IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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06JAN23

Outline

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

Executive Summary

- For the current report the following methodologies has been employed
  - Data Collection and Data Wrangling
  - Exploratory Data Analysis via SQL and Interactive Visual Analytics
  - Interactive Graphs and Map Generation via Dash and Folium
  - Predictive Analysis via Different Models Evaluation and Optimization
- Results Summary
  - Falcon 9 rocket first stage reusability reduces launch costs
  - Recovery probability can be predicted via Data Science with available data
  - Using API and Web data, prediction accuracy score is 83.33%

Introduction

- Project background and context
  - SpaceX has gained worldwide attention for a series of historic milestones.
  - It is the only private company ever to return a spacecraft from low-earth orbit, which it first accomplished in December 2010.
  - SpaceX advertises Falcon 9 rocket launches on its website with a cost of 62 million dollars whereas 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.
- Problems you want to find answers
  - Determining the likelihood of Falcon 9's first stage recovery from previous attempts

Section 1

Methodology

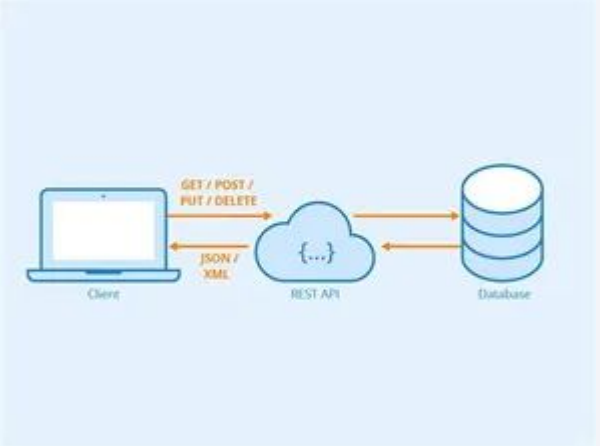
Methodology

Executive Summary

- Data collection methodology:
  - SpaceX REST API
  - Wiki Article Web Scrapping
- Perform data wrangling
  - Ensure data types are appropriate to deal with them
  - NaN values identified.
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - 4 models have been built and configuration parameters calculated for optimal accuracy

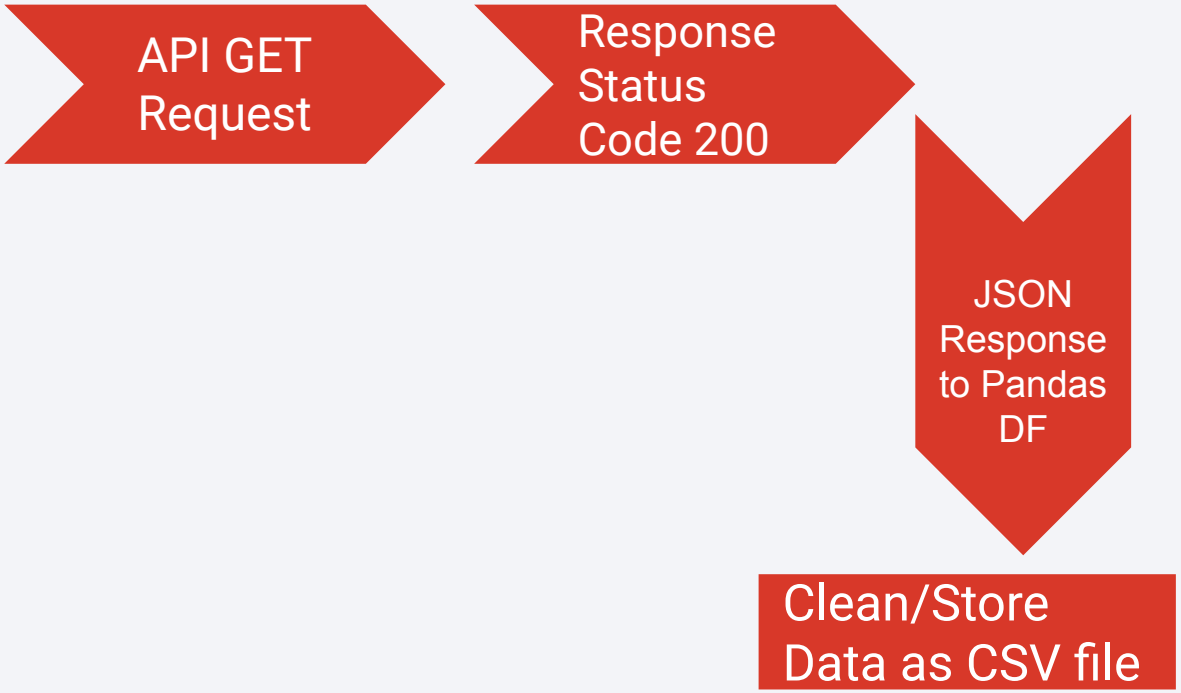
Data Collection

- Data sets were collected via:
  - REST API
  - Web Scrapping



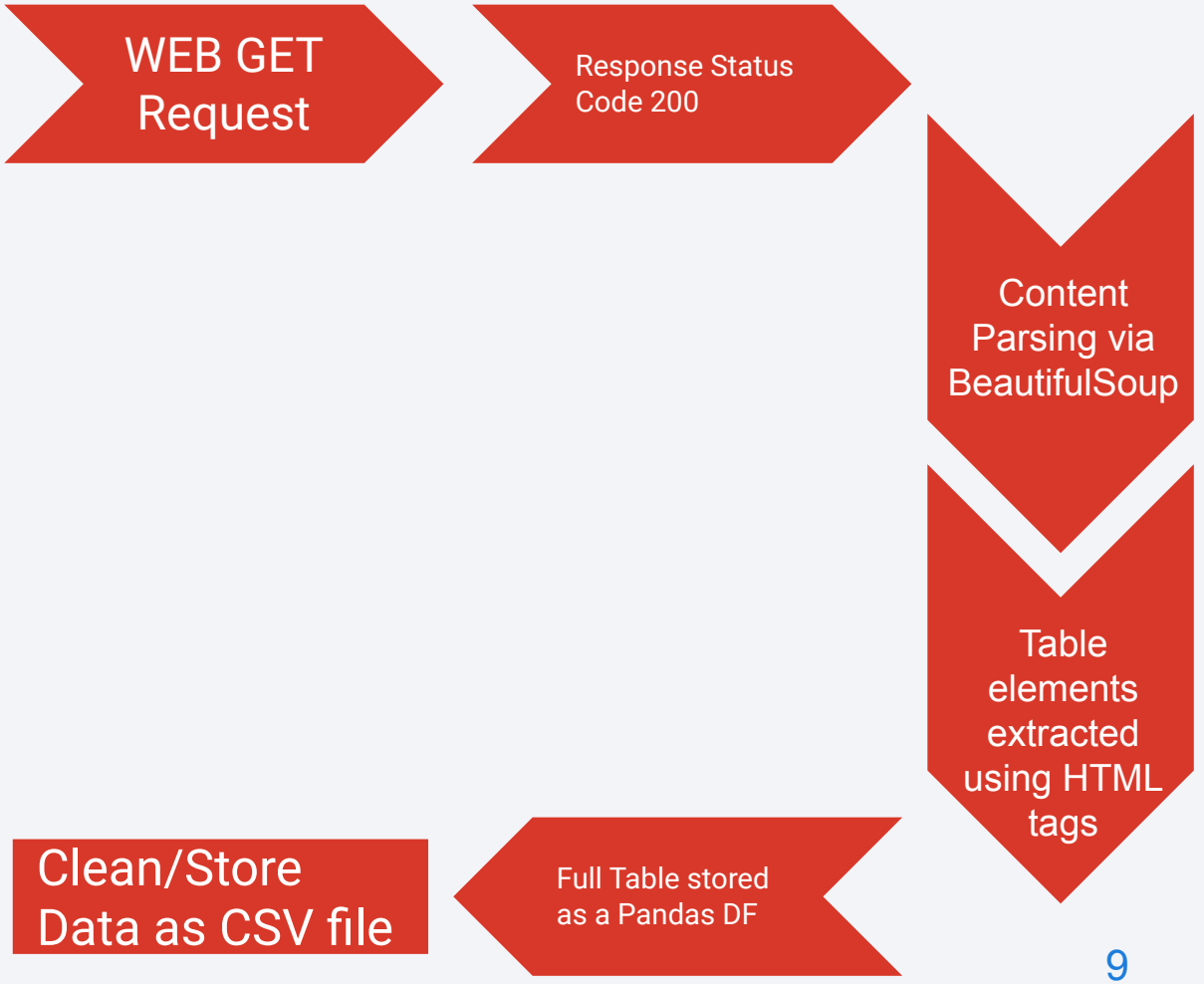
Data Collection – SpaceX API

- [GitHub URL of the completed SpaceX API calls notebook]



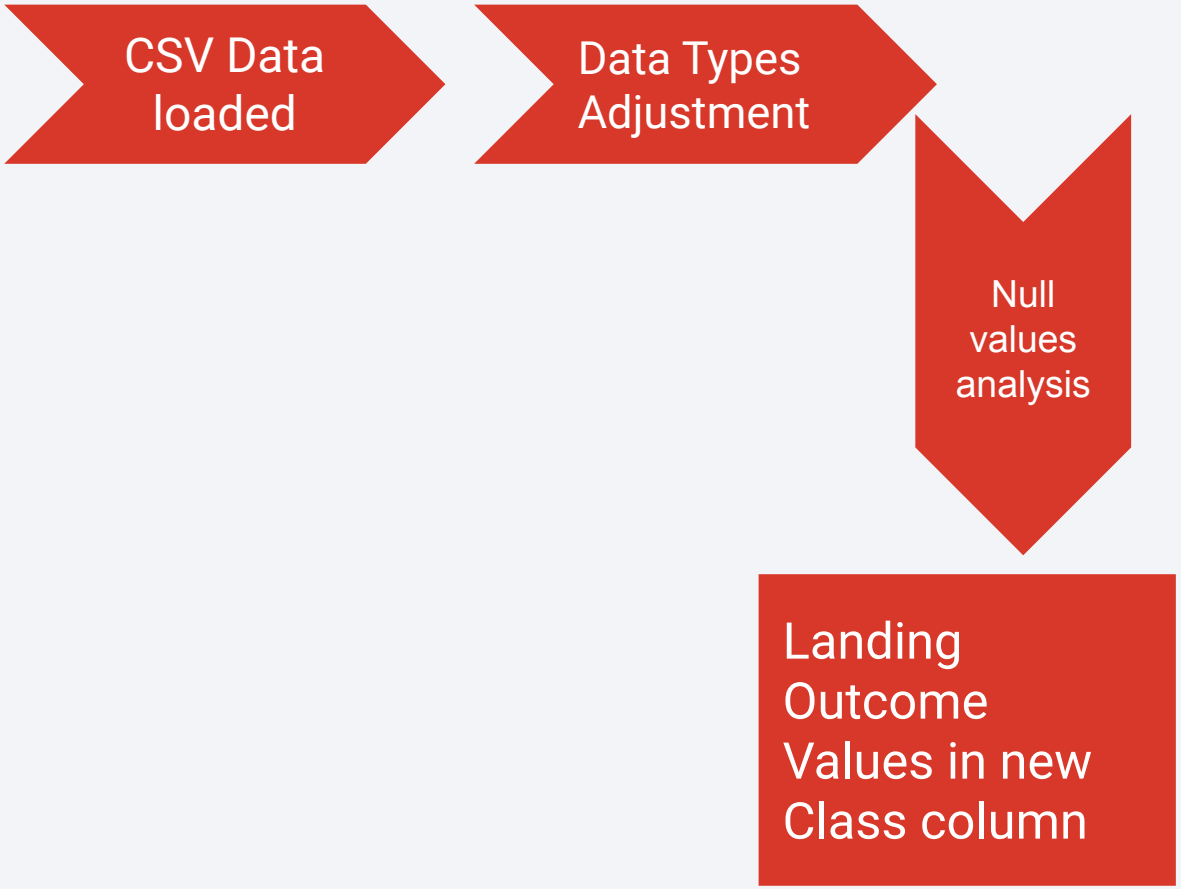
Data Collection - Scraping

- GitHub URL of the completed web scraping notebook



Data Wrangling

- Data has been processed as follows
  - Identify data types and its conversion.
  - Calculate the percentage of the missing values in each attribute.
  - Determine the number of launches on each site.
  - Determine the number and occurrence of each orbit.
  - Determine the number of landing outcomes.
  - Create a set of outcomes where the second stage did not land successfully.
  - Creation of a classification variable that represents the outcome of each launch (1:Success, 0:Failed).



- GitHub URL of your completed data wrangling related notebooks

EDA with Data Visualization

- Summary of plotted charts
  - Relationship between Flight Number and Launch Site
  - Relationship between Payload and Launch Site
  - Relationship between success rate of each orbit type
  - Relationship between FlightNumber and Orbit type
  - Relationship between Payload and Orbit type
  - Launch success yearly trend
- GitHub URL of your completed EDA with data visualization notebook

EDA with SQL

- Display the names of the unique launch sites in the space mission
  - SELECT DISTINCT(LAUNCH_SITE) FROM SPACEXTBL
- Display 5 records where launch sites begin with the string 'CCA'
  - SELECT * FROM SPACEXTBL WHERE LAUNCH_SITE LIKE 'CCA%' LIMIT 5
- Display the total payload mass carried by boosters launched by NASA (CRS)
  - SELECT SUM(PAYLOAD_MASS__KG_) AS "Total Payload Mass by NASA (CRS)" FROM SPACEXTBL WHERE CUSTOMER == 'NASA (CRS)'
- Display average payload mass carried by booster version F9 v1.1
  - SELECT AVG(PAYLOAD_MASS__KG_) AS "Average Payload Mass" FROM SPACEXTBL WHERE Booster_Version LIKE 'F9 v1.1%'
- List the date when the first succesful landing outcome in ground pad was acheived.
  - SELECT substr(MIN(Timestamp), 1, 10) AS Date FROM SPACEXTBL WHERE "Landing _Outcome" == 'Success (ground pad)'
- List the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000
  - SELECT Booster_Version FROM SPACEXTBL WHERE "Landing _Outcome" == 'Success (drone ship)' AND PAYLOAD_MASS__KG_ BETWEEN 4000 AND 6000
- List the total number of successful and failure mission outcomes
- SELECT (SELECT COUNT(Mission_Outcome) FROM SPACEXTBL WHERE Mission_Outcome LIKE '%Success%') AS SUCCESS, (SELECT COUNT(Mission_Outcome) FROM SPACEXTBL WHERE Mission_Outcome LIKE '%Failure%') AS FAILURE
- List the names of the booster_versions which have carried the maximum payload mass. Use a subquery
  - SELECT DISTINCT(Booster_Version) FROM SPACEXTBL WHERE PAYLOAD_MASS__KG_ == (SELECT MAX(PAYLOAD_MASS__KG_) FROM SPACEXTBL)
- 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.
  - SELECT SUBSTR(Date, 6, 2) AS Month, "Landing _Outcome", Booster_version, launch_site FROM SPACEXTBL WHERE SUBSTR(Date, 3, 2) == '15'
- Rank the count of successful landing_outcomes between the date 04-06-2010 and 20-03-2017 in descending order.
  - SELECT DISTINCT("Landing _Outcome"), COUNT(*) as "Count" FROM SPACEXTBL WHERE Date BETWEEN '2010-06-04' AND '2017-03-20' AND "Landing _Outcome" LIKE '%Success%' GROUP BY "Landing _Outcome" ORDER BY "Count" DESC

- GitHub URL of your completed EDA with SQL notebook

Build an Interactive Map with Folium

- Different markers and circles added to highlight NASA location, launch locations. Lines have also been added to indicate distances to different relevant entities like railways, highways, cities, coastline.
- All those indicators help to visually identify our location of interest and some associated metrics like distance or success/fail launch.
- GitHub URL of your completed interactive map with Folium map
    - Dear Peer Reviewer, please notice that GitHub does not show the maps. You will need to download and execute the Notebook locally, installing and troubleshooting any python library requirement if you want to check all generated maps.

Build a Dashboard with Plotly Dash

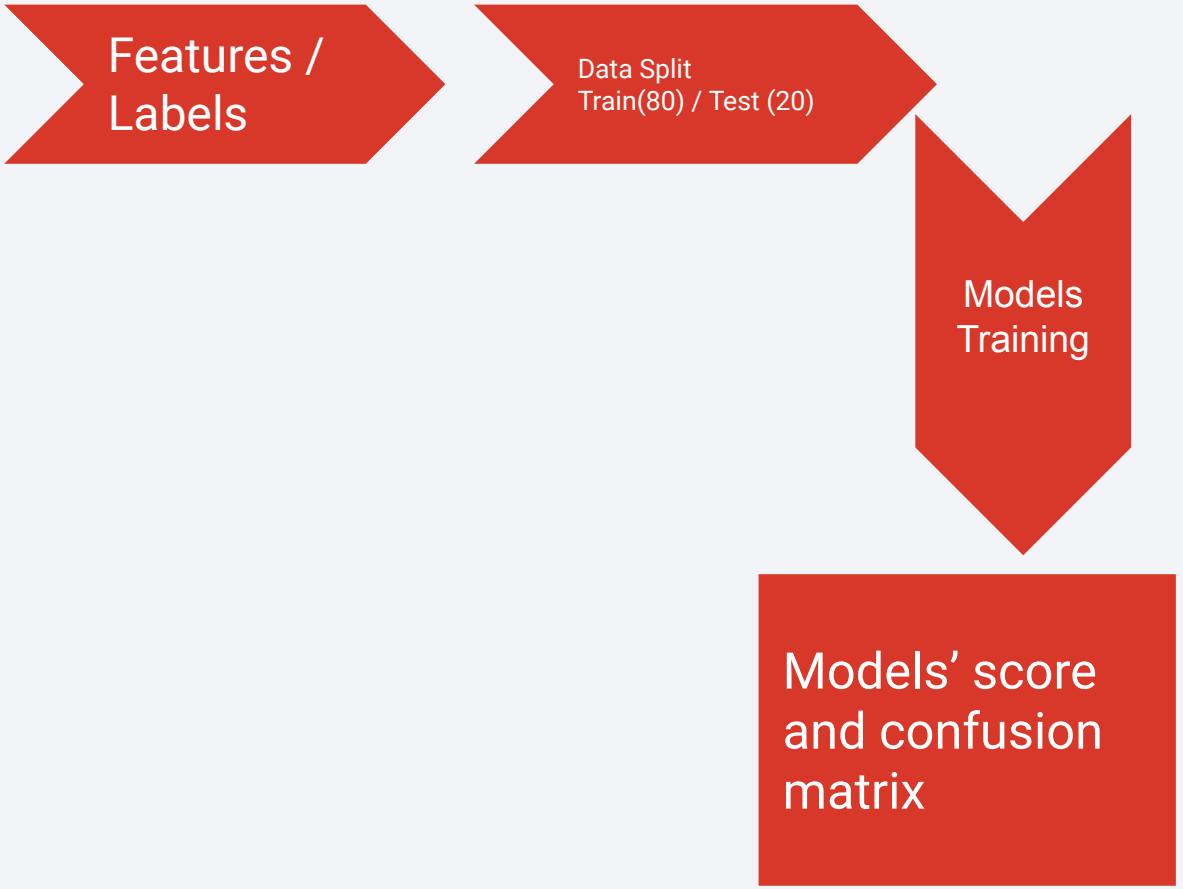
- User input dropdown menu for launch site
  - It allows to easily select the launch site and see the data
- Pie chart showing success rate at the user chosen site
  - It allows to visualize success rate very rapidly
- User input payload mass range slider
  - It allows to play with a payload mass range to see results per location
- GitHub URL of your completed Plotly Dash lab

Predictive Analysis (Classification)

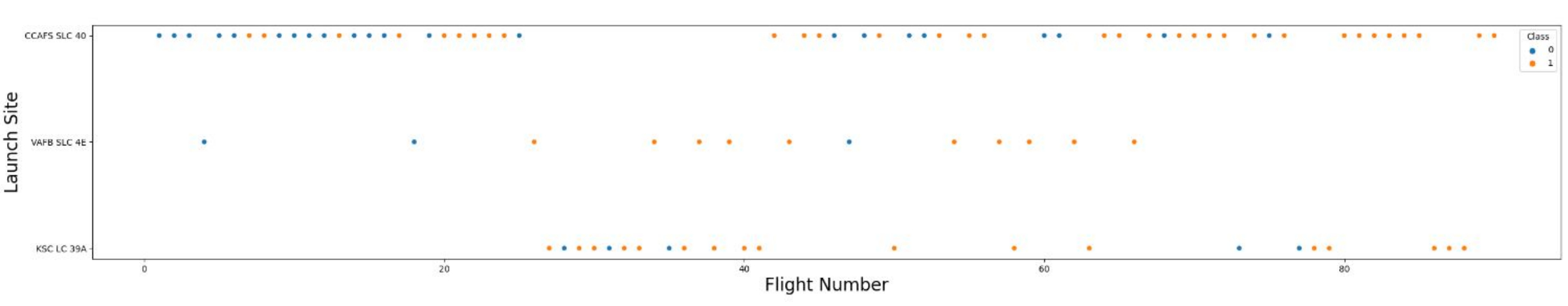
- Data separated into features and labels, setting the test sample to 20%
- Following scikit-learn models have been instantiated and trained
  - Logistic Regression
  - Support Vector Machines
  - Decision Tree
  - KNN
- GridSearchCV has been used to perform an exhaustive search over specified parameters, in order to find out the best configuration (higher accuracy score)
- Score calculation

- Dear Peer Reviewer, please notice that the parameter random_state=0 has been set to avoid variations in results after repeated tests. That makes all the models to have the same score. Without it, the Tree model would have an inferior score, most of the tested times.

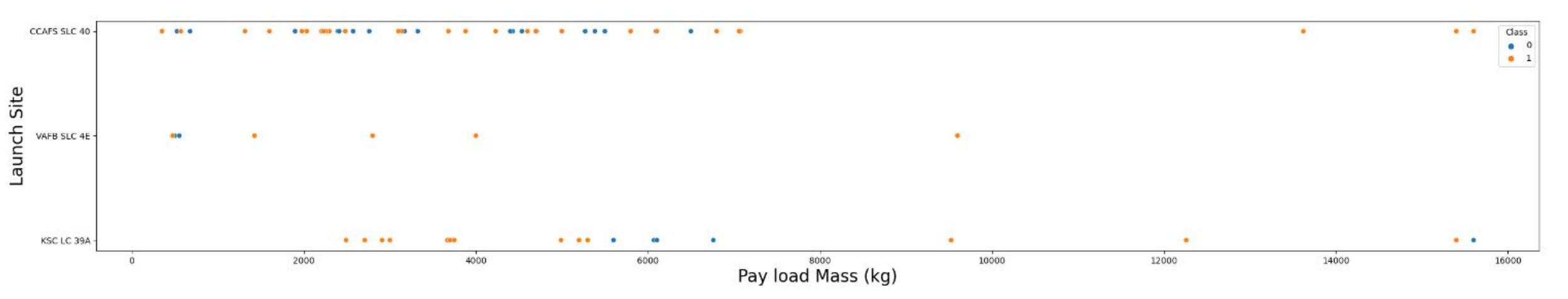
- GitHub URL of your completed predictive analysis lab



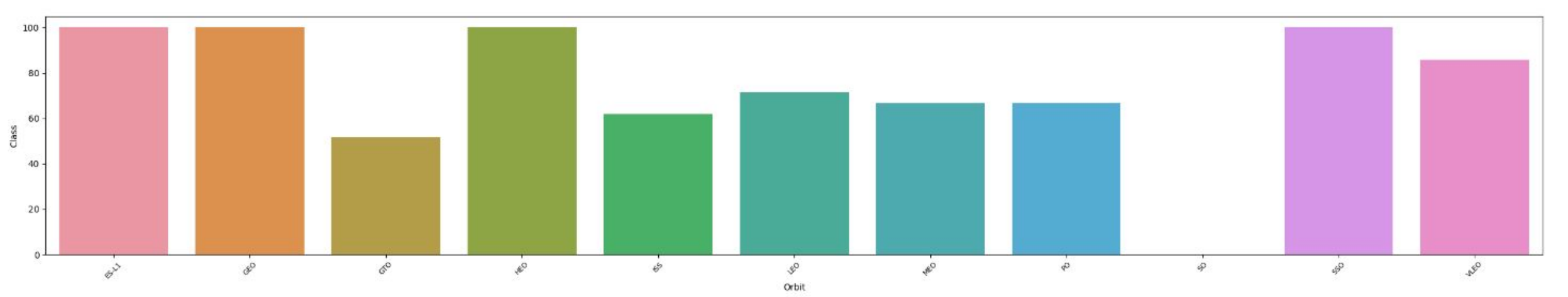
Results - EDA


CCAFS SLC 40
VAFB SLC 4E
KSC LC 39A
Launch Site
0
20
40
60
80
Flight Number
Class
0
1

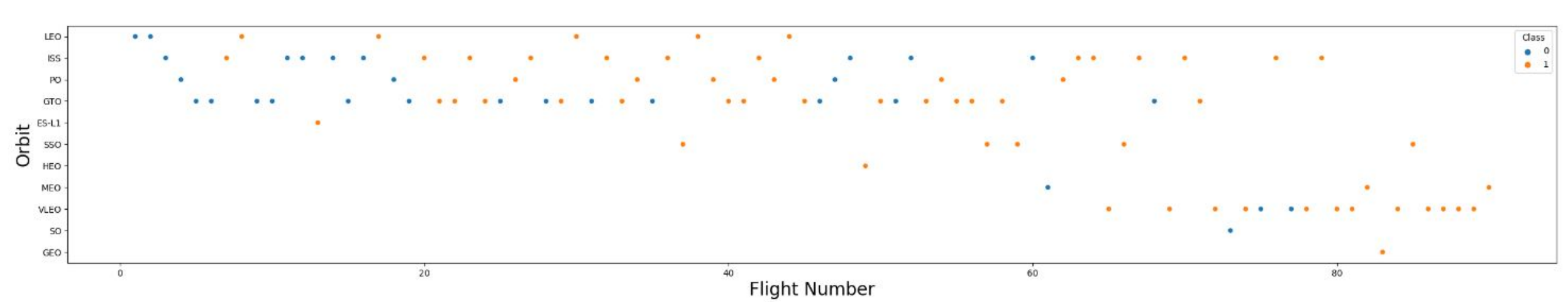
Results - EDA


CCAFS SLC 40
VAFB SLC 4E
KSC LC 39A
Launch Site
0
2000
4000
6000
8000
10000
12000
14000
16000
Pay load Mass (kg)
Class
0
1

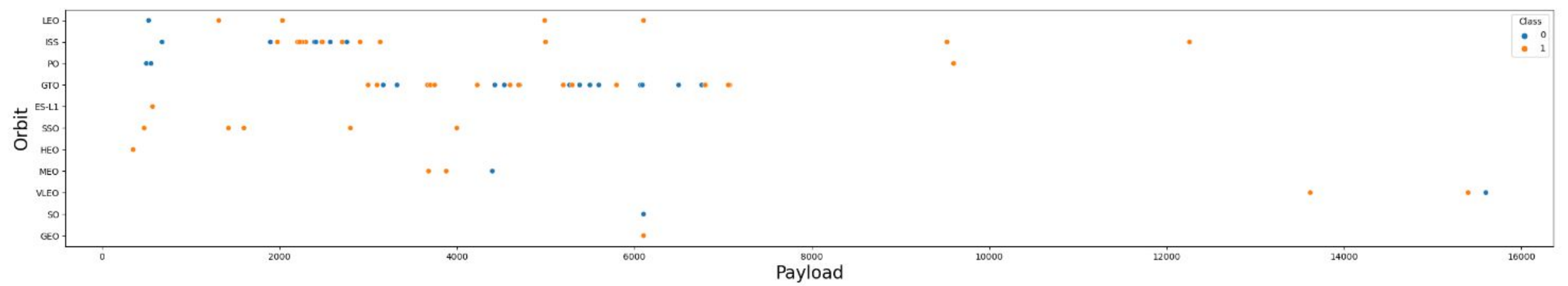
Results - EDA


Class
100
80
60
40
20
0
ES-L1
GEO
GTO
HEO
ISS
LEO
MEO
PO
SO
SSO
VLEO
Orbit

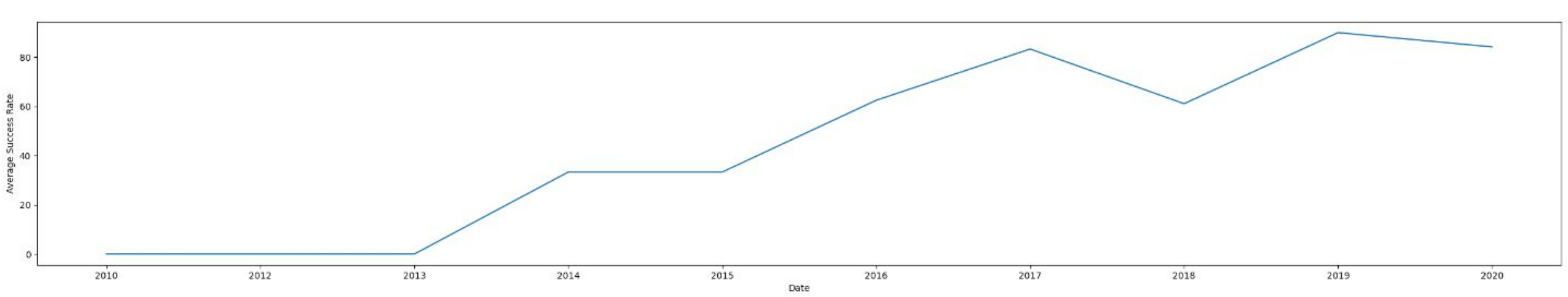
Results - EDA


LEO
ISS
PO
GTO
ES-L1
SSO
HEO
MEO
VLEO
SO
GEO
Orbit
0
20
40
60
80
Flight Number
Class
0
1

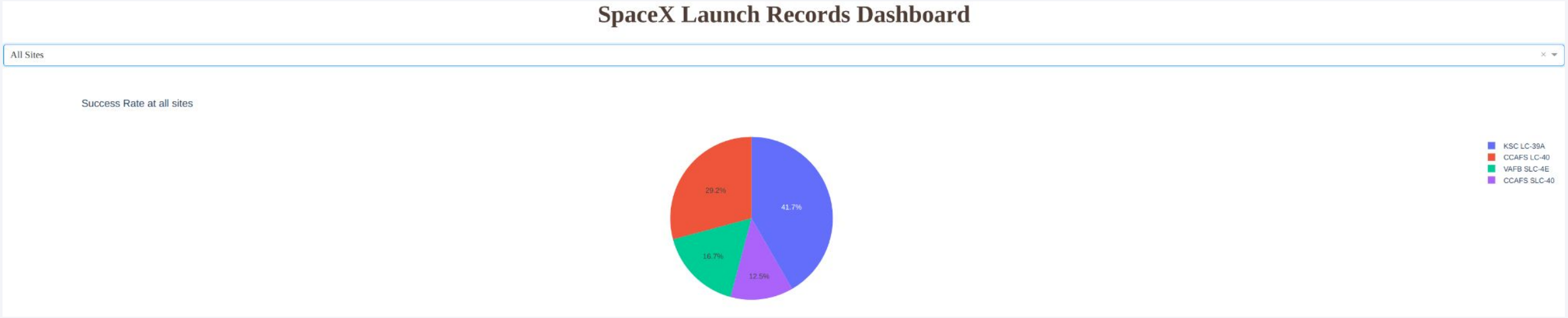
Results - EDA


LEO
ISS
PO
GTO
ES-L1
SSO
HEO
MEO
VLEO
SO
GEO
Orbit
0
2000
4000
6000
8000
10000
12000
14000
16000
Payload
Class
0
1

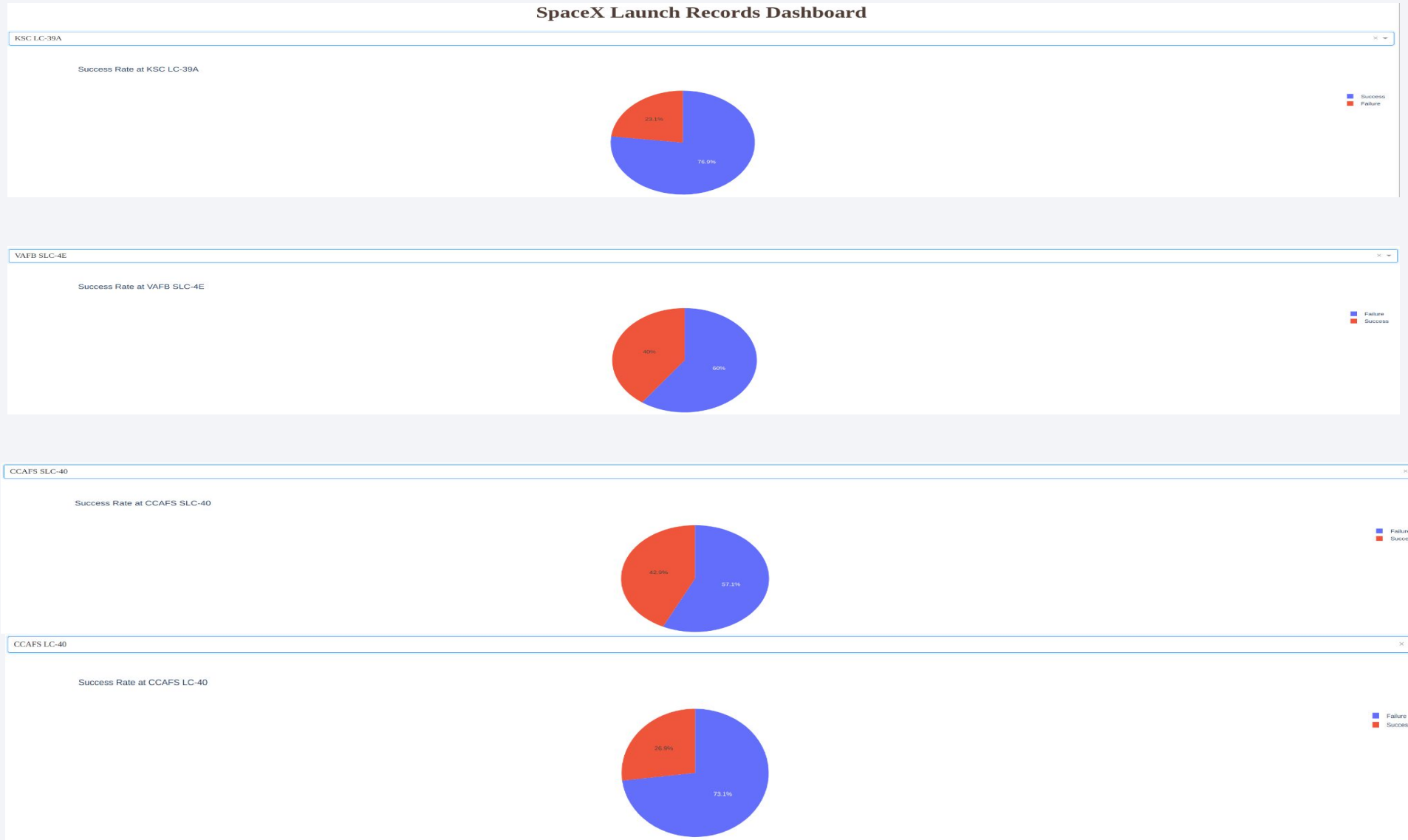
Results - EDA


Average Success Rate
0
20
40
60
80
2010
2012
2013
2014
2015
2016
2017
2018
2019
2020
Date

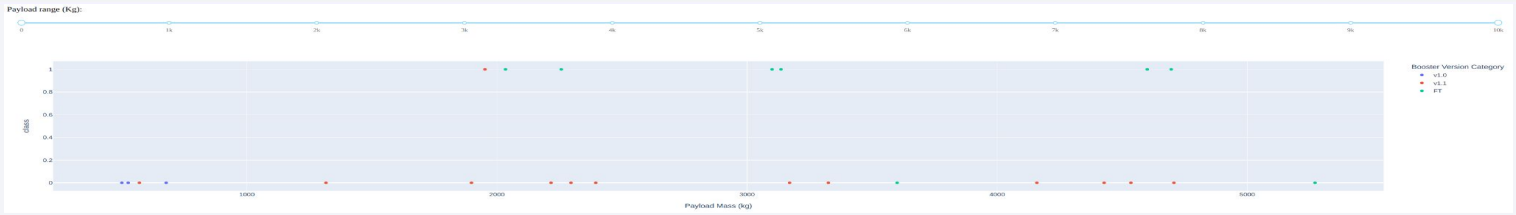
Results - Dashboards

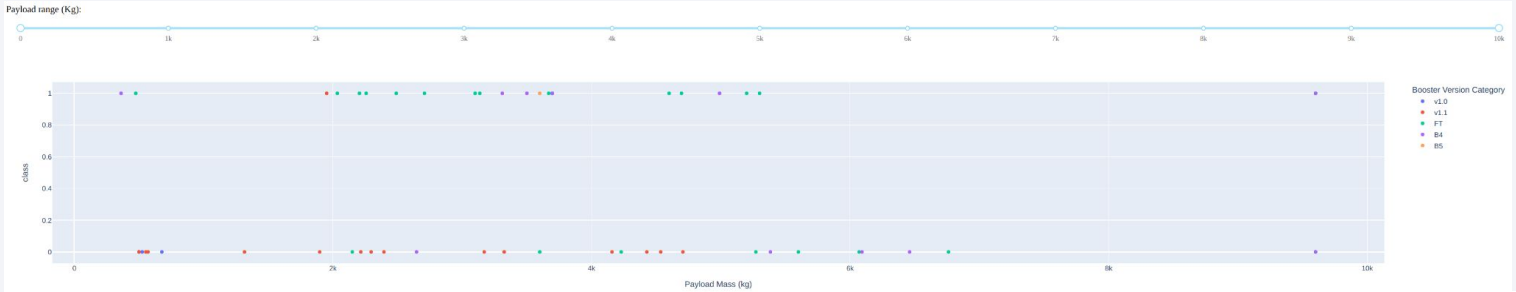


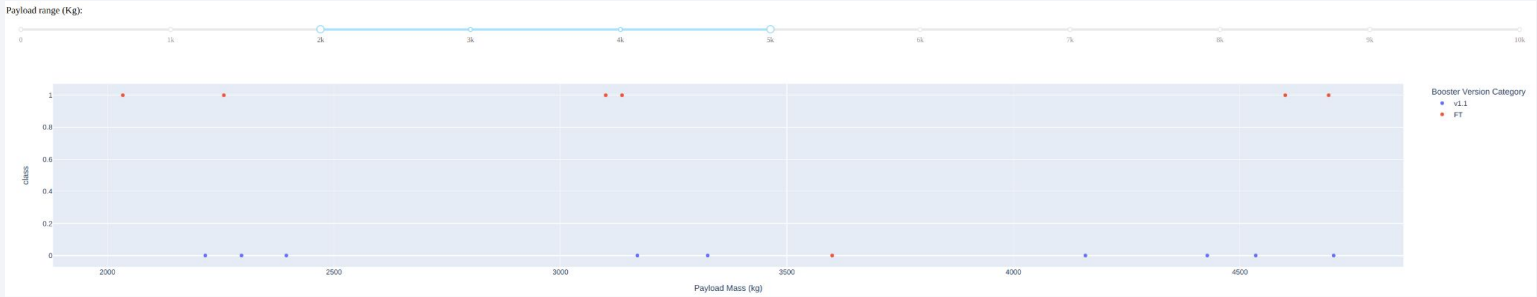
Results - Dashboards



Results - Dashboards

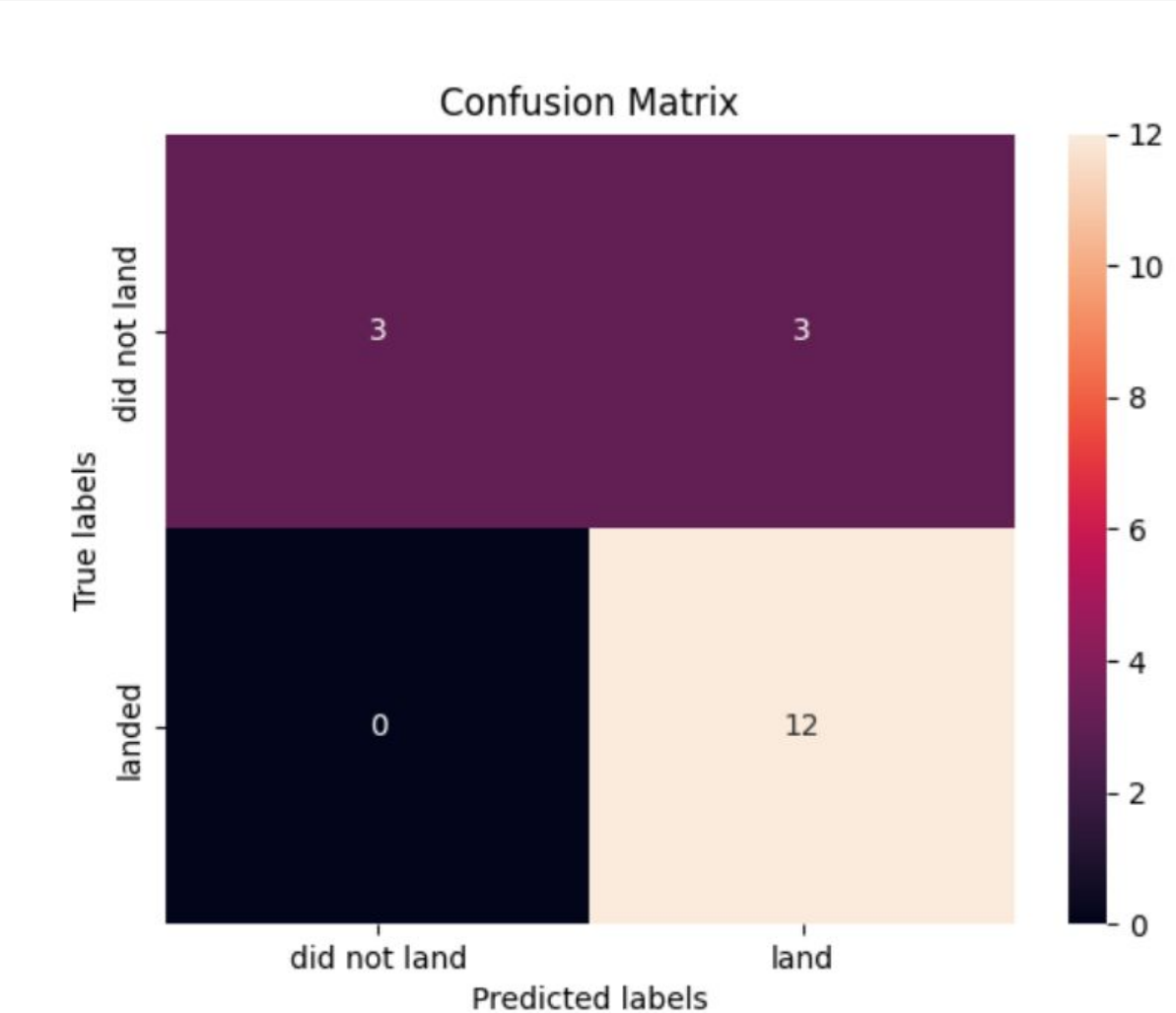




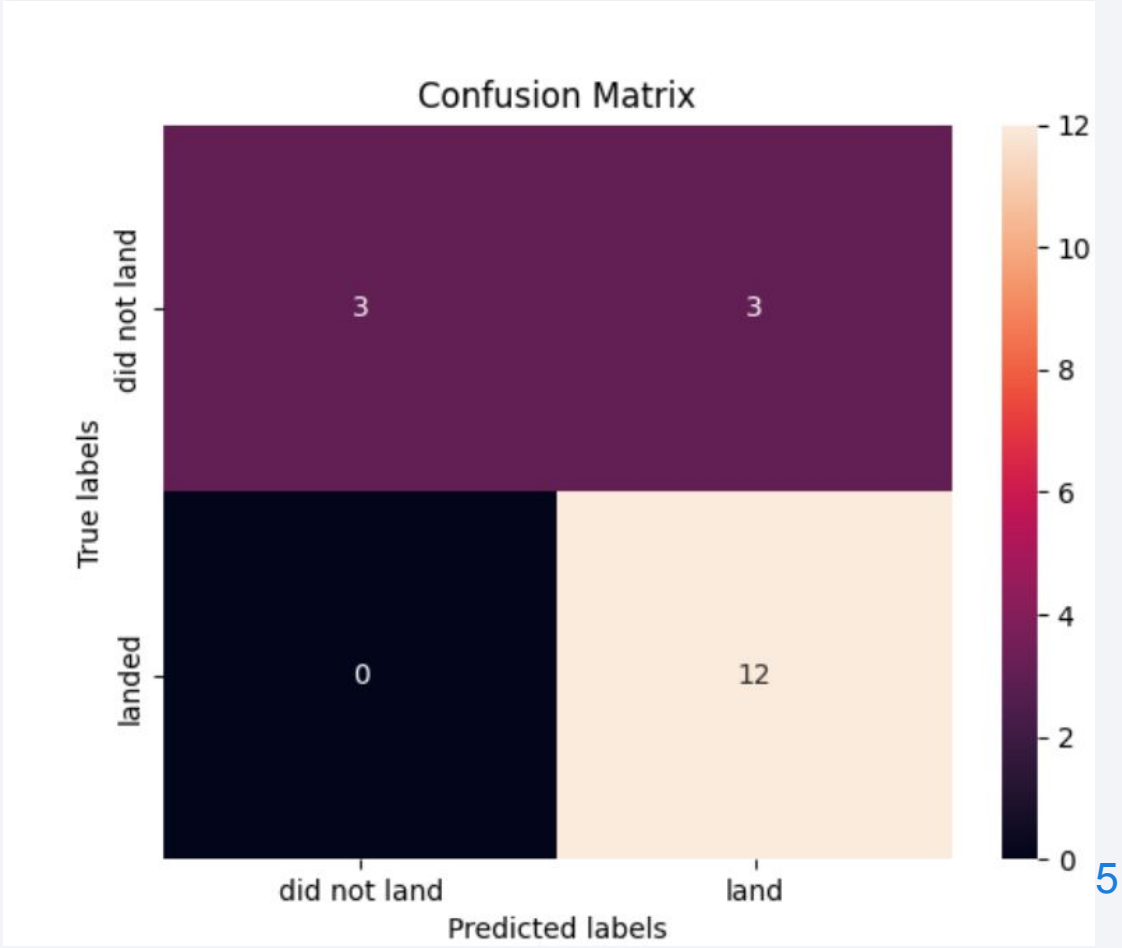


Results - Predictive Analysis

```
yhat=logreg_cv.predict(X_test)
plot_confusion_matrix(Y_test,yhat)
```

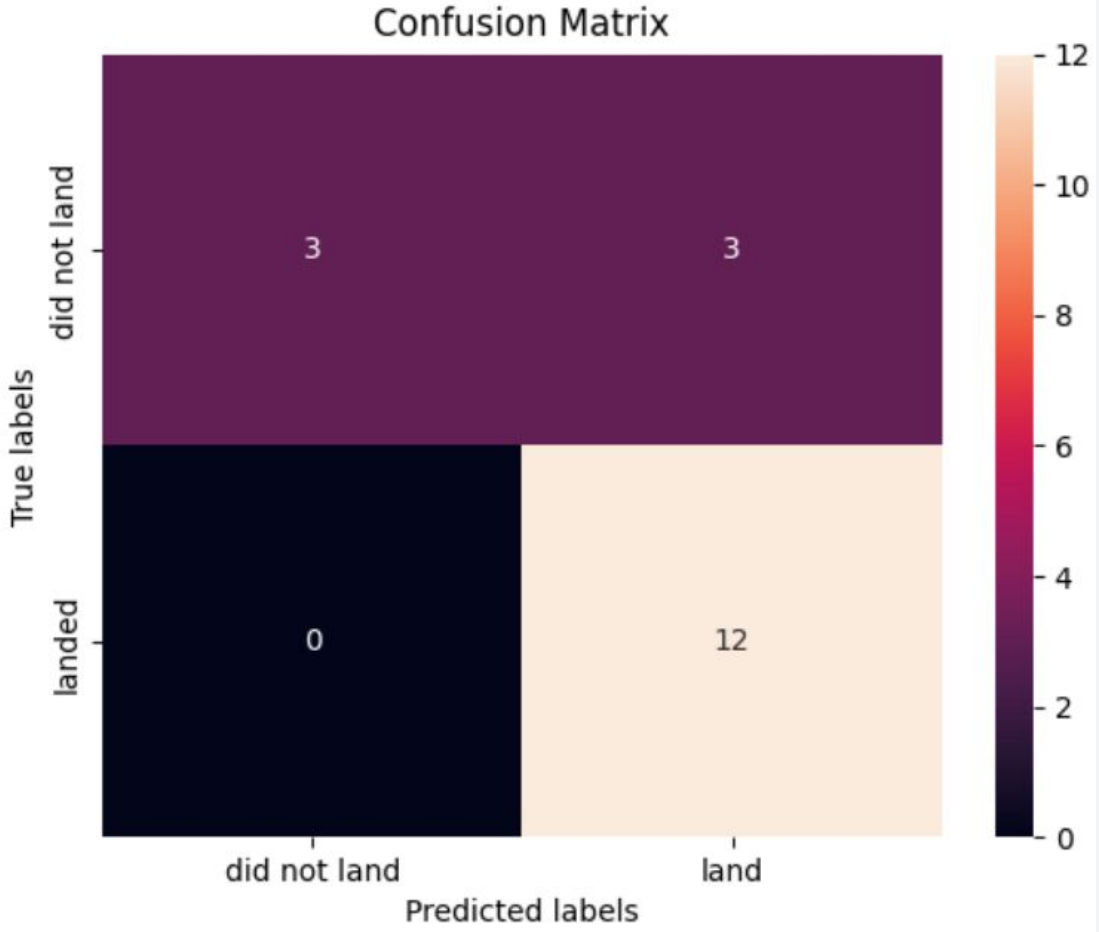



```
yhat=svm_cv.predict(X_test)
plot_confusion_matrix(Y_test,yhat)
```

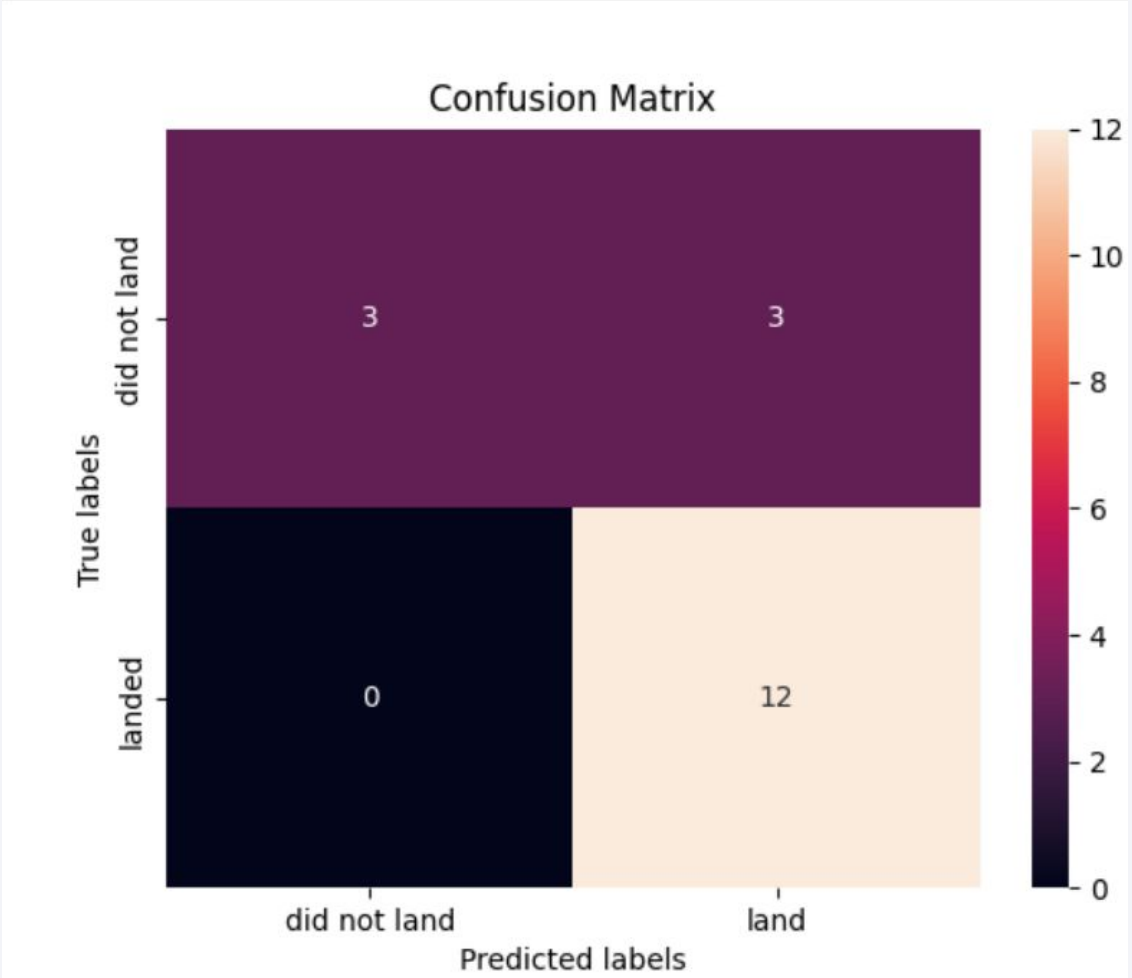


Results - Predictive Analysis

```
yhat = svm_cv.predict(X_test)
plot_confusion_matrix(Y_test,yhat)
```

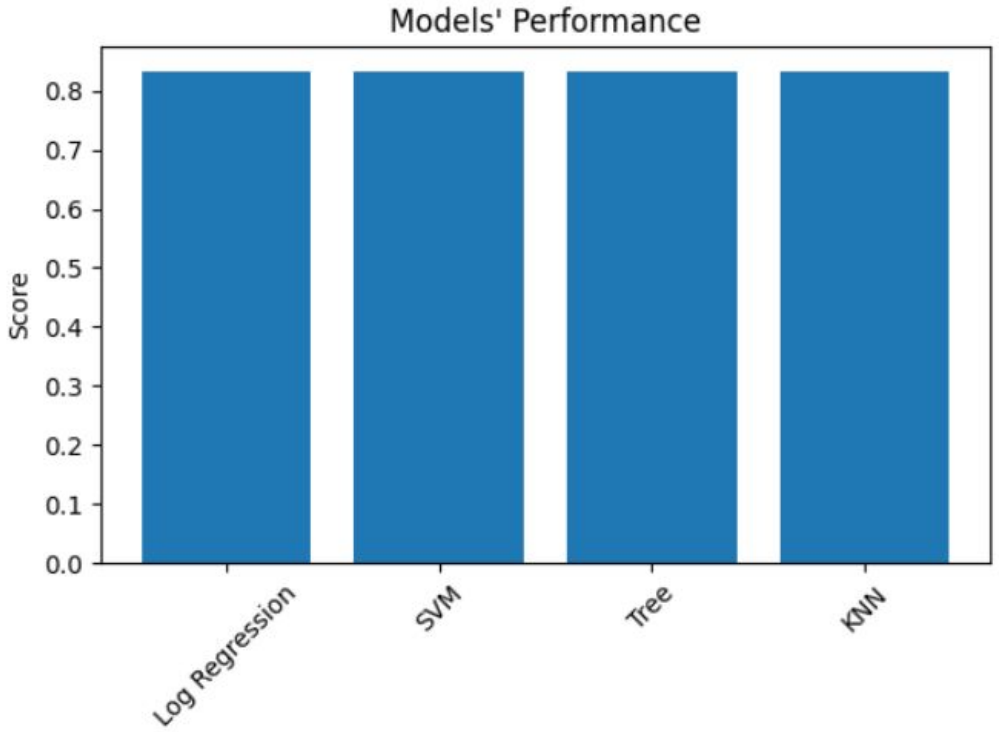



```
yhat = knn_cv.predict(X_test)
plot_confusion_matrix(Y_test,yhat)
```



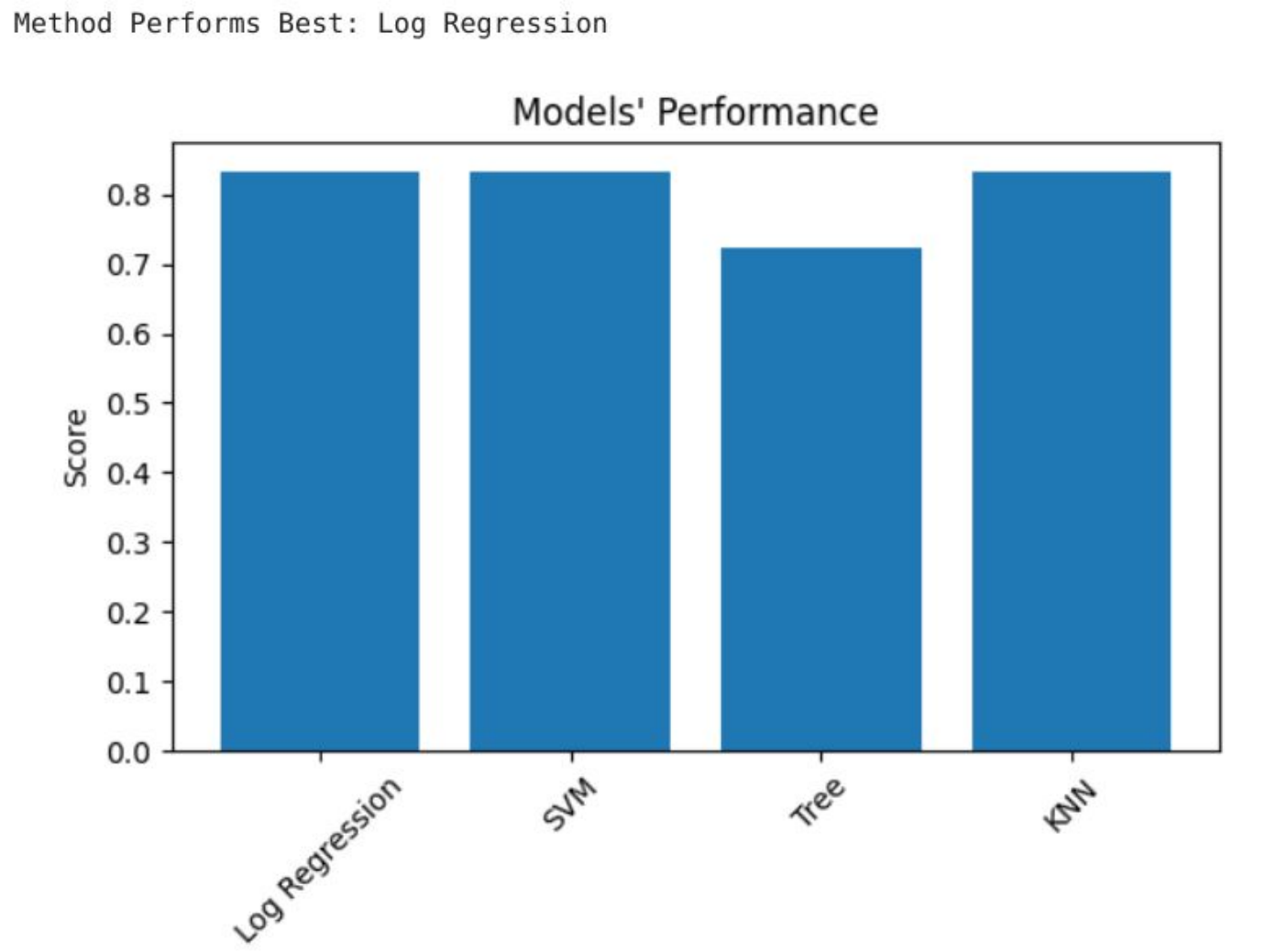
Results - Predictive Analysis (random_state=**0**)

```
All methods performs equally
```



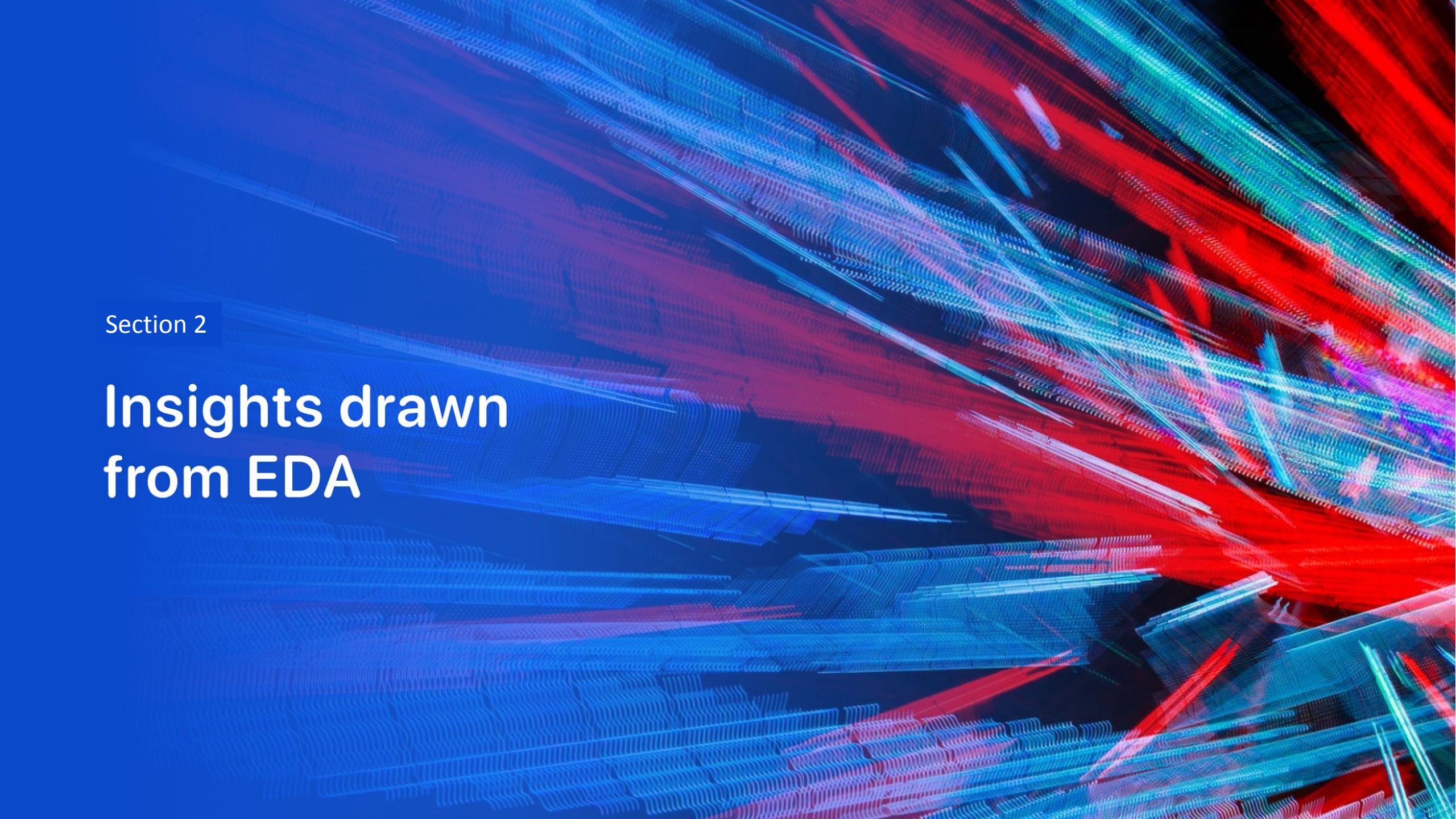

```
{'Log Regression': 0.8333333333333334, 'SVM': 0.8333333333333334, 'Tree': 0.8333333333333334, 'KNN': 0.8333333333333334}
```

Results - Predictive Analysis (random_state=1)

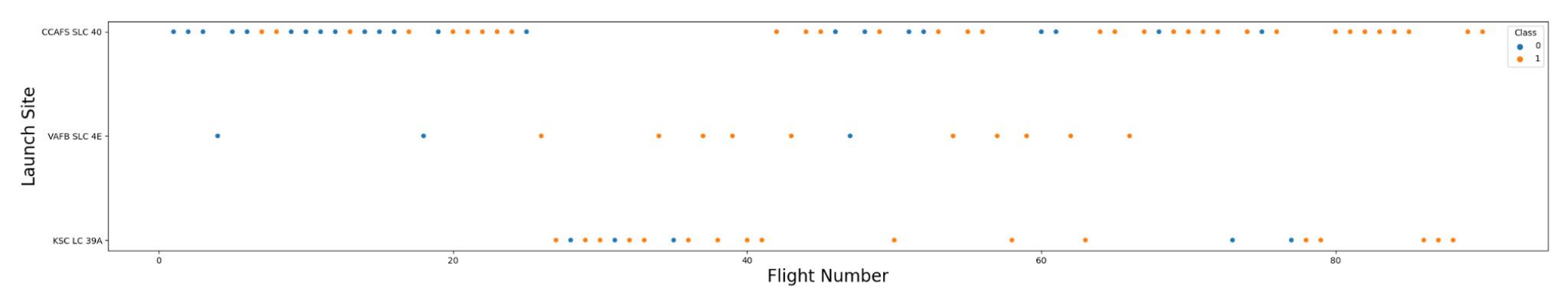


Section 2

Insights drawn from EDA



Flight Number vs. Launch Site



- CCAFS SLC 40 presents the highest number, being evident a predominance of 1 class (success) in the last third.
  - CCAFS SLC 40 is the most used
- VAFB SLC 4E presents a very low frequency, being interrupted definitively after flight number 66

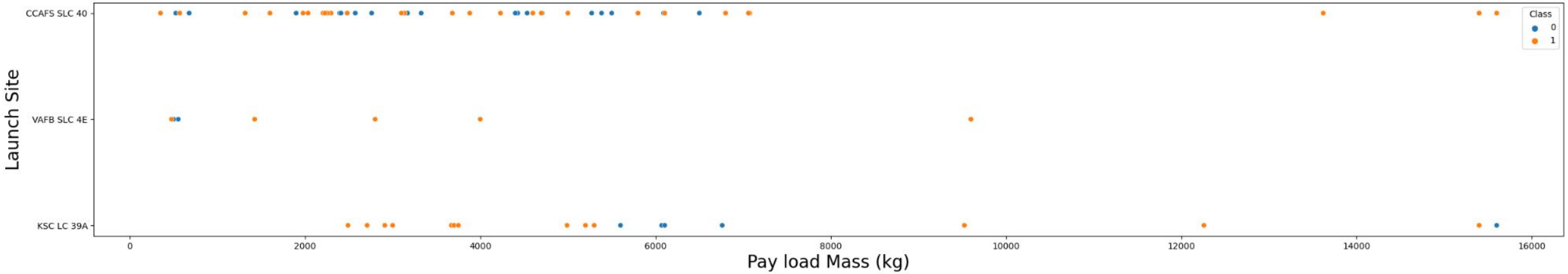
```
In [15]: df[df['LaunchSite'] == 'VAFB SLC 4E'].sort_values(by='FlightNumber', ascending=False)
```

Out[15]:

	FlightNumber	Date	BoosterVersion	PayloadMass	Orbit	LaunchSite	Outcome	Flights	GridFins	Reused	Legs	LandingPad	Block	Reu
65	66	2019-06-12	Falcon 9	1425.0	SSO	VAFB SLC 4E	True RTLS	2	True	True	True	5e9e3032383ecb554034e7c9	5.0	

- VAFB SLC 4E is the least employed

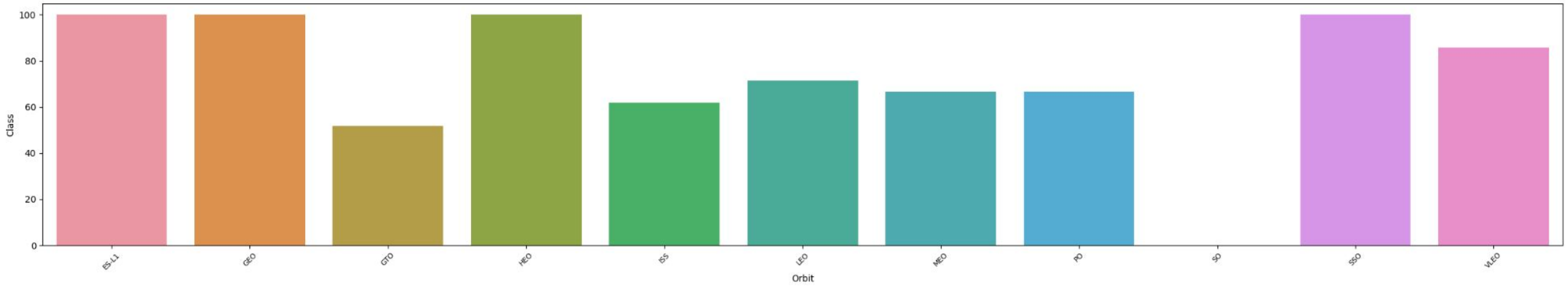
Payload vs. Launch Site



- Payload Mass between 8000 and 16000 Kg are much less frequent.

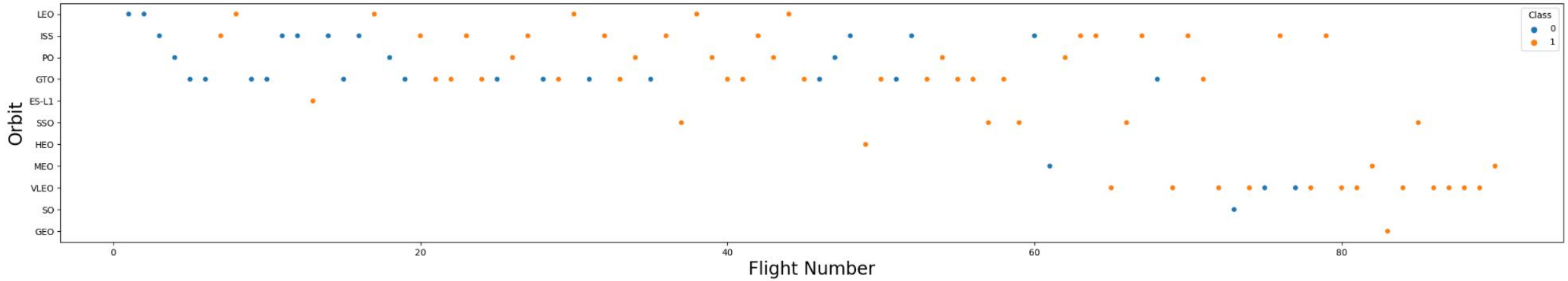
- VAFB SLC 4E presents a smaller number of payloads, being the maximum less than 10.000 Kg

Success Rate vs. Orbit Type



- Class = Success
- SO orbit presents the slower success rate
- GEO, ES L1, HEO and SSO present the higher success rate

Flight Number vs. Orbit Type



- LEO was interrupted after flight number 44

```
df[df['Orbit'] == 'LEO'].sort_values(by='FlightNumber', ascending=False).head(1)
```

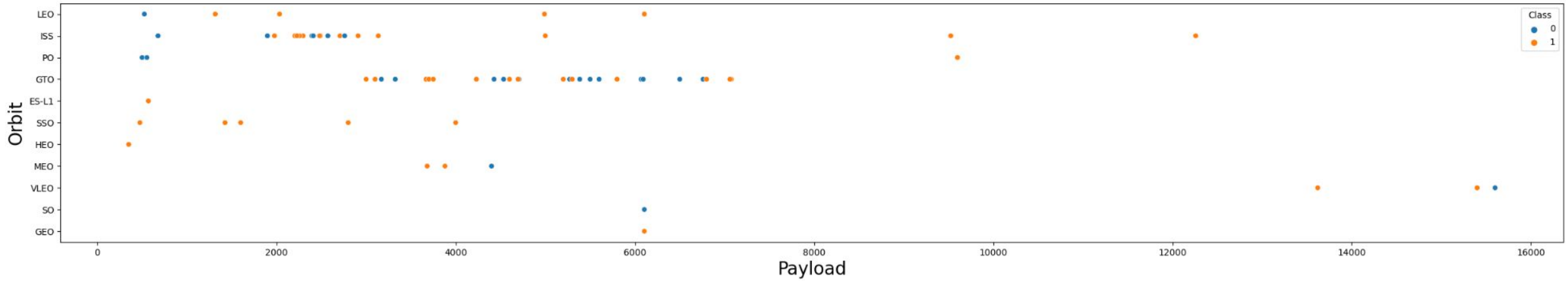
	FlightNumber	Date	BoosterVersion	PayloadMass	Orbit	LaunchSite	Outcome	Flights	GridFins	Reused
43	44	2018-01-08	Falcon 9	6104.959412	LEO	CCAFS SLC 40	True RTLS	1	True	False

- ISS and GTO are more used
- VLEO starts being used from 65 on

```
df[df['Orbit'] == 'VLEO'].sort_values(by='FlightNumber', ascending=True).head(1)
```

	FlightNumber	Date	BoosterVersion	PayloadMass	Orbit	LaunchSite	Outcome	Flights	GridFins	Reu
64	65	2019-05-24	Falcon 9	13620.0	VLEO	CCAFS SLC 40	True ASDS	3	True	T

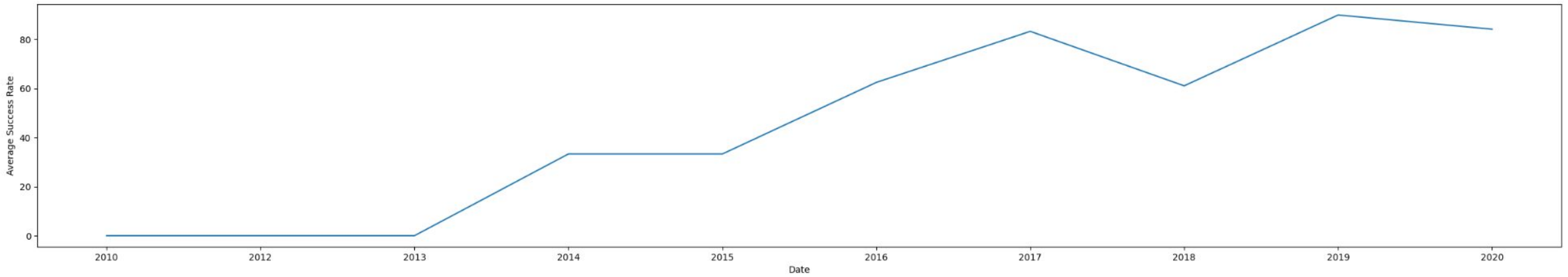
Payload vs. Orbit Type



- Show a scatter point of payload vs. orbit type

- Show the screenshot of the scatter plot with explanations

Launch Success Yearly Trend



All Launch Site Names

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

```
%%sql
SELECT DISTINCT(LAUNCH_SITE)
FROM SPACEXTBL
```

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

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

Launch Site Names Begin with 'CCA'

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

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

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

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing _Outcome	Timestamp	Timestamp_Formatt
2010-06-04 00:00:00	67500000000000	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)	2010-06-04 18:45:00	04-06-2010 18:45
2010-12-08 00:00:00	56580000000000	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)	2010-12-08 15:43:00	08-12-2010 15:43
2012-05-22 00:00:00	27840000000000	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt	2012-05-22 07:44:00	22-05-2012 07:44
2012-10-08 00:00:00	2100000000000	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt	2012-10-08 00:35:00	08-10-2012 00:35
2013-03-01 00:00:00	54600000000000	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt	2013-03-01 15:10:00	01-03-2013 15:10

Total Payload Mass

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

```
%%sql
SELECT SUM(PAYLOAD_MASS__KG_) AS "Total Payload Mass by NASA (CRS)"
FROM SPACEXTBL
WHERE CUSTOMER == 'NASA (CRS)'
```

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

Total Payload Mass by NASA (CRS)
45596

Average Payload Mass by F9 v1.1

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

```
%%sql
SELECT AVG(PAYLOAD_MASS__KG_) AS "Average Payload Mass"
FROM SPACEXTBL
WHERE Booster_Version LIKE 'F9 v1.1%'
-- # Booster_Version Included for the average calculation:
-- # F9 v1.1 B1003, F9 v1.1, F9 v1.1 B1011, F9 v1.1 B1010,
-- # F9 v1.1 B1012, F9 v1.1 B1013, F9 v1.1 B1014,
-- # F9 v1.1 B1015, F9 v1.1 B1016, F9 v1.1 B1018, F9 v1.1 B1017
```

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

Average Payload Mass
2534.6666666666665

First Successful Ground Landing Date

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

Hint:Use min function

```
%%sql
SELECT substr(MIN(Timestamp), 1, 10) AS Date
FROM SPACEXTBL
WHERE "Landing _Outcome" == 'Success (ground pad)'
```

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

Date
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 60

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

```
%%sql
SELECT Booster_Version
FROM SPACEXTBL
WHERE "Landing _Outcome" == 'Success (drone ship)'
      AND PAYLOAD_MASS__KG_ BETWEEN 4000 AND 6000
```

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

Booster_Version
F9 FT B1022
F9 FT B1026
F9 FT B1021.2
F9 FT B1031.2

Total Number of Successful and Failure Mission Outcc

List the total number of successful and failure mission outcomes

```
%%sql
SELECT
        (
            SELECT COUNT(Mission_Outcome) FROM SPACEXTBL WHERE Mission_Outcome LIKE '%Success%'
        ) AS SUCCESS,

        (
            SELECT COUNT(Mission_Outcome) FROM SPACEXTBL WHERE Mission_Outcome LIKE '%Failure%'
        ) AS FAILURE
```

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

SUCCESS	FAILURE
100	1

Boosters Carried Maximum Payload

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

```
%%sql
SELECT DISTINCT(Booster_Version)
FROM SPACEXTBL
WHERE PAYLOAD_MASS__KG_ == (
                            SELECT MAX(PAYLOAD_MASS__KG_)
                            FROM SPACEXTBL
                           )
```

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

Booster_Version
F9 B5 B1048.4
F9 B5 B1049.4
F9 B5 B1051.3
F9 B5 B1056.4
F9 B5 B1048.5
F9 B5 B1051.4
F9 B5 B1049.5
F9 B5 B1060.2
F9 B5 B1058.3
F9 B5 B1051.6
F9 B5 B1060.3
F9 B5 B1049.7

2015 Launch Records

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.

```
%%sql
SELECT SUBSTR(Date, 6, 2) AS Month, "Landing _Outcome", Booster_version, launch_site
FROM SPACEXTBL
WHERE SUBSTR(Date, 3, 2) == '15'
```

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

Month	Landing _Outcome	Booster_Version	Launch_Site
01	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
02	Controlled (ocean)	F9 v1.1 B1013	CCAFS LC-40
03	No attempt	F9 v1.1 B1014	CCAFS LC-40
04	Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40
04	No attempt	F9 v1.1 B1016	CCAFS LC-40
06	Precluded (drone ship)	F9 v1.1 B1018	CCAFS LC-40
12	Success (ground pad)	F9 FT B1019	CCAFS LC-40

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

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

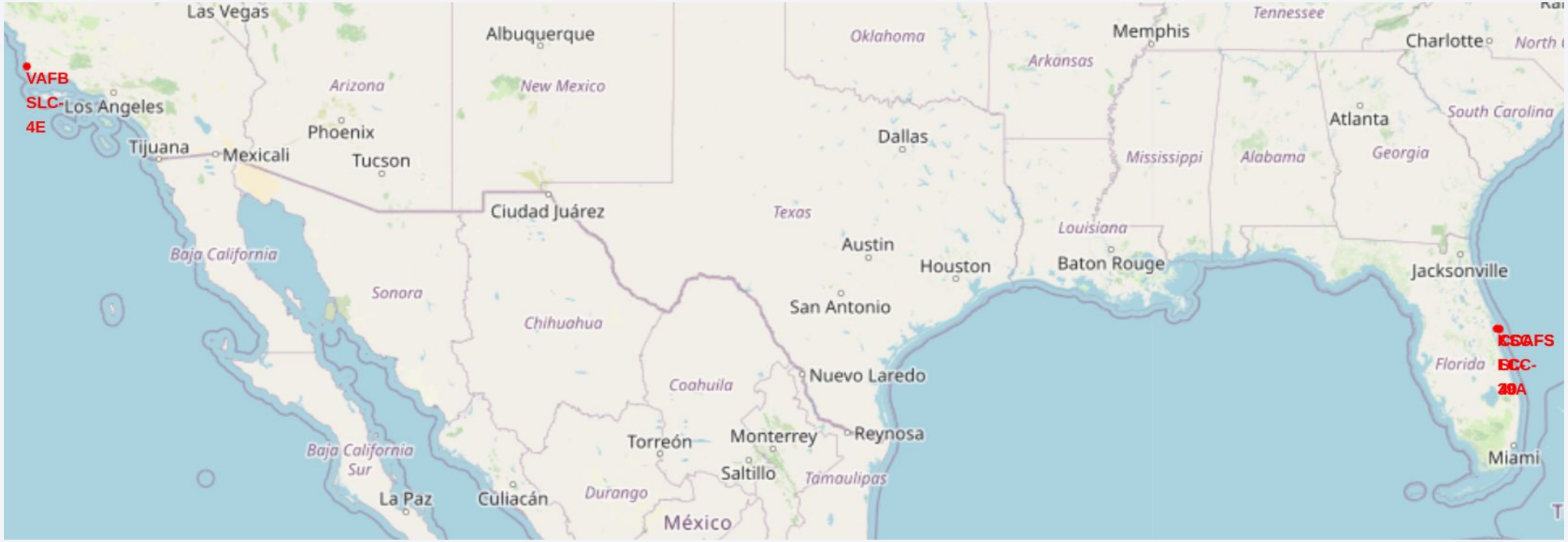
```
%%sql
SELECT DISTINCT("Landing _Outcome"), COUNT(*) as "Count"
FROM SPACEXTBL
WHERE Date BETWEEN '2010-06-04' AND '2017-03-20' AND "Landing _Outcome" LIKE '%Success%'
GROUP BY "Landing _Outcome" ORDER BY "Count" DESC
```

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

Landing _Outcome	Count
Success (drone ship)	5
Success (ground pad)	3

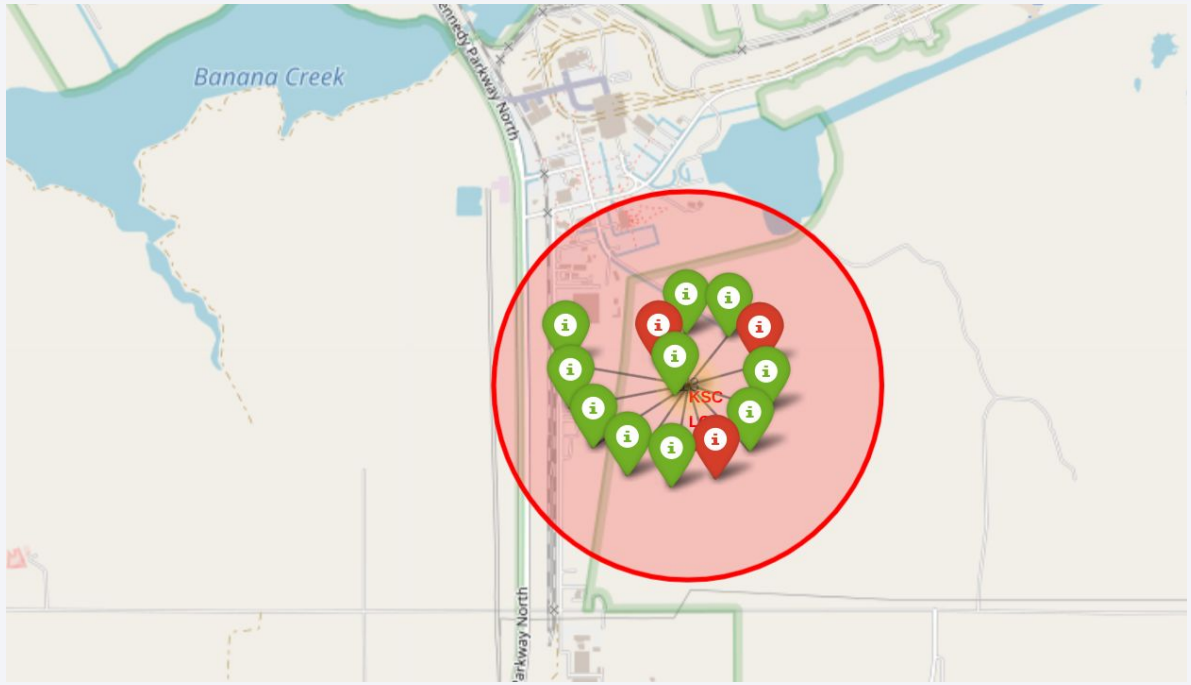

Section 3
Launch Sites
Proximities Analysis

All Launch Sites (Falcon 9)



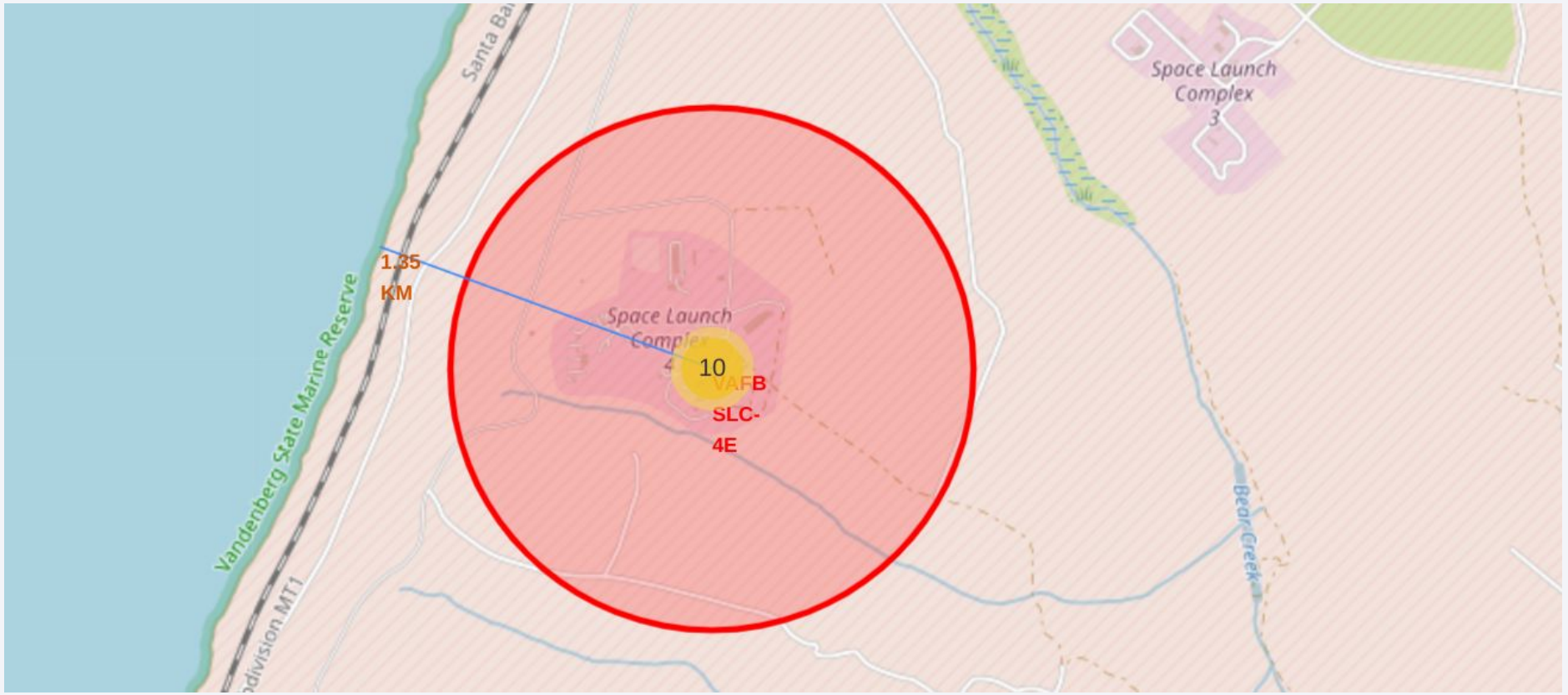
- Red circles to mark the place
- Labels also in red

Launch Outcomes for KSC LC 39A

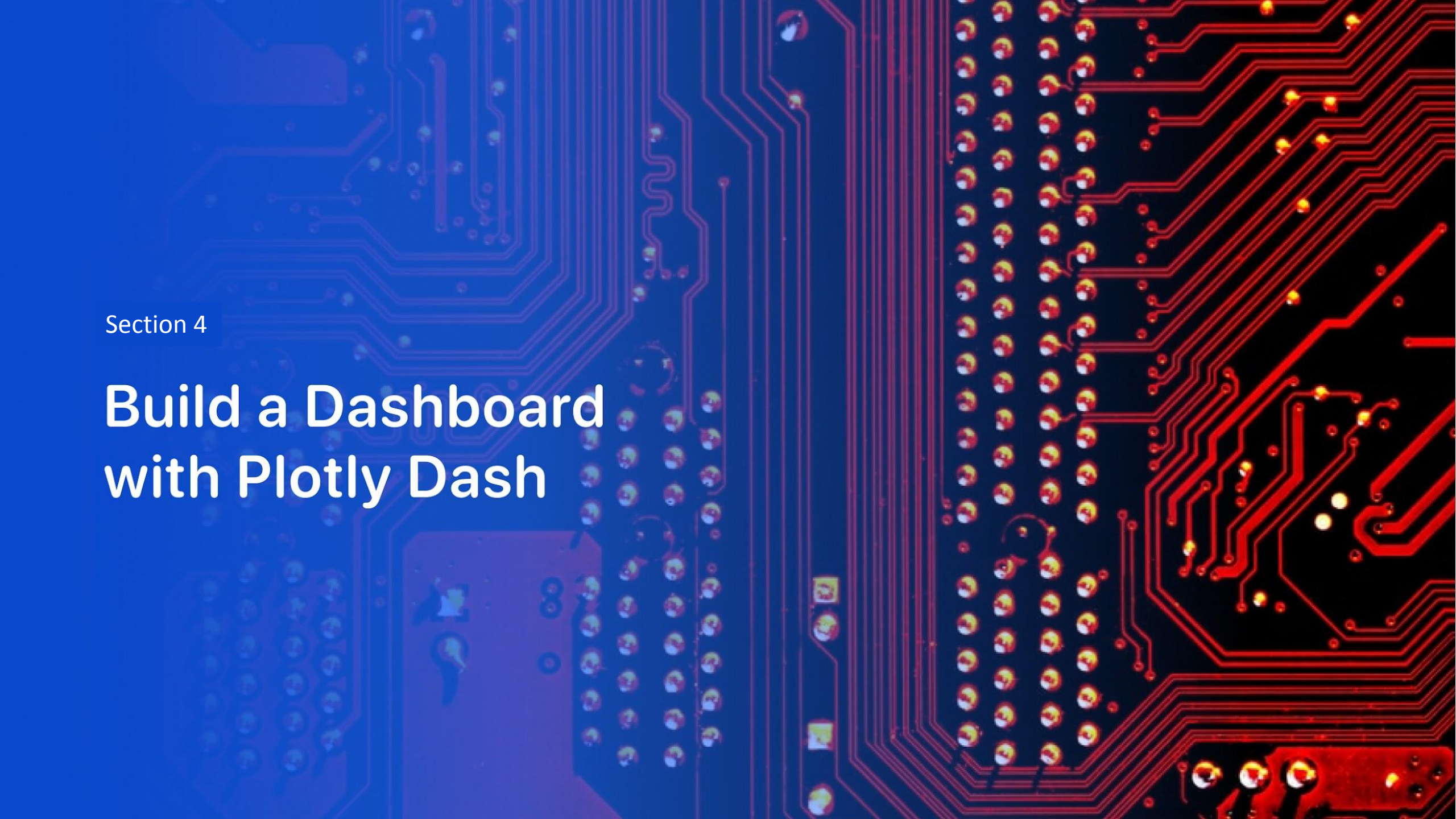


- KSC LC 39A
  - Green informational icons indicate successful outcomes
  - Red information icons indicate failed outcomes

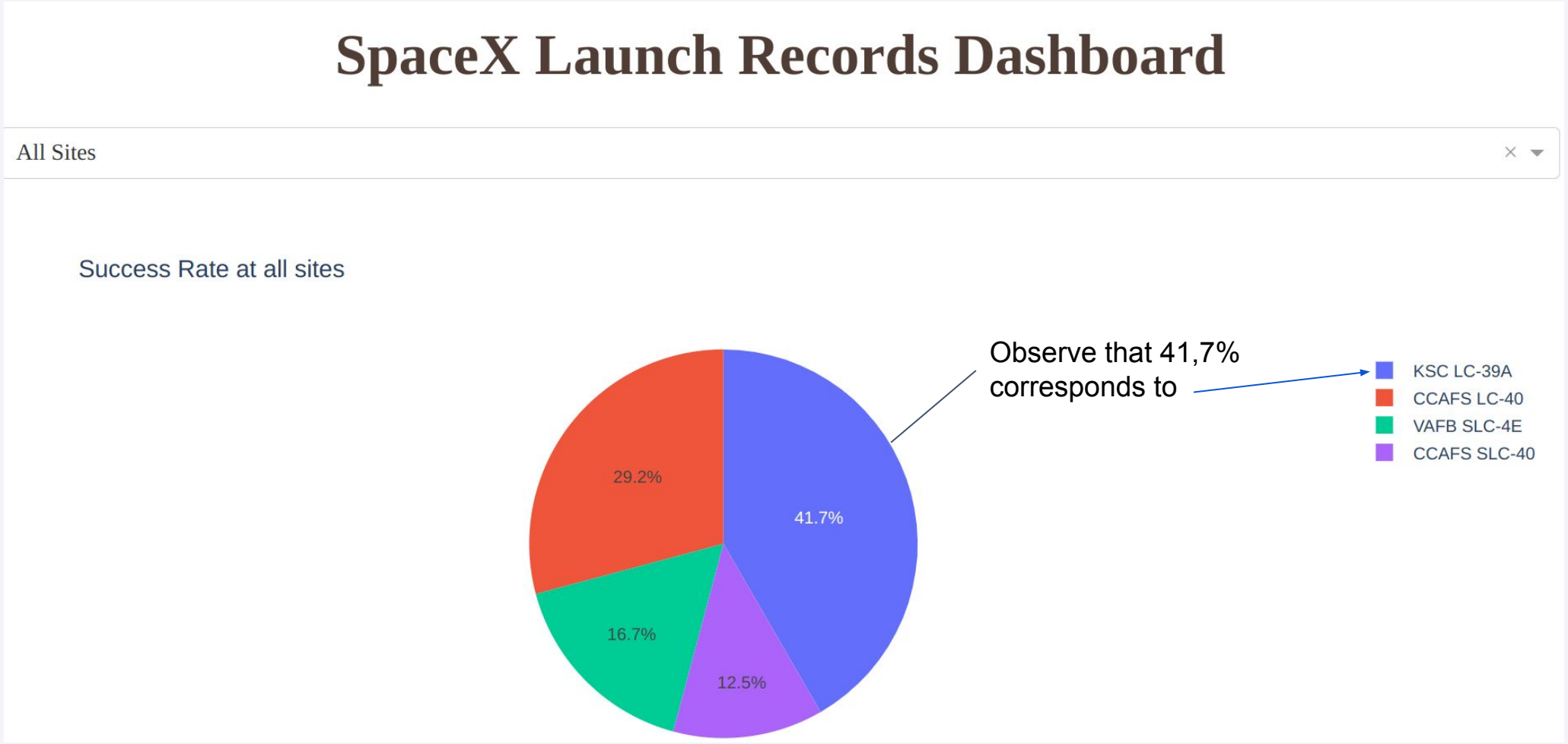
Distance from VAFB SLC 4E to Coastline



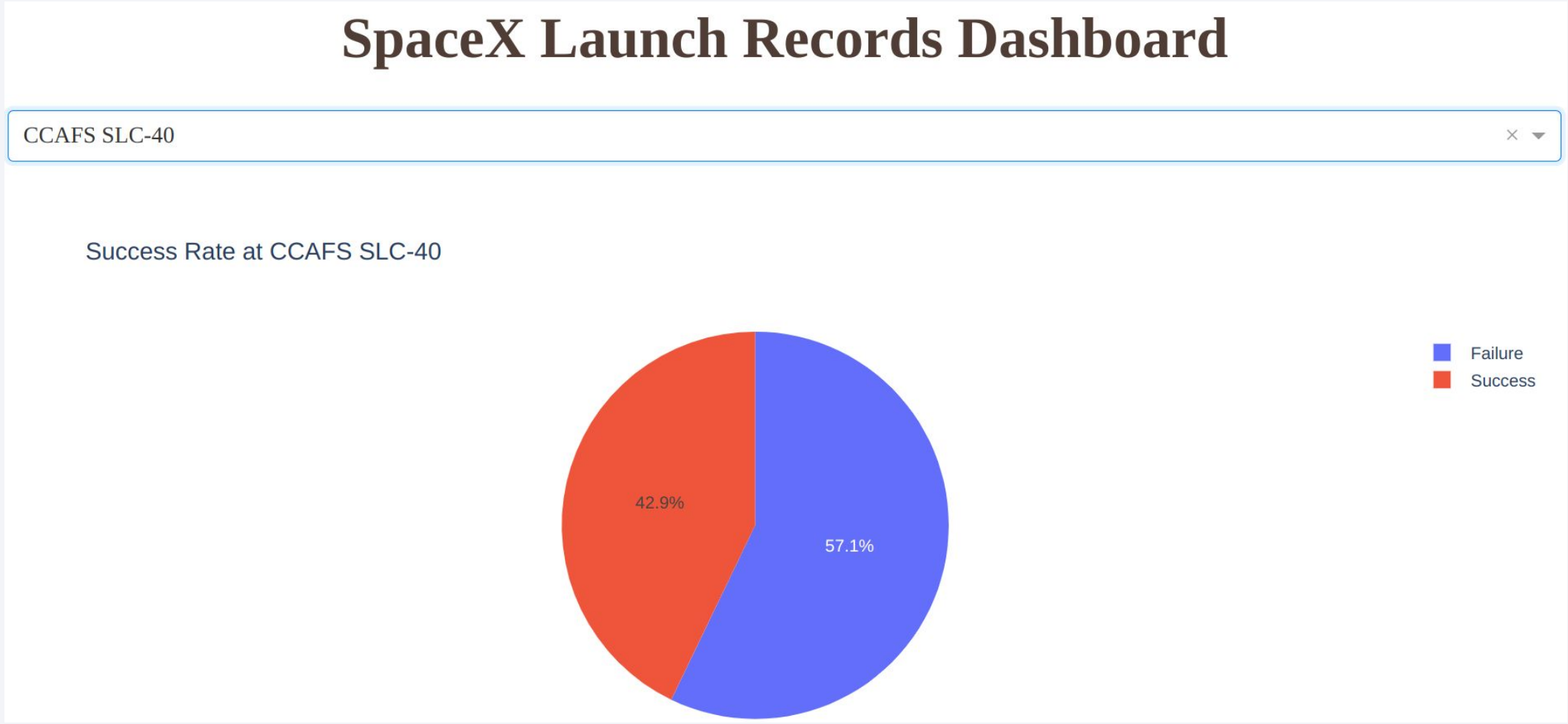
- Distance to coastline from VAFB SLC 4E is 1.35 Km


Section 4
Build a Dashboard with Plotly Dash

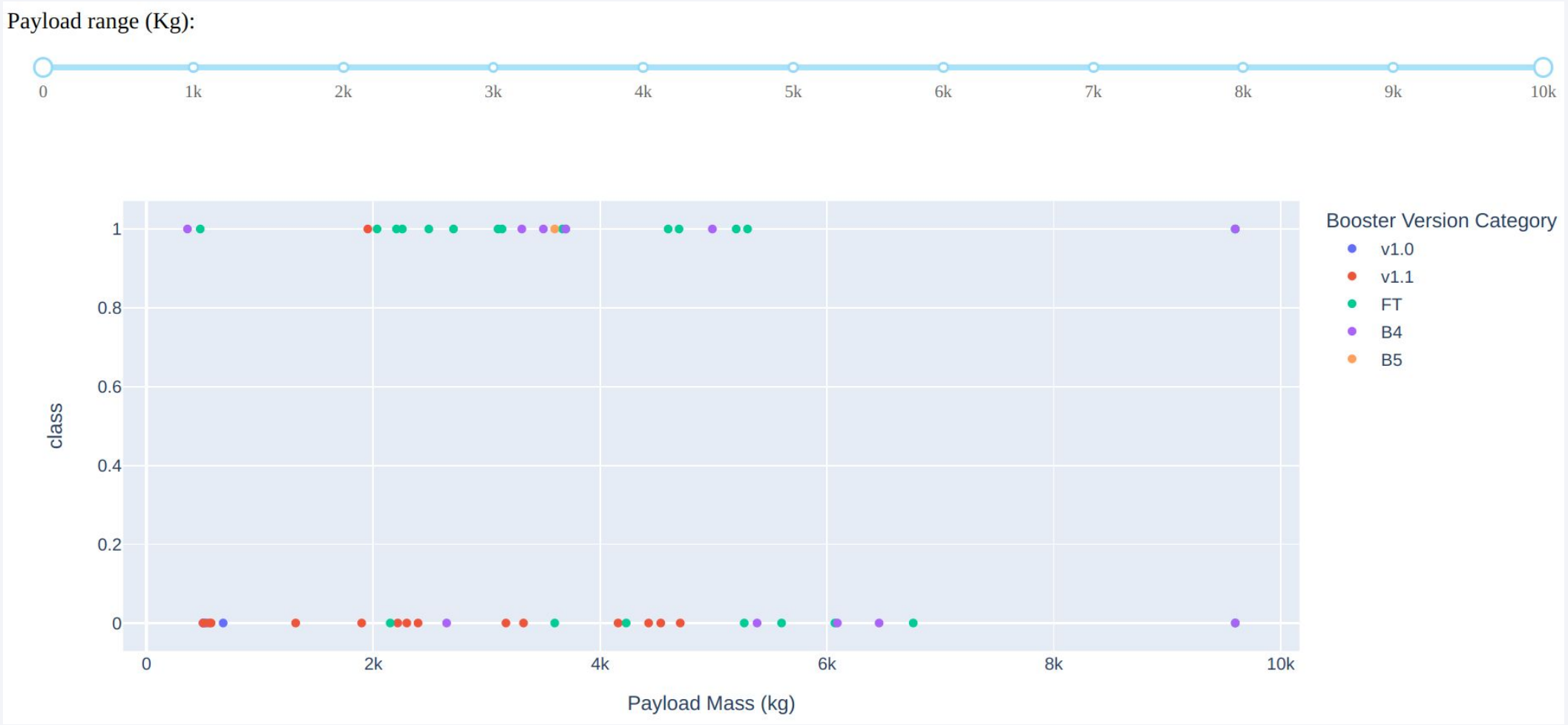
Success Rates at All Sites



Higher Failure Rate is for CCAFS SLC-40



Payload Mass for All Locations

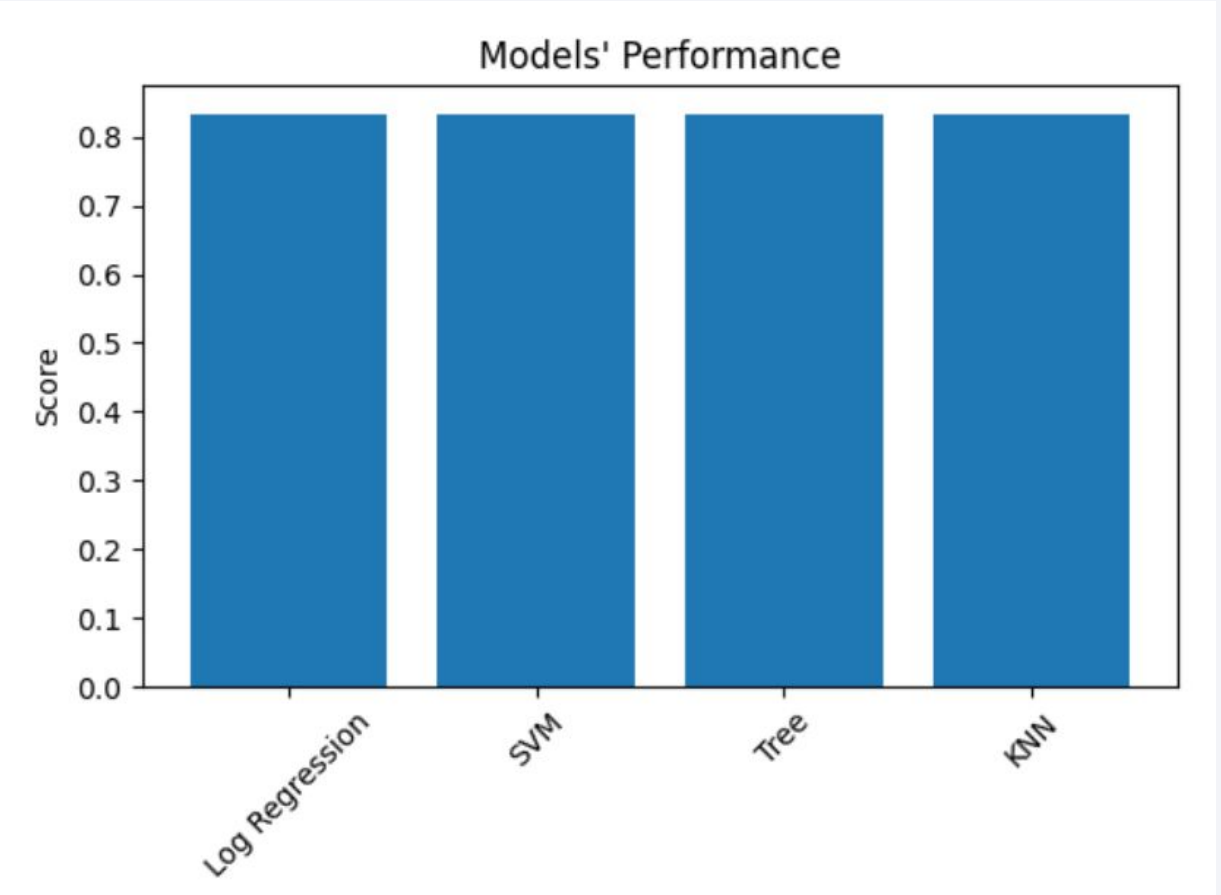


Section 5

Predictive Analysis (Classification)

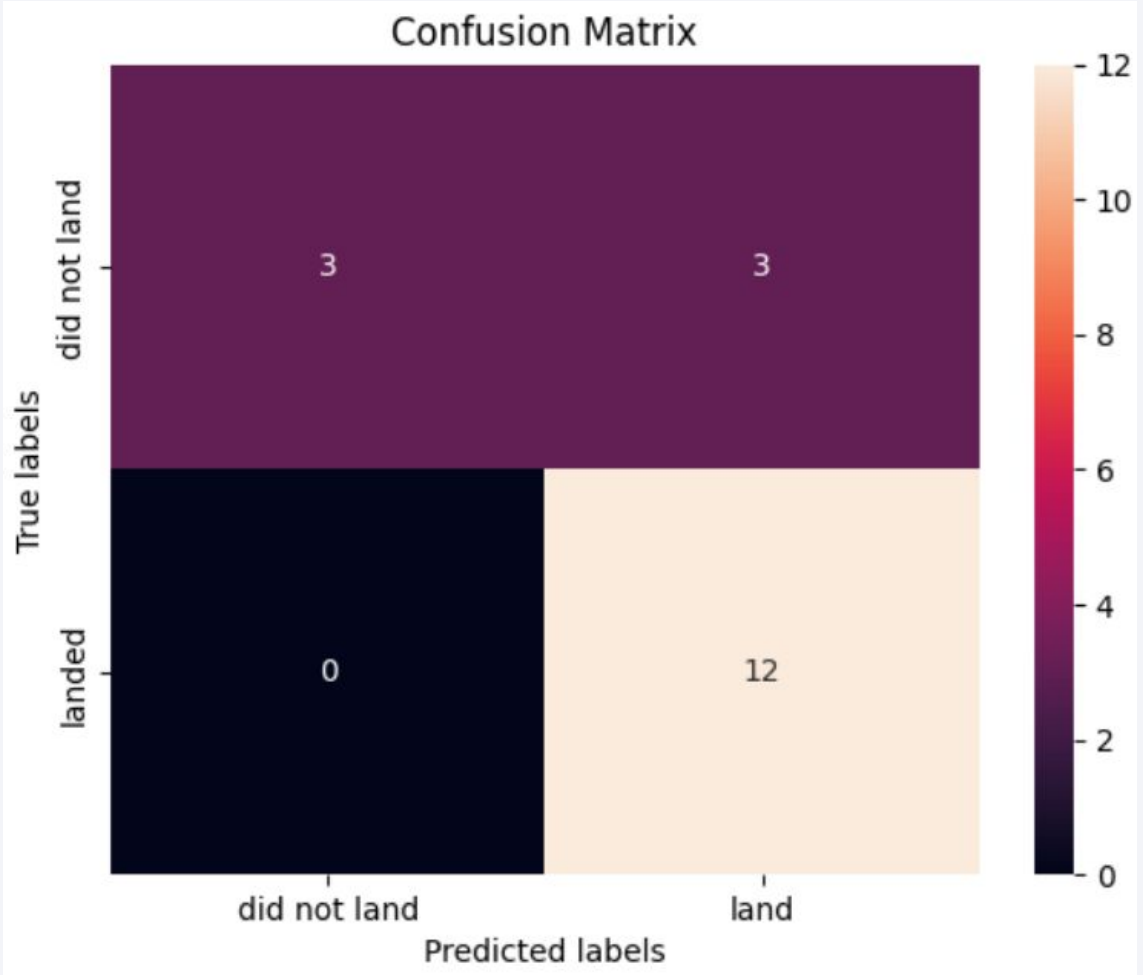
Classification Accuracy

- According to the graph and the programmed function, all models present the same accuracy score for the **cv** models.
    - 0.8333333333333334
- For this to be true, we need to set the **random_state = 0** in the tree model in order to avoid different results with different executions of the Notebook's Code.
- Optimal CV configurations have been manually tested in the last cell of the Notebook for checking purposes with same results.
- When random_state is not set to 0, the tree model presents an inferior score in the CV models.



Confusion Matrix

- Logistic Regression
  - Observe the great difference depending on the case
    - 3/3 when not-landed
    - 0/12 when landed



Conclusions

- Launch Sites Location follows security and logistics principles
  - As far as possible from cities
  - As close as possible to highways, railways and coastline.

- There is enough data to predict with an acceptable accuracy score
  - At this point, highest probability of first stage recovery: KSC LC 39A

- Falcon 9 First Stage Landing Average Success Increases Over Time

- Future launches will increase accuracy score with retraining of the prediction model

Appendix

- Nothing to remark

Thank you!