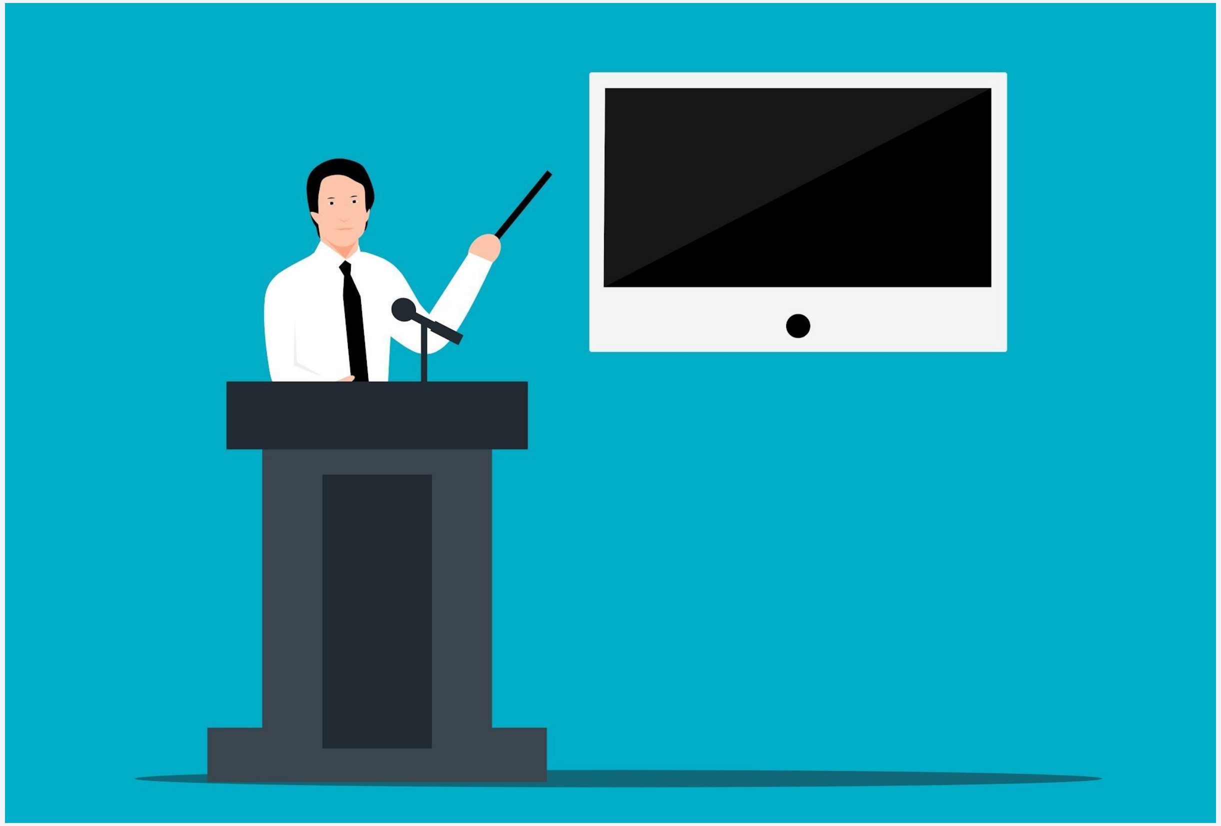
Winning Space Race with Data Science

Parshv Patel
6 January 2025

Outline

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



Executive Summary

Summary of methodologies:

- Data collection using Rest API and Web Scraping
- Data wrangling and preparation
- Exploratory Data Analysis with Data Visualization
- Exploratory Data Analysis with SQL
- Building an interactive map with Folium
- Building a Dashboard with Plotly Dash
- Modeling Classification Predictive analysis

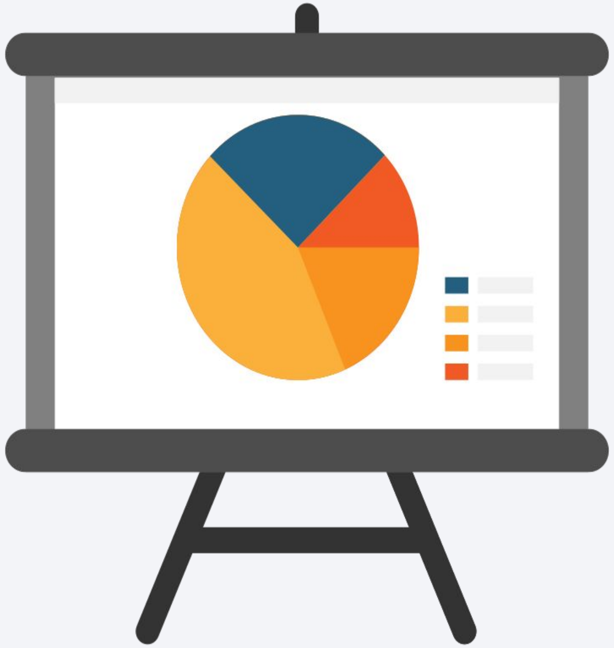
Summary of all results:

- Exploratory Data Analysis results
- Interactive analytics demo in screenshots
- Model evaluation and Predictive analysis results

Introduction

Project background and context:

SpaceX is the most successful company of the commercial space age, making space travel affordable. The company advertises Falcon 9 rocket launches on its website, with a cost of 62 million dollars; other providers cost upward of 165 million dollars each, much of the savings is because SpaceX can reuse the first stage. Therefore, if we can determine if the first stage will land, we can determine the cost of a launch. Based on public information and machine learning models, we are going to predict if SpaceX will reuse the first stage.



Questions to be answered:

- How do variables such as payload mass, launch site, number of flights, and orbits affect the success of the first stage landing?
- Does the rate of successful landings increase over the years?
- What is the best algorithm that can be used for binary classification in this case?

Section 1

Methodology

Methodology

Data collection methodology:

- Using SpaceX Rest API
- Using Web Scraping from Wikipedia

Perform data wrangling:

- Filtering the data
- Dealing with missing values
- Using One Hot Encoding to prepare the data to a binary classification

Perform exploratory data analysis (EDA) using visualization and SQL

Perform interactive visual analytics using Folium and Plotly Dash

Perform predictive analysis using classification models:

- Modeling different types of classification, hyperparameter tuning using GridSerach, and evaluating the model using accuracy, F1-score, and jaccard index to ensure the best results.

Data Collection

Data collection process involved a combination of API requests from SpaceX REST API and Web Scraping data from a table in SpaceX’s Wikipedia entry.

We had to use both of these data collection methods in order to get complete information about the launches for a more detailed analysis.

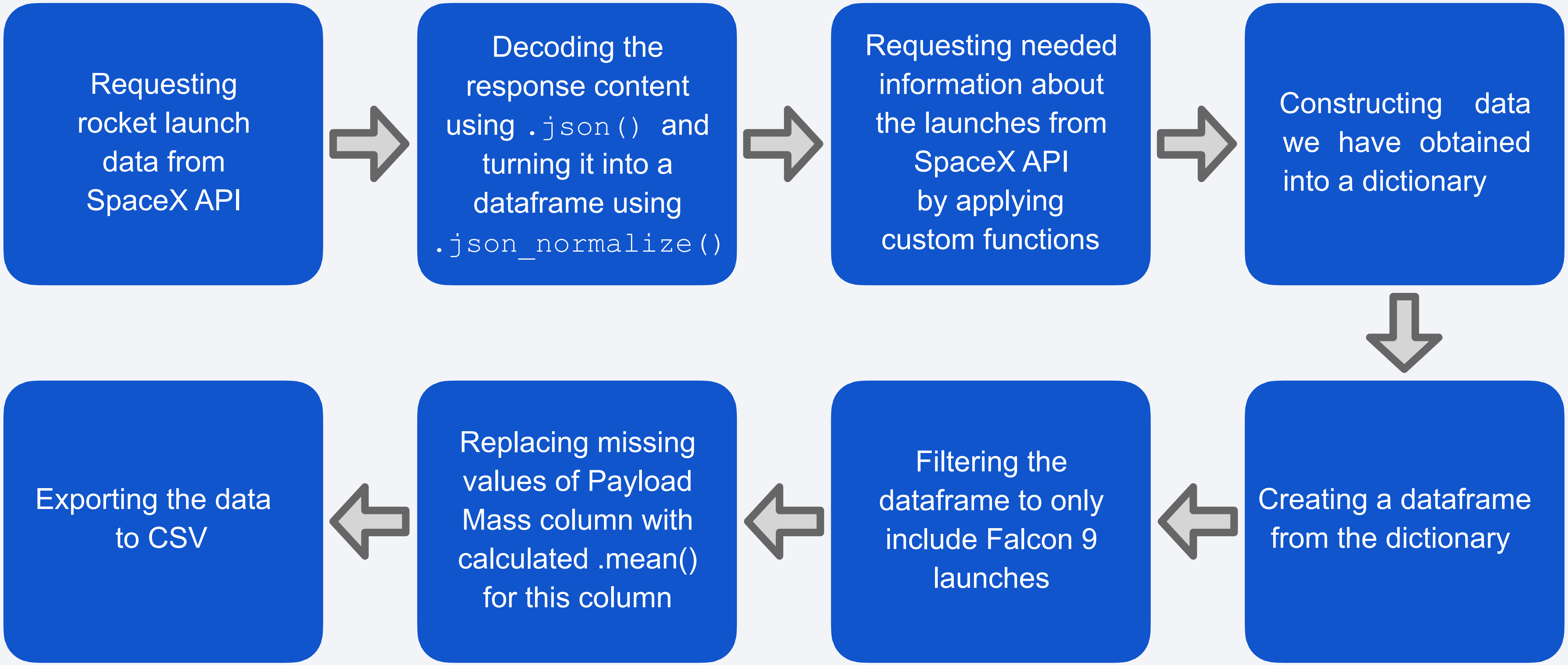
Data columns are obtained by using SpaceX REST API:

FlightNumber, Date, BoosterVersion, PayloadMass, Orbit, LaunchSite, Outcome, Flights, GridFins, Reused, Legs, LandingPad, Block, ReusedCount, Serial, Longitude, Latitude

Data columns are obtained by using Wikipedia Web Scraping:

Flight No., Launch site, Payload, PayloadMass, Orbit, Customer, Launch outcome, Version Booster, Booster landing, Date, Time

Data Collection- SpaceX API



Requesting rocket launch data from SpaceX API

Decoding the response content using `.json()` and turning it into a dataframe using `.json_normalize()`

Requesting needed information about the launches from SpaceX API by applying custom functions

Constructing data we have obtained into a dictionary

Creating a dataframe from the dictionary

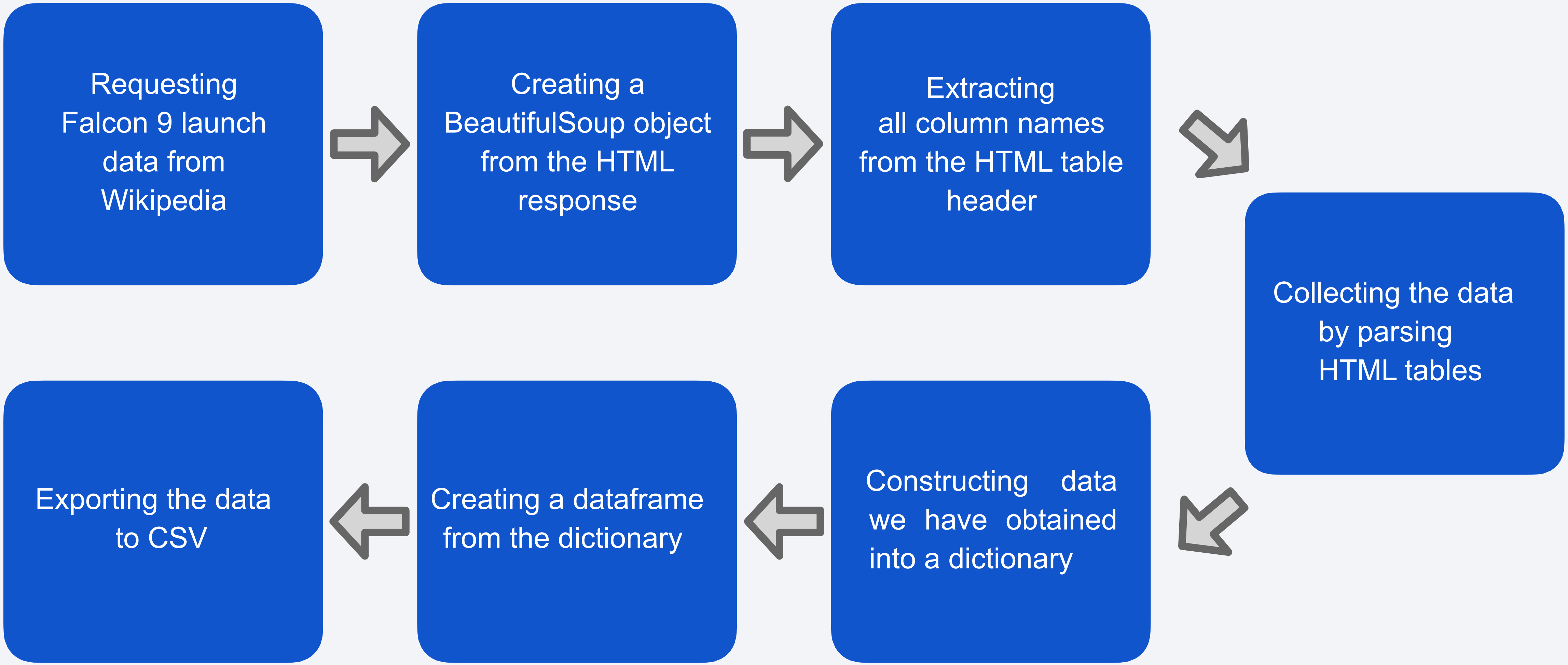
Filtering the dataframe to only include Falcon 9 launches

Replacing missing values of Payload Mass column with calculated .mean() for this column

Exporting the data to CSV

GitHub URL: Data Collection API

Data Collection - Web Scraping



Requesting Falcon 9 launch data from Wikipedia

Creating a BeautifulSoup object from the HTML response

Extracting all column names from the HTML table header

Collecting the data by parsing HTML tables

Constructing data we have obtained into a dictionary

Creating a dataframe from the dictionary

Exporting the data to CSV

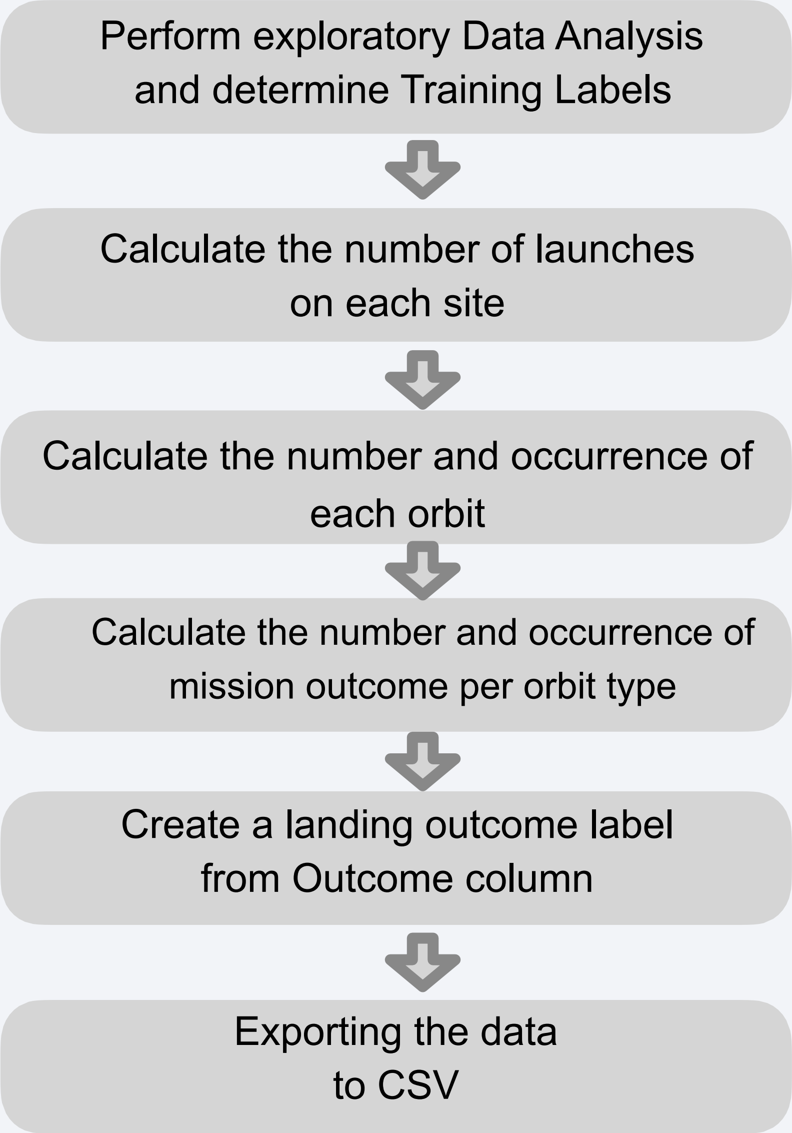
GitHub URL: Data Collection with Web Scraping

Data Wrangling

In the data set, there are several different cases where the booster did not land successfully. Sometimes a landing was attempted but failed due to an accident; for example, True Ocean means the mission outcome was successfully landed to a specific region of the ocean while False Ocean means the mission outcome was unsuccessfully landed to a specific region of the ocean. True RTLS means the mission outcome was successfully landed to a ground pad False RTLS means the mission outcome was unsuccessfully landed to a ground pad.True ASDS means the mission outcome was successfully landed on a drone ship False ASDS means the mission outcome was unsuccessfully landed on a drone ship.

We mainly convert those outcomes into Training Labels with “1” means the booster successfully landed, “0” means it was unsuccessful.

[GitHub URL: Data Wrangling]



Perform exploratory Data Analysis and determine Training Labels

Calculate the number of launches on each site

Calculate the number and occurrence of each orbit

Calculate the number and occurrence of mission outcome per orbit type

Create a landing outcome label from Outcome column

Exporting the data to CSV

EDA with Data Visualization

Charts plotted:

- Flight Number vs. Payload Mass,
- Flight Number vs. Launch Site,
- Payload Mass vs. Launch Site,
- Orbit Type vs. Success Rate,
- Flight Number vs. Orbit Type,
- Payload Mass vs Orbit Type and Success Rate Yearly Trend

Scatter plots show the relationship between variables. If a relationship exists, they could be used in machine learning model.

Bar charts show comparisons among discrete categories. The goal is to show the relationship between the specific categories being compared and a measured value.

Line charts show trends in data over time (time series).

GitHub URL: EDA with Data Visualization

EDA with SQL

Performed SQL Queries:

- Displaying the names of the unique launch sites in the space mission
- Displaying 5 records where launch sites begin with the string ‘CCA'
- Displaying the total payload mass carried by boosters launched by NASA (CRS)
- Displaying average payload mass carried by booster version F9 v1.1
- Listing the date when the first successful landing outcome in ground pad was achieved
- Listing the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000
- Listing the total number of successful and failure mission outcomes
- Listing the names of the booster versions which have carried the maximum payload mass
- Listing the failed landing outcomes in drone ship, their booster versions and launch site names for the months in year 2015
- Ranking 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

GitHub URL: EDA with SQL

Build an Interactive Map with Folium

Markers of all Launch Sites:

- Added Marker with Circle, Popup label and Text label of NASA Johnson Space Center using its latitude and longitude coordinates as a start location.
- Added Markers with Circle, Popup label and Text label of all Launch Sites using their latitude and longitude coordinates to show their geographical locations and proximity to Equator and coasts.

Coloured Markers of the launch outcomes for each Launch Site:

- Added coloured Markers of success (Green) and failed (Red) launches using Marker Cluster to identify which launch sites have relatively high success rates.

Distances between a Launch Site to its proximities:

- Added coloured Lines to show distances between the Launch Site KSC LC-39A (as an example) and its proximities like Railway, Highway, Coastline and Closest City.

GitHub URL: Interactive Visual Analytics with Folium

Build a Dashboard with Plotly Dash

Launch Sites Dropdown List:

- Added a dropdown list to enable Launch Site selection.

Pie Chart showing Success Launches (All Sites/Certain Site):

- Added a pie chart to show the total successful launches count for all sites and the Success vs. Failed counts for the site, if a specific Launch Site was selected.

Slider of Payload Mass Range:

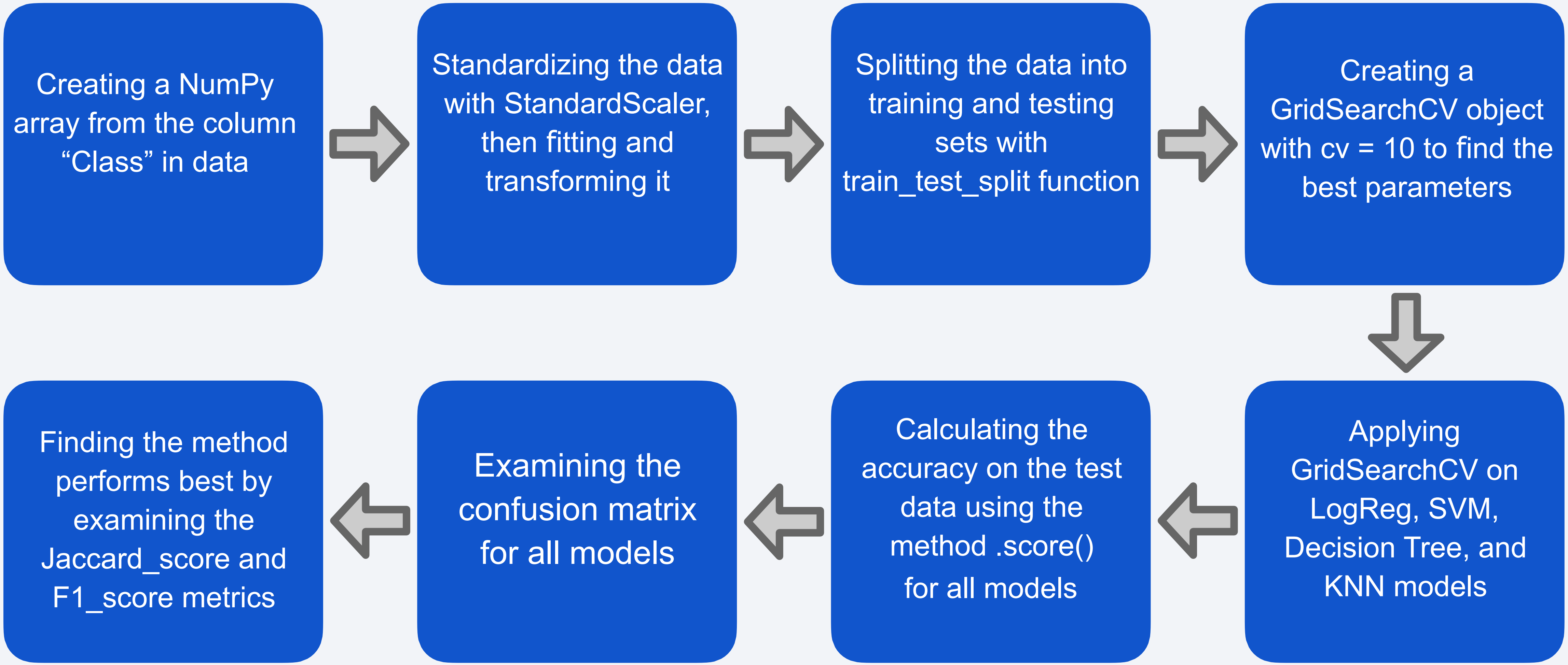
- Added a slider to select Payload range.

Scatter Chart of Payload Mass vs. Success Rate for the different Booster Versions:

- Added a scatter chart to show the correlation between Payload and Launch Success.

GitHub URL: SpaceX Dash Application

Predictive Analysis (Classification)



Creating a NumPy array from the column “Class” in data

Standardizing the data with StandardScaler, then fitting and transforming it

Splitting the data into training and testing sets with train_test_split function

Creating a GridSearchCV object with cv = 10 to find the best parameters

Applying GridSearchCV on LogReg, SVM, Decision Tree, and KNN models

Calculating the accuracy on the test data using the method .score() for all models

Examining the confusion matrix for all models

Finding the method performs best by examining the Jaccard_score and F1_score metrics

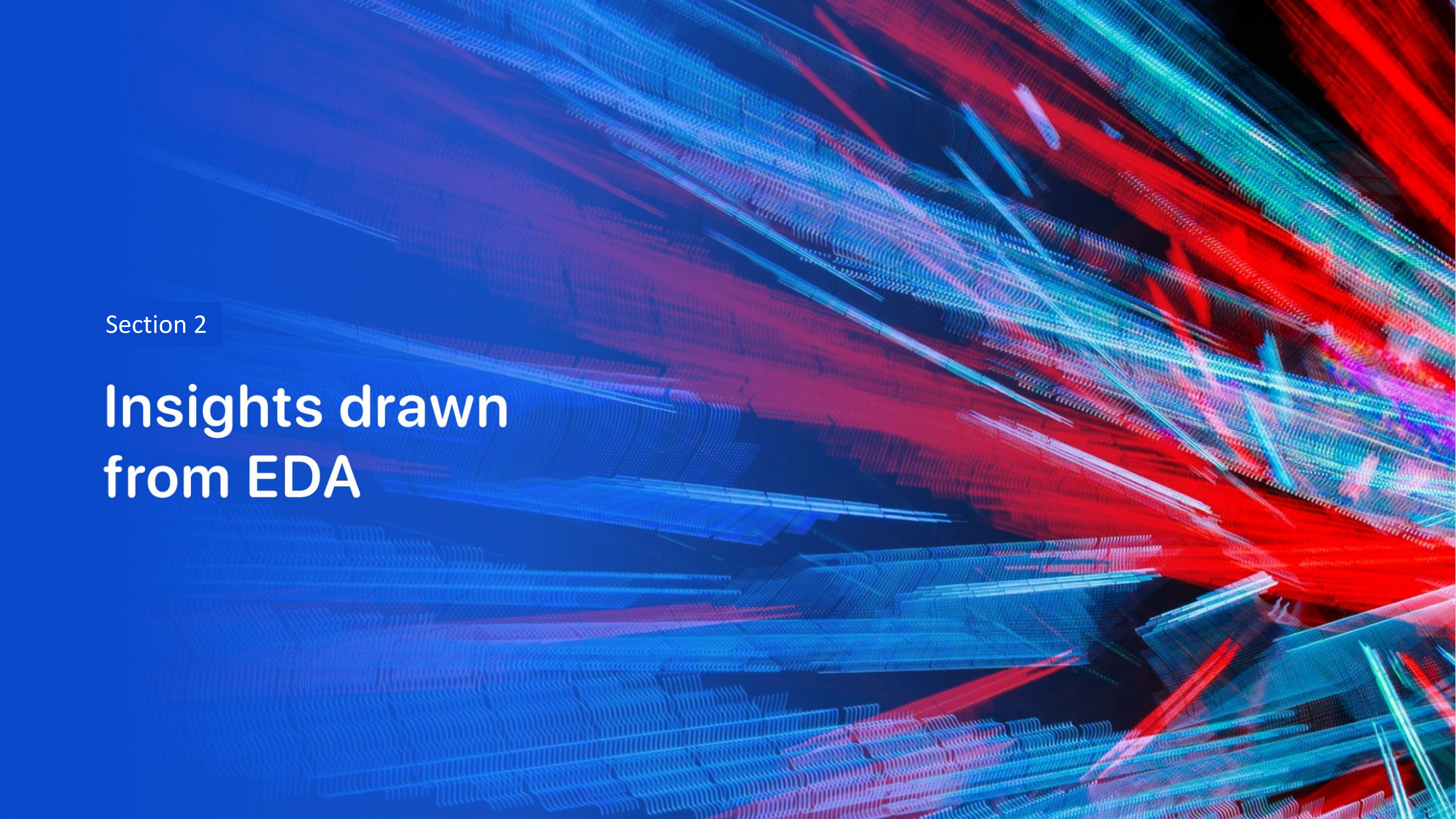
GitHub URL: Machine Learning Prediction

Results

- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

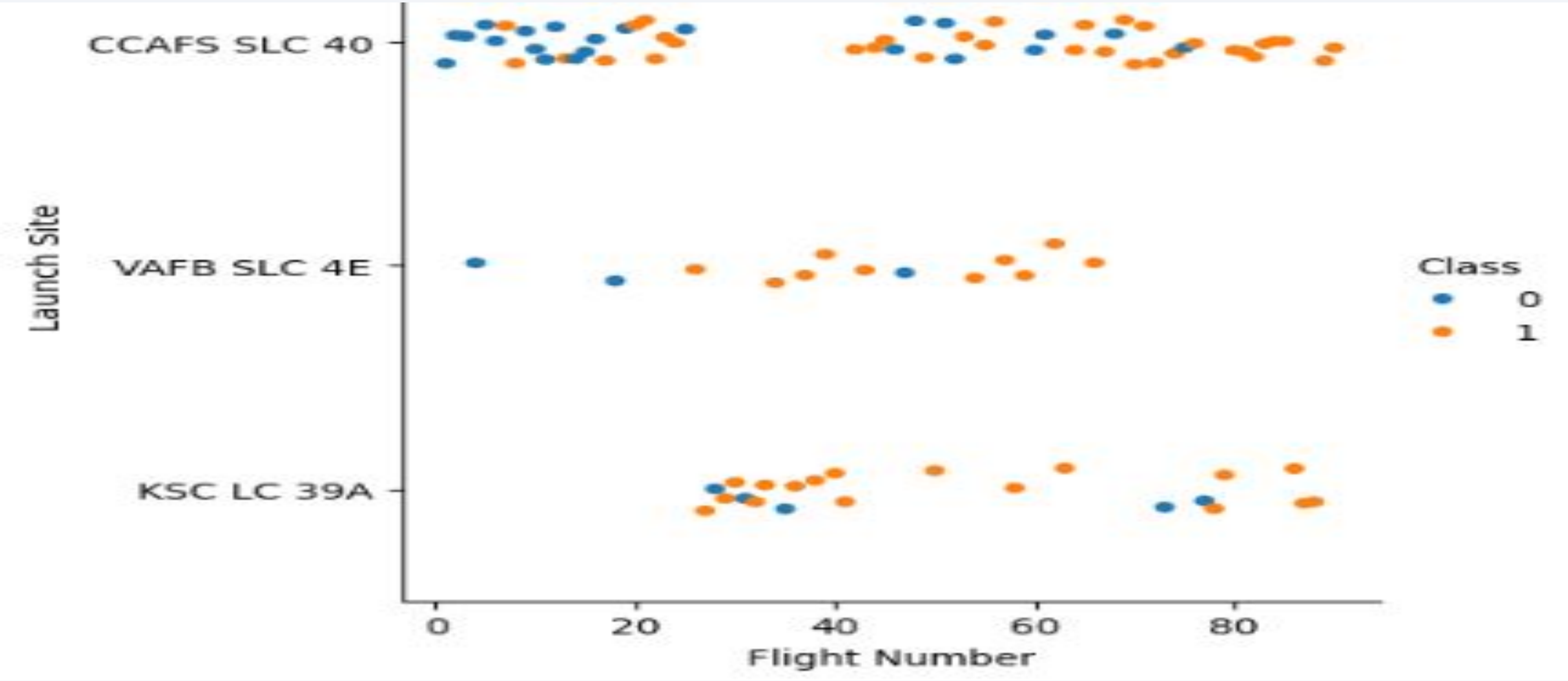
Section 2

Insights drawn from EDA



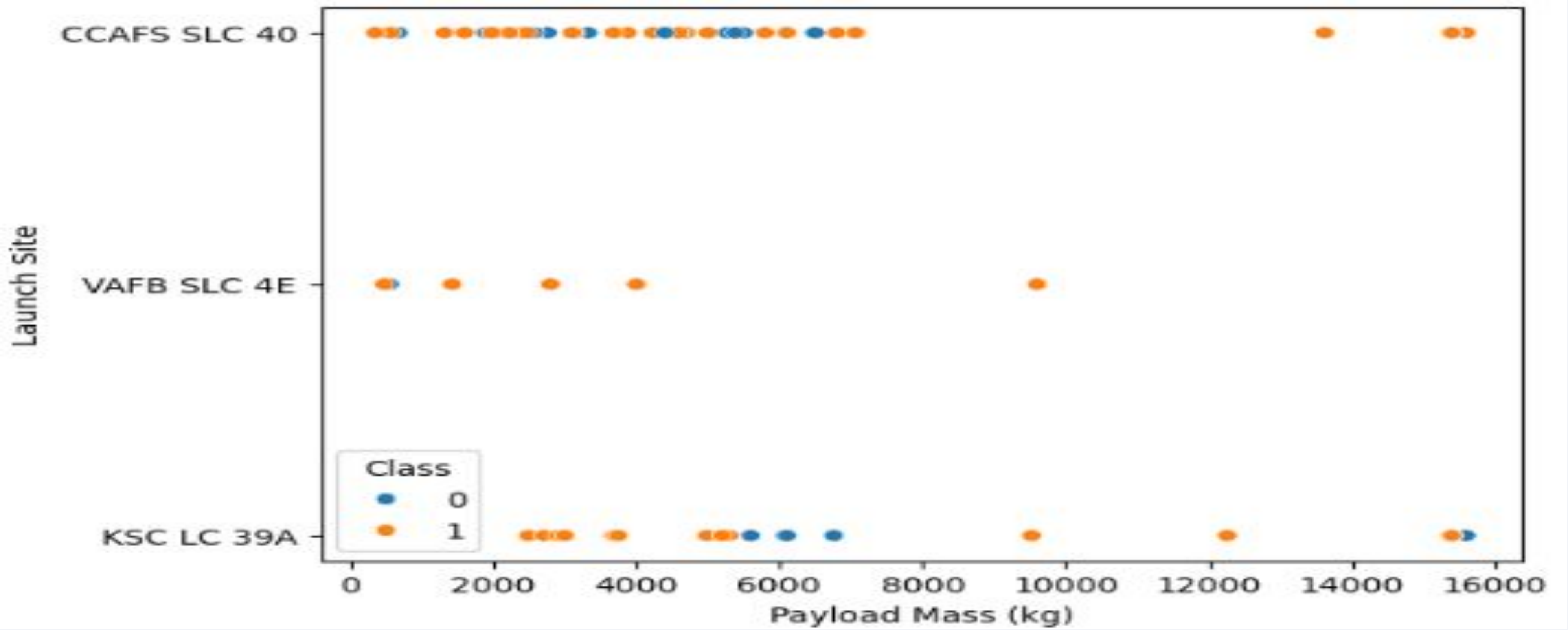
EDA with Visualization

Flight Number vs. Launch Site



- The earliest flights all failed while the latest flights all succeeded.
- The CCAFS SLC 40 launch site has about a half of all launches and higher chance of failure when the flight number was low.
- VAFB SLC 4E and KSC LC 39A have higher success rates.
- It can be assumed that each new launch has a higher rate of success.

Payload Mass vs. Launch Site

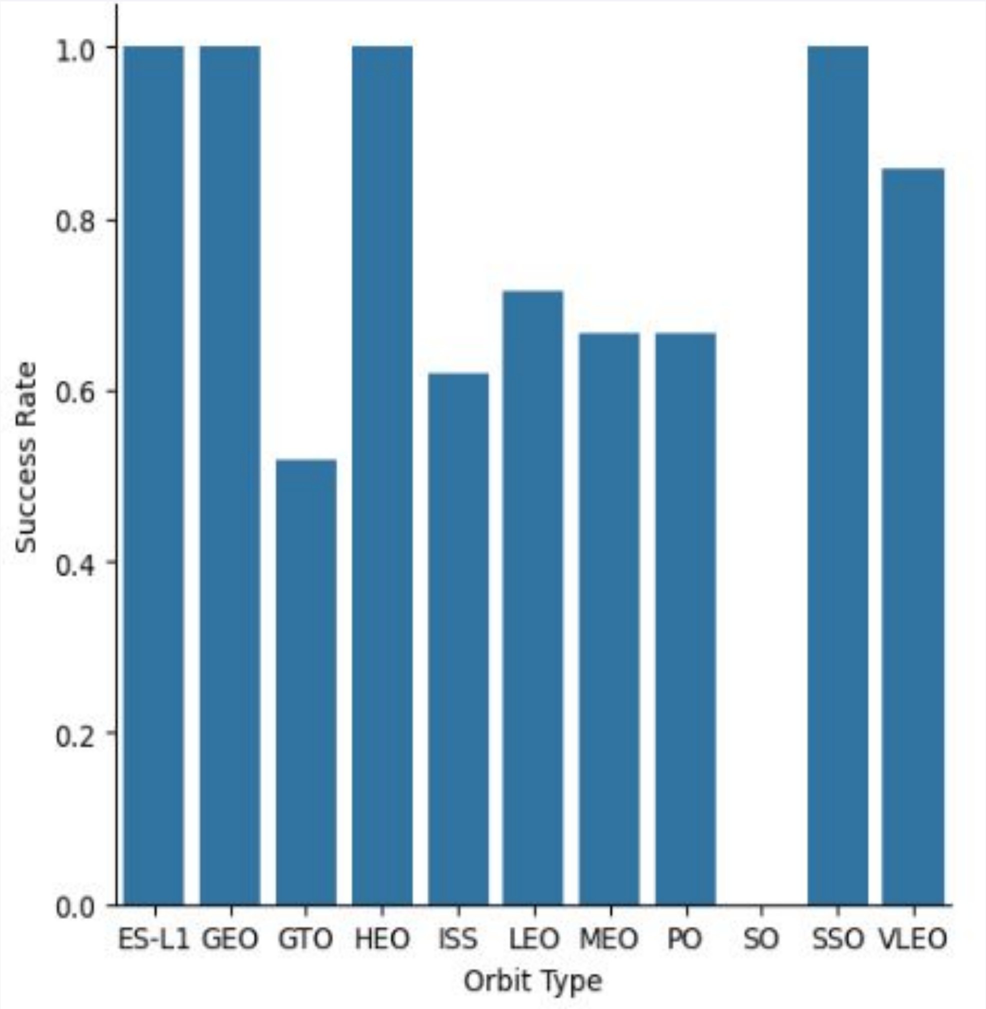


- For every launch site the higher the payload mass, the higher the success rate.
- Most of the launches with payload mass over 7000 kg were successful.
- KSC LC 39A has a 100% success rate for payload mass under 5500 kg too.
- VAFB-SLC has no rockets launched for heavypayload mass (greater than 10000 kg).

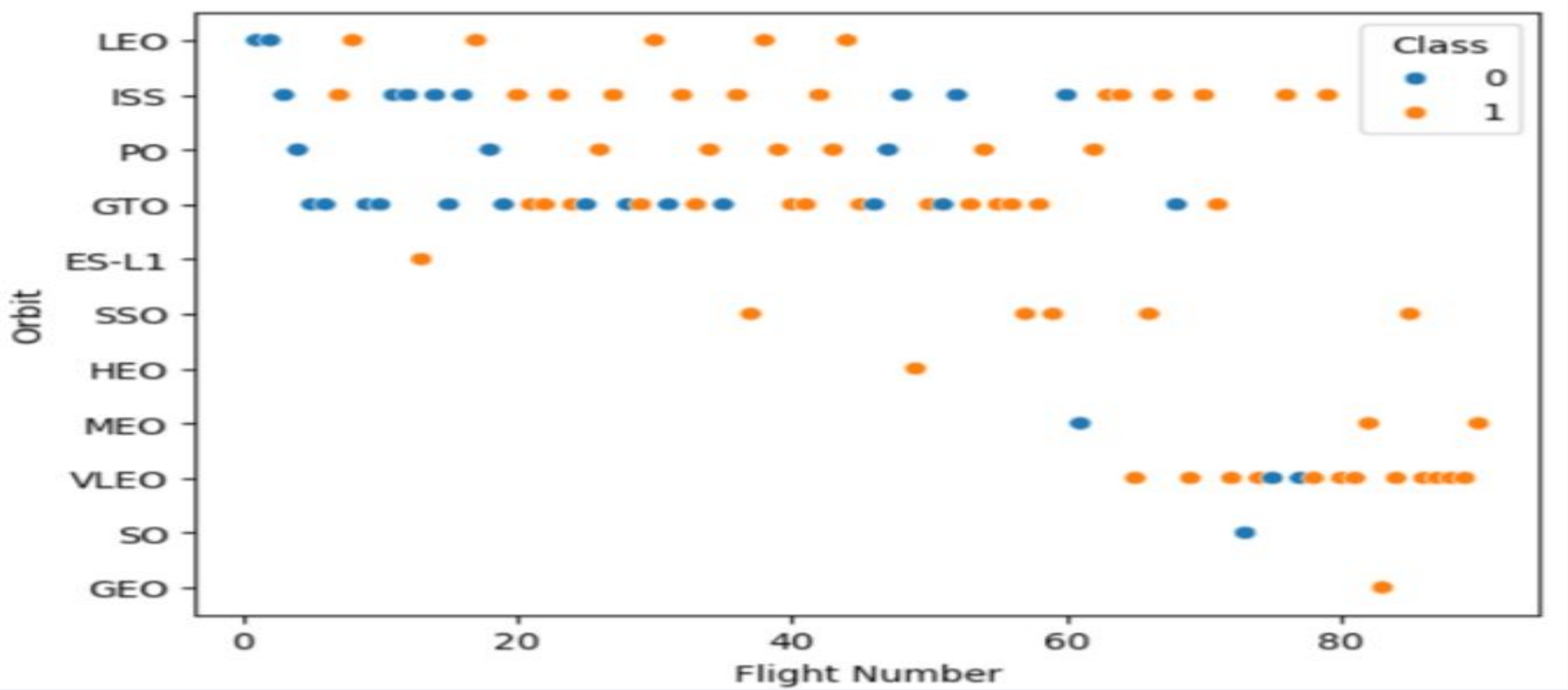
Success Rate vs. Orbit Type

Explanation:

- Orbits with 100% success rate:
  - ES-L1
  - GEO
  - HEO
  - SSO
- Orbits with 0% success rate:
  - SO
- Orbits with success rate between 50% and 85%:
  - GTO
  - ISS
  - LEO
  - MEO
  - PO

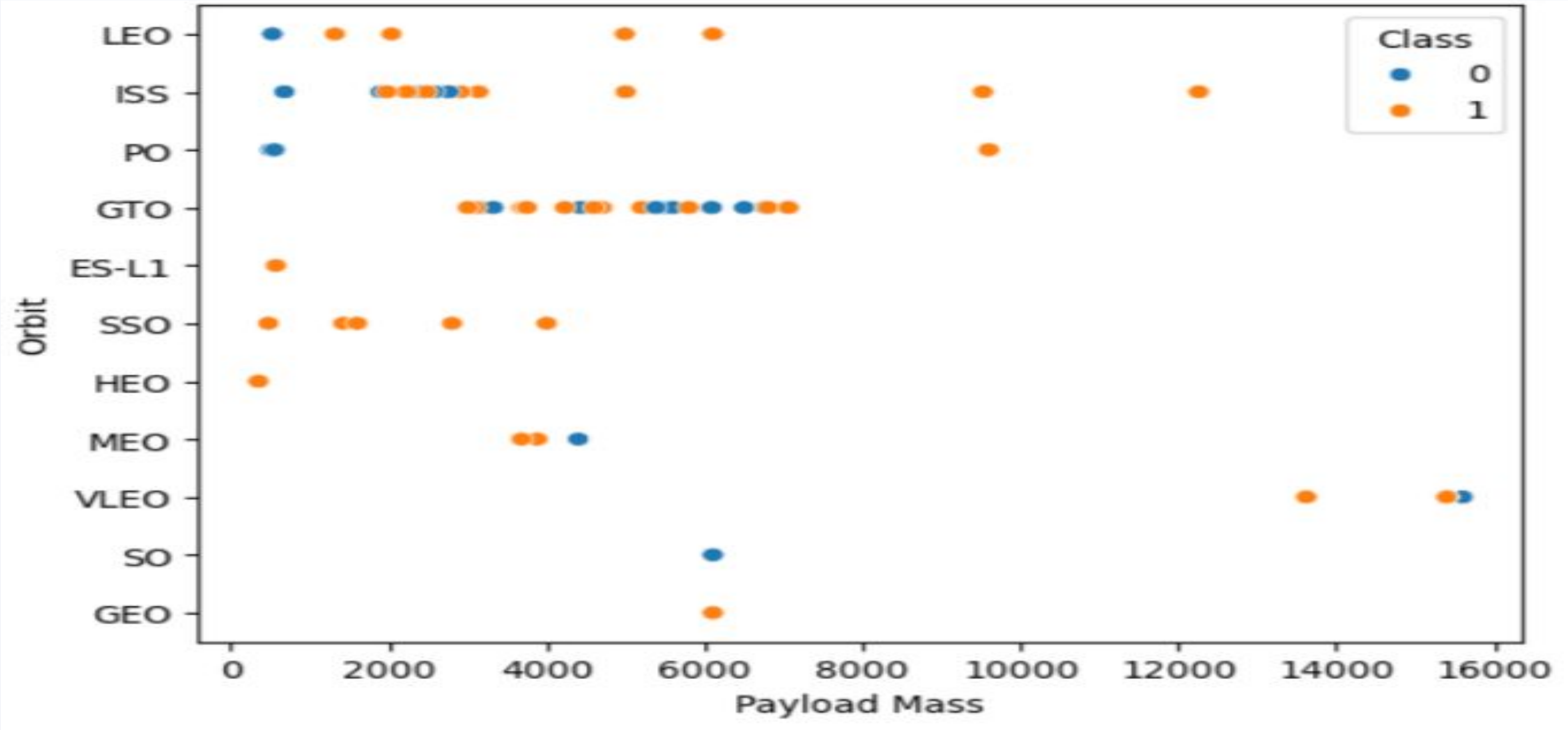


Flight Number vs. Orbit Type



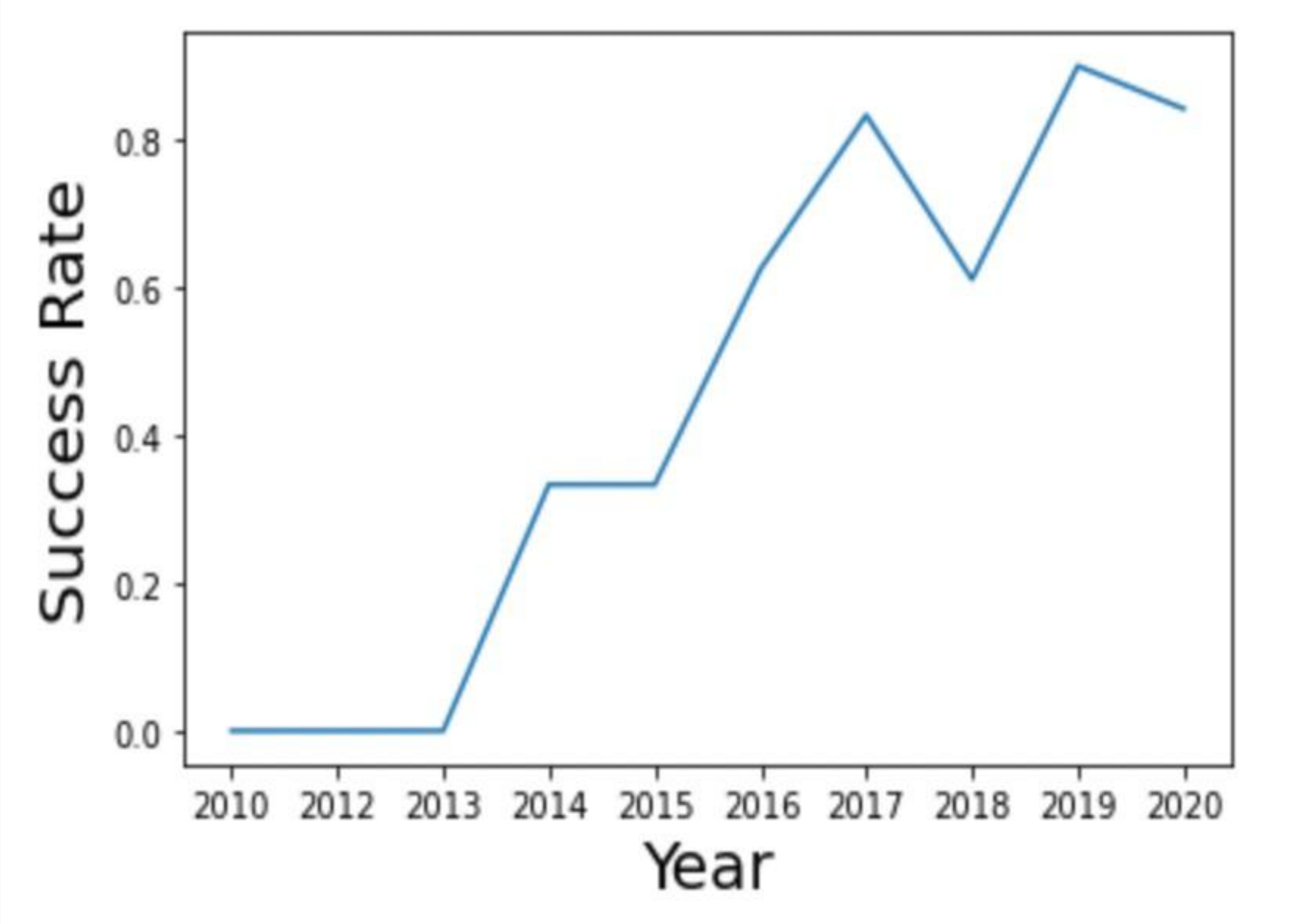
- In the LEO orbit, success appears related to the number of flights; on the other hand, there seems to be no relationship between flight number and success in GTO orbit.

Payload Mass vs. Orbit Type



- Heavy payloads have a negative influence on GTO orbits and positive on Polar, LEO, and ISS orbits.

Launch Success Yearly Trend

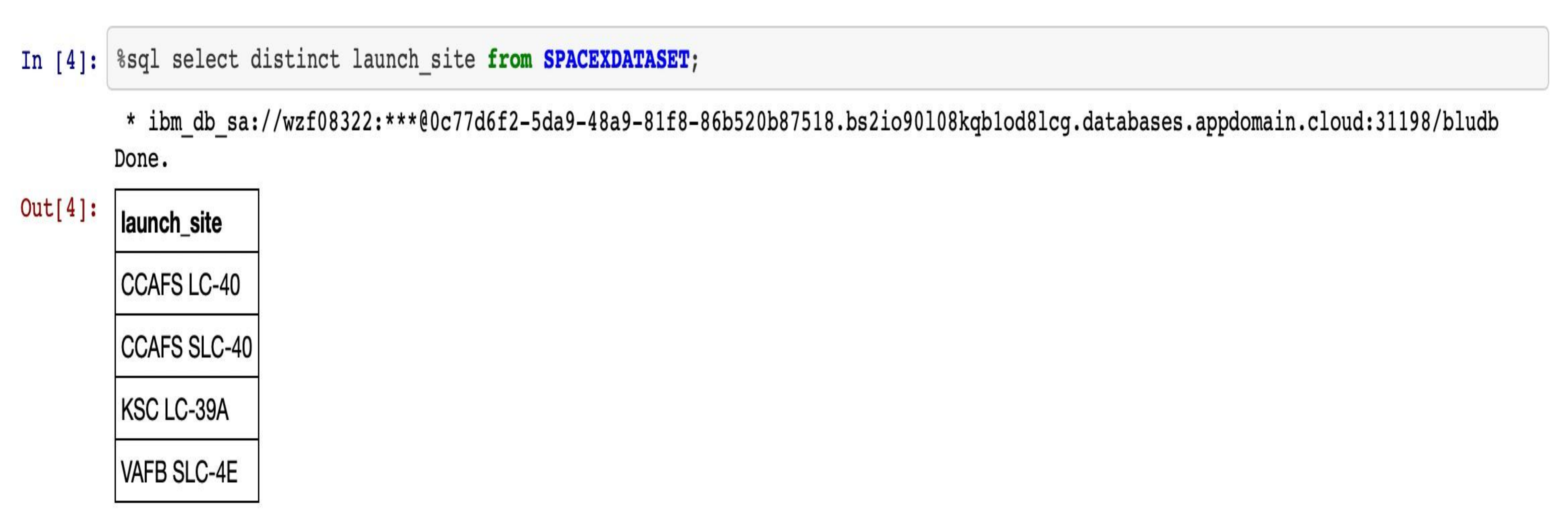


Explanation:

- The success rate since 2013 kept increasing till 2020.

EDA with SQL

All Launch Site Names



In [4]:
```
%sql select distinct launch_site from SPACEXDATASET;
```

```
 * ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
Done.
```

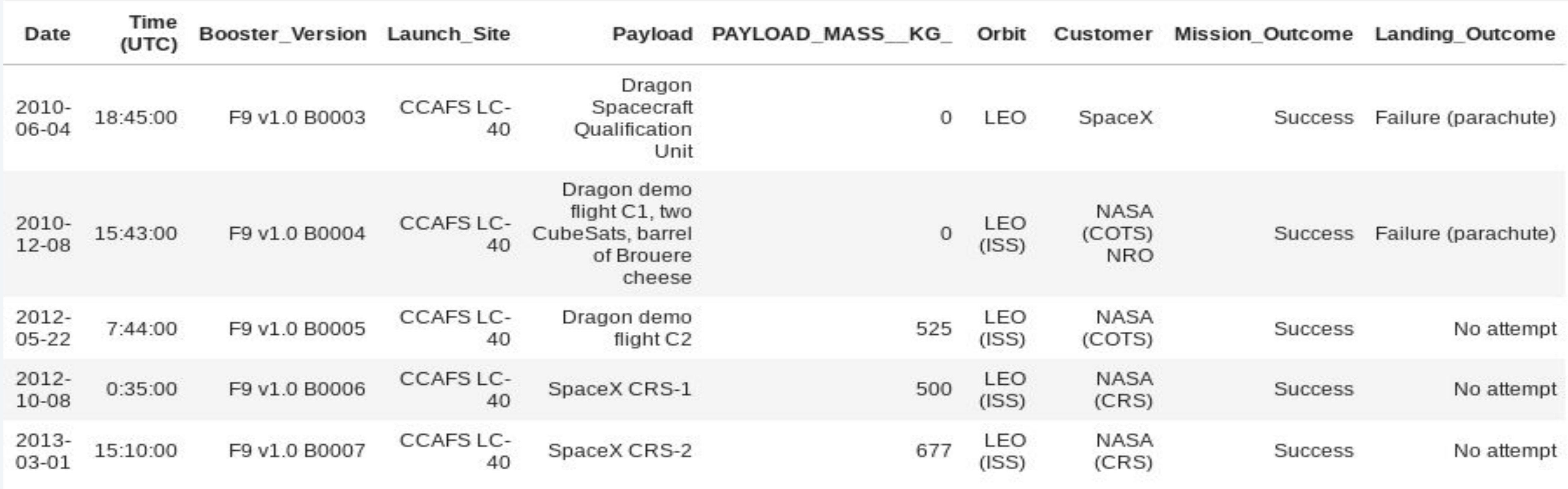
Out[4]:

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

Explanation:

- Displaying the names of the unique launch sites in the space mission.

Launch Site Names Begin with 'CCA'

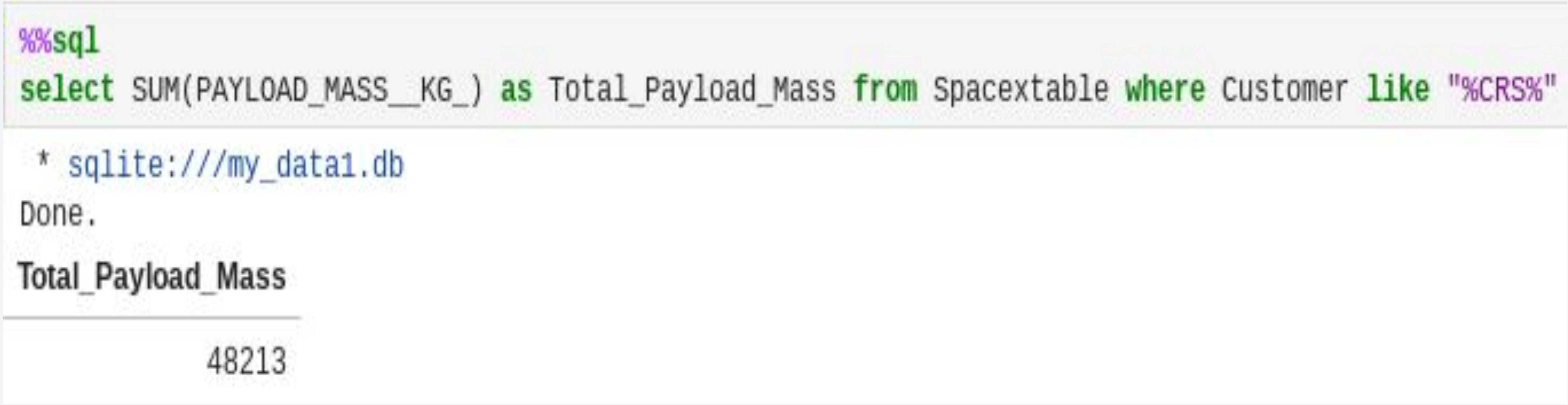


Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing_Outcome
2010-06-04	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-12-08	15:43:00	F9 v1.0 B0004	CCAFS LC-40	Dragon demo flight C1, two CubeSats, barrel of Brouere cheese	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2012-05-22	7:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	0:35:00	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

Explanation:

- Displaying 5 records where launch sites begin with the string 'CCA'.

Total Payload Mass



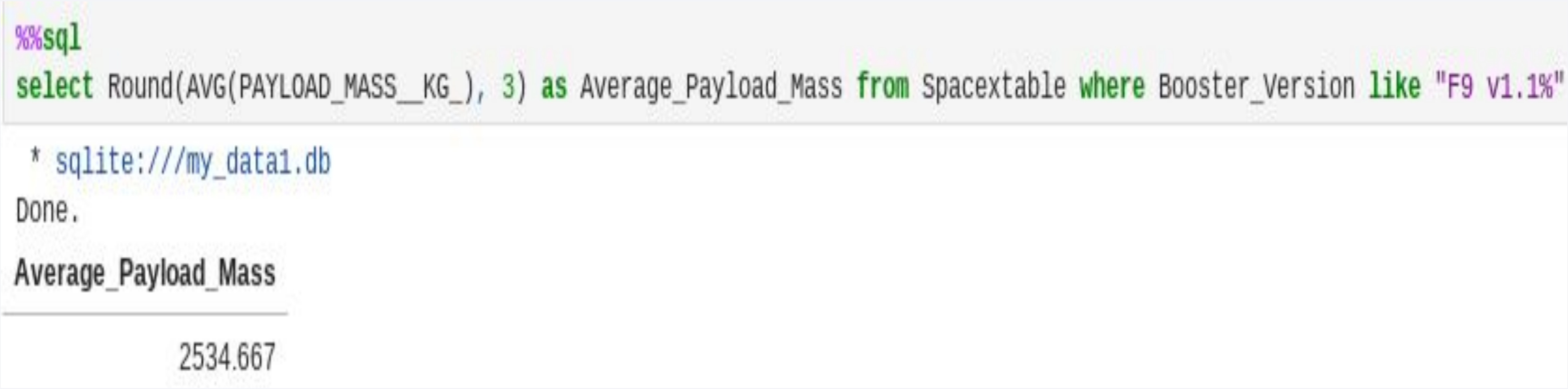
```
%%sql
select SUM(PAYLOAD_MASS__KG_) as Total_Payload_Mass from Spacextable where Customer like "%CRS%"
```

```
 * sqlite:///my_data1.db
Done.
Total_Payload_Mass
            48213
```

Explanation:

- Displaying the total payload mass carried by boosters launched by NASA (CRS).

Average Payload Mass by F9 v1.1



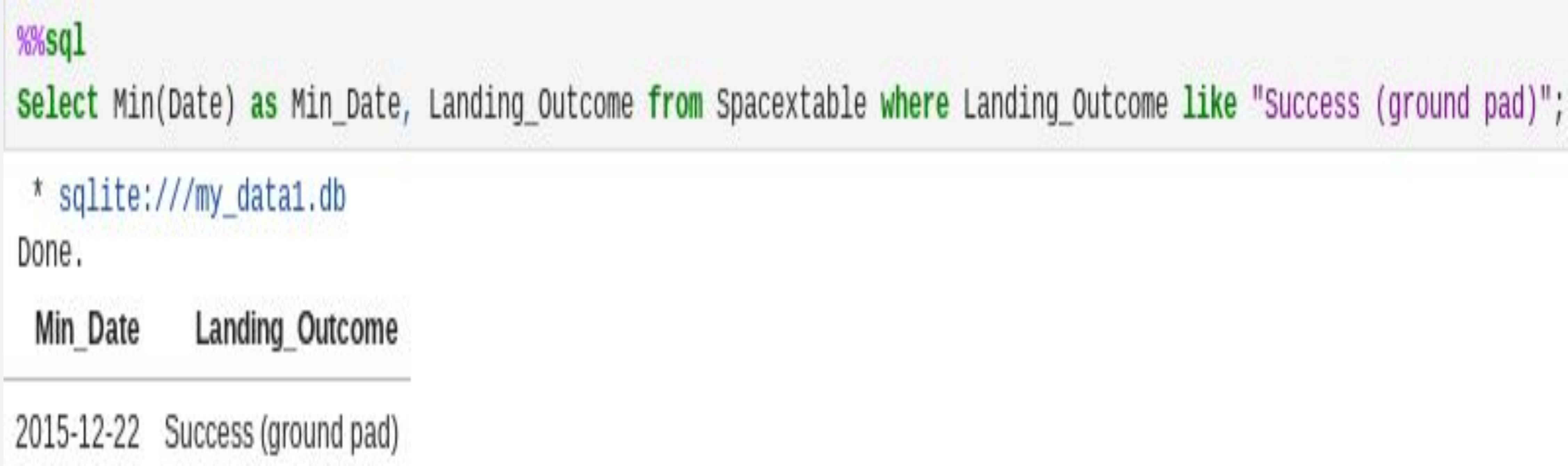
```
%%sql
select Round(AVG(PAYLOAD_MASS__KG_), 3) as Average_Payload_Mass from Spacextable where Booster_Version like "F9 v1.1%"
```

```
 * sqlite:///my_data1.db
Done.
Average_Payload_Mass
            2534.667
```

Explanation:

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

First Successful Ground Landing Date



```
%%sql
Select Min(Date) as Min_Date, Landing_Outcome from Spacextable where Landing_Outcome like "Success (ground pad)";
```

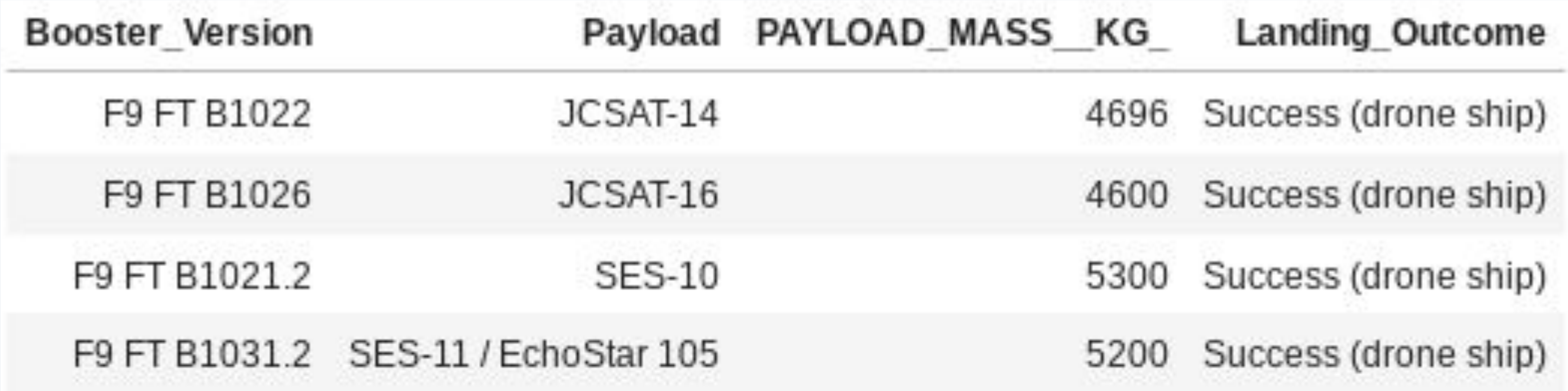
```
 * sqlite:///my_data1.db
Done.
```

Min_Date	Landing_Outcome
2015-12-22	Success (ground pad)

Explanation:

- Listing the date when the first successful landing outcome in ground pad was achieved.

Successful Drone Ship Landing with Payload between 4000 and 6000

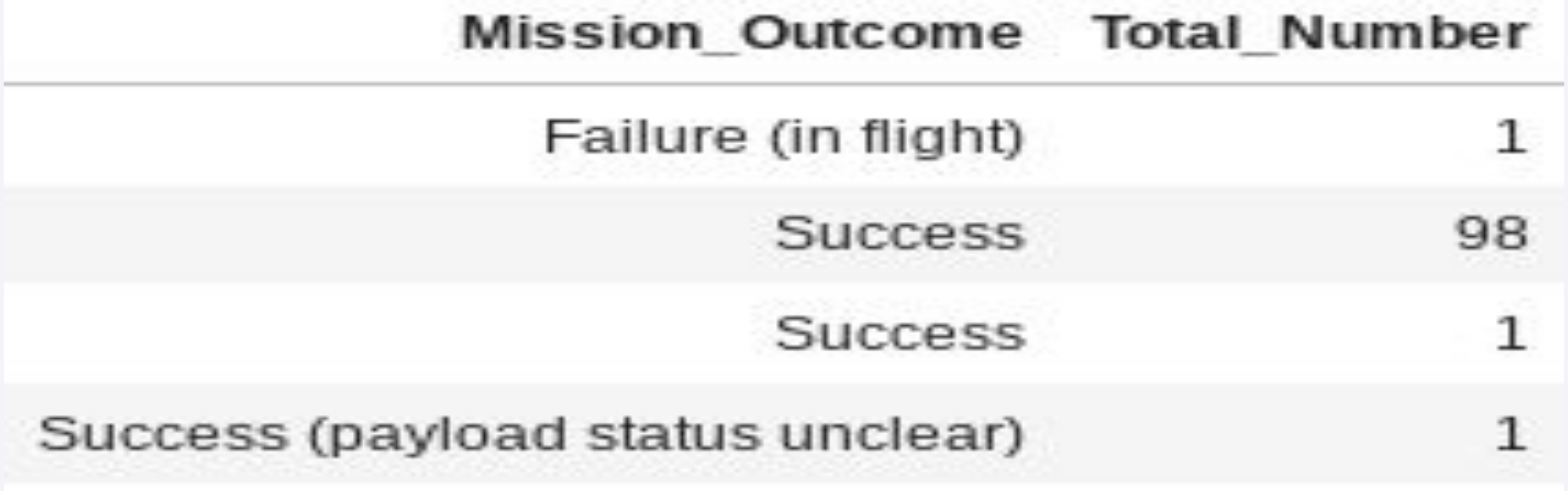


Booster_Version	Payload	PAYLOAD_MASS__KG_	Landing_Outcome
F9 FT B1022	JCSAT-14	4696	Success (drone ship)
F9 FT B1026	JCSAT-16	4600	Success (drone ship)
F9 FT B1021.2	SES-10	5300	Success (drone ship)
F9 FT B1031.2	SES-11 / EchoStar 105	5200	Success (drone ship)

Explanation:

- Listing 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

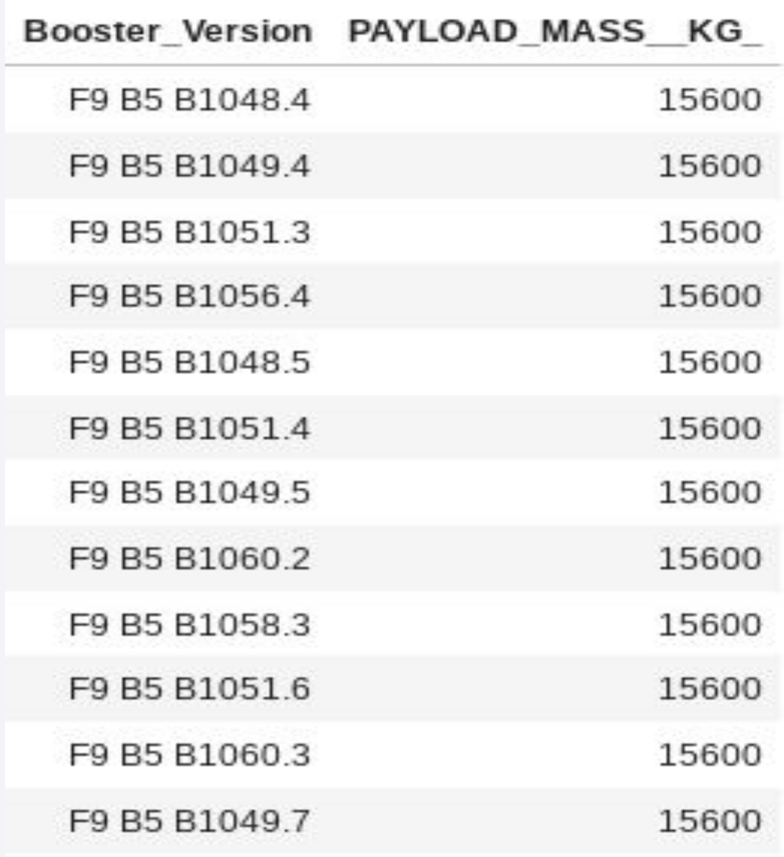


Mission_Outcome	Total_Number
Failure (in flight)	1
Success	98
Success	1
Success (payload status unclear)	1

Explanation:

- Listing the total number of successful and failure mission outcomes.

Boosters Carried Maximum Payload

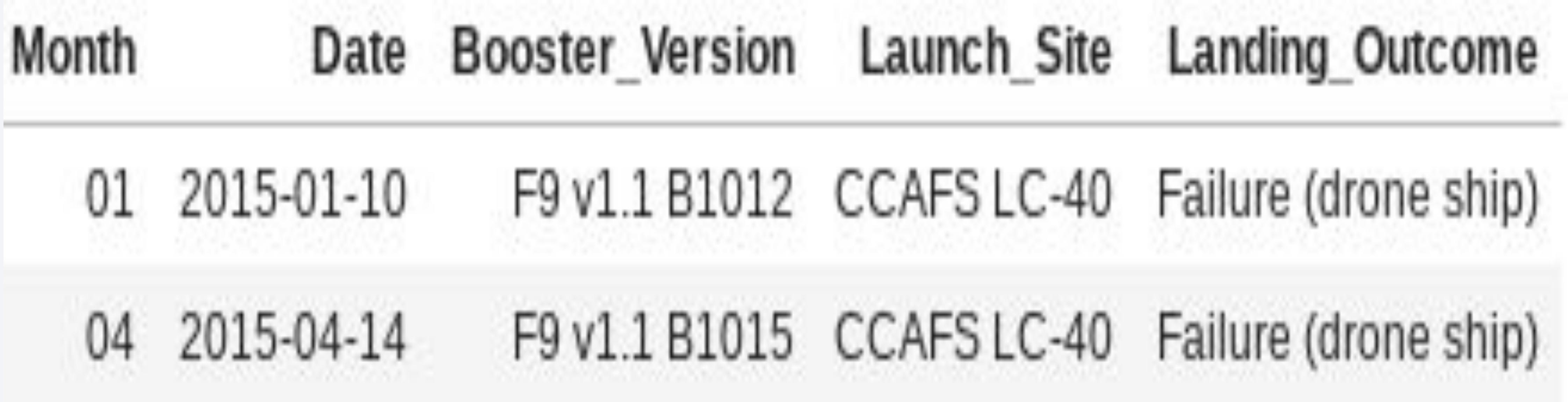


Booster_Version	PAYLOAD_MASS__KG_
F9 B5 B1048.4	15600
F9 B5 B1049.4	15600
F9 B5 B1051.3	15600
F9 B5 B1056.4	15600
F9 B5 B1048.5	15600
F9 B5 B1051.4	15600
F9 B5 B1049.5	15600
F9 B5 B1060.2	15600
F9 B5 B1058.3	15600
F9 B5 B1051.6	15600
F9 B5 B1060.3	15600
F9 B5 B1049.7	15600

Explanation:

- Listing the names of the booster versions which have carried the maximum payload mass.

2015 Launch Records

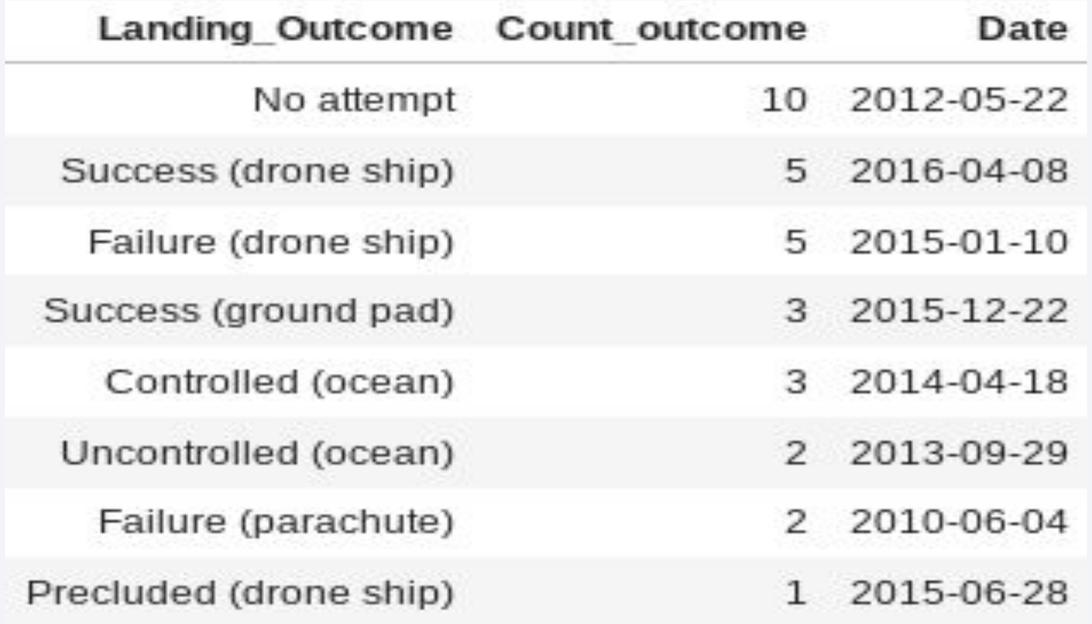


Month	Date	Booster_Version	Launch_Site	Landing_Outcome
01	2015-01-10	F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)
04	2015-04-14	F9 v1.1 B1015	CCAFS LC-40	Failure (drone ship)

Explanation:

- Listing the failed landing outcomes in drone ship, their booster versions and launch site names for the months in year 2015.

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



Landing_Outcome	Count_outcome	Date
No attempt	10	2012-05-22
Success (drone ship)	5	2016-04-08
Failure (drone ship)	5	2015-01-10
Success (ground pad)	3	2015-12-22
Controlled (ocean)	3	2014-04-18
Uncontrolled (ocean)	2	2013-09-29
Failure (parachute)	2	2010-06-04
Precluded (drone ship)	1	2015-06-28

Explanation:

- Ranking 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

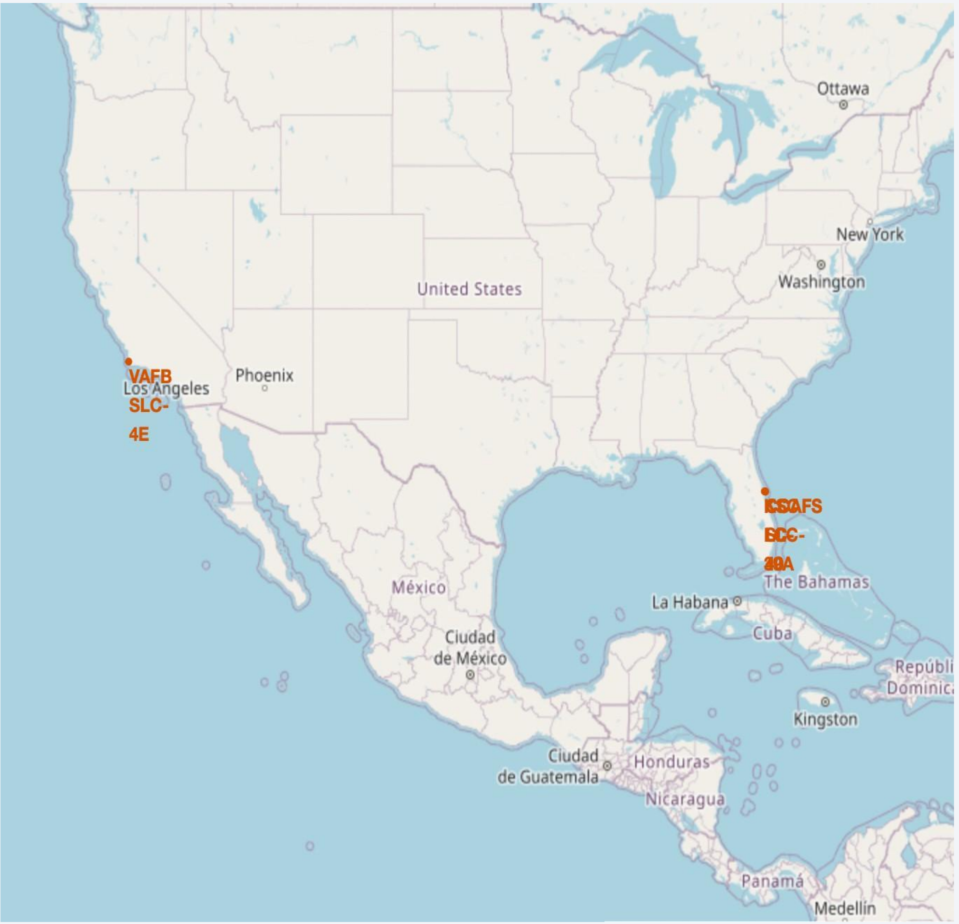
Launch Sites Proximities Analysis

All launch sites' location markers on a Global Map

Explanation:

- Most of Launch sites are in proximity to the Equator line. The land is moving faster at the equator than any other place on the surface of the Earth. Anything on the surface of the Earth at the equator is already moving at 1670 km/hour. If a ship is launched from the equator it goes up into space, and it is also moving around the Earth at the same speed it was moving before launching. This is because of inertia. This speed will help the spacecraft keep up a good enough speed to stay in orbit.

- All launch sites are in very close proximity to the coast, while launching rockets towards the ocean it minimises the risk of having any debris dropping or exploding near people.



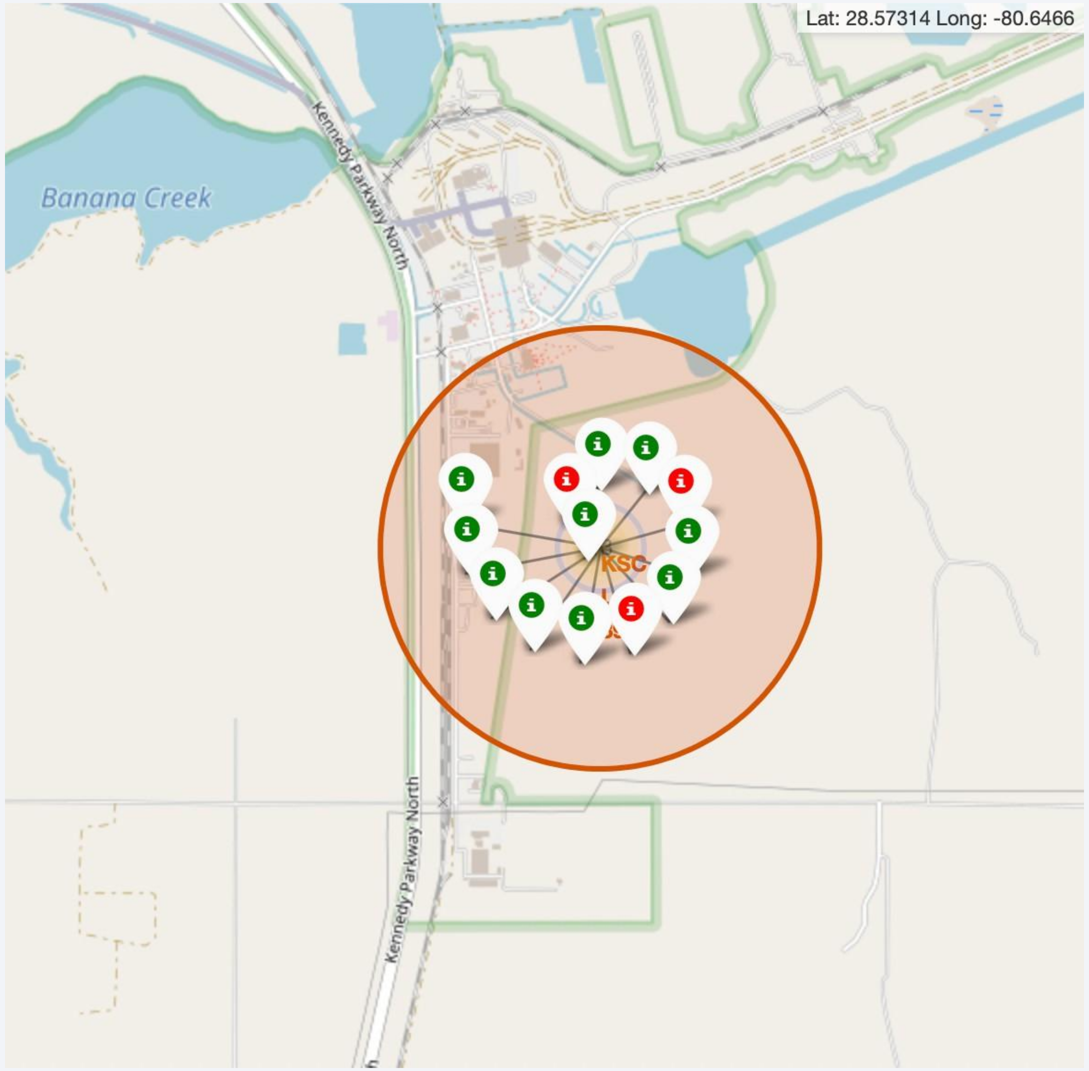
Clustered color labeled launch records on the map

Explanation:

- From the colour-labeled markers we should be able to easily identify which launch sites have relatively high success rates.

- **Green Marker** = Successful Launch
- **Red Marker** = Failed Launch

- Launch Site KSC LC-39A has a very high Success Rate.



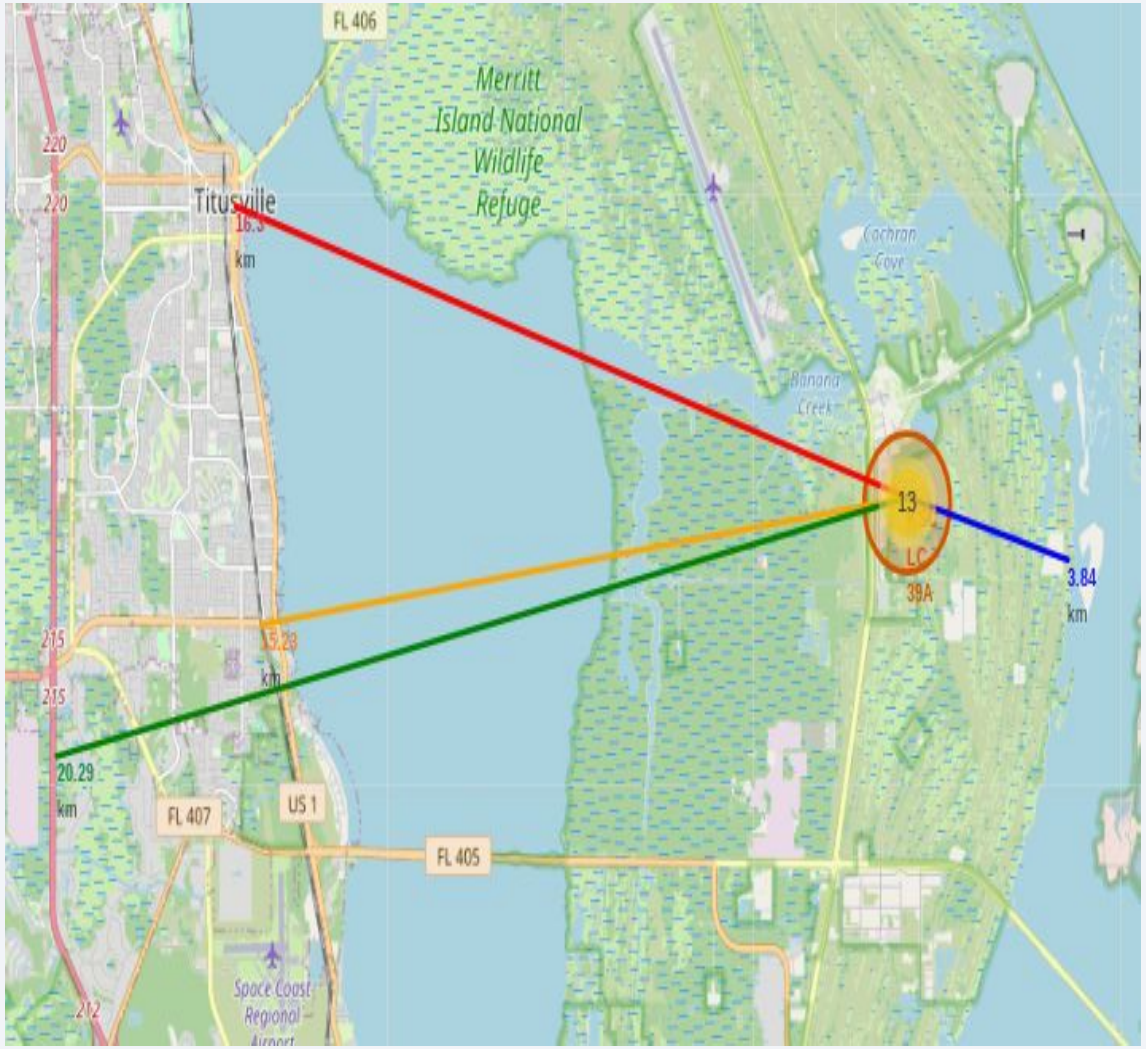
Distance from the launch site KSC LC-39A to its proximites

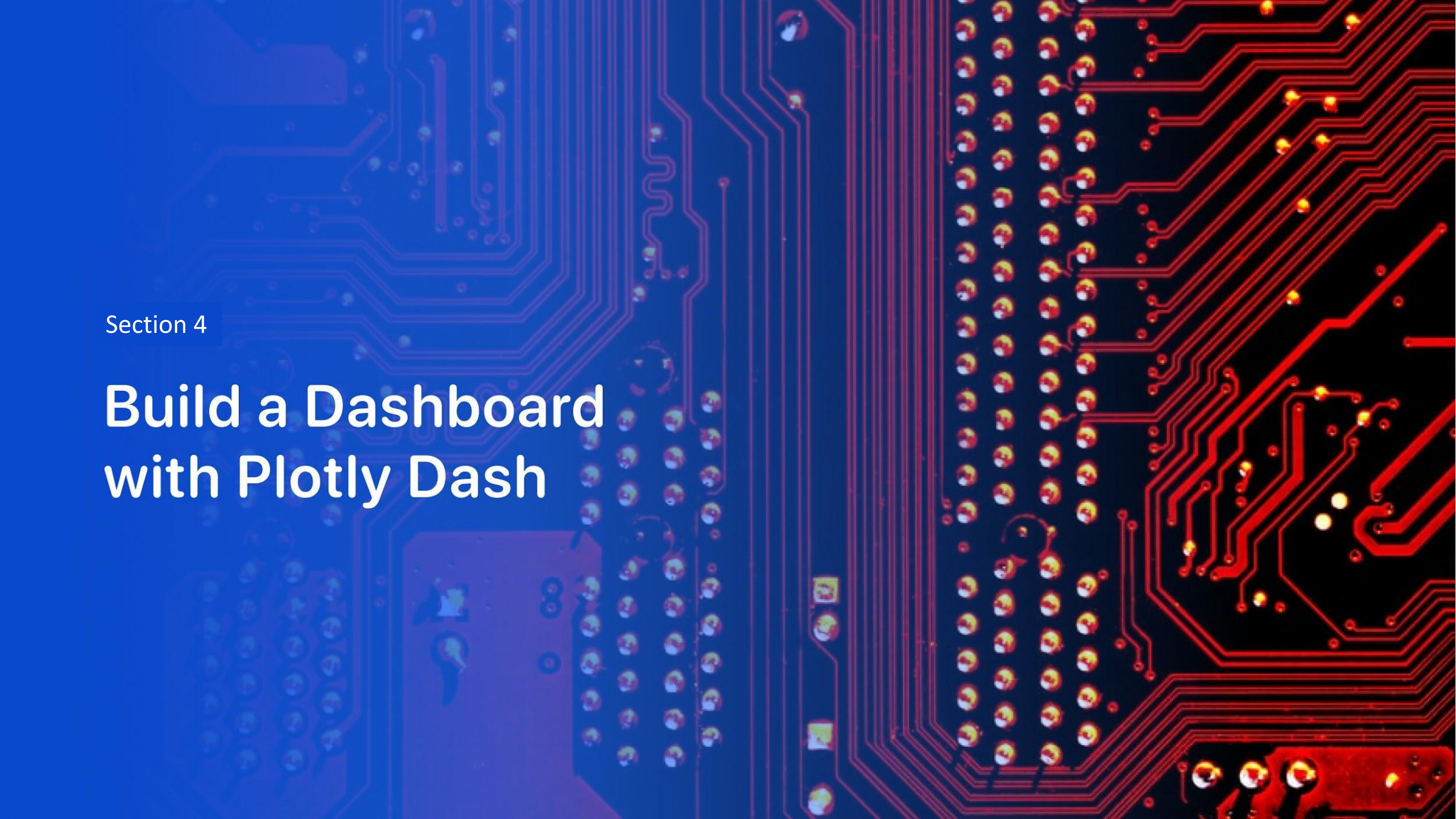
Explanation:

- From the visual analysis of the launch site KSC LC-39A we can clearly see that it is:
  - relative close to railway (15.23 km)
  - relative close to highway (20.29 km)
  - relative close to coastline (3.84 km)

- Also the launch site KSC LC-39A is relative close to its closest city Titusville (16.32 km).

- Failed rocket with its high speed can cover distances like 15-20 km in few seconds. It could be potentially dangerous to populated areas.

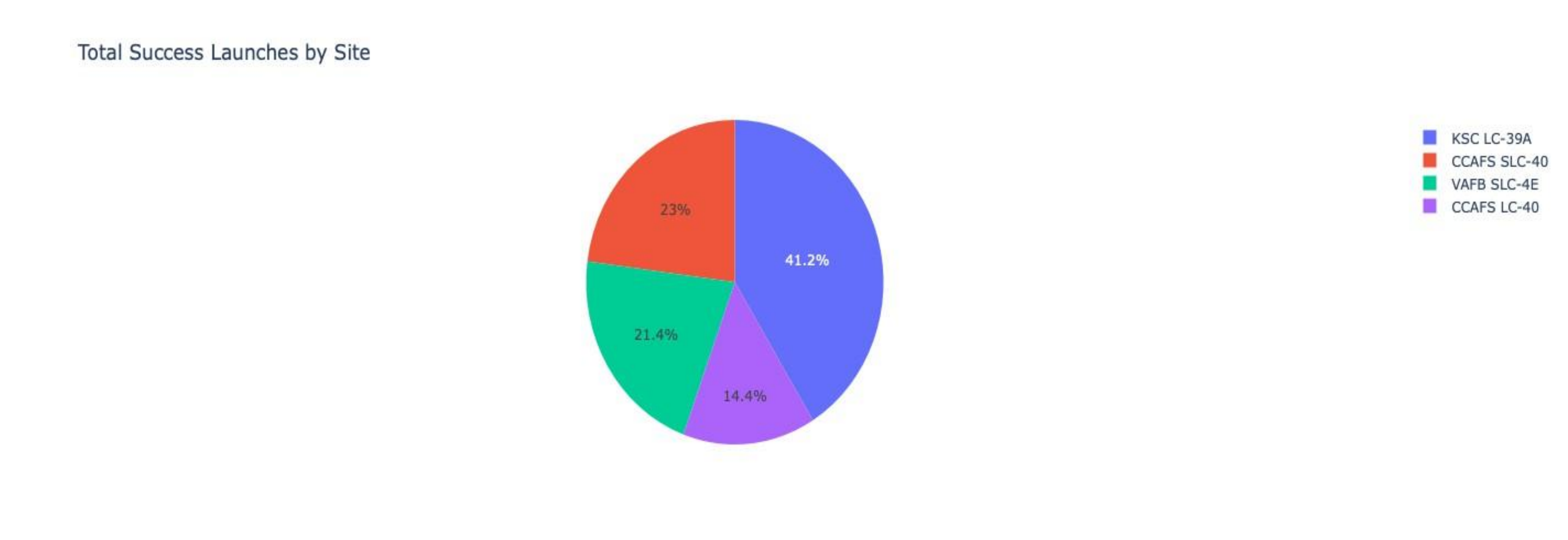




Section 4

Build a Dashboard with Plotly Dash

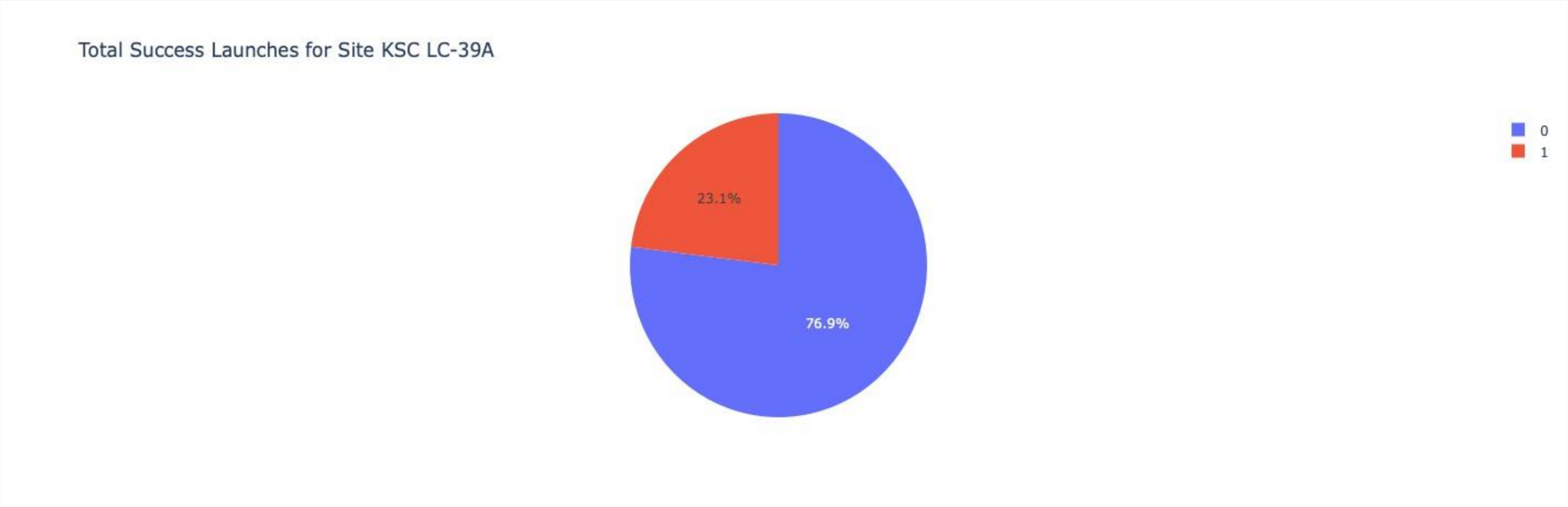
Launch success count for all sites



Explanation:

- The chart clearly shows that from all the sites, KSC LC-39A has the most successful launches with 41.2%

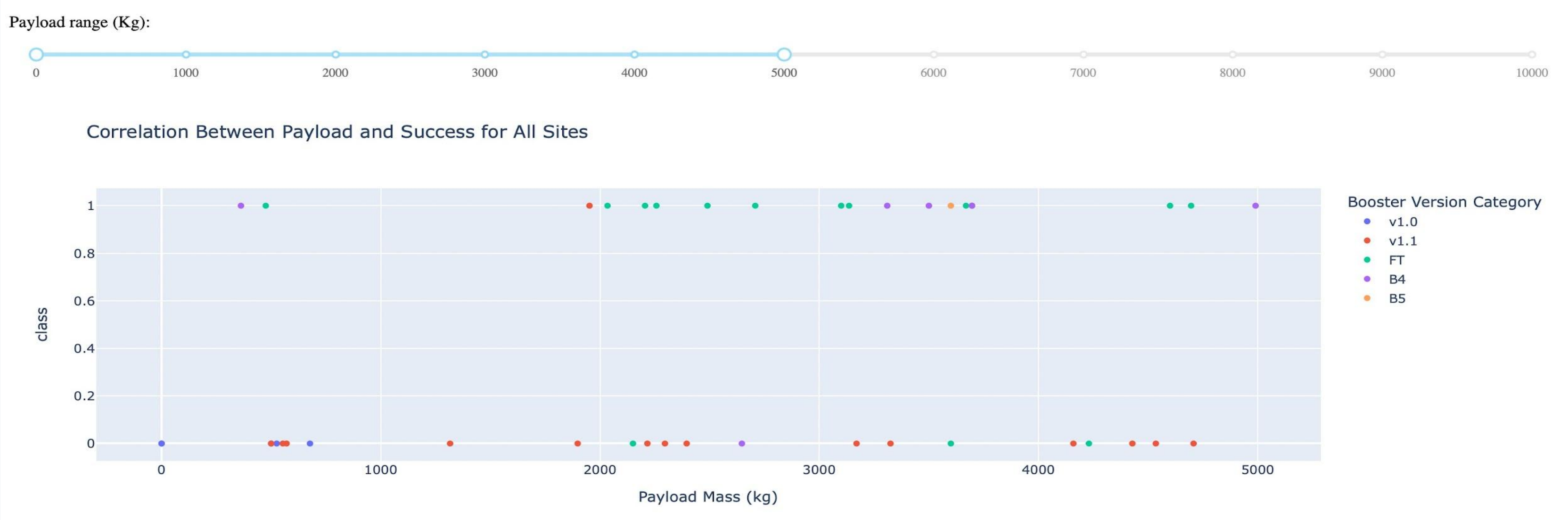
Launch site with highest launch success ratio

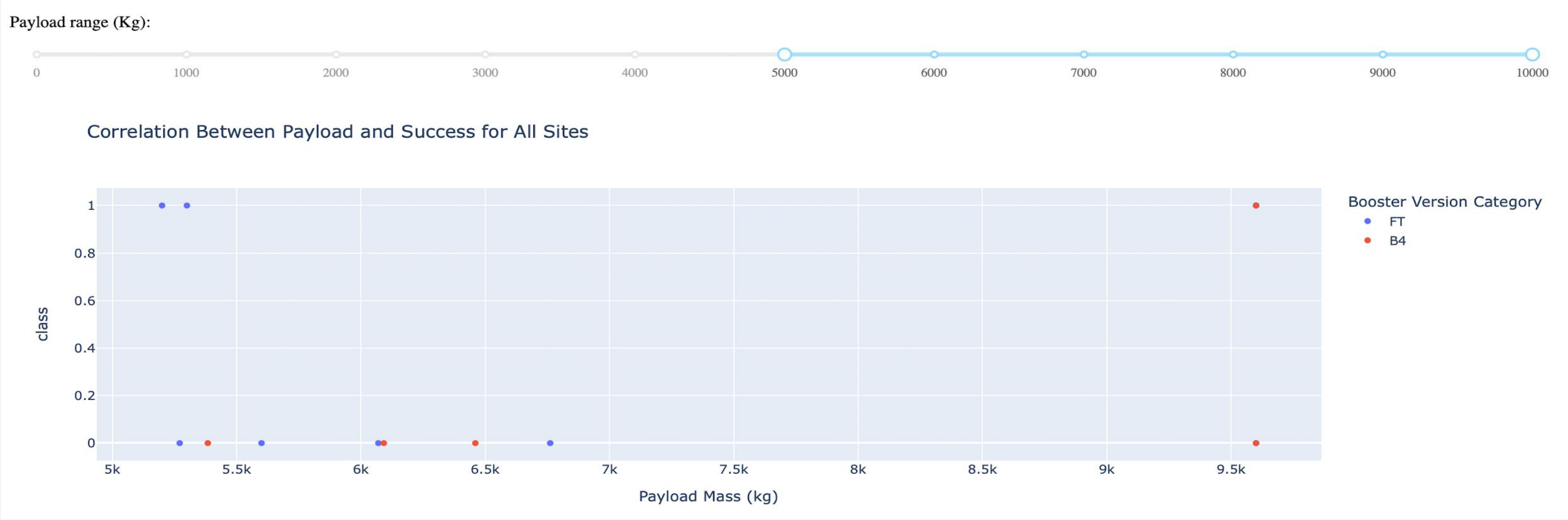


Explanation:

- KSC LC-39A has the highest launch success rate (76.9%) with 10 successfu and only 3 failed landings.

Payload Mass vs. Launch Outcome for all sites





Explanation:

- The charts show that payloads between 2000 and 5500 kg have the highest success rate.

Section 5

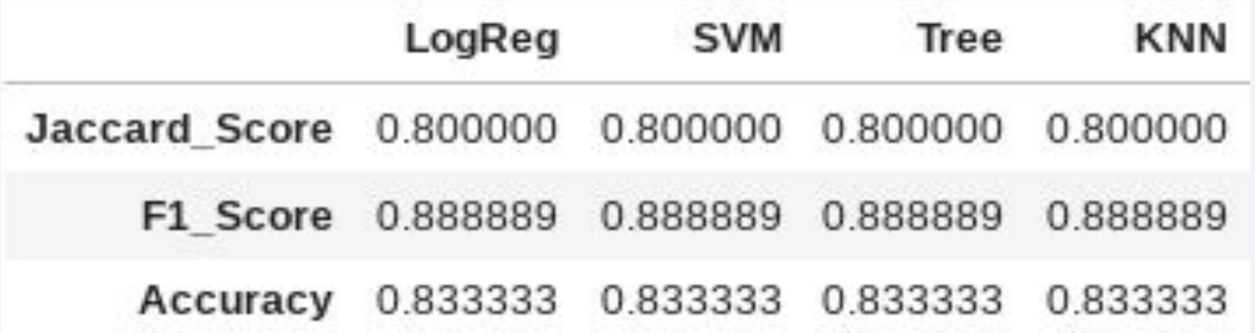
Predictive Analysis (Classification)

Classification Accuracy

Explanation:

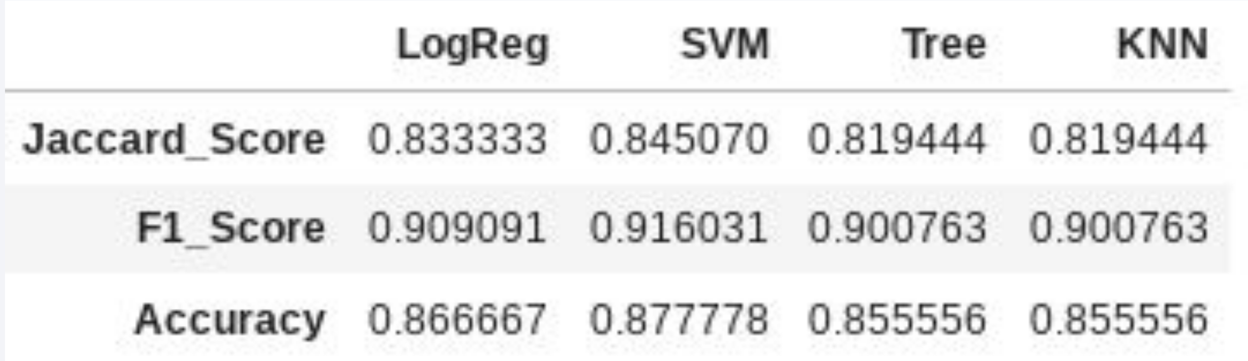
- Based on the scores of the Test Set, we can not confirm which method performs best.
- Same Test Set scores may be due to the small test sample size (18 samples). Therefore, we tested all methods based on the whole Dataset.
- The scores of the whole Dataset confirm that the best model is the Support Vector Machine. This model has not only higher scores, but also the highest accuracy (88%)

Scores and Accuracy of the Test Set



	LogReg	SVM	Tree	KNN
Jaccard_Score	0.800000	0.800000	0.800000	0.800000
F1_Score	0.888889	0.888889	0.888889	0.888889
Accuracy	0.833333	0.833333	0.833333	0.833333

Scores and Accuracy of the Entire Data Set

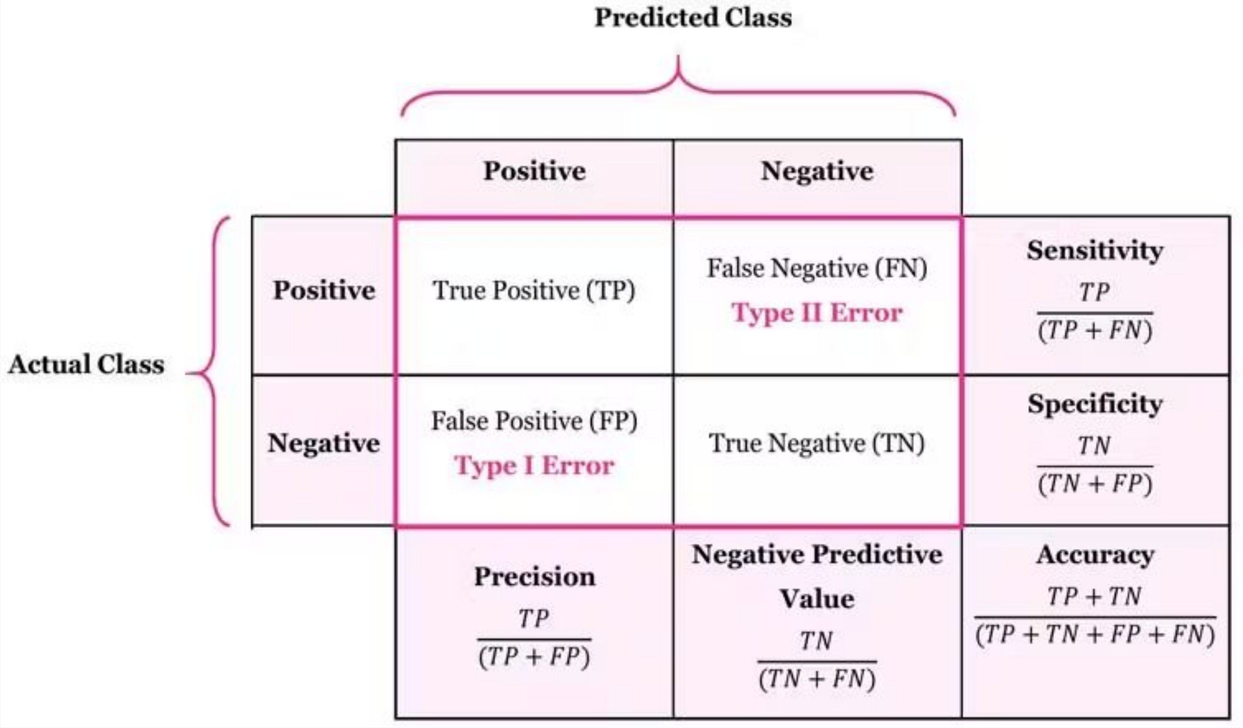


	LogReg	SVM	Tree	KNN
Jaccard_Score	0.833333	0.845070	0.819444	0.819444
F1_Score	0.909091	0.916031	0.900763	0.900763
Accuracy	0.866667	0.877778	0.855556	0.855556

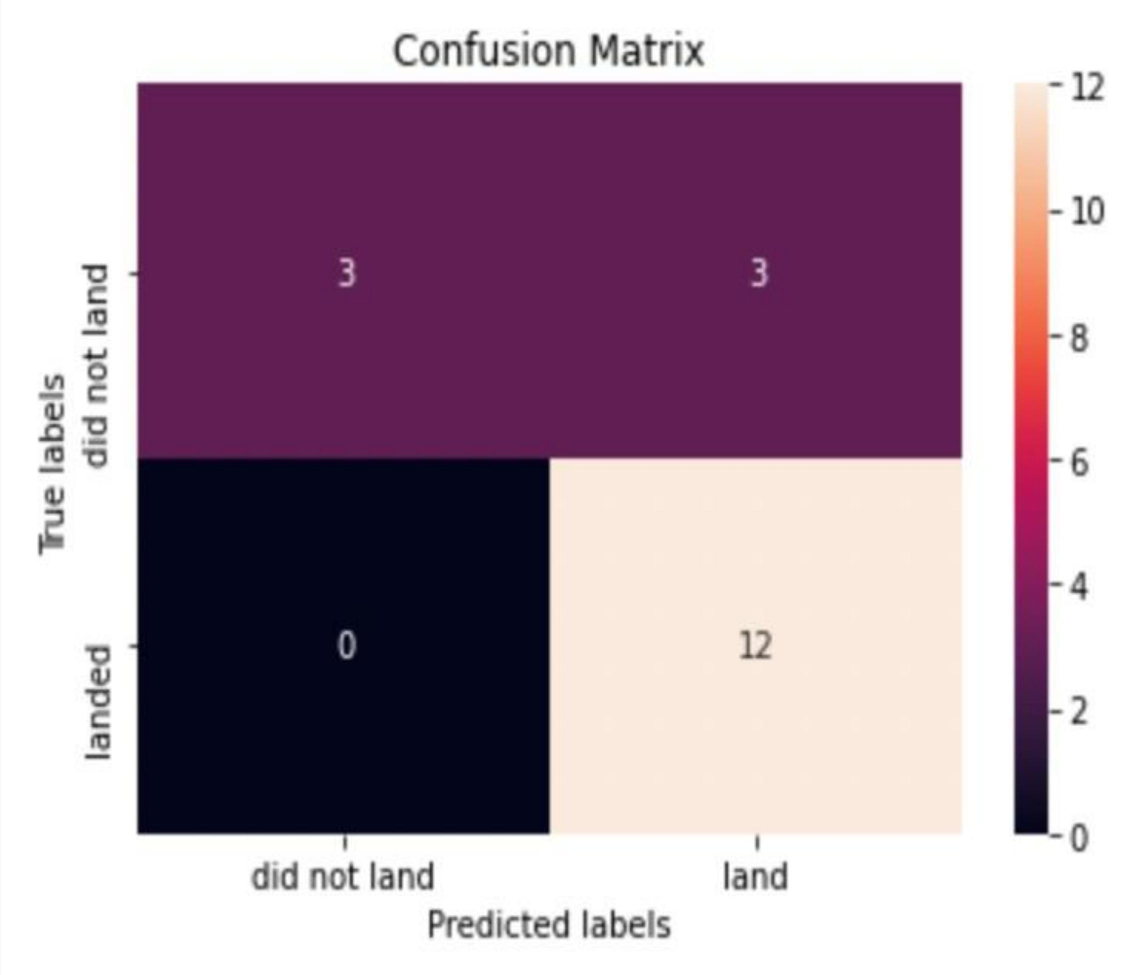
Confusion Matrix

Explanation:

- Examining the confusion matrix, we see that logistic regression can distinguish between the different classes. We see that the major problem is false positives.



		Predicted Class		
		Positive	Negative	
Actual Class	Positive	True Positive (TP)	False Negative (FN) Type II Error	Sensitivity $\frac{TP}{(TP+FN)}$
	Negative	False Positive (FP) Type I Error	True Negative (TN)	Specificity $\frac{TN}{(TN+FP)}$
		Precision $\frac{TP}{(TP+FP)}$	Negative Predictive Value $\frac{TN}{(TN+FN)}$	Accuracy $\frac{TP+TN}{(TP+TN+FP+FN)}$



Conclusions

- Support Vector Machine (SVM) is the best algorithm for this dataset.
- Launches with a low payload mass show better results than launches with a larger payload mass.
- Most of launch sites are in proximity to the Equator line and all the sites are in very close proximity to the coast.
- The success rate of launches increases over the years.
- KSC LC-39A has the highest success rate of the launches from all the sites.
- Orbits ES-L1, GEO, HEO and SSO have 100% success rate.

Appendix

Considerable mentions:

- Instructors
- Coursera: IBM Professional Data Science Course
- IBM

Thank you!