IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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<Dec 12, 2025>

Outline

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

Executive Summary

- Summary of methodologies:
  - Data collection
  - Data wrangling
  - Exploratory data analysis (EDA)
  - Interactive visual analysis
  - Predictive analysis (classification)
- Summary of all results:
  - EDA results
  - Geospatial analysis
  - Interactive dashboard
  - Predictive analysis of classification models

Introduction

- **Background**

SpaceX advertises Falcon 9 rocket launches on its website with a cost of 62 million dollars wheras 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 SpaceX for a rocket launch.

- **Problems**
  - Any patterns in the data?
  - What would be the label for training supervised models.
  - Best predictive model for falcon 9 first stage successful landing.

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - Collection using SpaceX REST API and web scraping from wikipedia page.
- Perform data wrangling
  - Filtering data,dealing with missing data and one hot encoding for categorical data.
  - Preparation for following analysis and modeling.
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - Build logistic regression, decision tree, svm, and knn model using classification method (scikit learn)
  - Evaluate model performance using accuracy, precision, F1, recall (scikit learn)

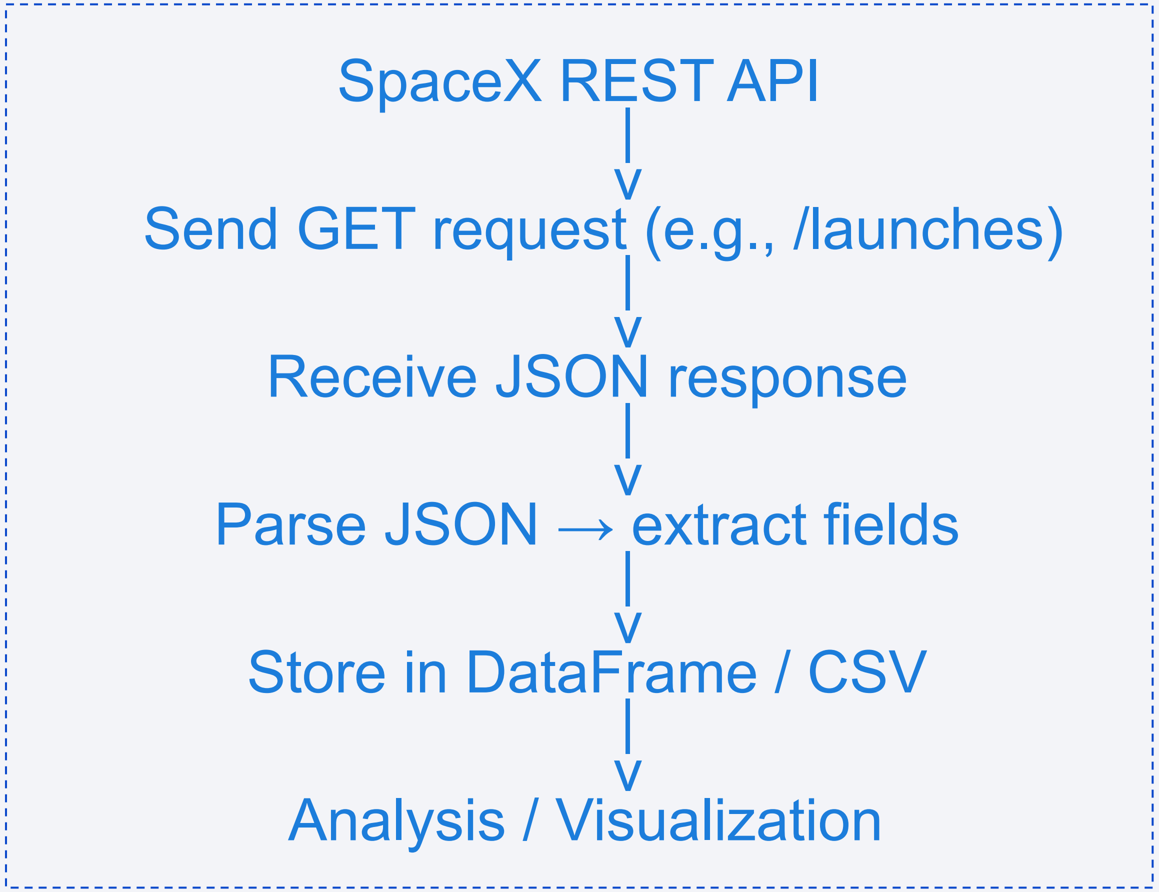
Data Collection

1. Request from SpaceX API
    a. Collect past launch data via open-source API (GET request) to get JSON data.
    b. Filled missing value of payload mass column with mean.
2. Web scraping
    a. Request Falcon 9 launch data from wikipedia page.
    b. Extracted all the column names from the HTML table.
    c. Transformed the table into a Panda dataframe.

Data Collection – SpaceX API

- GET /launches → retrieve launch info
- parse JSON → extract fields like flight_number, launch_site
- store in DataFrame → save data in pandas for analysis

GitHub url: https://github.com/lingwanggatech/IBM-SpaceX-Capstone/blob/main/1-spacex-data-collection-api.ipynb



SpaceX REST API
|
v
Send GET request (e.g., /launches)
|
v
Receive JSON response
|
v
Parse JSON → extract fields
|
v
Store in DataFrame / CSV
|
v
Analysis / Visualization

Data Collection - Scraping

Workflow

1. Send HTTP request (GET)
2. Receive HTML response
3. Parse HTML (BeautifulSoup)
4. Extract data (soup.title attributes)
5. Extract relevant column from HTML table header
6. Parse the launch HTML tables
7. Store data in Pandas dataframe

GitHub url:
https://github.com/lingwanggatech/IBM-SpaceX-Capstone/blob/main/2-spacex-webscraping.ipynb

SpaceX REST API
|
v
Send GET request (Falcon 9)
|
v
Receive HTML response
|
v
Parse HTML → extract tables
|
v
Store in DataFrame / CSV

Data Wrangling

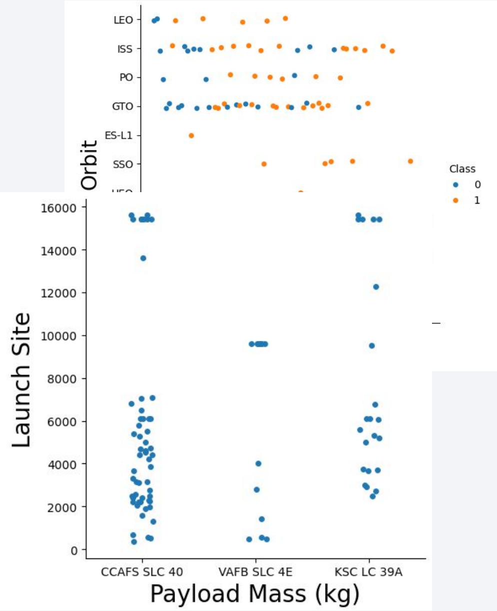
1. Calculate the number of launchers on each site(.value_counts()
2. Calculate the occurrence of each orbit (.value_counts())
3. Determine the landing outcomes and create a landing outcome label
4. Determine the success rate (.mean())
5. Save processed data to csv.

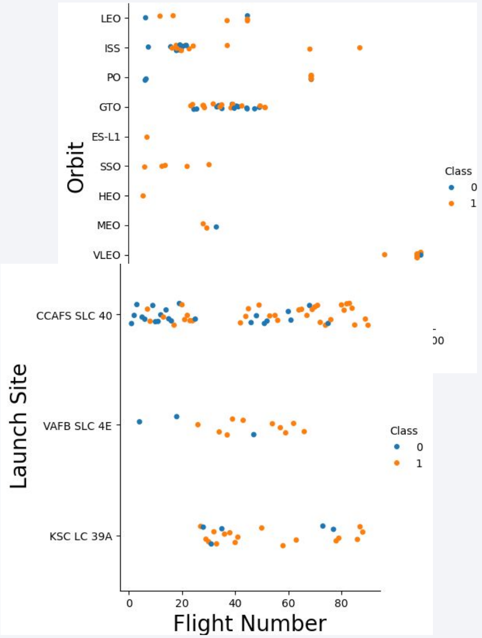
https://github.com/lingwanggatech/IBM-SpaceX-Capstone/blob/main/3-spacex-Data%20wrangling.ipynb

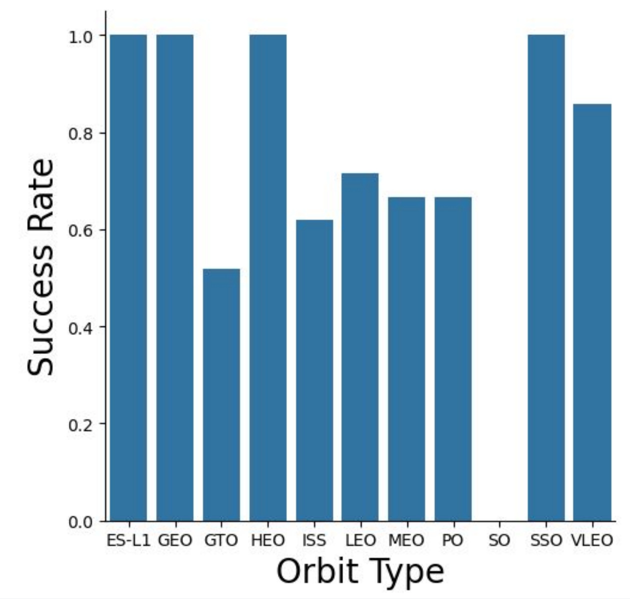
EDA with Data Visualization

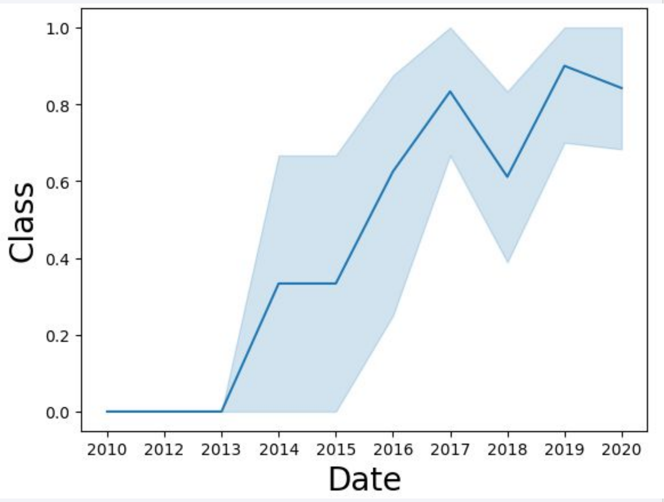
scatter plot, **bar plot** and **line plot** to visualize:

1. Relationship among orbit type, payload mass, flight number, launch site
2. Relationship between success rate of each orbit type
3. Trend of successful launch.









https://github.com/lingwanggatech/IBM-SpaceX-Capstone/blob/main/5-spacex-eda-sql-dataviz.ipynb

EDA with SQL

- Using bullet point format, summarize the SQL queries you performed
- Find unique launch sites (Distinct)
- Display 5 records where launch site begin with “CCA” (Limit 5, Like ‘CCA%’)
- Total payload mass by NASA (CRS) (sum)
- Average payload mass by booster version is F9 v1.1
- First successful landing date in ground pad (min(Date))
- Listing names of booster have success in drone ship and 4000 < payload mass < 6000
- Total number of successful and failure outcomes (count)
- Find booster version with max(payload mass)
- List records has failure landing in 2025
- Count landing outcome between 06-04-2016 and 03-20-2017

https://github.com/lingwanggatech/IBM-SpaceX-Capstone/blob/main/4-spacex-eda-sql_sqllite.ipynb

Build an Interactive Map with Folium

-

circle,marker

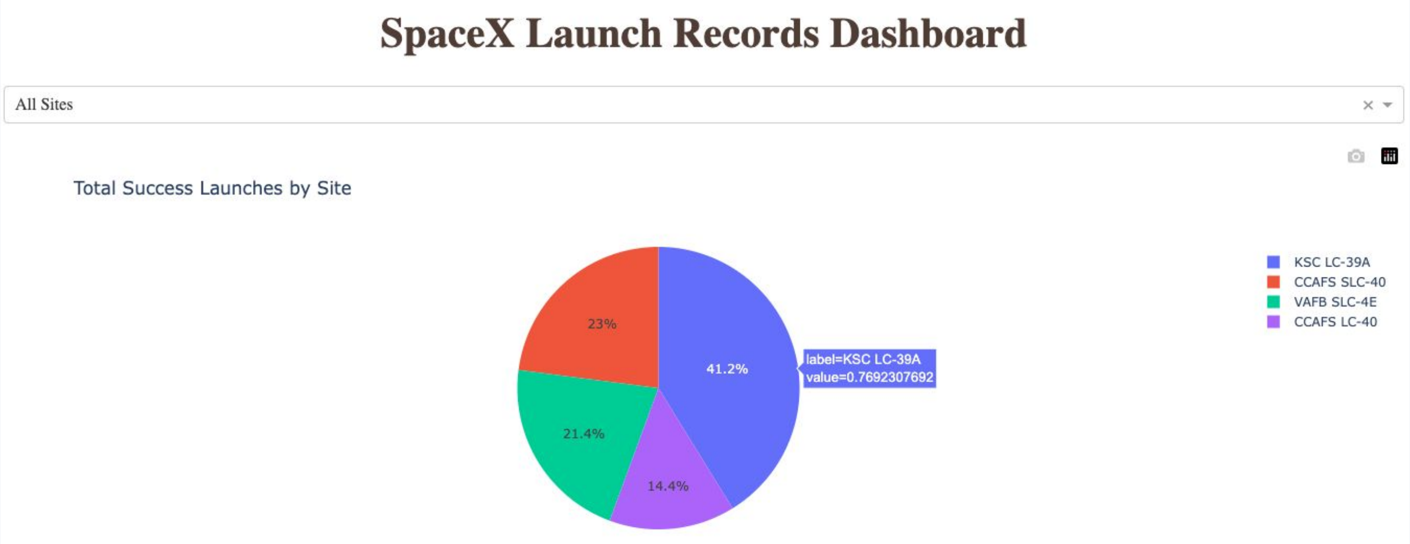
Mark all launch sites on map

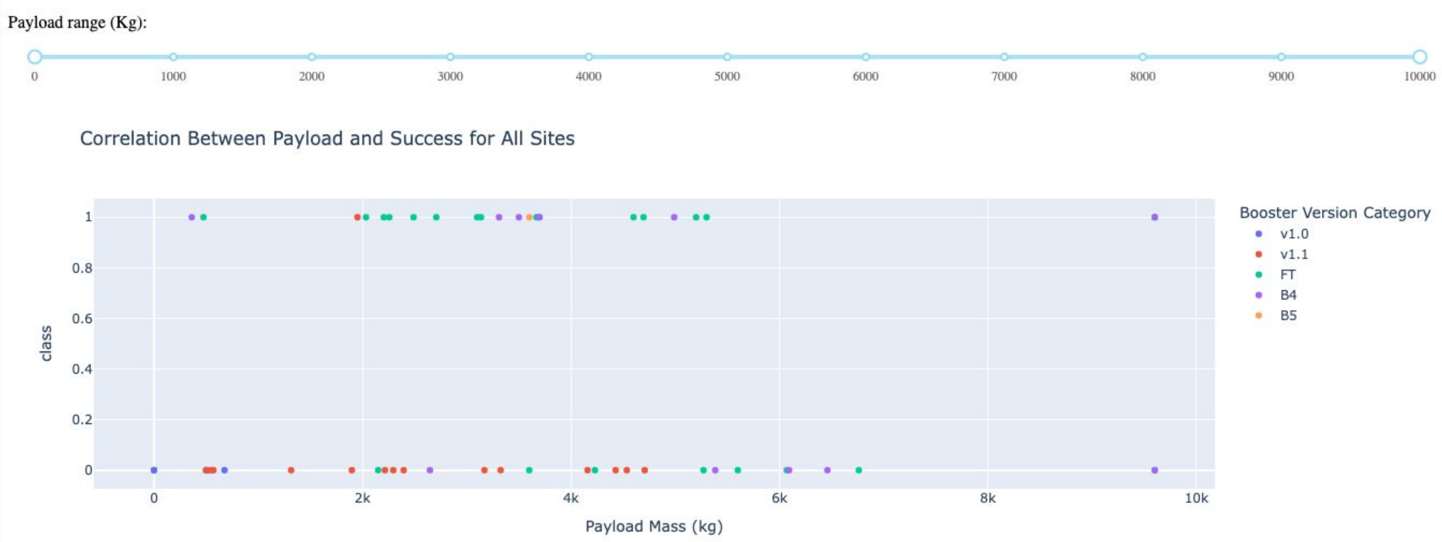
Mark the success/failed launches for each sites on map

Calculate the distances between a launch site to its proximities.

https://github.com/lingwanggatech/IBM-SpaceX-Capstone/blob/main/6-spacex_launch_site_location_Folium.ipynb

Build a Dashboard with Plotly Dash





https://github.com/lingwanggatech/IBM-SpaceX-Capstone/blob/main/7-spacex-dash-app.py

Predictive Analysis (Classification)

- Split data into testing (20%)and training set (80%)
- Grid search to find the best hyperparameters
- Make prediction
- Evaluate the model using accuracy, confusion matrix.
- Compare models and find the best one.

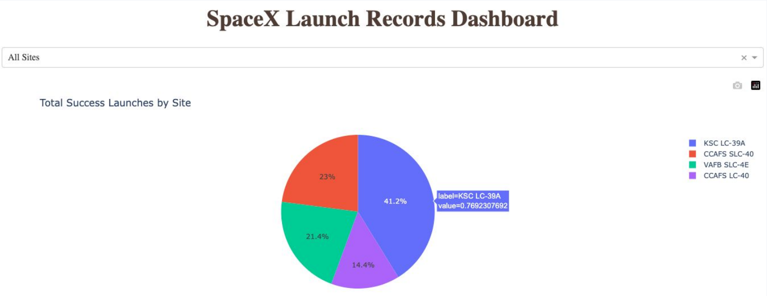
Load Data & Preprocessing
|
v
Split Train & Test Sets
|
v
Standardize / Scale Features
|
v
Train Models
(logistic regression, svm, knn, decision tree) —>
Grid search
|
v
Test models
|
v
Evaluate metric & compare models' performance

https://github.com/lingwanggatech/IBM-SpaceX-Capstone/blob/main/8-SpaceX_Machine%20Learning%20Prediction_Part_5.ipynb

Results

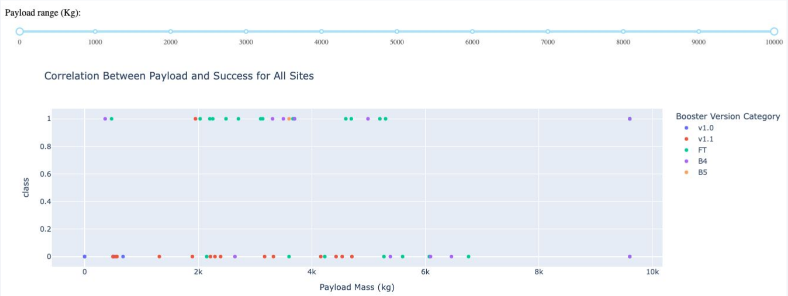
- Exploratory data analysis results
  1. Launch success has improved over time
  2. KSC LC-39A has the highest success rate

- Interactive analytics demo in screenshots

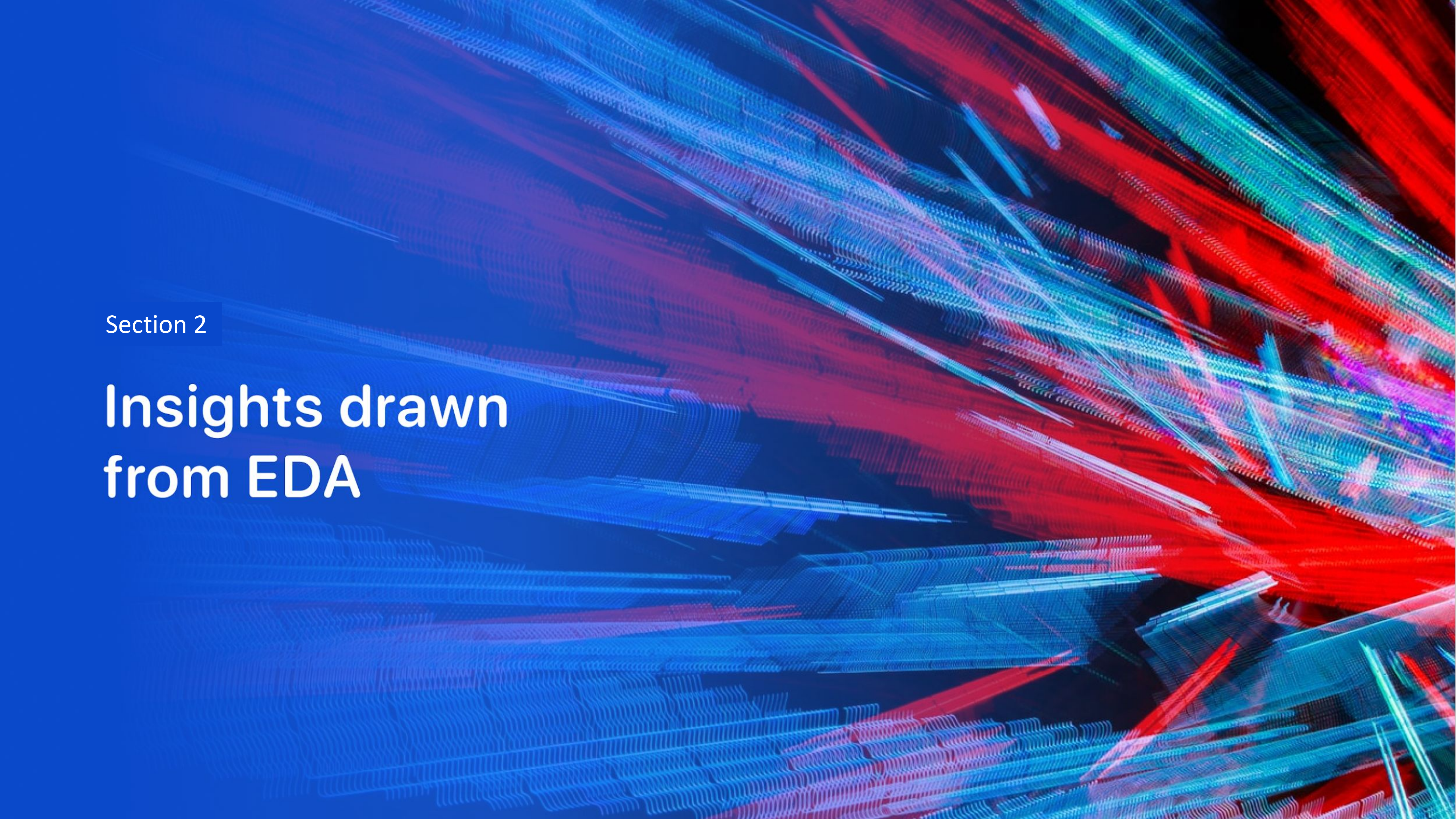


SpaceX Launch Records Dashboard

All Sites



- Predictive analysis results
  1. All fours models have similar performance.
  2. All models' accuracy is 83%, so i'd chose the logistic regression for less time complexity.

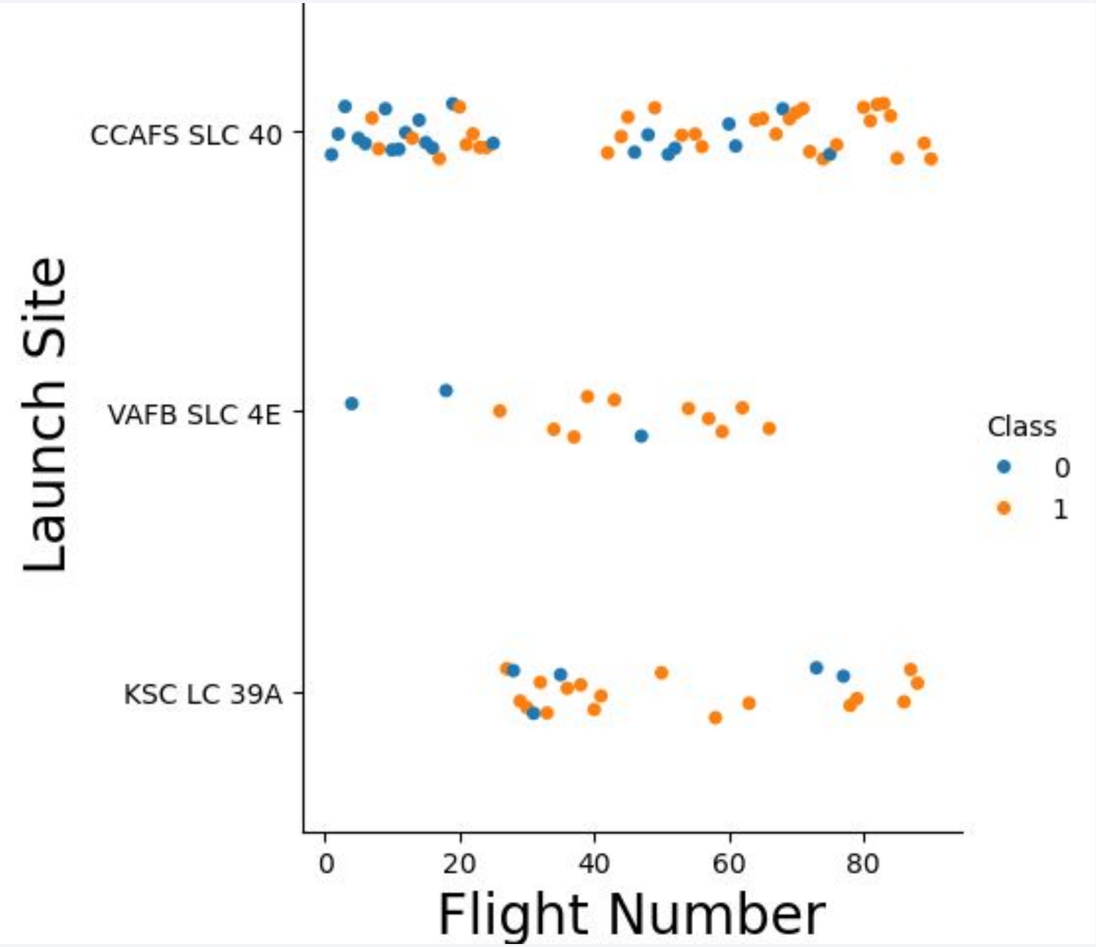


Section 2

Insights drawn from EDA

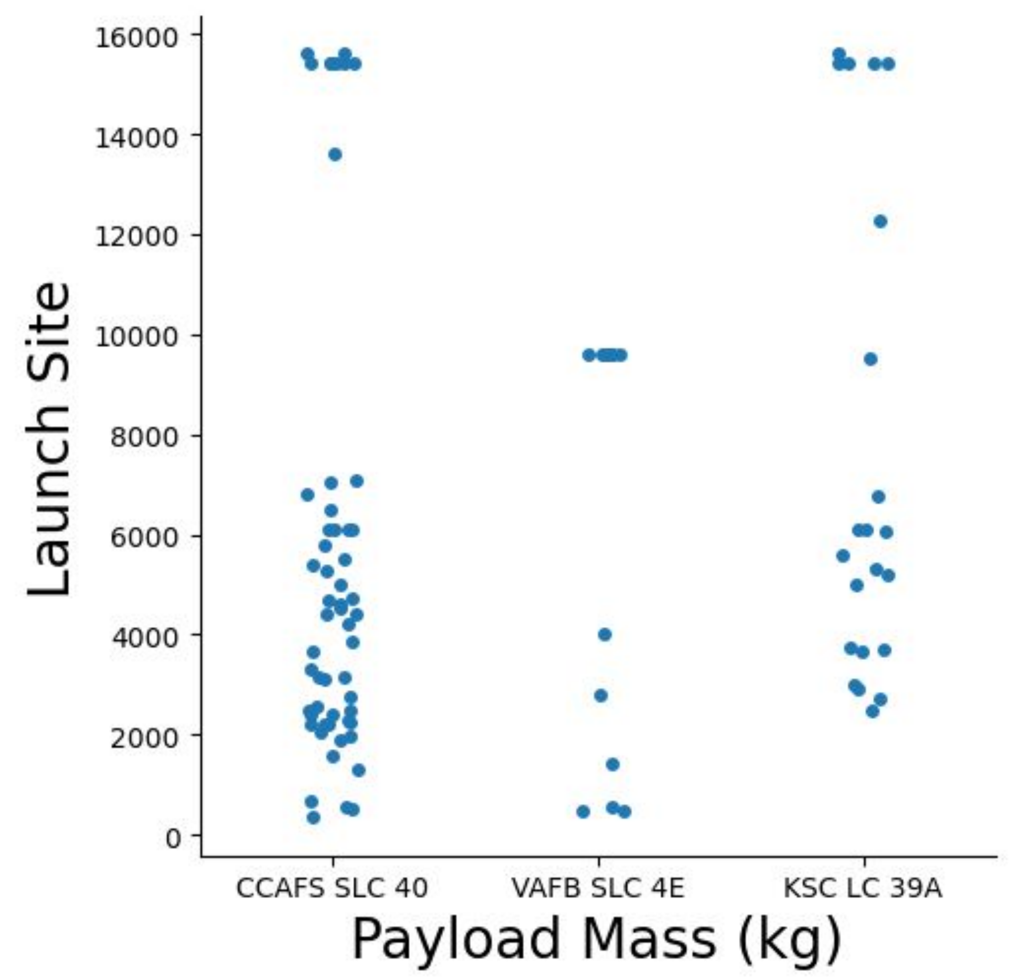
Flight Number vs. Launch Site

- There is not clear pattern of two classes among Launch site and Flight number.



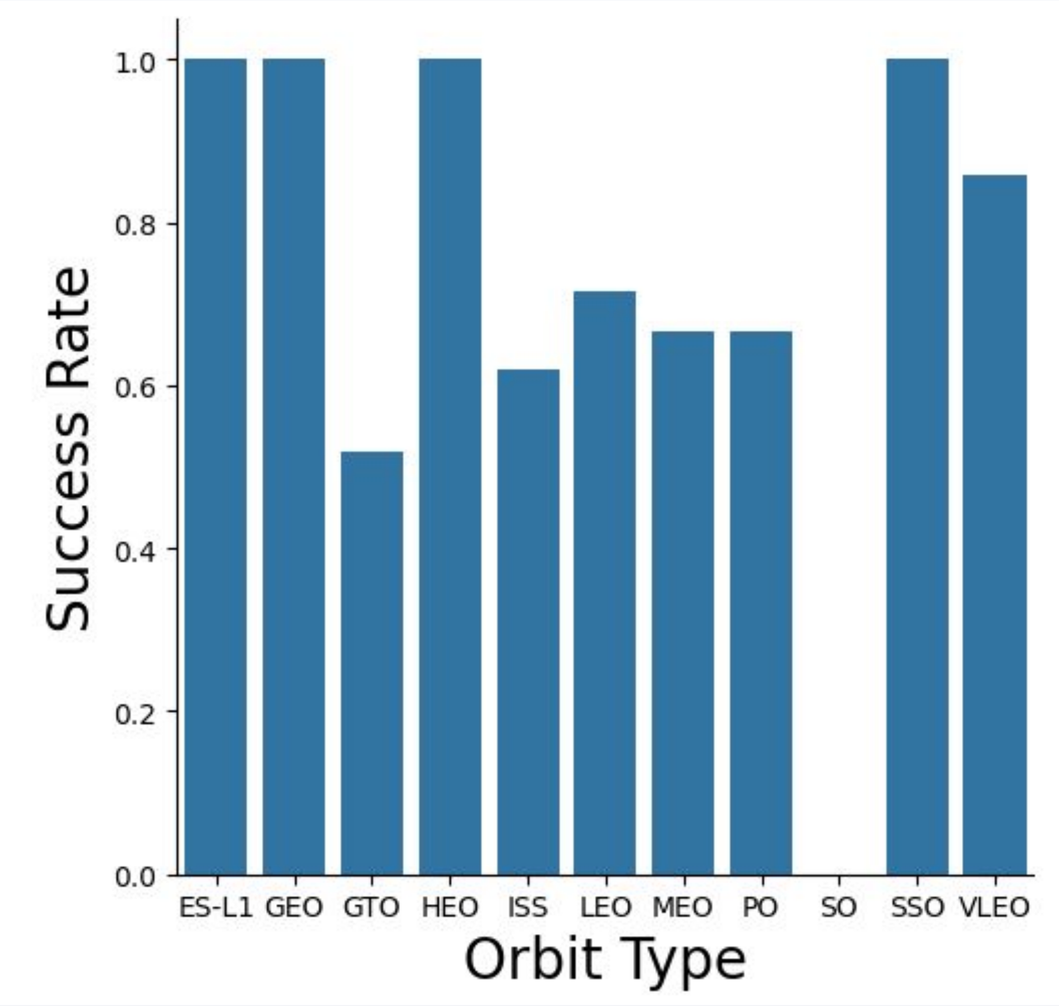
Payload vs. Launch Site

- For VAFB-SLC launchsite there are no rockets launched for heavy payload mass (> 100,000)



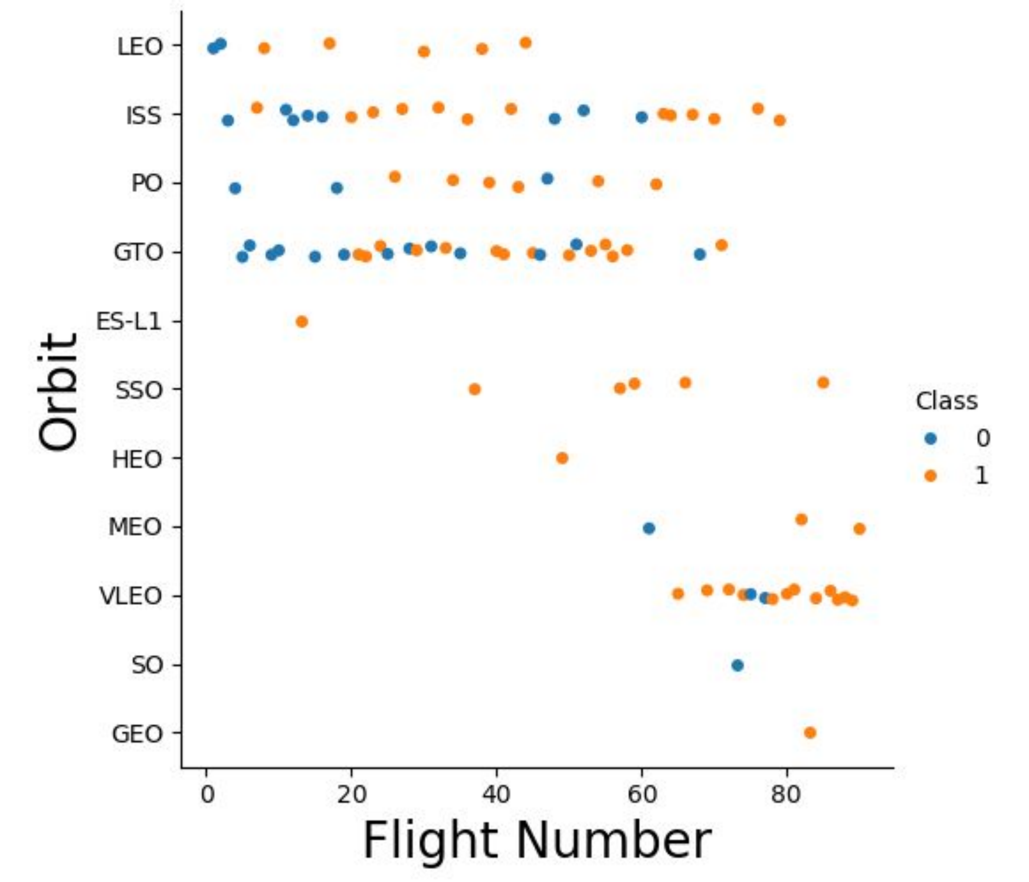
Success Rate vs. Orbit Type

- ES_L1, GEO,HEO and SSO have the highest (100%) success rate.



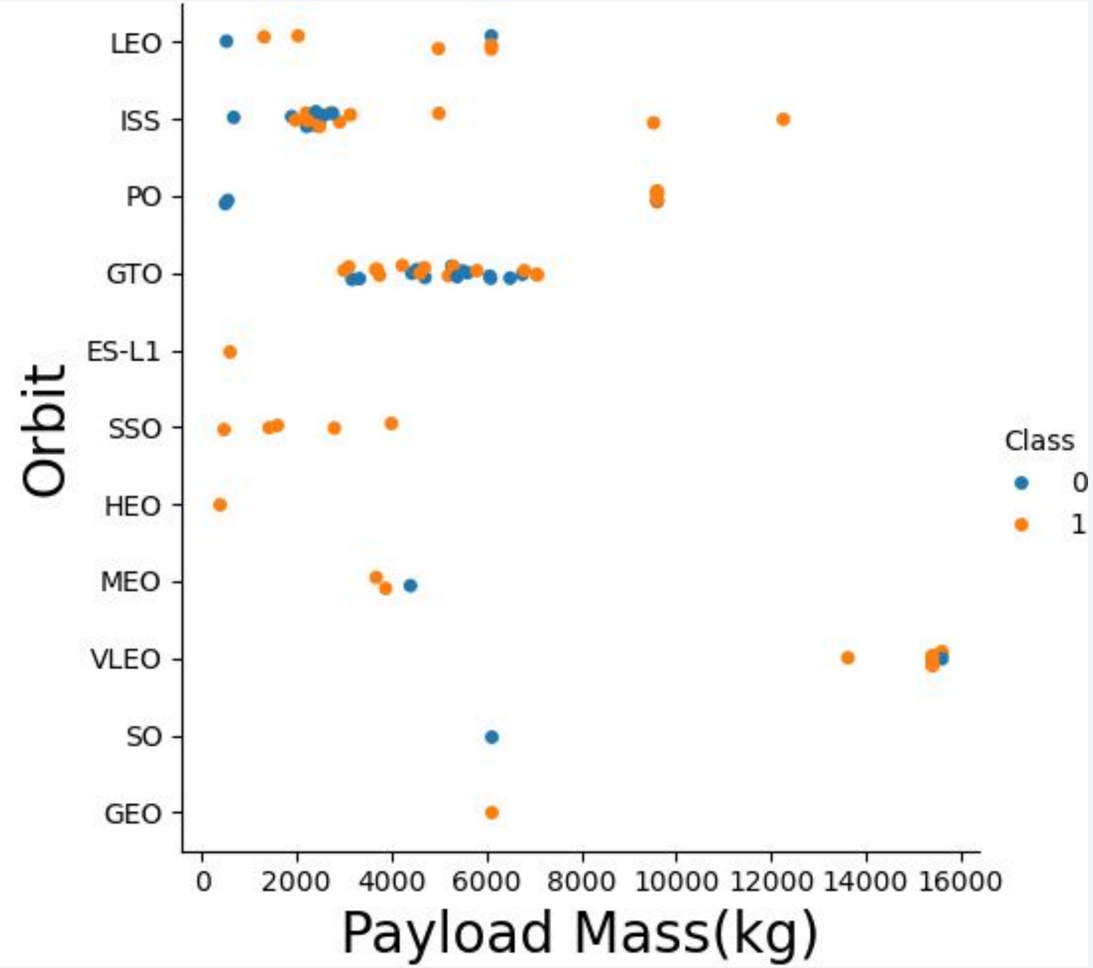
Flight Number vs. Orbit Type

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



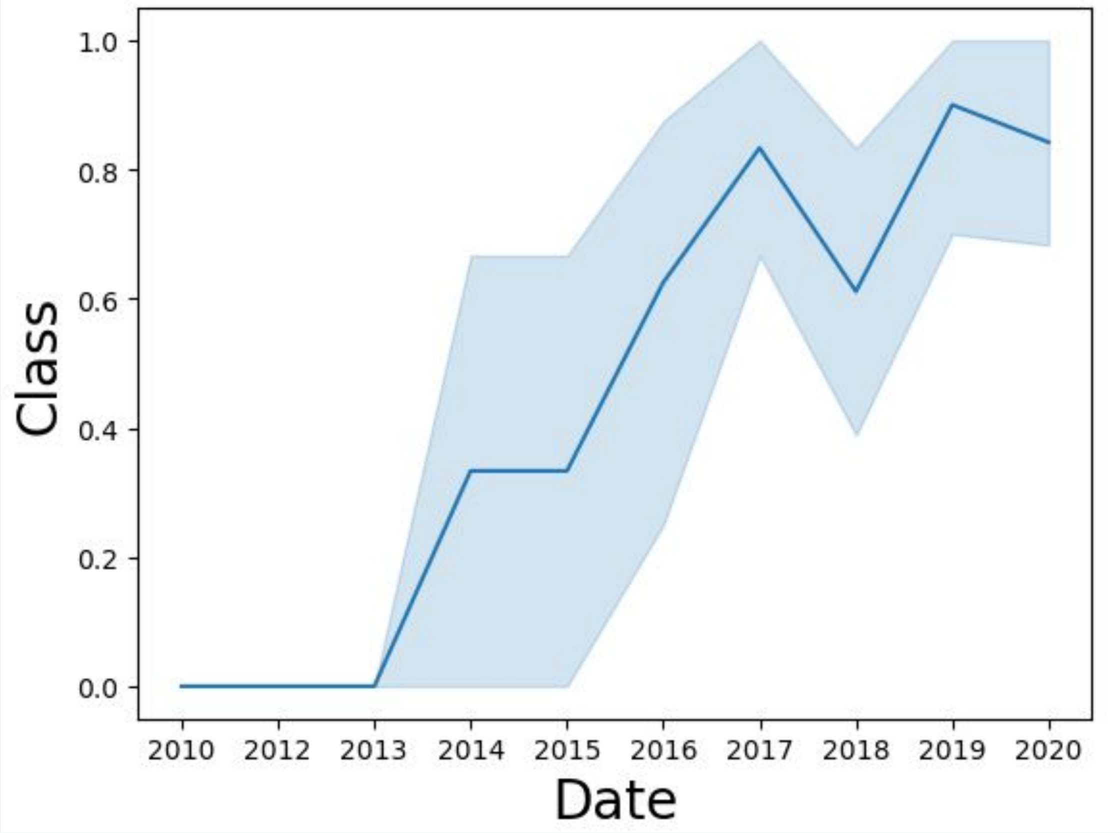
Payload vs. Orbit Type

- For Polar, LEO and ISS, with heavy payloads the successful landing rate are more.



Launch Success Yearly Trend

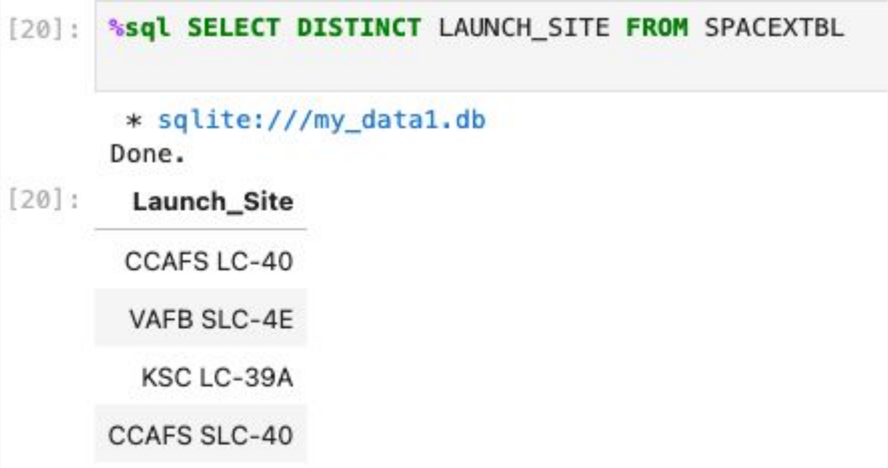
- Success rate kept increasing since 2013 until 2020.



All Launch Site Names

- Names of the unique launch sites
  - CCAFS LC-40
  - CCAFS SLC-40
  - KSC LC-39A
  - VAFB SLC-4E

- USing **DISTINCT** to query the unique launch site name

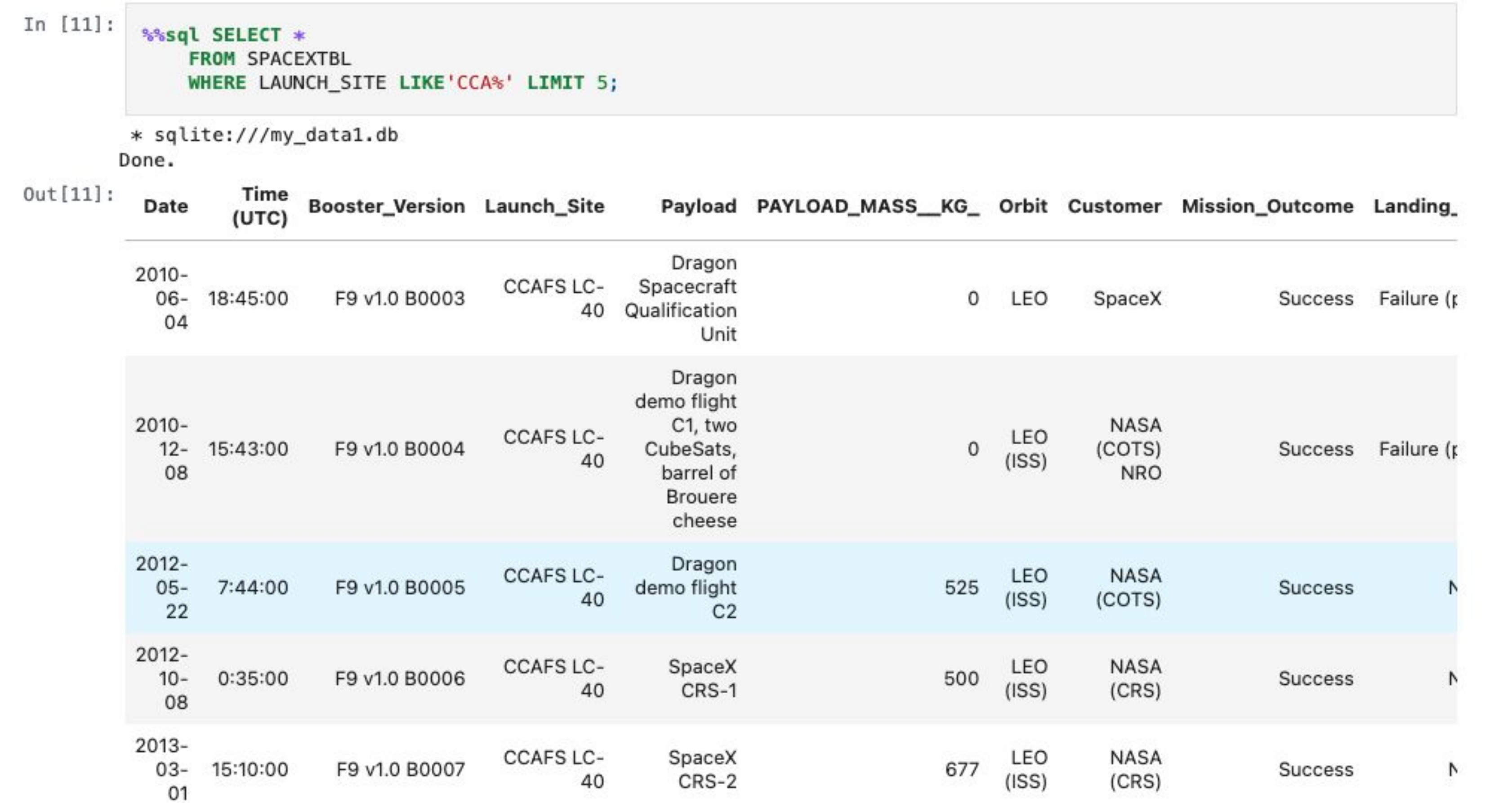


```
[20]: %sql SELECT DISTINCT LAUNCH_SITE FROM SPACEXTBL

 * sqlite:///my_data1.db
Done.
[20]:
```

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

Launch Site Names Begin with 'CCA'

- Find 5 records where launch sites begin with `CCA`
- Limit 5 to extract 5 records, LIKE in where clause to filter column having ‘CCA’



In [11]:
```
%%sql SELECT *
    FROM SPACEXTBL
    WHERE LAUNCH_SITE LIKE'CCA%' LIMIT 5;
```

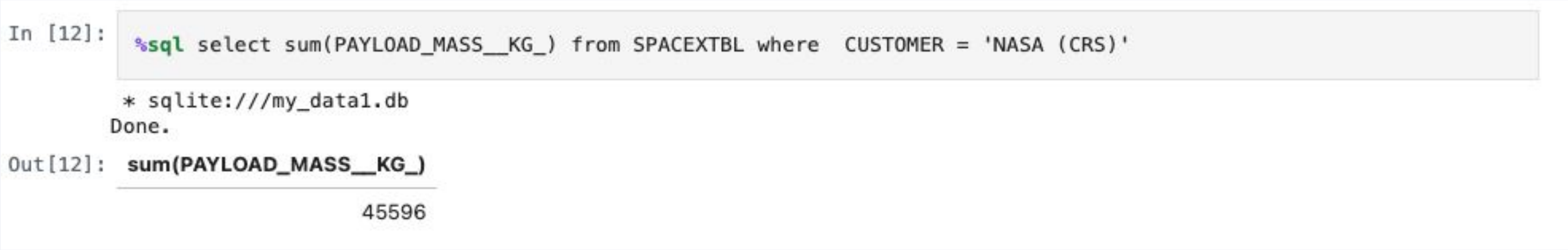
```
 * sqlite:///my_data1.db
Done.
```

Out[11]:

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing_
2010-06-04	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (p
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 (p
2012-05-22	7:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	N
2012-10-08	0:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	N
2013-03-01	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	N

Total Payload Mass

- Sum to calculate total payload mass, where to find certain condition (customer = ‘NASA (CRS)’)
- Total is 45,596 kg.

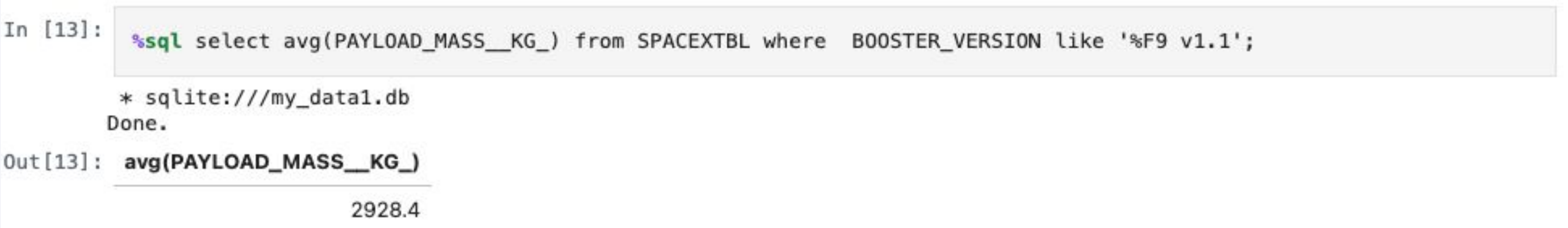


```
In [12]:  %sql select sum(PAYLOAD_MASS__KG_) from SPACEXTBL where  CUSTOMER = 'NASA (CRS)'

           * sqlite:///my_data1.db
          Done.

Out[12]:  sum(PAYLOAD_MASS__KG_)

                            45596
```

Average Payload Mass by F9 v1.1

- avg() to calculate the average payload mass carried by booster version F9 v1.1 using **where** condition clause

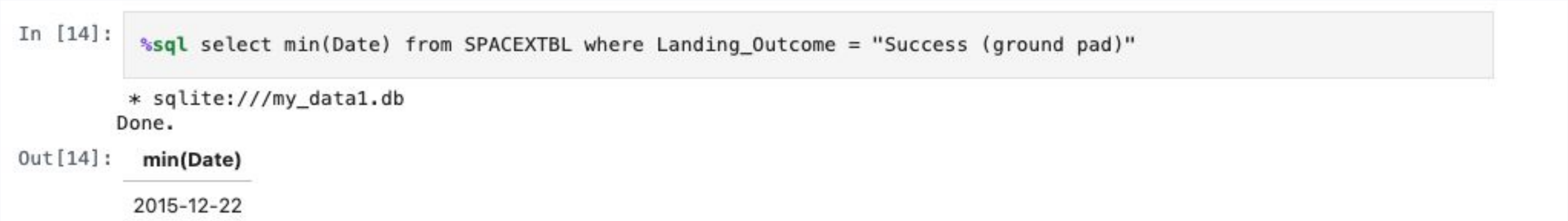
- Average is 2928.4 kg.



```
In [13]:  %sql select avg(PAYLOAD_MASS__KG_) from SPACEXTBL where  BOOSTER_VERSION like '%F9 v1.1';

           * sqlite:///my_data1.db
          Done.

Out[13]:  avg(PAYLOAD_MASS__KG_)
                          2928.4
```

First Successful Ground Landing Date

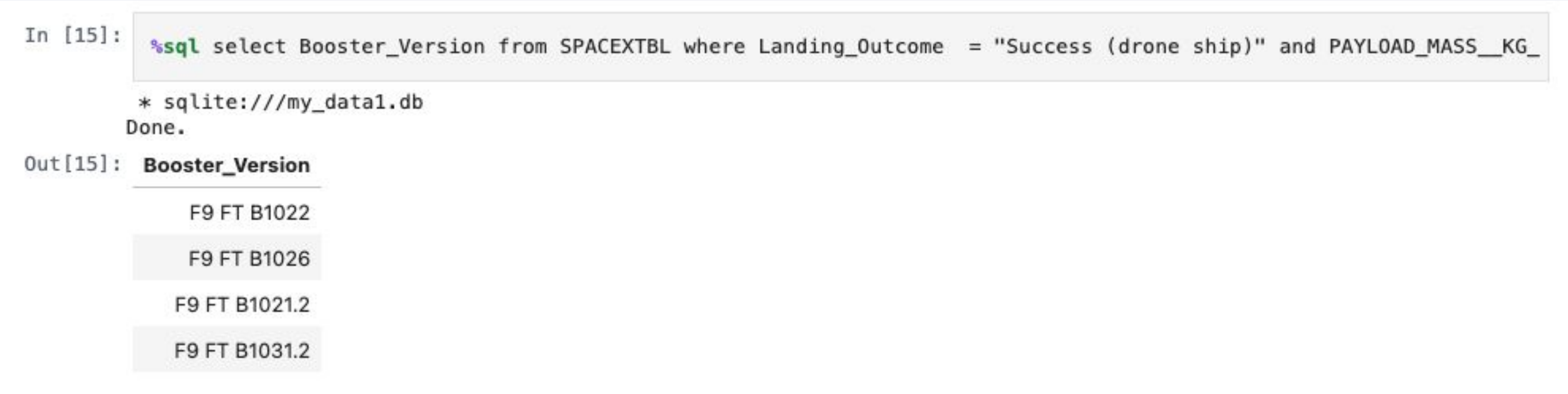
- min(Date)
- The first date of successful landing is 2015-12-12.



```
In [14]: %sql select min(Date) from SPACEXTBL where Landing_Outcome = "Success (ground pad)"

          * sqlite:///my_data1.db
         Done.
Out[14]:  min(Date)

          2015-12-22
```

Successful Drone Ship Landing with Payload between 4000 and 6000

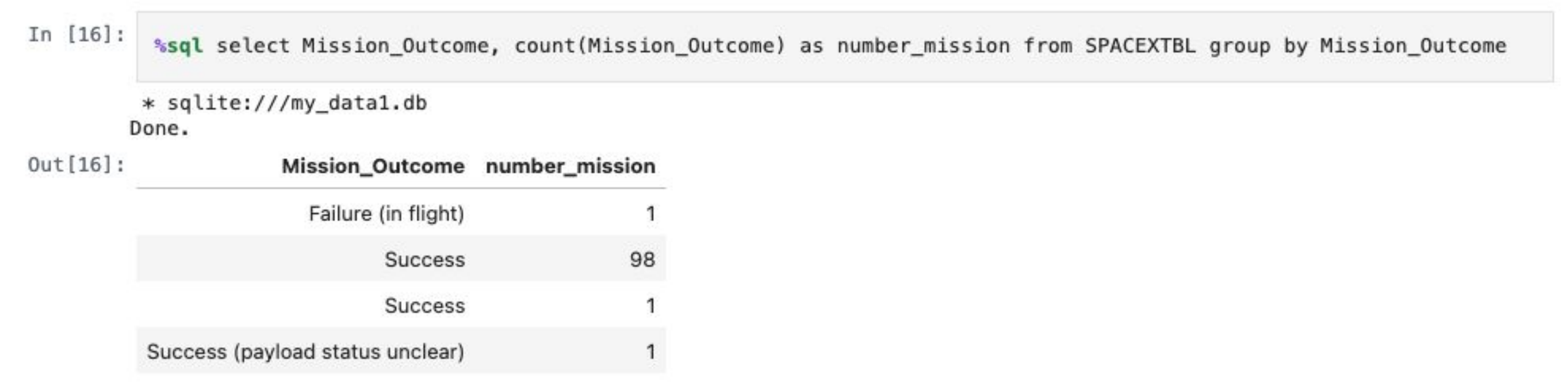
- List the names of boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 6000
  - F9 FT B1022
  - F9 FT B1026
  - F9 FT B1021.2
  - F9 FT B1031.2



```
In [15]:  %sql select Booster_Version from SPACEXTBL where Landing_Outcome  = "Success (drone ship)" and PAYLOAD_MASS__KG_

           * sqlite:///my_data1.db
          Done.

Out[15]:  Booster_Version
             F9 FT B1022
             F9 FT B1026
           F9 FT B1021.2
           F9 FT B1031.2
```

Total Number of Successful and Failure Mission Outcomes

- 1 failed in flight, 99 successed.

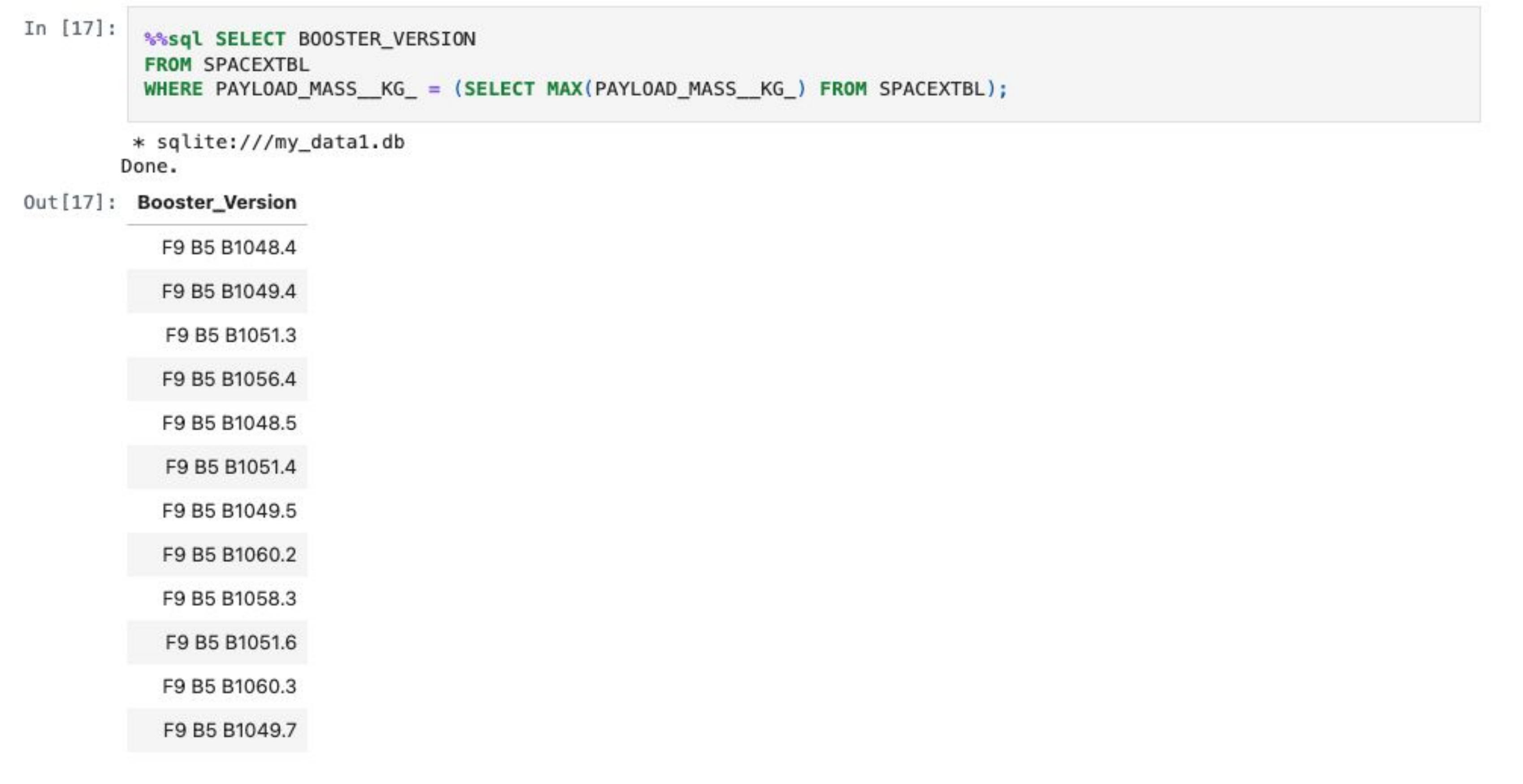


```
In [16]: %sql select Mission_Outcome, count(Mission_Outcome) as number_mission from SPACEXTBL group by Mission_Outcome

 * sqlite:///my_data1.db
Done.
Out[16]:
```

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

Boosters Carried Maximum Payload

- List the names of the booster which have carried the maximum payload mass



In [17]:

```
%%sql SELECT BOOSTER_VERSION
FROM SPACEXTBL
WHERE PAYLOAD_MASS__KG_ = (SELECT MAX(PAYLOAD_MASS__KG_) FROM SPACEXTBL);
```

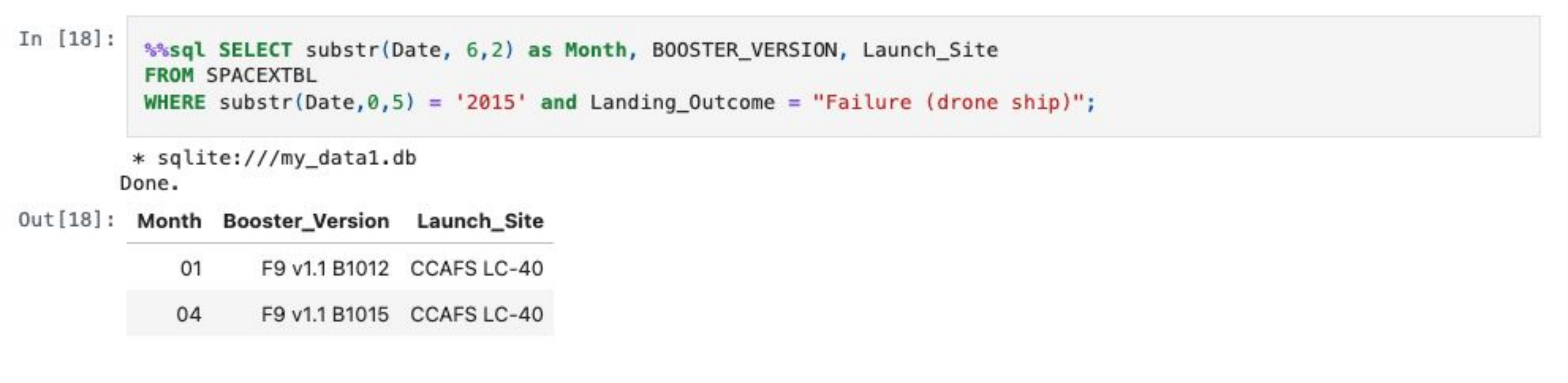
```
 * sqlite:///my_data1.db
Done.
```

Out[17]:

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

2015 Launch Records

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



In [18]:
```
%%sql SELECT substr(Date, 6,2) as Month, BOOSTER_VERSION, Launch_Site
FROM SPACEXTBL
WHERE substr(Date,0,5) = '2015' and Landing_Outcome = "Failure (drone ship)";
```

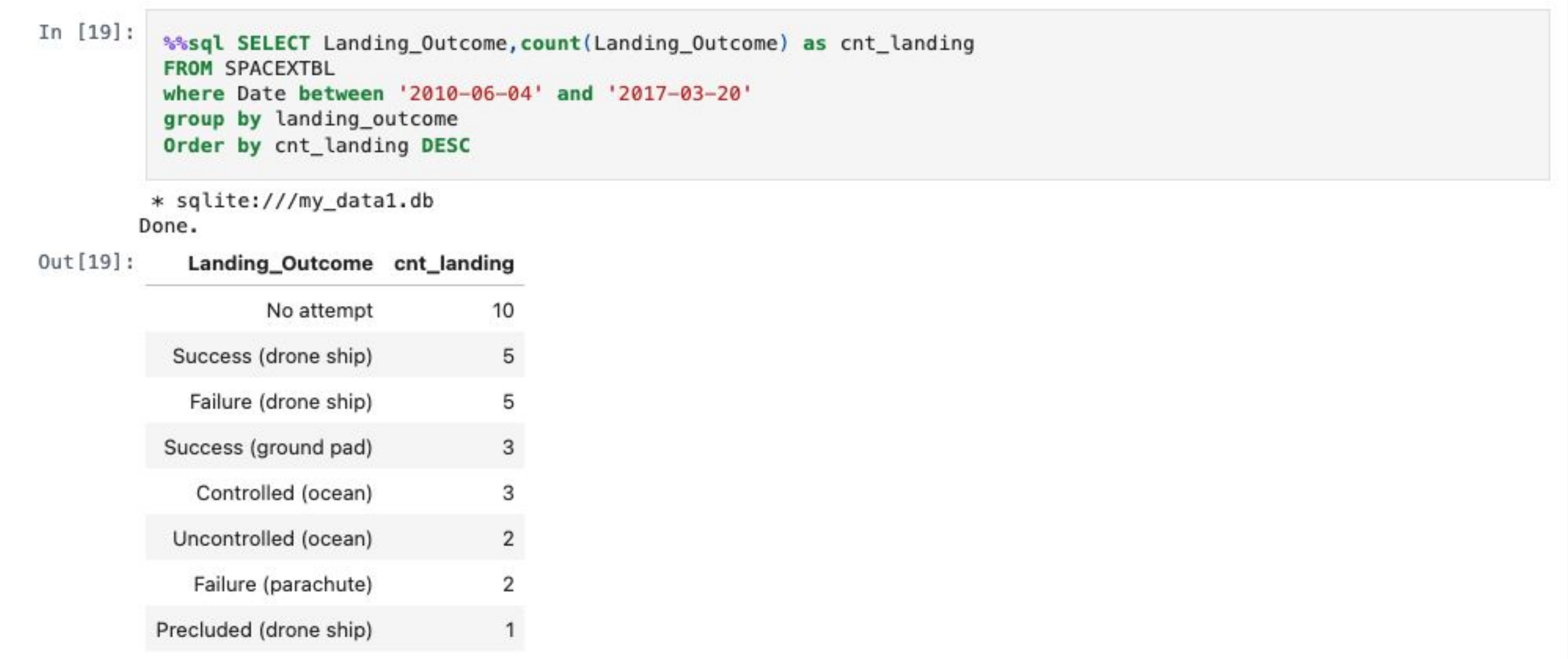
```
 * sqlite:///my_data1.db
Done.
```

Out[18]:

Month	Booster_Version	Launch_Site
01	F9 v1.1 B1012	CCAFS LC-40
04	F9 v1.1 B1015	CCAFS LC-40

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

- 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 [19]: %%sql SELECT Landing_Outcome,count(Landing_Outcome) as cnt_landing
         FROM SPACEXTBL
         where Date between '2010-06-04' and '2017-03-20'
         group by landing_outcome
         Order by cnt_landing DESC

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

Out[19]:

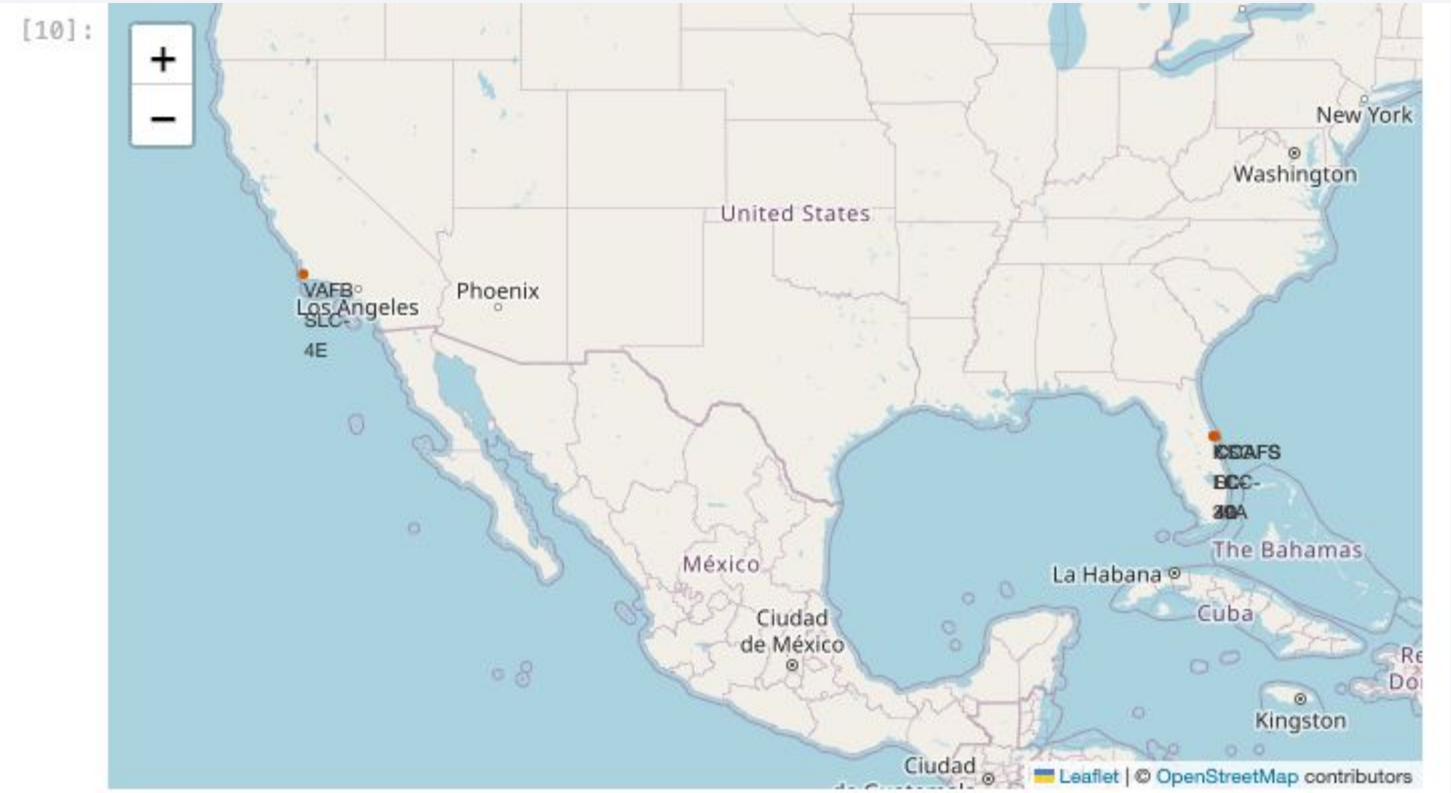
Landing_Outcome	cnt_landing
No attempt	10
Success (drone ship)	5
Failure (drone ship)	5
Success (ground pad)	3
Controlled (ocean)	3
Uncontrolled (ocean)	2
Failure (parachute)	2
Precluded (drone ship)	1

Section 3

Launch Sites Proximities Analysis

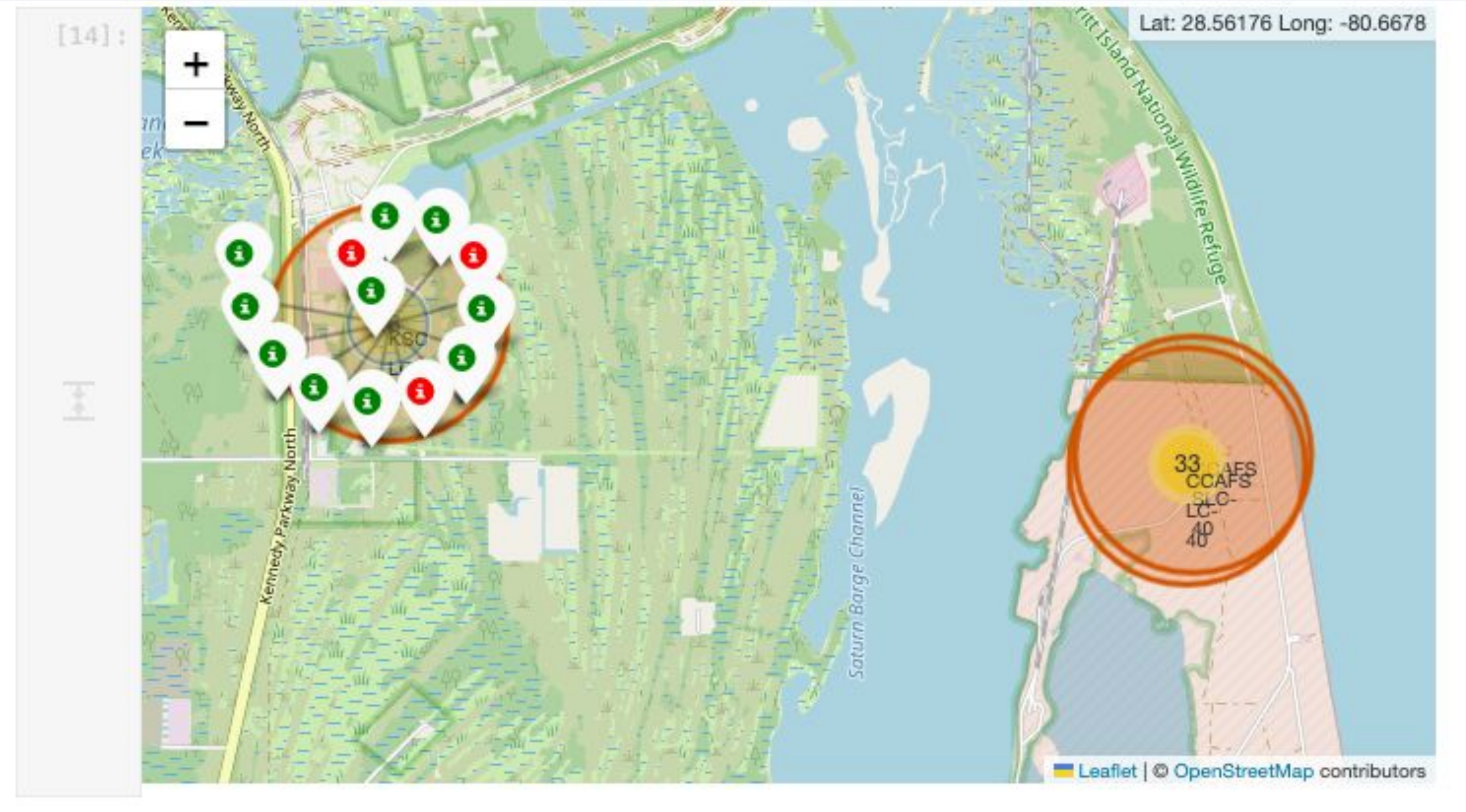
Launch Sites

- The closer to equator, the easier to launch to equatorial orbit.



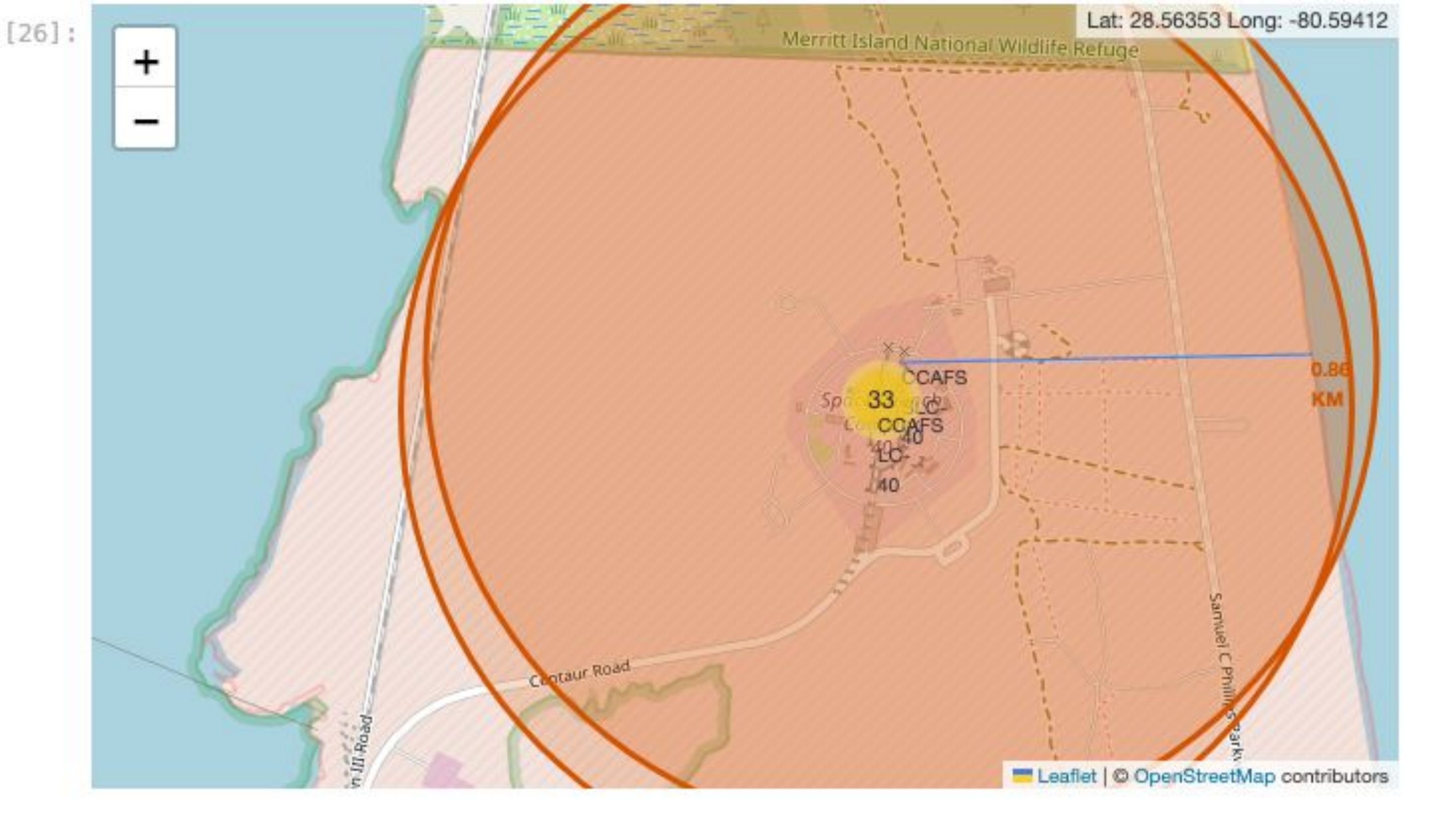
Launch Outcomes

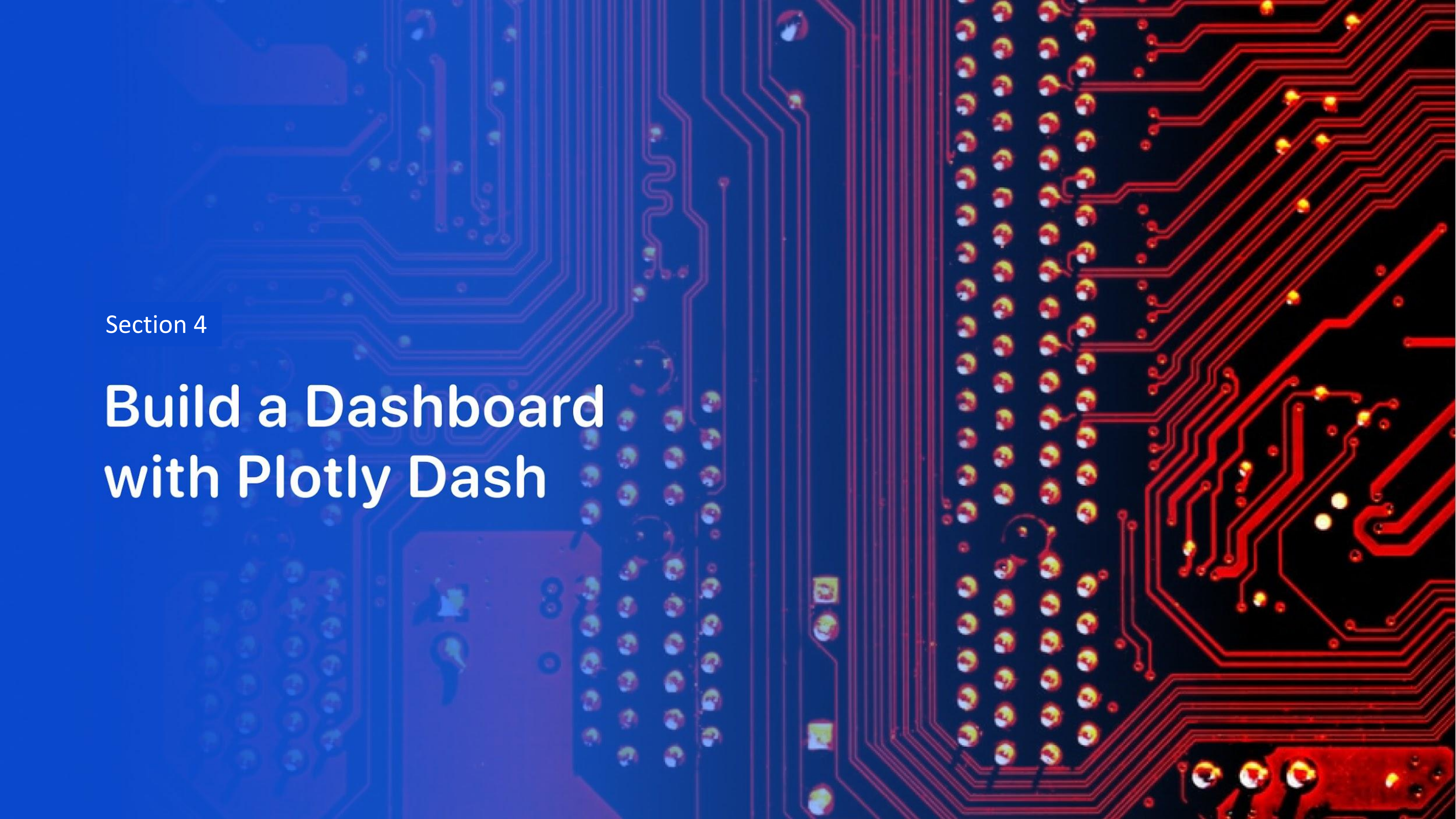
- Green markers for successful launches
- Red markers for failed launches


[14]:
+
−
Lat: 28.56176 Long: -80.6678
Kennedy Parkway North
Saturn Barge Channel
itt Island National Wildlife Refuge
KSC
33
CCAFS
SLC-
LC-
40
Leaflet | © OpenStreetMap contributors

Add distance to Proximities

- For CCAFS SLC-40, .0.86 km from nearest coastline


[26]:
+
−
Lat: 28.56353 Long: -80.59412
Merritt Island National Wildlife Refuge
33
CCAFS
SLC-
40
CCAFS
LC-
40
0.86
KM
Centaur Road
Samuel C Phillips Parkw
Leaflet | © OpenStreetMap contributors

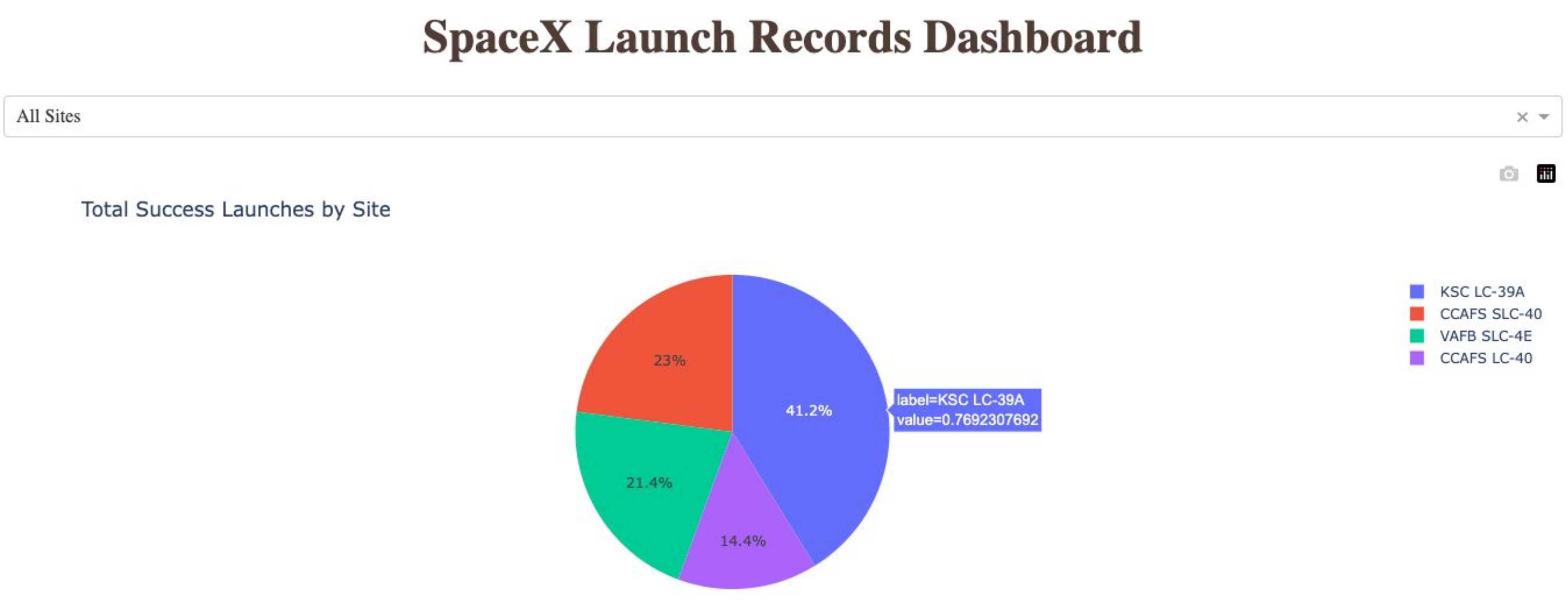


Section 4

Build a Dashboard with Plotly Dash

Dashboard: Launch Success of All Sites

- KSC LC-39A has the most successful launches among all launch sites. (41.2%)



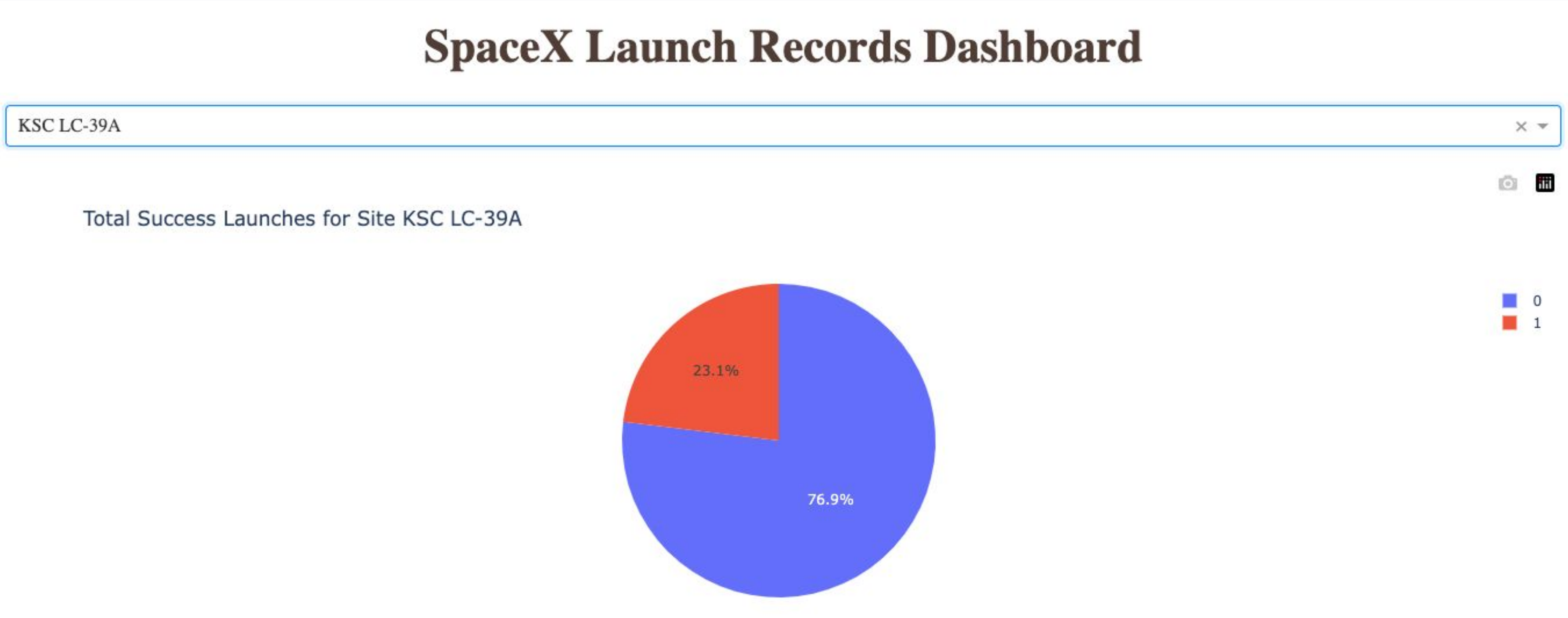
SpaceX Launch Records Dashboard

All Sites

Total Success Launches by Site

Dashboard: KSC LC-39A

- KSC LC-39A has the highest success rate (76.9%)



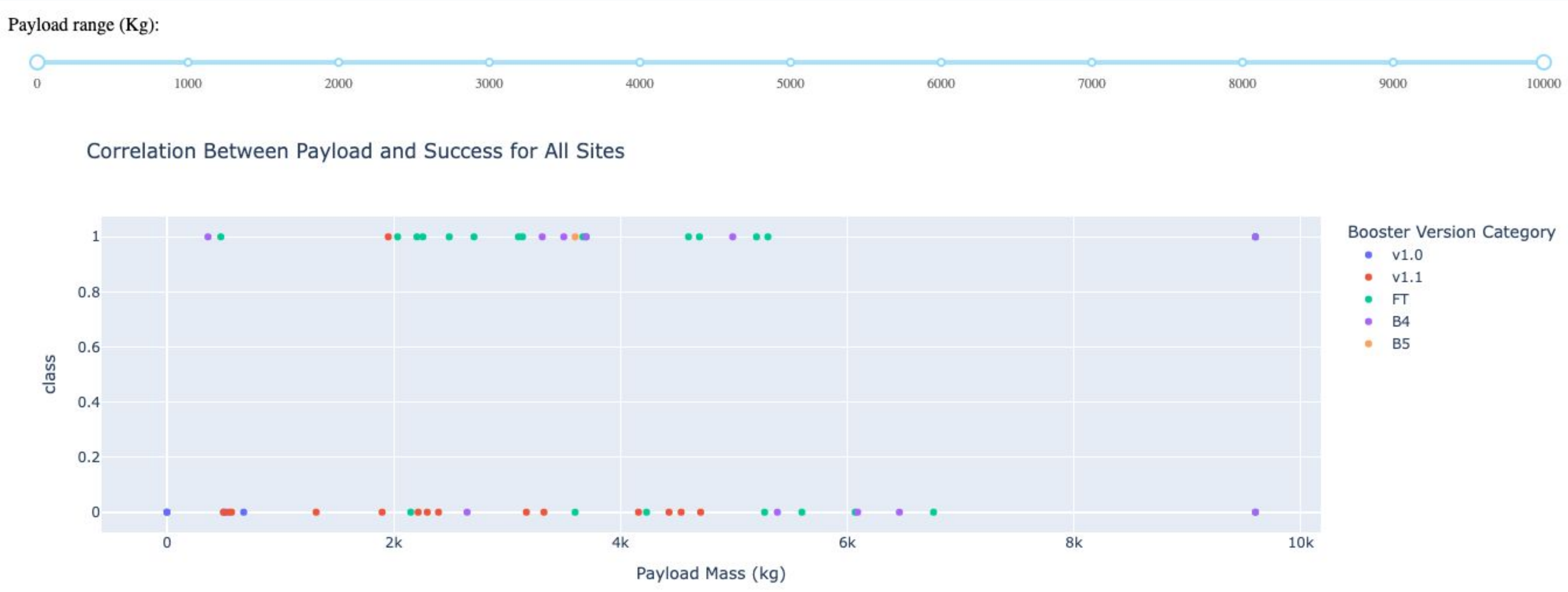
SpaceX Launch Records Dashboard

KSC LC-39A

Total Success Launches for Site KSC LC-39A

Dashboard: PayloadMass and Success

- Payload mass between 2,000 kg and 5,000 kg have the highest success rate.

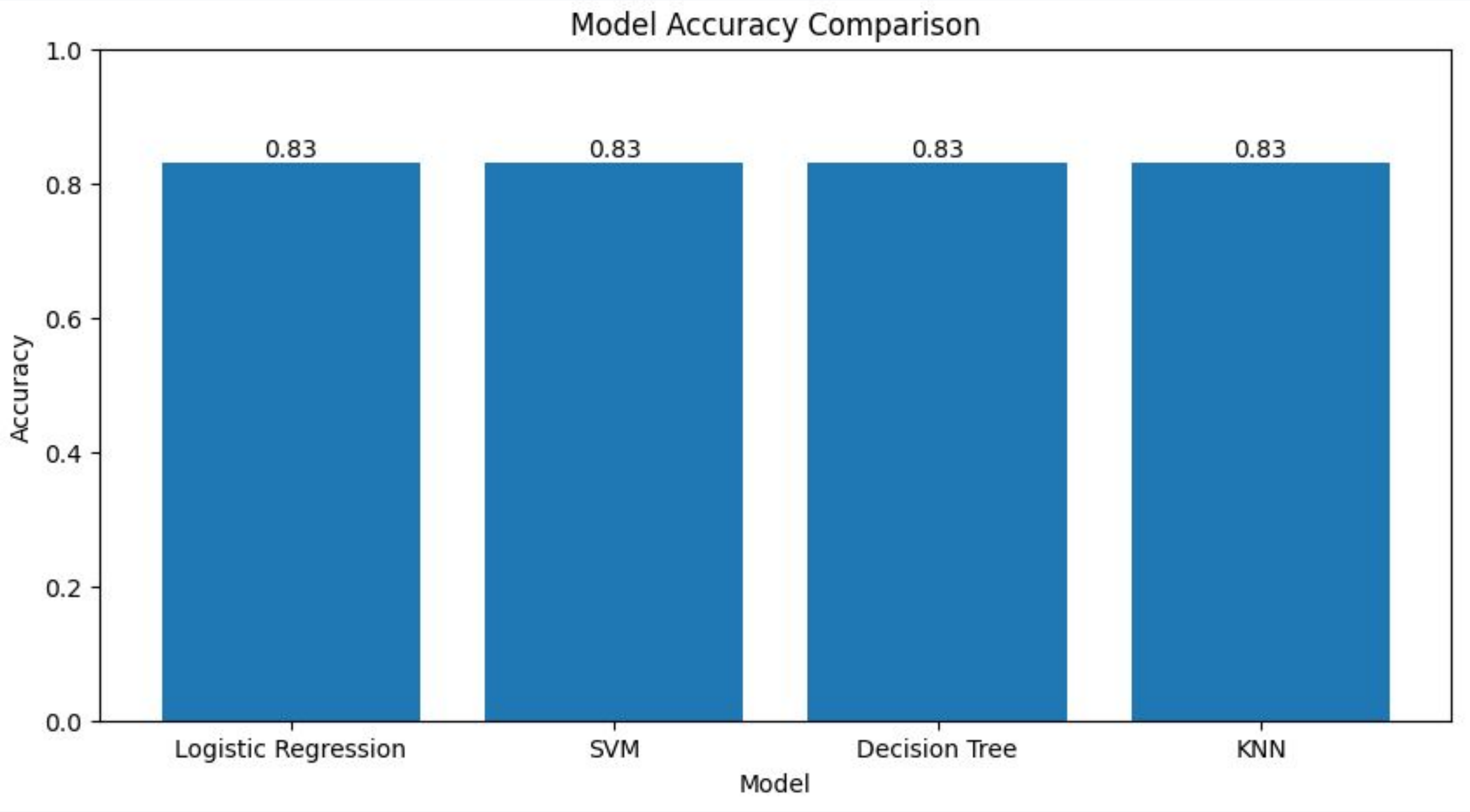


Section 5

Predictive Analysis (Classification)

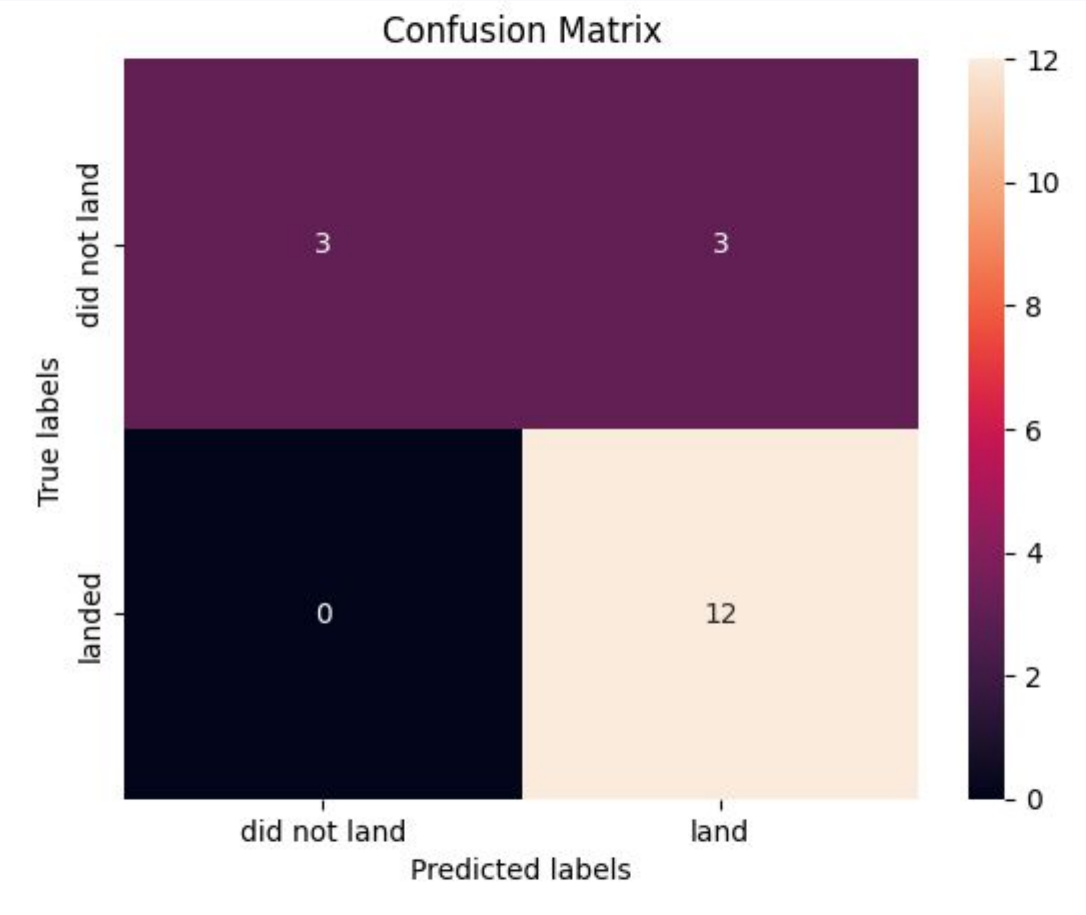
Classification Accuracy

- Models performed similarly on the test set with accuracy 83.33%



Confusion Matrix

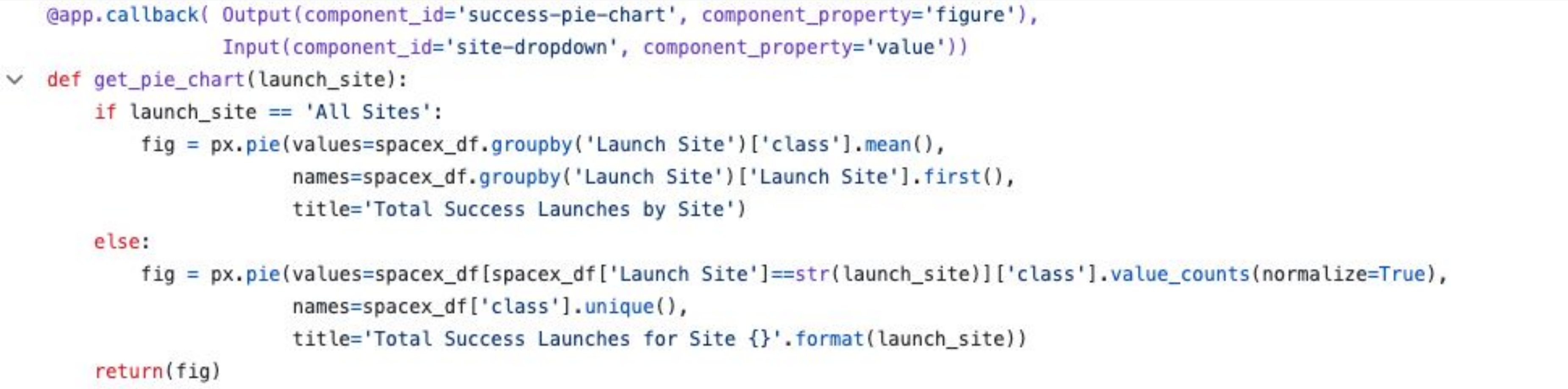
- TP: 12
- TN: 3
- FP: 3
- FN: 3



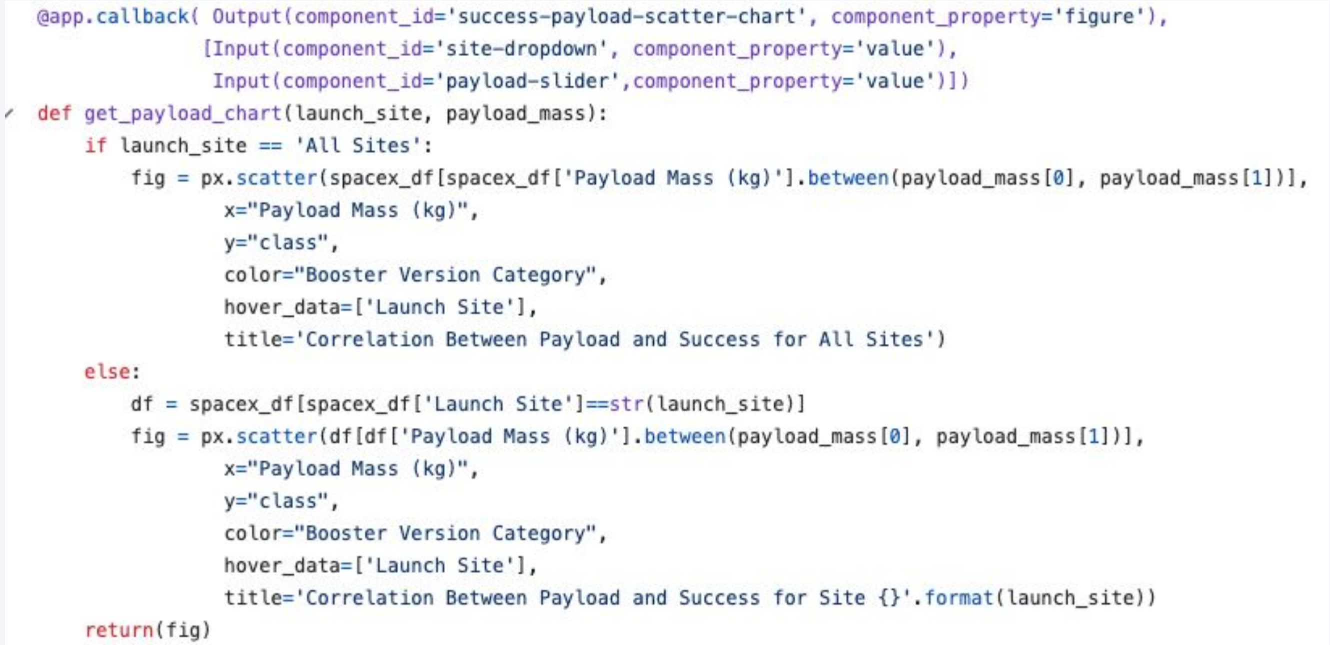
Conclusions

- Models performed similarly on the test set with accuracy 83.33%
- Collecting of more data might be worth to consider
- Try other predictive model, like model employed gradient boosting algorithm.

Appendix



```
@app.callback( Output(component_id='success-pie-chart', component_property='figure'),
               Input(component_id='site-dropdown', component_property='value'))
def get_pie_chart(launch_site):
    if launch_site == 'All Sites':
        fig = px.pie(values=spacex_df.groupby('Launch Site')['class'].mean(),
                     names=spacex_df.groupby('Launch Site')['Launch Site'].first(),
                     title='Total Success Launches by Site')
    else:
        fig = px.pie(values=spacex_df[spacex_df['Launch Site']==str(launch_site)]['class'].value_counts(normalize=True),
                     names=spacex_df['class'].unique(),
                     title='Total Success Launches for Site {}'.format(launch_site))
    return(fig)
```



```
@app.callback( Output(component_id='success-payload-scatter-chart', component_property='figure'),
              [Input(component_id='site-dropdown', component_property='value'),
               Input(component_id='payload-slider',component_property='value')])
def get_payload_chart(launch_site, payload_mass):
    if launch_site == 'All Sites':
        fig = px.scatter(spacex_df[spacex_df['Payload Mass (kg)'].between(payload_mass[0], payload_mass[1])],
                x="Payload Mass (kg)",
                y="class",
                color="Booster Version Category",
                hover_data=['Launch Site'],
                title='Correlation Between Payload and Success for All Sites')
    else:
        df = spacex_df[spacex_df['Launch Site']==str(launch_site)]
        fig = px.scatter(df[df['Payload Mass (kg)'].between(payload_mass[0], payload_mass[1])],
                x="Payload Mass (kg)",
                y="class",
                color="Booster Version Category",
                hover_data=['Launch Site'],
                title='Correlation Between Payload and Success for Site {}'.format(launch_site))
    return(fig)
```

Thank you!