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

✓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

✓Predictive analysis (Classification)

Executive Summary

- Summary of all results

✓Exploratory Data Analysis results

✓Interactive analytics demo in screenshots

✓Predictive analysis results

Introduction

- Project background and context

SpaceX stands out as the preeminent achiever in the era of commercial space exploration, playing a pivotal role in democratizing space travel. On its website, the company showcases Falcon 9 rocket launches, priced at a competitive $62 million per launch, a stark contrast to other providers whose charges exceed a staggering $165 million for each mission. A significant portion of this cost disparity stems from SpaceX's pioneering ability to recover and reuse the first stage of its rockets. Consequently, the ability to ascertain the successful landing of the first stage serves as a key determinant for launch cost estimation. Leveraging publicly available data and advanced machine learning algorithms, we endeavor to forecast the likelihood of SpaceX reusing the first stage in future missions.

Introduction

- 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:
  - Describe how data was collected
  - Using SpaceX Rest API
  - Using Web Scrapping from Wikipedia
- Perform data wrangling
  - Describe how data was processed
  - Filtering the data
  - Dealing with missing values
  - Using One Hot Encoding to prepare the data to a binary classification

Methodology

Executive Summary

- 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

The data collection process encompassed a dual approach, utilizing both API requests from SpaceX's REST API and web scraping techniques to extract data from a table within SpaceX's Wikipedia entry. This combined methodology was essential to obtain comprehensive information about their launches, enabling a more thorough and 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

GitHub URL: Data Collection API

Requesting rocket launch data from SpaceX API

Decoding the response content using .json() and turning it into a dataframe using .json_normalize()

Requesting needed information about the launches from SpaceX API by applying custom functions

Constructing data we have obtained into a dictionary

Creating a dataframe from the dictionary

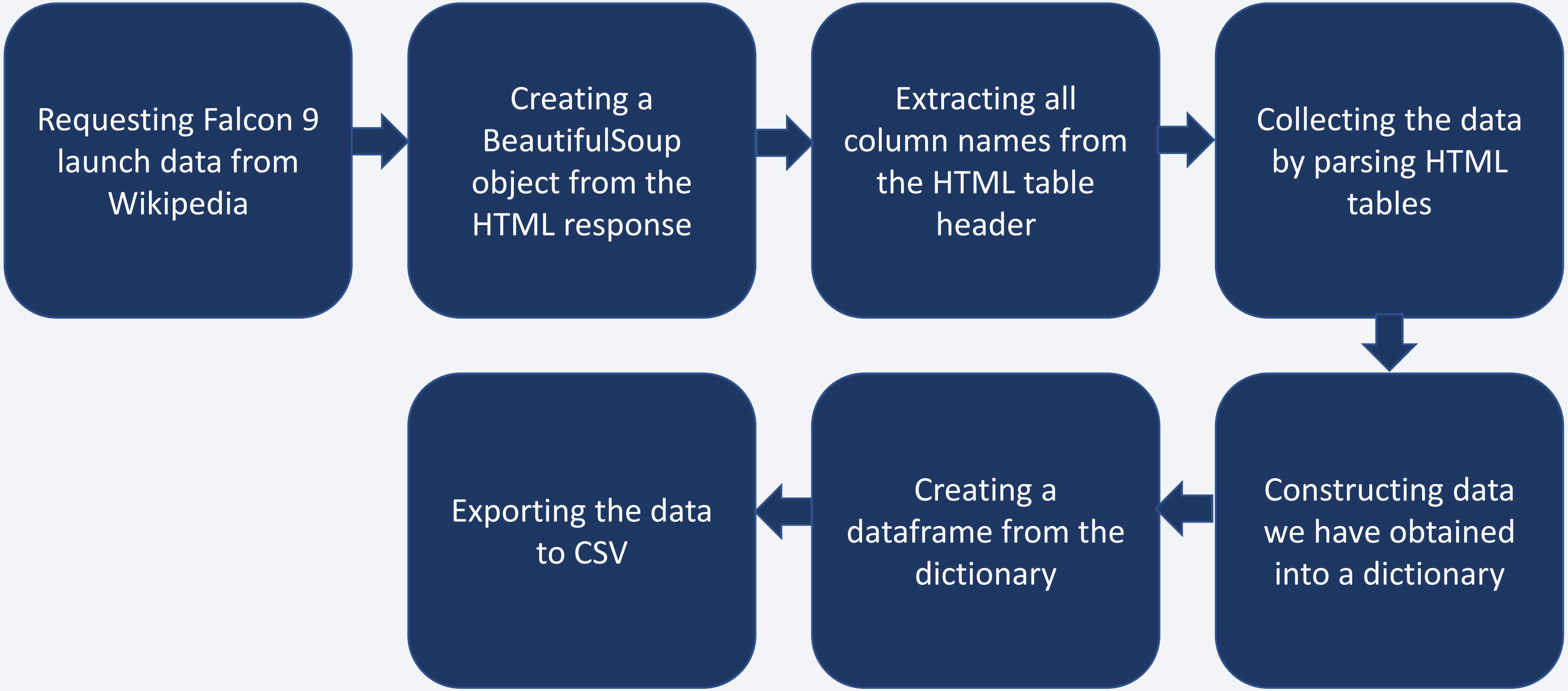
Filtering the dataframe to only include Falcon 9 launches

Replacing missing values of Payload Mass column with calculated .mean() for this column

Exporting the data to CSV

Data Collection - Scraping

GitHub URL: Web Scraping Notebook



Data Wrangling

GitHub URL: Data Wrangling

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

In the dataset, there are various scenarios where the booster's landing was not successful. These instances can be categorized based on different criteria. For instance, "True Ocean" indicates a successful landing in a specific oceanic region, while "False Ocean" signifies an unsuccessful landing in the ocean. Similarly, "True RTLS" denotes a successful landing on a ground pad, whereas "False RTLS" indicates an unsuccessful ground pad landing. Lastly, "True ASDS" represents a successful landing on a drone ship, while "False ASDS" corresponds to an unsuccessful drone ship landing.

To streamline these outcomes for analysis, we have translated them into training labels. A label of "1" signifies a successful landing, while “0" denotes an unsuccessful landing.

EDA with Data Visualization

GitHub URL: Data Visualization

We generated a series of charts to visually represent the data:

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, Success Rate Yearly Trend

- Scatter plots within these charts help uncover potential relationships between variables, which could be invaluable in constructing machine learning models.
- Bar charts were also employed to facilitate comparisons between discrete categories. These charts aim to elucidate the connection between specific categories being compared and the corresponding measured values.
- Furthermore, line charts were utilized to track data trends over time, providing a time-series perspective on the information.

EDA with SQL

GitHub URL: EDA with SQL

Conducted SQL queries encompassing various aspects of the space mission data:

- Retrieving the names of unique launch sites involved in the space mission.
- Displaying five records where launch sites commence with the string 'CCA.'
- Calculating the total payload mass transported by boosters launched under NASA's CRS program.
- Determining the average payload mass carried by boosters of the F9 v1.1 version.
- Listing the date when the initial successful ground pad landing outcome was achieved.
- Enumerating the names of boosters that achieved success on drone ships, with payload masses ranging from 4000 to 6000.
- Providing a tally of the total number of successful and failed mission outcomes.
- Identifying the booster versions responsible for transporting the maximum payload mass.
- Listing the unsuccessful landing outcomes on drone ships, including the booster versions and launch site names, specifically for the months within the year 2015.
- Ranking the count of landing outcomes Failure or Success between the dates 2010-06-04 and 2017-03-20 in descending order.

Build an Interactive Map with Folium 🔗 GitHub URL: Folium Map

Summary of Map Markers and Distances Visualization:

- Markers for All Launch Sites: We incorporated markers on the map to represent various launch sites. Specifically, we added markers for the NASA Johnson Space Center with circle indicators, popup labels, and text labels, using its latitude and longitude coordinates as the starting point. Additionally, we included markers for all other launch sites, each marked with circles, popup labels, and text labels, highlighting their geographical positions in relation to the Equator and nearby coastlines.
- Colored Launch Outcome Markers: To provide insights into launch outcomes, we introduced colored markers. Successful launches are denoted by green markers, while unsuccessful ones are marked in red. The use of Marker Clusters aids in identifying launch sites with higher success rates based on the clustering of green markers.
- Distance Visualization: We enhanced the visualization by adding colored lines that display distances between the KSC LC-39A launch site (as an example) and its proximity points, such as railways, highways, coastlines, and the nearest city. These lines help viewers understand the spatial relationships between the launch site and its surroundings.

Build a Dashboard with Plotly Dash

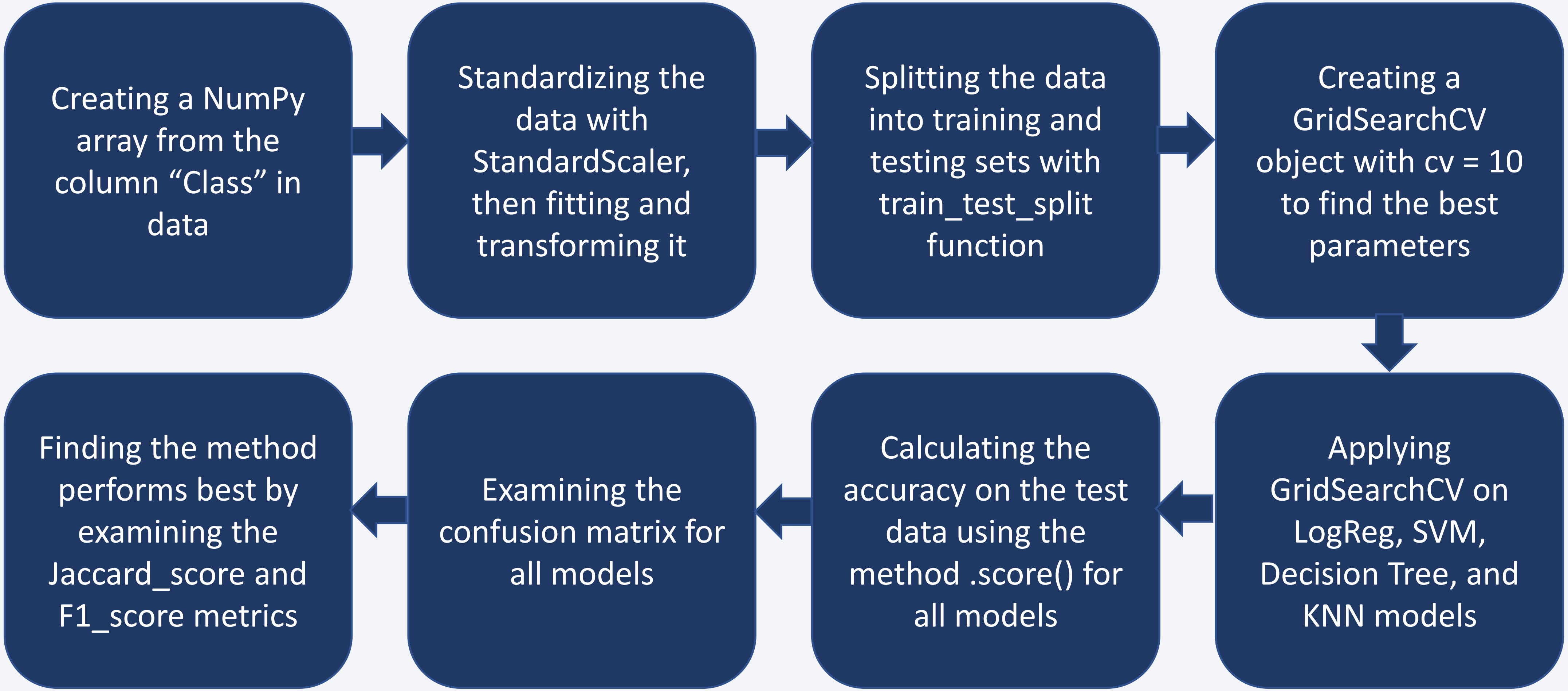
GitHub URL: Dashboard

Summary of the Dashboard

- Launch Sites Dropdown List: Implemented a convenient dropdown list feature, allowing users to select their preferred launch site effortlessly.
- Pie Chart for Launch Success: Introduced an informative pie chart to visualize the overall count of successful launches across all sites. Moreover, if users opt for a specific launch site, the chart dynamically displays the success versus failure counts for that particular site, providing valuable insights at a glance.
- Payload Mass Range Slider: Incorporated a user-friendly slider control that enables users to specify the desired payload mass range, enhancing the precision of data exploration.
- Scatter Chart for Payload vs. Success Rate: Introduced a scatter chart to depict the relationship between payload mass and launch success rate across different booster versions. This visualization aids in identifying potential correlations and patterns within the data.

Predictive Analysis (Classification)

GitHub URL: Classification



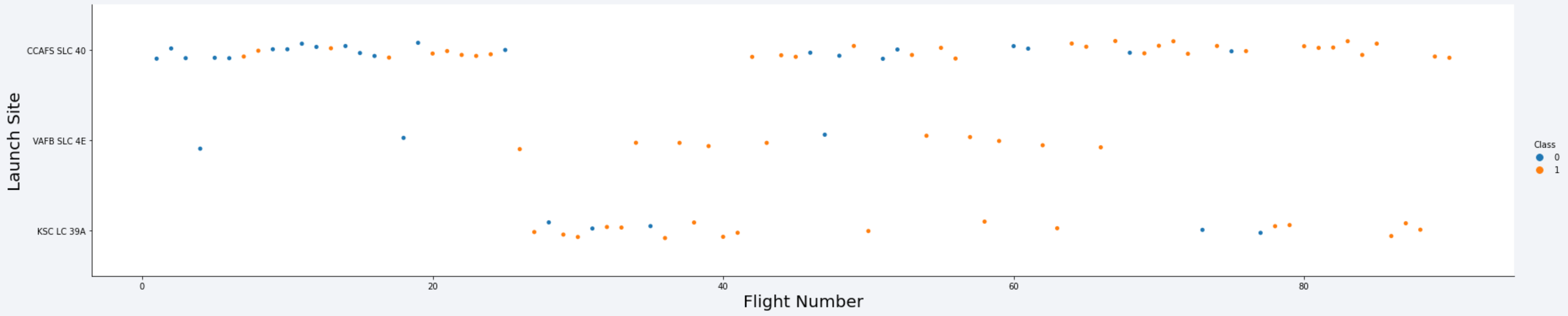
Results

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

Section 2

Insights drawn from EDA

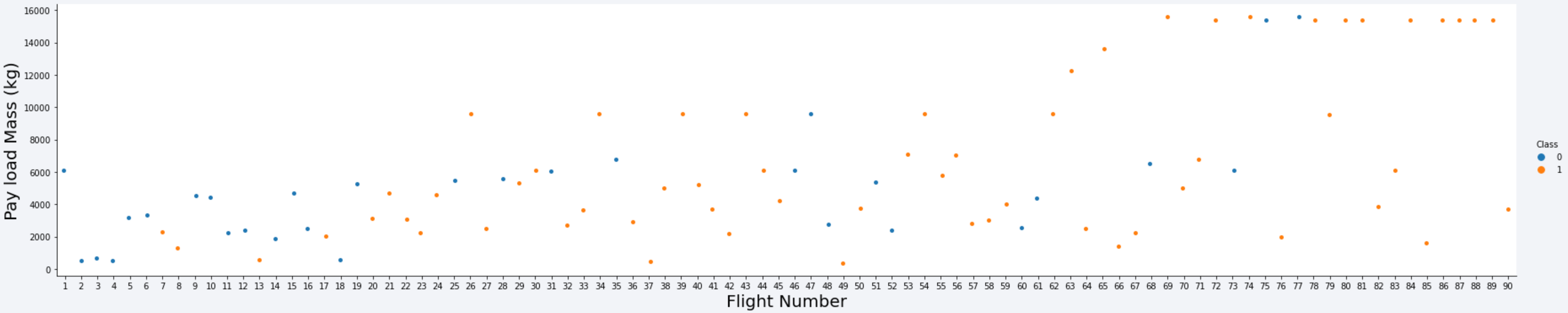
Flight Number vs. Launch Site



Explanation:

- The initial flights in the dataset experienced a series of failures, while the most recent flights achieved success. This suggests an improvement in mission outcomes over time.
- The CCAFS SLC 40 launch site accounts for approximately half of all launches, indicating its significance in the space mission program.
- Two specific launch sites, VAFB SLC 4E and KSC LC 39A, stand out with notably higher success rates compared to others. This underscores their effectiveness and reliability.
- There's a plausible assumption that each new launch in the dataset is associated with a higher likelihood of success, given the historical progression from failures to successes.

Payload vs. Launch Site



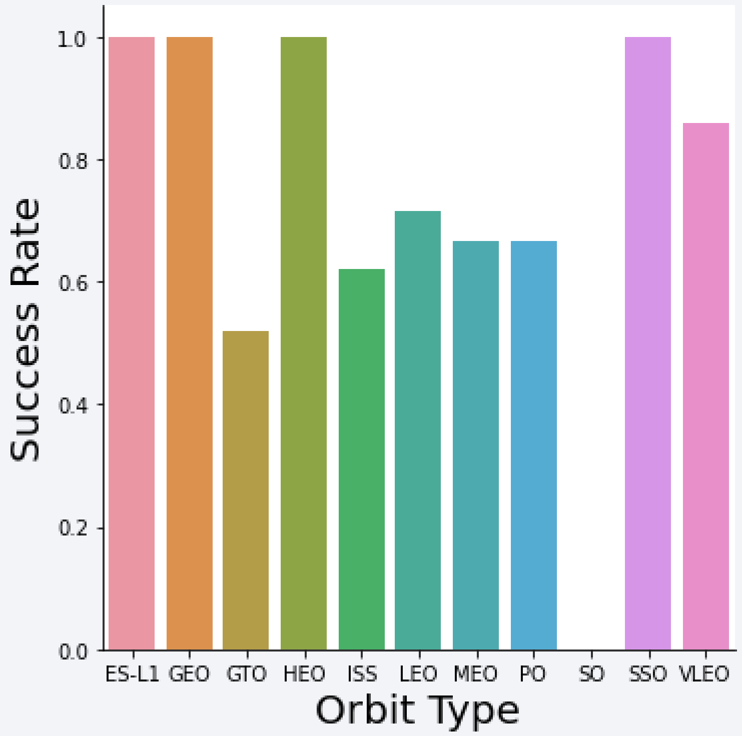
Explanation:

- For every launch site the higher the payload mass, the higher the success rate.
- Most of the launches with payload mass over 8000 kg were successful.

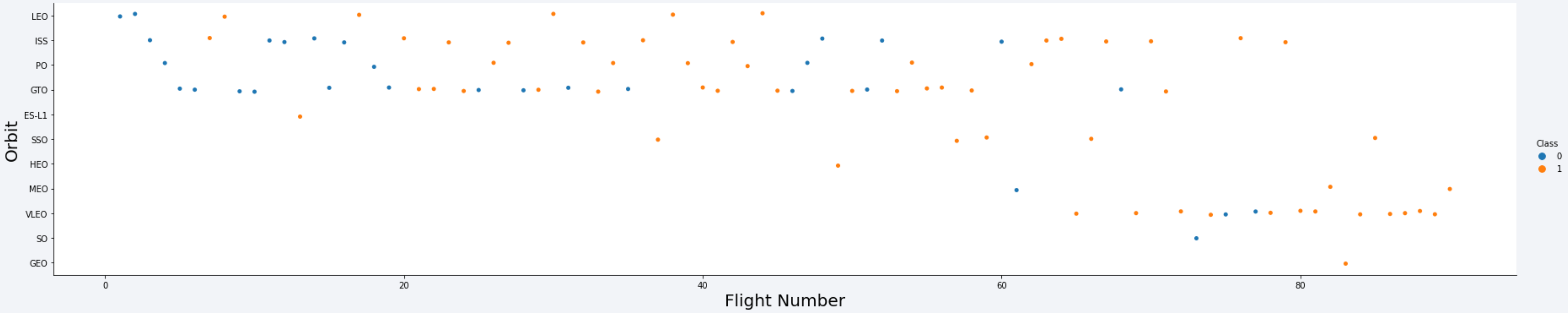
Success Rate vs. Orbit Type

Explanation:

- 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



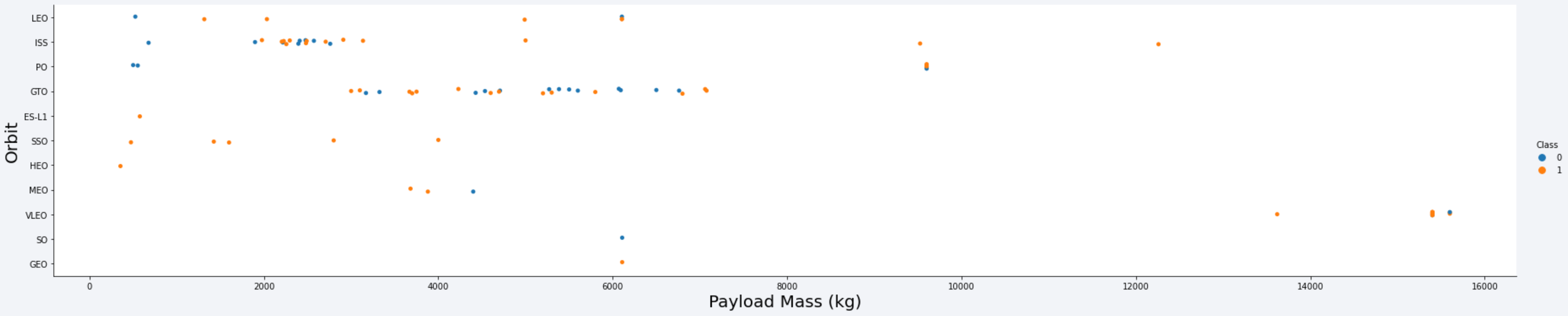
Flight Number vs. Orbit Type



Explanation:

- 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 and orbit type when the orbit is GTO orbit.

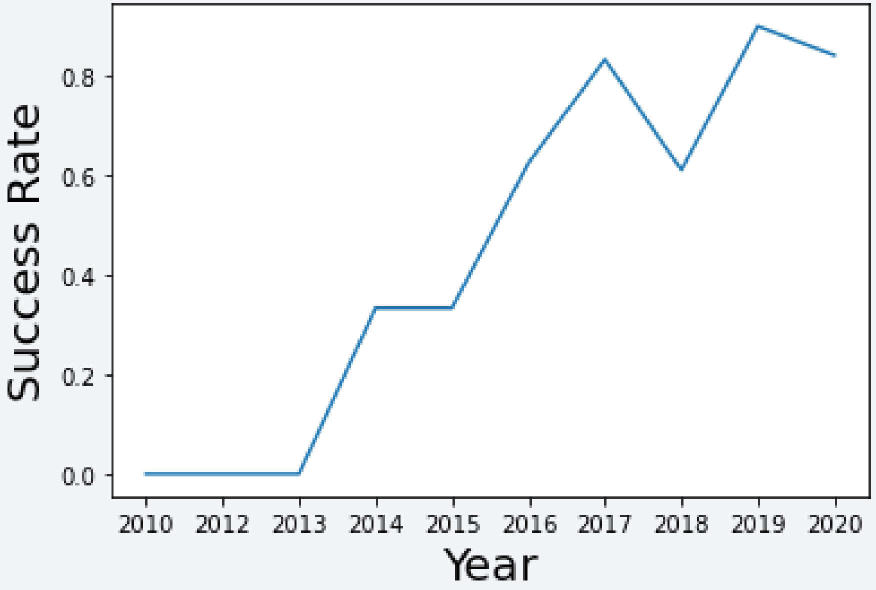
Payload vs. Orbit Type



Explanation:

- Payload mass seems to correlate with orbit LEO and SSO seem to have relatively low payload mass
- The other most successful orbit VLEO only has payload mass values in the higher end of the range

Launch Success Yearly Trend



Explanation:

- Success generally increases over time since 2013 with a slight dip in 2018 Success in recent years at around 80%

All Launch Site Names

```
%sql select distinct launch_site from SPACEXDATASET;
```

```
 * ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
Done.
```

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

Explanation:

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

Launch Site Names Begin with 'CCA'

```
%sql select * from SPACEXDATASET where launch_site like 'CCA%' limit 5;
```

```
* ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
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	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	00:35:00	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

Explanation:

- Displaying 5 records where launch sites begin with “CCA”

Total Payload Mass

```
%sql select sum(payload_mass__kg_) as total_payload_mass from SPACEXDATASET where customer = 'NASA (CRS)';
```

```
 * ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
Done.
```

total_payload_mass
45596

Explanation:

- 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_) as average_payload_mass from SPACEXDATASET where booster_version like '%F9 v1.1%';
```

```
 * ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
Done.
```

average_payload_mass
2534

Explanation:

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

First Successful Ground Landing Date

```
%sql select min(date) as first_successful_landing from SPACEXDATASET where landing__outcome = 'Success (ground pad)';
```

```
 * ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
Done.
```

first_successful_landing
2015-12-22

Explanation:

- Displaying 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 SPACEXDATASET where landing__outcome = 'Success (drone ship)' and payload_mass__kg_ betw
```

```
 * ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
Done.
```

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

Explanation:

- Displaying 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(*) as total_number from SPACEXDATASET group by mission_outcome;
```

```
 * ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
Done.
```

mission_outcome	total_number
Failure (in flight)	1
Success	99
Success (payload status unclear)	1

Explanation:

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

Boosters Carried Maximum Payload

```
%sql select booster_version from SPACEXDATASET where payload_mass__kg_ = (select max(payload_mass__kg_) from SPACEXDATASE
```

```
 * ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
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

Explanation:

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

2015 Launch Records

```
%%sql select monthname(date) as month, date, booster_version, launch_site, landing__outcome from SPACEXDATASET
      where landing__outcome = 'Failure (drone ship)' and year(date)=2015;
```

```
 * ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
Done.
```

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)

Explanation:

- Displaying 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_outcomes from SPACEXDATASET
      where date between '2010-06-04' and '2017-03-20'
      group by landing__outcome
      order by count_outcomes desc;
```

```
 * ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31198/bludb
Done.
```

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

Explanation:

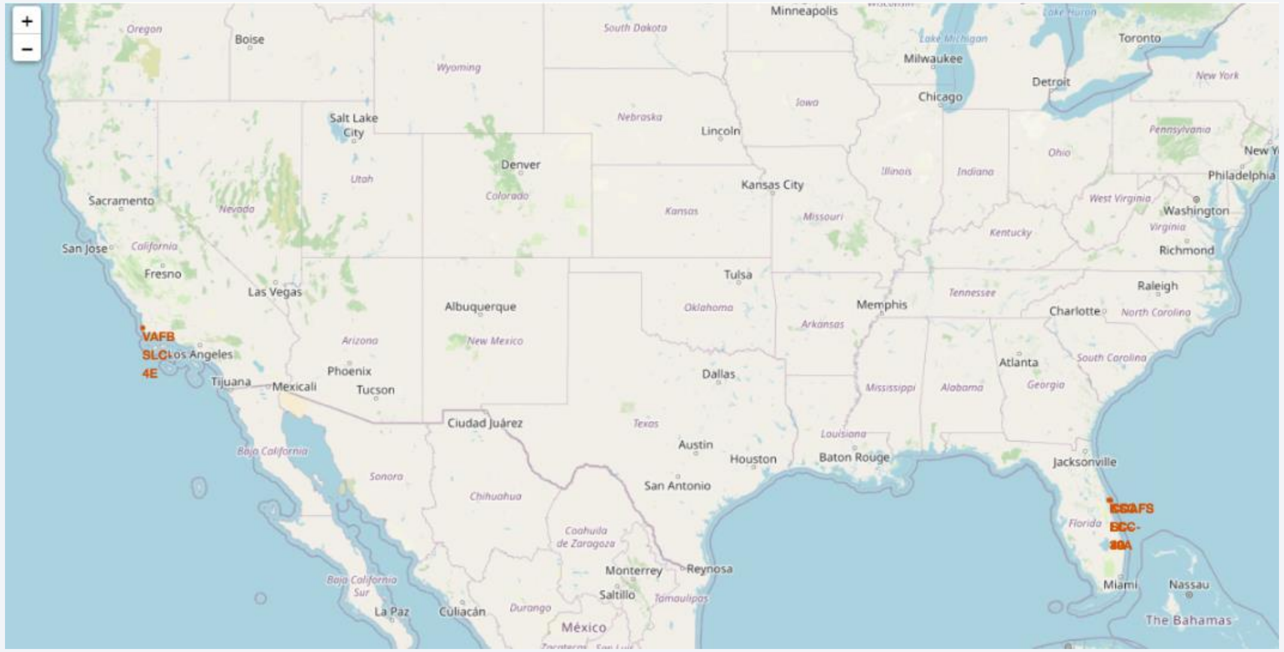
- Ranking the count of landing outcomes (such as Failure (drone ship) or Success (ground pad)) between the date 2010-06-04 and 2017-03-20 in descending order.

Section 3

Launch Sites Proximities Analysis

Launch Site Locations

Explanation:

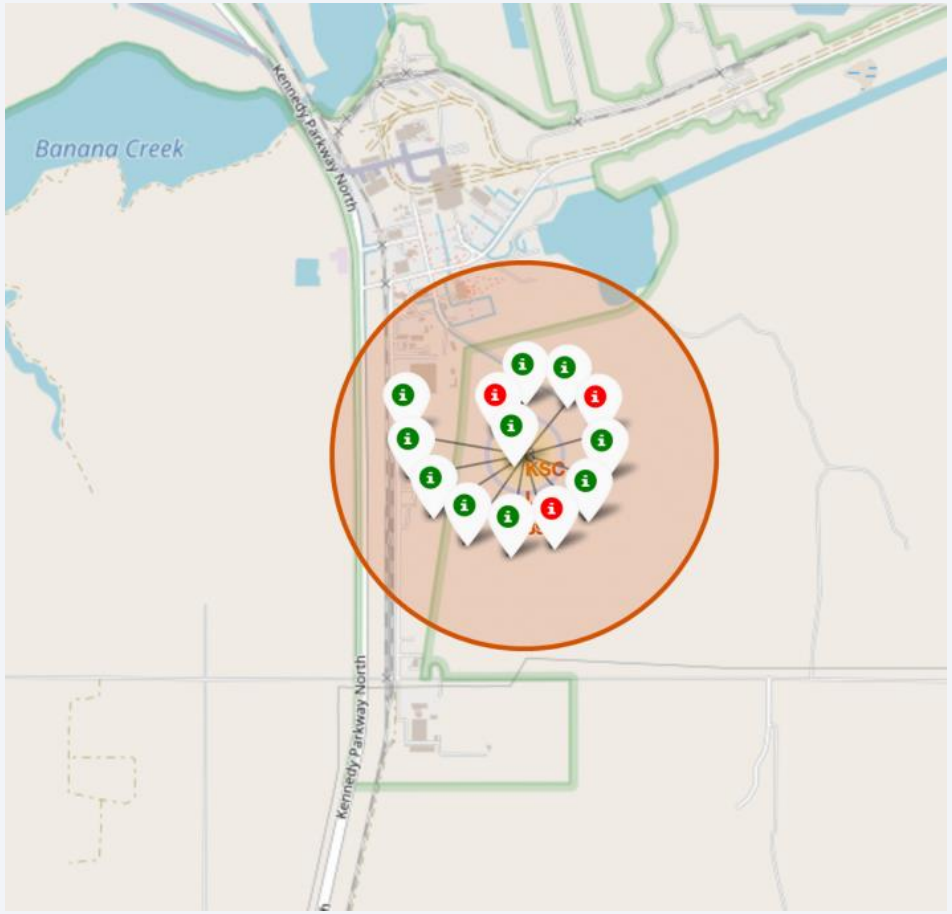


- Most launch sites are situated near the Equator due to the region's faster rotational speed. When a spacecraft is launched from this location, it not only ascends into space but also retains its pre-launch velocity. This velocity is crucial for maintaining the necessary speed to stay in orbit.
- Furthermore, all launch sites are strategically located in close proximity to coastlines. Launching rockets towards the ocean serves to minimize the potential danger of debris falling or exploding near populated areas.

Color-labeled Launch Markers

Explanation:

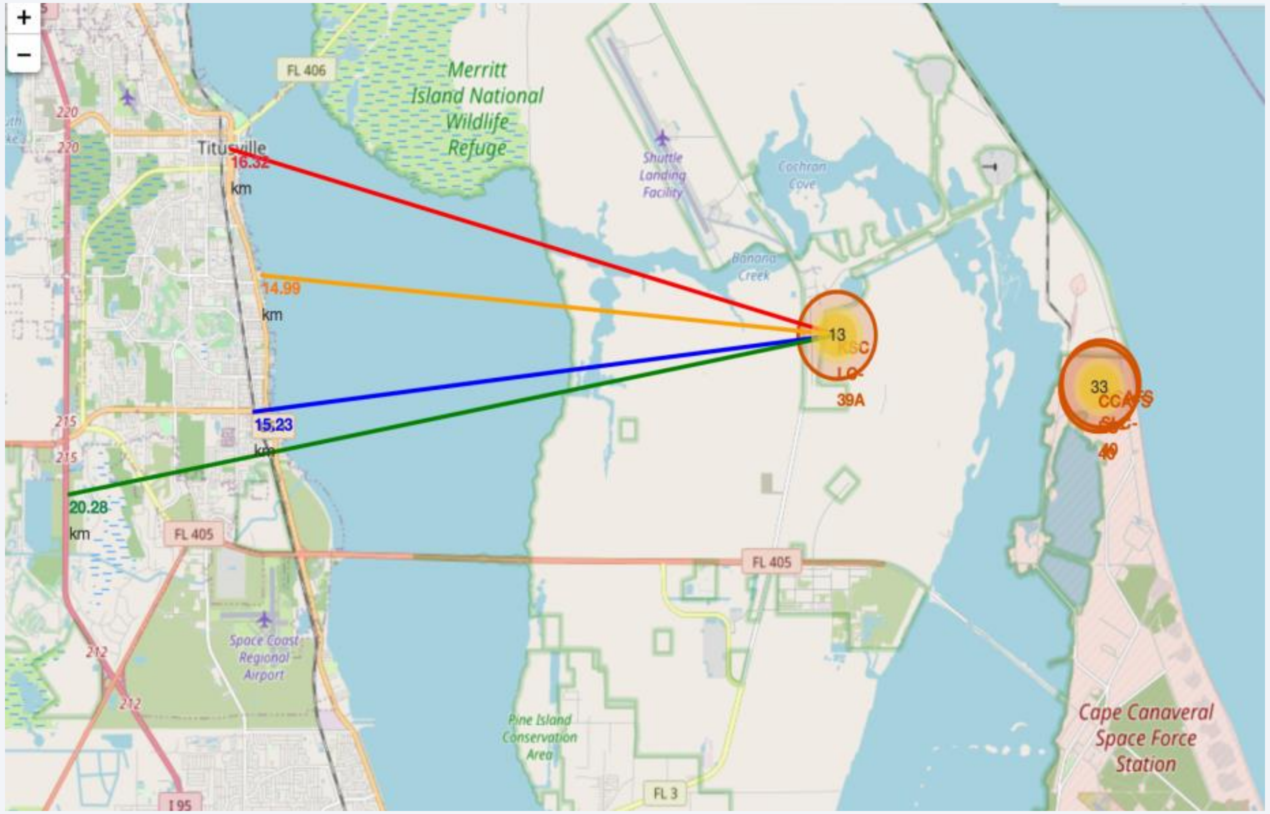
- By referencing color-coded markers, we can readily discern launch sites with notably high success rates. A green marker signifies a successful launch, while a red marker indicates a failed one.
- Launch Site KSC LC-39A boasts an exceptionally impressive track record of successful launches.



Location Proximities

Explanation:

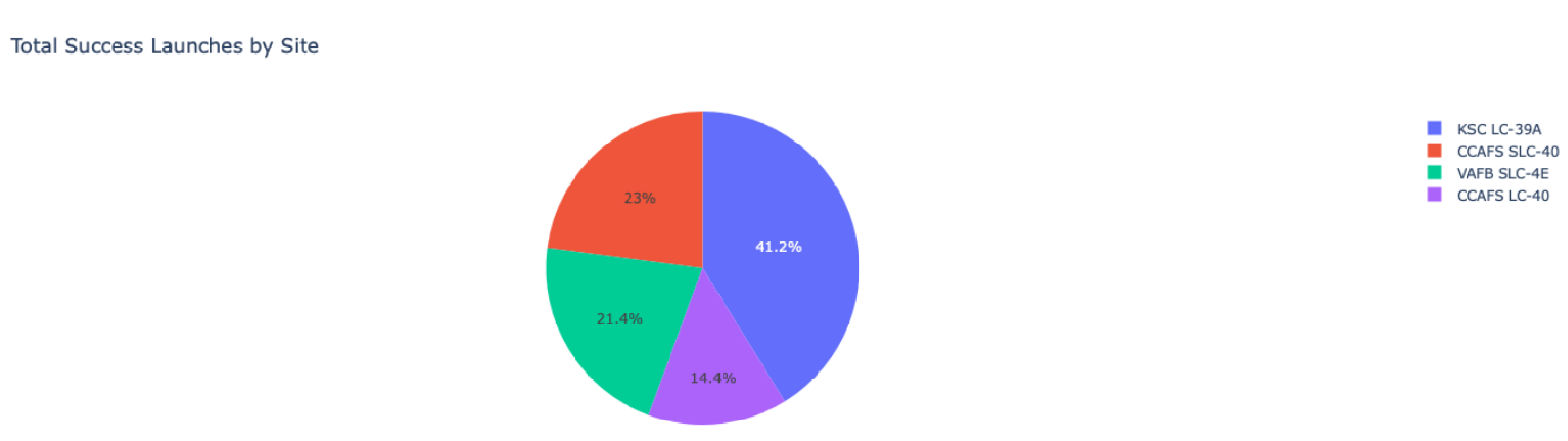
- From the visual analysis of the launch site KSC LC-39A we can clearly see that it is: relative close to railway (15.23 km) - relative close to highway (20.28 km) - relative close to coastline (14.99 km)
- Also the launch site KSC LC-39A is relative close to its closest city Titusville (16.32 km).
- 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

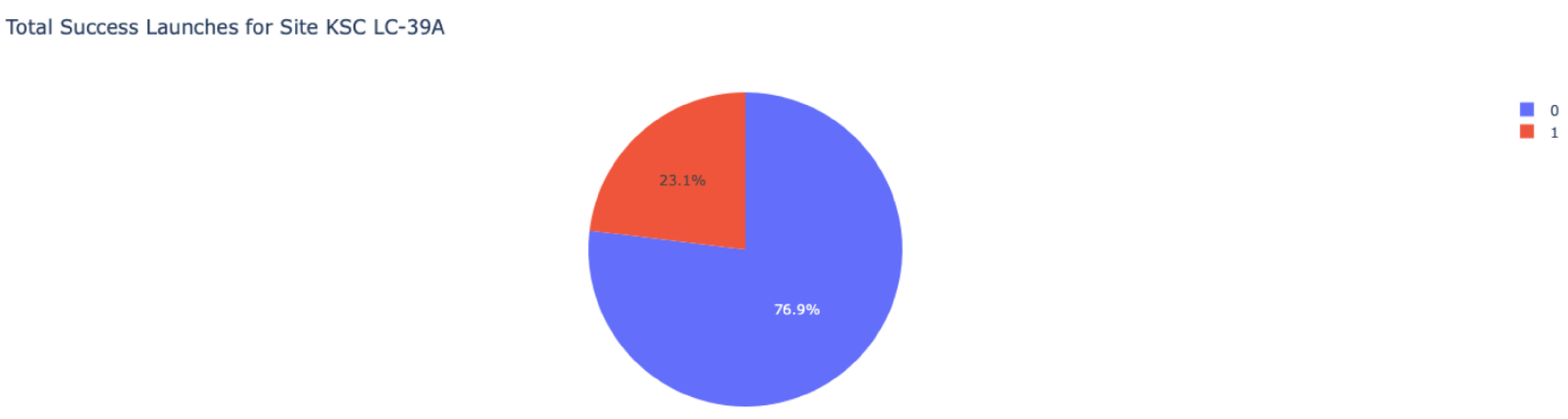
Launch Success Count For All Sites



Explanation:

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

Launch site with highest launch success ratio



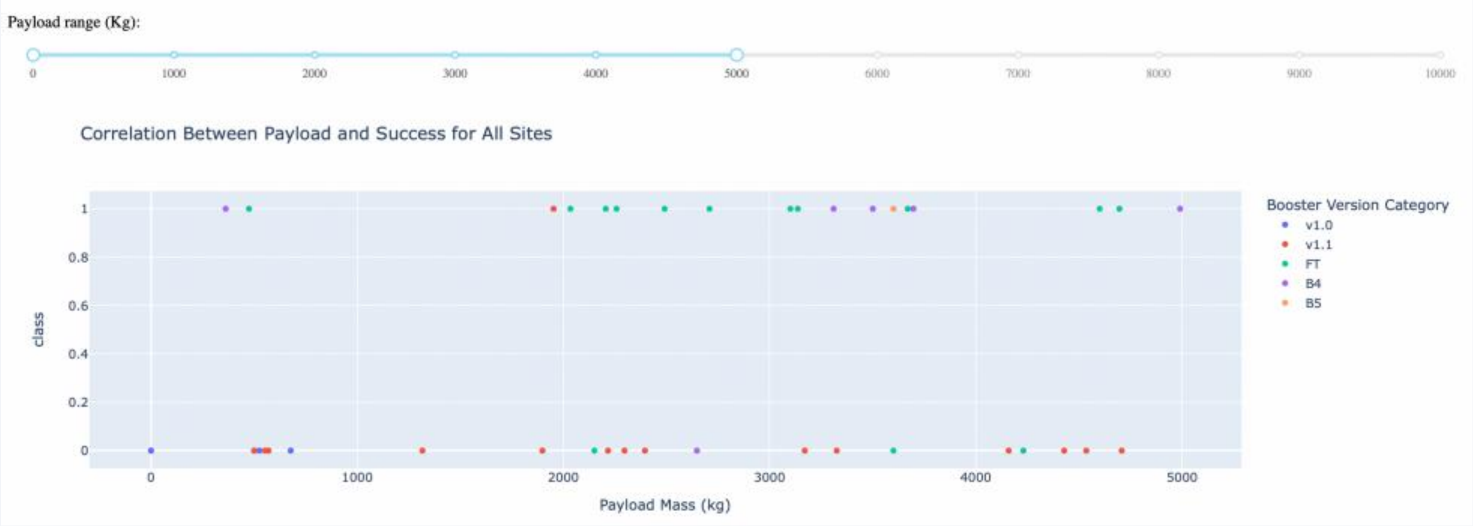
Explanation:

- 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

Explanation:

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



Section 5

Predictive Analysis (Classification)

Classification Accuracy

	LogReg	SVM	Tree	KNN
Jaccard_Score	0.800000	0.800000	0.800000	0.800000
F1_Score	0.888889	0.888889	0.888889	0.888889
Accuracy	0.833333	0.833333	0.833333	0.833333

Scores and Accuracy of the Test Set

	LogReg	SVM	Tree	KNN
Jaccard_Score	0.833333	0.845070	0.882353	0.819444
F1_Score	0.909091	0.916031	0.937500	0.900763
Accuracy	0.866667	0.877778	0.911111	0.855556

Scores and Accuracy of the Entire Data Set

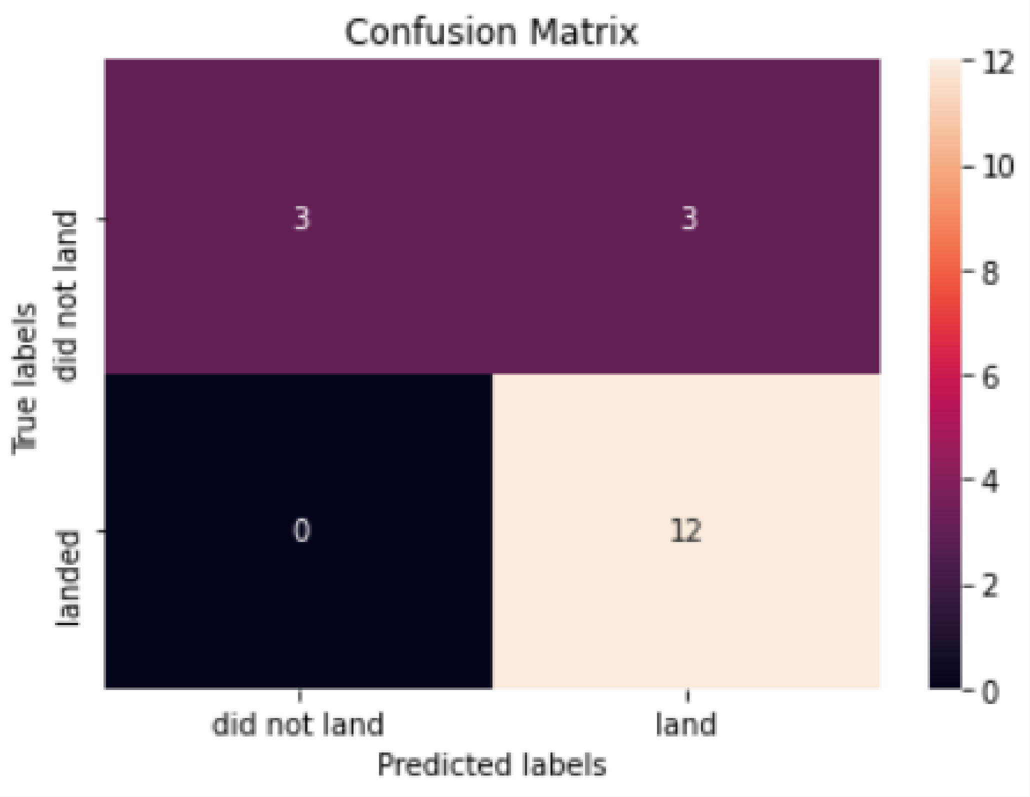
Explanation:

- Based on the scores of the Test Set, we can not confirm which method performs best.
- Same Test Set scores may be due to the small test sample size (18 samples). Therefore, we tested all methods based on the whole Dataset.
- The scores of the whole Dataset confirm that the best model is the Decision Tree Model. This model has the highest accuracy.

Confusion Matrix

Explanation:

- 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.
- 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

- GitHub Repository URL

  hasanhammad/Applied-Data-Science-Capstone:
  The final task of this capstone project (github.com)

- Special Thanks to All Instructors:

  Applied Data Science Capstone - IBM - Course Info | Coursera

- SpaceX data
- Wikipedia

Thank you!