



IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science



OUTLINE

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

The background of the slide is a collage of financial and data-related images. On the left, there's a bar chart with blue and orange bars. Above it, a line graph shows fluctuating data points. In the center, a large number '345771' is visible. To the right, there's a circular gauge or speedometer with numbers ranging from 100 to 210. The overall color scheme is a mix of blue, orange, and white on a dark background.

EXECUTIVE SUMMARY

- Summary of methodologies
- Summary of all results



INTRODUCTION

- SpaceX advertises Falcon 9 rocket launches on its website, with a cost of 62 million dollars; other providers cost upward of 165 million dollars each, much of the savings is because SpaceX can reuse the first stage. Therefore if we can determine if the first stage will land, we can determine the cost of a launch.
- The successful launch of SpaceX's Falcon 9 rockets
- Does the mass payload affect the success rate?
- Which is the best model we can use to predict the outcome of a launch

Section 1

Methodology

METHODOLOGY

- Executive Summary

- Data collection methodology:
 - Data was collected from digital sources
- Perform data wrangling
 - Data was cleaned, parsed, normalized, classified and subject to 4 different predictive models.
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium
- Perform predictive analysis using classification models

DATA COLLECTION



First, we imported various libraries in order to use SpaceX's own API



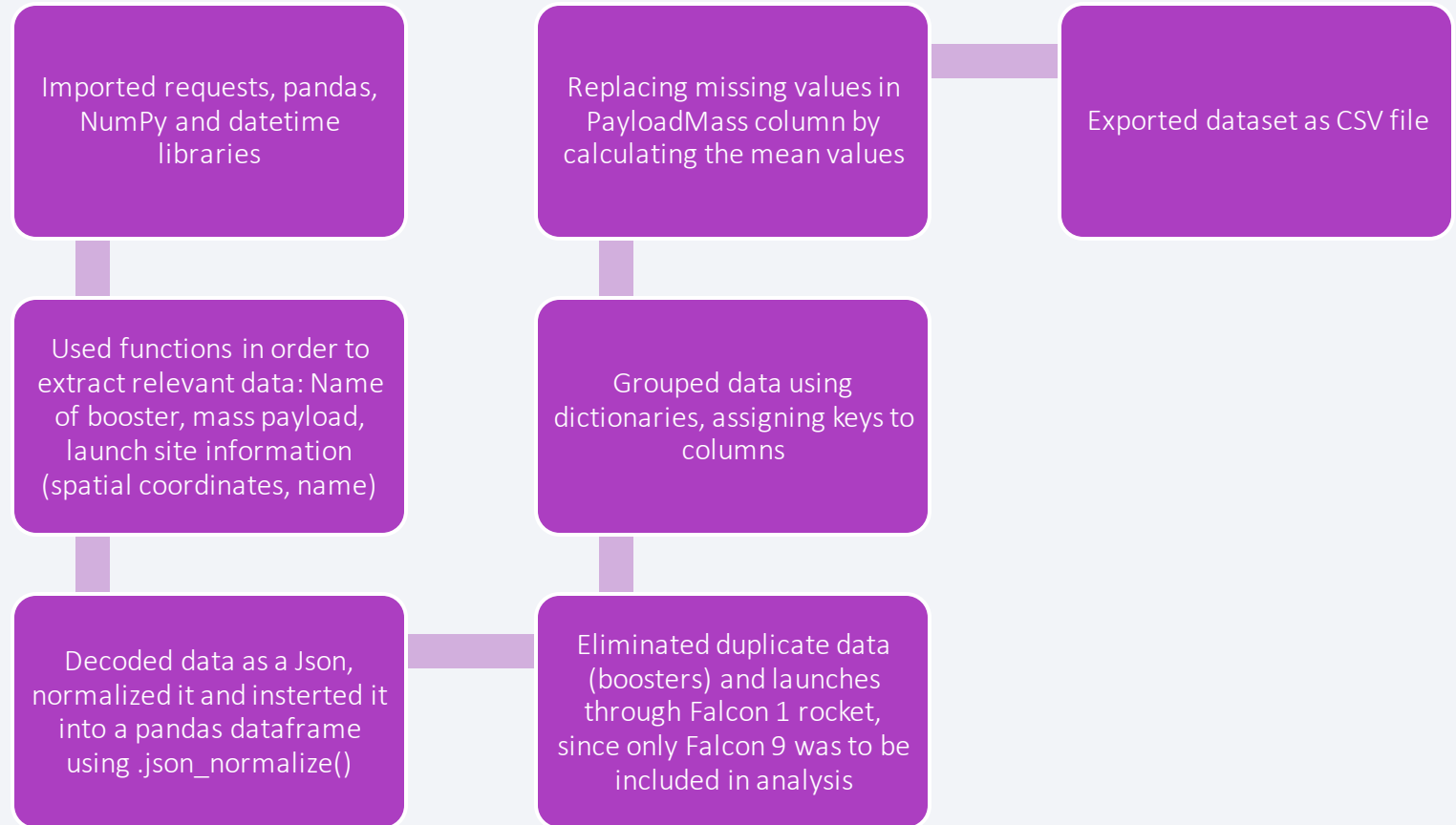
We were also able to find relevant information on public websites such as Wikipedia

Data Collection – SpaceX API

- We took advantage of Python's rich array of libraries to collect data from SpaceX's API and process it for later use

- Jupyter notebook is available at

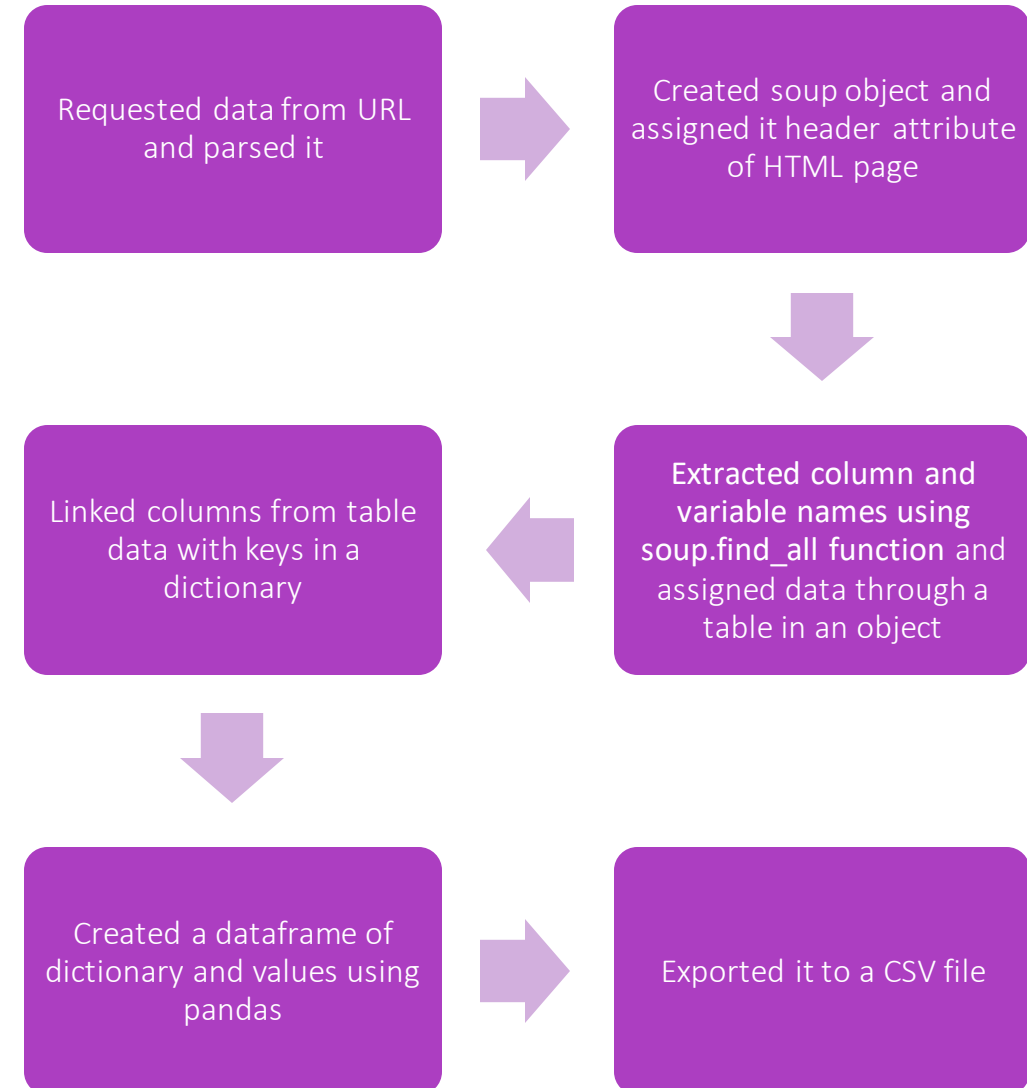
- <https://github.com/ADGit-cmyk/NR/blob/main/jupyter-labs-spacex-data-collection-api.ipynb>



Data Collection – Web Scrapping

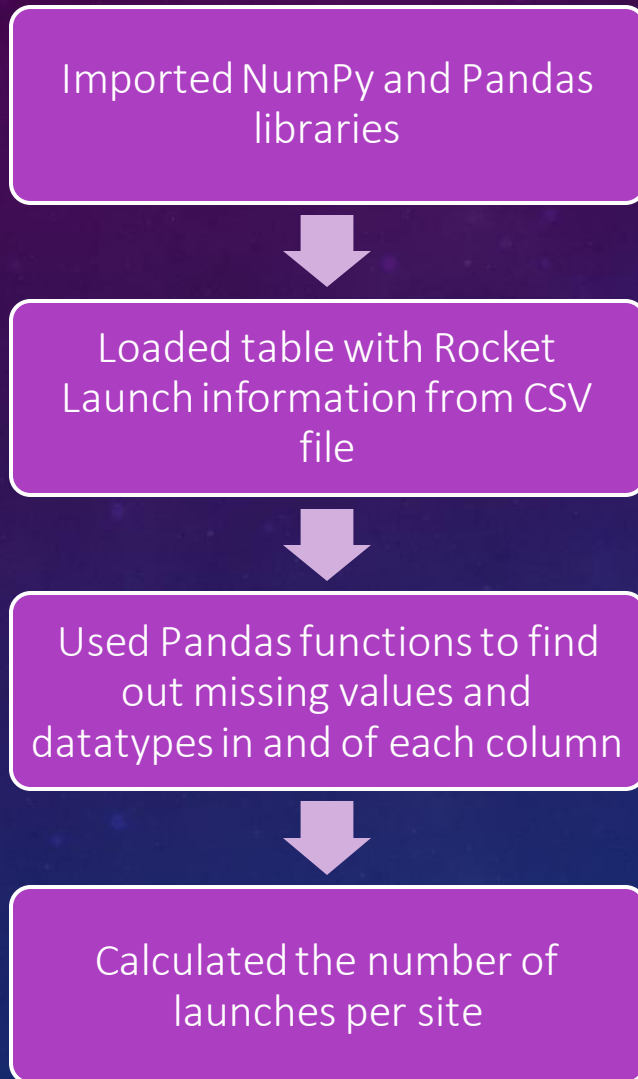
As before, we used external libraries such as pandas but also BeautifulSoup, in combination with Python methods to extract data from a Wikipedia page called: List of Falcon 9 and Falcon Heavy launches. It was updated on 9th June 2021.

The Jupyter notebook can be accessed on Github at <https://github.com/ADGit-cmyk/NR/blob/main/jupyter-labs-webscraping.ipynb>



DATA WRANGLING

We used some Exploratory Data Analysis (EDA) techniques in order to transform the scraped data and determine what attributes and values are suited best for achieving the target objective of being able to predict the success or failure of Falcon 9 rocket launches.



```
In [3]: df.isnull().sum()/df.count()*100
Out[3]: FlightNumber    0.000
         Date           0.000
         BoosterVersion 0.000
         PayloadMass    0.000
         Orbit          0.000
         LaunchSite     0.000
         Outcome        0.000
         Flights        0.000
         GridFins       0.000
         Reused         0.000
         Legs           0.000
         LandingPad     40.625
         Block          0.000
         ReusedCount    0.000
         Serial         0.000
         Longitude      0.000
         Latitude       0.000
         dtype: float64
```

```
In [4]: df.dtypes
Out[4]: FlightNumber    int64
         Date           object
         BoosterVersion object
         PayloadMass    float64
         Orbit          object
         LaunchSite     object
         Outcome        object
         Flights        int64
         GridFins       bool
         Reused         bool
         Legs           bool
         LandingPad     object
         Block          float64
         ReusedCount    int64
         Serial         object
         Longitude      float64
         Latitude       float64
         dtype: object
```

```
df['LaunchSite'].value_counts()
Out[5]: CCAFS SLC 40    55
         KSC LC 39A    22
         VAFB SLC 4E    13
         Name: LaunchSite, dtype: int64
```

There were a disproportional amount of missing values for the "LandingPad" attribute,

Certain columns did not have the proper data types and had to be changed

Number of launches for each of the 3 launch pads

DATA WRANGLING

Use the method `.value_counts()` to determine the number and occurrence of each orbit in the column Orbit



Calculated the number and occurrence of mission outcome per orbit type using `.value_counts()`

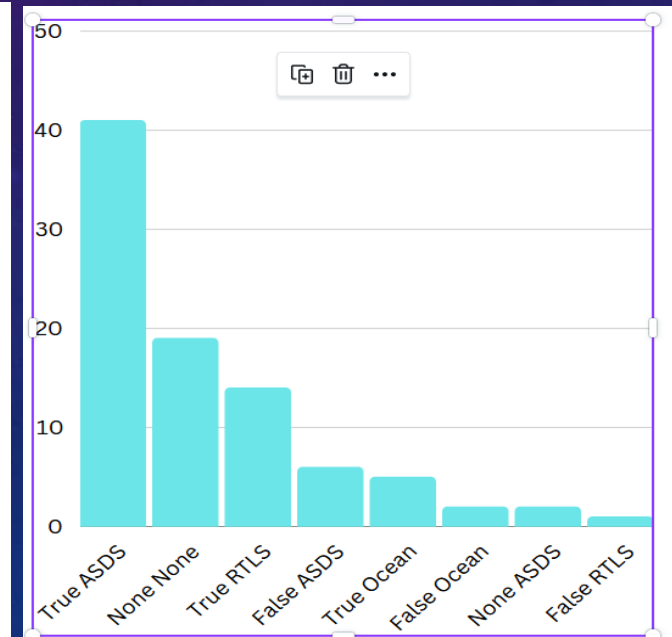
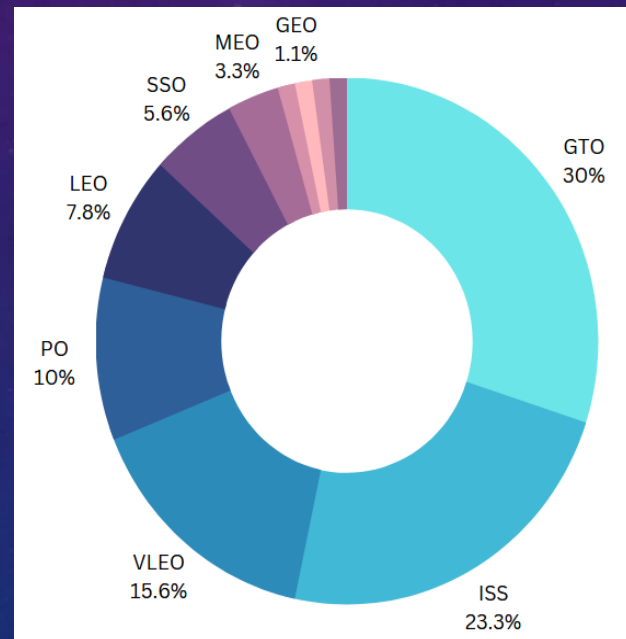


Created a landing outcome label from Outcome column

Jupyter notebook on Github
<https://github.com/ADGit-cmyk/NR/blob/main/labs-jupyter-spacex-Data%20wrangling.ipynb>

The orbital target of a rocket launch is essential in find out whether or not it will be successful. Rockets were launched up to different distances from the earth, but the two most common orbits were:

- Geosynchronous orbit (GTO) located at 22,236 miles (35,786 kilometers) above Earth's equator. It was the target of 27 out of 90 launches
 - International Space Station (ISS), for the purpose of resupplying astronauts. SpaceX provisioned the ISS through 21 launches.
- TRUE ASDS (meaning the mission outcome was successfully landed to a drone ship) was the most common outcome.



```
In [14]: df["Class"].mean()  
Out[14]: 0.6666666666666666
```

Using the `.mean()` function, we found out that the average success rate was 66%

EDA with Data Visualization

Training a machine learning model requires understanding on patterns and trends in relationships among different attributes. The comparisons made were the following:

- Flight Number and Launch Site
- Payload and Launch Site
- FlightNumber and Orbit type
- Payload and Orbit type

The following trends were observed, using bar and line plots:

- Launch success yearly trend
- Success rate of each orbit type

After analyzing the graphs, the columns most important for the analysis were: FlightNumber, PayloadMass, Orbit, LaunchSite, Flights, GridFins, Reused, Legs, LandingPad

Github Jupyter notebook can be found at <https://github.com/ADGit-cmyk/NR/blob/main/jupyter-labs-eda-dataviz.ipynb>

EDA WITH SQL

We performed queries in order to retrieve the following information:

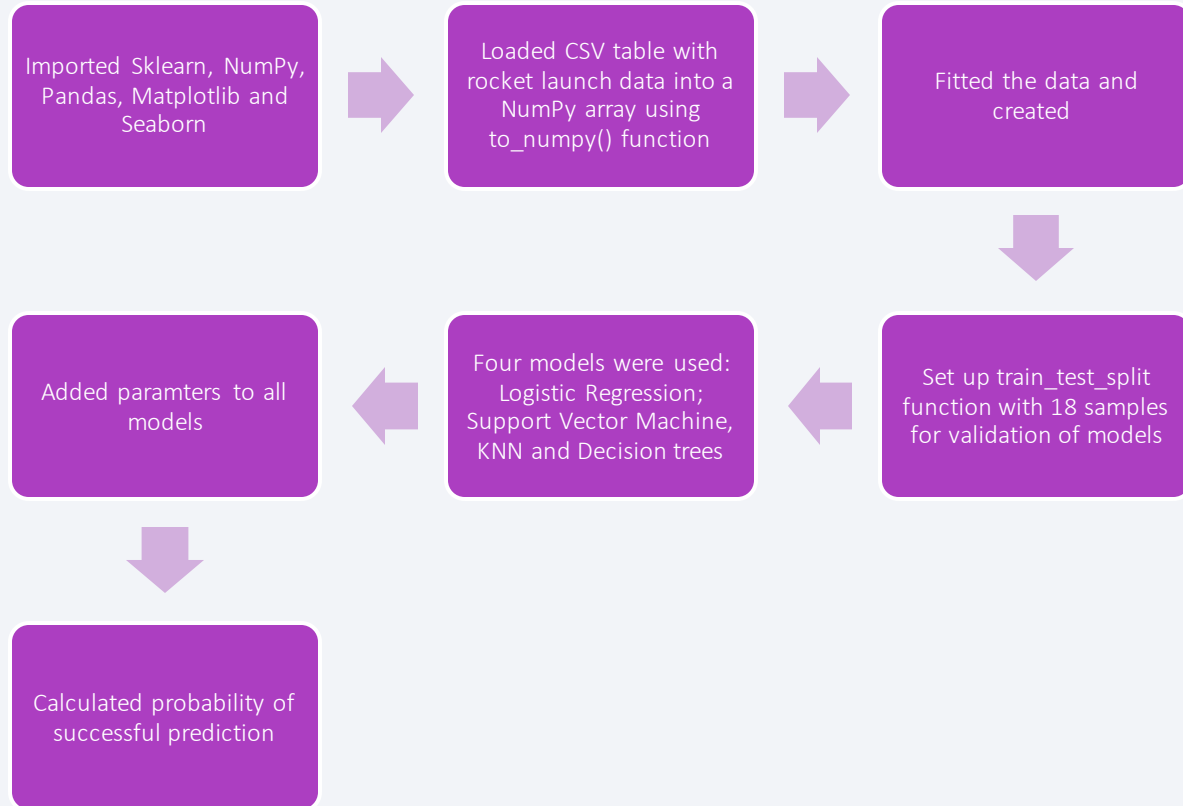
- Names of the unique launch sites in the space mission
- Five records where launch sites begin with the string 'CCA'
- The total payload mass carried by boosters launched by NASA (CRS)
- The average payload mass carried by booster version F9 v1.1
- Names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000
- Total number of successful and failure mission outcomes
- Names of the booster_versions which have carried the maximum payload mass. Use a subquery



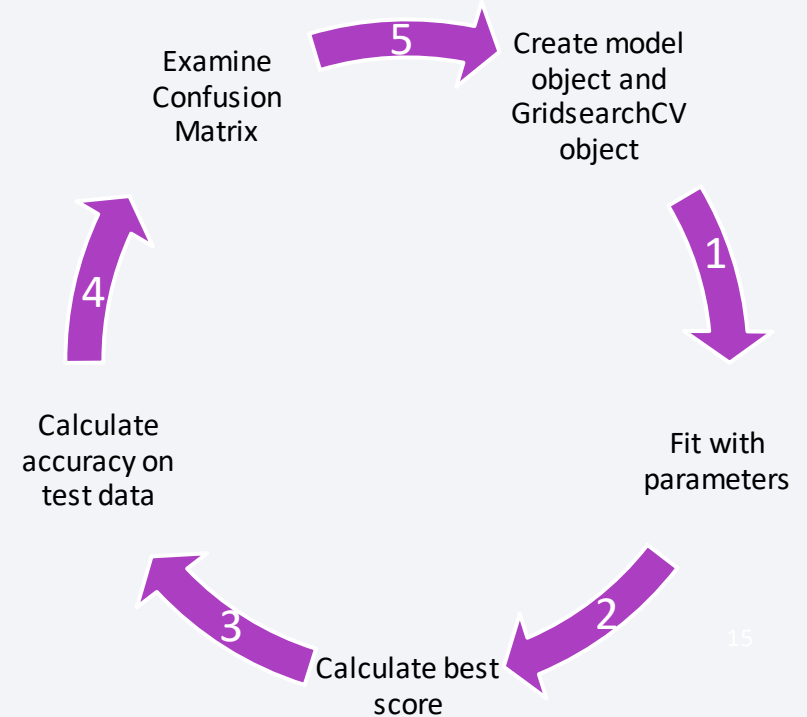
INTERACTIVE MAP WITH FOLIUM

- To identify the outcome for each launch site, the positive/negative outcomes were divided and marked with green and red respectively. Furthermore, the outcome marks for each launch pad were clustered.
- Lines were used to point out the distances between locations around the launch sites.
- Circles were used in order to observe where the launch sites actually are on the map
- Jupyter notebook on Github can be found at https://github.com/ADGit-cmyk/NR/blob/main/lab_jupyter_launch_site_location.ipynb

Predictive Analysis (Classification)



Lifecycle of Prediction Models



Github link for Jupyter Notebook:

https://github.com/ADGit-cmyk/NR/blob/main/SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb

RESULTS

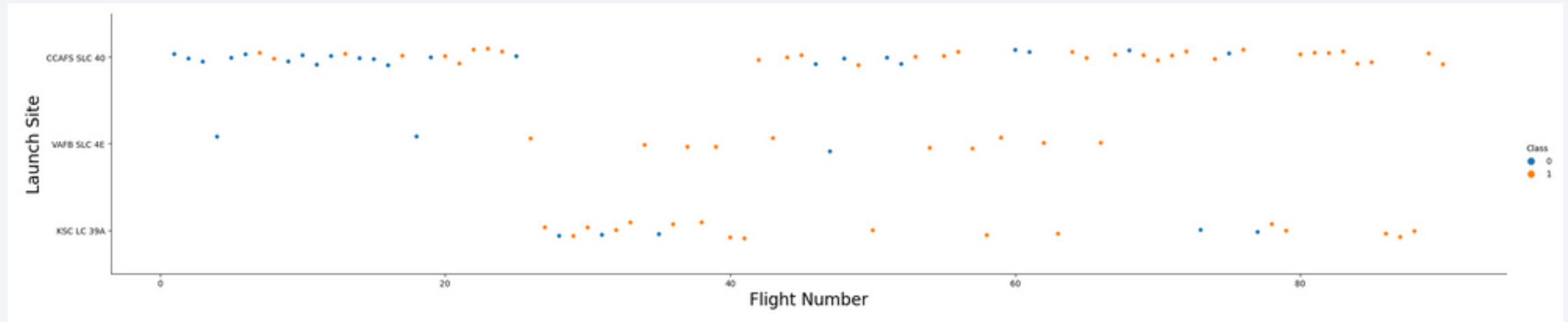
- A total of 90 launches were observed
- The decision-tree classifier method had the highest prediction accuracy at 88.75%
- The orbits ES-L1, GEO, HEO, SSO had success rates of 100%
- All cases where boosters did not land were accurately predicted by all models
- Standard deviation between Regression Model, SVM and K-Nearest Neighbour was $\sim 0.1\%$
- The success rate has dropped from 2019 to 2020, but it is still significantly higher compared to the first 3 years of launches

The background of the slide is an abstract composition. It features a dark blue field on the left side, which transitions into a complex pattern of diagonal streaks in shades of blue, red, and teal on the right. These streaks appear to be composed of many fine, overlapping lines, creating a sense of motion and depth. A faint, light-colored grid or mesh pattern is also visible, particularly in the upper right quadrant, adding a technical or digital feel to the design.

Section 2

Insights drawn from EDA

Flight Number vs. Launch Site

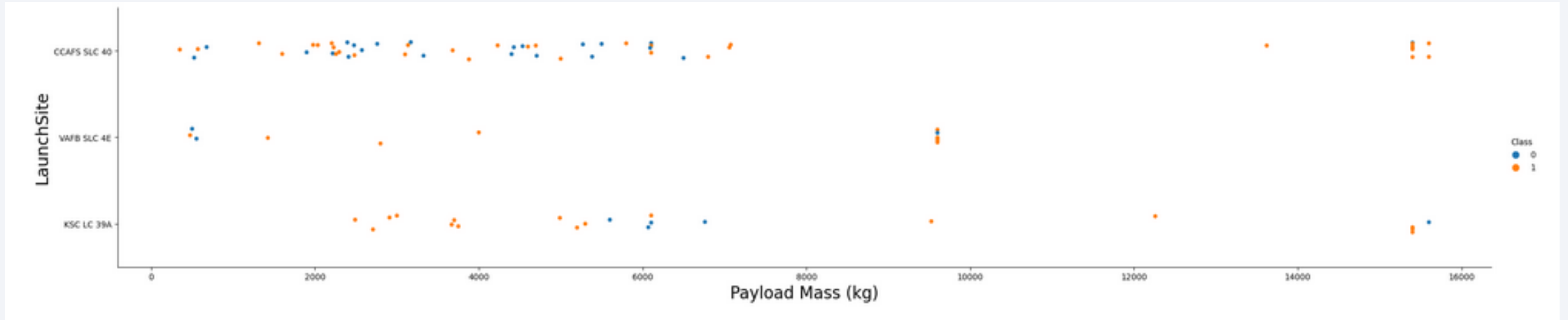


There is an upward trend in successful flights (class 1) as the flight number increases

The trend is positive regardless of the launch site

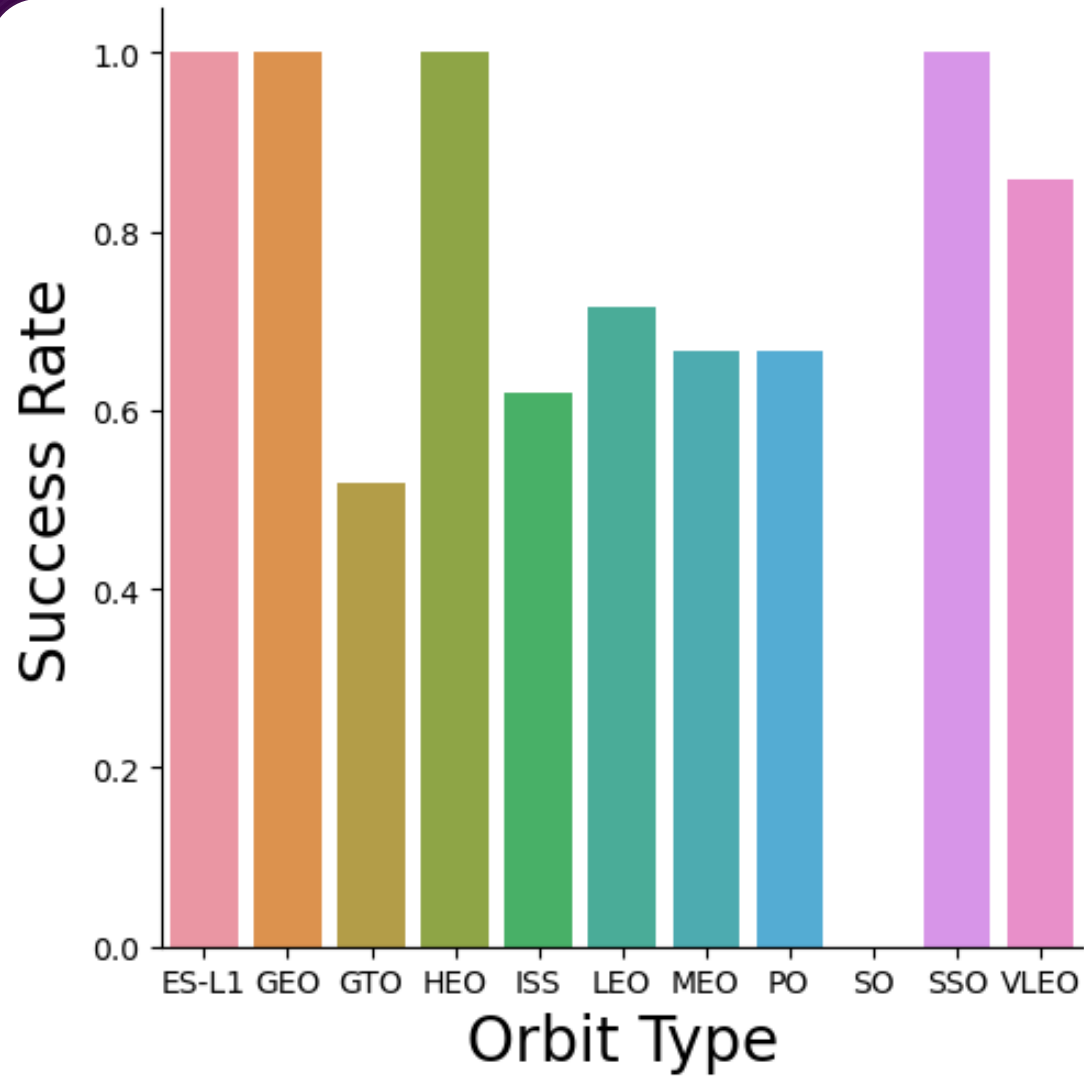
Launch site CCAFS SLC 40 has the largest number of successful launches

Payload vs. Launch Site



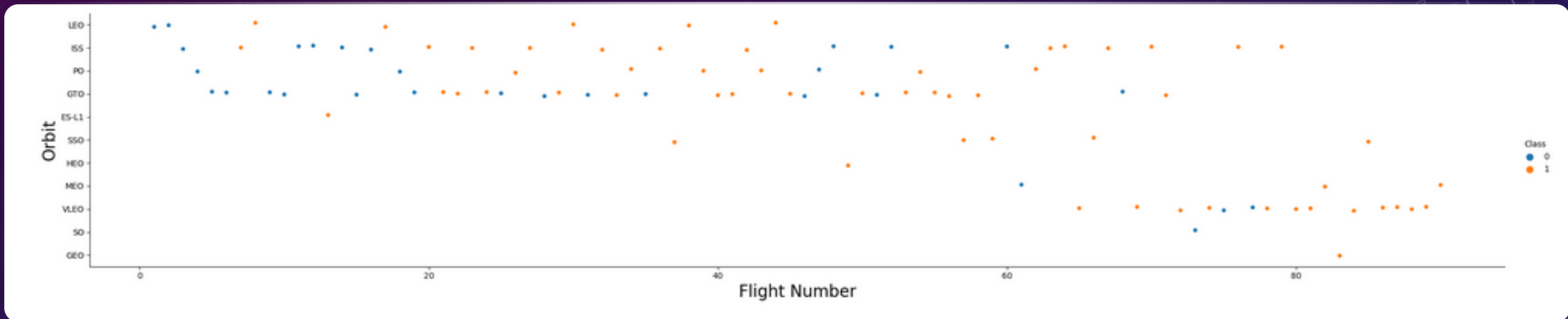
- Rockets launched from CCAFS SLC 40 pads with a payload above 8000kg are relatively more successful compared to those launched from KSC LC 39A. The opposite is true for a payload mass of less than 8000kg
- A correlation exists between higher payloads and successful launches and retrievals of 1st booster.

SUCCESS RATE VS. ORBIT TYPE

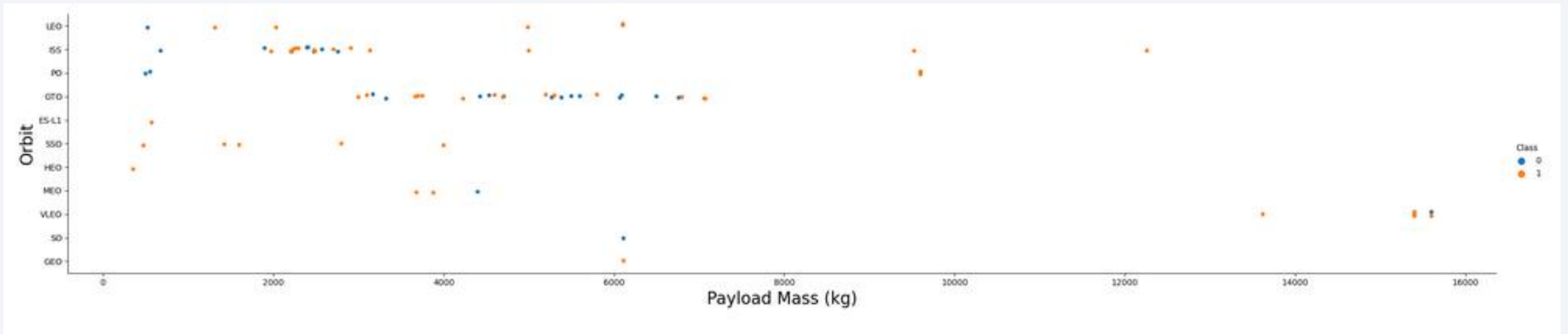


- Only 1 orbit type has a failure rate of 0%, while 4 orbit types have a success rate of 100%
- GEO and SO only have 1 flight sample each which makes it difficult to compare it to other values

FLIGHT NUMBER VS. ORBIT TYPE



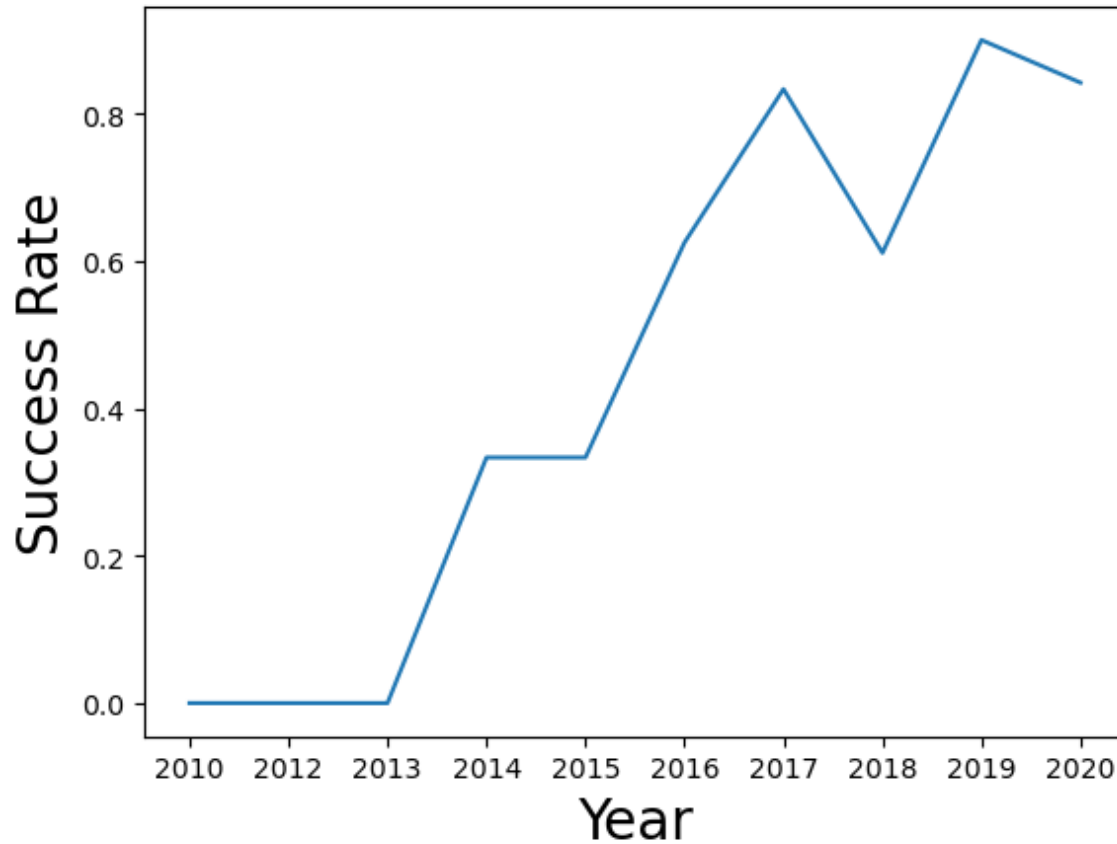
Payload vs. Orbit Type



- Mass payloads between 14,000kg and 16,000kg are more successful when launched towards VLEO compared to launches with a mass payload between 0kg and 2000kg for PO orbit

LAUNCH SUCCESS YEARLY TREND

- The success rate has dropped from 2019 to 2020, but it is still significantly higher compared to the first 3 years of launches and slightly above 2017 level



ALL LAUNCH SITE NAMES

```
In [7]: %sql SELECT DISTINCT LAUNCH_SITE FROM SPACEXTBL;
```

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

```
Out[7]:
```

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

- According to the query, SpaceX has used 4 launch sites so far:
 - CCAFS LC-40
 - VAFB SLC-4E
 - KSC LC-39A
 - CCAFS SLC-40

LAUNCH SITE NAMES BEGIN WITH 'CCA'

```
In [12]: %sql SELECT * FROM SPACEXTBL WHERE LAUNCH_SITE LIKE 'CCA%' LIMIT 5;
```

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

```
Out[12]:
```

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

- Limiting the results to 5, we can see the records from which pads the rockets were launched from, with name beginning with the letters 'CCA'

Total Payload Mass

```
In [17]: %sql SELECT SUM(PAYLOAD_MASS__KG_) as Total_Payload_Mass from SPACEXTBL
```

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

```
Out[17]: Total_Payload_Mass
```

619967

- SpaceX has carried almost 620t of payload to space according to the recorded data

Average Payload Mass by F9 v1.1

```
In [18]: %sql SELECT AVG(PAYLOAD_MASS__KG_) AS AVG_PAYLOAD FROM SPACEXTBL WHERE BOOSTER_VERSION = 'F9 v1.1';
```

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

```
Out[18]:  AVG_PAYLOAD
```

2928.4

- The average payload mass for booster version F9 v1.1 is 2928.4kg, almost 4 tons.

Total Number of Successful and Failure Mission Outcomes

```
sql SELECT MISSION_OUTCOME, COUNT(*) AS QTY FROM SPACEXTBL GROUP BY MISSION_OUTCOME ORDER BY MISSION_OUTCOME;
```

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

```
Done.
```

Mission_Outcome	QTY
Failure (in flight)	1
Success	98
Success	1
Success (payload status unclear)	1

- According to the query, there have been 100 successful missions with only 1 failure

Boosters Carried Maximum Payload

```
In [35]: %sql SELECT DISTINCT BOOSTER_VERSION FROM SPACEXTBL WHERE PAYLOAD_MASS_KG_ = (SELECT MAX(PAYLOAD_MASS_KG_) FROM SPACEXTBL)
Out[35]:
```

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

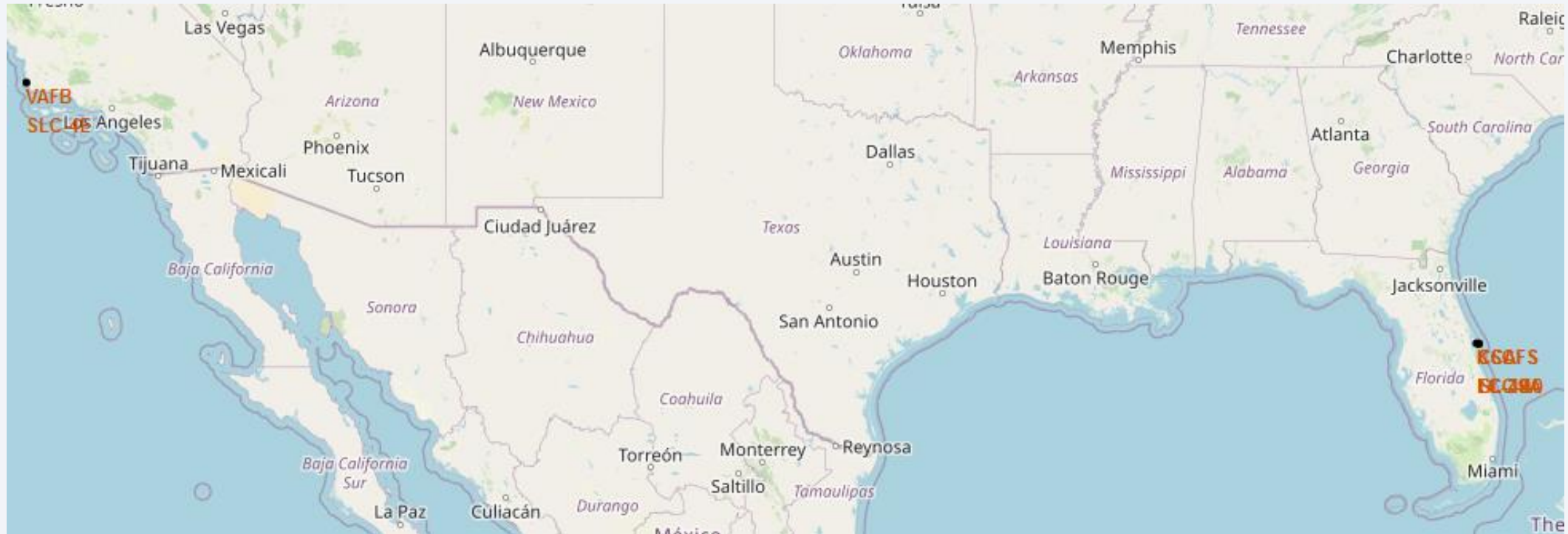
- Booster F9 B5 B1048.4 has carried the highest payload to space

A satellite view of Earth from space, showing the curvature of the planet and city lights at night. The background is a deep blue gradient.

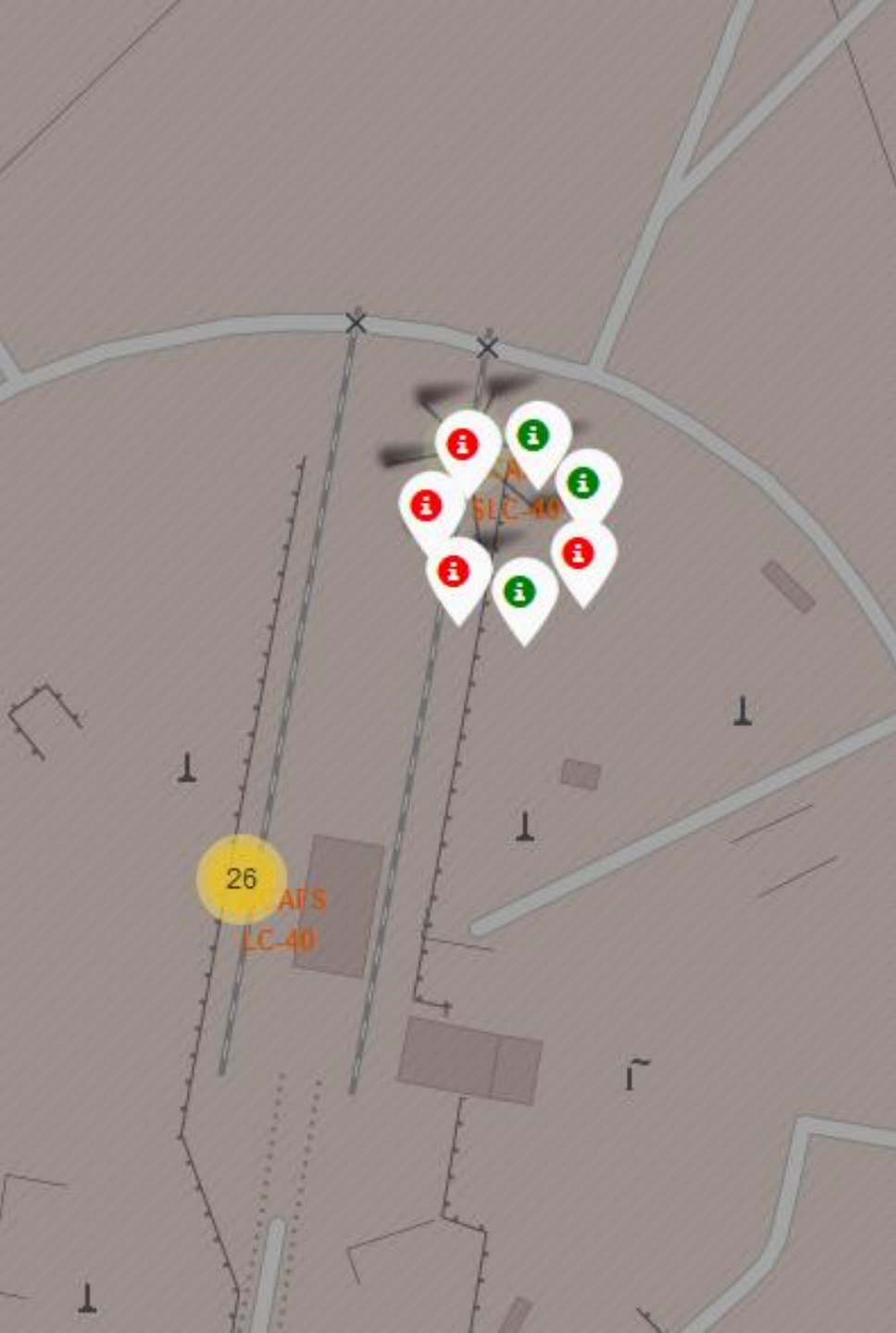
Section 3

Launch Sites Proximities Analysis

Location of Space launch pads – On Map



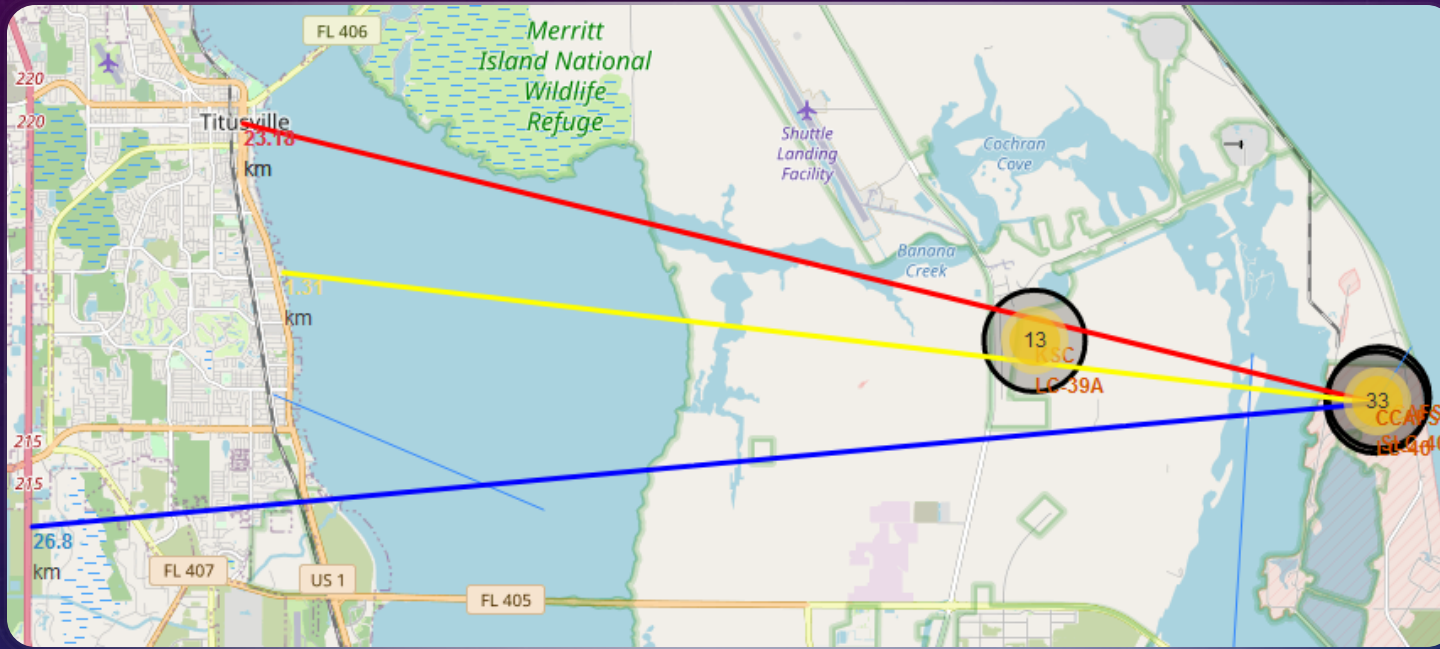
- Both launch pad clusters are on the Eastern and Western coasts respectively



OUTCOMES - ON MAP

- The green-colored marks represent successful launches, while the red represent failures.
- The cluster is tied to the launchpad CCAFS SLC-40

PROXIMITY OF LOCATIONS TO LAUNCHPAD – ON MAP



- The distance between CCAFS SLC-40 launch site and the city of Titusville, I-95 highway and Titus postal office are 23.18km, 26.8km and 21.31km respectively



Section 5

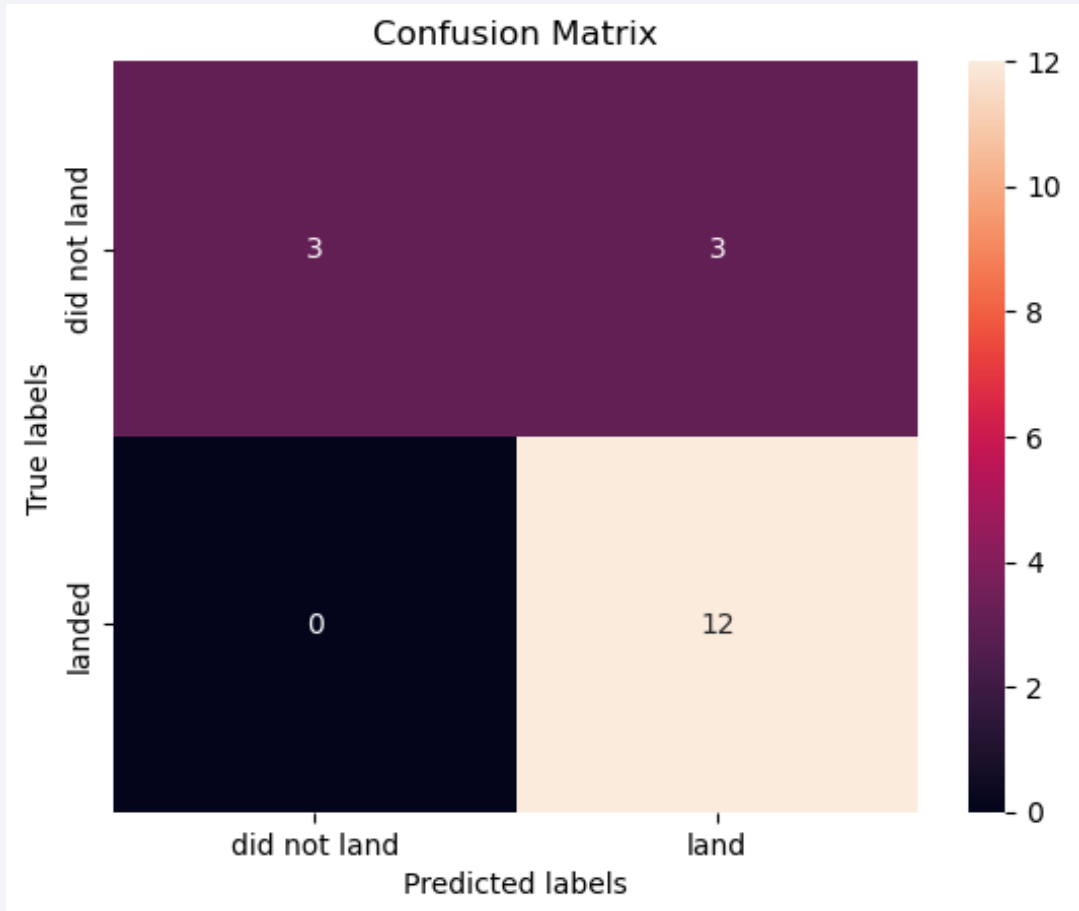
Predictive Analysis (Classification)

CLASSIFICATION ACCURACY

Model	Accuracy	TestAccuracy
LogReg	0.84643	0.83333
SVM	0.84821	0.83333
Tree	0.8875	0.83333
KNN	0.84821	0.83333

- The Logistic Regression model had the lowest overall accuracy while the Decision-Tree Classification model had the highest.

Confusion Matrix



- The matrix shows that the model accurately predicted all launches from which boosters did not land, while it had an 80% accuracy rate in predicting the launches where the boosters did land.

CONCLUSIONS

- The Decision-Tree Classification model is the most optimized for predicting future outcomes based on information gathered from this dataset
- Given the annual growth of successful launches since 2013 and a predictive model with a high accuracy, we expect more launches where the boosters will be successfully retrieved
- Launchpad CCAFS SLC 40 has the largest number of successful launches

Thank you!

