IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

- Executive Summary
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- Methodology
- Results
- Conclusion
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Executive Summary

- Summary of methodologies
- Summary of all 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.

- Questions to be answered

– 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 Space X Rest API; Using Web Scrapping from Wikipedia
- Perform data wrangling
  - Filtering the data; Dealing with missing values; Using One Hot Encoding to prepare the data to a binary classification
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform 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.

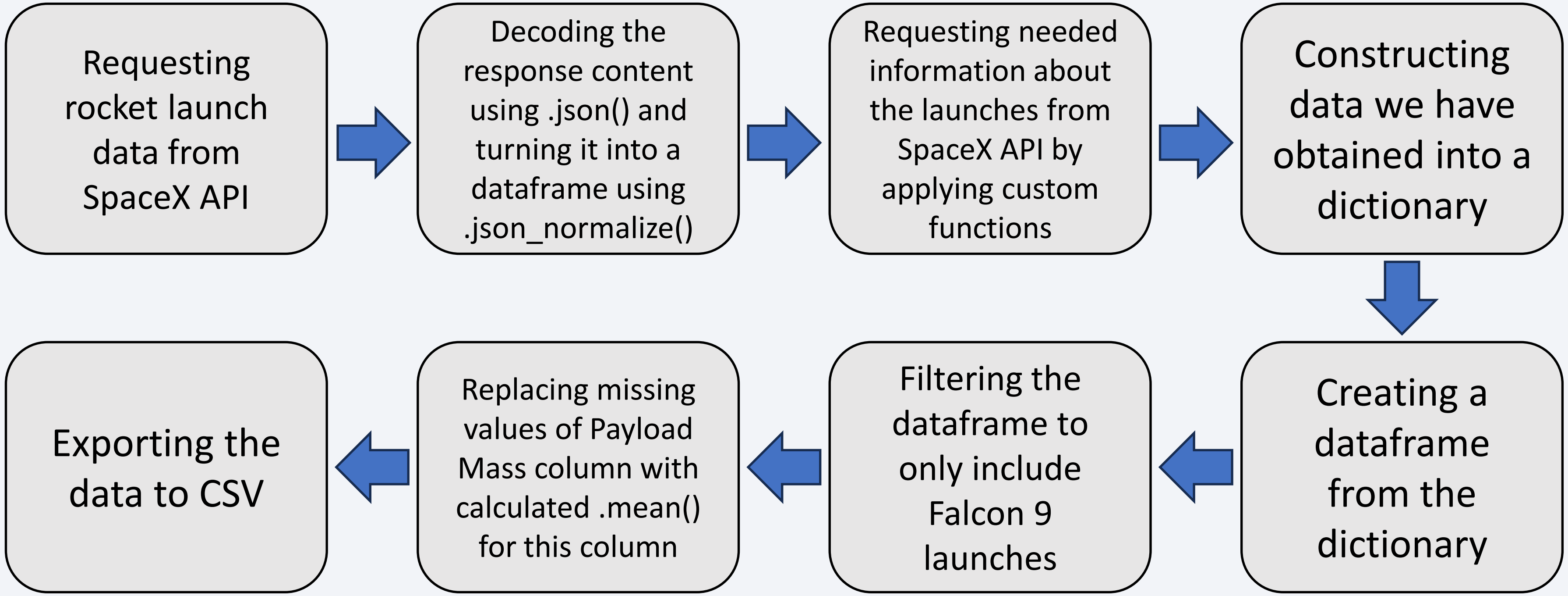
Data Columns are obtained by using SpaceX REST API:

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:

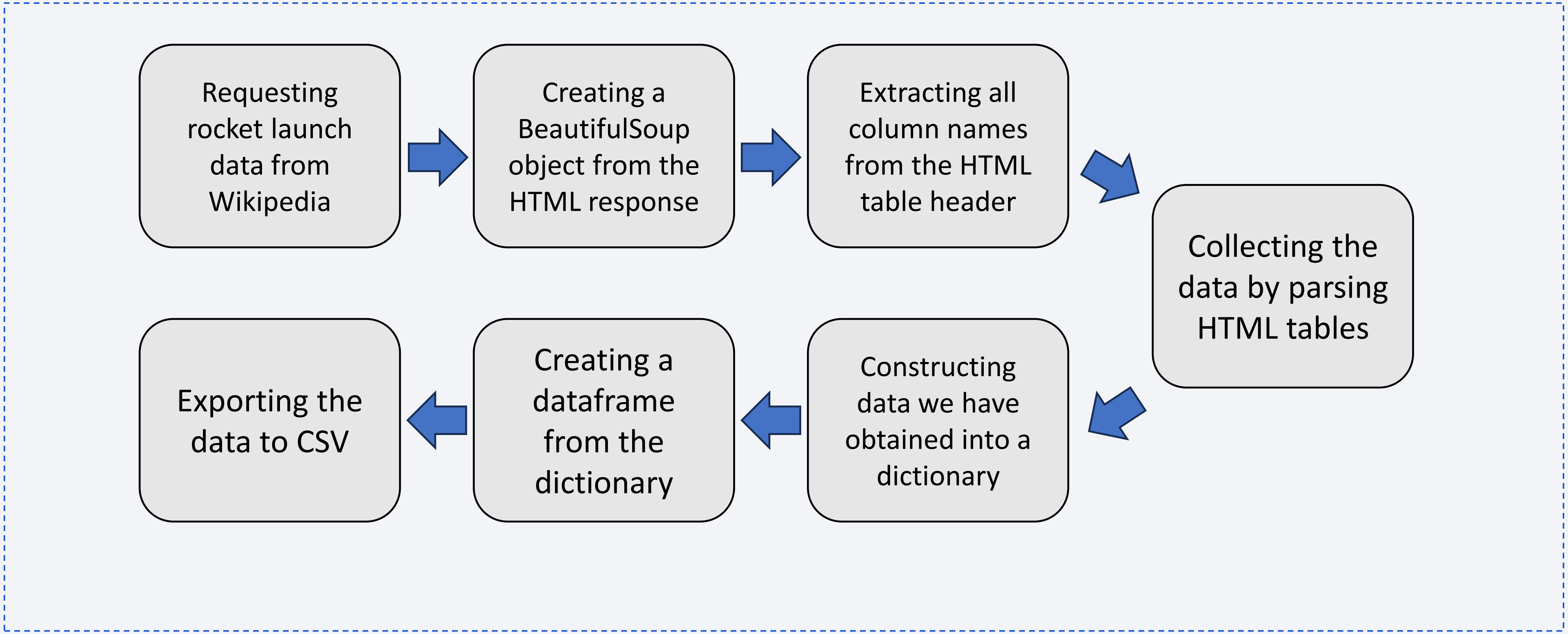
Flight No., Launch site, Payload, PayloadMass, Orbit, Customer, Launch outcome, Version Booster, Booster landing, Date, Time

Data Collection – SpaceX API



[Data Collection API]

Data Collection - Scraping



[Data Collection API with 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 ground pad.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

[Data Wrangling]

EDA with Data Visualization

Charts were 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).

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

[EDA with data visualization]

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.

Coloured Markers of the launch outcomes for each Launch Site:

- Added coloured 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 coloured Lines to show distances between the Launch Site KSC LC-39A (as an example) and its proximities like Railway, Highway, Coastline and Closest City.

Interactive Visual Analytics 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:

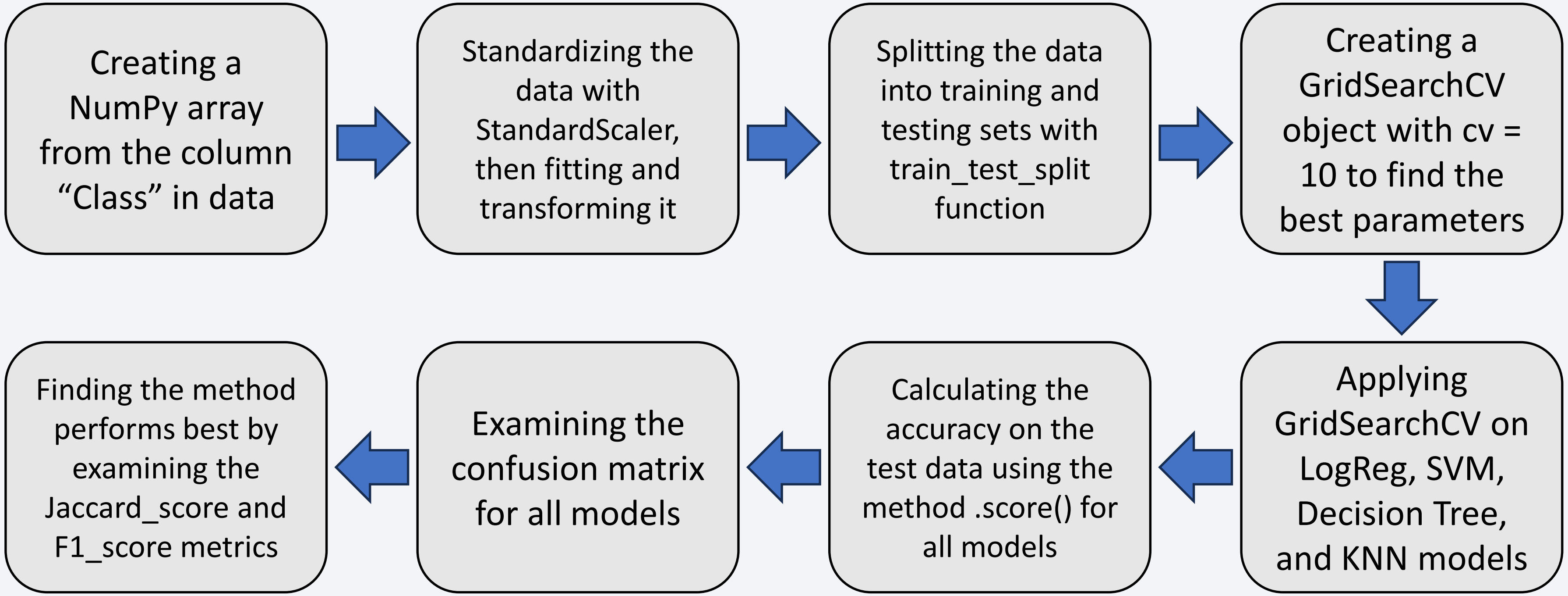
- Added a slider to select Payload range.

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.

[Dashboard code with plot]

Predictive Analysis (Classification)



[Predict with Machine Learning]

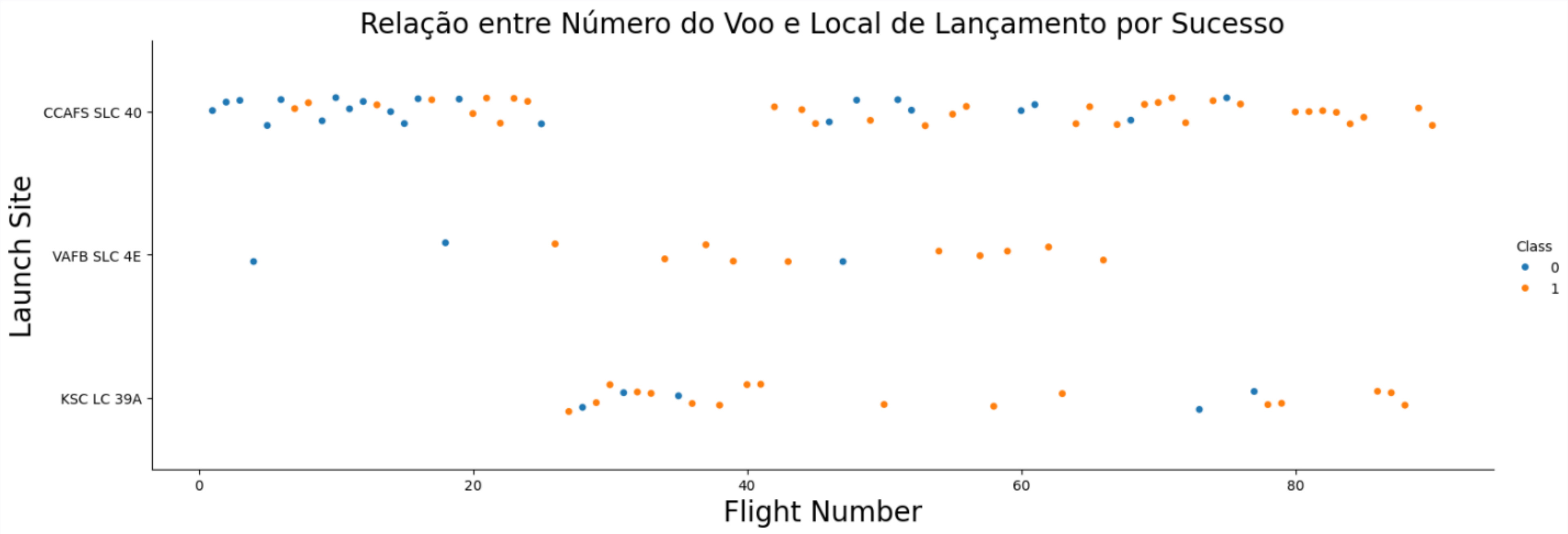
Results

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

Section 2

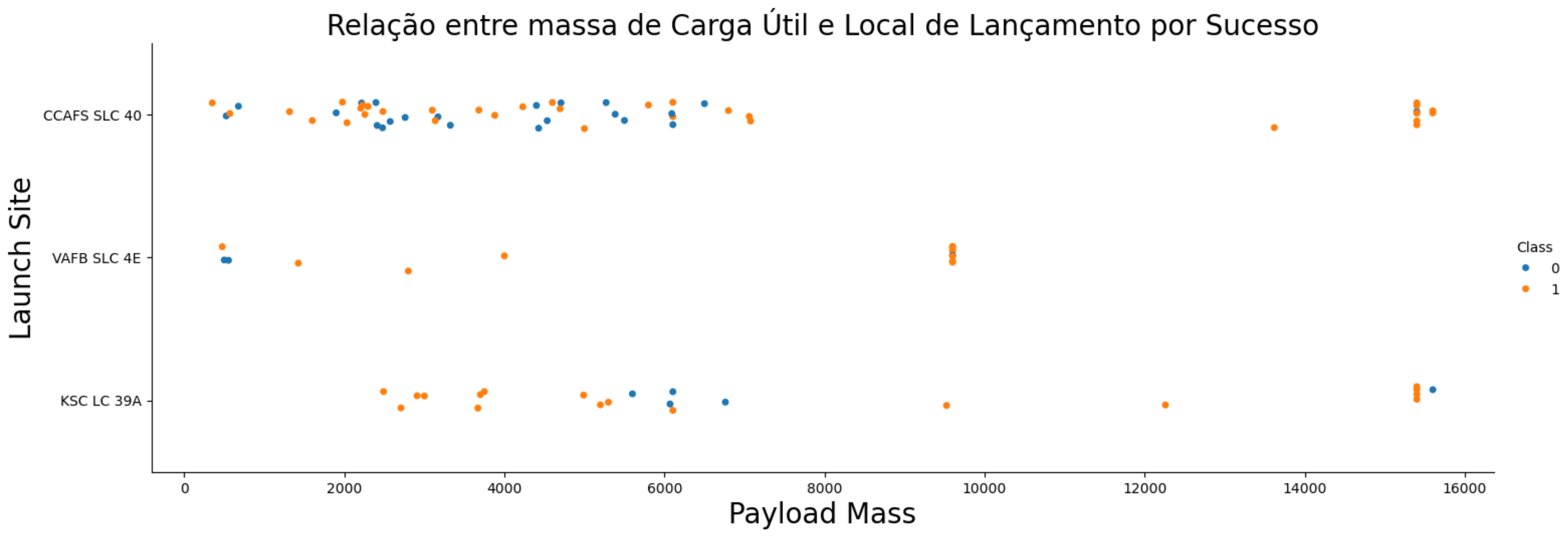
Insights drawn from EDA

Flight Number vs. Launch Site



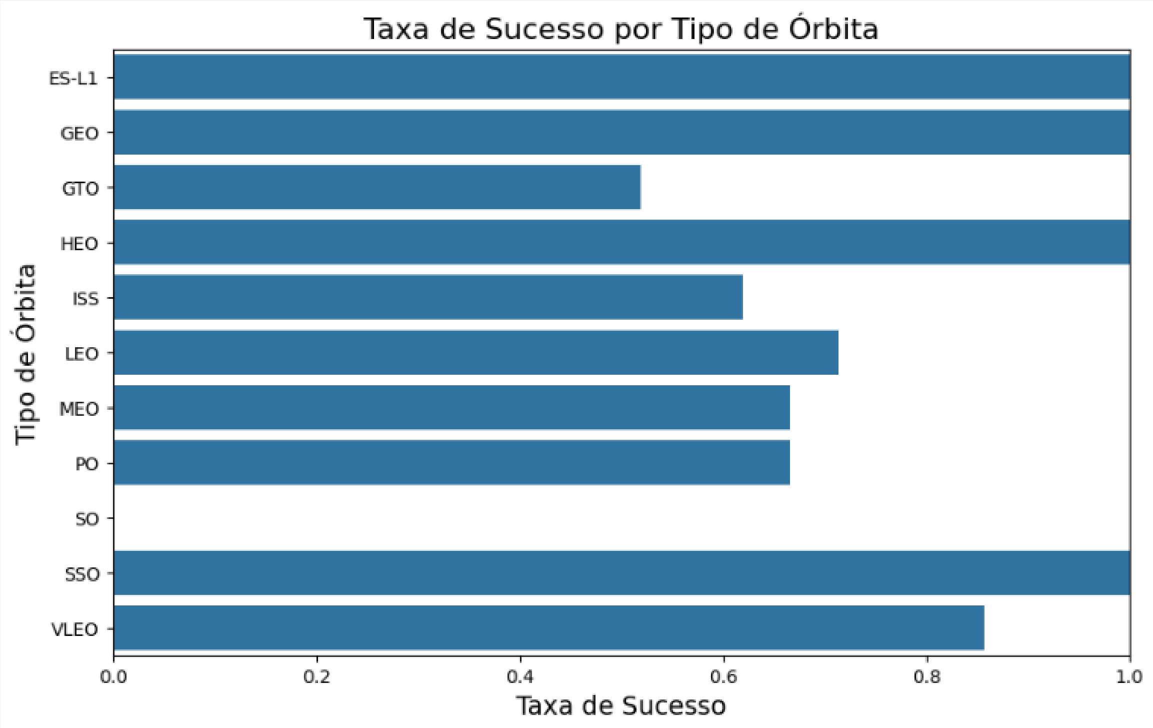
- The earliest flights all failed while the latest flights all succeeded.
- The CCAFS SLC 40 launch site has about a half of all launches.
- VAFB SLC 4E and KSC LC 39A have higher success rates.
- It can be assumed that each new launch has a higher rate of success.

Payload vs. Launch Site



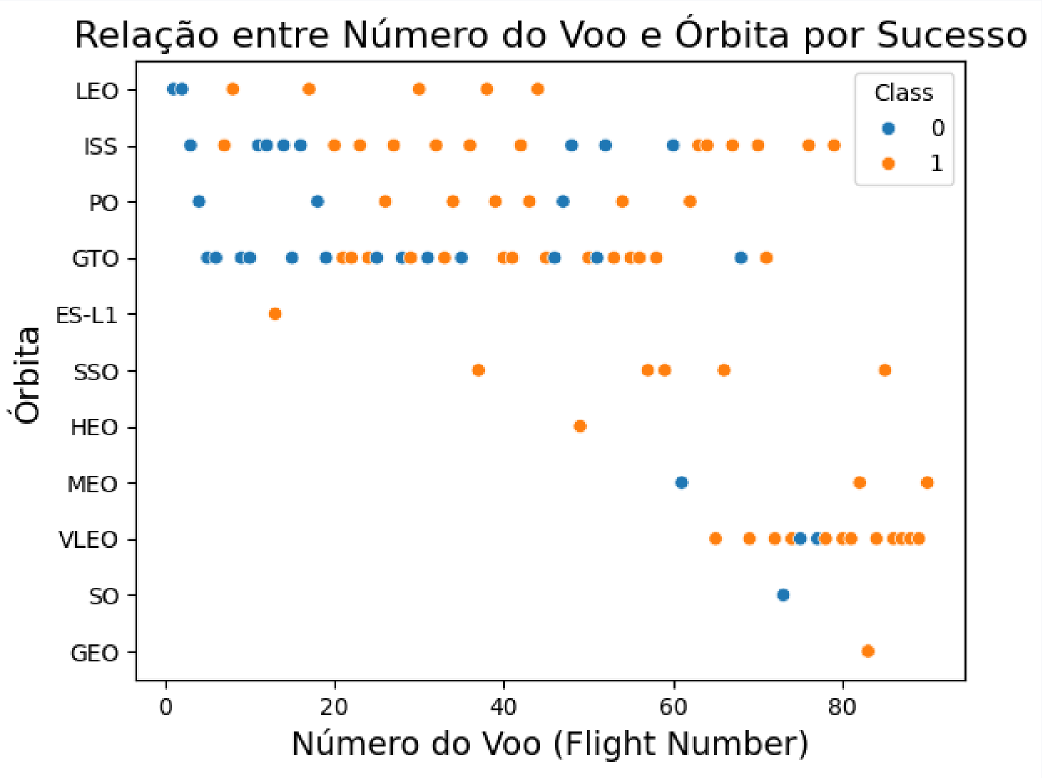
- For every launch site the higher the payload mass, the higher the success rate.
- Most of the launches with payload mass over 7000 kg were successful.
- KSC LC 39A has a 100% success rate for payload mass under 5500 kg too..

Success Rate vs. Orbit Type



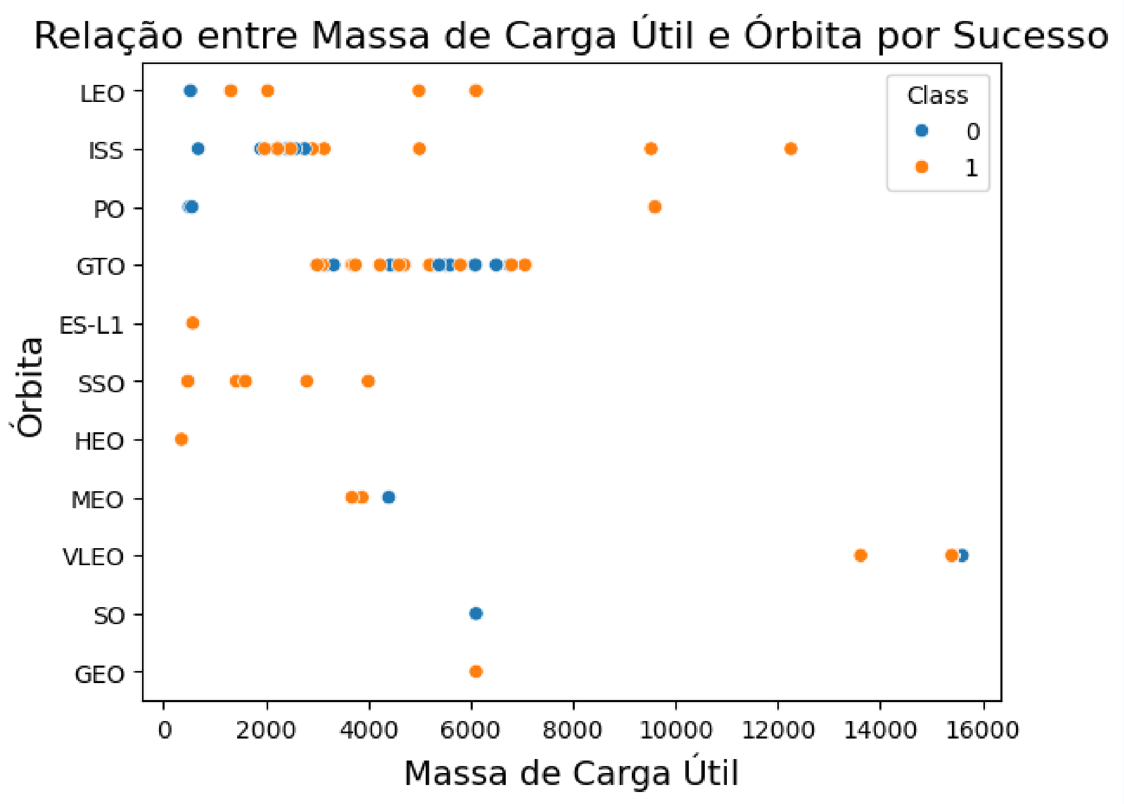
- Orbits with 100% success rate: ES-L1, GEO, HEO, SSO
- Orbits with 0% success rate: SO
- Orbits with success rate between 50% and 85%: GTO, ISS, LEO, MEO, PO

Flight Number vs. Orbit Type



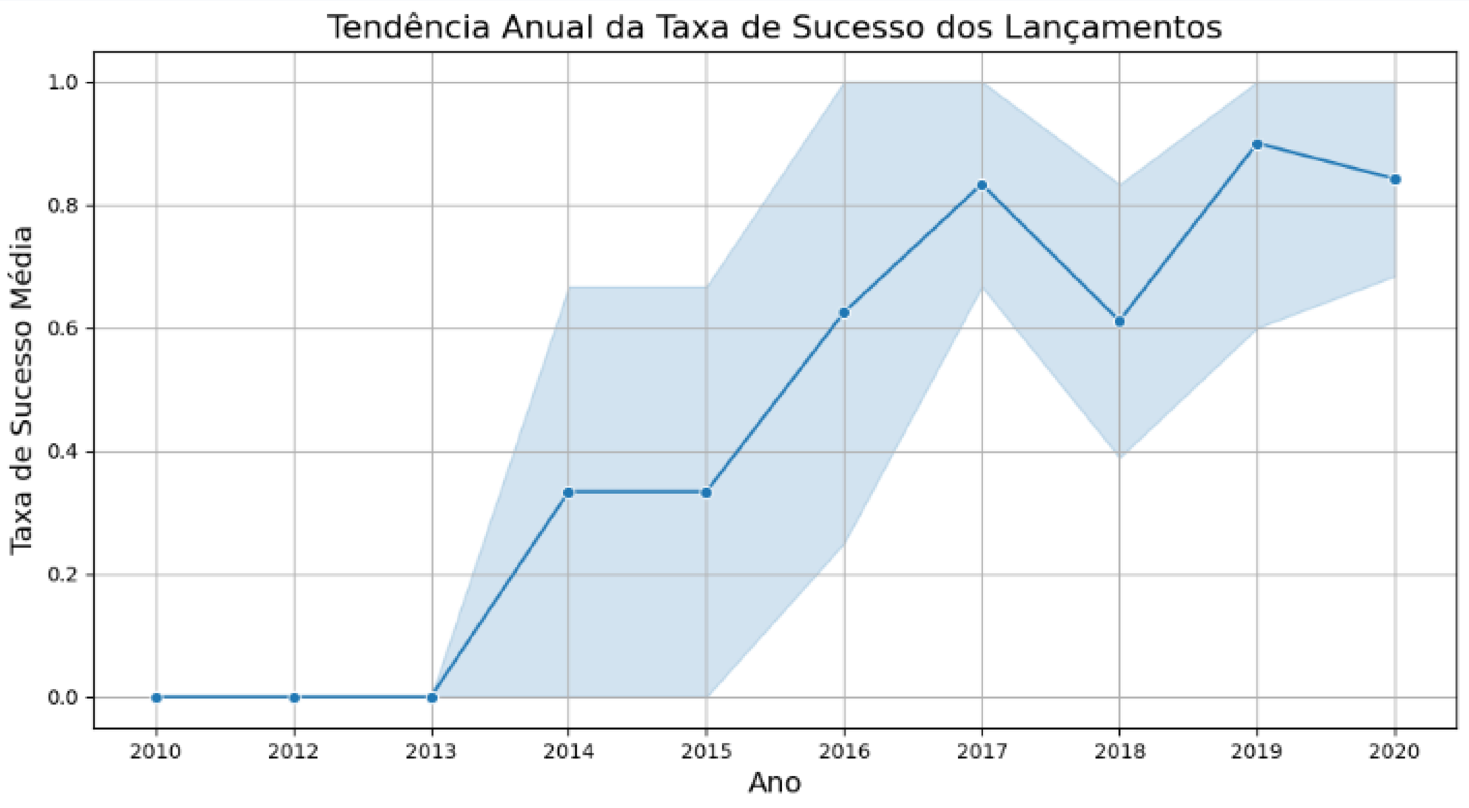
- In the LEO orbit the Success appears related to the number of flights; on the other hand, there seems to be no relationship between flight number when in GTO orbit.

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.

All Launch Site Names

```
%sql select distinct "Launch_Site" from SPACEXTABLE
```

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

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

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

Launch Site Names Begin with 'CCA'

```
%sql select * from SPACEXTABLE 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

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

Total Payload Mass

```
%sql select sum(PAYLOAD_MASS__KG_) from SPACEXTABLE where Customer = 'NASA (CRS)';
```

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

sum(PAYLOAD_MASS__KG_)
45596

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

Average Payload Mass by F9 v1.1

```
%sql select avg(PAYLOAD_MASS__KG_) from SPACEXTABLE where Booster_Version = 'F9 v1.1';

 * sqlite:///my_data1.db
Done.

avg(PAYLOAD_MASS__KG_)
                2928.4
```

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

First Successful Ground Landing Date

```
%sql select min(date) from SPACEXTABLE where Landing_Outcome = 'Success (ground pad)';
```

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

min(date)
2015-12-22

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

Successful Drone Ship Landing with Payload between 4000 and 6000

```
%sql select "Booster_Version" from SPACEXTABLE where "Landing_Outcome" = 'Success (drone ship)' and PAYLOAD_MASS__KG_ between 4001 AND 5999;
```

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

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

- Listing the names of the 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

```
%sql select Mission_Outcome, count(*) from SPACEXTABLE 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

- Listing the total number of successful and failure mission outcomes.

Boosters Carried Maximum Payload

```
%sql select distinct "Booster_Version" from SPACEXTABLE where PAYLOAD_MASS__KG_ = (select max(PAYLOAD_MASS__KG_) from SPACEXTABLE);
```

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

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

2015 Launch Records

```
%sql SELECT substr(Date, 6, 2) AS month, Landing_Outcome, Booster_Version, Launch_Site FROM SPACEXTABLE WHERE Landing_Outcome = 'Failure (drone ship)' AND substr(Date, 1, 4) = '2015';
```

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

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

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

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

```
%sql select Landing_Outcome, count(*) as COUNT_Out from SPACEXTABLE where Date between '2010-06-04' and '2017-03-20' group by Landing_Outcome order by COUNT_Out DESC;
```

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

Landing_Outcome	COUNT_Out
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

- 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.

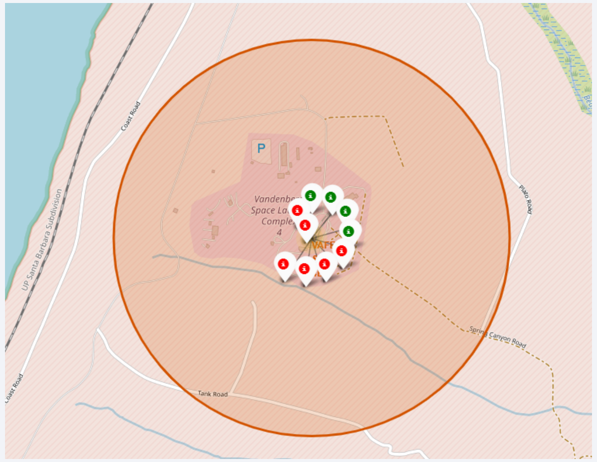
Section 3

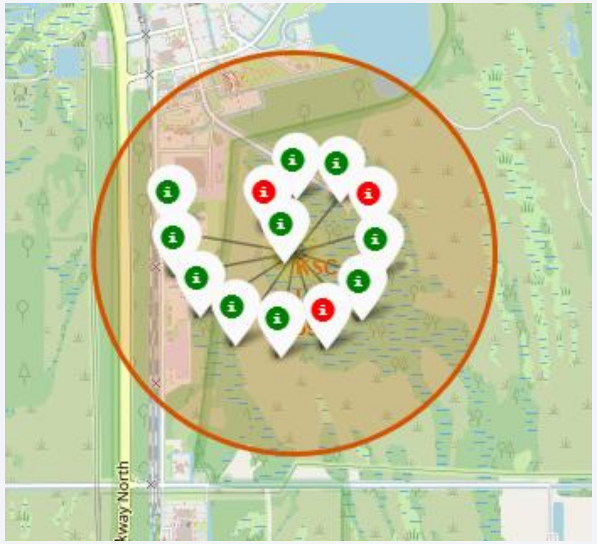
Launch Sites Proximities Analysis

Launch Sites location markers in a global map

- Launch sites are often near the equator because the Earth's faster rotation there (1670 km/hour) gives rockets an initial speed boost due to inertia, helping them achieve orbit. Proximity to the coast is also crucial for safety, as it allows for launching over the ocean, minimizing the risk of debris falling near populated areas.

Color-labeled markers in marker clusters

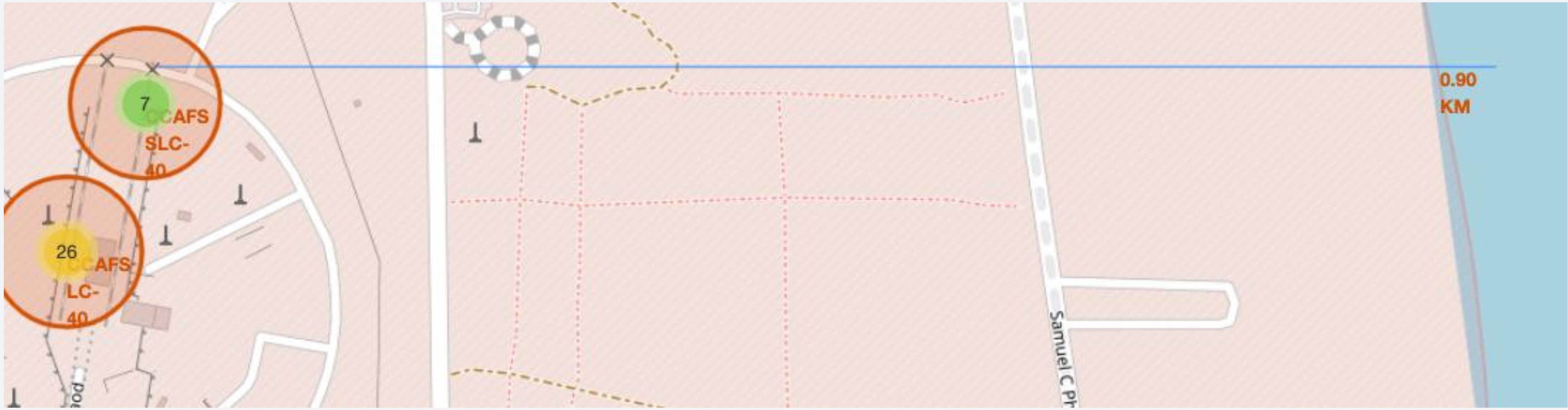




- From the colour-labeled markers we should be able to easily identify which launch sites have relatively high success rates.
  - Green = Sucessful Launch
  - Red = Failed Launch

- Launch Site KSC LC-39A has a very high Success Rate.

Distance between launch and sea

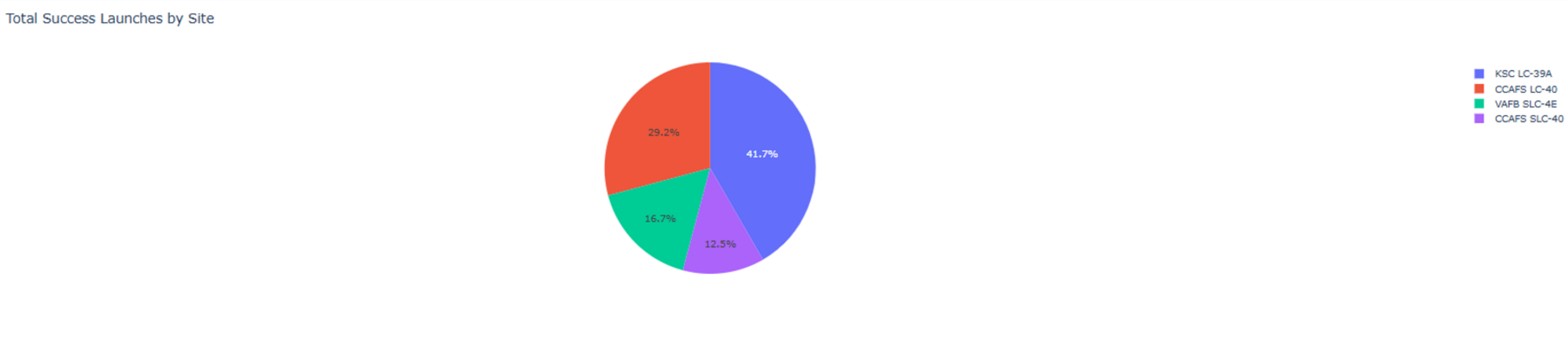


- The map shows the proximity of launches to the sea, showing that it is an important factor in defining a SpaceX launch site.

Section 4

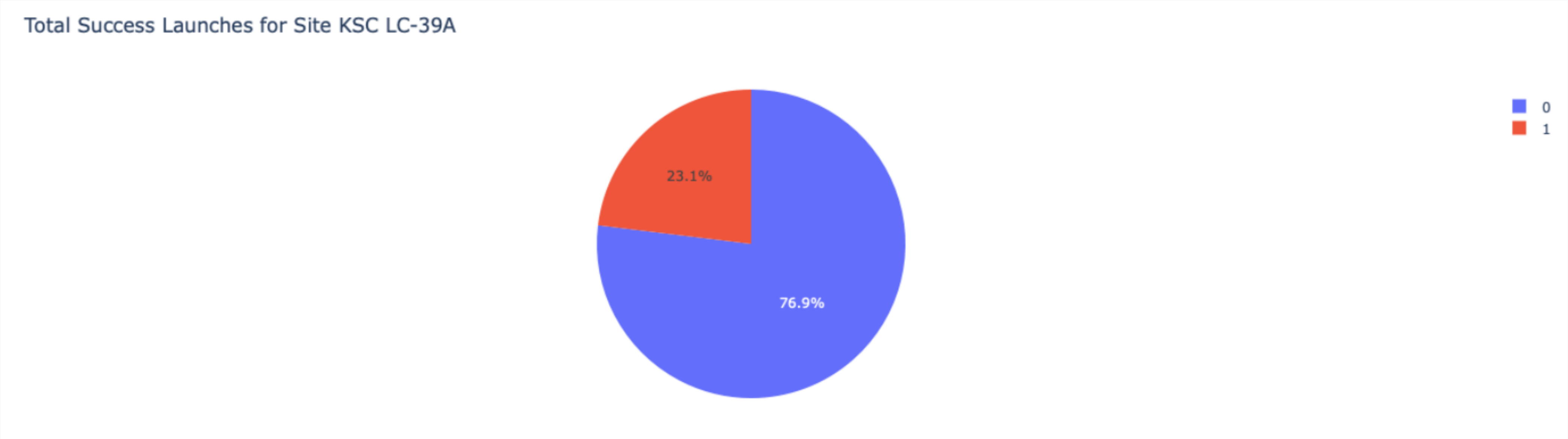
Build a Dashboard with Plotly Dash

Piechart with releases by sites



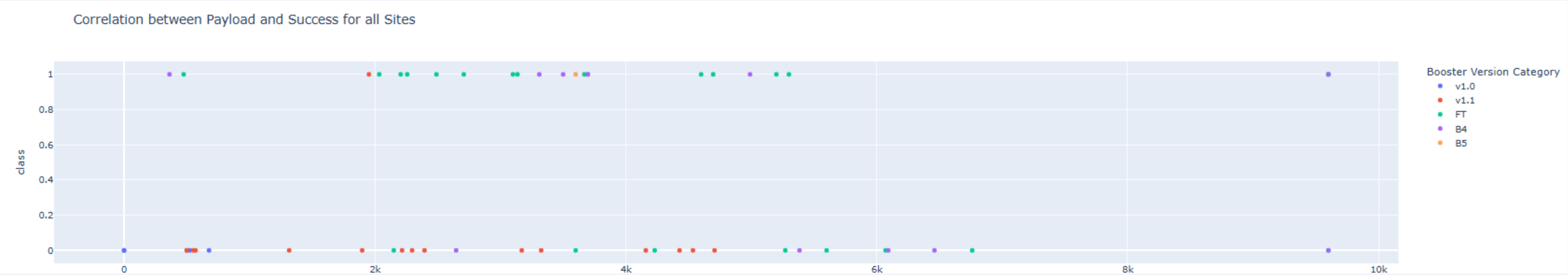
- The chart clearly shows that from all the sites, KSC LC-39A has the most successful launches.

Piechart with highest launch success ratio by site



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

Payload Mass vs Launch Outcome

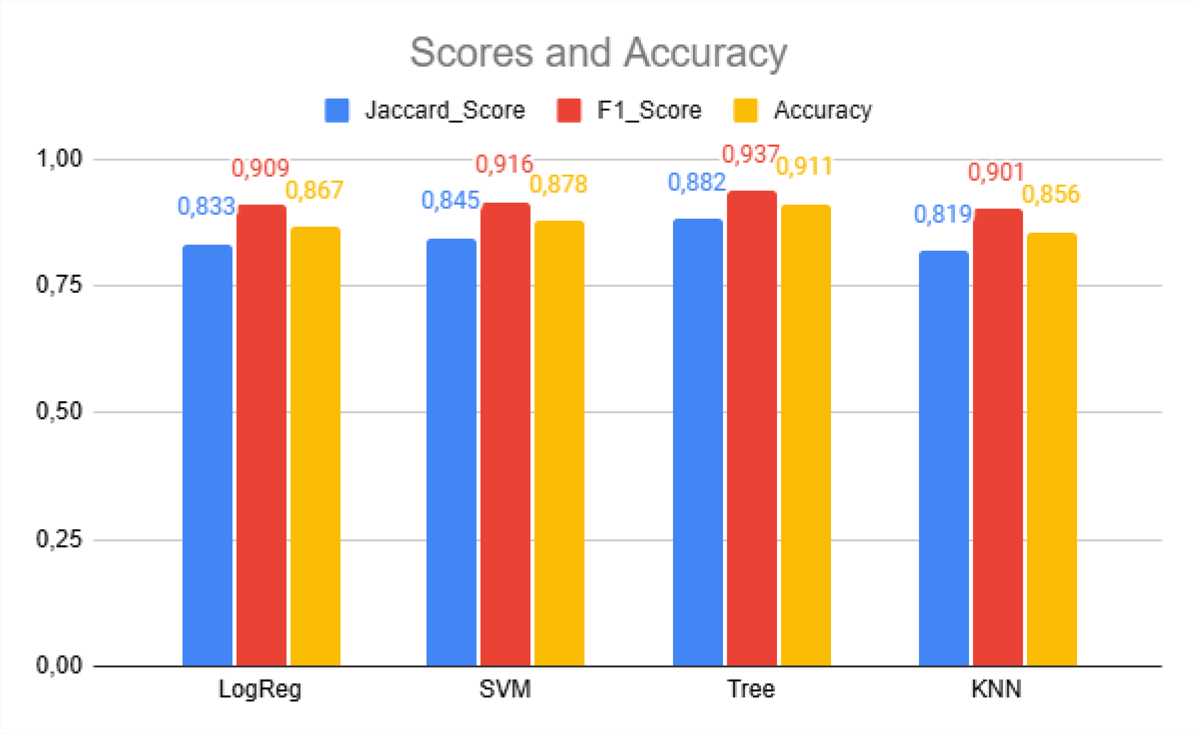


- The charts show that payloads between 2000 and 5500 kg have the highest success rate.

Section 5

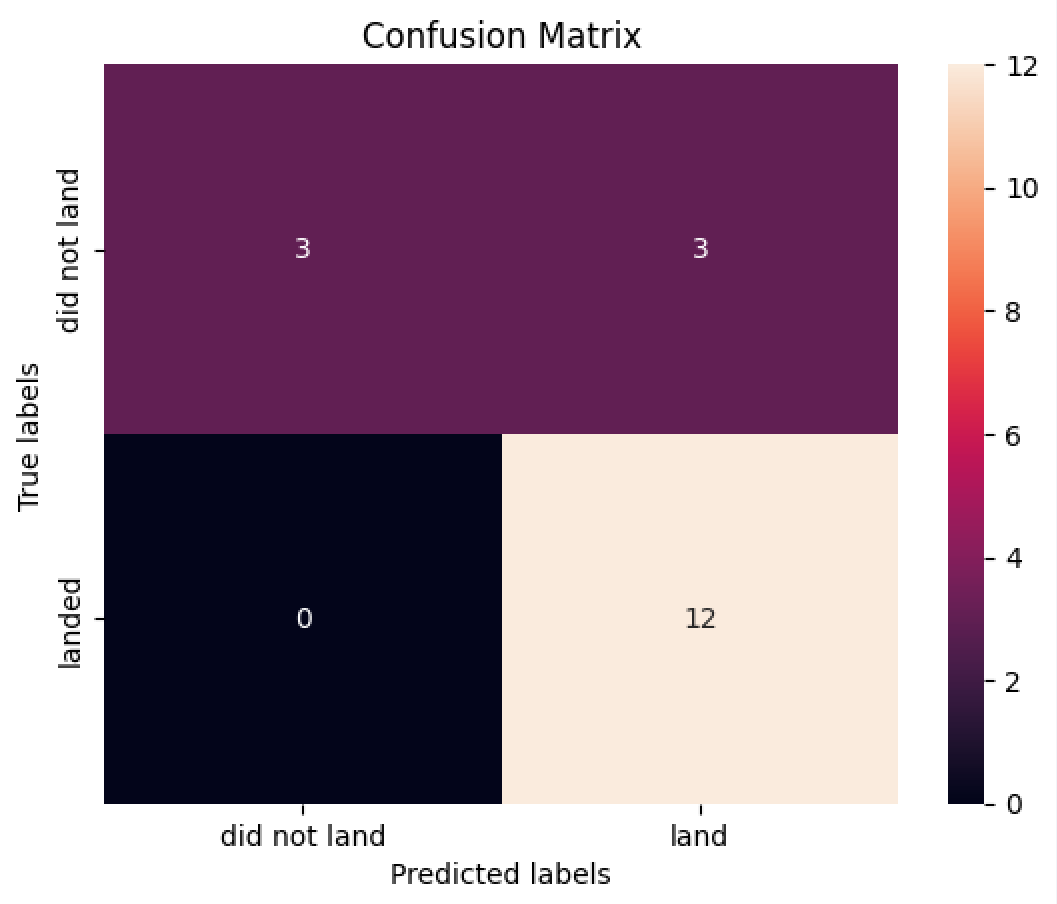
Predictive Analysis (Classification)

Classification Accuracy



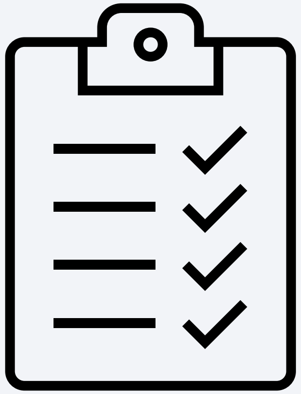
- Initial results from the Test Set were inconclusive for determining the best method, which can be attributed to the small sample size (18 samples).
- Therefore, we re-evaluated all methods using the entire dataset. The results confirmed that the Decision Tree Model is the top performer, achieving both higher scores and the greatest accuracy.

Confusion Matrix



- Examining the confusion matrix, we can see that the model is able to predict the result very well, having only presented around 16% false positives.

Conclusions



- The Decision Tree Model was identified as the most effective algorithm for this dataset.
- Launches with lower payload masses demonstrated better outcomes compared to those with heavier payloads.
- Most launch sites are located near the Equator, and all are in close proximity to a coast.
- The success rate of launches has shown a consistent increase over the years.
- Among all locations, the KSC LC-39A launch site has the highest success rate.
- The orbits ES-L1, GEO, HEO, and SSO all have a 100% success rate.

Appendix

Special Thanks

Coursera

IBM Data Science Professional

GitHub

Thank you!