

Winning Space Race with Data Science

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Outline

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

Executive Summary

- Summary of methodologies
 - DataCollectionviaAPI, WebScraping
 - ExploratoryDataAnalysis(EDA)withDataVisualization • EDAwithSQL
 - InteractiveMapwithFolium
 - DashboardswithPlotlyDash
 - PredictiveAnalysis
-
- Summary of all results
 - ExploratoryDataAnalysisresults
 - Interactivemapsanddashboard
 - Predictiveresults

Introduction

- Project background and context

- The aim of this project is to predict if the Falcon 9 first stage will successfully land. SpaceX says on its website that the Falcon 9 rocket launch cost 62 million dollars. Other providers cost upward of 165 million dollars each. The price difference is explained by the fact that SpaceX can reuse the first stage. By determining if the stage will land, we can determine the cost of a launch. This information is interesting for another company if it wants to compete with SpaceX for a rocket launch.

- Problems you want to find answers

- What are the main characteristics of a successful or failed landing?
- What are the effects of each relationship of the rocket variables on the success or failure of a landing?
- What are the conditions which will allow SpaceX to achieve the best landing success rate?

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
 - SpaceX REST API
 - Web Scrapping from Wikipedia
- Perform data wrangling
 - Dropping unnecessary columns
 - One Hot Encoding for classification 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
 - How to build, tune, evaluate classification models

Data Collection

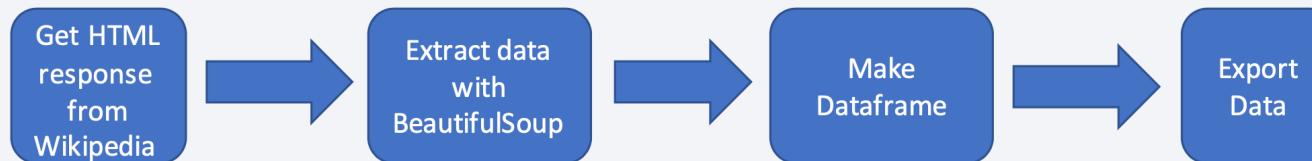
- Datasets are collected from Rest SpaceX API and webscrapping Wikipedia •
- The information obtained by the API is rocket, launches, payload information.
- The Space X REST API URL is api.spacexdata.com/v4/



The information obtained by the webscraping of Wikipedia are launches, landing, payload information.

- URL is

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



Data Collection – SpaceX API

1. Getting Response from API

```
spacex_url="https://api.spacexdata.com/v4/launches/past"
response = requests.get(spacex_url)
```

2. Convert Response to JSON File

```
data = response.json()
data = pd.json_normalize(data)
```

3. Transform data

```
getLaunchSite(data)
getPayloadData(data)
getCoreData(data)
getBoosterVersion(data)
```

4. Create dictionary with data

```
launch_dict = {'FlightNumber': list(data['flight_number']),
               'Date': list(data['date']),
               'BoosterVersion':BoosterVersion,
               'PayloadMass':PayloadMass,
               'Orbit':Orbit,
               'LaunchSite':LaunchSite,
               'Outcome':Outcome,
               'Flights':Flights,
               'GridFins':GridFins,
               'Reused':Reused,
               'Legs':Legs,
               'LandingPad':LandingPad,
               'Block':Block,
               'ReusedCount':ReusedCount,
               'Serial':Serial,
               'Longitude': Longitude,
               'Latitude': Latitude}
```

5. Create dataframe

```
data = pd.DataFrame.from_dict(launch_dict)
```

6. Filter dataframe

```
data_falcon9 = data[data['BoosterVersion']!='Falcon 1']
```

7. Export to file

```
data_falcon9.to_csv('dataset_part_1.csv', index=False)
```

[link](#)

Data Collection - Scraping

1. Getting Response from HTML

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

2. Create BeautifulSoup Object

```
soup = BeautifulSoup(response.text, "html5lib")
```

3. Find all tables

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

4. Get column names

```
for th in first_launch_table.findAll('th'):
    name = extract_column_from_header(th)
    if name is not None and len(name) > 0 :
        column_names.append(name)
```

5. Create dictionary

```
launch_dict= dict.fromkeys(column_names)

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

# Let's initial the launch_dict with each value to be an empty list
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']= []
```

6. Add data to keys

```
extracted_row = 0
#Extract each table
for table_number,table in enumerate(soup.findAll_all()):
    # get table row
    for rows in table.findAll_all("tr"):
        #check to see if first table heading is a
        if rows.th:
            if rows.th.string:
                flight_number=rows.th.string.strip()
                flag=flight_number.isdigit()

See notebook for the rest of code
```

7. Create dataframe from dictionary

```
df=pd.DataFrame(launch_dict)
```

8. Export to file

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

[link](#)

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Data Wrangling

- In the dataset, there are several cases where the booster did not land successfully.
 - True Ocean, True RTLS, True ASDS means the mission has been successful.
 - False Ocean, False RTLS, False ASDS means the mission was a failure.
- We need to transform string variables into categorical variables where 1 means the mission has been successful and 0 means the mission was a failure.

1. Calculate launches number for each site

```
df['LaunchSite'].value_counts()  
  
CCAFS SLC 40    55  
KSC LC 39A      22  
VAFB SLC 4E     13  
Name: LaunchSite, dtype: int64
```

2. Calculate the number and occurrence of each orbit

```
df['Orbit'].value_counts()  
  
GTO      27  
ISS      21  
VLEO     14  
PO       9  
LEO      7  
SSO      5  
MEO      3  
SO       1  
ES-L1    1  
HEO      1  
GEO      1  
Name: Orbit, dtype: int64
```

3. Calculate number and occurrence of mission outcome per orbit type

```
landing_outcomes = df['Outcome'].value_counts()  
landing_outcomes  
  
True ASDS      41  
None None      19  
True RTLS      14  
False ASDS     6  
True Ocean     5  
None ASDS      2  
False Ocean    2  
False RTLS     1  
Name: Outcome, dtype: int64
```

4. Create landing outcome label from Outcome column

```
landing_class = []  
for key,value in df["Outcome"].items():  
    if value in bad_outcomes:  
        landing_class.append(0)  
    else:  
        landing_class.append(1)  
df['Class']=landing_class
```

5. Export to file

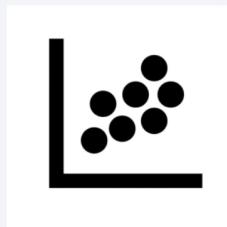
```
df.to_csv("dataset_part_2.csv", index=False)
```

[link](#)

EDA with Data Visualization

- Scatter Graphs

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



Scatter plots show relationship between variables. This relationship is called the correlation.

[link](#)

- Bar Graph

- Success rate vs. Orbit

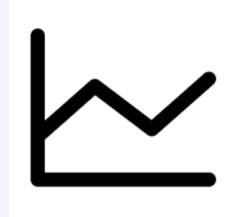
Bar graphs show the relationship between numeric and categoric variables.



- Line Graph

- Success rate vs. Year

*Line graphs show data variables and their trends.
Line graphs can help to show global behavior and make prediction for unseen data.*



EDA with SQL

- We performed SQL queries to gather and understand data from dataset:
- Displaying the names of the unique launch sites in the space mission.
- Display 5 records where launch sites begin with the string 'CCA'
- Display the total payload mass carried by boosters launched by NASA (CRS).
- Display average payload mass carried by booster version F9 v1.1.
- List the date when the first successful landing outcome in ground pad was achieved.
- List the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000.
- List the total number of successful and failure mission outcomes.
- List the names of the booster_versions which have carried the maximum payload mass.
- List the records which will display the month names, failure_landing_outcomes in drone ship, booster versions, launch_site for the months in year 2015.
- Rank the count of successful landing_outcomes between the date 04-06-2010 and 20-03-2017 in descending order.

[link](#)

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Build an Interactive Map with Folium

- Folium map object is a map centered on NASA Johnson Space Center at Houston, Texas
 - Red circle at NASA Johnson Space Center's coordinate with label showing its name (folium.Circle, folium.map.Marker).
 - Red circles at each launch site coordinates with label showing launch site name (folium.Circle, folium.map.Marker, folium.features.DivIcon).
 - The grouping of points in a cluster to display multiple and different information for the same coordinates (folium.plugins.MarkerCluster).
 - Markers to show successful and unsuccessful landings. **Green** for successful landing and **Red** for unsuccessful landing. (folium.map.Marker, folium.Icon).
 - Markers to show distance between launch site to key locations (railway, highway, coastway, city) and plot a line between them . (folium.map.Marker, folium.PolyLine, folium.features.DivIcon)
- These objects are created in order to understand better the problem and the data. We can show easily all launch sites, their surroundings and the number of successful and unsuccessful landings.

[link](#)

Build a Dashboard with Plotly Dash

- Dashboard has dropdown, pie chart, rangeslider and scatter plot components
 - Dropdown allows user to choose the launch site or all launch sites
 - (`dash_core_components.Dropdown`).
 - Pie chart shows the total success and total failure for the launch site chosen with the dropdown component (`plotly.express.pie`).
 - Range slider allows user to select a payload mass in a fixed range (`dash_core_components.RangeSlider`).
 - Scatter chart shows the relationship between two variables, in particular Success vs Payload Mass (`plotly.express.scatter`).

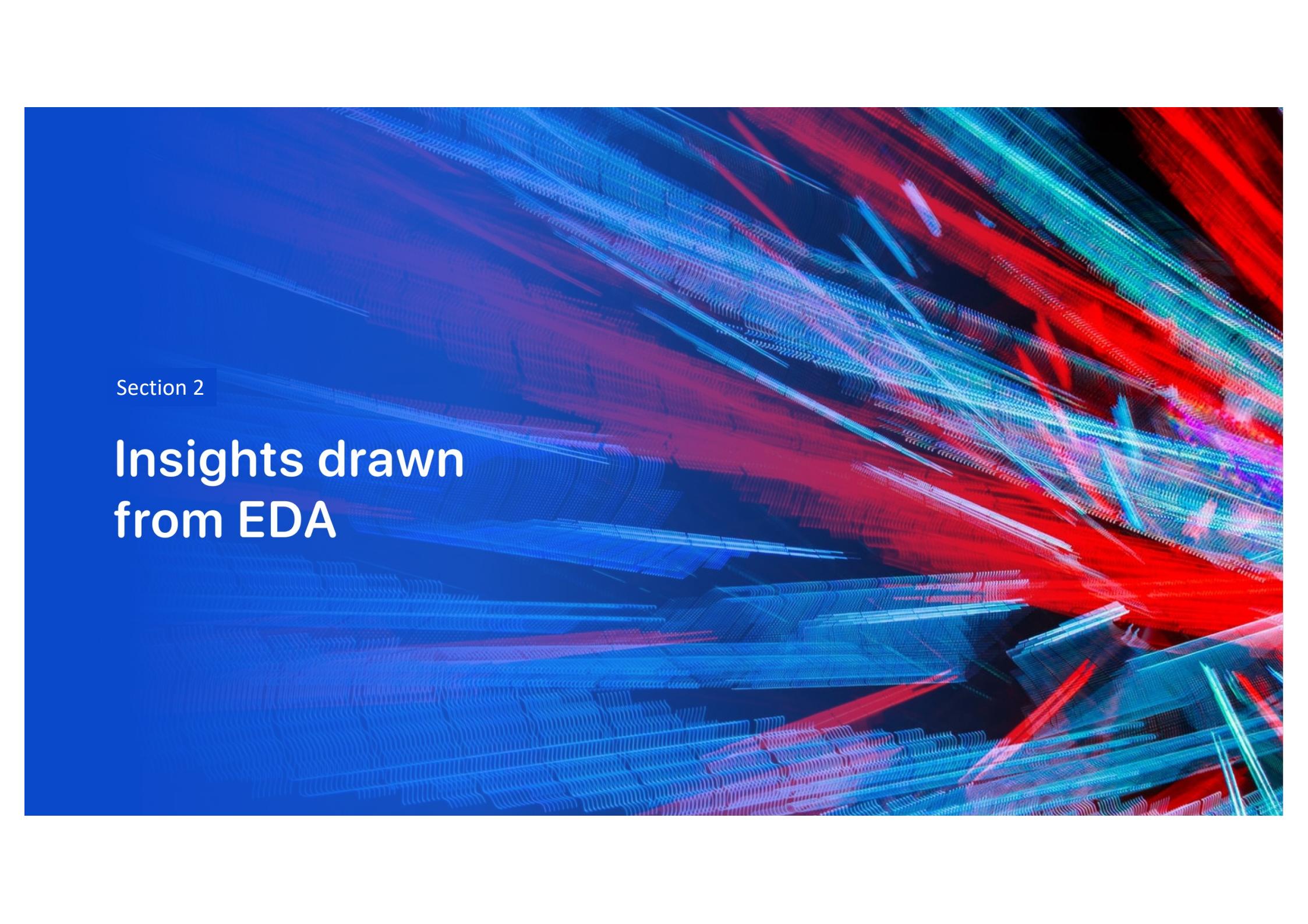
[link](#)

Predictive Analysis (Classification)

- **Datapreparation**
 - Load dataset
 - Normalize data
 - Split data into training and test sets.
- **Modelpreparation**
 - Selection of machine learning algorithms
 - Set parameters for each algorithm to GridSearchCV
 - Training GridSearchModel models with training dataset
- **Modelevaluation**
 - Get best hyperparameters for each type of model
 - Compute accuracy for each model with test dataset
 - Plot Confusion Matrix
- **Modelcomparison**
 - Comparison of models according to their accuracy
 - The model with the best accuracy will be chosen (see Notebook for result)

Results

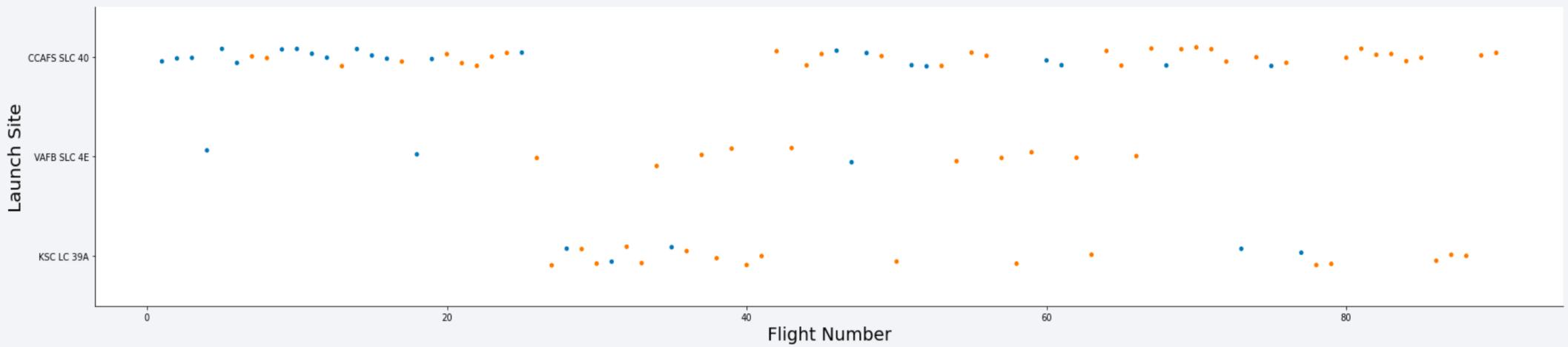
- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

The background of the slide features a complex, abstract pattern of glowing lines. These lines are primarily blue and red, creating a sense of depth and motion. They appear to be composed of numerous small, individual points of light, giving them a granular or digital appearance. The lines converge and diverge, forming various shapes and directions across the frame.

Section 2

Insights drawn from EDA

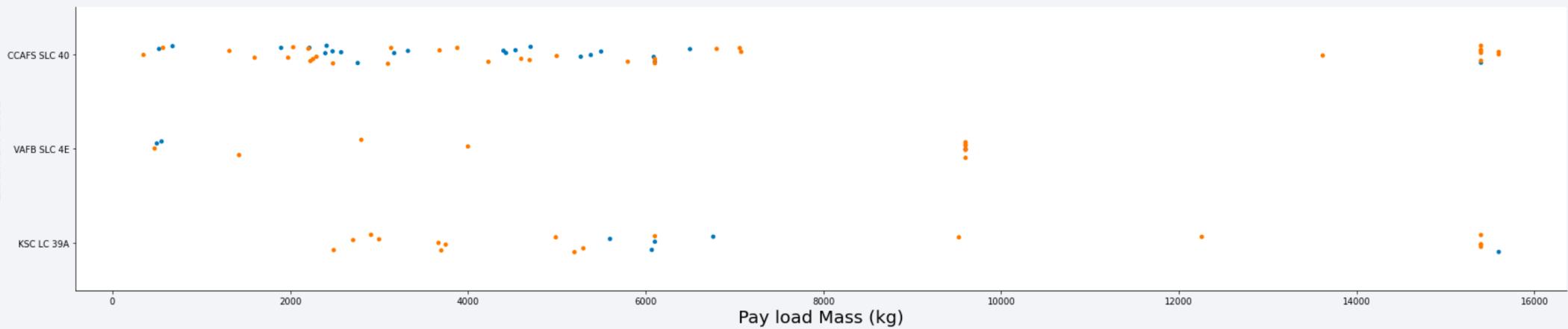
Flight Number vs. Launch Site



We observe that, for each site, the success rate is increasing.

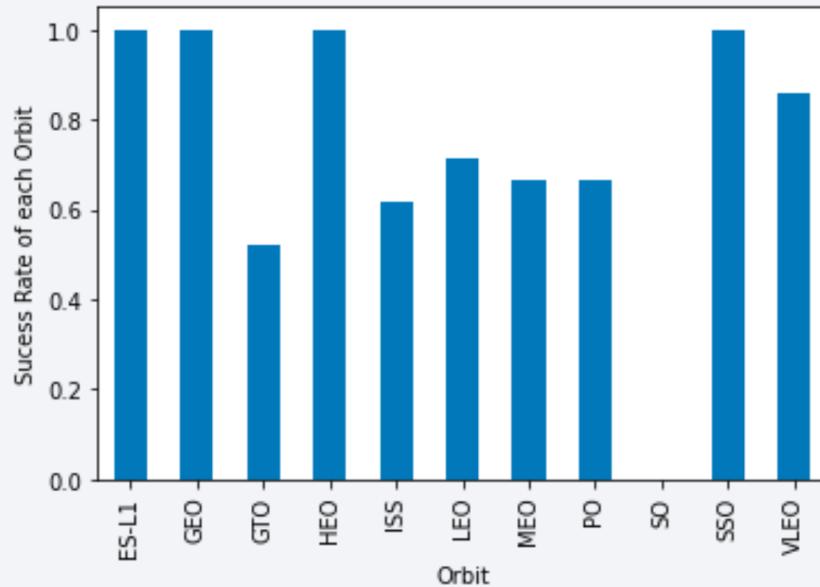
Payload vs. Launch Site

Launch Site



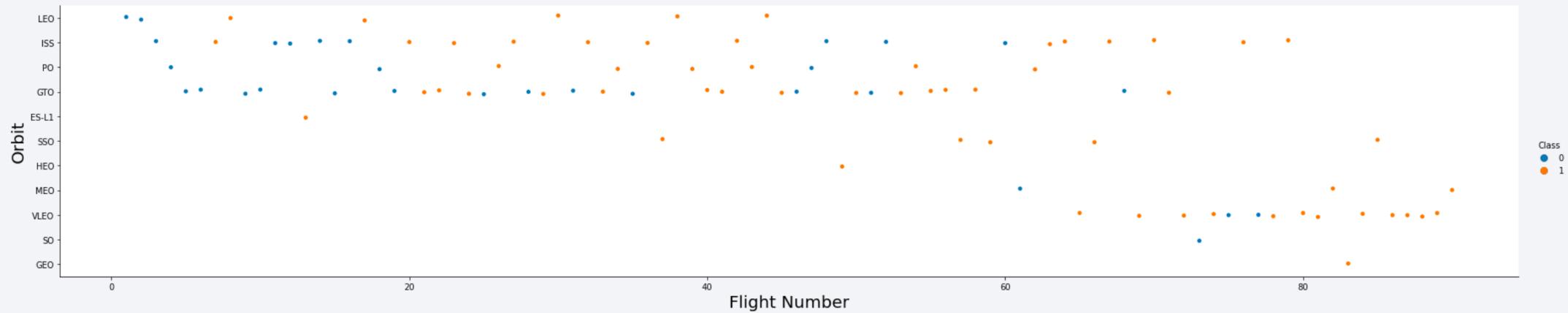
Depending on the launch site, a heavier payload may be a consideration for a successful landing. On the other hand, a too heavy payload can make a landing fail.

Success Rate vs. Orbit Type



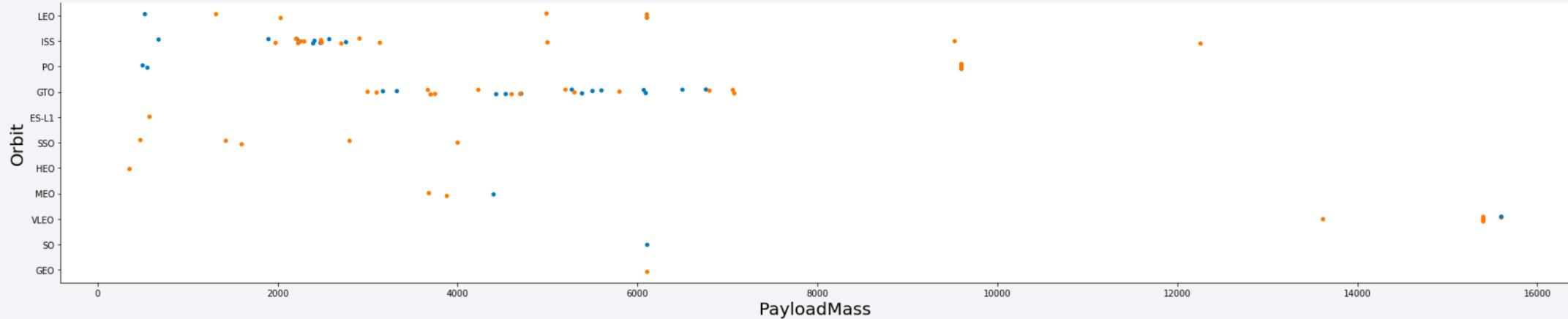
With this plot, we can see success rate for different orbit types. We note that ES-L1, GEO, HEO, SSO have the best success rate.

Flight Number vs. Orbit Type



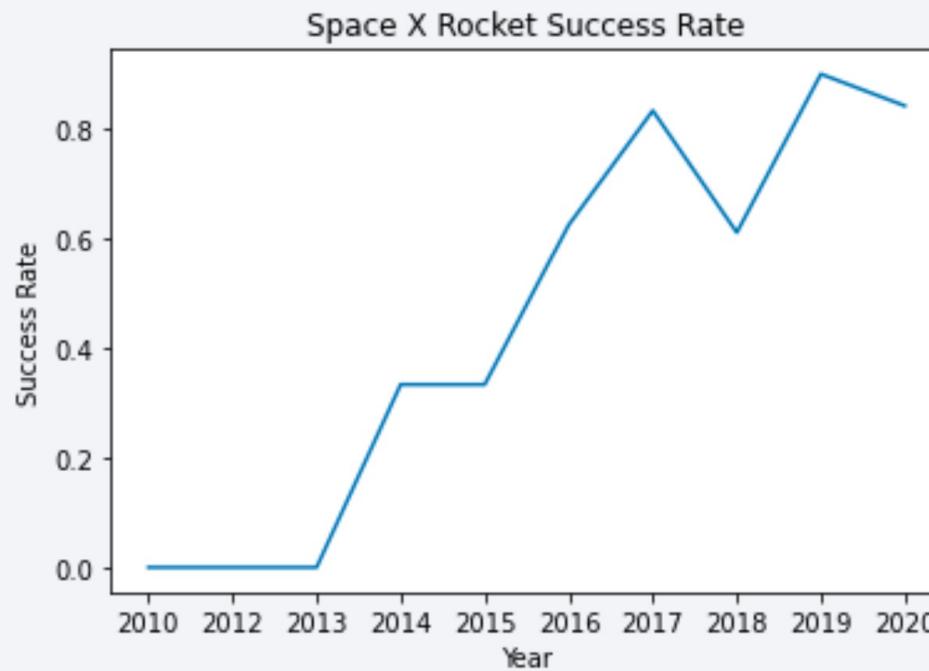
We notice that the success rate increases with the number of flights for the LEO orbit. For some orbits like GTO, there is no relation between the success rate and the number of flights. But we can suppose that the high success rate of some orbits like SSO or HEO is due to the knowledge learned during former launches for other orbits.

Payload vs. Orbit Type



The weight of the payloads can have a great influence on the success rate of the launches in certain orbits. For example, heavier payloads improve the success rate for the LEO orbit. Another finding is that decreasing the payload weight for a GTO orbit improves the success of a launch.

Launch Success Yearly Trend



Since 2013, we can see an increase in the Space X Rocket success rate.

All Launch Site Names

SQL Query

```
SELECT DISTINCT "LAUNCH_SITE" FROM SPACEXTBL
```

Results

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

- Explanation
- The use of DISTINCT in the query allows to remove duplicate LAUNCH_SITE.

Launch Site Names Begin with 'CCA'

SQL Query

```
SELECT * FROM SPACEXTBL WHERE "LAUNCH_SITE" LIKE '%CCA%' LIMIT 5
```

Results

| Date | Time (UTC) | Booster_Version | Launch_Site | Payload | PAYLOAD_MASS__KG_ | Orbit | Customer |
|------------|------------|-----------------|-------------|---|-------------------|-----------|-----------------|
| 04-06-2010 | 18:45:00 | F9 v1.0 B0003 | CCAFS LC-40 | Dragon Spacecraft Qualification Unit | 0 | LEO | SpaceX |
| 08-12-2010 | 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 |
| 22-05-2012 | 07:44:00 | F9 v1.0 B0005 | CCAFS LC-40 | Dragon demo flight C2 | 525 | LEO (ISS) | NASA (COTS) |
| 08-10-2012 | 00:35:00 | F9 v1.0 B0006 | CCAFS LC-40 | SpaceX CRS-1 | 500 | LEO (ISS) | NASA (CRS) |
| 01-03-2013 | 15:10:00 | F9 v1.0 B0007 | CCAFS LC-40 | SpaceX CRS-2 | 677 | LEO (ISS) | NASA (CRS) |

- Explanation
- The WHERE clause followed by LIKE clause filters launch sites that contain the substring CCA. LIMIT 5 shows 5 records from filtering.

Total Payload Mass

SQL Query

```
SELECT SUM("PAYLOAD_MASS__KG_") FROM SPACEXTBL WHERE "CUSTOMER" = 'NASA (CRS)'
```

Results

| SUM("PAYLOAD_MASS__KG_") |
|--------------------------|
| 45596 |

- Explanation
- This query returns the sum of all payload masses where the customer is NASA (CRS).

Average Payload Mass by F9 v1.1

SQL Query

```
SELECT AVG("PAYLOAD_MASS__KG_") FROM SPACEXTBL WHERE "BOOSTER_VERSION" LIKE '%F9 v1.1%'
```

Results

| |
|--------------------------|
| AVG("PAYLOAD_MASS__KG_") |
| 2534.6666666666665 |

- Explanation
- This query returns the average of all payload masses where the booster version contains the substring F9 v1.1.

First Successful Ground Landing Date

SQL Query

```
SELECT MIN("DATE") FROM SPACEXTBL WHERE "Landing _Outcome" LIKE '%Success%'
```

Results

MIN("DATE")

01-05-2017

- Explanation
- With this query, we select the oldest successful landing.
The WHERE clause filters dataset in order to keep only records where landing was successful.
With the MIN function, we select the record with the oldest date.

Successful Drone Ship Landing with Payload between 4000 and 6000

SQL Query

```
%sql SELECT "BOOSTER_VERSION" FROM SPACEXTBL WHERE "LANDING_OUTCOME" = 'Success (drone ship)' \
AND "PAYLOAD_MASS_KG_" > 4000 AND "PAYLOAD_MASS_KG_" < 6000;
```

Results

| Booster_Version |
|-----------------|
| F9 FT B1022 |
| F9 FT B1026 |
| F9 FT B1021.2 |
| F9 FT B1031.2 |

- Explanation
- This query returns the booster version where landing was successful and payload mass is between 4000 and 6000 kg. The WHERE and AND clauses filter the dataset.

Total Number of Successful and Failure Mission Outcomes

SQL Query

```
%sql SELECT (SELECT COUNT("MISSION_OUTCOME") FROM SPACEXTBL WHERE "MISSION_OUTCOME" LIKE '%Success%') AS SUCCESS, \
(SELECT COUNT("MISSION_OUTCOME") FROM SPACEXTBL WHERE "MISSION_OUTCOME" LIKE '%Failure%') AS FAILURE
```

Results

| SUCCESS | FAILURE |
|---------|---------|
| 100 | 1 |

- Explanation
- With the first SELECT, we show the subqueries that return results. The first subquery counts the successful mission. The second subquery counts the unsuccessful mission. The WHERE clause followed by LIKE clause filters mission outcome. The COUNT function counts records filtered.

Boosters Carried Maximum Payload

SQL Query

```
%sql SELECT DISTINCT "BOOSTER_VERSION" FROM SPACEXTBL \
WHERE "PAYLOAD_MASS__KG_" = (SELECT max("PAYLOAD_MASS__KG_") FROM SPACEXTBL)
```

Results

| Booster_Version |
|-----------------|
| F9 B5 B1048.4 |
| F9 B5 B1049.4 |
| F9 B5 B1051.3 |
| F9 B5 B1056.4 |
| F9 B5 B1048.5 |
| F9 B5 B1051.4 |
| F9 B5 B1049.5 |
| F9 B5 B1060.2 |
| F9 B5 B1058.3 |
| F9 B5 B1051.6 |
| F9 B5 B1060.3 |
| F9 B5 B1049.7 |

- Explanation
- We used a subquery to filter data by returning only the heaviest payload mass with MAX function. The main query uses subquery results and returns unique booster version (SELECT DISTINCT) with the heaviest payload mass.

2015 Launch Records

SQL Query

```
%sql SELECT substr("DATE", 4, 2) AS MONTH, "BOOSTER_VERSION", "LAUNCH_SITE" FROM SPACEXTBL\\
WHERE "LANDING_OUTCOME" = 'Failure (drone ship)' and substr("DATE",7,4) = '2015'
```

Results

| MONTH | Booster_Version | Launch_Site |
|-------|-----------------|-------------|
| 01 | F9 v1.1 B1012 | CCAFS LC-40 |
| 04 | F9 v1.1 B1015 | CCAFS LC-40 |

- Explanation
- This query returns month, booster version, launch site where landing was unsuccessful and landing date took place in 2015. Substr function process date in order to take month or year. Substr(DATE, 4, 2) shows month. Substr(DATE,7, 4) shows year.

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

SQL Query

```
%sql SELECT "LANDING _OUTCOME", COUNT("LANDING _OUTCOME") FROM SPACEXTBL\  
WHERE "DATE" >= '04-06-2010' and "DATE" <= '20-03-2017' and "LANDING _OUTCOME" LIKE '%Success%'\  
GROUP BY "LANDING _OUTCOME" \  
ORDER BY COUNT("LANDING _OUTCOME") DESC ;
```

Results

| Landing _Outcome | COUNT("LANDING _OUTCOME") |
|----------------------|---------------------------|
| Success | 20 |
| Success (drone ship) | 8 |
| Success (ground pad) | 6 |

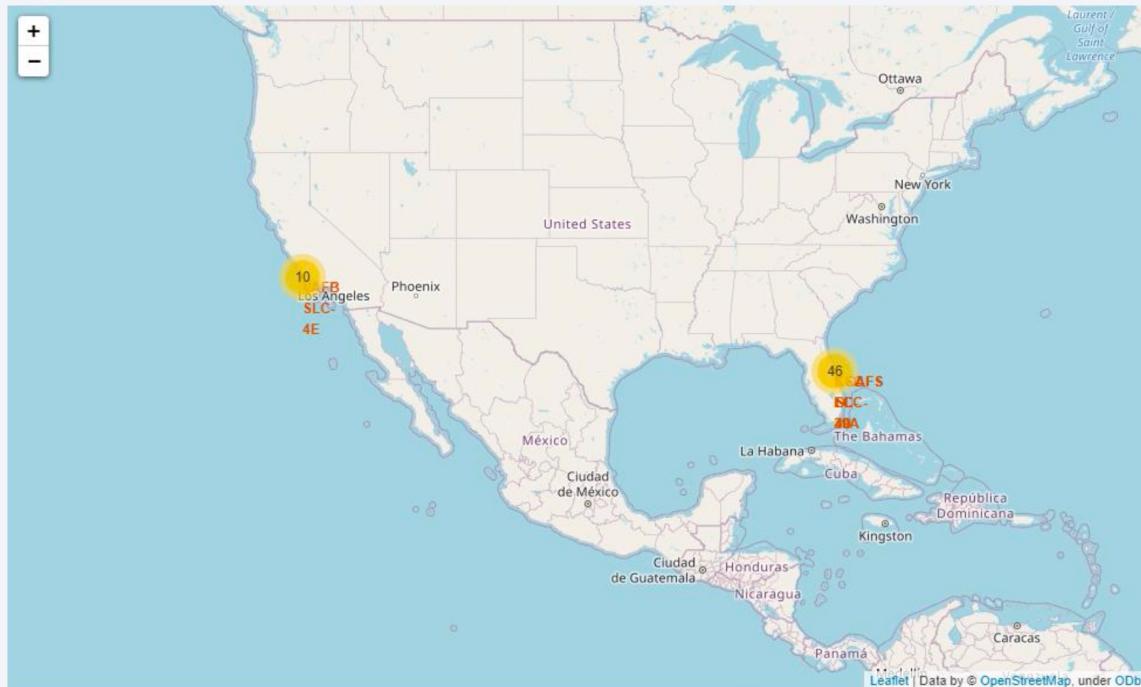
- Explanation
- This query returns landing outcomes and their count where mission was successful and date is between 04/06/2010 and 20/03/2017. The GROUP BY clause groups results by landing outcome and ORDER BY COUNT DESC shows results in decreasing order.

The background of the slide is a photograph taken from space at night. It shows the curvature of the Earth's horizon against the dark void of space. City lights are visible as numerous glowing yellow and white spots, primarily concentrated in the lower half of the image where continents appear as dark blue-grey shapes. The atmosphere is visible as a thin blue layer near the horizon, transitioning into a darker blue and then black.

Section 3

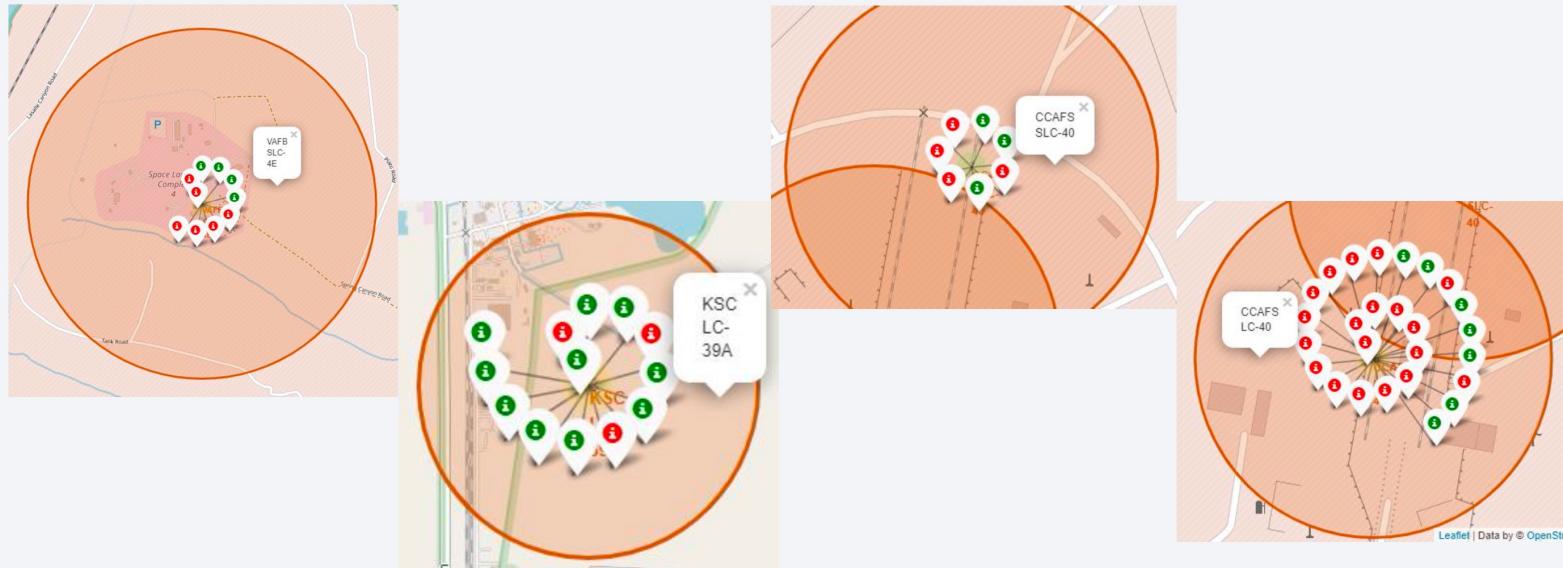
Launch Sites Proximities Analysis

Folium map – Ground stations



- We see that Space X launch sites are located on the coast of the United States

Folium map – Color Labeled Markers

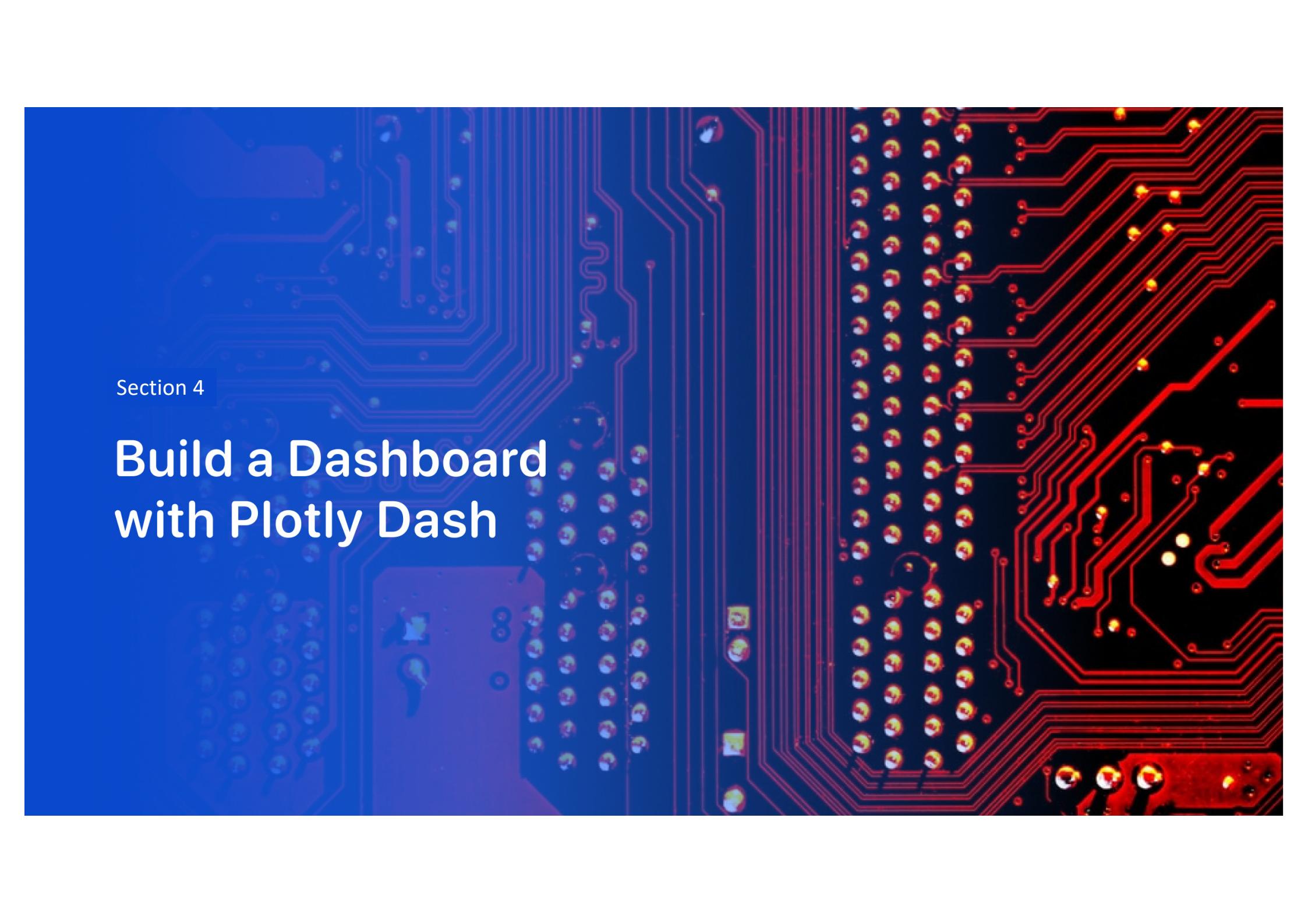


- **Green** marker represents successful launches. **Red** marker represents unsuccessful launches. We note that KSC LC-39A has a higher launch success rate.

Folium Map – Distances between CCAFS SLC-40 and its proximities



- Is CCAFS SLC-40 in close proximity to railways ? Yes
- Is CCAFS SLC-40 in close proximity to highways ? Yes
- Is CCAFS SLC-40 in close proximity to coastline ? Yes
- Do CCAFS SLC-40 keeps certain distance away from cities ? No



Section 4

Build a Dashboard with Plotly Dash

Dashboard – Total success by Site

Total Success Launches by Site



- We see that KSC LC-39A has the best success rate of launches.

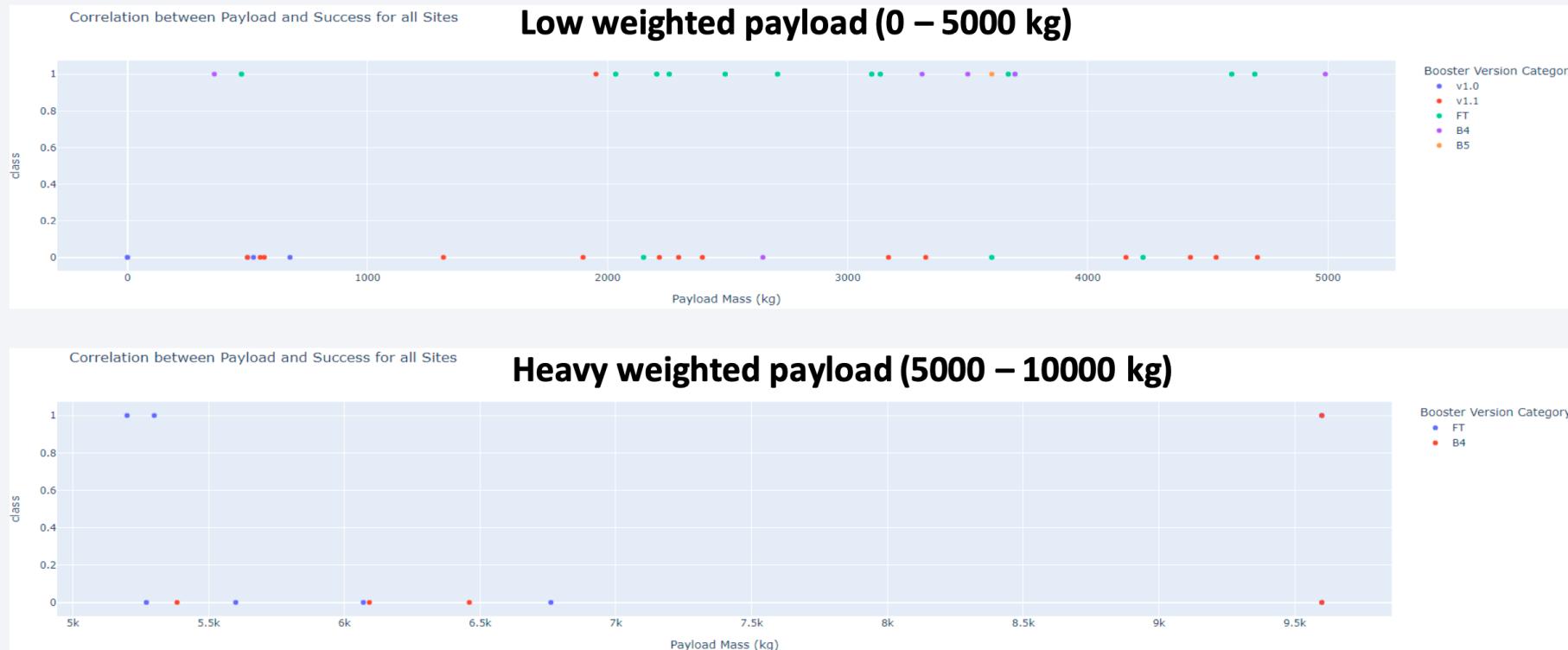
Dashboard – Total success launches for Site KSC LC-39A

Total Success Launches for Site KSC LC-39A



- We see that KSC LC-39A has achieved a 76.9% success rate while getting a 23.1% failure rate.

Dashboard – Payload mass vs Outcome for all sites with different payload mass selected



- Low weighted payloads have a better success rate than the heavy weighted payloads.

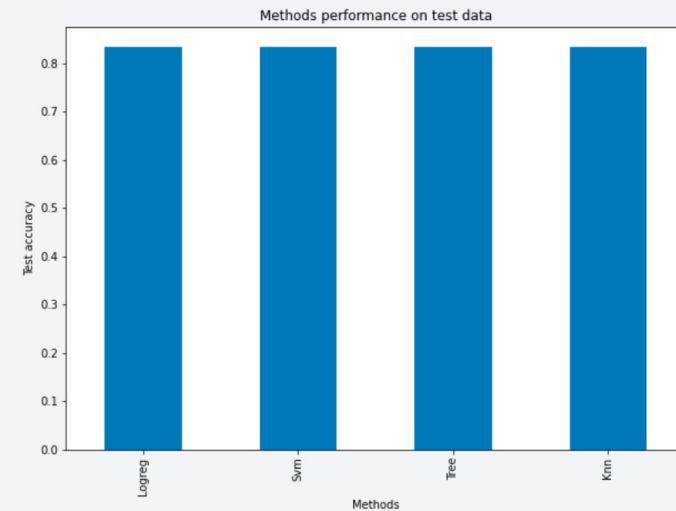
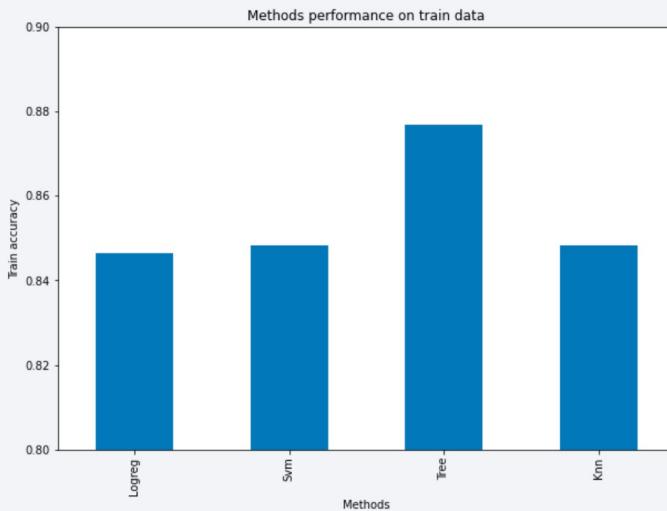
The background of the slide features a dynamic, abstract design. It consists of several curved, light-colored bands (yellow, white, and grey) that sweep across the frame from the top right towards the bottom left. These bands create a sense of motion and depth. In the lower-left quadrant, there is a solid blue rectangular area where the text is placed.

Section 5

Predictive Analysis (Classification)

Classification Accuracy

| | Accuracy Train | Accuracy Test |
|--------|----------------|---------------|
| Tree | 0.876786 | 0.833333 |
| Knn | 0.848214 | 0.833333 |
| Svm | 0.848214 | 0.833333 |
| Logreg | 0.846429 | 0.833333 |



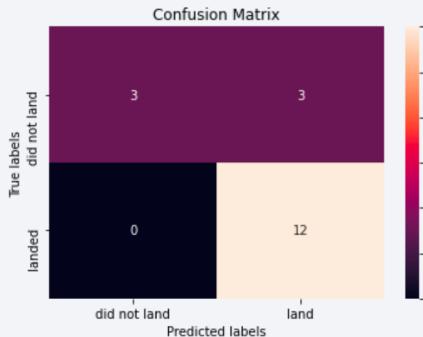
For accuracy test, all methods performed similar. We could get more test data to decide between them. But if we really need to choose one right now, we would take the decision tree.

Decision tree best parameters

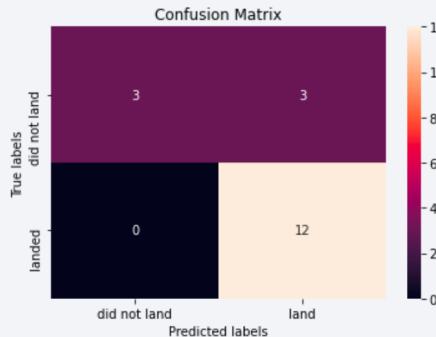
```
tuned hyperparameters :(best parameters) {'criterion': 'entropy', 'max_depth': 12, 'max_features': 'sqrt', 'min_samples_leaf': 4, 'min_samples_split': 2, 'splitter': 'random'}
```

Confusion Matrix

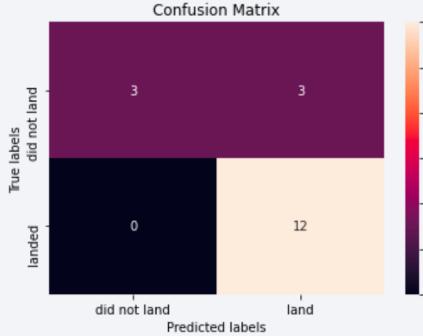
Logistic regression



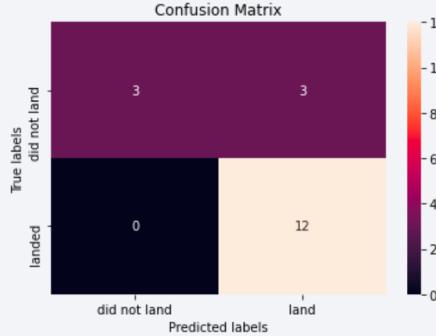
Decision Tree



kNN



SVM



As the test accuracy are all equal, the confusion matrices are also identical. The main problem of these models are false positives.

| | | Actual values | |
|------------------|---|---------------|----|
| | | 1 | 0 |
| Predicted values | 1 | TP | FP |
| | 0 | FN | TN |

Conclusions

- The success of a mission can be explained by several factors such as the launch site, the orbit and especially the number of previous launches. Indeed, we can assume that there has been a gain in knowledge between launches that allowed to go from a launch failure to a success.
- The orbits with the best success rates are GEO, HEO, SSO, ES-L 1.
- Depending on the orbits, the payload mass can be a criterion to take into account for the success of a mission. Some orbits require a light or heavy payload mass. But generally low weighted payloads perform better than the heavy weighted payloads.
- With the current data, we cannot explain why some launch sites are better than others (KSCLC-39A is the best launch site). To get an answer to this problem, we could obtain atmospheric or other relevant data.
- For this dataset, we choose the Decision Tree Algorithm as the best model even if the test accuracy between all the models used is identical. We choose Decision Tree Algorithm because it has a better train accuracy.

Thank you!

