IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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- Methodology
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Executive Summary

This project aims to identify the factors for a successful rocket landing. To analyze, the following methodologies were used:

- Collect data using SpaceX REST API and web scraping techniques
- Wrangle data to create success/fail outcome variable
- Explore data with data visualization techniques.
- Analyze the data with SQL, calculating the following statistics: total payload, payload, range for successful launches, and total number of successful and failed outcomes
- Visualize the launch sites with the most success and successful payload ranges
- Build Models to predict landing outcomes using logistic regression, support vector machine (SVM), decision tree and K-nearest neighbor (KNN)

Results:

Exploratory Data Analysis:

- Launch success improves over time
- KSC LC•39A has the highest success rate among landing sites

Visualization/Analytics:

- Most launch sites are near the equator, and all are close to the coast

Introduction

The commercial space industry, with companies like SpaceX, is revolutionizing space travel affordability. SpaceX's standout success is attributed to its cost-effective reusability of the initial rocket stage. Our project's goal is to forecast launch expenses by assessing the likelihood of the first stage's successful landing for reuse. This analysis leverages machine learning techniques and publicly available Falcon 9 data to make these predictions.

Section 1

Methodology

Methodology

Steps:

- Gather data using SpaceX REST API and web scraping methods.
- Cleanse and preprocess the data, including filtering, addressing missing values, and implementing one-hot encoding, to ready it for analysis and modeling.
- Conduct exploratory data analysis (EDA) using SQL and employ data visualization techniques for deeper insights.
- Utilize Folium and Plotly Dash for data visualization.
- Develop predictive models for forecasting landing results through classification models. Fine-tune and assess these models to identify the optimal model and parameter settings.

Data Collection – SpaceX API

- Request data from SpaceX API (rocket launch data)
- Decode response using .json() and convert to a dataframe using .json_normalize()
- Request information about the launches from SpaceX API using custom functions
- Create dictionary from the data
- Create dataframe from the dictionary
- Filter dataframe to contain only Falcon 9 launches
- Replace missing values of Payload Mass with calculated .mean()
- Export data to csv file

https://github.com/arhammehdi2/IBMDataScienceFinalProject/blob/81303c23a500c9355ece68ab8aee1ec4f2f72bed/datacollectionapi.ipynb

Data Collection - Scraping

Steps

- Request data (Falcon 9 launch data) from Wikipedia
- Create BeautifulSoup object from HTML response
- Extract column names from HTML table header
- Collect data from parsing HTML tables
- Create dictionary from the data
- Create dataframe from the dictionary
- Export data to csv file
- https://github.com/arhammehdi2/IBMDataScienceFinalProject/blob/259ca7e25de5b091228cedbc1f89bf98b0f0f6ac/webscrapingdatacollection.ipynb

Place your flowchart of web scraping here

Data Wrangling

- Perform EDA and determine data labels
- Calculate:

# of launches for each site

and occurrence of orbit

and occurrence of mission outcome per orbit type)

- Create binary landing outcome column (dependent variable)
- Export data to csv file

Landing Outcome

- Landing was not always successful
- True Ocean: mission outcome had a successful landing to a specific region of the ocean
- Landing Outcome Cont.
- False Ocean: represented an unsuccessful landing to a specific region of ocean
- True RTLS meant the mission had a successful landing on a ground pad
- False RTLS represented an unsuccessful landing on a ground pad
- True ASDS: meant the mission outcome had a successful landing on a drone ship
- False ASDS represented an unsuccessful landing on drone ship
- Outcomes converted into 1 for a successful landing and 0 for an unsuccessful landing
- https://github.com/arhammehdi2/IBMDataScienceFinalProject/blob/383c3222fba7112acdc1af8500a2564311987710/datawrangling.ipynb

EDA with Data Visualization

Charts

- Flight Number vs. Payload
- Flight Number vs. Launch Site
- Payload Mass (kg) vs. Launch Site
- Payload Mass (kg) vs. Orbit type

Analysis

• View relationship by using scatter plots. The variables could be useful for machine learning if a relationship exists

•Show comparisons among discrete categories with bar charts. Bar charts show the relationships among the categories and a measured value.

- https://github.com/arhammehdi2/IBMDataScienceFinalProject/blob/6ca15d1ed70eba52ad4f904b4b041268204ec21c/edadatavisualization.ipynb

EDA with SQL

Queries

Display:

- Names of unique launch sites
- 5 records where launch site begins with 'CCA'
- Total payload mass carried by boosters launched by NASA (CRS)
- Average payload mass carried by booster version F9 v1.1.

List:

Date of first successful landing on ground pad
Names of boosters which had success landing on drone ship and have
Payload mass greater than 4,000 but less than 6,000
Total number of successful and failed missions
Names of booster versions which have carried the max payload
Failed landing outcomes on drone ship, their booster version and launch site for the months in the year 2015
Count of landing outcomes between 2010-06-04 and 2017-03-20 (desc).

https://github.com/arhammehdi2/IBMDataScienceFinalProject/blob/0f860136021b6c9b7714a2c9c3cf525b000e6e23/edasql.ipynb

Build an Interactive Map with Folium

Markers Indicating Launch Sites

- Added blue circle at NASA Johnson Space Center's coordinate with a popup label showing its name using its latitude and longitude coordinates
- Added red circles at all launch sites coordinates with a popup label showing its name using its name using its latitude and longitude coordinates

Colored Markers of Launch Outcomes

- Added colored markers of successful (green) and unsuccessful (red) launches at each launch site to show which launch sites have high success rates

Distances Between a Launch Site to Proximities

- Added colored lines to show distance between launch site CCAFS SLC- 40 and its proximity to the nearest coastline, railway, highway, and city
- https://github.com/arhammehdi2/IBMDataScienceFinalProject/blob/72d28fabb29a1a0b21831d095643df9f08ef5d2e/folium.ipynb

Build a Dashboard with Plotly Dash

Dropdown List with Launch Sites

- Allow user to select all launch sites or a certain launch site

Pie Chart Showing Successful Launches

- Allow user to see successful and unsuccessful launches as a percent Of the total

Slider of Payload Mass Range

- Allow user to select payload mass range

Scatter Chart Showing Payload Mass vs. Success Rate by Booster Version

- Allow user to see the correlation between Payload and Launch Success

- https://github.com/arhammehdi2/IBMDataScienceFinalProject/blob/63d08ced28b8953bb0a98f12c56c2fca8540850e/spacex_dash_appplotly.py

Predictive Analysis (Classification)

Charts

- Create NumPy array from the Class column
- Standardize the data with StandardScaler. Fit and transform the data.
- Split the data using train_test_split
- Create a GridSearchCV object with cv—1 0 for parameter optimization
- Apply GridSearchCV on different algorithms: logistic regression (LogisticRegression()), support vector machine (SVC()), decision tree(DecisionTreeClassifer()), K-Nearest Neighbor (KNeighborsClassifier())
- Calculate accuracy on the test data using .score() for all models
- Assess the confusion matrix for all models
- Identify the best model using Jaccard_Score, F1_Score and Accuracy
- https://github.com/arhammehdi2/IBMDataScienceFinalProject/blob/56f7b1eae4ddc0f92f93ac11b0aed861ad50f5f0/IBM-DS0321EN-SkillsNetwork_labs_module_4_SpaceX_Machine_Learning_Prediction_Part_5.jupyterlite.ipynb

Results

Exploratory Data Analysis

- Launch success has improved over time
- KSC LC-39A has the highest success rate among landing sites
- Orbits ES-LI, GEO, HEO and SSO have a 100% success rate

Visual Analytics

- Most launch sites are near the equator, and all are close to the coast
- Launch sites are far enough away from anything a failed launch can damage (city, highway, railway), while sell close enough to bring people and material to support launch activities

Predictive Analytics

- Decision Tree model is the best predictive model for the dataset

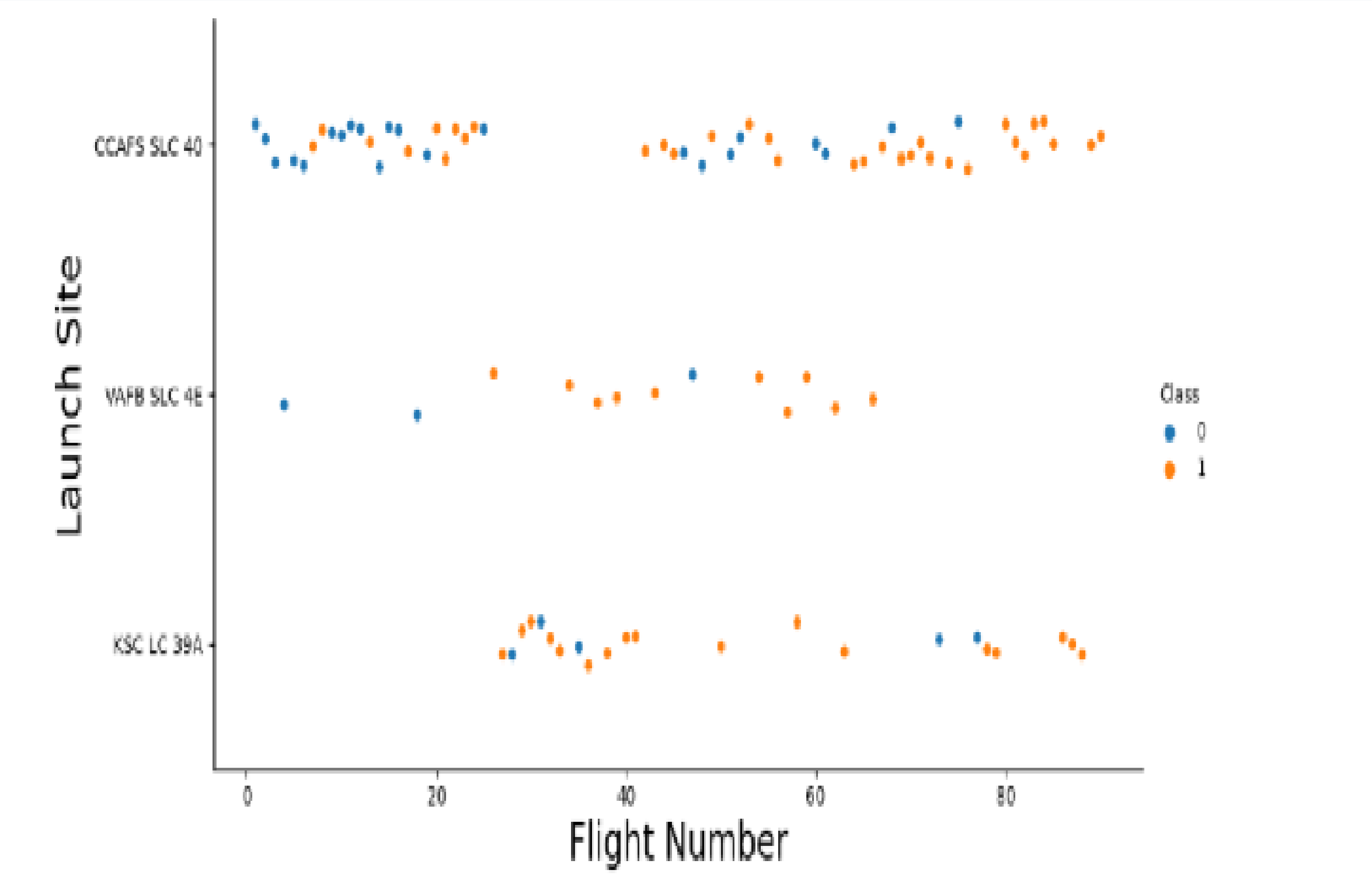
Section 2

Insights drawn from EDA

Flight Number vs. Launch Site

Exploratory Data Analysis

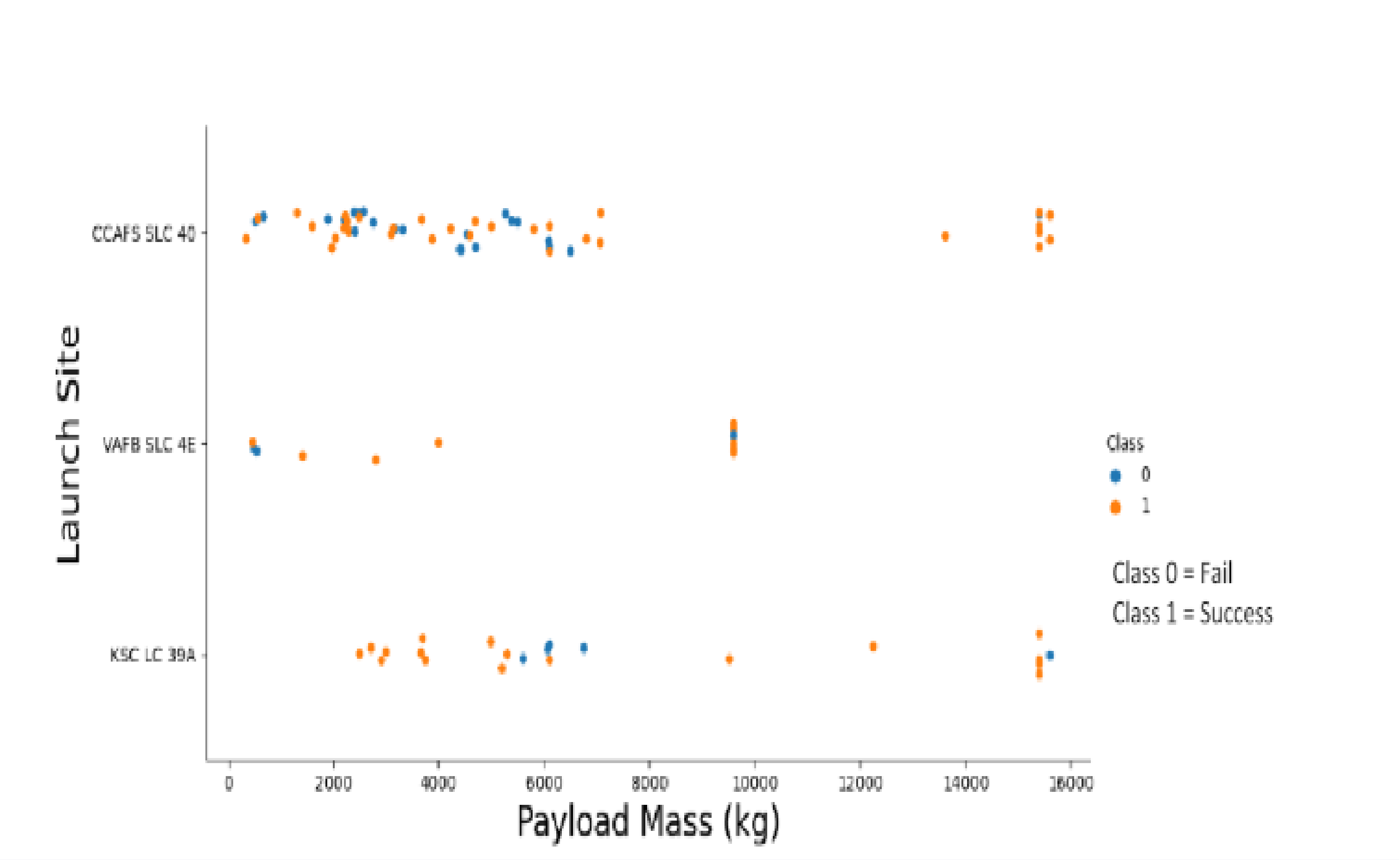
- Earlier flights had a lower success rate (blue fail)
- Later flights had a higher success rate (orange success)
- Around half of launches were from CCAFS SLC 40 launch site
- VAFB SLC 4E and KSC LC 39A have higher success rates
- We can infer that new launches have a higher success rate



Payload vs. Launch Site

Exploratory Data Analysis

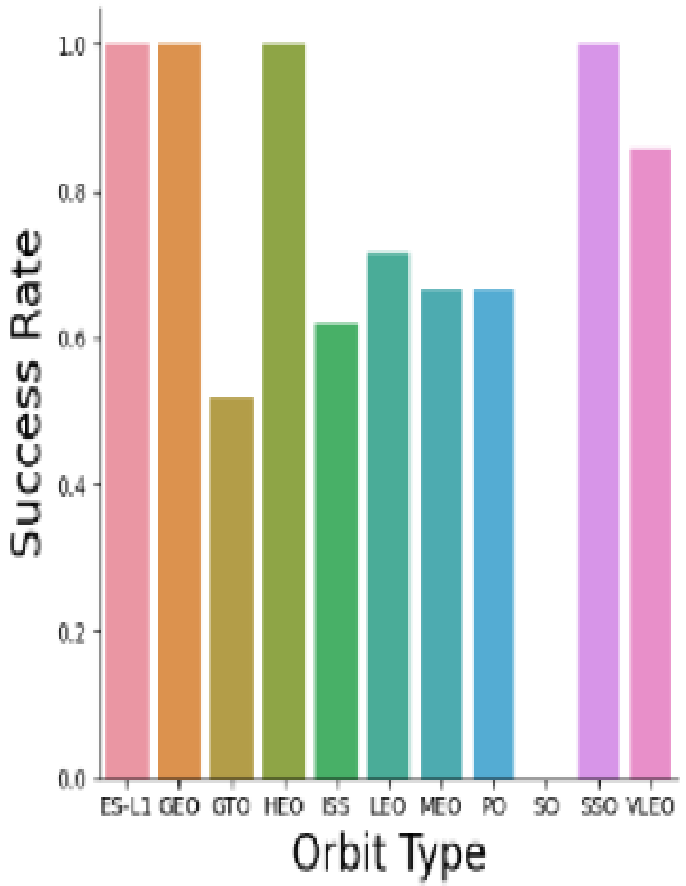
- Typically, the higher the payload mass (kg), the higher the success rate
- Most launces with a payload greater than 7,000 kg were successful
- KSC LC 39A has a 100% success rate for launches less than 5,500 kg
- VAFB SKC 4E has not launched anything greater than — 10,000 kg



Success Rate vs. Orbit Type

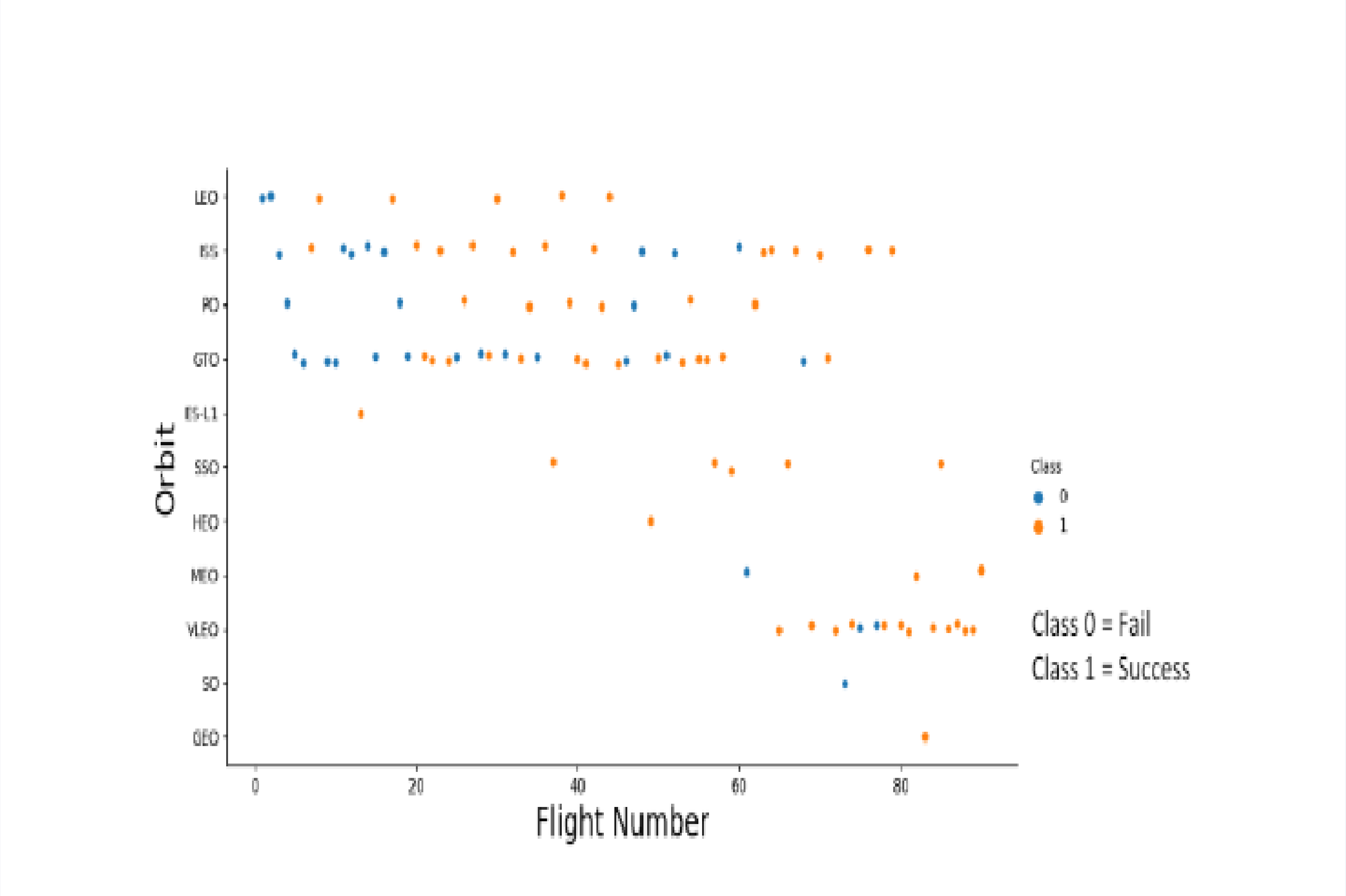
Exploratory Data Analysis

- 100% Success Rate: ES-LI, GEO, HEO and SSO
- Success Rate: GTO, ISS, LEO, MEO, PO
- 0% Success Rate: SO



Flight Number vs. Orbit Type

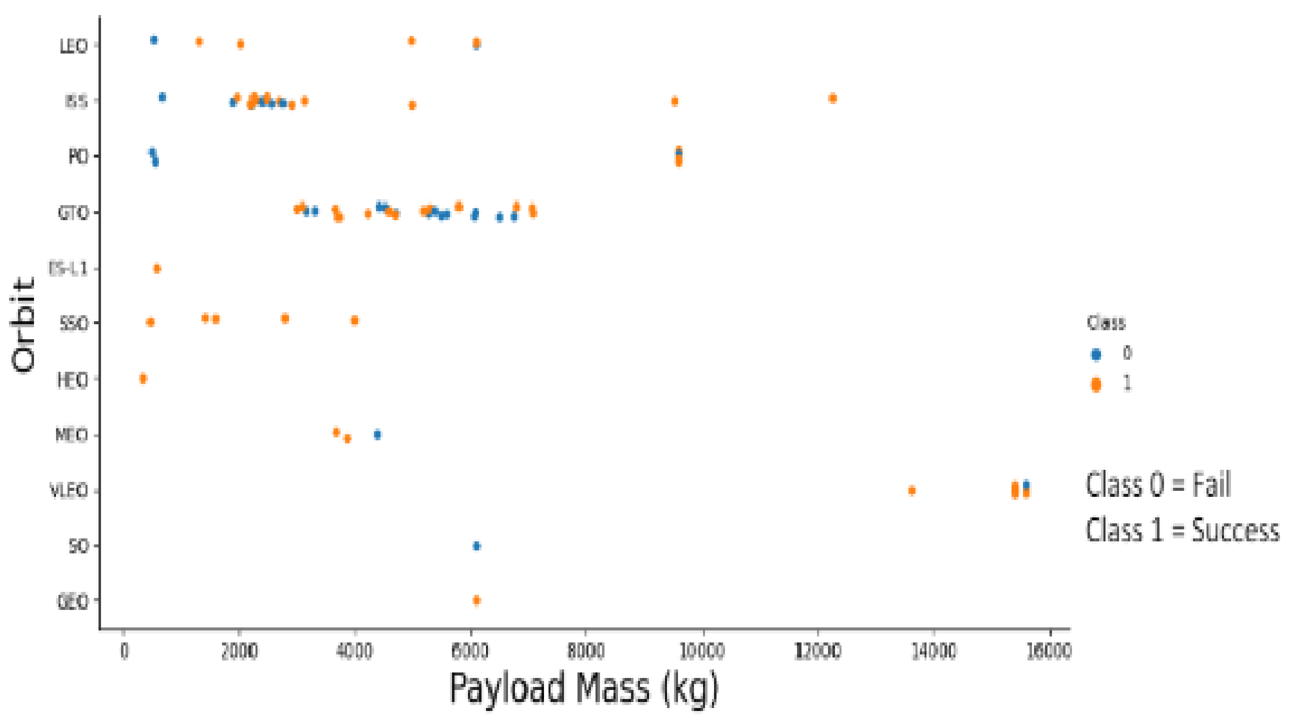
- Exploratory Data Analysis
- The success rate typically increases with the number of flights for each orbit
- This relationship is highly apparent for the LEO orbit
- The GTO orbit, however, does not follow this trend



Payload vs. Orbit Type

Exploratory Data Analysis

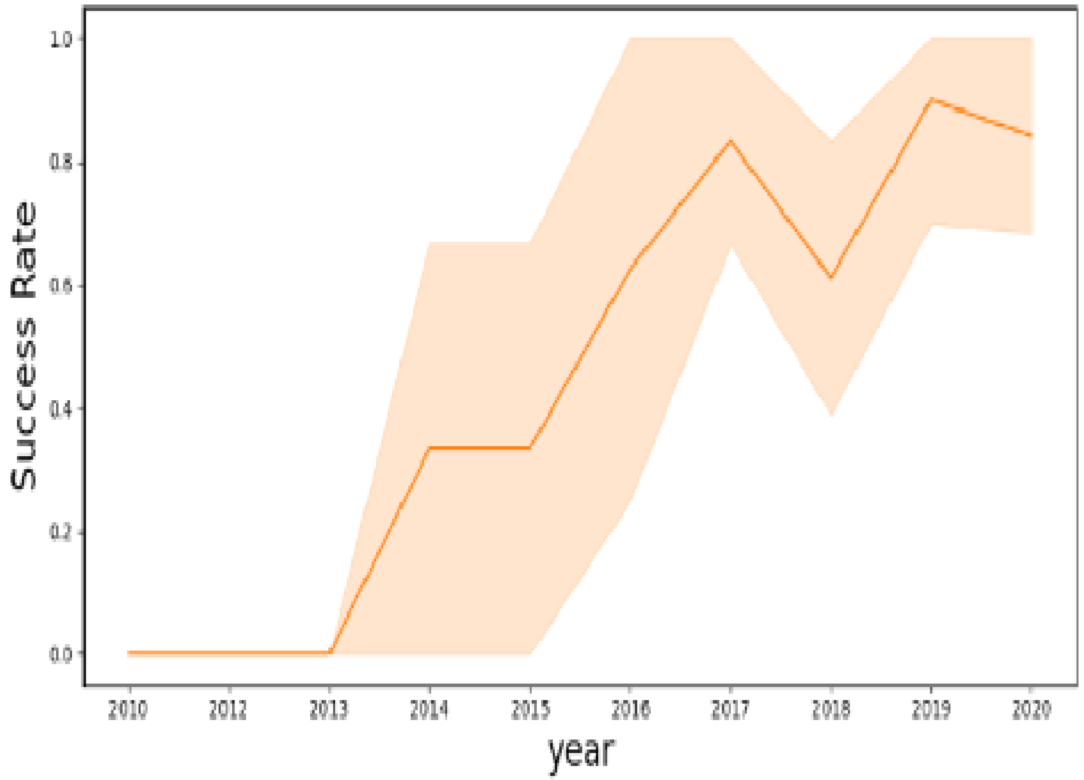
- Heavy payloads are better with LEO, ISS and PO orbits
- The GTO orbit has mixed success with heavier payloads



Launch Success Yearly Trend

Exploratory Data Analysis

- The success rate improved from 2013-2017 and 2018-2019
- The success rate decreased from 2017-2018 and from 2019-2020
- Overall, the success rate has improved since 2013



All Launch Site Names

- Find the names of the unique launch sites
- Present your query result with a short explanation here

Launch Site Names Begin with 'CCA'

Landing Outcome Cont.

```
[30]: %sql ibm_db_sa://yyy33800:dWNKg8J3L0IBd6CP@1bbf73c5
      %sql SELECT Unique(LAUNCH_SITE) FROM SPACEXTBL;
```

* ibm_db_sa://yyy33800:***@1bbf73c5-d84a-4bb0-85b9
  sqlite:///my_data1.db
Done.

[30]:

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

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

* ibm_db_sa://yyy33800:***@1bbf73c5-d84a-4bb0-85b9-ab1a4348f4a4.c3n41cmd0nqnrk39u98g.databases.appdomain.cloud:32286/BLUDB
  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	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	00:35:00	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

Launch Site Names
- CCAFS LC-40
- CCAFS SLC-40
- KSC LC-39A
- VAFB SLC-4E

Total Payload Mass

Total Payload Mass

- 45,596 kg (total) carried by boosters launched by NASA (CRS)

```
%sql SELECT SUM(PAYLOAD_MASS__KG_) \
    FROM SPACEXTBL \
    WHERE CUSTOMER = 'NASA (CRS)';
```

```
 * ibm_db_sa://yyy33800:***@1bbf73c5-d84a-4
   sqlite:///my_data1.db
Done.
```

1
45596

Average Payload Mass

- 2,928 kg (average) carried by booster version F9 v1.1

```
%sql SELECT AVG(PAYLOAD_MASS__KG_) \
    FROM SPACEXTBL \
    WHERE BOOSTER_VERSION = 'F9 v1.1';
```

```
 * ibm_db_sa://yyy33800:***@1bbf73c5-d84a-4
   sqlite:///my_data1.db
Done.
```

1
2928

Average Payload Mass by F9 v1.1

- Calculate the average payload mass carried by booster version F9 v1.1
- Present your query result with a short explanation here

First Successful Ground Landing Date

1st Successful Landing in Ground Pad

- 12/22/2015

```
%sql SELECT MIN(DATE) \
FROM SPACEXTBL \
WHERE LANDING__OUTCOME = 'Success (ground pad)'
```

```
 * ibm_db_sa://yyy33880:***@1bbf73c5-d84a-4bb0-85b
   sqlite:///my_data1.db
Done.
```

1
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

Booster Drone Ship Landing

- Booster mass greater than 4,000 but less than 6,000
- JSCAT-14,JSCAT-16, SES-10, SES-1 1 / EchoStar 105

```
%sql SELECT PAYLOAD \
FROM SPACEXTBL \
WHERE LANDING__OUTCOME = 'Success (drone ship)' \
AND PAYLOAD_MASS__KG_ BETWEEN 4000 AND 6000;
```

```
 * ibm_db_sa://yyy33800:***@1bbf73c5-d84a-4bb0-85b9
   sqlite:///my_data1.db
Done.
```

payload
JCSAT-14
JCSAT-16
SES-10
SES-11 / EchoStar 105

Total Number of Successful and Failure Mission Outcomes

- 1 Failure in Flight
- 99 Successes
- 1 Success(payload status unclear)

```
%sql SELECT MISSION_OUTCOME, COUNT(*) as total_number \
FROM SPACEXTBL \
GROUP BY MISSION_OUTCOME;
```

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

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

Boosters Carried Maximum Payload

Carrying Max Payload

- 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

```
%sql SELECT BOOSTER_VERSION \
FROM SPACEXTBL \
WHERE PAYLOAD_MASS__KG_ = (SELECT MAX(PAYLOAD_MASS__KG_) FROM SPACEXTBL);
```

```
 * 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

In 2015:

- Showing month, date, booster version, launch site and landing outcome.

```
%sql SELECT substr(Date,4,2) as month, DATE,BOOSTER_VERSION, LAUNCH_SITE, [Landing _Outcome] \
FROM SPACEXTBL \
where [Landing _Outcome] = 'Failure (drone ship)' and substr(Date,7,4)='2015';
```

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

month	Date	Booster_Version	Launch_Site	Landing _Outcome
01	10-01-2015	F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)
04	14-04-2015	F9 v1.1 B1015	CCAFS LC-40	Failure (drone ship)

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

```
%sql SELECT [Landing _Outcome], count(*) as count_outcomes \
FROM SPACEXTBL \
WHERE DATE between '04-06-2010' and '20-03-2017' group by [Landing _Outcome] order by count_outcomes DESC;
```

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

Landing _Outcome	count_outcomes
Success	20
No attempt	10
Success (drone ship)	8
Success (ground pad)	6
Failure (drone ship)	4
Failure	3
Controlled (ocean)	3
Failure (parachute)	2
No attempt	1

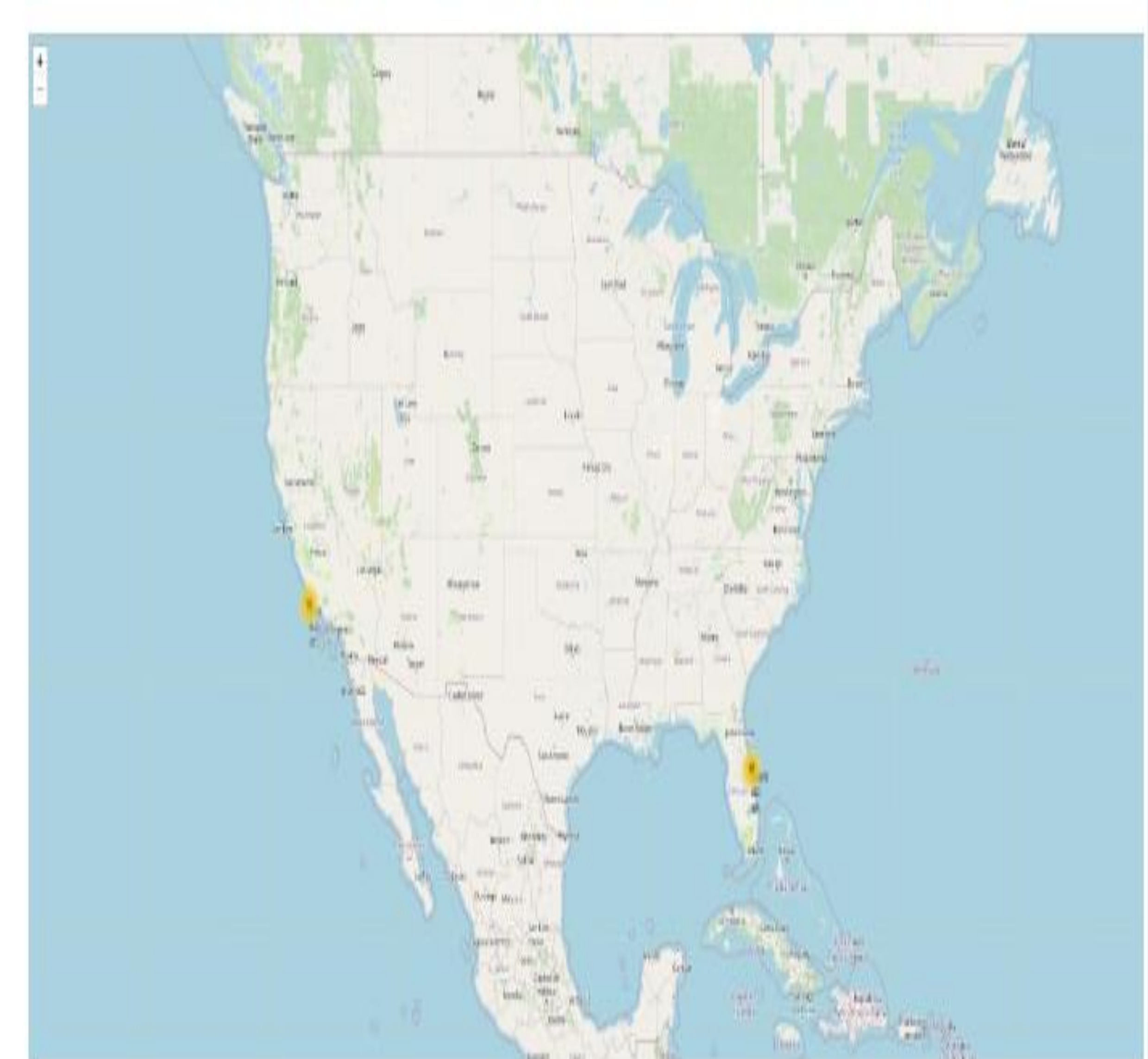
Section 3

Launch Sites Proximities Analysis

Launch Sites

With Markers

- Near Equator: the closer the launch site to the equator, the easier it is to launch to equatorial orbit, and the more help you get from Earth's rotation for a prograde orbit. Rockets launched from sites near the equator get an additional natural boost - due to the rotational speed of earth - that helps save the cost of putting in extra fuel and boosters.



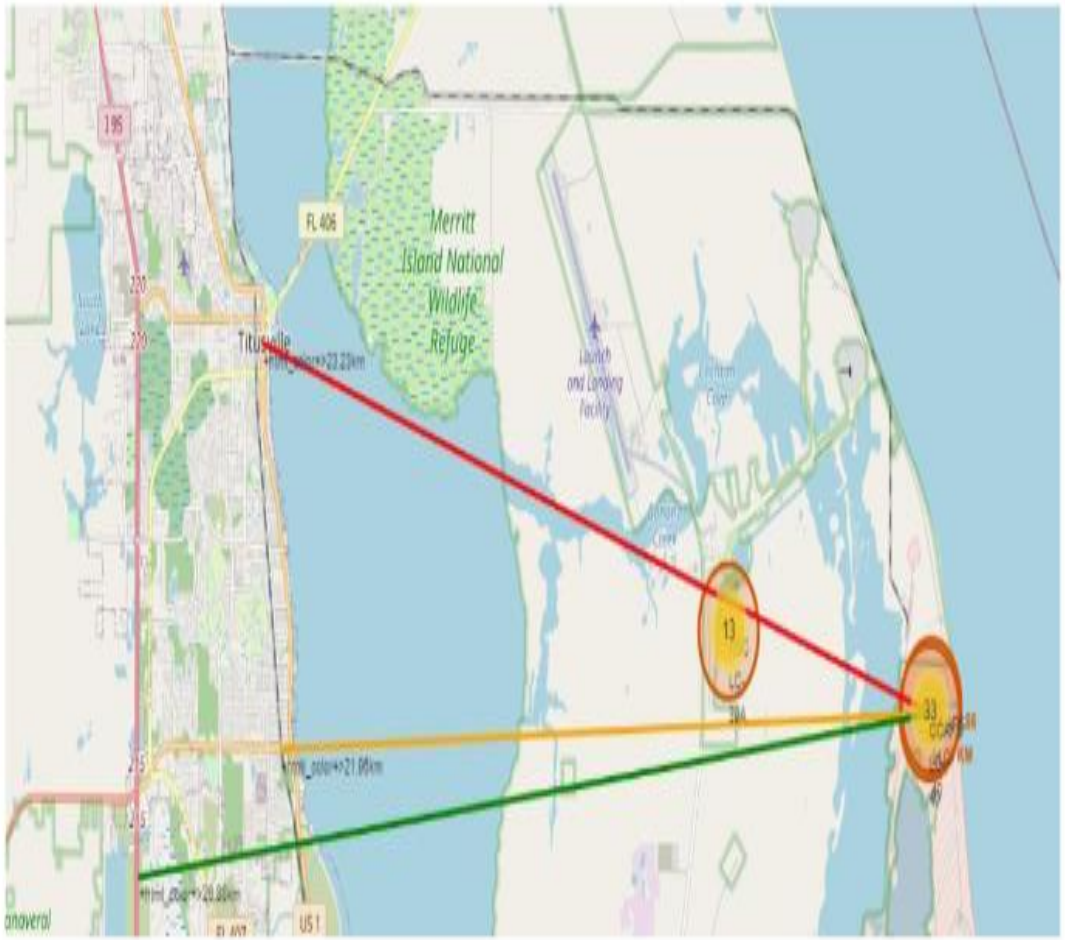
Launch Outcomes

At Each Launch Site
Outcomes.
Green markers for successful launches
Red markers for unsuccessful launches
Launch site CCAFS SLC-40 has a 3/7 success rate (42.9%)

Distance to proximities

CCAFS SLC-40

- .86 km from nearest coastline
- 21.96 km from nearest railway
- 23.23 km from nearest city
- 26.88 km from nearest highway



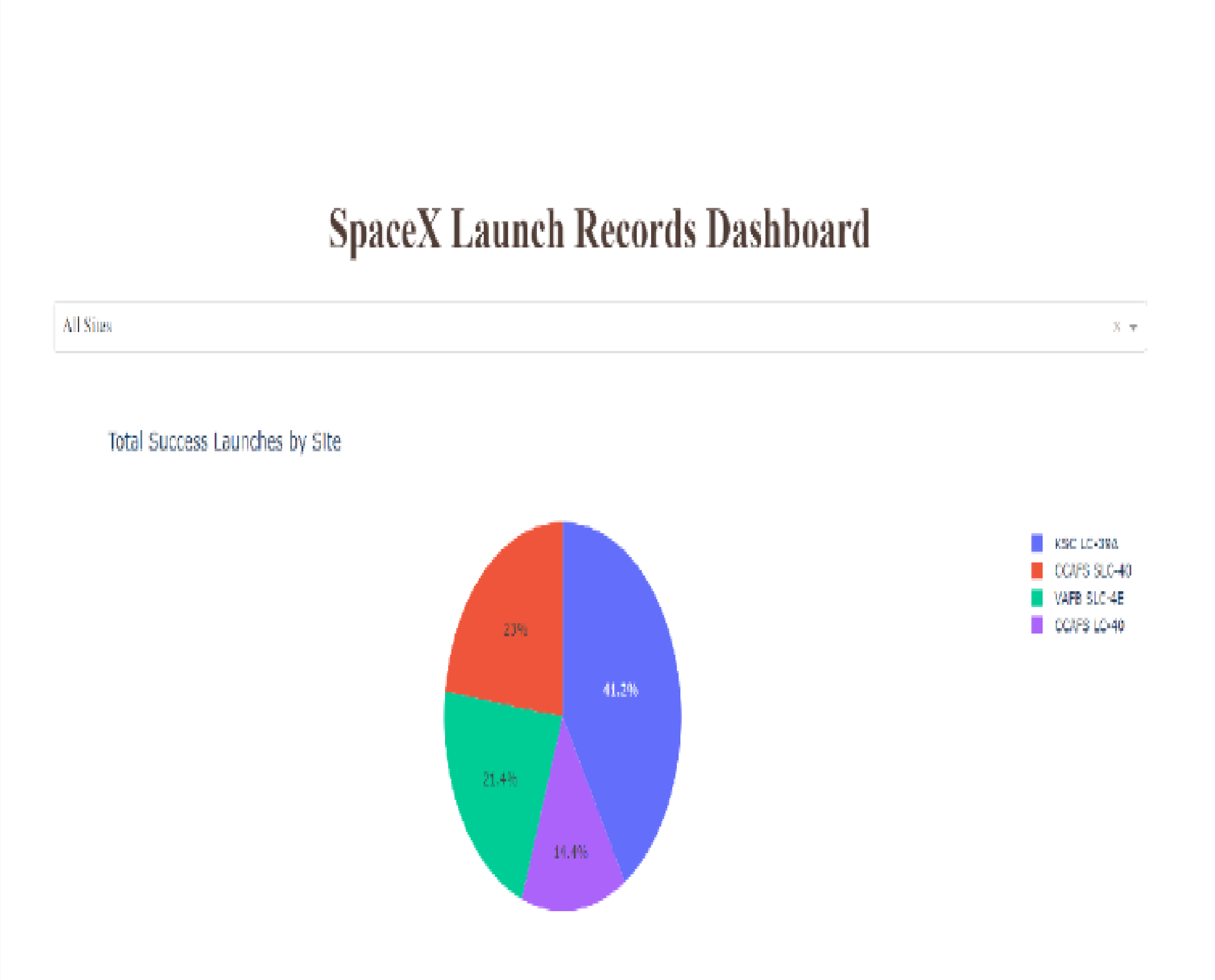
Section 4

Build a Dashboard with Plotly Dash

Launch Success by Title

Success as Percent of Total

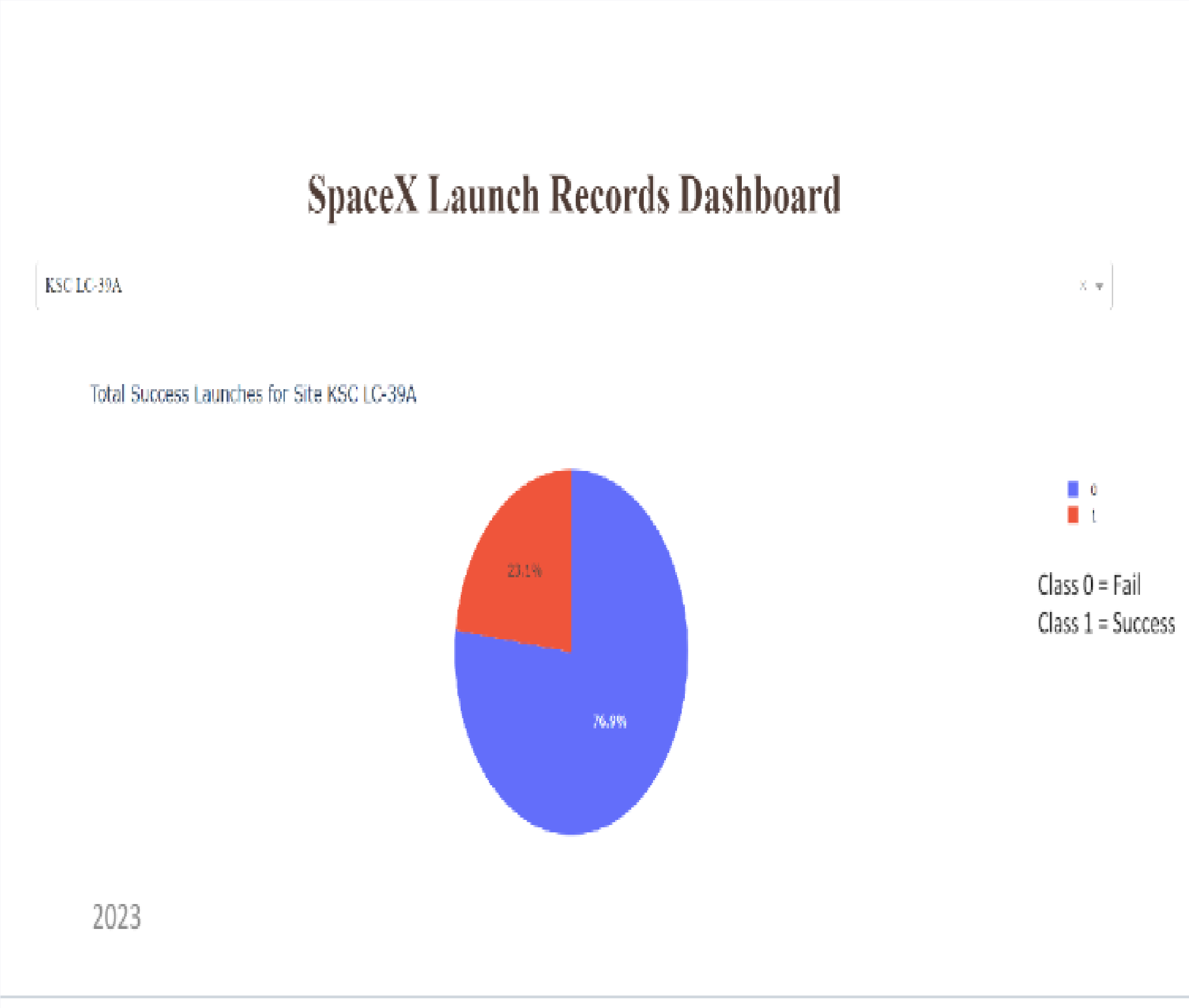
- KSC LC-39A has the most successful launches amongst launch sites (41.2%)



Launch Success

Success as Percent of Total

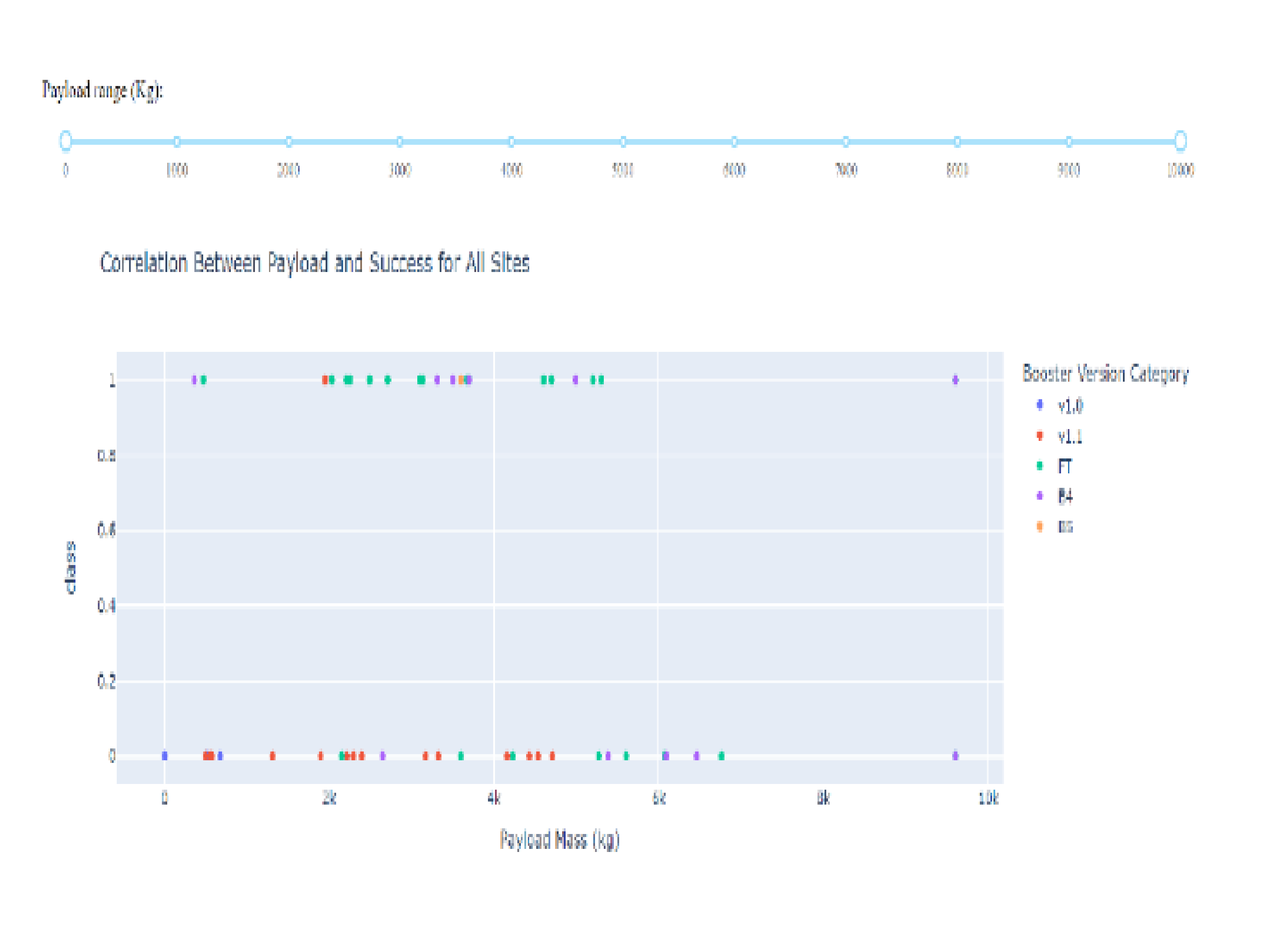
- KSC LC-39A has the highest success rate amongst launch sites (76.9%)
- 10 successful launches and 3 failed launches



<Dashboard Screenshot 3>

By Booster Version

- Payloads between 2,000 kg and 5,000 kg have the highest success rate
- 1 indicating successful outcome and 0 indicating an unsuccessful outcome



Section 5

Predictive Analysis (Classification)

Classification Accuracy

Accuracy

- All the models performed at about the same level and had the same scores and accuracy. This is likely due to the small dataset. The Decision Tree model slightly outperformed the rest when looking at .best_score_
- .best score _ is the average of all cv folds for a single combination of the parameters

	LogReg	SVM	Tree	KNN
Jaccard_Score	0.800000	0.800000	0.800000	0.800000
F1_Score	0.888889	0.888889	0.888889	0.888889
Accuracy	0.833333	0.833333	0.833333	0.833333

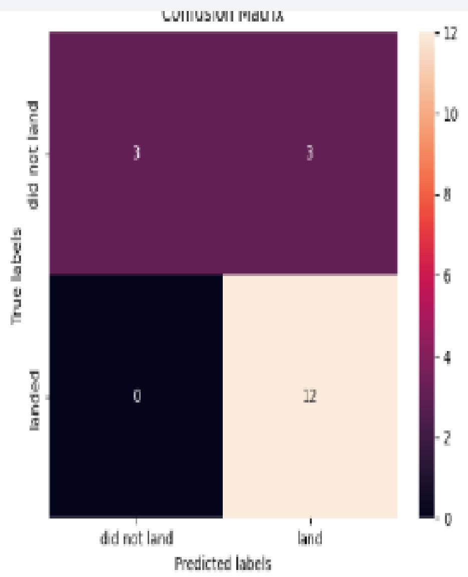
```
models = {'KNeighbors':knn_cv.best_score_,
              'DecisionTree':tree_cv.best_score_,
              'LogisticRegression':logreg_cv.best_score_,
              'SupportVector': svm_cv.best_score_}

bestalgorithm = max(models, key=models.get)
print('Best model is', bestalgorithm,'with a score of', models[bestalgorithm])
if bestalgorithm == 'DecisionTree':
    print('Best params is :', tree_cv.best_params_)
if bestalgorithm == 'KNeighbors':
    print('Best params is :', knn_cv.best_params_)
if bestalgorithm == 'LogisticRegression':
    print('Best params is :', logreg_cv.best_params_)
if bestalgorithm == 'SupportVector':
    print('Best params is :', svm_cv.best_params_)
```

```
Best model is DecisionTree with a score of 0.9017857142857142
Best params is : {'criterion': 'gini', 'max_depth': 16, 'max_features': 'auto', 'min_samples_leaf': 4, 'min_samples_split': 10, 'splitter': 'random'}
```

Confusion Matrix

Performance Summary

- A confusion matrix summarizes the performance of a classification algorithn
- All the confusion matrices were identical
- The fact that there are false positives (Type 1 error) is not good



  - 12 True positive
  - 3 True negative
  - 3 False positive
  - 0 False Negative
- **Precision** = TP / (TP + FP)
  - 12 / 15 = .80
- **Recall** = TP / (TP + FN)
  - 12 / 12 = 1
- **F1 Score** = 2 * (Precision * Recall) / (Precision + Recall)
  - 2 * (.8 * 1) / (.8 + 1) = .89
- **Accuracy** = (TP + TN) / (TP + TN + FP + FN) = .833

2023

Conclusions

Research

- 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•LI, 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!