IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

- Executive Summary
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- Methodology
- Results
- Conclusion
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Executive Summary

Summary of methodologies:

This project employed a systematic approach to data analysis, starting with data collection through SpaceX API calls and web scraping techniques, ensuring a comprehensive dataset. Data wrangling was conducted to clean and preprocess the data, using a combination of SQL and visualization methods for exploratory data analysis (EDA). Interactive analytics tools, such as Folium for mapping and Plotly Dash for dashboards, facilitated deeper insights and allowed for dynamic data exploration. Finally, predictive analysis was performed using classification models, with model tuning and evaluation to optimize performance and accuracy.

Executive Summary

Summary of all results:

The analysis uncovered several key findings, including [insert specific finding, e.g., "launch success rates by site and payload," "orbit-specific success trends," etc.]. The interactive maps and dashboards provided intuitive insights into spatial data relationships, while the predictive models demonstrated strong performance in identifying patterns and forecasting potential outcomes. Overall, the results suggest that [highlight main conclusion, e.g., "certain launch sites have higher success rates," "payload size impacts success probability," etc.], offering valuable guidance for [mention application or next steps, e.g., "future mission planning," "site selection," etc.].

Introduction

In this Project, we will predict if the Falcon 9 first stage will land successfully. SpaceX 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. This information can be used if an alternate company wants to bid against SpaceX for a rocket launch. In this presentation, we will provide an overview of the problem, and the tools required for the task.

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - Describe how data was collected.
- Perform data wrangling
  - Describe how data was processed.
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - How to build, tune, evaluate classification models.

Data Collection

- Collecting data through two methods:

1. Request to the SpaceX API.

```
[6]: spacex_url="https://api.spacexdata.com/v4/launches/past"

[7]: response = requests.get(spacex_url)
```

2. Web Scraping:

- Web scrap Falcon 9 launch records with **BeautifulSoup**:

    Extract a Falcon 9 launch records HTML table from Wikipedia

    Parse the table and convert it into a Pandas data frame

2020 [edit]

In late 2019, Gwynne Shotwell stated that SpaceX hoped for as many as 24 launches for Starlink satellites in 2020,[490] in addition to 14 or 15 non-Starlink launches. At 26 launches, 13 of which for Starlink satellites, Falcon 9 had its most prolific year, and Falcon rockets were second most prolific rocket family of 2020, only behind China's Long March rocket family.[491]

[hide] Flight No.	Date and time (UTC)	Version, Booster[b]	Launch site	Payload[c]	Payload mass	Orbit	Customer	Launch outcome	Booster landing
78	7 January 2020, 02:19:21[492]	F9 B5 △ B1049.4	CCAFS, SLC-40	Starlink 2 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Success (drone ship)
	Third large batch and second operational flight of Starlink constellation. One of the 60 satellites included a test coating to make the satellite less reflective, and thus less likely to interfere with ground-based astronomical observations.[493]								
79	19 January 2020, 15:30[494]	F9 B5 △ B1046.4	KSC, LC-39A	Crew Dragon in-flight abort test[495] (Dragon C205.1)	12,050 kg (26,570 lb)	Sub-orbital[496]	NASA (CTS)[497]	Success	No attempt
	An atmospheric test of the Dragon 2 abort system after Max Q. The capsule fired its SuperDraco engines, reached an apogee of 40 km (25 mi), deployed parachutes after reentry, and splashed down in the ocean 31 km (19 mi) downrange from the launch site. The test was previously slated to be accomplished with the Crew Dragon Demo-1 capsule;[498] but that test article exploded during a ground test of SuperDraco engines on 20 April 2019.[419] The abort test used the capsule originally intended for the first crewed flight.[499] As expected, the booster was destroyed by aerodynamic forces after the capsule aborted.[500] First flight of a Falcon 9 with only one functional stage — the second stage had a mass simulator in place of its engine.								
80	29 January 2020, 14:07[501]	F9 B5 △ B1051.3	CCAFS, SLC-40	Starlink 3 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Success (drone ship)
	Third operational and fourth large batch of Starlink satellites, deployed in a circular 290 km (180 mi) orbit. One of the fairing halves was caught, while the other was fished out of the ocean.[502]								
81	17 February 2020, 15:05[503]	F9 B5 △ B1056.4	CCAFS, SLC-40	Starlink 4 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Failure (drone ship)
	Fourth operational and fifth large batch of Starlink satellites. Used a new flight profile which deployed into a 212 km × 386 km (132 mi × 240 mi) elliptical orbit instead of launching into a circular orbit and firing the second stage engine twice. The first stage booster failed to land on the drone ship[504] due to incorrect wind data.[505] This was the first time a flight proven booster failed to land.								
82	7 March 2020, 04:50[506]	F9 B5 △ B1059.2	CCAFS, SLC-40	SpaceX CRS-20 (Dragon C112.3 △)	1,977 kg (4,359 lb)[507]	LEO (ISS)	NASA (CRS)	Success	Success (ground pad)
	Last launch of phase 1 of the CRS contract. Carries *Bartolomeo*, an ESA platform for hosting external payloads onto ISS.[508] Originally scheduled to launch on 2 March 2020, the launch date was pushed back due to a second stage engine failure. SpaceX decided to swap out the second stage instead of replacing the faulty part.[509] It was SpaceX's 50th successful landing of a first stage booster, the third flight of the Dragon C112 and the last launch of the cargo Dragon spacecraft.								

Data Collection – SpaceX API

- Data collection with SpaceX REST calls flowcharts

- GitHub Notebook URL:

https://github.com/MazenHamada/Applied-Data-Science-Capstone/blob/main/jupyter-labs-spacex-data-collection-api.ipynb

Rocket Data (/v4/rockets):

Collects the booster version based on the rocket ID.

Launch Site Data (/v4/launchpads):

Collects longitude, latitude, and launch site name.

Payload Data (/v4/payloads):

Gathers payload and orbit details.

Core Data (/v4/cores):

Retrieves details like block number, reuse count, serial and landing outcome.

Data Collection - Scraping

- Web scraping process flowcharts

- GitHub Notebook URL:

https://github.com/MazenHamada/Applied-Data-Science-Capstone/blob/main/jupyter-labs-webscraping.ipynb

Set Target URL:

Define static_url pointing to a static version of the Wikipedia page for Falcon 9 and Falcon Heavy launches.

Fetch Page Content:

Use requests.get() to retrieve the page content and store the response.

Parse HTML and Extract Data:

Use BeautifulSoup to parse the HTML response.

Extract required details (e.g., launch date, booster version, landing outcome, payload mass) from the parsed HTML.

Compile Data:

Organize the extracted information into a structured format, such as a pandas DataFrame, for further analysis or storage.

Data Wrangling

- Data wrangling process flowcharts.

- Add the GitHub Notebook URL:

https://github.com/MazenHamada/Applied-Data-Science-Capstone/blob/main/labs-jupyter-spacex-Data%20wrangling.ipynb

Check for Missing Values:

Use df.isnull().sum()/len(df)*100 to calculate the percentage of missing values for each column.

Examine Data Types:

Use df.dtypes to display the data types of each column.

Handle Missing Data (if applicable):

Apply data cleaning steps like filling missing values or dropping columns/rows with high missing value percentages.

Data Transformation (optional):

Conduct any transformations such as changing data types, encoding categorical variables, or creating new columns as needed.

Compile Cleaned Data:

Finalize the cleaned and transformed dataset for further analysis or export.

EDA with Data Visualization

Plots/Charts used:

1. A **Scatter plot** showing the relationship between **Flight Number** and **Launch Site.**
2. A **Scatter plot** showing the relationship between **Payload Mass** and **Launch Site.**
3. A **Bar Chart** showing the relationship between S**uccess Rate** of **Orbit Type.**
4. A **Scatter Plot** showing the relationship between **Flight Number** and **Orbit Type.**
5. A **scatter plot** showing the relationship between **Payload Mass** and **Orbit Type.**
6. A **Line Chart** showing the **Launch Success Yearly Trend.**

GitHub Notebook URL:

https://github.com/MazenHamada/Applied-Data-Science-Capstone/blob/main/edadataviz.ipynb

EDA with SQL

Summary of the SQL queries performed:

- Created a new table SPACEXTABLE with data from SPACEXTBL where the date is not null.
- Selected distinct launch sites from SPACEXTBL, ordering results.
- Filtered launches from SPACEXTBL with launch sites starting with 'CCA', limiting the results to 5.
- Calculated the total payload for records with payload description containing 'CRS'.
- Found the average payload for records where the booster version is 'F9 v1.1'.
- Retrieved the earliest successful landing on a ground pad.
- Selected distinct booster versions for payloads between 4000 and 6000 kg with successful drone ship landings.
- Counted and grouped launches by mission outcomes.
- Retrieved distinct booster versions for the maximum payload mass.
- Extracted records of failures on a drone ship in 2015, adding a month name column based on the date.

GitHub Notebook URL:

https://github.com/MazenHamada/Applied-Data-Science-Capstone/blob/main/jupyter-labs-eda-sql-coursera_sqllite.ipynb

Build an Interactive Map with Folium

1. **Markers:** Placed at specific coordinates to represent points of interest, such as launch sites. Each marker typically has a popup or tooltip to display additional information when clicked. Adding markers allows viewers to easily identify and obtain information on exact locations.

2. **Circles:** Used to draw areas around certain points to represent zones of influence or safety distances around the launch sites. Circles visually emphasize the proximity of other points to these central locations, making it easier to understand spatial relationships.

3. **Polylines:** Created between locations to illustrate paths, distances, or routes. This can help indicate directionality or show how close other sites are to each other.

- These map objects enhance the map's clarity by visually distinguishing between locations, distances, and areas of influence, making the data easier to interpret spatially.Explain why you added those objects

GitHub Notebook URL:

https://github.com/MazenHamada/Applied-Data-Science-Capstone/blob/main/lab_jupyter_launch_site_location.ipynb

Build a Dashboard with Plotly Dash

1. A Dropdown (input) component:
   - A dropdown list to enable Launch Site selection, The default select value is for ALL sites.
2. Pie chart (output) component:
   - A pie chart to show the total successful launches count for all sites, If a specific launch site was selected, show the Success vs. Failed counts for the site.
3. Range slider (input) component:
   - A slider to select payload range.
4. Scatter chart (output) component:
   - A scatter chart to show the correlation between payload and launch success.

- GitHub Notebook URL:

https://github.com/MazenHamada/Applied-Data-Science-Capstone/blob/main/spacex_dash_app.py

Predictive Analysis (Classification)

Model Development Process:

1- Data Preprocessing:

- Data Cleaning.
- Feature Engineering.
- Splitting Data into Training and Testing Sets.

2- Model Selection and Building:

- Selected models: Logistic Regression, Support Vector Machine (SVM), Decision Tree, Random Forest, and K-Nearest Neighbors (KNN).
- Initial Training on Base Models.

3- Model Evaluation:

- Metrics used: Accuracy.
- Confusion Matrix Analysis.

4- Model Improvement:

- Hyperparameter Tuning (using GridSearchCV or RandomizedSearchCV).
- Feature Selection/Engineering.
- Cross-Validation.

5- Best Model Selection:

- Comparing Metrics across Models.
- Final Model Selection based on Highest Performance.

- GitHub Notebook URL:

https://github.com/MazenHamada/Applied-Data-Science-Capstone/blob/main/SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb

Results

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

Section 2

Insights drawn from EDA

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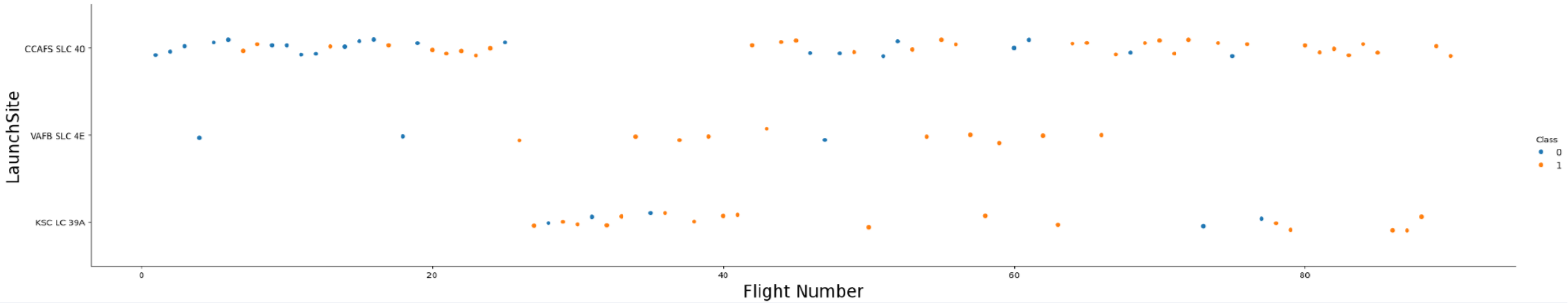
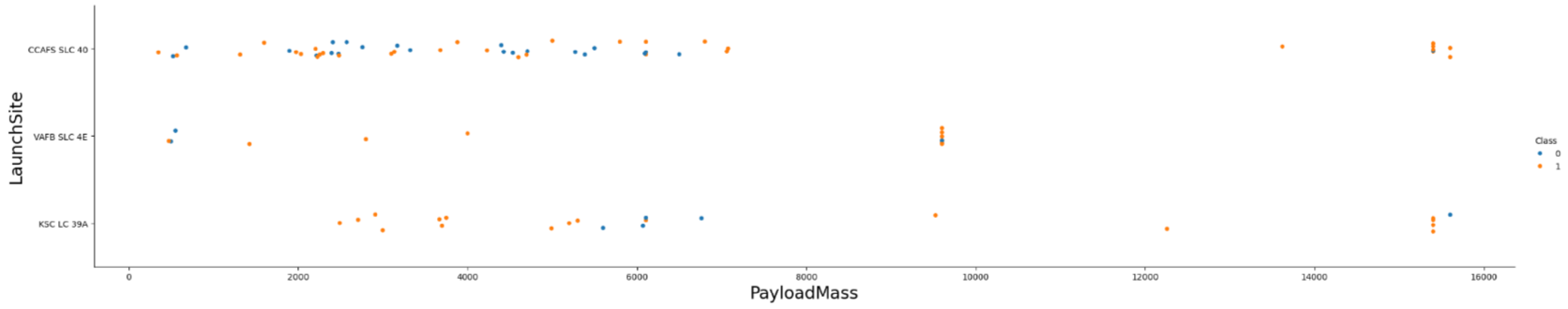
Flight Number vs. Launch Site



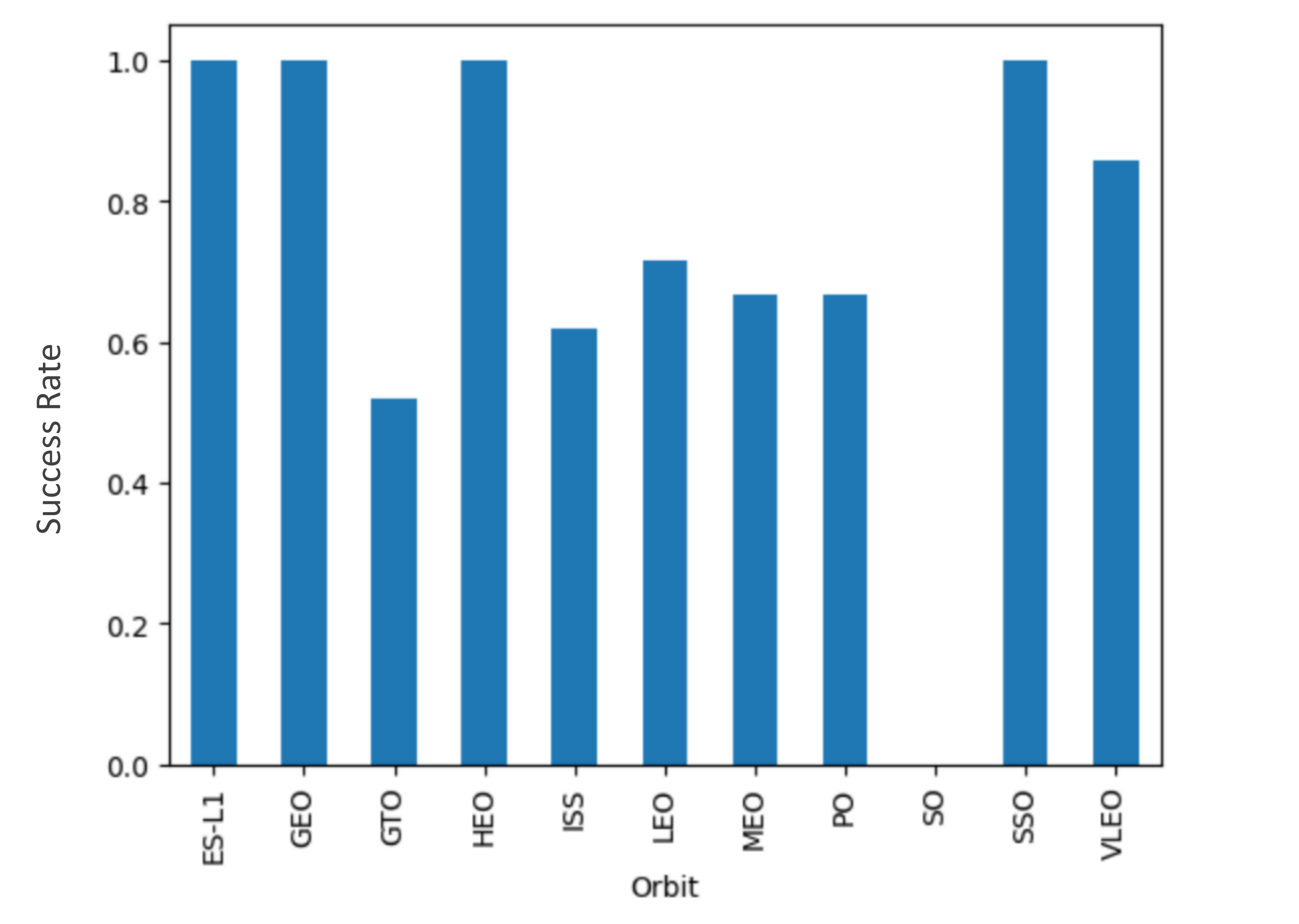
The bigger the flight number the more successful landings.

Payload vs. Launch Site



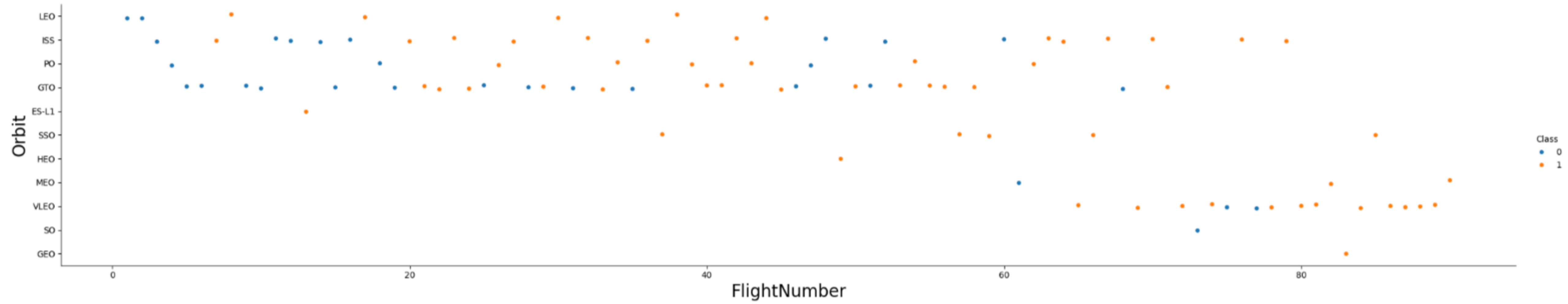
For the VAFB-SLC launchsite there are no rockets launched for heavy pay load mass(greater than 10000).

Success Rate vs. Orbit Type



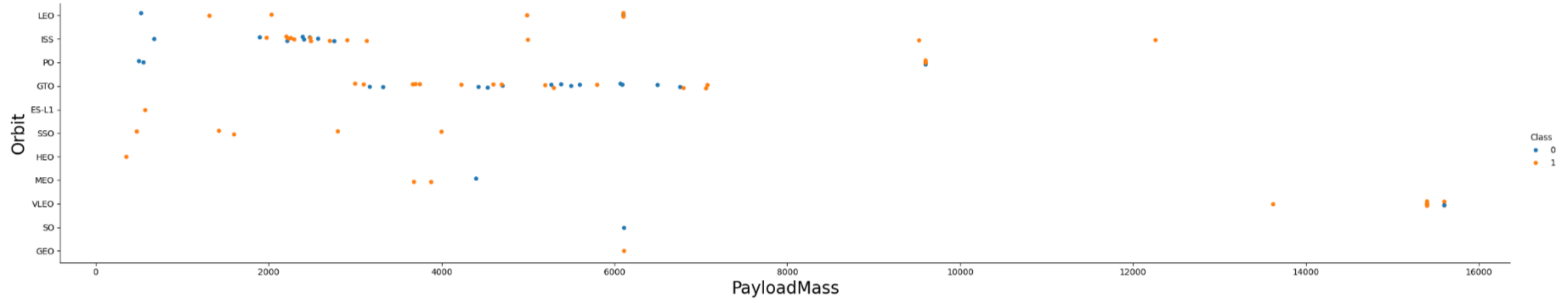
(ES-L1), (GEO), (HEO) and (SSO) have high success rate while (SO) has low success rate.

Flight Number vs. Orbit Type



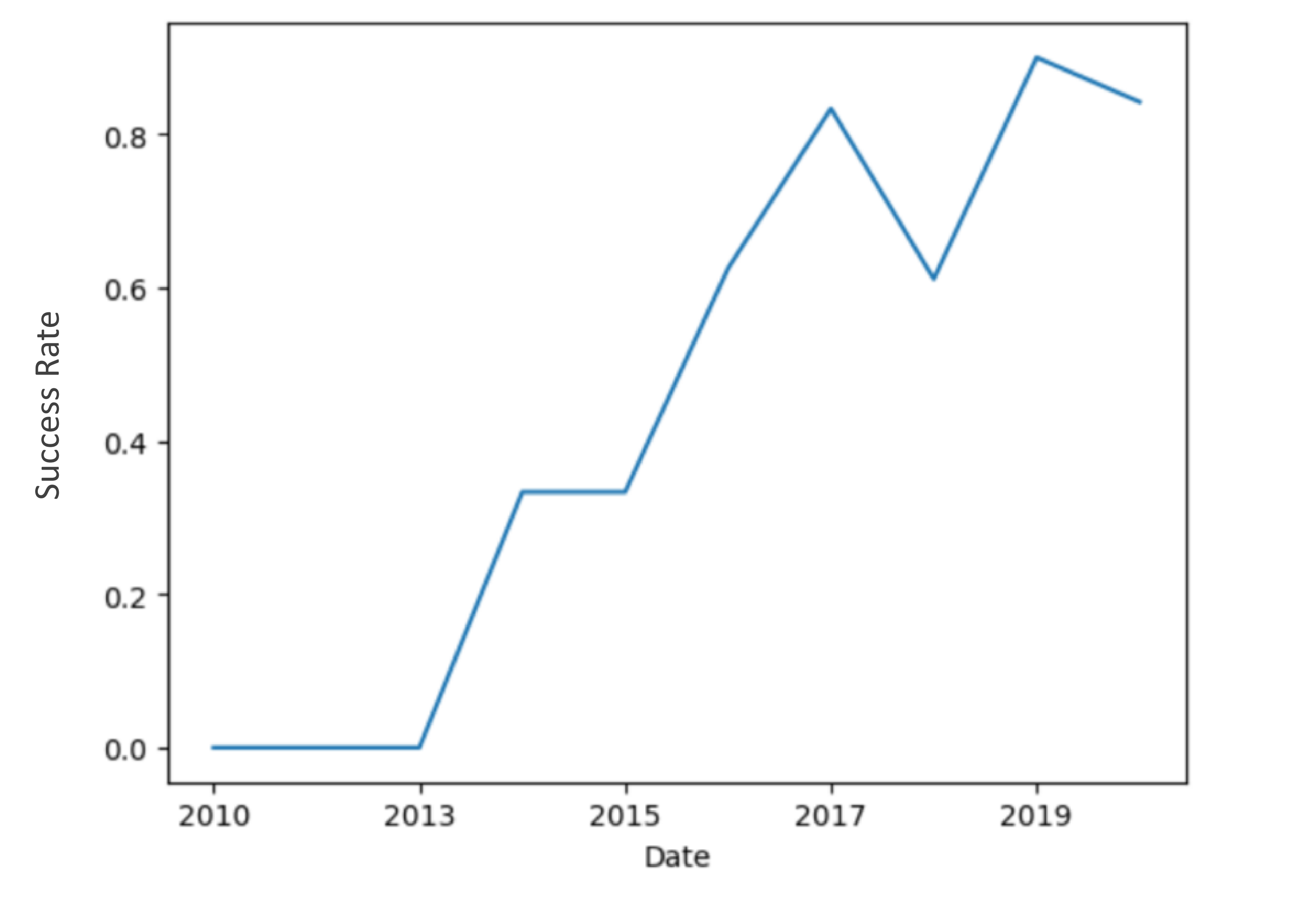
You can observe that in the LEO orbit, success seems to be related to the number of flights. Conversely, in the GTO orbit, there appears to be no relationship between flight number and success.

Payload vs. Orbit Type



With heavy payloads the successful landing or positive landing rate are more for Polar, LEO and ISS. However, for GTO, it's difficult to distinguish between successful and unsuccessful landings as both outcomes are present.

Launch Success Yearly Trend



You can observe that the success rate since 2013 kept increasing till 2020.

All Launch Site Names

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

In [23]:
```
%sql SELECT DISTINCT LAUNCH_SITE FROM SPACEXTBL ORDER BY 1;
```

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

Out[23]:

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

Launch Site Names Begin with 'CCA'

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

In [24]:
```
%sql SELECT * FROM SPACEXTBL WHERE LAUNCH_SITE LIKE 'CCA%' LIMIT 5;
```

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

Out[24]:

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

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

In [25]:
```
%sql SELECT SUM(PAYLOAD_MASS__KG_) AS TOTAL_PAYLOAD FROM SPACEXTBL WHERE PAYLOAD  LIKE '%CRS%';
```

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

Out[25]:

TOTAL_PAYLOAD
111268

Average Payload Mass by F9 v1.1

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

In [26]:
```
%sql SELECT AVG(PAYLOAD_MASS__KG_) AS AVG_PAYLOAD FROM SPACEXTBL WHERE BOOSTER_VERSION = 'F9 v1.1';
```

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

Out[26]:

AVG_PAYLOAD
2928.4

First Successful Ground Landing Date

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

Hint:Use min function

In [28]:

```
%sql SELECT MIN(DATE) AS FIRST_SUCCESS_GP FROM SPACEXTBL WHERE LANDING_OUTCOME = 'Success (ground pad)';
```

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

Out[28]:

FIRST_SUCCESS_GP
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

[29]:
```
%sql SELECT DISTINCT BOOSTER_VERSION FROM SPACEXTBL WHERE PAYLOAD_MASS__KG_ BETWEEN 4000 AND 6000 AND LANDING_OUTCOME = 'Success (drone ship)';
```

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

[29]:

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

Total Number of Successful and Failure Mission Outcomes

List the total number of successful and failure mission outcomes

[30]:
```
%sql SELECT MISSION_OUTCOME, COUNT(*) AS QTY FROM SPACEXTBL GROUP BY MISSION_OUTCOME ORDER BY MISSION_OUTCOME;
```

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

[30]:

Mission_Outcome	QTY
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

```
[31]: %sql SELECT DISTINCT BOOSTER_VERSION FROM SPACEXTBL WHERE PAYLOAD_MASS__KG_ = (SELECT MAX(PAYLOAD_MASS__KG_) FROM SPACEXTBL) ORDER BY BOOSTER_VERSION;
```

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

[31]:

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

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.

Note: SQLLite does not support monthnames. So you need to use substr(Date, 6,2) as month to get the months and substr(Date,0,5)='2015' for year.

[34]:
```
%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'
```

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

[34]:

Month	Booster_Version	Launch_Site	Landing_Outcome
January	F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)
April	F9 v1.1 B1015	CCAFS LC-40	Failure (drone ship)

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.

[37]:
```
%sql SELECT LANDING_OUTCOME, COUNT(*) AS QTY FROM SPACEXTBL WHERE DATE BETWEEN '2010-06-04' AND '2017-03-20' GROUP BY LANDING_OUTCOME ORDER BY QTY DESC;
```

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

[37]:

Landing_Outcome	QTY
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

Section 3

Launch Sites Proximities Analysis

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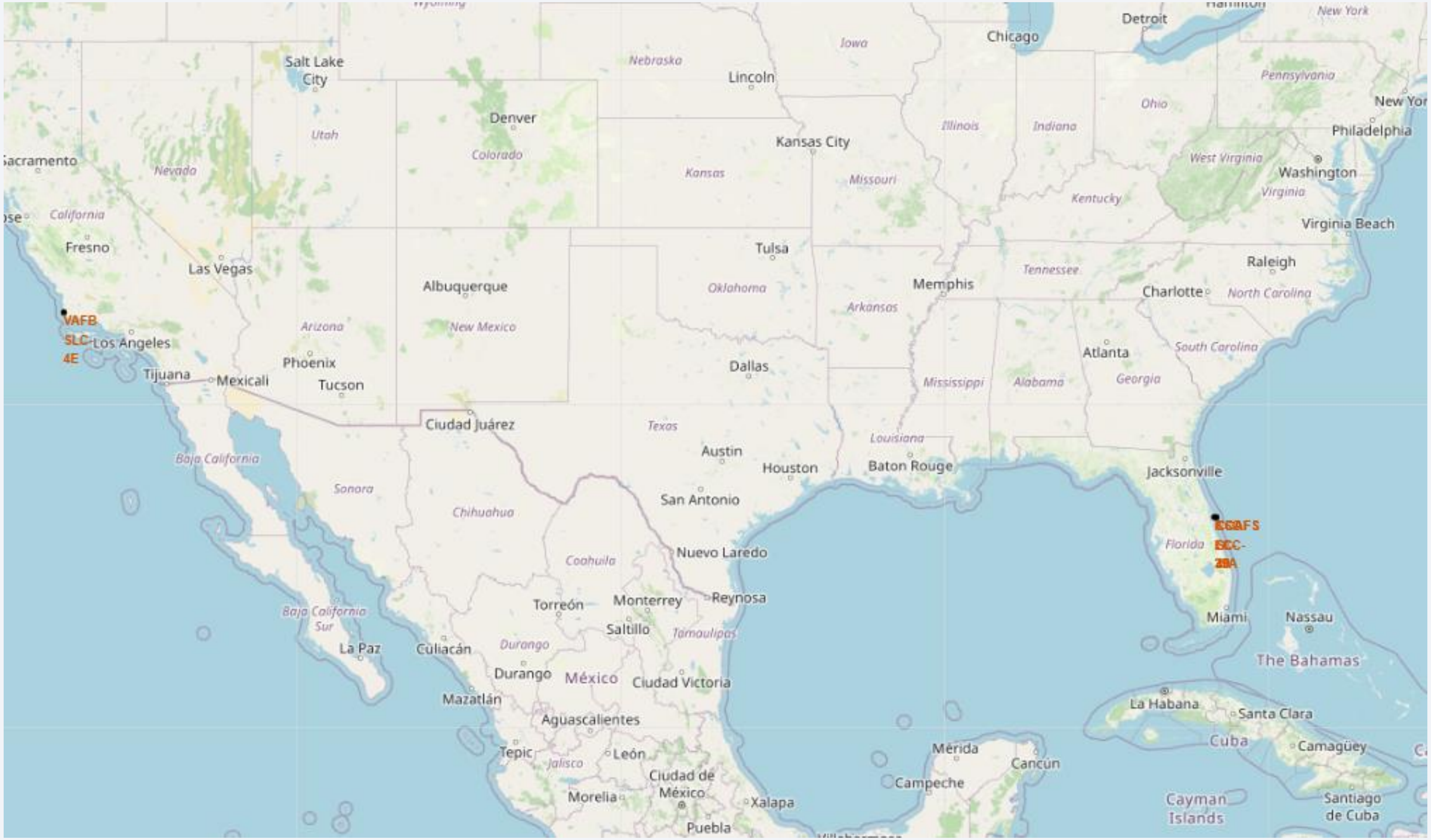
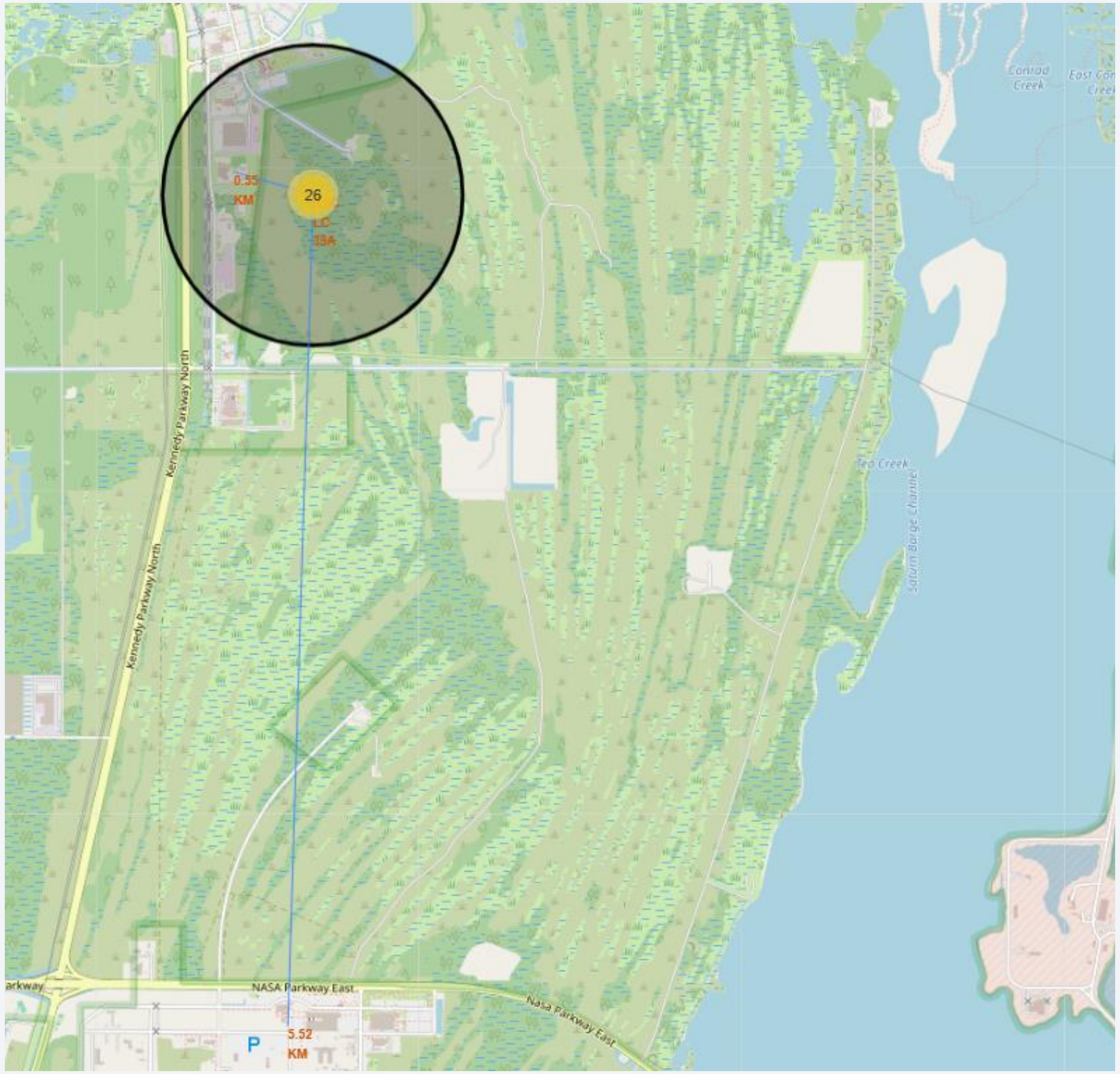
Launch Sites Location



Launch Results for each Launch Site

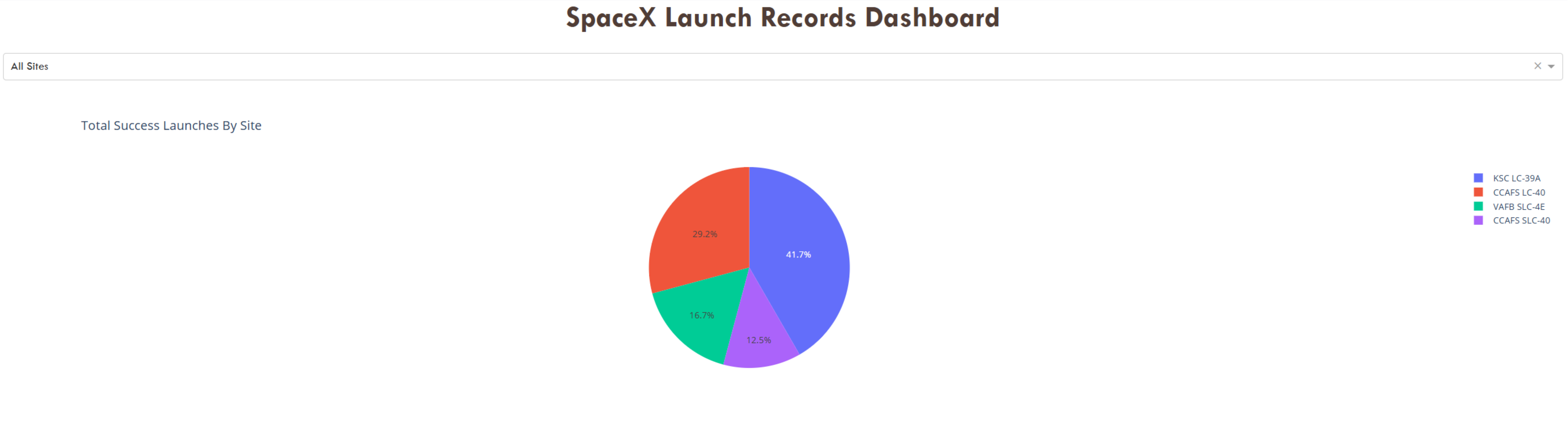
Launch Sites to its Proximities, with Distance Calculated and Displayed



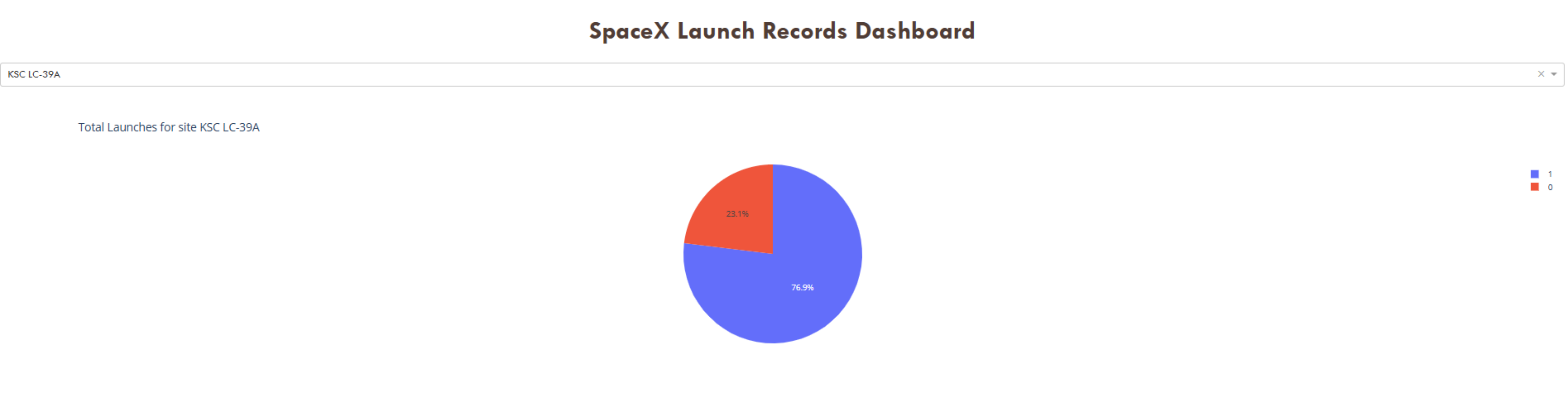
Section 4

Build a Dashboard with Plotly Dash

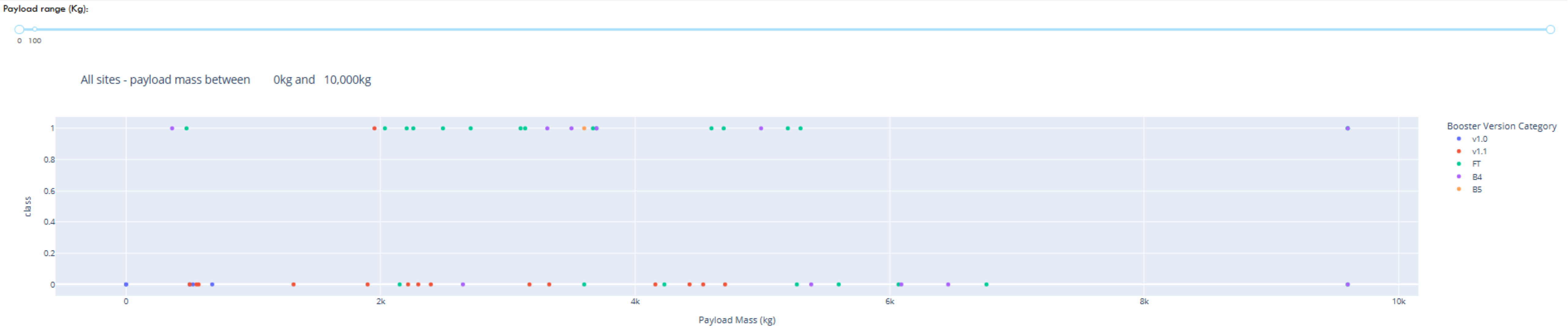
Launch Success Count for All Sites

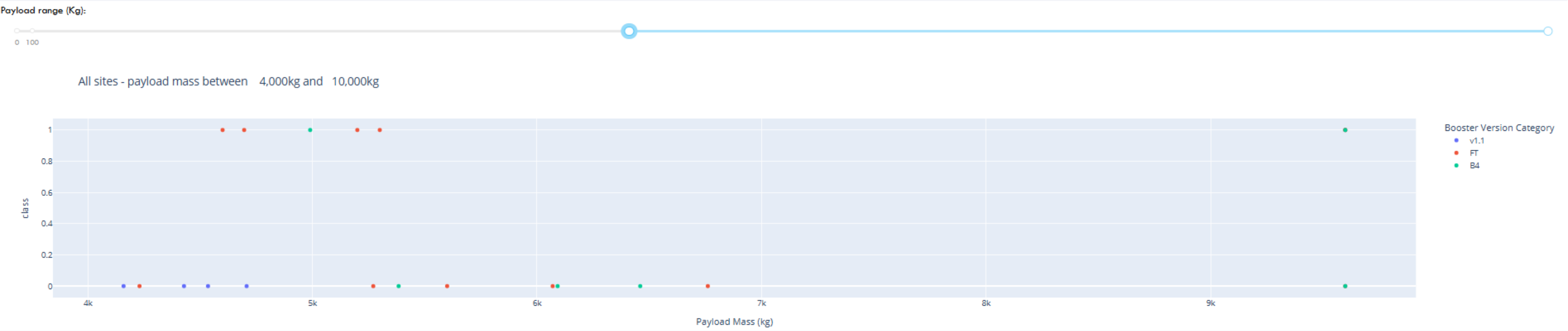


Launch Site with Highest Launch Success Ratio



Payload vs. Launch Outcome Scatter Plot for all Sites, with Different Payload





Section 5

Predictive Analysis (Classification)

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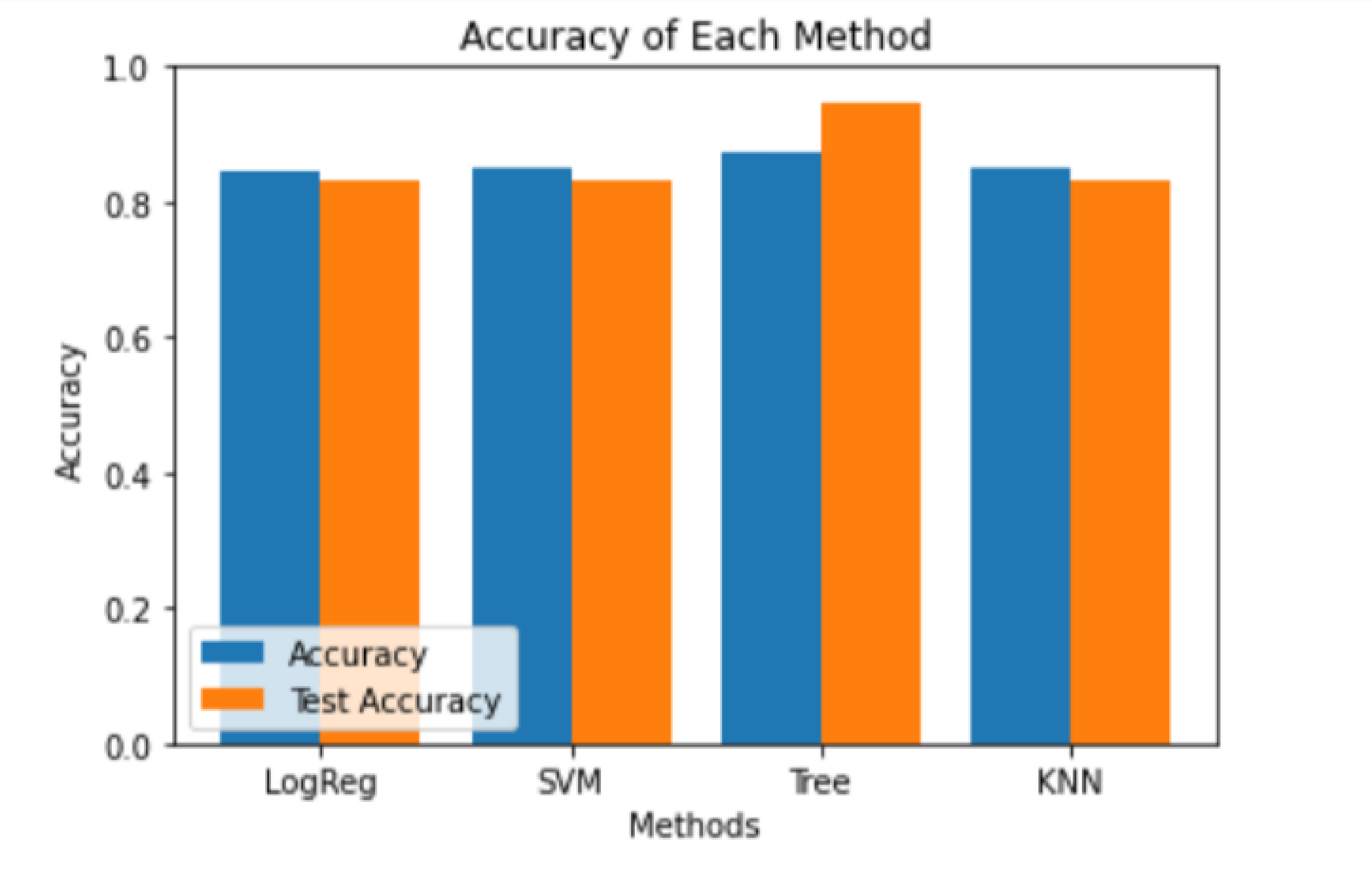
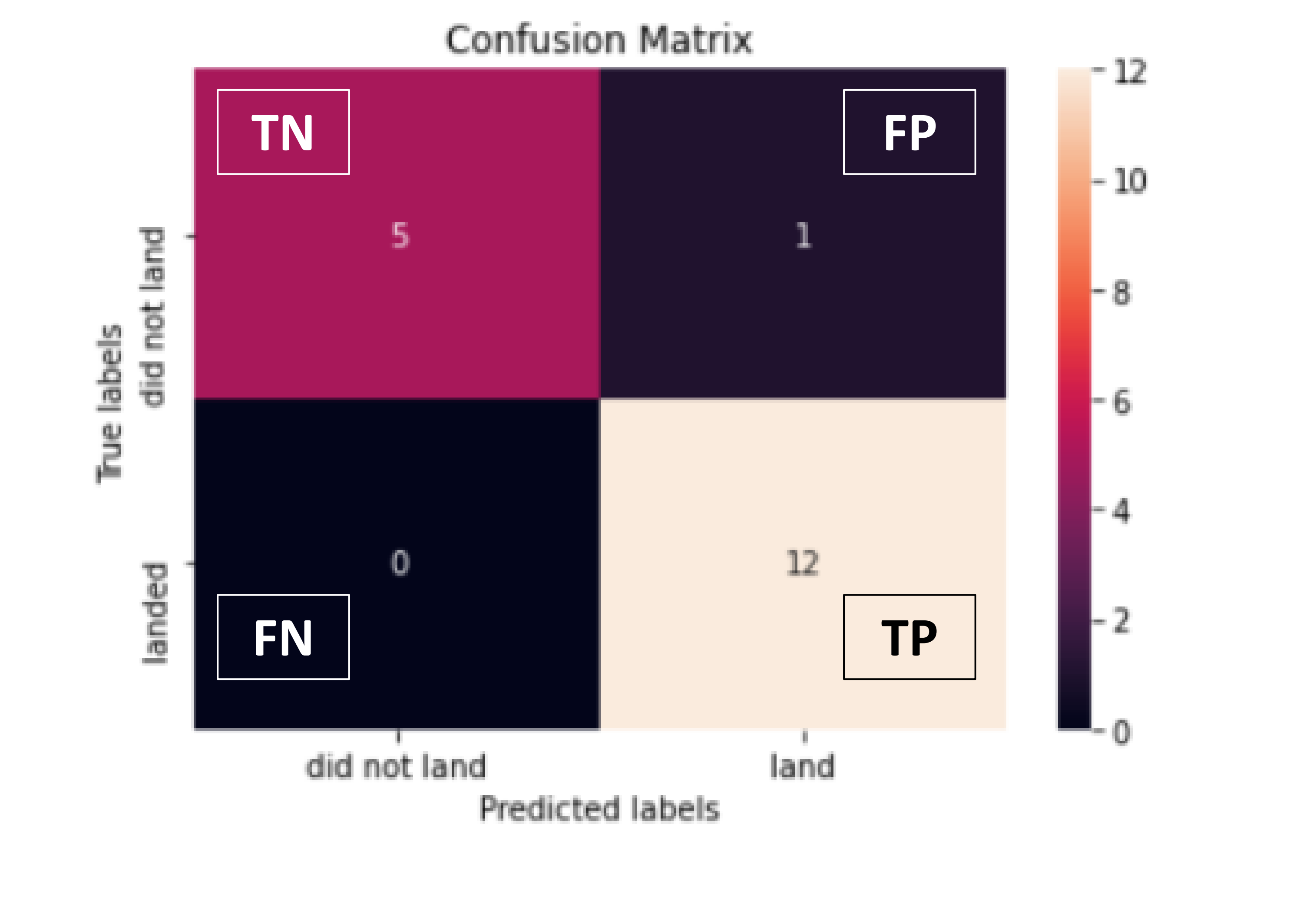
Classification Accuracy



Confusion Matrix



Conclusions

- Model Performance: The models performed similarly on the test set with the decision tree model slightly outperforming.
- Equator: Most of the launch sites are near the equator for an additional natural boost - due to the rotational speed of earth - which helps save the cost of putting in extra fuel and boosters.
- Coast: All the launch sites are close to the coast.
- Launch Success: Increases over time.
- KSC LC-39A: Has the highest success rate among launch sites. Has a 100% success rate for launches less than 5,500 kg.
- Orbits: ES-L1, GEO, HEO, and SSO have a 100% success rate.
- Payload Mass: Across all launch sites, the higher the payload mass (kg), the higher the success rate

Thank you!

Mazen