IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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

Executive Summary

Methodology Applied

- Data collection through API and Web Scraping
- Data wrangling
- EDA with SQL and Visualization
- Creating an interactive map with Folium
- Creating a dashboard with Plotly Dash
- Building models using Logistic Regression, Decision Tree and K-Nearest Neighbors

Summary

- Logistic regression model was chosen for its popularity and application in the business.
- Successful launches are determined by lighter payload, which orbit the launch is being sent to, the proximity of coast and highway, frequency of launches by launch site (increase in launches leads to higher success rate).

Introduction

Project Scope

- This report has been created as part of the IBM Applied Data Science Capstone Project.
- The Capstone Project is based on the Space industry, it analyses Space X data from its website to determine whether SpaceX Falcon 9 first stage will land successfully. Space X states that the cost of Falcon 9 launch is $62 million dollars compared to $165 million dollars stated by its competitors. Much of the savings are due to its ability to reuse its first stage components.
- In this project Space Y wants to compete with Space X, so uses machine learning techniques to establish whether Falcon 9 rocket launch first stage will land successfully. This information will help Space Y to bid against Space X for rocket launch business.

Insights to derive from machine learning

- What factors determine a successful launch?
- What are the key variables in determining success/failure?

Section 1

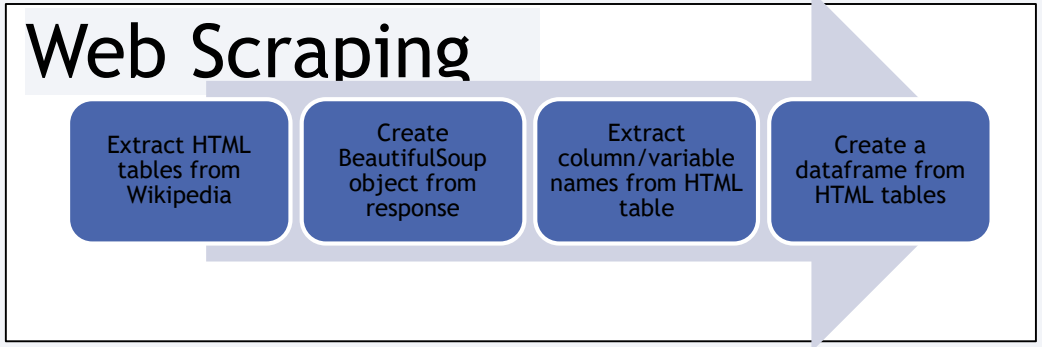
Methodology

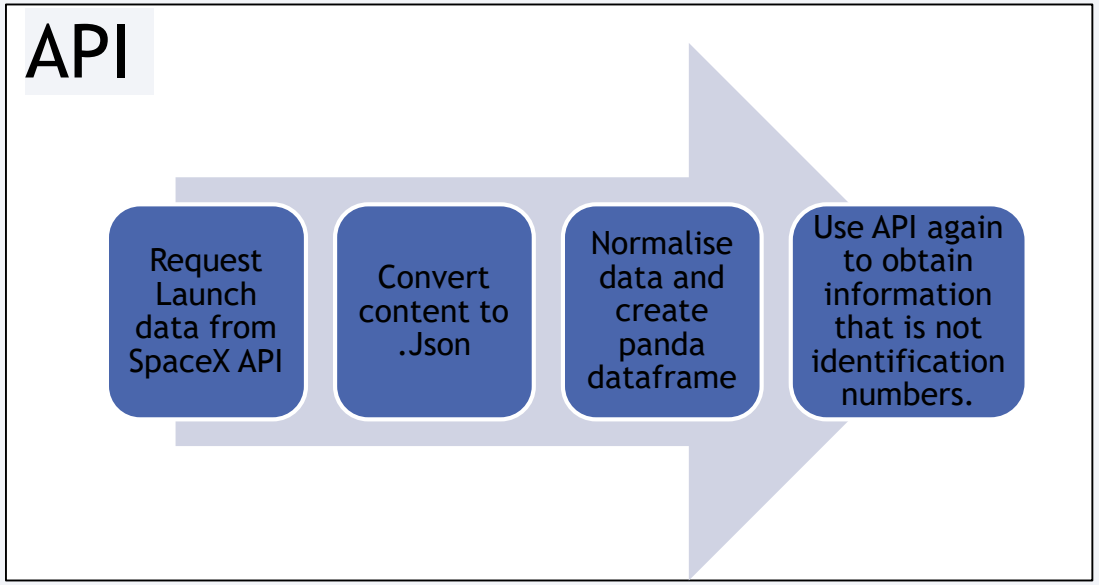
Methodology

- Data collection methodology: Data was collected using SpaceX Rest API and Web Scraping.
- Data Wrangling : Data preparation done by filling missing data using One Hot Encoding feature, selecting required data and column.
- Exploratory Data Analysis (EDA) using visualization and SQL: Analysis was done using SQL and visualization to determine relationship/correlation between variables.
- Interactive visual analytics using Folium and Plotly Dash: Explore launch data further by using folium maps and dashboard reporting.
- Predictive analysis using classification models: Build, tune, evaluate classification models

Data Collection

- Data was collected from Wikipedia through web scraping (BeautifulSoup) and REST API to predict success/failure of Falcon 9 First Stage landing.





- Data collected has Launch data information about Landing outcome, Launch sites, payload mass carried, rocket parts new/used for each launch.

Data Collection – SpaceX API

The flow chart below shows the steps taken to get information using API and convert it to a dataframe used for analysis.

Use API to request and parse SpaceX launch data

Use json_normalise method to convert into a dataframe

Clean data using customised functions

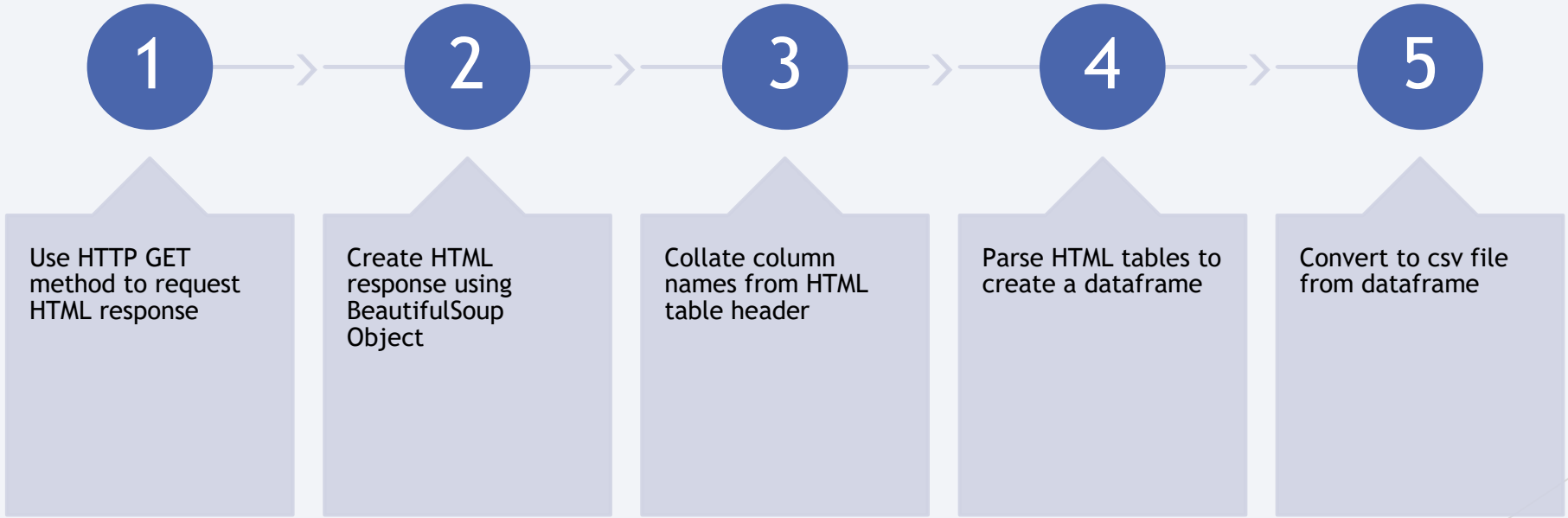
Combine columns to dictionary

Create a panda dataframe from the above dictionary

[Capstone-Project/Data Collection Api.ipynb at main · RohitMi/Capstone-Project (github.com)]

Data Collection – Web Scraping

The flow chart below shows the steps taken to get information using Web-scraping and convert it to a dataframe used for analysis.



Capstone-Project/Data Collection with Web Scrapping.ipynb at main · RohitMi/Capstone-Project (github.com)

Data Wrangling

- Data wrangling process helps prepare the data for analysis and to get insights from exploratory analysis to establish the right labels for training supervised models.
- This stage simplifies all successful/unsuccessful launch outcomes to a label called ‘Class’ which allows us to establish insight to launch site success rates.

CALCULATE NUMBER OF LAUNCHES ON EACH SITE

CALCULATE THE NUMBER AND OCCURRENCE OF EACH ORBIT

CALCULATE THE NUMBER AND OCCURRENCE OF MISSION OUTCOME PER ORBIT TYPE

CREATE LANDING OUTCOME LABEL FROM OUTCOME COLUMN

DETERMINE SUCCESS RATES

Capstone-Project/Data Wrangling.ipynb at main · RohitMi/Capstone-Project (github.com)

EDA with Data Visualization

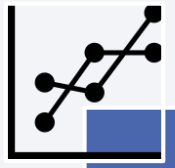
Visualizations are used to explore insights about the Launch data collected from website.

Scatter Plots

- Scatter plots are used to explore relationship between variables.
- The following scatter plots were created for EDA:
- Flight Number VS Launch Site
- Payload VS Launch Site
- Success rate VS orbit type
- Flight Number VS Payload
- Flight Number VS Orbit
- Flight number VS Orbit type

Bar Charts

- Bar charts are helpful to depict relationships between variables, changes and comparisons of different groups. The following relationships were explored:
- -Orbit VS Class



Line Plots

- Line graphs are effective in showing changes over short and long-term timeframes.
- - Success VS year

[Capstone-Project/EDA with Data Visualization.ipynb at main · RohitMi/Capstone-Project (github.com)]

EDA with SQL

SQL queries were performed to gather further insight into the data. The following queries were executed;

1. ***Display the names of the unique launch sites in the space mission***
2. ***Display 5 records where launch sites begin with the string 'CCA'***
3. ***Display the total payload mass carried by boosters launched by NASA (CRS)***
4. ***Display average payload mass carried by booster version F9 v1.1***
5. ***List the date when the first successful landing outcome in ground pad was achieved.***
6. ***List the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000***
7. ***List the total number of successful and failure mission outcomes***
8. ***List the names of the booster versions which have carried the maximum payload mass; use a subquery***
9. ***List the failed landing outcomes in drone ship, booster versions and launch site names in year 2015***
10. ***Rank the count of landing outcomes (such as Failure (drone ship) or Success (ground pad)) between the date 2010-06-04 and***

2017-03-20, in descending order

Capstone-Project/EDA with SQL.ipynb at main · RohitMi/Capstone-Project (github.com)

Build an Interactive Map with Folium

An interactive map with Folium was built to provide Launch Site analysis.

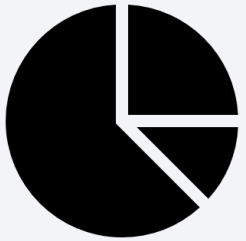
- A circle marker was created using latitude and longitude from the dataset, so we can visually see all the launch sites.
- A color marker of green and red was created to mark launch success and failures in the map.
- Several distance calculations were made against launch site and other markers such as Railway, Coastline, Highway and City to determine their proximity to launch sites and whether that is a determining factor in success/failure of launch sites.

Capstone-Project/Visual Analytics.ipynb at main · RohitMi/Capstone-Project (github.com)

Build a Dashboard with Plotly Dash

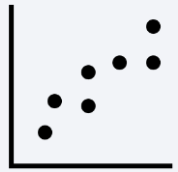
Plotly Dash was used to create an interactive dashboard to analyse/visualise launch data.

PIE CHART



Pie chart was created to analyse total launch success rates VS launch sites. The interactive pie chart also allows user to drill down to look at success rates of each specific sites. This was achieved by adding drop down 'Input components' along with 'call back functions' to initialise user choice of dropdown option.

SCATTER PLOT



Scatter plot highlights any relationship between 'Payload Mass' and launch success outcome by 'Booster Version Category'. Scatter plots are useful as it allows comparison of large number of datapoints and shows whether variables are positively or negatively correlated.

Scatter plot included 'Range Slider' to assess 'Payload Mass' and 'Call back function' to interactively drill down information by Payload mass.

Capstone-Project/SpaceX Dashboard.ipynb at main · RohitMi/Capstone-Project (github.com)

Predictive Analysis (Classification)

Model Build

- Load data frame
- Standardize data
- Creating training/test datasets
- Set up parameters
- Use GridSearchCV function to loop through predefined parameters

Evaluation

- Check model score
- Analyse model using Confusion Matrix

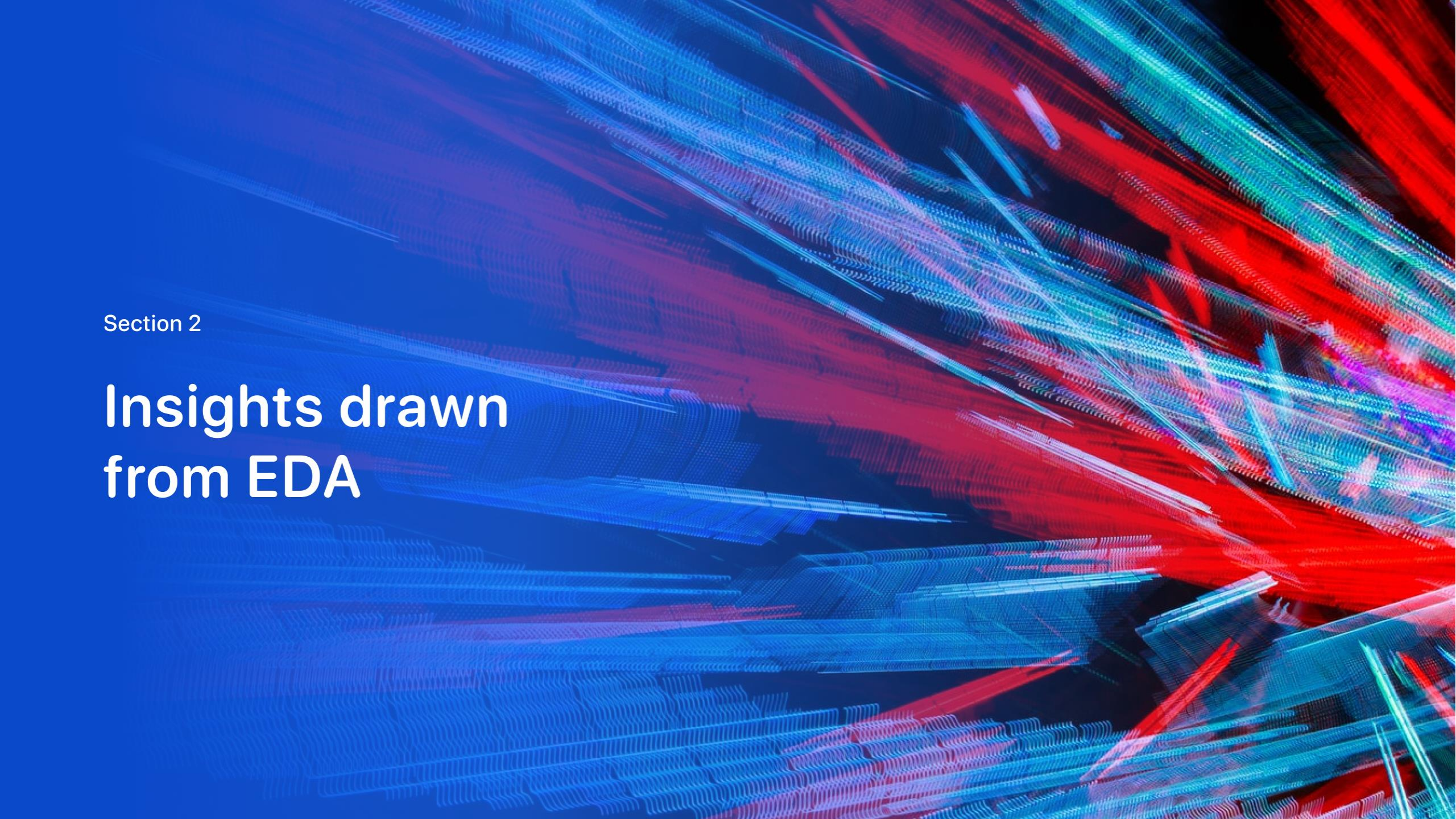
Best Fit Model

- Assess best Model

Capstone-Project/Machine Learning Prediction.ipynb at main · RohitMi/Capstone-Project (github.com)

RESULTS

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

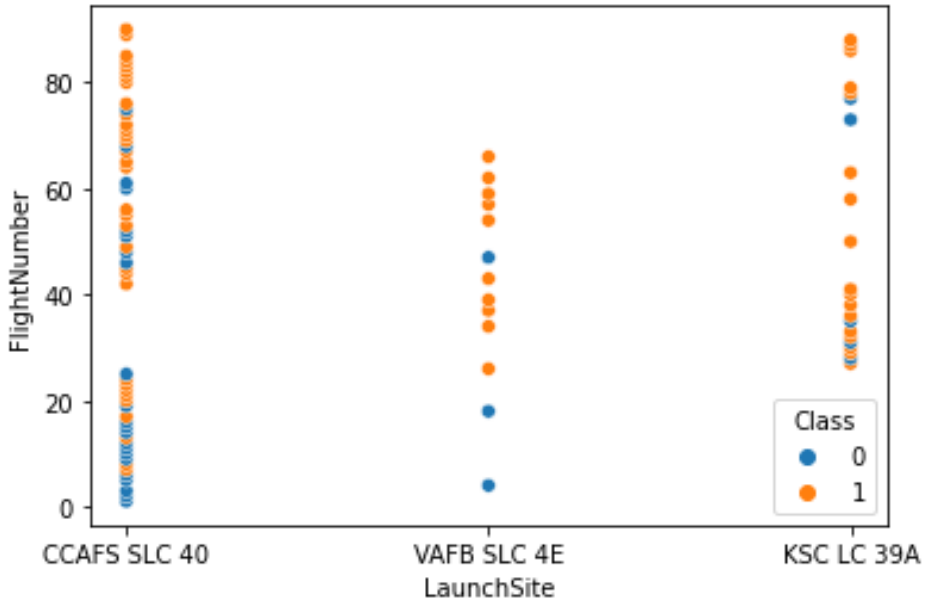


Section 2

Insights drawn from EDA

Flight Number vs. Launch Site

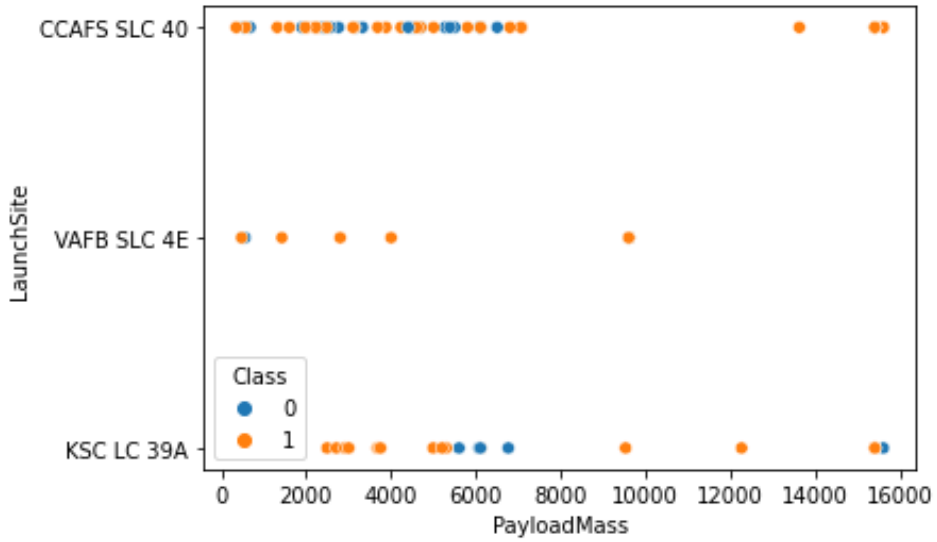
- The scatter plot shows frequency of flights is correlated with launch success.
- As flight number increases so does the success rate of launch site.



Payload vs. Launch Site

The scatter plot highlights several things;

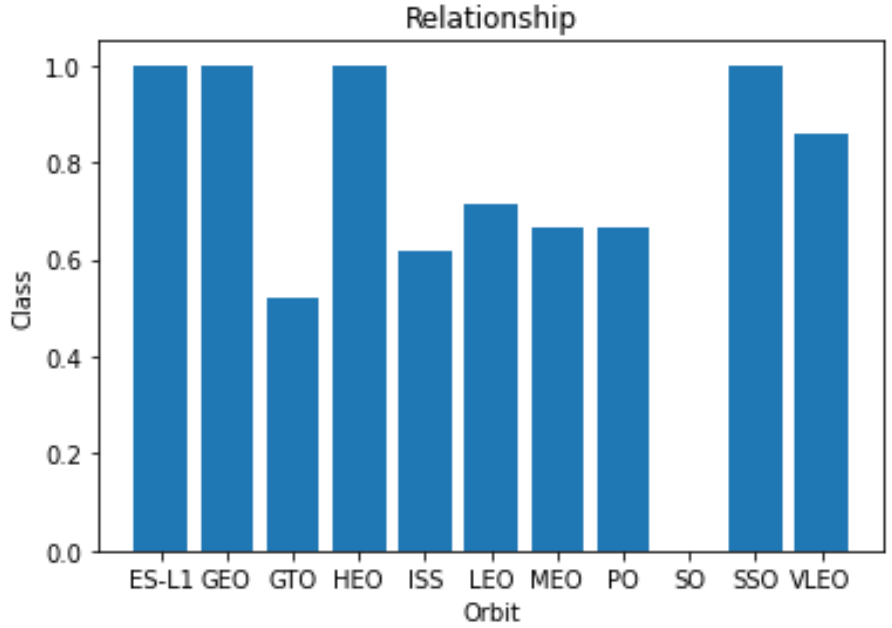
1. All three sites have launched mostly lighter rockets with successful outcome.
2. CCAFS SLC 40 have launched heavier payload rockets with successful outcomes, the site also launched the most rockets overall. This suggests number of flights leads to more successful outcome with heavier payload rockets. It suggests the more rockets they launches they gain experience in managing heavier payloads.



Success Rate vs. Orbit Type

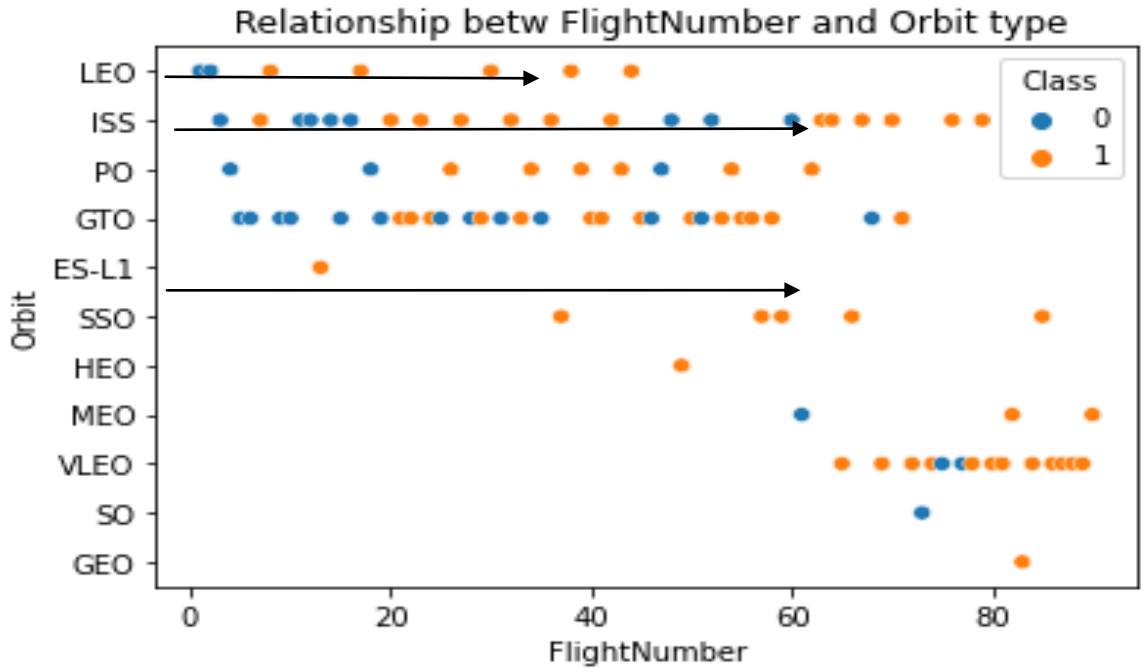
- The bar chart highlights the relationship between Class and Orbit.

- Rocket launched in ES-L1, GEO, HEO and SSO orbit demonstrate the highest success rate.



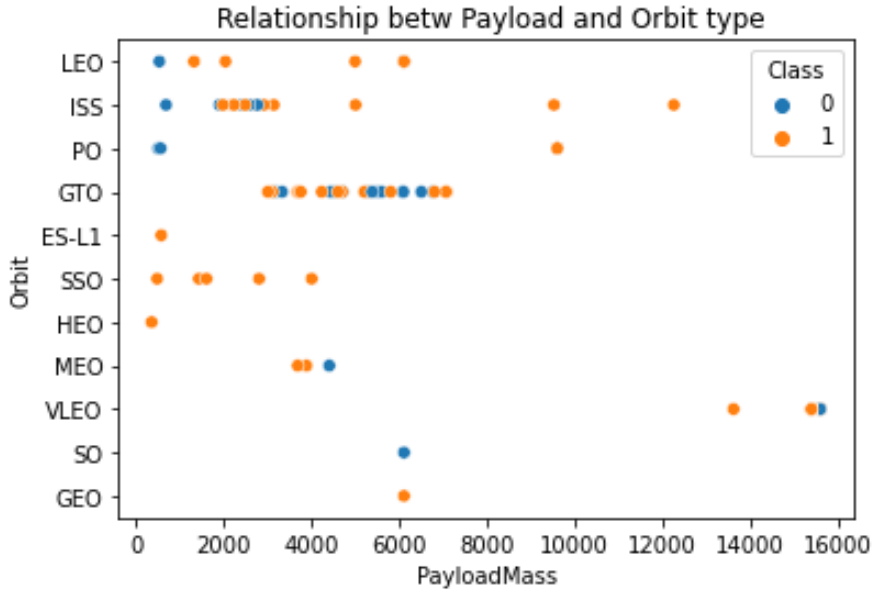
Flight Number vs. Orbit Type

- The frequency of flights is correlated with launch success. As volumes of flight increases so does the likelihood of successful launches.
- There appears to be no relationship between GTO orbit and flight number.



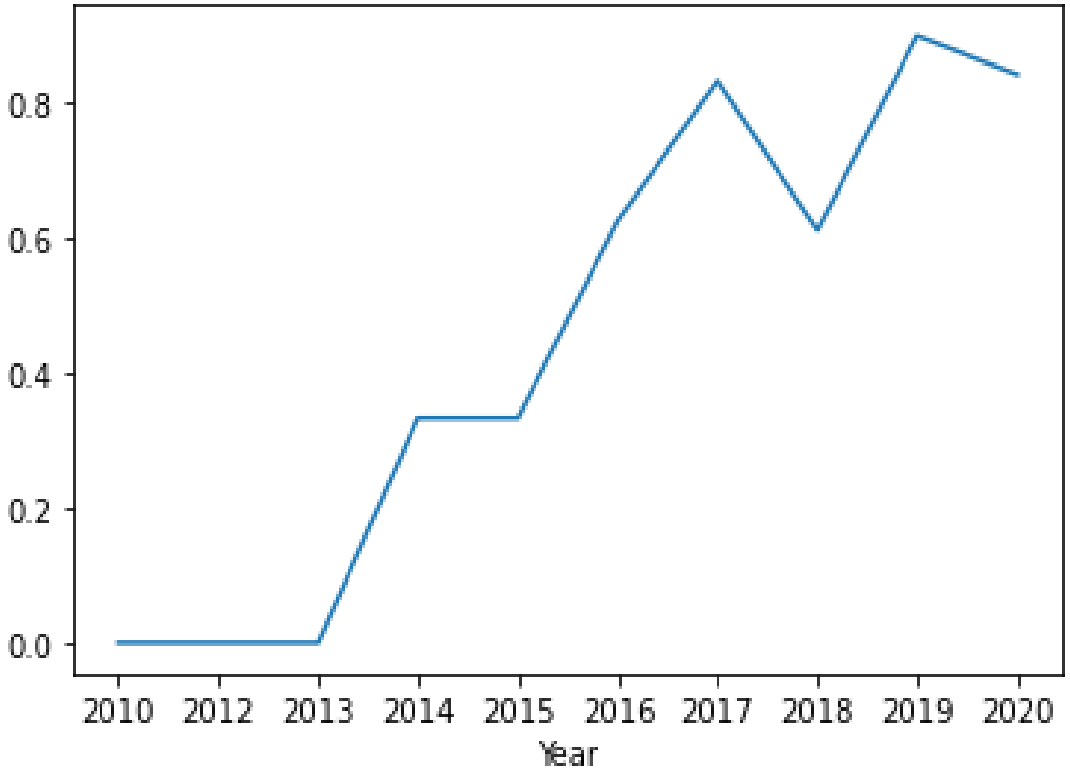
Payload vs. Orbit Type

- ISS orbit demonstrates most successful rocket launches with heavy payloads, over 8000 kg.
- Heavy payloads have a negative influence on GTO orbits.
- SSO/LEO show multiple successful launches with lighter pay



Launch Success Yearly Trend

The line chart demonstrates the increase in successful launches since 2013, which peaked in 2019. The drop in 2020 could be the effects of shut down of operations due to Covid.



EDA WITH SQL

All Launch Site Names

```
%sql SELECT DISTINCT (LAUNCH SITE) FROM SPACEDATASET
```

UNIQUE LAUNCH SITES
CCAFS LC-40
CCAFS SLC-40
KSC LC-39A
VAFB SLC-4E

The query returns only unique (‘distinct’) values from the column ‘Launch site’.

Launch Site Names Begin with 'CCA'

```
%sql SELECT * FROM SPACEDATASET WHERE LAUNCH_SITE LIKE 'CCA%' LIMIT 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

Asterics (*) returns all values from the table and ‘Like’ is an SQL operator that looks for specified pattern in a column.
‘Limit 5’ retrieves the top 5 rows of the table.

Total Payload Mass

```
%sql SELECT SUM(PAYLOAD_MASS_KG_)AS TOT_PAYLOAD_MASS FROM SPACEDATASET WHERE CUSTOMER='NASA (CRS)'
```

tot_payload_mass
45596

The ‘sum’ function returns the ‘sum’ of all payload mass kg that falls under customer ‘NASA (CRS)’

Average Payload Mass by F9 v1.1

```
%sql SELECT AVG(PAYLOAD_MASS_KG_)AS AVG_PAYLOAD_MASS FROM
SPACEDATASET WHERE BOOSTER_VERSION = 'F9 V1.1'
```

AVG_PAYLOAD_MA
2928

'AVG' function returns the average of 'payload mass kg', the 'where' function returns an average when booster version is 'F9 V1.1'

First Successful Ground Landing Date

```
%sql SELECT MIN(DATE) AS FIRST_DATE FROM SPACEDATASET WHERE
LANDING_OUTCOME LIKE 'SUCCESS (GROUND PAD)'
```

FIRST_DATE
2015-12-22

'Min' function returns the earliest date of the successful ground pad launch. The 'where' selects the specified landing outcome and 'Like' operator matches the string and retrieves the value.

Successful Drone Ship Landing with Payload between 4000 and 6000

```
%sql SELECT BOOSTER_VERSION FROM SPACEDATASET WHERE
PAYLOAD_MASS_KG_ BETWEEN 4000 AND 6000 AND
LANDING_OUTCOME LIKE 'SUCCESS (DRONE SHIP)'
```

BOOSTER_VERSION
F9 FT B1022
F9 FT B1026
F9 FT B1021.2
F9 FT B1031.2

The query selects Booster version with a 'where' clause. The 'where' clause selects payload between 4000 and 6000 and the 'like' operator retrieves only successful drone ship landing. The 'and' allows multiple conditions to be specified.

Total Number of Successful and Failure Mission Outcomes

```
%sql SELECT MISSION_OUTCOME, COUNT(MISSION_OUTCOME) AS
TOTAL_OUTCOME FROM SPACEDATASET GROUP BY
MISSION_OUTCOME ORDER BY MISSION_OUTCOME
```

TOTAL_OUTCOME	
Failure (in flight)	1
Success	99
Success (payload status unclear)	1

The query calculates the total number of failure and success as defined in mission_outcome. The ‘count’ function and ‘group by’ aggregates the values in the mission_outcome and ‘order by’ organizes it alphabetically. The default is always ascending.

Boosters Carried Maximum Payload

```
%sql SELECT BOOSTER_VERSION, PAYLOAD, PAYLOAD_MASS_KG FROM SPACEDATASET  WHERE PAYLOAD_MASS_KG_ IN (SELECT MAX(PAYLOAD_MASS_KG_) AS PAYLOAD FROM SPACEDATASET ORDER BY PAYLOAD)
```

booster_version	payload	payload_mass__kg_
F9 B5 B1048.4	Starlink 1 v1.0, SpaceX CRS-19	15600
F9 B5 B1049.4	Starlink 2 v1.0, Crew Dragon in-flight abort test	15600
F9 B5 B1051.3	Starlink 3 v1.0, Starlink 4 v1.0	15600
F9 B5 B1056.4	Starlink 4 v1.0, SpaceX CRS-20	15600
F9 B5 B1048.5	Starlink 5 v1.0, Starlink 6 v1.0	15600
F9 B5 B1051.4	Starlink 6 v1.0, Crew Dragon Demo-2	15600
F9 B5 B1049.5	Starlink 7 v1.0, Starlink 8 v1.0	15600
F9 B5 B1060.2	Starlink 11 v1.0, Starlink 12 v1.0	15600
F9 B5 B1058.3	Starlink 12 v1.0, Starlink 13 v1.0	15600
F9 B5 B1051.6	Starlink 13 v1.0, Starlink 14 v1.0	15600
F9 B5 B1060.3	Starlink 14 v1.0, GPS III-04	15600
F9 B5 B1049.7	Starlink 15 v1.0, SpaceX CRS-21	15600

- Selects Booster version, payload and payload mass kg, sub query selects max payload mass, order by organizes the payload in ascending order.

2015 Drone Ship Failure Launch Records

```
%sql SELECT LANDING_OUTCOME, BOOSTER_VERSION, LAUNCH_SITE
FROM SPACEXDATASET WHERE LANDING_OUTCOME LIKE 'FAILURE
(DRONE SHIP)' AND YEAR (DATE) = 2015
```

landing__outcome	booster_version	launch_site
Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40

The 'where' selects all failed drone ship launches and year (date) function converts the date into year.

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

```
%sql COUNT(LANDING_OUTCOME) AS COUNT, LANDING_OUTCOME FROM SPACEXDATASET WHERE LANDING_OUTCOME IN (‘SUCCESS(GROUND_PAD’, ‘FAILURE (DRONE SHIP), ‘SUCCESS (DRONE_SHIP) ”) AND DATE BETWEEN ‘2010-06-04’ AND ‘2017-03-20’ ORDER BY COUNT(LANDING_OUTCOME) DESC
```

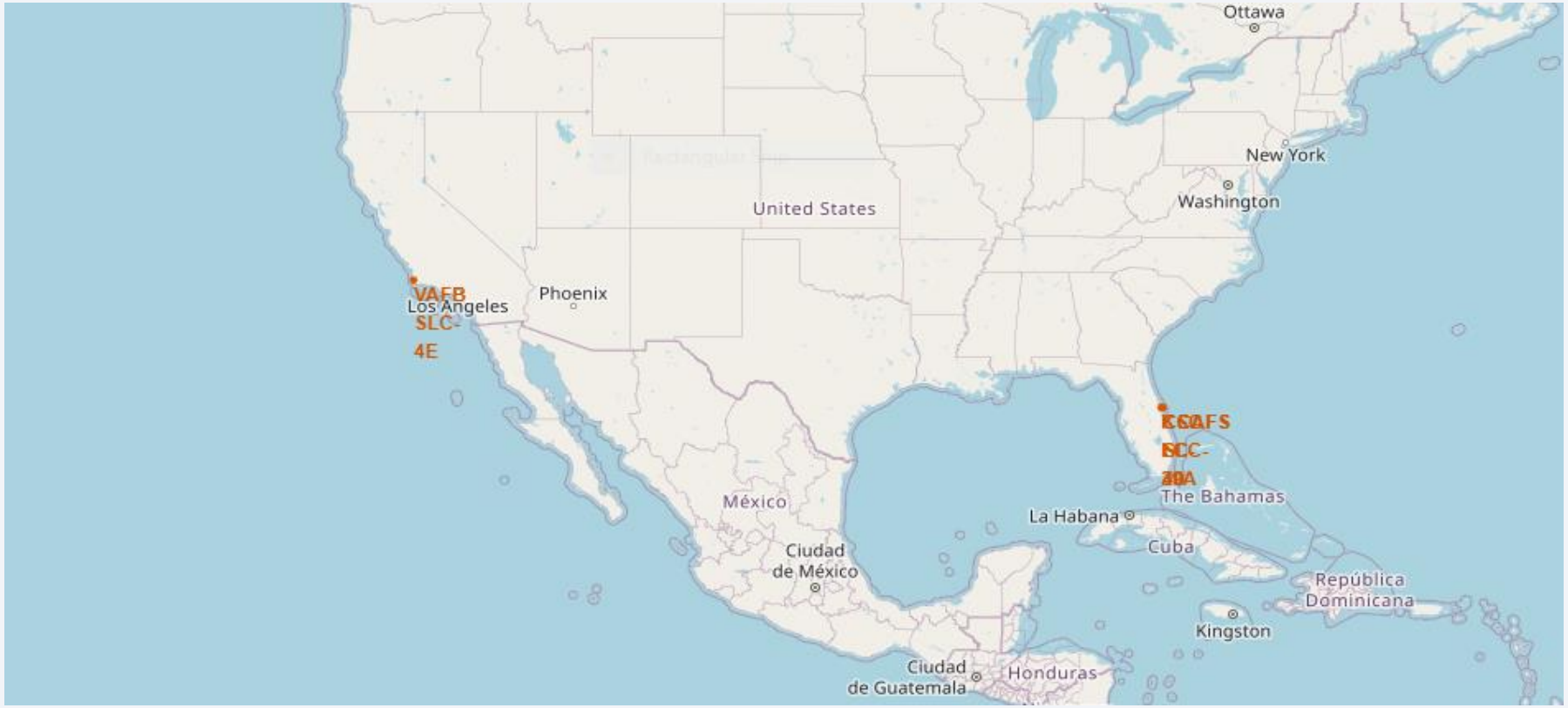
COUNT	landing__outcome
5	Failure (drone ship)
5	Success (drone ship)
3	Success (ground pad)

Count function aggregates landing outcome for the selected ones specified in the ‘where’ condition. ‘Date between’ ensures landing outcome is only aggregated for those that meet the time frame criteria. The ‘and’ allows multiple condition to be specified.

Section 4

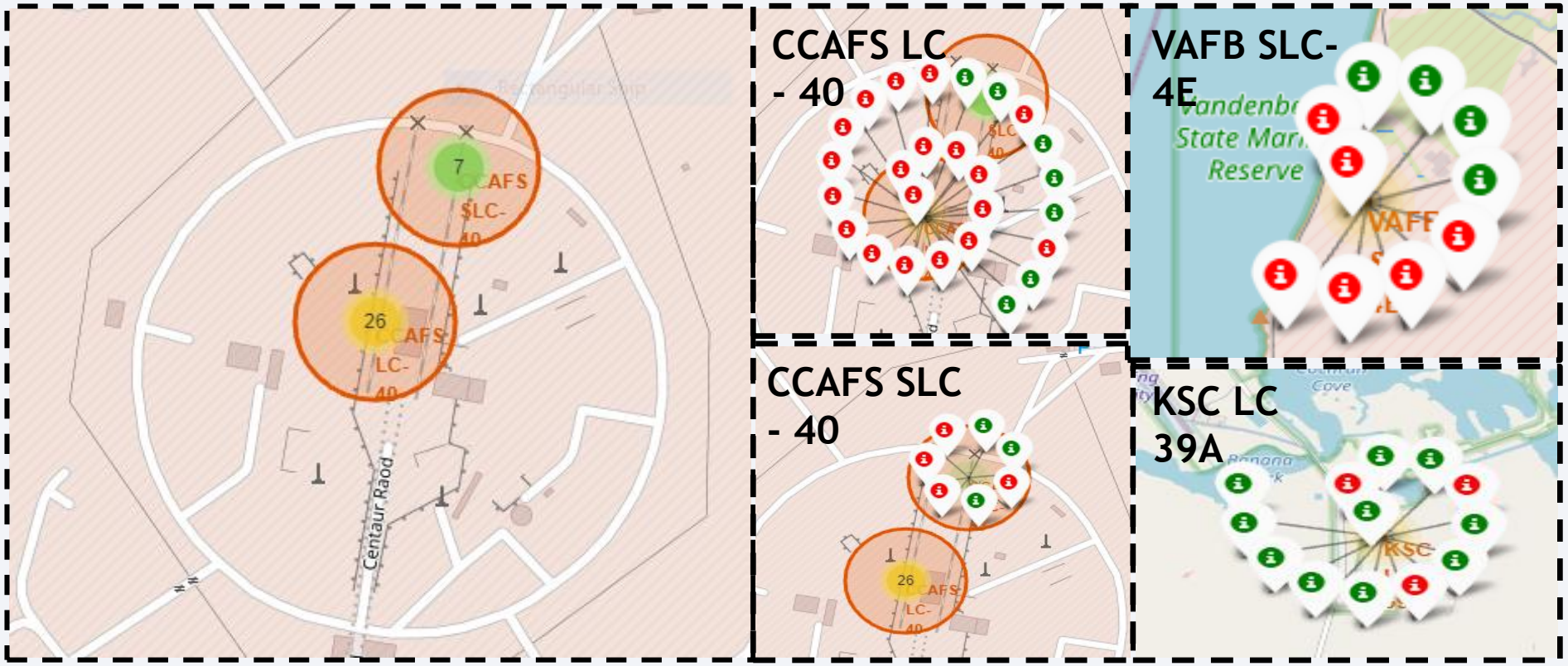
Launch Sites Proximities Analysis

Space X Launch Sites



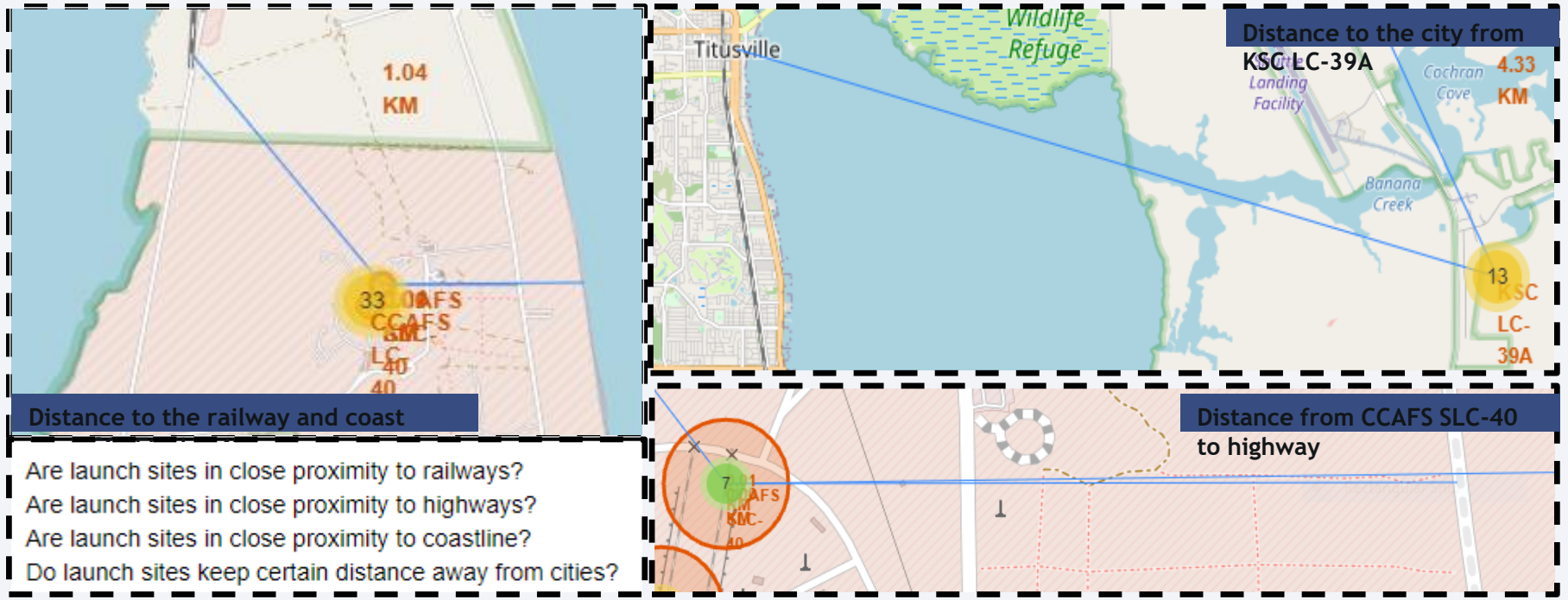
The map highlights Space X launch sites in America, distributed around the coasts of California and Florida.

Color Markers Displaying Successful/Unsuccessful Launches



The above map highlights KSC LC-39A launch site as the most successful launch site in Florida.

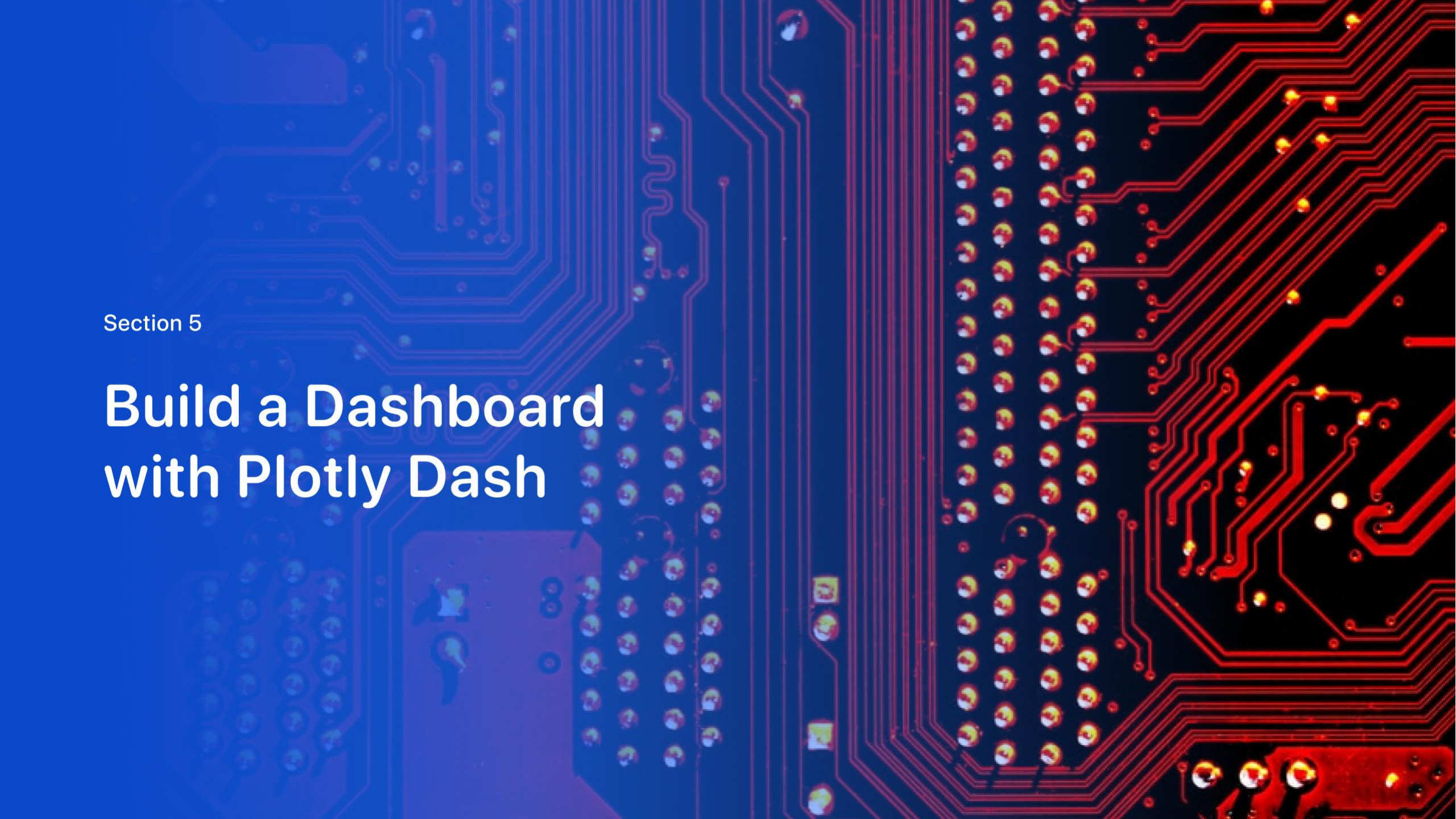
Are launch sites located near landmarks?



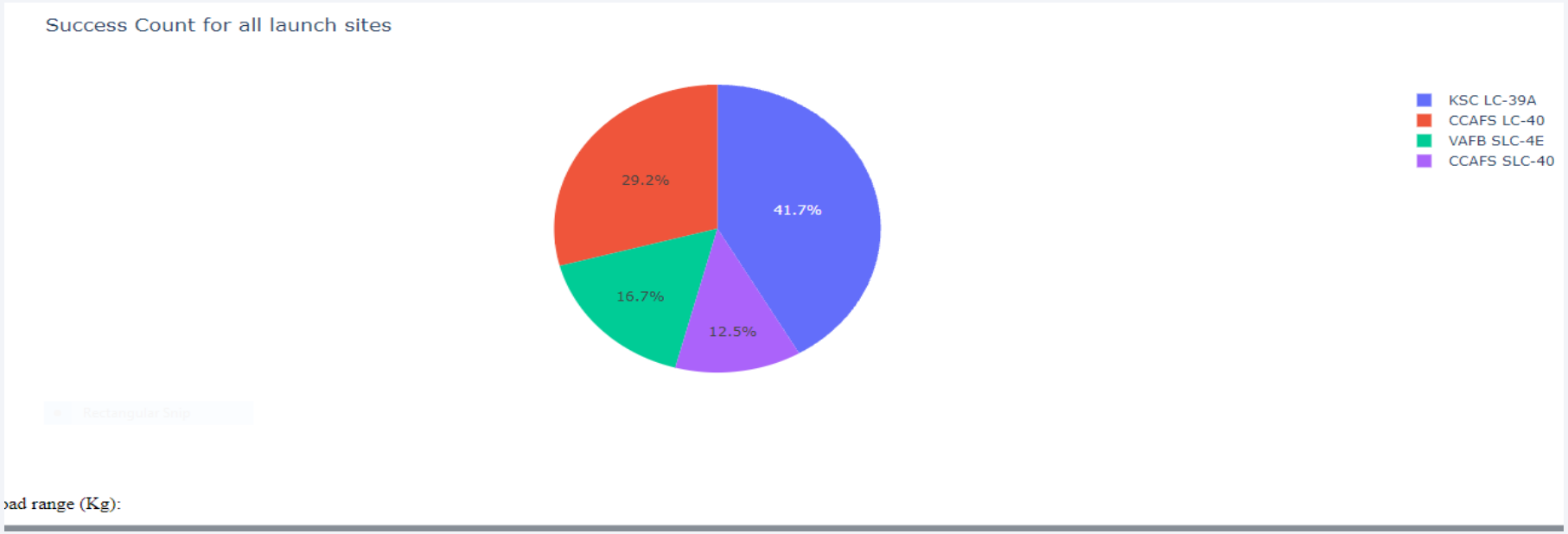
Launch sites are build in close proximity to coastline and highways as rocket launch is transported to coastline via highways.
Distance is also maintained between railway and launch sites but not with as much distance as cities.
It is also crucial for launch sites not to be in close proximity of cities as shown above.

Section 5

Build a Dashboard with Plotly Dash

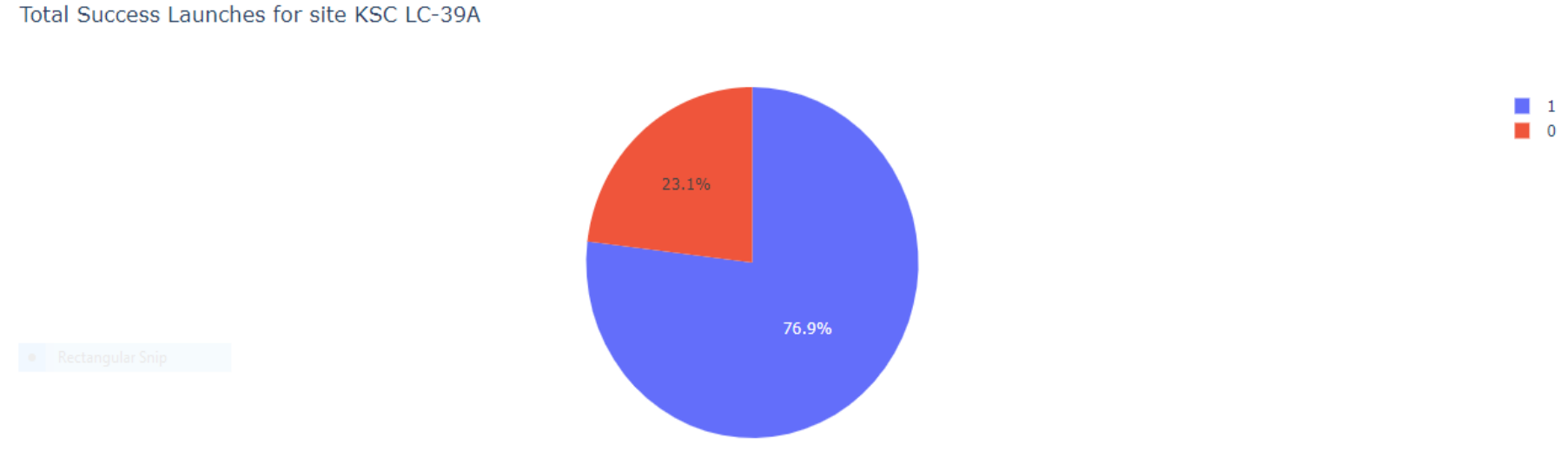


Launch Site Success



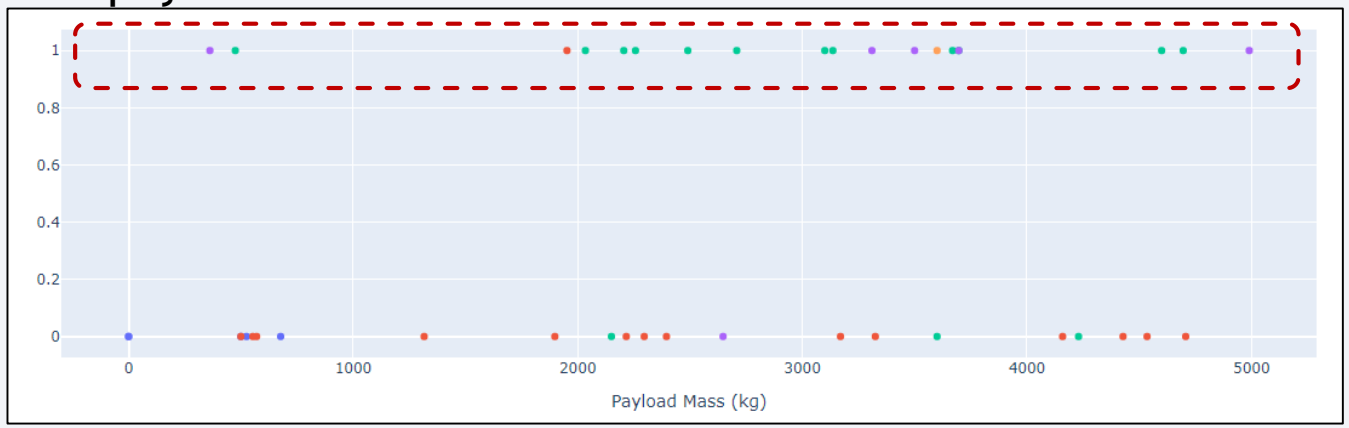
The graph shows KSC LC-39A launch sites have been most successful with its rocket launch.

77% of launches have been successful at KSC LC-39A

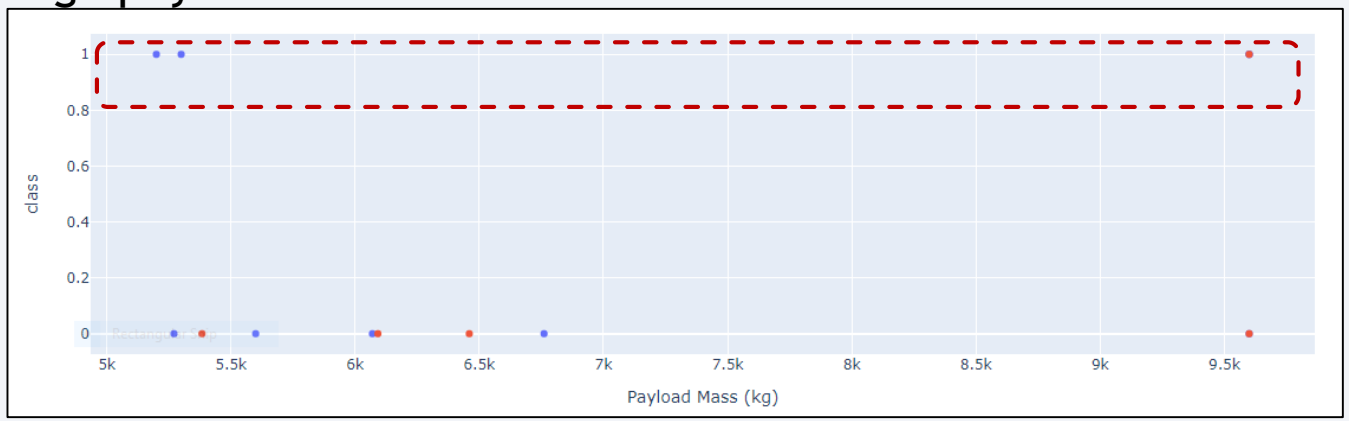


Payload Range Analysis

Low payload mass



High payload mass



The graphs demonstrate low payload launches are more successful than high load payload mass.

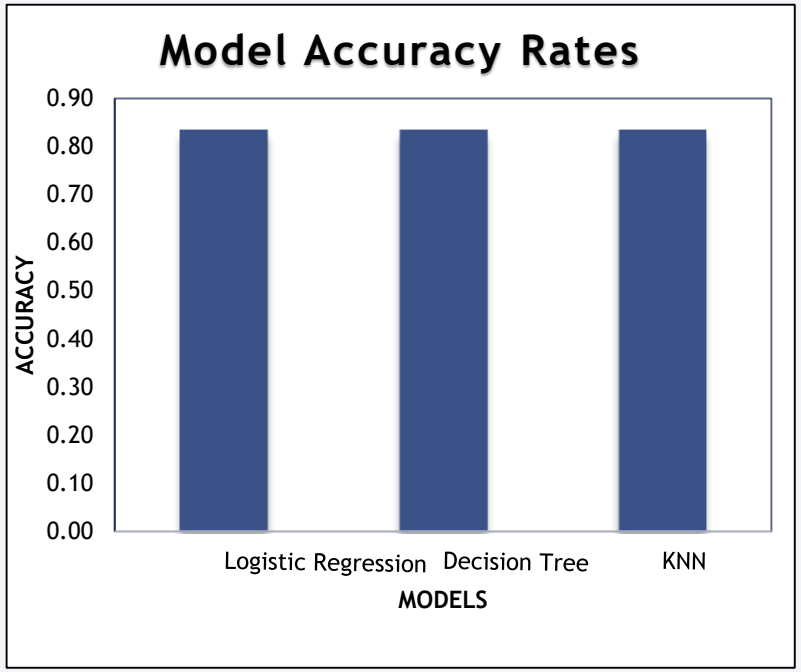
Therefore, launches with low pay load mass are more likely to be successfully launched than heavier payload rocket launches.

Section 6

Predictive Analysis (Classification)

Classification Accuracy

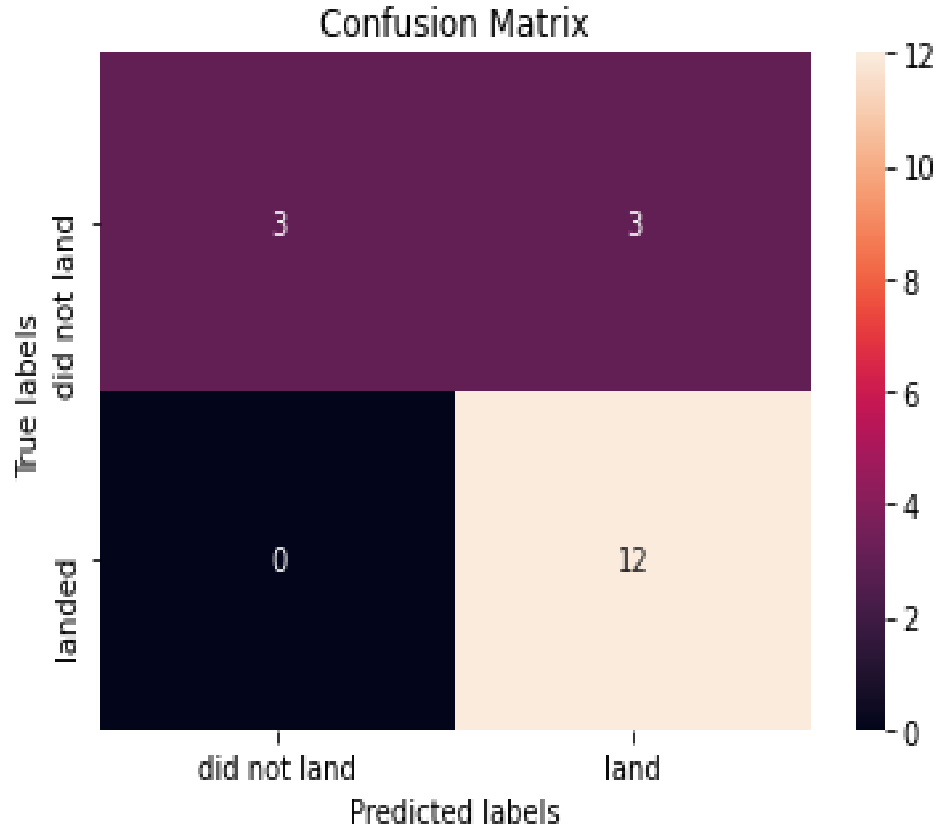
Models	Accuracy %
Logistic Regression	0.83
Decision Tree	0.83
KNN	0.83



- All the models shows the same accuracy rate.
- This could be due to small samples.
- The models show 83% accuracy rate using test data.

Selected input models: FlightNumber, Date, BoosterVersion, PayloadMass, Orbit, LaunchSite, Outcome, Flights, GridFins,Reused, Legs,LandingPad, Block,ReusedCount,Serial,Longitude, Latitude, Class

Confusion Matrix



- The confusion matrix highlight how the model has performed, it breaks down predicted values against actual values.
- We can see there is an issue of False Positive, 3 customers have been misclassified by the model as landed.
- The model has accurately predicted 12 launches that landed successfully as based on the actual data.

Conclusions

- Logistic regression is the chosen model as its easy to apply and explain across the business as all the models have same accuracy results.
- KSC LC-39A launch site has launched the most successful launches and is near a coast and highway.
- Low weighted payload rocket launches are more successful than heavier payloads.
- There is relationship between flight number and success rate, successful launch increases with number of flights.
- ISS, SSO and LEO orbits have also demonstrated higher success rate with lighter payloads.

Appendix

- Plotly dash reports python code

Plotly Dash report python code

```
max_payload = spacex_df['Payload Mass (kg)'].max()
min_payload = spacex_df['Payload Mass (kg)'].min()
app = dash.Dash(__name__)
app.layout = html.Div(children=[html.H1('SpaceX Launch Records
Dashboard',
                                style={'textAlign': 'center', 'color':
'#503D36',
                                       'font-size': 40}),
dcc.Dropdown(
id='site-dropdown',
options=[
{'label': 'All Sites', 'value': 'ALL'}, {'label': 'CCAFS LC-40', 'value': 'CCAFS
LC-40'}, {'label': 'VAFB SLC-4E', 'value': 'VAFB SLC-4E'},
{'label': 'KSC LC-39A', 'value': 'KSC LC-39A'}, {'label': 'CCAFS SLC-40',
'value': 'CCAFS SLC-40'},],
                                value='ALL',
                                placeholder="Select a Launch Site",
                                searchable=True),
html.Br(),
html.Div(dcc.Graph(id='success-pie-chart')),
html.Br(),
html.P("Payload range (Kg):"),
dcc.RangeSlider(id='payload-slider',
min=0, max=10000, step=1000,
value=[min_payload,max_payload],
marks={0: '0 kg', 2500: '2500 kg', 5000: '5000 kg', 7500: '7500 kg',
10000: '10000 kg'}),
html.Div(dcc.Graph(id='success-payload-scatter-chart')),])
@app.callback(Output(component_id='success-pie-chart',
component_property='figure'),
        Input(component_id='site-dropdown',
component_property='value'))
def get_pie(entered_site):
    filtered_df = spacex_df
    if entered_site == 'ALL':
        fig = px.pie(spacex_df, values='class', names='Launch Site',
title='Total Success Launches By Site')
        return fig
 else:
        filtered_df = spacex_df[spacex_df['Launch Site'] ==
value].groupby(['Launch Site', 'class']). \
        size().reset_index(name='class count')
        title = "Total Success Launches for site {value}"
        fig = px.pie(filtered_df,values='class count', names='class',
title=title)
        return fig
html.P("Payload Range (Kg):"),
html.Div(dcc.Graph(id='success-payload-scatter-chart')),
@app.callback(Output(component_id='success-payload-scatter-
chart', component_property='figure'),
        [Input(component_id='site-dropdown',
component_property='value'),
        Input(component_id='payload-slider',
component_property='value')]
        )
def get_scatter(value1,value2):
    filtered_df2_1=spacex_df[(spacex_df['Payload Mass (kg)'] >
value2[0]) & (spacex_df['Payload Mass (kg)'] < value2[1])]
    if value1=='ALL':
        fig= px.scatter(filtered_df2_1,x="Payload Mass
(kg)",y="class",color="Booster Version Category",\
        title="Correlation between Payload and Success for All
sites")
        return fig
    else:
        filtered_df2_2=filtered_df2_1[filtered_df2_1['Launch
Site']==value1]
        fig= px.scatter(filtered_df2_2,x="Payload Mass
(kg)",y="class",color="Booster Version Category",\
        title="Correlation between Payload and Success for site
{value1}")
        return fig
# Run the app
if __name__ == '__main__':
    app.run_server()
```

Thank you!