IBM Developer
SKILLS NETWORK

Winning space race with data science

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Outline

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

Executive Summary

Summary of methodologies

Data was collected from the SpaceX public API and publically available data on Wikipedia. Data wrangling included extracting launch outcome information to serve as the dependent variable in the Machine Learning models. SQL queries and data visualizations (static plots, interactive maps, and an interactive dashboard) were created to discover insights about the data set and answer questions. Predictive analysis was pursued using Logistic Regression, SVM (Support Vector Machine), Decision Tree, and KNN (k-Nearest Neighbors) Machine Learning models.

Summary of all results

Machine learning models on the data set were performed equally. Launch data included information about flight number, date of launch, payload mass, orbit type, launch site, mission outcome and other variables. Logistic Regression, SVM (Support Vector Machine), and KNN (k-Nearest Neighbors).

Introduction

Having undertaken the role of a Data Scientist, I have been tasked to predict if the Falcon 9 first stage will land successfully. SpaceX advertises Falcon 9 rocket launches on its website with a cost of US$62 million. Other provider's cost is around US$ 165 million each, much of the which due to the first stage reuse by SpaceX. The first stage is determined through successful rocket landings and the factors that contributed to the success or failure. This presentation aims at understanding the launch performances of Falcon 9 that are also applied to other rockets, where Data Science have been useful in improving the future space exploration endeavours.

Problems

Firstly, we develop the problem statements to ascertain the objective of this project and they are as such:

- Conditions will the rocket be able to land safely

- Effects of each relationship of rocket variables on outcome

- Criteria that will aid SpaceX to achieve best results

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  Data is compiled through SpaceX API and web scrapping from Wikipedia. Data was cleaned to prepare for visualisation, queries and machine learning model creation

- Perform data wrangling
  One hot encoding data fields for machine learning and dropping irrelevant columns (Transforming data for Machine Learning).

Methodology (cont'd)

- Perform exploratory data analysis (EDA) using visualization and SQL
  Visualisations such as scatter and bar plots that show data behaviour

- Perform interactive visual analytics using Folium and Plotly Dash
  Such as Folium and Plotly Dash visualization

- Perform predictive analysis using classification models
  Develop and assess classification models

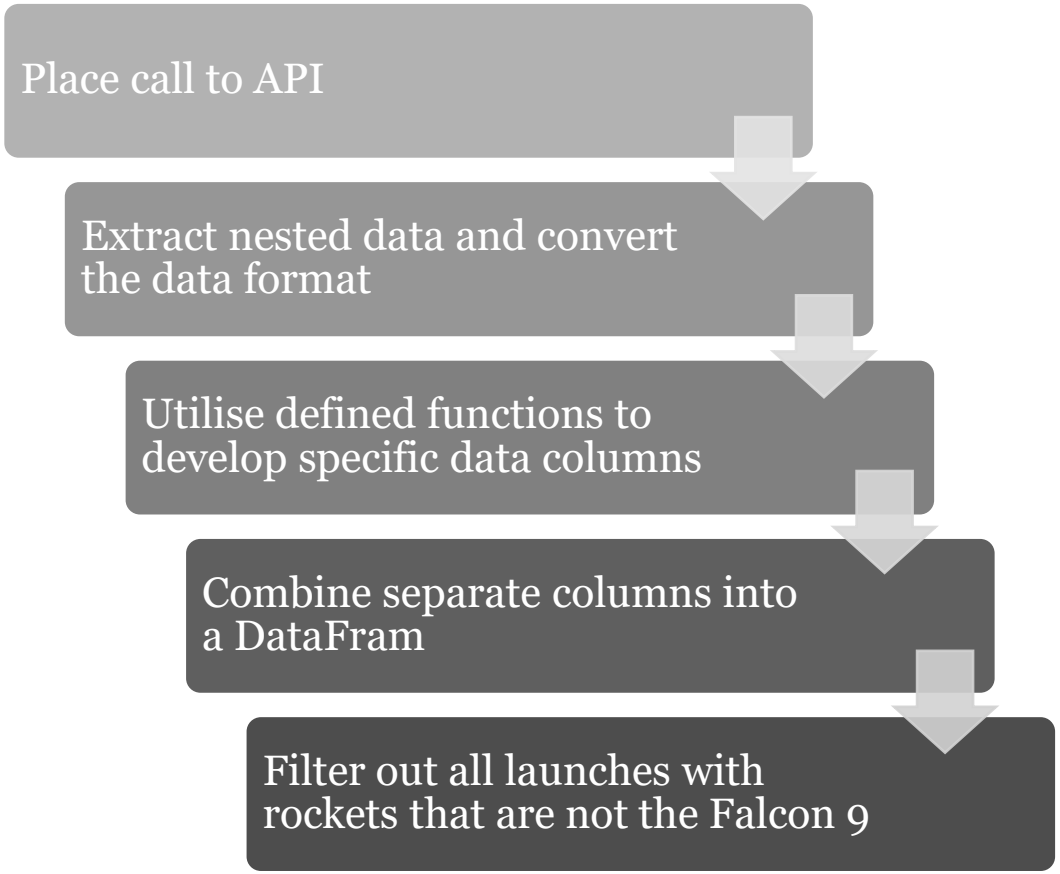
Data collection

Getting data from API or webpage → Develop data frame → Filter data frame according to requirement → Export to flat file (csv)

Data collection entails information gathering process from an established system. Collected data is used to Explanation relevant questions and evaluated the outcomes. Data collection process for this project includes using get request to the SpaceX API. Data is decoded the response content as a Json using .json() function call and turn it into a pandas dataframe using .json_normalize(). Data undergoes cleaning and checked for missing values and fill in missing values where necessary. Then, web scraping is performed from Wikipedia for Falcon 9 launch records with BeautifulSoup. The objective is to extract the launch records as HTML table, parse the table and convert it to a pandas data frame for future analysis.

Data Collection – SpaceX API

SpaceX API Calls Flowchart



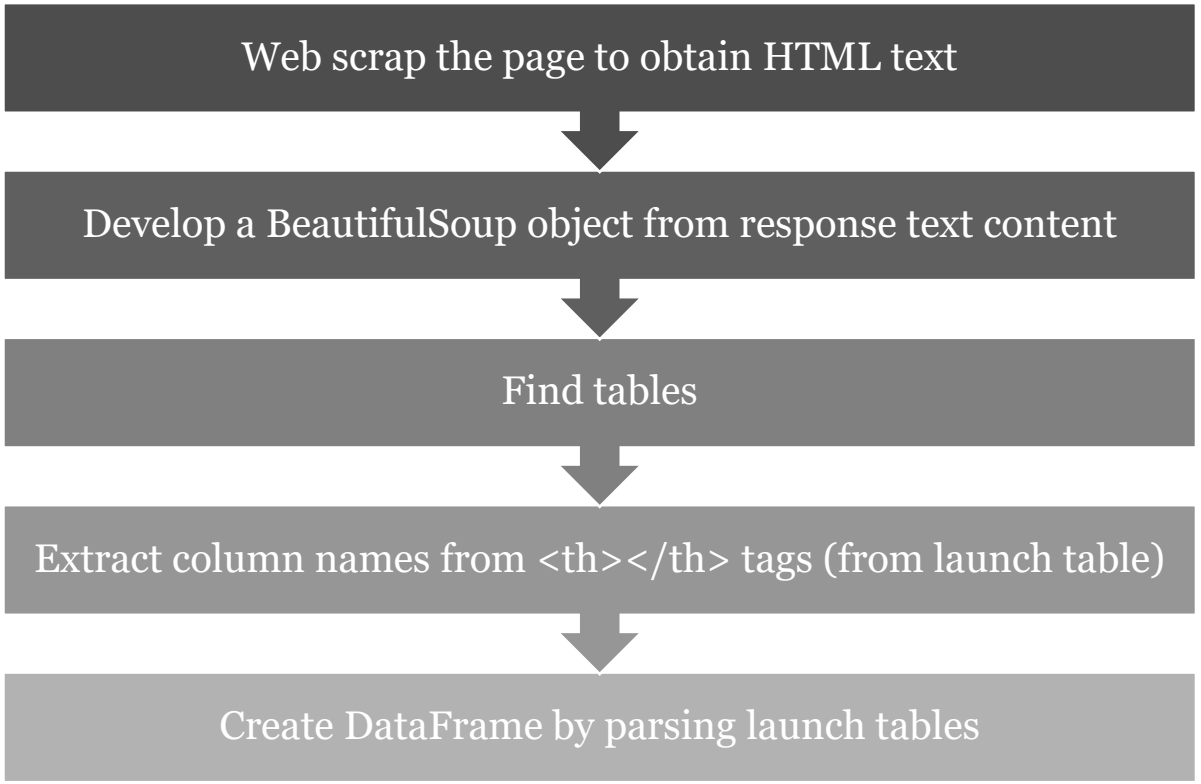
The SpaceX API data is publicly available, where a GET request was made to the SpaceX API. Once response was received, further analysis was performed when the data was placed into a Pandas DataFrame

GitHub URL (Data Collection):

https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%201(A)%20Data%20collection%20API%20checkpoint.ipynb

Data Collection – Scraping

Web Scraping Flowchart



Wikipedia contains tables of data about SpaceX launches and these tables were scraped to extract launch data. Then, the data were placed into a Pandas DataFrame for further analysis.

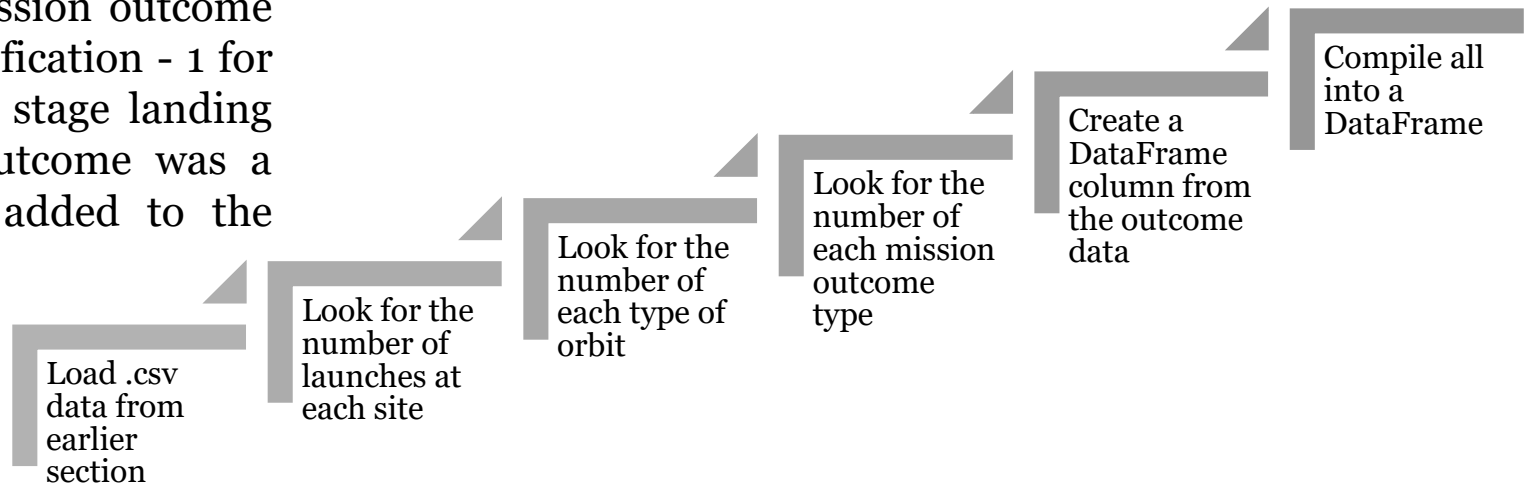
GitHub URL (Web Scraping):

https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%201(B)%20Data%20Collection%20with%20Web%20Scraping%20lab.ipynb

Data Wrangling

The .csv file from the first section contains the data that needed to be cleaned. Details cleaned were such as orbit types, mission outcomes and launch sites, orbit types and mission outcomes. Mission outcome types were translated to a binary classification - 1 for the outcome where the Falcon 9 first stage landing was successful and “0” where the outcome was a failure. This new classification was added to the DataFrame for further analysis.

Data Wrangling Flowchart



GitHub URL (Data Wrangling):
https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%201(C)%20Data%20Wrangling.ipynb

EDA with Data Visualisation

- **The following charts were created to look at Launch Site trends**
  Scatterplot - **mission outcome** relationship via **Launch Site** and **Flight Number**.
  Scatterplot - **mission outcome** relationship via **Launch Site** and **Payload**.

- **The following charts were created to look at Orbit Type trends.**
  Bar chart - **mission outcome** relationship with **Orbit Type**.
  Scatterplot - **mission outcome** relationship via **Orbit Type** and **Flight Number**.
  Scatterplot - **mission outcome** relationship via **Orbit Type** and **Payload**.

- **The following chart was created to look at trends based on time.**
  Line plot - **mission outcome** trend with **year**.

GitHub URL (EDA with Data Visualisation): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%202(B)%20EDA%20with%20Visualisation%20lab.pdf

EDA with SQL

Queries were written to extract information about:

- Date
- Booster types
- Launch sites
- Mission outcomes
- Payload masses

GitHub URL (EDA with SQL): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%202(A)%20EDA%20with%20SQL%20(2).ipynb

Build an Interactive Map with Folium

Markers, circles and lines were added to the Folium map for the reasons below:

- **Markers** for launch sites and for the NASA Johnson Space Center.
- **Circles** for the launch sites.
- **Lines** to show the distance to the nearby features:
  - Distance from CCAFS LC-40 to the coastline
  - Distance from CCAFS LC-40 to the rail line
  - Distance from CCAFS LC-40 to the perimeter road

GitHub URL (Folium Maps): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%203A%20Interactive%20Visual%20Analytics%20with%20Folium%20lab.pdf

Build a Dashboard with Plotly Dash

- The **pie chart** displays the below attributes:
  (1) For One Site –successful and failed Falcon 9 first stage landings distribution of this specific site
  (2) For All Sites –successful Falcon 9 first stage landings distributions between the sites

- **The input slider**: is used to refine the payload masses result of the scatterplot.

- **The input dropdown:** is used to pick one or all launch sites represented by the pie chart and scatterplot.

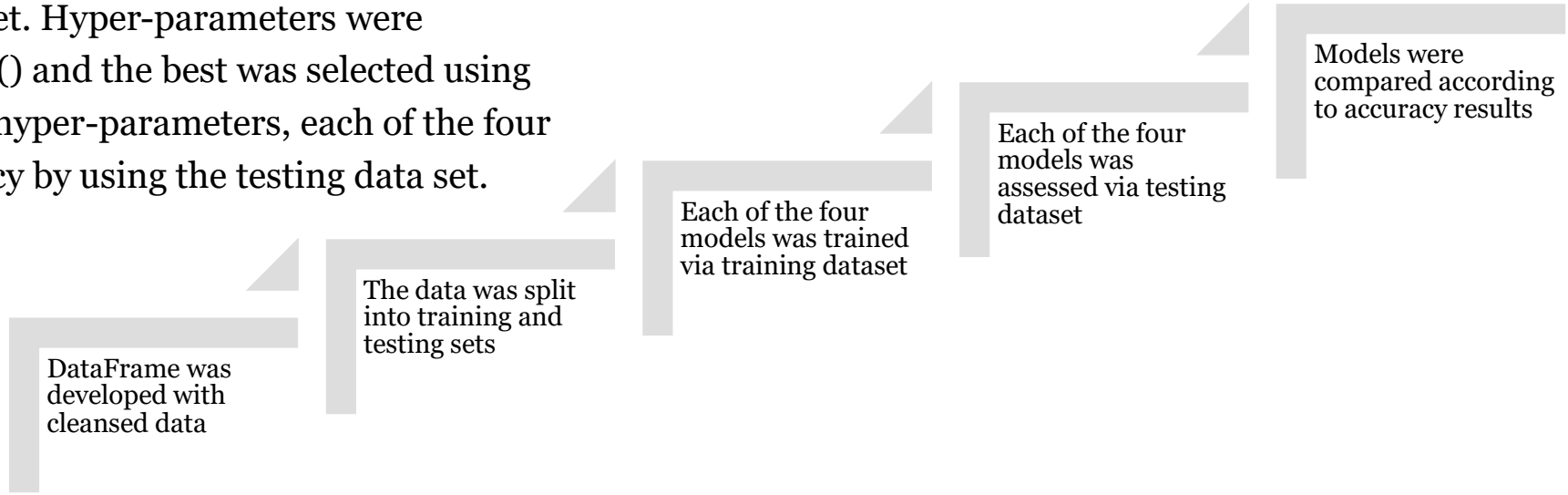
- The scatterplot: shows Falcon 9 first stage landings distribution divided via booster version category, mission outcomes and payload mass.

GitHub URL (Dashboard File): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%203(B)Plotly%20Dash.py

Predictive Analysis (Classification)

The dataset was split into training and testing sets. Logistic Regression, Support Vector Machine (SVM), decision tree and k-Nearest Neighbors (KNN) machine learning models were trained on the training data set. Hyper-parameters were assessed using GridSearchCV() and the best was selected using '.best_params_'. From these hyper-parameters, each of the four models was scored on accuracy by using the testing data set.

Machine Learning Flowchart



GitHub URL (Machine Learning):
https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%204%20Machine%20Learning%20Prediction%20lab.pdf

Results

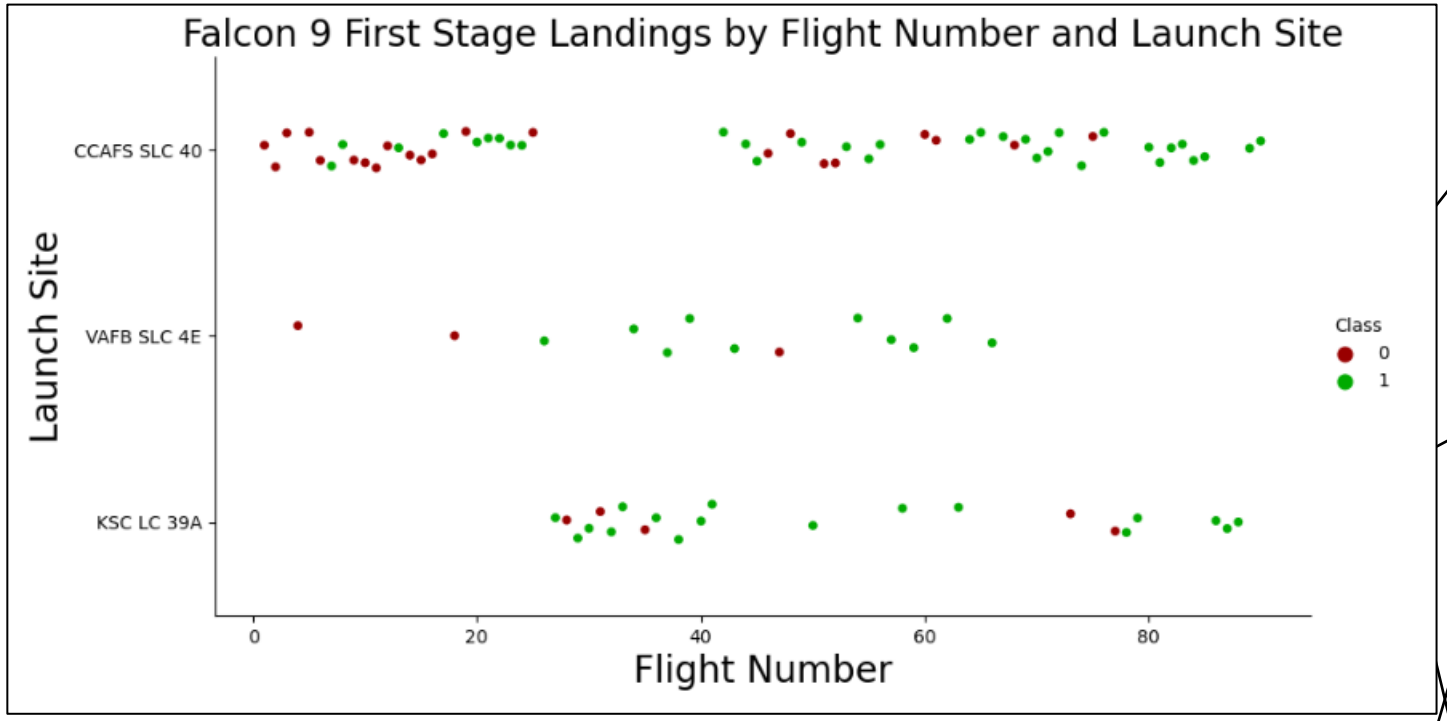
- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

Section 2

Data insights drawn from EDA

Flight Number vs. Launch Site

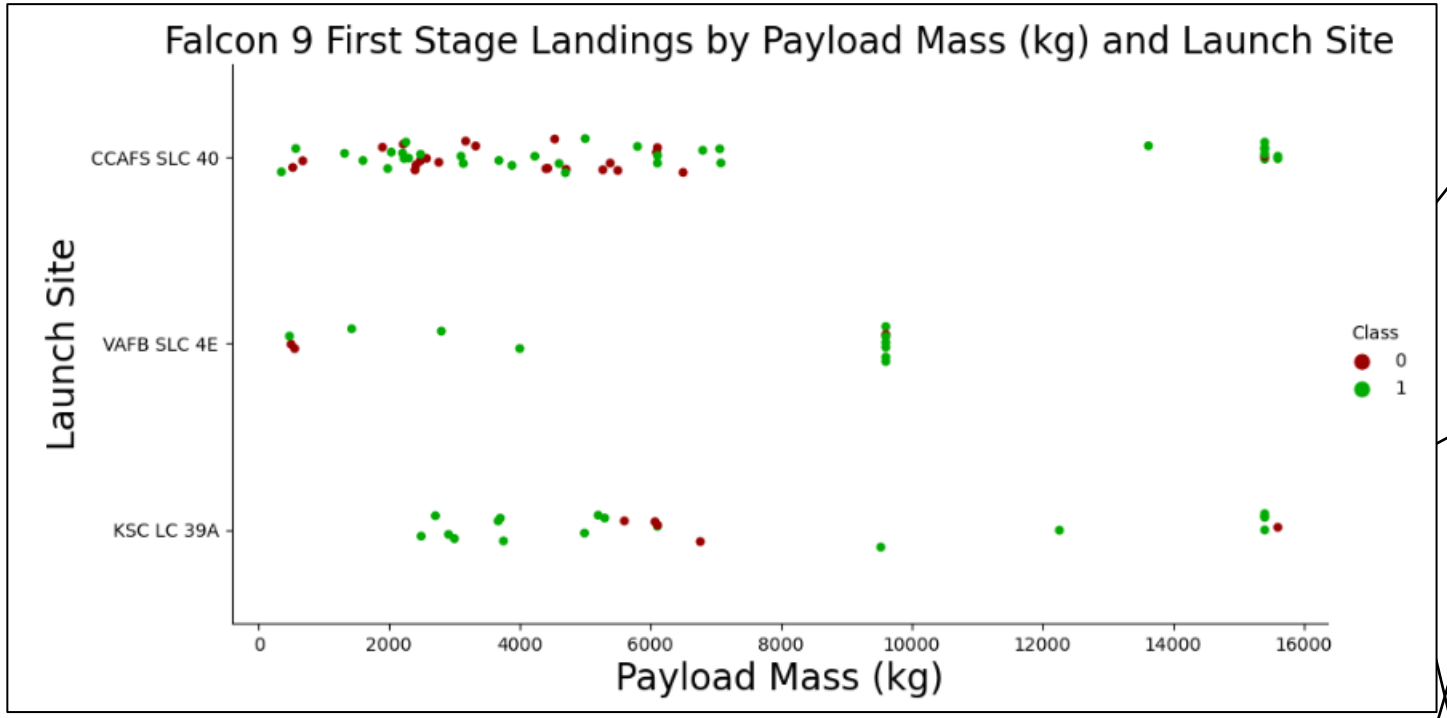
- Success outcomes prominently differs with launch site.
- As the flight number increases, the first stage landings of Falcon 9 appears to be successful.
- This relationship tells us that the more frequent the flight number, the more successful the landings.



Falcon 9 first stage failed landings are indicated by the '0' class (red markers) and successful landings by the '1' class (green markers)

Payload vs. Launch Site

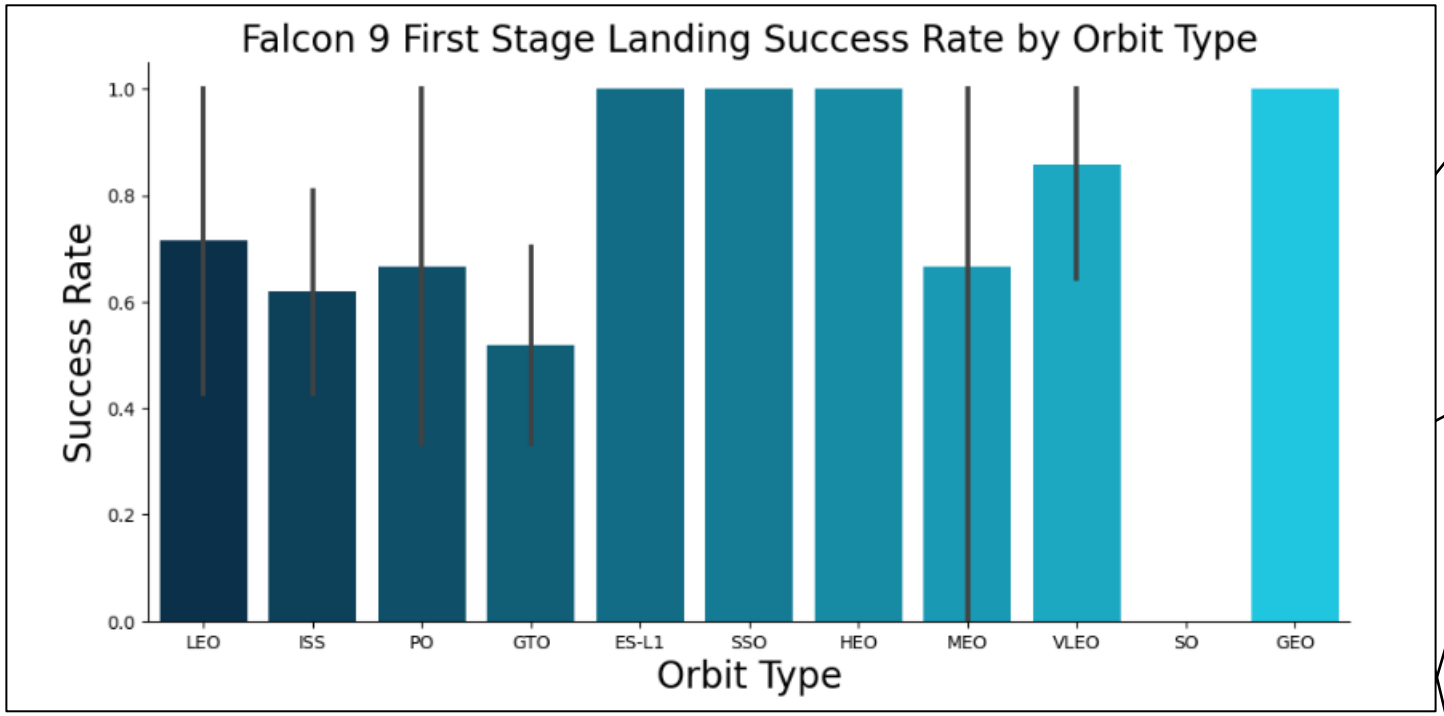
- For the CCAFS SLC 40 launch site, the payload mass and the landing outcomes appear to not be strongly correlated.
- The failed landings at the KSC LC 39A launch site is shown in the scatter plot through a group of a narrow band of payload masses.



Falcon 9 first stage failed landings are indicated by the '0' class (red markers) and successful landings by the '1' class (green markers)

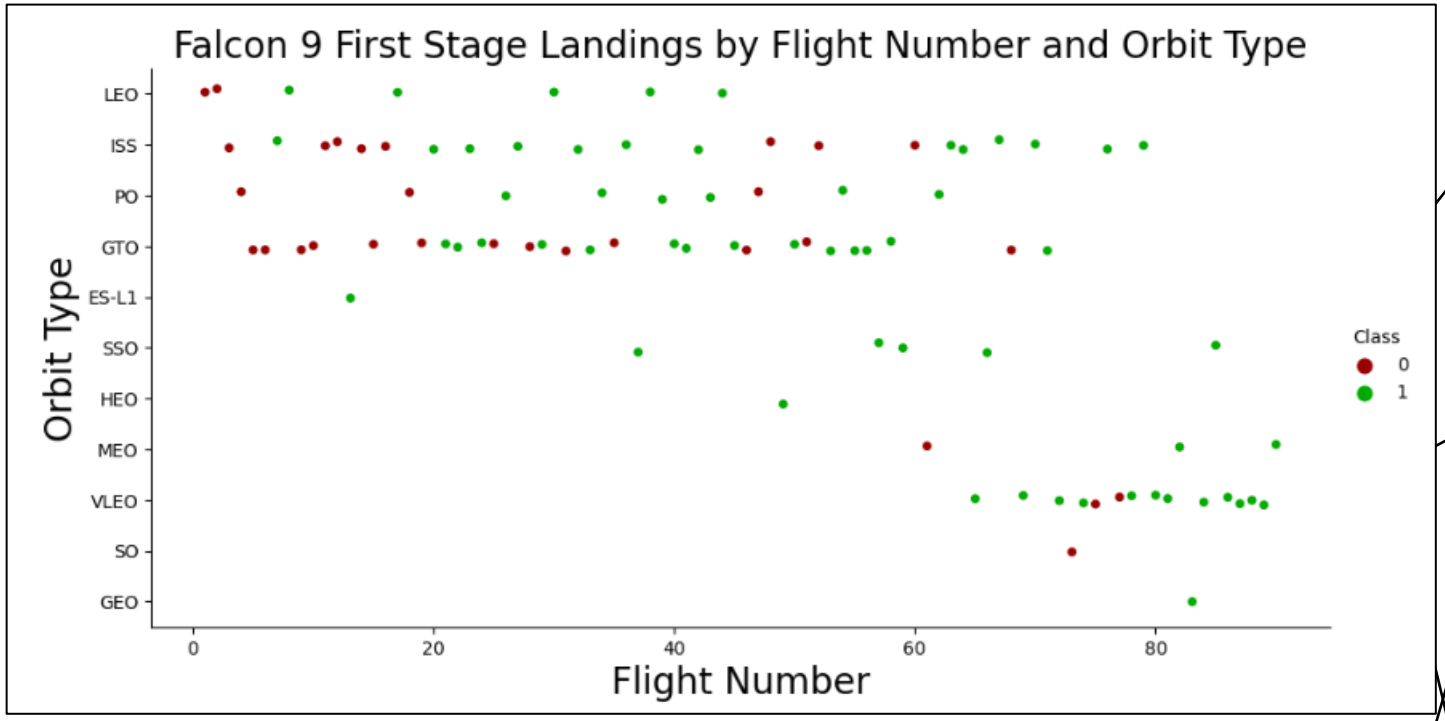
Success Rate vs. Orbit Type

- There are four orbits that have the highest success rate of stage landing for Falcon 9 which are the ES-L1, SSO, HEO and GEO.
- The rate of success of first stage landing for SO is nill. Only SO has no successful first stage landing.



Flight Number vs. Orbit Type

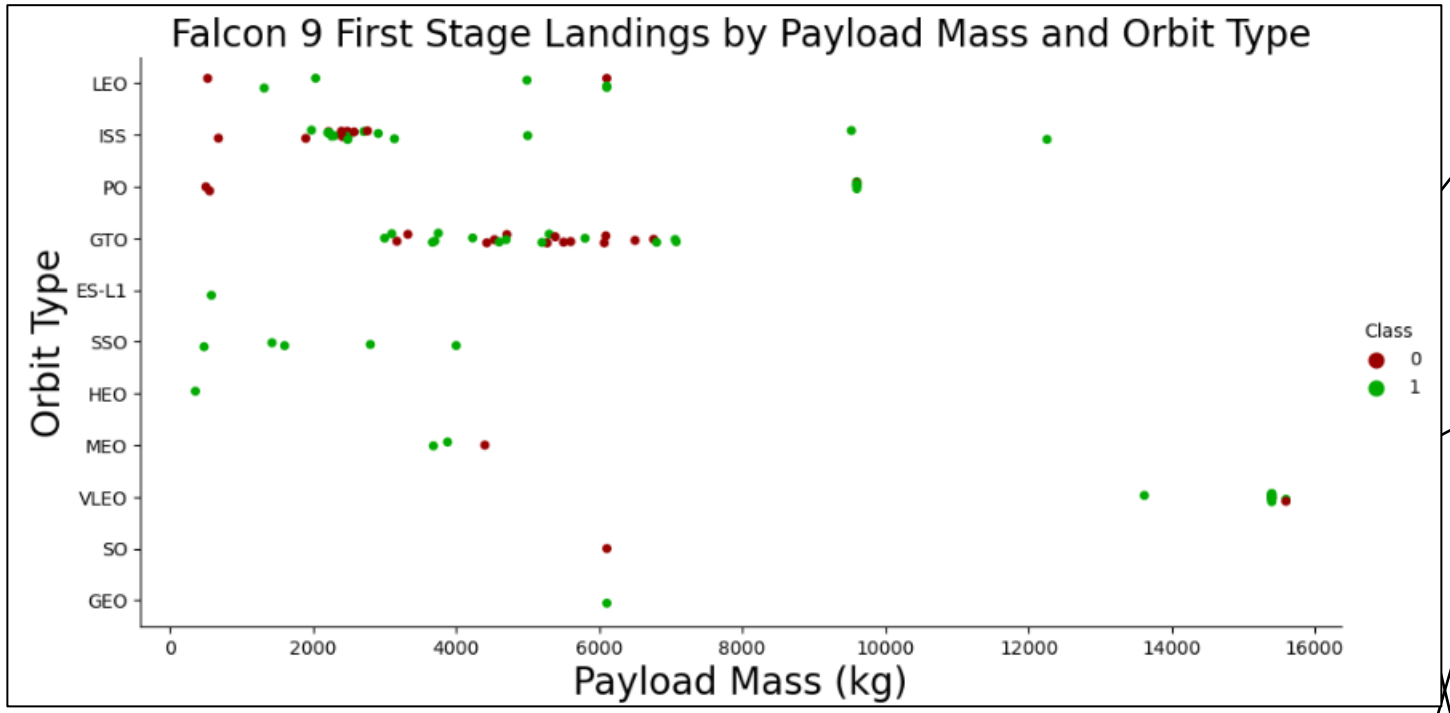
- There is a correlation between flight number and success rate with larger flight numbers being associated with higher success rates



Falcon 9 first stage failed landings are indicated by the ‘0’ class (red markers) and successful landings by the ‘1’ class (green markers)

Payload vs. Orbit Type

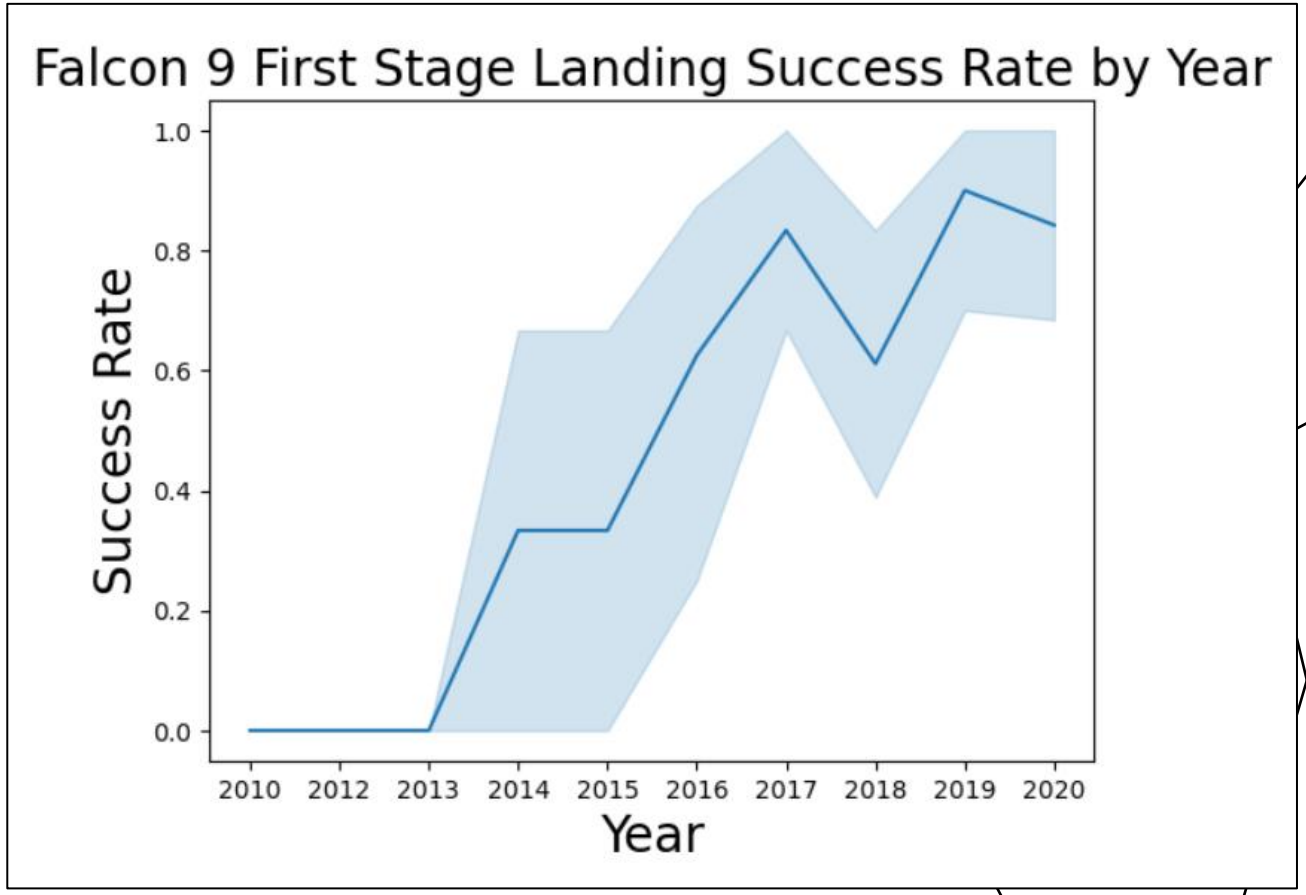
- Some orbit types have better success rates than others.
- Success rate appears to have no obvious correlation with payload mass.



Falcon 9 first stage failed landings are indicated by the '0' class (red markers) and successful landings by the '1' class (green markers)

Launch Success Yearly Trend

- The line chart shows an increasing trend of success rate. This appears to be significant over the years given several first stage landing and launches.



All Launch Site Names

- Task: What are the names of the unique launch sites?
- Query: SELECT DISTINCT LAUNCH_SITE FROM SPACEXDATASET;
- Result:

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

- Explanation: There are four unique launch sites.

Launch Site Names Begins with ‘CCA’

- Task: Find 5 records with launch sites that begin with `CCA`.
- Query: SELECT * FROM SPACEXDATASET WHERE launch_site LIKE 'CCA%' LIMIT 5;
- Result:

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

- Explanation: This sampling mechanism is used to gather pattern of the data from the database table. Launch Site Names That Begin with 'CCA' SELECT * FROM SPACEXDATASET WHERE launch_site LIKE 'CCA%' LIMIT 5;

Total Payload Mass

- Task: What is the total payload mass carried by booster from Nasa
- Query: SELECT sum(payload_mass__kg_) AS "Total Payload Mass (kg)" FROM SPACEXDATASET WHERE customer LIKE '%NASA (CRS)%';
- Result:

Total Payload Mass (kg)
48213

- Explanation: The total payload carried by boosters from NASA is 48,213 kg

Average Payload Mass by F9 v1.1

- Task: What is the average payload mass carried by booster version F9 v1.1?
- Query: SELECT sum(payload_mass__kg_) / count(payload_mass__kg_) AS “Average Payload Mass (kg)"
  FROM SPACEXDATASET WHERE booster_version LIKE 'F9 v1.1';
- Result:

Average Payload Mass (kg)
2928

- Explanation: The average payload mass carried by booster version F9 v1.1 is 2,928 kg

First Successful Ground Landing Date

- Task: On which date did the first successful landing outcome on ground pad occur?
- Query: SELECT min(DATE) AS "First Successful Landing Outcome Date" FROM SPACEXDATASET
  WHERE landing__outcome LIKE 'Success (ground pad)';
- Result:

First Successful Landing Outcome Date
2015-12-22

- Explanation: The first successful landing outcome on ground pad occurred on 22 December 2015.

Successful Drone Landing with Payload between 4000 and 6000

- Task: What are the names of the boosters which have successfully landed on drone ship and had a payload mass greater than 4000 but less than 6000?
- Query: SELECT DISTINCT booster_version FROM SPACEXDATASET WHERE landing__outcome = 'Success (drone ship)' and payload_mass__kg_ BETWEEN 4000 and 6000;
- Result:

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

- Explanation: The four booster versions that have successfully landed on drone ship with a payload mass greater than 4,000 kg but less than 6,000 kg are listed above.

Total Number of Successful and Failure Mission Outcomes

- Task: What was the total number of successful and failed mission outcomes?
- Query: SELECT (SELECT count(*) FROM SPACEXDATASET WHERE lcase(landing__outcome) LIKE '%success%') AS "Success“, count(*) AS "Failure" FROM SPACEXDATASET WHERE lcase(landing__outcome) NOT LIKE '%success%';
- Result:

Success	Failure
61	40

- Explanation: There were 61 successful and 40 failed mission outcomes

Boosters Carried Maximum Payload

- Task: What were the names of the boosters which have carried the maximum payload mass?
- Query: SELECT booster_version, payload_mass__kg_ FROM SPACEXDATASET WHERE payload_mass__kg_ = (SELECT max(payload_mass__kg_) FROM SPACEXDATASET);
- Result:

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

Explanation: The maximum payload mass carried is 15,600 kg. Twelve separate Falcon 9 boosters carried this amount of payload mass.

2015 Launch Records

- Task: List the failed landing_outcomes in drone ship, their booster versions, and launch site names for records in year 2015.
- Query: SELECT MONTHNAME(DATE) AS “Month”, landing__outcome, booster_version, launch_site FROM SPACEXDATASET WHERE landing__outcome = 'Failure (drone ship)' AND YEAR(DATE) = 2015;
- Result:

Month	landing__outcome	booster_version	launch_site
January	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
April	Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40

- Explanation: There were two failed landing outcomes with a drone ship in 2015. Both launched from CCAFS LC-40 - one occurred in January and the other in April.

Rank Landing Outcomes between 2010-06-04 and 2017-03-20

- Task: 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.
- Query: SELECT landing__outcome, count(landing__outcome) AS "Count" FROM SPACEXDATASET WHERE DATE BETWEEN '2010-06-04' AND '2017-03-20' GROUP BY landing__outcome ORDER BY count(landing__outcome) DESC;
- Result:

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
Precluded (drone ship)	1

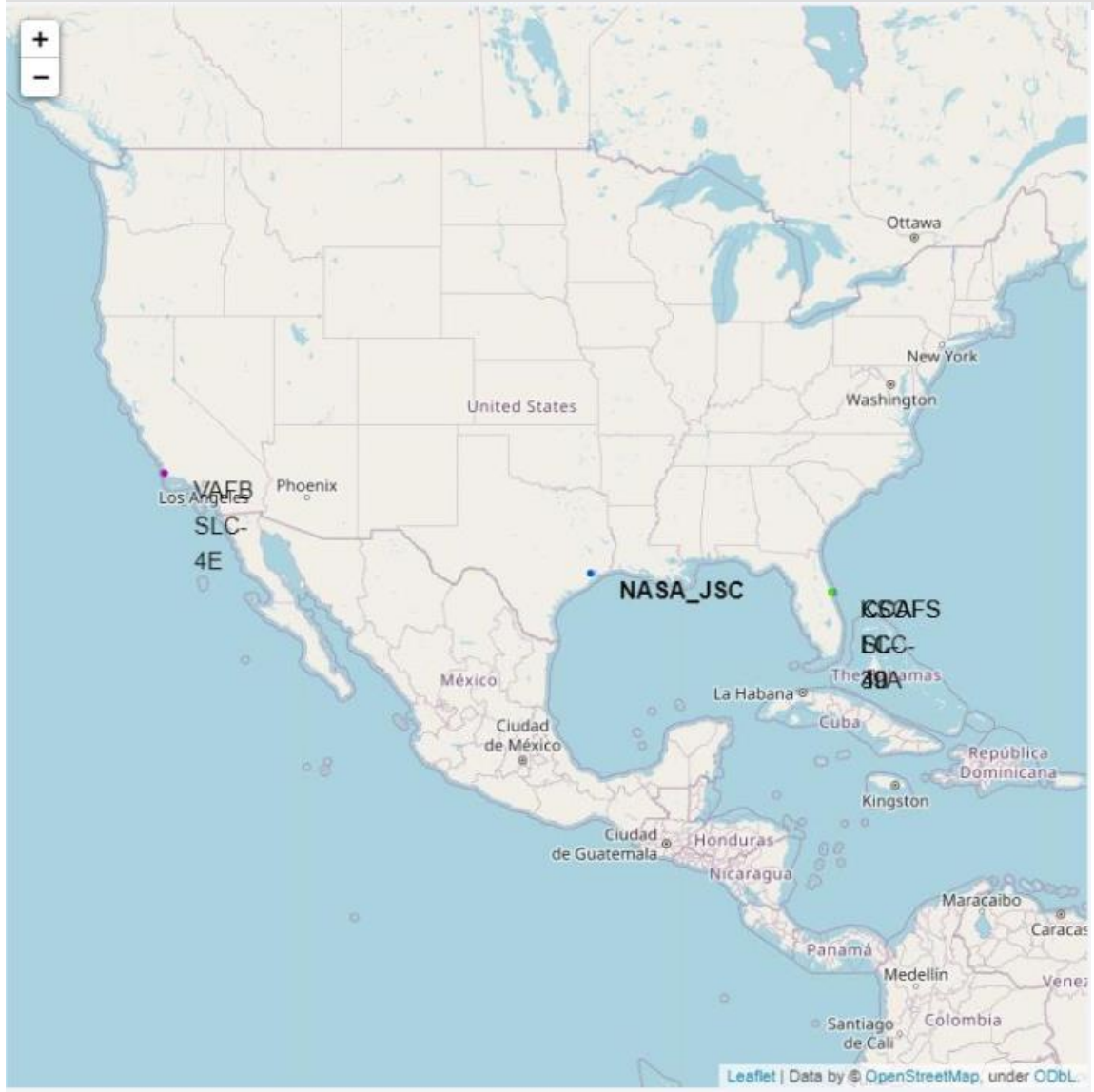
- Explanation: The above list shows the outcomes in descending order. The most common landing outcome was ‘not attempted’.

Section 3

Launch sites proximity analysis

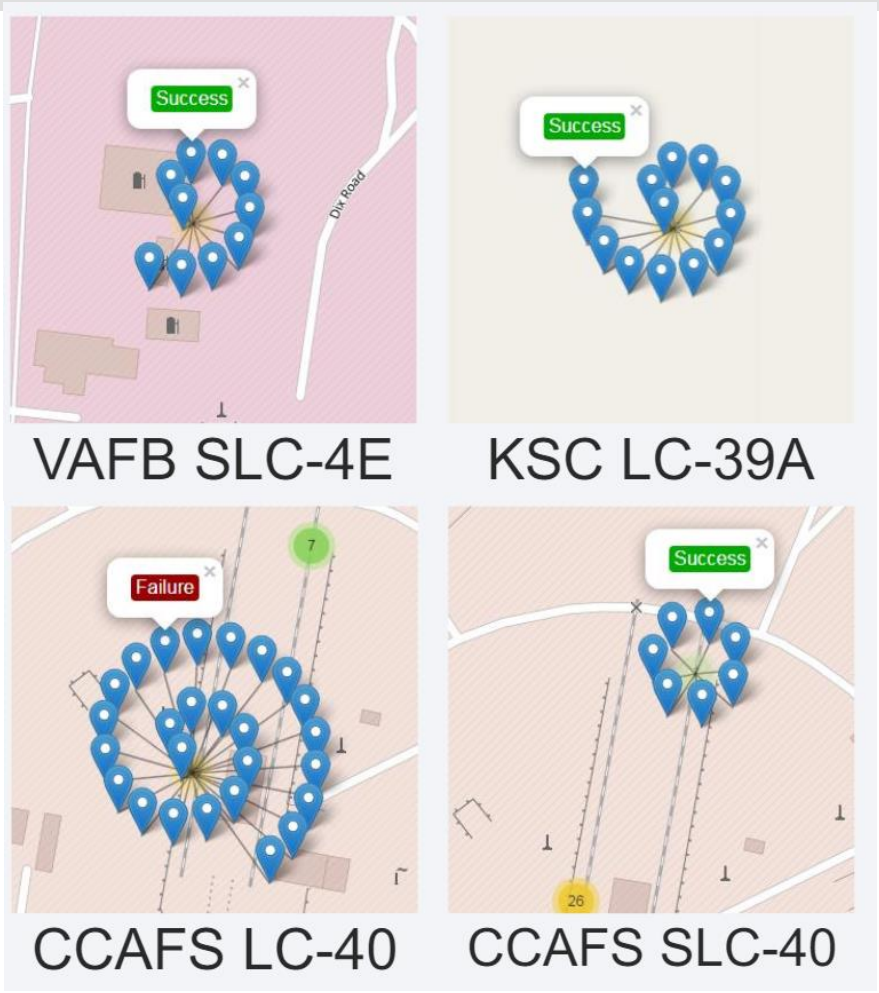
Falcon 9 Launch Site Locations

- **CCAFS LC-40 (Florida, USA)**
  Cape Canaveral Air Force Station Launch Complex 40
- **CCAFS SLC-40 (Florida, USA)**
  Cape Canaveral Air Force Station Space Launch Complex 40
- **VAFB SLC-4E (California, USA)**
  Vandenberg Air Force Base Space Launch Complex 4E
- **KSC LC-39A (Florida, USA)**
  Kennedy Space Center Launch Complex 39A



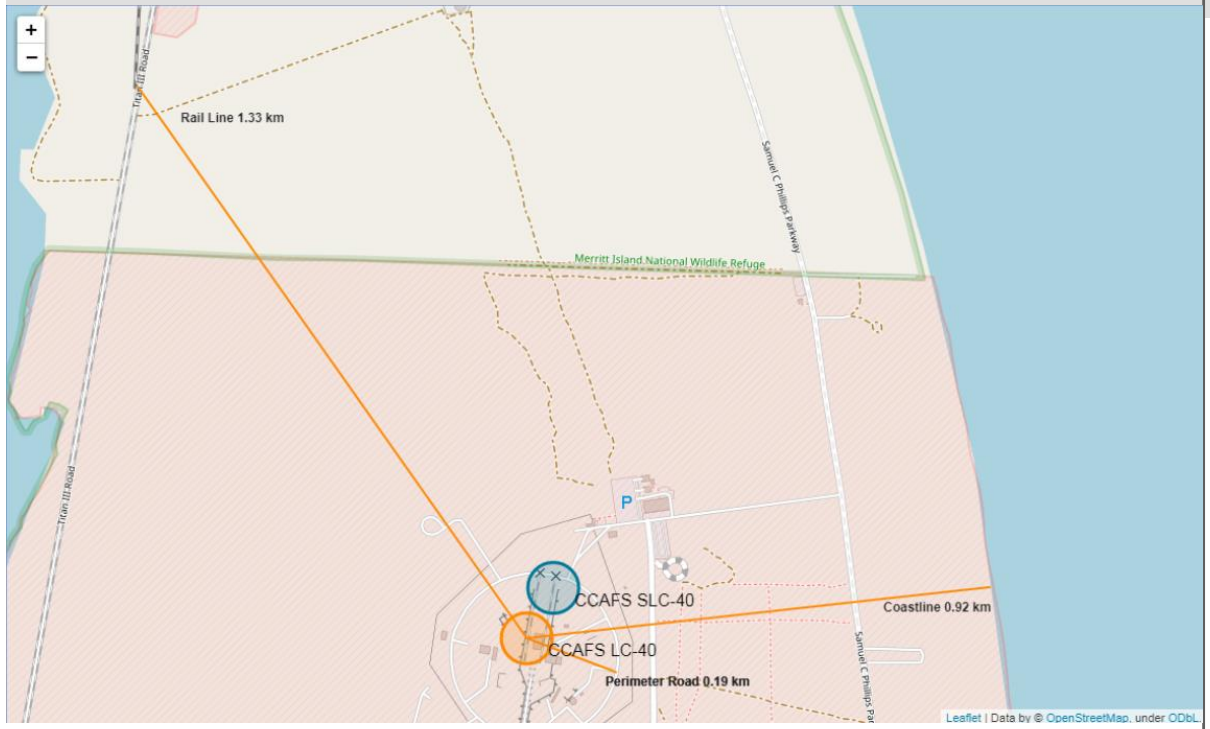
Success/ Failure Landings Markers

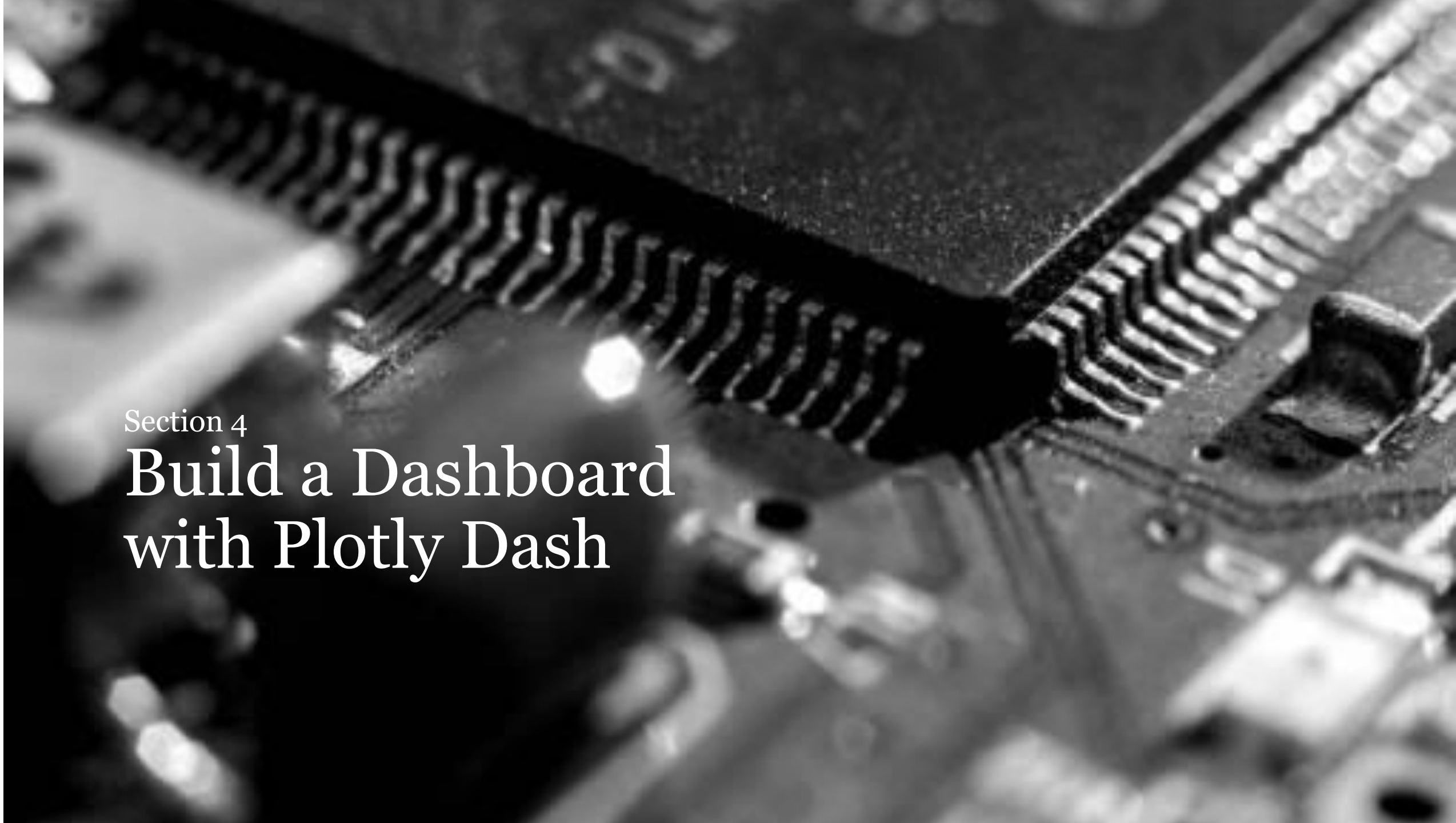
- The markers (success/failure) show the mission outcomes for Falcon 9 first stage landings. They are categorised according to the geographical coordinates for the purpose of the launch.
- The relative number of green success markers to red failure markers indicate the launch site's success rate for Falcon 9 first stage landings.



Distance of Launch Sites to Proximities

- The CCAFS LC-40 and CCAFS SLC-40 launch sites have coordinates that are close but and opposite to each other.
- The rail line is 1.33 km away from CCAFS LC-40.
- The perimeter road around CCAFS LC-40 is 0.19 km away from the launch site coordinates.
- The coastline is 0.92 km away from CCAFS LC-40.
- The distance is appropriate for the launch pads where rockets were launched.



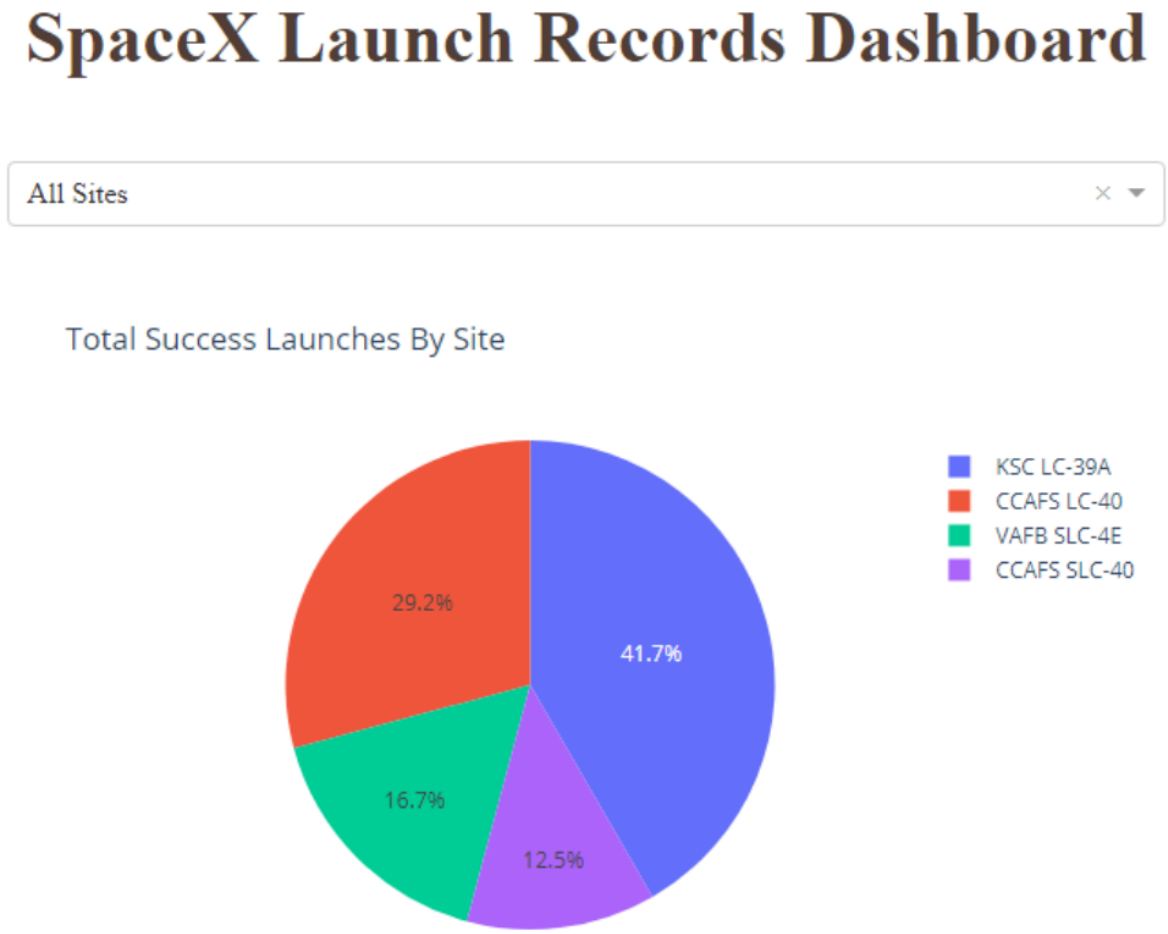


Section 4

Build a Dashboard with Plotly Dash

Launch Success Count for All Sites

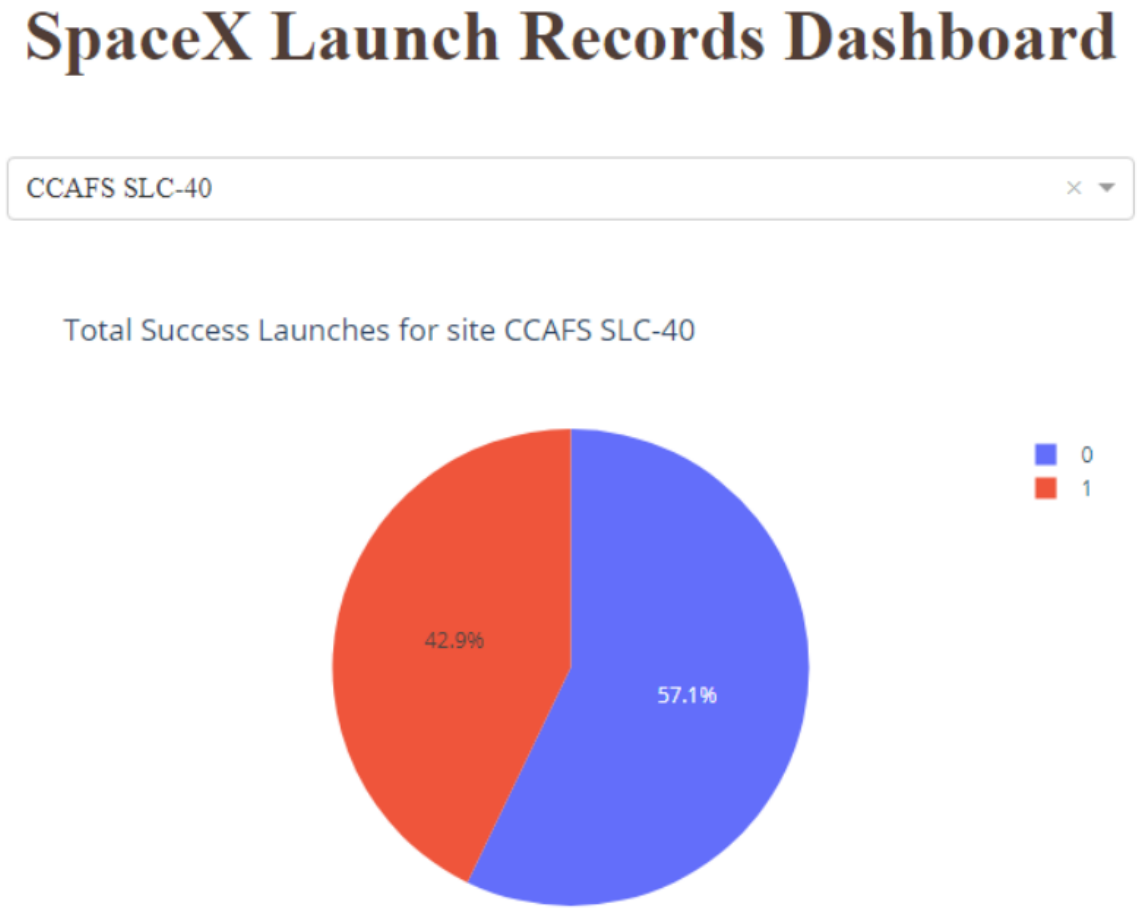
- The dropdown menu offers the selection of one or all launch sites.
- When all launch sites is selected, the pie chart shows the successful Falcon 9 first stage landing outcomes distribution between different launch sites.
- **KSC LC-39A** depicts the highest share of successful Falcon 9 first stage landing outcomes which is at **41.7%**.



Launch Site with the Highest Launch Success Ratio

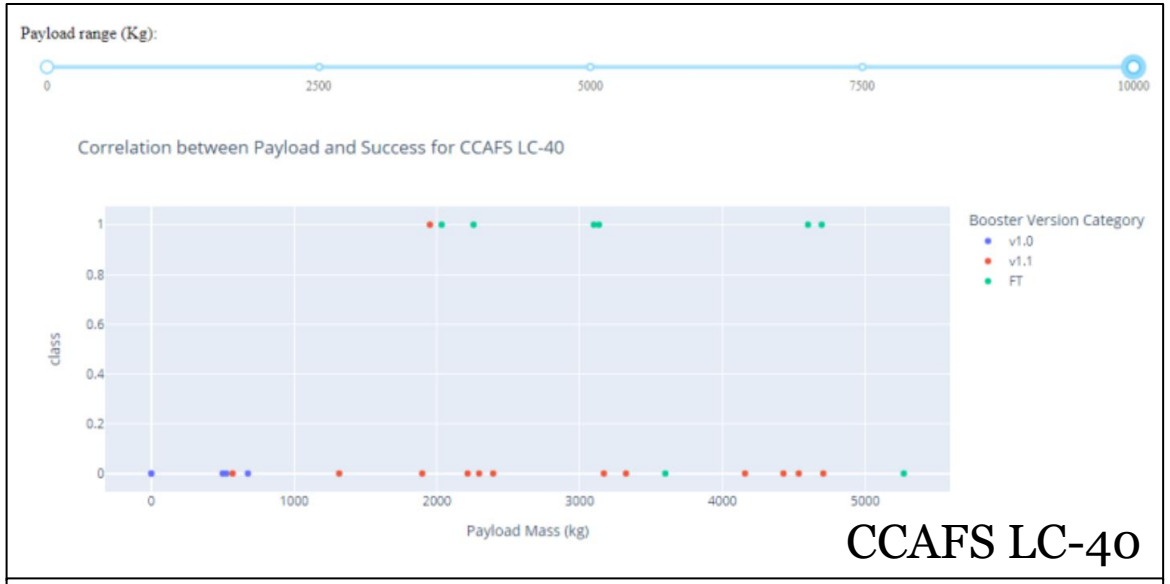
- Falcon 9 first stage **failed landings** are indicated by the ‘0’ Class (blue wedge in the pie chart) and **successful landings** by the ‘1’ Class (red wedge in the pie chart).

- **CCAFS SLC-40** launch site has the highest Falcon 9 first stage landing success rate which is at **42.9%**.

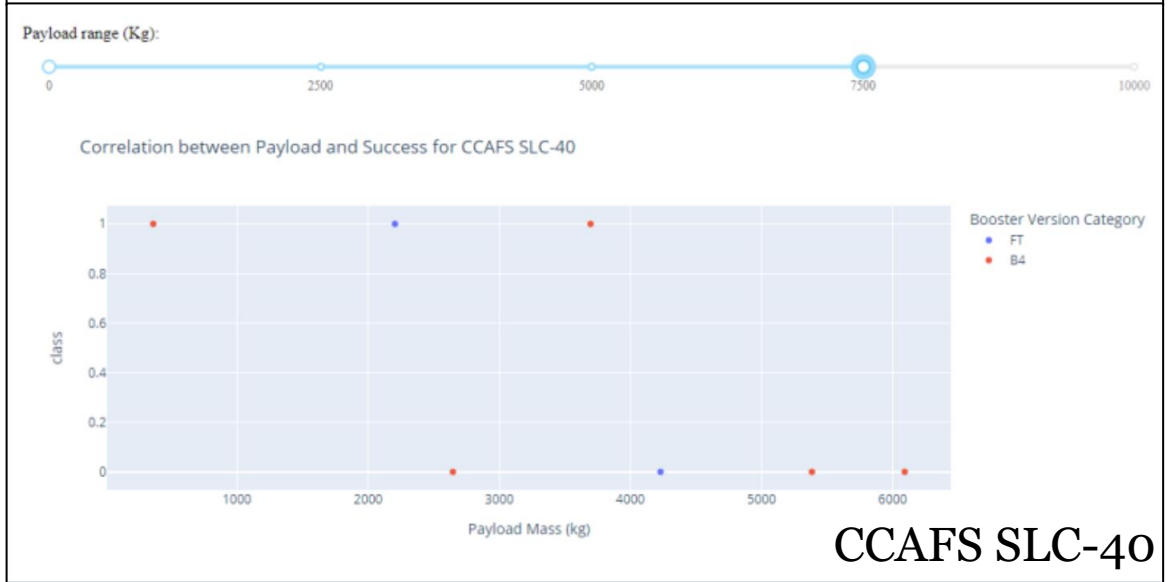


Payload vs. Launch Outcome

- The payload vs. launch outcome scatter plots show all sites with different payload range.
- The payload range of **2,000 kg to 5,000 kg** shows the largest success rate.
- The largest success rate is the **FT booster version**



CCAFS LC-40



CCAFS SLC-40

Payload vs. Launch Outcome

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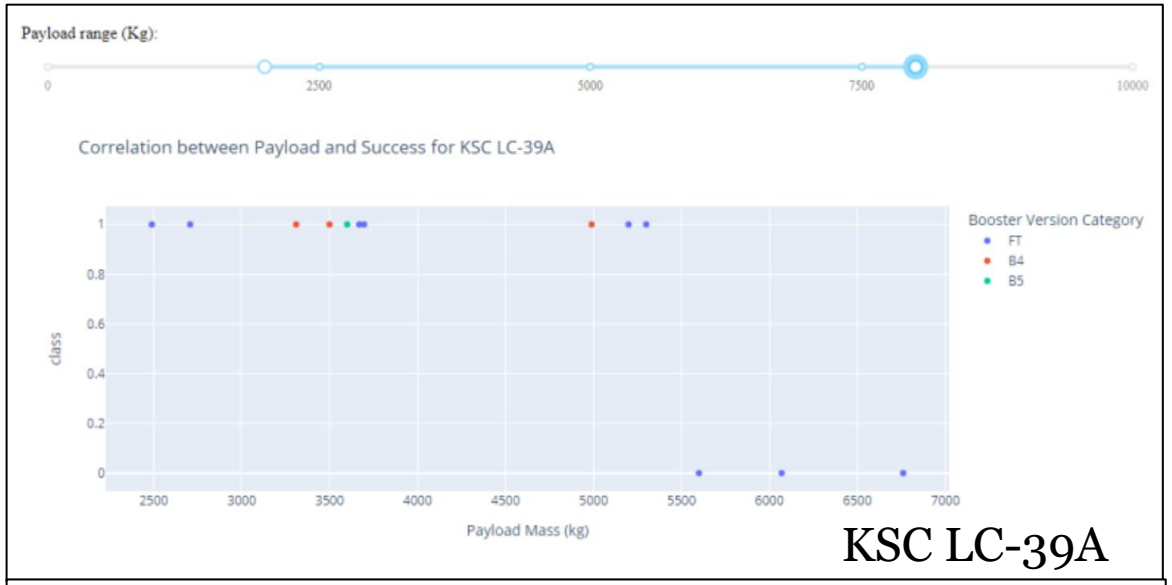
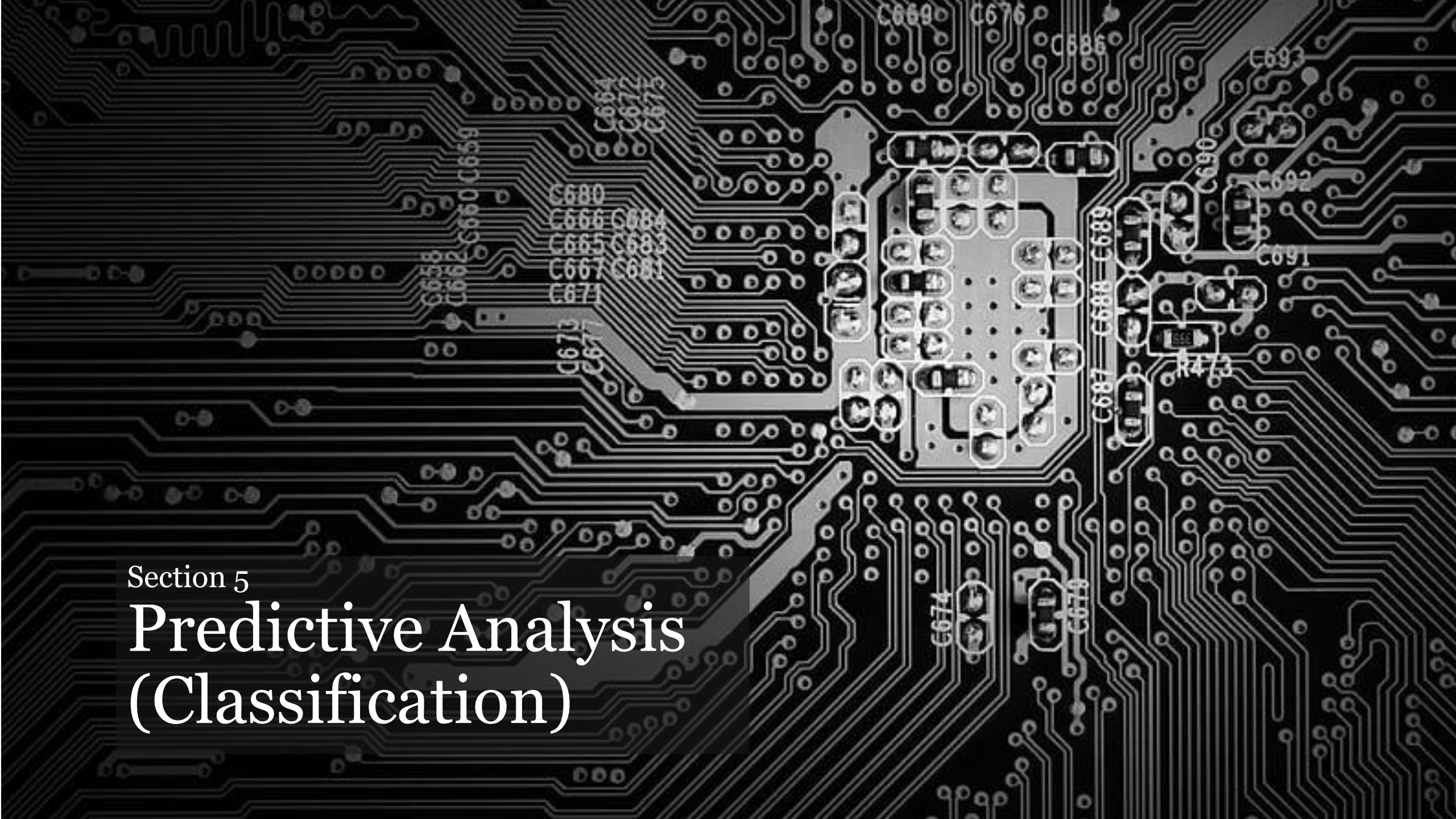


KSC LC-39A

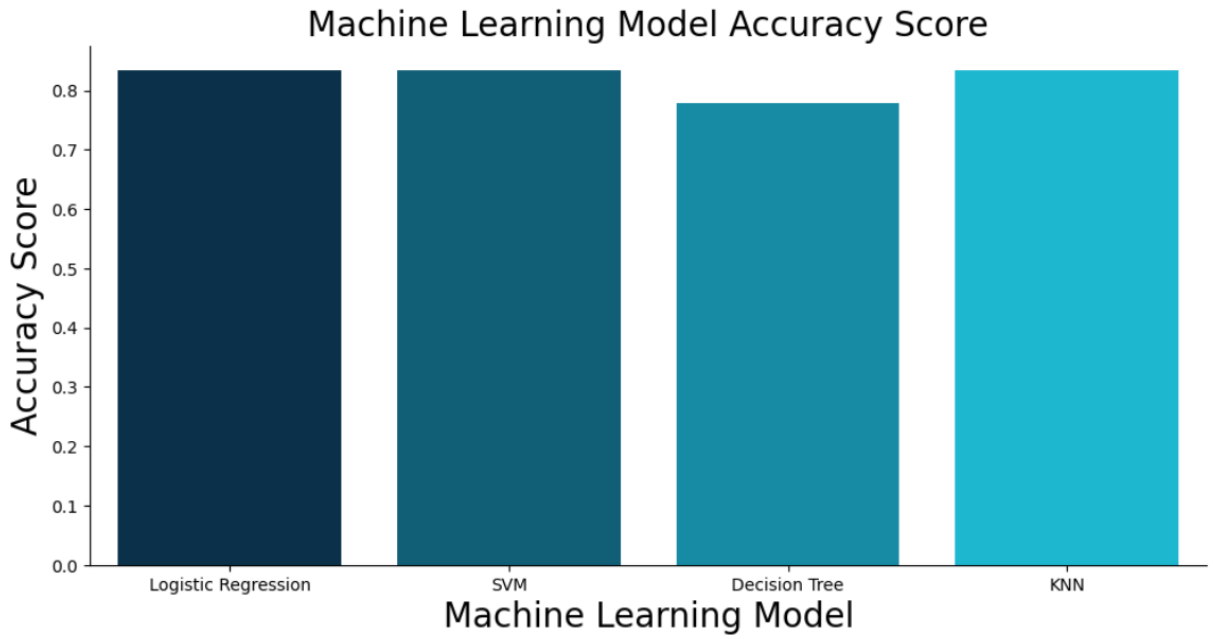
VAFB SLC-4E



Section 5

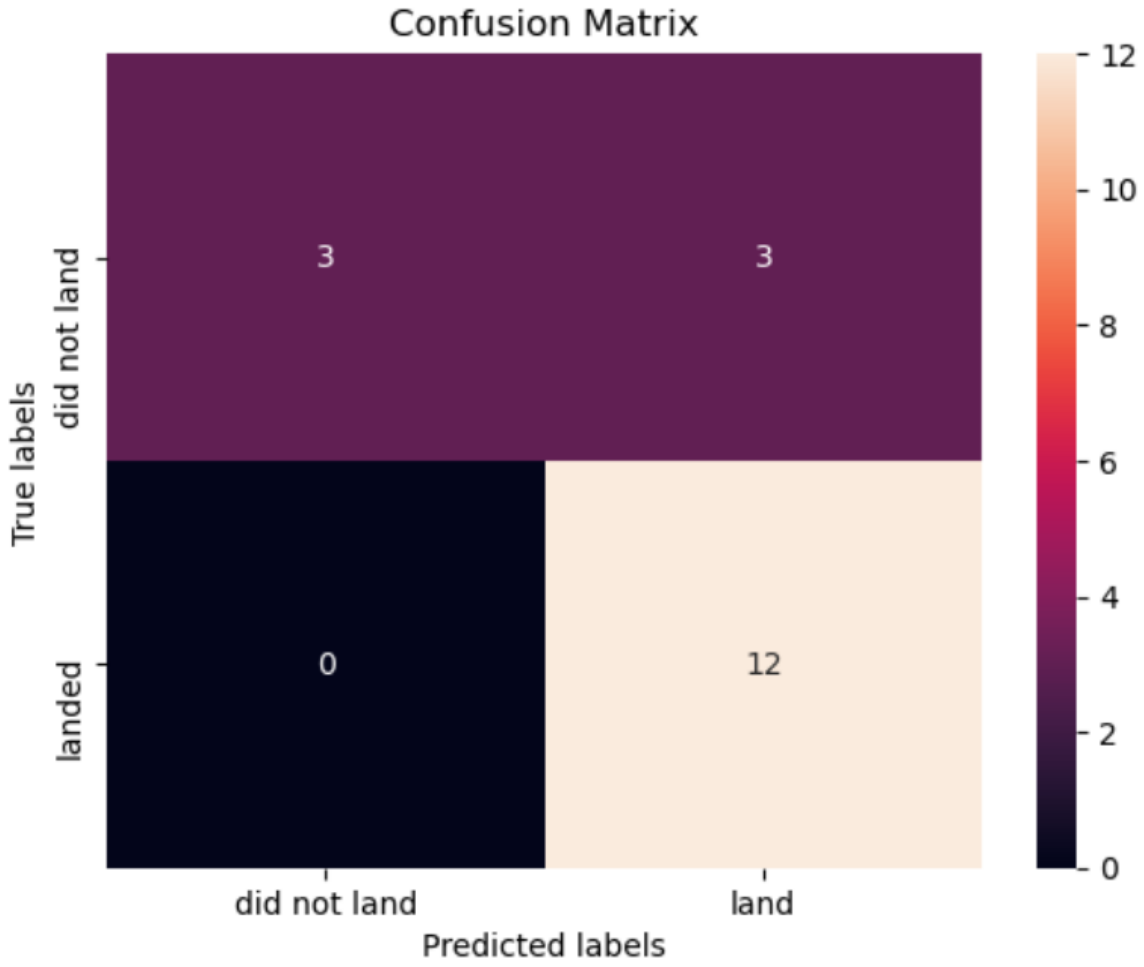
Predictive Analysis (Classification)

Classification Accuracy



- All models performed equally well except for the Decision Tree model in relation to other models.

Confusion Matrix



- Confusion matrices can be read as:

True Negative	False Positive
False Negative	True Positive

- Prediction Breakdown is shown as below:
  - 3 False Positives and 0 False Negatives
  - 12 True Positives and 3 True Negatives

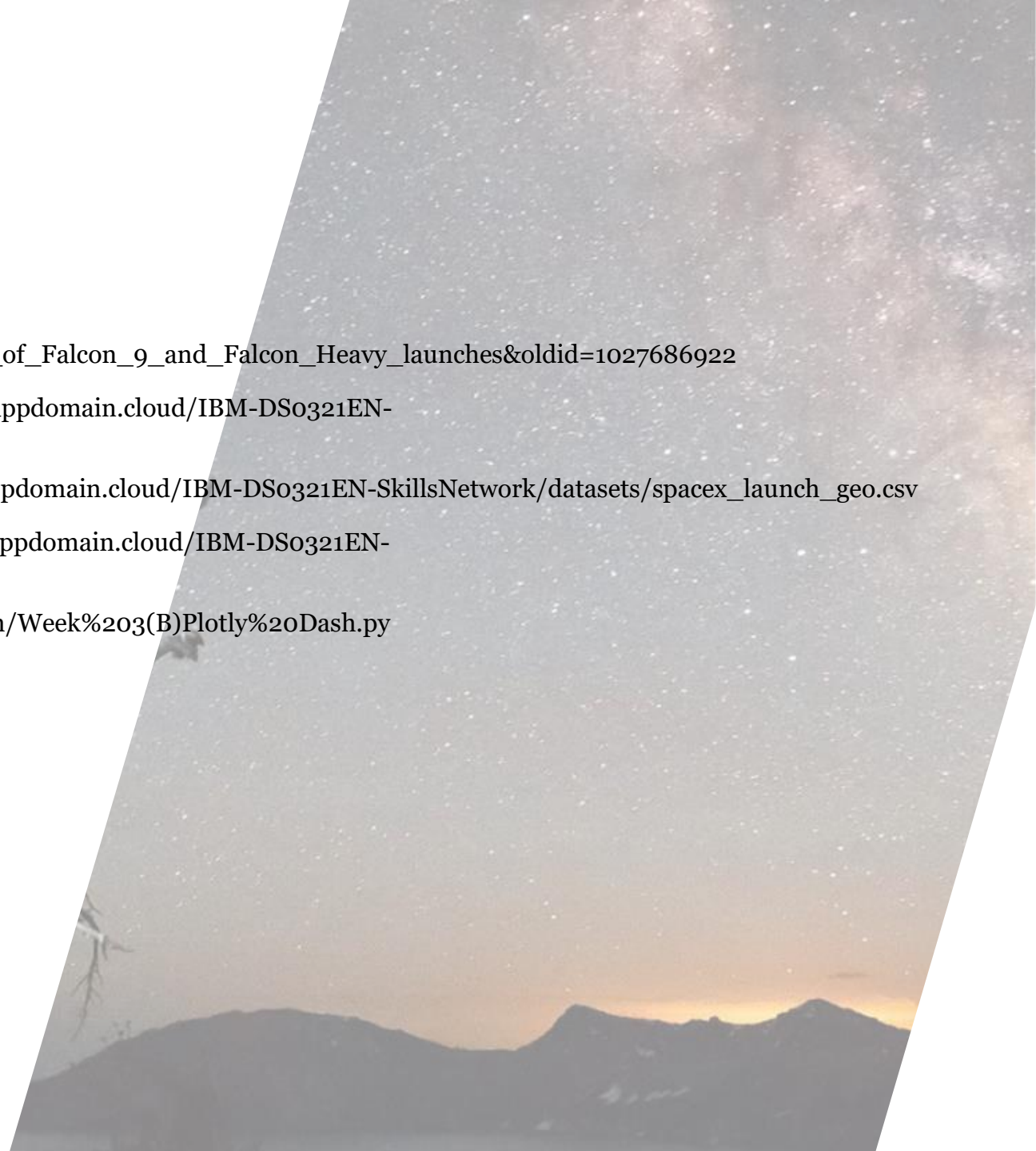
Conclusions

- SpaceX has shown significant improvement of Falcon 9 first stage landing outcome over the years. This goes along with frequent launches, as the saying goes “practice makes perfect”.

- Falcon 9 has never had a perfect track record of performing stage landing outcomes.

- Machine learning models are very useful when it concerns first stage landing. It can be further explored to predict future SpaceX Falcon 9 or any rockets’ first stage landing outcomes.

Appendix



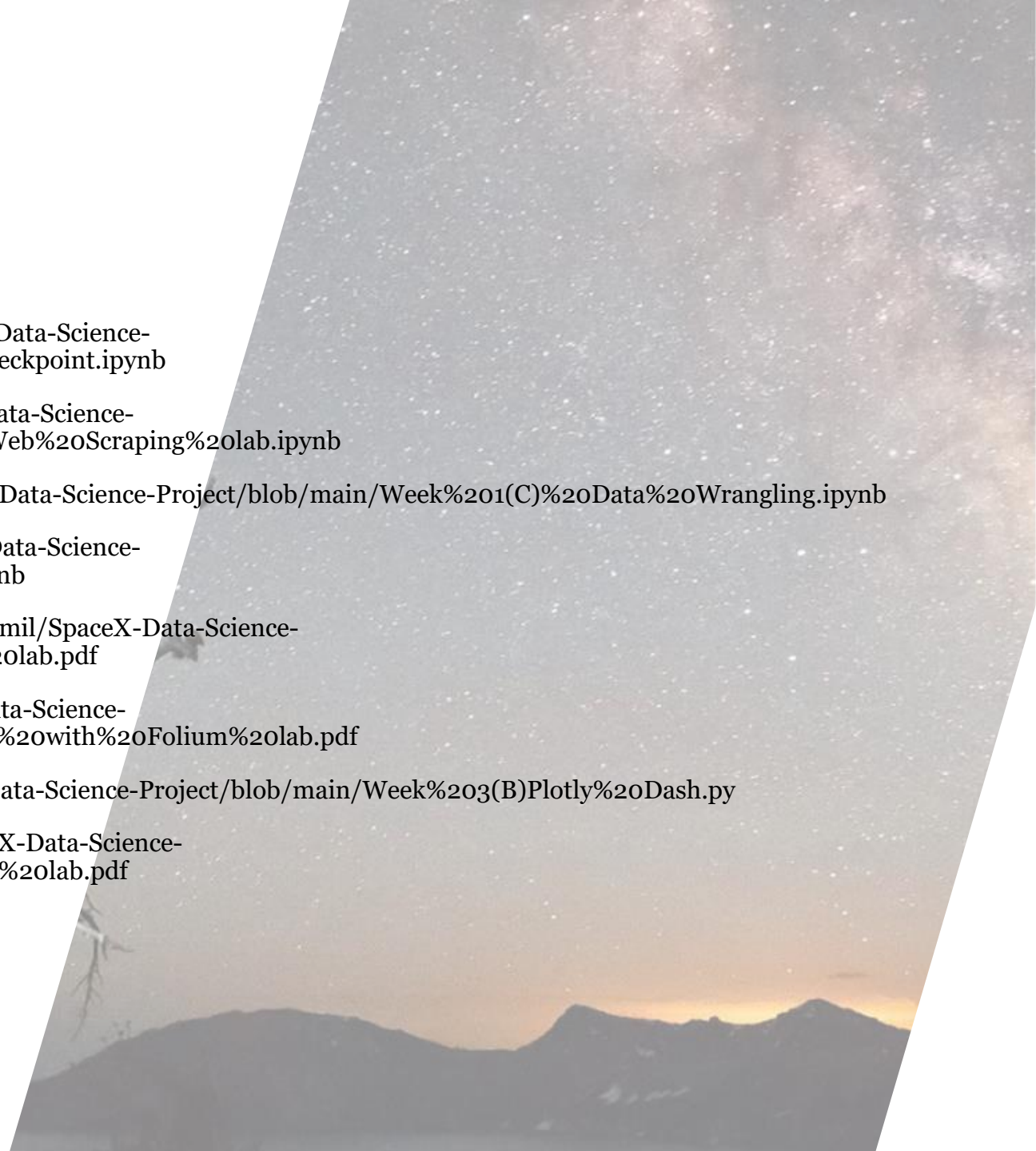
Initial Data Sets

- Wikipedia (Webpage): https://en.wikipedia.org/w/index.php?title=List_of_Falcon_9_and_Falcon_Heavy_launches&oldid=1027686922
- SpaceX API (JSON): https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/IBM-DS0321EN-SkillsNetwork/datasets/API_call_spacex_api.json
- Launch Geo (CSV): https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/IBM-DS0321EN-SkillsNetwork/datasets/spacex_launch_geo.csv
- Launch Dash (CSV): https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/IBM-DS0321EN-SkillsNetwork/datasets/spacex_launch_dash.csv
- https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%203(B)Plotly%20Dash.py

Appendix

Jupyter Notebooks and Dashboard Python File

- GitHub URL (Data Collection): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%201(A)%20Data%20collection%20API%20checkpoint.ipynb
- GitHub URL (Web Scraping): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%201(B)%20Data%20Collection%20with%20Web%20Scraping%20lab.ipynb
- GitHub URL (Data Wrangling): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%201(C)%20Data%20Wrangling.ipynb
- GitHub URL (EDA with SQL): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%202(A)%20EDA%20with%20SQL%20(2).ipynb
- GitHub URL (EDA with Data Visualization): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%202(B)%20EDA%20with%20Visualisation%20lab.pdf
- GitHub URL (Folium Maps): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%203A%20Interactive%20Visual%20Analytics%20with%20Folium%20lab.pdf
- GitHub URL (Dashboad File): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%203(B)Plotly%20Dash.py
- GitHub URL (Machine Learning): https://github.com/snajiajamil/SpaceX-Data-Science-Project/blob/main/Week%204%20Machine%20Learning%20Prediction%20lab.pdf




Thank you!