IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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

Executive Summary

- Analyze SpaceX launch records to identify success patterns, payload correlations, and booster performance.
- Data collection via SpaceX REST API , Interactive dashboard, and Predictive modeling.
- Real-time insights for mission planning and strategic decision-making.
- Conclusions from predictive analysis find that there’s and ~87% chance of accuracy

Introduction

What Determines a Successful Landing?

- Key Factors We Investigated:
- Payload Size – How the weight of the mission cargo influences landing outcomes
- Booster Version – Differences in reliability across Falcon 9 variants
- Launch Details – Timing, mission type, and mission complexity
- Launch Location – Impact of site conditions (Cape Canaveral, Vandenberg, Kennedy)
- Launch Distance – Orbital destination and mission trajectory
- Landing Location – Ground pad vs. drone ship recovery

Section 1

Methodology

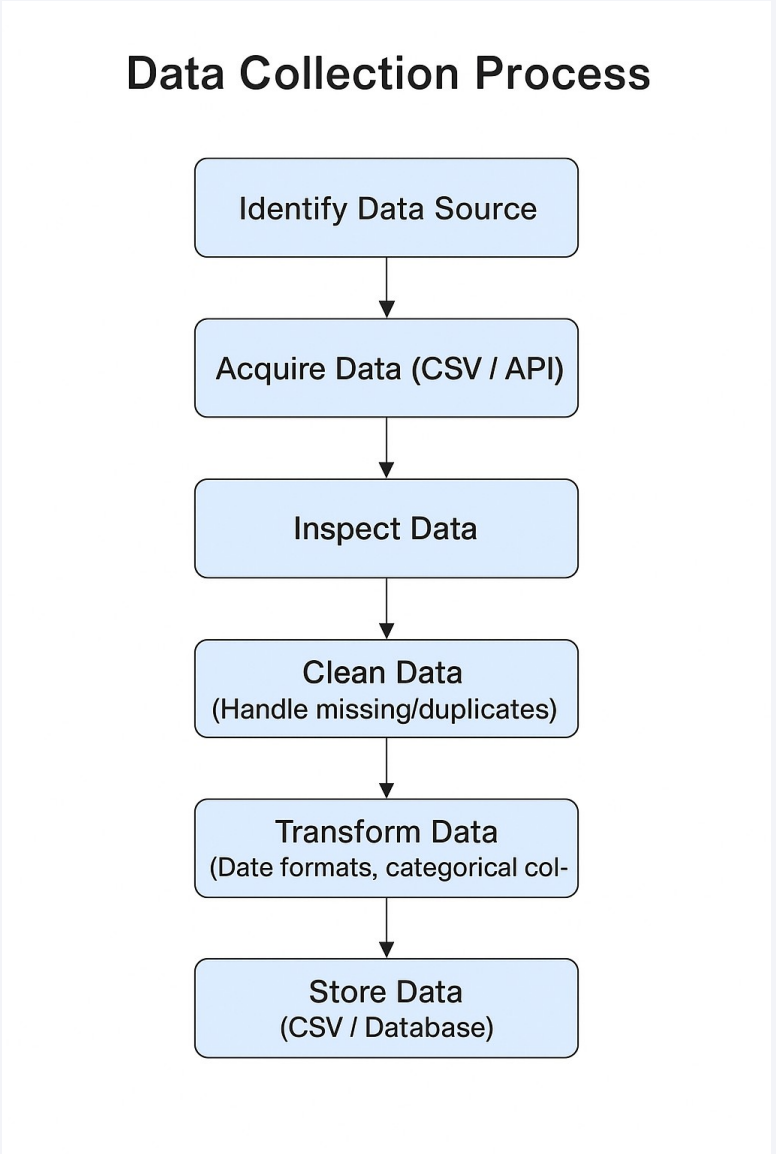
Methodology

Executive Summary

- Data collection methodology:
  - API pulls and web scraping from trusted public sources
- Perform data wrangling
  - Launch details, orbit distance, and outcome classification
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - Trained and tested the data set utilizing LogisticalRegression, KNN, Decision Trees, and SVM

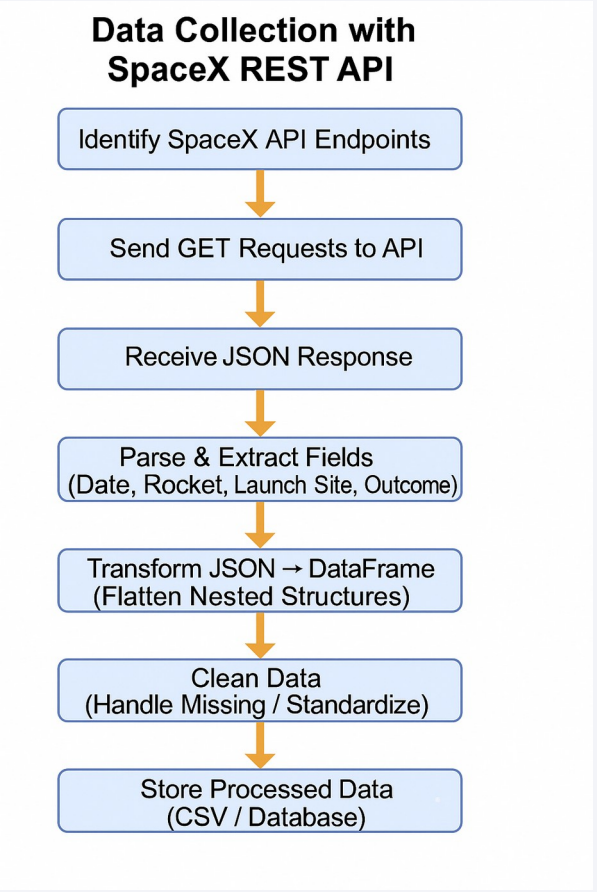
Data Collection

- Source Identification: Identify reliable data sources (e.g., public SpaceX launch datasets, Kaggle, APIs).
- Data Acquisition: Download CSV files or query APIs to gather structured launch data.
- Data Inspection: Check column names, data types, and completeness.
- Data Cleaning: Handle missing values, duplicates, and inconsistent formats.
- Data Transformation: Convert dates to standard formats, categorize outcomes (success/failure).
- Data Storage: Save the cleaned dataset in CSV or database for further analysis.



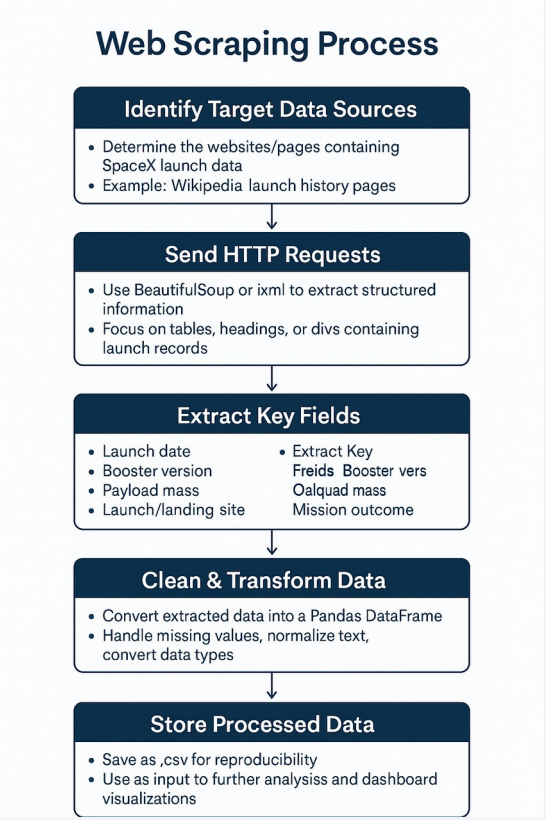
Data Collection – SpaceX API

- Identify API Endpoints
- Parse & Extract Fields
- Important attributes: date_utc, rocket, launchpad, payloads, success
- Clean Data
- Handle missing values (e.g., payload mass for failed missions)
- Standardize outcomes (success → 1, failure → 0)
- Normalize categorical values
- GitHub link



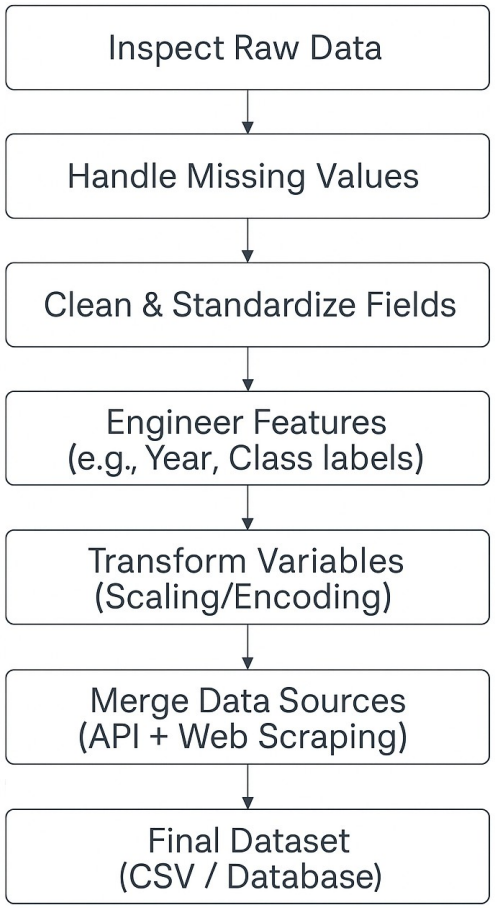
Data Collection - Scraping

- Identify Target Data Source
- Select websites containing SpaceX launch data (e.g., Wikipedia)
- Extract Key Fields
- Launch date, booster version, payload mass, launch site, outcome
- Clean & Transform Data
- Handle missing values, normalize text, standardize formats
- Store Processed Data
- GitHub Link



Data Wrangling

- Data Inspection – Checked dataset structure, column names, and data types
- Handling Missing Values – Filled or removed incomplete rows (e.g., payload mass missing for failed launches)
- Data Cleaning – Standardized categorical variables (success/failure → 1/0, booster versions normalized)
- Feature Engineering – Extracted year from launch date, derived launch outcome labels, and created numerical encodings for categorical fields
- Data Transformation – Scaled payloads and continuous variables with StandardScaler
- Data Integration – Merged API, web-scraped, and cleaned data into one consistent DataFrame
- Final Storage – Saved clean dataset into .csv for analysis and dashboard use
- GitHub Link



EDA with Data Visualization

- Bar Charts - Compare success rates across orbit types
- Line Charts - Track success rate trends over time (by year)
- Scatter Plots - Visualize relationship between payload & outcomes, color-coded by booster version
- GitHub Link

EDA with SQL

- Filter: Launch sites starting with 'CCA'
- Aggregate:
- Total payload mass by NASA (CRS)
- Average payload mass for F9 v1.1
- Date: First successful ground pad landing
- Conditional: Boosters with successful drone ship landings & payload 4000–6000
- Counts: Successful vs failed mission outcomes
- Subquery: Booster versions with maximum payload mass
- Year/Month: Drone ship landing failures in 2015
- Ranking: Landing outcomes ranked (2010–2017)
- GitHub Link

Build an Interactive Map with Folium

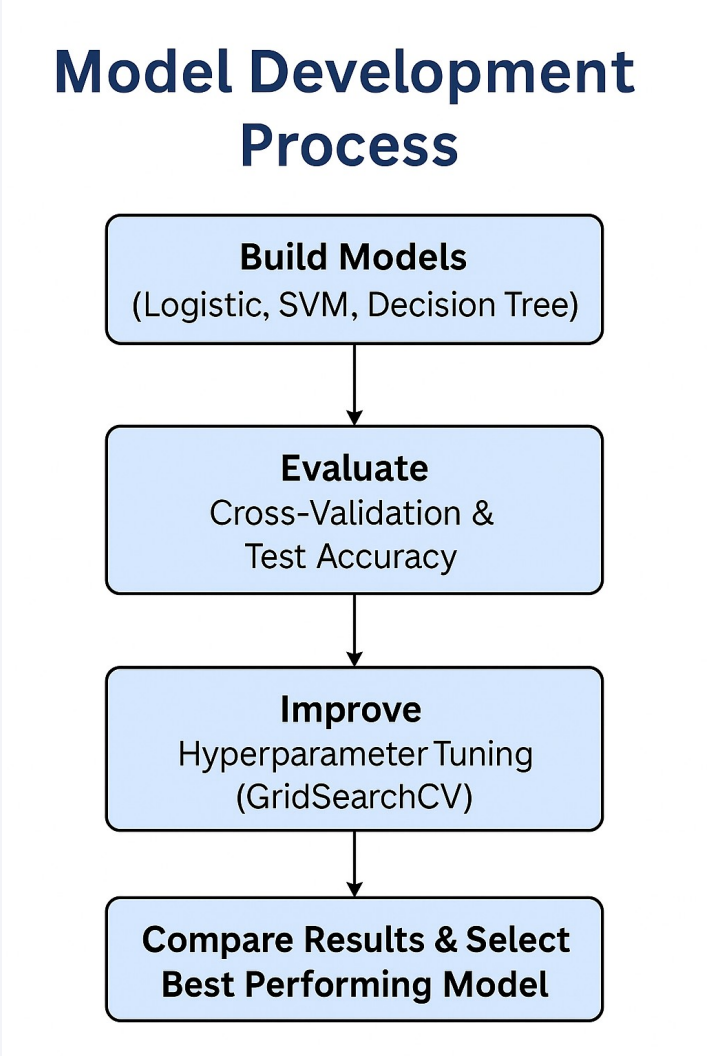
- Markers - Identify launch sites & coastline points
- Circles - Show launch site boundaries (1 km radius)
- Lines - Connect sites to coastlines/cities, show distances
- DivIcon Labels - Display site names & distances directly on map
- GitHub Link

Build a Dashboard with Plotly Dash

- Pie Chart - Shows success vs. failure (per site or all sites)
  - Why: Easy way to compare proportions at a glance
- Scatter Plot - Plots payload vs. outcome, color-coded by booster version
  - Why: Reveals correlations between payload size and success, and booster performance differences
- Interactions:
  - Dropdown (Launch Site): Filter visualizations by site or view all sites
  - Range Slider (Payload): Filter results by payload size range
- Github Link

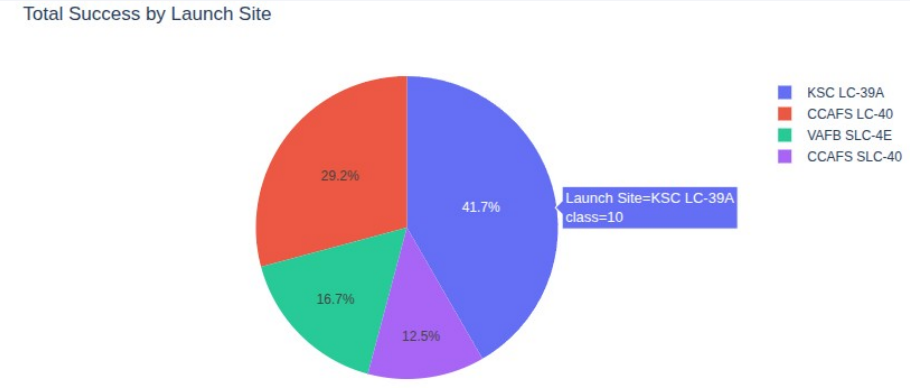
Predictive Analysis (Classification)

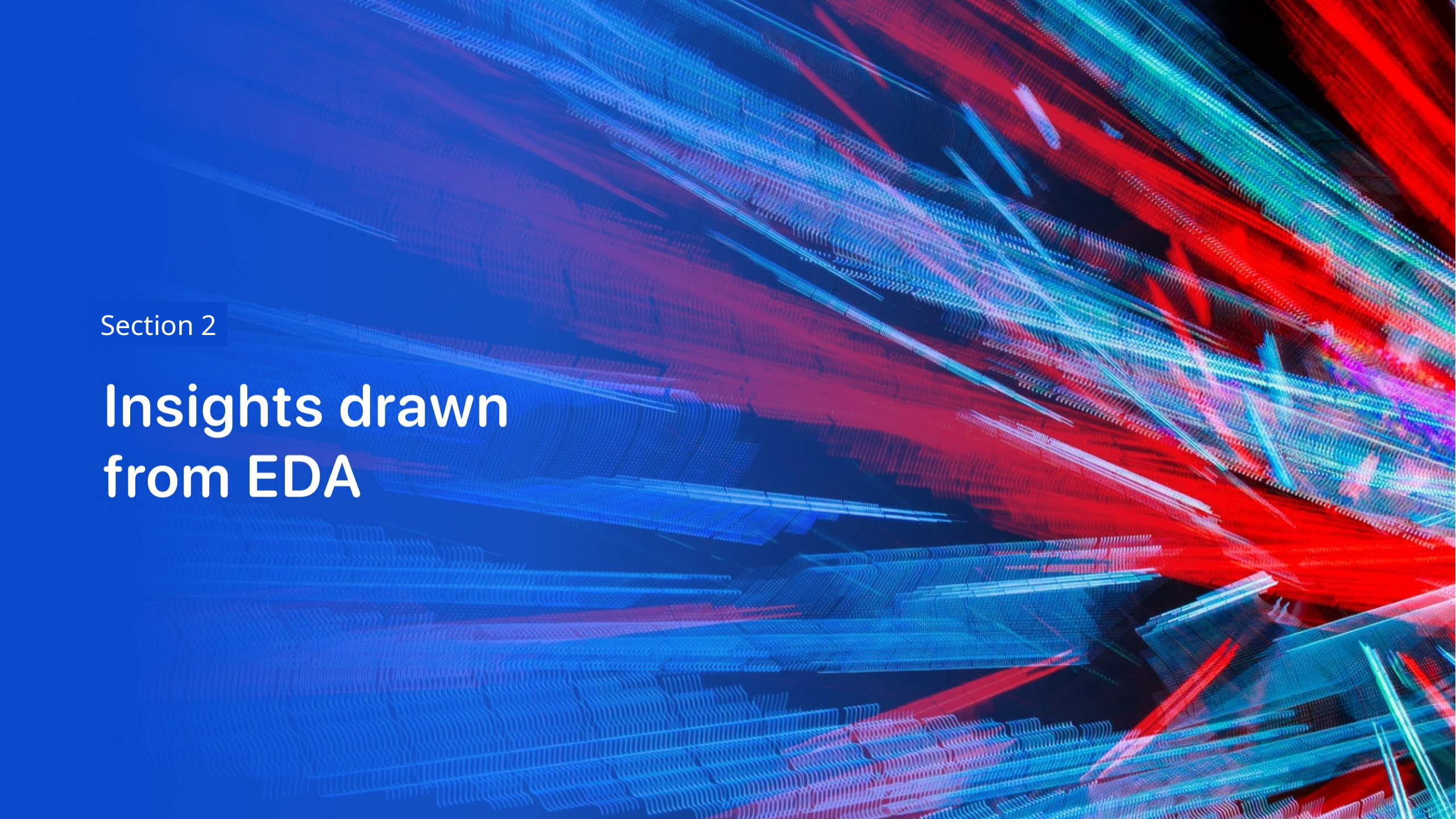
- Build: Trained multiple classifiers (Logistic Regression, SVM, Decision Tree, KNN)
- Evaluate: Used cross-validation (cv=10) and accuracy score on test set
- Improve: Performed hyperparameter tuning with GridSearchCV
- Select Best: Compared test accuracies, identified Decision Tree as best performer (~87%)
- GitHub Link



Results

- KSC LC-39A consistently had higher success rates
- Scatter plots revealed heavier payloads (2k-4k) sometimes linked to higher failure probability
- Booster version FT also influenced outcomes
- Bar charts highlighted variation in success depending on orbit type (LEO vs GTO, etc.)
- Line charts showed increasing success rates year over year, improving reliability
- Folium maps confirmed all launch sites are near coastlines
- Distances to landing locations were important for mission recovery planning
- Models Tested: Logistic Regression, SVM, Decision Tree, KNN
- Evaluation Method: 10-fold cross-validation + accuracy on test set
- Best Performing Model: Decision Tree Classifier (~87% accuracy) - Outperformed others by capturing strong categorical relationships (launch site, booster version)
- Other Models:SVM & KNN ≈ 85%, Logistic Regression ≈ 84%
- Key Insight:
- Launch outcome is highly influenced by site, booster type, and payload range
- Predictive modeling shows reliable accuracy for future mission outcomes

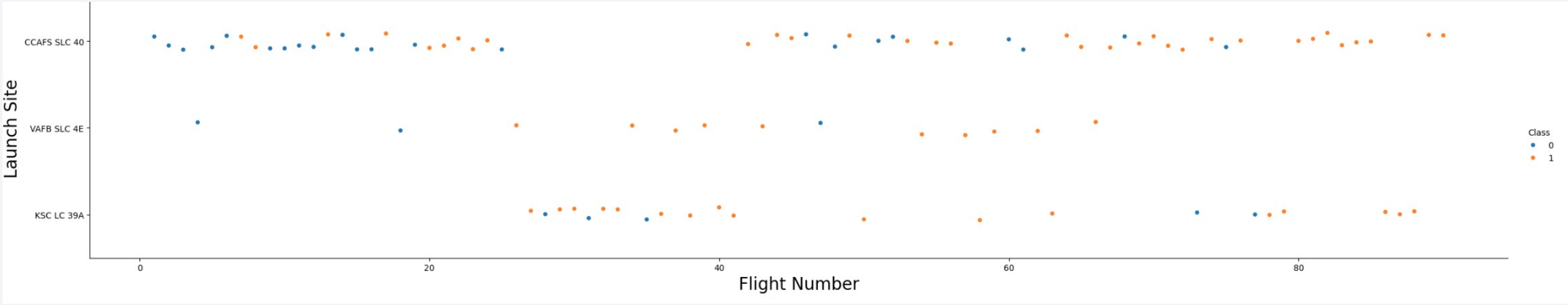




Section 2

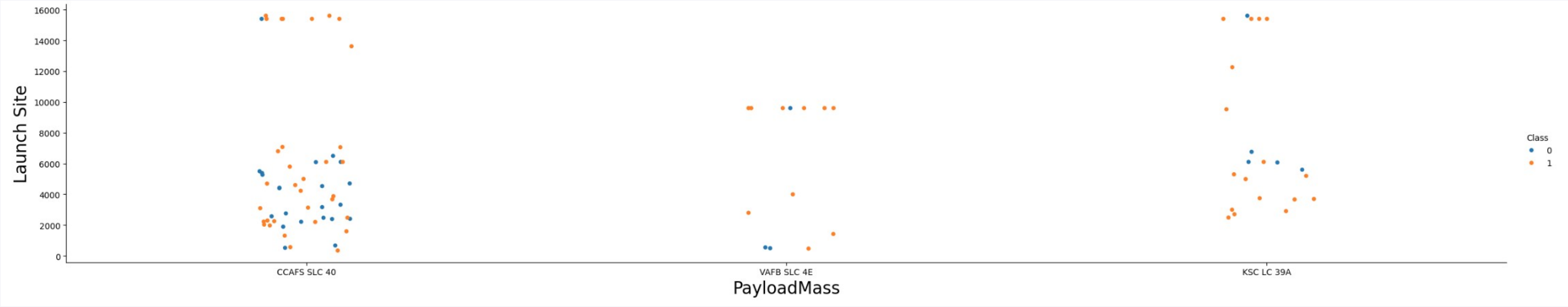
Insights drawn from EDA

Flight Number vs. Launch Site



- Early launches concentrated in a few sites (e.g., CCAFS LC-40).
- Over time, more sites were added (KSC LC-39A, VAFB SLC-4E), shown by points appearing at new Y-axis categories.
- The scatter pattern shows SpaceX increasing launch cadence while diversifying across multiple sites.
- Success rates improved as flight numbers increased, across different sites.

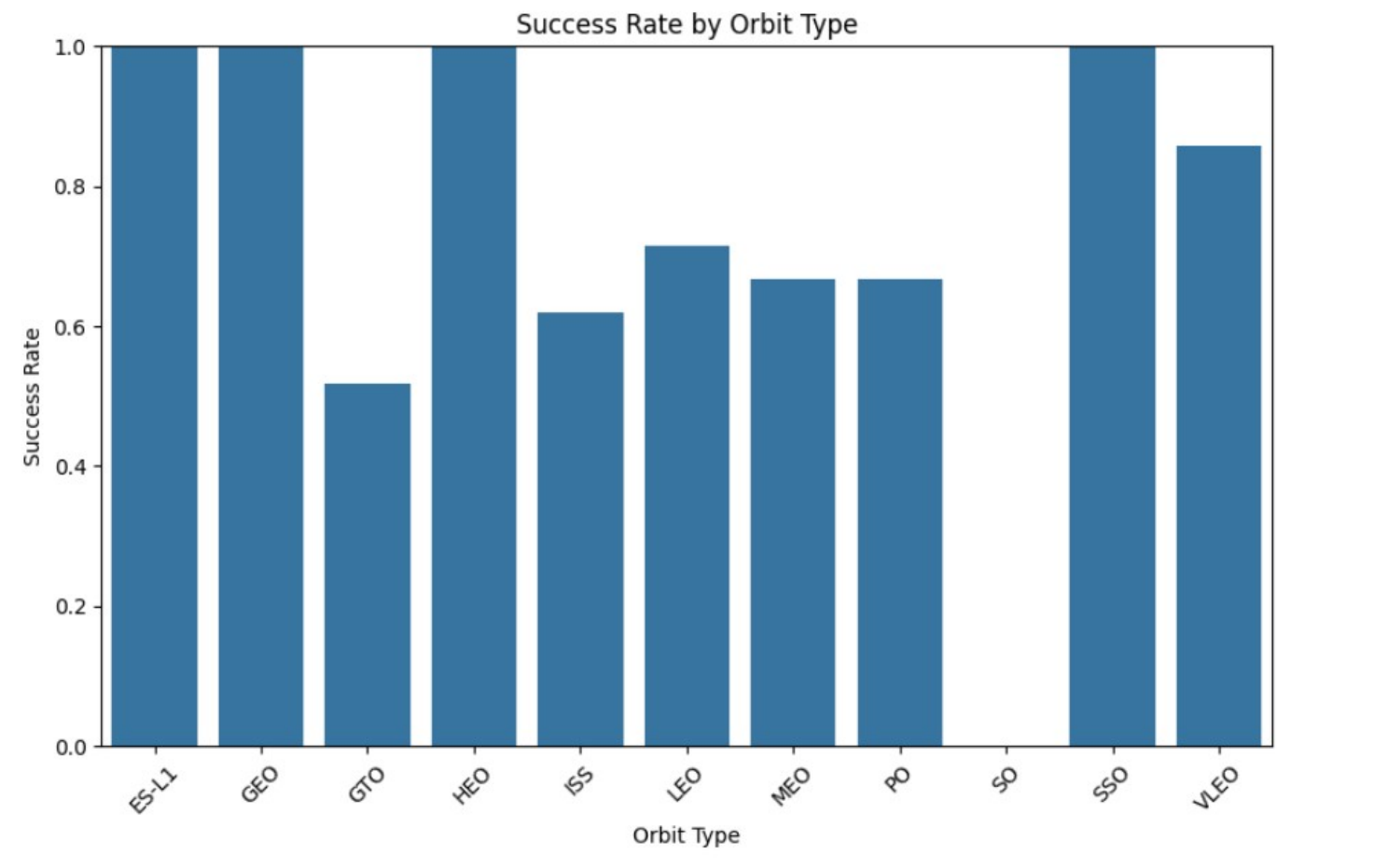
Payload vs. Launch Site



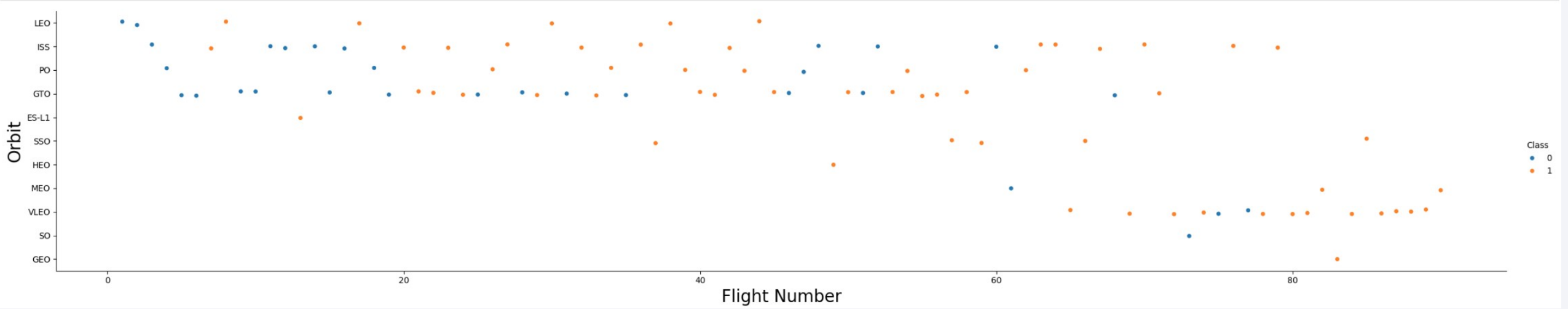
- Variation by site: Some launch sites consistently supported larger payloads (e.g., Kennedy LC-39A), while others handled smaller or medium payloads.
- Success patterns: Heavier payloads showed slightly lower success probability at certain sites (especially early missions).
- Operational strategy: The plot shows how SpaceX assigns missions strategically, with certain launch pads dedicated to high-capacity missions.

Success Rate vs. Orbit Type

- Higher Success in Common Orbits:
  - Missions to LEO (Low Earth Orbit) and ISS resupply (NASA CRS) had the highest success rates, reflecting routine, well-optimized missions.
- Lower Success in Complex Orbits:
  - Launches to GTO (Geostationary Transfer Orbit) and Polar orbits had lower success rates, due to heavier payloads and more complex trajectories.
- Operational Learning Curve:
  - Early missions to advanced orbits had more failures, but the chart shows improvement over time, as experience and technology matured.

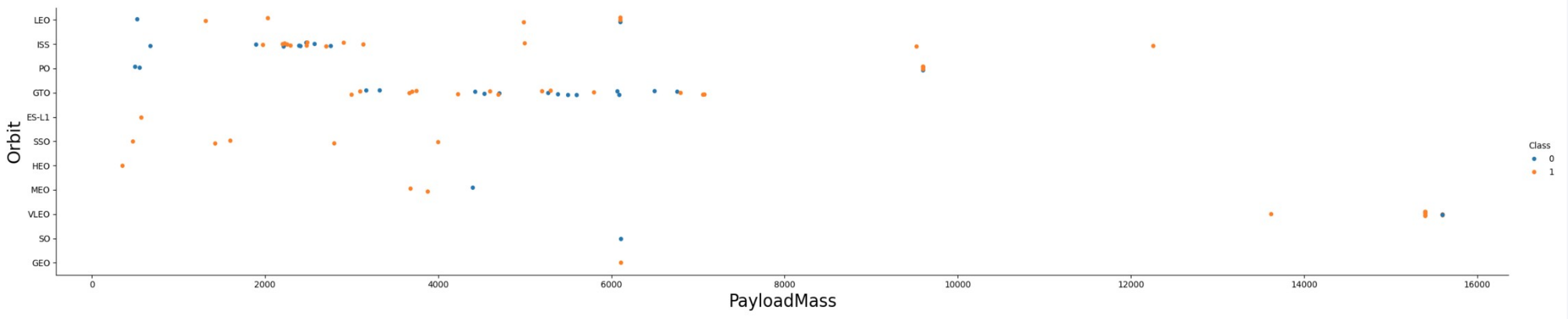


Flight Number vs. Orbit Type



- Expansion of Mission Types:
  - Early flights (low flight numbers) were mostly LEO missions, indicating simpler, short-distance launches during SpaceX's learning phase.
  - As flight numbers increased, more orbit types appeared (e.g., GTO, Polar), showing diversification of capabilities.
- Improving Reliability Over Time:
  - Early missions to new orbits had mixed success rates.
  - Later missions in the same orbit types showed higher success consistency, reflecting improved technology and operational experience.
- Orbit-Specific Patterns:
  - ISS/LEO missions show consistently high success once operational maturity was reached.
  - GTO and Polar orbits initially displayed lower reliability but improved over time.

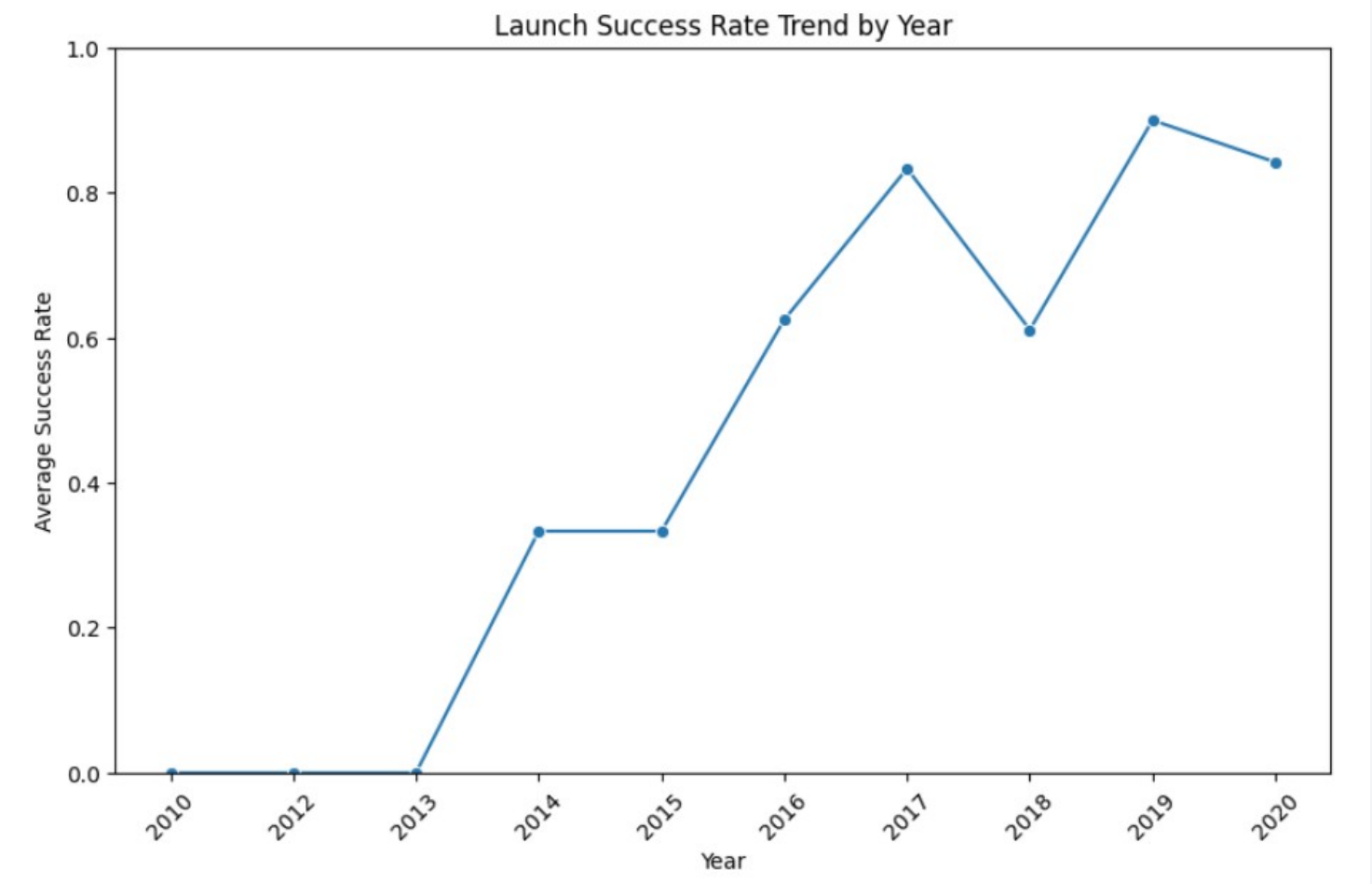
Payload vs. Orbit Type



- LEO & ISS Missions:
  - Typically carried lighter to medium payloads.
  - Very high success rate once operational maturity was achieved.
- GTO Missions:
  - Concentrated in the heavier payload range.
  - Showed higher risk/failure rate in earlier flights but improved over time.
- Polar & Other Orbits:
  - Payloads were in a broad middle range.
  - Fewer launches overall, making them less common but strategically important.
- General Pattern:
  - As payload mass increased, missions were more likely associated with complex orbits (GTO, Polar).
  - Success rates improved with experience and booster evolution, even for heavy payload missions.

Launch Success Yearly Trend

- Early Years (2010–2013):
  - Success rate was low and inconsistent
  - Reflected SpaceX’s testing and early operational learning curve
- Mid-Years (2014–2016):
  - Noticeable improvement in reliability
  - More frequent successes, fewer mission failures
- Recent Years (2017 onward):
  - Success rate reached consistently high levels (approaching 1.0)
  - Demonstrated maturity of Falcon 9 reusability and operations
- Overall Trend:
  - Clear upward trajectory in success rate over time
  - Shows continuous innovation and learning leading to operational excellence



All Launch Site Names

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

```
]: %sql SELECT DISTINCT "Launch_Site" FROM SPACEXTBL;
 * sqlite:///my_data1.db
Done.
```

]:

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

Launch Site Names Begin with 'CCA'

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

```
%%sql SELECT *
FROM SPACEXTABLE
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

Task 3

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

```
%%sql SELECT SUM(PAYLOAD_MASS__KG_) AS total_payload_mass
FROM SPACEXTABLE
WHERE Customer = 'NASA (CRS)';
```

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

total_payload_mass
45596

Average Payload Mass by F9 v1.1

Task 4

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

```
31]: %%sql SELECT AVG(PAYLOAD_MASS__KG_) AS avg_payload_mass
FROM SPACEXTABLE
WHERE Booster_Version = 'F9 v1.1';
```

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

31]:

avg_payload_mass
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

```
%%sql SELECT MIN(Date) AS first_successful_landing
FROM SPACEXTABLE
WHERE Landing_Outcome = 'Success (ground pad)';
```

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

first_successful_landing
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 Booster_Version
FROM SPACEXTABLE
WHERE Landing_Outcome = 'Success (drone ship)'
  AND PAYLOAD_MASS__KG_ > 4000
  AND PAYLOAD_MASS__KG_ < 6000;
```

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

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

```
%%sql SELECT Mission_Outcome, COUNT(*) AS total
FROM SPACEXTABLE
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 all the booster_versions that have carried the maximum payload mass, using a subquery with a suitable aggregate function.

```
%%sql
SELECT Booster_Version
FROM SPACEXTABLE
WHERE PAYLOAD_MASS__KG_ = (
    SELECT MAX(PAYLOAD_MASS__KG_)
    FROM SPACEXTABLE
);
```

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

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

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.

```
%%sql
SELECT
    substr(Date, 6, 2) AS Month,
    Booster_Version,
    Launch_Site,
    Landing_Outcome
FROM SPACEXTABLE
WHERE substr(Date, 1, 4) = '2015'
  AND Landing_Outcome = 'Failure (drone ship)';
```

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

Month	Booster_Version	Launch_Site	Landing_Outcome
01	F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)
04	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.

```
%%sql
SELECT Landing_Outcome, COUNT(*) AS count
FROM SPACEXTABLE
WHERE Date BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY Landing_Outcome
ORDER BY count DESC;
```

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

Landing_Outcome	count
No attempt	10
Success (drone ship)	5
Failure (drone ship)	5
Success (ground pad)	3
Controlled (ocean)	3
Uncontrolled (ocean)	2
Failure (parachute)	2
Precluded (drone ship)	1

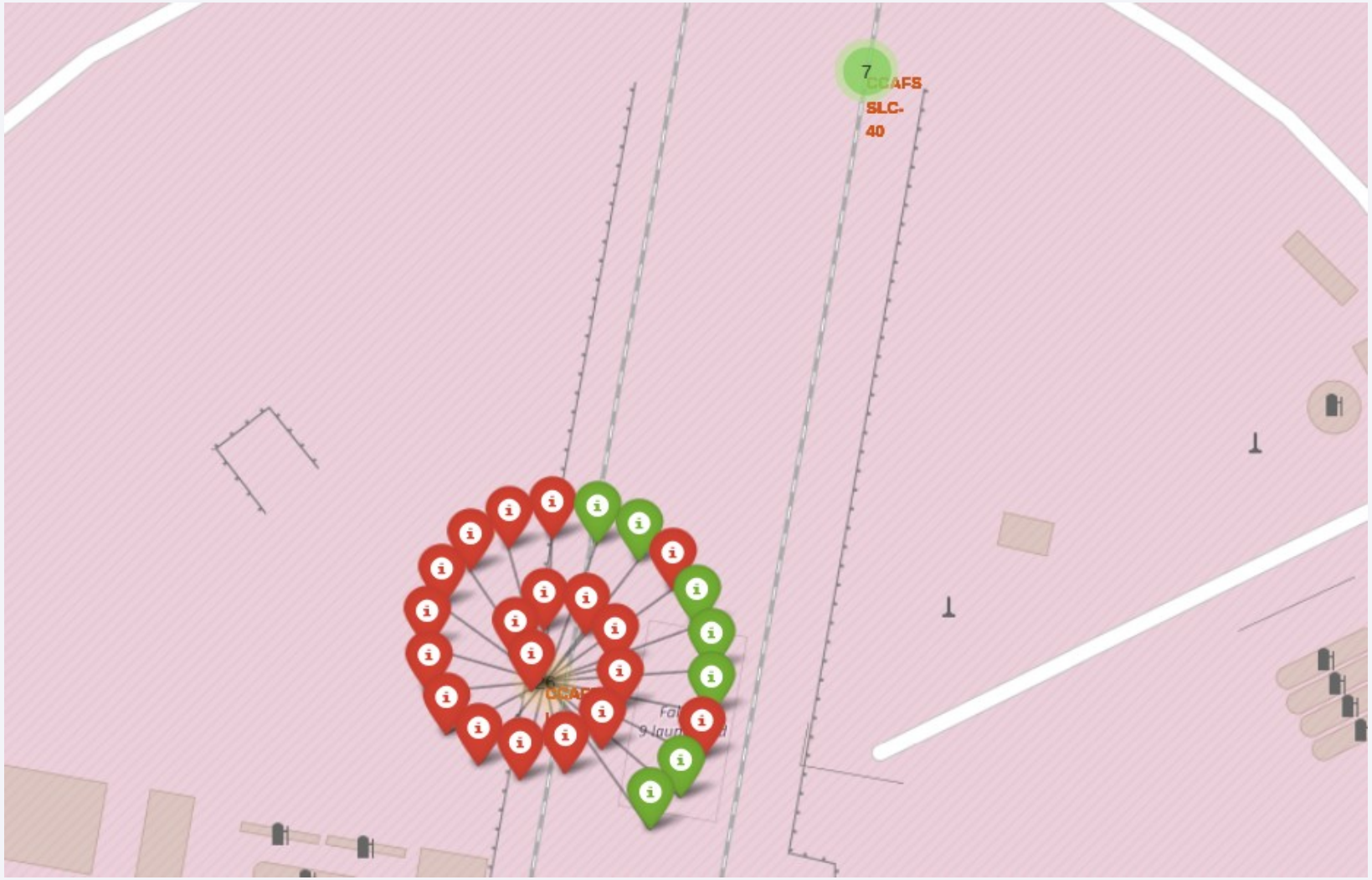
Section 3

Launch Sites Proximities Analysis

Folium Launch Site Map

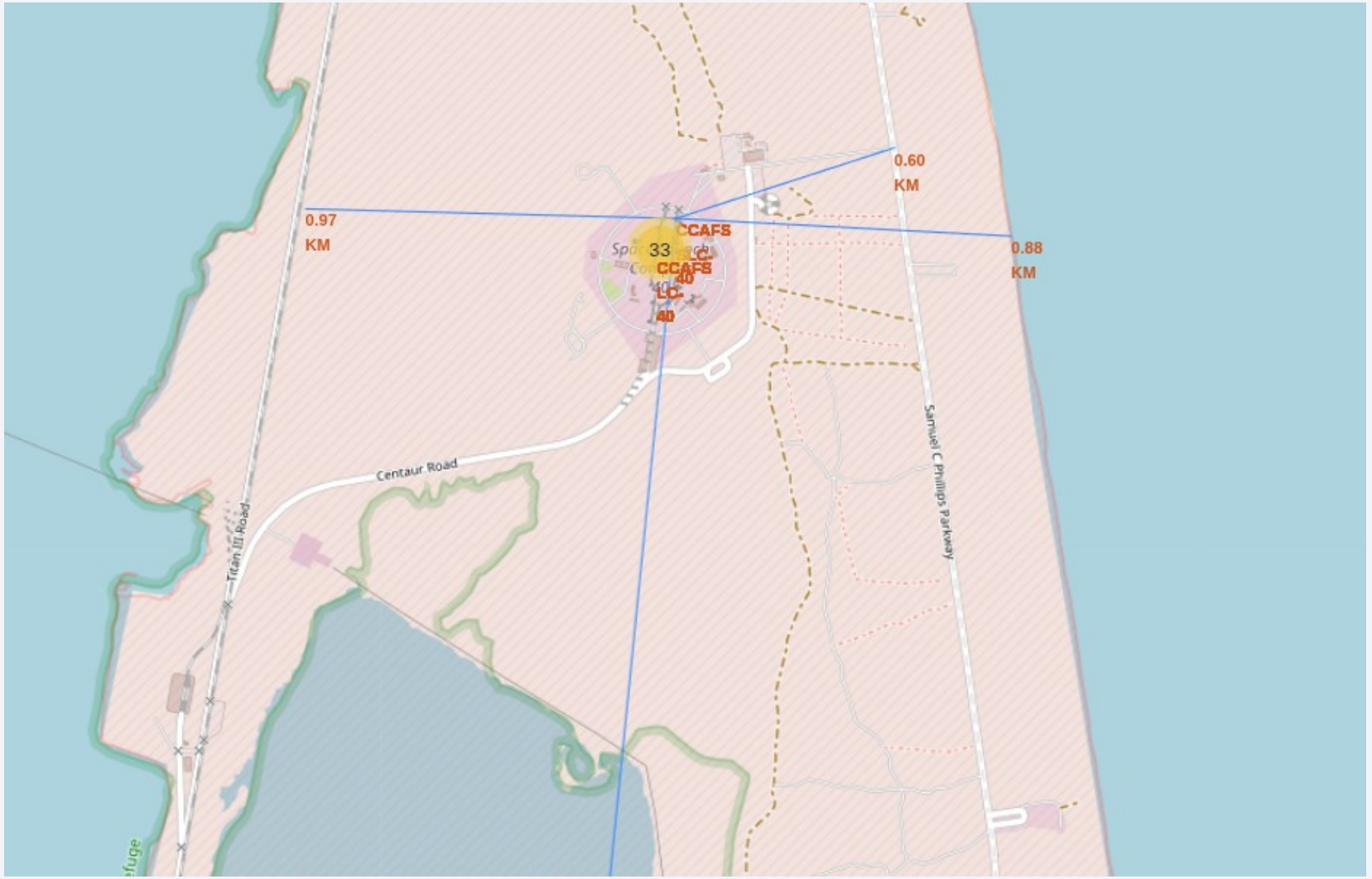
Space X primarily launched from the east coast.

Folium Launch Outcome Map

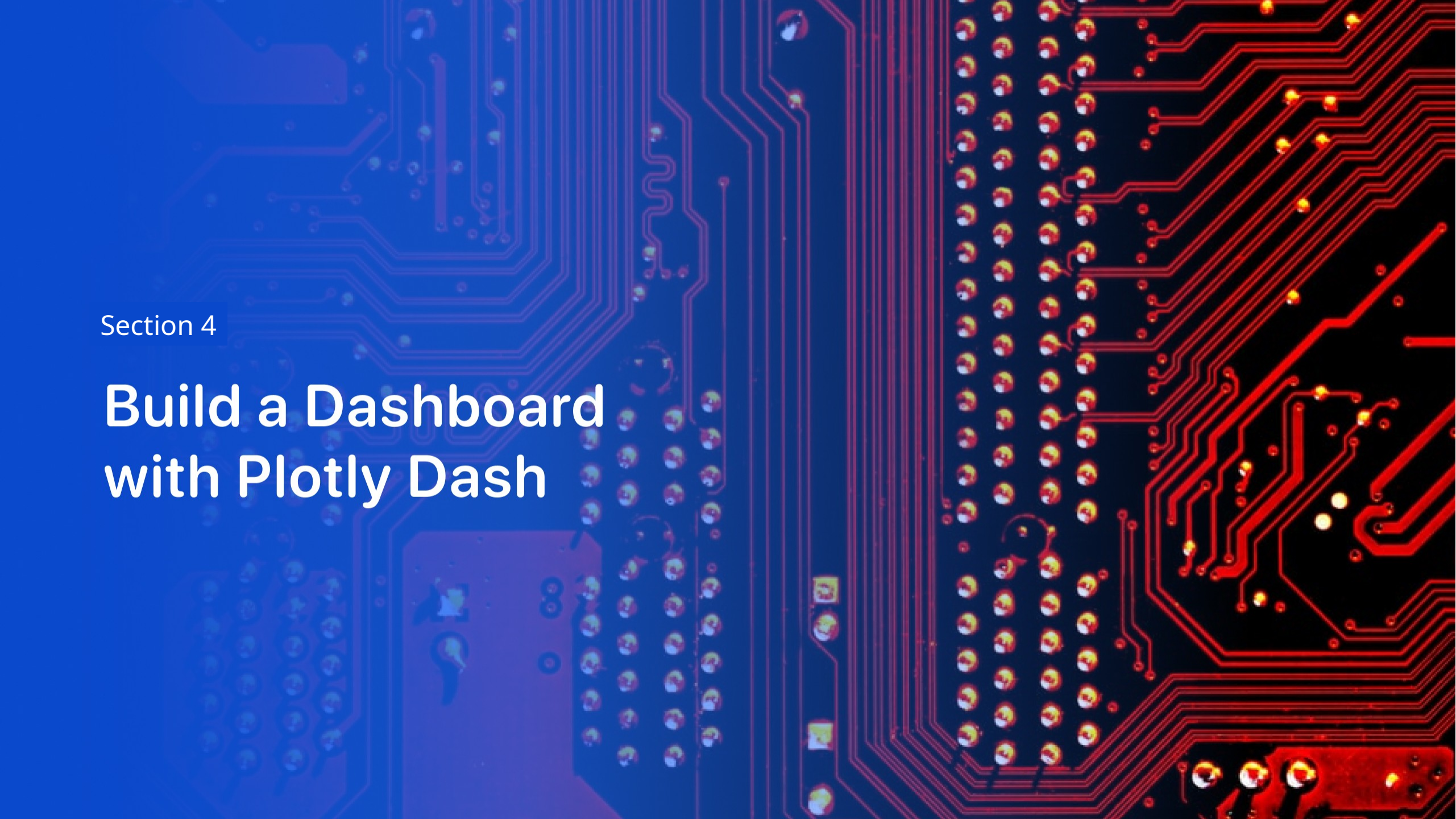


Each launch marker expands to show the number of successful (green) and unsuccessful (red) launches at a given site.

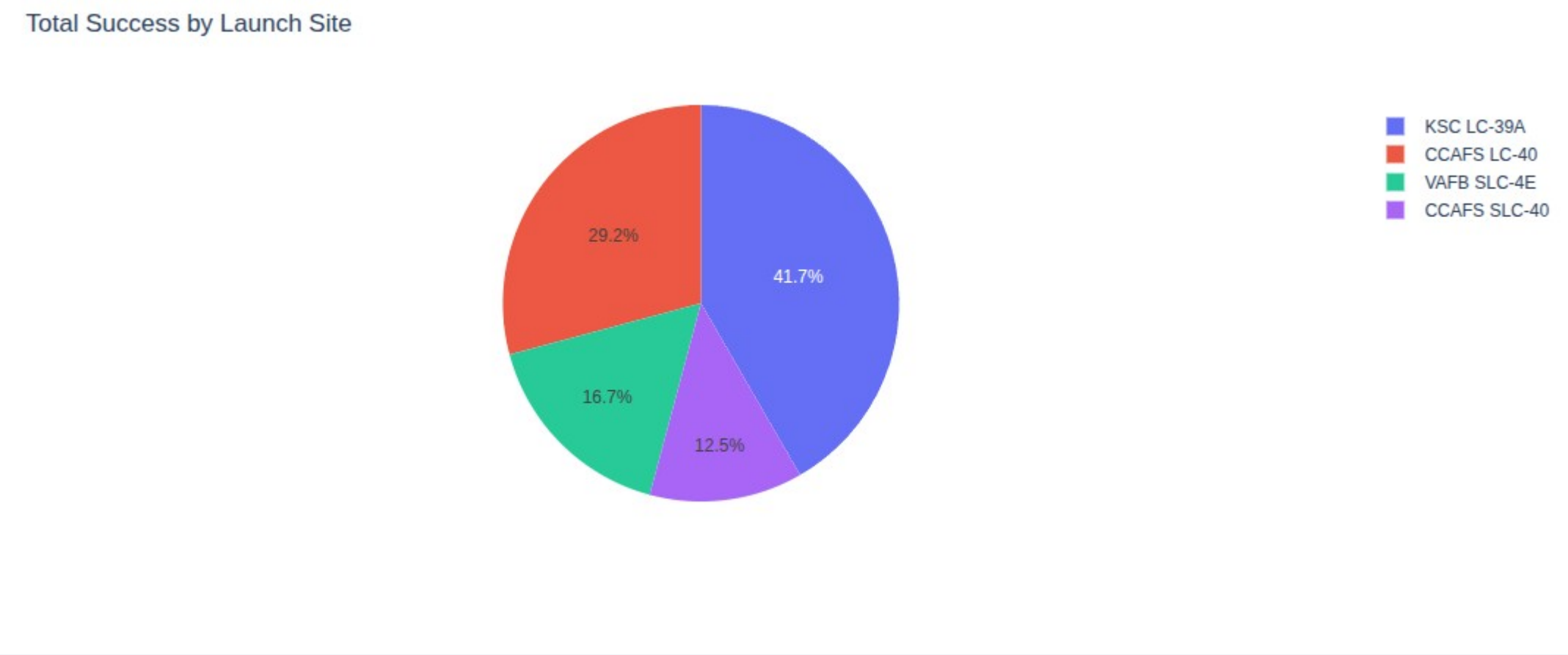
Folium Launch Site Proximity Map



Launch sites have close proximity to coast lines and supporting infrastructure, such as railroads and highways, while maintaining a minimum 15km distance from cities.

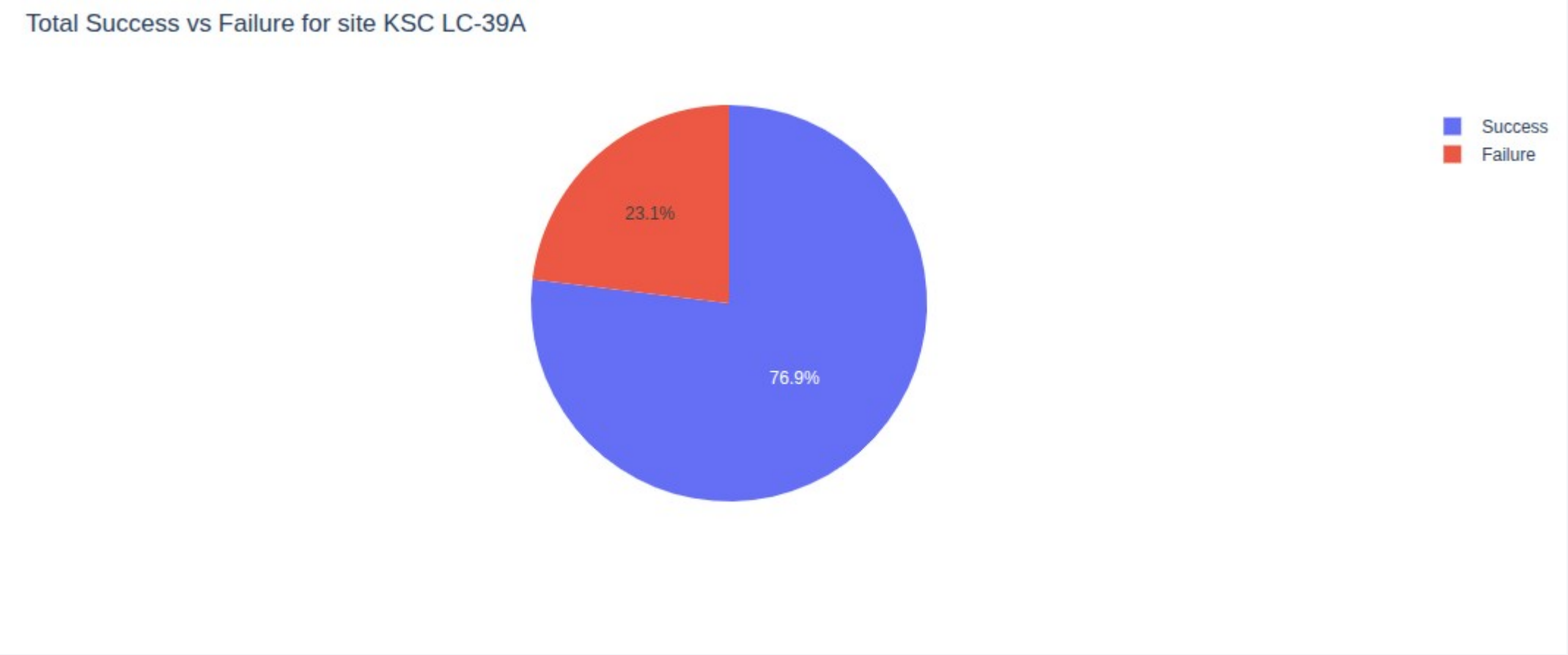

Section 4
Build a Dashboard with Plotly Dash

Total Success by Launch Site



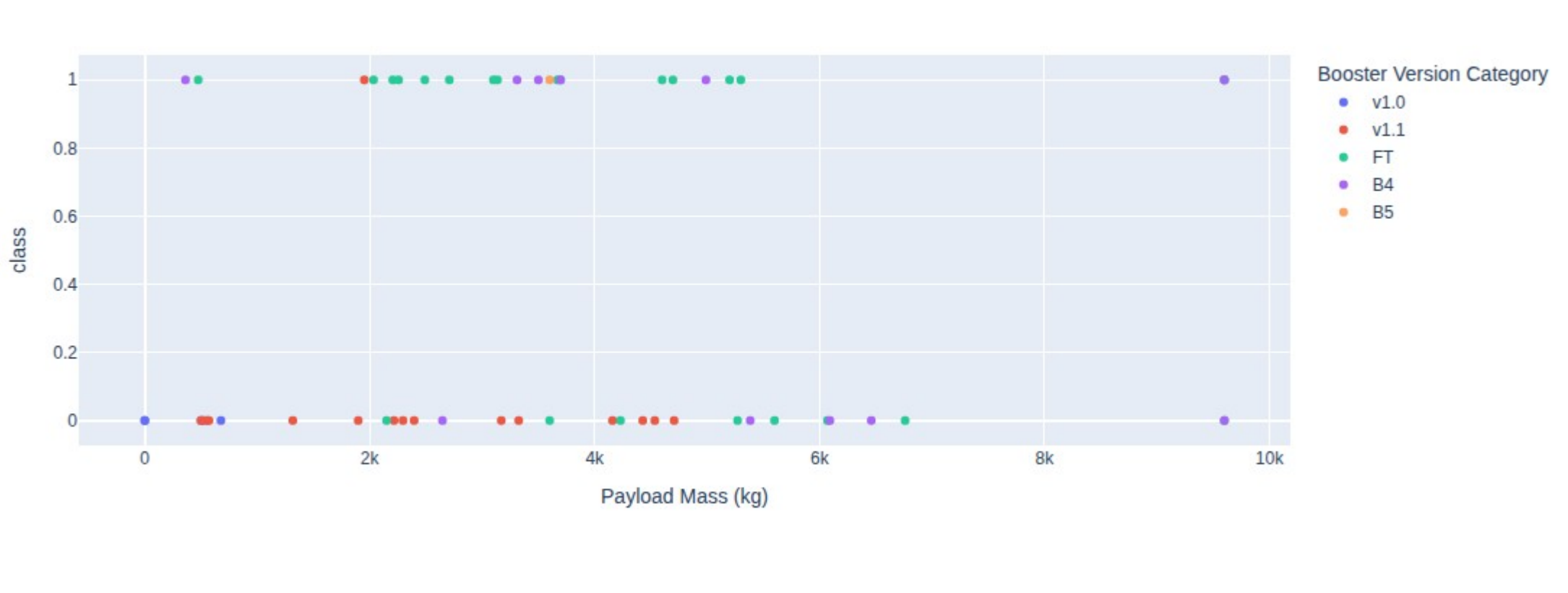
Most successful launches originated from KSC LC-39A

Total Success vs. Failure of KSC LC-39A



KSC LC39A had a 76.9% Success rate and 23.1% Failure rate.

Payload Outcome for All Sites



The most successful payload range was between 2000 kg – 4000 kg.
The most failures for a payload range was between 4000 kg – 7000 kg.
The FT Booster Version was the most successful booster.

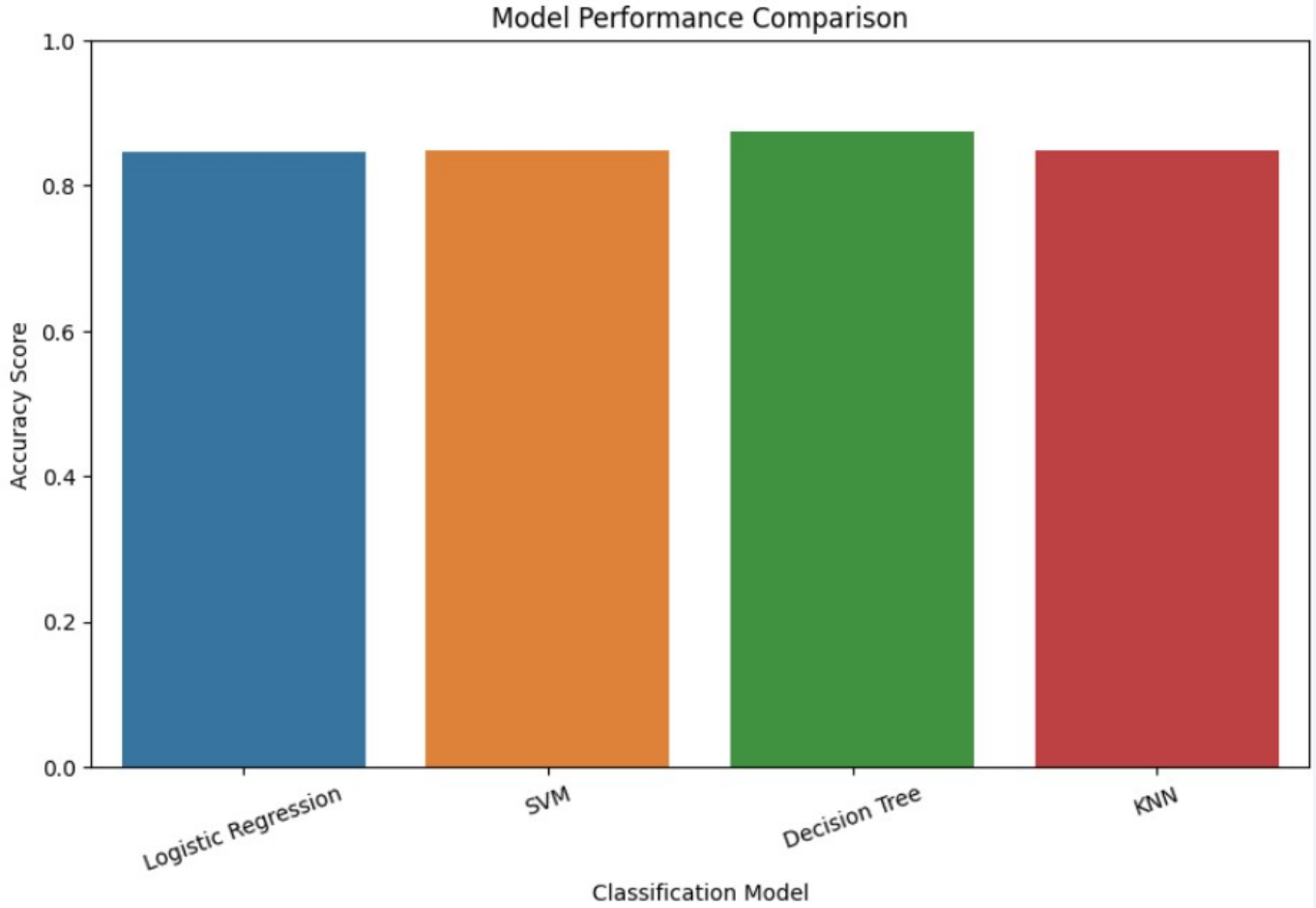
Section 5

Predictive Analysis (Classification)

Classification Accuracy

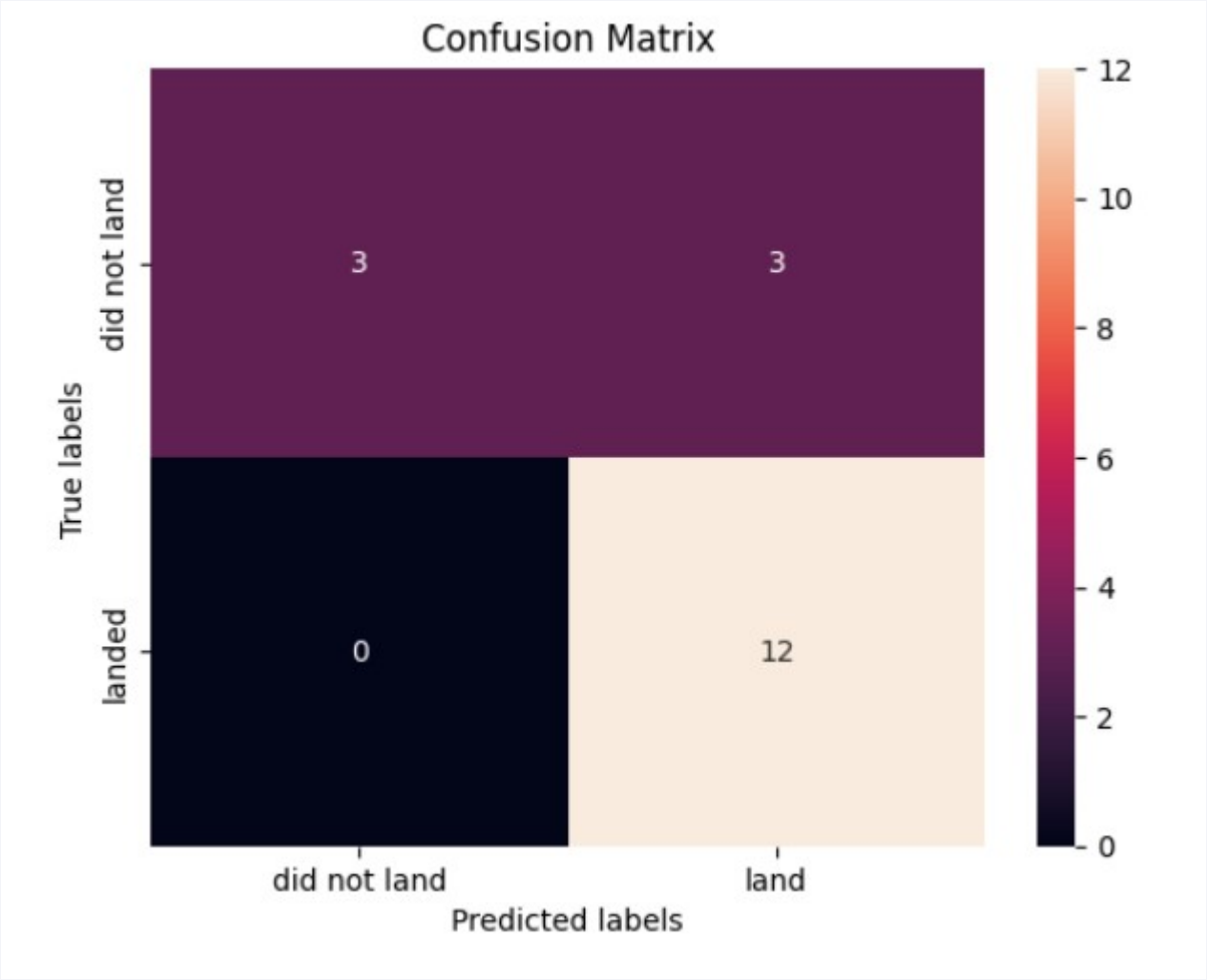
```
Logistic Regression score: 0.8464285714285713
SVM score: 0.8482142857142856
Decision Tree score: 0.875
KNN score: 0.8482142857142858

Decision Tree has the best score: 0.875
```



Confusion Matrix

The Decision Tree model not only had the highest accuracy (~87%), but its confusion matrix confirmed that it predicts both successes and failures reliably, with only a small number of missed classifications. This balance makes it the strongest candidate for forecasting future mission outcomes.



Conclusions

- Comprehensive Analysis
  - Collected, cleaned, and integrated SpaceX data from API & web scraping
  - Built interactive dashboard for exploratory insights
- Key Findings
  - Launch success varies by site, payload, orbit, and booster version
  - Success rates have steadily improved year over year
  - Geospatial context highlights importance of site and landing location
- Predictive Modeling
  - Tested multiple ML models with cross-validation
  - Decision Tree achieved best performance (~87% accuracy)
  - Confusion matrix confirmed strong reliability in predicting outcomes
- Impact
  - Provides both historical insights and a predictive framework
  - Supports better understanding of what drives successful launches

Appendix

GitHub link to the entire repository.

Thank you!