IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

Simamkele Ntlombe

14-02-2023

Outline

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

Executive Summary

The Collection and Analysis methodologies were as follows:

- Data Collection using web scraping and SpaceX API;
- Exploratory Data Analysis which included Data Wrangling, Data Visualisation and Interactive Visual Analytics;
- Machine Learning Prediction.

Summary of all results

- Valuable data was collected from public sources;
- EDA allowed us identify which features are the best to predict success of launches;
- Machine Learning Prediction showed the best model to predict which characteristics are important to grasp this opportunity, utilising all collected data.

Introduction

- The objective is to evaluate the viability of the new company Space Y to compete with Space X.

- Desirable answers:
- The best way to estimate the total cost for launches, by predicting successful landings of the first stage of rockets;

- Where is the most favourable location 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 summarising and analysing features
- Perform Exploratory Data Analysis using visualisation and SQL

Methodology

Executive Summary

- Perform interactive visual analytics using Folium and Plotly Dash. This allows us to interact with the data

- Perform predictive analysis using ML classification models

- Data that was collected until this step were normalised, divided in training and test data sets and evaluated by four different classification models, the accuracy of each model evaluated using different combinations of parameters.

Data Collection

- All the datasets were obtained from the 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). Webscrapping methods were used.

Data Collection – SpaceX API

- SpaceX offers a public API where data can be obtained and then utilised;

- This API was used according to the flowchart beside and then data is persisted.

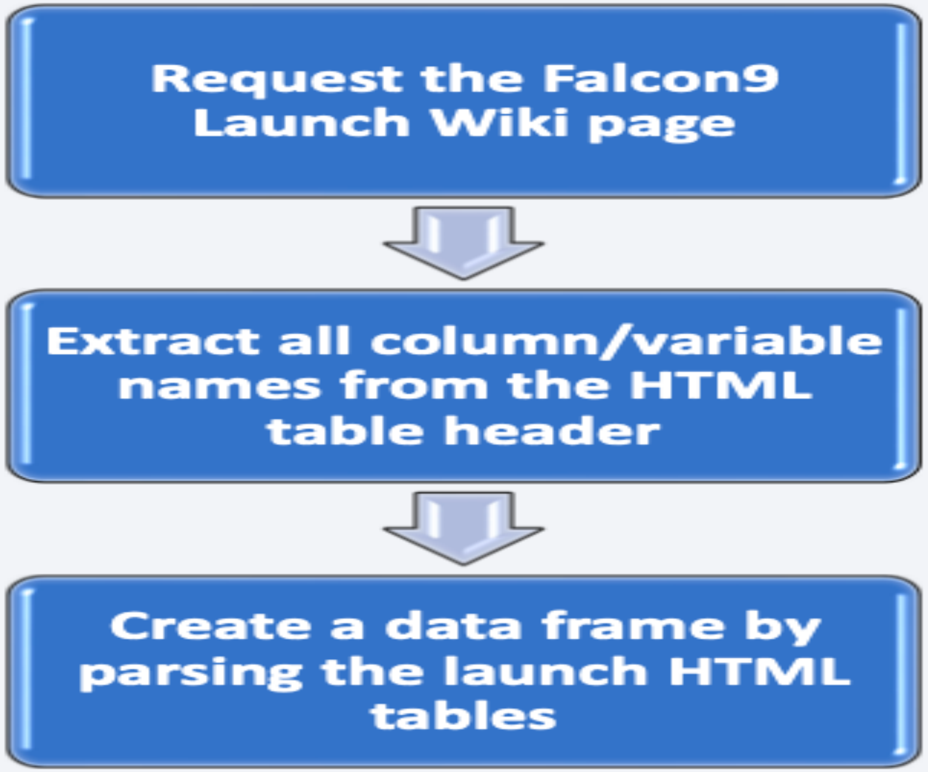
Source code: https://github.com/Sam-366/Space-X-Falcon-9-Project/blob/main/Data%20Collection%20with%20Webscraping_%20Falcon%209%20(1).ipynb

Data Collection - Scraping

- Data from SpaceX launches can also be obtained from Wikipedia;

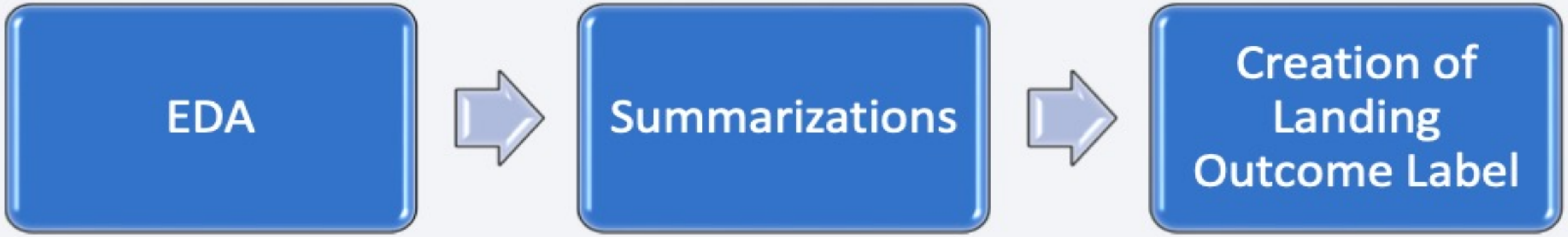
- Data are downloaded from Wikipedia according to the flowchart and then persisted.

Source code: https://github.com/Sam-366/Space-X-Falcon-9-Project/blob/main/Data%20Collection%20with%20Webscrapping_%20Falcon%209%20(1).ipynb



Data Wrangling

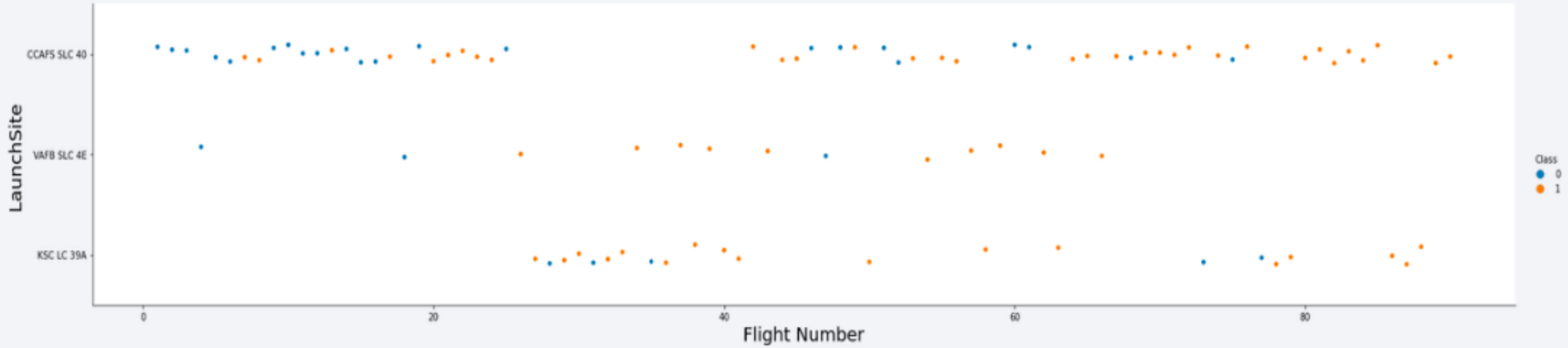
- Initially some Exploratory Data Analysis was performed on the dataset.
- Then the summaries launches per site, occurrences of each orbit and occurrences of mission outcome per orbit type were calculated.
- Finally, the landing outcome label was created from Outcome column.



Source code: https://github.com/Sam-366/Space-X-Falcon-9-Project/blob/main/Data%20Wrangling%20Falcon%209%20Space%20X%20(1).ipynb

EDA with Data Visualization

- To explore data, scatterplots and bar plots were used to visualise 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



Source code:

https://github.com/Sam-366/Space-X-Falcon-9-Project/blob/main/Visualisation.ipynb

Exploratory Data Analysis 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.

Source code: https://github.com/Sam-366/Space-X-Falcon-9-Project/blob/main/jupyter-labs-eda-sql-coursera_sqllite%20(1).ipynb

Build an Interactive Map with Folium

Markers, circles, lines and marker clusters were used using the Folium library

- Markers indicate points like launch sites;
- Circles indicate highlighted areas around specific coordinates, like NASA Johnson Space Centre;
- 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.

Source code: https://github.com/Sam-366/Space-X-Falcon-9-Project/blob/main/Interactive%20Visual%20Analytics%20with%20Folium%20lab.ipynb

Build a Dashboard with Plotly Dash

The following graphs and plots were used to visualize data

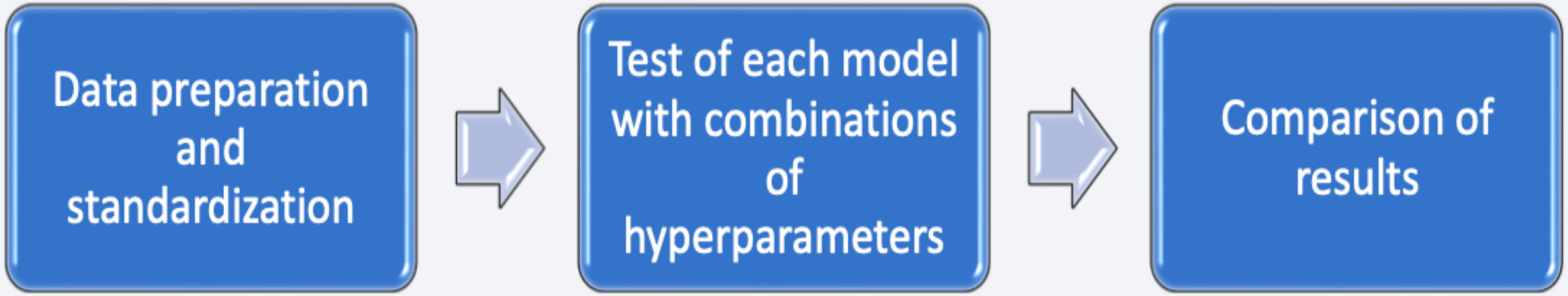
- Percentage of launches by site
- Payload range

This combination allowed to quickly analyse the relation between payloads and launch sites, helping to identify where is best place to launch according to payloads.

Source code: https://github.com/Sam-366/Space-X-Falcon-9-Project/blob/main/dash_app_01.png

Predictive Analysis (Classification)

- A comparison was made between four classification models were compared: logistic regression, support vector machine, decision tree and k nearest neighbours.

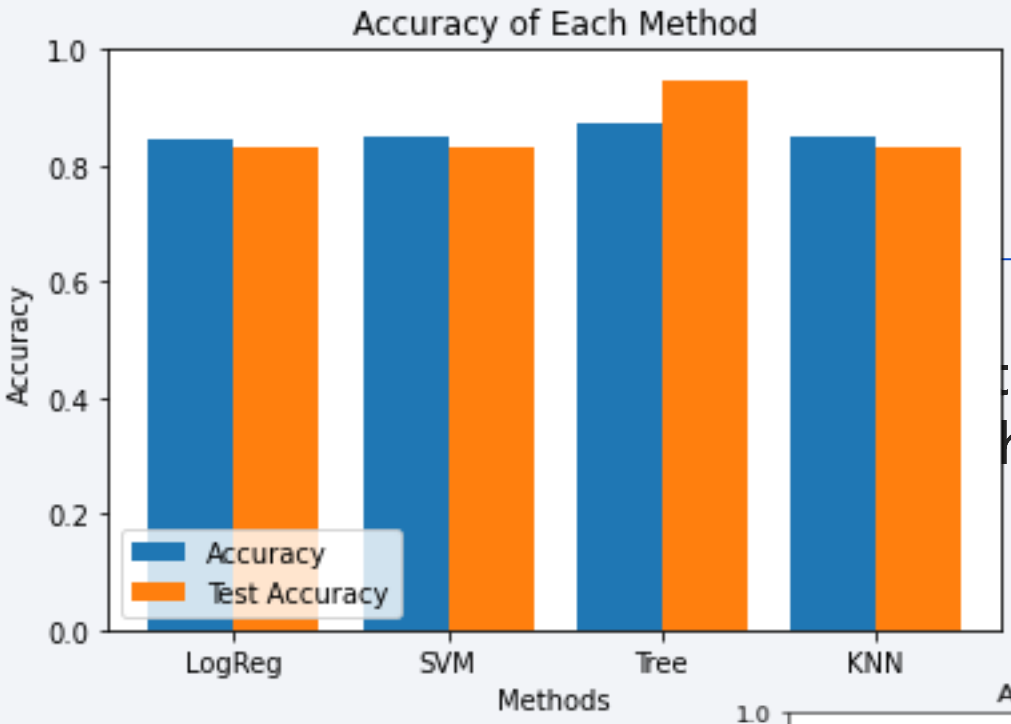


Results

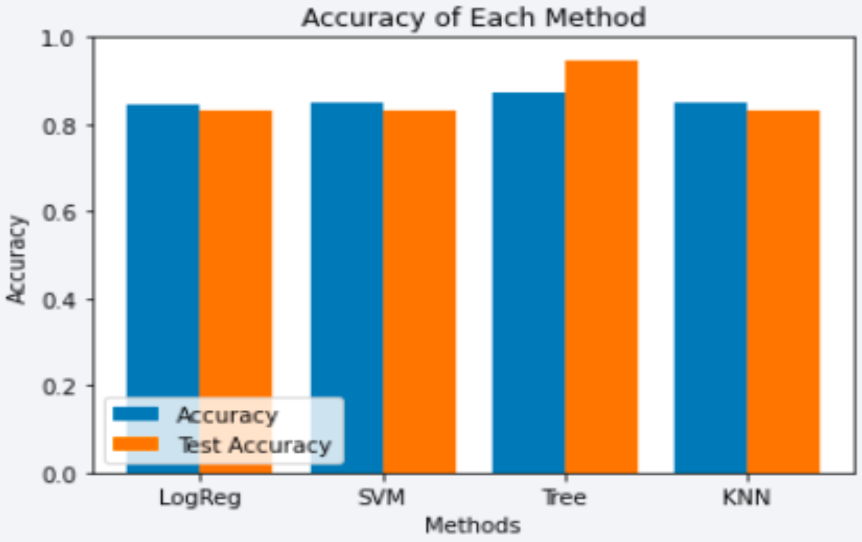
Exploratory data analysis results:

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

y places, near



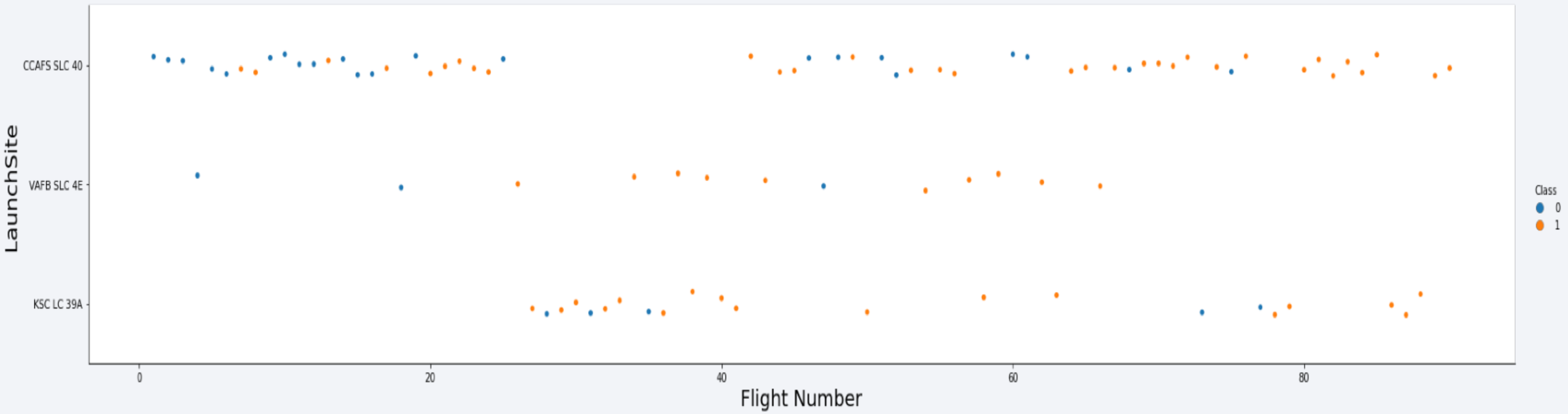
that Decision Tree Classifier is the best model to having accuracy over 87% and accuracy for test



Section 2

Insights drawn from EDA

Flight Number vs. Launch Site

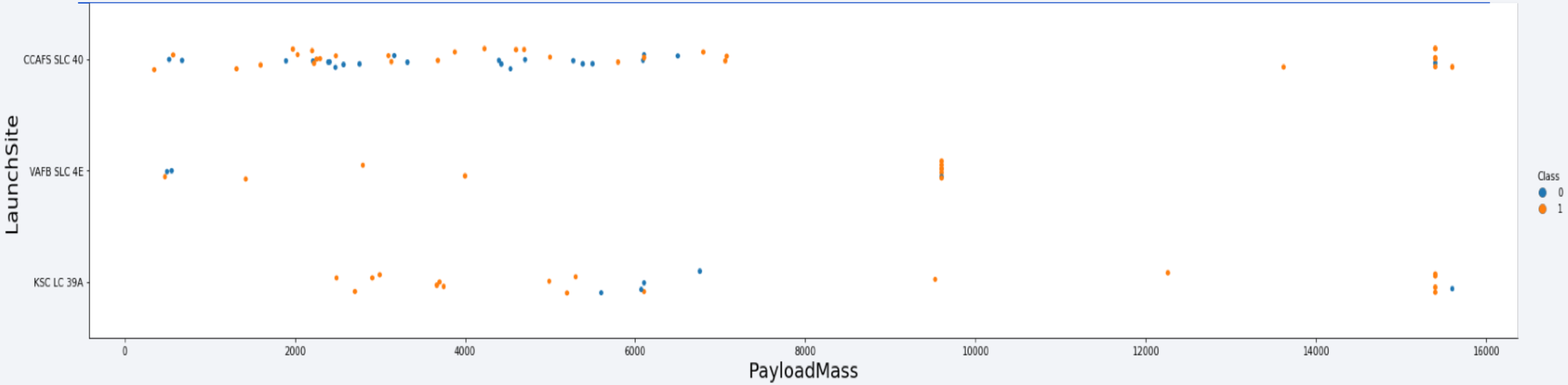


According to the plot above, it's possible to verify that the best launch site nowadays is CCAF5 SLC 40, where most of recent launches were successful;

In second place VAFB SLC 4E and third place KSC LC 39A;

It's also possible to see that the general success rate improved over time.

Payload vs. Launch Site



- Payloads over 9,000kg have excellent success rate;

- Payloads over 12,000kg seems to be possible only on CCAFS SLC 40 and KSC LC 39A launch sites.

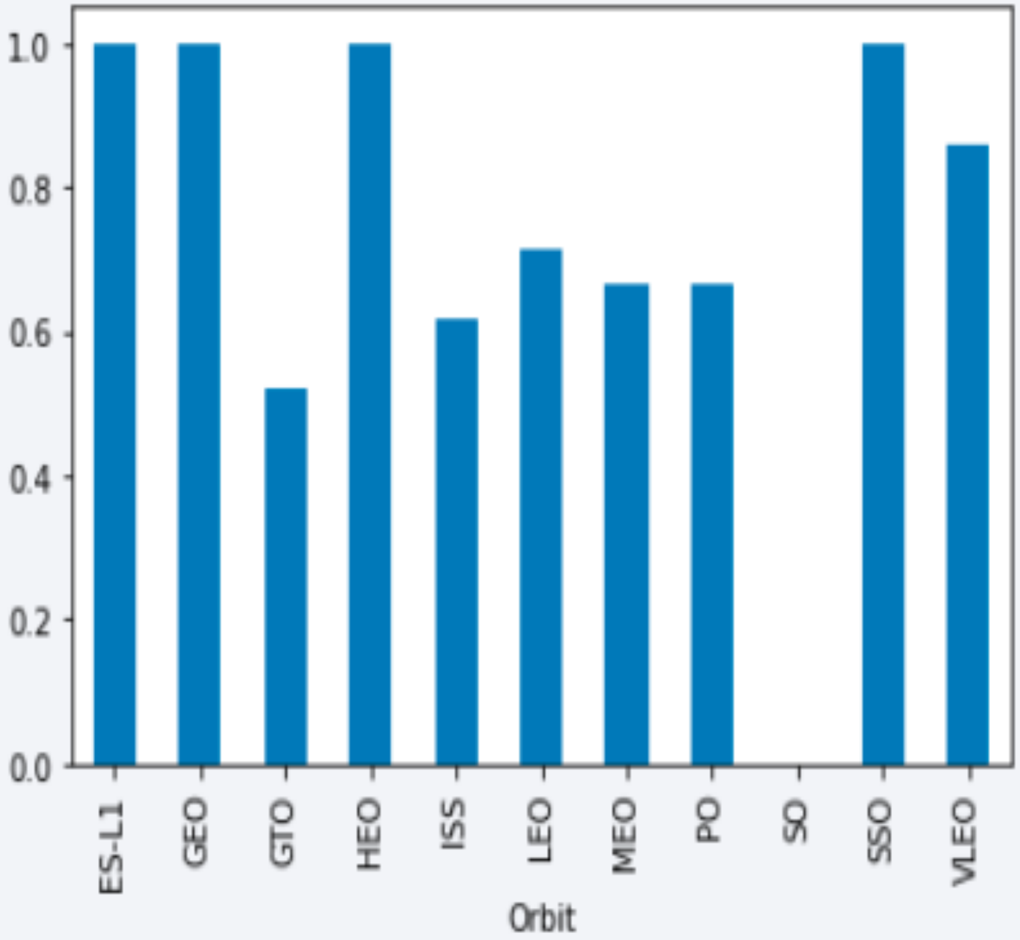
Success Rate vs. Orbit Type

- The biggest success rates happens to orbits:

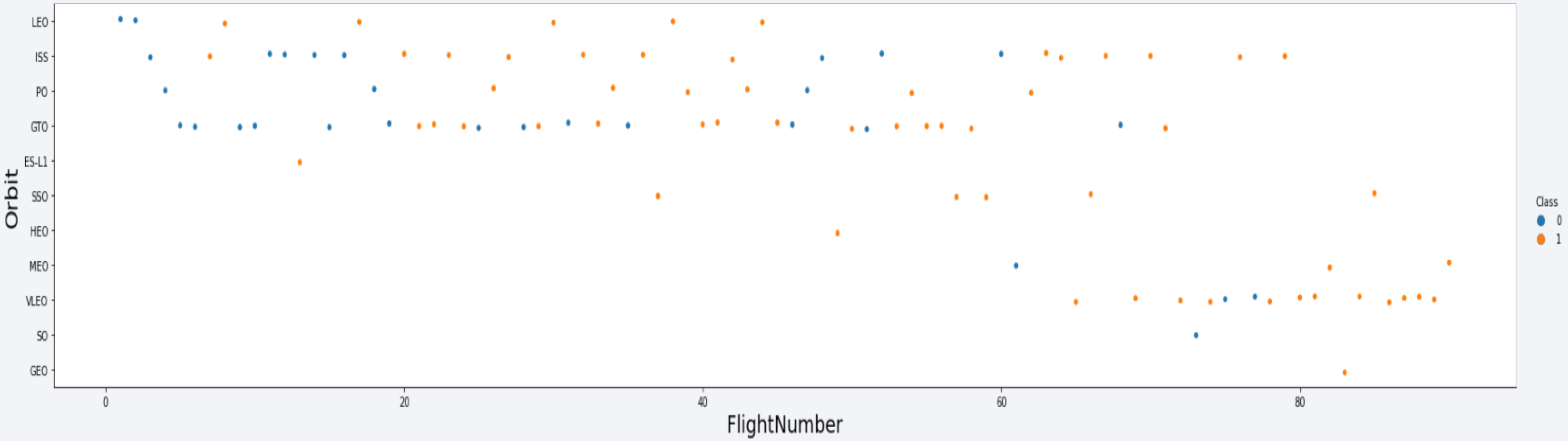
- ES-L1;
- GEO;
- HEO;
- SSO.

Followed by:

- VLEO (above 80%);
- LFO(above70%).

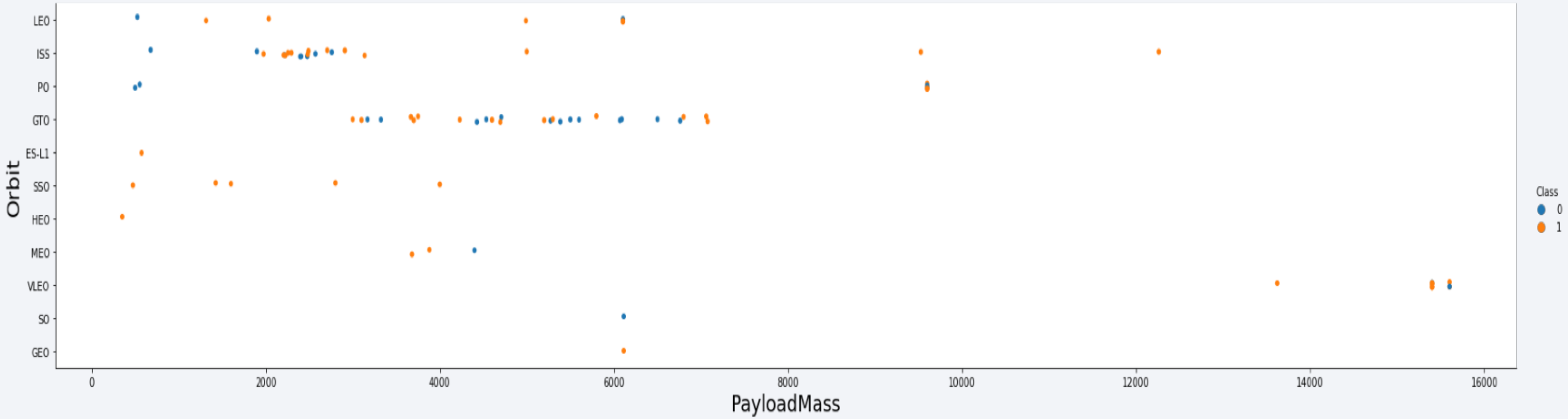


Flight Number vs. Orbit Type



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

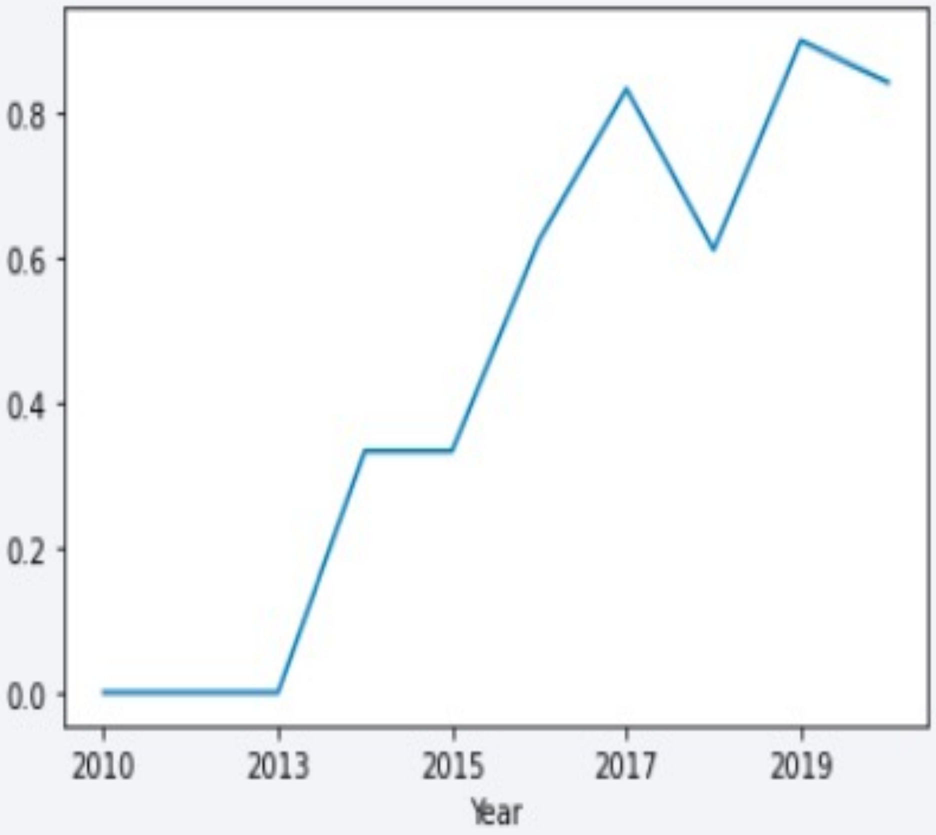
Payload vs. Orbit Type



- Apparently, there is no relation between payload and success rate to orbit GTO;
- ISS orbit has the widest range of payload and a good rate of success;
- There are few launches to the orbits SO and GEO.

Launch Success Yearly Trend

- There was a significant increase the success rate from 2013 and kept until 2020;
- It seems that the first three years were a period of adjusts and improvement of technology.



All Launch Site Names

According to data, there are four launch sites:

They are obtained by selecting unique occurrences of "launch_site" values from the dataset.

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`:
- Here we can see five samples of Cape Canaveral launches.

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

Total Payload (kg)
111.268

Average Payload Mass by F9 v1.1

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

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

Avg Payload (kg)
2.928

First Successful Ground Landing Date

- First successful landing outcome on ground pad:

- By filtering data by successful landing outcome on ground pad and getting the minimum value for date it's possible to identify the first occurrence, that happened on 12/22/2015.

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

- Selecting distinct booster versions according to the filters above, these 4 are the result.

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

- Grouping mission outcomes and counting records for each group led us to the summary above.

Boosters Carried Maximum Payload

Boosters which have carried the maximum payload mass

These are the boosters which have carried the maximum payload mass registered in the dataset.

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

Booster Version
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 in year 2015

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

- The list above has the only two occurrences.

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

- Ranking of all landing outcomes between the date 2010-06-04 and 2017- 03-20:
- This view of data alerts us that “No attempt” must be taken in account.

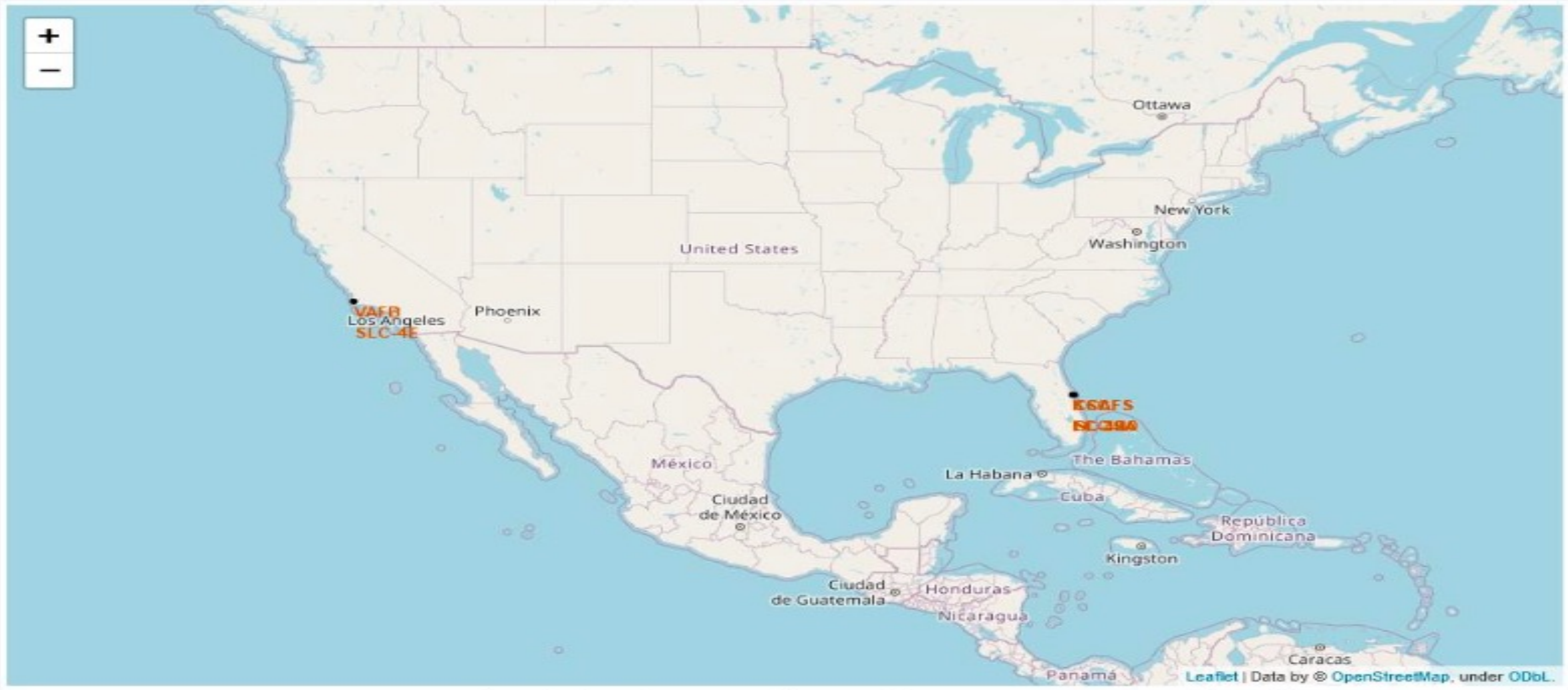
Landing Outcome	Occurrences
No attempt	10
Failure (drone ship)	5
Success (drone ship)	5
Controlled (ocean)	3
Success (ground pad)	3
Failure (parachute)	2
Uncontrolled (ocean)	2
Precluded (drone ship)	1

Section 3

Launch Sites Proximities Analysis

All Launch Sites

- Launch sites are near sea, probably by safety, but not too far from roads and railroads.

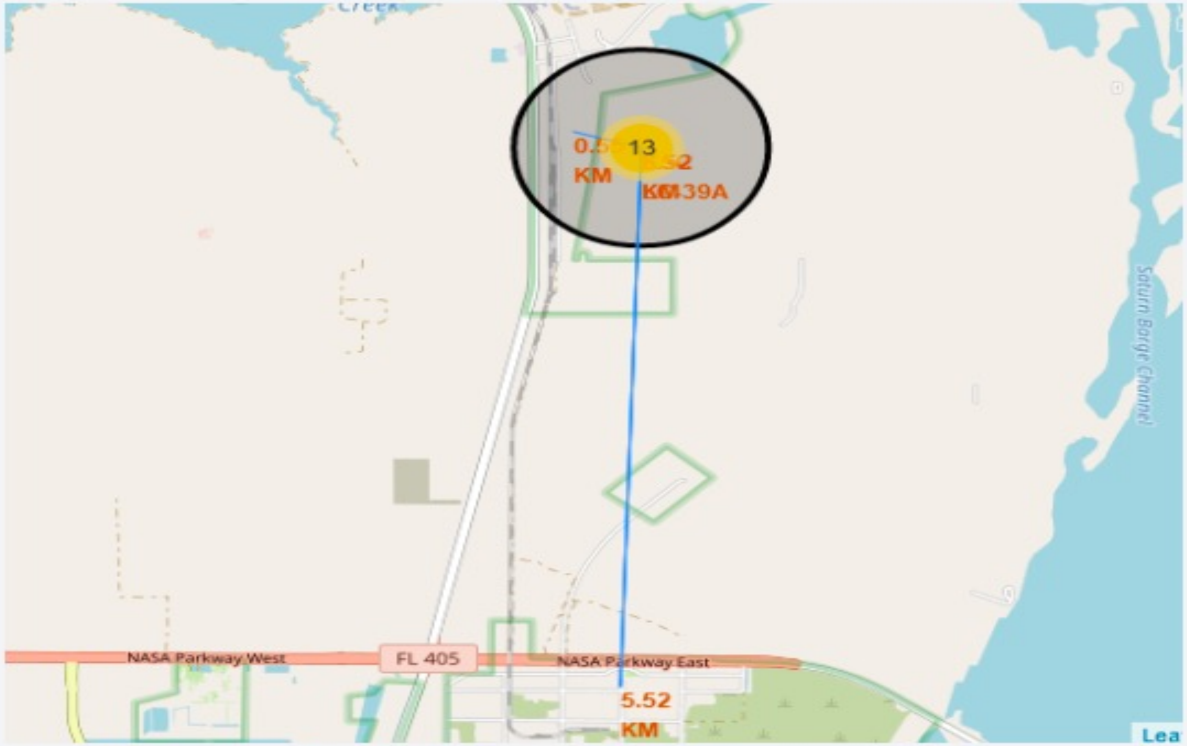


Launch Outcomes by Site

- Example of KSC LC-39A launch site launch outcomes
- Green markers indicate successful and red ones indicate failure.

Logistics And Safety

- Launch site KSC LC-39A has good logistical aspects, being near railroad and road and relatively far from inhabited areas and local population.

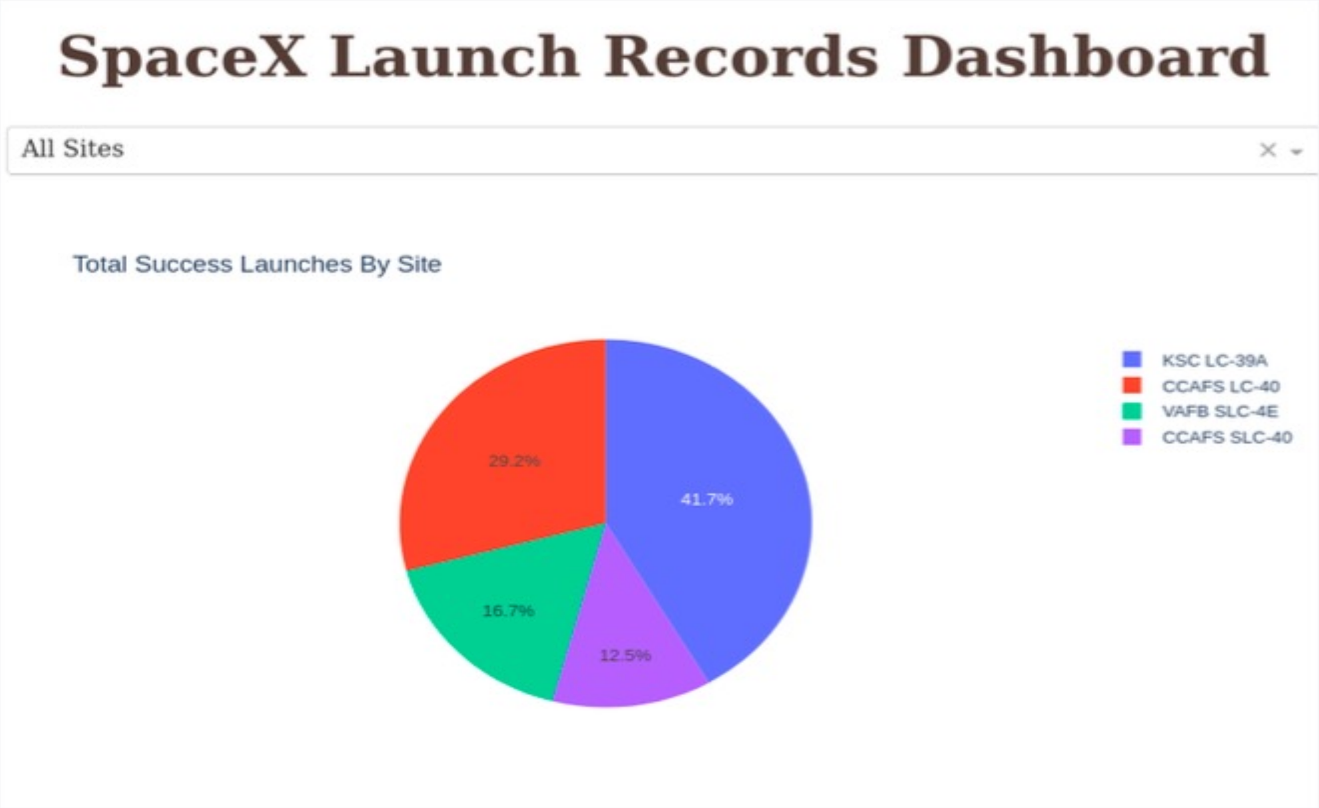


Section 4

Build a Dashboard with Plotly Dash

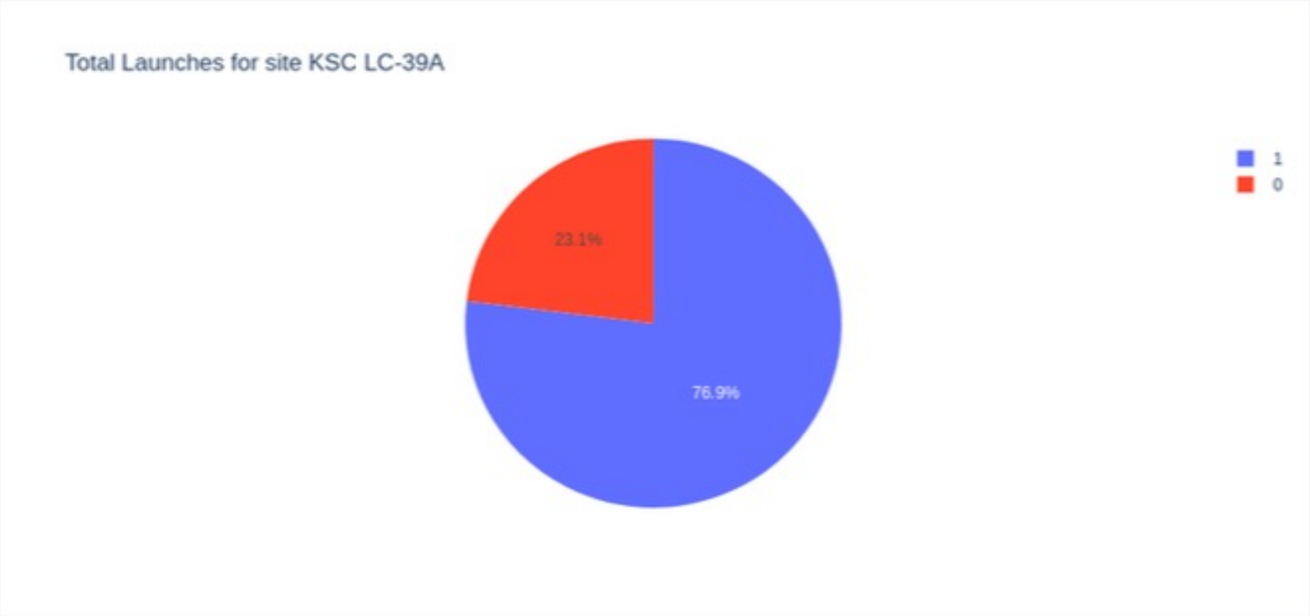
Successful Launches by Site

- The place from where launches are done seems to be a very important factor of success of missions.



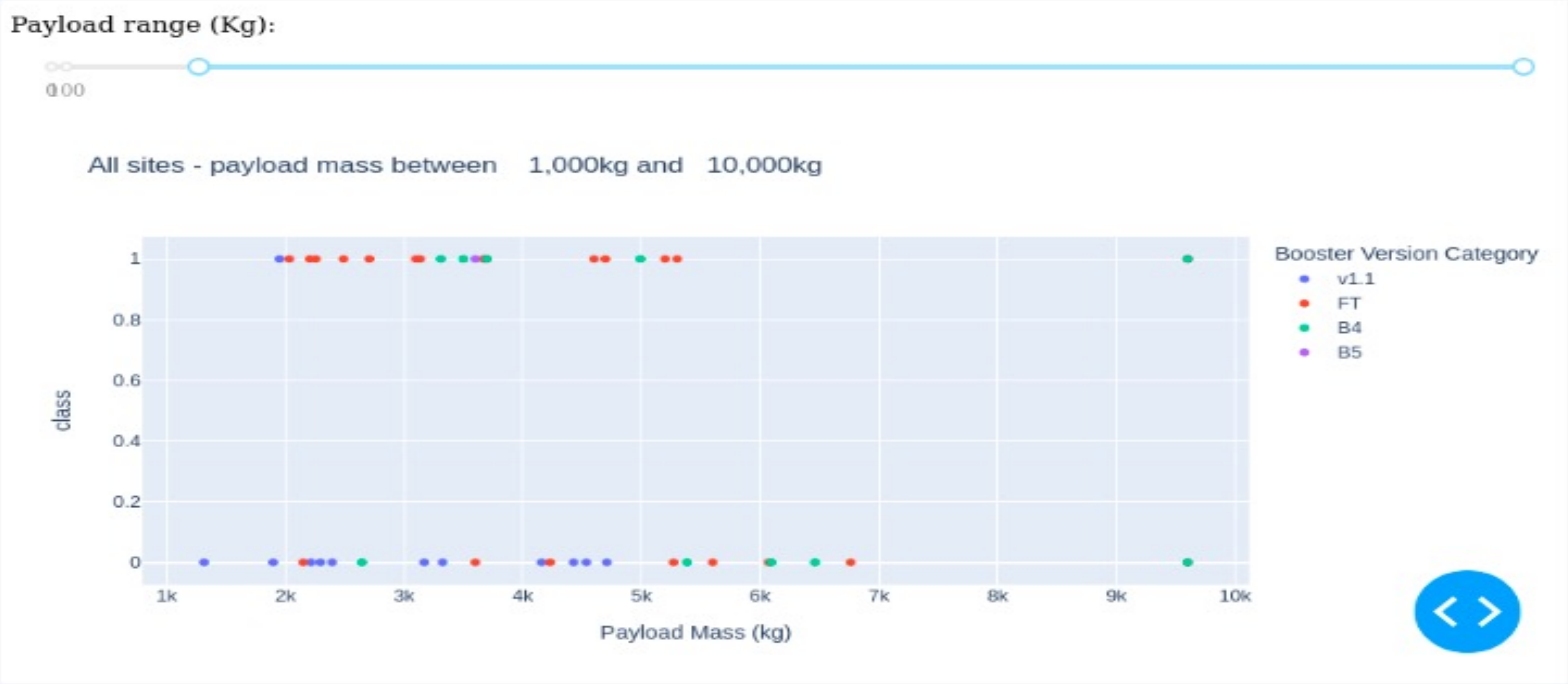
Launch Success Ratio for KSC LC-39A

- 76.9% of launches are successful in this site.



Payload vs. Launch Outcome

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



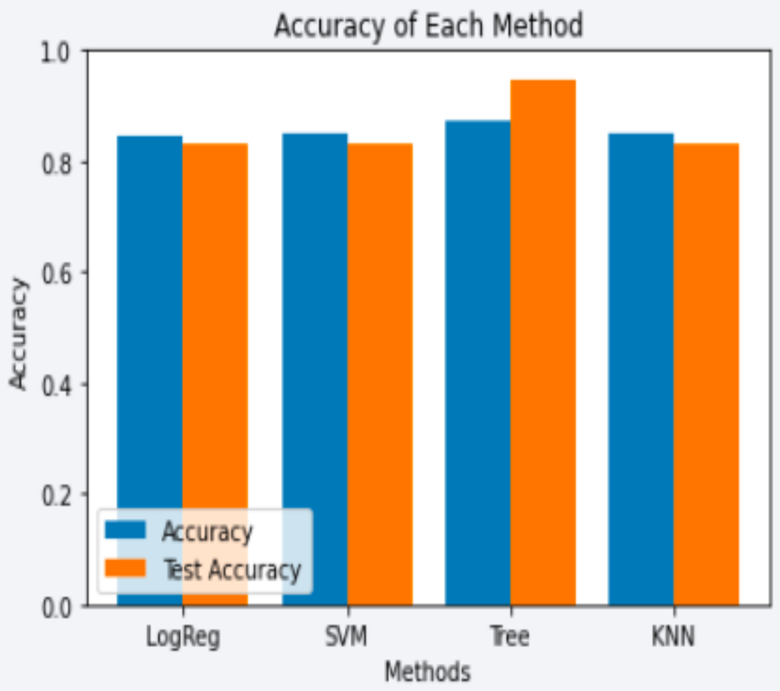
Section 5

Predictive Analysis (Classification)

Classification Accuracy

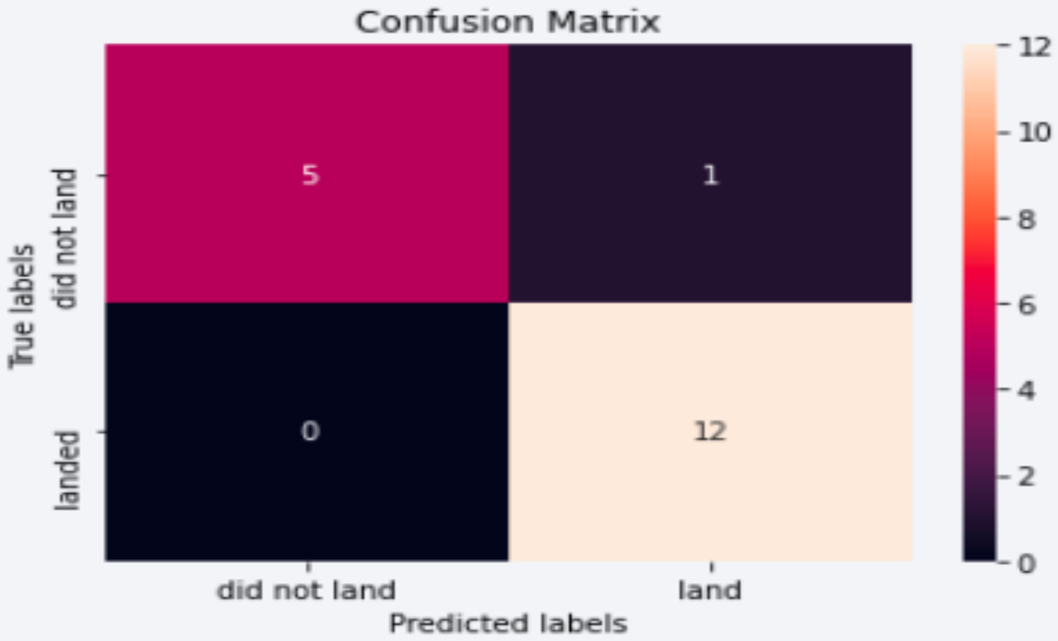
- Four classification models were tested, and their accuracies are plotted beside;

- The model with the highest classification accuracy is Decision Tree Classifier, which has accuracies over than 87%.



Confusion Matrix

- Confusion matrix of Decision Tree Classifier proves its accuracy by showing the big numbers of true positive and true negative compared to the false ones.



Conclusions

- Different data sources were analysed, refining conclusions along the process;
- The best launch site was discovered to be KSC LC-39A;
- Launches above 7,000kg 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;
- Therefore, Decision Tree Classifier can be used to predict successful landings and increase profits.

Appendix

- As an improvement for model tests, it's important to set a value to `np.random.seed` variable;
- Folium didn't show maps on Github, so I had to improvise with screenshots.

Thank you!