IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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

- Summary of methodologies
  - Data Collection through API
  - Data Collection with Web Scraping
  - Data Wrangling
  - Exploratory Data Analysis with SQL
  - Exploratory Data Analysis with Data Visualization
  - Interactive Visual Analytics with Folium
  - Machine Learning Prediction
- Summary of all results
  - Exploratory Data Analysis result with the help of SQL and visualization
  - Interactive visual analytics result
  - Predictive Analytics result

Introduction

- Project background and context

  Space X 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 Space X can reuse the first stage. Therefore, if we can determine if the first stage will land, we can determine the cost of a launch. This information can be used if an alternate company wants to bid against space X for a rocket launch. This goal of the project is to create a machine learning pipeline to predict if the first stage will land successfully.

- Problems you want to find answers
  - A reliable method to estimate the total cost of launches is by predicting the successful landings of the first stage of rockets.
  - What factors determine if the rocket will land successfully?

Section 1

Methodology

Methodology

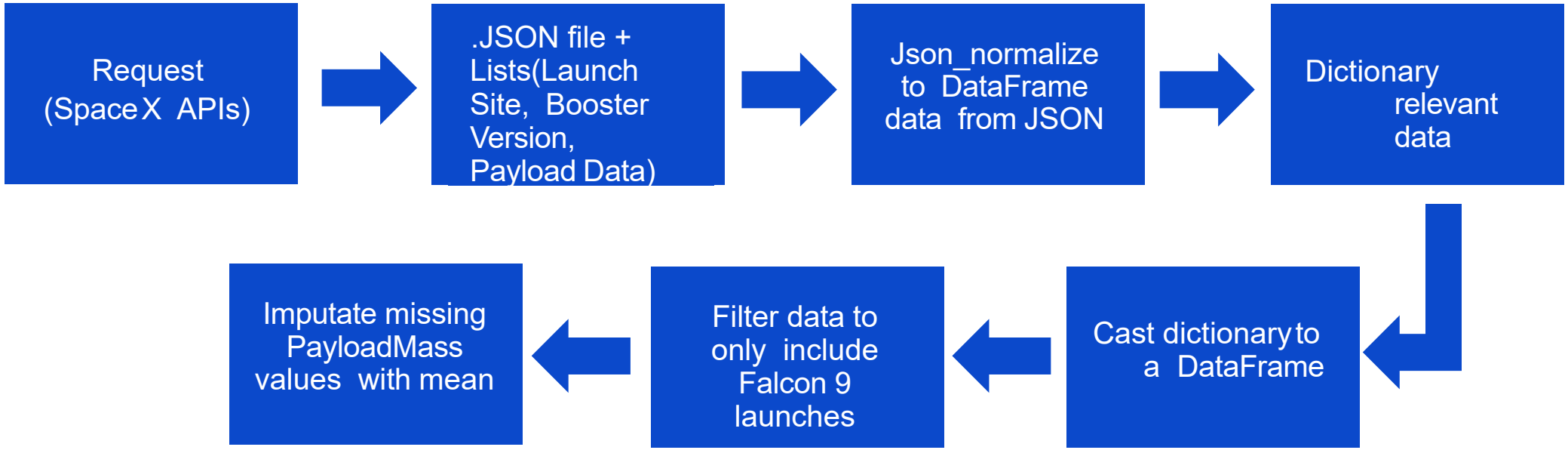
Executive Summary

- Data collection methodology:
  - Gathered data from SpaceX public API and by scrapping SpaceX Wikipedia page
- Perform data wrangling
  - One-hot encoding was applied to categorical features
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - We tuned the models using GridSearchCV

Data Collection

- The data was collected using various methods
  - Data collection was done using get request to the SpaceX API.
  - Next, we decoded the response content as a Json using .json() function call and turn it into a pandas dataframe using .json_normalize().
  - We then cleaned the data, checked for missing values and fill in missing values where necessary.
  - In addition, we performed web scraping from Wikipedia for Falcon 9 launch records with BeatifulSoup.
  - The objective was to extract the launch records as HTML table, parse the table and convert it to a pandas dataframe for future analysis.

Data Collection – SpaceX API



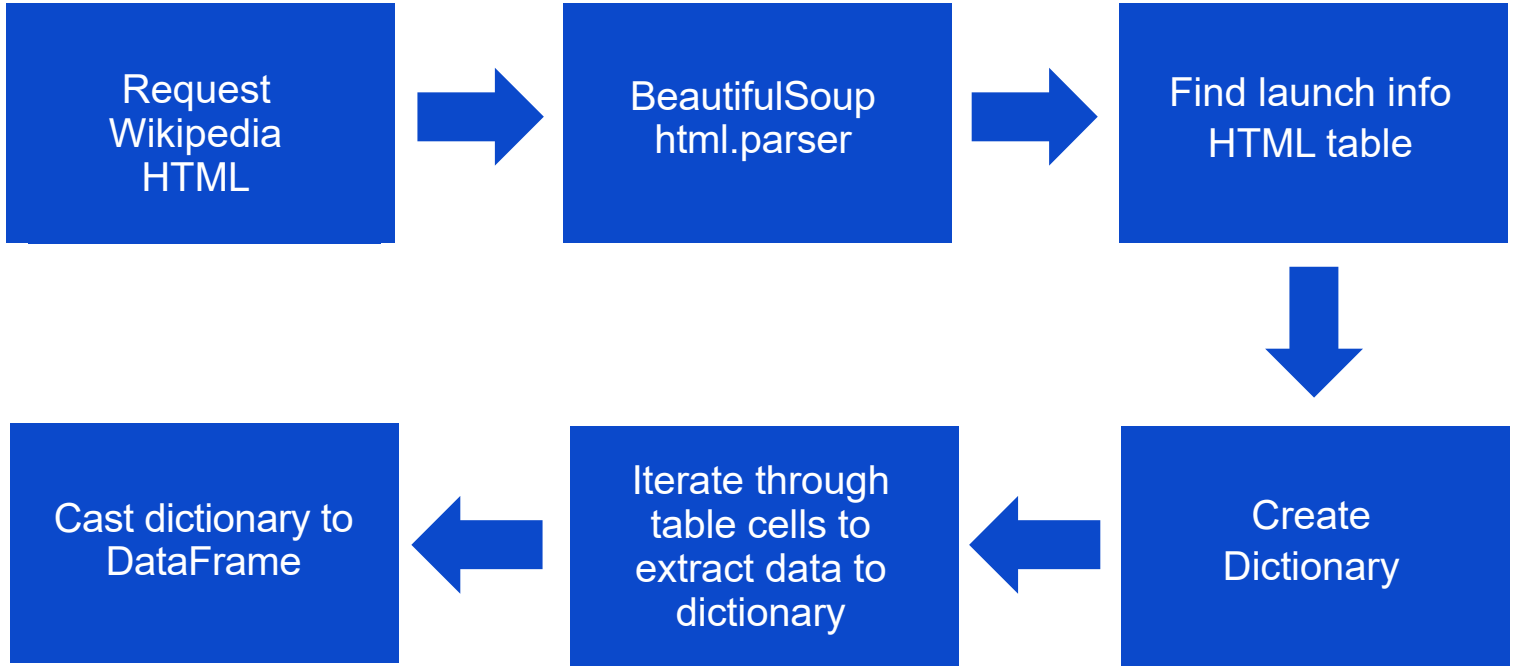
GitHub URL:

https://github.com/ashuyadav2030/IBM-Applied-Data-Science-Capstone-Project/blob/main/Data%20Collection%20API.ipynb

Data Collection - Scraping

GitHub URL:

https://github.com/ashuyadav2030/IBM-Applied-Data-Science-Capstone-Project/blob/main/Data%20Collection%20with%20Web%20Scraping.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/ashuyadav2030/IBM-Applied-Data-Science-Capstone-Project/blob/main/Data Wrangling.ipynb

EDA with Data Visualization

- We explored the data by visualizing the relationship between flight number and launch Site, payload and launch site, success rate of each orbit type, flight number and orbit type, the launch 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/ashuyadav2030/IBM-Applied-Data-Science-Capstone-Project/blob/main/EDA-Datavisualization.ipynb.jupyterlite.ipynb

EDA with SQL

- We loaded the SpaceX dataset into the lab and run sql queries in the jupyter notebook.
- We applied EDA with SQL to get insight from the data. We wrote queries to

find out for instance:

- The names of unique launch sites in the space mission.
- The total payload mass carried by boosters launched by NASA (CRS)
- The average payload mass carried by booster version F9 v1.1
- The total number of successful and failure mission outcomes
- The failed landing outcomes in drone ship, their booster version and launch site names.

GitHub URL:

- https://github.com/ashuyadav2030/IBM-Applied-Data-Science-Capstone-Project/blob/main/EDA%20with%20SQL.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.

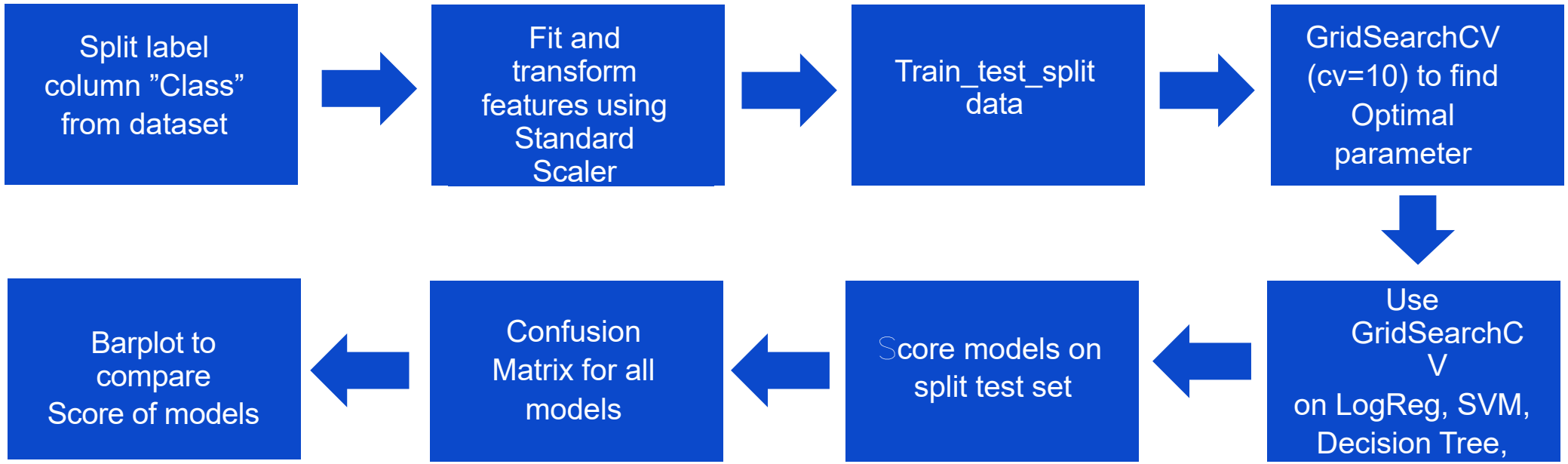
GitHub URL:

https://github.com/ashuyadav2030/IBM-Applied-Data-Science-Capstone-Project/blob/main/Interactive%20Visual%20Analytics%20with%20Folium%20lab.ipynb

Build a Dashboard with Plotly Dash

- We built an interactive dashboard with Plotly dash.
- We plotted pie charts showing the total launches by a certain sites.
- We plotted scatter graph showing the relationship with Outcome and Payload Mass (Kg) for the different booster version.

Predictive Analysis (Classification)



GitHub URL:

https://github.com/ashuyadav2030/IBM-Applied-Data-Science-Capstone-Project/blob/main/Machine%20Learning%20Prediction.jupyterlite.ipynb

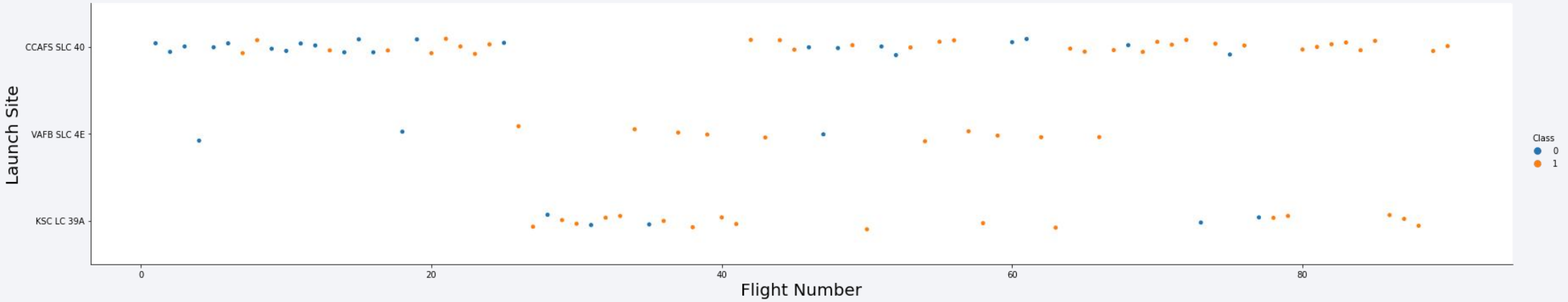
Results

- Exploratory data analysis results with the help of SQL and visualization
  - Space X uses 4 different launch sites;
  - Many Falcon 9 booster versions were successful at landing in drone ships having payload above the average;
  - Almost 100% of mission outcomes were successful;
  - The number of landing outcomes became as better as years passed.
- Interactive visual analytics results
  - The relation between payloads and launch sites, helping to identify where is best place to launch according to payloads.
- Predictive analysis results
  - We created a machine learning model with an accuracy of 83%

Section 2

Insights drawn from EDA

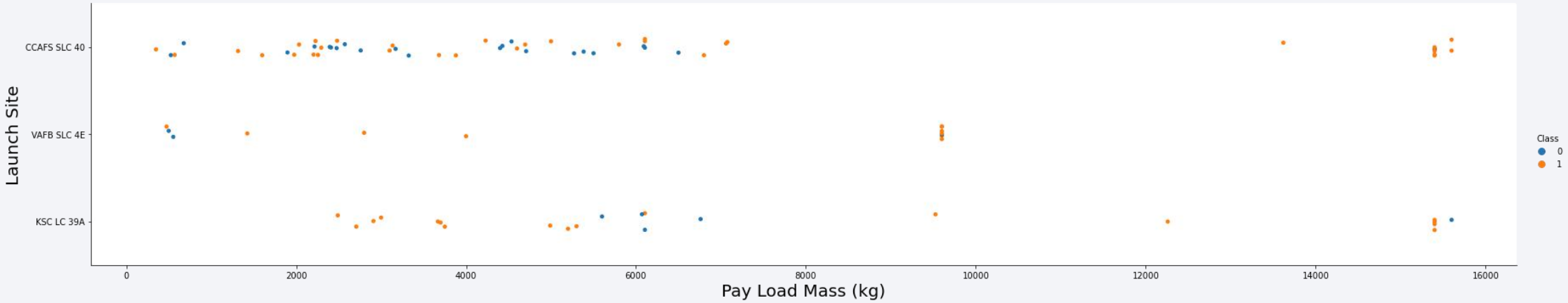
Flight Number vs. Launch Site



Blue indicates successful launch and orange 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



Blue indicates successful launch and orange 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

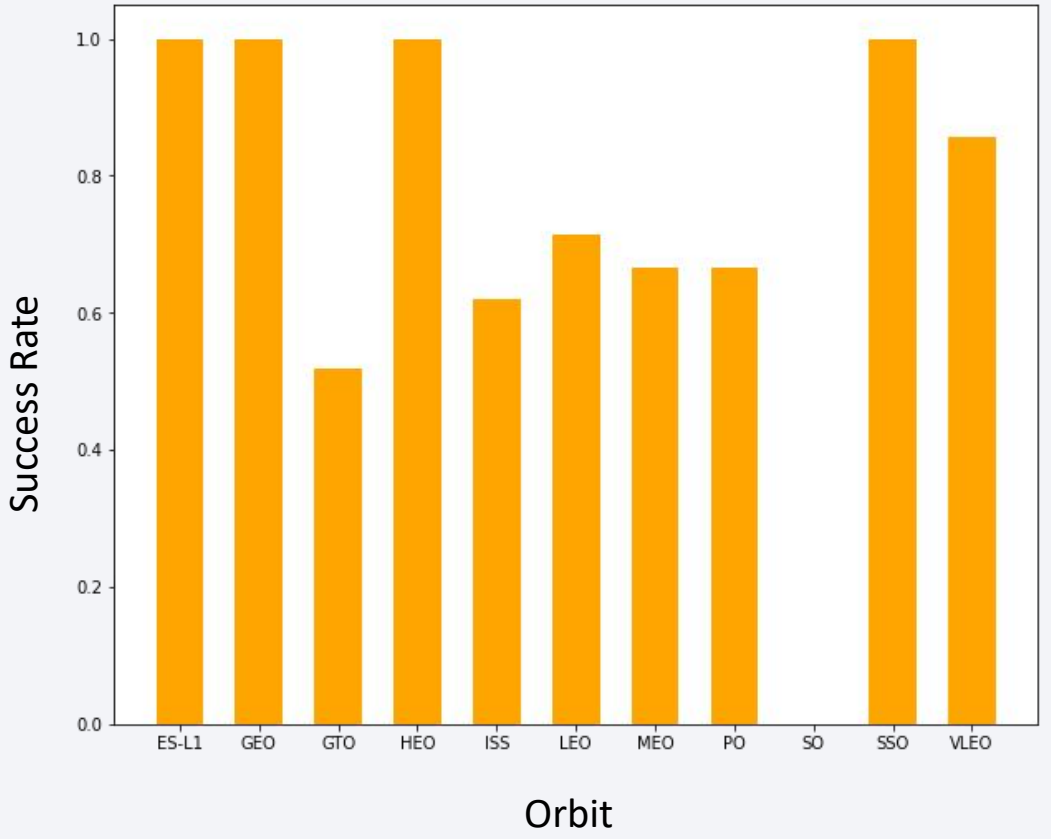
ES-L1 (1), GEO (1), HEO (1) have 100% success rate (sample sizes in parenthesis)

SSO (5) has 100% success rate

VLEO (14) has decent success rate and attempts

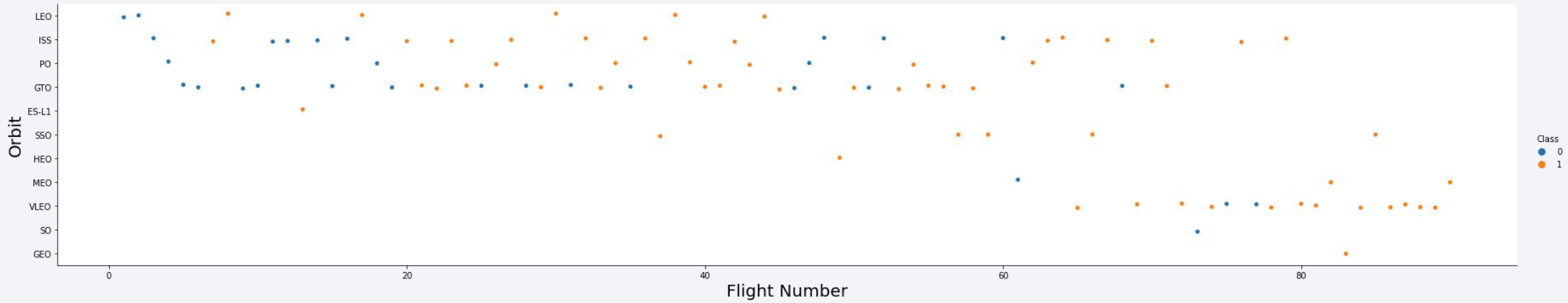
SO (1) has 0% success rate

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



Success Rate Scale with 0 as 0%, 0.6 as 60%, 1 as 100%

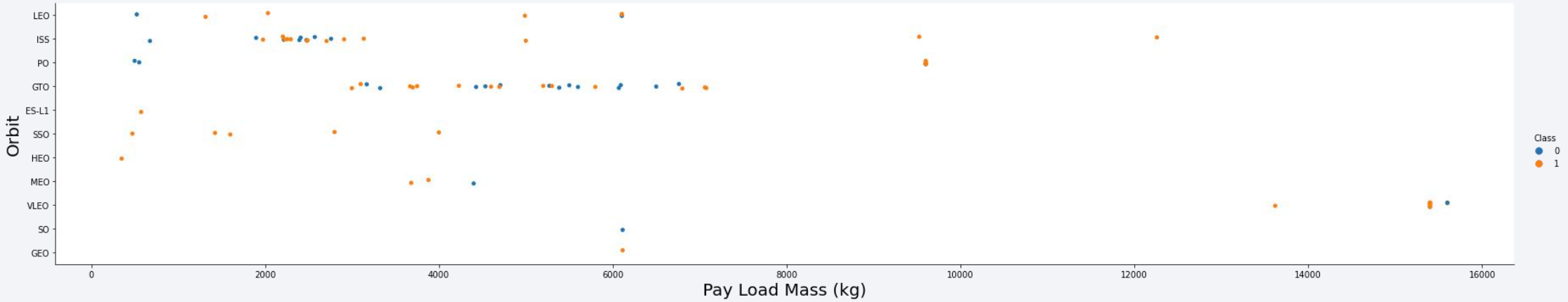
Flight Number vs. Orbit Type



Blue indicates successful launch and orange 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

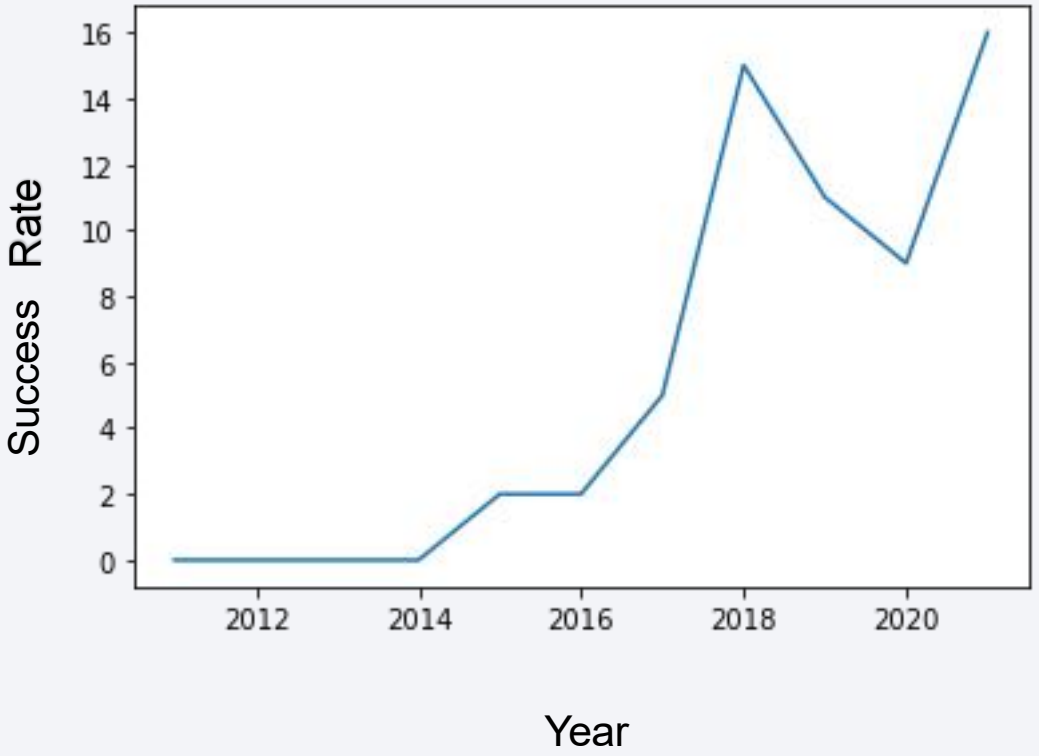


Blue indicates successful launch and orange indicates unsuccessful launch.

- 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

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



95% confidence interval (light blue shading)

All Launch Site Names

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

```
% %sql

SELECT DISTINCT
LAUNCH_SITE FROM
SPACEXTBL;
```

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

Launch Site Names Begin with 'CCA'

```
% %sql

SELECT * FROM SPACEXTBL WHERE LAUNCH_SITE LIKE 'CCA%' LIMIT 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

sum_payload:

45596

```
% %sql

SELECT SUM (payload_mass__kg_) AS
SUM_PAYLOAD FROM SPACEXDATASET
WHERE customer = 'NASA (CRS)';
```

sum_payload
45596

Average Payload Mass by F9 v1.1

avg_payload:

2928

```
% %sql

SELECT AVG (payload_mass__kg_) AS
AVG_PAYLOAD FROM SPACEXDATASET
WHERE BOOSTER_VERSION ='F9 v1.1';
```

avg_payload
2928

First Successful Ground Landing Date

min_date:

2015-12-22

```
% %sql

SELECT MIN(DATE) AS MIN_DATE FROM SPACEXDATASET WHERE landing__outcome = 'Success (ground pad)';
```

min_date
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

```
% %sql

SELECT booster_version FROM SPACEXDATASET WHERE
payload_mass__kg_ > '4000’ AND payload_mass__kg_ <
'6000’ AND landing__outcome = 'Success (drone ship)';
```

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

Total Number of Successful and Failure Mission Outcomes

Success: 100

```
% %sql

SELECT COUNT(*) AS SUCCESS FROM
SPACEXDATASET WHERE
mission_outcome LIKE 'Success%';
```

success
100

Boosters Carried Maximum Payload

- This query returns the booster versions that carried the highest payload mass of 15600 kg.
- These booster versions are very similar.
- This likely indicates payload mass correlates with the booster version that is used.

```
% %sql

SELECT booster_version,(SELECT
MAX(payload_mass__kg_) FROM
SPACEXDATASET) AS MAX_Booster
FROM SPACEXDATASET ;
```

booster_version	max_booster
F9 v1.0 B0003	15600
F9 v1.0 B0004	15600
F9 v1.0 B0005	15600
F9 v1.0 B0006	15600
F9 v1.0 B0007	15600
F9 v1.1 B1003	15600
F9 v1.1	15600
F9 v1.1	15600
F9 v1.1	15600
F9 v1.1	15600
F9 v1.1	15600
F9 v1.1 B1011	15600
F9 v1.1 B1010	15600
F9 v1.1 B1012	15600
F9 v1.1 B1013	15600
F9 v1.1 B1014	15600

2015 Launch Records

```
% %sql

SELECT Date, booster_version, launch_site,landing__outcome FROM
SPACEXDATASET WHERE landing__outcome = 'Failure (drone ship)' AND YEAR(Date)
= 2015;
```

DATE	booster_version	launch_site	landing__outcome
2015-01-10	F9 v1.1 B1012	CCAFS LC-40	Failure (drone ship)
2015-04-14	F9 v1.1 B1015	CCAFS LC-40	Failure (drone ship)

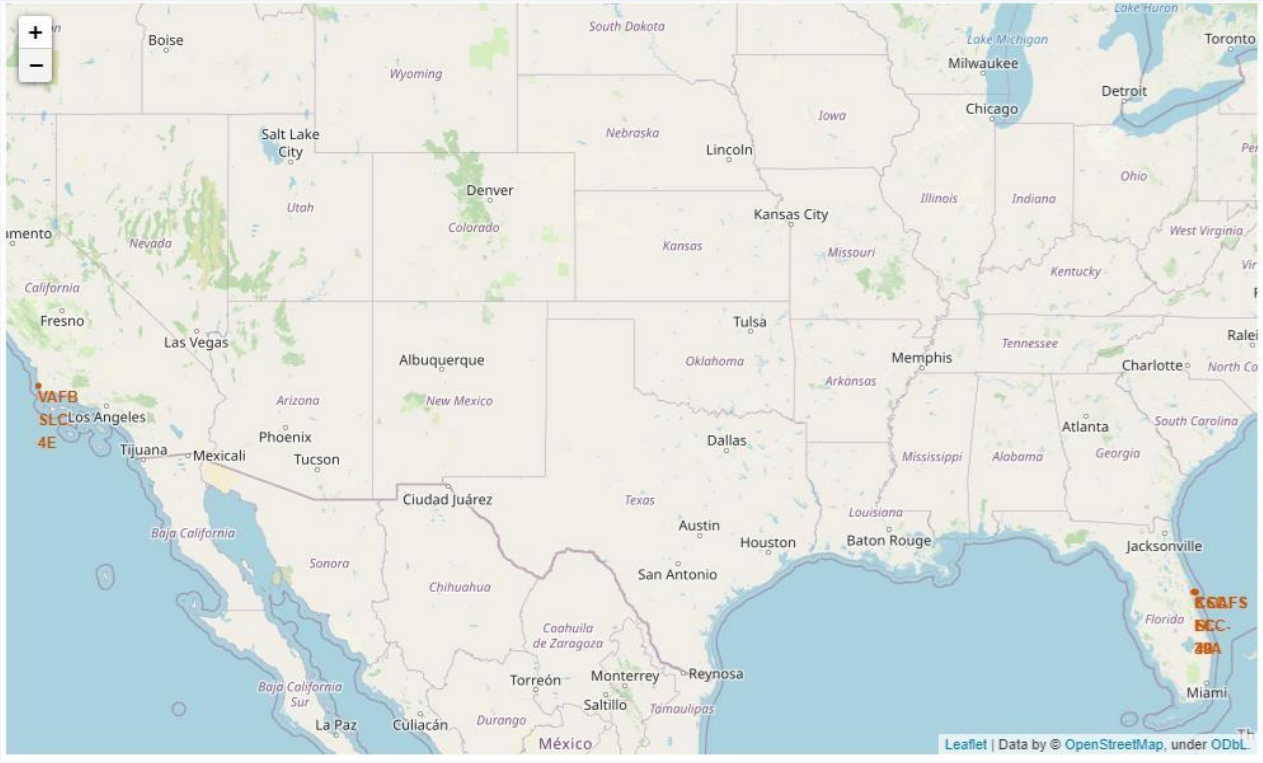
Rank Landing Outcomes Between 2010-06-04 and 2017-03-20

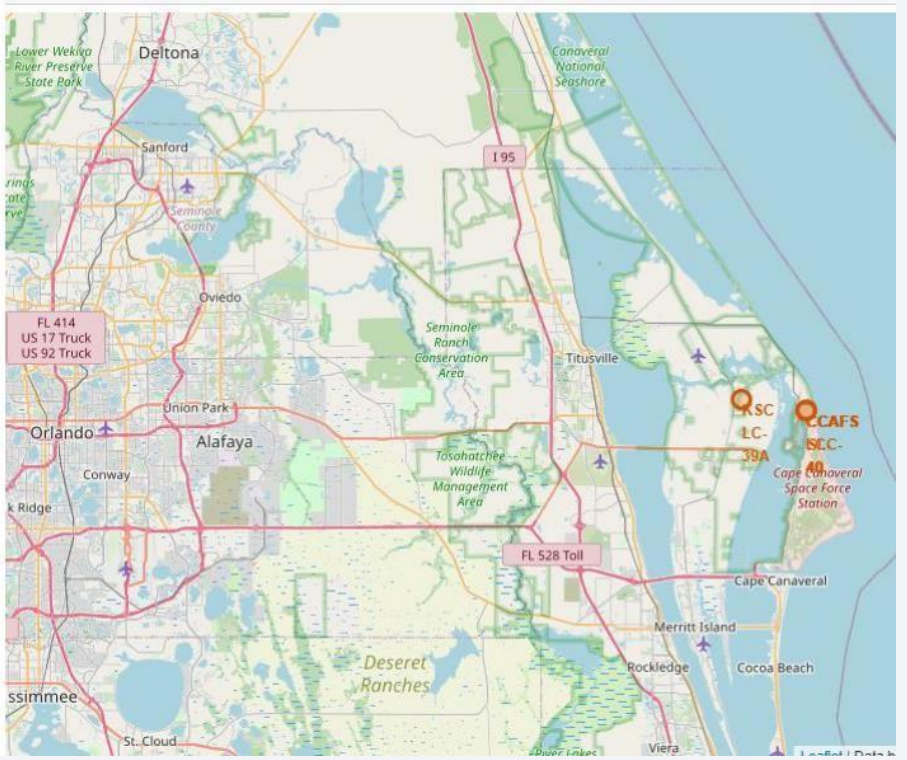
```
% %sql

SELECT landing__outcome FROM SPACEXDATASET WHERE
Date > '2010-06-04' AND Date < '2017-03-20' GROUP BY
landing__outcome ORDER BY COUNT(landing__outcome)
DESC;
```

landing__outcome
No attempt
Failure (drone ship)
Success (drone ship)
Controlled (ocean)
Success (ground pad)
Uncontrolled (ocean)
Failure (parachute)
Precluded (drone ship)


Section 3
Launch Sites
Proximities Analysis

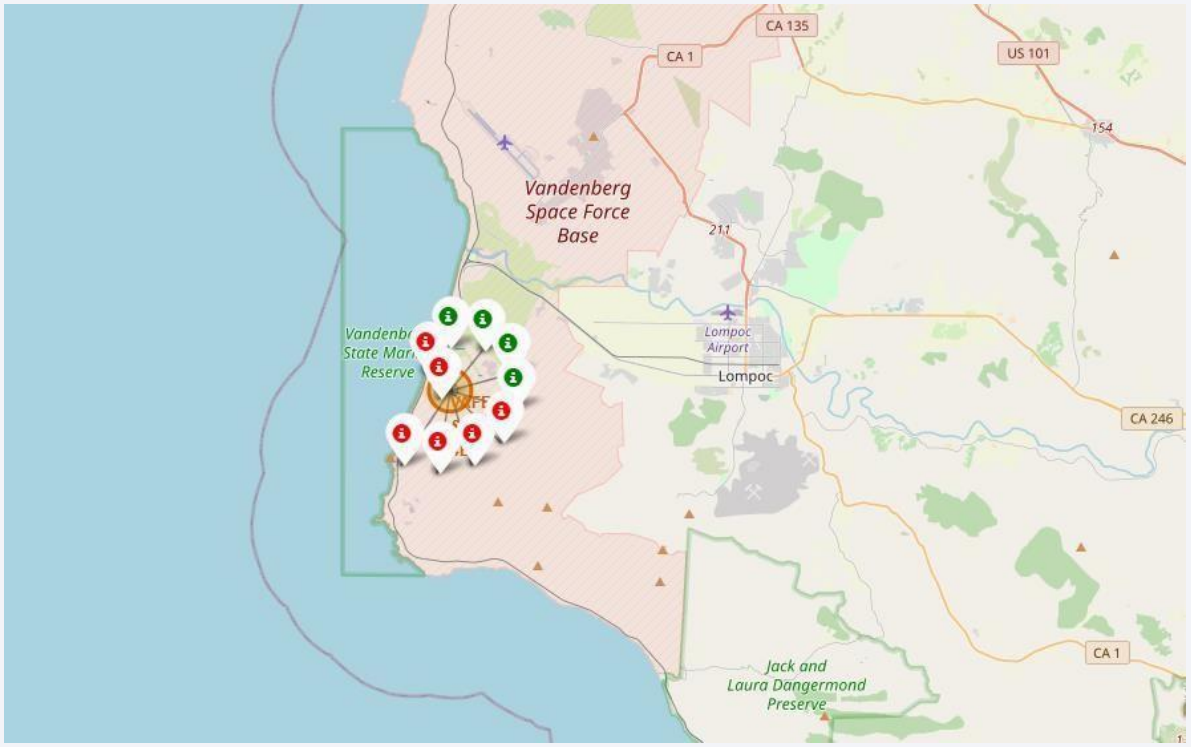
Launch Site Locations





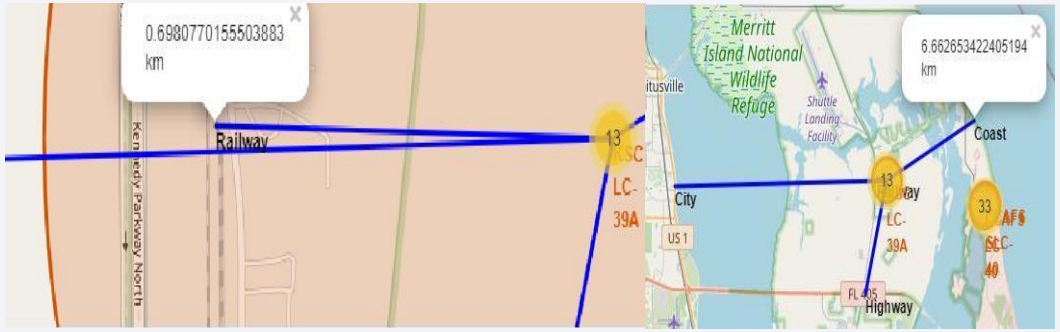
The left map shows all launch sites relative US map. The right map shows the two Florida launch sites since they are very close to each other. All launch sites are near the ocean.

Color Coded Launch Markers

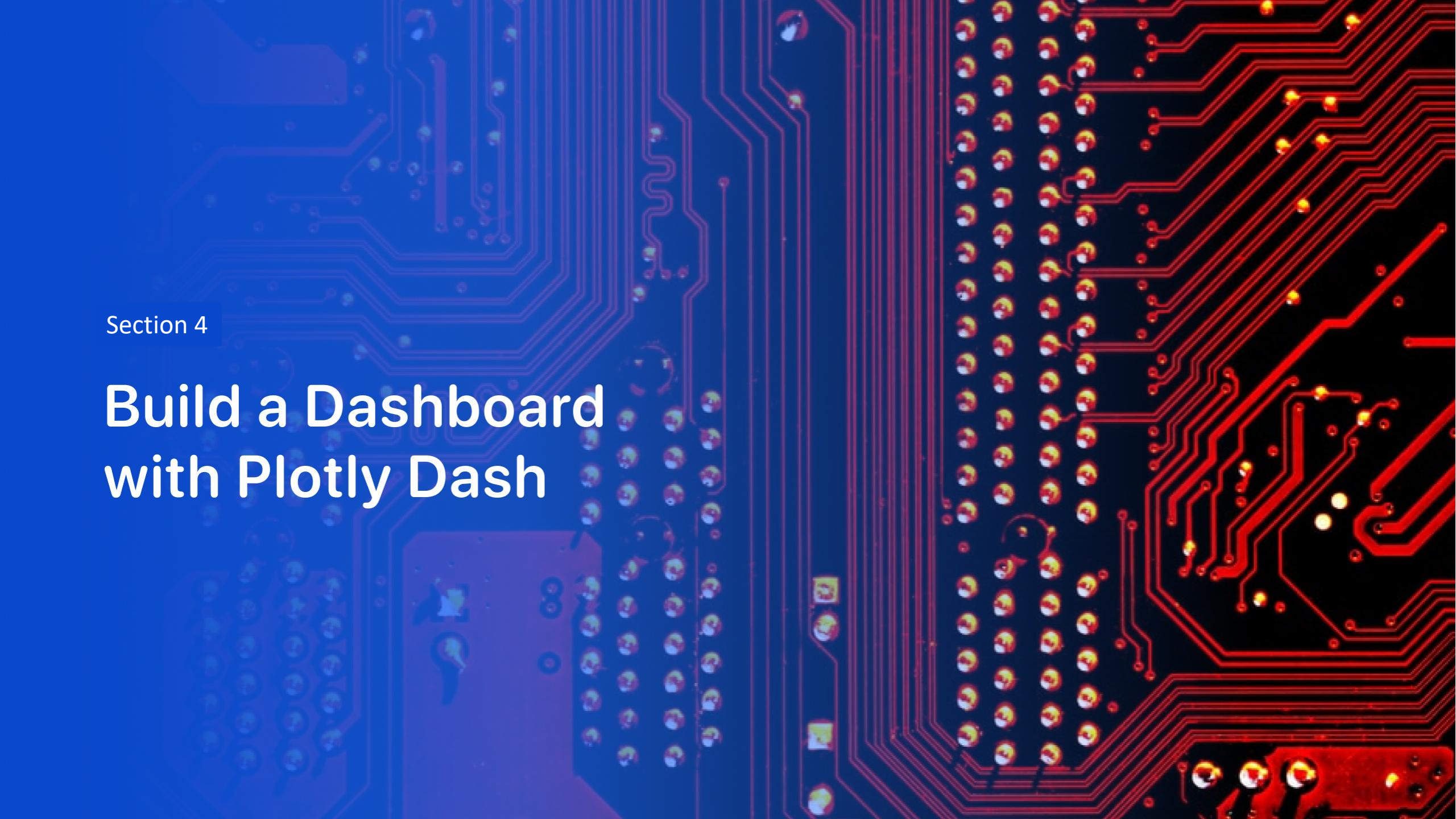


Clusters on Folium map can be clicked on to display each successful landing (green icon) and failed landing (red icon). In this example VAFB SLC-4E shows 4 successful landings and 6 failed landings.

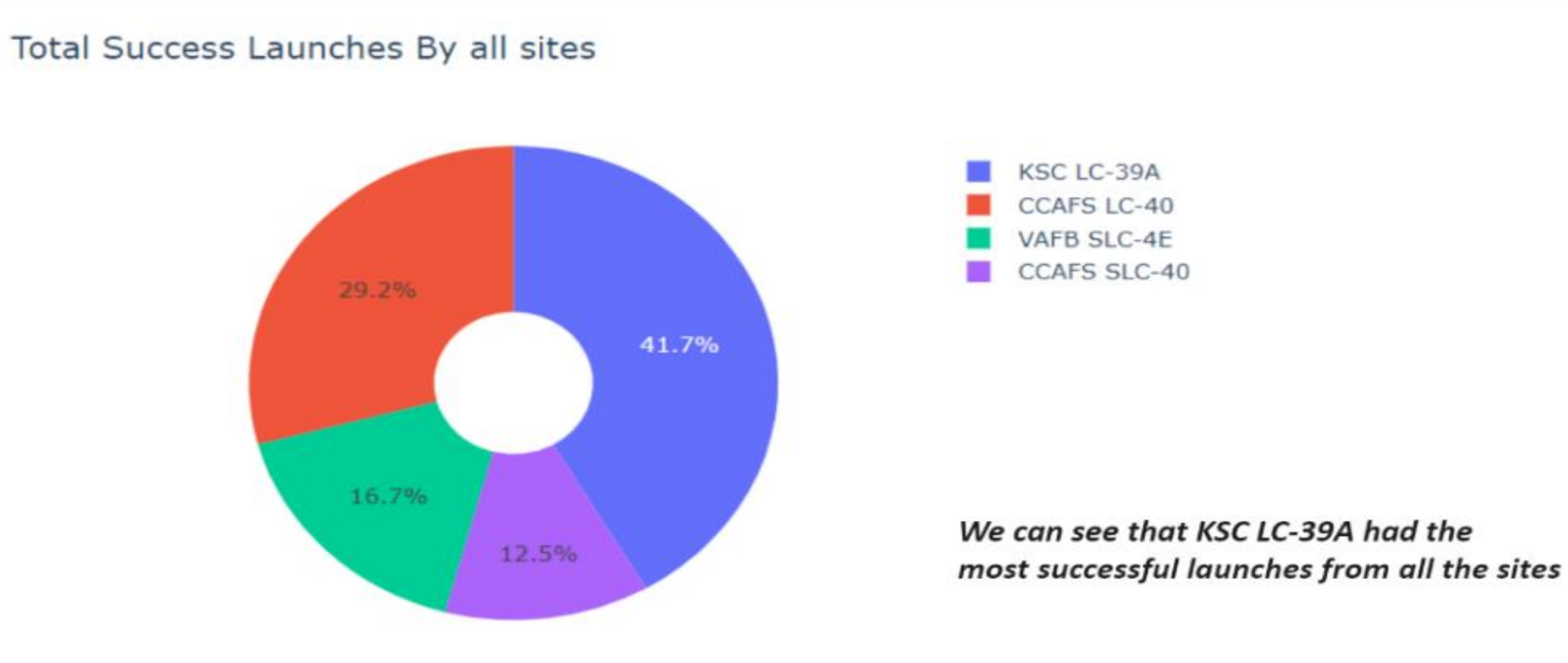
Key Location Proximities



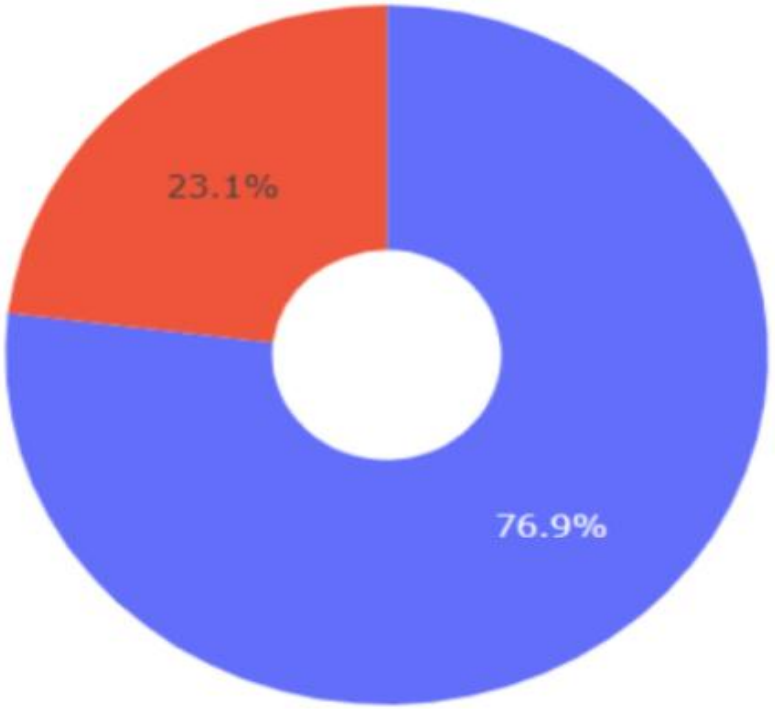
Using KSC LC-39A as an example, launch sites are very close to railways for large part and supply transportation. Launch sites are close to highways for human and supply transport. Launch sites are also close to coasts and relatively far from cities so that launch failures can land in the sea to avoid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


Section 4
Build a Dashboard with Plotly Dash

Pie chart showing the success percentage achieved by each launch site

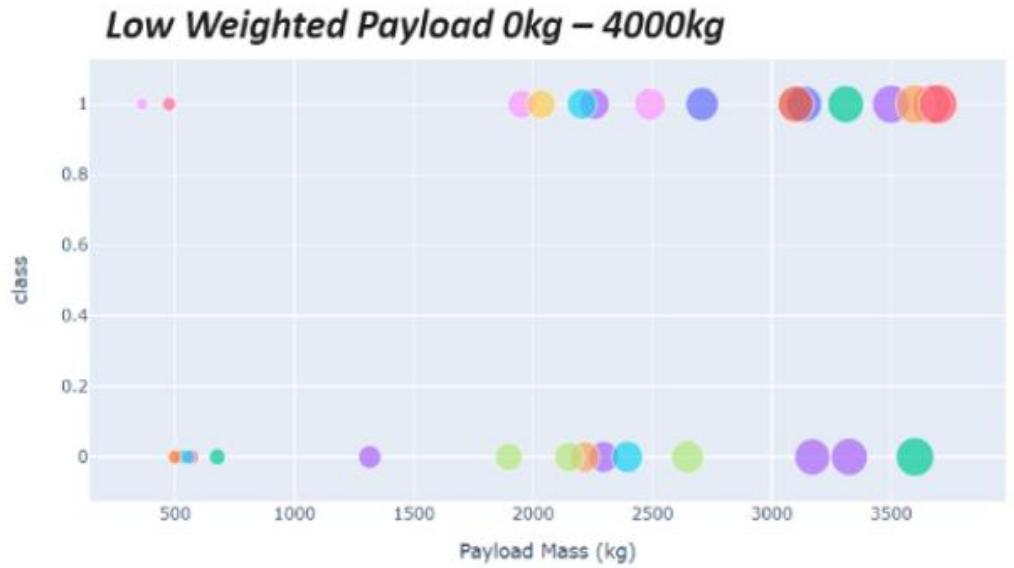


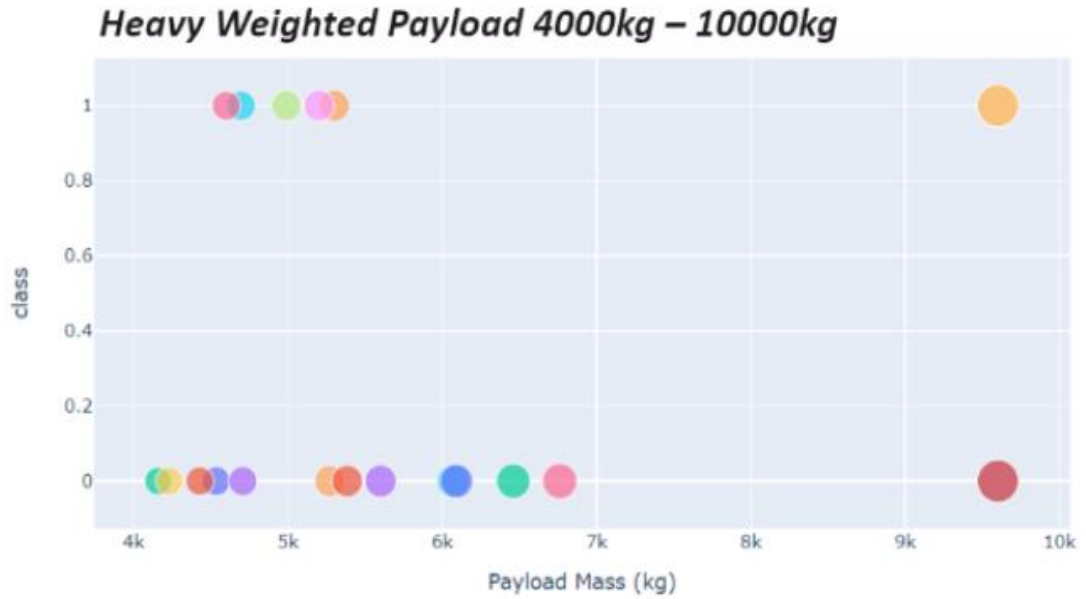
Pie chart showing the Launch site with the highest launch success ratio



KSC LC-39A achieved a 76.9% success rate while getting a 23.1% failure rate

Scatter plot of Payload vs Launch Outcome for all sites, with different payload selected in the range slider





We can see the success rates for low weighted payloads is higher than the heavy weighted payloads

Section 5

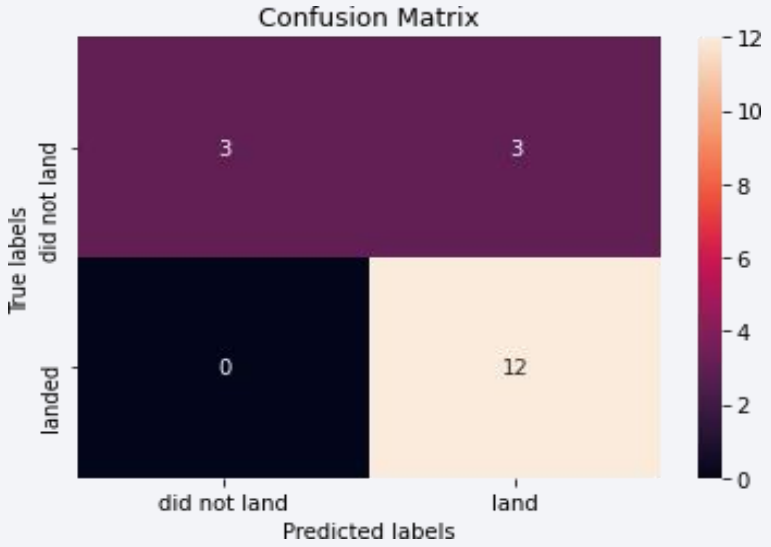
Predictive Analysis (Classification)

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



Correct predictions are on a diagonal from top left to bottom right.

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 Repository URL:

https://github.com/ashuyadav2030/IBM-Applied-Data-Science-Capstone-Project/tree/main

Instructors:

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

Special Thanks to All Instructors:

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

Thank you!