IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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January 2, 2022

Executive Summary

- SpaceY is a new commercial rocket company founded by Billionaire industrialist, Allon Mask, that would like to join the space race.
- The main competitor, SpaceX, advertises launch services starting at $62 million versus their competitors services upwards of $165 million dollars.
- The reason for this is SpaceX reuses the first stage of rocket launches, saving millions of dollars.
- By using past public data from the Space X Falcon 9 launches, SpaceY will determine which parameters are important for successful first stage launches and reusability.
- As a result, SpaceY will be able to make more informed bids against SpaceX by using 1st stage landing predictions as the basis for their future launches.

Allon Mask

Table of Contents

Introduction: Background

- This project is being presented in the role of a data scientist working for the fictitious new rocket company, SpaceY, that would like to compete with SpaceX founded by Billionaire industrialist Allon Mask.

- It was prepared for the IBM Applied Data Science Capstone course.

- This report includes the data scientist methodology, results, and conclusions on their findings.

Introduction: Business Problem

- SpaceX advertises Falcon 9 rocket launches with a cost of 62 million dollars because they can reuse the first stage of rocket launches.
- The first stage is estimated to cost upwards of 15 million dollars to create.
- This report aims to accurately predict the likelihood of the first stage rocket landing successfully for reusability.

Section 1

Methodology

Methodology

<u>Overview of methodologies used by data scientist</u>

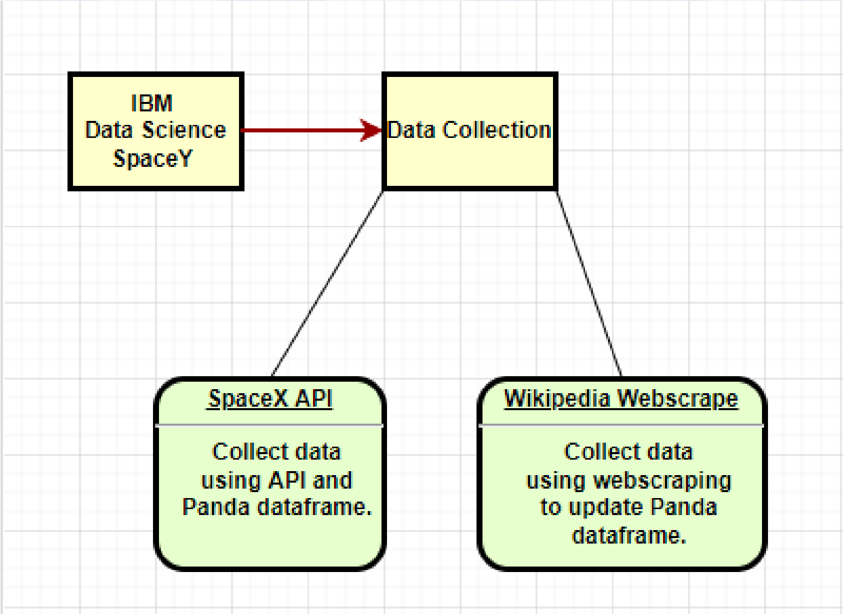
- Data Collection
- Data Wrangling
- Exploratory Data Analysis: Visual Analytics
- Exploratory Data Analysis: SQL
- Data Visualization: Map
- Data Visualization: Dashboard
- Predictive Analysis (Classification)
- Results

Methodology: Data Collection

Two methods were used to collect data.

Open-Source Rest API: Application programming interfaces was used with request library to get data using SpaceX API.

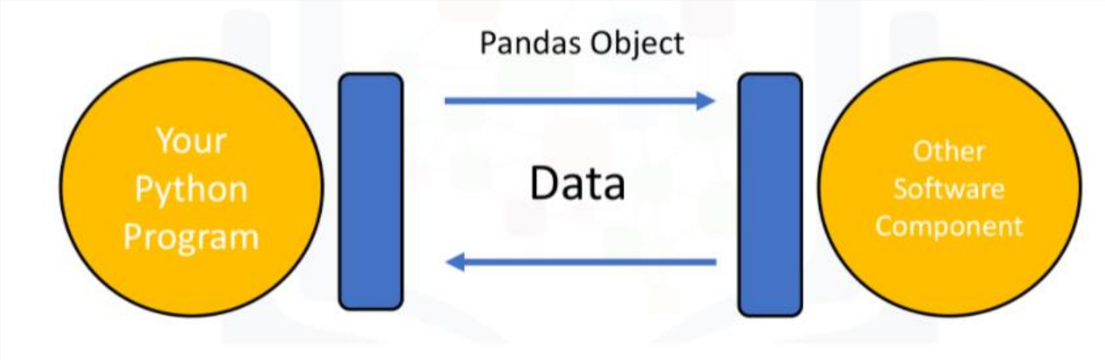
Web scraping: the process of using beautifulsoup library to extract content and data from a website. The data was collected using the public website, Wikipedia.



Methodology: Data Collection – SpaceX API

SpaceX API

- Gathered historical public data using Open-Source API for SpaceX:
  - Request and parse the SpaceX launch data using the GET request.
  - Loaded information with Get Functions and loaded into Panda Dataframe.
  - Filtered data to only use Falcon 9 launches.



https://github.com/viettwoone/ibm_data_science/blob/main/jupyter-labs-spacex-data-collection-api.ipynb

Methodology: Data Collection - Scraping

<u>Webscraping Wikipedia</u>

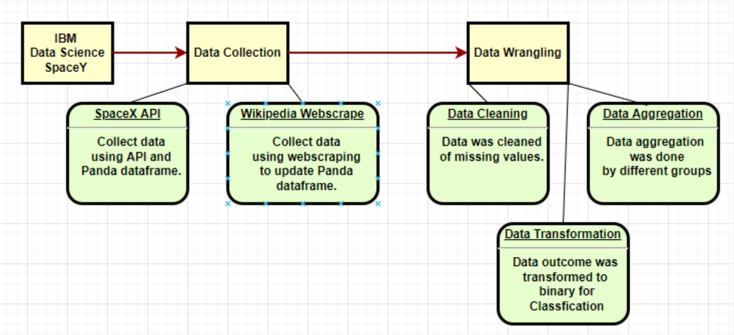
- Webscraping Wikipedia for public knowledge:
  - Request the Falcon9 Launch Wiki page from its URL.
  - Extract all column/variable names from the HTML table header.
  - Create a data frame by parsing the launch HTML tables using Panda's Dataframe

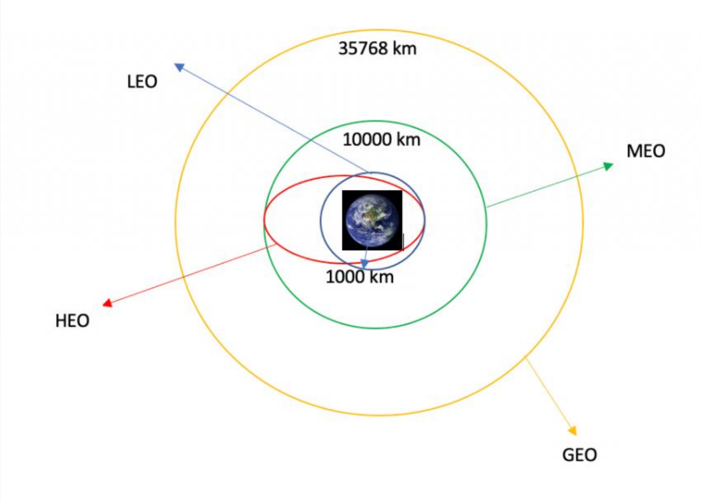
[hide] Flight No.	Date and time (UTC)	Version, Booster[b]	Launch site	Payload[c]	Payload mass	Orbit	Customer	Launch outcome	Booster landing
78	7 January 2020, 02:19:21[492]	F9 B5 ♺ B1049.4	CCAFS, SLC-40	Starlink 2 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Success (drone ship)
	Third large batch and second operational flight of Starlink constellation. One of the 60 satellites included a test coating to make the satellite less reflective, and thus less likely to interfere with ground-based astronomical observations.[493]								
79	19 January 2020, 15:30[494]	F9 B5 ♺ B1046.4	KSC, LC-39A	Crew Dragon in-flight abort test[495] (Dragon C205.1)	12,050 kg (26,570 lb)	Sub-orbital[496]	NASA (CTS)[497]	Success	No attempt
	An atmospheric test of the Dragon 2 abort system after Max Q. The capsule fired its SuperDraco engines, reached an apogee of 40 km (25 mi), deployed parachutes after reentry, and splashed down in the ocean 31 km (19 mi) downrange from the launch site. The test was previously slated to be accomplished with the Crew Dragon Demo-1 capsule;[498] but that test article exploded during a ground test of SuperDraco engines on 20 April 2019.[419] The abort test used the capsule originally intended for the first crewed flight.[499] As expected, the booster was destroyed by aerodynamic forces after the capsule aborted.[500] First flight of a Falcon 9 with only one functional stage — the second stage had a mass simulator in place of its engine.								
80	29 January 2020, 14:07[501]	F9 B5 ♺ B1051.3	CCAFS, SLC-40	Starlink 3 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Success (drone ship)
	Third operational and fourth large batch of Starlink satellites, deployed in a circular 290 km (180 mi) orbit. One of the fairing halves was caught, while the other was fished out of the ocean.[502]								
81	17 February 2020, 15:05[503]	F9 B5 ♺ B1056.4	CCAFS, SLC-40	Starlink 4 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Failure (drone ship)
	Fourth operational and fifth large batch of Starlink satellites. Used a new flight profile which deployed into a 212 km × 386 km (132 mi × 240 mi) elliptical orbit instead of launching into a circular orbit and firing the second stage engine twice. The first stage booster failed to land on the drone ship[504] due to incorrect wind data.[505] This was the first time a flight proven booster failed to land.								
82	7 March 2020, 04:50[506]	F9 B5 ♺ B1059.2	CCAFS, SLC-40	SpaceX CRS-20 (Dragon C112.3 ♺)	1,977 kg (4,359 lb)[507]	LEO (ISS)	NASA (CRS)	Success	Success (ground pad)
	Last launch of phase 1 of the CRS contract. Carries *Bartolomeo*, an ESA platform for hosting external payloads onto ISS.[508] Originally scheduled to launch on 2 March 2020, the launch date was pushed back due to a second stage engine failure. SpaceX decided to swap out the second stage instead of replacing the faulty part.[509] It was SpaceX's 50th successful landing of a first stage booster, the third flight of the Dragon C112 and the last launch of the cargo Dragon spacecraft.								
83	18 March 2020, 12:16[510]	F9 B5 ♺ B1048.5	KSC, LC-39A	Starlink 5 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Failure (drone ship)
	Fifth operational launch of Starlink satellites. It was the first time a first stage booster flew for a fifth time and the second time the fairings were reused (Starlink flight in May 2019).[511] Towards the end of the first stage burn, the booster suffered premature shut down of an engine, the first of a Merlin 1D variant and first since the CRS-1 mission in October 2012. However, the payload still reached the targeted orbit.[512] This was the second Starlink launch booster landing failure in a row, later revealed to be caused by residual cleaning fluid trapped inside a sensor.[513]								
84	22 April 2020, 19:30[514]	F9 B5 ♺ B1051.4	KSC, LC-39A	Starlink 6 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Success (drone ship)

Methodology: Data Wrangling

Data wrangling

- The process of cleaning and unifying messy and complex data sets for easy access and analysis.
  - Data was loaded into Panda's Dataframe
  - Identify and calculate the percentage of the missing values in each attribute
  - Changing missing values and imputing their mean
  - Identify which columns are numerical and categorical
  - Calculate the number of launches on each site
  - Calculate the number and occurrence of each orbit
  - Calculate the number and occurence of mission outcome per orbit type
  - Transformed data to binary column, class, where 0 = unsuccessful, 1 = successful



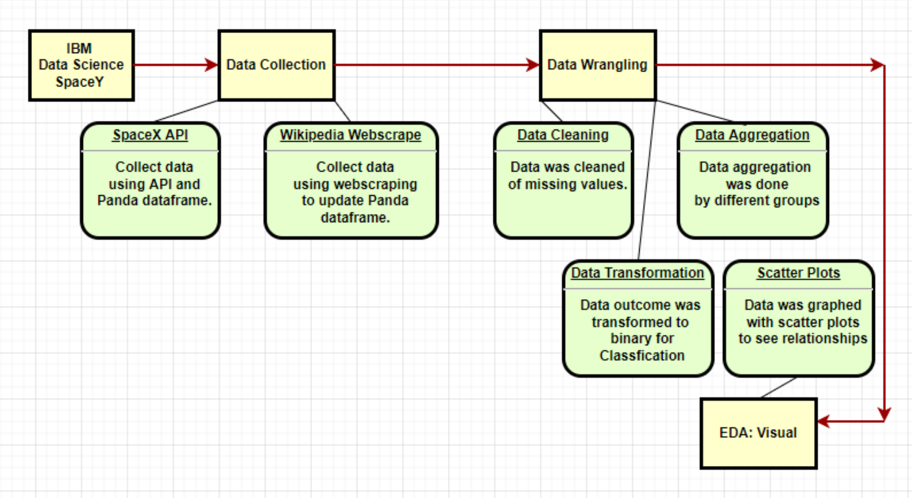


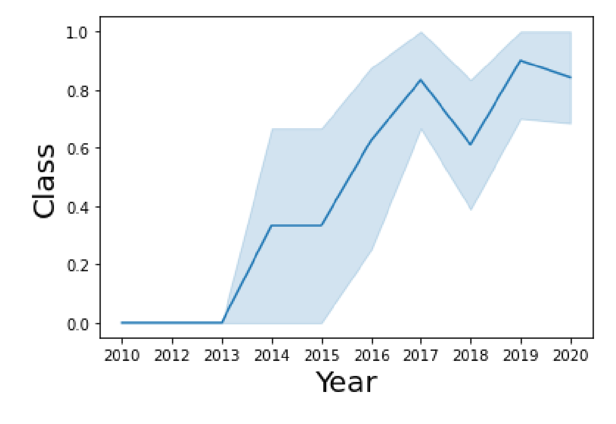
https://github.com/viettwoone/ibm_data_science/blob/main/labs-jupyter-spacex-Data%20wrangling.ipynb

Methodology: EDA with Data Visualization

<u>EDA: Data Visualization</u>

- Exploratory data analysis (EDA) is used by data scientists to analyze and investigate data sets and summarize their main characteristics, often employing data visualization methods.
    - Scatter plots were used to explore the target variable (class) and the different relationships it had with various features.
    - Bar graphs to see frequency.
    - Line graphs to see trends.
    - Features included: payload in weight, launch-site locations, orbit, time, landing pad, block, grid fins, re-used counts, and serials.



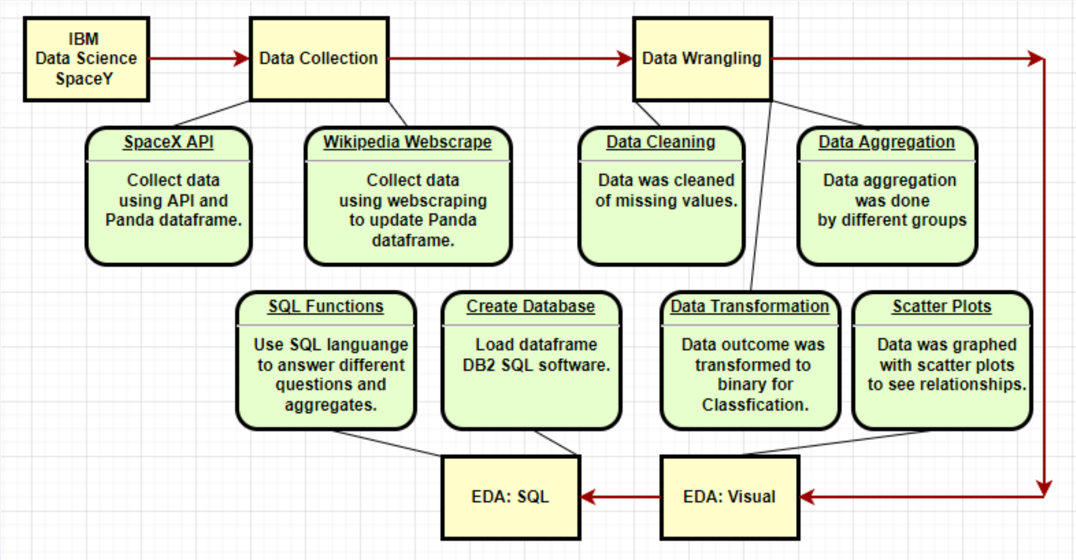


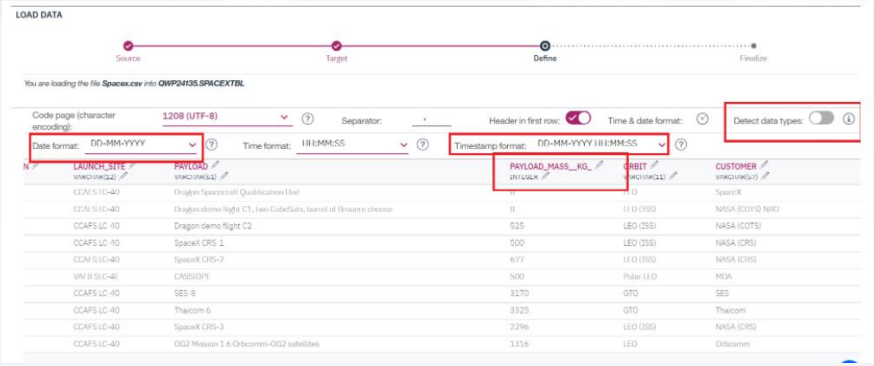
https://github.com/viettwoone/ibm_data_science/blob/main/jupyter-labs-eda-dataviz.ipynb

Methodology: EDA with SQL

<u>EDA: SQL</u>

- Exploratory data analysis (EDA) is used by data scientists to analyze and investigate data sets and summarize their main characteristics, this time using SQL (Structured Query Language).
- Loaded dataframe as a database using DB2
- Used SQL to answer questions about features.
  - Ex1. *List the total number of successful and failure mission outcomes*

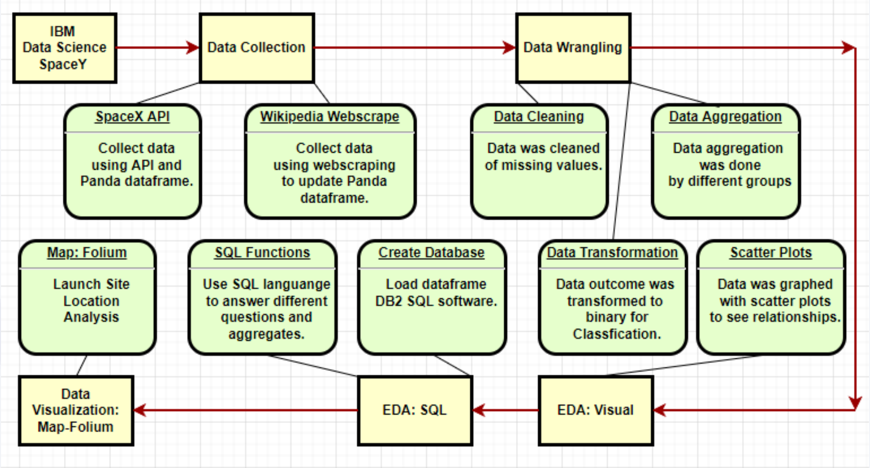


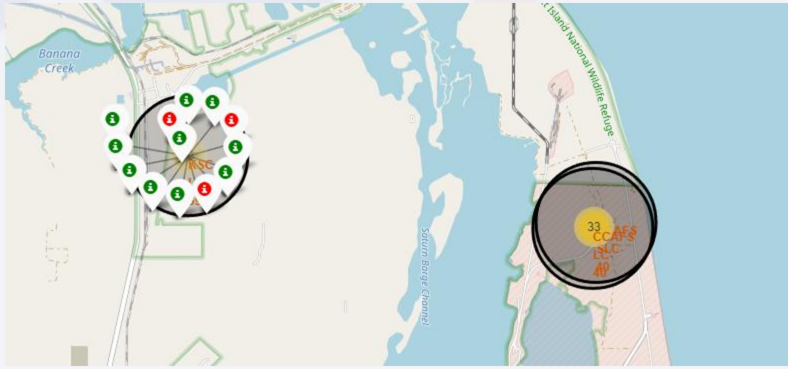


Methodology: Build an Interactive Map with Folium

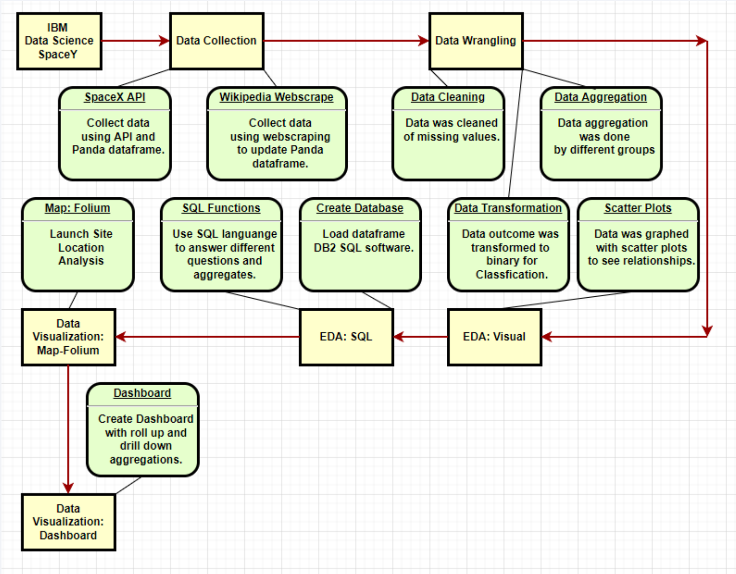
<u>Data Visualization: Launch Sites Locations Analysis with Folium</u>

- Data visualization is the graphical representation of information and data. By using visual elements like charts, graphs, and maps, data visualization tools provide an accessible way to see and understand trends, outliers, and patterns in data.
    - The data scientist wanted to determine if location was an important feature of target variable.
    - Visual map is one approach to see success rate of different launch sites and their surroundings.
    - The data scientist can engage in risk management, transportation, and other location factors.



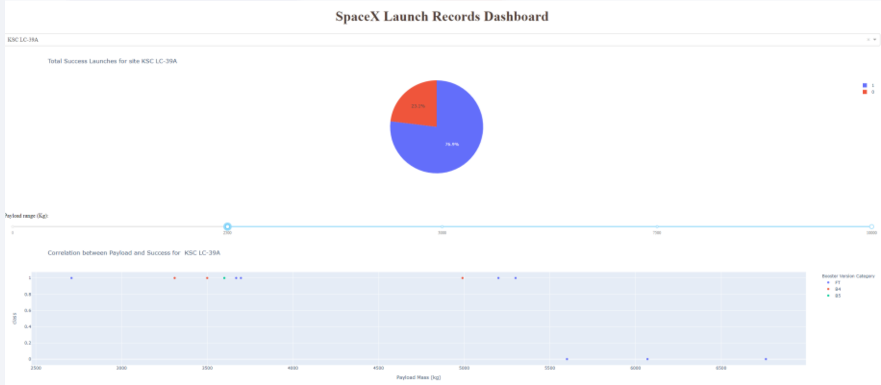


Methodology: Build a Dashboard with Plotly Dash



<u>Data Visualization: Dashboard</u>

- A dashboard is a type of graphical user interface which often provides at-a-glance views of key performance indicators (KPIs) relevant to a particular objective or business process.
  - Dashboard was created to help stakeholders visualize findings through roll up/drill down and different menus to see data at different angles.
  - Strong features and aggregations were shown with biggest impact on target variable.

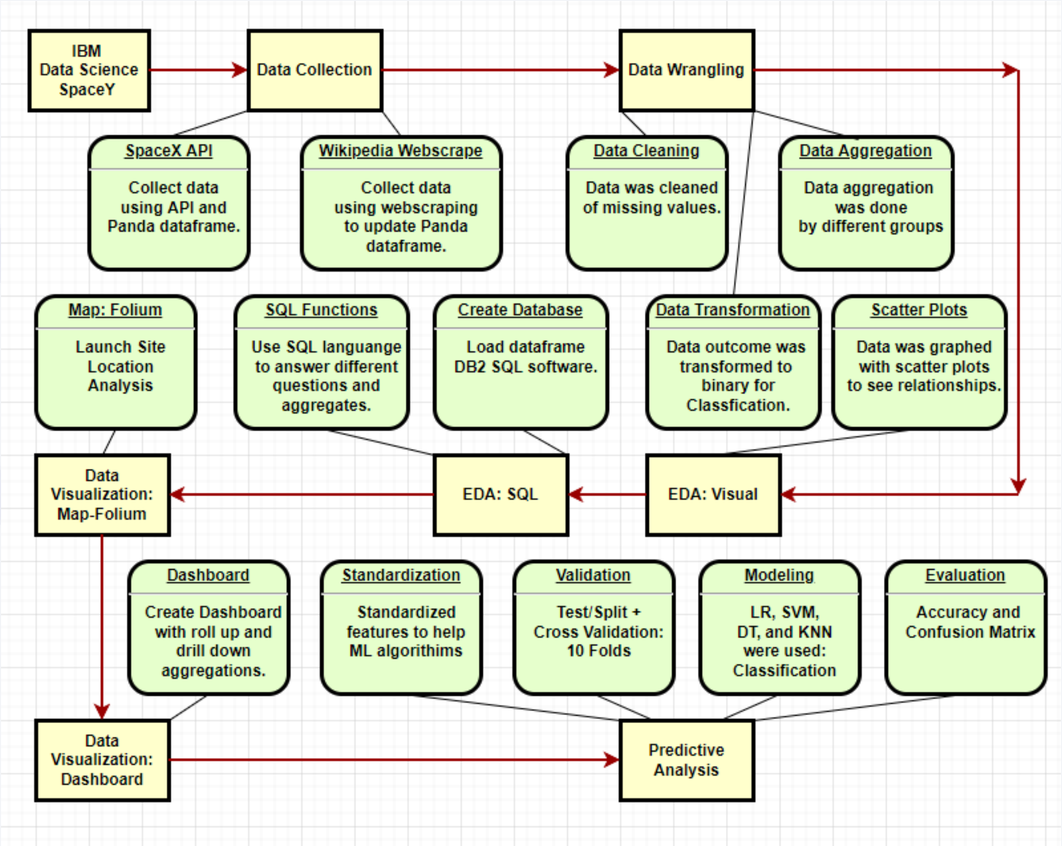


https://github.com/viettwoone/ibm_data_science/blob/main/spacex_dash_app.ipynb

Methodology: Predictive Analysis (Classification)

<u>Predictive analytics: Classification</u>

- Use of data, statistical algorithms and machine learning techniques to identify the likelihood of future outcomes based on historical data.
  - Classification was used since the data scientist used a binary target variable with success rate outcome 0 = unsuccessful and 1 = successful
  - Standardized features to help ML algorithm train
  - Train/Test Split and Cross Validation: 10 folds were used to validate the data
  - Tried 4 different ML methods of logistic regression, sector vector machine, decision tree, and k nearest neighbors
  - Evaluation methods included accuracy check of classification and confusion matrix



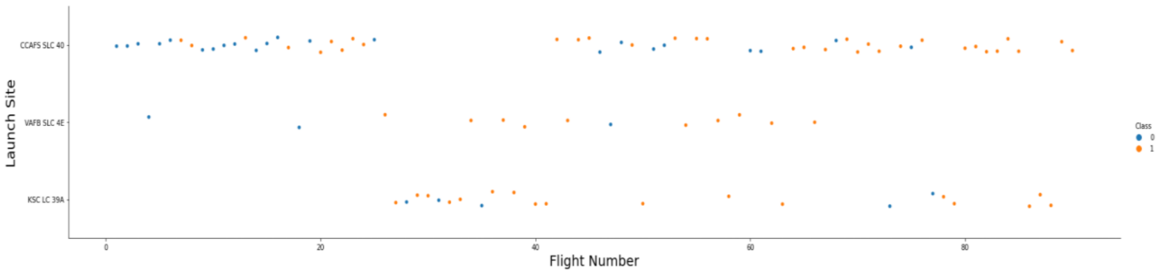
https://github.com/viettwoone/ibm_data_science/blob/main/SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb

Results

- EDA: Visualization Results
- EDA: SQL Results
- Data Visualization: Map Results
- Data Visualization: Dashboard
- Predictive Analysis
- Evaluation

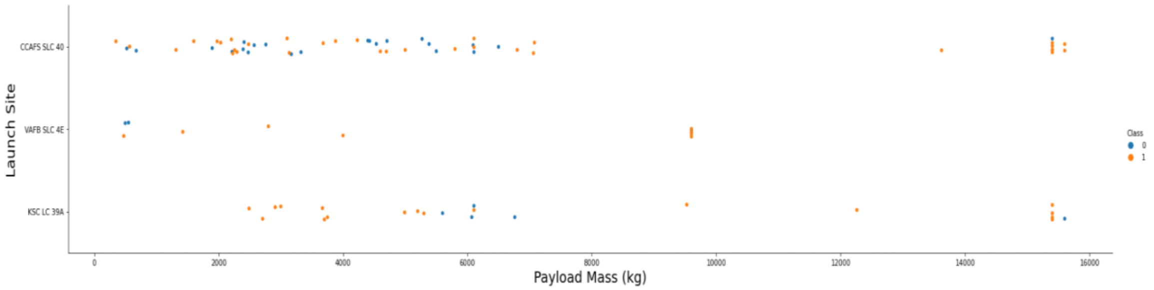
Section 2

Insights drawn from EDA



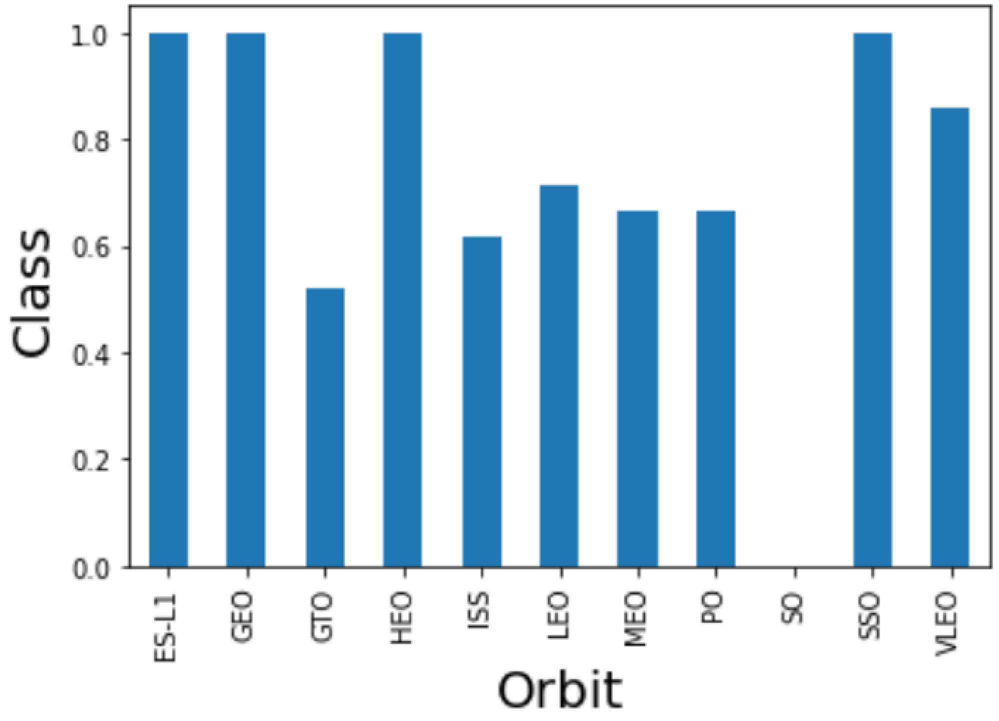
Flight Number vs. Launch Site

- The data scientist used an EDA visualization scatter plot graph using Seaborn and Matplotlib, where x = Flight Number and Y = Launch Site.
- Blue dots were unsuccessful, orange dots were successful.
- Success rate affected by Location feature?
- Visually, yes, more orange/blue dot ratio on VAFB and KSC locations. Need further investigation.



Payload vs. Launch Site

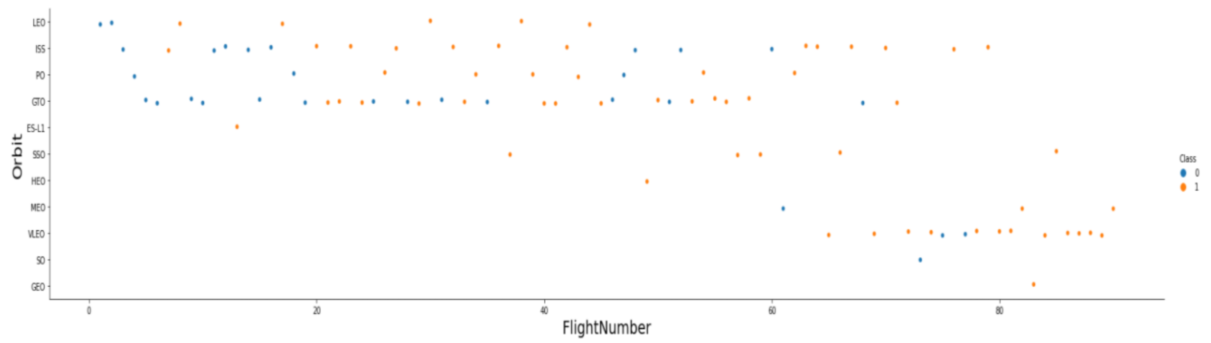
- The data scientist used an EDA visualization scatter plot graph using Seaborn and Matplotlib, where x = Payload Mass (kg) and Y = Launch Site.
- Blue dots were unsuccessful, orange dots were successful.
- Success rate affected by Location/Weight features?
- Visually, yes, more orange/blue dot ratio on VAFB and KSC locations. Need further investigation.



Success Rate vs. Orbit Type

- The data scientist used an EDA visualization bar graph using Seaborn and Matplotlib, where x = Orbit and Y = Success Rate.
- Success rate affected by Orbit feature?
- Visually, not enough information. Not enough samples on some categories.

Flight Number vs. Orbit Type



- The data scientist used an EDA visualization scatter plot graph using Seaborn and Matplotlib, where x = Flight Number and Y = Orbit.
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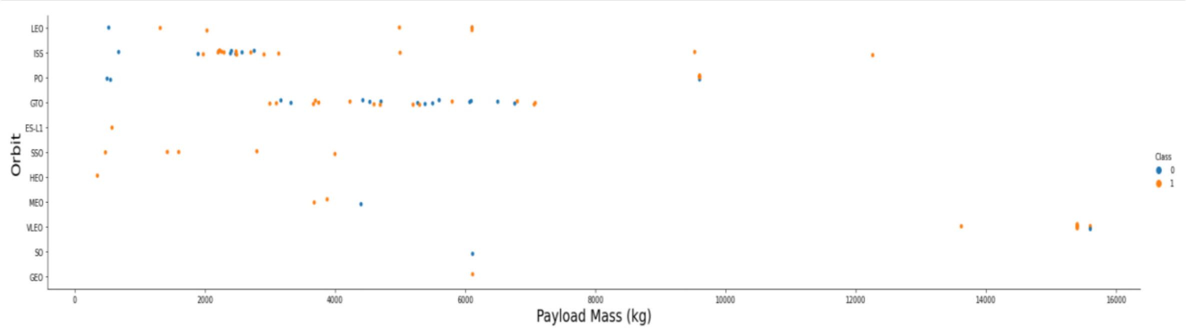
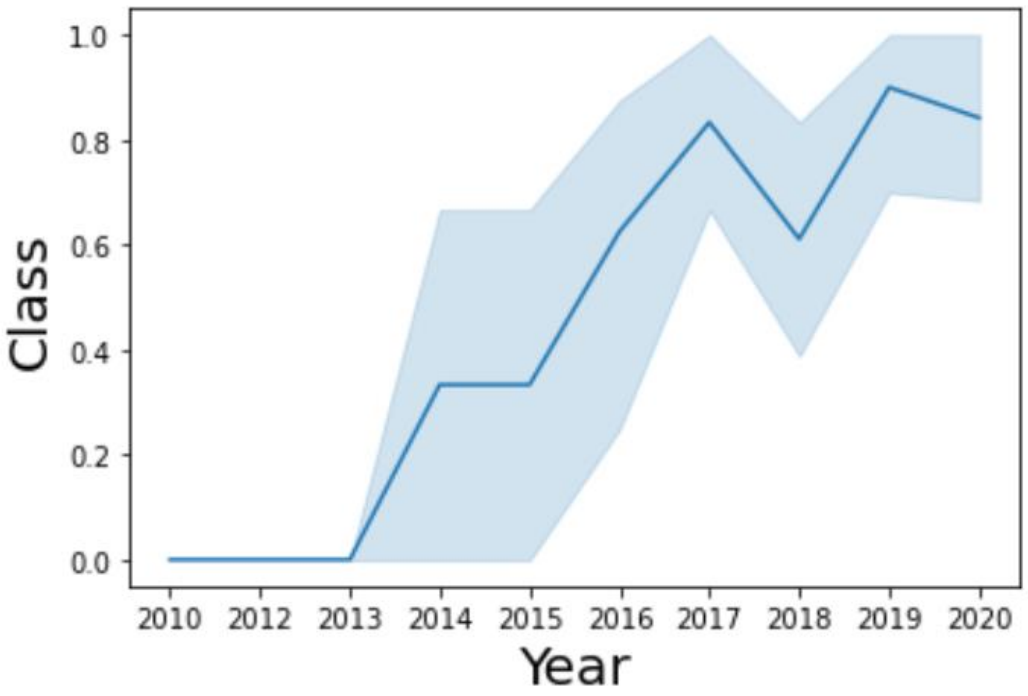


Payload vs. Orbit Type

- The data scientist used an EDA visualization scatter plot graph using Seaborn and Matplotlib, where x = Payload Mass (kg) and Y = Orbit.
- Blue dots were unsuccessful, orange dots were successful.
- Success rate affected by Weight/Orbit features?
- Visually, not enough information. Not enough samples on some categories.



Launch Success Yearly Trend

- The data scientist used an EDA visualization line graph using Seaborn and Matplotlib, where x = Time and Y = Success Rate.
- Success rate affected by Time feature?
- Visually, definite yes, but still need further investigation.

```
%%sql
SELECT DISTINCT launch_site
FROM spacex
```

```
 * ibm_db_sa://tjf73799:***@
Done.
```

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

All Launch Site Names

- The data scientist used an EDA SQL Database and SQL query to answer the following question:
- ***Display the names of the unique launch sites in the space mission?***
- Answer:
    - CCAFS LC-40
    - CCAFS SLC-40
    - KSC LC-39A
    - VAFB SLC-4E

Launch Site Names Begin with 'CCA'

```
%%sql
SELECT launch_site
FROM spacex
WHERE launch_site LIKE 'CCA%'
LIMIT 5
```

```
 * ibm_db_sa://tjf73799:***@2
Done.
```

launch_site
CCAFS LC-40
CCAFS LC-40
CCAFS LC-40
CCAFS LC-40
CCAFS LC-40

- The data scientist used an EDA SQL Database and SQL query to answer the following question:
- ***Display 5 records where launch sites begin with the string 'CCA'***
- Answer:
    - CCAFS LC-40

```
%%sql
SELECT SUM(payload_mass__kg_)
FROM spacex
WHERE customer = 'NASA (CRS)'
```

```
 * ibm_db_sa://tjf73799:***@2f
Done.
```

1
45596

Total Payload Mass

- The data scientist used an EDA SQL Database and SQL query to answer the following question:
- ***Display the total payload mass carried by boosters launched by NASA (CRS)***
- Answer:
  - 45596

```
%%sql
SELECT avg(payload_mass__kg_)
FROM spacex
WHERE booster_version = 'F9 v1.1'
```

```
 * ibm_db_sa://tjf73799:***@2f3279
Done.
```

1
2928

Average Payload Mass by F9 v1.1

- The data scientist used an EDA SQL Database and SQL query to answer the following question:
- ***Display average payload mass carried by booster version F9 v1.1***
- Answer:
    - 2928

```
%%sql
SELECT MIN(date)
FROM spacex
WHERE landing__outcome = 'Success (ground pad)'
```

```
 * ibm_db_sa://tjf73799:***@2f3279a5-73d1-4859-
Done.
```

1
2015-12-22

First Successful Ground Landing Date

- The data scientist used an EDA SQL Database and SQL query to answer the following question:
- ***List the date when the first successful landing outcome in ground pad was achieved.***
- Answer:
  - 12/22/2015

```
%%sql
SELECT booster_version
FROM spacex
WHERE landing__outcome = 'Success (drone ship)'
AND 4000 < payload_mass__kg_ < 6000
```

```
 * ibm_db_sa://tjf73799:***@2f3279a5-73d1-4859-8
Done.
```

booster_version
F9 FT B1021.1
F9 FT B1023.1
F9 FT B1029.2
F9 FT B1038.1
F9 B4 B1042.1
F9 B4 B1045.1
F9 B5 B1046.1

Successful Drone Ship Landing with Payload between 4000 and 6000

- The data scientist used an EDA SQL Database and SQL query to answer the following question:
- ***List the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000***
- Answer:
  - F9 FT B1021.1
  - F9 FT B1023.1
  - F9 FT B1029.2
  - F9 FT B1038.1
  - F9 B4 B1042.1
  - F9 B4 B1045.1
  - F9 B4 B1046.1

Total Number of Successful and Failure Mission Outcomes

```
%%sql
SELECT mission_outcome, COUNT(*)
FROM spacex
GROUP BY mission_outcome
```

```
 * ibm_db_sa://tjf73799:***@2f327
Done.
```

mission_outcome	2
Failure (in flight)	1
Success	99
Success (payload status unclear)	1

- The data scientist used an EDA SQL Database and SQL query to answer the following question:
- ***List the total number of successful and failure mission outcomes***
- Answer:
  - Failure: 1
  - Success: 99
  - Unclear: 1

Boosters Carried Maximum Payload

- The data scientist used an EDA SQL Database and SQL query to answer the following question:
- ***List the names of the booster_versions which have carried the maximum payload mass. Use a subquery***
- Answer:
    - F9 FT B1048.4
    - F9 FT B1048.4
    - F9 FT B1051.3
    - F9 FT B1056.4
    - F9 FT B1048.5
    - F9 FT B1051.4
    - F9 FT B1049.5
    - F9 FT B1060.2
    - F9 FT B1058.3
    - F9 FT B1051.6
    - F9 FT B1060.3
    - F9 FT B1049.7

```
%%sql
SELECT booster_version
FROM spacex
WHERE payload_mass__kg_ IN (SELECT MAX(payload_mass__kg_)
                            FROM spacex)
```

```
 * ibm_db_sa://tjf73799:***@2f3279a5-73d1-4859-88f0-a6c3e
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

- The data scientist used an EDA SQL Database and SQL query to answer the following question:
- ***List the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015***
- Answer:
    - Failure (drone ship) F9 v1.1 B1012 CCAFS LC-40 2015-01-10
    - Failure (drone ship) F9 v1.1 B1015 CCAFS LC-40 2015-04-14

```
%%sql
SELECT landing__outcome, booster_version, launch_site, date
FROM spacex
WHERE landing__outcome = 'Failure (drone ship)'
AND YEAR(date) = 2015
```

```
 * ibm_db_sa://tjf73799:***@2f3279a5-73d1-4859-88f0-a6c3e6b4
Done.
```

landing__outcome	booster_version	launch_site	DATE
Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40	2015-01-10
Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40	2015-04-14

```
%%sql
SELECT landing__outcome, count(landing__outcome)
FROM spacex
WHERE date BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY landing__outcome
ORDER BY 2 DESC
```

```
 * ibm_db_sa://tjf73799:***@2f3279a5-73d1-4859-88
Done.
```

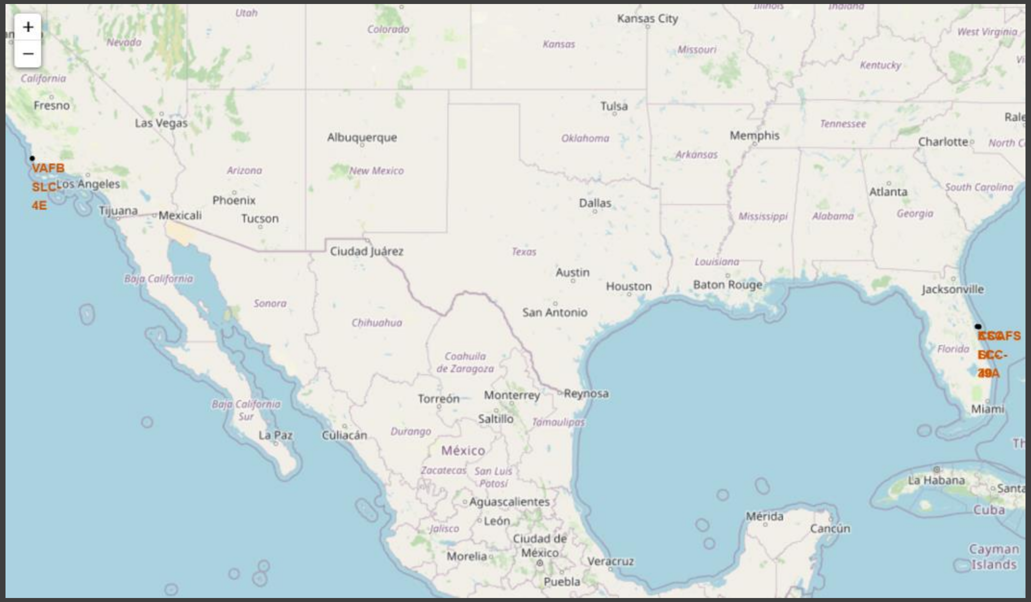
landing__outcome	2
No attempt	10
Failure (drone ship)	5
Success (drone ship)	5
Controlled (ocean)	3
Success (ground pad)	3
Failure (parachute)	2
Uncontrolled (ocean)	2
Precluded (drone ship)	1

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

- The data scientist used an EDA SQL Database and SQL query to answer the following question:
- ***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***
- Answer:
  - 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

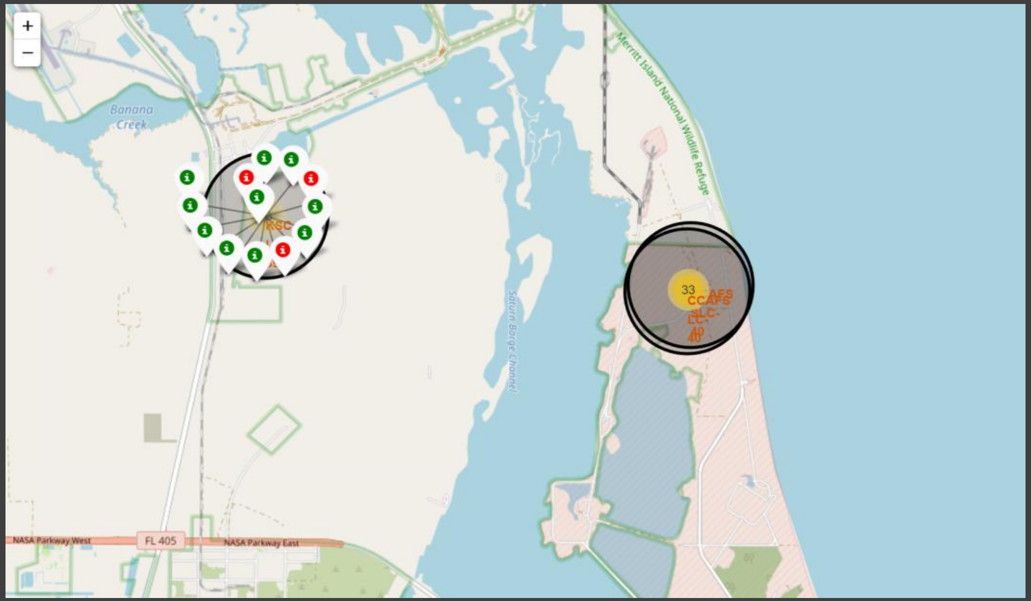
Section 4

Launch Sites Proximities Analysis



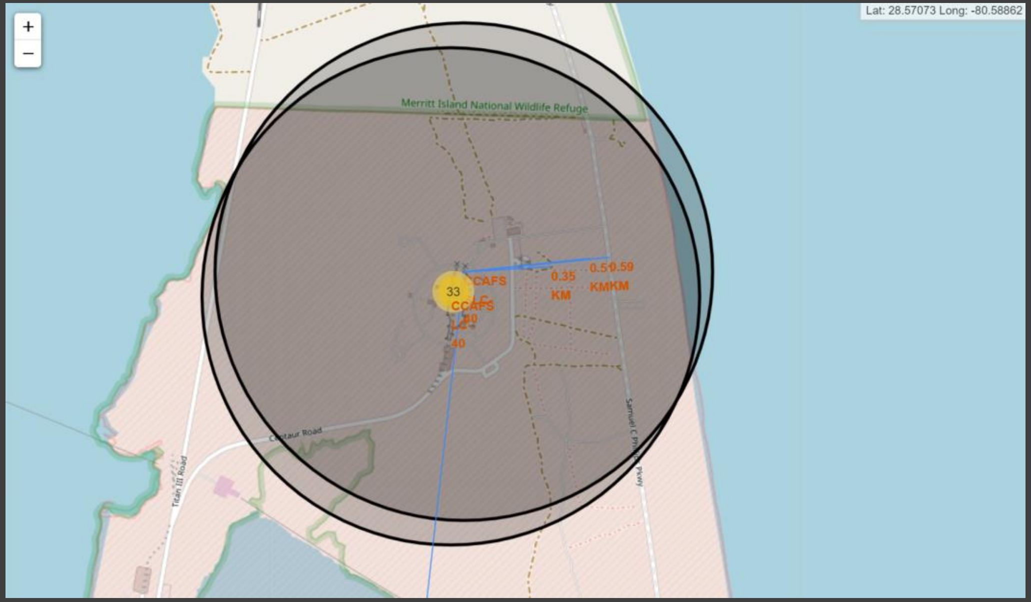
All Launch Sites

- This map was produced by using the panda library: folium and inputting the data location through the data frame.
- The importance of data visualization is to help the data scientist understand if location has any effect on successful launches and their risks.
- This map shows all the locations of the launches.



Success Rate by Launch-Site

- This map was produced by using the panda library of folium and inputting the data location through the data frame.
- The importance of data visualization is to help the data scientist understand if location has any effect on successful launches and their risks.
- This map shows the success/failed launches of each site by clicking on any circled marker, green means success and red means failure.

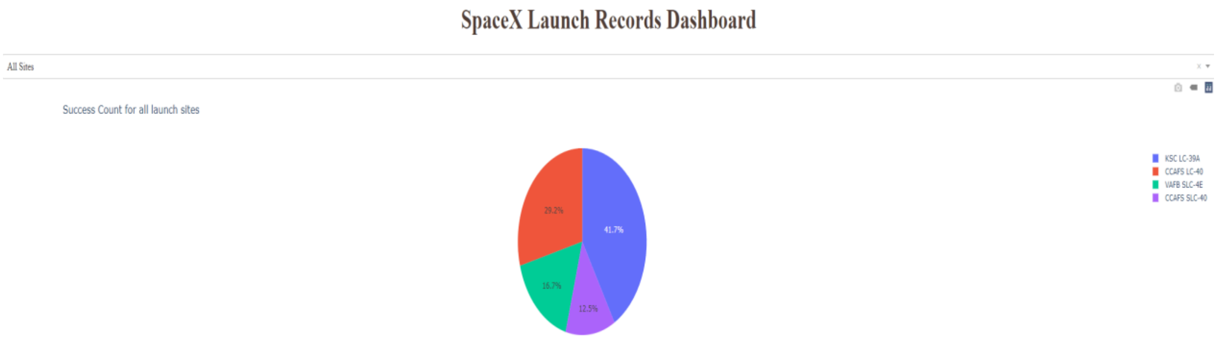


Nearest Risks/Transportation

- This map was produced by using the panda library of folium and inputting the data location through the data frame.
- The importance of data visualization is to help the data scientist understand if location has any effect on successful launches and their risks.
- This map shows the nearest railroads, highways, and cities to determine the risks and modes of transportations from CCAFS LC 40 launch site.
    - Nearest Railroad = 0.35130446057664205 km
    - Nearest Highway = 0.5890306859613954 km
    - Nearest City = 25.065251129546912 km

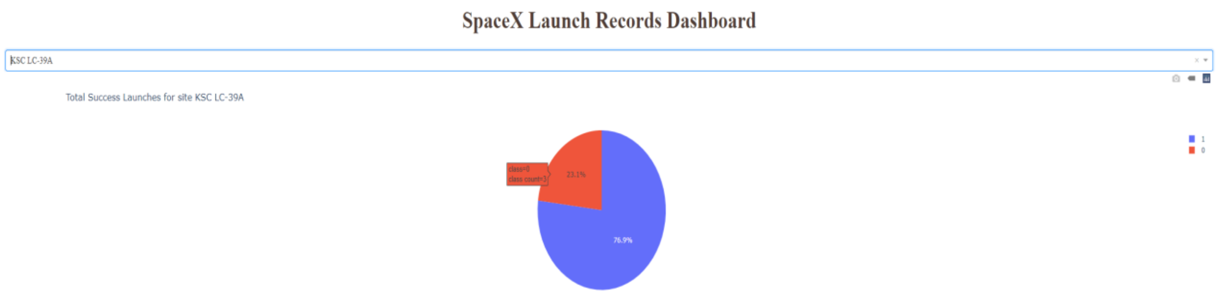
Section 5

Build a Dashboard with Plotly Dash



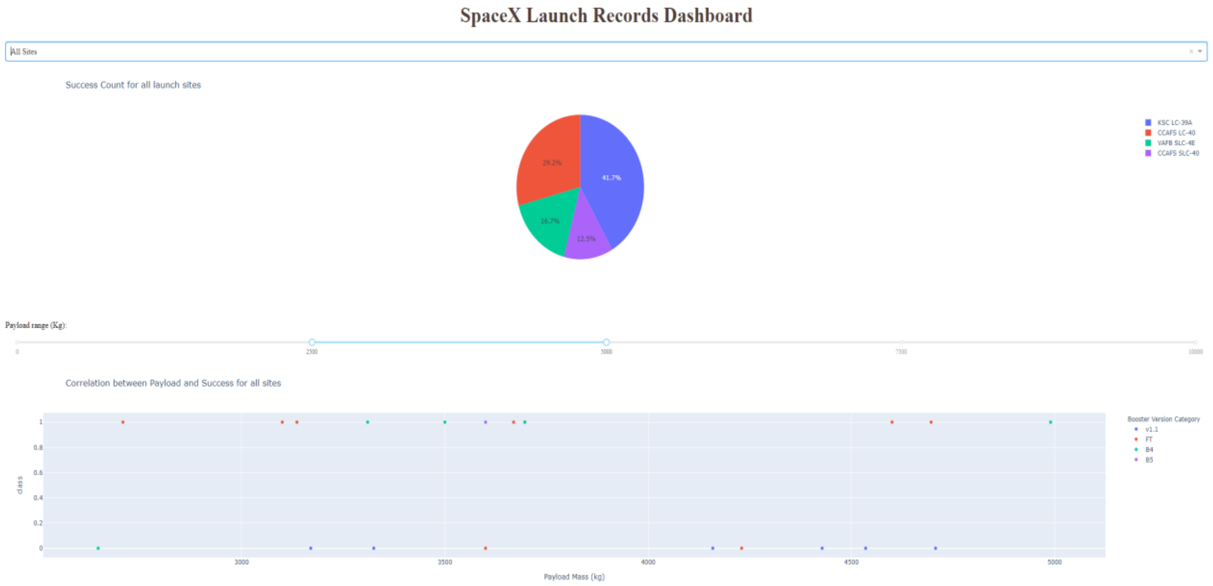
Successful Launches All Sites

- The data scientist made this dashboard using dash and plotly libraries.
- The following Pie Chart represents all of the successful launches through the 4 sites.
- Descending Order
  - KSC LC-39A: 41.7%
  - CCAFS LC-40: 29.2%
  - VAFB SLC-4E: 16.7%
  - CCAFS SLC-40: 12.5%



KSC LC-39A Pie Chart

- The data scientist made this dashboard using dash and plotly libraries.
- The following Pie Chart represents the launch site with the highest success ratio.
- KSC LC-39A had 3 failed launches and 10 successful launches.
- KSC LC-39A had the highest success rate of 10/13 = 76.9%.



All Sites, 2500-5000 Payload + FT Booster

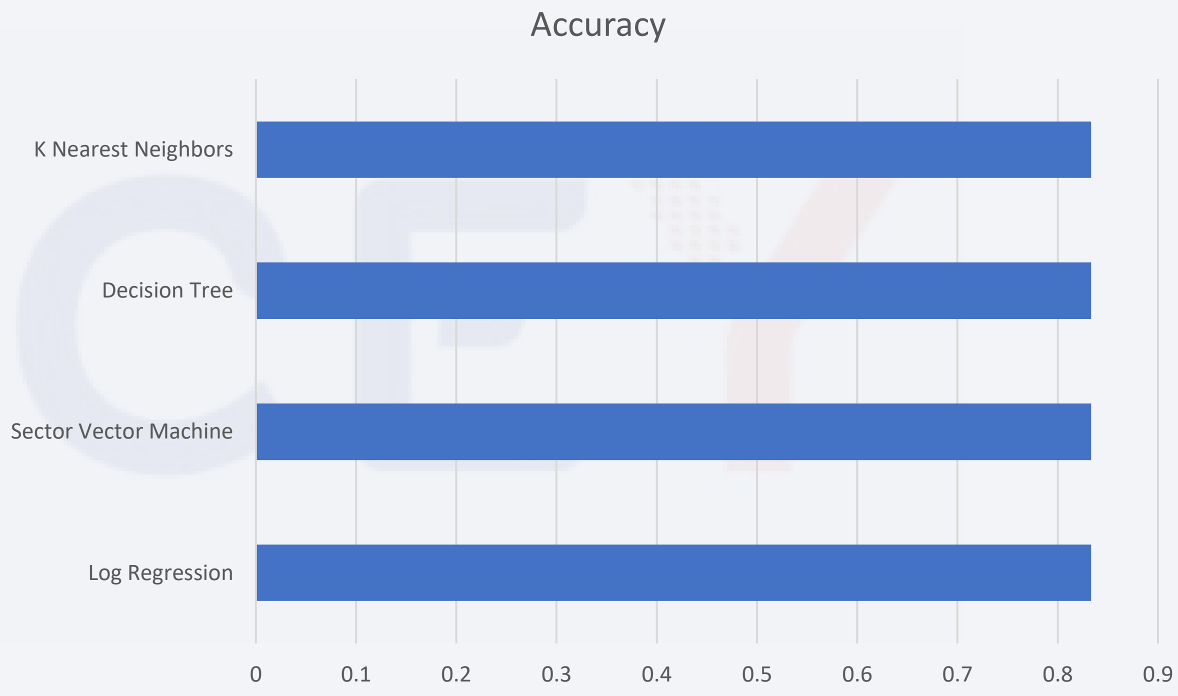
- The data scientist made this dashboard using dash and plotly libraries.
- The following Line Chart represents the launch site with the highest success ratio with payloads and boosters.
- The following success rate of payload are as follows:
- 0 – 2500 Success/Failure 7/12 36%
- 2500-5000 Success/Failure 11/9 55%
- 5000-7500 Success/Failure 2/7 22%
- 7500-10000 Success/Failure 1/1 50%
- The most successful booster within the payload range of 2500-5000 is the FT booster.

Section 6

Predictive Analysis (Classification)

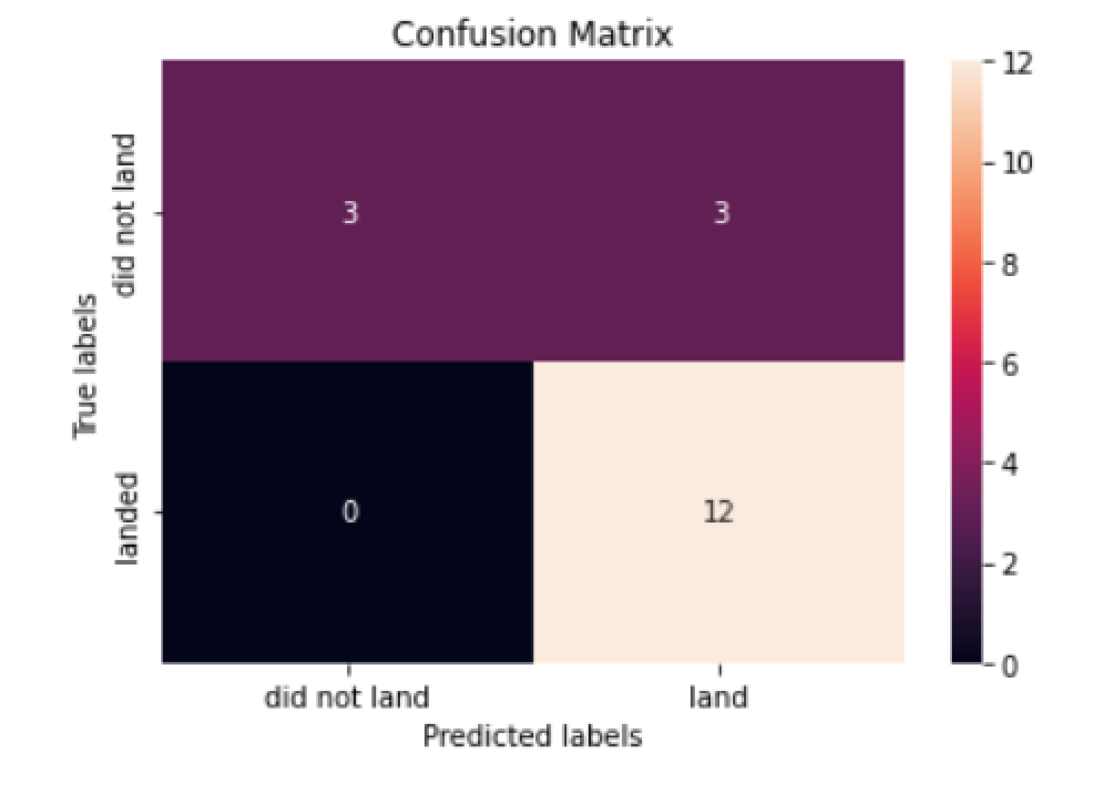
Classification Accuracy

- The following bar chart represents the accuracy of all 4 Machine Learning algorithms used for classification.
- K Nearest Neighbors, Decision Tree, Sector Vector Machine, and Log Regression.
- All of them have the same accuracy rating of 83.3%.



Confusion Matrix

- 4 confusion matrices were used for each classification machine learning method, with all 4 methods having the same end-product.
- The matrix shows that there were 12 true positives, 3 false positives, 0 false negatives, and 3 true negatives.
- This means all 4 ML methods had 83.3% accurate at classifying each event besides false positives.



Conclusions

- Classification models from this report will help SpaceY predict successful 1st stage landings with 83.3% accuracy.
- SpaceX indicates the 1st stage booster costs upwards of $15 million to build.
- Statistically, these findings can help SpaceY attribute each launch to $2.5 million with this accuracy. (15 * .167 = ~2.5)
- Understanding the data with the best parameters will also increase the success rate.
    - Some of the findings suggest the organization can optimize: launch sites, weight, booster, etc.
- This data and models should be iterative and can be further approved with every launch.

Appendix & Acknowledgements

Appendix

- The following links were produced on Juypter Notebooks using Python code and libraries. These libraries include: Panda, Numpy, Matplotlib, Seaborn, Dash, Request, Beautifulsoup, API, Ski-Learn, SQL, DB2, SqlAlchemy, IBM, Ipython, Datetime, Folium, and Wget.
- https://github.com/viettwoone/ibm_data_science/blob/main/SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb
- https://github.com/viettwoone/ibm_data_science/blob/main/jupyter-labs-eda-dataviz.ipynb
- https://github.com/viettwoone/ibm_data_science/blob/main/jupyter-labs-eda-sql-coursera.ipynb
- https://github.com/viettwoone/ibm_data_science/blob/main/jupyter-labs-spacex-data-collection-api.ipynb
- https://github.com/viettwoone/ibm_data_science/blob/main/jupyter-labs-webscraping.ipynb
- https://github.com/viettwoone/ibm_data_science/blob/main/lab_jupyter_launch_site_location.ipynb
- https://github.com/viettwoone/ibm_data_science/blob/main/labs-jupyter-spacex-Data%20wrangling.ipynb
- https://github.com/viettwoone/ibm_data_science/blob/main/spacex_dash_app.ipynb

Acknowledgements

Thank you for the IBM team for writing this awesome course.

Thank you!