Winning Space Race with Data Science

<Name>
<Date>

Outline

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

Executive Summary

- Summary of methodologies
  - Data Collection
  - Web Scraping
  - Data Wrangling
  - SQL EDA
  - Data Visualization EDA
  - Folium – Interactive Geospatial Visualizations
  - Dashboard Application built with Plotly Dash
  - Predictive Analysis
- Summary of all results
  - EDA results
  - Interactive Analytics – Dashboard
  - Predictive Analysis – Machine Learning Models

Introduction

- Background:
  - Companies are attempting to make space travel affordable for everyone. SpaceX can provide similar offerings at a much lower cost than competitors. Where other companies provide offerings at around $165 million, SpaceX advertises a cost of $65 million for the Falcon 9 rocket. Mainly due to the Falcon 9 rocket having a reusable 1st stage.
- Problems you want to find answers
  - For the cost merit to become reality, the launch must land successfully. The analysis is focused on analyzing history of successful launches and predicting the success rates of future launches using Machine Learning models.

Section 1

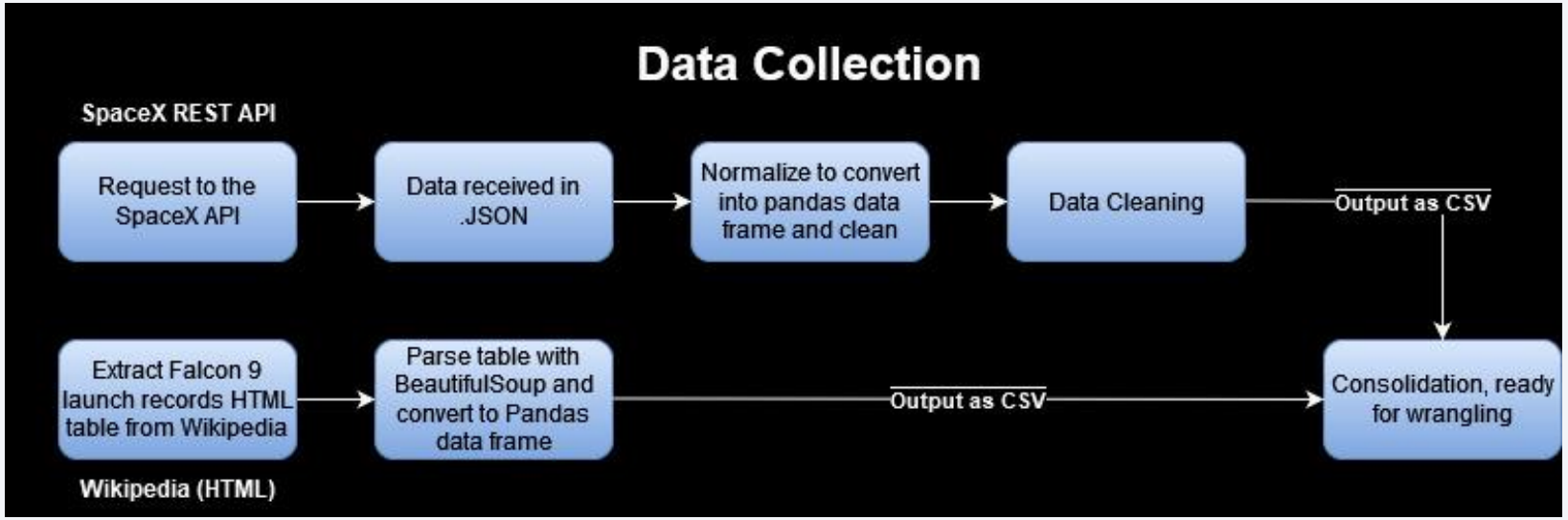
Methodology

Methodology

Executive Summary

- Data collection methodology:
  - SpaceX Rest API
  - Wikipedia Web-Scraping
- Perform data wrangling
  - One hot encoding to prepare for Machine Learning Methods
  - Data was “cleaned” by removing null values and removing unnecessary fields
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - Models Built and evaluated:
    - Logistic Regression
    - K-Nearest Neighbor
    - Support Vector Classification
    - Decision Tree Classifier

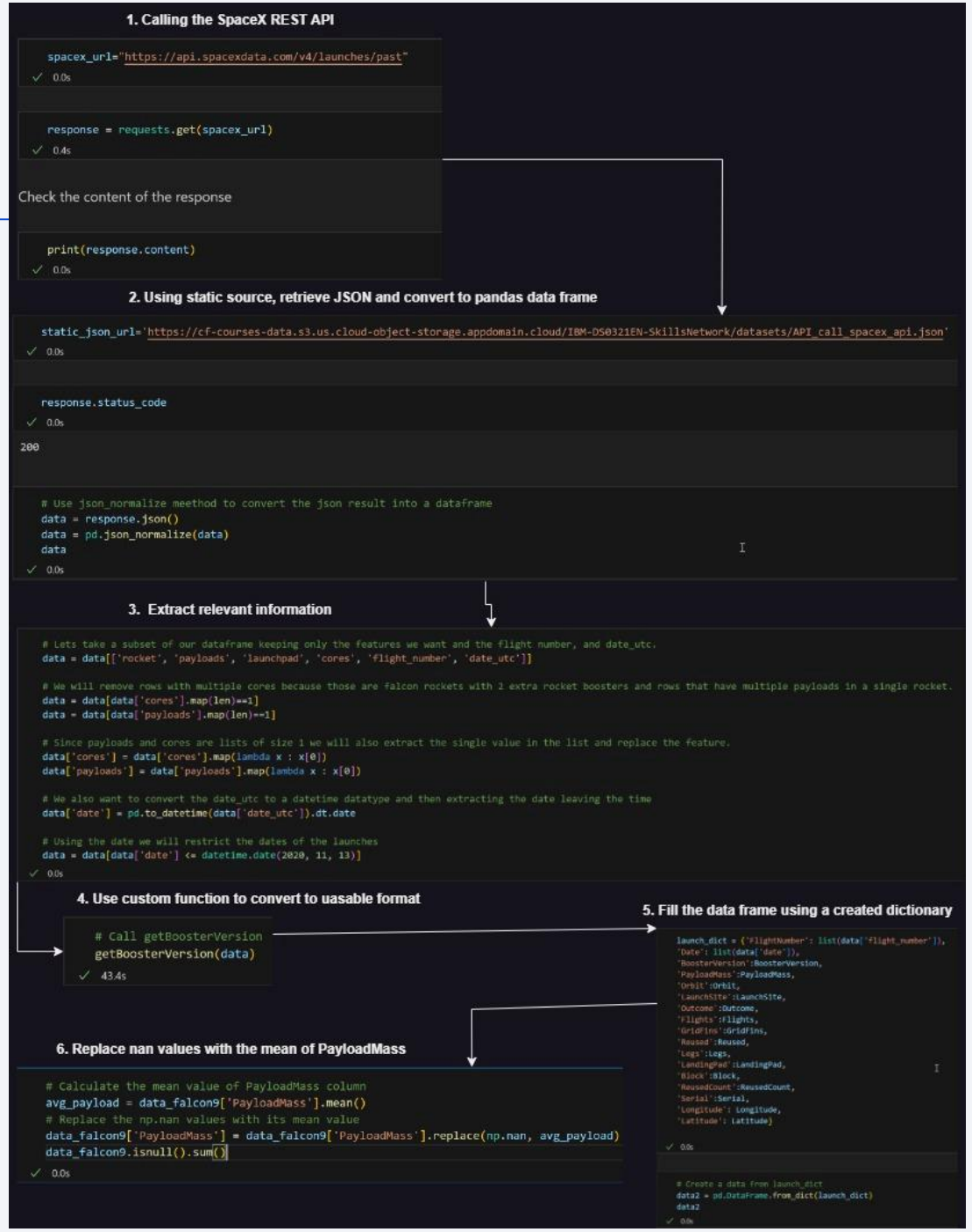
Data Collection



- Collected from 2 sources:
  - SpaceX REST API
  - Wikipedia web scraping
- Made compatible, and then consolidated

Data Collection – SpaceX API

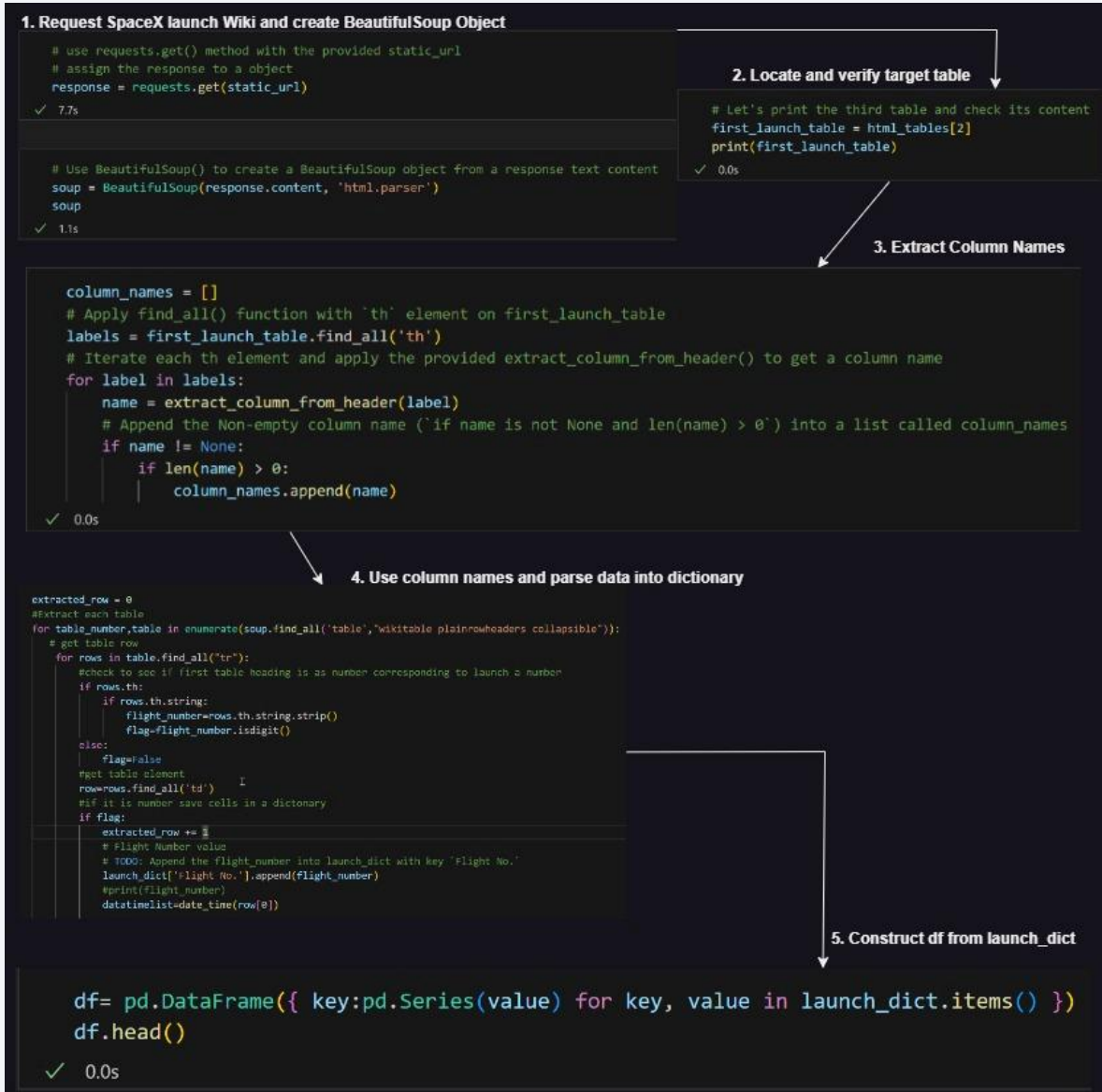
1. Calling the SpaceX REST API
2. Retrieve JSON and convert to pd df
3. Extract relevant info
4. Use custom function to convert to usable format
5. Populate dictionary from JSON and create df
6. Replace nan with mean of PayloadMass column



https://github.com/MLiebhart/IBM_Python_for_Data_Science/blob/1e32bfa8537bc7e5b2dfd5d5c6fc95129ff0e50d/Part1_jupyter-labs-spacex-data-collection-api.ipynb

Data Collection – Webscraping

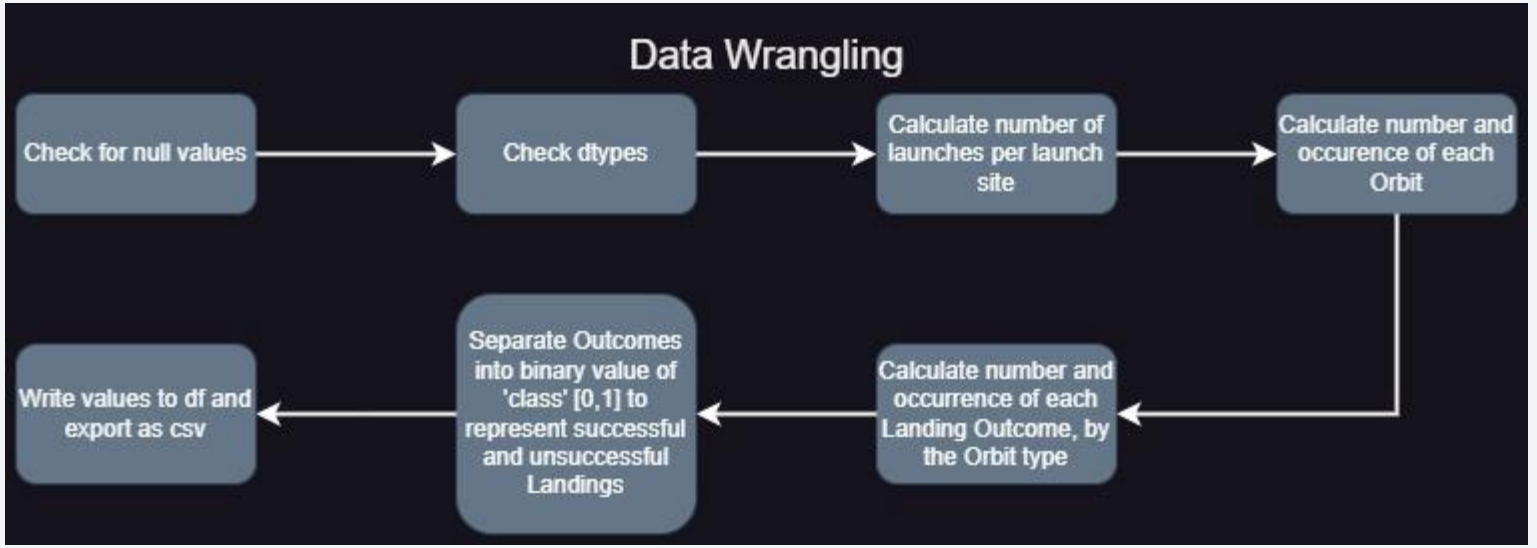
1. Request launch Wiki and create BeautifulSoup object
2. Locate target table on page
3. Extract column names
4. From column names, parse data into launch_dict
5. Construct df from launch_dict



https://github.com/MLiebhart/IBM_Python_for_Data_Science/blob/cb432e8e208b14b7d797541d0f278b6703ac6286/Part2_jupyter-labs-webscraping_SpaceX.ipynb

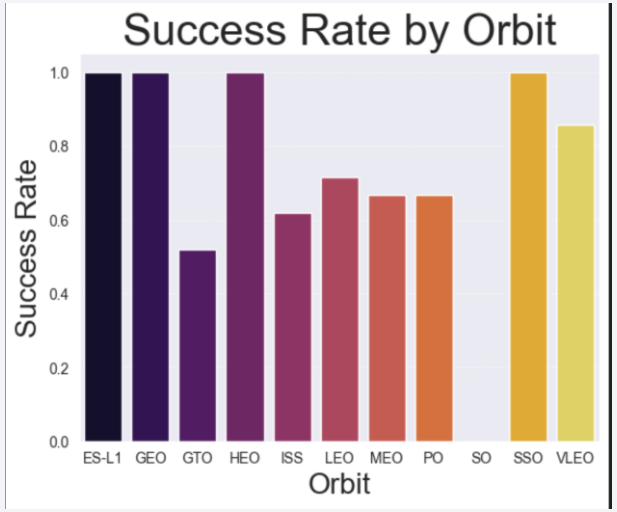
Data Wrangling

1. Check for null values
2. Check dtypes
3. Calculate number of launches per site
4. Calculate Orbits
5. Calculate Outcomes
6. Classify and separate outcomes into binary
7. Write values to df and export as csv



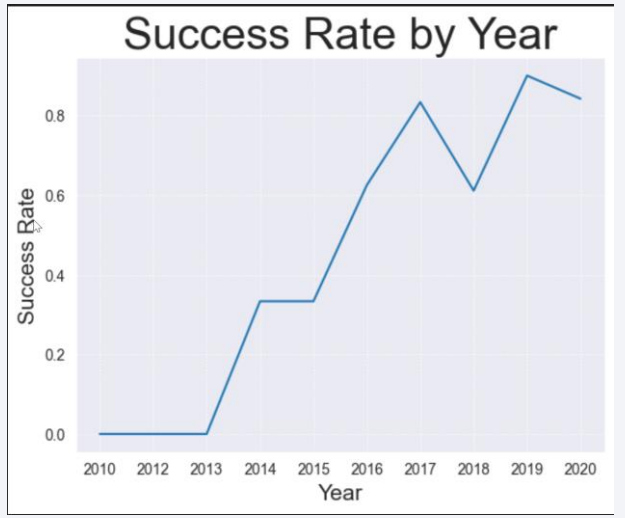
https://github.com/MLiebhart/IBM_Python_for_Data_Science/blob/4664f147d53f4def701fbaa909e687d813d8b458/Part3_labs-jupyter-spacex-Data%20wrangling.ipynb

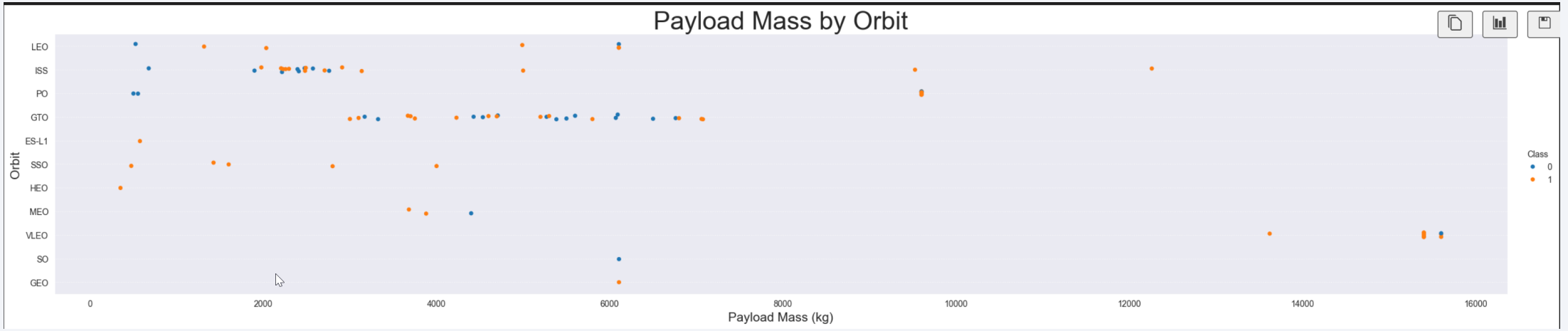
EDA with Data Visualization



These are a few of the graphs made for EDA.

Please visit the link at the bottom for the full Jupyter Notebook





https://github.com/MLiebhart/IBM_Python_for_Data_Science/blob/b440785ed2901e0076f172bf9118ba67fa4f9798/Part5_jupyter-labs-eda-dataviz.ipynb.jupyterlite.ipynb

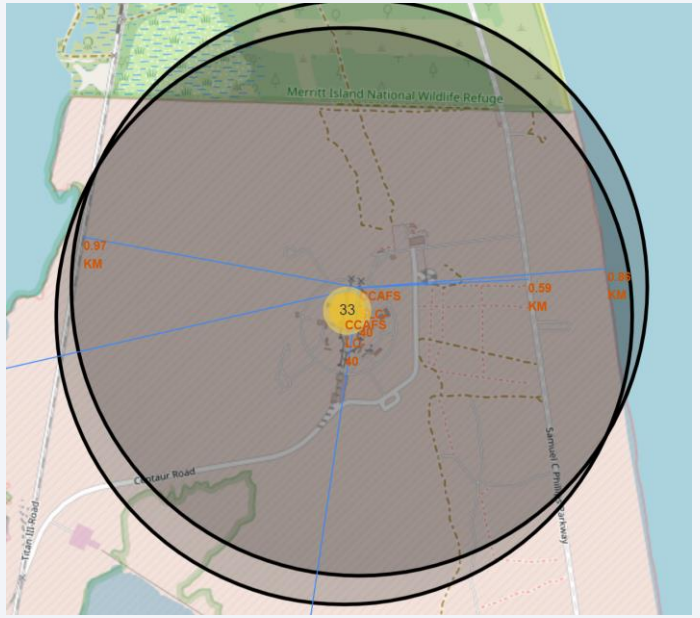
EDA with SQL

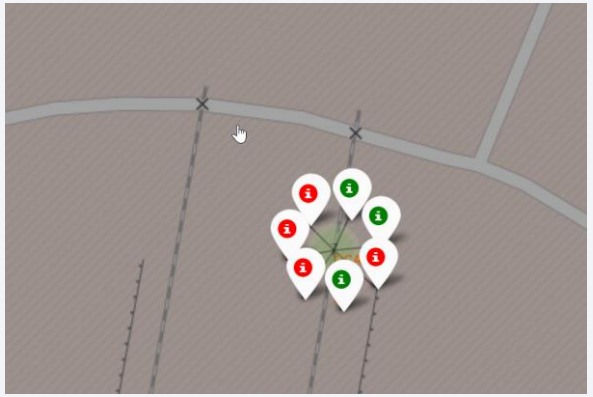
- SQL Query using SQLite, a light-weight Relational database management system (RDBMS) in Python.
  - Create table where date value is not null for analysis
  - Display unique values for column (launch site)
  - Display records with specific launch site (CCA)
  - Display total payload mass launched by specific customer (NASA)
  - Display average payload mass carried by specific booster version (F9 v1.1)
  - Display the date of the first successful launch
  - Display distinct combinations of 2 categorical fields (landing outcome, mission outcome)
  - Listing booster version names with success on drone ship and payload mass between 4000 and 6000 kg
  - Total counts of outcomes by type
  - Display names of booster versions that have carried the maximum payload using a subquery
  - List records which display the month, failure landing outcomes in “drone ship”, booster versions, and launch site by month for the year 2015
  - Rank counts of landing outcomes for date range (2010-06-04 – 2017-03-20)

https://github.com/MLiebhart/IBM_Python_for_Data_Science/blob/1cd14a6c841a09aadf7074e4cacf0d86c82b9b9a/Part4_jupyter-labs-eda-sql-coursera_sqllite.ipynb

Build an Interactive Map with Folium

- Map markers added at launch sites
- Features added for interactive viewing:
  - Marker clusters
  - Circle markers
  - Icons
  - Identified and calculated distances to objects of interest:
    - Nearest City, Railroad track, Highway, and Disney World

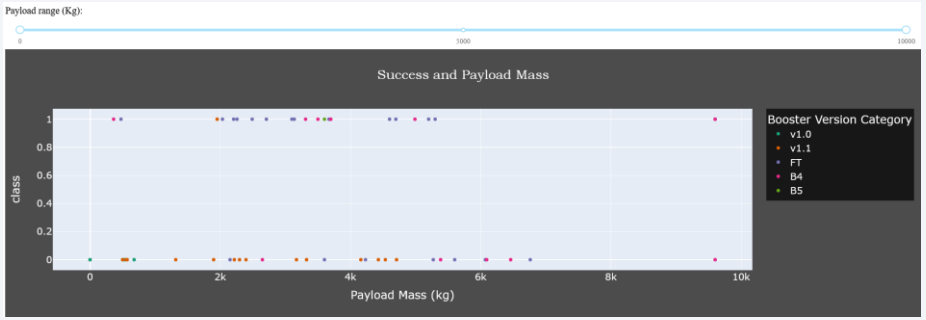


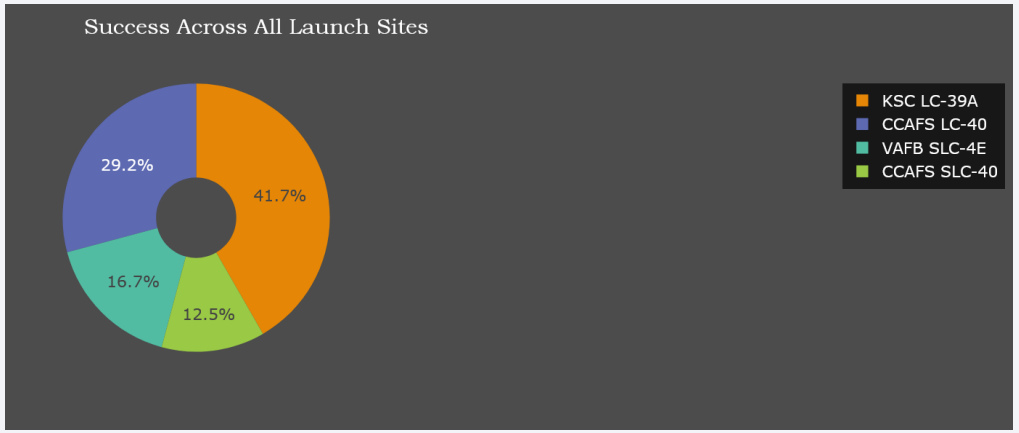


https://github.com/MLiebhart/IBM_Python_for_Data_Science/blob/b440785ed2901e0076f172bf9118ba67fa4f9798/Part6_Folium_Maps.jupyterlite.ipynb

Build a Dashboard with Plotly Dash

- Dash application was made with pie charts representing the success rates by launch site – which is filterable.
- Scatter plot representing success rates for payloads and a slider to filter out and select certain payload ranges.
- These plots were made to highlight and visualize factors that may contribute to success rate.

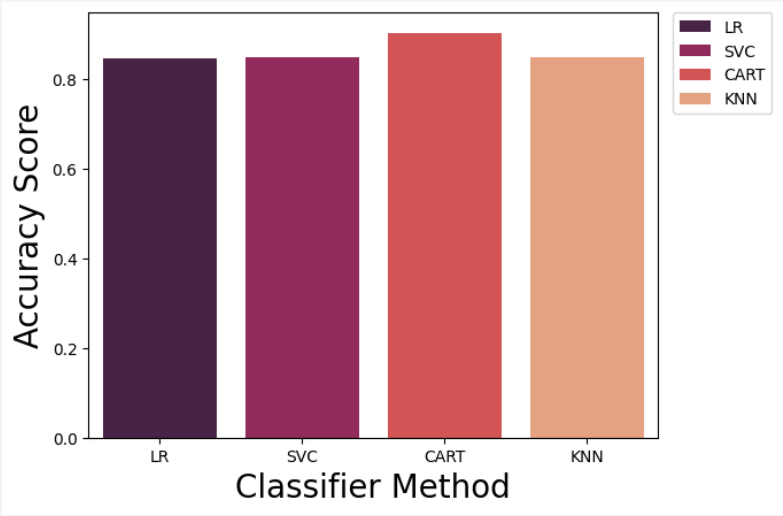




https://github.com/MLiebhart/IBM_Python_for_Data_Science/blob/f13d8b09d578e5ef32d6b72ce5e9c6546916b175/Part7_spacex_launch_data_dash_app.py

Predictive Analysis (Classification)

- Used 4 common supervised machine learning models for classification:
  - Logistic Regression (LR)
  - Support Vector Machine (SVM)
  - K-Nearest Neighbor (KNN)
  - Decision Tree Classification (CART)

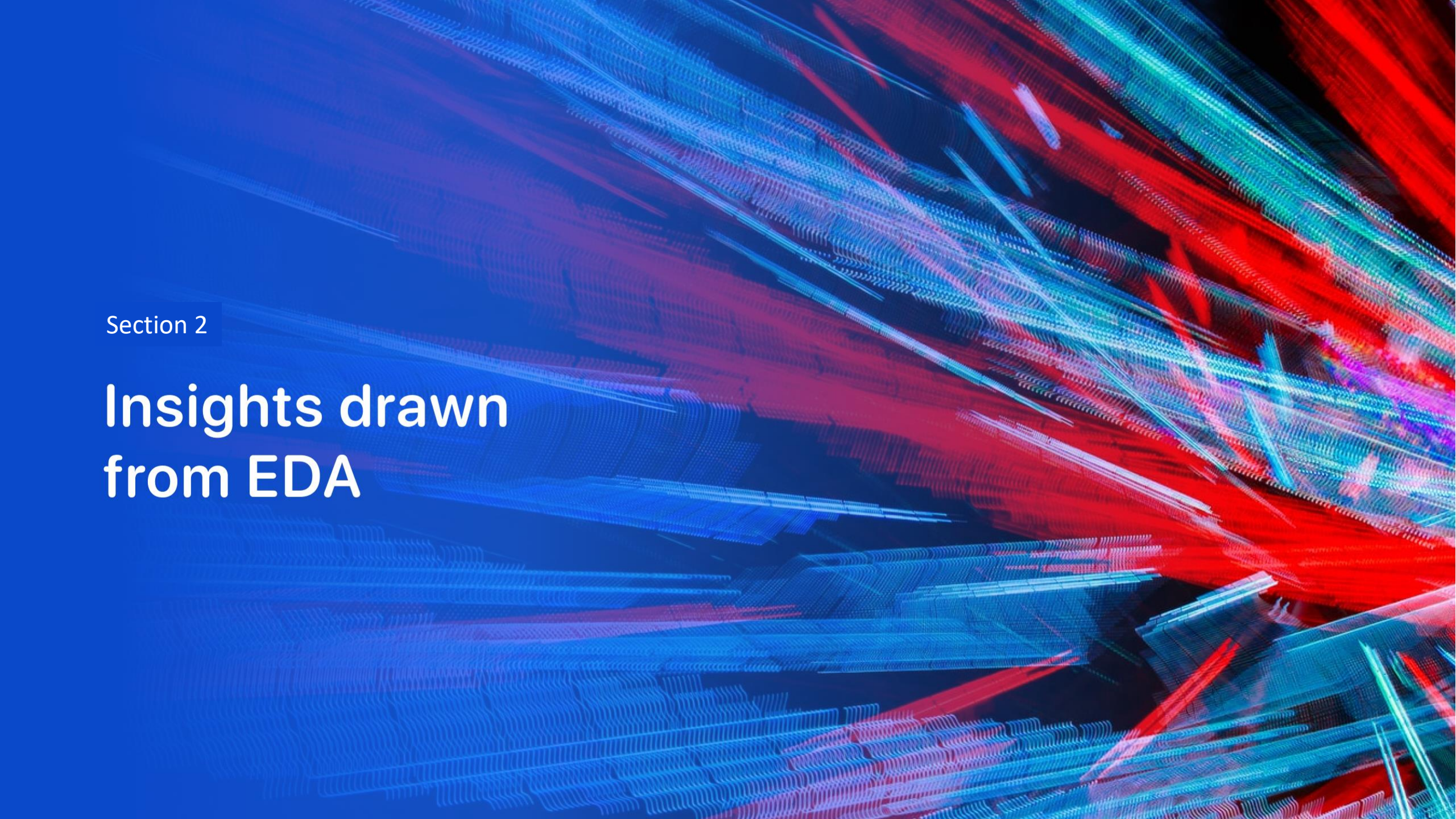


- Data was split into 80/20 (train/test) and the same training data was used to train each model.
- Using a grid search with cross-validation, each model selected the best predictors out of a dictionary of provided parameters.
- The model with the best accuracy on the training set was the Decision Tree Classifier (CART)

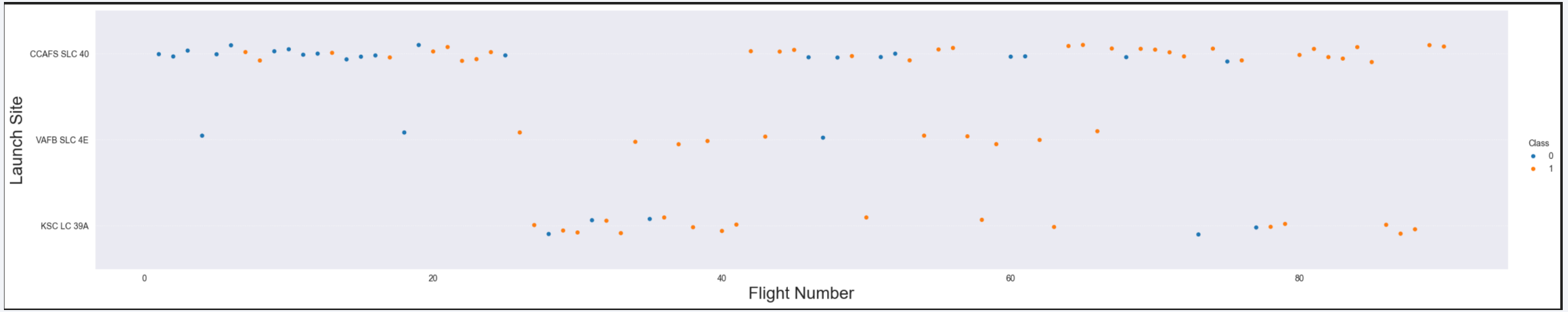
https://github.com/MLiebhart/IBM_Python_for_Data_Science/blob/a24feeb67114f0fbe3a88465aab72e14d3bab562/Part8_SpaceX_Machine_Learning_Prediction.jupyterlite.ipynb

Results

- Results of the following to be shared next in greater detail:
  - Exploratory data analysis results:
  - Interactive analytics demo in screenshots
  - Predictive analysis results

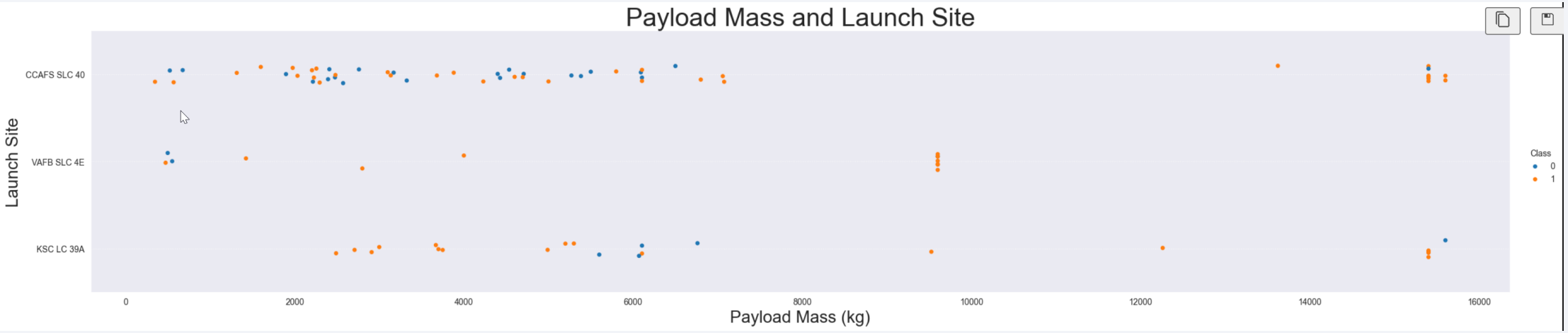

Section 2
Insights drawn from EDA

Flight Number vs. Launch Site



- CCAFS is the most common launch site over time.
- Considering rates of success (0=Failure 1=Success), CCAFS may sit on the low end as the data also suggests probability of success may have increased over time
  - Likely due to “lessons learned” and process/technology improvements

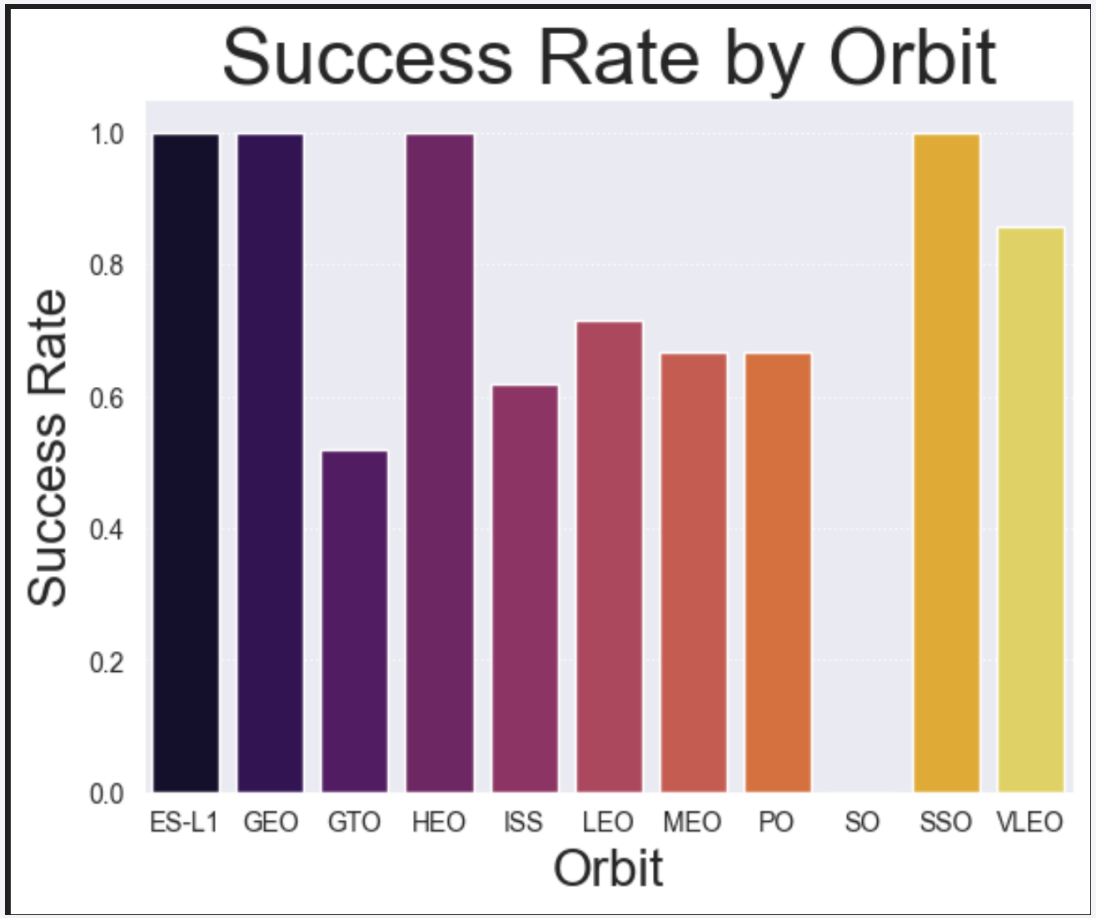
Payload vs. Launch Site



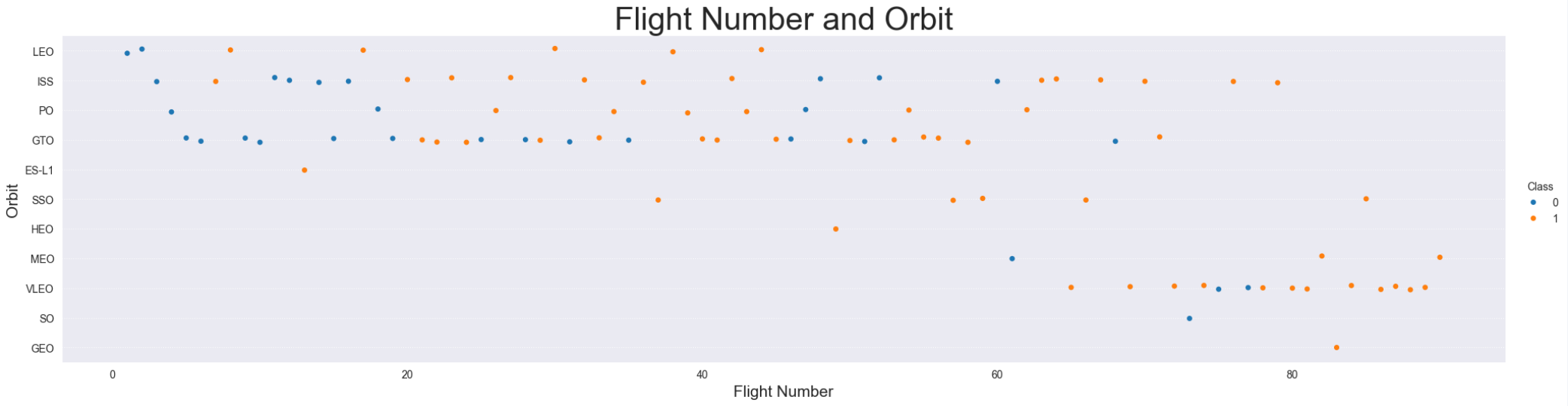
- CCAFS is the most common launch site over time.
- VAFB is favored for payloads between 8,000 to 12,000 kg. Which also have a 100% success rate in this range across all sites.

Success Rate vs. Orbit Type

- Orbits ES-L1, GEO, HEO, and SSO are most successful.
- GTO is the least successful

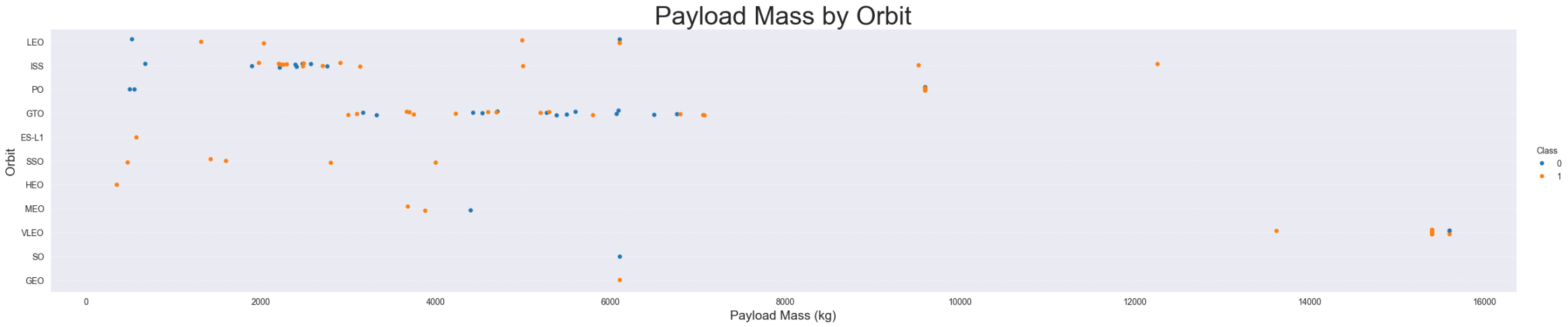


Flight Number vs. Orbit Type



- Orbits with highest success rates are underrepresented by quantity.
- Over time, SpaceX seems to have transitioned focus towards VLEO orbit.

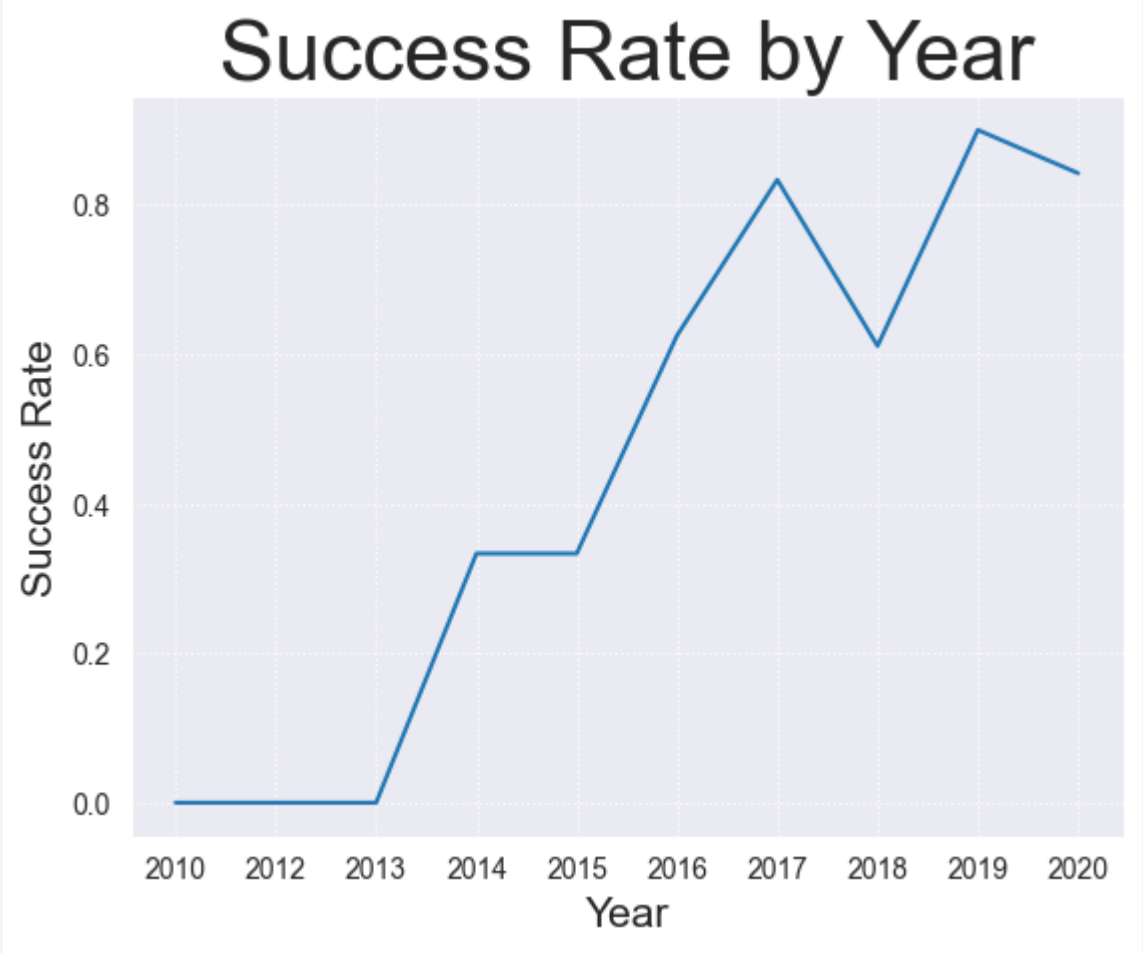
Payload vs. Orbit Type



- There seems to be a relationship between payload mass and some Orbit levels.
  - VLEO favors heavier payloads.
  - ISS has tight grouping 2k-4k, and a few outliers.
  - GTO 3k-8k.

Launch Success Yearly Trend

- Success rates have climbed significantly since 2013.
- In the year 2020, SpaceX achieved just over 80% success rate.



All Launch Site Names

- Launch sites from data:
  - CCAFS LC-40
  - CCAFS SLC-40
  - VAFB SLC-4E
  - KSC LC-39A
- Query is run in SQL syntax through SQLite extension for Python.
  - The query returns unique values within the column launch_site

```
%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'

```
%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
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	7:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	0:35:00	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

- SQL query displays (limit 5) from all records in data table where the value within Launch_Site contains CCA as the first 3 characters

Total Payload Mass

- This represents payloads carried by SpaceX where NASA (CRS) was the customer.

```
%sql select sum(PAYLOAD_MASS__KG_) from SPACEXTBL where Customer = "NASA (CRS)"
```

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

sum(PAYLOAD_MASS__KG_)
45596

- This number represents the total payload mass delivered by SpaceX to the ISS as a part of NASA's Commercial Resupply Services (CRS)

Average Payload Mass by F9 v1.1

- Query displays average payload mass carried by booster version Falcon 9 v1.1

```
%sql select avg(PAYLOAD_MASS__KG_) from SPACEXTBL where Booster_Version like 'F9 v1.1%'
```

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

avg(PAYLOAD_MASS__KG_)
2534.6666666666665

First Successful Ground Landing Date

- After reviewing all Landing Outcomes, I queried the table to show the date of first success.

```
# -- %sql select distinct Landing_Outcome from SPACEXTBL
%sql  select min(Date) from SPACEXTBL where Landing_Outcome like 'Success%'
```

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

min(Date)
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

- Booster versions with successful drone ship landings with payload mass between 4000 and 6000 kg.

```
%sql select Booster_Version, Landing_Outcome, PAYLOAD_MASS__KG_ from SPACEXTBL where Landing_Outcome is 'Success (drone ship)' and PAYLOAD_MASS__KG_ between 4000 AND 6000
```

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

Booster_Version	Landing_Outcome	PAYLOAD_MASS__KG_
F9 FT B1022	Success (drone ship)	4696
F9 FT B1026	Success (drone ship)	4600
F9 FT B1021.2	Success (drone ship)	5300
F9 FT B1031.2	Success (drone ship)	5200

Total Number of Successful and Failure Mission Outcomes

- SpaceX has had a total of 1 Failure and 101 Successful Mission Outcomes.

```
%sql select Mission_Outcome, count(*) as status from SPACEXTBL group by Mission_Outcome
```

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

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

Boosters Carried Maximum Payload

- Falcon 9 B5 is the only Booster version to have carried the maximum Payload.
- It has done this 12 times!

```
%sql select substr(Booster_Version, 1, 5), count(*) as num_trips from SPACEXTBL where PAYLOAD_MASS__KG_ = (select max(PAYLOAD_MASS__KG_) from SPACEXTBL)
```

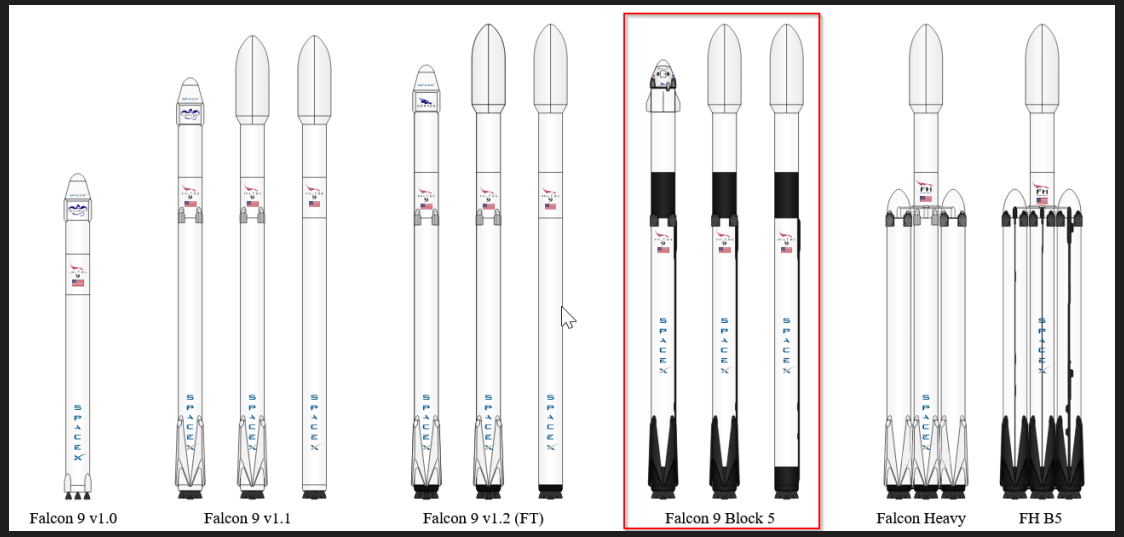
```
 * sqlite:///my_data1.db
Done.
```

substr(Booster_Version, 1, 5)	num_trips
F9 B5	12

```
%sql select distinct Booster_Version, PAYLOAD_MASS__KG_ from SPACEXTBL where PAYLOAD_MASS__KG_ = (select max(PAYLOAD_MASS__KG_) from SPACEXTBL) order by Booster_Version
#%sql select distinct substr(Booster_Version, 1, 5) from SPACEXTBL where PAYLOAD_MASS__KG_ = (select max(PAYLOAD_MASS__KG_) from SPACEXTBL) order by Booster_Version
```

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

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



2015 Launch Records

- 3 attempts were made for drone ship landings in the months of January, April, and June during 2015.
- Out of these 3 attempts there were no successful landings on drone ship.

```
%sql select substr(Date,6,2) as month, substr(Date,0,5) as year, Landing_Outcome, Booster_Version, Launch_Site from SPACEXTBL where substr(Date,0,5) = '2015' and Landing_Outcome like '%drone ship%'
```

Python

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

month	year	Landing_Outcome	Booster_Version	Launch_Site
01	2015	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
04	2015	Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40
06	2015	Precluded (drone ship)	F9 v1.1 B1018	CCAFS LC-40

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

- Between 2010-06-04 and 2017-03-20 Landing Outcomes ranked by count.
- There are most attempts on drone ship
- No outcomes other than success on ground pad for date range.

```
%sql select Landing_Outcome, count(Landing_Outcome) from SPACEXTBL where Date between '2010-06-04' and '2017-03-20' group by Landing_Outcome order by count(Landing_Outcome) desc
```

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

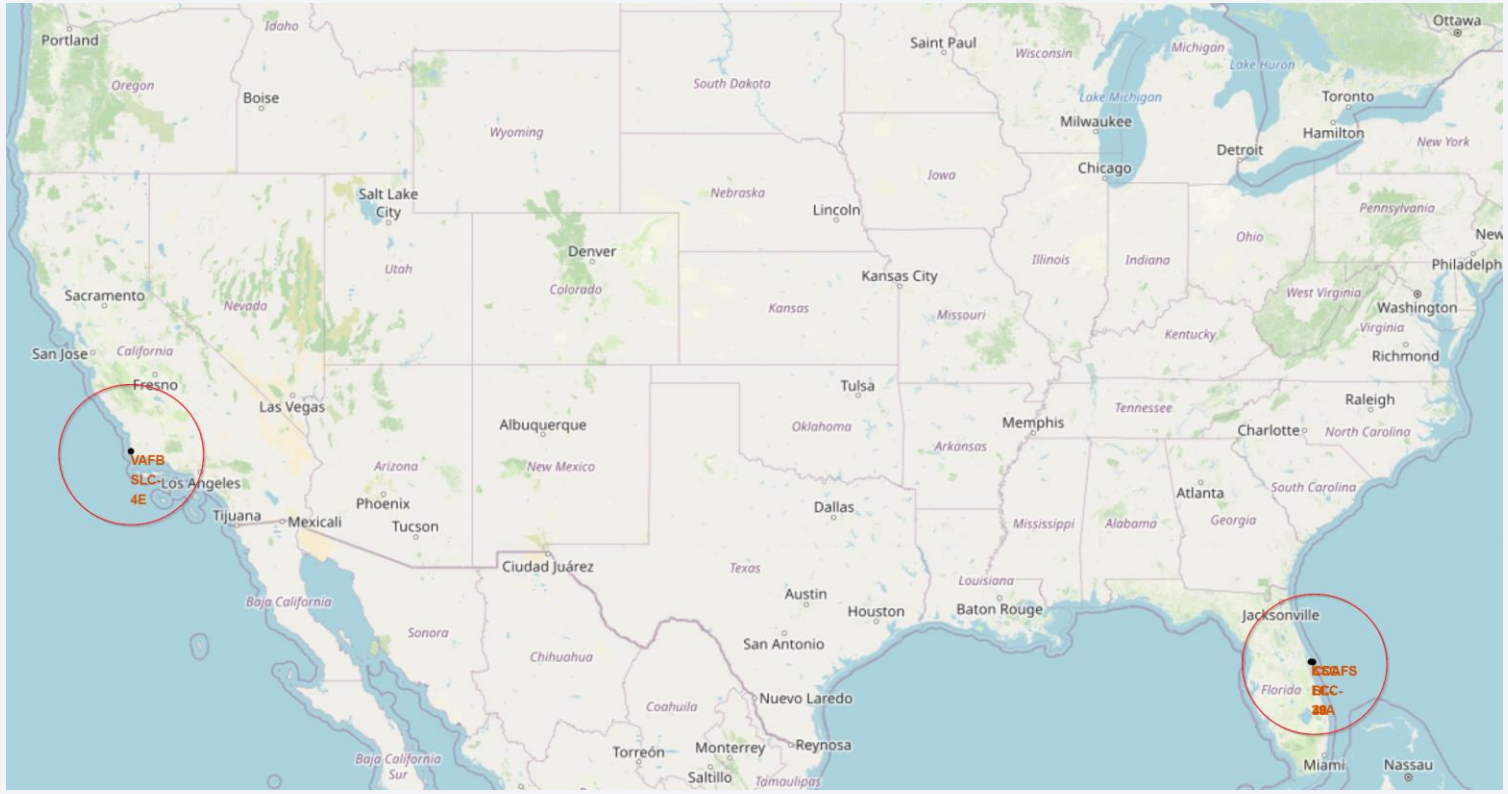
Landing_Outcome	count(Landing_Outcome)
No attempt	10
Success (drone ship)	5
Failure (drone ship)	5
Success (ground pad)	3
Controlled (ocean)	3
Uncontrolled (ocean)	2
Failure (parachute)	2
Precluded (drone ship)	1

Section 3

Launch Sites Proximities Analysis

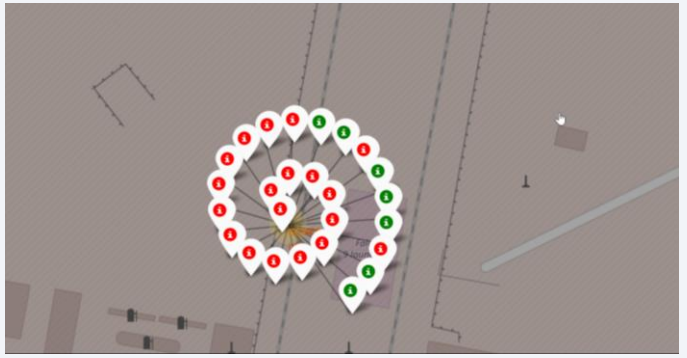
Launch Sites

- Launch Locations are at both the East and West coast in very close proximity to the ocean.



Folium Map Features (Circle markers, clusters, etc.)

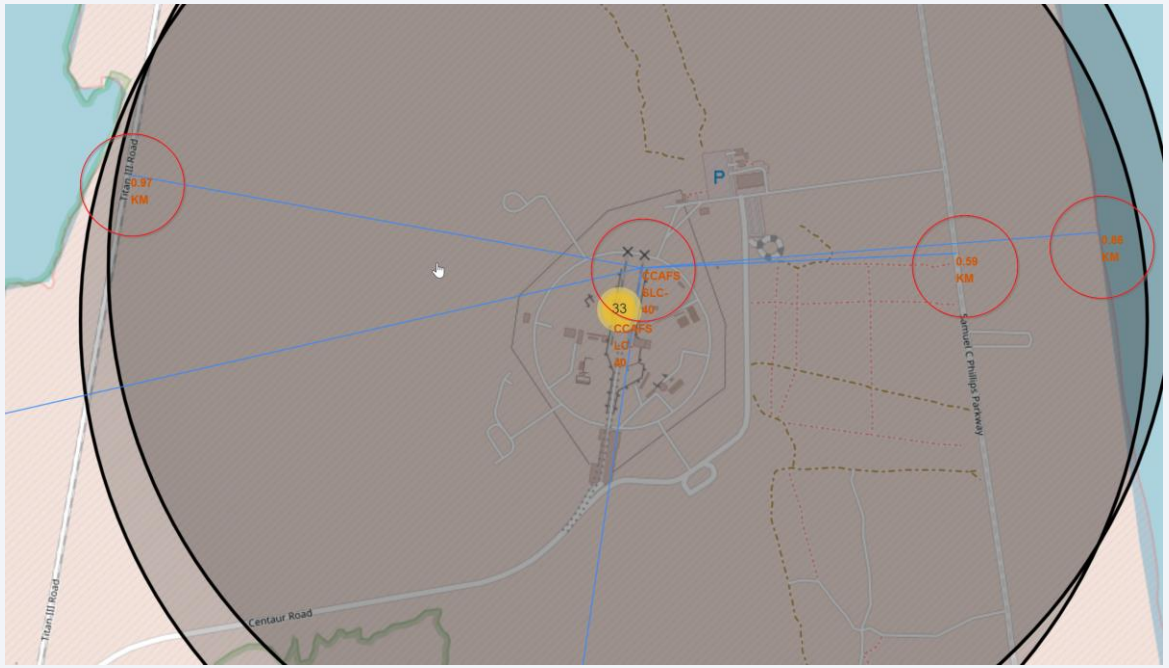
- The majority of launches have occurred in florida.
- Interactive maps were generated and launch locations were clustered by [lat, long].
- Features were expanded to show green and red popup icons to indicate a success (Green) or failure (Red).
- Site CCAFS has two listed launch sites that are nearly on top of eachother.

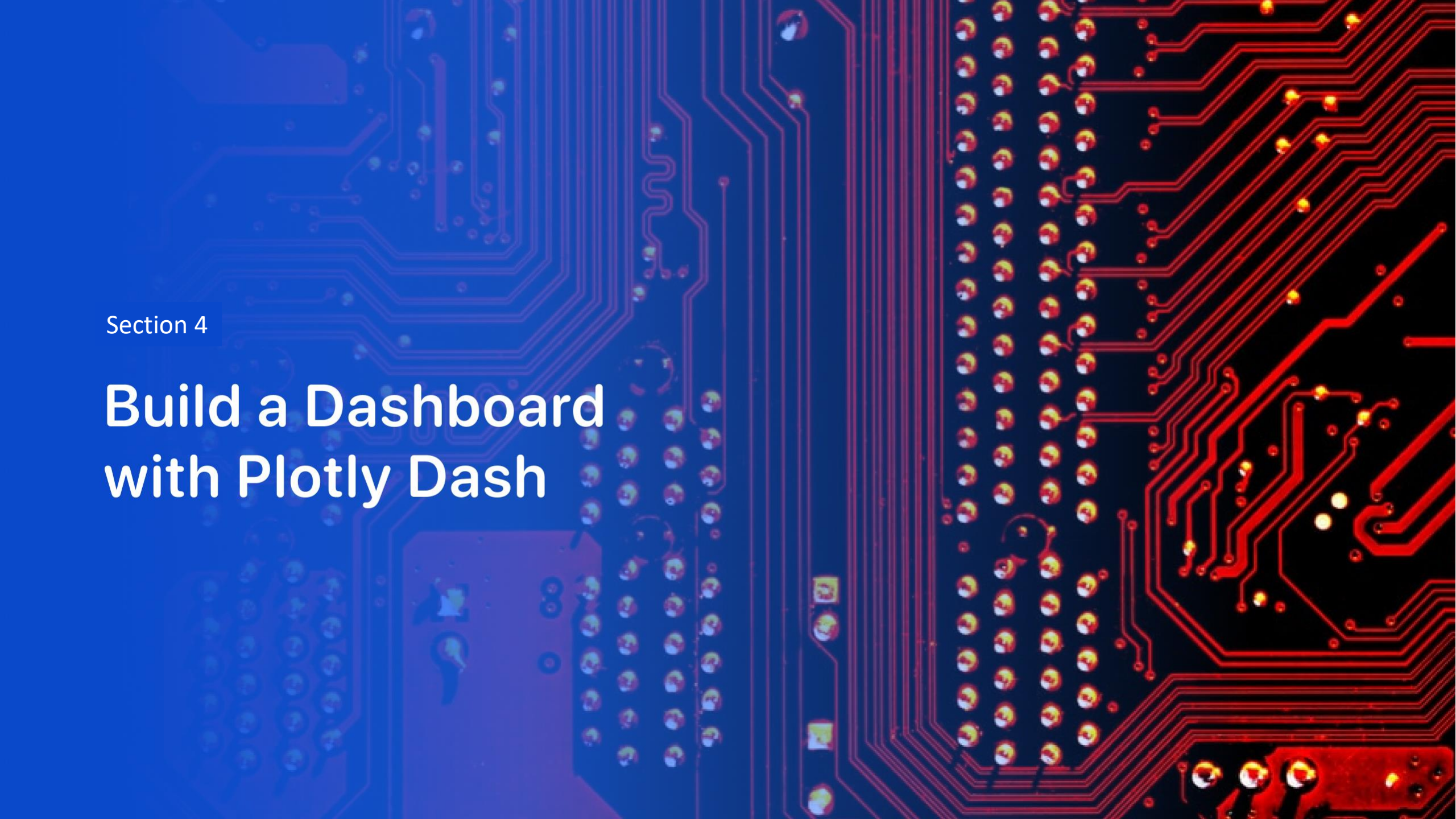


Proximity to points of interest

- Due to the amount of launches I chose site CCAFS to analyze proximity of Objects of interest.
  - Drew a polyline to these points and calculated the length of the line taking account the curvature of the earth.
- This site in particular is close to railways and highways – this is likely for ease of supply transport.
- Launch site is far from the nearest city – likely for safety and to reduce noise pollution.

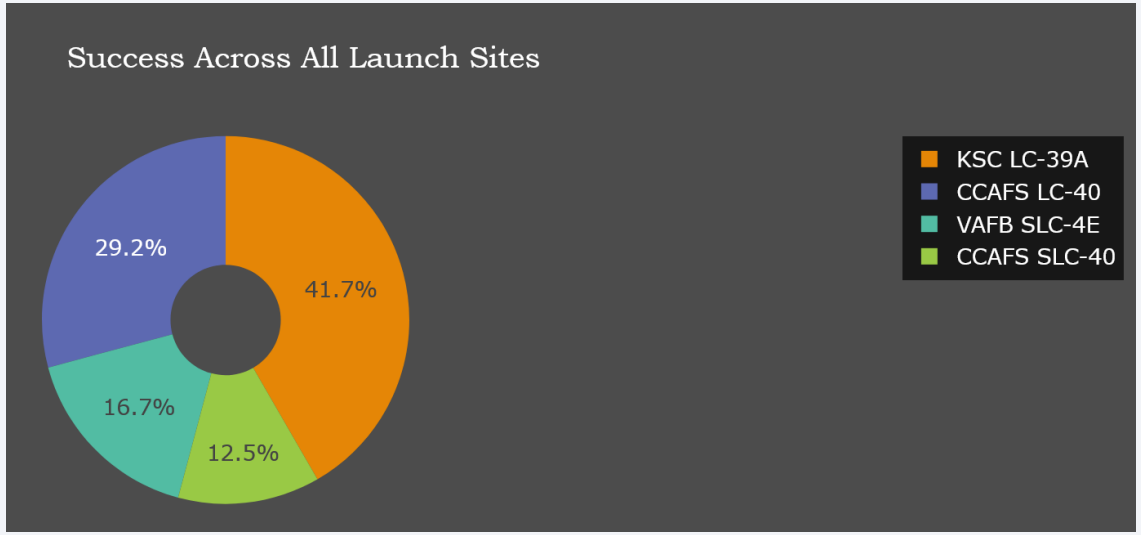
```
Distances of nearest landmarks to Launch Site CCAFS SLC-40:
highway: 0.5887264310853515 km
city: 18.497697056288423 km
railroad: 0.9739935974925776 km
Disney World: 99.19703464318563 km
```



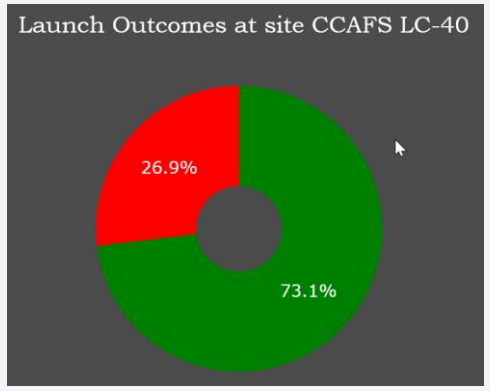

Section 4
Build a Dashboard with Plotly Dash

Dashboard Application – All sites, rate of Success

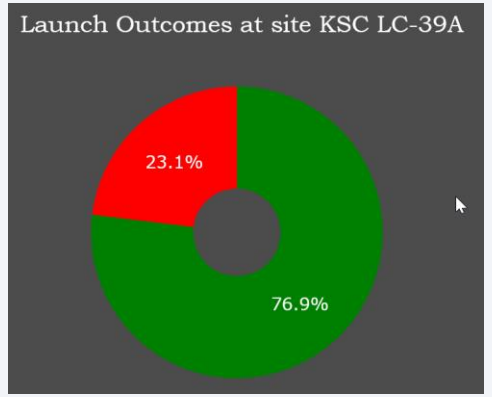
- From the data KSC LC-39A has the highest share of successful launches.
- Using the Folium Maps it was identified that sites CCAFS LC-40 and CCAFS SLC-40 were at a nearly identical location.
  - More information is needed to identify whether these two location are materially different, or why they are listed differently. When combined (41.7%) they are the same as KSC LC-39A. More on the next slide.

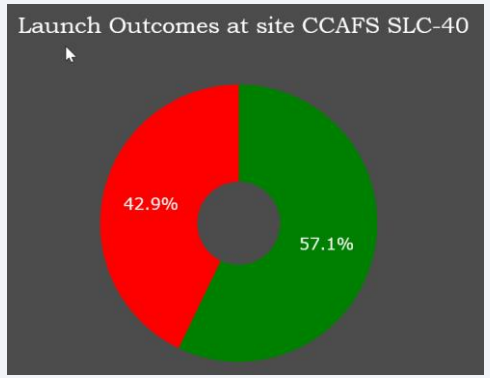


Sites with highest success rates



- On right: KSC LC-39A shows the highest success rate by single location. It also has the largest share of success across all sites.

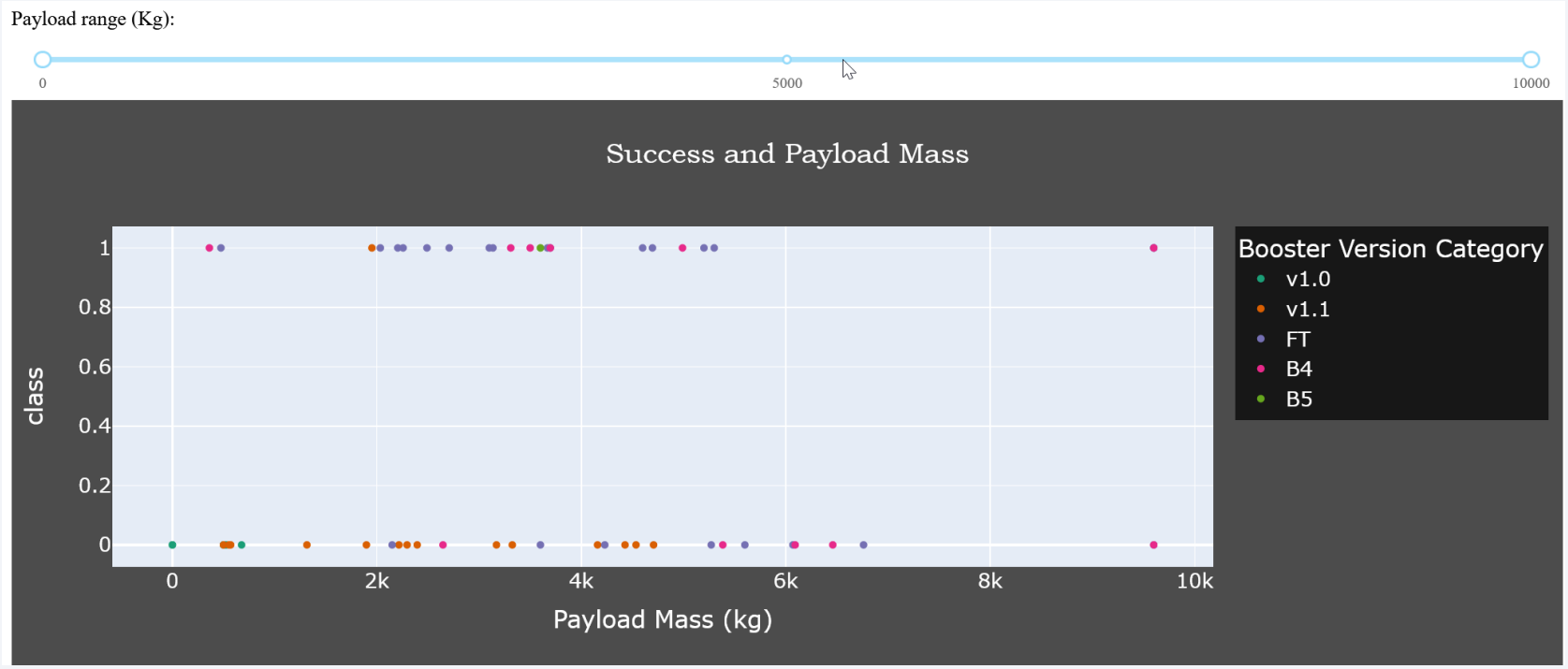




- On left: CCAFS locations when combined show equal share (41.7%) of all successes. As individual locations they each show lower than KSC. Naturally, if combined they would show lower than KSC as a single site. CCAFS SLC-40 is the lowest success rate among those in the study.

Payload and launch outcome

- Dash Application was given a payload range slider to slice the graph for preference.
- There does not seem to be a clear relationship between Payload mass and success.



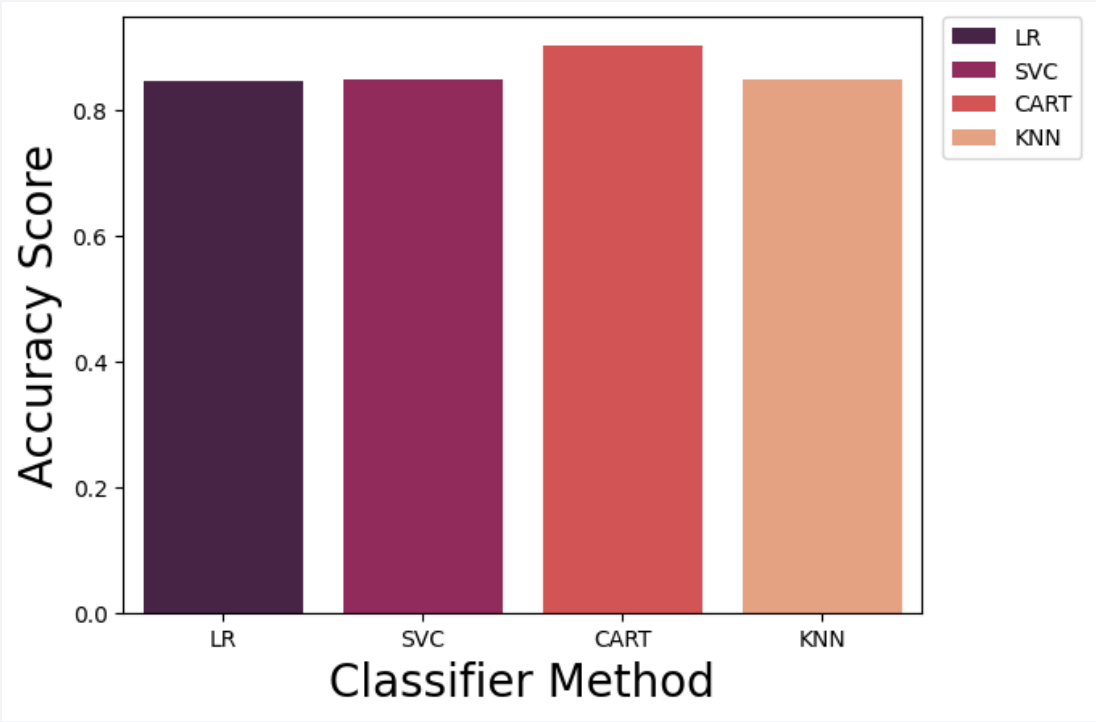
Section 5

Predictive Analysis (Classification)

Classification Accuracy

- Decision Tree Model (CART) had the highest classification accuracy.
  - It should be noted that I adjusted some of the parameters to improve the model.
  - The provided parameters would continue to fail so I adjusted the 'max_features" to include 0<floats<1 as described in sklearn documentation.
  - As shown below my hyperparameters tuned by cross-validation then selected a value outside the parameters provided by the IBM course.

```
parameters = {'criterion': ['gini', 'entropy'],
     'splitter': ['best', 'random'],
     'max_depth': [2*n for n in range(1,10)],
     'max_features': [0.1, .25, .5, .75, 1.0],
     'min_samples_leaf': [1, 2, 4],
     'min_samples_split': [2, 5, 10]
}
tree = DecisionTreeClassifier()
```



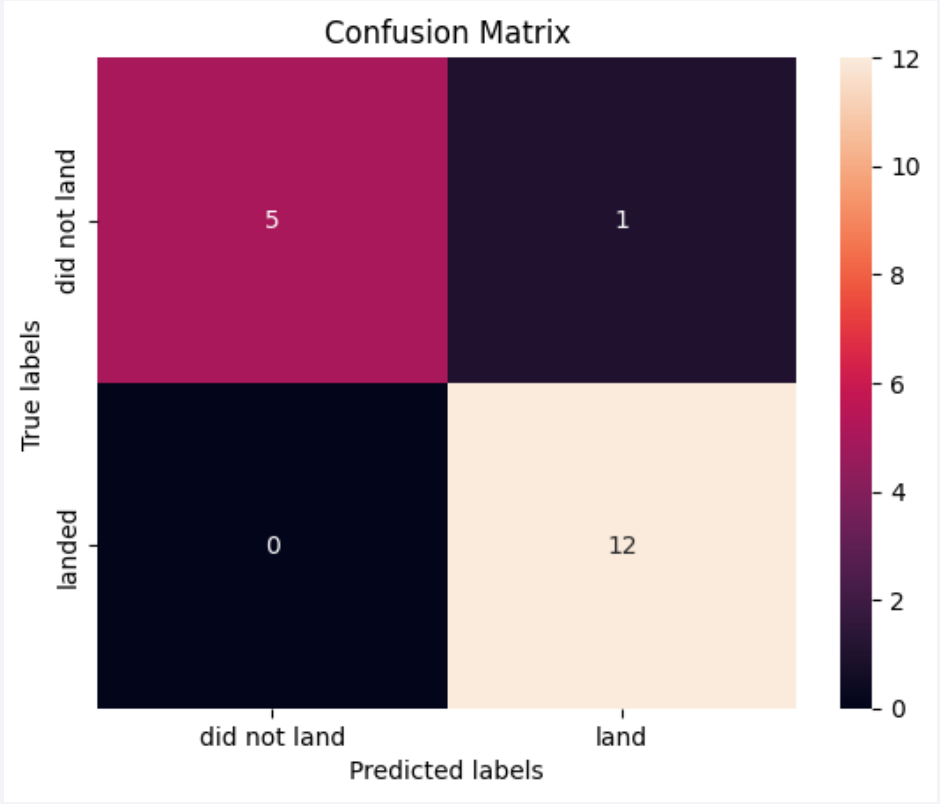

```
Using the LR method, the accuracy is 0.8464285714285713
Using the SVC method, the accuracy is 0.8482142857142856
Using the CART method, the accuracy is 0.9035714285714287
Using the KNN method, the accuracy is 0.8482142857142858
```

Tuned Hyperparameters:

```
tuned hyperparameters :(best parameters)  {'criterion': 'entropy', 'max_depth': 4, 'max_features': 0.25, 'min_samples_leaf': 2, 'min_samples_split': 10, 'splitter': 'random'}
accuracy : 0.9035714285714287
```

Confusion Matrix

- The model accuracy was very good when evaluated against the test set with only one false positive.
- The model correctly predicted 12 successful landings and 5 non-landings.



Conclusions

- SpaceX shows a rapidly increasing success rate over time.
- The data reflects an increase in success over time and additionally, using a CART model we are able to reliably predict successes.
- SpaceX will continue to be a reliable provider of comparably low-cost commercial Space travel if they can continue to reuse components where competitors cannot.
- The data might suggest a change in mission due to the newly found prevalence of VLEO orbits.
    - Due to this being new, the model may need adjusted, retrained, or remade periodically to maintain efficacy.

Appendix

Thank you!