

# Winning Space Race with Data Science

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# Outline

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

# Executive Summary

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- Summary of methodologies

The following methodologies were used to analyze data:

- Data Collection using web scraping and SpaceX API;
- Exploratory Data Analysis (EDA), including data wrangling, data visualization and interactive visual analytics;
- Machine Learning Prediction.
- Summary of all results

# Introduction

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The objective is to evaluate the viability of the new company Space Y to compete with Space X.

Desirable answers:

- The best way to estimate the total cost for launches, by predicting successful landings of the first stage of rockets;
- Where is the best place to make launches.

Section 1

# Methodology

# Methodology

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## Executive Summary

- Data collection methodology:
  - Data from Space X was obtained from 2 sources:  
Space X API (<https://api.spacexdata.com/v4/rockets/>)  
• WebScraping([https://en.wikipedia.org/wiki/List\\_of\\_Falcon\\_9\\_and\\_Falcon\\_Heavy\\_launches](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
  - Perform exploratory data analysis (EDA) using visualization and SQL
  - Perform interactive visual analytics using Folium and Plotly Dash
  - Perform predictive analysis using classification models

# Methodology

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## Executive Summary

- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
- Data that was collected until this step were normalized, divided in training and test data sets and evaluated by four different classification models, being the accuracy of each model evaluated using different combinations of parameters.

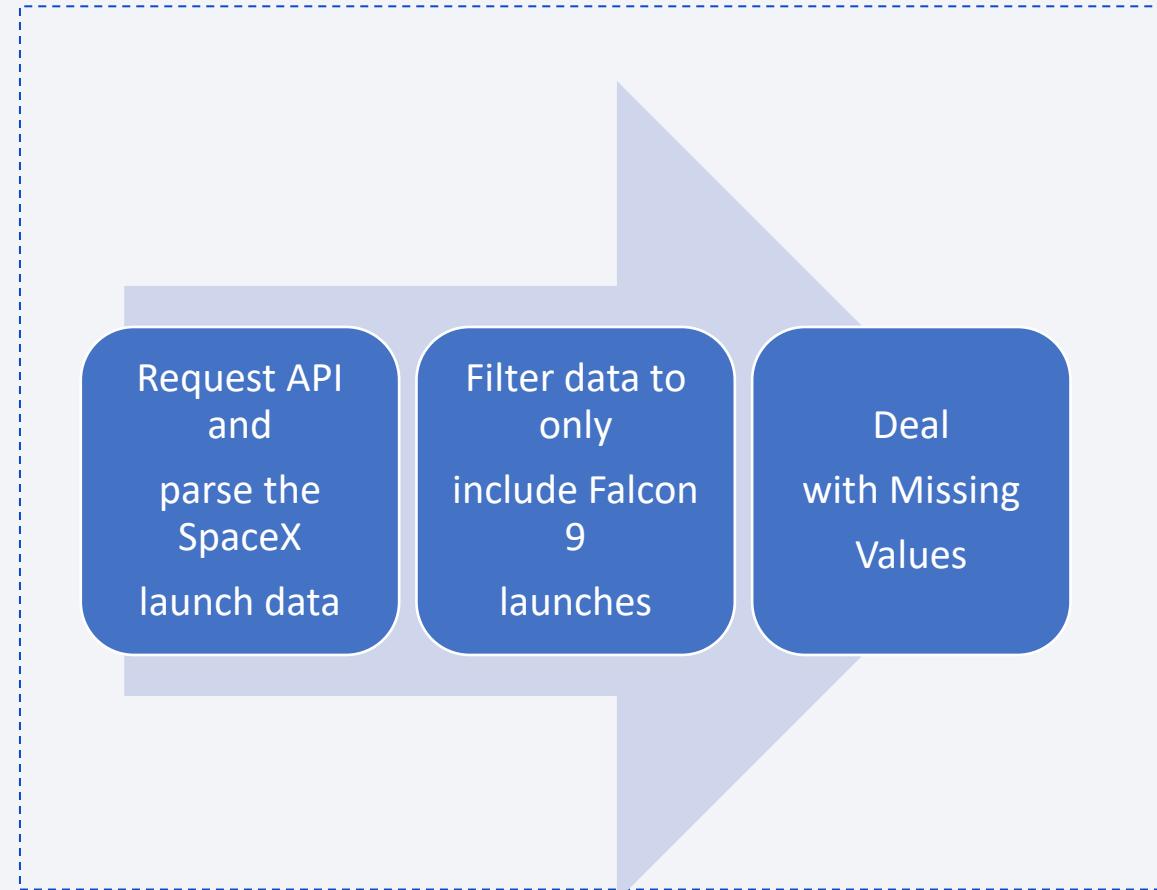
# Data Collection

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- Data sets were collected from Space X API (<https://api.spacexdata.com/v4/rockets/>) and from Wikipedia ([https://en.wikipedia.org/wiki/List\\_of\\_Falcon\\_9\\_and\\_Falcon\\_Heavy\\_launches](https://en.wikipedia.org/wiki/List_of_Falcon_9_and_Falcon_Heavy_launches)), using web scraping technics.

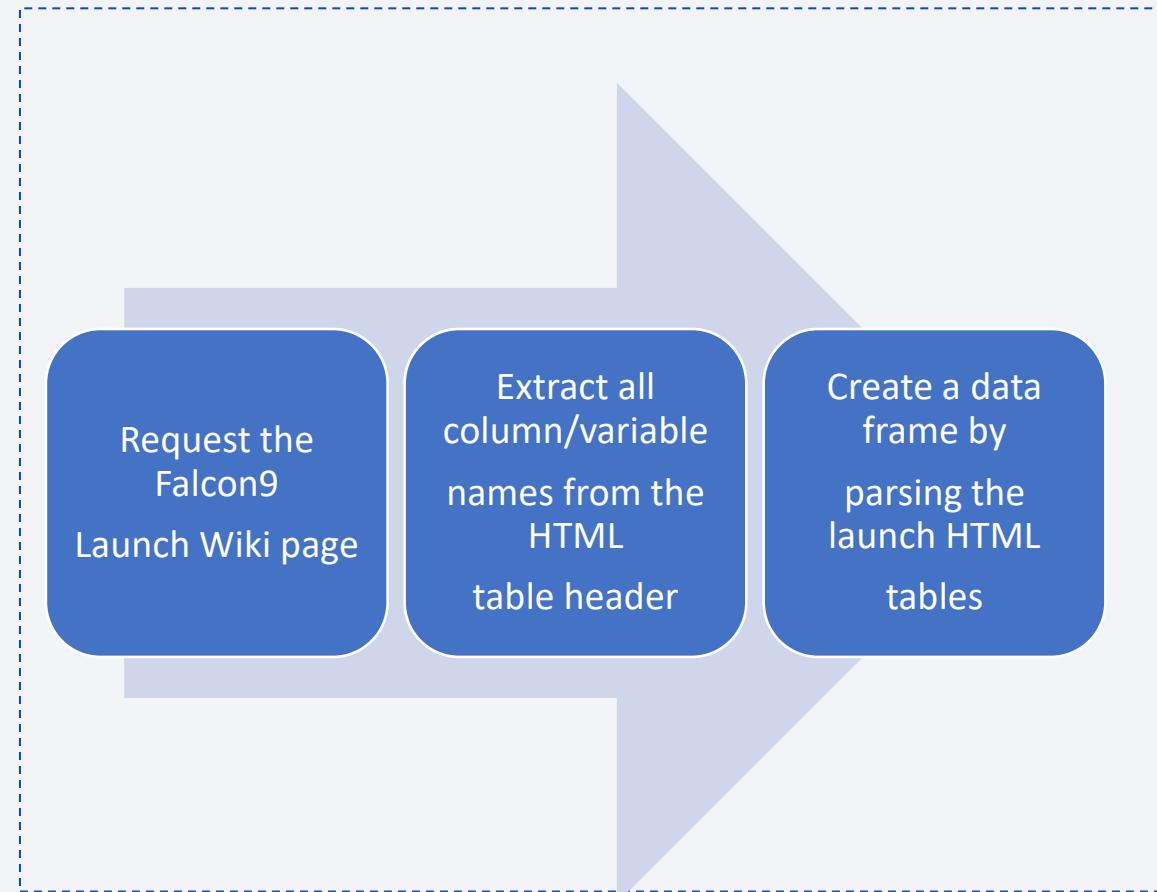
# Data Collection – SpaceX API

- 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.
- Source Code:  
<https://github.com/JuniorMkhatshwa/IBM-Data-Science-Capstone/blob/93f885b81191f1eb9ccdebdb14eda3ce5cd89c00/Data%20Collection%20API.ipynb>



# Data Collection - Scraping

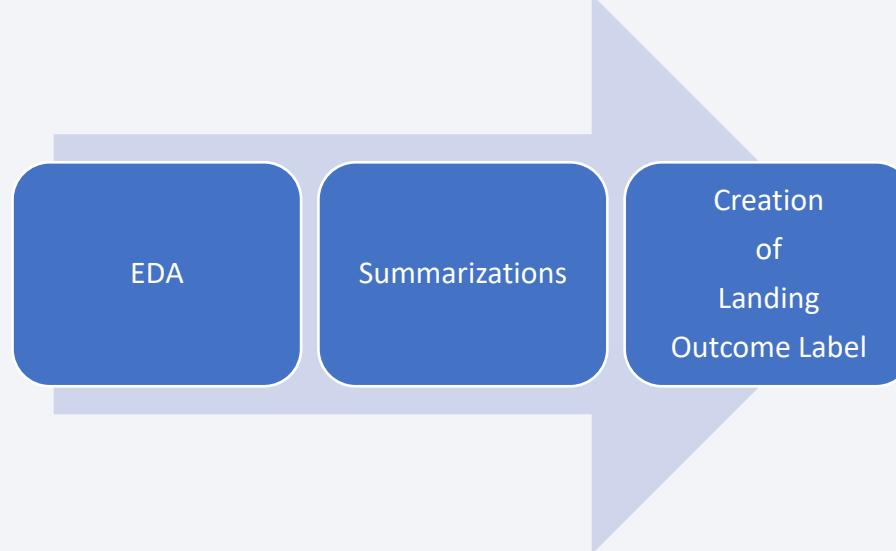
- Data from SpaceX launches can also be obtained from Wikipedia;
- Data are downloaded from Wikipedia according to the flowchart and then persisted.
- Source Code:  
<https://github.com/JuniorMkhatshwa/IBM-Data-Science-Capstone/blob/93f885b81191f1eb9ccdebdb14eda3ce5cd89c00/Data%20Collection%20with%20Web%20Scraping.ipynb>



# Data Wrangling

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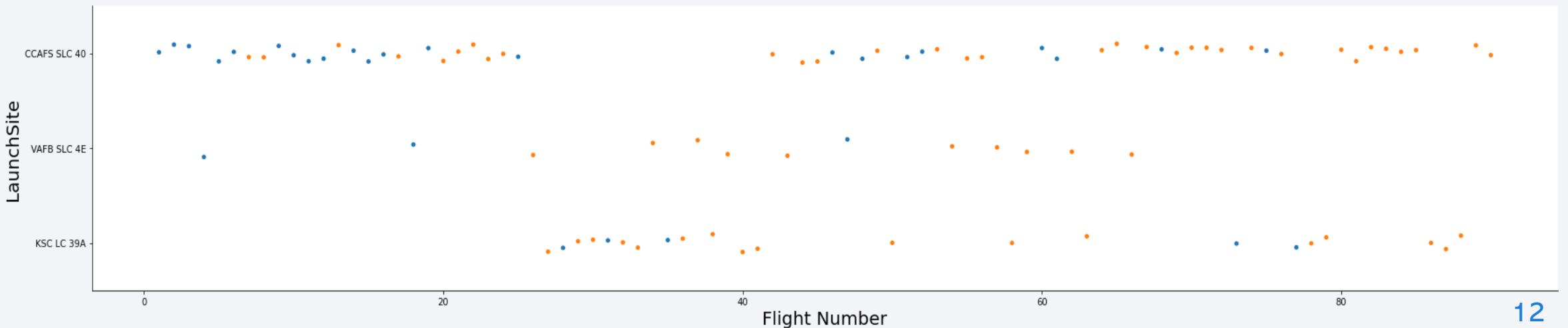
- Initially some Exploratory Data Analysis (EDA) was performed on the dataset.
- Then the summaries launches per site, occurrences of each orbit and occurrences of mission outcome per orbit type were calculated.
- Finally, the landing outcome label was created from Outcome column.
- Source Code: <https://github.com/JuniorMkhatshwa/IBM-Data-Science-Capstone/blob/93f885b81191f1eb9ccdebdb14eda3ce5cd89c00/Data%20Wrangling.ipynb>



# EDA with Data Visualization

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- To explore data, scatterplots and barplots 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/JuniorMkhatshwa/IBM-Data-Science-Capstone/blob/93f885b81191f1eb9ccdebdb14eda3ce5cd89c00/EDA%20with%20Data%20Visualization.ipynb>



# EDA with SQL

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- The following SQL queries were performed:
  - Names of the unique launch sites in the space mission;
  - Top 5 launch sites whose name begin with the string 'CCA';
  - Total payload 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 outcomes in drone ship, their booster versions, and launch site names for in year 2015; and
  - Rank of the count of landing outcomes (such as Failure (drone ship) or Success (ground pad)) between the date 2010-06-04 and 2017-03-20.
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- Source Code: <https://github.com/JuniorMkhatshwa/IBM-Data-Science-Capstone/blob/934129475b9c3f5ffad82aa5ceabc5e45c4d75c2/EDA.ipynb>

# Build an Interactive Map with Folium

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- 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.
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- Source Code: <https://github.com/JuniorMkhatshwa/IBM-Data-Science-Capstone/blob/934129475b9c3f5ffad82aa5ceabc5e45c4d75c2/Interactive%20Visual%20Analytics%20with%20Folium%20lab.ipynb>

# Build a Dashboard with Plotly Dash

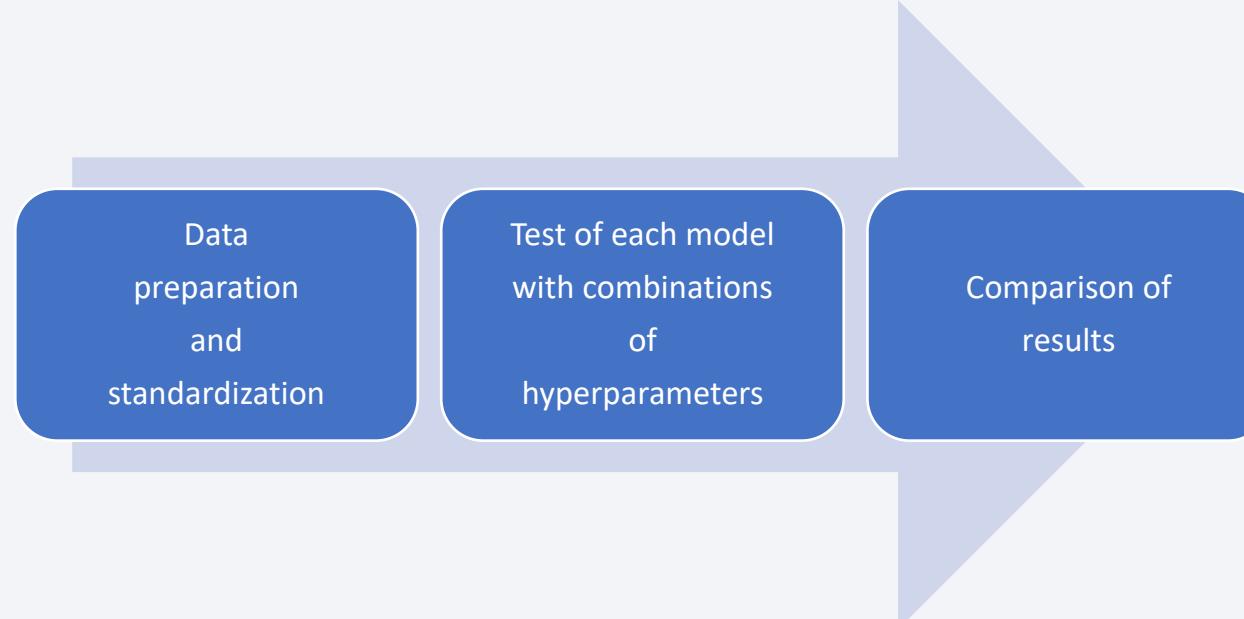
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- The following graphs and plots were used to visualize data
  - Percentage of launches by site
  - Payload range
- This combination allowed to quickly analyze the relation between payloads and launch sites, helping to identify where is best place to launch according to payloads.
- Source Code: [https://github.com/JuniorMkhatshwa/IBM-Data-Science-Capstone/blob/8899db071ae834926caff59f6fd35b6504f0f45e/spacex\\_dash\\_app.py](https://github.com/JuniorMkhatshwa/IBM-Data-Science-Capstone/blob/8899db071ae834926caff59f6fd35b6504f0f45e/spacex_dash_app.py)

# Predictive Analysis (Classification)

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- Four classification models were compared: logistic regression, support vector machine, decision tree and k nearest neighbors.
- Source Code: <https://github.com/JuniorMkhatshwa/IBM-Data-Science-Capstone/blob/8899db071ae834926caff59f6fd35b6504f0f45e/Machine%20Learning%20Prediction.ipynb>



# Results

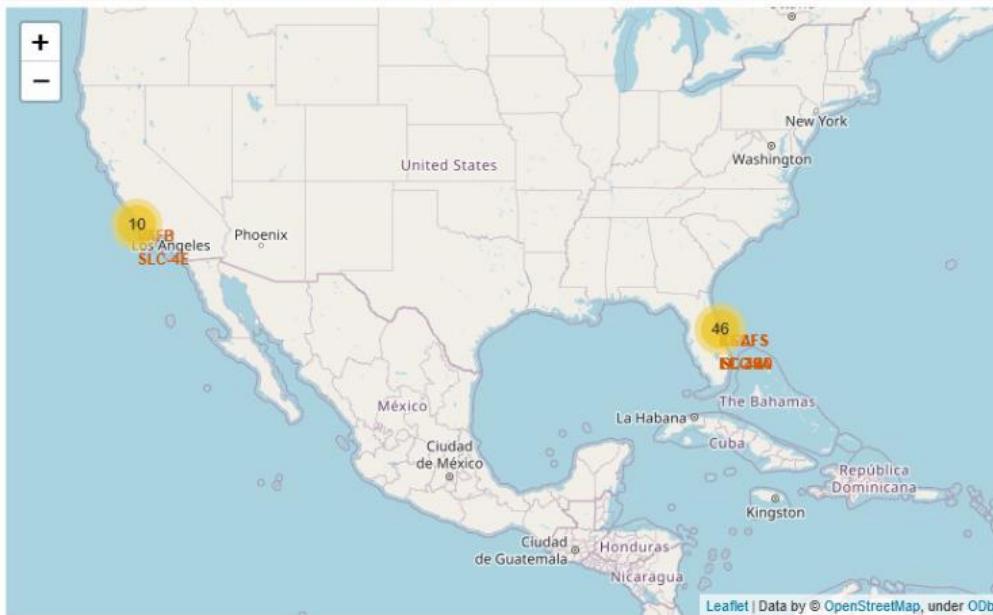
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- **Exploratory data analysis results:**
  - Space X uses 4 different launch sites;
  - The first launches were done to Space X itself and NASA;
  - The average payload of F9 v1.1 booster is 2,928 kg;
  - The first success landing outcome happened 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

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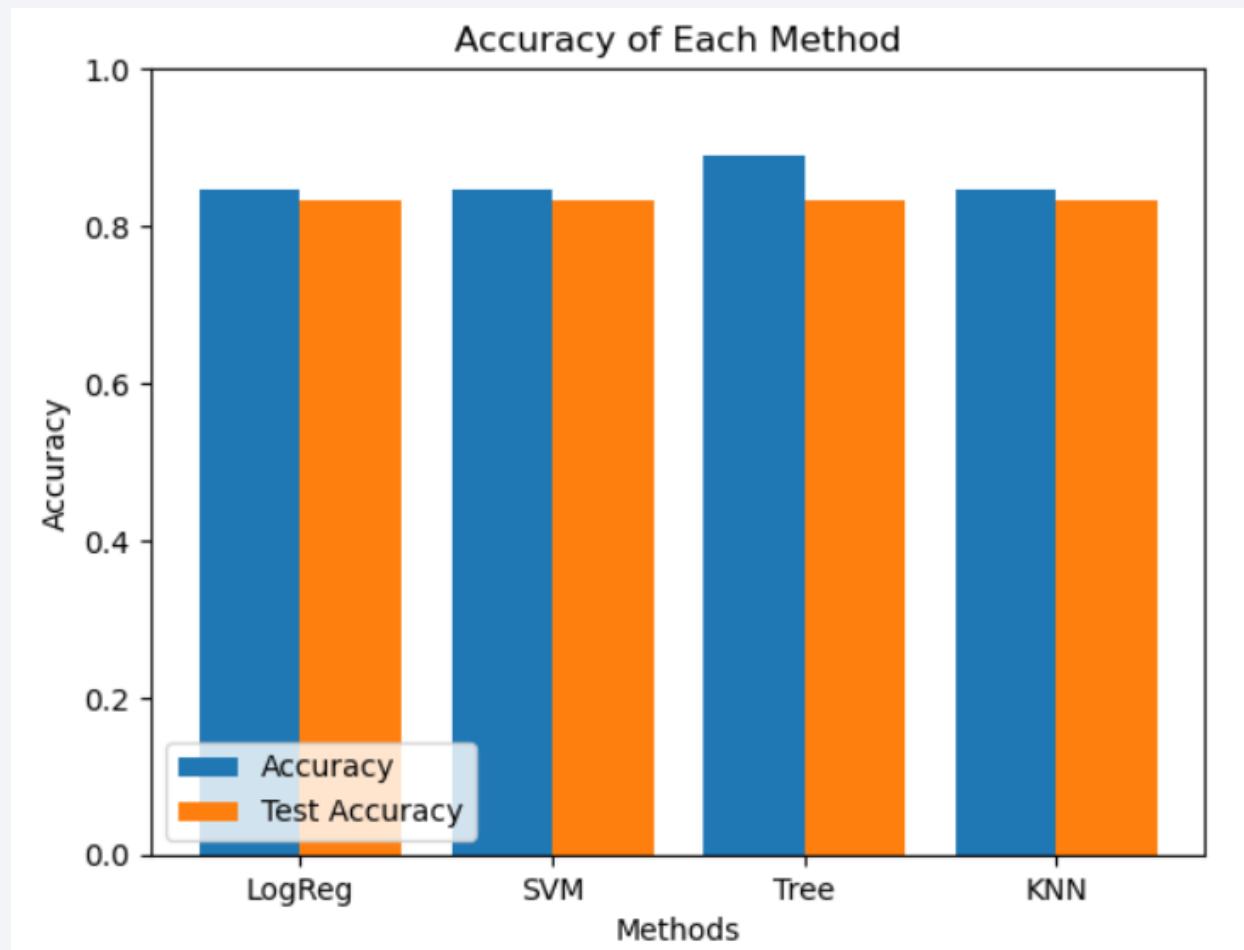
- Using interactive analytics was possible to identify that launch sites use to be in safety places, near sea, for example and have a good logistic infrastructure around.
- Most launches happens at east cost launch sites.

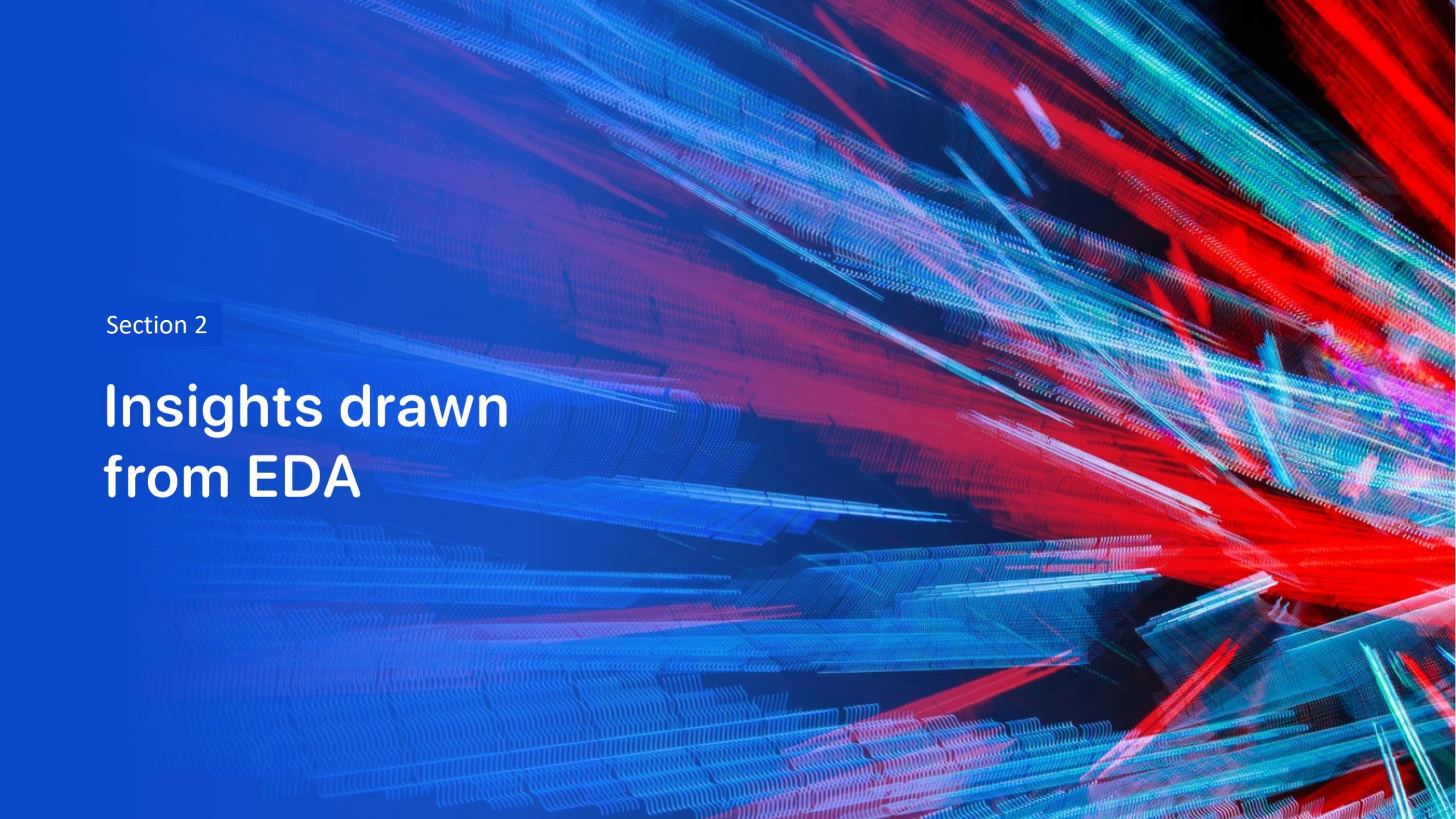


# Results

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Predictive Analysis showed that Decision Tree Classifier is the best model to predict successful landings, having accuracy over 87% and accuracy for test data over 94%.



The background of the slide features a complex, abstract digital visualization. It consists of numerous thin, glowing lines that create a sense of depth and motion. The lines are primarily blue and red, with some green and purple highlights. They form a grid-like structure that curves and twists across the frame, resembling a three-dimensional space or a network of data points. The overall effect is futuristic and dynamic.

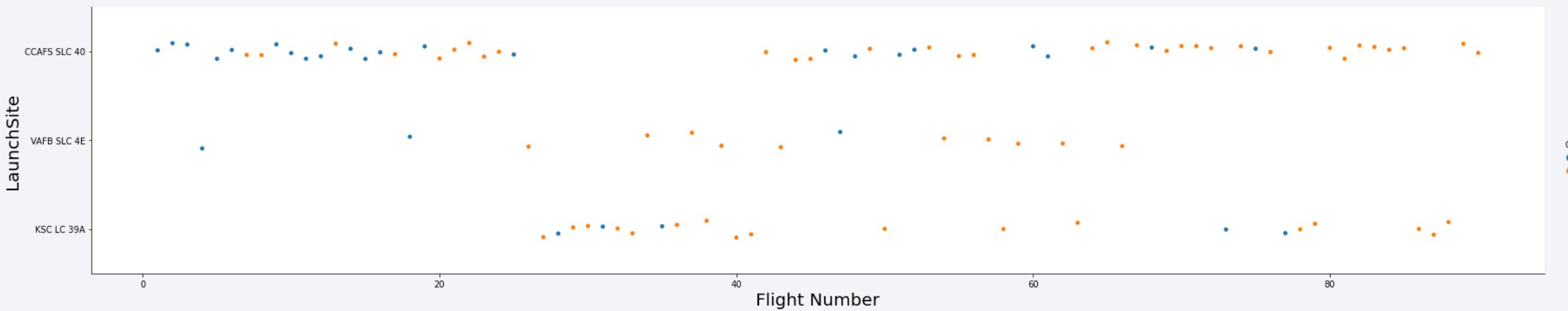
Section 2

## Insights drawn from EDA

# Flight Number vs. Launch Site

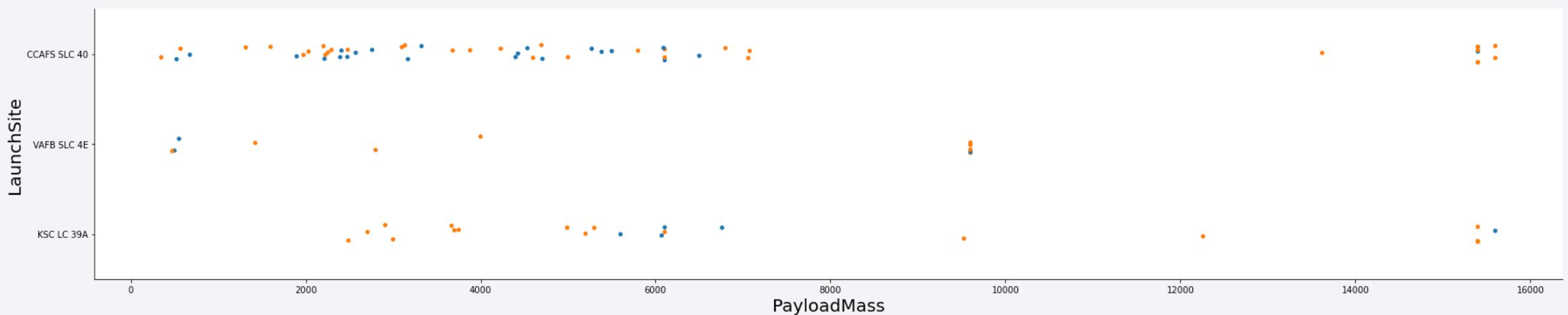
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- According to the plot above, it's possible to verify that the best launch site nowadays is CCAF5 SLC 40, where most of recent launches were successful;
- In second place VAFB SLC 4E and third place KSC LC 39A;
- It's also possible to see that the general success rate improved over time.



# Payload vs. Launch Site

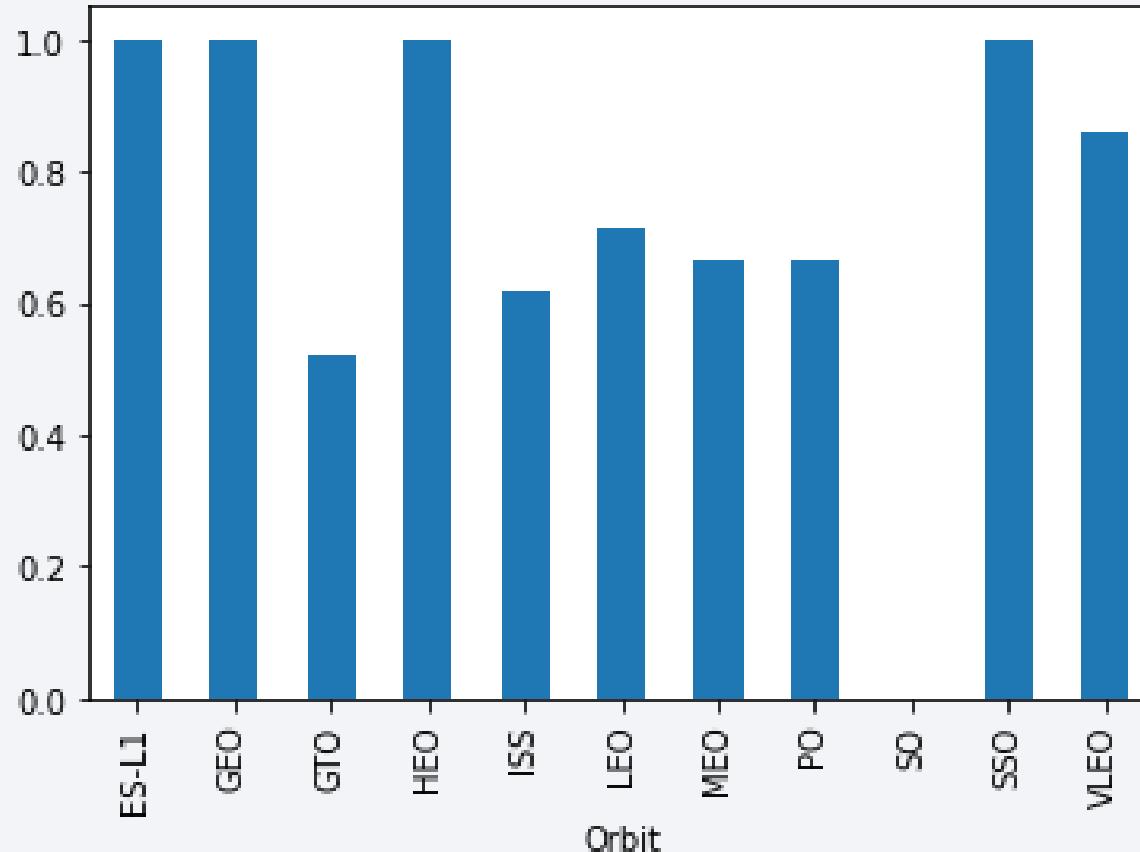
- Payloads over 9,000kg (about the weight of a school bus) have excellent success rate;
- Payloads over 12,000kg seems to be possible only on CCAFS SLC 40 and KSC LC 39A launch sites.



# Success Rate vs. Orbit Type

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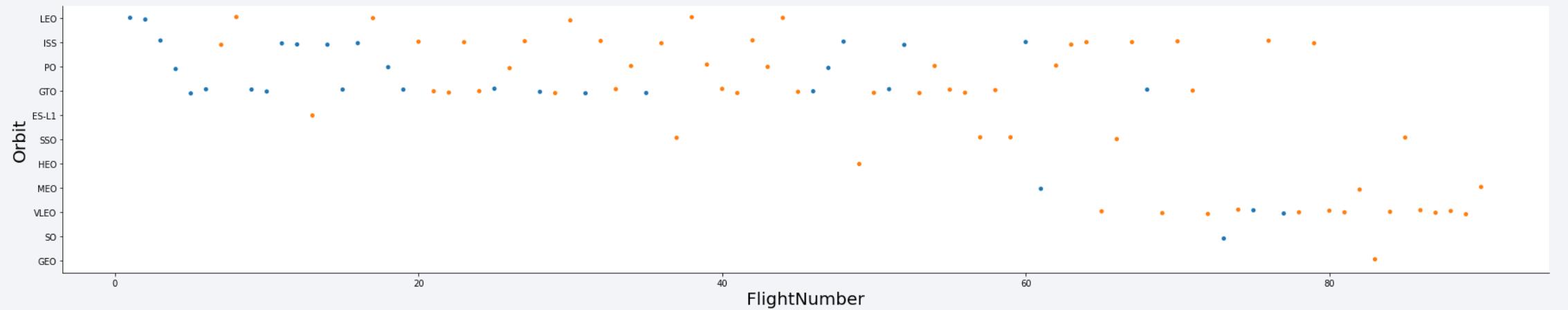
- The biggest success rates happens to orbits:
  - ES-L1;
  - GEO;
  - HEO; and
  - SSO.
- Followed by:
  - VLEO (above 80%); and
  - LFO (above 70%).



# Flight Number vs. Orbit Type

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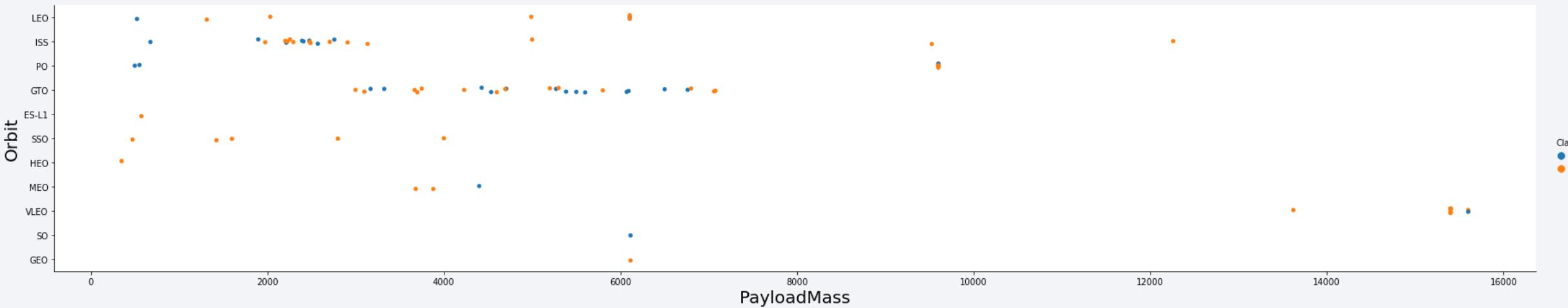
- Apparently, success rate improved over time to all orbits;
- VLEO orbit seems a new business opportunity, due to recent increase of its frequency.



# Payload vs. Orbit Type

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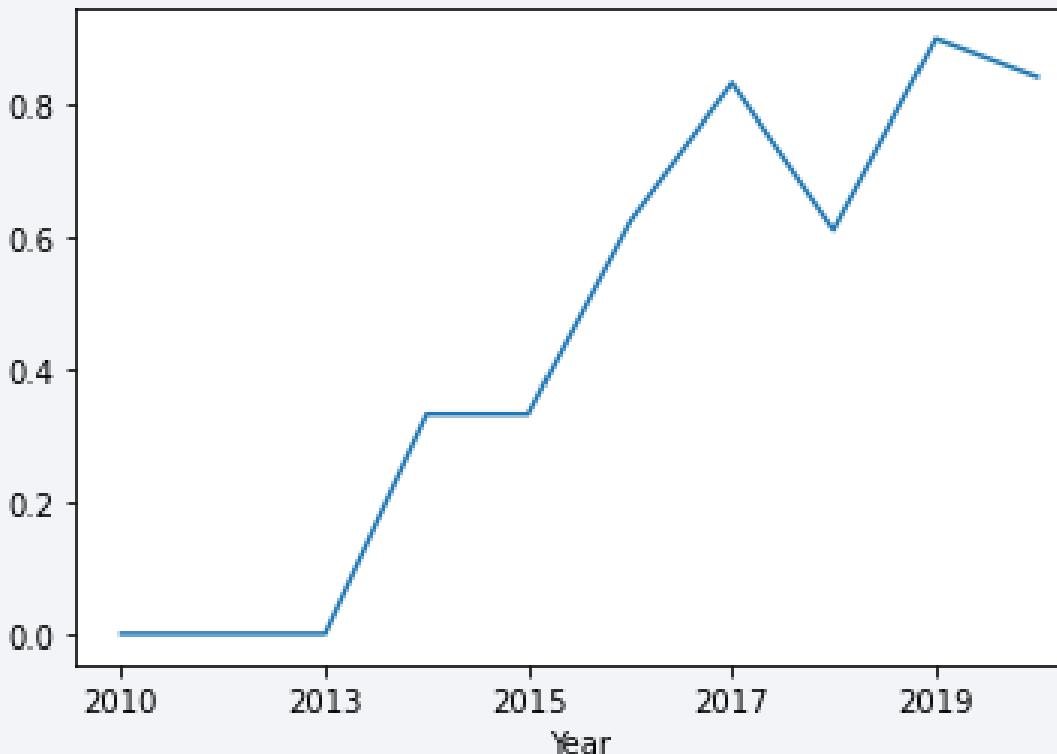
- Apparently, there is no relation between payload and success rate to orbit GTO;
- ISS orbit has the widest range of payload and a good rate of success;
- There are few launches to the orbits SO and GEO.



# Launch Success Yearly Trend

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- Success rate started increasing in 2013 and kept until 2020;
- It seems that the first three years were a period of adjusts and improvement of technology.



# All Launch Site Names

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- According to data, there are four launch sites:

LaunchSite
CCAFS SLC 40
CCAFS SLC 40
CCAFS SLC 40
VAFB SLC 4E
CCAFS SLC 40

- They are obtained by selecting unique occurrences of “launch\_site” values from the dataset.

# Launch Site Names Begin with 'CCA'

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- Find 5 records where launch sites begin with `CCA`
- Present your query result with a short explanation here

FlightNumber	PayloadMass	Orbit	Launch Site	Flights	GridFins	Reused	Legs	LandingPad	Block	ReusedCount	Serial	
0	1	6104.959412	LEO	CCAFS SLC 40	1	False	False	False	NaN	1.0	0	B0003
1	2	525.000000	LEO	CCAFS SLC 40	1	False	False	False	NaN	1.0	0	B0005
2	3	677.000000	ISS	CCAFS SLC 40	1	False	False	False	NaN	1.0	0	B0007
3	4	500.000000	PO	VAFB SLC 4E	1	False	False	False	NaN	1.0	0	B1003
4	5	3170.000000	GTO	CCAFS SLC 40	1	False	False	False	NaN	1.0	0	B1004

# Total Payload Mass

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- Total payload carried by boosters from NASA:

Total Payload (Kg)
111.268

- Total payload calculated above, by summing all payloads whose codes contain 'CRS', which corresponds to NASA.

# Average Payload Mass by F9 v1.1

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- Average payload mass carried by booster version F9 v1.1:

AVG Payload (Kg)
2.928

- Filtering data by the booster version above and calculating the average payload mass we obtained the value of 2,928 kg.

# First Successful Ground Landing Date

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- First successful landing outcome on ground pad:

Min Date
2015-12-22

- By filtering data by successful landing outcome on ground pad and getting the minimum value for date it's possible to identify the first occurrence, that happened on 12/22/2015.

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

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- Boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 6000
- **BoosterVersion**
- F9 FT B1021.2
- F9 FT B1031.2
- F9 FT B1022
- F9 FT B1026
- Selecting distinct booster versions according to the filters above, these 4 are the result.

# Total Number of Successful and Failure Mission Outcomes

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- Number of successful and failure mission outcomes:

Mission Outcome	Occurrences
Success	99
Success (Payload status unclear)	1
Failure (in flight)	1

- Grouping mission outcomes and counting records for each group led us to the summary above.

# Boosters Carried Maximum Payload

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- Boosters which have carried the maximum payload mass

BoosterVersion(...)	BoosterVersion
F9 B5 B1048.4	
F9 B5 B1048.5	
F9 B5 B1049.4	
F9 B5 B1049.5	
F9 B5 B1049.7	
F9 B5 B1051.3	
	F9 B5 B1051.4
	F9 B5 B1051.6
	F9 B5 B1056.4
	F9 B5 B1058.3
	F9 B5 B1060.2
	F9 B5 B1060.3

- These are the boosters which have carried the maximum payload mass registered in the dataset.

# 2015 Launch Records

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- Failed landing outcomes in drone ship, their booster versions, and launch site names for in year 2015
- **Booster Version Launch Site**
- F9 v1.1 B1012 CCAFS LC-40
- F9 v1.1 B1015 CCAFS LC-40
- The list above has the only two occurrences.

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

- Ranking of all landing outcomes between the date 2010-06-04 and 2017-03-20:

Landing Outcome	Occurrences
No attempt	10
Failure(drone ship)	5
Success(drone ship)	5
Controlled(ocean)	3
Success(groundpad)	3
Failure(parachute)	2
Uncontrolled(ocean)	2
Precluded(drone ship)	1

- This view of data alerts us that “No attempt” must be taken in account.

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. Numerous glowing yellow and white points represent city lights, concentrated in coastal and urban areas. In the upper right quadrant, there are bright green and yellow bands of light, likely the Aurora Borealis or Australis. The overall atmosphere is dark and mysterious.

Section 3

# Launch Sites Proximities Analysis

# All launch sites

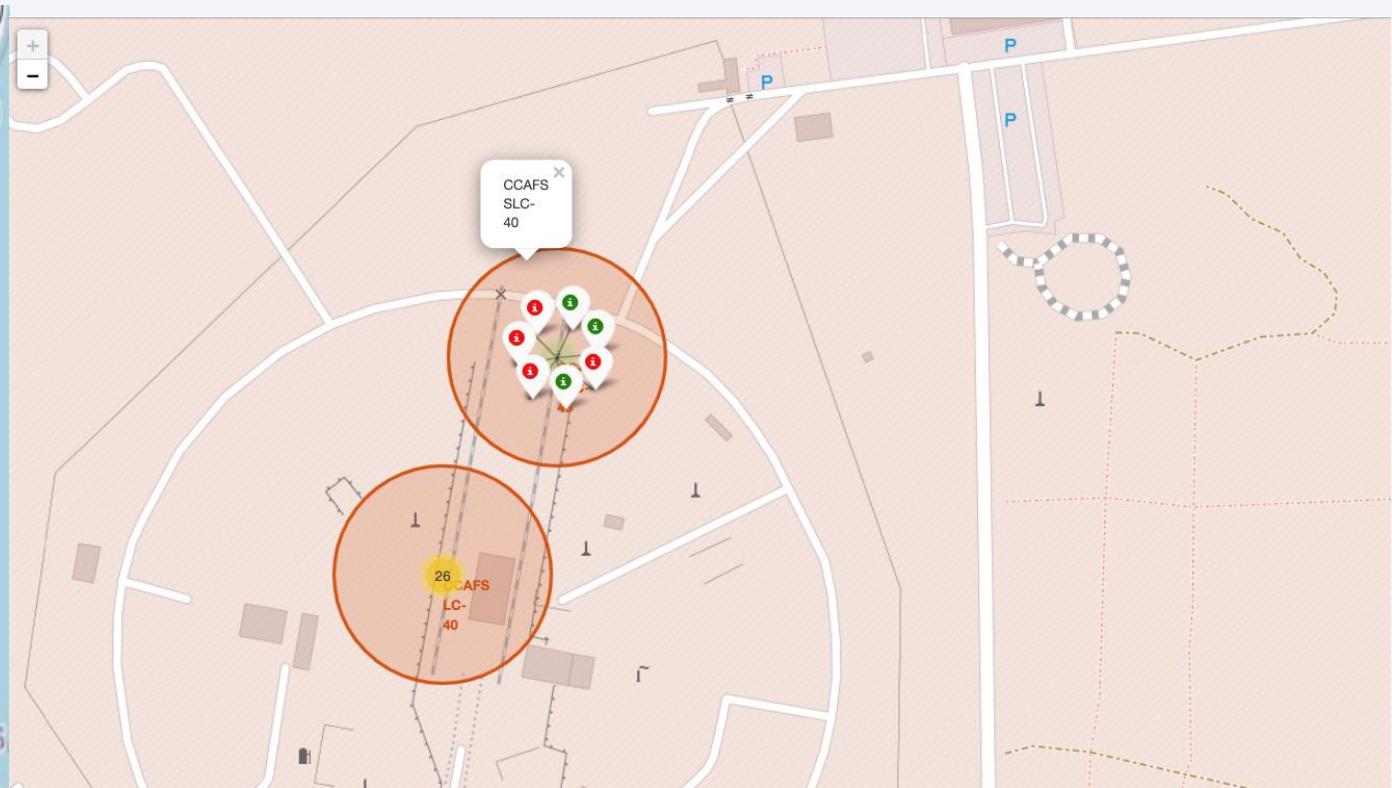
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- Launch sites are near sea, probably by safety, but not too far from roads and railroads.



# Launch Outcomes by Site

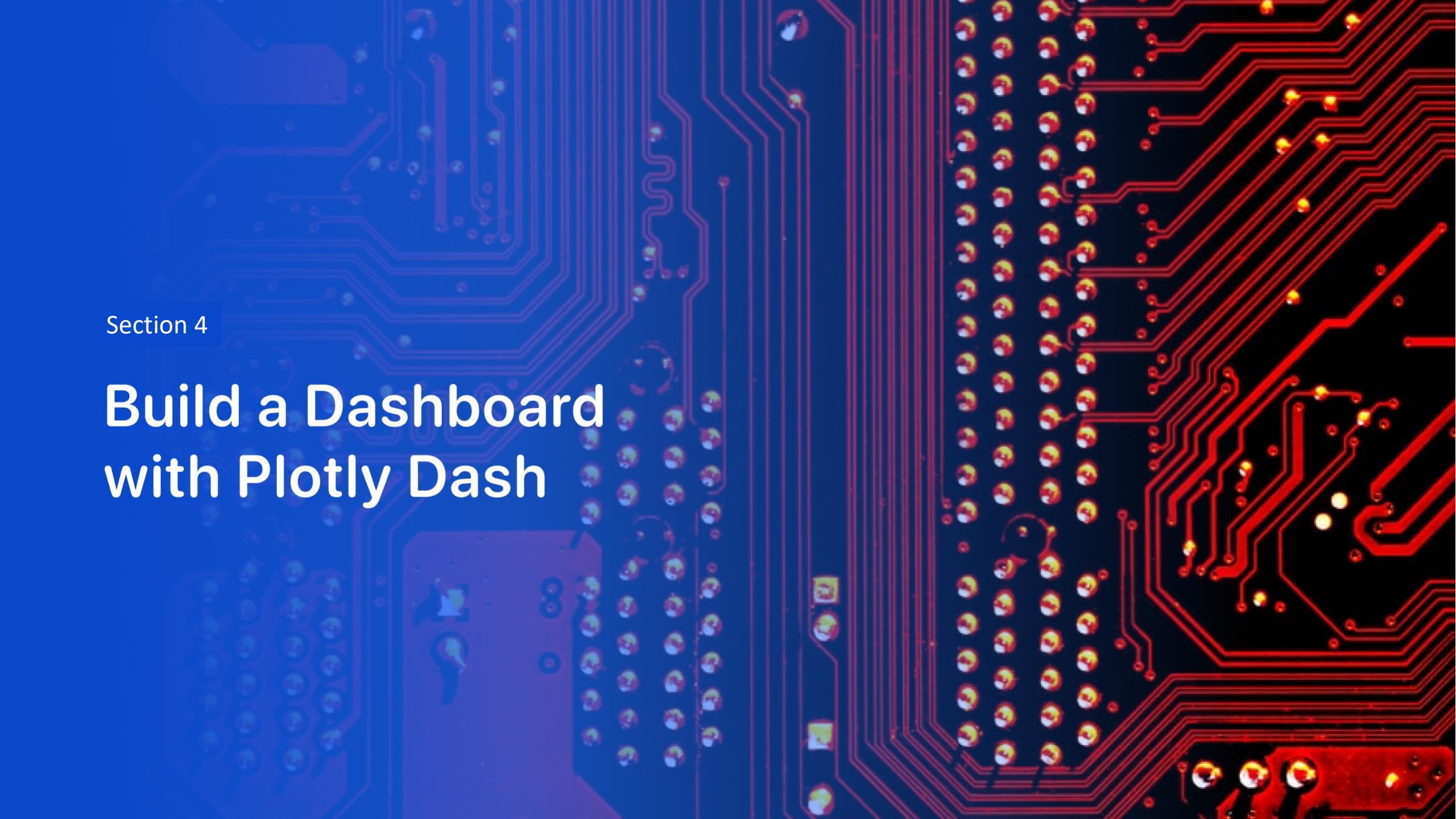
- Example of KSC LC-39A launch site launch outcomes
- Green markers indicate successful and red ones indicate failure.



# Logistics and Safety

- This Launch Site has good logistics aspects, being near railroad and road.





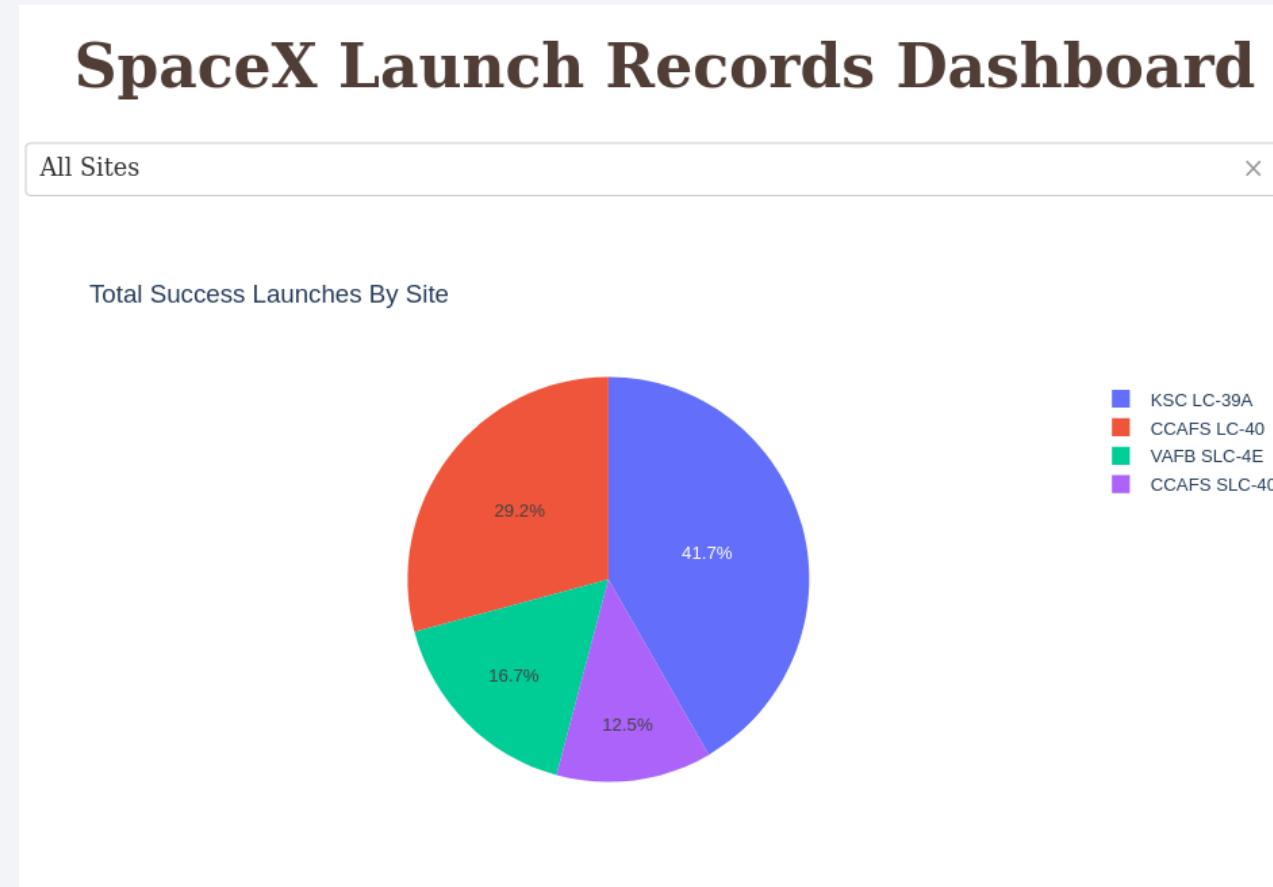
Section 4

# Build a Dashboard with Plotly Dash

# Successful Launches by Site

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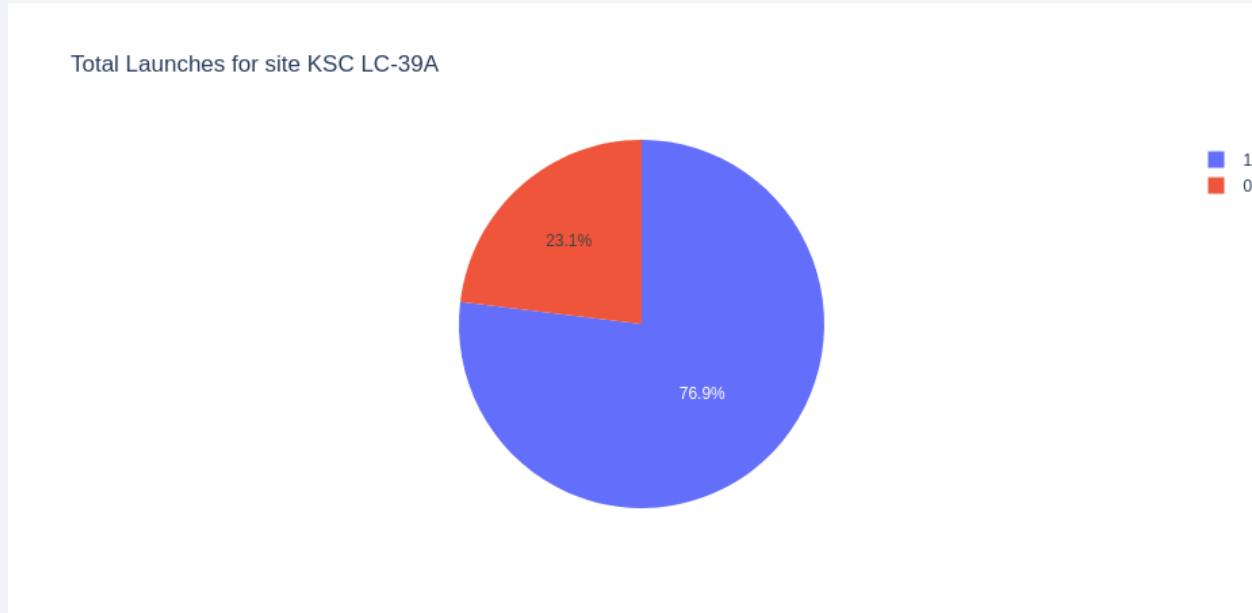
- The place from where launches are done seems to be a very important factor of success of missions.



## Launch Success Ratio for KSC LC 39A

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- 76.9% of launches are successful in this site.



# Payload vs. Launch Outcome

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- Payloads under 6,000kg and FT boosters are the most successful combination.



The background of the slide features a dynamic, abstract design. It consists of several curved, overlapping bands of color. A prominent band on the left is a bright blue, while another on the right is a warm yellow. These colors transition into lighter shades of blue and yellow towards the edges. The overall effect is one of motion and depth, suggesting a tunnel or a path through a digital space.

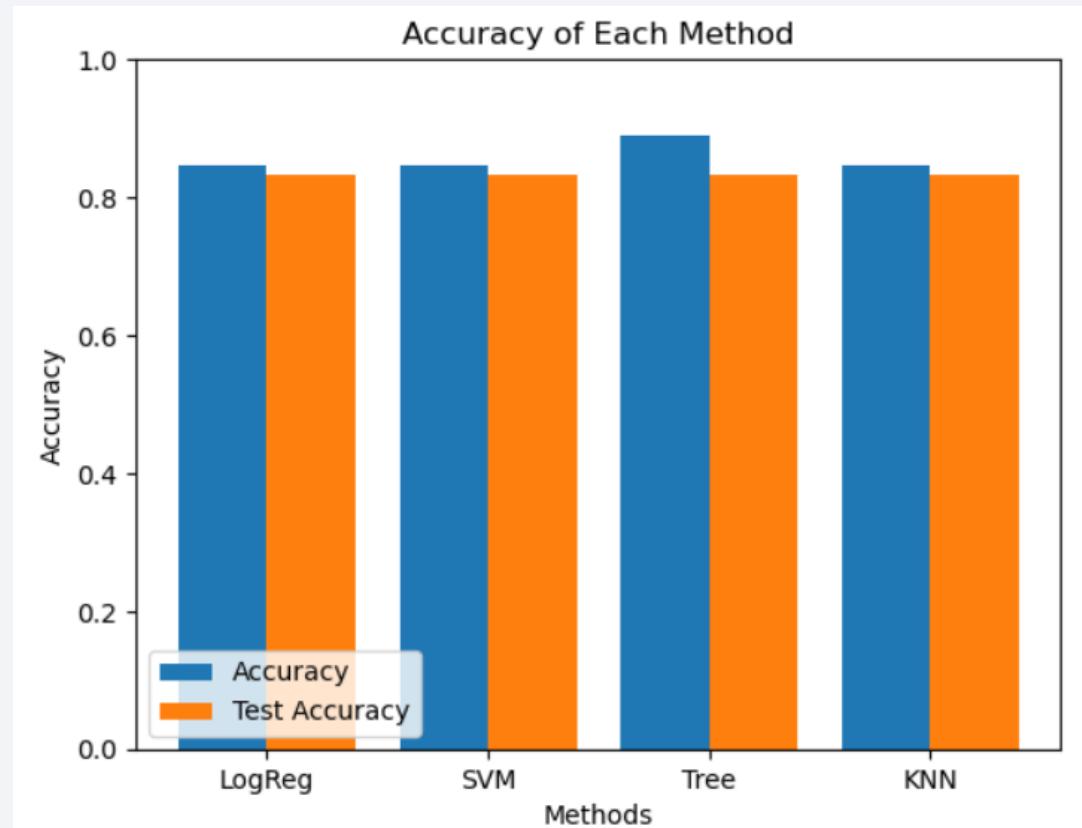
Section 5

# Predictive Analysis (Classification)

# Classification Accuracy

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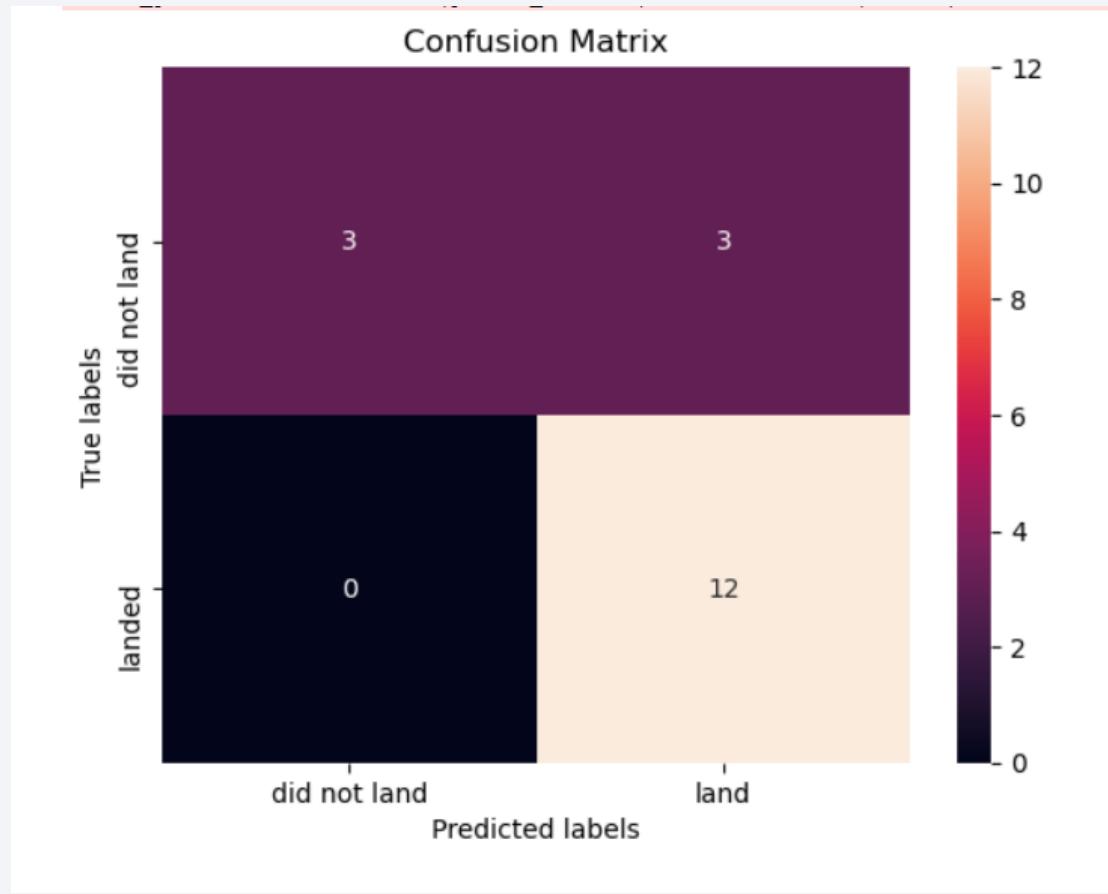
- Four classification models were tested, and their accuracies are plotted beside;
- The model with the highest classification accuracy is Decision Tree Classifier, which has accuracies over than 87%.



# Confusion Matrix

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- Confusion matrix of Decision Tree Classifier proves its accuracy by showing the big numbers of true positive and true negative compared to the false ones.



# Conclusions

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- Different data sources were analyzed, refining conclusions along the process;
- The best launch site is KSC LC-39A;
- Launches above 7,000kg are less risky;
- Although most of mission outcomes are successful, successful landing outcomes seem to improve over time, according the evolution of processes and rockets;
- Decision Tree Classifier can be used to predict successful landings and increase profits.

# Appendix

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- Include any relevant assets like Python code snippets, SQL queries, charts, Notebook outputs, or data sets that you may have created during this project

Thank you!

