



IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

Suraj D S
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OUTLINE

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

EXECUTIVE SUMMARY

- The capstone project aims to predict the successful landing of SpaceX Falcon 9's first stage through machine learning classification algorithms.
- The project involves the following main steps:
 - Data collection, wrangling, and formatting
 - Exploratory data analysis
 - Interactive data visualization
 - Machine learning prediction
- Based on the graphs, certain features of the rocket launches show a correlation with the success or failure of the launches.
- The decision tree algorithm is considered the best machine learning approach to predict the successful landing of the Falcon 9's first stage.

INTRODUCTION

- Capstone goal: Predict successful landing of Falcon 9 first stage.
- SpaceX's Falcon 9 launches cost \$62 million, whereas other providers' costs exceed \$165 million, largely because SpaceX can reuse the first stage.
- Determining first stage landing success will determine launch cost, important for companies bidding against SpaceX.
- Most unsuccessful landings are planned, with controlled landing in the ocean.
- Main question: Can we predict if the first stage of a Falcon 9 rocket will land successfully given certain features, such as payload mass, orbit type, launch site, etc.?

METHODOLOGY

Overall methodology includes:

1. Data collection, wrangling, and formatting, utilizing:
 1. SpaceX API
 2. Web scraping
2. Exploratory data analysis (EDA), utilizing:
 1. Pandas and NumPy
 2. SQL
3. Data visualization, utilizing:
 1. Matplotlib and Seaborn
 2. Folium
 3. Dash
4. Machine learning prediction, utilizing:
 1. Logistic regression
 2. Support vector machine (SVM)
 3. Decision tree
 4. K-nearest neighbors (KNN)

METHODOLOGY

① Data collection, wrangling, and formatting

SpaceX API:

- Utilized API: <https://api.spacexdata.com/v4/rockets/>
- API provides data on various types of SpaceX rocket launches; data filtered to include only Falcon 9 launches.
- Missing values in data replaced with column mean.
- Resulting data: 90 rows/instances and 17 columns/features.
- First few rows of data shown in the picture below.

	FlightNumber	Date	BoosterVersion	PayloadMass	Orbit	LaunchSite	Outcome	Flights	GridFins	Reused	Legs		LandingPad	Block	ReusedCount	Serial	Longitude	Latitude
4	1	2010-06-04	Falcon 9	NaN	LEO	CCSFS SLC 40	None None	1	False	False	False		None	1.0	0	B0003	-80.577366	28.561857
5	2	2012-05-22	Falcon 9	525.0	LEO	CCSFS SLC 40	None None	1	False	False	False		None	1.0	0	B0005	-80.577366	28.561857
6	3	2013-03-01	Falcon 9	677.0	ISS	CCSFS SLC 40	None None	1	False	False	False		None	1.0	0	B0007	-80.577366	28.561857
7	4	2013-09-29	Falcon 9	500.0	PO	VAFB SLC 4E	False Ocean	1	False	False	False		None	1.0	0	B1003	-120.610829	34.632093
8	5	2013-12-03	Falcon 9	3170.0	GTO	CCSFS SLC 40	None None	1	False	False	False		None	1.0	0	B1004	-80.577366	28.561857

METHODOLOGY

① Data collection, wrangling, and formatting

Web scraping:

- Data scraped from:

[https://en.wikipedia.org/w/index.php?title=List of Falcon 9 and Falcon Heavy launches&oldid=1027686922](https://en.wikipedia.org/w/index.php?title=List_of_Falcon_9_and_Falcon_Heavy_launches&oldid=1027686922)

- Website only contains Falcon 9 launch data.
- Resulting data: 121 rows/instances and 11 columns/features.
- First few rows of data shown in the picture below.

	Flight No.	Launch site	Payload	Payload mass	Orbit	Customer	Launch outcome	Version Booster	Booster landing	Date	Time
0	1	CCAFS	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success\n	F9 v1.0B0003.1	Failure	4 June 2010	18:45
1	2	CCAFS	Dragon	0	LEO	NASA	Success	F9 v1.0B0004.1	Failure	8 December 2010	15:43
2	3	CCAFS	Dragon	525 kg	LEO	NASA	Success	F9 v1.0B0005.1	No attempt\n	22 May 2012	07:44
3	4	CCAFS	SpaceX CRS-1	4,700 kg	LEO	NASA	Success\n	F9 v1.0B0006.1	No attempt	8 October 2012	00:35
4	5	CCAFS	SpaceX CRS-2	4,877 kg	LEO	NASA	Success\n	F9 v1.0B0007.1	No attempt\n	1 March 2013	15:10

METHODOLOGY

① Data collection, wrangling, and formatting

- The data is later processed so that there are no missing entries and categorical features are encoded using one-hot encoding.
- An extra column called 'Class' is also added to the data frame. The column 'Class' contains 0 if a given launch is failed and 1 if it is successful.
- In the end, we end up with 90 rows or instances and 83 columns or features.

METHODOLOGY

② Exploratory Data Analysis (EDA)



- Pandas and NumPy
 - Functions from the Pandas and NumPy libraries are used to derive basic information about the data collected, which includes:
 - The number of launches on each launch site
 - The number of occurrence of each orbit
 - The number and occurrence of each mission outcome
- SQL
 - The data is queried using SQL to answer several questions about the data such as:
 - The names of the unique launch sites in the space mission
 - The total payload mass carried by boosters launched by NASA (CRS)
 - The average payload mass carried by booster version F9 v1.1



METHODOLOGY

3 Data Visualization

matplotlib

seaborn

- Matplotlib and Seaborn

- Functions from the Matplotlib and Seaborn libraries are used to visualize the data through scatterplots, bar charts, and line charts.
- The plots and charts are used to understand more about the relationships between several features, such as:
 - The relationship between flight number and launch site
 - The relationship between payload mass and launch site
 - The relationship between success rate and orbit type

Folium

- Folium

- Functions from the Folium libraries are used to visualize the data through interactive maps.
- The Folium library is used to:
 - Mark all launch sites on a map
 - Mark the succeeded launches and failed launches for each site on the map
 - Mark the distances between a launch site to its proximities such as the nearest city, railway, or highway

METHODOLOGY

3 Data Visualization



- Dash
 - Functions from Dash are used to generate an interactive site where we can toggle the input using a dropdown menu and a range slider.
 - Using a pie chart and a scatterplot, the interactive site shows:
 - The total success launches from each launch site
 - The correlation between payload mass and mission outcome (success or failure) for each launch site

METHODOLOGY

④ Machine Learning Prediction

- Functions from the Scikit-learn library are used to create our machine learning models.
- The machine learning prediction phase include the following steps:
 - Standardizing the data
 - Splitting the data into training and test data
 - Creating machine learning models, which include:
 - Logistic regression
 - Support vector machine (SVM)
 - Decision tree
 - K nearest neighbors (KNN)
 - Fit the models on the training set
 - Find the best combination of hyperparameters for each model
 - Evaluate the models based on their accuracy scores and confusion matrix



RESULTS

- The results are split into 5 sections:
 - SQL (EDA with SQL)
 - Matplotlib and Seaborn (EDA with Visualization)
 - Folium
 - Dash
 - Predictive Analysis
- In all of the graphs that follow, class 0 represents a failed launch outcome while class 1 represents a successful launch outcome.

RESULTS

1 SQL (EDA with SQL)

- The names of the unique launch sites in the space mission

Launch_Sites

CCAFS LC-40

CCAFS SLC-40

KSC LC-39A

VAFB SLC-4E

- 5 records where launch sites 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 attempt
2012-10-08	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-03-01	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

RESULTS

① SQL (EDA with SQL)

- The total payload mass carried by boosters launched by NASA (CRS)

Total payload mass by NASA (CRS)

45596

- The average payload mass carried by booster version F9 v1.1

Average payload mass by Booster Version F9 v1.1

2928

- The date when the first successful landing outcome in ground pad was achieved

Date of first successful landing outcome in ground pad

2015-12-22

RESULTS

1 SQL (EDA with SQL)

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

booster_version

F9 FT B1022

F9 FT B1026

F9 FT B1021.2

F9 FT B1031.2

- The total number of successful and failure mission outcomes

number_of_success_outcomes number_of_failure_outcomes

100

1

RESULTS

1 SQL (EDA with SQL)

- The names of the booster versions which have carried the maximum payload mass

booster_version

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

RESULTS

① SQL (EDA with SQL)

- The failed landing outcomes in drone ship, their booster versions, and launch site names for in year 2015

DATE	booster_version	launch_site
2015-01-10	F9 v1.1 B1012	CCAFS LC-40
2015-04-14	F9 v1.1 B1015	CCAFS LC-40

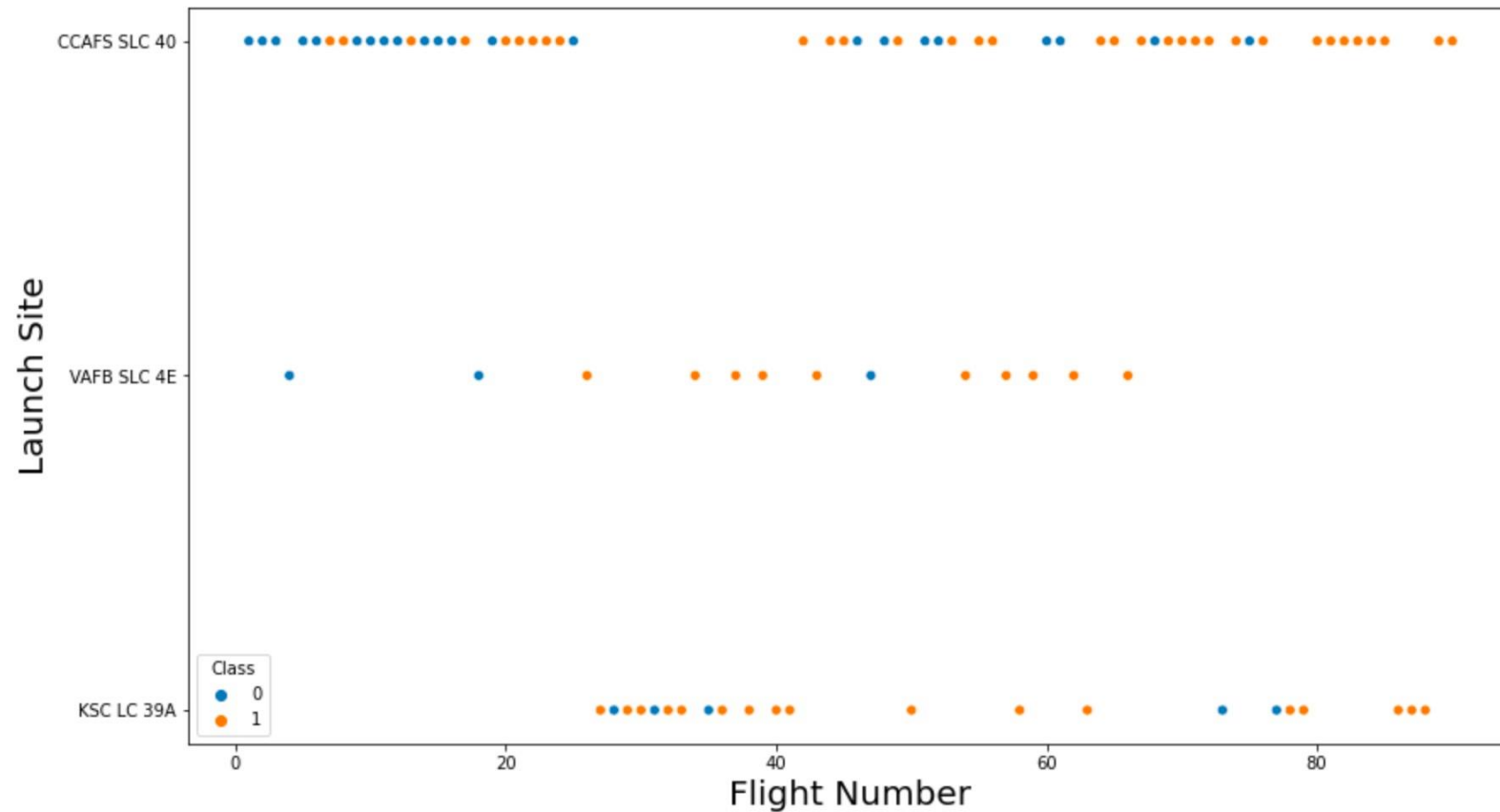
- The count of landing outcomes between the date 2010-06-04 and 2017-03-20, in descending order

landing__outcome	landing_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
Precluded (drone ship)	1

RESULTS

2 Matplotlib and Seaborn (EDA with Visualization)

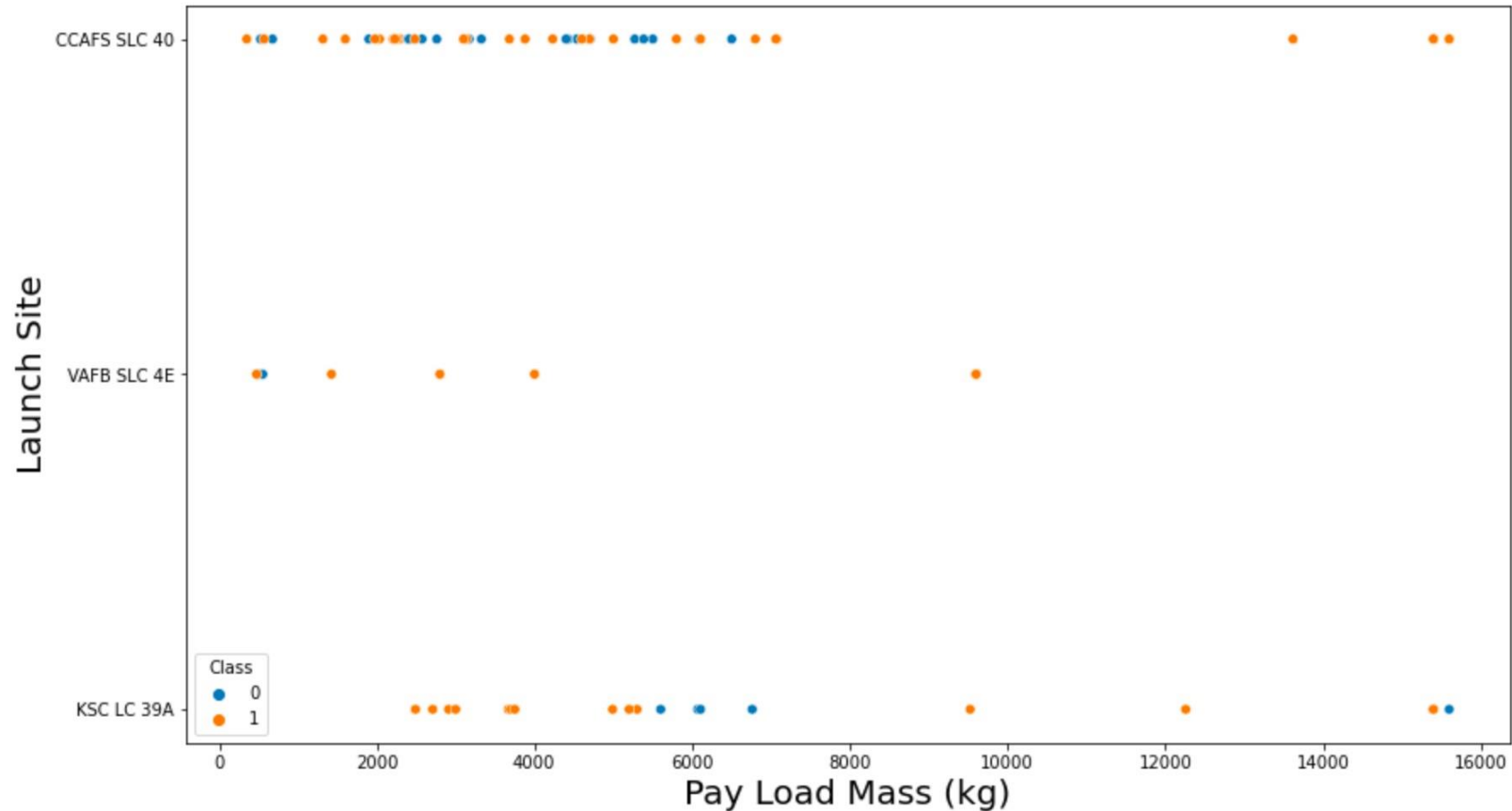
- The relationship between flight number and launch site



RESULTS

2 Matplotlib and Seaborn (EDA with Visualization)

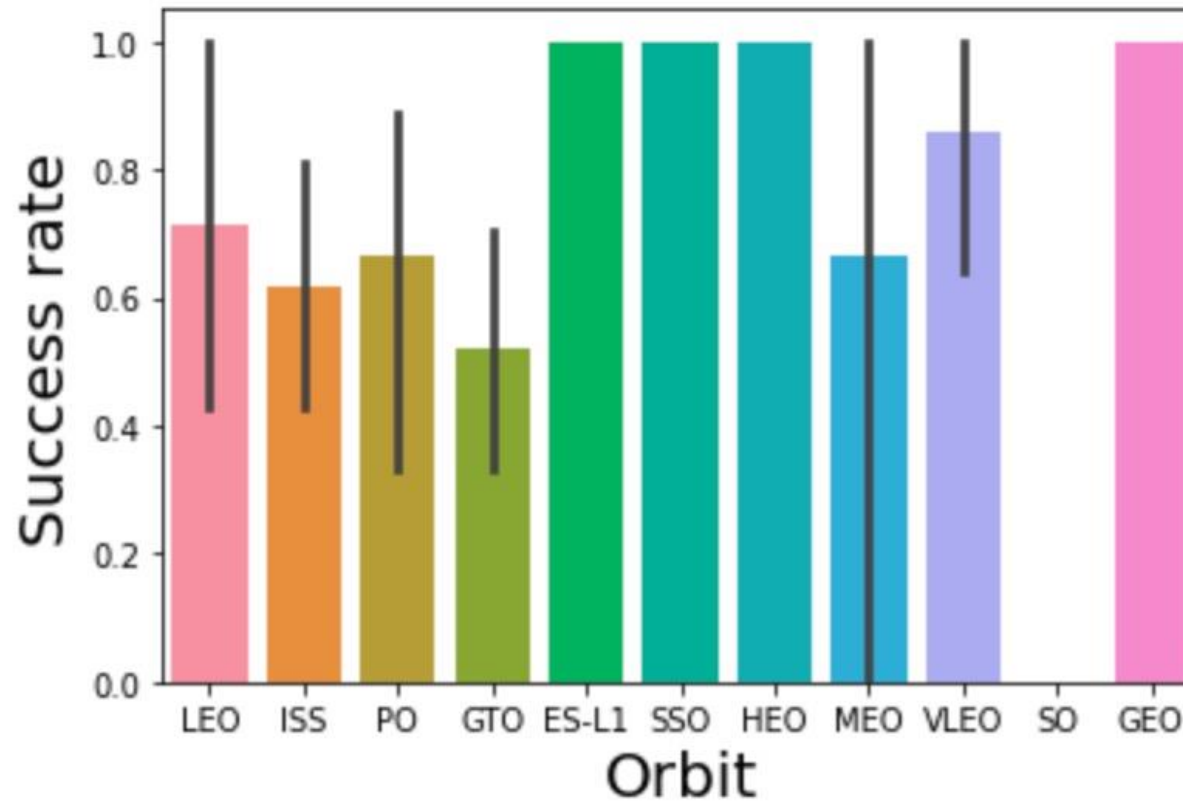
- The relationship between payload mass and launch site



RESULTS

② Matplotlib and Seaborn (EDA with Visualization)

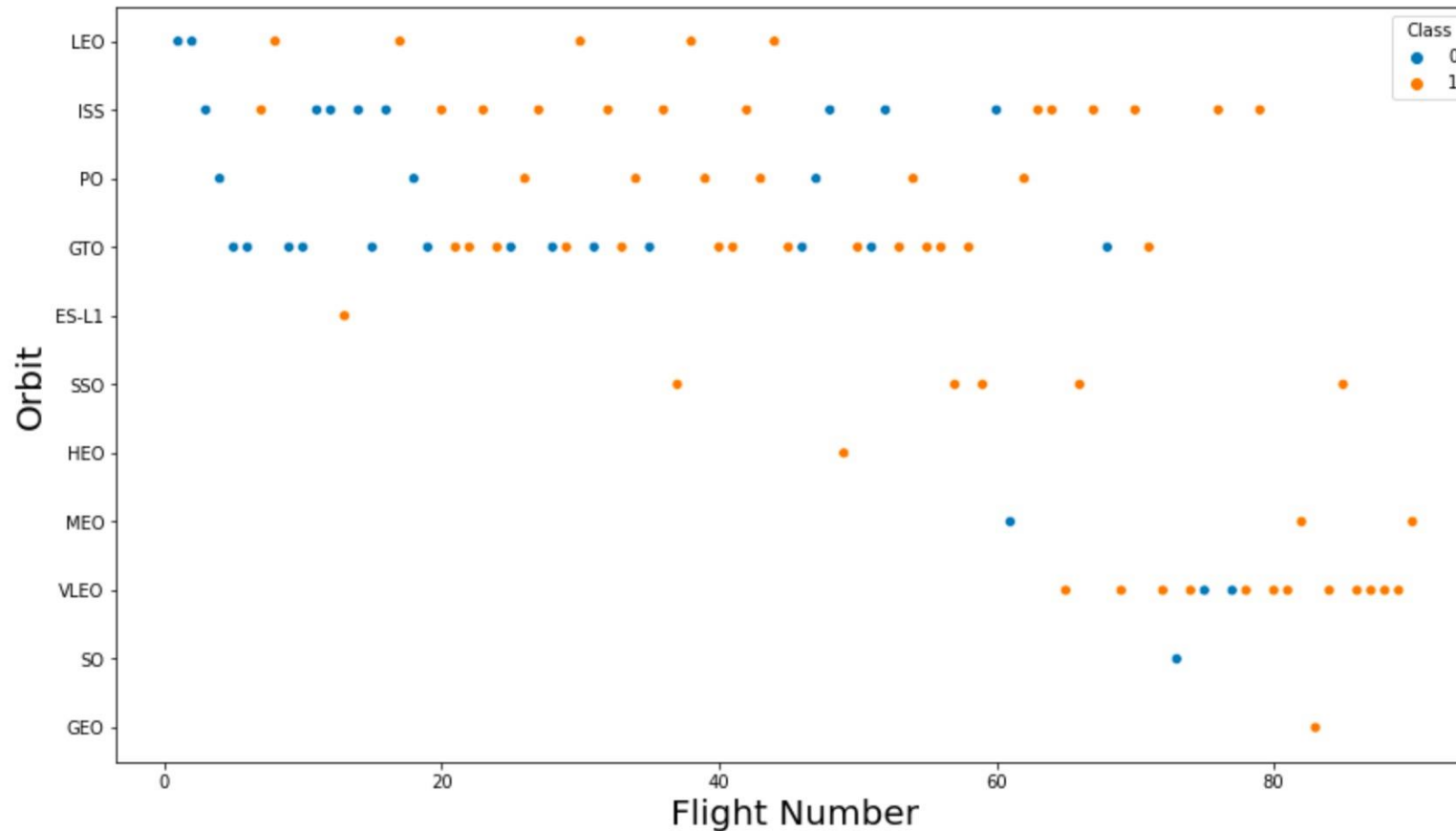
- The relationship between success rate and orbit type



RESULTS

2 Matplotlib and Seaborn (EDA with Visualization)

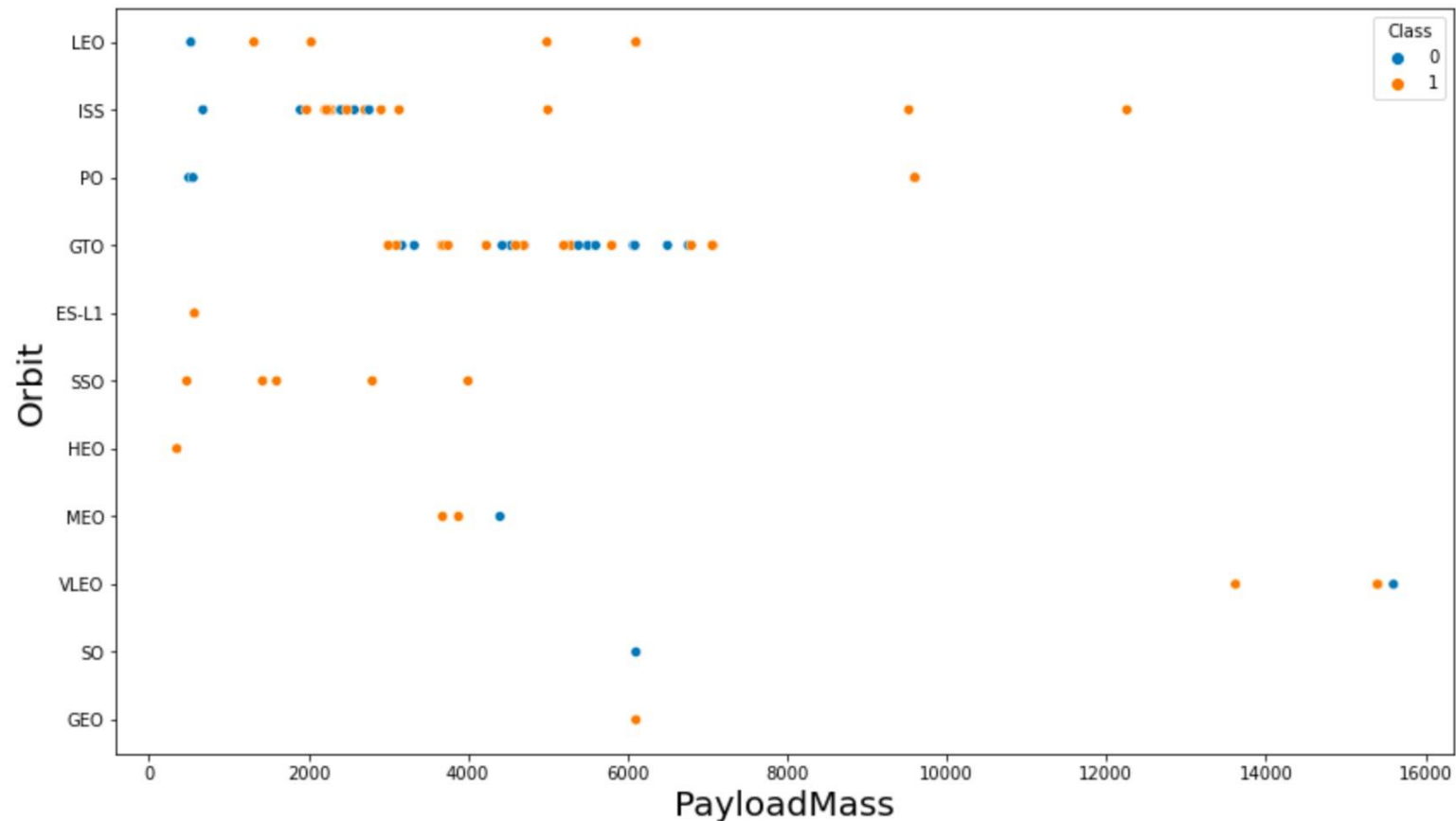
- The relationship between flight number and orbit type



RESULTS

2 Matplotlib and Seaborn (EDA with Visualization)

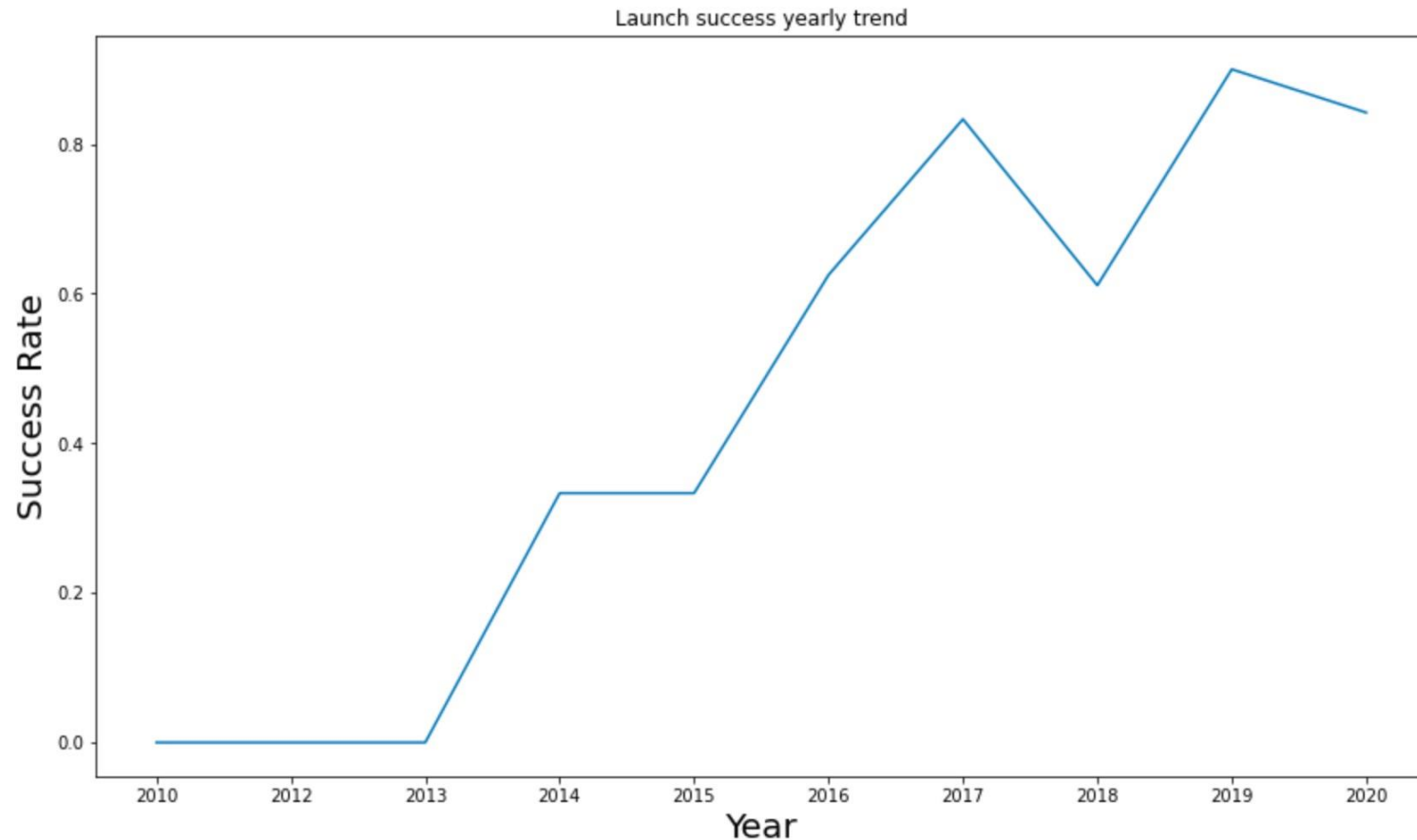
- The relationship between payload mass and orbit type



RESULTS

2 Matplotlib and Seaborn (EDA with Visualization)

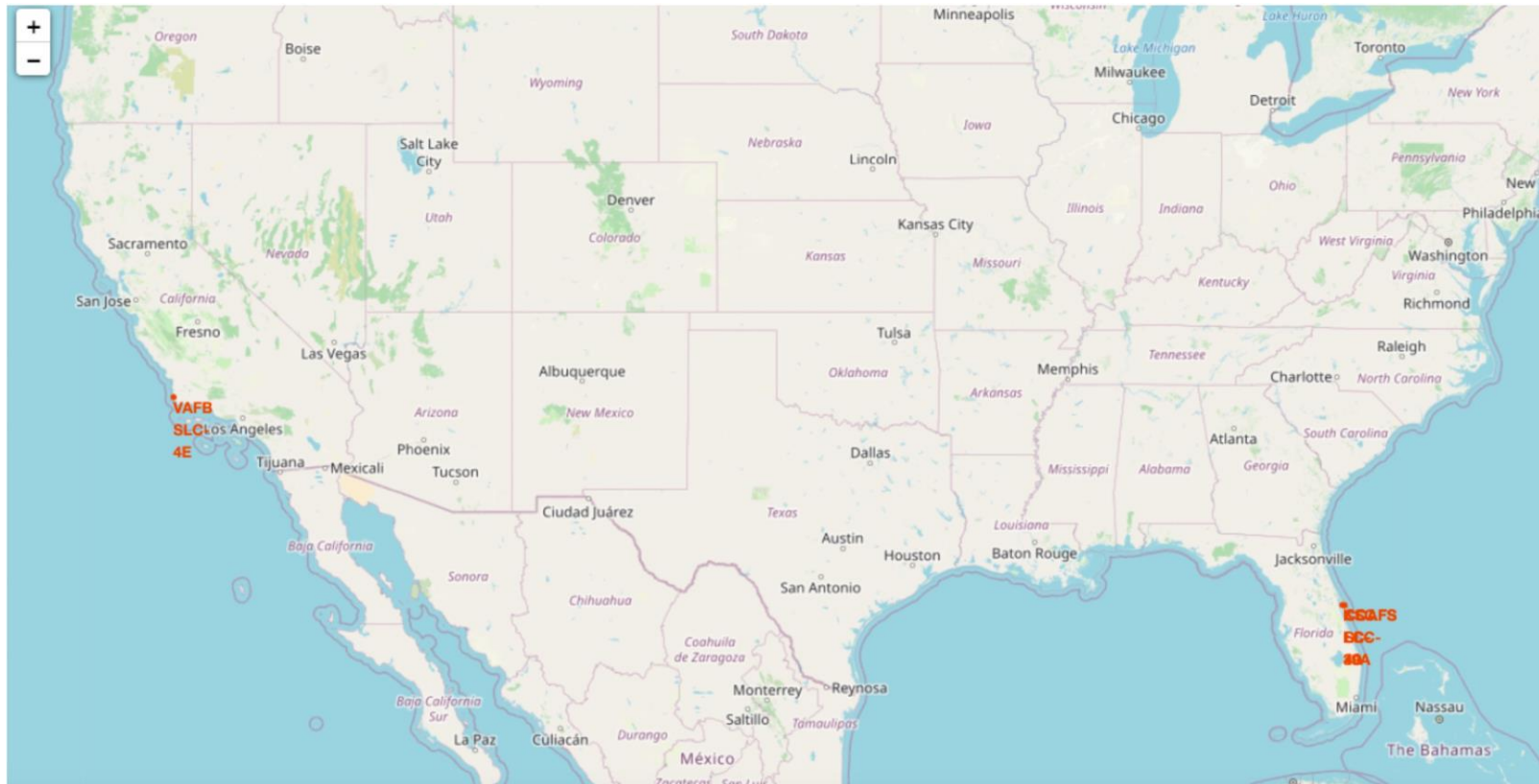
- The launch success yearly trend



RESULTS

3 Folium

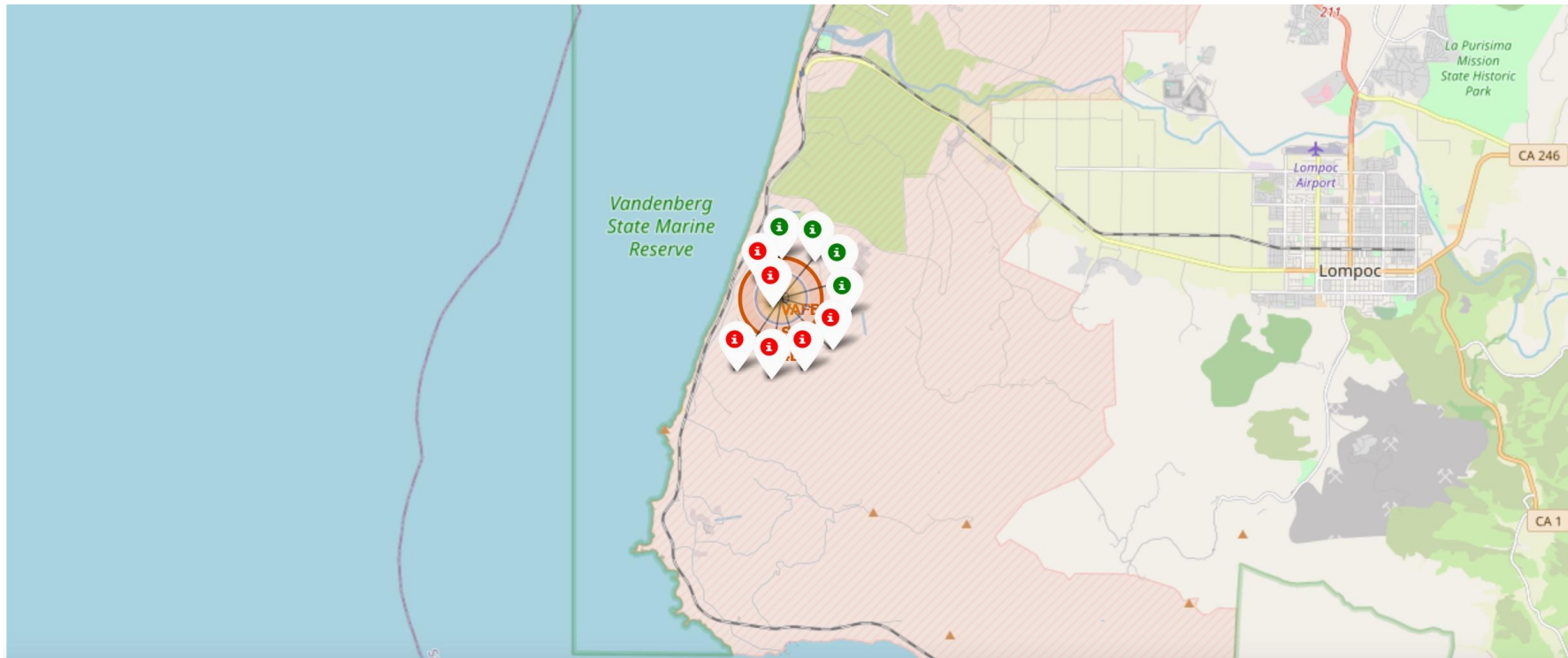
- All launch sites on map



RESULTS

3 Folium

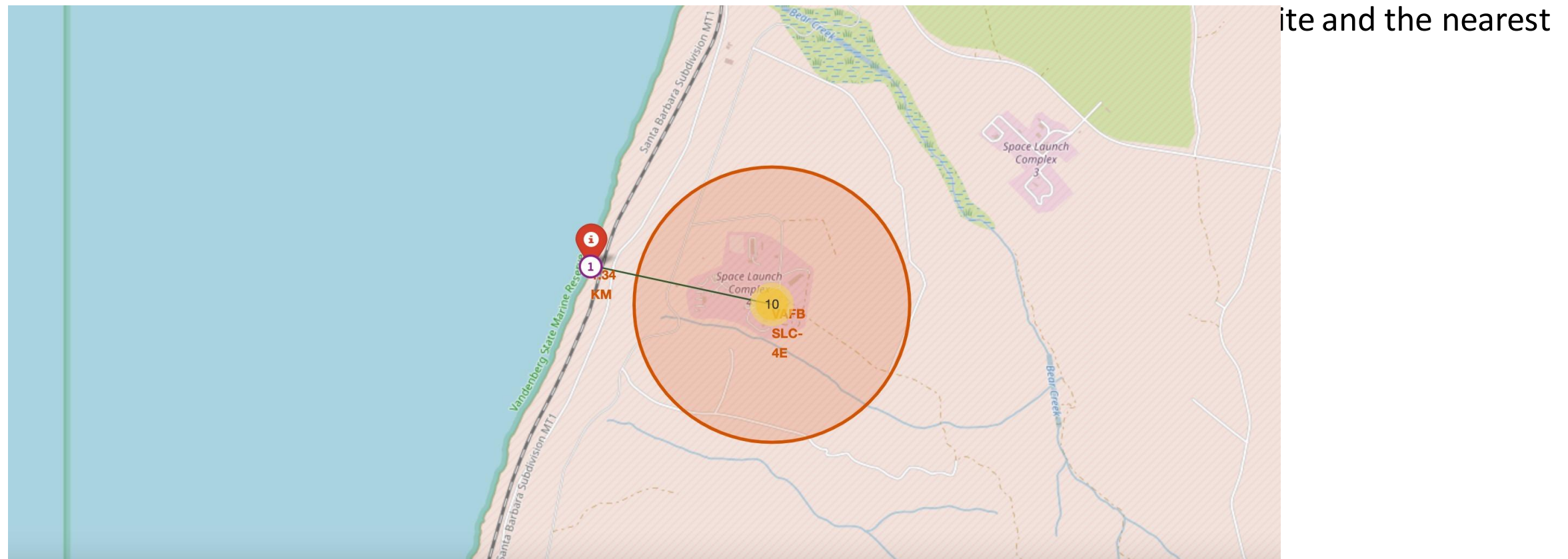
- The succeeded launches and failed launches for each site on map
 - If we zoom in on one of the launch site, we can see green and red tags. Each green tag represents a successful launch while each red tag represents a failed launch



RESULTS

3 Folium

- The distances between a launch site to its proximities such as the nearest city, railway, or highway



RESULTS

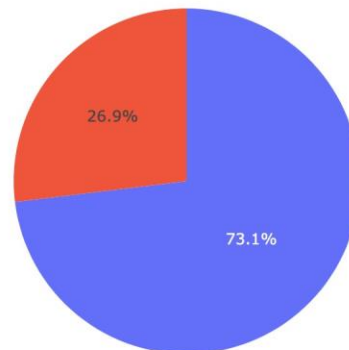
4 Dash

- The picture below shows a pie chart when launch site CCAFS LC-40 is chosen.
- 0 represents failed launches while 1 represents successful launches. We can see that 73.1% of launches done at CCAFS LC-40 are failed launches.

SpaceX Launch Records Dashboard

CCAFS LC-40

Total Success Launches for Site → CCAFS LC-40



0
1

RESULTS

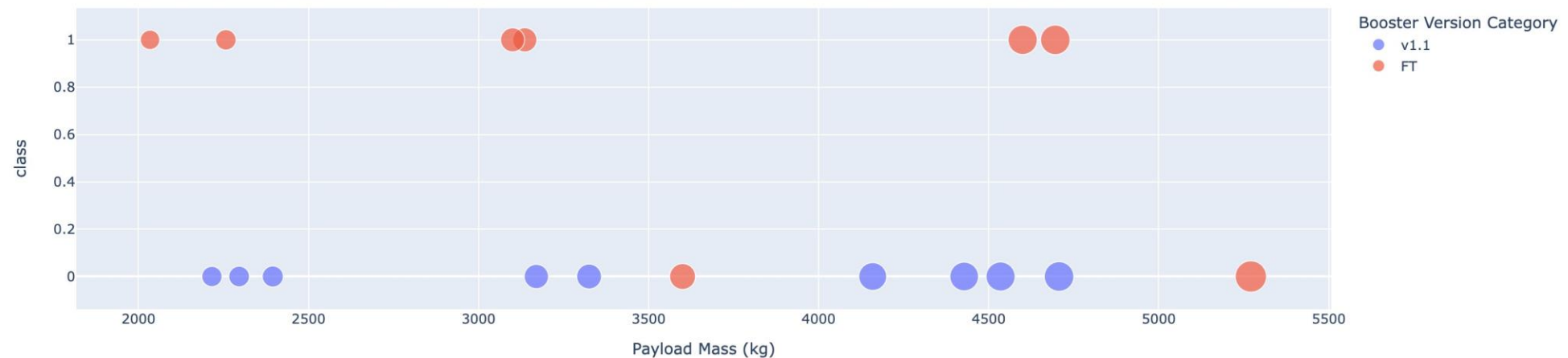
4 Dash

- The picture below shows a scatterplot when the payload mass range is set to be from 2000kg to 8000kg.
- Class 0 represents failed launches while class 1 represents successful launches.

Payload range (Kg):



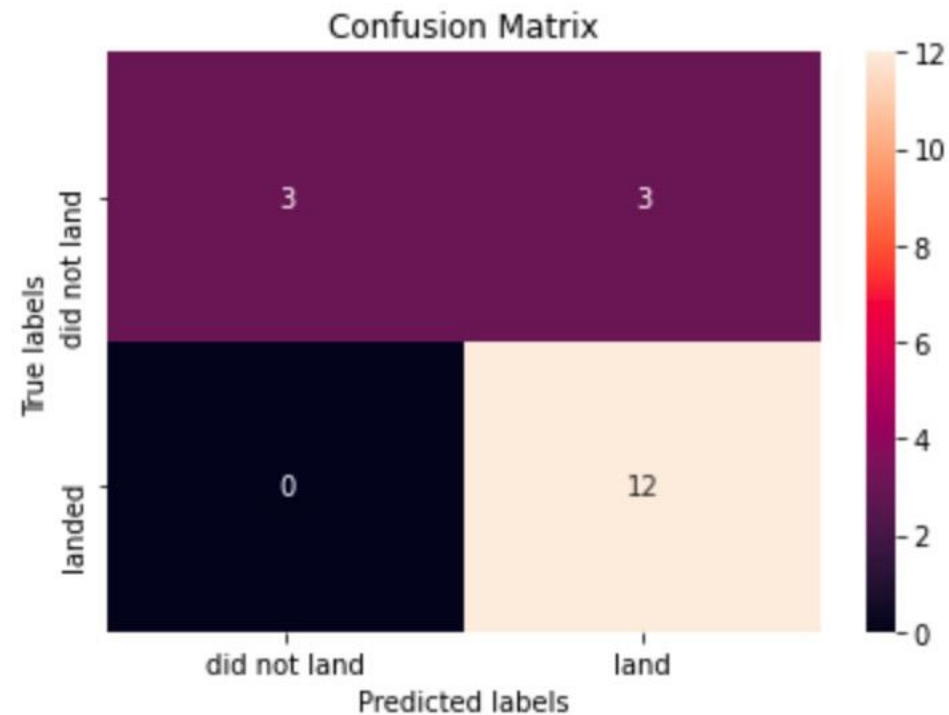
Correlation Between Payload and Success for Site → CCAFS LC-40



RESULTS

5 Predictive Analysis

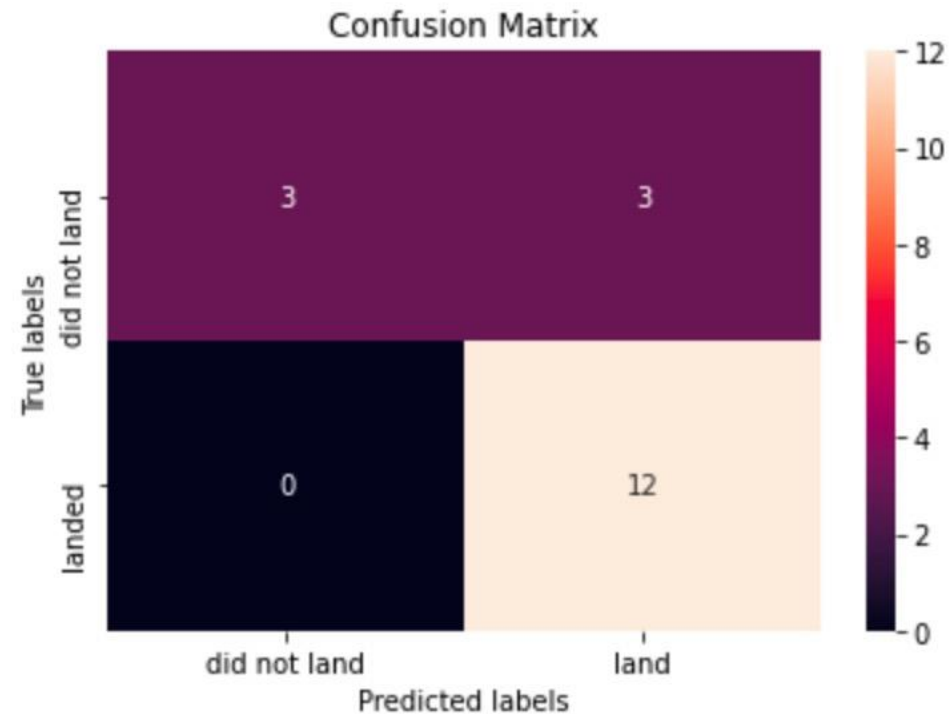
- Logistic regression
 - GridSearchCV best score: 0.8464285714285713
 - Accuracy score on test set: 0.8333333333333334
 - Confusion matrix:



RESULTS

5 Predictive Analysis

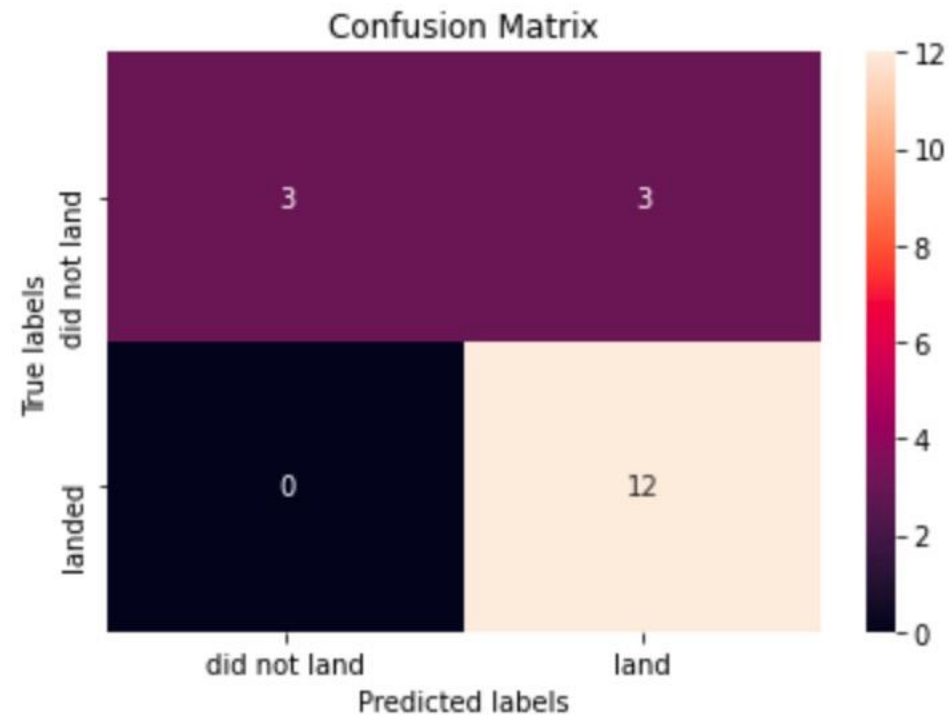
- Support vector machine (SVM)
 - GridSearchCV best score: 0.8482142857142856
 - Accuracy score on test set: 0.8333333333333334
 - Confusion matrix:



RESULTS

5 Predictive Analysis

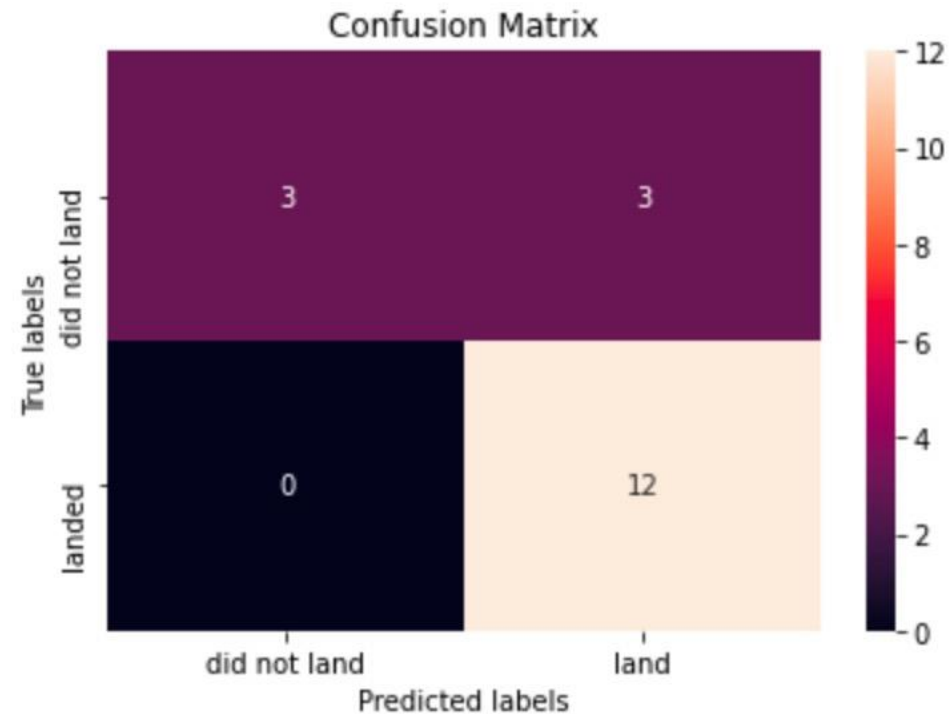
- Decision tree
 - GridSearchCV best score: 0.8892857142857142
 - Accuracy score on test set: 0.8333333333333334
 - Confusion matrix:



RESULTS

5 Predictive Analysis

- K nearest neighbors (KNN)
 - GridSearchCV best score: 0.8482142857142858
 - Accuracy score on test set: 0.8333333333333334
 - Confusion matrix:



RESULTS

5 Predictive Analysis

- Putting the results of all 4 models side by side, we can see that they all share the same accuracy score and confusion matrix when tested on the test set.
- Therefore, their GridSearchCV best scores are used to rank them instead. Based on the GridSearchCV best scores, the models are ranked in the following order with the first being the best and the last one being the worst:
 1. Decision tree (GridSearchCV best score: 0.8892857142857142)
 2. K nearest neighbors, KNN (GridSearchCV best score: 0.8482142857142858)
 3. Support vector machine, SVM (GridSearchCV best score: 0.8482142857142856)
 4. Logistic regression (GridSearchCV best score: 0.8464285714285713)

DISCUSSION

- From the data visualization section, we can see that some features may have correlation with the mission outcome in several ways. For example, with heavy payloads the successful landing or positive landing rate are more for orbit types Polar, LEO and ISS. However, for GTO, we cannot distinguish this well as both positive landing rate and negative landing(unsuccesful mission) are both there here.
- Therefore, each feature may have a certain impact on the final mission outcome. The exact ways of how each of these features impact the mission outcome are difficult to decipher. However, we can use some machine learning algorithms to learn the pattern of the past data and predict whether a mission will be successful or not based on the given features.

CONCLUSION

- In this project, we try to predict if the first stage of a given Falcon 9 launch will land in order to determine the cost of a launch.
- Each feature of a Falcon 9 launch, such as its payload mass or orbit type, may affect the mission outcome in a certain way.
- Several machine learning algorithms are employed to learn the patterns of past Falcon 9 launch data to produce predictive models that can be used to predict the outcome of a Falcon 9 launch.
- The predictive model produced by decision tree algorithm performed the best among the 4 machine learning algorithms employed.

THANK YOU