

Winning Space Race with Data Science

Vaibhav Vemula
05/09/2021



Outline

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

Executive Summary

- Collected data from public SpaceX API and scraped SpaceX Wikipedia page. Created labels column ‘class’ which classifies successful landings. Explored data using SQL, visualisation, folium maps, and dashboards. Gathered relevant columns to be used as features. Changed all categorical variables to binary using one hot encoding. Standardised data and used GridSearchCV to find best parameters for machine learning models. Visualise accuracy score of all models.
- Four machine learning models were produced: Logistic Regression, Support Vector Machine, Decision Tree Classifier, and K Nearest Neighbours. All produced similar results with accuracy rate of about 83.3%. All models over predicted successful landings. More data is needed for better model determination and accuracy.

Introduction

Background:

- Commercial Space Age is Here
- Space X has best pricing (\$62 million vs. \$165 million USD)
- Largely due to ability to recover part of rocket (Stage 1)
- Space Y wants to compete with Space X

Problem:

- Space Y gives us a task to train a machine learning model to predict successful Stage 1 recovery/landing.

Section 1

Methodology

Methodology

- Data collection methodology:
 - Combined data from SpaceX public API and SpaceX Wikipedia page
- Performed data wrangling
 - Classifying true landings as successful and unsuccessful otherwise
- Performed exploratory data analysis (EDA) using visualisation and SQL
- Performed interactive visual analytics using Folium and Plotly Dash
- Performed predictive analysis using classification models
 - Tuned models using GridSearchCV with a cv value of 10

Data Collection

Data collection process involved a combination of API requests from Space X public API and web scraping data from a table in Space X's Wikipedia entry.

The next slide will show the flowchart of data collection from API and the one after will show the flowchart of data collection from web scraping.

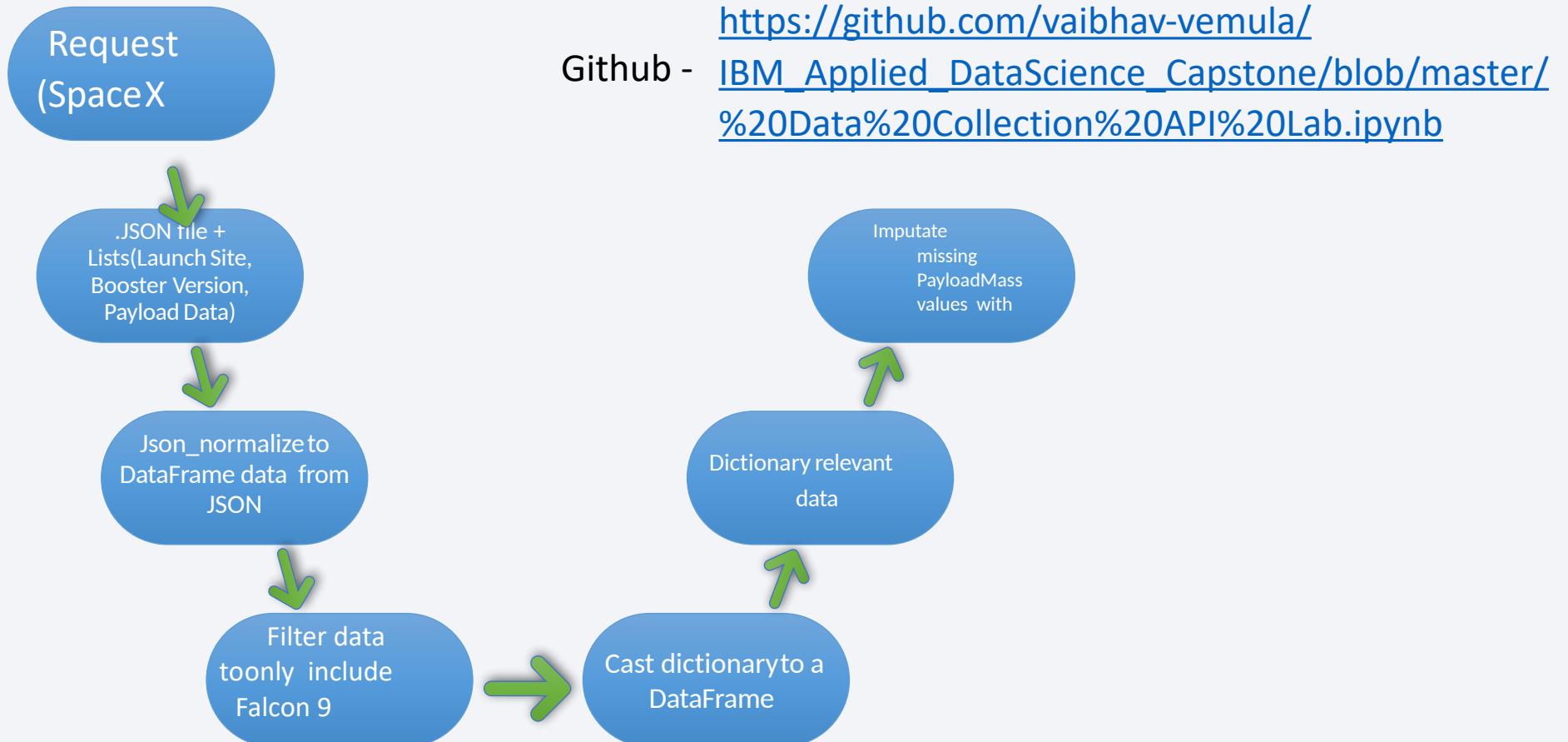
Space X API Data Columns:

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

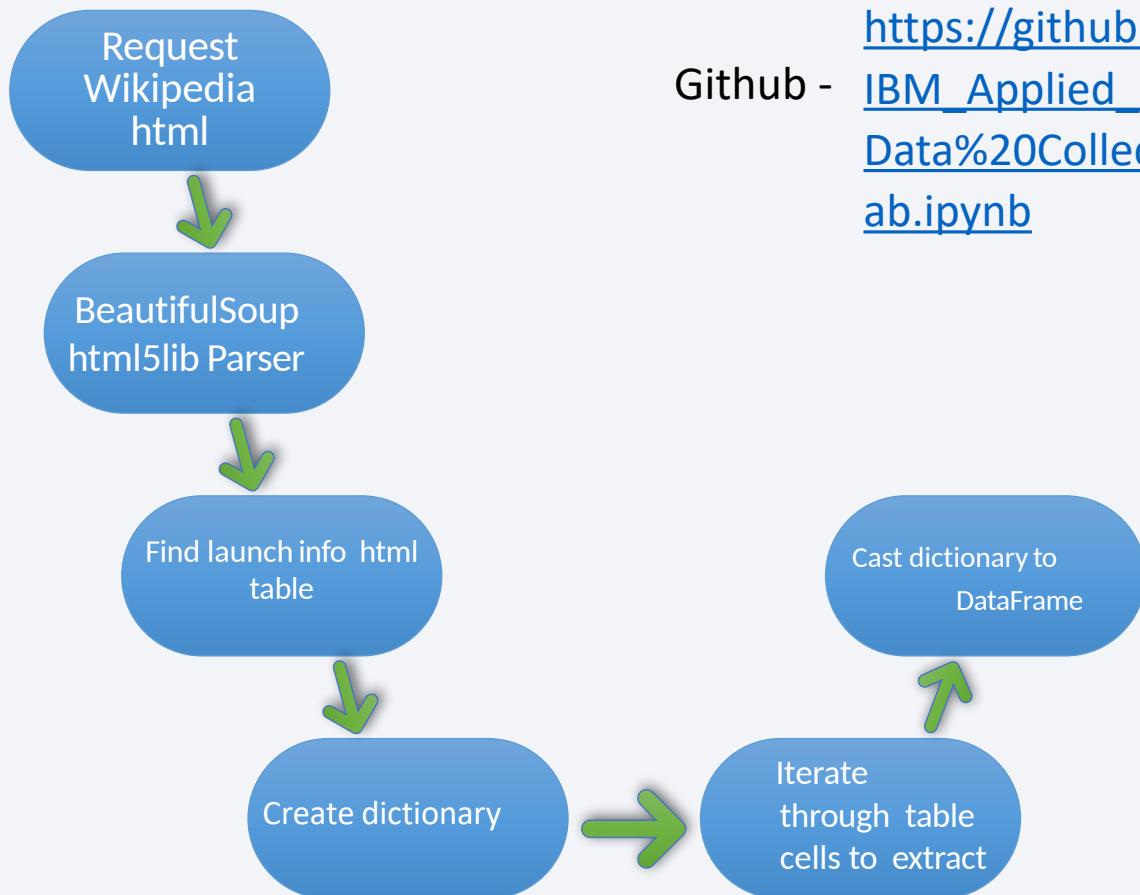
Wikipedia Webscrape Data Columns:

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

Data Collection – SpaceX API



Data Collection - Scraping



GitHub - [https://github.com/vaibhav-vemula/
IBM_Applied_DataScience_Capstone/blob/master/
Data%20Collection%20with%20Web%20Scraping%20Iab.ipynb](https://github.com/vaibhav-vemula/IBM_Applied_DataScience_Capstone/blob/master/Data%20Collection%20with%20Web%20Scraping%20Iab.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

<https://github.com/vaibhav-vemula/>

Github - [IBM_Applied_DataScience_Capstone/blob/master/
Data%20Wrangling%20lab.ipynb](https://github.com/vaibhav-vemula/IBM_Applied_DataScience_Capstone/blob/master/Data%20Wrangling%20lab.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.

<https://github.com/vaibhav-vemula/>

Github - [IBM_Applied_DataScience_Capstone/blob/master/
EDA%20with%20Visualization%20lab.ipynb](https://github.com/vaibhav-vemula/blob/master/EDA%20with%20Visualization%20lab.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

<https://github.com/vaibhav-vemula/>

Github - [IBM_Applied_DataScience_Capstone/blob/master/
EDA%20with%20SQL%20lab.ipynb](https://github.com/vaibhav-vemula/IBM_Applied_DataScience_Capstone/blob/master/EDA%20with%20SQL%20lab.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.

<https://github.com/vaibhav-vemula/>

Github - [IBM_Applied_DataScience_Capstone/blob/master/
Interactive%20Visual%20Analytics%20with%20Folium
%20lab.ipynb](https://github.com/vaibhav-vemula/IBM_Applied_DataScience_Capstone/blob/master/Interactive%20Visual%20Analytics%20with%20Folium%20lab.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.

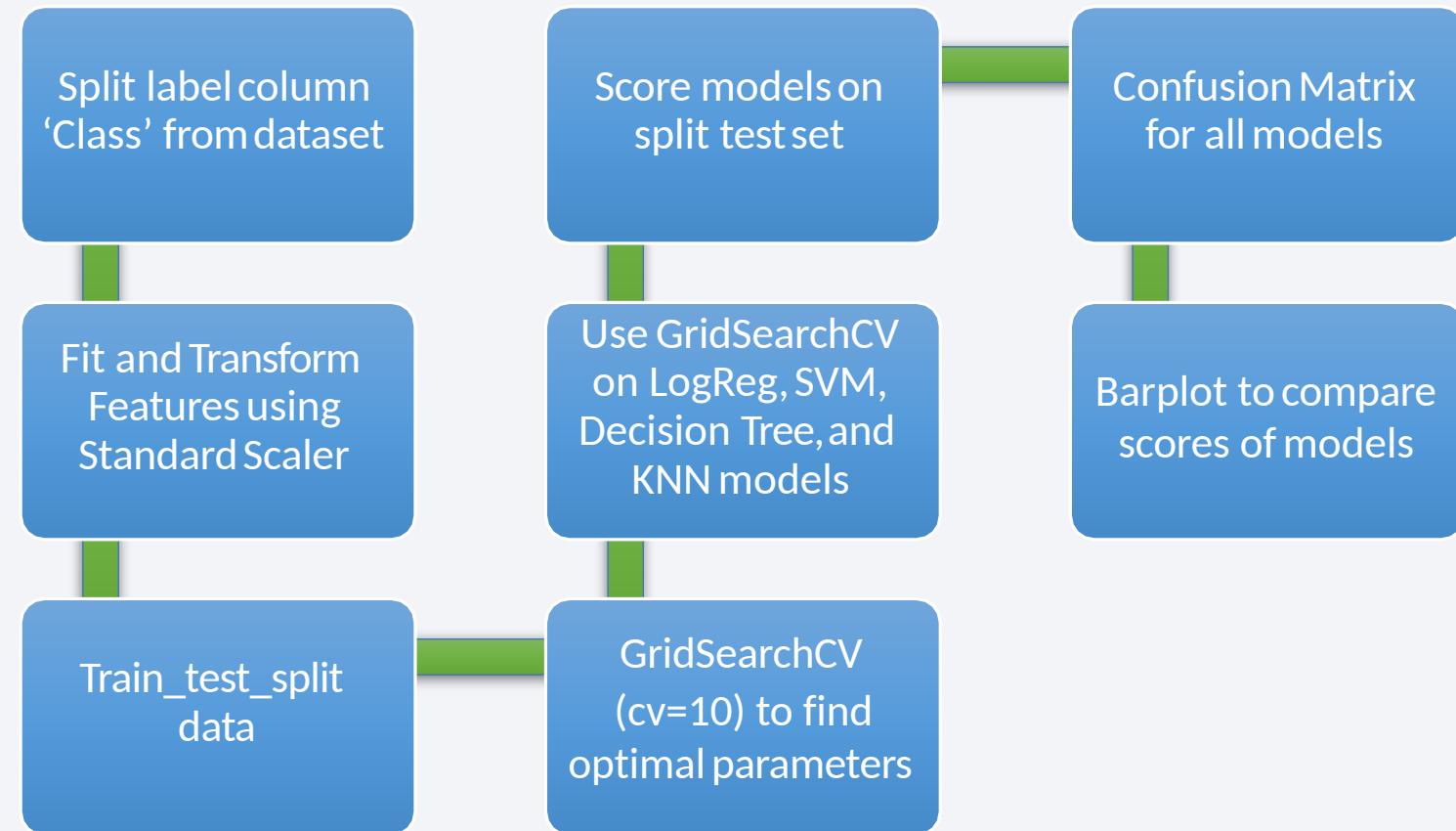
The pie chart is used to visualize launch site success rate.

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

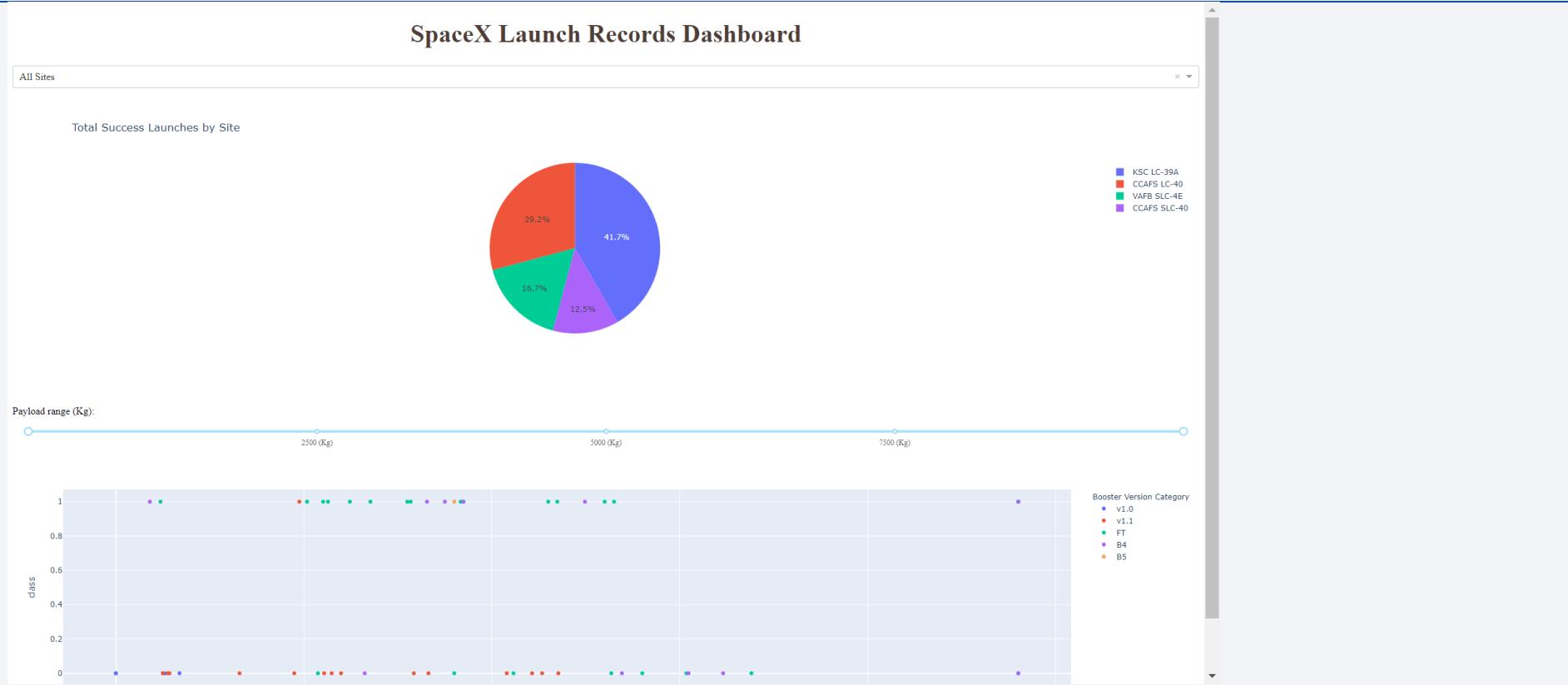
Predictive Analysis (Classification)

Github -

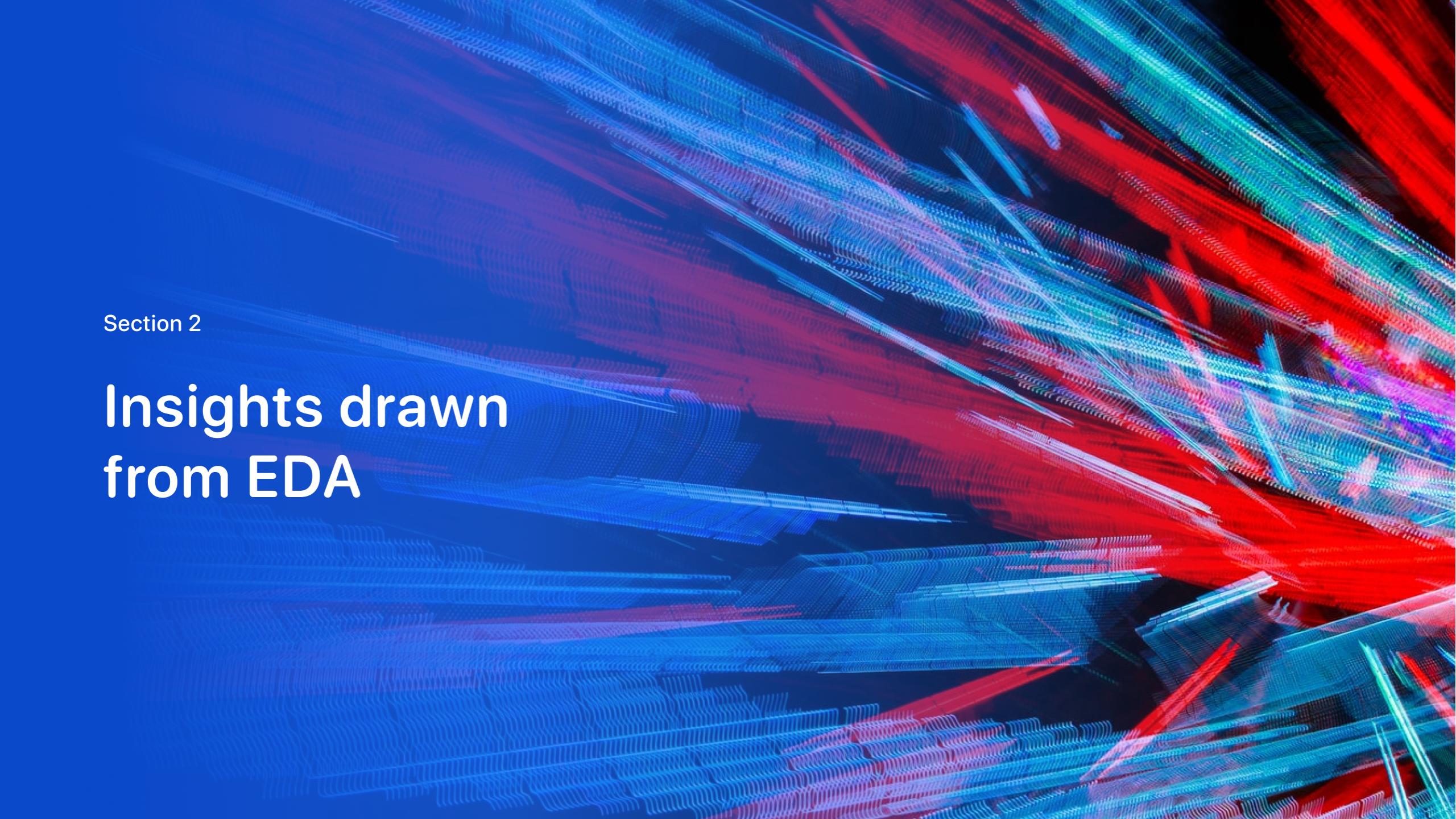
https://github.com/vaibhav-vemula/IBM_Applied_DataScience_Capstone/blob/master/Machine%20Learning%20Prediction%20lab.ipynb



Results



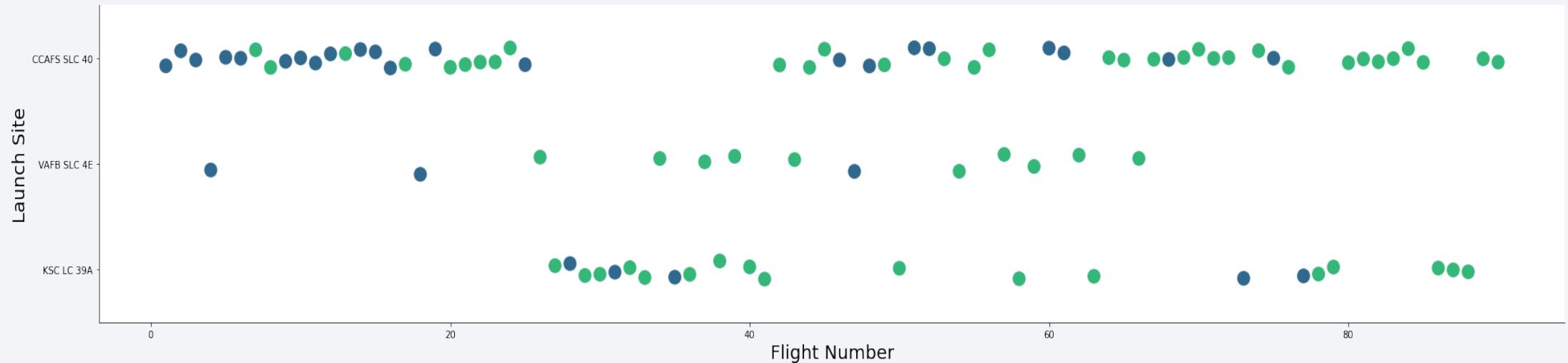
This is a preview of the Plotly dashboard. The following slides will show the results of EDA with visualization, EDA with SQL, Interactive Map with Folium, and finally the results of our model with about 83.33% accuracy.

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 white highlights. They form a grid-like structure that is more dense and vibrant towards the right side of the frame, while appearing more sparse and blue-tinted on the left. The overall effect is reminiscent of a high-energy particle simulation or a futuristic circuit board.

Section 2

Insights drawn from EDA

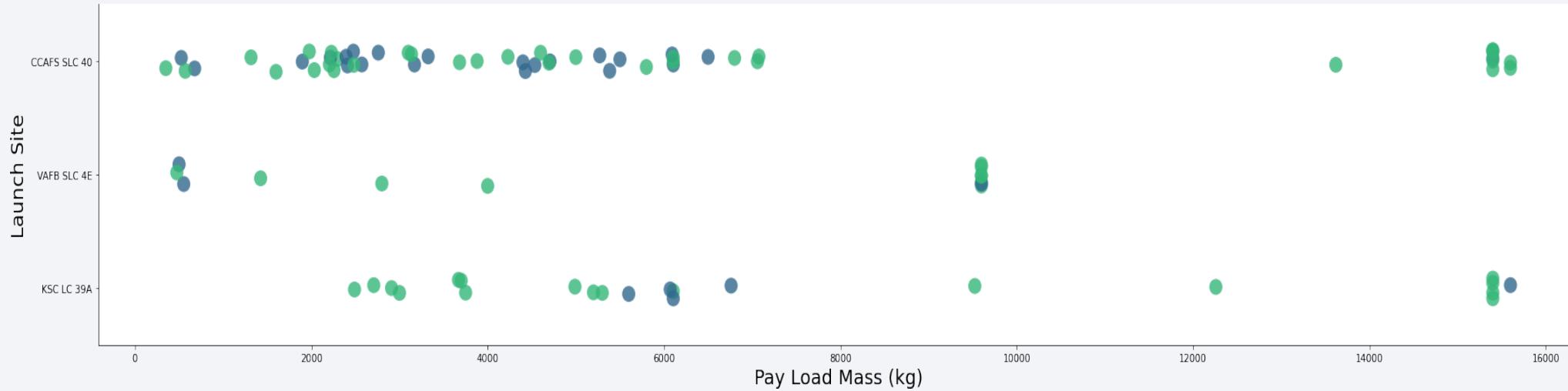
Flight Number vs. Launch Site



Green indicates successful launch; Purple indicates unsuccessful launch.

Graphic suggests an increase in success rate over time (indicated in Flight Number). Likely a big breakthrough around flight 20 which significantly increased success rate. CCAFS appears to be the main launch site as it has the most volume.

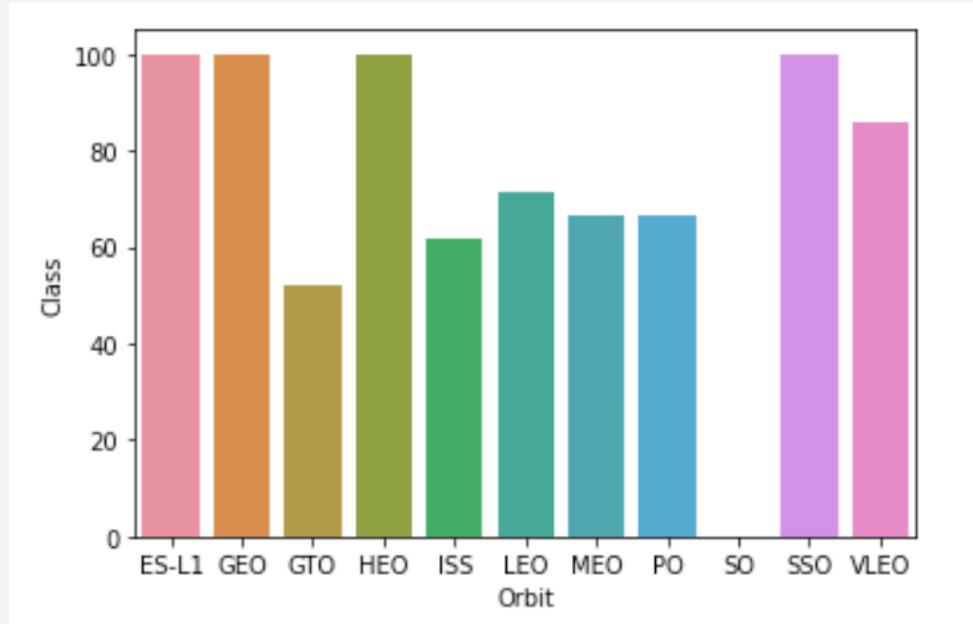
Payload vs. Launch Site



Green indicates successful launch; Purple indicates unsuccessful launch.

Payload mass appears to fall mostly between 0-6000 kg. Different launch sites also seem to use different payload mass.

Success Rate vs. Orbit Type



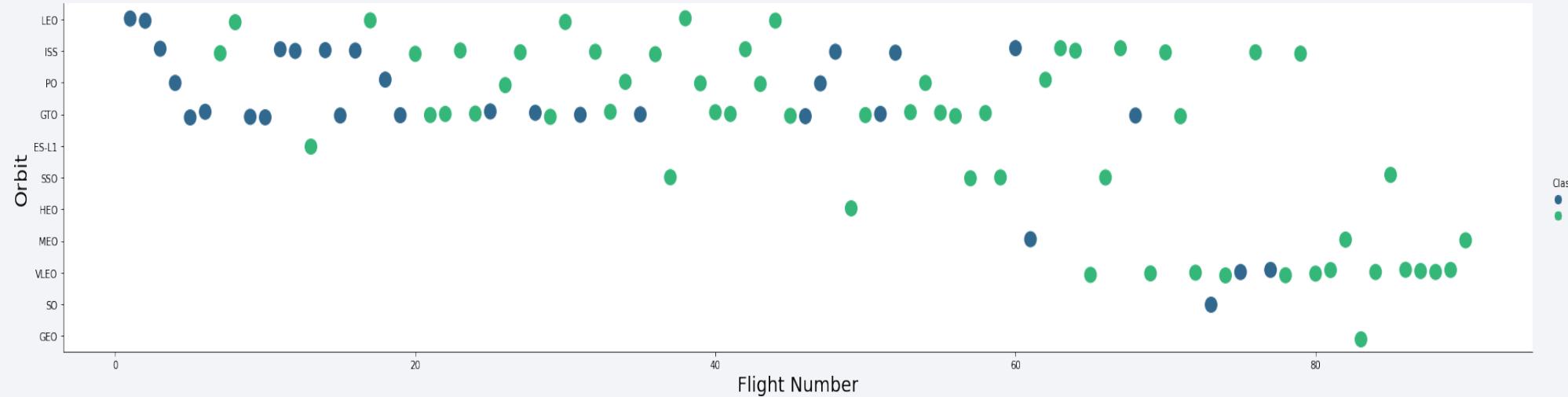
ES-L1 (1), GEO (1), HEO (1) have 100% success rate (sample sizes in parenthesis) SSO (5) has 100% success rate

VLEO (14) has decent success rate and attempts

SO (1) has 0% success rate

GTO (27) has the around 50% success rate but largest sample

Flight Number vs. Orbit Type



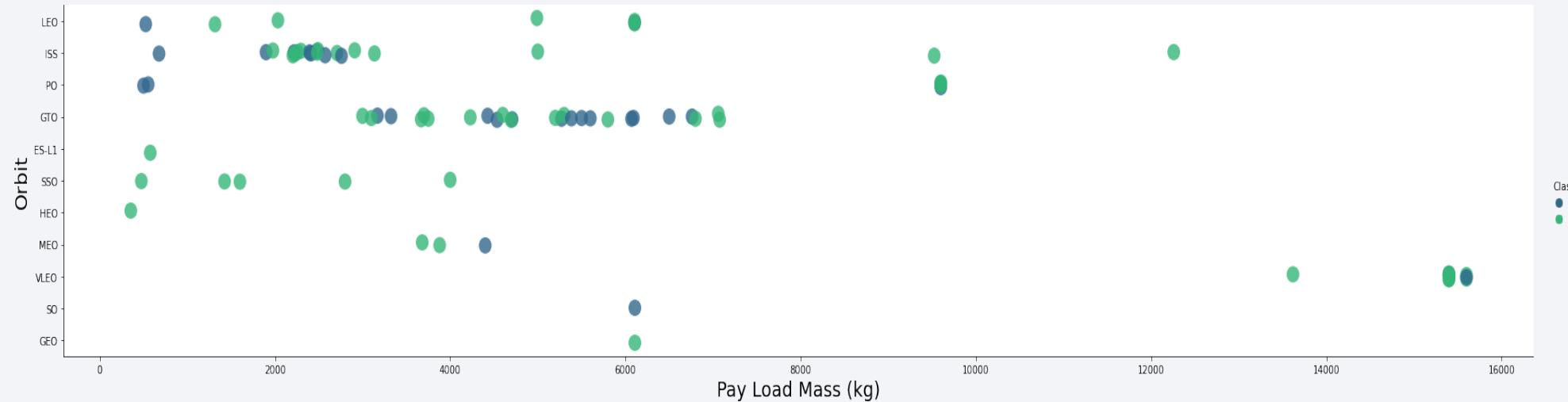
Green indicates successful launch; Purple indicates unsuccessful launch.

Launch Orbit preferences changed over Flight Number.

Launch Outcome seems to correlate with this preference.

SpaceX started with LEO orbits which saw moderate success LEO and returned to VLEO in recent launches. SpaceX appears to perform better in lower orbits or Sun-synchronous orbits

Payload vs. Orbit Type



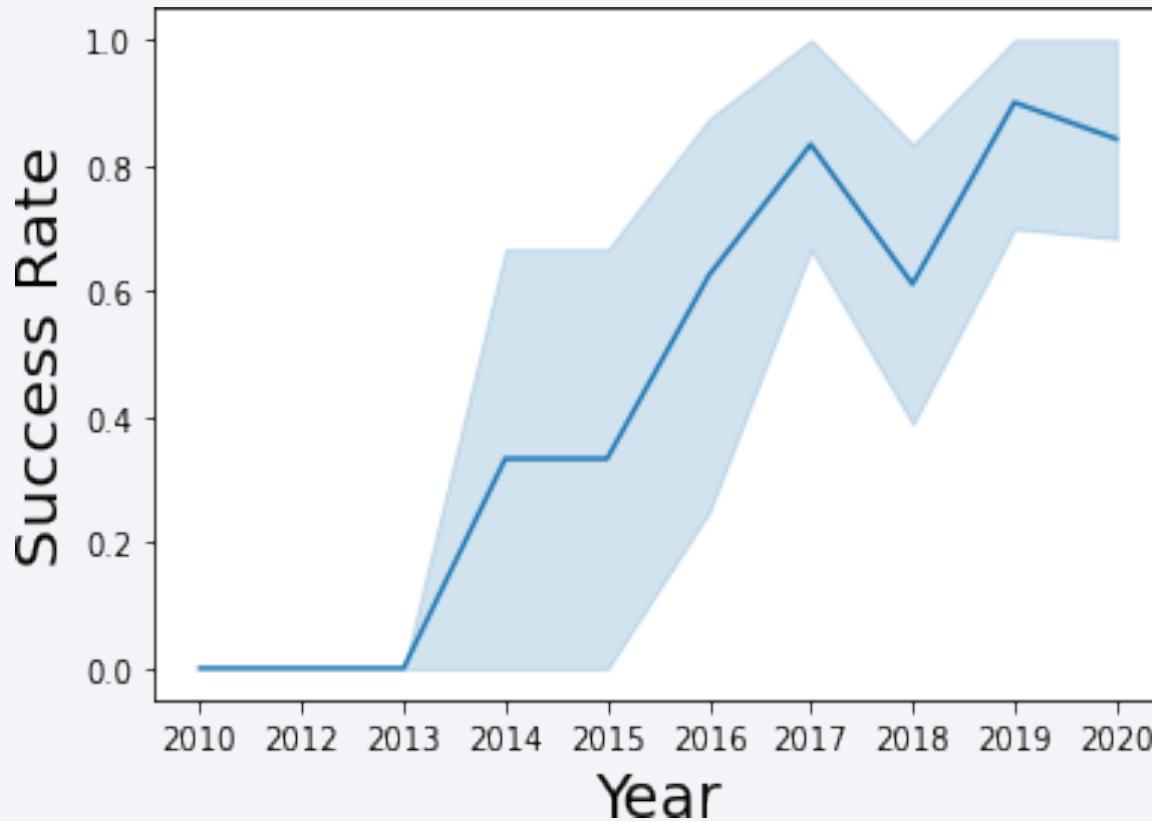
Green indicates successful launch; Purple indicates unsuccessful launch.

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



95% confidence
interval (light
blue shading)

Success generally increases over time since 2013 with a slight dip in 2018

Success in recent years at around 80%

All Launch Site Names

```
In [4]: %%sql  
SELECT UNIQUE LAUNCH_SITE  
FROM SPACEXDATASET;  
* ibm_db_sa://ftb12020:***@0c77d6f:  
Done.  
  
Out[4]:  


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


```

Query unique launch site names from database.

CCAFS SLC-40 and CCAFSSLC-40 likely all represent the same launch site with data entry errors.

CCAFS LC-40 was the previous name.

Likely only 3 unique launch_site values:

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

Launch Site Names Begin with 'CCA'

```
In [5]: %%sql
SELECT *
FROM SPACEXDATASET
WHERE LAUNCH_SITE LIKE 'CCA%'
LIMIT 5;

* ibm_db_sa://ftb12020:***@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

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

Total Payload Mass

```
%%sql
SELECT SUM(PAYLOAD_MASS__KG_) AS SUM_PAYLOAD_MASS_KG
FROM SPACEXDATASET
WHERE CUSTOMER = 'NASA (CRS)';

* ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86
Done.
```

sum_payload_mass_kg
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

```
%%sql
SELECT AVG(PAYLOAD_MASS__KG_) AS AVG_PAYLOAD_MASS_KG
FROM SPACEXDATASET
WHERE booster_version = 'F9 v1.1'

* ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-8e
Done.

avg_payload_mass_kg
2928
```

This query calculates the average payload mass of 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_SUCCESS
FROM SPACEXDATASET
WHERE landing_outcome = 'Success (ground pad)';
* ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81
Done.
```

first_success
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 SPACEXDATASET
WHERE landing_outcome = 'Success (drone ship)' AND payload_mass_kg_ BETWEEN 4001 AND 5999;
* ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.database
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 noninclusively.

Total Number of Successful and Failure Mission Outcomes

```
%%sql
SELECT mission_outcome, COUNT(*) AS no_outcome
FROM SPACEXDATASET
GROUP BY mission_outcome;
* ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-1
Done.
```

mission_outcome	no_outcome
Failure (in flight)	1
Success	99
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, PAYLOAD_MASS__KG_
FROM SPACEXDATASET
WHERE PAYLOAD_MASS__KG_ = (SELECT MAX(PAYLOAD_MASS__KG_) FROM SPACEXDATASET);
* ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1
Done.
```

booster_version	payload_mass_kg
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

This query returns the booster versions that carried the highest payload mass of 15600 kg.

These booster versions are very 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

```
%%sql
SELECT MONTHNAME(DATE) AS MONTH, landing__outcome, booster_version, PAYLOAD_MASS__KG_, launch_site
FROM SPACEXDATASET
WHERE landing__outcome = 'Failure (drone ship)' AND YEAR(DATE) = 2015;
```

```
* ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90l08kqb1od8lcg.databases.app
Done.
```

MONTH	landing__outcome	booster_version	payload_mass__kg_	launch_site
January	Failure (drone ship)	F9 v1.1 B1012	2395	CCAFS LC-40
April	Failure (drone ship)	F9 v1.1 B1015	1898	CCAFS LC-40

This query returns the Month, Landing Outcome, Booster Version, Payload Mass (kg), and Launch site of 2015 launches where stage 1 failed to land on a drone ship.

There were two such occurrences.

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

```
%%sql
SELECT landing_outcome, COUNT(*) AS no_outcome
FROM SPACEXDATASET
WHERE landing_outcome LIKE 'Succes%' AND DATE BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY landing_outcome
ORDER BY no_outcome DESC;

* ibm_db_sa://ftb12020:***@0c77d6f2-5da9-48a9-81f8-86b520b87518.bs2io90108kqb1od81cg
Done.
```

landing_outcome	no_outcome
Success (drone ship)	5
Success (ground pad)	3

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.

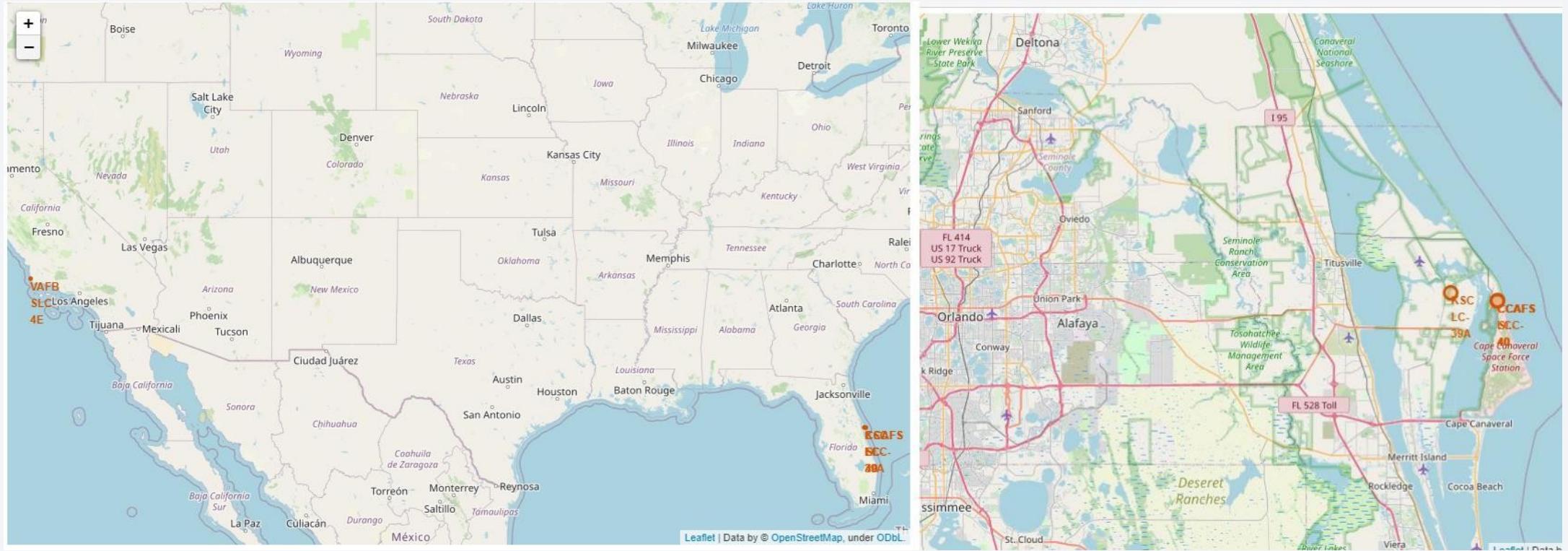
There were 8 successful landings in total during this time period

The background of the slide is a photograph taken from space at night. It shows the curvature of the Earth against a dark blue and black void of space. City lights are visible as small white dots and larger clusters of light, primarily concentrated in the lower right quadrant where the United States appears. In the upper right, there are bright green and yellow bands of the Aurora Borealis (Northern Lights) dancing across the sky.

Section 4

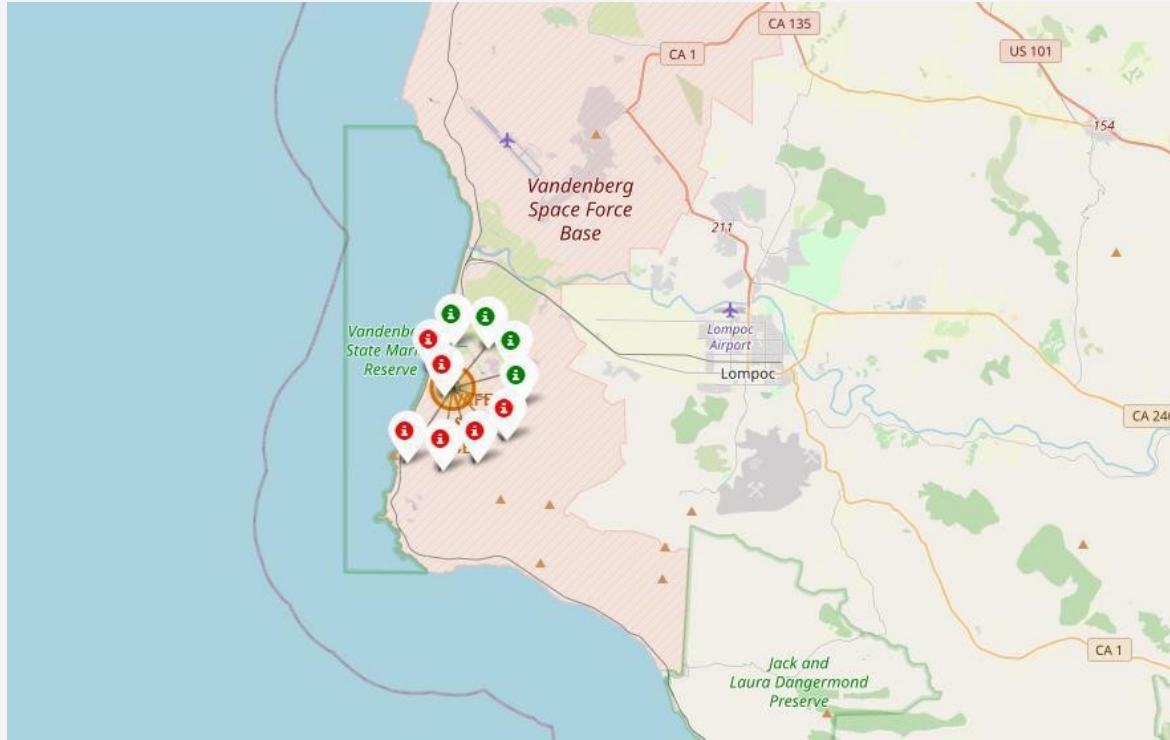
Launch Sites Proximities Analysis

<Folium Map Screenshot 1>



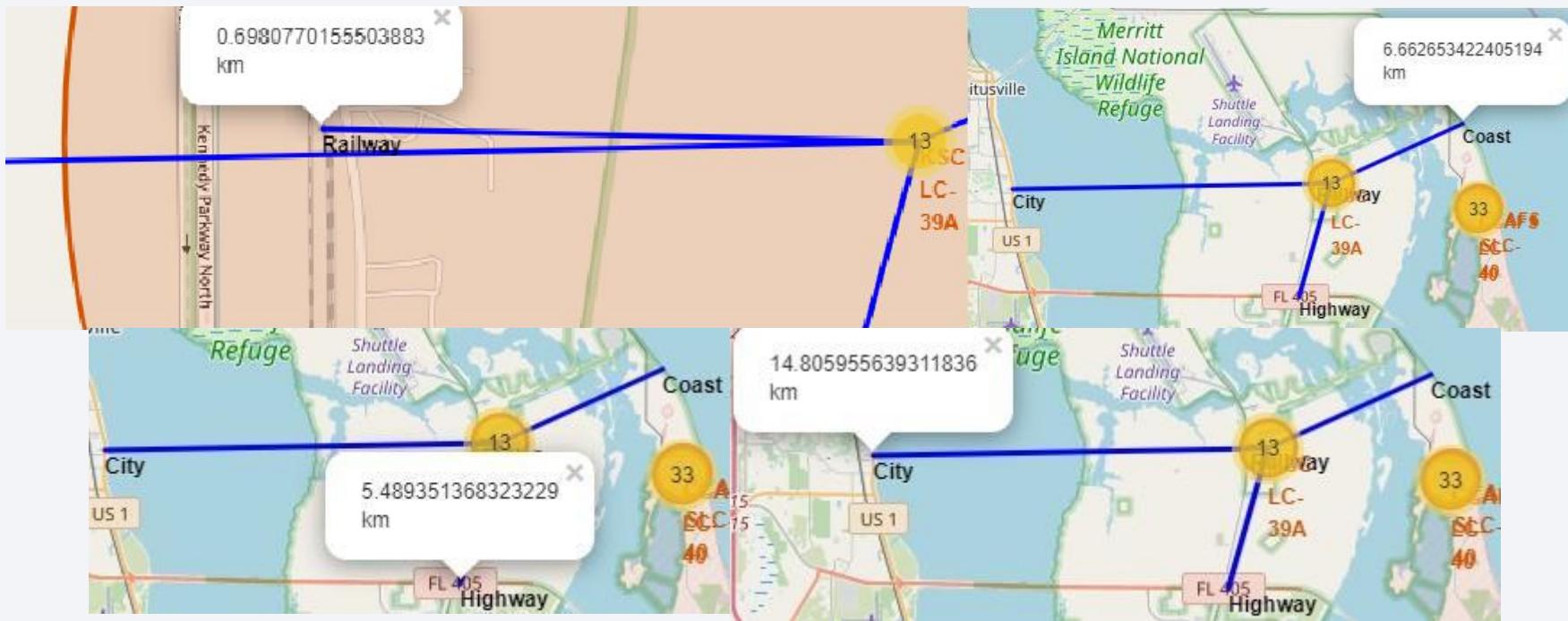
The left map shows all launch sites relative US map. The right map shows the two Florida launch sites since they are very close to each other. All launch sites are near the ocean.

<Folium Map Screenshot 2>



Clusters on Folium map can be clicked on to display each successful landing (green icon) and failed landing (red icon). In this example VAFB SLC-4E shows 4 successful landings and 6 failed landings.

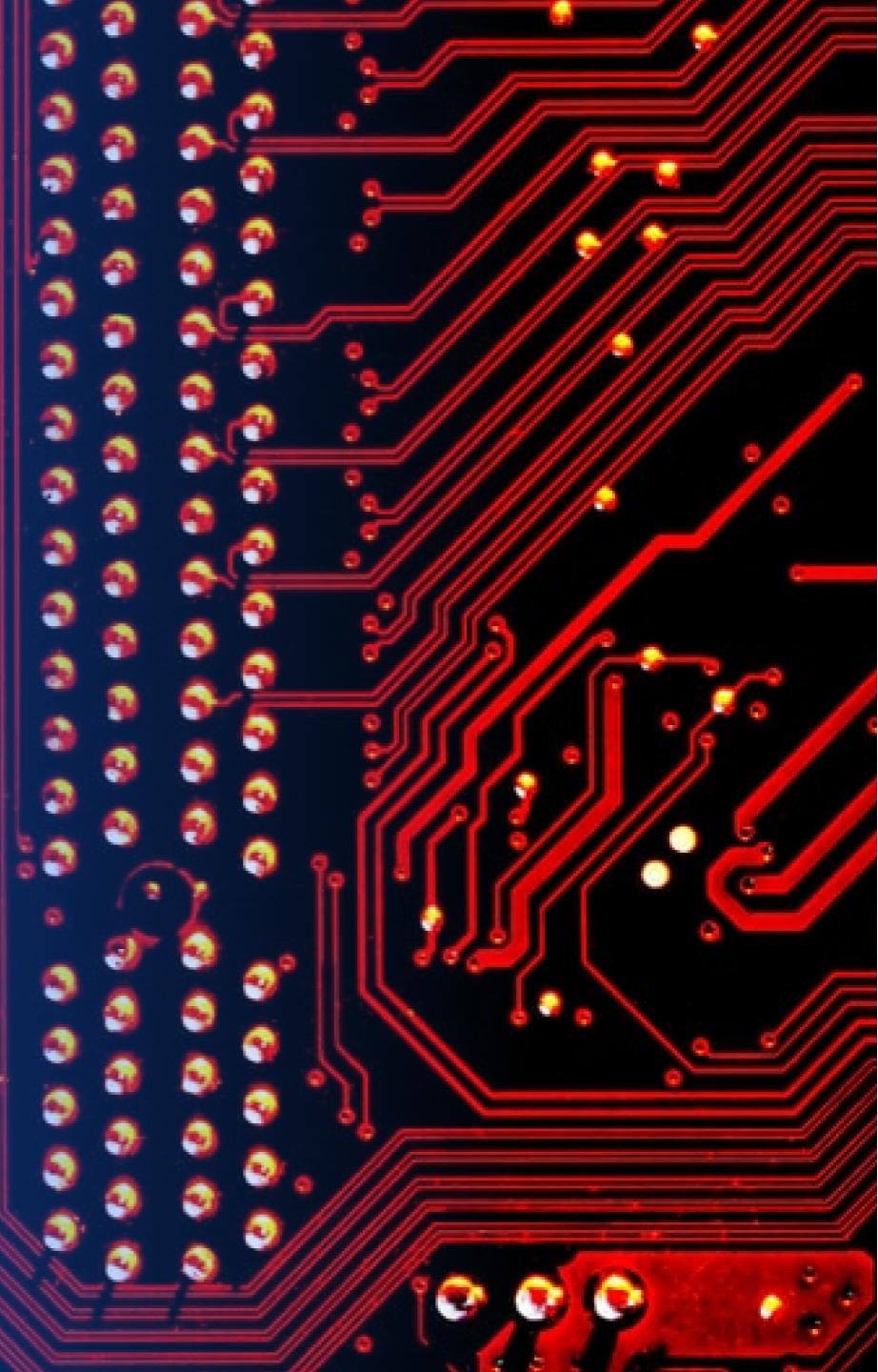
<Folium Map Screenshot 3>



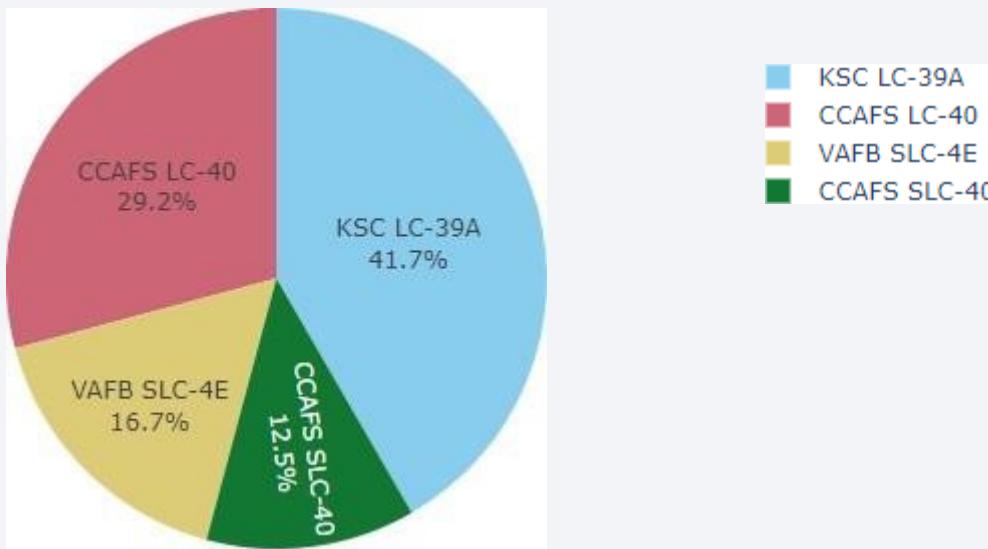
Using KSC LC-39A as an example, launch sites are very close to railways for large part and supply transportation. Launch sites are close to highways for human and supply transport. Launch sites are also close to coasts and relatively far from cities so that launch failures can land in the sea to avoid rockets falling on densely populated areas.

Section 5

Build a Dashboard with Plotly Dash



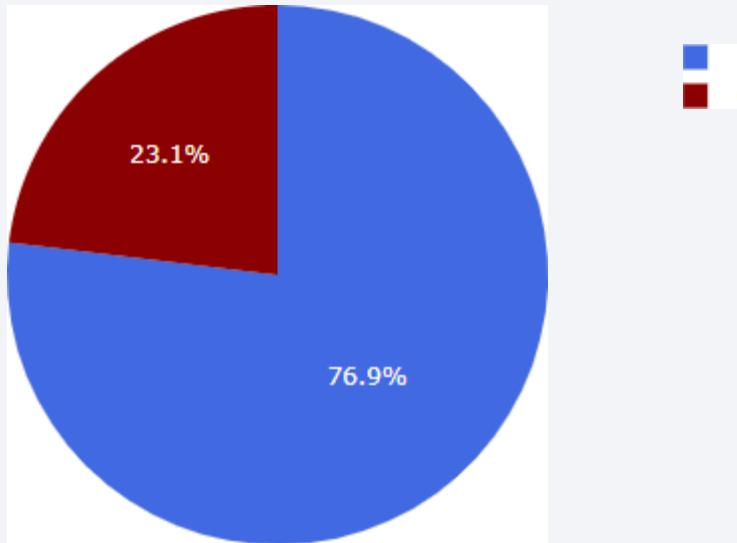
<Dashboard Screenshot 1>



This is the distribution of successful landings across all launch sites. CCAFS LC-40 is the old name of CCAFS SLC-40 so CCAFS and KSC have the same amount of successful landings, but a majority of the successful landings were performed before the name change. 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.

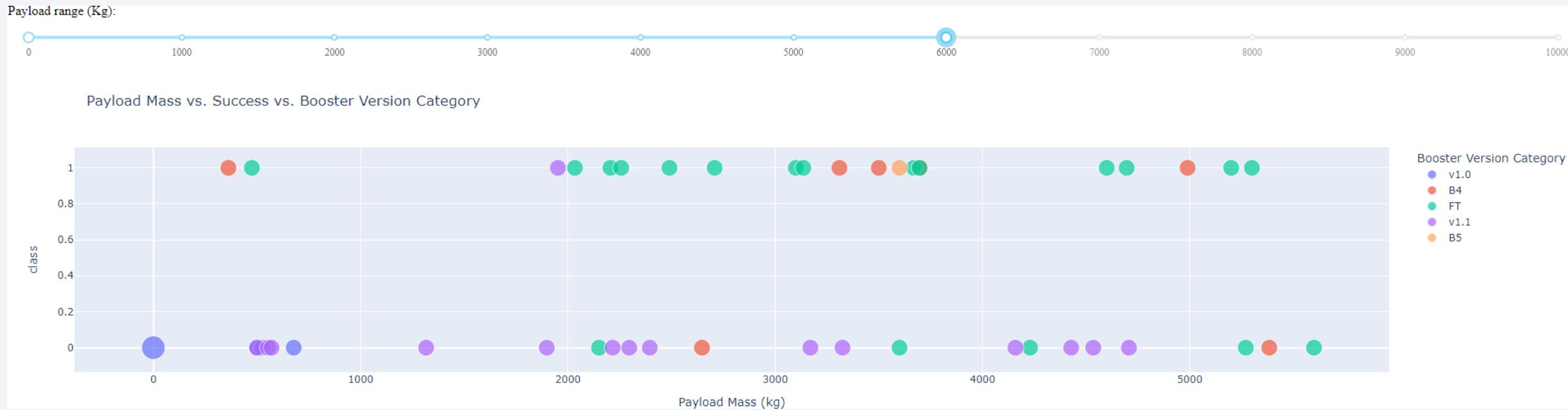
<Dashboard Screenshot 2>

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



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

<Dashboard Screenshot 3>



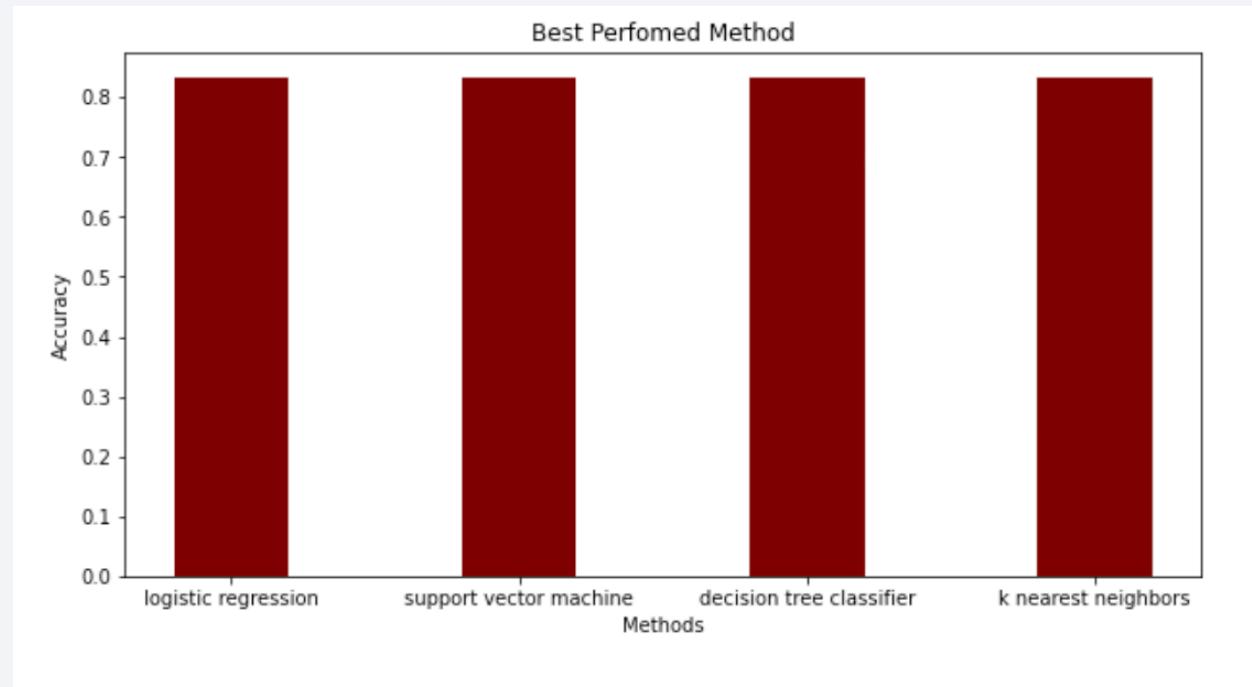
Plotly dashboard has a Payload range selector. However, this is set from 0-10000 instead of the max Payload of 15600. Class indicates 1 for successful landing and 0 for failure. Scatter plot also accounts for booster version category in color and number of launches in point size. In this particular range of 0-6000, interestingly there are two failed landings with payloads of zero kg.

The background of the slide features a dynamic, abstract design. It consists of several curved, overlapping bands of color. A prominent band in the center-left is a bright blue, while another band on the right is a warm yellow. These colors transition into lighter shades of blue and yellow towards the edges. The overall effect is one of motion and depth, suggesting a tunnel or a path through a digital space.

Section 6

Predictive Analysis (Classification)

Classification Accuracy



All models had virtually the same accuracy on the test set at 83.33% accuracy.

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.

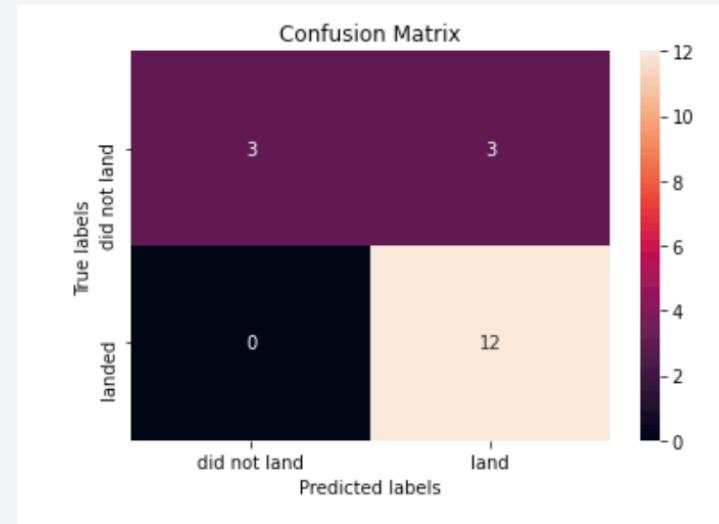
We likely need more data to determine the best model.

Confusion Matrix

Since all models performed the same for the test set, the confusion matrix is the same across all models. The models predicted 12 successful landings when the true label was successful landing.

The models predicted 3 unsuccessful landings when the true label was unsuccessful landing.

The models predicted 3 successful landings when the true label was unsuccessful landings (false positives). Our models over predict successful landings.



Conclusions

- Our task: to develop a machine learning model for Space Y who wants to bid against SpaceX
- The goal of model is to predict when Stage 1 will successfully land to save ~\$100 million USD
- Used data from a public SpaceX API and web scraping SpaceX Wikipedia page
- Created data labels and stored data into a DB2 SQL database
- Created a dashboard for visualization
- We created a machine learning model with an accuracy of 83%
- Allon Mask of SpaceY can use this model to predict with relatively high accuracy whether a launch will have a successful Stage 1 landing before launch to determine whether the launch should be made or not
- If possible more data should be collected to better determine the best machine learning model and improve accuracy

Appendix

Github -

https://github.com/vaibhav-vemula/IBM_Applied_DataScience_Capstone

Instructors:

Instructors: Rav Ahuja, Alex Akison, Aije Egwaikhide, Svetlana Levitan, Romeo Kienzler, Polong Lin, Joseph Santarcangelo, Azim Hirjani, Hima Vasudevan, Saishruthi Swaminathan, Saeed Aghabozorgi, Yan Luo

Thanks to All Instructors:

<https://www.coursera.org/professional-certificates/ibm-data-science?#instructors>

Thank you!

