
# Winning Space Race with Data Science

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20th March/2022

# Outline

# Executive Summary



**Problem Statement**

According to CB Insights statistics, 20% of startups fail because they got outcompeted while 8% of startups were sunk because of poor products. Our competitor SpaceX, dominates the market because of the reusability of its rockets. To outcompete them, it is imperative to determine our product performance. In this case, we need a way to predict the landing outcome of our rockets after they are launched.

**Solution**

We collected data on SpaceX's Falcon 9 rocket launches and used it to train Machine Learning models that will predict whether the first stage of the rocket will land successfully. This was done through the following ways:

- Data Collection
- Data Analysis
- Predictive Modeling using Machine Learning Algorithms

Note that the data collection stage was carried out using API requests and Web Scraping in order to minimize costs.

**Value**

The predictive models enabled the company to determine the success of a rocket landing. This was especially important, because a failed landing could result in a loss of tens of millions of dollars. Furthermore, it enabled the company to determine costs and make more attractive offers than SpaceX.

**Final Thoughts and Next Steps**

Powerful Analytics and Machine Learning  tools not only increase our competitiveness – they can also increase customer confidence in our offerings.  With the attention of these offerings, we expect to break into a market projected to reach USD 26.16 billion by 2027. For more information, visit the full project repository: https://github.com/Molo-M/SpaceX_Landing_Prediction

# Introduction



The primary objective of this Data Science project is to allow the company to compete with SpaceX. In order to achieve this goal, it is necessary to predict if the first stage of the SpaceX Falcon 9 rocket will land successfully.

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.

Therefore if we can accurately predict the likelihood of the first stage rocket landing successfully, we can determine the cost of a launch. With the help of the Data Science findings and models, the company can make more informed bids against SpaceX for a rocket launch.

Section 1

# Methodology

# Methodology



## Executive Summary

- Data collection methodology:
  - Make requests to the SpaceX API.
  - Perform web scraping to collect Falcon 9 historical launch records on the Wikipedia page titled: List of Falcon 9 and Falcon Heavy launches
- Perform data wrangling
  - Clean the data and explore it to find patterns in the data to determine the labels for training supervised models.
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - Create a machine learning pipeline to predict if the first stage will land given the data.
  - Train the best performing model to make accurate predictions.

# Data Collection



The data collection stage is arguably the most crucial stage in the project. This is because we use data to train our machine learning models to make precise predictions.

There are different ways to go about collecting the data but we used two methods:

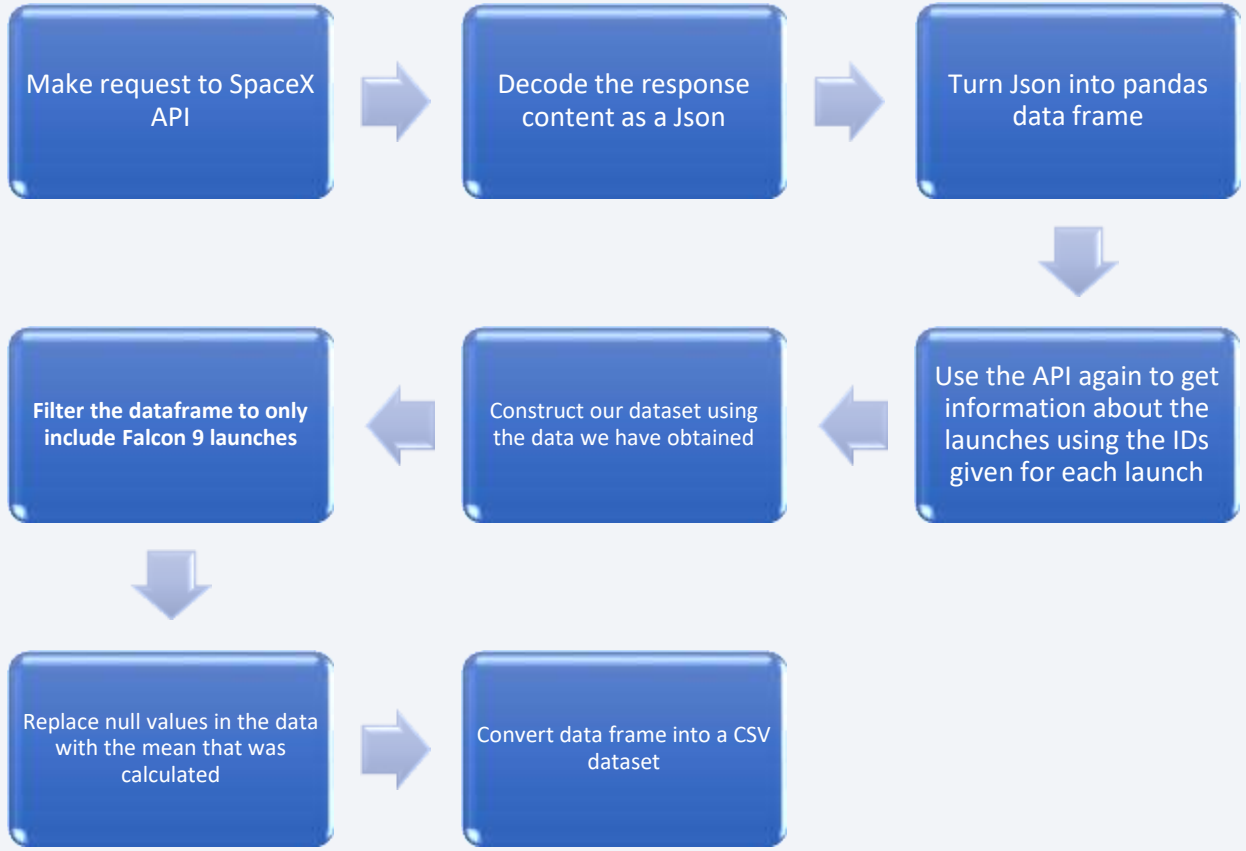
- Data collection by SpaceX API request.
- Data collection by Web Scraping

These are all low-cost methods that only require a functioning internet connection.

# Data Collection – SpaceX API



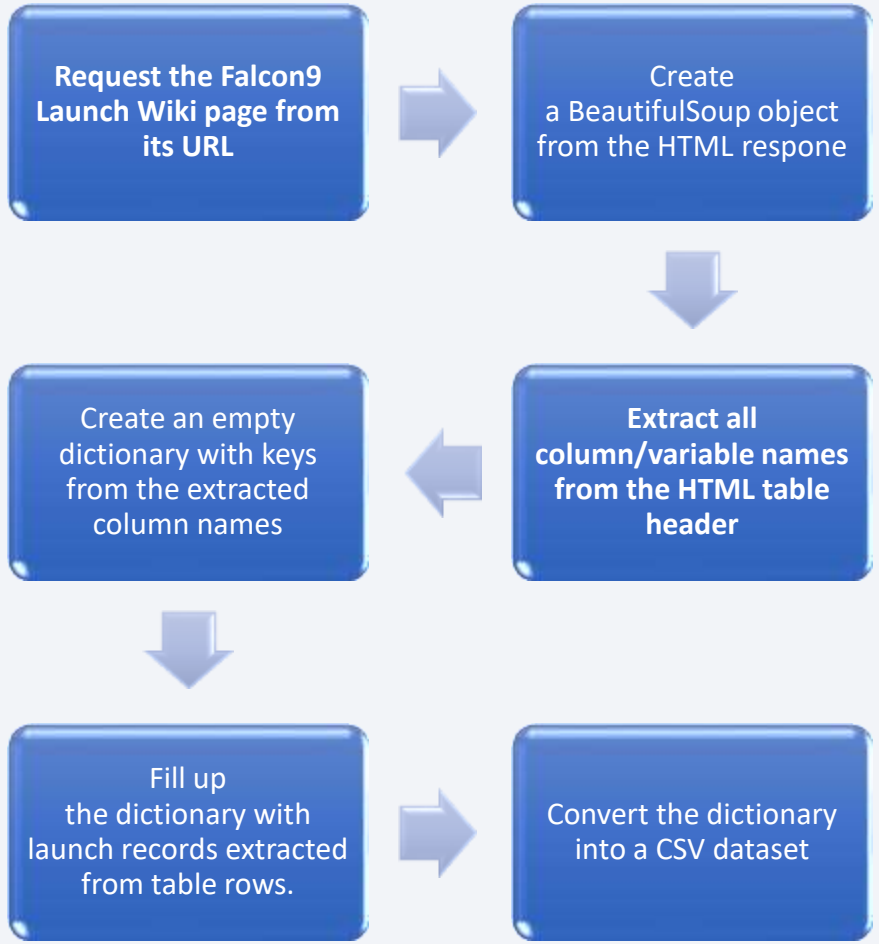
- Make a request to SpaceX API and make sure the data is in the correct format.
- Perform some basic data wrangling and formatting in order to clean the requested data.
- Convert our data frame into a CSV dataset.
- URL link: https://github.com/Molo-M/SpaceX_Landing_Prediction/blob/main/SpaceX-data-collection-api.ipynb



# Data Collection - Web Scraping



- Using BeautifulSoup, perform web scraping on the wikipedia page with title: List of Falcon 9 and Falcon Heavy launches
- Store the launch records in an HTML table.
- Parse the table and convert it into a CSV dataset.
- URL link: https://github.com/Molo-M/SpaceX_Landing_Prediction/blob/main/SpaceX-webscraping.ipynb



# Data Wrangling

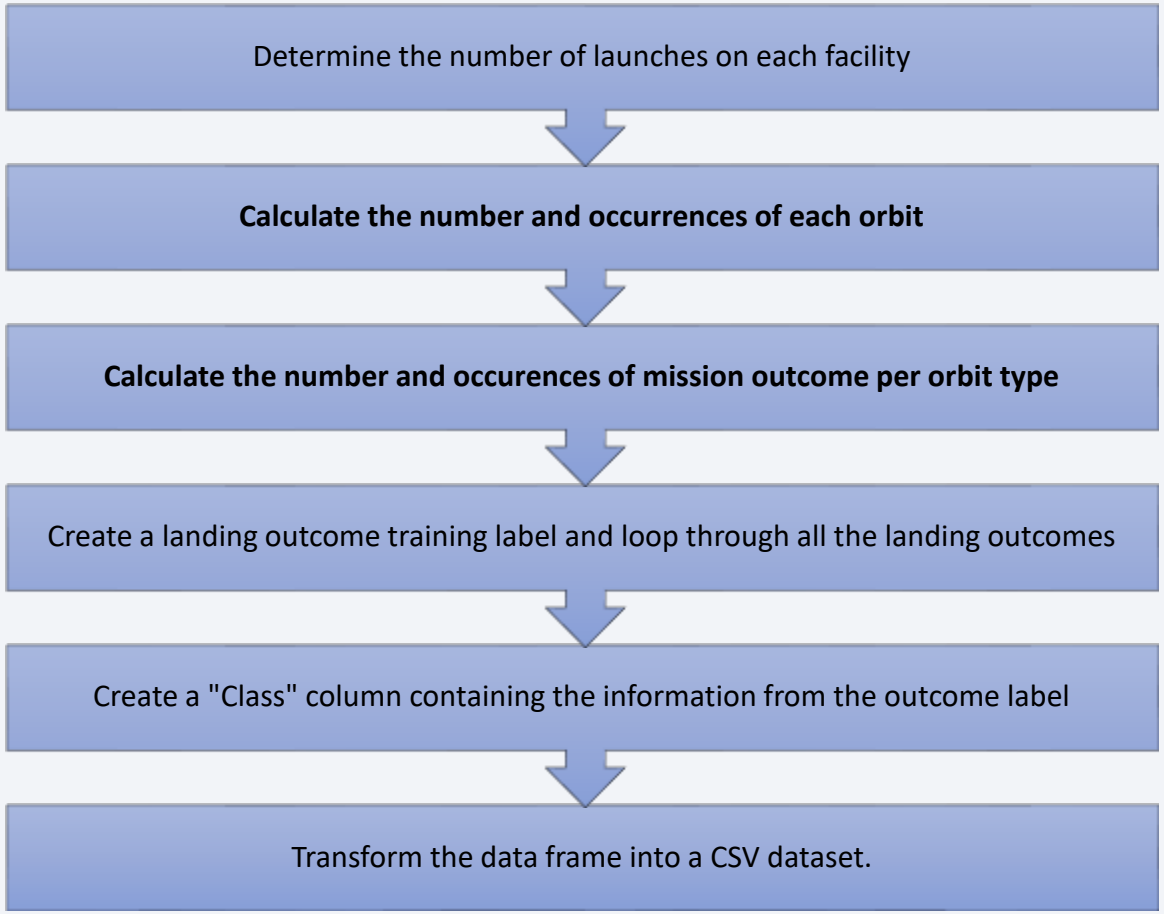


The goal in this stage is to find patterns in the data and determine the label for training supervised machine learning models.

In the data set, there are several different cases where the rocket did not land successfully. For example, *True RTLS* means the rocket successfully landed on a ground pad while *False RTLS* means the rocket unsuccessfully landed on a ground pad.

Those outcomes were converted into Training Labels whereby *1* means the rocket landed successfully while *0* means it was unsuccessful.

URL link: https://github.com/Molo-M/SpaceX_Landing_Prediction/blob/main/SpaceX-Data%20wrangling.ipynb



# EDA with Data Visualization



Data visualization helps us understand data by curating it into a form that's easier to understand, highlighting the trends and outliers. Several types of charts were used in the visualization of the data:

- Cat plots and scatter plots were used to view the relationships of categorical variables like ***Launch Site*** and ***Orbit***.
- A bar chart was used to visualize the success rate of each orbit type.
- A line chart was used to visualize the launch success yearly trend.

URL link: https://github.com/Molo-M/SpaceX_Landing_Prediction/blob/main/SpaceX-EDA-data%20visualization.ipynb

# EDA with SQL



Summary of SQL queries that were used:

- Display the names of the unique launch sites in the space mission
- Compare the payload mass with boosters launched by NASA (CRS)
- Display average payload mass carried by booster version F9 v1.1
- List the total number of successful and failure mission outcomes
- Determine the dates of different landing outcomes

URL link: https://github.com/Molo-M/SpaceX_Landing_Prediction/blob/main/SpaceX_EDA_SQL.ipynb

# Build an Interactive Map with Folium



- Folium Markers were used to show the SpaceX launch sites and their nearest important landmarks like railways, highways, cities and coastlines.
- Polylines were used to connect the launch sites to their nearest land marks.
- Furthermore, Folium Circles were used to highlight circle area of launch sites.
- In order to mark the success/failed launches for each site, marker clusters were used on the map. Whereby Red represents rocket launch failures while Green represents the successes.
- URL link: https://github.com/Molo-M/SpaceX_Landing_Prediction/blob/main/SpaceX_launch_site_location.ipynb

# Build a Dashboard with Plotly Dash



- Pie charts and scatter charts were used to visualize the launch records of SpaceX.
- These charts displayed the rocket launch success rate per launch site. We are were able to get an understanding of the factors that may have been influencing the success rate at each site. Such as the payload mass and booster versions.
- Successful launches were represented by 1 while failures were represented by 0.
- URL link: https://github.com/Molo-M/SpaceX_Landing_Prediction/blob/main/SpaceX_Dashboard.ipynb

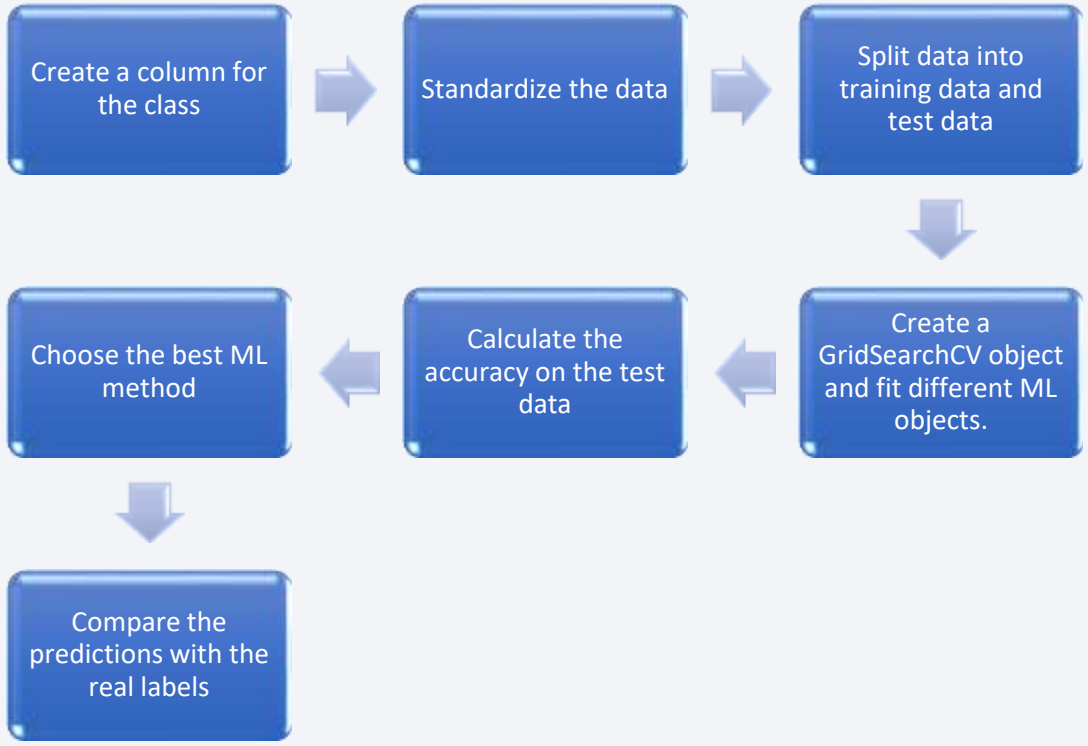
# Predictive Analysis (Classification)



Scikit-learn is the primary ML(machine learning) library that was used for predictive analysis. The following took place:

- Created a machine learning pipeline to predict if the first stage will land given the data.
- Using *GridSearchCV*, found the best ML method for predictions.
- Compared the predictions with the real labels.
- The ML model scored an accuracy of 83.33%

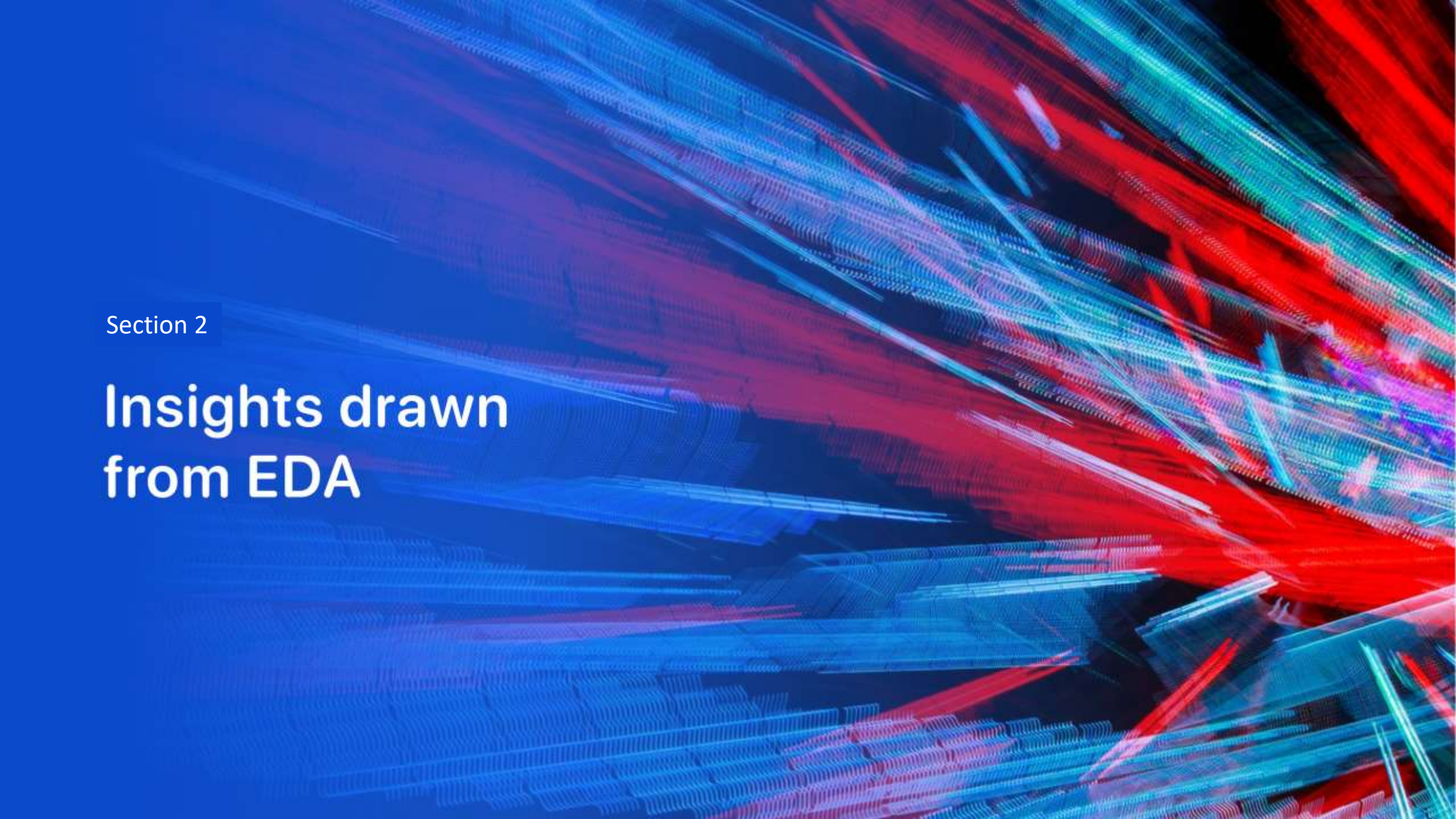
URL link: https://github.com/Molo-M/SpaceX_Landing_Prediction/blob/main/SpaceX_Machine%20Learning%20Prediction.ipynb



# Results



- The exploratory data analysis has shown us that successful landing outcomes are somewhat correlated with flight number. It was also apparent that successful landing outcomes have had a significant increase since the year 2015.
- All launch sites are located near the coast line. Perhaps, this makes it easier to test rocket landings in the water.
- Furthermore, the sites are also located near highways and railways. This may facilitate transportation of equipment and research material.
- The machine learning models that were built, were able to predict the landing success of rockets with an accuracy score of 83.33%. This accuracy can be increased in future projects with more data.

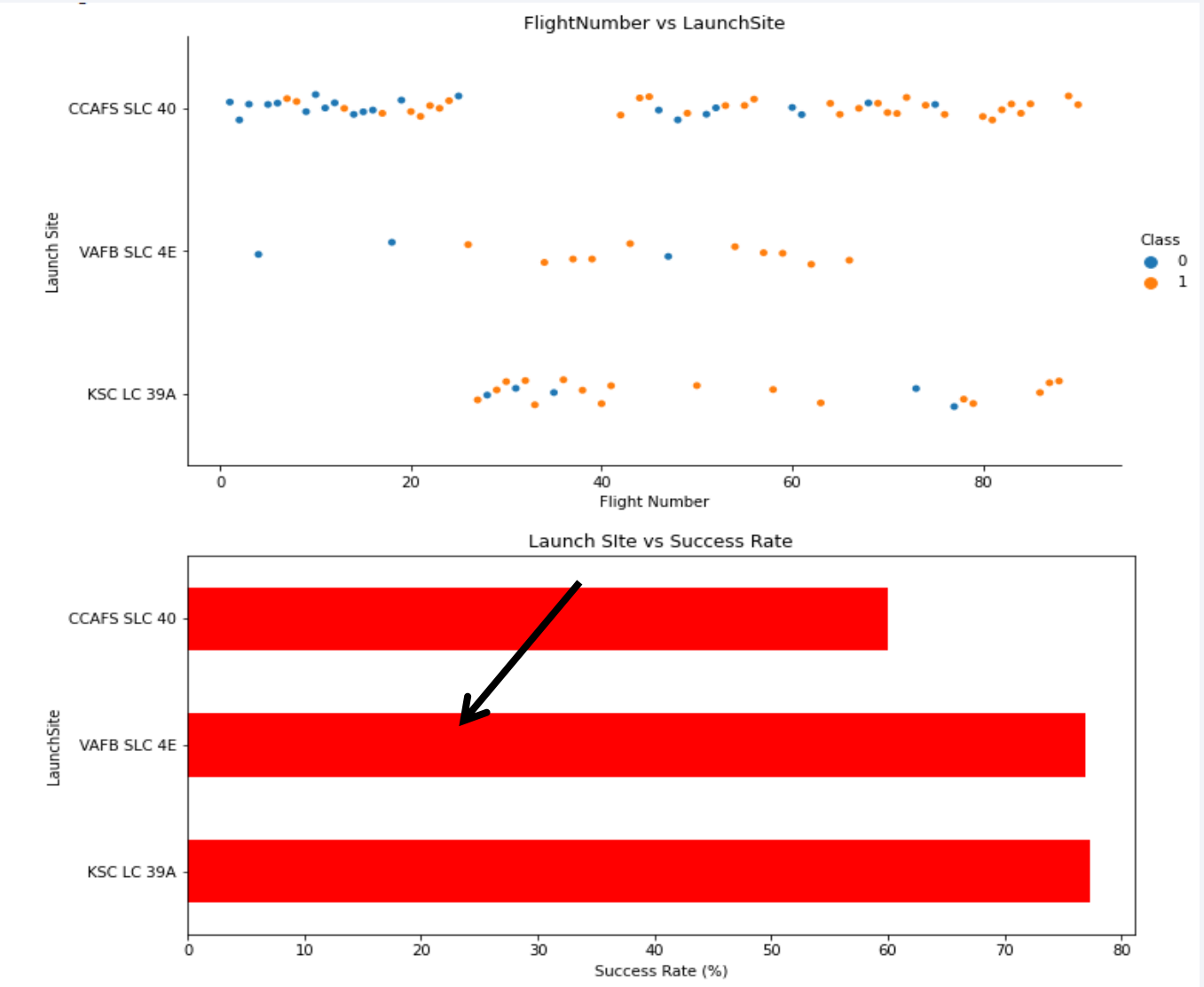

Section 2
Insights drawn
from EDA

# Flight Number vs. Launch Site



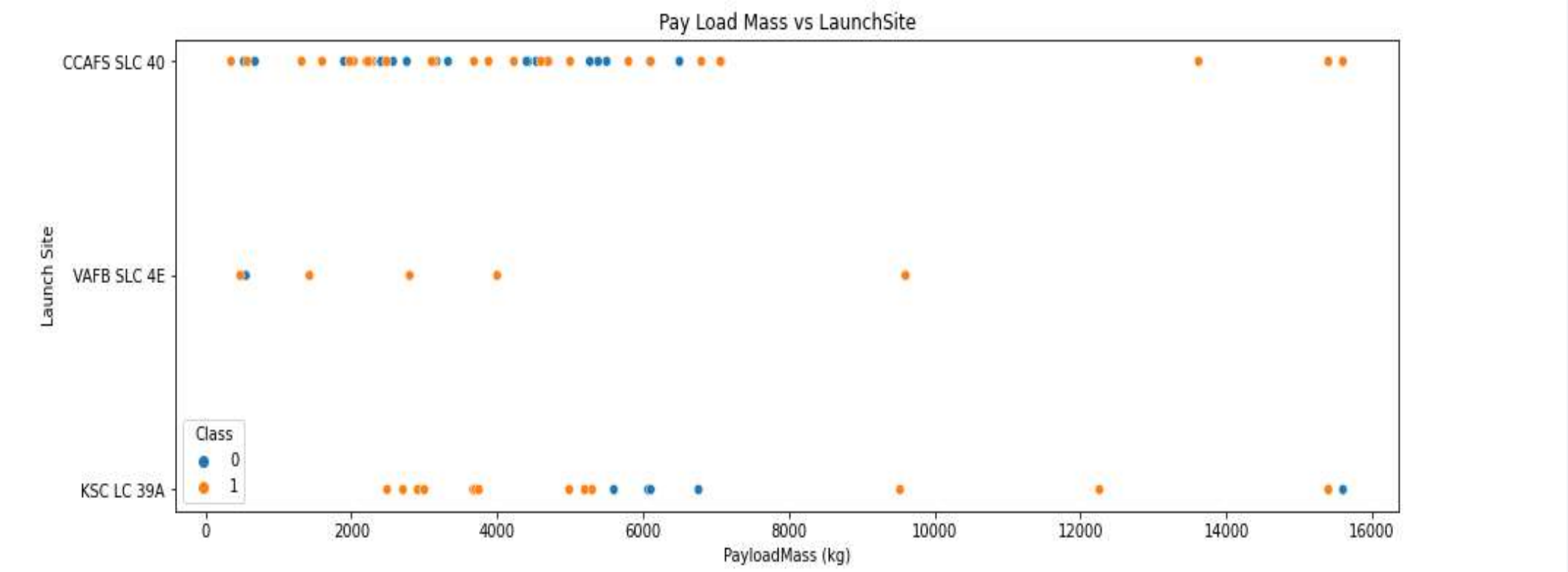
- It appears that there were more successful landings as the flight numbers increased. It also seems that launch site **CCAFS SLC 40** had the most number of landing attempts while the site **VAFB SLC 4E** had the least number of attempts.

- Looking at the second chart, we can see that there is no Launch Site with a success rate below 60%.



# Payload vs. Launch Site



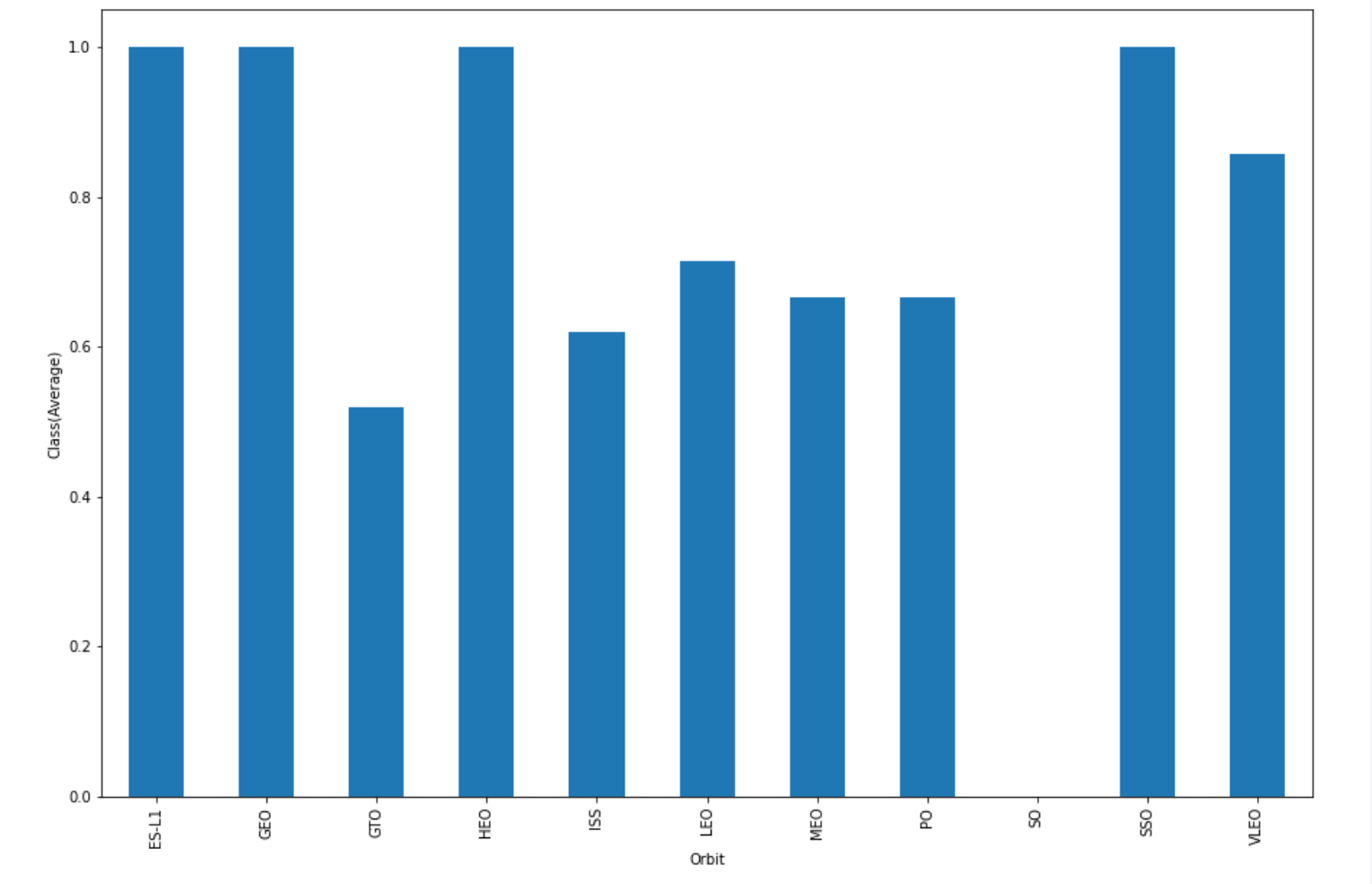



- Now if you observe the scatter point chart, you will find for the VAFB-SLC launch site there are no rockets launched for heavy payload mass(greater than 10000).

# Success Rate vs. Orbit Type

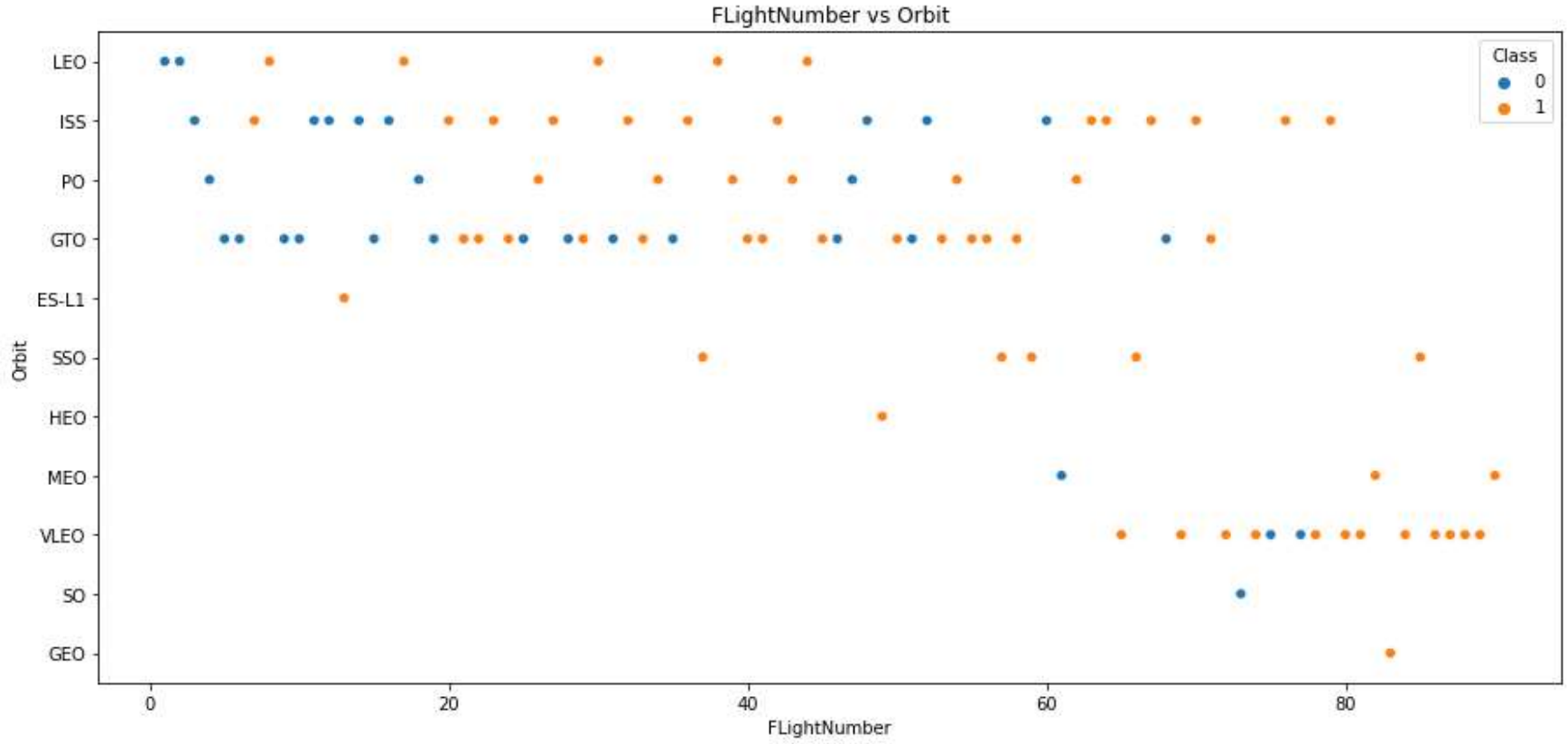


The orbit types **SSO**, **HEO**, **GEO** and **ES-L1** had the highest success rate.



# Flight Number vs. Orbit Type

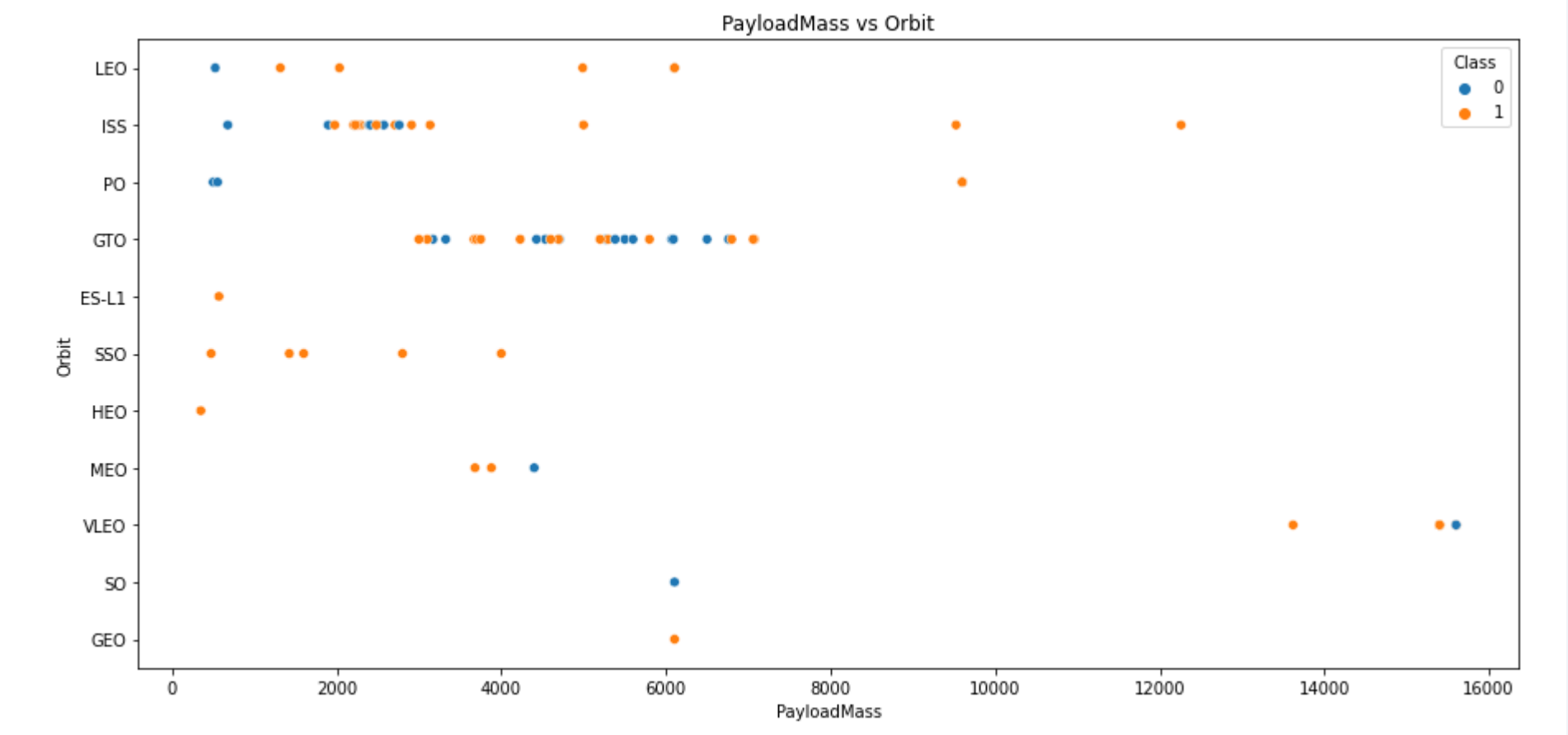





You can see that in the LEO orbit the Success appears related to the number of flights; on the other hand, there seems to be no relationship between flight number when in GTO orbit.

# Payload vs. Orbit Type

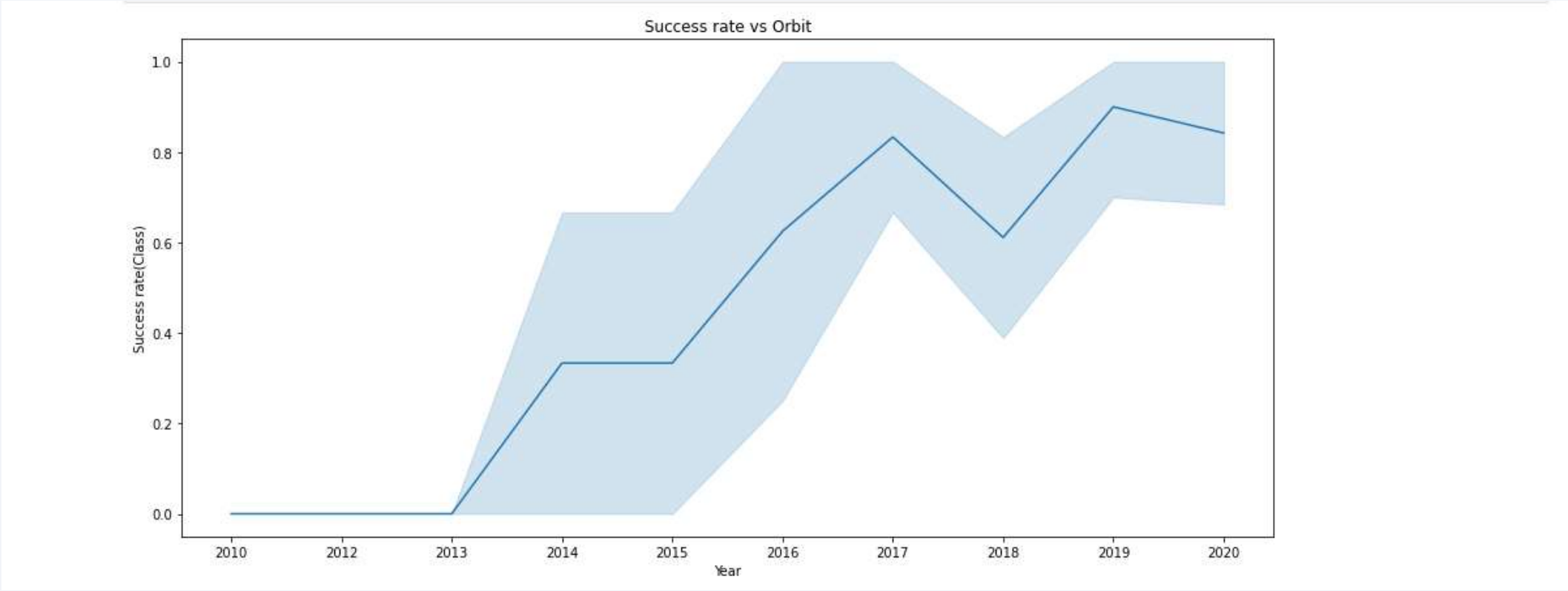





- With heavy payloads the successful landing or positive landing rate are more for Polar, LEO and ISS.
- However for GTO we cannot distinguish this well as both positive landing rate and negative landing(unsuccessful mission) are both there.

# Launch Success Yearly Trend






It is apparent that the success rate has significantly increased from 2013 to 2020.

# All Launch Site Names



Given the data, these are the names of the launch sites where different rocket landings where attempted:

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

# Launch Site Names Beginning with 'CCA'



| Date | Launch_Site | Orbit | Customer | Mission_Outcome | Landing_Outcome |
|---|---|---|---|---|---|
| 04-06-2010 | CCAFS LC-40 | LEO | SpaceX | Success | Failure (parachute) |
| 08-12-2010 | CCAFS LC-40 | LEO (ISS) | NASA (COTS) NRO | Success | Failure (parachute) |
| 22-05-2012 | CCAFS LC-40 | LEO (ISS) | NASA (COTS) | Success | No attempt |
| 08-10-2012 | CCAFS LC-40 | LEO (ISS) | NASA (CRS) | Success | No attempt |
| 01-03-2013 | CCAFS LC-40 | LEO (ISS) | NASA (CRS) | Success | No attempt |

These are 5 records where launch sites begin with the letters 'CCA'. As we can see, there are other organizations besides SpaceX that were testing their rockets.

# Total Payload Mass



- The information in the table displays the total payload mass carried by boosters launched by NASA .
- It seems that *NASA (CRS)* had a significantly higher total payload mass compared to the rest.

| Customer | Total_Payload_Mass |
|---|---|
| NASA (CRS) | 45596 |
| NASA (CCDev) | 12530 |
| NASA (CCP) | 12500 |
| NASA (CCD) | 12055 |
| NASA (CTS) | 12050 |
| NASA (CRS), Kacific 1 | 2617 |
| NASA / NOAA / ESA / EUMETSAT | 1192 |
| NASA (LSP) NOAA CNES | 553 |
| NASA (COTS) | 525 |
| NASA (LSP) | 362 |
| NASA (COTS) NRO | 0 |

# Average Payload Mass by F9 v1.1



| Average_Payload_Mass (kg) | Booster_Version |
|---|---|
| 2928.4 | F9 v1.1 |

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

# First Successful Ground Landing Date



| Date | Landing_Outcome |
|---|---|
| 22-12-2015 | Success (ground pad) |

- The first successful ground pad landing took place in December 2015. This was a historic reusable-rocket milestone for both SpaceX and the world.
- Prior to this, no one had ever brought an orbital class booster back intact.

# Successful Drone Ship Landing with Payload between 4000 and 6000



| Booster_Version | PAYLOAD_MASS__KG_ | Landing_Outcome |
|---|---|---|
| F9 FT B1022 | 4696 | Success (drone ship) |
| F9 FT B1026 | 4600 | Success (drone ship) |
| F9 FT B1021.2 | 5300 | Success (drone ship) |
| F9 FT B1031.2 | 5200 | Success (drone ship) |

- It appears that there only 4 Boosters with a payload mass between 4000 and 6000.
- It is interesting to see that they all had successful landing outcomes.

# Total Number of Successful and Failure Mission Outcomes



| Mission_Outcome | Outcomes |
|---|---|
| Failure (in flight) | 1 |
| Success | 99 |
| Success (payload status unclear) | 1 |

- It appears that missions generally tend to be successful with the exception of one failure.

# Boosters That Carried  the Maximum Payload Mass



- 12 boosters have carried the maximum payload mass of 15600 kg.
- Since the version names are similar, they might be from the same manufactures.

| 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 |

# 2015 Launch Records - Failed Landing Outcomes



| Date | Launch_Site | Booster_Version | Landing_Outcome |
|---|---|---|---|
| 10-01-2015 | CCAFS LC-40 | F9 v1.1 B1012 | Failure (drone ship) |
| 14-04-2015 | CCAFS LC-40 | F9 v1.1 B1015 | Failure (drone ship) |

- It appears that 2 boosters failed to land at the beginning of the year..
- The first successful landing took place later that year in December as we saw earlier.

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



- If we observe the table, it is apparent that the number of successful landings have increased since 2015.
- Before 2013, it seems that there were no attempts to land the boosters.

| _date_ | Landing_Outcome | Outcomes |
|---|---|---|
| 2016-04-08 | Success (drone ship) | 14 |
| 2015-12-22 | Success (ground pad) | 9 |
| 2015-06-28 | Precluded (drone ship) | 1 |
| 2015-01-10 | Failure (drone ship) | 5 |
| 2014-04-18 | Controlled (ocean) | 5 |
| 2013-09-29 | Uncontrolled (ocean) | 2 |
| 2012-05-22 | No attempt | 22 |

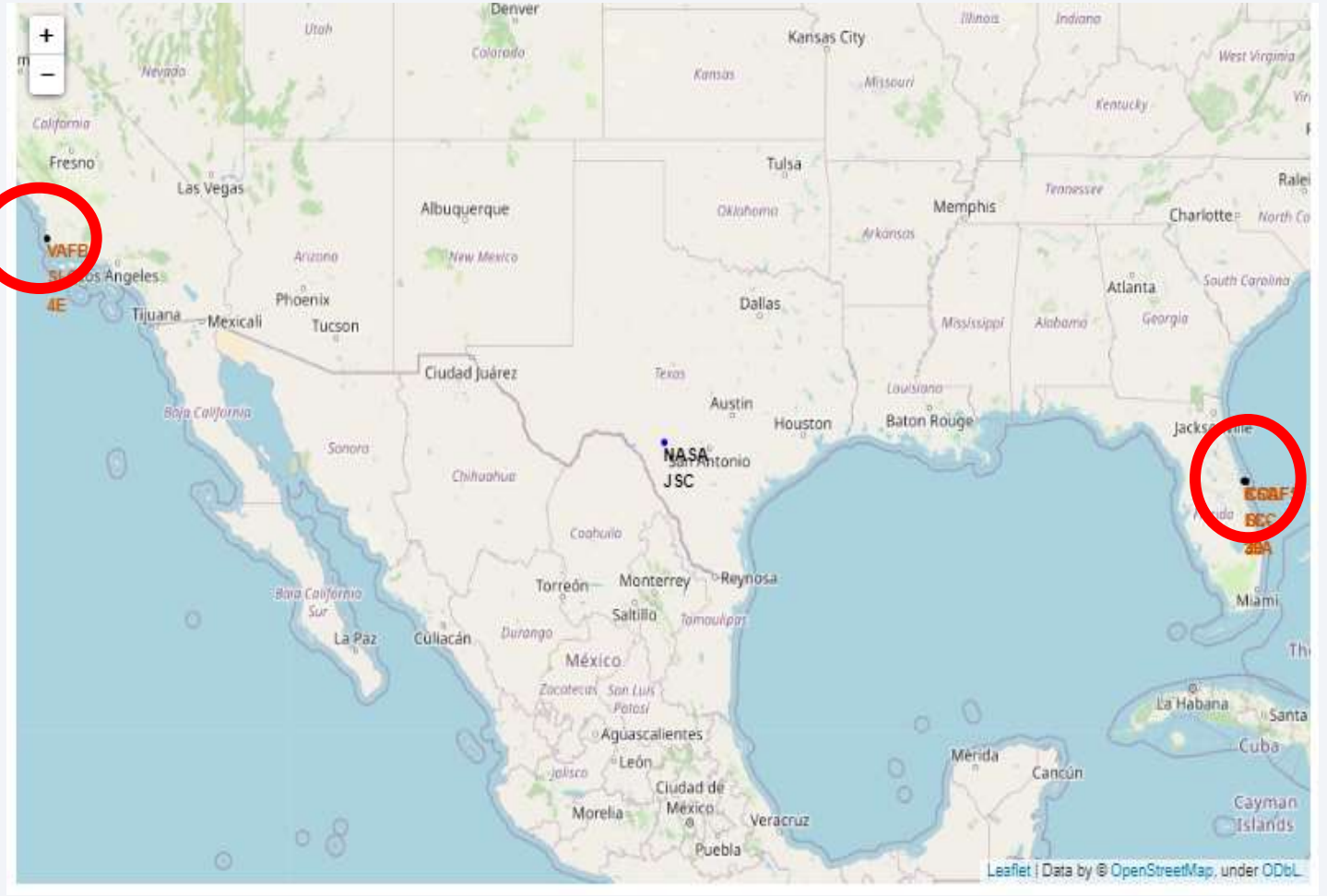
Section 3

# Launch Sites Proximities Analysis

# Launch Site Locations



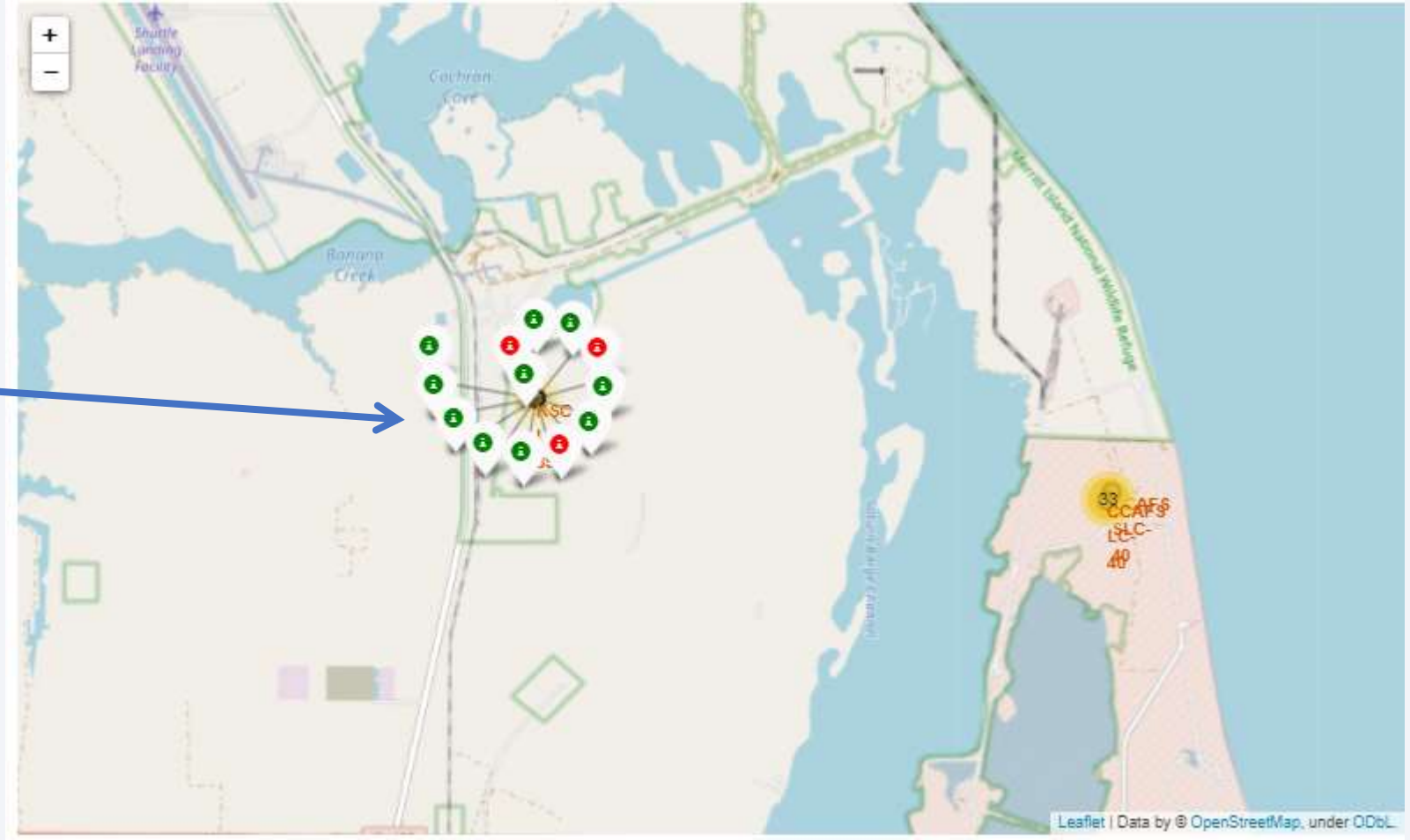
- We can see that all launch sites are in very close proximity to the coast and they are also a couple thousand kilometers away from the equator line.
- It is interesting to see that most launch sites are concentrated near Miami.



# Success Rate of Rocket Launches



- The successful launches are represented by a green marker while the red marker represents failed rocket launches.
- It appears that **KSC LC-39A** had the highest success rate of rocket launches compared to other launch sites.

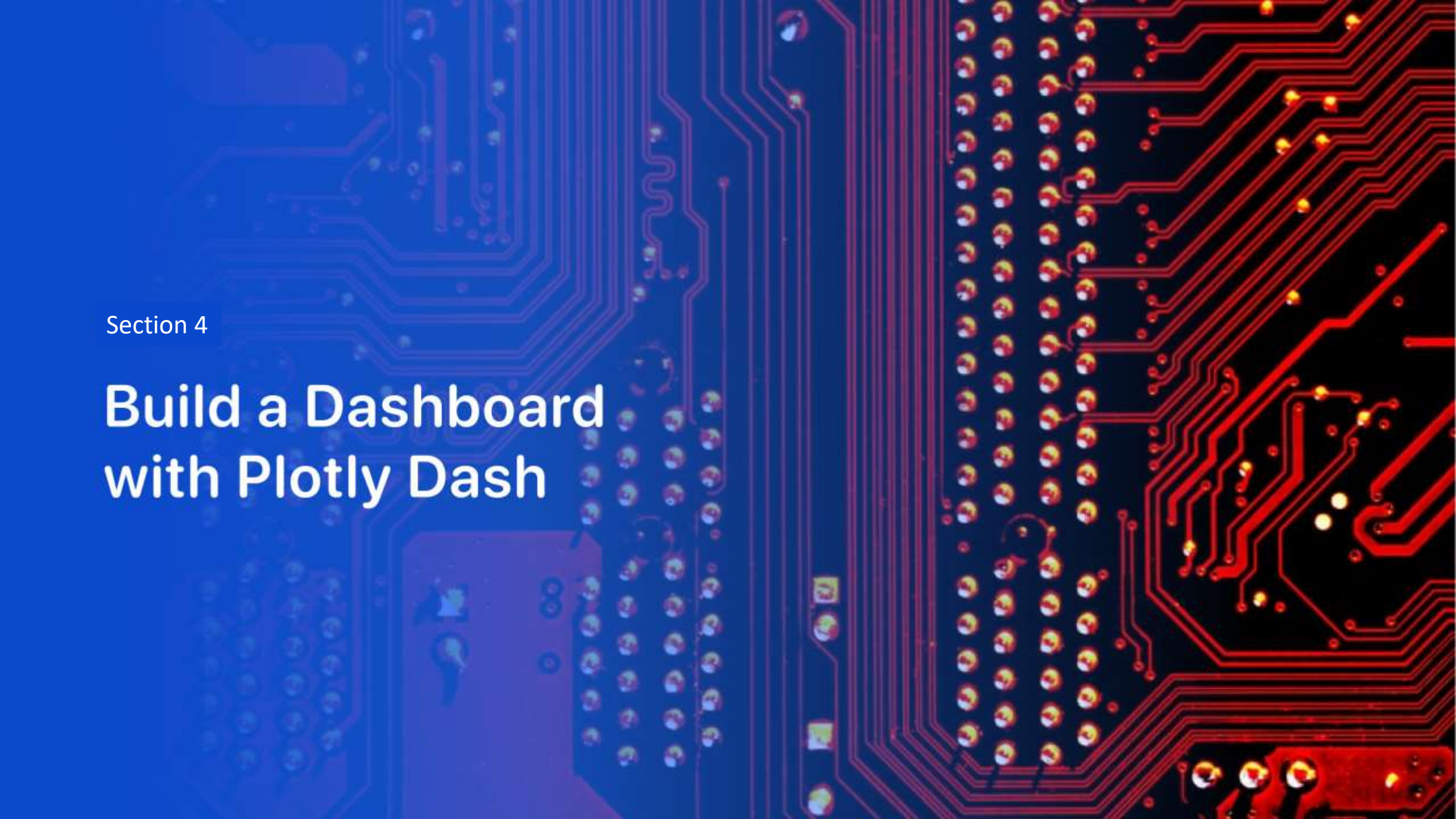


# Surrounding Landmarks



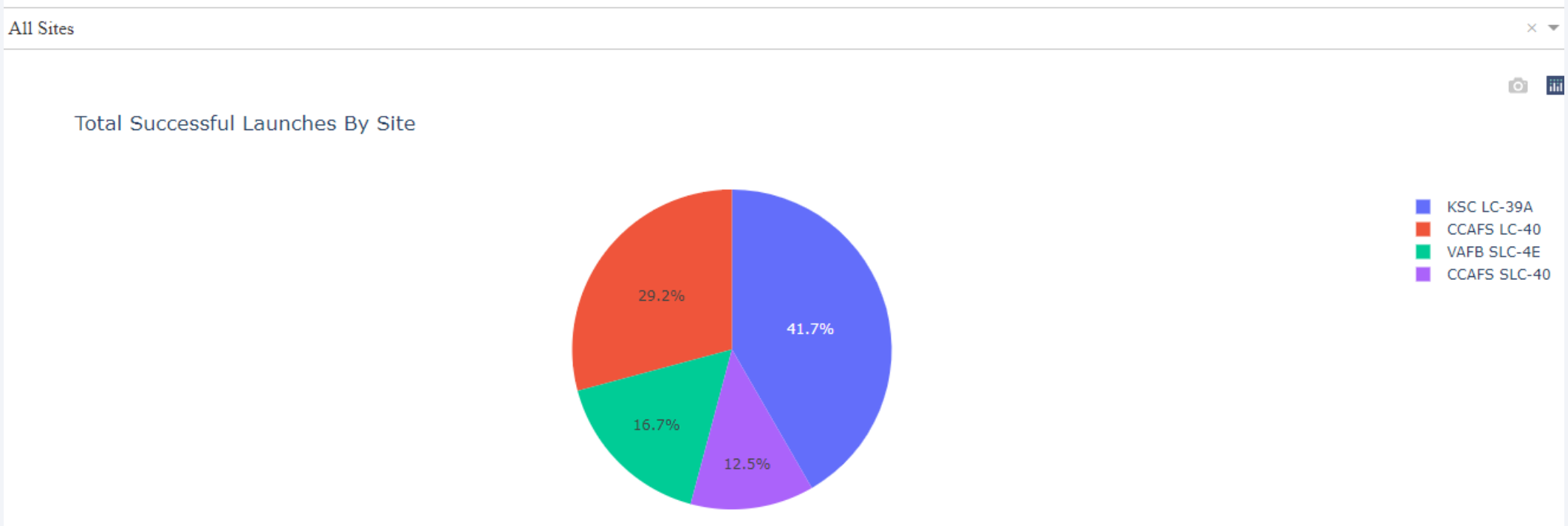
- It appears that launch sites are usually set up at least 18 km away from cities. This may be because of the desire to prevent any crashes near populated areas.
- It is also apparent that launch sites are in very close proximity to railways and highways. Perhaps, due to the necessary transportation requirements for rocket parts.
- The sites are close the coast line. This is evident with the many rocket landing tests on water bodies like the ocean.


| Map Object | Colour |
|---|---|
| Nearest Highway | Green |
| Nearest Railway | Purple |
| Nearest City | Crimson |
| Nearest Coastline | Dark Blue |


Section 4
Build a Dashboard with Plotly Dash

# Successful Launches by Site

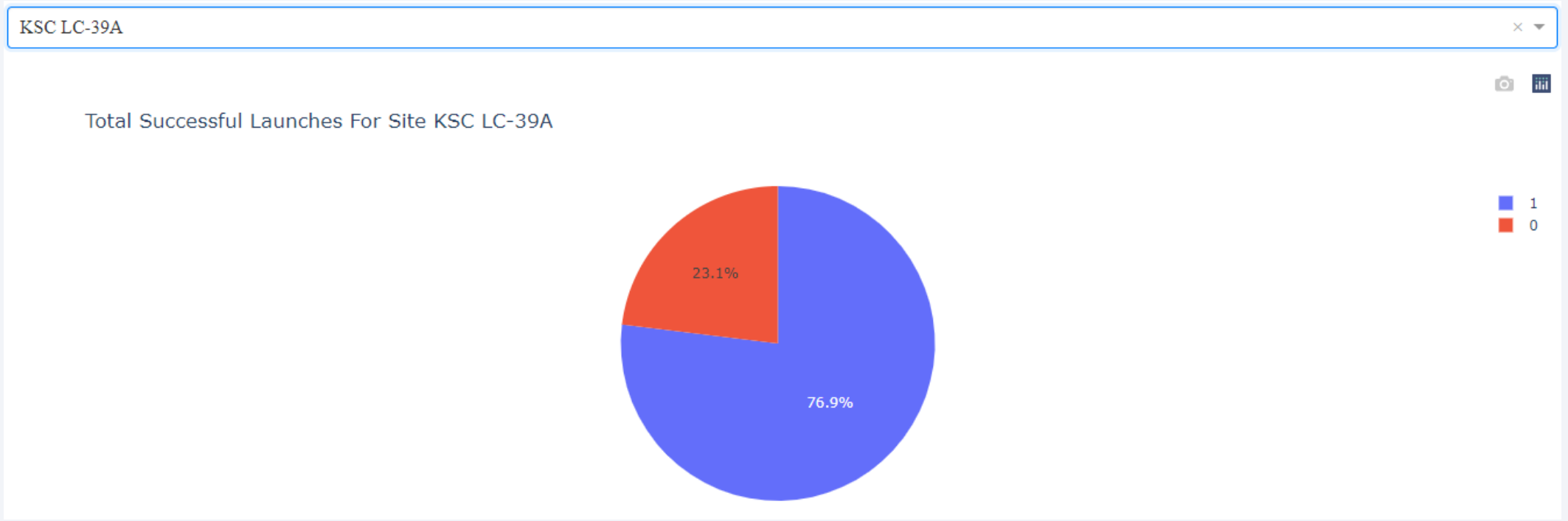





- Site KSC LC-39A has the largest successful launches as well the highest launch success rate.
- More investigation may be needed to determine why KSC LC-39A is the preferred launch site.

# Total Successful Launches for Site KSC LC-39A

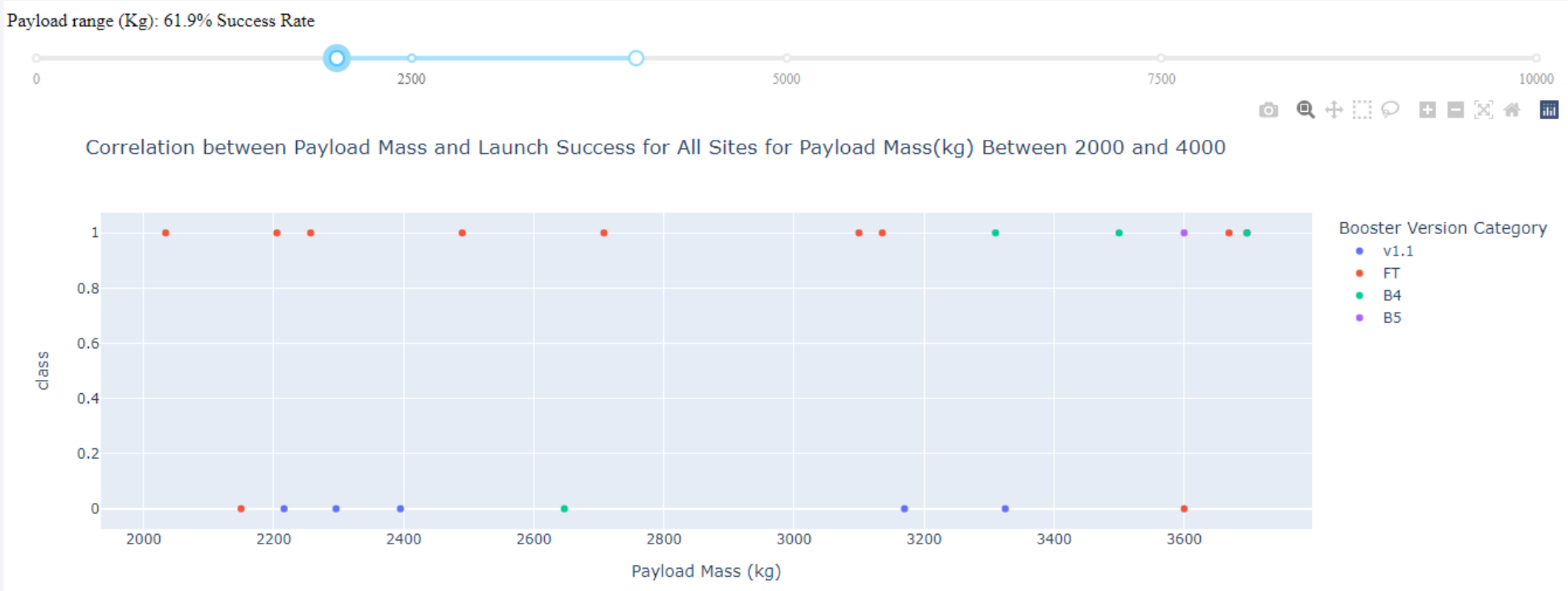





- As we can see, 76.9% of the total launches at site KSC LC-39A were successful. This is a the highest success rate of all the different launch sites.
- However, this success rate was only around 3% higher than the runner up; site CCAFS LC-40.

# Payload Mass vs. Launch Success for All Sites






- It appears that the payload range between 2000 kg and 4000 kg has the highest success rate.
- The launch success rate was also dramatically low between the payload range of 0kg and 2500kg. Perhaps very low masses decrease launch success.
- The booster version **FT**, seems to have a higher success rate than other booster versions

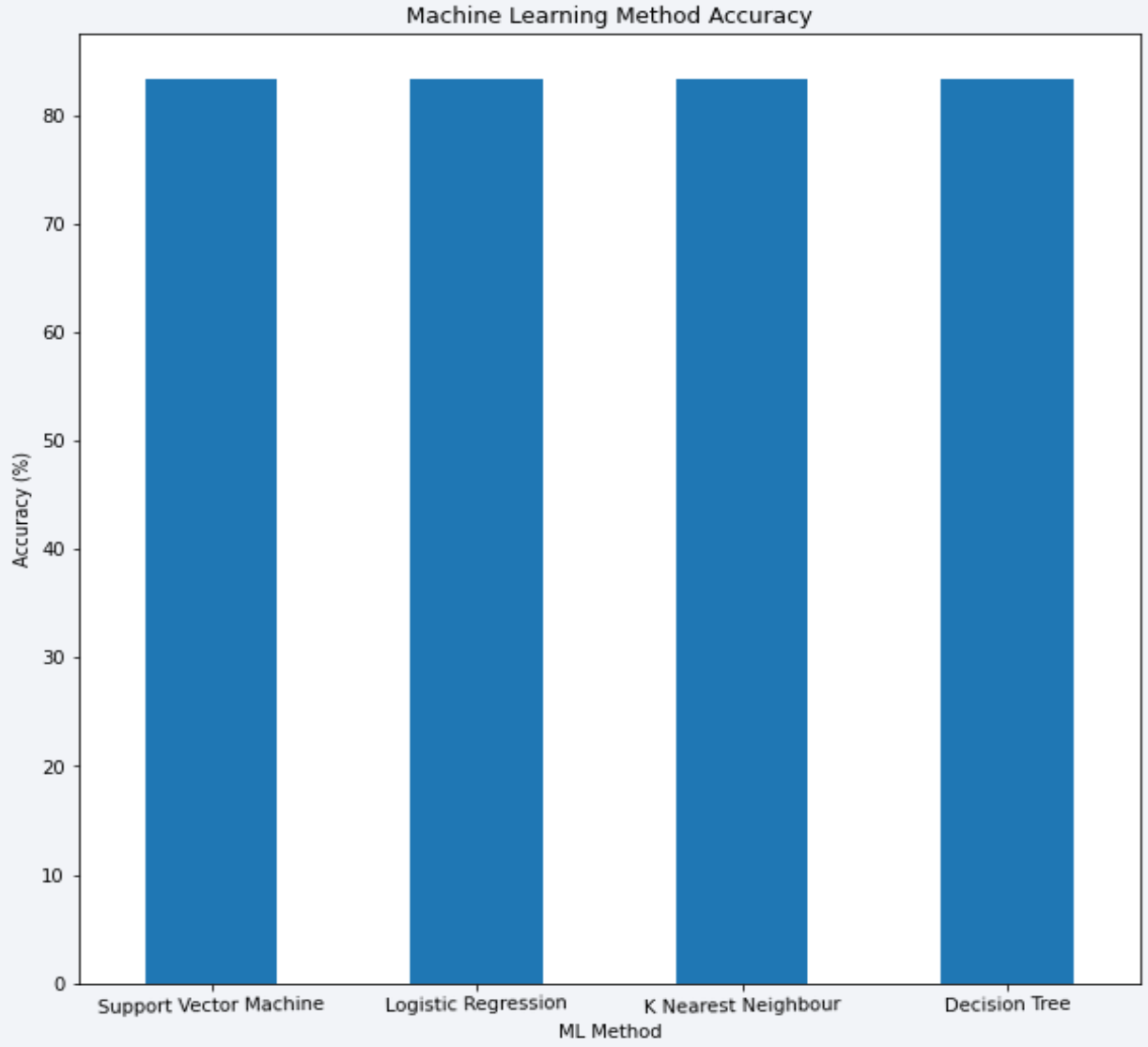
Section 5

# Predictive Analysis (Classification)

# Classification Accuracy



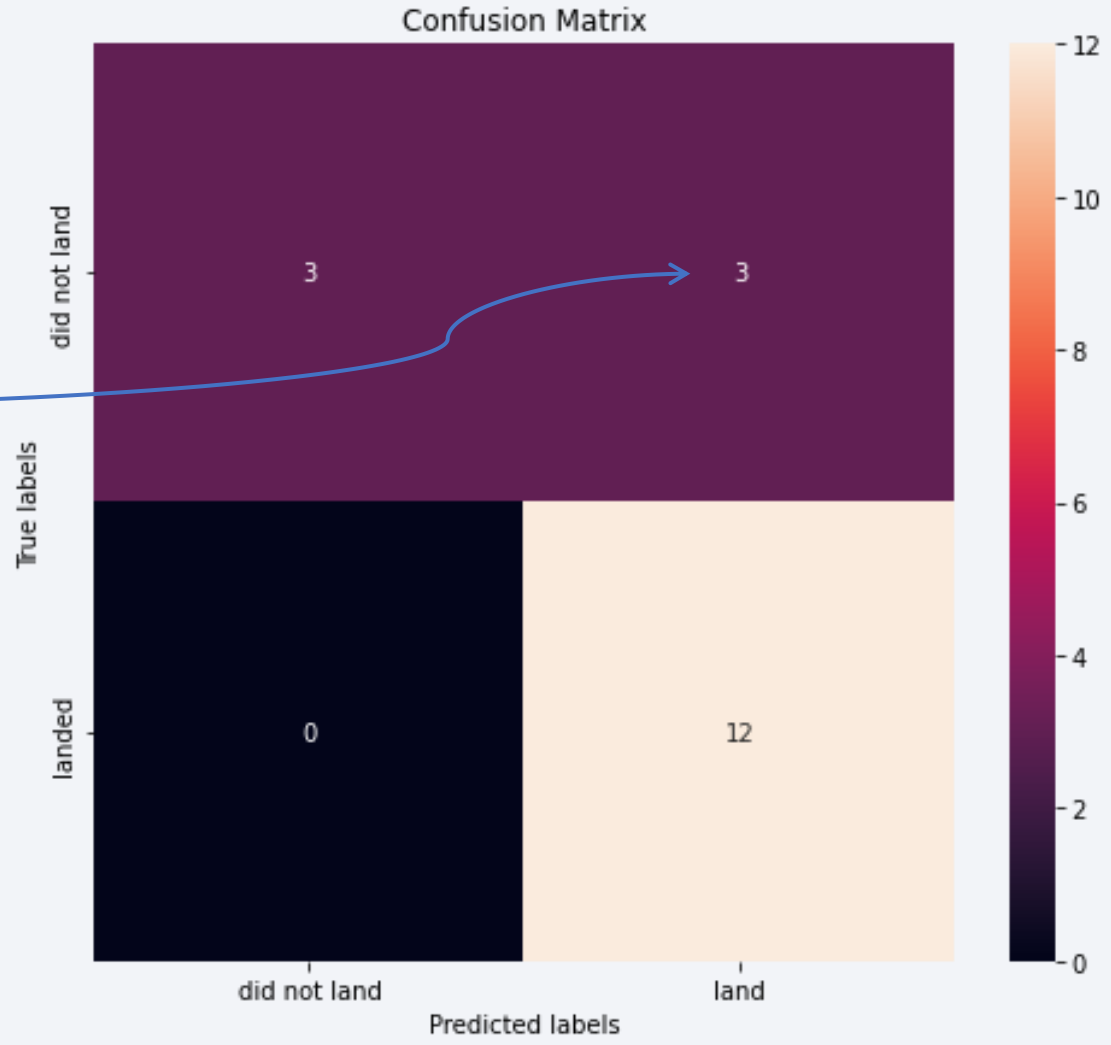
- Since all the methods have an identical accuracy score of 83.33%, we decided to use Logistic Regression for the classification



# Confusion Matrix



- The chart shows the confusion matrix of the Logistic Regression model that was chosen.
- The model only failed to accurately predict 3 labels.



# Conclusions



In order to compete with SpaceX, it was crucial to analyze their data. Through this process, a general picture of their success methods was produced.

- All their launch sites are located near the coast, away from nearby cities. This enabled to them to test their rocket landings without much interference.
- Site KSC LC-39A had the highest launch success rate out of all the launch sites.
- From 2015 onwards, the success rate of rocket landings significantly increased. It was also apparent that landing success increased with flight number

All this data was used to train a machine learning model that is able to predict the landing outcome of rocket launches with 83.33% accuracy.

This will allow our company to make more attractive offers than SpaceX and increase the confidence of our investors and customers. Can anyone say “No” to a company that can predict the success of their product?

# References




- Fortune Business Insights (2020). *Space launch services market*. https://www.fortunebusinessinsights.com/industry-reports/space-launch-services-market-101931
- CB Insights. *The Top 12 Reasons Startups Fail.* *https://www.cbinsights.com/research/startup-failure-reasons-top/*
- IBM. *Data Science Professional Certificate.* *https://www.coursera.org/professional-certificates/ibm-data-science*
- *Space.com. SpaceX Lands Orbital Rocket Successfully in Historic First.* *https://www.space.com/31420-spacex-rocket-landing-success.html*

# Appendix



## SQLite Data Set

- The table structure belongs to the SQLite data set used for SQL queries.
- URL link: https://github.com/Molo-M/SpaceX_Landing_Prediction/blob/main/Datasets_Created/SpaceEx.sqlite

**Tables (1)**

| Name | Type | Schema |
|---|---|---|
| **Spacex** | | CREATE TABLE "Spacex" ( "Date" TEXT, "Time(UTC)" TEXT, "Booster_Version" TEXT, "Launch_Site" TEXT, "Payload" TEXT, "PAYLOAD_MASS__KG_" INTEGER, "Orbit" TEXT, "Customer" TEXT, "Mission_Outcome" TEXT, "Landing_Outcome" TEXT ) |
| Date | TEXT | "Date" TEXT |
| Time(UTC) | TEXT | "Time(UTC)" TEXT |
| Booster_Version | TEXT | "Booster_Version" TEXT |
| Launch_Site | TEXT | "Launch_Site" TEXT |
| Payload | TEXT | "Payload" TEXT |
| PAYLOAD_MASS__KG_ | INTEGER | "PAYLOAD_MASS__KG_" INTEGER |
| Orbit | TEXT | "Orbit" TEXT |
| Customer | TEXT | "Customer" TEXT |
| Mission_Outcome | TEXT | "Mission_Outcome" TEXT |
| Landing_Outcome | TEXT | "Landing_Outcome" TEXT |

# Thank you!