



Winning Space Race with Data Science

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Outline

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

Executive Summary

- Summary of methodologies
 - Data collection through API
 - Data collection with Web Scraping
 - Data wrangling
 - Exploratory Data Analysis with SQL
 - Exploratory Data Analysis with Data Visualization
 - Interactive Visual Analytics with Folium
 - Machine Learning Prediction
- Summary of all result
 - Exploratory data analysis result
 - Interactive analytics in screenshots
 - Predictive analytics result

Introduction

- Project background and context

Space X advertises Falcon 9 rocket launches on its website with a cost of 62 million dollars, other providers cost upward of 165 million dollars each, much of the savings is because Space X can reuse the first stage. Therefore, if we can determine if the first stage will land, we can determine the cost of a launch. This information can be used if an alternate company wants to bid against space X for a rocket launch. This goal of the project is to create a machine learning pipeline to predict if the first stage will land successfully.

- Problems you want to find answers

- What factors determine if the rocket will land successfully?
- The interaction amongst various features that determine the success rate of a successful landing.
- What operating conditions need to be in place to ensure a successful landing program.

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
Data from SpaceX was obtained from 2 sources:
 - SpaceX API (<https://api.spacexdata.com/v4/rockets/>)
 - Web Scraping
(https://en.wikipedia.org/wiki/List_of_Falcon_9_and_Falcon_Heavy_launches)
- Perform data wrangling
 - Collected data was enriched by creating a landing outcome label based on outcome data after summarizing and analyzing features

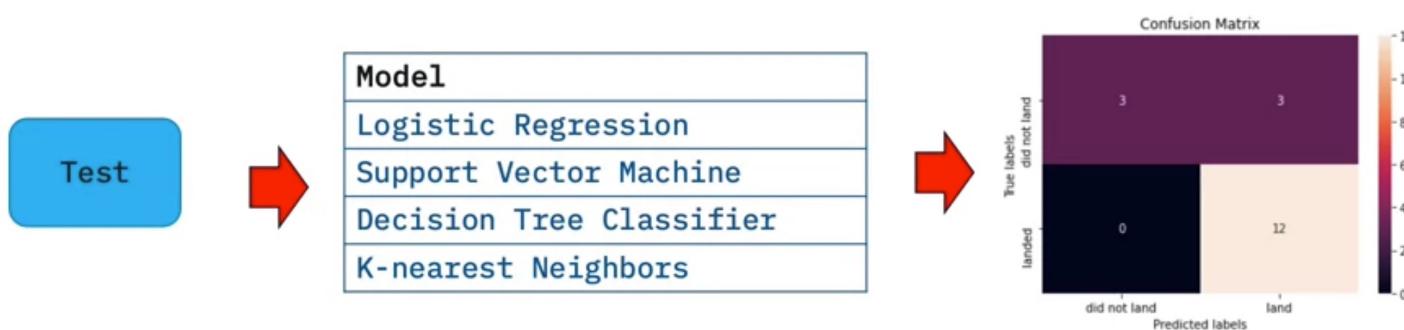
Methodology

Executive Summary

- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
 - Determine model with best accuracy using model Logistic Regression, Support Vector Machine, Decision Tree Classifier, and K-nearest Neighbors.

Perform Predictive Analysis Using Classification Models

Determine Model with Best Accuracy



Data Collection

Datasets were collected from :

- SpaceX API
(<https://api.spacexdata.com/v4/rockets/>) and
- Wikipedia (https://en.wikipedia.org/wiki/List_of_Falcon_9_and_Falcon_Heavy_launches), using web scraping technics.

Data Collection – SpaceX API

- SpaceX offers a public API from where data can be obtained and then used;
- This API was used according to the flowchart beside and then data is persisted.
- <https://github.com/Herxmann/AppliedDataScience/blob/main/her%2001%20jupyter-labs-spacex-data-collection-api.ipynb>



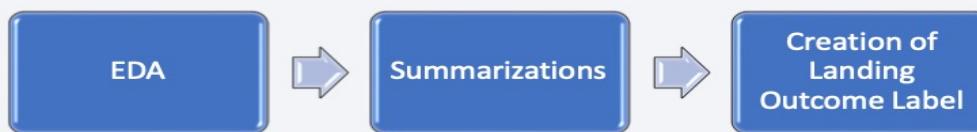
Data Collection - Scraping

- Data from SpaceX launches can also be obtained from Wikipedia;
 - Data are downloaded from Wikipedia according to the flowchart and then persisted.
- Source code:
- <https://github.com/Herxmann/AppliedDataScience/blob/main/her%2002%20jupyter-labs-webscraping.ipynb>



Data Wrangling

- Initially some Exploratory Data Analysis (EDA) was performed on the dataset.
- Then the summary launches per site, occurrences of each orbit and occurrences of mission outcome per orbit type were calculated.
- Finally, the landing outcome label was created from Outcome column.



- Source code:
<https://github.com/Herxmann/AppliedDataScience/blob/main/her03%20labs-jupyter-spacex-Data%20wrangling.ipynb>

EDA with Data Visualization

- The following SQL queries were performed:
 - Names of the unique launch sites in the space mission;
 - Top 5 launch sites whose name begins with the string 'CCA';
 - Total pay load mass carried by boosters launched by NASA (CRS);
 - Average payload mass carried by booster version F9 v1.1;
 - Date when the first successful landing outcome in ground pad was achieved;
 - Names of the boosters which have success in drone ship and have payload mass between 4000 and 6000 kg;
 - Total number of successful and failure mission outcomes;
 - Names of the booster versions which have carried the maximum payload mass;
 - Failed landing out comes in droneship, their booster versions, and launch site names for in year 2015; and
 - Rank of the count of landing outcomes (such as Failure (droneship) or Success (ground pad)) between the date 2010-06-04 and 2017-03-20.
- Source code: https://github.com/Herxmann/AppliedDataScience/blob/main/her_04_jupyter-labs-eda-sql-coursera_sqlite.ipynb

EDA with SQL

- To explore data, scatterplots and bar plots were used to visualize the relationship between pair of features:
- Payload Mass X Flight Number, Launch Site X Flight Number, Launch Site X Payload Mass, Orbit and Flight Number, Payload and Orbit



- Source code: <https://github.com/Herxmann/AppliedDataScience/blob/main/her 05 jupyter-labs-edatviz.ipynb>

Build an Interactive Map with Folium

- Markers, circles, lines and marker clusters were used with Folium Maps
- Markers indicate points like launch sites;
- Circles indicate highlighted areas around specific coordinates, like NASA Johnson Space Center;
- Marker clusters indicates groups of events in each coordinate, like launches in a launch site; and
- Lines are used to indicate distances between two coordinates.
- Source code: https://github.com/Herxmann/AppliedDataScience/blob/main/her_06_lab_jupyter_launch_site_location.ipynb

Build a Dashboard with Plotly Dash

- We built an interactive dashboard with Plotly dash
- We plotted pie charts showing the total launches by a certain sites
- We plotted scatter graph showing the relationship with Outcome and Payload Mass (Kg) for the different booster version.
- Source code:
[https://github.com/Herxmann/AppliedDataScience/blob/main/her 07 Build a Dashboard Application with Plotly Dash.ipynb](https://github.com/Herxmann/AppliedDataScience/blob/main/her%2007%20Build%20a%20Dashboard%20Application%20with%20Plotly%20Dash.ipynb)

Predictive Analysis (Classification)

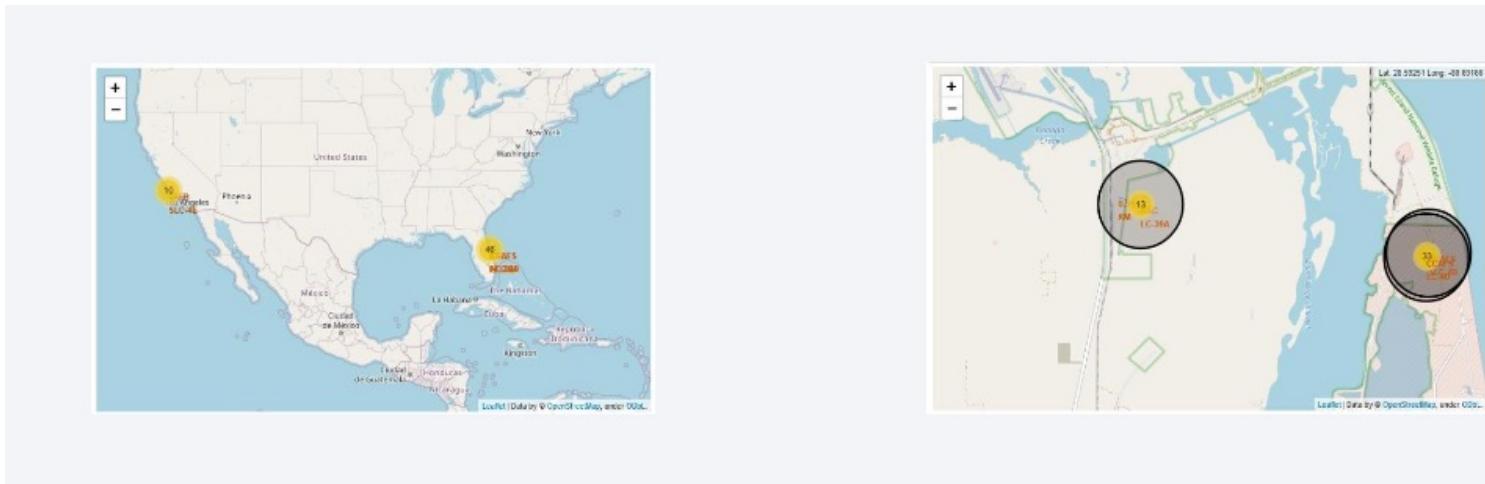
- We loaded the data using numpy and pandas, transformed the data, split our data into training and testing.
- We built different machine learning models and tune different hyperparameters using GridSearchCV.
- We used accuracy as the metric for our model, improved the model using feature engineering and algorithm tuning.
- We found the best performing classification model.
- Source code:
https://github.com/Herxmann/AppliedDataScience/blob/main/her_08_SpaceX_Machine_Learning_Prediction_Part_5.jupyterlite_230802.ipynb

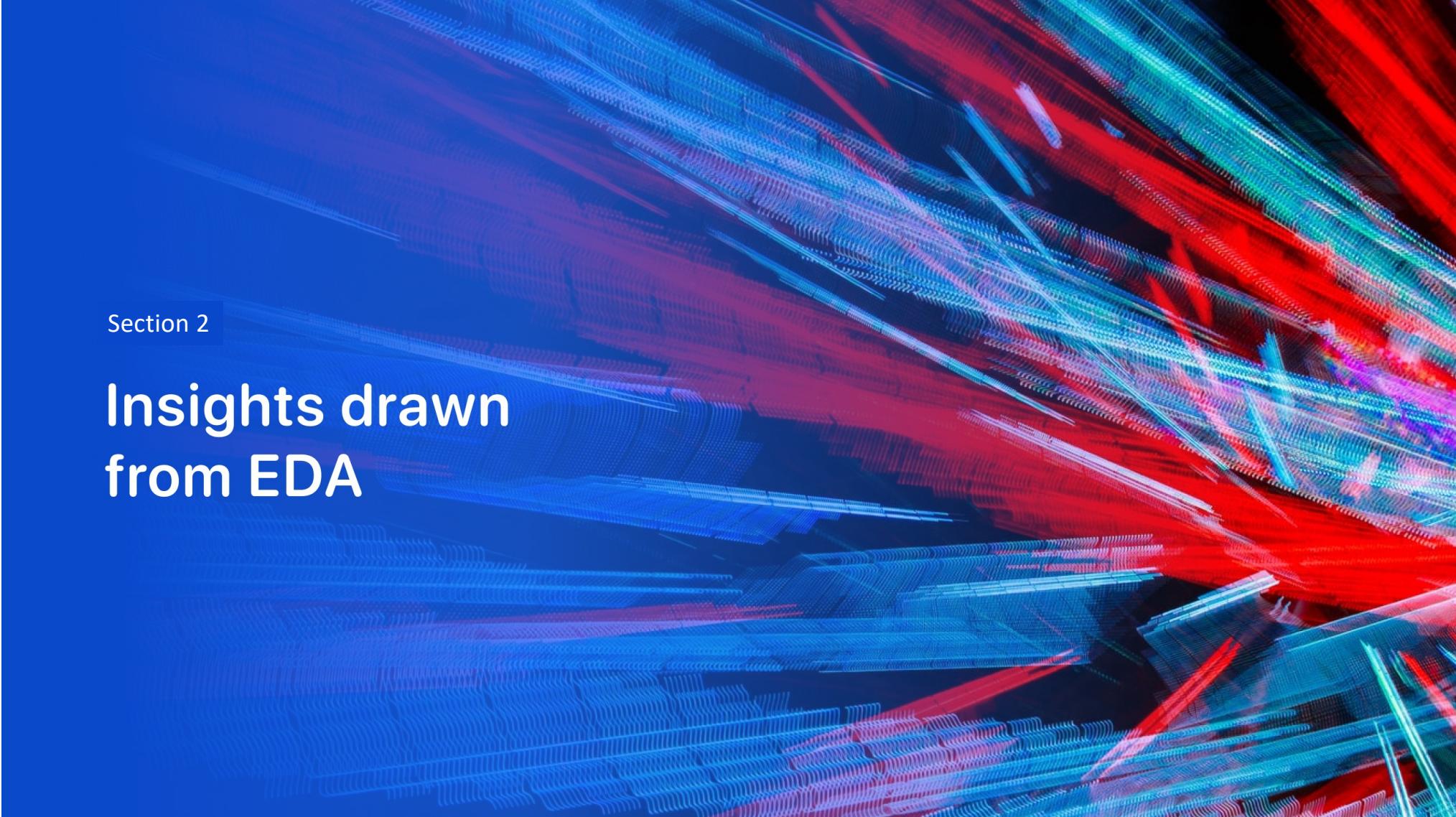
Results

- Exploratory data analysis results:
 - Space X uses 4 different launch sites;
 - The first launches were done to Space X itself and NASA;
 - The average payload of F9 v1.1 booster is 2,928 kg;
 - The first success landing outcome happened in 2015 five years after the first launch;
 - Many Falcon 9 booster versions were successful at landing in drone ships having payload above the average;
 - Almost 100% of mission outcomes were successful;
 - Two booster versions failed at landing in drone ships in 2015: F9 v1.1 B1012 and F9 v1.1 B1015;
 - The number of landing outcomes became better as years passed.

Results

- Using interactive analytics was possible to identify that launch sites use to be in safety places, near sea, for example and have a good logistic infrastructure around.
- Most launches happens at east cost launch sites.



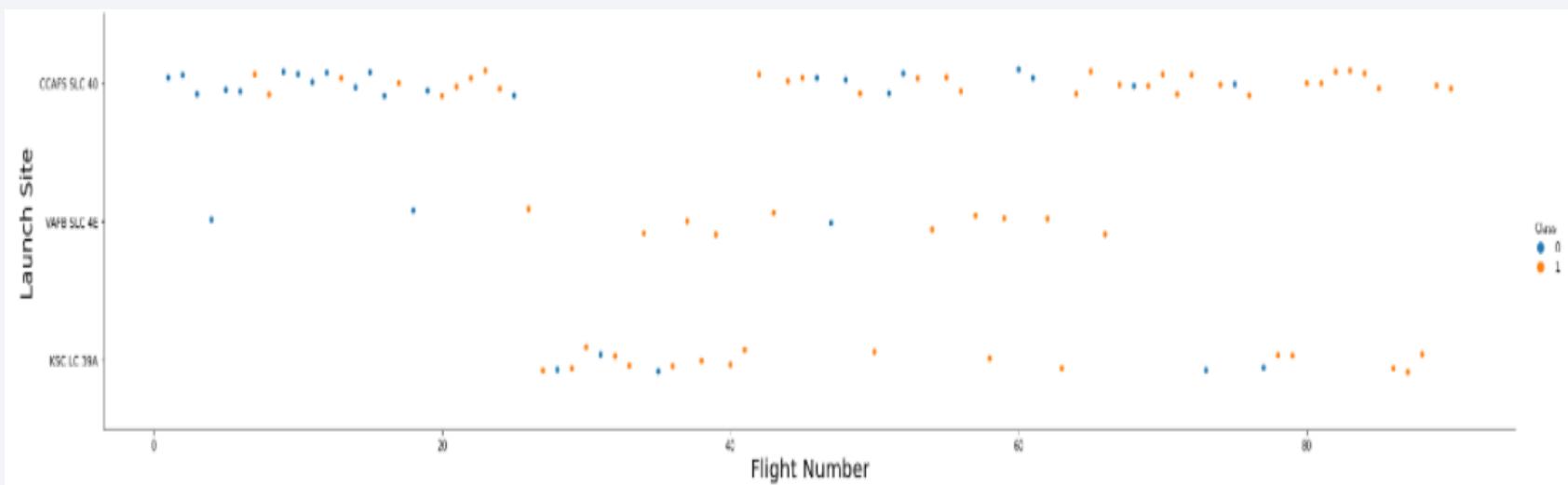


Section 2

Insights drawn from EDA

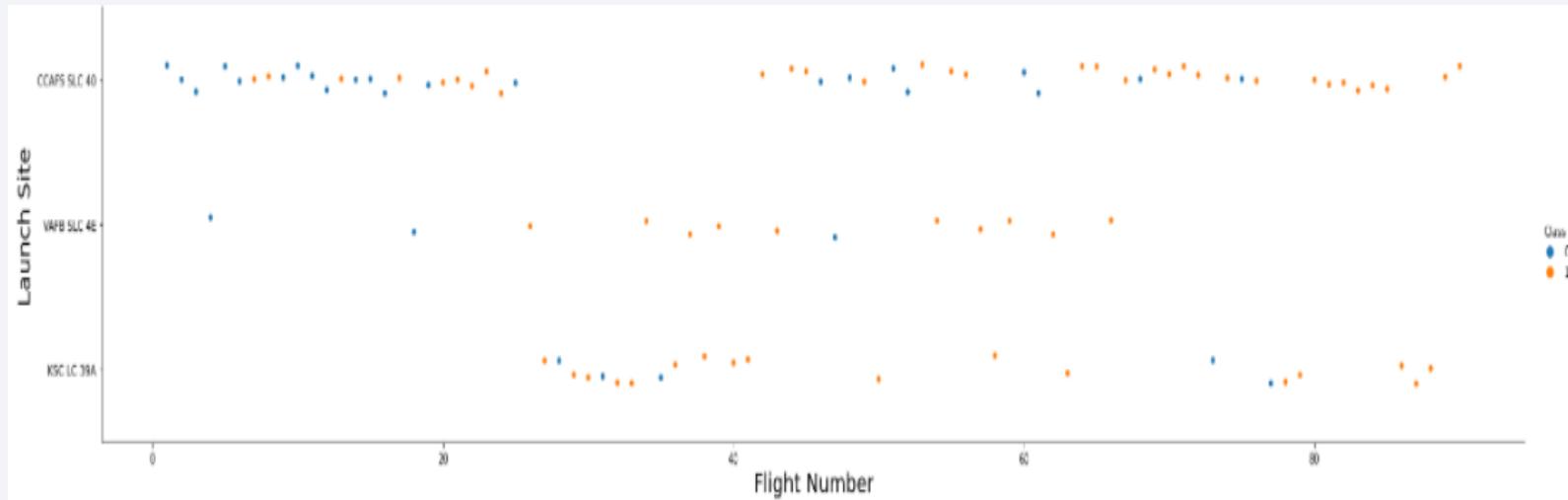
Flight Number vs. Launch Site

- From the plot, we found that the larger the flight amount at a launch site, the greater the success rate at a launch site.



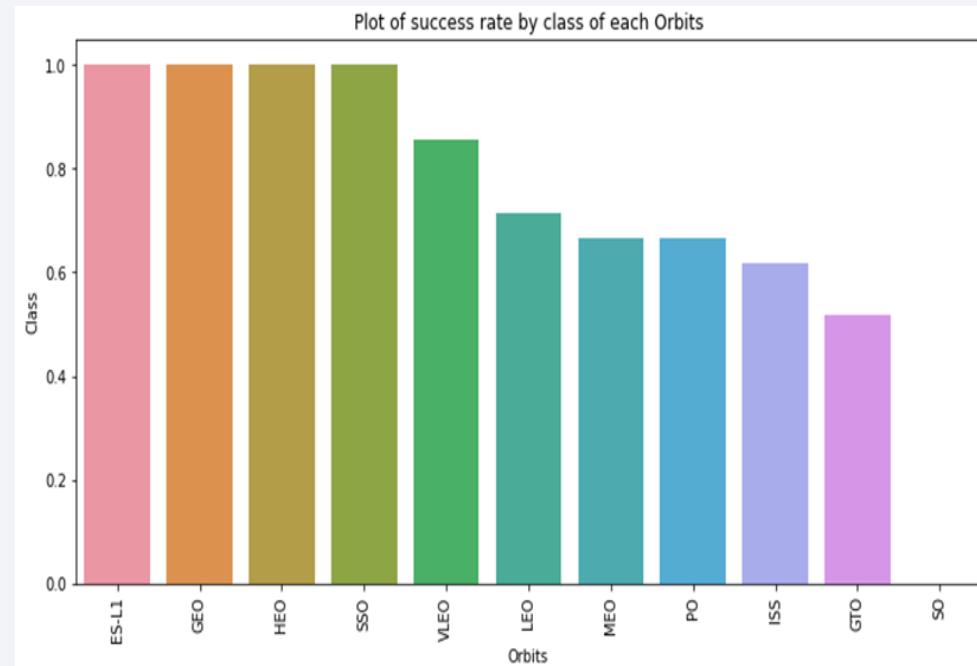
Payload vs. Launch Site

- The greater the payload mass for launch site CCAFS SLC 40 the higher the success rate for the rocket



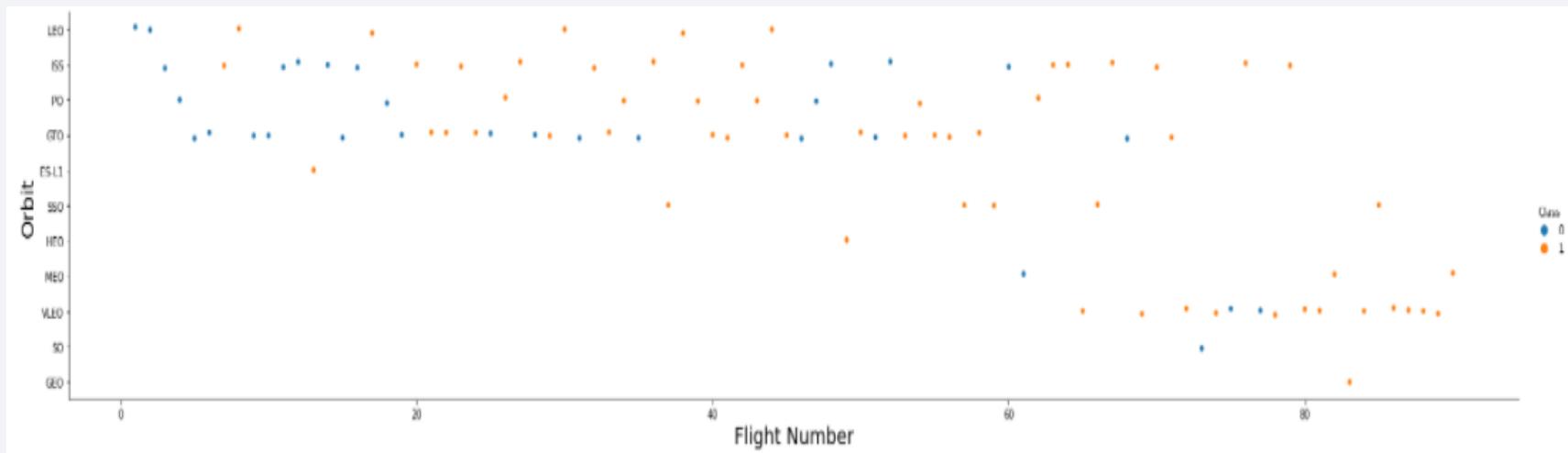
Success Rate vs. Orbit Type

- From the plot, we can see that ES-L1, GEO, HEO, SSO, VLEO had the most success rate.



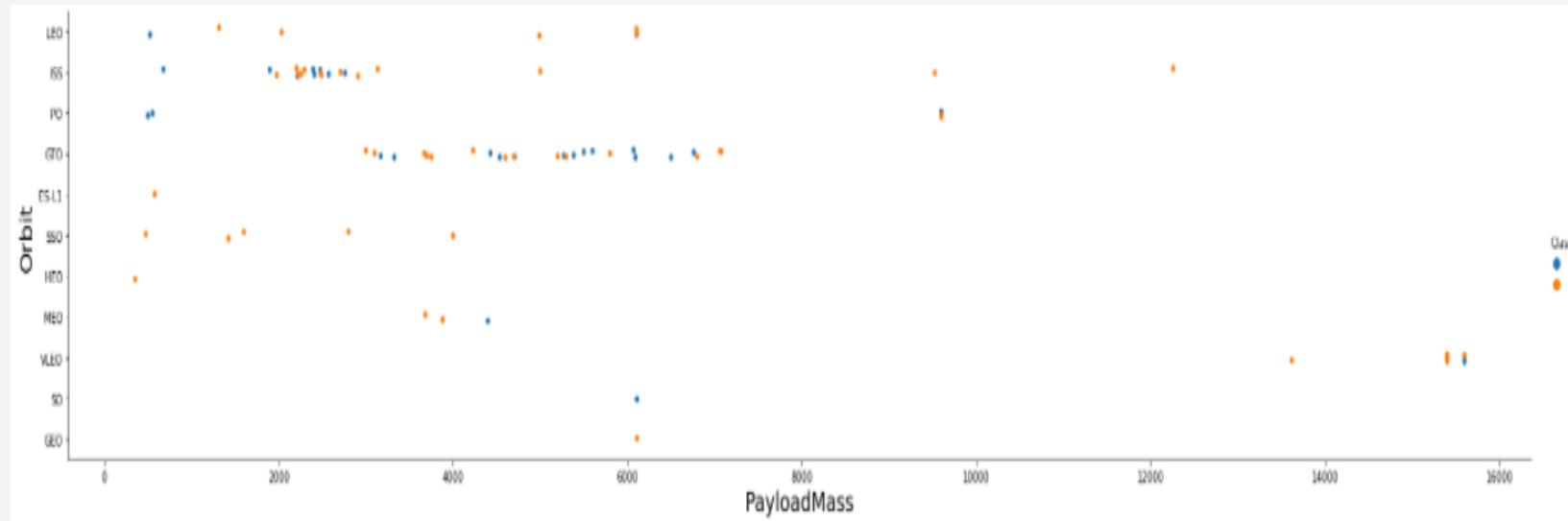
Flight Number vs. Orbit Type

- The plot below shows the Flight Number vs. Orbit type. We observe that in the LEO orbit, success is related to the number of flights whereas in the GTO orbit, there is no relationship between flight number and the orbit



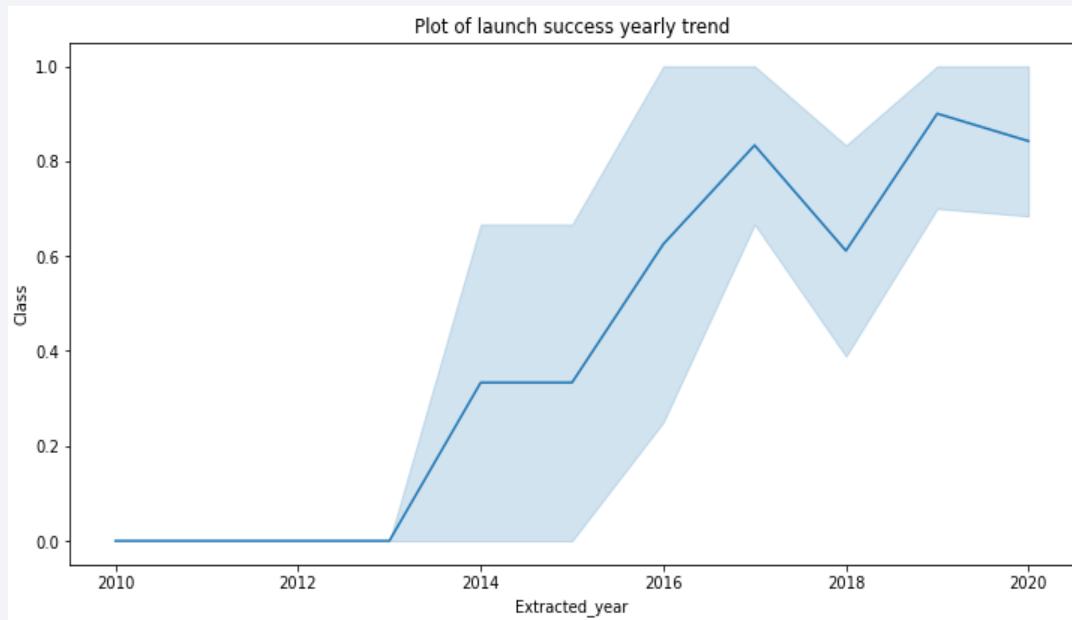
Payload vs. Orbit Type

- We can observe that with heavy payloads, the successful landing are more for PO, LEO and ISS orbits.



Launch Success Yearly Trend

- From the plot, we can observe that success rate since 2013 kept on increasing till 2020.



All Launch Site Names

- We used the key word **DISTINCT** to show only unique launch sites from the SpaceX data.

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

```
In [10]: task_1 = """
    SELECT DISTINCT LaunchSite
    FROM SpaceX
"""
create_pandas_df(task_1, database=conn)
```

Out[10]:

	launchsite
0	KSC LC-39A
1	CCAFS LC-40
2	CCAFS SLC-40
3	VAFB SLC-4E

Launch Site Names Begin with 'CCA'

- We used the query above to display 5 records where launch sites begin with 'CCA'

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

In [11]: task_2 = """
        SELECT *
        FROM SpaceX
        WHERE LaunchSite LIKE 'CCA%'
        LIMIT 5
        """
create_pandas_df(task_2, database=conn)

Out[11]:
```

	date	time	boosterversion	launchsite	payload	payloadmasskg	orbit	customer	missionoutcome	landingoutcome
0	2010-04-06	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
1	2010-08-12	15:43:00	F9 v1.0 B0004	CCAFS LC-40	Dragon demo flight C1, two CubeSats, barrel of...	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2	2012-05-22	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
3	2012-08-10	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
4	2013-01-03	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

Total Payload Mass

- We calculated the total payload carried by boosters from NASA as 45596 using the query below

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

In [12]:

```
task_3 = """
    SELECT SUM(PayloadMassKG) AS Total_PayloadMass
    FROM SpaceX
    WHERE Customer LIKE 'NASA (CRS)'
    """
create_pandas_df(task_3, database=conn)
```

Out[12]:

total_payloadmass

0	45596
---	-------

Average Payload Mass by F9 v1.1

- Average payload mass carried by booster version F9 v1.1 is 2928.4 kg.

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

In [13]:

```
task_4 = """
    SELECT AVG(PayloadMassKG) AS Avg_PayloadMass
    FROM SpaceX
    WHERE BoosterVersion = 'F9 v1.1'
    """
create_pandas_df(task_4, database=conn)
```

Out[13]:

avg_payloadmass

0	2928.4

First Successful Ground Landing Date

- The dates of the first successful landing outcome on ground pad is 22 Dec 2015.

In [14]:

```
task_5 = """
    SELECT MIN(Date) AS FirstSuccessfull_landing_date
    FROM SpaceX
    WHERE LandingOutcome LIKE 'Success (ground pad)'
    """
create_pandas_df(task_5, database=conn)
```

Out[14]:

firstsuccessfull_landing_date

0

2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

- List the names of boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 6000

```
In [15]: task_6 = """
    SELECT BoosterVersion
    FROM SpaceX
    WHERE LandingOutcome = 'Success (drone ship)'
        AND PayloadMassKG > 4000
        AND PayloadMassKG < 6000
    """
create_pandas_df(task_6, database=conn)
```

```
Out[15]:   boosterversion
0      F9 FT B1022
1      F9 FT B1026
2      F9 FT B1021.2
3      F9 FT B1031.2
```

Total Number of Successful and Failure Mission Outcomes

- Calculate the total number of successful and failure mission outcomes

```
List the total number of successful and failure mission outcomes

In [16]: task_7a = """
    SELECT COUNT(MissionOutcome) AS SuccessOutcome
    FROM SpaceX
    WHERE MissionOutcome LIKE 'Success%'
    """

task_7b = """
    SELECT COUNT(MissionOutcome) AS FailureOutcome
    FROM SpaceX
    WHERE MissionOutcome LIKE 'Failure%'
    """

print('The total number of successful mission outcome is:')
display(create_pandas_df(task_7a, database=conn))
print()
print('The total number of failed mission outcome is:')
create_pandas_df(task_7b, database=conn)

The total number of successful mission outcome is:
successoutcome
_____
0      100

The total number of failed mission outcome is:
Out[16]: failureoutcome
_____
0      1
```

Boosters Carried Maximum Payload

- List the names of the booster which have carried the maximum payload mass

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

```
In [17]: task_8 = """
    SELECT BoosterVersion, PayloadMassKG
    FROM SpaceX
    WHERE PayloadMassKG = (
        SELECT MAX(PayloadMassKG)
        FROM SpaceX
    )
    ORDER BY BoosterVersion
"""
create_pandas_df(task_8, database=conn)
```

Out[17]:

	boosterversion	payloadmasskg
0	F9 B5 B1048.4	15600
1	F9 B5 B1048.5	15600
2	F9 B5 B1049.4	15600
3	F9 B5 B1049.5	15600
4	F9 B5 B1049.7	15600
5	F9 B5 B1051.3	15600
6	F9 B5 B1051.4	15600
7	F9 B5 B1051.6	15600
8	F9 B5 B1056.4	15600
9	F9 B5 B1058.3	15600
10	F9 B5 B1060.2	15600
11	F9 B5 B1060.3	15600

2015 Launch Records

- List the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015

List the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015

In [18]:

```
task_9 = """
    SELECT BoosterVersion, LaunchSite, LandingOutcome
    FROM SpaceX
    WHERE LandingOutcome LIKE 'Failure (drone ship)'
        AND Date BETWEEN '2015-01-01' AND '2015-12-31'
    ...
create_pandas_df(task_9, database=conn)
```

Out[18]:

	boosterversion	launchsite	landingoutcome
0	F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)
1	F9 v1.1 B1015	CCAFS LC-40	Failure (drone ship)

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

Rank the count of landing outcomes (such as Failure (drone ship) or Success (ground pad))

```
In [19]: task_10 = """
    SELECT LandingOutcome, COUNT(LandingOutcome)
    FROM SpaceX
    WHERE DATE BETWEEN '2010-06-04' AND '2017-03-20'
    GROUP BY LandingOutcome
    ORDER BY COUNT(LandingOutcome) DESC
"""

create_pandas_df(task_10, database=conn)
```

Out[19]:

	landingoutcome	count
0	No attempt	10
1	Success (drone ship)	6
2	Failure (drone ship)	5
3	Success (ground pad)	5
4	Controlled (ocean)	3
5	Uncontrolled (ocean)	2
6	Precluded (drone ship)	1
7	Failure (parachute)	1

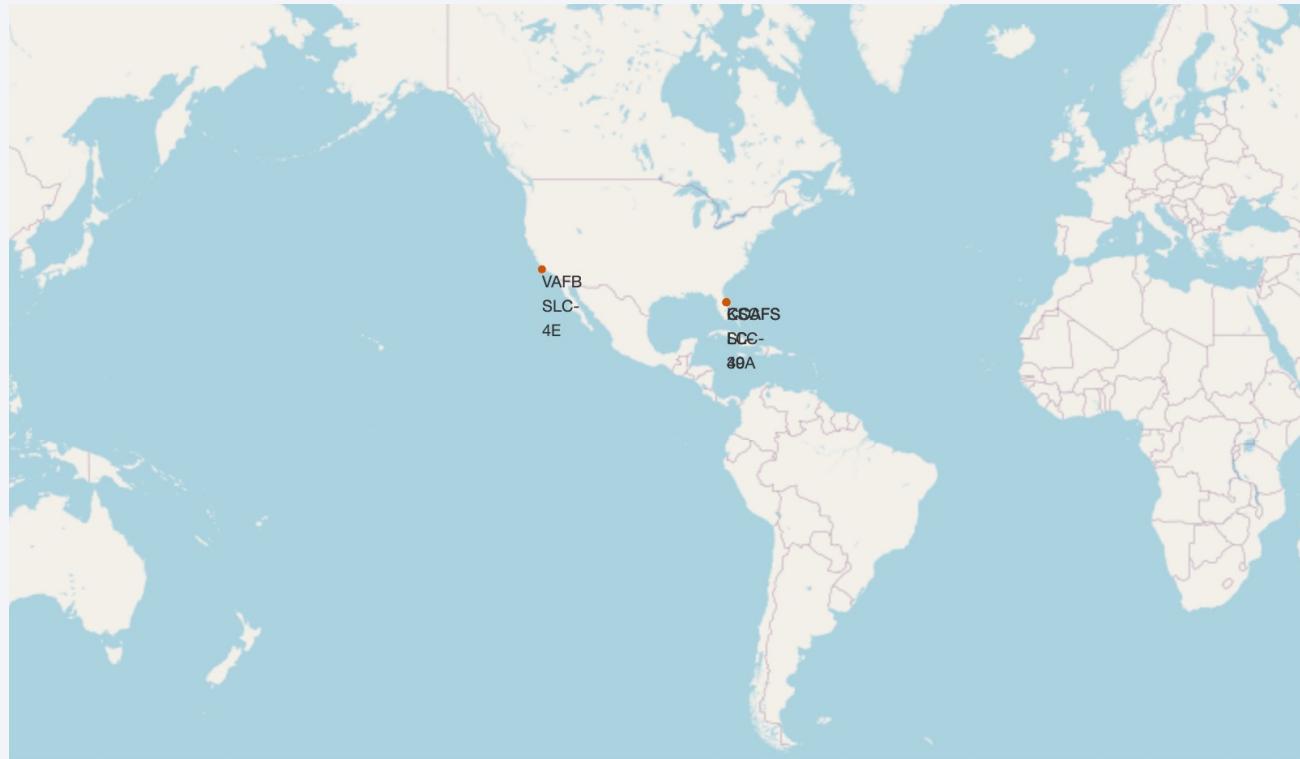
A nighttime satellite view of Earth from space, showing city lights and auroras.

Section 3

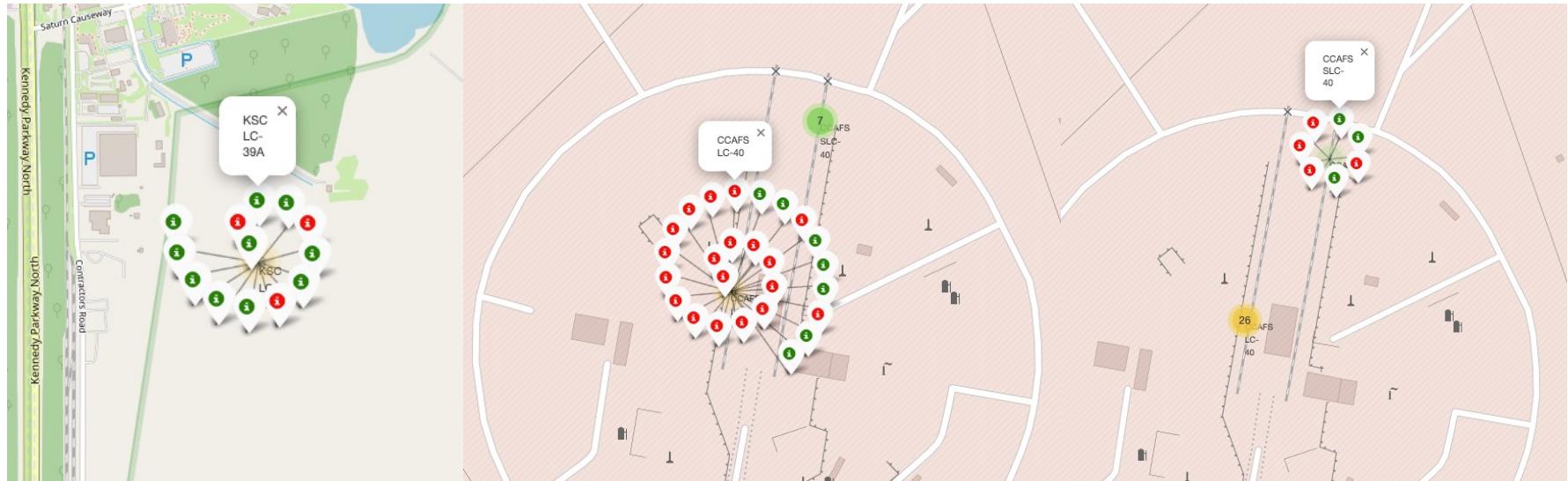
Launch Sites Proximities Analysis

All Launch Site Location

- SpaceX launch sites are all in coast area of United States of America: Florida and California

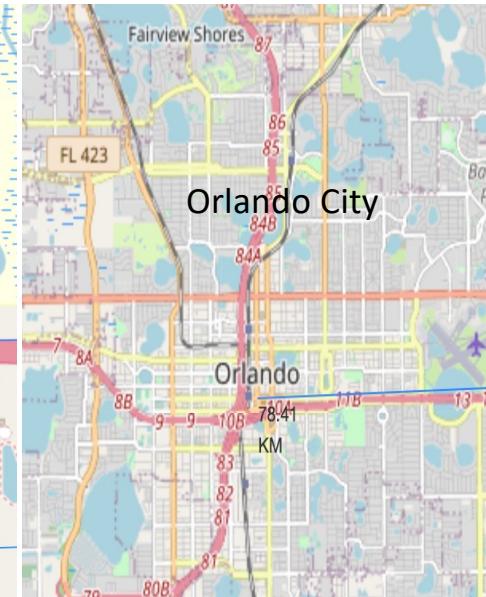
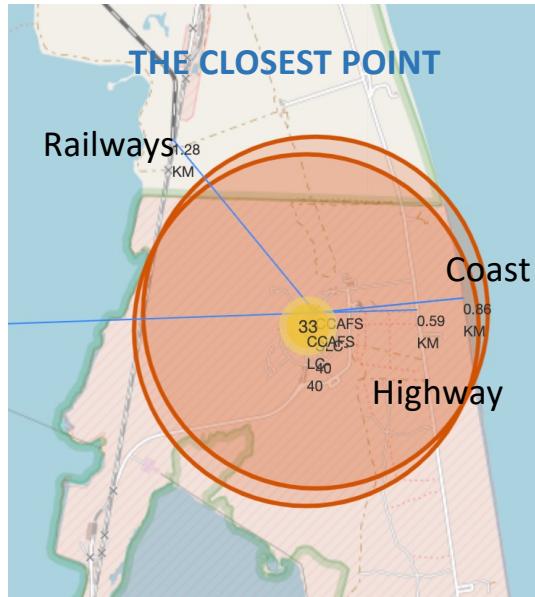


Color-labeled Launch Outcomes On The Map



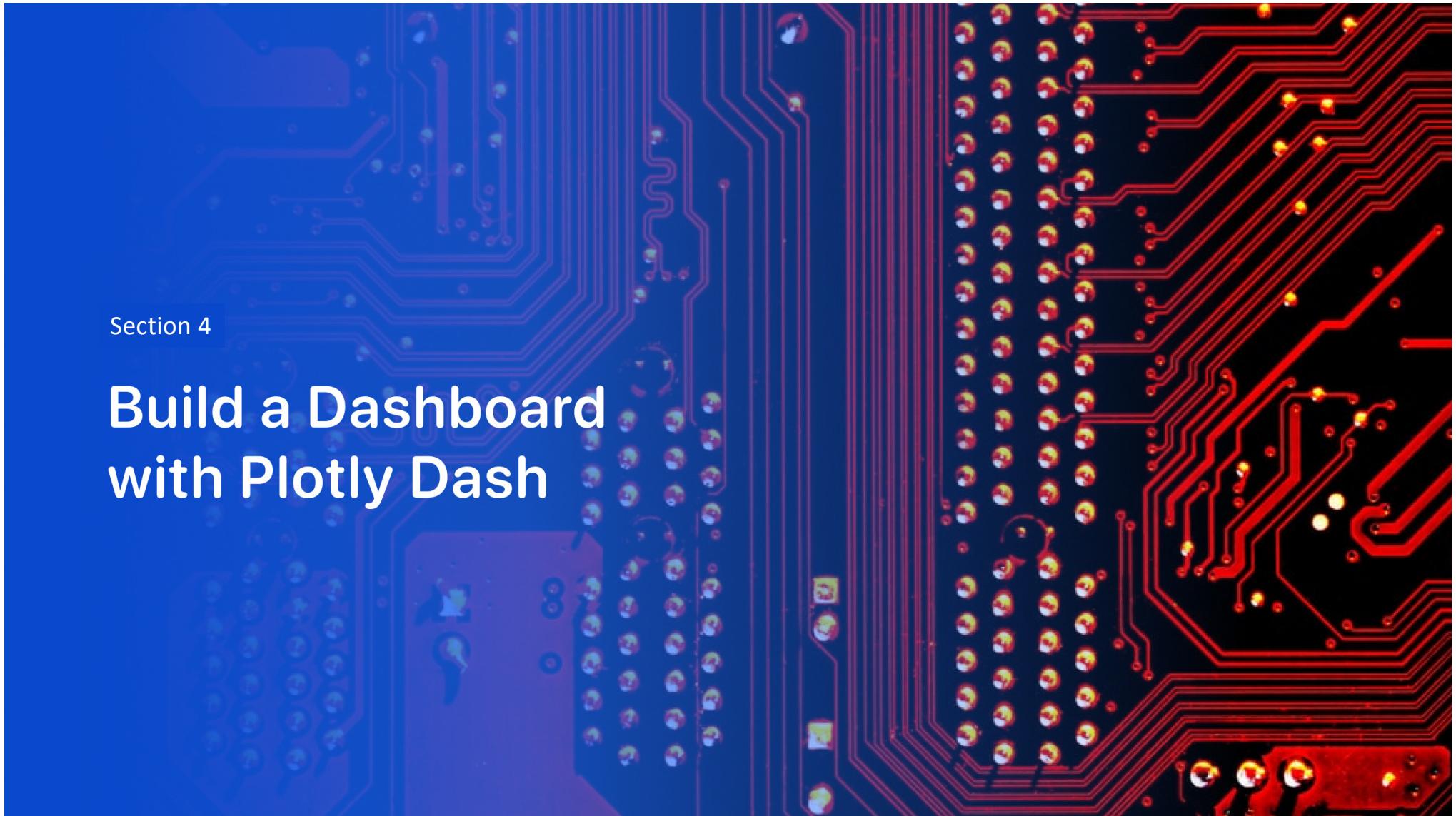
Three launch site in Merrit Island - Florida and successful rate each location are
CCAFS SLC-40: 43%, CCAFS LC-40: 27% : , and KSC LC-39A: 77% . Green marker shows successful launches and red marker shows failures.

Launch Site To Proximities

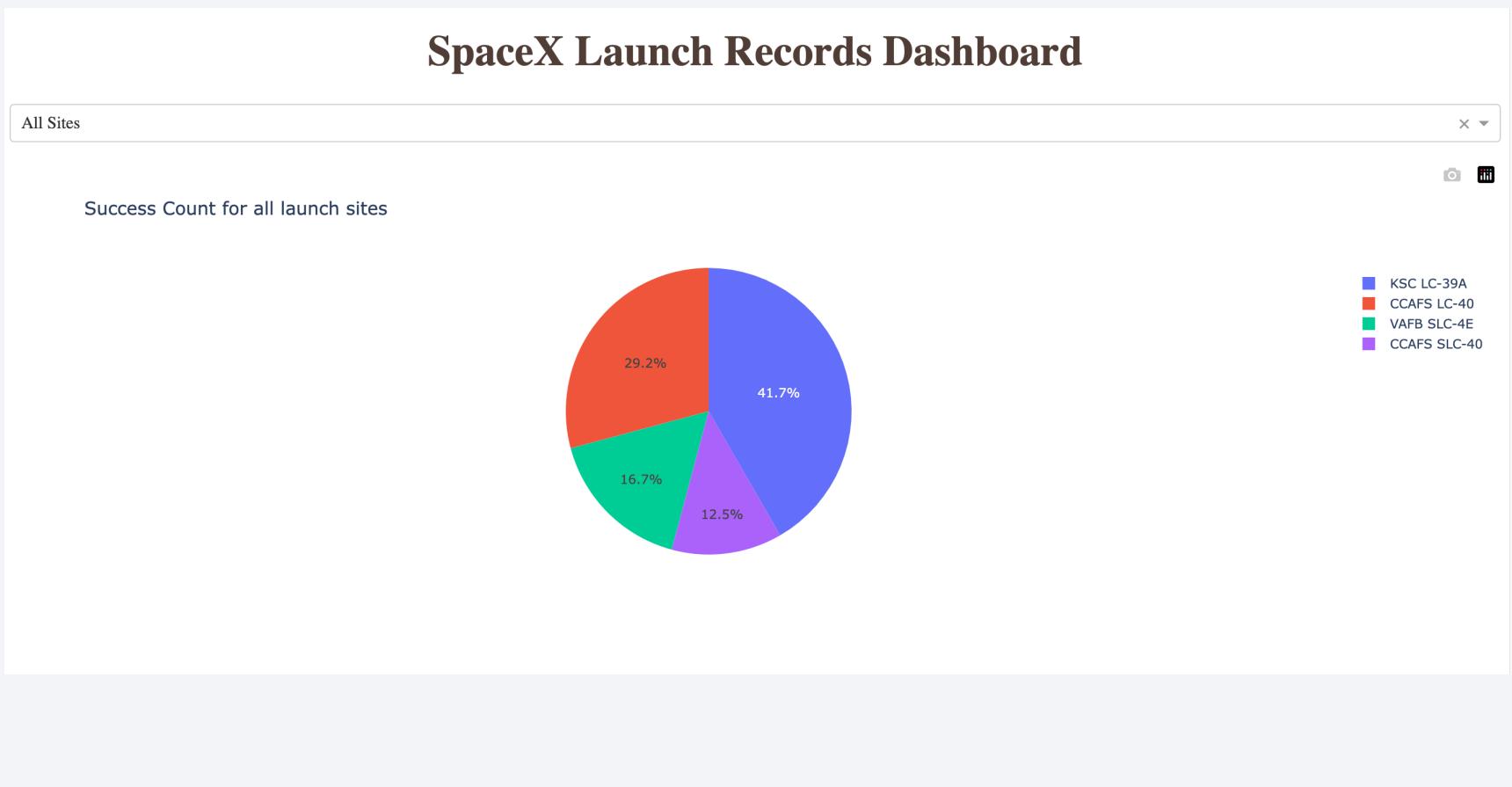


Section 4

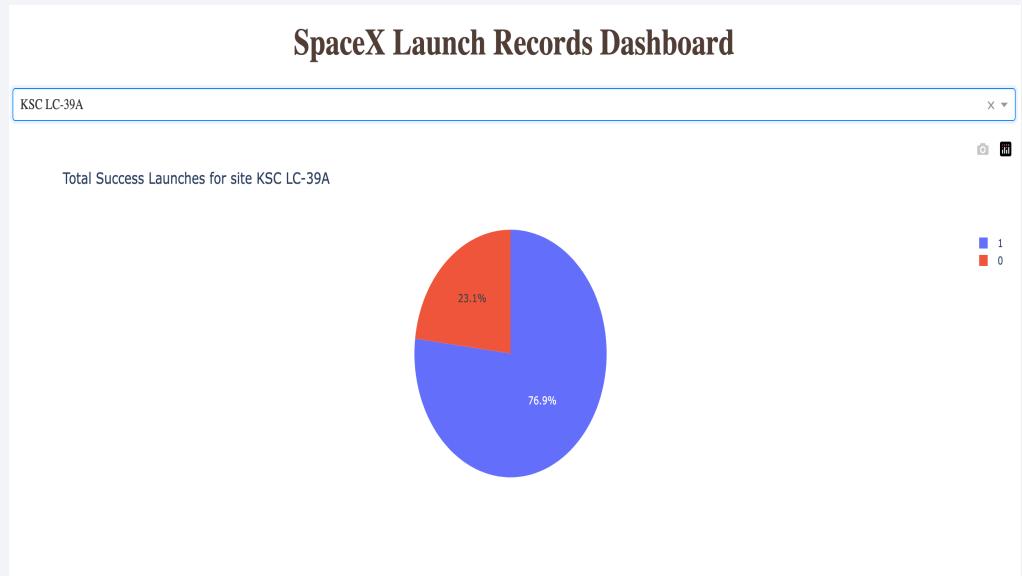
Build a Dashboard with Plotly Dash



Success Count for All Launch Sites

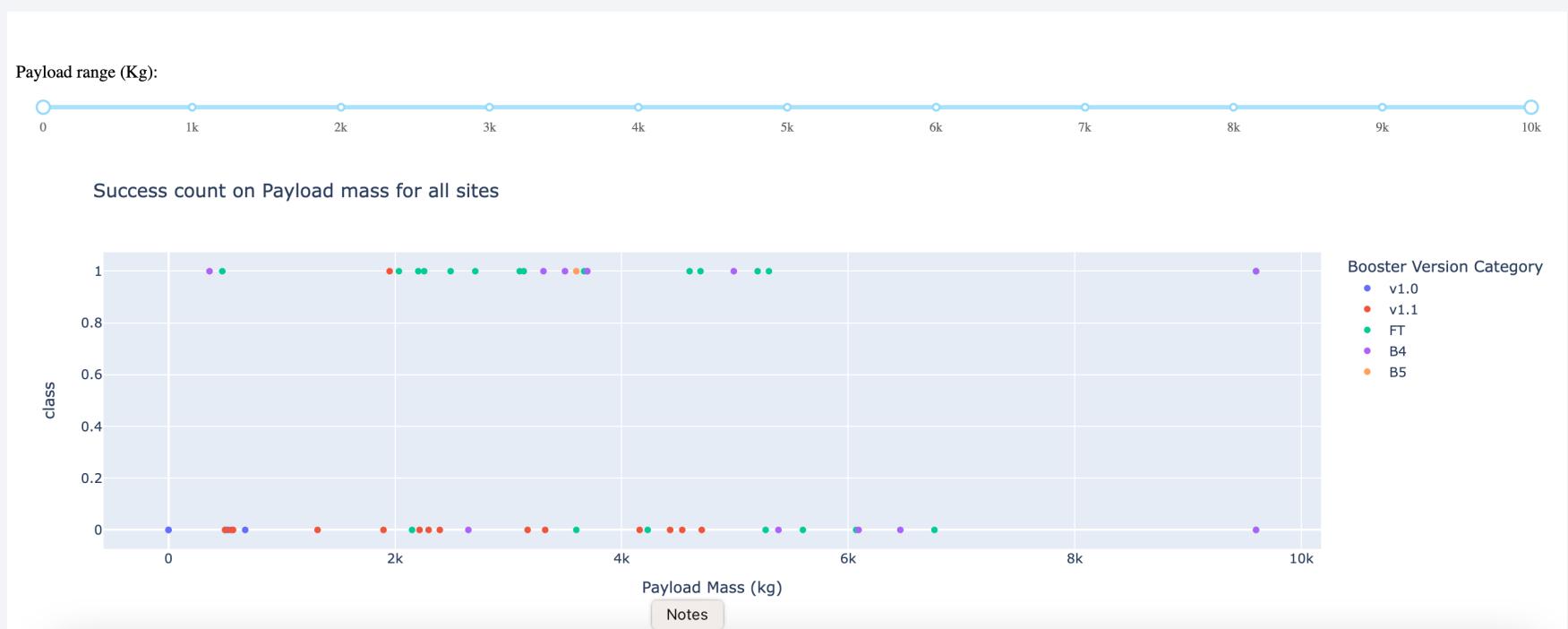


The Launch Site With Highest Launch Success Ratio



- Launch site KSC LC-39A has the highest launch success ratio.
- Success ratio is 76.9%.

Payload vs. Launch Outcome for All Mass Load

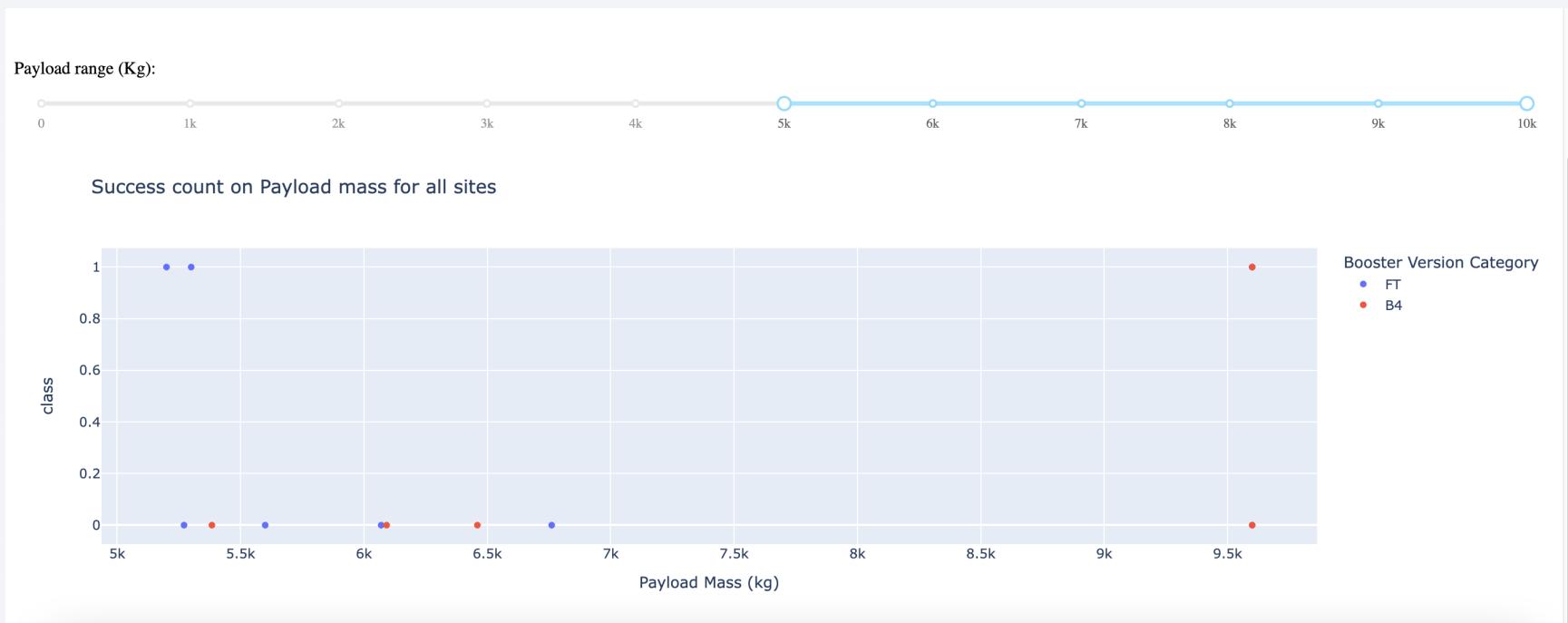


Payload vs. Launch Outcome for 0 to 5000 kg Mass Load



- For mass load 0 to 5000 kg success booster are booster version category B4, FT, V1.1 and B5.
- V 1.0 is never success..

Payload vs. Launch Outcome for 5000 to 10000 kg Mass Load



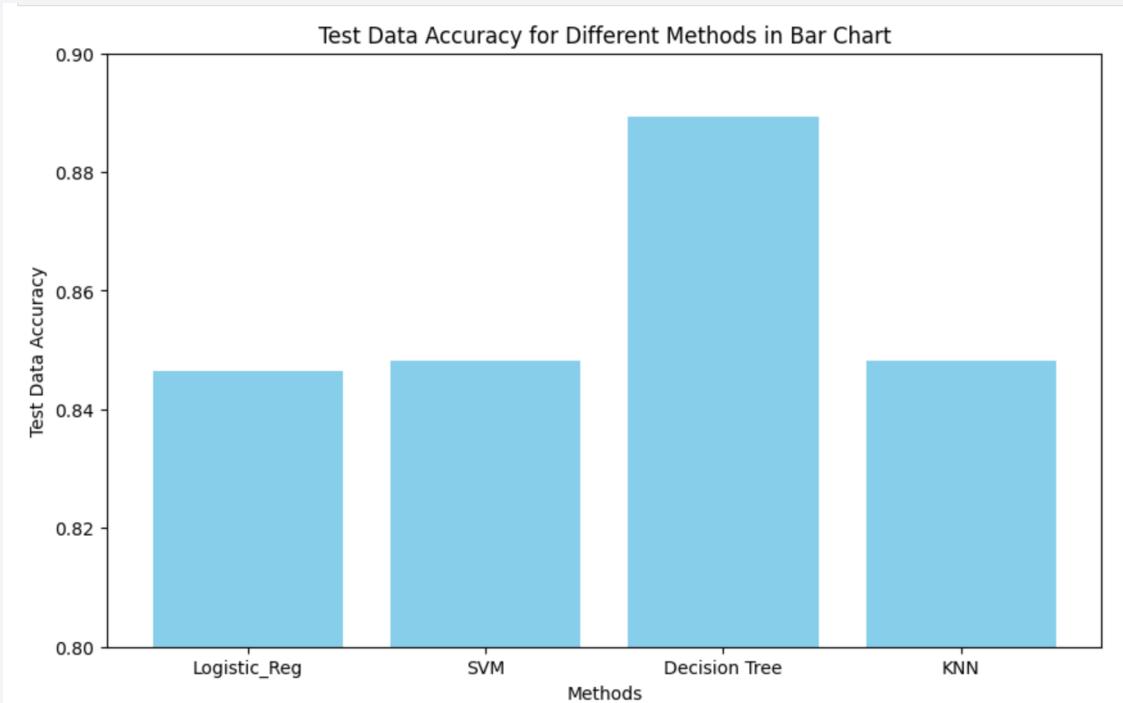
- Booster version category FT and B4 are used for payload mass between 5000 to 10000 kg.
- Booster version category B4 is the only booster success for payload mass above 9000 kg.

The background of the slide features a dynamic, abstract design. It consists of several thick, curved lines that transition from a bright yellow at the top right to a deep blue at the bottom left. These lines create a sense of motion and depth, resembling a tunnel or a stylized landscape. The overall effect is modern and professional.

Section 5

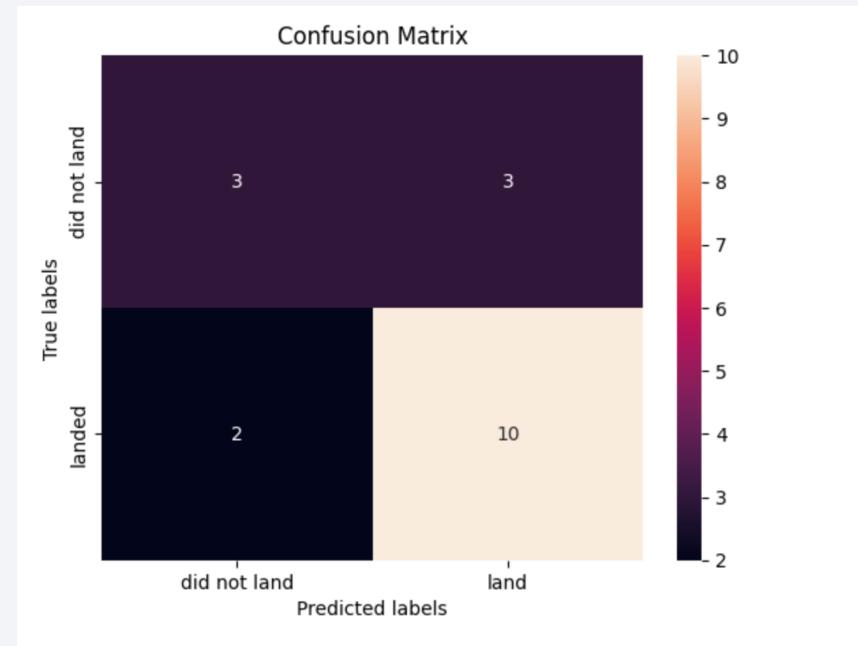
Predictive Analysis (Classification)

Classification Accuracy



Decision Tree is the highest classification accuracy

Confusion Matrix (Decision Tree)

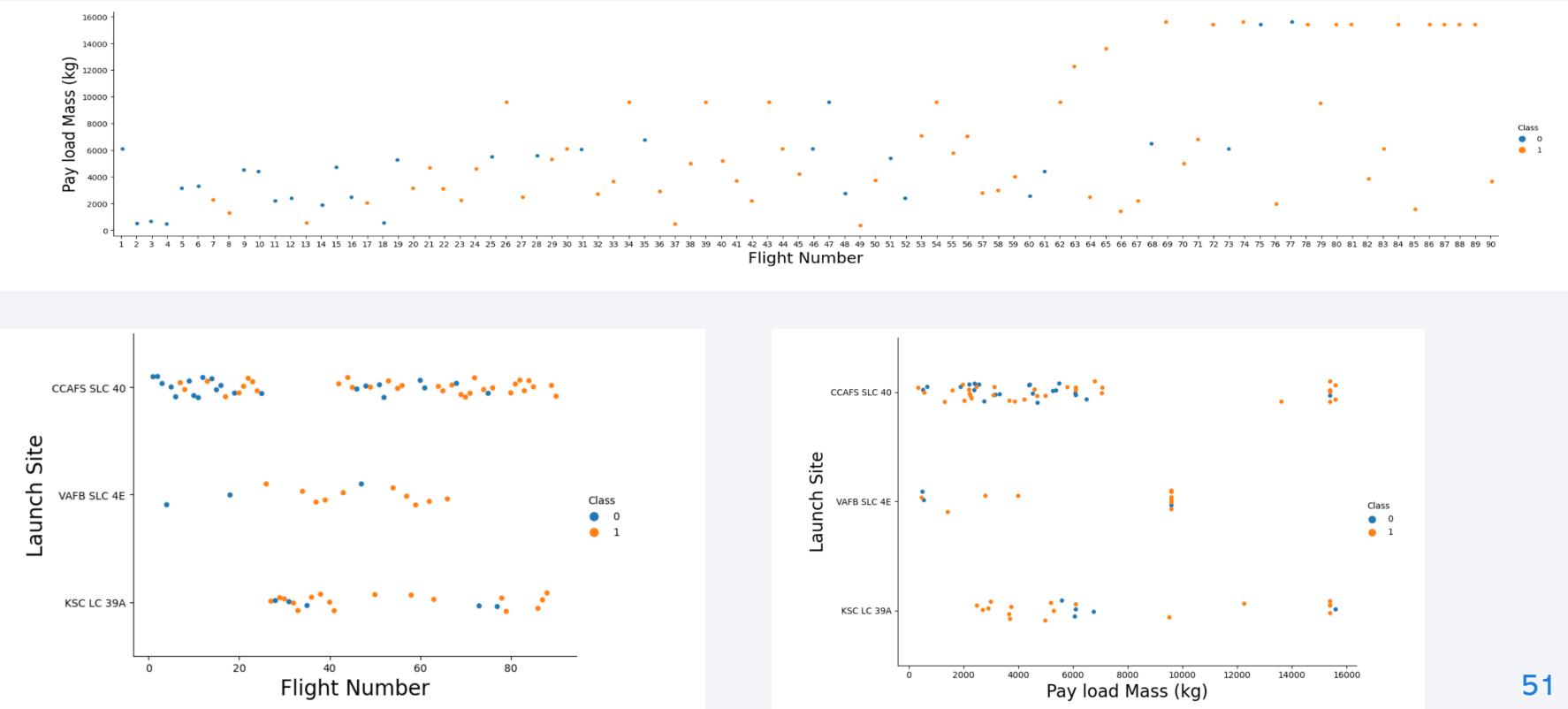


- True Positif : 10 False Positif : 3
- True Negatif : 2 False Negatif : 2

Conclusions

- The larger the flight amount at a launch site, the greater the success rate at a launch site.
- Launch success rate started to increase in 2013 till 2020.
- Most of success are payload under 6000 kg.
- Orbits ES-L1, GEO, HEO, SSO, had the most success rate.
- KSC LC-39A had the most successful launches of any sites.
- The Decision tree classifier is the best machine learning algorithm for this task.

Appendix



Thank you!

