IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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

Executive Summary

- Summary of methodologies
- Summary of all results

Introduction

- Project background and context
- Problems you want to find answers

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - Data were collected using the SpaceX Rest API and web scraping techniques.
- Perform data wrangling
  - Data wrangling was performed by filtering the data, handling missing values and applying one hot encoding to prepare the data for analysis and modelling.
- Perform exploratory data analysis (EDA) using visualization and SQL
  - Via EDA with SQL and data visualization techniques.
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - This is done using classification models. Tuning and evaluating models to find the best model and parameters.

Data Collection - API

- Collecting data were done following the steps below:
    1. Requesting data from SpaceX API (Rocket launch data)
    2. Decoding responses using .json() and converting it to a dataframe using .json_normalize()
    3. Requesting information about launches from the API using custom functions
    4. Creating dictionary from the data.
    5. Creating dataframe from the dictionary.
    6. Filtering dataframe to contain only the Falcon 9 launches.
    7. Replacing missing values of Payload Mass with the calculated .mean()
    8. Exporting data to a csv file.

Data Collection – Web Scraping

- Collecting data were done following the steps below:
    1. Requesting data (Falcon 9 launch data) via Wikepedia
    2. Creating BeautifulSoup object from HTML response
    3. Extract column names from HTML table header
    4. Collect data from parsing HTML tables
    5. Create dictionary from the data
    6. Create dataframe from the dictionary
    7. Export data to csv file

Data Wrangling Steps

1. Perform EDA and determine data labels
2. Calculate the number of launches for each site, the orbit occurrences, and the mission outcomes per orbital type.
3. Create binary landing outcome column (dependent variable)
4. Exporting data to a csv file.

Landing Outcome:

1. Landing was not always successful.
2. True ocean: mission outcome had a successful landing to a specific region of the ocean.
3. False ocean: denotes an unsuccessful landing to a specific region of ocean.
4. True RTLS: denotes the mission had a successful landing on a ground pad.
5. False RTLS: denotes an unsuccessful landing on a ground pad.
6. Trues ASDS: denotes the mission outcome had a successful landing on a drone ship.
7. False ASDS: denotes an unsuccessful landing on drone ship.
8. Outcomes converted into 1 for a successful landing and 0 for an unsuccessful landing.

EDA with Data Visualization

- Charts:
  - ❑ Flight Number vs Payload
  - ❑ Flight Number vs Launch Site
  - ❑ Payload Mass (kg) vs Launch Site
  - ❑ Payload Mass (kg) vs Orbital Type
- Analysis:
  - ✓ View relationship using scatter plots. The variables could be useful for ML if a relationship exists.
  - ✓ Show comparisons among discrete categories with bar charts which shows the relationships among the categories and a measured value.

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
- Queries 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)

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 SLC40 and its proximity to the nearest coastline, railway, highway, and city

Build a Dashboard with Plotly Dash

- Dropdown List with Launch Sites
  - Allow user to select all launch sites or a certain launch site
- Slider of Payload Mass Range
  - Allow user to select payload mass range
- Pie Chart Showing Successful Launches
  - Allow user to see successful and unsuccessful launches as a percent of the total
- Scatter Chart Showing Payload Mass vs. Success Rate by Booster Version
  - Allow user to see the correlation between Payload and Launch Success

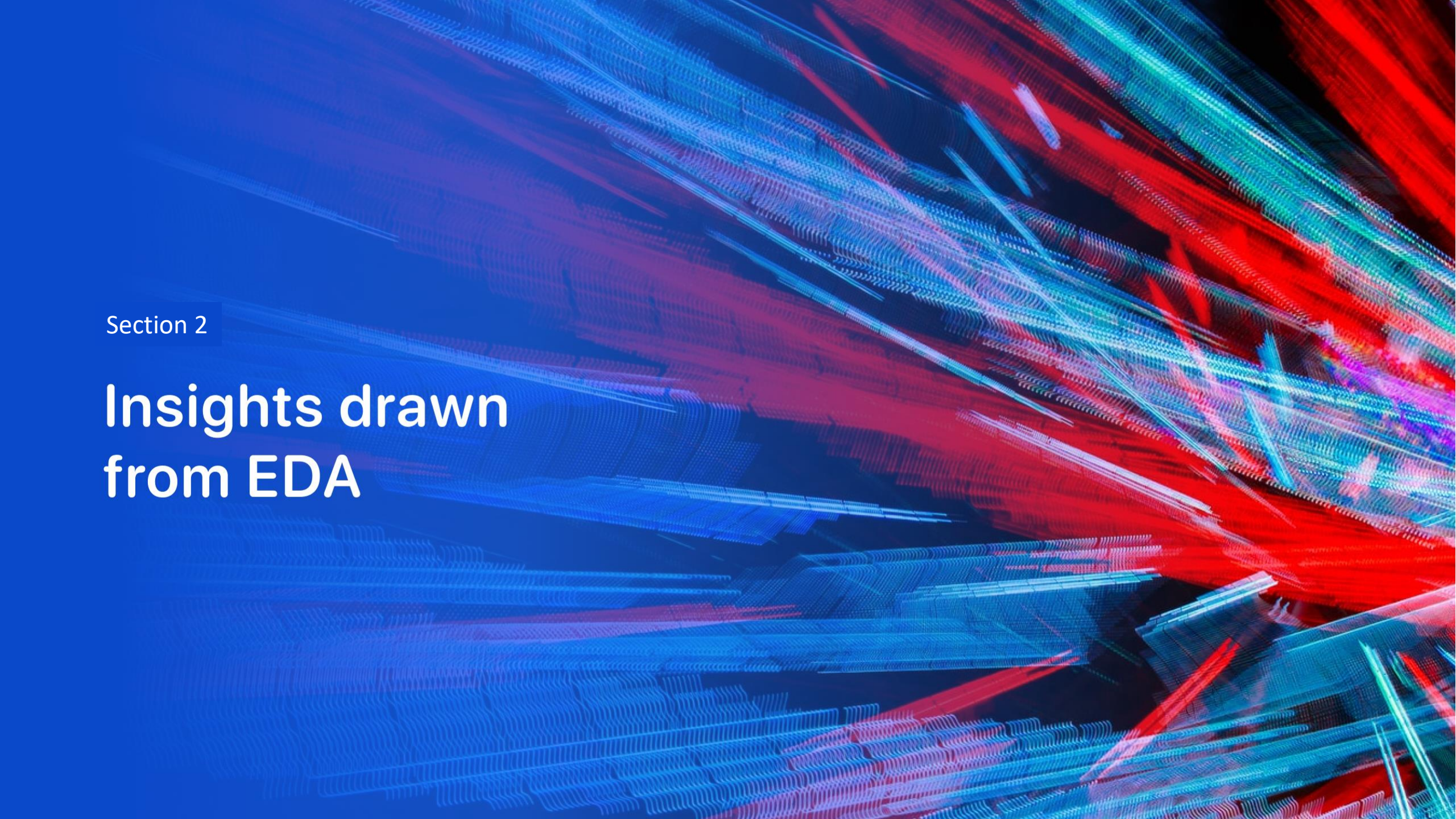
Predictive Analysis (Classification)

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=10 for parameter optimization
- Apply GridSearchCV on different algorithms: logistic regression (LogisticRegression()), support vector machine (SVC()), decision tree (DecisionTreeClassifier()), 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

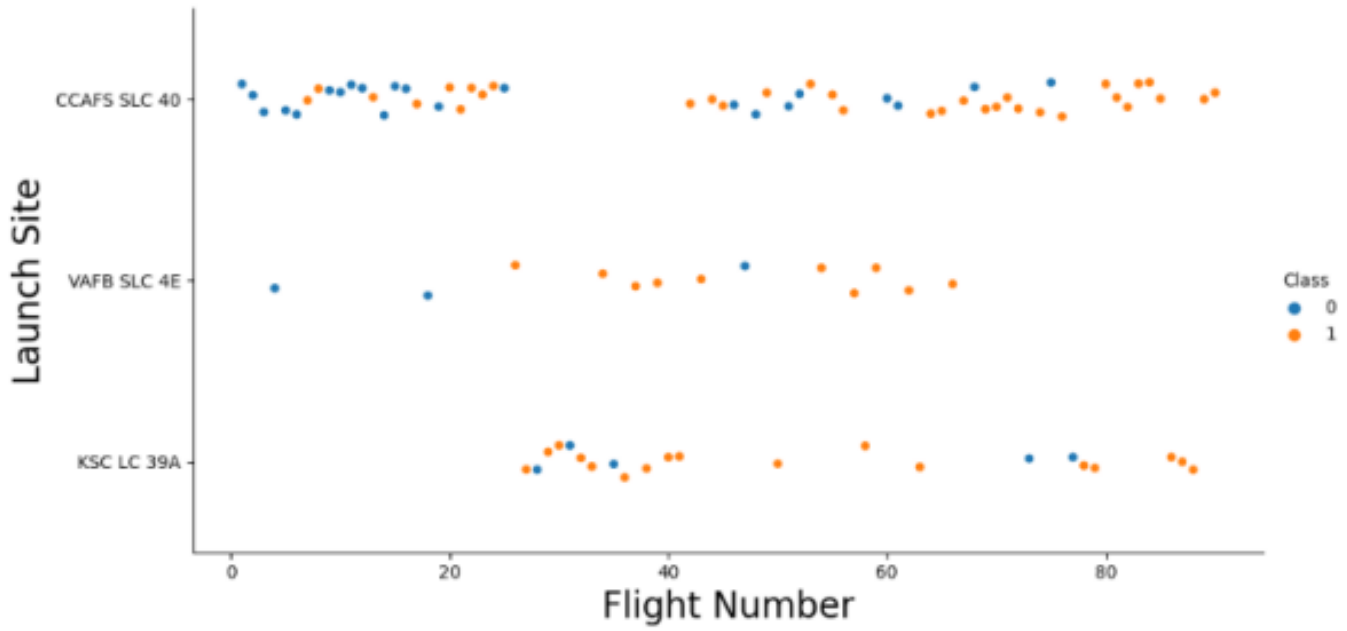
Results

- Exploratory data analysis results
  - Launch success has improved over time
  - KSC LC-39A has the highest success rate among landing sites
  - Orbits ES-L1, GEO, HEO and SSO have a 100% success rate
- Interactive analytics demo in screenshots
  - 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 still close enough to bring people and material to support launch activities
- Predictive analysis results
  - Decision Tree model is the best predictive model for the dataset


Section 2
Insights drawn from EDA

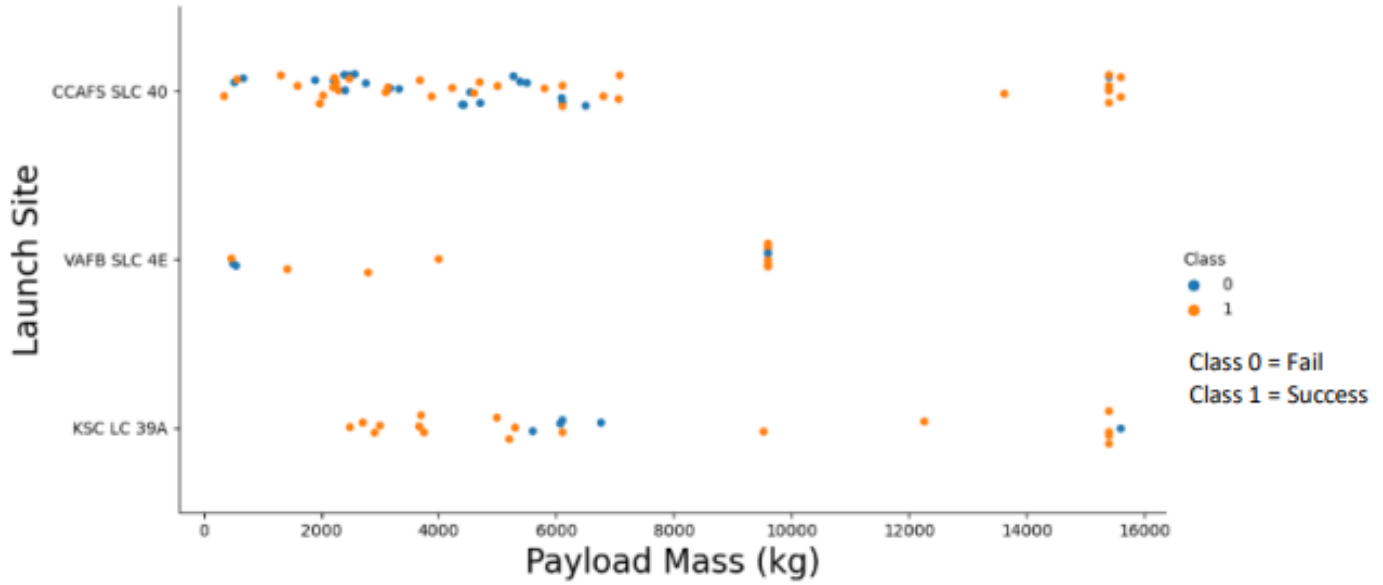
Flight Number vs. Launch Site

- 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



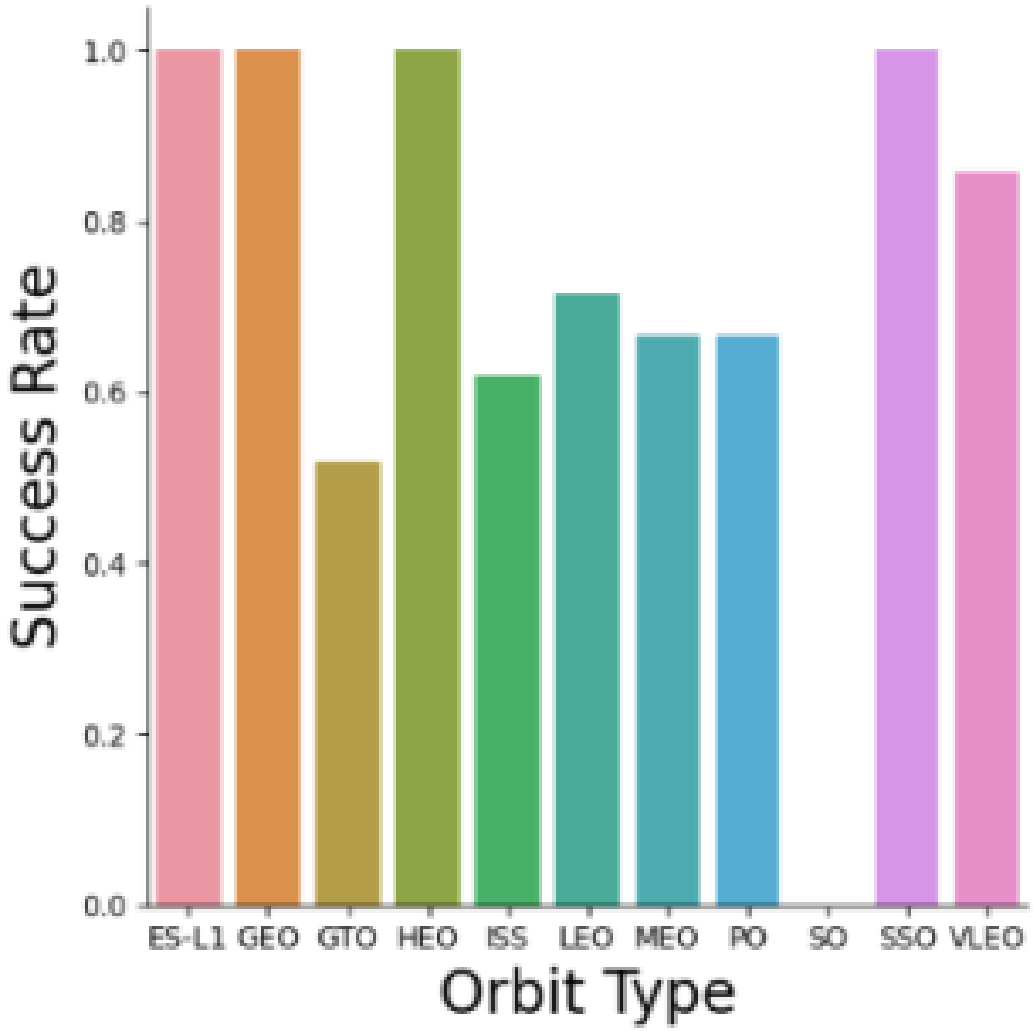
Payload vs. Launch Site

- 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



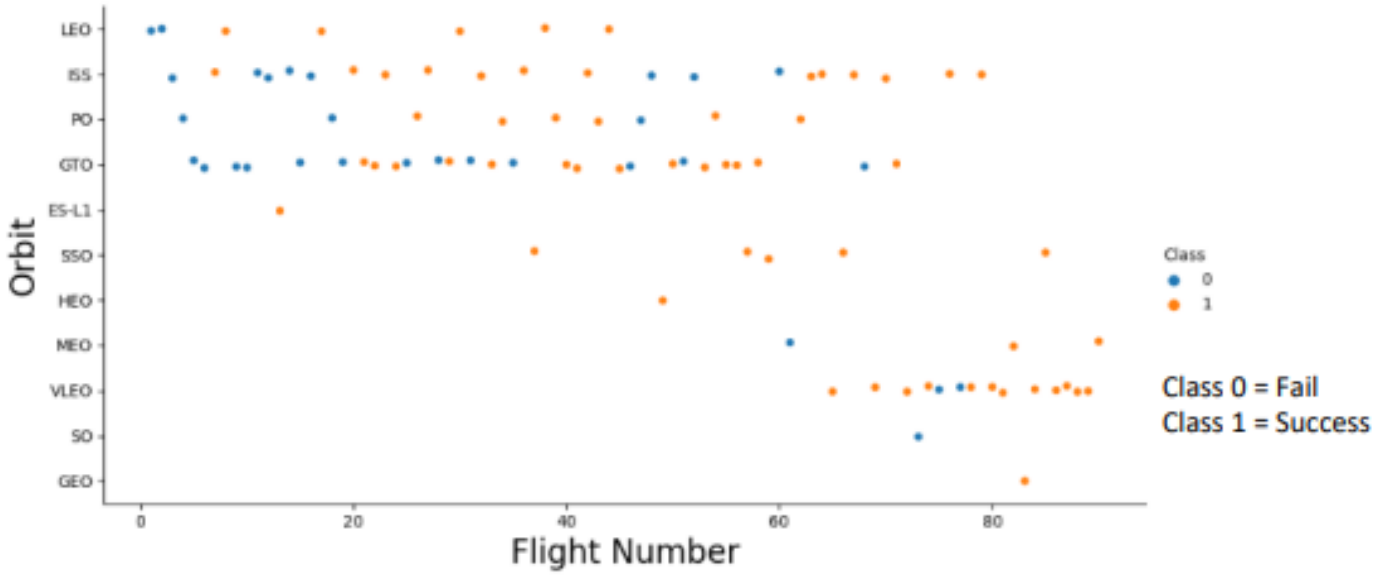
Success Rate vs. Orbit Type

- Exploratory Data Analysis
- 100% Success Rate: ES-L1, GEO, HEO and SSO
- 50%-80% Success Rate: GTO, ISS, LEO, MEO, PO
- 0% Success Rate: SO



Flight Number vs. Orbit Type

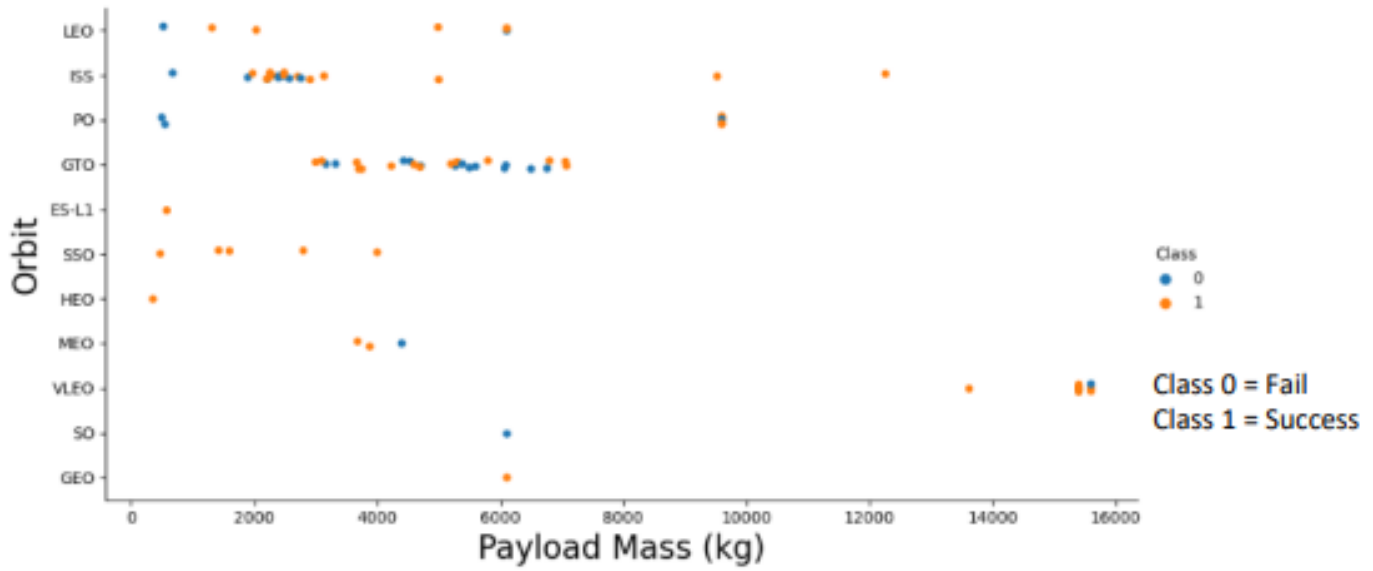
- Exploratory Data Analysis
- The success rate typically increases with the number of flights for each orbit
- This relationship is highly apparent for the LEO orbit
- The GTO orbit, however, does not follow this trend



Payload vs. Orbit Type

Exploratory Data Analysis

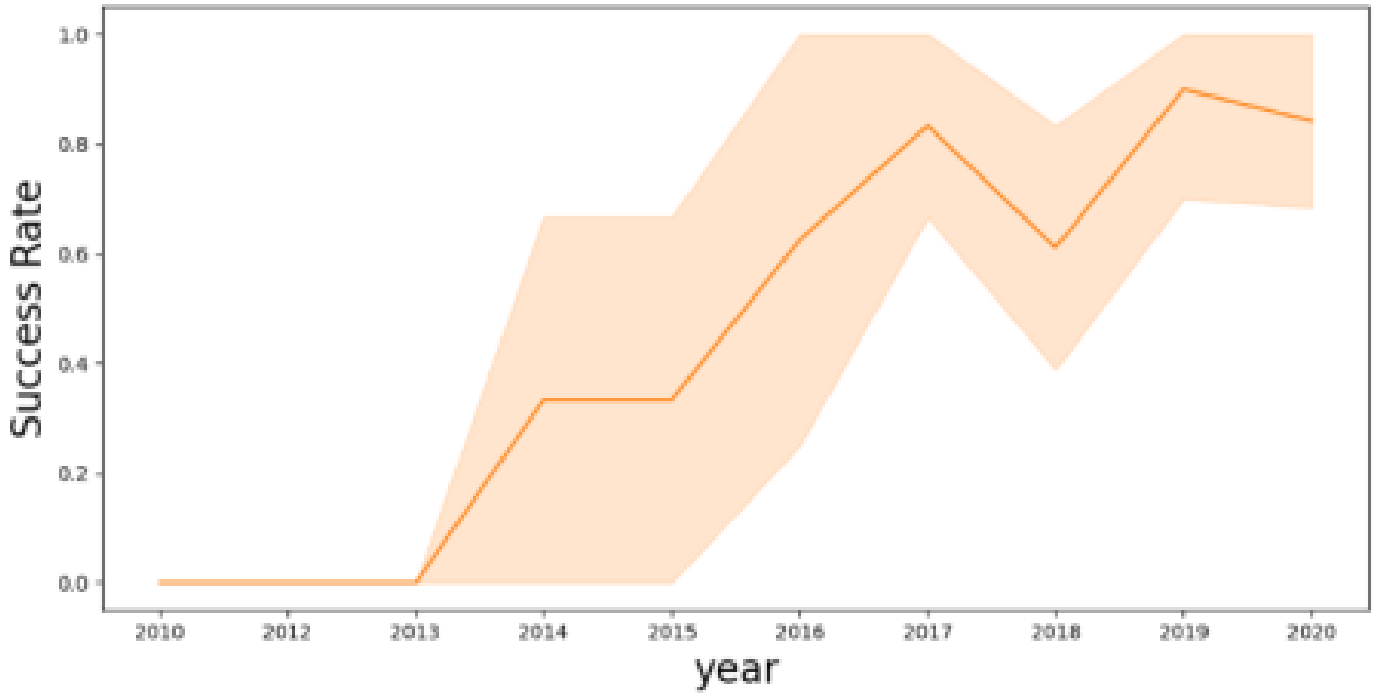
- Heavy payloads are better with LEO, ISS and PO orbits
- The GTO orbit has mixed success with heavier payloads



Launch Success Over Time

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 Information

Launch Site Names

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

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

Records with Launch Site Starting with CCA

- Displaying 5 records below

```
%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

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

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

Failed Landings on Drone Ship

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)

Count of Successful Landings

Ranked Descending

- Count of landing outcomes between 2010-06-04 and 2017-03-20 in descending order

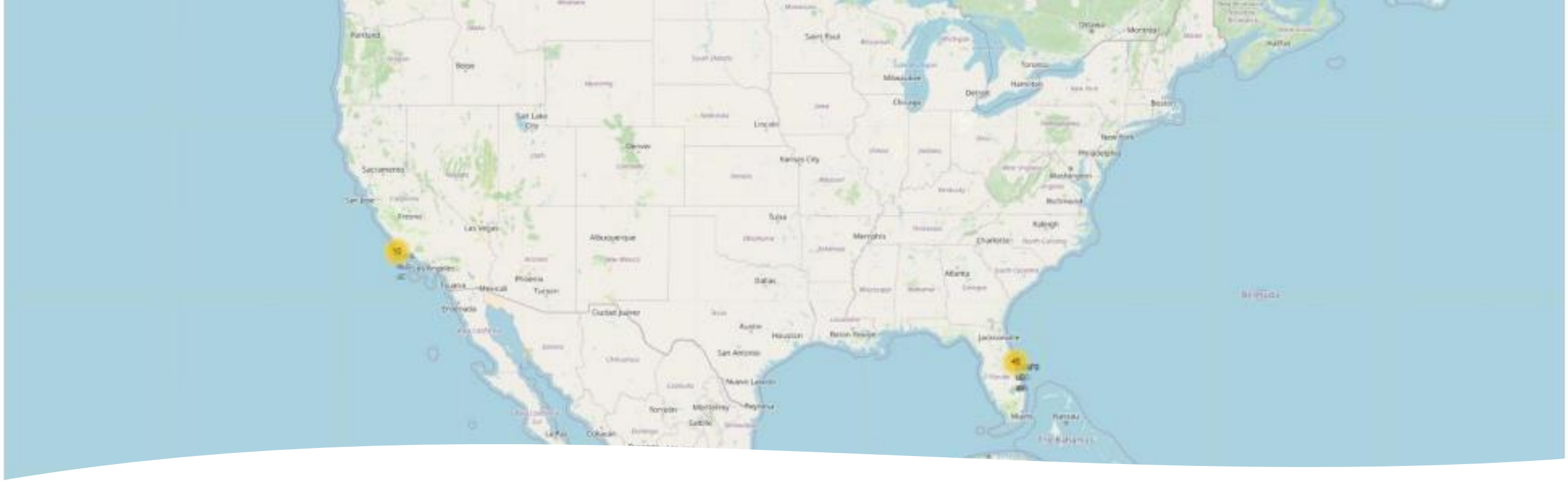
```
%sql SELECT [Landing _Outcome], count(*) as count_outcomes \
FROM SPACEXTBL \
WHERE DATE between '04-06-2010' and '20-03-2017' group by [Landing _Outcome] order by count_outcomes DESC;
```

```
 * 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

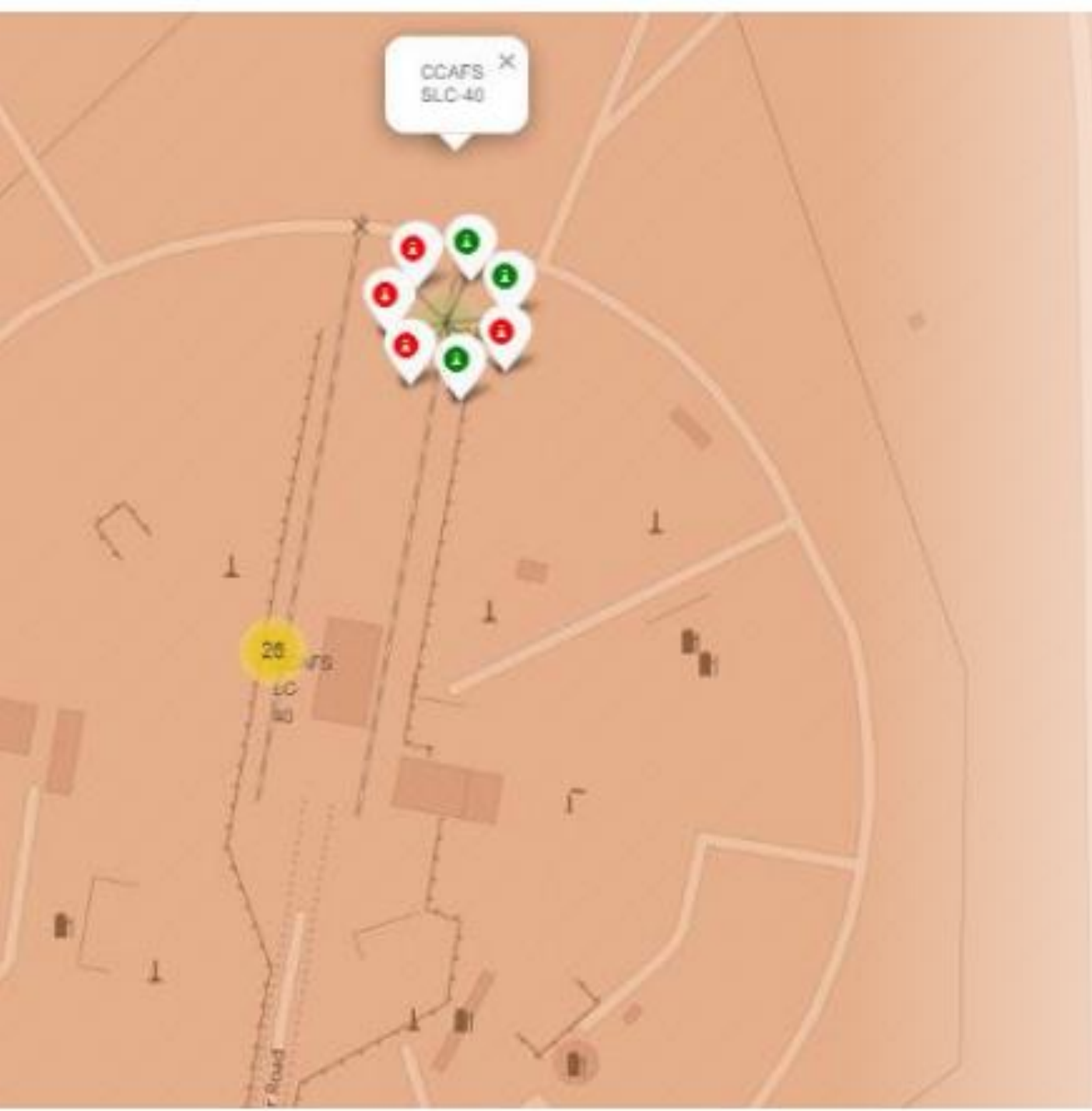
Section 3

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%)

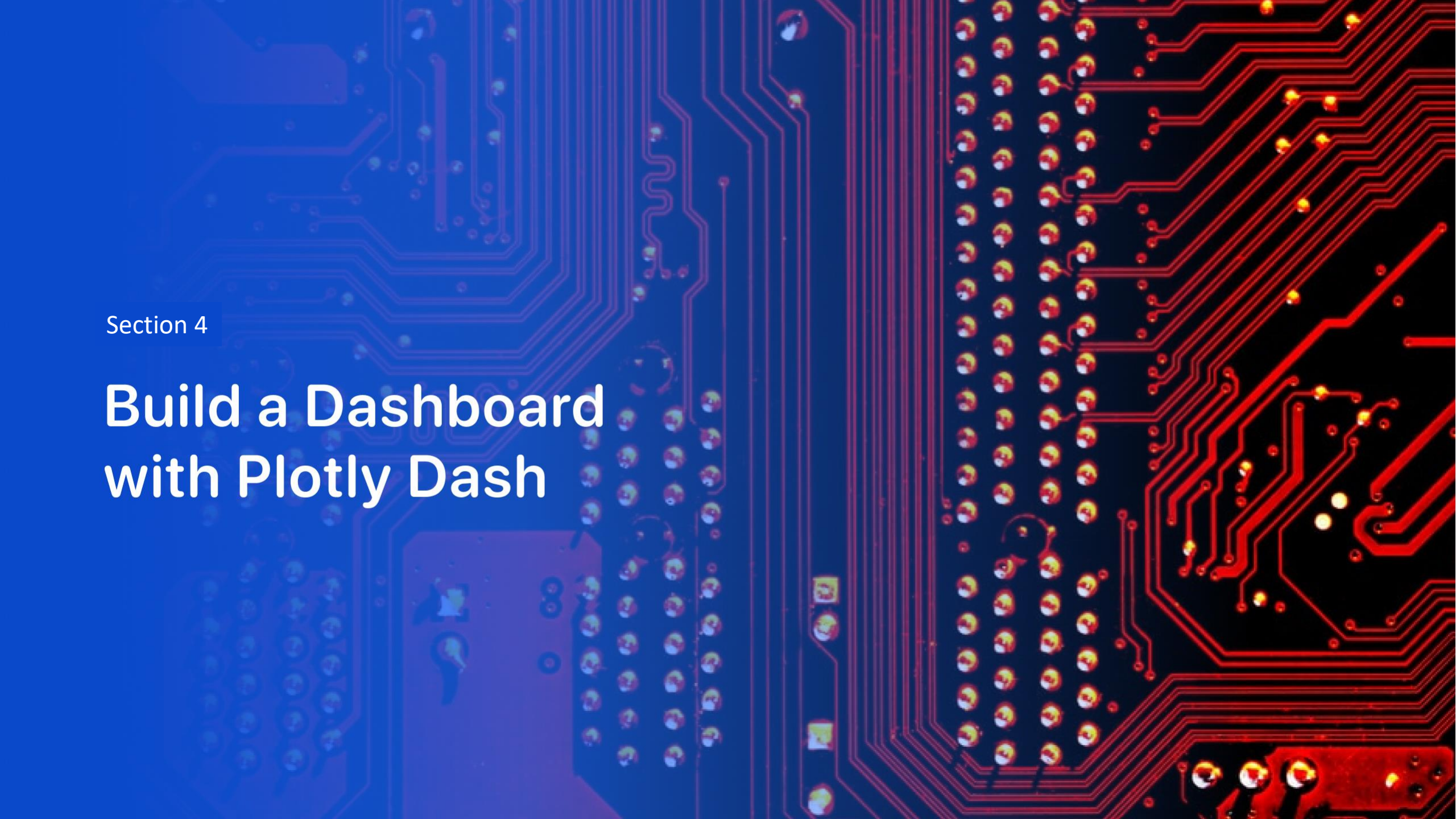
Distance to Proximities

- CCAFS SLC-40
  - 0.86 km from nearest coastline
  - 21.96 km from nearest railway
  - 23.23 km from nearest city
  - 26.88 km from nearest highway

Distance to Proximities

CCAFS SLC-40

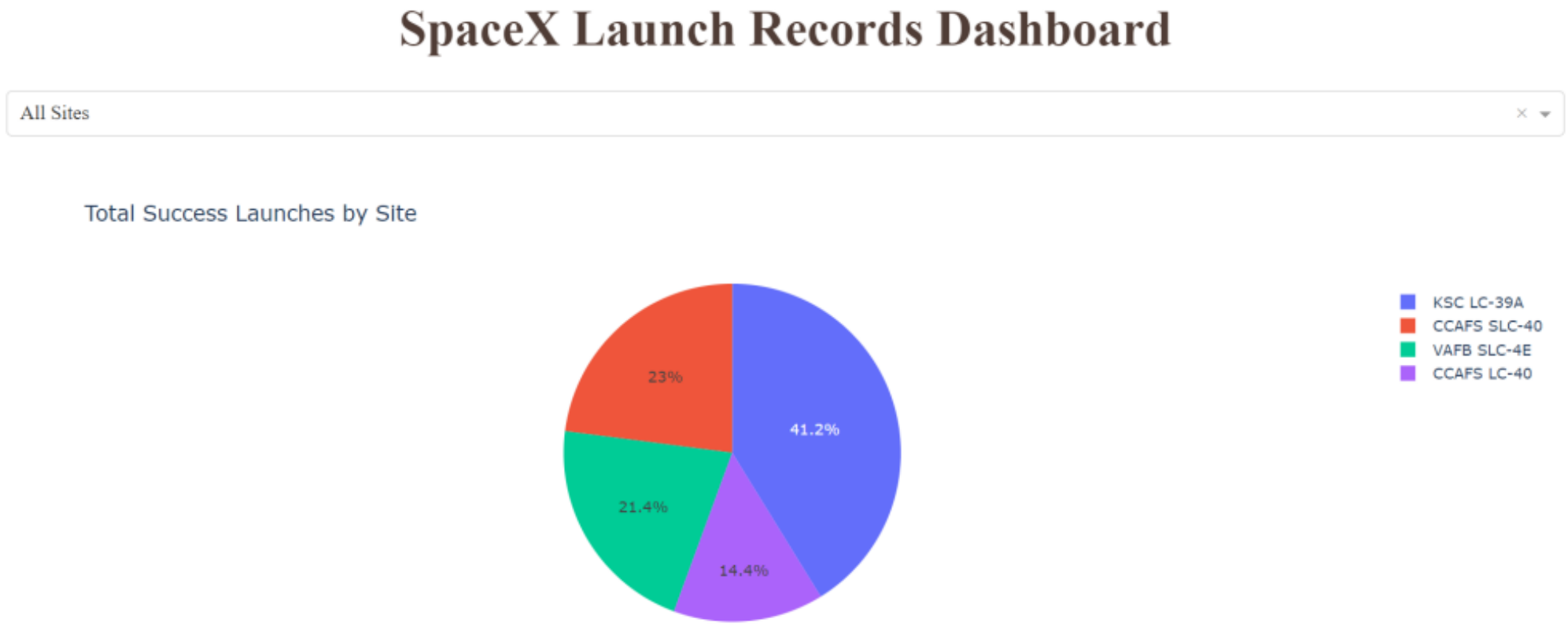
- Coasts: help ensure that spent stages dropped along the launch path or failed launches don't fall on people or property.
- Safety / Security: needs to be an exclusion zone around the launch site to keep unauthorized people away and keep people safe.
- Transportation/Infrastructure and Cities: need to be away from anything a failed launch can damage, but still close enough to roads/rails/docks to be able to bring people and material to or from it in support of launch activities.


Section 4
Build a Dashboard with Plotly Dash

Launch Success by Site

Success as Percent of Total

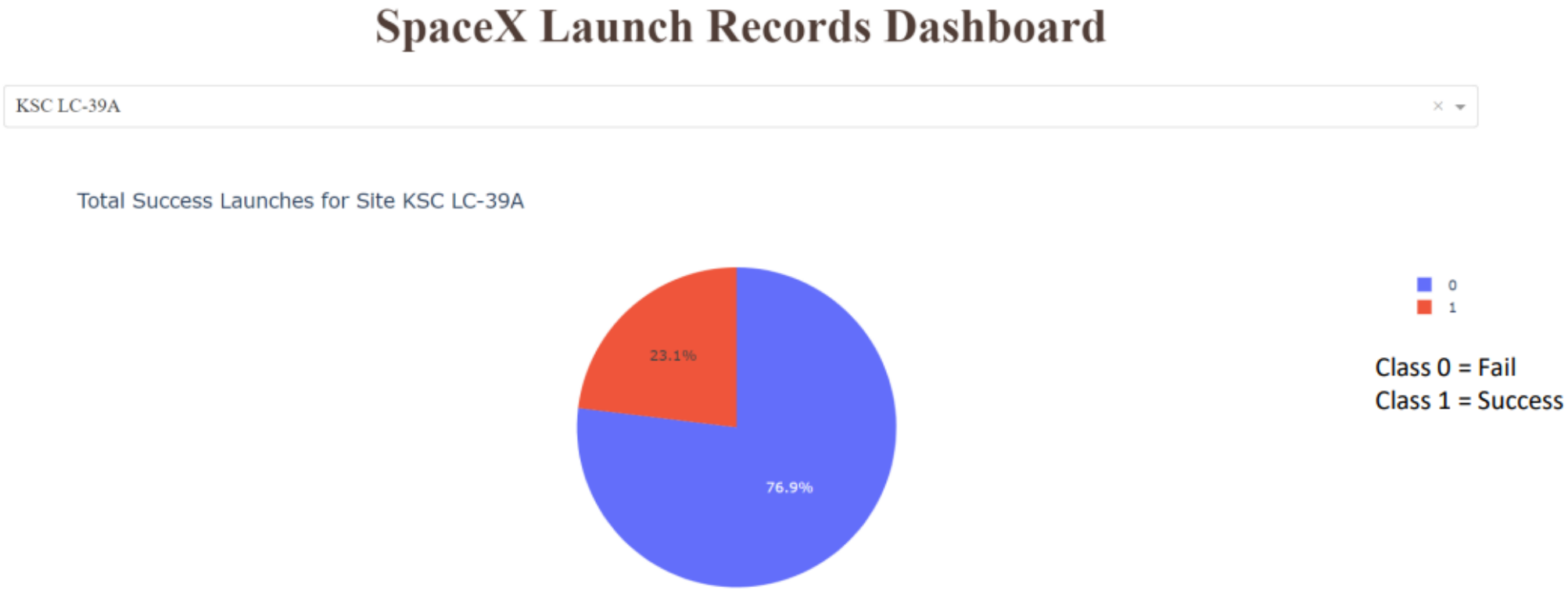
- KSC LC-39A has the most successful launches amongst launch sites (41.2%)



Launch Success by Site

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



Payload Mass and Success

- 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

	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

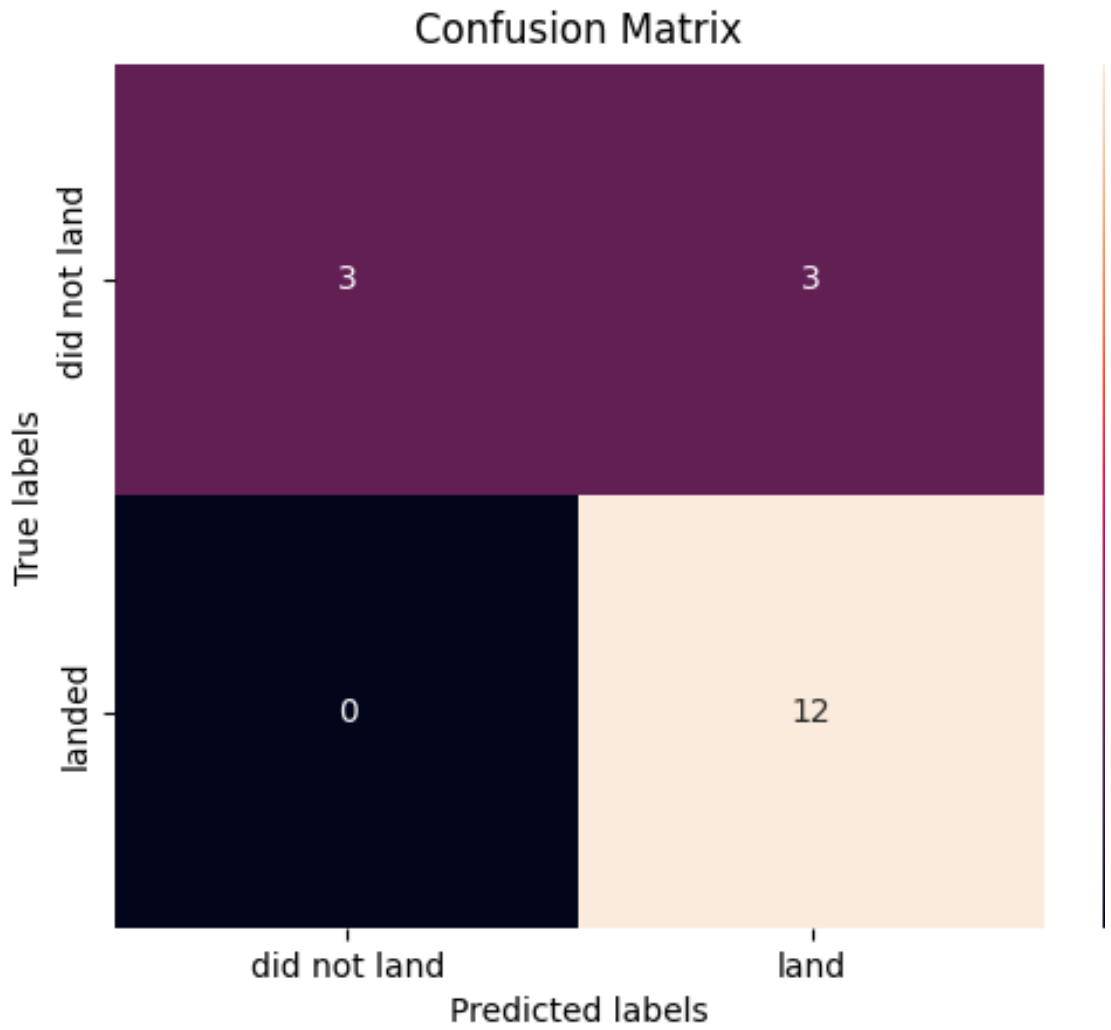
```
models = {'KNeighbors':knn_cv.best_score_,
          'DecisionTree':tree_cv.best_score_,
          'LogisticRegression':logreg_cv.best_score_,
          'SupportVector': svm_cv.best_score_}

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,
```

- 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

Confusion Matrix

- Performance Summary
- A confusion matrix summarizes the performance of a classification algorithm
- All the confusion matrices were identical
- The fact that there are false positives (Type 1 error) is not good
- Confusion Matrix Outputs:
    - 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



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 5,500kg
- 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

Conclusions

Things to Consider

- Dataset: A larger dataset will help build on the predictive analytics results to help understand if the findings can be generalizable to a larger data set
- Feature Analysis / PCA: Additional feature analysis or principal component analysis should be conducted to see if it can help improve accuracy
- XGBoost: Is a powerful model which was not utilized in this study. It would be interesting to see if it outperforms the other classification models

Thank you!