Winning Space Race with Data Science

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GitHub: https://github.com/ssharifigolru/Applied-Data-Science-Capstone-IBM-Course

Outline

- Executive Summary
- Introduction
- Methodology
- Results
- Conclusion

Executive Summary

Summary of methodologies

- Data collection (request from SpaceX API) by Webscraping
- Data wrangling
- Exploratory Data Analysis (EDA) Using Data Visualization and SQL
- Building an interactive map with Folium
- Building a Dashboard with Plotly Dash
- Classification Predictive Analysis

Summary of all results

- EDA Results
- ML Results

Introduction

- **Project background and context**

  SpaceX advertises Falcon 9 rocket launches on its website with a cost of $62 million, a significantly lower cost compared to the $165 million estimated by other providers. The distinctive feature of SpaceX lies in the ability to reuse the rocket following a successful first-stage landing. Hence, increasing the frequency of successful first-stage landings is crucial for maximizing rocket reuse and minimizing costs.

- **Problems you want to find answers**

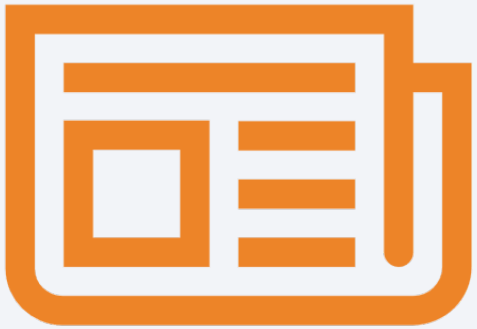
  The objective of the project is to forecast the successful landing of the first stage of the SpaceX Falcon 9 rocket. Rather than tackling complex mathematical and physics equations, our approach involves leveraging data science to create a machine learning model. This model will be developed using historical observational data from previous Falcon 9 launches.

Section 1

Methodology

Methodology

Executive Summary:

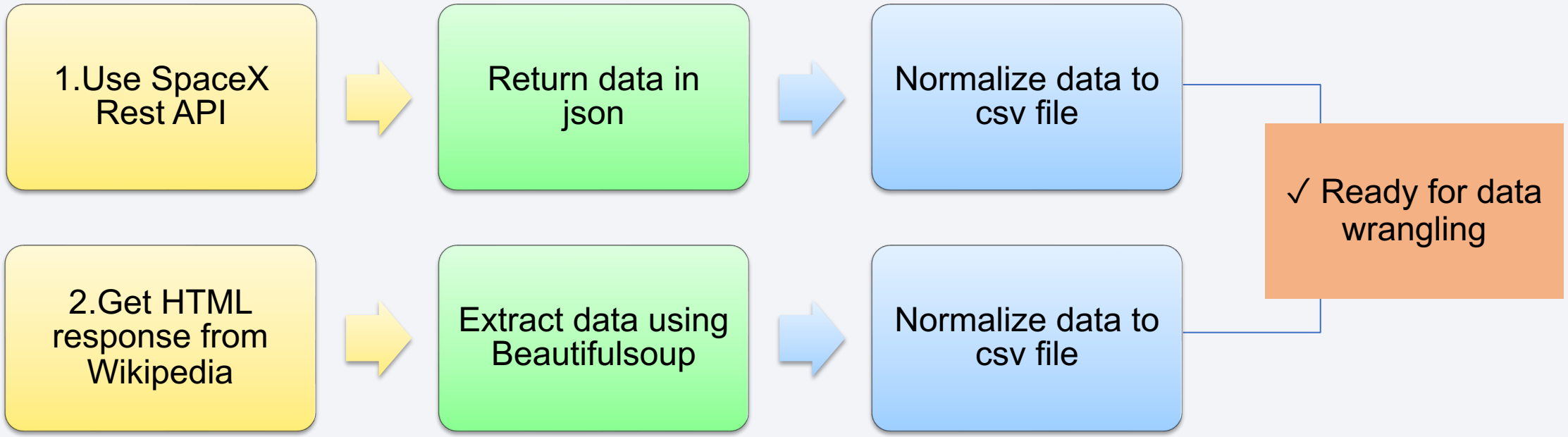


1. Data collection methodology:
   - SpaceX's API Website
   - Web scraping data : Extract a Falcon 9 launch records HTML table from Wikipedia
2. Perform data wrangling
   - Identify the missing values in each attribute
   - Replacing missing numerical data with the mean value of parameter
   - Using One Hot Encoding to transform categorical variables to numerical ones
3. Perform exploratory data analysis (EDA) using visualization and SQL
   - Utilizing categorical, bar, and scatter plots to visually represent data and discern relationships between parameters
   - Using SQL queries to perfom the data analysis process
4. Perform interactive visual analytics using Folium and Plotly Dash
   - Interactive Plotly Dashboard to visualize payload and success launch data
   - Using interactive Folium Maps to explore Launch Sites
5. Perform predictive analysis using classification models
   - Standardizing parameters
   - Predictive multiple classification models (Logistic, SVM, Decision Tree, KNN)
   - Finding Best performance model

Data Collection

SpaceX launch data that is gathered from the SpaceX REST API or web scraping Wiki.

1. Using SpaceX REST API to gather data on rocket launches: https://api.spacexdata.com/v4
2. Other data source for collecting Falcon 9 Launch data is web scraping Wikipedia using Beautiful Soup.



Link to : Data collection using API

Data Collection – SpaceX API

1- Request data frame from SpaceX API

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

response = requests.get(spacex_url)
```

2- Transform the json file to a Pandas data frame

```
# Use json_normalize meethod to convert the json result into a dataframe

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

3- Extract required data and make lists

```
# Takes the dataset and uses the rocket column to call the API and append the data to the list
def getBoosterVersion(data):
    for x in data['rocket']:
       if x:
        response = requests.get("https://api.spacexdata.com/v4/rockets/"+str(x)).json()
        BoosterVersion.append(response['name'])
```

4- Transform lists to a data frame

```
# Create a data from launch_dict
df=pd.DataFrame(launch_dict)
```

5- Keep Falcon V9 boosters and remove others

```
data_falcon9=df[df['BoosterVersion']!='Falcon 1']
data_falcon9.head(5)
```

6- Convert data frame to a csv file

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

Link to: Data collection using web scraping

Data Collection - Scraping

1- Getting response from HTML

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

```
htmlpage.status_code
```

```
200
```

2- Creating BeautifulSoup object

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

3- Finding Tables

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

4- Getting column names

```
column_names = []
for i in first_launch_table.find_all('th'):
    if extract_column_from_header(i)!=None:
        if len(extract_column_from_header(i))>0:
            column_names.append(extract_column_from_header(i))
```

5- Creating disctionary

```
launch_dict= dict.fromkeys(column_names)

# Remove an irrelvant 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- Appending data to keys

```
extracted_row = 0
#Extract each table
for table_number,table in enumerate(soup.find_all('table',"wikitable plainrowheaders collapsible")):
   # get table row
    for rows in table.find_all("tr"):
        #check to see if first table heading is as number corresponding to launch a number
        if rows.th:
            if rows.th.string:
                flight_number=rows.th.string.strip()
                flag=flight_number.isdigit()
```

7-Create a dataframe from launch_dict

```
df= pd.DataFrame({ key:pd.Series(value) for key, value in launch_dict.items() })
```

8-Export data frame to a CSV file

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

Data Wrangling

Missing values

1.Finding missing values in each attribute

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

```
FlightNumber      0
Date              0
BoosterVersion    0
PayloadMass       5
Orbit             0
LaunchSite        0
Outcome           0
Flights           0
GridFins          0
Reused            0
Legs              0
LandingPad       26
Block             0
ReusedCount       0
Serial            0
Longitude         0
Latitude          0
dtype: int64
```

2.Imputing missing values ➔ replace missing values with Mean

```
Payloadmassmean=data_falcon9['PayloadMass'].mean()
# Replace the np.nan values with its mean value
data_falcon9['PayloadMass']=data_falcon9['PayloadMass'].replace(np.nan, Payloadmassmean)
```

Exploratory data analysis

1.Calculate the number of launches on 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
ES-L1     1
HEO       1
SO        1
GEO       1
Name: Orbit, dtype: int64
```

3.Calculate the 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
False Ocean     2
None ASDS       2
False RTLS      1
Name: Outcome, dtype: int64
```

4.Create landing outcome label from Outc column

```
def  function(item):
    if item in bad_outcomes:
        return 0
    else:
        return 1
landing_class = df["Outcome"].apply(function)
landing_class
```

```
df['Class']=landing_class
df[['Class']].head(8)
```

5.Export results to CSV

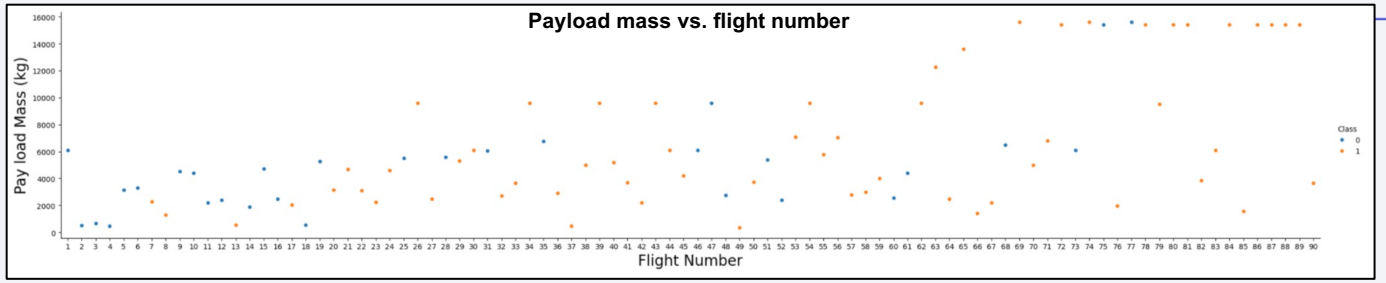
```
df.to_csv("dataset_part_2.csv", index=False)
```

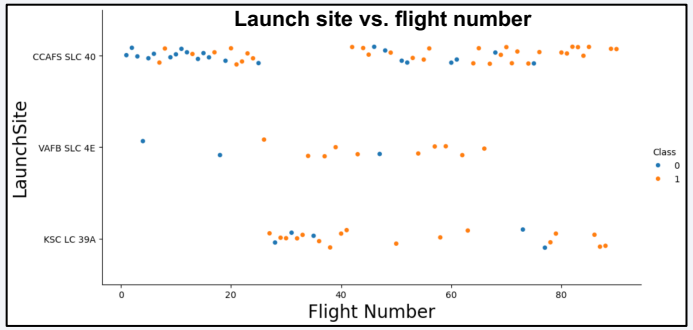
Link to : Data collection using API

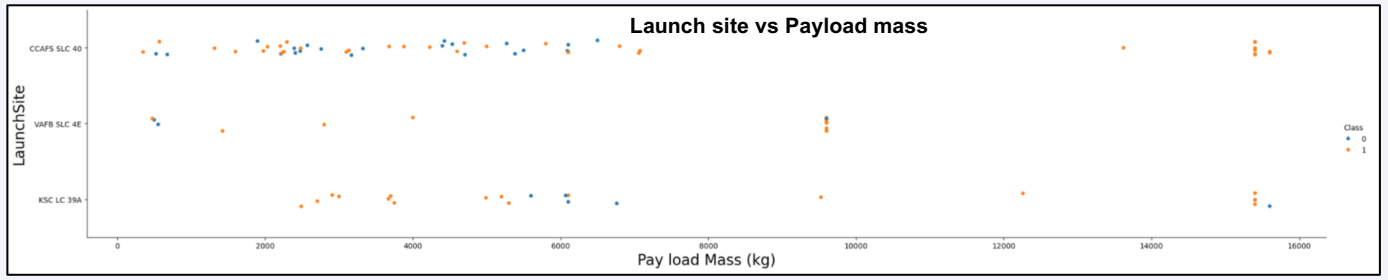
Link to: Data wrangling

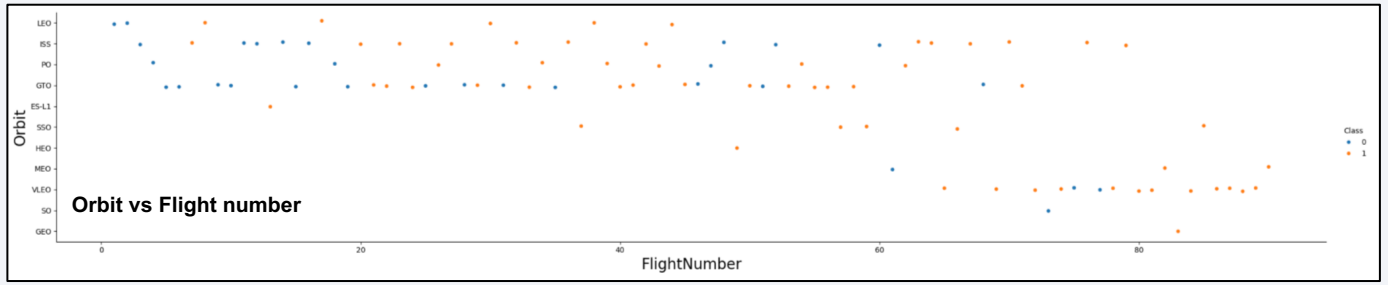
Link to: EDA with data visualization

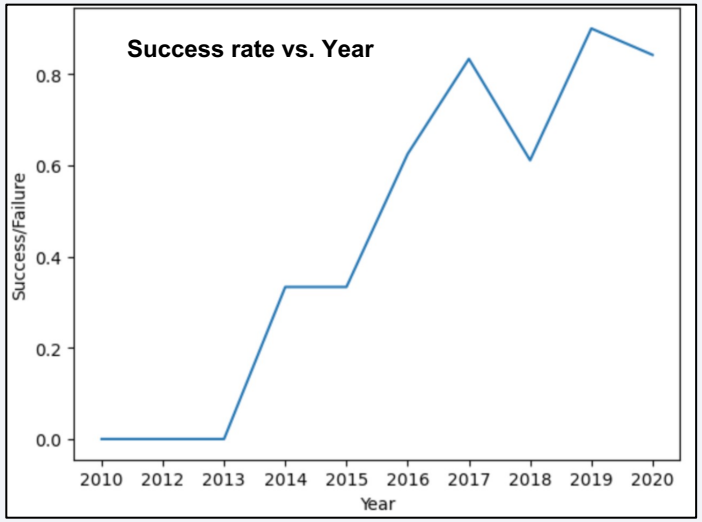
EDA with Data Visualization

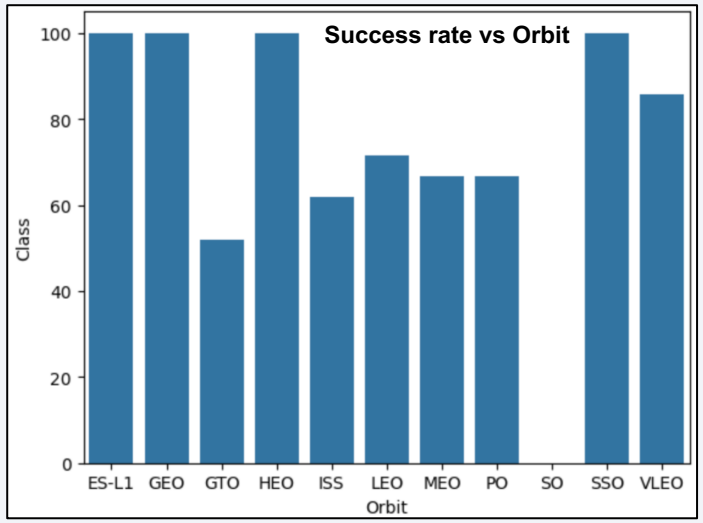








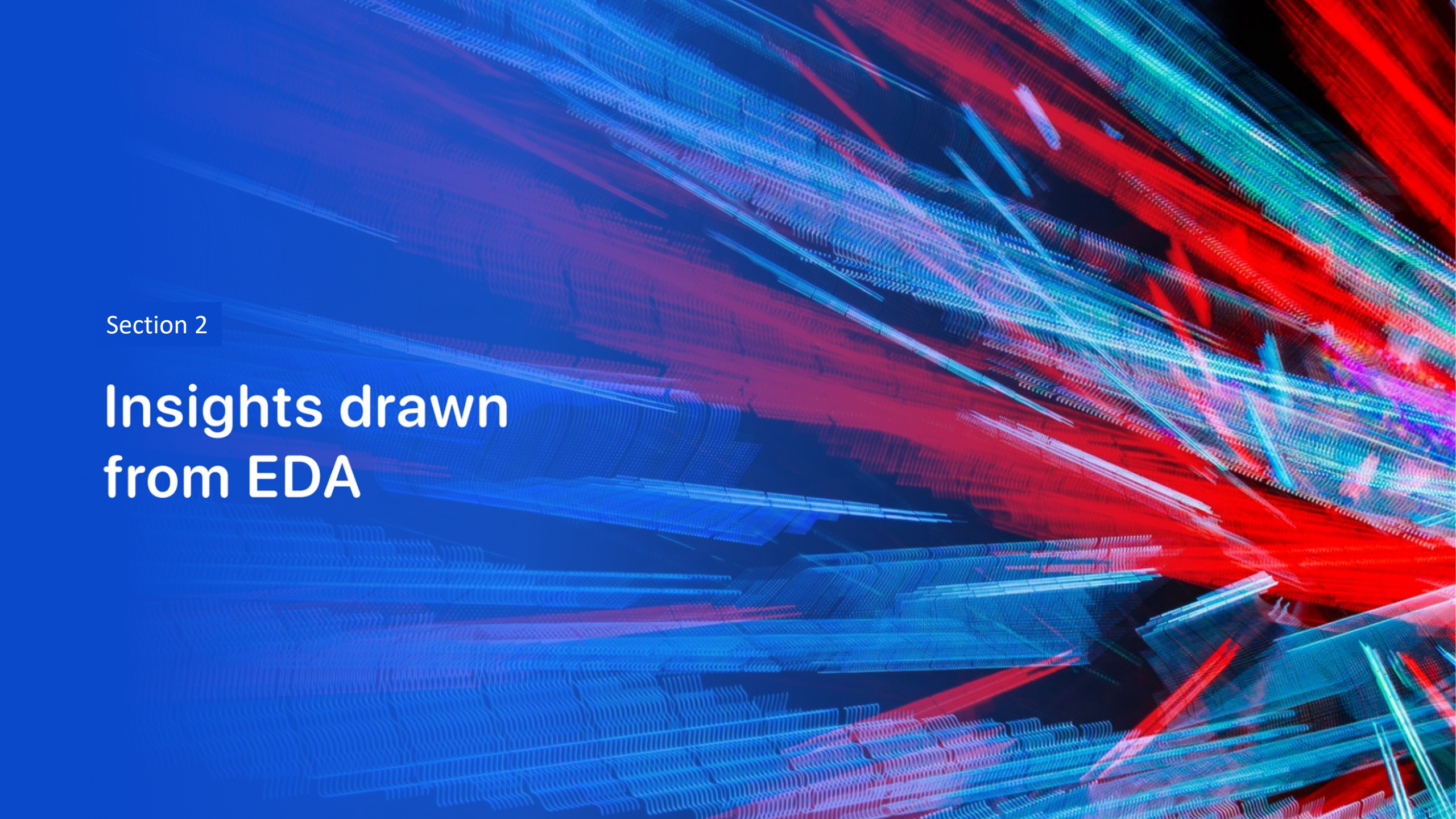




Link to: EDA with SQL

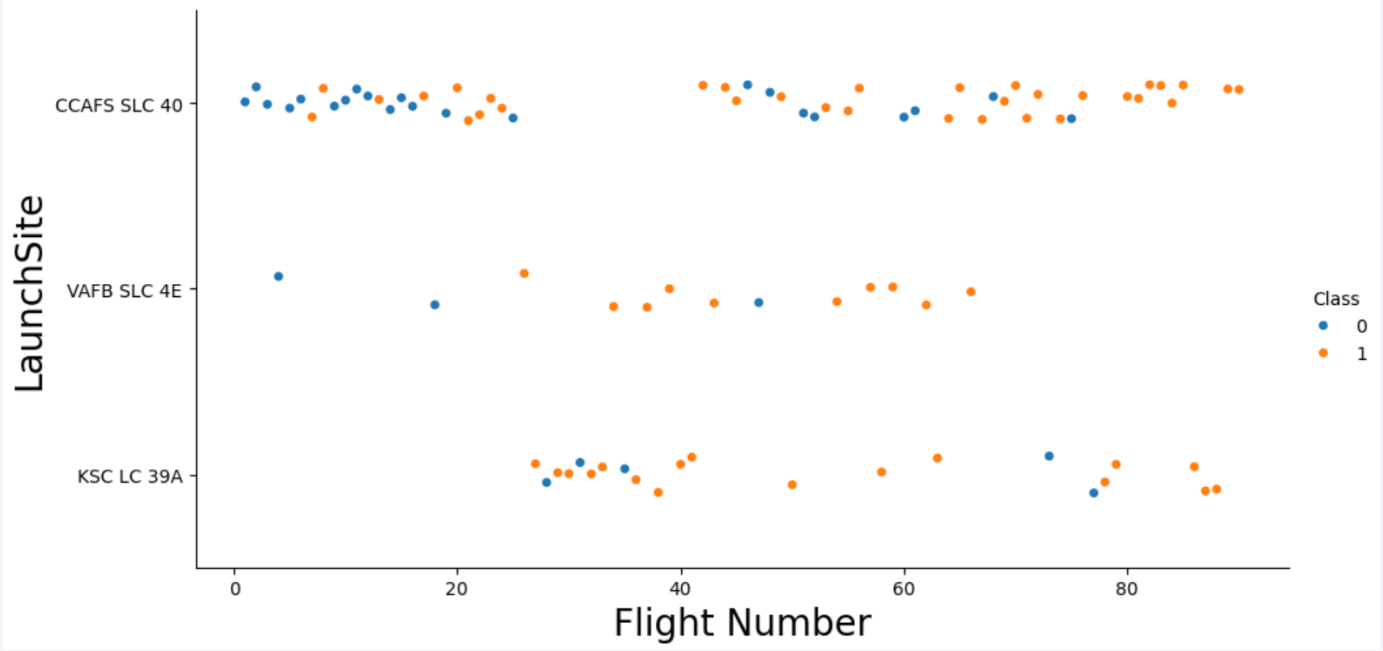
EDA with SQL

- Displaying the names of the unique launch sites in the space mission
- Displaying 5 records where launch sites begin with the string 'KSC
- Displaying the total payload mass carried by boosters launched by NASA (CRS)
- Displaying average payload mass carried by booster version F9 v1.1
- Listing the date when the first successful landing outcome in ground pad was achieved.
- Listing the names of the boosters which have success in ground pad and have payload mass greater than 4000 but less than 6000
- Listing the total number of successful and failure mission outcomes
- Listing the names of the booster versions which have carried the maximum payload mass
- Listing the records which will display the month names, successful landing outcomes in ground pad booster versions, launch months in year 2015
- Ranking the count of landing outcomes between the date 2010-06-04 and 2017-03-20, in descending order.


Section 2
Insights drawn
from EDA

Link to: EDA with data visualization

Flight Number vs. Launch Site

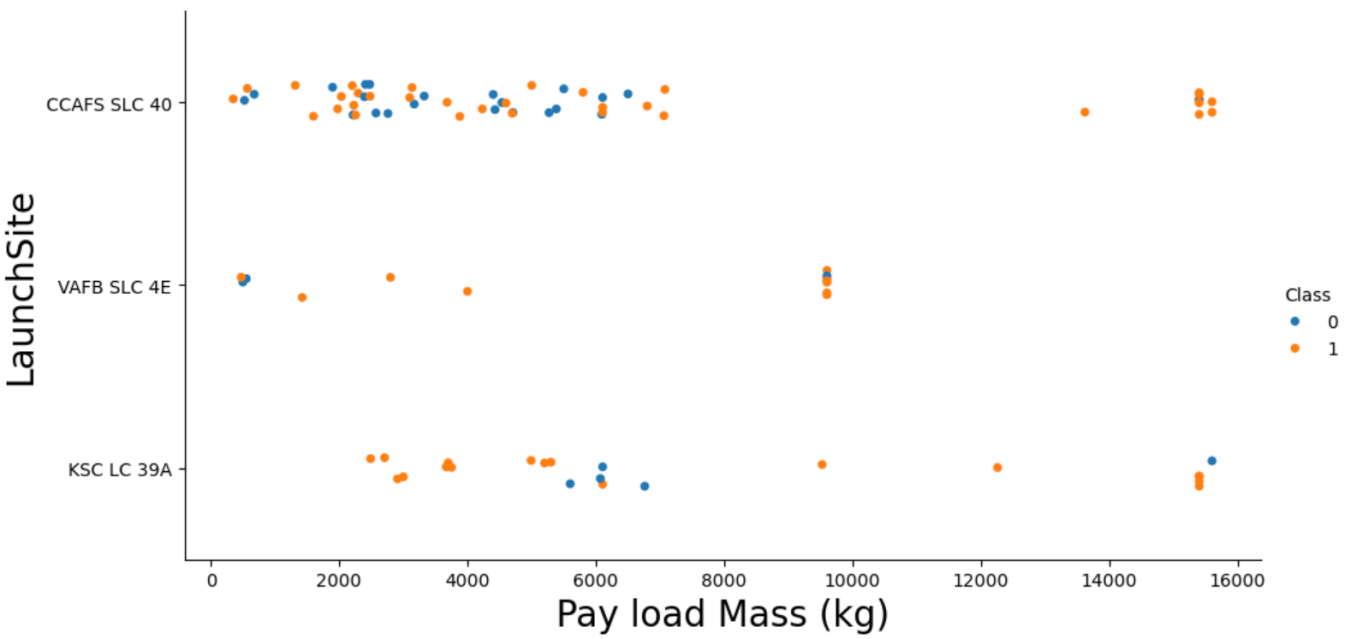


CCAFS LC-40 has a success rate of 60 %, while KSC LC-39A and VAFB SLC 4E have a success rate of 77%.

- **Launch Site: CCAFS SLC 40**: Flight numbers<20 ➔ mostly failed, 80<Flight numbers ➔ mostly successful, This launch site has the highest number of launches compared to other sites.
- **Launch Site_VAFB SLC 4E**: 20<Flight numbers ➔ mostly successfully
- **Launch Site_ KSL LC 39A:** 20<Flight numbers<40 ➔ mostly successful

Link to: EDA with data visualization

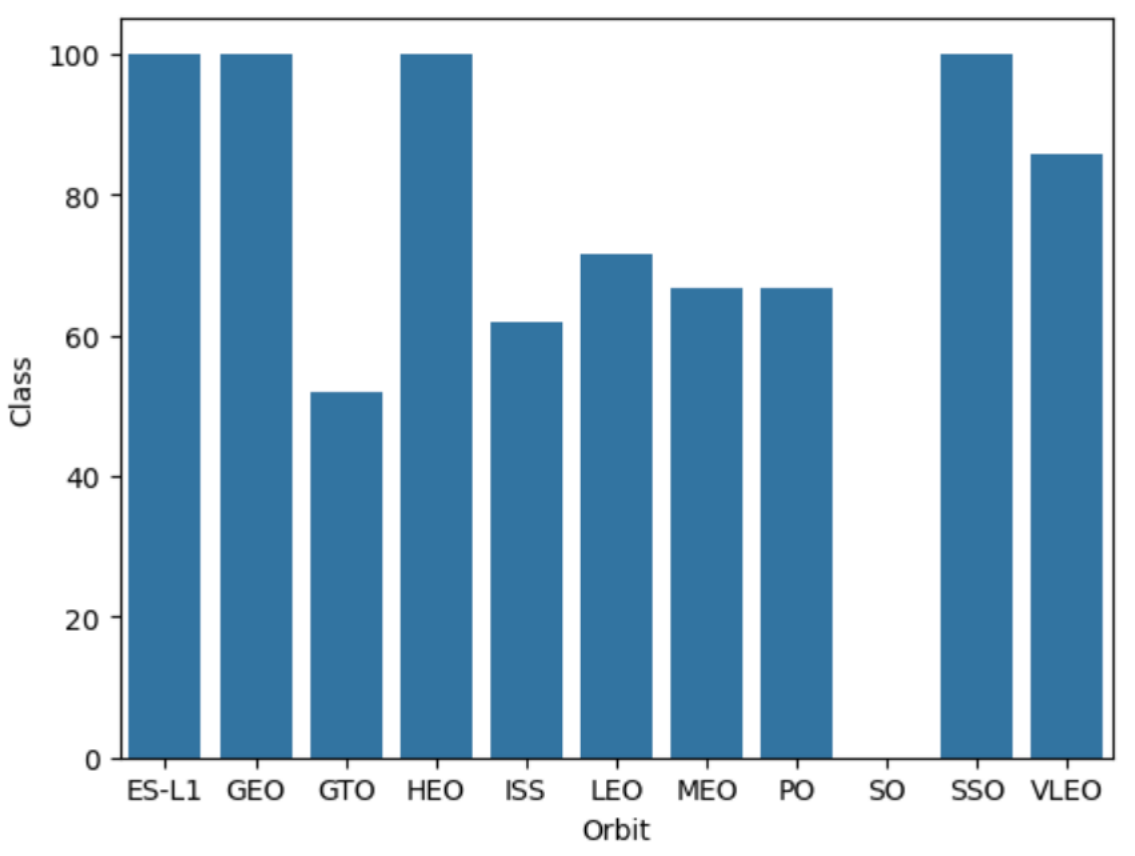
Payload vs. Launch Site



- CCAFS SLC 40: launches with higher pay load mass have higher success probability.
- VAFB-SLC 4E launch site: No rockets launched for payload mass greater than 10000.

Link to: EDA with data visualization

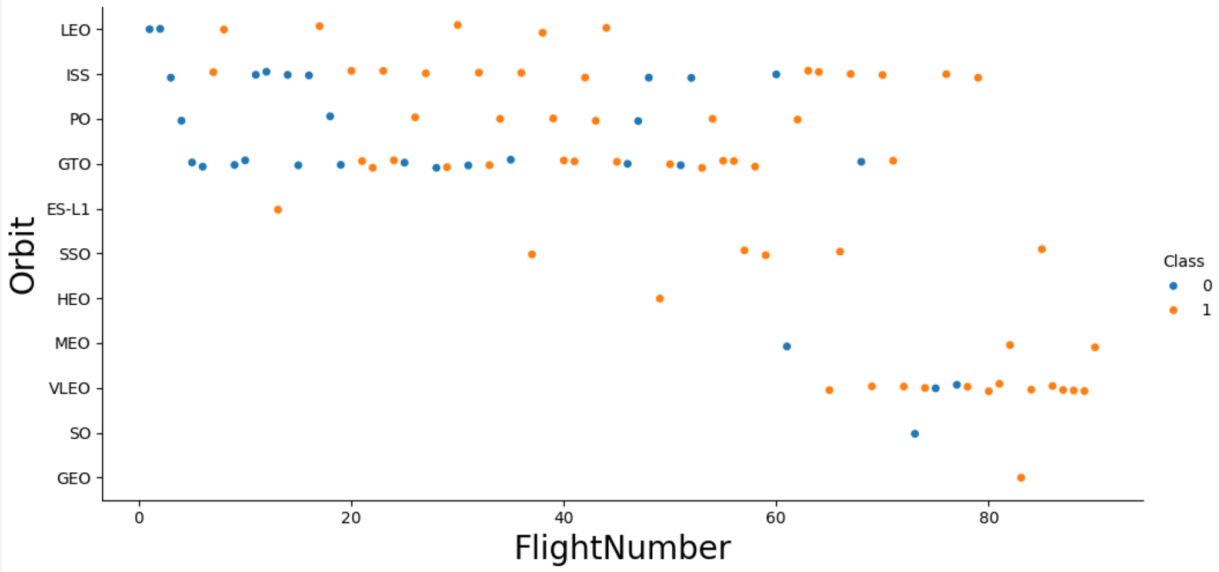
Success Rate vs. Orbit Type



- ES-L1, GEO, HEO, and SSO ➔ Success rate of 100%
- VLEO ➔> 80% success rate
- LEO ➔ >70% success

Link to: EDA with data visualization

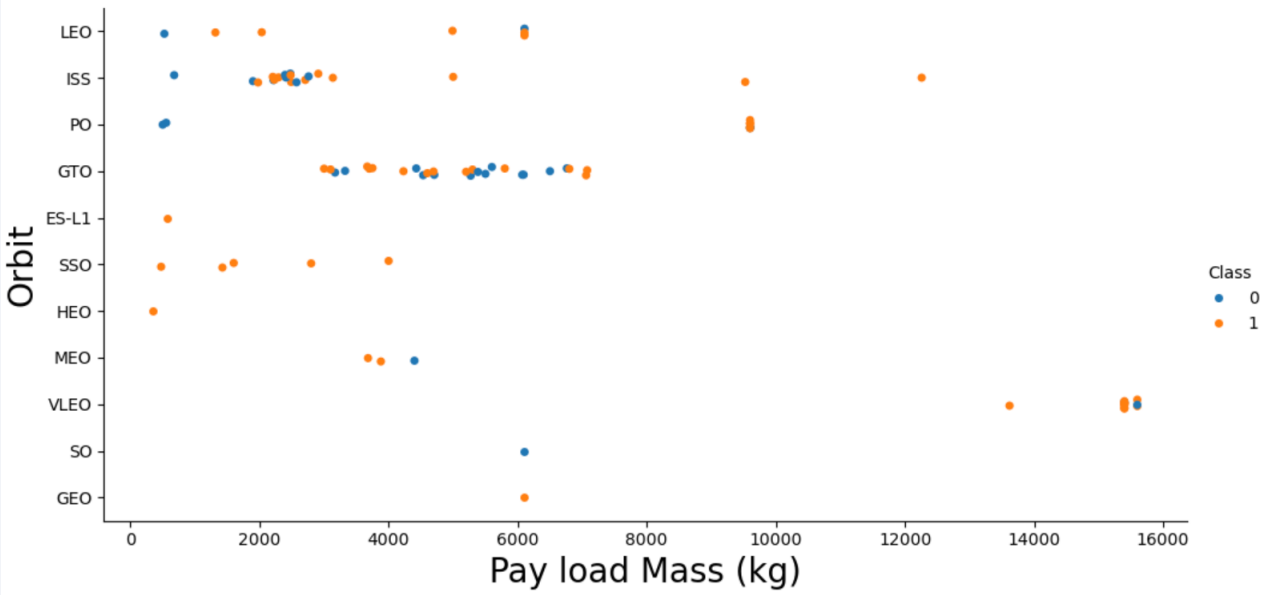
Flight Number vs. Orbit Type



- ISS, GTO, LEO, MEO, & VLEO orbits: higher flight number ➔higher chance of success
- SSO, ES-L1, GEO & HEO orbits: 100% success for all flight numbers

Link to: EDA with data visualization

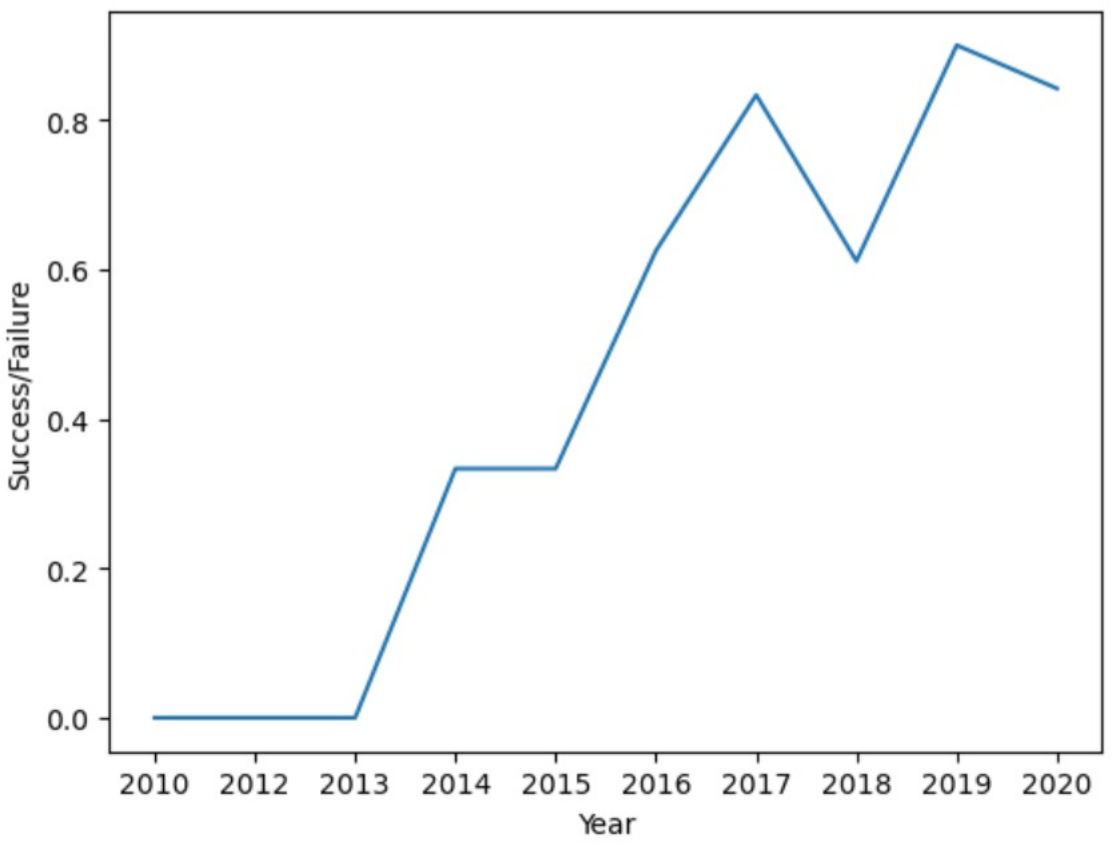
Payload vs. Orbit Type



- Most of launches for ISS orbit have pay load mass of 2000 to 4000kg.
- Most of launches for GTO orbit have pay load mass of 3000 to 8000kg.

Link to: EDA with data visualization

Launch Success Yearly Trend



- The success rate was zero before 2013, and it has increased over time. However, a decline in the success rate was observed in 2018 and 2020.
- Maximum success rate (0.9) happened in 2019.

All Launch Site Names

```
%sql SELECT DISTINCT LAUNCH_SITE FROM SPACEXTBL;
```

```
 * sqlite:///my_data1.db
Done.
```

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

- "DISTINCT" is used to list the unique categories or values present in a specific column of data set.

Link to: EDA with SQL

Launch Site Names Begin with 'CCA'

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

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

```
 * sqlite:///my_data1.db
Done.
```

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing_
2010-06-04	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (p
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 (p
2012-05-22	7:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	N
2012-10-08	0:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	N
2013-03-01	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	N

Link to: EDA with SQL

Total Payload Mass

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

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

```
 * sqlite:///my_data1.db
Done.
```

SUM(PAYLOAD_MASS__KG_)
45596

- SUM function is used to calculate The total payload mass for customers with the name 'NASA (CRS)'
  .

Link to: EDA with SQL

Average Payload Mass by F9 v1.1

Display average payload mass carried by booster version F9 v1.1

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

```
 * sqlite:///my_data1.db
Done.
```

AVG(PAYLOAD_MASS__KG_)
2928.4

- AVG function was used to calculate the average payload mass carried by booster version F9 v1.1.

Link to: EDA with SQL

First Successful Ground Landing Date

List the date when the first succesful landing outcome in ground pad was acheived.

Hint:Use min function

```
%sql SELECT MIN(DATE) FROM SPACEXTBL WHERE LANDING_OUTCOME='Success (ground pad)';
```

```
 * sqlite:///my_data1.db
Done.
```

MIN(DATE)
2015-12-22

- SQL query was used to find the date of the first successful ground pad landing.

Link to: EDA with SQL

Successful Drone Ship Landing with Payload between 4000 and 6000

List the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000

```
%sql SELECT Booster_Version FROM SPACEXTBL WHERE Landing_Outcome = 'Success (drone ship)' AND PAYLOAD_MASS__KG_ >
```

```
 * sqlite:///my_data1.db
Done.
```

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

- Using the keywords “BETWEEN” and “AND”, the names of boosters that had payload masses between 4000kg and 6000kg and had successfully landed on a drone ship were shown.

Link to: EDA with SQL

Total Number of Successful and Failure Mission Outcomes

List the total number of successful and failure mission outcomes

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

```
 * sqlite:///my_data1.db
Done.
```

Mission_Outcome	Total_Count
Failure (in flight)	1
Success	98
Success	1
Success (payload status unclear)	1

- COUNT function was used to calculate the total number of successful and failed missions.
- Results show that there were 100 successful missions and 1 failed mission.

Link to: EDA with SQL

Boosters Carried Maximum Payload

List the names of the booster_versions which have carried the maximum payload mass. Use a subquery

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

```
 * sqlite:///my_data1.db
Done.
```

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

- The boosters that carried the maximum payload were lisetd using a sub-query with the MAX function, and a total of 12 were found.

Link to: EDA with SQL

2015 Launch Records

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.

Note: SQLLite does not support monthnames. So you need to use substr(Date, 6,2) as month to get the months and substr(Date,0,5)='2015' for year.

```
%sql SELECT substr(Date,4,2) as month, DATE,BOOSTER_VERSION, LAUNCH_SITE,Landing_Outcome FROM SPACEXTBL where (La
```

```
 * sqlite:///my_data1.db
(sqlite3.OperationalError) incomplete input
[SQL: SELECT substr(Date,4,2) as month, DATE,BOOSTER_VERSION, LAUNCH_SITE,Landing_Outcome FROM SPACEXTBL where (Lan
ding_Outcome = 'Failure (drone ship)' and substr(Date,7,4)='2015']
(Background on this error at: http://sqlalche.me/e/e3q8)
```

```
%sql SELECT substr(Date,6,2) AS Month, substr(Date,1,4) AS Year, DATE, BOOSTER_VERSION, LAUNCH_SITE, Landing_Outc
```

```
 * sqlite:///my_data1.db
Done.
```

Month	Year	Date	Booster_Version	Launch_Site	Landing_Outcome
01	2015	2015-01-10	F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)
04	2015	2015-04-14	F9 v1.1 B1015	CCAFS LC-40	Failure (drone ship)

- Results show that landing outcome of Failure (Drone Ship) and launch date in the year 2015

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

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.

```
%sql SELECT Date, Landing_Outcome, COUNT(*) AS Count_Landing_Outcome FROM SPACEXTBL WHERE Date BETWEEN '2010-06-0
```

```
 * sqlite:///my_data1.db
Done.
```

Date	Landing_Outcome	Count_Landing_Outcome
2012-05-22	No attempt	10
2016-04-08	Success (drone ship)	5
2015-01-10	Failure (drone ship)	5
2015-12-22	Success (ground pad)	3
2014-04-18	Controlled (ocean)	3
2013-09-29	Uncontrolled (ocean)	2
2010-06-04	Failure (parachute)	2
2015-06-28	Precluded (drone ship)	1

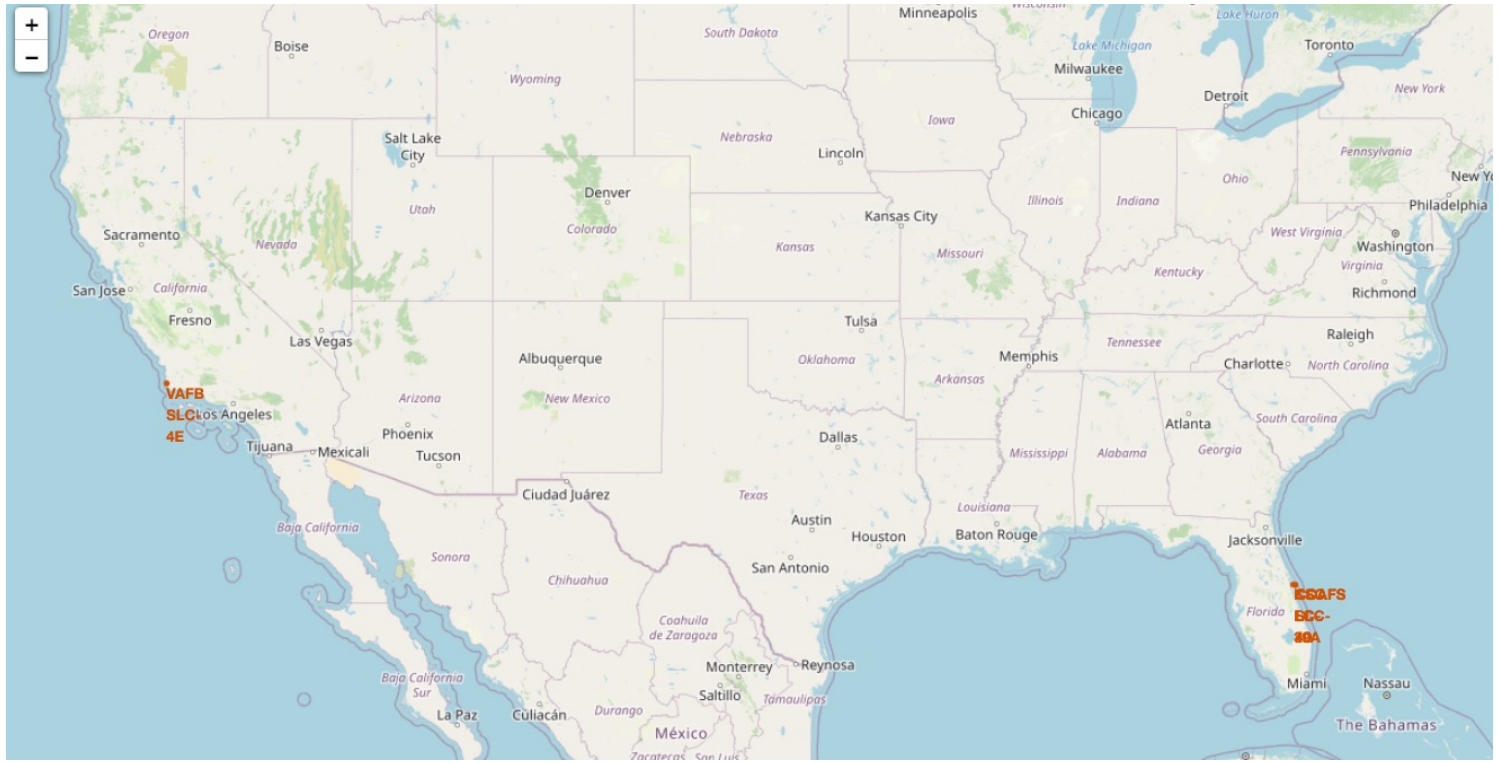
- Landing outcomes from 2010-06-04 to 2017-03-20 were listed and sorted in descending order.

Section 3

Launch Sites Proximities Analysis

Link to: Launch Sites Locations Analysis with Folium

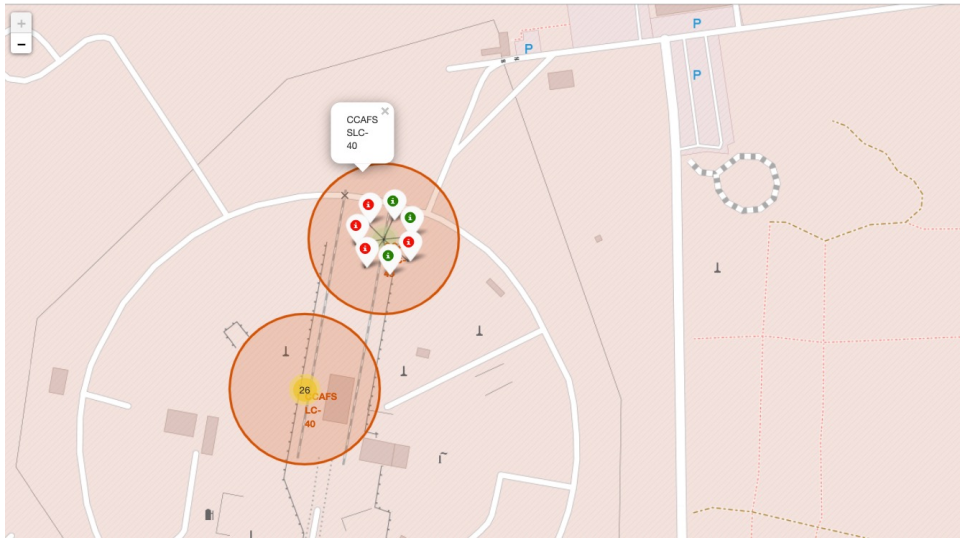
Interactive map with Folium: Launch site locations for SpaceX Falcon 9



This analysis shows that launch sites are located on the west coast in California, and the east coast in Florida.

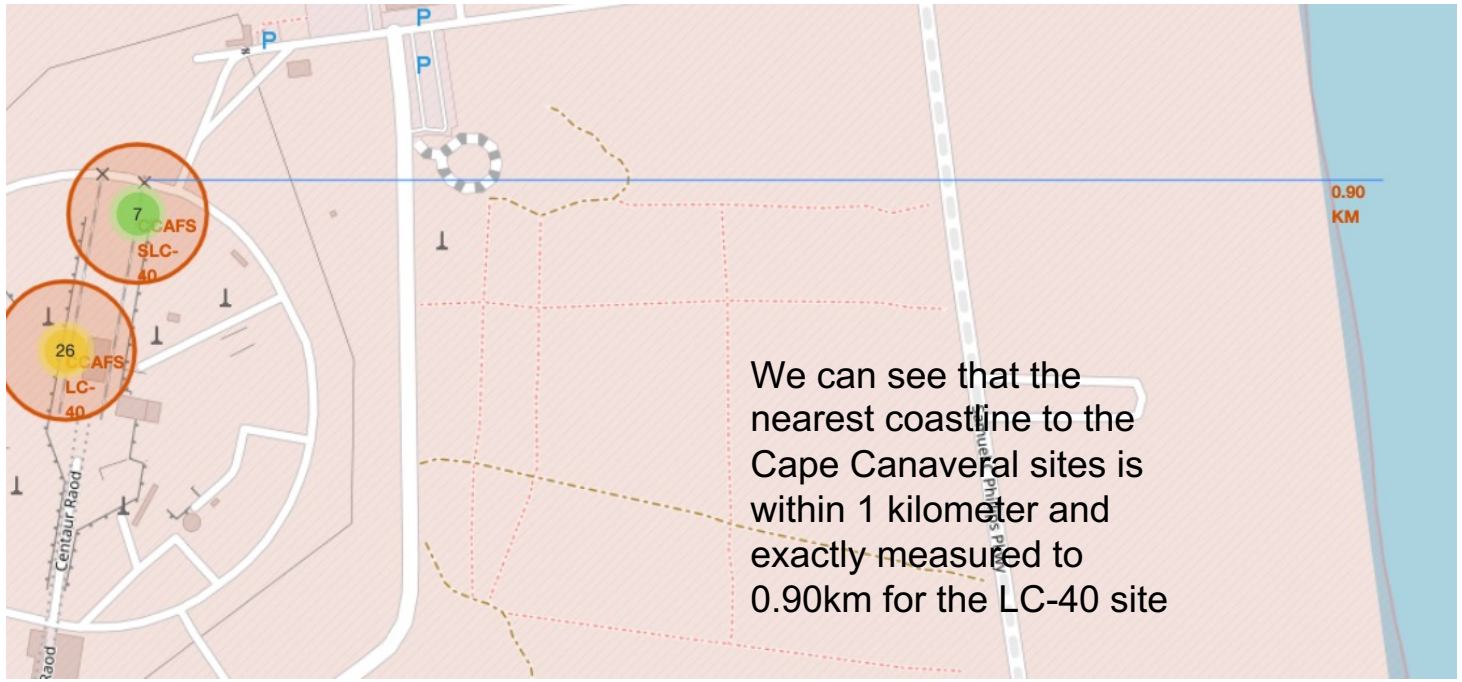
[Link to: Launch Sites Locations Analysis with Folium]

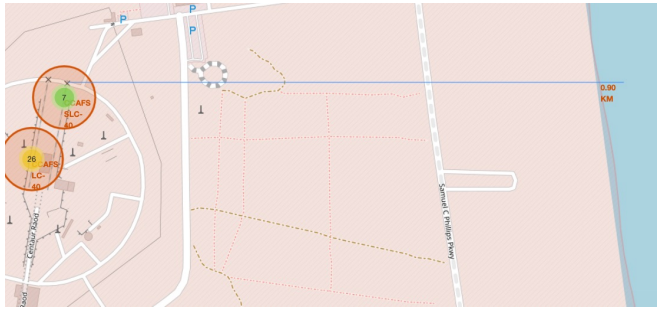
Interactive map with Folium: Successful/failed launches for each site

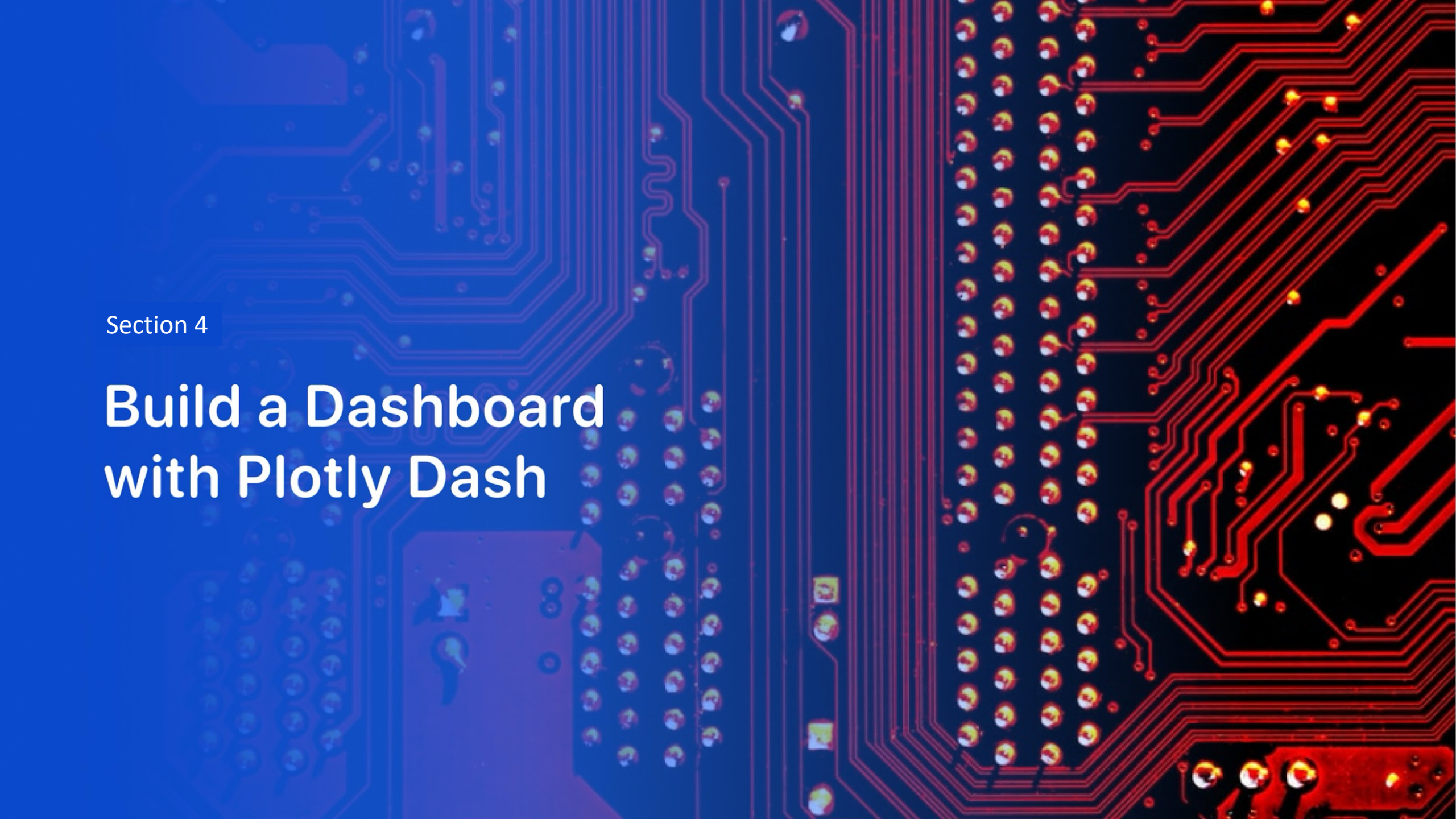


Link to: Launch Sites Locations Analysis with Folium

Interactive map with Folium: Launch site distance from coastline

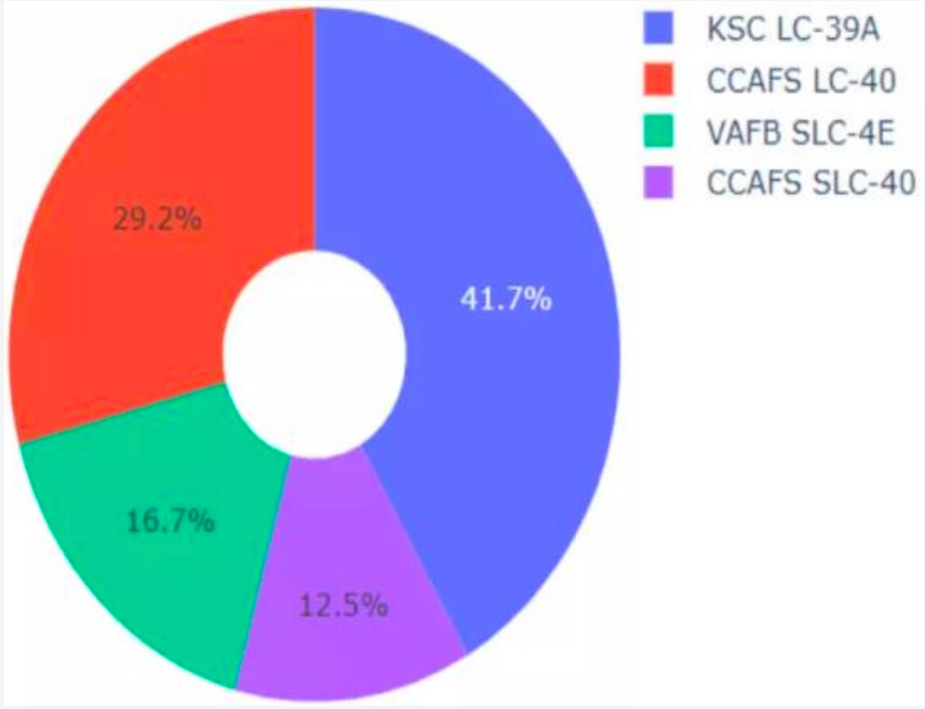





Section 4
Build a Dashboard with Plotly Dash

Link to: Dashboard with Plotly Dash

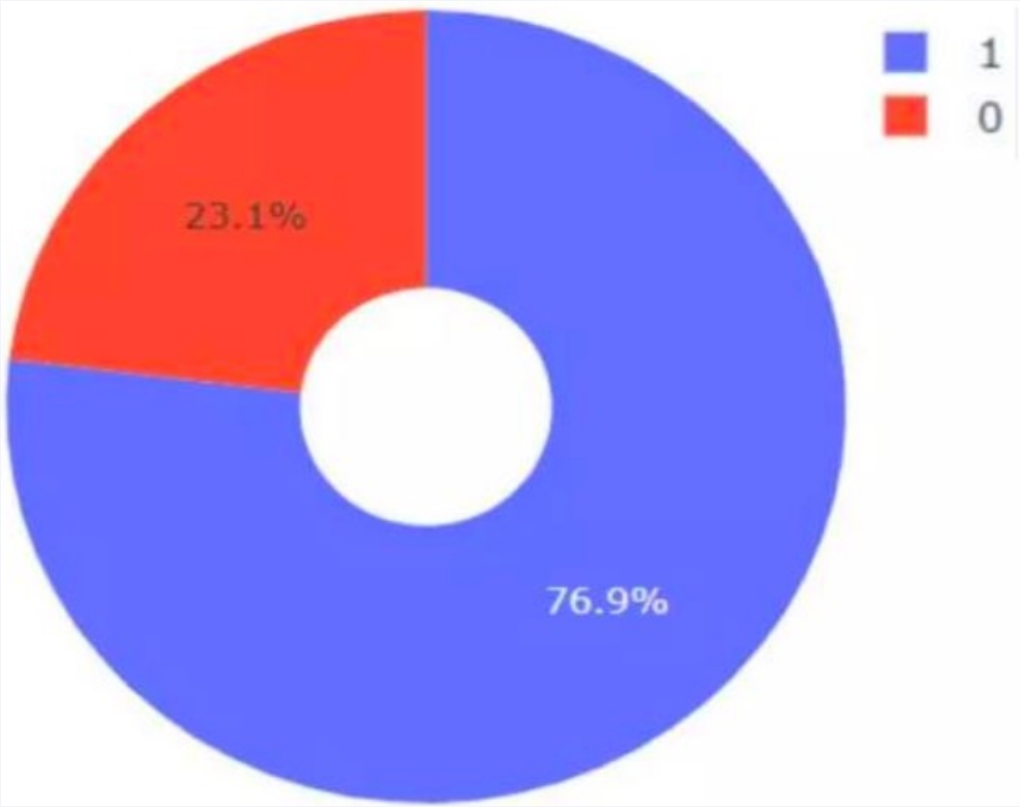
Pie chart for launch success count for all sites



KSC LC-39A Launch site ➔ Most successful launches compared to other sites (41.7%)

Link to: Dashboard with Plotly Dash

Pie chart for KSC LC-39A launch site which has the highest launch success ratio

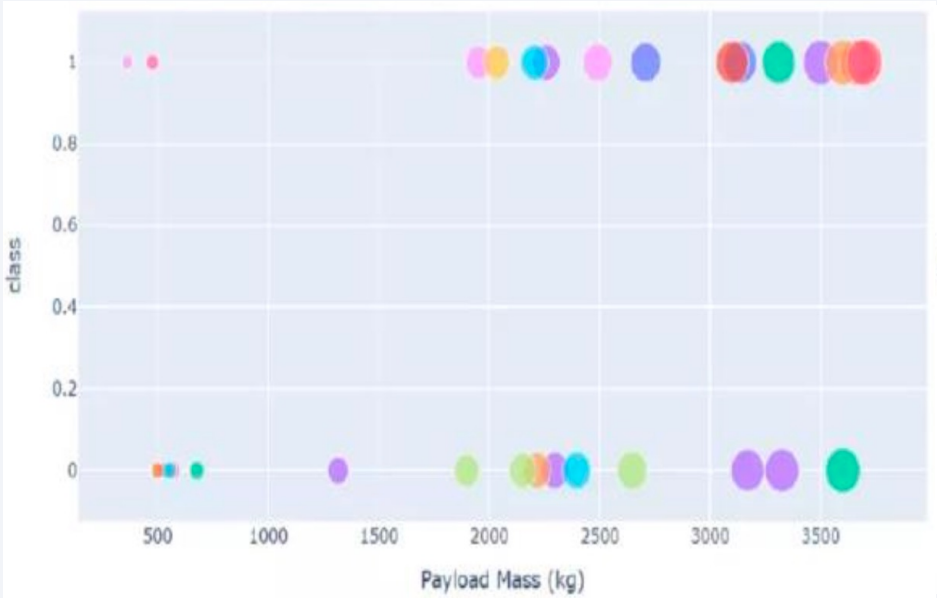


KSC LC-39A launch sit ➔ 76.9% success rate, and 23.1% failure rate.

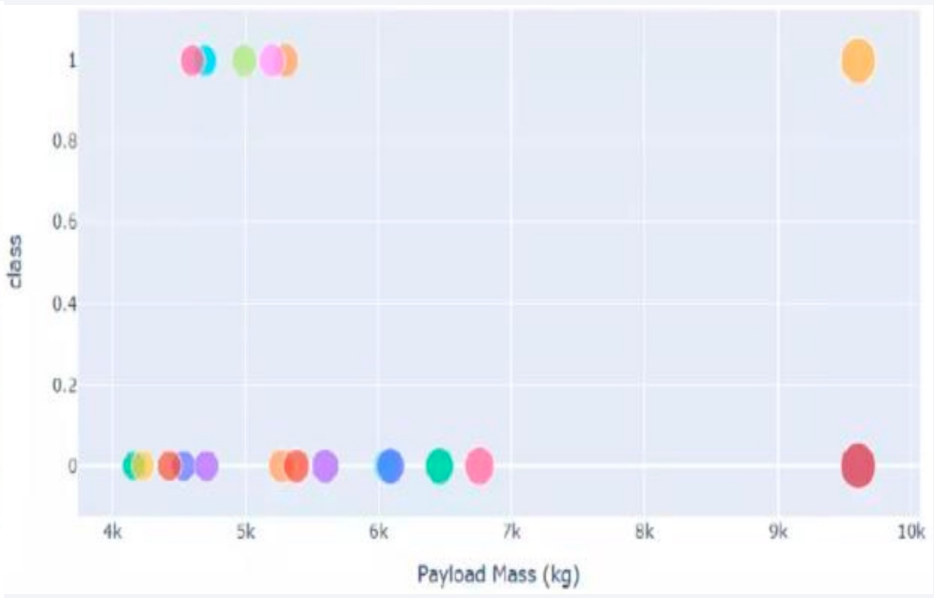
Link to: Dashboard with Plotly Dash

Payload vs. Launch Outcome scatter plot for all sites

Low weighted payload (0 kg to 4000 kg)



Heavy weighted payload (4000 kg to 10000 kg)

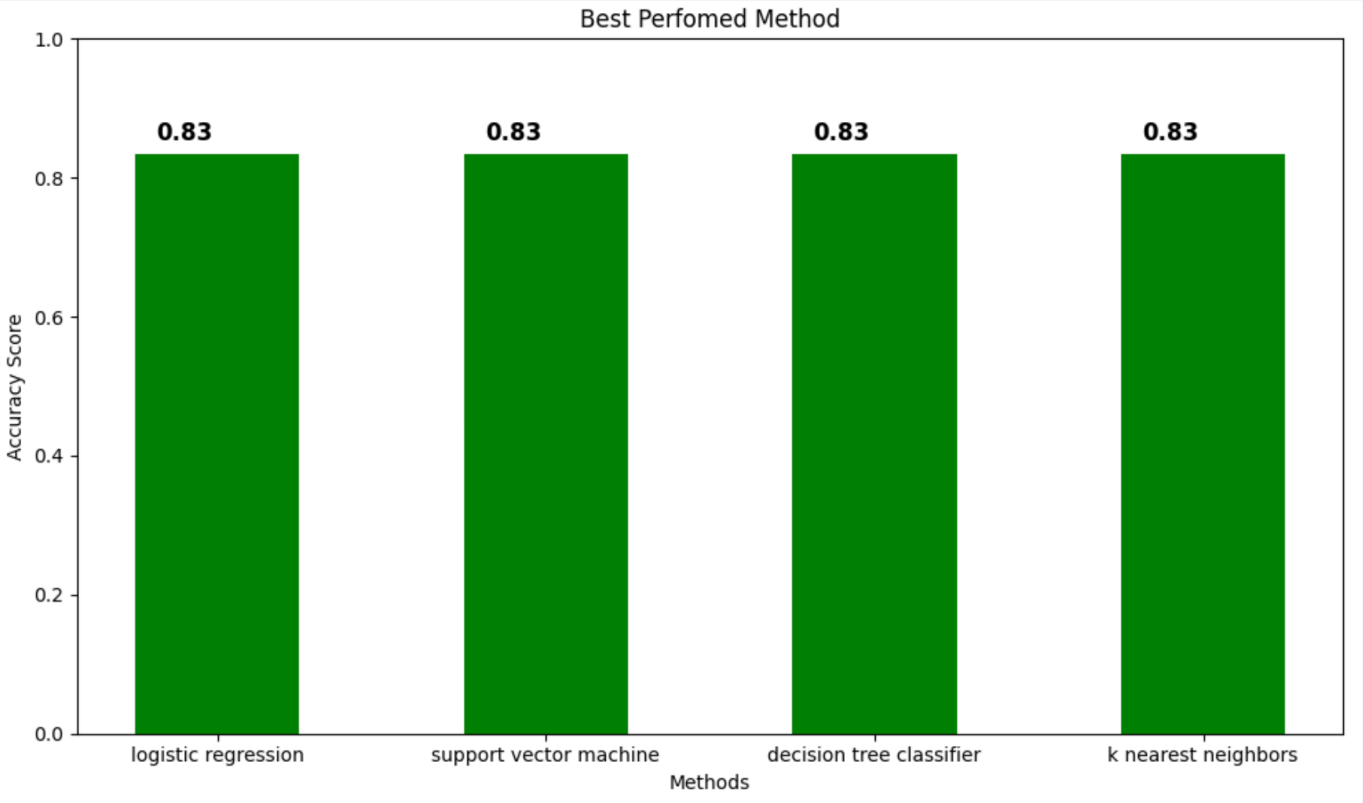


Success rates for low weighted is higher than heavy weighted payload!

Predictive Analysis (Classification)

Link to: ML prediction

Classification Accuracy



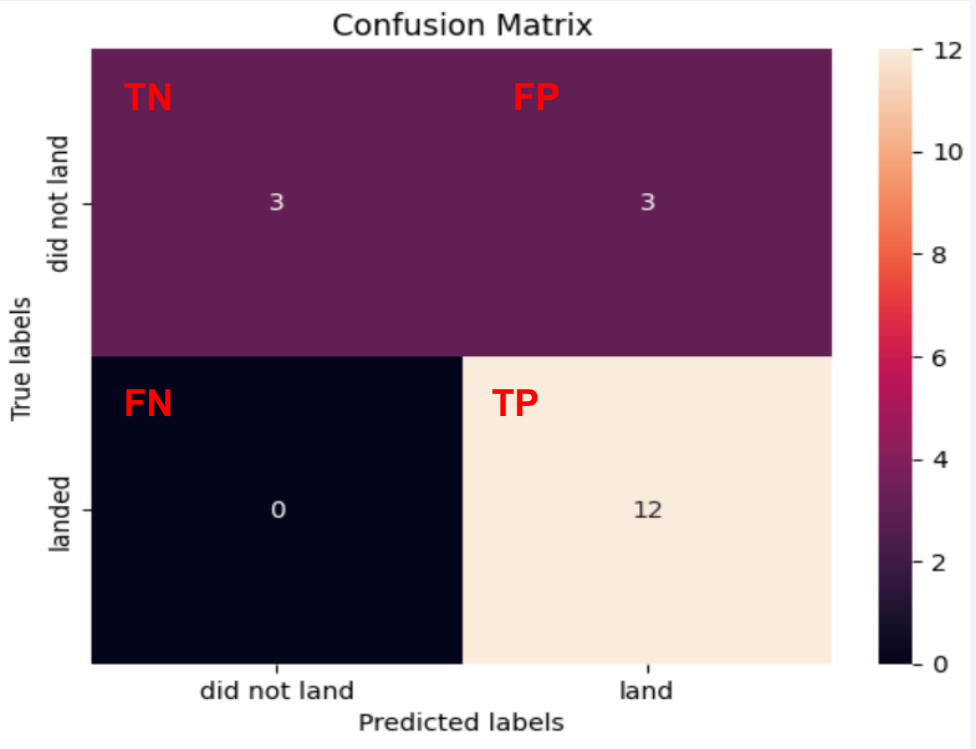
Accuracy scores for all four models are the same.

Confusion Matrix for all models

Confusion matrix for all four models are also the same.

We see that among 18 samples,15 sample were correctly predicted (3TN+12TP), and 3 samples were not predicted correctly (0FN+3FP).

- Sensitivity: 12/(12+0)=100%
- Specificity = 3/(3+3) = 50%
- Accuracy: (3+12)/(3+3+0+12)=83%



Conclusions

- All Models showed the same accuracy (%83) and confusion matrix in this analysis.
- Low-weighted payloads perform better than the heavier payloads.
- KSC LC-39A Launch Site has the highest probability of success rate.
- ES-L1, SSO, HEO and GEO Orbits have the highest rate of landing successfully.
- The success rate for SpaceX launches has improved by time from years 2013 to 2020.

Thank you!