Data Science Capstone Project

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GitHub URL:
https://github.com/amruthkarun/IBM-Data-Science-Assignment

Outline:

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

Executive Summary

- This project uses data gathered from the public SpaceX API and the SpaceX Wikipedia page. A 'class' label column is added to show successful landings. This data is explored using SQL, visualization tools plotly, matplotlib, folium maps, and dashboards. Collected pertinent columns for usage as features. Using one-hot encoding, all categorical variables were converted to binary. GridSearchCV was used to discover the best parameters for machine learning models using standardized data. The accuracy score of all models is visualized.

- Logistic Regression, Support Vector Machine, Decision Tree Classifier, and K Nearest Neighbors models are trained on the cleaned dataset. All the above mentioned models produced similar results with an accuracy of about 83%. There were some false predictions for successful landings. More data and analysis is needed to produce a model with better performance and accuracy.

Introduction

Background:

- In this commercial space age SpaceX's competitive advantages in reusable rockets, cost-efficiency, and their long-term goals.
- SpaceX has cutting edge space technology and huge financial resources.
- SpaceX has a competitive pricing of 62 million in its medium-lift Falcon 9 rocket.
- SpaceY wants to compete with SpaceX in

Problem Statement:

- The task is to train a machine learning model to predict successful Stage 1 recovery

Methodology

- Data collection methodology:
  - Combined data from SpaceX public API and SpaceX Wikipedia page

- Perform data wrangling
  - True landings are classified as either successful or unsuccessful.

- Perform exploratory data analysis (EDA) using visualization and SQL

- Perform interactive visual analytics using Folium and Plotly Dash

- Perform predictive analysis using classification models
  - Tuned machine learning models using GridSearchCV

Methodology

- OVERVIEW OF DATA COLLECTION

- WRANGLING

- VISUALIZATION

- DASHBOARD

- MODEL METHODS

Data Collection Overview

The data was gathered through a combination of API queries to Space X's public API and web scraping data from a table in Space X's Wikipedia entry.

The following slide will demonstrate the flowchart of data collection from API, followed by the flowchart of data collection from webscraping.
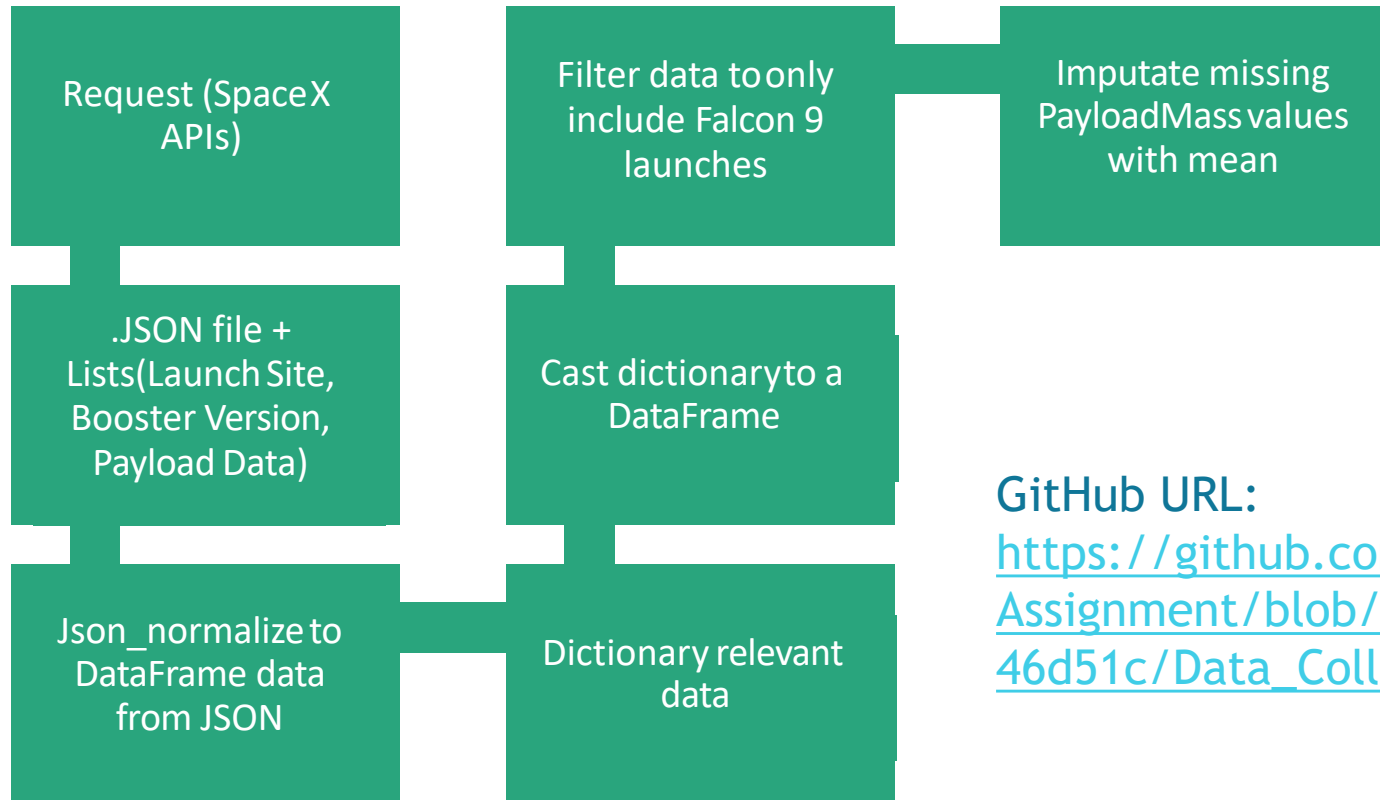
Space X API Data Columns:

FlightNumber, Date, BoosterVersion, PayloadMass, Orbit, LaunchSite, Outcome, Flights, GridFins, Reused, Legs, LandingPad, Block, ReusedCount, Serial, Longitude, Latitude

Wikipedia Webscrape Data Columns:

Flight No., Launch site, Payload, PayloadMass, Orbit, Customer, Launch outcome, Version Booster, Booster landing, Date, Time
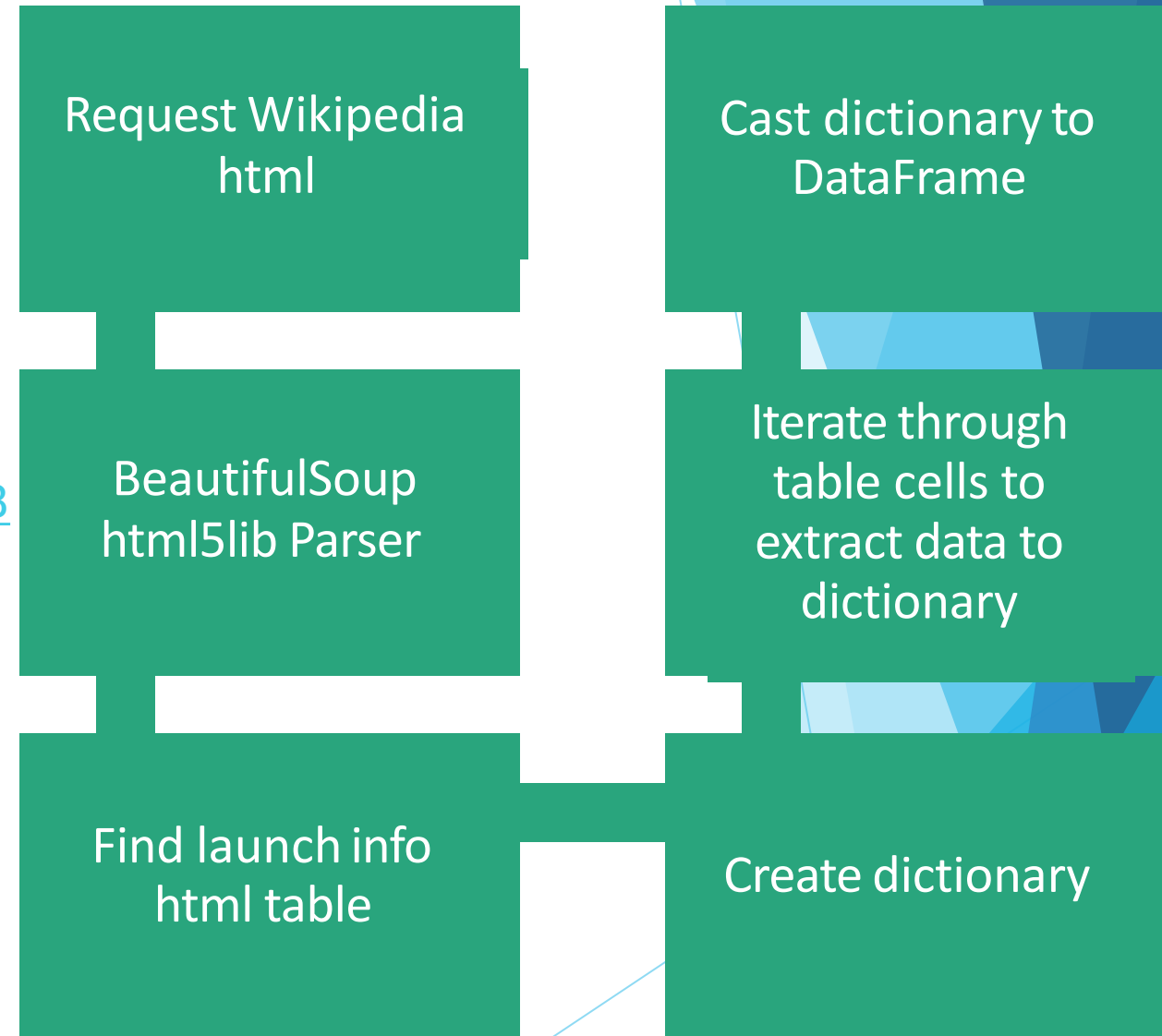
Data Collection – SpaceX API

Request (SpaceX APIs)

.JSON file + Lists(Launch Site, Booster Version, Payload Data)

Json_normalize to DataFrame data from JSON

Filter data to only include Falcon 9 launches

Cast dictionary to a DataFrame

Dictionary relevant data

Imputate missing PayloadMass values with mean

GitHub URL:
https://github.com/amruthkarun/IBM-Data-Science-Assignment/blob/f42aea7e20e76a2f765ceb765798d8cc76 46d51c/Data_Collection_API.ipynb

Data Collection – Web Scraping

GitHub URL:
https://github.com/amruthkarun/IBM-Data-Science-Assignment/blob/1e94142a016b78af633e99c4f2e8f4b063dd26de/Data_Collection_With_Web_Scraping.ipynb

Request Wikipedia html

BeautifulSoup html5lib Parser

Find launch info html table

Cast dictionary to DataFrame

Iterate through table cells to extract data to dictionary

Create dictionary

Data Wrangling

❖ Create a training label with landing outcomes where successful = 1 & failure = 0.

❖ Outcome column has two components: 'Mission Outcome' 'Landing Location'

❖ New training label column 'class' with a value of 1 if 'Mission Outcome' is True and 0 otherwise.

Value Mapping:

❖ True ASDS, True RTLS, & True Ocean – set to -> 1

❖ None None, False ASDS, None ASDS, False Ocean, False RTLS – set to -> 0

GitHub URL: https://github.com/amruthkarun/IBM-Data-Science-Assignment/blob/330a24e3d003cd563506e16d5d2fd2ee4dfea9f1/Data_Wrangling.ipynb

EDA with Data Visualization

Exploratory Data Analysis performed on variables Flight Number, Payload Mass, Launch Site, Orbit, Class and Year.

Plots Used:

Flight Number vs. Payload Mass, Flight Number vs. Launch Site, Payload Mass vs. Launch Site, Orbit vs. Success Rate, Flight Number vs. Orbit, Payload vs Orbit, and Success Yearly Trend

Scatter plots, line charts, and bar plots were used to compare relationships between variables to decide if a relationship exists so that they could be used in training the machine learning model

GitHub URL: https://github.com/amruthkarun/IBM-Data-Science-Assignment/blob/d907f147207d982e6103aecfe7577464e367066f/EDA_Visualization.ipynb

EDA with SQL

- Loaded data set into IBM DB2 Database.

- Queried using SQL Python integration.

- Queries were made to get a better understanding of the dataset.

- Queried information about launch site names, mission outcomes, various pay load sizes of customers and booster versions, and landing outcomes

GitHub URL: https://github.com/amruthkarun/IBM-Data-Science-Assignment/blob/e9d78bff0674bca82787d9393f4d675740e1ce4e/EDA_With_SQL.ipynb

Build an Interactive Map with Folium

- Folium maps mark Launch Sites, successful and unsuccessful landings, and a proximity example to key locations: Railway, Highway, Coast, and City.

- This allows us to understand why launch sites may be located where they are. Also visualizes successful landings relative to location.

GitHub URL:

https://github.com/amruthkarun/IBM-Data-Science-

Assignment/blob/053b92a52752804c10c3608d6cc5f33043398b2a/Build_Interactive_M

aps_with_Folium.ipynb

Build a Dashboard with Plotly Dash

- Dashboard includes a pie chart and a scatter plot.

- Pie chart can be selected to show distribution of successful landings across all launch sites and can be selected to show individual launch site success rates.

- Scatter plot takes two inputs: All sites or individual site and payload mass on a slider between 0 and 10000 kg.

- The pie chart is used to visualize launch site success rate.

- The scatter plot can help us see how success varies across launch sites, payload mass, and
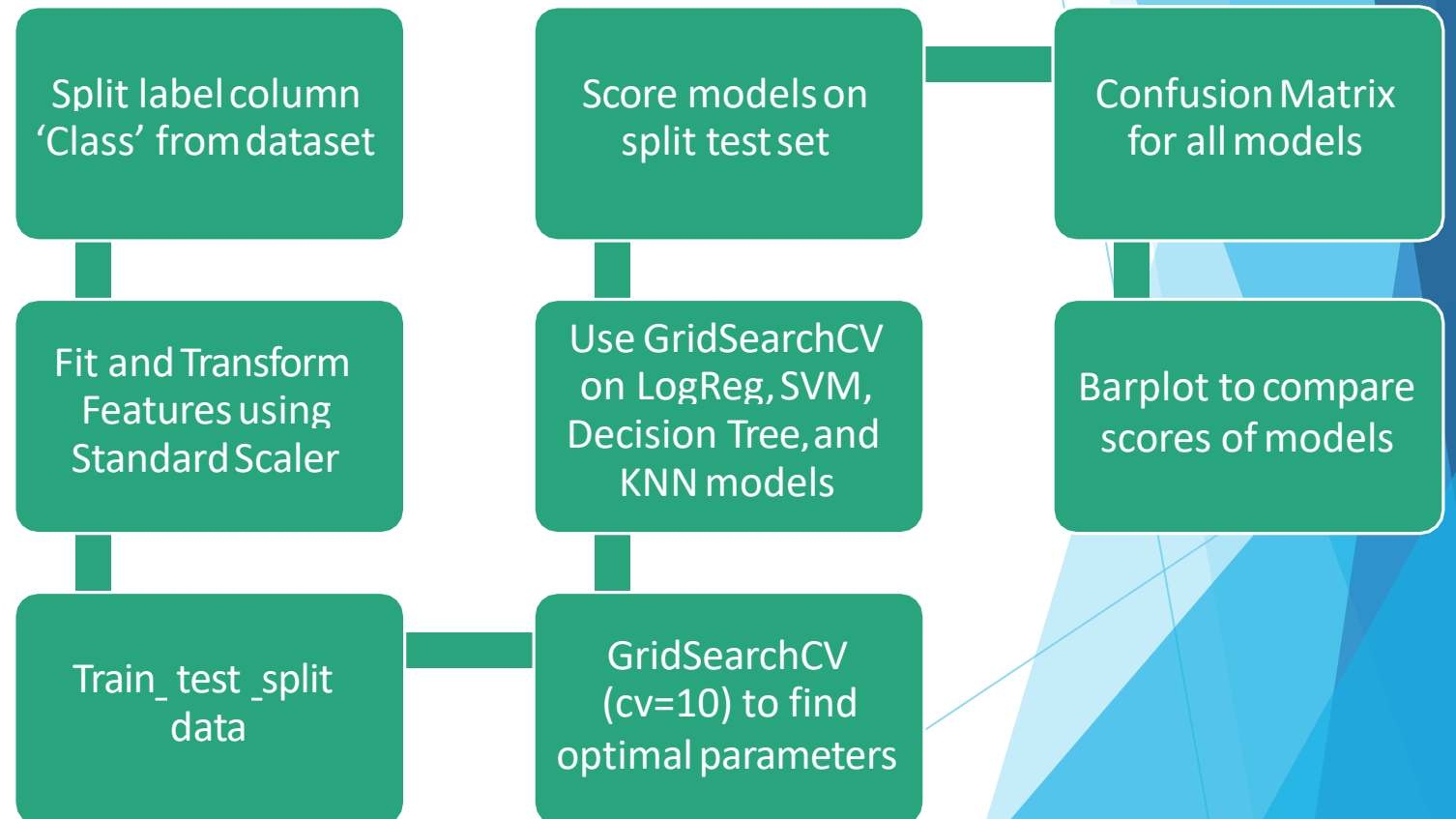- booster version category.

GitHub URL:

https://github.com/amruthkarun/IBM-Data-Science-

Assignment/blob/8f619b6d6ed6ad187baee12dc73befe0fb1a0c4f/spacex_dash_ap

p.py

Predictive analysis - Classification

GitHub URL:
https://github.com/amruthk
arun/IBM-Data-Science-
Assignment/blob/27e9b876f
38d74e36bebd90f44fbf22c9
e71c1d4/Machine_Learning_
Prediction.ipynb

Split label column 'Class' from dataset

Fit and Transform Features using Standard Scaler

Train_test_split data

GridSearchCV (cv=10) to find optimal parameters

Use GridSearchCV on LogReg, SVM, Decision Tree, and KNN models

Score models on split test set

Confusion Matrix for all models

Barplot to compare scores of models

Results:

This is a preview of the Plotly dashboard. The following sides will show the results of EDA with visualization, EDA with SQL, Interactive Map with Folium, and finally the results of our model with about 83% accuracy.
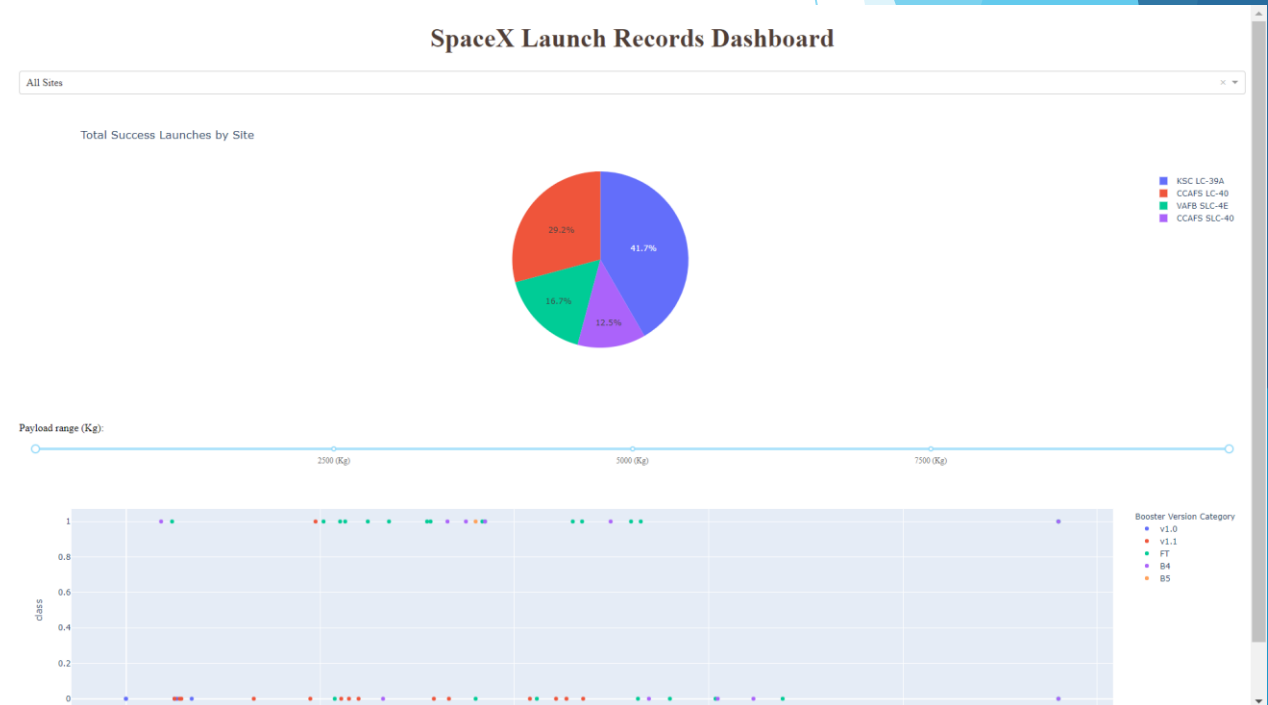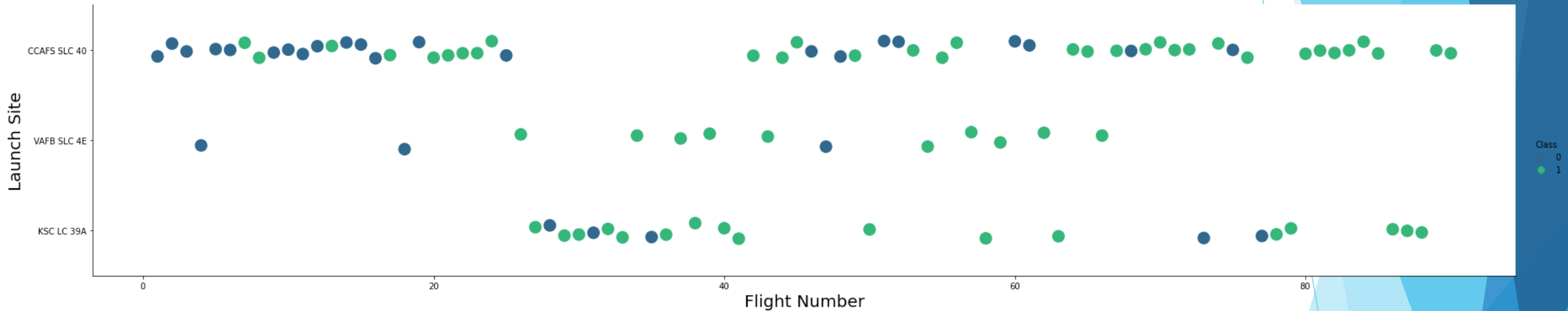
EDA with Visualization

EXPLORATORY DATA ANALYSIS WITH SEABORN PLOTS

Flight Number vs. Launch Site

Green indicates successful launch; Purple indicates unsuccessful launch.

Graphic suggests an increase in success rate over time (indicated in Flight Number).   Likely a big breakthrough around flight 20 which significantly increased success rate. CCAFS appears to be the main launch site as it has the most volume.
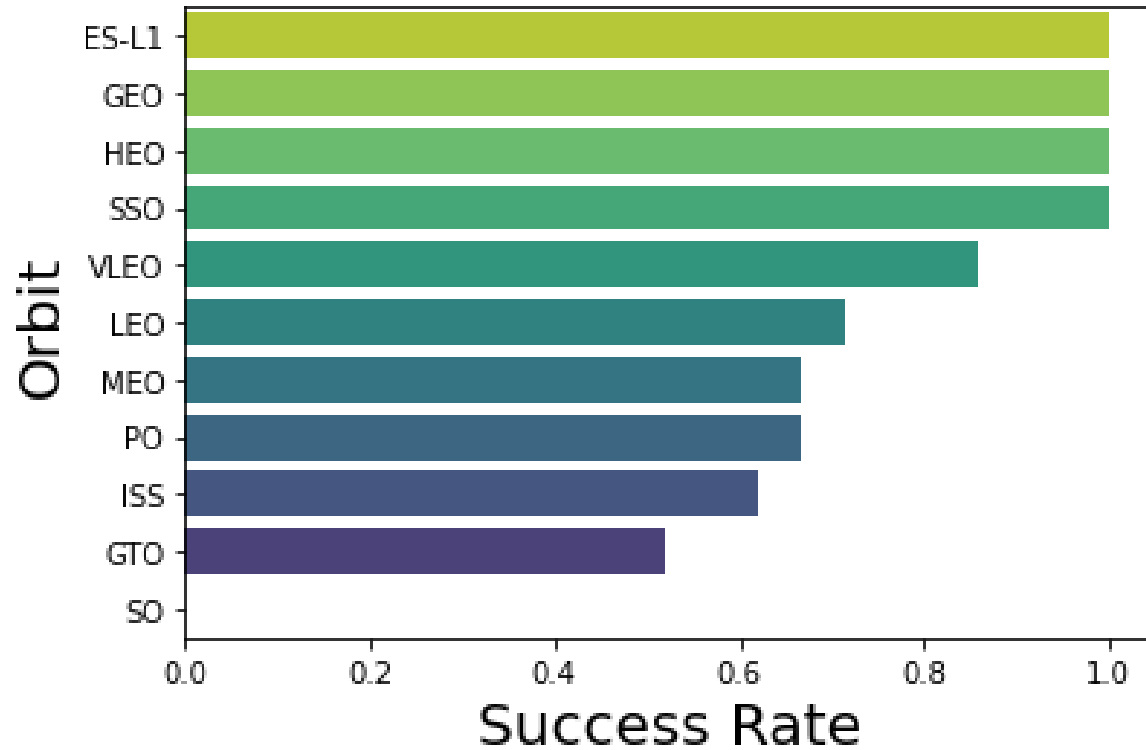
Payload vs. Launch Site
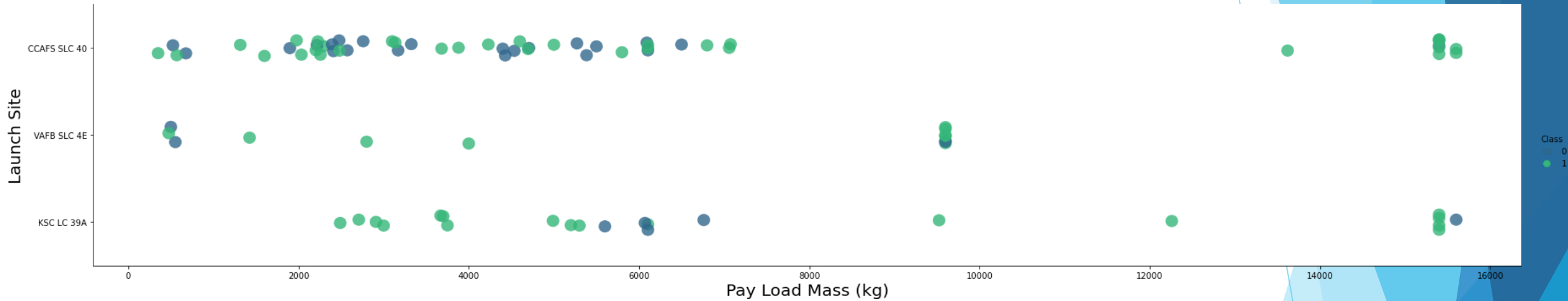
Green indicates successful launch; Purple indicates unsuccessful launch.

Payload mass appears to fall mostly between 0-6000 kg.

Different launch sites also seem to use different payload mass.
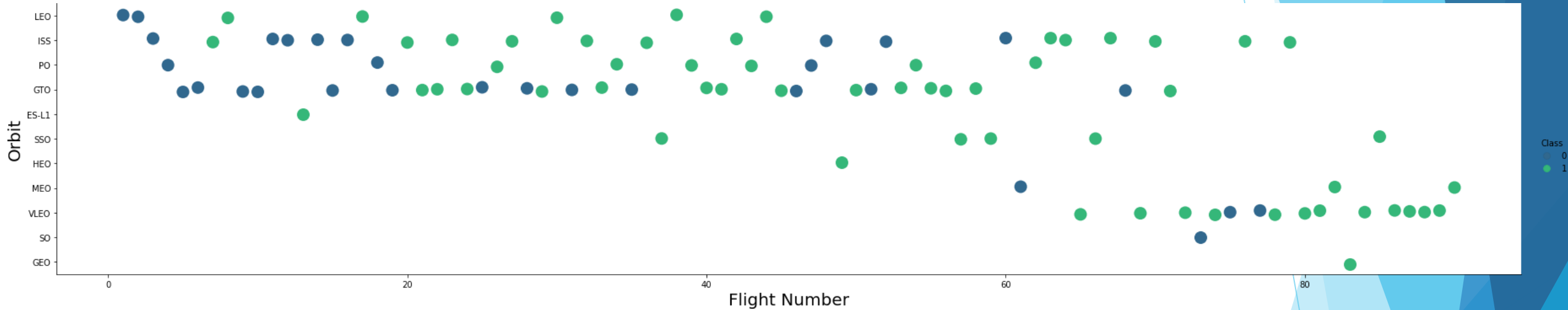
Success Rate vs. Orbit Type

Success Rate Scale
with 0 as 0%
0.6 as
60% 1
as 100%

ES-L1 (1), GEO (1), HEO (1) have 100% success rate (sample sizes in parenthesis)

SSO (5) has 100% success rate

VLEO (14) has decent success rate and attempts

SO (1) has 0% success rate

GTO (27) has the around 50% success rate but largest sample

Flight Number vs. Orbit Type

Green indicates successful launch; Purple indicates unsuccessful launch.

Launch Orbit preferences changed over Flight
Number. Launch Outcome seems to correlate with
this preference.
SpaceX started with LEO orbits which saw moderate success LEO and returned to VLEO in
recent launches SpaceX appears to perform better in lower orbits or Sun-synchronous orbits

Payload vs. Orbit Type
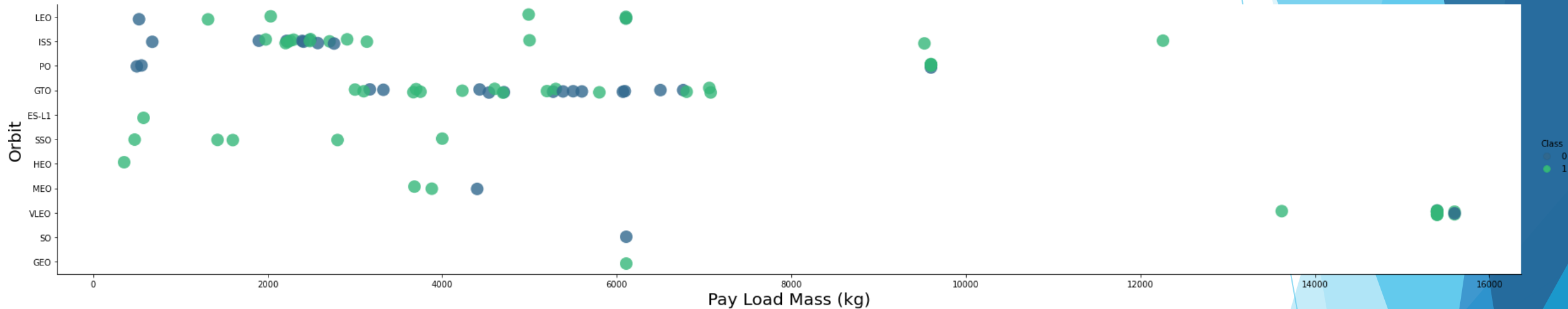
Green indicates successful launch; Purple indicates unsuccessful launch.

Payload mass seems to correlate with orbit

LEO and SSO seem to have relatively low payload mass

The other most successful orbit VLEO only has payload mass values in the higher end of the range

Launch Success Yearly Trend
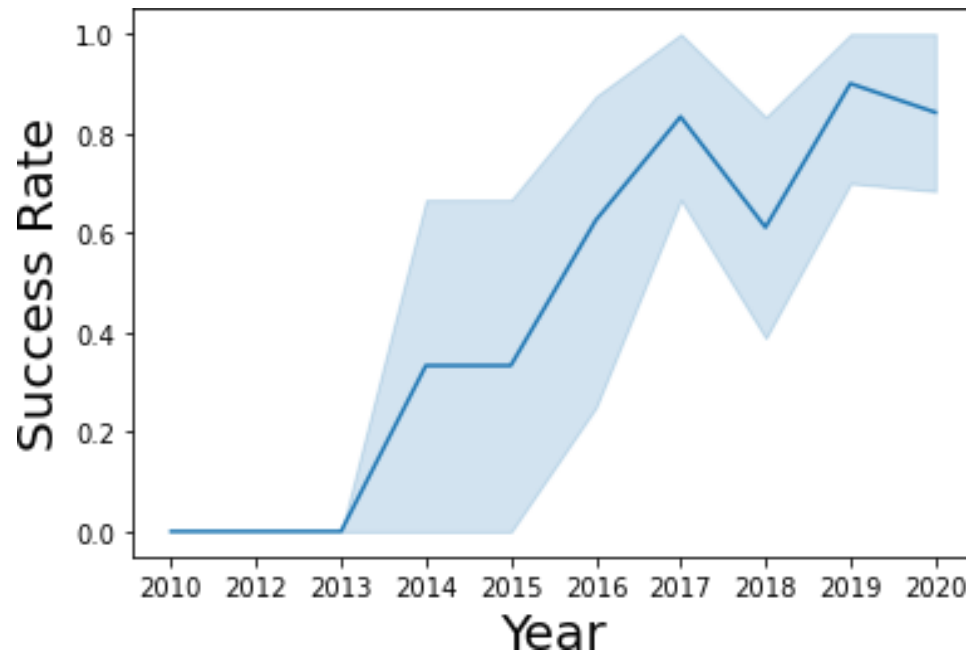
95% confidence interval (light blue shading)

Success generally increases over time since 2013 with a slight dip in 2018

Success in recent years at around 80%

EDA with SQL

EXPLORATORY DATA ANALYSIS WITH SQL DB2

INTEGRATED IN PYTHON WITH SQLALCHEMY

Launch Site Names

```
In [4]: %%sql
        SELECT UNIQUE LAUNCH_SITE
        FROM SPACEXDATASET;

         * ibm_db_sa://ftb12020:***@0c77d6f2
        Done.
```

Out[4]:

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

Query unique launch site names from database.

CCAFS SLC-40 and CCAFSSLC-40 likely all represent the same
launch site with data entry errors.

CCAFS LC-40 was the previous name.

Likely only 3 unique launch_site values:

CCAFS SLC-40, KSC LC-39A, VAFB

SLC-4E

Launch Site Names Beginning with `CCA`

```
In [5]: %%sql
        SELECT *
        FROM SPACEXDATASET
        WHERE LAUNCH_SITE LIKE 'CCA%'
        LIMIT 5;
```

  * ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
  Done.

Out[5]:

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

First five entries in database with Launch Site name beginning with CCA.

Total Payload Mass from NASA

```
%%sql
SELECT SUM(PAYLOAD_MASS__KG_) AS SUM_PAYLOAD_MASS_KG
FROM SPACEXDATASET
WHERE CUSTOMER = 'NASA (CRS)';
```

 * ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86
Done.

sum_payload_mass_kg
45596

This query sums the total payload mass in kg where NASA was the customer.

CRS stands for Commercial Resupply Services which indicates that these payloads were sent to the International Space Station (ISS).

Average Payload Mass by F9 v1.1

```
%%sql
SELECT AVG(PAYLOAD_MASS__KG_) AS AVG_PAYLOAD_MASS_KG
FROM SPACEXDATASET
WHERE booster_version = 'F9 v1.1'
```

 * ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86
Done.

avg_payload_mass_kg
2928

This query calculates the average payload mass or launches which used booster version F9 v1.1

Average payload mass of F9 1.1 is on the low end of our payload mass range

First Successful Ground Pad Landing Date

```
%%sql
SELECT MIN(DATE) AS FIRST_SUCCESS
FROM SPACEXDATASET
WHERE landing__outcome = 'Success (ground pad)';
```

 * ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81
Done.

first_success
2015-12-22

This query returns the first successful ground pad landing date.

First ground pad landing wasn't until the end of 2015.

Successful landings in general appear starting 2014.

Successful Drone Ship Landing with Payload Between 4000 and 6000

```
%%sql
SELECT booster_version
FROM SPACEXDATASET
WHERE landing__outcome = 'Success (drone ship)' AND payload_mass__kg_ BETWEEN 4001 AND 5999;
```

 * ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.database
Done.

booster_version
F9 FT B1022
F9 FT B1026
F9 FT B1021.2
F9 FT B1031.2

This query returns the four booster versions that had successful drone ship landings and a payload mass between 4000 and 6000 noninclusively.

Total Number of Each Mission Outcome

```
%%sql
SELECT mission_outcome, COUNT(*) AS no_outcome
FROM SPACEXDATASET
GROUP BY mission_outcome;
```

 * ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-
Done.

mission_outcome	no_outcome
Failure (in flight)	1
Success	99
Success (payload status unclear)	1

- This query returns a count of each
- mission outcome.

- SpaceX appears to achieve its mission outcome nearly 99% of the time.

- This means that most of the landing
- failures are intended.

- Interestingly, one launch has an unclear payload status and unfortunately one failed in flight.

Boosters that Carried Maximum Payload

```
%%sql
SELECT booster_version, PAYLOAD_MASS__KG_
FROM SPACEXDATASET
WHERE PAYLOAD_MASS__KG_ = (SELECT MAX(PAYLOAD_MASS__KG_) FROM SPACEXDATASET);
```

 * ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1
Done.

booster_version	payload_mass__kg_
F9 B5 B1048.4	15600
F9 B5 B1049.4	15600
F9 B5 B1051.3	15600
F9 B5 B1056.4	15600
F9 B5 B1048.5	15600
F9 B5 B1051.4	15600
F9 B5 B1049.5	15600
F9 B5 B1060.2	15600
F9 B5 B1058.3	15600
F9 B5 B1051.6	15600
F9 B5 B1060.3	15600
F9 B5 B1049.7	15600

- This query returns the booster versions that carried the highest payload mass of 15600 kg.

- These booster versions are very similar, and all are of the F9 B5 B10xx.x variety.

- This likely indicates payload mass correlates with the booster version that is used.

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2015 Failed Drone Ship Landing Records

```
%%sql
SELECT MONTHNAME(DATE) AS MONTH, landing__outcome, booster_version, PAYLOAD_MASS__KG_, launch_site
FROM SPACEXDATASET
WHERE landing__outcome = 'Failure (drone ship)' AND YEAR(DATE) = 2015;
```

 * ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.app
Done.

MONTH	landing__outcome	booster_version	payload_mass__kg_	launch_site
January	Failure (drone ship)	F9 v1.1 B1012	2395	CCAFS LC-40
April	Failure (drone ship)	F9 v1.1 B1015	1898	CCAFS LC-40

- This query returns the Month, Landing Outcome, Booster Version, Payload Mass (kg), and Launch site of 2015 launches where stage 1 failed to land on a drone ship.

- There were two such occurrences.

Ranking Counts of Successful Landings Between 2010-06-04 and 2017-03-20

```
%%sql
SELECT landing__outcome, COUNT(*) AS no_outcome
FROM SPACEXDATASET
WHERE landing__outcome LIKE 'Succes%' AND DATE BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY landing__outcome
ORDER BY no_outcome DESC;
```

 * ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg
Done.

landing__outcome	no_outcome
Success (drone ship)	5
Success (ground pad)	3

- This query returns a list of successful landings and between 2010-06-04 and 2017-03-20 inclusively.

- There are two types of successful landing outcomes: drone ship and ground pad landings.

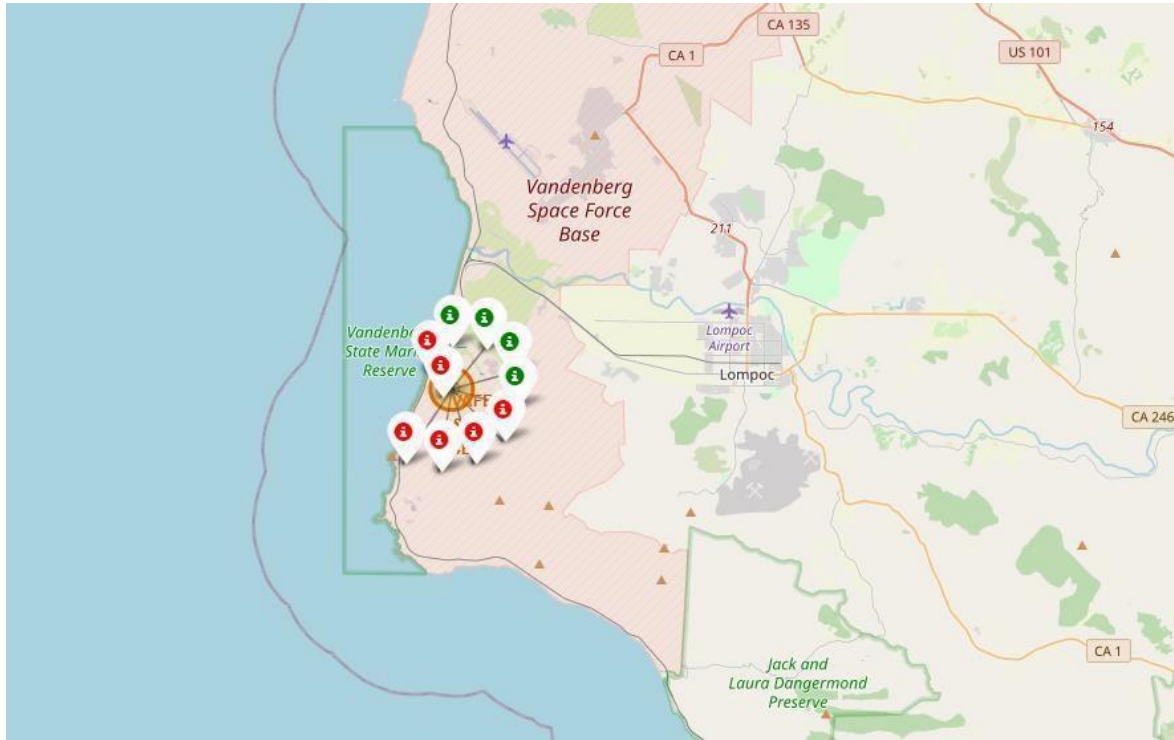- There were 8 successful landings in total during this

  time period

Interactive Maps with Folium

Launch Site Locations
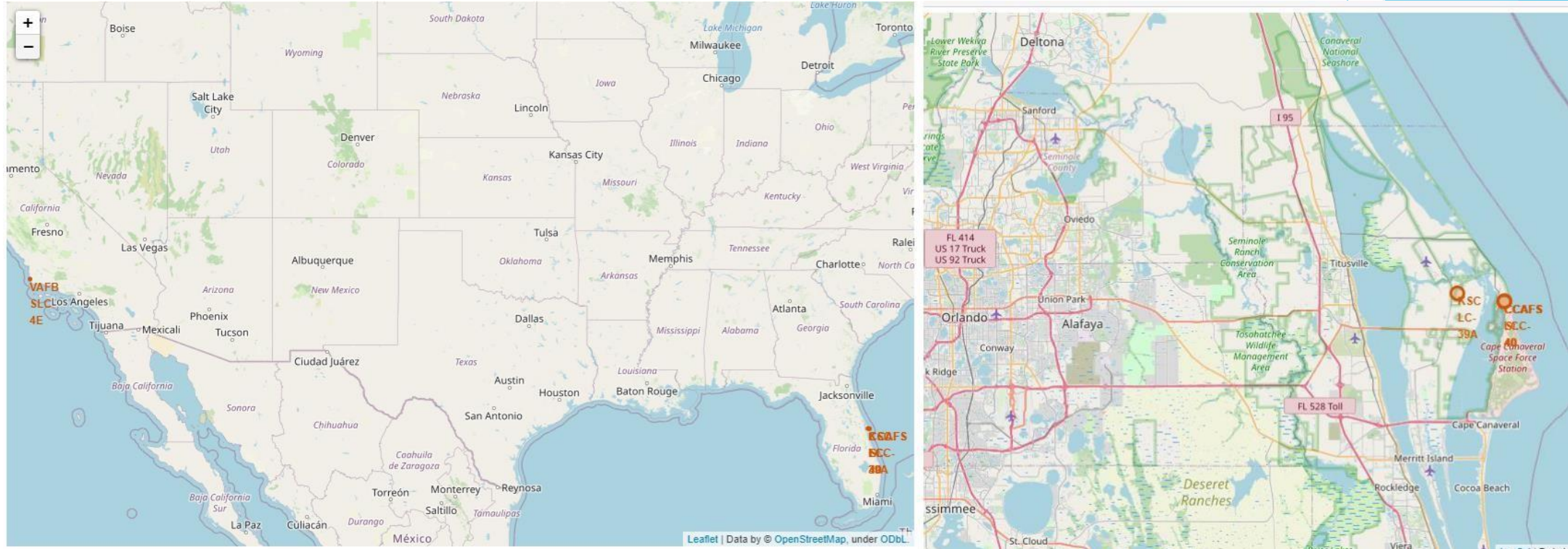
- The left map shows all launch sites relative US map. The right map shows the two Florida launch sites since they are very close to each other. All launch sites are near the ocean.
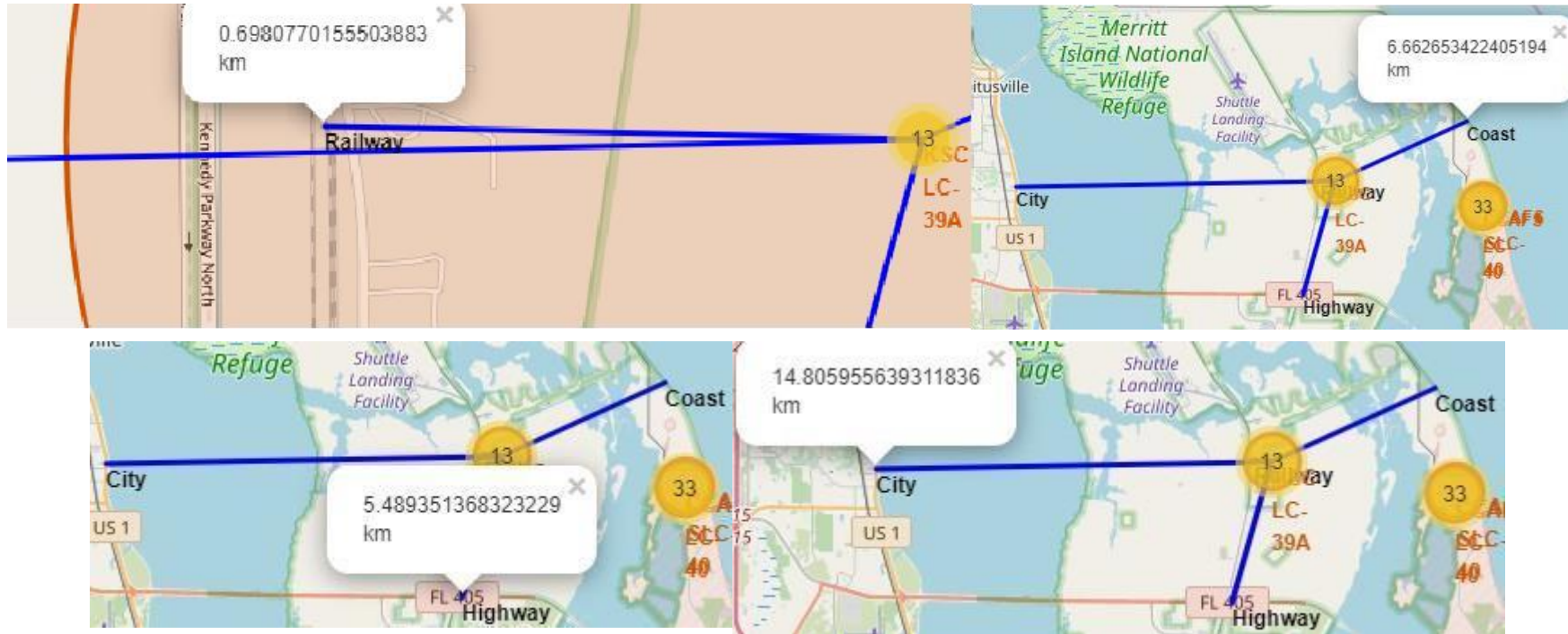
Color-Coded Launch Markers

Clusters on Folium map can be clicked on to display each successful landing (green icon) and failed landing (red icon). In this example VAFB SLC-4E shows 4 successful landings and 6 failed landings.

Key Location Proximities

Using KSC LC-39A as an example, launch sites are very close to railways for large part and supply transportation. Launch sites are close to highways for human and supply transport. Launch sites are also close to coasts and relatively far from cities so that launch failures can land in the sea to avoid rockets falling on densely populated areas.

Build a Dashboard with Plotly Dash

# Successful Launches Across Launch Sites
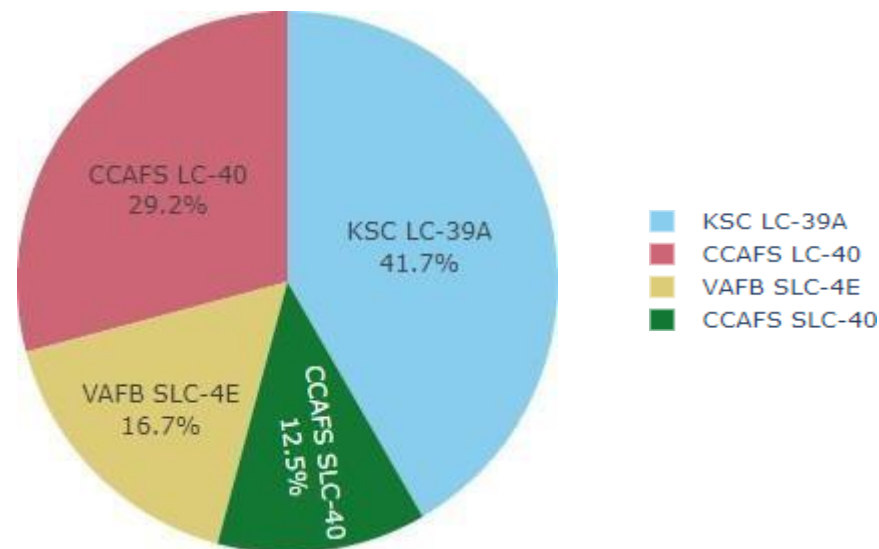
This is the distribution of successful landings across all launch sites. CCAFS LC-40 is the old name of CCAFS SLC-40 so CCAFS and KSC have the same number of successful landings, but many of the successful landings were performed before the name change. VAFB has the smallest share of successful landings. This may be due to smaller sample and increase in difficulty of launching in the west coast.

Highest Success Rate Launch Site

KSC LC-39A Success Rate (blue=success)

23.1%

76.9%

- 1
- 0
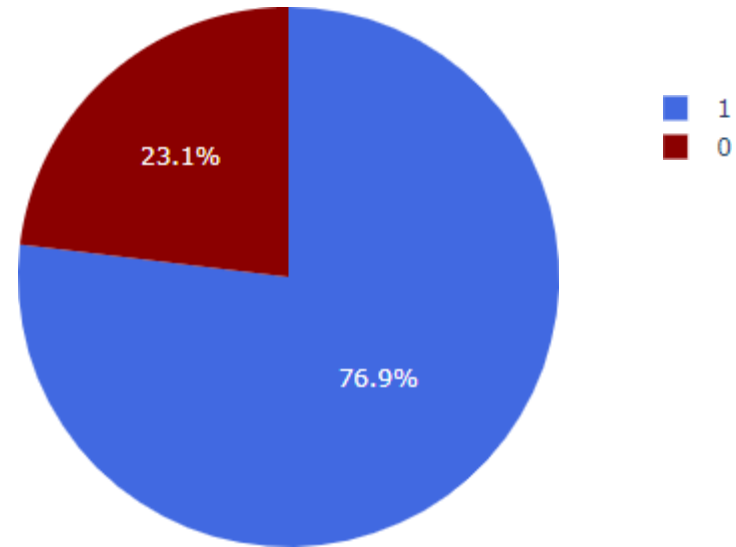
KSC LC-39A has the highest success rate with 10 successful landings and 3 failed landings.

# Payload Mass vs. Success vs. Booster Version Category

Plotly dashboard has a Payload range selector. However, this is set from 0-10000 instead of the max Payload of 15600. Class indicates 1 for successful landing and 0 for failure. Scatter plot also accounts for booster version category in color and number of launches in point size. In this particular range of 0-6000, interestingly there are two failed landings with payloads of zero kg.

Predictive Analysis - Classification

GRIDSEARCHCV (CV=10) ON LOGISTIC REGRESSION, SVM, DECISION TREE, AND KNN

Classification Accuracy

Model Accuracy Score
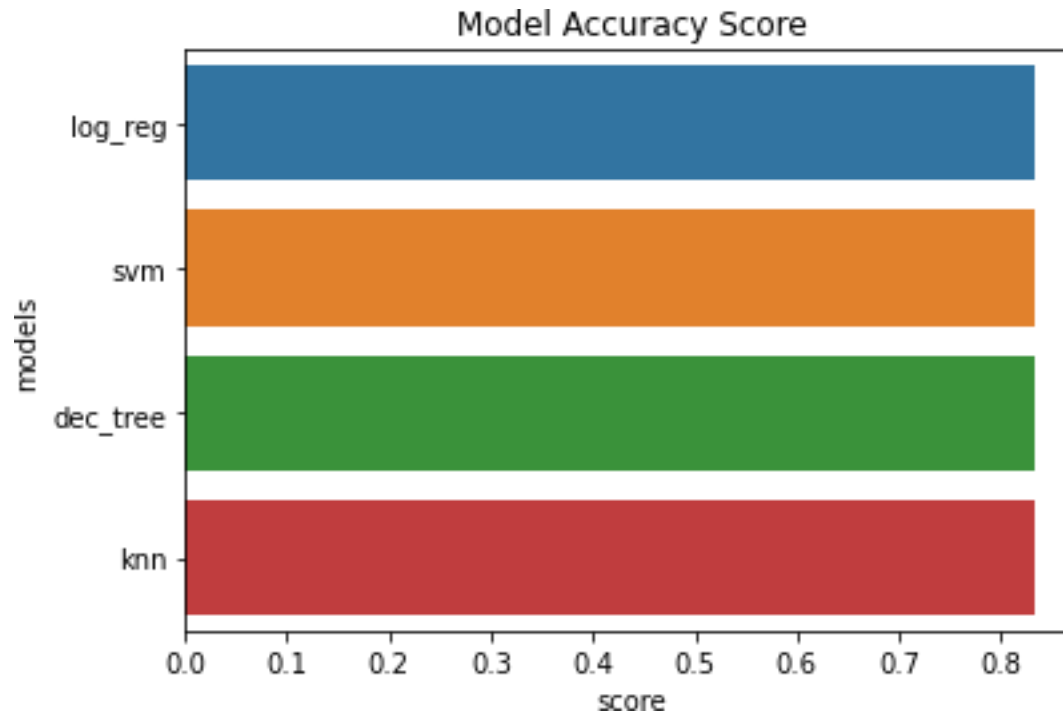
- All models had virtually the same accuracy on the test set at 83.33% accuracy. It should be noted that test size is small at only sample size of 18.
- This can cause large variance in accuracy results, such as those in Decision Tree Classifier model in repeated runs.
- We likely need more data to determine the best model.

Confusion Matrix
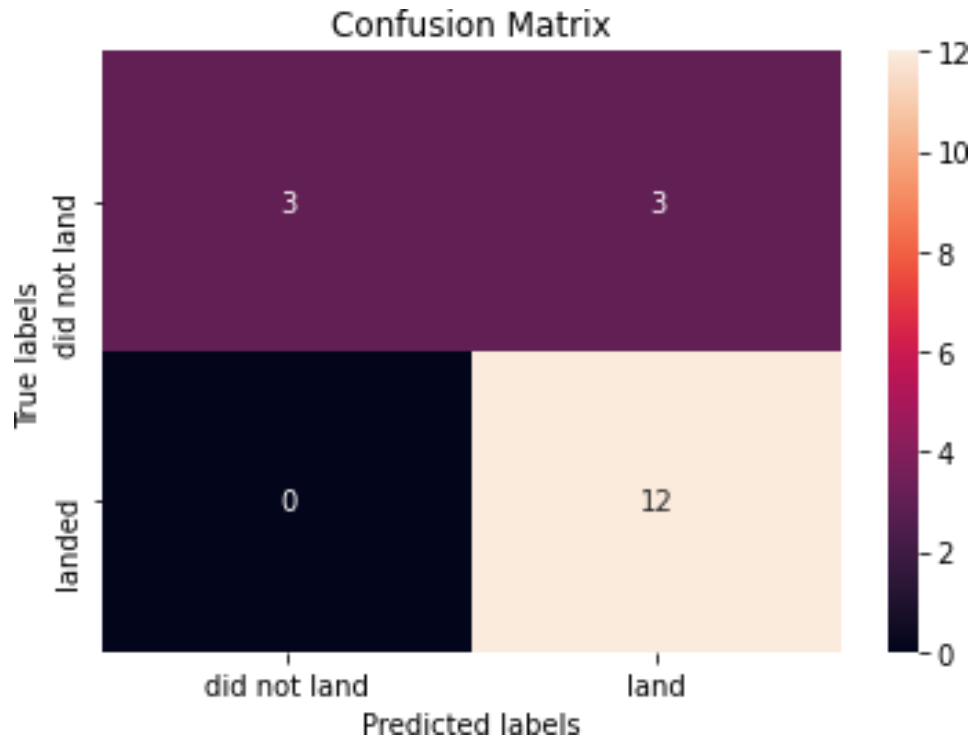
Correct predictions are on a diagonal from top left to bottom right.

Since all models performed the same for the test set, the confusion matrix is the same across all models. The models predicted 12 successful landings when the true label was successful landing.

The models predicted 3 unsuccessful landings when the true label was unsuccessful landing.

The models predicted 3 successful landings when the true label was unsuccessful landings (false positives). Our models over predict successful landings.

CONCLUSION

- Our task: to develop a machine learning model for Space Y who wants to bid against SpaceX
- The goal of model is to predict when Stage 1 will successfully land to save ~$100 million USD
- Used data from a public SpaceX API and web scraping SpaceX Wikipedia page
- Created data labels and stored data into a DB2 SQL database
- Created a dashboard for visualization
- We created a machine learning model with an accuracy of 83%
- Allon Mask of SpaceY can use this model to predict with relatively high accuracy whether a launch will have a successful Stage 1 landing before launch to determine whether the launch should be made or not
- If possible, more data should be collected to better determine the best machine learning model and improve accuracy

APPENDIX

GitHub Repository URL:

https://github.com/amruthkarun/IBM-Data-Science-Assignment

Course Instructors:

Alex Aklson, Rav Ahuja, Aije Egwaikhide, Svetlana Levitan, Romeo Kienzler, Polong Lin, Joseph Santarcangelo, Azim Hirjani, Hima Vasudevan, Saishruthi Swaminathan, Saeed Aghabozorgi, Yan Luo

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https://www.coursera.org/professional-certificates/ibm-data-science