IBM Developer
SKILLS NETWORK

# Winning Space Race with Data Science

Vivian Chika-Ezeagu
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# Outline

- Executive Summary
- Introduction
- Methodology
- Results
- Conclusion
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# Executive Summary

- The data for was collected from two sources: Space X API GET request and webscraping.
- The data was processed and then wrangled to gain insight from the data; exploratory data analysis was carried out through visualizations.
- Interactive visual analysis was carried out through Folium and Plotly Dash.
- Predictive analysis was performed using classification models. The models were evaluated on train and test data to determine accuracy levels.
- It was determined that heavy payload masses have a negative effect on the success of a launch while the success rate increases with higher flight numbers and as the years go by could be determined.
- All this information can be used to determine if Space X will reuse its first stage.

# Introduction

- SpaceX's accomplishments include: Sending spacecraft to the International Space Station.

- SpaceX advertises Falcon 9 rocket launches on its website with a cost of 62 million dollars; other providers cost upward of 165 million dollars each, much of the savings is because SpaceX can reuse the first stage.

- The aim of the project is to determine the price of each launch. Instead of using rocket science to determine if the first stage will land successfully, a machine learning model is trained and used.

- To determine the cost of a launch, the model is used to determine if the first stage will land. This information can be used if an alternate company wants to bid against SpaceX for a rocket launch.

Section 1

# Methodology

# Methodology

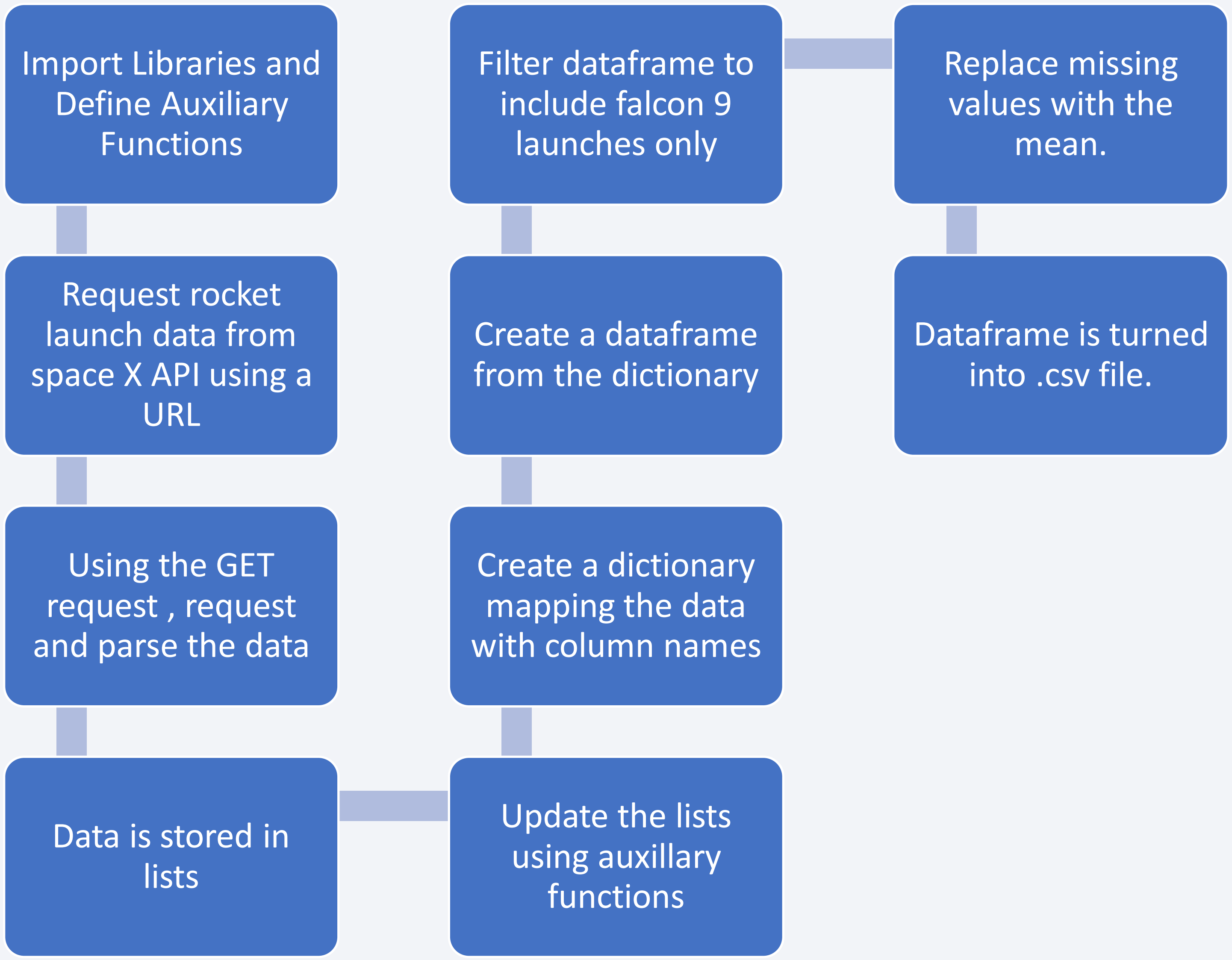
## Executive Summary

- Data collection methodology:
  - Rocket launch data was requested from SpaceX API using a URL.
  - Falcon launch 9 records  were extracted from Wikipedia through web scraping.
  - Some columns of data were filtered out and data wrangling by replacing with missing values with the mean values of the corresponding column.
- Performed exploratory data analysis (EDA) using visualization and SQL
- Performed interactive visual analytics using Folium and Plotly Dash
- Performed predictive analysis using classification models
  - How to build, tune, evaluate classification models

# Data Collection

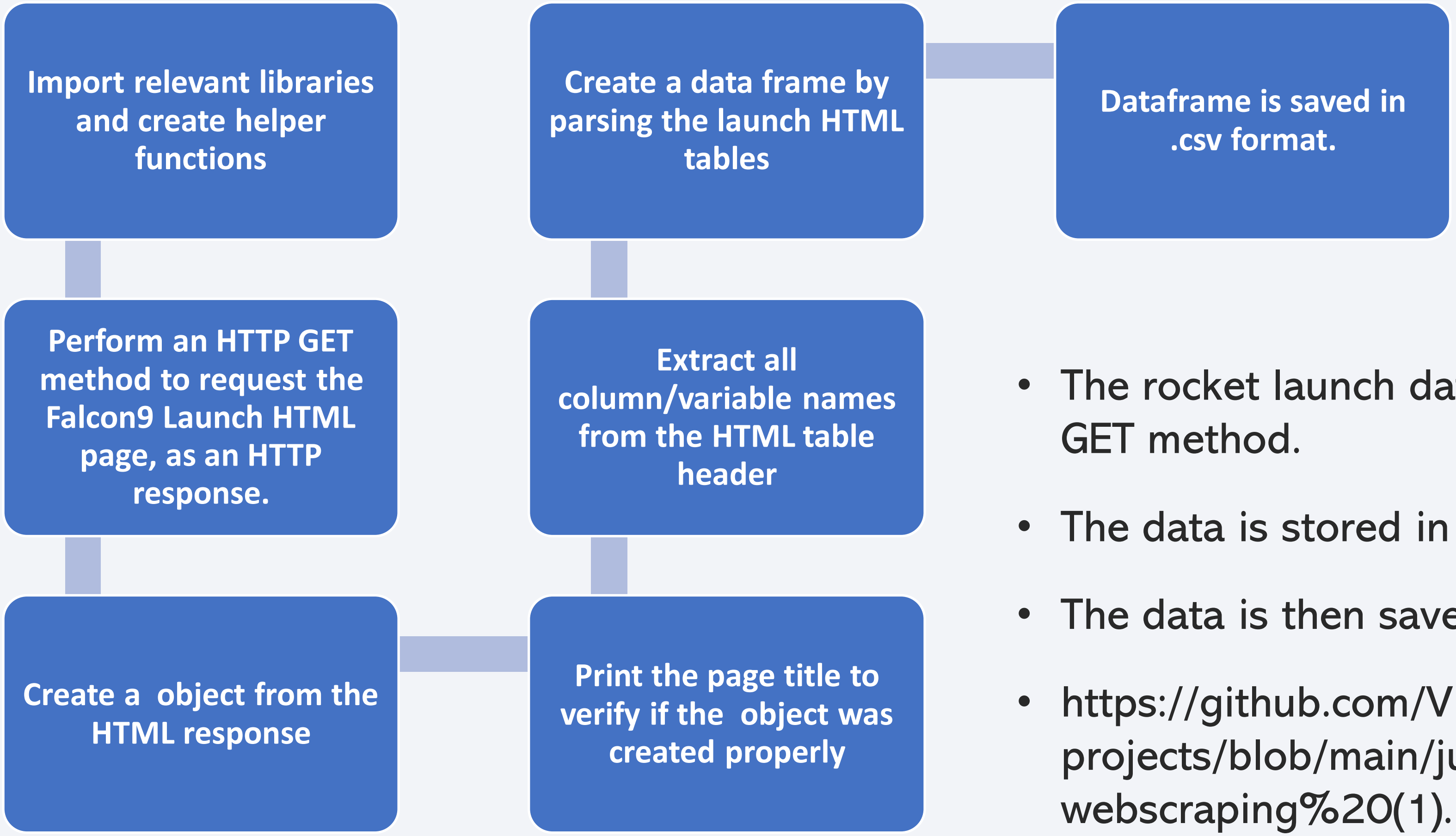
- Data was collected through requests from the Space X API.
- Data was also collected from wikipedia through a web scraping process.

# Data Collection – SpaceX API



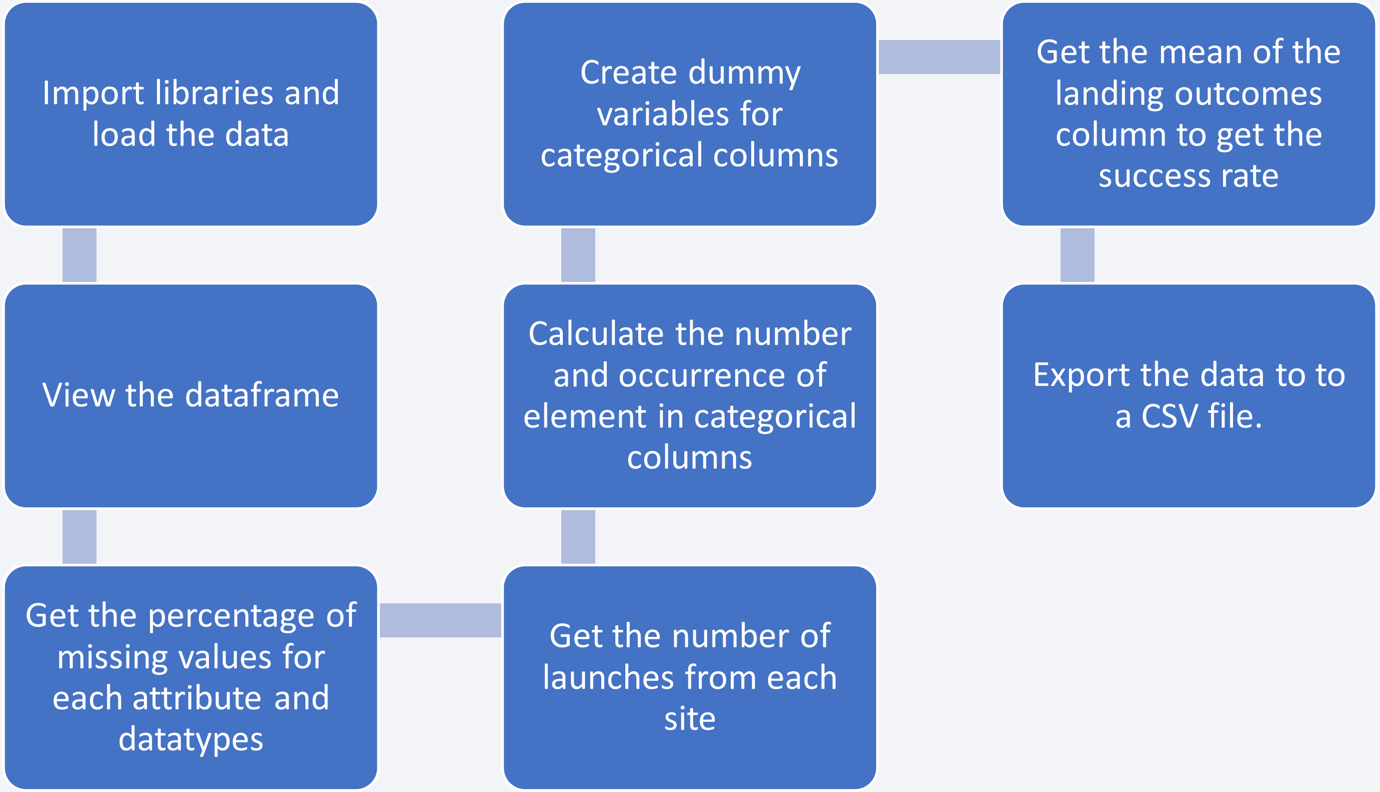

- Launch data is requested using a URL.
- The data is parsed and stored in a list.
- The data is stored in a dataframe, filtered, wrangled and stored in .csv format.
- https://github.com/VivianEzeagu/ibm-projects/blob/main/jupyter-labs-spacex-data-collection-api%20(1).ipynb

# Data Collection - Scraping




- The rocket launch data is requested using a HTTP GET method.
- The data is stored in a data frame.
- The data is then saved in a .csv format.
- https://github.com/VivianEzeagu/ibm-projects/blob/main/jupyter-labs-webscraping%20(1).ipynb

# Data Wrangling




- The missing values were found and replaced by mean values.
- The categorical variables where presented and replaced with dummy variables.
- Determination of success rate of landing outcome.
- https://github.com/VivianEzeagu/ibm-projects/blob/main/IBM-DS0321EN-SkillsNetwork_labs_module_1_L3_labs-jupyter-spacex-data_wrangling_jupyterlite.jupyterlite%20(1).ipynb

# EDA with Data Visualization

- Various scatterplots were created to aid data visualization.
- The scatterplots were created in order to view the relationships between variables and determine the extent of the effect on outcome of the launch.
- The Plot of the flight number vs payload mass showed that the first stage is more likely to succeed with a higher flight number and the less likely to succeed with higher payload mass.
- A bar chart was created to visualize the success rate of each orbit.
- Based on the information gotten from the data visualization, a new table was created with the variable that can help predict the outcome of the first stage.
- https://github.com/VivianEzeagu/ibm-projects/blob/main/IBM-DS0321EN-SkillsNetwork_labs_module_2_jupyter-labs-eda-dataviz.ipynb.jupyterlite.ipynb

# EDA with SQL

- The dataset was downloaded and loaded into the database table.
- A connection to the database was established.
- Exploratory analysis was carried out on the data after important libraries were imported to gain insight on the data.
- https://github.com/VivianEzeagu/ibm-projects/blob/main/login.html

# Build an Interactive Map with Folium

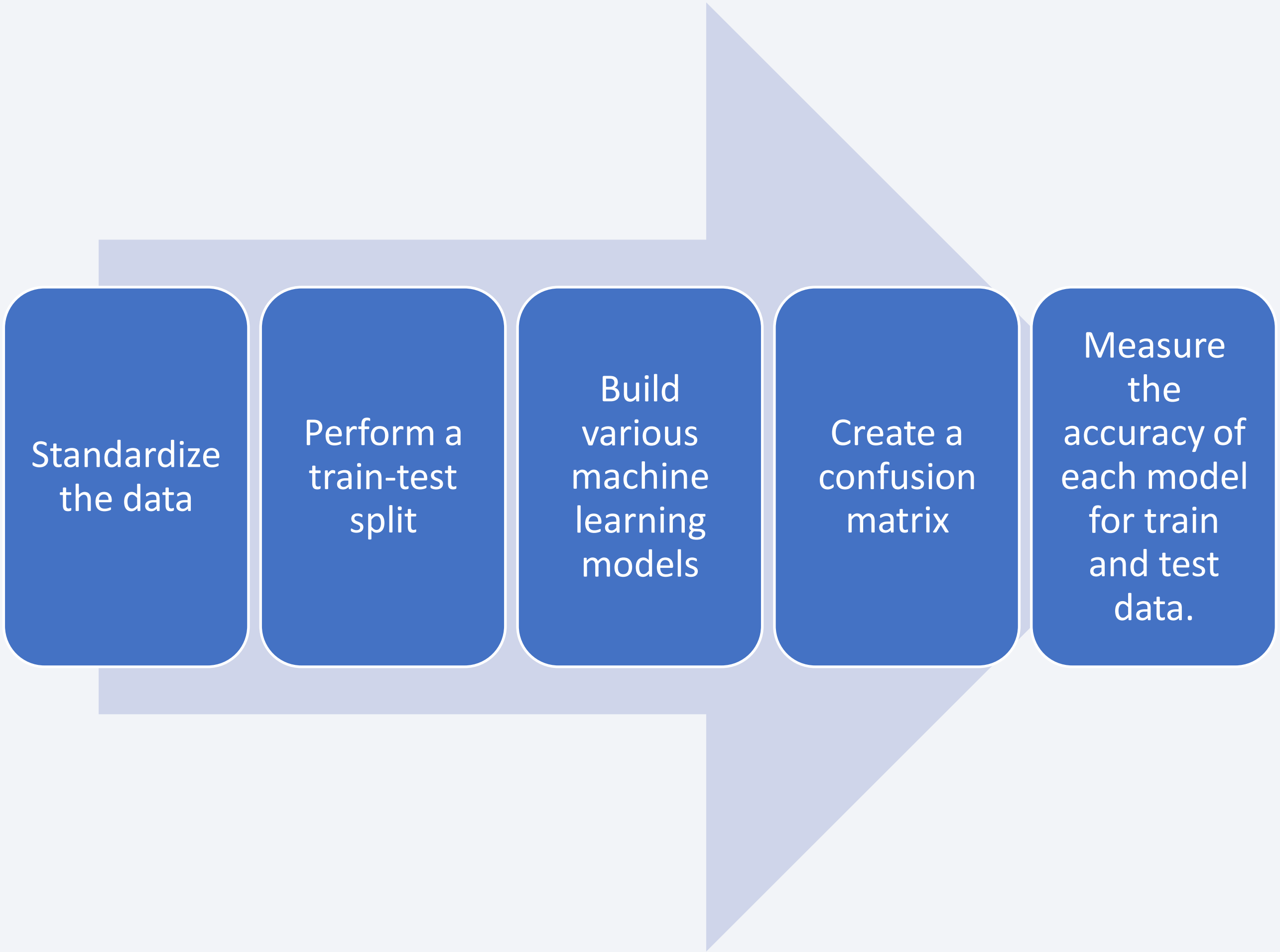
- Launch success may also depend on the location and proximities of a launch site, i.e., the initial position of rocket trajectories. Finding an optimal location for building a launch site certainly involves many factors ,we could discover some of the factors by analyzing the existing launch site locations.
- Markers were where created to visualize each of the launch sites on the map. The circle was created to highlight the site locaions and aid visualization.
- A marker color object was also added to enhance the map by adding the launch outcomes for each site represented by different colors, and see which sites have high success rates.
- A mouse pointer was added to easily get the longitude and latitude of the launch sites.
- A line was added to visualize the distance between launch sites and significant structures like railways.
- https://github.com/VivianEzeagu/ibm-projects/blob/main/dashboard%20api.ipynb

# Build a Dashboard with Plotly Dash

- A dropdown list was added to enable Launch Site selection.
- A pie chart was added to show the total successful launches count for all sites.
- Added a scatter chart to show the correlation between payload masses and launch success.
- https://github.com/VivianEzeagu/ibm-projects/blob/main/dashboard.ipynb

# Predictive Analysis (Classification)

- An object was created for each model then a GridSearchCV object was also created.
- The object was fitted to find the best parameters from the dictionary parameters.
- An output of the GridSearchCV object for each model.
- The best parameters were displayed and the accuracy on the validation data was calculated.
- https://github.com/VivianEzeagu/ibm-projects/blob/main/IBM-DS0321EN-SkillsNetwork_labs_module_4_SpaceX_Machine_Learning_Prediction_Part_5.jupyterlite%20(1).ipynb



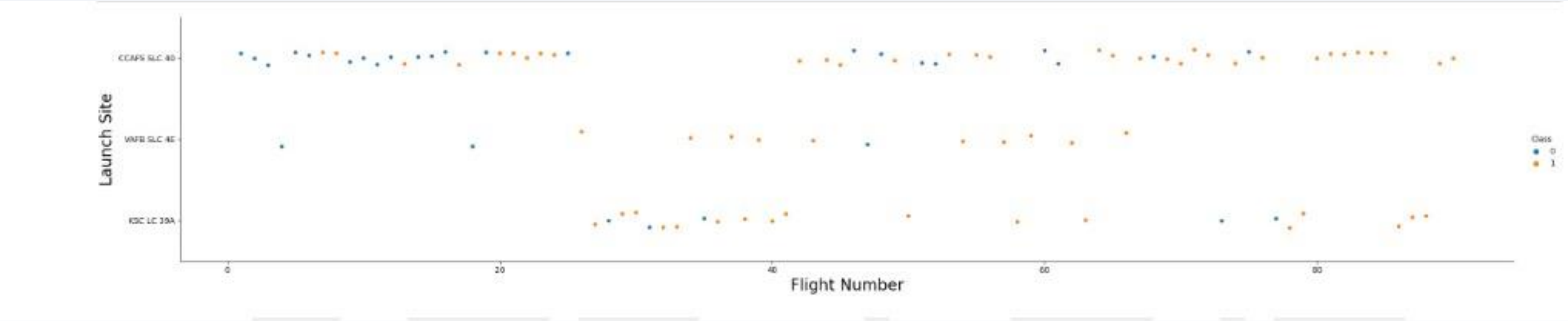
# Results

- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

Section 2

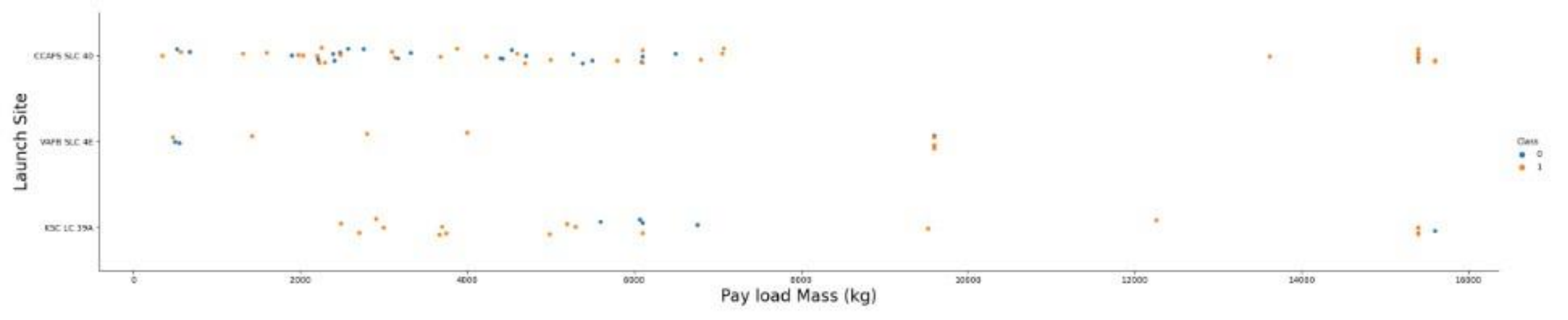
# Insights drawn from EDA

# Flight Number vs. Launch Site



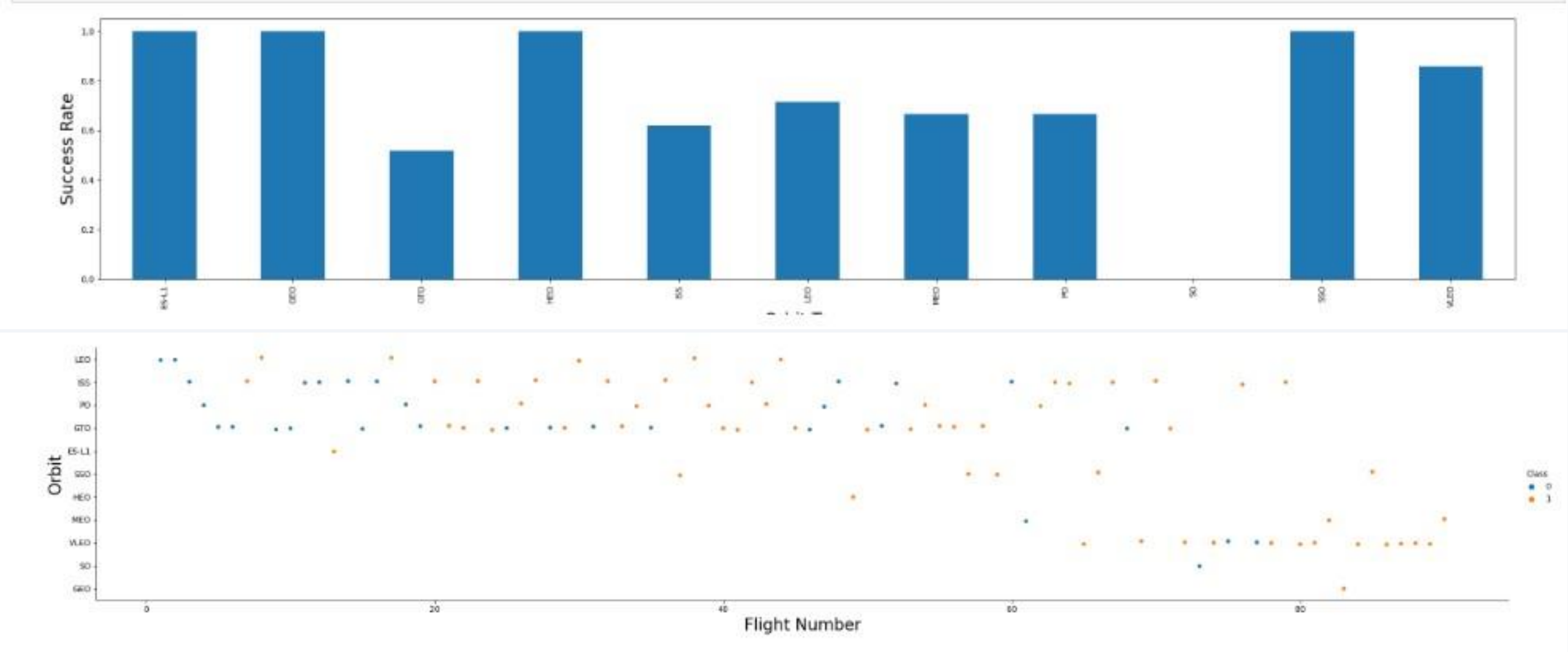

- This scatter plot shows that as the flight number increases the first stage is more likely to be successful.
- KSC LC 39A had more successful launches than unsuccessful.
- CCAFS SLC 40 had more unsuccessful launches at the initial flight attempts, the launches became more successful with increasing flight number.
- VAFB SLC 46 had more successful launches than unsuccessful.

# Payload vs. Launch Site



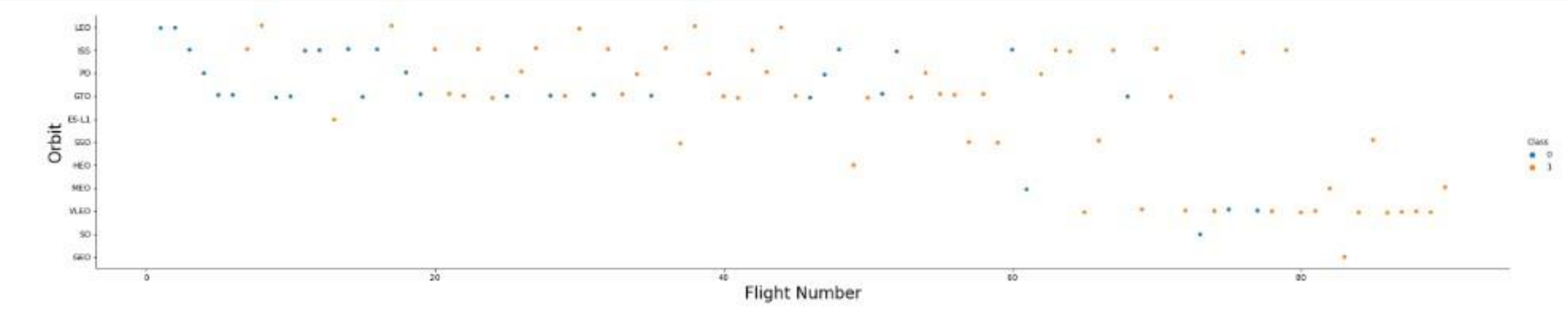

- VAFB SLC 46 had fewer lauches than the other sites but had more successful launches.
- KSC LC 39A had more launches with a wide range of payload mass but had more successful launches.
- CCAFS SLC 40 had most of the launches with lower pay load mass but has a nearly fair number of successful and unsuccessful launches.
- More Launches generally took place with lighter payload mass.

# Success Rate vs. Orbit Type



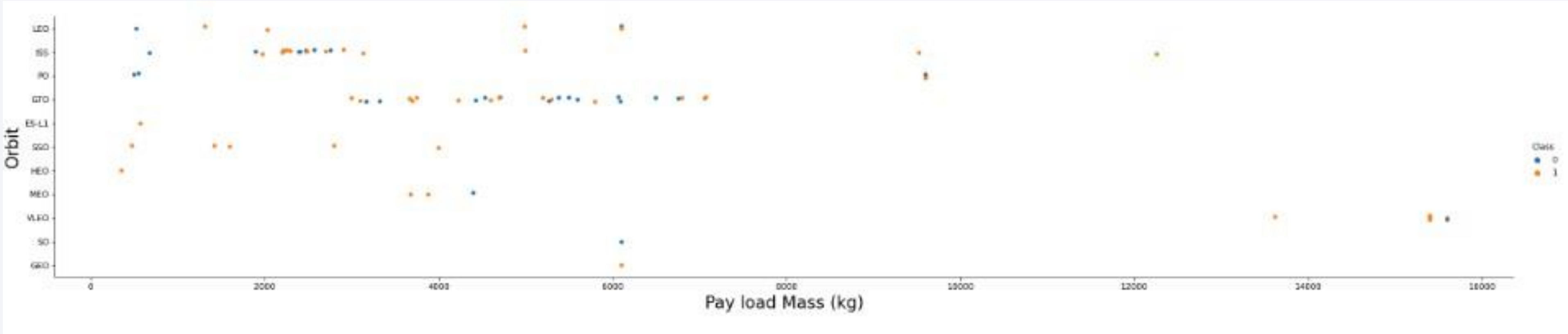

- The success rate of LEO, PO are moderate whereas VLEO success rate is a little higher.
- ES –L1, HEO, SSO, GEO had very high success rates.

# Flight Number vs. Orbit Type



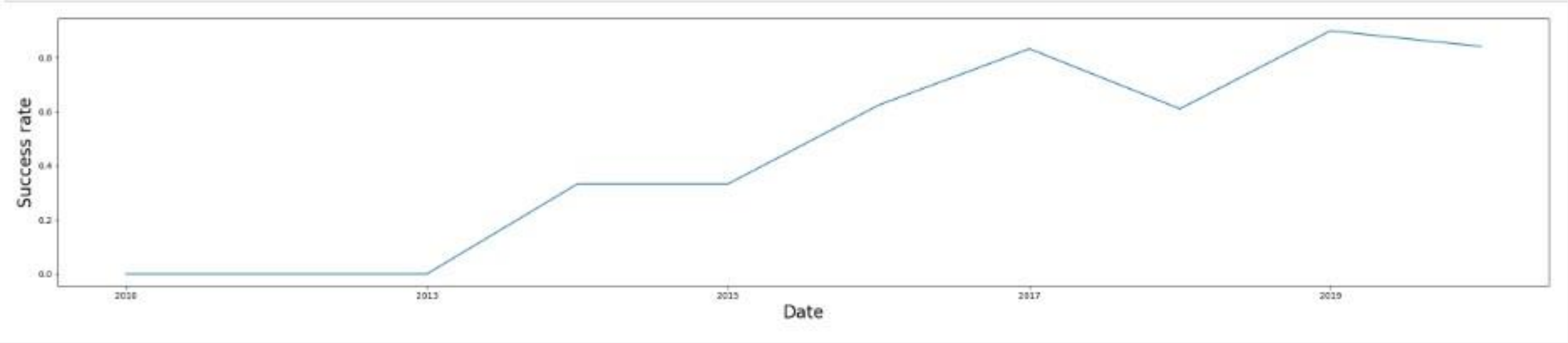

- The success rate of LEO, PO are mostly related to flight number whereas GTO success rate has no correlation with the flight number.
- ES –L1, HEO, SSO, GEO had very few launch attempts with later flights which explains their success rate.

# Payload vs. Orbit Type




- With heavy payloads the successful landing rate are more for Polar,LEO and ISS.
- However for GTO we cannot distinguish this well as both positive landing rate and negative landing(unsuccessful mission) are both there here.
- ES L1, SSO, HEO have launches only with light payload mass and they were all successful.

# Launch Success Yearly Trend




- The success rate was constant between 2010 and 2013.
- From 2013, the success rate had a continual increase till 2015, where theres a slight decrease, theres a continued increase after till 2017 ,where theres a decrease then another increase from 2018 till 2019 then a decrease past 2019.

# All Launch Site Names

```
[12]: %%sql
      select distinct LAUNCH_SITE from "SPACEXTBL"

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

[12]:

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

- There are four unique launch sites:
- CCAFS LC-40
- VAFB SLC -4E
- KSC LC -39A
- CCAFS SLC -40

# Launch Site Names Begin with 'CCA'

## Task 2

Display 5 records where launch sites begin with the string 'CCA'

```
19]: %%sql
select launch_site
from "SPACEXTBL"
where launch_site like "CCA%"
limit 5
```

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

19]:

| Launch_Site |
|---|
| CCAFS LC-40 |
| CCAFS LC-40 |
| CCAFS LC-40 |
| CCAFS LC-40 |
| CCAFS LC-40 |

- The above are five launch records that have launch site names beginning with “CCA”

# Total Payload Mass

### Task 3

Display the total payload mass carried by boosters launched by NASA (CRS)

[22]:
```
%%sql
select sum(payload_mass__kg_)
from SPACEXTBL
where customer="NASA (CRS)"
```

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

[22]:

| sum(payload_mass__kg_) |
|---|
| 45596 |

- The above shows the total payload mass carried by all the boosters launched by NASA(CRS).

# Average Payload Mass by F9 v1.1

### Task 4

Display average payload mass carried by booster version F9 v1.1

[23]:
```
%%sql
select avg(payload_mass__kg_)
from SPACEXTBL
where booster_version="F9 v1.1"
```

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

[23]:

| avg(payload_mass__kg_) |
|---|
| 2928.4 |

- The average payload mass carried by booster F9 v1.1 is 2928.4kg.

# First Successful Ground Landing Date

### Task 5

List the date when the first succesful landing outcome in ground pad was acheived.

*Hint:Use min function*

[61]:
```
%%sql
select min(DATE)
from SPACEXTBL
where "Landing _Outcome"  = 'Success (ground pad)'
```

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

[61]:

| min(DATE) |
|---|
| 01-05-2017 |

- The above query shows the first successful landing that took place on a ground pad, which was on the 1st of May, 2017.

# Successful Drone Ship Landing with Payload between 4000 and 6000

## Task 6

List the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000

[63]:
```
%%sql
select booster_version,payload_mass__kg_
from SPACEXTBL
where "Landing _Outcome" = "Success (drone ship)" and payload_mass__kg_ between 4000 and 6000
```

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

[63]:

| Booster_Version | PAYLOAD_MASS__KG_ |
|---|---|
| F9 FT B1022 | 4696 |
| F9 FT B1026 | 4600 |
| F9 FT B1021.2 | 5300 |
| F9 FT B1031.2 | 5200 |

- The above shows boosters which has landing success in drone ship with a payload mass between 4000kg and 6000kg

# Total Number of Successful and Failure Mission Outcomes

## Task 7

List the total number of successful and failure mission outcomes

[72]:
```
%%sql
select count(mission_outcome)
from SPACEXTBL
where mission_outcome like "Success%"
```

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

[72]:

| count(mission_outcome) |
|---|
| 100 |

- The above shows the total number of successful and failure mission outcomes.

# Boosters Carried Maximum Payload

```
[75]: %%sql
select booster_version,payload_mass__kg_
from SPACEXTBL
where payload_mass__kg_ = (select max(payload_mass__kg_) from SPACEXTBL)

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

[75]:

| 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 |

- The boosters that have carried maximum payload mass are shown in the table above.

# 2015 Launch Records

## Task 9

List the records which will display the month names, failure landing_outcomes in drone ship ,booster versions, launch_site for the months in year 2015.

**Note: SQLLite does not support monthnames. So you need to use substr(Date, 4, 2) as month to get the months and substr(Date,7,4)='2015' for year.**

[78]:
```
%%sql
select substr(Date, 4, 2),booster_version,"Landing _Outcome",launch_site from SPACEXTBL
where substr(Date,7,4)='2015'
and "Landing _Outcome" = "Failure (drone ship)"
```

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

[78]:

| substr(Date, 4, 2) | Booster_Version | Landing _Outcome | Launch_Site |
|---|---|---|---|
| 01 | F9 v1.1 B1012 | Failure (drone ship) | CCAFS LC-40 |
| 04 | F9 v1.1 B1015 | Failure (drone ship) | CCAFS LC-40 |

- The result shows the months and other records in 2015 that landing failed in the drone ship.

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

## Task 10

Rank the count of successful landing_outcomes between the date 04-06-2010 and 20-03-2017 in descending order.

```
[100]: %%sql  SELECT Date, "Landing _Outcome",count("Landing _Outcome")as LANDING_OUTCOME_COUNT
from SPACEXTBL
where   substr(Date,7,4) || substr(Date,4,2) || substr(Date,1,2) between '20100604'and '20170320'
and  "Landing _Outcome" like "%Success%"
group by "Landing _Outcome"
order by count("Landing _Outcome")
desc
```

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

[100]:

| Date | Landing _Outcome | LANDING_OUTCOME_COUNT |
|---|---|---|
| 08-04-2016 | Success (drone ship) | 5 |
| 22-12-2015 | Success (ground pad) | 3 |

- The number of successful landing outcomes between 4th of June,2010 and 20th of March, 2017 are shown in descending order.

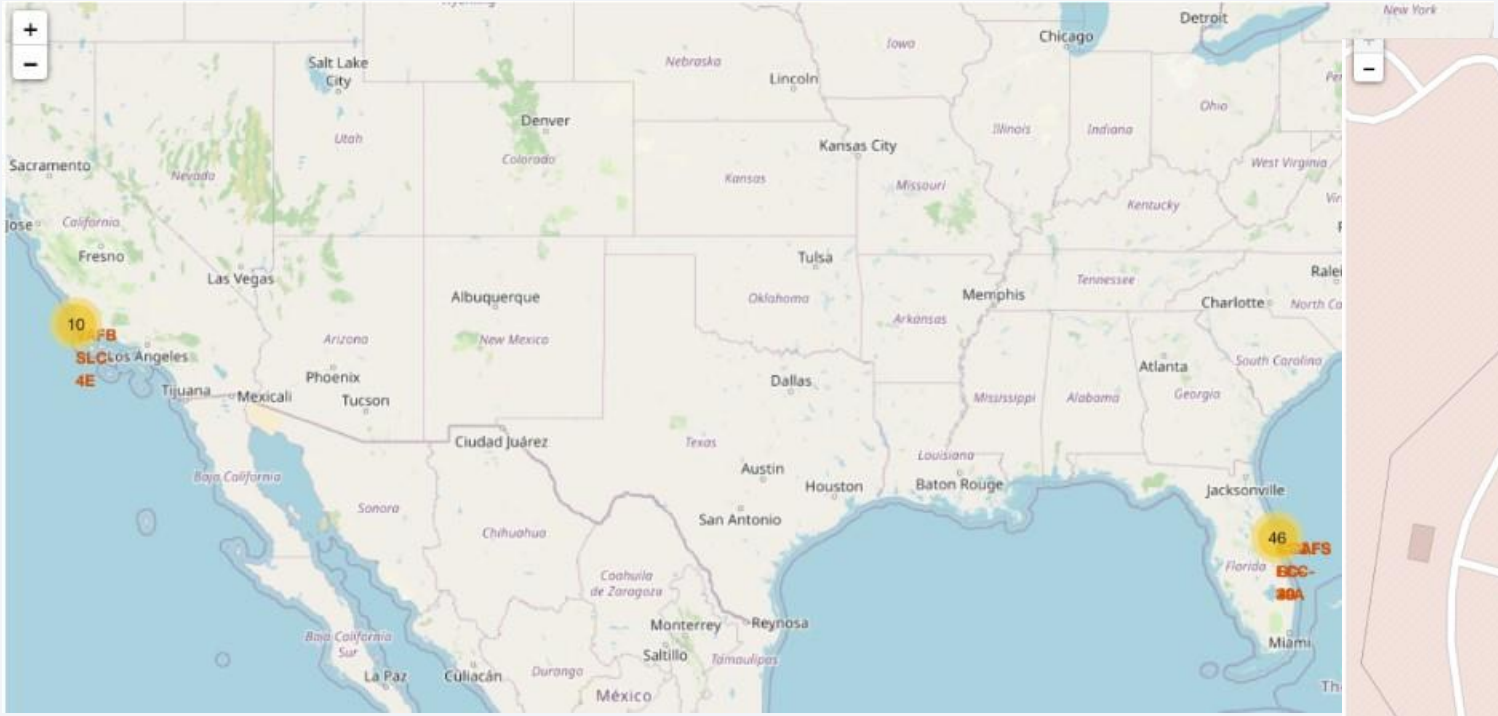
Section 3

# Launch Sites Proximities Analysis

# Global map displaying launch site locations


- This map shows the locations of all the launch sites on a global map.
- The launch sites are all at close proximity to the coastline which is safe area because it is far away from cities, highroads and other areas where it could be harmful to humans.

# Folium map displaying the launch outcomes of the launch sites





- The map shows the color-labeled launch outcomes for each site, where green represents successful launch outcomes and red represents the unsuccessful outcomes.

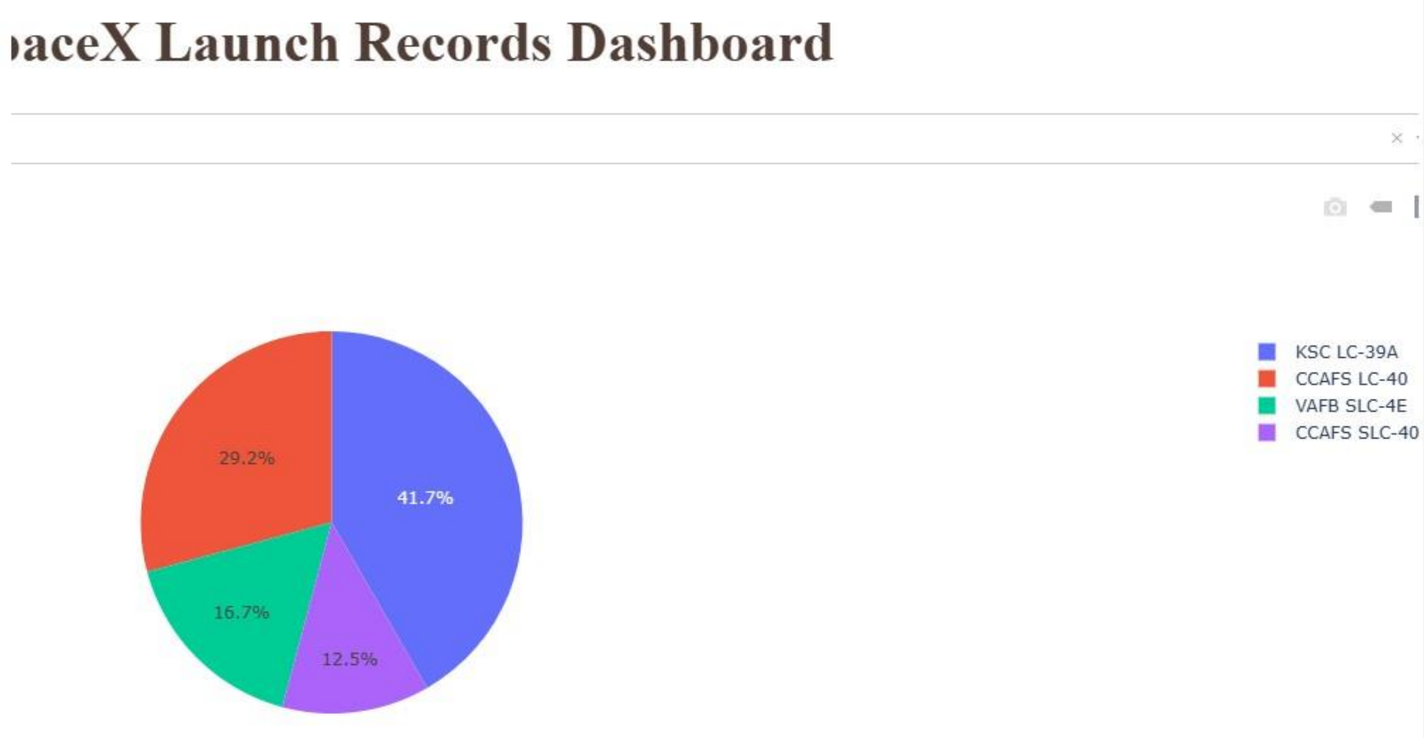
## Folium map displaying the distance of VFAB SLC-4E from the coastline


- This shows the distance of VFAB SLC-4E from the coastline.

Section 4

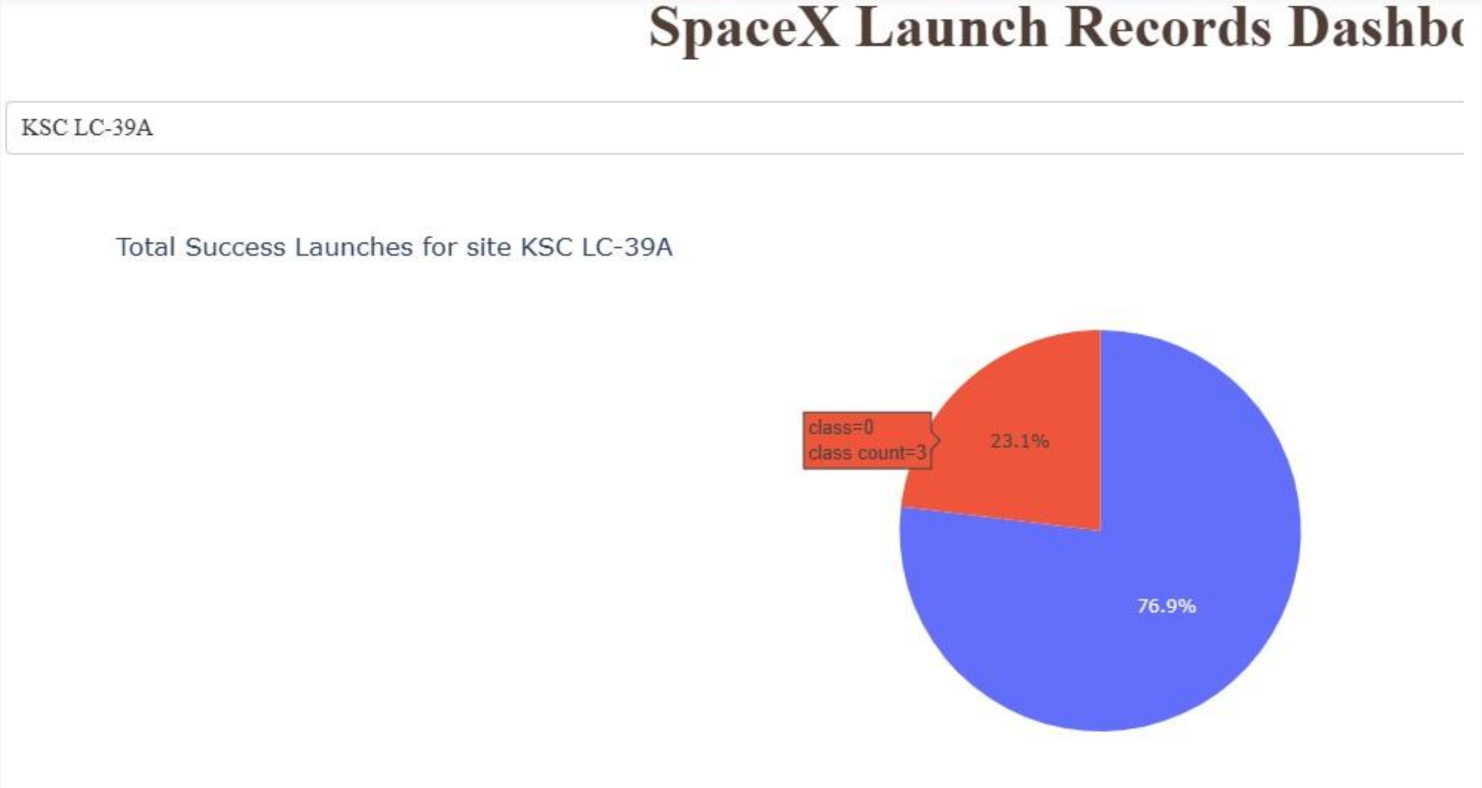
# Build a Dashboard with Plotly Dash

# Pie chart of success count for all launch sites



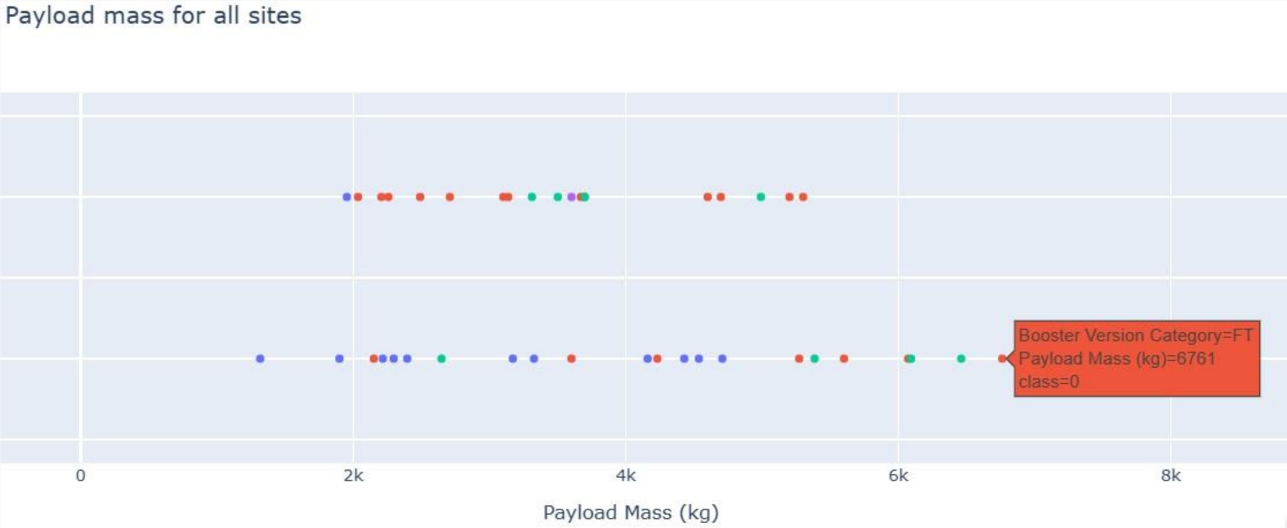

- The KSC LC 39A has the highest percentage of successful landings.
- The CCAFS SLC -40 has the least successful launches.

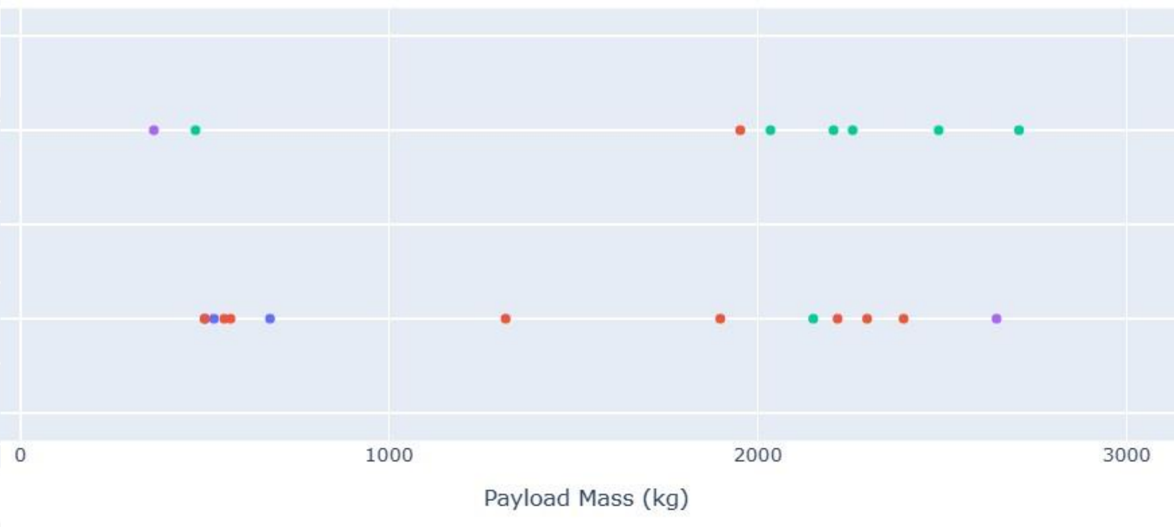
# Pie chart of the KSC LC -39A

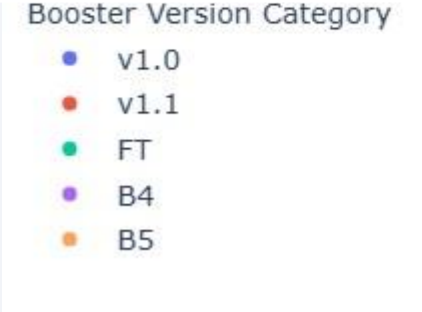



- The KSC LC -39A launch site has the most successful launches overall with 76.9% of the launches being successful.

# Scatter plots of Payload vs. Launch Outcome




- The scatter plots show the success rate of the booster versions per payload mass.
- Booster v1.1 has high success rate with payload mass between 2000kg and 6000kg while v1.0 experiences the opposite.
- Booster FT has more successes within 500kg-3000kg payload range.

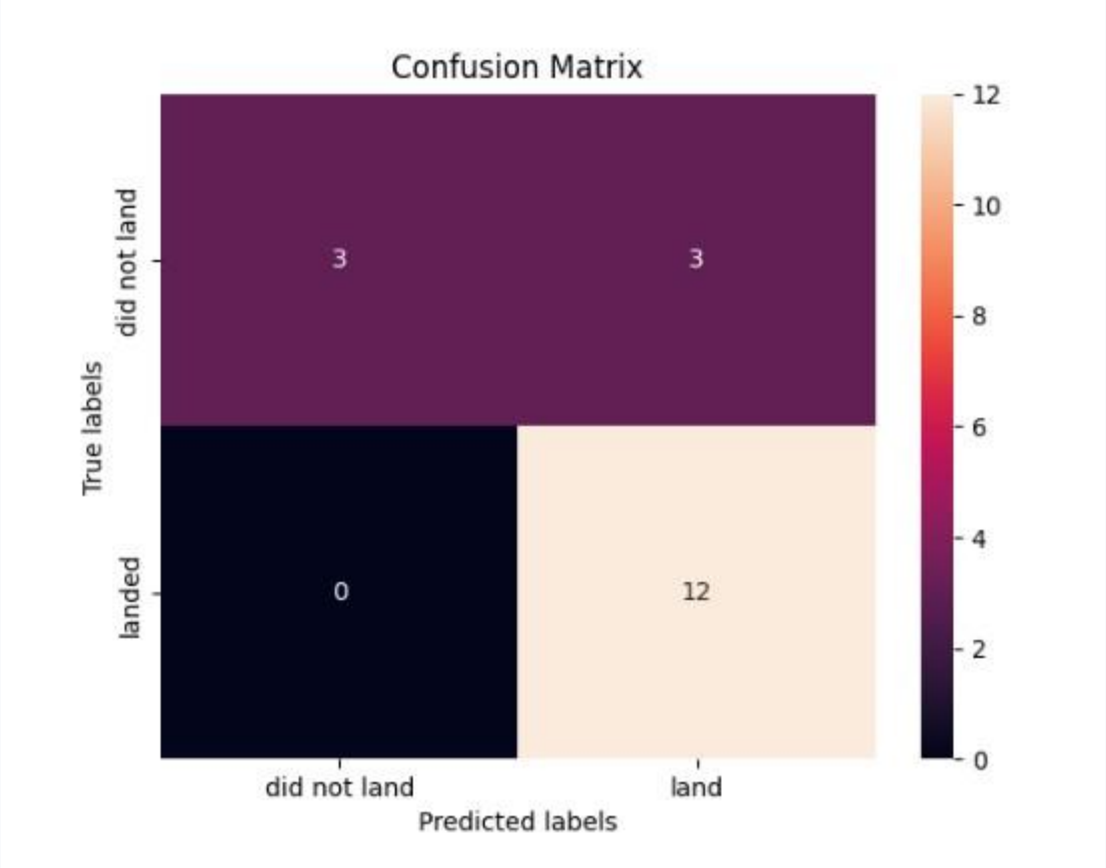
Section 5

# Predictive Analysis (Classification)

# Classification Accuracy

- The decision tree has the highest accuracy with an accuracy of 0.94.

# Confusion Matrix




- The best performing model is the decision tree model.
- The confusion matrix shows that 12 successful launches were correctly predicted and 3 incorrect, 3 unsuccessful launches were correctly predicted.

# Conclusions

- This data set revealed interesting insights; the payload can determine the landing outcome of the launch depending on the  booster version that carries it.
- As the flight number increases, the success rate increases.
- The booster v1.1 has a lot of successful outcomes across wide payload range.
- The KSC LC -39A has the most successful launches, which could be influenced by orbit, boosters and payload mass.
- The optimal machine learning model to be used is the decision tree model because of the high accuracy level of 0.94.
- These variables can be used to determine if the first stage will return which will enable the determination of the price of the launch.

# Appendix

[5]:

| | FlightNumber | Date | BoosterVersion | PayloadMass | Orbit | LaunchSite | Outcome | Flights | GridFins | Reused | Legs | LandingPad | Block | Reused( |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 78 | 79 | 2020-05-30 | Falcon 9 | 9525.000000 | ISS | KSC LC 39A | True ASDS | 1 | True | False | True | 5e9e3032383ecb6bb234e7ca | 5.0 | |
| 79 | 80 | 2020-06-04 | Falcon 9 | 15400.000000 | VLEO | CCAFS SLC 40 | True ASDS | 5 | True | True | True | 5e9e3033383ecbb9e534e7cc | 5.0 | |
| 80 | 81 | 2020-06-13 | Falcon 9 | 15400.000000 | VLEO | CCAFS SLC 40 | True ASDS | 3 | True | True | True | 5e9e3032383ecb6bb234e7ca | 5.0 | |
| 81 | 82 | 2020-06-30 | Falcon 9 | 3880.000000 | MEO | CCAFS SLC 40 | True ASDS | 1 | True | False | True | 5e9e3033383ecbb9e534e7cc | 5.0 | |
| 82 | 83 | 2020-07-20 | Falcon 9 | 6104.959412 | GEO | CCAFS SLC 40 | True ASDS | 2 | True | True | True | 5e9e3033383ecbb9e534e7cc | 5.0 | |
| 83 | 84 | 2020-08-18 | Falcon 9 | 15400.000000 | VLEO | CCAFS SLC 40 | True ASDS | 6 | True | True | True | 5e9e3032383ecb6bb234e7ca | 5.0 | |
| 84 | 85 | 2020-08-30 | Falcon 9 | 1600.000000 | SSO | CCAFS SLC 40 | True RTLS | 4 | True | True | True | 5e9e3032383ecb267a34e7c7 | 5.0 | |
| 85 | 86 | 2020-09-03 | Falcon 9 | 15400.000000 | VLEO | KSC LC 39A | True ASDS | 2 | True | True | True | 5e9e3032383ecb6bb234e7ca | 5.0 | |
| 86 | 87 | 2020-10-06 | Falcon 9 | 15400.000000 | VLEO | KSC LC 39A | True ASDS | 3 | True | True | True | 5e9e3032383ecb6bb234e7ca | 5.0 | |
| 87 | 88 | 2020-10-18 | Falcon 9 | 15400.000000 | VLEO | KSC LC 39A | True ASDS | 6 | True | True | True | 5e9e3032383ecb6bb234e7ca | 5.0 | |

- Dataset worked on is shown above.

# Thank you!