IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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

Executive Summary

Summary of methodologies

- Data Collection through API, SQL and Web Scraping
- Interactive maps with Folium
- Data Wrangling
- Data Analysis
- Predictive Analysis

Summary of all results

- Exploratory Data Analysis Results
- Interactive Analytics
- Predictive Analysis Results

Introduction

- **Project background and context**

We predicted if the Falcon 9 first stage 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 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 SpaceX for a rocket launch.

- **Problems you want to find answers**

- What influences if the rocket will land successfully?
- The effect each relationship with certain rocket variables will impact in determining the success rate of a successful landing.
- What conditions does SpaceX have to achieve to get the best results and ensure the best rocket success landing rate.

Methodology

SPACEX FALCON 9 ROCKET LAUNCH ANALYSIS

Methodology

- Data collection methodology:
  - SpaceX Rest API
  - (Web Scrapping) from Wikipedia
- Performed data wrangling (Transforming data for Machine Learning)
  - One Hot Encoding data fields for Machine Learning and dropping irrelevant columns
- Performed exploratory data analysis (EDA) using visualization and SQL
  - Plotting : Scatter Graphs, Bar Graphs to show relationships between variables to show patterns of data.
- Performed interactive visual analytics using Folium and Plotly Dash
- Performed predictive analysis using classification models
  - How to build, tune, evaluate classification models

Data Collection

- We worked with SpaceX launch data that is gathered from the SpaceX REST API.
- This API will give us data about launches, including information about the rocket used, payload delivered, launch specifications, landing specifications, and landing outcome.
- Our goal is to use this data to predict whether SpaceX will attempt to land a rocket or not.
- The SpaceX REST API endpoints, or URL, starts with api.spacexdata.com/v4/.
- Another popular data source for obtaining Falcon 9 Launch data is web scraping Wikipedia using BeautifulSoup.

Data Collection – SpaceX API

[GitHub URL to Notebook]

Getting Response from API

- SpaceX URL="https://api.spacexdata.com/v4/launches/past"
- response=requests.Get(SpaceX URL)

Converting Response to a json file

- jlist=requests.get(static_json_url).json()
- df2=pd.json_normalize(jlist)
- df2.head()

Clean data

- getBoosterVersion(data)
- getLaunchSite(data)
- getPayloadData(data)
- getCoreData(data)

Create Dataframe

- launch_dict={'FlightNumber':list(data['flight_number']),…

Filter Dataframe and export to flat file

- data_falcon9.drop(data_falcon9[data_falcon9['BoosterVersion']!='Falcon 9'].index,inplace=**True**)
- data_falcon9.loc[:,'FlightNumber']=list(range(1,data_falcon9.shape[0]+1))
- data_falcon9
- data_falcon9.to_csv('dataset_part_1.csv',index=**False**)

	FlightNumber	Date	BoosterVersion	PayloadMass	Orbit	LaunchSite	Outcome	Flights	GridFins	Reused	Legs	LandingPad	Block	ReusedCount	Serial	Longitude	Latit
0	1	2006-03-24	Falcon 1	20.0	LEO	Kwajalein Atoll	None None	1	False	False	False	None	NaN	0	Merlin1A	167.743129	9.047
1	2	2007-03-21	Falcon 1	NaN	LEO	Kwajalein Atoll	None None	1	False	False	False	None	NaN	0	Merlin2A	167.743129	9.047
2	4	2008-09-28	Falcon 1	165.0	LEO	Kwajalein Atoll	None None	1	False	False	False	None	NaN	0	Merlin2C	167.743129	9.047
3	5	2009-07-13	Falcon 1	200.0	LEO	Kwajalein Atoll	None None	1	False	False	False	None	NaN	0	Merlin3C	167.743129	9.047
4	6	2010-06-04	Falcon 9	NaN	LEO	CCSFS SLC 40	None None	1	False	False	False	None	1.0	0	B0003	-80.577366	28.561

Data Collection – Web Scraping

[GitHub URL]

Get Response from HTML

- static_url="https://en.wikipedia.org/w/index.php?title=List_of_Falcon_9_and_Falcon_Heavy_launches&oldid=1027686922"
- html_data=requests.get(static_url)
- html_data.status_code

Creating Beautiful Soup Object

- soup=BeautifulSoup(html_data.text,'html.parser')

Finding Tables

- html_tables=soup.find_all('table')
- first_launch_table=html_tables[2]

Getting Column Names

- element=soup.find_all('th')
- **for** row **in** range(len(element)):
- **try**:
- name=extract_column_from_header(element[row])
- **if**(name **is not None and** len(name)>0):
- column_names.append(name)
- **except**:

Creating Dictionary

- launch_dict=dict.fromkeys(column_names)

Converting dictionary to dataframe

Converting dataframe to CSV

- df.to_csv('spacex_web_scraped.csv',index=**False**)

	Flight No.	Launch site	Payload	Payload mass	Orbit	Customer	Launch outcome	Version Booster	Booster landing	Date	Time
0	1	CCAFS	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	F9 v1.0B0003.1	Failure	4 June 2010	18:45
1	2	CCAFS	Dragon	0	LEO	NASA	Success	F9 v1.0B0004.1	Failure	8 December 2010	15:43
2	3	CCAFS	Dragon	525 kg	LEO	NASA	Success	F9 v1.0B0005.1	No attempt	22 May 2012	07:44
3	4	CCAFS	SpaceX CRS-1	4,700 kg	LEO	NASA	Success	F9 v1.0B0006.1	No attempt	8 October 2012	00:35
4	5	CCAFS	SpaceX CRS-2	4,877 kg	LEO	NASA	Success	F9 v1.0B0007.1	No attempt	1 March 2013	15:10

Data Wrangling

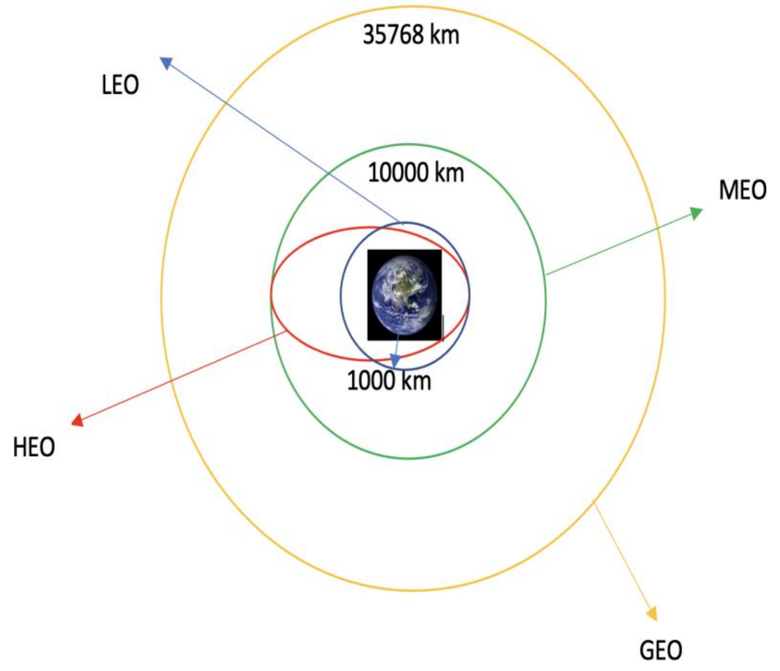
GitHub URL

Introduction

In the data set, there are several different cases where the booster did not land successfully. Sometimes a landing was attempted but failed due to an accident; for example, True Ocean means the mission outcome was successfully landed to a specific region of the ocean while False Ocean means the mission outcome was unsuccessfully landed to a specific region of the ocean. True RTLS means the mission outcome was successfully landed to a ground pad False RTLS means the mission outcome was unsuccessfully landed to a ground pad. True ASDS means the mission outcome was successfully landed on a drone ship False ASDS means the mission outcome was unsuccessfully landed on a drone ship. We mainly convert those outcomes into Training Labels with 1 means the booster successfully landed 0 means it was unsuccessful.

Perform Exploratory Data Analysis on Dataset

- Calculate the number of launches at each site
- Calculate the number and occurrence of each orbit
- Calculate the number and occurrence of mission outcome per orbit type
- Export dataset as .CSV
- Work out success rate for every landing in dataset



EDA with Data Visualization

GitHub URL

Scatter Graphs being drawn:

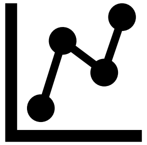
Flight Number VS. Payload Mass

Flight Number VS. Launch Site

Payload VS. Launch Site

Orbit VS. Flight Number

Payload VS. Orbit Type



Bar Graph being drawn:

Mean VS. Orbit

Line Graph being drawn:

Success Rate VS. Year

Orbit VS. Payload Mass

Line graphs are useful in that they show data variables and trends very clearly and can help to make predictions about the results of data not yet recorded A bar diagram makes it easy to compare sets of data between different groups at a glance. The graph represents categories on one axis and a discrete value in the other. The goal is to show the relationship between the two axes. Bar charts can also show big changes in data over time. Scatter plots show how much one variable is affected by another. The relationship between two variables is called their correlation . Scatter plots usually consist of a large body of data.

EDA with SQL

GitHub URL

Performed SQL queries to gather information about the dataset.

For example of some questions we were asked about the data we needed information about. Which we are using SQL queries to get the answers in the dataset :

• Displaying the names of the unique launch sites in the space mission

• Displaying 5 records where launch sites begin with the string 'KSC'

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

• Displaying average payload mass carried by booster version F9 v1.1

• Listing the date where the successful landing outcome in drone ship was achieved.

• Listing the names of the boosters which have success in ground pad and have payload mass greater than 4000 but less than 6000

• Listing the total number of successful and failure mission outcomes

• Listing the names of the booster versions which have carried the maximum payload mass.

• Listing the records which will display the month names, successful landing outcomes in ground pad ,booster versions, launch site for the months in year 2017

• Ranking the count of successful landing outcomes between the date 2010-06-04 and 2017-03-20 in descending order.

Build an Interactive Map with Folium

GitHub URL

To visualize the Launch Data into an interactive map. We took the Latitude and Longitude Coordinates at each launch site and added a Circle Marker around each launch site with a label of the name of the launch site.

We assigned the dataframe launch_outcomes(failures, successes) to classes 0 and 1 with Green and Red markers on the map in a MarkerCluster()

Using Haversine's formula we calculated the distance from the Launch Site to various landmarks to find various trends about what is around the Launch Site to measure patterns. Lines are drawn on the map to measure distance to landmarks

Example of some trends in which the Launch Site is situated in.

- 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

Build a Dashboard with Plotly Dash

GitHub URL

The dashboard has been built with Plotly Dash

Graphs

- Pie Chart showing the total launches by a certain site/all sites
  - display relative proportions of multiple classes of data.
  - size of the circle can be made proportional to the total quantity it represents.

Scatter Graph showing the relationship with Outcome and Payload Mass (Kg) for the different Booster Versions

- It shows the relationship between two variables.
- It is the best method to show you a non-linear pattern.
- The range of data flow, i.e. maximum and minimum value, can be determined.
- Observation and reading are straightforward.

Predictive Analysis (Classification)

GitHubURL

BUILDING MODEL

- • Load our dataset into NumPy and Pandas
- • Transform Data
- • Split our data into training and test data sets
- • Check how many test samples we have
- • Decide which type of machine learning algorithms we want to use
- • Set our parameters and algorithms to GridSearchCV
- • Fit our datasets into the GridSearchCV objects and train our dataset.

EVALUATING MODEL

- • Check accuracy for each model
- • Get tuned hyperparameters for each type of algorithms
- • Plot Confusion Matrix

IMPROVING MODEL

- • Feature Engineering
- • Algorithm Tuning

FINDING THE BEST PERFORMING CLASSIFICATION MODEL

- • The model with the best accuracy score wins the best performing model

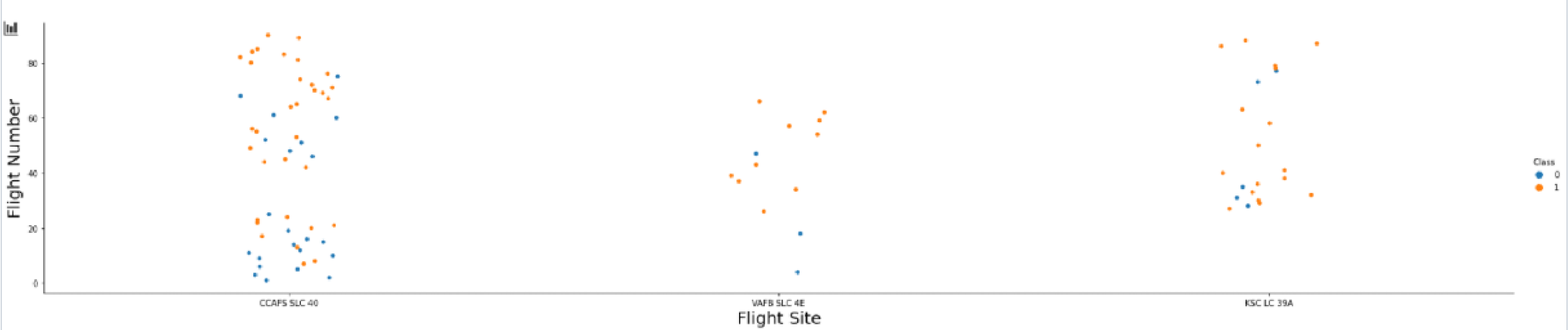
Results

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

EDA with Visualization

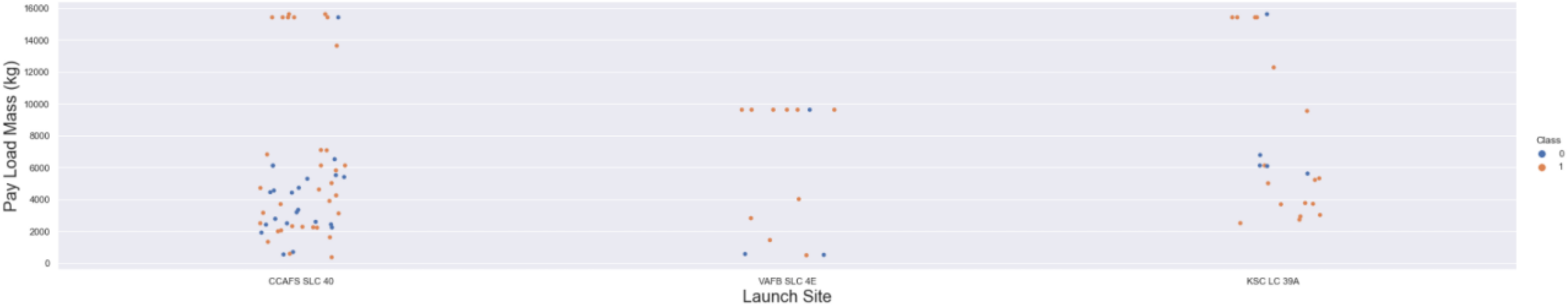
Flight Number vs. Launch Site

Flight Number vs. Launch Site



The more amount of flights at a launch site the greater the success rate at a launch site.

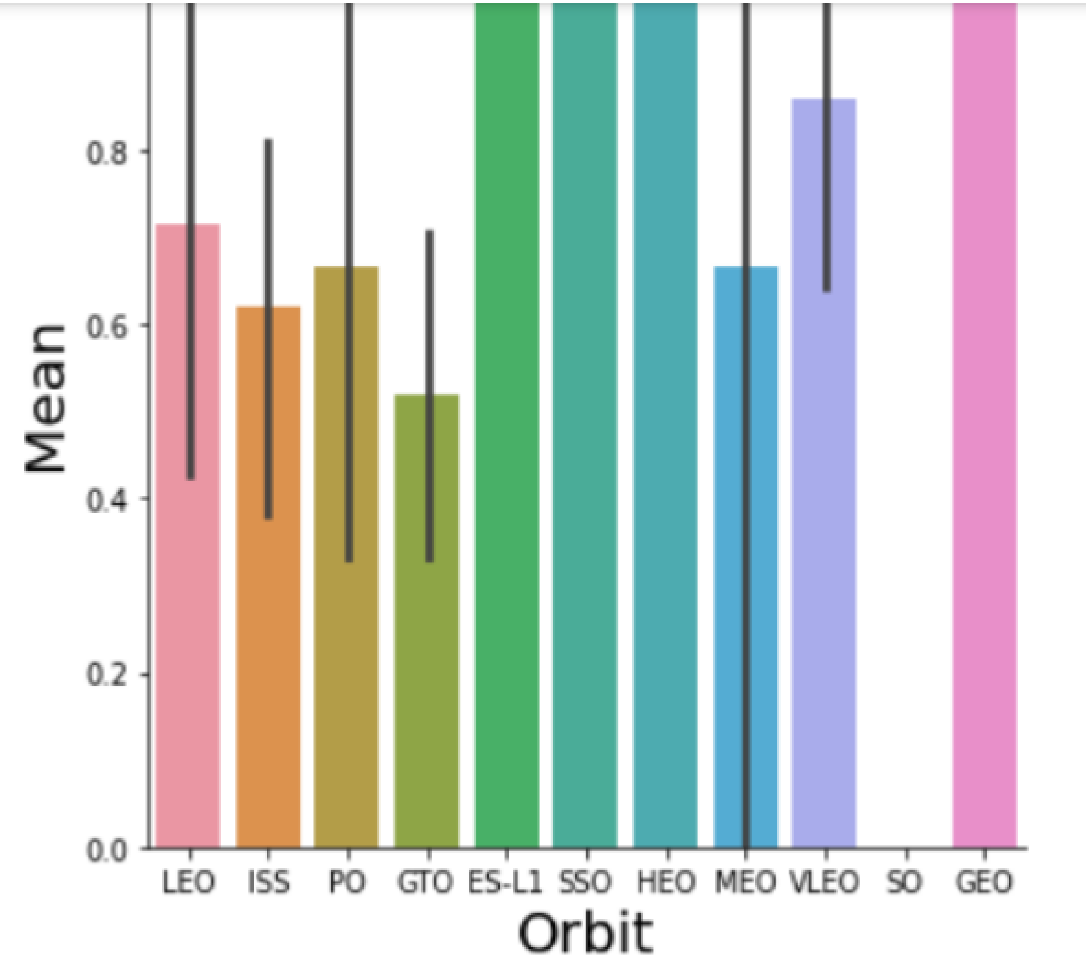
Payload vs. Launch Site



The greater the payload mass for Launch Site CCAFS SLC 40 the higher the success rate for the Rocket. There is not quite a clear pattern to be found using this visualization to make a decision if the Launch Site is dependent on Pay Load Mass for a success launch.

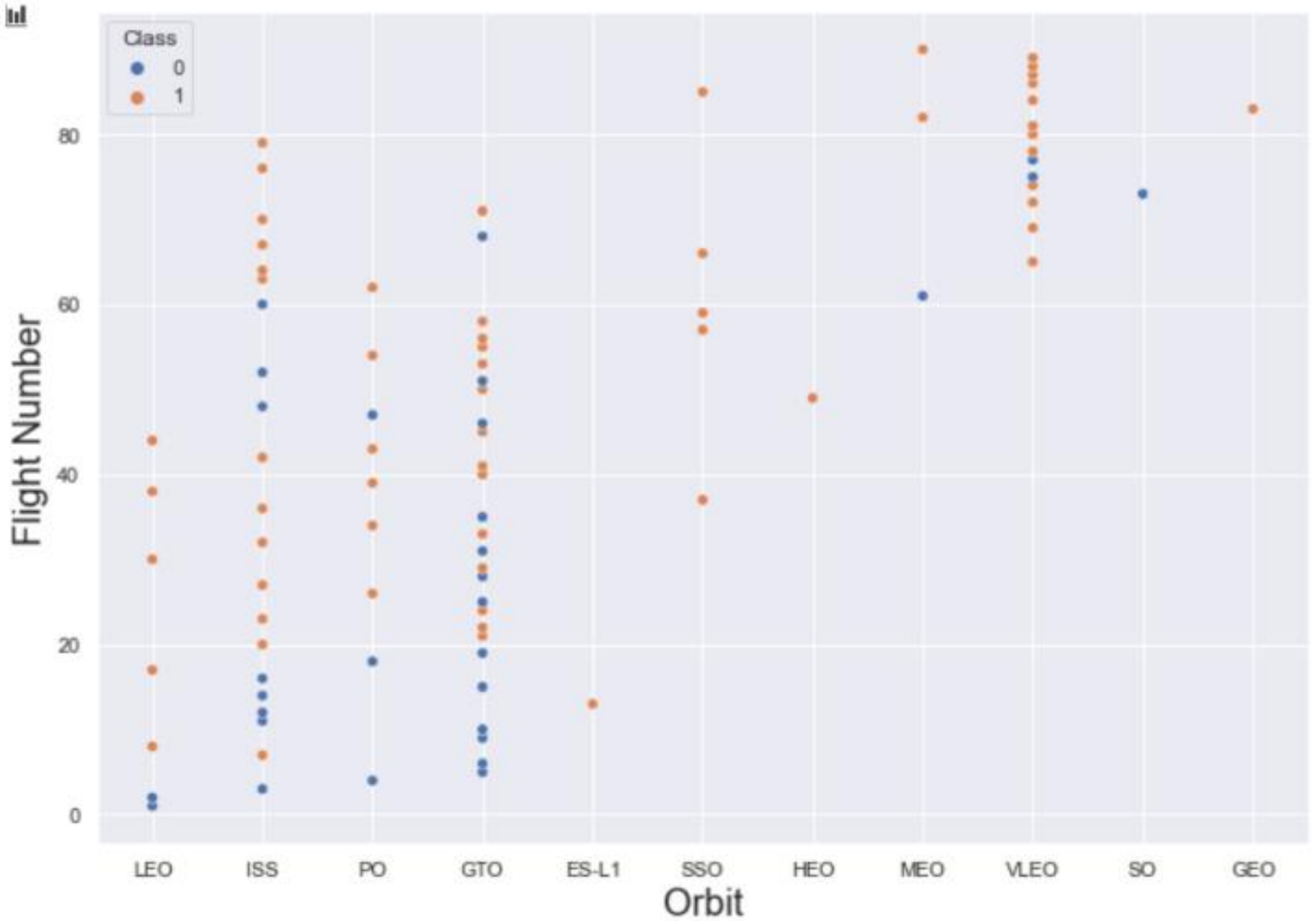
Success Rate vs. Orbit Type

Orbit GEO,HEO,SSO,ES-L1 has the best Success Rate



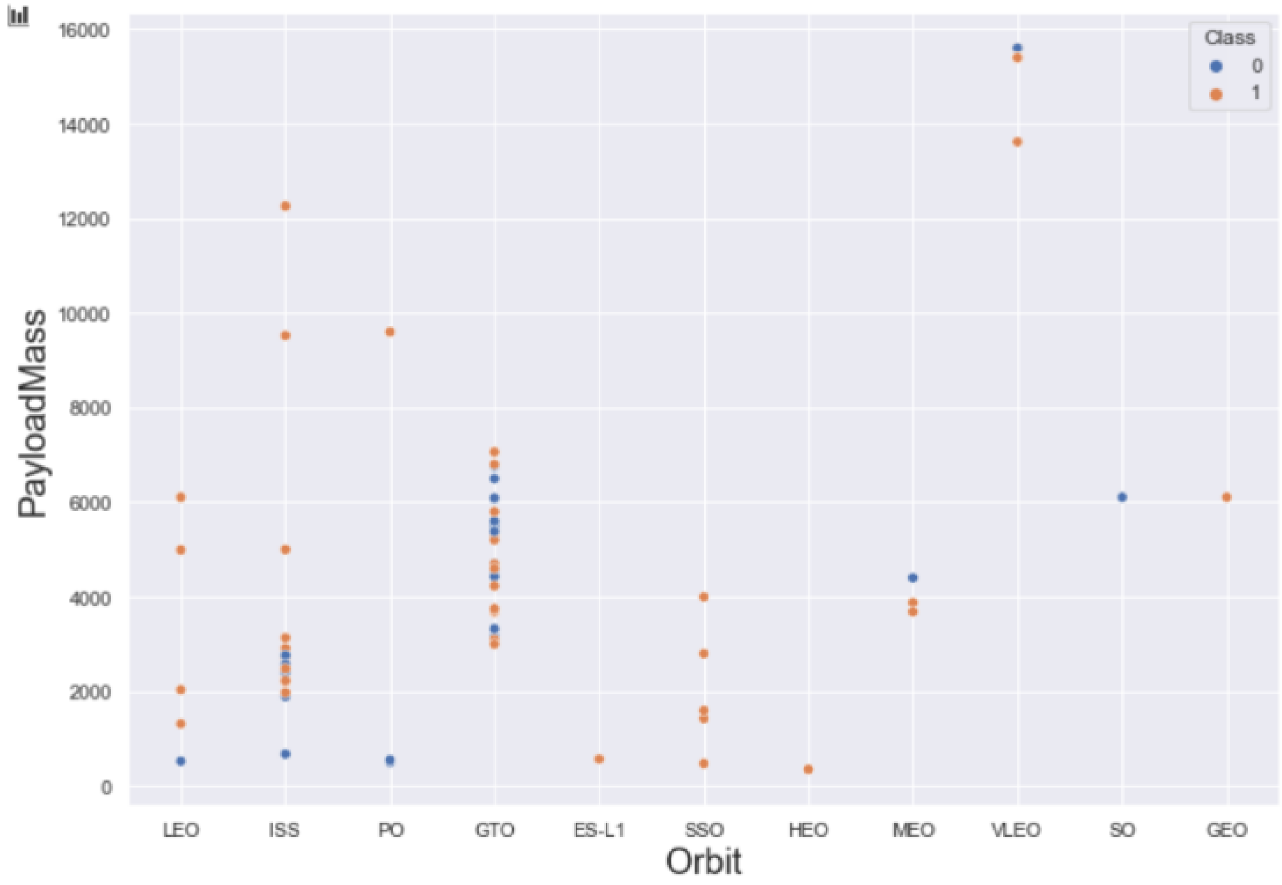
Flight Number vs. Orbit Type

You should 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.



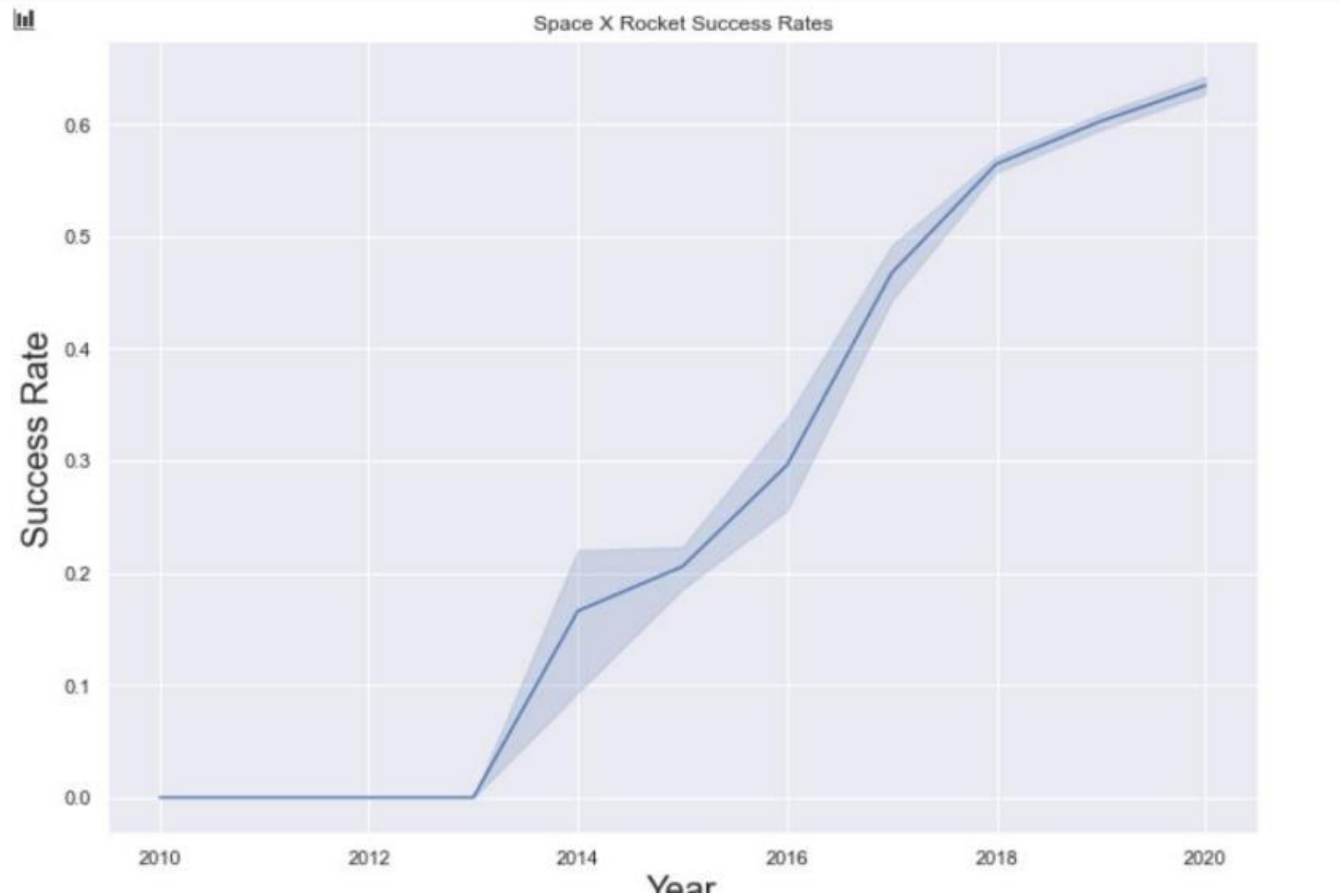
Payload vs. Orbit Type

You should observe that Heavy payloads have a negative influence on GTO orbits and positive on GTO and Polar LEO (ISS) orbits.



Launch Success Yearly Trend

you can observe that the success rate since 2013 kept increasing till 2020



All Launch Site Names

select DISTINCT Launch_Site

from tblSpaceX

QUERY EXPLAINATION

Using the word DISTINCT in the query

means that it will only show

Unique values in the Launch_Site

column from tblSpaceX

Unique Launch Sites
CCAFS LC-40
CCAFS SLC-40
CCAFS SLC-40
KSC LC-39A
VAFB SLC-4E

Launch Site Names Begin with 'KSC'

select TOP 5 * from tblSpaceX
WHERE Launch_Site LIKE 'KSC%'

Using the word TOP 5 in the query means that it will only show 5 records from tblSpaceX and LIKE keyword has a wild card with the words 'KSC%' the percentage in the end suggests that the Launch Site name must start with KSC.

	Date	Time_UTC	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS_KG_	Orbit	Customer	Mission_Outcome	Landing_Outcome
0	19-02-2017	2021-07-02 14:39:00.0000000	F9 FT B1031.1	KSC LC-39A	SpaceX CRS-10	2490	LEO (ISS)	NASA (CRS)	Success	Success (ground pad)
1	16-03-2017	2021-07-02 06:00:00.0000000	F9 FT B1030	KSC LC-39A	EchoStar 23	5600	GTO	EchoStar	Success	No attempt
2	30-03-2017	2021-07-02 22:27:00.0000000	F9 FT B1021.2	KSC LC-39A	SES-10	5300	GTO	SES	Success	Success (drone ship)
3	01-05-2017	2021-07-02 11:15:00.0000000	F9 FT B1032.1	KSC LC-39A	NROL-76	5300	LEO	NRO	Success	Success (ground pad)
4	15-05-2017	2021-07-02 23:21:00.0000000	F9 FT B1034	KSC LC-39A	Inmarsat-5 F4	6070	GTO	Inmarsat	Success	No attempt

Total Payload Mass

SQL QUERY

select SUM(PAYLOAD_MASS_KG_) TotalPayloadMass from tblSpaceX where Customer = 'NASA (CRS)"','TotalPayloadMass

	Total Payload Mass
0	45596

QUERY EXPLAINATION :
Using the function SUM summates the total in the column PAYLOAD_MASS_KG_ The WHERE clause filters the dataset to only perform calculations on Customer NASA (CRS)

Average Payload Mass by F9 v1.1

SQL QUERY

select AVG(PAYLOAD_MASS_KG_) AveragePayloadMass from tblSpaceX where Booster Version = 'F9 v1.1'

	Average Payload Mass
0	2928

Using the function AVG works out the the column PAYLOAD_MASS_KG_ The WHERE clause filters the dataset to only perform calculations on Booster version

F9 v1.1

First Successful Ground Landing Date

SQL QUERY

select MIN(Date) SLO from tblSpaceX where Landing Outcome = "Success (drone ship)"

	Date which first Successful landing outcome in drone ship was acheived.
0	06-05-2016

QUERY EXPLAINATION:

Using the function MIN works out the date in the column Date The WHERE clause filters the dataset to only perform calculations on Landing Outcome Success (drone ship)

Successful Drone Ship Landing with Payload between 4000 and 6000

SQL QUERY

select Booster Version from tblSpaceX where Landing Outcome = 'Success (ground pad)' AND Payload_MASS_KG_ > 4000 AND Payload_MASS_KG_ < 6000

	Date which first Successful landing outcome in drone ship was acheived.
0	F9 FT B1032.1
1	F9 B4 B1040.1
2	F9 B4 B1043.1

QUERY EXPLAINATION

Selecting only Booster Version The WHERE clause filters the dataset to Landing Outcome = Success (drone ship) The AND clause specifies additional filter conditions Payload_MASS_KG_ > 4000 AND Payload_MASS_KG_ < 6000

Total Number of Successful and Failure Mission Outcomes

SQL QUERY

SELECT(SELECT Count(Mission_Outcome) from tblSpaceX where Mission_Outcome LIKE '%Success%') as Successful_Mission_Outcomes, (SELECT Count(Mission_Outcome) from tblSpaceX where Mission_Outcome LIKE '%Failure%') as Failure_Mission_Coutcomes

	Successful_Mission_Outcomes	Failure_Mission_Outcomes
0	100	1

QUERY EXPLAINATION: we used subqueries here to produce the results. The LIKE '%foo%' wildcard shows that in the record the foo phrase is in any part of the string in the records for example. PHRASE "(Drone Ship was a Success)"

LIKE '%Success%' Word 'Success' is in the phrase the filter will include it in the dataset

Boosters Carried Maximum Payload

SQL QUERY

SELECT DISTINCT Booster_Version, MAX(PAYLOAD _MASS _KG_) AS [Maximum Payload Mass] FROM tblSpaceX GROUP BY Booster_Version ORDER BY [Maximum Payload Mass] DESC

QUERY EXPLAINATION: Using the word DISTINCT in the query means that it will only show Unique values in the Booster_Version column from tblSpaceX GROUP BY puts the list in order set to a certain condition. DESC means its arranging the dataset into descending order

	Booster_Version	Maximum Payload Mass
0	F9 B5 B1048.4	15600
1	F9 B5 B1048.5	15600
2	F9 B5 B1049.4	15600
3	F9 B5 B1049.5	15600
4	F9 B5 B1049.7	15600
...	...	...
92	F9 v1.1 B1003	500
93	F9 FT B1038.1	475
94	F9 B4 B1045.1	362
95	F9 v1.0 B0003	0
96	F9 v1.0 B0004	0

97 rows × 2 columns

2017 Launch Records

SQL QUERY

SELECT DATENAME(month, DATEADD

(month, MONTH

(CONVERT(date, Date, 105)), 0) - 1)

AS Month, Booster_Version, Launch_Site,

Landing_Outcome FROM tblSpaceX

WHERE (Landing_Outcome LIKE N'%Success%')

AND (YEAR(CONVERT(date, Date, 105)) = '2017')

QUERY EXPLAINATION: a much more complex query

as I had my Date fields in SQL Server stored as NVARCHAR

the MONTH function returns name month. The function

CONVERT converts NVARCHAR to Date. WHERE clause filters

Year to be 2017

Month	Booster_Version	Launch_Site	Landing_Outcome
January	F9 FT B1029.1	VAFB SLC-4E	Success (drone ship)
February	F9 FT B1031.1	KSC LC-39A	Success (ground pad)
March	F9 FT B1021.2	KSC LC-39A	Success (drone ship)
May	F9 FT B1032.1	KSC LC-39A	Success (ground pad)
June	F9 FT B1035.1	KSC LC-39A	Success (ground pad)
June	F9 FT B1029.2	KSC LC-39A	Success (drone ship)
June	F9 FT B1036.1	VAFB SLC-4E	Success (drone ship)
August	F9 B4 B1039.1	KSC LC-39A	Success (ground pad)
August	F9 FT B1038.1	VAFB SLC-4E	Success (drone ship)
September	F9 B4 B1040.1	KSC LC-39A	Success (ground pad)
October	F9 B4 B1041.1	VAFB SLC-4E	Success (drone ship)
October	F9 FT B1031.2	KSC LC-39A	Success (drone ship)
October	F9 B4 B1042.1	KSC LC-39A	Success (drone ship)
December	F9 FT B1035.2	CCAFS SLC-40	Success (ground pad)

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

SQL QUERY

SELECT COUNT(Landing_Outcome)

FROM tblSpaceX WHERE

(Landing_Outcome LIKE '%Success%')

	Successful Landing Outcomes Between 2010-06-04 and 2017-03-20
0	34

QUERY EXPLAINATION: Function COUNT counts records in column WHERE filters data

LIKE (wildcard) AND (conditions) AND (conditions)AND (Date > '04-06-2010') AND

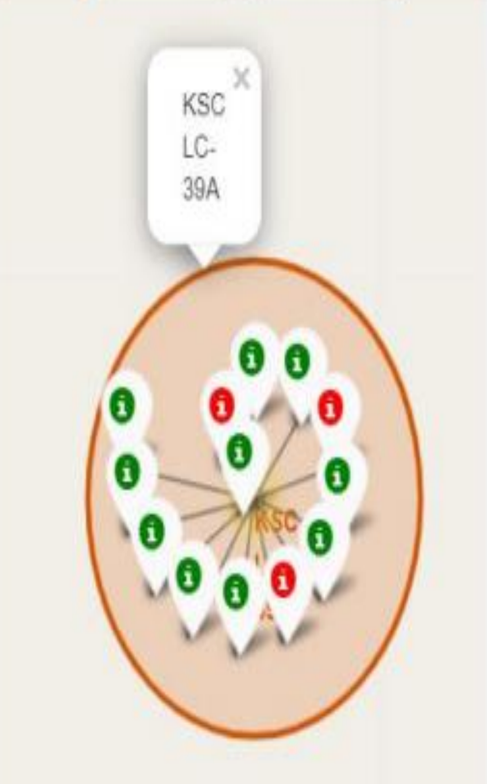
(Date < '20-03-2017')

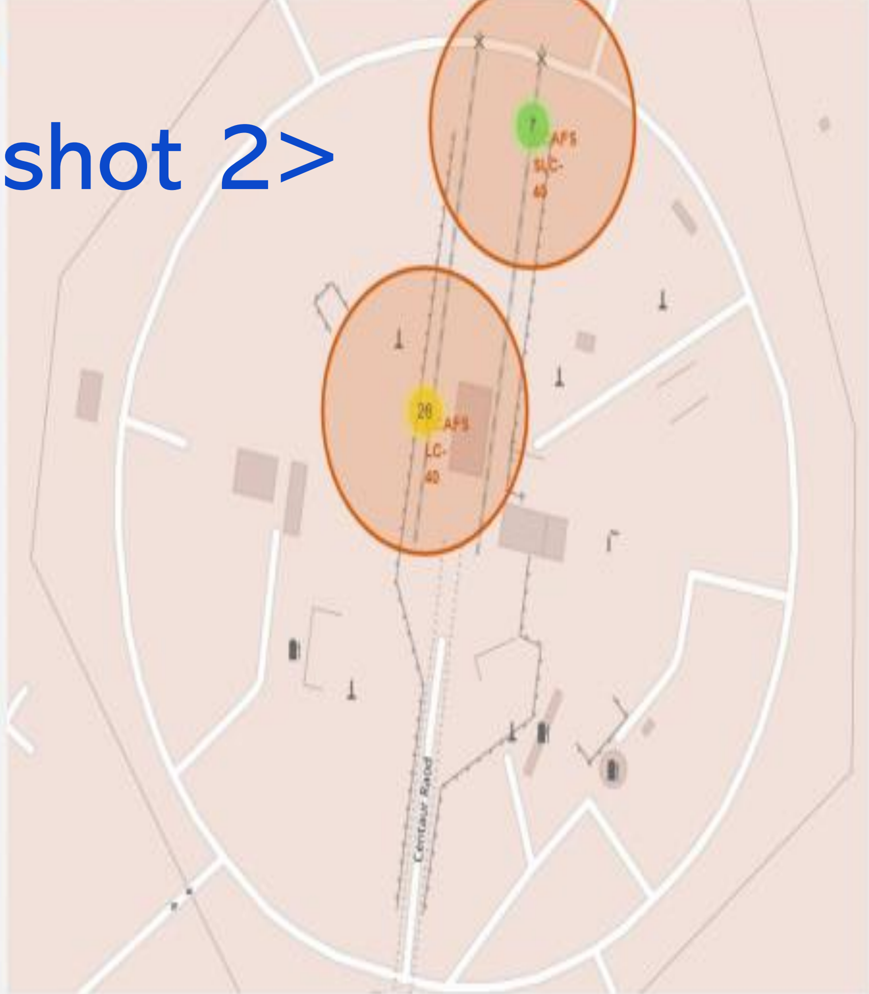
Interactive Map With Folium

<Folium Map Screenshot 1>

We can see that the SpaceX launch sites are in the United States of America coasts. Florida and California

<Folium Map Screenshot 2>



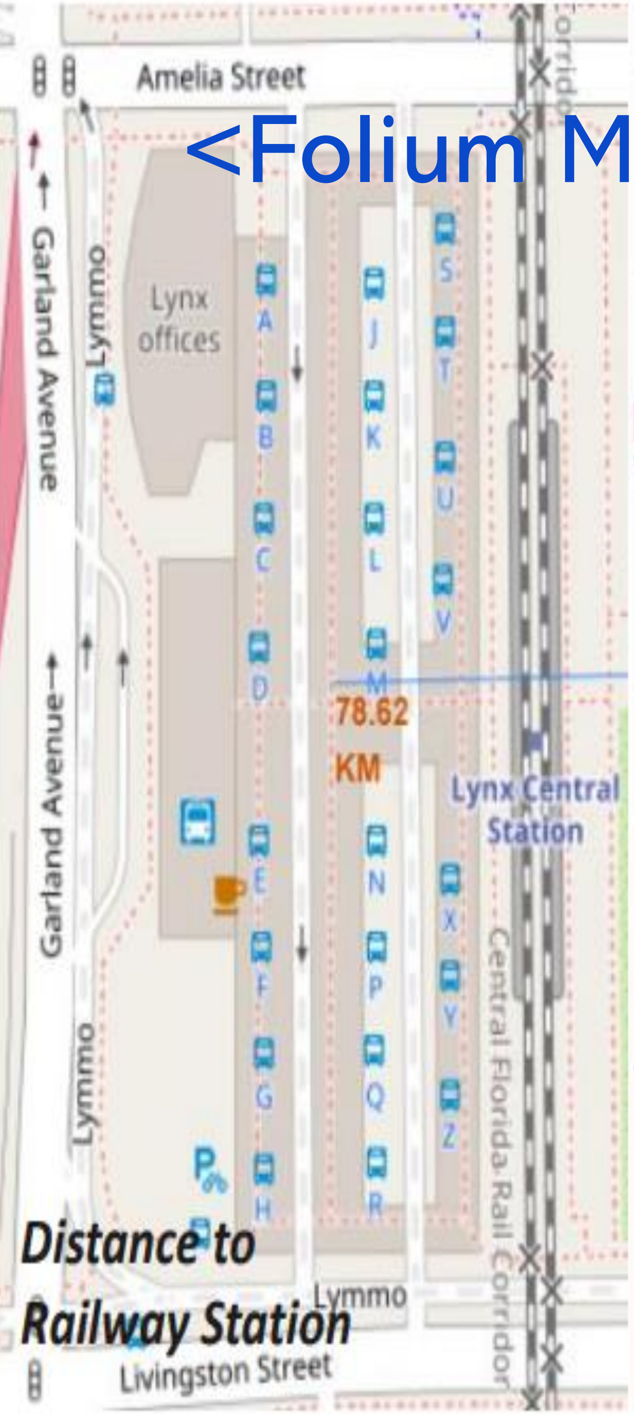


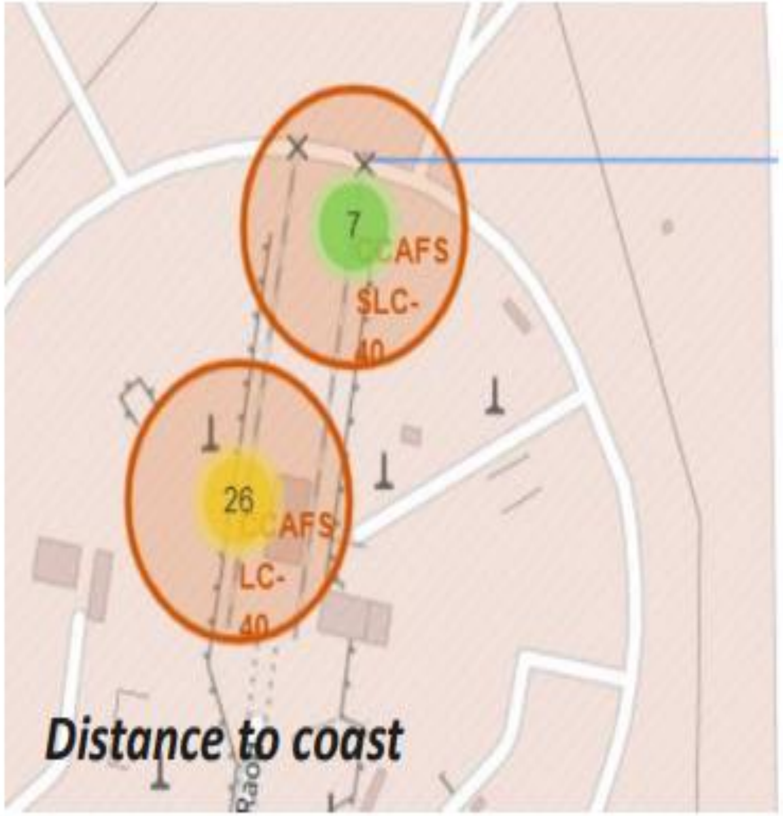
Florida Launch Sites

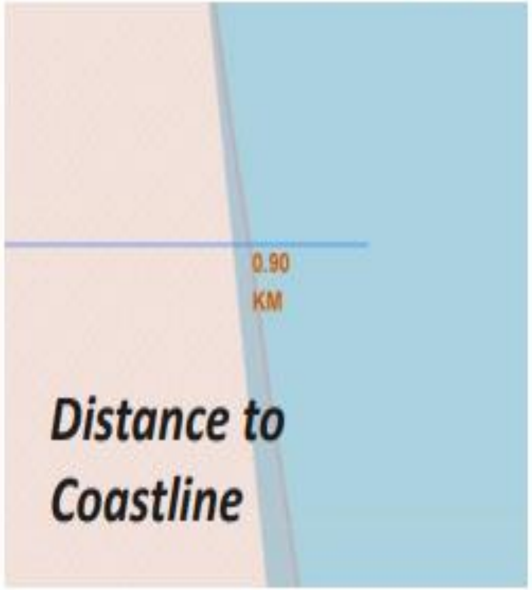
Green Marker shows successful Launches and Red Marker shows Failures

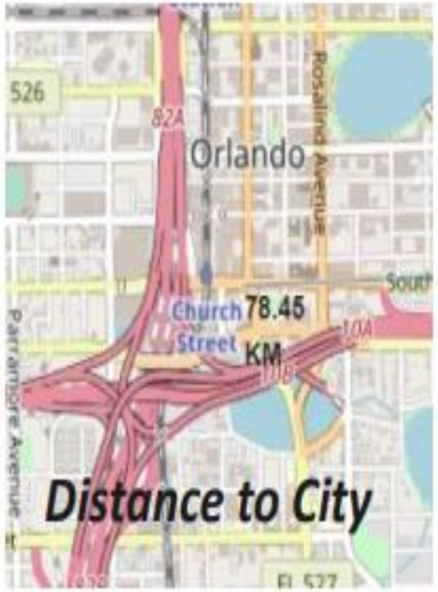
California Launch Site

<Folium Map Screenshot 3>





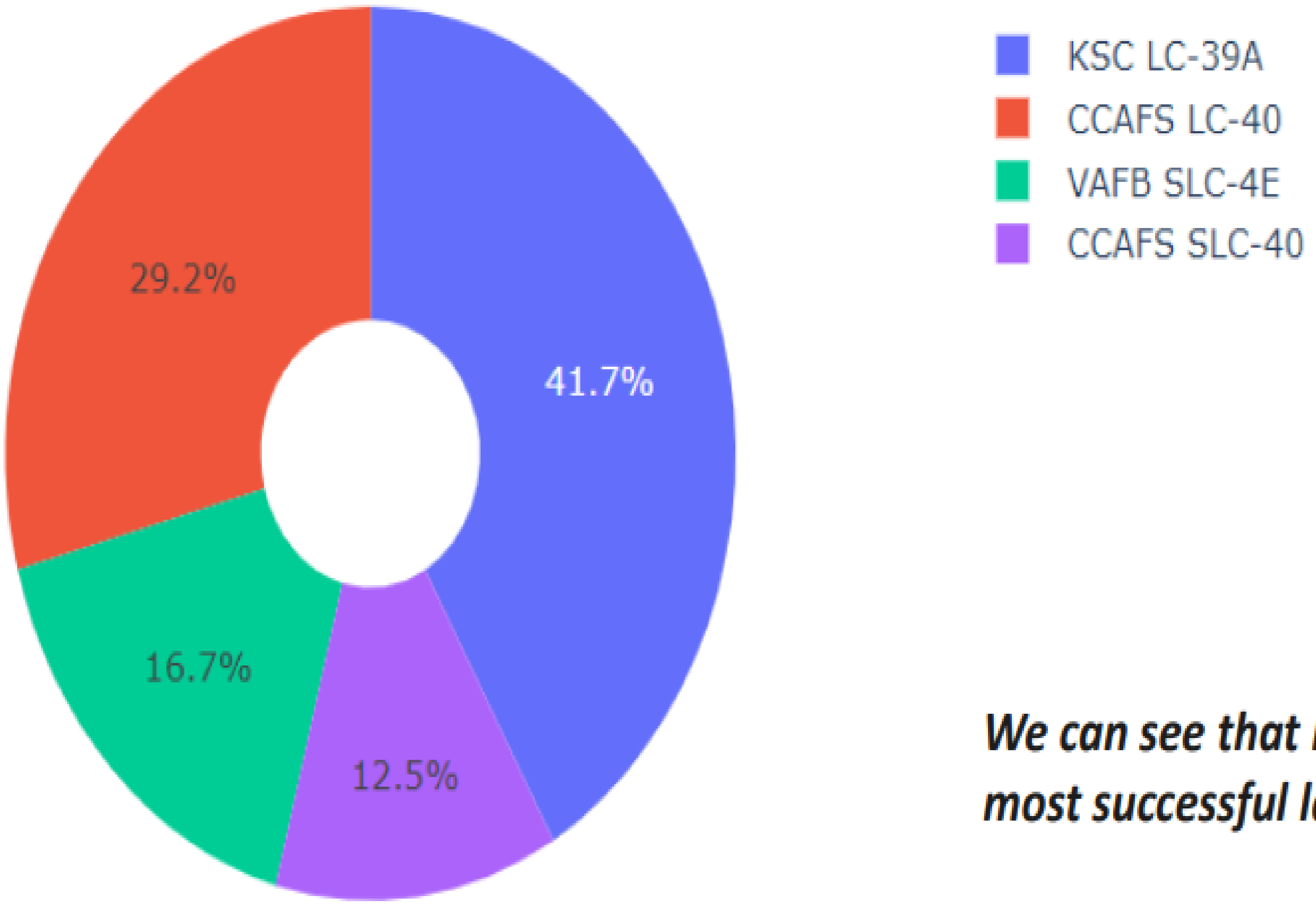




- Are launch sites in close proximity to railways? No
- Are launch sites in close proximity to highways? No
- Are launch sites in close proximity to coastline? Yes
- Do launch sites keep certain distance away from cities? Yes

Dashboard with Plotly Dash

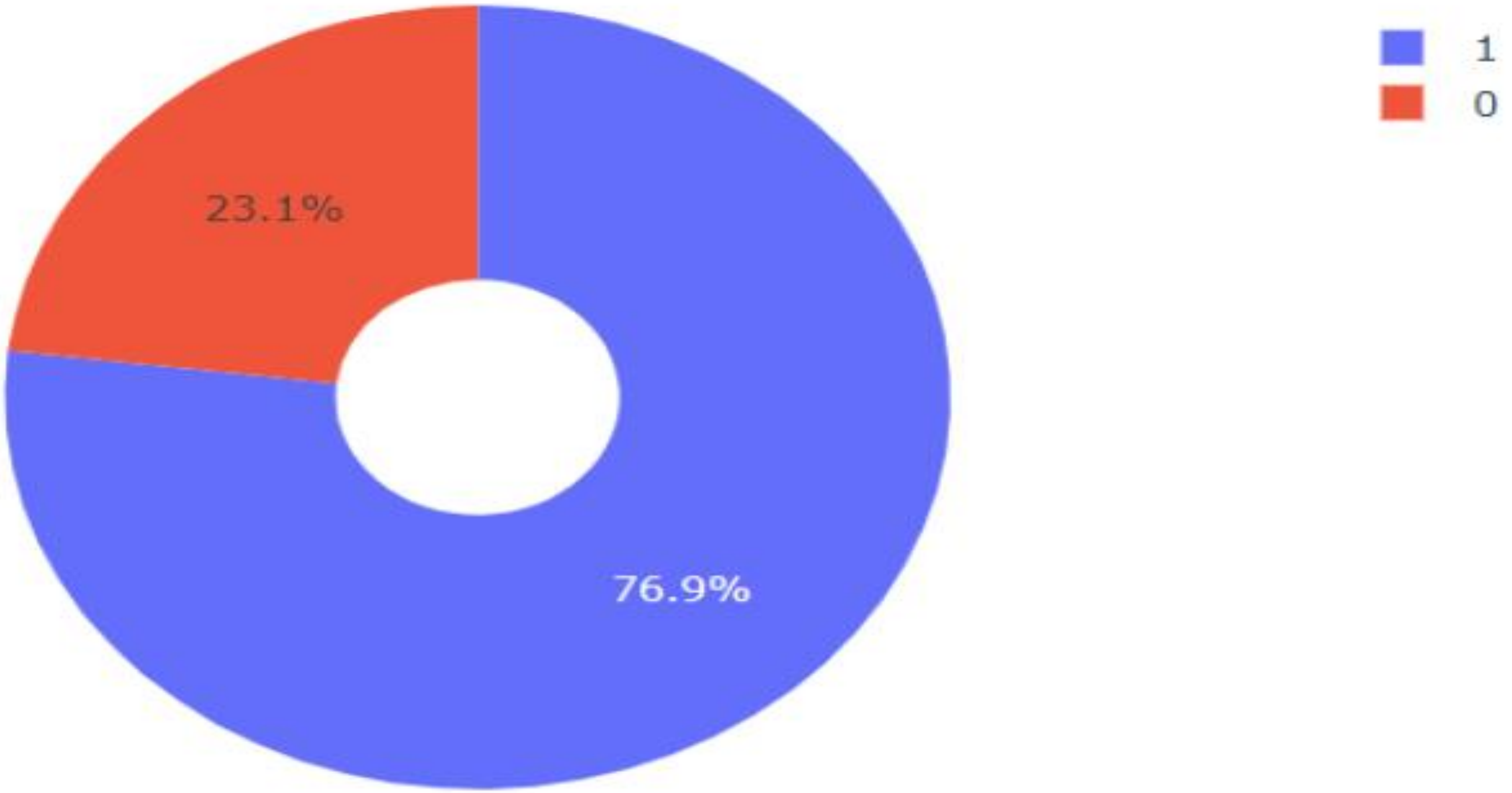
Total Success Launches By all sites



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

Dashboard 2

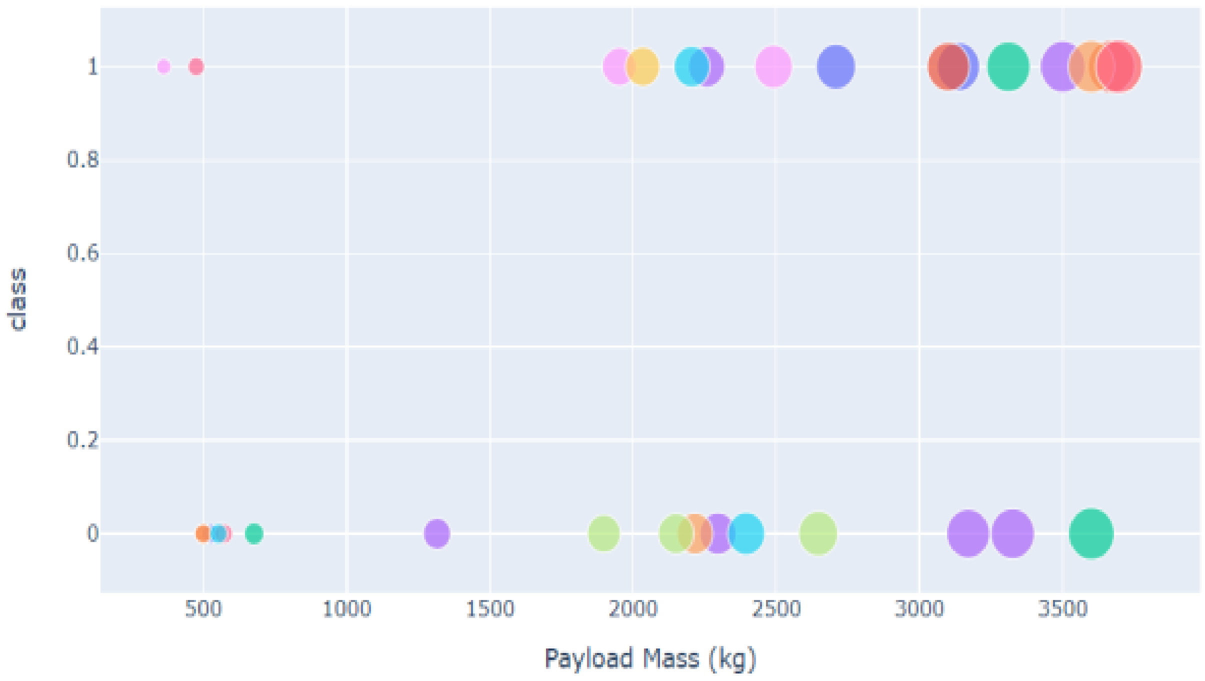
DASHBOARD – Pie chart for the launch site with highest launch success ratio



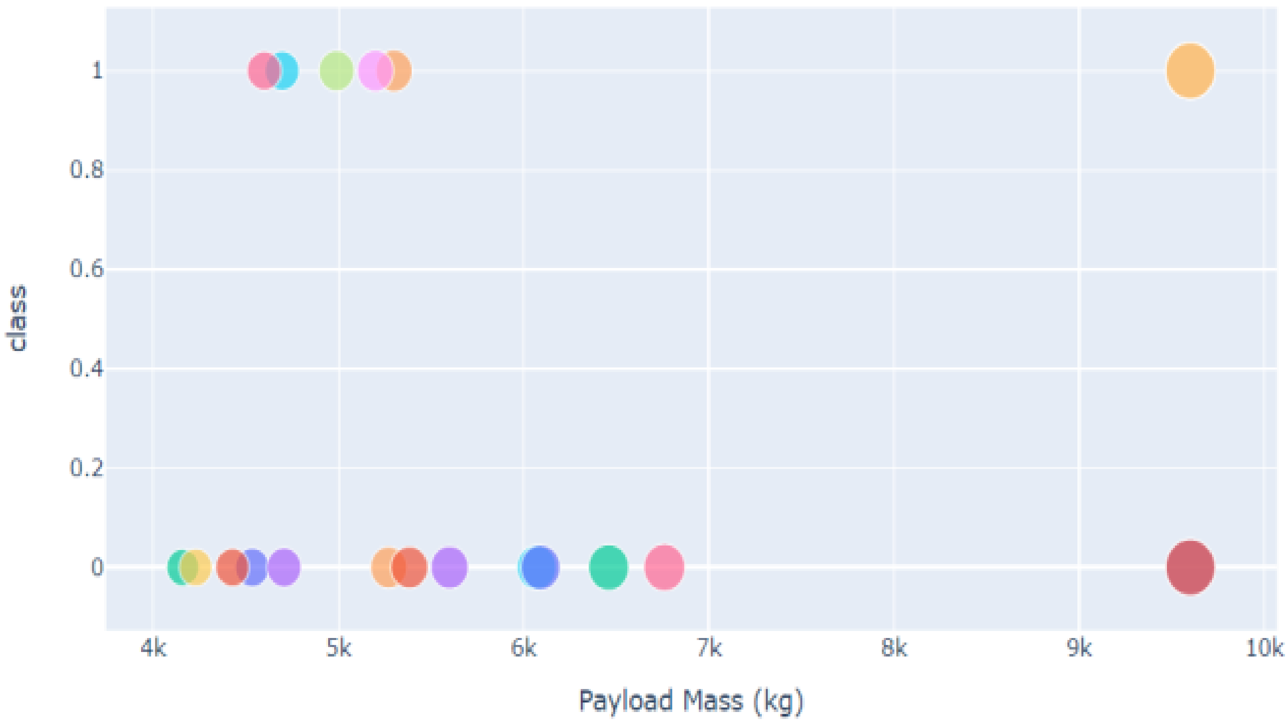
KSC LC-39A achieved a 76.9% success rate while getting a 23.1% failure rate

DASHBOARD – Payload vs. Launch Outcome scatter plot for all sites

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

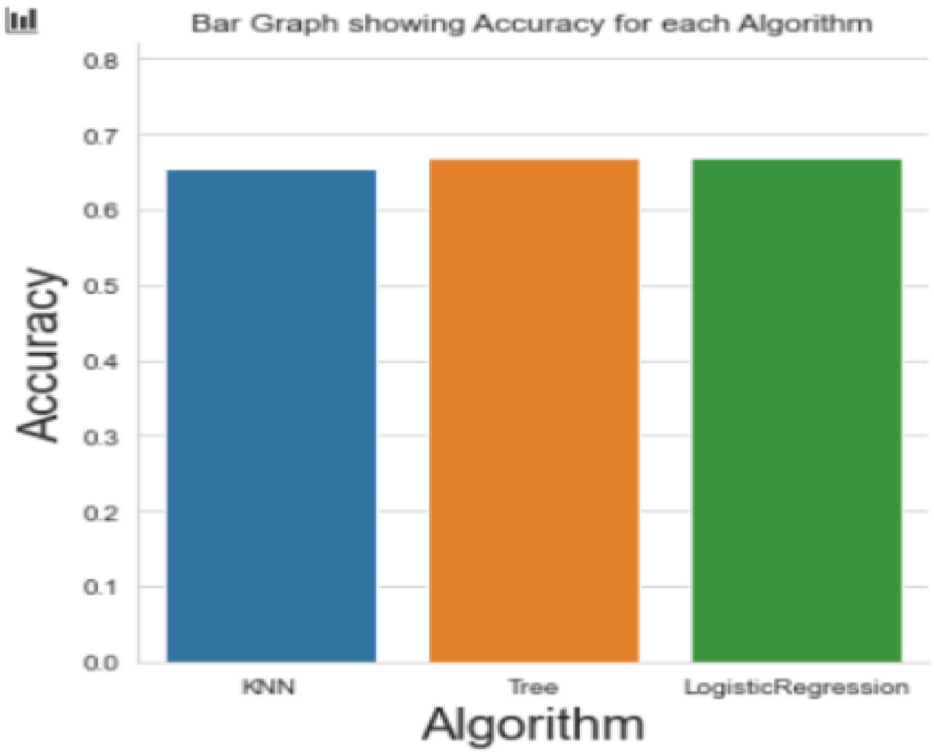
Predictive Analysis(Classification)

Classification Accuracy using training data

As you can see our accuracy is extremely close but we do have a winner its down to decimal places! using this function

```
bestalgorithm = max(algorithms, key=algorithms.get)
```

	Accuracy	Algorithm
0	0.653571	KNN
1	0.667857	Tree
2	0.667857	LogisticRegression



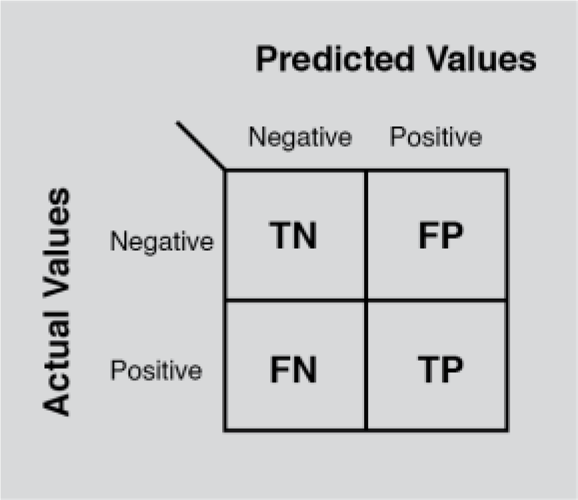
The tree algorithm wins!!

```
Best Algorithm is Tree with a score of 0.6678571428571429
Best Params is : {'criterion': 'gini', 'max_depth': 2, 'max_features': 'auto', 'min_samples_leaf': 1, 'min_samples_split': 2, 'splitter': 'best'}
```

After selecting the best hyperparameters for the decision tree classifier using the validation data, we achieved 83.33% accuracy on the test data.

Confusion Matrix for the Tree

Examining the confusion matrix, we see that Tree can distinguish between the different classes. We see that the major problem is false positives.



Conclusions

- The Tree Classifier Algorithm is the best for Machine Learning for this dataset
- Low weighted payloads perform better than the heavier payloads
- The success rates for SpaceX launches is directly proportional time in years they will eventually perfect the launches
- We can see that KSC LC-39A had the most successful launches from all the sites
- Orbit GEO,HEO,SSO,ES-L1 has the best Success Rate

Appendix

- Haversine formula
- Module sqlserver (ADGSQLSERVER)
- PythonAnywhere 24/7 dashboard