IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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May 5th, 2025

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Predictive analysis results

Introduction

- Project background and context

- SpaceX is the most successful company of the commercial space age, making space travel affordable. The company advertises Falcon 9 rocket launches on its website, with a cost of 62 million dollars; other providers cost upward of 165 million dollars each, much of the savings is because SpaceX can reuse the first stage. Therefore, if we can determine if the first stage will land, we can determine the cost of a launch. Based on public information and machine learning models, we are going to predict if SpaceX will reuse the first stage.

- Problems you want to find answers
    - How do variables such as payload mass, launch site, number of flights, and orbits affect the success of the first stage landing?
    - Does the rate of successful landings increase over the years?
    - What is the best algorithm that can be used for binary classification in this case?

Section 1

Methodology

Methodology

Executive Summary

Data collection methodology

Using SpaceX Rest API	Using Web Scrapping from Wikipedia

Performed data wrangling

Filtering the data	Dealing with missing values	Using One Hot Encoding to prepare the data to a binary classification

Performed exploratory data analysis (EDA) using visualization and SQL

Performed interactive visual analytics using Folium and Plotly Dash

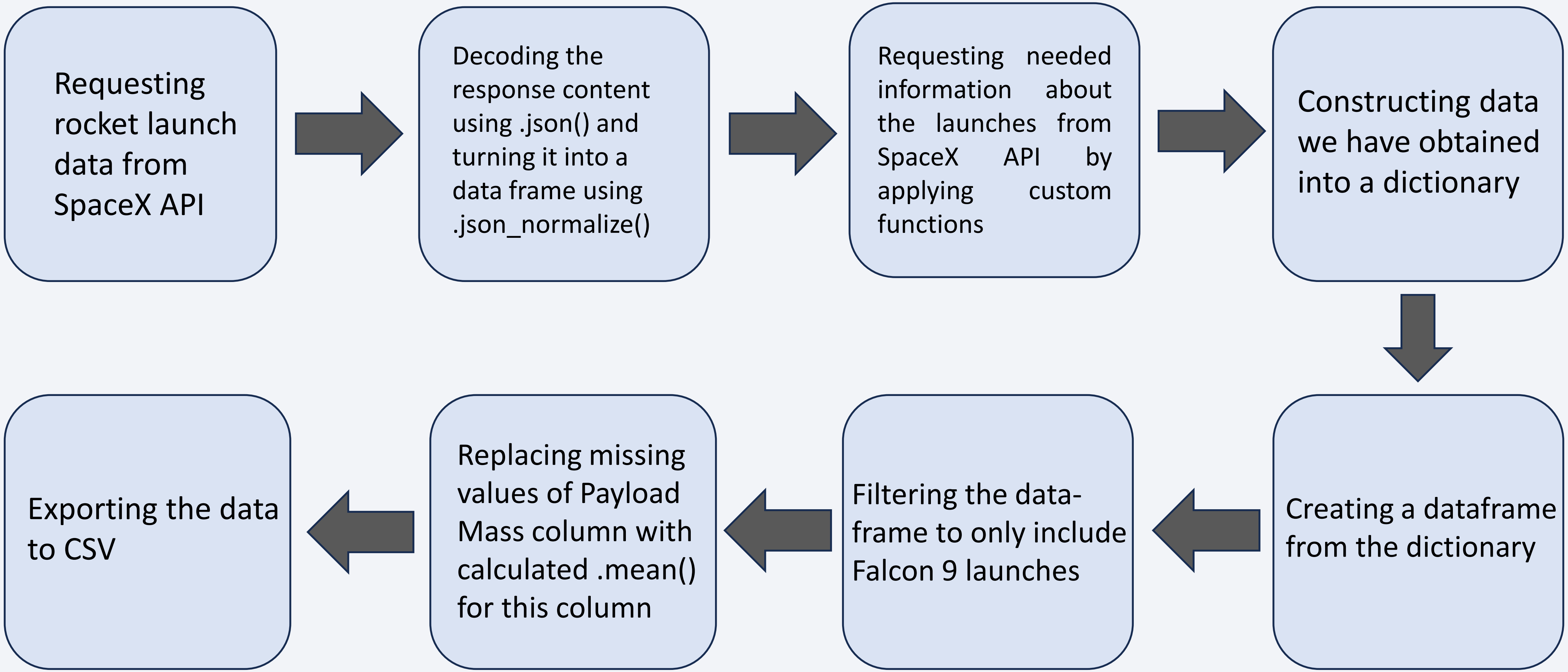
Performed predictive analysis using classification models

Building, tuning and evaluation of classification models to ensure the best results

Data Collection

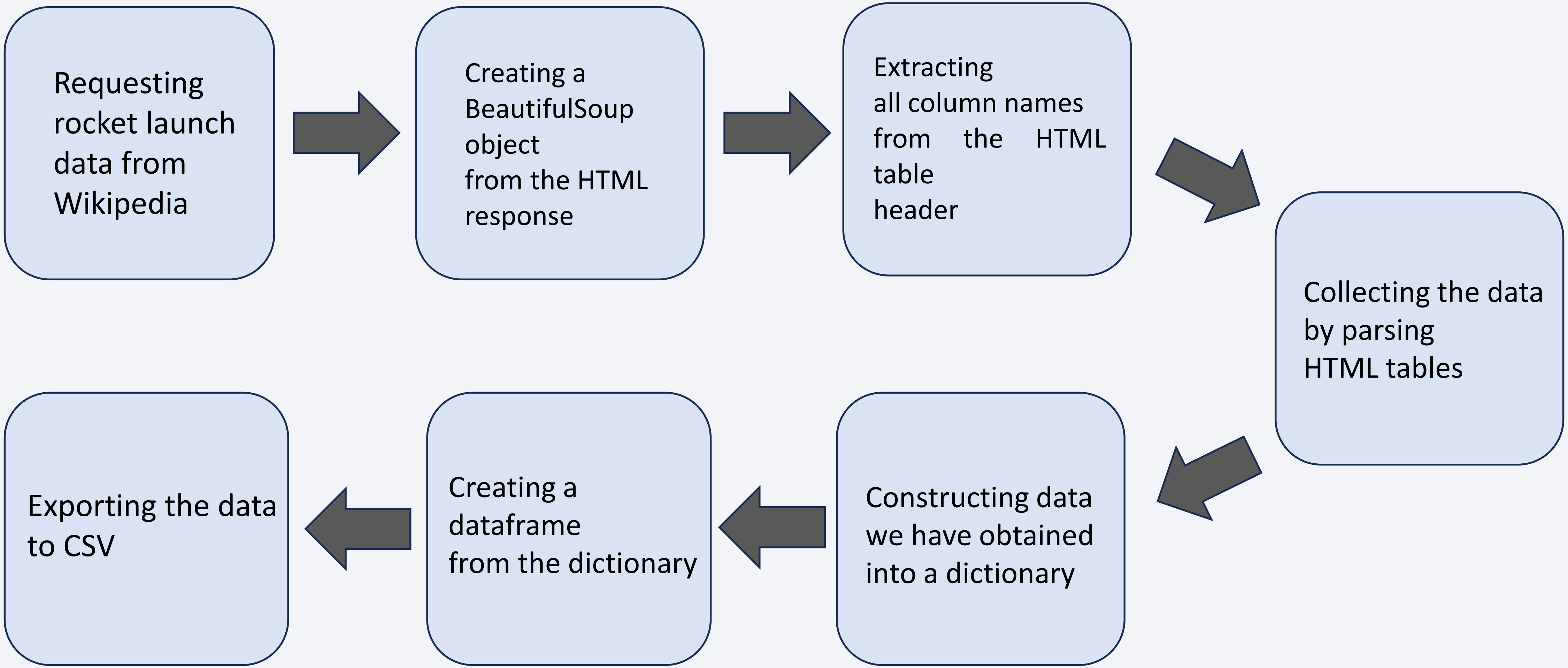
- Data collection process involved a combination of API requests from SpaceX REST API and Web Scraping data from a table in SpaceX's Wikipedia entry. We had to use both of these data collection methods in order to get complete information about the launches for a more detailed analysis.
- **Data Columns are obtained by using SpaceX REST API:**
- **Columns:** FlightNumber, Date, BoosterVersion, PayloadMass, Orbit, LaunchSite, Outcome, Flights, GridFins, Reused, Legs, LandingPad, Block, ReusedCount, Serial, Longitude, Latitude.
- **Data Columns are obtained by using Wikipedia Web Scraping:**
- **Columns:** Flight No., Launch site, Payload, PayloadMass, Orbit, Customer, LaunchOutcome, Version Booster, Booster landing, Date, Time.

Data Collection – SpaceX API



GitHub URL: Data Collection SpaceX API

Data Collection – Scraping



[GitHub URL: Data Collection through Web Scraping]

Data Wrangling

In the data set, there are several different cases where the booster did not land successfully. Sometimes a landing was attempted but failed due to an accident; for example, True Ocean means the mission outcome was successfully landed to a specific region of the ocean while False Ocean means the mission outcome was unsuccessfully landed to a specific region of the ocean. True RTLS means the mission outcome was successfully landed to a ground pad False RTLS means the mission outcome was unsuccessfully landed to a groundpad. True ASDS means the mission outcome was successfully landed on a drone ship False ASDS means the mission outcome was unsuccessfully landed on a drone ship.

We mainly convert those outcomes into Training Labels with “1” means the booster successfully landed, “0” means it was unsuccessful.

- Perform Exploratory Data Analysis and determine Training Labels
- Calculate the number of launches on each site
- Calculate the number and occurrence of each orbit
- Calculate the number and occurrence of mission outcome per orbit type
- Create a landing outcome label from Outcome column
- Exporting the data to CSV

GitHub: Data Wrangling

EDA with Data Visualization

- **Charts plotted :**
- Flight Number vs. Payload Mass, Flight Number vs. Launch Site, Payload Mass vs. Launch Site, Orbit Type vs. Success Rate, Flight Number vs. Orbit Type, Payload Mass vs Orbit Type and Success Rate Yearly Trend.
- Scatter plots show the relationship between variables. If a relationship exists, they could be used in machine learning model.
- Bar charts show comparisons among discrete categories. The goal is to show the relationship between the specific categories being compared and a measured value.
- Line charts show trends in data over time (time series).

[GitHub: EDA with Data Visualization]

EDA with SQL

Performed SQL Queries:

- Displaying the names of the unique launch sites in the space mission
- Displaying 5 records where launch sites begin with the string ‘CCA'
- Displaying the total payload mass carried by boosters launched by NASA (CRS)
- Displaying average payload mass carried by booster version F9 v1.1
- Listing the date when the first successful landing outcome in ground pad was achieved
- Listing the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000
- Listing the total number of successful and failure mission outcomes
- Listing the names of the booster versions which have carried the maximum payload mass
- Listing the failed landing outcomes in drone ship, their booster versions and launch site names for the months in year 2015
- Ranking 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

[GitHub: EDA with SQL]

Build an Interactive Map with Folium

- **Markers of all Launch Sites:**
- - Added Marker with Circle, Popup Label and Text Label of NASA Johnson Space Center using its latitude and longitude coordinates as a start location.
- - Added Markers with Circle, Popup Label and Text Label of all Launch Sites using their latitude and longitude coordinates to show their geographical locations and proximity to Equator and coasts.
- **Colored Markers of the launch outcomes for each Launch Site:**
- - Added colored Markers of success (Green) and failed (Red) launches using Marker Cluster to identify which launch sites have relatively high success rates.
- **Distances between a Launch Site to its proximities:**
- - Added colored Lines to show distances between the Launch Site KSC LC-39A (as an example) and its proximities like Railway, Highway, Coastline and Closest City.

GitHub: Interactive Map with Folium

Build a Dashboard with Plotly Dash

Launch Sites Dropdown List:

- Added a dropdown list to enable Launch Site selection. Pie Chart showing Success Launches (All Sites/Certain Site).

- Added a pie chart to show the total successful launches count for all sites and the Success vs. Failed counts for the site, if a specific Launch Site was selected.

Slider of Payload Mass Range.

- Added a slider to select Payload range. Scatter Chart of Payload Mass vs. Success Rate for the different Booster Versions.

- Added a scatter chart to show the correlation between Payload and Launch Success.

GitHub: Dashboard with Plotly Dash

Predictive Analysis (Classification)

Creating a NumPy array from the column "Class" in data

→ Standardizing the data with StandardScaler(), then fitting and transforming it

→ Splitting the data into training and testing sets with train_test_split() function

→ Creating a GridSearchCV() object with cv = 10 to find the best parameters

→ Applying GridSearchCV on LogReg, SVM, Decision Tree, and KNN models

→ Calculating the accuracy on the test data using the method .score() for all models

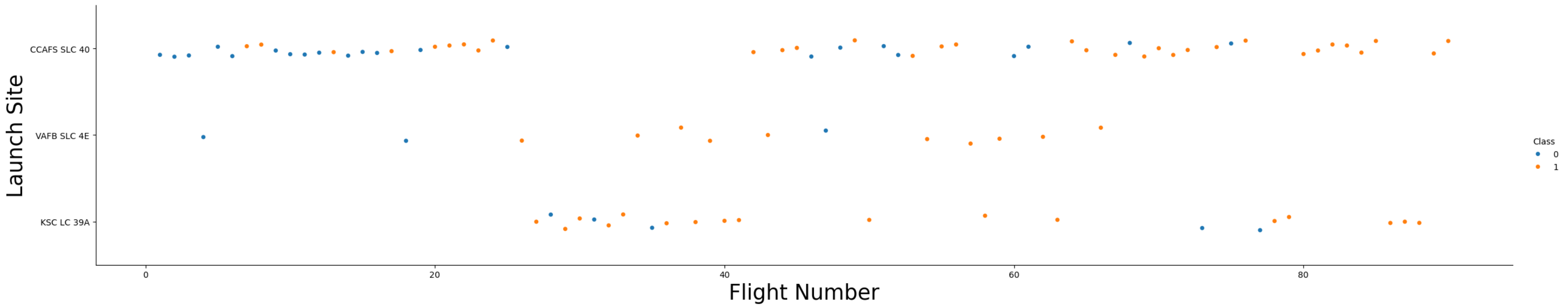
→ Examining the confusion matrix for all models

→ Finding the method performs best by examining the Jaccard_score and F1_score metrics

[GitHub: Predictive Analysis (Classification)]

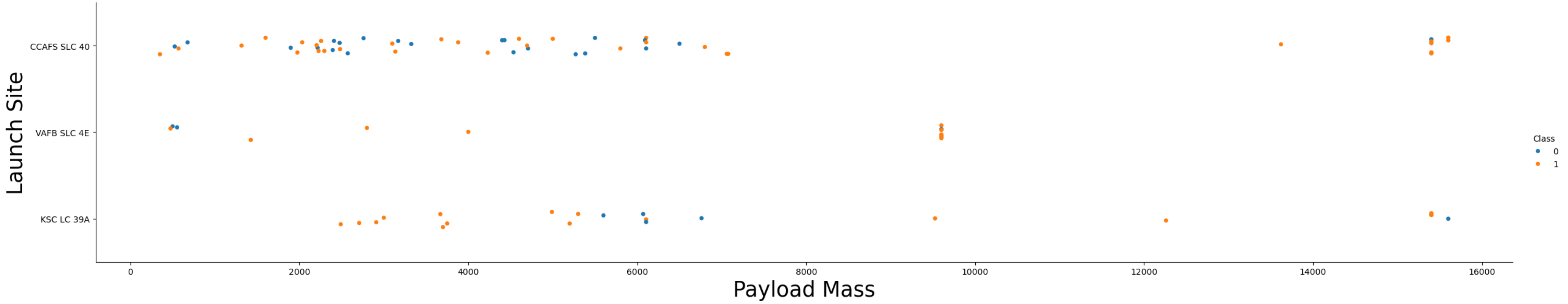
Section 2

Insights drawn from EDA



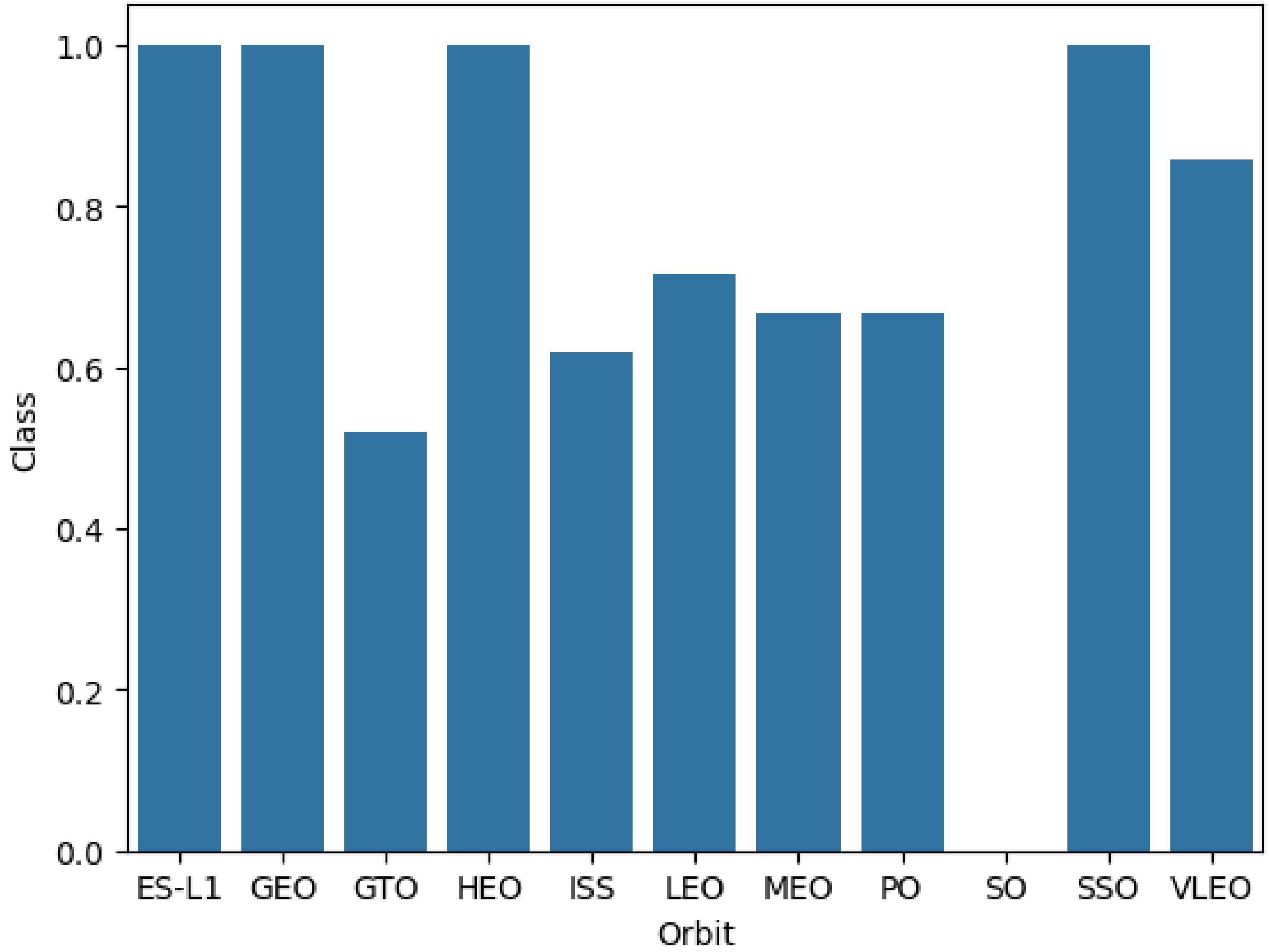
Flight Number vs. Launch Site

- Show a scatter plot of Flight Number vs. Launch Site
- The earliest flights all failed while the latest flights all succeeded.
- The CCAFS SLC 40 launch site has about a half of all launches.
- VAFB SLC 4E and KSC LC 39A have higher success rates.
- It can be assumed that each new launch has a higher rate of success.



Payload vs. Launch Site

- Show a scatter plot of Payload vs. Launch Site
- For every launch site the higher the payload mass, the higher the success rate.
- Most of the launches with payload mass over 7000 kg were successful.
- KSC LC 39A has a 100% success rate for payload mass under 5500 kg too.



Success Rate vs. Orbit Type

- Orbits with 100% success rate:

    - ES-L1, GEO, HEO, SSO

- Orbits with 0% success rate:

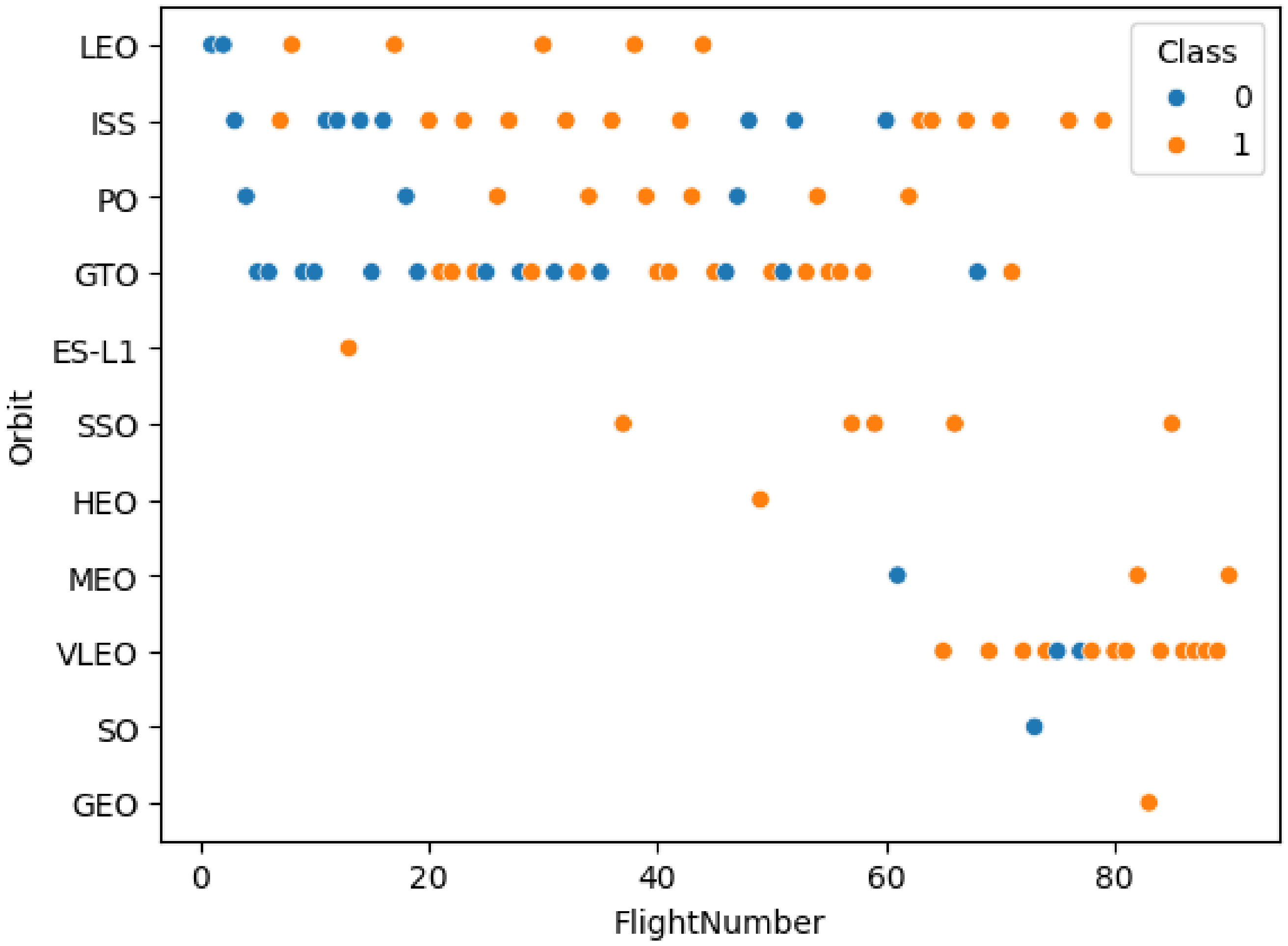
    - SO

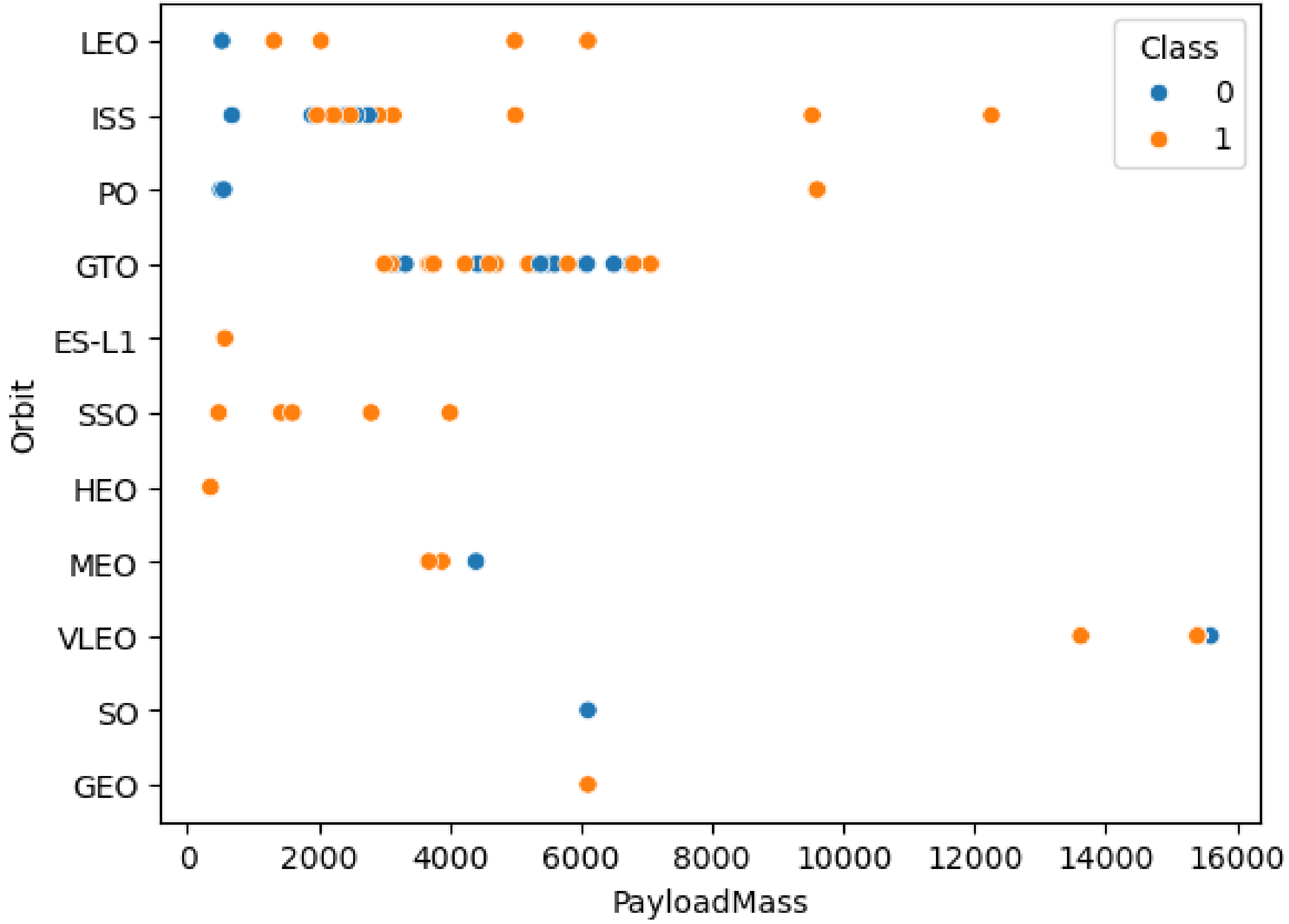
- Orbits with success rate between 50% and 85%:

    - GTO, ISS, LEO, MEO, PO

Flight Number vs. Orbit Type

In the LEO orbit the Success appears related to the number of flights; on the other hand, there seems to be no relationship between flight number when in GTO orbit.



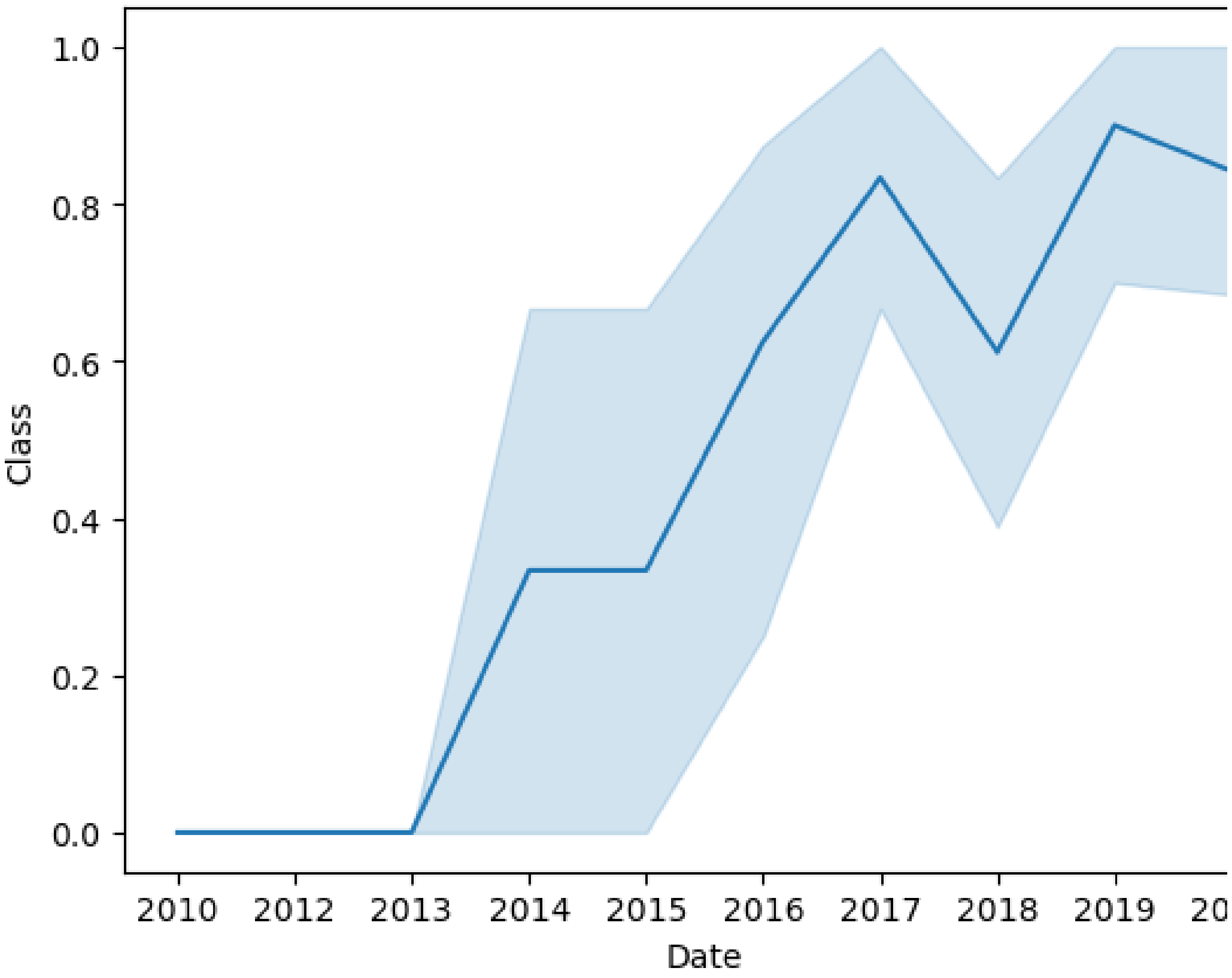


Payload vs. Orbit Type

Heavy payloads have a negative influence on GTO orbits and positive on GTO and Polar LEO (ISS) orbits.

Launch Success Yearly Trend

The success rate since 2013 kept increasing till 2020.



[11]:
```
%sql select distinct("Launch_Site") from SPACEXTABLE;
```

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

[11]:

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

All Launch Site Names

Displaying the names of the unique launch sites in the space mission.

Launch Site Names Begin with 'CCA'

Displaying 5 records where launch sites begin with the string 'CCA'.

Display 5 records where launch sites begin with the string 'CCA'

```
[12]: %sql select * from SPACEXTABLE where "Launch_Site" like "CCA%" limit 5;
```

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

[12]:

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

```
[13]: %sql select sum("PAYLOAD_MASS__KG_") from SPACEXTABLE where Customer = "NASA (CRS)";

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

sum("PAYLOAD_MASS__KG_")
45596

Total Payload Mass

Displaying the total payload mass carried by boosters launched by NASA (CRS).

Average Payload Mass by F9 v1.1

Displaying average payload mass carried by booster version F9 v1.1.

```
[15]: %sql select avg("PAYLOAD_MASS__KG_") as Average_Payload_Mass from SPACEXTABLE where "Booster_Version" like "%F9 v1.1%";

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

[15]:

Average_Payload_Mass
2534.6666666666665

[16]:
```
%sql select min("Date") from SPACEXTABLE where "Landing_Outcome" = "Success (ground pad)";
```

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

[16]:

min("Date")
2015-12-22

First Successful Ground Landing Date

Listing the date when the first successful landing outcome in ground pad was achieved.

Successful Drone Ship Landing with Payload between 4000 and 6000

Listing the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000.

[17]:
```
%%sql select distinct("Booster_Version") from SPACEXTABLE where "Landing_Outcome" = "Success (drone ship)"
    and "PAYLOAD_MASS__KG_" < 6000 and "PAYLOAD_MASS__KG_" > 4000;
```

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

[17]:

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

Total Number of Successful and Failure Mission Outcomes

Listing the total number of successful and failure mission outcomes.

```
[18]: %%sql select  mission_outcome, count(*) as Total_Outcome from SPACEXTABLE
          group by mission_outcome;
```

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

[18]:

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

Boosters Carried Maximum Payload

Listing the names of the booster versions which have carried the maximum payload mass.

```
[19]: %%sql SELECT DISTINCT("Booster_Version")
FROM SPACEXTABLE
WHERE "PAYLOAD_MASS__KG_" = (SELECT MAX("PAYLOAD_MASS__KG_") FROM SPACEXTABLE);

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

[19]:

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

Listing the failed landing outcomes in drone ship, their booster versions and launch site names for the months in year 2015.

[21]:
```
%%sql SELECT
    CASE SUBSTR(Date, 6, 2)
        WHEN '01' THEN 'January' WHEN '02' THEN 'February' WHEN '03' THEN 'March'
        WHEN '04' THEN 'April' WHEN '05' THEN 'May' WHEN '06' THEN 'June'
        WHEN '07' THEN 'July' WHEN '08' THEN 'August' WHEN '09' THEN 'September'
        WHEN '10' THEN 'October' WHEN '11' THEN 'November' WHEN '12' THEN 'December'
        ELSE 'Unknown'
    END AS Month,
    date,
    "Booster_Version",
    "Launch_Site",
    "Landing_Outcome" FROM SPACEXTABLE WHERE SUBSTR(Date, 1, 4) = '2015'
    AND "Landing_Outcome" = 'Failure (drone ship)';
```

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

[21]:

Month	Date	Booster_Version	Launch_Site	Landing_Outcome
January	2015-01-10	F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)
April	2015-04-14	F9 v1.1 B1015	CCAFS LC-40	Failure (drone ship)

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

Ranking 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.

[22]:
```
%%sql SELECT "Landing_Outcome", count(*) as Countoutcome from SPACEXTABLE
where Date <= "2017-03-20" and Date >= "2010-06-04"
group by "Landing_Outcome"
order by Countoutcome desc;
```

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

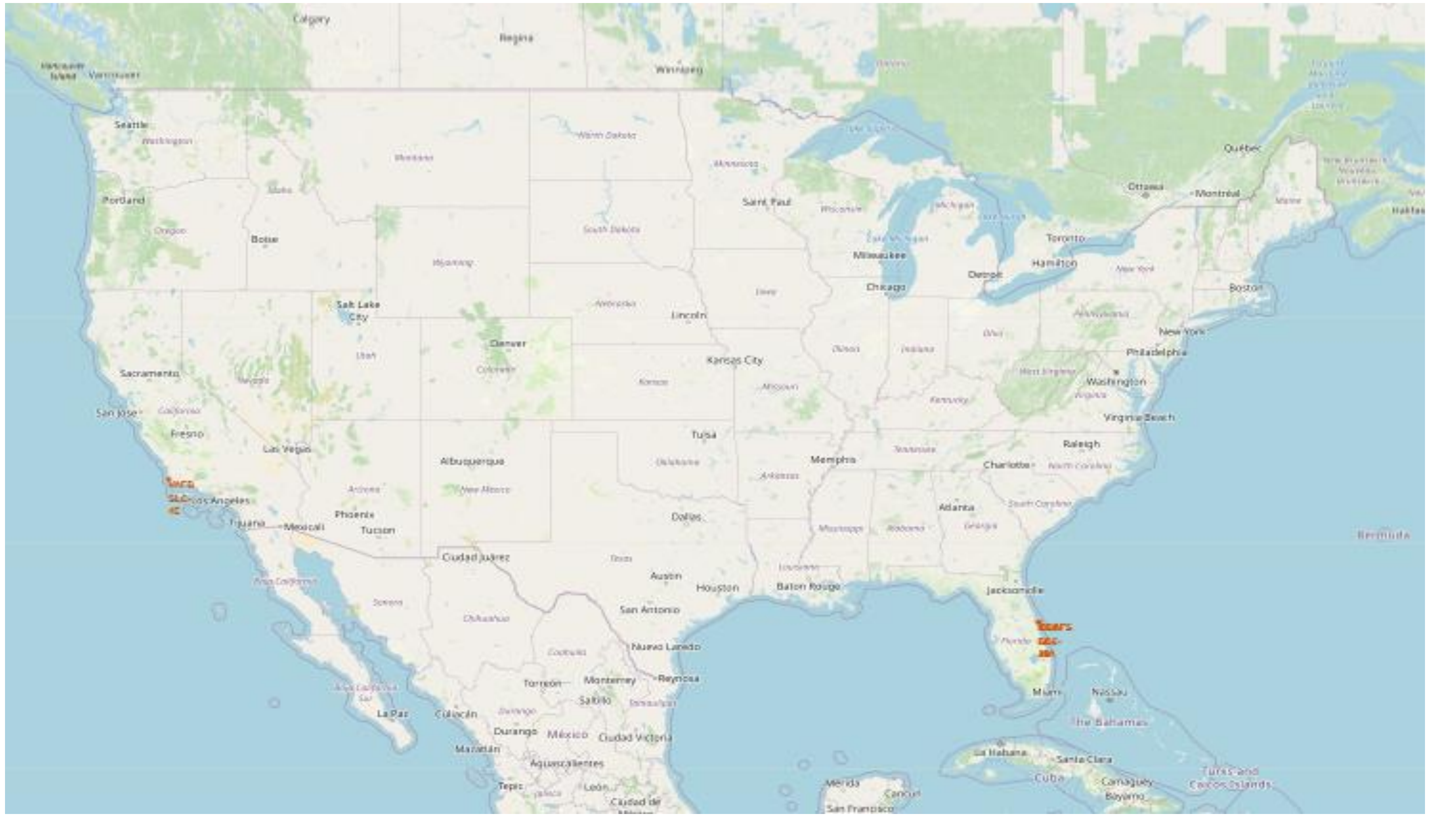
[22]:

Landing_Outcome	Countoutcome
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

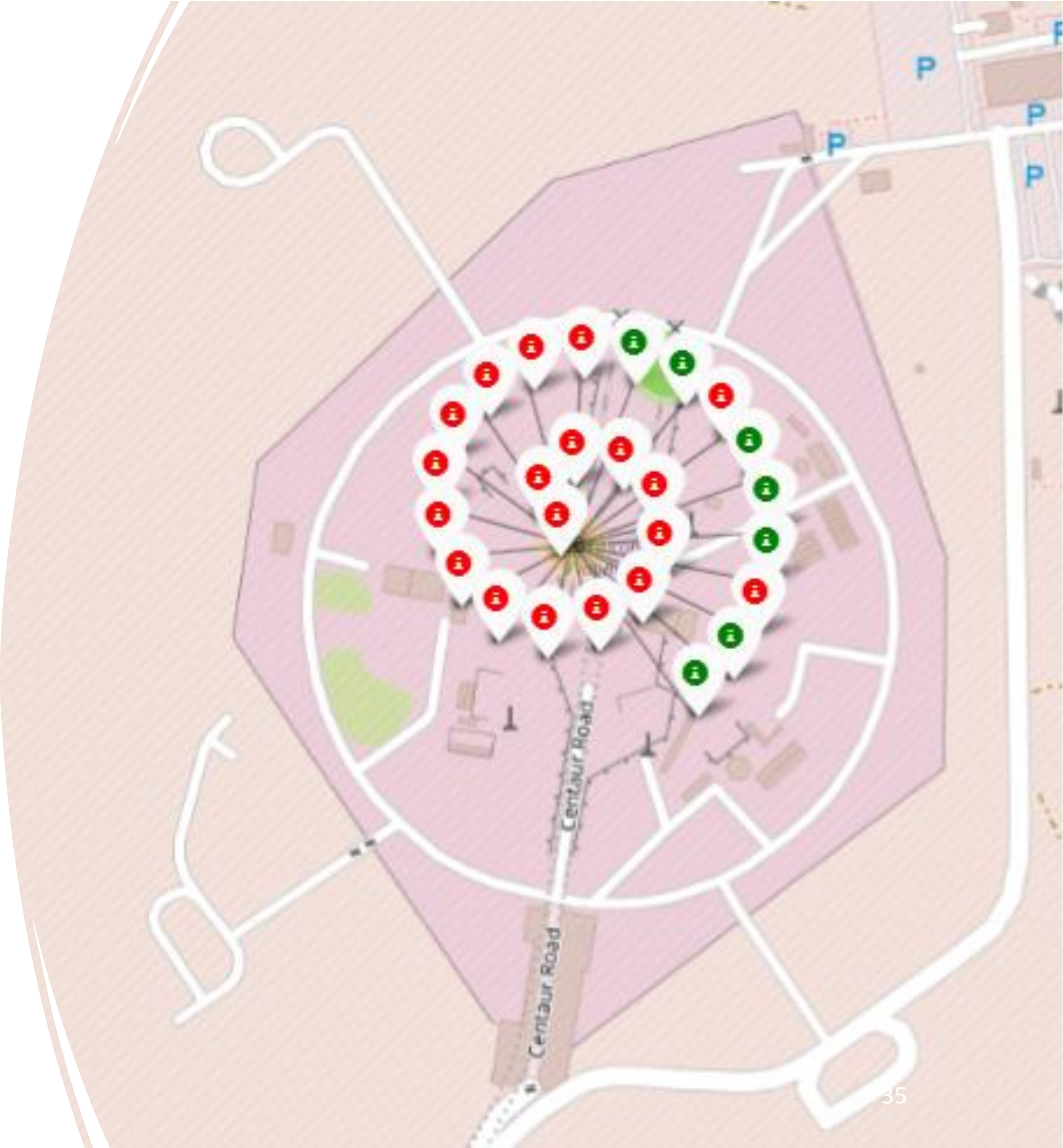
- Most of Launch sites are in proximity to the Equator line. The land is moving faster at the equator than any other place on the surface of the Earth. Anything on the surface of the Earth at the equator is already moving at 1670 km/hour. If a ship is launched from the equator it goes up into space, and it is also moving around the Earth at the same speed it was moving before launching. This is because of inertia. This speed will help the spacecraft keep up a good enough speed to stay in orbit.
- All launch sites are in very close proximity to the coast, while launching rockets towards the ocean it minimizes the risk of having any debris dropping or exploding near people.



All launch sites' location markers on a global map

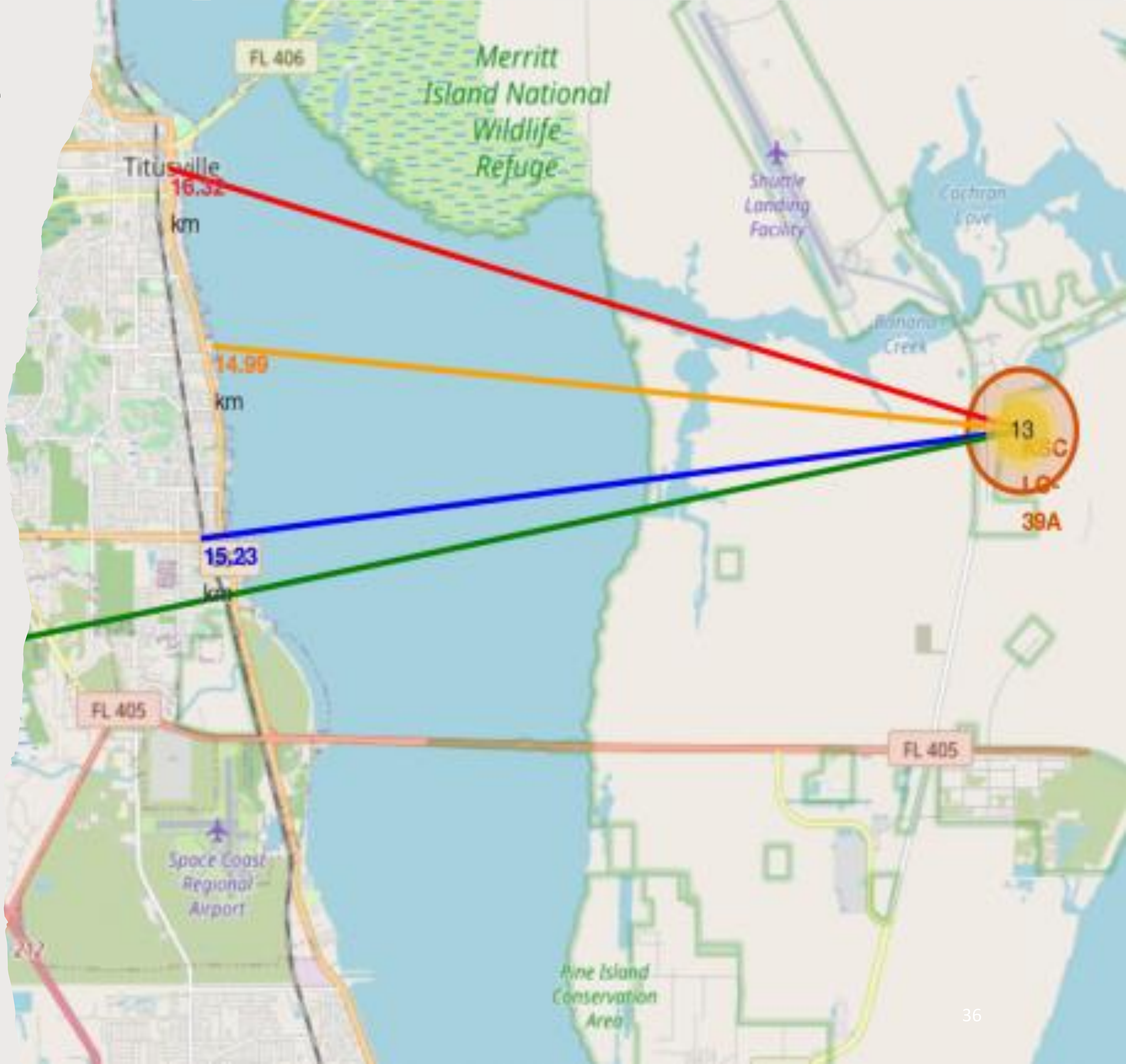
Color-labeled launch records on the map

- From the color-labeled markers we should be able to easily identify which launch sites have relatively high success rates.
  - Green Marker = Successful Launch
  - Red Marker = Failed Launch
- Launch Site KSC LC-39A has a very high Success Rate.



Distance from the launch site KSC LC-39A to its proximities

- From the visual analysis of the launch site KSC LC-39A we can clearly see that it is:
  - relatively close to railway (15.23 km)
  - relatively close to highway (20.28 km)
  - relatively close to coastline (14.99 km)
- The launch site KSC LC-39A is relatively close to its closest city Titusville (16.32 km).
- Failed rocket with its high speed can cover distances like 15-20 km in few seconds. It could be potentially dangerous to populated areas.

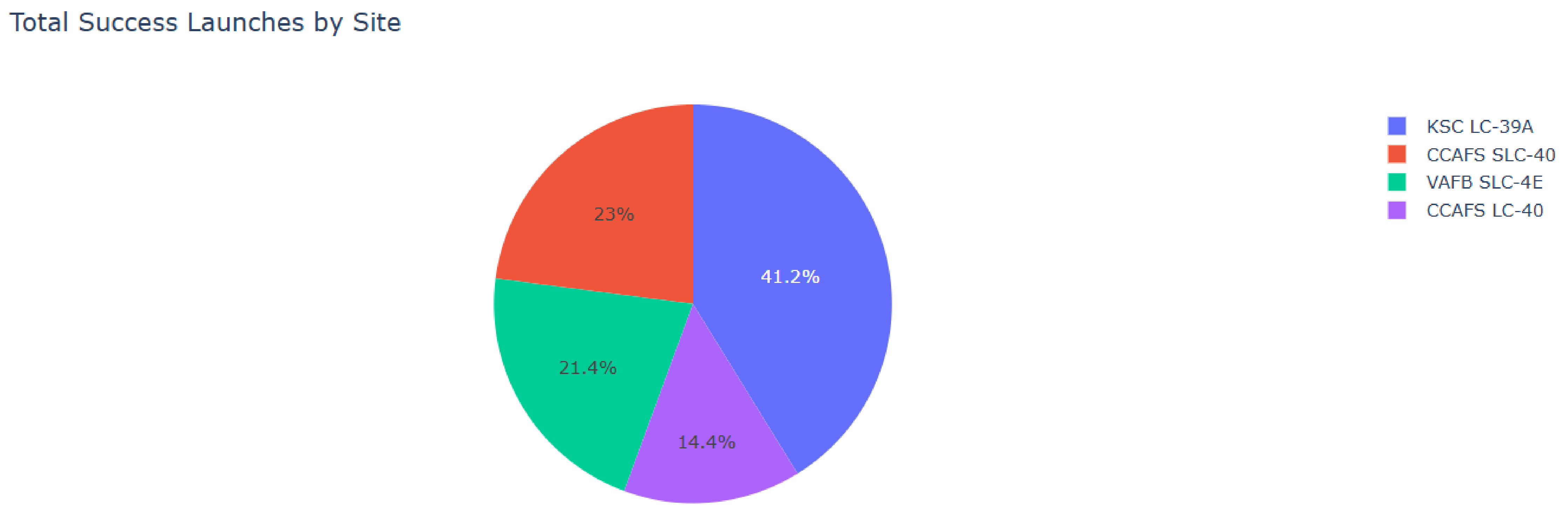


Section 4

Build a Dashboard with Plotly Dash

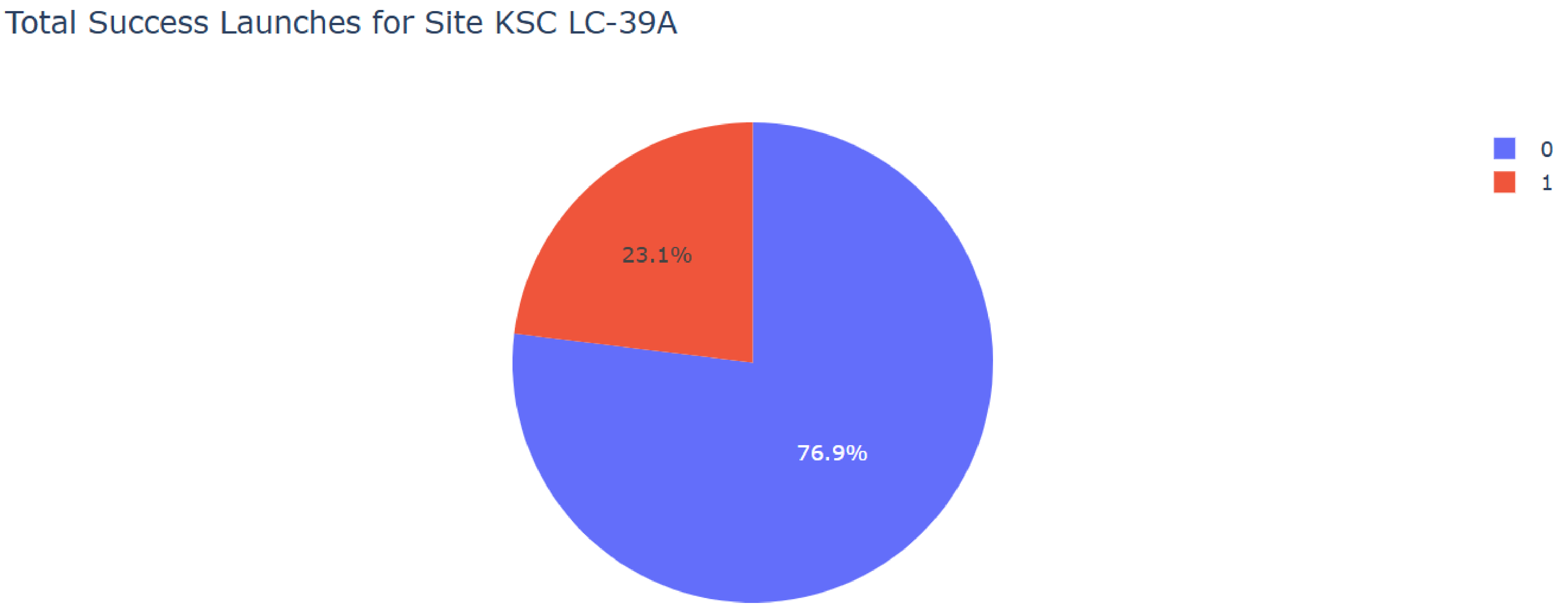
Launch success count for all sites

The chart clearly shows that from all the sites, KSC LC-39A has the most successful launches.

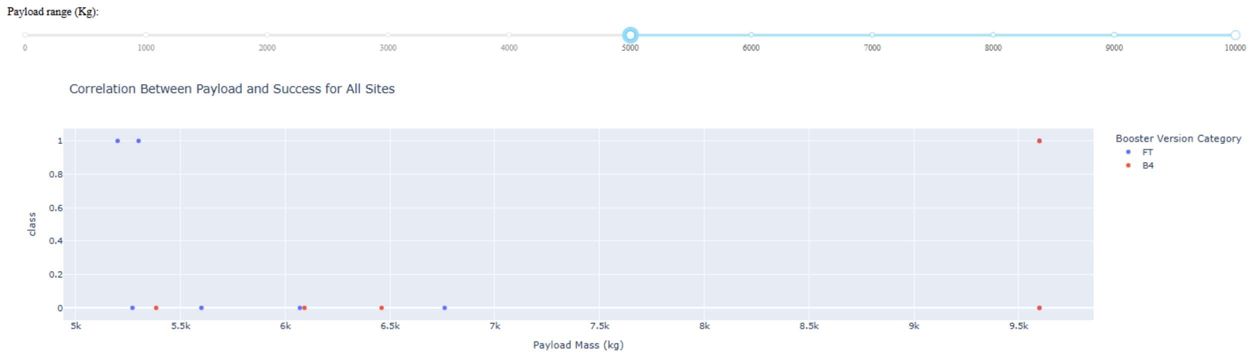


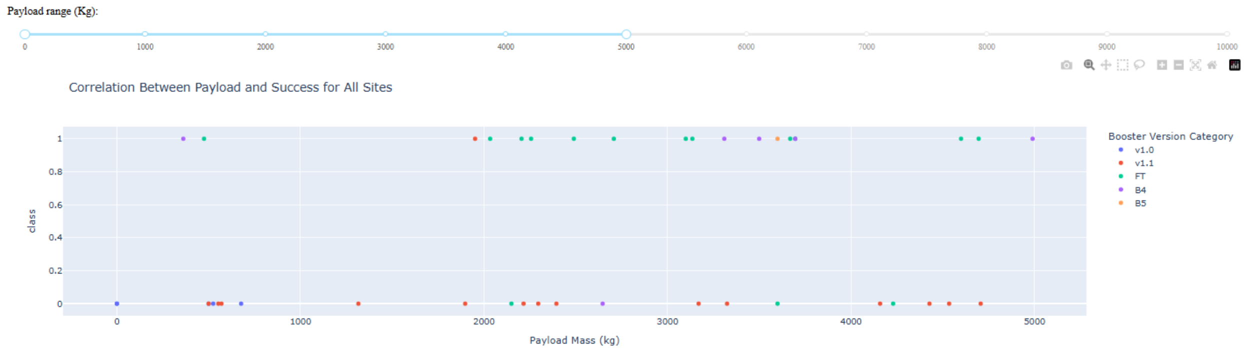
Launch site with highest launch success ratio

KSC LC-39A has the highest launch success rate (76.9%) with 10 successful and only 3 failed landings.



Payload Mass vs. Launch Outcome for all sites





The charts show that payloads between 2000 and 5500 kg have the highest success rate.

Section 5

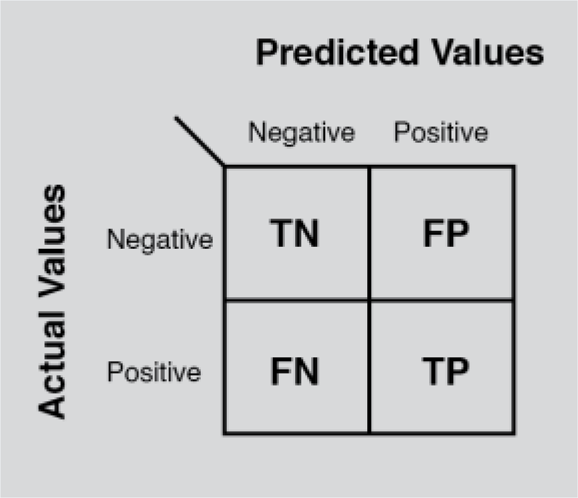
Predictive Analysis (Classification)

	LogReg	SVM	Tree	KNN
Jaccard_Score	0.833333	0.845070	0.880597	0.819444
F1_Score	0.909091	0.916031	0.936508	0.900763
Accuracy	0.866667	0.877778	0.911111	0.855556

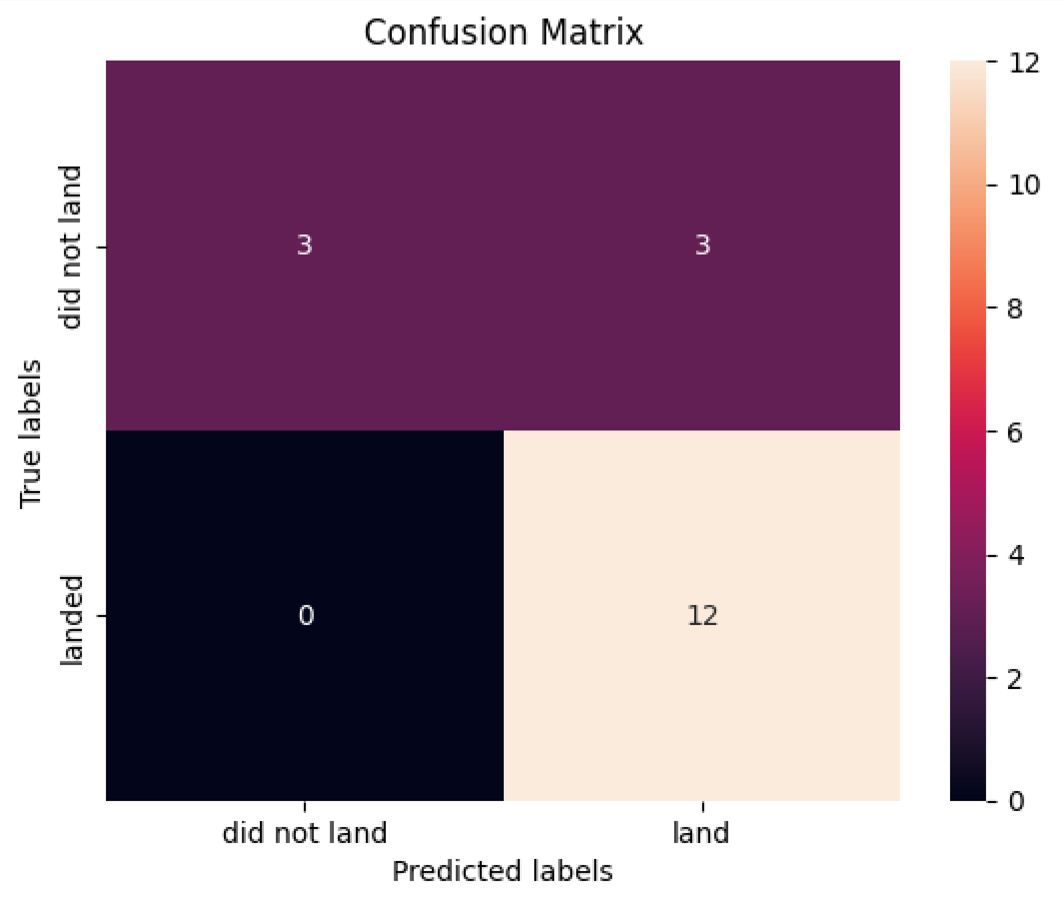
Classification Accuracy

The scores of the whole Dataset confirm that the best model is the Decision Tree Model. This model has not only higher scores, but also the highest accuracy.

Confusion Matrix



Examining the confusion matrix, we see that logistic regression can distinguish between the different classes. We see that the major problem is false positives.



Conclusions

- Decision Tree Model is the best algorithm for this dataset.
- Launches with a low payload mass show better results than launches with a larger payload mass.
- Most of launch sites are in proximity to the Equator line and all the sites are in very close proximity to the coast.
- The success rate of launches increases over the years.
- KSC LC-39A has the highest success rate of the launches from all the sites.
- Orbits ES-L1, GEO, HEO and SSO have 100% success rate.

Thank you!