Winning Space Race with Data Science

<Name>
<Date>

Outline

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

Executive Summary

- Summary of methodology
  - Launch Data is gathered from the SpaceX REST API including web scrapping from a Wiki page and data wrangling
  - Exploratory data analysis (EDA) using visualization and SQL including interactive visual analytics (Folium and Plotly Dash)
  - Predictive analysis using ML classification models including model building, tuning and performance evaluation of the classification models
- Summary of all results
  - A Decision Tree classifier has the highest accuracy of the tested models (88.9 accuracy on the test data

Introduction

In this capstone project for *the Applied Data Science Capstone* module, we will predict if the Falcon 9 first stage will land successfully. This has a direct application on determining the cost of a launch by knowing if the first stage will land

All the process is detailed from collecting the data, wrangling, analysing and machine learning building to final conclusions

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - SpaceX Launch Data is gathered from the SpaceX REST API
  - Web scrapping from a Wiki page is performed to collect Falcon 9 historical launch records
- Perform data wrangling
  - Describe how data was processed
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - How to build, tune, evaluate classification models

Data Collection

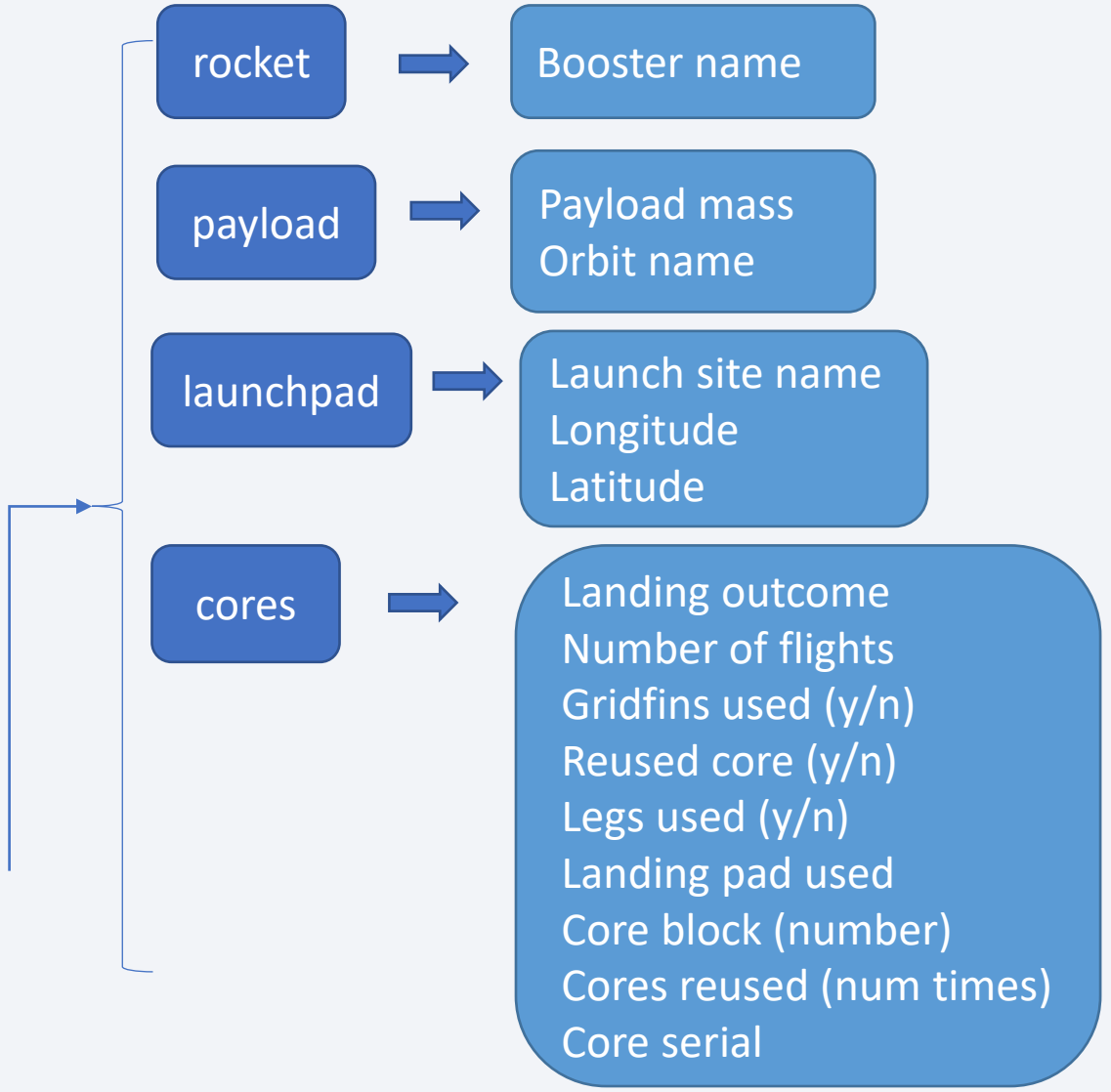
GitHub Link here

- SpaceX Launch Data is gathered from the SpaceX REST API
  - Data about launches: rocket used, payload delivered, launch specifications, landing specifications, and landing outcome.
- Wrangling Data using an API to convert data (json) into a pandas Dataframe
  - Data = *pd.json_normalize(response.json())*
- Web scraping is performed to obtain Falcon 9 Launch data
  - Python BeautifulSoup package is used for web scraping HTML tables (wiki pages) with Falcon 9 launch records.

Data Collection – SpaceX API

GitHub Link here

- Helper functions are used to extract API information using identification numbers
- Data is requested from the URL (endpoint):
  - https://api.spacexdata.com/v4/launches/past
- Data is requested and parsed using the GET request (*response = requests.get(url)*)
  - Response content is decoded as Json and turned into padas DF (*.json_normalize()*)
- Only Falcon 9 launches data is kept
- Data wrangling using an API is also used to target targeting another endpoint to gather specific data for each ID number
  - the mean of PayloadMass is used to replace np.nan values in the data (*replace()* function)



Data Collection - Scraping

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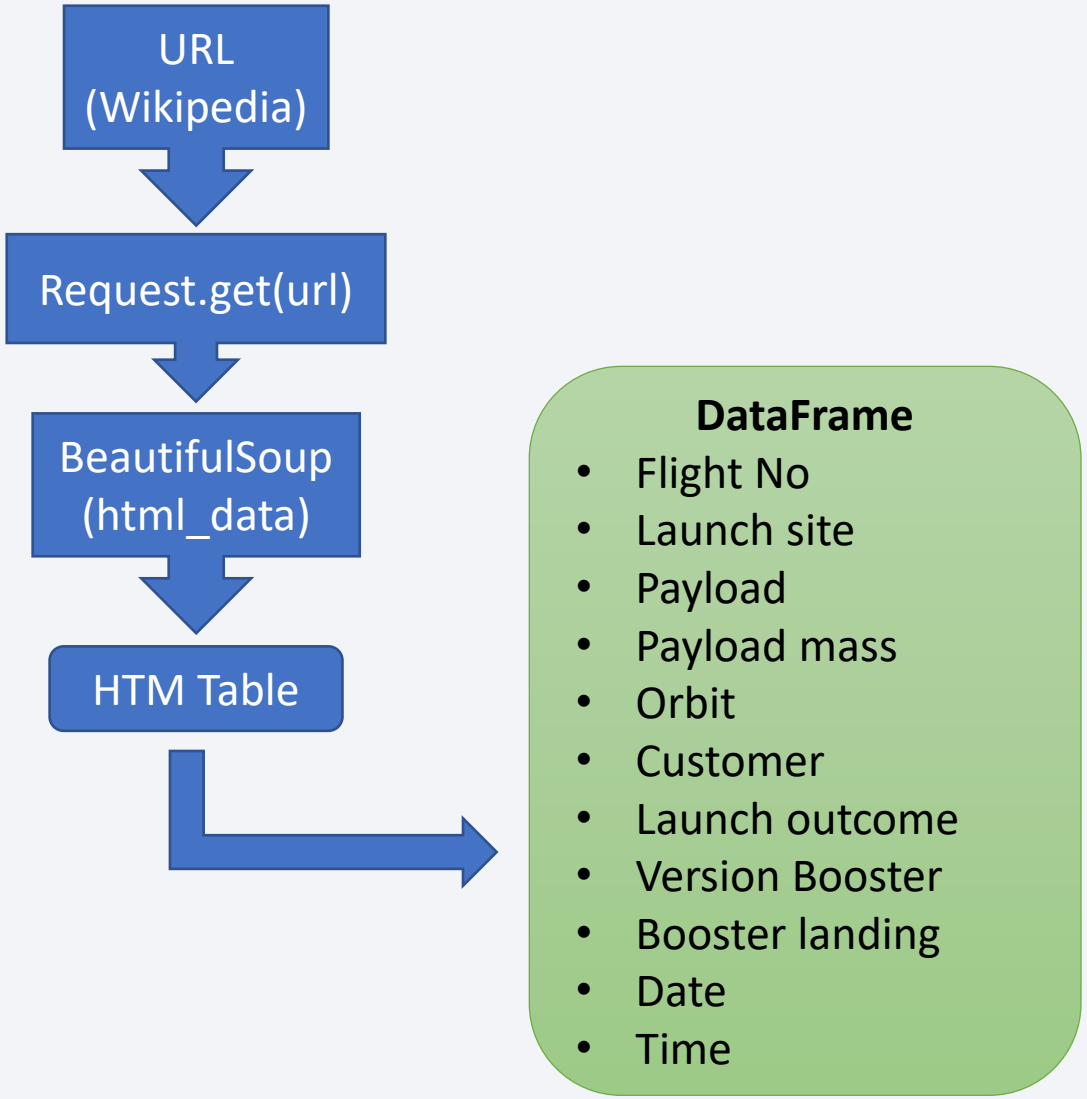

- Web scrapping from a Wiki page is performed using Python's BeautifulSoup
  - to collect **Falcon 9** historical launch records
  - Table is parsed and converted into a pandas DF
- https://en.wikipedia.org/w/index.php?title=List_of_Falcon_9_and_Falcon_Heavy_launches&oldid=1027686922

Data Wrangling (EDA)

GitHub Link here

- There are 17 different attributes in the Data Set
  - Numerical and categorical columns

FlightNumber	int64	Reused	bool
Date	object	Legs	bool
BoosterVersion	object	LandingPad	object
PayloadMass	float64	Block	float64
Orbit	object	ReusedCount	int64
LaunchSite	object	Serial	object
Flights	int64	Longitude	float64
GridFins	bool	Latitude	float64

  - Missing values are identified for each attribute
- There are 3 types of launches for each site with different counts and 11 types of orbits

CCAFS SLC 40	55
KSC LC 39A	22
VAFB SLC 4E	13

True ASDS	41
None None	19
True RTLS	14
False ASDS	6
True Ocean	5
False Ocean	2
None ASDS	2
False RTLS	1

- The Outcome indicates if the first stage successfully landed. There are 8 of them

True ASDS	41
None None	19
True RTLS	14
False ASDS	6
True Ocean	5
False Ocean	2
None ASDS	2
False RTLS	1

- The Landing Outcomes are converted to Classes
  - 0: bad outcome, the booster did not land.
  - 1: good outcome, the booster did land.
  - This is the classification variable that represents the outcome of each launch (66.6% of success rate)

EDA with Data Visualization

GitHub Link here

- Following charts were plotted
  - FlightNumber vs. PayloadMass
  - FlightNumber vs. LauchSite
  - Payload mass vs. LauchSite
  - Success rate vs. Orbit type
  - FlightNumber vs. Orbit type
  - Payload mass vs. Orbit type
  - Launch success yearly trend
- These are done to evaluate relationships between variables and with between variables and the outcome

EDA with SQL

GitHub Link here

- Following information was retrieved using SQL queries
  - Unique launch sites names in the space mission
  - 5 records where lauch sites name begin with the string ‘CCA’
  - Total payload mass carried by boosters NASA (CRS)
  - Average payload mass carried by booster F9 v1.1
  - Date when the first successful landing outcome in ground pad was achieved
  - 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
  - Booster versions which have carried the maximum payload mass

Build an Interactive Map with Folium

GitHub Link here

- For each Launch site, a circle marker is added into the map (*folium.Circle* and *folium.Marker*)
  - All launch sites are very close in proximity to the coast and relatively close to the Equator line (CCAFS LC-40, CCAFS SLC-40 and KSC LC-39A being the closest in Florida
- Markers are classified for all launch records:
  - Successful launch (class=1), a green marker is used; failed launch (class=0), a red marker is used
- For each launch result, a folium.Marker to marker_cluster is added
  - Marker clusters are used to simplify a map containing many markers with the same coordinates
- Proximities of launch sites are explored and analyzed:
  - MousePosition is added on the map to get coordinates for a mouse over a point on the map
  - PolyLine are added between a launch site to the selected points of interests (city, railway, highway)
  - Markers with distances are also added
  - Launch sites in Florida are close to highways, railways and coastlines but further apart from a major city (70 km from Orlando)

Build a Dashboard with Plotly Dash

GitHub Link here

- A dashboard completed so it can be used to analyze SpaceX launch data
  - It contains input components which allow to interact with a pie chart and a scatter point chart
- Launch Site Drop-down Input Component
  - To select one specific site and check its detailed success rate (class=0 vs. class=1)
- A callback function to render success-pie-chart based on selected site dropdown
  - To get the selected launch site from site-dropdown and render a pie chart visualizing launch success count
- Add a Range Slider to Select Payload
  - To easily select different payload range and see if some visual patterns can be identified
- Add a callback function to render the success-payload-scatter-chart scatter plot
  - To observe how payload may be correlated with mission outcomes for selected site(s)

Predictive Analysis (Classification)

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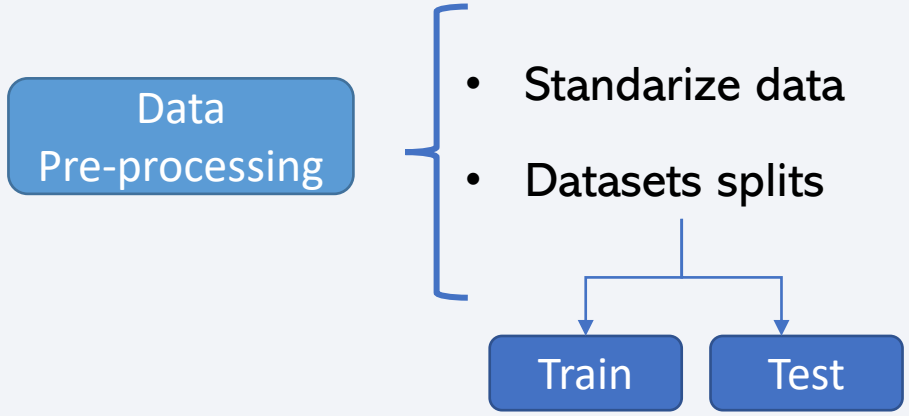
- For the Predictive Analysis, a ML (machine learning) pipeline is built
  - The goal is to predict if the first stage of the Falcon 9 lands successfully
  - Scikit-learn Python library is used to pre-process the data



- The model is trained and a Grid Search is performed

We find the best hyperparameters

With these parameters we determine the model with the best accuracy using the test set

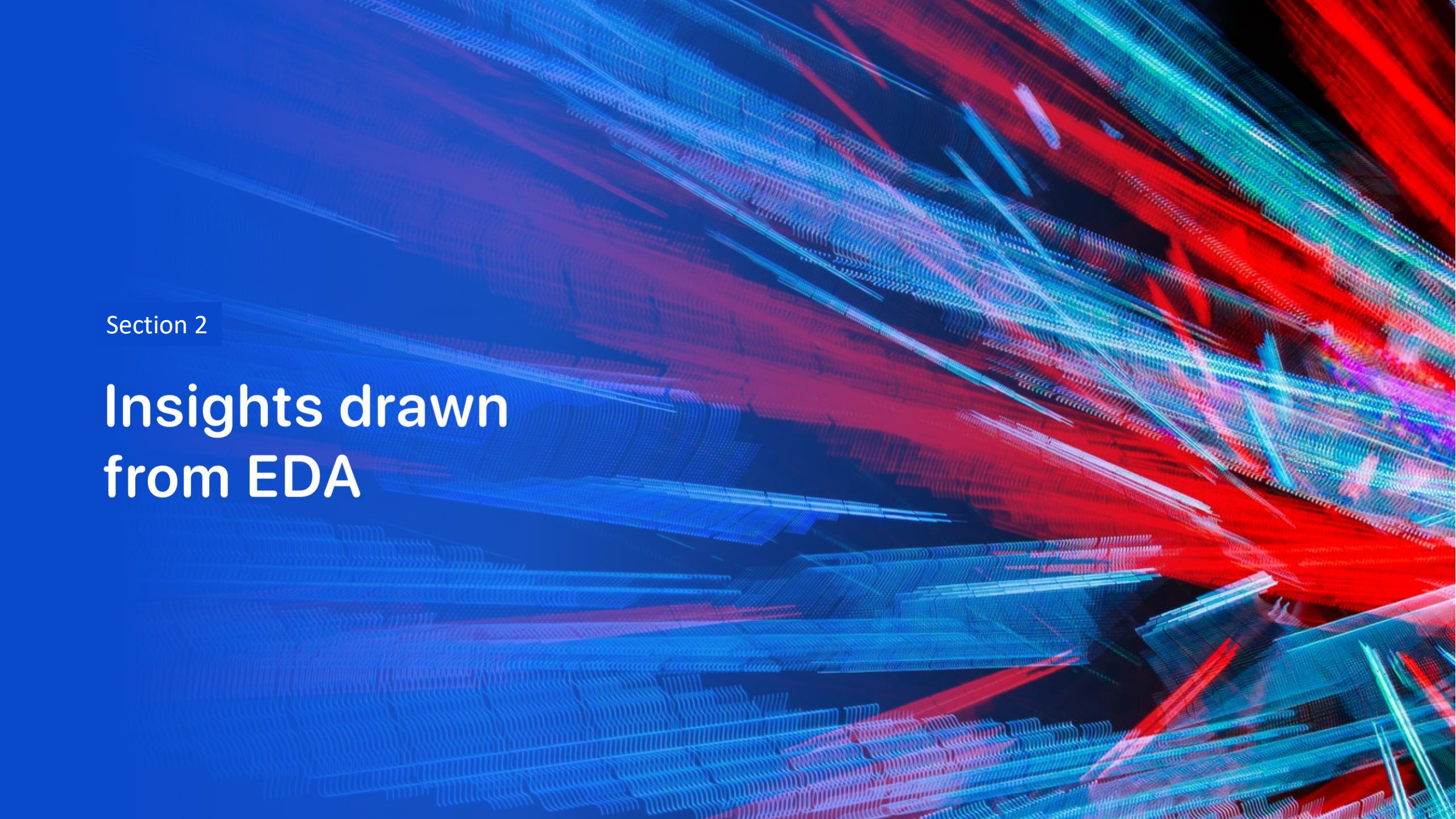
Different ML algorithms are tested

- Logistic regression (LR)
- Support Vector Machine (SVM)
- Decision Tree Classifier (DT)
- K-nearest Neighbours (K-NN)

Confusion Matrix

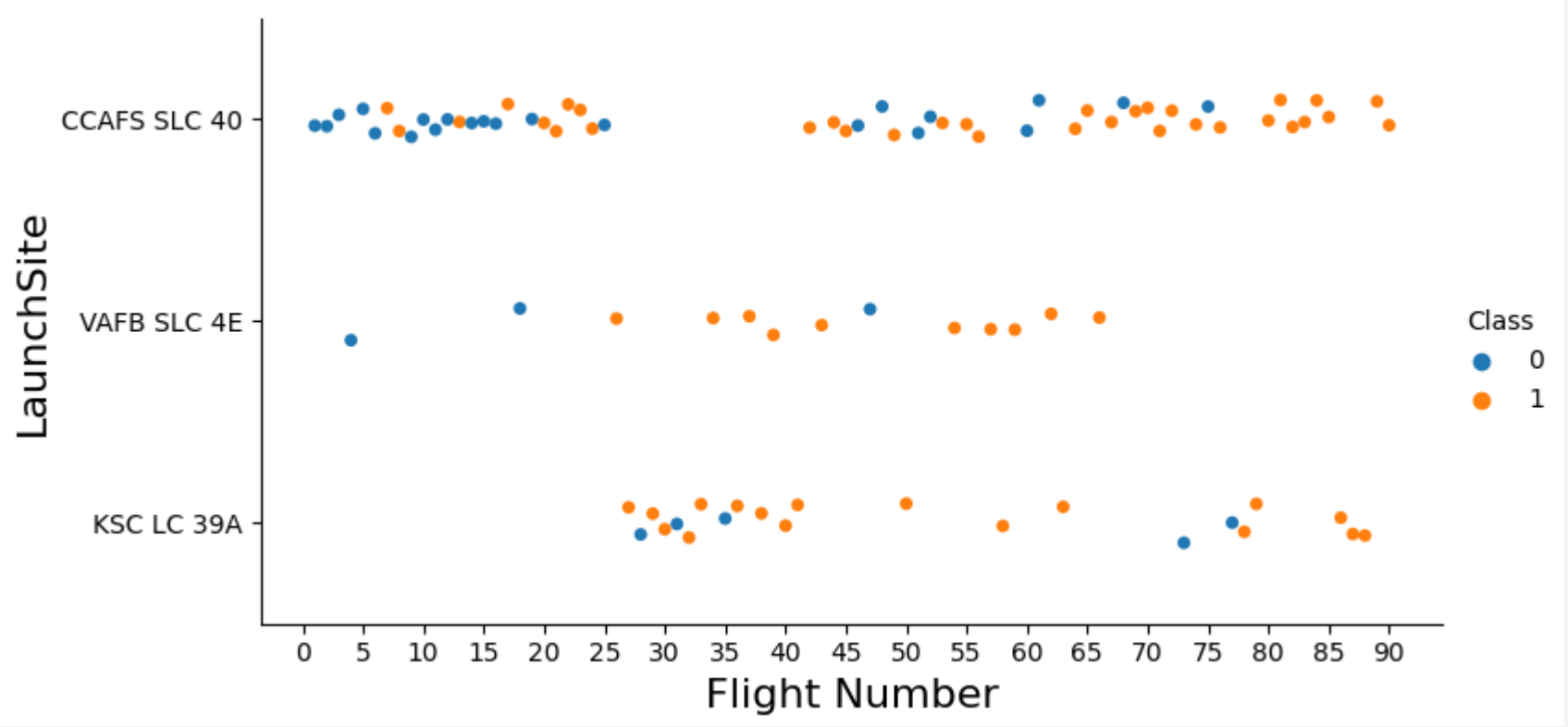
Results

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


Section 2
Insights drawn from EDA

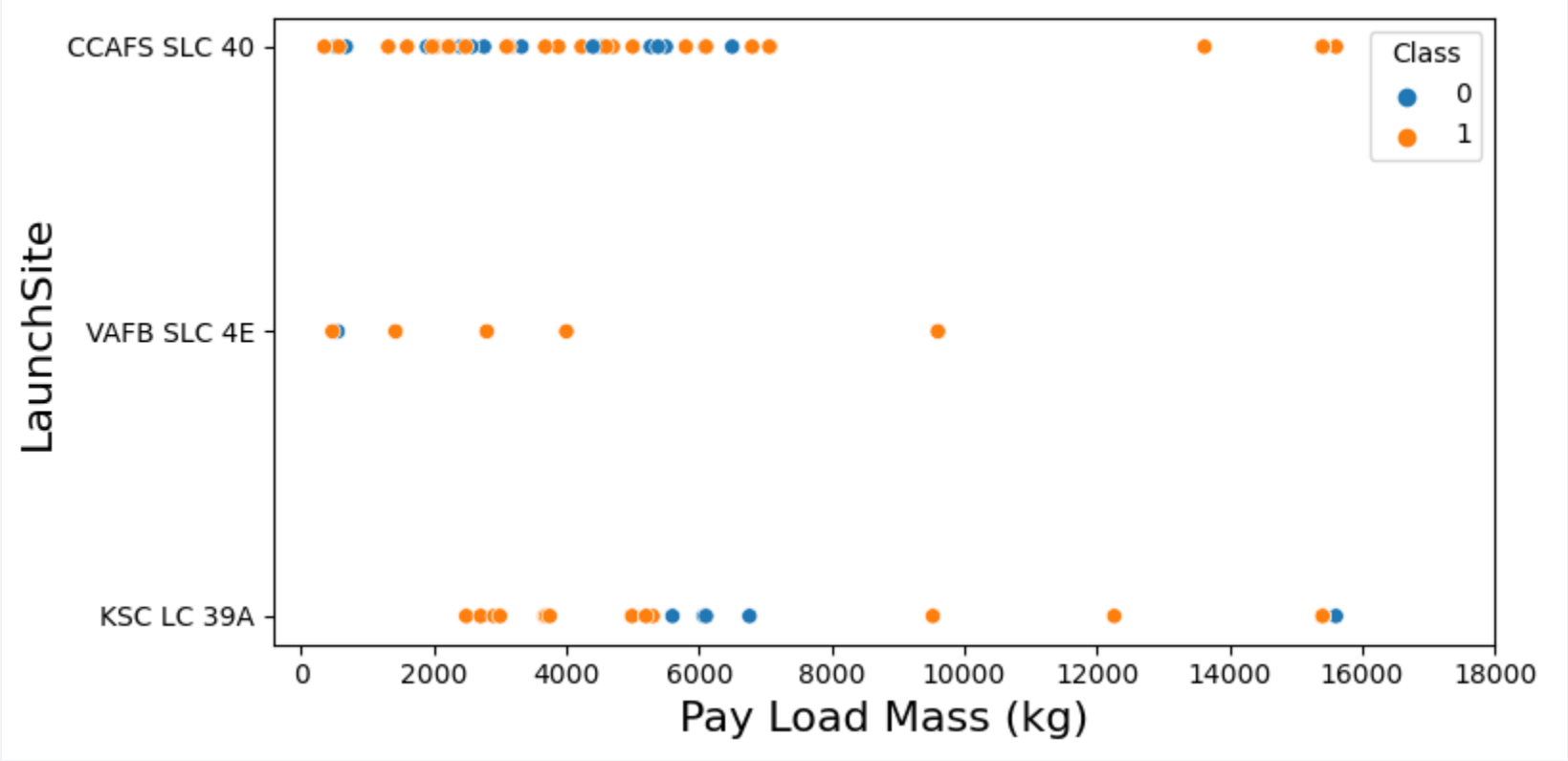
Flight Number vs. Launch Site

- For the three launch sites, as Flight Number increases, the success rate also increases
- VAFB-SLC-4 has the highest success rate with the smallest number of flights



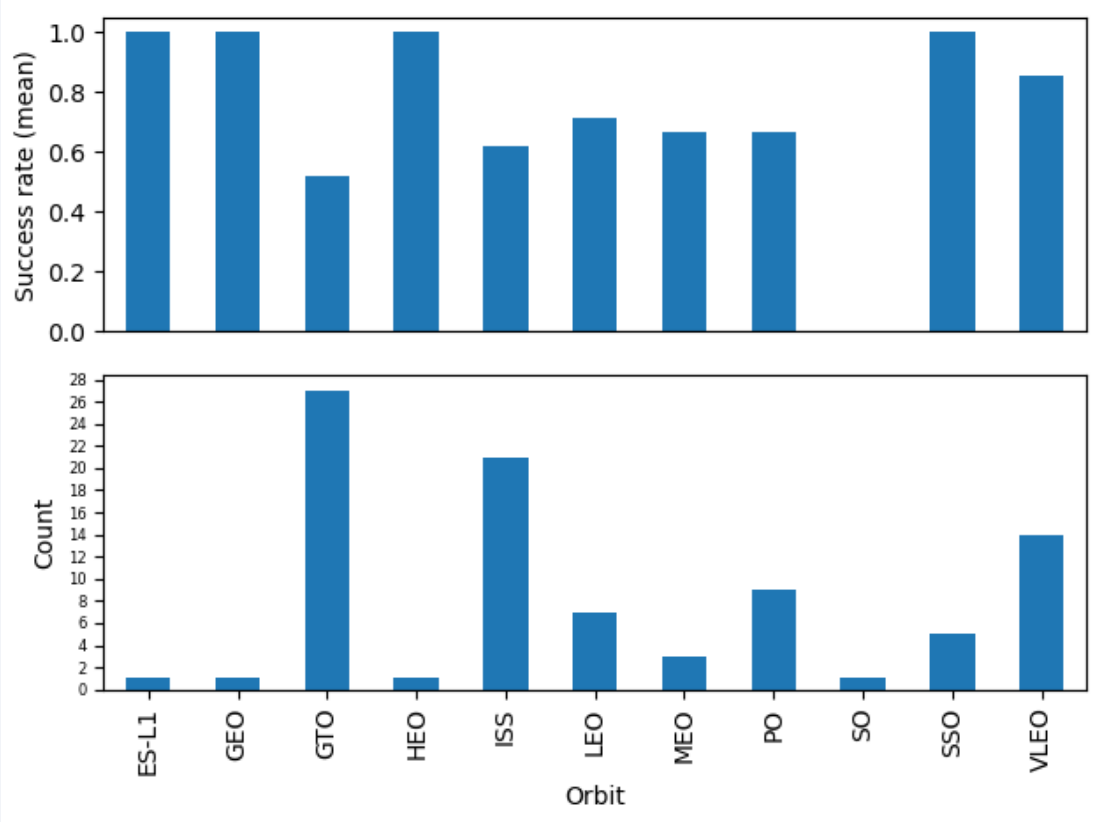
Payload vs. Launch Site

- For the VAFB-SLC launchsite there are no rockets launched for heavy payload mass (greater than 10000 Kg)
  - 96% and 86% of launches are below the 10,000 Kg mark for CCAFS-SLC and VAFB-SLC respectively



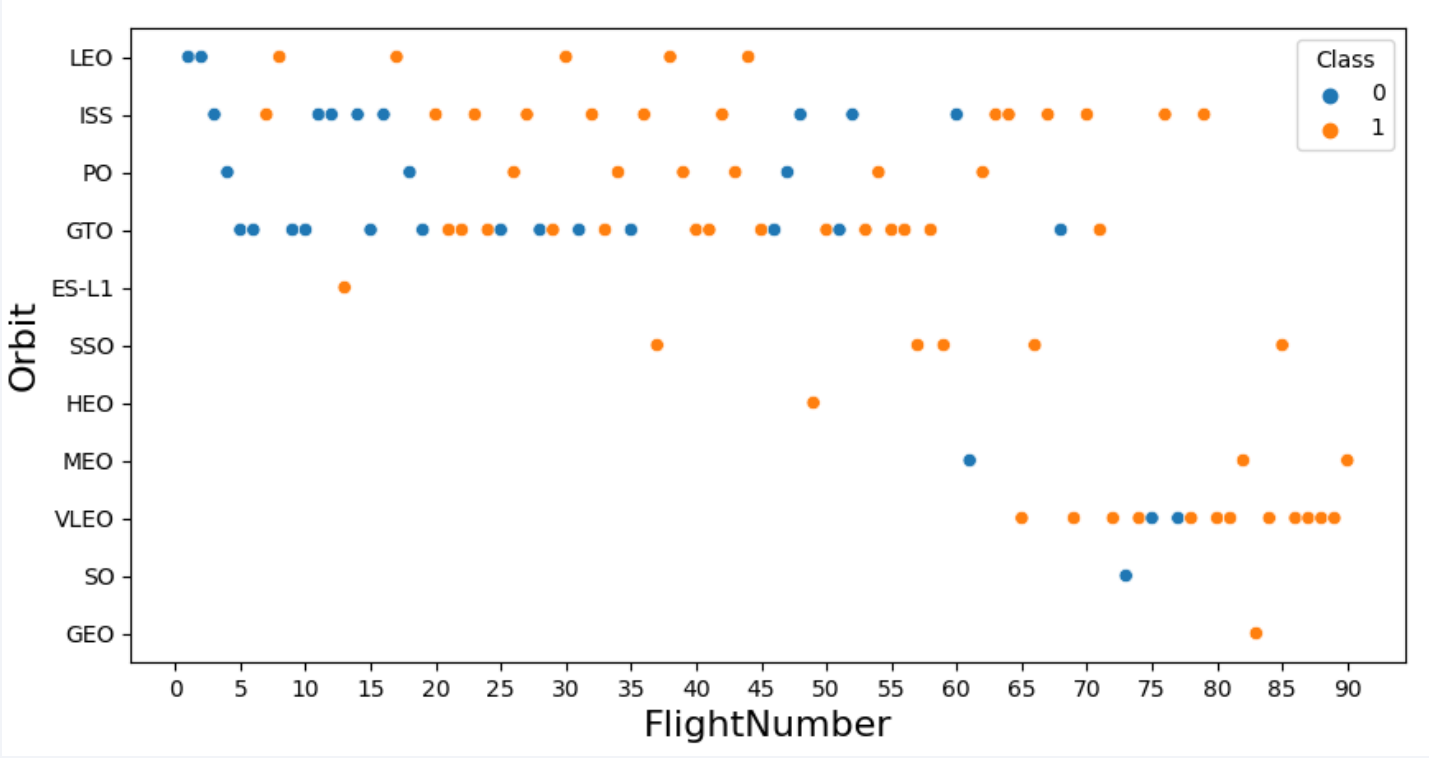
Success Rate vs. Orbit Type

- SSO has 100% success rate, with 5 launches (count)
  - Three orbits (ES-L1, GEO, HEO) have a 100% success rate, but with only one launch
- Orbits with highest number of launches are GTO and ISS (27 and 21), with 52% and 62% success rates, respectively



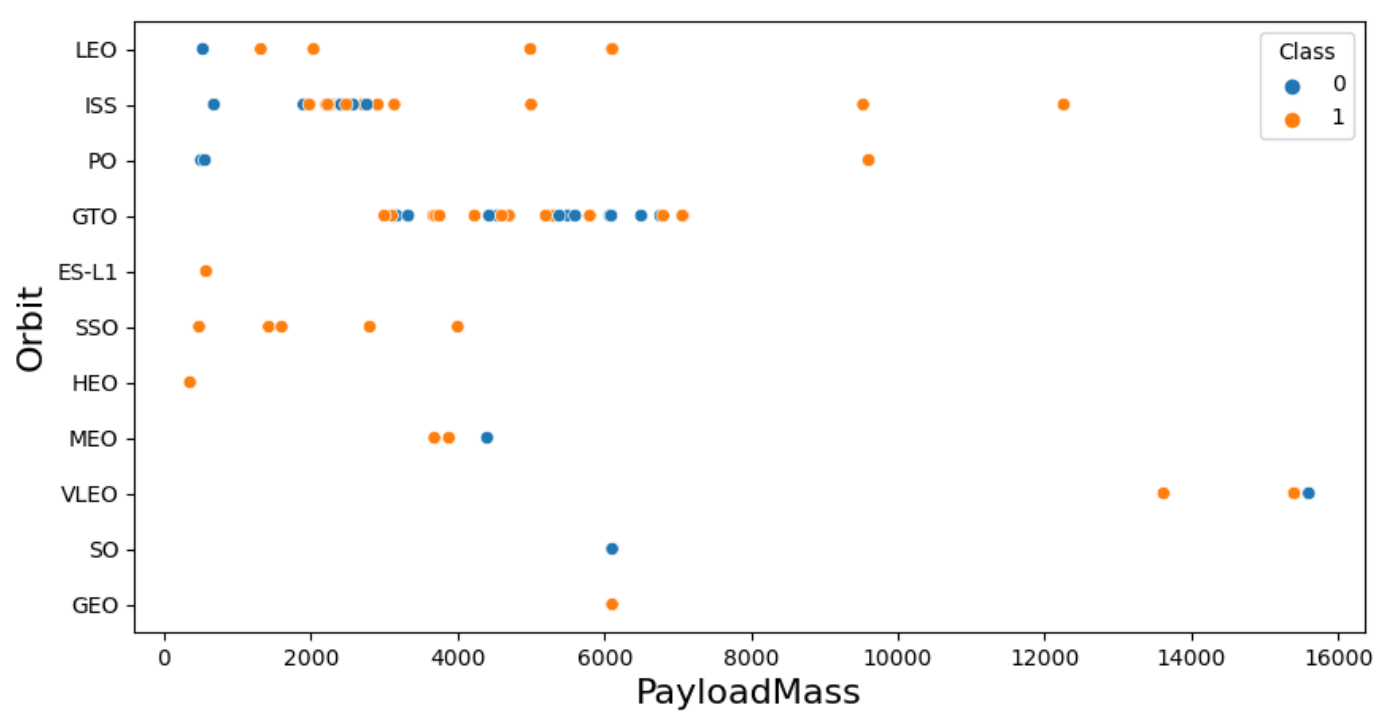
Flight Number vs. Orbit Type

- For LEO orbit the success appears related to the number of flights;
- No clear relationship between flight number and other orbits



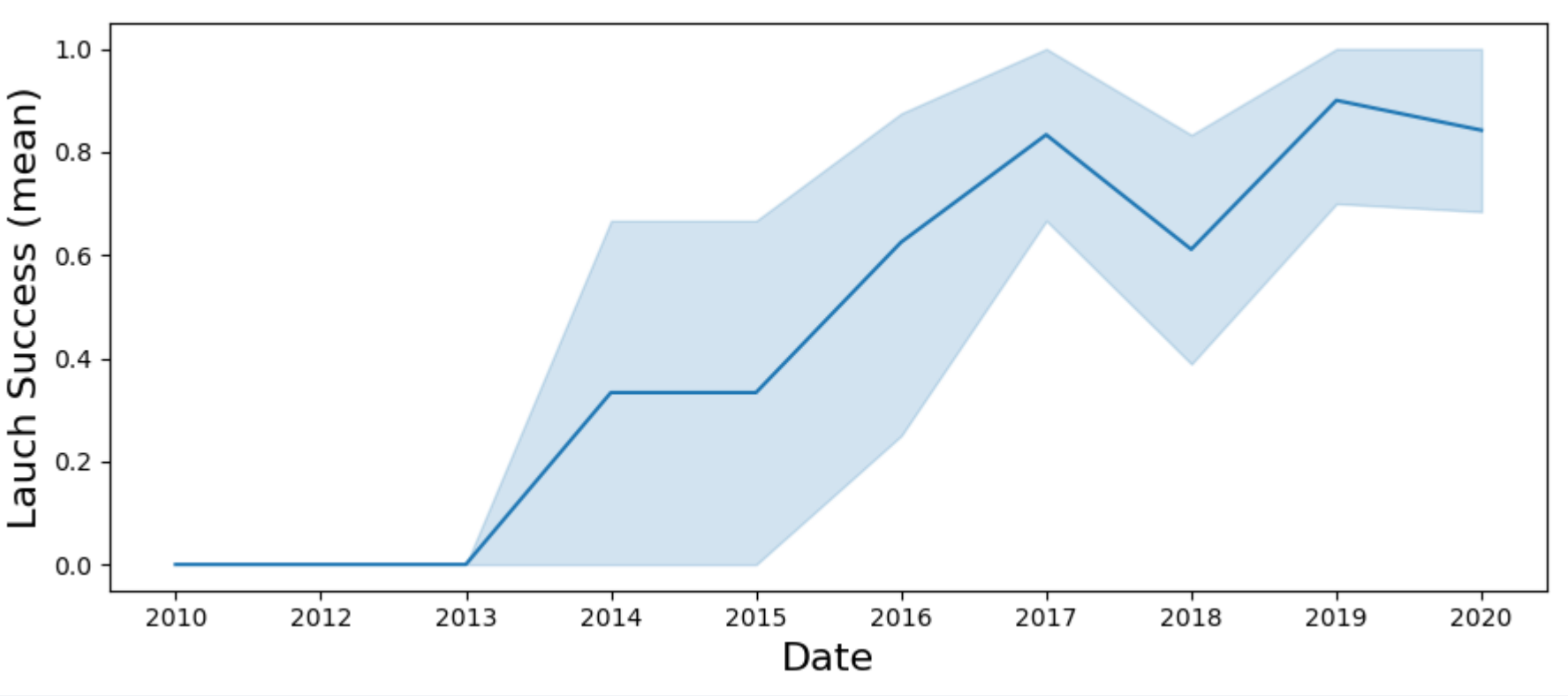
Payload vs. Orbit Type

- LEO and ISS orbits show increasing number of success landing with heavier payloads



Launch Success Yearly Trend

- The success rate has been increasing since 2013
  - Except between 2017 and 2018 and between 2019 and 2020



All Launch Site Names

- There are 4 different Launch Sites
  - CCAFS SLC-40 has the higher count, VAFB the lowest

```
%%sql

SELECT "Launch_Site", COUNT("Launch_Site") AS "Count"
FROM SPACEXTBL
GROUP BY "Launch_Site"
```

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

Launch_Site	Count
CCAFS LC-40	26
CCAFS SLC-40	34
KSC LC-39A	25
VAFB SLC-4E	16

Launch Site Names Begin with 'CCA'

- 5 records where Launch sites begin with the string “CCA”

```
%%sql

SELECT *
FROM SPACEXTBL
WHERE "Launch_Site" LIKE 'CCA%'
LIMIT 5
```

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

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing _Outcome
2010-06-04 00:00:00	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-12-08 00:00:00	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 00:00:00	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 00:00:00	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-03-01 00:00:00	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

Total Payload Mass

- The total Payload Mass carried by boosters launched by NASA (CRS) is 45,596 Kg

```
%%sql

SELECT SUM("PAYLOAD_MASS__KG_") AS "Total Mass"
FROM SPACEXTBL
WHERE "Customer" IS 'NASA (CRS)'
```

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

Total Mass
45596

Average Payload Mass by F9 v1.1

- Average Payload Mass carried by booster version F9 v1.1 is 2,534.67 Kg

```
%%sql

SELECT AVG("PAYLOAD_MASS__KG_") AS "Avg Mass"
FROM SPACEXTBL
WHERE "Booster_Version" LIKE '%F9 v1.1%'
```

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

Avg Mass
2534.6666666666665

First Successful Ground Landing Date

- The first successful landing outcome in ground pad was achieved in 22/12/2015

```
%%sql

SELECT MIN(Date) FROM SPACEXTBL
WHERE "Landing _Outcome" = "Success (ground pad)"
```

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

MIN(Date)
2015-12-22 00:00:00

Successful Drone Ship Landing with Payload between 4000 and 6000

- These are the names of the boosters which have success in drone ship and have payload mass between 4,000 and 5,000 Kg

```
%%sql

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

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

Booster_Version	PAYLOAD_MASS__KG_
F9 FT B1022	4696
F9 FT B1026	4600
F9 FT B1021.2	5300
F9 FT B1031.2	5200

Total Number of Successful and Failure Mission Outcomes

- This is the total number of successful and failure mission outcomes
  - 100 success (3 types) and 1 failure

```
%%sql

SELECT "Mission_Outcome", COUNT("Mission_Outcome") AS "Count"
FROM SPACEXTBL
GROUP BY "Mission_Outcome"
```

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

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

Boosters Carried Maximum Payload

- These are the booster versions which have carried the maximum payload mass (15,600 Kg)

```
%%sql

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

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

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

2015 Launch Records

- These are the records for failure landing outcomes in drone ship versions for 2015
  - Displaying month and year

```
%%sql

SELECT "Booster_Version", "Launch_Site", "Landing _Outcome", substr(Date, 6, 2) AS "Month", substr(Date,1,4) AS "Year"
FROM SPACEXTBL
WHERE "Date" LIKE "%2015%" AND "Landing _Outcome" is "Failure (drone ship)"
```

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

Booster_Version	Launch_Site	Landing _Outcome	Month	Year
F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)	01	2015
F9 v1.1 B1015	CCAFS LC-40	Failure (drone ship)	04	2015

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

- This is the rank of successful landing_outcomes between the date 04-06-2010 and 20-03-2017
  - in descending order

```
%%sql

SELECT "Landing _Outcome", COUNT("Landing _Outcome") AS "Count"
FROM SPACEXTBL
WHERE "Landing _Outcome" LIKE "%Success%"   AND   "Date" BETWEEN "2010-06-04" AND "2022-03-20"
GROUP BY "Landing _Outcome"
```

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

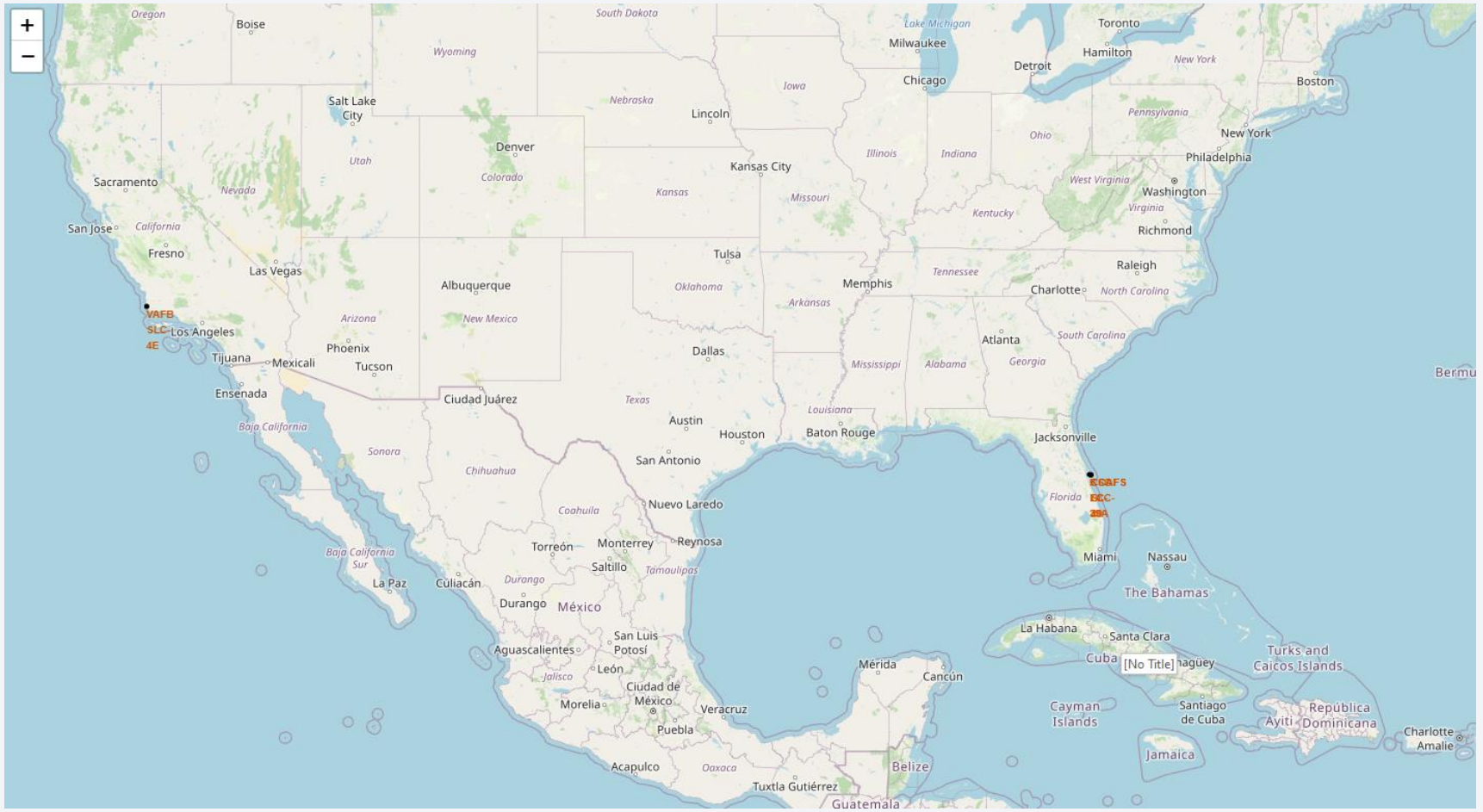
Landing _Outcome	Count
Success	38
Success (drone ship)	14
Success (ground pad)	9

Section 3

Launch Sites Proximities Analysis

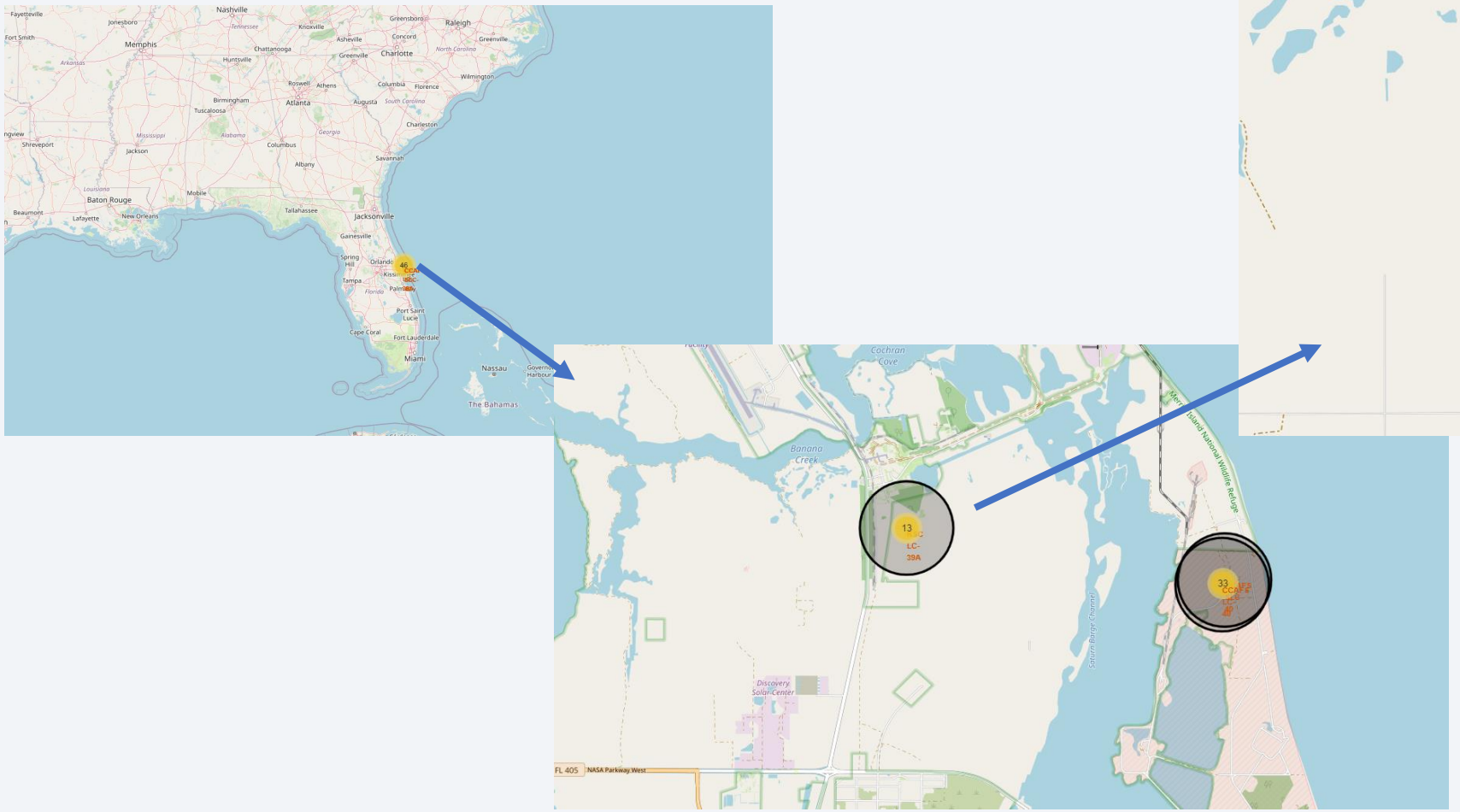
Folium Map Screenshot 1: Launch Sites on the map

All Launch sites are situated in two main locations:



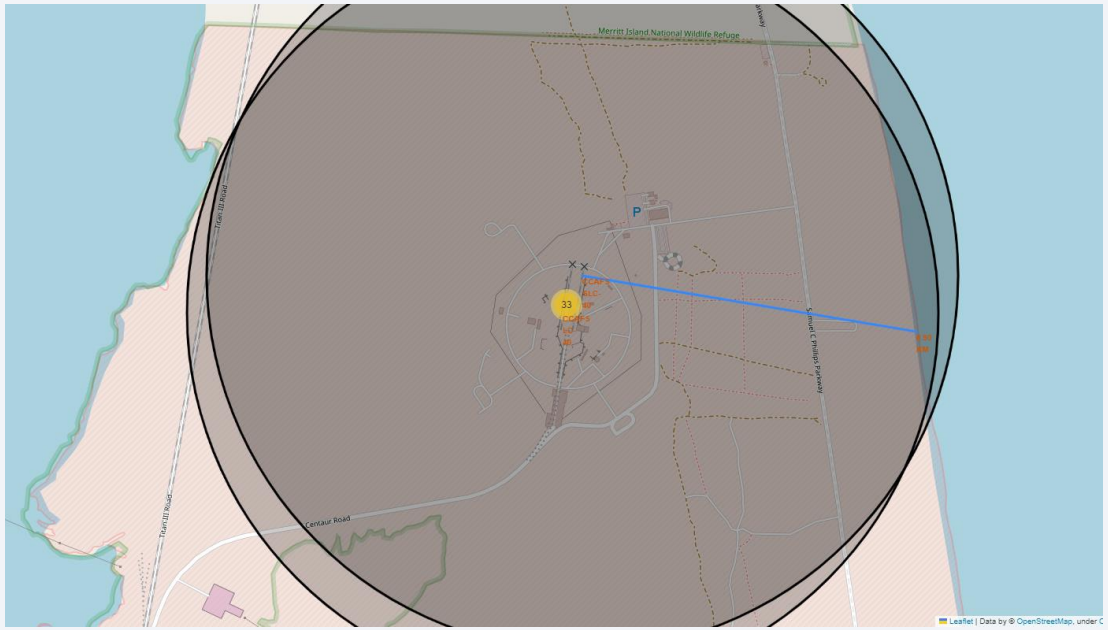
Folium Map Screenshot 2: success/failed launches for each site

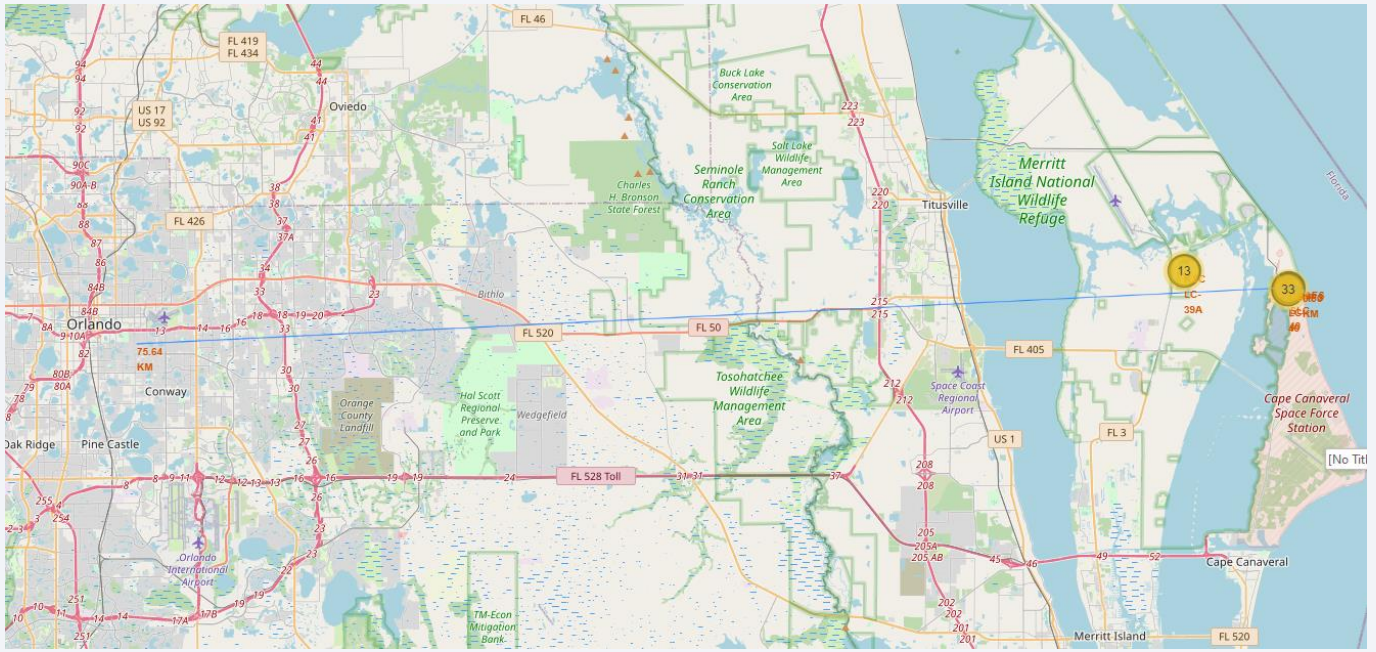
Launch outcomes for each site are marked (red/green) to identify which sites have high success rates

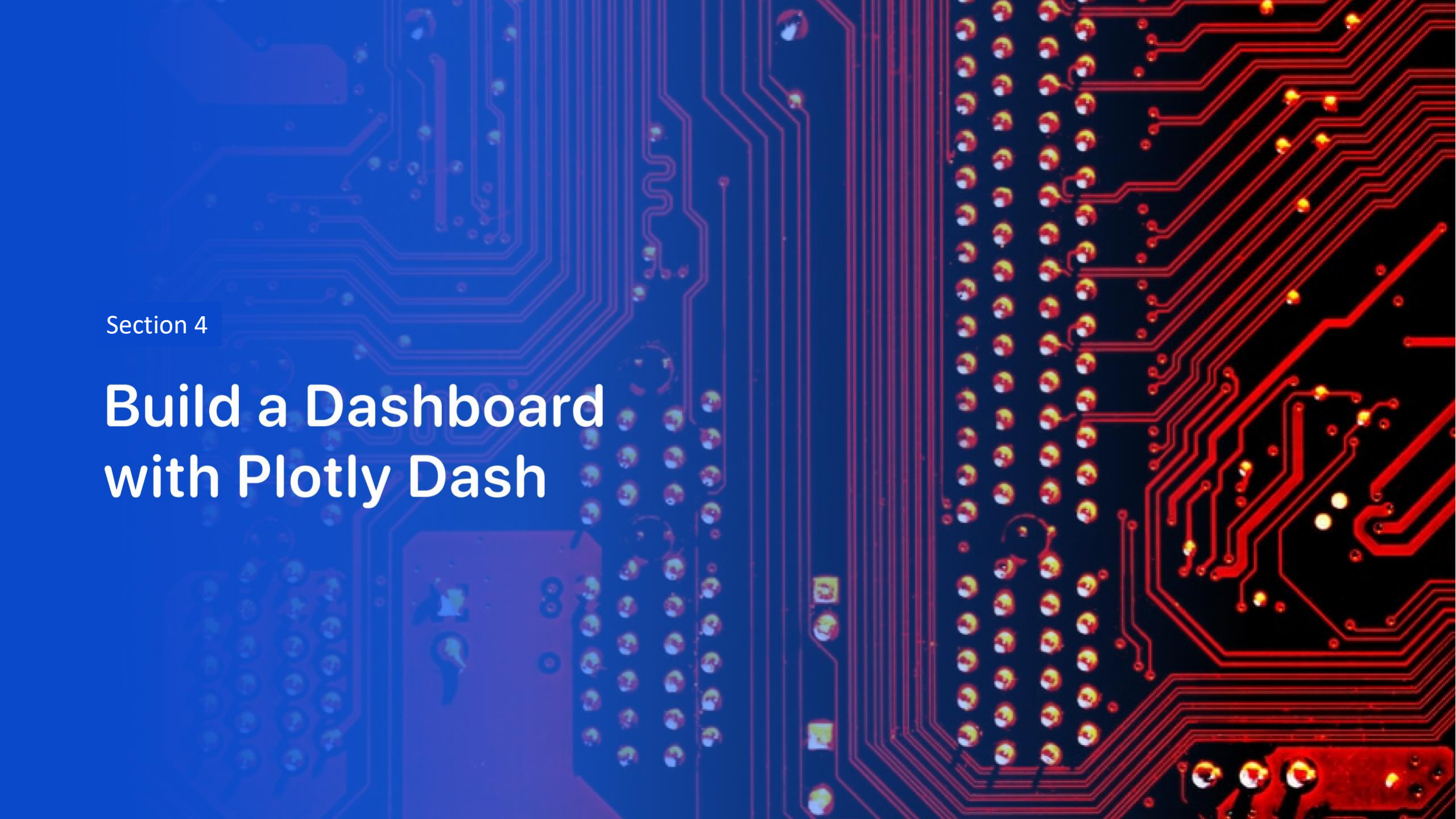


Folium Map Screenshot 3: distances between a launch site to its proximities

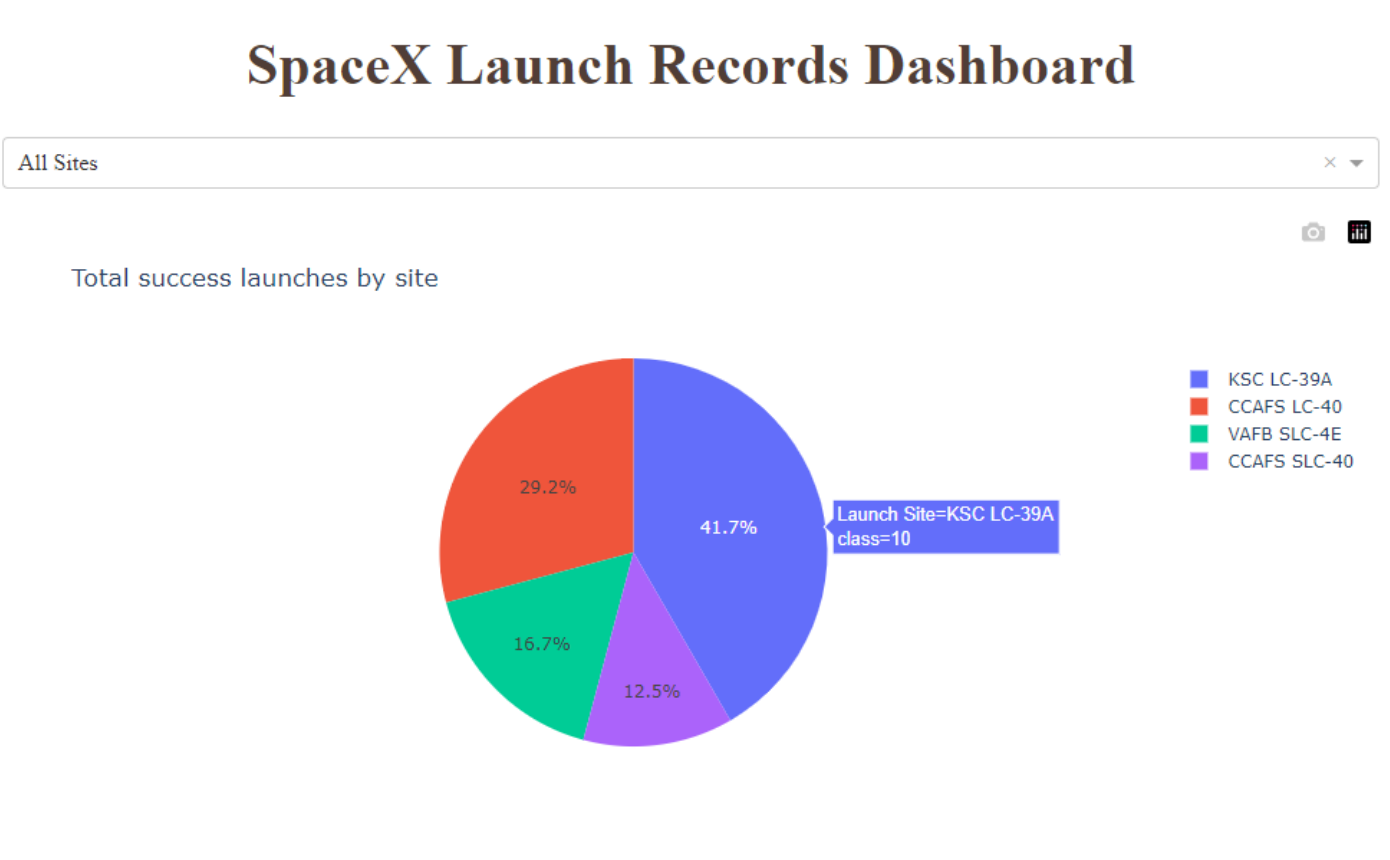
CCAFS LC-40 and CCAFS SLC-40 Launch sites are located 0.9 Km to the coastline and 75Km to a major city (Orlando)





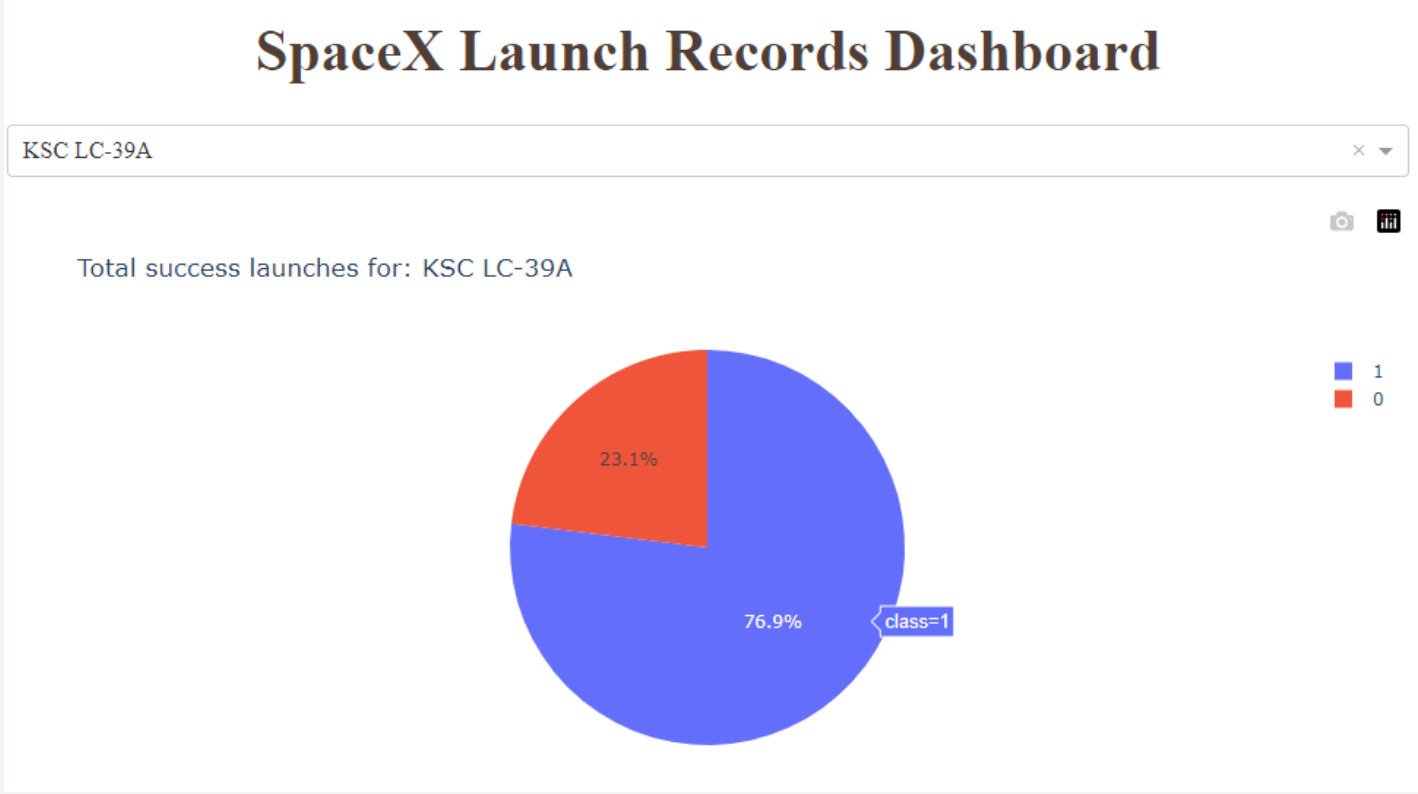

Section 4
Build a Dashboard with Plotly Dash

Dashboard Screenshot 1: launch success count for all sites



KSC LC-39A Launch Site has the highest count of success launches (41.7%)

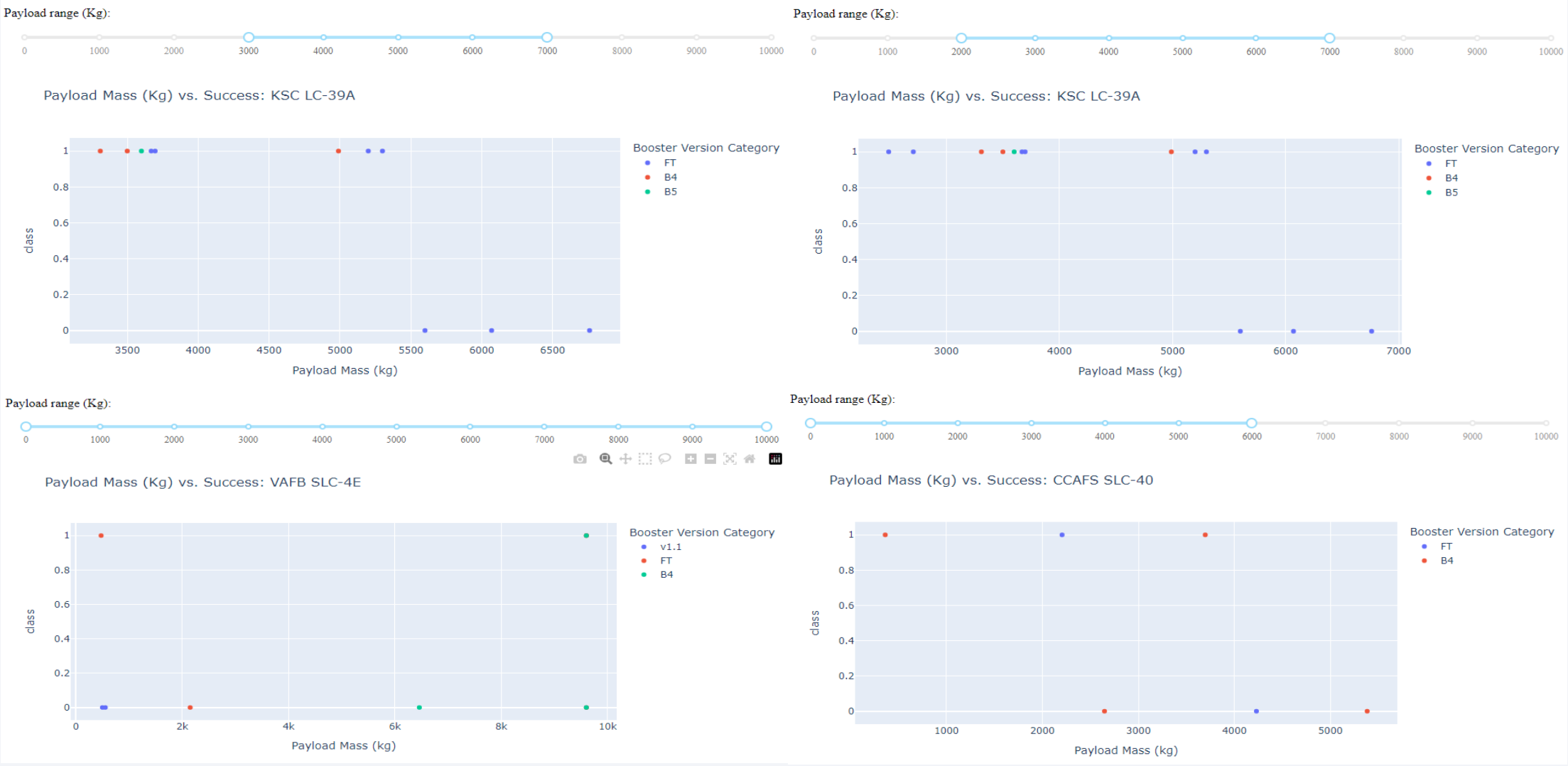
Dashboard Screenshot 2: launch site with highest launch success ratio



KSC LC-39A Launch Site has the highest launch success ratio (76.9%)

Dashboard Screenshot 3: Payload vs. Launch Outcome

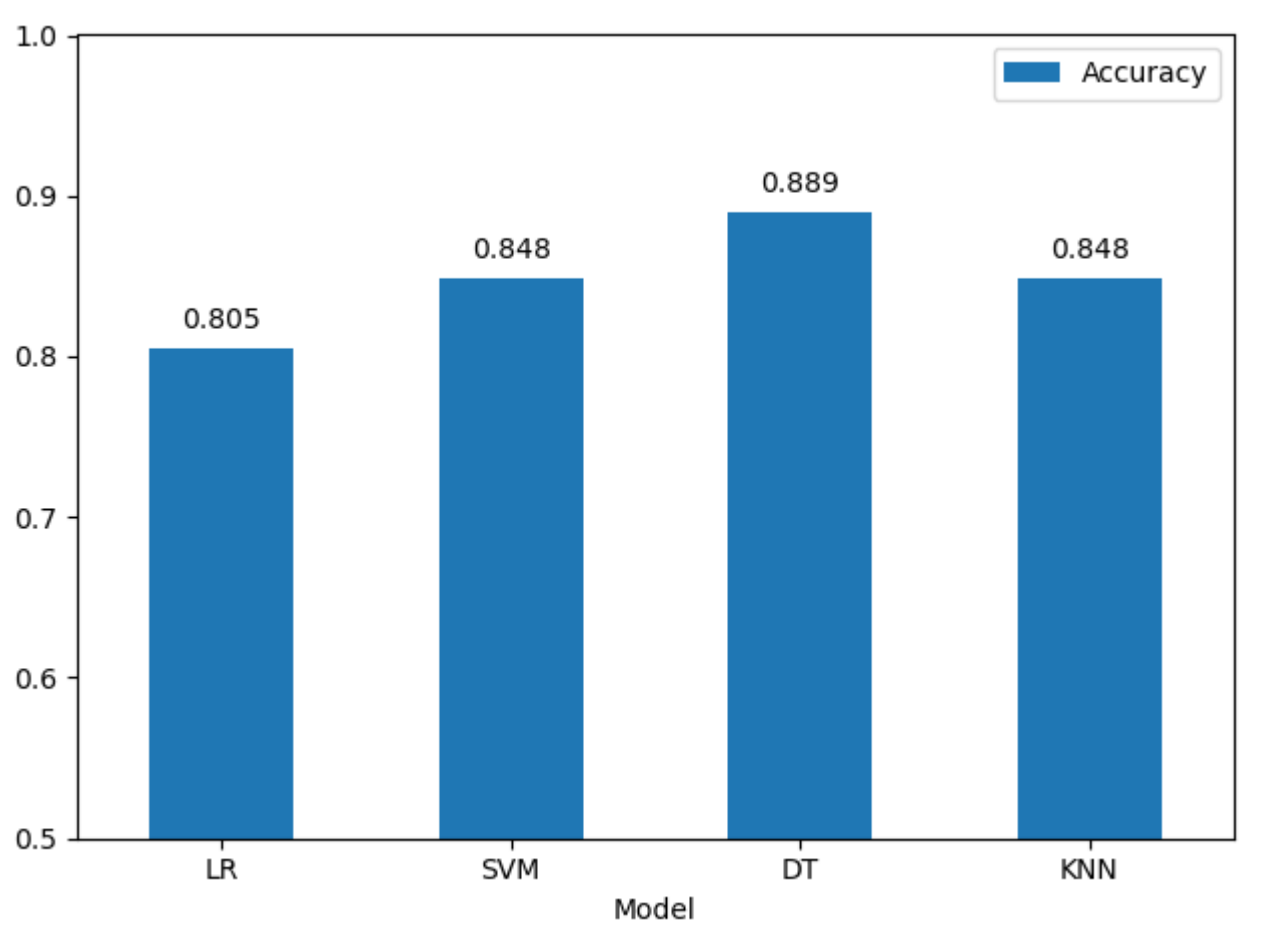
KSC LC-39A Launch Site has the highest number of successful launches with 10 against 3 unsuccessful (all FT)



Section 5

Predictive Analysis (Classification)

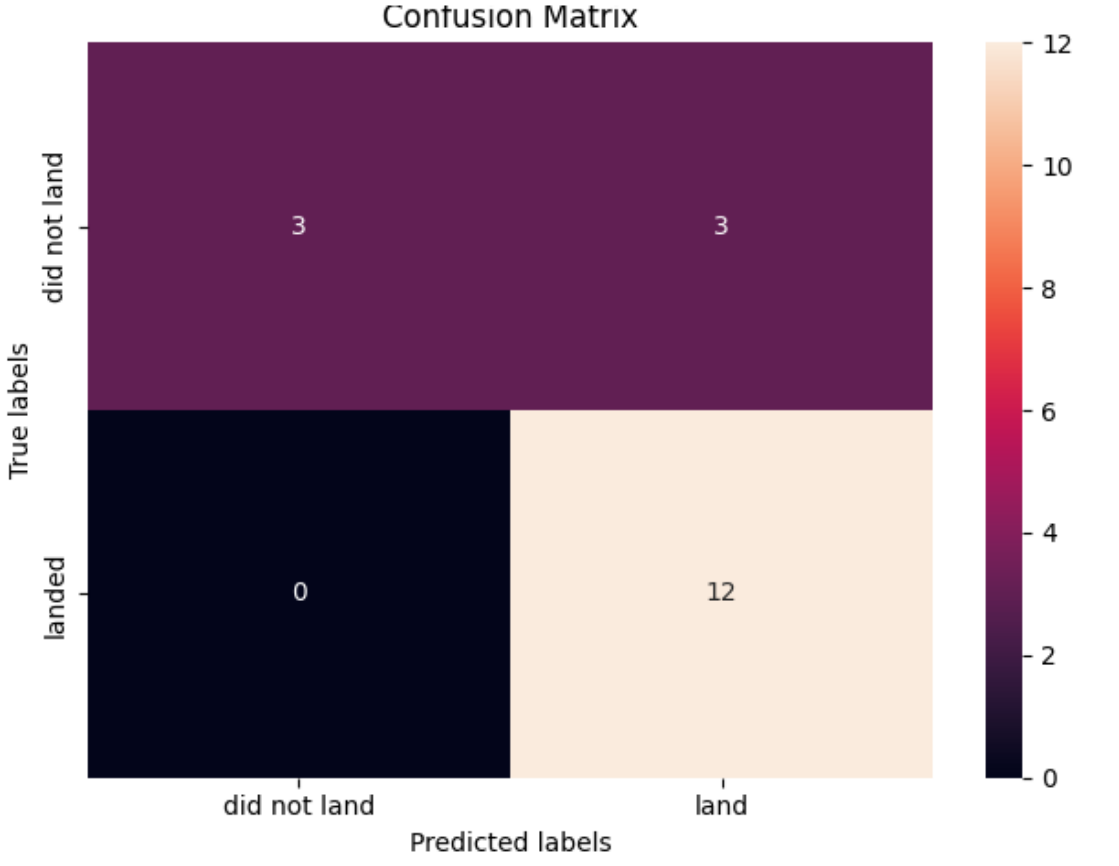
Classification Accuracy



The Decision Tree classifier has the highest accuracy of the models (test data set)

Confusion Matrix

This is the Confusion Matrix for the Decision Tree classifier:



- From the 18 test samples (test dataset):
  - Out of 6 labelled as “did not land”
    - 3 were classified as “did not land” (true negative)
    - 3 were classified as “landed” (false negative)
  - Out of 12 labelled as “landed”
    - 0 were classified as “did not land” (false positive)
    - 12 were classified as “landed” (true positive)

Conclusions

- Following are the key conclusions from this project
  - The Decision Tree classifier has the highest accuracy of the models with 88.9% on the test data
  - For the three launch sites, as Flight Number increases, the success rate also increases
  - Orbits with highest number of launches are GTO and ISS (27 and 21), with 52% and 62% success rates, respectively
  - KSC LC-39A Launch Site has the highest launch success ratio (76.9%)
  - The success rate on the launches has been increasing since 2013
  - All Launch sites are situated in two main locations
  - Launch sites are located close to the coastline

Appendix

- All Jupiter Notebooks containing code, SQL queries, charts and data sets created during this project are available at Github following the link below
  - https://github.com/mjbaldomir/Capstone_IBMDS

Thank you!