IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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

Executive Summary

- **Summary of methodologies**
  - Data collection and data wrangling
  - Exploratory data analysis with data visualization
  - Exploratory Data Analysis with SQL
  - Building an interactive map with Folium
  - Building a dashboard with Plotly – Dash
  - Using Classification in predictive analysis
- **Summary of all results**
  - Results of an exploratory data analysis
  - Interactive Analytics Demi
  - Predictive analysis results

Introduction

Project background and context

SpaceX is a renowned American aerospace manufacturer and space transportation company founded by entrepreneur Elon Musk in 2002. SpaceX has rapidly become a trailblazer in the space industry, with a primary focus on reducing space transportation costs. The Falcon 9 rocket is advertised on SpaceX's website at a price of $62 million, a significant contrast to other providers whose costs often exceed $165 million per launch. A substantial portion of these cost savings is attributed to SpaceX's ability to reuse the first stage of the rocket. Consequently, if we can accurately forecast whether the first stage will be reused, we can estimate the overall launch cost.

Problems you want to find answers

- In what way do variables like payload mass, launch site, number of flights, and orbits influence the success of the first stage landing?
- Is there an upward trend in the rate of successful landings over the years?
- Among machine learning models, which one exhibits the highest accuracy in classifying the landing outcomes?

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - SpaceX Rest API
  - Webscrapping from Wikipedia
- Perform data wrangling
  - Filtering the data
  - Dealing with missing values
  - Using one hot encoding to prepare the data for binary classification

Methodology (part 2)

- 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, fine tuning and evaluating classification model for maximum accuracy

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 page.
- Both methods had to be used to get complete information about the launches for an in depth analysis.

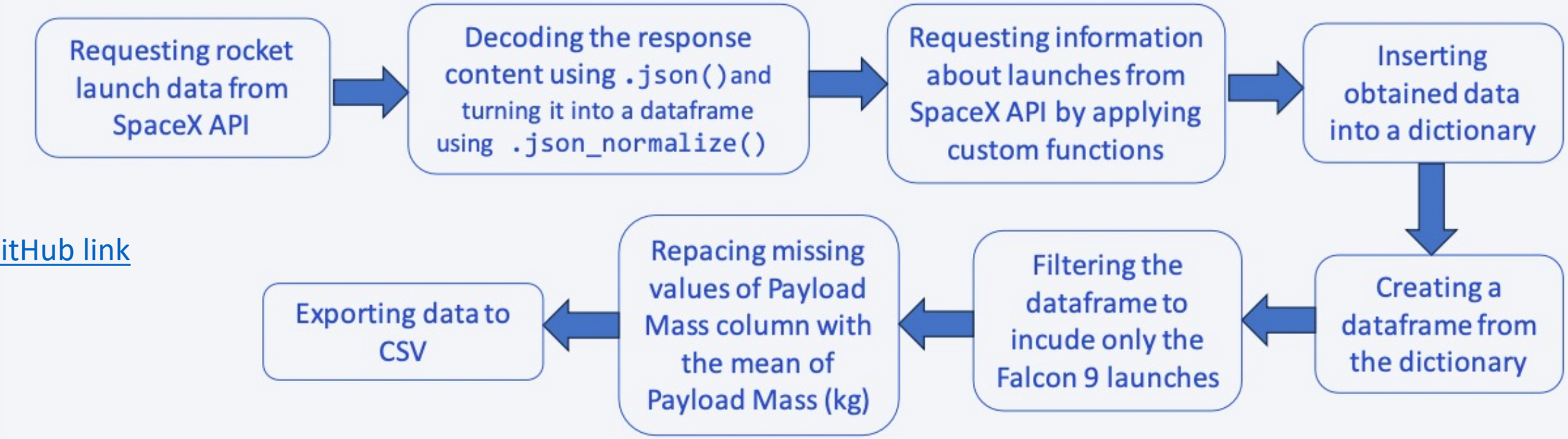
Fields collected by using the SpaceX REST API:

- FlightNumber
- Date
- BoosterVersion
- PayloadMass
- Orbit
- LaunchSite
- Outcome
- Flights
- GridFins
- Reused
- Legs
- LandingPad
- Block
- ReusedCount
- Serial
- Longitude
- Latitude

Fields collected by using Wikipedia web scrapping:

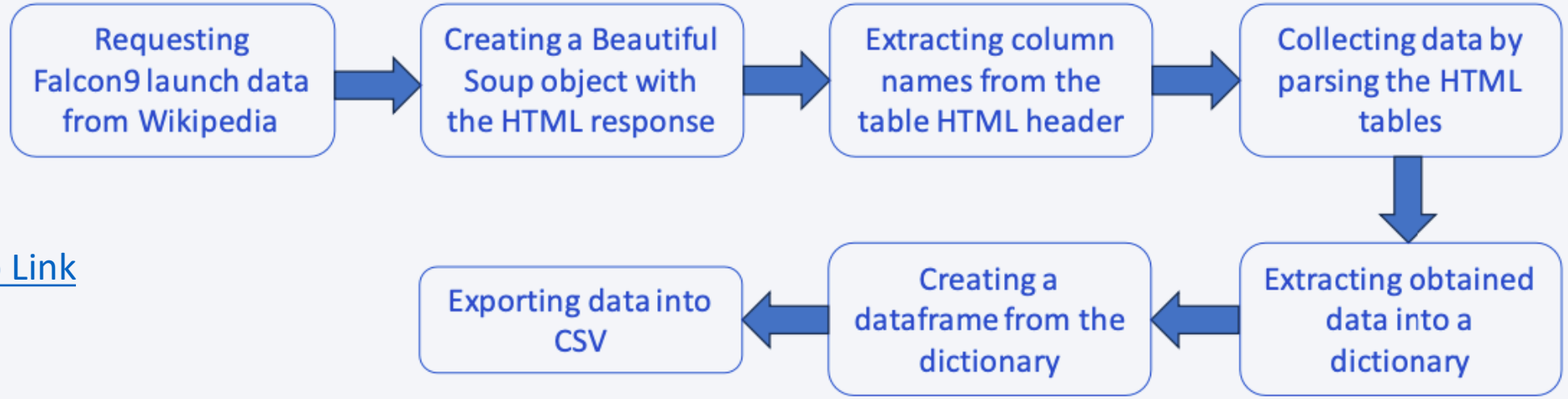
- FlightNo
- Launch Site
- Payload
- PayloadMass
- Orbit
- Customer
- Launch outcome
- Version Booster
- Booster Landing
- Date
- Time

Data Collection – SpaceX API



GitHub link

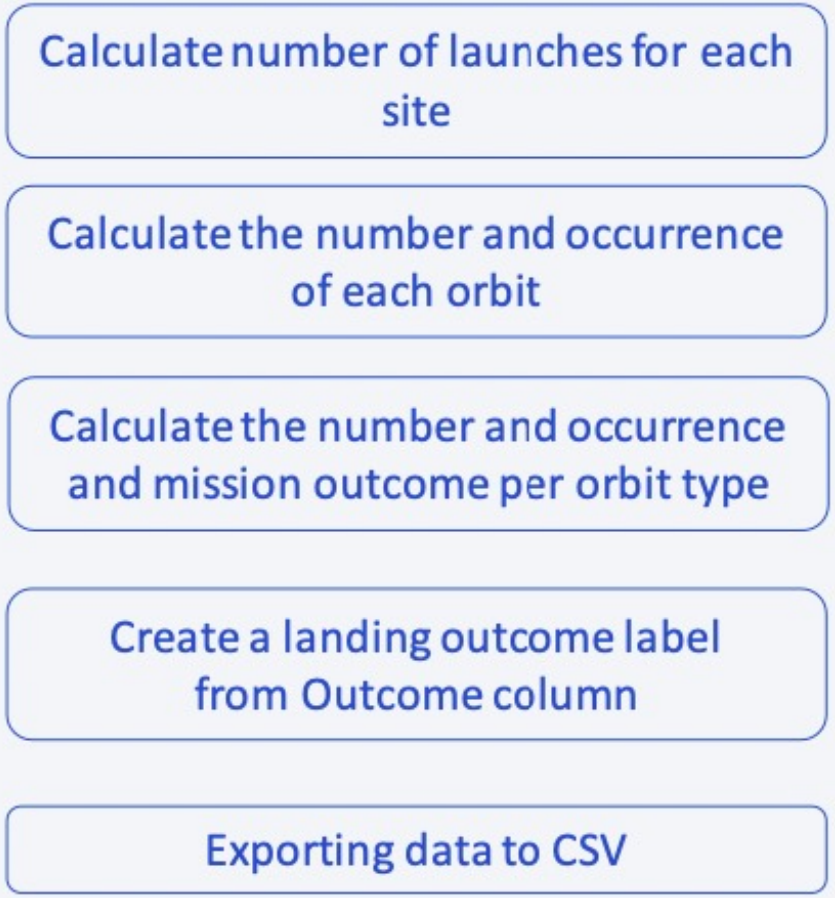
Data Collection - Scraping



GitHub Link

Data Wrangling

GitHub Link



EDA with Data Visualization

The charts plotted were:

- Flight Number / PayloadMass
- Flight Number / Launch site
- Payload Mass / Launch site
- Success rate per orbit Type
- Flight number /orbit type
- Payload / orbit type
- Yearly Success Rate

Scatter plots visually depict the relationship between distinct variables, and if a correlation is identified, they can be employed in machine learning models to classify landing outcomes.
Bar charts are utilized to illustrate the impact of categorical variables on the success rate of landings.
Line charts provide a representation of how the success rate evolves over time.

GitHub Link

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 succesful landing outcome in ground pad was acheived
- 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 per month for the 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 Link

Build an Interactive Map with Folium

- Markers of all launch sites
  - Added marker with Circle, Popup Label and Text Label for NASA Johnson Space Center using its latitude and longitude coordinates as a start location
  - Added marker with Circle, Popup Label and Text Label for all launsh sites using their latitude and longitude coordinates to show theiw geographical location and proximity to Equator and coasts.
- Coloured markers of launch outcomes for each launch site
  - Added coloured markers of successful (green) and failed (red) launch outomes per launch site to display launch sites with highest success rates.
- Distances between a launch site to its proximities
  - Added coloured lines to show the distance between launch site KSC LC-39A and its proximities including Railway, Highway, Coastline and closest city.

GitHub Link

Build a Dashboard with Plotly Dash

Launch Sites Dropdown List

- Added a dropdown list to enable launch site selection.

Pie Chart showing success launches for all sites

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

Slider of Payload Mass range

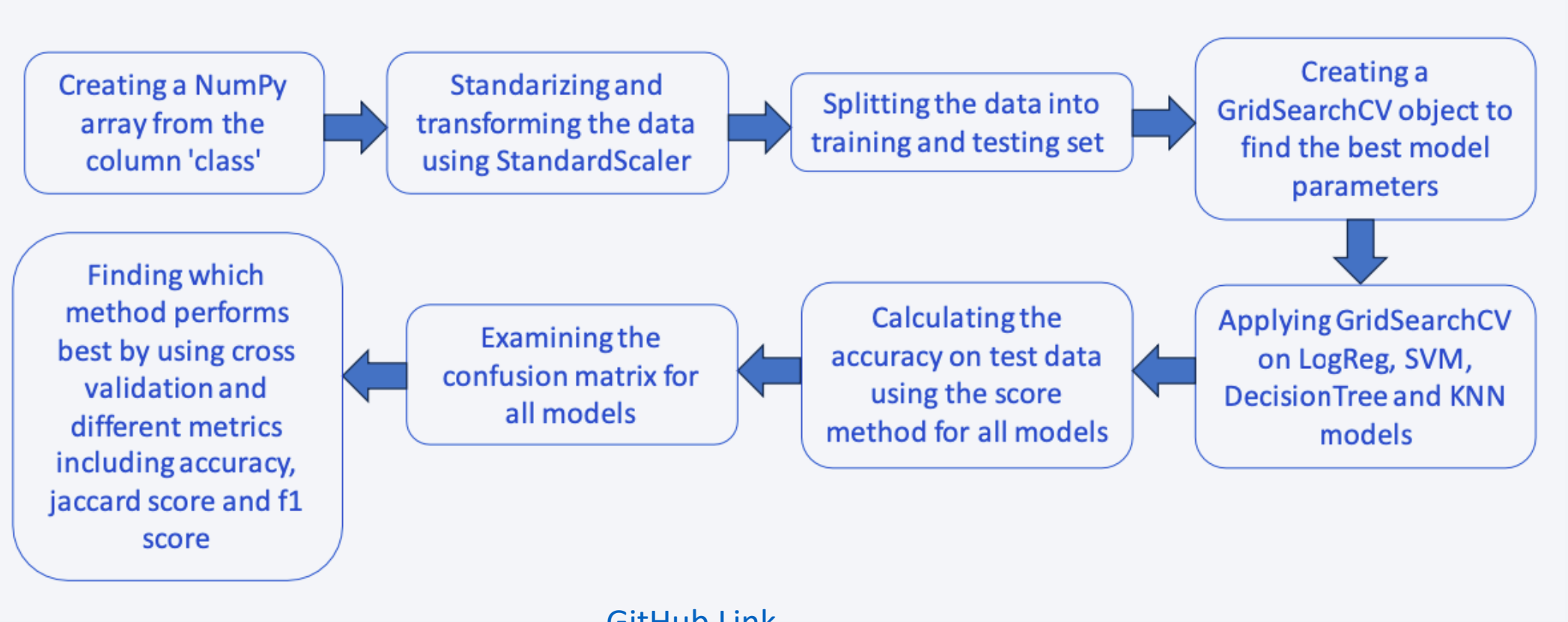
- Added a pie chart to display the total count of successful launches for all sites and the Success vs Failed launches count for a site, if a specific site was selected.

Scatter plot of Payload Mass vs Success Rate for different Booster Versions

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

GitHub Link

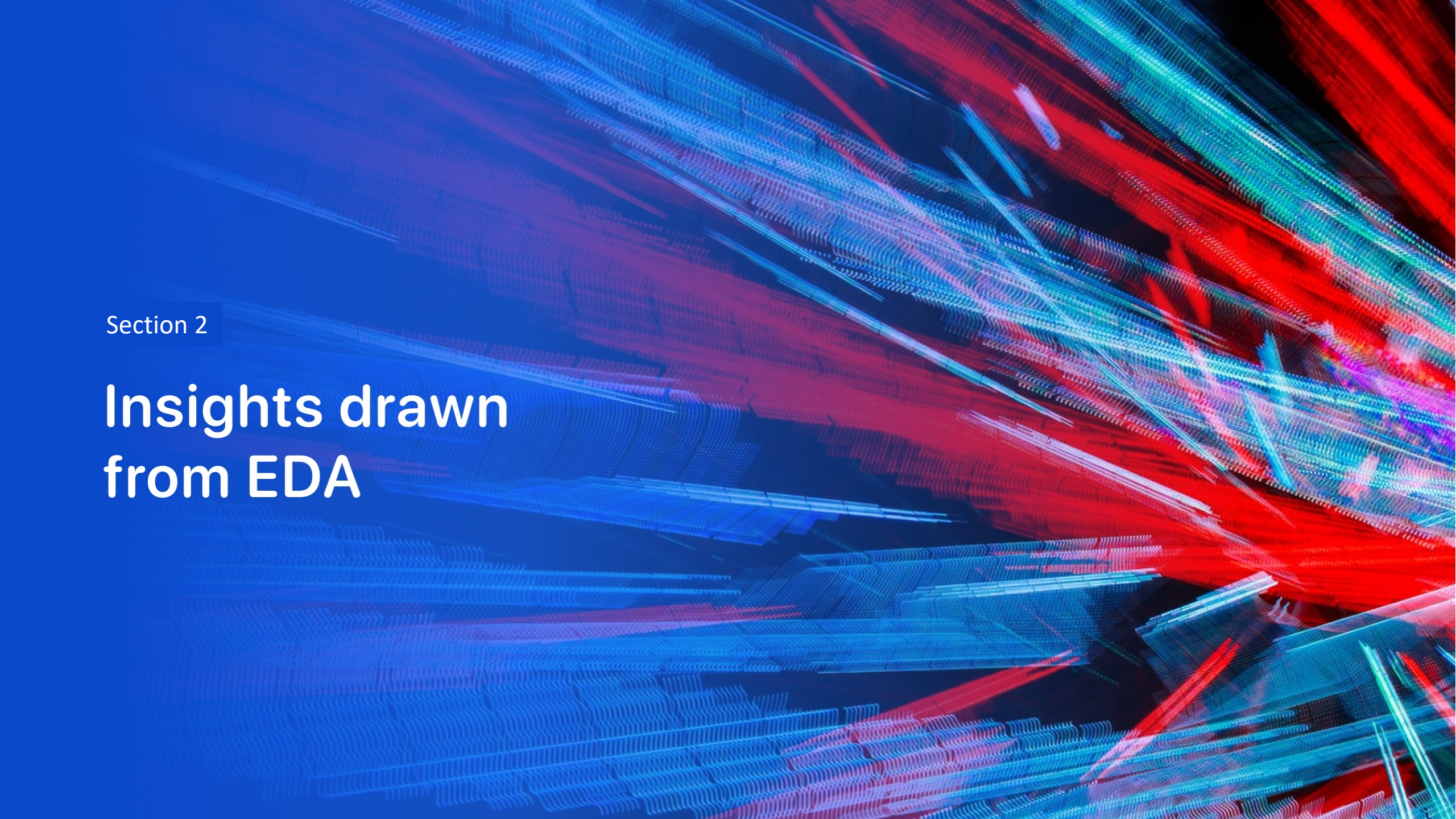
Predictive Analysis (Classification)



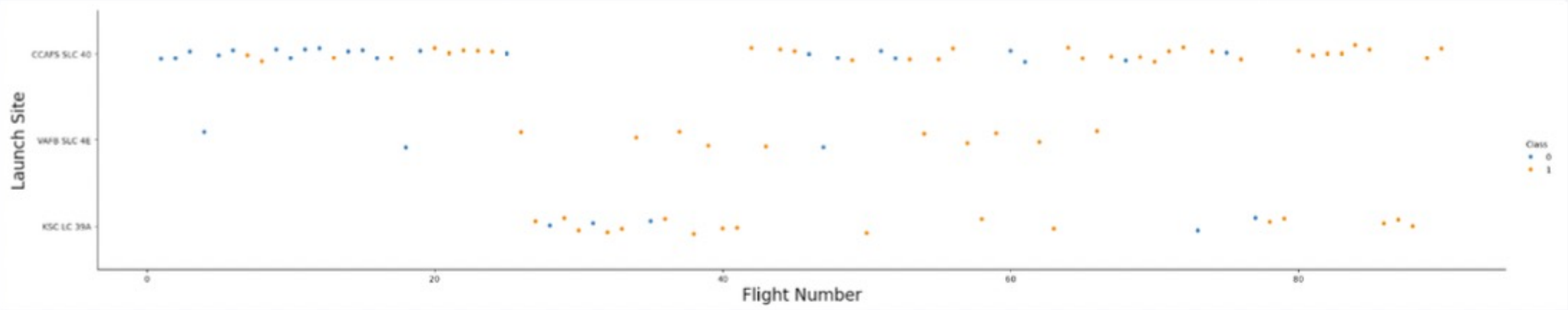
GitHub Link

Results

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

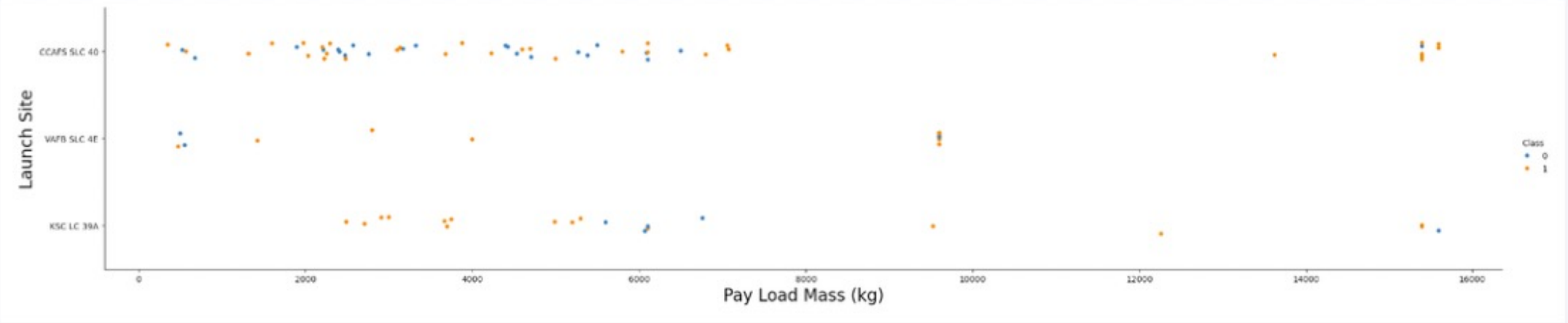

Section 2
Insights drawn from EDA

Flight Number vs. Launch Site



- The earliest flights failed while the latest flights succeeded
- The launch site CCAFS SCL 40 has about half of all launches
- VAFB SLC 4E and KSC LC 39A have higher success rates

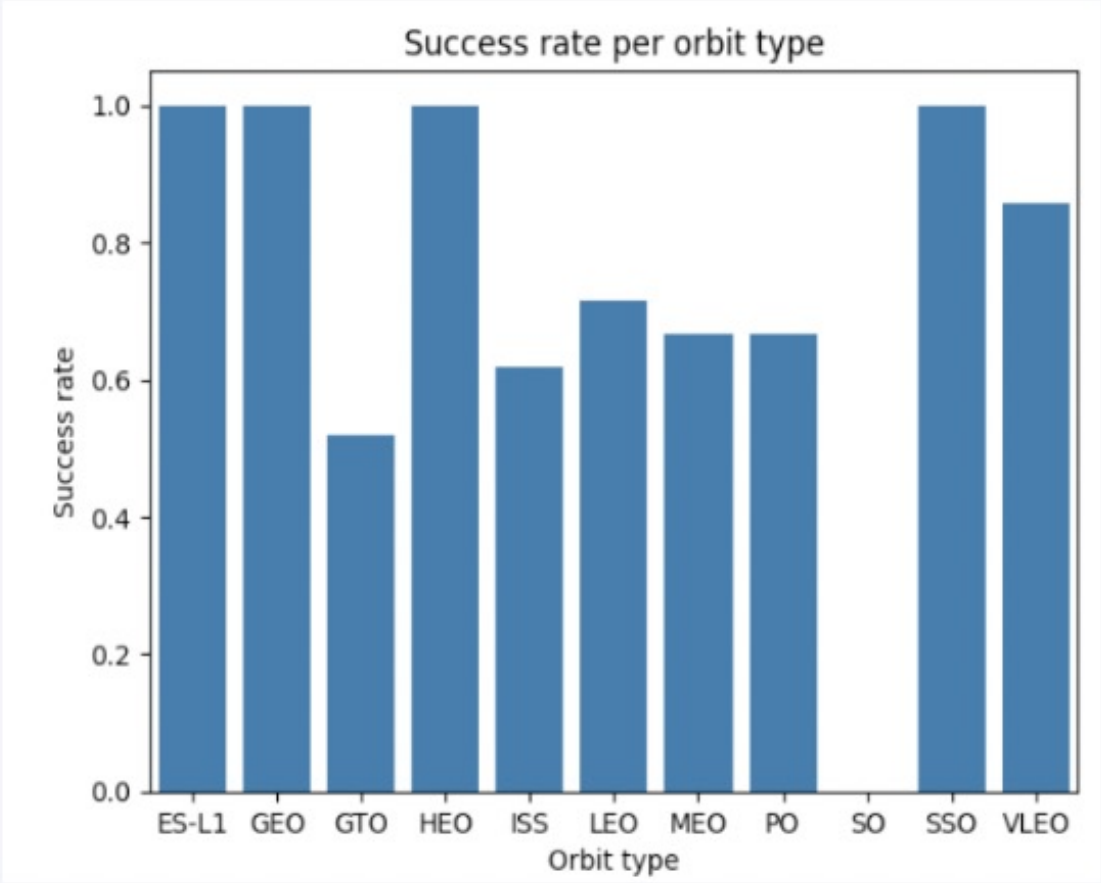
Payload vs. Launch Site



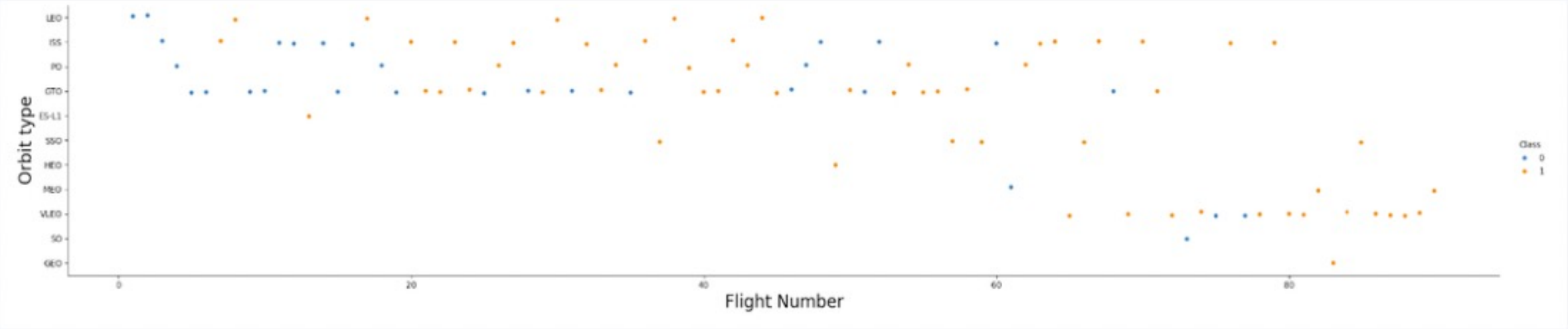
- The higher the payload mass, the higher the success rate for each launch site
- Most of the launches with payload mass over 7000 kg were successful
- KSC LC 39A has 100% success rate for payload mass under 5500 kg

Success Rate vs. Orbit Type

- Orbits ES-L1,GEO,HEO AND SSO have 100% success rate
- Orbits GTO,ISS,LEO,MEO and PO have success rate between 50% and 80%
- Orbit SO has 0% success rate

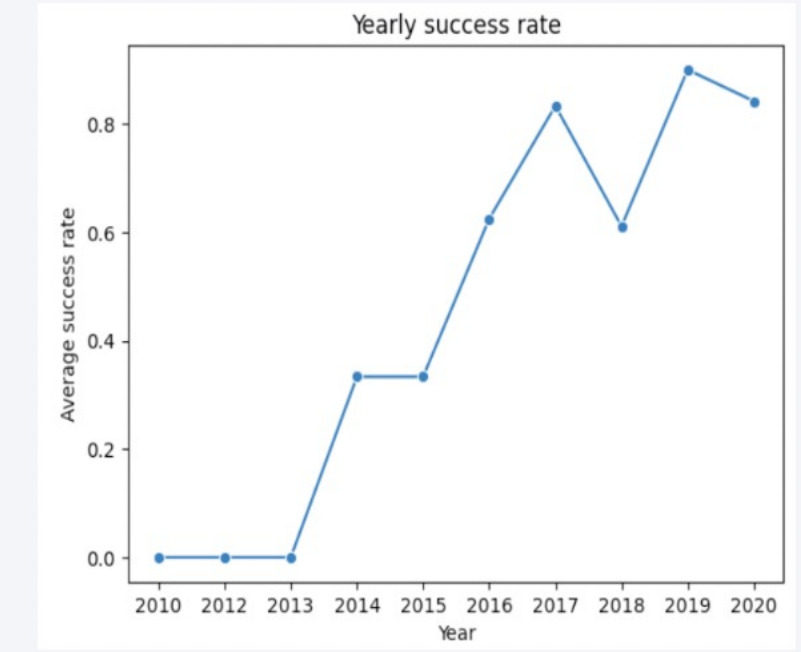


Flight Number vs. Orbit Type



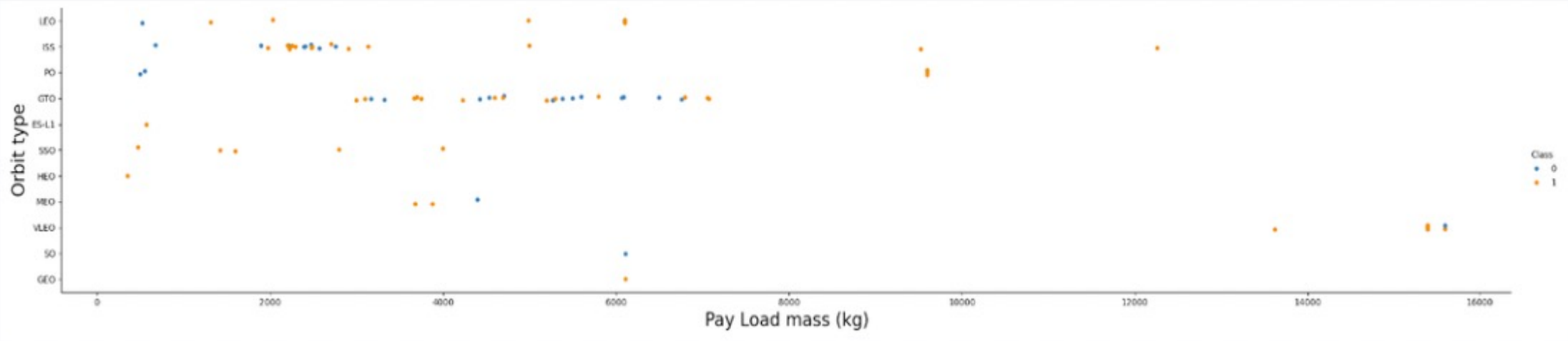
In the LEO orbit the success rate appears related to the number of flights. On the other hand, there seems to be no relationship between flight number when in GTO orbit.

Launch Success Yearly Trend



We can observe that success rate kept increasing since 2013 till 2020

Payload vs. Orbit Type



- With heavy payloads the successful landing or positive landing rate are more for Polar,LEO and ISS.
- However for GTO we cannot distinguish this well as both positive landing rate and negative landing are here and there.

All Launch Site Names

- CCAFS LC-40
- VAFB SLC-4^{E}
- KSC LC-39A
- CCAFS SLC-40

Launch Site Names Begin with 'CCA'

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

Out[8]:

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing_Outcome
2010-04-06	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-08-12	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	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-08-10	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-01-03	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

```
%%sql

select * from SPACEXTABLE
where "Launch_Site" like 'CCA%' limit 5
```

Total Payload Mass

```
%%sql

select Customer, sum("PAYLOAD_MASS__KG_") as Total_payload_mass
from SPACEXTABLE
where Customer = 'NASA (CRS)'
```

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

Customer	Total_payload_mass
NASA (CRS)	45596

Explanation: displaying the total payload mass carried by boosters launched by NASA (CRS).

Average Payload Mass by F9 v1.1

```
%%sql

select "Booster_version", avg("PAYLOAD_MASS__KG_") as Average_payload_mass
from SPACEXTABLE
where "Booster_version" = 'F9 v1.1'
```

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

Booster_Version	Average_payload_mass
F9 v1.1	2928.4

Explanation: displaying average payload mass carried by booster version F9 v1.1

First Successful Ground Landing Date

```
%%sql

select "Landing_Outcome", min(Date) as First_successful_landing
from SPACEXTABLE
where "Landing_Outcome" = 'Success (ground pad)'
```

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

Landing_Outcome	First_successful_landing
Success (ground pad)	2015-12-22

Listing the date when the first succesful landing outcome in ground pad was acheived.

Successful Drone Ship Landing with Payload between 4000 and 6000

```
%%sql

select distinct("Booster_Version") as Booster_Version_successful_in_drone_ship
from SPACEXTABLE
where "Landing_Outcome" = 'Success (drone ship)' and "PAYLOAD_MASS__KG_" between 4000 and 6000
```

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

Booster_Version_successful_in_drone_ship
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

List the total number of successful and failure mission outcomes

```
%%sql

select "Mission_Outcome", count("Mission_Outcome")
from SPACEXTABLE
group by "Mission_Outcome"
```

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

Mission_Outcome	count("Mission_Outcome")
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 "Booster_Version" as max_payload_mass_booster_versions
from SPACEXTABLE
where "PAYLOAD_MASS__KG_" in
(select max("PAYLOAD_MASS__KG_")
from SPACEXTABLE)
```

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

max_payload_mass_booster_versions
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

- List the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015

```
%%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,0,5) = '2015'
```

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

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

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

- 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

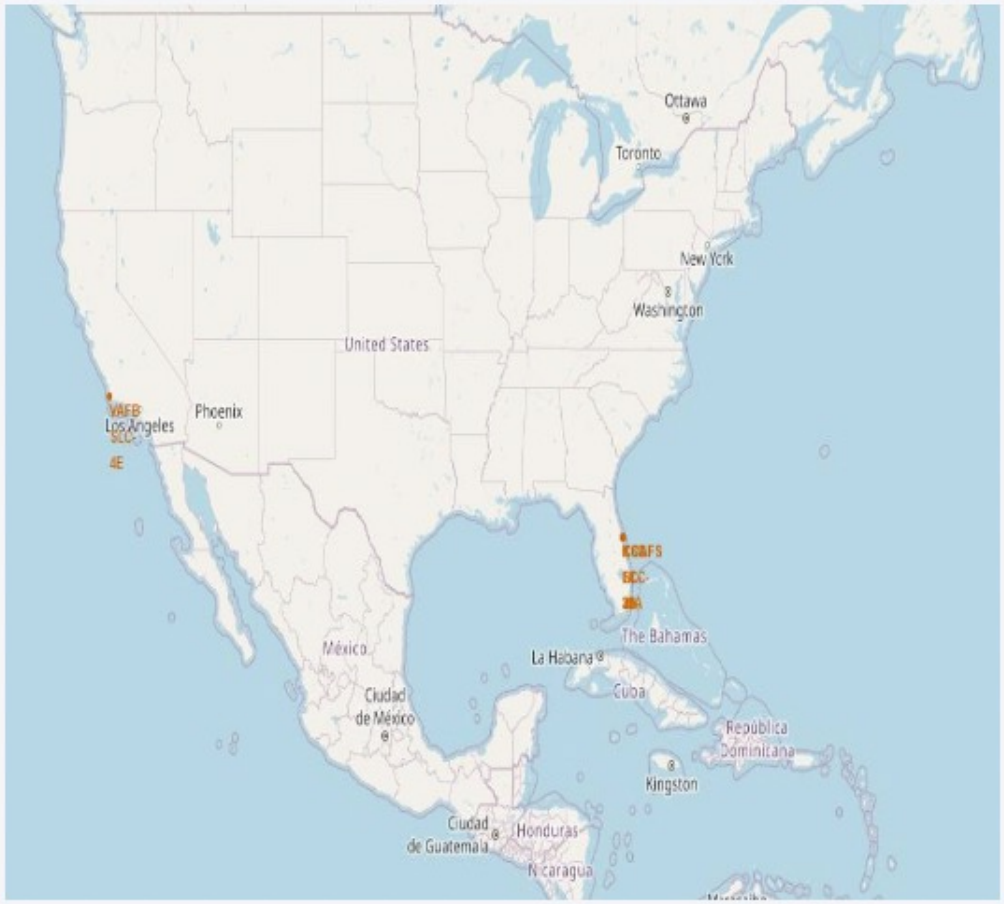
```
%%sql

select Date, "Landing_Outcome", count("Landing_Outcome") as Landing_Outcome_count
from SPACEXTABLE
where Date between '2010-06-04' and '2017-03-20'
group by "Landing_Outcome"
order by Landing_Outcome_count desc
```

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

Date	Landing_Outcome	Landing_Outcome_count
2012-05-22	No attempt	10
2015-12-22	Success (ground pad)	5
2016-08-04	Success (drone ship)	5
2015-10-01	Failure (drone ship)	5
2014-04-18	Controlled (ocean)	3
2013-09-29	Uncontrolled (ocean)	2
2015-06-28	Precluded (drone ship)	1
2010-08-12	Failure (parachute)	1


Section 3
Launch Sites
Proximities Analysis

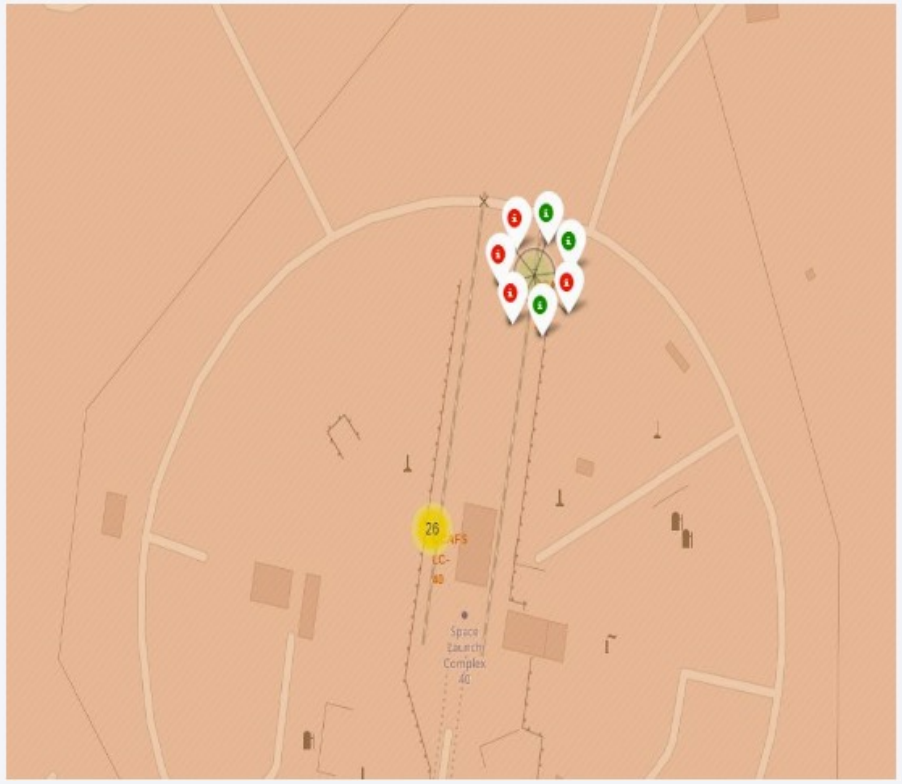
All Launch sites' location markers on american map



•All launch sites are situated near the equator, where the land moves faster than at any other location on Earth's surface, reaching a speed of 1670 km/hr. Objects at the equator are already in motion at this significant speed. When a spacecraft is launched from the equator, it ascends into space while retaining the Earth's rotational speed due to inertia. This retained speed is crucial for the spacecraft to maintain an adequate velocity for orbital stability.

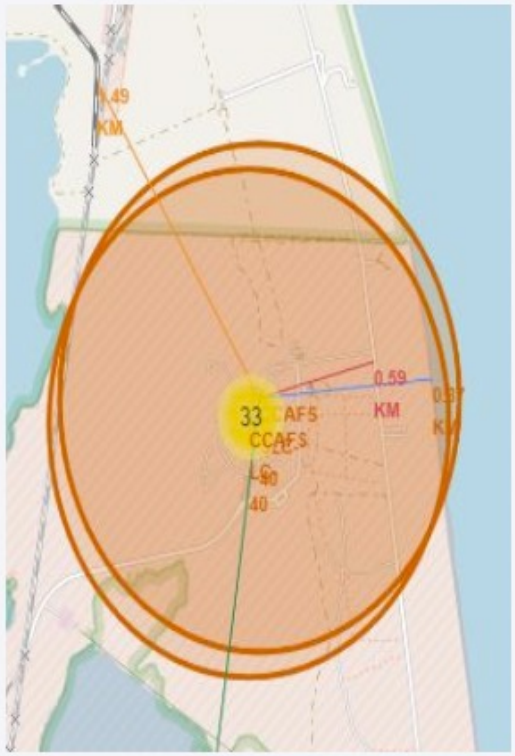
•Additionally, all launch sites are positioned in close proximity to the coast. Launching rockets towards the ocean is a strategic choice to minimize the risk of debris falling or exploding near populated areas. This safety measure is adopted to ensure the protection of human lives and property.

Launch records on the map : Color-labeled

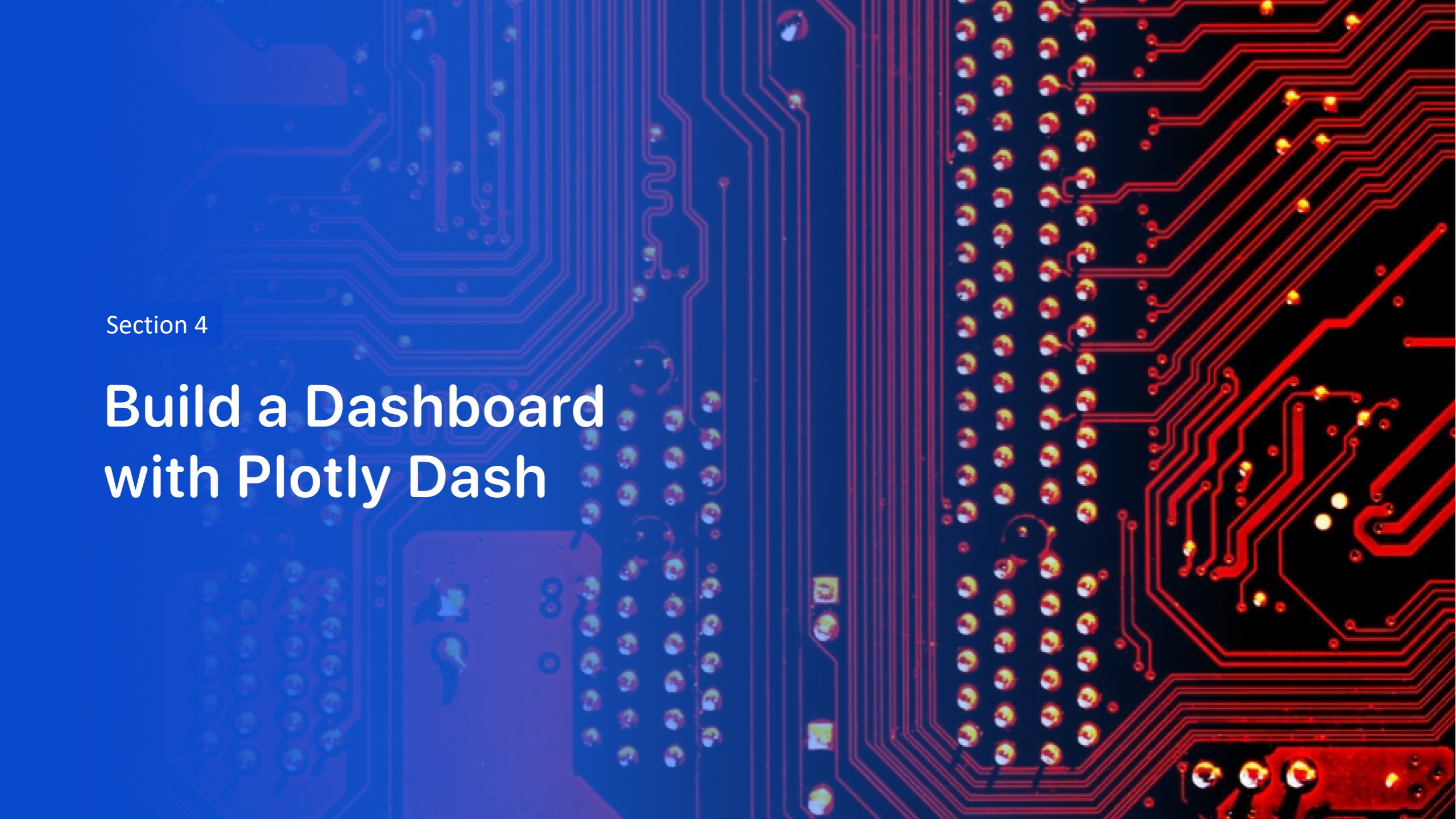


- Colored markers are used to help us identify the
- launch sites with the highest success rate.
- ✓ Green Marker = successful launch
- ✓ Red Marker = failed launch
- It seems that launch site CCAFS SLC- 40 has relatively low success rate.

Distance – Launch site CCAFS SLC-40 to its proximities



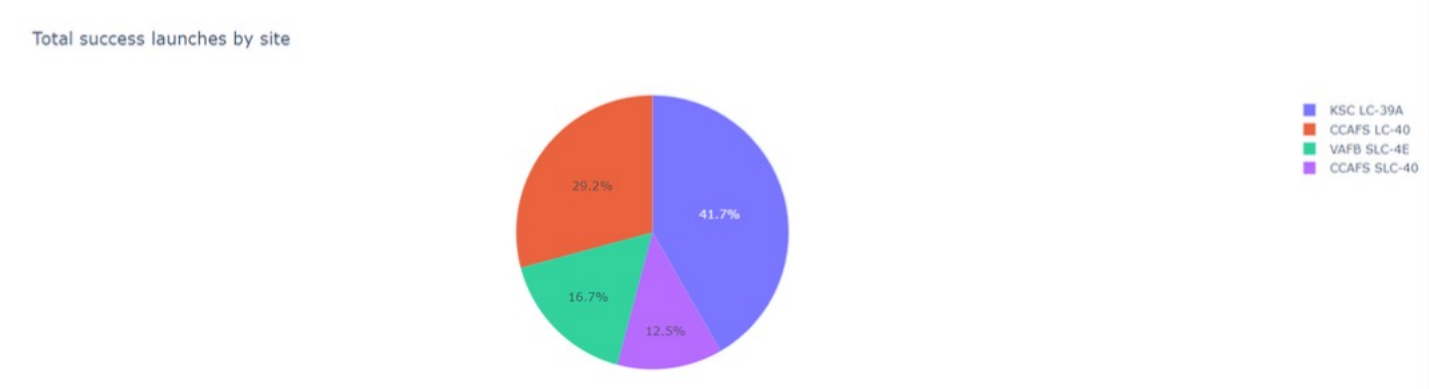
- It is very close to railway (Nasa Railway: 1.49 km)
- It is very close to highway (Samuel C Phillips Highway: 1.49 km)
- It is very close to coastline (0.87 km)
- It is relatively close to its closest city (Cape Carneval: 18.16 km)



Section 4

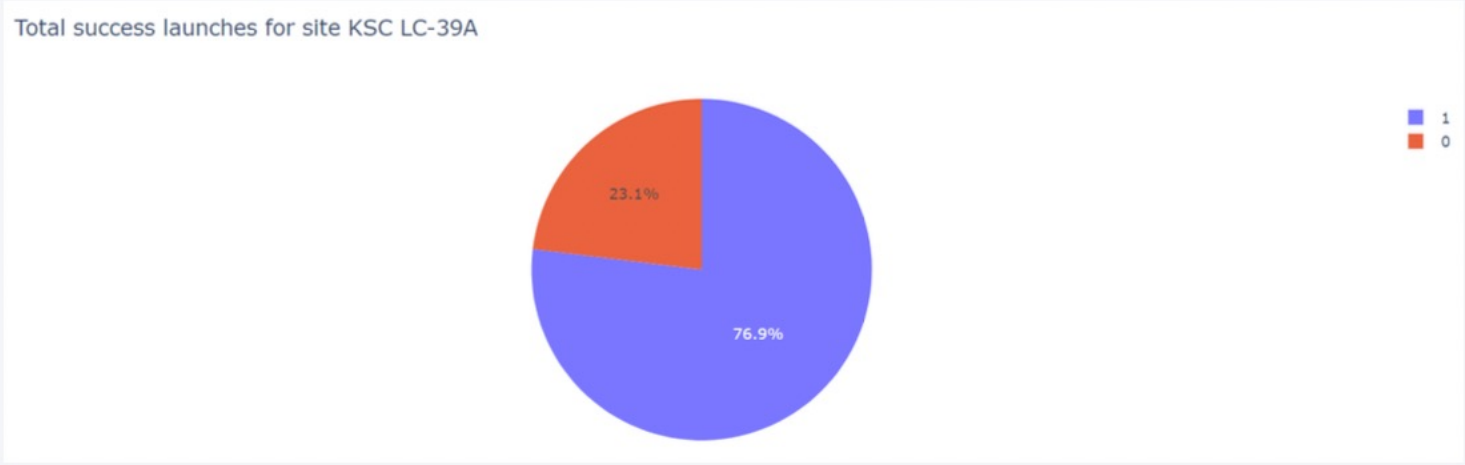
Build a Dashboard with Plotly Dash

Launch success count for all sites



From the pie chart we can clearly see that that launch site KSC LC-39A has the highest success rate in launches.

Total success launches for site KSC LC-39A



KSC LC-39A has the highest success rate – 76,9%

Payload Mass vs Launch Outcome for all sites

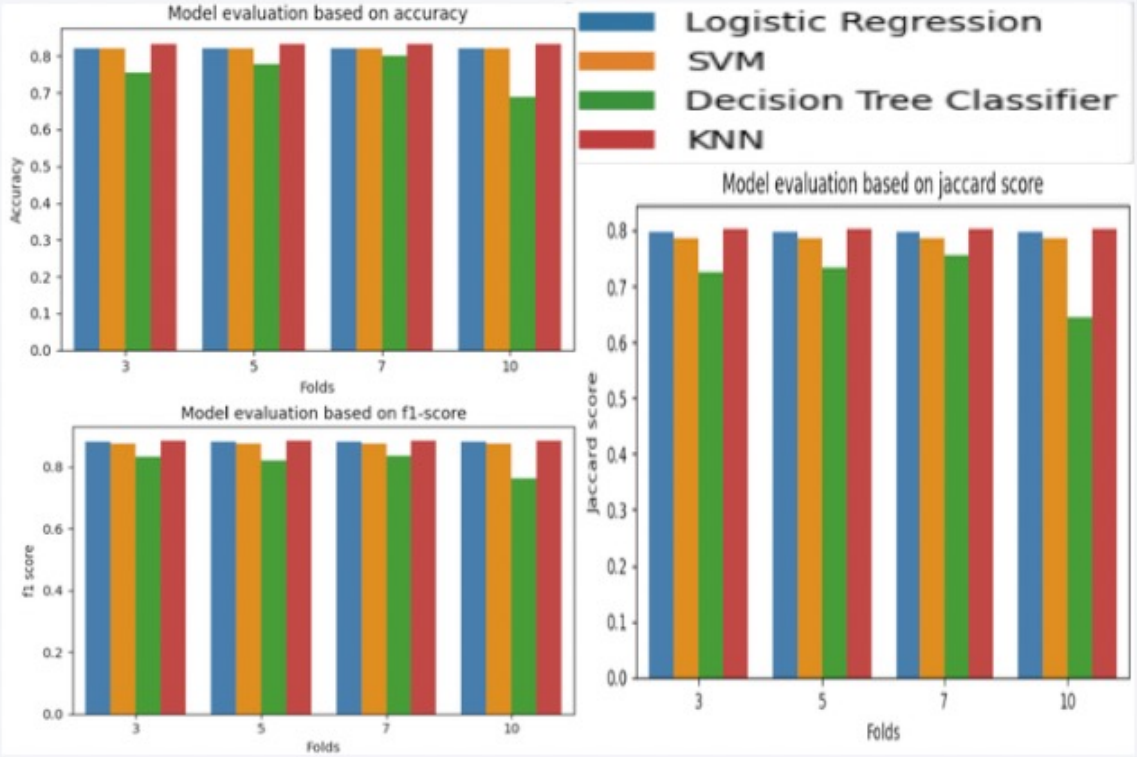
Payloads between 2000 and 5000 kg have the highest success rate.

Payloads between 5000 and 10000 kg have the lowest success rate.

Section 5

Predictive Analysis (Classification)

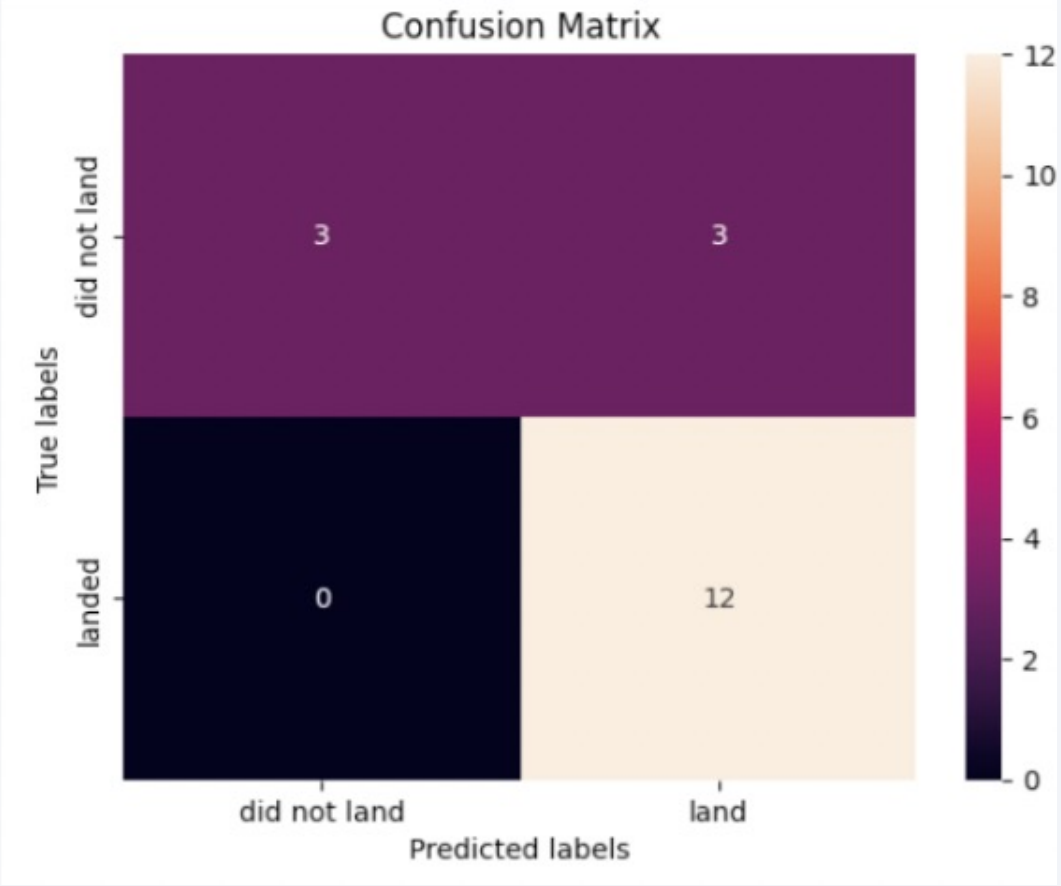
Classification Accuracy



Because of the small test sample size we use K-Fold cross- validation to determine the model that performs the best. We split the dataset into different number of folds and for each number of folds we calculate the mean of different classification metrics, including accuracy, f1-score and jaccard score.

KNN has the best performance across all folds and metrics.

Confusion Matrix



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

Conclusions

- K Nearest Neighbors is the best classification algorithm for this dataset.
- Launches with a low payload mass show better results than launches with a higher payload mass.
- Most of launch sites are in proximity to the Equator line and all launch sites are in very close proximity to the coastline.
- The launch success rate increases over the years. Orbits ES-L1,GEO,HEO and SSO have 100% success rate.
- Booster Version B5 has the highest success rate.

Appendix

- Include any relevant assets like Python code snippets, SQL queries, charts, Notebook outputs, or data sets that you may have created during this project

Thank you!