

Winning Space Race with Data Science

Saniya Behzadpour
26/09/2023



Outline

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

Executive Summary

- Summary of methodologies
 - Data Collection via API, Web Scraping
 - Exploratory Data Analysis (EDA) with Data Visualization
 - EDA with SQL
 - Interactive Map with Folium
 - Dashboards with Plotly Dash
 - Predictive Analysis
- Summary of all results
 - Exploratory Data Analysis results
 - Interactive maps and dashboard
 - Predictive results

Introduction

- Project background and context
 - The objective of this project is to forecast the successful landing of the Falcon 9's initial stage. SpaceX has stated on its website that the launch cost for the Falcon 9 rocket is \$62 million, while alternative providers charge in excess of \$165 million for each launch. This substantial price variation can be attributed to SpaceX's capability to recycle the first stage. By ascertaining the likelihood of the stage's successful landing, we can estimate the overall launch cost. This data holds significant relevance for any other company seeking to rival SpaceX in the rocket launch industry.
- 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

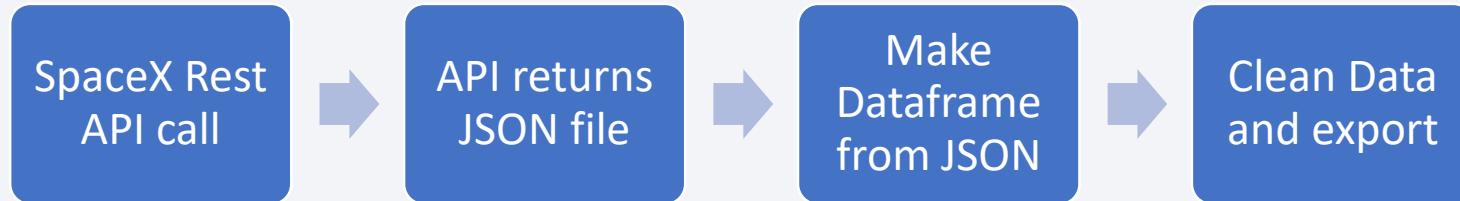
Methodology

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 SpaceX Rest API and webscrapping from Wikipedia
 - The information obtained by the API are rocket, launches, payload information



- The information obtained by the webscrapping are launches, landing, payload information



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)
```

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(
    # get table row
    for rows in table.findAll("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

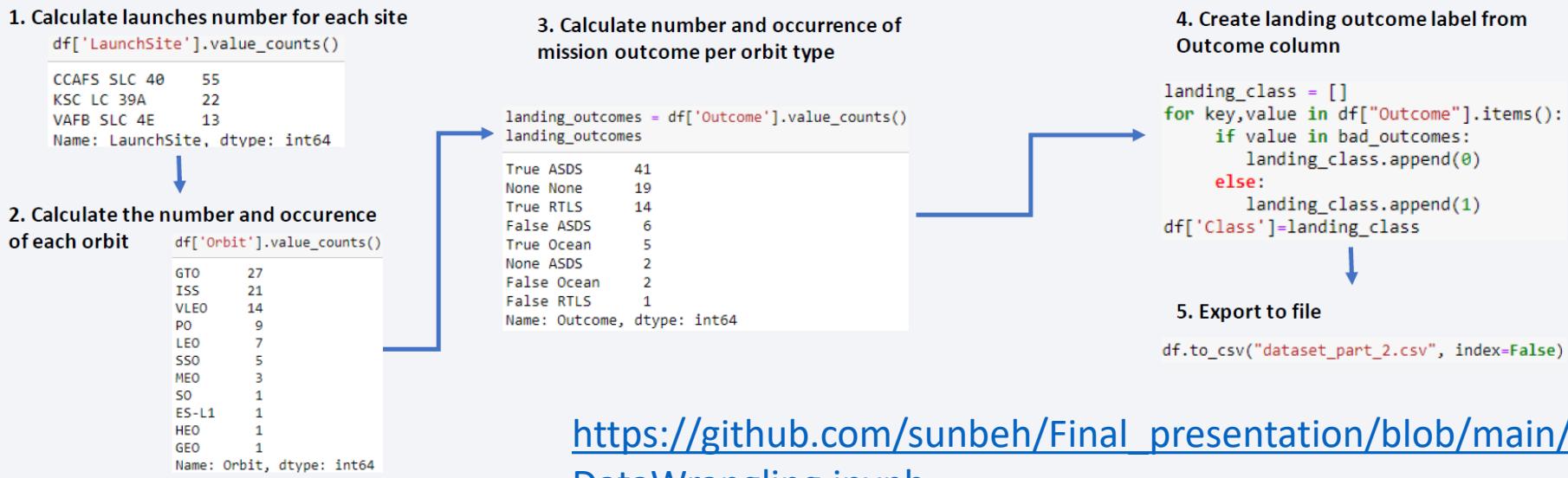
```
df=pd.DataFrame(launch_dict)
```

8. Export to file

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

Data Wrangling

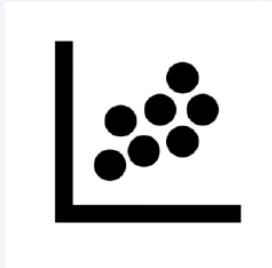
- In the dataset, there are several cases where the booster did not land successfully.
 - True Ocean, True RTLS, True ASDS means the mission has been successful.
 - False Ocean, False RTLS, False ASDS means the mission was a failure.
- We need to transform string variables into categorical variables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



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.

- 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.



https://github.com/sunbeh/Final_presentation/blob/main/EDA_DataVisualization.ipynb

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.

https://github.com/sunbeh/Final_presentation/blob/main/EDA_SQL.ipynb

Build an Interactive Map with Folium

- Folium map object is a map centered on NASA Johnson Space Center at Houson, 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.

https://github.com/sunbeh/Final_presentation/blob/main/LaunchSite_Location.ipynb

Build a Dashboard with Plotly Dash

- Dashboard has dropdown, pie chart, rangeslider and scatter plot components
 - Dropdown allows a user to choose the launch site or all launch sites (*dash_core_components.Dropdown*).
 - Pie chart shows the total success and the total failure for the launch site chosen with the dropdown component (*plotly.express.pie*).
 - Rangeslider allows a 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*).

https://github.com/sunbeh/Final_presentation/blob/main/spacesx_dash/app.py

Predictive Analysis (Classification)

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

https://github.com/sunbeh/Final_presentation/blob/main/Machine%20Learning%20Prediction.ipynb

Results

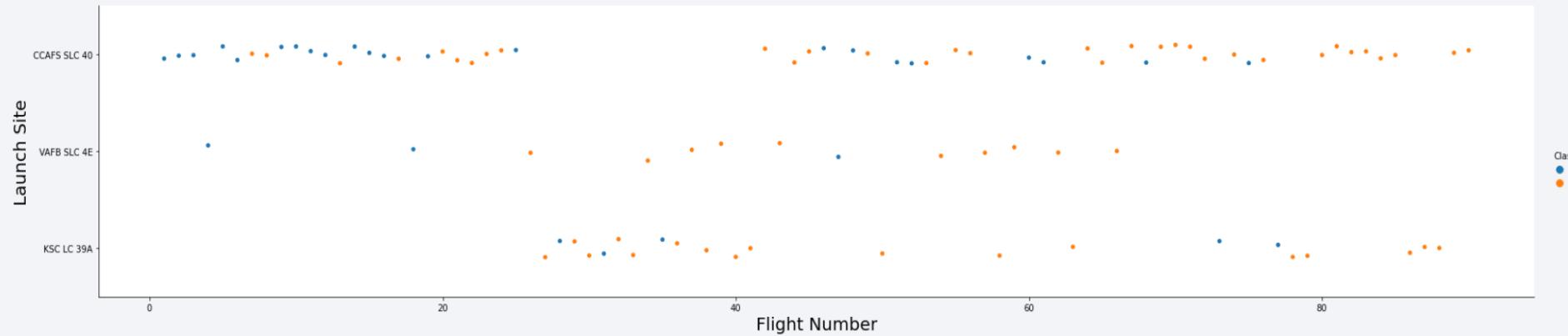
- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

The background of the slide features a complex, abstract digital visualization. It consists of numerous thin, glowing lines that create a sense of depth and motion. The lines are primarily blue and red, with some green and purple highlights. They form a grid-like structure that curves and twists across the frame, resembling a three-dimensional space or a network of data points. The overall effect is futuristic and dynamic.

Section 2

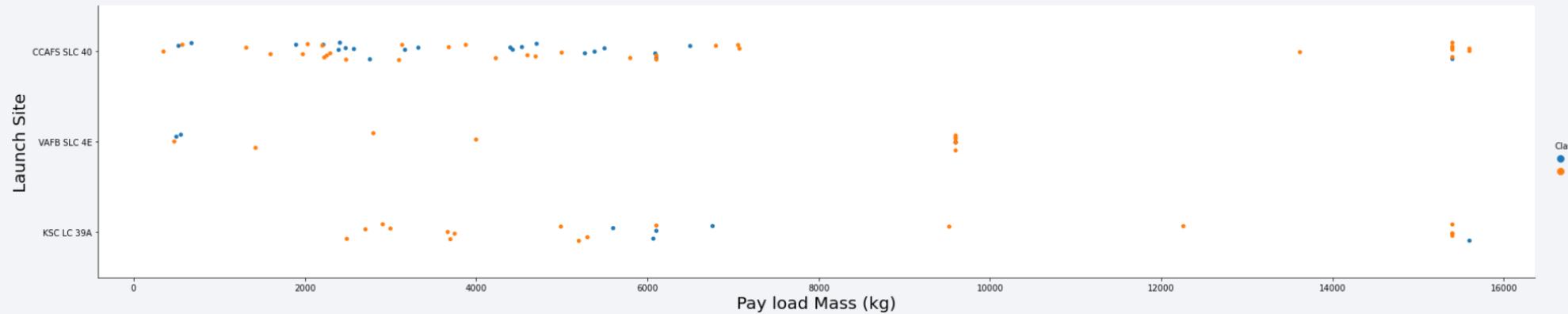
Insights drawn from EDA

Flight Number vs. Launch Site



- For each site, the success rate is increasing

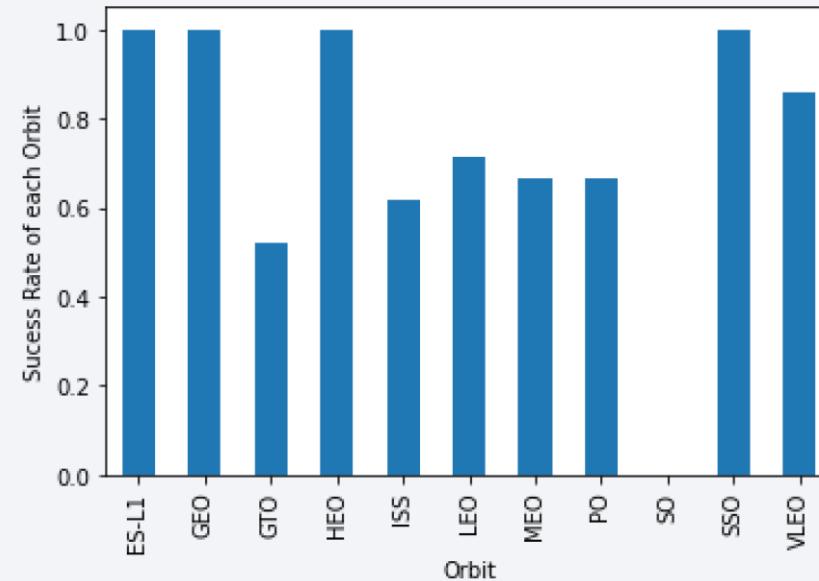
Payload vs. Launch Site



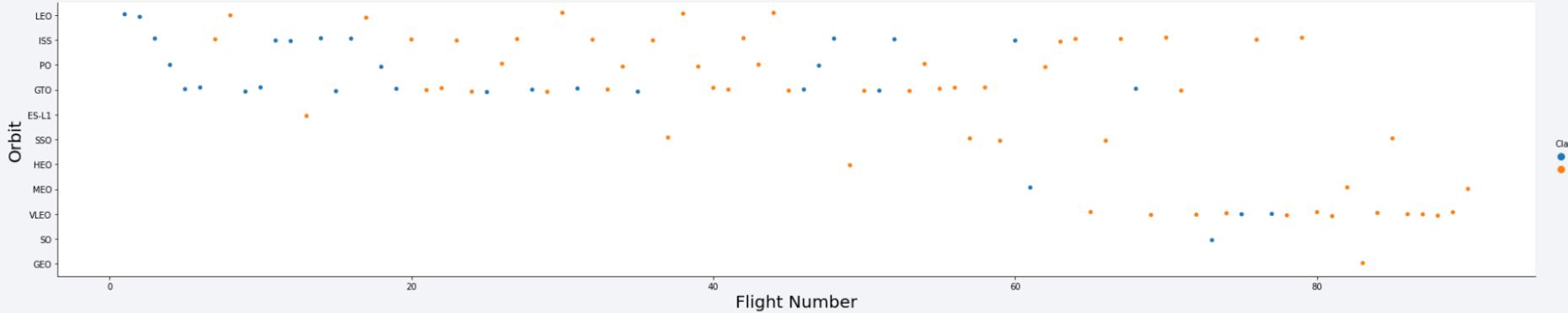
Depending on the launch site, a heavier payload may be a consideration for a successful landing. On the other hand, a too heavy payload can make a landing fail.

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.

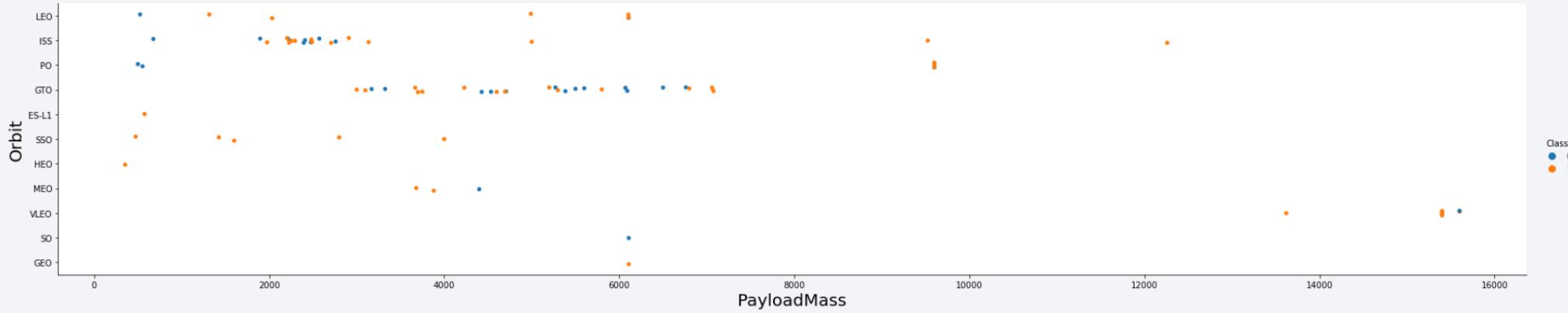


Flight Number vs. Orbit Type



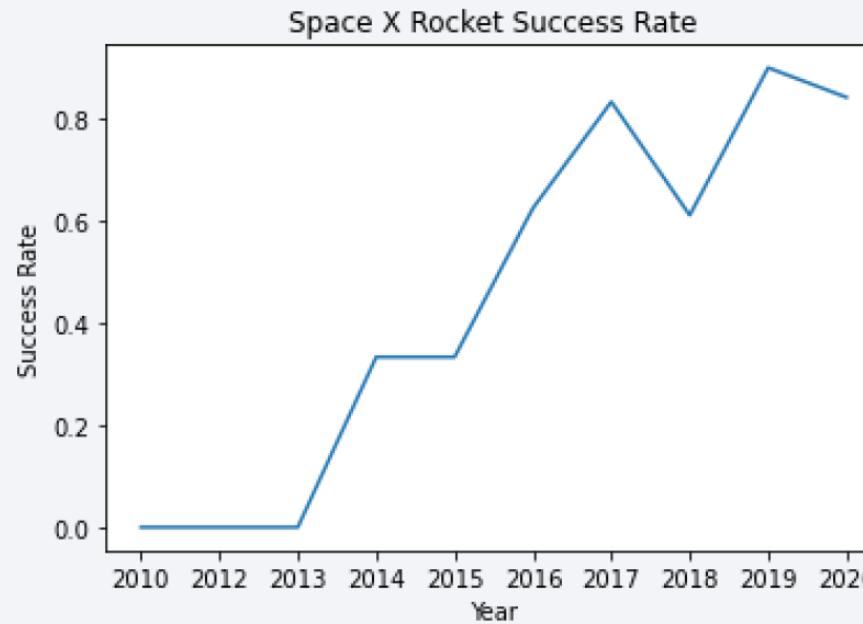
We notice that the success rate increases with the number of flights for the LEO orbit. For some orbits like GTO, there is no relation between the success rate and the number of flights. But we can suppose that the high success rate of some orbits like SSO or HEO is due to the knowledge learned during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

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

Launch Site Names Begin with 'CCA'

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

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)

Total Payload Mass

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

SQL Query

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

Results

SUM("PAYLOAD_MASS_KG_")
45596

Average Payload Mass by F9 v1.1

- This query returns the average of all payload masses where the booster version contains the substring 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

First Successful Ground Landing Date

- 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.

SQL Query

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

Results

MIN("DATE")

01-05-2017

Successful Drone Ship Landing with Payload between 4000 and 6000

- 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.

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

Total Number of Successful and Failure Mission Outcomes

- 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.

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

Boosters Carried Maximum Payload

- 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.

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

2015 Launch Records

- 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.

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

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

- 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.

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

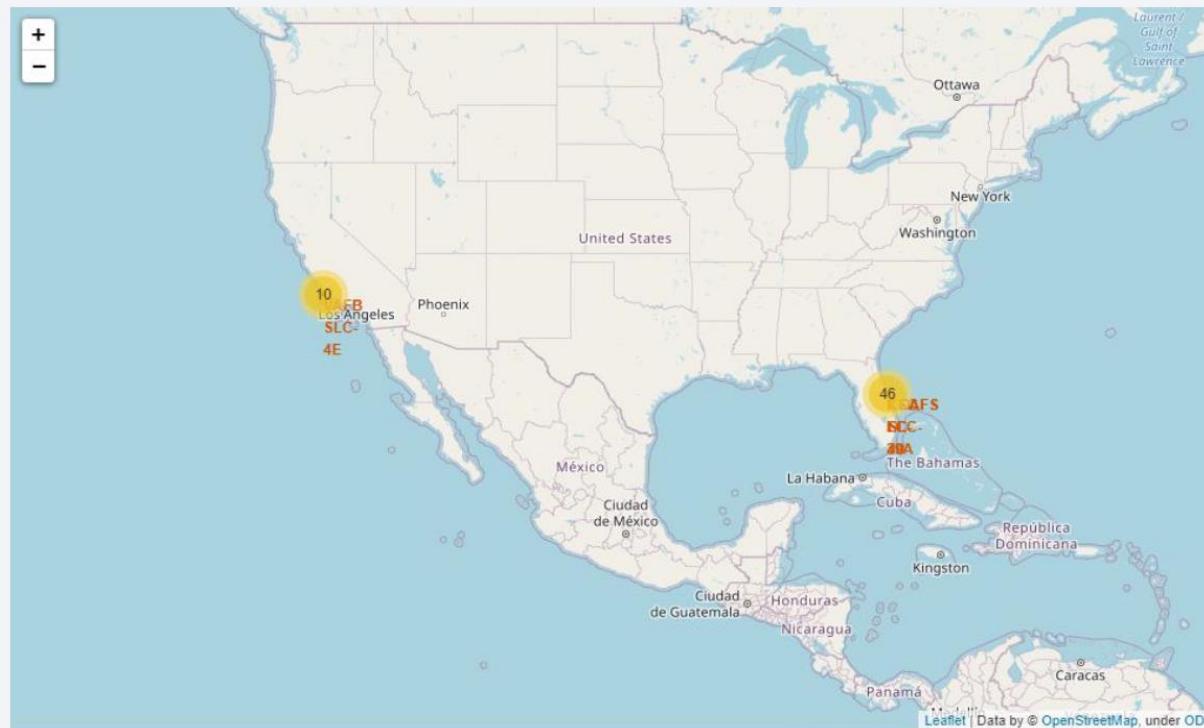
The background of the slide is a photograph taken from space at night. It shows the curvature of the Earth's horizon against a dark blue sky. Numerous glowing yellow and white points represent city lights, concentrated in coastal and urban areas. In the upper right quadrant, there are bright green and yellow bands of light, likely the Aurora Borealis or Australis. The overall atmosphere is dark and mysterious.

Section 3

Launch Sites Proximities Analysis

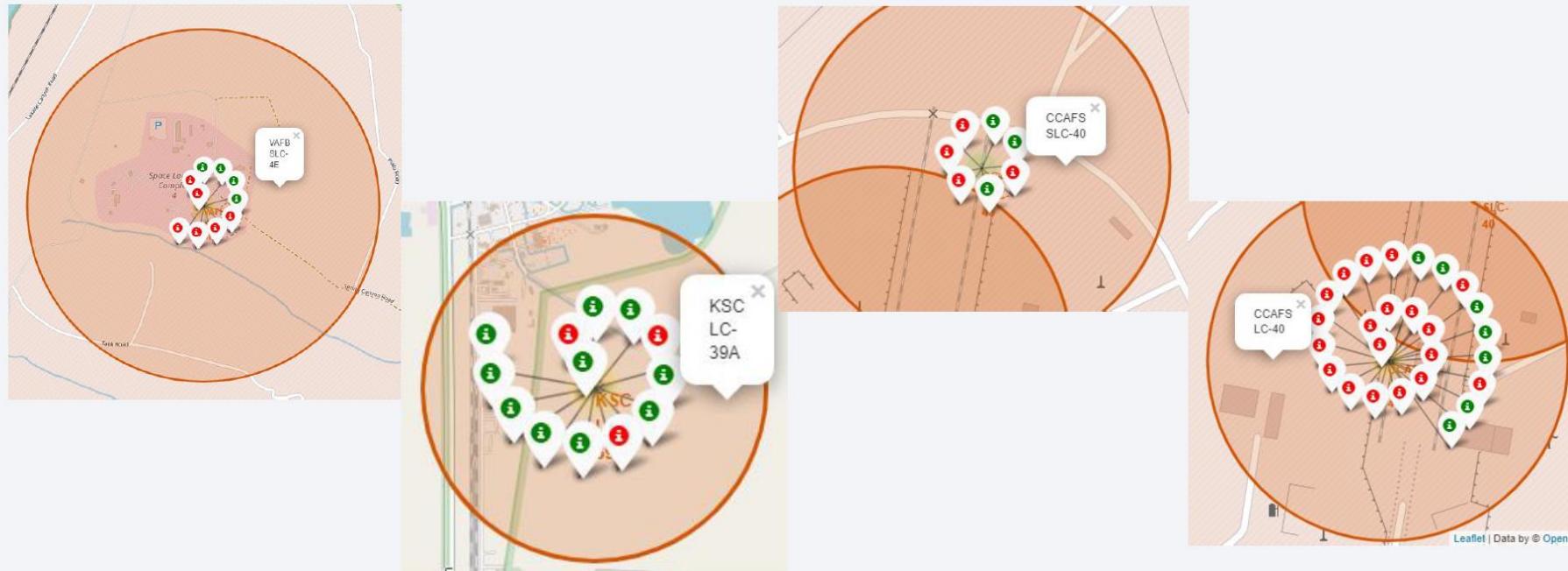
Folium map – Ground stations

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

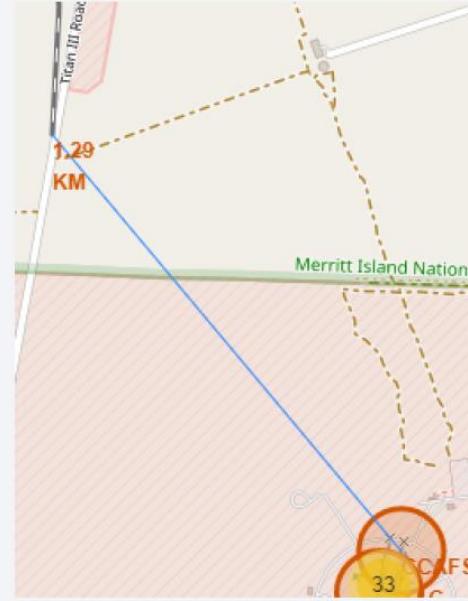
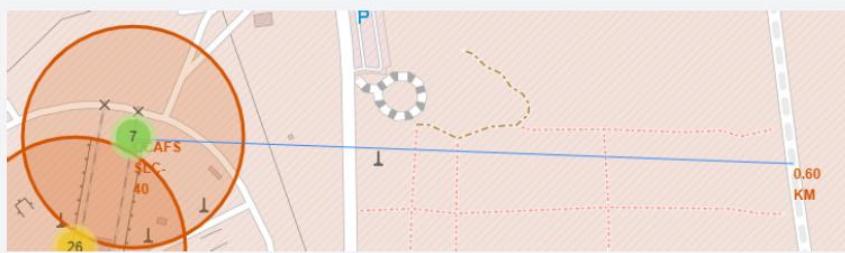


Folium map – Color Labeled Markers

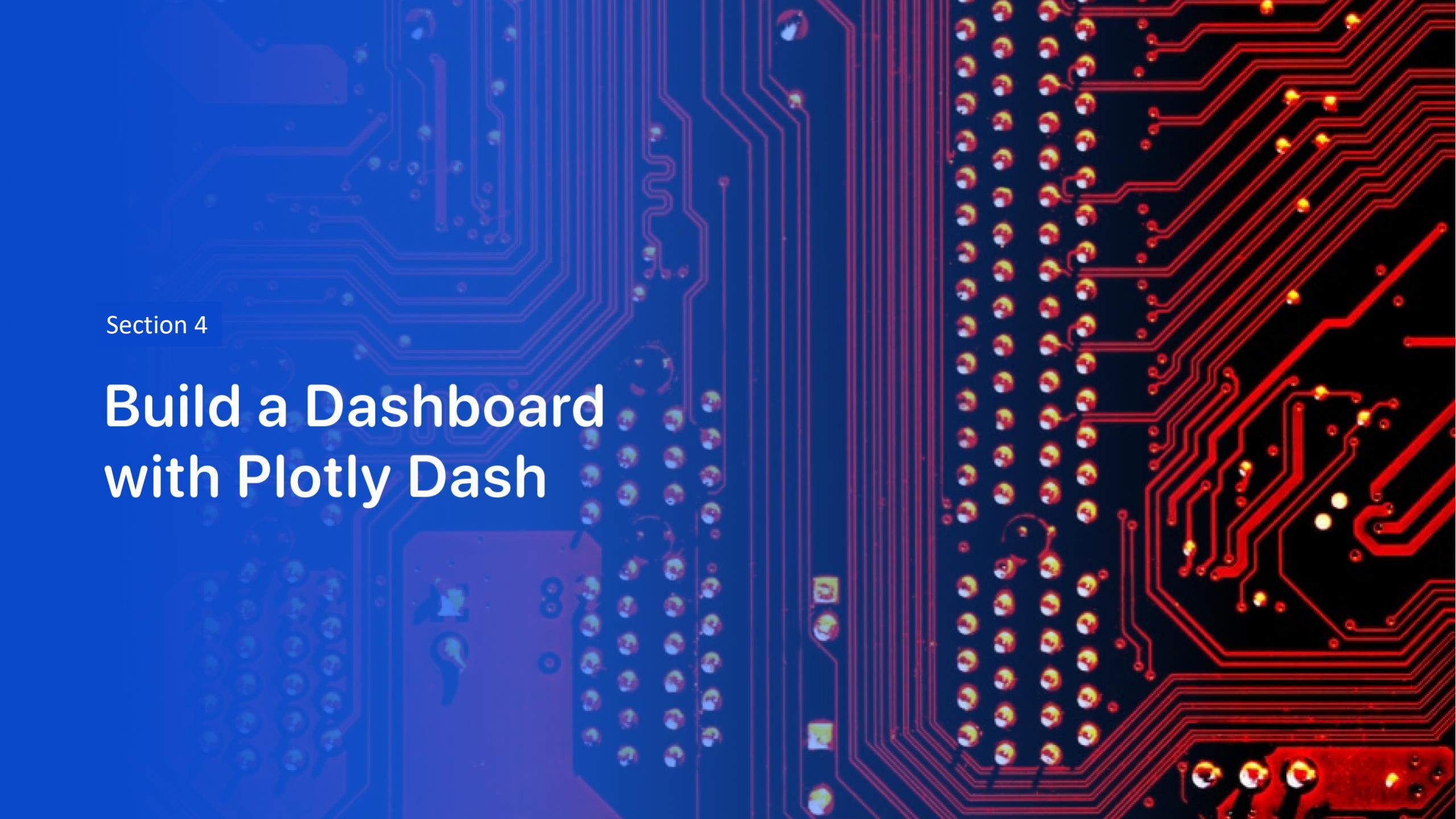
- Green marker represents successful launches. Red marker represents unsuccessful launches. We note that KSC LC 39A has a higher launch success rate.



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

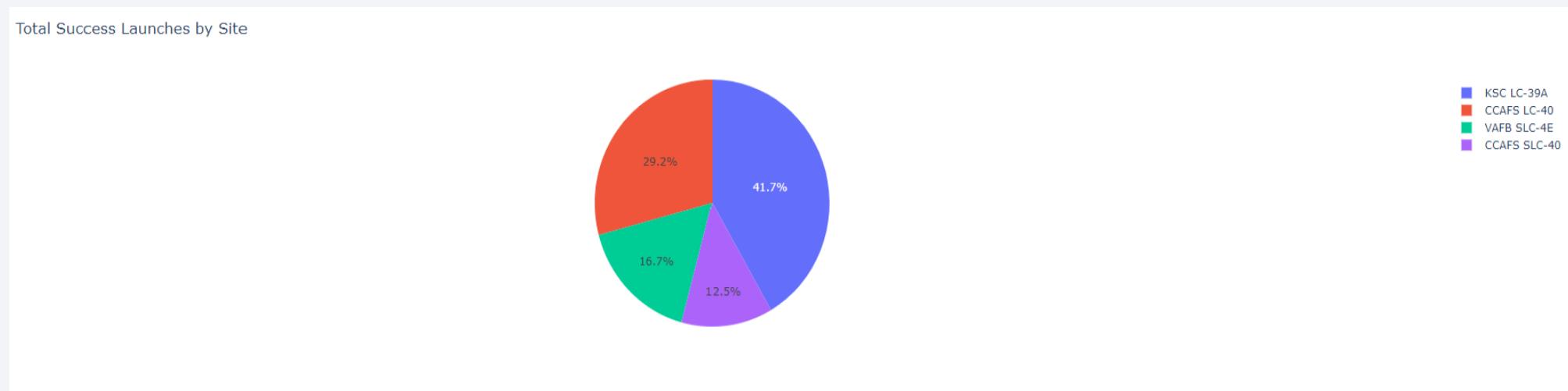


Section 4

Build a Dashboard with Plotly Dash

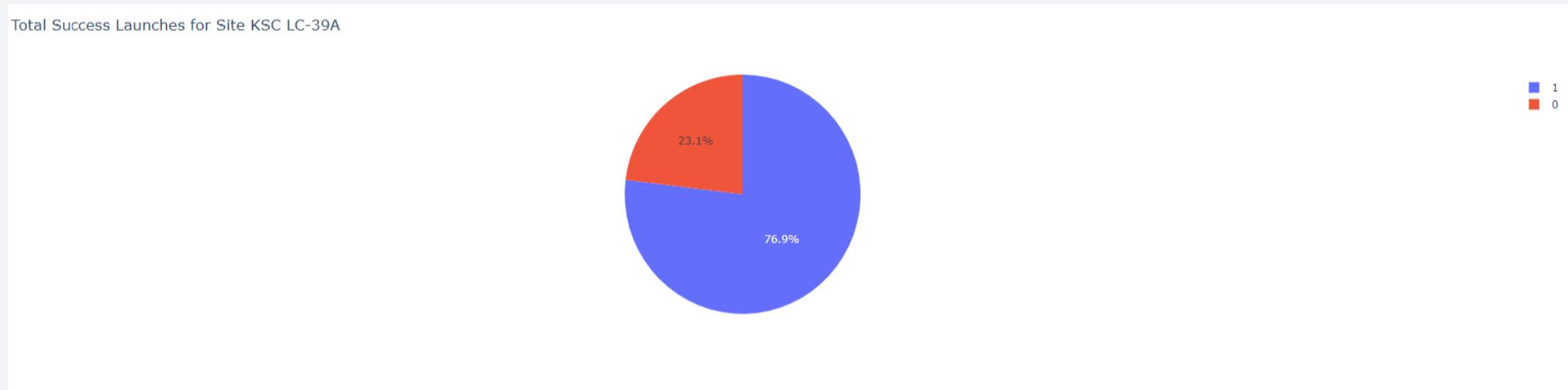
Dashboard - Total success by Site

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



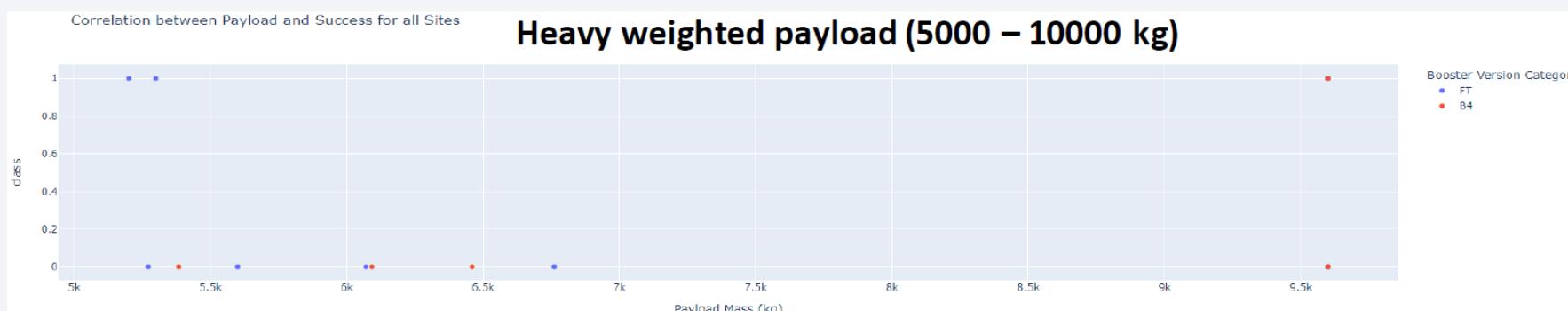
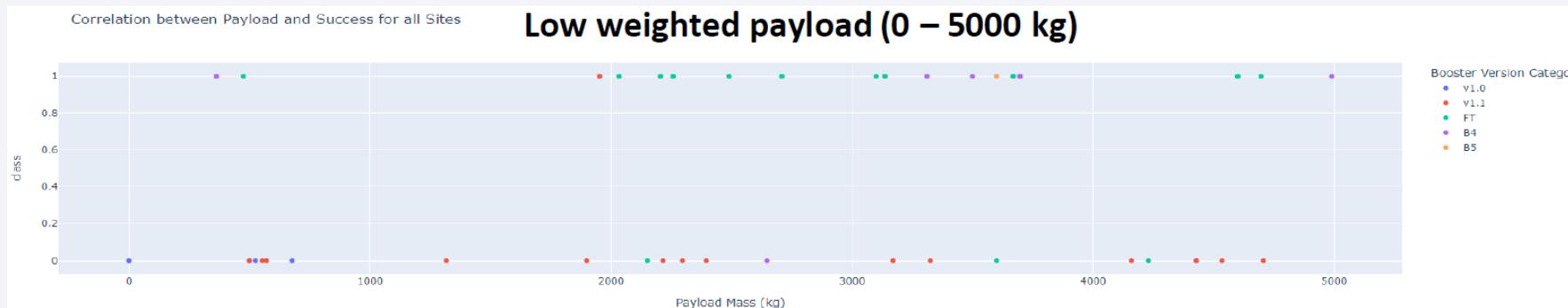
Dashboard - Total success launches for Site KSC LC 39A

- 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, overlapping bands of color. A prominent band on the left is a bright blue, while another on the right is a warm yellow. These colors transition into lighter shades of blue and yellow towards the edges. The overall effect is one of motion and depth, suggesting a tunnel or a path through a digital space.

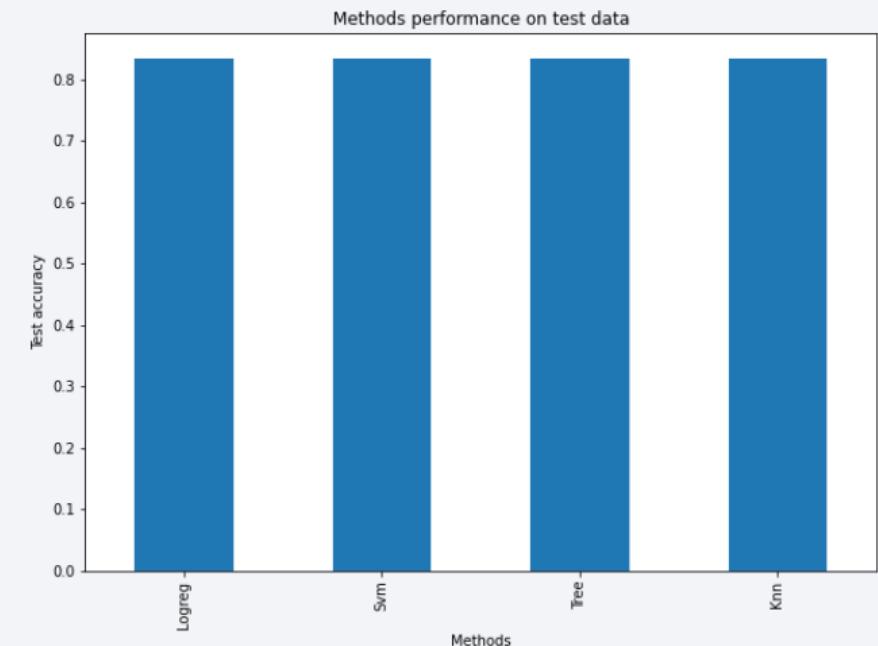
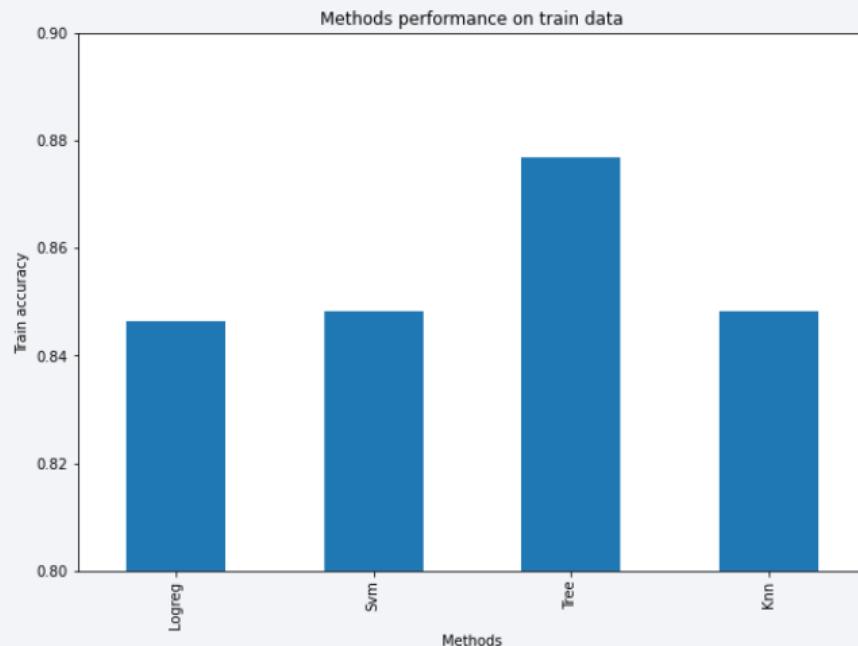
Section 5

Predictive Analysis (Classification)

Classification Accuracy

- For accuracy test, all methods performed similar: maybe decision tree.

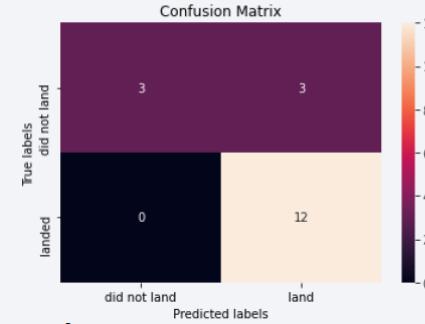
	Accuracy Train	Accuracy Test
Tree	0.876786	0.833333
Knn	0.848214	0.833333
Svm	0.848214	0.833333
Logreg	0.846429	0.833333



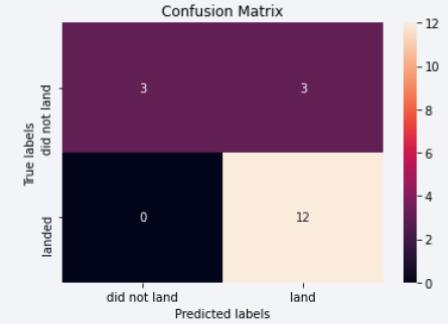
Confusion Matrix

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

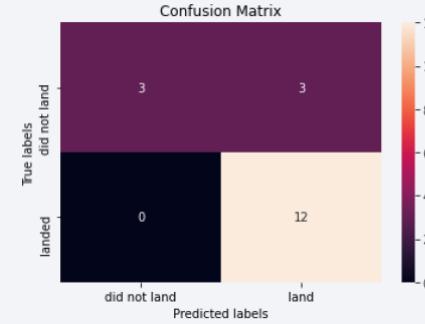
Logistic regression



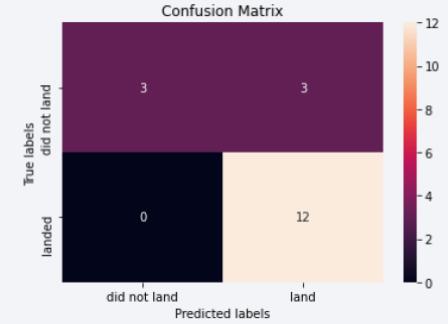
Decision Tree



kNN



SVM



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 L1.
- 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 (KSC LC-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!

