IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Executive Summary

- Summary of methodologies
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    - Space X Exploratory Data Analysis using SQL
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    - Space X Launch Sites Analysis with Folium-Interactive Visual Analytics and Ploty Dash
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    - EDA Results
    - Interactive Visual Analytics and Dashboards
    - Predictive Analysis (Classification)

Introduction

- Project background and context

In this capstone project, the goal is to predict whether the Falcon 9 rocket's first stage will land successfully. SpaceX advertises its Falcon 9 launches at a cost of $62 million, significantly lower than other providers, who charge upwards of $165 million per launch. This cost advantage stems largely from SpaceX's ability to reuse the first stage of the rocket. Accurately predicting the success of the first-stage landing is crucial in determining the total cost of a launch, which is valuable for competitors who may wish to bid against SpaceX for rocket launches.

- Problems You Want to Find Answers
    - Can we predict the success of the Falcon 9 first stage landing?
    - How can this prediction impact the overall cost of a rocket launch?
    - What value does this information hold for other companies looking to compete with SpaceX for launch contracts?
    - How can data be collected and formatted properly from APIs to ensure accurate predictions?

Section 1

Methodology

Methodology

Executive Summary

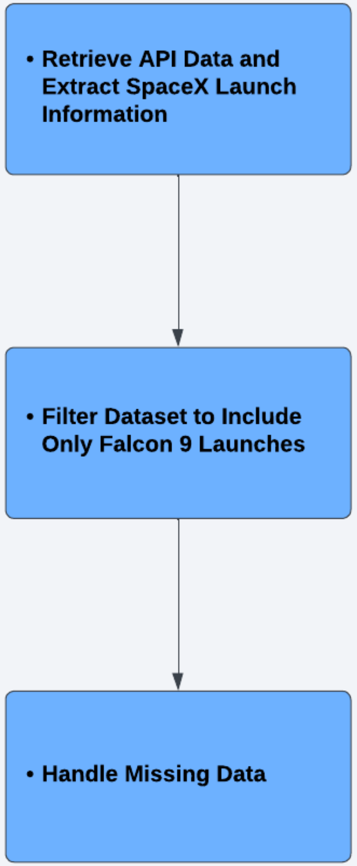
- Data collection methodology:
  - Describe how data was collected
- Perform data wrangling
  - Describe how data was processed
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - How to build, tune, evaluate classification models

Data Collection

- Using SpaceX API: Data was initially collected from the SpaceX API by making a GET request. To facilitate the use of the API, a series of helper functions were defined, which helped extract information using specific identification numbers from the launch data. Rocket launch data was retrieved from the SpaceX API URL.
- The requested JSON results were then parsed to ensure consistency. The response content was decoded into JSON format and subsequently converted into a Pandas DataFrame for further analysis.
- Web Scraping from Wikipedia: In addition to API data, historical launch records for Falcon 9 were collected by web scraping the "List of Falcon 9 and Falcon Heavy launches" page on Wikipedia. Using BeautifulSoup and the requests library, the Falcon 9 launch table was extracted from the HTML, parsed, and converted into a Pandas DataFrame.

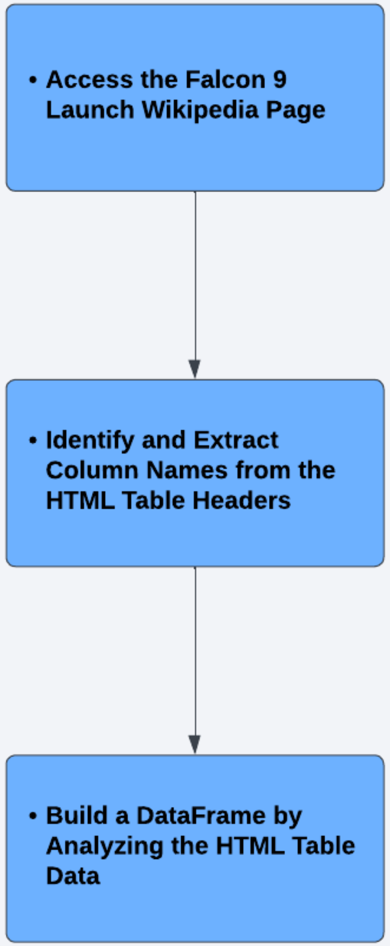
Data Collection – SpaceX API

- Data was collected from the SpaceX API (a RESTful API) by sending a GET request to retrieve launch data. The response was parsed and decoded into a JSON format, which was subsequently converted into a Pandas DataFrame for analysis.



Data Collection - Scraping

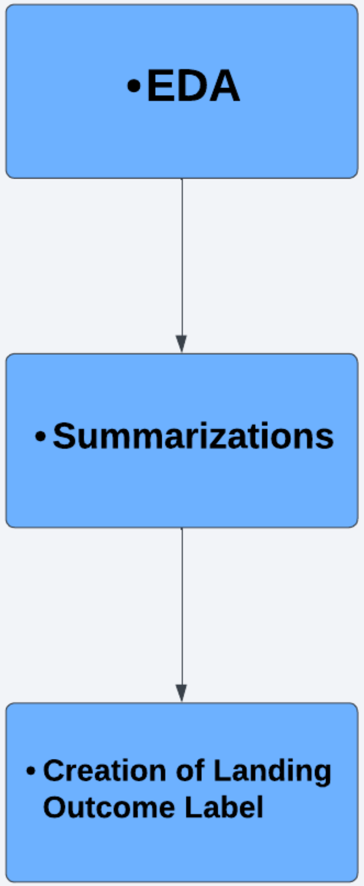
- • Conducted web scraping to gather Falcon 9 historical launch data from a Wikipedia page using BeautifulSoup and the requests library. The launch records were extracted from the HTML table on the page and parsed to create a DataFrame for further analysis.



Data Wrangling

- After collecting and creating a Pandas DataFrame, the data was filtered using the **BoosterVersion** column to retain only Falcon 9 launches. Missing values in the **LandingPad** and **PayloadMass** columns were addressed, with missing entries in **PayloadMass** being replaced by the column's mean value.

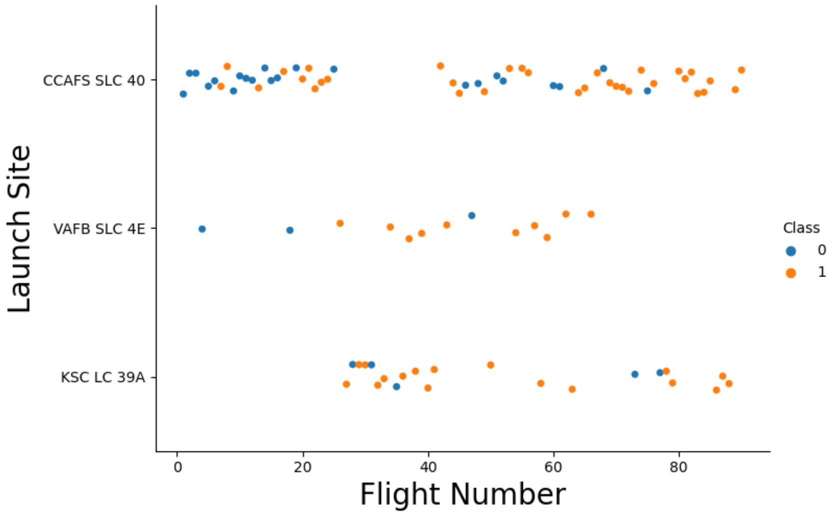
- Additionally, exploratory data analysis (EDA) was performed to identify patterns in the data and define the target label for training supervised models.

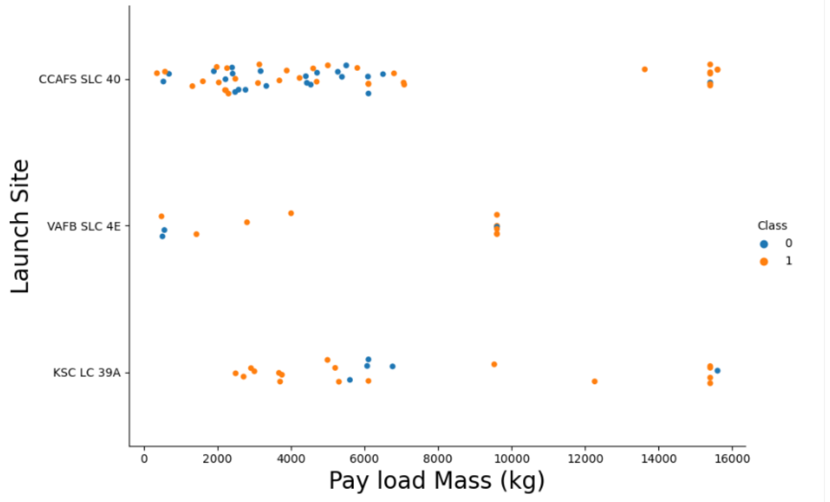


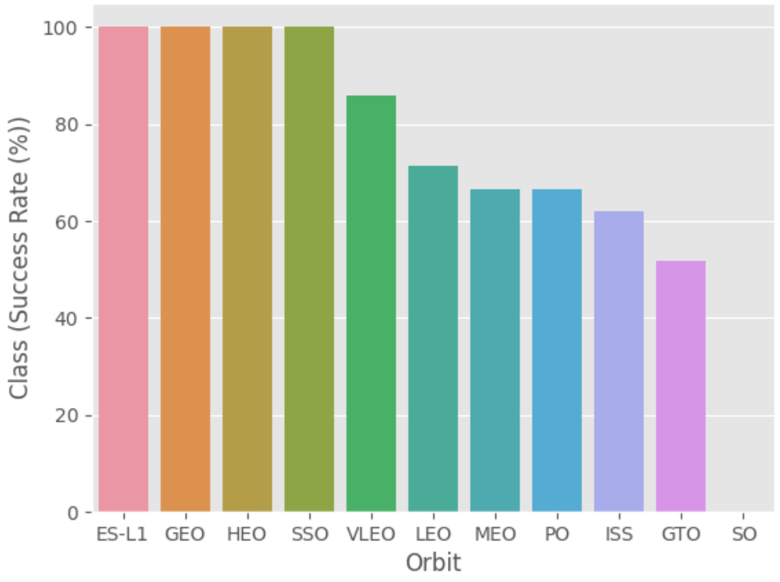
EDA with Data Visualization

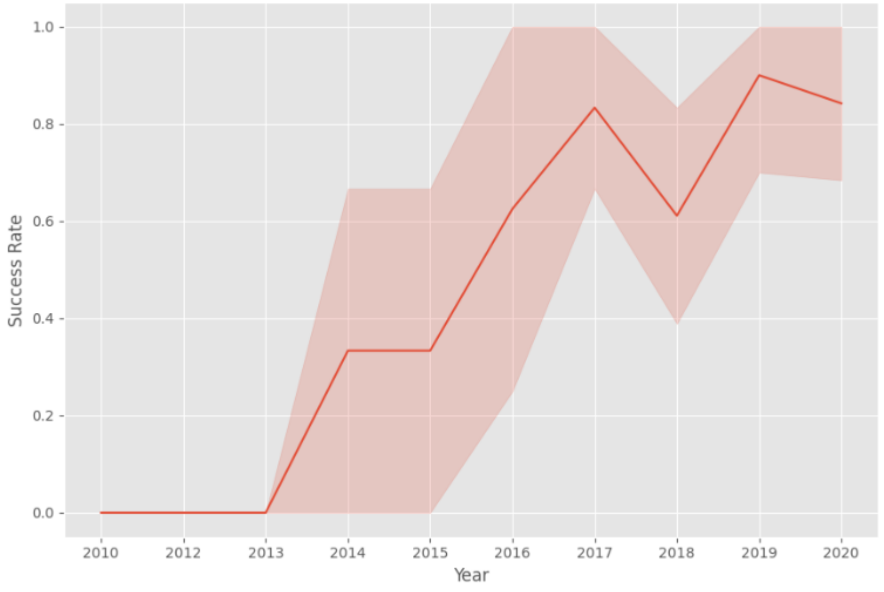
- Performing exploratory data analysis (EDA)
- Preparing data through feature engineering
- Utilizing scatter plots to visualize relationships between Flight Number and Launch Site, Payload and Launch Site, Flight Number and Orbit Type, as well as Payload and Orbit Type
- Creating bar charts to display the success rate of each orbit type
- Using line plots to illustrate the yearly trend of launch success.

EDA with Data Visualization Plots









EDA with SQL

- Following SQL Queries were made for EDA

Task 1

Display the names of the unique launch sites in the space mission

In [31]:
```
%sql SELECT DISTINCT LAUNCH_SITE as "Launch_Sites" FROM SPACEXTBL;
```

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

Task 2

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

In [72]:
```
%sql SELECT * FROM 'SPACEXTBL' WHERE Launch_Site LIKE 'CCA%' LIMIT 5;
```

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

Task 3

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

In [17]:
```
%sql SELECT SUM(PAYLOAD_MASS__KG_) as "Total Payload Mass(Kgs)", Customer FROM 'SPACEXTBL' WHERE Customer = 'NASA (C
```

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

EDA with SQL (continued)

Task 4

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

In [19]:
```
%sql SELECT AVG(PAYLOAD_MASS__KG_) as "Payload Mass Kgs", Customer, Booster_Version FROM 'SPACEXTBL' WHERE Booster_V
```

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

Out[19]:

Payload Mass Kgs	Customer	Booster_Version
2534.6666666666665	MDA	F9 v1.1 B1003

Task 8

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

In [30]:
```
%sql SELECT "Booster_Version",Payload, "PAYLOAD_MASS__KG_" FROM SPACEXTBL WHERE "PAYLOAD_MASS__KG_" = (SELECT MAX("P
```

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

Task 9

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, 4, 2) as month to get the months and substr(Date,7,4)='2015' for year.

In [68]:
```
%sql SELECT substr(Date,7,4), substr(Date, 4, 2),"Booster_Version", "Launch_Site", Payload, "PAYLOAD_MASS__KG_", "Mi
```

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

Task 10

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

In [74]:
```
%sql SELECT * FROM SPACEXTBL WHERE "Landing _Outcome" LIKE 'Success%' AND (Date BETWEEN '04-06-2010' AND '20-03-2017
```

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

EDA with SQL (continued)

- Retrieved unique launch site names involved in the space mission.
- Listed the top 5 launch sites starting with the string "CCA."
- Calculated the total payload mass transported by boosters launched by NASA (CRS).
- Computed the average payload mass carried by booster version F9 v1.1.
- Identified the date of the first successful landing on a ground pad.
- Retrieved the names of boosters that succeeded in drone ship landings and carried payloads between 4000 and 6000 kg.
- Determined the total number of successful and failed mission outcomes.
- Listed booster versions that carried the highest payload mass.
- Retrieved details of failed drone ship landings, including booster versions and launch sites for the year 2015.
- Ranked landing outcomes (success on ground pad or failure on drone ship) between June 4, 2010, and March 20, 2017.

Build an Interactive Map with Folium

- Markers show specific points like launch sites.
- Circles highlight areas around specific coordinates (e.g., NASA Johnson Space Center).
- Marker clusters represent groups of events at a location (e.g., launches at a site).
- Lines indicate distances between two coordinates.

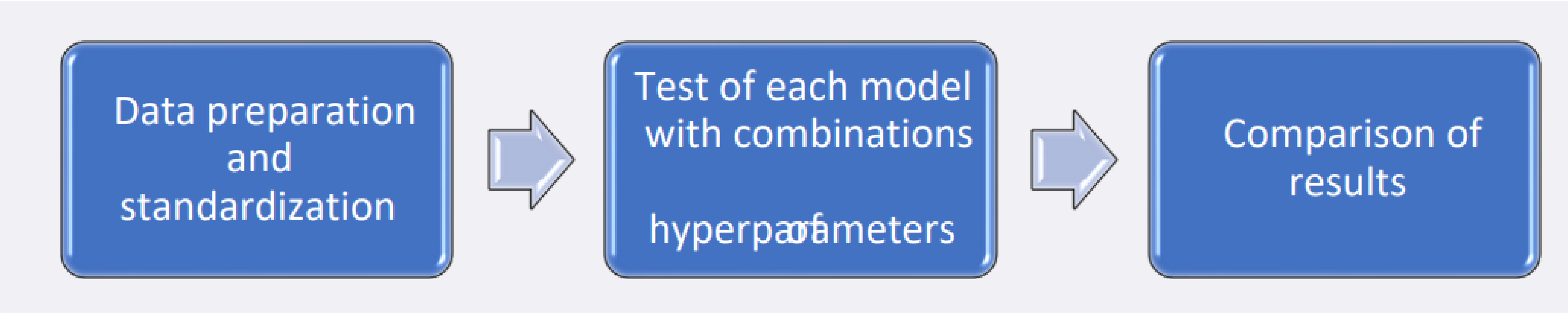
Build a Dashboard with Plotly Dash

- Developed an interactive dashboard using Plotly Dash.
- Implemented a launch site drop-down input.
- Created a callback to generate a success pie chart based on the selected site.
- Integrated a range slider for payload selection.
- Added a callback to render a success-payload scatter plot.

Predictive Analysis (Classification)

- Data Preparation:
  - Loaded data into a Pandas DataFrame.
  - Extracted training labels as a NumPy array from the Class column and assigned it to variable Y.
  - Standardized features using preprocessing.
  - StandardScaler() from Scikit-learn.Split the dataset into training and testing sets with train_test_split (test size = 20%, random state = 2).
- Model Evaluation:
  - Evaluated four models: SVM, Classification Trees, k-Nearest Neighbors (k-NN), and Logistic Regression.
  - Created and tuned models using GridSearchCV with a 10-fold cross-validation.
  - For each model, fitted the training data to GridSearchCV to find the best hyperparameters.
  - Assessed the best parameters and accuracy on validation data with best_params_ and best_score_.
  - Calculated accuracy on test data and plotted confusion matrices for each model.
- Results:
  - Compared the test data accuracy scores of SVM, Classification Trees, k-NN, and Logistic Regression to identify the top-performing model.

Predictive Analysis (Classification) Flowchart



Results

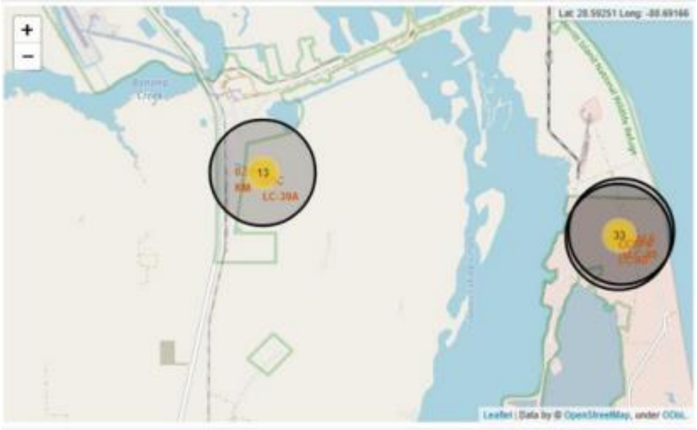
- Exploratory data analysis results:
  - SpaceX operates four different launch sites.
  - Initial launches were conducted for SpaceX and NASA.
  - The average payload capacity for the Falcon 9 v1.1 booster is 2,928 kg.
  - The first successful landing of a Falcon 9 booster occurred in 2015, five years after the initial launch.
  - Many versions of the Falcon 9 booster successfully landed on drone ships, particularly those with payloads above the average.
  - Nearly all missions achieved successful outcomes.
  - In 2015, two Falcon 9 v1.1 boosters, B1012 and B1015, failed to land on drone ships.
  - The success rate for landing outcomes improved over the years.

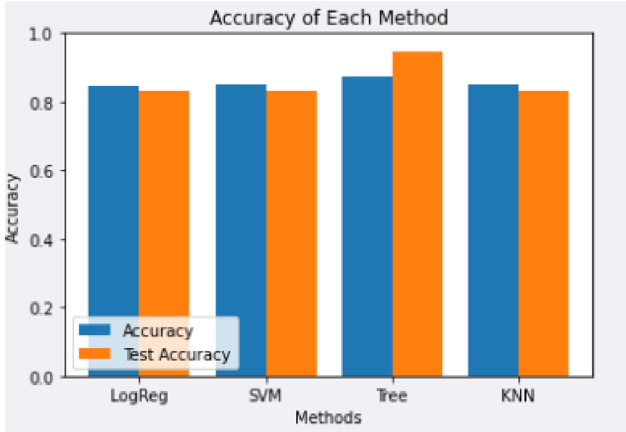
Results contd.

Launch Site Distribution:
Most launches take place at East Coast launch sites.

Site Characteristics:
Interactive analytics identified that these launch sites are usually situated in secure locations, often near the sea, and are supported by strong logistical infrastructure.

Predictive analysis:
Indicated that the Decision Tree Classifier is the most effective model for predicting successful landings, achieving an accuracy of over 87% and more than 94% on test data.

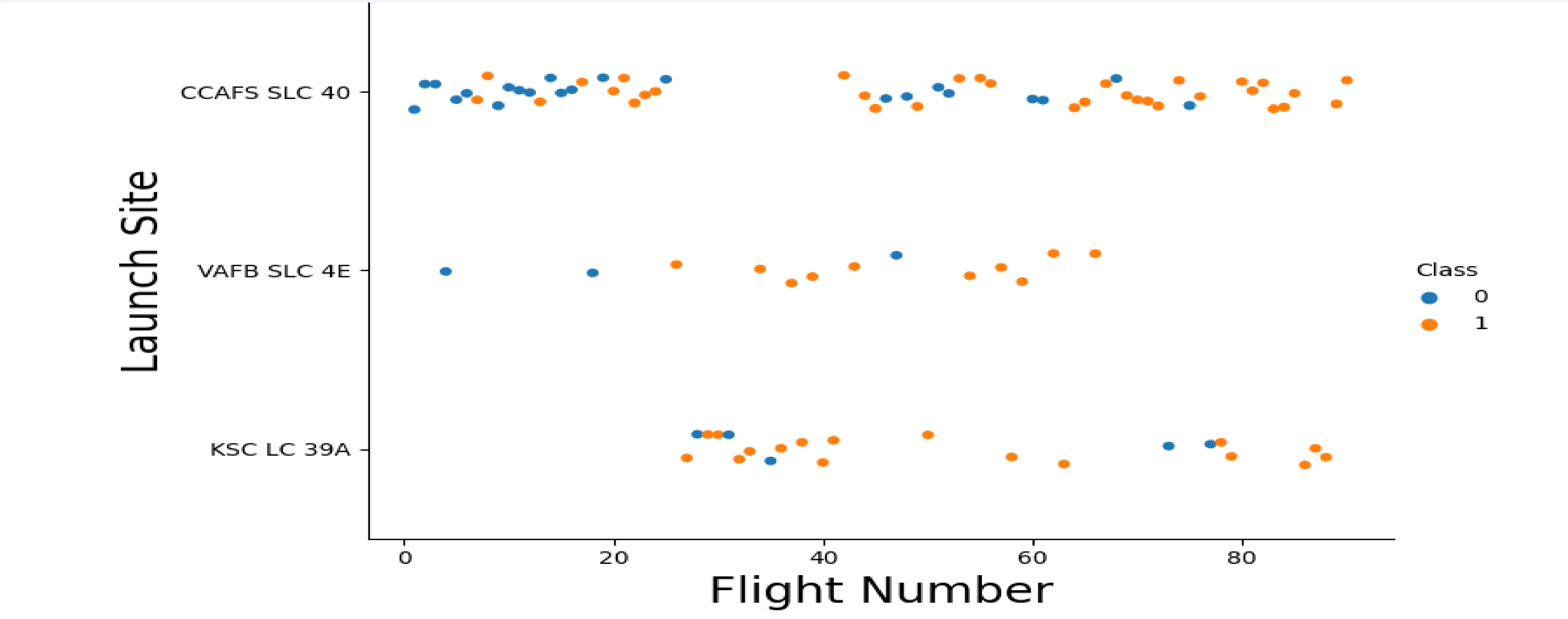




Section 2

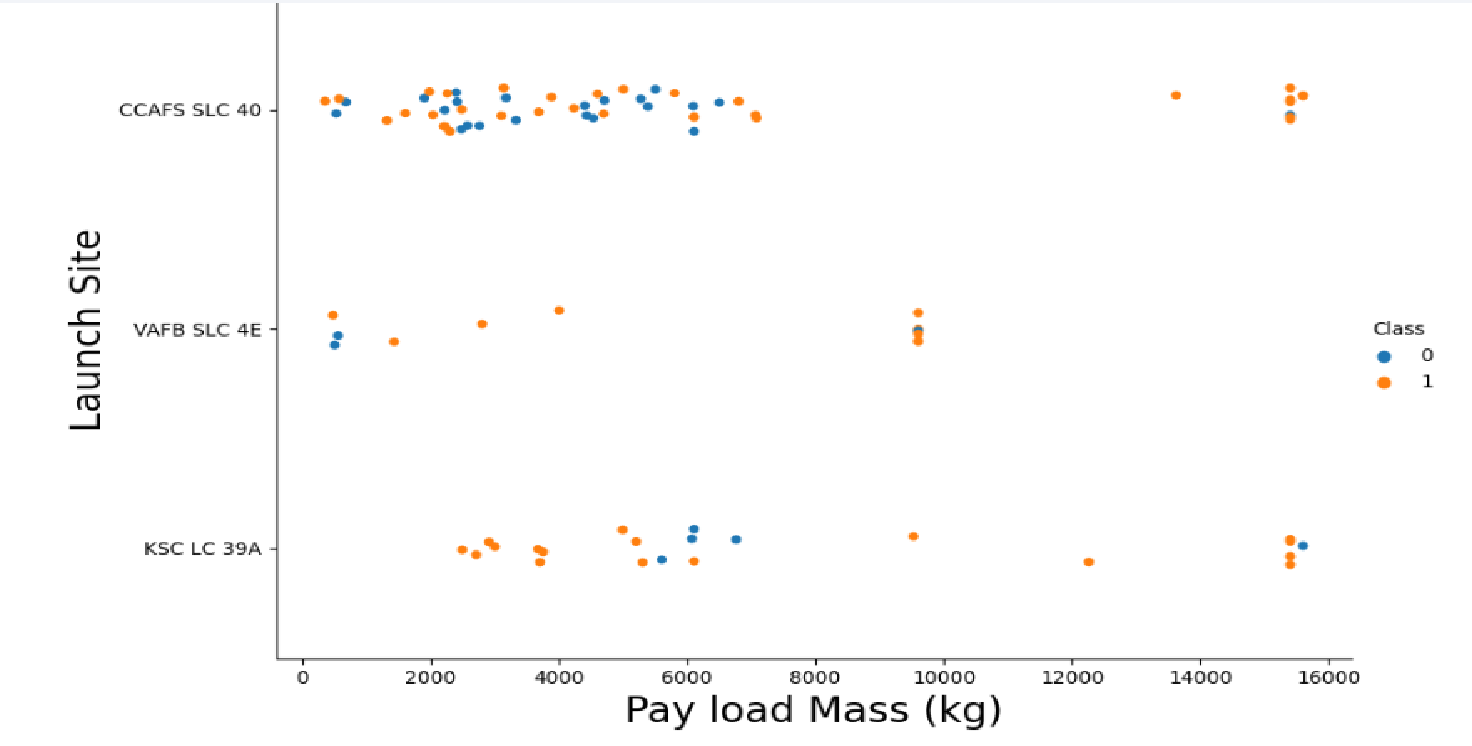
Insights drawn from EDA

Flight Number vs. Launch Site



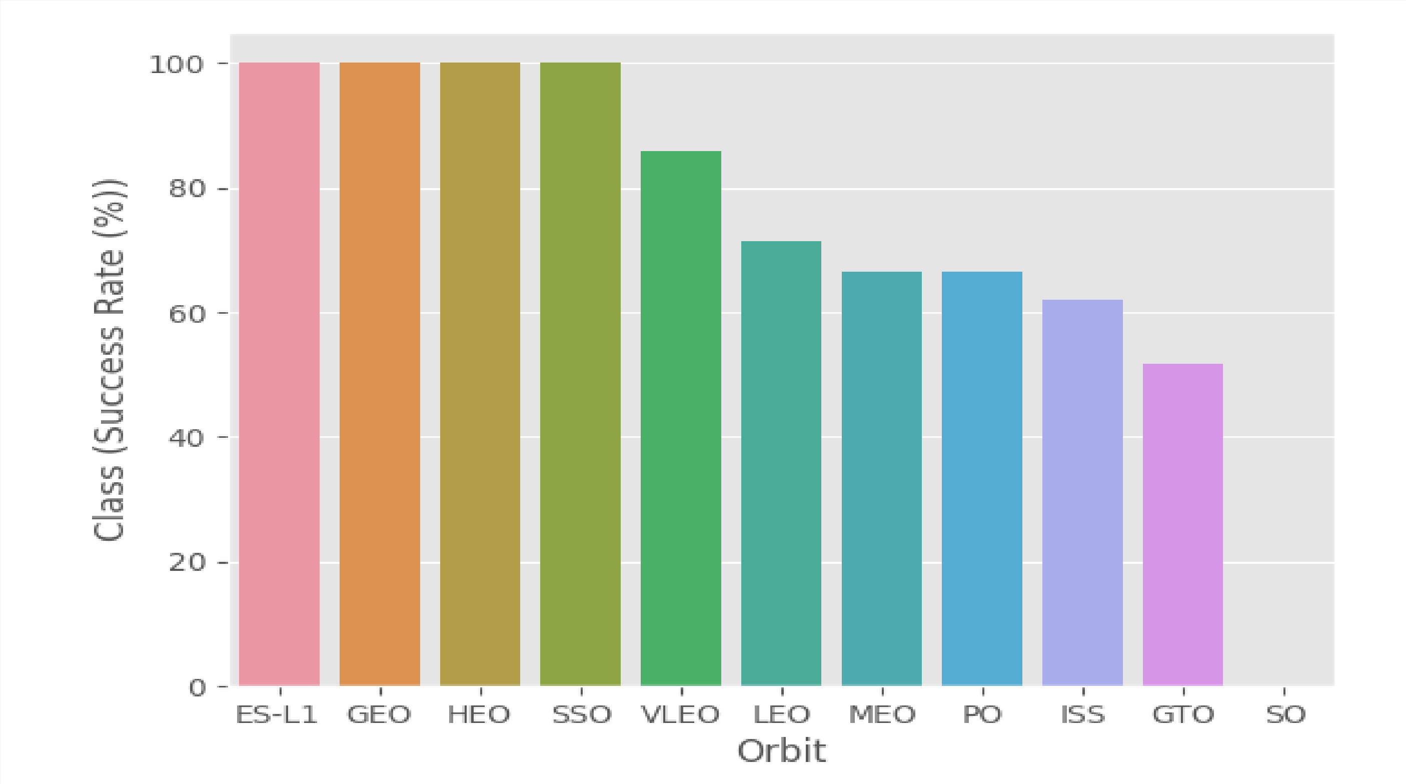
It can be observed that as the flight number increases at each of the three launch sites, the success rate also improves. For example, the VAFB SLC 4E launch site achieves a 100% success rate after the 50th flight, while both KSC LC 39A and CCAFS SLC 40 reach a 100% success rate after the 80th flight.

Payload vs. Launch Site



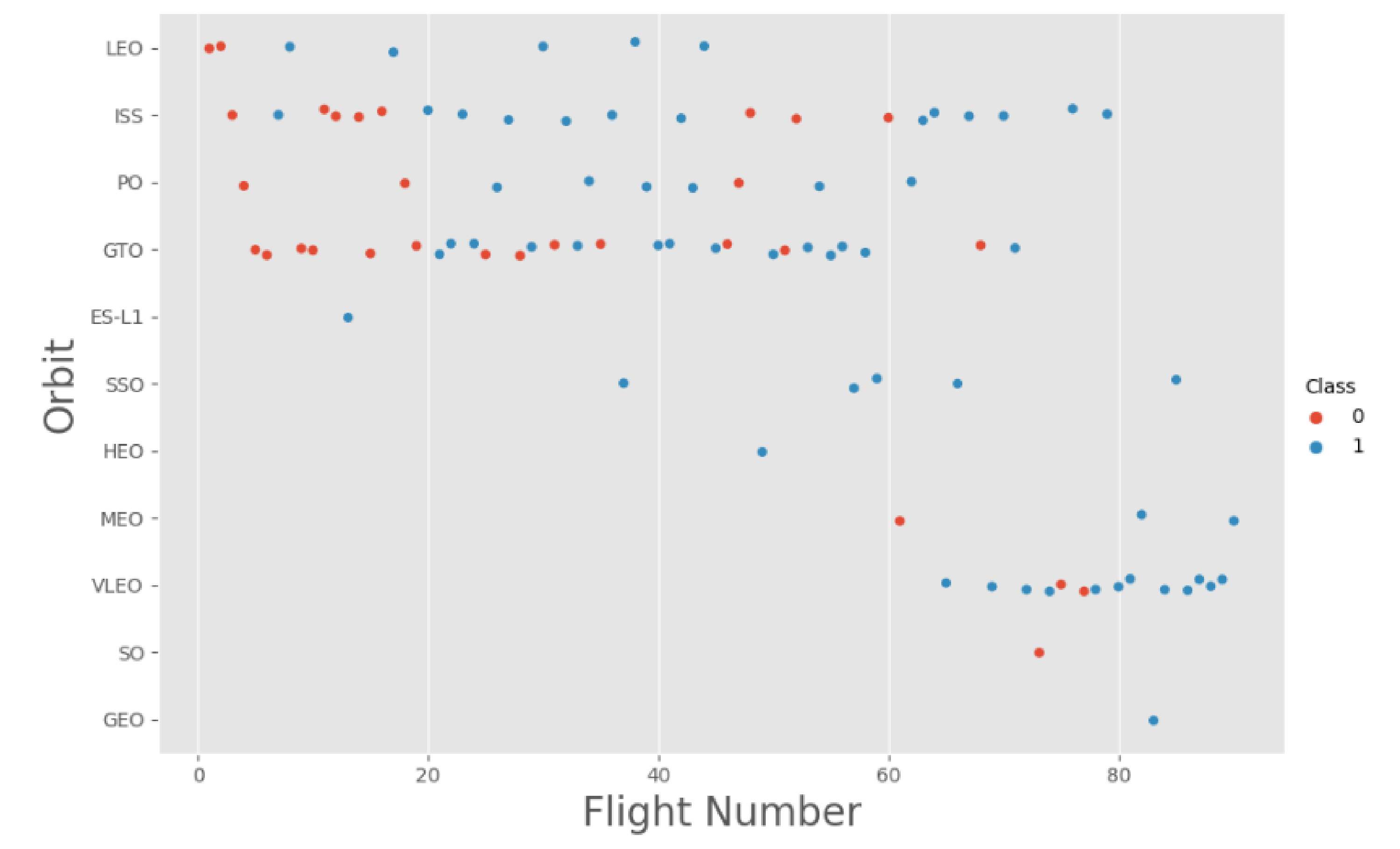
Examining the Payload vs. Launch Site scatter plot reveals that no rockets have been launched from the VAFB-SLC site with a payload mass greater than 10,000.

Success Rate vs. Orbit Type



Orbits ES-L1, GEO, HEO, and SSO all exhibit the highest success rates of 100%, whereas the SO orbit has the lowest success rate at approximately 50%, with an actual success rate of 0%

Flight Number vs. Orbit Type

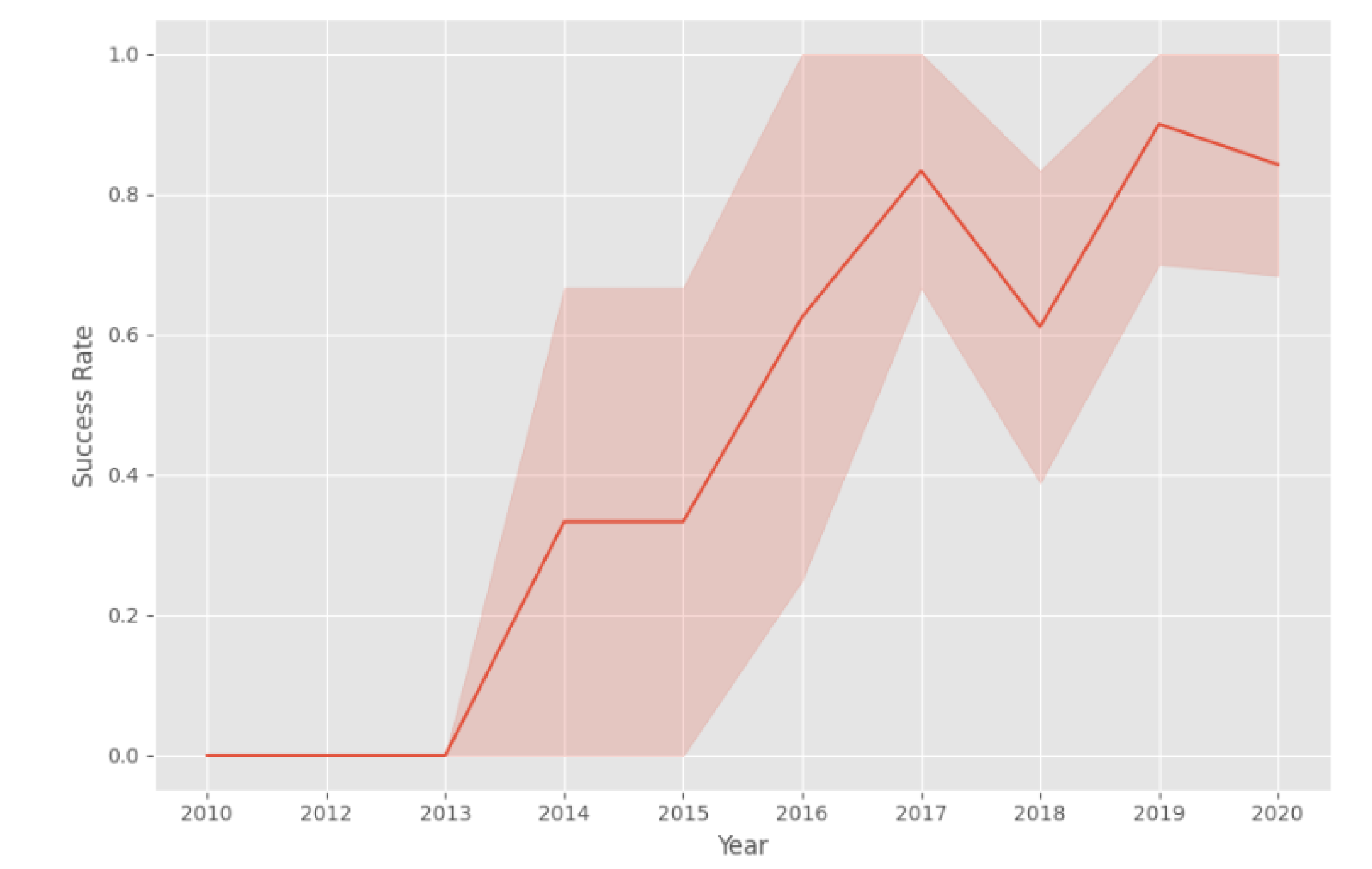


In the LEO orbit, success rates appear to be associated with the number of flights, whereas no clear relationship between flight number and success rate is observed in the GTO orbit.

Payload vs. Orbit Type

For heavy payloads, the successful landing rates are higher for Polar, LEO, and ISS orbits. However, in the GTO orbit, it is difficult to distinguish this trend as both successful and unsuccessful landing rates are observed.

Launch Success Yearly Trend



Success rate kept rising from 2013 kept increasing till 2020

All Launch Site Names

Display the names of the unique launch sites in the space mission

In [31]:
```
%sql SELECT DISTINCT LAUNCH_SITE as "Launch_Sites" FROM SPACEXTBL;
```

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

Out[31]:

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

We have the names of all the unique test-sites using a SQL query.

Launch Site Names Begin with 'CCA'

Task 2

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

In [72]:
```
%sql SELECT * FROM 'SPACEXTBL' WHERE Launch_Site LIKE 'CCA%' LIMIT 5;
```

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

Out[72]:

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing _Outcome
04-06-2010	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
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	Success	Failure (parachute)
22-05-2012	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
08-10-2012	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
01-03-2013	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

We have the names of all the test-sites starting with “CCA” using a SQL query.

Total Payload Mass

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

In [17]:
```
%sql SELECT SUM(PAYLOAD_MASS__KG_) as "Total Payload Mass(Kgs)", Customer FROM 'SPACEXTBL' WHERE Customer = 'NASA (CRS)';
```

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

Out[17]:

Total Payload Mass(Kgs)	Customer
45596	NASA (CRS)

•Utilized the 'SUM()' function to calculate and display the total sum of the 'PAYLOAD_MASS_KG' column for the customer 'NASA (CRS)'.

Average Payload Mass by F9 v1.1

Task 4

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

In [19]:

```
%sql SELECT AVG(PAYLOAD_MASS__KG_) as "Payload Mass Kgs", Customer, Booster_Version FROM 'SPACEXTBL' WHERE Booster_Version
```

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

Out[19]:

Payload Mass Kgs	Customer	Booster_Version
2534.6666666666665	MDA	F9 v1.1 B1003

Used the AVG() function to return and display the average payload mass for F9 v1.1

First Successful Ground Landing Date

Task 5

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

Hint:Use min function

In [21]:
```
%sql SELECT MIN(DATE) FROM 'SPACEXTBL' WHERE "Landing _Outcome" = "Success (ground pad)";
```

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

Out[21]:

MIN(DATE)
01-05-2017

The MIN() function returns the value by the oldest date when the launch was successful.

Successful Drone Ship Landing with Payload between 4000 and 6000

Task 6

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

In [26]:
```
# %sql SELECT * FROM 'SPACEXTBL'
```

In [27]:
```
%sql SELECT DISTINCT Booster_Version, Payload FROM SPACEXTBL WHERE "Landing _Outcome" = "Success (drone ship)" AND PAYLOAD_I
```

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

Out[27]:

Booster_Version	Payload
F9 FT B1022	JCSAT-14
F9 FT B1026	JCSAT-16
F9 FT B1021.2	SES-10
F9 FT B1031.2	SES-11 / EchoStar 105

- Employed the 'Select Distinct' statement to list unique booster names with operators between 4000 and 6000, filtering for boosters with payloads in the 4000-6000 range and a landing outcome of 'Success (drone ship)'.

Total Number of Successful and Failure Mission Outcomes

Task 7

List the total number of successful and failure mission outcomes

In [28]:
```
%sql SELECT "Mission_Outcome", COUNT("Mission_Outcome") as Total FROM SPACEXTBL GROUP BY "Mission_Outcome";
```

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

Out[28]:

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

Used the 'COUNT()' together with the 'GROUP BY' statement to return total number of missions outcomes

Boosters Carried Maximum Payload

Task 8

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

In [30]:

```
%sql SELECT "Booster_Version",Payload, "PAYLOAD_MASS__KG_" FROM SPACEXTBL WHERE "PAYLOAD_MASS__KG_" = (SELECT MAX("PAYLOAD_I
```

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

Out[30]:

Booster_Version	Payload	PAYLOAD_MASS__KG_
F9 B5 B1048.4	Starlink 1 v1.0, SpaceX CRS-19	15600
F9 B5 B1049.4	Starlink 2 v1.0, Crew Dragon in-flight abort test	15600
F9 B5 B1051.3	Starlink 3 v1.0, Starlink 4 v1.0	15600
F9 B5 B1056.4	Starlink 4 v1.0, SpaceX CRS-20	15600
F9 B5 B1048.5	Starlink 5 v1.0, Starlink 6 v1.0	15600
F9 B5 B1051.4	Starlink 6 v1.0, Crew Dragon Demo-2	15600
F9 B5 B1049.5	Starlink 7 v1.0, Starlink 8 v1.0	15600
F9 B5 B1060.2	Starlink 11 v1.0, Starlink 12 v1.0	15600
F9 B5 B1058.3	Starlink 12 v1.0, Starlink 13 v1.0	15600
F9 B5 B1051.6	Starlink 13 v1.0, Starlink 14 v1.0	15600
F9 B5 B1060.3	Starlink 14 v1.0, GPS III-04	15600
F9 B5 B1049.7	Starlink 15 v1.0, SpaceX CRS-21	15600

Utilized a subquery to retrieve and pass the maximum payload value, then listed all boosters that have carried this maximum payload of 15,600 kg.

2015 Launch Records

Task 9

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, 4, 2) as month to get the months and substr(Date,7,4)='2015' for year.

In [68]:

```
%sql SELECT substr(Date,7,4), substr(Date, 4, 2),"Booster_Version", "Launch_Site", Payload, "PAYLOAD_MASS__KG_", "Mission_Ou
```

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

Out[68]:

substr(Date,7,4)	substr(Date, 4, 2)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Mission_Outcome	Landing _Outcome
2015	01	F9 v1.1 B1012	CCAFS LC-40	SpaceX CRS-5	2395	Success	Failure (drone ship)
2015	04	F9 v1.1 B1015	CCAFS LC-40	SpaceX CRS-6	1898	Success	Failure (drone ship)

- Applied the 'substr()' function in the select statement to extract the month and year from the date column, with the condition `substr(Date,7,4)='2015'` for the year and `Landing_outcome = 'Failure (drone ship')`, and returned the records that matched the filter.

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

Task 10

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

In [74]:
```
%sql SELECT * FROM SPACEXTBL WHERE "Landing _Outcome" LIKE 'Success%' AND (Date BETWEEN '04-06-2010' AND '20-03-2017
```

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

Out[74]:

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	_O
19-02-2017	14:39:00	F9 FT B1031.1	KSC LC-39A	SpaceX CRS-10	2490	LEO (ISS)	NASA (CRS)	Success	
18-10-2020	12:25:57	F9 B5 B1051.6	KSC LC-39A	Starlink 13 v1.0, Starlink 14 v1.0	15600	LEO	SpaceX	Success	
18-08-2020	14:31:00	F9 B5 B1049.6	CCAFS SLC-40	Starlink 10 v1.0, SkySat-19, -20, -21, SAOCOM 1B	15440	LEO	SpaceX, Planet Labs, PlanetIQ	Success	
18-07-2016	04:45:00	F9 FT B1025.1	CCAFS LC-40	SpaceX CRS-9	2257	LEO (ISS)	NASA (CRS)	Success	
18-04-2018	22:51:00	F9 B4 B1045.1	CCAFS SLC-40	Transiting Exoplanet Survey Satellite (TESS)	362	HEO	NASA (LSP)	Success	
17-12-2019	00:10:00	F9 B5 B1056.3	CCAFS SLC-40	JCSat-18 / Kacific 1, Starlink 2 v1.0	6956	GTO	Sky Perfect JSAT, Kacific 1	Success	
16-11-2020	00:27:00	F9 B5B1061.1	KSC LC-39A	Crew-1, Sentinel-6 Michael Freilich	12500	LEO (ISS)	NASA (CCP)	Success	
15-12-2017	15:36:00	F9 FT B1035.2	CCAFS SLC-40	SpaceX CRS-13	2205	LEO (ISS)	NASA (CRS)	Success	
15-11-2018	20:46:00	F9 B5 B1047.2	KSC LC-39A	Es hail 2	5300	GTO	Es hailSat	Success	

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

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

In [78]:
```
%sql SELECT DISTINCT Launch_Site FROM SPACEXTBL;
```

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

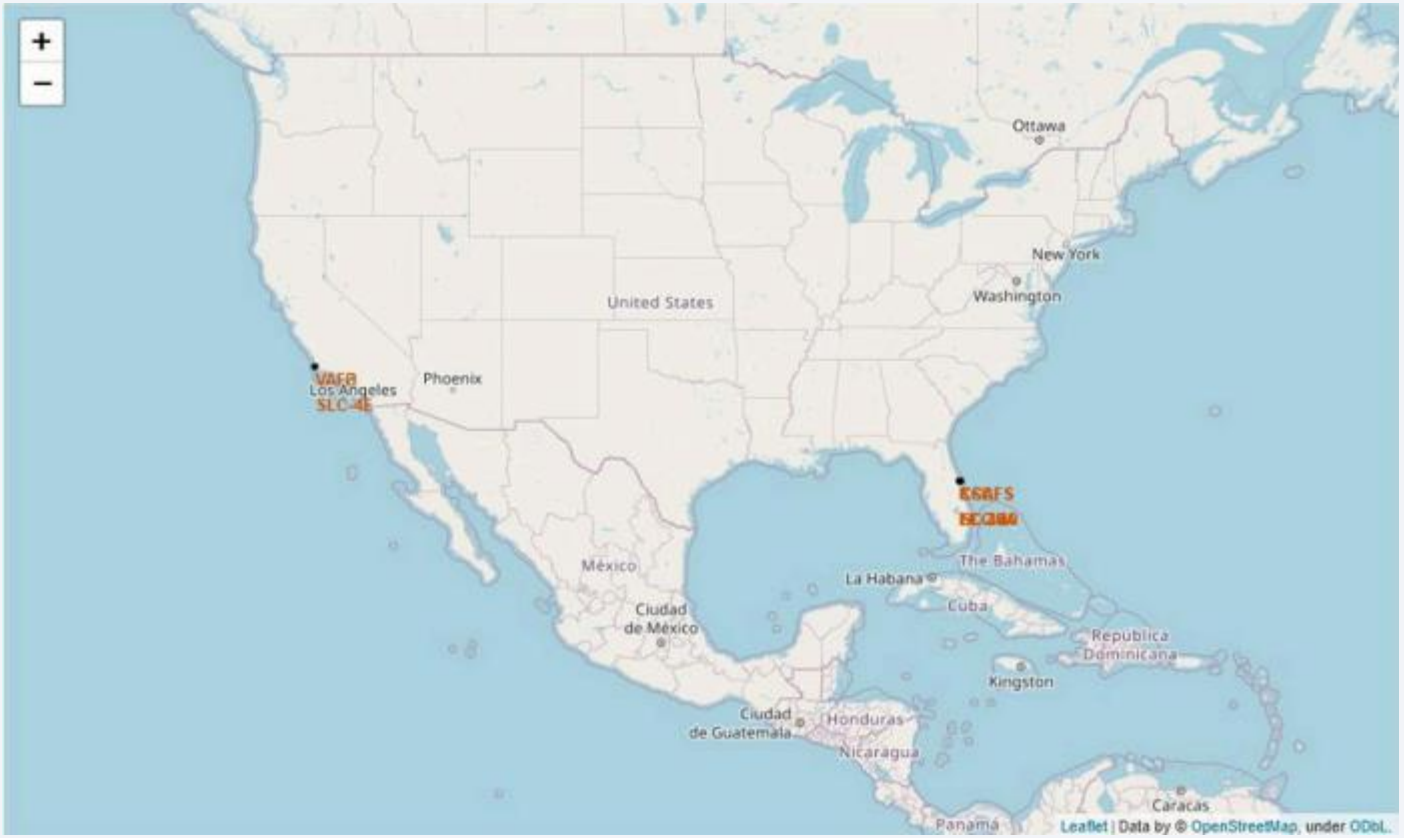
Out[78]:

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

Section 3

Launch Sites Proximities Analysis

All Launch Sites

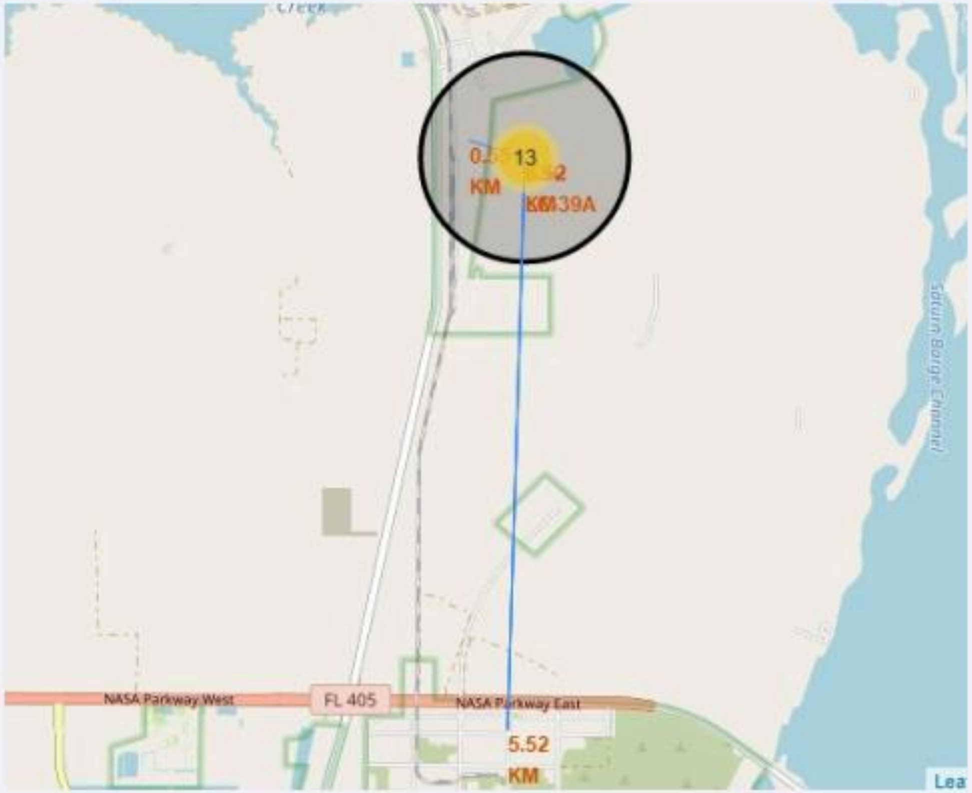


Launch sites are near sea, probably by safety, but not too far from roads and railroads.

Launch Outcomes by Site

Shows launch outcomes for KSC-LC 39A
Green markers indicate successful launches and red show failures.

Logistics and Safety

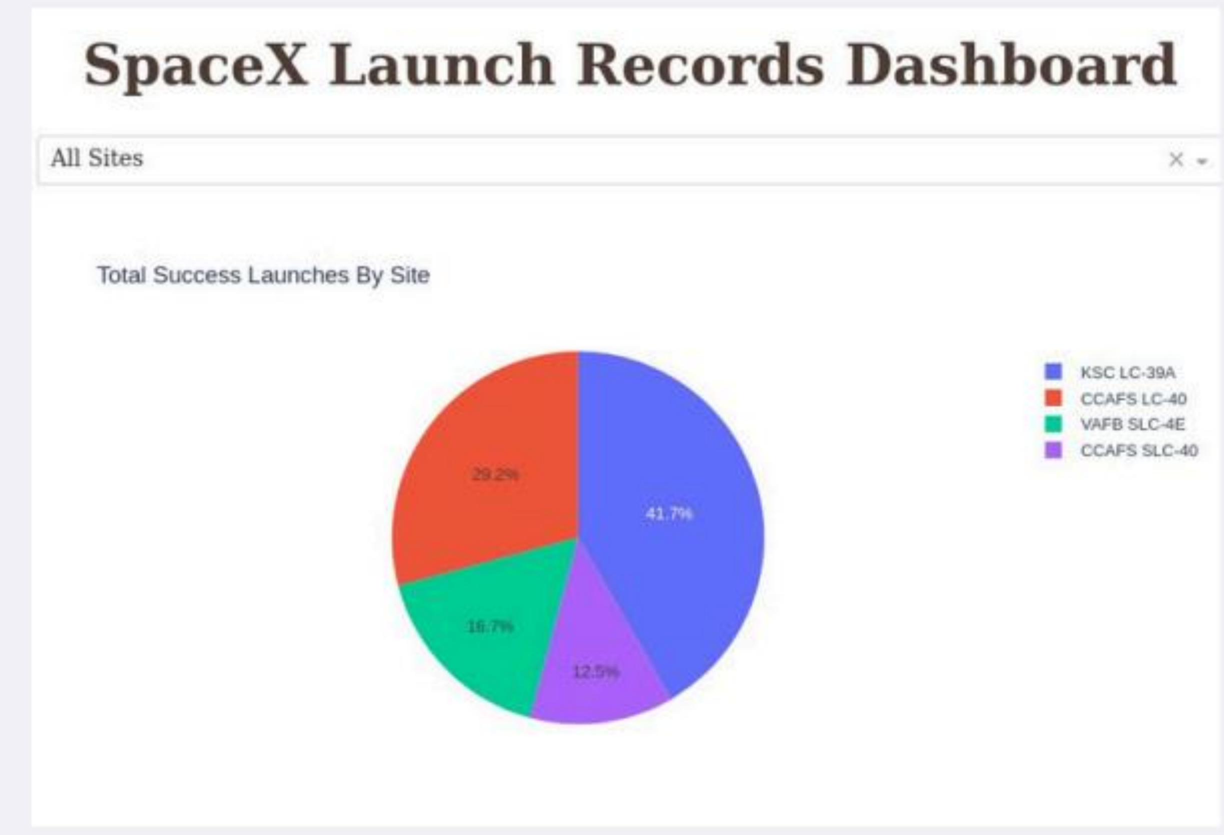


The KSC LC-39A launch site benefits from strong logistical features, including proximity to railroads and roads, and is situated relatively far from populated areas.

Section 4

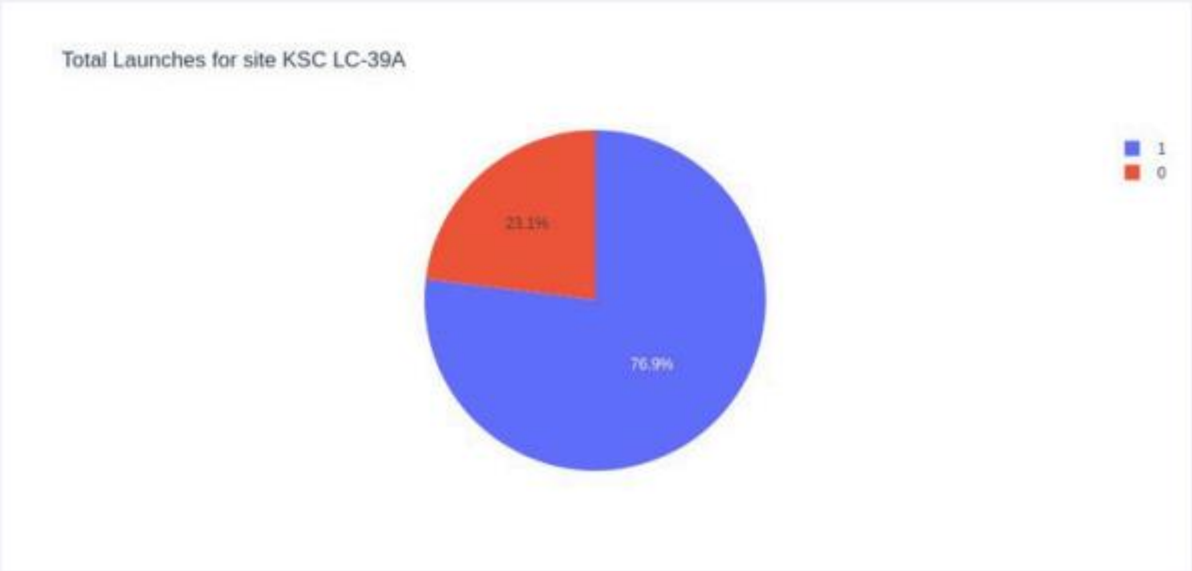
Build a Dashboard with Plotly Dash

Successful Launches by Sites



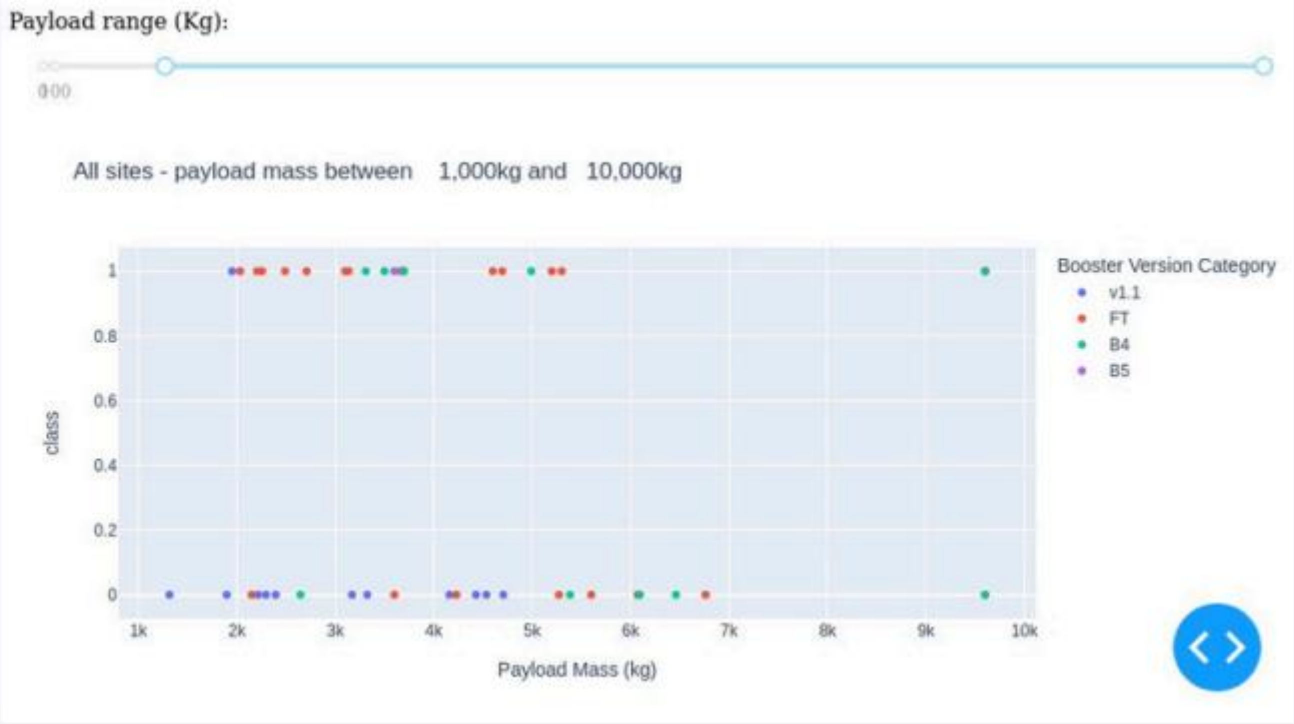
The launch site KSC LC-39A boasts the highest success rate at 42%, followed by CCAFS LC-40 at 29%, VAFB SLC-4E at 17%, and CCAFS SLC-40 with the lowest success rate of 13%.

Launch Success Ratio for KSC LC-39A



76.9% of all launches on this site were successful.

Payload vs Launch Outcome



This gives a comparison between all launches and the most successful combination being Payloads under 6000kg, and CCAFS LC-40 version FT has the highest success rate.

Section 5

Predictive Analysis (Classification)

Classification Accuracy

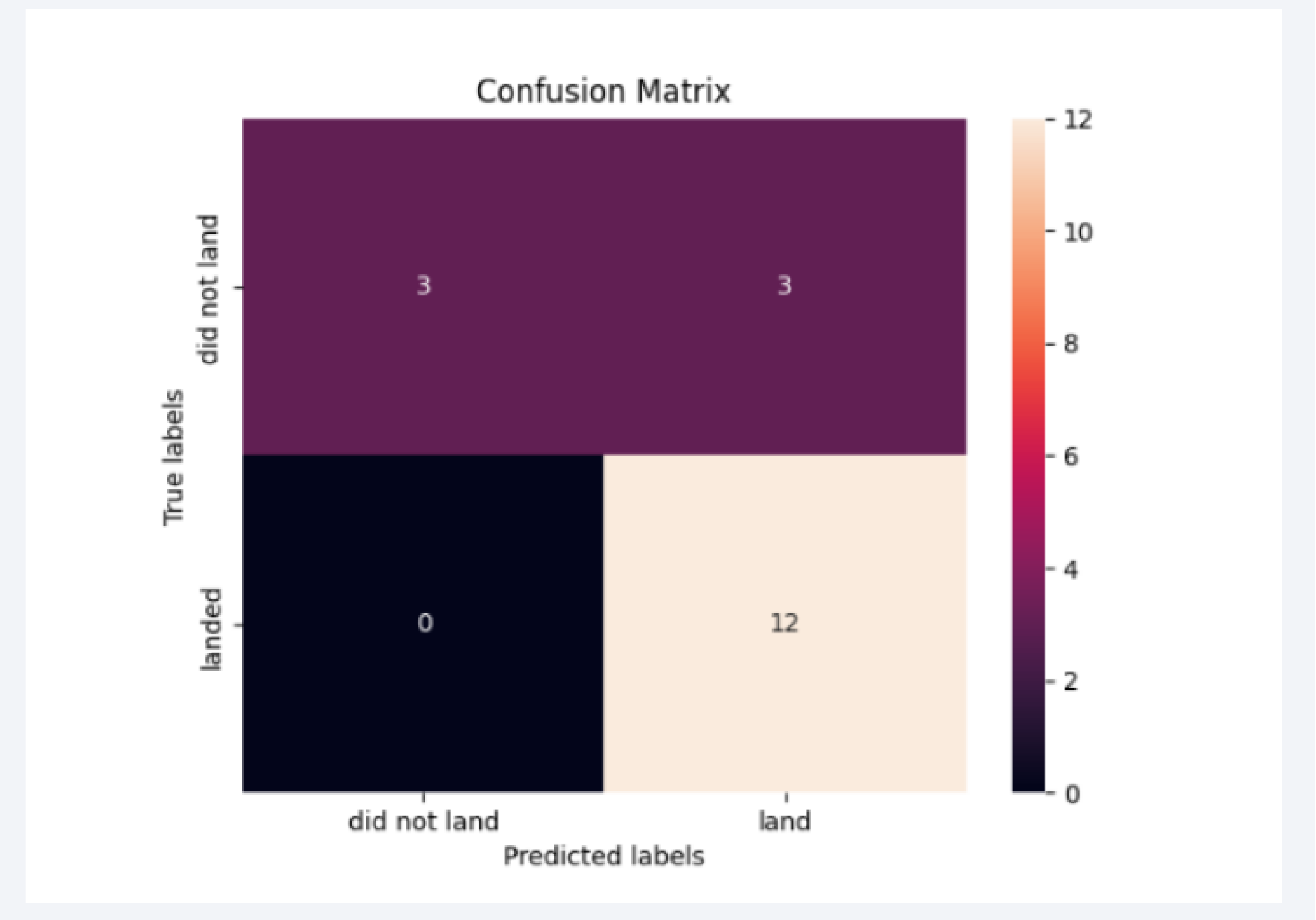
Out[68]:

	0
Method	Test Data Accuracy
Logistic_Reg	0.833333
SVM	0.833333
Decision Tree	0.833333
KNN	0.833333

Analysis Suggests that all models have the same accuracy.

Confusion Matrix

All four classification models produced identical confusion matrices and were equally effective at distinguishing between different classes. The main issue across all models is the presence of false positives.



Conclusions

- Launch Site Success Rates:
    - CCAFS LC-40 has a success rate of 60%.
    - KSC LC-39A and VAFB SLC 4E both have a success rate of 77%.
- Success Rate Trends by Flight Number:
    - Success rates increase with the number of flights at each launch site.
    - VAFB SLC 4E achieves a 100% success rate after the 50th flight.
    - KSC LC-39A and CCAFS LC-40 reach a 100% success rate after the 80th flight.
- Payload Mass Observations:
    - The VAFB-SLC launch site has not launched rockets with heavy payloads (greater than 10,000).
- Orbit Success Rates:
    - Orbits ES-L1, GEO, HEO, and SSO have the highest success rates at 100%.
    - The SO orbit has the lowest success rate, around 50%, with an actual 0% success rate.
- Flight Number vs. Success Rate:
    - In LEO orbit, success appears to be related to the number of flights.
    - No clear relationship between flight number and success rate is observed in the GTO orbit.
- Heavy Payload Success Rates:
    - Successful landings with heavy payloads are higher for Polar, LEO, and ISS orbits.
    - The GTO orbit shows mixed results with both successful and unsuccessful missions.
- Overall Success Rate Trend:
    - The success rate has steadily increased from 2013 to 2020.

Thank you!