IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

VATSAL DAVE
https://github.com/007vats/testrepo
07/04/2025

Outline

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

Executive Summary

- Summary of methodologies
  - Data was collected from public SpaceX API and SpaceX Wikipedia page.
  - Created labels column 'class' which classifies successful landings.
  - Data exploration performed using SQL, visualization, folium maps, and dashboards.
  - Gathered relevant columns to be used as features.
  - Changed all categorical variables to binary using one hot encoding.
  - Standardized data and used GridSearchCV to find best parameters for machine learning models. Visualize accuracy score of all models.

- Summary of all results
  - Four machine learning models were produced: Logistic Regression, Support Vector Machine, Decision Tree Classifier, and K Nearest Neighbors.
  - All produced similar results with accuracy rate of about 83.33%. All models over predicted successful landings.
  - More data is needed for better model determination and accuracy.

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

- Problems you want to find answers
  - 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

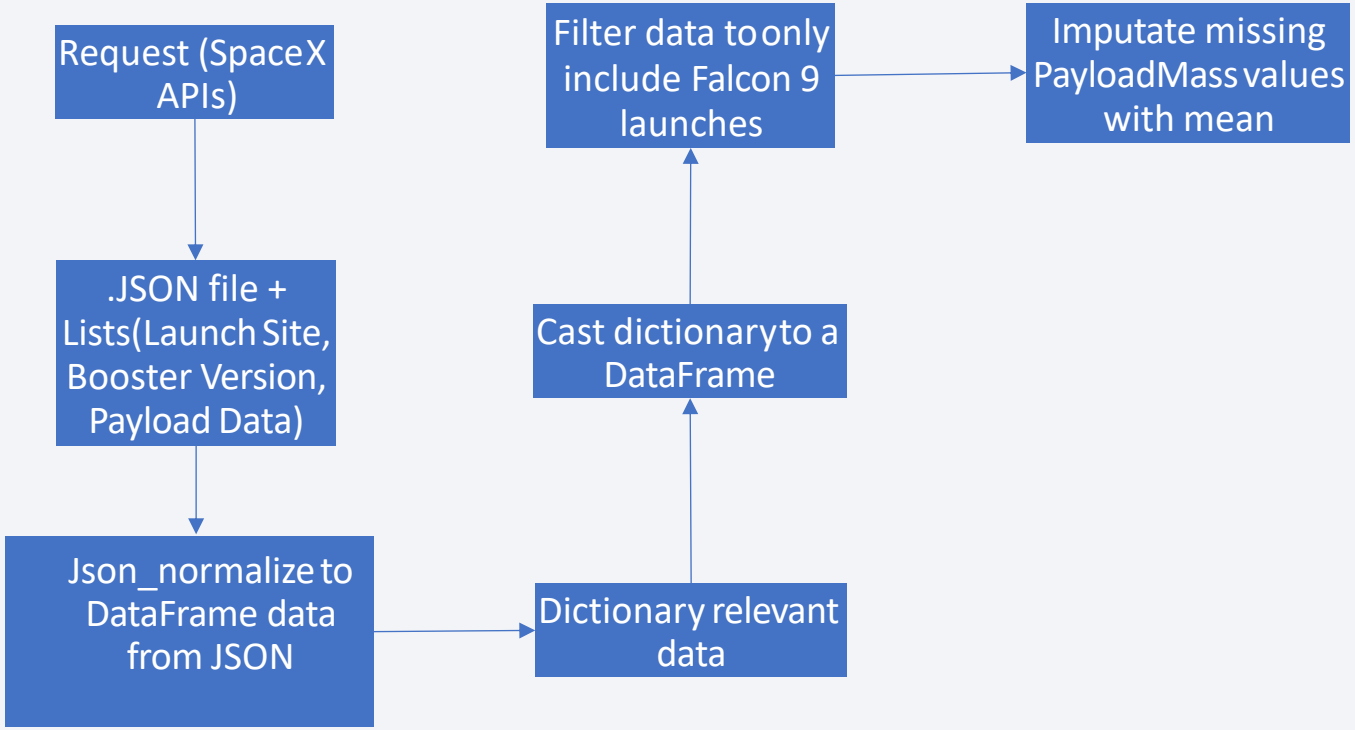
Executive Summary

- Data collection methodology:
  - Combined data from SpaceX public API and SpaceX Wikipedia page
- Perform data wrangling
  - Classifying true landings as successful and unsuccessful otherwise
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - Classifying true landings as successful and unsuccessful otherwise

Data Collection

- Classifying true landings as successful and unsuccessful otherwise.
- The next slide will show the flowchart of data collection from API and the one after will show the flowchart of data collection from webscraping.
- Space X API Data Columns
  - FlightNumber, Date, BoosterVersion, PayloadMass, Orbit, LaunchSite, Outcome, Flights, GridFins,Reused, Legs, LandingPad, Block, ReusedCount, Serial, Longitude, Latitude
- Wikipedia Webscrape Data Columns:
  - Flight No., Launch site, Payload, PayloadMass, Orbit, Customer, Launch outcome, Version Booster, Booster landing, Date, Time

Data Collection – SpaceX API



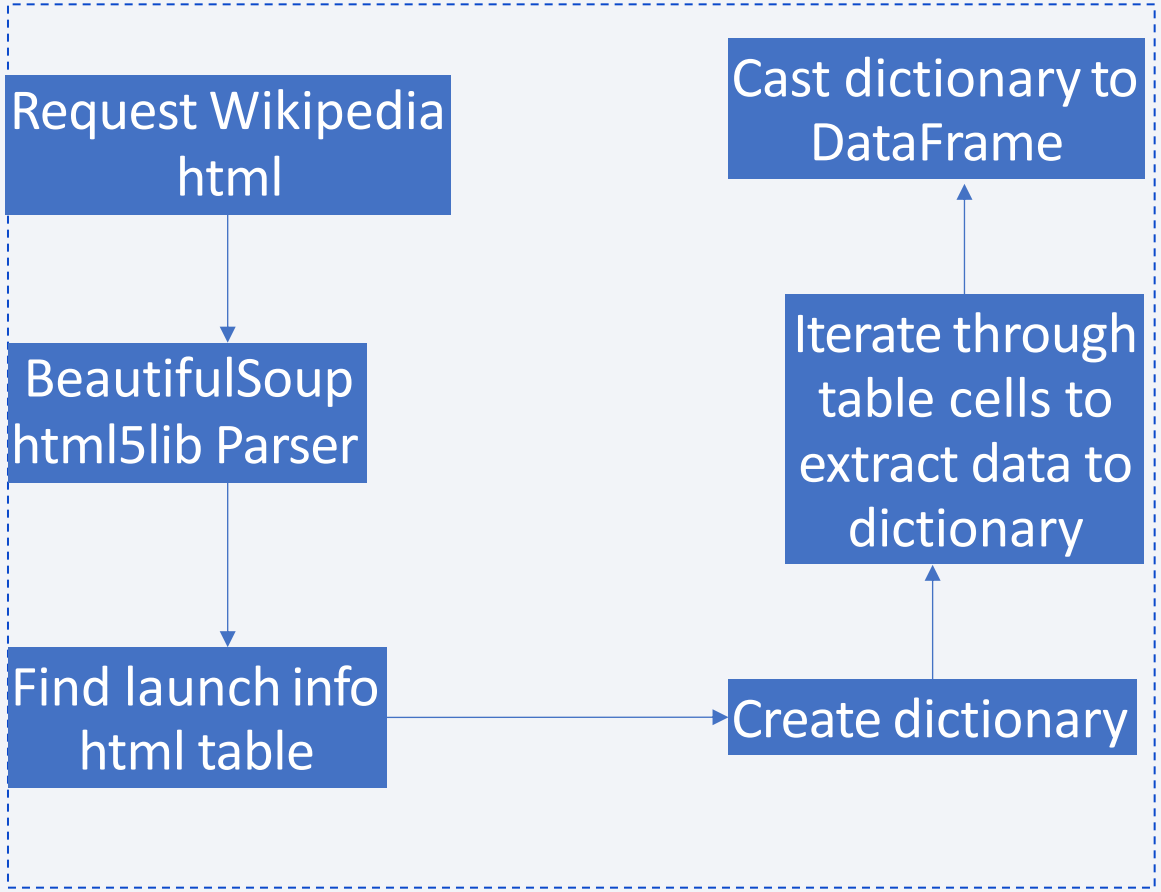
- GIT HUB URL:

https://github.com/007vats/testrepo/blob/main/jupyter-labs-spacex-data-collection-api.ipynb

Data Collection - Scraping

GIT HUB URL:

https://github.com/007vats/testrepo/blob/main/jupyter-labs-webscraping.ipynb



Data Wrangling

Create a training label with landing outcomes where successful = 1 & failure = 0.

Outcome column has two components: ‘Mission Outcome’ ‘Landing Location’

New training label column ‘class’ with a value of 1 if ‘Mission Outcome’ is True and 0 otherwise. Value Mapping:

True ASDS, True RTLS, & True Ocean – set to -> 1

None None, False ASDS, None ASDS, False Ocean, False RTLS – set to -> 0

GitHub url:

https://github.com/007vats/testrepo/blob/main/labs-jupyter-spacex-Data%20wrangling.ipynb

EDA with Data Visualization

Exploratory Data Analysis performed on variables Flight Number, Payload Mass, Launch Site, Orbit, Class and Year.

Plots Used:

Flight Number vs. Payload Mass, Flight Number vs. Launch Site, Payload Mass vs. Launch Site, Orbit vs. Success Rate, Flight Number vs. Orbit, Payload vs Orbit, and Success Yearly Trend

Scatter plots, line charts, and bar plots were used to compare relationships between variables to decide if a relationship exists so that they could be used in training the machine learning model

GitHub url:

https://github.com/007vats/testrepo/blob/main/edadataviz.ipynb

EDA with SQL

Loaded data set into IBM DB2 Database.

Queried using SQL Python integration.

Queries were made to get a better understanding of the dataset.

Queried information about launch site names, mission outcomes, various pay load sizes of customers and booster versions, and landing outcomes

GitHub url:

https://github.com/007vats/testrepo/blob/main/jupyter-labs-eda-sql-coursera_sqllite.ipynb

Build an Interactive Map with Folium

Folium maps mark Launch Sites, successful and unsuccessful landings, and a proximity example to key locations: Railway, Highway, Coast, and City.

This allows us to understand why launch sites may be located where they are. Also visualizes successful landings relative to location.

GitHub url:

https://github.com/007vats/testrepo/blob/main/lab_jupyter_launch_site_location.ipynb

Build a Dashboard with Plotly Dash

Dashboard includes a pie chart and a scatter plot.

Pie chart can be selected to show distribution of successful landings across all launch sites and can be selected to show individual launch site success rates.

Scatter plot takes two inputs: All sites or individual site and payload mass on a slider between 0 and 10000 kg.

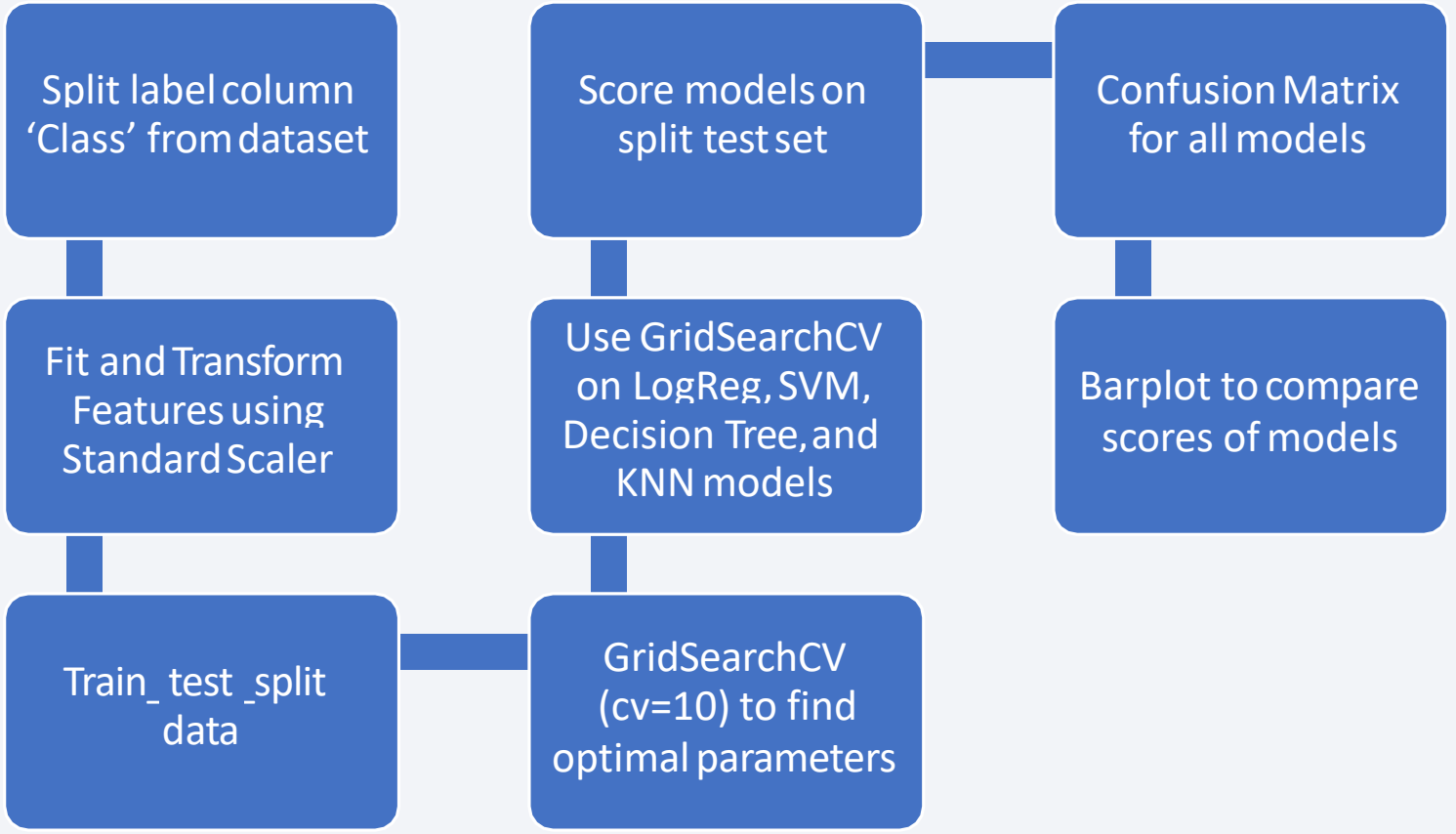
The pie chart is used to visualize launch site success rate.

The scatter plot can help us see how success varies across launch sites, payload mass, and booster version category.

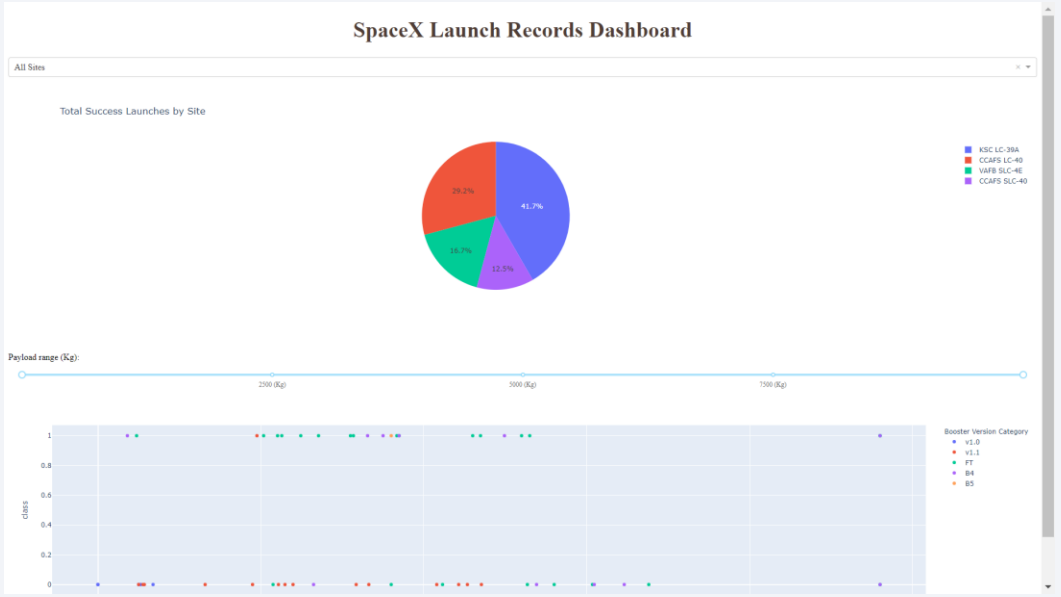
Predictive Analysis (Classification)

GitHub url:

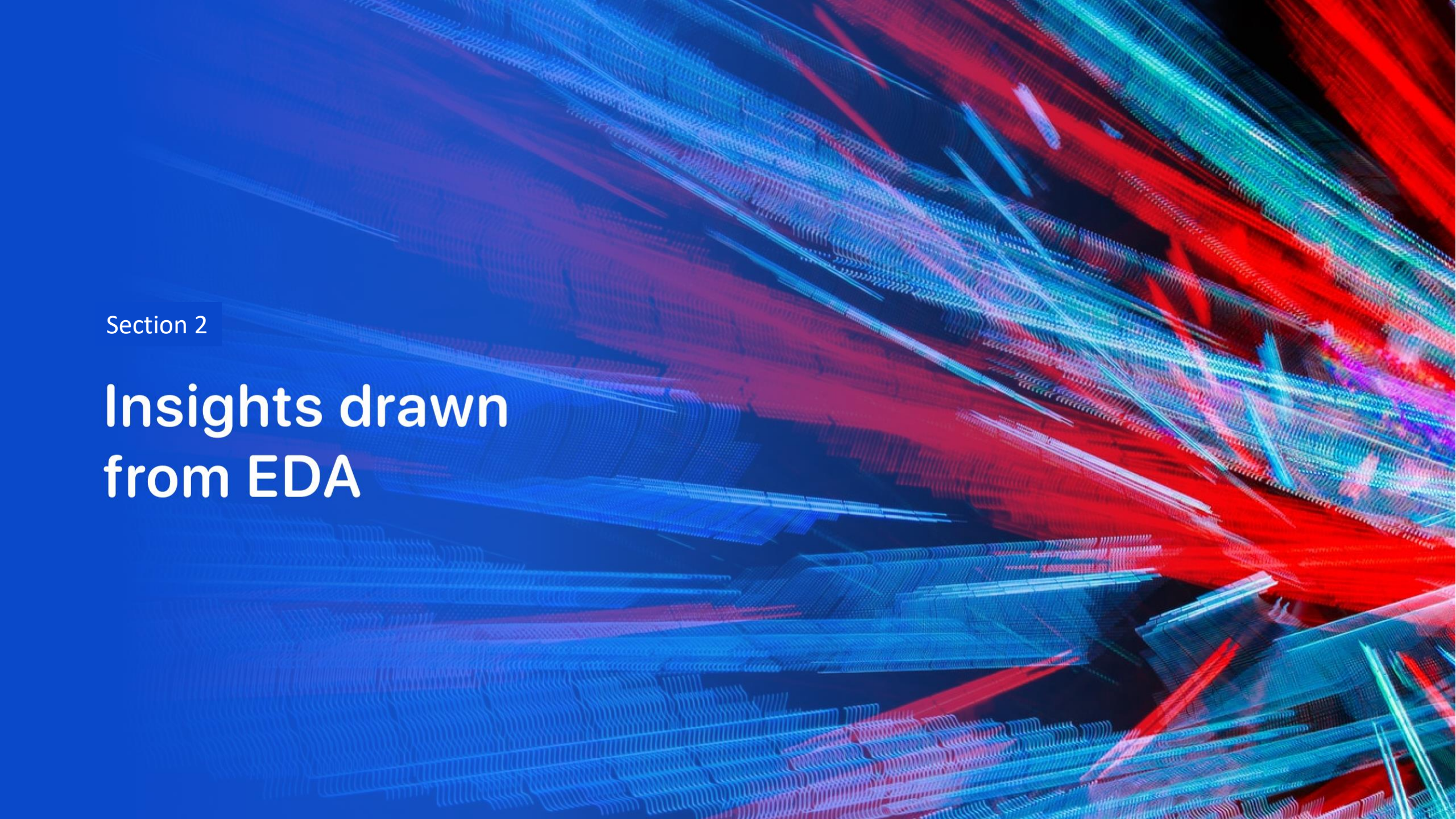
https://github.com/007vats/testrepo/blob/main/SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb



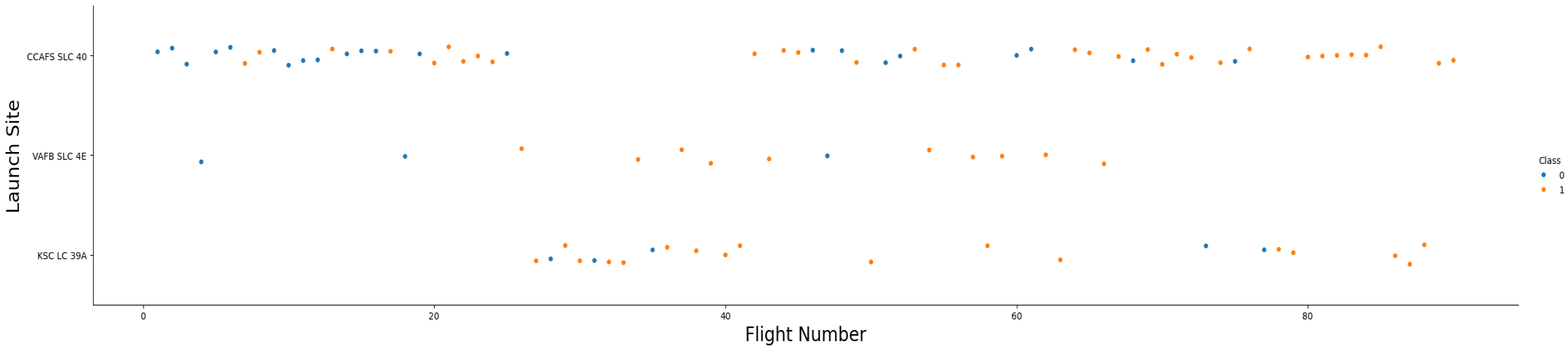
Results



This is a preview of the Plotly dashboard. The following sides will show the results of EDA with visualization, EDA with SQL, Interactive Map with Folium, and finally the results of our model with about 83% accuracy.

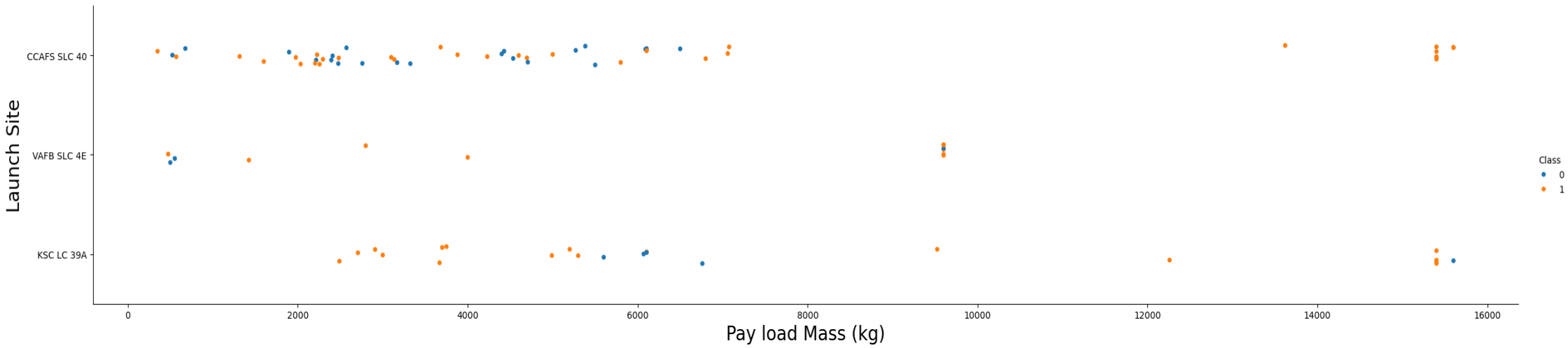

Section 2
Insights drawn from EDA

Flight Number vs. Launch Site



- 0 (blue) indicates unsuccessful landing, 1 (orange) indicates successful landing.
- 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.

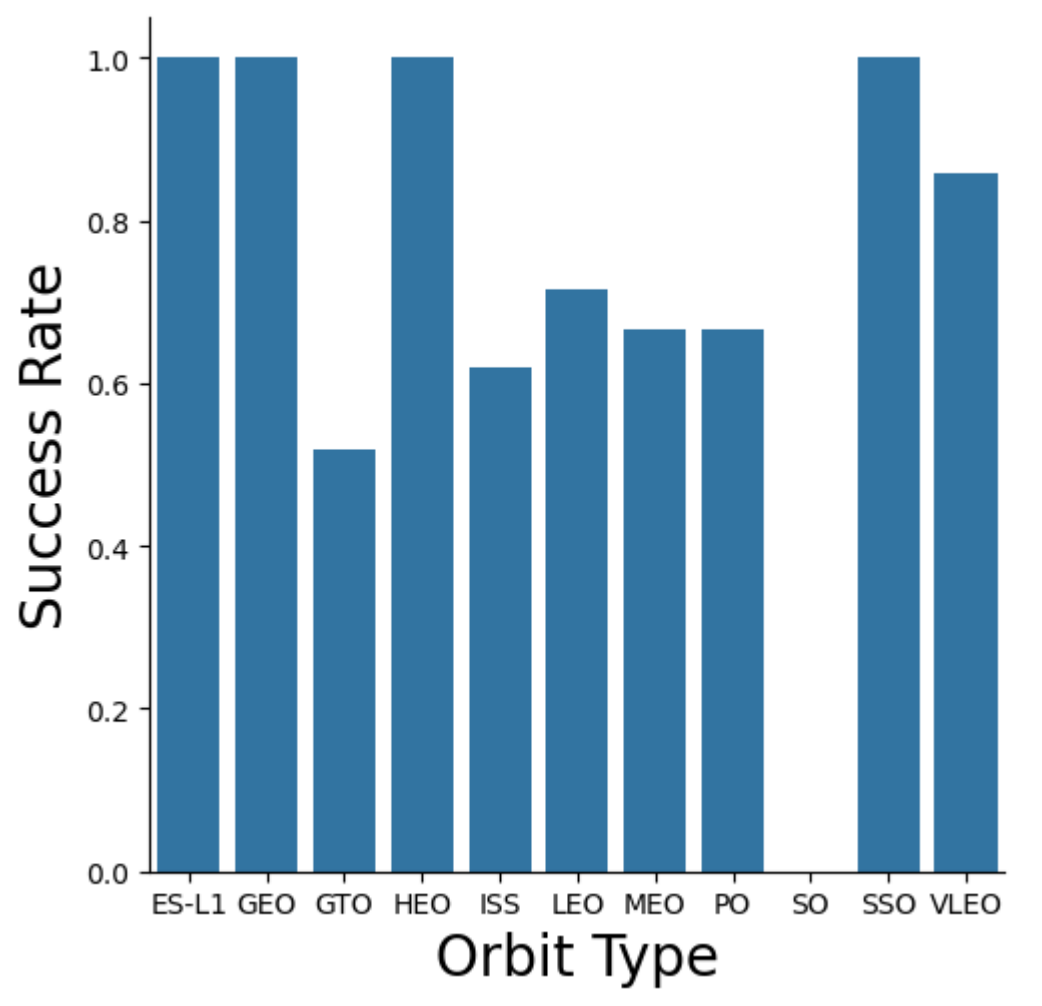
Payload vs. Launch Site



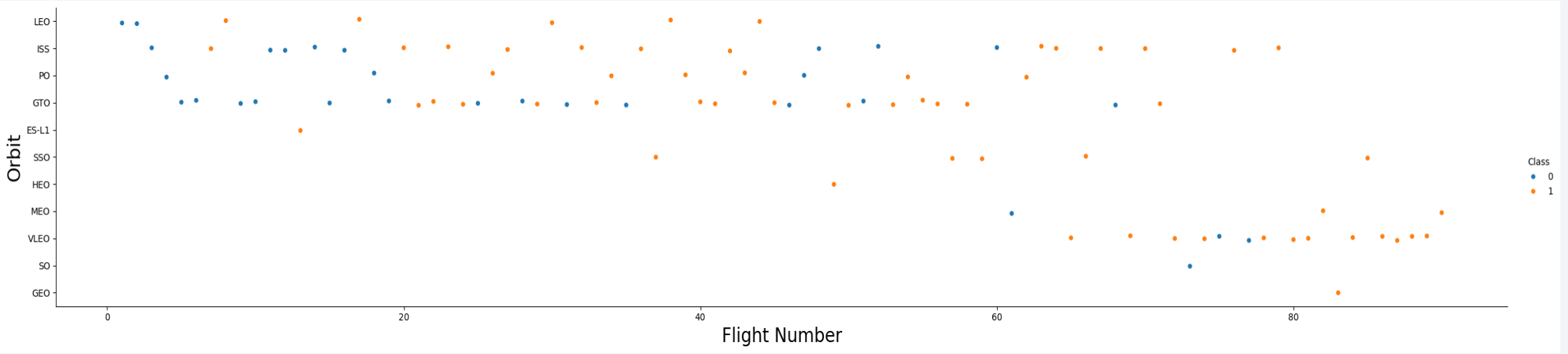
- 0 (blue) indicates unsuccessful landing, 1 (orange) indicates successful landing.
- For VAFB-SLC launch site there are no rockets launched for heavy payload mass (greater than 10000).

Success Rate vs. Orbit Type

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

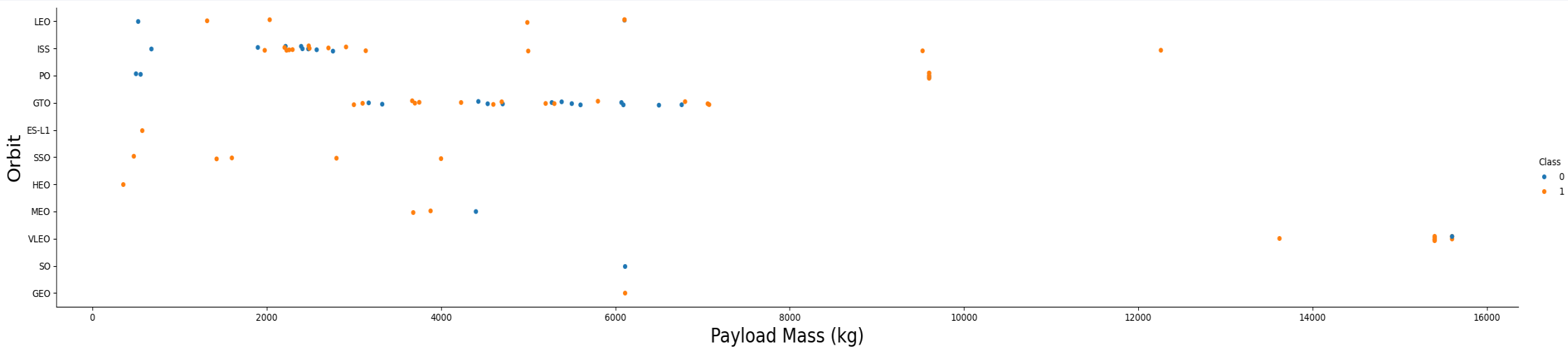


Flight Number vs. Orbit Type



- In the LEO orbit, success seems to be related to the number of flights. Conversely, in the GTO orbit, there appears to be no relationship between flight number and success.

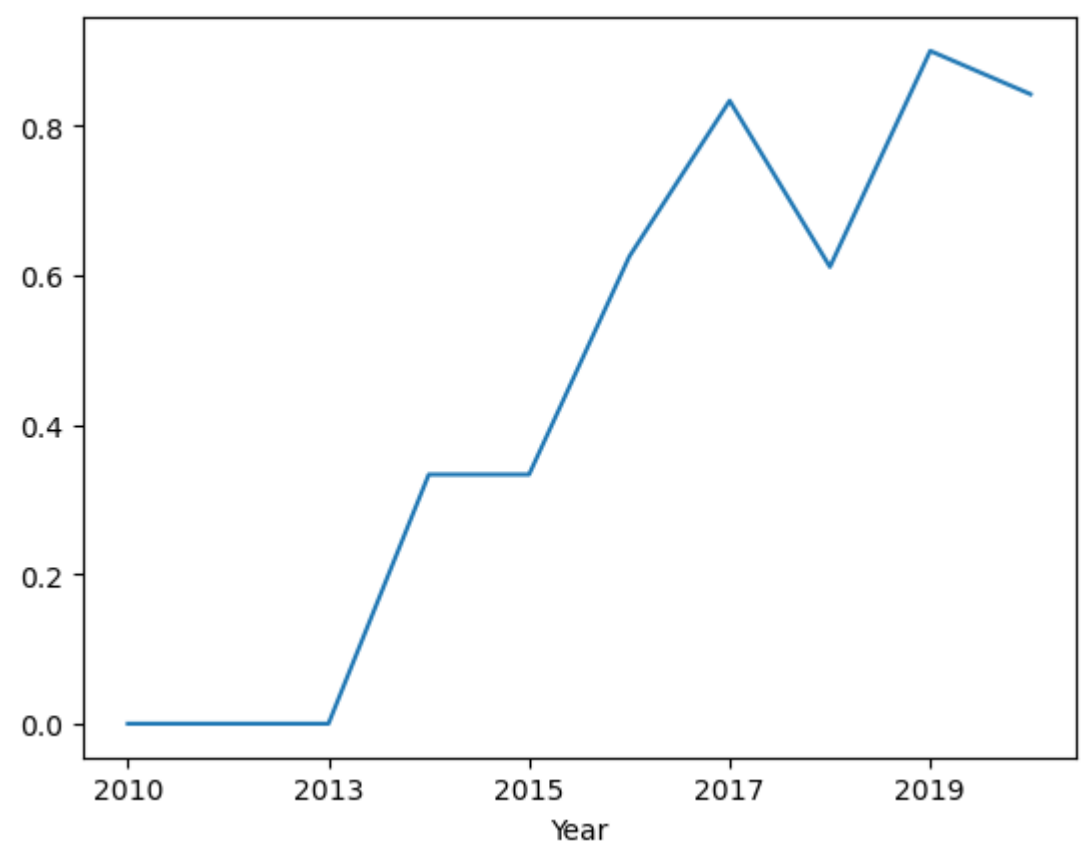
Payload vs. Orbit Type



- With heavy payloads the successful landing or positive landing rate are more for Polar, LEO and ISS.
- However, for GTO, it's difficult to distinguish between successful and unsuccessful landings as both outcomes are present.

Launch Success Yearly Trend

- The success rate since 2013 kept increasing till 2020
- Success in recent years is around 80%, with a slight dip in 2018.



All Launch Site Names

- Query unique launch site names from database.
- CCAFS SLC-40 and CCAFSSLC-40 likely represent the same launch site with data entry errors.
- Likely only 3 unique

  launch sites:

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

```
In [13]: %sql select distinct launch_site from SPACEXTBL;
 * sqlite:///my_data1.db
Done.
```

Out[13]:

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

Launch Site Names Begin with 'CCA'

```
In [14]: %sql select * from SPACEXTBL where launch_site like 'CCA%' limit 5;
 * sqlite:///my_data1.db
Done.
```

Out[14]:

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing_Outcome
2010-06-04	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-12-08	15:43:00	F9 v1.0 B0004	CCAFS LC-40	Dragon demo flight C1, two CubeSats, barrel of Brouere cheese	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2012-05-22	7:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	0:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-03-01	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

- First five entries in database with Launch Site name beginning with CCA.

Total Payload Mass

```
In [21]: %sql select sum(payload_mass__kg_) as total_payload_mass from SPACEXTBL where customer = 'NASA (CRS)';
 * sqlite:///my_data1.db
Done.
Out[21]:
```

total_payload_mass
45596

- This query sums the total payload mass in kg where NASA was the customer.
- CRS stands for Commercial Resupply Services which indicates that these payloads were sent to the International Space Station (ISS).

Average Payload Mass by F9 v1.1

```
In [17]: %sql select avg(payload_mass__kg_) as average_payload_mass from SPACEXTBL where booster_version like '%F9 v1.1%';
 * sqlite:///my_data1.db
Done.
```

Out[17]:

average_payload_mass
2534.6666666666665

- This query calculates the average payload mass or launches which used booster version F9 v1.1
- Average payload mass of F9 1.1 is on the low end of our payload mass range

First Successful Ground Landing Date

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

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

first_successful_landing
2015-12-22

- This query returns the first successful ground pad landing date.
- First ground pad landing wasn’t until the end of 2015.
- Successful landings in general appear starting 2014.

Successful Drone Ship Landing with Payload between 4000 and 6000

```
%sql select booster_version from SPACEXTBL where Landing_Outcome = 'Success (drone ship)' and payload_mass__kg_ between 4000 and 6000;
```

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

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

- This query returns the four booster versions that had successful drone ship landings and a payload mass between 4000 and 6000 non inclusively.

Total Number of Successful and Failure Mission Outcomes

```
[22]: %sql select mission_outcome, count(*) as total_number from SPACEXTBL group by mission_outcome;
 * sqlite:///my_data1.db
Done.
```

[22]:

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

- This query returns a count of each mission outcome.
- SpaceX appears to achieve its mission outcome nearly 99% of the time.
- This means that most of the landing failures are intended.
- Interestingly, one launch has an unclear payload status and unfortunately one failed in flight.

Boosters Carried Maximum Payload

```
%sql select booster_version from SPACEXTBL where payload_mass__kg_ = (select max(PAYLOAD_MASS__KG_) from SPACEXTBL);
```

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

Booster_Version
F9 B5 B1048.4
F9 B5 B1049.4
F9 B5 B1051.3
F9 B5 B1056.4
F9 B5 B1048.5
F9 B5 B1051.4
F9 B5 B1049.5
F9 B5 B1060.2
F9 B5 B1058.3
F9 B5 B1051.6
F9 B5 B1060.3
F9 B5 B1049.7

- This query returns the booster versions that carried the highest payload mass of 15600 kg.
- These booster versions are similar, and all are of the F9 B5 B10xx.x variety.
- This likely indicates payload mass correlates with the booster version that is used.

2015 Launch Records

- This query returns the Month, Landing Outcome, Booster Version, and Launch site of 2015 launches where stage 1 failed to land on a drone ship.
- There were two such occurrences.

```
%%sql
SELECT strftime('%m', date) as month,
       date,
       booster_version,
       Launch_Site,
       Landing_Outcome
FROM SPACEXTBL
WHERE Landing_Outcome = 'Failure (drone ship)'
  AND strftime('%Y', date) = '2015';
```

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

month	Date	Booster_Version	Launch_Site	Landing_Outcome
01	2015-01-10	F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)
04	2015-04-14	F9 v1.1 B1015	CCAFS LC-40	Failure (drone ship)

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

- This query returns a list of successful landings and between 2010-06-04 and 2017-03-20 inclusively.
- There are two types of successful landing outcomes: drone ship and ground pad landings.
- There were 8 successful landings in total during this time period

```
]: %%sql select Landing_Outcome, count(*) as count_outcomes from SPACEXTBL
       where date between '2010-06-04' and '2017-03-20'
       group by Landing_Outcome
       order by count_outcomes desc;
```

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

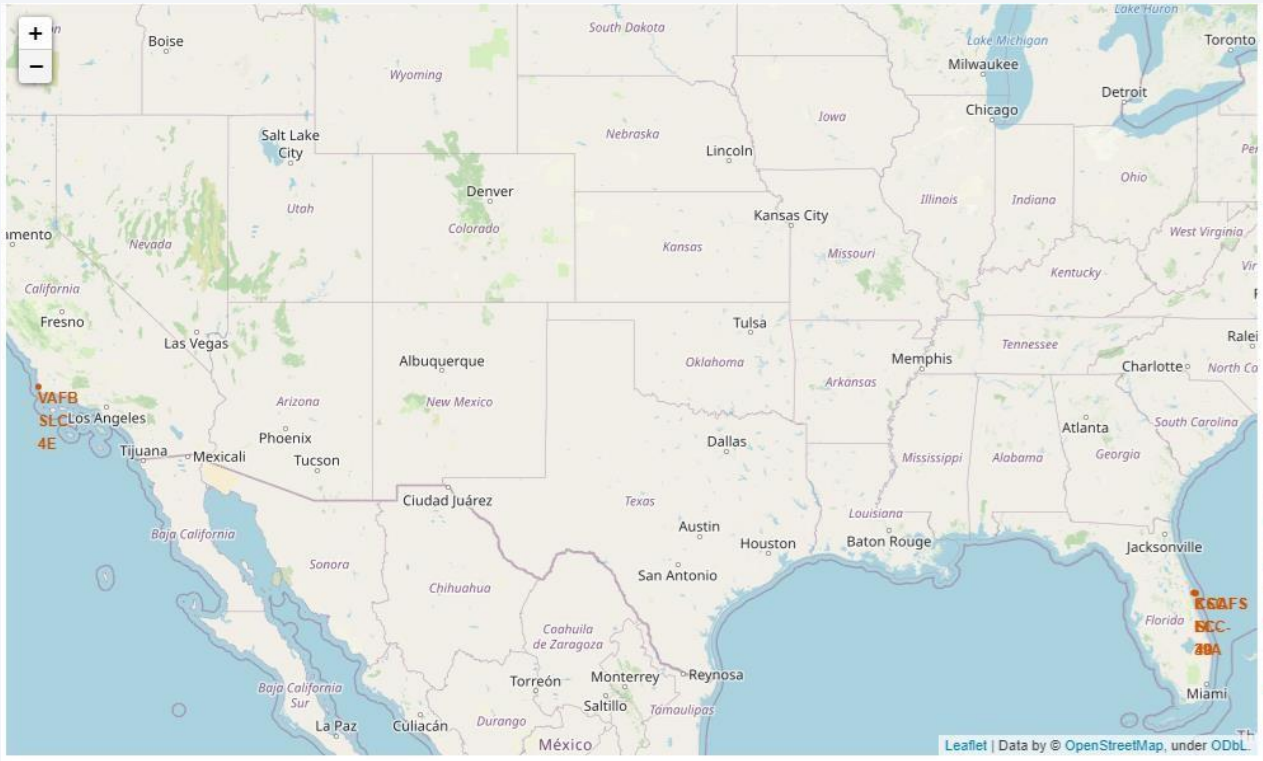
]:

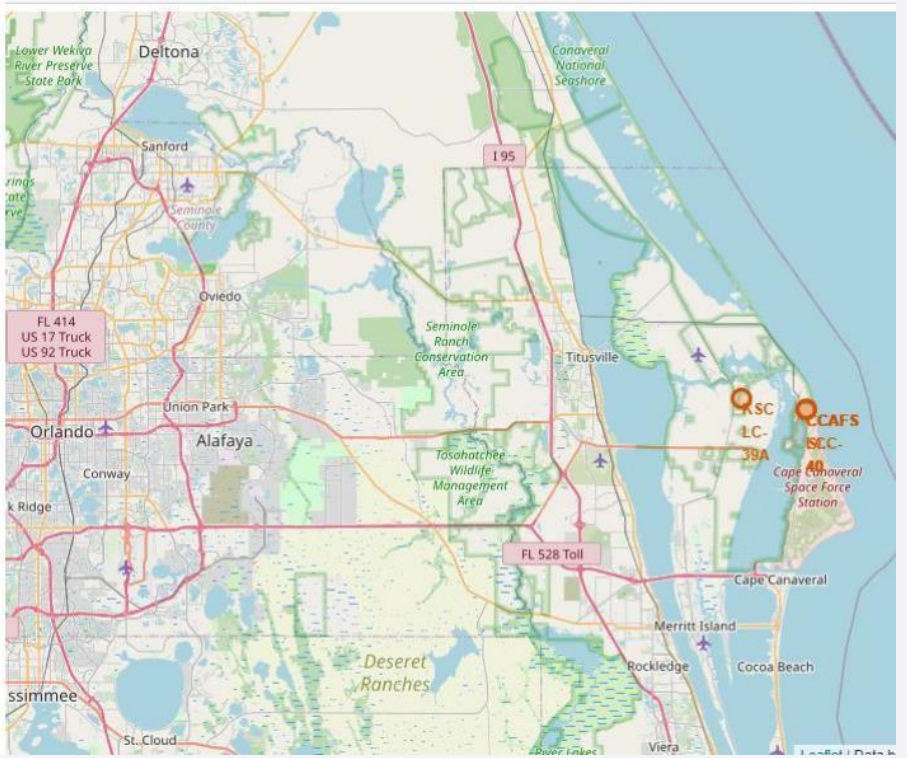
Landing_Outcome	count_outcomes
No attempt	10
Success (drone ship)	5
Failure (drone ship)	5
Success (ground pad)	3
Controlled (ocean)	3
Uncontrolled (ocean)	2
Failure (parachute)	2
Precluded (drone ship)	1

Section 3

Launch Sites Proximities Analysis

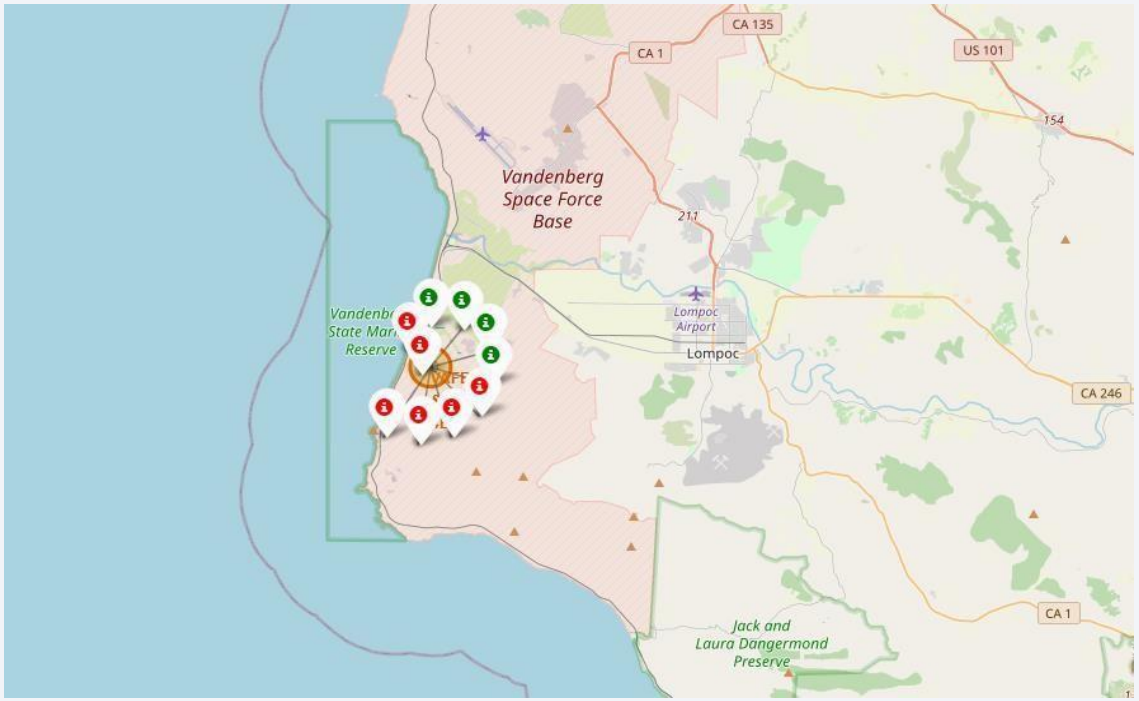
Launch Site Locations





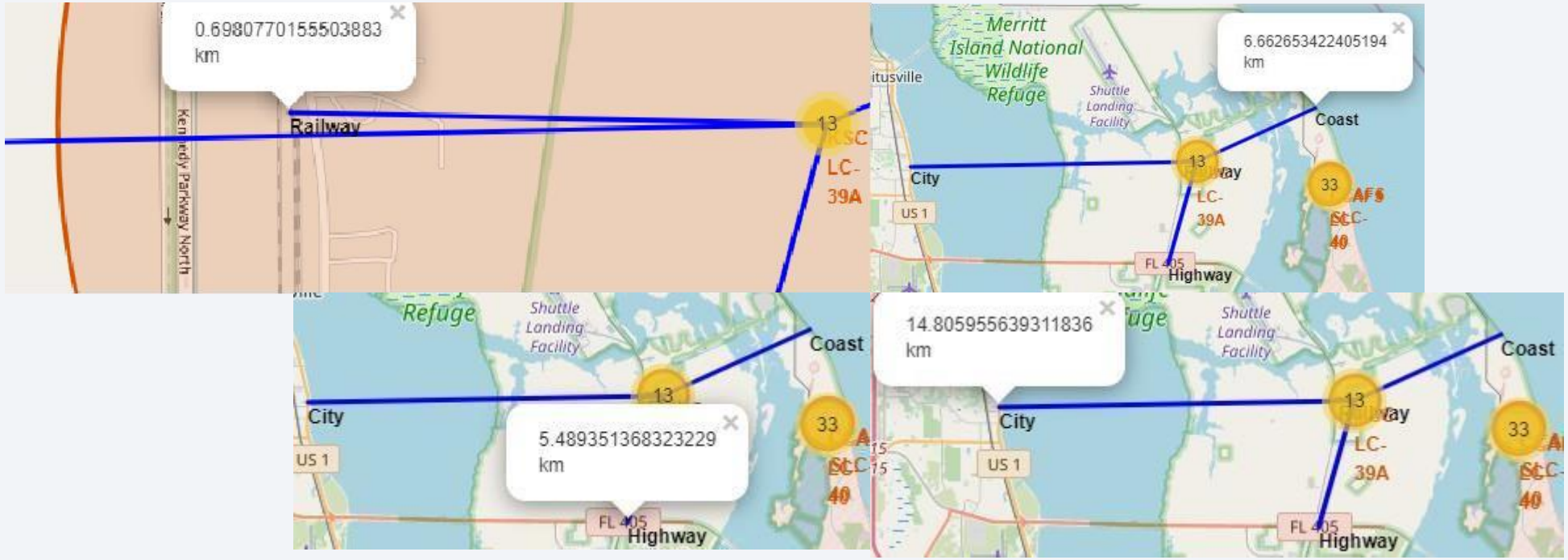
Map on the left shows all launch sites relative the US. Map on the right shows the two Florida launch sites since they are very close to each other. All launch sites are near the ocean.

Color-Coded Launch Markers



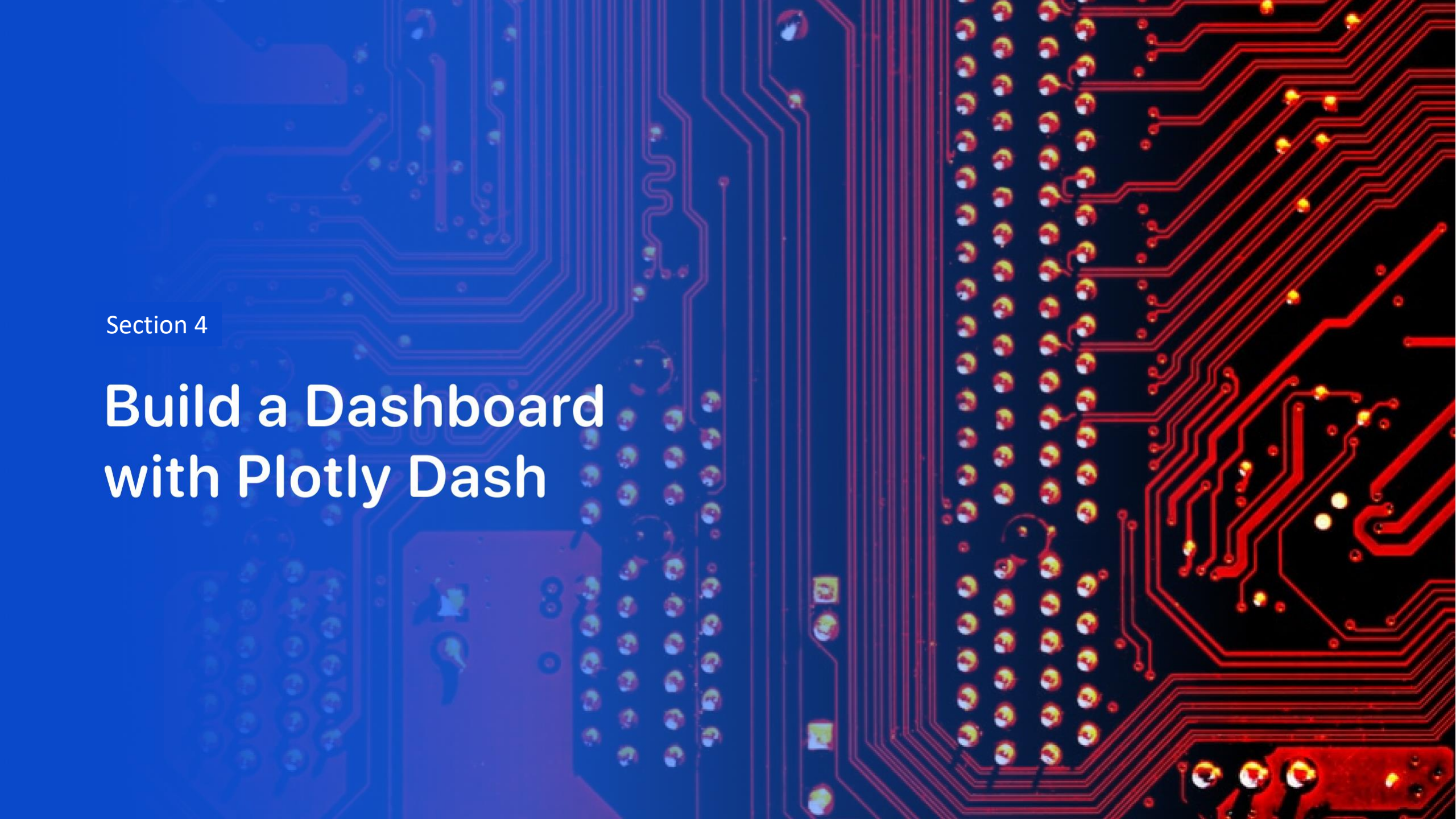
- Successful landing- Green icon
- Failed landing- Red icon
- VAFB SLC-4E shows 4 successful landings and 6 failed landings.

<Folium Map Screenshot 3>



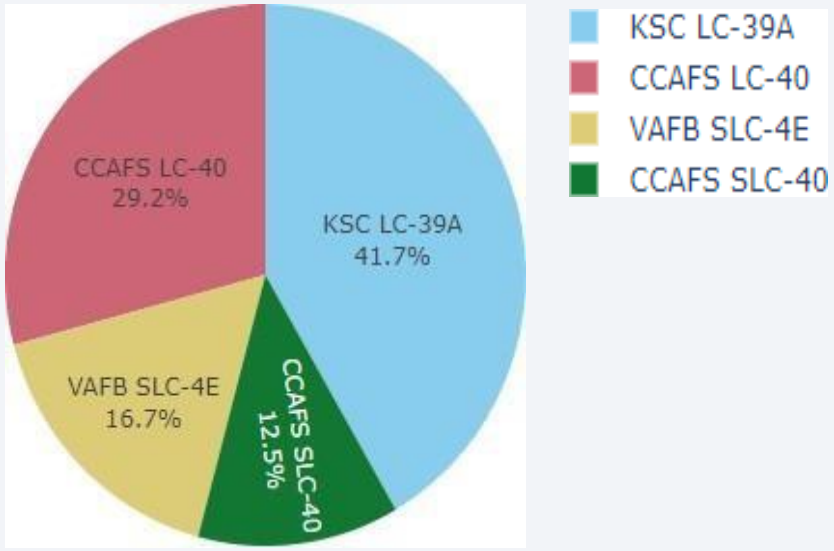
Using KSC LC-39A as an example, launch sites are very close to railways for large machineries and transportation.

Launch sites are close to highways for human resource and supplies transportation. Launch sites are also close to coasts and relatively far from cities so that launch failures can land in the sea to avoid rockets falling on densely populated areas.


Section 4
Build a Dashboard with Plotly Dash

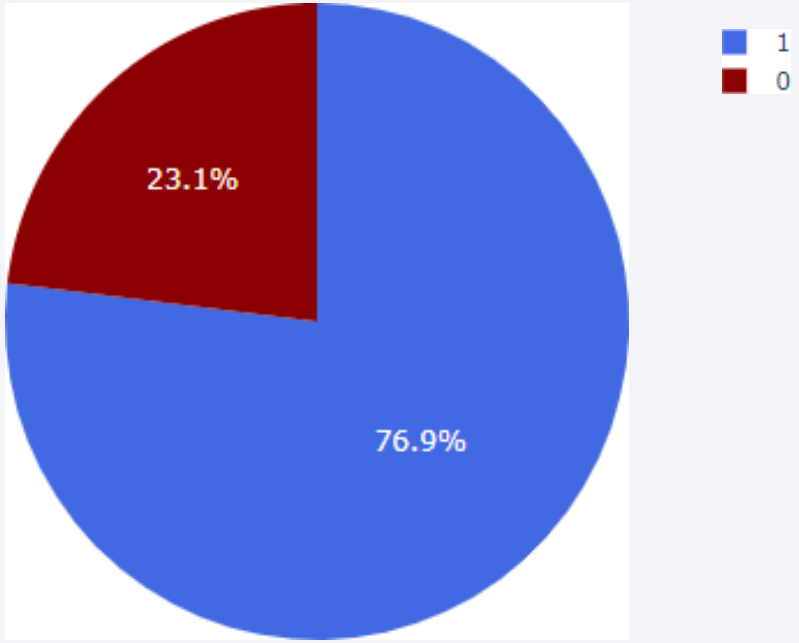
Successful Launches across Launch sites

- VAFB has the smallest share of successful landings. This may be due to smaller sample and increase in difficulty of launching in the west coast.



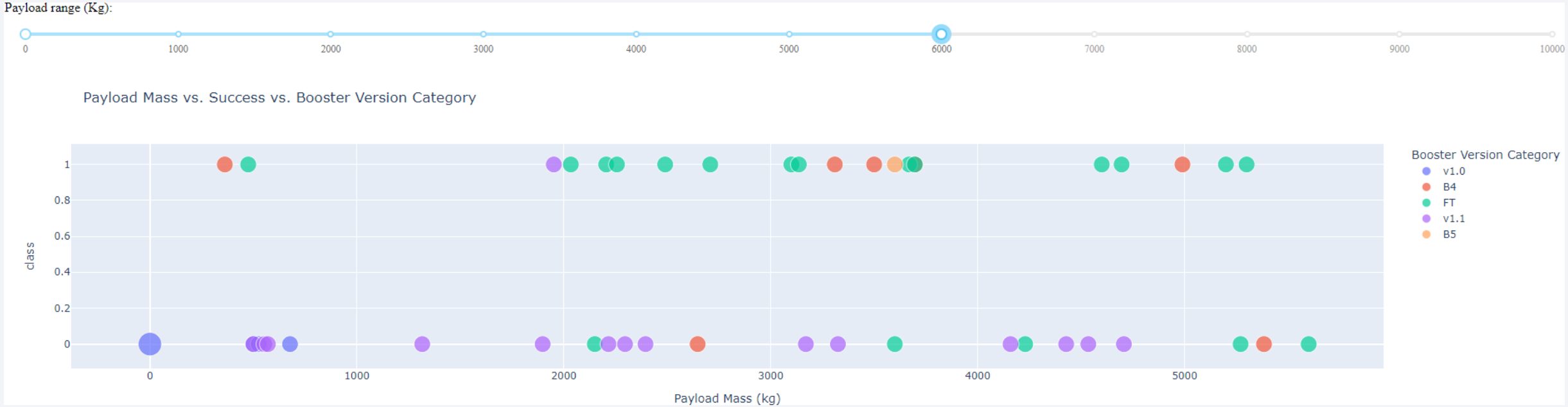
Launch site Success Rate

- KSC LC-39A has the highest success rate with 10 successful landings and 3 failed landings.



KSC LC-39A Success Rate (blue=success)

Payload Mass vs. Success vs. Booster Version Category



1 : successful landing;

0: failure.

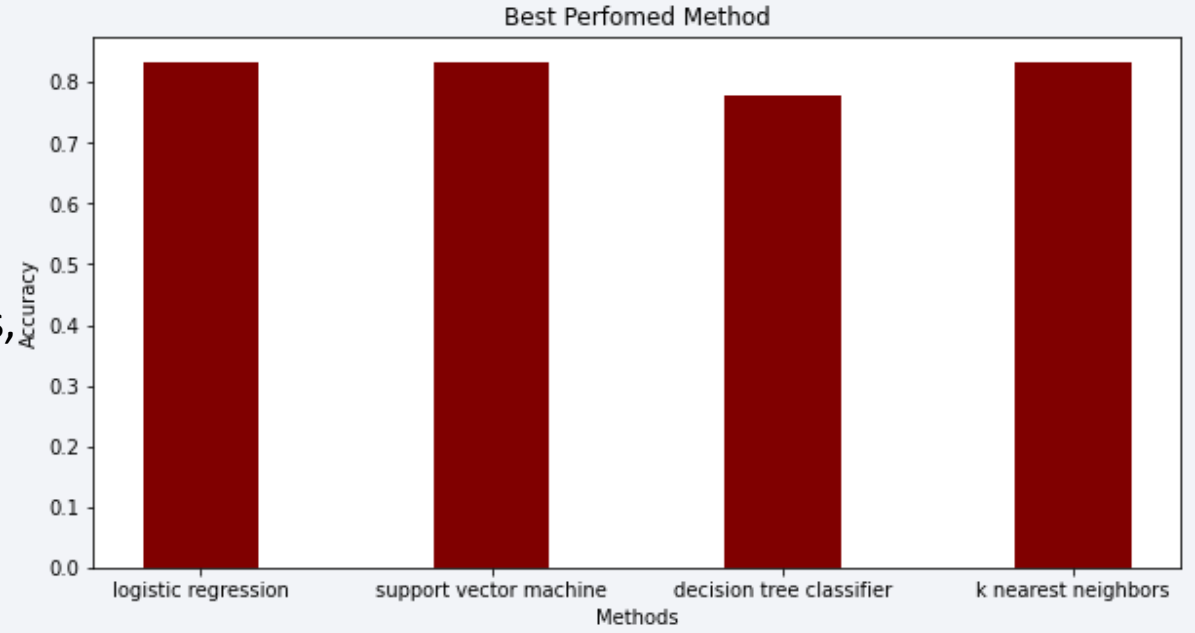
There are two failed landings with payloads of zero kg.

Section 5

Predictive Analysis (Classification)

Classification Accuracy

- All models had similar accuracy on the test set ~83.33%.
- It should be noted that test size is small at only sample size of 18.
- This can cause large variance in accuracy results, such as those in Decision Tree Classifier model in repeated runs.
- We likely need more data to determine the best model.



	LogReg	SVM	Tree	KNN
Jaccard_Score	0.800000	0.800000	0.846154	0.800000
F1_Score	0.888889	0.888889	0.916667	0.888889
Accuracy	0.833333	0.833333	0.888889	0.833333

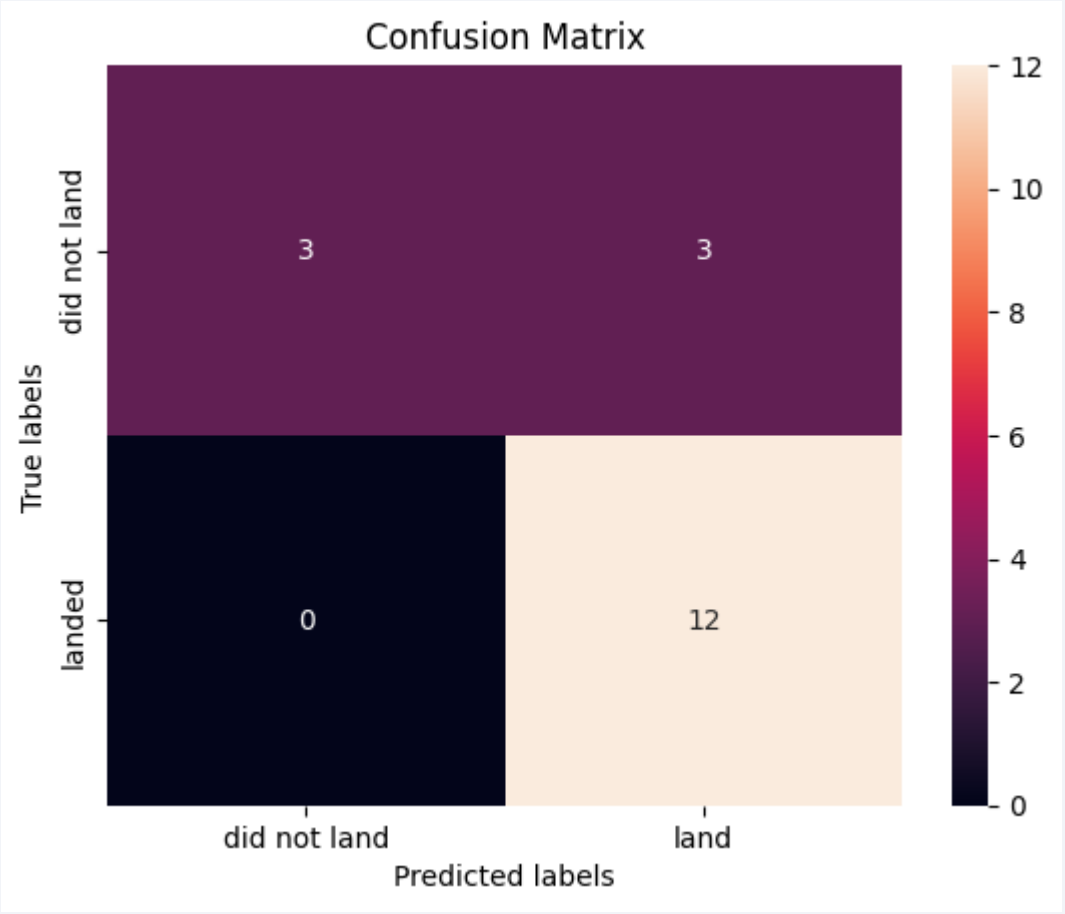
Confusion Matrix

Since all models performed the same for the test set, the confusion matrix is the same for all models.

The models predicted 12 successful landings.

The models predicted 3 unsuccessful landings.

The models predicted 3 successful landings.



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

- Git Hub repository URL: https://github.com/007vats/testrepo/tree/main
- Special thanks to all course era instructors: https://www.coursera.org/professional-certificates/ibm-data-science?#instructors

Thank you!