IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

Executive Summary

- The following methodologies were used to analyze data: Data Collection using 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 It was possible to collected valuable data from public sources; EDA allowed to identify which features are the best to predict success of launchings; Machine Learning Prediction showed the best model to predict which characteristics are important to drive this opportunity by the best way, using all collected data.

Introduction

- The objective is to evaluate the viability of the new company SpaceY 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 best place to make launches.

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - Data from Space X was obtained from 2 sources:
  - SpaceX API (https://api.spacexdata.com/v 4/rockets/)
  - Web Scraping (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

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 normalized, 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 XAPI (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 – SpaceX API

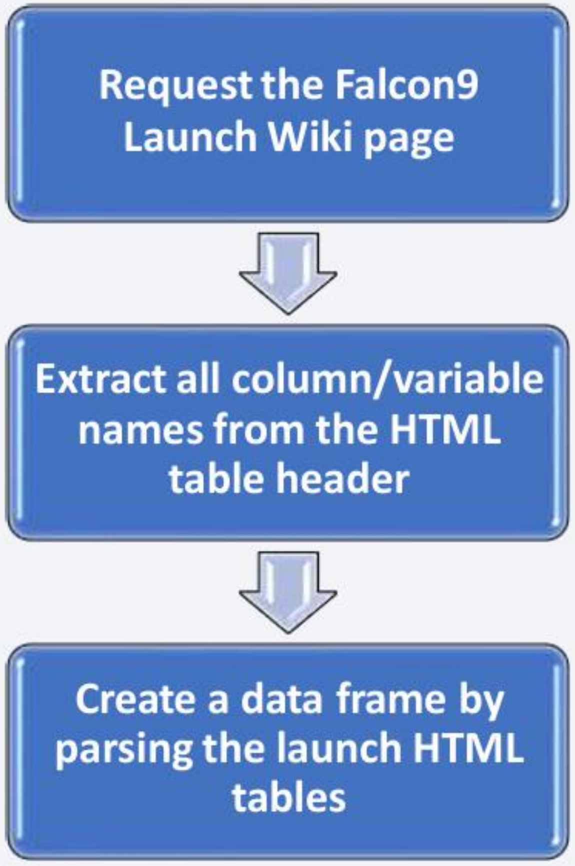
- SpaceX offers a public API from where data can be obtained and then used;
- This API was used according to the flowchart beside and then data is persisted.
- [Source Code - Applied-Data-Science-Capstone/jupyter-labs-spacex-data-collection-api.ipynb at main · JOSHcaleb/Applied-Data-Science-Capstone]

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 - [Applied-Data-Science-Capstone/Hands-on Lab _ Data Collection with Web Scraping.ipynb at main · JOSHcaleb/Applied-Data-Science-Capstone]



Data Wrangling

- Initially some Exploratory Data Analysis (EDA) was per formed 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.

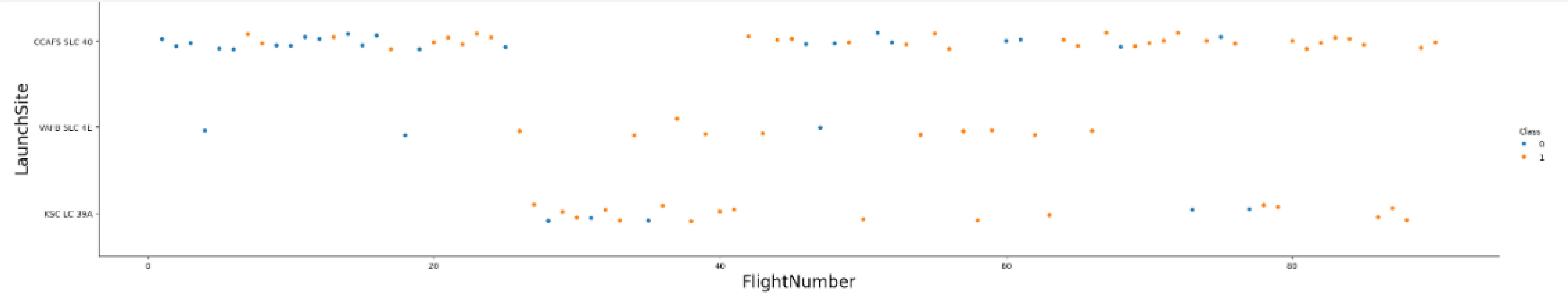
Source code - Applied-Data-Science-Capstone/Hands-On Lab   Data Wrangling.ipynb at main · JOSHcaleb/Applied-Data-Science-Capstone

EDA with Data Visualization

- To explore data, scatterplots and barplots were used to visualize the relationship between pair of features:

• Payload MassXFlight Number, LaunchSite XFlight Number, LaunchSite XPayload Mass, Orbit and Flight Number, Payload and Orbit

[Source code - Applied-Data-Science-Capstone/Hands-On Lab _ Data Wrangling.ipynb at main · JOSHcaleb/Applied-Data-Science-Capstone]()



EDA with SQL

- The following SQL queries were performed:
- Names of the unique launch sites in the space mission;
- Top5 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 - [Applied-Data-Science-Capstone/Hands-on Lab Complete the EDA with SQL.ipynb at main · JOSHcaleb/Applied-Data-Science-Capstone]()

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 to indicate distances between two coordinates.
- Source code - Applied-Data-Science-Capstone/lab_jupyter_launch_site_location.ipynb at main · JOSHcaleb/Applied-Data-Science-Capstone

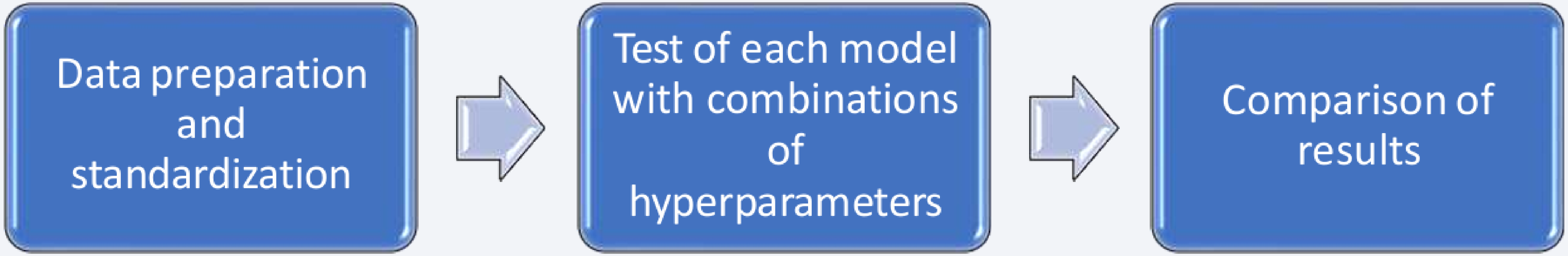
Build a Dashboard with Plotly Dash

- 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 - Applied-Data-Science-Capstone/Hands-on Lab _ Build an Interactive Dashboard with Ploty Dash (1).ipynb at main · JOSHcaleb/Applied-Data-Science-Capstone

Predictive Analysis (Classification)

- Four classification models were compared: logistic regression, support vector machine, decision tree and k nearest neighbors.
- Source code - Applied-Data-Science-Capstone/SpaceX_Machine Learning Prediction_Part_5.ipynb at main · JOSHcaleb/Applied-Data-Science-Capstone



Results

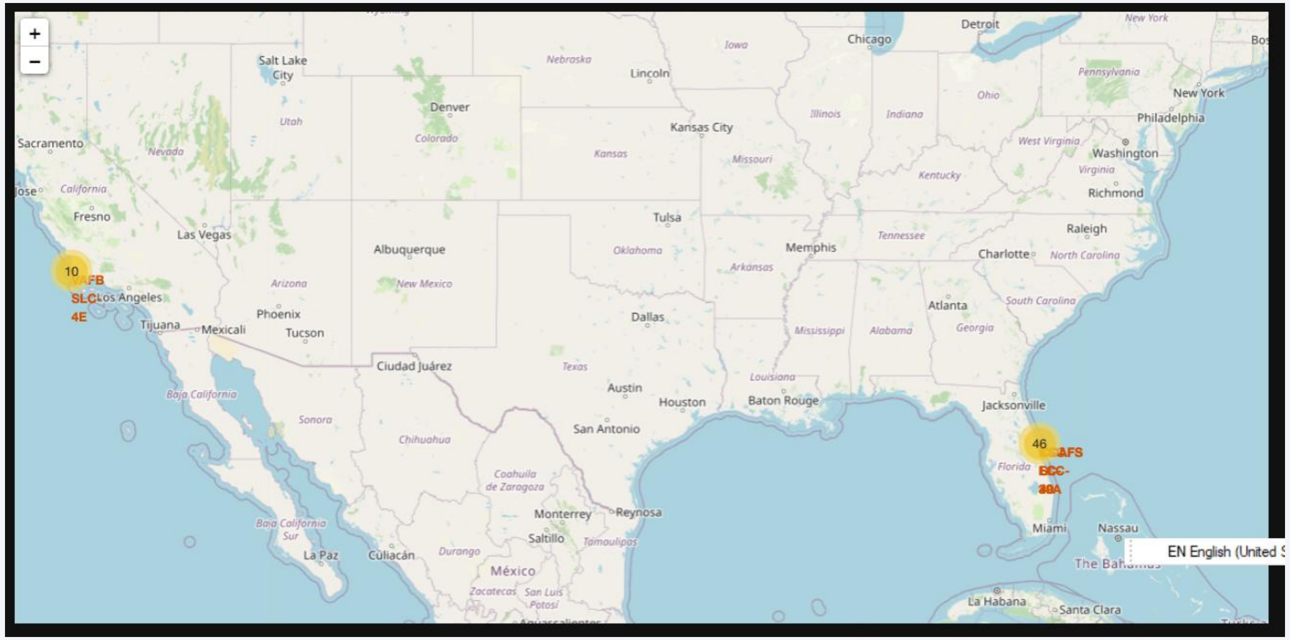
- Exploratory data analysis results

- SpaceX uses 4 different launch sites;
- The first launches were done to SpaceX itself and NASA;
- The average payload of F9 v1.1 booster is 2,928 kg;
- The first success landing outcome happened in 2015 fiver 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

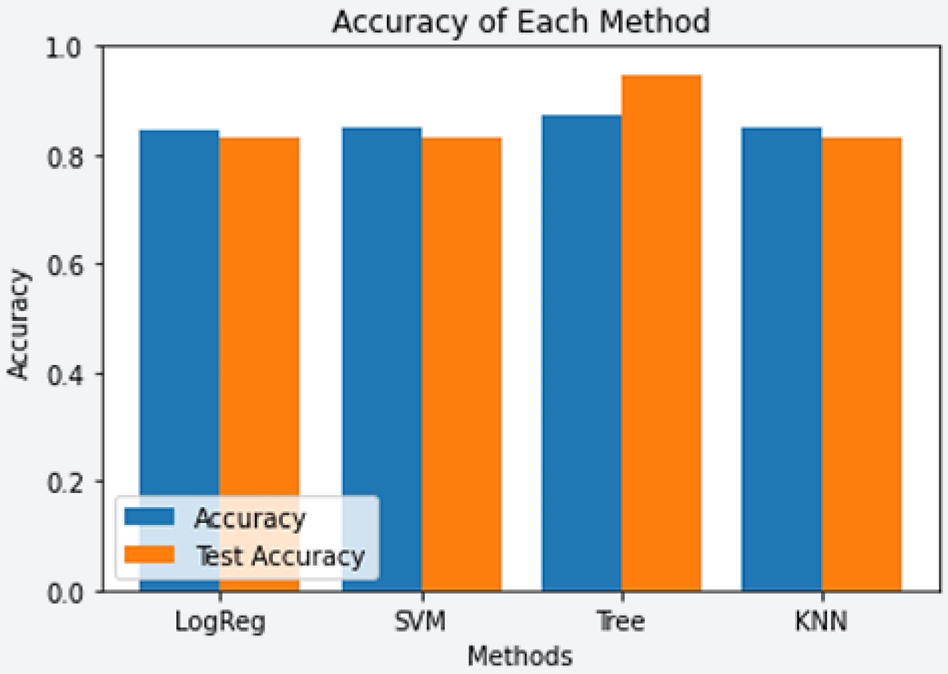
- Using interactive analytics was possible to identify that launch sites use to be in safety places, near sea, for example and have a good logistic infrastructure around.

- 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 over 94%.

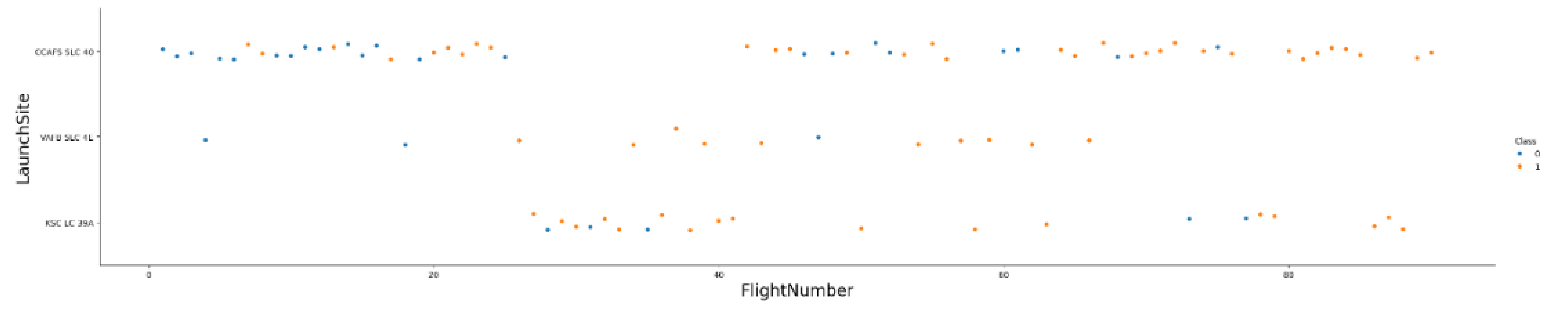


Section 2

Insights drawn from EDA

Flight Number vs. Launch Site

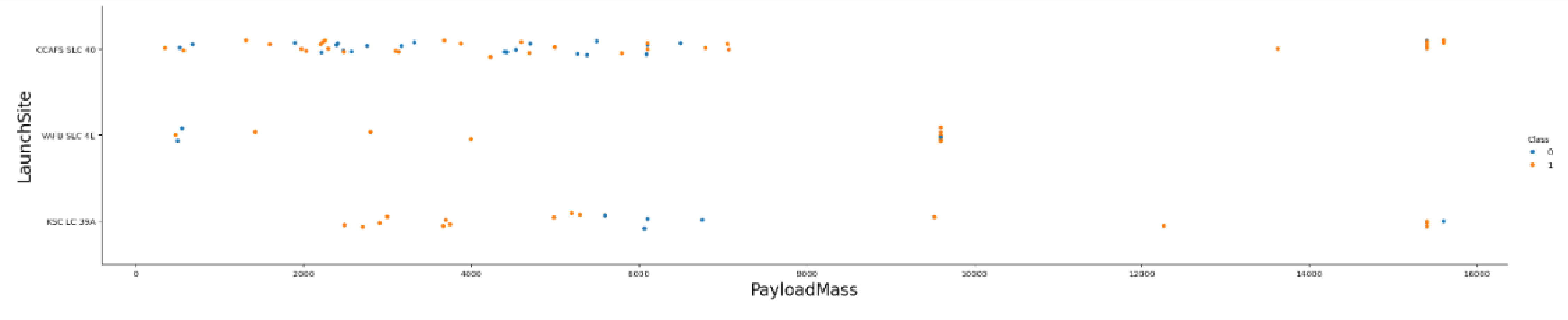
- According to the plot above, it’s possible to verify that the best launch site nowadays is CCAF5 SLC40, where most of recent launches were successful;
- In second place VAFB SLC4E and third place KSCLC 39A;
- It’s also possible to see that the general success rate improved over time.



Payload vs. Launch Site

- Payloads over 9,000kg (about the weight of a school bus) have excellent success rate;

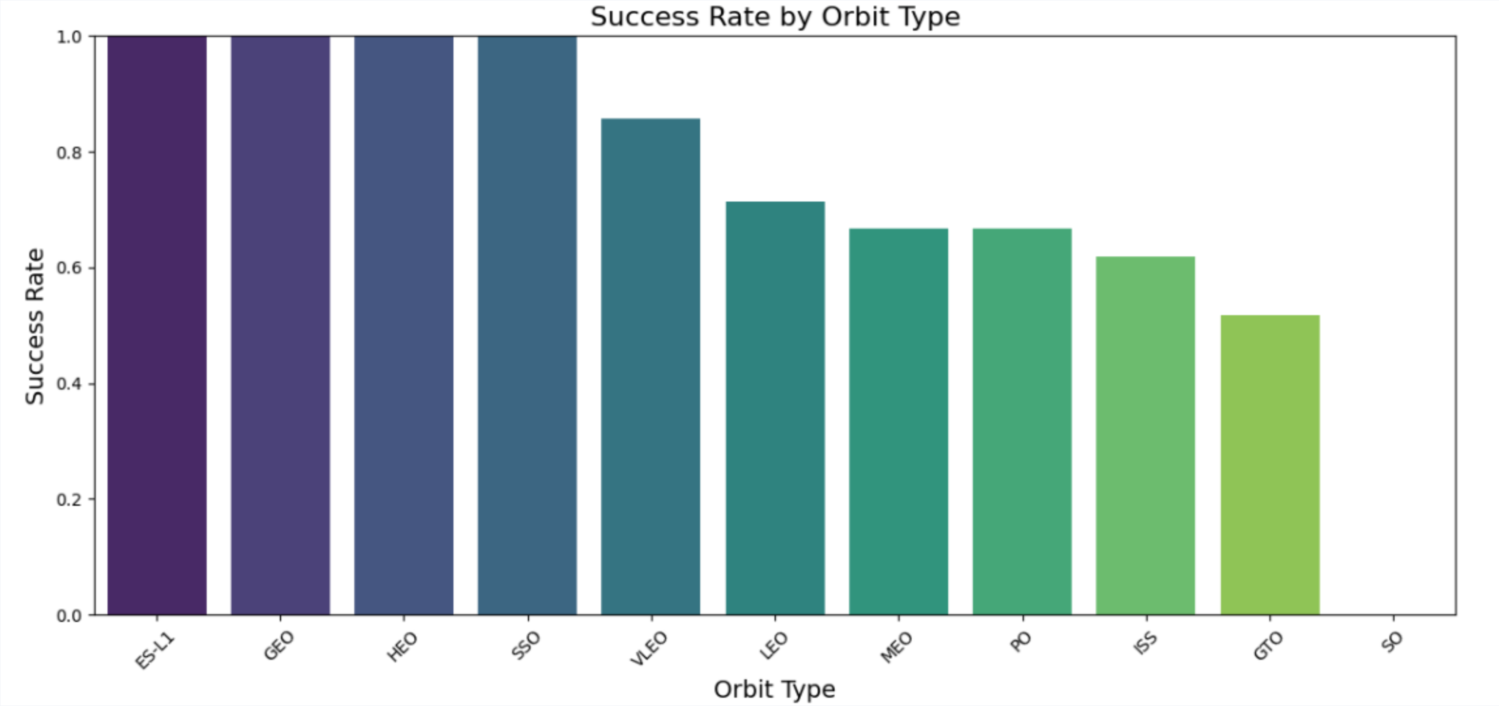
- Payloads over 12,000kg seems to be possible only on CCAFSSLC40 and KSC LC 39A launch sites.



Success Rate vs. Orbit Type

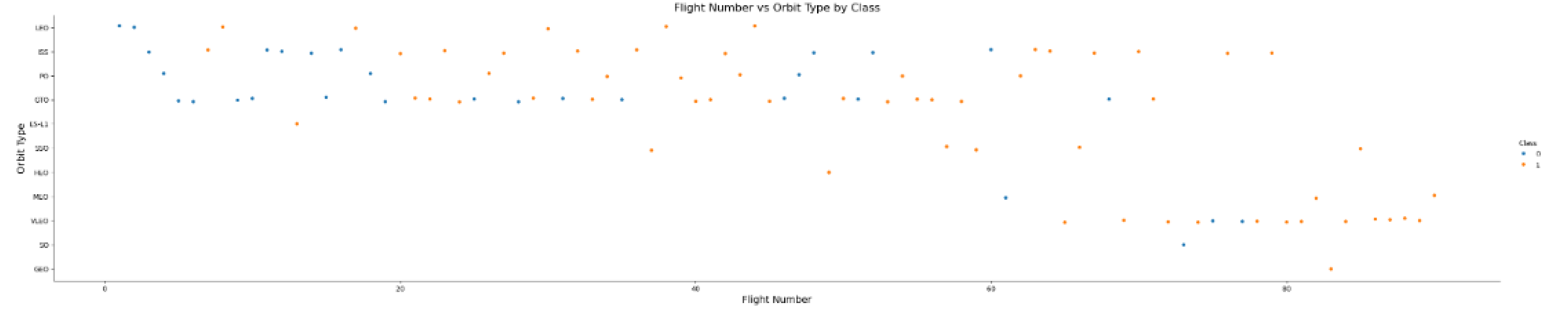
- The biggest success rates happens to orbits:
- ES-L1;
- GEO;
- HEO; and
- SSO.

- Followed by:
- VLEO(above80%); and
- LFO(above70%).



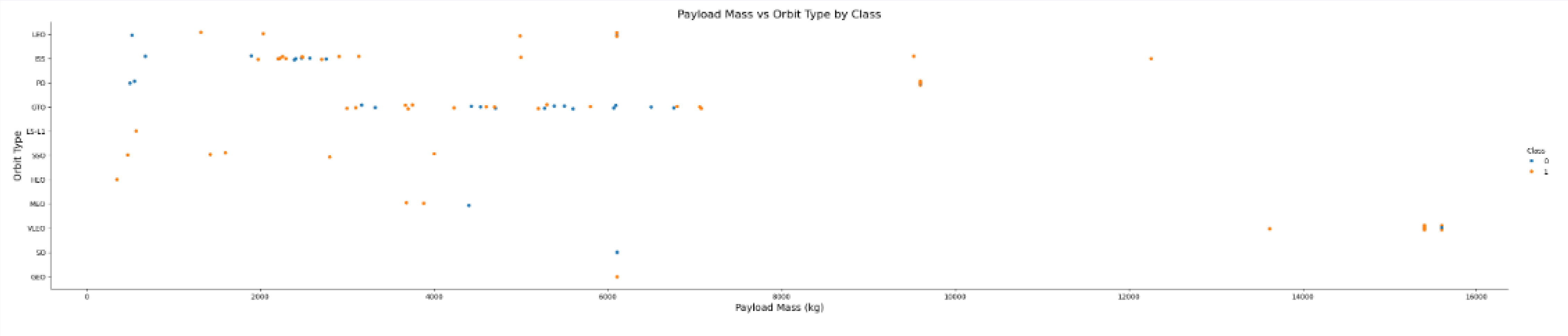
Flight Number vs. Orbit Type

- Apparently, success rate improved over time to all orbits;
- VLEOorbit seemsanew business opportunity, due to recent increase of its frequency.



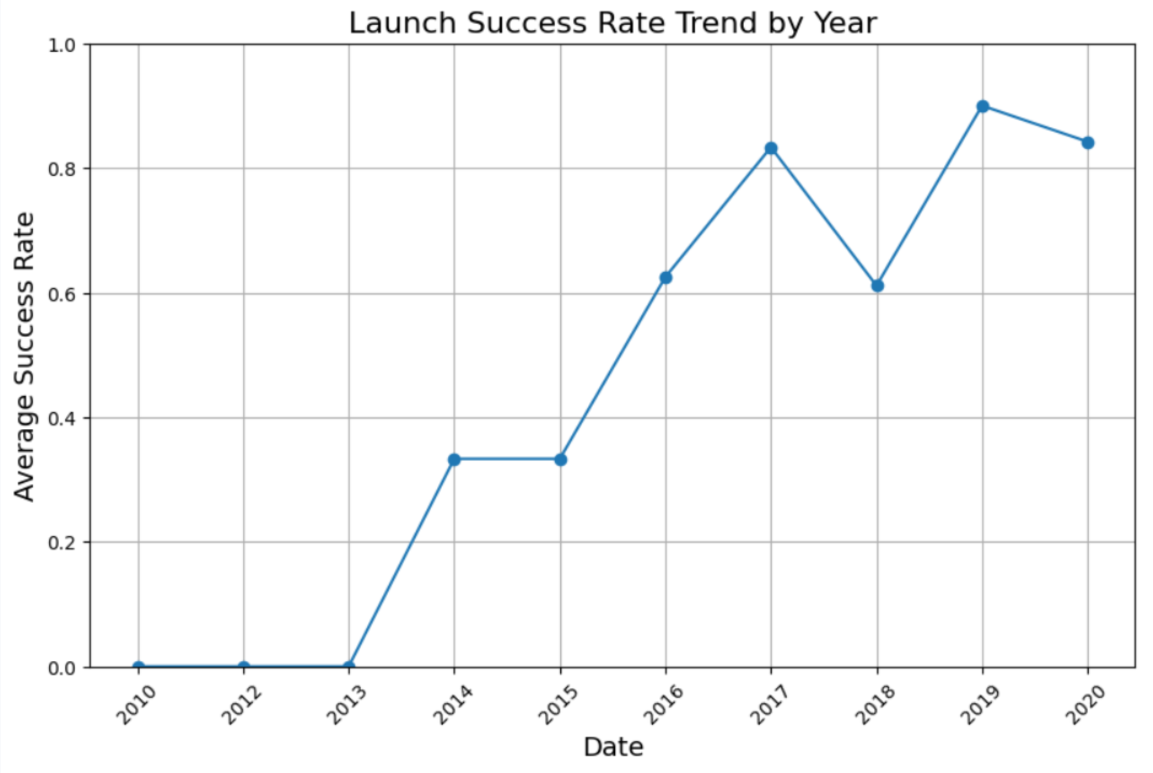
Payload vs. Orbit Type

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

```
%sql select distinct Launch_Site from SPACEXTABLE;
```

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

Launch Site Names Begin with 'CCA'

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

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing_Outco
2010-06-04	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachu
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 (parachu
2012-05-22	7:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No atten
2012-10-08	0:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No atten
2013-03-01	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No atten

Total Payload Mass

- the total payload carried by boosters from NASA

Total_Payload_Mass
48213

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

Average Payload Mass by F9 v1.1

- the average payload mass carried by booster version F9 v1.1

avg_payload_mass
2534.6666666666665

- Filtering data by the booster version above and calculating the average payload mass we obtained the value of 2,534.6 kg.

First Successful Ground Landing Date

- the dates of the first successful landing outcome on ground pad

min(Date)
2010-06-04

- 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 04/06/2010.

Successful Drone Ship Landing with Payload between 4000 and 6000

- List the names of boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 6000

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

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

Total Number of Successful and Failure Mission Outcomes

- the total number of successful and failure mission outcomes

Mission_Outcome	total
Failure (in flight)	1
Success	98
Success	1
Success (payload status unclear)	1

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

Boosters Carried Maximum Payload

- the names of the booster which have carried the maximum payload mass

Booster_Version
F9 B5 B1048.4
F9 B5 B1049.4
F9 B5 B1051.3
F9 B5 B1056.4
F9 B5 B1048.5
F9 B5 B1051.4
F9 B5 B1049.5
F9 B5 B1060.2
F9 B5 B1058.3
F9 B5 B1051.6
F9 B5 B1060.3
F9 B5 B1049.7

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

2015 Launch Records

- List the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015

Month	Landing_Outcome	Booster_Version	Launch_Site
January	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
April	Failure (drone ship)	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

- 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

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

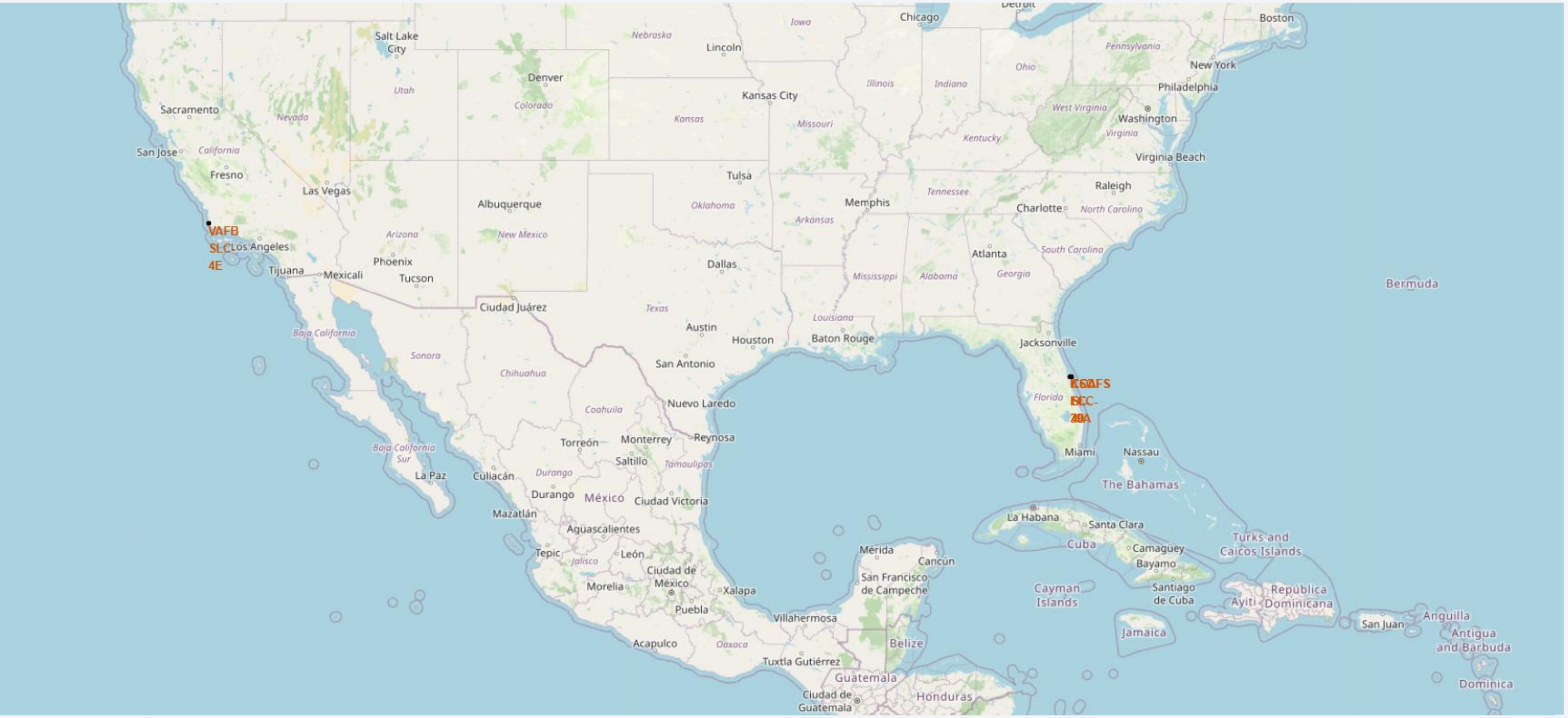
- This view of data alerts us that “No attempt” must be taken in account.

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.

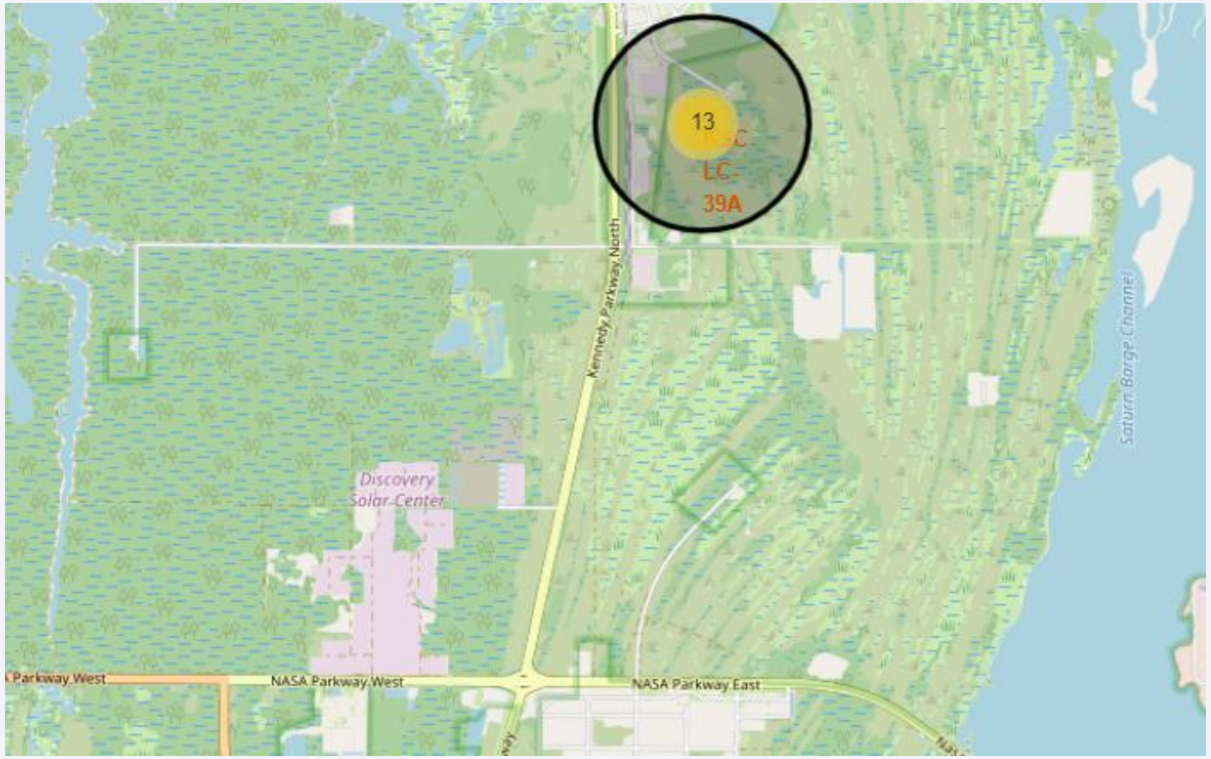


Launch Outcomes by Site

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

- Green markers indicate successful and red ones indicate failure

Logistics and Safety

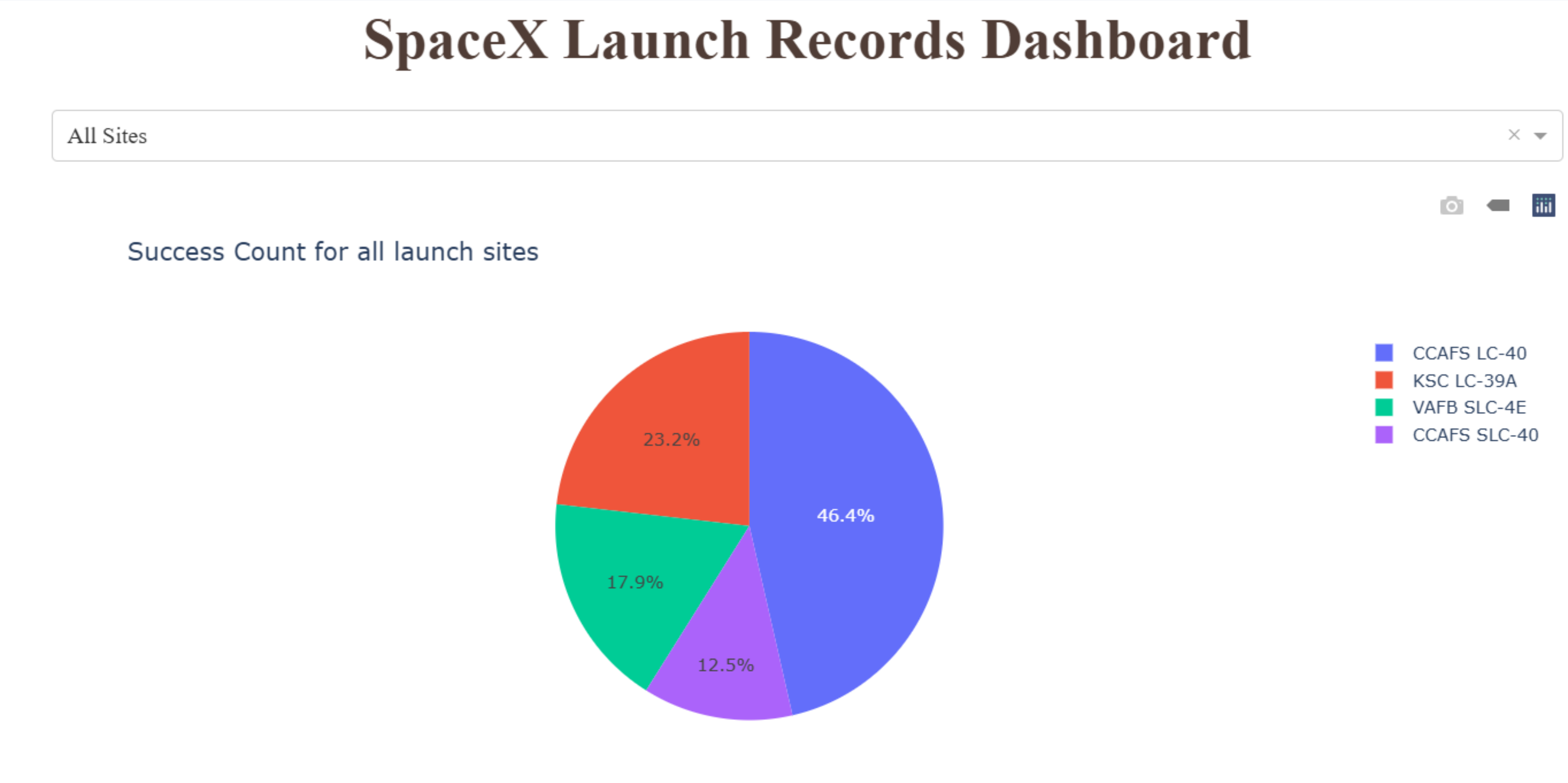


- Launch site KSCLC-39A has good logistics aspects, being near railroad and road and relatively far from inhabited areas.

Section 4

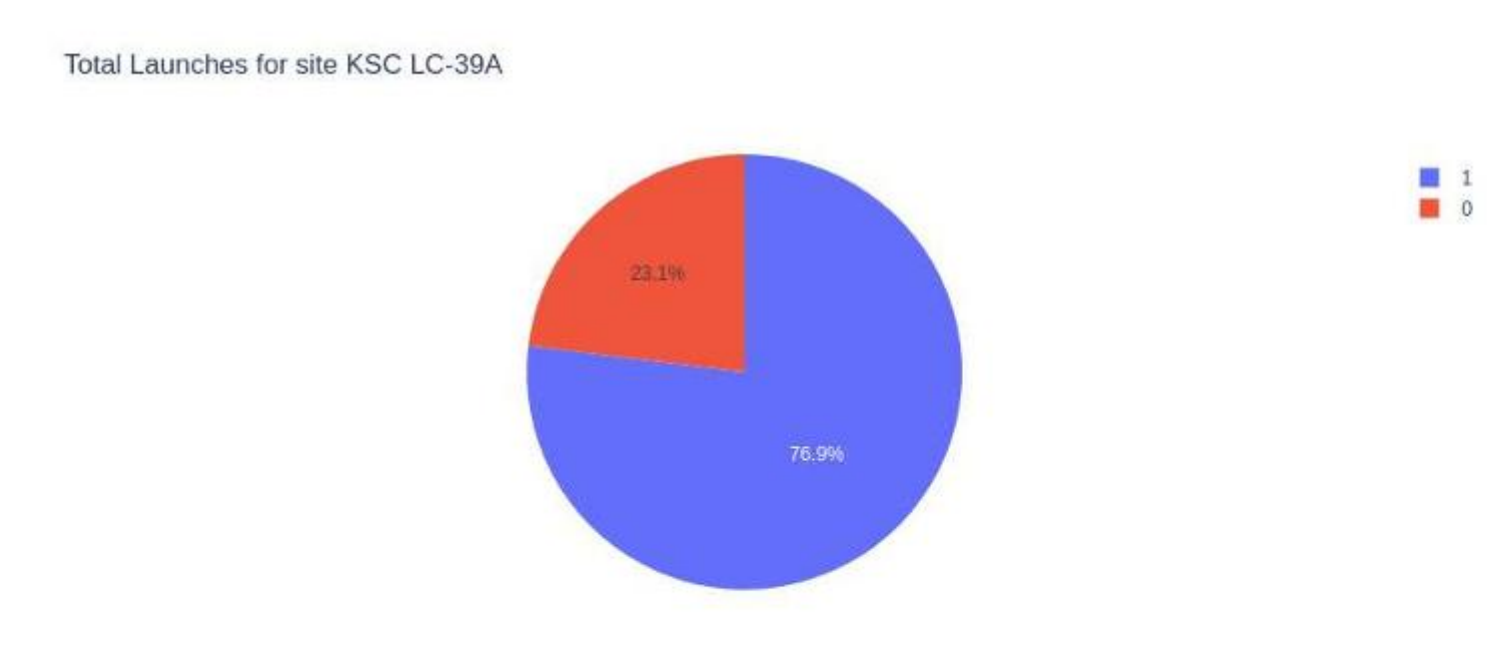
Build a Dashboard with Plotly Dash

Successful Launches by Site



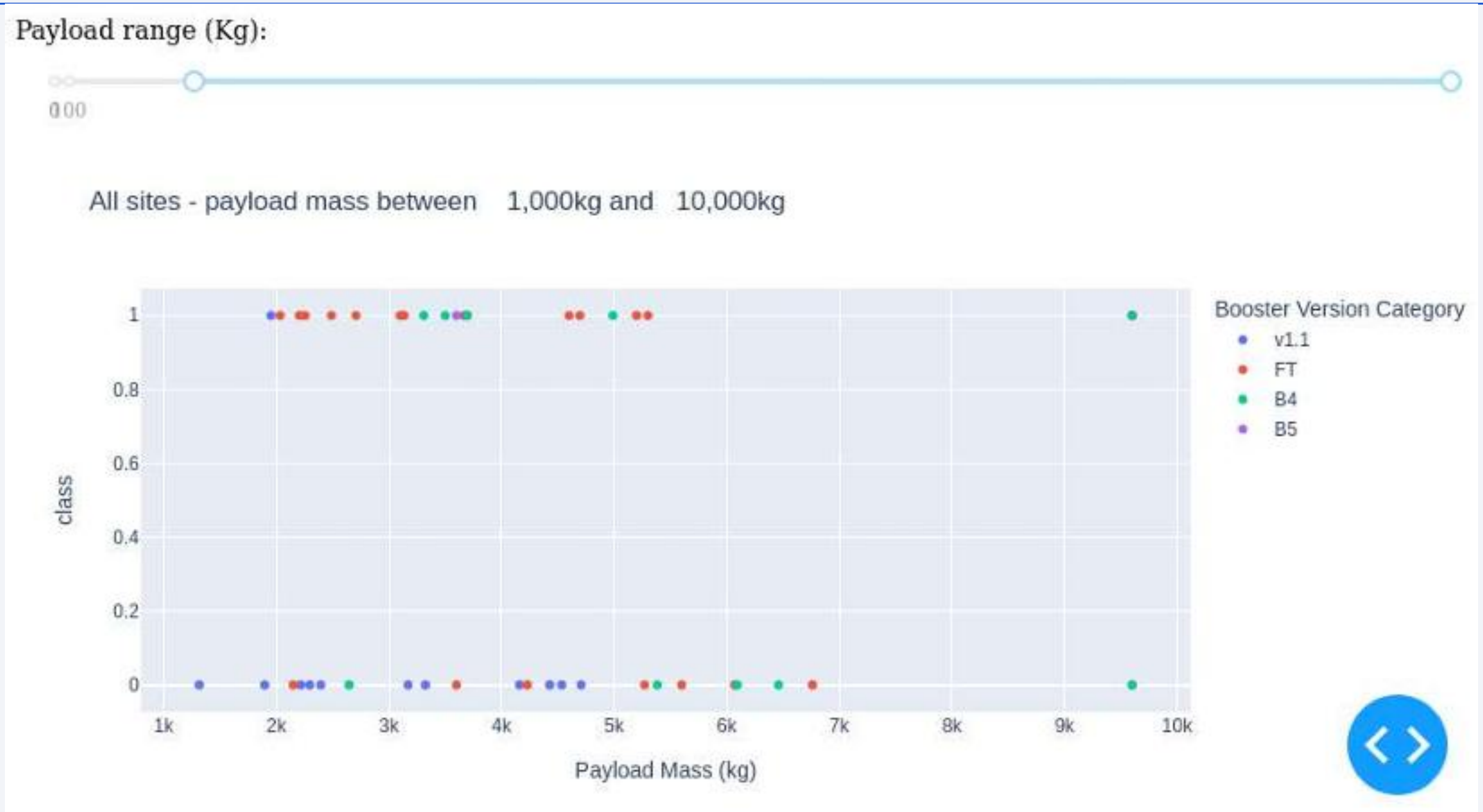
- The place from where launches are done seems to be a very important factor of success of missions.

Launch Success Ratio for KSCLC-39A



- 76.9% of launches are successful in this site.

Payload vs. Launch Outcome



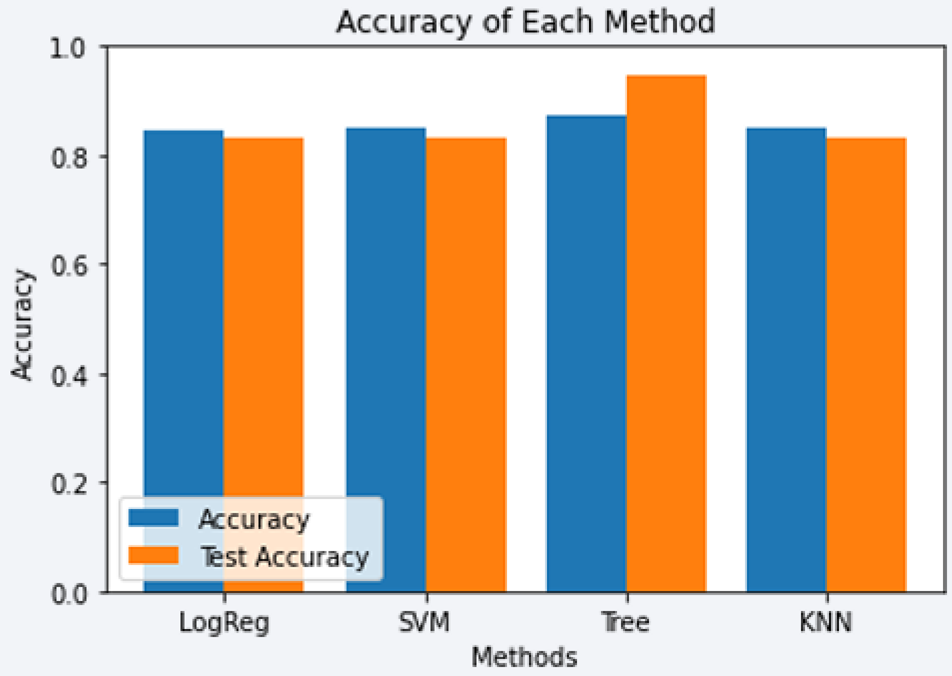
- Payloads under 6,000kg and FT boosters are the most successful combination.

Section 5

Predictive Analysis (Classification)

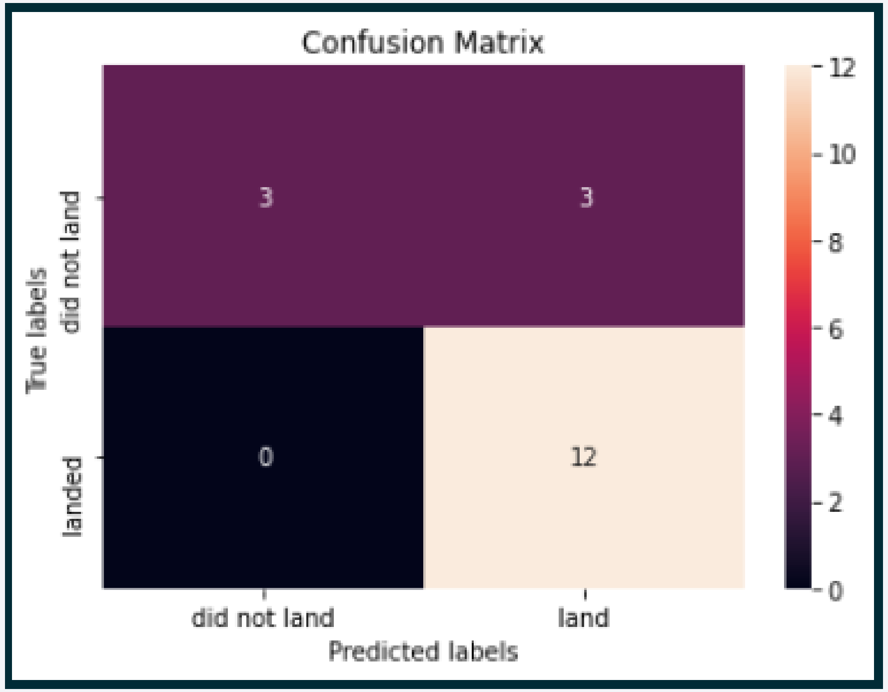
Classification Accuracy

- 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 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 KSCLC-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 didn’t show maps on Github, so I took screenshots.

Thank you!