Winning Space Race with Data Science

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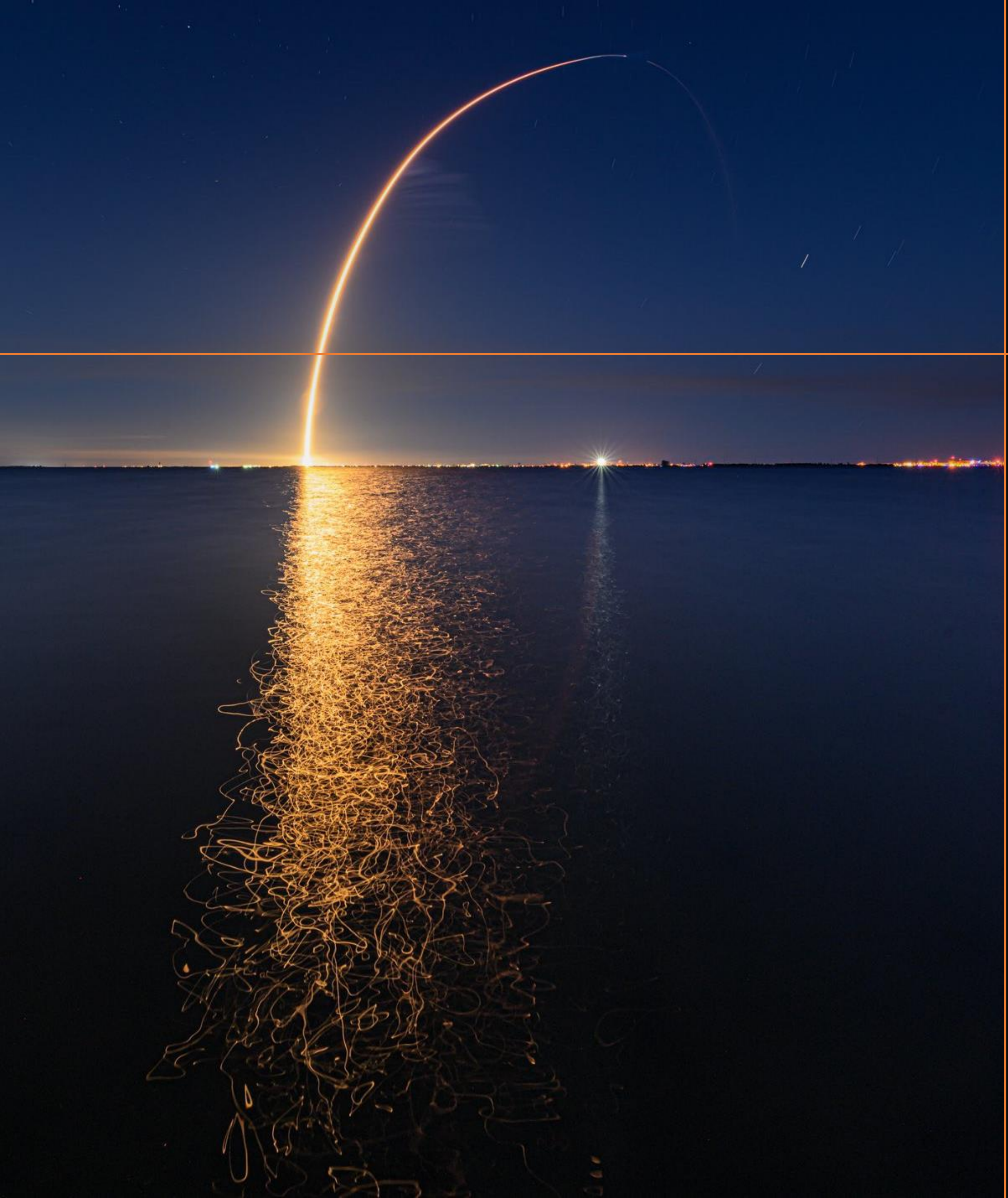
30/09/2023

IBM Developer SKILLS NETWORK



Outline

- Executive Summary
- Introduction
- Methodology
- Results
- Conclusion

Executive Summary

Summary of methodologies

The research attempts to identify the factors for a successful rocket landing. To make this determination, the following methodologies where 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, considering the following factors: payload, launch site, flight number and yearly trend,
- ✓ Analyze the data with SQL, calculating the following statistics: total payload, payload range for successful launches, and total # of successful and failed outcomes,
- ✓ Explore launch site success rates and proximity to geographical markers,
- ✓ 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 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

Visualization / Analytics:

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

Predictive Analytics

All models performed similarly on the test set. The decision tree model slightly outperformed

Introduction

Background

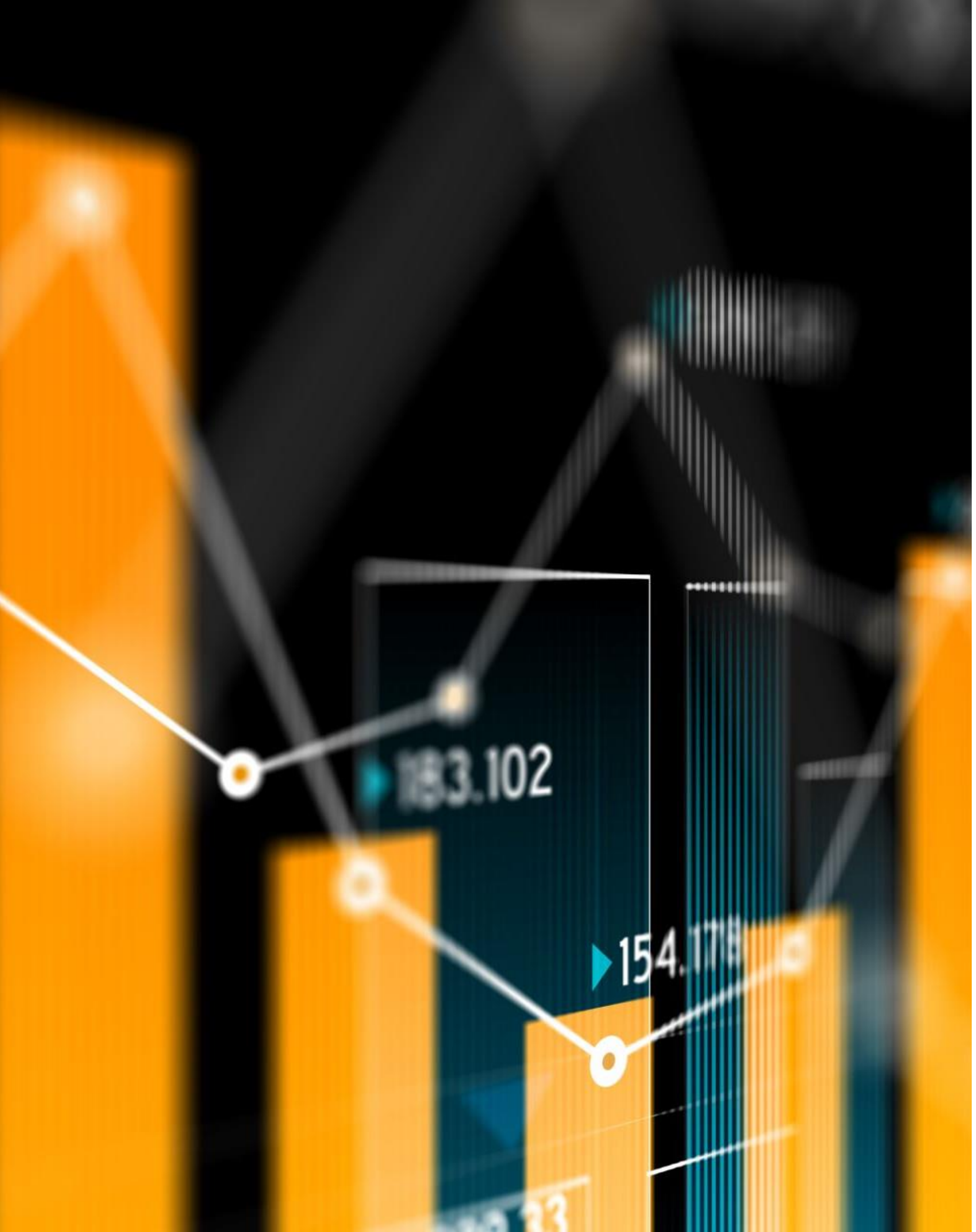
SpaceX, a leader in the space industry, strives to make space travel affordable for everyone. Its accomplishments include sending spacecraft to the international space station, launching a satellite constellation that provides internet access and sending manned missions to space. SpaceX can do this because the rocket launches are relatively inexpensive ($62 million per launch) due to its novel reuse of the first stage of its Falcon 9 rocket. Other providers, which are not able to reuse the first stage, cost upwards of $165 million each. By determining if the first stage will land, we can determine the price of the launch. To do this, we can use public data and machine learning models to predict whether SpaceX – or a competing company – can reuse the first stage.

Explore

- How payload mass, launch site, number of flights, and orbits affect first-stage landing success
- Rate of successful landings over time
- Best predictive model for successful landing (binary classification)
- Problems you want to find answers

Section 1

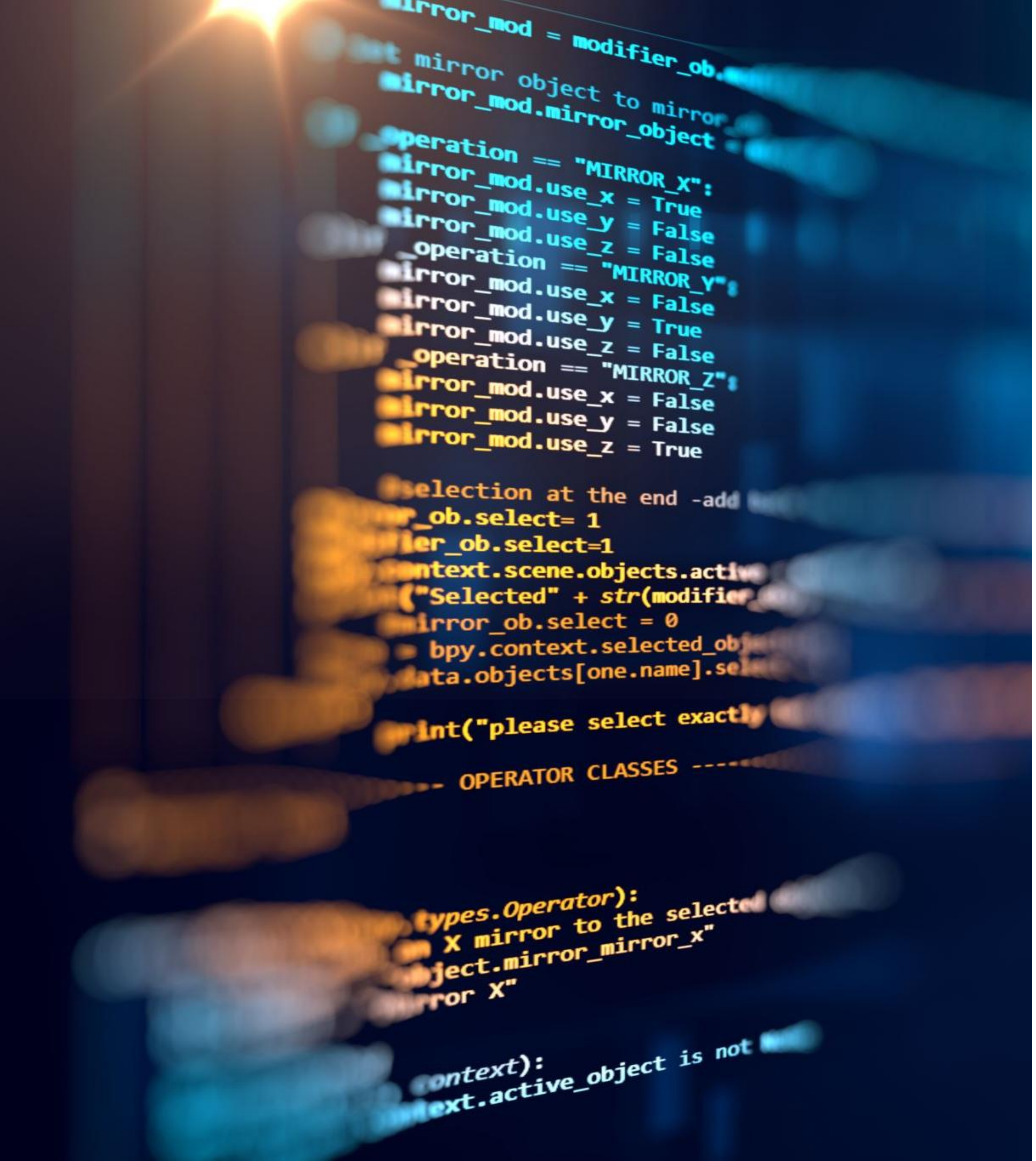
Methodology



Methodology

Steps

- Collect data using SpaceY REST API and web scraping techniques
- Wrangle data –by filtering the data, handling missing values and applying one hot encoding –to prepare the data for analysis and modeling
- Explore data via EDA with SQL and data visualization techniques
- Visualize the data using Folium and Plotly Dash
- Build Models to predict landing outcomes using classification models. Tune and ecaluate models to find best model and parametes



Data Collection

Steps

- 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

Data Collection – SpaceX API

Request	• Request data (Falcon 9 launch data) from Wikipedia
Create	• Create BeautifulSoup object from HTML response
Extract	• Extract column names from HTML table header
Collect	• Collect data from parsing HTML tables
Create	• Create dictionary from the data
Create	• Create dataframe from the dictionary
Export	• Export data to csv file
Add	• Add the GitHub URL of the completed SpaceX API calls notebook (must include completed code cell and outcome cell), as an external reference and peer-review purpose

Data Wrangling

- Steps
- Perform EDA and determing data lables
- 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)
- 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 the ocean

True RTLS: meant the mission had a successful landing on a ground pad

Fals RTLS: represented an unsuccessful landing on a ground pad

True ASDS: meant the mission outcoume had a successful landing on a drone ship

False ASDS: represented a unsuccessful landing on drone ship

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. Orbit Type

Analysis

- View relationship by using scatter plots. The variable could be useful for machin 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

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 NAS (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 4000 but less than 6000
- Total number of successful and failed missions
- Names of booster version 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 2010-006-04 and 2017-03-20 (desc)

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

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

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 Summary

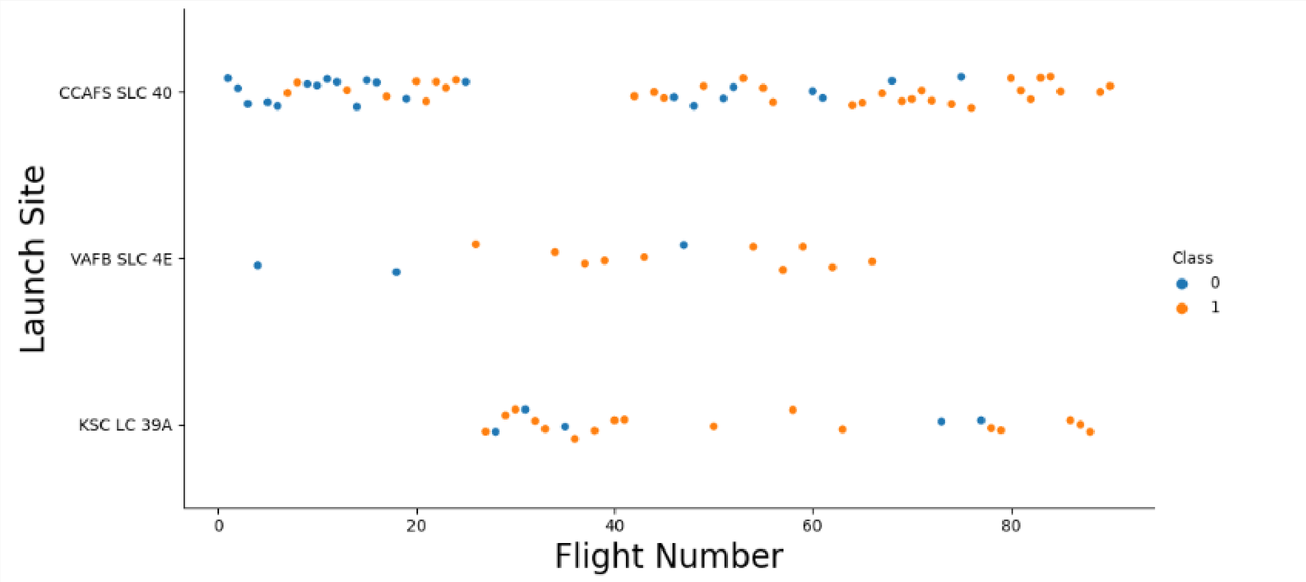
ExploratoryData Analysis
Launch success has improved over time
KSC LC-39A has the highest success rate among landing sites
Orbits ES-L1, GEO, HEO and SSO have a 100% success rate

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 still 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

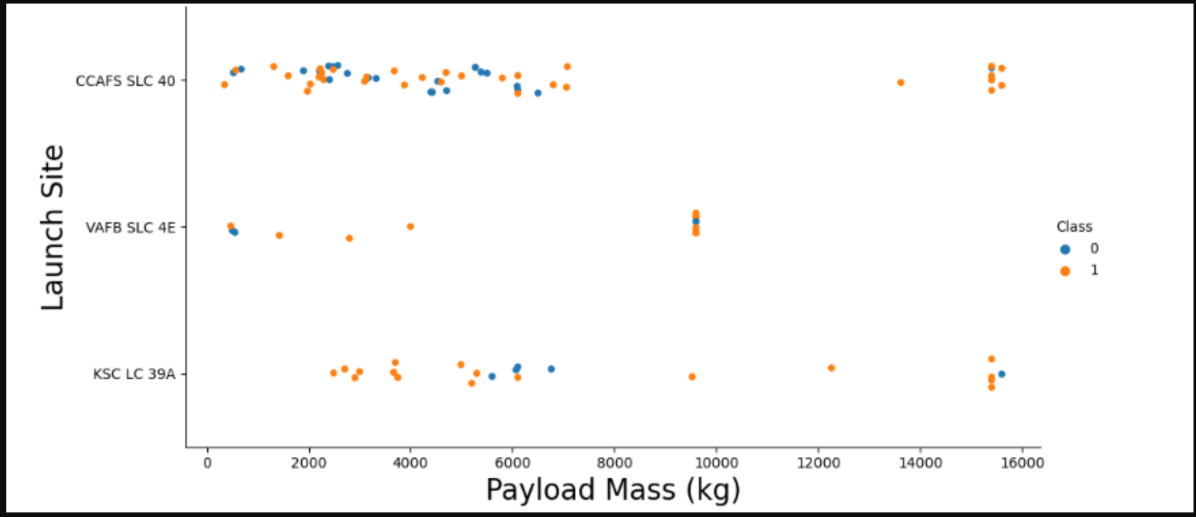


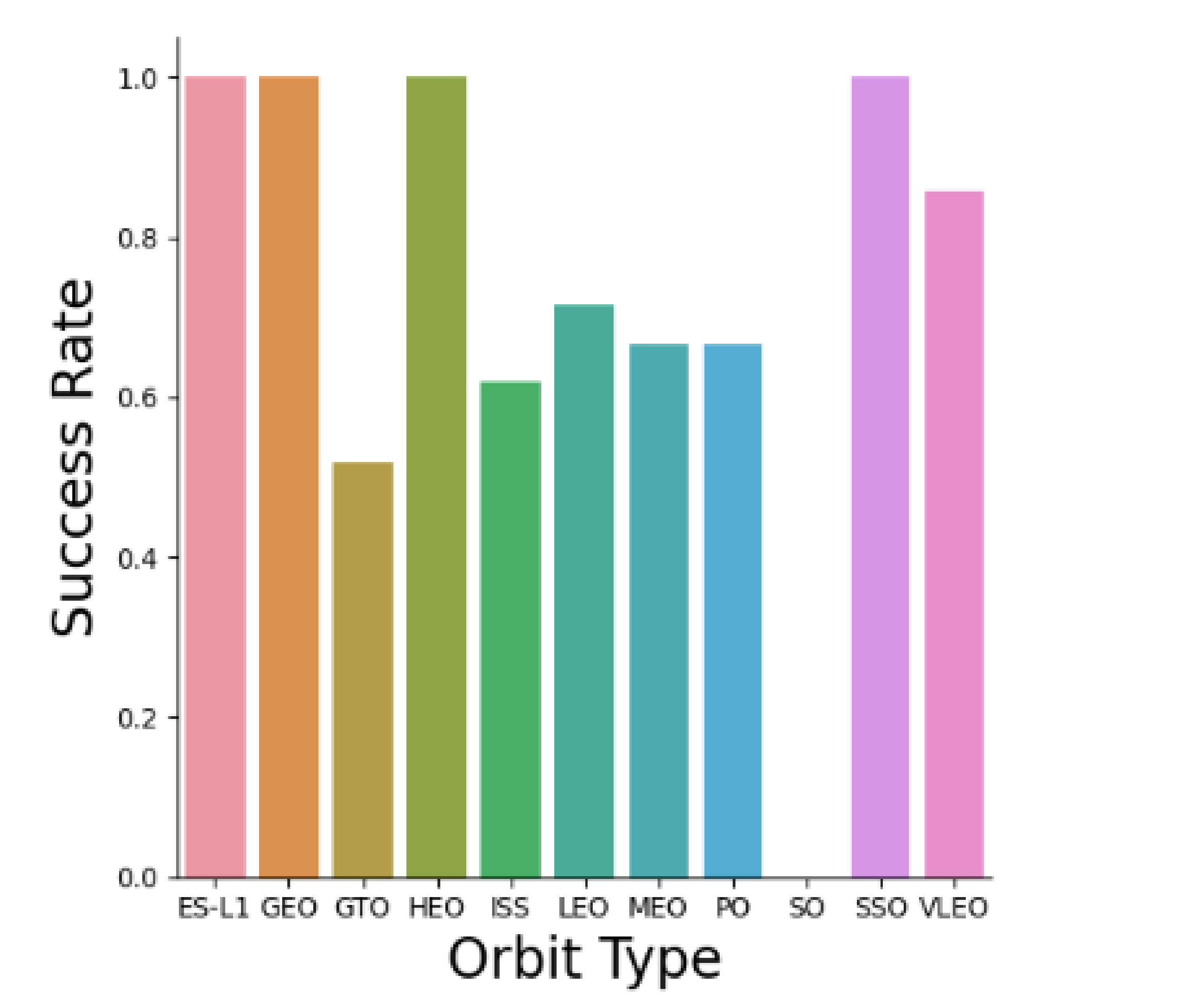
Flight Number vs. Launch Site

- **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



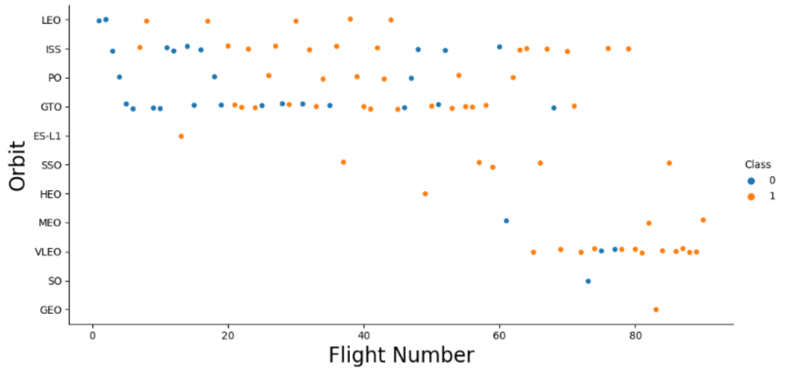


Success Rate vs. Orbit Type

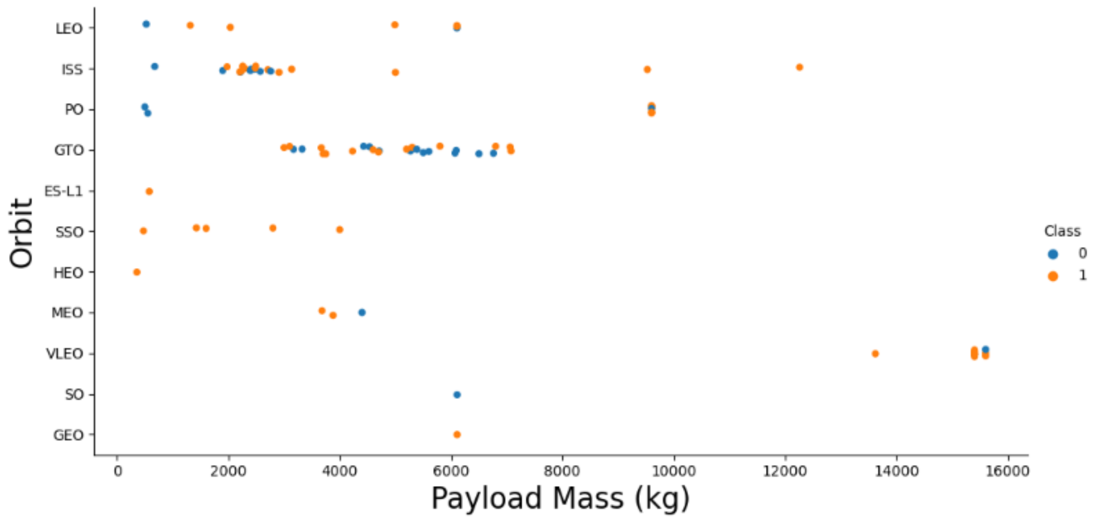
- **Exploratory Data Analysis**
- **100% Success Rate**: ES-L1, GEO, HEO and SSO
- **50%-80% Success Rate**: GTO, ISS, LEO, MEO, PO
- **0% Success Rate**: SO

Flight Number vs. Orbit Type

- 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



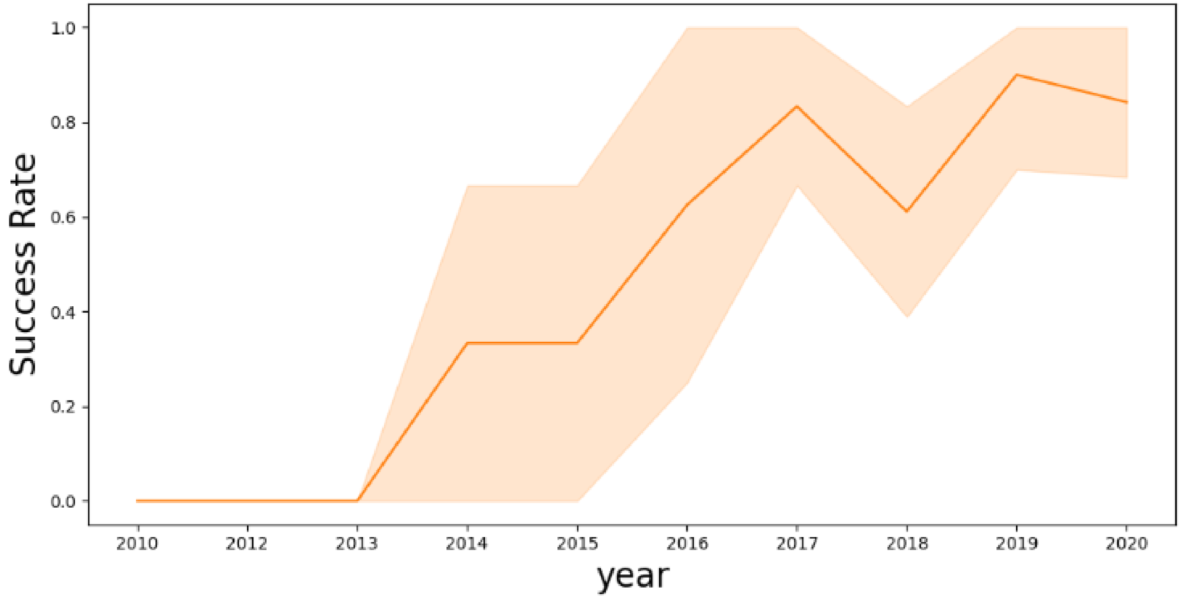
Exploratory Data Analysis

- 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

- **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-4l
   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

Landing & Mission Info

- **1st Successful Landing in Ground Pad**
- 12/22/2015

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

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

1
2015-12-22

- **Booster Drone Ship Landing**
- Booster mass greater than 4,000 but less than 6,000
- •JSCAT-14, JSCAT-16, SES-10, SES-11 / 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 Failed Mission Outcomes**
- 1 Failure in Flight
- 99 Success
- 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

- **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

```
%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)

In 2015

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

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

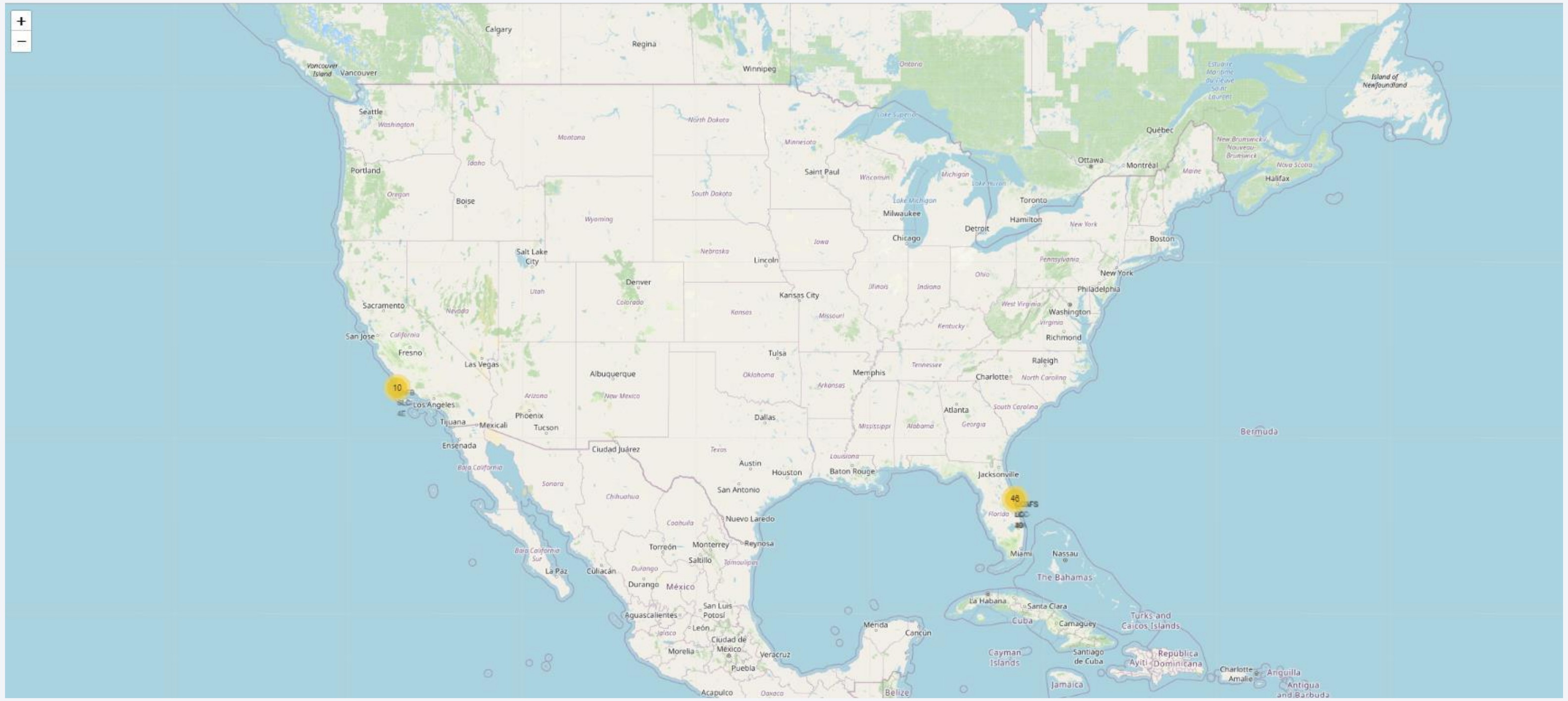
Section 3

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

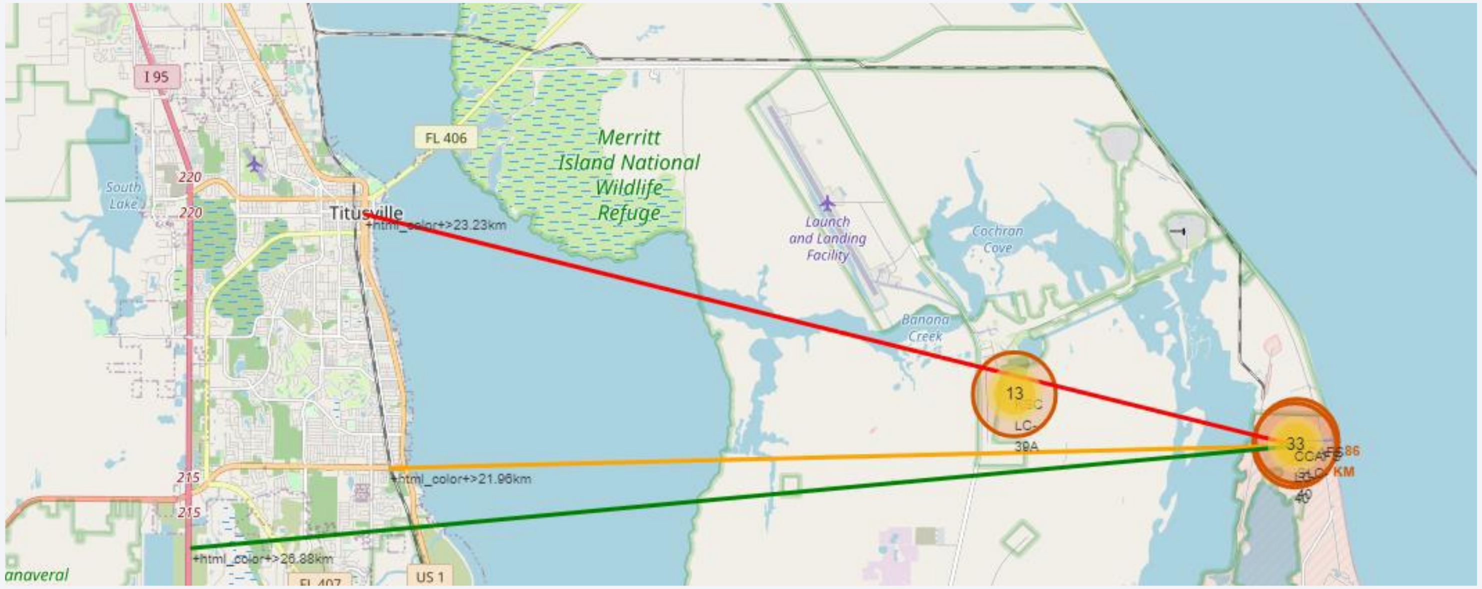
RED MARKERS FOR UNSUCCESSFUL LAUNCHES

LAUNCH SITE **CCAFS SLC-40** HAS A **3/7 SUCCESS RATE (42.9%)**

Distance to Proximities

- **CCAFS SLC-40**
- **.86 km** from nearest coastline
- **21.96 km** from nearest railway
- **23.23 km** from nearest city
- **26.88 km** from nearest highway

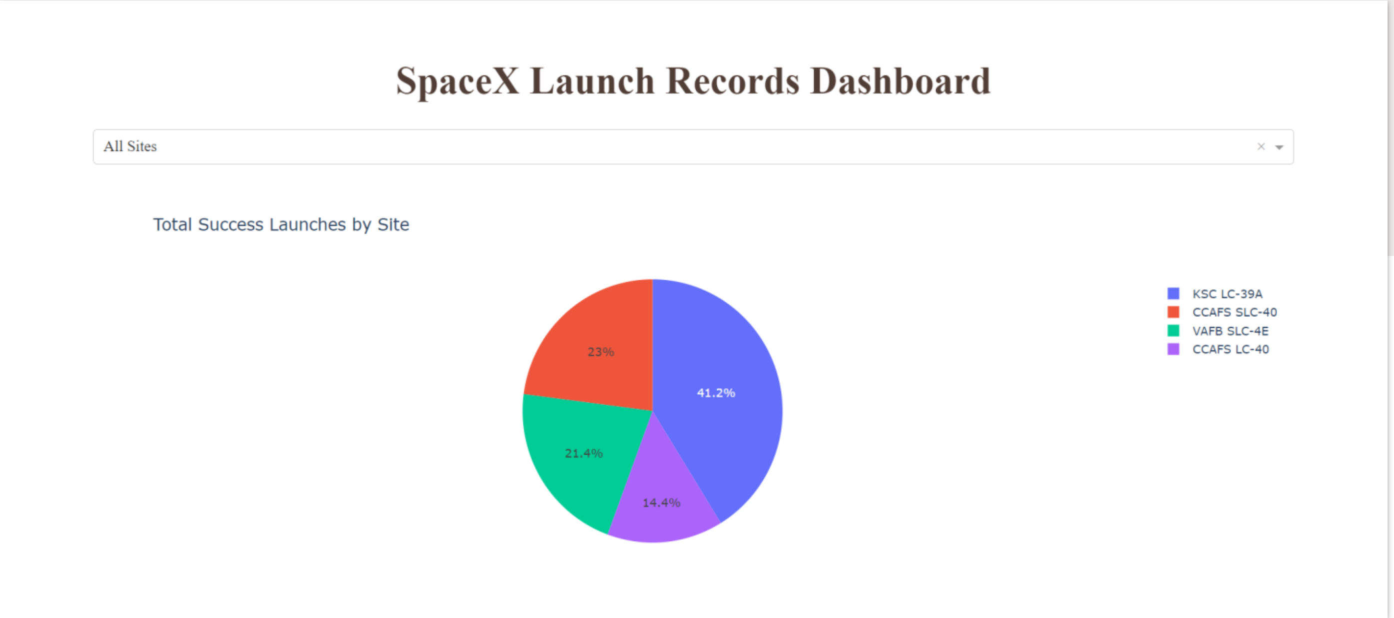
- **Coasts**: help ensure that spent stages dropped along the launch path or failed launches don't fall on people or property.
- **Safety / Security:** needs to be an exclusion zone around the launch site to keep unauthorized people away and keep people safe.
- **Transportation/Infrastructure and Cities**: 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

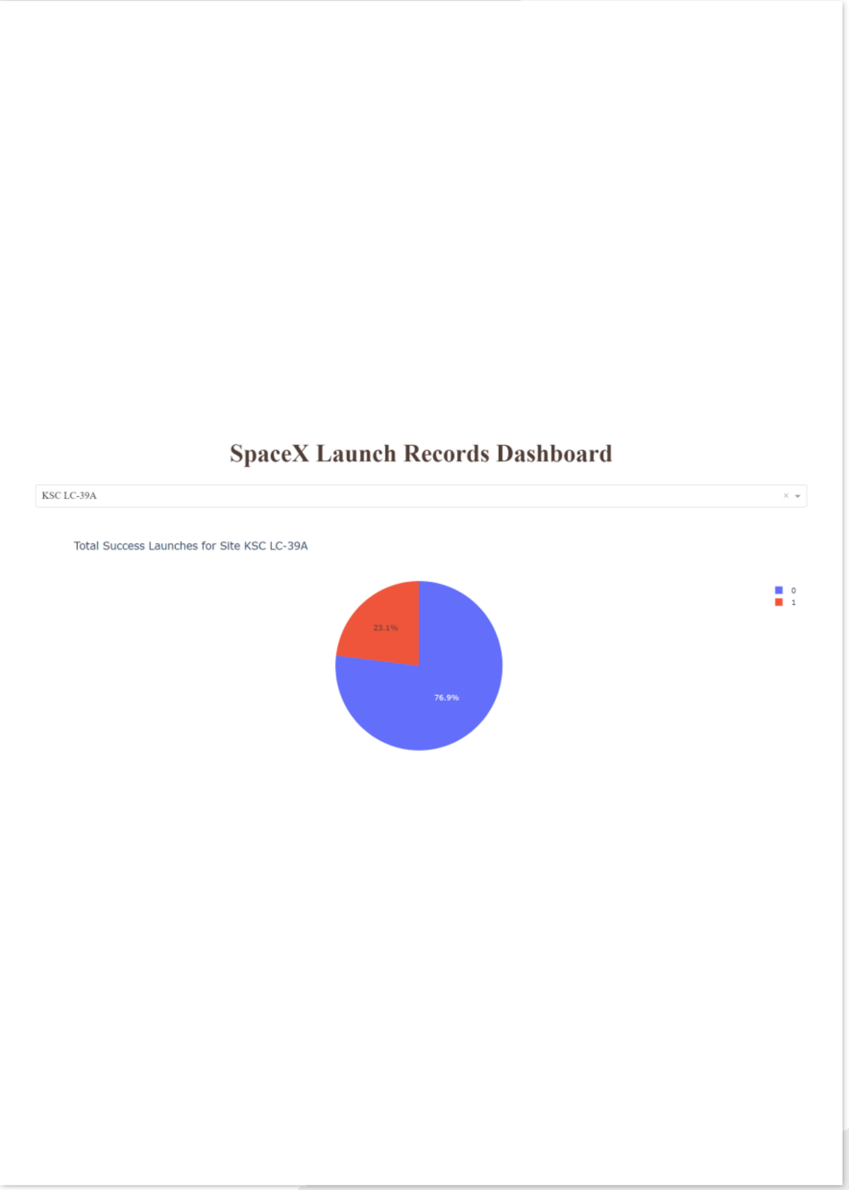
Launch Success by Site



- **Success as Percent of Total**
- **KSC LC-39A** has the **most successful launches** amongst launch sites (**41.2%**)

Launch Success (KSC LC-29A)

- **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 between2,000 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**
- **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 modelslightly outperformed** the restwhenlookingat.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 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

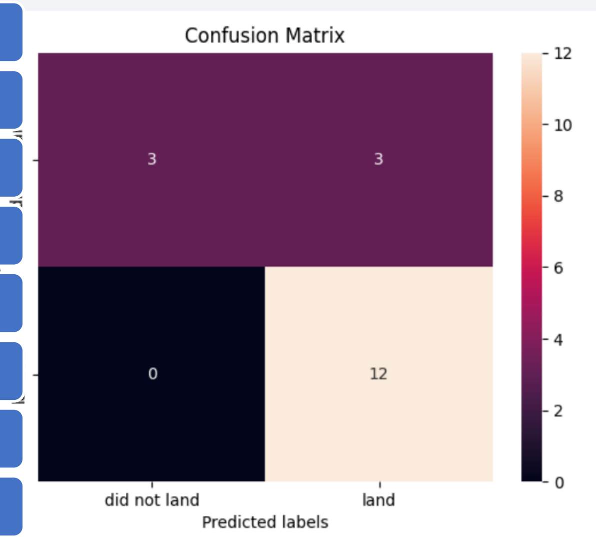
0 False Negative

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



Conclusion

Research

Equator: Most of the launch sites are near the equator for an additional natural boost -due to the rotational speed of earth -whichhelps save the cost of putting in extra fuel and boosters

Launch Success: Increases over time

Orbits: ES-L1, GEO, HEO, and SSO have a 100% success rate

Model Performance: The models performed similarly on the test set with the decision tree model slightly outperforming

Coast: All the launch sites are close to the coast

KSC LC-39A: Has the highest success rate among launch sites. Has a 100% success rate for launches less than 5,500 kg

Payload Mass: Across all launch sites, the higher the payload mass (kg), the higher the success rate

- **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!