Data Science Capstone Project

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29/03/2024

Outline

Executive Summary

- Methodologies

Data -

Data source - public SpaceX API data and Wikipedia
Exploratory Data Analysis - Python libraries, SQL, visualization tools, folium maps, and dashboards
Feature Engineering - Extracting relevant columns, Converting categorical variables into binary format using one-hot encoding and utilizing GridSearchCV to identify the optimal parameters for machine learning models.
Data cleaning and preprocessing - Data standardization , dealing with missing values and outliers.

Executive Summary

- Methodologies

Machine Learning Algorithms -

- Logistic Regression
- Support Vector Machine
- Decision Tree Classifier
- K Nearest Neighbour

Based on the training of the mentioned algorithms, it can be reasonably conclude that the results achieved an accuracy rate of approximately 83.33%.

That is for sure more data is needed for better model determination and accuracy.

Introduction

- **Project background and context**
  - The Space Exploration Technologies (SpaceX) mission is to make affordable rockets. Its first two rockets were the Falcon 1 (first launched in 2006) and the larger Falcon 9 (first launched in 2010), which were designed to cost much less than competing rockets. ($62 million vs. $165 million USD)
  - Space X has largely gained an advantage due to its capability to recover parts of the rocket, particularly Stage 1.
  - **Y Space Y has been competing with Space X.**

- **Problems you want to find answers**
  - **Space Y wants us to develop a predictive model to predict successful Stage 1 recovery.**

Section 1

Methodology

Methodology

- Data collection methodology:
  - Data collection is conducted from SpaceX API and Web scraping from Space X's Wikipedia
- Perform data wrangling
  - Classifying true landing as **successful** and **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 for best parameters using GridSearchCV

Data Collection

Overview

Data collection process involved a combination of API requests from Space X public API and web scraping data from a table in Space X's Wikipedia entry.

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:

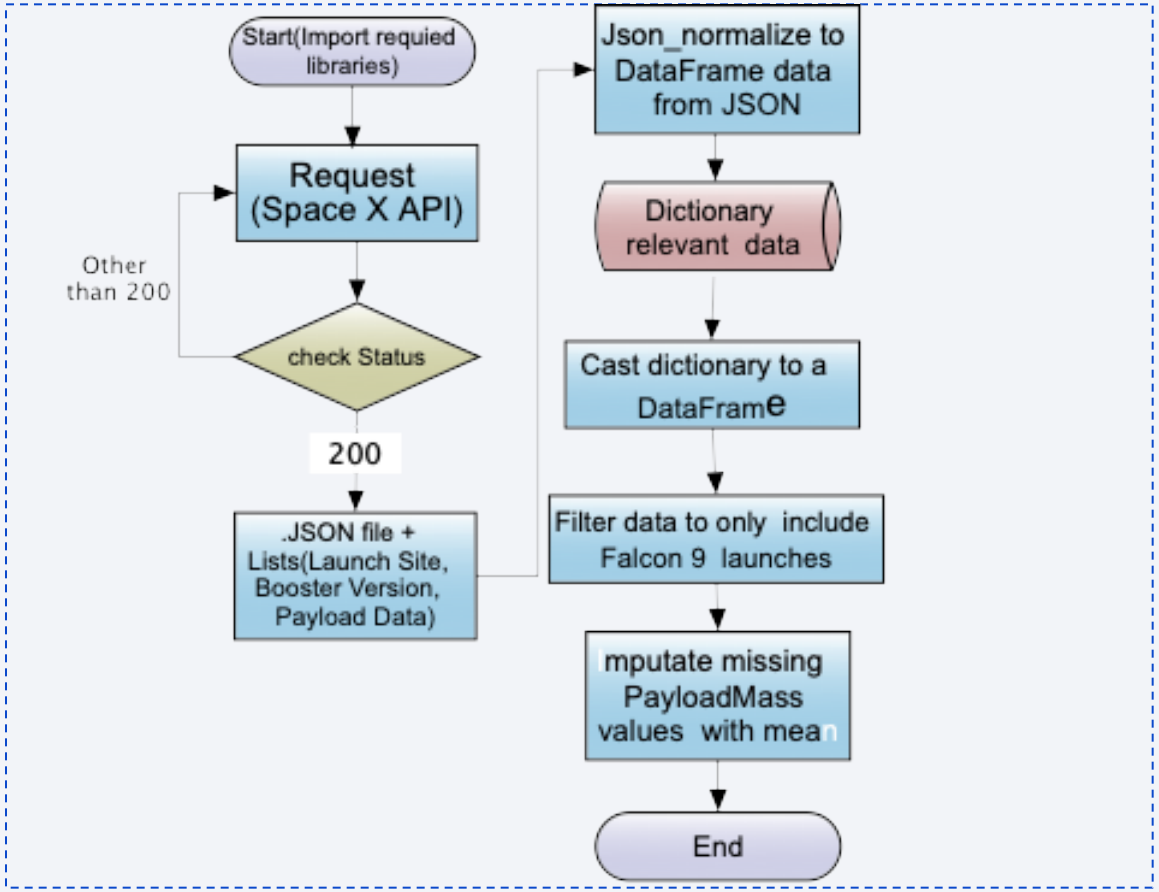
Flight No., Launch site, Payload, PayloadMass, Orbit, Customer, Launch outcome, Version Booster, Booster landing, Date, Time

Data Collection – SpaceX API

- Data Collection - SpaceX API

- GitHub URL:

https://github.com/MaryamBeik/testrepo/blob/main/SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb

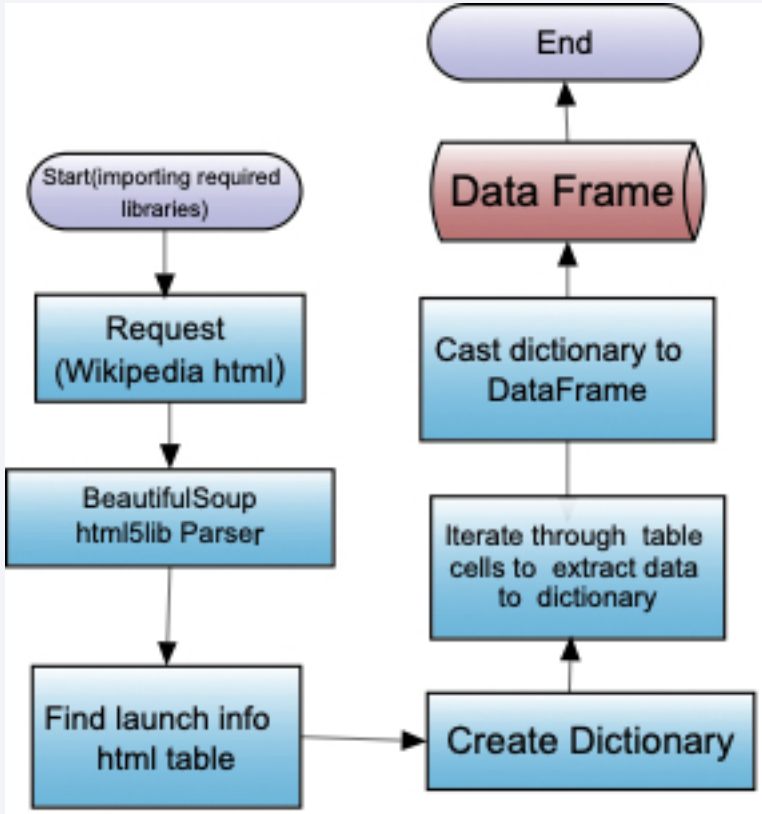


Data Collection – Web Scraping

- Data Collection - Web Scraping

- GitHub URL:

https://github.com/MaryamBeik/testrepo/blob/main/jupyter-labs-webscraping.ipynb



Data Wrangling

Creating a training label (Y) 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/MaryamBeik/testrepo/blob/main/labs-jupyter-spacex-Data%20wrangling.ipynb

EDA with Data Visualization

Exploratory Data Analysis performed on

- V**ariables**:

Flight Number, Payload Mass, Launch Site, Orbit, Class and Year.

- **Plots** :

Scatter plots, line charts, and bar plots

to compare relationships between variables to decide if a relationship exists so that they could be used in training the machine learning model

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

GitHub URL:https://github.com/MaryamBeik/testrepo/blob/main/jupyter-labs-eda-dataviz.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/MaryamBeik/testrepo/blob/main/jupyter-labs-eda-sql-coursera_sqllite.ipynb

Build an Interactive Map with Folium

- **Map objects**

markers, circles, lines, circleMarker, markerCluster

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/MaryamBeik/testrepo/blob/main/Interactive%20Visual%20Analytics%20with%20Folium.ipynb

Build a Dashboard with Plotly Dash

Plots in Dashboard

pie chart, scatter plot

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

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

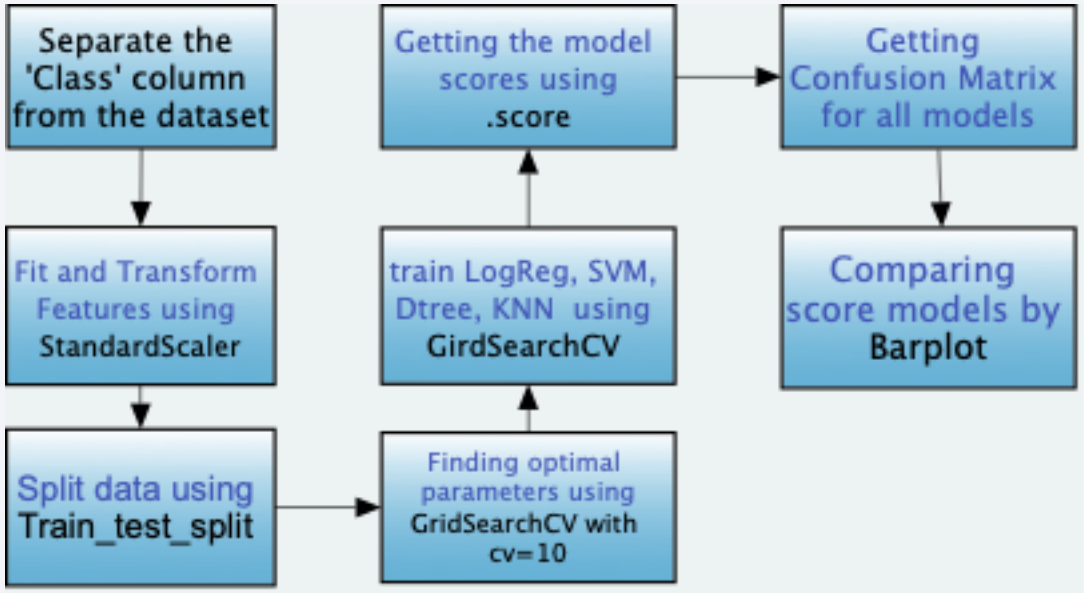
The pie chart is used to visualize launch site success rate.

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

- GitHub URL: https://github.com/MaryamBeik/testrepo/blob/main/Create%20Dashboard%20using%20plotly%20and%20Dash.ipynb

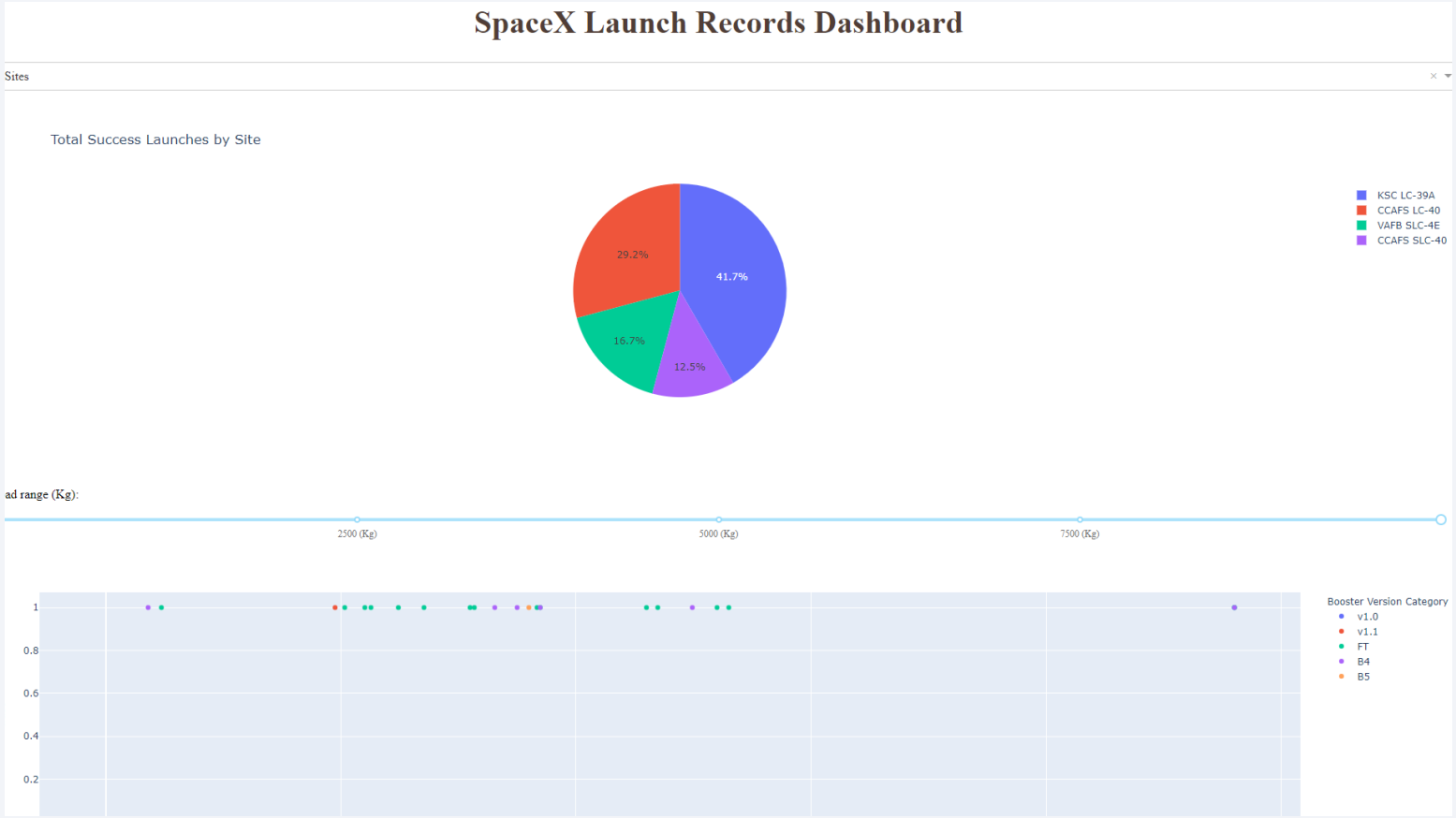
Predictive Analysis (Classification)

- GitHub URL:https://github.com/MaryamBeik/testrepo/blob/main/SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb



Results

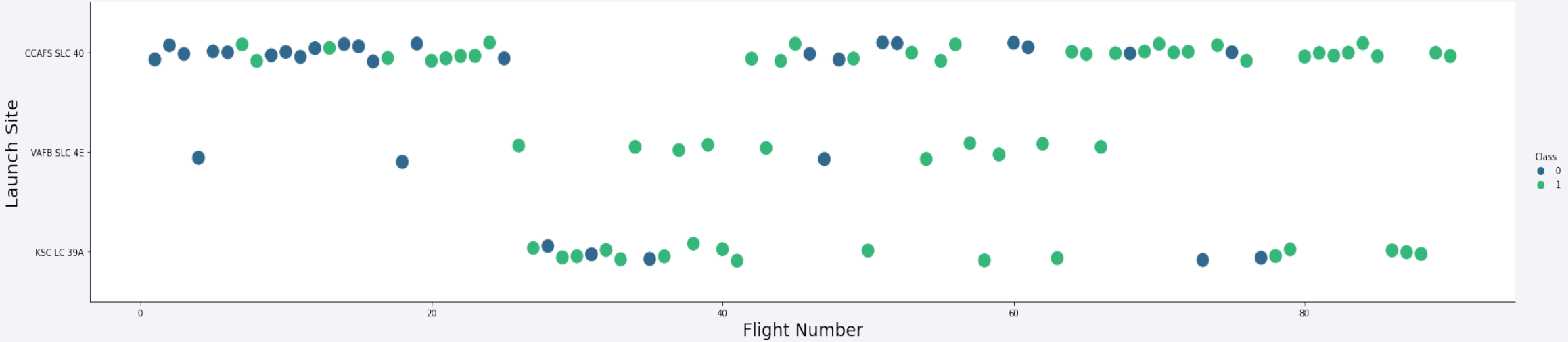
This is a preview of the Plotly dashboard. The following sides will show the results of EDA with visualization, EDA with SQL, Interactive Map with Folium, and finally the results of our model with about 83% accuracy.



Section 2

Insights drawn from EDA

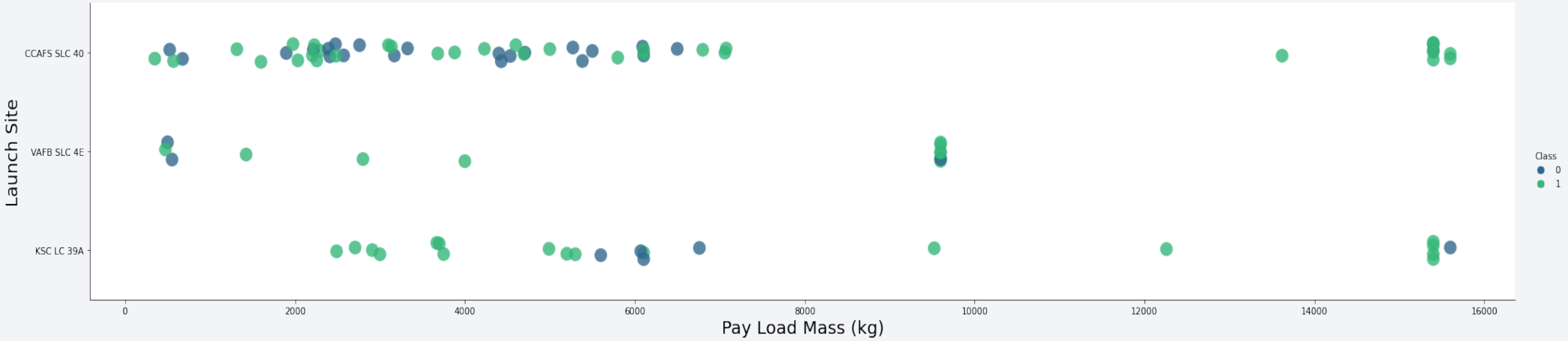
Flight Number vs. Launch Site



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.

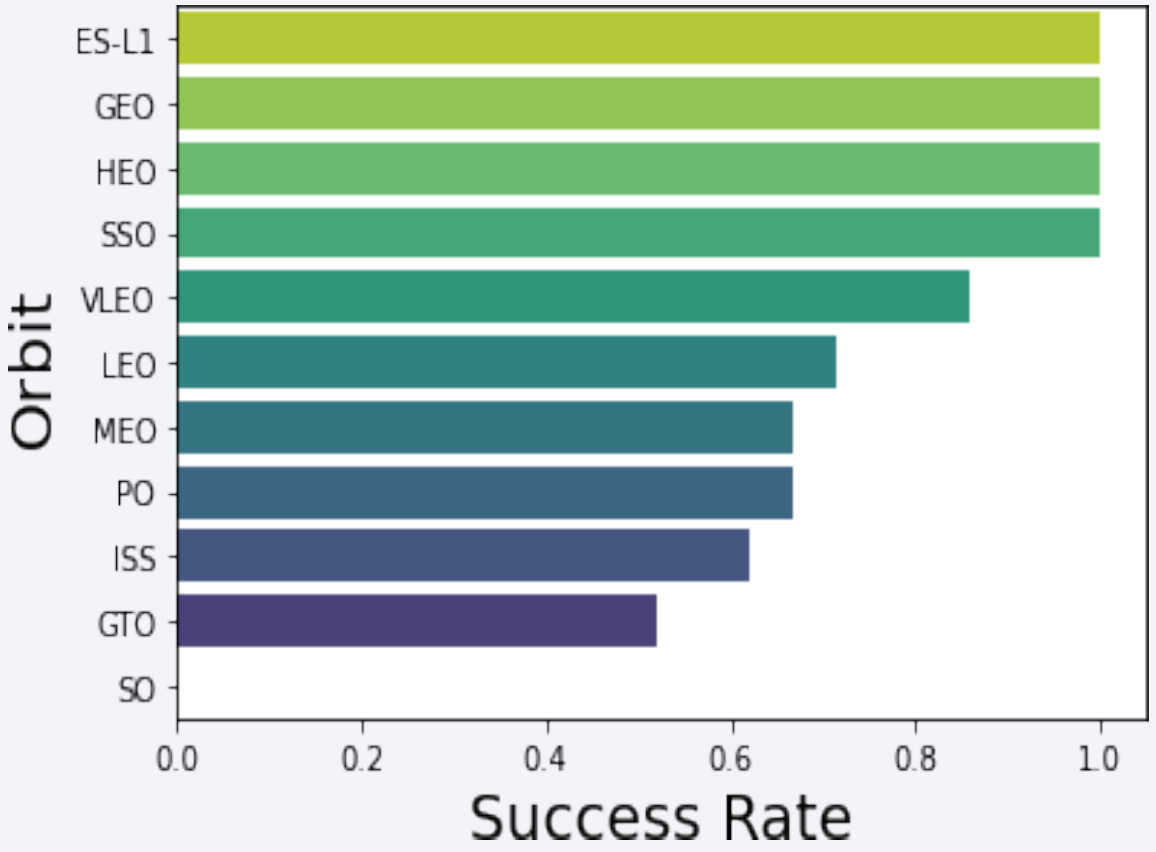
Success Rate vs. Orbit Type

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

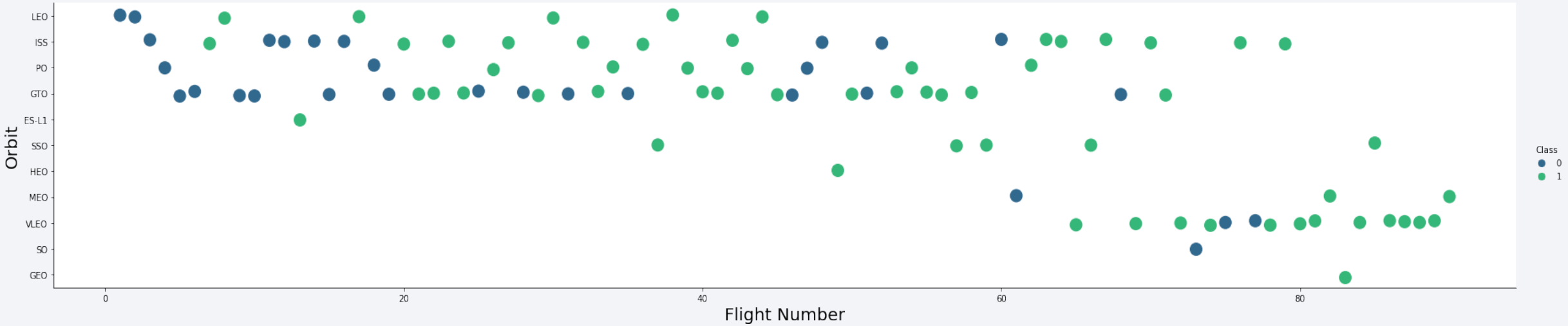
SO (1) has 0% success rate

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



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

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

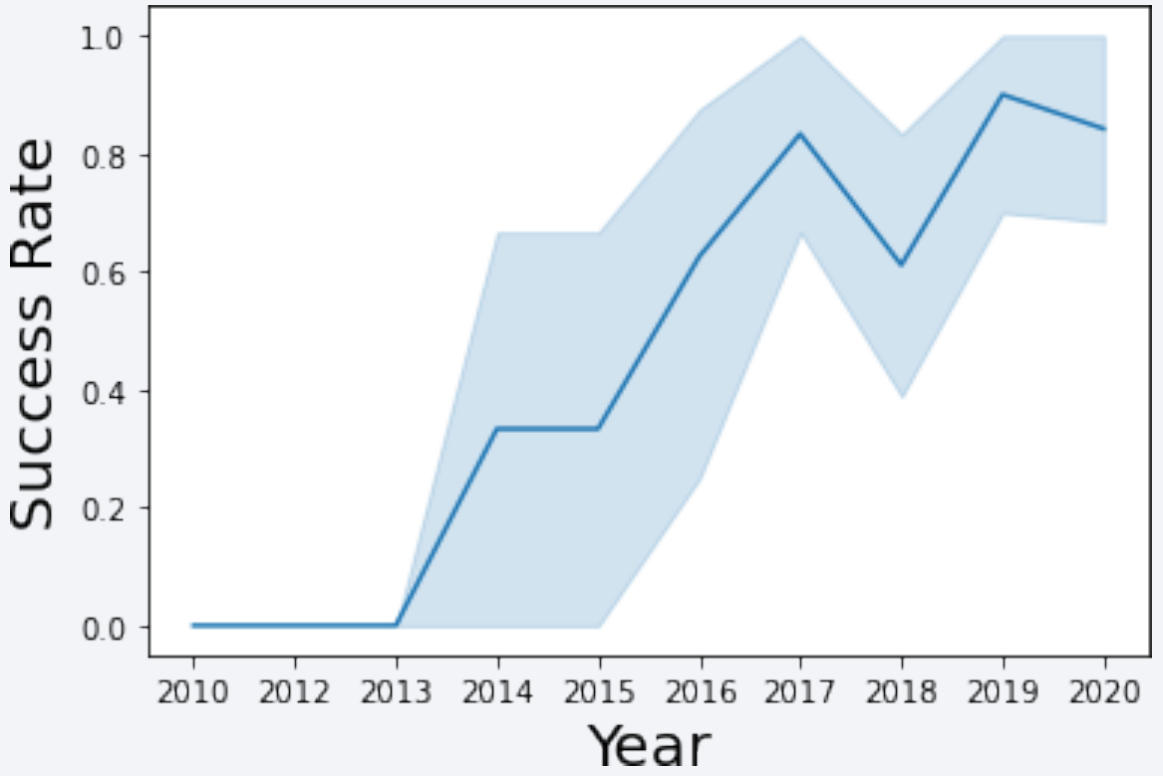
LEO and SSO seem to have relatively low payload mass

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

Launch Success Yearly Trend

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

Success in recent years at around 80%



95% confidence interval
(light blue shading)

EDA with SQL

Exploratory Data Analysis

SLQ DB2

All Launch Site Names

Query unique launch site names from database.

```
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

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 Begin with 'CCA'

First five entries in database with Launch Site name 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

Total Payload Mass

Total payload carried by boosters 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

Average payload mass carried by booster version 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 Landing Date

Dates of the first successful landing outcome on ground pad

```
%%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

Names of boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 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 Successful and Failure Mission Outcomes

Total number of successful and failure mission outcomes

```
%%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 Carried Maximum Payload

Names of the booster which have carried the maximum payload mass

```
%%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.

2015 Launch Records

Failed landing_outcomes in drone ship, booster versions, launch site names in year 2015

```
%%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.

Rank Landing Outcomes 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.

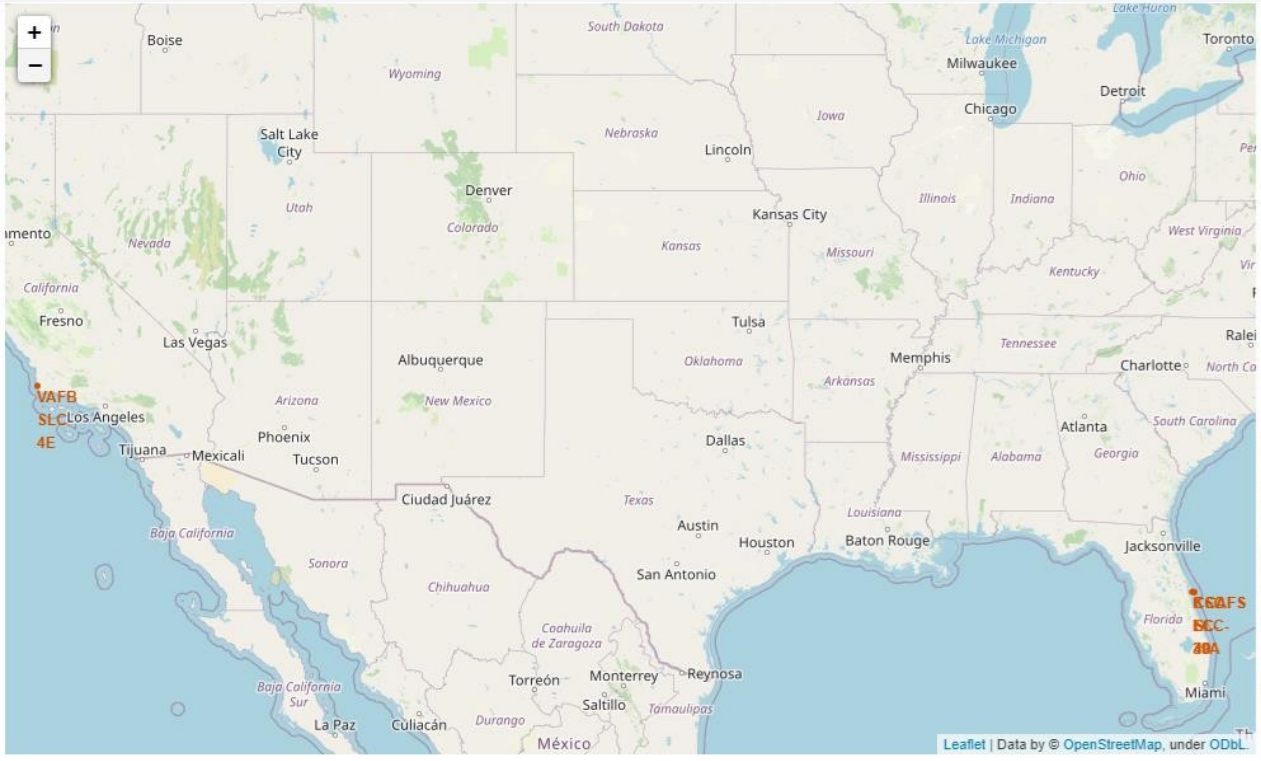
There are two types of successful landing outcomes: drone ship and ground pad landings.

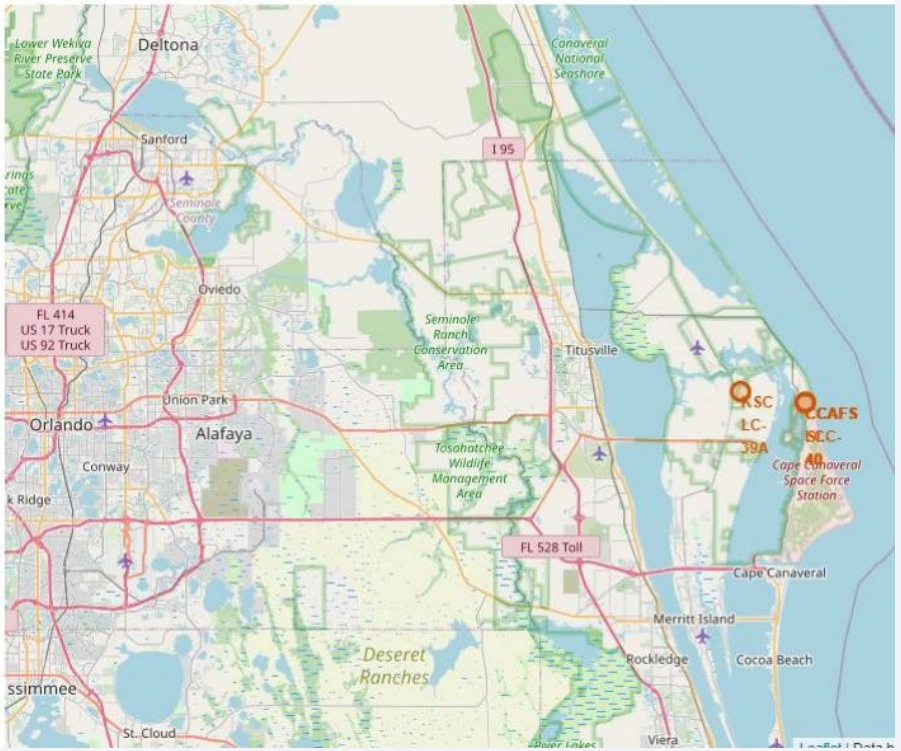
There were 8 successful landings in total during this time period

Section 3

Launch Sites Proximities Analysis

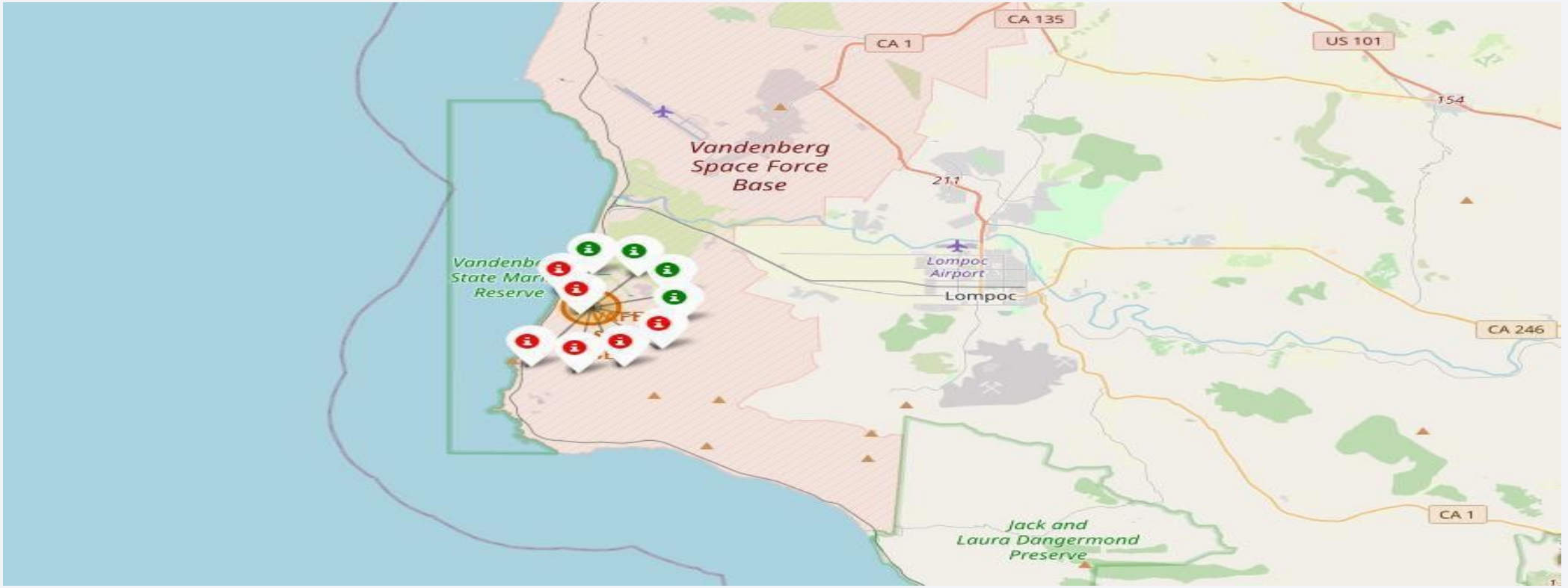
Launch Site Locations





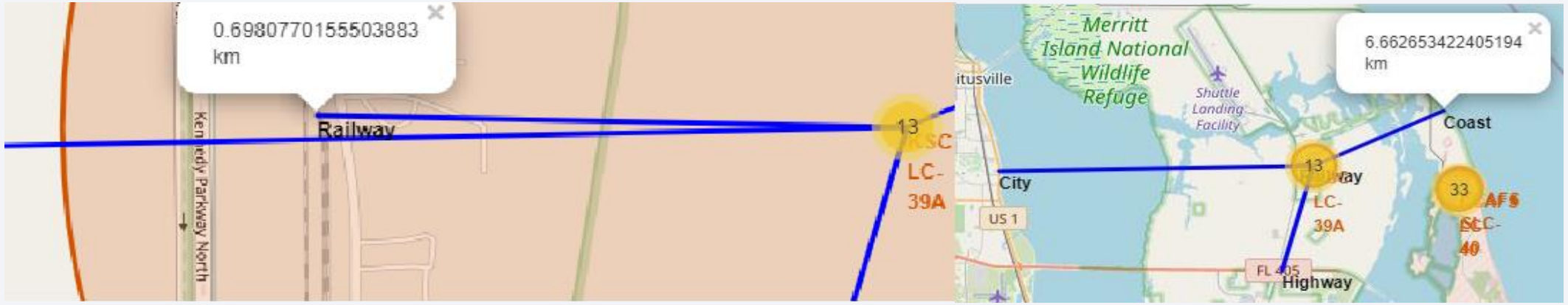
The left map shows all launch sites relative US map. The right map shows the two Florida launch sites since they are very close to each other. All launch sites are near the ocean.

Launch Markers with Color-Coding

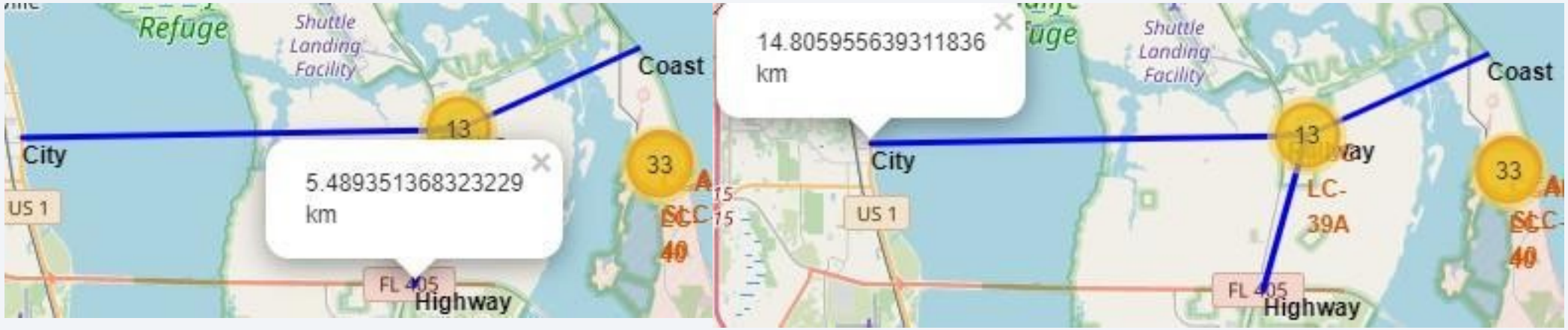


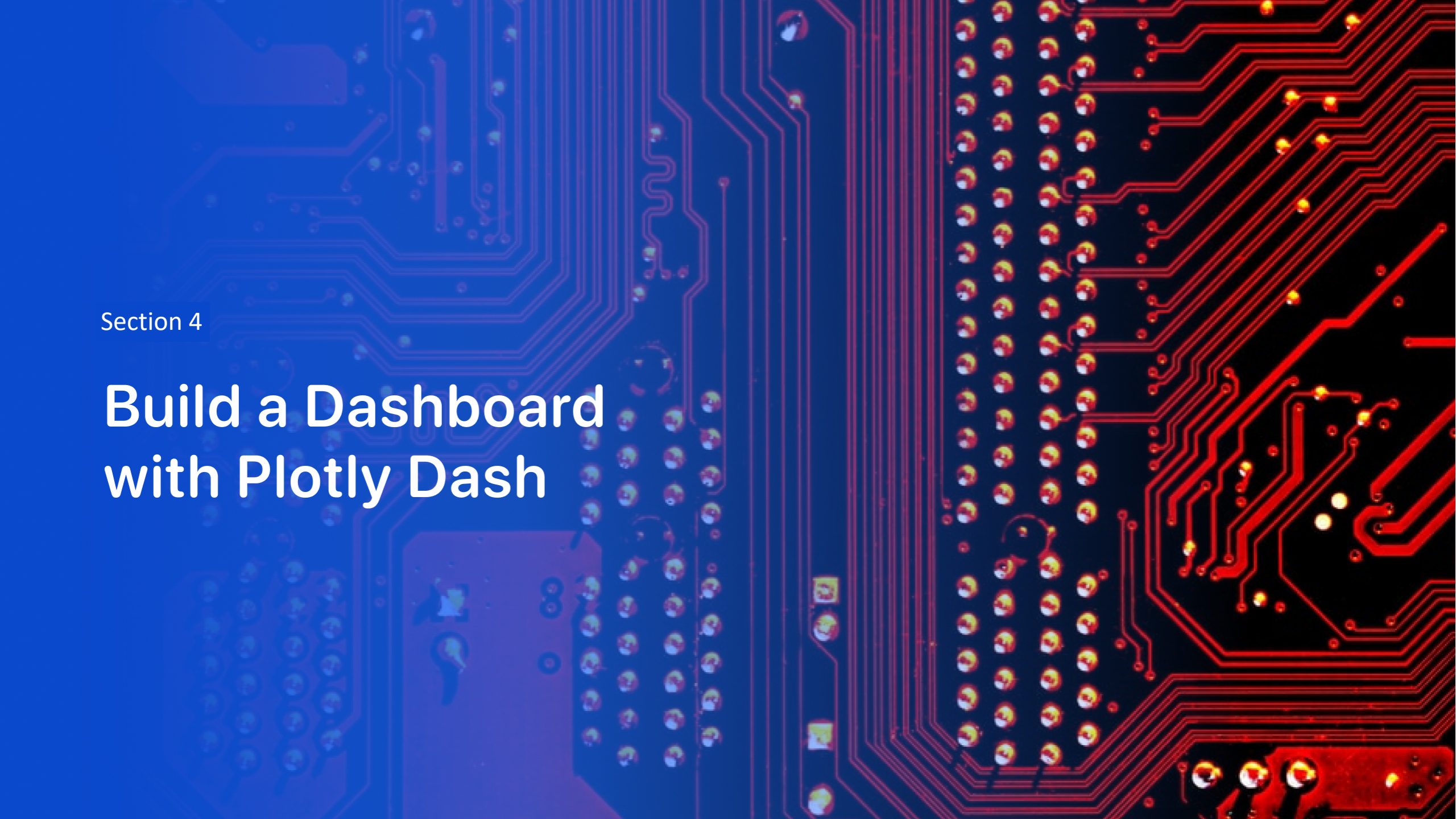
Clusters on Folium map can be clicked on to display each successful landing (green icon) and failed
landing (red icon). In this example VAFB SLC-4E shows 4 successful landings and 6 failed landings.

Proximities of Key Locations

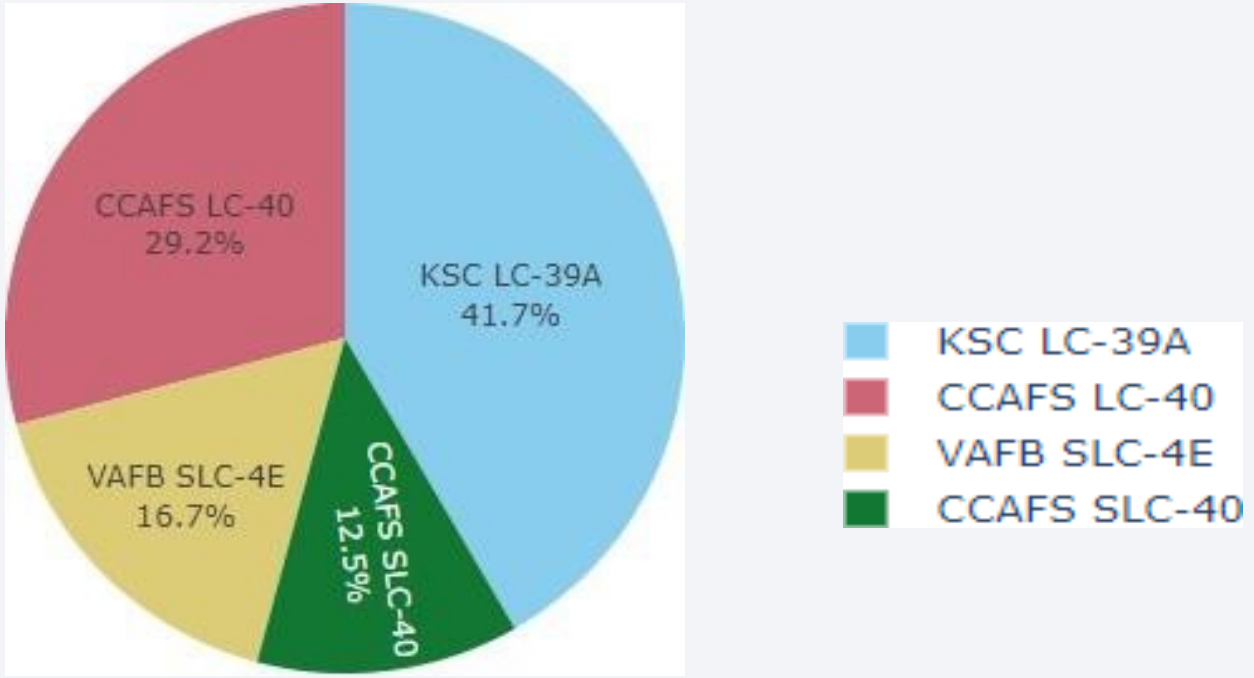


Using KSC LC-39A as an example, launch sites are very close to railways for large part and supply transportation. Launch sites are close to highways for human and supply transport. Launch sites are also close to coasts and relatively far from cities so that launch failures can land in the sea to avoid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



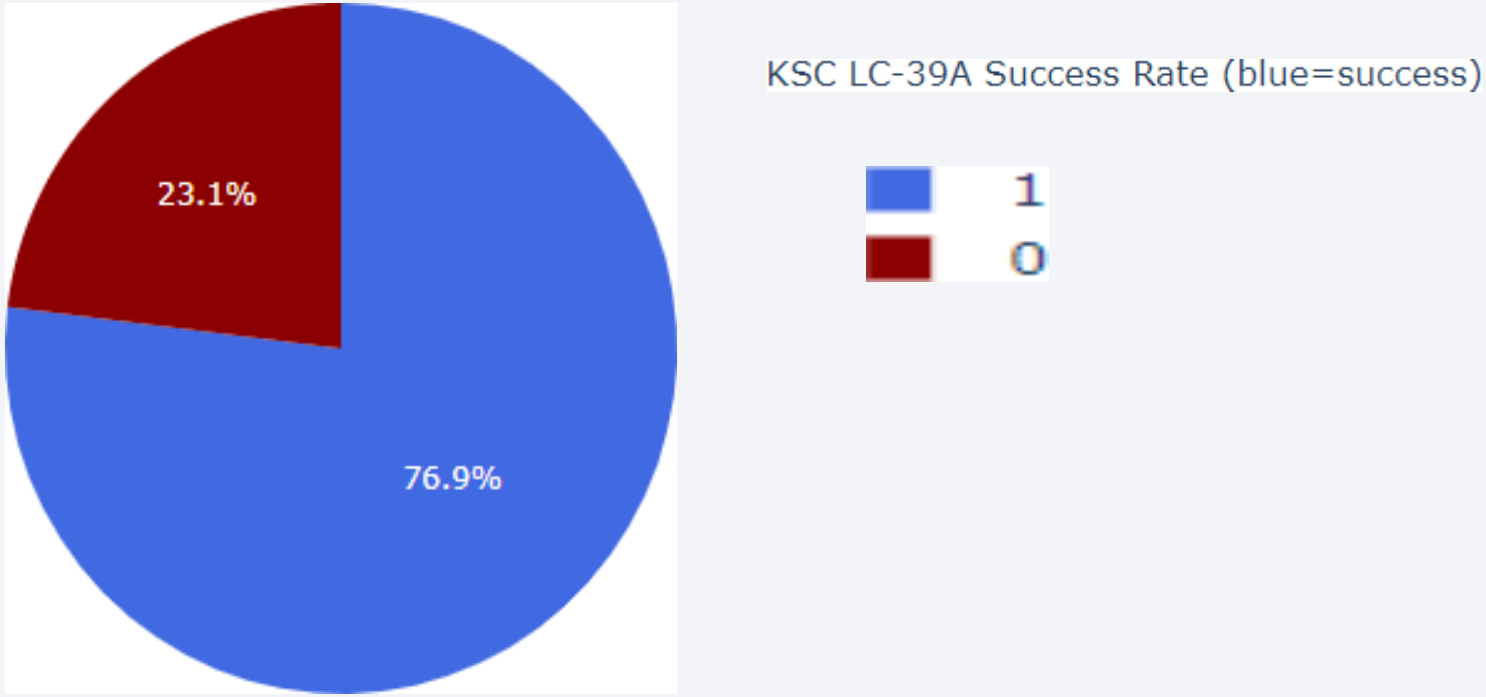

Section 4
Build a Dashboard with Plotly Dash

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 amount of successful landings, but a majority of the successful landings where 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 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.

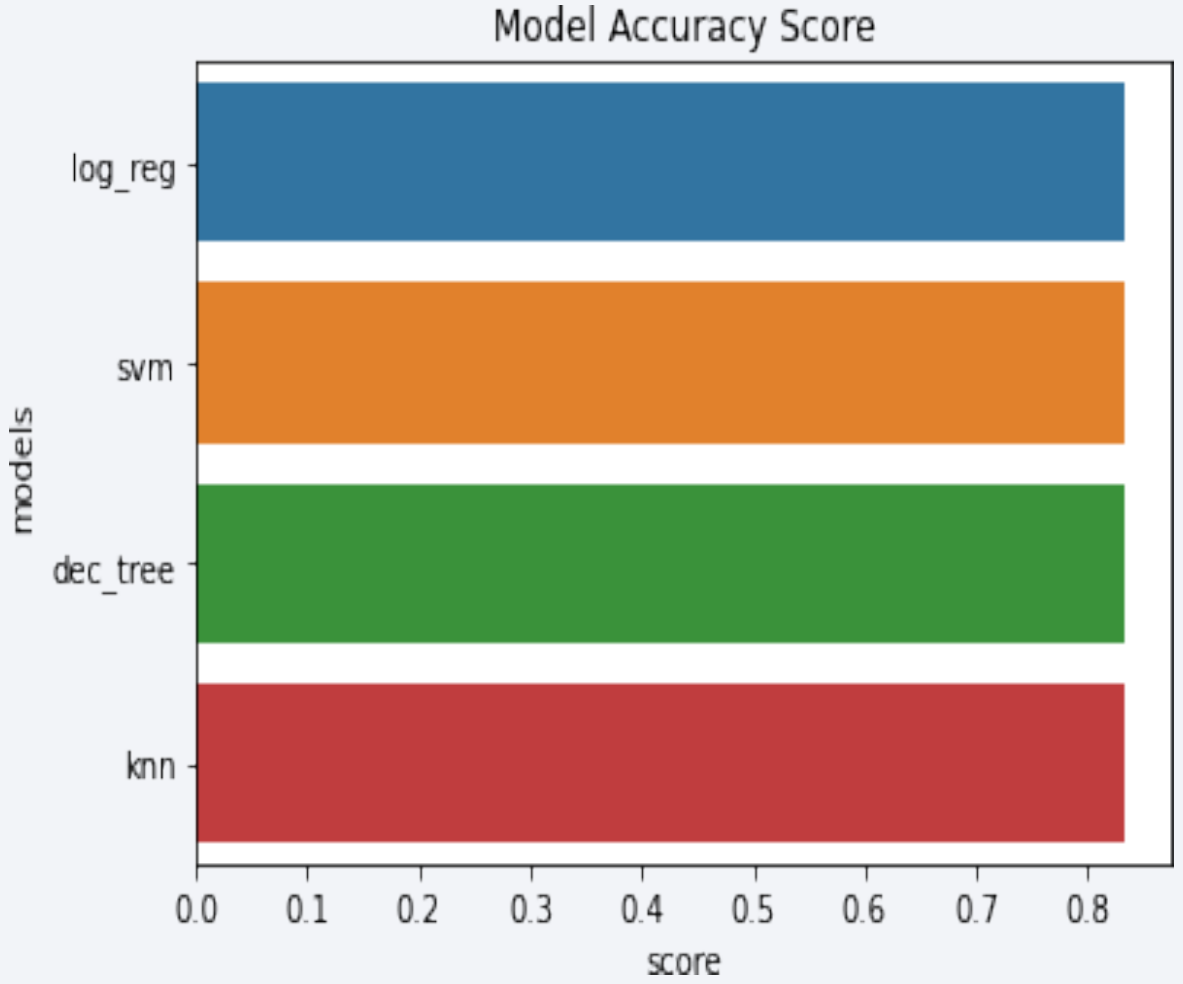
Section 5

Predictive Analysis (Classification)

Classification Accuracy

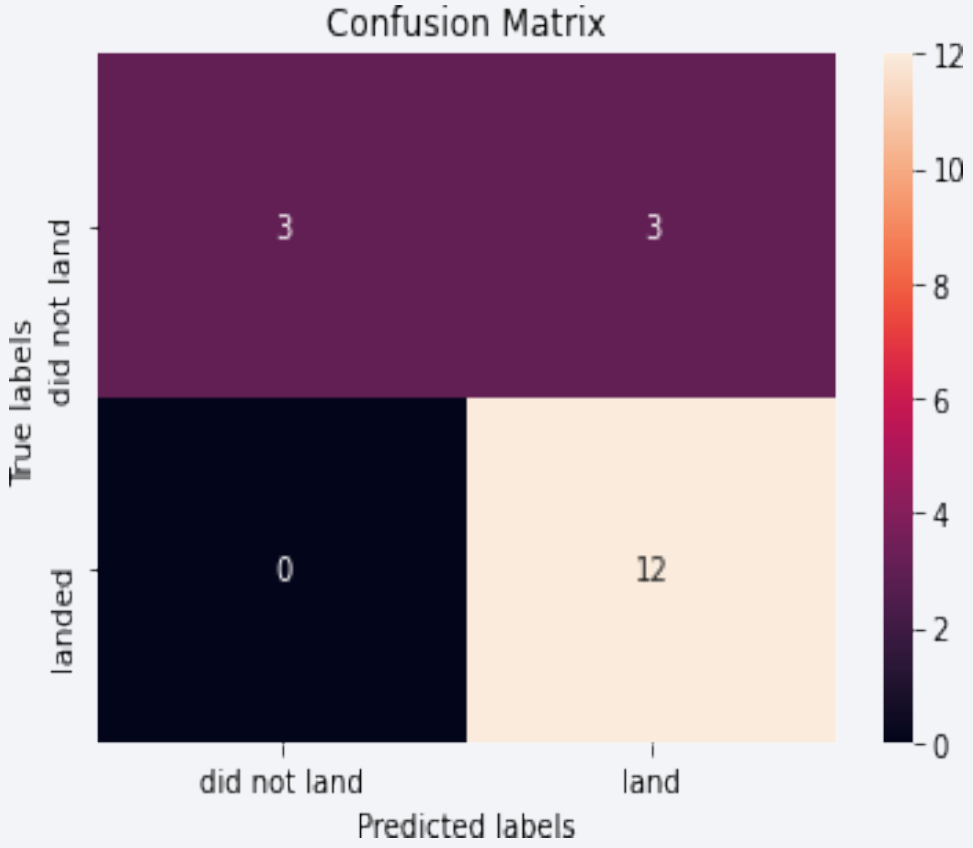
All models had virtually the same accuracy on the test set at 83.33% accuracy. It should be noted that test size is small at only sample size of 18. This can cause large variance in accuracy results, such as those in Decision Tree Classifier model in repeated runs.

We likely need more data to determine the best model.



Confusion Matrix

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.



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

Conclusions

- Objective - develop a machine learning model for Space Y, aiming to compete with SpaceX.
- Model's aim - forecast the successful landing of Stage 1 to potentially save approximately $100 million USD.
- To achieve this following steps were taken,
  - Data collection - sources from SpaceX API and web scraping of SpaceX Wikipedia.
  - Data preparation - labeling and storing data into a DB2 SQL database.
  - Data visualization - plotting and making dashboard for data visualization.
- **Machine Learning Model results an accuracy rate of 83.33%.**
  - This model enables Allon Mask of SpaceY to predict, with considerable accuracy, whether a launch will feature a successful Stage 1 landing prior to its execution.
  - This prediction aids in deciding whether the launch should proceed or not.

Furthermore,
It has been always recommended acquiring additional data to fine-tune the machine learning model and boost its predictive accuracy.

Appendix

Credit and Acknowledgments:

Project Lead: Rav Ahuja
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Lab Authors: Joseph Santarcangelo, Yan Luo, Azim Hirjani, Lakshmi Holla
Technical Advisor: Yan Luo
Publishing: Grace Barker, Rachael Jones
Project Coordinators: Kathleen Bergner
Narration: Bella West
Video Production: Simer Preet, Lauren Hall, Hunter Bay, Tanya Singh, Om Singh
Teaching Assistants and Forum Moderators: Malika Singla, Duvvana Mrutyunjaya Naidu, Lakshmi Holla, Anita Verma

Special Thanks to Coursera for this opportunity.

Github URL: https://github.com/MaryamBeik/testrepo/blob/main/SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb

Thank you!