IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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

Executive Summary

- **Methodologies:**
  - **Data Collection:** Reliable sources for Falcon 9 landing data.
  - **Data Wrangling:** Cleaning and preprocessing for quality data.
  - **EDA:** Visualizations and SQL for insights.
  - **Interactive Analytics:** Folium and Plotly Dash for accessibility.
  - **Predictive Analysis:** Classification models for landing prediction.
- **Results**:
  - **Successful Landing Prediction:** Significant cost savings.
  - **Cost Implications:** Influence on launch decisions.
  - **Data Insights:** Valuable findings from EDA.
  - **Model Performance:** Achieved high-performance metrics (e.g., accuracy, precision, recall, F1-score) validating the model's effectiveness.

Introduction

- **Project Background and Context:**
  - SpaceX Falcon 9 Rocket Launches and Cost-Efficiency.
  - **Reusability of the First Stage:** Cost-saving advantage.
  - **Cost Discrepancy:** SpaceX vs. competitors.
  - Significance of Predicting Landings for Cost Estimation.

- **Problems to Solve:**
  - **Challenge:** Predicting landing success for cost estimation.
  - **Competitive Advantage:** Affecting rocket launch market competition.
  - **Data-Driven Approach:** Leveraging data science and predictive modeling.
  - **Real-World Impact:** Aerospace industry implications.

Section 1

Methodology

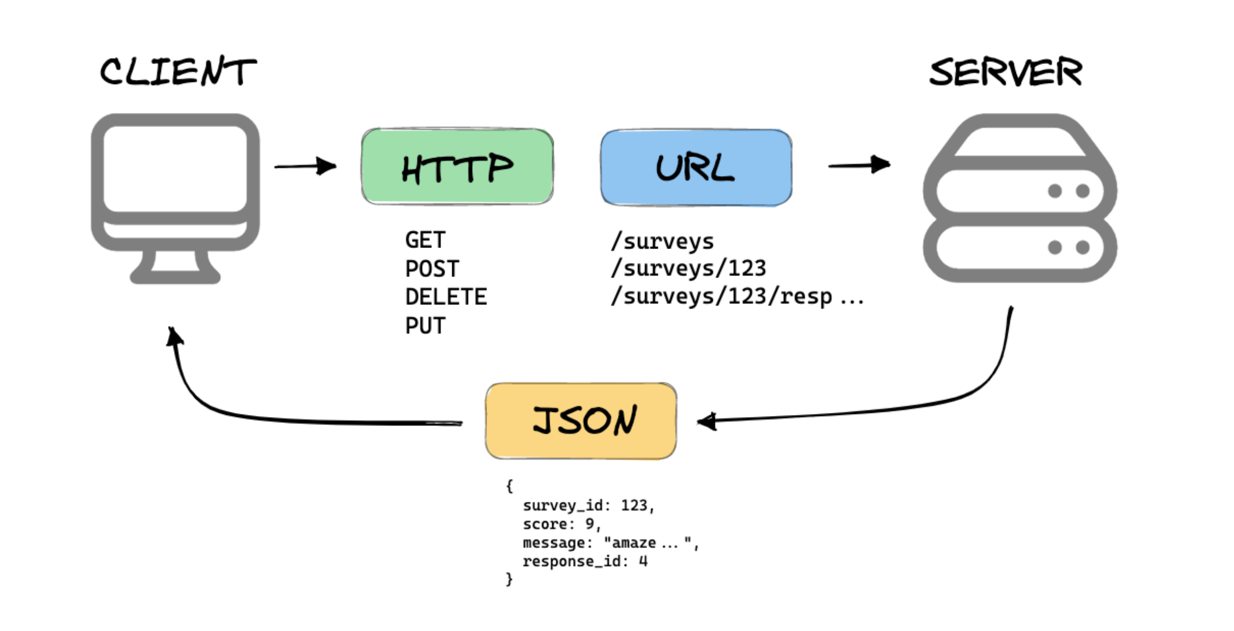
Methodology

Executive Summary

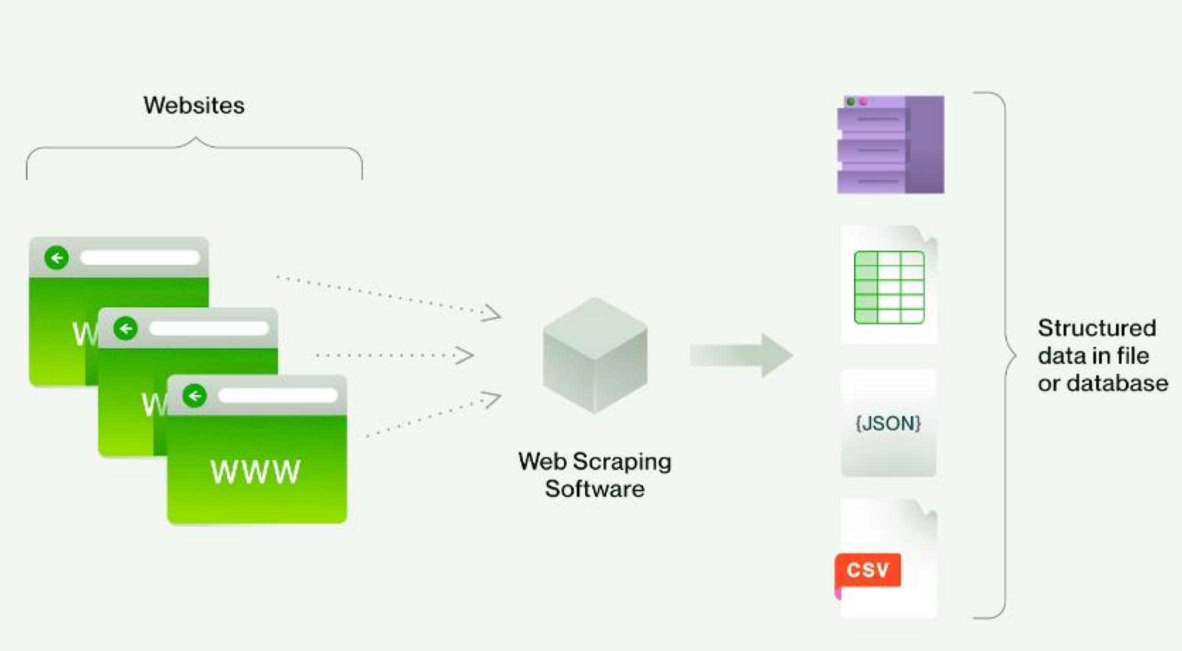
- **Data Collection Methodology:** Collected Falcon 9 first-stage landing data using a **REST API** and **web scraping.**
- **Data Wrangling:** Transformed collected data into a Pandas data frame and performed initial data wrangling by **cleaning** & **processing** the data.
- **Exploratory Data Analysis (EDA):**
  - Conducted exploratory data analysis by manipulating data, created scatter plots and bar charts for data analysis in a **Pandas** data frame.
  - Executed **SQL** queries to select and sort data for analysis.
  - Utilized **data visualization** skills to extract meaningful patterns.
- **Interactive Visual Analytics:**
  - Built an interactive dashboard with **Plotly Dash** containing pie charts and scatter plots.
  - Calculated distances, generated interactive maps, plotted coordinates, and marked clusters with **Folium**.
- **Predictive Analysis using Machine Learning Classification Models:**
  - Trained different classification models, including **Logistic Regression, SVM**, **Decision Trees**, and **KNN**.
  - Optimized hyperparameters using **grid search**.
  - Utilized machine learning skills to build a **predictive model** for determining first-stage Falcon 9 landing success.

Data Collection

- **Data Sets Collection Process:**
  - **REST API Usage:** Data retrieval through a REST API.
  - **Web Scraping:** Data gathering via web scraping.



Using REST API



Using Web Scraping

Data Collection – SpaceX API

- **SpaceX REST GET :**Requested and parse the SpaceX launch data using the GET request to get the JSON Object.
- Converted JSON into the pandas DataFrame.
- Filtered the DataFrame to only include `Falcon 9` launches

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

response = requests.get(spacex_url)

data_json = response.json()

data = pd.json_normalize(data_json)

data_falcon = data1[data1['BoosterVersion']='Falcon 9']
```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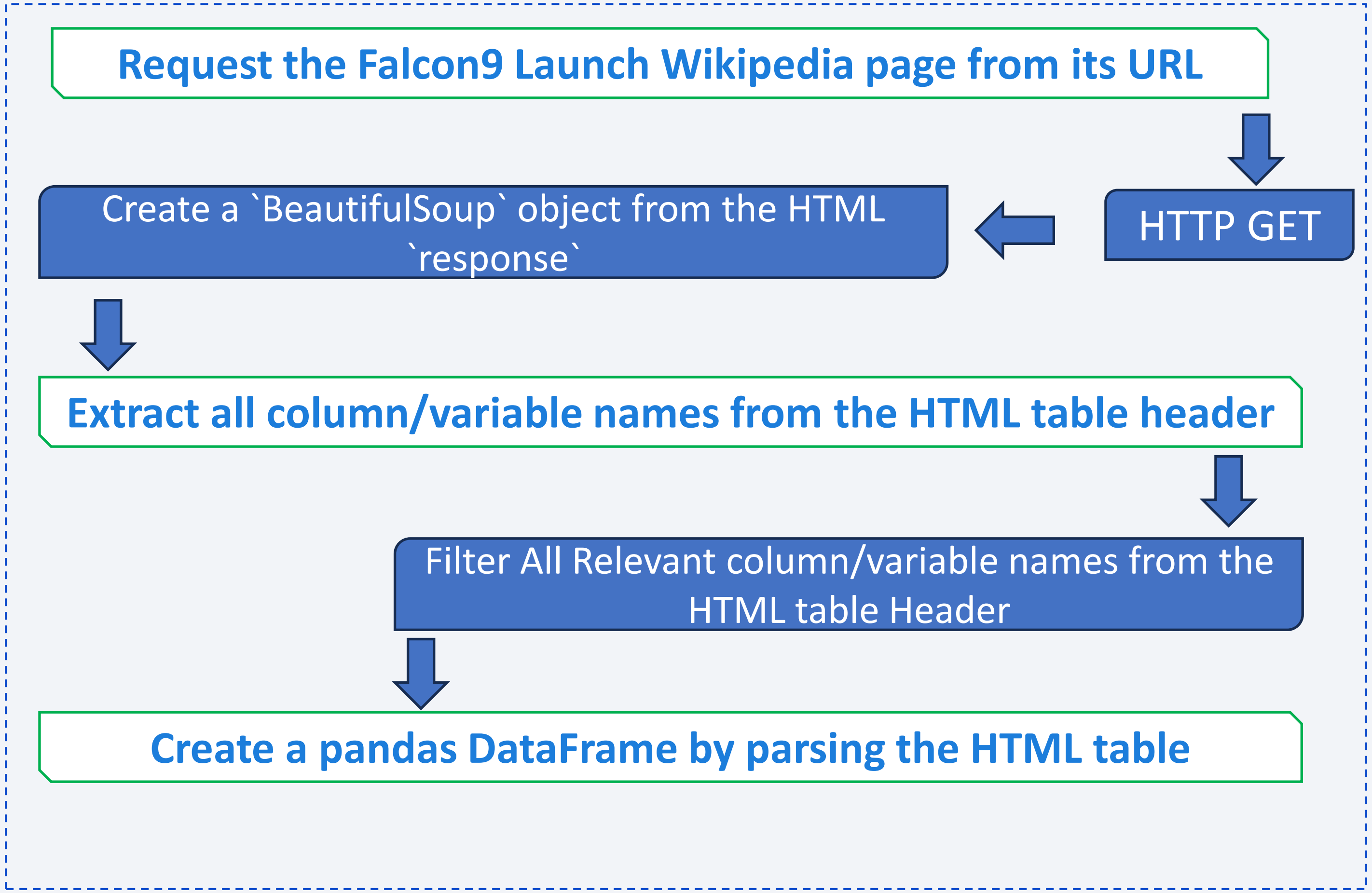
Data Collection - Scraping

- **Web scrap Falcon 9 launch records with `BeautifulSoup`:**
  - Extracted a Falcon 9 launch records HTML table from Wikipedia.
  - Parsed the table and converted it into a Pandas dataFrame.



Data Wrangling

- **Data Processing Description:**

  - Dealt with **missing values** for the columns 'PayloadMass' & 'LandingPad' by replacing them with the averages.

  - Observed the bar chart Visualizations - number of launches on each site, number and occurrence of each orbit, number and occurrence of mission outcome per orbit type.

  - Created a New column named "**Class**" having data type as bool for landing outcome label from Outcome column.

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EDA with Data Visualization

- Charts Summary:
  - **Charts Plotted:**
    - **Scatter Plots:**
      - Flight Number vs. Payload Mass, overlaying the Launch Success(Class) :(To see the launch success with payload mass)
      - Flight Number vs Launch Site, overlaying the Launch Success(Class) :(To see the launch success at Launch sites)
      - Payload Mass vs Launch Site, overlaying the Launch Success(Class) :(To see the launch success with Both PayloadMass & Launch site)
      - Flight Number vs Orbit type, overlaying the Launch Success(Class) :(To see the launch success with with orbit types)
      - Payload Mass vs Orbit type, overlaying the Launch Success(Class) :(To see the launch success with both Payload Mass & Orbit type)
    - **Bar Chart:**
      - Avg Launch Success rate for each Orbit type :(To see the launch success rate with orbit type)
      - Avg Launch Success rate for Each year :(To see the launch success rate per year)
    - **Line plot:**
      - Launch success yearly trend :(To see the continuous trend for launch success with year)
  - **Reasons:**

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EDA with SQL

- **SQL Queries Summary:**
  - Displayed unique launch site names in the space mission data.
  - Displayed 5 records where launch sites begin with 'CCA'.
  - Displayed the total payload mass carried by boosters launched by NASA (CRS).
  - Displayed the average payload mass carried by booster version F9 v1.1.
  - Listed the date of the first successful landing outcome on the ground pad using the min function.
  - Listed the names of boosters with success in drone ship landings and payload mass between 4000 and 6000.
  - Listed the total number of successful and failure mission outcomes.
  - Listed the names of booster versions that carried the maximum payload mass using a subquery.
  - Listed records displaying month names, failure landing outcomes on the drone ship, booster versions, and launch sites for the year 2015.
  - Ranked the count of landing outcomes (e.g., Failure (drone ship) or Success (ground pad)) between June 4, 2010, and March 20, 2017, in descending order.

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Build an Interactive Map with Folium

- **Utilized Map Objects Summary:**
  - **Markers:** Added markers to represent launch sites on the map.
  - **Circles:** Utilized circles to visualize launch site proximity areas.
  - **Marker Clusters:** Implemented marker clusters to showcase successes at each launch site.
  - **Polylines (Lines):** Incorporated polylines to showcase distances between proximities and launch sites.
- **Object Justification:**
  - **Markers:** Added for clear launch site identification and location reference.
  - **Circles:** Included to display launch site proximity for analytical purposes.
  - **Marker Clusters:** Utilized for efficient grouping and display of success outcomes.
  - **Polylines (Lines):** Used to showcase distances and spatial relationships for better data interpretation.

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Build a Dashboard with Plotly Dash

- **Dashboard Components Summary:**
  - **Pie Charts:** Added pie charts to visualize launch success distributions among all sites. And launch success & failure distributions for each Individual sites also(By changing the dropdown) .
  - **Scatter Plots:** Included scatter plots to showcase Correlation between Payload Mass and Launch Success for All Sites and individual sites as well.
  - **Dropdown Menus:** Implemented dropdown menus for interactive site selection.
  - **Slider Controls:** Utilized slider controls to filter data based on payload mass.
- **Component Justification:**
  - **Pie Charts:** Added for a clear overview of launch success and failure rates.
  - **Scatter Plots:** Included to allow users to explore relationships and patterns in the data.
  - **Dropdown Menus:** Implemented for interactive site selection, enhancing user experience.
  - **Slider Controls:** Utilized to filter data by payload mass, enabling data exploration.

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Predictive Analysis (ML Classification)

- **Model Development Summary:**
  - **Built Multiple Models:** Developed various ML classification models to predict Falcon 9 first-stage landing success.
  - **Evaluation and Improvement:** Evaluated model performance using metrics and iteratively improved them.
  - **Best Performing Model:** Identified the best-performing classification model for accurate predictions.
- **Model Development Process:**

Data Splitting (Train, Test): → Model Selection (e.g. Logistic Regression, SVM, Decision Trees, KNN)

↓

Hyperparameter Tuning (Optimized model hyperparameters)

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Evaluation Metrics: key metrics (e.g., accuracy, F1-score) for model performance.

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Select Model having highest performance (Evaluation Metrics)

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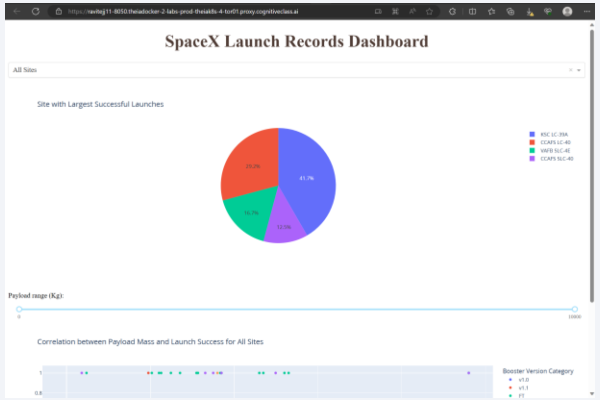
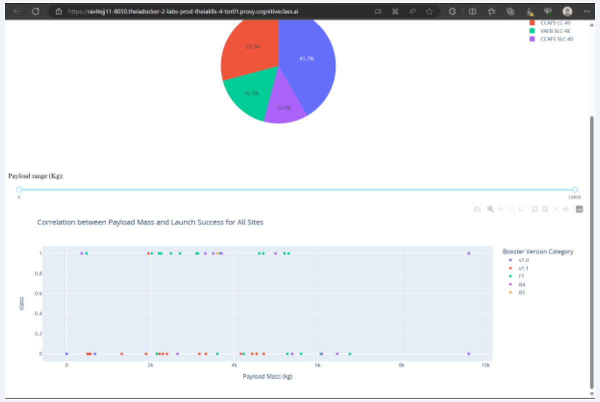
Results

- **Exploratory Data Analysis Results:**
  - **Key Findings:**
    - **Success Rates:** Uptrend with progressing year, except some of the downs in 2018 & 2020.
    - **Payload Mass distribution:** Success is more within (1952,5300).
    - **Launch Site analysis:** Highest Success Launches at KSC LC – 39A.
- **Interactive Analytics Demo Screenshots:**





- **Predictive Analysis Results:**
  - **Model Performance: (** Best Performance Model - DECISION TREE CLASSIFIER)
    - **Accuracy:** '0.8888888888888888' (For - DECISION TREE CLASSIFIER)
    - **False Positives in the CONFUSION MATRIX:** '1' (For - DECISION TREE CLASSIFIER)
    - **Key Findings:** With the given Features about the Falcon 9, we can Predict the First stage launch success close to 89%.

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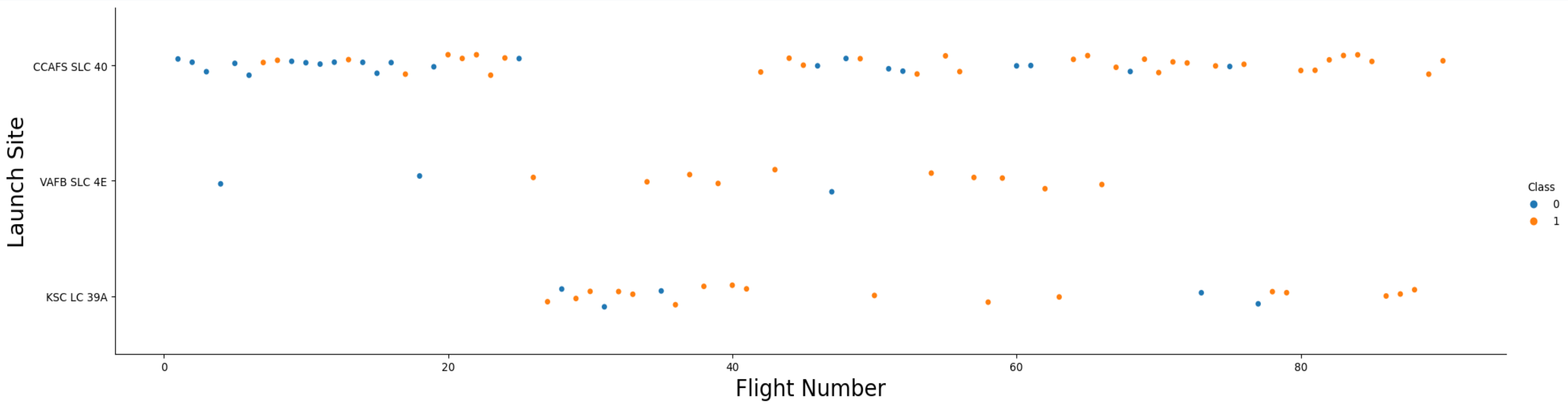
Section 2

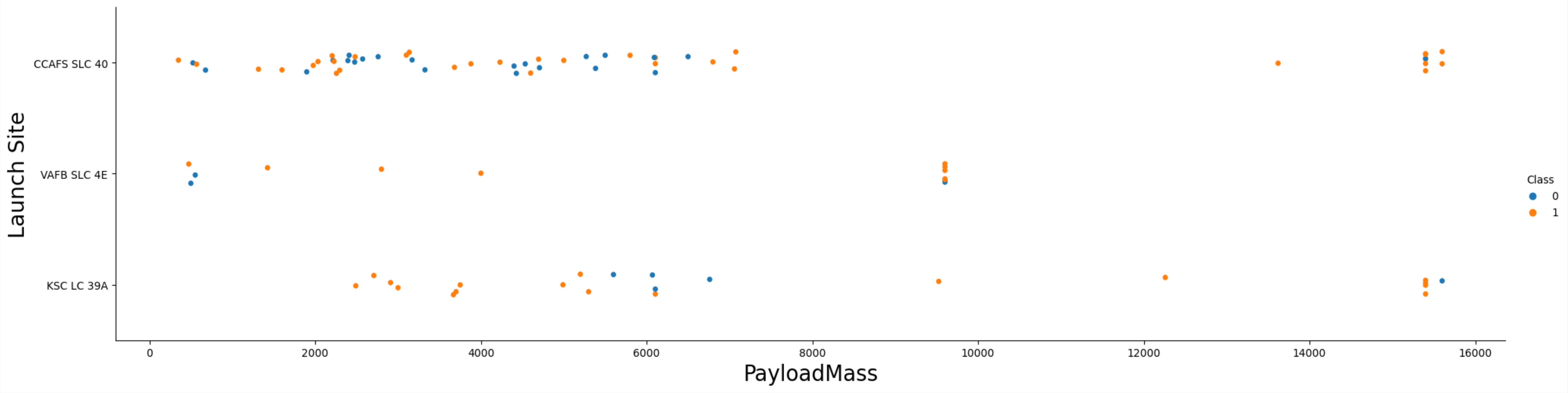
Insights drawn from EDA

Flight Number vs. Launch Site



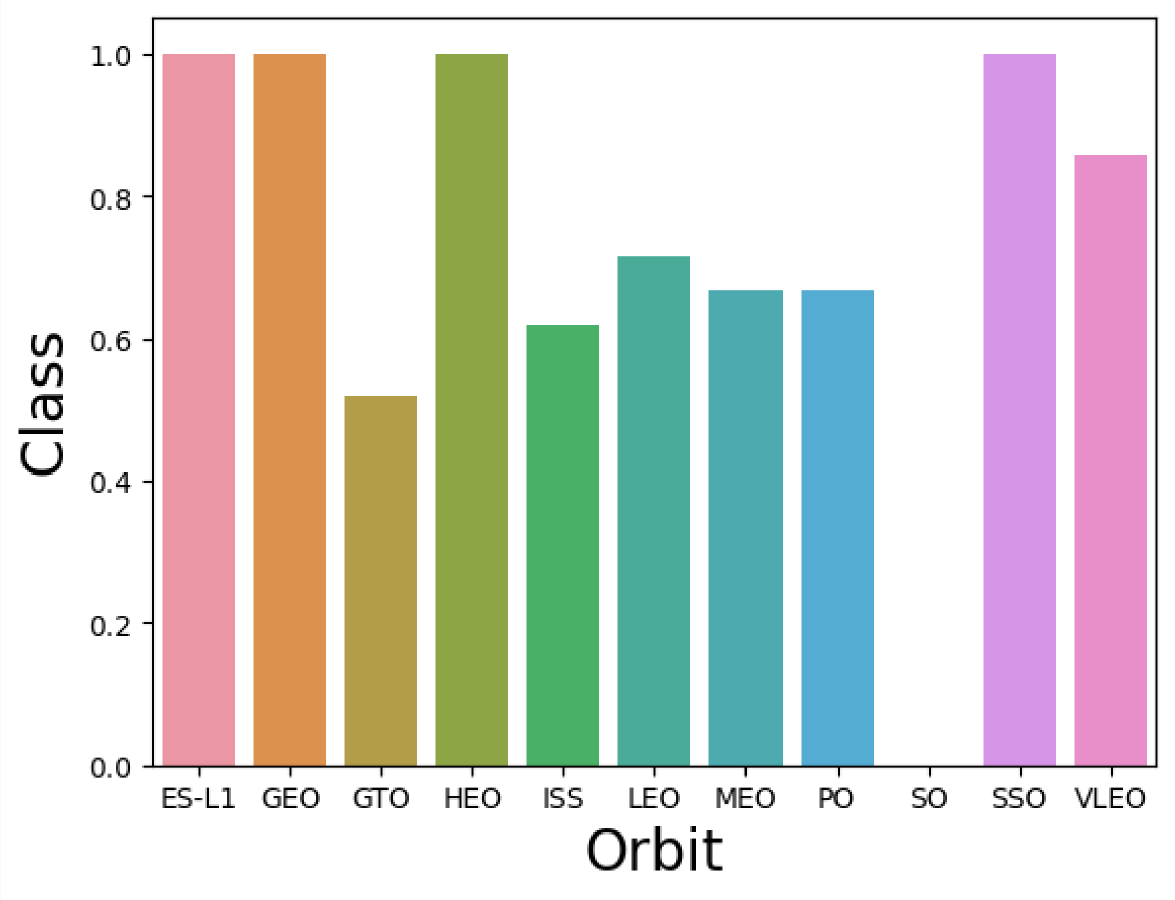
- Explanations:
  - For Launch site 'CCAFS 40' Success has increased with higher Flight Number.
  - For Launch Site 'KSC LC 39A' very few (=5) of Failures have been there.

Payload vs. Launch Site



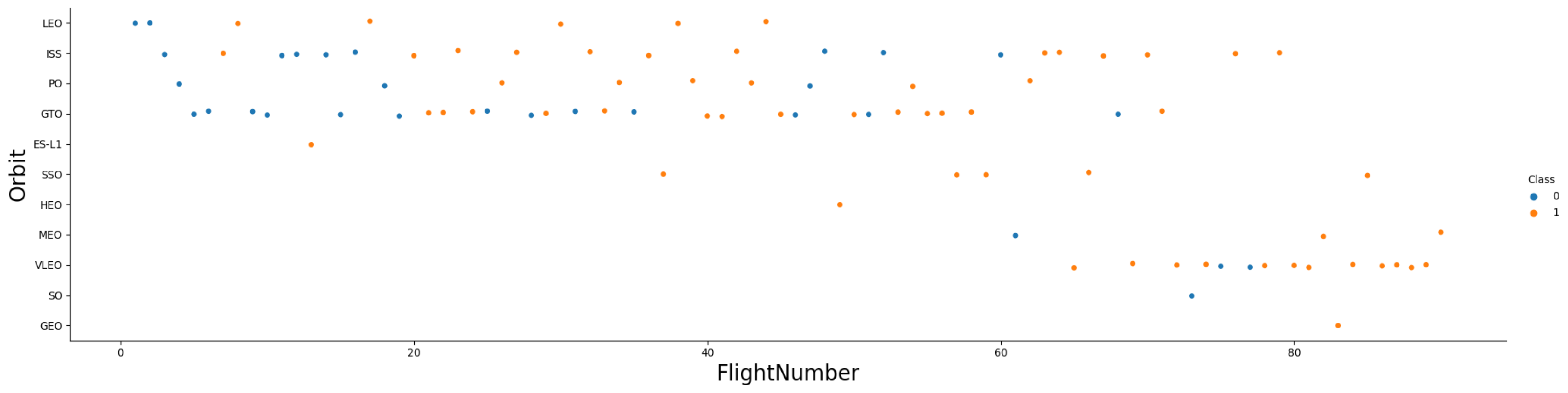
- Explanations:
  - For Launch site ‘CCAFS 40’ & ‘KSC LC 39A’ Success has also been for heavy payload mass(>10000kg).
  - For Launch Site ‘VAFB-SLC’, there are no rockets launched for heavy payload mass(>10000kg).

Success Rate vs. Orbit Type



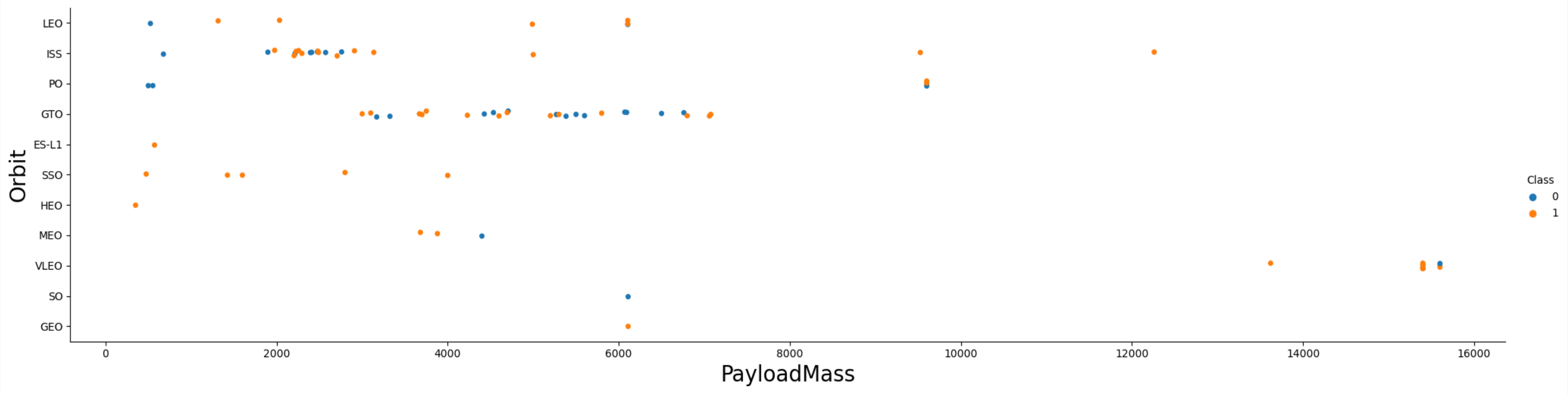
- Explanations:
  - For Orbit types 'ES-L1(Lagrange point)', 'GEO(Circular Geosynchronous)', 'HEO(highly Elliptical Orbit)', and 'SSO(Sun-synchronous orbit)' Success rate has been **100%.**
  - For Orbit type 'GTO(Geosynchronous)' Success rate has been **least** (around **50%).**

Flight Number vs. Orbit Type



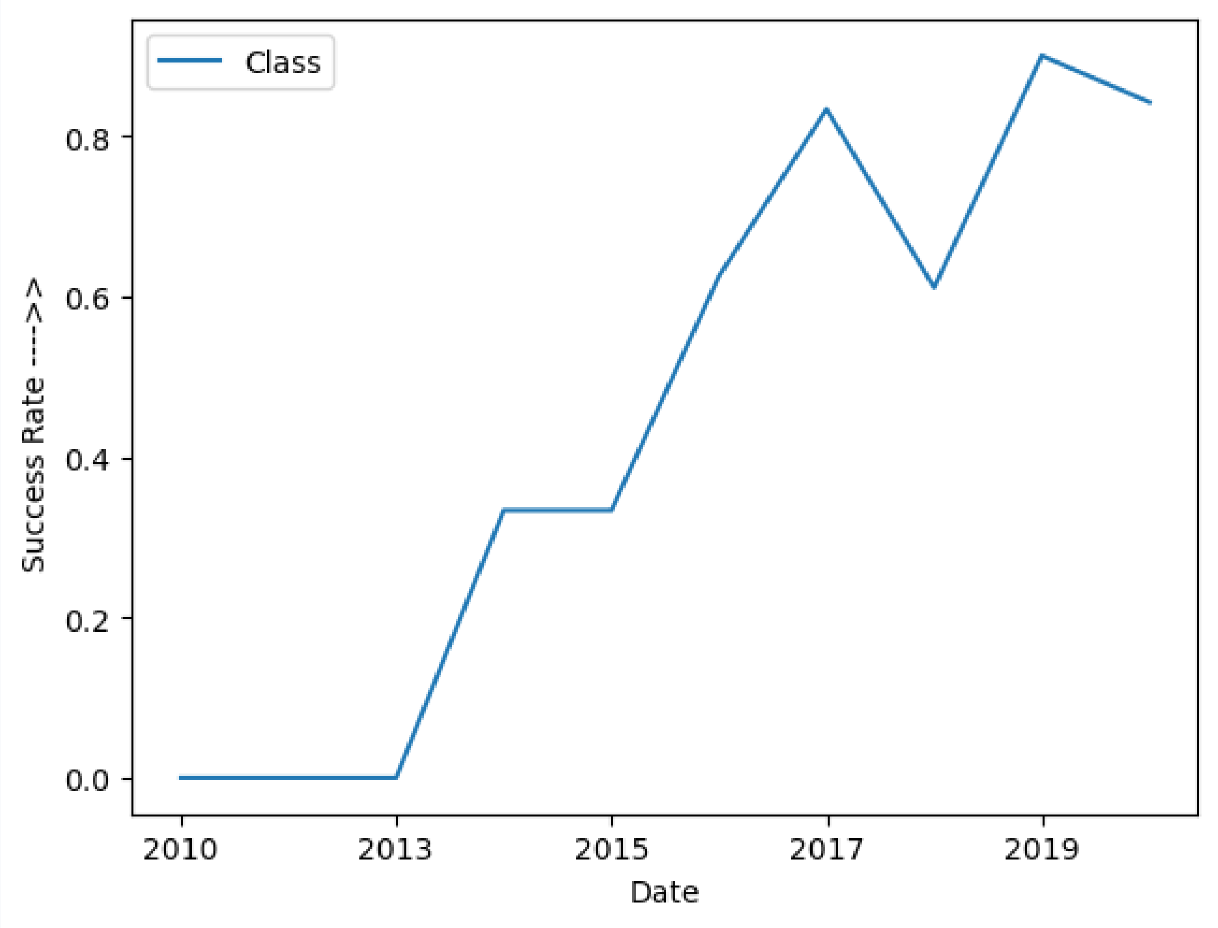
- Explanations:
  - At Larger Flight Number(around 80 and greater than 80), almost all the orbit types are giving Success
  - 'LEO(Low Earth orbit)' orbit the Success appears related to the number of flights.
  - There seems to be no relationship between flight number when in 'GTO(Geosynchronous)' orbit.

Payload vs. Orbit Type



- Explanations:
  - There have been very Few Launches with heavy Payload Mass(>8000kg), and most of them have success.
  - 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) are both there here.

Launch Success Yearly Trend



- **Explanations:**
  - Success rate has been increased monotonically over time from 2013 onwards, except some of the small falls in 2017 and 2020.

All Launch Site Names

- **'CCAFS LC-40’**
- **'CCAFS SLC-40’**
- **'KSC LC-39A’**
- **'VAFB SLC-4E’**

	Launch Site	Lat	Long
0	CCAFS LC-40	28.562302	-80.577356
1	CCAFS SLC-40	28.563197	-80.576820
2	KSC LC-39A	28.573255	-80.646895
3	VAFB SLC-4E	34.632834	-120.610745

- Maximum Lunches from site **'CCAFS LC-40’ .**

Launch Site Names Begin with 'CCA'

	Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing_Outcome
0	2010-04-06	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
1	2010-08-12	15:43:00	F9 v1.0 B0004	CCAFS LC-40	Dragon demo flight C1, two CubeSats, barrel of...	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2	2012-05-22	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
3	2012-08-10	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
4	2013-01-03	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

- 5 Records where launch sites begin with `CCA`

- There are only two site names begin with `CCA`:
  - **'CCAFS LC-40’**
  - **'CCAFS SLC-40’**

Total Payload Mass

- **Query Result:** Total Payload Mass Carried by NASA (CRS) Boosters: 45596 kg

- **Explanation:**
  - Understanding the total payload mass carried by NASA is crucial for mission planning, cost estimation, and evaluating NASA's contribution to space missions.
  - It provides valuable insights into the significance of NASA's involvement in space exploration.

Average Payload Mass by F9 v1.1

- **Query Result:** Average Payload Mass Carried by Booster Version 'F9 v1.1': **2928.4 kg**

- **Explanation:**
  - Analyzing the average payload mass for "F9 v1.1" booster versions provides insights into their performance and capabilities.
  - Aiding in mission planning and cost-efficiency assessments.

First Successful Ground Landing Date

- **Query Result:** Date of First Successful Landing on Ground Pad: **2015-12-22**

- **Explanation:**
  - The first successful ground landing outcome marks a historic achievement for SpaceX.
  - It significantly reduced launch costs by enabling booster reusability.
  - This milestone is a testament to SpaceX's innovation and commitment to revolutionizing space travel.

Successful Drone Ship Landing with Payload between 4000 and 6000

- **Query Result:**
  - Names of Desired Boosters (Dron ship Landing Criteria)
    - **F9 FT B1022**
    - **F9 FT B1026**
    - **F9 FT B1021.2**
    - **F9 FT B1031.2**

- **Explanation:**
  - Identifying boosters with successful drone ship landings in this specific payload range is essential for evaluating their performance and reliability in handling medium-sized payloads for cost-effective space missions.

Boosters Carried Maximum Payload

- **Query Result:**
  - Booster Versions with Maximum Payload Mass:
    - **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:**
  - Identifying the booster(s) that achieved the maximum payload mass showcases their exceptional capabilities in handling heavy payloads.
  - It is pivotal for cost-effective space missions and demonstrates SpaceX's engineering achievements.

2015 Launch Records

- **Query Result:** List of failed landing outcomes in drone ship, along with their booster versions and launch site names for the year 2015.

“Month”	“ Landing Outcome”	“Booster Version”	“Launch Site”
October	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
April	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40

- **Explanation:**
  - Analyzing the launch records from 2015, specifically focusing on failed landing outcomes in drone ships, provides valuable insights for SpaceX's continuous improvement in space missions.
  - Understanding the specific incidents and their details can lead to enhanced performance and safety.

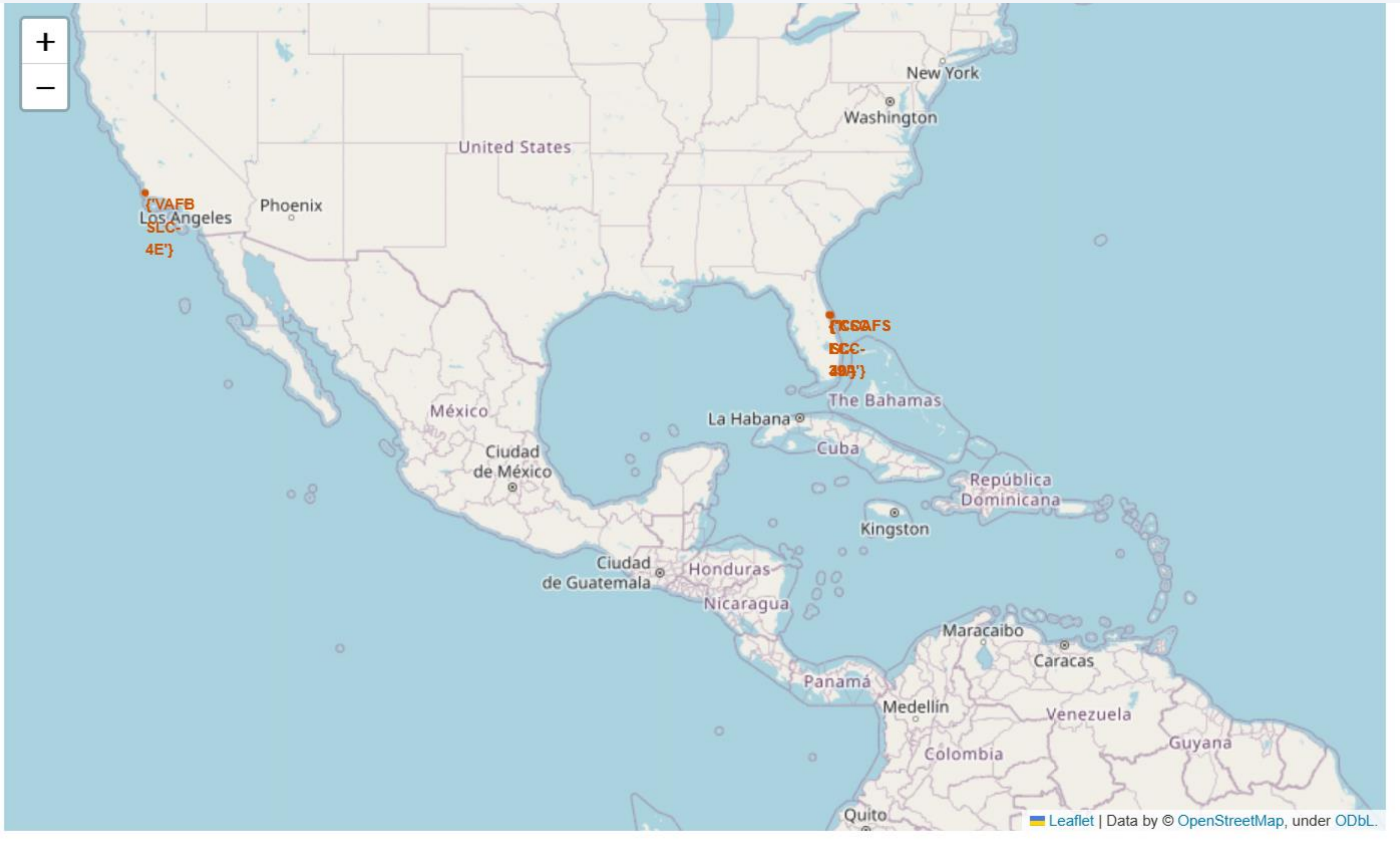
Rank Landing Outcomes Between 2010-06-04 and 2017-03-20

- **Query Result:**
  - Ranked Landing Outcomes between 2010-06-04 and 2017-03-20 in Descending Order:
    - No attempt :- 10
    - Success (drone ship) :- 5
    - Success (ground pad) :- 5
    - Failure (drone ship) :- 5
    - Controlled (ocean) :- 3
    - Uncontrolled (ocean) :- 2
    - Failure (parachute) :- 1
    - Precluded (drone ship) :- 1
- **Explanation:**
  - Ranking the landing outcomes during this specific time frame offers valuable insights into the overall performance of SpaceX missions.
  - It helps identify trends and patterns in mission outcomes, aiding in continuous improvement and decision-making.

Section 3

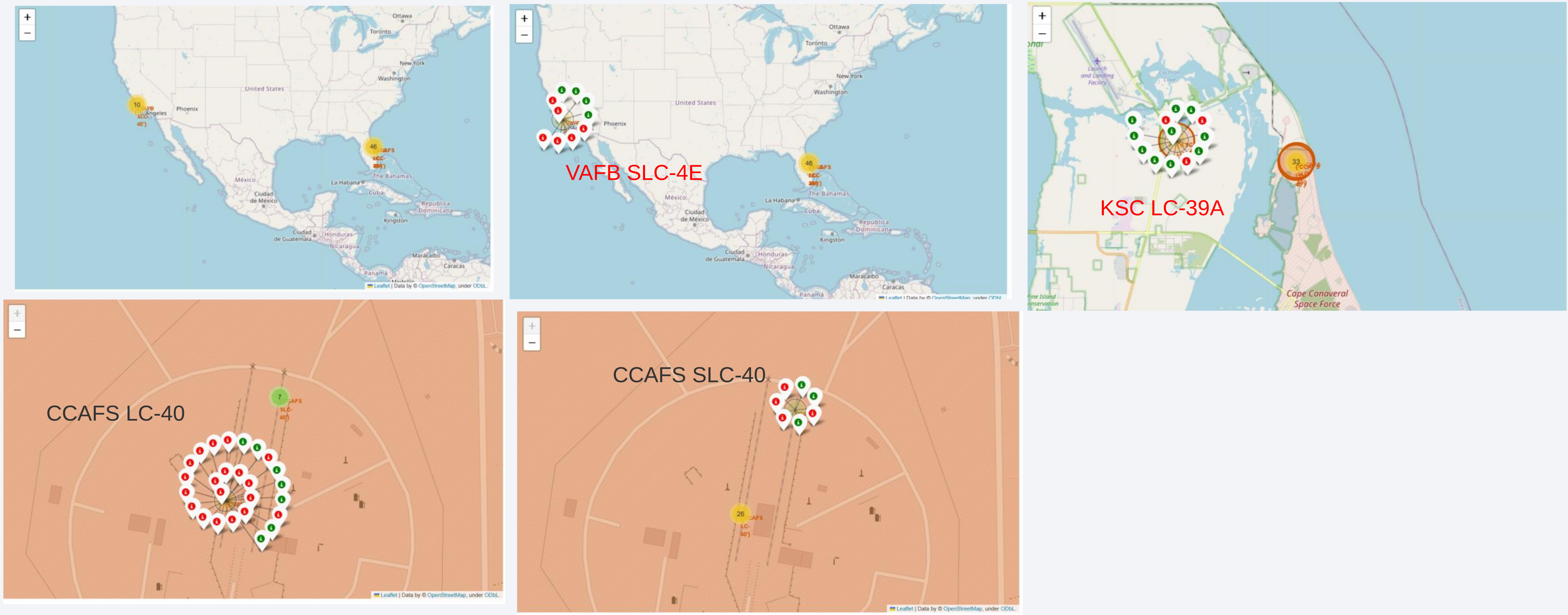
Launch Sites Proximities Analysis

Folium Map: All Launch sites Location Markers on a Global Map



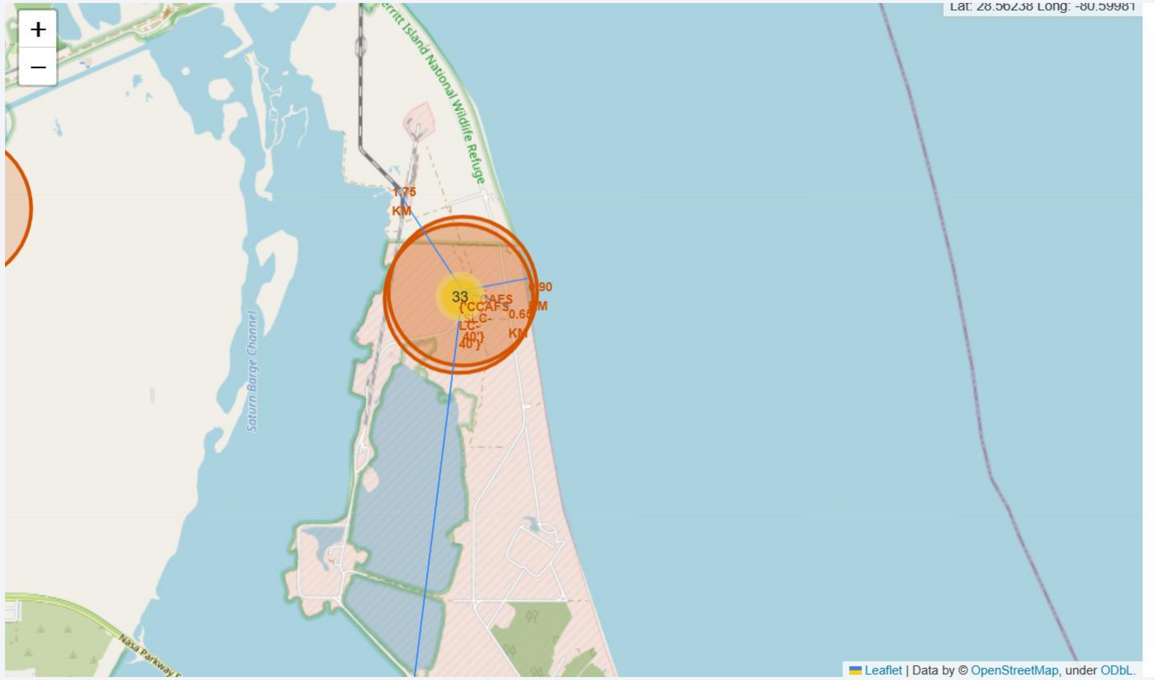
- **Explanation:** Almost all the sites are in very close proximity to the coast.

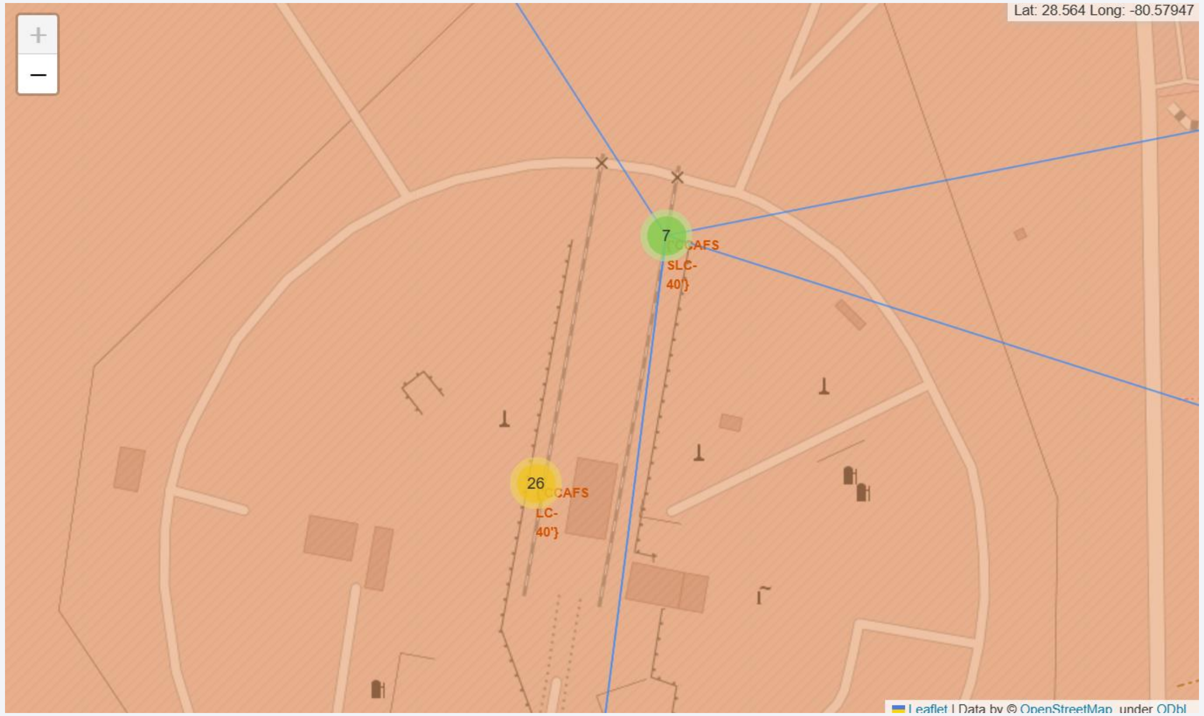
Folium Map: Color Labeled launch Outcome for each site on the map



- Explanation:
  - Site “KSC LC-39A” have Relatively high Success Rate

Folium Map: Distances between a launch site (CCAFS SLC-40) to its proximities.



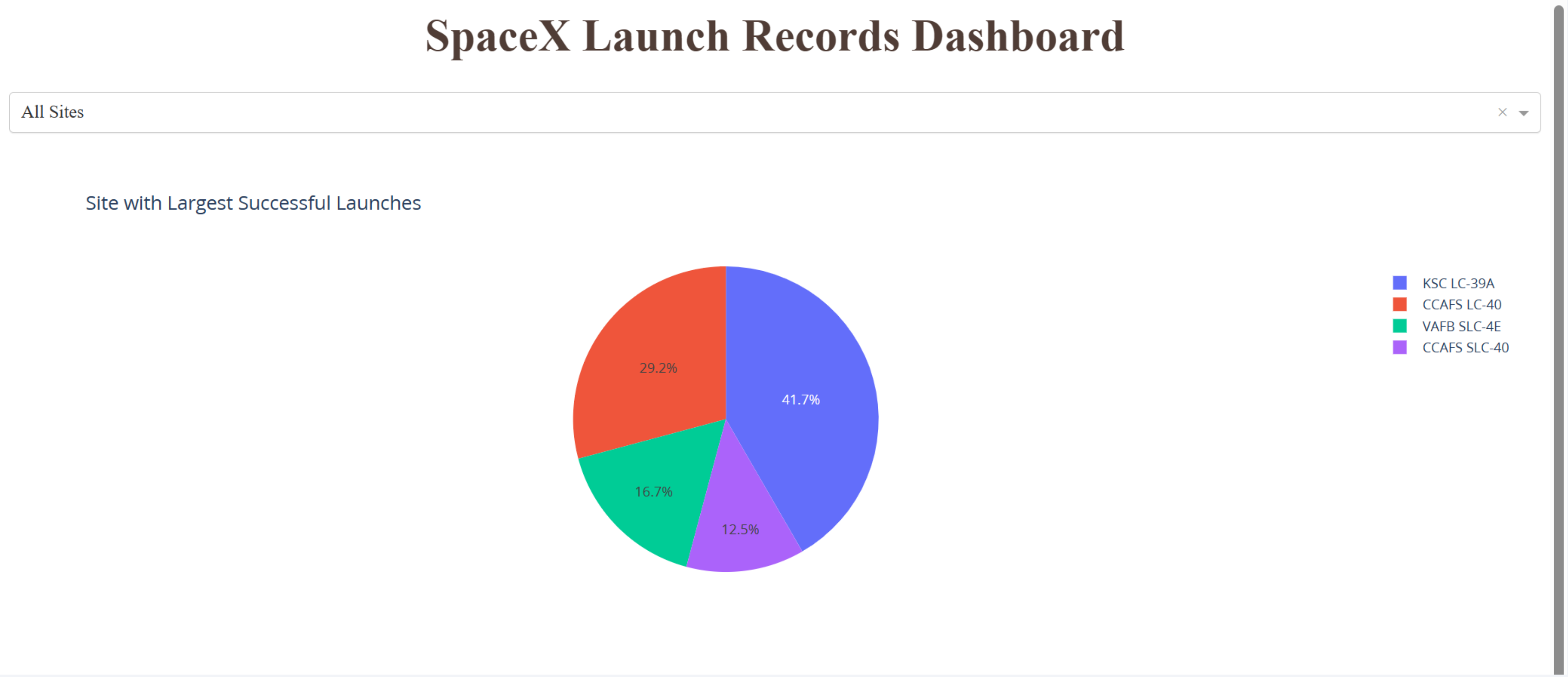


- Explanation:
  - We found that Launch site "CCAFS SLC-40" is in close proximity to Railway, Highway,& Coastline (1.7491725095424817 Km, 0.6532857532514599 Km, and 0.90 km respectively)
  - But not to the city (51.499840490511794 Km).

Section 4

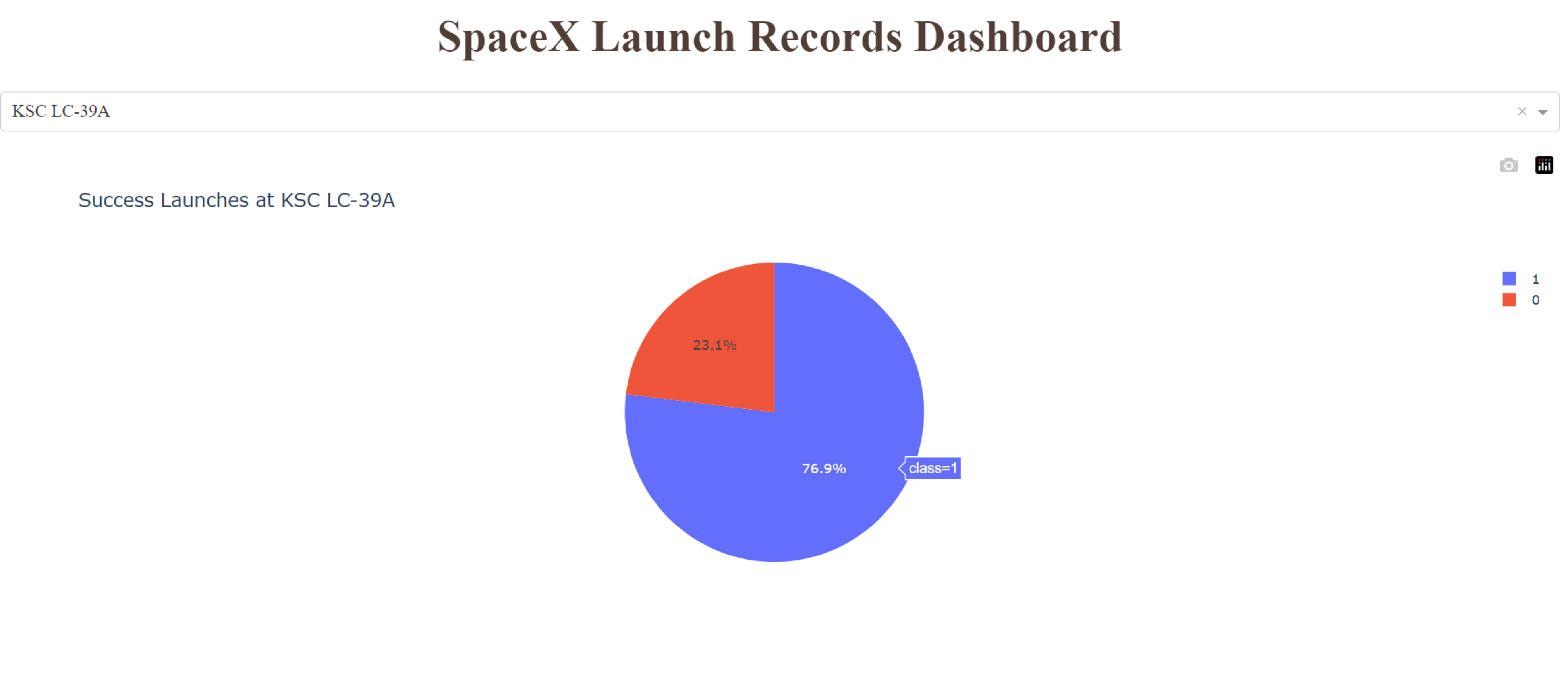
Build a Dashboard with Plotly Dash

Pie Chart: Launch Success counts for All Sites



- Explanation:
  - Site with Largest Successful Launches is "KSC LC-39A".

Pie Chart: Launch Site with Highest Launch Success Ratio



- **Explanation:**
  - At site “KSC LC-39A” Launch landing Success is 76.9%
  - At site “KSC LC-39A” Launch landing Failure is 76.9%

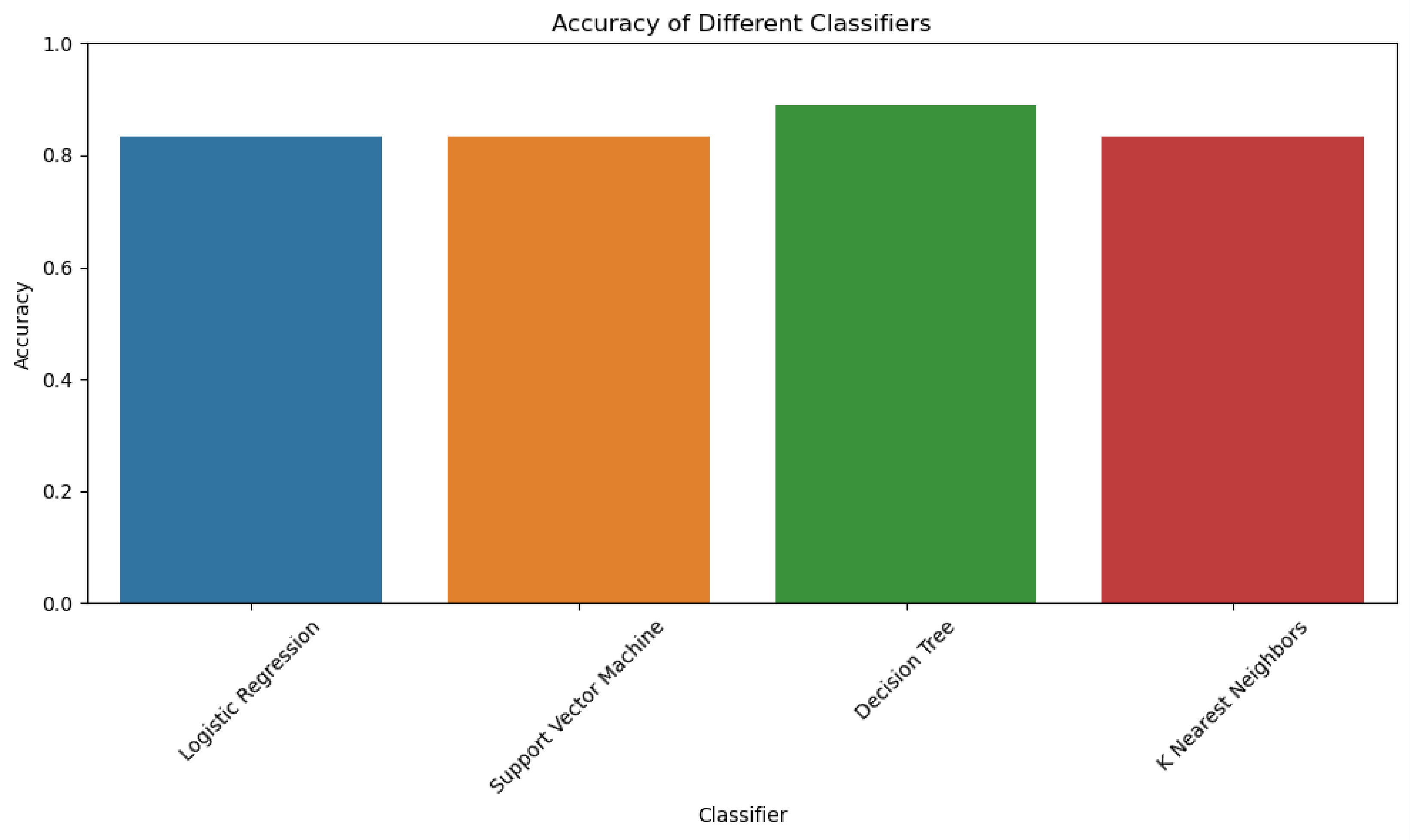
Scatter Plot: Payload vs Launch Outcome for All Sites

- **Explanation:**
  - 2000 kg to 4000 kg Payload mass have highest Success.
  - Booster Version “FT” given highest Success.

Section 5

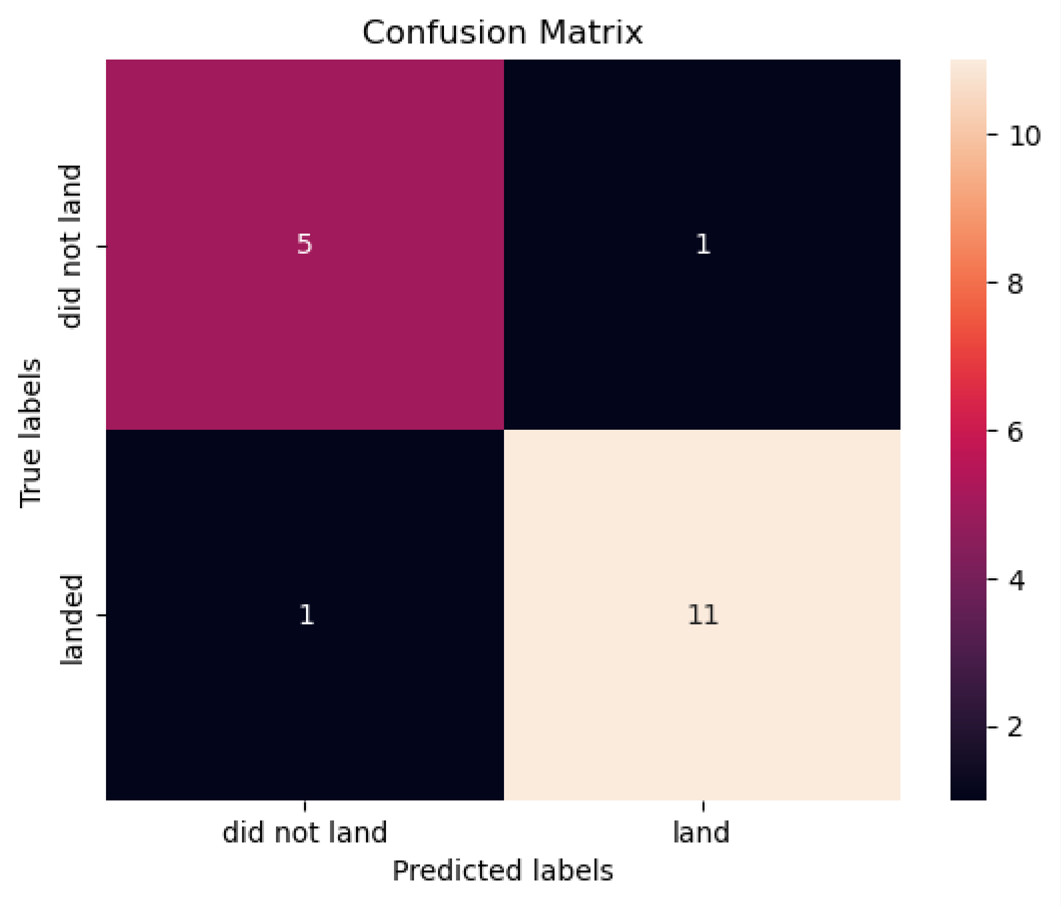
Predictive Analysis (Classification)

Classification Accuracy



- **Highest classification accuracy:**
  - DECISION TREE CLASSIFIER - 0.8888888888888888

Confusion Matrix



- **Decision Tree Classifier** (Best Performance Model)
  - Accuracy: 0.8888888888888888

- **Explanation:**

  Out of 18 test Samples

  - True Positives: 11
  - True Negatives: 5
  - False Negatives: 1
  - False Positives: 1

- In our Objective the False Positives(i.e. we expected to get success in first stage landing But Actually it didn't Land) are very crucial.
- Here we have **Least FALSE POSITIVES (= 1)**
- **Best Optimized Model**

Conclusions

- **Predictive Model Success:**
  - Successfully determines first stage landing outcomes with close to **89% Model accuracy**,
  - Enables accurate **cost estimations** for space missions.
- **Launch Site Analysis:**
  - Analysis of launch sites (Like “KSC LC-39A”) reveals their impact on mission success & **strategic site selection**.
- **Payload Mass Significance:**
  - Payload mass analysis (Like 2000 kg to 4000 kg &) provides insights into booster (Like “FT”) performance, affects mission success.
- **Historical Trends:**
  - historical trends(Like Uptrend from 2013) and patterns informs future mission planning and decision-making.
- **Global View:** A global perspective of launch site locations aids in strategic decision-making and mission planning.
- **Improvement Areas:** Such as enhancing booster capabilities, optimizing Payload Mass, and optimizing launch site selection
- **SpaceX's Competitive Edge:** The project findings contribute to SpaceX's competitive advantage in the space exploration industry.

Appendix

- Data Sets:
  - spacex_url = https://api.spacexdata.com/v4/launches/past
  - Wikipedia = https://en.wikipedia.org/w/index.php?title=List_of_Falcon_9_and_Falcon_Heavy_launches&oldid=1027686922
  - Geo_URL = https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/IBM-DS0321EN-SkillsNetwork/datasets/spacex_launch_geo.csv
  - dataset_part_1.csv , dataset_part_2.csv, dataset_part_3.csv

- Notebooks: Python code snippets used for data analysis, visualization, and modeling.

- SQL Queries: Attach SQL queries used for data manipulation and analysis in the project.

Thank you!