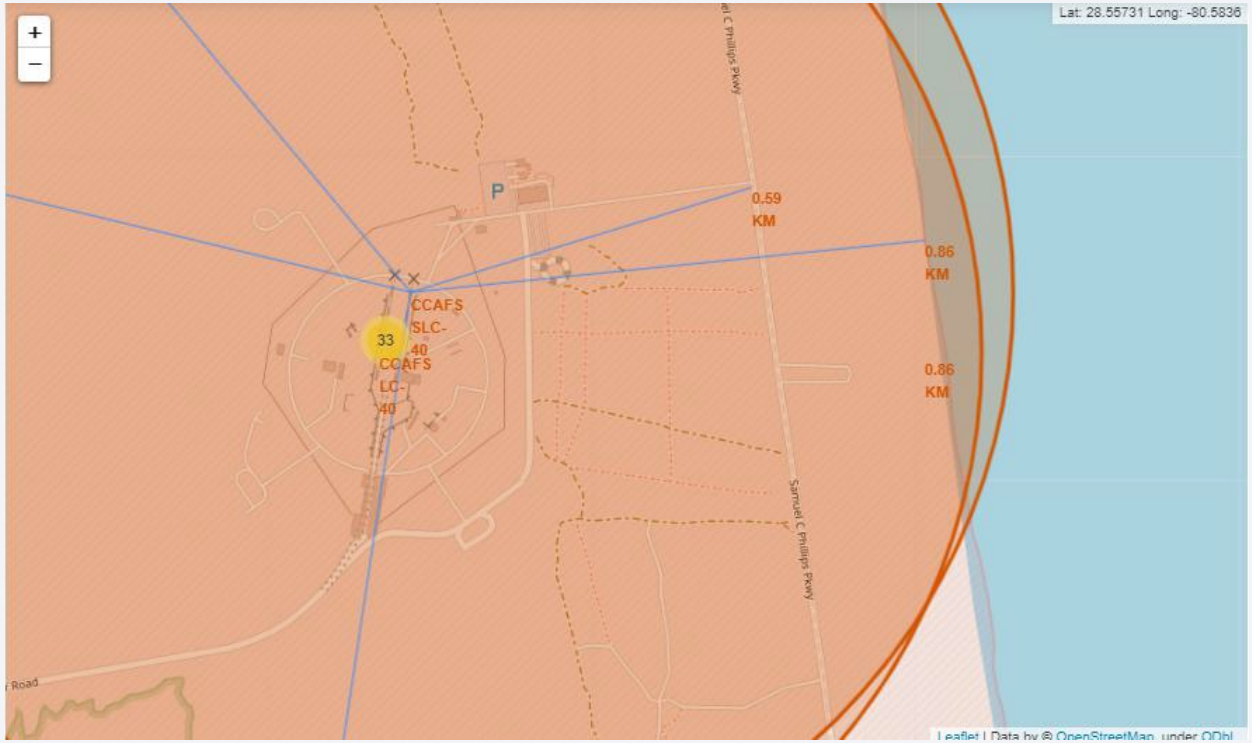
<Folium Map Screenshot 2>

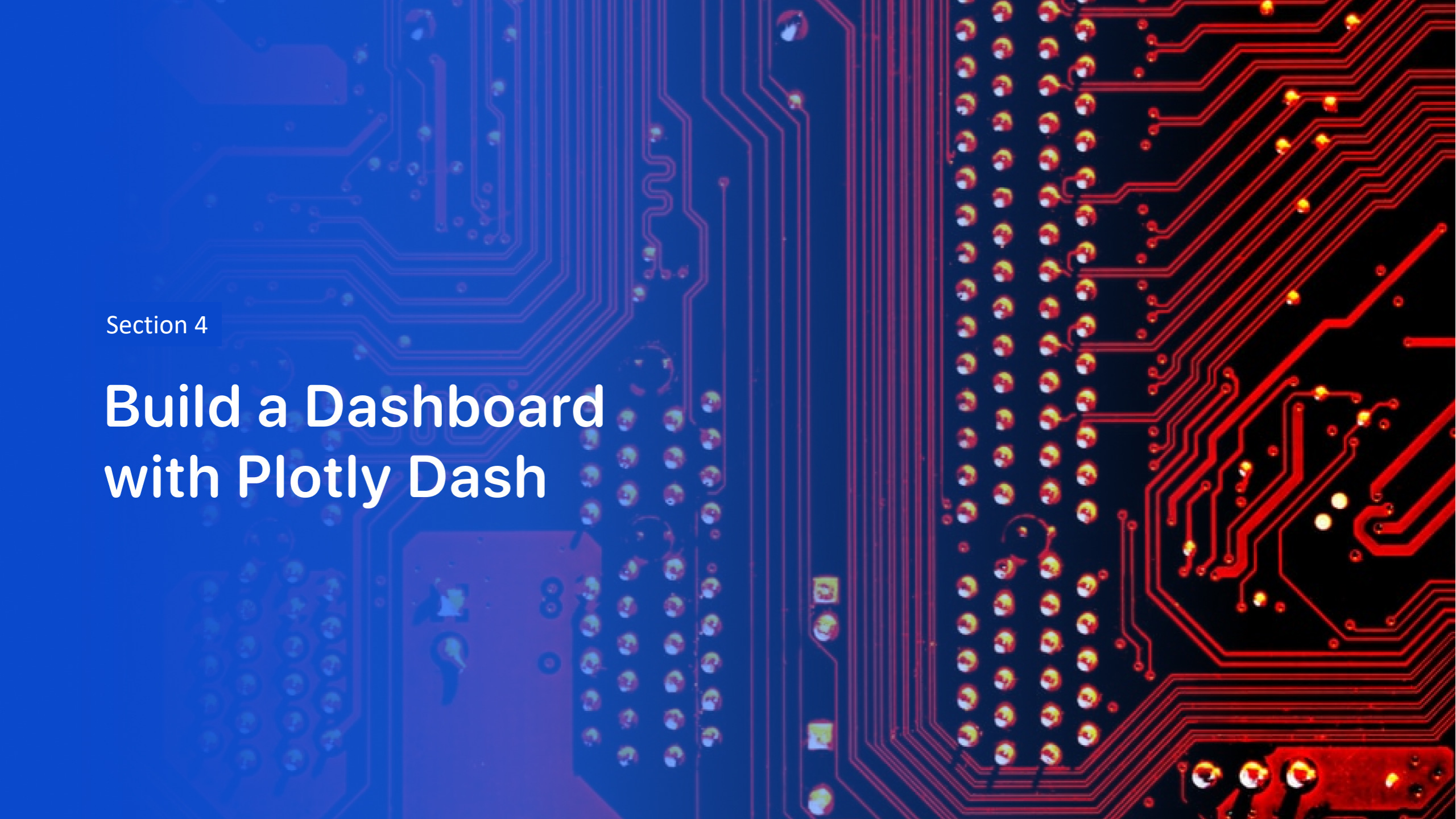
- When we zoom in on a launch site, we can click on the launch site which will display marker clusters of successful landings (green) or failed landing (red).



<Folium Map Screenshot 3>

- The generated map shows that the selected launch site is close to a highway for transportation of personnel and equipment. The launch site is also close to the coastlines for launch failure testing.
- The launch sites also maintain a certain distance from the cities. (Can be viewed in notebook).

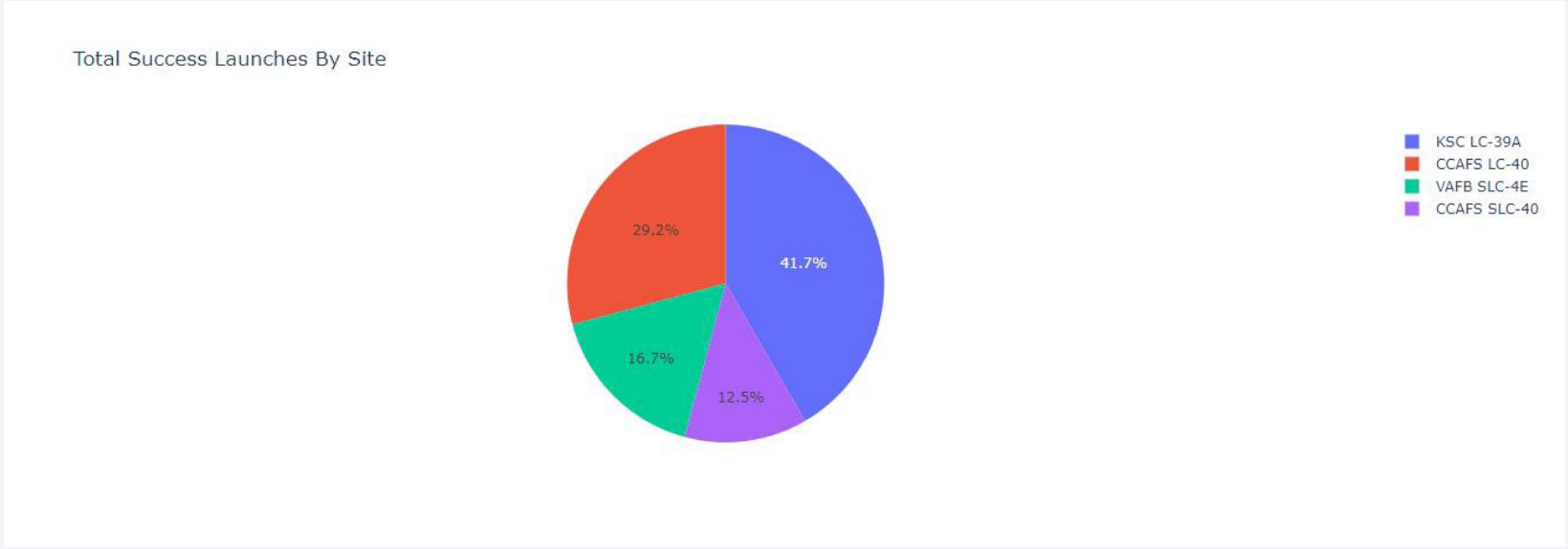



Section 4
Build a Dashboard with Plotly Dash

<Dashboard Screenshot 1>

Total Successful Launches By Site

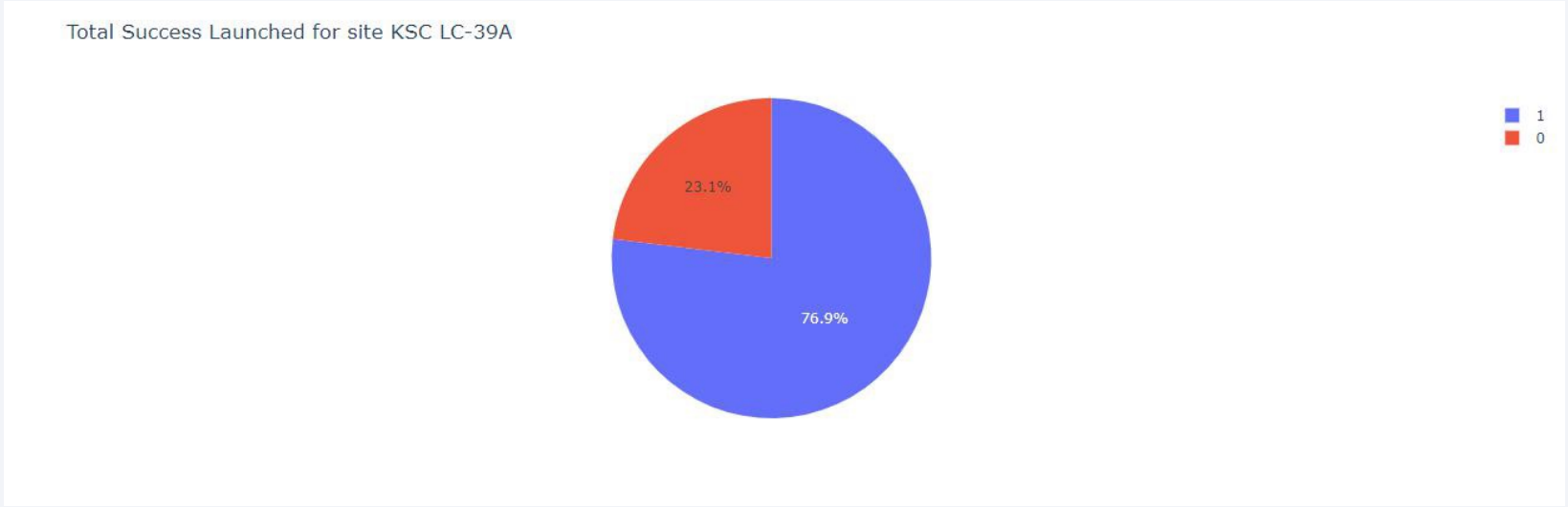
- The KSC LC-39A Launch site has the most successful launches with 10 in total.



<Dashboard Screenshot 2>

Launch Site With Highest Success Ratio

- The KSLC-39A has the highest success rate with 76.9%.



<Dashboard Screenshot 3>

Payloads vs Launch Outcome

- The launch success rate for payloads 0-2500 kg is slightly lower than that of payloads 2500-5000 kg. There is in fact not much difference between the two.
- The booster version that has the largest success rate, in both weight ranges is the v1.1.

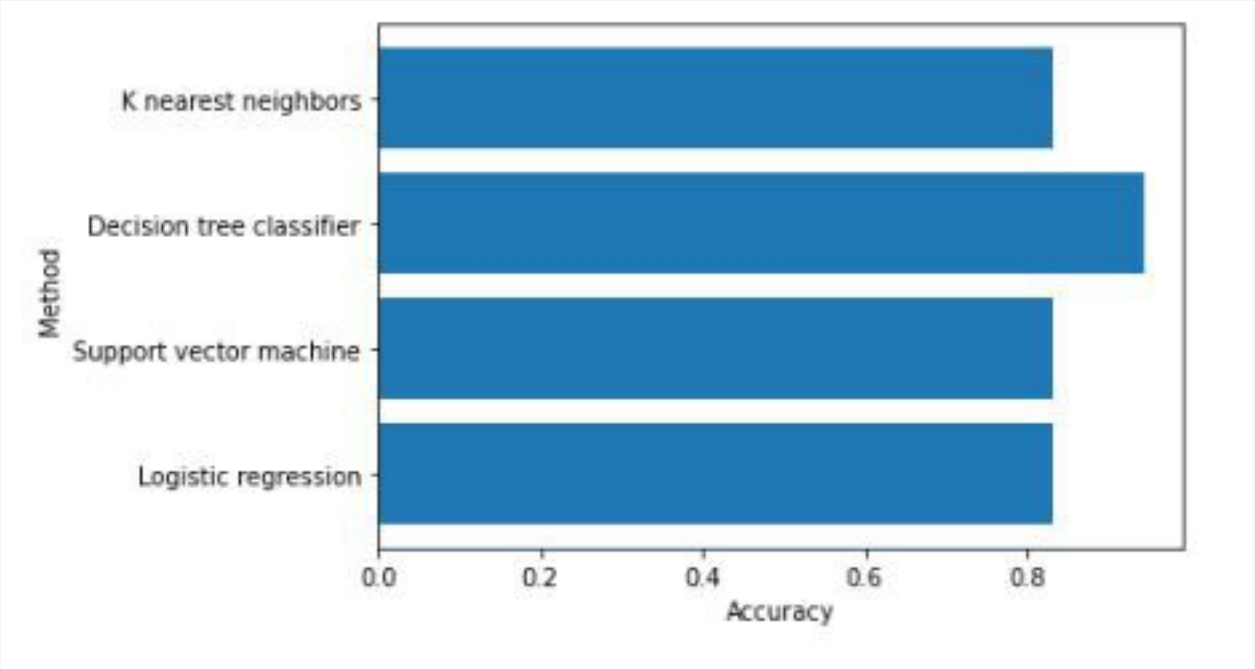
Section 5

Predictive Analysis (Classification)

Classification Accuracy

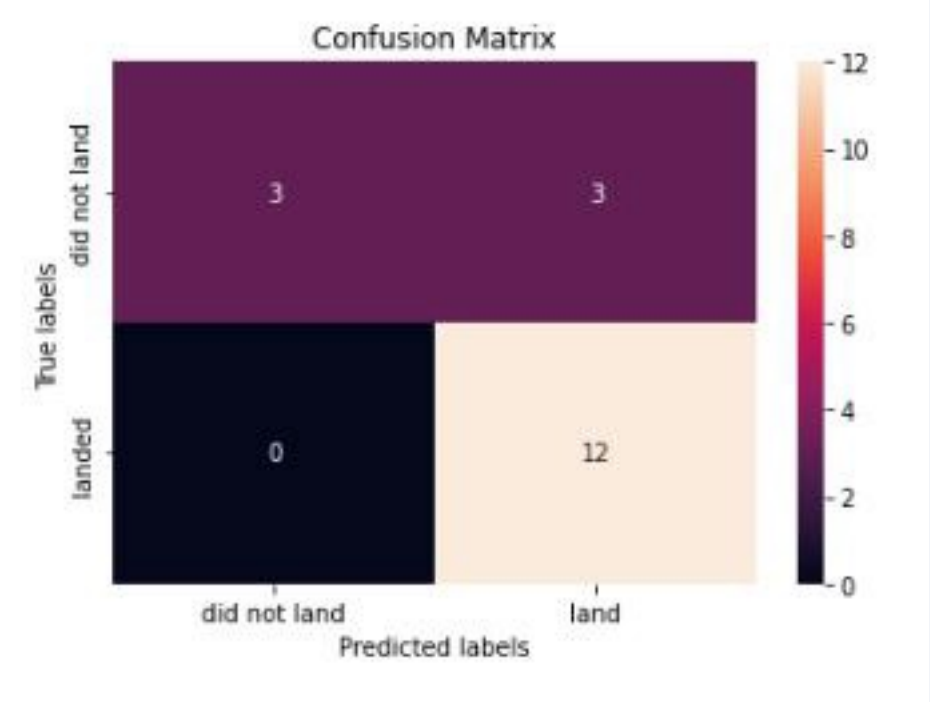
- The Decision Tree classifier had the best accuracy at 94%.

	method	accuracy
0	Logistic regression	0.833333
1	Support vector machine	0.833333
2	Decision tree classifier	0.944444
3	K nearest neighbors	0.833333



Confusion Matrix

- The model predicted 12 successful landings when the True label was successful (True Positive) and 3 unsuccessful landings when the True label was failure (True Negative).
- The model also predicted 3 successful landings when the True label was unsuccessful landing (False Positive).
- The model generally predicted successful landings.



Conclusions

- The analysis showed that there is a positive correlation between number of flights and success rate as the success rate has improved over the years.
- There are certain orbits like SSO, HEO, GEO, and ES-L1 where launches were the most successful.
- Success rate can be linked to payload mass as the lighter payloads generally proved to be more successful than the heavier payloads.
- The launch sites are strategically located near highways and railways for transportation of personal and cargo, but also far away from cities for safety.
- The best predictive model to use for this dataset is the Decision Tree Classifier as it had the highest accuracy with 94%.

Appendix

- GitHub Repository: https://github.com/DrMajed86/hello-world.git

Thank you!