IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

Executive Summary

- The following methodologies are applied to analyze the SpaceX data:
  - Data is collection using data collection API with web scrapping and SpaceX API,
  - Exploratory Data Analysis (EDA) which includes data wrangling, data visualization, and interactive visual analytics,
  - Predictive analysis using Machine Learning techniques.
- Summary of all results
  - It is possible to collect the data from public sources, and with suitable data processing, it is ready to analyze,
  - Exploratory Data Analysis (EDA) allows to investigate the data set and summarize their main characteristics,
  - Various Machine Learning techniques allow to get the best models with the high accuracy.

Introduction

- The objective of this project is to predict how an alternate company wants to bid against SpaceX for a rocket launch.
- Problems to find answers:
  - Estimate the total cost of launch by predicting successful landings of first stage of Falcon 9 rockets,
  - Find the best place to launch the rockets.

Section 1

Methodology

Methodology

Executive Summary:

- Data Collection Methodology:
  - Data is collected from 2-sources:
    - SpaceX API (https://api.spacexdata.com/v4/rockets, https://api.spacexdata.com/v4/launchpads, https://api.spacexdata.com/v4/payloads, https://api.spacexdata.com/v4/cores)
    - Web Scrapping (https://en.wikipedia.org/wiki/List_of_Falcon_9_and_Falcon_Heavy_launches)
- Perform Data Wrangling:
  - Exploratory Data Analysis (EDA) to find some patterns in the data and determine what would be the label for training supervised models.

Methodology

Executive Summary:

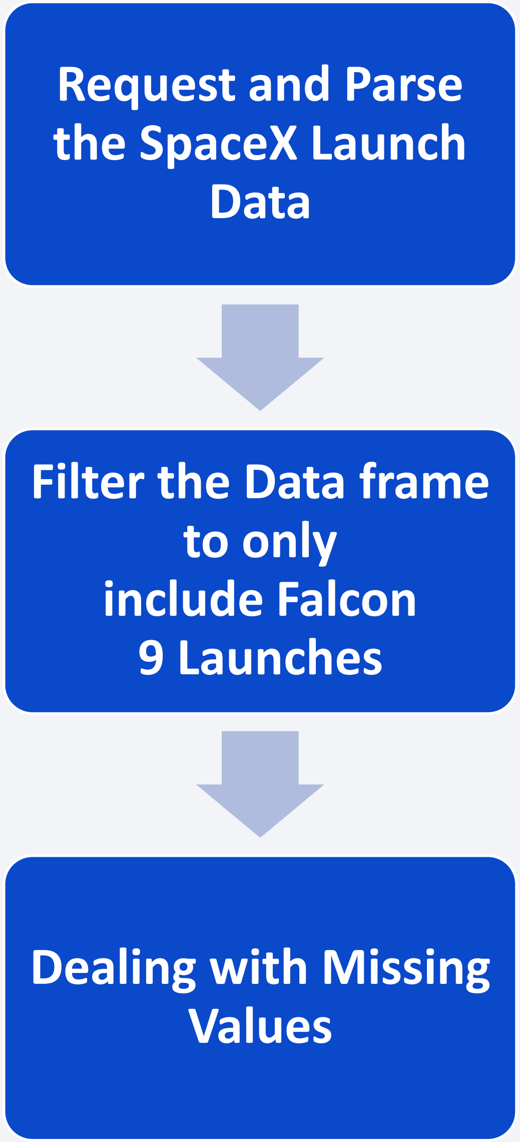
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
    - Data that was collected until this step were standardized,
    - Divide the data set into training and test data sets, and evaluate the data by four different classification models,
    - Evaluate the accuracy of each model using different combinations of parameters.

Data Collection

- Data is collected from 2-sources:
  - SpaceX API (https://api.spacexdata.com/v4/rockets, https://api.spacexdata.com/v4/launchpads, https://api.spacexdata.com/v4/payloads, https://api.spacexdata.com/v4/cores)
  - Web scraping to collect Falcon 9 historical launch records from a Wikipedia page title "List of Falcon 9 and Falcon Heavy launches". (https://en.wikipedia.org/wiki/List_of_Falcon_9_and_Falcon_Heavy_launches)

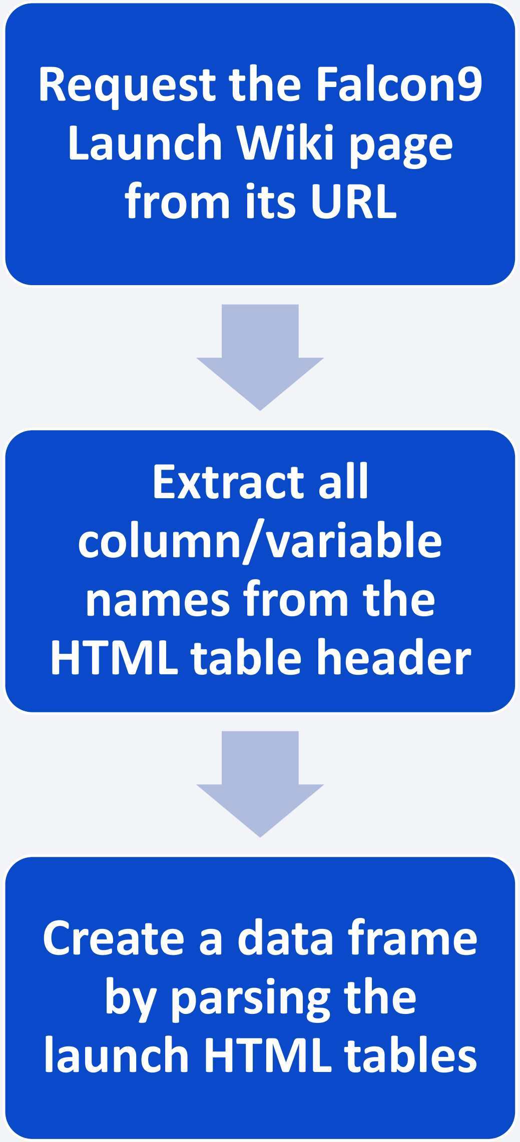
Data Collection – SpaceX API

- Processing of data using SpaceX API is shown in the flowchart here.
    - Request and Parse the SpaceX Launch Data using GET request to make the requested JSON results more accurate,
    - Filter the data frame by removing Falcon 1 launches,
    - Dealing the missing values by replacing the mean value.
- GitHub URL:
    - https://github.com/Dkap911/Applied-Data-Science-Capstion/blob/master/jupyter-labs-spacex-data-collection-api.ipynb



Data Collection - Scraping

- Processing of data using web scraping is shown in the flowchart here.
    - Request data from its Wikipedia page using its URL,
    - Collect all relevant column names from the HTML table header,
    - Create a data frame by parsing the launch HTML tables.
- GitHub URL:
    - https://github.com/Dkap911/Applied-Data-Science-Capstion/blob/master/jupyter-labs-webscraping.ipynb



Data Wrangling

- Exploratory Data Analysis (EDA) is performed to find some patterns in the data,
- Also, determines what would be the label for training supervised models.
- GitHub URL:
    - https://github.com/Dkap911/Applied-Data-Science-Capstion/blob/master/labs-jupyter-spacex-Data%20wrangling.ipynb

Calculate the number of launches per site

↓

Calculate the number and occurrence of each orbit and mission outcome per orbit type

↓

Create a landing outcome label from outcome column

EDA with Data Visualization

- Several scatterplots and bar charts are plotted to know the relationship among various features of the data. Few plots are:
  - Flight Number vs. Pay Load Mass, Flight Number vs. Launch Site, Launch Site vs. Pay Load Mass, Obrit vs. Class, Flight Number vs. Orbit, and Pay Load Mass vs. Orbit.
- GitHub URL:
  - https://github.com/Dkap911/Applied-Data-Science-Capstion/blob/master/jupyter-labs-eda-dataviz.ipynb

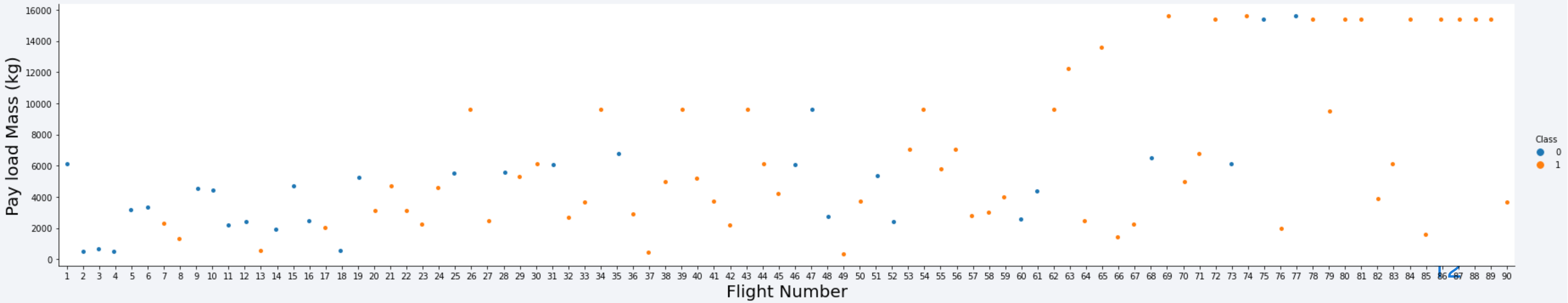


Fig. 1: Scatter Plot of Flight Number and Pay Load Mass

EDA with SQL

- The following SQL queries performed:
  - Display 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 failed landing outcomes in drone ship, their booster versions, and launch site names for in year 2015,
  - Rank the count of landing outcomes (such as Failure (drone ship) or Success (ground pad)) between the date 2010-06-04 and 2017-03-20, in descending order.
- GitHub URL: https://github.com/Dkap911/Applied-Data-Science-Capstion/blob/master/jupyter-labs-eda-sql-coursera.ipynb

Build an Interactive Map with Folium

- Different markers, circles, lines, and marker clusters are used with Folium Maps.
  - Markers are used to indicate points such launch sites,
  - Circle are used to highlight the areas around specific coordinates,
  - Lines are used to get the distances between two coordinates,
  - Marker clusters are used to indicate groups of events in each coordinate.
- GitHub URL:
  - https://github.com/Dkap911/Applied-Data-Science-Capstion/blob/master/lab_jupyter_launch_site_location.ipynb

Build a Dashboard with Plotly Dash

- The following graphs and plots were used to visualize data
  - Percentage of launches by site
  - Payload range
- This combination allowed to quickly analyze the relation between payloads and launch sites, helping to identify where is best place to launch according to payloads.
- GitHub URL:
  - https://github.com/Dkap911/Applied-Data-Science-Capstion/blob/master/space_dash_plotly.py

Predictive Analysis (Classification)

- Perform Exploratory Data Analysis and determine training labels to find best hyperparameter for Logistic Regression, Support Vector Machine, Tree Classifier, and k-Nearest Neighbors.
- GitHub URL:
  - https://github.com/Dkap911/Applied-Data-Science-Capstion/blob/master/SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb

Results

- Exploratory Data Analysis (EDA) results:
  - Space X uses 4 different launch sites,
  - Launch Site CCAFS SLC 40 has the high success rate compare to others,
  - Orbit ES-L1, GEO, HEO, and SSO has the 100% success rate,
  - Orbit SSO has the highest rate of success for less than 4000 kg of payload, and VLEO has the highest rate of success for over 14000 kg of payload,
  - From year 2013 to 2017, consecutive rate of success is shown by the graph,
  - The number of landing outcomes became as better as years passed.

Results

- Interactive Analytics results:
  - Using interactive analytics was possible to identify that launch sites use to be in safety places, near sea, for example and have a good logistic infrastructure around,
  - Most launches happens at east cost launch sites.

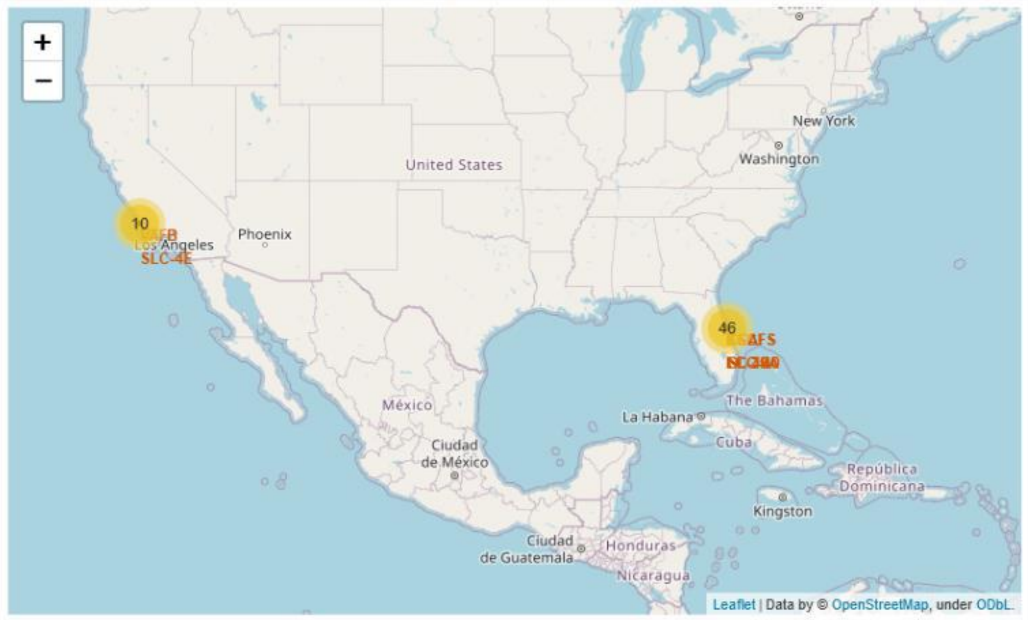


Fig. 2: Interactive Analytics show success rate for different launch sites on both coasts

Results

- Predictive Analytics results:
  - Using different predictive analytics, Decision Tree Classifier shows the highest accuracy in both data sets.
  - It has accuracy of 87% and accuracy for test data is of 94%.

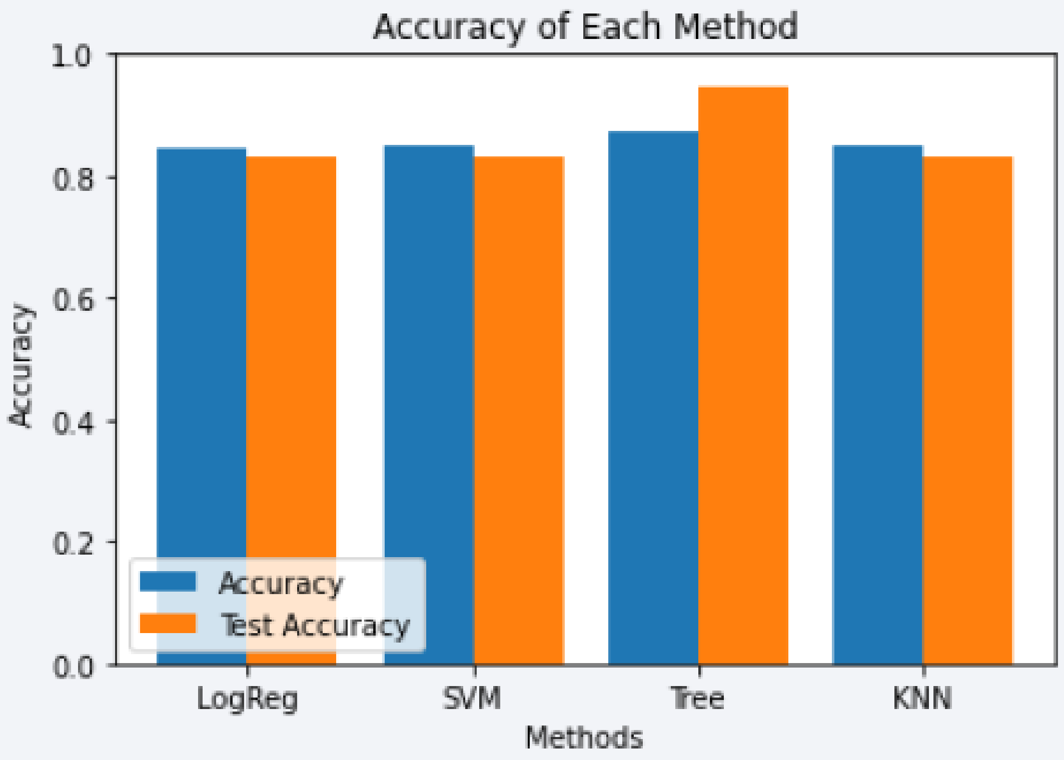


Fig. 3: Accuracy of Different Methods

Section 2

Insights drawn from EDA

Flight Number vs. Launch Site

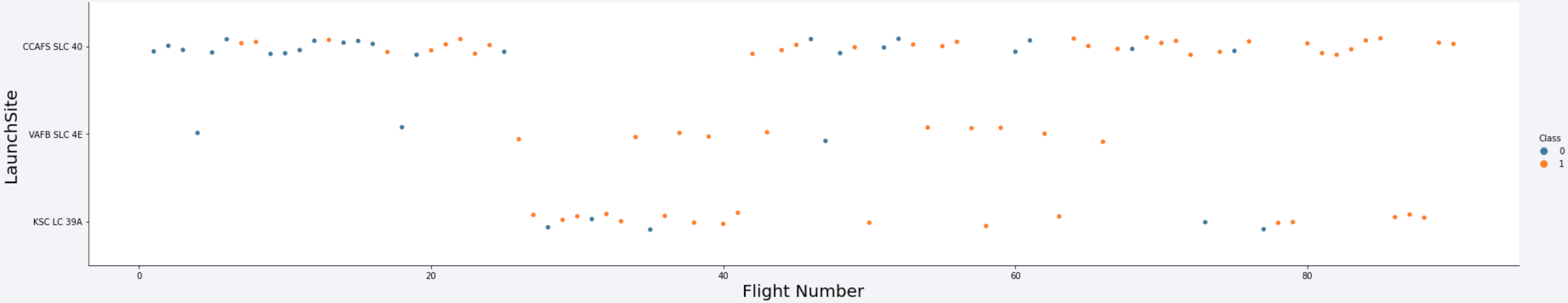


Fig. 4: Scatter Plot of Flight Number vs. Launch Site

- From the above plot, it can see that Launch Site CCAFS SLC 40 has the high success rate compare to other twos.
- Over the time, rate of success is also increased.

Payload vs. Launch Site

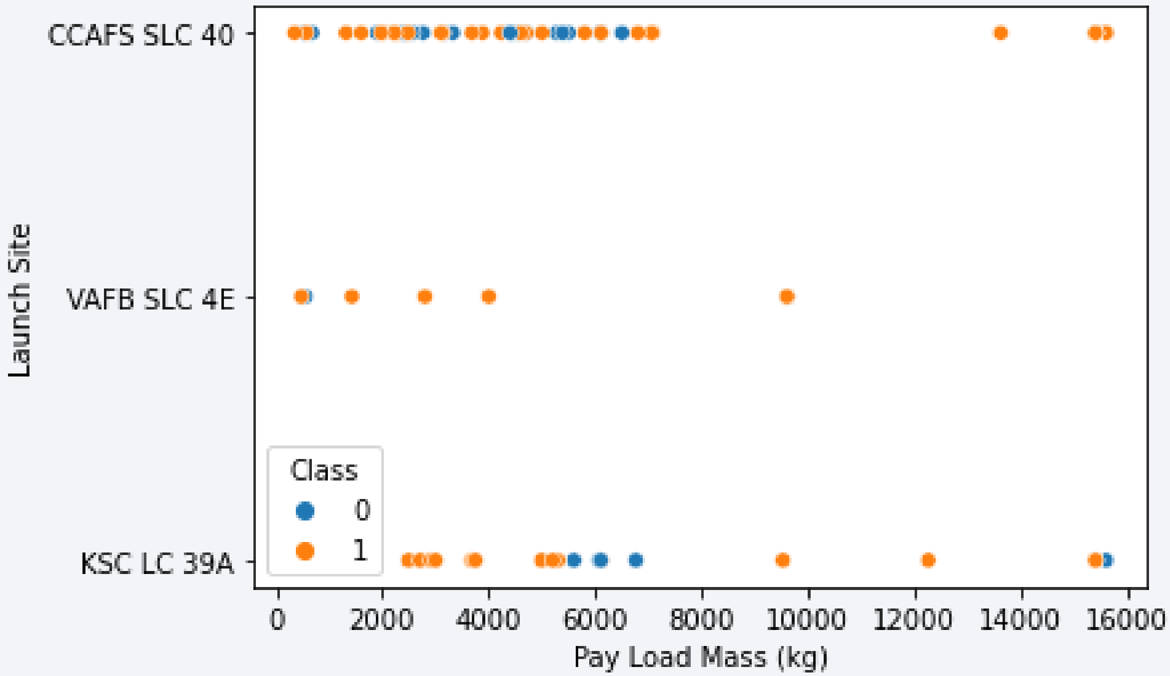


Fig. 5: Scatter Plot of Pay Load Mass (kg) vs. Launch Site

- From the above plot, it can see that CCAFS SLC 40 has high success rate for less than 8000 kg of payload mass.
- Launch site VAFB SLC 4E has high success rate for pay load up to 10000 kg.

Success Rate vs. Orbit Type

- From the bar chart, it is observed that ES-L1, GEO, HEO, and SSO has the 100% success rate,
- Orbit SO has the lowest rate of success.

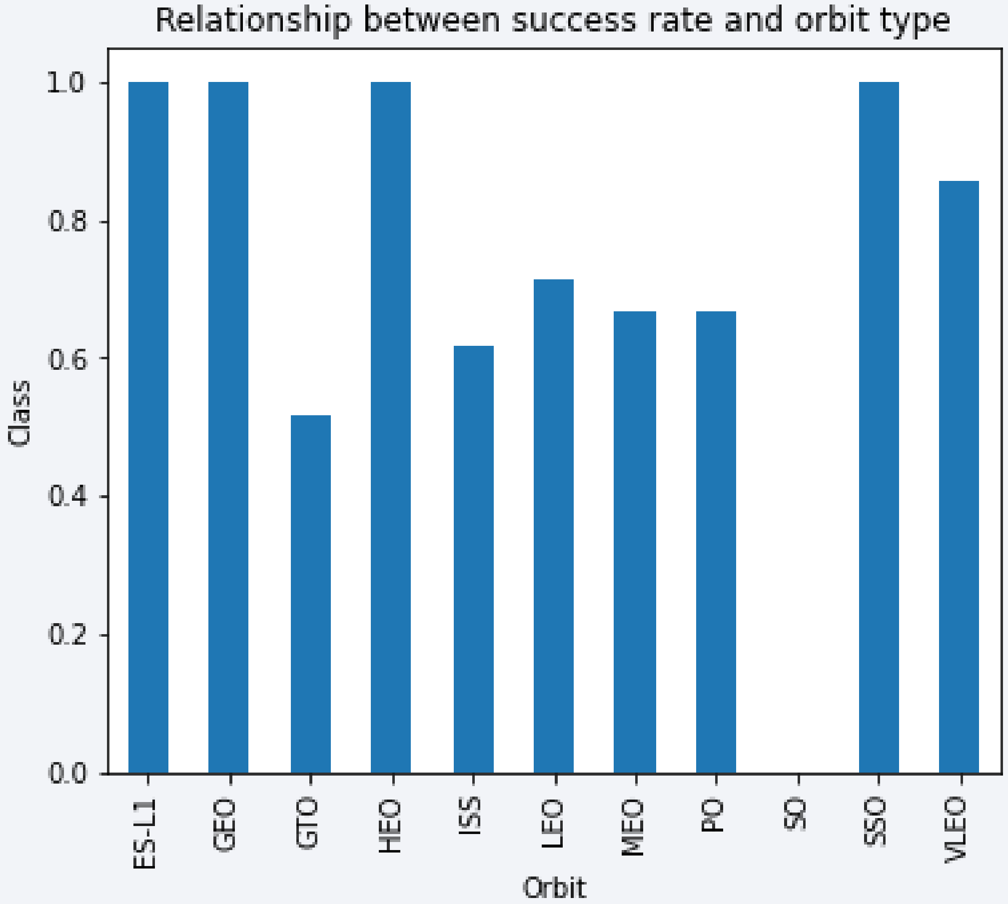


Fig. 6: Bar Chart of Success Rate vs. Orbit Type

Flight Number vs. Orbit Type

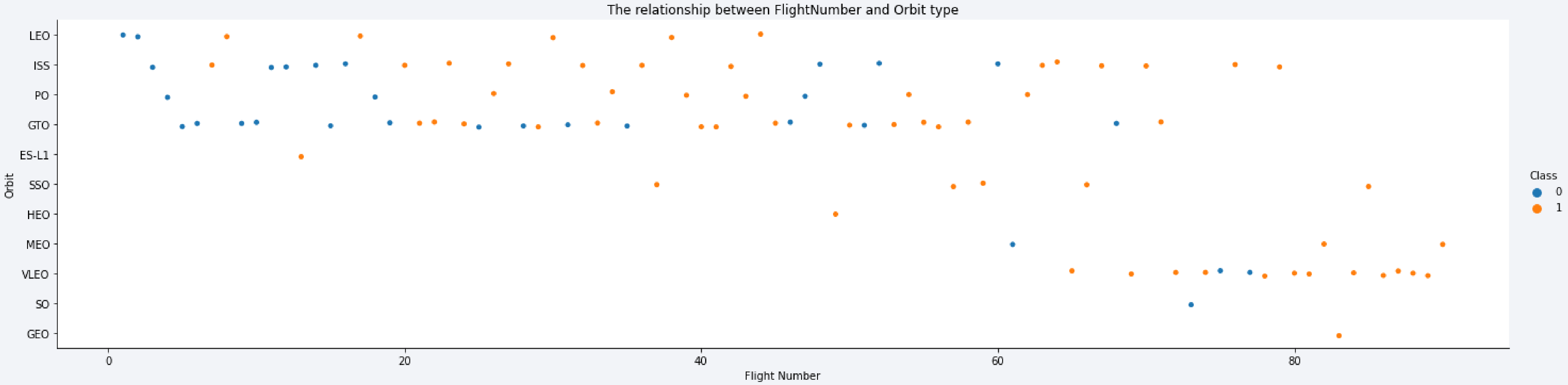


Fig. 7: Scatter Plot of Flight Number vs. Orbit Type

- SSO and VLEO has the highest rate of success followed by LEO, and PO,
- Over the time, rate of success has increased.

Payload vs. Orbit Type

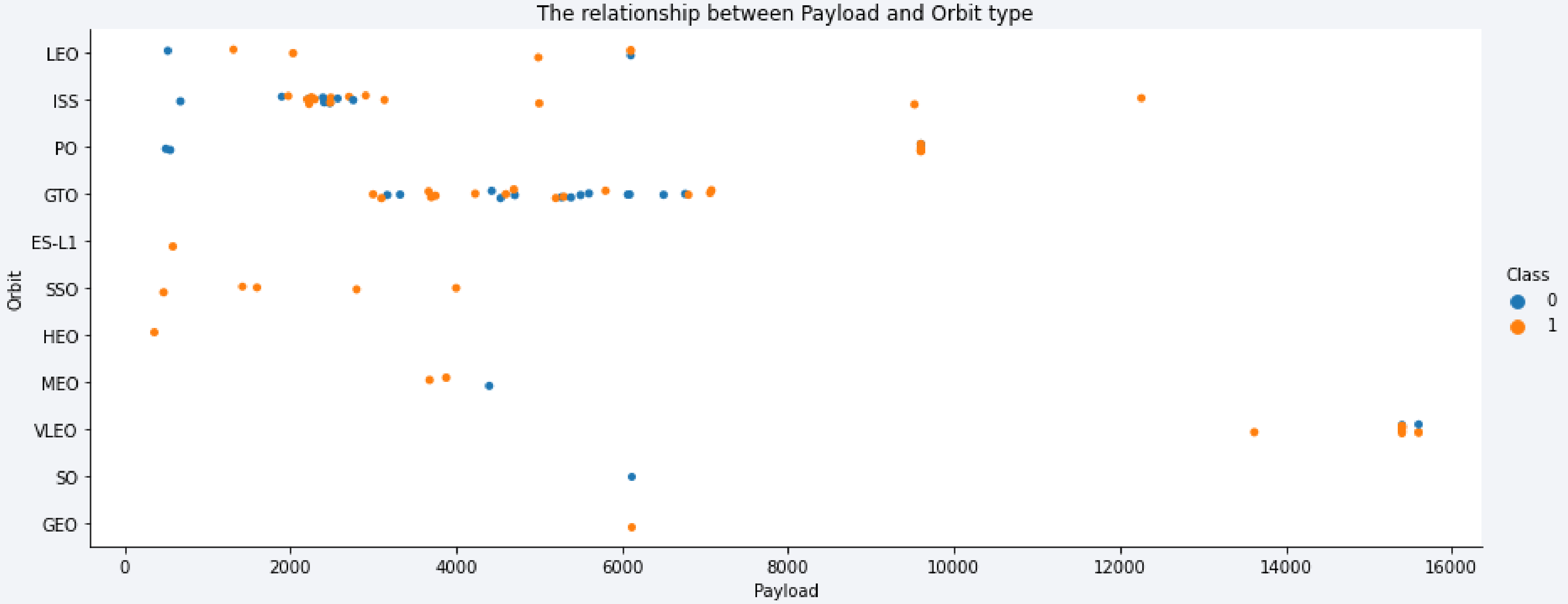


Fig. 8: Scatter Plot of Pay Load vs. Orbit Type

- SSO has the highest rate of success for less than 4000 kg of payload, and VLEO has the highest rate of success for over 14000 kg of payload,
- There is a mixed relation for ISS and GTO.

Launch Success Yearly Trend

- Over the time, success rate is increased,
- From year 2013 to 2017, consecutive rate of success is shown by the graph,
- From year 2017-18 and 2019-20, few failures are observed.

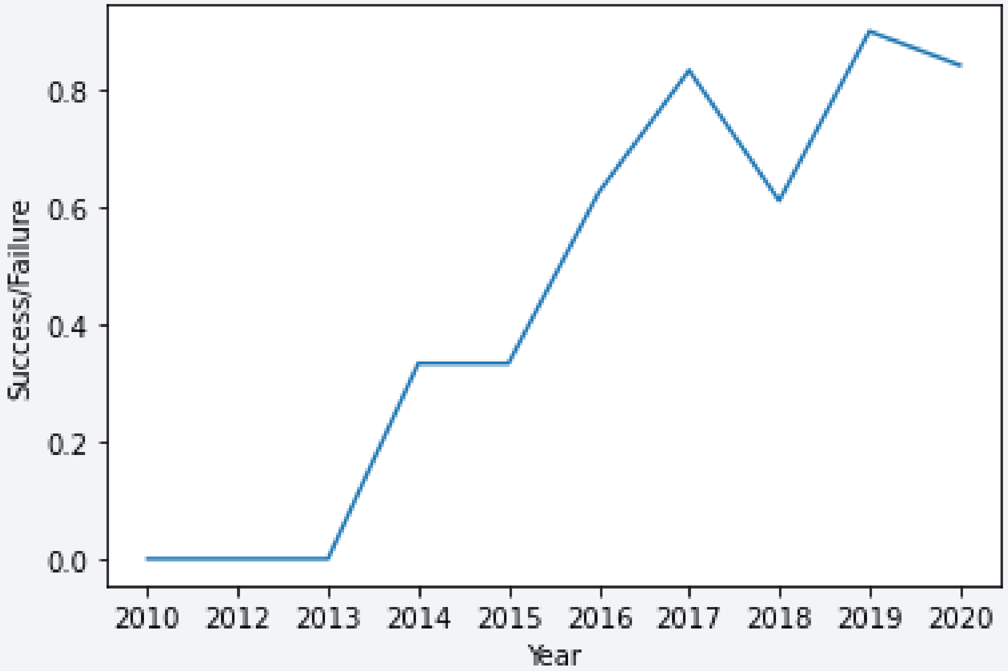


Fig. 9: Year vs Success/Failure

All Launch Site Names

- All launch site names are as per the table-1,
- Distinct launch sites are obtained by selecting “Launch Site” by data frame.

Table – 1: Launch Site Names

Launch Site
CCAFS LC-40
CCAFS SLC-40
KSC LC-39A
VAFB SLC-4E

Launch Site Names Begin with 'CCA'

- All launch site names begin with ‘CCA’ are as per the table-2,
- Launch sites names with ‘CCA’ are obtained by selecting “Launch Site” by data frame.

Table – 2: Launch Site Names Begin with ‘CCA’

Date	Time	Booster Version	Launch Site	Pay Load	Payload Mass (kg)	Orbit	Customer	Mission Outcome	Landing Outcome
2010-04-06	18:45:00	F9 v1.0 B0003	**CCA**FS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-08-12	15:43:00	F9 v1.0 B0004	**CCA**FS LC-40	Dragon demo flight C1, two CubeSats, barrel of Brouere cheese	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2012-08-10	00:35:00	F9 v1.0 B0006	**CCA**FS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-01-03	15:10:00	F9 v1.0 B0007	**CCA**FS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-03-12	22:41:00	F9 v1.1	**CCA**FS LC-40	SES-8	3170	GTO	SES	Success	No attempt

Total Payload Mass

- The total payload mass carried by boosters launched by NASA (CRS) is shown in the table-3,
- Total payload calculated above, by summing all payloads whose codes contain ‘CRS’, which corresponds to NASA.

Table – 3: Total Payload Mass

Total Payload Mass (kg)
22007

Average Payload Mass by F9 v1.1

- The average payload mass carried by booster version F9 v1.1 is shown in the table-4,
- Average payload mass by F9 v1.1 is obtained by averaging all payloads whose codes contain ‘F9 v1.1’, which corresponds to Booster Version.

Table – 4: Average Payload Mass by F9 v1.1

Average Payload (kg)
3676

First Successful Ground Landing Date

- The date when the first successful landing outcome in ground pad is achieved and shown in the table-5,
- First successful ground landing date is obtained by minimizing the date whose code contains Success (ground pad), which corresponds to Landing Outcome.

Table – 5: First Successful Ground Landing Date

Min. Date
2017-01-05

Successful Drone Ship Landing with Payload between 4000 and 6000

- The names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000 is achieved and shown in the table-6,
- Successful drone ship landing with payload between 4000 and 6000 kg is obtained by selecting success (drone ship), which corresponds to Landing Outcome.
- Also, payload mass is selected between 4000 and 6000 kg.

Table – 6: Successful Drone Ship Landing with Payload between 4000 and 6000

Booster Version
F9 FT B1022
F9 FT B1031.2

Total Number of Successful and Failure Mission Outcomes

- The total number of successful and failure mission outcomes is achieved and shown in the table-7,
- Grouping mission outcomes and counting records for each group led us to the summary above.

Table – 7: Total Number of Successful and Failure Mission Outcomes

Mission Outcomes	Frequency
Success	44
Success (payload status unclear)	1
Total	**45**

Boosters Carried Maximum Payload

- The names of the booster versions which have carried the maximum payload mass is achieved and shown in the table-8,
- There are five booster versions which are carried maximum payload.

Table – 8: Boosters Carried Maximum Payload

Booster Version
F9 B5 B1048.4
F9 B5 B1049.4
F9 B5 B1049.5
F9 B5 B1060.2
F9 B5 B1058.3

2015 Launch Records

- The failed landing outcomes in drone ship, their booster versions, and launch site names for in year 2015 is achieved and shown in the table-9,
- Only one outcome is achieved by the query here.

Table – 9: The failed landing outcomes in drone ship, their booster versions, and launch site names for in year 2015

Booster Version	Launch Site	Landing Outcome	Date
F9 v1.1 B1012	CCAFS LC-40	Failure (Drone Ship)	2015-10-01

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

- Rank the count of landing outcomes (such as Failure (drone ship) or Success (ground pad)) between the date 2010-06-04 and 2017-03-20, in descending order is achieved and shown in the table-10,

Table – 10: Rank Landing Outcomes Between 2010-06-04 and 2017-03-20

Landing Outcome	Frequency
No attempt	7
Failure (drone ship)	2
Success (drone ship)	2
Success (ground pad)	2
Controlled (ocean)	1
Failure (parachute)	1
Success	0
Total	**15**

Section 3

Launch Sites Proximities Analysis

Launch Sites

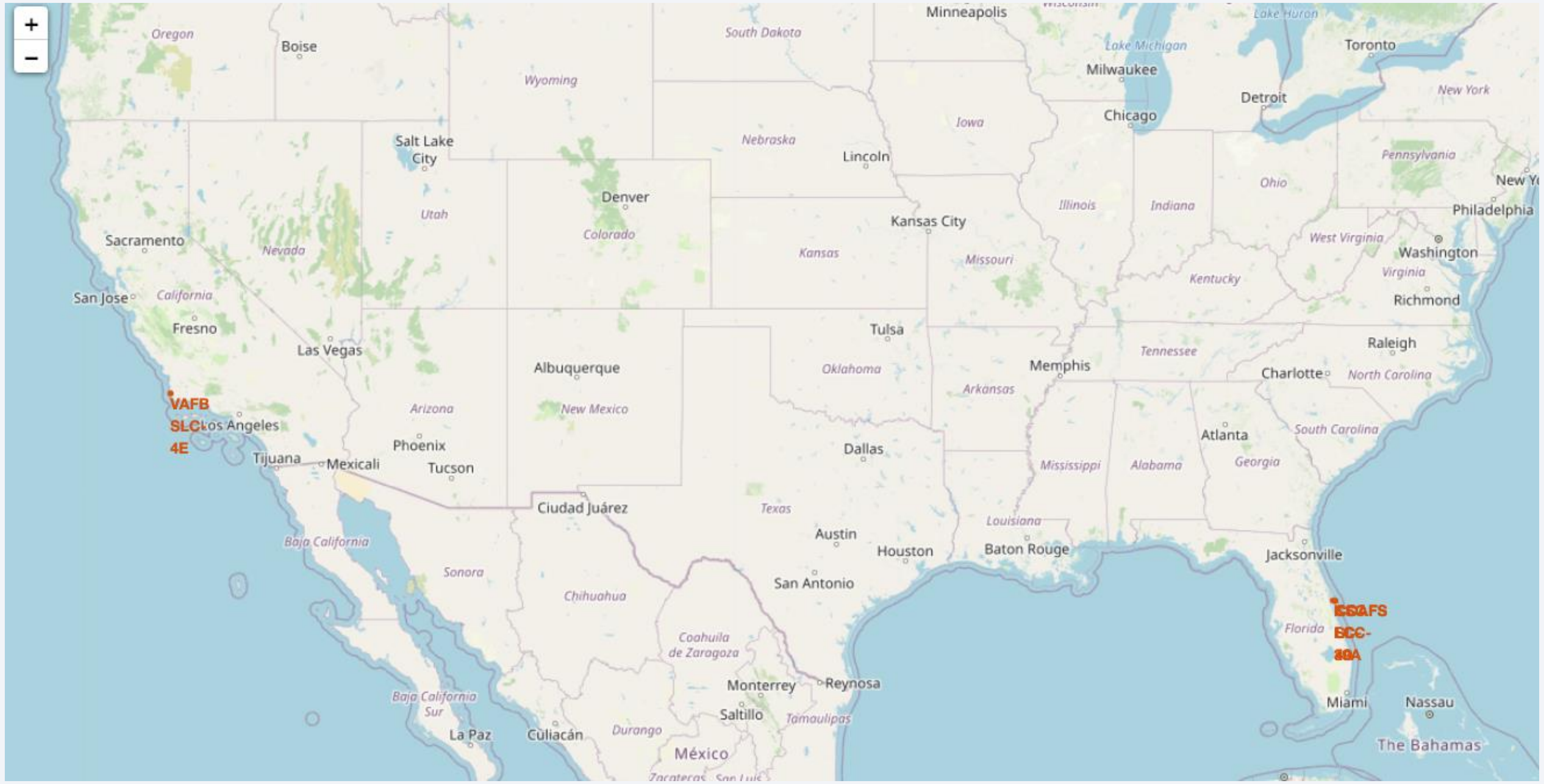


Fig. 10: All launch sites

- All launch sites are located on east-coast or on west-coast near ocean.

Launch Site by Success Rate

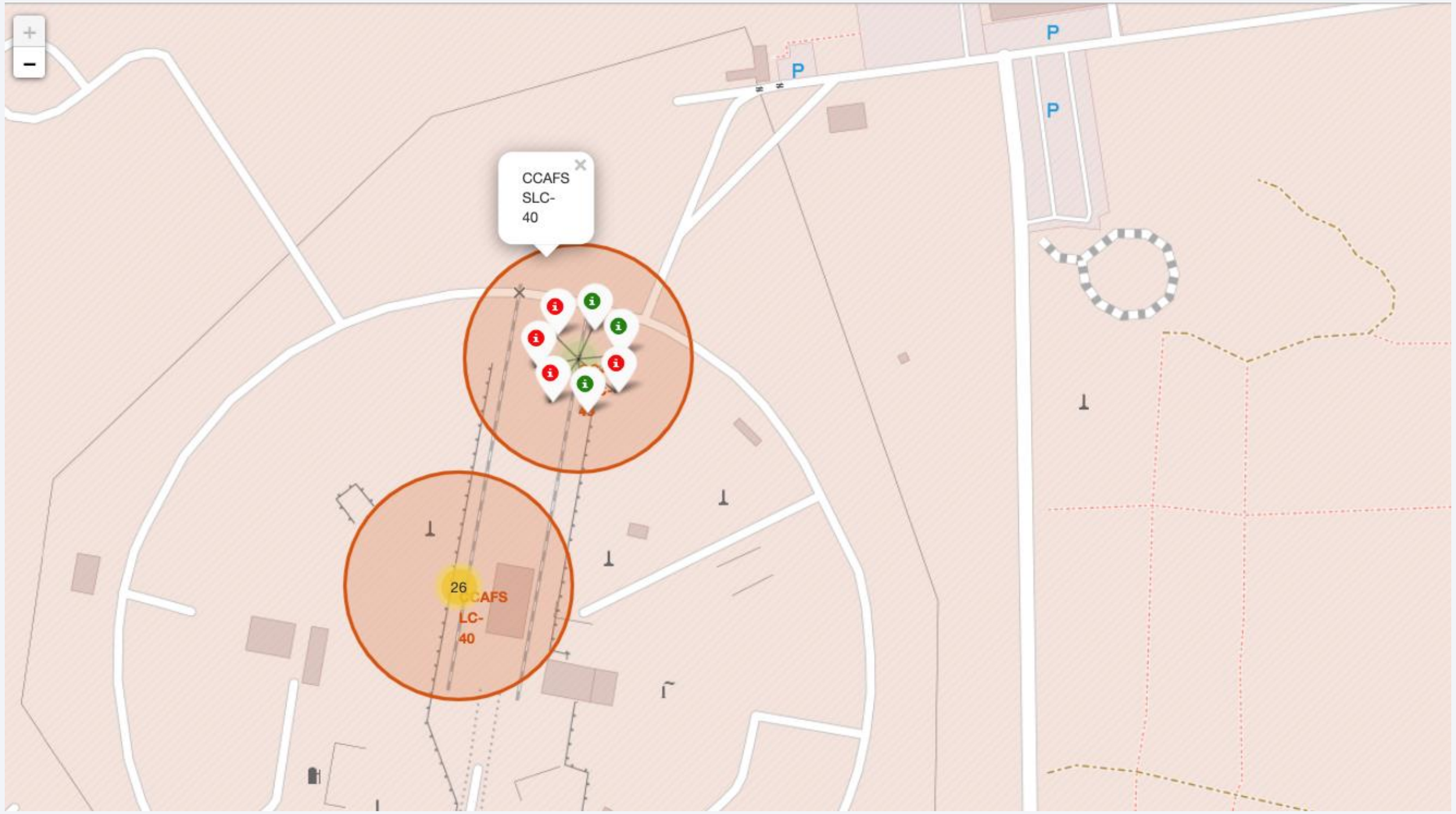


Fig. 11: Launch Site by Success Rate

- Launch site CCAFS SLC-40 is shown in the above figure with its success rate. Red color shows failure and green color shows success.

Map with Highways

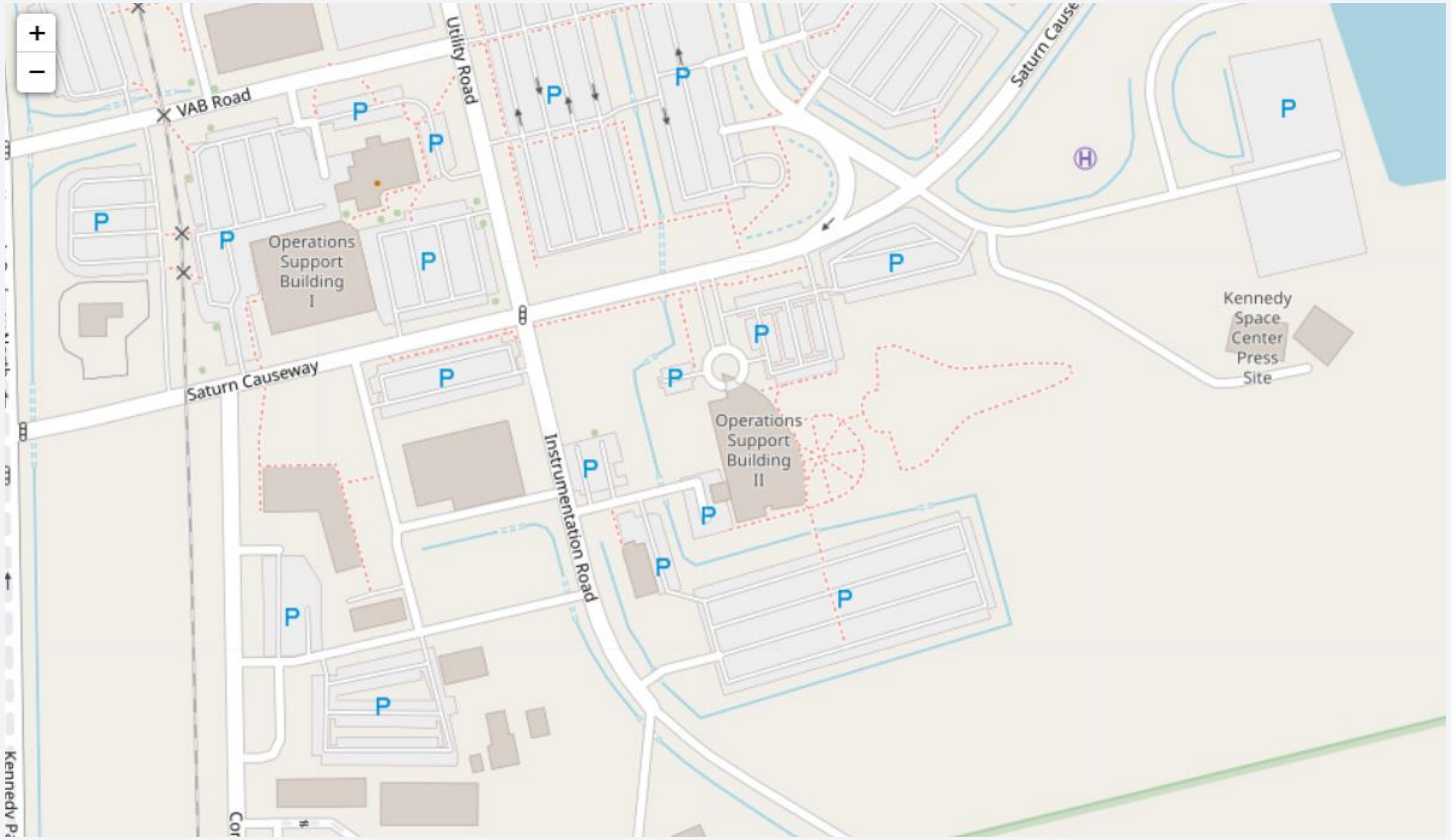


Fig. 12: Map with Highways

- Above diagram is shown map with highway label.

Section 4

Build a Dashboard with Plotly Dash

SpaceX Launch Records Dashboard

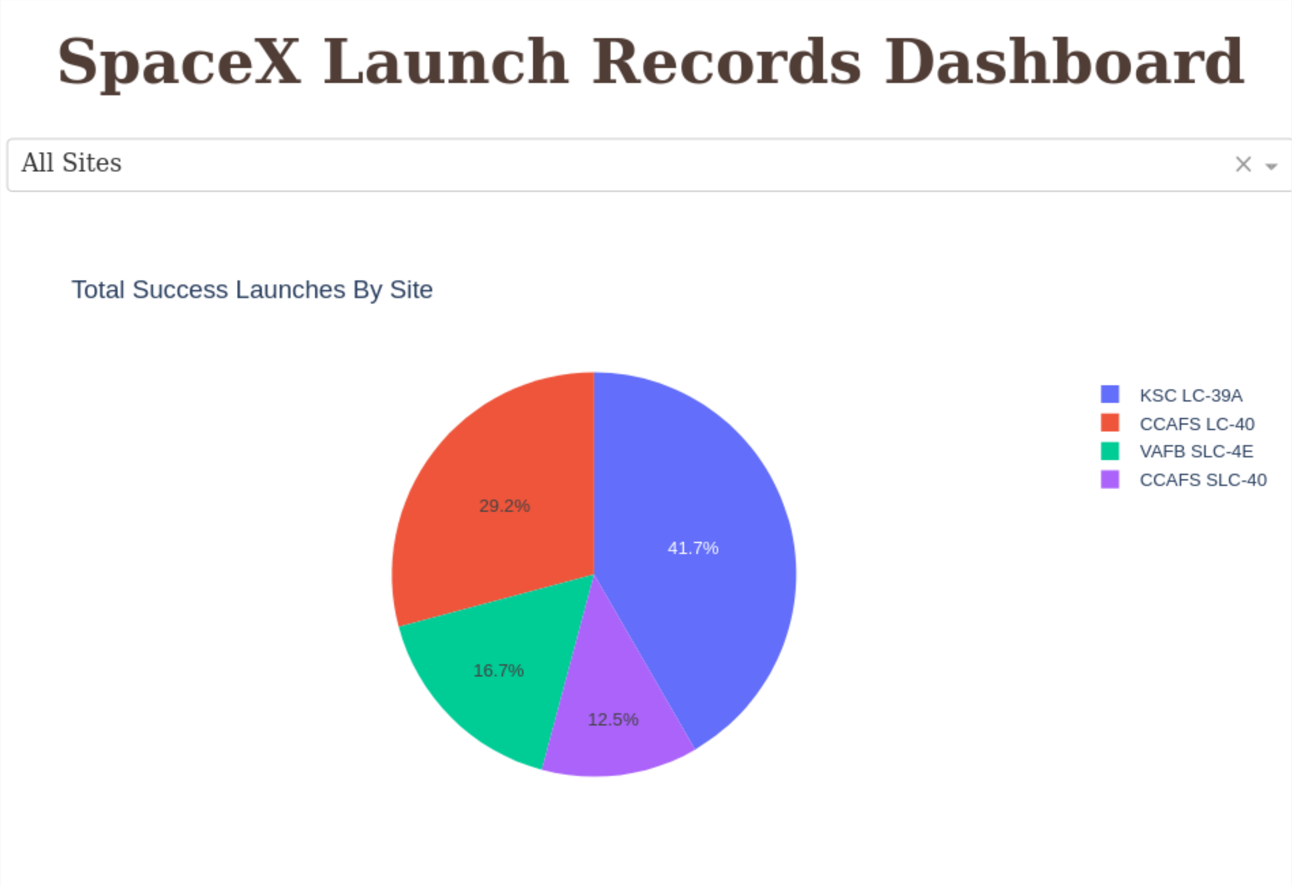


Fig. 13: SpaceX Launch Records Dashboard

- The pie chart shows the total successes lunches by sites.

Launch Success Ratio for KSC LC-39A

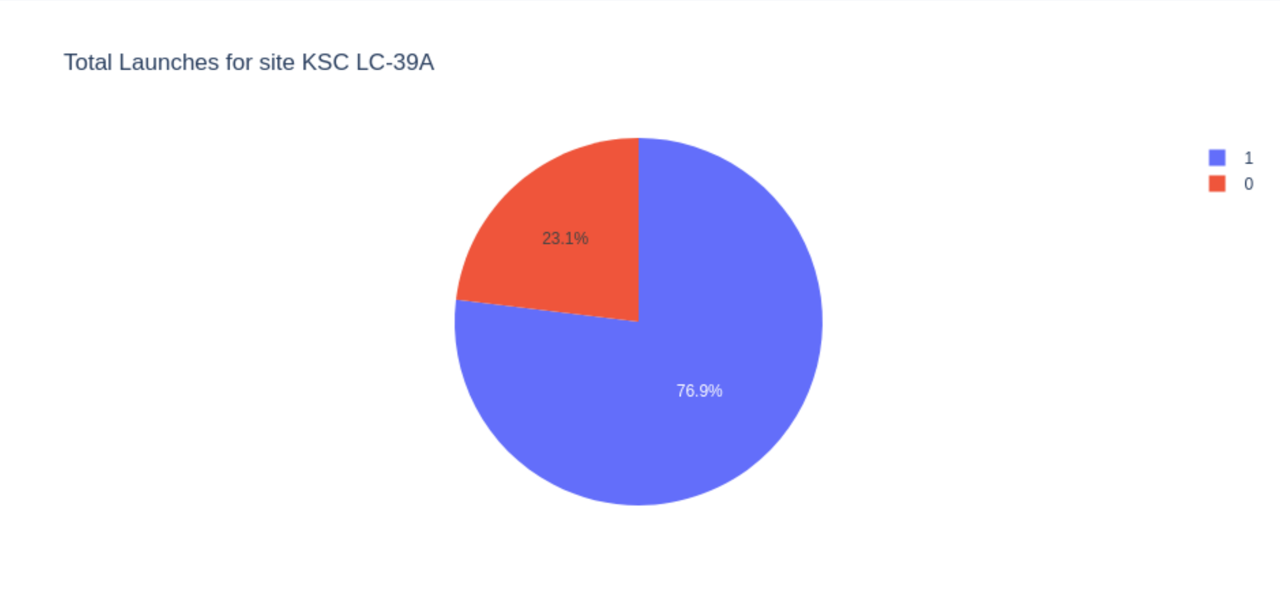


Fig. 14: Launch Success Ratio for KSC LC-39A

- The success ratio of KSC LC-39A is 76.9%.

Payload vs. Launch Outcome

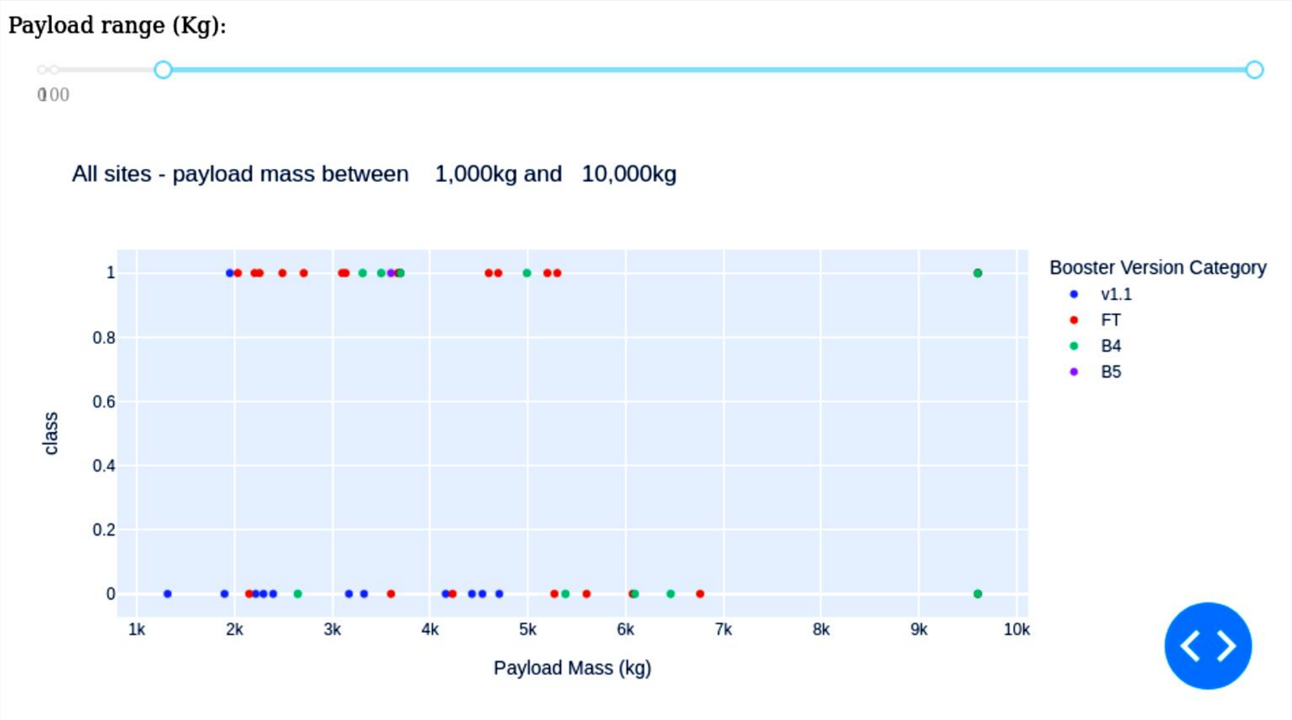


Fig. 15: Payload vs. Launch Outcome

- FT boosters have the highest rate of success among all four booster version.

Section 5

Predictive Analysis (Classification)

Classification Accuracy

- Four classification models were tested, and their accuracies are plotted beside with the help of bar chart,
- As per the chart, Decision Tree Classifier has the highest accuracies in both categories.

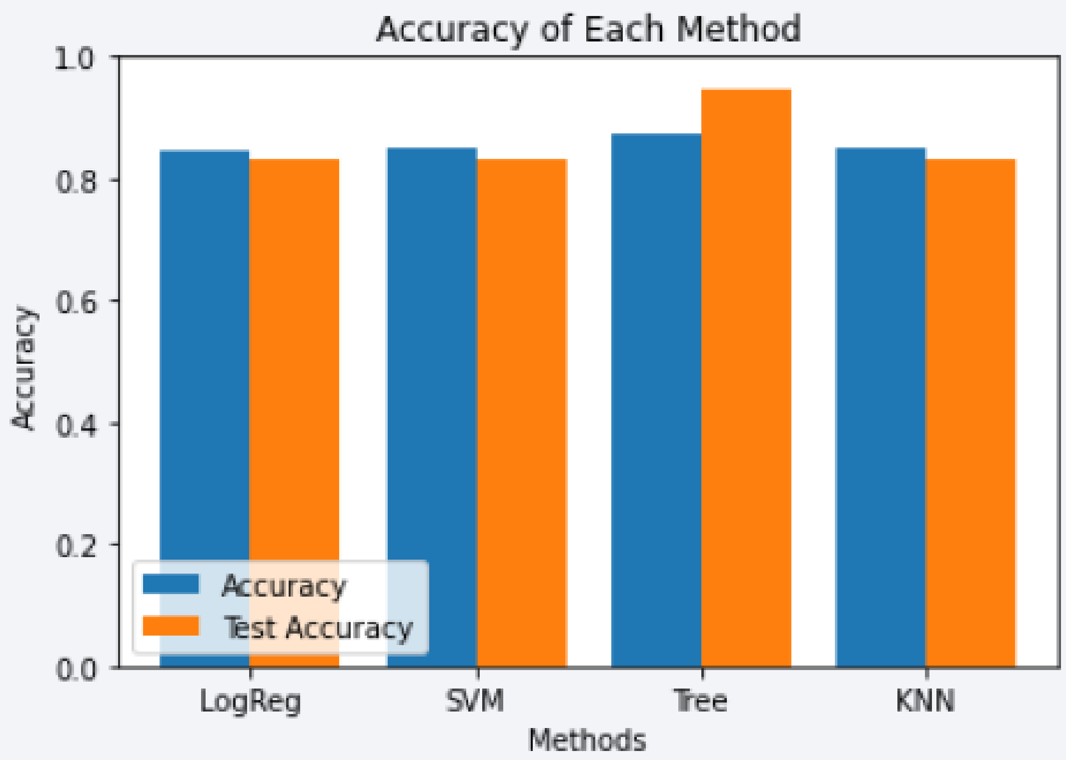


Fig. 16: Accuracy of each method

Confusion Matrix

- Confusion Matrix is a performance measurement for machine learning classification.
- Confusion Matrix of the Decision Tree Classifier is as shown in fig.

Fig. 17: Confusion Matrix of Decision Tree Classifier

Conclusions

- Different data sources were analyzed, refining conclusions along the process,
- The best launch site is KSC LC-39A,
- Launches above 7,000 kg are less risky,
- Although most of mission outcomes are successful, successful landing outcomes seem to improve over time, according the evolution of processes and rockets,
- Decision Tree Classifier can be used to predict successful landings and increase profits.

Appendix

- All the codes are included in the GitHub,
- Link to GitHub: https://github.com/Dkap911/Applied-Data-Science-Capstion/tree/master

Thank you!