



IBM Developer  
SKILLS NETWORK

# Predicting SpaceX's Falcon 9 First Stage Landings with Data Science & Machine Learning

**IBM – Data Science and Machine Learning Capstone Project**

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# Executive Summary

This project aims to predict the successful landing of the Falcon 9 first stage.

Summary of Methodologies:

- **Data Collection** with the SpaceX Rest API & Web Scraping of Falcon 9 and Falcon Heavy launches records from Wikipedia
- **Data Wrangling** to find patterns in the data & determine what would be the label for training supervised models
- **Exploratory Data Analysis** (EDA) with **SQL** & with **Data Visualizations** in order to prepare Data Feature Engineering
- **Interactive Visual Analytics** using Folium to find geographical patterns about launch sites
- **Interactive Dashboard** with Plotly Dash to visualize different success factors like payload and launch site
- **Machine Learning** pipeline to predict if the first stage will land

Summary of the Results:

Factors for a successful landing:

- Among all launch sites **KSC LC-39A** has the highest success rate
- Among all orbits **ES-L1, GEO, HEO, and SSO** have with 100% the highest success rate
- The higher the **payload**, the greater the success rate
- **Success rate for launches** grows over time

# Introduction

## **Project Background**

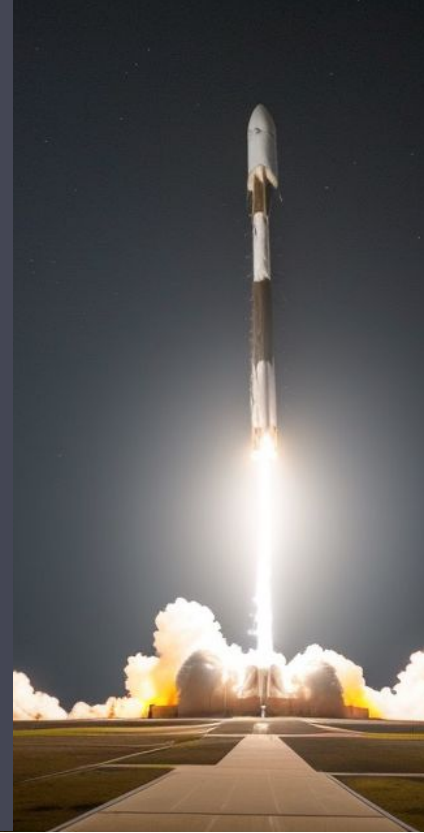
This project aims to predict the successful landing of the Falcon 9 first stage. SpaceX's cost-effective approach to rocket launches, with a price tag of \$62 million compared to competitors' \$165 million, hinges on reusing this stage. By accurately determining the landing outcome, we can estimate launch costs. Predictive insight like this is invaluable for alternate companies vying for rocket launch bids against SpaceX.

## **Problems to we want to solve**

Through this project, our objective is to examine the impact of payload, launch sites, number of flights, and orbits on the success rate of controlled stage one landings. We demonstrate our proficiency in achieving this goal utilizing Python, employing various data science tools and techniques such as Matplotlib, Folium, and machine learning methodologies.

## Section 1

# Methodology

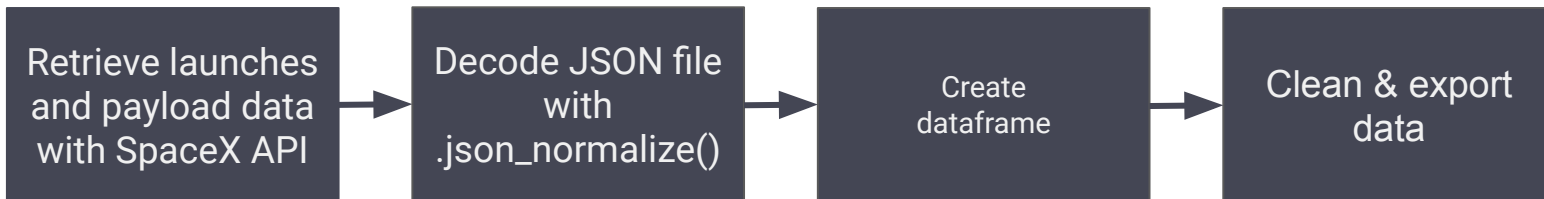


# Methodology

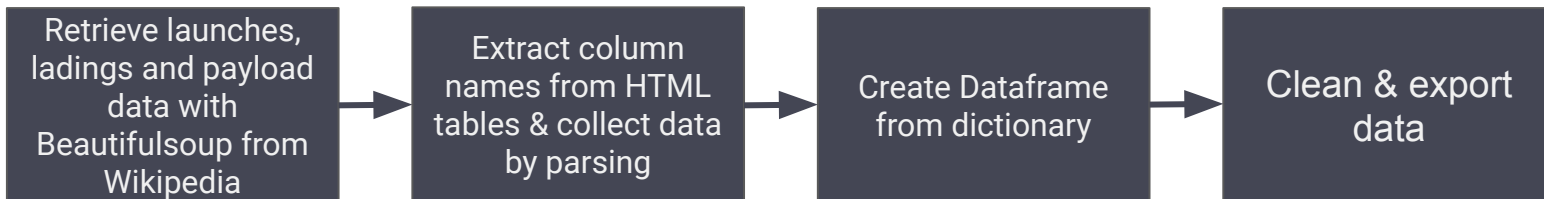
- **Data Collection** with:
  - SpaceX REST API
  - BeautifulSoup for web scraping from Wikipedia
- **Data Wrangling** with:
  - hot encoding, adding missing and deleting unnecessary values
- **Data Exploration** with:
  - Exploratory Data Analysis (EDA) using SQL and Visualization with Seaborn
- **Interactive Visualization** with:
  - Folium to find and mark geographical patterns
  - Plotly Dash
- **Machine Learning** with:
  - sklearn to perform predictive analysis using classification models

# Data Collection

## Data Collection from SpaceX REST API\*



## Data Collection with Web Scraping from Wikipedia\*\*



\*<https://api.spacexdata.com/v4/>

\*\*[https://en.wikipedia.org/w/index.php?title=List\\_of\\_Falcon\\_9\\_and\\_Falcon\\_Heavy\\_launches&oldid=1027686922](https://en.wikipedia.org/w/index.php?title=List_of_Falcon_9_and_Falcon_Heavy_launches&oldid=1027686922)

## API response

```

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

]: response = requests.get(spacex_url)

Check the content of the response

]: print(response.content)

b[{"fairings":{"reused":false,"recovery_attempt":false,"recovery_s2.imgbox.com/94/f2/NN6Ph45r_o.png","large":{"https://images2.imgch":"null","media":null,"recovery":null},"flickr":{"small":[],"orwatch?v=0a_00nJ_Y88","youtube_id":"0a_00nJ_Y88"},"article":{"http:

```

## Create JSON file

```
In [9]: static_json_url = "https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/

We should see that the request was successful with the 200 status response code

In [10]: response.status_code

Out[10]: 200

Now we decode the response content as a Json using .json() and turn it into a Pandas dataframe

In [11]: # Use json_normalize method to convert the json result into a dataframe
         data = pd.json_normalize(response.json())
```

## Transformation

```
In [19]: # Call getLaunchSite
          getLaunchSite(data)
```

```
In [20]: # Call getPayloadData
          getPayloadData(data)
```

```
In [21]: # Call getCoreData
          getCoreData(data)
```

## Create Dictionary

## Create Dataframe

## Clean & filter data

## Export

```
In [22]: 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}
```

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

```
In [29]: # Calculate the mean value of PayloadMass column
payload_mass_mean = data_falcon9['PayloadMass'].mean()
# Replace the np.nan values with its mean value
data_falcon9['PayloadMass'].replace(np.nan, payload_mass_mean, inplace = True)
data_falcon9.isnull().sum()
```

```
In [36]: data_falcon9.to_csv('dataset part 1.csv', index=False)
```

8



# Data Collection Web Scrapping

URL Access &  
Creating BeautifulSoup Object

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

200

Create a BeautifulSoup object from the HTML response

# Use BeautifulSoup() to create a BeautifulSoup object from a response text content
beautifulsoup_object = BeautifulSoup(response.text, 'html')

Print the page title to verify if the BeautifulSoup object was created properly

# Use soup.title attribute
beautifulsoup_object.title
```

Get columns  
names

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

Creating  
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']=[]
```

Add data to matching keys

```
extracted_row = 0
#Extract each table
for table_number,table in enumerate(beautifulsoup_object.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()
            else:
                flag=False
            #get table element
            row=rows.find_all('td')
            #if it is number save cells in a dictionary
            if flag:
                extracted_row += 1
                # Flight Number value
                # TODO: Append the flight_number into launch_dict with key 'Flight No.'
                launch_dict['Flight No.'].append(flight_number)
                #print(flight_number)
                datatimelist=date_time(row[0])
```

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

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

# Data Wrangling

The dataset covers cases where the first stage did not land successfully (false ocean/false RTLS, false ASDS). These strings have to be translated into 0 (=failure) and 1 (=success).

After determining the data labels, the launches or each site, occurrences in orbit, occurrences of mission have to be calculate, followed by transforming the landing outcome. These actions included following steps:

1. Calculating the number of launches on each site
2. Calculating the number and occurrence of each orbit
3. Calculate the number and occurrence of mission outcome per orbit type
4. Create a landing outcome label from Outcome column

1.

```
In [8]: # Apply value_counts() on column LaunchSite
df['LaunchSite'].value_counts()
```

```
Out[8]: CCAFS SLC 40      55
        KSC LC 39A      22
        VAFB SLC 4E      13
        Name: LaunchSite, dtype: int64
```

2.

```
In [9]: # Apply value_counts on Orbit column
df['Orbit'].value_counts()
```

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

3.

```
In [10]: # landing_outcomes = values on Outcome column
landing_outcomes = df['Outcome'].value_counts()
landing_outcomes
```

```
Out[10]: 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
```

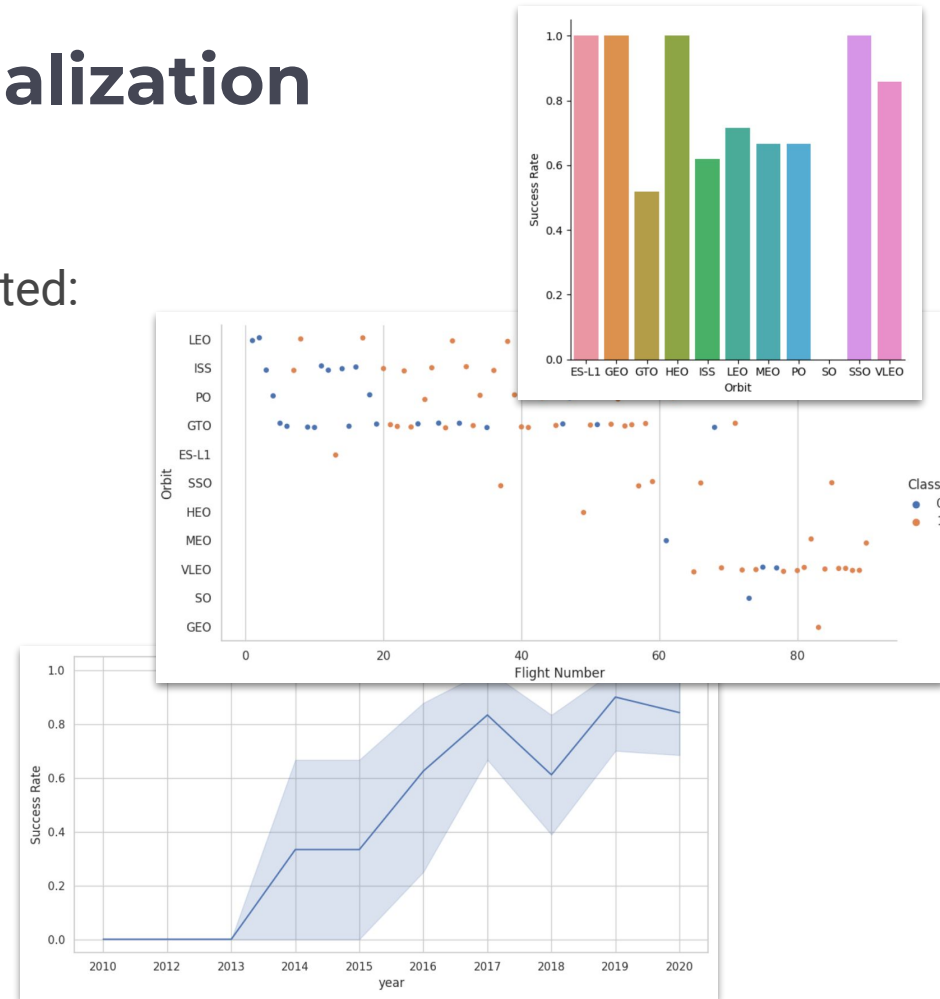
4.

```
In [14]: # landing_class = 0 if bad_outcome
# landing_class = 1 otherwise
landing_class = []
# appending outcome to list
for key, value in df['Outcome'].items():
    if value in bad_outcomes:
        landing_class.append(0)
    else:
        landing_class.append(1)
```

# EDA with Data Visualization

Following charts have been created:

- **Scatter Graphs**
  - number vs. payload
  - number vs. launch site
  - payload vs. launch site
  - payload vs. orbit
- **Bar Graph**
  - success rate vs. orbit
- **Line Graph**
  - success rate vs. year



# EDA with SQL

Following SQL queries were performed in order to gain more insights:

- 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 where the successful landing outcome in drone ship 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. Use a subquery
- Listing the records which will display the month names, successful landing\_outcomes in ground pad ,booster versions, launch\_site for the months in year 2017
- Ranking the count of successful landing\_outcomes between the date 04-06-2010 and 20-03-2017 in descending order.

```
%sql SELECT substr(Date,4,2) as month, DATE,BOOSTER_VERSION, LAUNCH_SITE, [LANDING_OUTCOME] \
FROM SPACEXTBL where [Landing_Outcome] = 'Success (ground pad)' and substr(Date,7,4)='2017' \
ORDER BY month;
```

\* sqlite:///my\_data1.db  
Done.

month	Date	Booster_Version	Launch_Site	Landing_Outcome
01	05/01/2017	F9 FT B1032.1	KSC LC-39A	Success (ground pad)
02	19/02/2017	F9 FT B1031.1	KSC LC-39A	Success (ground pad)
03	06/03/2017	F9 FT B1035.1	KSC LC-39A	Success (ground pad)
07	09/07/2017	F9 B4 B1040.1	KSC LC-39A	Success (ground pad)
08	14/08/2017	F9 B4 B1039.1	KSC LC-39A	Success (ground pad)
12	15/12/2017	F9 FT B1035.2	CCAFS SLC-40	Success (ground pad)

Example: Listing the records which will display the month names, successful landing\_outcomes in ground pad ,booster versions, launch\_site for the months in year 2017

# Building an Interactive Map with Folium

Using a Folium object, we generate a map centered on the NASA Johnson Space Center in Houston, Texas.

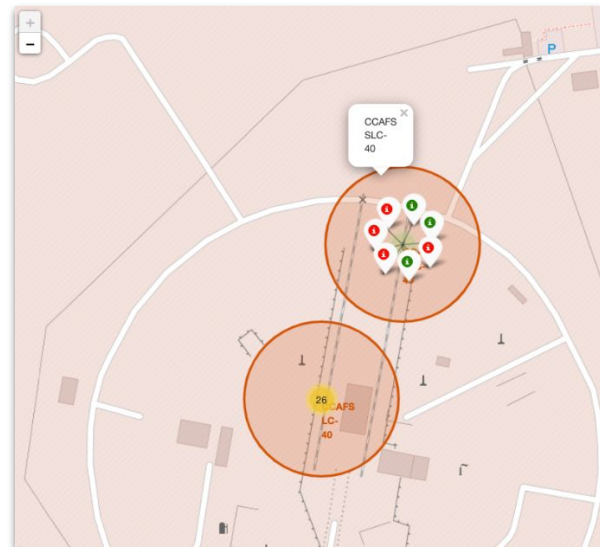
- Additionally, we plot a **blue** marker on the NASA Johnson Space Center location and **red** markers at each launch site for the Falcon 9, accompanied by labels indicating the respective launch site names.
- Furthermore, we mark successful landings **green** and unsuccessful landings **red**.
- ...and calculate the distance between the launch site and closest key locations, like railways, highways, cities, etc.

## Methods:

folium.Circle, folium.map.Marker, folium.plugin.MarkerCluster, folium.PolyLine, folium.features.DivIcon

## Explanation:

By utilizing Folium, we can easily generate interactive maps that provide a comprehensive view of launch site locations and their surrounding areas. This enables us to visually analyze the spatial distribution of launch sites and identify any noticeable patterns or trends.



Example: Folium Marker Cluster over CCAFS SLC-40 launch site.

# Building a Dashboard with Plotly Dash

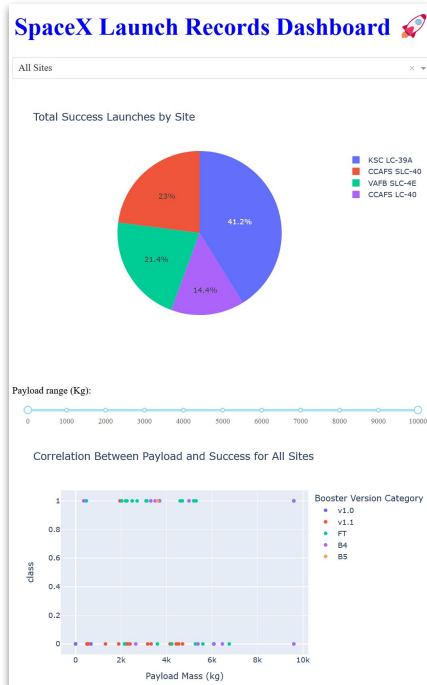
**Plotly Dash** is a **Python framework** that enables the creation of interactive web-based dashboards. It provides an integration of data visualization components and interactivity, allowing users to build and deploy dynamic dashboards for data exploration.

To gain insights into the relationship between success rates, payload mass, and launch sites, we have developed a dashboard using Plotly Dash. This dashboard incorporates various components created within a Python file, including:

- **Dropdown** to choose launch sites
- **Pie Chart** to compare success / failure rates by launch site
- **Range Slider** to select a payload range
- **Scatter Chart** to show the success rate for different payload masses.

## Methods:

`dash_core_components.Dropdown`, `plotly.express.pie`,  
`dash_core_components.RangeSlider`, `plotly.express.scatter`



Screenshot: SpaceX Launch Records Dashboard with Plotly Dash

# Predictive Analysis (Classification) & Results

## Get & prepare data

- Load dataset into a NumPy array
- Normalize the data with 'StandardScaler'
- Split the data into training and test set

## Prepare the models

- Choose a ML algorithm
- Create a GridSearchCV object for parameters optimization
- Train the data with GridSearchModel with SVM(), DecisionTreeClassifier(), LogisticRegression(), and KNeighborsClassifier()

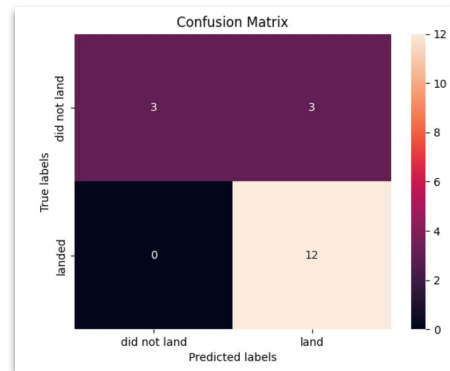
## Evaluate the models

- Retrieve the best hyperparameters Using .score() to calculate the accuracy for all models
- Plot a Confusion Matrix

## Result

- Compare the models regarding their accuracy
- Here: Decision Tree had highest accuracy (=0.877)

We used and compared multiple machine learning methods and presented the results in a dataframe. Finally, we identified **Decision Tree** with an **accuracy = 0.877** as the best model.



## Section 2

# Insights Drawn from EDA

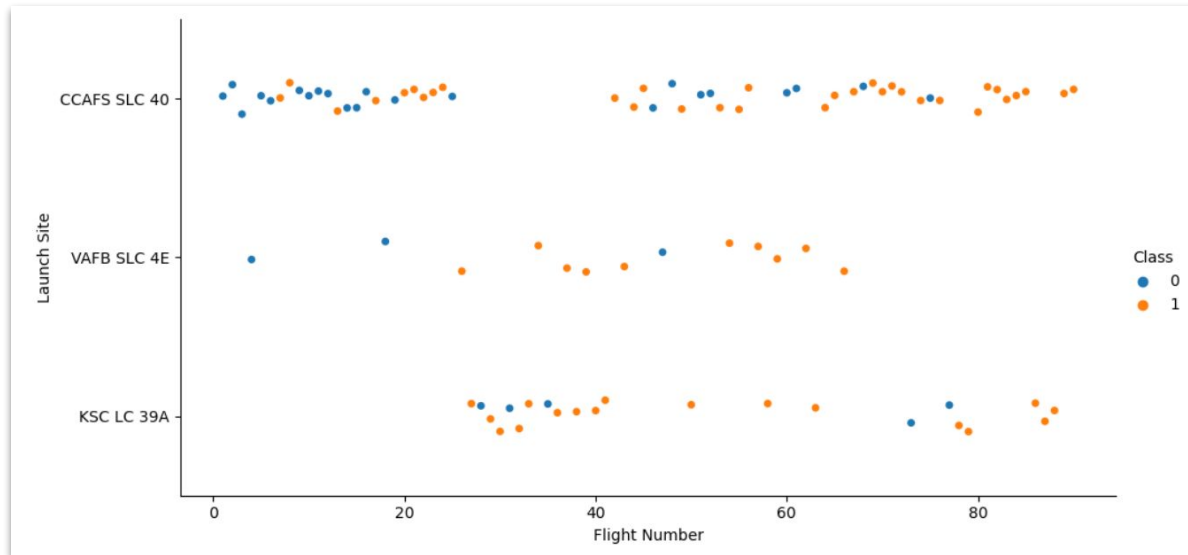




# Flight Number vs. Launch Site

Results:

- We can observe that the **success rate increases** over time.
- Errors are marked in **blue** (class=0) while successful landings are depicted in **orange** (class=1).
- Approximately half of the launches took place from **CCAFS SLC-40**.
- Overall, **KSC LC-39A** and **VAFB SLC-4E** exhibit higher success rates compared to other launch sites.

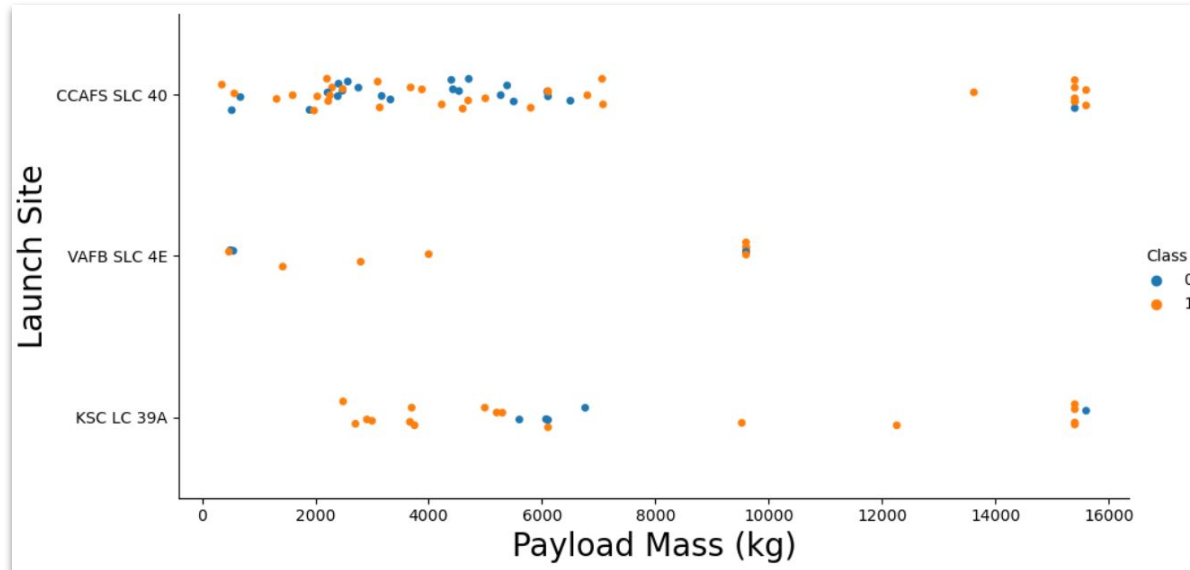


Scatter Plot: Flight Number vs. Launch Site

# Payload vs. Launch Site

Results:

- The higher the payload, the higher the success rate; nearly all launches with a payload exceeding 7,000 kg were successful.
- **KSC LC-39A** maintains a 100% success rate for payloads exceeding 5,000 kg.

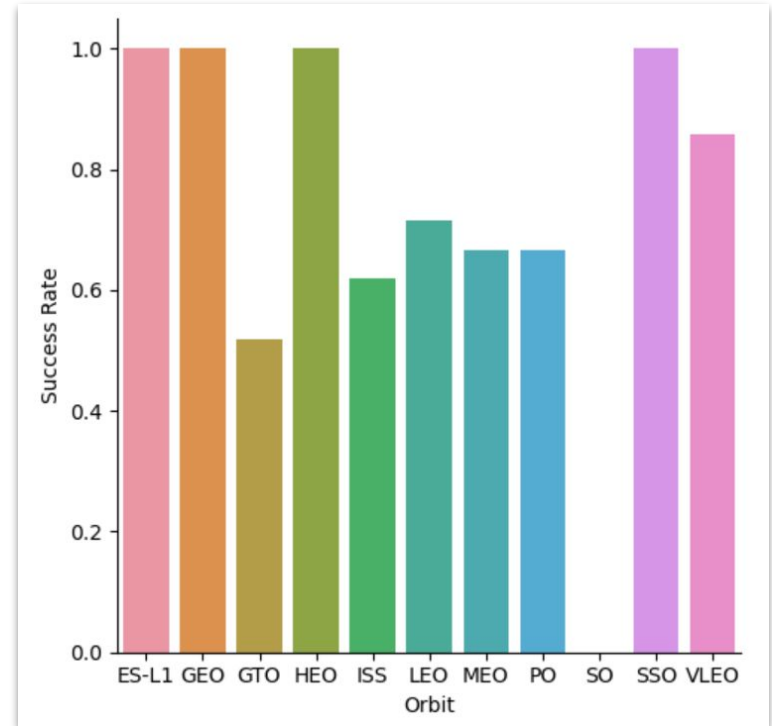


Scatter Plot: Payload vs. Launch Site

# Success Rate vs. Orbit Type

Results:

- The orbit types ES-L1, GEO, HEO, and SSO exhibit a **100% success** rate.
- The orbit type SO, on the other hand, stands out with a **0% success rate**, being the only category with such a distinction.

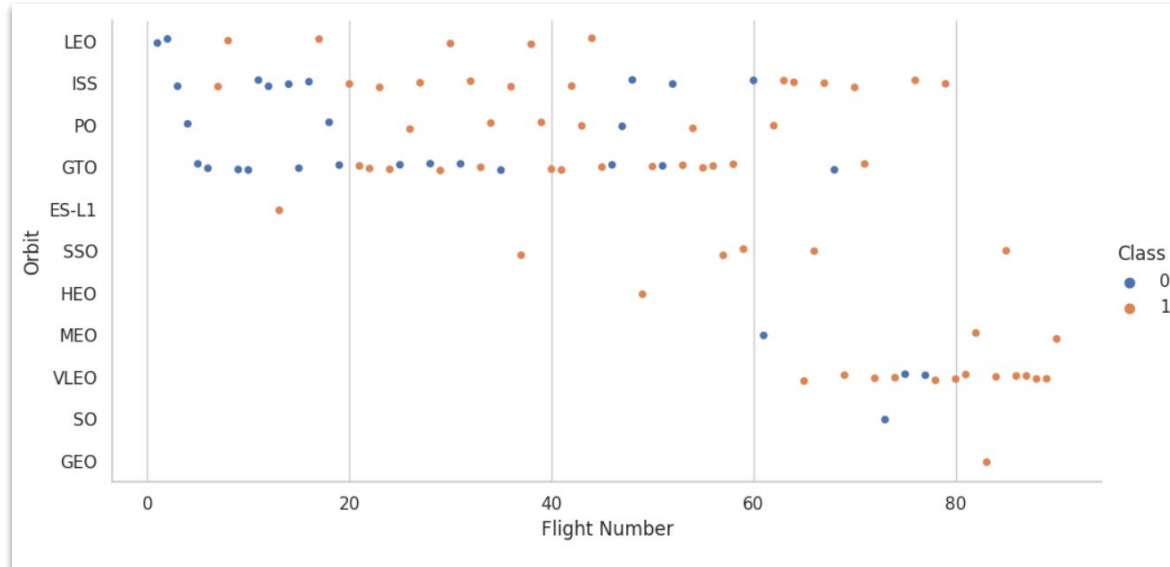


Bar Chart: Success Rate for each Orbit Type

# Flight Number vs. Orbit Type

Results:

- The **success rate (orange)** increases with the number of launches.
- The **LEO orbit** demonstrates a particularly strong **positive correlation** between the number of **previous launches** and the **success rate**.
- **GTO** exhibits little to **no correlation** between the number of previous launches and the success rate.

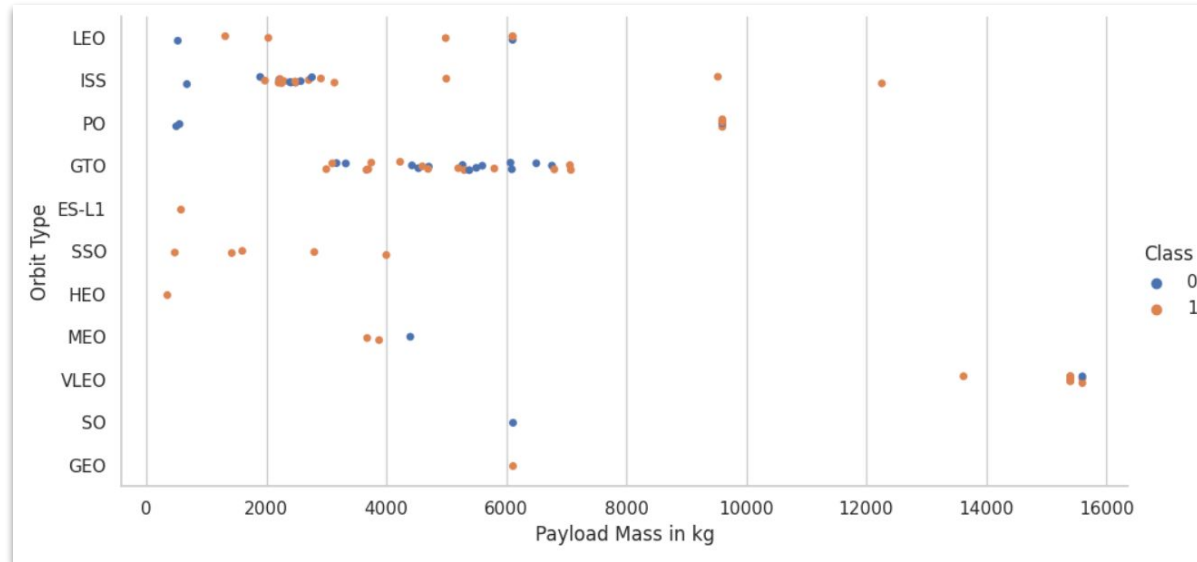


Scatter Plot: Flight Number vs. Orbit Type

# Payload vs. Orbit Typ

Results:

- Payloads and **success rate (orange)** are positively related. Particularly, the **ISS, LEO, and PO** orbits benefit from **higher payloads**, showing an **increase in success rate**.
- However, **GTO deviates from this trend**, experiencing higher **failure rates (blue)** for higher payloads.

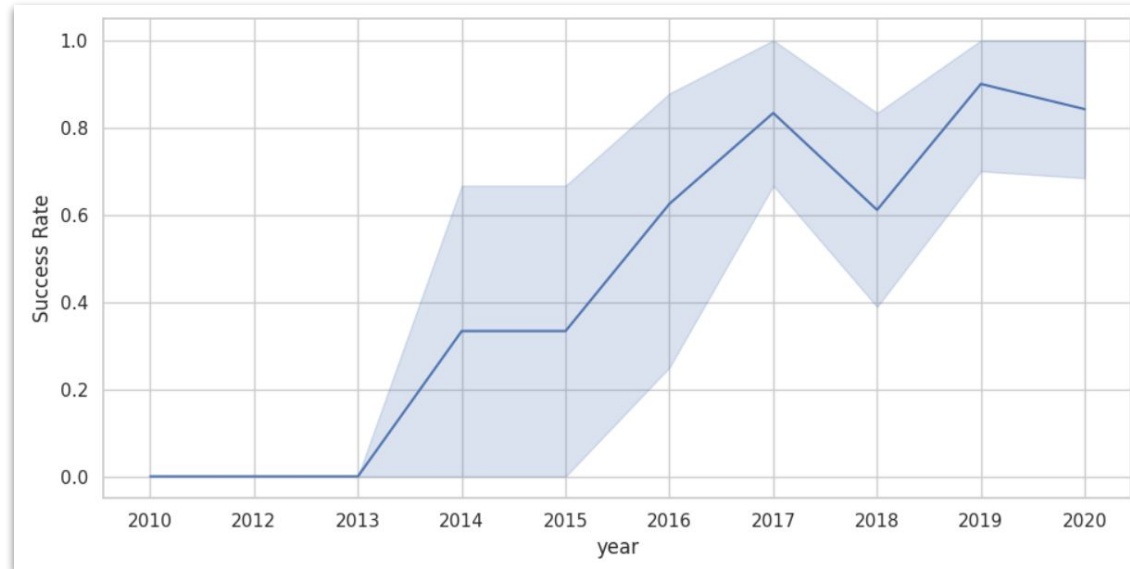


Scatter Plot: Payload vs. Orbit Type

# Launch Success Yearly Trend

Results:

- Since 2013, the success rate has shown a **positive trend**. The only exceptions occurred between 2017 and 2018, as well as between 2019 and 2020, during which it experienced a slight decline.



Line Chart: yearly average success rate

# All Launch Site Names

```
: print(df["Launch_Site"].unique())  
#Or: %sql SELECT Unique(LAUNCH_SITE) FROM SPACEXTBL;  
['CCAFS LC-40' 'VAFB SLC-4E' 'KSC LC-39A' 'CCAFS SLC-40' nan]
```

Launch sites can be retrieved either from a dataframe or using an SQL command. When using SQL, we retrieve the LAUNCH\_SITE column from the SPACEXTBL table, ensuring uniqueness with the addition of the UNIQUE keyword to eliminate duplicate launch sites.

# Launch Site Names Begin with 'KSC'

In [40]: %sql SELECT \* FROM SPACEXTBL WHERE LAUNCH\_SITE LIKE 'KSC%' LIMIT 5;

\* sqlite:///my\_data1.db  
Done.

Out[40]:

	Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS_KG	Orbit	Customer	Mission_Outcome	Landing_Outcome
	19/02/2017	14:39:00	F9 FT B1031.1	KSC LC-39A	SpaceX CRS-10	2490.0	LEO (ISS)	NASA (CRS)	Success	Success (ground pad)
	16/03/2017	6:00:00	F9 FT B1030	KSC LC-39A	EchoStar 23	5600.0	GTO	EchoStar	Success	No attempt
	30/03/2017	22:27:00	F9 FT B1021.2	KSC LC-39A	SES-10	5300.0	GTO	SES	Success	Success (drift ship)
	05/01/2017	11:15:00	F9 FT B1032.1	KSC LC-39A	NROL-76	5300.0	LEO	NRO	Success	Success (ground pad)
	15/05/2017	23:21:00	F9 FT B1034	KSC LC-39A	Inmarsat-5 F4	6070.0	GTO	Inmarsat	Success	No attempt

We are performing an SQL query to retrieve and present five records from the SPACEXTBL table where the launch sites are identified by a string starting with 'KSC'. By employing the LIKE operator with the pattern 'KSC%', the query selectively matches launch sites beginning with 'KSC'.

The inclusion of the LIMIT 5 clause ensures that only a limited number of records are fetched.



# 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_)
45596.0
```

We are executing an SQL query to retrieve the total payload mass of boosters launched by NASA under the CRS (Commercial Resupply Services) program. The query filters the SPACEXTBL table based on the CUSTOMER column, specifically selecting records where the customer is 'NASA (CRS)'.

The resulting sum of the PAYLOAD\_MASS\_KG\_ column is calculated and returned as the total payload mass, which amounts to 45,596.0 kilograms.

# Average Payload Mass by F9 v1.1

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

```
# print(df[df["Booster_Version"] == "F9 v1.1"]["PAYLOAD_MASS_KG_"].mean())  
%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
--------

We are executing an SQL query to calculate and display the average payload mass carried by boosters of version F9 v1.1. The query filters the SPACEXTBL table based on the BOOSTER\_VERSION column, specifically selecting records where the booster version is 'F9 v1.1'.

The resulting average payload mass, which amounts to 2928.4 kilograms, is calculated and returned.

# First Successful Ground Landing Date

List the date where the succesful landing outcome in drone ship was acheived.

*Hint: Use min function*

```
%sql SELECT MIN(DATE) FROM SPACEXTBL WHERE LANDING_OUTCOME = 'Success (drone ship)'
```

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

```
Done.
```

MIN(DATE)
-----------

04/08/2016
------------

We are executing an SQL query to retrieve the earliest date on which a successful landing outcome was achieved on a drone ship. The query filters the SPACEXTBL table based on the condition specified in the WHERE clause, selecting records where the landing outcome is 'Success (drone ship)'. The MIN function is used to calculate and return the minimum (earliest) date from the matching records.

The result indicates that the successful landing on a drone ship occurred on April 8, 2016.

# Successful Drone Ship Landing with Payload between 4000 and 6000

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

```
%sql SELECT PAYLOAD FROM SPACEXTBL WHERE LANDING_OUTCOME = 'Success (ground pad)' AND PAYLOAD_MASS_KG_ BETWEEN 4000 AND 6000
```

\* sqlite:///my\_data1.db  
Done.

Payload
NROL-76
Boeing X-37B OTV-5
Zuma

We are executing an SQL query to retrieve the names of boosters that achieved success in ground pad landings and had a payload mass greater than 4000 kilograms but less than 6000 kilograms. The query filters the SPACEXTBL table based on the criteria specified in the WHERE clause, specifically matching records where the landing outcome is 'Success (ground pad)' and the payload mass falls within the range of 4000 to 6000 kilograms.

The resulting names of the boosters meeting these conditions are returned as 'Payload', which include NROL-76, Boeing X-37B OTV-5, and Zuma.

# Total Number of Successful and Failure Mission Outcomes

We are executing an SQL query to obtain the total number of mission outcomes categorized as successful and failure. The query operates on the SPACEXTBL table and employs the GROUP BY clause to group the records based on the MISSION\_OUTCOME column. The COUNT(\*) function is used to calculate the total number of occurrences for each distinct mission outcome.

The results show that there are 898 missions with no specified outcome, 1 failure in flight, 98 successful missions, 1 ambiguous success, and 1 success with unclear payload status.

List the total number of successful and failure mission outcomes

```
%sql SELECT MISSION_OUTCOME, COUNT(*) as total_number \
FROM SPACEXTBL GROUP BY MISSION_OUTCOME;
```

\* sqlite:///my\_data1.db  
Done.

Mission_Outcome	total_number
None	898
Failure (in flight)	1
Success	98
Success	1
Success (payload status unclear)	1

# 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 SPACEXTBL);
```

```
* 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
```

We are executing an SQL query to retrieve the names of booster versions that have carried the maximum payload mass. The query utilizes a subquery to find the maximum payload mass value from the SPACEXTBL table. The main query then selects the booster versions from the table where the payload mass matches the maximum value obtained from the subquery.

The result displays the names of the booster versions that achieved this maximum payload mass, such as F9 B5 B1048.4, F9 B5 B1049.4, F9 B5 B1051.3, and others.

# Landing Outcomes in 2017

List the records which will display the month names, succesful landing\_outcomes in ground pad ,booster versions, launch\_site for the months in year 2017

**Note: SQLite does not support monthnames. So you need to use substr(Date, 4, 2) as month to get the months and substr(Date,7,4)='2017' for year.**

```
|: %sql SELECT substr(Date,4,2) as month, DATE,BOOSTER_VERSION, LAUNCH_SITE, [LANDING_OUTCOME] \
FROM SPACEXTBL where [Landing_Outcome] = 'Success (ground pad)' and substr(Date,7,4)='2017' \
ORDER BY month;
```

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

	month	Date	Booster_Version	Launch_Site	Landing_Outcome
:	01	05/01/2017	F9 FT B1032.1	KSC LC-39A	Success (ground pad)
	02	19/02/2017	F9 FT B1031.1	KSC LC-39A	Success (ground pad)
	03	06/03/2017	F9 FT B1035.1	KSC LC-39A	Success (ground pad)
	07	09/07/2017	F9 B4 B1040.1	KSC LC-39A	Success (ground pad)
	08	14/08/2017	F9 B4 B1039.1	KSC LC-39A	Success (ground pad)
	12	15/12/2017	F9 FT B1035.2	CCAFS SLC-40	Success (ground pad)

We are executing an SQL query to retrieve records that display the month names, dates, booster versions, launch sites, and successful landing outcomes in ground pad for the months in the year 2017. As SQLite does not have a built-in month name function, we are using the substr(Date, 4, 2) expression to extract the month from the date column. Additionally, we filter the results to only include records with a landing outcome of 'Success (ground pad)' and where the year portion of the date is '2017' using substr(Date, 7, 4)='2017'.

The result is ordered by the month column, showing the month, date, booster version, launch site, and landing outcome for each record.

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

Rank the count of successful landing\_outcomes between the date 04-06-2010 and 20-03-2017 in descending order.

```
%sql SELECT [Landing_Outcome], count(*) as count_outcomes FROM SPACEXTBL \
WHERE DATE between '04-06-2010' and '20-03-2017' group by [Landing_Outcome] \
order by count_outcomes DESC;
```

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

Done.

```
%sql SELECT [Landing_Outcome], count_outcomes
```

Landing_Outcome	count_outcomes
Success	20
No attempt	10
Success (drone ship)	8
Success (ground pad)	7
Failure (drone ship)	3
Failure	3
Failure (parachute)	2
Controlled (ocean)	2
No attempt	1

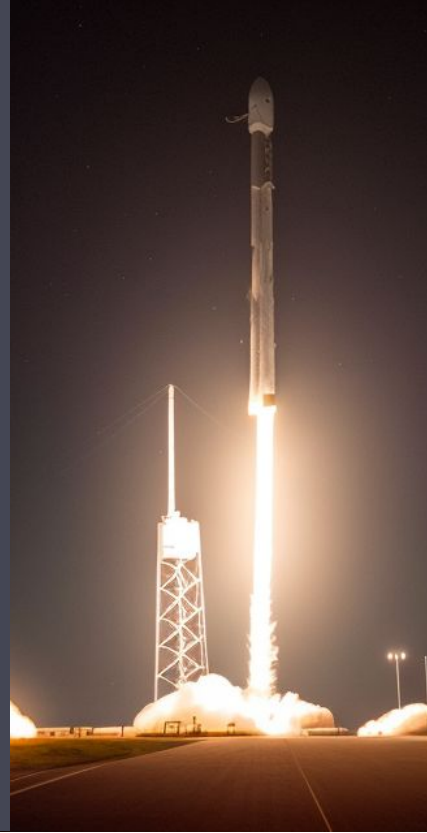
We are executing an SQL query to rank the count of successful landing outcomes between the dates '04-06-2010' and '20-03-2017' in descending order. The query operates on the SPACEXTBL table and uses the WHERE clause to filter the records based on the date range specified. The COUNT(\*) function is used to calculate the total count of each landing outcome category, and the results are grouped by the landing outcome. The ORDER BY clause is applied to sort the results in descending order based on the count of outcomes.

The output displays the landing outcomes and their corresponding counts, with the most frequent successful landing outcomes appearing first.

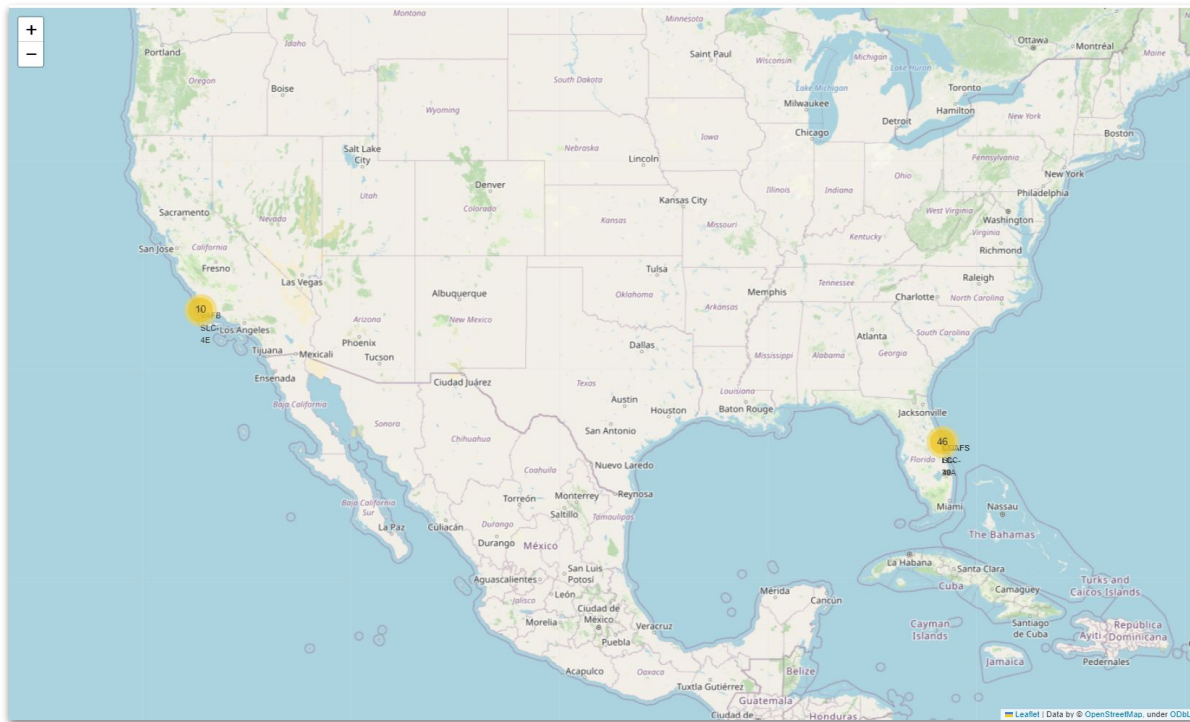


## Section 3

# Launch Sites Proximities Analysis



# Folium Map Launch Site

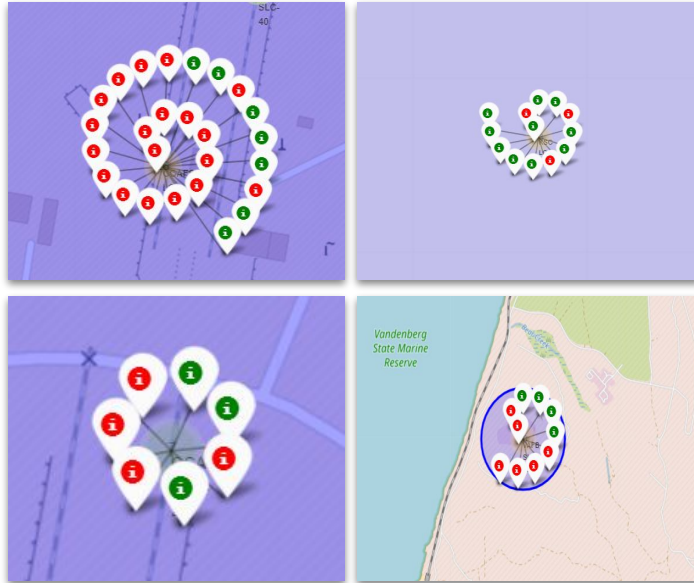


Map with Folium: showing all Falcon 9 launch sites.

We have marked the launch sites, both on the east and west coast of the U.S.A., **yellow**.

The launch sites are close to the equator because this offers advantages such as increased orbital velocity, efficient energy use, safety considerations, and accessibility to various orbital inclinations.

# Folium Map Markers for Launch Success



Map with Folium: launch success by launch site

WIn the visualization provided, we can observe the launch outcomes categorized by different launch sites. Successful launches are represented by **green markers**, while failed launches are depicted by **red markers**.

For instance, upon examination, it is evident that CCAF SLC-40 exhibits a success rate of 42.9%. This information offers insights into the performance of each launch site in terms of successful mission outcomes.

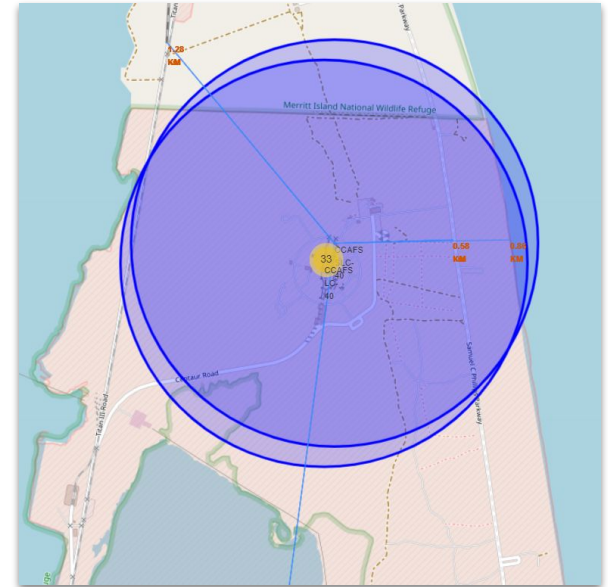
# Distances to Proximities

Using the visualization capabilities of Folium, we are able to draw lines between coordinates and measure distances. As a result, we have determined that CCAFS SLC-40 is located:

- 21.96 km away from the nearest railway line,
- 0.86 km from the coastline,
- 23.23 km from the nearest city, and
- 26.88 km from the nearest highway.

This information provides valuable insights into the geographical positioning of CCAFS SLC-40, highlighting its distances from key landmarks and transportation infrastructure.

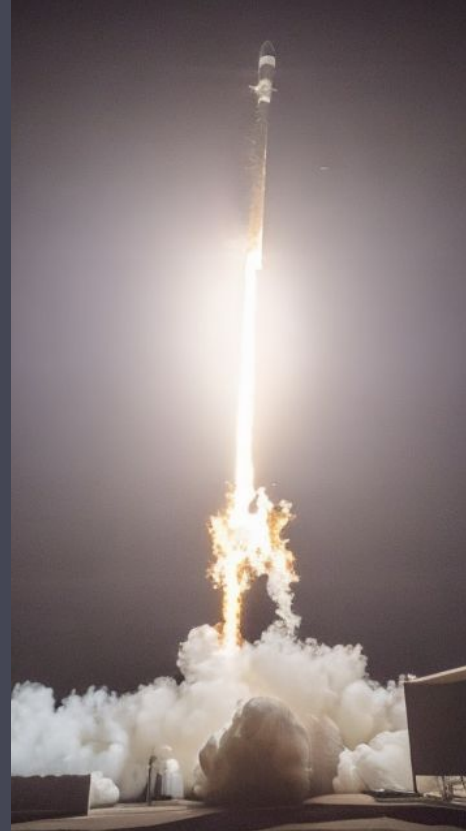
These distances inform logistical planning, safety considerations, and impact assessment, ensuring effective and responsible launch operations.



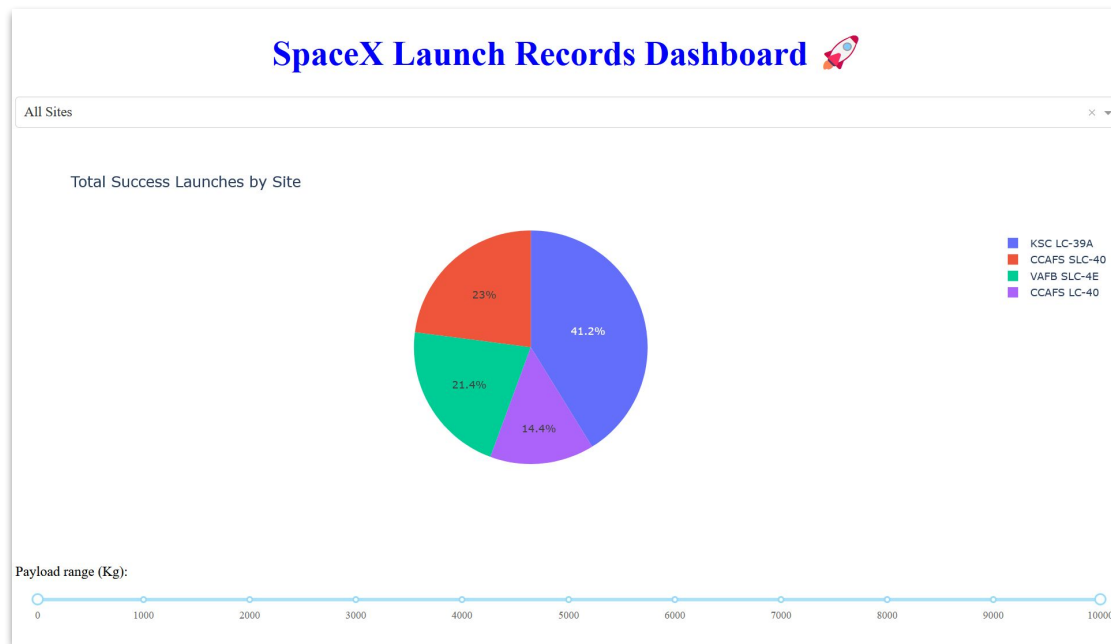
Map with Folium: drawing lines to proximities like railroads and cities

## Section 4

# Build a Dashboard with Plotly Dash



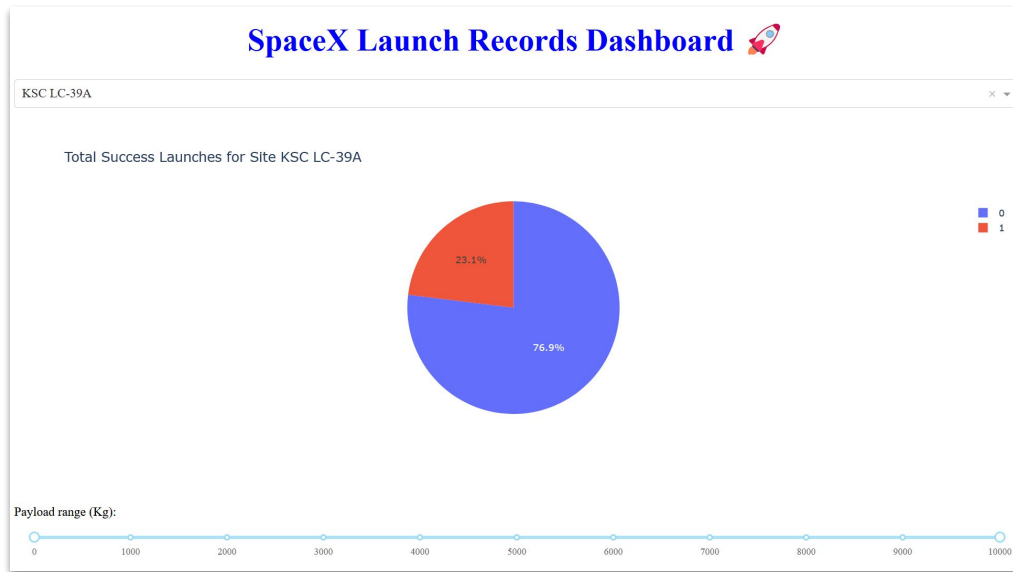
# Launch Success Rates by Site



## Result:

KSC LC-39 boasts the highest success rate among all launch sites.

# Launch Success Rate of KSC LC-39A



## Result:

KSC LC-39A holds the highest success rate at 76.9%, while the failure rate stands at a significantly lower 23.1%.

# Launch Success Rate: Payload vs. Mass



## Result:

KSC LC-39A holds the highest success rate at 76.9%, while the failure rate stands at a significantly lower 23.1%. From this graph, we can infer that payloads up to 5000 have a higher success rate.



## Section 6

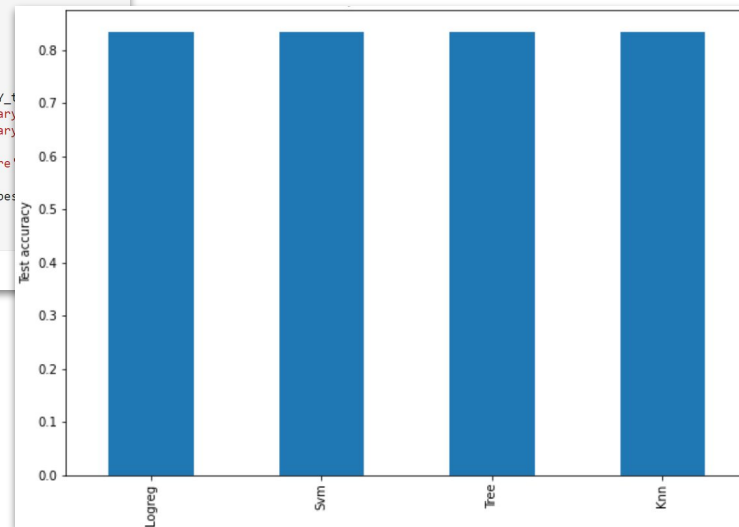
# Predictive Analysis (Classification)



# Classification Accuracy

```
from sklearn.metrics import f1_score, jaccard_score
#Calculationg accuracy
accuracy = [svm_cv_score, logreg_score, knn_cv_score, tree_cv_score]
accuracy = [i * 100 for i in accuracy]
#Comparing methods
method = ['SVM', 'Logistic Regression', 'K Nearest', 'Decision Tree']
models = {'ML Method':method, 'Accuracy Score (%)':accuracy}
#Show results
results=pd.DataFrame(models)
print("ML method accuracy: ")
results
f1_scores =[f1_score(Y_test, yhat, average='binary'),f1_score(Y_test, yhat, average='binary'), f1_score(Y_t
jaccard_scores = [jaccard_score(Y_test, yhat, average='binary'),jaccard_score(Y_test, yhat, average='binary
jaccard_score(Y_test, yhat, average='binary'),jaccard_score(Y_test, yhat, average='binary
results2 = [logreg_score, svm_cv_score, tree_cv_score, knn_cv_score]
results3 = pd.DataFrame(np.array([f1_scores, jaccard_scores, accuracy]), index=['Jaccard_Score', 'F1_Score'
results3
models = {'Decision Tree':tree_cv.best_score_, 'Logistic Regression':logreg_cv.best_score_, 'SVM': svm_cv.be
results4=max(models, key=models.get)
print("Best Model: ",results4," with ",models[results4])

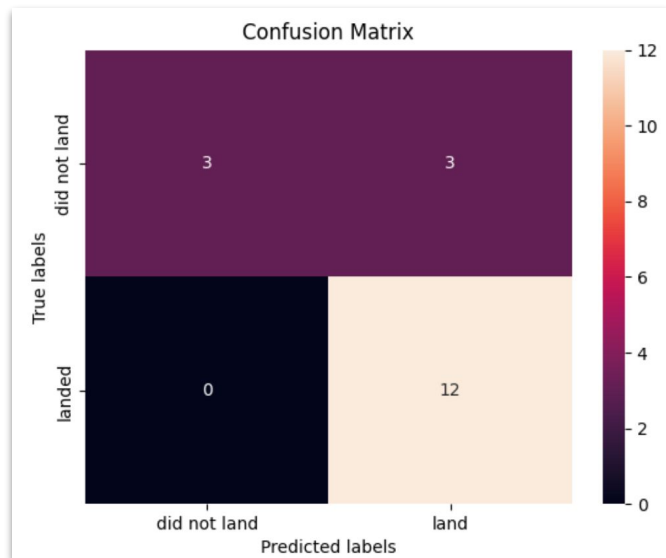
ML method accuracy:
Best Model: Decision-Tree with 0.8767857142857143
```



## Result:

The performance of the ML models is consistently high, with an accuracy of over 80%. Among the models, the Decision Tree performs the best, achieving an accuracy of 87.7% in our case.

# Confusion Matrix of Best Performing Model



Here, we plot the confusion matrix by predicting the labels (yhat) using the `tree_cv` model and passing the true labels (`Y_test`) to the `plot_confusion_matrix` function.

## Result:

We can see that 3 "did not land" and 12 "land" were predicted correctly. 3 true labels "did not land" were predicted incorrectly.

# Conclusion

This project aims to uncover factors that influence the success or failure of a Stage One landing. Based on the data provided by the SpaceX REST API and Wikipedia, the following observations can be made:

- The success rate has significantly improved over time.
- KSC LC-39A is the launch site with the highest success rate. It achieves a 100% success rate for payloads below 5000 kg.
- The ES-L1, GEO, HEO, and SSO orbits have a 100% success rate.
- Higher or lower payloads lead to higher success rates in different cases. Further investigation could be conducted to explore the relationship between payload, velocity, and altitude for specific orbits.

Furthermore:

- The dataset does not include the latest data from the 2020s.
- The data does not explain why some launch sites have higher success rates than others.
- The various ML models perform similarly, but the Decision Tree model is preferred in this case due to its slight advantage.



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# Thank you!

**IBM – Data Science and Machine Learning Capstone Project**

Björn Thomsen, M.A.

June 18th, 2023

# Appendix

## Github Repository Master:

[https://github.com/pyo-bit/capstone\\_project\\_ibm/tree/master](https://github.com/pyo-bit/capstone_project_ibm/tree/master)

## Jupyter Files by Chapter:

[https://github.com/pyo-bit/capstone\\_project\\_ibm/blob/f493b9fae223f972442dbea99f71d3b1f59bf446/1\\_jupyter-labs-spacex-data-collection-api.ipynb](https://github.com/pyo-bit/capstone_project_ibm/blob/f493b9fae223f972442dbea99f71d3b1f59bf446/1_jupyter-labs-spacex-data-collection-api.ipynb)

[https://github.com/pyo-bit/capstone\\_project\\_ibm/blob/0f3450907c80ca74864883993a817de4fb546f47/2\\_jupyter-labs-webscraping.ipynb](https://github.com/pyo-bit/capstone_project_ibm/blob/0f3450907c80ca74864883993a817de4fb546f47/2_jupyter-labs-webscraping.ipynb)

[https://github.com/pyo-bit/capstone\\_project\\_ibm/blob/0a74185c8558a6a2ee6bc4e0298dc851a34ae331/3\\_jupyter-labs-spacex-data-wrangling.ipynb](https://github.com/pyo-bit/capstone_project_ibm/blob/0a74185c8558a6a2ee6bc4e0298dc851a34ae331/3_jupyter-labs-spacex-data-wrangling.ipynb)

[https://github.com/pyo-bit/capstone\\_project\\_ibm/blob/b8bc810db86c6e32ffd626de11127e24dd33c2ca/4\\_jupyter-labs-eda-sql-edx-sqlite.ipynb](https://github.com/pyo-bit/capstone_project_ibm/blob/b8bc810db86c6e32ffd626de11127e24dd33c2ca/4_jupyter-labs-eda-sql-edx-sqlite.ipynb)

[https://github.com/pyo-bit/capstone\\_project\\_ibm/blob/03be254c6c0abf3ac1d98271b14aeed21668e416/5\\_jupyter\\_lab\\_eda\\_with\\_visualization.ipynb](https://github.com/pyo-bit/capstone_project_ibm/blob/03be254c6c0abf3ac1d98271b14aeed21668e416/5_jupyter_lab_eda_with_visualization.ipynb)

[https://github.com/pyo-bit/capstone\\_project\\_ibm/blob/3d4de4c5054ee0c57d9ff7e6126a68288157dc12/6\\_interactive\\_visual\\_analytics\\_with\\_folium.ipynb](https://github.com/pyo-bit/capstone_project_ibm/blob/3d4de4c5054ee0c57d9ff7e6126a68288157dc12/6_interactive_visual_analytics_with_folium.ipynb)

[https://github.com/pyo-bit/capstone\\_project\\_ibm/blob/95c53468d14c7d4c859071f952194c893a758551/7\\_interactive\\_visual\\_analytics\\_with\\_plotly\\_dashboard.py](https://github.com/pyo-bit/capstone_project_ibm/blob/95c53468d14c7d4c859071f952194c893a758551/7_interactive_visual_analytics_with_plotly_dashboard.py)

[https://github.com/pyo-bit/capstone\\_project\\_ibm/blob/4463bdc0fc67f62a78ad87b34b830f19c3f0d2fa/8\\_machine\\_learning\\_prediction\\_lab.ipynb](https://github.com/pyo-bit/capstone_project_ibm/blob/4463bdc0fc67f62a78ad87b34b830f19c3f0d2fa/8_machine_learning_prediction_lab.ipynb)

## Additional Files:

[https://github.com/pyo-bit/capstone\\_project\\_ibm/blob/4463bdc0fc67f62a78ad87b34b830f19c3f0d2fa/spacex\\_launch\\_dash.csv](https://github.com/pyo-bit/capstone_project_ibm/blob/4463bdc0fc67f62a78ad87b34b830f19c3f0d2fa/spacex_launch_dash.csv)