IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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

Executive Summary

- Summary of methodologies

  - SpaceX Data Collection using SpaceX API
  - SpaceX Data Collection with Web Scraping
  - SpaceX Data Wrangling
  - SpaceX Exploratory Data Analysis using SQL
  - Space-X EDA DataViz Using Python Pandas and Matplotlib
  - Space-X Launch Sites Analysis with Folium-Interactive Visual Analytics and Ploty Dash
  - SpaceX Machine Learning Landing Prediction

- Summary of all results

  - EDA results
  - Interactive Visual Analytics and Dashboards
  - Predictive Analysis(Classification)

Introduction

- Project background and context

  SpaceX 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. This information can be used if an alternate company wants to bid against SpaceX for a rocket launch.

- Problems you want to find answers

  In this capstone, we will predict if the Falcon 9 first stage will land successfully using data from Falcon 9 rocket launches advertised on its website.

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - Describe how data was collected
- Perform data wrangling
  - Describe how data was processed
- 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

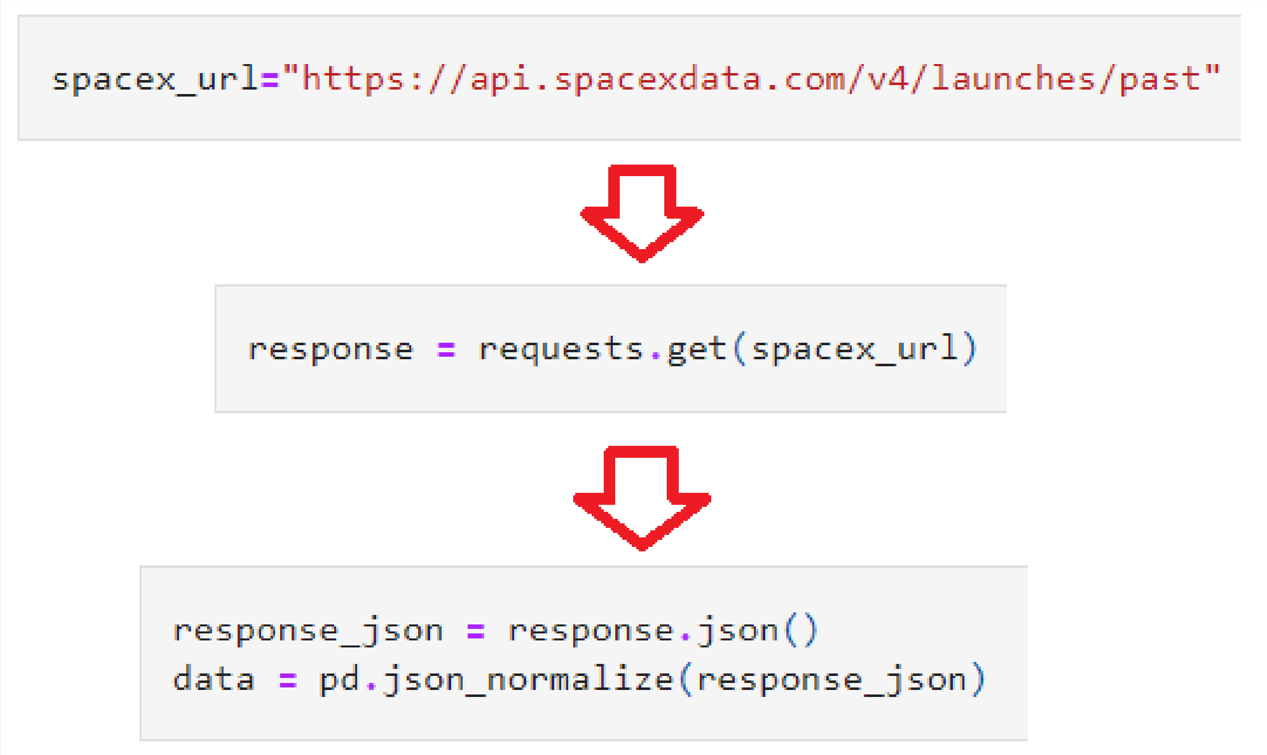
- Description of how SpaceX Falcon9 data was collected.
  - Data was first collected using SpaceX API (a RESTful API) by making a get request to the SpaceX API. This was done by first defining a series helper functions that would help in the use of the API to extract information using identification numbers in the launch data and then requesting rocket launch data from the SpaceX API URL.

  - Finally, to make the requested JSON results more consistent, the SpaceX launch data was requested and parsed using the GET request and then decoded the response content as a Json result which was then converted into a Pandas data frame.

  - Also performed web scraping to collect Falcon 9 historical launch records from a Wikipedia page titled List of Falcon 9 and Falcon Heavy launches of the launch records are stored in a HTML. Using BeautifulSoup and request Libraries, I extract the Falcon 9 launch HTML table records from the Wikipedia page, Parsed the table and converted it into a Pandas data frame.

Data Collection – SpaceX API

- Data collected using SpaceX API (a RESTful API) by making a get request to the SpaceX API then requested and parsed the SpaceX launch data using the GET request and decoded the response content as a Json result which was then converted into a Pandas data frame
- Here is the GitHub URL of the completed SpaceX API calls notebook



```
spacex_url="https://api.spacexdata.com/v4/launches/past"
```

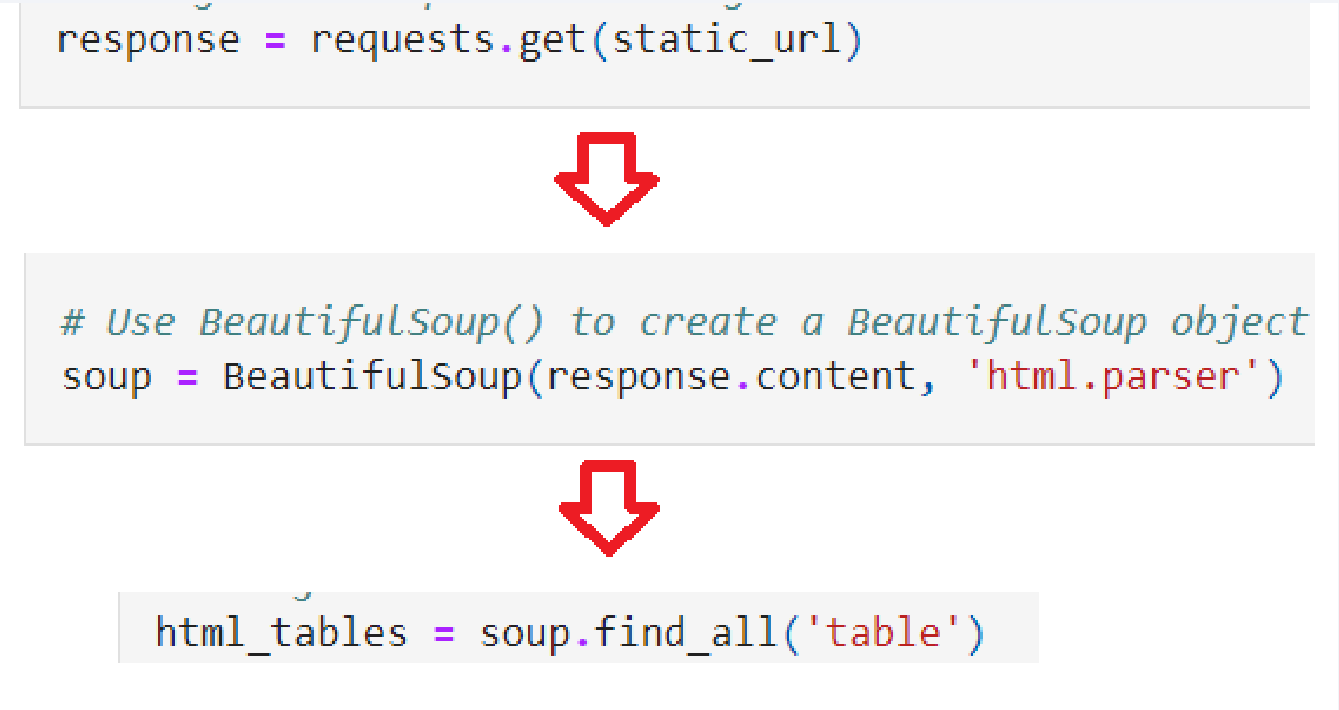
```
response = requests.get(spacex_url)
```

```
response_json = response.json()
data = pd.json_normalize(response_json)
```

Data Collection - Scraping

Performed web scraping to collect Falcon 9 historical launch records from a Wikipedia using BeautifulSoup and request, to extract the Falcon 9 launch records from HTML table of the Wikipedia page, then created a data frame by parsing the launch HTML.

- Here is the GitHub URL of the completed web scraping notebook.



```
response = requests.get(static_url)
```

```
# Use BeautifulSoup() to create a BeautifulSoup object
soup = BeautifulSoup(response.content, 'html.parser')
```

```
html_tables = soup.find_all('table')
```

Data Wrangling

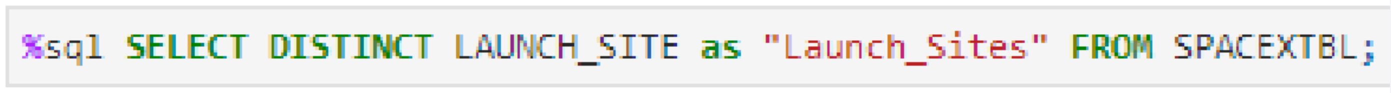
- After obtaining and creating a Pandas DF from the collected data, data was filtered using the Booster Version column to only keep the Falcon 9 launches, then dealt with the missing data values in the Landing Pad and Payload Mass columns. For the Payload Mass ,missing data values were replaced using mean value of column.
- Also performed some Exploratory Data Analysis (EDA) to find some patterns in the data and determine what would be the label for training supervised models
- Here is the GitHub URL of the completed data wrangling related notebooks.

EDA with Data Visualization

- Performed data Analysis and Feature Engineering using Pandas and Matplotlib.i.e.
- Exploratory Data Analysis
- Preparing Data Feature Engineering
- Used scatter plots to Visualize the relationship between Flight Number and LaunchSite, Payload and Launch Site, FlightNumber and Orbit type, Payload and Orbittype.
- Used Bar chart to Visualize the relationship between success rate of each orbittype
- Line plot to Visualize the launch success yearly trend.
- Here is the GitHub URL of your completed EDA with data visualization notebook,

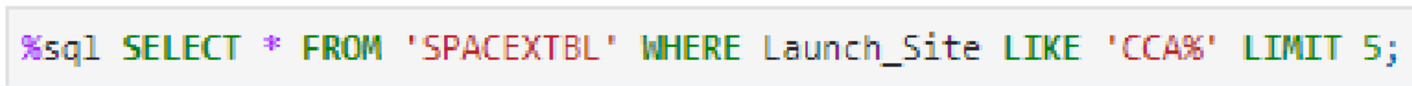
EDA with SQL

- The following SQL queries were performed for EDA
  - Display the names of the unique launch sites in the space mission.



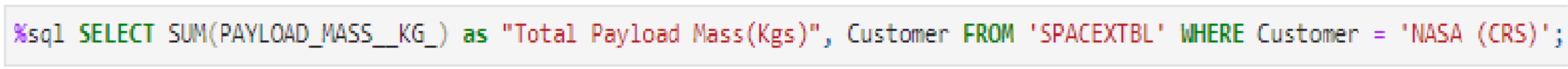
```
%sql SELECT DISTINCT LAUNCH_SITE as "Launch_Sites" FROM SPACEXTBL;
```

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



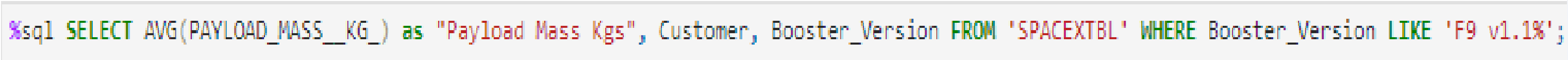
```
%sql SELECT * FROM 'SPACEXTBL' WHERE Launch_Site LIKE 'CCA%' LIMIT 5;
```

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



```
%sql SELECT SUM(PAYLOAD_MASS__KG_) as "Total Payload Mass(Kgs)", Customer FROM 'SPACEXTBL' WHERE Customer = 'NASA (CRS)';
```

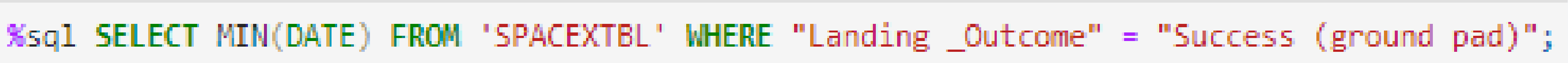
  - Display average payload mass carried by booster version F9 v1.1



```
%sql SELECT AVG(PAYLOAD_MASS__KG_) as "Payload Mass Kgs", Customer, Booster_Version FROM 'SPACEXTBL' WHERE Booster_Version LIKE 'F9 v1.1%';
```

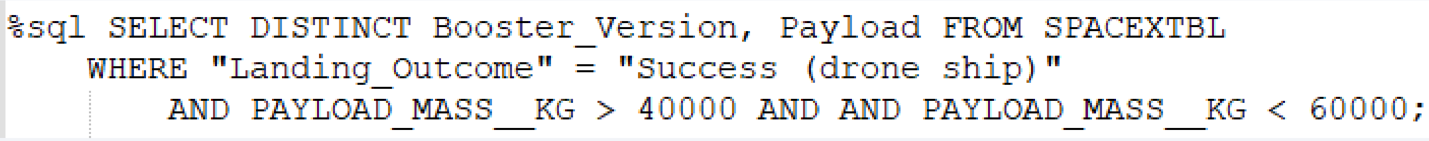
EDA with SQL (Cont…)

- List the date when the first successful landing outcome in ground pad was achieved



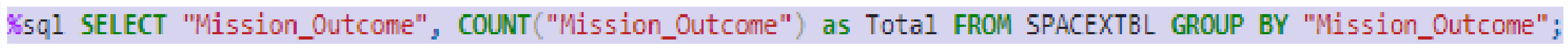
```
%sql SELECT MIN(DATE) FROM 'SPACEXTBL' WHERE "Landing _Outcome" = "Success (ground pad)";
```

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



```
%sql SELECT DISTINCT Booster_Version, Payload FROM SPACEXTBL
    WHERE "Landing_Outcome" = "Success (drone ship)"
        AND PAYLOAD_MASS__KG > 40000 AND AND PAYLOAD_MASS__KG < 60000;
```

- List the total number of successful and failure mission outcomes



```
%sql SELECT "Mission_Outcome", COUNT("Mission_Outcome") as Total FROM SPACEXTBL GROUP BY "Mission_Outcome";
```

- Here is the GitHub URL of your completed EDA with SQL notebook.

Build an Interactive Map with Folium

- Created folium map to marked all the launch sites, and created map objects such as markers, circles, lines to mark the success or failure of launches for each launch site.
- Created a launch set outcomes (failure=0 or success=1).
- Here is the GitHub URL of the completed interactive map with Folium map, as an external reference and peer-review purpose.

Build a Dashboard with Plotly Dash

- Built an interactive dashboard application with Plotly dash by:
  - Adding a Launch Site Drop-down Input Component
  - Adding a callback function to render success-pie-chart based on selected site dropdown
  - Adding a Range Slider to Select Payload
  - Adding a callback function to render the success-payload-scatter-chart scatter plot
- Here is the GitHub URL of your completed Plotly Dash lab.

Predictive Analysis (Classification)

Test data using various ML models include SVM, Classification Trees, k nearest neighbors and Logistic Regression;

1. First created an object for each of the algorithms then created a GridSearchCV object and assigned them a set of parameters for each model.
2. GridsearchCV object was created with cv=10, then fit the training data into the GridSearch object for each to Find best Hyperparameter.
3. Output GridSearchCV object for each of the models, then displayed the best parameters using the data attribute best_params_ and the accuracy on the validation data using the data attribute best_score_.
4. Finally using the method score to calculate the accuracy on the test data for each model and plotted a confussion matrix for each using the test and predicted outcomes.
5. The table shows the test data accuracy score for each of the methods comparing them to show which performed best using the test data between SVM, Classification Trees, k nearest neighbors and LogisticRegression;

Here the GitHub URL of the completed predictive analysis lab

Results

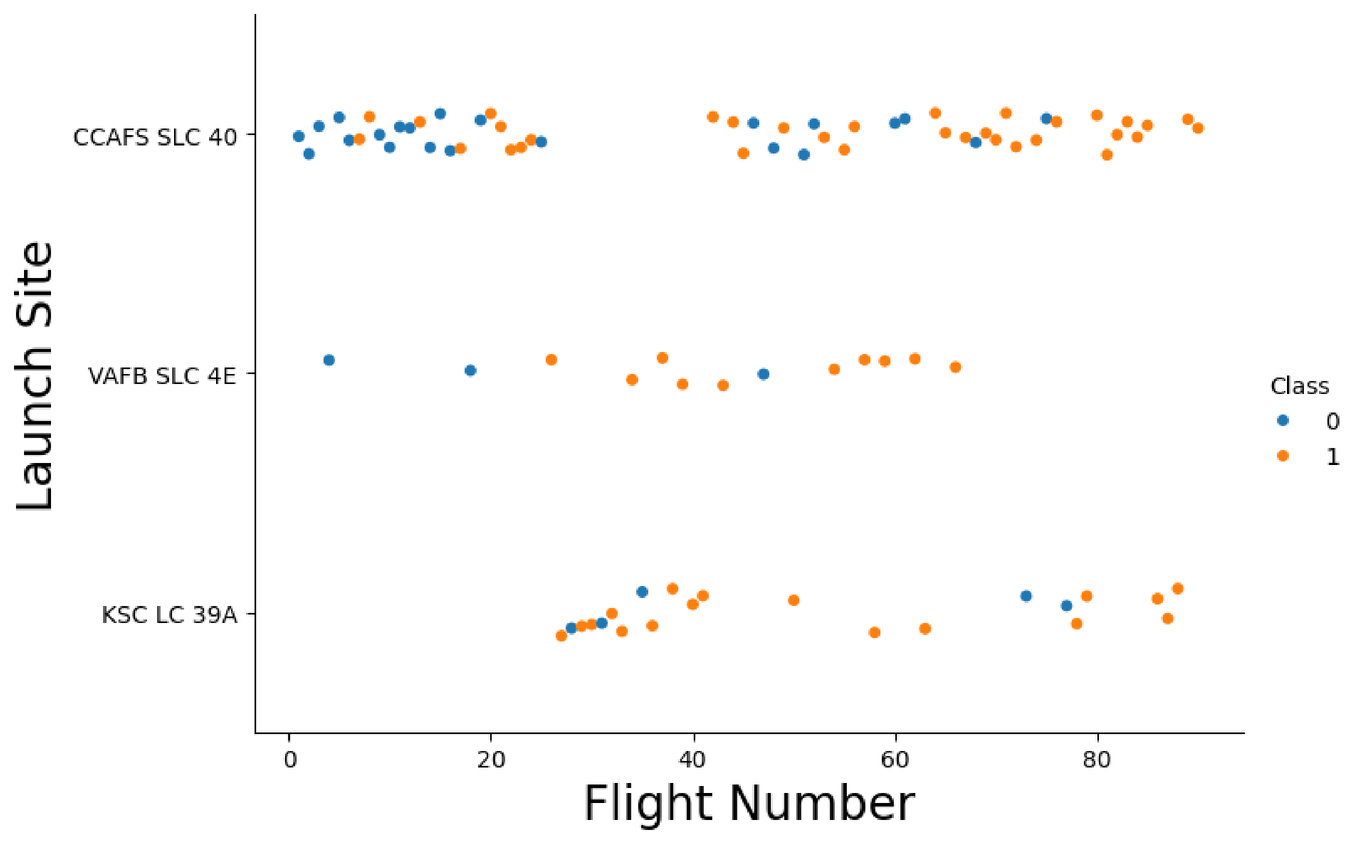
- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

Refer Github link.

Section 2

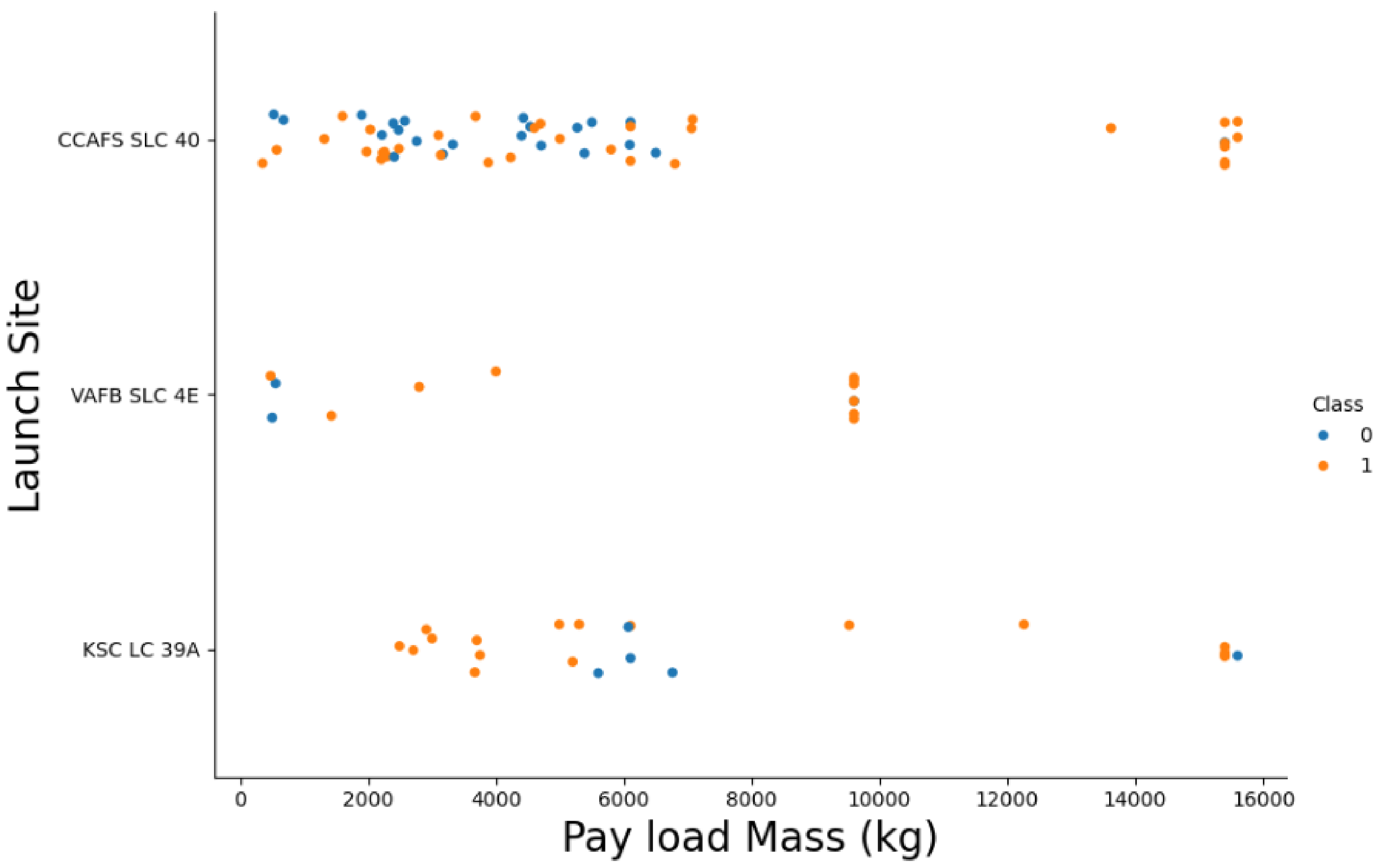
Insights drawn from EDA

Flight Number vs. Launch Site



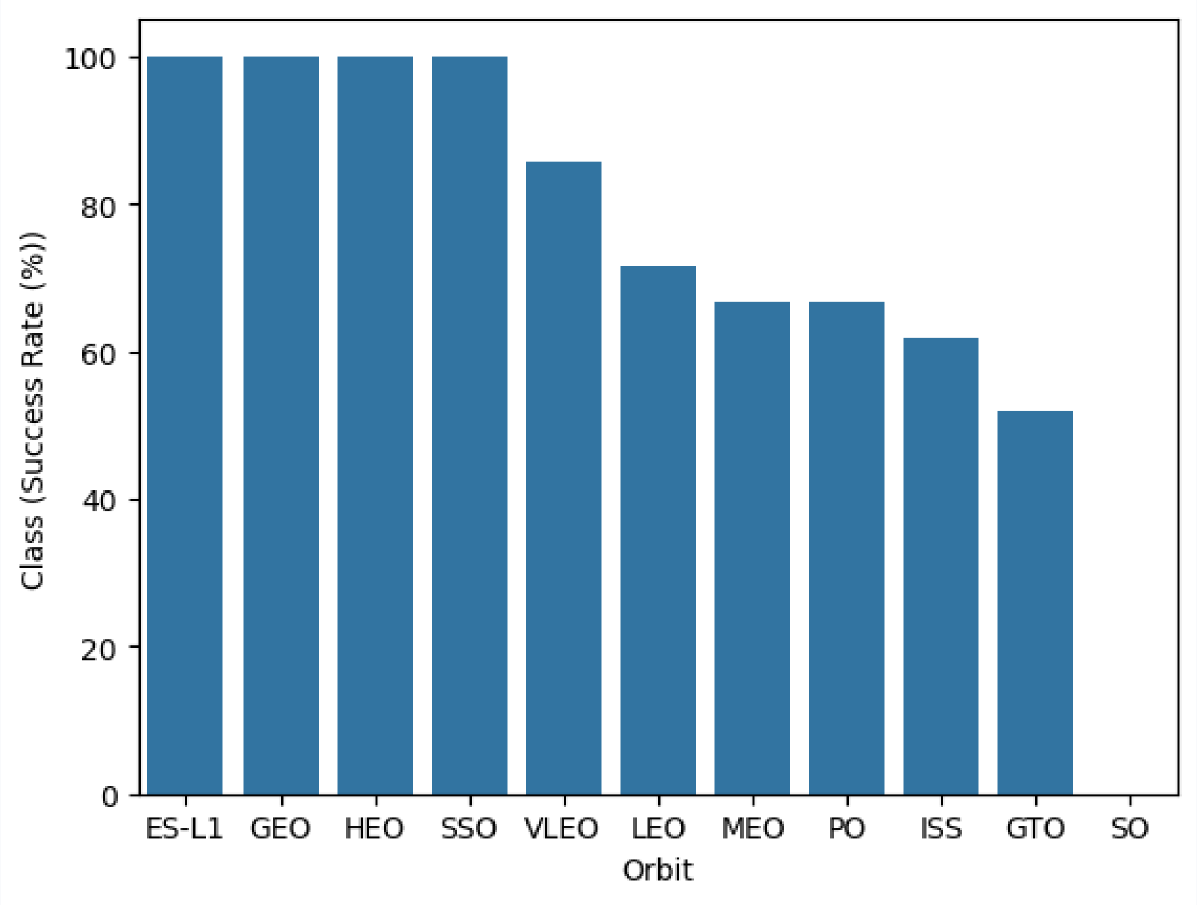
It can be inferred that with an increase in the flight number at each of the three launch sites, the success rate also rises. Specifically, for the VAFB SLC 4E launch site, the success rate reaches 100% after the 50th flight. Similarly, both KSC LC 39A and CCAFS SLC 40 achieve a 100% success rate after the 80th flight.

Payload vs. Launch Site



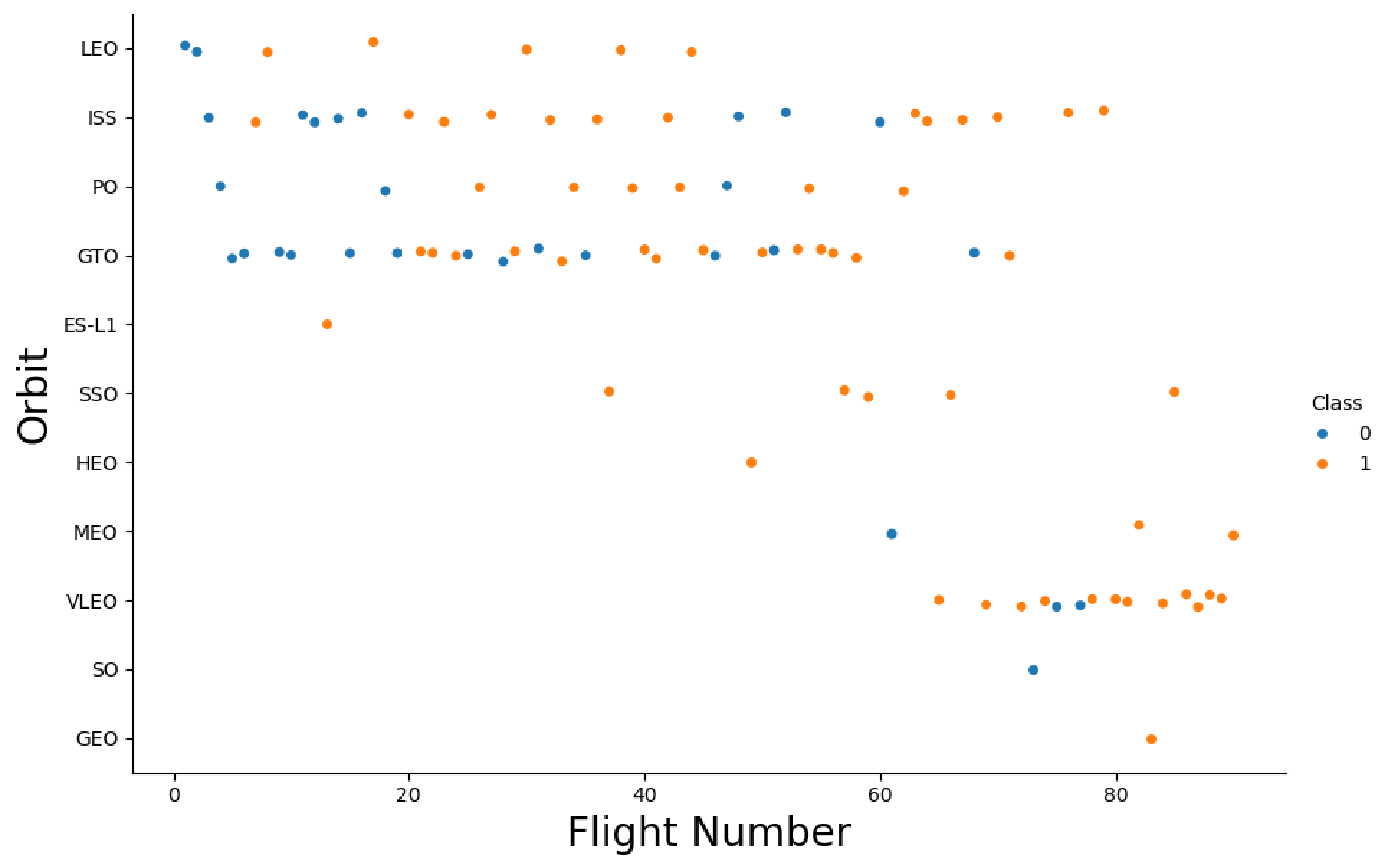
The VAFB-SLC launch site there are no rockets launched for heavy payload mass(greater than 10000).

Success Rate vs. Orbit Type



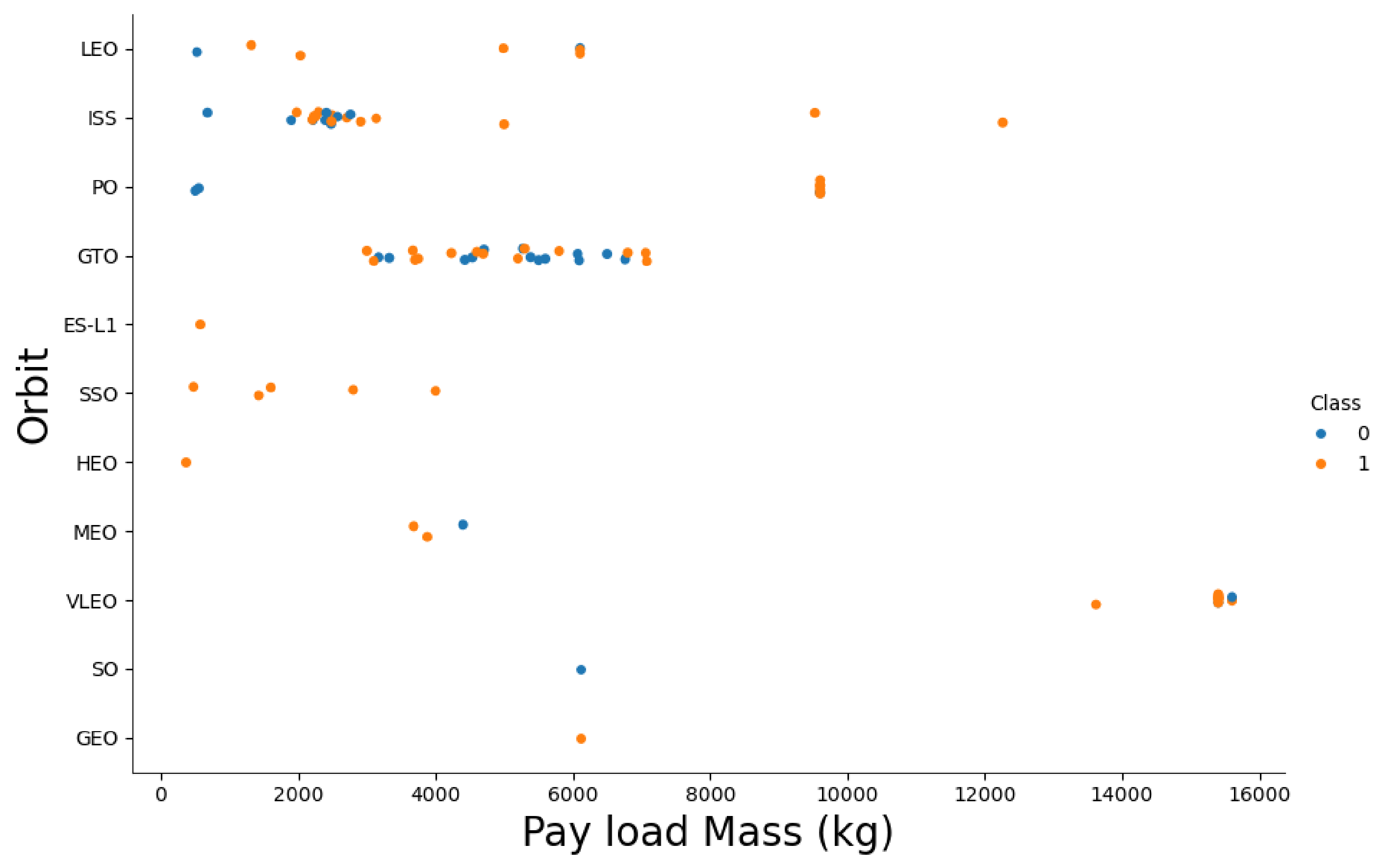
Orbits ES-L1, GEO, HEO & SSO have the highest success rates at 100%, with SO orbit having the lowest success rate at 0%.

Flight Number vs. Orbit Type



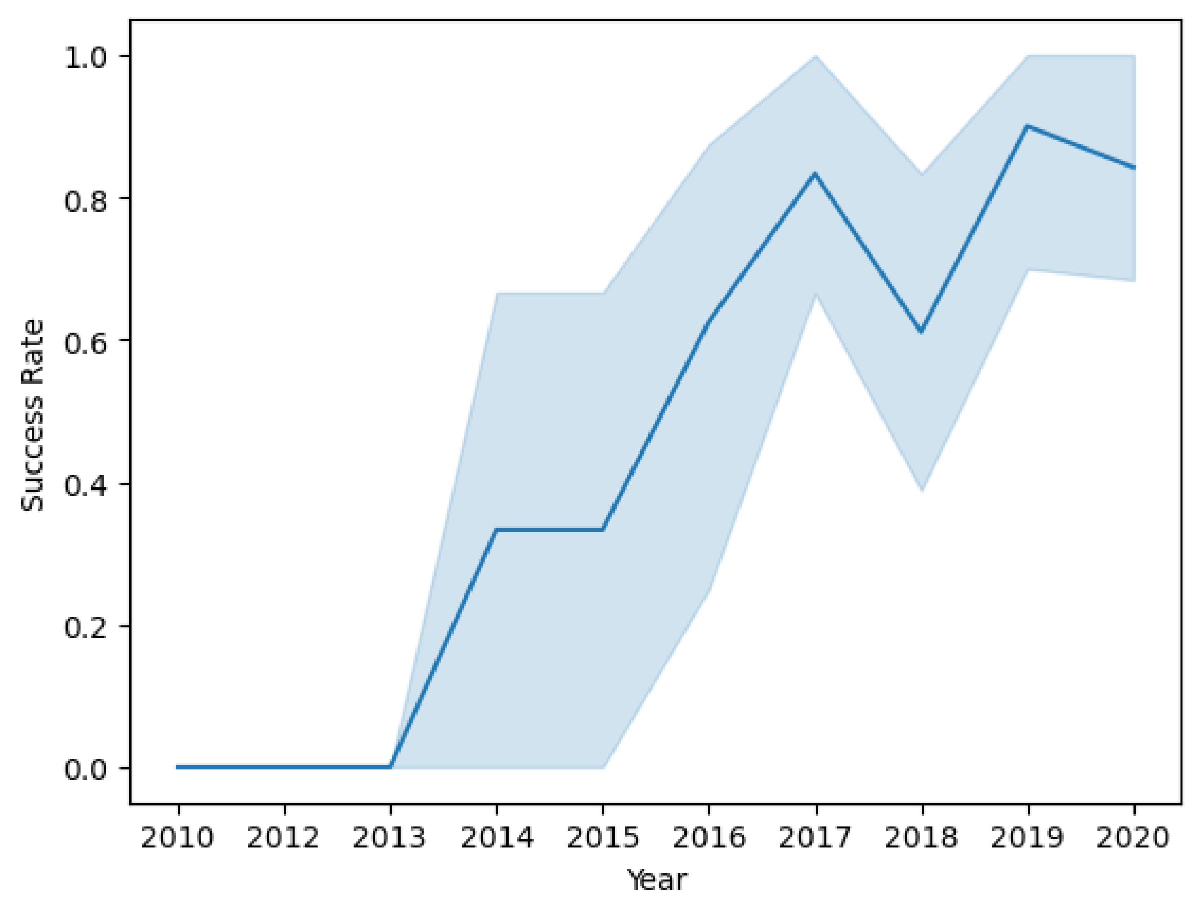
The LEO orbit the Success appears related to the number of flights; on the other hand, there seems to be no relationship between flight number when in GTO orbit.

Payload vs. Orbit Type



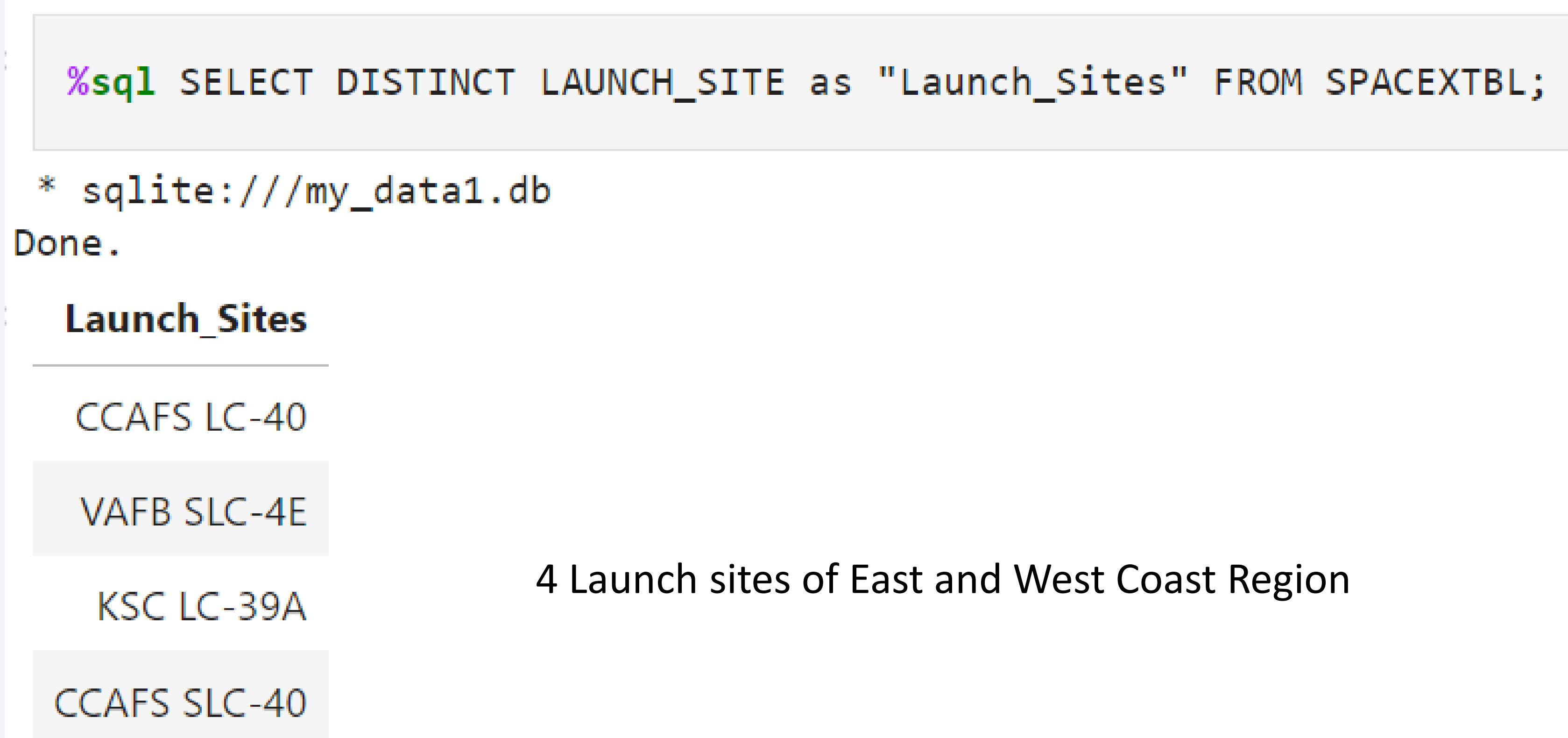
With heavy payloads the successful landing or positive landing rate are more for Polar, LEO and ISS. However for GTO we cannot distinguish this well as both positive landing rate and negative landing(unsuccessful mission) are both there here.

Launch Success Yearly Trend



The success rate since 2013 kept increasing till 2020

All Launch Site Names



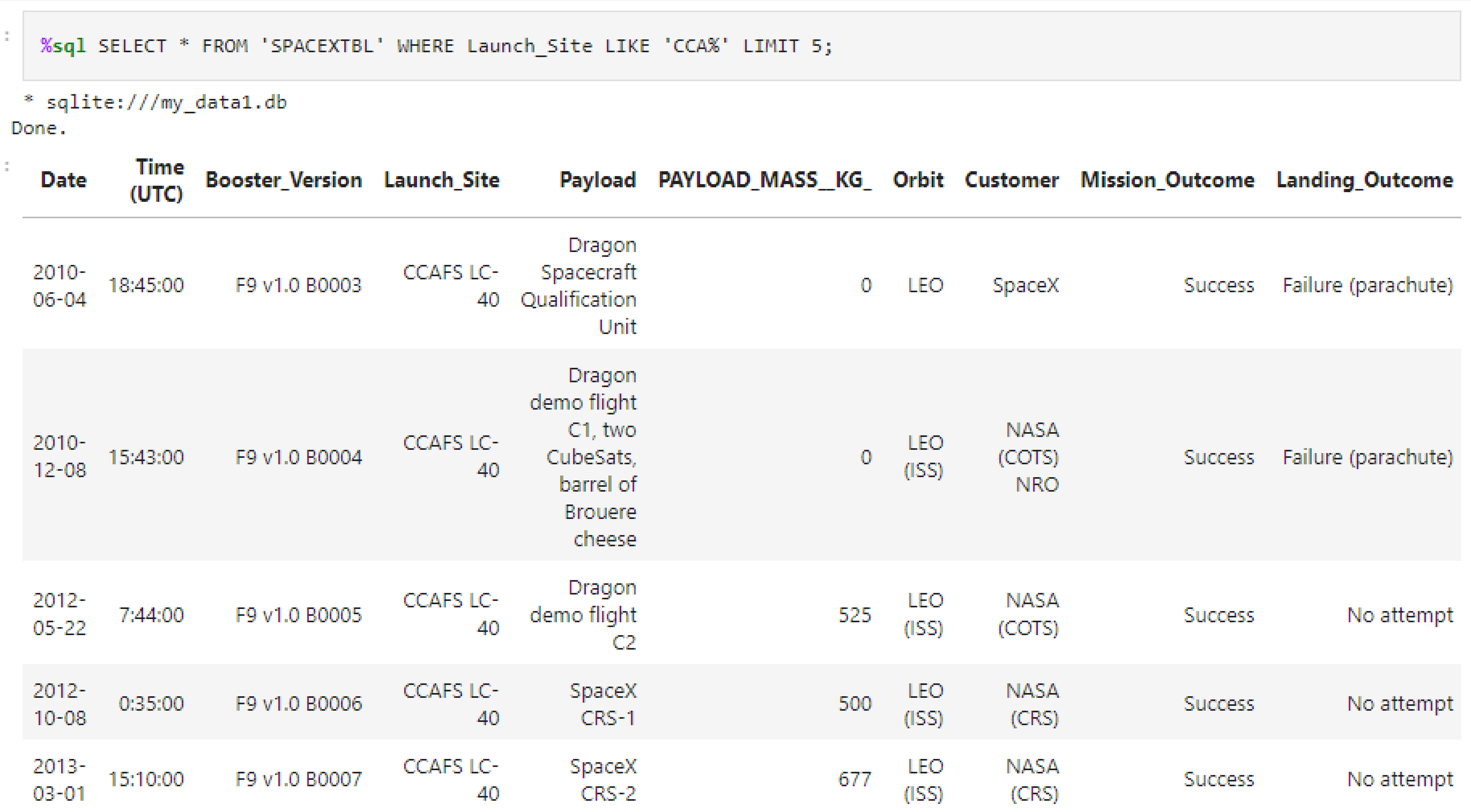
```
%sql SELECT DISTINCT LAUNCH_SITE as "Launch_Sites" FROM SPACEXTBL;
```

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

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

4 Launch sites of East and West Coast Region

Launch Site Names Begin with 'CCA'

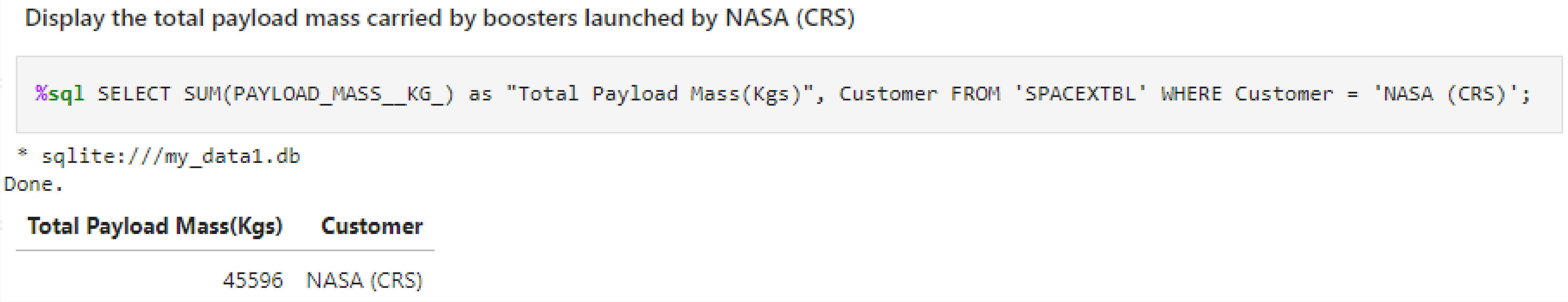


```
%sql SELECT * FROM 'SPACEXTBL' WHERE Launch_Site LIKE 'CCA%' LIMIT 5;
```

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

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

Total Payload Mass



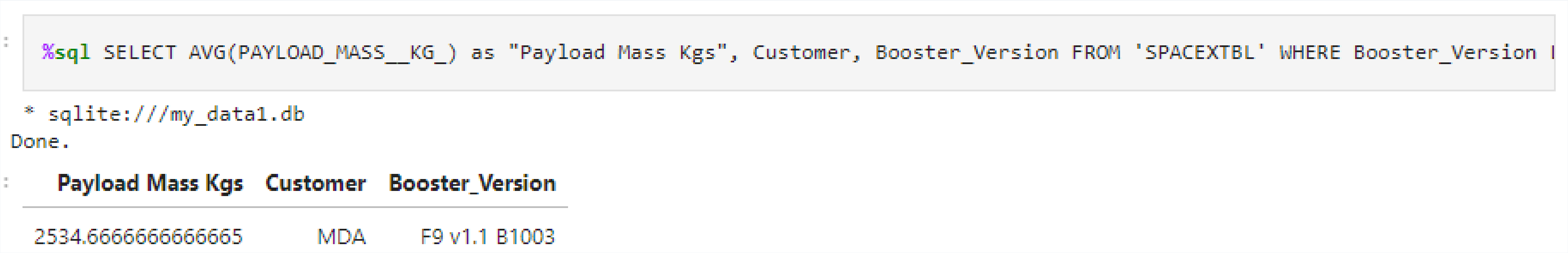
Display the total payload mass carried by boosters launched by NASA (CRS)

```
%sql SELECT SUM(PAYLOAD_MASS__KG_) as "Total Payload Mass(Kgs)", Customer FROM 'SPACEXTBL' WHERE Customer = 'NASA (CRS)';
```

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

Total Payload Mass(Kgs)	Customer
45596	NASA (CRS)

Average Payload Mass by F9 v1.1



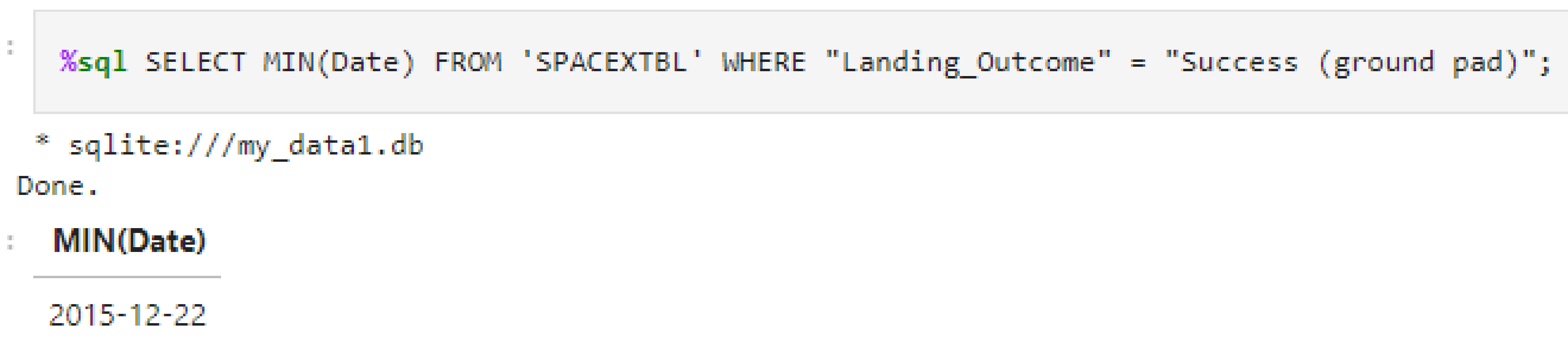
```
%sql SELECT AVG(PAYLOAD_MASS__KG_) as "Payload Mass Kgs", Customer, Booster_Version FROM 'SPACEXTBL' WHERE Booster_Version
```

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

Payload Mass Kgs	Customer	Booster_Version
2534.6666666666665	MDA	F9 v1.1 B1003

Payload of 2534 KG is the mean PAYLOAD_MASS__KG_ of all Falcon 9 Missions

First Successful Ground Landing Date



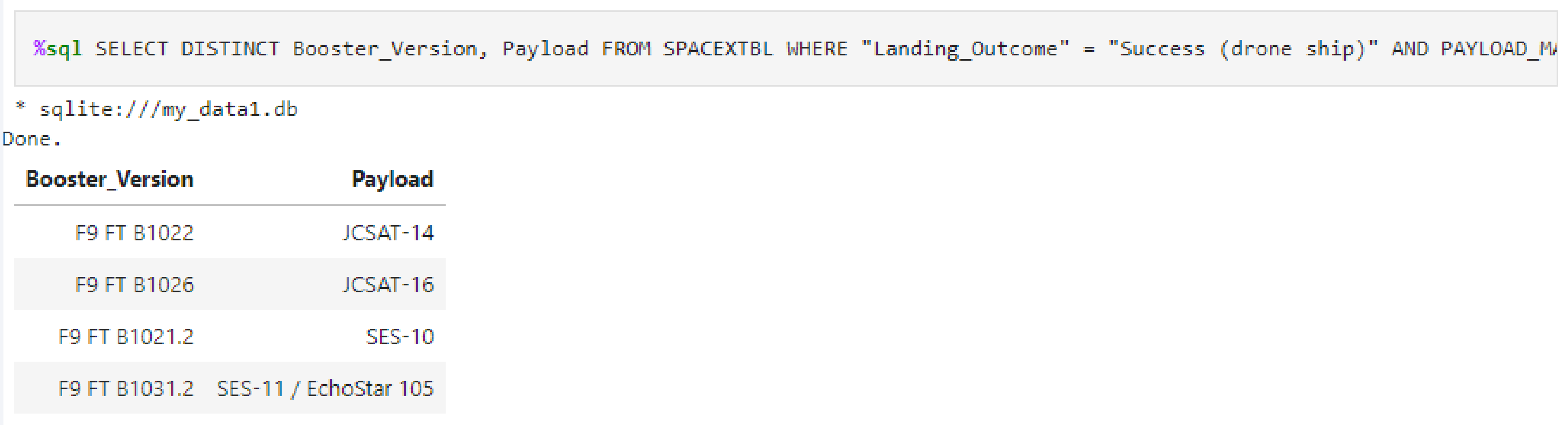
```
%sql SELECT MIN(Date) FROM 'SPACEXTBL' WHERE "Landing_Outcome" = "Success (ground pad)";
```

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

MIN(Date)
2015-12-22

December 2015, Falcon 9 became the first rocket to land propulsively after delivering a payload into orbit. This reusability results in significantly reduced launch costs, as the cost of the first stage constitutes the majority of the cost of a new rocket

Successful Drone Ship Landing with Payload between 4000 and 6000

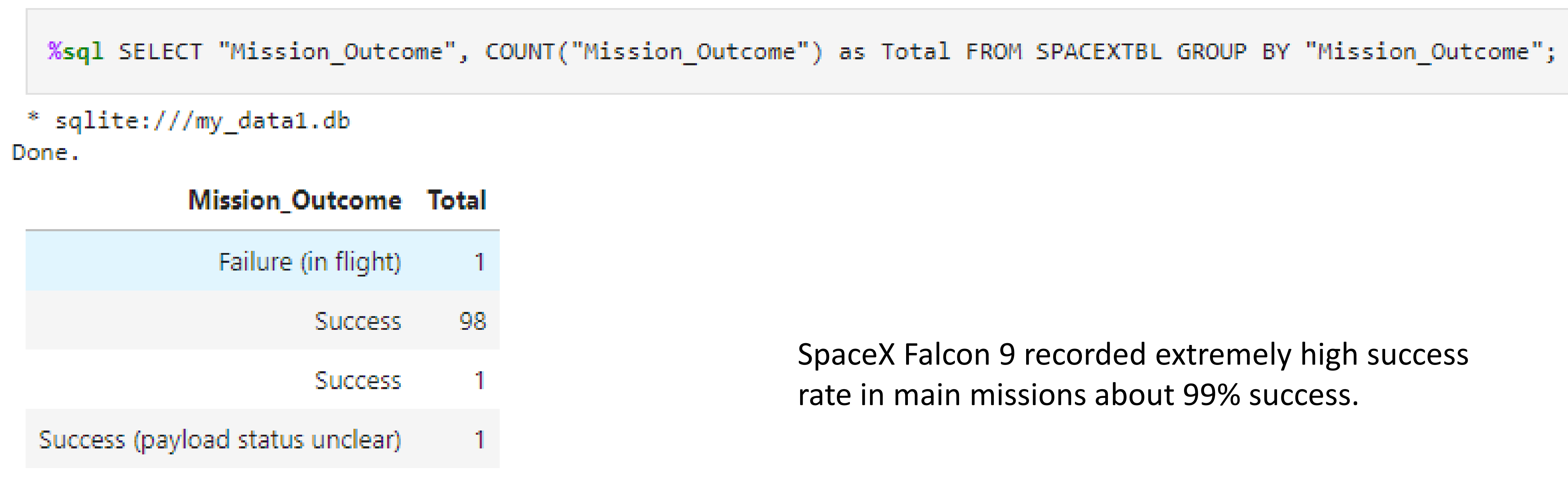


```
%sql SELECT DISTINCT Booster_Version, Payload FROM SPACEXTBL WHERE "Landing_Outcome" = "Success (drone ship)" AND PAYLOAD_M
```

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

Booster_Version	Payload
F9 FT B1022	JCSAT-14
F9 FT B1026	JCSAT-16
F9 FT B1021.2	SES-10
F9 FT B1031.2	SES-11 / EchoStar 105

Total Number of Successful and Failure Mission Outcomes



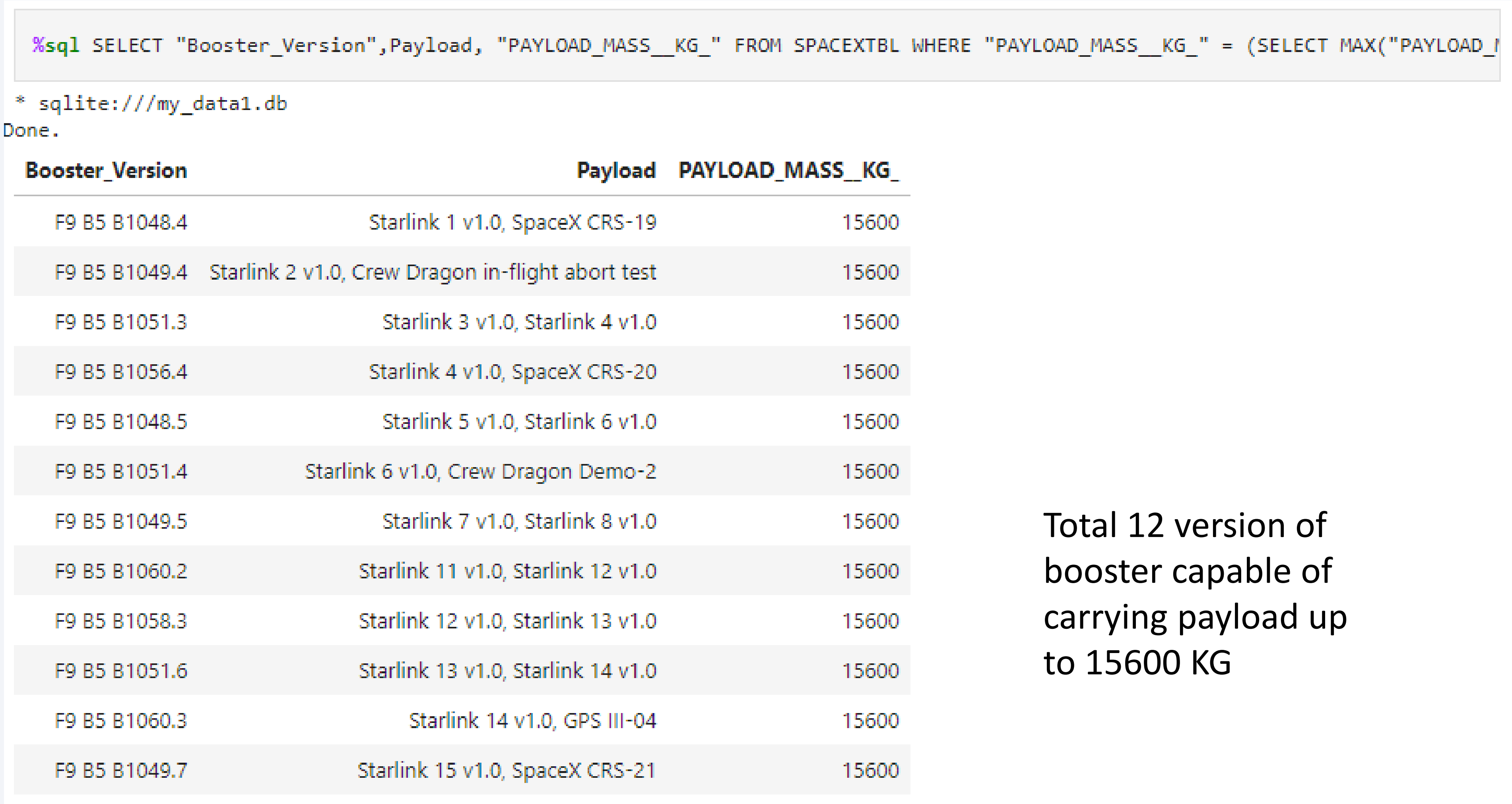
```
%sql SELECT "Mission_Outcome", COUNT("Mission_Outcome") as Total FROM SPACEXTBL GROUP BY "Mission_Outcome";
```

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

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

SpaceX Falcon 9 recorded extremely high success rate in main missions about 99% success.

Boosters Carried Maximum Payload



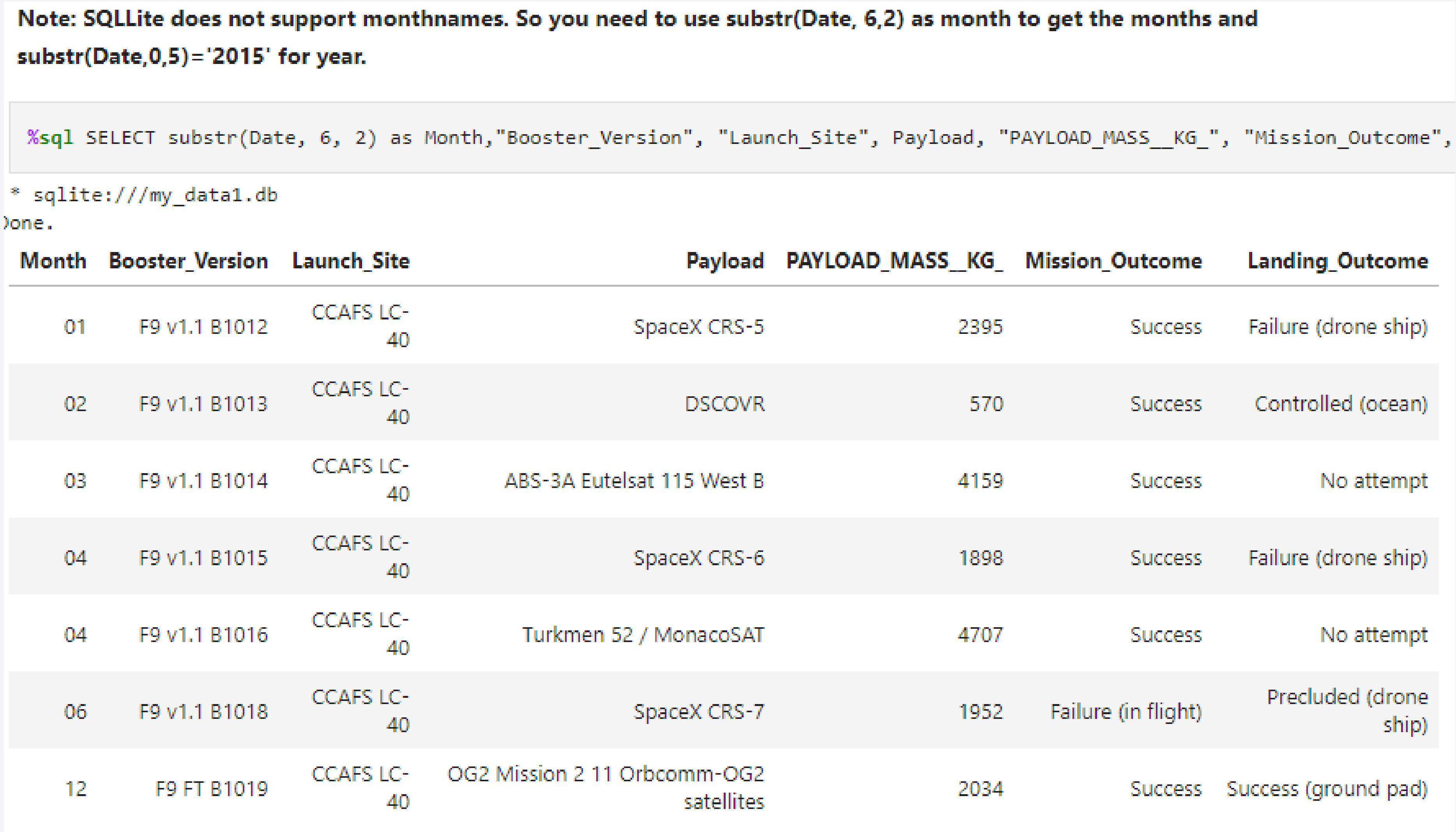
```
%sql SELECT "Booster_Version",Payload, "PAYLOAD_MASS__KG_" FROM SPACEXTBL WHERE "PAYLOAD_MASS__KG_" = (SELECT MAX("PAYLOAD_I
```

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

Booster_Version	Payload	PAYLOAD_MASS__KG_
F9 B5 B1048.4	Starlink 1 v1.0, SpaceX CRS-19	15600
F9 B5 B1049.4	Starlink 2 v1.0, Crew Dragon in-flight abort test	15600
F9 B5 B1051.3	Starlink 3 v1.0, Starlink 4 v1.0	15600
F9 B5 B1056.4	Starlink 4 v1.0, SpaceX CRS-20	15600
F9 B5 B1048.5	Starlink 5 v1.0, Starlink 6 v1.0	15600
F9 B5 B1051.4	Starlink 6 v1.0, Crew Dragon Demo-2	15600
F9 B5 B1049.5	Starlink 7 v1.0, Starlink 8 v1.0	15600
F9 B5 B1060.2	Starlink 11 v1.0, Starlink 12 v1.0	15600
F9 B5 B1058.3	Starlink 12 v1.0, Starlink 13 v1.0	15600
F9 B5 B1051.6	Starlink 13 v1.0, Starlink 14 v1.0	15600
F9 B5 B1060.3	Starlink 14 v1.0, GPS III-04	15600
F9 B5 B1049.7	Starlink 15 v1.0, SpaceX CRS-21	15600

Total 12 version of booster capable of carrying payload up to 15600 KG

2015 Launch Records



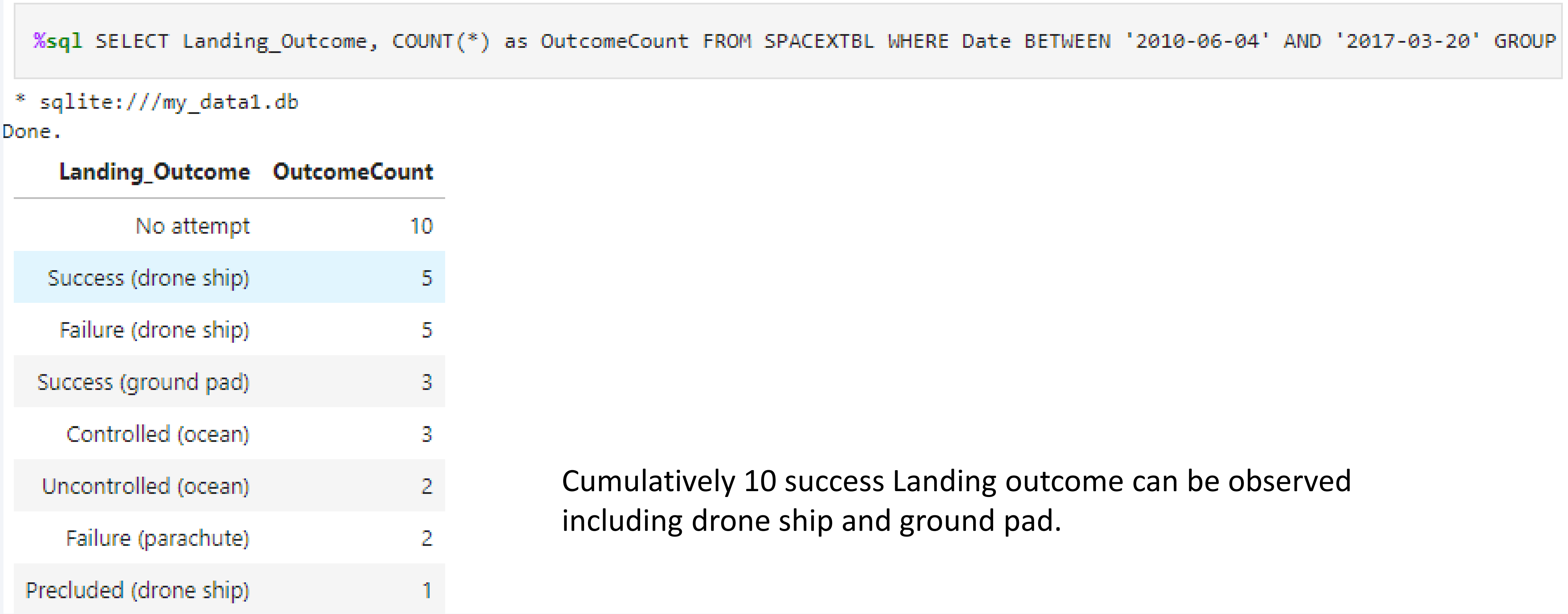
Note: SQLLite does not support monthnames. So you need to use substr(Date, 6,2) as month to get the months and substr(Date,0,5)='2015' for year.

```
%sql SELECT substr(Date, 6, 2) as Month,"Booster_Version", "Launch_Site", Payload, "PAYLOAD_MASS__KG_", "Mission_Outcome",
```

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

Month	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Mission_Outcome	Landing_Outcome
01	F9 v1.1 B1012	CCAFS LC-40	SpaceX CRS-5	2395	Success	Failure (drone ship)
02	F9 v1.1 B1013	CCAFS LC-40	DSCOVR	570	Success	Controlled (ocean)
03	F9 v1.1 B1014	CCAFS LC-40	ABS-3A Eutelsat 115 West B	4159	Success	No attempt
04	F9 v1.1 B1015	CCAFS LC-40	SpaceX CRS-6	1898	Success	Failure (drone ship)
04	F9 v1.1 B1016	CCAFS LC-40	Turkmen 52 / MonacoSAT	4707	Success	No attempt
06	F9 v1.1 B1018	CCAFS LC-40	SpaceX CRS-7	1952	Failure (in flight)	Precluded (drone ship)
12	F9 FT B1019	CCAFS LC-40	OG2 Mission 2 11 Orbcomm-OG2 satellites	2034	Success	Success (ground pad)

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



```
%sql SELECT Landing_Outcome, COUNT(*) as OutcomeCount FROM SPACEXTBL WHERE Date BETWEEN '2010-06-04' AND '2017-03-20' GROUP
```

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

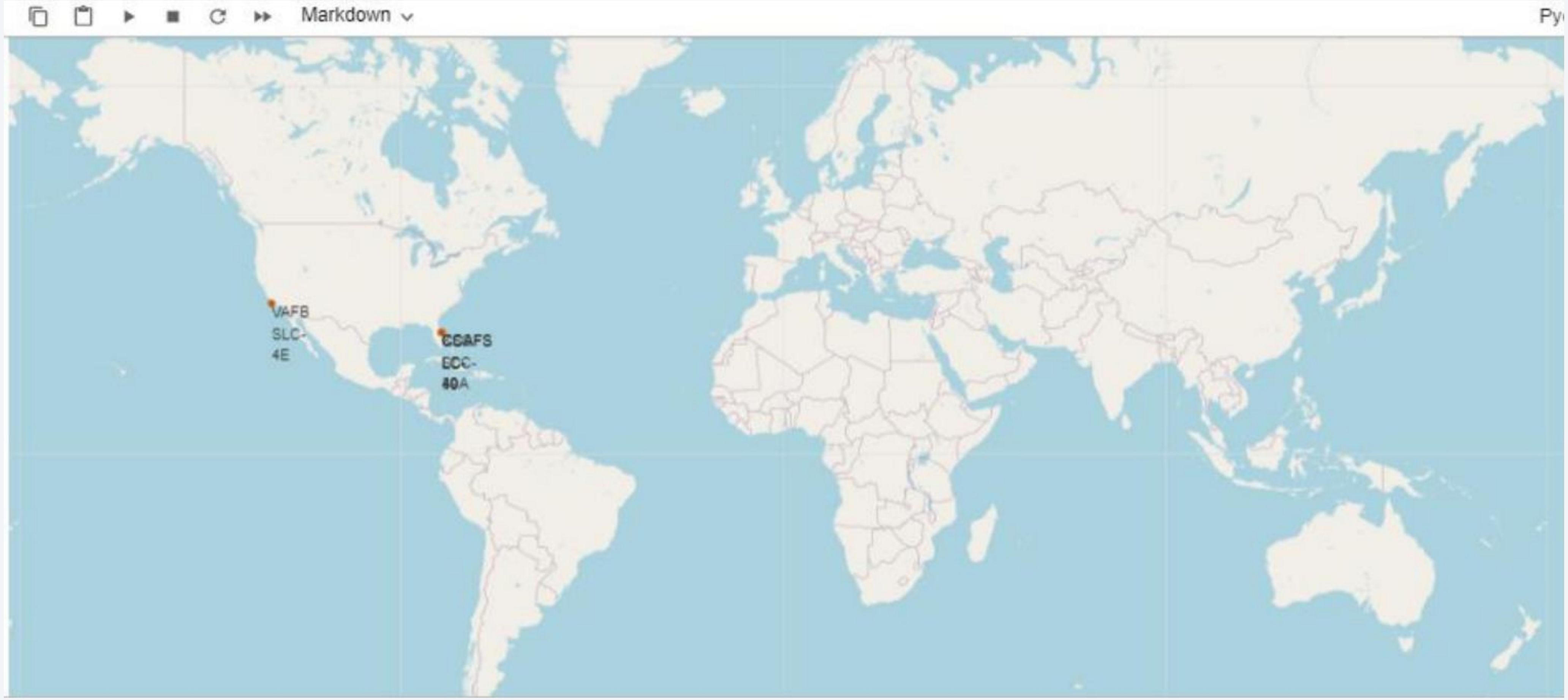
Landing_Outcome	OutcomeCount
No attempt	10
Success (drone ship)	5
Failure (drone ship)	5
Success (ground pad)	3
Controlled (ocean)	3
Uncontrolled (ocean)	2
Failure (parachute)	2
Precluded (drone ship)	1

Cumulatively 10 success Landing outcome can be observed including drone ship and ground pad.

Section 3

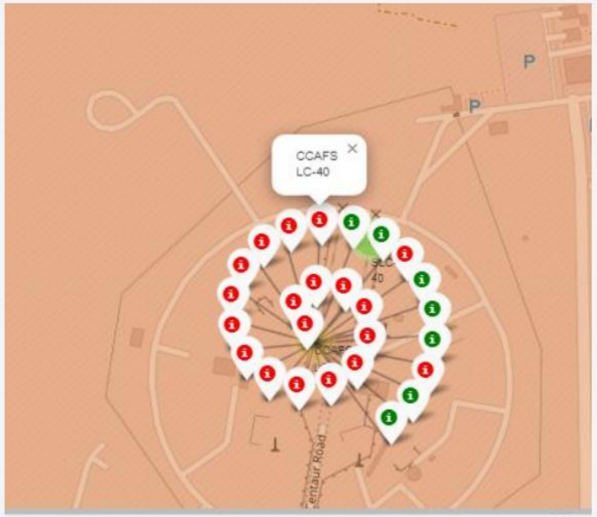
Launch Sites Proximities Analysis

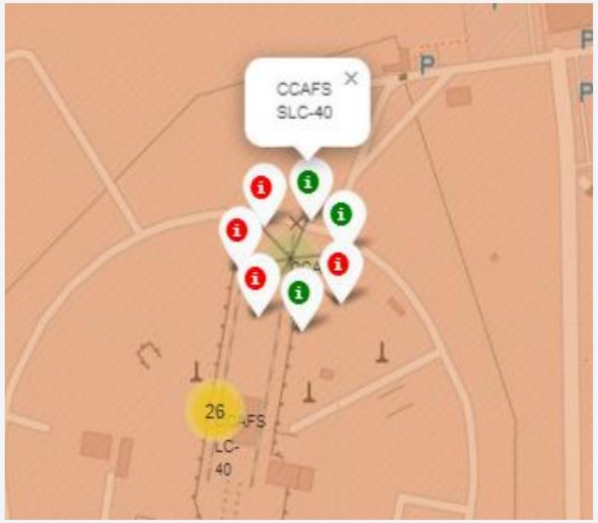
Markers of all launch sites on global map

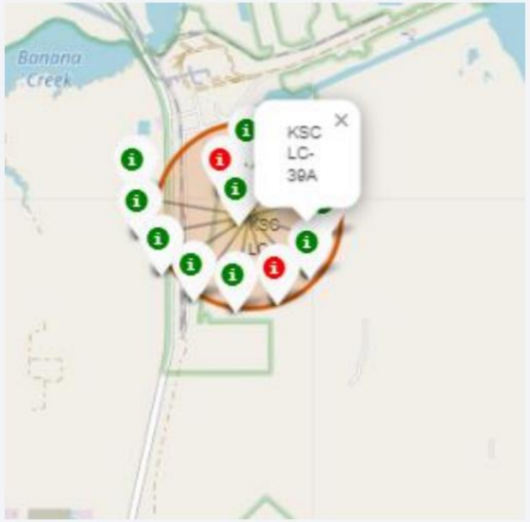


Main Launch site region include Eastern Coast (Florida) and West Coast (California)

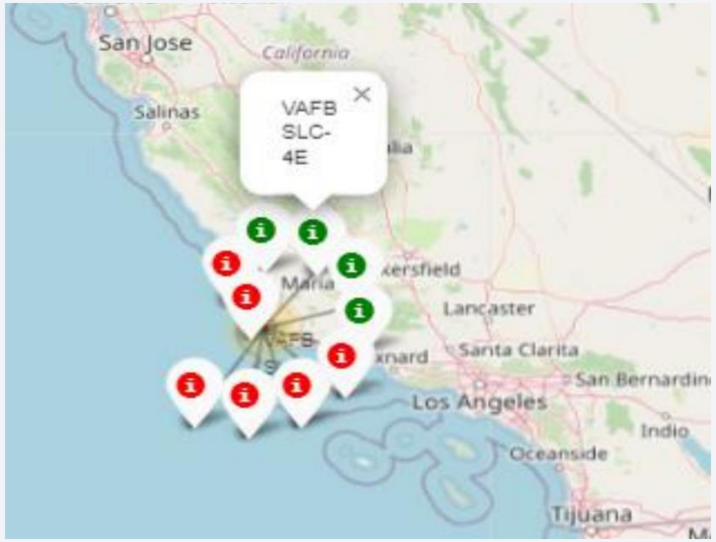
Launch outcomes for each site on the map With Color Markers





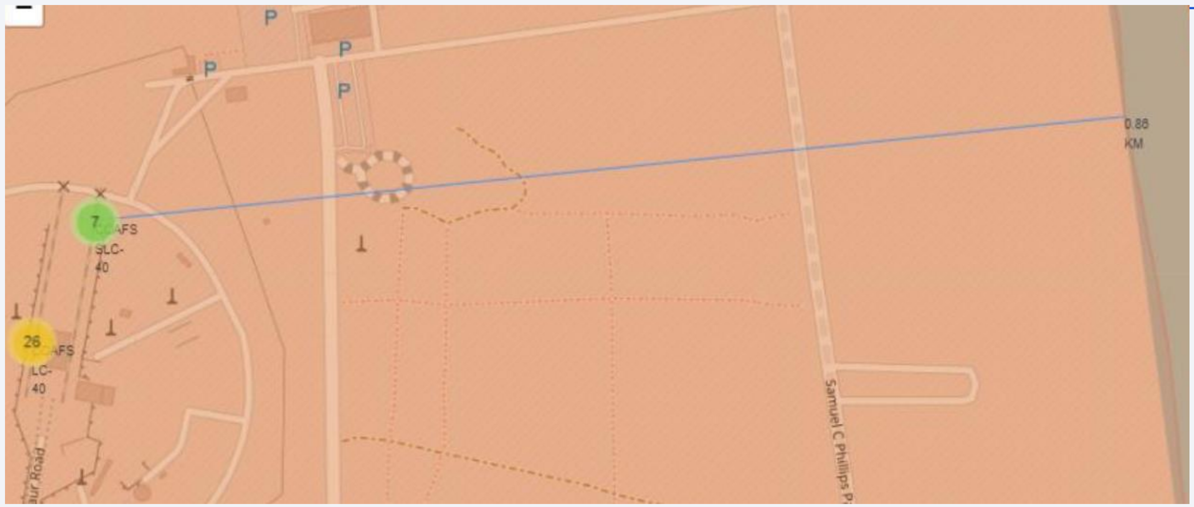


Eastern coast (Florida) Launch site KSC LC-39A has relatively high success rates compared to CCAFS SLC-40 & CCAFS LC-40



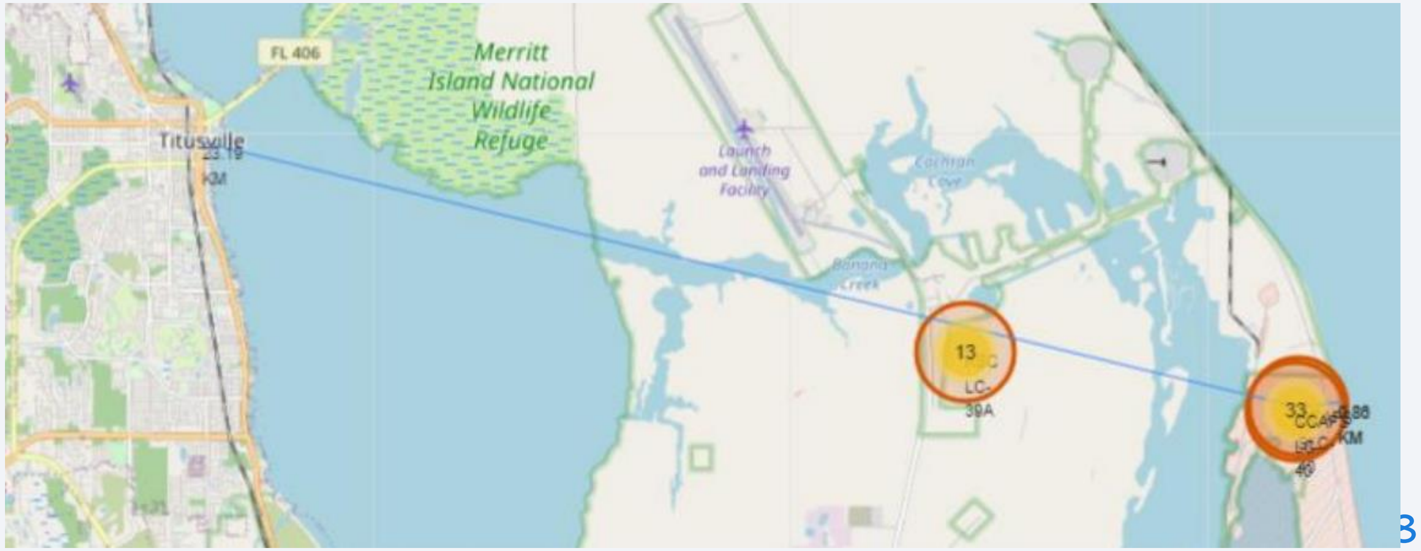
In the West Coast (California) Launch site VAFB SLC-4E has relatively lower success rates 4/10 compared to KSC LC-39A launch site in the Eastern Coast of Florida.

Distances between a launch site to its proximities



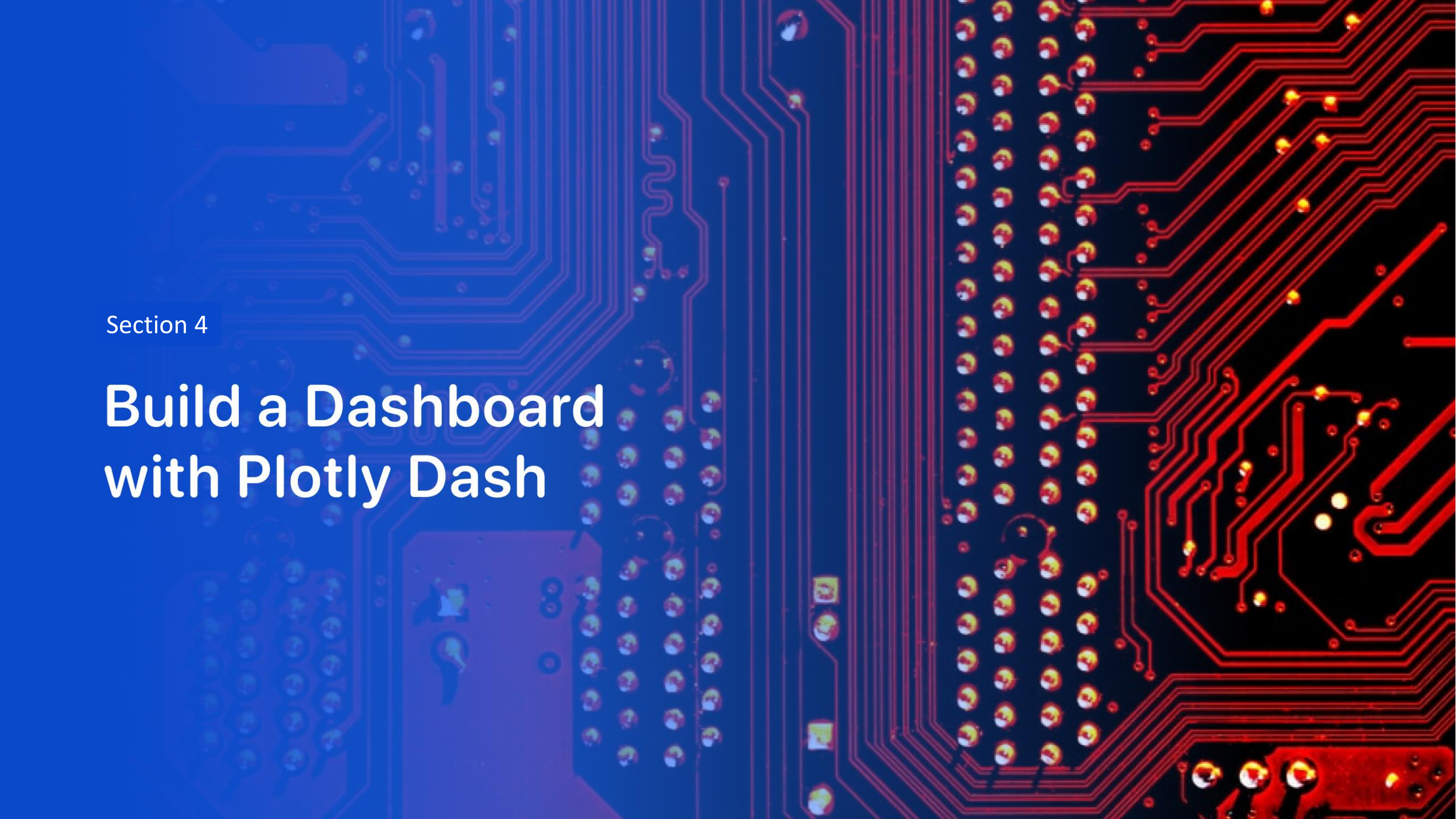
Launch site CCAFS SLC-40 proximity to coastline is 0.86km

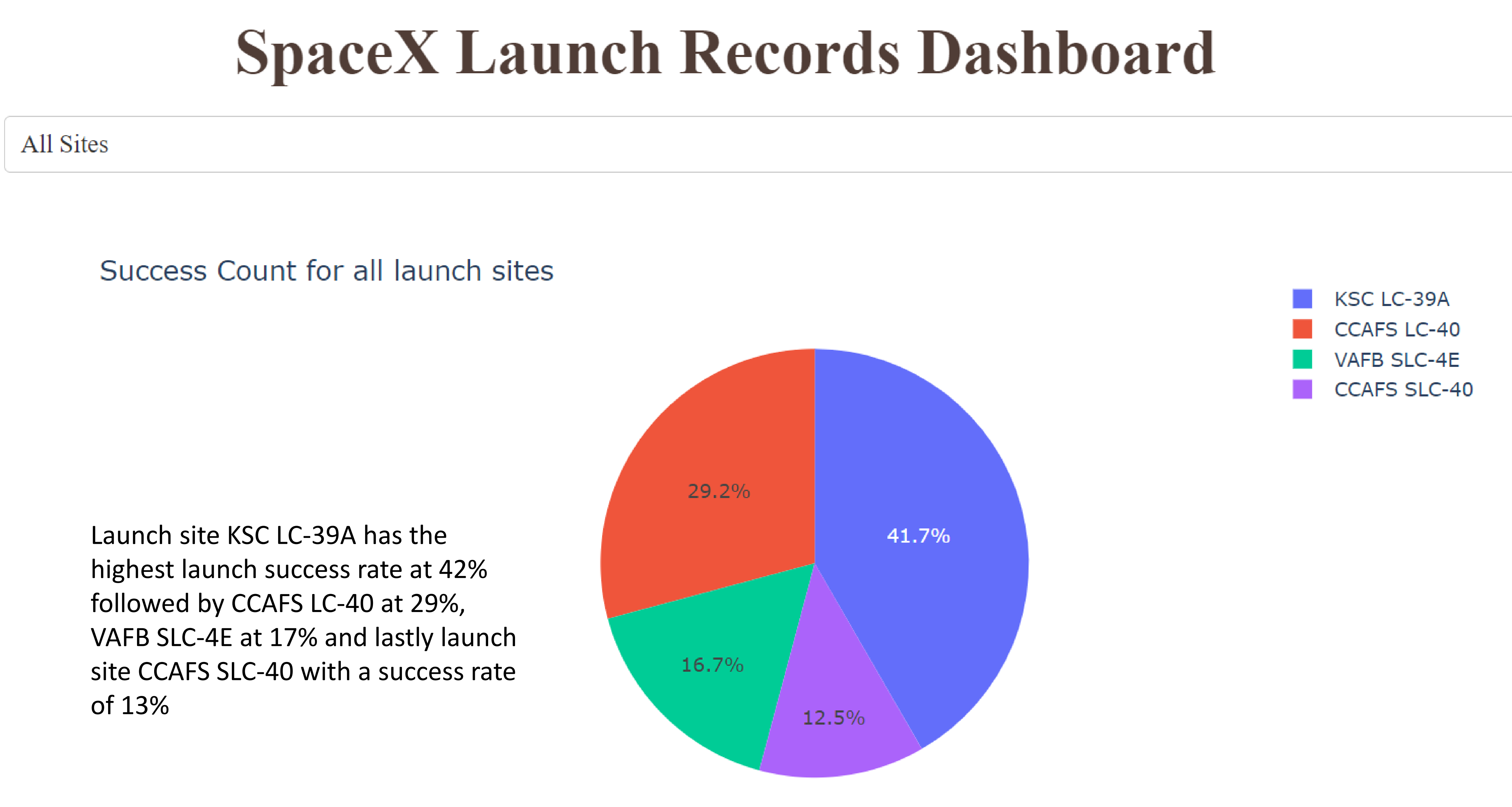
Launch site CCAFS SLC-40 closest to highway (Washington Avenue) is 23.19km



Section 4

Build a Dashboard with Plotly Dash



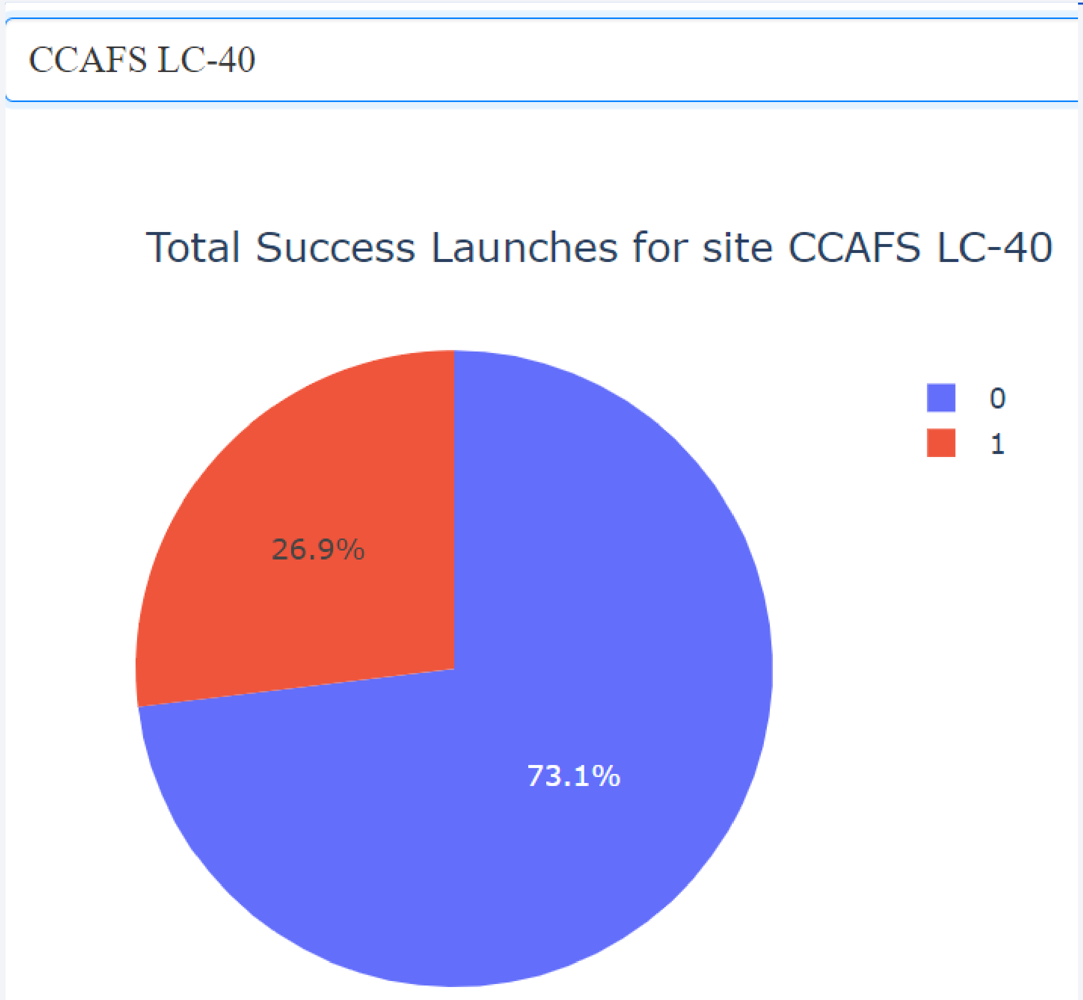


SpaceX Launch Records Dashboard

All Sites

Launch site KSC LC-39A has the highest launch success rate at 42% followed by CCAFS LC-40 at 29%, VAFB SLC-4E at 17% and lastly launch site CCAFS SLC-40 with a success rate of 13%

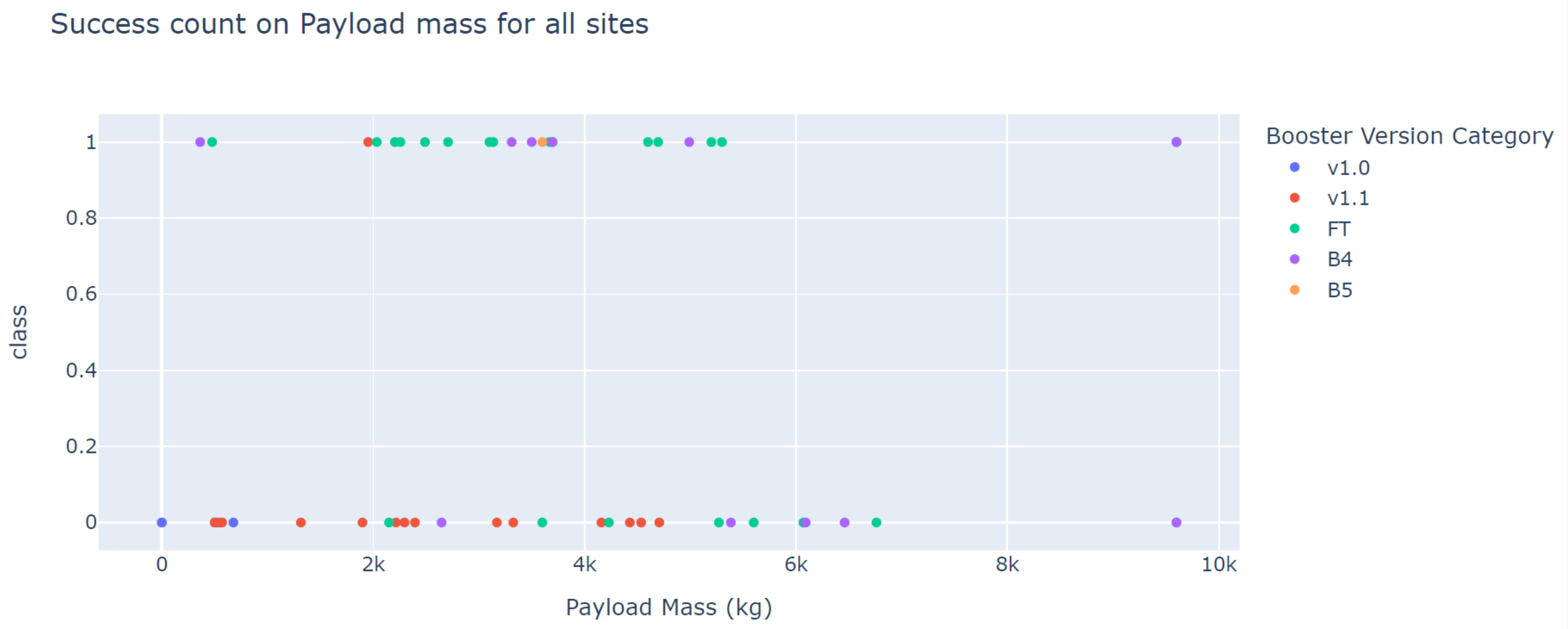
2nd Highest Launch Site Record



CCAFS LC-40

Launch site CCAFS LC-40 had the 2nd highest success ratio of 73% success against 27% failed launches

Payload vs. Launch Outcome scatter plot for all sites



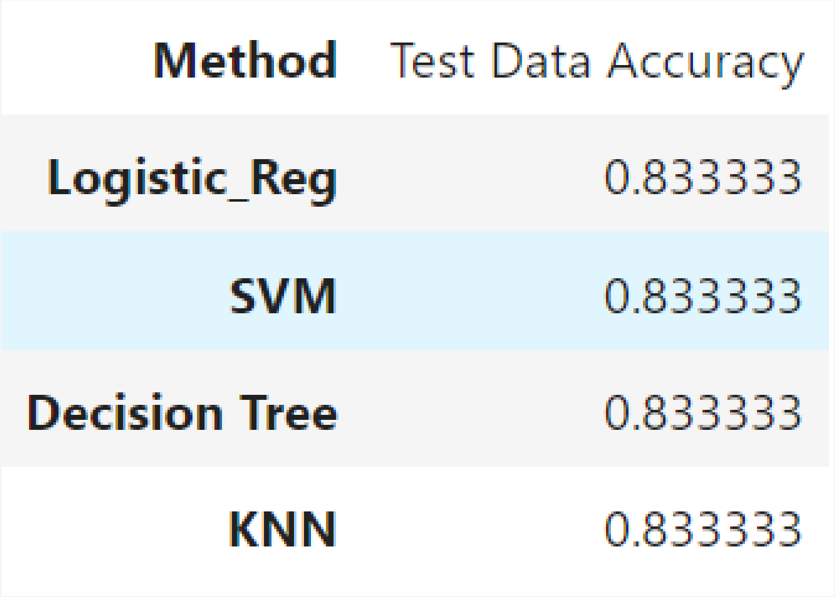
For Launch site CCAFS LC-40 the booster version FT has the largest success rate from a payload mass of >2000kg

Section 5

Predictive Analysis (Classification)

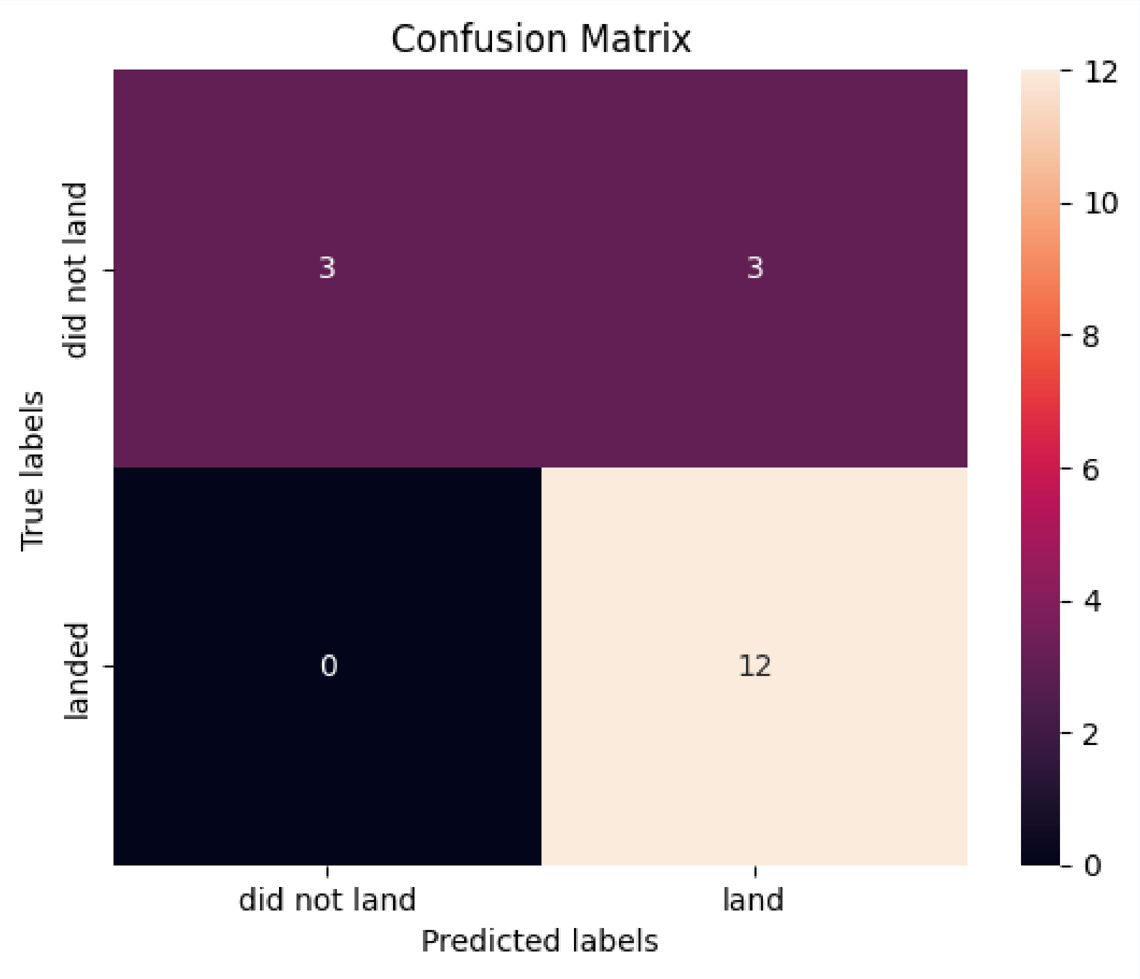
Classification Accuracy

- All the methods **perform equally** on the test data: i.e. They all have the same accuracy of **0.833333** on the test Data.



Method	Test Data Accuracy
Logistic_Reg	0.833333
SVM	0.833333
Decision Tree	0.833333
KNN	0.833333

Confusion Matrix



All the 4 classification model had the same confusion matrixes and were able equally distinguish between the different classes. The major problem is false positives for all the models.

Conclusions

- Different launch sites have different success rates. CCAFS LC-40, has a success rate of 60 %,while KSC LC-39A and VAFB SLC 4E has a success rate of 77%.

- We can deduce that, as the flight number increases in each of the 3 launching sites, so does the success rate. For instance, the success rate for the VAFB SLC 4E launch site is 100% after the Flight number 50. Both KSC LC 39A and CCAFS SLC 40 have a 100% success rates after 80thflight

- If you observe Payload Vs. Launch Site scatter point chart you will find for the VAFB-SLC launch site there are no rockets launched for heavy payload mass(greater than 10000).

- Orbits ES-L1, GEO, HEO & SSO have the highest success rates at 100%, with SO orbit having the lowest success rate at ~50%. Orbit SO has 0% success rate.

- LEO orbit the Success appears related to the number of flights; on the other hand, there seems to be no relationship between flight number when in GTO orbitConclusions57

- With heavy payloads the successful landing or positive landing rate are more for Polar, LEO and ISS. However, for GTO we cannot distinguish this well as both positive landing rate and negative landing(unsuccessful mission) are both there here

- The success rate since 2013 kept increasing till 2020.

Thank you!