

# Winning Space Race with Data Science

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Dec 26, 2021



# Outline

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- Executive Summary .....(slide 3)
- Introduction .....(slide 4)
- Methodology .....(slide 6)
- Results .....(slides 17-44)
- Conclusion .....(slide 45)
- Appendix .....(slide 46)

# Executive Summary

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## Summary of methodologies

The objective of this thesis is to apply a complete data-driven analytic approach to predict favorable outcome to winning the space race with SpaceX landing data

It involves data collection, data wrangling, EDA with data visualization, EDA with SQL, Building interactive map with Folium, Building a Dashboard with Plotly Dash and Data Classification using Predictive Analysis methodologies

## Summary of results

The results are summarized with Exploratory data analysis results, Interactive analytics demo (with screenshots) and Predictive analysis results

# Introduction

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## Project background and Context

In the age of commercial space travelling, SpaceX advertises on its website that Falcon 9 rocket launches 260+% cheaper (with a cost of 62 million dollars while other providers cost upward of 165 million dollars each), much of the savings is because SpaceX can reuse the first stage

## Problems to find answers

- 1) Will SpaceX land successfully in first stage?
- 2) What are the parameters that influence its optimal success in landing?
- 3) How to leverage the insight to potentially bid against SpaceX for rocket launch?

Section 1

# Methodology

# Methodology

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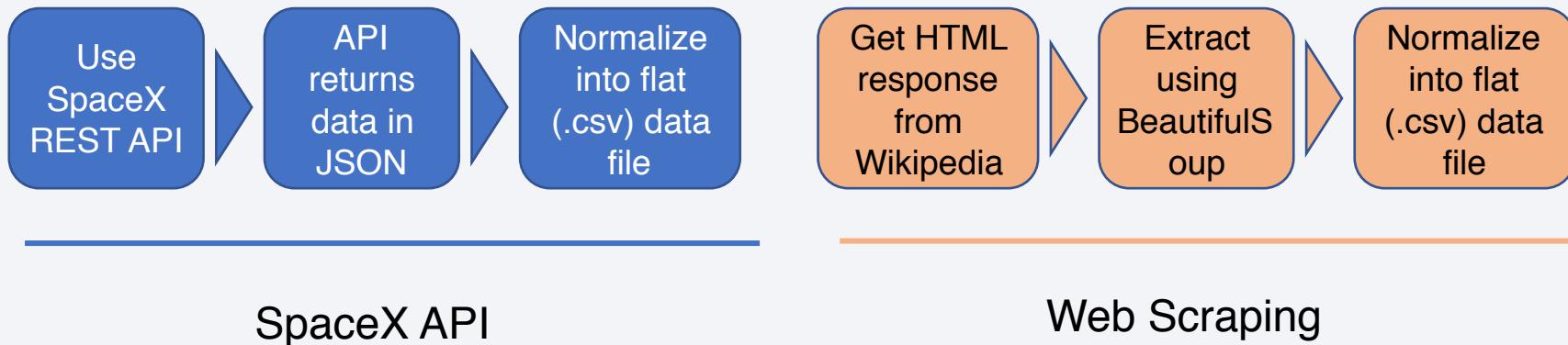
- Data collection methodology:
  - The data was collected by sending get request to SpaceX API and by web scraping Falcon 9 and Falcon Heavy Launches Records from Wikipedia.
- Perform data wrangling
  - Dealing with missing values, creating new columns, dropping irrelevant columns and visualizing through Panda's data frames
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - Chose the best performing model from testing four different models of classification: Logistic regression, Tree, SVM and KNN

# Data Collection

How was the data collected?

Data collection process

- The data is collected from the SpaceX REST API, and the API will give us data about launches including information about the rocket used, payload delivered, launch specifications, landing specifications, and landing outcome.
- Another data is collected from Wikipedia using BeautifulSoup



# Data Collection – SpaceX API

SpaceX REST calls  
using key phrases  
and flowcharts

## GitHub URL

[Data Collection API.ipynb](https://github.com)  
[github.com](https://github.com)

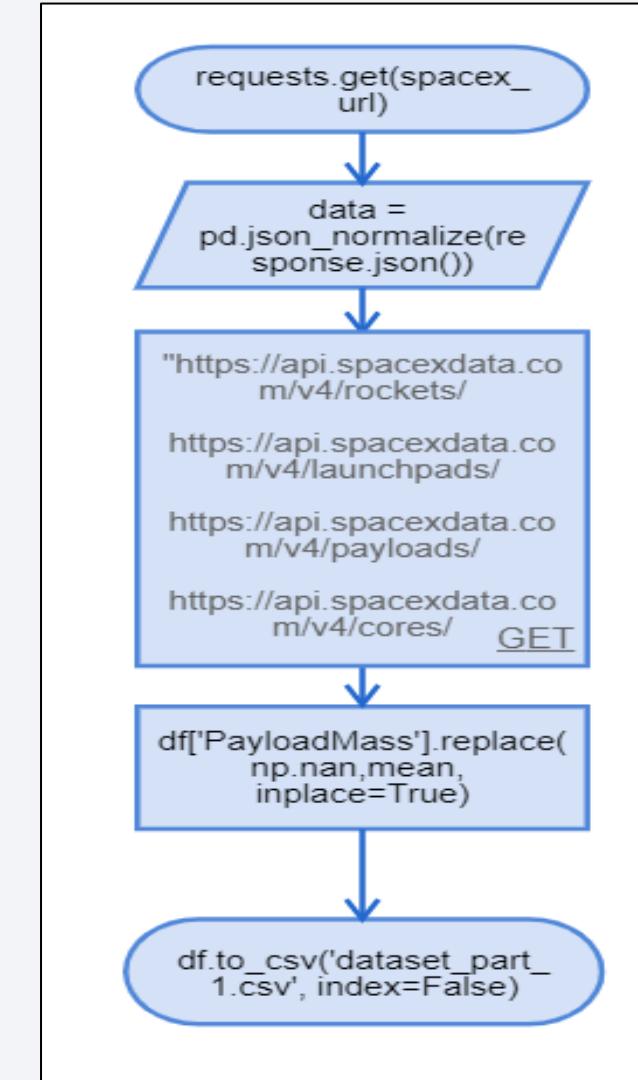
Request and parse the SpaceX launch data using the GET request

Decode the response content as a Json using json ()  
and turn it into a Pandas dataframe using json\_normalize

Use the API again to get information about the launches using the IDs given for each launch. Specifically, will be using columns

- Rocket
- Payloads
- Launchpad
- Cores

The mean and the replace () function to replace np.nan values in the data with the mean calculated



# Data Collection - Scraping

Web scraping  
process

GitHub URL

[Web Scraping.ipynb \(github.com\)](#)

Extract a Falcon 9 launch records HTML table from Wikipedia

Parse the table and convert it into a Pandas data frame

TASK 1: Request the Falcon9 Launch Wiki page from its URL

TASK 2: Extract all column/variable names from the HTML table header

TASK 3: Create a data frame by parsing the launch HTML tables

```
response =  
    requests.get(static_url  
)
```

```
bs =  
    BeautifulSoup(response.content)
```

```
bs.find_all('table')  
  
for rows in first_launch_table.find_all("th"):  
    name = extract_column_from_header(rows)  
  
    launch_dict= dict.fromkeys(column_names)
```

```
fill up the 'launch_dict'  
with launch records  
extracted from table rows.
```

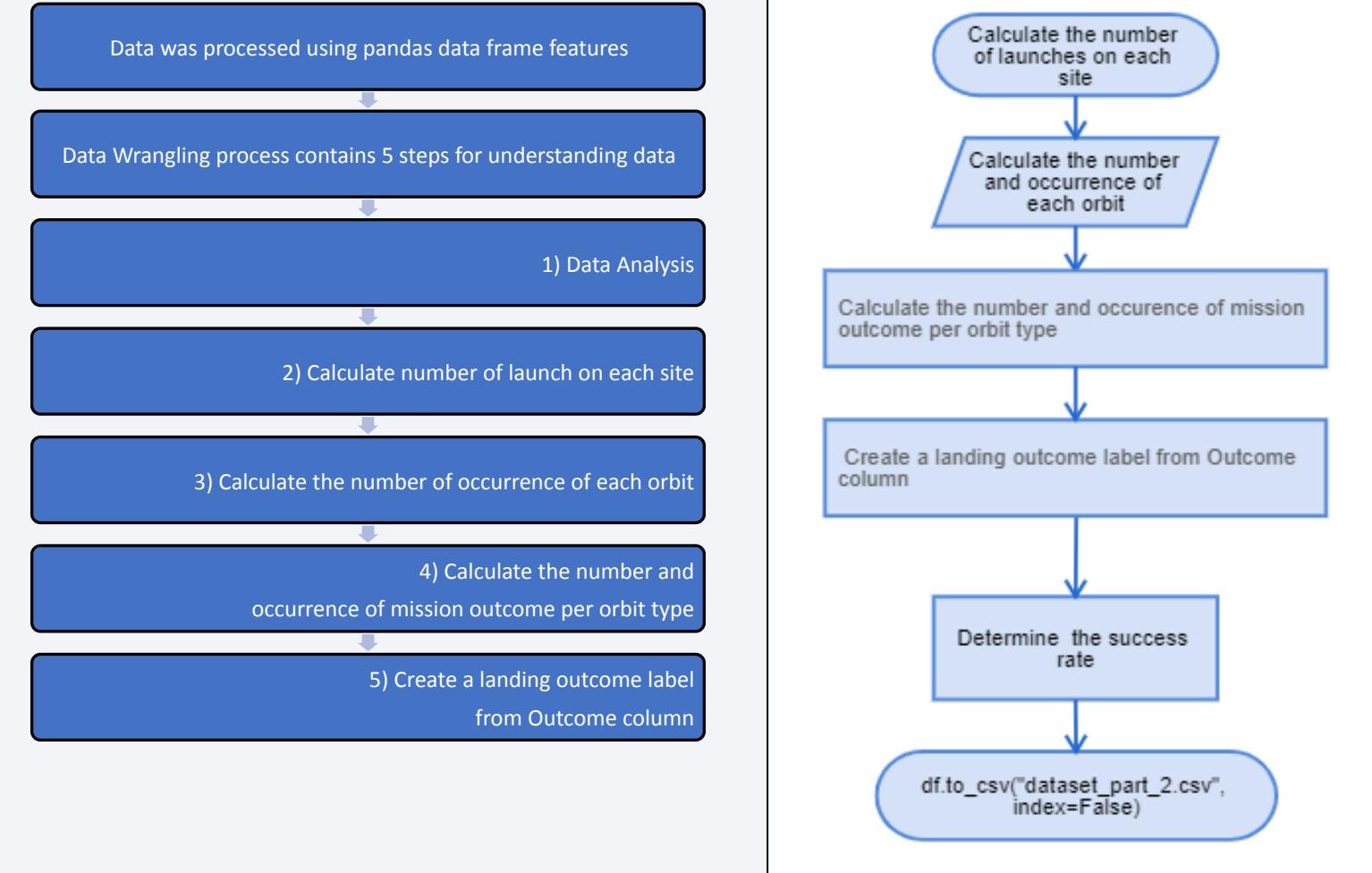
```
pd.DataFrame.from_dict(launch_dict,  
orient='index')
```

# Data Wrangling

## Data Wrangling process

## GitHub URL

[SpacexDataWrangling.ipynb  
\(github.com\)](https://github.com)



# EDA with Data Visualization

---

Visualization charts  
and reason for the  
choice of the chart

- Scatter Graphs helps to visualize the data - show the data pattern & identify correlation between variables. Scatter plots consist of a larger body of data - Fight Number vs. Payload Mass, Fight Number vs. Launch Site, Payload vs. Launch Site, Orbit vs. Fight Number, Payload vs. Orbit Type, Orbit vs. Payload Mass
- Bar Graph makes it easy to compare sets of data between different groups immediately. The graph represents categories on one axis and a discrete value in the other. The goal is to show the relationship between the two axes. Bar charts can also show big changes in data over time. Mean vs. Orbit
- Line Graphs are useful in that they show data variables and trends very clearly and can help to make predictions about the results of data not yet recorded

GitHub URL

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[jupyter-labs-eda-dataviz  
\(1\).ipynb \(github.com\)](https://github.com)

# EDA with SQL

---

SQL Queries  
performed to  
explore the dataset

1. Display the names of the unique launch sites in the space mission
2. Display 5 records where launch sites begin with the string 'CCA'
3. Display the total payload mass carried by boosters launched by NASA (CRS)
4. Display average payload mass carried by booster version F9 v1.1
5. List the date when the first successful landing outcome in ground pad was achieved
6. List the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000
7. List the total number of successful and failure mission outcomes
8. List the names of the booster versions which have carried the maximum payload mass. Use a subquery
9. List the failed landing outcomes in drone ship, their booster versions, and launch site names for in year 2015
10. 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

GitHub URL

---

[EDA with SQL.ipynb](#)  
[\(github.com\)](#)

# Build an Interactive Map with Folium

---

Folium map  
Summary

- Marked all launch sites visually on a map with latitude, longitude coordinates circled
- Marked the success/failed launches for each site, assigned the data frame `launch_outcomes` (failures, successes) to classes 0 and 1 with Green and Red markers on the map in a `MarkerCluster()`
- Calculated the distance from the launch site to various land markers. Lines are drawn on the map to measure distance to landmarks
- This helps to answer below questions easily:
  - *Are launch sites in close proximity to railways?*
  - *Are launch sites in close proximity to highways?*
  - *Are launch sites in close proximity to coastline?*
  - *Do launch sites keep certain distance away from cities?*

GitHub URL

---

[Interactive Visual Analytics with  
Folium lab.ipynb \(github.com\)](https://github.com/udacity/Folium-lab.ipynb)

# Build a Dashboard with Plotly Dash

---

## Dashboard Summary

- Plotly is a python wrapper on the JavaScript library 'leaflet'. It enables us to interact with our data visualizations and host it as a website:

What's included:

Pie Chart: That shows number of launches from each launch site as well as number of successful and failed launches from those sites

Callback function for `site dropdown` as input, `success pie chart` as output

Callback function for `site dropdown` and `payload slider` as inputs, `success payload scatter chart` as output

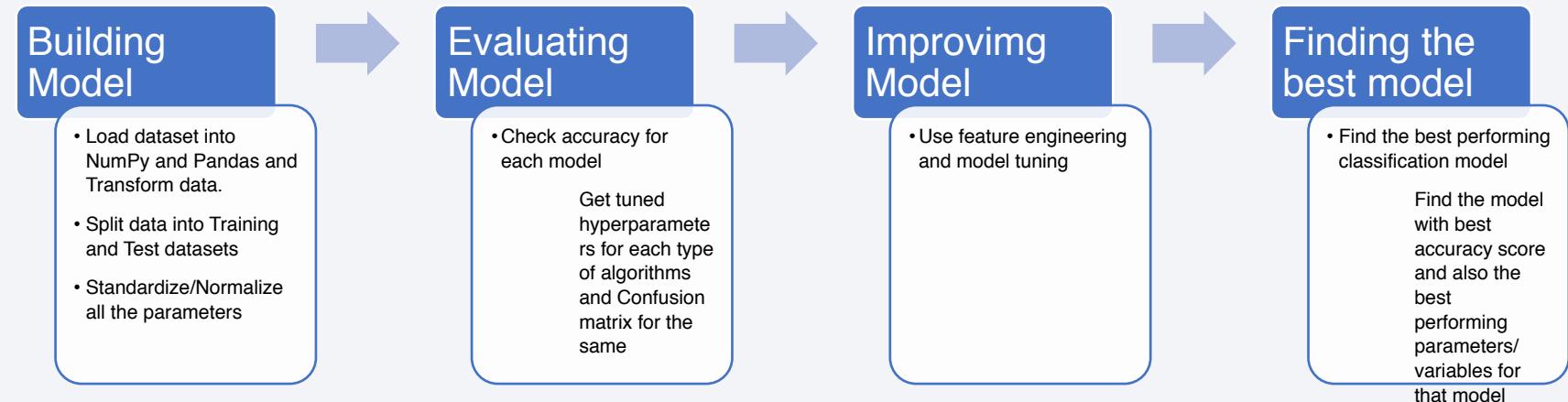
Scatter Graph: Relationship between the success of a launch (Outcome) and Payload (in kg) for different versions of boosters

## GitHub URL

[Capstone-SpaceX-Launch/  
Dashboard at main · msln007/  
Capstone-SpaceX-Launch  
\(github.com\)](https://github.com/msln007/Capstone-SpaceX-Launch)

# Predictive Analysis (Classification)

## Classification Model Summary



## GitHub URL

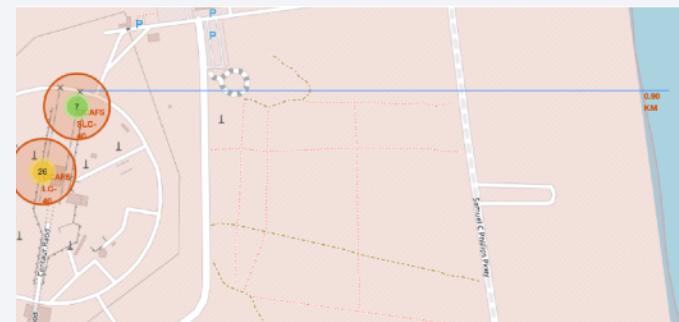
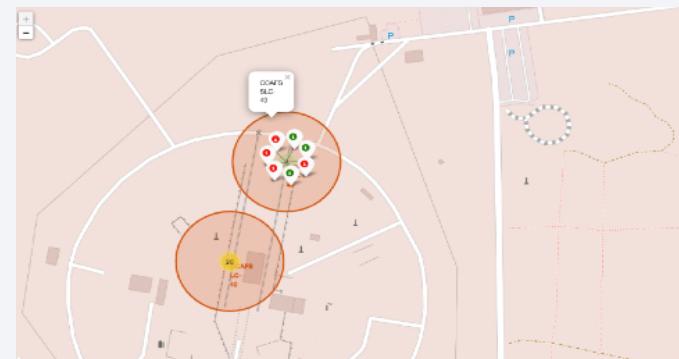
[SpaceX-ML-Prediction.ipynb](https://github.com)  
([github.com](https://github.com))

# Results

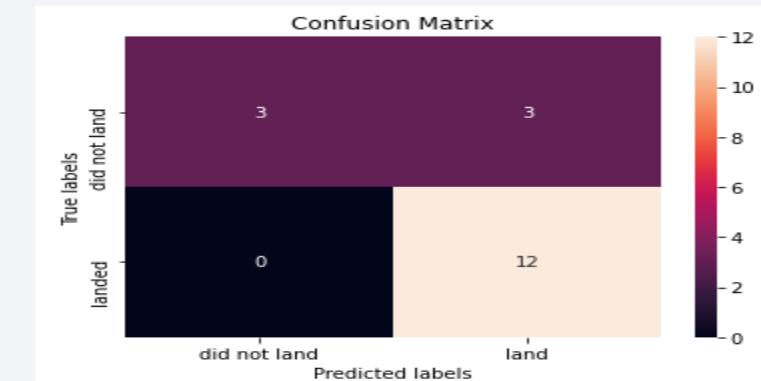
## Exploratory data analysis results

landing_outcome	COUNT
Success (drone ship)	2
Success (ground pad)	2
Failure (drone ship)	1
No attempt	1

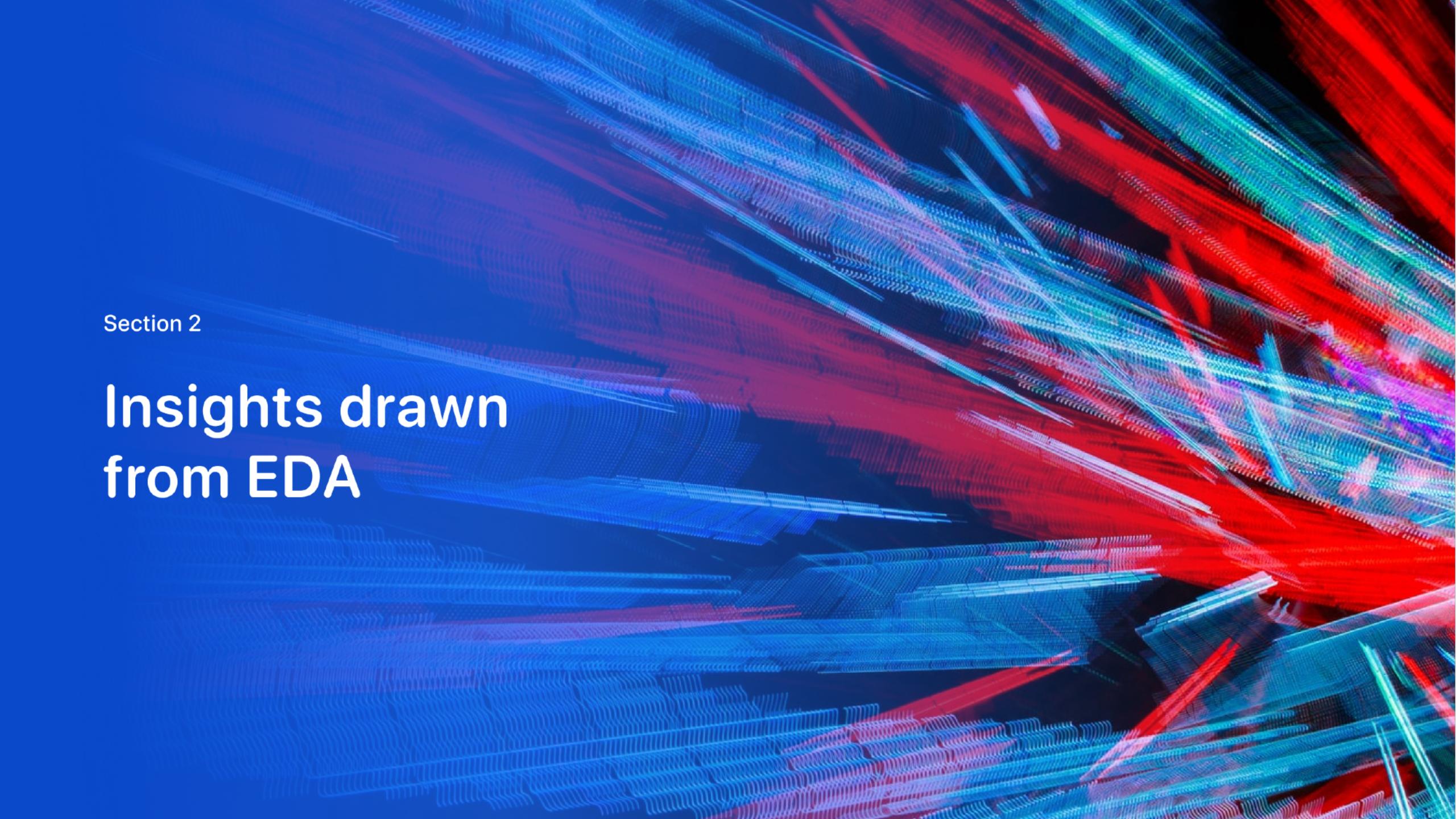
## Interactive analytics demo in screenshots



## Predictive analysis results



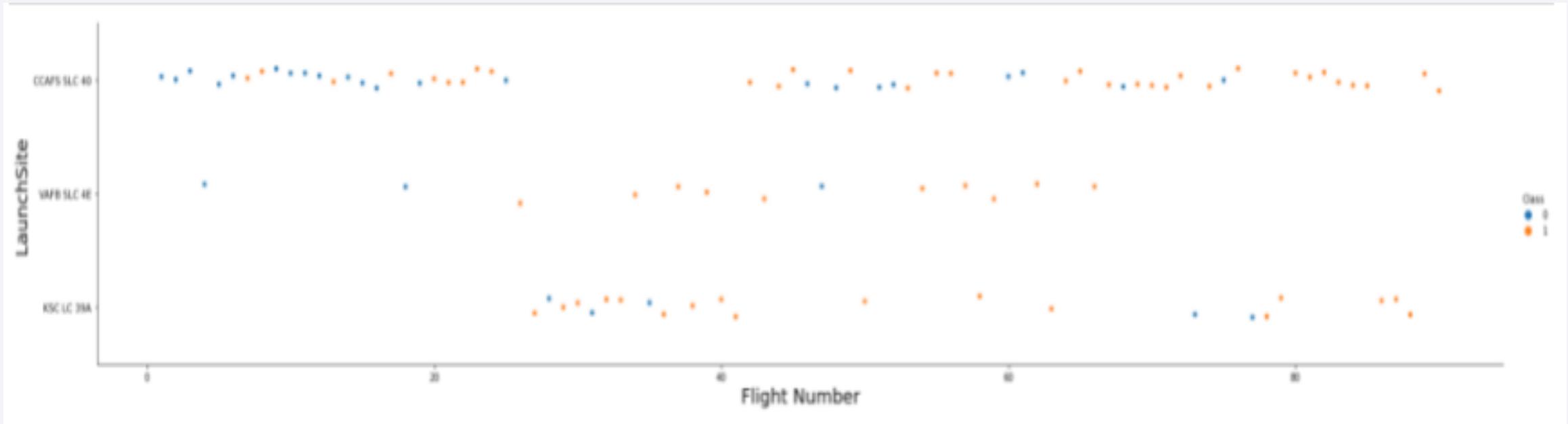
Accuracy for Logistics Regression method: 0.833333333333334  
Accuracy for Support Vector Machine method: 0.833333333333334  
Accuracy for Decision tree method: 0.611111111111112  
Accuracy for K nearest neighbors method: 0.833333333333334

The background of the slide features a complex, abstract digital pattern. It consists of numerous thin, glowing lines that create a sense of depth and motion. The colors used are primarily shades of blue, red, and purple, which are bright against a dark, almost black, background. These lines form a grid-like structure that is more dense and vibrant towards the right side of the frame, while appearing more sparse and blurred towards the left.

Section 2

## Insights drawn from EDA

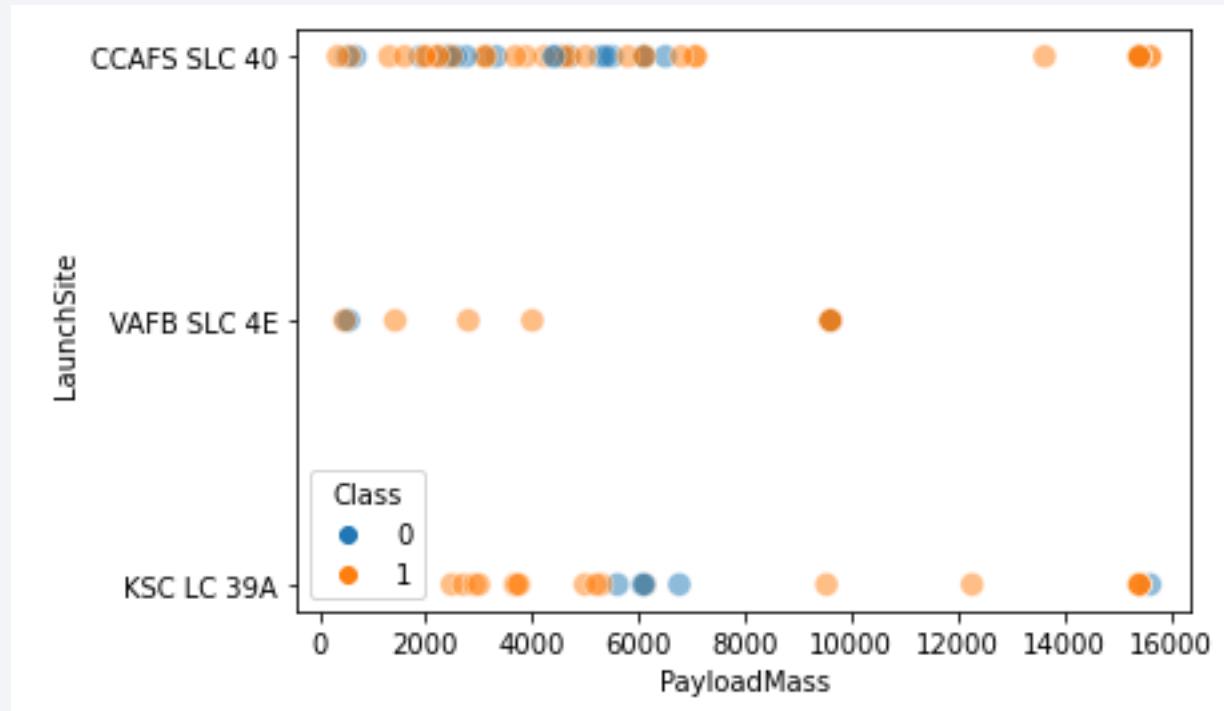
# Flight Number vs. Launch Site



*“Depicts the total launches by flight and launch site. The CCAFS SLC 40 has most launches across all flight numbers and have most failed launches in lower flight numbers and reduces as flight number increases”*

# Payload vs. Launch Site

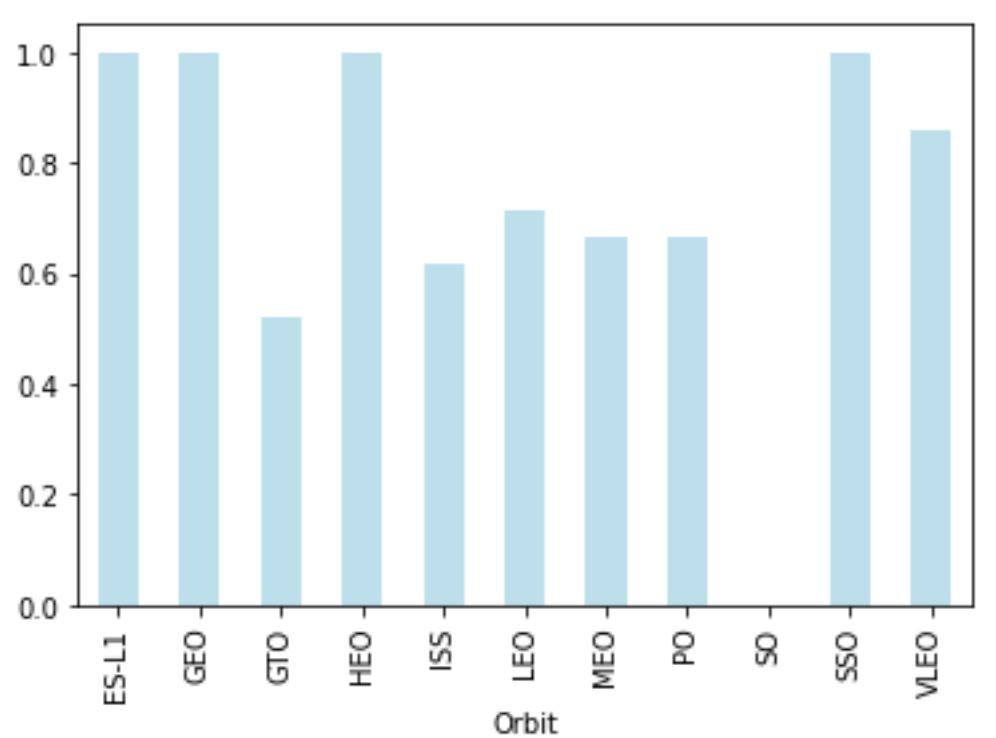
---



*“No launches of VAFB SLC 4E beyond 10000 PayloadMass. No failed launches in the 8000-15000 PayloadMass range and just 1 failed launch of KSC LC 39A in the 8000-16000 range”*

# Success Rate vs. Orbit Type

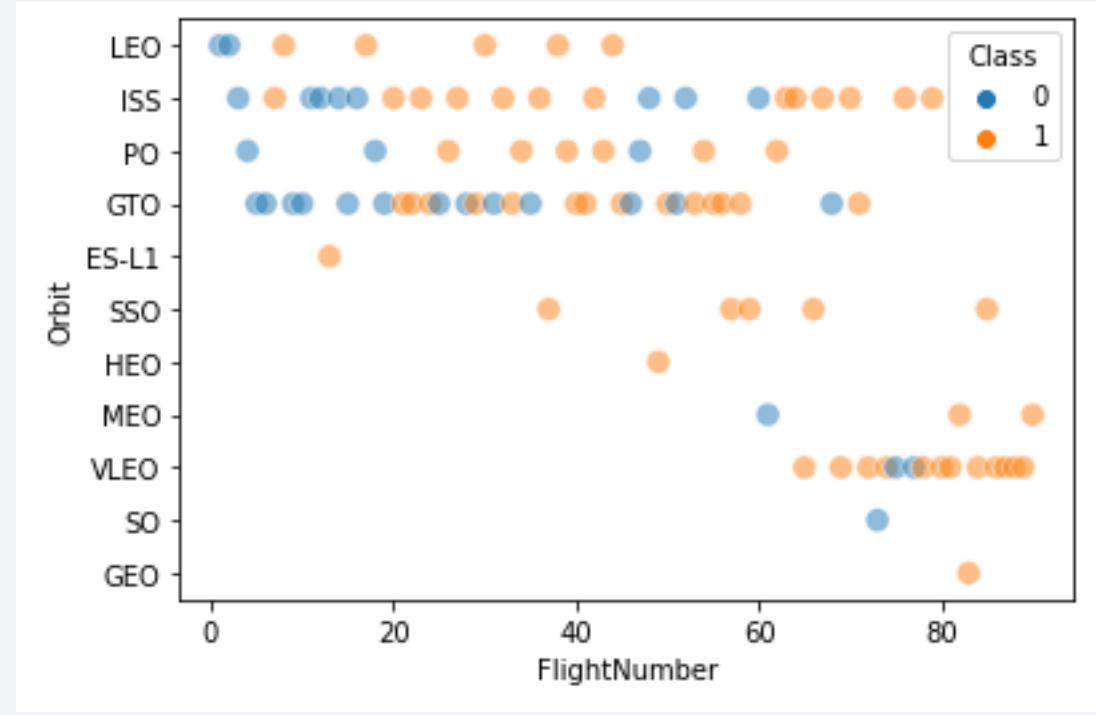
---



*“ES-L1, GEO, HEO and SSO have 100% Success Rate”*

# Flight Number vs. Orbit Type

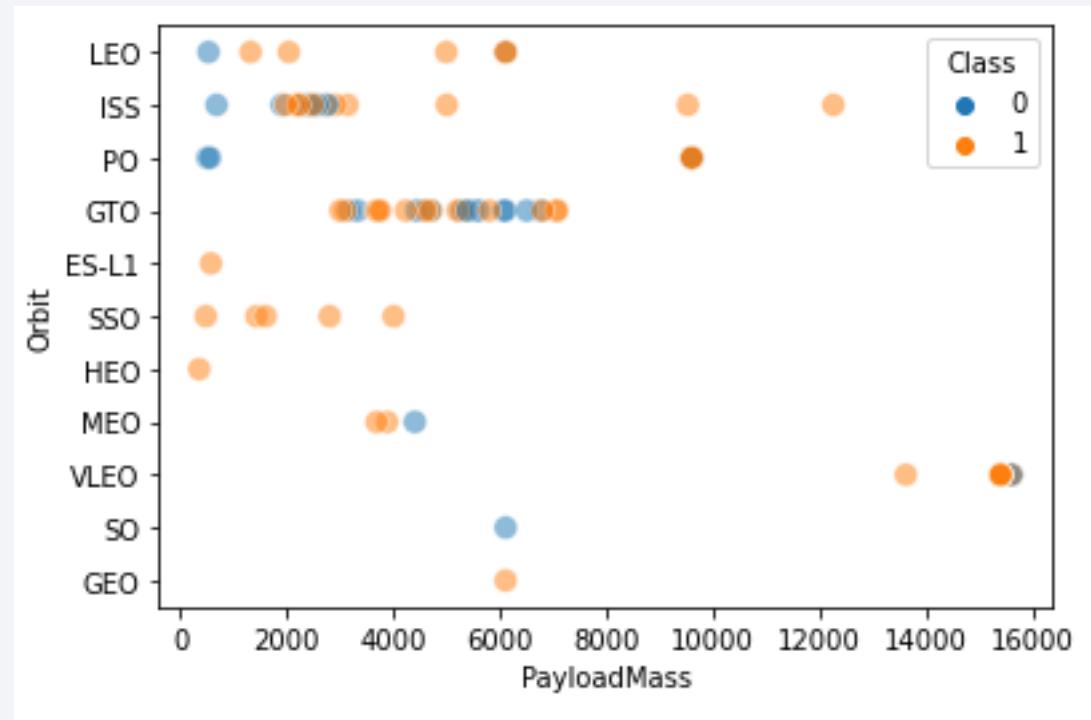
---



*“LEO Orbit, SSO, HEO, GEO seems to have direct correlation to Success and GTO Orbit seems to have Failures at all Flight Numbers”*

# Payload vs. Orbit Type

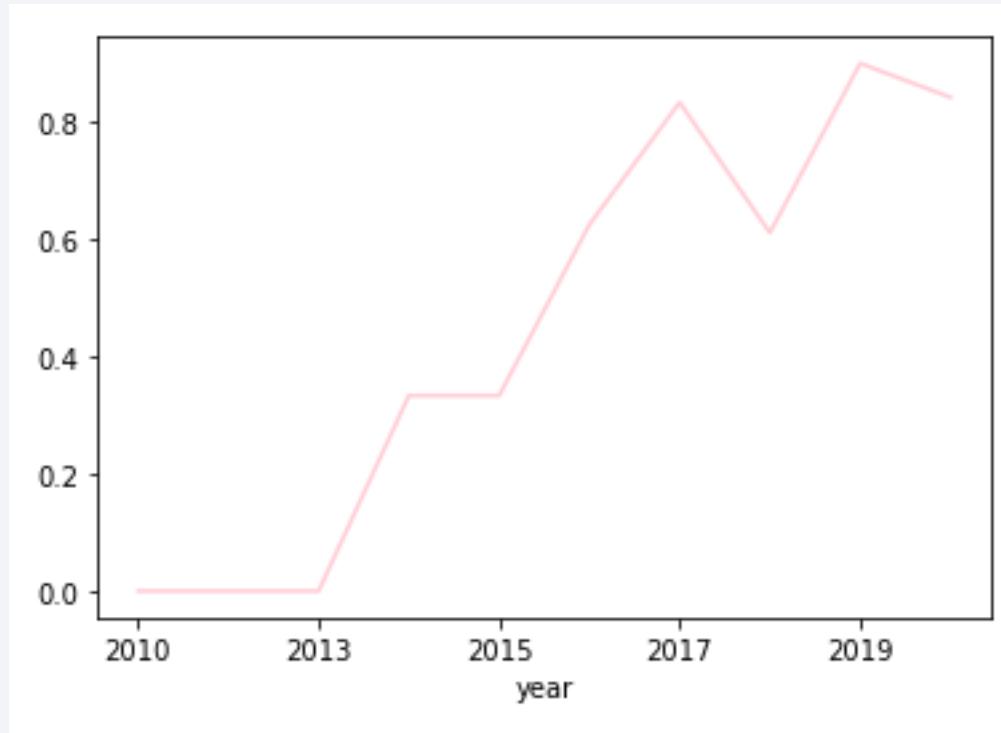
---



*“LEO, ISS, PO, SSO seems to have direct correlation to Success by PayloadMass. While SSO has high Success in lower PayloadMass, LEO, ISS, PO have higher Success in higher PayloadMass category”*

# Launch Success Yearly Trend

---



*"Overall, there's continuous increase in Success Rate from 2013-2020 years range (despite a flat 2014 and a small dip in 2018)"*

# All Launch Site Names

---

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

```
*sql SELECT DISTINCT(LAUNCH_SITE) FROM SPACEXTBL;
```

*“Selecting unique launches sites from LAUNCH\_SITE column from SpaceX launches dataset using SQL Query”*

# Launch Site Names Begin with 'CCA'

DATE	time_utc_	booster_version	launch_site	payload	payload_mass_kg_	orbit	customer	mission_outcome	landing_outcome
2010-06-04	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
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 (parachute)
2012-05-22	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attemp
2012-10-08	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attemp
2013-03-01	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attemp

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

*“Selecting 5 records from SpaceX dataset with Launch Site names starting with CCA”*

# Total Payload Mass

---

45596

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

*“Calculating total of all booster’s ‘Payload Mass’ from SpaceX dataset launches by ‘NASA (CRS)’ customer”*

# Average Payload Mass by F9 v1.1

---

2534

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

*“Calculating average payload mass of Booster version F9 v1.1 only”*

# First Successful Ground Landing Date

---

2015-12-22

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

*“Calculating first successful ground landing date using MIN function on landing date column”*

## Successful Drone Ship Landing with Payload between 4000 and 6000

---

booster_version	landing_outcome	payload_mass_kg_
F9 FT B1021.2	Success (drone ship)	5300
F9 FT B1031.2	Success (drone ship)	5200
F9 FT B1022	Success (drone ship)	4696
F9 FT B1026	Success (drone ship)	4600

```
%%sql
SELECT DISTINCT BOOSTER_VERSION, LANDING_OUTCOME, PAYLOAD_MASS_KG_
FROM SPACEXTBL
WHERE LANDING_OUTCOME = 'Success (drone ship)' AND PAYLOAD_MASS_KG_ BETWEEN 4000 AND 6000;
```

*“Getting list of booster versions which have successful drone ship landing and their payload is in the range of 4000 to 6000 KG”*

# Total Number of Successful and Failure Mission Outcomes

---

successful\_missions

61

failure\_missions

10

```
%%sql
SELECT COUNT(LANDING_OUTCOME) AS SUCCESSFUL_MISSIONS
FROM SPACEXTBL
WHERE LANDING_OUTCOME LIKE 'Success%';
```

```
%%sql
SELECT COUNT(LANDING_OUTCOME) AS FAILURE_MISSIONS
FROM SPACEXTBL
WHERE LANDING_OUTCOME LIKE 'Failure%';
```

*“Getting count of total successful and failure missions from SpaceX dataset based on landing outcome name starting with ‘Success’ for successful missions and ‘Failure’ for failure missions”*

# Boosters Carried Maximum Payload

booster_version	payload_mass_kg_
F9 B5 B1048.4	15600
F9 B5 B1048.5	15600
F9 B5 B1049.4	15600
F9 B5 B1049.5	15600
F9 B5 B1049.7	15600
F9 B5 B1051.3	15600
F9 B5 B1051.4	15600
F9 B5 B1051.6	15600
F9 B5 B1056.4	15600
F9 B5 B1058.3	15600
F9 B5 B1060.2	15600
F9 B5 B1060.3	15600

```
%%sql  
SELECT DISTINCT(BOOSTER_VERSION), PAYLOAD_MASS_KG_  
FROM SPACEXTBL  
WHERE PAYLOAD_MASS_KG_ = (SELECT MAX(PAYLOAD_MASS_KG_) FROM SPACEXTBL)
```

*“Obtained boosters carrying maximum payload by first selecting maximum of payload from SpaceX dataset and then selecting the booster version, payload using a subquery (query inside a query)”*

# 2015 Launch Records

---

landing_outcome	booster_version	launch_site	date_year
Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40	2015
Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40	2015

```
%%sql
SELECT LANDING_OUTCOME, BOOSTER_VERSION, LAUNCH_SITE, YEAR(DATE) AS DATE_YEAR
FROM SPACEXTBL
WHERE LANDING_OUTCOME = 'Failure (drone ship)' AND YEAR(DATE) = '2015'
```

*“Get list of failed landing\_outcome along with the booster version and launch site for the year 2015 from SpaceX table using WHERE clause”*

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

---

landing_outcome	COUNT
No attempt	10
Failure (drone ship)	5
Success (drone ship)	5
Controlled (ocean)	3
Success (ground pad)	3
Failure (parachute)	2
Uncontrolled (ocean)	2
Preculated (drone ship)	1

```
%%sql
SELECT LANDING_OUTCOME, COUNT(LANDING_OUTCOME) AS COUNT
FROM SPACEXTBL
WHERE DATE BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY LANDING_OUTCOME
ORDER BY COUNT DESC
```

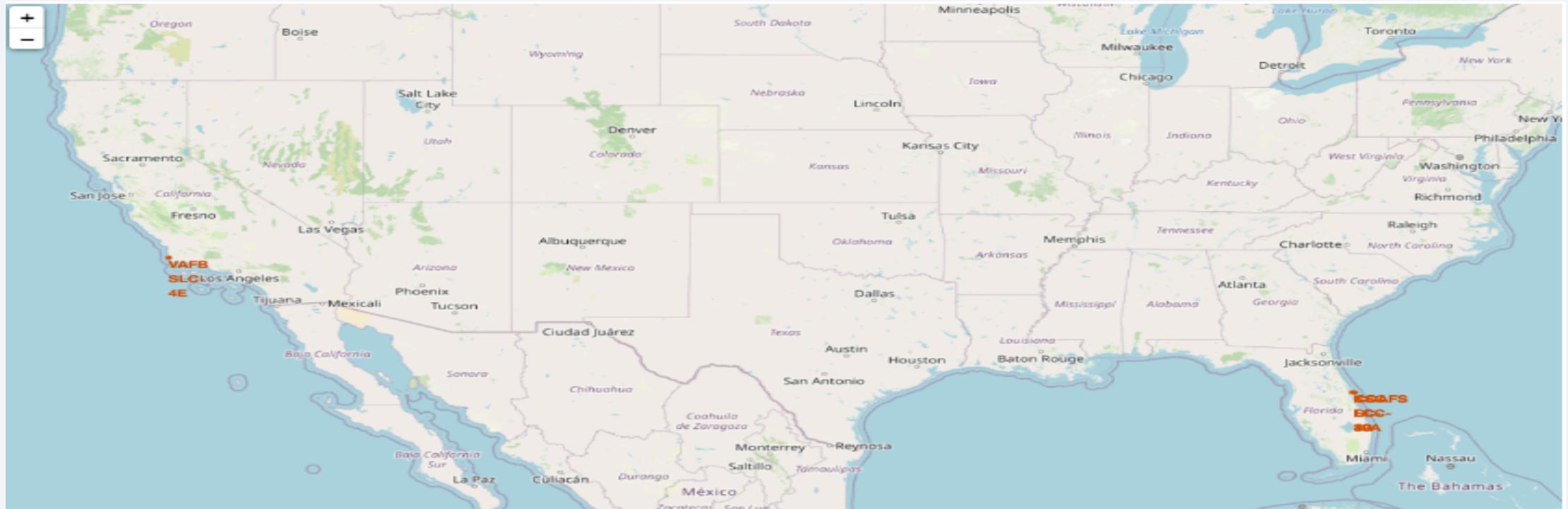
*“Obtained count of landing\_outcome in descending order occurred between above 2 dates by GROUP BY and ORDER BY clauses ”*

The background of the slide is a photograph taken from space at night. It shows the curvature of the Earth's horizon against a dark blue sky. City lights are visible as numerous small white and yellow dots, primarily concentrated in the lower right quadrant where a large urban area is illuminated. In the upper right corner, there is a faint, greenish glow of the aurora borealis or a similar atmospheric phenomenon.

Section 4

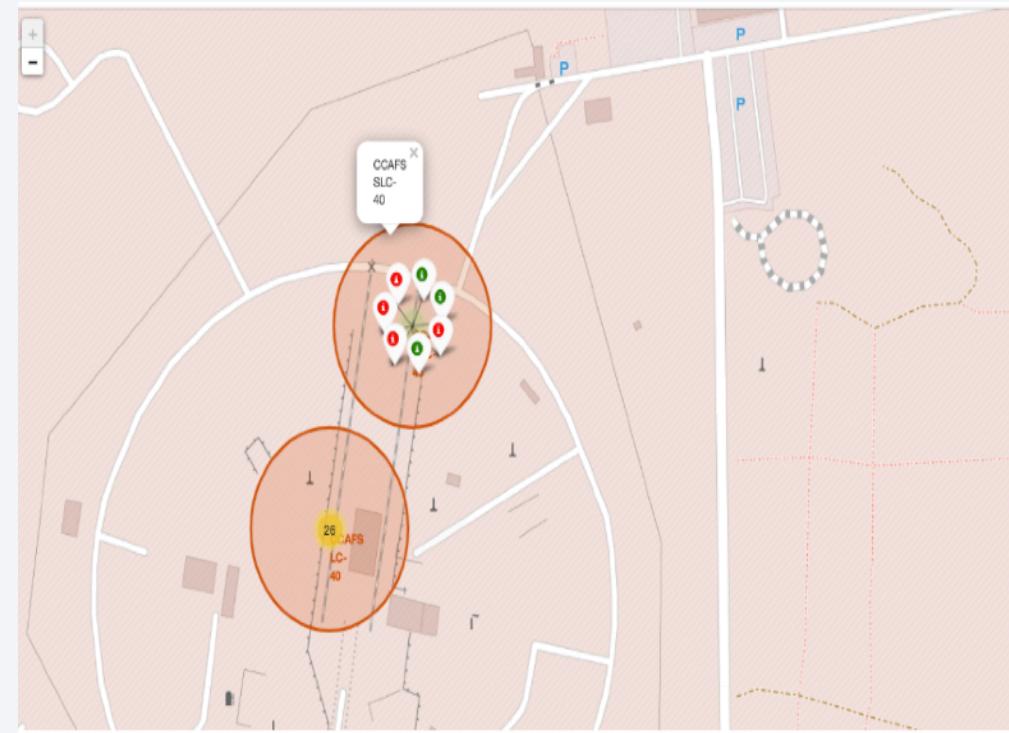
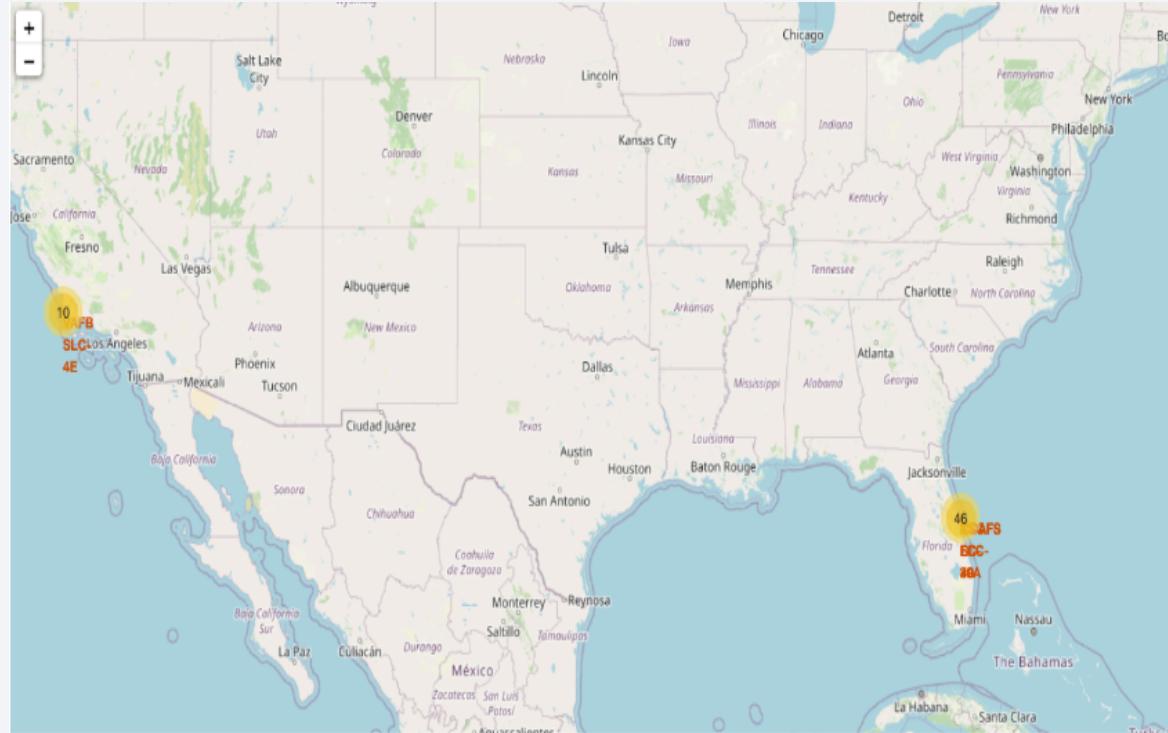
# Launch Sites Proximities Analysis

# Launch Sites On A Map



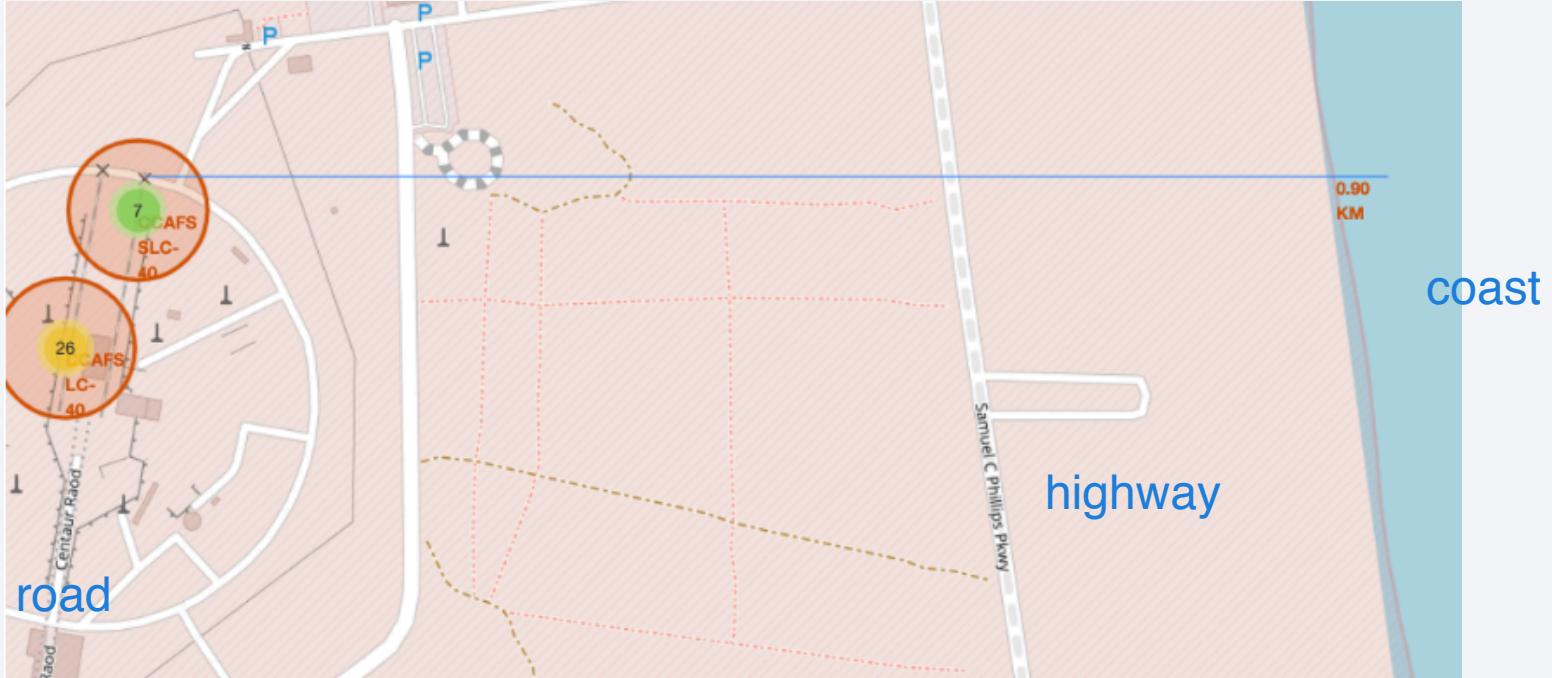
*“SpaceX launch sites are in– Florida on the USA east coast and California on the USA west coast”*

# Sites And Launch Outcomes On A Map



*“Green colored are the successful launches and red colored are the failed launches”*

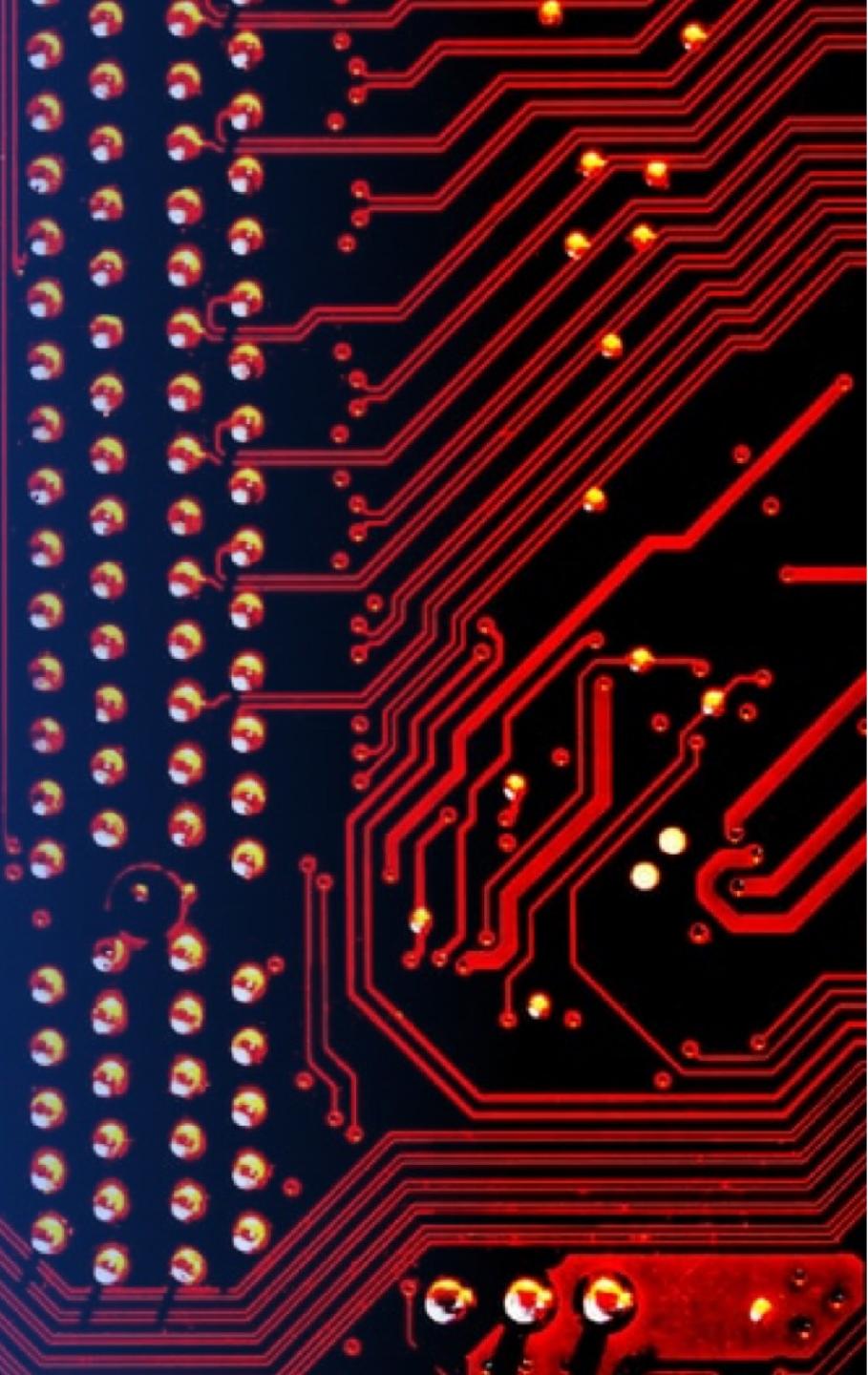
# Launch Site Proximities On A Map



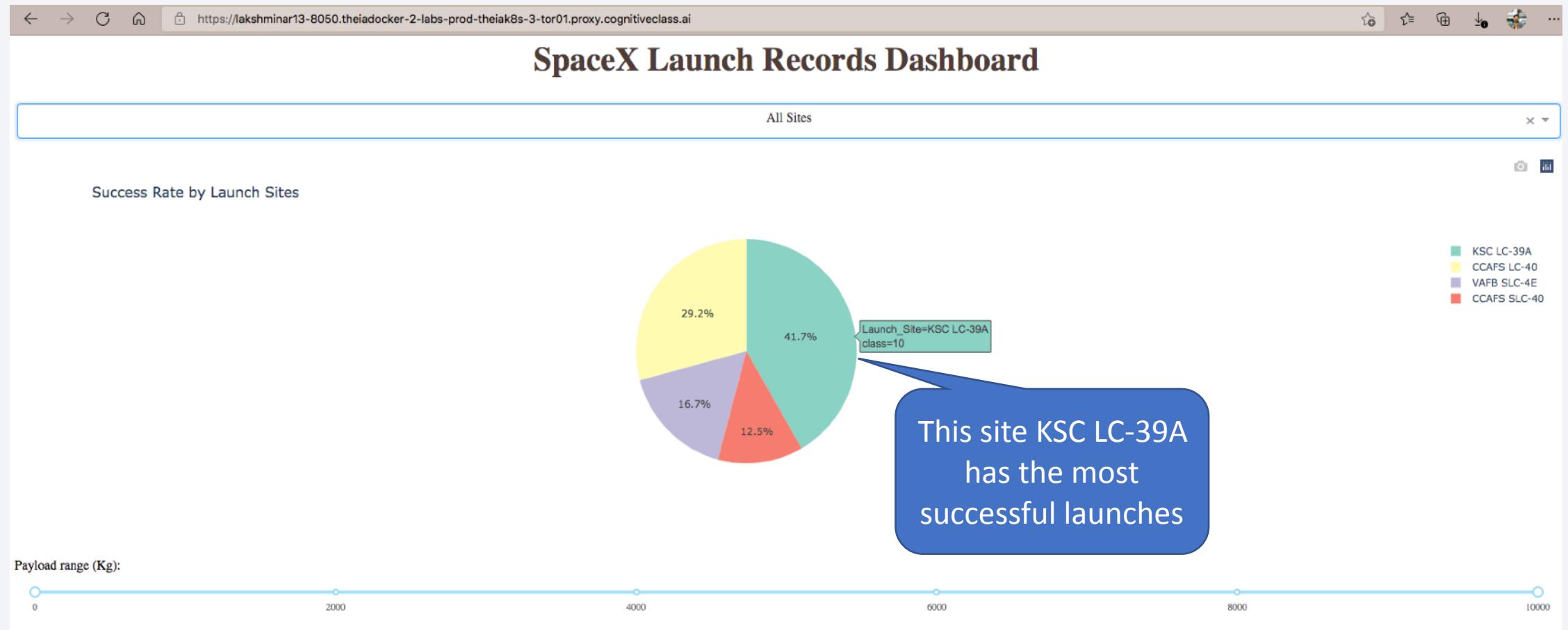
*“Here, we can observe distance of launch sites from east coast, highways, key road, railway line visualized”*

Section 5

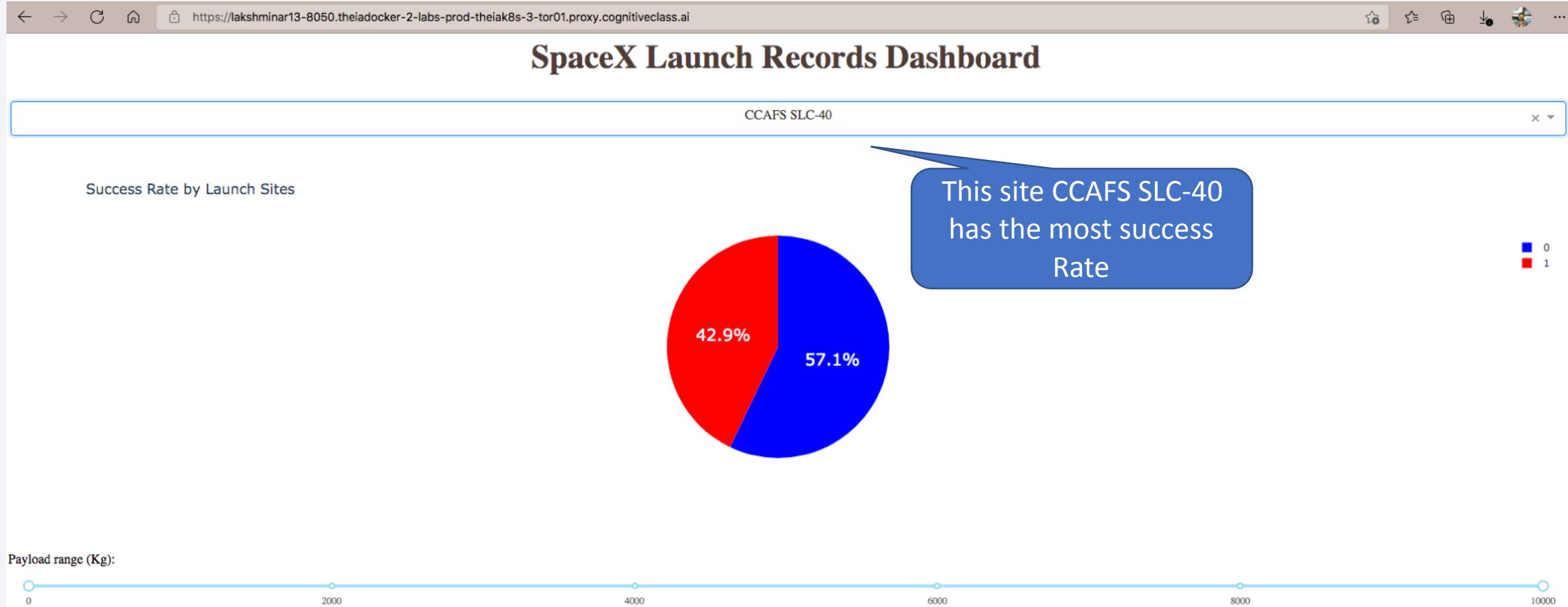
# Build a Dashboard with Plotly Dash



# Success Rate by Launch Sites



# Most Successful Launch Site



# Success by Payload Mass & Booster Version



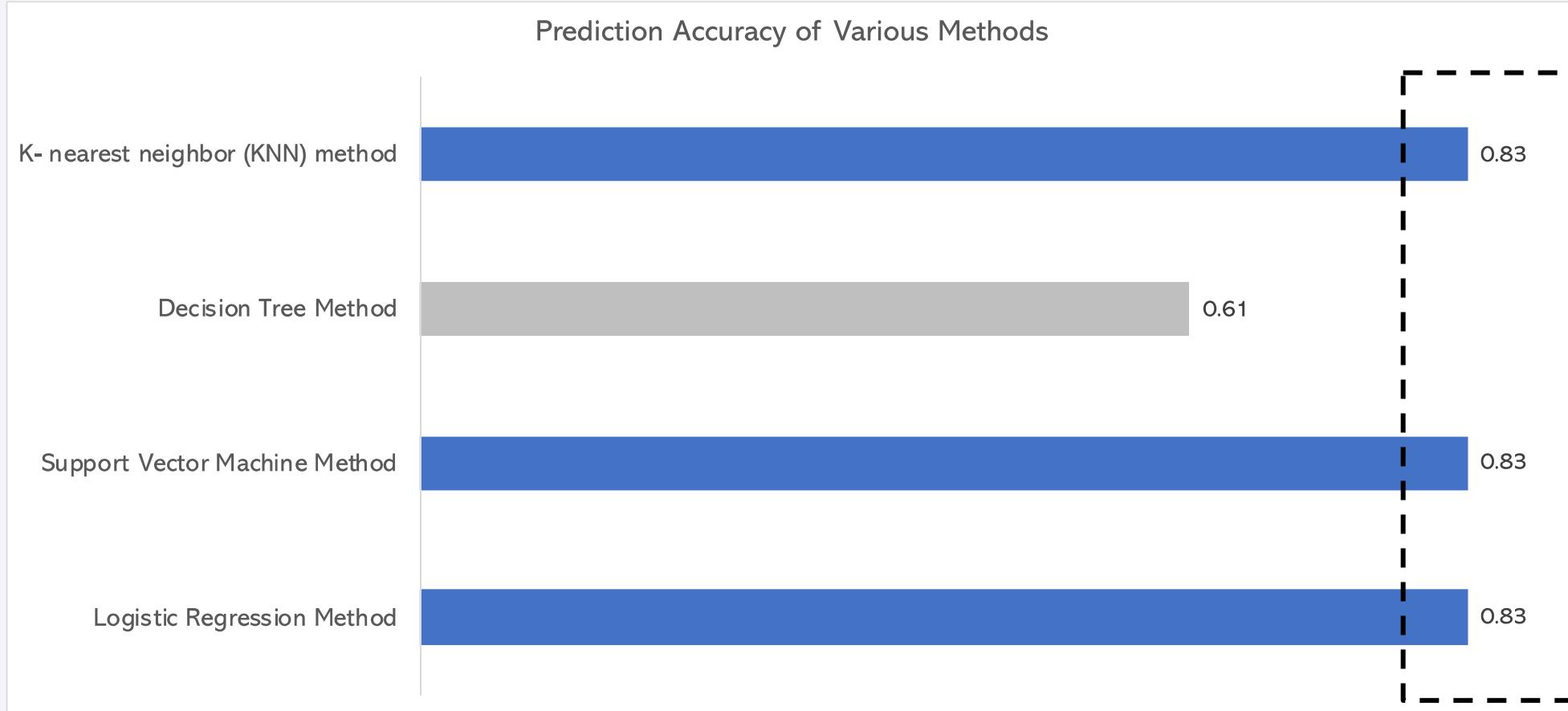
*“Lower Payload launches (up to 6,000 kg) are more successful”*

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 6

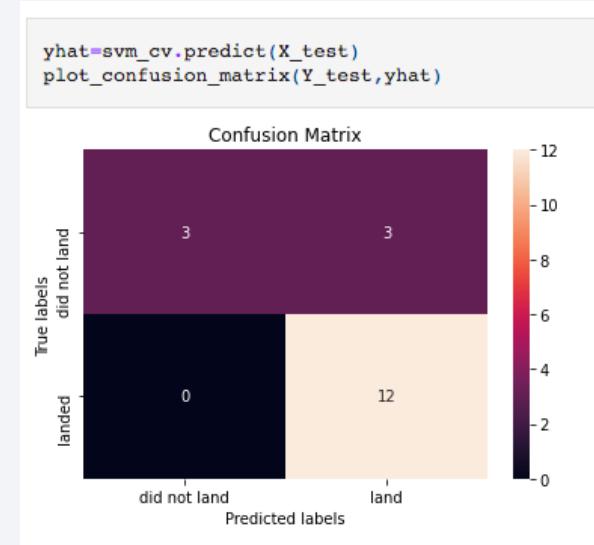
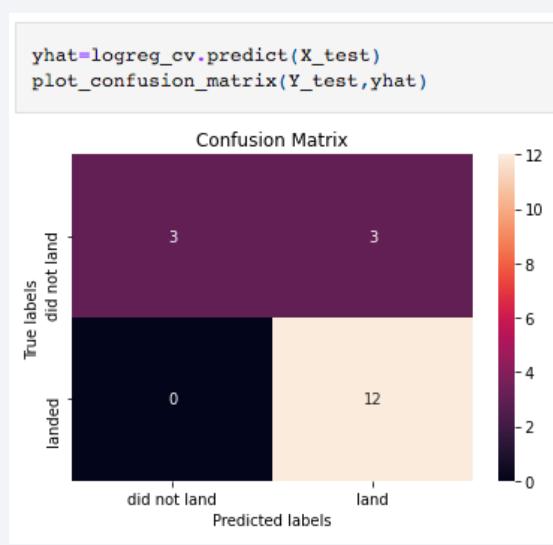
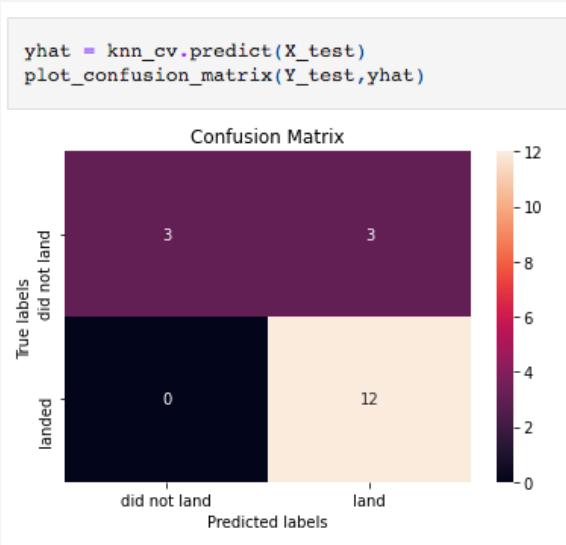
# Predictive Analysis (Classification)

# Classification Accuracy



*“KNN, Support Vector & Logistic Regression Methods have high accuracy”*

# Confusion Matrix



*"The above confusion matrix shows that all 3 models – KNN, Logistic Regression & SVM have highest true positives and least false negatives"*

# Conclusions

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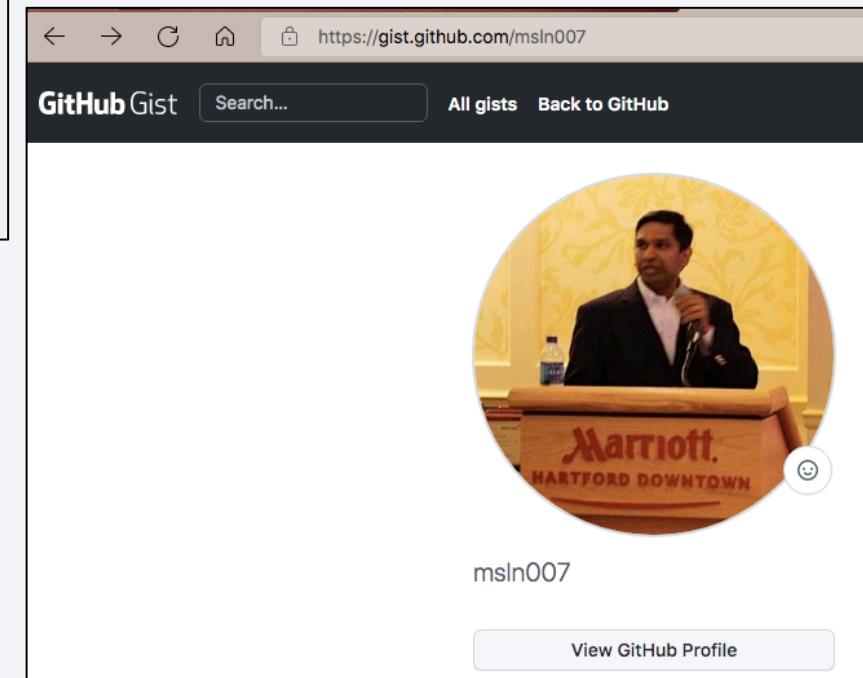
- KNN, Logistic Regression and SVM are the best classifier models for this dataset
- The lower payload launches have higher success rate than heavier payloads
- Site KSC LC-39A has the most successful launches from all sites
- F9 Booster versions v1.0, v1.1, FT, B4, B5 have the highest launch success rates
- The SpaceX launches have been continuously getting better from year 2013 to 2020 based on data so they have the best chances for perfecting their launches in the future years

# Appendix

Name	Shared	Scheduled	Status	Language	Last editor	Last modified
Prediction with ML				Python 3.8	Lakshminarayanan Madrasudaran	Dec 25, 2021
The best classifier notebook				Python 3.8	Lakshminarayanan Madrasudaran	Dec 22, 2021
Project Loan Notebook				Python 3.8	Lakshminarayanan Madrasudaran	Dec 22, 2021
SpaceX ML Prediction				Python 3.8	Lakshminarayanan Madrasudaran	Dec 05, 2021
Interactive Visual Analytics with Folium lab				Python 3.8	Lakshminarayanan Madrasudaran	Nov 28, 2021
jupyter-labs-edia-datasviz (1)				Python 3.8	Lakshminarayanan Madrasudaran	Nov 28, 2021
EDM with SQL				Python 3.8	Lakshminarayanan Madrasudaran	Nov 07, 2021
SpaceXDataWrangling				Python 3.8	Lakshminarayanan Madrasudaran	Nov 07, 2021
Web Scraping				Python 3.8	Lakshminarayanan Madrasudaran	Oct 24, 2021
Data Collection API				Python 3.8	Lakshminarayanan Madrasudaran	Oct 23, 2021
The Best classifier				Python 3.8	Lakshminarayanan Madrasudaran	Oct 18, 2021

My GitHub, Gists →

← IBM Cloud Pak Assignments



# Credits

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Primary Instructors: Joseph Santarcangelo, Yan Luo

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Malika Singla

Duvvana Mrutyunjaya Naidu

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