IBM

DATA SCIENCE CAPSTONE PROJECT

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SPACEX

Outline

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

Executive Summary

Summary of methodologies

- Data collection
- Data wrangling
- Exploratory Data Analysis with Data Visualization
- Exploratory Data Analysis with SQL
- Building an interactive map with Folium
- Building a Dashboard with Plotly Dash
- Predictive analysis (Classification)

Summary of all results

- Exploratory Data Analysis results
- Interactive analytics demo in 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.

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?

Methodology

Data collection methodology:

- Using SpaceX Rest API
- Using Web Scrapping from Wikipedia

Performed data wrangling

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

Performed exploratory data analysis (EDA) using visualization and SQL

Performed interactive visual analytics using Folium and Plotly Dash

Performed predictive analysis using classification models

- Building, tuning and evaluation of classification models to ensure the best results

Section 1

Methodology

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: Space X 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: Space X Data Collection Web Scraping]()

Data Wrangling

In the data set, there are several different cases where the booster did not land successfully like (True Ocean, Fales Ocean, True RTLS, Fales RTLS, True ASDS, Fales ASDS)

In this step we mainly convert those outcomes into training labels with “1” means the booster successfully landed, “0” means it was unsuccessful.

[GitHub URL: Space X Data Wrangling]()

1. Perform exploratory Data Analysis and determine Training Labels
2. Calculate the number of launches on each site
3. Calculate the number and occurrence of each orbit
4. Calculate the number and occurrence of mission outcome per orbit type
5. Create a landing outcome label from Outcome column
6. Exporting the data to CSV

EDA Using 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 Using SQL

EDA Data Visualization

Charts were 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

In this step we used pandas and Matplotlib libraries.

Types of Charts we Used it:

- 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.

GitHub URL: EDA Data Visualization

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 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: Build an Interactive Map 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 App

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

EDA Using SQL

All Launch Site Name

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

```
%sql SELECT DISTINCT LAUNCH_SITE AS "Launch_Sites" FROM SPACEXTBL;
```

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

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

Launch Site Names Begin with 'CCA'

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

```
%sql SELECT * FROM 'SPACEXTBL' WHERE Launch_Site LIKE 'CCA%' LIMIT 5;
```

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

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

Total Payload Mass

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

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

```
%sql SELECT SUM(PAYLOAD_MASS__KG_) AS "Total Payload Mass(Kgs)", Customer FROM 'SPACEXTBL' WHERE Customer = 'NASA (CRS)';
```

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

Total Payload Mass(Kgs)	Customer
45596	NASA (CRS)

Average Payload Mass by F9 v1.1

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

```
%sql SELECT AVG(PAYLOAD_MASS__KG_) AS "Payload Mass Kgs", Customer, Booster_Version FROM 'SPACEXTBL' WHERE Booster_Version l
```

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

Payload Mass Kgs	Customer	Booster_Version
2534.6666666666665	MDA	F9 v1.1 B1003

Fist Successful Ground Landing Data

List the date when the first successful landing outcome in ground pad was achieved

```
%sql SELECT MIN(DATE) FROM 'SPACEXTBL' WHERE "Landing_Outcome" = "Success (ground pad)";
```

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

MIN(DATE)
2015-12-22

Successful Drone Ship Landing with Payload Between 4000 and 6000

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

```
%sql SELECT DISTINCT Booster_Version, Payload FROM SPACEXTBL WHERE "Landing_Outcome" = "Success (drone ship)" AND PAYLOAD_MA
```

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

Booster_Version	Payload
F9 FT B1022	JCSAT-14
F9 FT B1026	JCSAT-16
F9 FT B1021.2	SES-10
F9 FT B1031.2	SES-11 / EchoStar 105

Total Number of Successful and Failure Mission Outcomes

List the total number of successful and failure mission outcomes

```
%sql SELECT "Mission_Outcome", COUNT("Mission_Outcome") AS Total FROM SPACEXTBL GROUP BY "Mission_Outcome";
```

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

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

Boosters Carried Maximum Payload

List the names of the booster_versions which have carried the maximum payload mass. Use a subquery

```
%sql SELECT "Booster_Version","Payload", "PAYLOAD_MASS__KG_" FROM SPACEXTBL WHERE "PAYLOAD_MASS__KG_" = (SELECT MAX("PAYLOAD
```

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

Booster_Version	Payload	PAYLOAD_MASS__KG_
F9 B5 B1048.4	Starlink 1 v1.0, SpaceX CRS-19	15600
F9 B5 B1049.4	Starlink 2 v1.0, Crew Dragon in-flight abort test	15600
F9 B5 B1051.3	Starlink 3 v1.0, Starlink 4 v1.0	15600
F9 B5 B1056.4	Starlink 4 v1.0, SpaceX CRS-20	15600
F9 B5 B1048.5	Starlink 5 v1.0, Starlink 6 v1.0	15600
F9 B5 B1051.4	Starlink 6 v1.0, Crew Dragon Demo-2	15600
F9 B5 B1049.5	Starlink 7 v1.0, Starlink 8 v1.0	15600
F9 B5 B1060.2	Starlink 11 v1.0, Starlink 12 v1.0	15600
F9 B5 B1058.3	Starlink 12 v1.0, Starlink 13 v1.0	15600
F9 B5 B1051.6	Starlink 13 v1.0, Starlink 14 v1.0	15600
F9 B5 B1060.3	Starlink 14 v1.0, GPS III-04	15600
F9 B5 B1049.7	Starlink 15 v1.0, SpaceX CRS-21	15600

2015 Launch Records

List the records which will display the month names, failure landing_outcomes in drone ship ,booster versions, launch_site for the months in year 2015.

```
%sql SELECT "Booster_Version", "Launch_Site", "PAYLOAD_MASS__KG_", "Mission_Outcome", "Date", "Landing_Outcome" FROM SPACEXT
```

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

Booster_Version	Launch_Site	PAYLOAD_MASS__KG_	Mission_Outcome	Date	Landing_Outcome
F9 v1.1 B1012	CCAFS LC-40	2395	Success	2015-01-10	Failure (drone ship)
F9 v1.1 B1015	CCAFS LC-40	1898	Success	2015-04-14	Failure (drone ship)

Rank Success Count 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

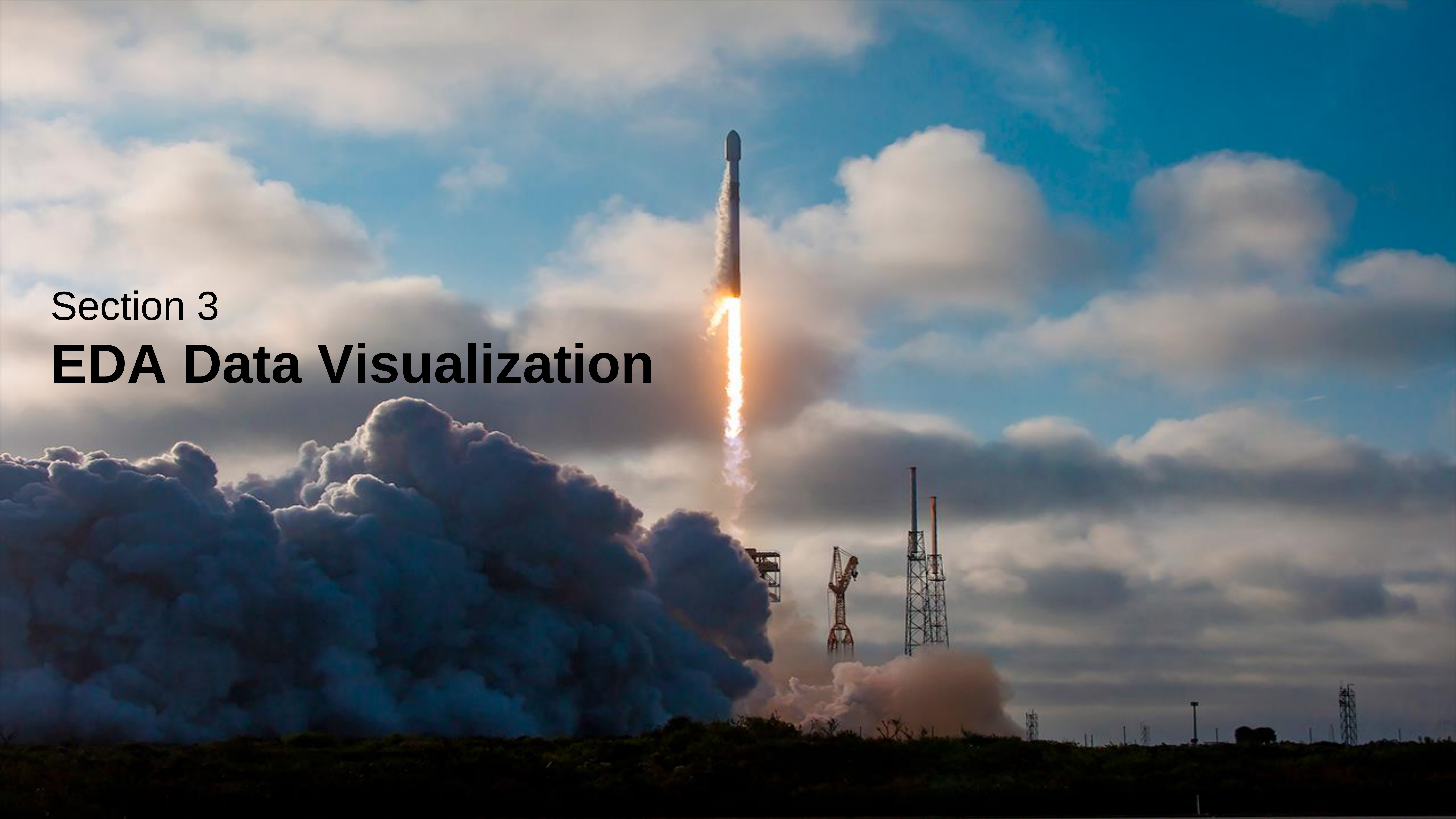
```
%sql SELECT * FROM SPACEXTBL WHERE ("Landing_Outcome"= 'Failure (drone ship)' OR 'Success (ground pad)') AND (Date BETWEEN
```

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

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing_Outcome
2016-06-15	14:29:00	F9 FT B1024	CCAFS LC-40	ABS-2A Eutelsat 117 West B	3600	GTO	ABS Eutelsat	Success	Failure (drone ship)
2016-03-04	23:35:00	F9 FT B1020	CCAFS LC-40	SES-9	5271	GTO	SES	Success	Failure (drone ship)
2016-01-17	18:42:00	F9 v1.1 B1017	VAFB SLC-4E	Jason-3	553	LEO	NASA (LSP) NOAA CNES	Success	Failure (drone ship)
2015-04-14	20:10:00	F9 v1.1 B1015	CCAFS LC-40	SpaceX CRS-6	1898	LEO (ISS)	NASA (CRS)	Success	Failure (drone ship)
2015-01-10	9:47:00	F9 v1.1 B1012	CCAFS LC-40	SpaceX CRS-5	2395	LEO (ISS)	NASA (CRS)	Success	Failure (drone ship)

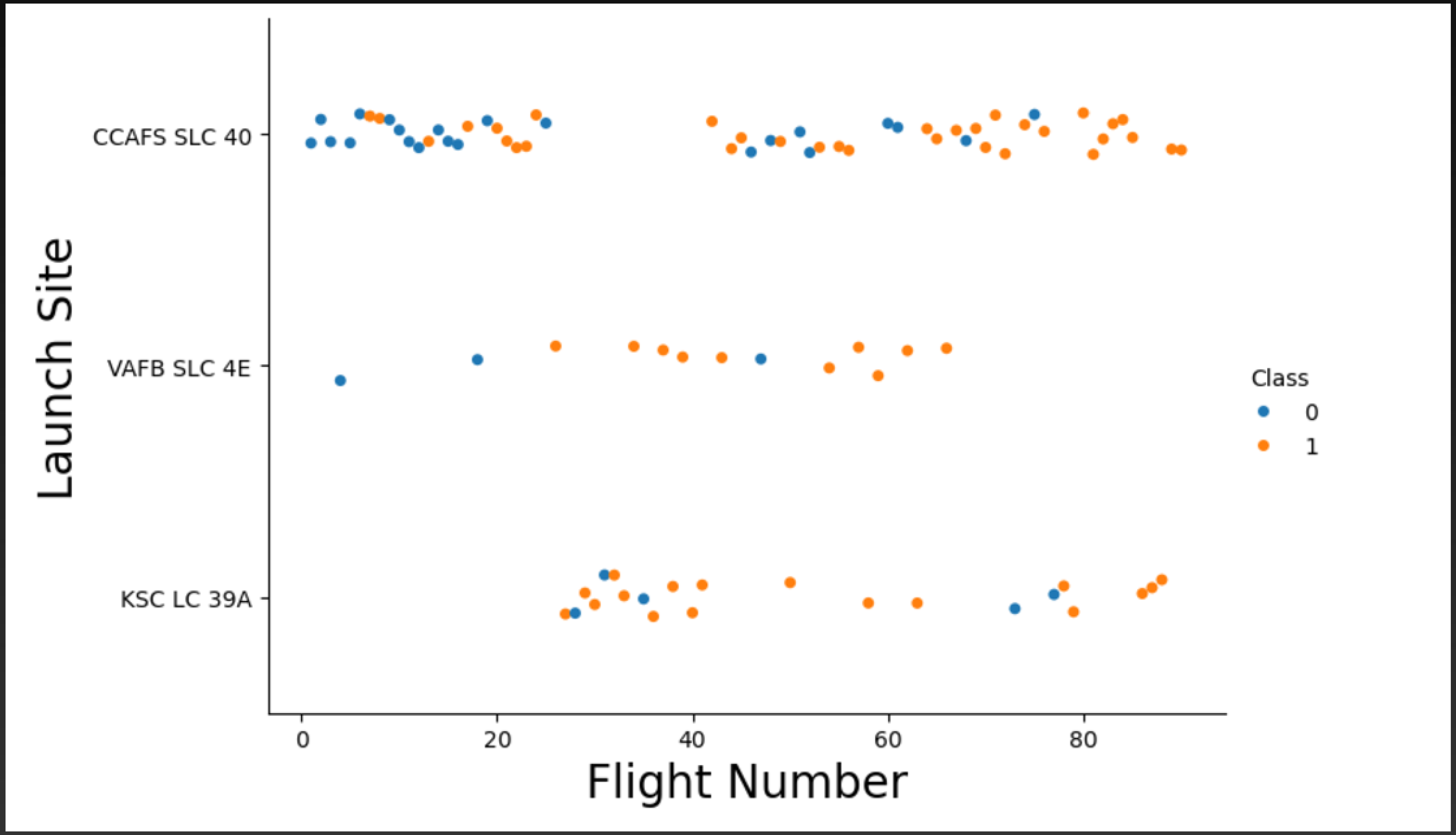
Section 3

EDA Data Visualization



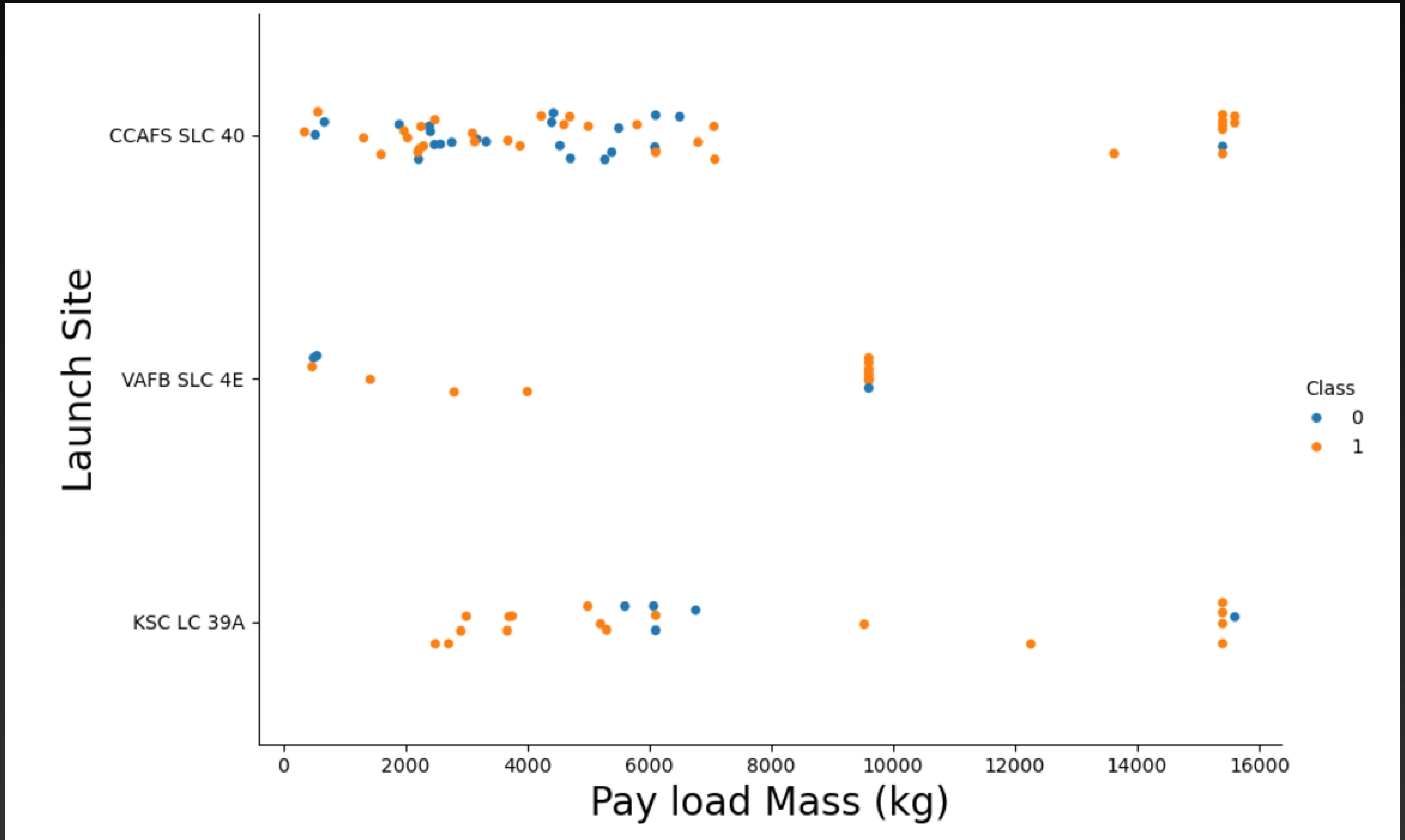
Flight Number vs. Launch Site

- The earliest flights, most of them 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.
- we can be assumed that each new launch has a higher rate of success.



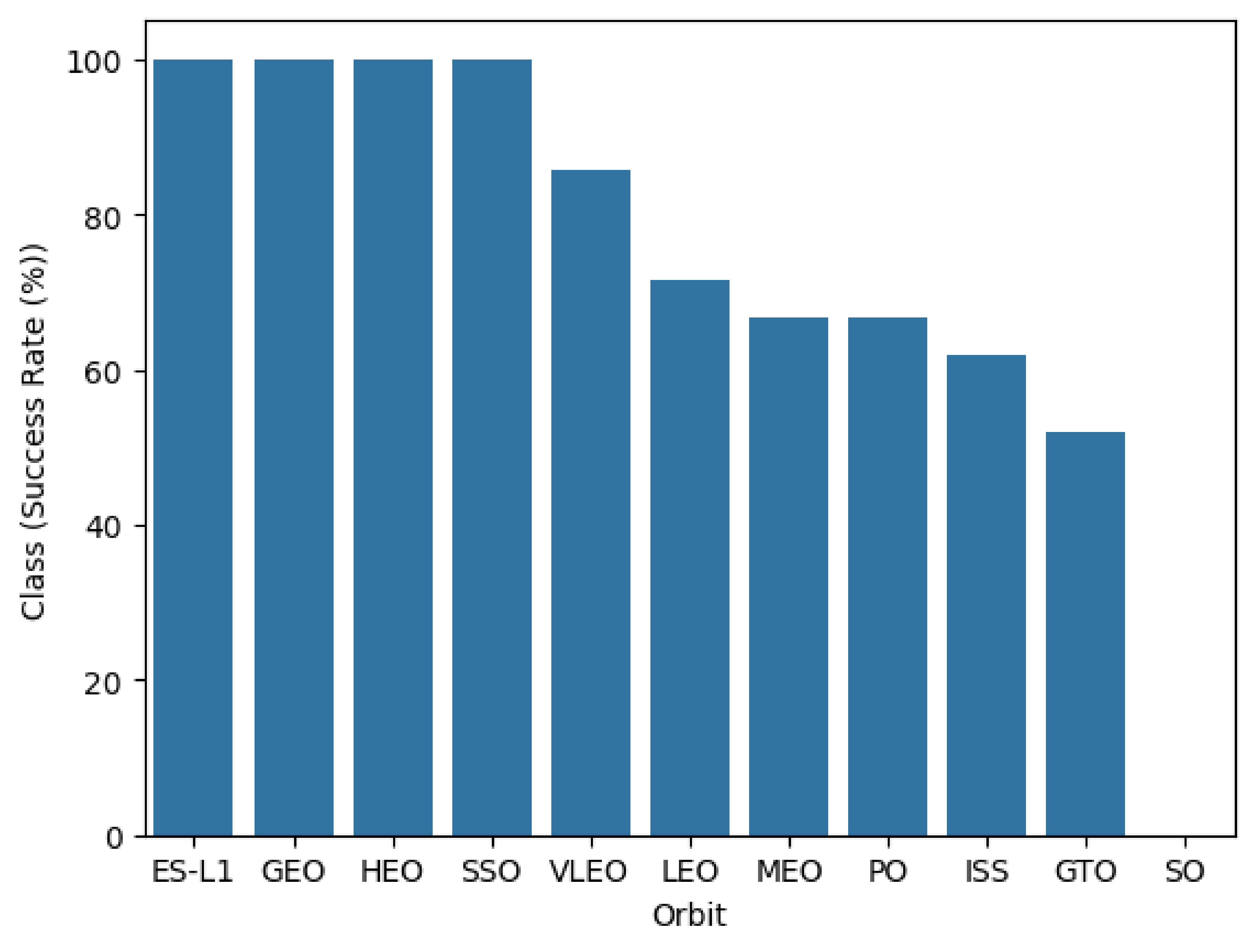
Payload vs. Launch Site

- 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.
- The most of CCAFS SLC 40 launches were successful



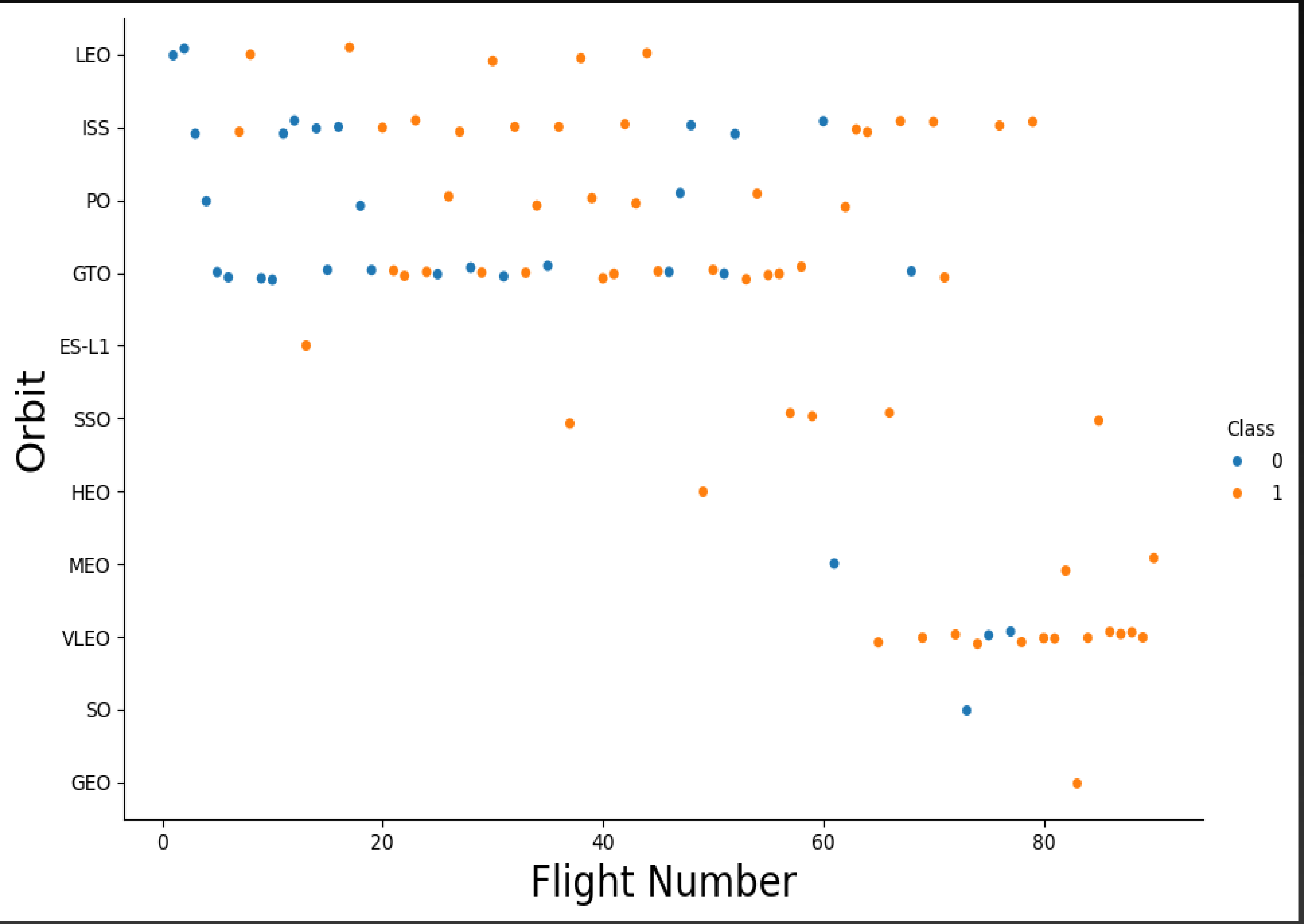
Success Rate vs. Orbit Type

- Orbits with 100% success rate were:
  - ES-L1, GEO, HEO, SSO
- Orbits with 0% success rate was:
  - SO
- Orbits with success rate between 90% to 50% were:
  - GTO, ISS, LEO, MEO, PO



Flight Number vs. Orbit Type

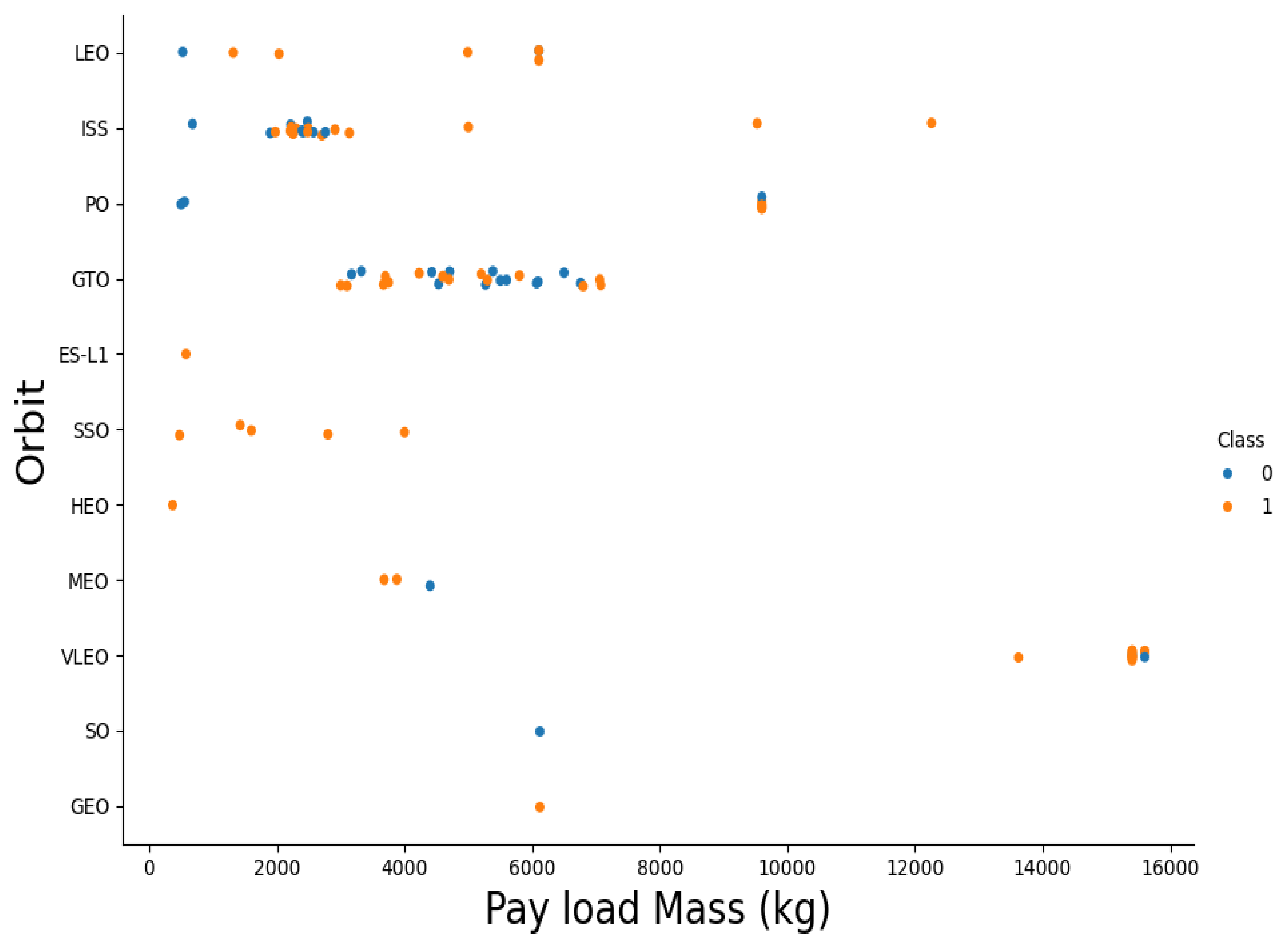
- We can observe that in the LEO orbit, success seems to be related to the number of flights. Conversely, in the GTO orbit, there appears to be no relationship between flight number and success



Payload Mass vs. Orbit Type

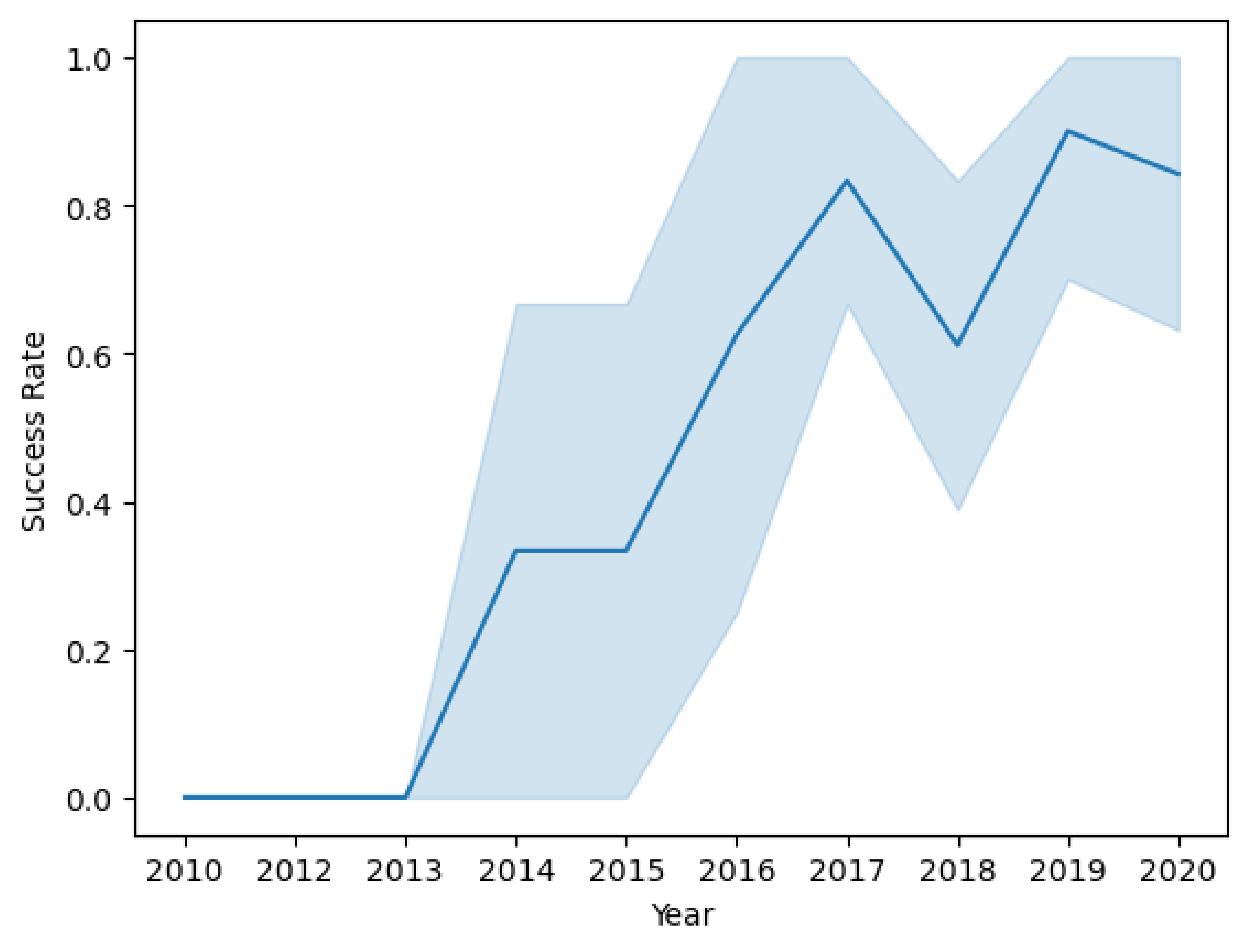
- With heavy payloads the successful landing or positive landing rate are more for Polar, LEO and ISS.

- For GTO, it's difficult to distinguish between successful and unsuccessful landings as both outcomes are present.



Launch Success Yearly Trend

- The success rate since 2013 kept increasing till 2020.

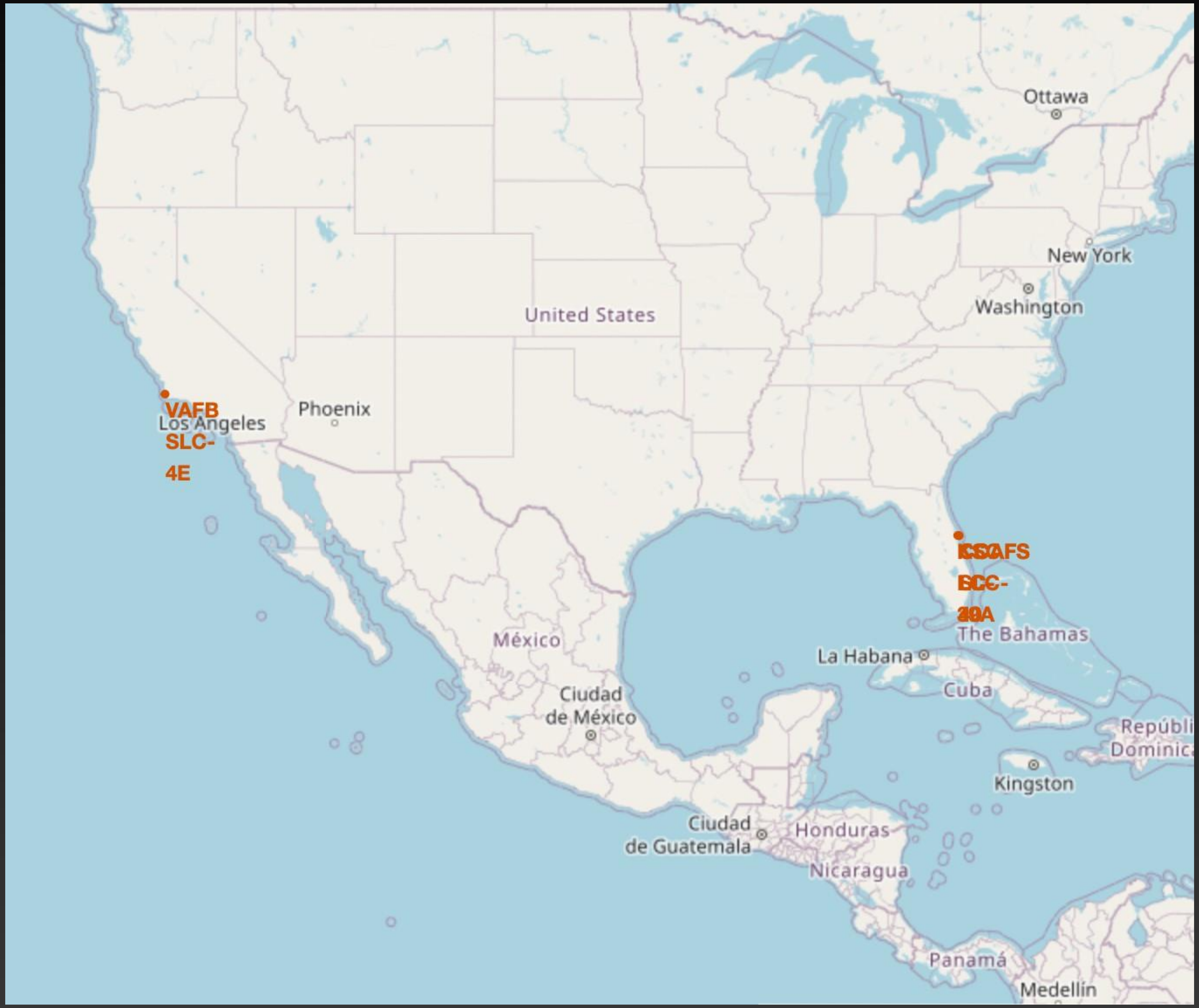


Section 4

Interactive Map with Folium

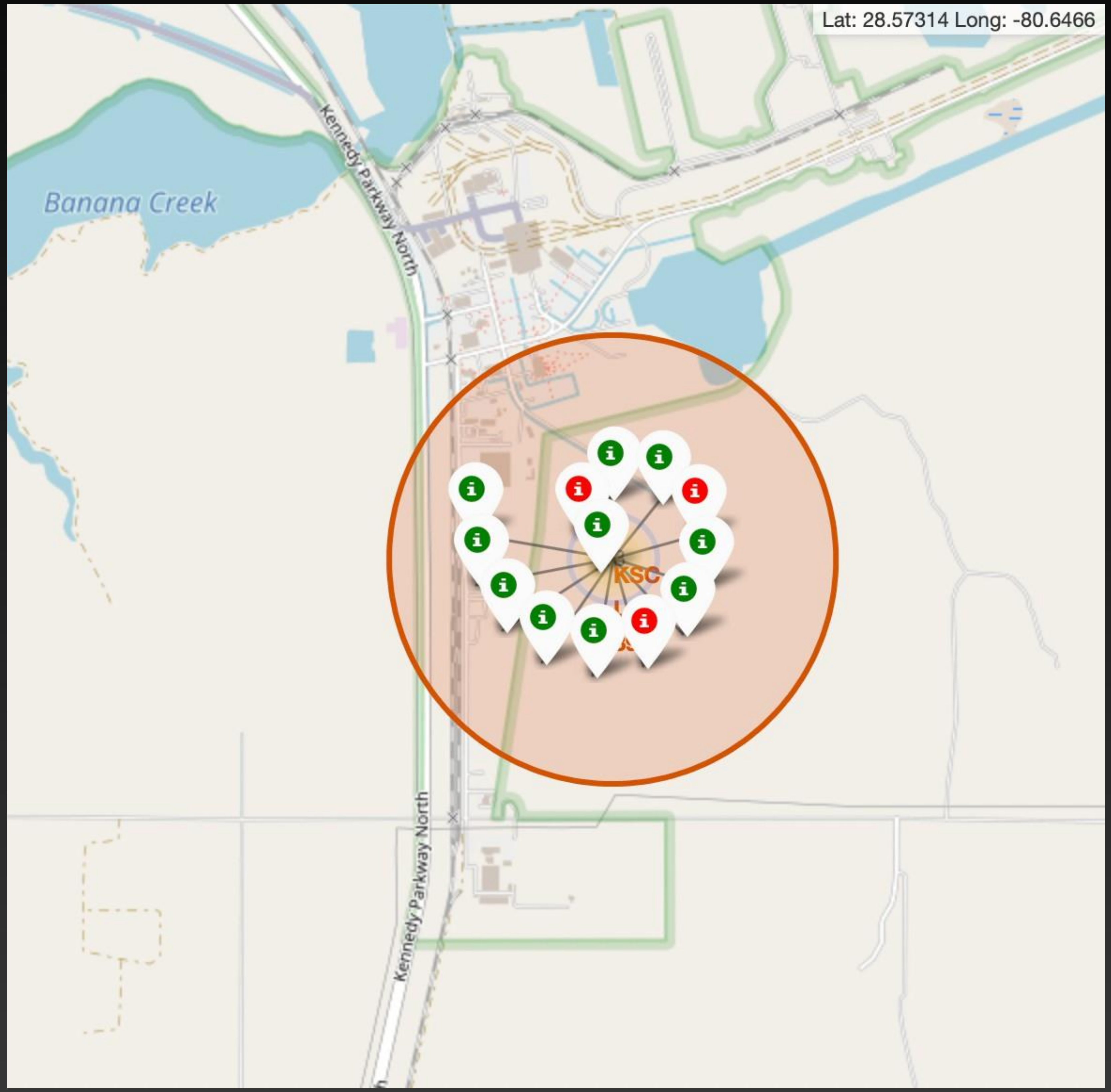
All Launch Sites’ Location Markers on a Global Map

- Most of Launch sites were 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 were 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.



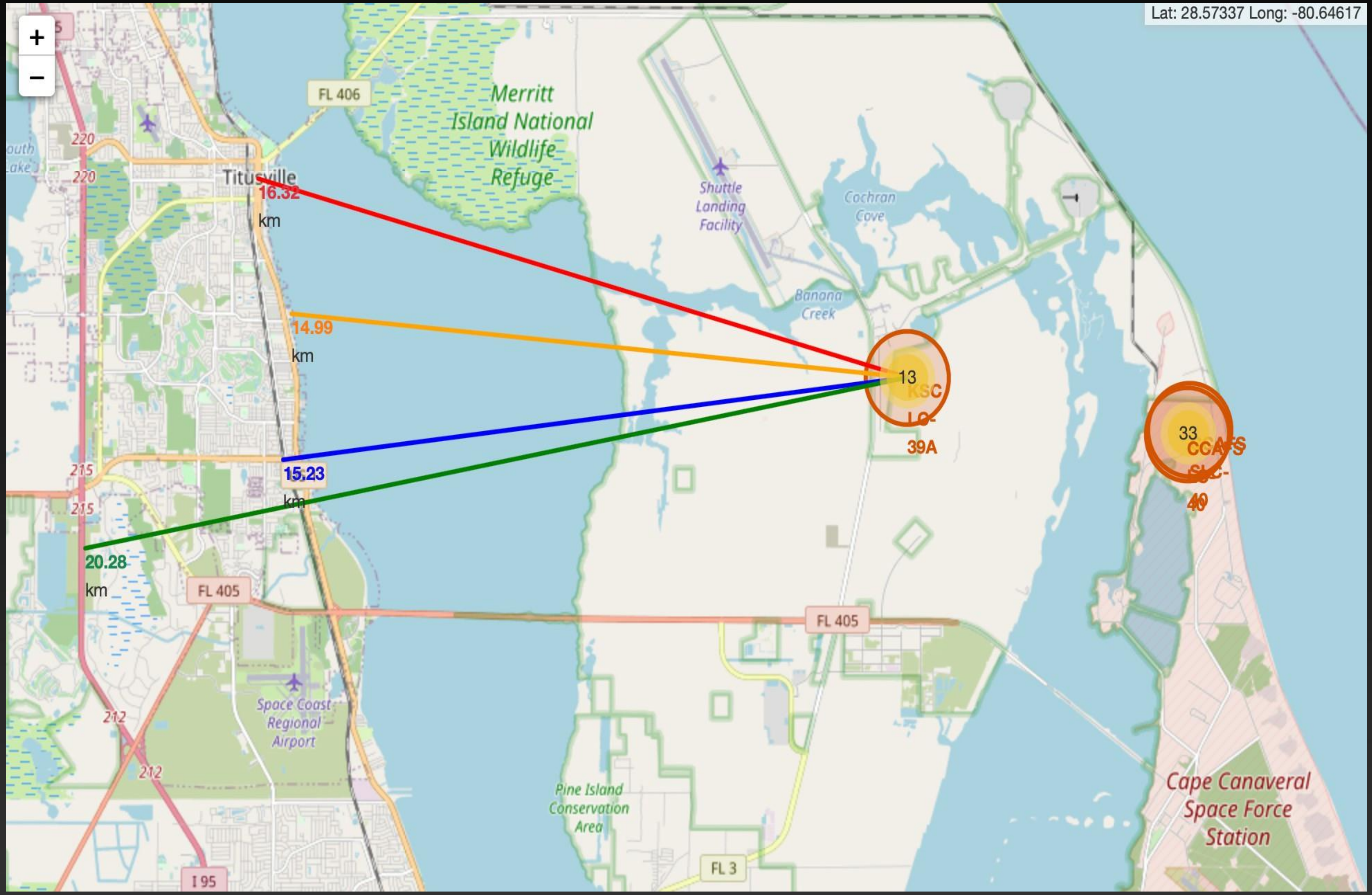
Colour- Labeled Launch Records on the Map

- 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 Proximities

- 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 (20.28 km)
  - relative close to coastline (14.99 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.

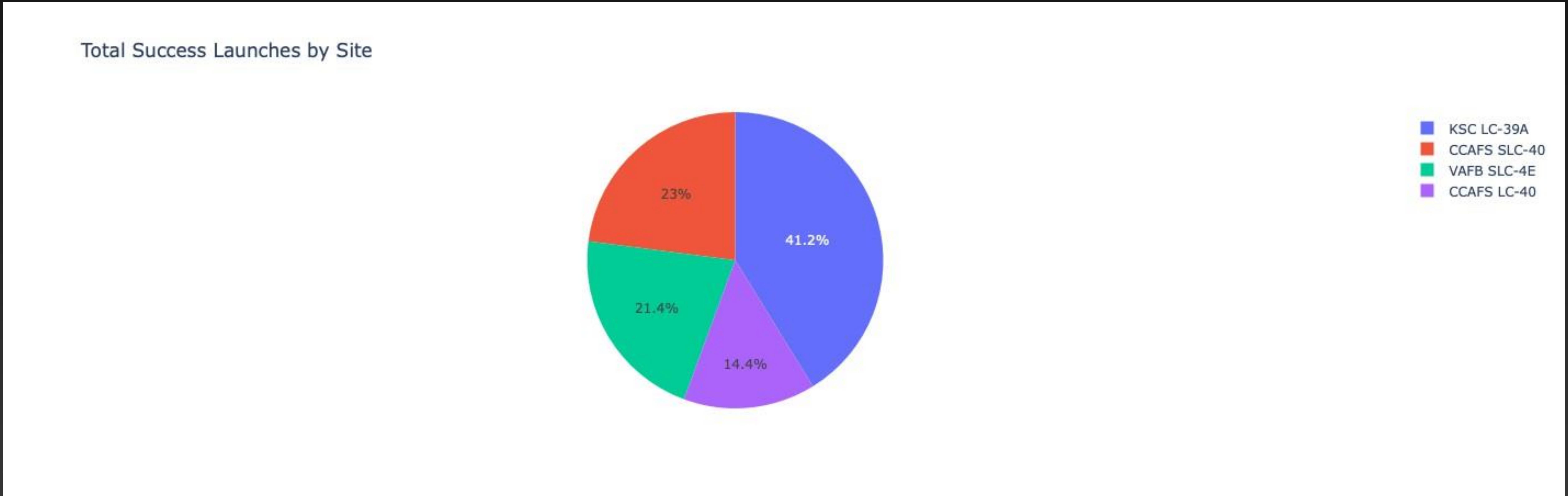


Section 5

Build a Dashboard with Plotly Dash

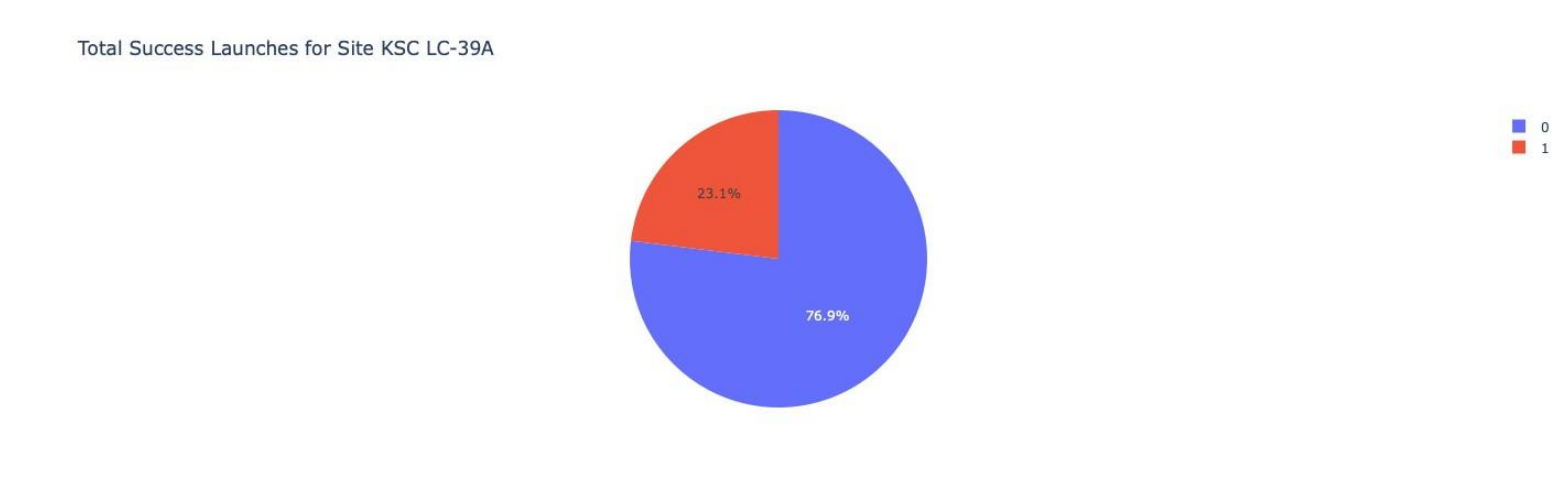
Launch Success Count for all Sites

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



Launch Site with Highest Launch Success Ratio

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



Payload Mass vs. Launch Outcome for all Sites

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

Section 5

Predictive Analysis (Classification)

Classification Models Accuracy

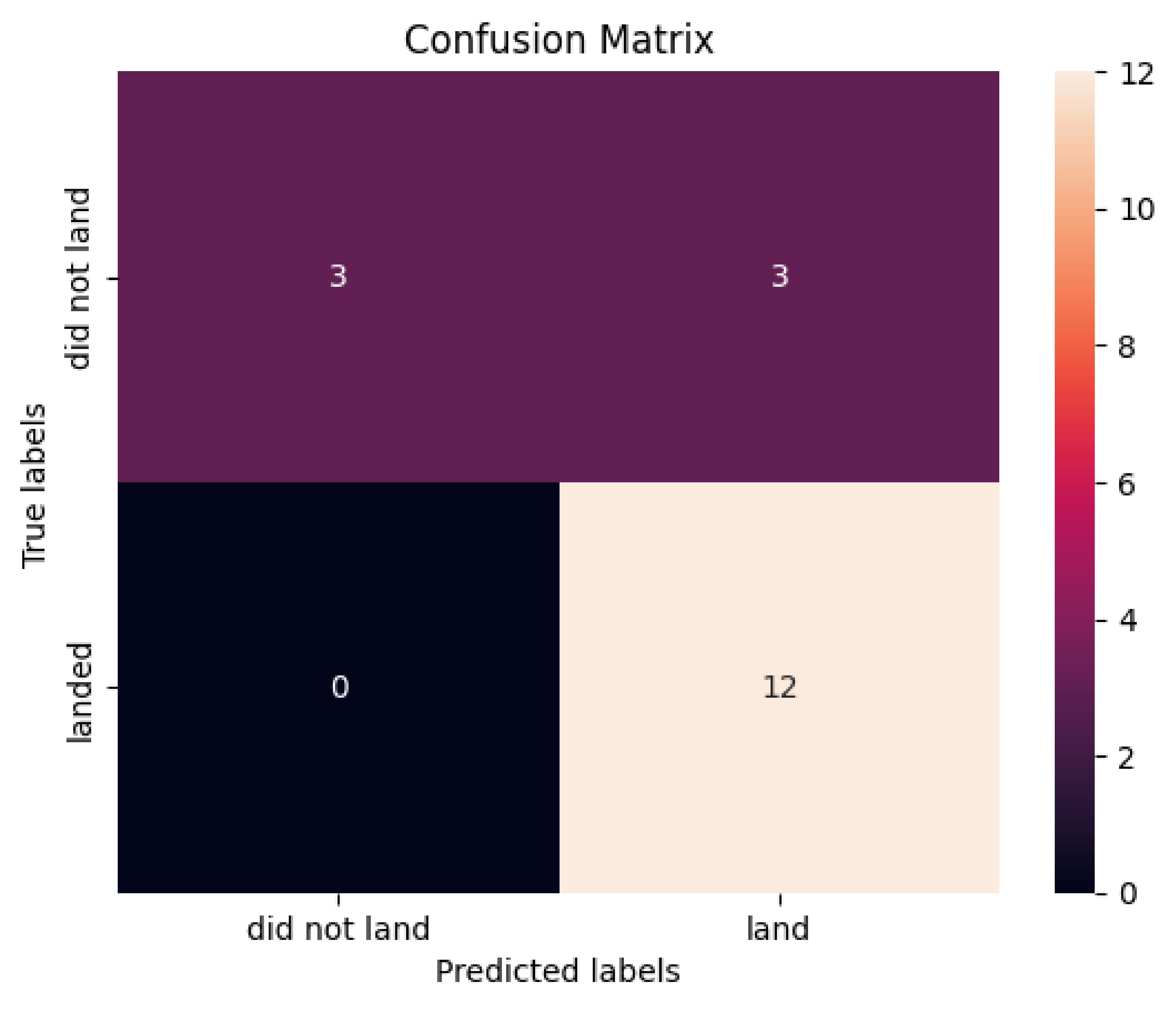
- Based on the scores of the Test Set, we can not confirm which method performs best.
- Same Test Set scores may be due to the small test sample size (18 samples). Therefore, we tested all methods based on the whole Dataset.
- The scores of the whole Dataset confirm that the best model is the Decision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

Scores and Accuracy of the Test Set

Method	Test Data Accuracy
Logistic_Reg	0.833333
SVM	0.833333
Decision Tree	0.888889
KNN	0.833333

Confusion Matrix

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



Conclusion

- KSC LC-39A has the highest success rate of the launches from all the sites.
- Different launch sites had different success rate
- Orbits ES-L1, GEO, HEO and SSO have 100% success rate.
- 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.
- Decision Tree Model is the best algorithm for this dataset.

THANK YOU