IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

<AMGOTH SUNIL>
<18-02-2025>

Outline

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

Executive Summary

Summary of methodologies

- Data Collection
- Data Wrangling
- Exploratory Data Analysis
- Data Visualization
- Data Analysis with Structured Query Language
- Building maps with Folium
- Building Dashboards with Plotly
- Predictive Analysis (Classification)

Summary of all results

- Exploratory Data Analysis Results
- Dashboards Screenshots
- 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.

- Problems you want to find answers

  - 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

Executive Summary

- Data collection methodology:
  - Using SpaceX Rest API
  - Using Web Scraping From Wikipedia
- Perform data wrangling
  - Filtering the data
  - Dealing with missing Values
  - Converting Categorical Values using One Hot Encoding for 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
  - Model Building, Tuning and Evaluating Classification Model 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.

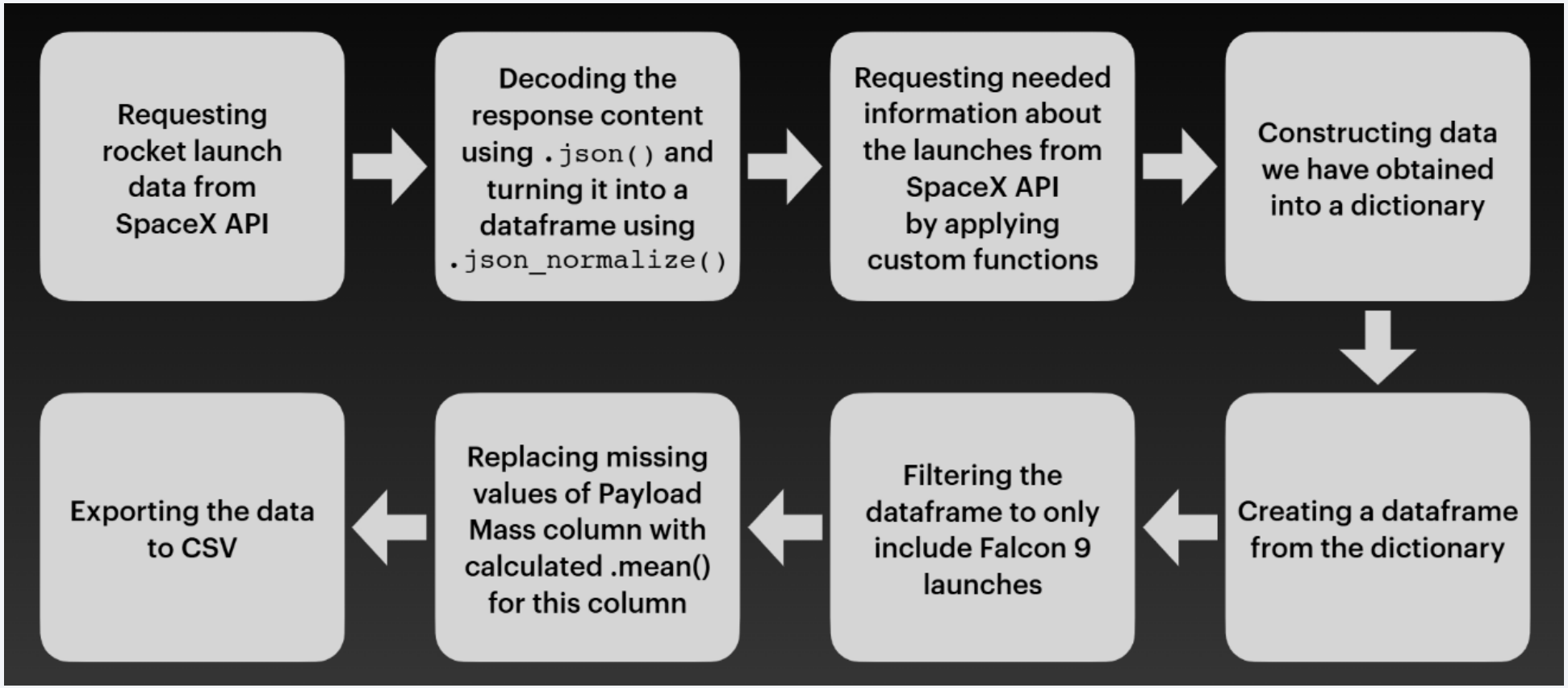
Data Columns are obtained by using SpaceX REST API:

- 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:

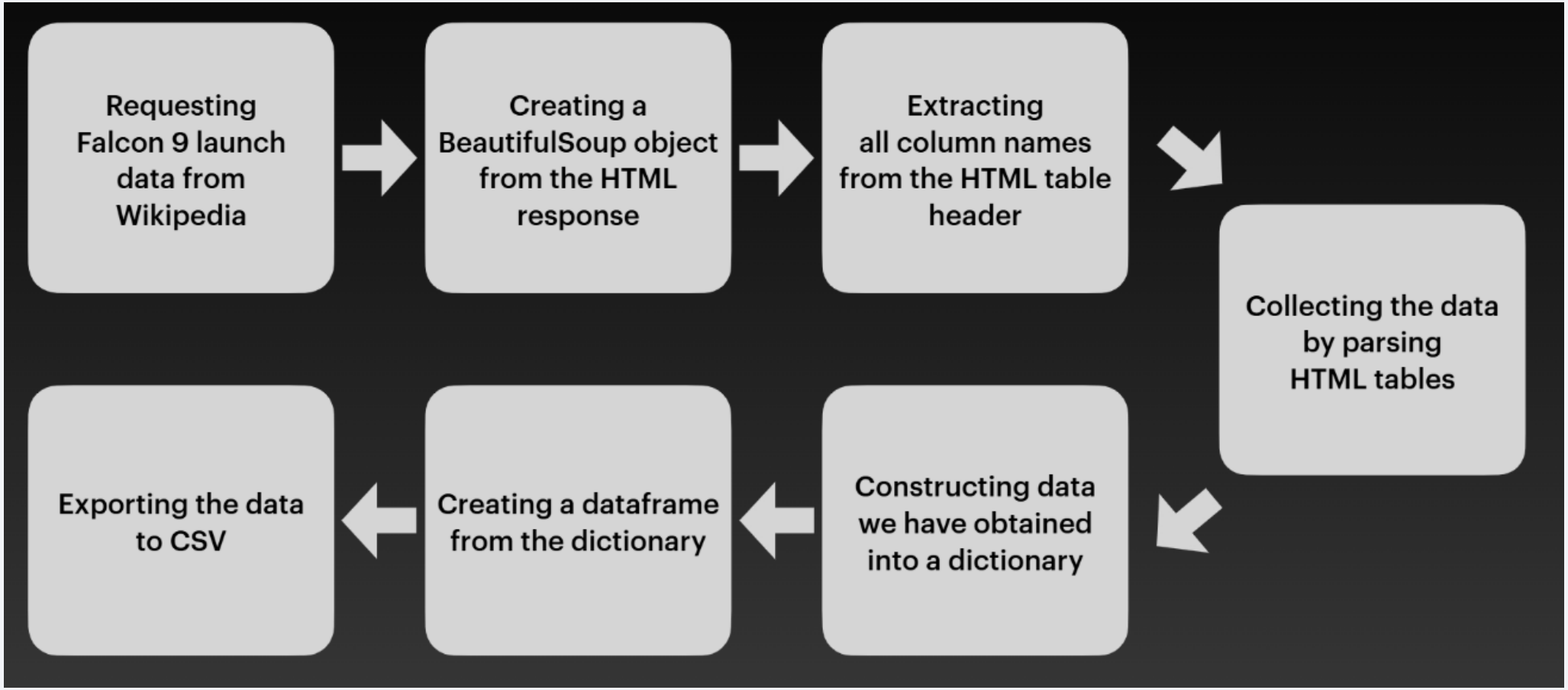
- Flight No., Launch site, Payload, PayloadMass, Orbit, Customer, Launch outcome, Version Booster, Booster landing, Date, Time

Data Collection – SpaceX API



GitHub URL --- Data Collection API

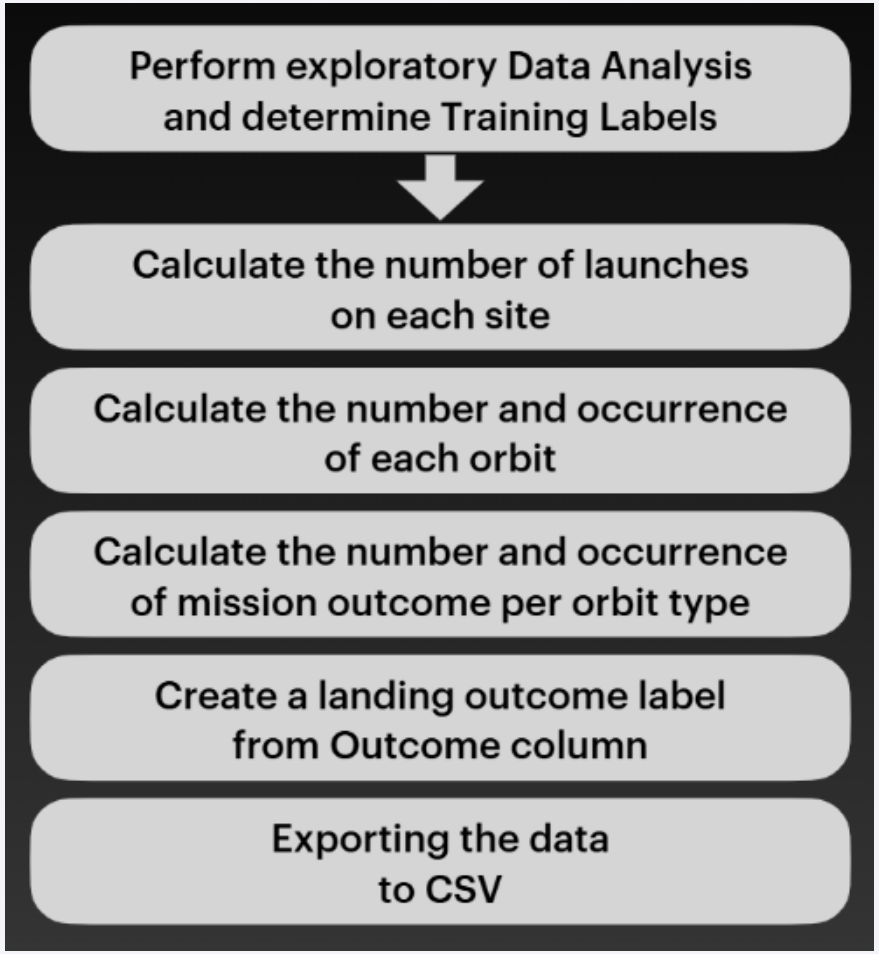
Data Collection – Web Scraping



GitHub URL --- 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, "O" means it was unsuccessful.



GitHub URL --- Data Wrangling

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

- 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.

Colored Markers of the launch outcomes for each Launch Site:

- Added colored 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 colored 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 Maps 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:

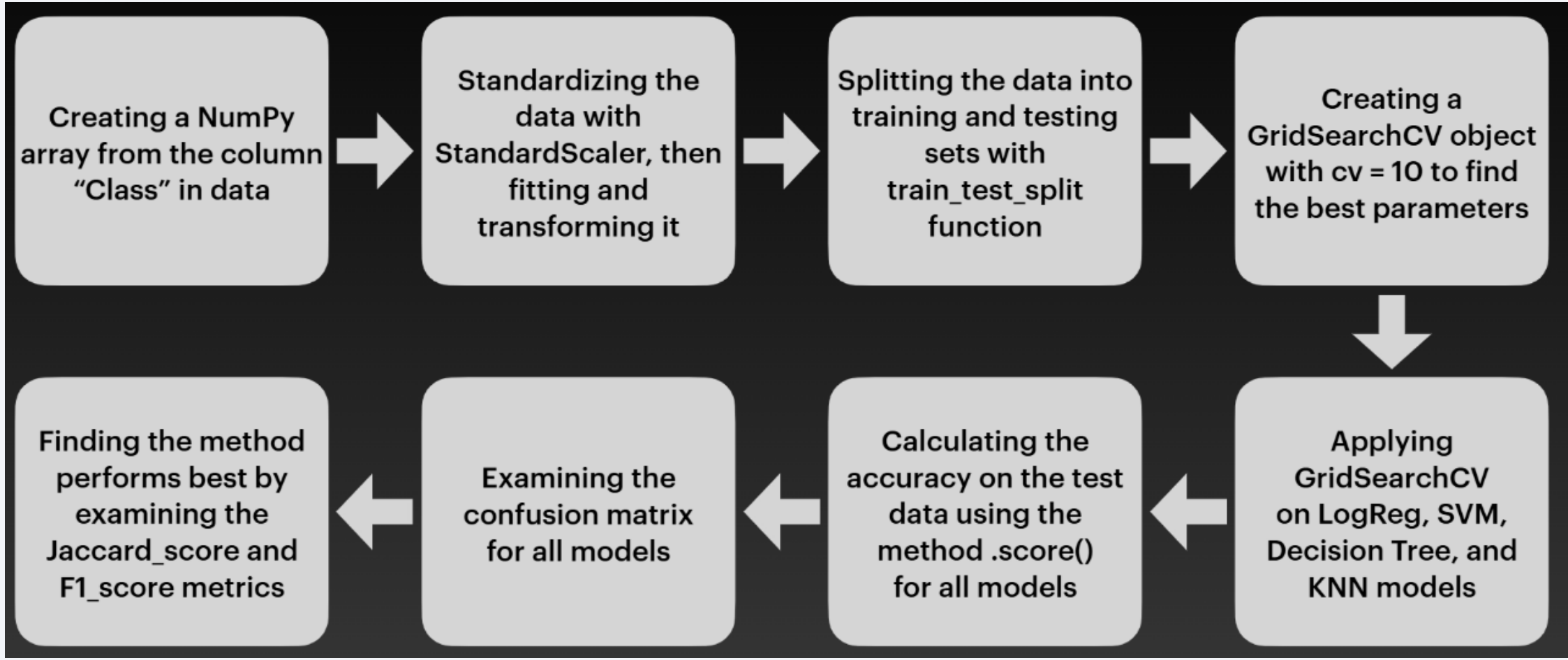
- Added a slider to select Payload range.

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 --- Dashboard with Plotly

Predictive Analysis (Classification)



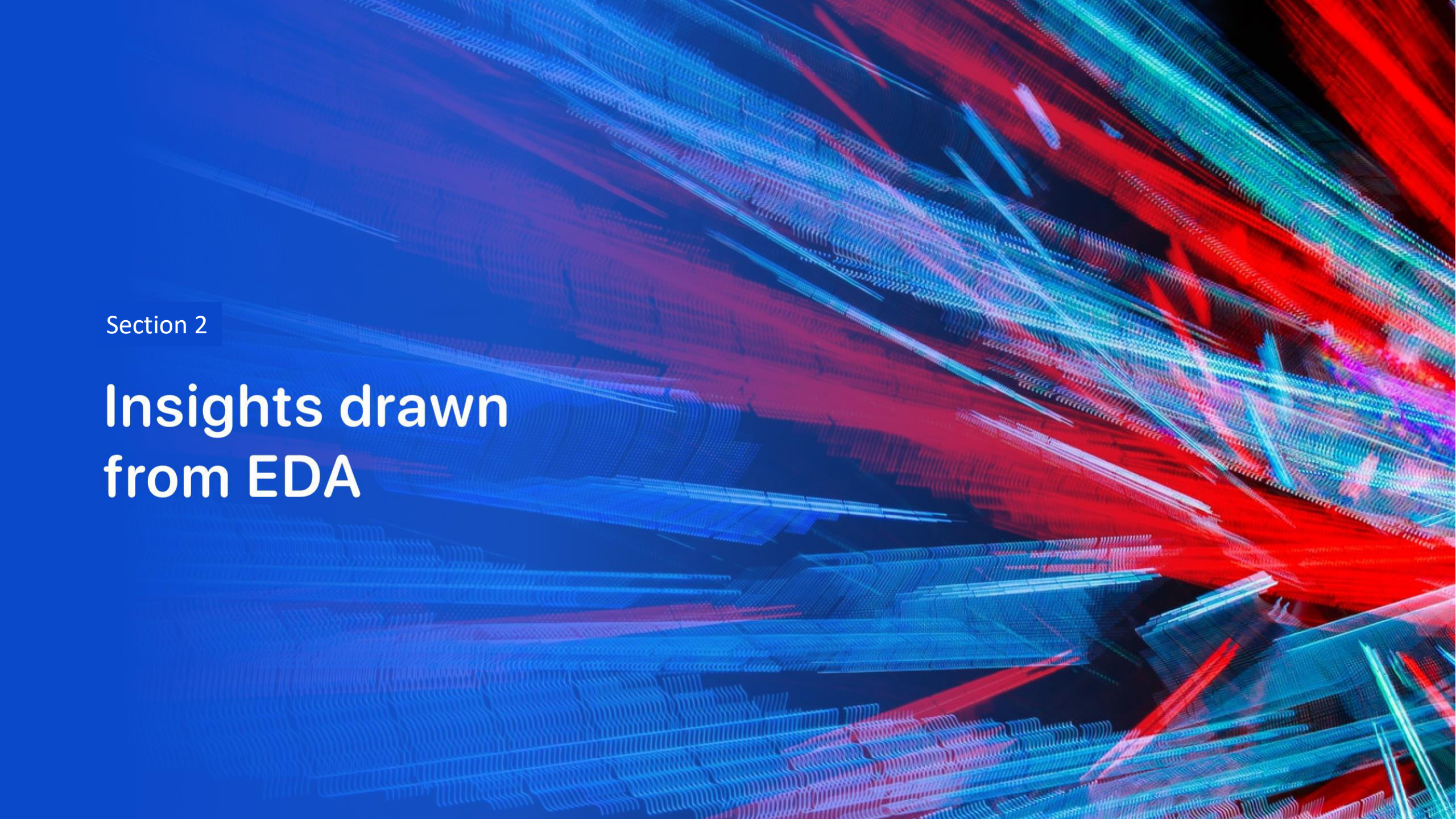
GitHub URL --- [Predictive Analysis]

Results

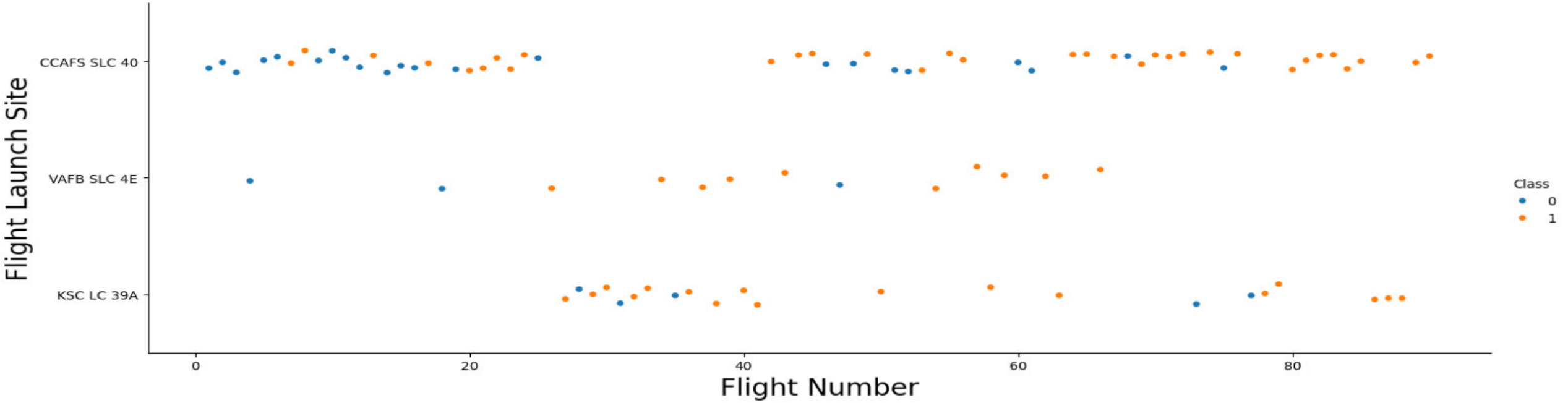
- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

Section 2

Insights drawn from EDA



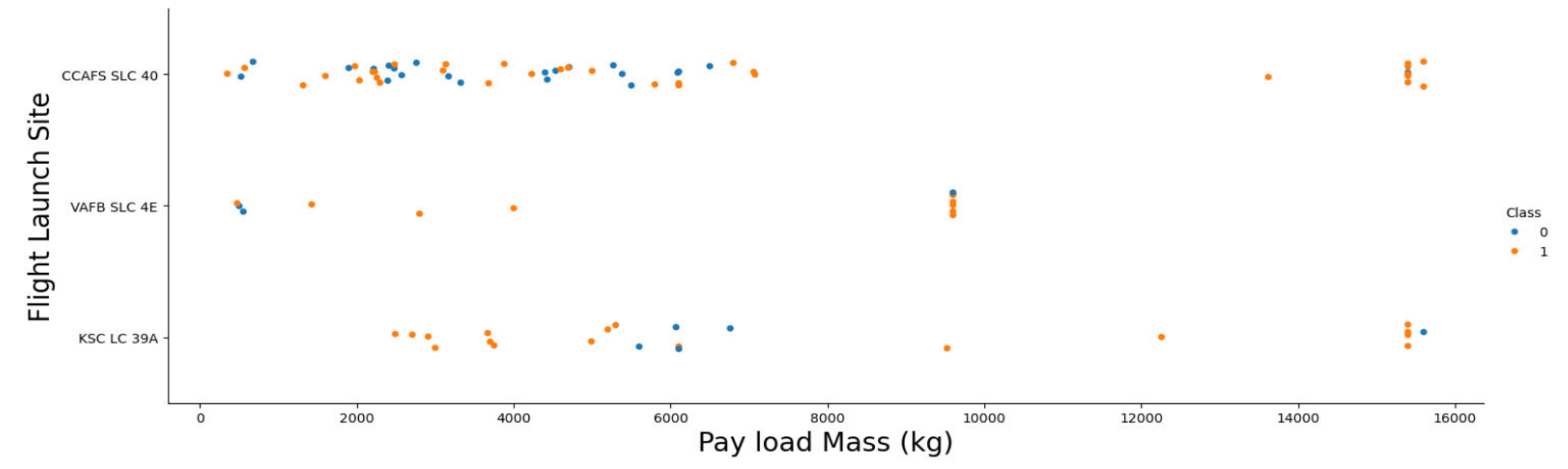
Flight Number vs. Launch Site



Explanation:

- The earliest flights all failed while the latest flights all succeeded.
- The CCAFS SLC 40 launch site has about a half of all launches.
- 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.

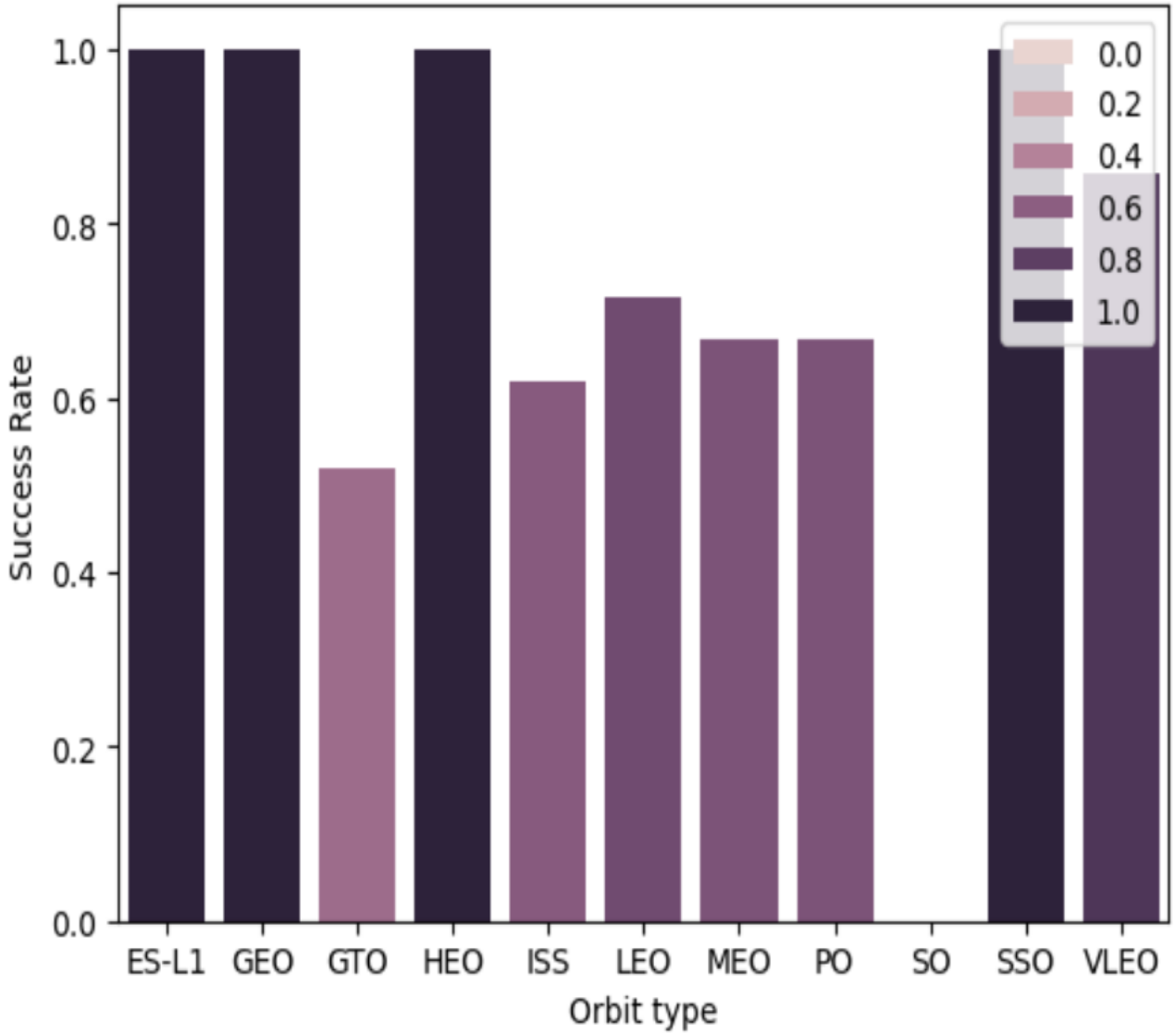
Payload vs. Launch Site



Explanation:

- 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.

Success Rate vs. Orbit Type



Explanation:

Orbits with 100% success rate:

- ES-L1, GEO, HEO, SSO

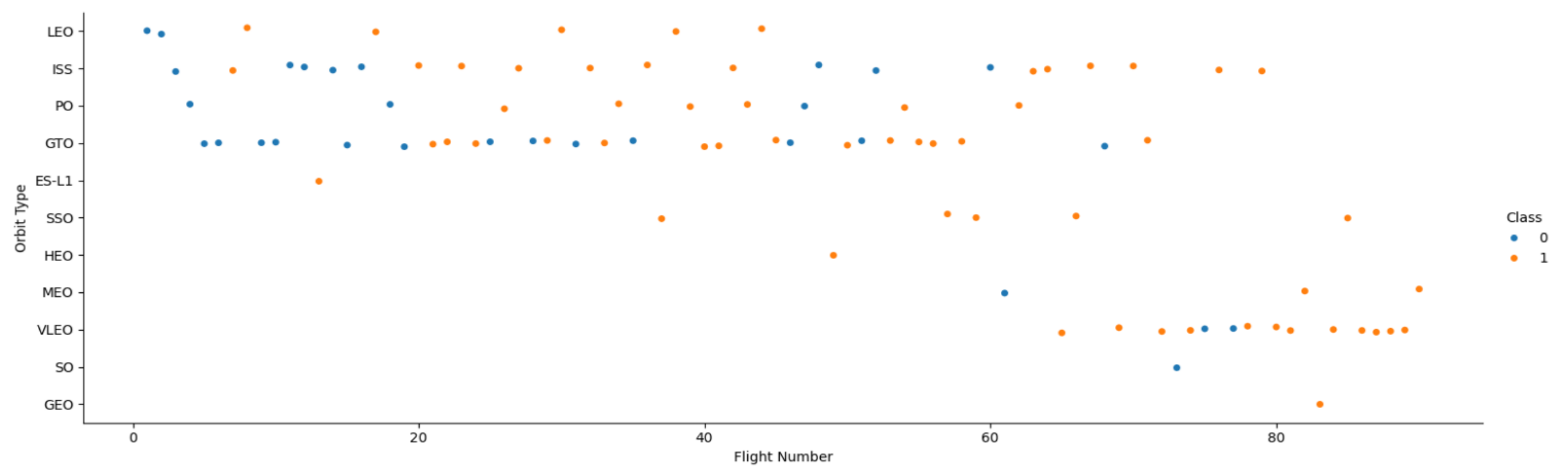
Orbits with 0% success rate:

- -SO

Orbits with success rate between 50% and 85%:

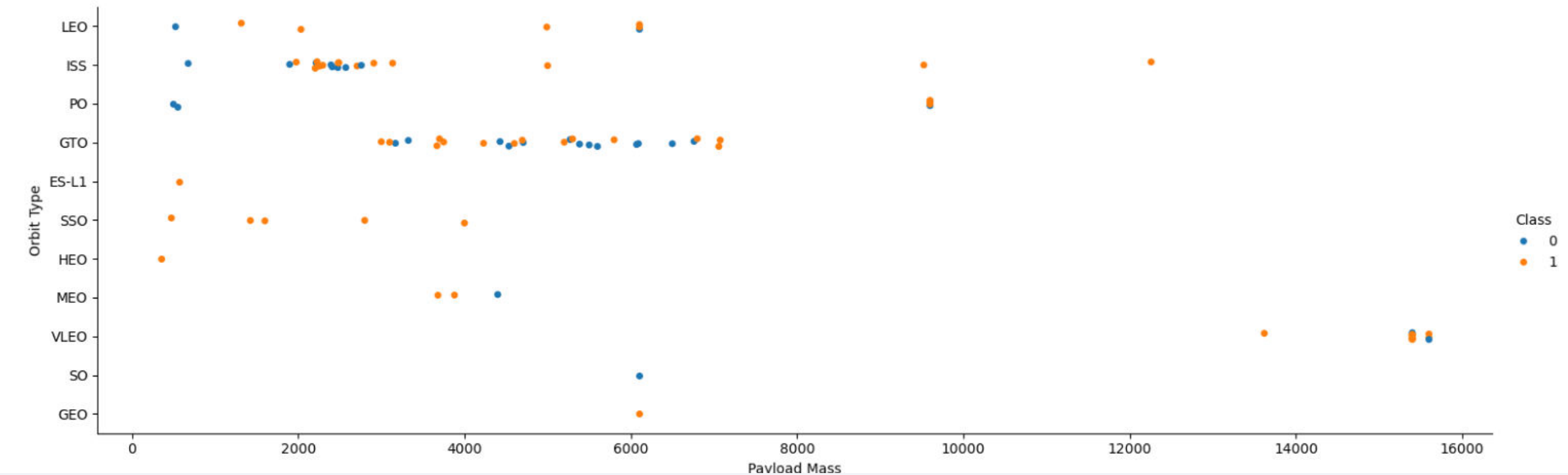
- -GTO, ISS, LEO, MEO, PO

Flight Number vs. Orbit Type



- Explanation:
  - 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.

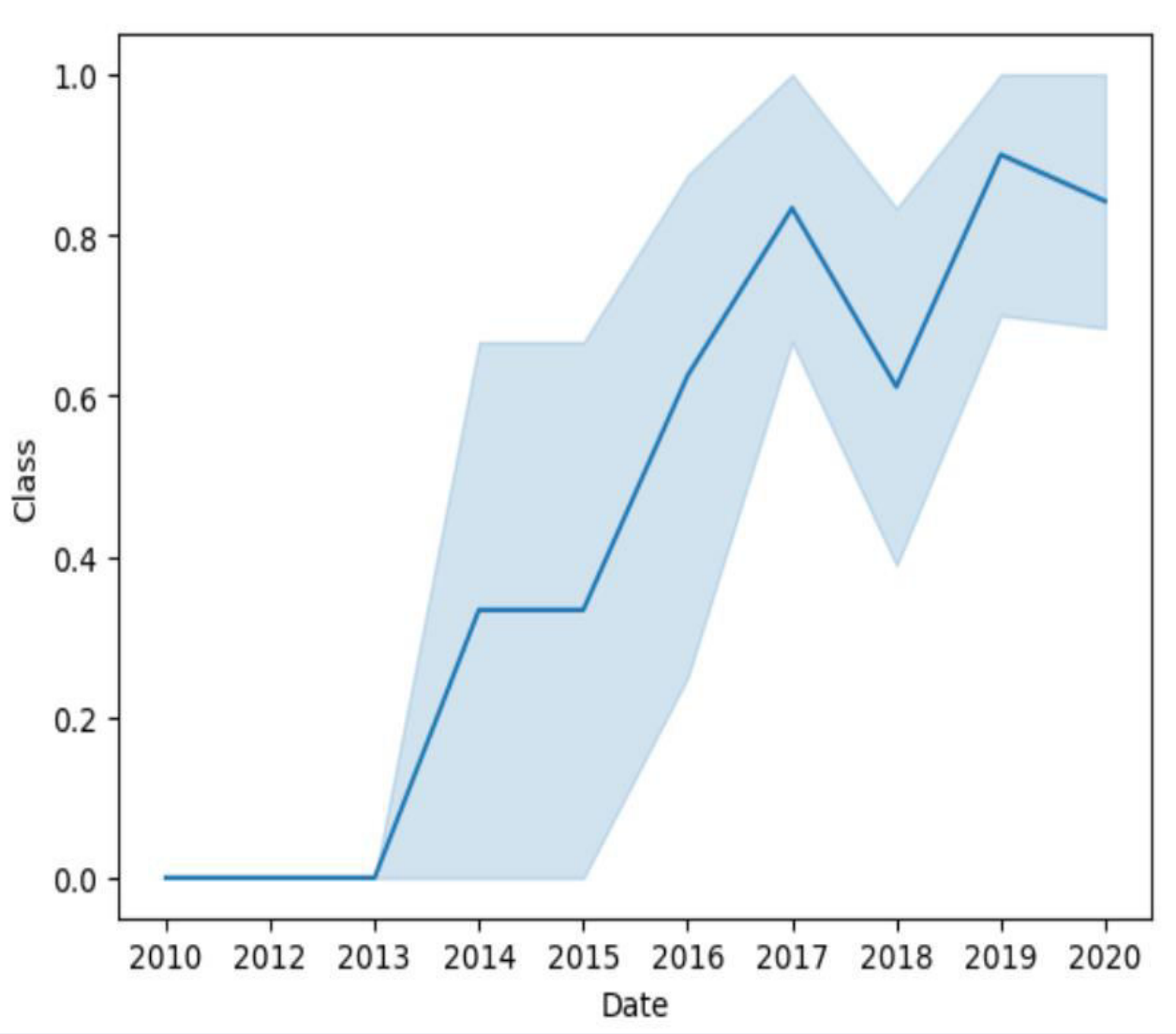
Payload vs. Orbit Type



Explanation:

- Heavy loads have a negative impact on GTO orbits and positive on GTO and Polar LEO Orbits

Launch Success Yearly Trend



Explanation:

- The Success Rate since 2013 kept increasing till 2020

Exploratory Data Analysis With Structured Query Language (SQL)

All Launch Site Names

```
[15]: %sql select distinct Launch_Site from SPACEXTBL
```

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

[15]:

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

Explanation:

- Displaying all the Unique Launch Site Names in the space mission

Launch Site Names Begin with 'CCA'

[20]:
```
%sql SELECT * FROM SPACEXTBL WHERE Launch_Site like 'CCA%' LIMIT 5
```

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

[20]:

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 Site begin with string “CCA”

Total Payload Mass

```
[27]: %sql select sum(PAYLOAD_MASS__KG_) as total_payload_mass from SPACEXTBL where Customer = 'NASA (CRS)'
 * sqlite:///my_data1.db
Done.
```

[27]:

total_payload_mass
45596

Explanation:

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

Average Payload Mass by F9 v1.1

```
[33]: %sql select avg(PAYLOAD_MASS__KG_) as avg_payload_mass from SPACEXTBL where Booster_Version='F9 v1.1'
 * sqlite:///my_data1.db
Done.
```

[33]:

avg_payload_mass
2928.4

Explanation:

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

First Successful Ground Landing Date

```
[45]: %sql select min(Date) from SPACEXTBL where Landing_Outcome='Success (ground pad)'
```

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

[45]:

min(Date)
2015-12-22

Explanation:

- Date when the first succesful landing outcome in ground pad was acheived.

Successful Drone Ship Landing with Payload between 4000 and 6000

[46]:
```
%%sql
select Booster_Version from SPACEXTBL where Landing_Outcome='Success (ground pad)'
and PAYLOAD_MASS__KG_ between 4000 and 6000
```

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

[46]:

Booster_Version
F9 FT B1032.1
F9 B4 B1040.1
F9 B4 B1043.1

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

[72]:
```
%%sql
select Mission_Outcome,count(*) as total_number from SPACEXTBL
group by Mission_Outcome
```

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

[72]:

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

```
[73]: %%sql
      select Booster_Version from SPACEXTBL
      where PAYLOAD_MASS__KG_ = (select max(PAYLOAD_MASS__KG_) from SPACEXTBL)
```

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

[73]:

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

Explanation:

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

2015 Launch Records

[74]:
```
%%sql
SELECT CASE
         WHEN substr(Date, 6, 2) = '01' THEN 'January'
         WHEN substr(Date, 6, 2) = '02' THEN 'February'
         WHEN substr(Date, 6, 2) = '03' THEN 'March'
         WHEN substr(Date, 6, 2) = '04' THEN 'April'
         WHEN substr(Date, 6, 2) = '05' THEN 'May'
         WHEN substr(Date, 6, 2) = '06' THEN 'June'
         WHEN substr(Date, 6, 2) = '07' THEN 'July'
         WHEN substr(Date, 6, 2) = '08' THEN 'August'
         WHEN substr(Date, 6, 2) = '09' THEN 'September'
         WHEN substr(Date, 6, 2) = '10' THEN 'October'
         WHEN substr(Date, 6, 2) = '11' THEN 'November'
         WHEN substr(Date, 6, 2) = '12' THEN 'December'
    END AS Month_Name,
    Landing_Outcome,
    Booster_Version,
    Launch_Site
FROM SPACEXTBL
WHERE Landing_Outcome = 'Failure (drone ship)'
AND substr(Date, 0, 5) = '2015';
```

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

[74]:

Month_Name	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

Explanation:

- Listing 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

[75]:
```
%%sql
SELECT Landing_Outcome, COUNT(*) AS Outcome_Count
FROM SPACEXTBL
WHERE Date BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY Landing_Outcome
ORDER BY Outcome_Count DESC;
```

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

[75]:

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

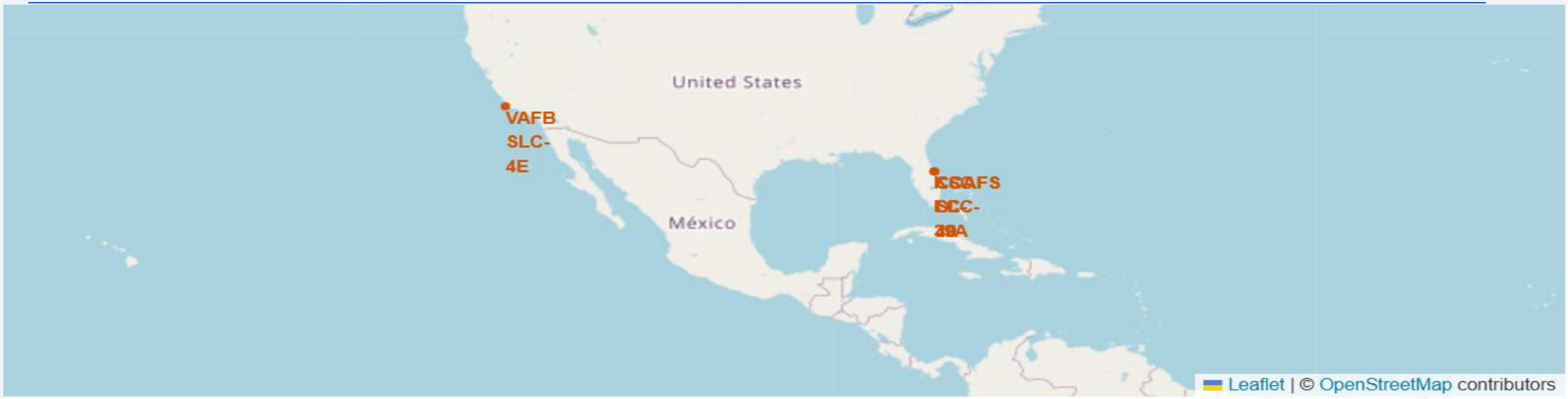
Explanation:

- 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

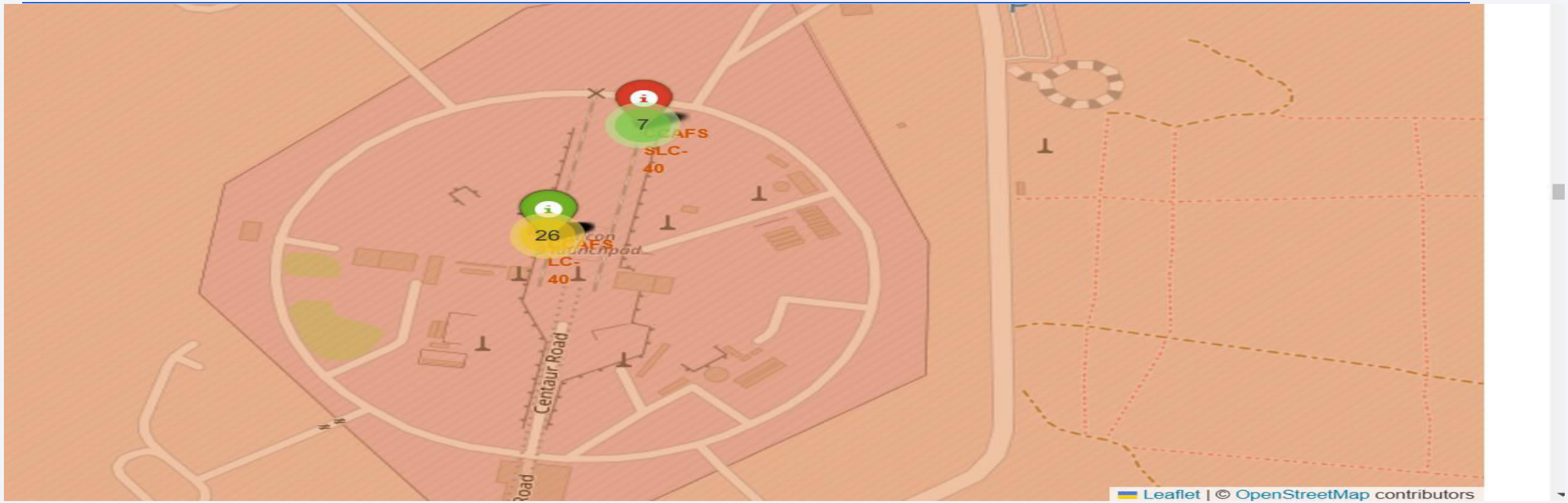
Launch Sites Proximities Analysis

All Launch Sites location markers on global map



- 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

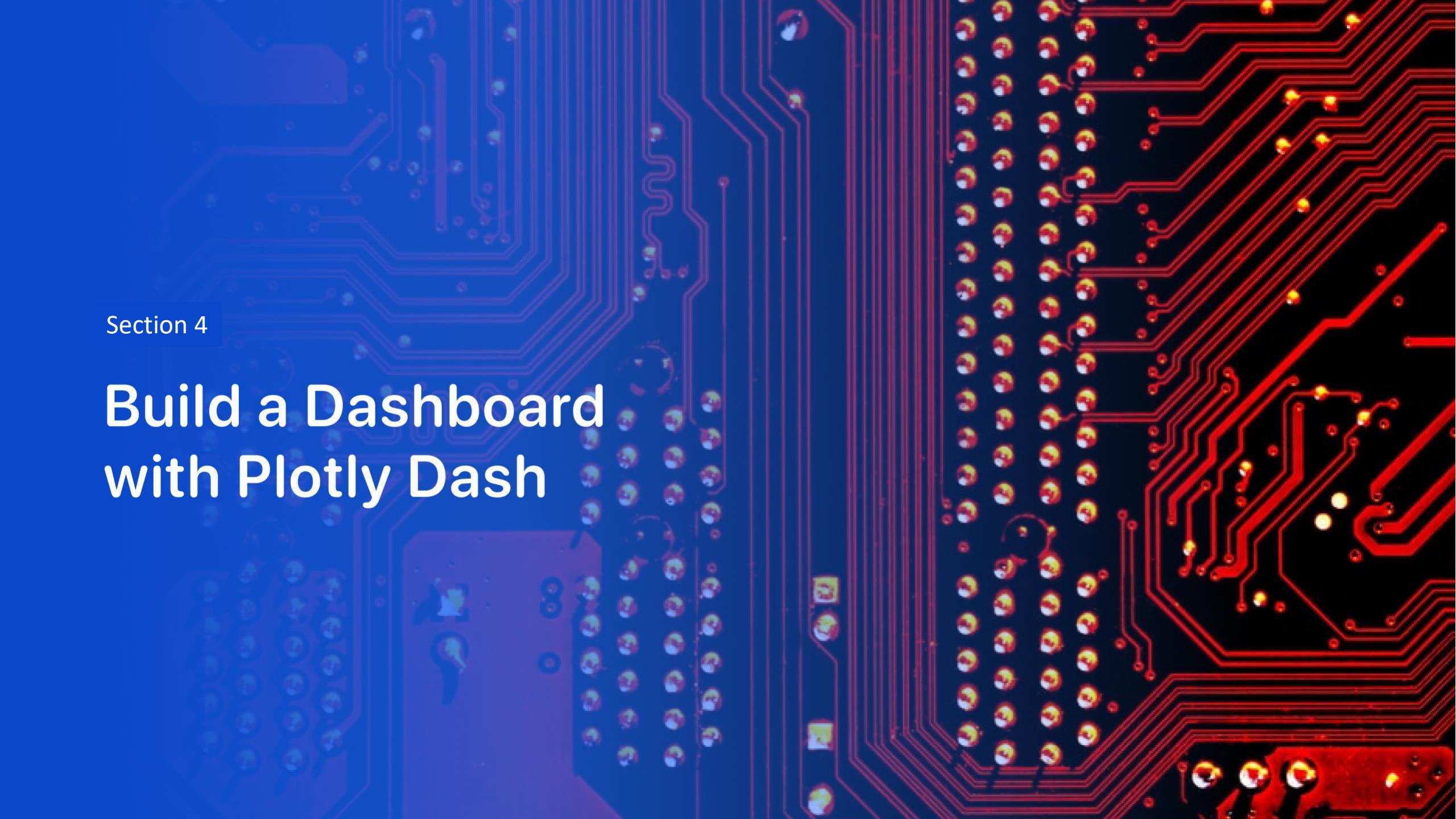
Color-labeled launch records on the map



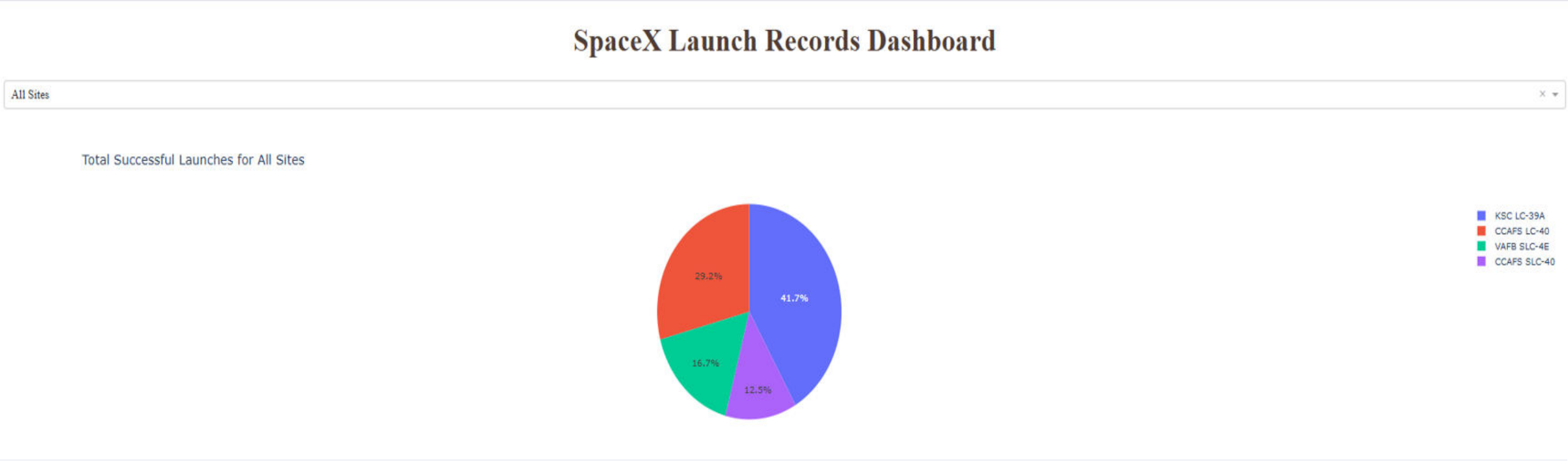
Explanation:

- From the color-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 CCAFS LC-40 has a very high Success Rate.

Distance from the launch site


Section 4
Build a Dashboard with Plotly Dash

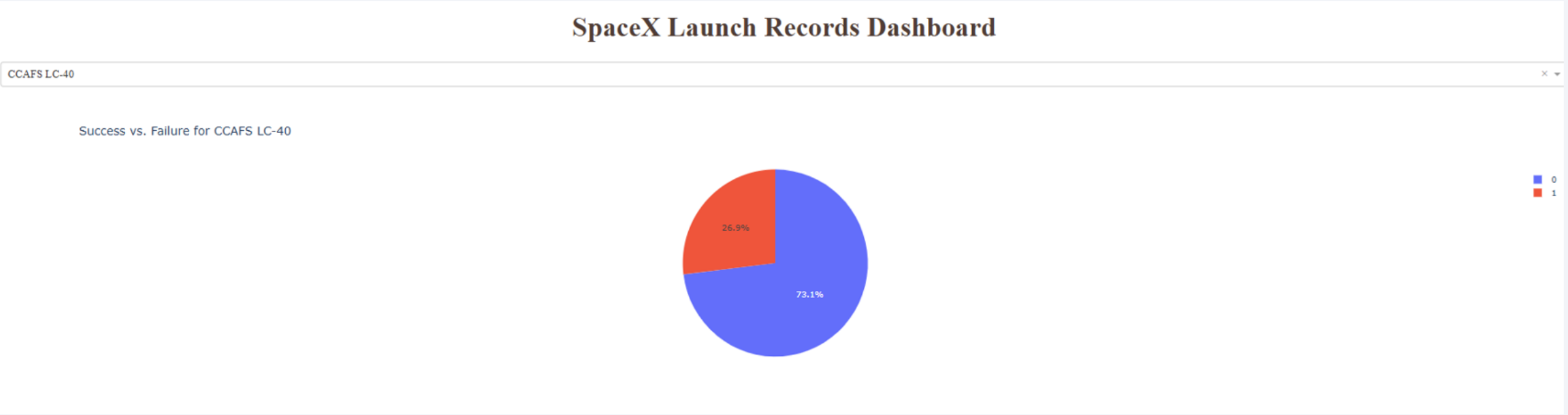
Launch success count for all sites



Explanation:

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

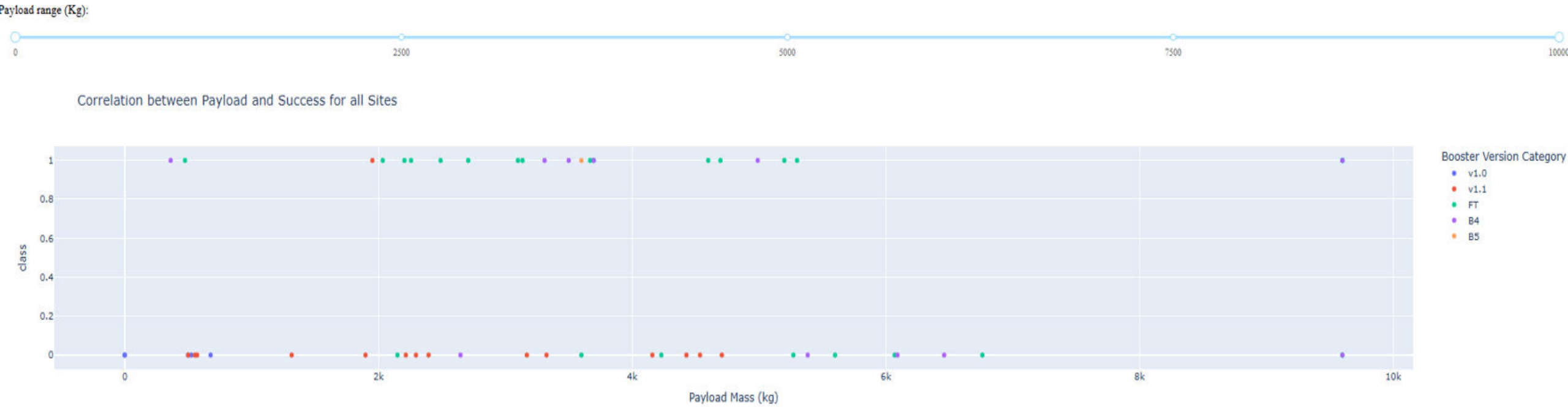
Launch site with highest launch success ratio



Explanation:

- CCAFLC-40 has the highest launch success rate (73.1%) and only 26.9% failure rate

Payload Mass vs. Launch Outcome for all sites



Explanation:

- The charts show that payloads between 0 and 10000 kg .

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 Decision Tree Model. This model has not only higher scores, but also the highest accuracy.

Scores and Accuracy of the Test Set

[32]:

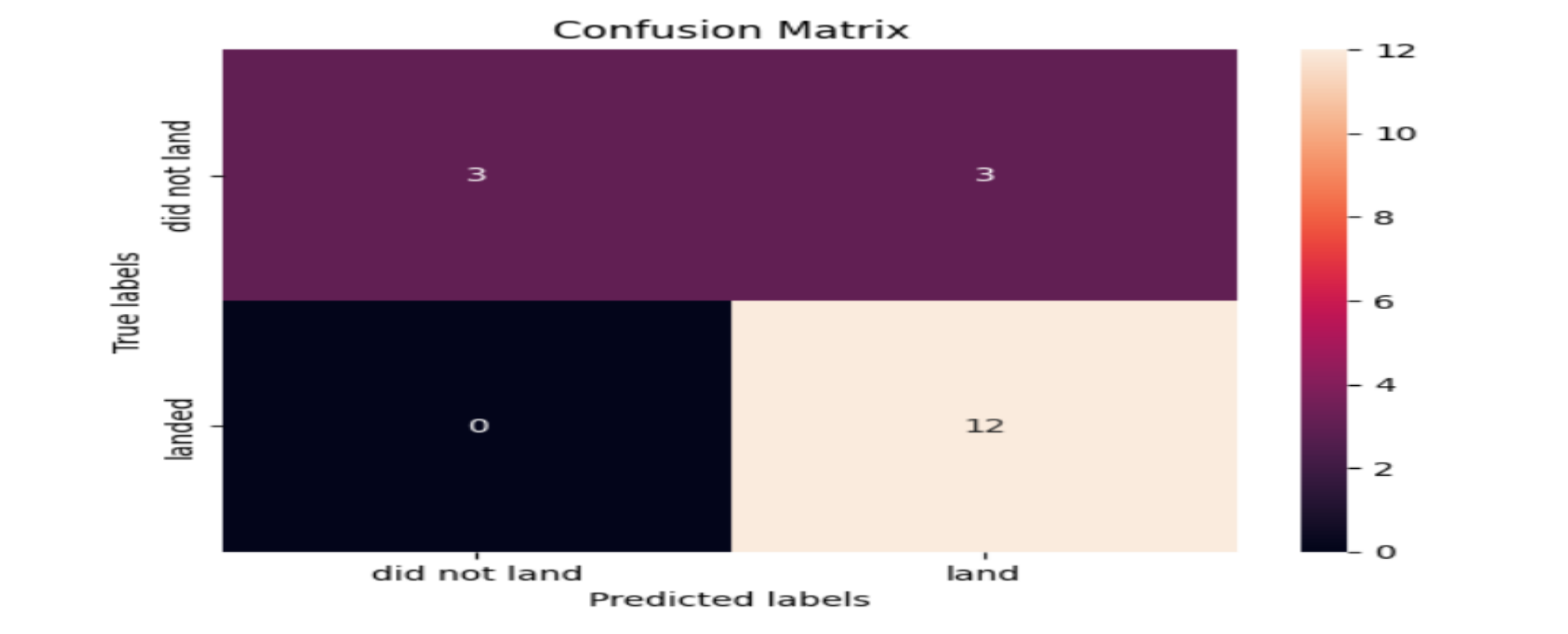
	LogReg	SVM	Tree	KNN
F1_Score	0.888889	0.888889	0.888889	0.888889
Accuracy	0.833333	0.833333	0.777778	0.833333

Scores and Accuracy of the Entire Data Set

[34]:

	LogReg	SVM	Tree	KNN
F1_Score	0.909091	0.916031	0.918033	0.900763
Accuracy	0.866667	0.877778	0.888889	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.

Conclusions

Summary:

- Decision Tree Model 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

- Thanks to Coursera Instructors For Providing the Best Data Science Capstone Course.

Thank you!