winning space race with data science

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Executive Summary

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Introduction

- Project background and context

  Space X 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 Space X can reuse the first stage. Therefore, if we can determine if the first stage will land, we can determine the cost of a launch. This information can be used if an alternate company wants to bid against space X for a rocket launch. This goal of the project is to create a machine learning pipeline to predict if the first stage will land successfully.

- Problems you want to find answers

  - What factors determine if the rocket will land successfully?
  - The interaction amongst various features that determine the success rate of a successful landing.
  - What operating conditions needs to be in place to ensure a successful landing program.

Section 1

Methodology

Methodology

Executive Summary

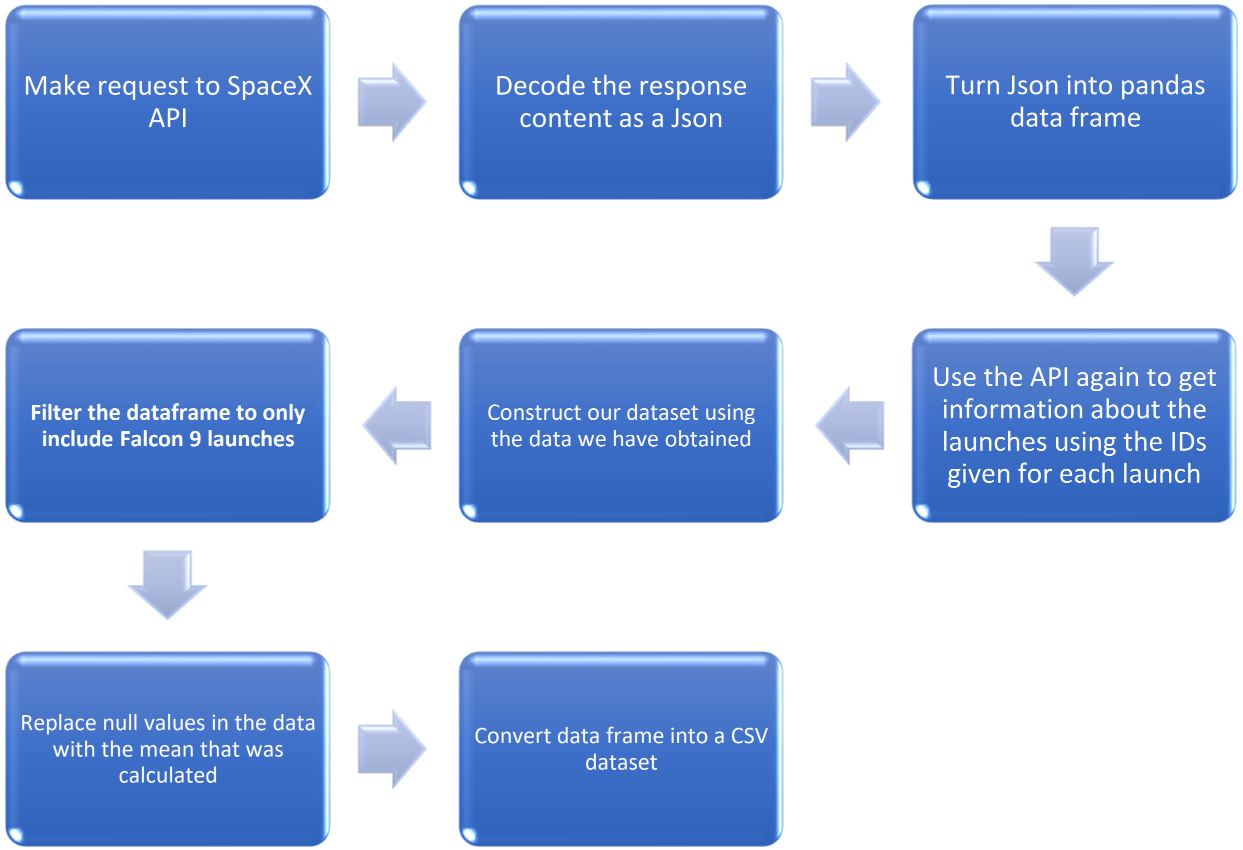
- Data collection methodology:
  - Make requests to the SpaceX API.
  - Perform web scraping to collect Falcon 9 historical launch records on the Wikipedia page titled: List of Falcon 9 and Falcon Heavy launches
- Perform data wrangling
  - Clean the data and explore it to find patterns in the data to 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 was collected using various methods
  - Data collection was done using get request to the SpaceX API.
  - Next, we decoded the response content as a Json using .json() function call and turn it into a pandas dataframe using .json_normalize().
  - We then cleaned the data, checked for missing values and fill in missing values where necessary.
  - In addition, we performed web scraping from Wikipedia for Falcon 9 launch records with BeautifulSoup.
  - The objective was to extract the launch records as HTML table, parse the table and convert it to a pandas dataframe for future analysis.

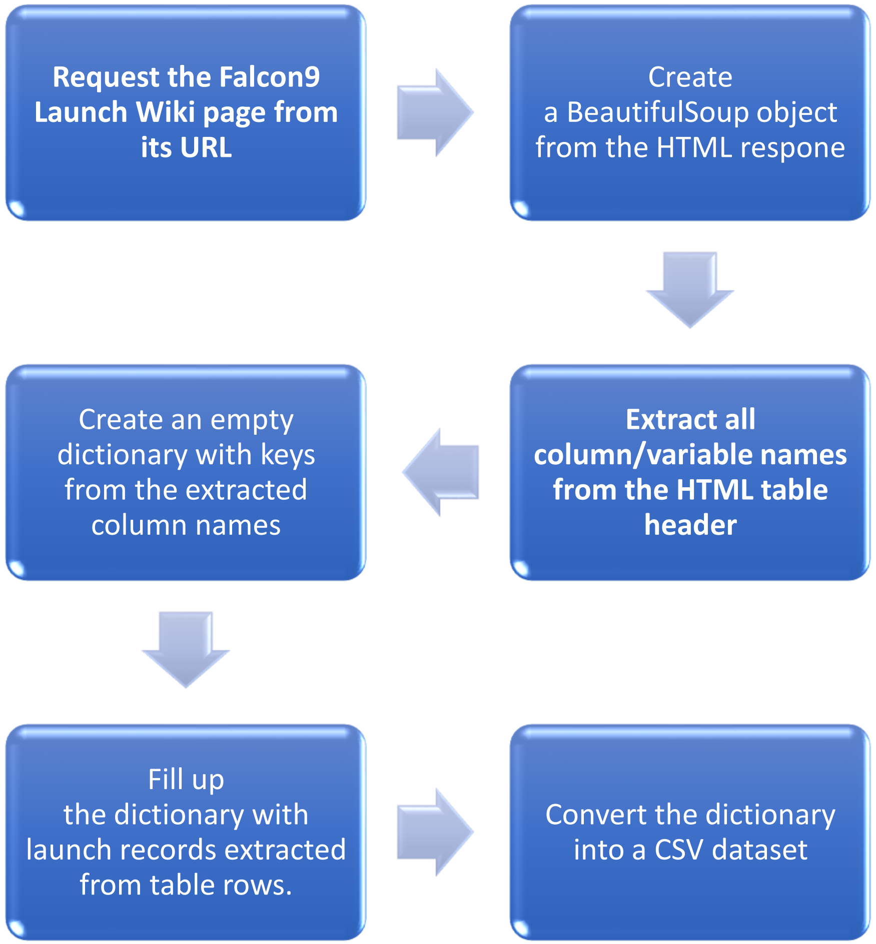
Data Collection – SpaceX API

- 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/alpha970/Data_Science_Capstone/blob/main/jupyter-labs-spacex-data-collection-api%20(4).ipynb

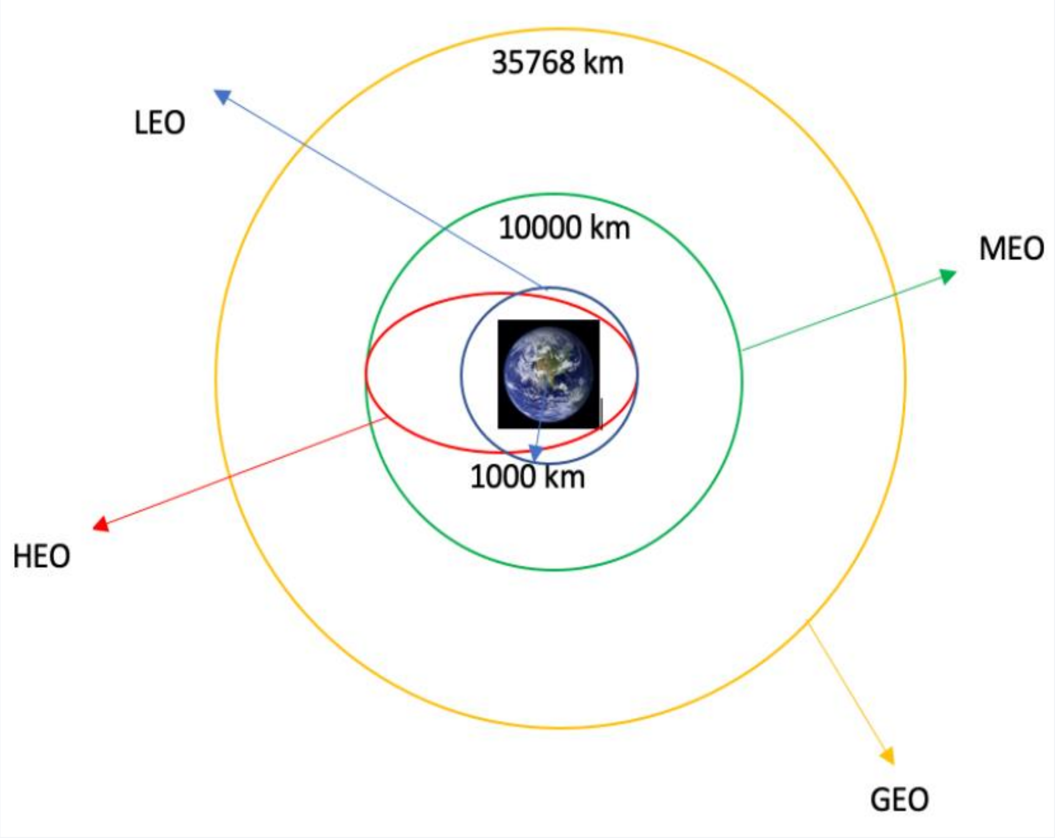


Data Collection - Web Scraping

- 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/alpha970/Data_Science_Capstone/blob/main/jupyter-labs-webscraping.ipynb



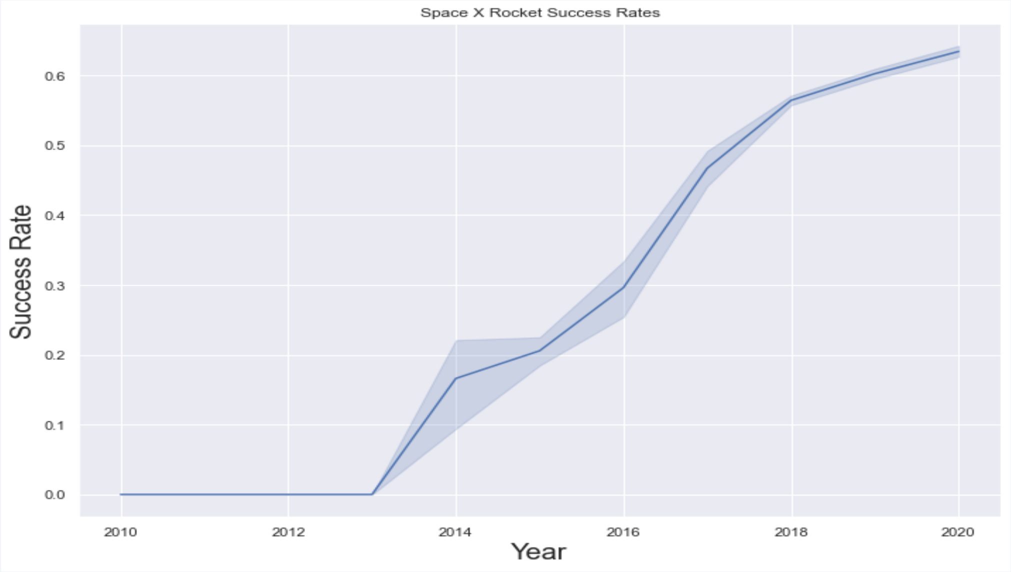
Data Wrangling

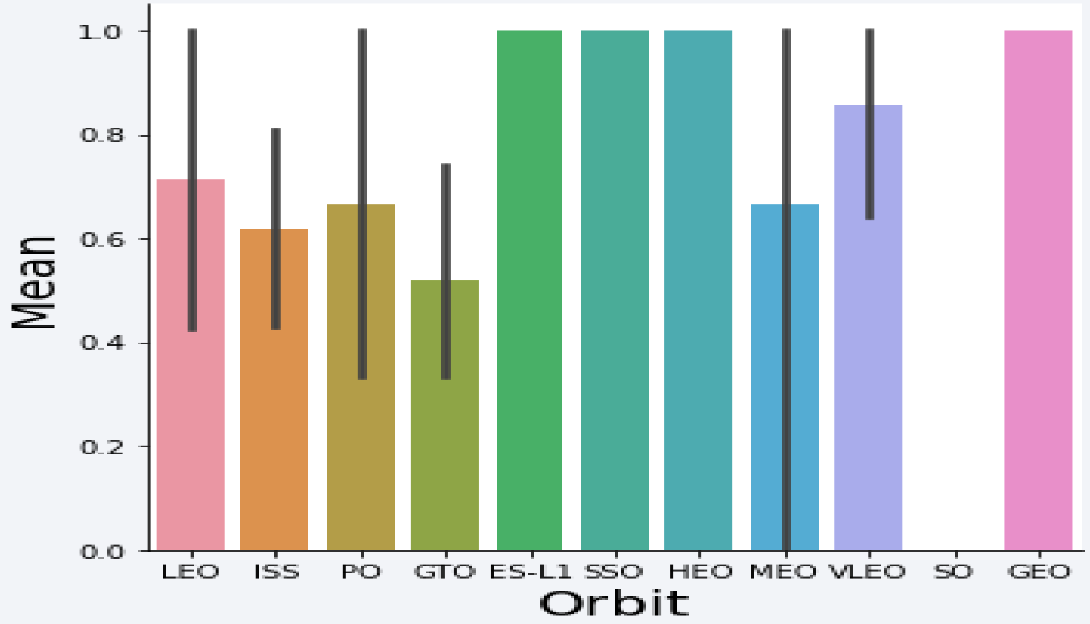


- We performed exploratory data analysis and determined the training labels.
- We calculated the number of launches at each site, and the number and occurrence of each orbits
- We created landing outcome label from outcome column and exported the results to csv.
- The link to the notebook is https://github.com/alpha970/Data_Science_Capstone/blob/main/labs-jupyter-spacex-Data%20wrangling.ipynb

EDA with Data Visualization

- We explored the data by visualizing the relationship between flight number and launch Site, payload and launch site, success rate of each orbit type, flight number and orbit type, the launch success yearly trend.





- The link to the notebook is https://github.com/alpha970/Data_Science_Capstone/blob/main/jupyter-labs-eda-dataviz.ipynb

EDA with SQL

- We loaded the SpaceX dataset into a PostgreSQL database without leaving the jupyter notebook.
- We applied EDA with SQL to get insight from the data. We wrote queries to find out for instance:
  - The names of unique launch sites in the space mission.
  - The total payload mass carried by boosters launched by NASA (CRS)
  - The average payload mass carried by booster version F9 v1.1
  - The total number of successful and failure mission outcomes
  - The failed landing outcomes in drone ship, their booster version and launch site names.
- The link to the notebook is: https://github.com/alpha970/Data_Science_Capstone/blob/main/jupyter-labs-eda-sql-coursera.ipynb

Build an Interactive Map with Folium

- We marked all launch sites, and added map objects such as markers, circles, lines to mark the success or failure of launches for each site on the folium map.
- We assigned the feature launch outcomes (failure or success) to class 0 and 1.i.e., 0 for failure, and 1 for success.
- Using the color-labeled marker clusters, we identified which launch sites have relatively high success rate.
- We calculated the distances between a launch site to its proximities. We answered some question for instance:
  - Are launch sites near railways, highways and coastlines.
  - Do launch sites keep certain distance away from cities.

  https://github.com/alpha970/Data_Science_Capstone/blob/main/lab_jupyter_launch_site_location.ipynb

Build a Dashboard with Plotly Dash

- We built an interactive dashboard with Plotly dash
- We plotted pie charts showing the total launches by a certain sites
- We plotted scatter graph showing the relationship with Outcome and Payload Mass (Kg) for the different booster version.
- The link to the notebook is https://github.com/alpha970/Data_Science_Capstone/blob/main/spacex_app.py

Predictive Analysis (Classification)

- We loaded the data using numpy and pandas, transformed the data, split our data into training and testing.
- We built different machine learning models and tune different hyperparameters using GridSearchCV.
- We used accuracy as the metric for our model, improved the model using feature engineering and algorithm tuning.
- We found the best performing classification model.
- The link to the notebook is: https://github.com/alpha970/Data_Science_Capstone/blob/main/SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb

Results

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

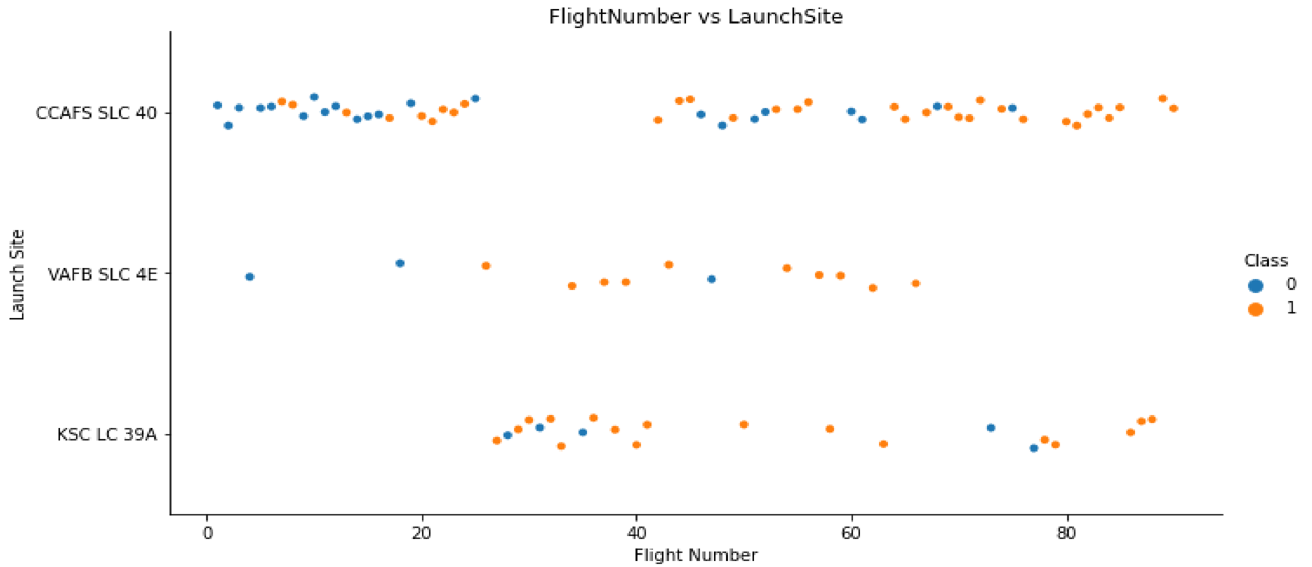
Section 2

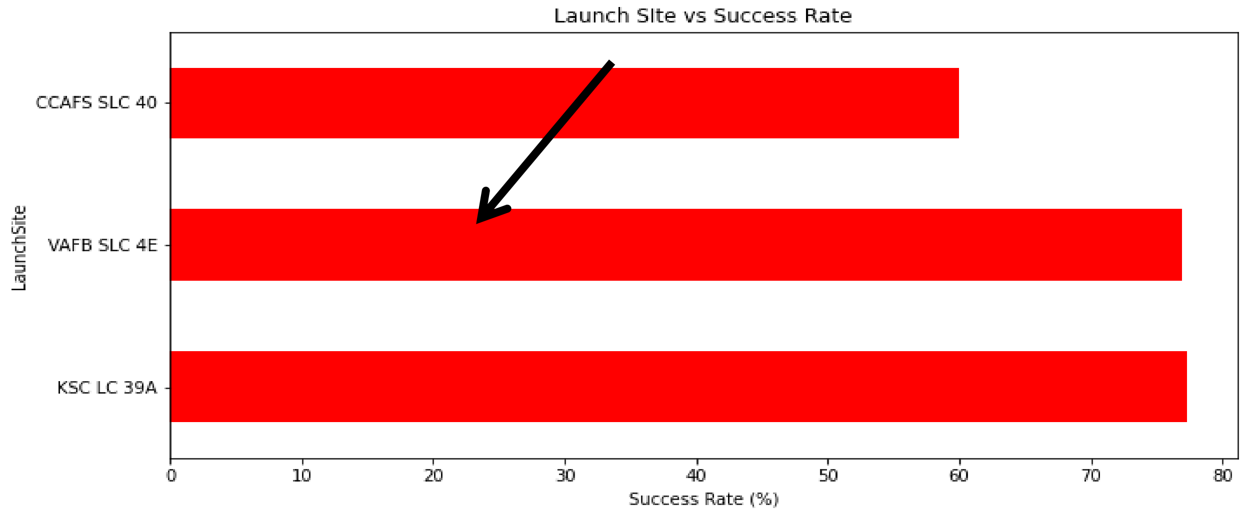
Insights drawn from EDA

Flight Number vs. Launch Site

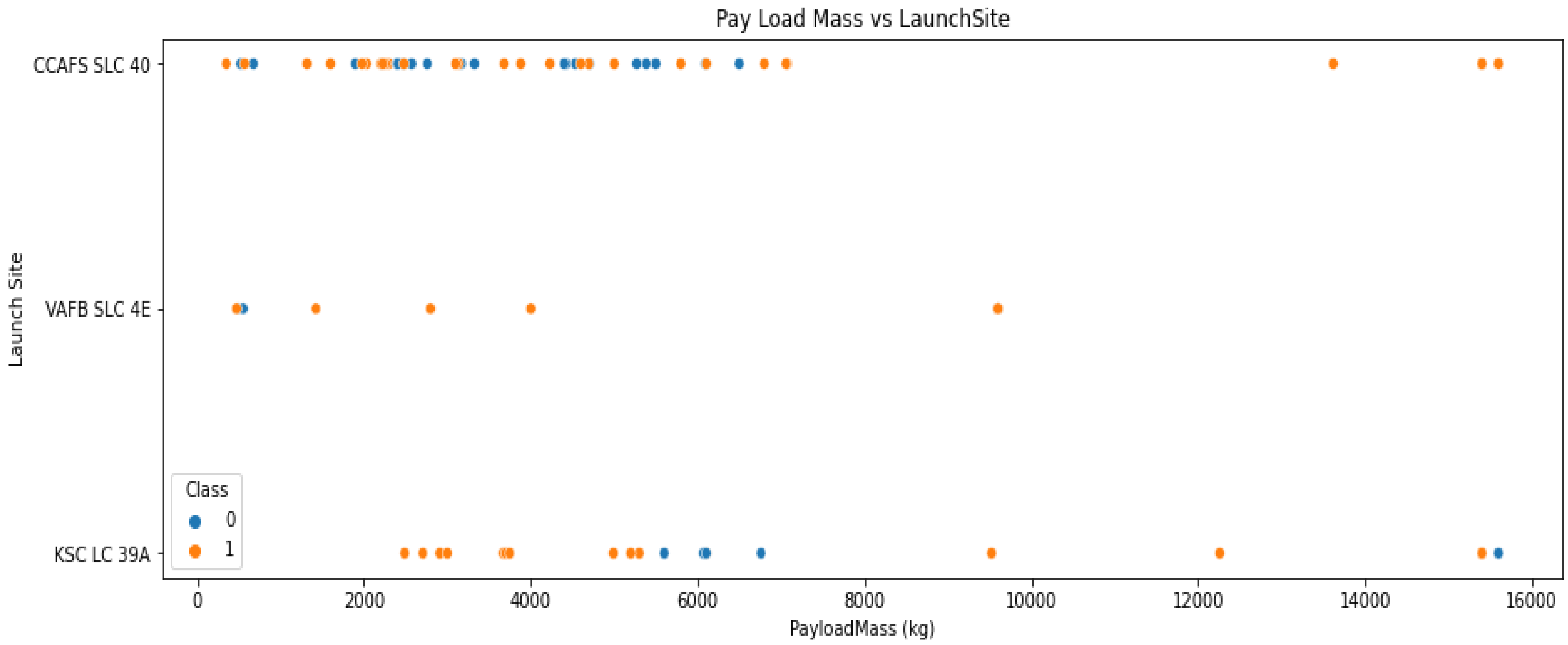
- It appears that there were more successful landings as the flight numbers increased. It also seems that launch site **CCAFS SLC 40** had the most number of landing attempts while the site **VAFB SLC 4E** had the least number of attempts.

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





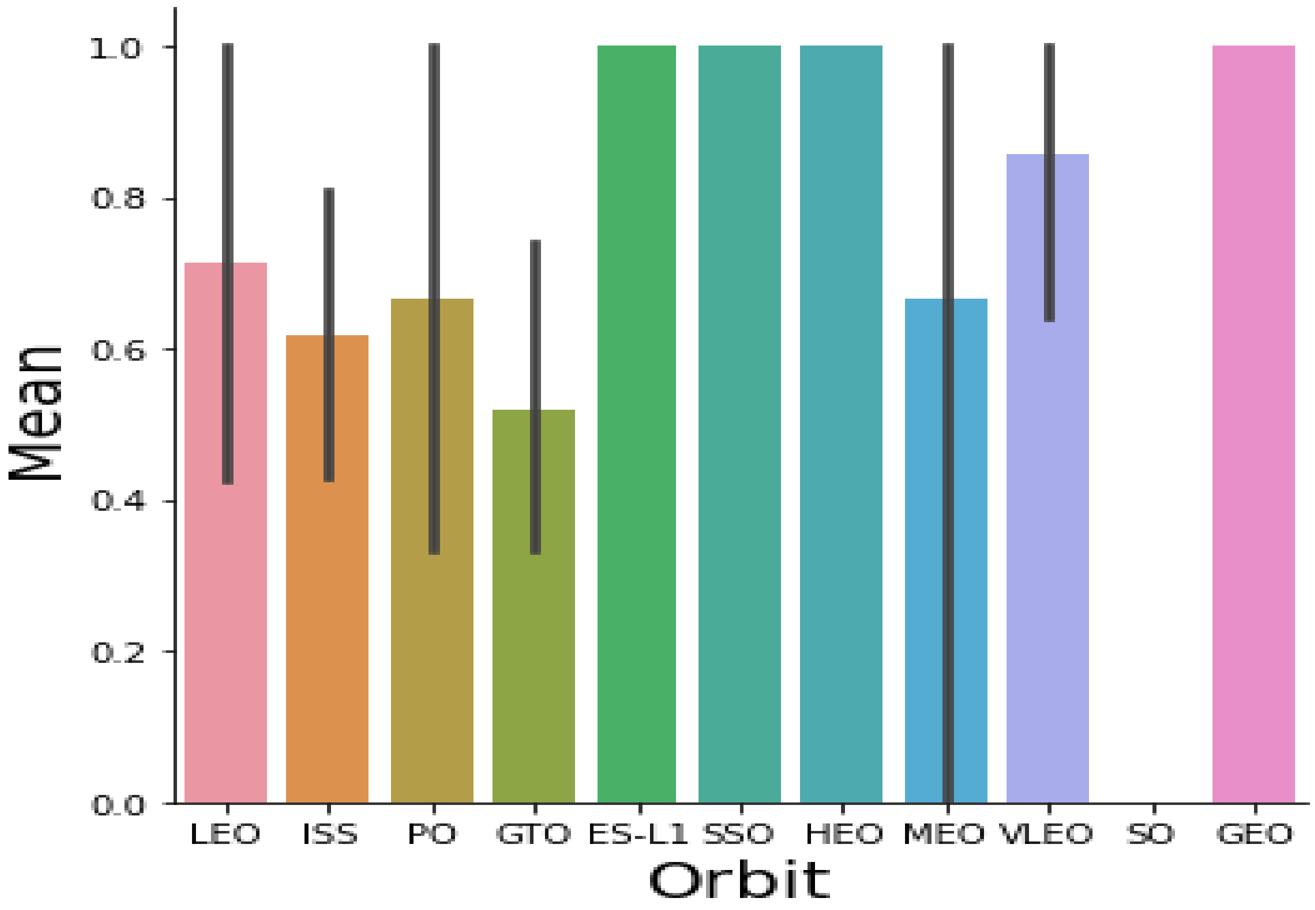
Payload vs. Launch Site



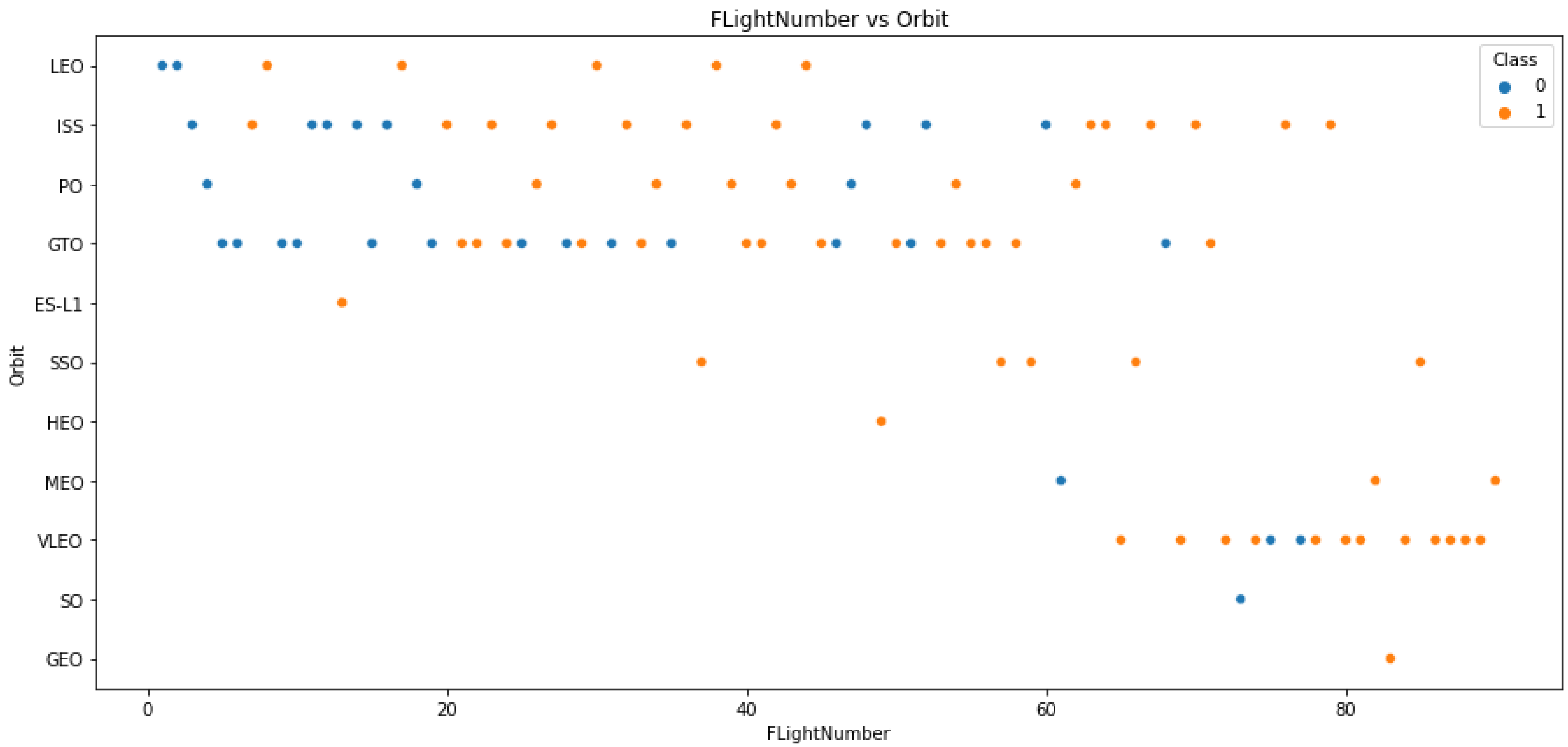
- Now if you observe the scatter point chart, you will find for the VAFB-SLC launch site there are no rockets launched for heavy payload mass(greater than 10000).

Success Rate vs. Orbit Type

- From the plot, we can see that ES-L1, GEO, HEO, SSO, VLEO had the most success rate.

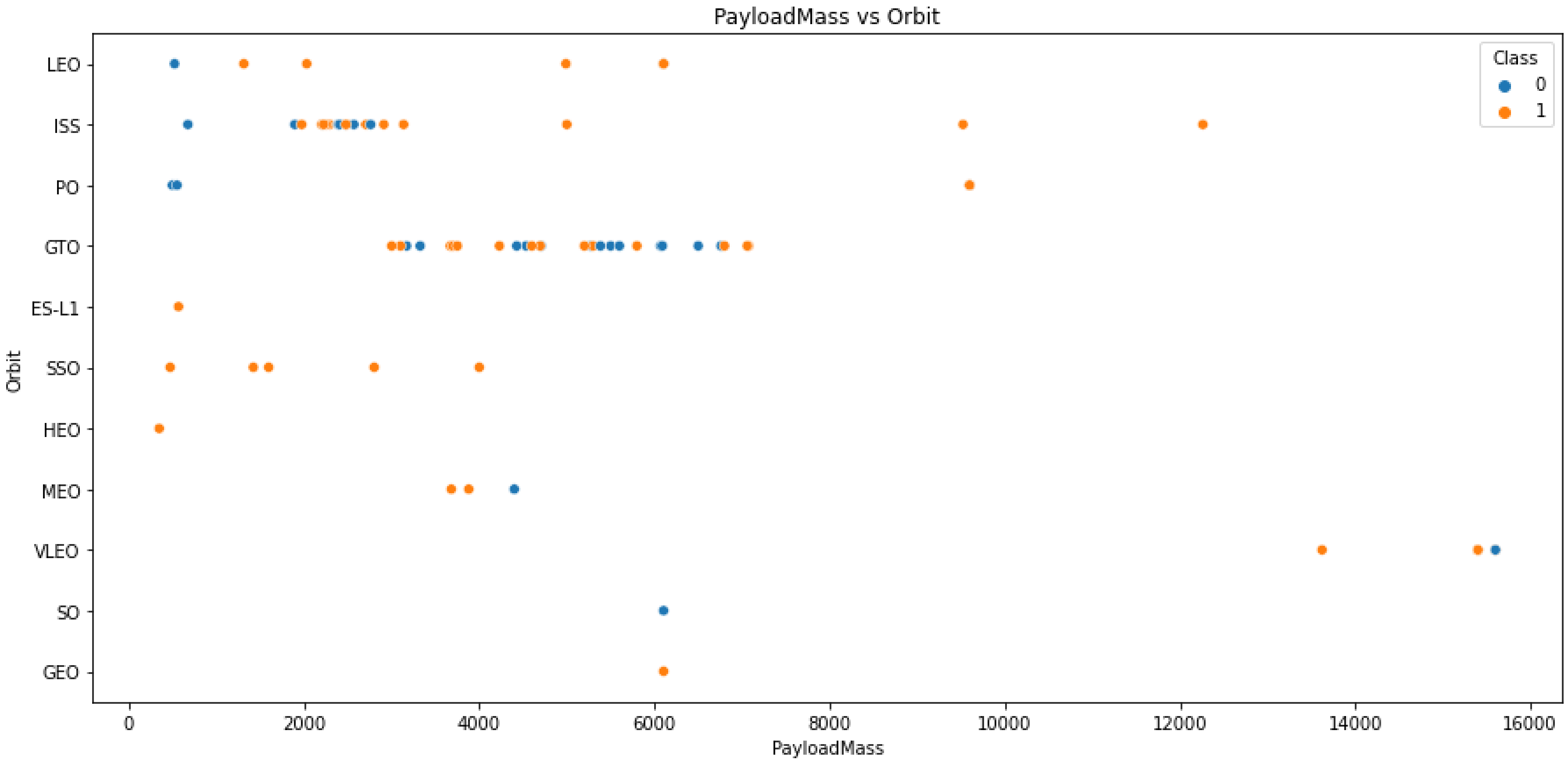


Flight Number vs. Orbit Type



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

- From the plot, we can observe that success rate since 2013 kept on increasing till 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 beginnnig 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

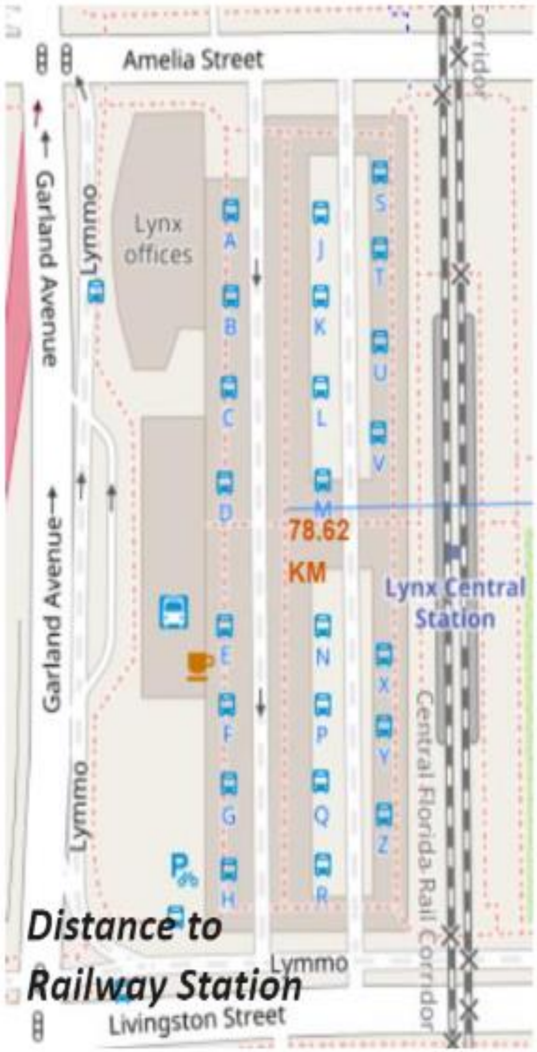
Section 4

Launch Sites Proximities Analysis

All launch sites global map markers

Markers showing launch sites with color labels

Launch Site distance to landmarks

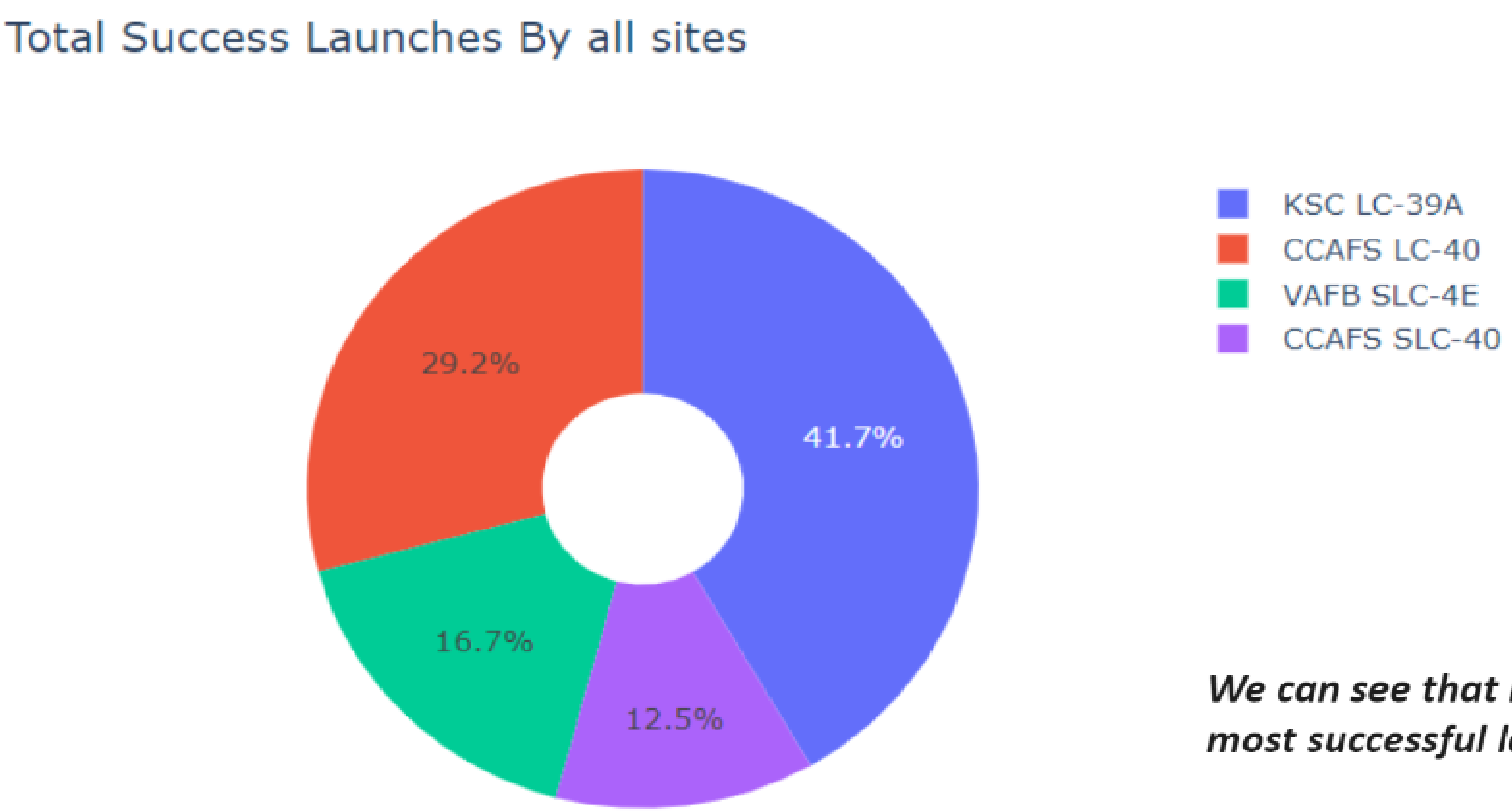


- Are launch sites in close proximity to railways? No
- Are launch sites in close proximity to highways? No
- Are launch sites in close proximity to coastline? Yes
- Do launch sites keep certain distance away from cities? Yes

Section 5

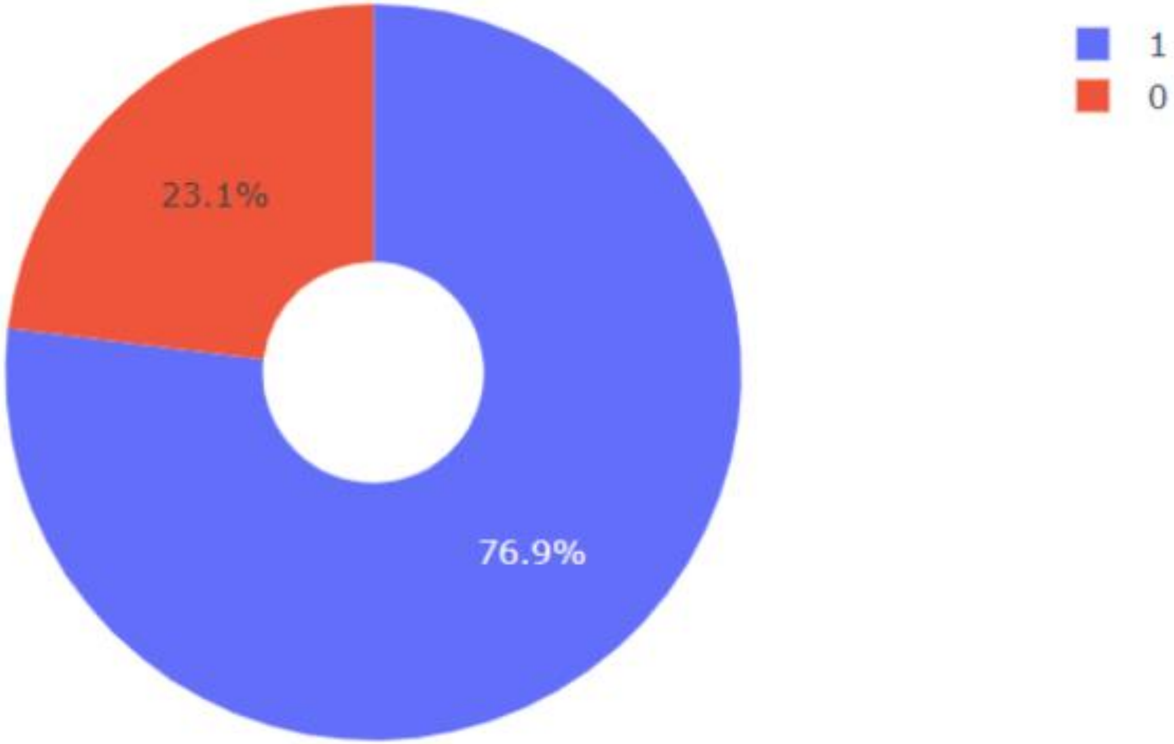
Build a Dashboard with Plotly Dash

Pie chart showing the success percentage achieved by each launch site



We can see that KSC LC-39A had the most successful launches from all the sites

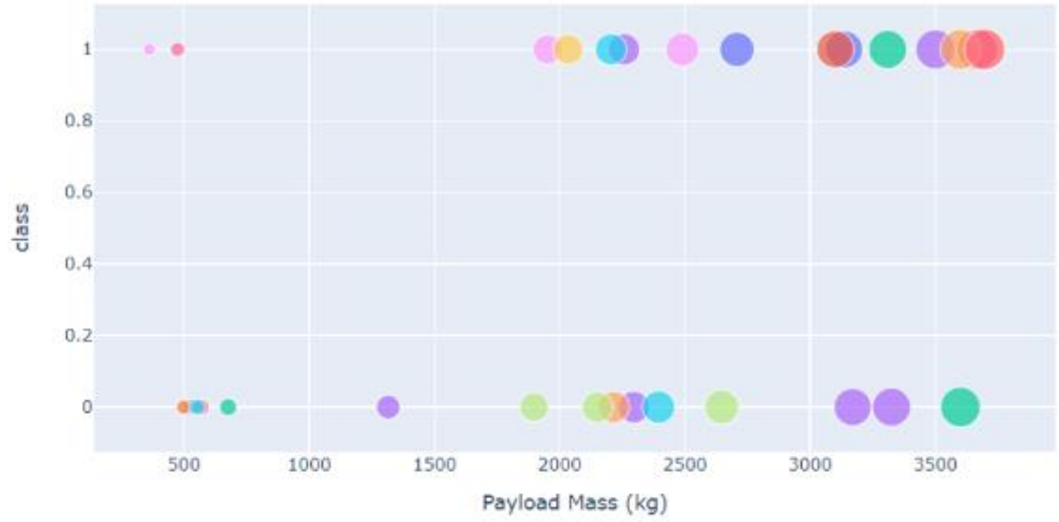
Pie chart showing the Launch site with the highest launch success ratio



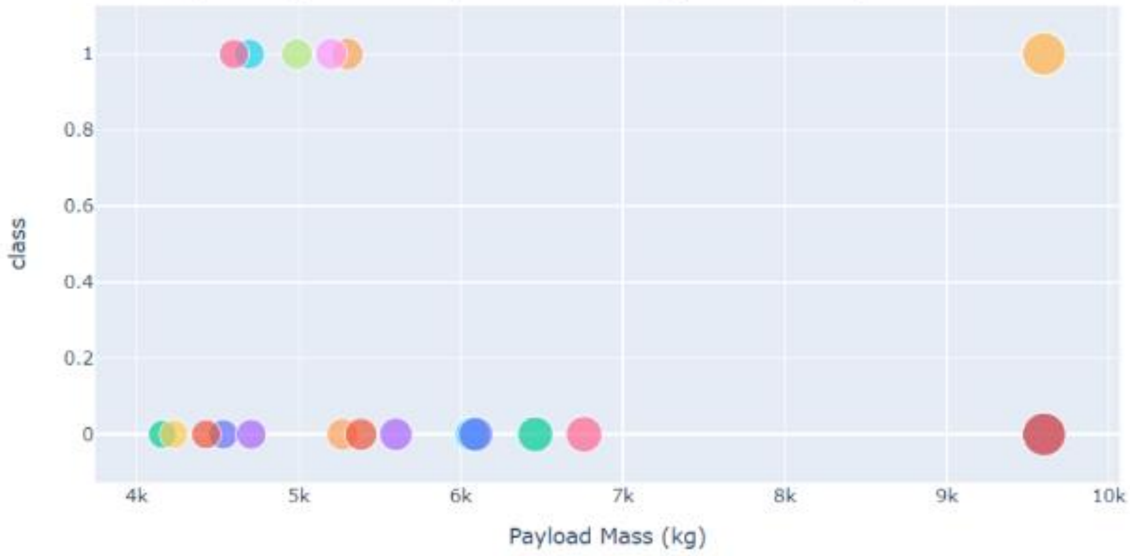
KSC LC-39A achieved a 76.9% success rate while getting a 23.1% failure rate

Scatter plot of Payload vs Launch Outcome for all sites, with different payload selected in the range slider

Low Weighted Payload 0kg – 4000kg



Heavy Weighted Payload 4000kg – 10000kg



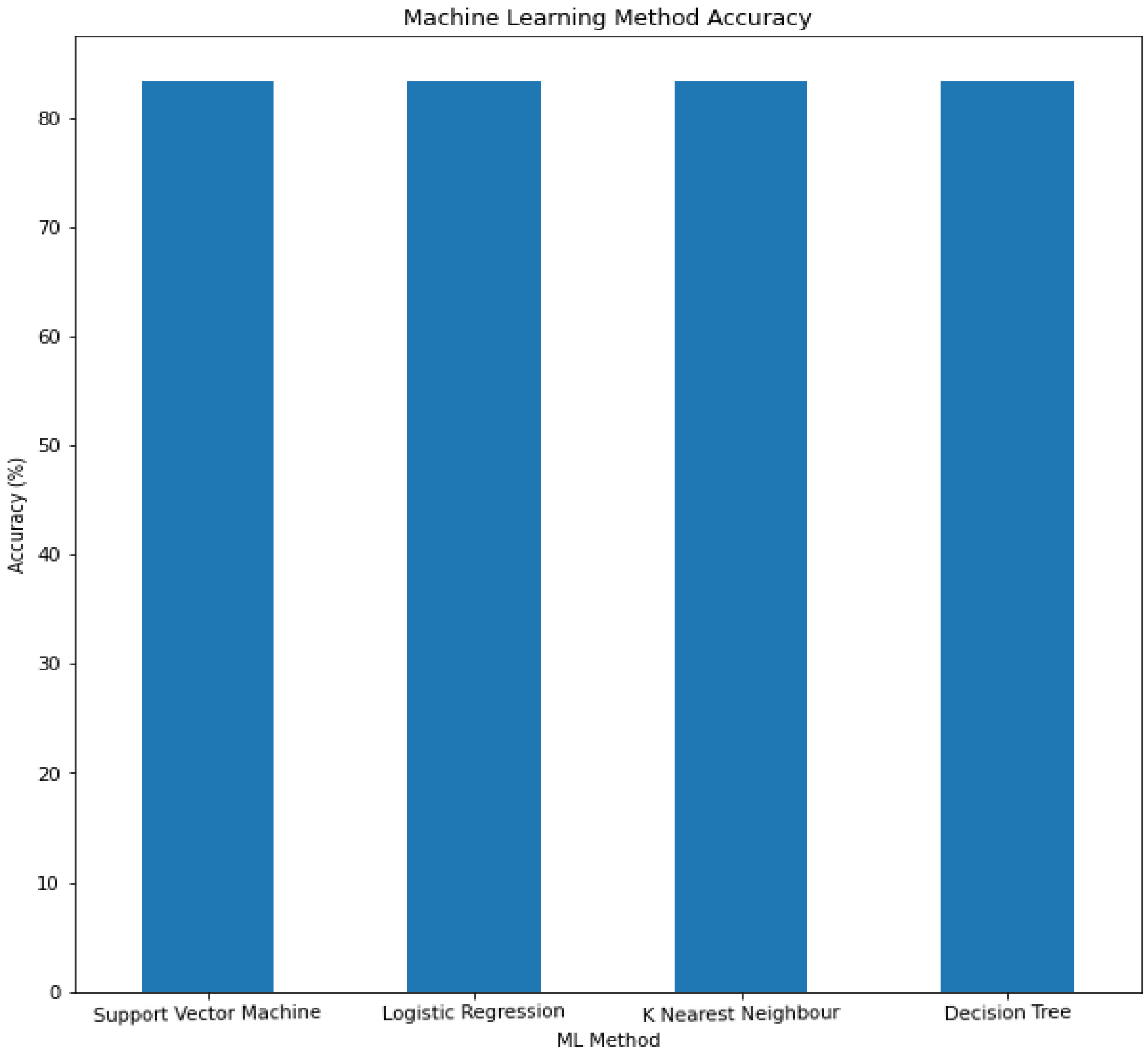
We can see the success rates for low weighted payloads is higher than the heavy weighted payloads

Section 6

Predictive Analysis (Classification)

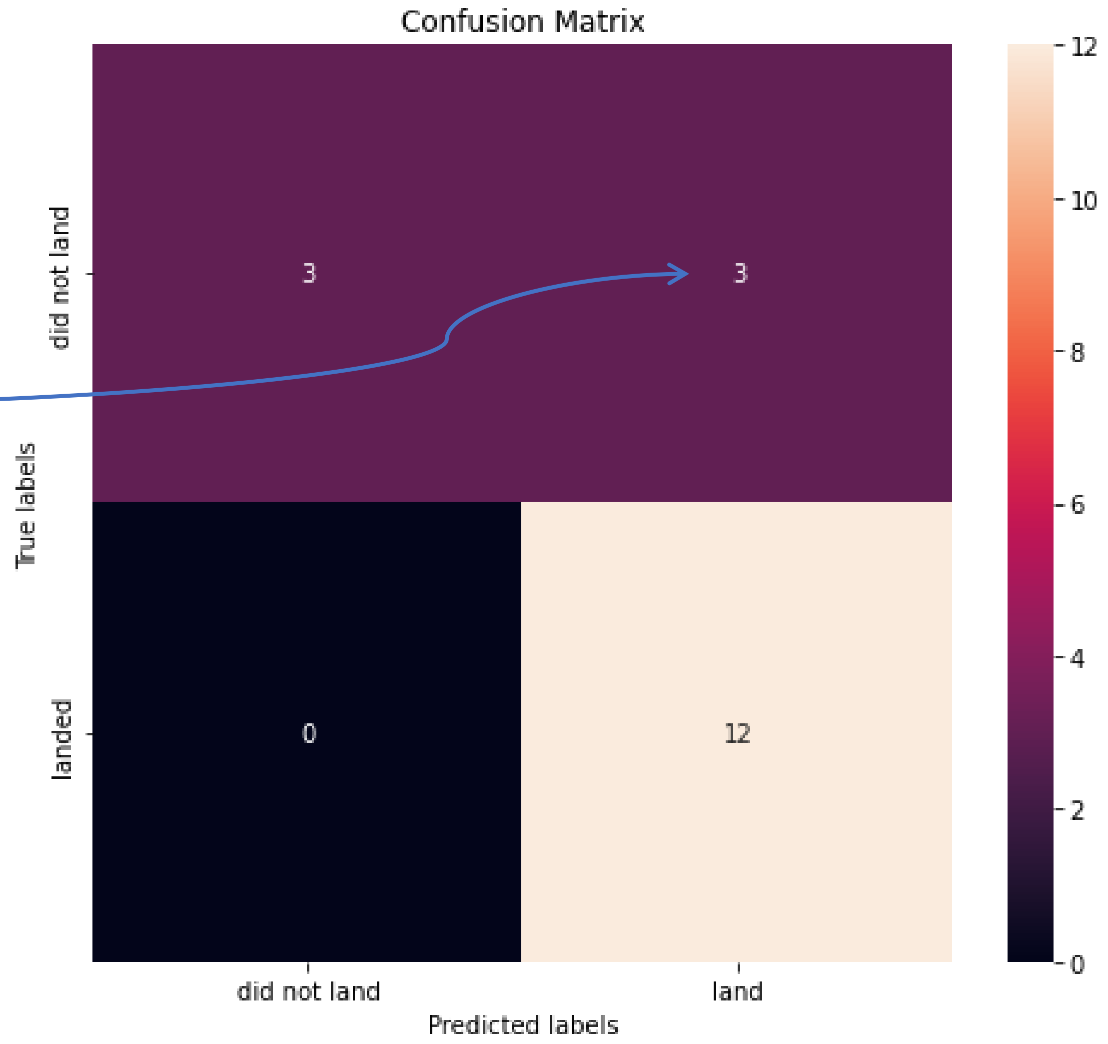
Classification Accuracy

- 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*

Thank you!