

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)

Summary of all results

- Exploratory Data Analysis results
- Interactive analytics demo

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

1. Data collection methodology:
 - Using SpaceX Rest API
 - Using Web Scrapping from Wikipedia
2. Perform data wrangling:
 - Filtering the data
 - Dealing with missing values
 - Using One Hot Encoding to prepare the data to a binary classification
3. Perform exploratory data analysis (EDA) using visualization and SQL
4. Perform interactive visual analytics using Folium and Plotly Dash
5. 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:

- Flight Number, Date, Booster Version, Payload Mass, Orbit, Launch_site, Outcome, Flights, Grid Fins, Reused, Legs, Landing Pad, Block, Reused Count, Serial, Longitude, Latitude

Data Columns are obtained by using Wikipedia Web Scraping:

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

Data Collection – SpaceX 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



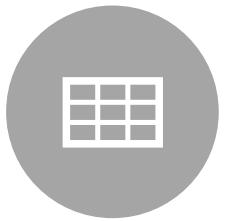
CONSTRUCTING DATA WE
HAVE OBTAINED INTO A
DICTIONARY



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

1

Requesting Falcon 9
launch data from
Wikipedia

2

Creating a
BeautifulSoup object
from the HTML
response

3

Extracting all column
names from the
HTML table header

4

Collecting the data
by parsing HTML
tables

5

Constructing data we
have obtained into a
dictionary

6

Creating a dataframe
from the dictionary

7

Exporting the data to
CSV

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

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 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

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.

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.

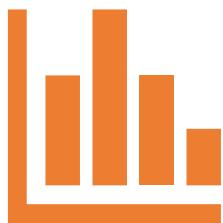
Scatter Chart of Payload Mass vs. Success Rate for the different Booster Versions:

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

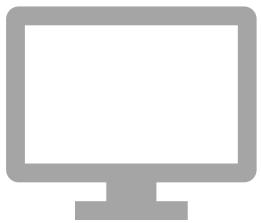
Predictive Analysis (Classification)

Creating	Creating a NumPy array from the column “Class” in data
Standardizing	Standardizing the data with StandardScaler, then fitting and transforming it
Splitting	Splitting the data into training and testing sets with train_test_split function
Creating	Creating a GridSearchCV object with cv = 10 to find the best parameters
Applying	Applying GridSearchCV on LogReg, SVM, Decision Tree, and KNN models
Calculating	Calculating the accuracy on the test data using the method .score() for all models
Examining	Examining the confusion matrix for all models
Finding	Finding the method performs best by examining the Jaccard_score and F1_score metrics

Results



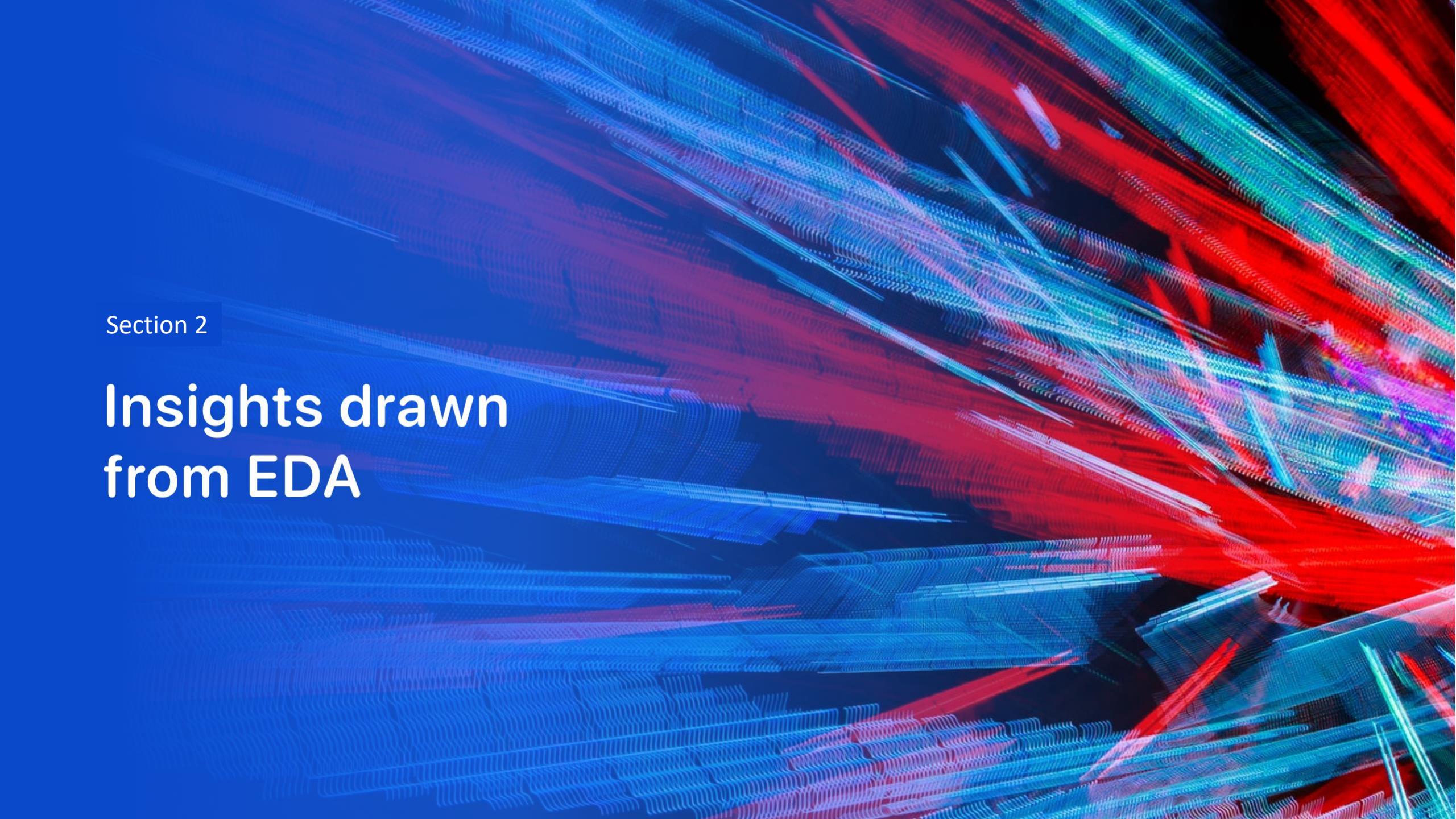
Exploratory data analysis
results



Interactive analytics
demo in screenshots



Predictive analysis
results

The background of the slide features a complex, abstract digital visualization. It consists of numerous thin, glowing lines that create a sense of depth and motion. The lines are primarily blue and red, with some green and purple highlights. They form a grid-like structure that curves and twists across the frame, resembling a three-dimensional space or a network of data points. The overall effect is futuristic and dynamic.

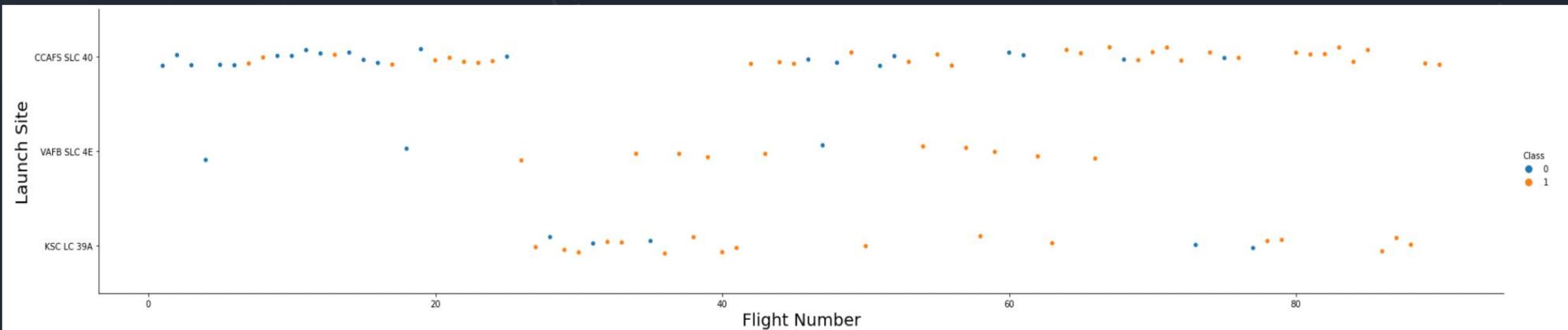
Section 2

Insights drawn from EDA

Flight Number vs. Launch Site

Explanation:

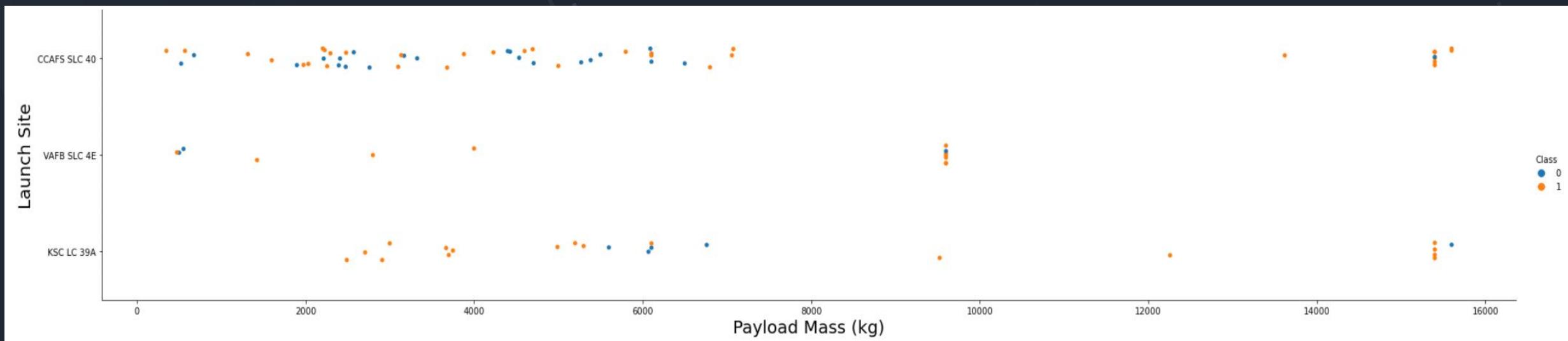
- The earliest flights all failed while the latest flights all succeeded.
- The CCAFS SLC 40 launch site has about a half of all launches.
- VAFB SLC 4E and KSC LC 39A have higher success rates.
- It can be assumed that each new launch has a higher rate of success.



Payload vs. Launch Site

Explanation:

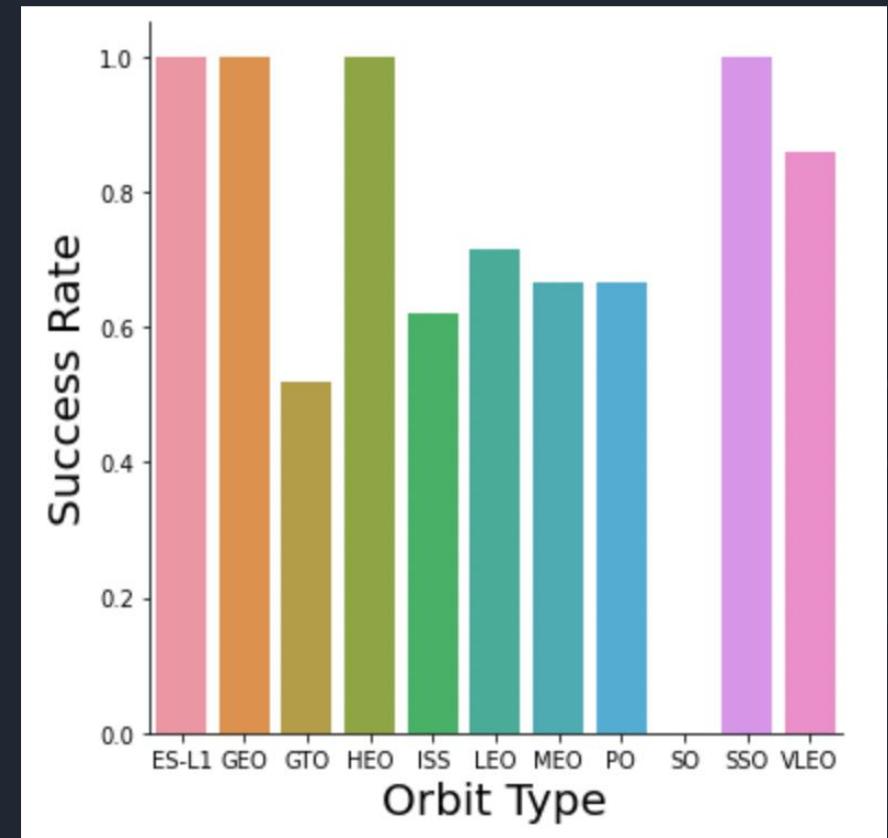
- For every launch site the higher the payload mass, the higher the success rate.
- Most of the launches with payload mass over 7000 kg were successful.
- KSC LC 39A has a 100% success rate for payload mass under 5500 kg too.



Success Rate vs. Orbit Type

Explanation:

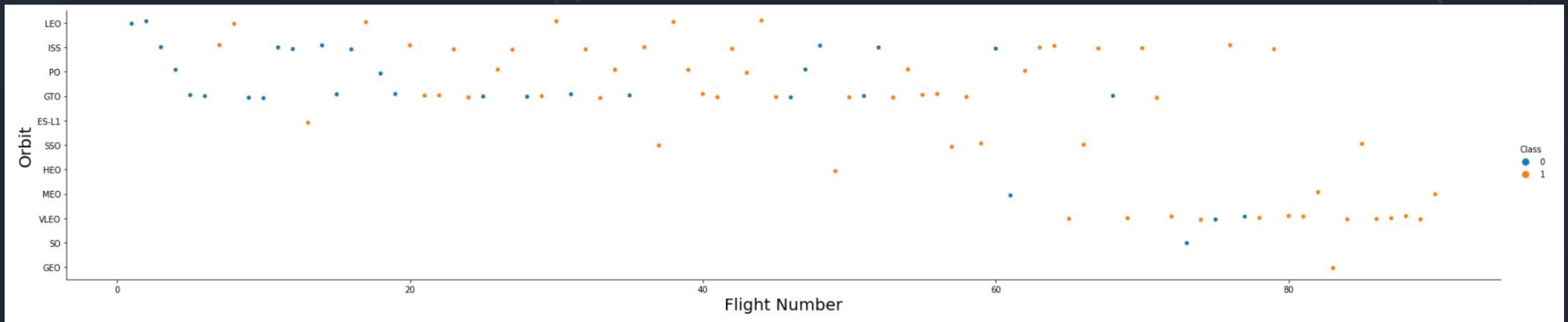
- Orbit types with 100% success rate:
ES-L1, GEO, HEO, SSO
- Orbit types with 0% success rate:
SO
- Orbit types with success rate between 50% and 85%:
GTO, ISS, LEO, MEO, PO



Flight Number vs. Orbit Type

Explanation:

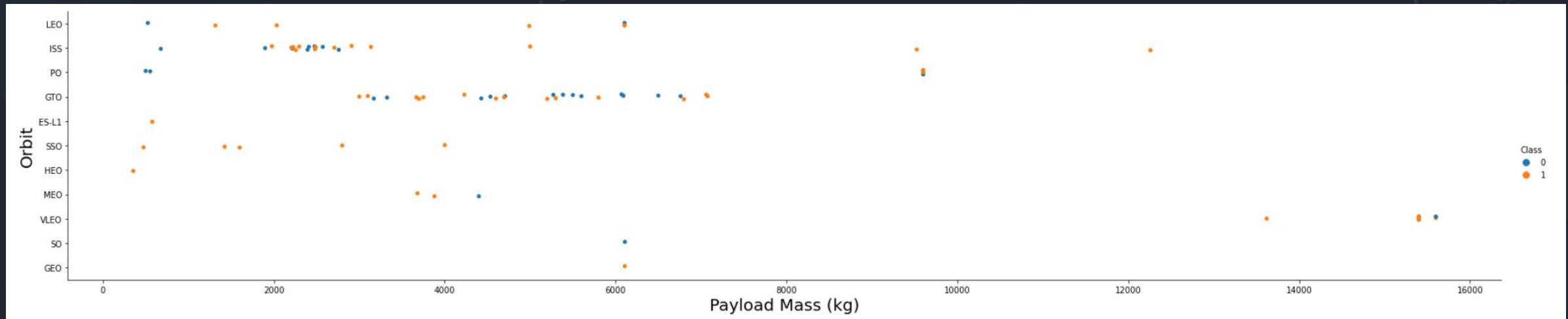
- In the LEO orbit the Success appears related to the number of flights; on the other hand, there seems to be no relationship between flight number when in GTO orbit.



Payload vs. Orbit Type

Explanation:

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

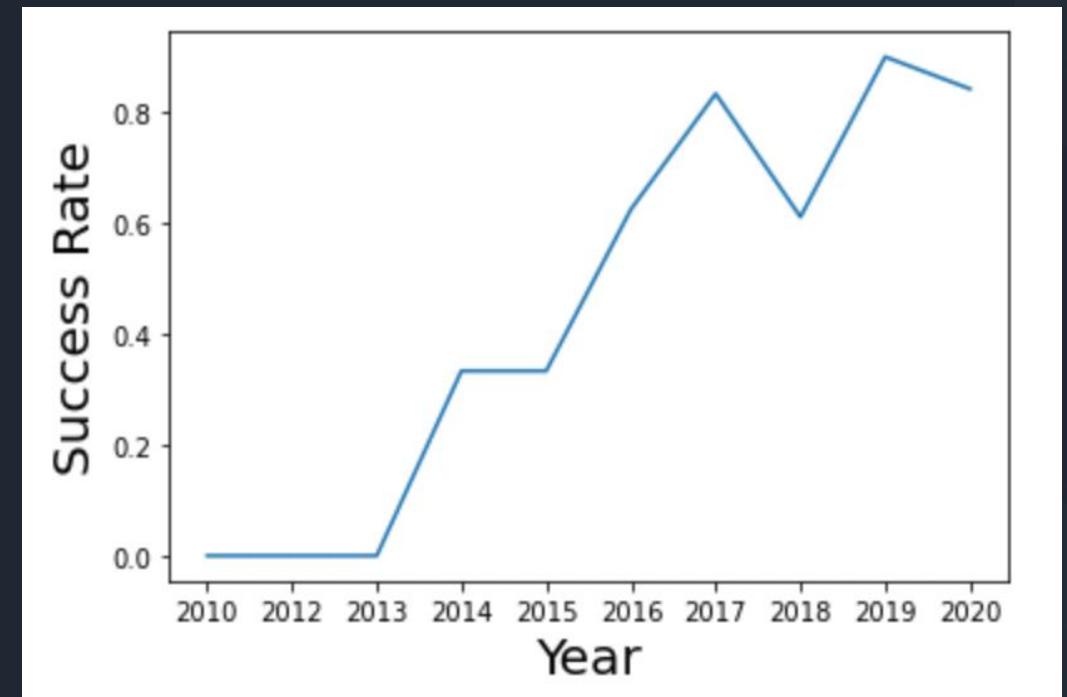


Launch Success Yearly Trend



Explanation:

- The success rate since 2013 kept increasing till 2020.



All Launch Site Names

Explanation:

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

```
In [4]: %sql select distinct launch_site from SPACEXDATASET;  
* ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90108kqb1od81cg.databases.appdomain.cloud:31198/bludb  
Done.
```

Out[4]:

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

Launch Site Names Begin with 'CCA'

Explanation:

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

```
In [5]: %sql select * from SPACEXDATASET where launch_site like 'CCA%' limit 5;
* ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90108kqb1od81cg.databases.appdomain.cloud:31198/bludb
Done.
```

Out[5]:

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

Total Payload Mass

Explanation:

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

```
In [6]: %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.bs2io90108kqb1od81cg.databases.appdomain.cloud:31198/bludb  
Done.  
Out[6]: total_payload_mass  
45596
```

Average Payload Mass by F9 v1.1

Explanation:

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

```
In [7]: %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.bs2io90108kqb1od81cg.databases.appdomain.cloud:31198/bludb
Done.
```

```
Out[7]: average_payload_mass
2534
```

First Successful Ground Landing Date

Explanation:

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

```
In [8]: %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.bs2io90108kqb1od81cg.databases.appdomain.cloud:31198/bludb  
Done.  
Out[8]: first_successful_landing  
2015-12-22
```

Successful Drone Ship Landing with Payload between 4000 and 6000

Explanation:

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

```
In [9]: %sql select booster_version from SPACEXDATASET where landing__outcome = 'Success (drone ship)' and payload_mass__kg_ between 4000 and 6000;
* ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90108kqb1od8lcg.databases.appdomain.cloud:31198/bludb
Done.
```

Out[9]:

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

Total Number of Successful and Failure Mission Outcomes

Explanation:

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

```
In [10]: %sql select mission_outcome, count(*) as total_number from SPACEXDATASET group by mission_outcome;
* ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90108kqb1od81cg.databases.appdomain.cloud:31198/bludb
Done.
```

Out[10]:

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

Boosters Carried Maximum Payload

Explanation:

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

```
In [11]: %sql select booster_version from SPACEXDATASET where payload_mass_kg_ = (select max(payload_mass_kg_) from SPACEXDATASET);
* ibm_db_sa://wzf08322:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90108kqb1od81cg.databases.appdomain.cloud:31198/bludb
Done.

Out[11]: 

| 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

Explanation:

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

```
In [12]: %%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.bs2io90108kqb1od81cg.databases.appdomain.cloud:31198/bludb  
Done.
```

Out[12]:

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

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.

```
In [13]: %%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.
```

Out[13]:

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

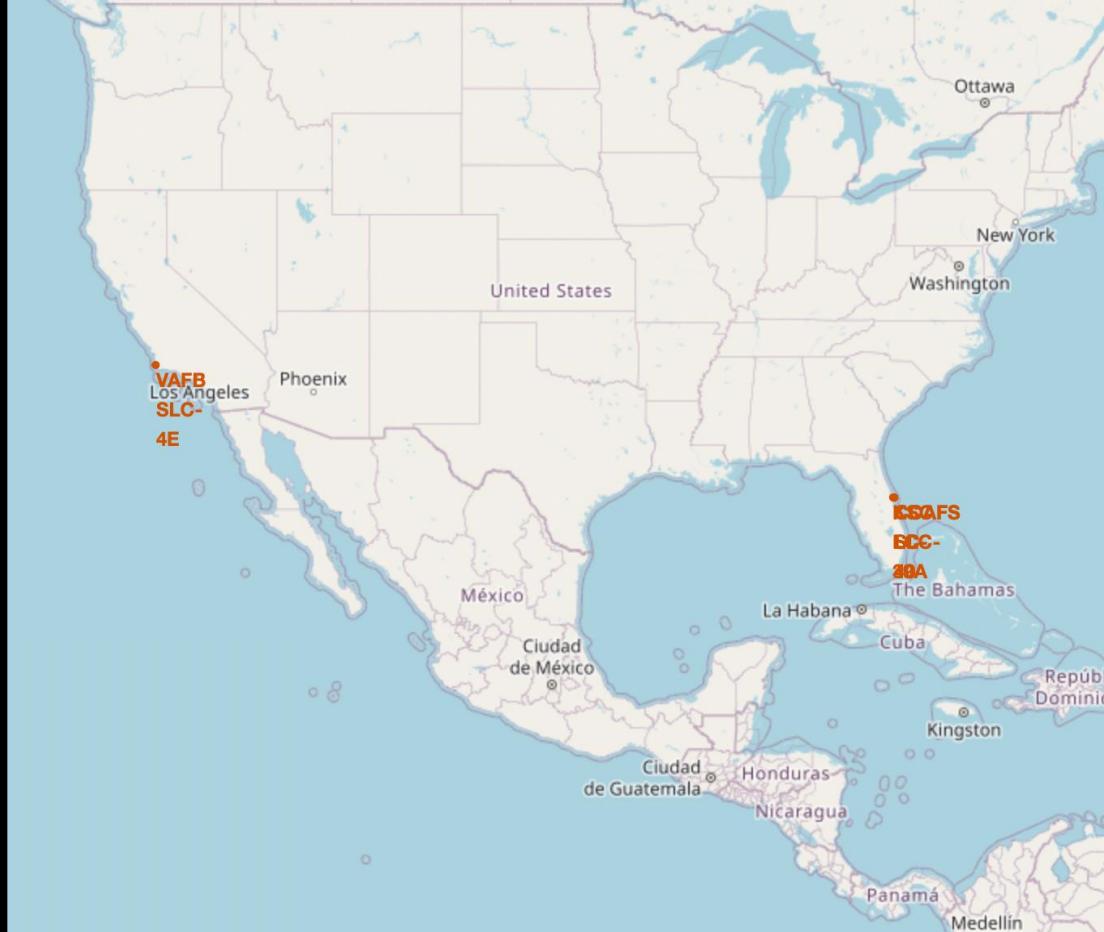
The background of the slide is a photograph taken from space at night. It shows the curvature of the Earth's horizon against a dark blue sky. Numerous glowing yellow and white points represent city lights, concentrated in coastal and urban areas. In the upper right quadrant, there are bright green and yellow bands of light, likely the Aurora Borealis or Australis. The overall atmosphere is dark and mysterious.

Section 3

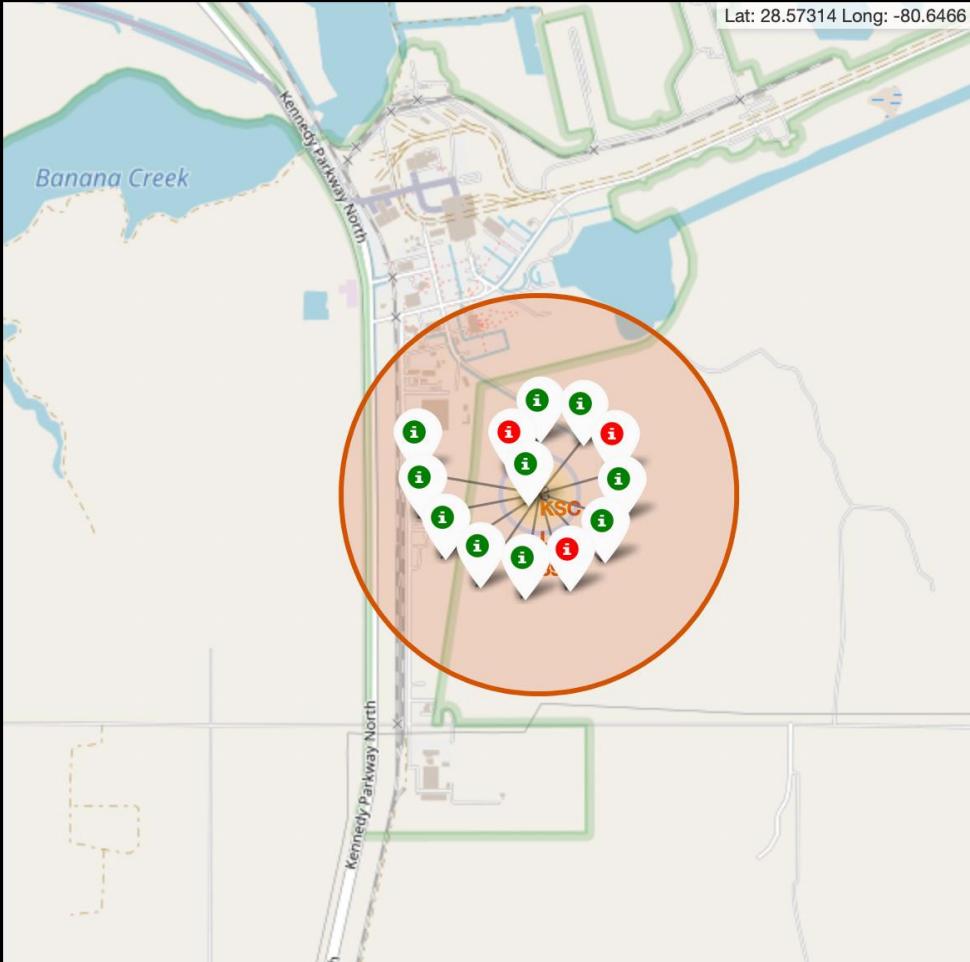
Launch Sites Proximities Analysis

All launch sites' location markers on a global map

Explanation:



- 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.



Color-labeled launch records on the map

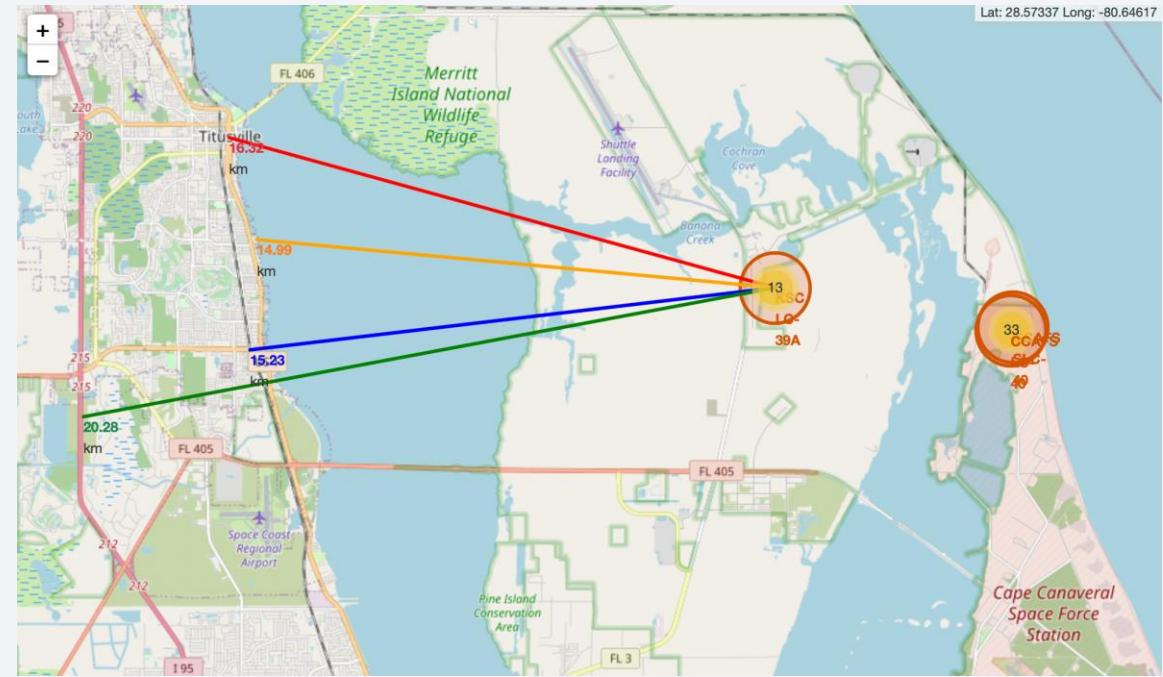
Explanation:

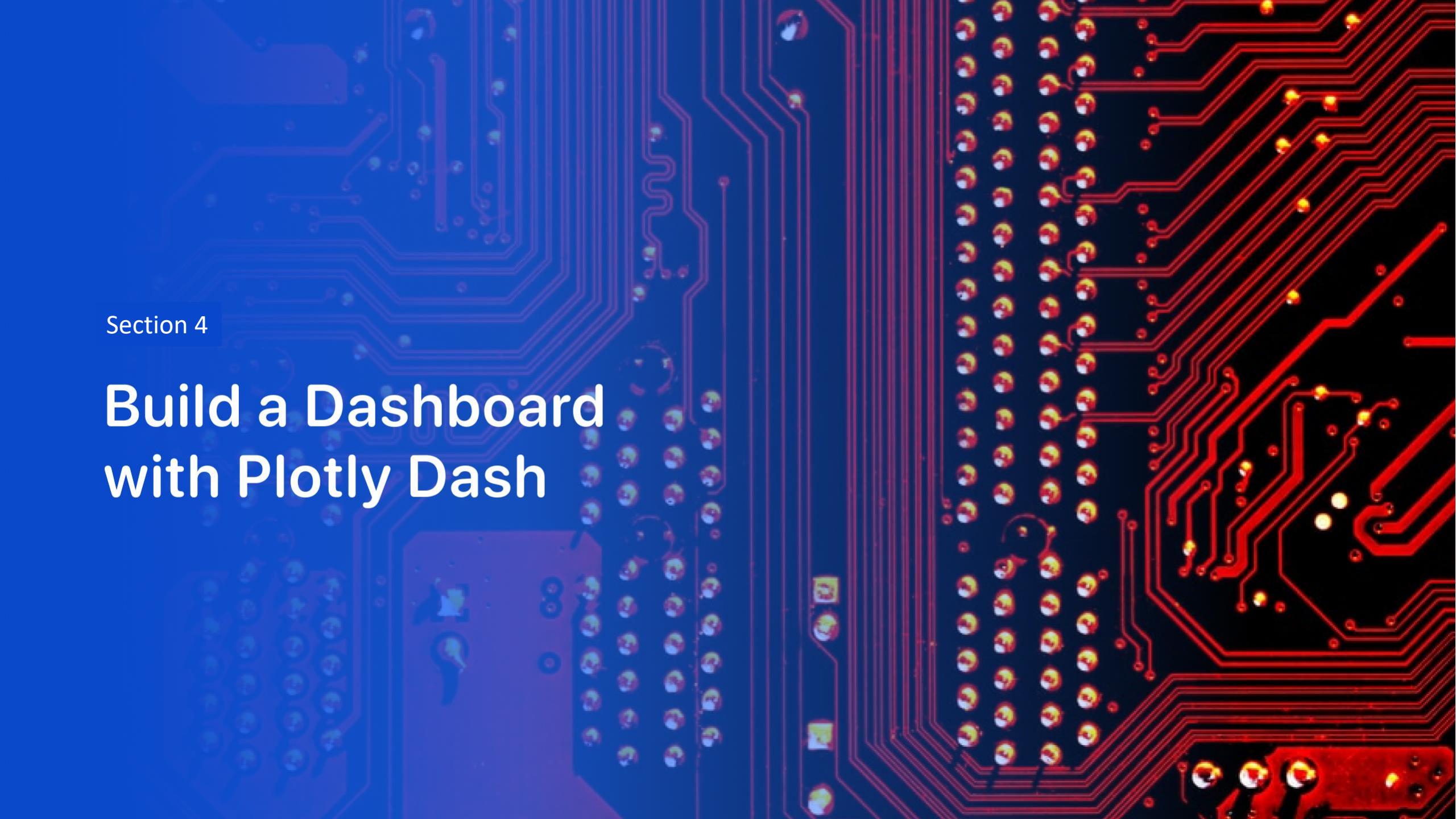
- From the color-labeled markers we should be able to easily identify which launch sites have relatively high success rates.
 - Green Marker = Successful Launch
 - Red Marker = Failed Launch
- Launch Site KSC LC-39A has A Very high Success Rate.

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

Explanation:

- 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)
- Also, 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.





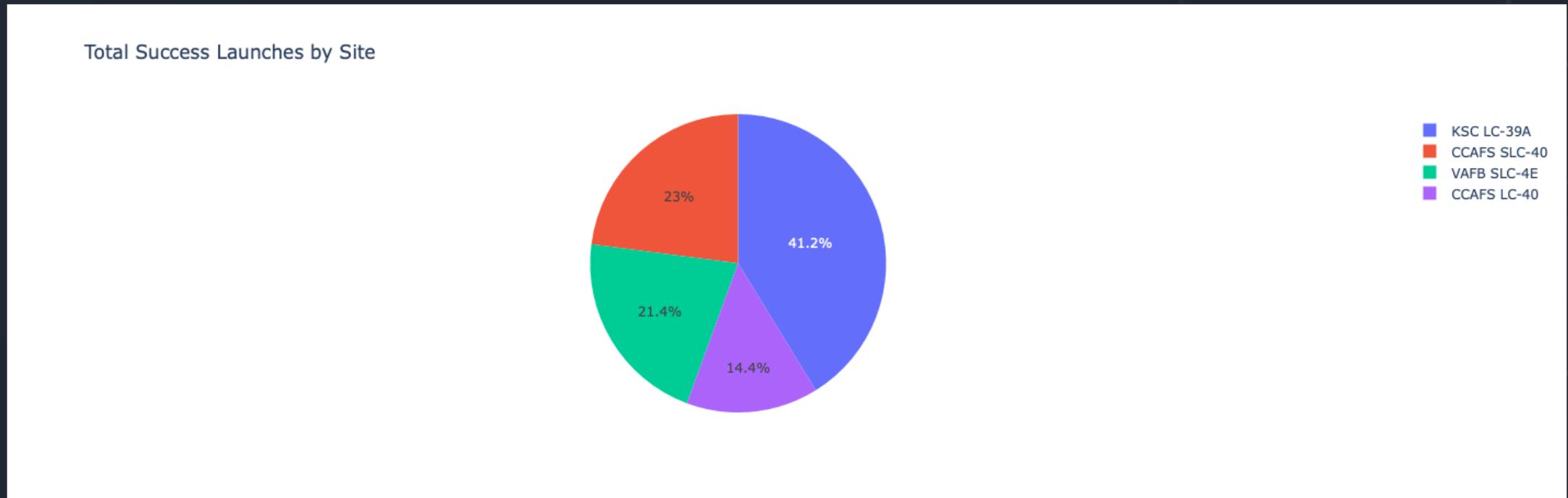
Section 4

Build a Dashboard with Plotly Dash

Launch success count for all sites

Explanation:

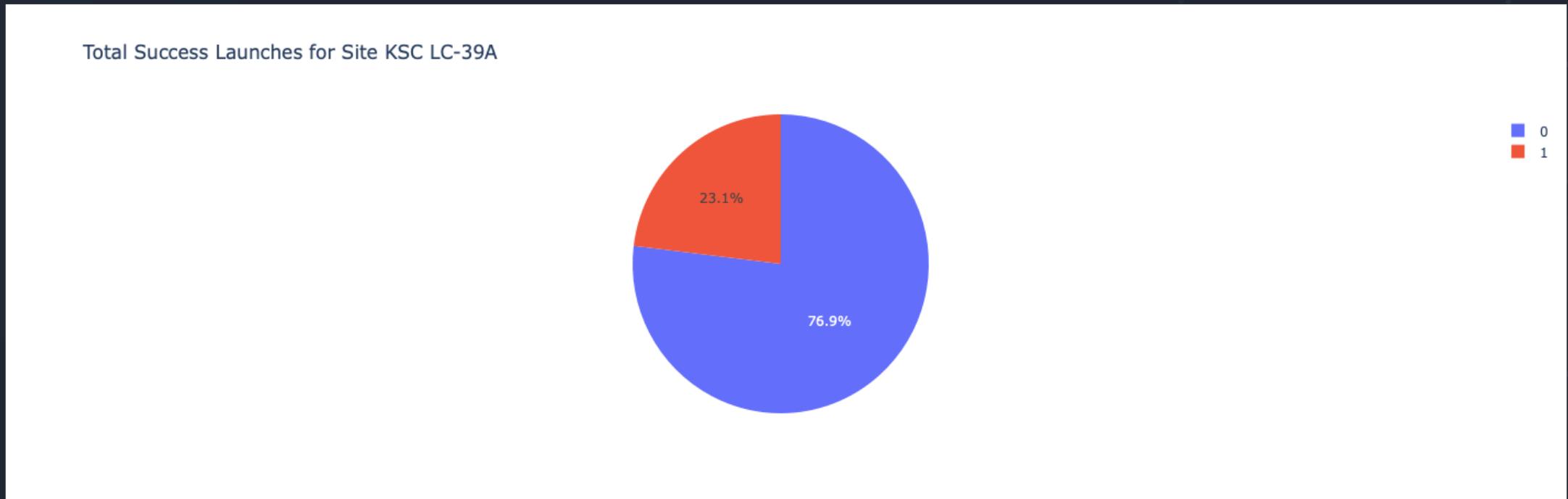
- The chart clearly shows that from all the sites, KSC LC-39A has the most successful launches.



Launch site with highest launch success ratio

Explanation:

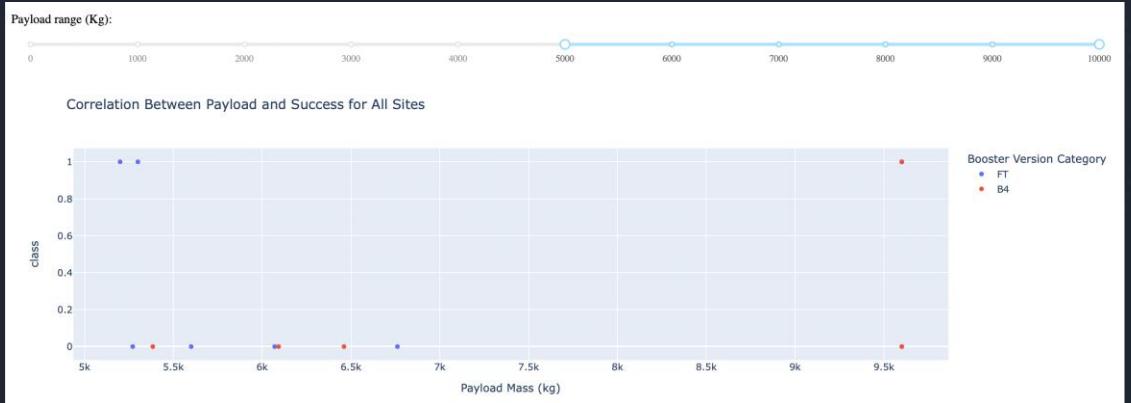
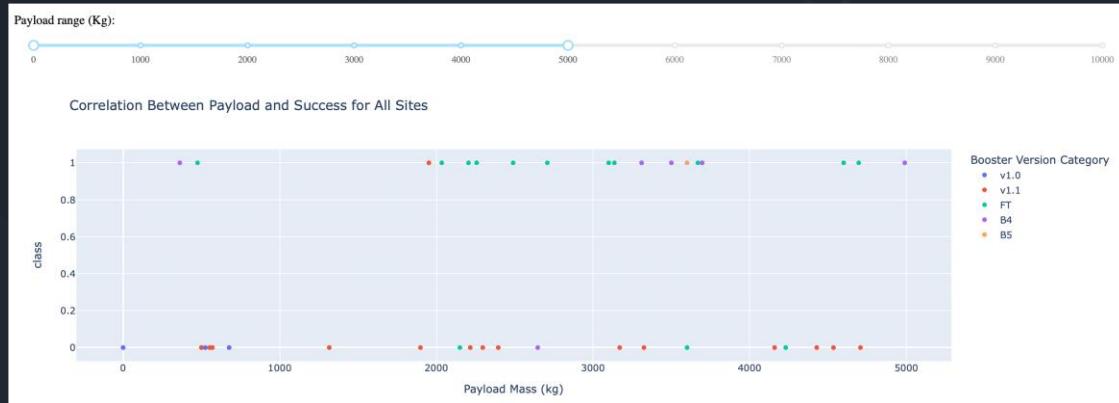
- KSC LC-39A has the highest launch success rate (76.9%) with 10 successful and only 3 failed landings.



Payload Mass vs. Launch Outcome for all sites

Explanation:

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



The background of the slide features a dynamic, abstract design. It consists of several curved, overlapping bands of color. A prominent band on the left is a bright blue, while another on the right is a warm yellow. These colors transition into lighter, more diffused versions of themselves towards the edges of the frame. The overall effect is one of motion and depth.

Section 5

Predictive Analysis (Classification)

Classification Accuracy

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 not only higher scores, but also the highest accuracy.

Scores and Accuracy of the Entire Data 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

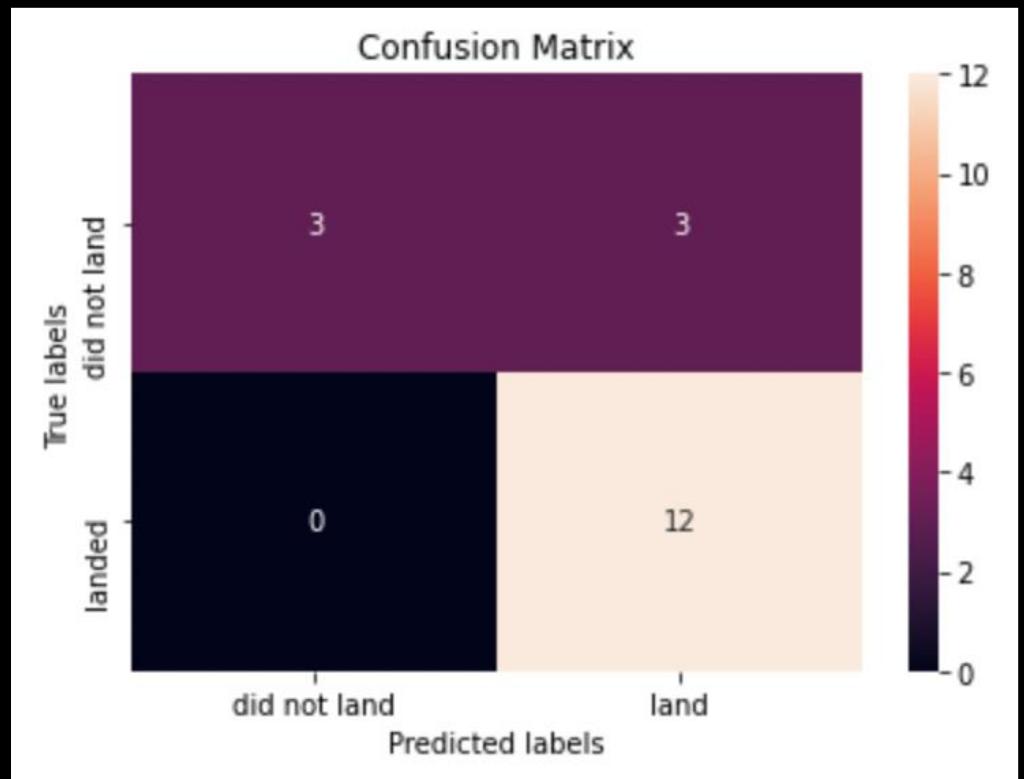
Scores and Accuracy of the Test Set

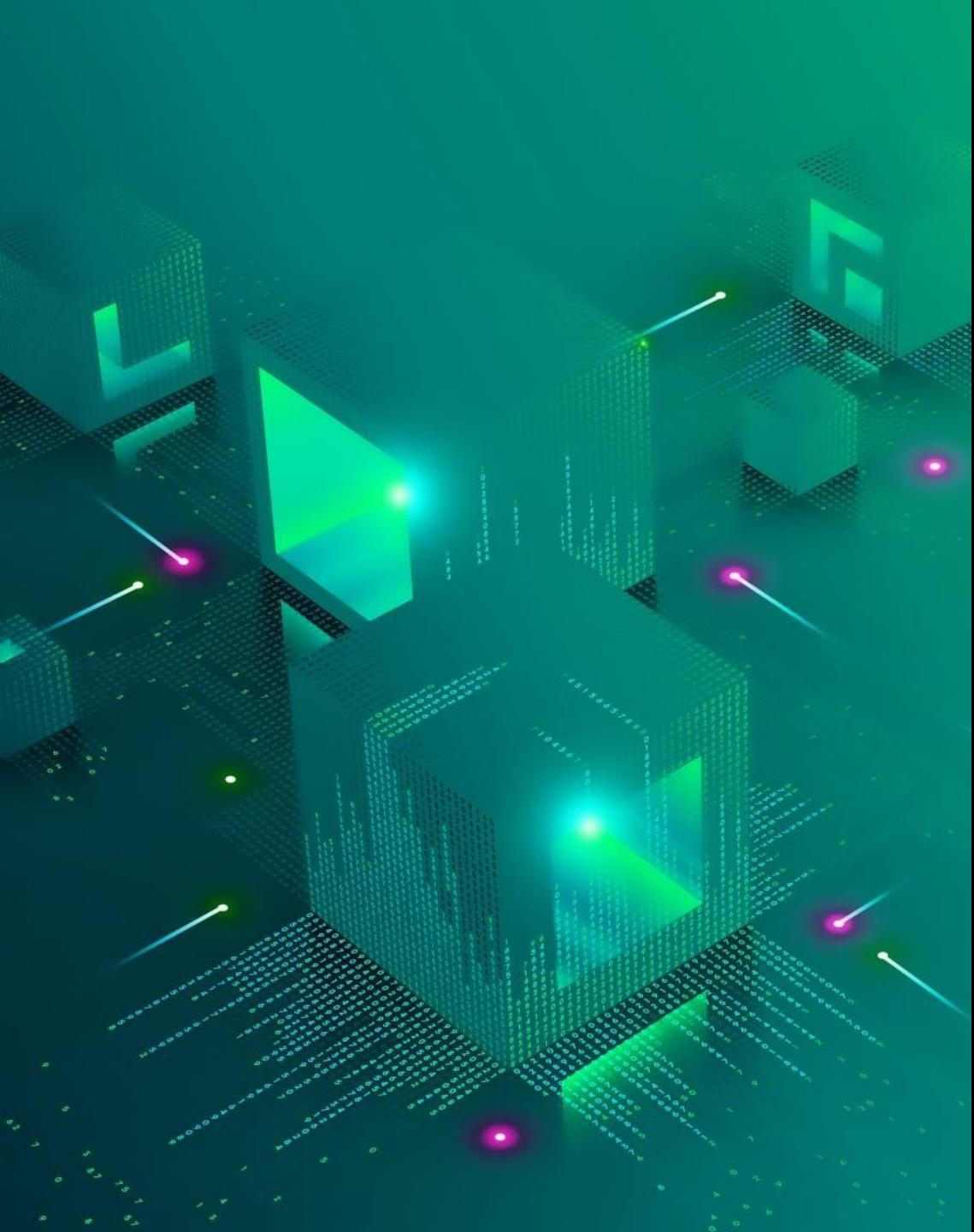
	LogReg	SVM	Tree	KNN
Jaccard_Score	0.800000	0.800000	0.800000	0.800000
F1_Score	0.888889	0.888889	0.888889	0.888889
Accuracy	0.833333	0.833333	0.833333	0.833333

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.
- 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.



Appendix

All Jupyter Notebook of this project is provided on [GitHub](#)

Thank you!

