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

This project contains different types of methodologies to carry out a data science project;

  - Data Collection
  - Data Wrangling
  - Exploratory Data Analysis with Data Visualization
  - Exploratory Data Analysis using SQL
  - Constructing an interactive map using Folium Library
  - Building an interactive dashboard using Plotly Dash
  - Predictive Modeling using different algorithms

- Summary of all results

  - Exploratory Data Analysis Results along with screenshots and deliverables
  - Interactive Analytics Web Application (Dashboard)
  - Predictive Analysis Results (Classification)

Introduction

- Project background and context

  SpaceX is the most successful commercial company of space age, making space travel affordable. The company advertises Falcon 9 rocket launches on its website, with a cost of 62 million dollars. At the heart of SpaceX's spate of successes is the Falcon 9, which has brought down the cost of reaching space and become a springboard. While 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.

- Objectives
  - 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:
  - Data Collected using SpaceX REST API and web scraped from Wikipedia
- Perform data wrangling
  - Filtered data, dealt with missing values, transformed the data using One Hot Encoding
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - Selected required features, split the data, build models, tuned and performed evaluation to ensure an optimized model

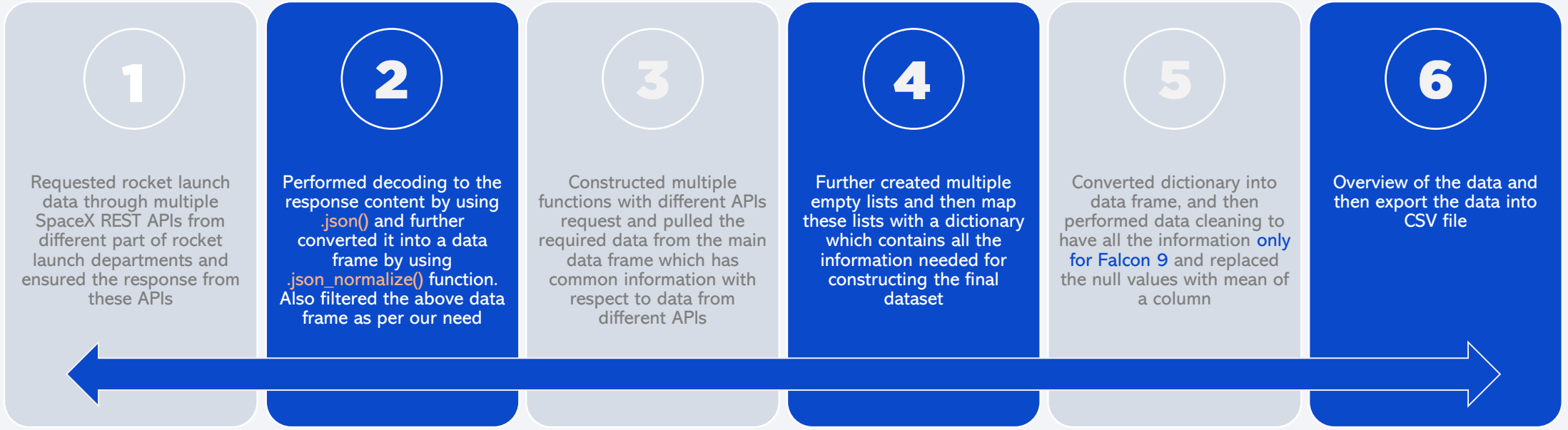
Data Collection

After understanding the context and objectives of project, 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 data collection methods in order to get complete information about the launches for a more detailed analysis.

Multiple columns are obtained by using SpaceX REST API, such as FlightNumber, Date, BoosterVersion, PayloadMass, Orbit, LaunchSite, Outcome, Flights, GridFins, Reused, Legs, LandingPad, Serial, Longitude, Latitude and more.

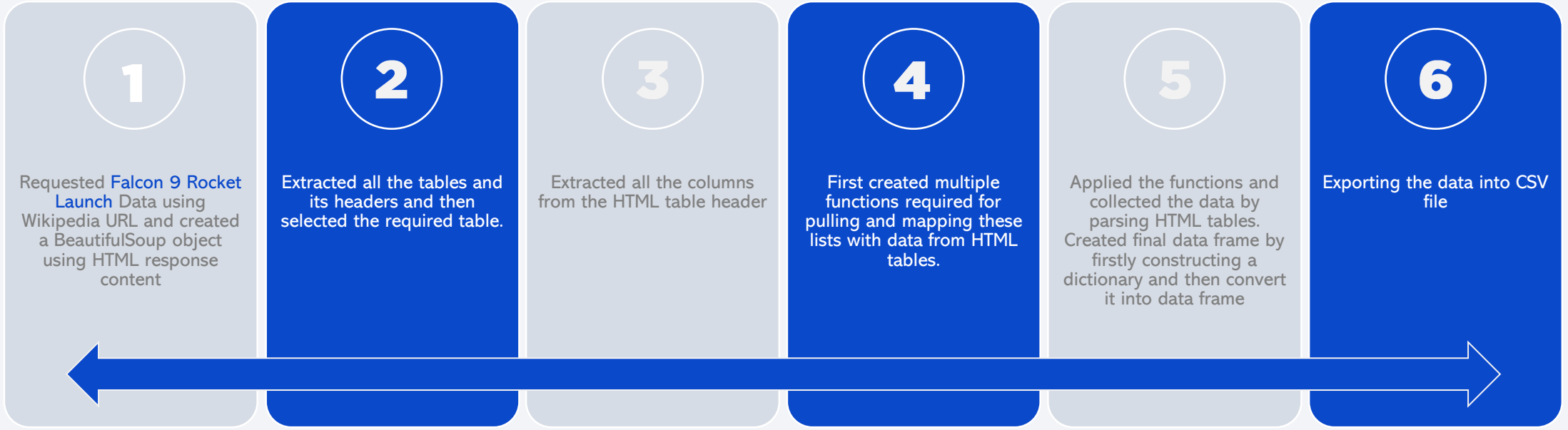
Data Columns are obtained by using Wikipedia Web Scraping: Flight No., Launch site, Payload, PayloadMass, Orbit, Customer, Launch outcome, Version Booster, Booster landing, Date, Time.

Data Collection – SpaceX API



Github URL

Data Collection - Scraping



Github URL

Data Wrangling

Before training the supervised models, some Exploratory Data Analysis (EDA) were conducted to find some patterns in the data and determine what would be the label for training supervised models.

Descriptive Exploration

Conducted basic data exploration using pandas and identified the data types of all the columns, null values, and more

Calculation

Performed basic calculations to get familiar with data such as total number of launches for each launch site etc.

Data Transformation

Transformed landing outcomes into a new column (Class) with binary values where 0 for Failure/None, and 1 for Successful landings

Export CSV File

Convert Data frame into CSV and export it

Github URL

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 plus represents the success rate among Orbit type. Moreover, 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 URL

EDA with SQL

Tasks completed using 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 URL

Build an Interactive Map with Folium

- Markers of all Launch Sites:
  - ✓ First created a map object and further, 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 landing 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 VAFB SLC-4E (as an example) and its proximities like Railway, Highway, Coastline and Closest City.


Github URL

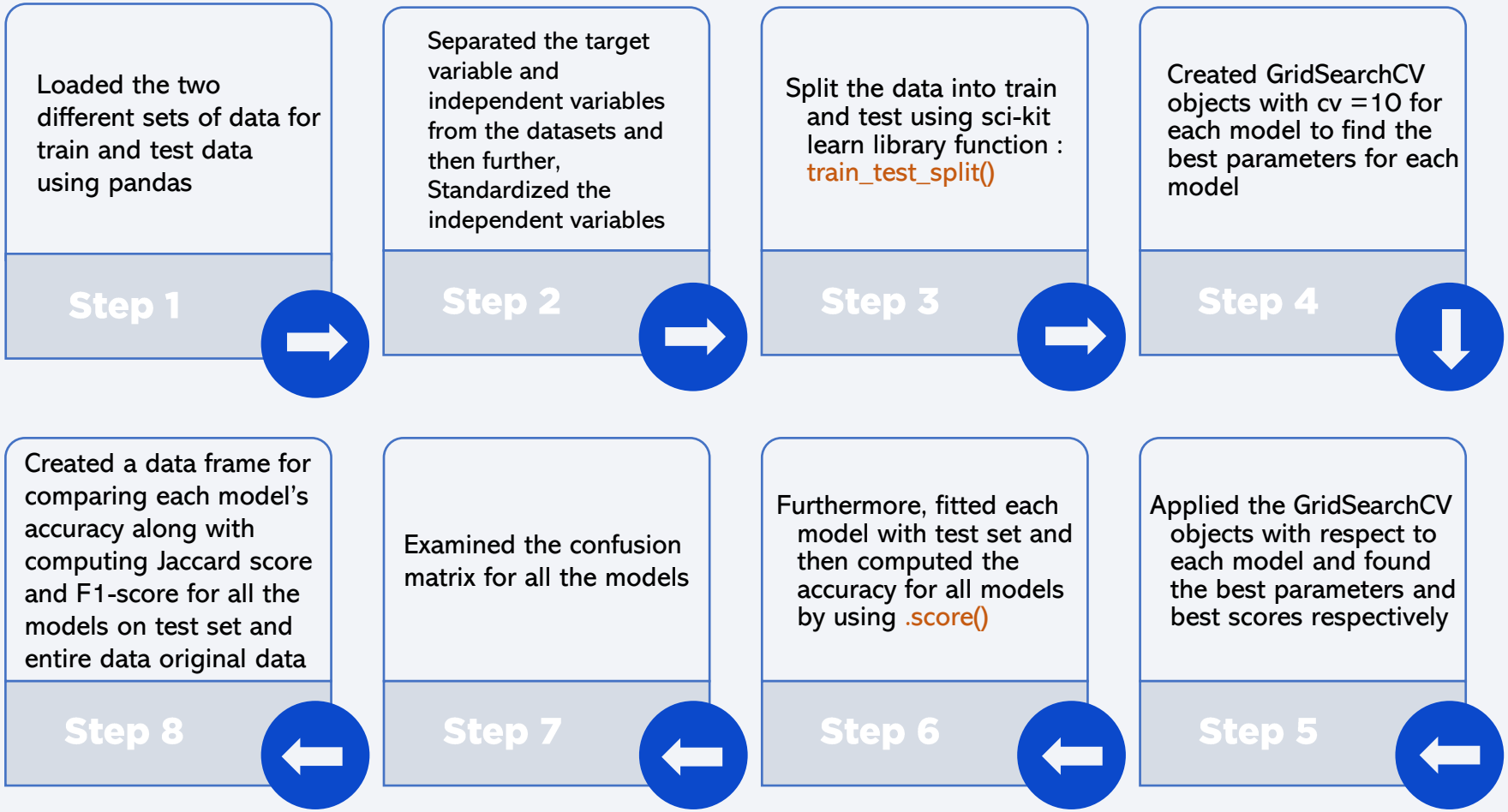
Build a Dashboard with Plotly Dash

- 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 % of successful landings for all sites and % of Success vs. Failed landings for each site, if a specific Launch Site is 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 with respect to booster version.

Github URL

Predictive Analysis (Classification)

Github URL



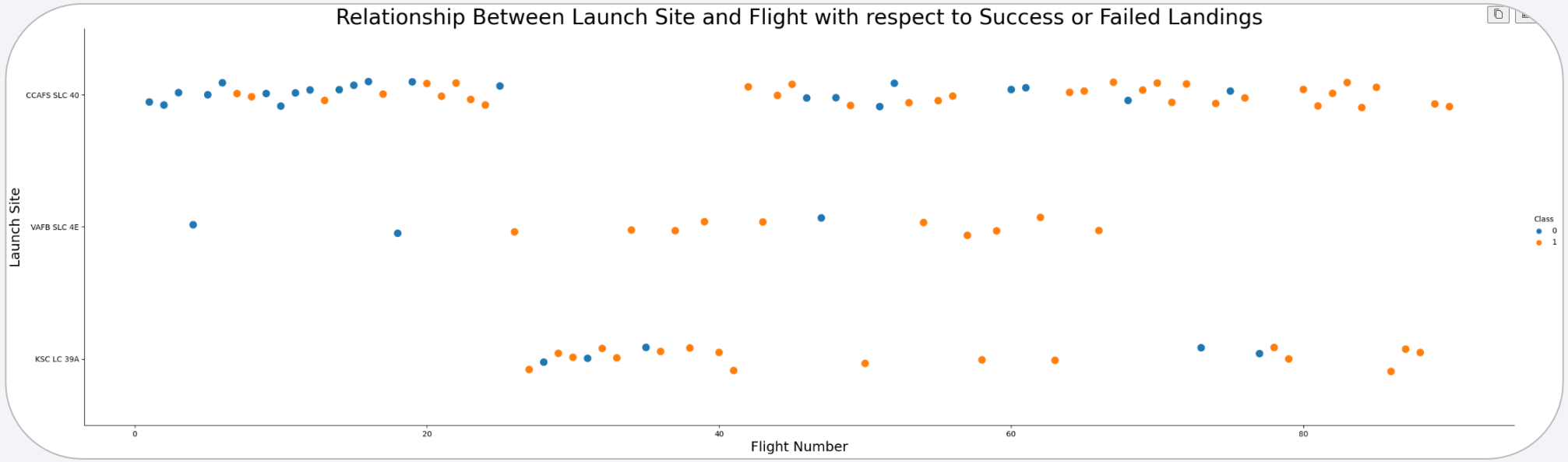
Results

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

Section 2

Insights drawn from EDA

Flight Number vs. Launch Site



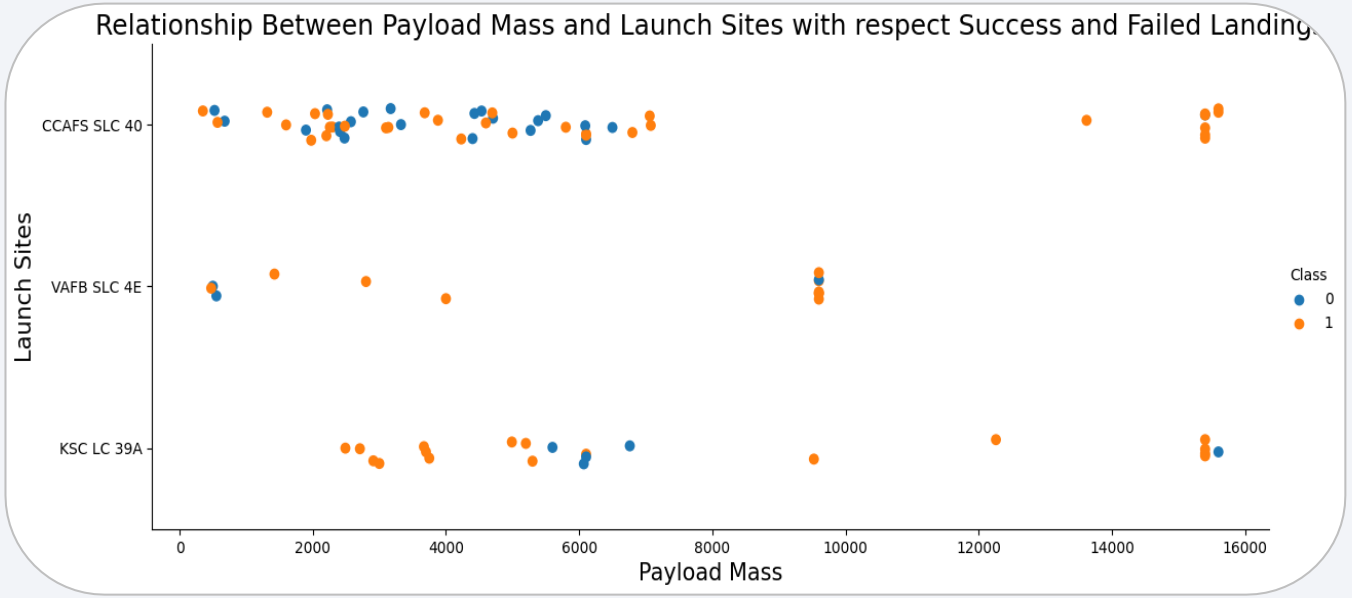
Key Insights

- ✓ The earliest flights mostly failed while the latest flights mostly succeeded.
- ✓ The CCAFS SLC 40 launch site has performed the most launchings than any other launch sites.
- ✓ 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.

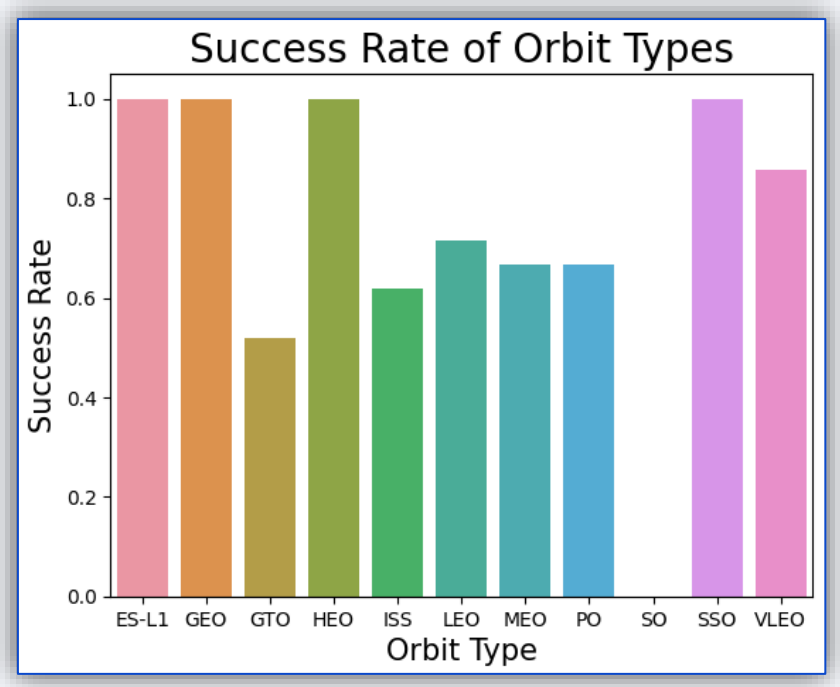
Payload vs. Launch Site

Key Insights:

- ✓ As mentioned above, for the VAFB-SLC launch site there are no rockets launched for heavy payload mass(greater than 10000).
- ✓ 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.
- ✓ For Payload mass between 7100 and 15000, launches for any site didn't take place much as compared to other payload mass.



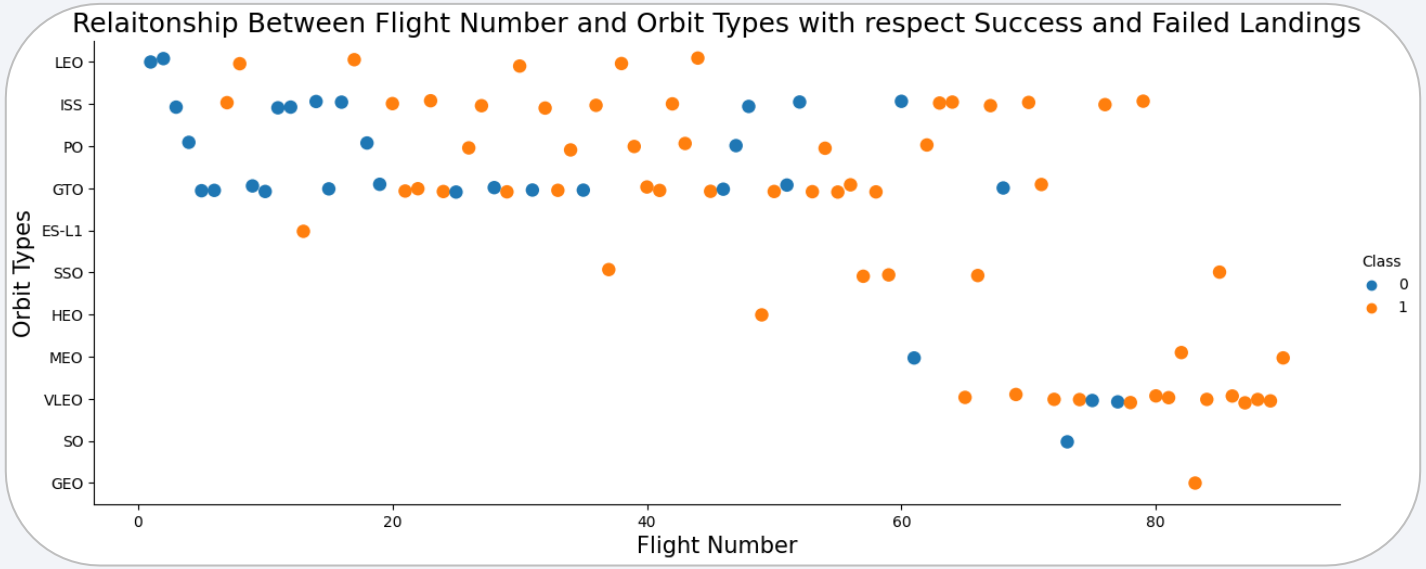
Success Rate vs. Orbit Type



Key Insights:

- ✓ The success rate of Orbit Types; ES-L1, GEO, SSO, and HEO are 100%
- ✓ GTO orbit has the lowest success rate among other orbits
- ✓ Orbit with 0% success rate is SO
- ✓ Orbits with above 60% success rate are ISS, LEO, MEO, PO, and VLEO

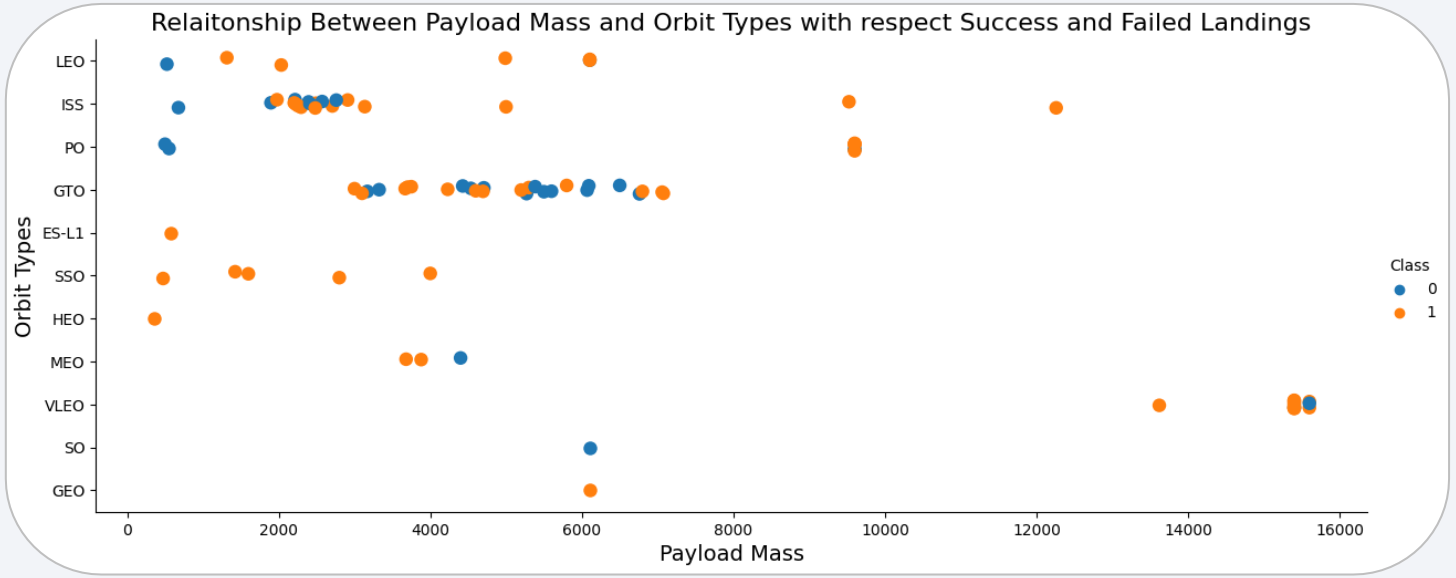
Flight Number vs. Orbit Type



Key Insights:

- ✓ As we can that earliest flights between 0-20 are less successful comparatively.
- ✓ Whereas the flights after 55, the success rate seems be more effective across all orbits.
- ✓ VLEO and ISS appear to be having more successful flights.

Payload vs. Orbit Type



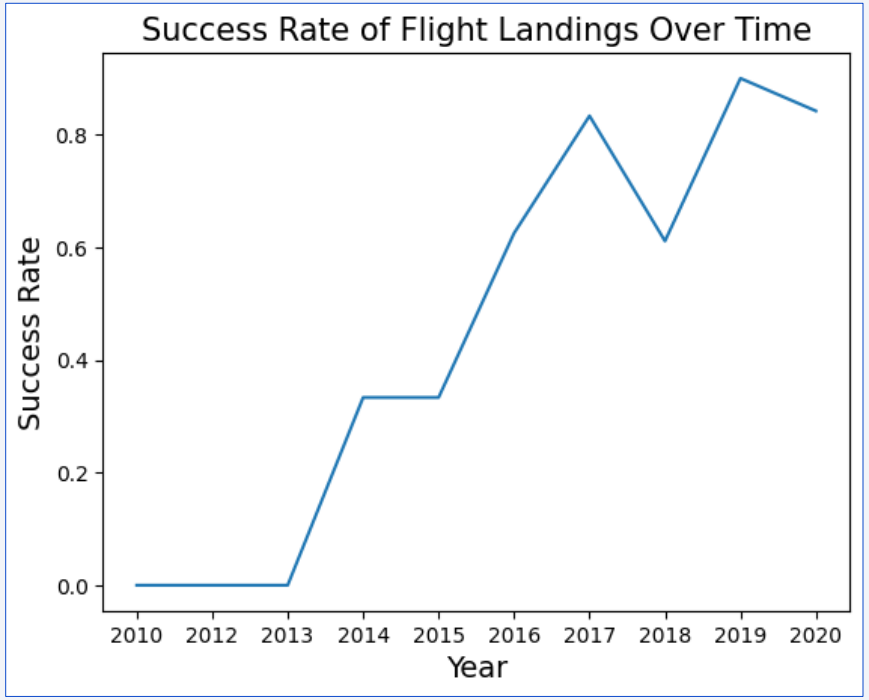
Key Insights:

- ✓ Successful landings, for ES-L1, SSO, HEO, and MEO, appear to be more effective for the payload mass between 100 - 4000.
- ✓ With heavy payloads the successful landing or positive landing rate are more for Polar, LEO and ISS.

Launch Success Yearly Trend

Key Insights:

- ✓ We can observe that the success rate since 2013 kept increasing till 2020
- ✓ Success rate is highest for year 2019.
- ✓ While success rate is lowest in the initial years (2010-2013).
- ✓ We can also observe there is a decline in success rate in year 2018.



EDA Using SQL : All Launch Site Names

The result shows the unique name of all the launch sites of SpaceX

```
%%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

Launch Site Names Begin with 'CCA'

Find 5 records where launch sites begin with `CCA`

Display 5 records where launch sites begin with the string '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
2010-04-06	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

Total Payload Mass

Calculate the total payload carried by boosters from NASA

```
%%sql
SELECT
    Customer,
    sum("PAYLOAD_MASS__KG_") AS total_payload_mass
FROM SPACEXTABLE
WHERE Customer = "NASA (CRS)"
GROUP BY Customer
ORDER BY total_payload_mass DESC;
```

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

Customer	total_payload_mass
NASA (CRS)	45596

Average Payload Mass by F9 v1.1

Calculate the average payload mass carried by booster version F9 v1.1

```
%%sql

SELECT
    "Booster_Version",
    AVG(PAYLOAD_MASS__KG_) AS avg_payload_mass
FROM SPACEXTABLE
WHERE "Booster_Version" = 'F9 v1.1'
GROUP BY "Booster_Version"
```

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

Booster_Version	avg_payload_mass
F9 v1.1	2928.4

First Successful Ground Landing Date

Find the dates of the first successful landing outcome on ground pad

```
%%sql

SELECT
    MIN("Date") as first_time_successful_landing_ground
FROM SPACEXTABLE
WHERE "Landing_Outcome" = "Success (ground pad)";
```

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

first_time_successful_landing_ground
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

```
%%sql

SELECT
    "Booster_Version",
    "Landing_Outcome",
    "PAYLOAD_MASS__KG_" AS payload_mass
FROM SPACEXTABLE
WHERE "PAYLOAD_MASS__KG_" BETWEEN 4000 AND 6000
AND "Landing_Outcome" = "Success (drone ship)"
```

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

Booster_Version	Landing_Outcome	payload_mass
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

List of names of boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 6000

Total Number of Successful and Failure Mission Outcomes

Calculate the total number of successful and failure mission outcomes

```
%%sql

SELECT
    "Mission_Outcome",
    COUNT(*) AS "total_mission_outcomes"
FROM SPACEXTABLE
GROUP BY "Mission_Outcome"
```

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

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

Boosters Carried Maximum Payload

List the names of the booster which have carried the maximum payload mass

```
%%sql

SELECT
    "Booster_Version",
    "PAYLOAD_MASS__KG_" max_payload
FROM SPACEXTABLE
WHERE "PAYLOAD_MASS__KG_" = (SELECT MAX("PAYLOAD_MASS__KG_") FROM SPACEXTABLE)
```

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

Booster_Version	max_payload
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

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

```
%%sql

SELECT
    "Date",
    substr("Date", 6, 2) AS "Month",
    strftime('%Y', "Date") AS "Year", -- we can also use this method to extract year or month or day etc.
    "Landing_Outcome",
    "Booster_Version",
    "Launch_Site"
FROM SPACEXTABLE
WHERE "Landing_Outcome" = "Failure (drone ship)" AND "Year" = "2015"
```

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

Date	Month	Year	Landing_Outcome	Booster_Version	Launch_Site
2015-10-01	10	2015	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
2015-04-14	04	2015	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
    "Landing_Outcome",
    count(*) AS "Count"
FROM SPACEXTABLE
WHERE "Date" BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY "Landing_Outcome"
ORDER BY "Count" DESC
```

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

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

Section 3

Launch Sites Proximities Analysis

SpaceX Launch Sites Location

Explanation:

- ✓ Most of Launch sites considered in this project are in proximity to the Equator line. Launch sites are made at the closest point possible to Equator line, because anything on the surface of the Earth at the equator is already moving at the maximum speed (1670 kilometers per hour). For example; launching from the equator makes the spacecraft move almost 500 km/hour faster once it is launched compared halfway to north pole.

- ✓ All launch sites considered in this project are in very close proximity to the coast. Before deploying the rockets in the sky, SpaceX makes sure to minimize the risk of having any debris dropping or exploding near people.

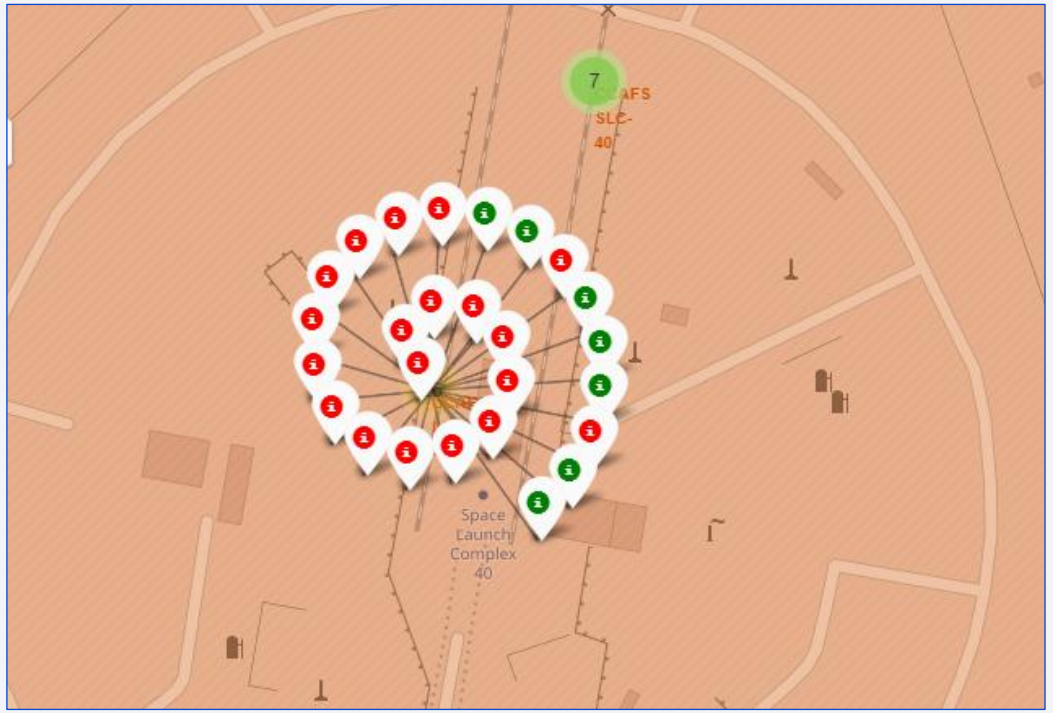
Color-labeled Launch Outcomes

Explanation:

From the color-labeled markers, we can easily identify which launch sites have relatively high success rates or failure rate.

- Green Marker = Successful Launch
- Red Marker = Failed Launch

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



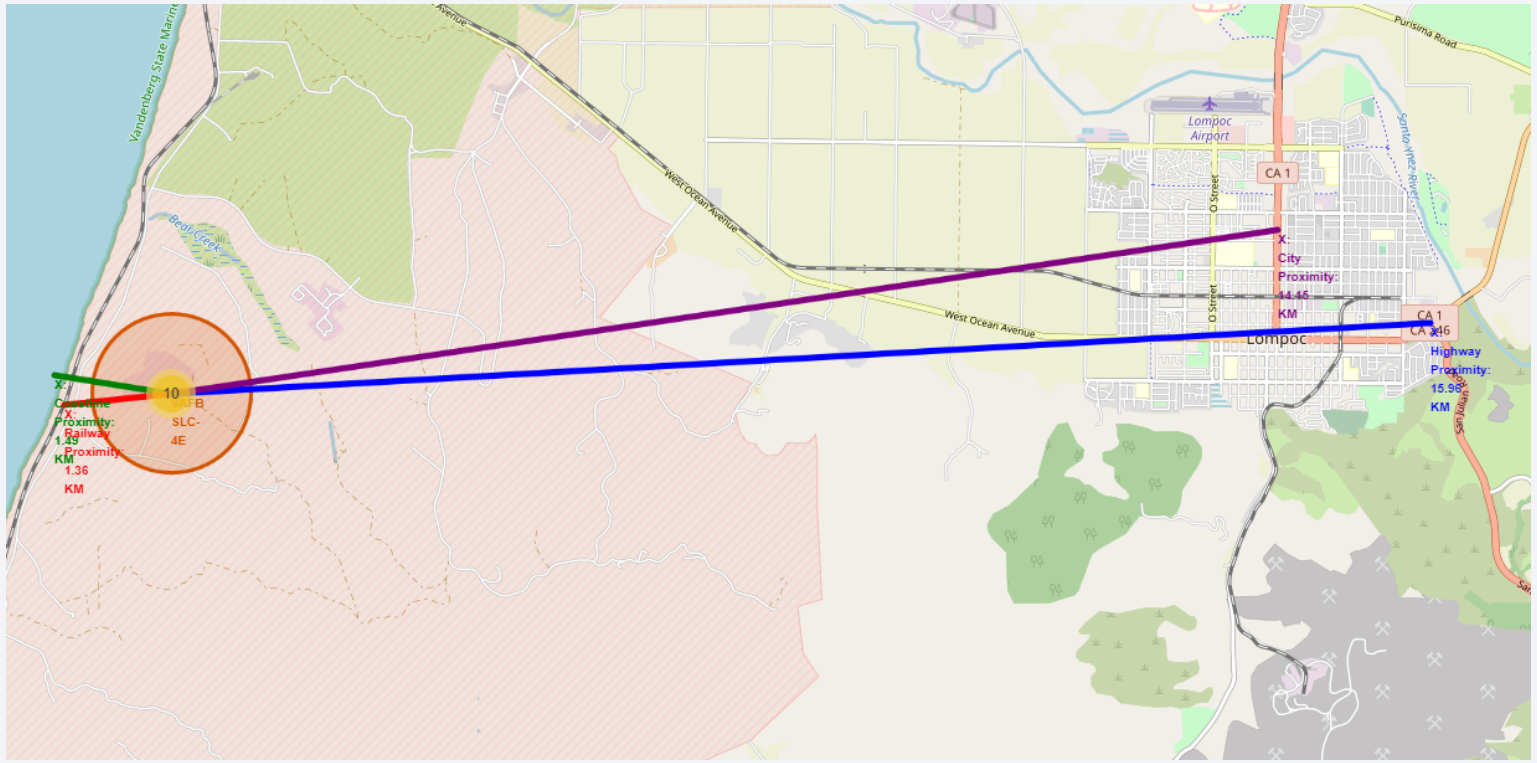
Launch Site and its proximities

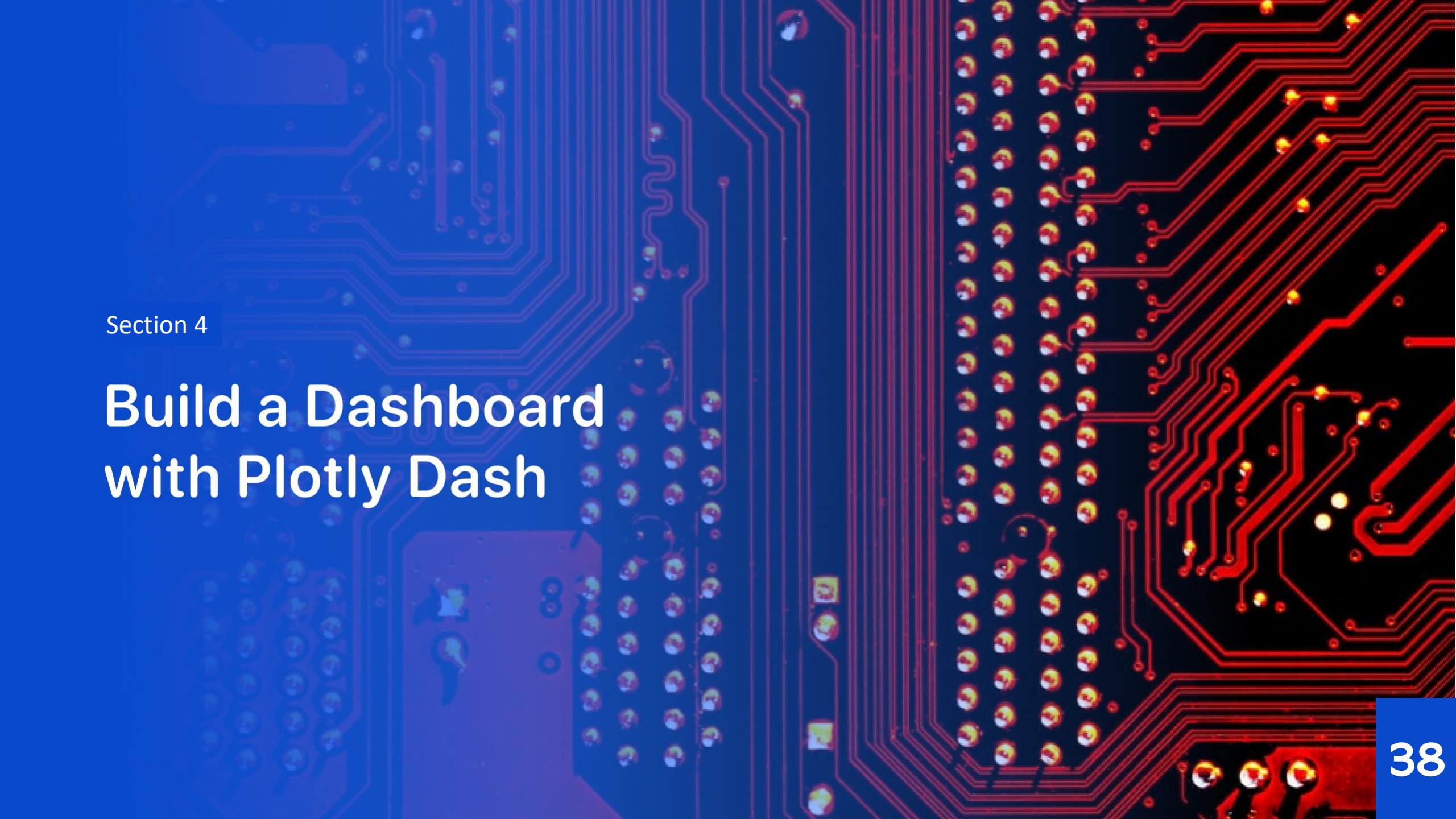
Explanation:

From the visual analysis of the launch site VAFB SLC-4E we can clearly see that it is:

- relatively close to railway proximity (1.36 KM)
- relatively close to highway (15.96 km)
- relatively close to coastline (1.49 km)

Also, the launch site VAFB SLC-4E is relatively close to its closest city Lompoc (14.45 km).



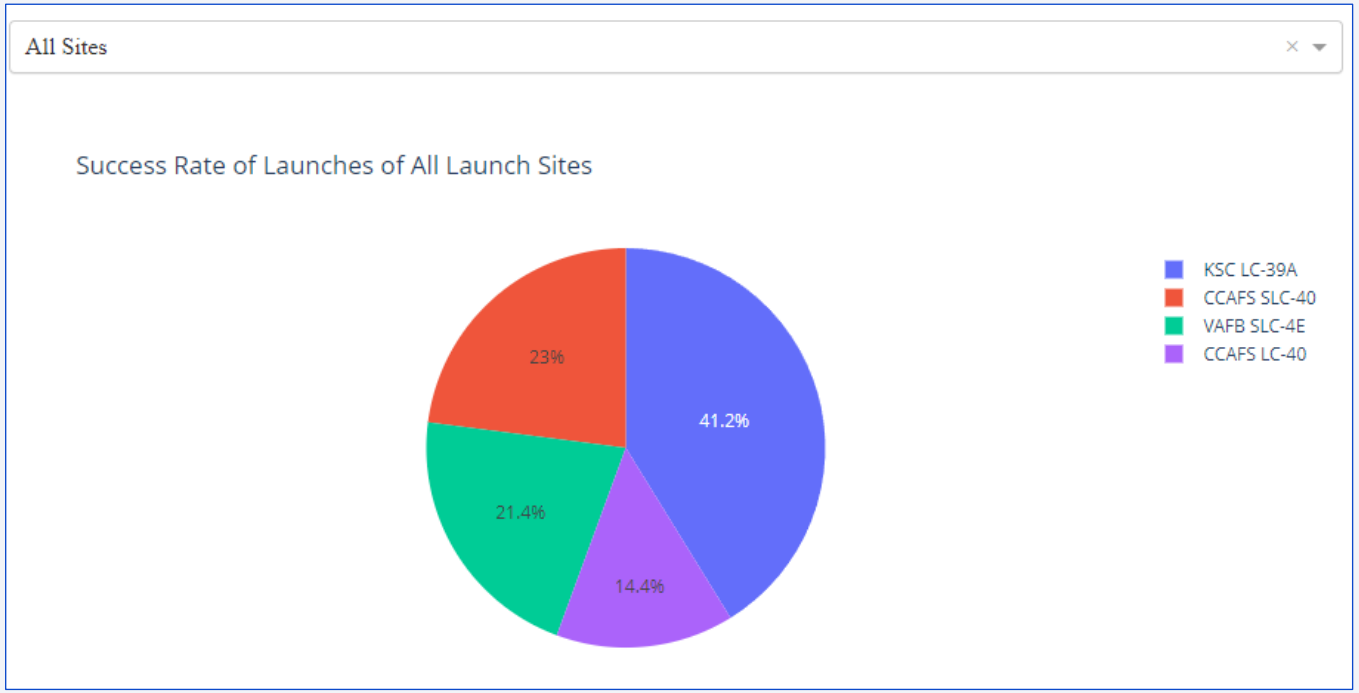


Section 4

Build a Dashboard with Plotly Dash

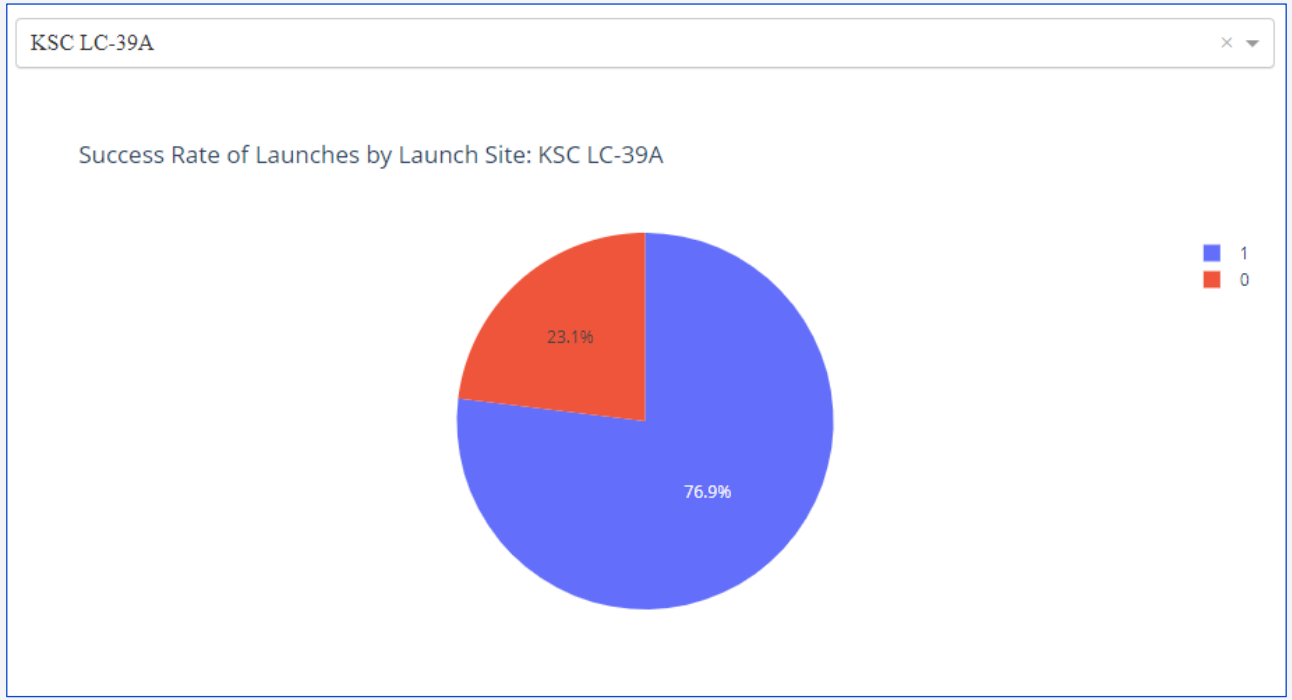
SpaceX Launch Site Successful Launches (%)

It clearly shows that the KSC LC-39A has the highest rate of success launches among others despite the fact how many launches have been taken placed at each launch site.



KSC LC-39A Success Rate

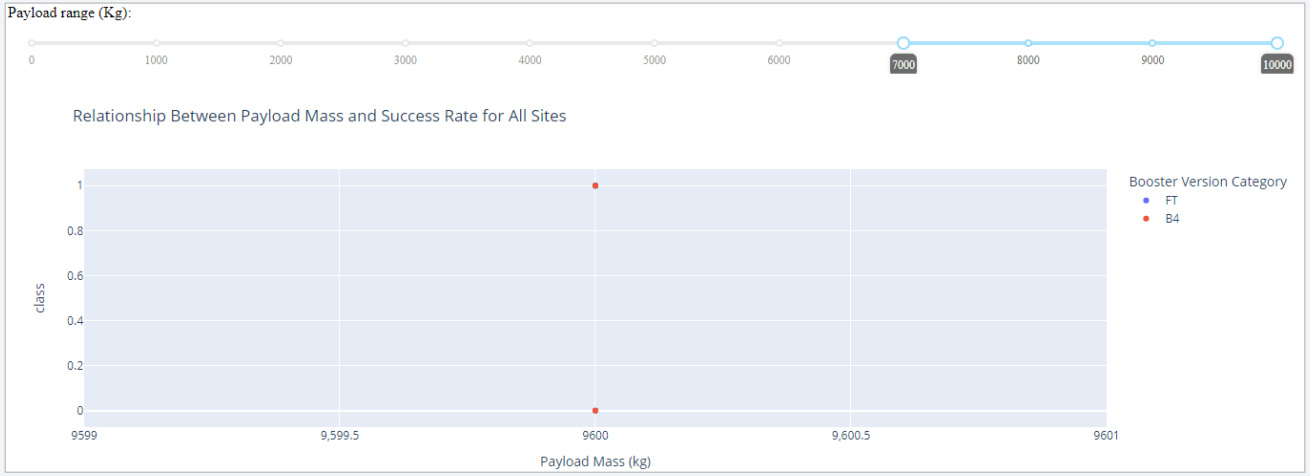
As we can see that KSC LC-39A has the highest rate (~77%) of the success launches with 10 successful landings and 3 failed landings.



Payload Mass vs. Launch Outcomes

Between 0 – 7000 of payload mass, the most successful booster is FT whereas booster v1.1 has most failed launch outcomes.

Between 7000 – 10000 of payload mass, the most successful booster is B4 among others.



Section 5

Predictive Analysis (Classification)

Classification Accuracy

- From these screenshots, we can observe that, based on the test sets, the KKN model has the highest scores along with accuracy among other models.

- While based on the original data performance, we can't confirm which model is the best. However, it apparently appears that KNN model has the best accuracy among others despite the scores taken into consideration.

Accuracy and Scores on Test sets

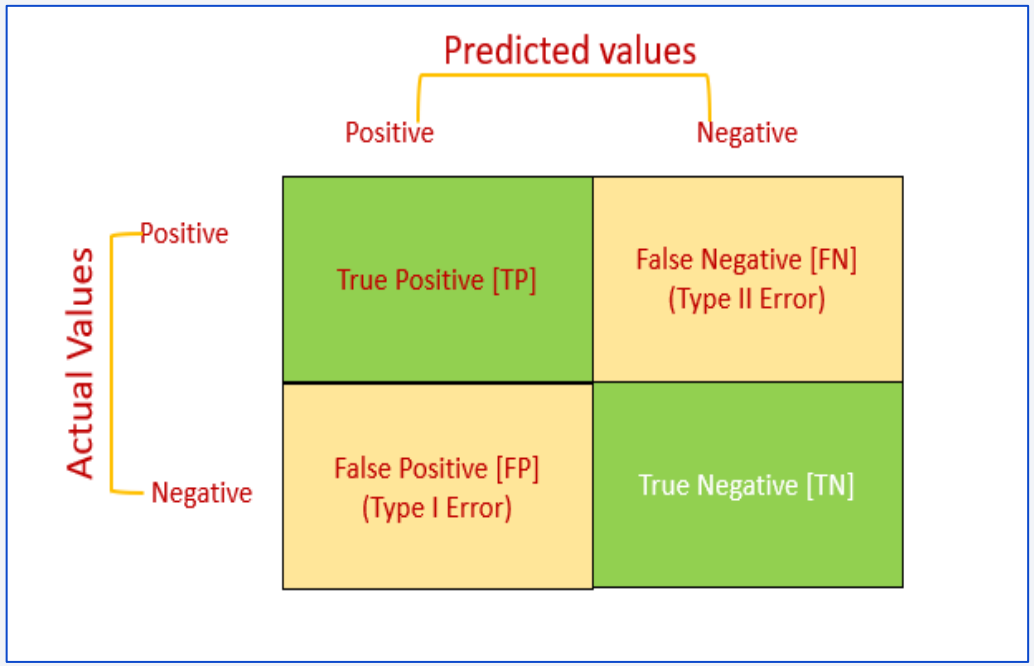
	Model Name	Jaccard Score	F1-Score	Accuracy
0	Logistic Regression	0.80	0.888889	0.833333
1	Support Vector Machine	0.80	0.888889	0.833333
2	Decision Tree	0.75	0.857143	0.777778
3	K-Nearest Neighbours	1.00	1.000000	1.000000

Accuracy and Scores on entire data

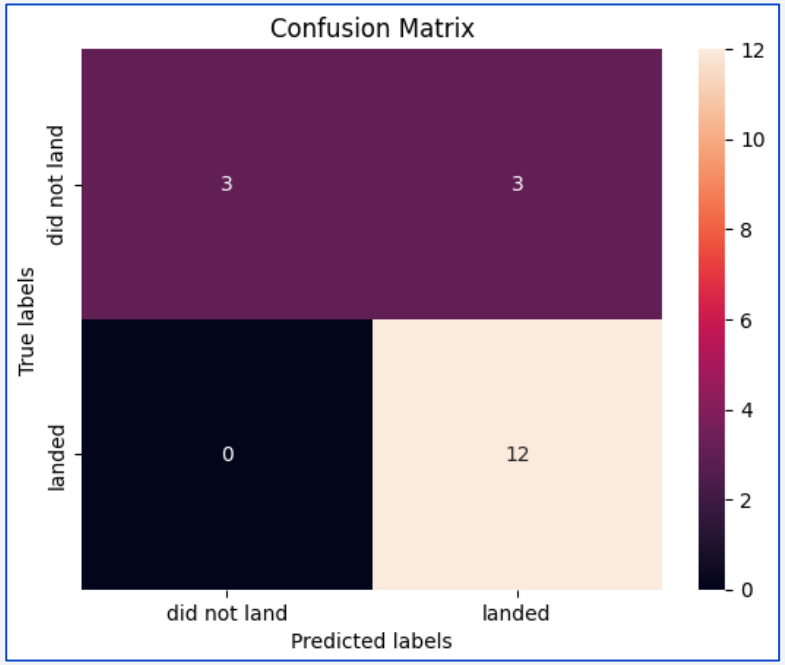
	Model Name	Jaccard Score	F1-Score	Accuracy
0	Logistic Regression	0.833333	0.909091	0.833333
1	Support Vector Machine	0.845070	0.916031	0.833333
2	Decision Tree	0.753247	0.859259	0.777778
3	K-Nearest Neighbours	0.732394	0.845528	1.000000

Confusion Matrix

A confusion matrix presents a table layout of the different outcomes of the prediction and results of a classification problem and helps visualize its outcomes. It plots a table of all the predicted and actual values of a classifier.



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

- KNN 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 successful booster is FT for payload of under 7000.
- 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.

Appendix

Hi! I am Satyndra - a proud father, self-motivated, go-getter, and self-taught individual

With a proven knack of providing data-driven actionable insights along with recommending informed-decision making to the stakeholders, I always thrive on learning about in-demand tools and technologies and adding them into my expertise, is what keeps me motivated and inspired on a daily basis. I started this project with a broader picture which includes – to advance my skills in Data Science and gain bigger picture on different kind of machine learning models. Not only I was exposed to many aspects of Data Science but also, I have embarked on many new tools and techniques throughout this course, which, I believe, will lead me to bring a unique blend of technical skills on the table.

My passion for data analytics manifests with each passing day. Keeping this in mind, I performed each task and hand-on practices with all my sincerities, enthusiasm, and determination. While completing this course, I concurrently started working on one of my very first web apps (dashboards) by using Plotly Dash and one them is this.

If anyone interested in collaborating on any aspect of learning/developing skills, let's hop on this journey and make the world a better, safer, and peaceful by using our analytical skills. You can contact me at email or more details (not updated yet) or Github.

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