

Winning Space Race with Data Science

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Outline

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

Executive Summary

- The following methodologies were used to analyze data:
 - Data Collection using SpaceX API and Web Scraping;
 - Data Wrangling;
 - Exploratory Data Analysis (EDA) with Python and SQL, including data visualization
 - Interactive Visual Analytics and Dashboards with Folium and Plotly;
 - Predictive Analysis using Machine Learning techniques.
- Summary of all results
 - It was possible to collect valuable data from public sources;
 - EDA made it possible to determine which features best predict success of launchings;
 - Using all of the obtained data, Machine Learning Prediction demonstrated the best model to forecast which attributes are crucial to maximising this opportunity.

Introduction

- The goal is to determine whether Space Y, a new corporation, can effectively compete with Space X.
- Required answers:
 - Predicting successful rocket first-stage landings is the best way to estimate the entire cost of launches;
 - 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
 - After assessing and summarising the features, the collected data was enhanced by producing a landing outcome label based on the outcome data.
- 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
 - The data collected until this stage was normalised, split into training and test data sets, and subjected to four separate classification models, each of which assessed accuracy using a different set of parameters by Grid search.

Data Collection

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

Data Collection – SpaceX 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.

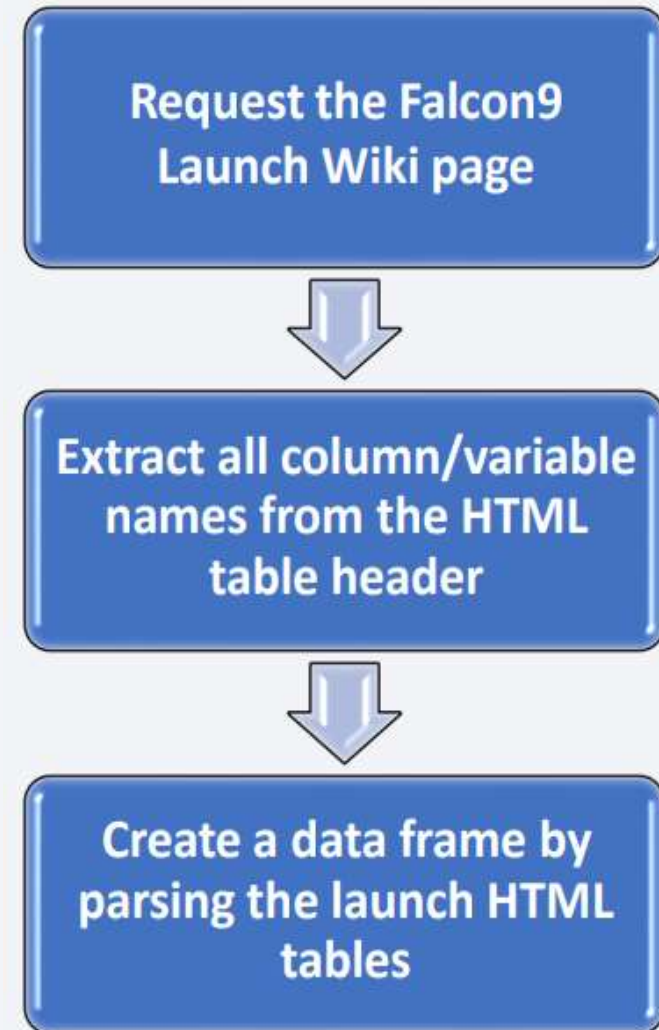


Source Code:

https://github.com/Nazaruk-Anton/SpaceY_launching_success/blob/main/1_Data_Collection_Api.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/Nazaruk-Anton/SpaceY_launching_success/blob/main/2_Data_Collection_with_Web_Scraping.ipynb

Data Wrangling

- On the dataset, some exploratory data analysis (EDA) was first carried out.
- After that, the summaries of launch per site, occurrences of each orbit, and occurrences of mission outcome per orbit type were calculated.
- And finally, the landing outcome label was created from the Outcome column.



Source Code:

https://github.com/Nazaruk-Anton/SpaceY_launching_success/blob/main/3_Data_Wrangling.ipynb

EDA with SQL

• The following SQL queries were performed to analyze the data:

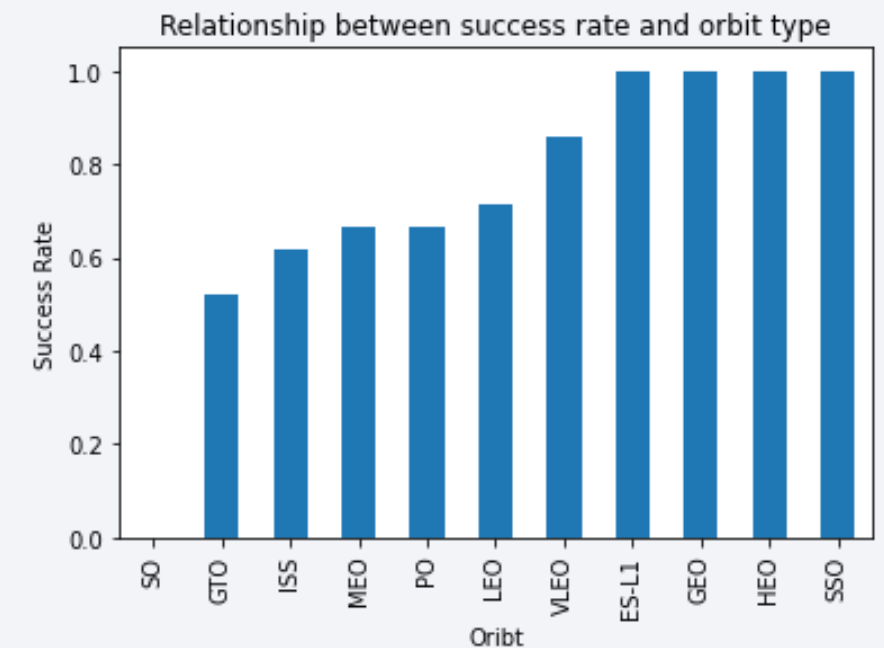
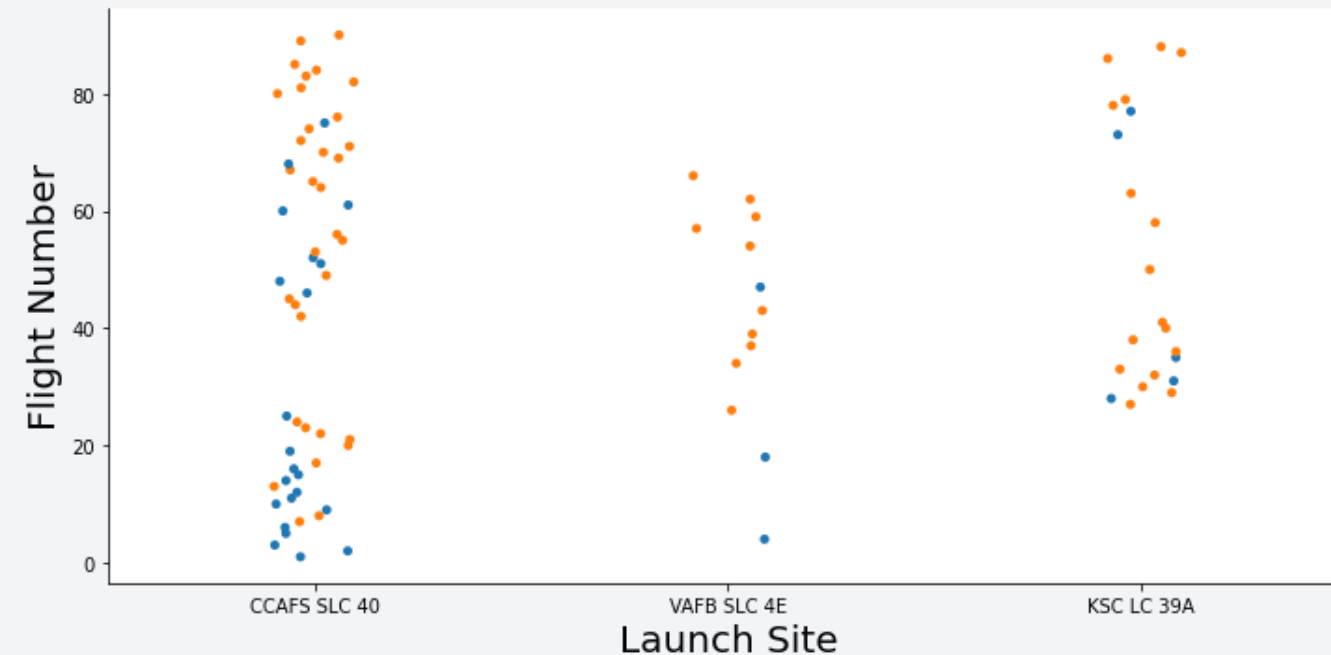
- Names of the unique launch sites in the space mission;
- Top 5 launch sites whose name begin with the string 'CCA';
- Total payload mass carried by boosters launched by NASA (CRS);
- Average payload mass carried by booster version F9 v1.1;
- Date when the first successful landing outcome in ground 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;
- 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/Nazaruk-Anton/SpaceY_launching_success/blob/main/4_EDA_with_SQL.ipynb

EDA with Data Visualization

- Scattered plots and bar plots were used to explore the data and show the relationship between pair of features:
 - Payload Mass and Flight Number, Launch Site and Flight Number, Launch Site and Payload Mass, Orbit and Flight Number, Payload and Orbit



Source Code:

https://github.com/Nazaruk-Anton/SpaceY_launching_success/blob/main/5_EDA_with_Visualization.ipynb

Build an Interactive Map with Folium

- Markers, circles, lines and marker clusters were used with 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



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.

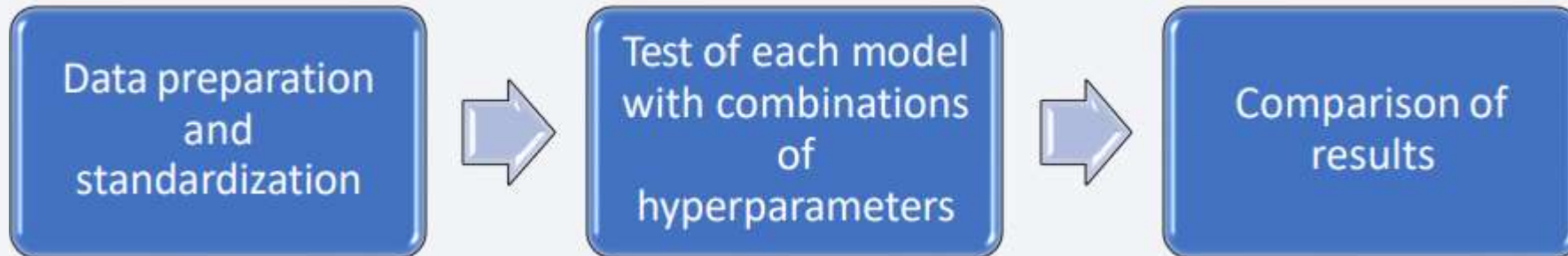
Source Code:

[https://github.com/Nazaruk-Anton/SpaceY_launching_success/blob/main/7 Interactive Dashboard with Plotly Dash.py](https://github.com/Nazaruk-Anton/SpaceY_launching_success/blob/main/7%20Interactive%20Dashboard%20with%20Plotly%20Dash.py)



Predictive Analysis (Classification)

- Four classification models were compared:
 - Logistic regression,
 - Support vector machine (SVM),
 - Decision tree,
 - K-nearest neighbors.



Source Code:

https://github.com/Nazaruk-Anton/SpaceY_launching_success/blob/main/8_Machine_Learning_Prediction.ipynb

Results

- Exploratory data analysis results:
 - Space X uses 4 different launch sites;
 - The first launches were done to Space X itself and NASA;
 - The average payload of F9 v1.1 booster is 2,928 kg;
 - The first success landing outcome happened in 2015 five year after the first 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.

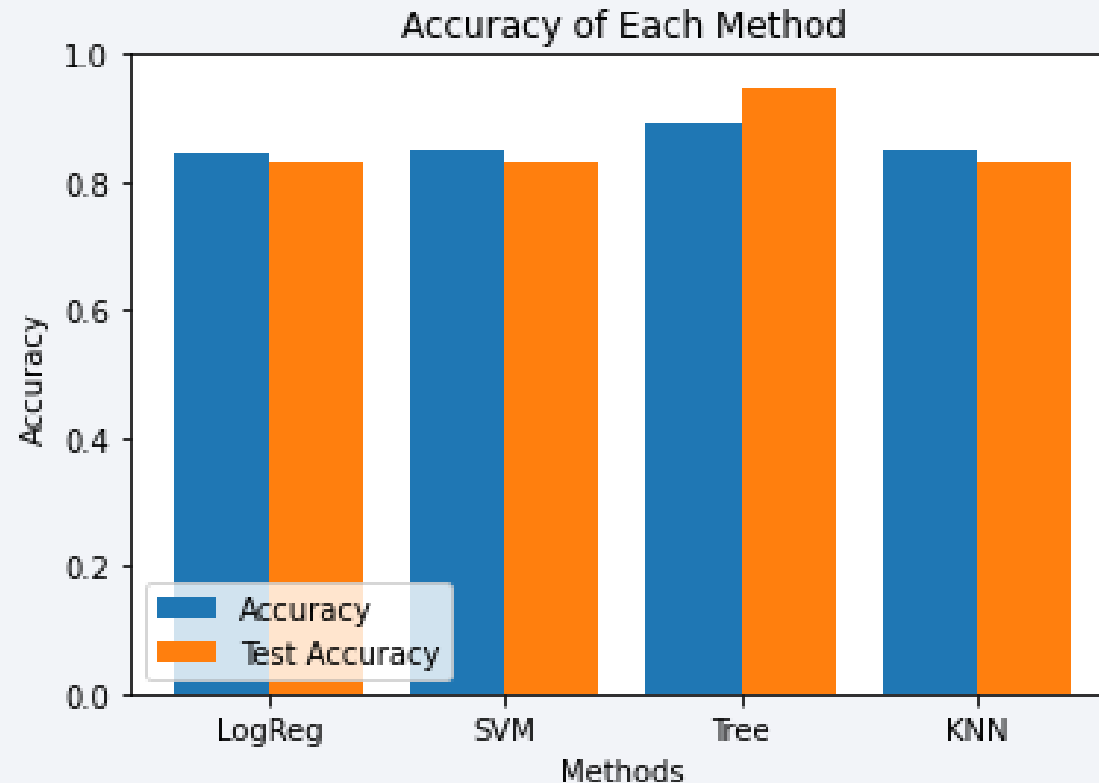
Results

- 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 about 94%.



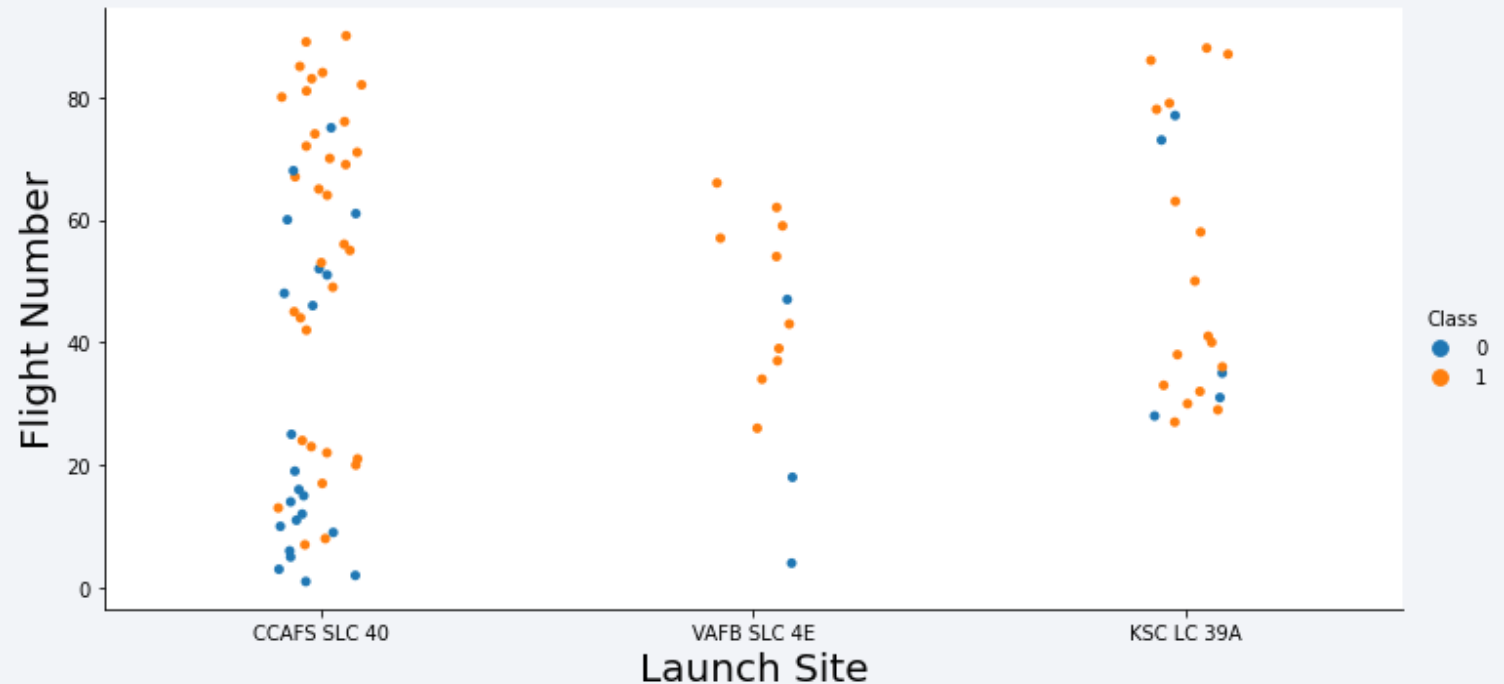


Section 2

Insights drawn from EDA

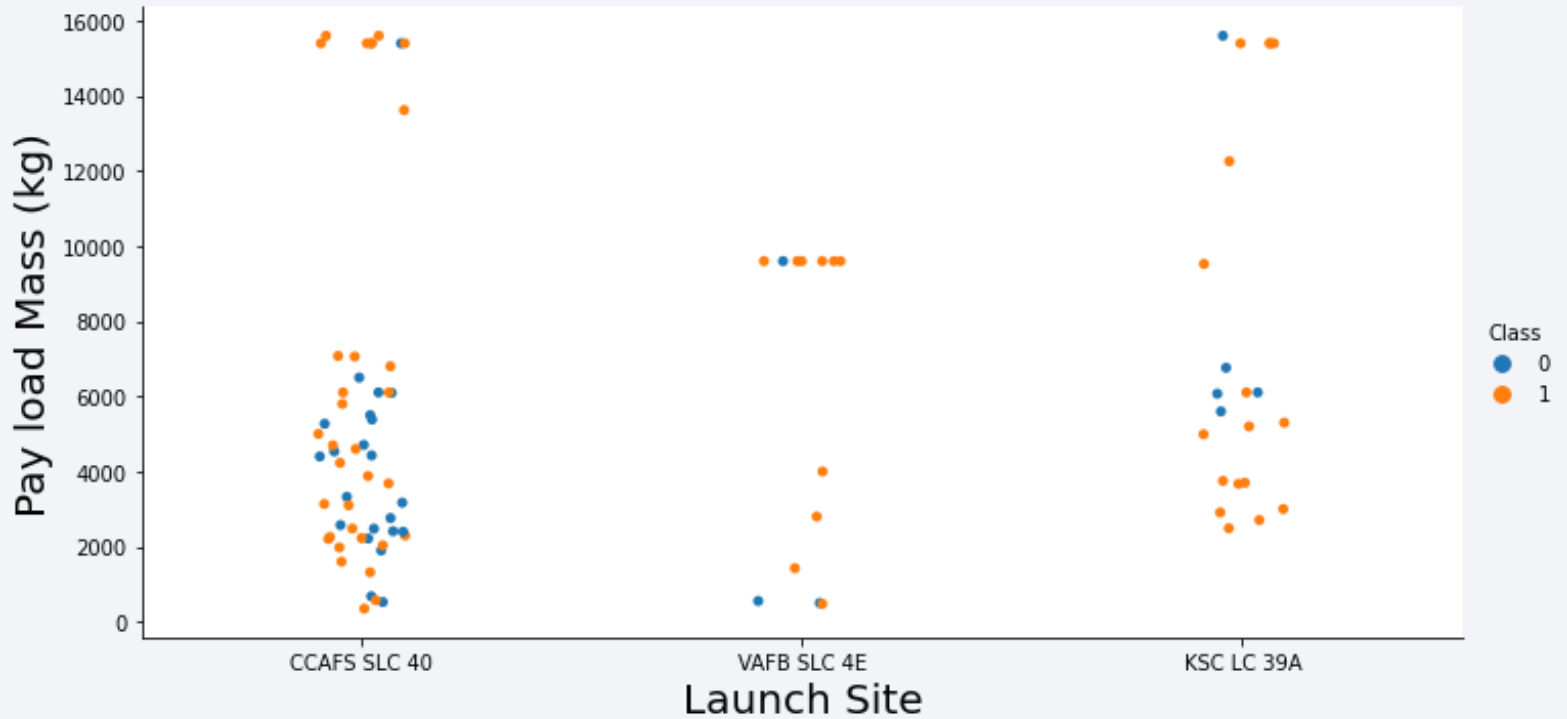
Flight Number vs. Launch Site

- According to the plot, 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 KSCLC 39A;
- It's also possible to see that the general success rate improved over time.



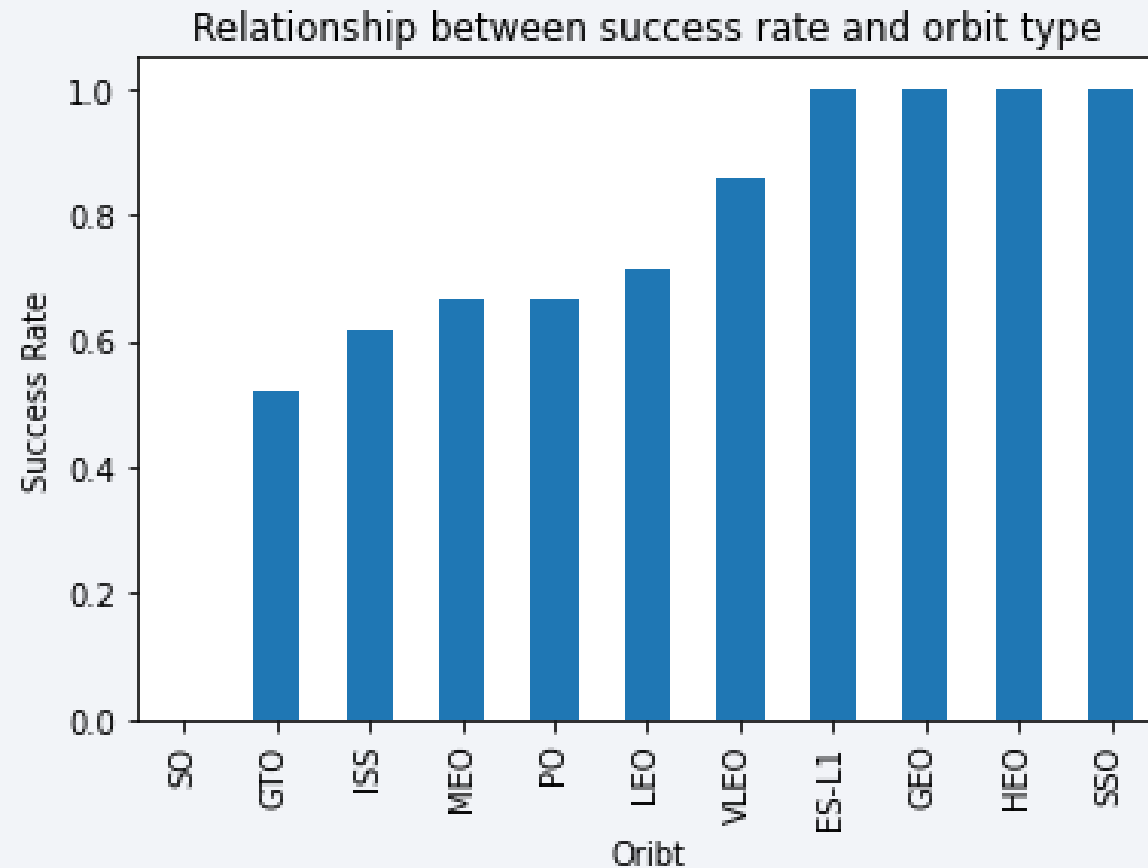
Payload vs. Launch Site

- 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.

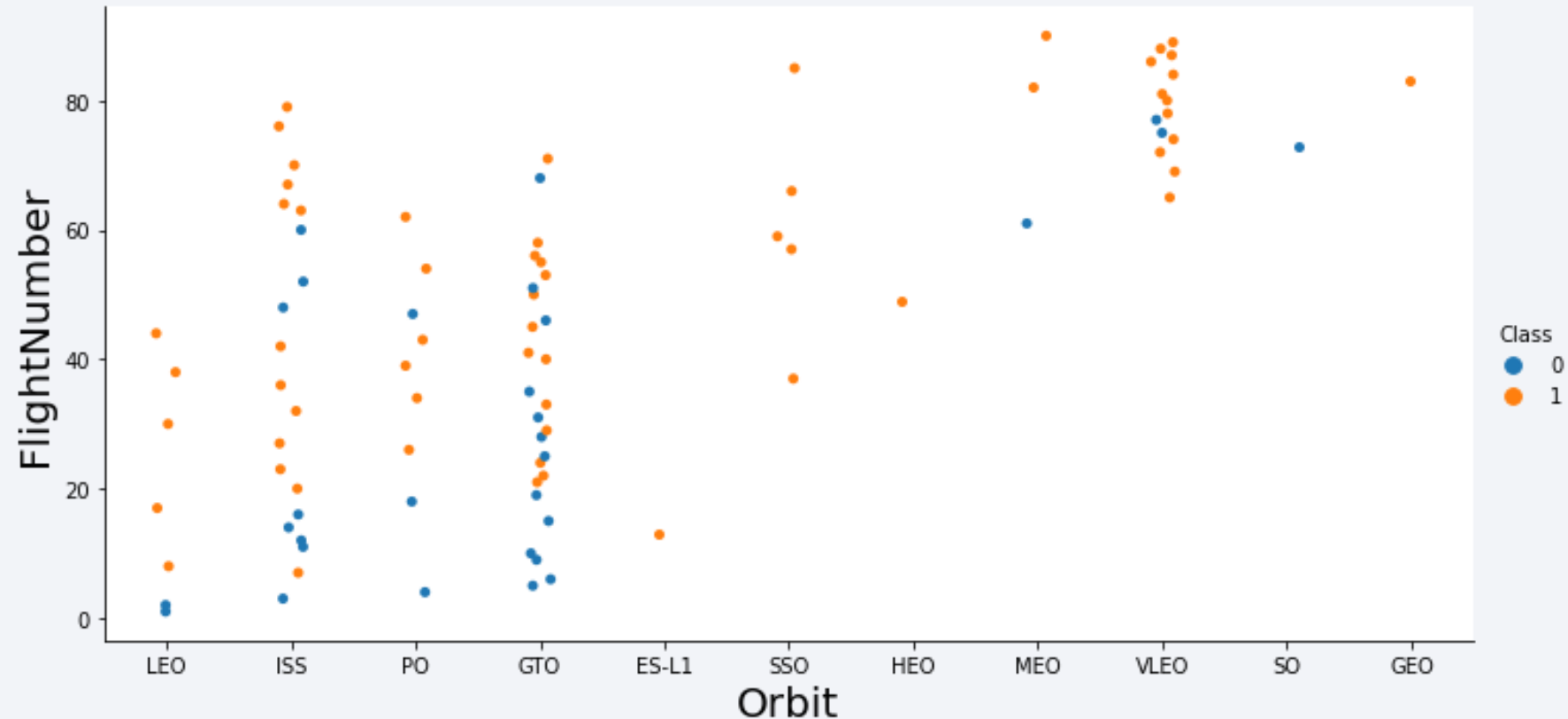


Success Rate vs. Orbit Type

- The biggest success rates happens to orbits:
 - ES-L1;
 - GEO;
 - HEO;
 - SSO.
- Followed by:
 - VLEO (above 80%)
 - LFO (above 70%).



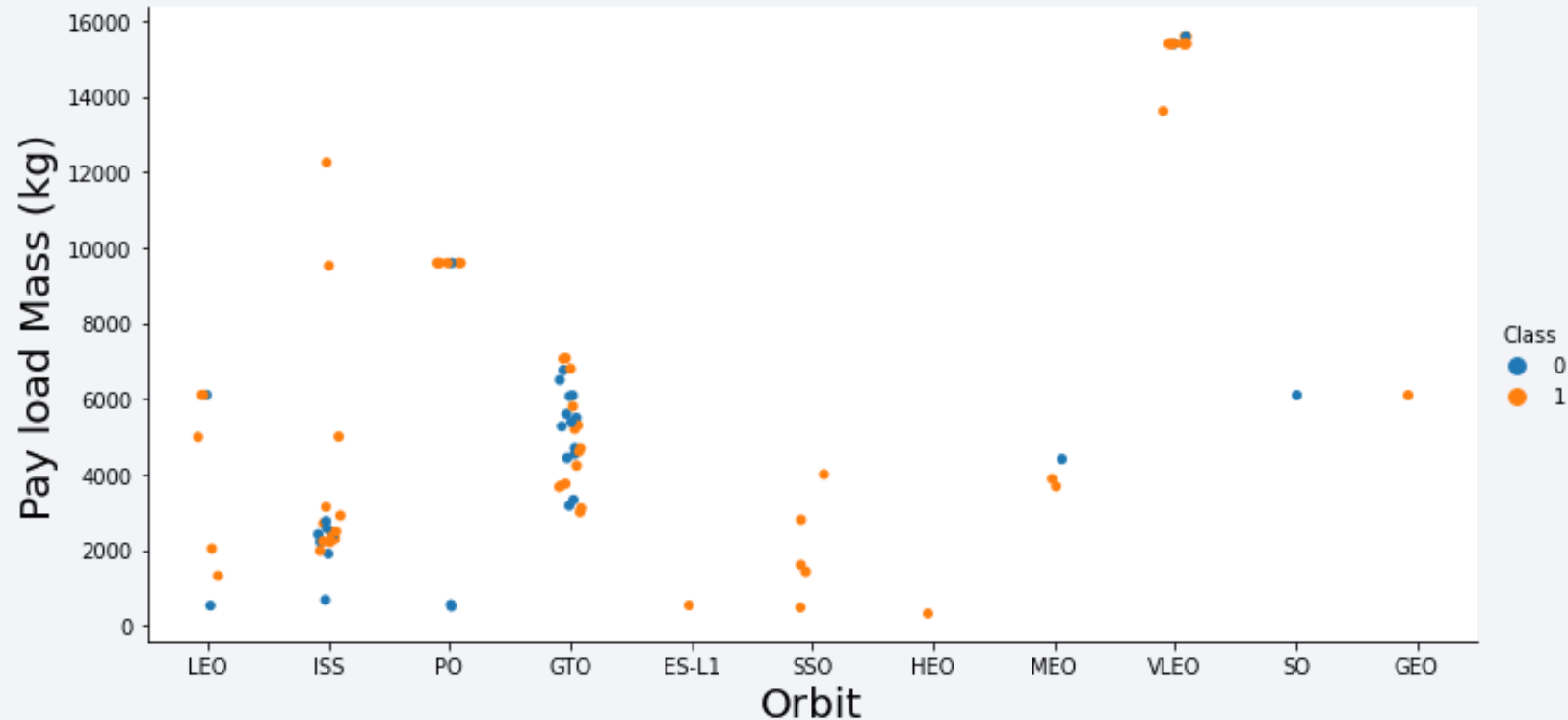
Flight Number vs. Orbit Type



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

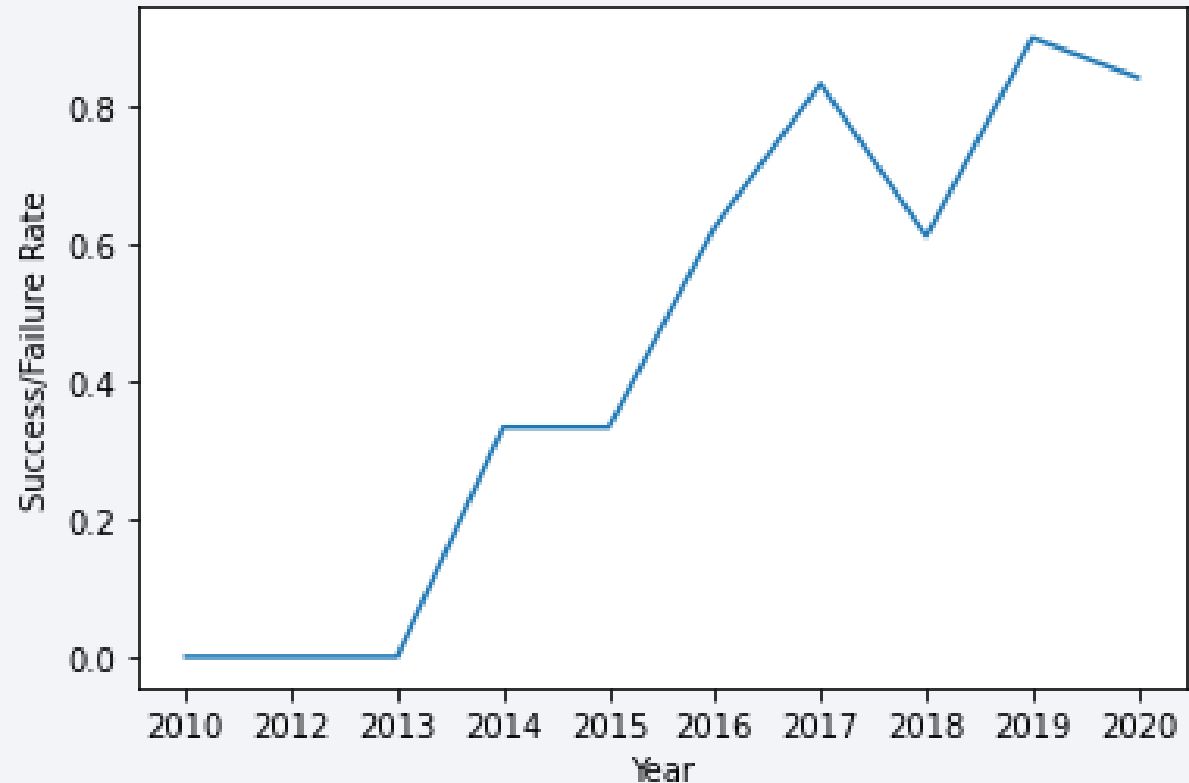
Payload vs. Orbit Type

- 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

- Success rate started increasing in 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:

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

- They are obtained by selecting unique occurrences of “launch_site” values from the dataset.

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	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

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

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

- Average 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

- 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 22/12/2015.

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

Booster Version (...)	Booster Version
F9 B5 B1048.4	F9 B5 B1051.4
F9 B5 B1048.5	F9 B5 B1051.6
F9 B5 B1049.4	F9 B5 B1056.4
F9 B5 B1049.5	F9 B5 B1058.3
F9 B5 B1049.7	F9 B5 B1060.2
F9 B5 B1051.3	F9 B5 B1060.3

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

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

- 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:

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

- This view of data alerts us that “No attempt” must be taken in account.

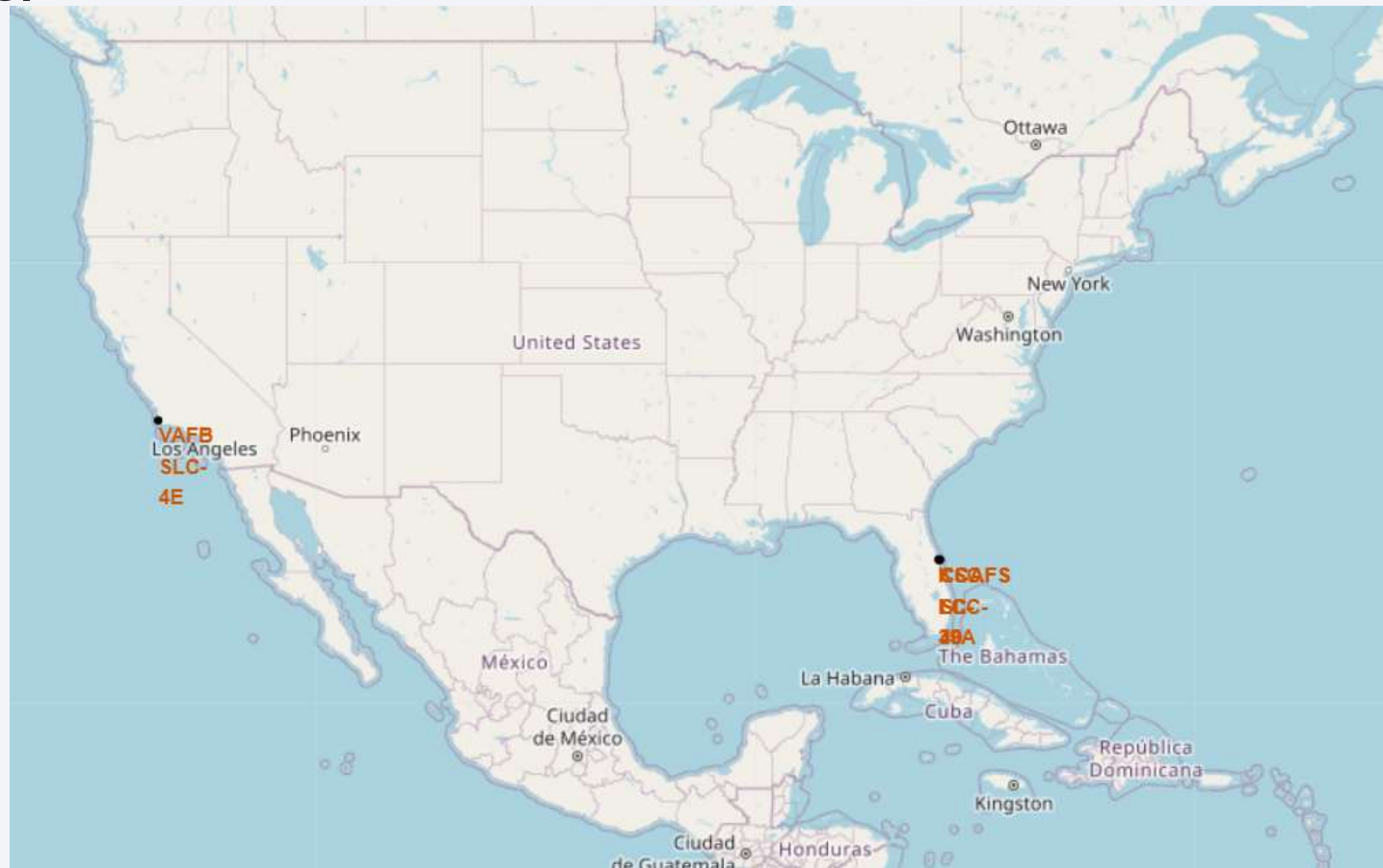
A satellite view of Earth from space, showing the curvature of the planet and city lights at night. The image is a composite of a solid blue background on the left and a satellite photograph of Earth on the right. The Earth's surface is dark, with numerous bright yellow and orange lights representing cities and urban areas. The horizon line of the Earth is visible, separating the dark surface from the deep blue of the upper atmosphere and space.

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

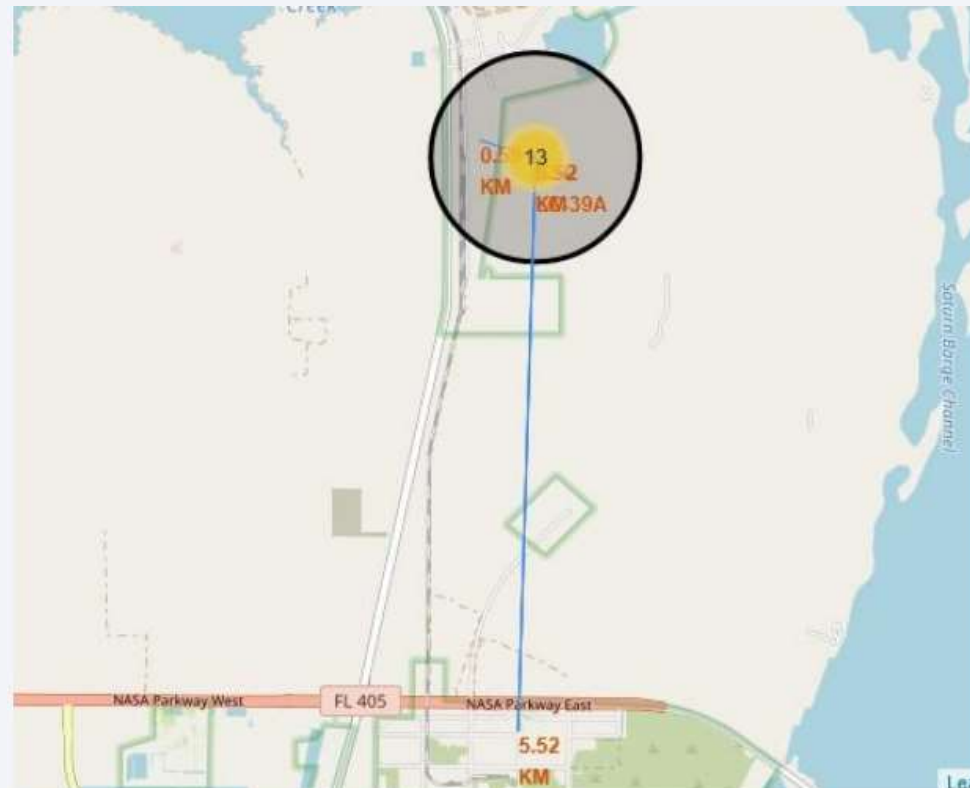
- Example of KSC LC-39A launch site launch outcomes



- Green markers indicate successful and red ones indicate failure.

Logistics and Safety

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



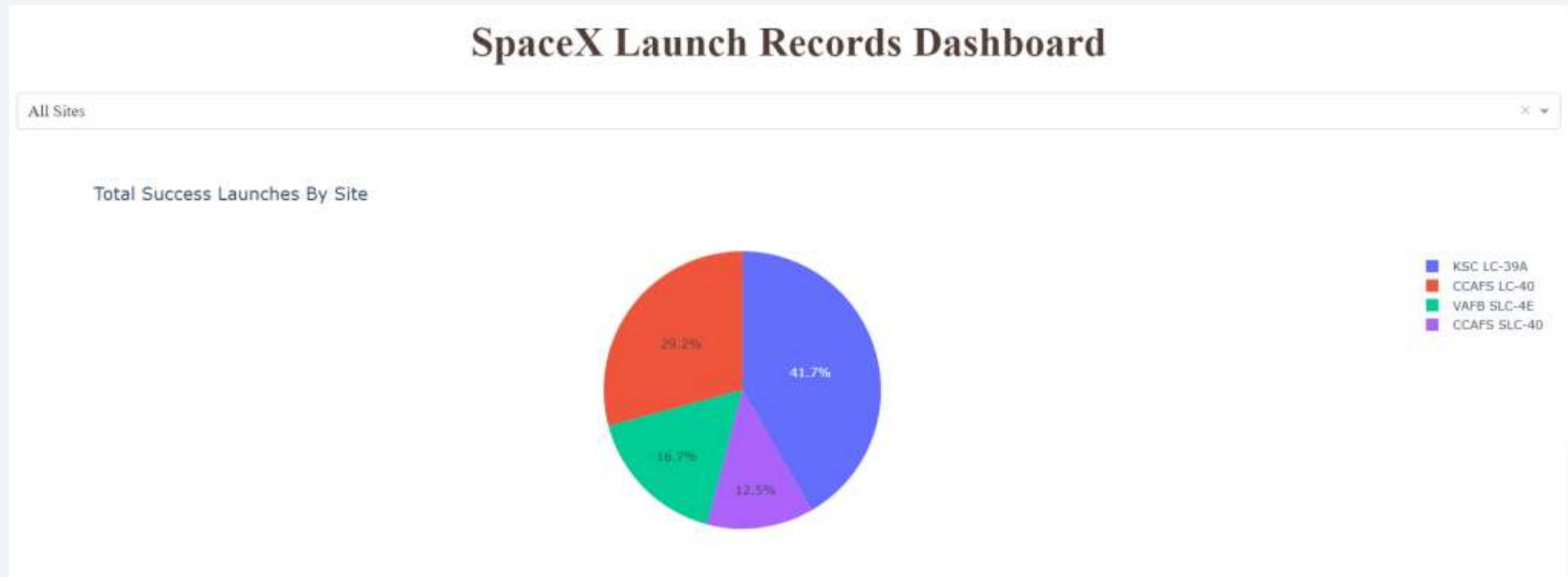


Section 4

Build a Dashboard with Plotly Dash

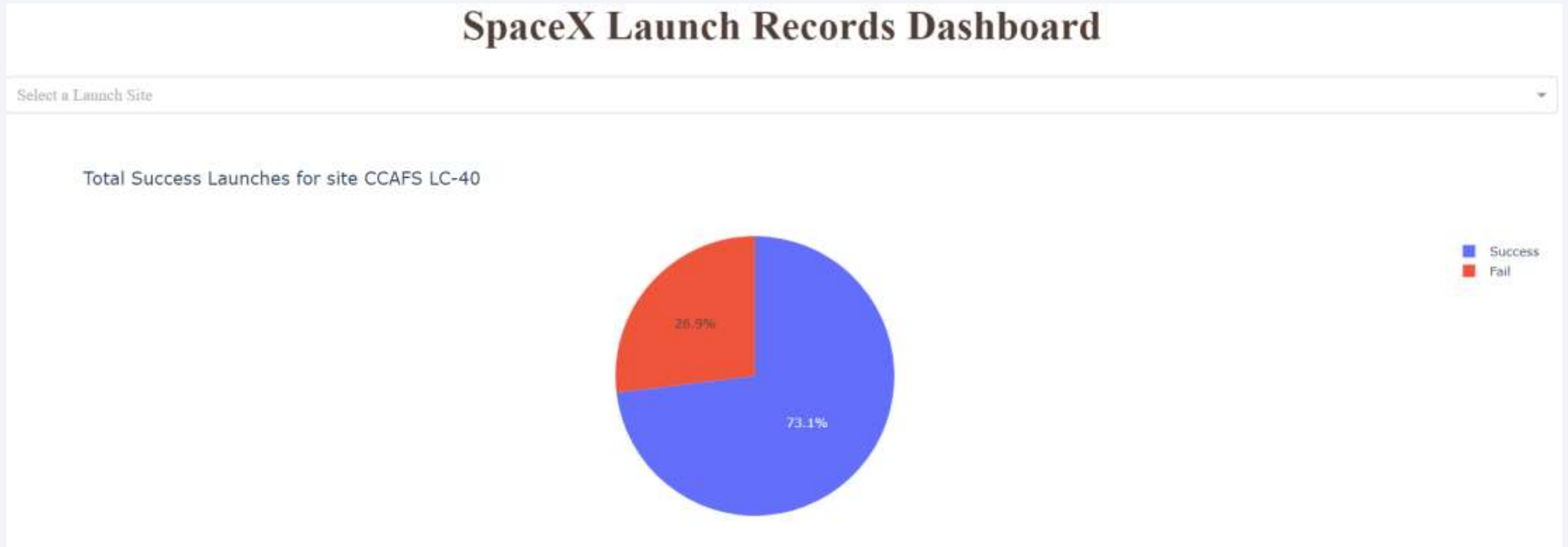
Successful Launches by Site

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



Launch Success Ratio for

- 73.1% of launches are successful in this site.



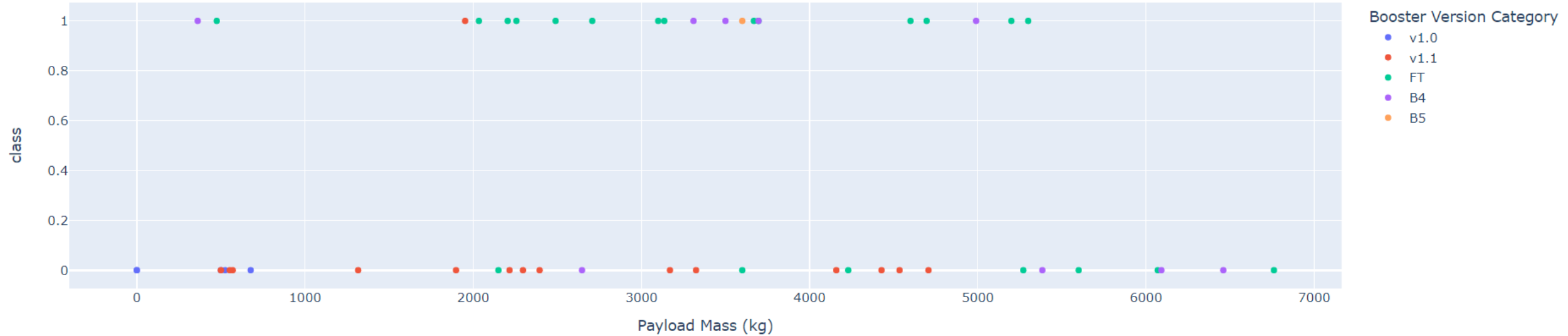
Payload vs. Launch Outcome

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

Payload range (Kg):

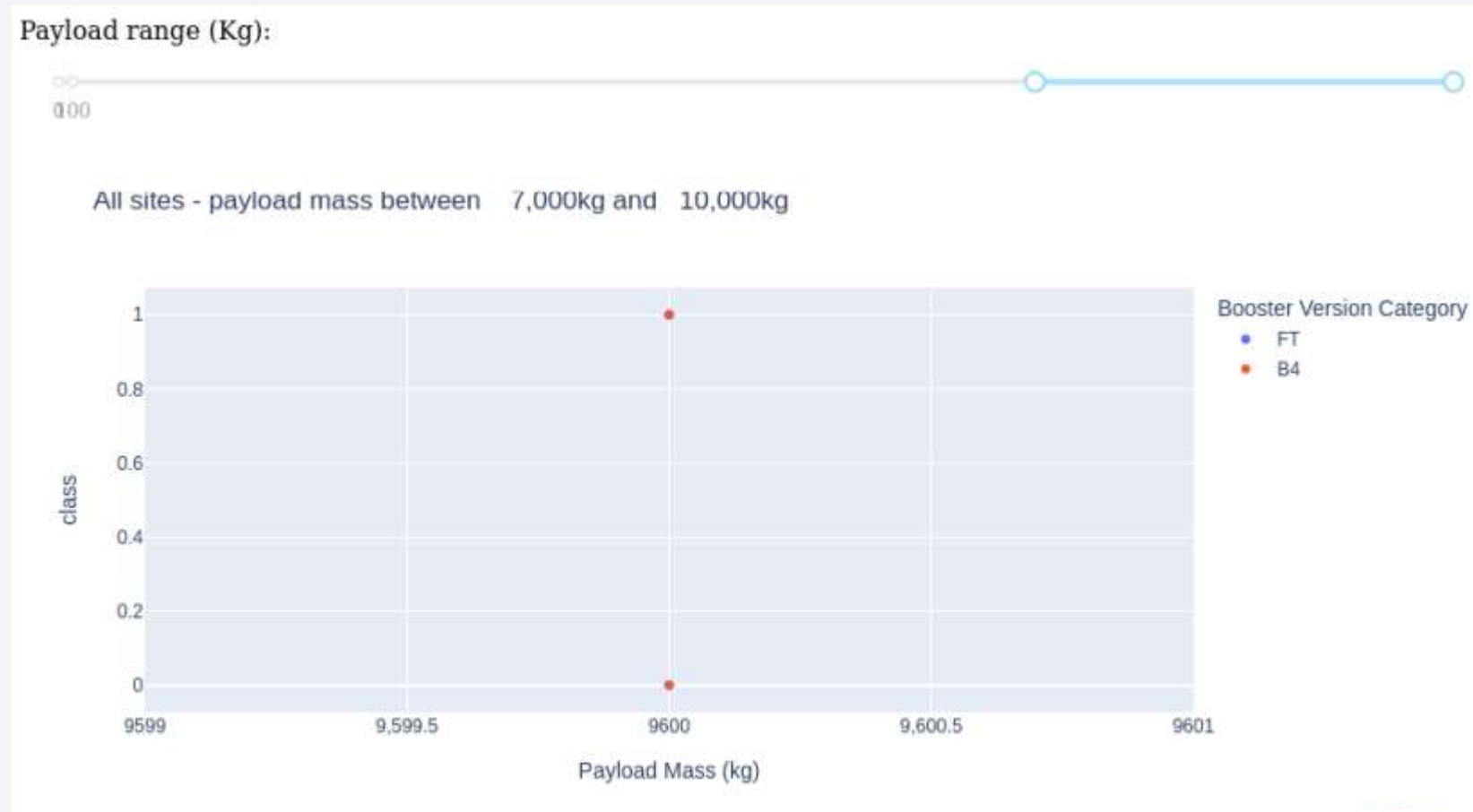


Correlation between Payload and Success for all Sites



Payload vs. Launch Outcome

- There's not enough data to estimate risk of launches over 7,000kg



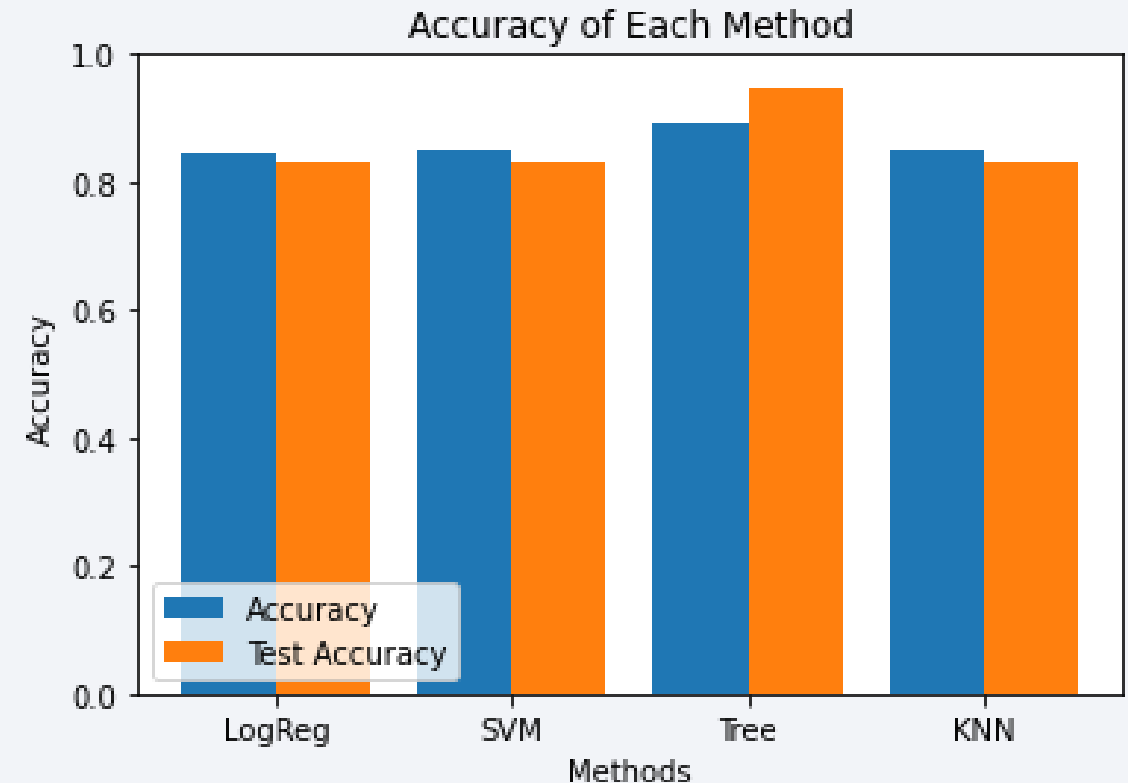


Section 5

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 accuracy about 85% for train set and accuracy for test data about 94%.



Confusion Matrix of Decision Tree Classifier

- 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 analyzed, refining conclusions along the process;
- The best launch site is 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;
- 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 doesn't show maps on Github, so screenshots were taken.

Thank you!

