PREDICTION OF FALCON-9 LANDING

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Outline

- Executive Summary
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- Methodology
- Results
- Conclusion
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Executive Summary

In this project, we present data collected from SpaceX and Wikipedia.

We explored the data using Exploratory Data Analysis EDA using Python and SQL.

Visualisation maps (Folium) and Dashboards were also generated to show relevant information as regards successful landings.

Machine Learning models (Logistic Regression, Support Vector Machine, Decision Tree Classifier and K Nearest Neighbours) were also deployed to model the dataset.

Table of Contents

Introduction

- The launching of a SpaceX Falcon 9 rockets cost approx. $62m
- This is way cheaper compared to other providers (Cost approx. $165m)
- The difference is price is because SpaceX rockets can land, and be re-used again.
- If we can determine if the first stage will land, we can determine the cost of the launch.
- This information will guide us if our new company Space Y should compete in the Space travel sector

SpaceX Falcon 9 Rocket – The Verge

Methodology

Methodology

- **Data Collection**
  - Using GET requests from SpaceX REST API
  - Web scraping from Wikipedia's page
- **Data Wrangling and Manipulation**
  - Removing NaN values with the .fillna() method
  - Calculating number of launches and missions using the .value_counts() method
- **Exploratory Data Analysis (EDA)**
  - Using SQL, Python Libraries (Pandas, Matplotlib) to visualise data and explore realtionships
- **Interactive Data Analysis**
  - Generating geospatial analysis using Folium and interactive dashboards using Plotly Dash
- **Data Modelling and Evaluation**

  Preprocessing and Different algorithms are applied to find the best. Using sklearn

Data Collection (SPACEX REST API)

Step 1

Make GET requests from SpaceX REST API

```
spacex_url="https://api.spacexdata.com/v4/launches/past"
```

```
response = requests.get(spacex_url)
```

Convert the response to a .json file and use pandas to generate the data frame.

```
# Use json_normalize meethod to convert the json result into a dataframe
response= requests.get(static_json_url).json()
data = pd.json_normalize(response)
```

Step 2

Clean Data

```
# We also want to convert the date_utc to a datetime datatype and then ext
racting the date leaving the time
data['date'] = pd.to_datetime(data['date_utc']).dt.date

# Using the date we will restrict the dates of the launches
data = data[data['date'] <= datetime.date(2020, 11, 13)]
```

Create Lists

Call Functions

Convert the response to a .json file

```
#Global variables
BoosterVersion = []
PayloadMass = []
Orbit = []
LaunchSite = []
Outcome = []
Flights = []
GridFins = []
Reused = []
Legs = []
LandingPad = []
Block = []
ReusedCount = []
Serial = []
Longitude = []
Latitude = []
```

Step 3

Create Pandas Dataframe

```
# Create a data from launch_dict

data2 = pd.DataFrame(launch_dict)
```

Step 4

Filter Data in the dataframe, Replace missing values

```
# Calculate the mean value of PayloadMass column
mean_pay=data_falcon9['PayloadMass'].mean()
# Replace the np.nan values with its mean value
data_falcon9['PayloadMass'].replace(np.nan,mean_pay,inplace=True)

data_falcon9.isnull().sum()
```

Data Collection (WEB SCRAPING)

Step 1

Request HTML page

```
static_url = "https://en.wikipedia.org/w/index.php?title=List_of_Falcon_9_and_Falcon_Heavy_launches&oldid=1027686922"
```

Assign response to an object

```
# use requests.get() method with the provided static_url
response = requests.get(static_url)
# assign the response to a object
response=response.text
```

Step 2

Create BeautifulSoup object

```
soup = BeautifulSoup(page.text, 'html.parser')
```

Find all the table in the HTML Page

```
html_tables=soup.find_all('table')
```

Step 3

Extract Column Names from tables in HTML Page

```
column_names = []
temp = soup.find_all('th')

for i in range(len(temp)):
    try:
        name = extract_column_from_header(temp[i])
        if name is not None and len(name)>0:
            column_names.append(name)
    except:
        pass
```

Step 4

Use column names as keys in dictionaries
Convert to Pandas

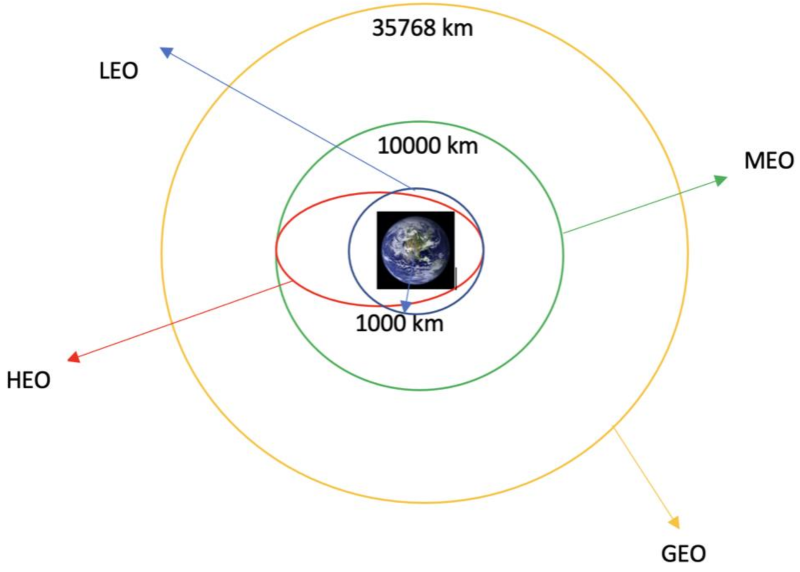
```
launch_dict= dict.fromkeys(column_names)

# Remove an irrelvant column
del launch_dict['Date and time ( )']

# Let's initial the launch_dict with each
launch_dict['Flight No.'] = []
launch_dict['Launch site'] = []
launch_dict['Payload'] = []
launch_dict['Payload mass'] = []
launch_dict['Orbit'] = []
launch_dict['Customer'] = []
launch_dict['Launch outcome'] = []
# Added some new columns
launch_dict['Version Booster']=[]
launch_dict['Booster landing']=[]
launch_dict['Date']=[]
launch_dict['Time']=[]
```

Data Wrangling and Manipulation

- The dataset contains several SpaceX launch facilities and each location is in the LaunchSite column.




```
# Apply value_counts() on column LaunchSite

df["LaunchSite"].value_counts()
```

```
CCAFS SLC 40    55
KSC LC 39A      22
VAFB SLC 4E     13
Name: LaunchSite, dtype: int64
```

- <u>Initial Data Exploration:</u>

[No of Launches, Occurrence of eachOrbit, Landing outcome per orbit]

```
# Apply value_counts on Orbit column

df["Orbit"].value_counts()
```

```
GTO      27
ISS      21
VLEO     14
PO        9
LEO       7
SSO       5
MEO       3
ES-L1     1
HEO       1
SO        1
GEO       1
Name: Orbit, dtype: int64
```

```
# landing_outcomes = values on Outcome column

landing_outcomes = df["Outcome"].value_counts()
landing_outcomes
```

```
True ASDS      41
None None      19
True RTLS      14
False ASDS      6
True Ocean      5
False Ocean     2
None ASDS       2
False RTLS      1
Name: Outcome, dtype: int64
```

Data Wrangling and Manipulation

- Displaying the Landing Outcome Columns

```
# landing_outcomes = values on Outcome column

landing_outcomes = df["Outcome"].value_counts()
landing_outcomes
```

```
True ASDS      41
None None      19
True RTLS      14
False ASDS      6
True Ocean      5
False Ocean     2
None ASDS       2
False RTLS      1
Name: Outcome, dtype: int64
```

- Creating a list [landing_class] to check if the booster would land successfully or not.

```
# landing_class = 0 if bad_outcome
# landing_class = 1 otherwise
landing_class = []

list_outcome = list(df['Outcome'])
list_outcome
for out in list_outcome:
    if out in bad_outcomes:
        landing_class.append(0)
    else : landing_class.append(1)
landing_class
```

Exploratory Data Analysis [EDA] with Data Visualisation

- Exploratory Data Analysis was performed on certain variables and displayed using various tools

SCATTER PLOTS

- Flight Number vs Launch Site
- Payload vs Launch Site
- Orbit Type vs Flight Number
- Payload vs Orbit Type

BAR CHARTS

- Success Rate vs Orbit Type

LINE CHARTS

- Success Rate vs Year

**This analysis were used to compare relationships between different variables in the dataset

Exploratory Data Analysis [EDA] with SQL

- Loading the Dataset using the IBM DB2 Database
- Query the Data using Python
- Performed different queries (10) to understand the dataset better
- Queries included [Displaying: names of unique launch sites, average payload mass carried by booster version etc……]

Interactive Visual Analysis [IVA]

FOLIUM

- Visualising the Data on Folium was done in the following steps
  - Marking all the launch sites on a map
  - Marking successful and unsuccessful landing on the map
  - Calculating distance from launch sites to key locations
  - (E.g. Railway, Highway and City)

Interactive Dashboard

PLOTLY DASH

- Creating an interactive dashboard with Pie charts and Scatter Plots/Graphs
- Pie chart
  - Used to show distribution of successful launches across all launch sites
  - Shows success/failure ratio for each individual site
- Scatter plot
  - Shows us how success varies across different launch sites, payload mass and booster version

Predictive Analysis [Classification]

Model Development

Steps for model development:

- Loading dataset
- Performing necessary data transformations (standardise and pre-process)
- Split data into training and test data sets, using train_test_split()
- Decide which type of machine learning algorithms are most appropriate
- Creating a GridSearchCV (Logreg, SVM, Decision Tree and KNN Model)
- Fitting the object to the parameters
- Using the training data set to train the model

Model Evaluation

- Plotting and examining the Confusion matrix
- Checking accuracy
- Checking tuned hyperparameters

Best Fit Classification

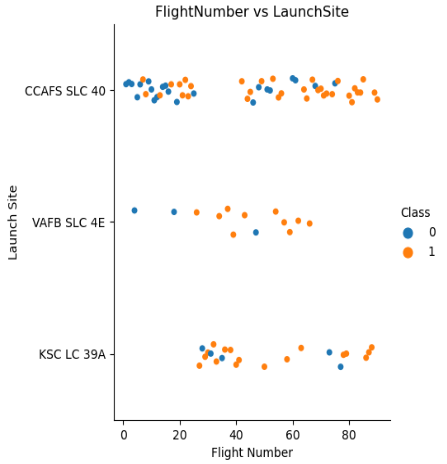
- Review Accuracy Score
- Check which accuracy score is the highest to determine the best performing model

Results and Discussion

- **Exploratory Data Analysis**
- **Interactive Analysis**
- **Predictive Analysis**

Exploratory Data Analysis with Visualization

Launch Site vs Flight Number

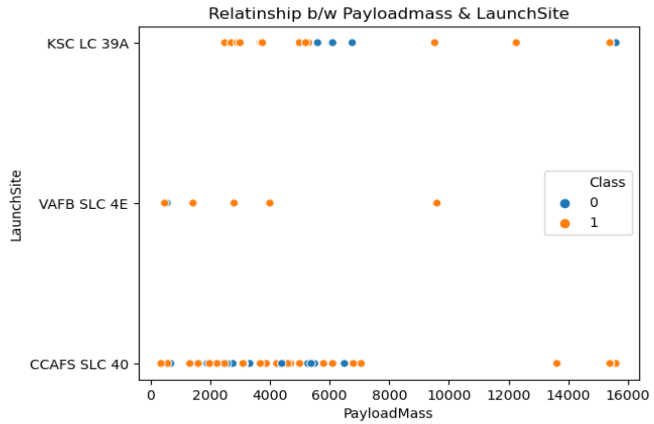


The scatter plot of Launch Site vs. Flight Number shows that:

- Most of the early flights that were launched from CCAFS SLC 40 were generally unsuccessful.
- Flights launched from KSC LC 39A were successful.

Exploratory Data Analysis with Visualization

Payload Mass vs Launch Site



The scatter plot of Payload mass vs Launch Site shows that:

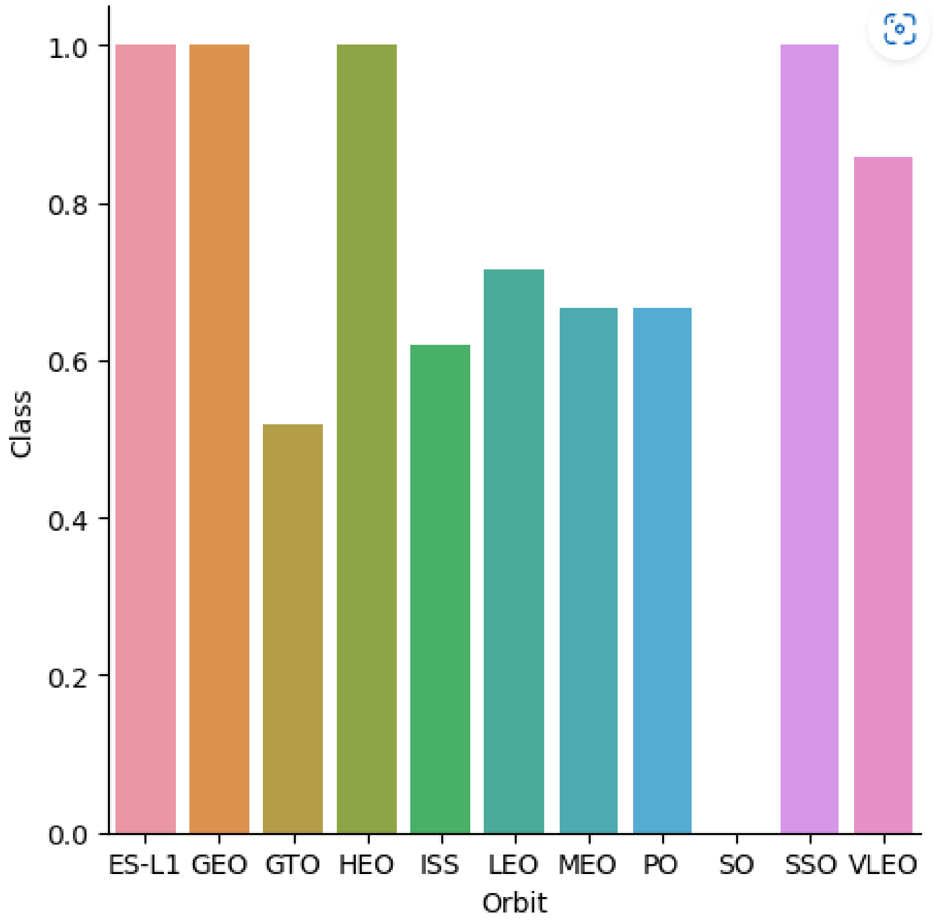
- Payload mass above 7000 kg have some successful landing, but little data for this launches
- There is no correlation between payload mass and success rate for launch sites

Exploratory Data Analysis with Visualization

Success rate of each orbit type

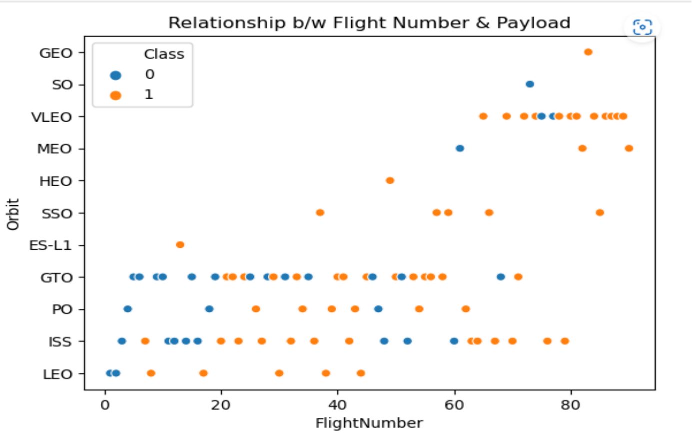
- Orbits with 100% success rate
  ES-L1 (Earth-Sun First Lagrangian Point),
  GEO (Geostationary Orbit),
  HEO (High Earth Orbit),
  SSO (Sun-synchronous Orbit)

- Orbits with 0% success rate
  SO (Heliocentric Orbit)



Exploratory Data Analysis with Visualization

Orbit Type vs Flight Number

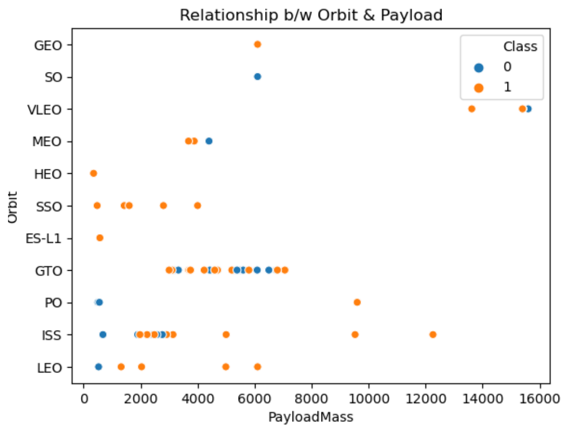


The scatter plot of Orbit Type vs Flight Number shows that:

- The 100% success rate of GEO, HEO, and ES-L1 orbits can be explained by only having 1 flight into the respective orbits.
- Success rate in SSO is more impressive, with 5 successful flights.

Exploratory Data Analysis with Visualization

Orbit Type vs Payload Mass



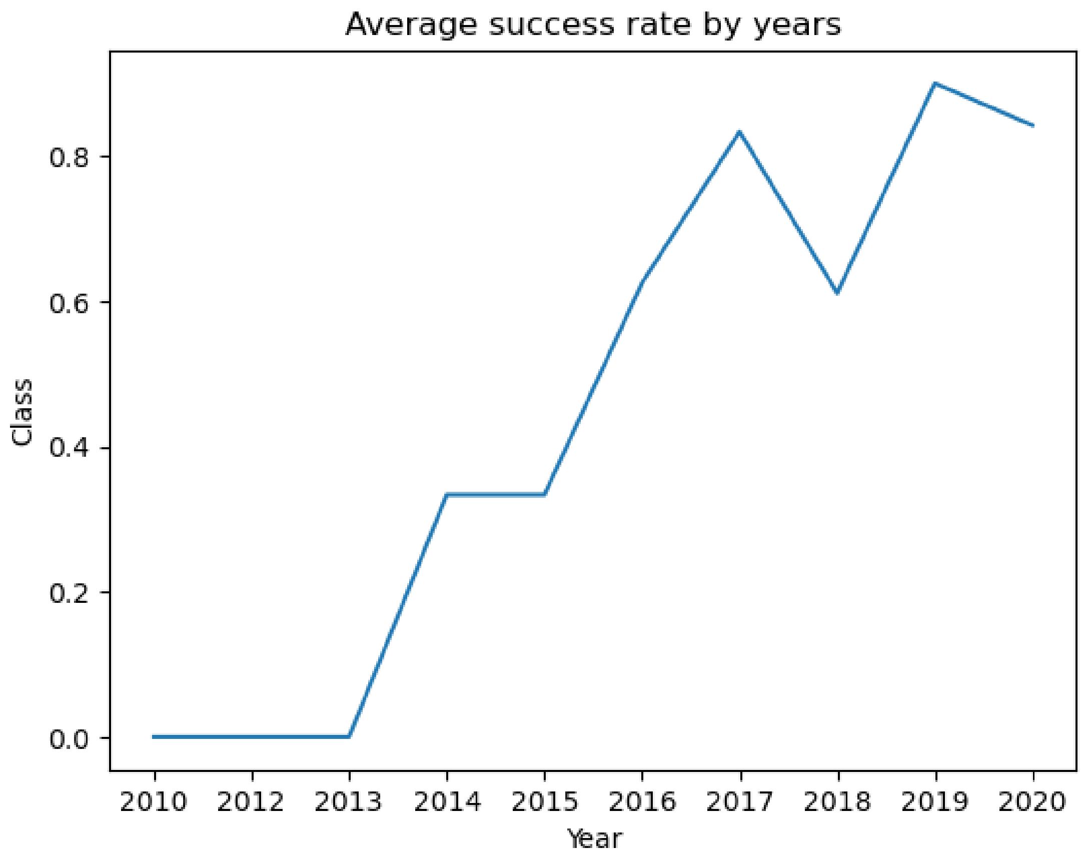
The scatter plot of Orbit Type vs Payload Mass shows that:

- Relationship between payload mass and success rate in GTO is unclear.
- VLEO (Very Low Earth Orbit) launches are associated with heavier payloads.

Exploratory Data Analysis with Visualization

Launch Success Yearly Trend

- Between 2010 – 2013, all landings were unsuccessful
- After 2013, success rate for launches increased (minor dips in 2018 and 2020)



Exploratory Data Analysis with SQL

All Launch Name Sites

Find the names of the unique sites.

```
%%sql
SELECT DISTINCT (Launch_Site) AS UNIQUE_LAUNCH_SITES FROM SPACEXTBL;
```

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

**The word UNIQUE returns only unique values from the LAUNCH_SITE column of the SPACEXTBL table.

Exploratory Data Analysis with SQL

Launch Sites with names beginning with 'CCA'

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

```
%%sql
SELECT * FROM SPACEXTBL WHERE Launch_Site LIKE 'CCA%' LIMIT 5;
```

```
 * ibm_db_sa://gvz61100:***@55fbc997-9266-4331-afd3-888b05e734c0.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31929/BLUDB
Done.
```

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

**<u>LIMIT 5</u> fetches only 5 records, and the <u>LIKE</u> keyword is used with the wild card <u>'CCA%'</u> to retrieve string values beginning with 'CCA'.

Exploratory Data Analysis with SQL

Total payload mass carried by Boosters from NASA

```
%%sql
SELECT  SUM(PAYLOAD_MASS__KG_) AS Total_mass_carried FROM SPACEXTBL WHERE Customer ='NASA (CRS)';
```

```
 * ibm_db_sa://gvz61100:***@55fbc997-9266-4331-afd3-888b05e734c0.bs2io90l08kqb1od8lcg.databases.app
Done.
```

total_mass_carried
45596

**The SUM keyword is used to calculate the total of the payloadmass_column, and the SUM keyword (and the associated condition) filters the results to only boosters from NASA (CRS).

Average Payload Mass Carried by Booster Version F9 v1.1

```
%%sql
SELECT AVG(PAYLOAD_MASS__KG_) AS Average_Payload FROM SPACEXTBL WHERE Booster_Version ='F9 v1.1';
```

```
 * ibm_db_sa://gvz61100:***@55fbc997-9266-4331-afd3-888b05e734c0.bs2io90l08kqb1od8lcg.databases.appdomain.
Done.
```

average_payload
2928

*The AVG keyword is used to calculate the average of the PAYLOAD_MASS__KG_ column, and the WHERE keyword (and the associated condition) filters the results to only the F9 v1.1 booster version.

Exploratory Data Analysis with SQL

First Successful Landing Date

```
%%sql
SELECT date FROM spacex
WHERE landing__outcome='Success (ground pad)'
ORDER BY date ASC
LIMIT 1
```

```
 * ibm_db_sa://gvz61100:***@55fbc997-9266-4331-afd3
Done.
```

DATE
2015-12-22

*The first date, and the WHERE keyword (and the associated condition) filters the results to only the successful ground pad landings.

Exploratory Data Analysis with SQL

Names of Boosters with Success in Drone Ship and Payload Mass > 4000 and < 6000.

```
%%sql
SELECT Booster_Version FROM SPACEXTBL WHERE landing__outcome = 'Success (drone ship)'
AND (PAYLOAD_MASS__KG_ BETWEEN 4000 AND 6000);
```

```
 * ibm_db_sa://gvz61100:***@55fbc997-9266-4331-afd3-888b05e734c0.bs2io90108kqb1od8lcg.data
Done.
```

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

**The WHERE keyword is used to filter the results to include only those that satisfy both conditions in the brackets (as the AND keyword is also used). The BETWEEN keyword allows for 4000 < x < 6000 values to be selected.

Exploratory Data Analysis with SQL

Total Number of Successful and Failure Missions

```
%%sql
SELECT Mission_Outcome,COUNT(Mission_Outcome) AS COUNT_MISSION_OUTCOME FROM SPACEXTBL GROUP BY Mission_Outcome;
```

```
 * ibm_db_sa://gvz61100:***@55fbc997-9266-4331-afd3-888b05e734c0.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31929
Done.
```

mission_outcome	count_mission_outcome
Failure (in flight)	1
Success	99
Success (payload status unclear)	1

**The <u>COUNT</u> keyword is used to calculate the total number of mission outcomes, and the <u>GROUPBY</u> keyword is also used to group these results by the type of mission outcome.

Exploratory Data Analysis with SQL

Names of Booster_Versions that have carried Maximum Payload Mass

```
%%sql
SELECT DISTINCT(Booster_Version) FROM SPACEXTBL WHERE PAYLOAD_MASS__KG_ = (SELECT MAX(PAYLOAD_MASS__KG_) FROM SPACEXTBL);
```

booster_version
F9 B5 B1048.4
F9 B5 B1048.5
F9 B5 B1049.4
F9 B5 B1049.5
F9 B5 B1049.7
F9 B5 B1051.3
F9 B5 B1051.4
F9 B5 B1051.6
F9 B5 B1056.4
F9 B5 B1058.3
F9 B5 B1060.2
F9 B5 B1060.3

**The <u>SELECT</u> statement within the brackets finds the maximum payload, and this value is used in the <u>WHERE</u> condition. The DISTINCT keyword is then used to retrieve only distinct /unique booster versions.

Exploratory Data Analysis with SQL

Failed Landing Outcomes in Drone Ship for 2015

```
%%sql
SELECT MONTHNAME(Date) AS MONTH ,landing__outcome,Booster_Version,launch_site FROM SPACEXTBL
WHERE landing__outcome like 'Failure (drone ship)'
AND
YEAR(Date) =2015;
```

```
 * ibm_db_sa://gvz61100:***@55fbc997-9266-4331-afd3-888b05e734c0.bs2io90l08kqb1od8lcg.databases.appd
Done.
```

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

**The WHERE keyword is used to filter the results for only failed landing outcomes, AND only for the year of 2015.

Exploratory Data Analysis with SQL

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

```
%%sql
select landing__outcome, count(landing__outcome) as count from SPACEXTBL
where landing__outcome like 'Success%' AND (Date >= '2010-06-04' AND Date <= '2017-03-20')
GROUP by landing__outcome ORDER BY count Desc
```

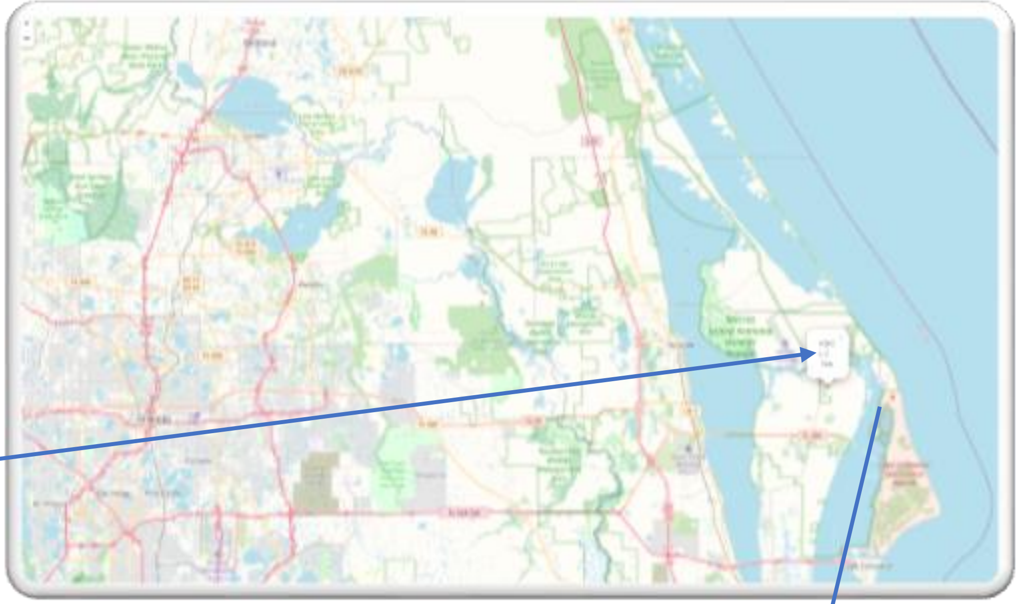
```
 * ibm_db_sa://gvz61100:***@55fbc997-9266-4331-afd3-888b05e734c0.bs2io90l08kqb1od8lcg.databases.
Done.
```

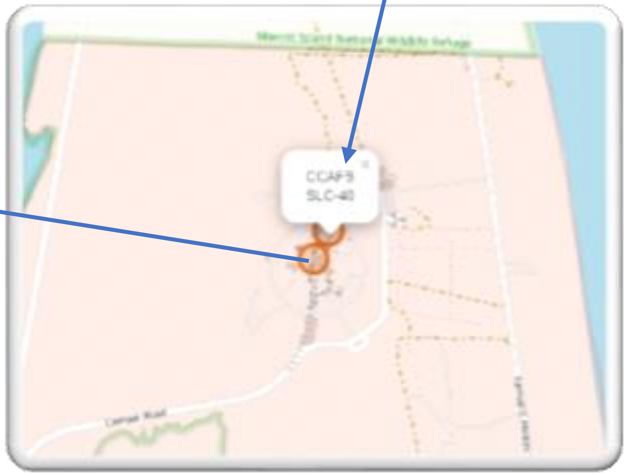
landing__outcome	COUNT
Success (drone ship)	5
Success (ground pad)	3

**The WHERE keyword is used with the BETWEEN keyword to filter the results to dates only within those specified. The results are then grouped and ordered, using the keywords GROUP BY and ORDER BY, respectively, where DESC is used to specify the descending order.

Interactive Analysis with FOLIUM

Launch Site Locations

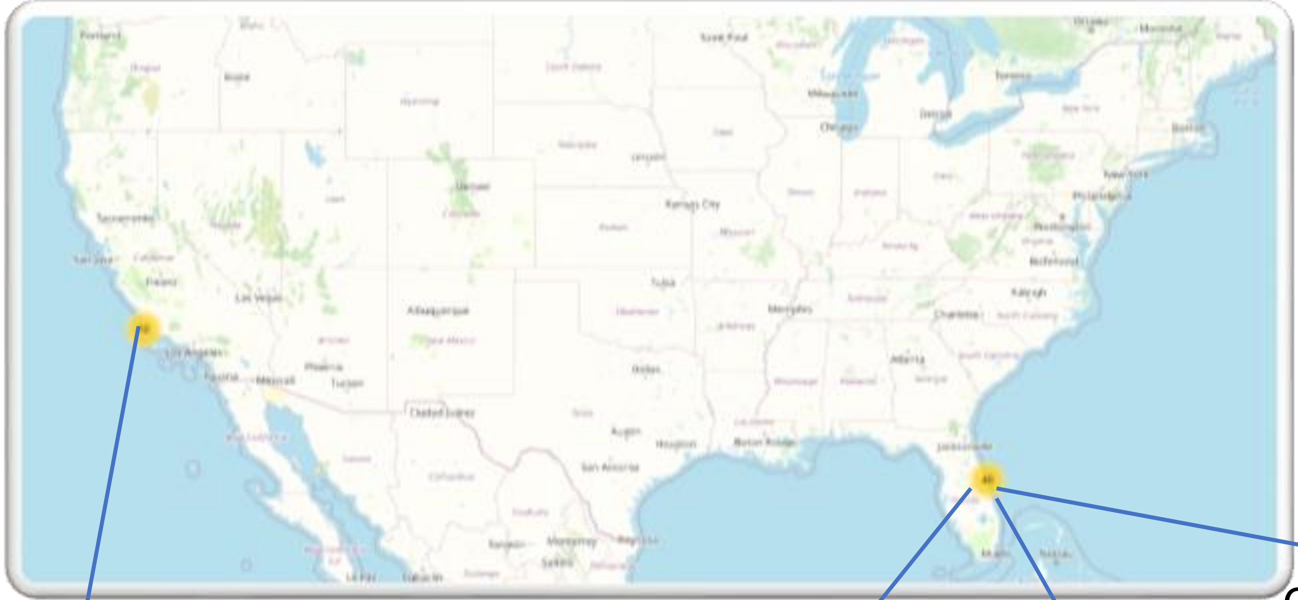




SpaceX launch sites are on coasts of the United States of America, specifically Florida and California.

Interactive Analysis with FOLIUM

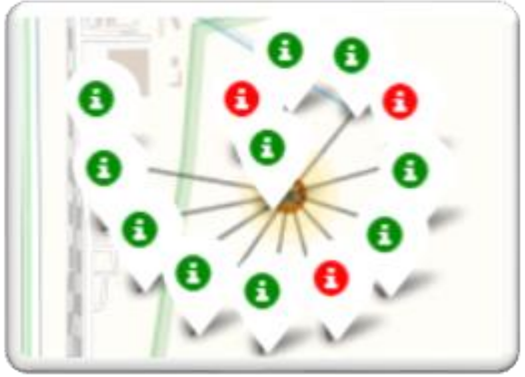
Success and Failed Launches For Each Site



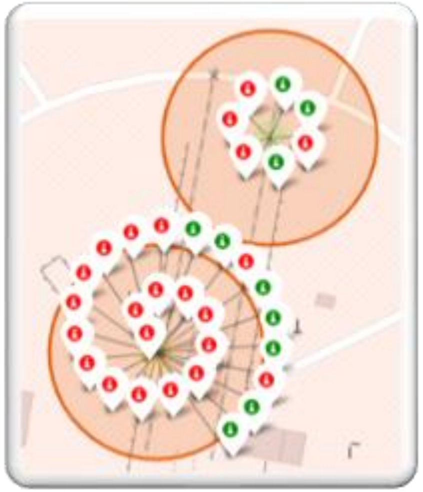
Launches have been grouped into clusters, green icons for successful launches, and red icons for failed launches.

VAFB SLC-4E

KSC LC-39A

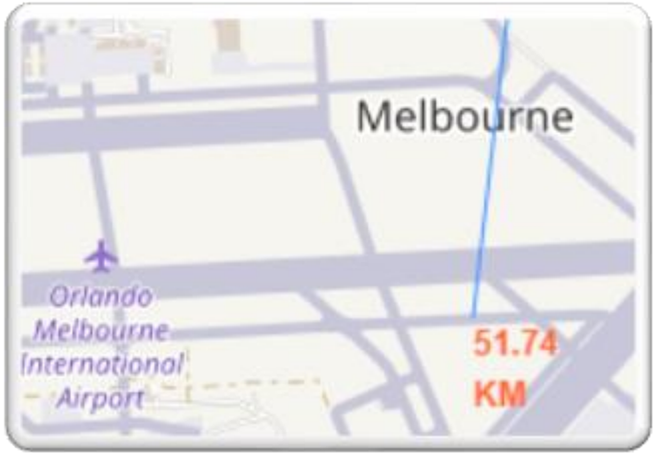


CCAFS SLC-40 and CCAFS LC-40



Interactive Analysis with FOLIUM

Location Proximities of Launch Sites to Key Locations



- Launch sites in close proximity to railways? YES.
- Launch sites in close proximity to highways? YES.

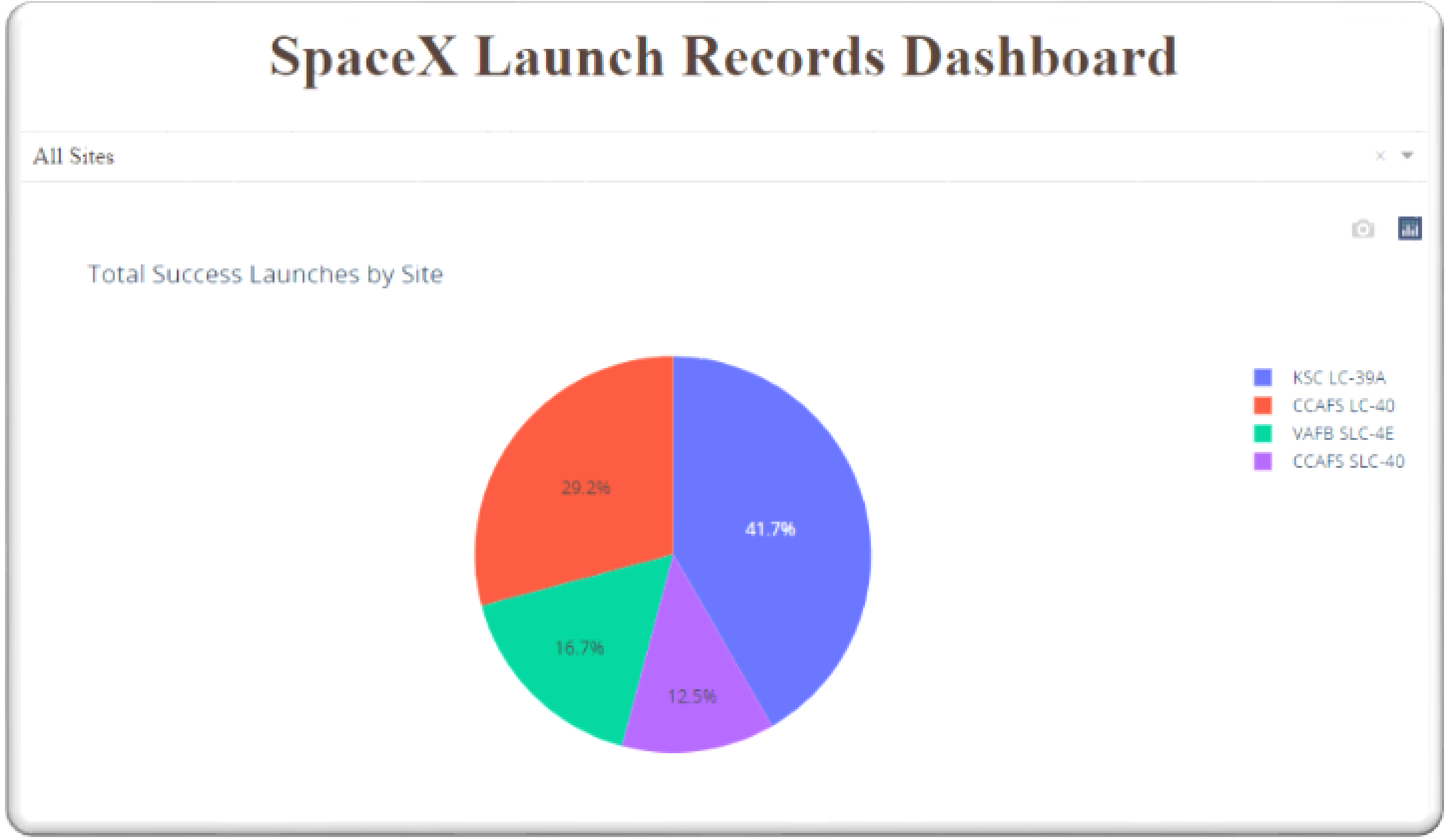
Nearest highway = 0.59km away.

- Launch sites in close proximity to railways? YES.

Nearest railway = 1.29 km away.

Interactive Dashboard with PLOTLY DASH

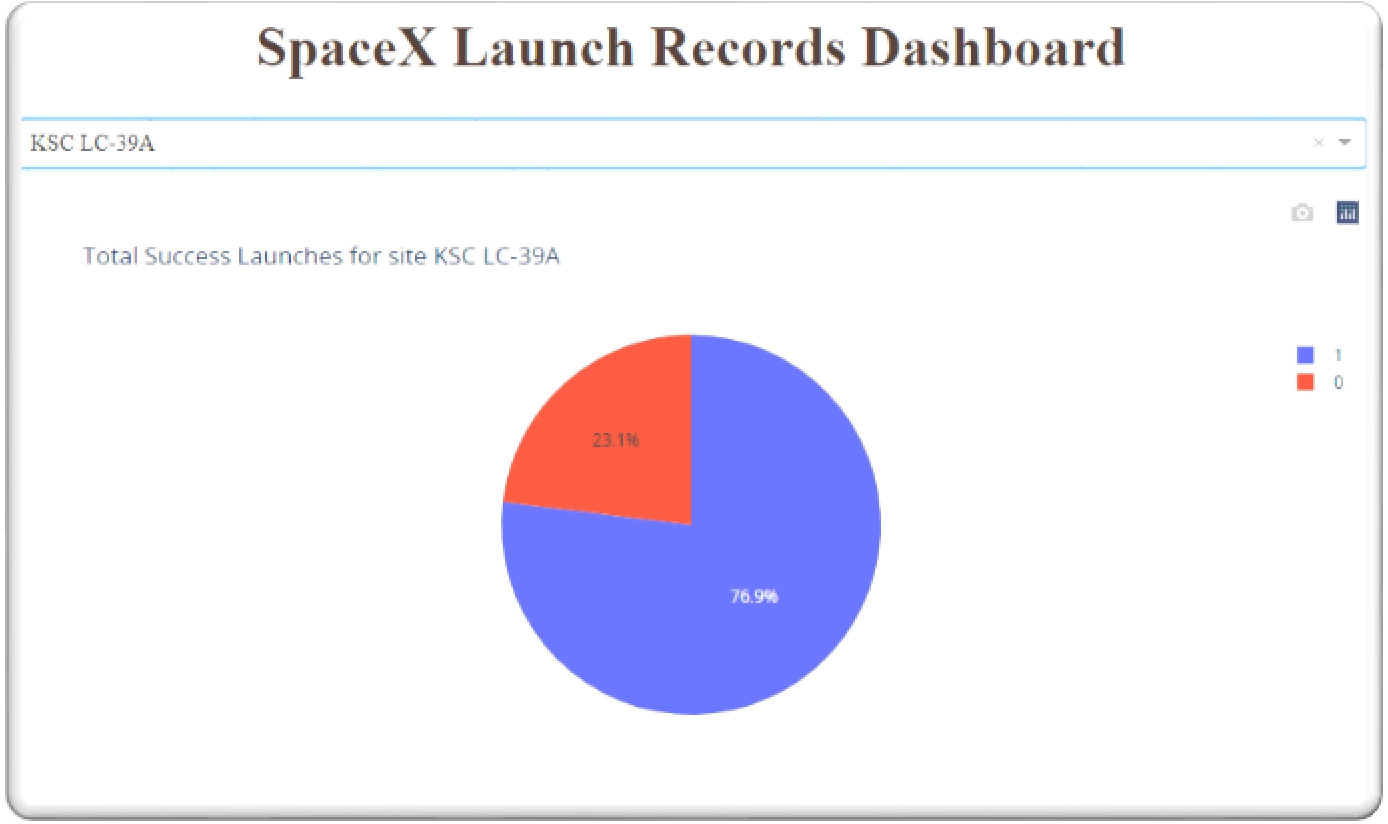
Launch Success Count for All Sites



- The launch site KSC LC-39 A had the most successful launches, with 41.7% of the total successful launches.

Interactive Dashboard with PLOTLY DASH

Highest Launching Success Ratio



- Launch site KSC LC-39 also has the highest ratio success ratio with a ratio of 76.9%.

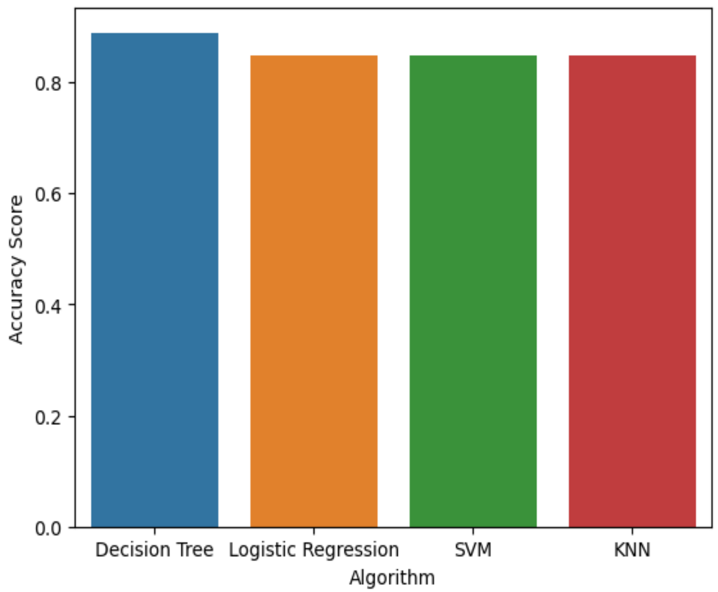
Interactive Dashboard with PLOTLY DASH

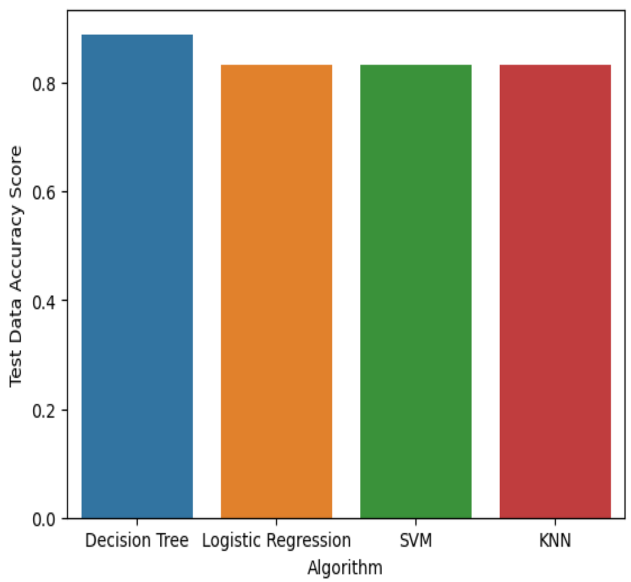
Payload Mass vs Success vs Booster version Cateegory

Predictive Analysis - Classification

Classification Accuracy

	Algorithm	Accuracy Score	Test Data Accuracy Score
0	Decision Tree	0.888889	0.722222
1	Logistic Regression	0.847222	0.833333
2	SVM	0.847222	0.833333
3	KNN	0.847222	0.833333



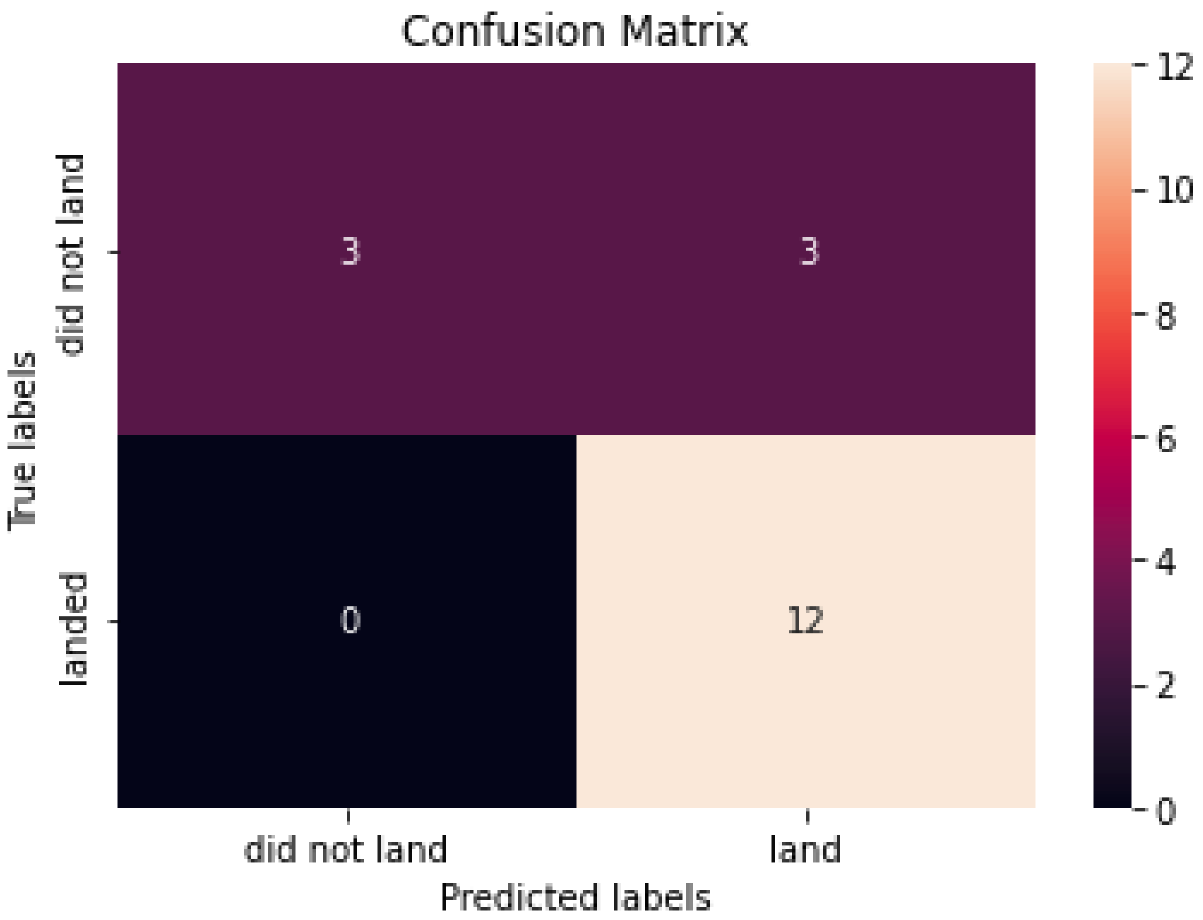


- The Decision Tree model has the highest classification accuracy

Predictive Analysis - Classification

Confusion Matrix

- The models predicted 12 successful landings when the true label was successful landing.
- The models predicted 3 unsuccessful landings when the true label was unsuccessful landing.
- The models predicted 3 successful landings when the true label was unsuccessful landings (false positives).



Conclusion

Conclusion

- As the number of flights increased, the rate of success at a launch site increased.
- Most of the early flights were unsuccessful.
- Between 2010 and 2013, all landings were unsuccessful
- After 2013, the success rate generally increased, despite small dips in 2018 and 2020.
- Orbit types ES-L1, GEO, HEO, and SSO, have the highest success rate of 100%.
- Launch site KSC LC-39 A had the most successful launches, with 41.7% of the total successful launches, and also the highest rate of successful launches, with a 76.9% success rate.

Appendix

Github Link

- https://github.com/ManojB22/DS_Projects