IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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15/02/2023

Outline

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

Executive Summary

- The following methodologies were used to analyze data:
  - Data Collection with web scraping and SpaceX API;
  - Exploratory Data Analysis (“EDA”), including data wrangling, data visualization and interactive visual analytics;
  - Machine Learning Prediction.
- Summary of all results
  - Data collected from sources publicly available;
  - EDA allowed to identify which features are the best to predict success of launchings
  - Best features for successful landing prediction via EDA;
  - ML Prediction showed the best model.

Introduction

- The objective is to evaluate the viability of the Startup Space Y competitor of Space X.
- Questions:
  - How to estimate the total cost for launches, by predicting successful landings of the first stage of rockets?
  - Where is the best place to make launches?

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - Data from Space X was obtained from 2 sources:
    - Space X API (https://api.spacexdata.com/v4/rockets/)
    - WebScraping (https://en.wikipedia.org/wiki/List_of_Falcon/_9/_and_Falcon_Heavy_launches)
- Perform data wrangling
  - Collected data was enriched by creating a landing outcome label based on outcome data after summarizing and analyzing features
- Perform exploratory data analysis (EDA) using visualization and SQL

Methodology

Executive Summary

- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
    - Data – normalized and divided in training and test data sets and evaluated by four different classification models, being the accuracy of each model evaluated using different combinations of parameters.

Data Collection

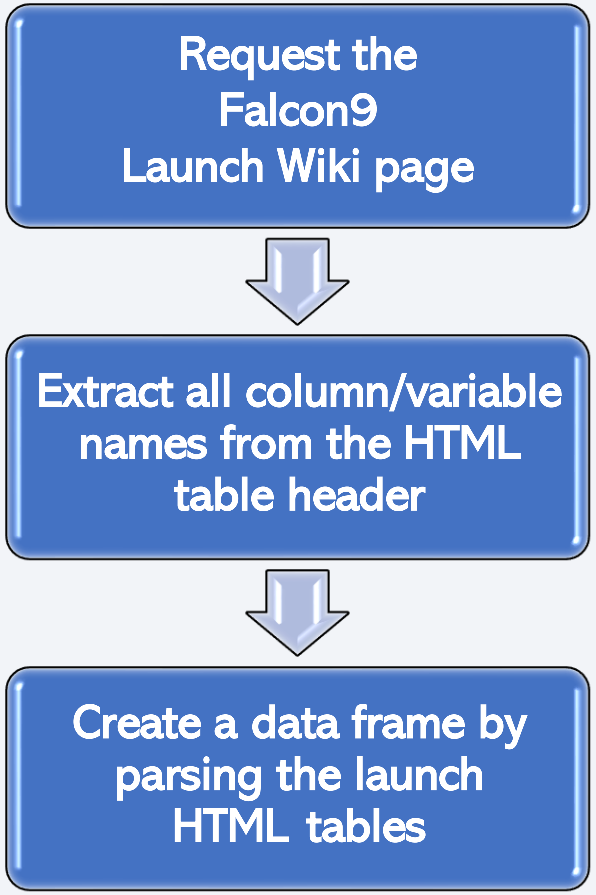
- Data sets were collected from Space X API (https://api.spacexdata.com/v4/rockets/) and from Wikipedia (https://en.wikipedia.org/wiki/List_of_Falcon/_9/_and_Falcon_Heavy_launches), using web scraping technics.

Data Collection – API

- SpaceX offers a public API from where data can be obtained and then used;
- This API was used according to the flowchart beside and then data is persisted.

Data Collection – Data Scraping

- Data from SpaceX launches can also be obtained from Wikipedia;
- Data are downloaded from Wikipedia according to the flowchart and then persisted.

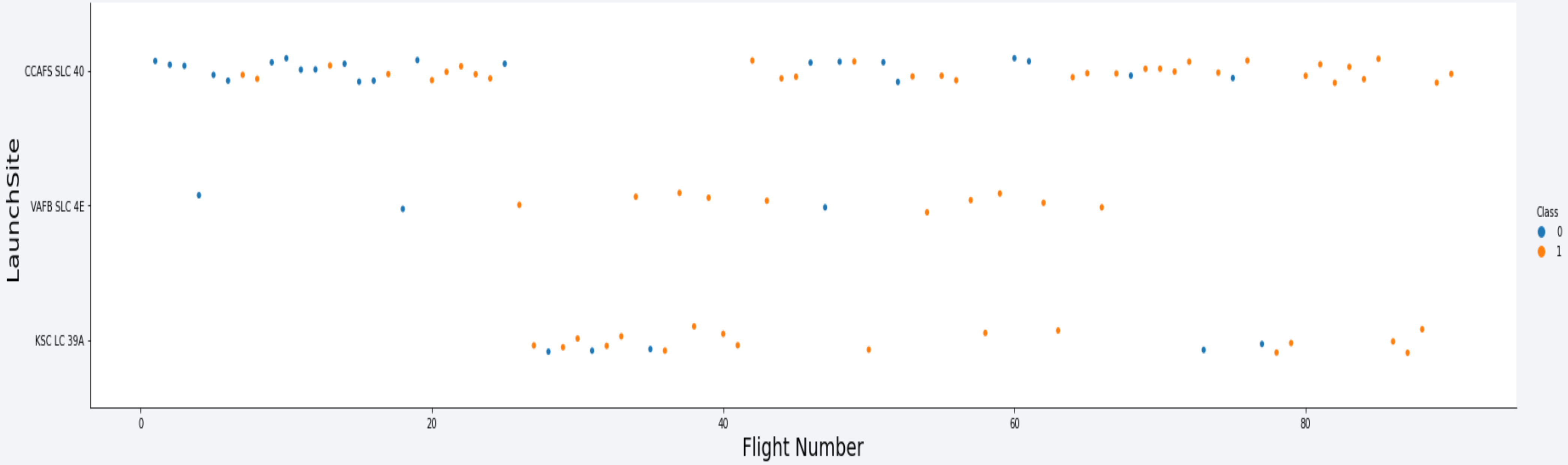


Data Wrangling

- Initially some EDA was performed on the dataset.
- Then the summaries launches per site, occurrences of each orbit and occurrences of mission outcome per orbit type were calculated.
- The landing outcome label was created from Outcome.

EDA and Data Visualization

- To explore data, scatterplots and barplots were used to visualize the relationship between pair of features:
  - Payload Mass X Flight Number, Launch Site X Flight Number, Launch Site X Payload Mass, Orbit and Flight Number, Payload and Orbit



EDA with SQL

- The following SQL queries were performed:
  - Names of the unique launch sites in the space mission;
  - Top 5 launch sites whose name begin with the string 'CCA';
  - Total payload mass carried by boosters launched by NASA (CRS);
  - Average payload mass carried by booster version F9 v1.1;
  - Date when the first successful landing outcome in ground pad was achieved;
  - Names of the boosters which have success in drone ship and have payload mass between 4000 and 6000 kg;
  - Total number of successful and failure mission outcomes;
  - Names of the booster versions which have carried the maximum payload mass;
  - Failed landing outcomes in drone ship, their booster versions, and launch site names for in year 2015; and
  - Rank of the count of landing outcomes (such as Failure (drone ship) or Success (ground pad)) between the date 2010-06-04 and 2017-03-20.

Build an Interactive Map with Folium

- Folium Maps
  - Markers indicate points like launch sites;
  - Circles indicate highlighted areas around specific coordinates, like NASA Johnson Space Center;
  - Marker clusters indicates groups of events in each coordinate, like launches in a launch site; and
  - Lines are used to indicate distances between two coordinates.

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.

Predictive Analysis (Classification)

- Methods: logistic regression, support vector machine, decision tree and k nearest neighbors.

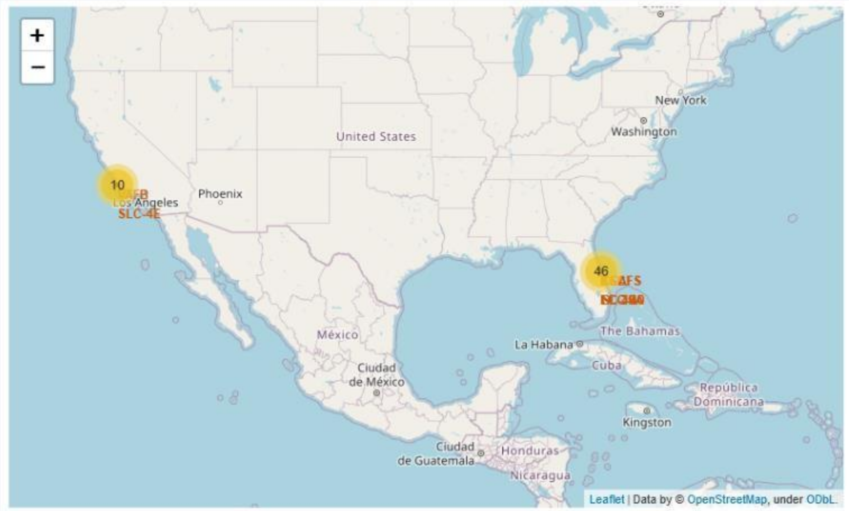
Comparison of results

Results

1. Space X uses 4 different launch sites;
2. The first launches were done to Space X itself and NASA;
3. The average payload of F9 v1.1 booster is 2,928 kg;
4. The first success landing outcome happened in 2015 fiver year after the first launch;
5. Many Falcon 9 booster versions were successful at landing in drone ships having payload above the average;
6. Almost 100% of mission outcomes were successful;
7. Two booster versions failed at landing in drone ships in 2015: F9 v1.1 B1012 and F9 v1.1 B1015;
8. The number of landing outcomes became as better as years passed.

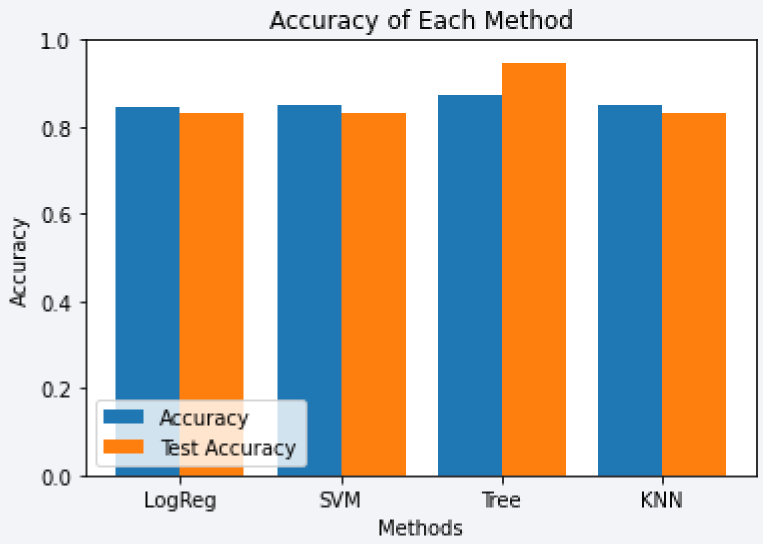
Results

- 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.



Results

- Predictive Analysis showed that Decision Tree Classifier is the best model to predict successful landings, having accuracy over 87% and accuracy for test data over 94%.

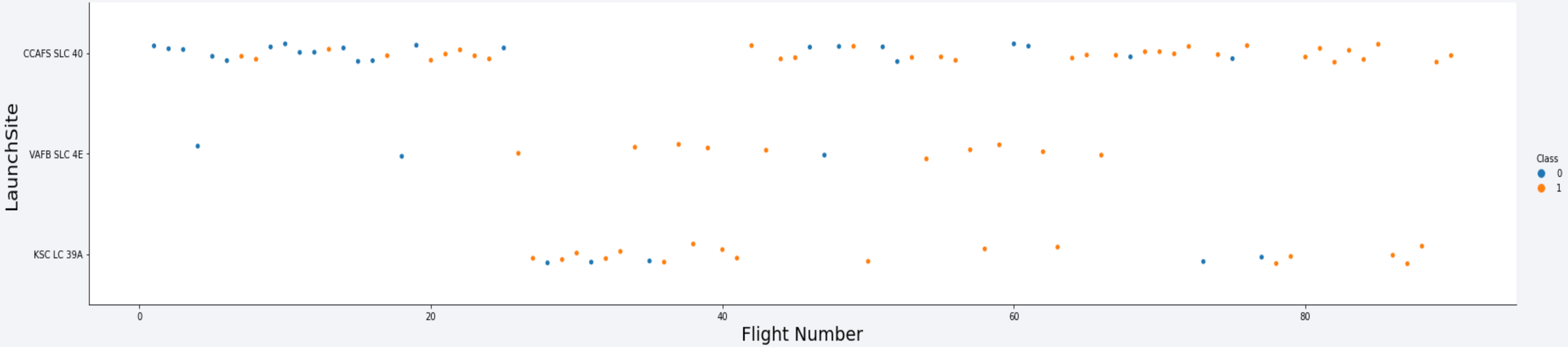


Section 2

Insights drawn from EDA

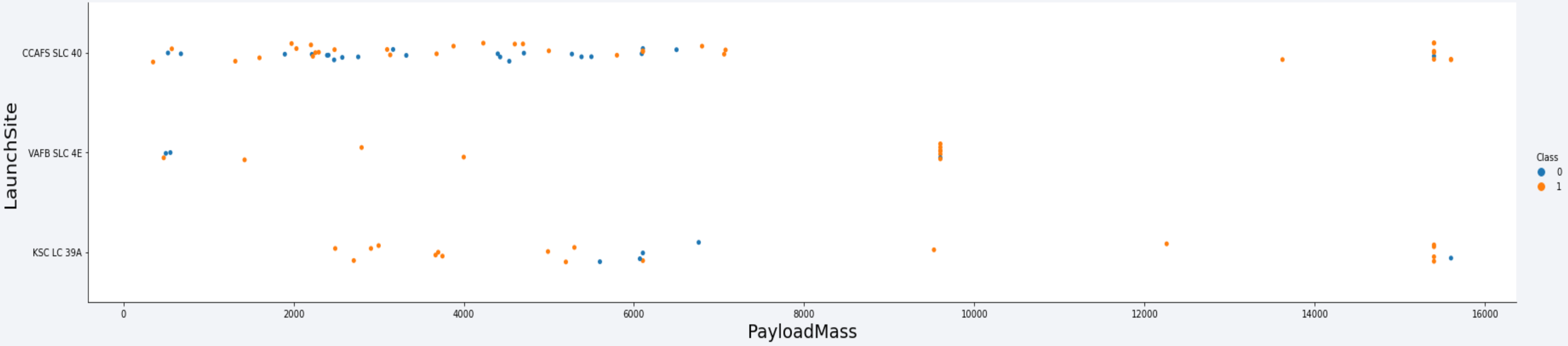
Flight Number vs. Launch Site

- According to the catplot below, the best launch site is CCAF5 SLC 40, as the most of recent launches were successful;
- 2nd VAFB SLC 4E and 3rd KSC LC 39A;



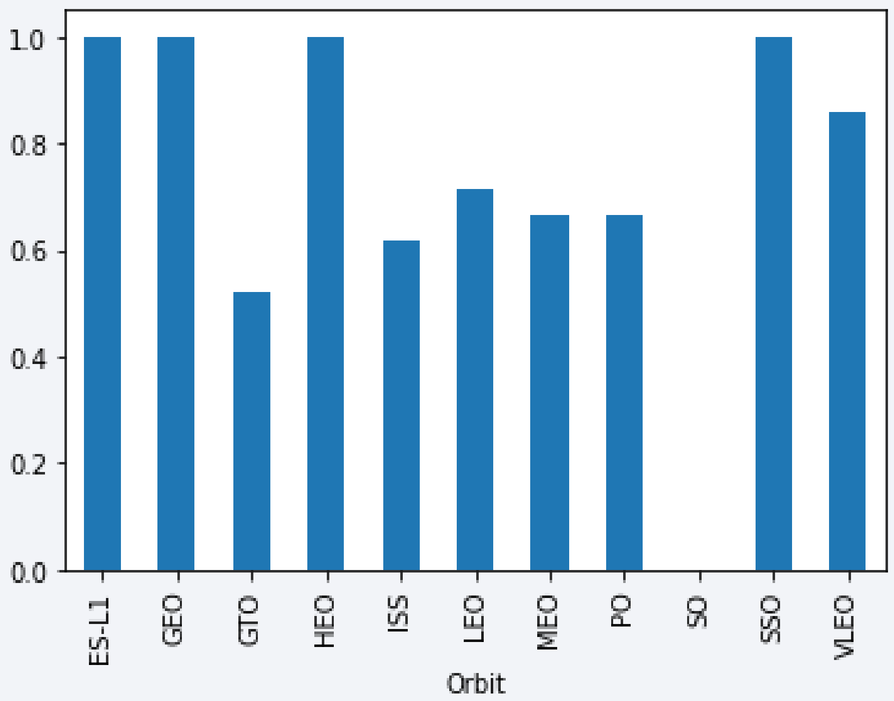
Payload vs. Launch Site

- Payloads over 9,000kg (about the weight of a school bus) have excellent success rate;
- Payloads over 12,000kg seems to be possible only on CCAFS SLC 40 and KSC LC 39A launch sites.



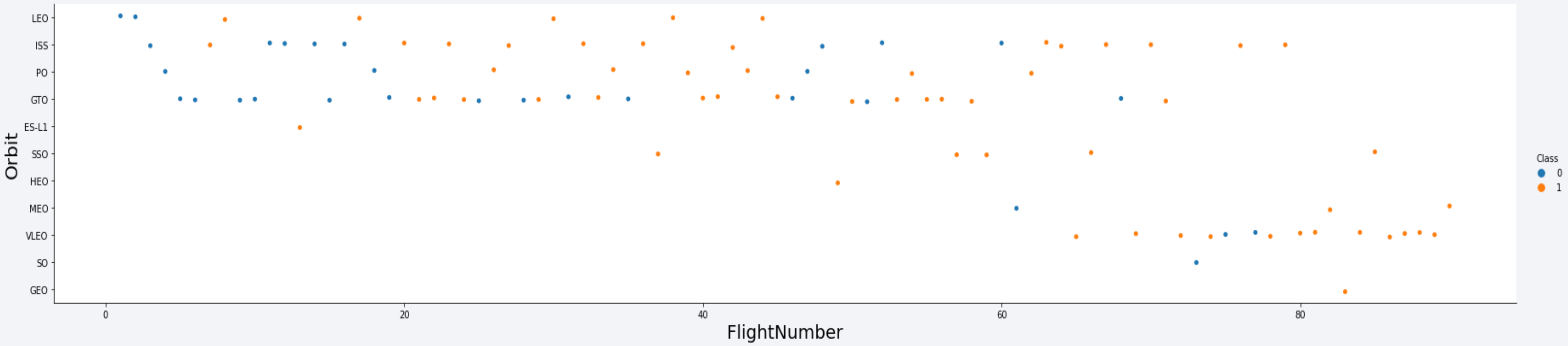
Success Rate vs. Orbit Type

- Orbits with highest success rates:
    - ES-L1;
    - GEO;
    - HEO; and
    - SSO.
    - VLEO
    - LFO



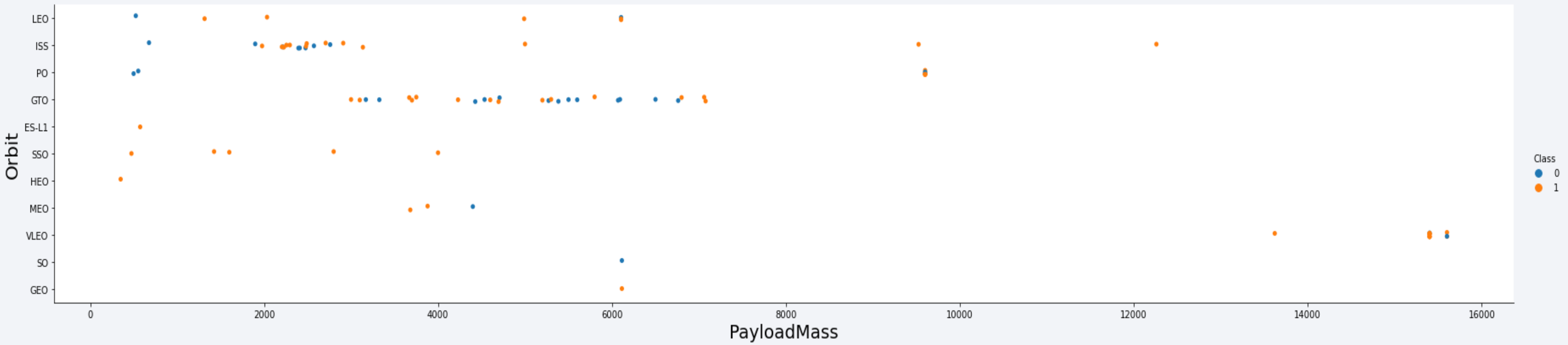
Flight Number vs. Orbit Type

- Success rate improved over time to all orbits;
- VLEO orbit seems a new business opportunity, due to recent increase of its frequency.



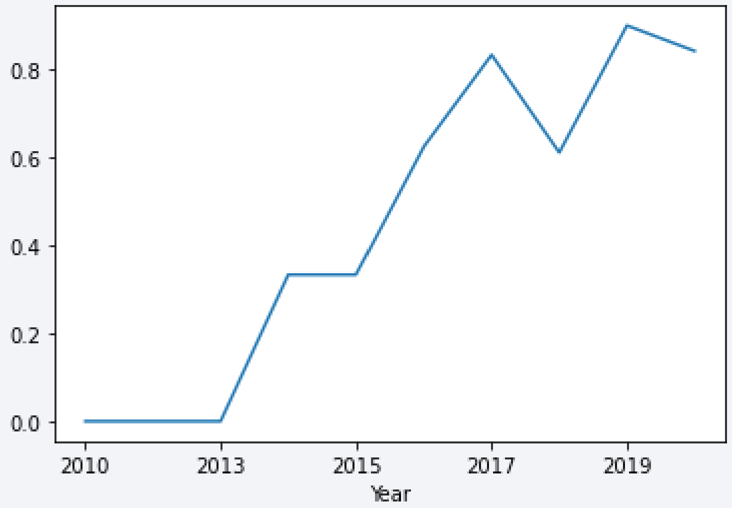
Payload vs. Orbit Type

- No relation between payload and success rate to orbit GTO;
- ISS orbit has the widest range of payload and a good rate of success;



Success Annual Trend

- Success rate started increasing from 2013;



Site Names

- According to data, there are four launch sites:

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

Launch Site Names Begin with 'CCA'

- 5 records where launch sites begin 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	**CCA**FS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-12-08	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)
2012-05-22	07:44:00	F9 v1.0 B0005	**CCA**FS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	00:35:00	F9 v1.0 B0006	**CCA**FS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-03-01	15:10:00	F9 v1.0 B0007	**CCA**FS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attemp

Total Payload Mass

- Total payload carried by boosters from NASA:

Total Payload (kg)
111.268

- Total payload calculated above, by summing all payloads whose codes contain 'CRS', which corresponds to NASA.

Average Payload Mass by F9 v1.1

- Avg payload mass carried by booster version F9 v1.1:

Avg Payload (kg)
2.928

- Filtering data by the booster version above and calculating the average payload mass we obtained the value of 2,928 kg.

First Successful Ground Landing Date

- First successful landing outcome on ground pad:

Min Date
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

- Boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 6000

Booster Version
F9 FT B1021.2
F9 FT B1031.2
F9 FT B1022
F9 FT B1026

Total Number of Successful and Failure Mission Outcomes

- Number of successful and failure mission outcomes:

Mission Outcome	Occurrences
Success	99
Success (payload status unclear)	1
Failure (in flight)	1

Boosters Carried Maximum Payload

- Boosters which have carried the maximum payload mass

Booster Version
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

2015 Launch Records

- Failed landing outcomes in drone ship, their booster versions, and launch site names for in year 2015

Booster Version	Launch Site
F9 v1.1 B1012	CCAFS LC-40
F9 v1.1 B1015	CCAFS LC-40

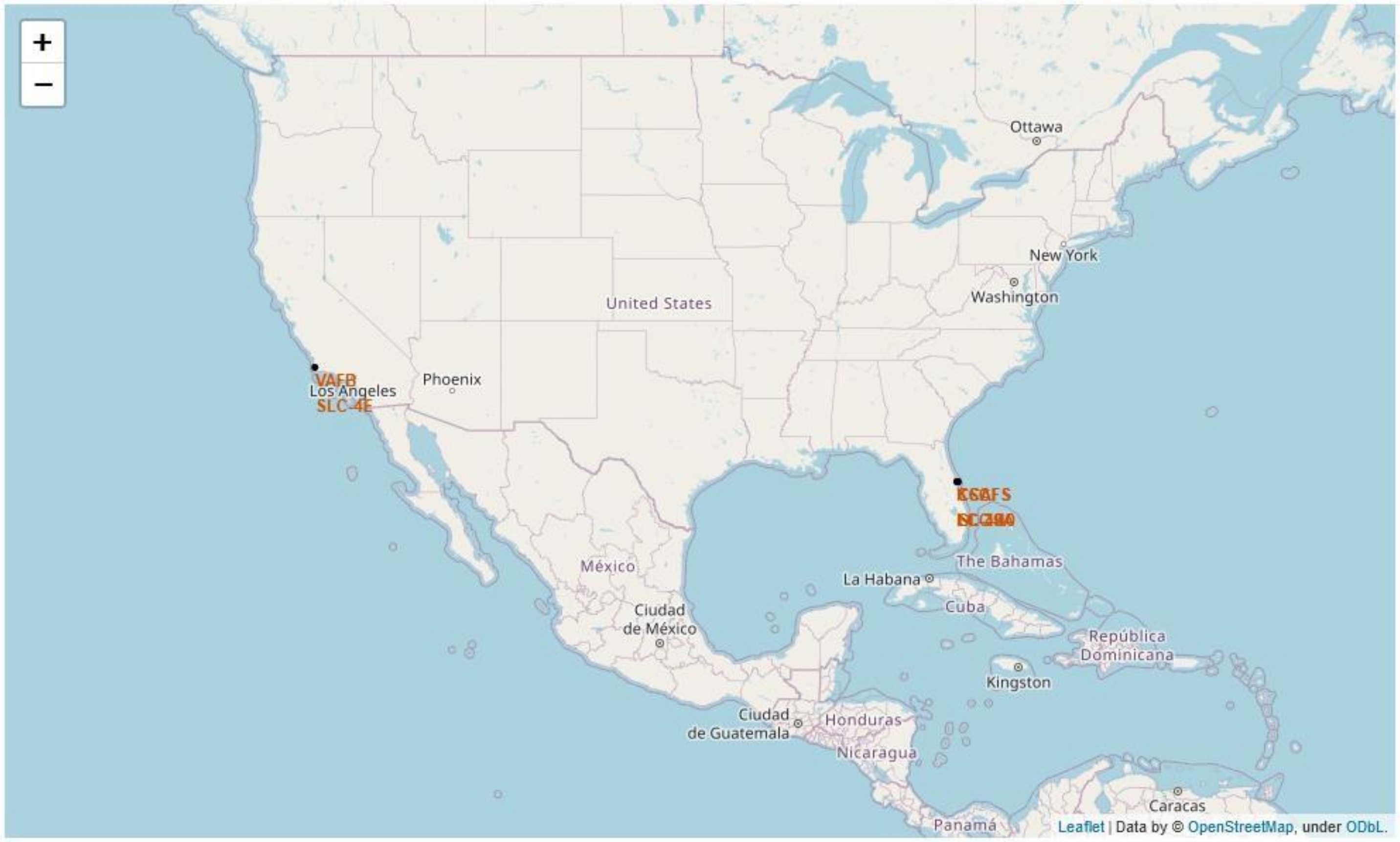
Rank Landing Outcomes Between 2010-06-04 and 2017-03-20

Landing Outcome	Occurrences
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 4

Launch Sites Proximities Analysis

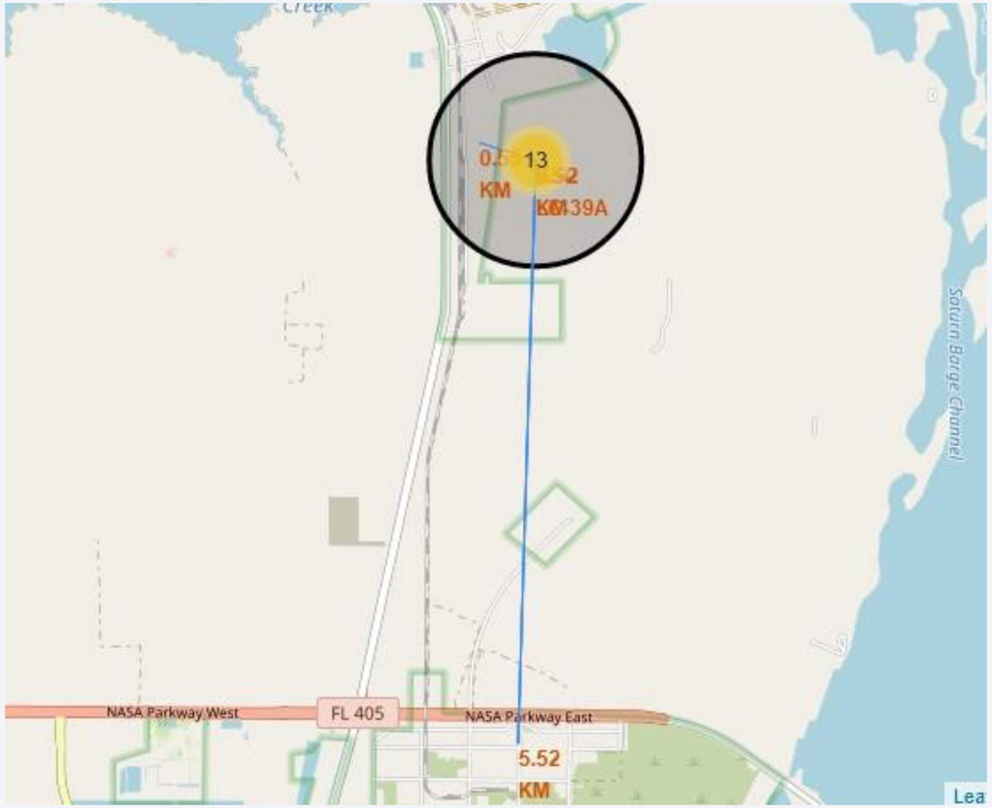
All launch sites



Launch Outcomes by Site

- Green markers depict the successful and red ones failure.

Logistics and Safety



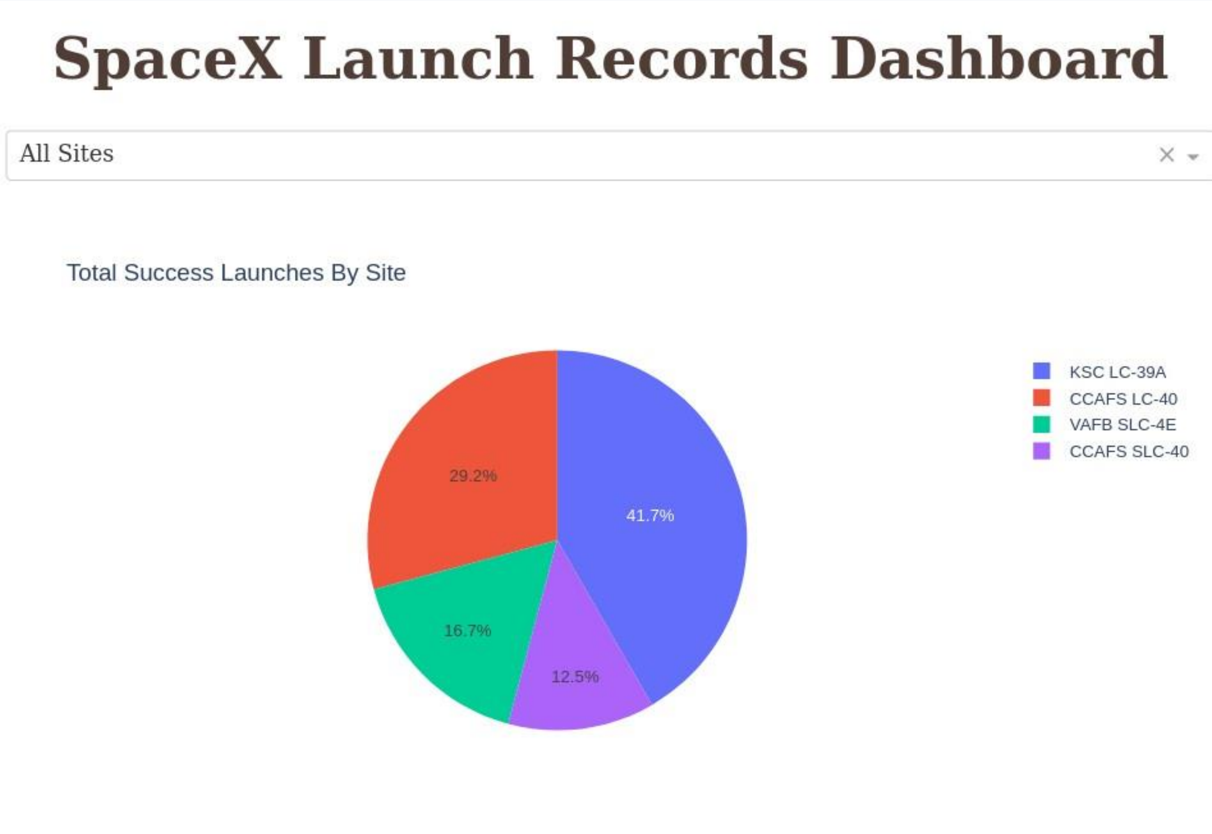
- Launch site KSCLC-39A isbeing near railroad and road and relatively far from inhabited areas.

Section 5

Build a Dashboard with Plotly Dash

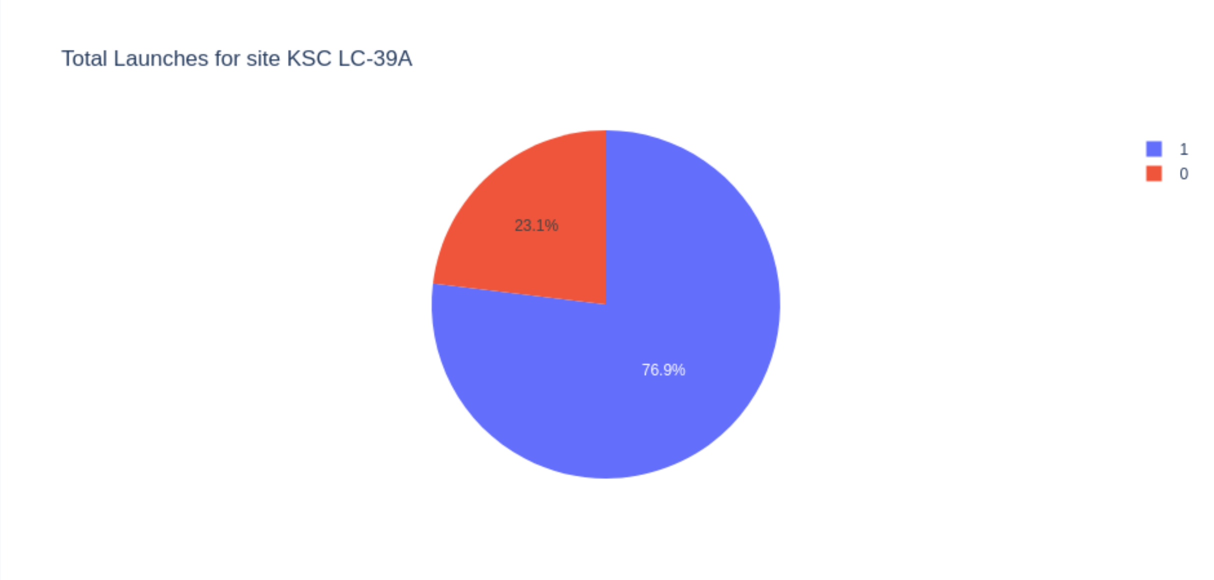
Successful Launches by Site

- The place from where launches are realised looks like a significant factor for successful missions.



Launch Success Ratio for KSC LC-39A

- More than the 2/3 of the launches from this site are successful.



Payload vs. Launch Outcome

- Payloads under 6,000kg and FT boosters are the most successful combination.

Payload vs. Launch Outcome

- No estimation for over 7,000kg

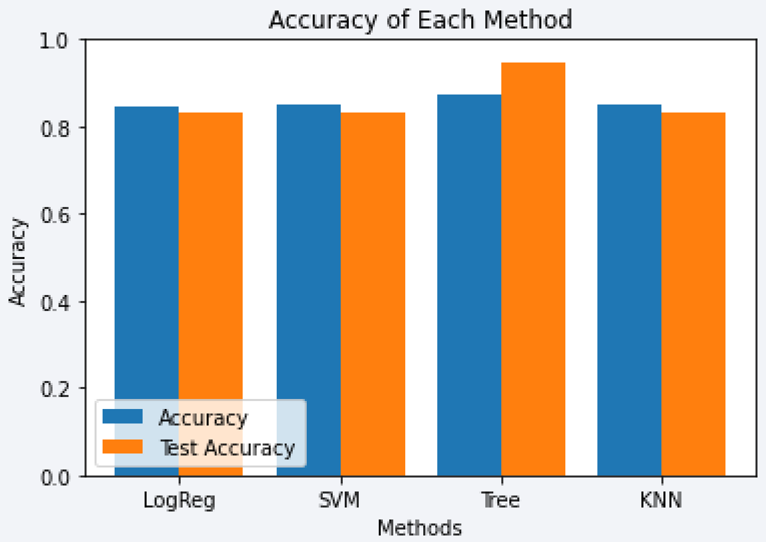
Section 6

Predictive Analysis (Classification)

Classification Accuracy

- 4 classification models were tested, the accuracy and score of which are plotted underneath.

- The model with the highest classification accuracy is Decision Tree Classifier, which has accuracies over than 85%.



Confusion Matrix of Decision Tree Classifier

- Confusion matrix of Decision Tree Classifier: Up left True Negatives, Up right False Positives, Down left False Negatives, Down right True Positives

- The high accuracy is observable.

Conclusions

The best launch site is KSC LC-39A;

Launches above 7,000kg are less risky;

Decision Tree Classifier can be used to predict successful landings and increase profits.

Thank you!