IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

yasser saifi
08/01/2025

Outline

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

Executive Summary

➢ **Summary of methodologies:**

Data Collection using API

Data Collection with Web Scraping

Data Wrangling

Exploratory Data Analysis using SQL

EDA DataViz Using Python Pandas and Matplotlib

Launch Sites Analysis with Folium-Interactive Visual Analytics and Ploty Dash

Machine Learning Landing

➢ **Summary of all results:**

- EDA results
- Interactive Visual Analytics and Dashboards 3-
- Predictive Analysis

Introduction

- Project background and context

  The space industry is evolving with frequent launches and increasing data availability.

  Data science plays a crucial role in analyzing launch outcomes, mission success rates, and risk factors. This project follows a full data science workflow to support better launch decision-making.

- Problems you want to find answers

  What factors influence the success or failure of space launches?

  Can we predict the likelihood of a successful mission using available data?

  Where are the high-risk launch sites or conditions?

  How can interactive tools support mission planning and monitoring?

Section 1

Methodology

Methodology

Executive Summary

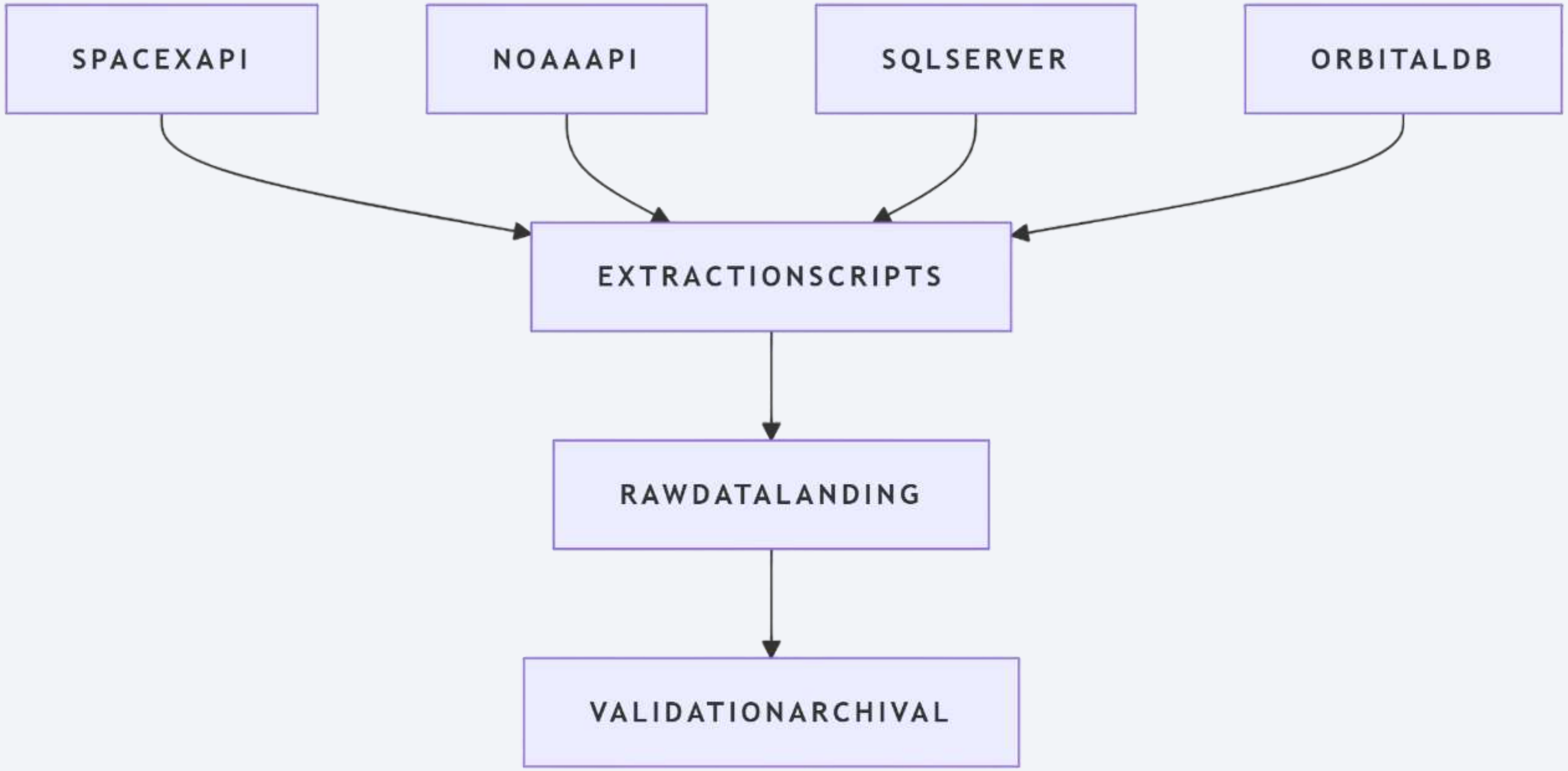
- Data collection methodology: Aggregated launch records from public APIs (e.g. SpaceX) and legacy SQL databases; pulled weather and orbital data via REST endpoints.
- Perform data wrangling: Cleaned missing values, standardized units (mass, coordinates), engineered features (e.g. payload-to-mass ratio, launch-site weather risk).
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - Trained classification models (Logistic Regression, Random Forest) with feature selection, hyperparameter tuning (GridSearchCV), and cross-validation..

Data Collection

- **Data Sources**
  - SpaceX Launch API (mission metadata, success/failure flags)
  - NOAA Weather REST API (launch-day conditions)
  - Orbital Tracking Database (TLE satellite orbital elements)
  - Historical SQL archive (legacy launch records)
- **Key Phrases**
  - RESTful API calls → JSON payloads
  - Scheduled ETL jobs (cron + Python)
  - Bulk SQL exports → CSV dumps
  - Incremental ingest → Delta Lake

Data Collection

- Global Flowchart



Data Collection – SpaceX API

- Key Phrases

  -**RESTful GET Endpoints:** /launches, /rockets/{id}, /launchpads/{id}, /payloads/{id>

  -**Query Parameters:** ?start=YYYY-MM-DD&end=YYYY-MM-DD for date filtering

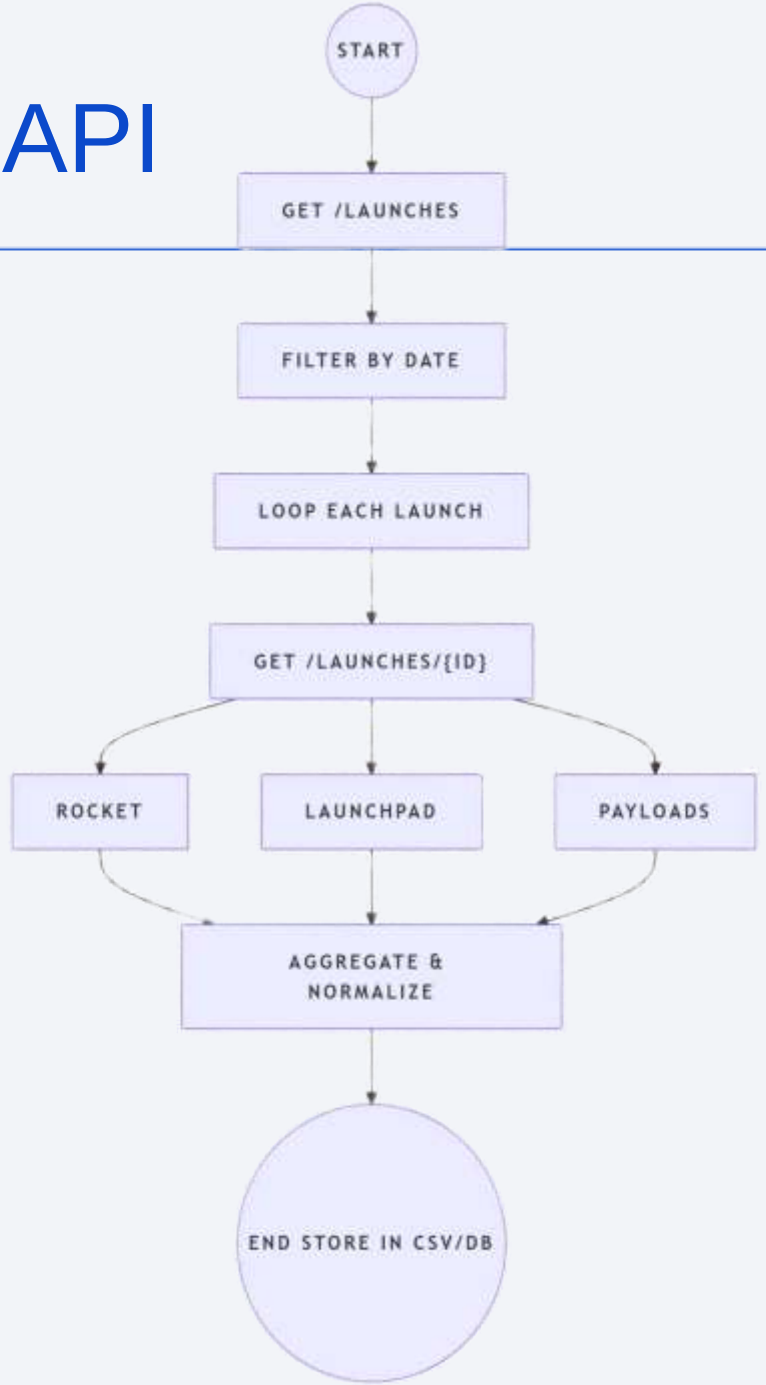
  -**Pagination & Rate-Limiting**: handle bulk pulls with page tokens and back-off -logic

  JSON Normalization: flatten nested objects into tabular row

  -**Batch vs. Incremental:** full refresh monthly, incremental daily

  -**ETL Pipeline**: Python scripts scheduled via cron → raw JSON → Parquet in Data Lake

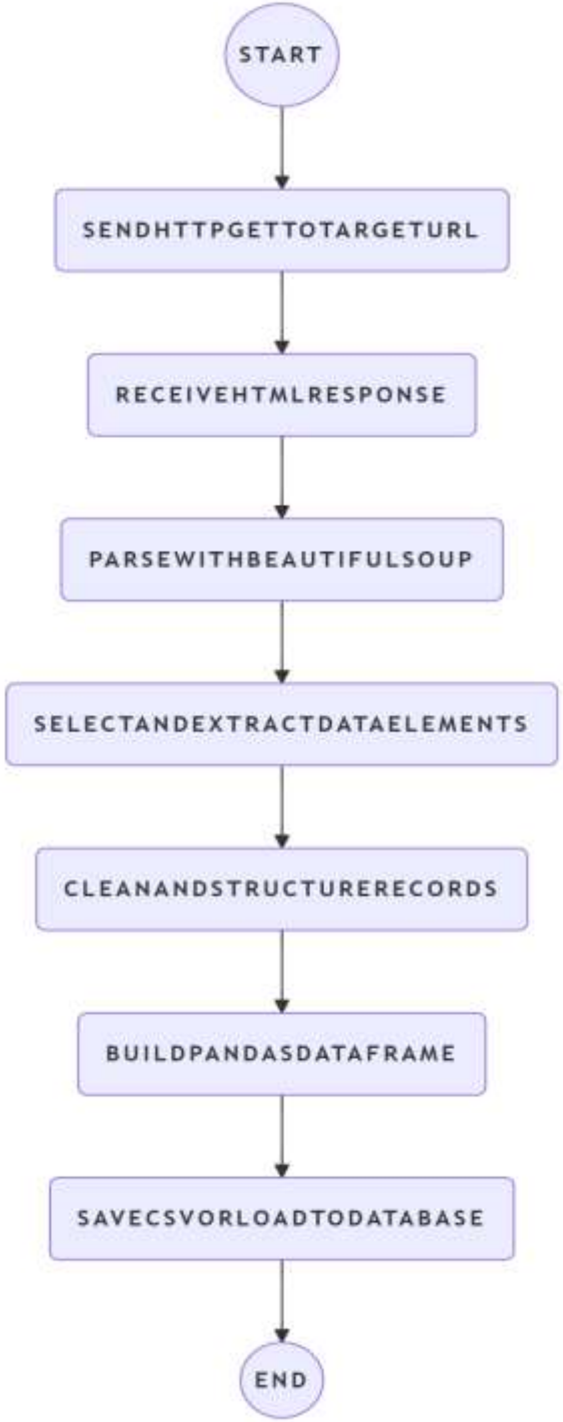
- **GitHub URL of the completed SpaceX API >**
- https://github.com/yassfix/Capstone/blob/main/Data%20Collection.ipynb



Data Collection - Scrapin

Key Phrases

- **Sent HTTP request to Wikipedia page using requests**
- **Loaded HTML content into BeautifulSoup parser**
- **Located HTML table containing Falcon 9 launch records**
- **Extracted table rows (<tr> elements)**
- **Parsed launch data from table cells (<td> elements)**
- **Stored extracted data into a list of dictionaries**
- **Converted parsed data into a Pandas DataFrame**
- the GitHub URL of the completed web scraping notebook: https://github.com/yassfix/Capstone/blob/main/scraping.ipynb

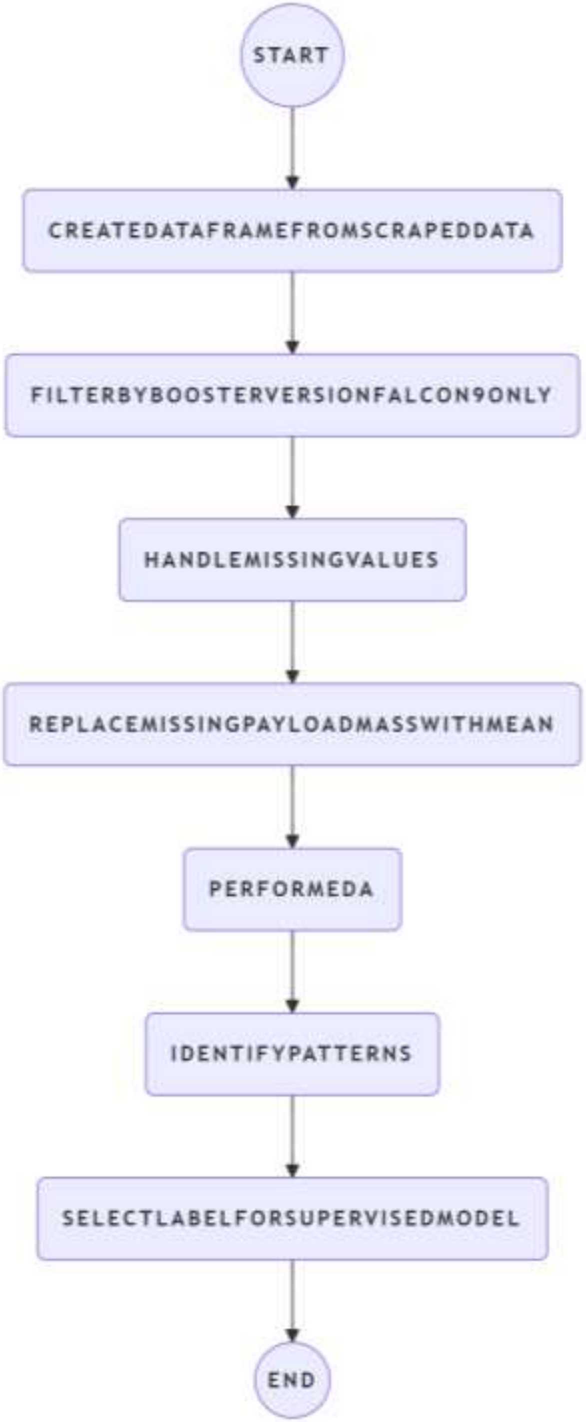


Data Wrangling

Key Phrases

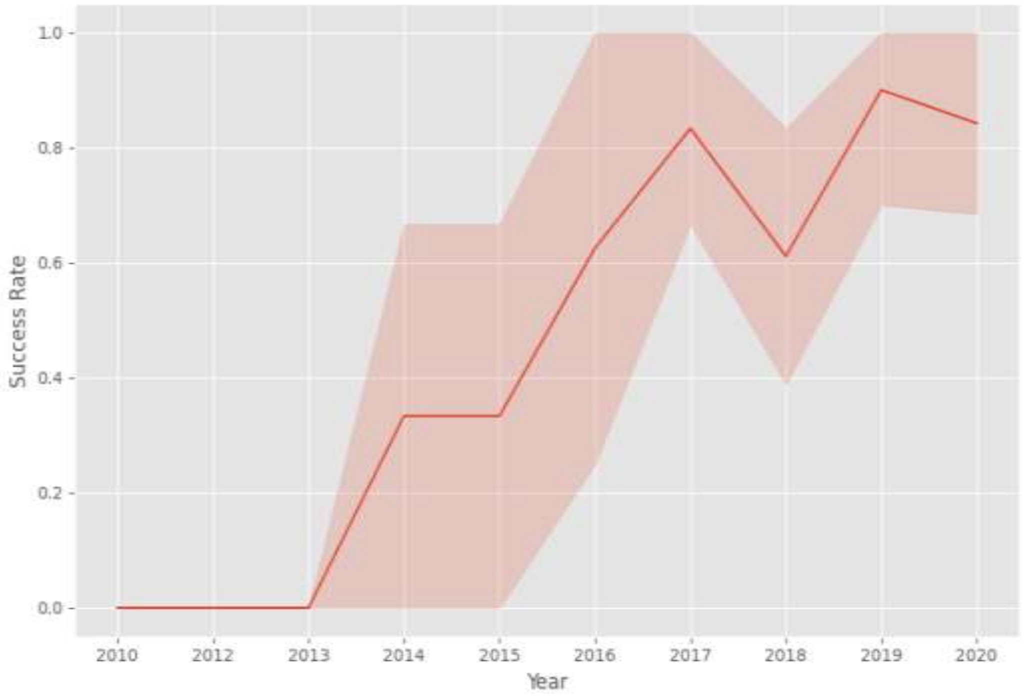
- **Created Pandas DataFrame from scraped data**
- **Filtered DataFrame by `BoosterVersion` to keep Falcon 9 launches**
- **Handled missing values in `LandingPad` and `PayloadMass` columns**
- **Replaced missing `PayloadMass` values with column mean**
- **Performed Exploratory Data Analysis (EDA)**
- **Identified patterns in launch data**
- **Selected target label for supervised learning models**

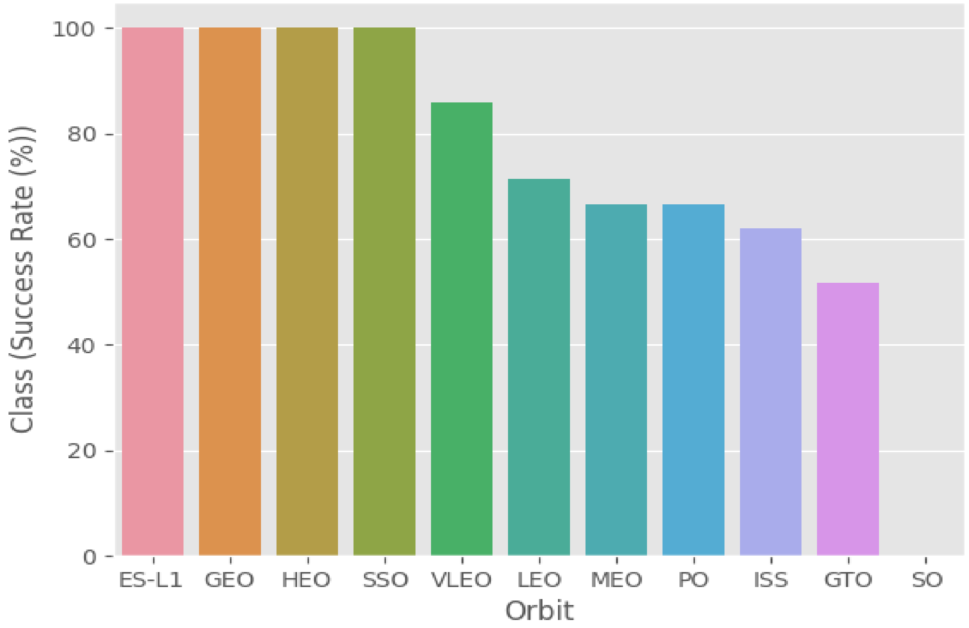
- GitHub URL of completed data wrangling related notebooks:
- https://github.com/yassfix/Capstone/blob/main/Data%20Wrangling.ipynb



EDA with Data Visualization

- -Conducted data analysis and feature engineering with Pandas and Matplotlib
- Performed Exploratory Data Analysis (EDA) to understand key patterns
- Engineered relevant features for model training
- Created scatter plots to explore relationships between: Flight Number and Launch Site, Payload and Launch Site, Flight Number and Orbit Type, Payload and Orbit Type
- Built bar chart to display success rates by orbit type
- Generated line plot to visualize yearly launch success trends
- **the GitHub URL of completed EDA with data visualization** https://github.com/yassfix/Capstone/blob/main/EDA%20with%20Data%20Visualization.ipynb





EDA with SQL

- SQL queries executed with EDA :

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

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

%sql SELECT DISTINCT Booster_Version, Payload FROM SPACEXTBL WHERE "Landing _Outcome" = "Success (drone ship)" AND PAYLOAD_MASS__KG_ >
4000 AND PAYLOAD_MASS__KG_ < 6000;
```

- Selected unique booster versions and payloads for drone ship landings with payloads between 4000–6000 kg.
- Calculated total payload mass for launches by NASA (CRS).
- Retrieved all unique launch site names from the dataset.

- **the GitHub URL of your completed EDA with SQL:**
- https://github.com/yassfix/Capstone/blob/main/EDA%20Using%20SQL.ipynb

Build an Interactive Map with Folium

- Created a Folium map to mark all launch sites
- Added map objects including markers, circles, and lines to indicate launch success or failure at each site
- Defined launch outcome labels with failure = 0 and success = 1

- **the GitHub URL of completed interactive map with Folium map:**

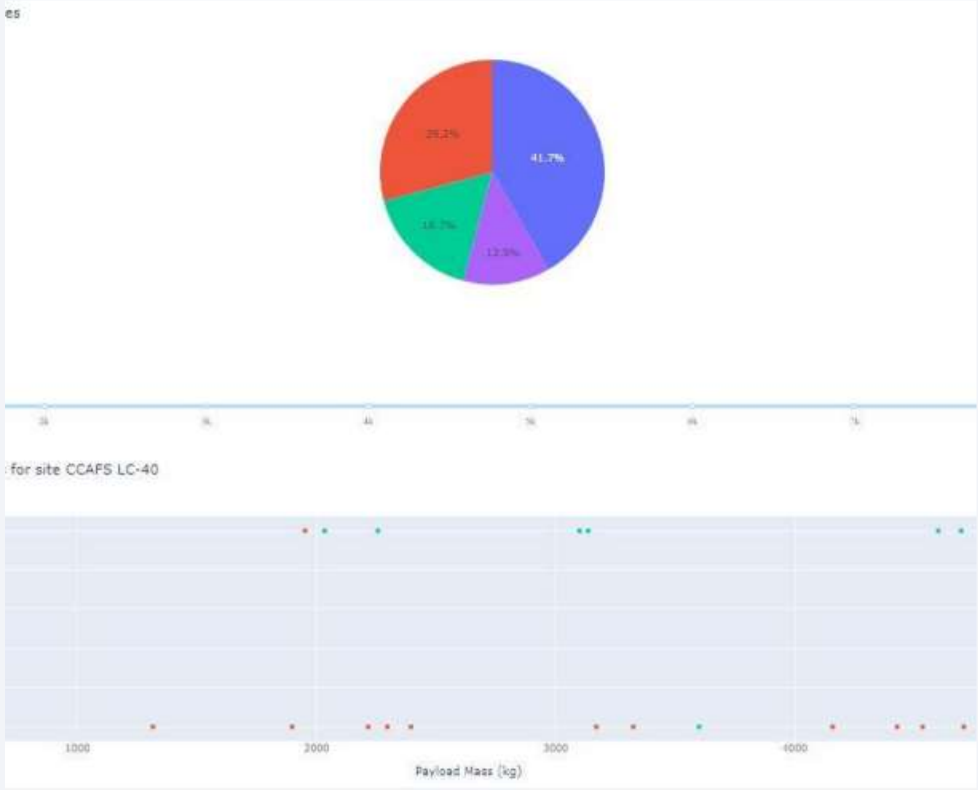
https://github.com/yassfix/Capstone/blob/main/interactive%20map%20with%20Folium%20map.ipynb

Build a Dashboard with Plotly Dash

- Built an interactive dashboard using Plotly Dash
- Added a launch site dropdown input component
- Implemented callback function to render success pie chart based on selected site
- Included a payload range slider for user input
- Added callback function to display success vs payload scatter plot

the GitHub URL of completed Plotly Dash lab:

https://github.com/yassfix/Capstone/blob/main/Interactive%20Dashboard.py



Predictive Analysis (Classification)

- Loaded data into Pandas DataFrame for analysis

- Performed Exploratory Data Analysis (EDA) to define training labels

- Converted 'Class' column to NumPy array and assigned it to outcome variable Y

- Standardized feature dataset X using `StandardScaler` from sklearn.preprocessing

- Split data into training and testing sets using `train_test_split` (test_size=0.2, random_state=2)

- Evaluated multiple classification models: SVM, Decision Tree, K-Nearest Neighbors, and Logistic Regression

- Created model objects and corresponding `GridSearchCV` instances for hyperparameter tuning

- Used 10-fold cross-validation (`cv=10`) during grid search

- Fitted each model using training data to identify best hyperparameters

- Retrieved best parameters (`best_params_`) and validation accuracy (`best_score_`)

- Calculated test accuracy using `.score()` method

- Plotted confusion matrix for each model to compare prediction performance

Created a comparison table of test accuracy scores for all models

-Comparing performance of:
- Support Vector Machine (SVM)
- Classification Trees
- K-Nearest Neighbors (KNN)
- Logistic Regression

-Analyzed test accuracy to identify the best performing model and Used results to determine which model generalizes best to unseen data

Out[68]:

	0
Method	Test Data Accuracy
Logistic_Reg	0.833333
SVM	0.833333
Decision Tree	0.833333
KNN	0.833333

GitHub URL of the completed predictive analysis

https://github.com/yassfix/Capstone/blob/main/Machine%20Learning%20Prediction.ipynb

Results

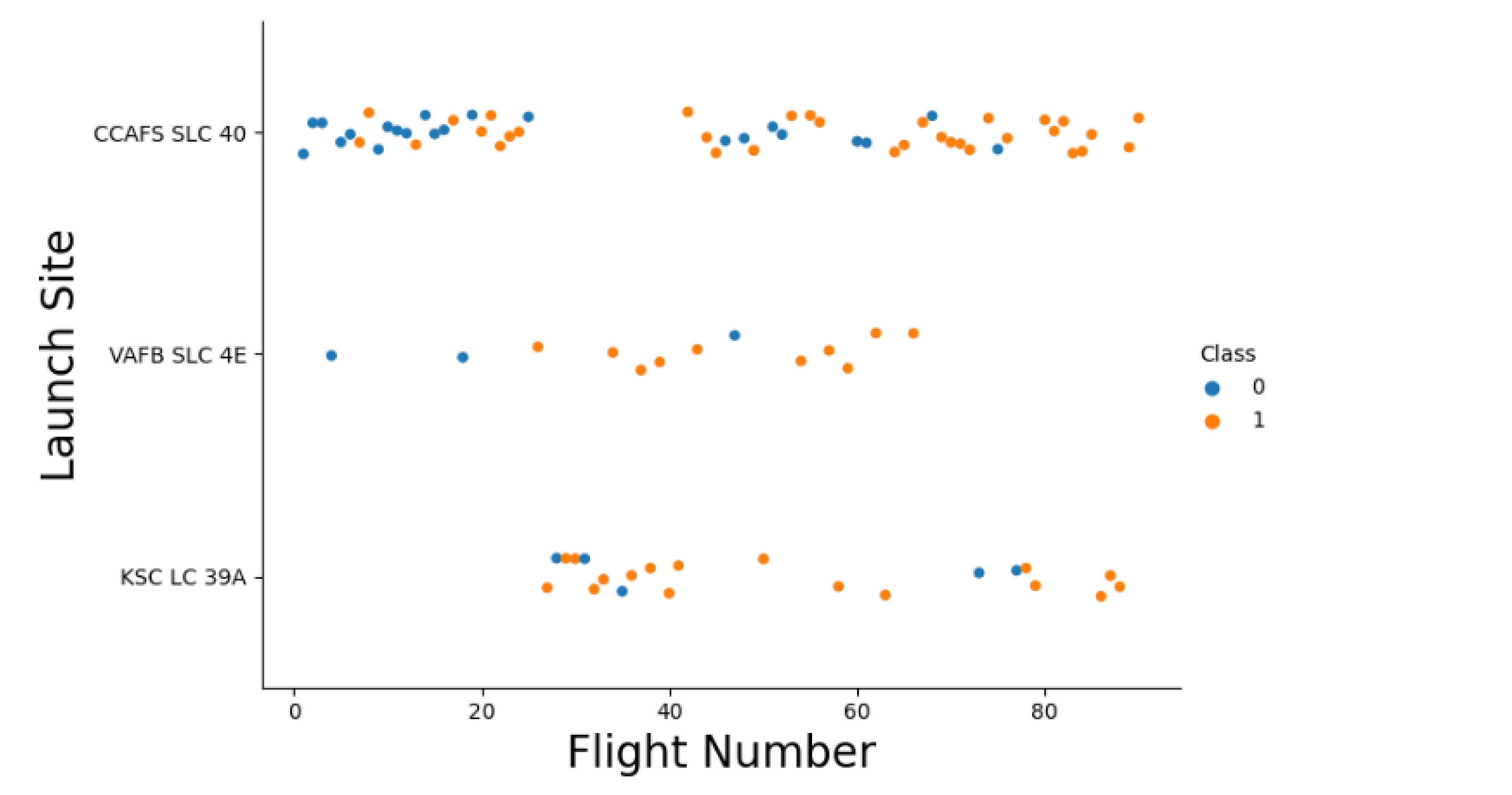
- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

Section 2

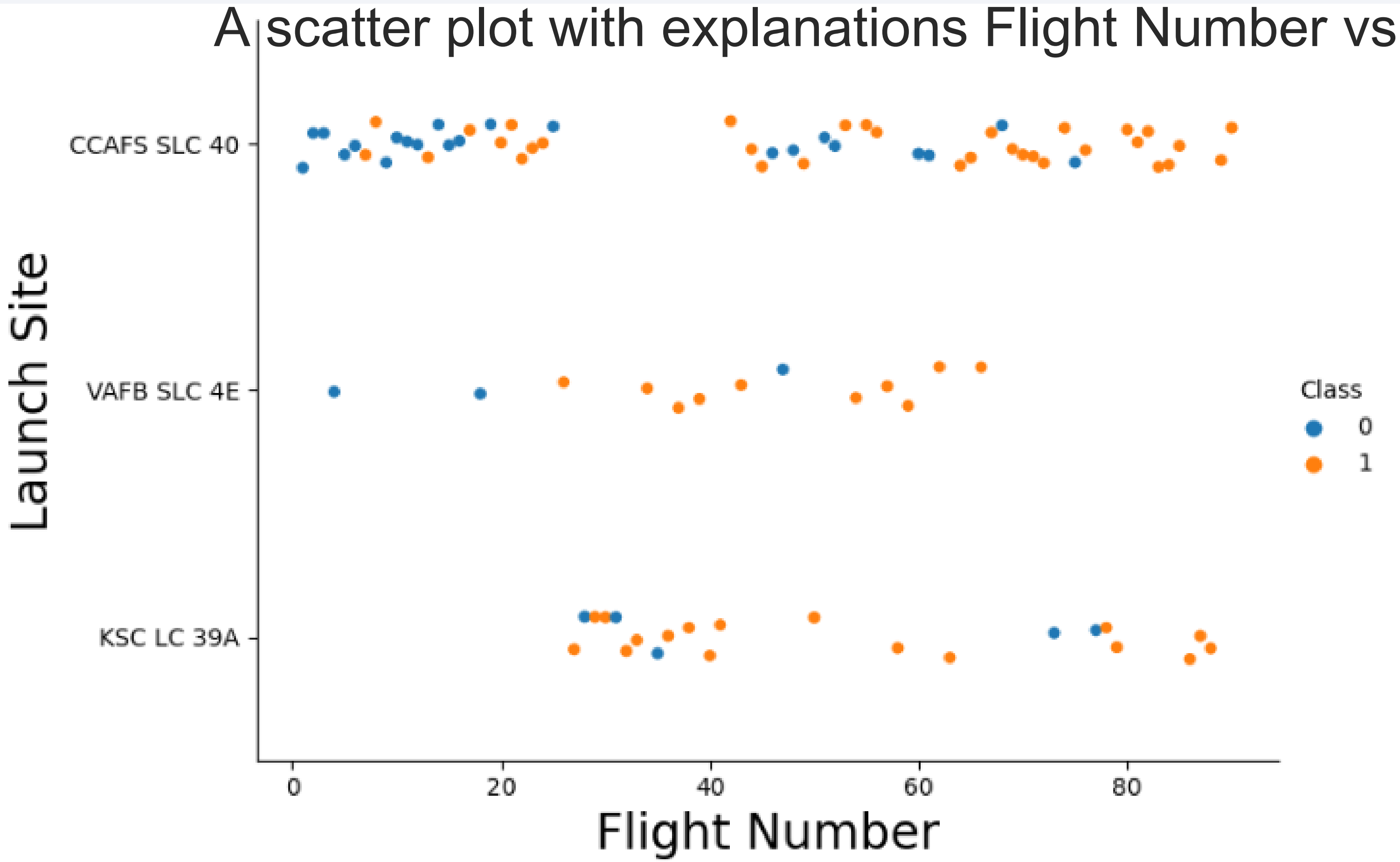
Insights drawn from EDA

Flight Number vs. Launch Site

A scatter plot of Flight Number vs. Launch Site



Flight Number vs. Launch Site with explanations

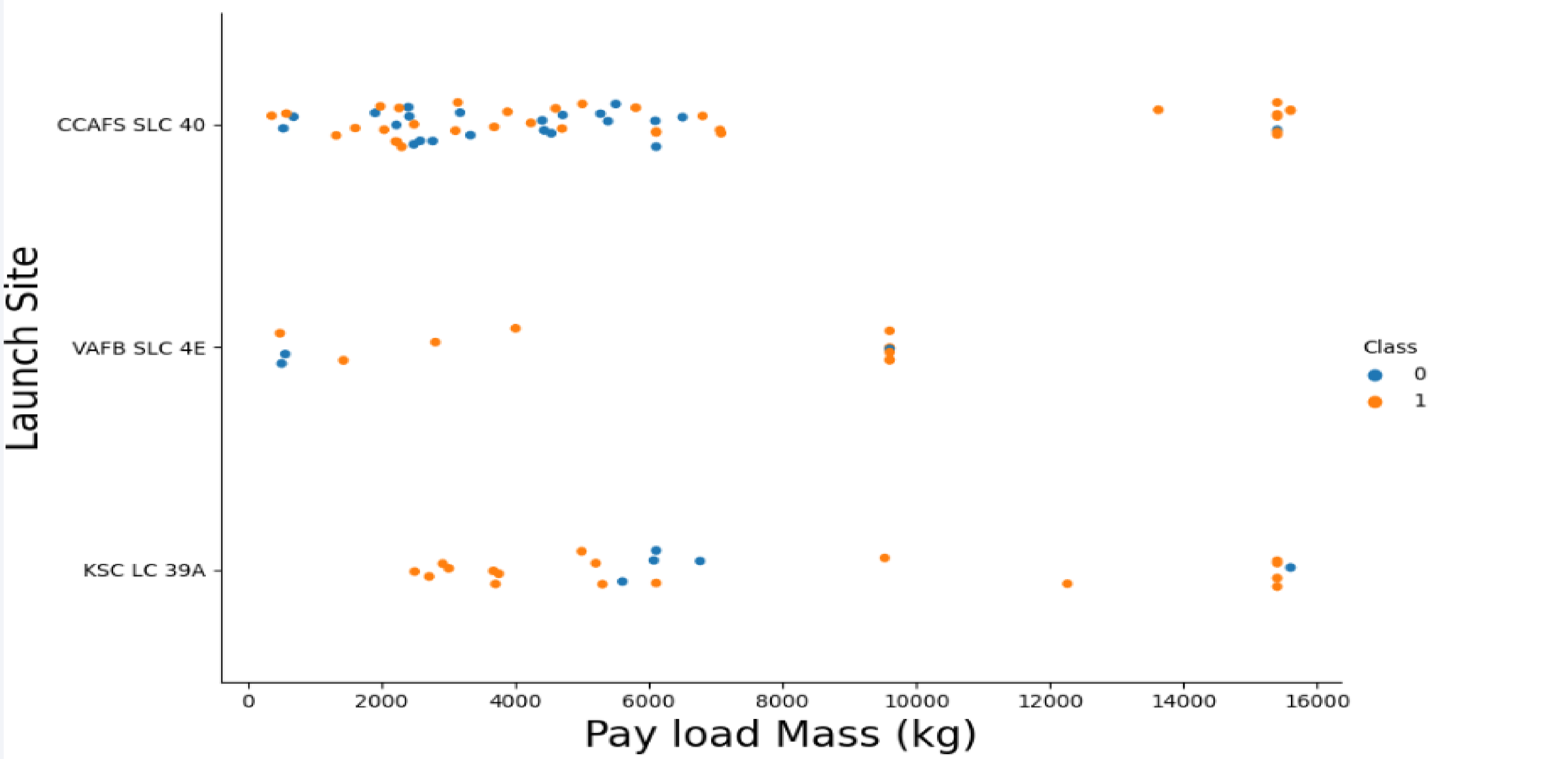


Now try to explain the patterns you found in the Flight Number vs. Launch Site scatter point plots.

We can deduce that, as the flight number increases in each of the 3 launcg sites, so does the success rate. For instance, the success rate for the VAFB SLC 4E launch site is 100% after the Flight number 50. Both KSC LC 39A and CCAFS SLC 40 have a 100% success rates after 80th flight.

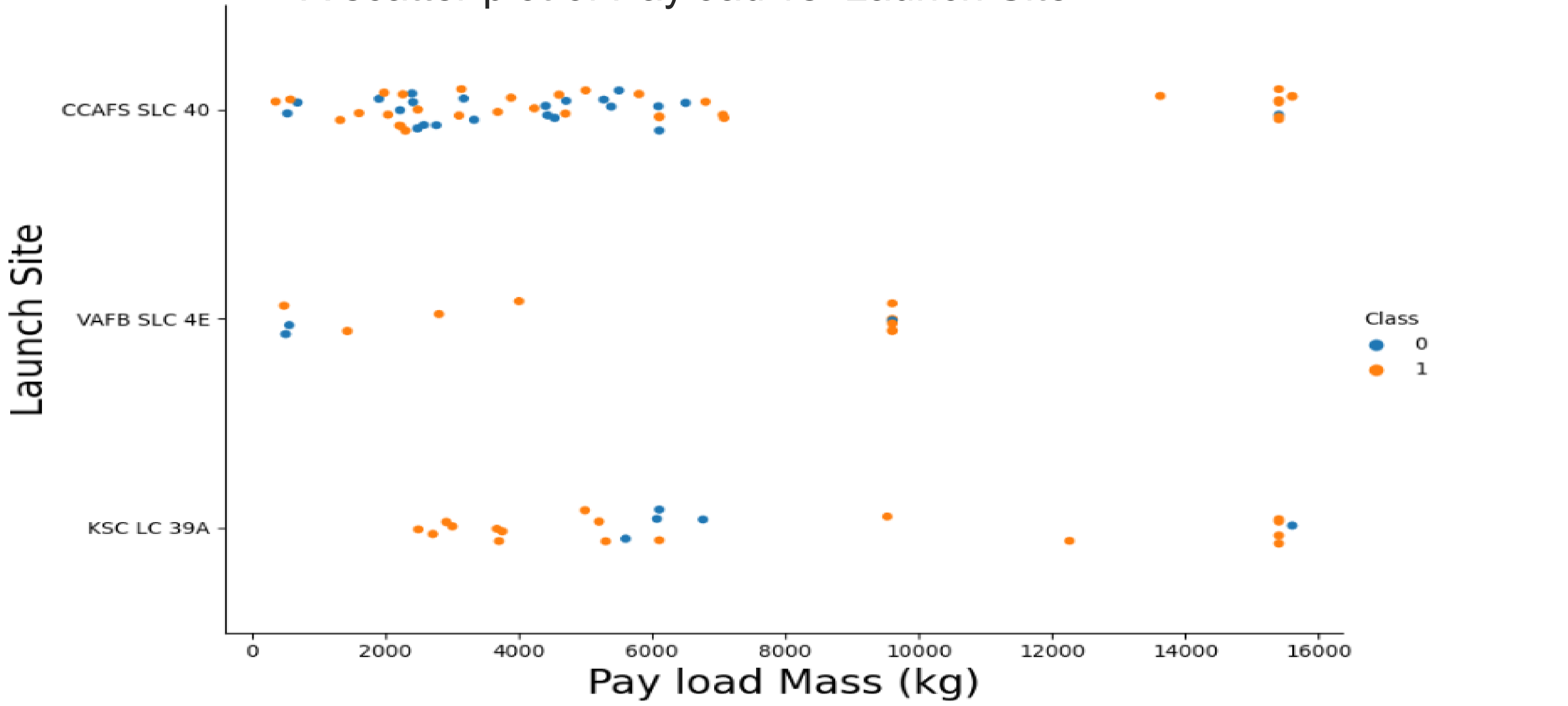
Payload vs. Launch Site

A scatter plot of Payload vs. Launch Site



Payload vs. Launch Site with explanations

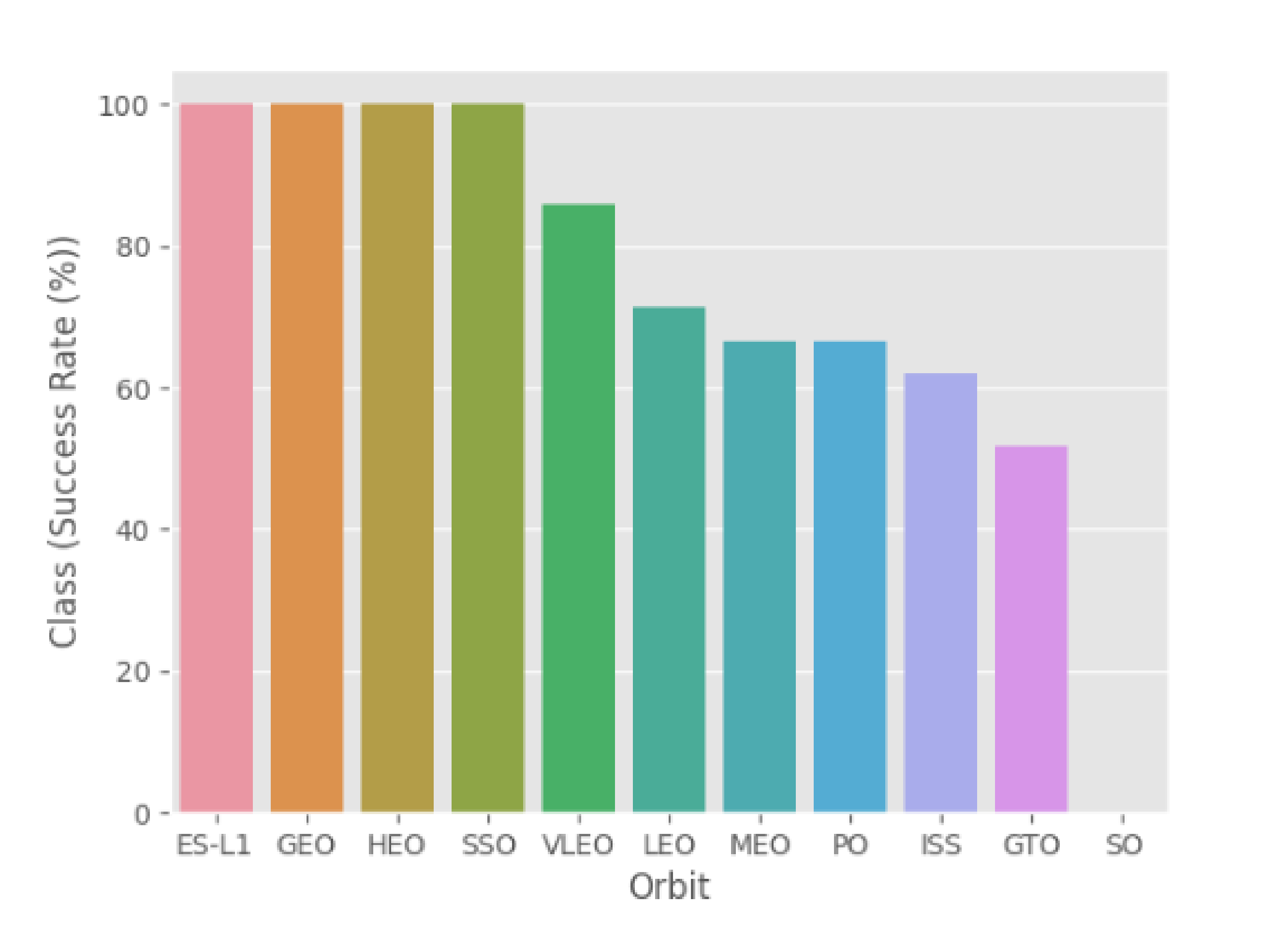
A scatter plot of Payload vs. Launch Site



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).

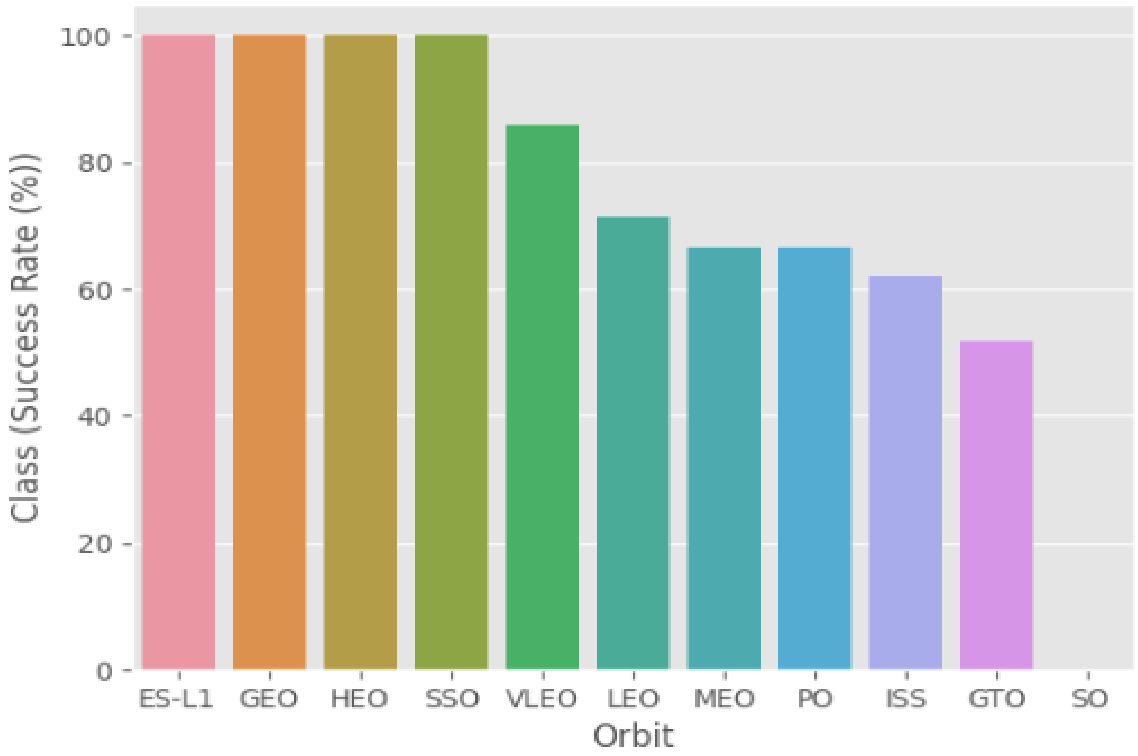
Success Rate vs. Orbit Type

- Show a bar chart for the success rate of each orbit type



Success Rate vs. Orbit Type with explanations

- Show the screenshot of the bar chart with explanations

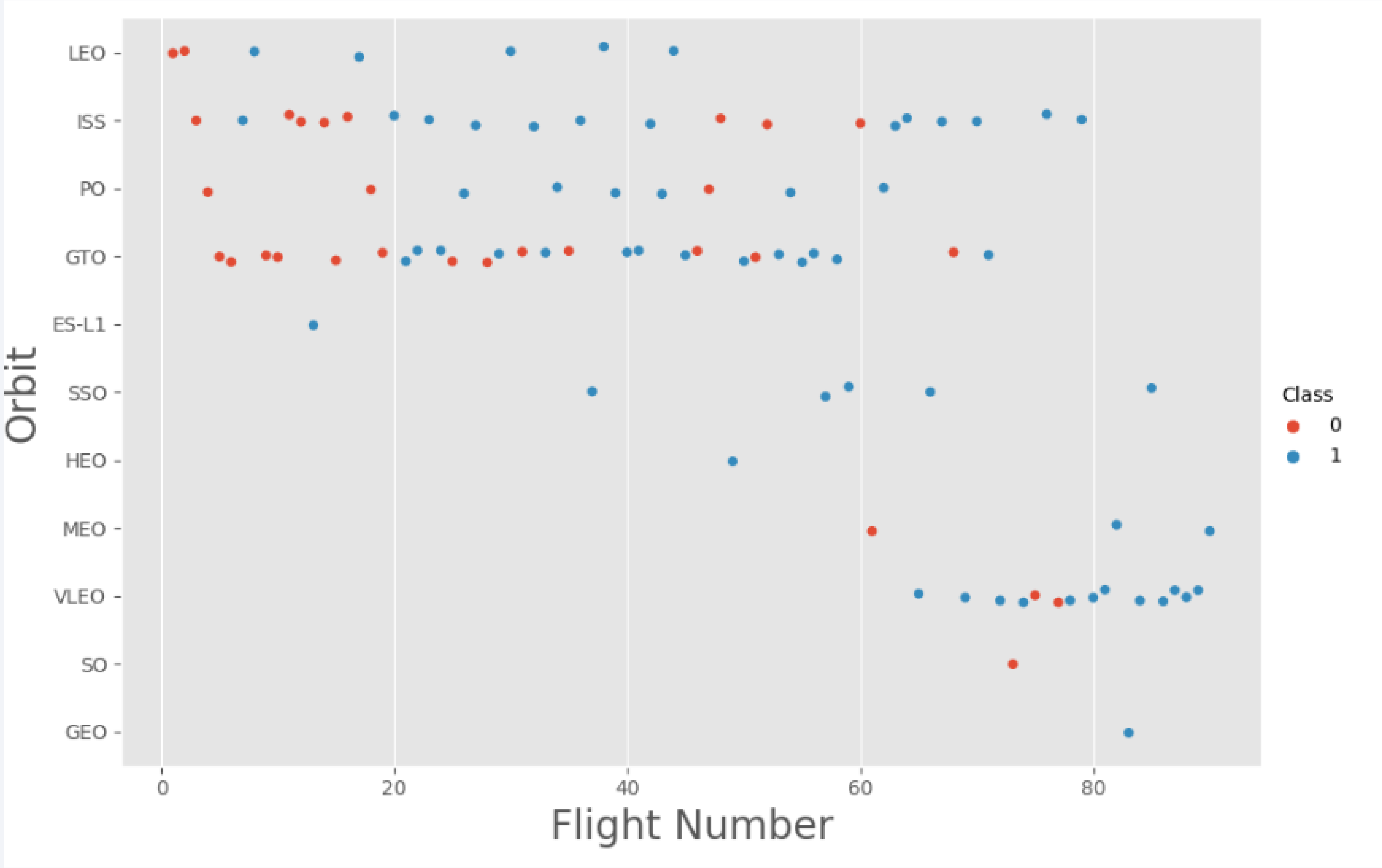


Analyze the ploted bar chart try to find which orbits have high sucess rate.

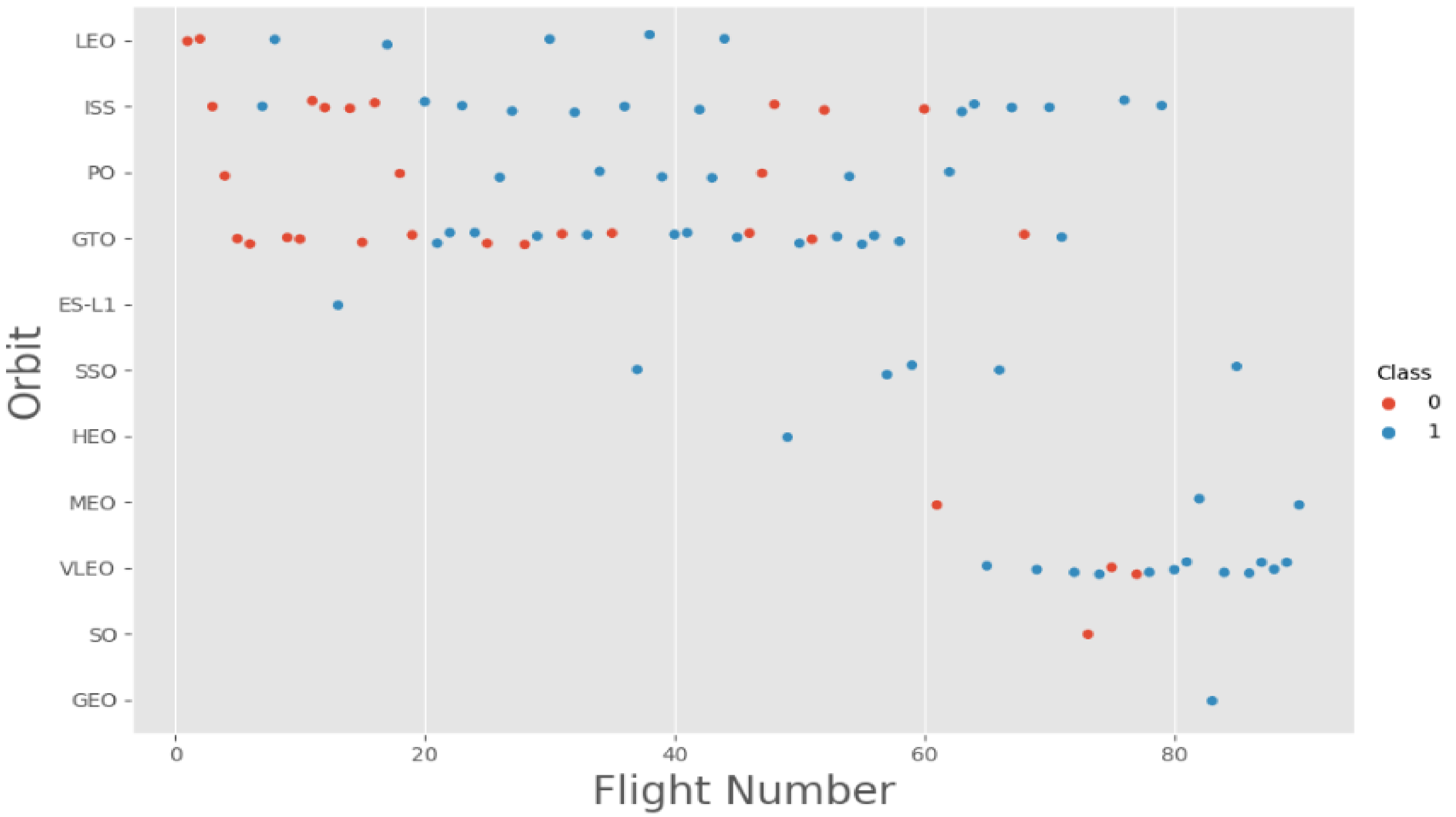
Orbits ES-L1, GEO, HEO & SSO have the highest success rates at 100%, with SO orbit having the lowest success rate at ~50%. Orbit SO has 0% success rate.

Flight Number vs. Orbit Type

- A scatter point of Flight number vs. Orbit type



Flight Number vs. Orbit Typewith explanations



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.

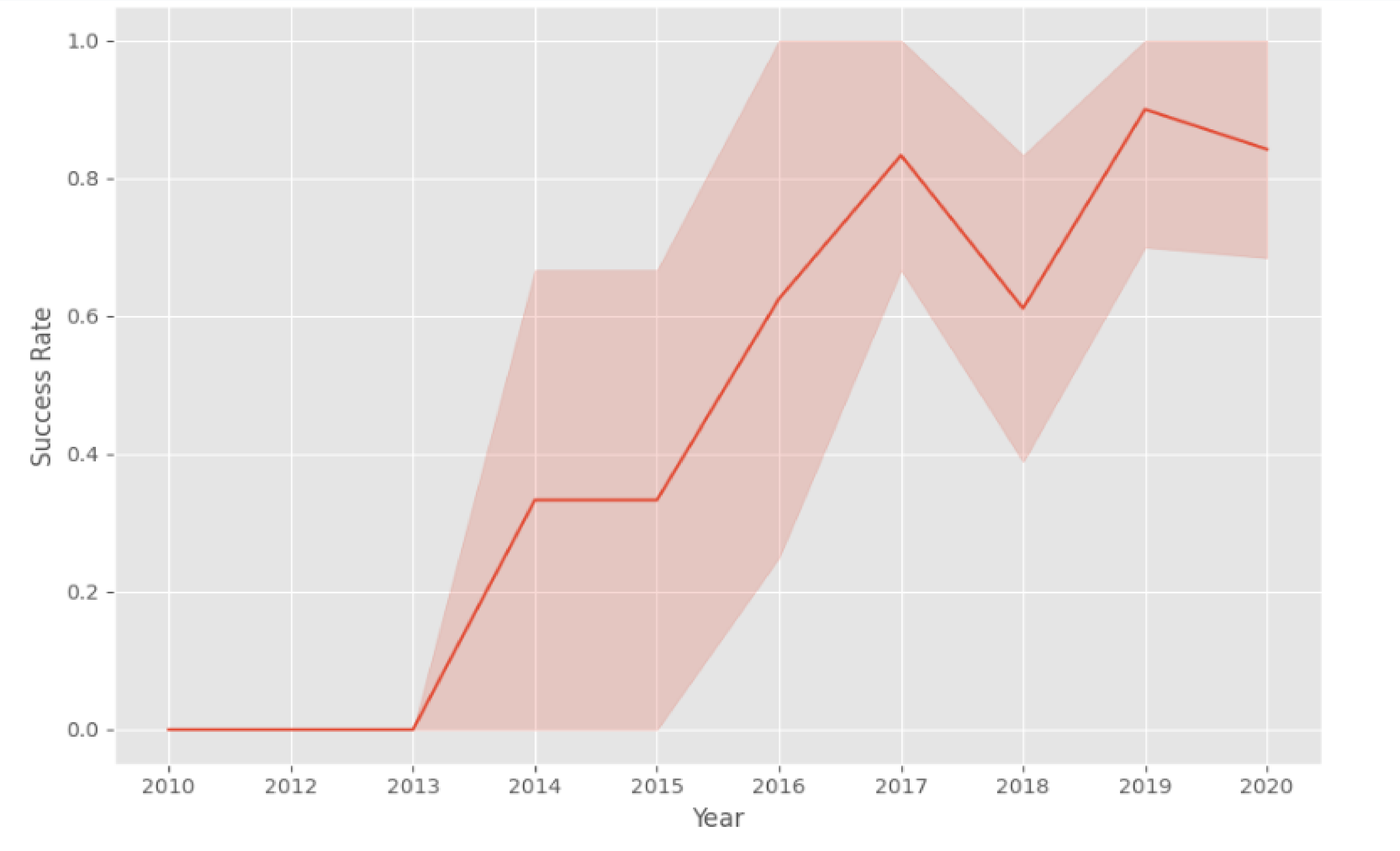
Payload vs. Orbit Type

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

Launch Success Yearly Trend

- Since 2013, the success rate kept going up till 2020

A line chart of yearly average success rate



All Launch Site Names

- Find the names of the unique launch sites

- Used ‘SELECT DISTINCT’ statement to return only the unique launch sites from the ‘LAUNCH_SITE’ column of the SPACEXTBL table

Task 1

Display the names of the unique launch sites in the space mission

In [31]:

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

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

Out[31]:

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

Launch Site Names Begin with 'CCA'

- Find 5 records where launch sites begin with `CCA`

Task 2

Display 5 records where launch sites begin with the string 'CCA'

In [72]:
```
%sql SELECT * FROM 'SPACEXTBL' WHERE Launch_Site LIKE 'CCA%' LIMIT 5;
```

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

Out[72]:

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

- Used ‘LIKE’ command with ‘%’ wildcard in ‘WHERE’ clause to select and dispay a table of all records where **launch sites begin with the string 'CCA'**

Total Payload Mass

- Calculate and Display the total payload carried by boosters from NASA

Task 3

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

In [17]:
```
%sql SELECT SUM(PAYLOAD_MASS__KG_) as "Total Payload Mass(Kgs)", Customer FROM 'SPACEXTBL' WHERE Customer = 'NASA (CRS)';
```

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

Out[17]:

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

- Used the ‘SUM()’ function to return and dispaly the total sum of ‘**PAYLOAD_MASS_KG**’ column for Customer ‘**NASA(CRS**’

Average Payload Mass by F9 v1.1

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

Task 4

Display 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 LIKE 'F9 v1.1%';
```

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

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

- Used the ‘AVG()’ function to return and dispaly the average payload mass carried by booster version F9 v1.1

First Successful Ground Landing Date

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

Task 5

List the date when the first succesful landing outcome in ground pad was acheived.

Hint:Use min function

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

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

MIN(DATE)
01-05-2017

- Used the 'MIN()' function to return and dispaly the first (oldest) date when first successful landing outcome on ground pad '***Success (ground pad)***' happened.

Successful Drone Ship Landing with Payload between 4000 and 6000

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

Task 6

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 * FROM 'SPACEXTBL'
```

```
%sql SELECT DISTINCT Booster_Version, Payload FROM SPACEXTBL WHERE "Landing _Outcome" = "Success (drone ship)" AND PAYLOAD_MASS__KG_ > 4000 AND PAYLOA
```

```
 * 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

- Used ‘Select Distinct’ statement to return and list the ‘unique’ names of boosters with operators >4000 and <6000 to only list booster with payloads btween 4000-6000 with landing outcome of ‘Success (drone ship)’.

Total Number of Successful and Failure Mission Outcomes

- Calculate the total number of successful and failure mission outcomes

Task 7

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

- Used the 'COUNT()' together with the 'GROUP BY' statement to return total number of missions outcomes

Boosters Carried Maximum Payload

- List of the boosters which have carried the maximum payload mass

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

```
 * 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

- Using a Subquerry to return and pass the Max payload and used it list all the boosters that have carried the Max payload of 15600kgs

2015 Launch Records

- List of failed landing outcomes in drone ship, with their booster versions, and launch site names in 2015

Task 9

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 substr(Date,7,4), substr(Date, 4, 2),"Booster_Version", "Launch_Site", Payload, "PAYLOAD_MASS__KG_", "Mission_Outcome", "Landing _Outcome"
```

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

substr(Date,7,4)	substr(Date, 4, 2)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Mission_Outcome	Landing _Outcome
2015	01	F9 v1.1 B1012	CCAFS LC-40	SpaceX CRS-5	2395	Success	Failure (drone ship)
2015	04	F9 v1.1 B1015	CCAFS LC-40	SpaceX CRS-6	1898	Success	Failure (drone ship)

- Used the 'subsrt()' in the select statement to get the month and year from the date column where substr(Date,7,4)='2015' for year and Landing_outcome was 'Failure (drone ship') and return the records nmatching the filter.

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

Task 10

Rank the count of successful landing_outcomes between the date 04-06-2010 and 20-03-2017 in descending order.

```
%sql SELECT * FROM SPACEXTBL WHERE "Landing _Outcome" LIKE 'Success%' AND (Date BETWEEN '04-06-2010' AND '20-03-2017') ORDER BY Date DESC;
```

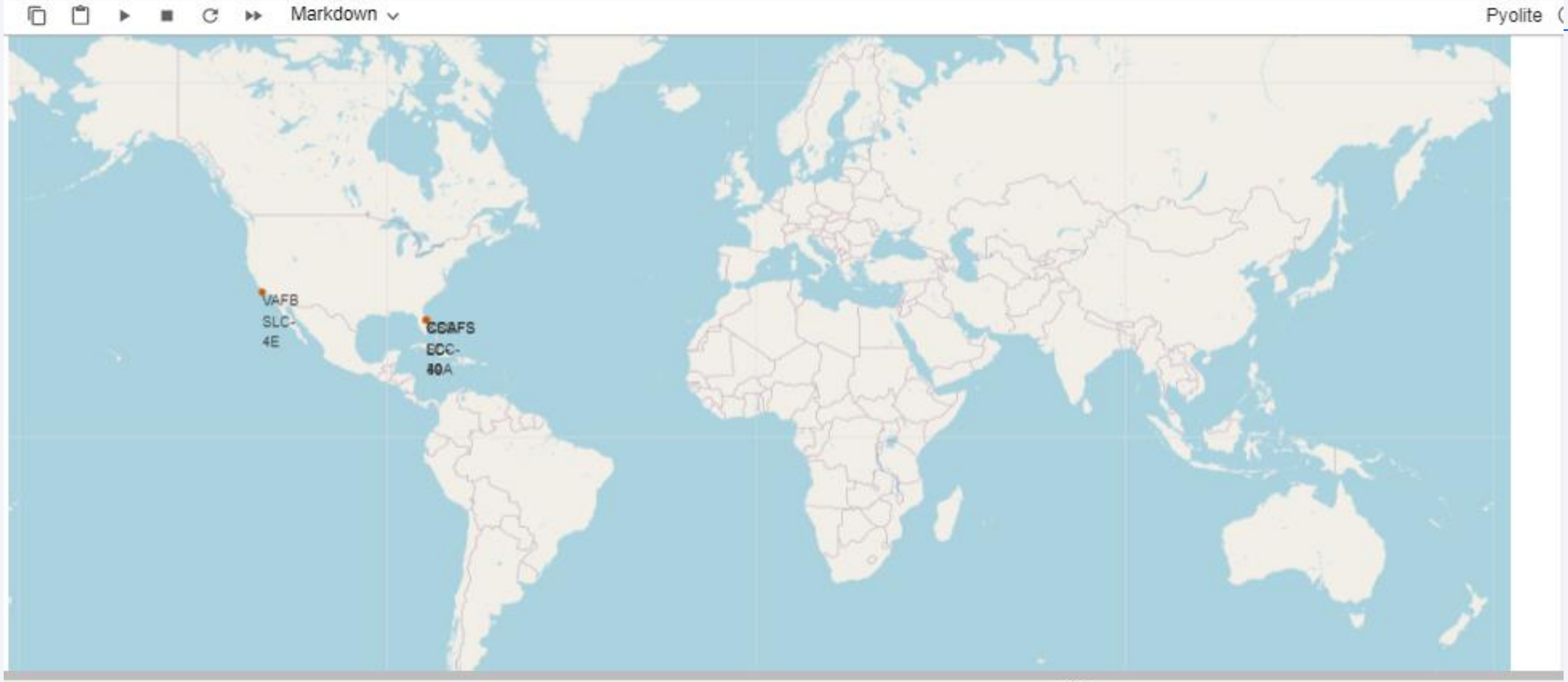
```
 * sqlite:///my_data1.db
Done.
```

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS_KG_	Orbit	Customer	Mission_Outcome	Landing _Outcome
19-02-2017	14:39:00	F9 FT B1031.1	KSC LC-39A	SpaceX CRS-10	2490	LEO (ISS)	NASA (CRS)	Success	Success (ground pad)
18-10-2020	12:25:57	F9 B5 B1051.6	KSC LC-39A	Starlink 13 v1.0, Starlink 14 v1.0	15600	LEO	SpaceX	Success	Success
18-08-2020	14:31:00	F9 B5 B1049.6	CCAFS SLC-40	Starlink 10 v1.0, SkySat-19, -20, -21, SAOCOM 1B	15440	LEO	SpaceX, Planet Labs, PlanetIQ	Success	Success
18-07-2016	04:45:00	F9 FT B1025.1	CCAFS LC-40	SpaceX CRS-9	2257	LEO (ISS)	NASA (CRS)	Success	Success (ground pad)
18-04-2018	22:51:00	F9 B4 B1045.1	CCAFS SLC-40	Transiting Exoplanet Survey Satellite (TESS)	362	HEO	NASA (LSP)	Success	Success (drone ship)

Section 3

Launch Sites Proximities Analysis

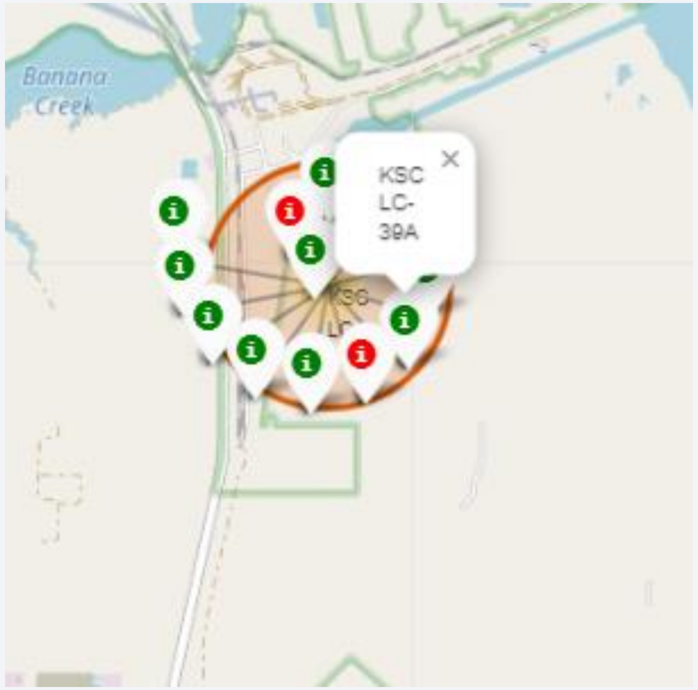
Markers of all launch sites on global map



- All launch sites are in proximity to the Equator, (located southwards of the US map). Also all the laumch sites are in very close proximity to the coast.

Launch outcomes for each site on the map With Color Markers

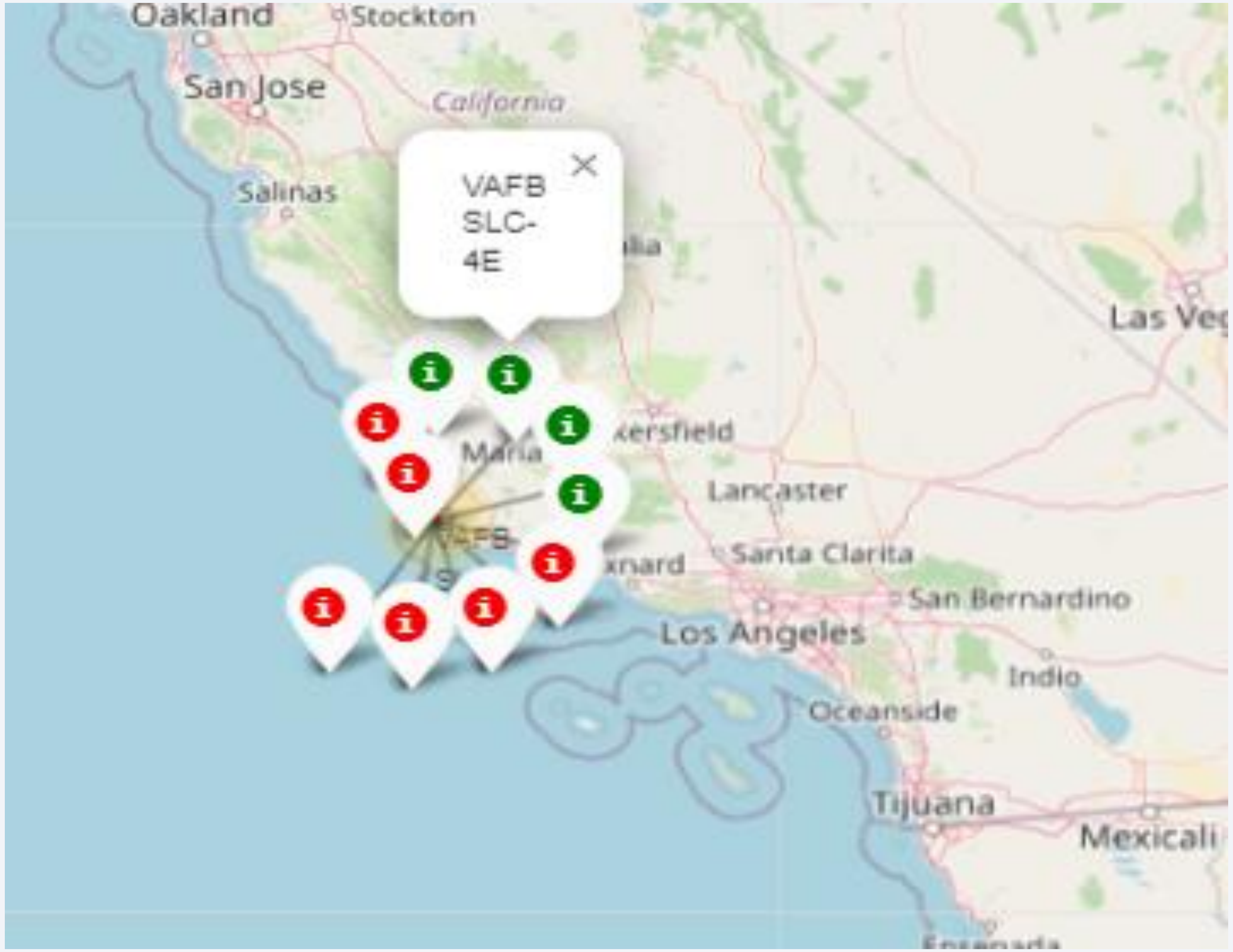
Florida Sites



- In the Eastern coast (Florida) Launch site KSC LC-39A has relatively high success rates compared to CCAFS SLC-40 & CCAFS LC-40.

Launch outcomes for each site on the map With Color Markers

West Coast/ Carlifonia

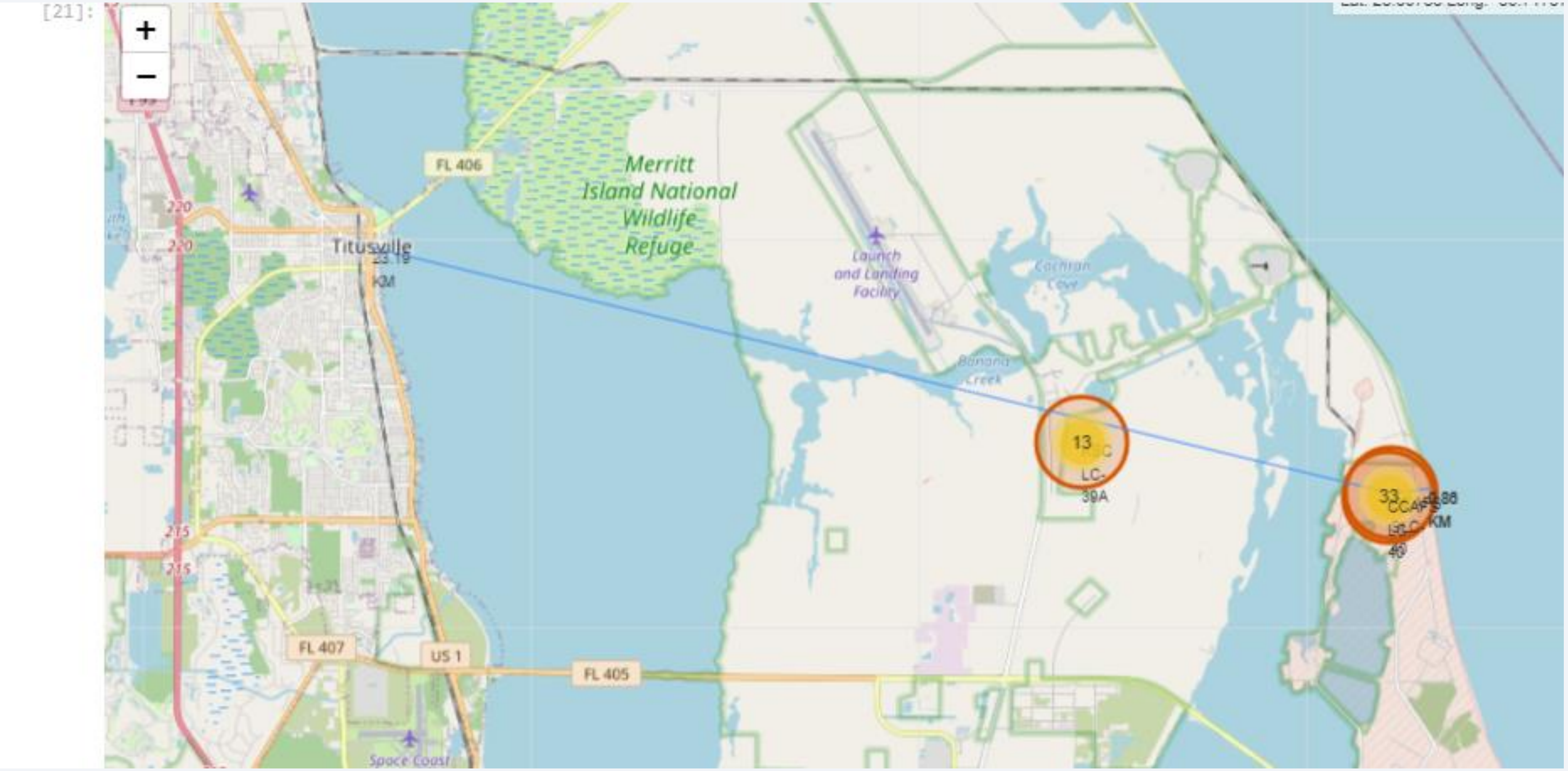


- In the West Coast (Californai) Launch site VAFB SLC-4E has relatively lower success rates 4/10 compared to KSC LC-39A launch site in the Eastern Coast of Florida.

Distances between a launch site to its proximities

- Launch site CCAFS SLC-40 proximity to coastline is 0.86km

Distances between a launch site to its proximities

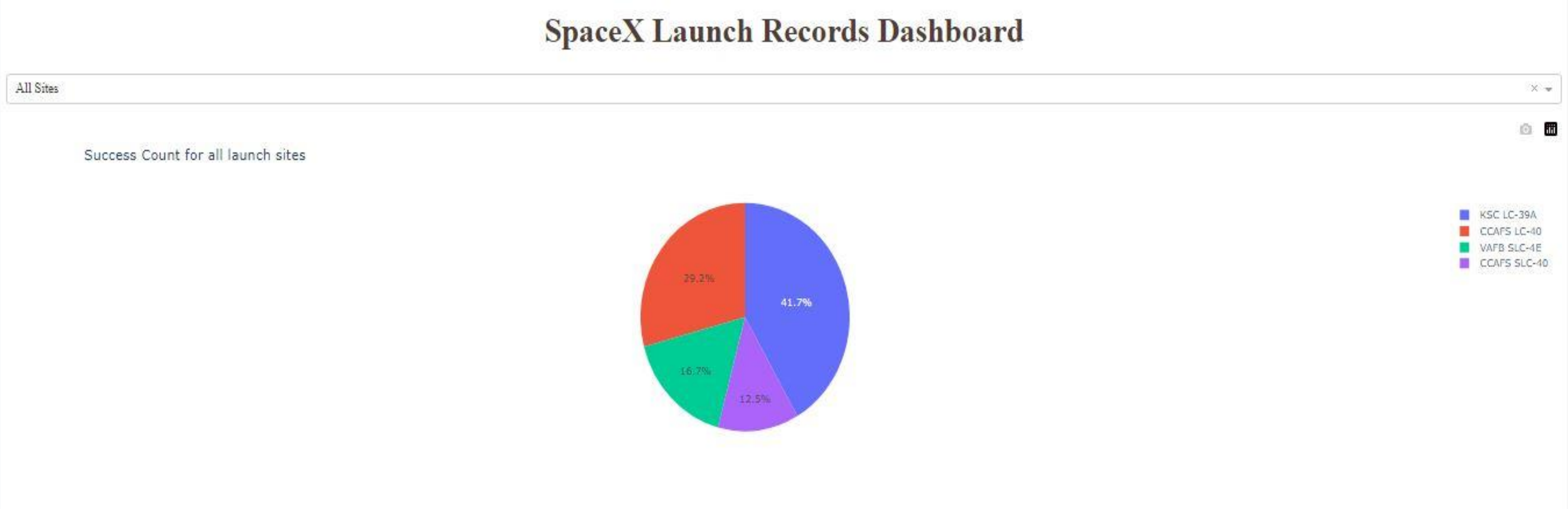


- Launch site CCAFS SLC-40 closest to highway (Washington Avenue) is 23.19km

Section 4

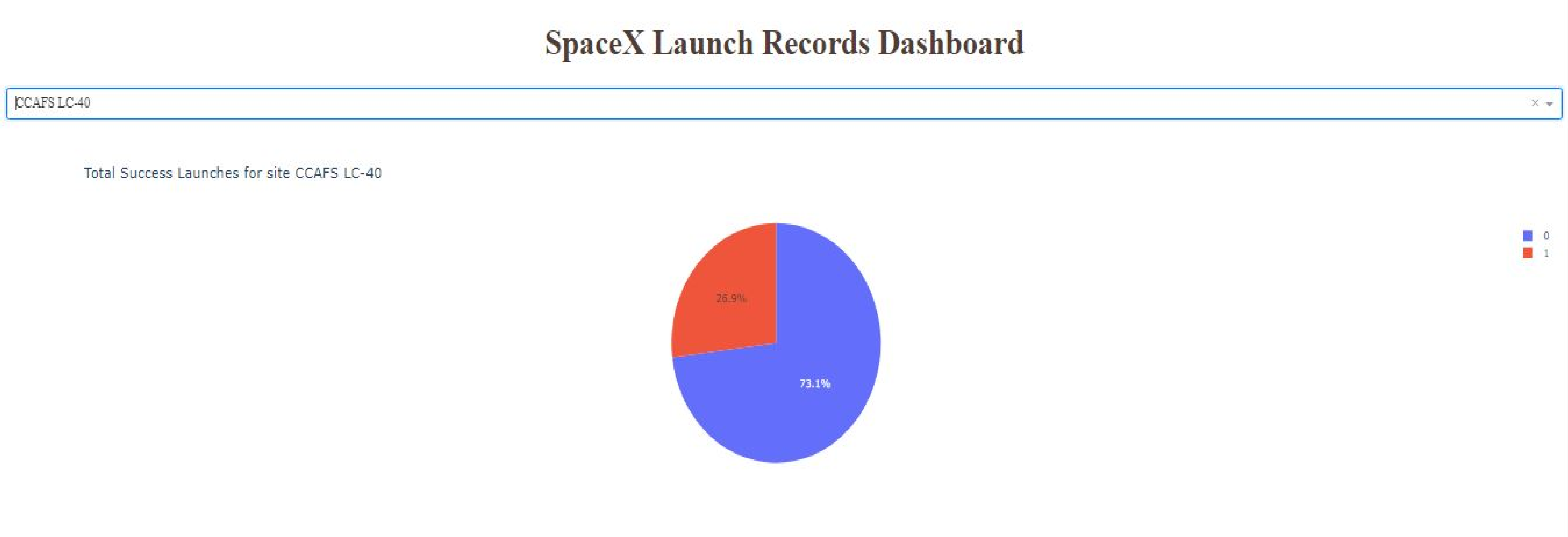
Build a Dashboard with Plotly Dash

Pie-Chart for launch success count for all sites



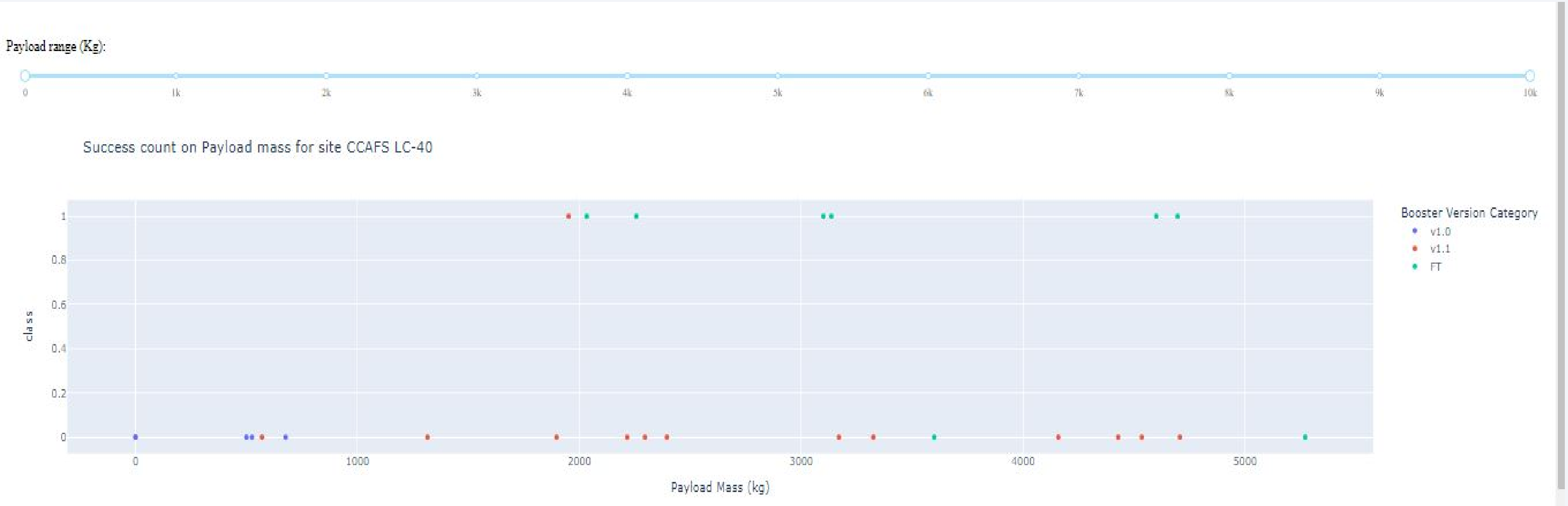
- Launch site KSC LC-39A has the highest launch success rate at 42% followed by CCAFS LC-40 at 29%, VAFB SLC-4E at 17% and lastly launch site CCAFS SLC-40 with a success rate of 13%

Pie chart for the launch site with 2nd highest launch success ratio



- Launch site CCAFS LC-40 had the 2nd highest success ratio of 73% success against 27% failed launches

Payload vs. Launch Outcome scatter plot for all sites



- For Launch site CCAFS LC-40 the booster version FT has the largest success rate from a payload mass of >2000kg

Section 5

Predictive Analysis (Classification)

Classification Models Accuracy

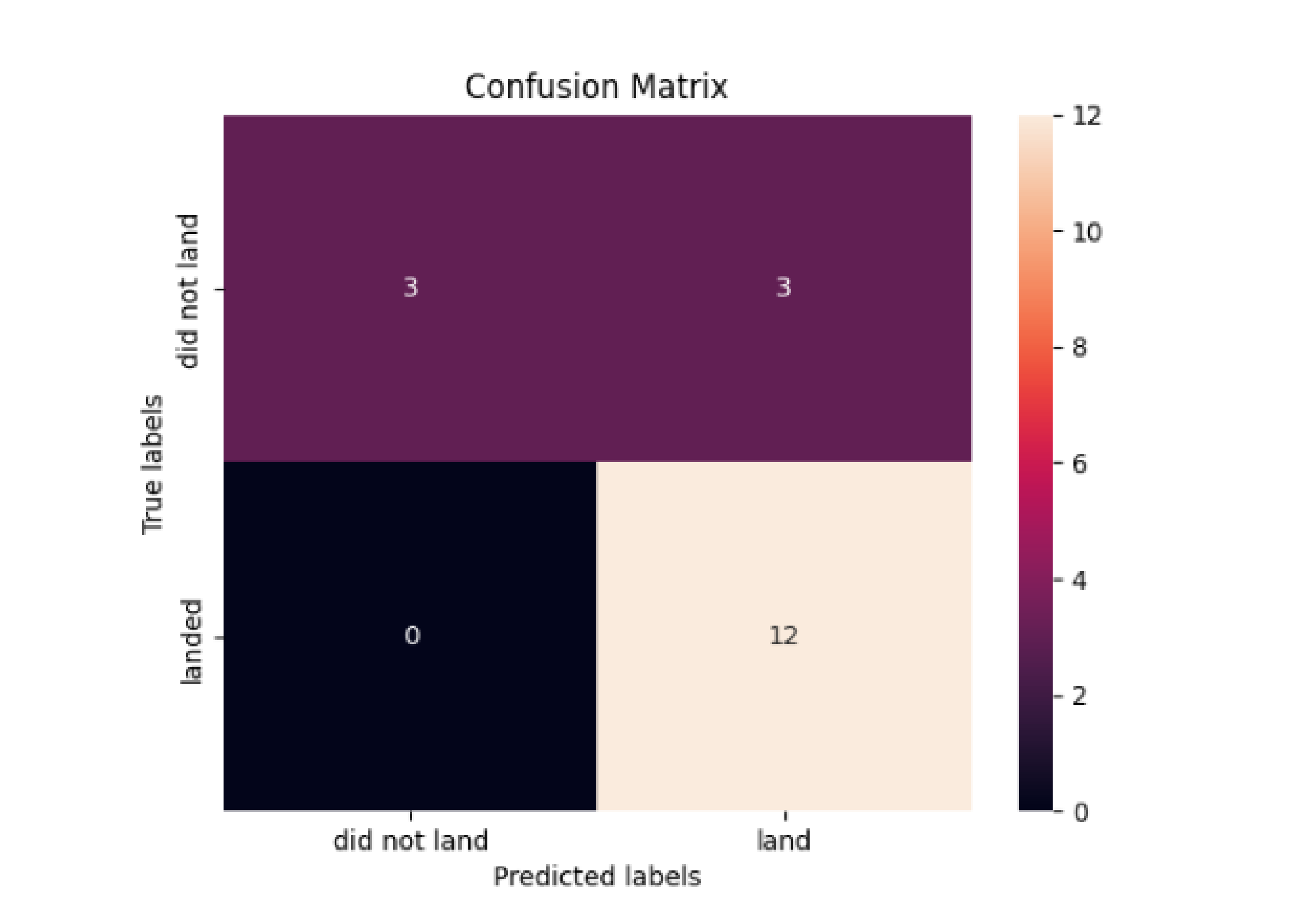
Out[68]:

	0
Method	Test Data Accuracy
Logistic_Reg	0.833333
SVM	0.833333
Decision Tree	0.833333
KNN	0.833333

All the methods perform equally on the test data: i.e. They all have the same accuracy of 0.833333 on the test Data

Confusion Matrix

- All the 4 classification model had the same confusion matrixes and were able equally distinguish between the different classes. The major problem is false positives for all the models.



Conclusions

- Launch sites have varying success rates:
- - CCAFS LC-40: 60% success rate
- - KSC LC-39A and VAFB SLC-4E: 77% success rate
- Success rate increases with flight number at each site
- - VAFB SLC-4E: 100% success rate after Flight 50
- - KSC LC-39A and CCAFS LC-40: 100% success rate after Flight 80
- Scatter plot (Payload vs. Launch Site) shows:

- Orbit success rates:
- - ES-L1, GEO, HEO, SSO: 100% success rate
- - SO orbit: 0% success rate (lowest)
- LEO orbit: Success improves with number of flights
- GTO orbit: No clear relation between success and flight number
- Heavy payloads show higher successful landing rates in Polar, LEO, and ISS orbits
- For GTO orbit, landing success is inconsistent – both successful and failed landings occur

Thank you!