IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

EBUKA NWAFORNSO
28 November, 2022

Outline

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

Executive Summary

- Summary of methodologies

In this project, we will predict if the Falcon 9 first stage will land successfully. On its website, SpaceX promotes Falcon 9 rocket launches for 62 million dollars; other suppliers charge upwards of 165 million dollars for each launch. A large portion of the savings is due to SpaceX's ability to reuse the first stage. Therefore, if we can figure out if the first stage will land, we can figure out how much a launch will cost. If a different business wants to compete with SpaceX for a rocket launch, it may use the information provided here.

  - Data Collection
  - Data wrangling
  - EDA with data visualization
  - EDA with SQL
  - Building a dashboard with Plotly Dash
  - Predictive analysis (Classification)
- Summary of all results
  - EDA results
  - Interactive analytics
  - Predictive analysis

Introduction

- Project background and context

  On its website, SpaceX promotes Falcon 9 rocket launches for 62 million dollars; other suppliers charge upwards of 165 million dollars for each launch. A large portion of the savings is due to SpaceX's ability to reuse the first stage.

- Problems you want to find answers

  The main task of the project is to predict if the first stage of the SpcaeX Falcon 9 rocket will land successfully. if we can figure out if the first stage will land, we can figure out how much a launch will cost.

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - SpaceX REST API
  - Web Scraping SpaceX data from Wikipedia
- Perform data wrangling
  - One Hot Encoding of data fields for Machine Learning and data cleaning of null values and irrelevant columns
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - LR, KNN, SVM, DT models have been built and evaluated to determine the best classifier

Data Collection

- The following datasets were collected;

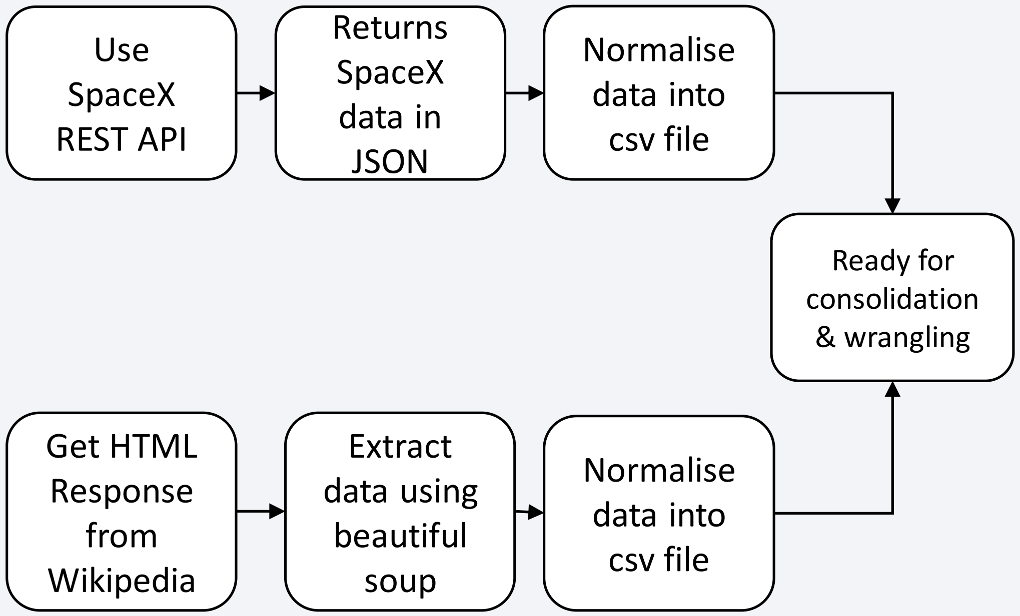
  - SpaceX launch data that is generated from the SpaceX REST API.

  - This API will give us data about launches, including information about the rocket used, payload delivered, launch specifications, landing specifications, and landing outcome.

  - The SpaceX REST API endpoints or URL starts with ap.spacexdata.com/v4/.

  - Another popular data source for obtaining Falcon 9 Launch data is web scraping Wikipedia using BeautifulSoup.

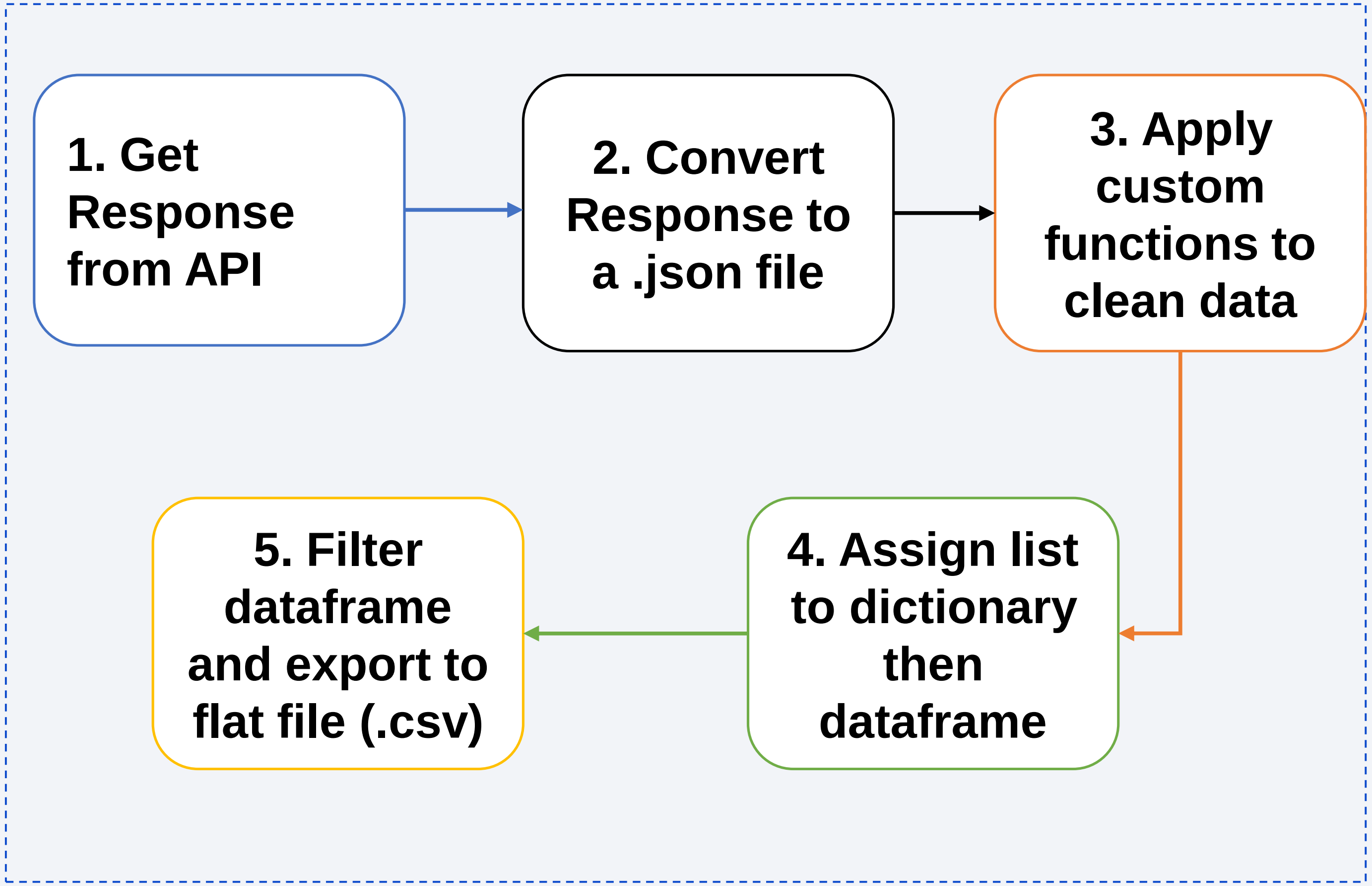
The Process



Data Collection – SpaceX API

Data collection with SpaceX REST calls

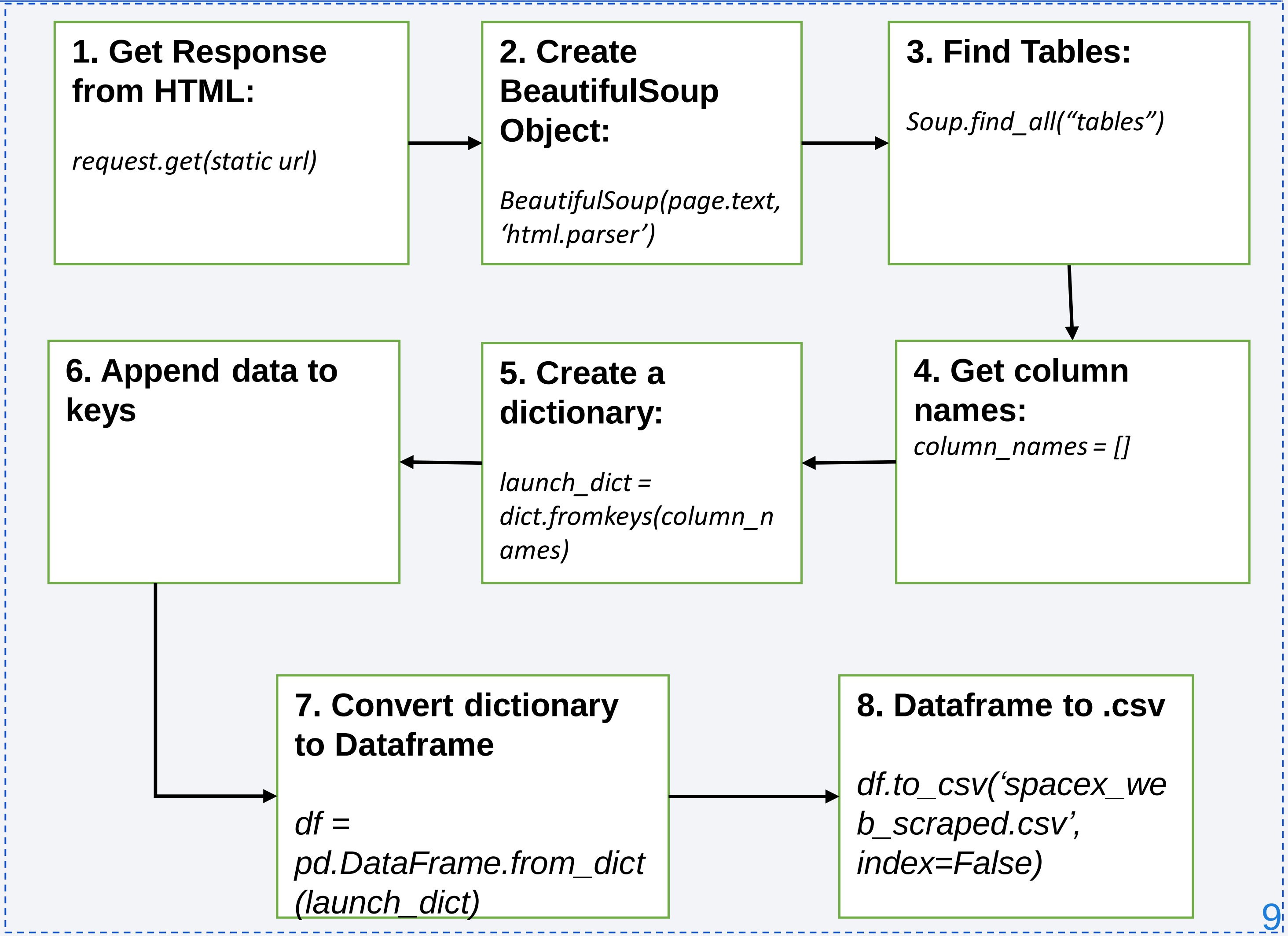
https://github.com/sabimechanic/SpaceX_Capstone_project/blob/main/Data_collection_SpaceX-api.ipynb



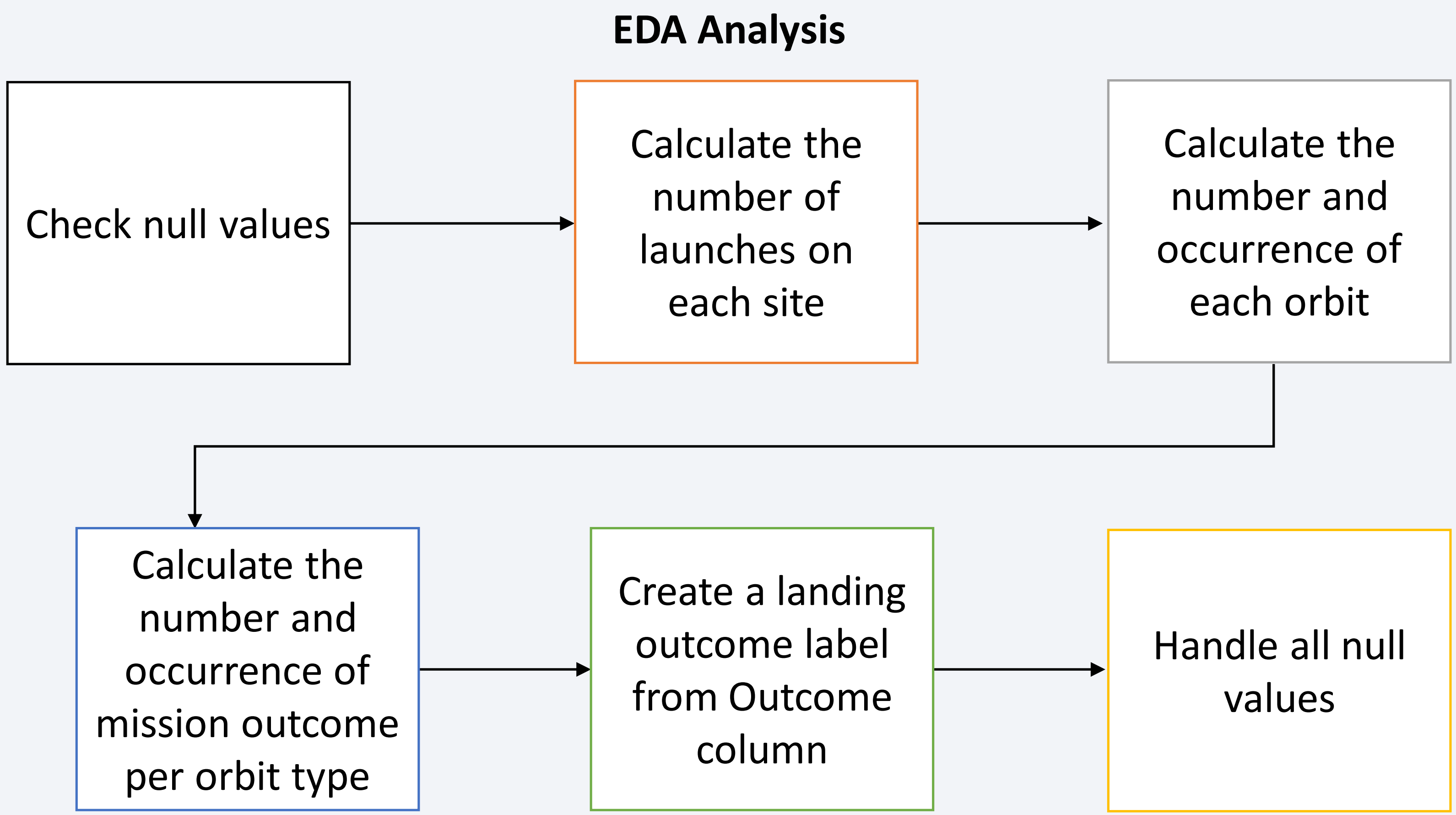
Data Collection - Scraping

Web Scraping data from Wikipedia

https://github.com/sabimechanic/SpaceX_Capstone_project/blob/main/Webscraping_SpaceX.ipynb



Data Wrangling



https://github.com/sabimechanic/SpaceX_Capstone_project/blob/main/SpaceX-data_wrangling.jupyterlite.ipynb

EDA with Data Visualization

The charts used in the EDA include the following:

- **Line chart:** This chart was used to show the average launch success trend by plotting Year on the x-axis and Average success rate on the y-axis.
- **Bar chart:** I used a bar chart to visually check if there are any relationship between success rate and orbit type.
- **Scatter plot:** Multiple scatter plots were plotted in this project showing the linear relationship between the following variables;

1. Flight Number vs Payload Mass
2. Payload Mass vs Launch sites
3. Flight Number vs Orbit type
4. Payload vs Orbit type

https://github.com/sabimechanic/SpaceX_Capstone_project/blob/main/EDA_dataviz.ipynb.jupyterlite.ipynb

EDA with SQL

- SQL queries performed include:
  - SELECT the names of the unique launch sites in the space mission.
  - SELECT 5 records where launch sites begin with the string ‘KSC’.
  - SELECT the total payload mass carried by boosters launched by NASA (CRS).
  - SELECT average payload mass carried by booster version F9 v1.1.
  - List the dates where successful landing outcome in drone ship was achieved.
  - List the names of the boosters which have success on the ground pad and have payload mass greater than 4000kg but less than 6000kg.
  - List the total number of successful and failed mission outcomes.
  - List the names of the booster versions which have carried the maximum payload mass.
  - SELECT the month names, successful landing outcome on the ground pad, booster versions, launch site for the months in the year 2015
  - RANK the count pf successful lamding outcomes between 04-06-2010 and 20-03-2017 in descending order.

https://github.com/sabimechanic/SpaceX_Capstone_project/blob/main/EDA_SQL_sqllite.ipynb

Build an Interactive Map with Folium

Objects created and added to a folium map include the following;

- **Circles:** Folium.Circle was used to add a text label and a highlighted circle area at a particular coordinate.
- **Markers:** By pinning the locations on a map, markers make coordinates in plain numbers easier to understand.
- **Markclusters:** Mark clusters can be a highly useful tool for streamlining a map with numerous markers that share the same coordinate.
- **MousePosition:** To obtain coordinates for a mouse over a point on the map, use MousePosition. As a result, you may simply locate the coordinates of any points of interest while exploring the map (such a as highway).

Map markers have been added to the map with aim to finding an optimal location for building a launch site

https://github.com/sabimechanic/SpaceX_Capstone_project/blob/main/data_visualization_with_folium.jupyterlite.ipynb

Build a Dashboard with Plotly Dash

The following plots and interactions were added to the dashboard;

- **Site-dropdown:** This interaction is used to select a desired launch site and renders a pie chart visualizing launch success counts.
- **Pie chart:** This plot visualizes launch success counts.
- **Range Slider:** We want to find if variable payload is correlated to mission outcome. This interaction allows you to easily select different payload range and see if we can identify some visual patterns.
- **Scatter chart:** With “Payload” on the x-axis and “Launch outcome” on the y-axis, we can visually observe how payload may be correlated with mission outcomes for selected site(s).

https://github.com/sabimechanic/SpaceX_Capstone_project/blob/main/spacex_dash_web_app.py

Predictive Analysis (Classification)

- Summary of how I built, evaluated, improved, and found the best-performing classification model:
- Performed exploratory Data Analysis and determined Training Labels
    - Created a column for the class and created a NumPy array from this column by applying the method “to_numpy()” and assigned the array to a variable Y.
    - Standardized the data in X then reassign it to the variable X using “transform = preprocessing.StandardScaler()”
    - I split the data into training data and test data using the function “train_test_split” and set the parameter test size to 0.2 and random state to 2. The training data is divided into validation data, a second set was used for training data; then the models are trained and hyperparameters are selected using the function GridSearchCV.
    - Created a logistic regression object then create a GridSearchCV object logreg_cv with cv = 10. Fitted the object to find the best parameters from the dictionary parameters. I output the GridSearchCV object for logistic regression. I displayed the best parameters using the data attribute best_params_ and the accuracy on the validation data using the data attribute best_score_.
    - Calculated the accuracy on the test data using the method score and created a confusion matrix. We can tell that logistic regression can distinguish between the various groups by looking at the confusion matrix. We can observe that false positives are the main issue.
    - Performed the last two steps for “SVC()”, “DecisionTreeClassifier()” and “KNeighborsClassifier()”
- Found the best Hyperparameter for SVM, Classification Trees and Logistic Regression. Using test data I found the best-performing method.
- The SVM, KNN, and Logistic Regression model achieved the highest accuracy at 83.3%, while the SVM performs the best in terms of Area Under the Curve at 0.958. Predictive Analysis (Classification)

https://github.com/sabimechanic/SpaceX_Capstone_project/blob/main/SpaceX_Machine_Learning_Prediction.jupyterlite.ipynb

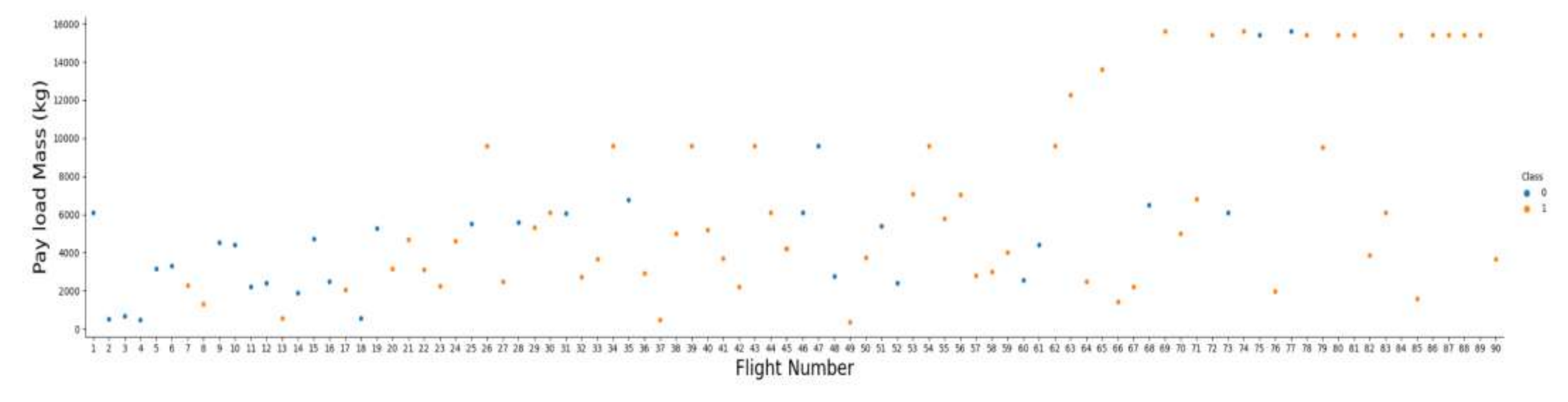
Results

- The SVM, KNN, and Logistic Regression models are the best in terms of prediction accuracy for this dataset.
- Low weighted payloads perform better than the heavier payloads.
- The success rates for SpaceX launches is directly proportional time in years they will eventually perfect the launches.
- KSC LC 39A had the most successful launches from all the sites.
- Orbit GEO,HEO,SSO,ES L1 has the best Success Rate.

Section 2

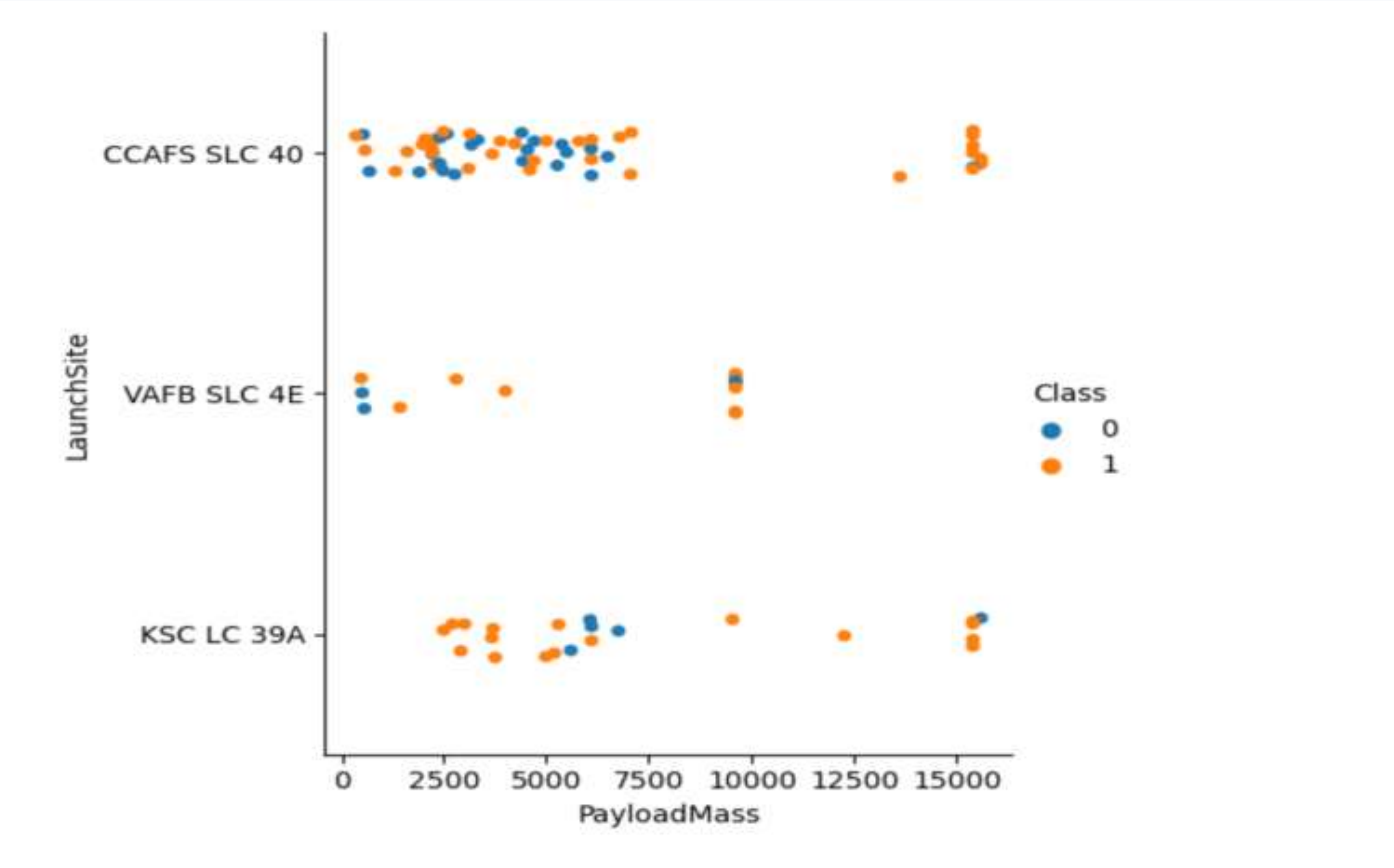
Insights drawn from EDA

Flight Number vs. Launch Site



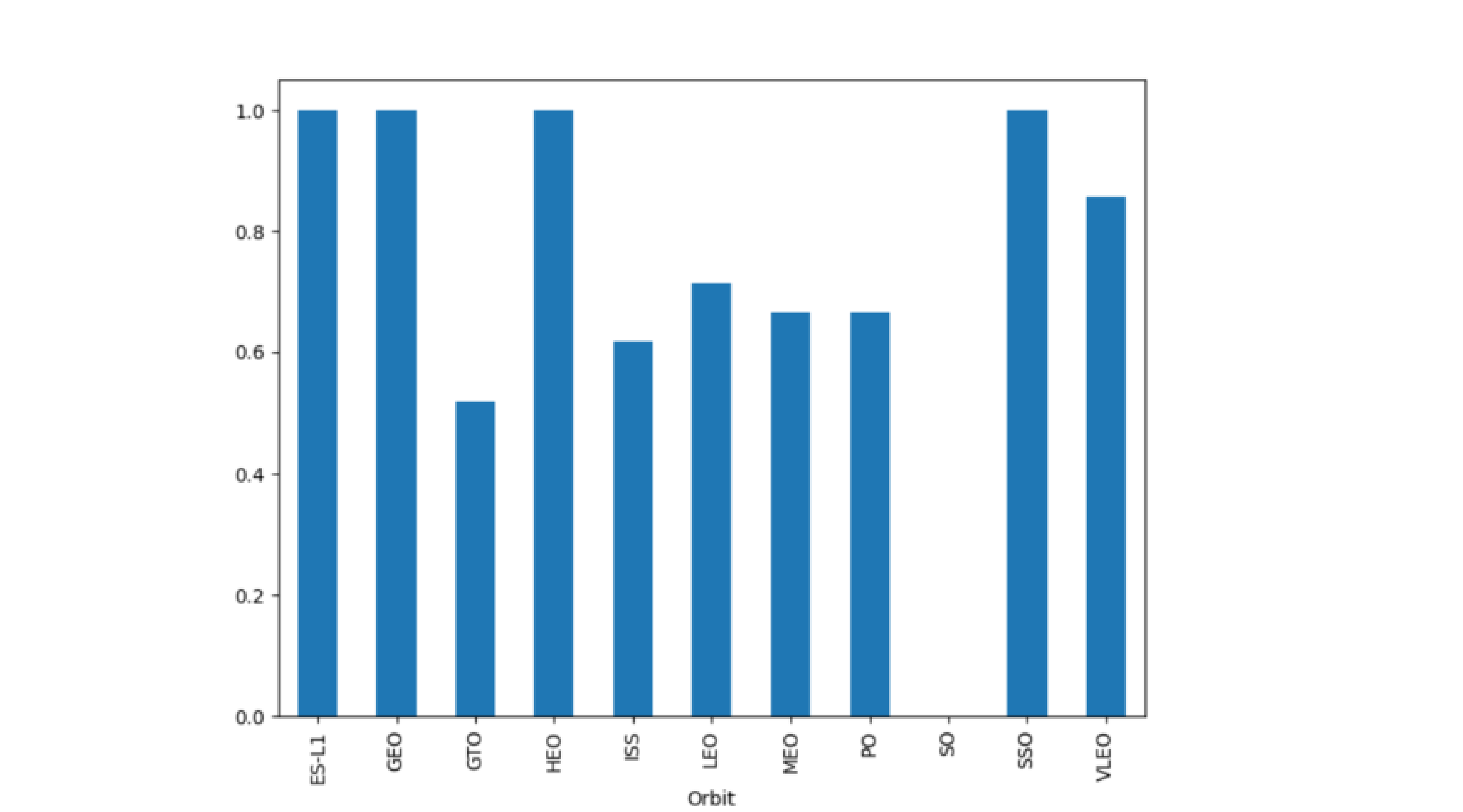
We see that as the flight number increases, the first stage is more likely to land successfully. The payload mass is also important; it seems the more massive the payload, the less likely the first stage will return.

Payload vs. Launch Site



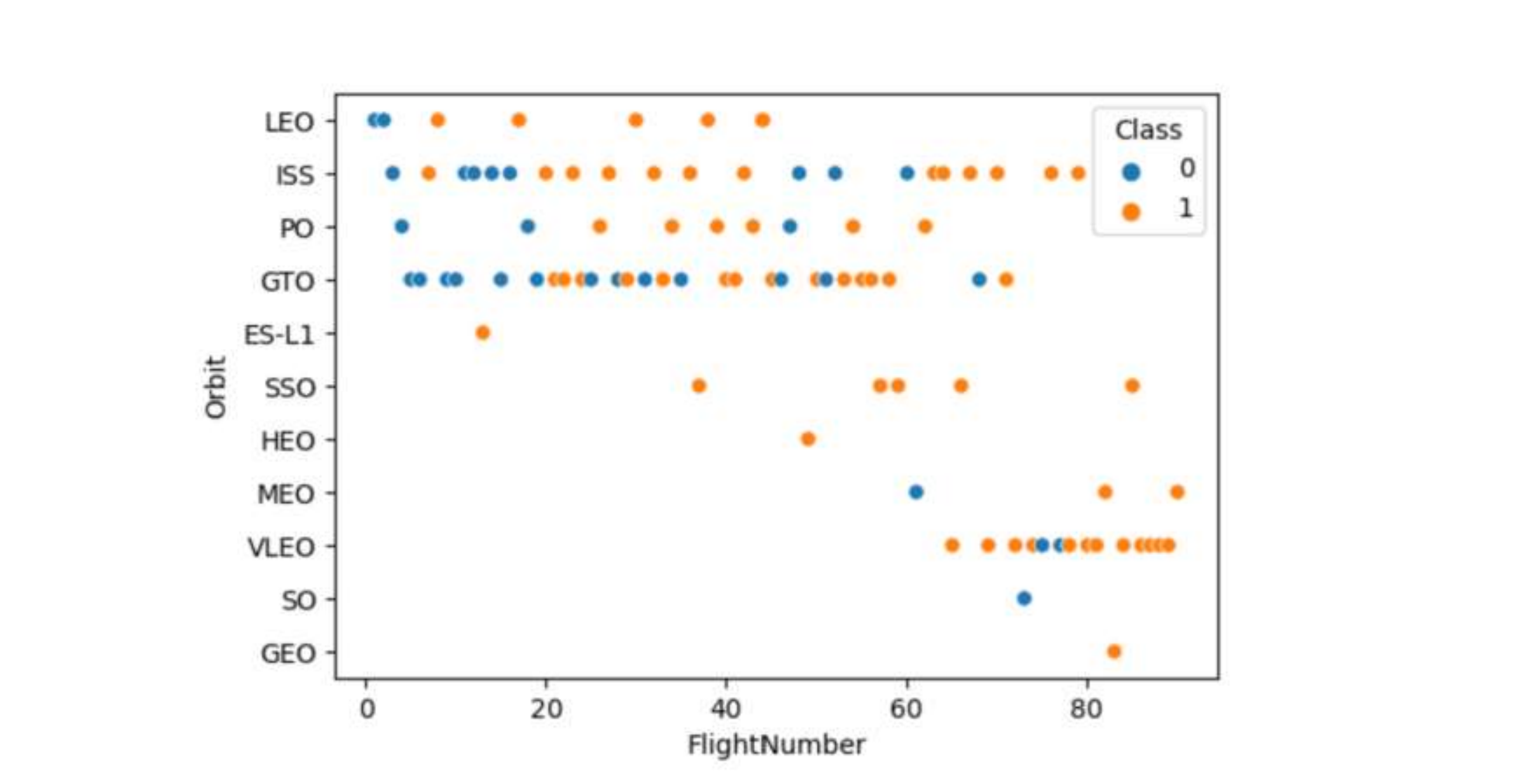
Now if you observe Payload Vs. Launch Site scatter point chart you will find for the VAFB-SLC launchsite there are no rockets launched for heavypayload mass(greater than 10000).

Success Rate vs. Orbit Type



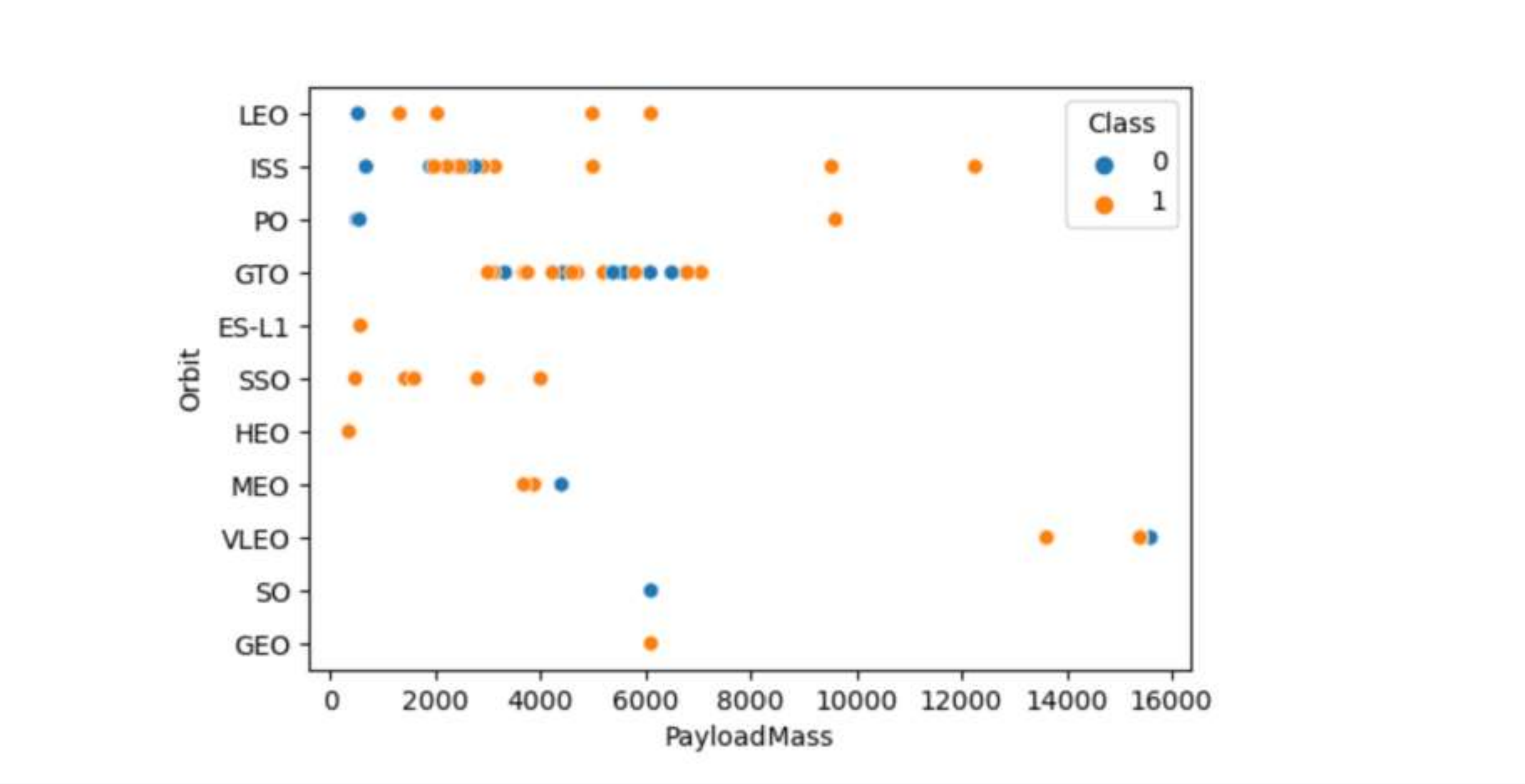
From the bar chart ES-L1, GEO, HEO and SSO are the orbit types with the highest success rate

Flight Number vs. Orbit Type



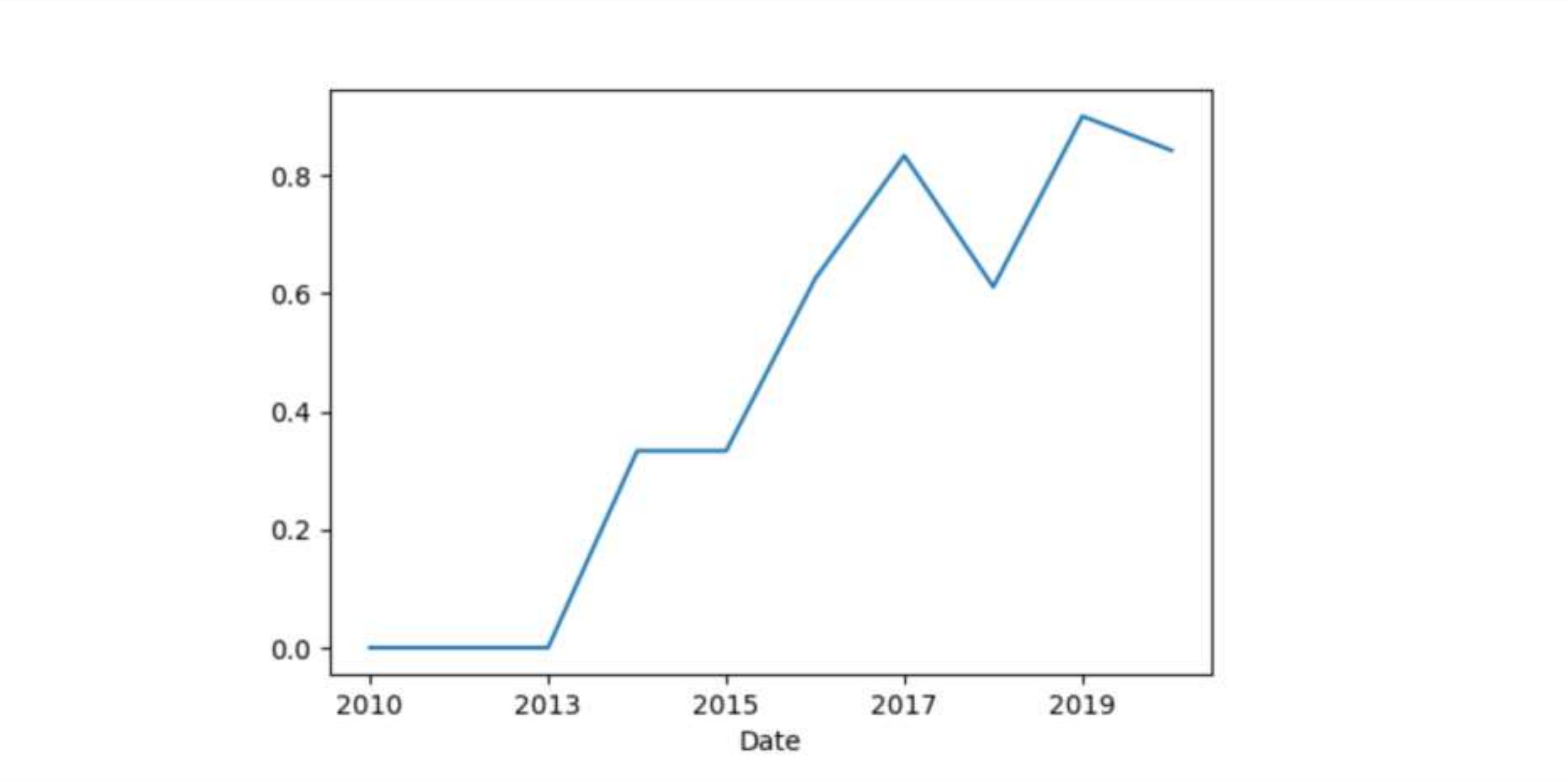
You should see that in the LEO orbit the Success appears related to the number of flights; on the other hand, there seems to be no relationship between flight number when in GTO orbit.

Payload vs. Orbit Type



With heavy payloads, the successful landing or positive landing rate is more for Polar, LEO and ISS. However, for GTO we cannot distinguish this well as both positive landing rate and negative landing(unsuccessful mission) are both there.

Launch Success Yearly Trend



From the chart we can observe that the sucess rate since 2013 kept increasing till 2020

All Launch Site Names

Out[8]:

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

- **%sql select distinct “launch_site” from SPACEXTBL**

This query displays the names of unique launch sites in the space mission.

Launch Site Names Begin with 'CCA'

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing _Outcome
04-06-2010	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
08-12-2010	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)
22-05-2012	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
08-10-2012	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
01-03-2013	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

- %sql select * from SPACEXTBL WHERE launch_site LIKE'CCA%' LIMIT 5

This sql query Displays 5 records where launch sites begin with the string 'CCA'

Total Payload Mass

PAYLOAD_MASS__KG_
500
677
2296
2216
2395
1898
1952
3136
2257
2490
2708
3310
2205
2647
2697
2500
2495
2268
1977
2972

- **%sql** select payload_mass__kg_ from SPACEXTBL where customer LIKE 'NASA (CRS)'

This query selects the payload mass for NASA(CRS)

Average Payload Mass by F9 v1.1

```
%sql SELECT AVG(payload_mass__kg_) FROM SPACEXTBL WHERE booster_version LIKE 'F9 v1.1%'
```

```
 * sqlite:///my_data1.db
Done.
```

AVG(payload_mass__kg_)
2534.6666666666665

- **%sql SELECT AVG(payload_mass__kg_) FROM SPACEXTBL WHERE booster_version LIKE 'F9 v1.1%'**

This SQL query Display average payload mass carried by booster version F9 v1.1

First Successful Ground Landing Date

```
%sql SELECT min(DATE) FROM SPACEXTBL WHERE "Landing _Outcome" LIKE 'Success (ground pad)'
```

```
 * sqlite:///my_data1.db
Done.
```

min(DATE)
01-05-2017

- %sql SELECT min(DATE) FROM SPACEXTBL WHERE "Landing _Outcome" LIKE 'Success (ground pad)’

This query lists the date when the first successful landing outcome in the ground pad was achieved.

Successful Drone Ship Landing with Payload between 4000 and 6000

```
%sql SELECT booster_version FROM SPACEXTBL WHERE "Landing _Outcome" LIKE 'Success (drone ship)' and payload_mass__kg_ > 4000 and payload_mass__kg_ <

 * sqlite:///my_data1.db
Done.
```

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

- %sql SELECT booster_version FROM SPACEXTBL WHERE "Landing _Outcome" LIKE 'Success (drone ship)' and payload_mass__kg_ > 4000 and payload_mass__kg_ < 6000

This query lists the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000

Total Number of Successful and Failure Mission Outcomes

```
%sql SELECT mission_outcome,Count(DATE) as Count FROM SPACEXTBL GROUP BY mission_outcome
```

```
 * sqlite:///my_data1.db
Done.
```

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

- **%sql SELECT mission_outcome,Count(DATE) as Count FROM SPACEXTBL GROUP BY mission_outc**

This query lists the total number of successful and failure mission outcomes

Boosters Carried Maximum Payload

```
%sql SELECT booster_version,payload_mass__kg_ from SPACEXTBL WHERE payload_mass__kg_ = (SELECT max(payload_mass__kg_) FROM SPACEXTBL)
```

```
 * sqlite:///my_data1.db
Done.
```

Booster_Version	PAYLOAD_MASS__KG_
F9 B5 B1048.4	15600
F9 B5 B1049.4	15600
F9 B5 B1051.3	15600
F9 B5 B1056.4	15600
F9 B5 B1048.5	15600
F9 B5 B1051.4	15600
F9 B5 B1049.5	15600
F9 B5 B1060.2	15600
F9 B5 B1058.3	15600
F9 B5 B1051.6	15600
F9 B5 B1060.3	15600
F9 B5 B1049.7	15600

- **%sql SELECT booster_version,payload_mass__kg_ from SPACEXTBL WHERE payload_mass__kg_ = (SELECT max(payload_mass__kg_) FROM SPACEXTBL)**

This query lists the names of the booster_versions which have carried the maximum payload mass.

2015 Launch Records

```
%sql select substr(Date, 4, 2) as month, "Landing _Outcome", booster_version, launch_site, date FROM SPACEXTBL WHERE "Landing _Outcome" = 'Failure (
```

```
 * sqlite:///my_data1.db
Done.
```

month	Landing _Outcome	Booster_Version	Launch_Site	Date
01	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40	10-01-2015
04	Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40	14-04-2015

- **%sql select substr(Date, 4, 2) as month, "Landing _Outcome", booster_version, launch_site, date FROM SPACEXTBL WHERE "Landing _Outcome" = 'Failure (drone ship)' and substr(Date,7,4)='2015'**

This query lists the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015

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

```
%sql select count("Landing _Outcome") as COUNT, "Landing _Outcome" from SPACEXTBL where WHERE "Landing _Outcome" LIKE 'Success%' and substr(Date,7,4
```

```
 * sqlite:///my_data1.db
Done.
```

COUNT	Landing _Outcome
4	Controlled (ocean)
5	Failure (drone ship)
12	No attempt
1	Precluded (drone ship)
12	Success (drone ship)
8	Success (ground pad)
2	Uncontrolled (ocean)

- **%sql select count("Landing _Outcome") as COUNT, "Landing _Outcome" from SPACEXTBL where WHERE "Landing _Outcome" LIKE 'Success%' and substr(Date,7,4)>'2010-06-04' and substr(Date,7,4)<'2017-03-20' GROUP BY "Landing _Outcome"**

This query ranks 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

Section 3

Launch Sites Proximities Analysis

Launch sites and their locations

From the map we can see all launch sites are in close proximity to the coast

Color-Labeled launch outcomes on Map

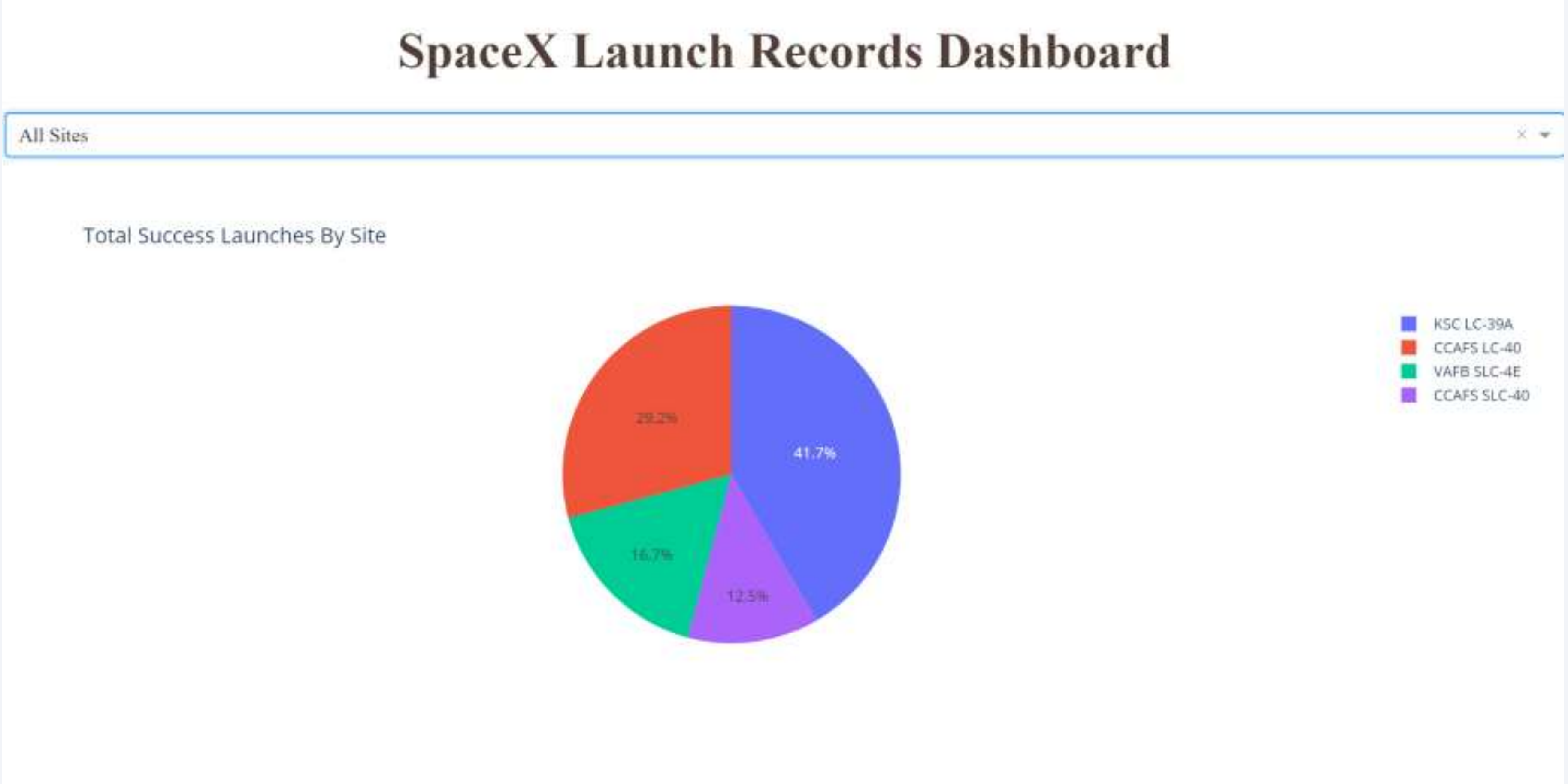
From the color-labeled markers in marker clusters, you should be able to easily identify which launch sites have relatively high success rates.

Launch site and it’s proximities

Section 4

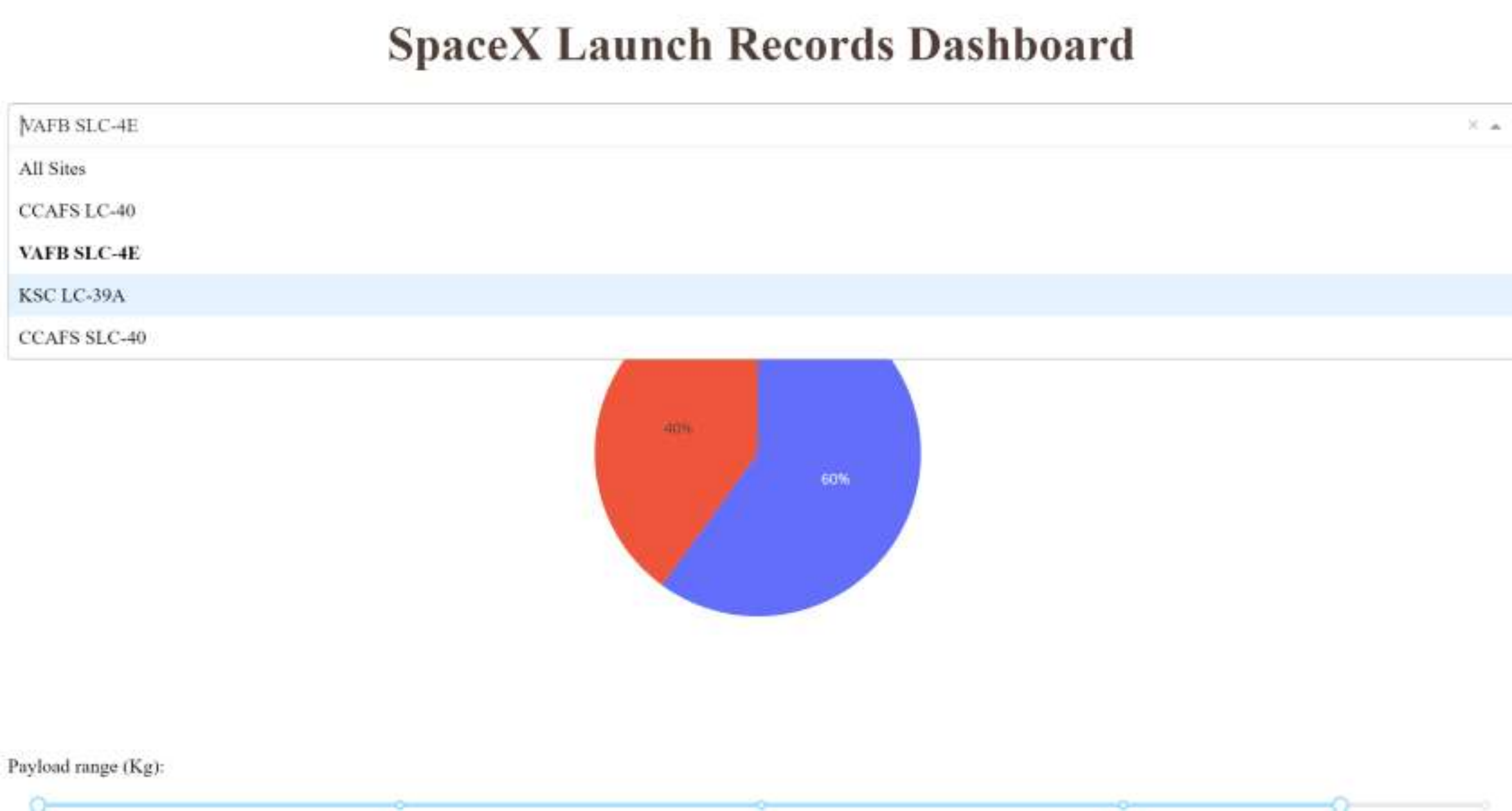
Build a Dashboard with Plotly Dash

Total Success Launches By Site



From the pie chart we can see that KSC LC-39A was the site with the most successful launches.

Interactive Drop-down feature



This screenshot illustrates the interactive drop-down feature of the web app showing all Launch site options.

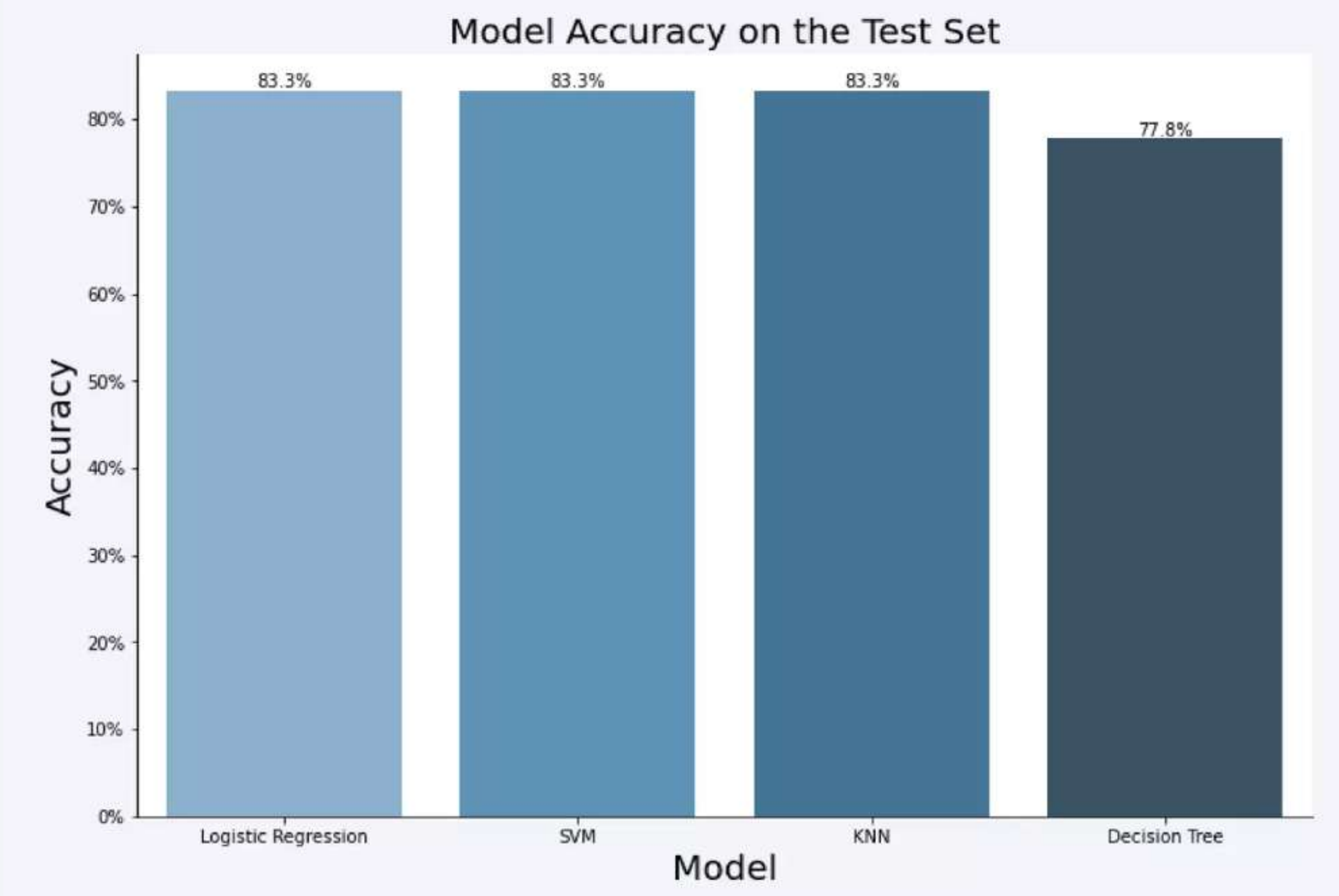
Payload vs Launch Outcome with payload range slider

Overview of Payload vs. Launch Outcome scatter plot for all sites, with all payloads selected in the range slider. From the chart, greater payload mass of above 6000kg have no success

Section 5

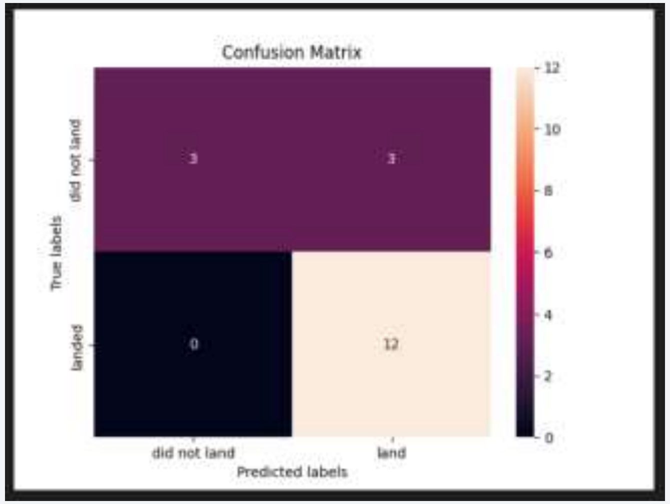
Predictive Analysis (Classification)

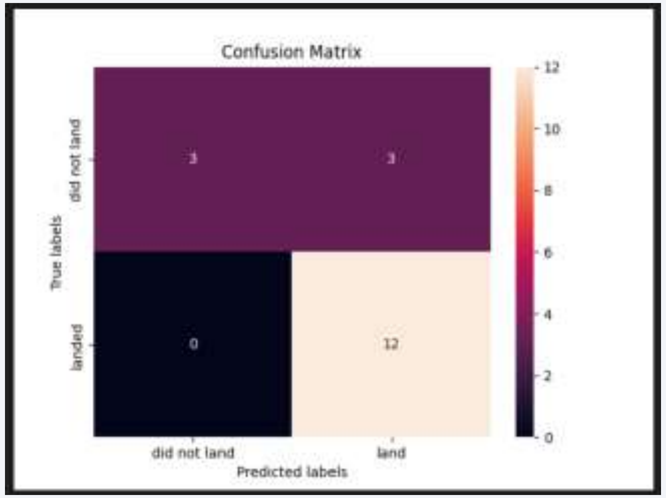
Classification Accuracy

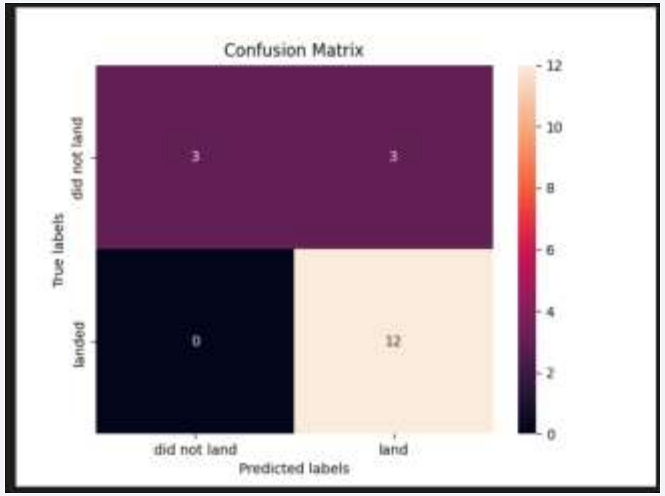


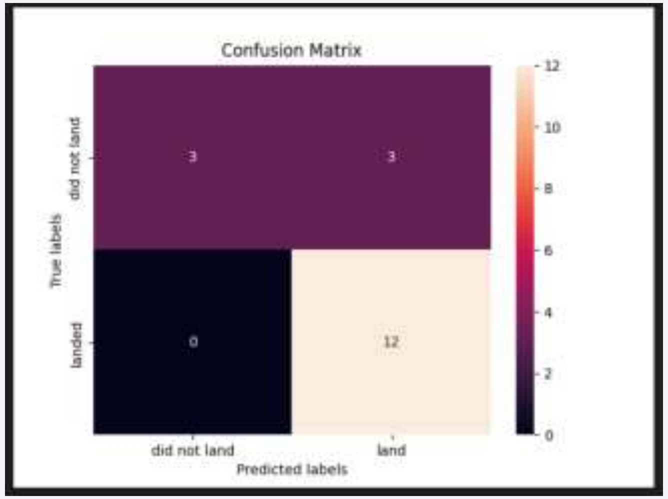
From the bar chart, SVM, KNN, and Logistic Regression models are the best performers

Confusion Matrix









Conclusions

- The SVM, KNN, and Logistic Regression models are the best in terms of prediction accuracy for this dataset.
- Low-weighted payloads perform better than heavier payloads.
- The success rates for SpaceX launches are directly proportional time in years they will eventually perfect the launches.
- KSC LC 39A had the most successful launches from all the sites.
- Orbit GEO, HEO, SSO, ES L1 has the best Success Rate.

Thank you!