IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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<04/2022>

Outline

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

Executive Summary

- Summary of methodologies
  - Data Collection API
  - Data Collection with Web Scraping
  - Data Wrangling
  - Exploratory Data Analysis with Data Visualization
  - Exploratory Data Analysis with SQL
  - Interactive Visual Analytics with Folium
  - Predictive Analysis with Machine Learning
- Summary of all results
  - Exploratory Data Analysis
  - Interactive Analytics in Screenshots
  - Predictive Analytics Results

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
  - What factors determine if the rocket will land successfully?
  - The interaction amongst various features that determine the success rate of a successful landing.
  - What operating conditions needs to be fullfilled to ensure a successful landing program.

Section 1

Methodology

Methodology

- Data collection methodology:
  - Data was collected using SpaceX API and web scraping from Wikipedia
- 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
  - How to build, tune, evaluate classification models

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 BeautifulSoup.
  - 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

- We used the GET request to the SpaceX API to collect data, clean the requested data and did some data wrangling and formatting, finally store it in a data frame.

- Using GET request to SpaceX API
- Decode response content as a json by using .json()
- Turn the result into Pandas dataframe using .json_normalize()
- Clean and construct a dataset and store in new dataframe
- Filter data to keep the Falcon 9 launches only
- Dealing with missing value by replacing null value with mean

- The link to the notebook is https://github.com/NgocAnLam/Appliced-Data-Science-Capstone/blob/main/Data%20Collection%20API.ipynb

Data Collection - Scraping

- We applied web scrapping to webscraping Falcon 9 launch records with BeautifulSoup
- We parsed the table and converted it into a pandas dataframe.
- The link to the notebook is: https://github.com/NgocAnLam/Appliced-Data-Science-Capstone/blob/main/Data%20Collection%20with%20Web%20Scraping.ipynb

- Request the Falcon 9 Launch Wiki page from URL
- Create a BeautifulSoup object from HTML table
- Extract all column/variable names from the HTML table header
- Create a data frame by parsing the launch HTML tables

Data Wrangling

- We performed exploratory data analysis and determined the training labels.
- We calculated the number of launches at each site, and the number and occurrence of each orbits.
- We created landing outcome label from outcome column and exported the results to csv.
- The link to the notebook is: https://github.com/NgocAnLam/Appliced-Data-Science-Capstone/blob/main/EDA.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.
- The link to the notebook is: https://github.com/NgocAnLam/Appliced-Data-Science-Capstone/blob/main/EDA%20with%20Visualization.ipynb

EDA with SQL

- We loaded the SpaceX dataset into a PostgreSQL database without leaving the jupyter notebook.
- We applied EDA with SQL to get insight from the data. We wrote queries to find out for instance:

  - The name 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.

- The link to the notebook is: https://github.com/NgocAnLam/Appliced-Data-Science-Capstone/blob/main/EDA%20with%20SQL.ipynb

Build an Interactive Map with Folium

- We marked all launch sites, and added map objects such as markers, circles, lines to mark the success or failure of launches for each site on the folium map.
- We assigned the feature launch outcomes (failure or success) to class 0 and 1.

  i.e., 0 for failure, and 1 for success.
- Using the color-labeled marker clusters, we identified which launch sites have relatively high success rates.
- We calculated the distances between a launch site to its proximities. We answered some question for instance:

  - Are launch sites near railways, highways and coastlines.

  - Do launch sites keep certain distance away from cities.

  - The link to the notebook is: https://github.com/NgocAnLam/Appliced-Data-Science-Capstone/blob/main/The%20Interactive%20Visual%20Analytics%20with%20Folium.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.
- The link to the notebook is: https://github.com/NgocAnLam/Appliced-Data-Science-Capstone/blob/main/The%20Interactive%20Visual%20Analytics%20with%20Folium.ipynb

Predictive Analysis (Classification)

- We loaded the data using numpy and pandas, transformed the data, split our data into training and testing.
- We built different machine learning models and tune different hyperparameters using GridSearchCV.
- We used accuacy as the metric for our model, improved the model using feature engineering and algorithm tuning.
- We found the best performing classification model.
- The link to the notebook is: https://github.com/NgocAnLam/Appliced-Data-Science-Capstone/blob/main/The%20Machine%20Learning%20Prediction.ipynb

Results

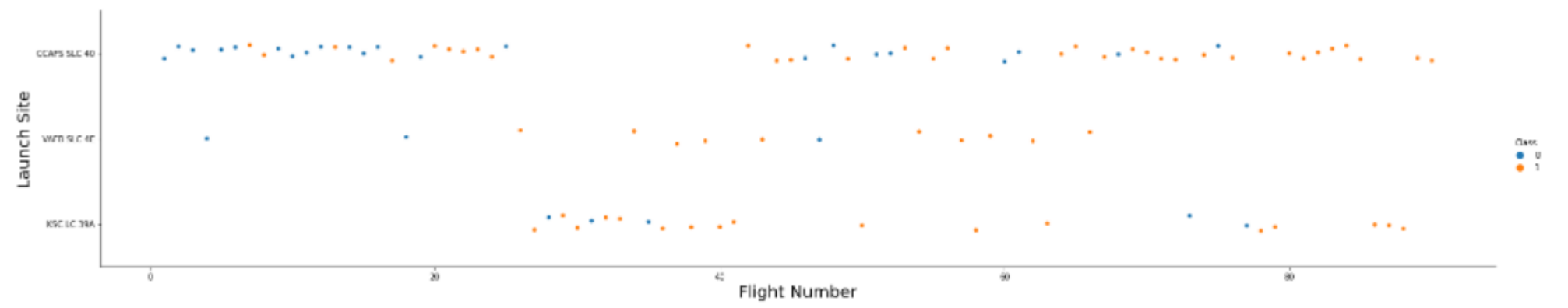
- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

Section 2

Insights drawn from EDA

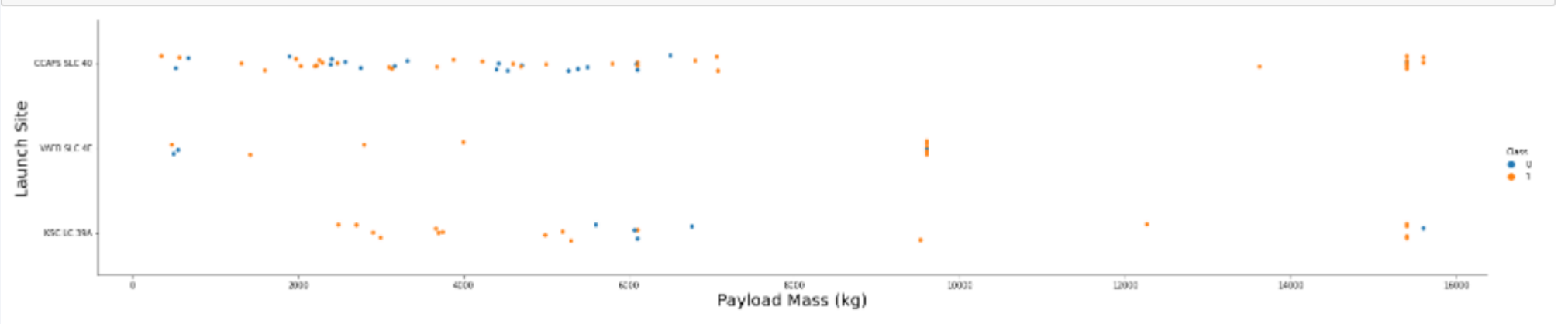
Flight Number vs. Launch Site

- From the plot, we found that the larger the flight amount at a launch site, the greater the success rate at a launch site.



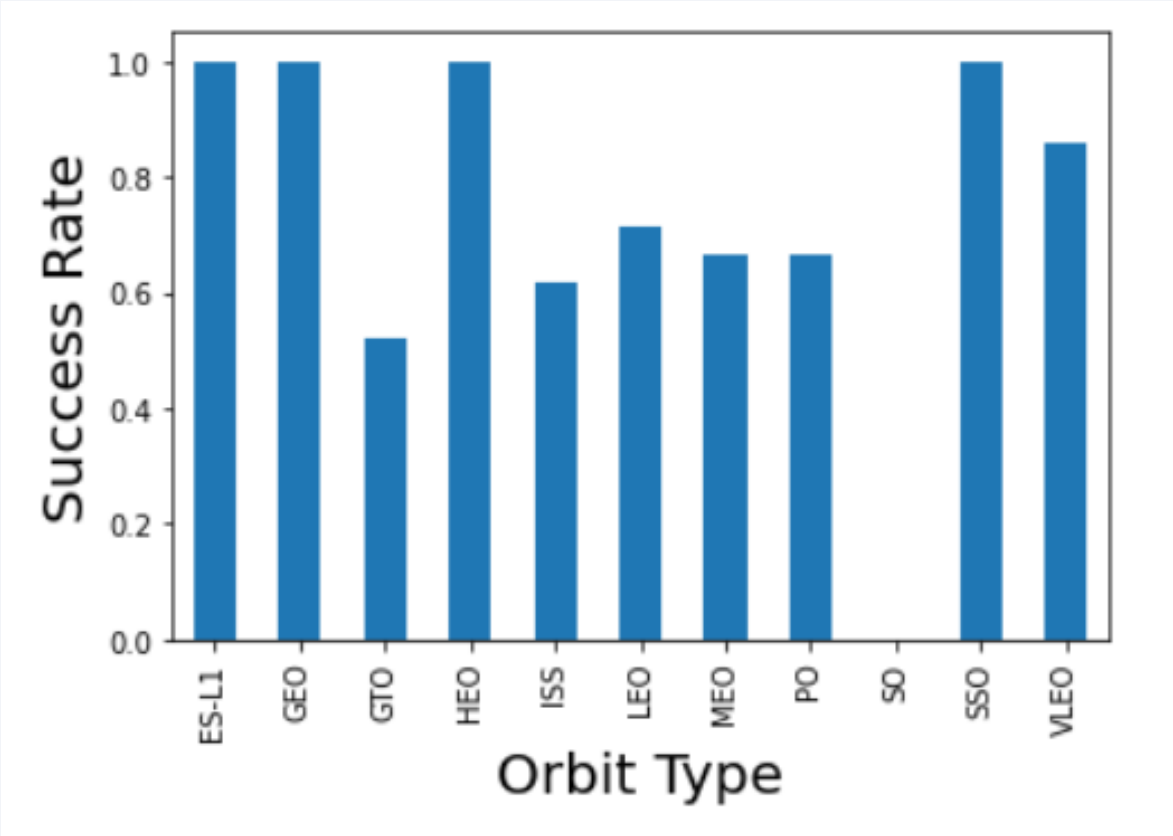
Payload vs. Launch Site

- The greater the payload mass for launch site CCAFS SLC 40 the higher the success rate for the rocket.



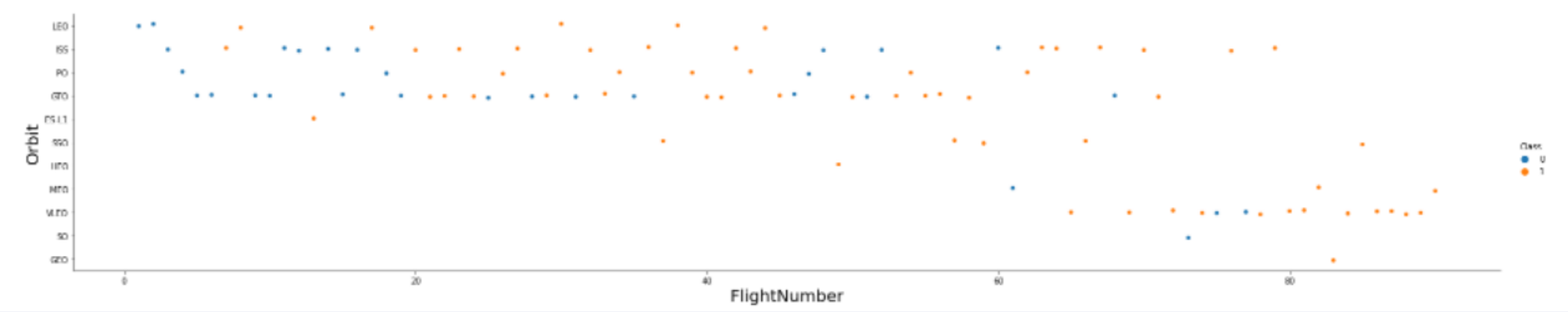
Success Rate vs. Orbit Type

- From the plot, we can see that ES-L1, GEO, HEO, SSO, VLEO had the most success rate.



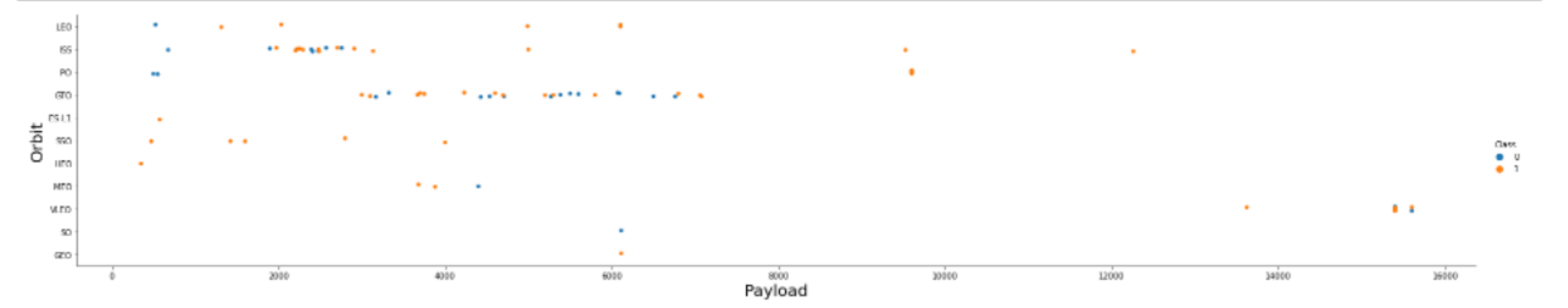
Flight Number vs. Orbit Type

- The plot below shows the Flight Number vs. Orbit type. We observe that in the LEO orbit, success is related to the number of flights whereas in the GTO orbit, there is no relationship between flight number and the orbit.



Payload vs. Orbit Type

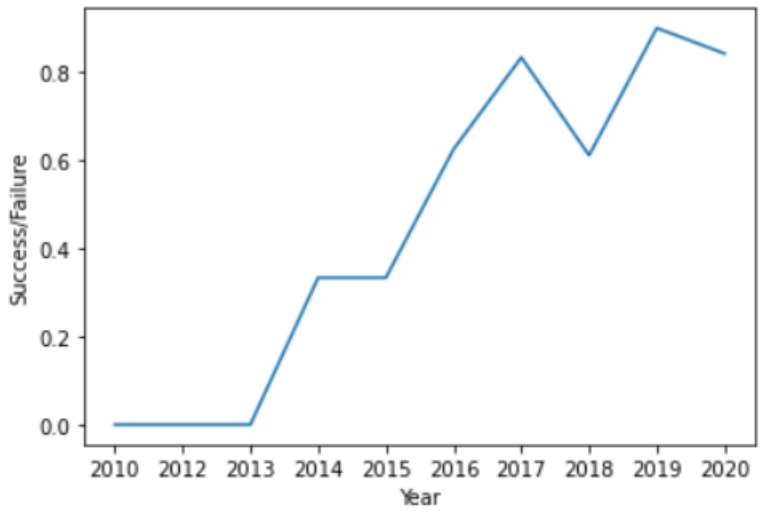
- We can observe that with heavy payloads, the successful landing are more for PO, LEO and ISS orbits.



Launch Success Yearly Trend

- From the plot, we can observe that success rate since 2013 kept on increasing till 2020.

```
In [30]: # Plot a line chart with x axis to be the extracted year and y axis to be the success rate
plt.plot(average_by_year["Year"],average_by_year["Class"])
plt.xlabel("Year")
plt.ylabel("Success/Failure")
plt.show()
```



All Launch Site Names

- We used the key word **DISTINCT** to show only unique launch sites from the SpaceX data.

Display the names of the unique launch sites in the space mission

In [62]:
```
%%sql
select distinct LAUNCH_SITE
from SPACEXTBL;
```

```
 * ibm_db_sa://bql93821:***@1bbf73c5-d84a-4bb0-85b9-ab1a4348f4a4.c3n41cmd0nqnrk39u98g.databases.appdomain.cloud:32286/bludb
Done.
```

Out[62]:

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

Launch Site Names Begin with 'CCA'

- We used the query above to display 5 records where launch sites begin with 'CCA%'

Display 5 records where launch sites begin with the string 'CCA'

In [63]:
```
%%sql
select * from SPACEXTBL
where LAUNCH_SITE like 'CCA%'
limit 5;
```

```
 * ibm_db_sa://bql93821:***@1bbf73c5-d84a-4bb0-85b9-ab1a4348f4a4.c3n41cmd0nqnrk39u98g.databases.appdomain.cloud:32286/bludb
Done.
```

Out[63]:

DATE	time__utc_	booster_version	launch_site	payload	payload_mass__kg_	orbit	customer	mission_outcome	landing_outcome
2010-04-06	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-08-12	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)
2012-08-10	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-01-03	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-03-12	22:41:00	F9 v1.1	CCAFS LC-40	SES-8	3170	GTO	SES	Success	No attempt

Total Payload Mass

- We calculated the total payload carried by boosters from NASA as 45596 using the query below

Display the total payload mass carried by boosters launched by NASA (CRS)

In [64]:
```
%%sql
select sum(PAYLOAD_MASS__KG_)
from SPACEXTBL
where Customer = 'NASA (CRS)';
```

```
 * ibm_db_sa://bql93821:***@1bbf73c5-d84a-4bb0-85b9-ab1a4348f4a4.c3n41cmd0nqnrk39u98g.databases.appdomain.cloud:32286/bludb
Done.
```

Out[64]:

1
22007

Average Payload Mass by F9 v1.1

- We calculated the average payload mass carried by booster version F9 v1.1

Display average payload mass carried by booster version F9 v1.1

In [65]:
```
%%sql
select AVG(payload_mass__kg_) as avg from SPACEXTBL
where booster_version like 'F9 v1.1%'
```

```
 * ibm_db_sa://bql93821:***@1bbf73c5-d84a-4bb0-85b9-ab1a4348f4a4.c3n41cmd0nqnrk39u98g.databases.appdomain.cloud:32286/bludb
Done.
```

Out[65]:

AVG
3226

First Successful Ground Landing Date

- We used **DISTINCT** to find the right value representing successful ground landing and then used MIN-function found the dates of the first successful landig outcome on ground pad

```
%%sql
select distinct landing__outcome from SPACEXTBL
```

```
   ibm_db_sa://jxd70927:***@ea286ace-86c7-4d5b-8580-3fbfa46b1c66.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31505/bludb
 * ibm_db_sa://jxd70927:***@ea286ace-86c7-4d5b-8580-3fbfa46b1c66.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31505/bludb;security=SSL
Done.
```

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

```
%%sql
select min(date) from SPACEXTBL where landing__outcome = 'Success (ground pad)'
```

```
   ibm_db_sa://jxd70927:***@ea286ace-86c7-4d5b-8580-3fbfa46b1c66.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31505/bludb
 * ibm_db_sa://jxd70927:***@ea286ace-86c7-4d5b-8580-3fbfa46b1c66.bs2io90l08kqb1od8lcg.databases.appdomain.cloud:31505/bludb;security=SSL
Done.
```

1
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

- We used the **WHERE** clause to filter for boosters which have successfully landed on drone ship and applied AND condition to determine successful landing with payload mass greater than 4000 but less than 6000.

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

In [67]:
```
%%sql
select booster_version, payload_mass__kg_ from SPACEXTBL
where landing_outcome = 'Success (drone ship)' and 4000 < payload_mass__kg_ and payload_mass__kg_ < 6000
group by booster_version, payload_mass__kg_
```

```
 * ibm_db_sa://bql93821:***@1bbf73c5-d84a-4bb0-85b9-ab1a4348f4a4.c3n41cmd0nqnrk39u98g.databases.appdomain.cloud:32286/bludb
Done.
```

Out[67]:

booster_version	payload_mass__kg_
F9 FT B1031.2	5200
F9 FT B1022	4696

Total Number of Successful and Failure Mission Outcomes

- We used WHERE Mission Outcome was a success.

List the total number of successful and failure mission outcomes

In [68]:
```
%%sql
select mission_outcome, count(mission_outcome) as total_nr
from SPACEXTBL
group by mission_outcome
```

```
 * ibm_db_sa://bql93821:***@1bbf73c5-d84a-4bb0-85b9-ab1a4348f4a4.c3n41cmd0nqnrk39u98g.databases.appdomain.cloud:32286/bludb
Done.
```

Out[68]:

mission_outcome	total_nr
Success	44
Success (payload status unclear)	1

Boosters Carried Maximum Payload

- We determined the booster that have carried the maximum payload using a subquery in the WHERE clause and the MAX() function.

List the names of the booster_versions which have carried the maximum payload mass. Use a subquery

In [69]:
```
%%sql
SELECT DISTINCT booster_version
FROM SPACEXTBL
WHERE payload_mass__kg_ = (
    SELECT max(payload_mass__kg_)
    FROM SPACEXTBL
)
```

```
 * ibm_db_sa://bql93821:***@1bbf73c5-d84a-4bb0-85b9-ab1a4348f4a4.c3n41cmd0nqnrk39u98g.databases.appdomain.cloud:32286/bludb
Done.
```

Out[69]:

booster_version
F9 B5 B1048.4
F9 B5 B1049.4
F9 B5 B1049.5
F9 B5 B1058.3
F9 B5 B1060.2

2015 Launch Records

- We used a combinations of the WHERE clause, LIKE, AND, and BETWEEN conditions to filter for failed landing outcomes in drone ship, their booster versions, and launch site names for year 2015

List the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015

In [70]:
```
%%sql
select landing_outcome, booster_version,launch_site
from SPACEXTBL
where landing_outcome = 'Failure (drone ship)' and year(date) = 2015
group by landing_outcome, booster_version,launch_site
```

```
 * ibm_db_sa://bql93821:***@1bbf73c5-d84a-4bb0-85b9-ab1a4348f4a4.c3n41cmd0nqnrk39u98g.databases.appdomain.cloud:32286/bludb
Done.
```

Out[70]:

landing_outcome	booster_version	launch_site
Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40

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

- We used **GROUP BY** and **ORDER BY** to rank the count of landing outcomes (such as Failure (drone ship) or Success (ground pad)) between 2016-06-04 to 2010-03-20 in a descending order.

Rank 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 [71]:
```
%%sql
select landing_outcome, count(landing_outcome) as total_nr
from SPACEXTBL
where date between '2010-06-04' and '2017-03-20'
group by landing_outcome
order by total_nr desc
```

```
 * ibm_db_sa://bql93821:***@1bbf73c5-d84a-4bb0-85b9-ab1a4348f4a4.c3n41cmd0nqnrk39u98g.databases.appdomain.cloud:32286/bludb
Done.
```

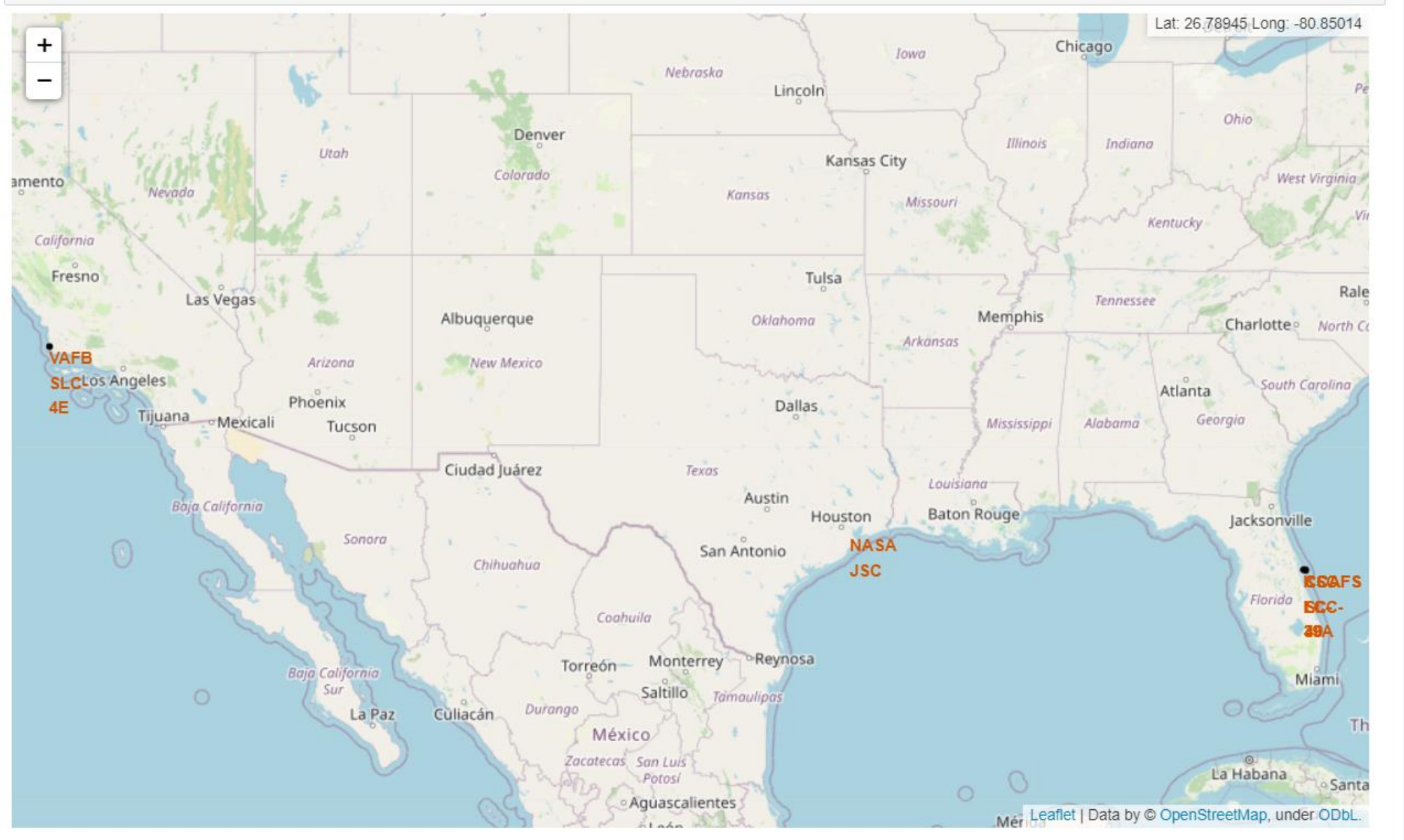
Out[71]:

landing_outcome	total_nr
No attempt	7
Failure (drone ship)	2
Success (drone ship)	2
Success (ground pad)	2
Controlled (ocean)	1
Failure (parachute)	1

Section 3

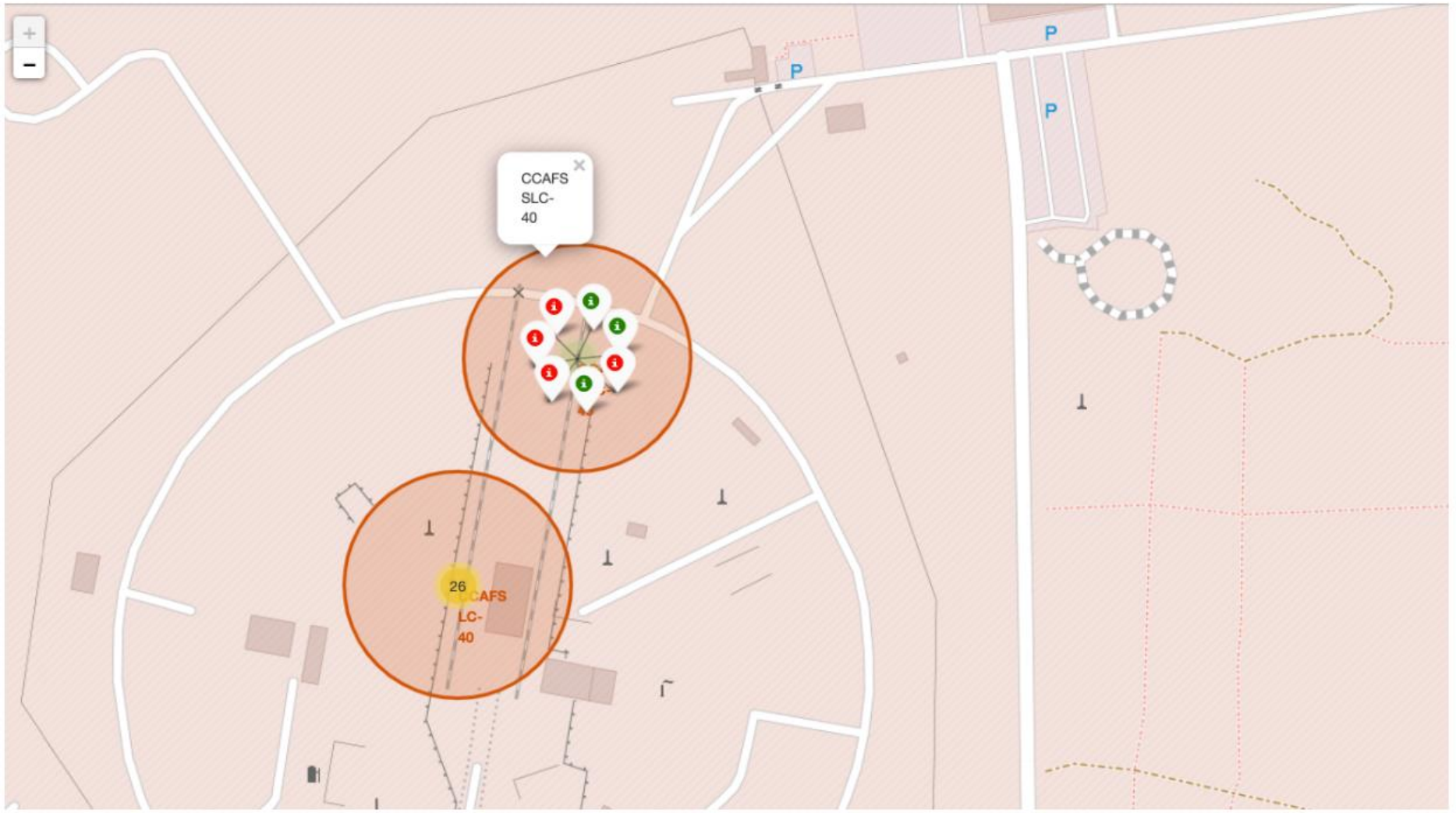
Launch Sites Proximities Analysis

Folium Map



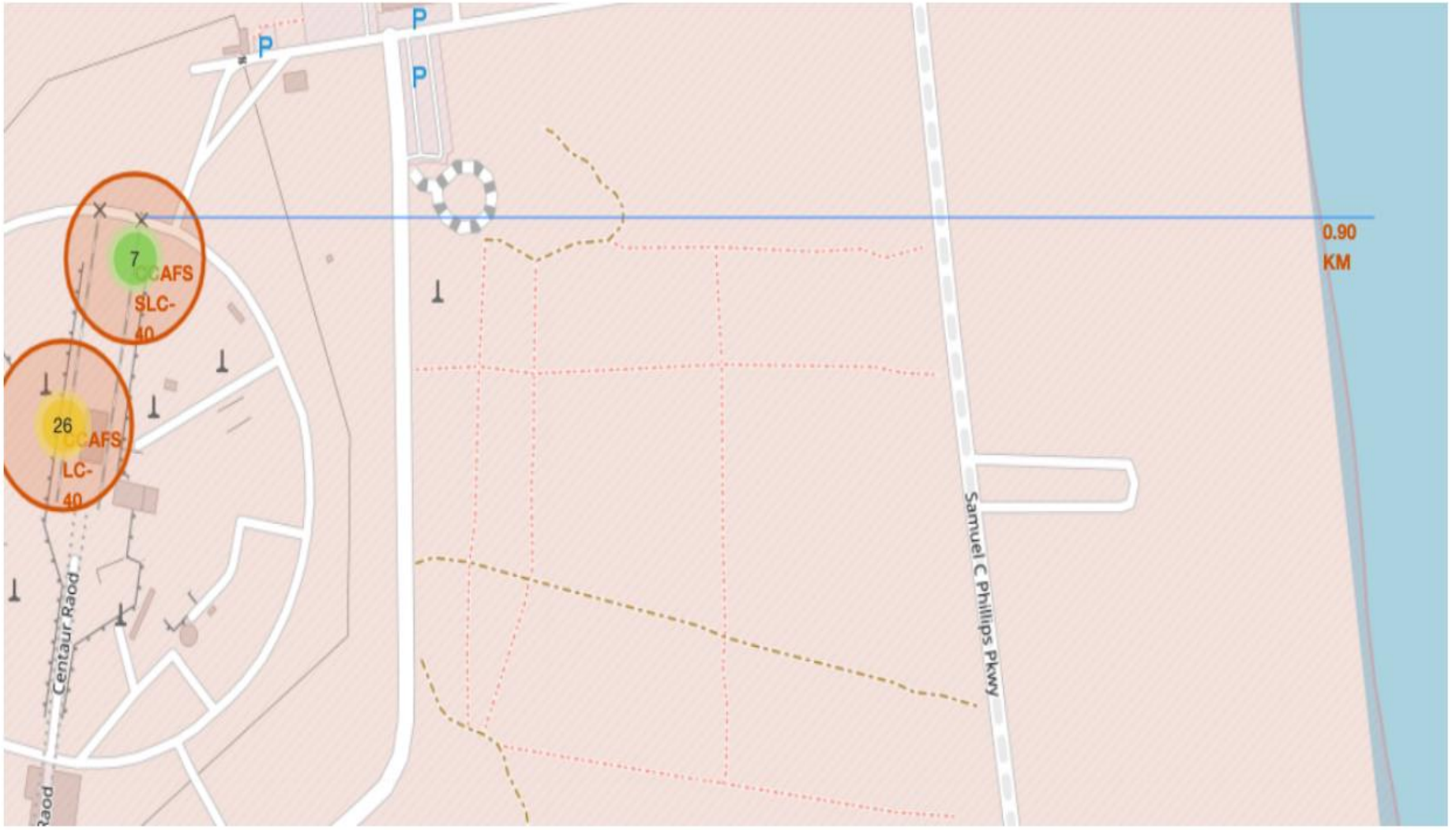
All SpaceX launch sites are in the US coasts, Florida and California

Folium Map

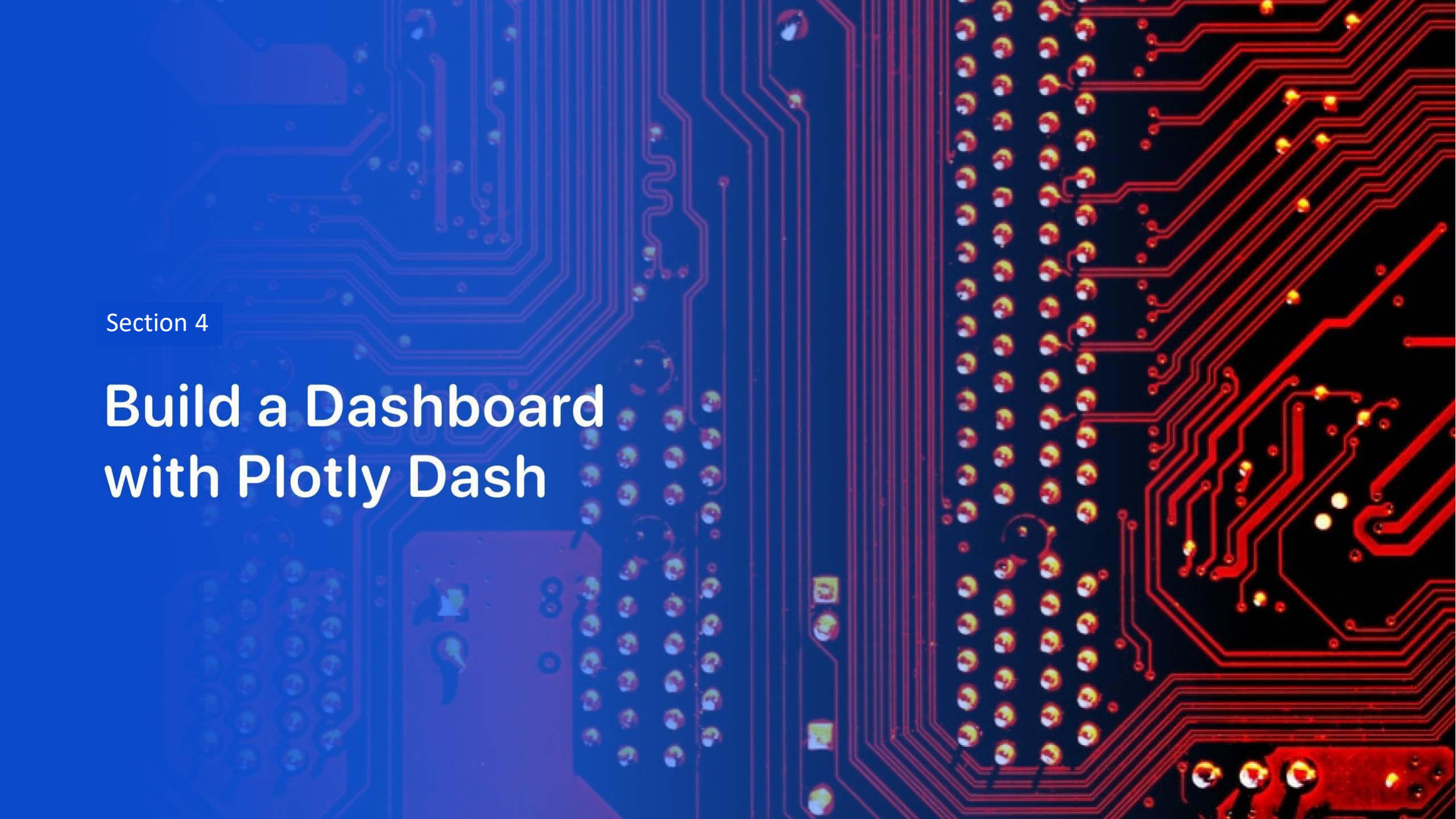


- Green Marker: successful launches
- Red Marker: failures

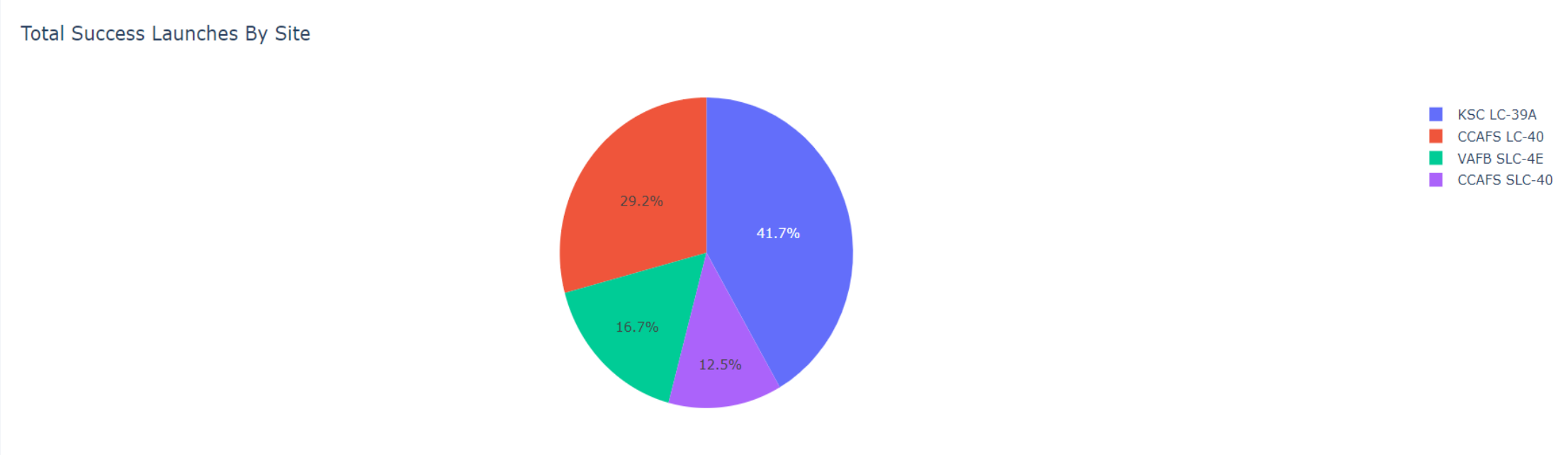
<Folium Map Screenshot 3>



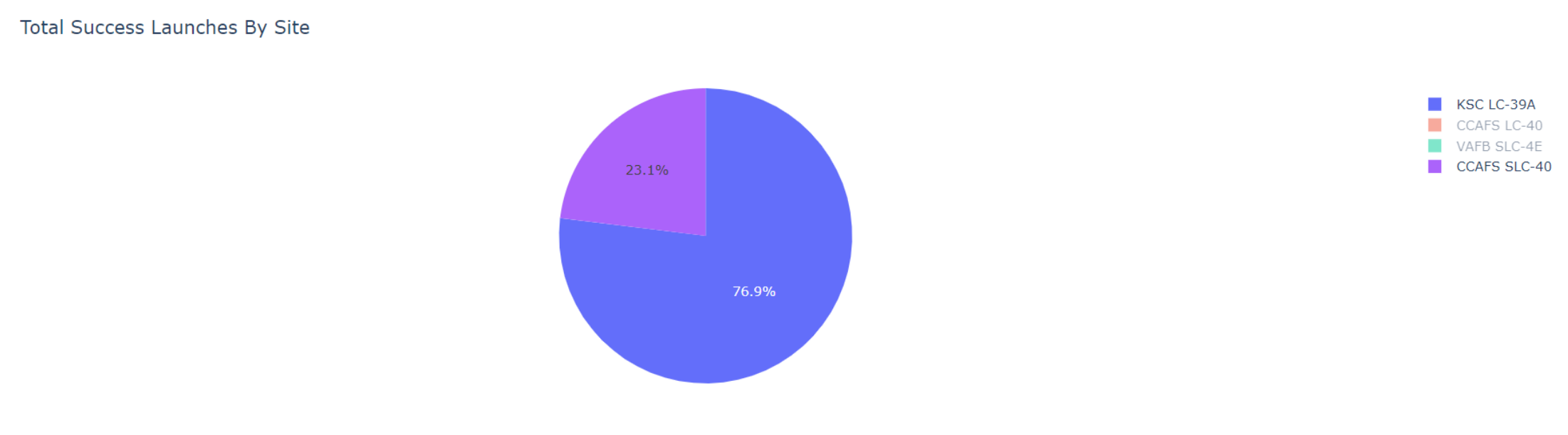
Launch site are relatively close to railway and highway for transport reasons.


Section 4
Build a Dashboard with Plotly Dash

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



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



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

Section 5

Predictive Analysis (Classification)

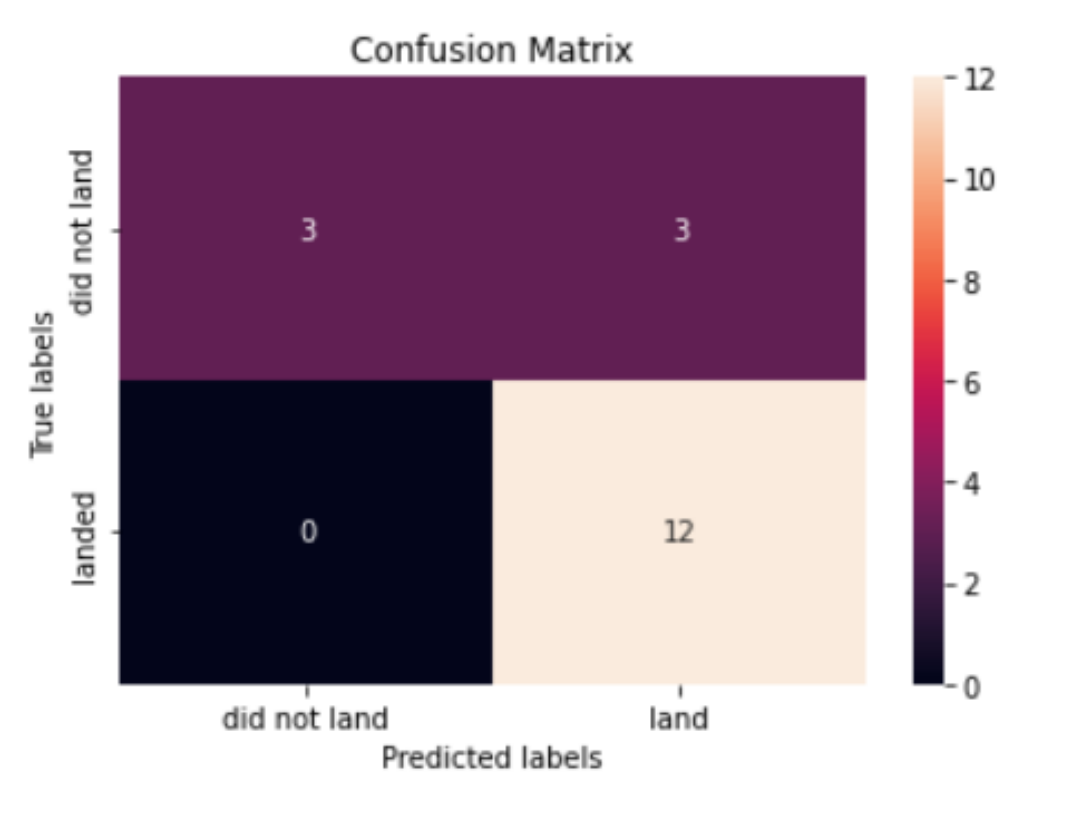
Classification Accuracy

- The decision tree classifier is the model with the highest classification accuracy

```
In [26]: tree_cv = GridSearchCV(tree,parameters,cv=10)
         tree_cv.fit(X_train, Y_train)

Out[26]: GridSearchCV(cv=10, estimator=DecisionTreeClassifier(),
                      param_grid={'criterion': ['gini', 'entropy'],
                                  'max_depth': [2, 4, 6, 8, 10, 12, 14, 16, 18],
                                  'max_features': ['auto', 'sqrt'],
                                  'min_samples_leaf': [1, 2, 4],
                                  'min_samples_split': [2, 5, 10],
                                  'splitter': ['best', 'random']})

In [27]: print("tuned hpyerparameters :(best parameters) ",tree_cv.best_params_)
         print("accuracy :",tree_cv.best_score_)

         tuned hpyerparameters :(best parameters)  {'criterion': 'entropy', 'max_depth': 12, 'max_features': 'sqrt', 'min_samples_leaf':
         4, 'min_samples_split': 2, 'splitter': 'random'}
         accuracy : 0.8767857142857143
```

Confusion Matrix

- The confusion matrix for the decision tree classifier shows that the classifier can distinguish between the different classes. The major problem is the false positives. i.e., unsuccessful landing marked as successful landing by the classifier.



Conclusions

We can conclude that:

- The larger the flight amount at a launch site, the greater the success rate at a launch site.
- Launch success rate started to increase in 2013 till 2020.
- Orbits ES-L1, GEO, HEO, SSO, VLEO had the most success rate.
- KSC LC-39A had the most successful launches of any sites.
- The Decision tree classifier is the best machine learning algorithm for this task.

Appendix

- Include any relevant assets like Python code snippets, SQL queries, charts, Notebook outputs, or data sets that you may have created during this project

Thank you!