IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

Nikhilesh Agrawal

Outline

- Executive Summary
- Introduction
- Methodology
- Results
  - EDA with Visualization and SQL
  - Interactive Maps with Folium
  - Plotly Dash Dashboard
  - Predictive Analytics
- Conclusion

Executive Summary

Executive Summary

- Summary of methodologies

  The research attempts to identify the factors for a successful rocket landing. To make this determination, the following methodologies where used:
  • **Collect** data using SpaceX REST API and web scraping techniques
  • **Wrangle** data to create success/fail outcome variable
  • **Explore** data using SQL and data visualization techniques
  • **Visualize** the launch sites with the most success and successful payload ranges
  • **Build Models** to predict landing outcomes using logistic regression, support vector machine (SVM), decision tree and K-nearest neighbor (KNN)

- Summary of all results

  Exploratory Data Analysis:
  - Launch success has improved over time
  - KSC LC-39A has the highest success rate among landing sites
  - Orbits ES-L1, GEO, HEO, and SSO have a 100% success rate

  Visualization/Analytics:
  - Most launch sites are near the equator, and all are close to the coast

  Predictive Analytics:
  - All models performed similarly on the test set. The decision tree model slightly outperformed

Introduction

Introduction

- Background

  SpaceX, a leader in the space industry, strives to make space travel affordable for everyone. Its accomplishments include sending spacecraft to the international space station, launching a satellite constellation that provides internet access and sending manned missions to space. SpaceX can do this because the rocket launches are relatively inexpensive ($62 million per launch) due to its novel reuse of the first stage of its Falcon 9 rocket. Other providers, which are not able to reuse the first stage, cost upwards of $165 million each. By determining if the first stage will land, we can determine the price of the launch. To do this, we can use public data and machine learning models to predict whether SpaceX – or a competing company – can reuse the first stage.

- Explore
  - How payload mass, launch site, number of flights, and orbits affect first-stage landing success
  - Rate of successful landings over time
  - Best predictive model for successful landing (binary classification)

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - Using API and Web Scraping
- Perform data wrangling
  - By filtering the data, handling missing values and applying one hot encoding – to prepare the data for 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
  - Tune and evaluate models to find best model and parameters

Data Collection

The data was collected via Rest API and Web Scraping, details below:

- Rest API
  - 1st SpaceX Rest API call
  - 2nd API returns a json file
  - 3rd Construction of a dataframe from the json file
  - 4th Performing a data cleaning and export the output
- Web Scraping
  - 1st From html response from Wikipedia
  - 2nd Data extraction using beasutifulSoup python lib
  - 3rd Construction of a dataframe
  - 4th Export the output

Data Collection – SpaceX API

SpaceX Rest API call

```
spacex_url="https://api.spacexdata.com/v4/launches/past"
response = requests.get(spacex_url)
```

API response

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

Dataframe

```
launch_dict = {'FlightNumber': list(data['flight_number']),
'Date': list(data['date']),
'BoosterVersion':BoosterVersion,
'PayloadMass':PayloadMass,
'Orbit':Orbit,
'LaunchSite':LaunchSite,
'Outcome':Outcome,
'Flights':Flights,
'GridFins':GridFins,
'Reused':Reused,
'Legs':Legs,
'LandingPad':LandingPad,
'Block':Block,
'ReusedCount':ReusedCount,
'Serial':Serial,
'Longitude': Longitude,
'Latitude': Latitude}

data = pd.DataFrame.from_dict(launch_dict)
```

Export the output - file

```
data_falcon9.to_csv('dataset_part_1.csv', index=False)
```

Data Collection - Scraping

html response

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

Data extraction using BeasutifulSoup

```
soup = BeautifulSoup(response.text, "html5lib")
```

Dataframe

```
launch_dict= dict.fromkeys(column_names)

# Remove an irrelvant column
del launch_dict['Date and time ( )']

# Let's initial the launch_dict with each value to be an empty list
launch_dict['Flight No.'] = []
launch_dict['Launch site'] = []
launch_dict['Payload'] = []
launch_dict['Payload mass'] = []
launch_dict['Orbit'] = []
launch_dict['Customer'] = []
launch_dict['Launch outcome'] = []
# Added some new columns
launch_dict['Version Booster']=[]
launch_dict['Booster landing']=[]
launch_dict['Date']=[]
launch_dict['Time']=[]

df=pd.DataFrame(launch_dict)
```

Export the output - file

```
df.to_csv('spacex_web_scraped.csv', index=False)
```

Data Wrangling

The dataset contains instances of both successful and unsuccessful booster landings. A successful mission is denoted by True Ocean, True RTLS, and True ASDS values, while a failed mission is indicated by False Ocean, False RTLS, and False ASDS values. To convert the string variables into categorical variables, we assign the value of 1 to indicate a successful mission and 0 to represent a failed mission.

Following steps were performed for data wragling:

- **Calculate the number of launches on each site**

```
# Apply value_counts() on column LaunchSite
df['LaunchSite'].value_counts()
```

- **Calculate the number and occurrence of each orbit**

```
# Apply value_counts on Orbit column
df['Orbit'].value_counts()
```

- **Calculate the number and occurrence of mission outcome per orbit type**

```
# landing_outcomes = values on Outcome column
landing_outcomes = df['Outcome'].value_counts()
landing_outcomes
```

- **Final output – stored**

```
df.to_csv("dataset_part_2.csv", index=False)
```

EDA with Data Visualization

We conducted an exploratory data analysis and feature engineering using Pandas and Matplotlib, presenting the results in charts.

- Scatter plot charts :
  - Flight Number vs Payload Max
  - Flight Number vs Launch Site
  - Payload vs Launch Site
  - Orbit vs Flight Number
  - Playload vs Orbit Type
  - Orbit vs Payload Mass
- Bar Charts
  - Success rate vs Orbit
- Scatter Plots were used to view relationship. The variables could be useful for machine learning if a relationship exists. Bar charts were used to show the relationships among the categories and a measured value

EDA with SQL

We conducted SQL queries to collect and analyze data from the dataset, and the results are as follows:

1. Displaying the names of the unique launch sites in the space mission.
2. Display 5 records where launch sites begin with the string 'CCA'.
3. Display the total payload mass carried by boosters launched by NASA (CRS).
4. Display the average payload mass carried by the booster version F9 v1.1.
5. List the date when the first successful landing outcome on a ground pad was achieved.
6. List the names of the boosters that achieved success on a drone ship and carried a payload mass greater than 4000 but less than 6000.
7. List the total number of successful and failure mission outcomes.
8. List the names of the booster versions that carried the maximum payload mass.
9. List the records displaying the month names, failure landing outcomes on a drone ship, booster versions, and launch site for the months in the year 2015.
10. Rank the count of successful landing outcomes between the dates 04-06-2010 and 20-03-2017 in descending order.

Build an Interactive Map with Folium

Markers Indicating Launch Sites

- Added blue circle at NASA Johnson Space Center's coordinate with a popup label showing its name using its latitude and longitude coordinates
- Added red circles at all launch sites coordinates with a popup label showing its name using its name using its latitude and longitude coordinates

Colored Markers of Launch Outcomes

- Added colored markers of successful (green) and unsuccessful (red) launches at each launch site to show which launch sites have high success rates

Distances Between a Launch Site to Proximities

- Added colored lines to show distance between launch site CCAFS SLC40 and its proximity to the nearest coastline, railway, highway, and city

Build a Dashboard with Plotly Dash

Dropdown List with Launch Sites

- Allow user to select all launch sites or a certain launch site

Slider of Payload Mass Range

- Allow user to select payload mass range

Pie Chart Showing Successful Launches

- Allow user to see successful and unsuccessful launches as a percent of the total

Scatter Chart Showing Payload Mass vs. Success Rate by Booster Version

- Allow user to see the correlation between Payload and Launch Success

Predictive Analysis (Classification)

These are the steps performed for predictive analysis :

- Create NumPy array from the Class column
- Standardize the data with StandardScaler. Fit and transform the data.
- Split the data using train_test_split
- Create a GridSearchCV object with cv=10 for parameter optimization
- Apply GridSearchCV on different algorithms:
    - logistic regression (LogisticRegression()),
    - support vector machine (SVC()),
    - decision tree (DecisionTreeClassifier()),
    - K-Nearest Neighbor (KNeighborsClassifier())
- Calculate accuracy on the test data using .score() for all models
- Assess the confusion matrix for all models
- Identify the best model using Jaccard_Score, F1_Score and Accuracy

Results

Results Summary

Exploratory Data Analysis

- Launch success has improved over time
- KSC LC-39A has the highest success rate among landing sites
- Orbits ES-L1, GEO, HEO and SSO have a 100% success rate

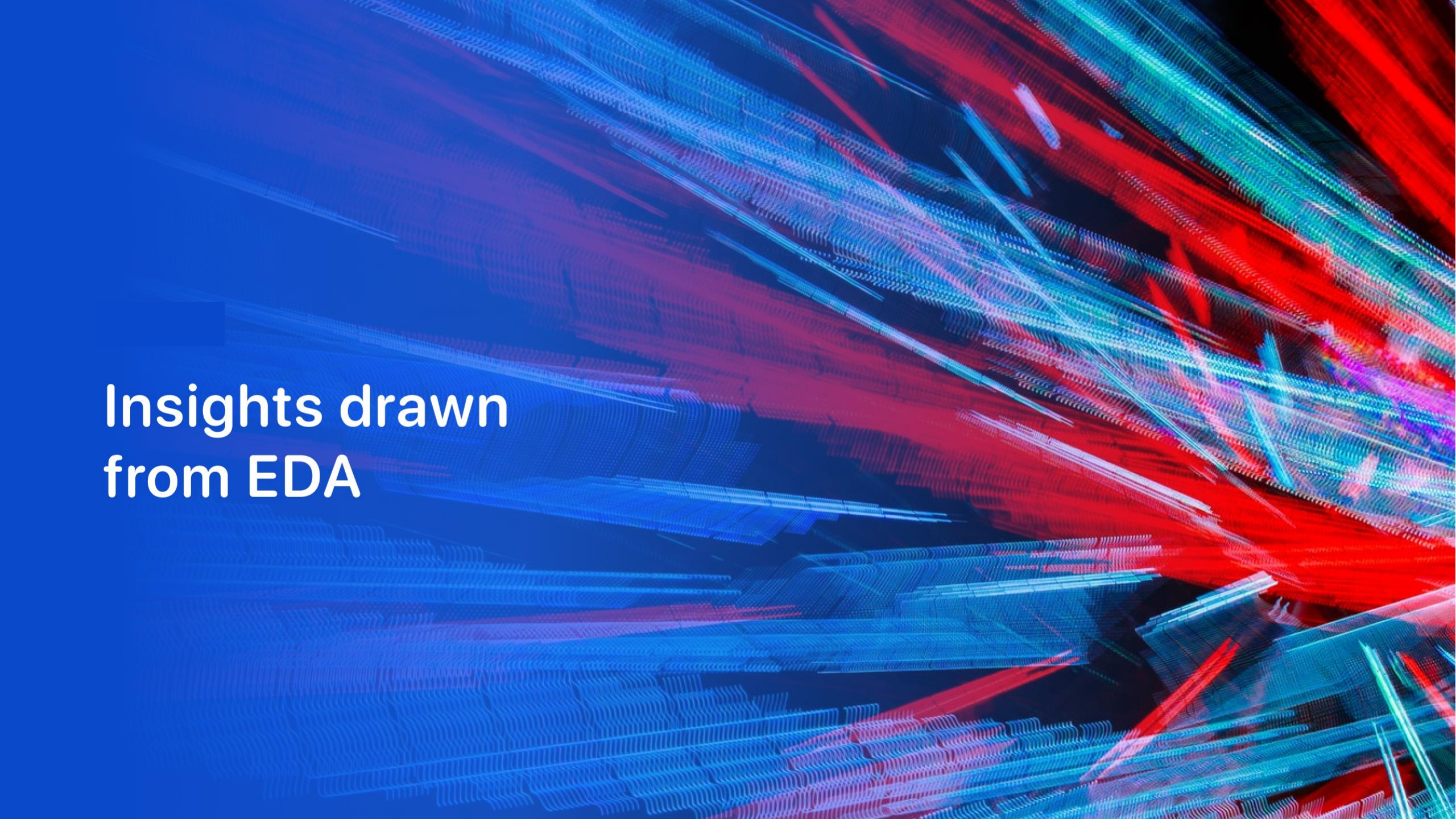
Visual Analytics

- Most launch sites are near the equator, and all are close to the coast
- Launch sites are far enough away from anything a failed launch can damage (city, highway, railway), while still close enough to bring people and material to support launch activities

Predictive Analytics

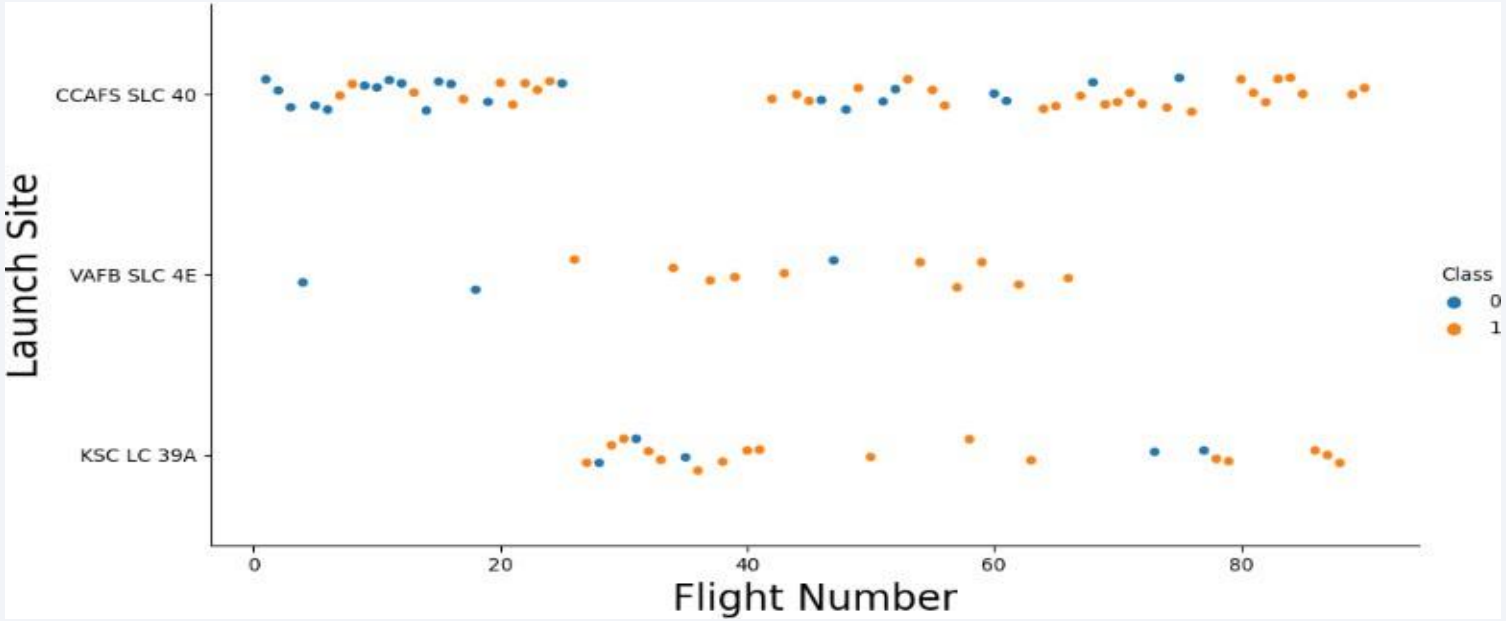
- Decision Tree model is the best predictive model for the dataset

Insights drawn from EDA



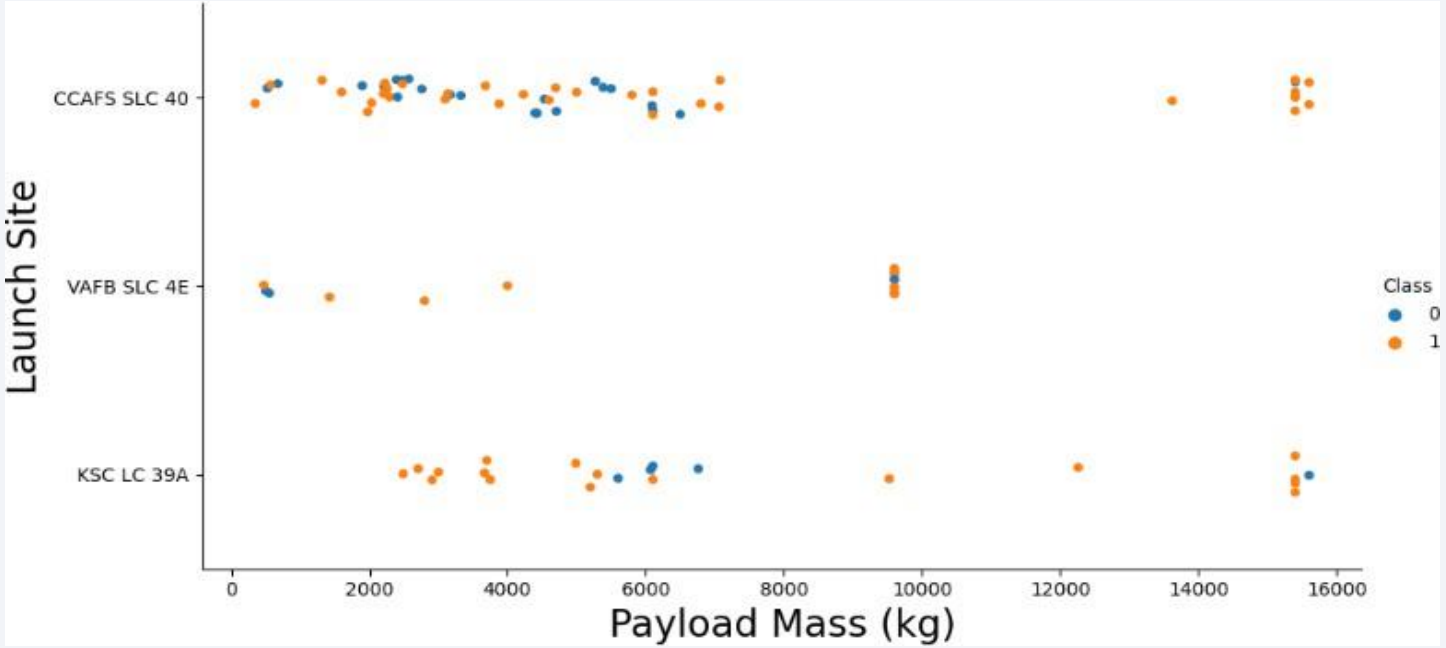
Flight Number vs. Launch Site

- Earlier flights had a lower success rate (blue = fail)
- Later flights had a higher success rate (orange = success)
- Around half of launches were from CCAFS SLC 40 launch site
- VAFB SLC 4E and KSC LC 39A have higher success rates
- We can infer that new launches have a higher success rate



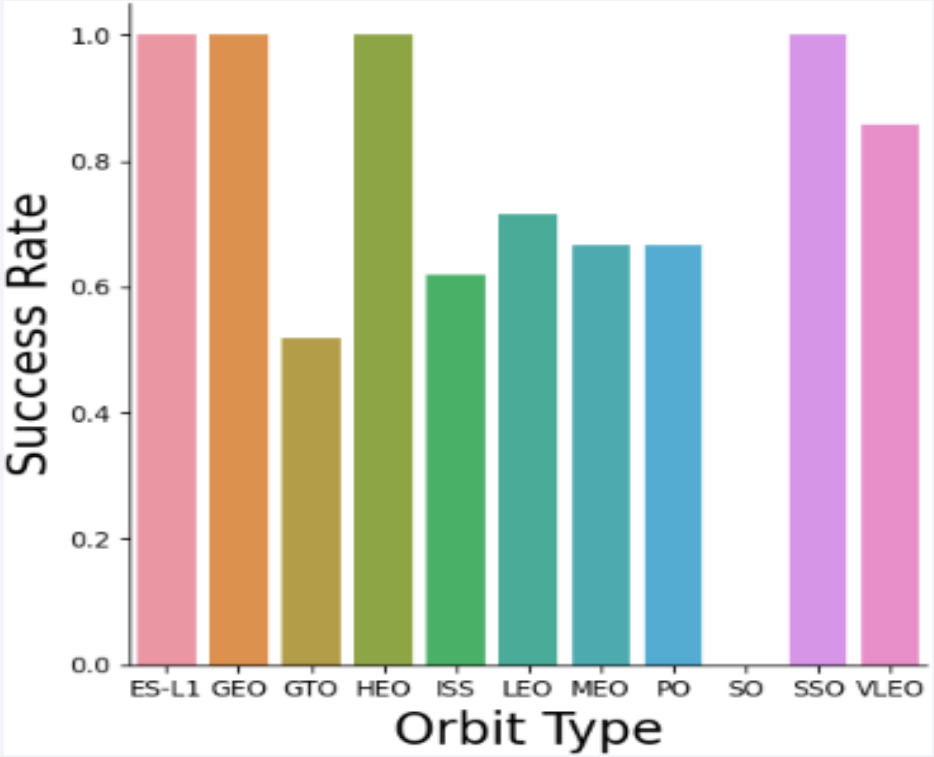
Payload vs. Launch Site

- Typically, the higher the payload mass (kg), the higher the success rate
- Most launces with a payload greater than 7,000 kg were successful
- KSC LC 39A has a 100% success rate for launches less than 5,500 kg
- VAFB SKC 4E has not launched anything greater than ~10,000 kg



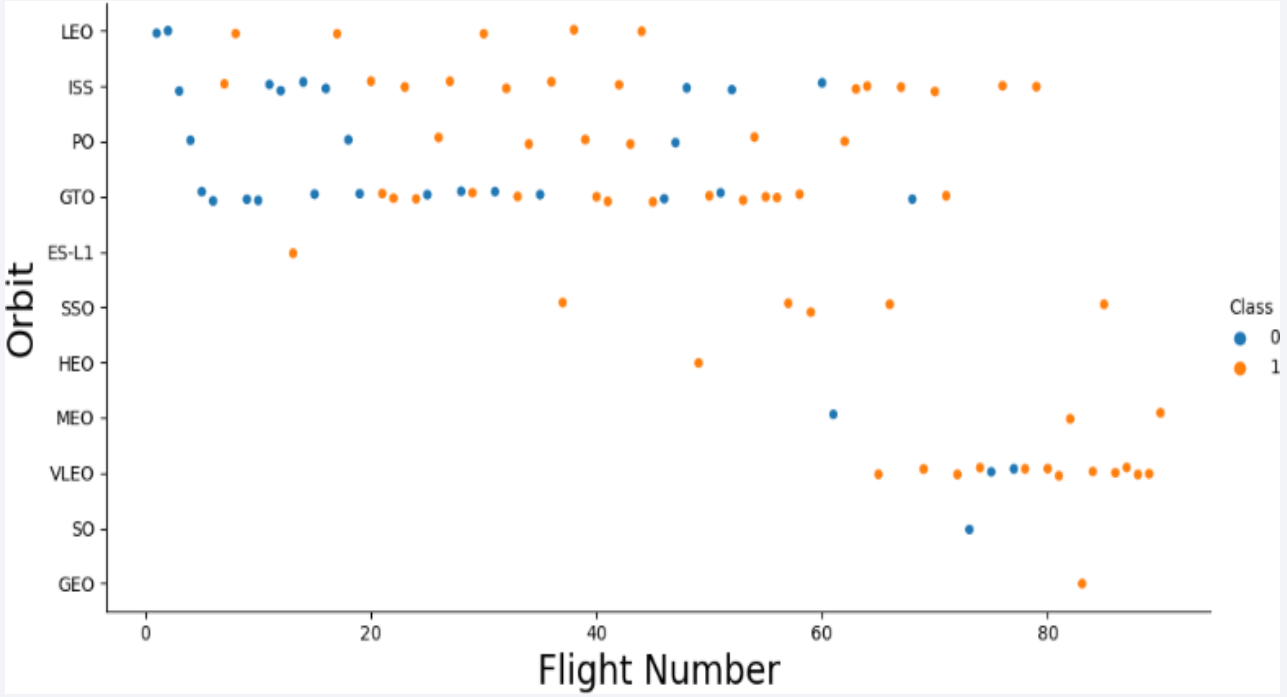
Success Rate vs. Orbit Type

- 100% Success Rate: ES-L1, GEO, HEO and SSO
- 50%-80% Success Rate: GTO, ISS, LEO, MEO, PO
- 0% Success Rate: SO



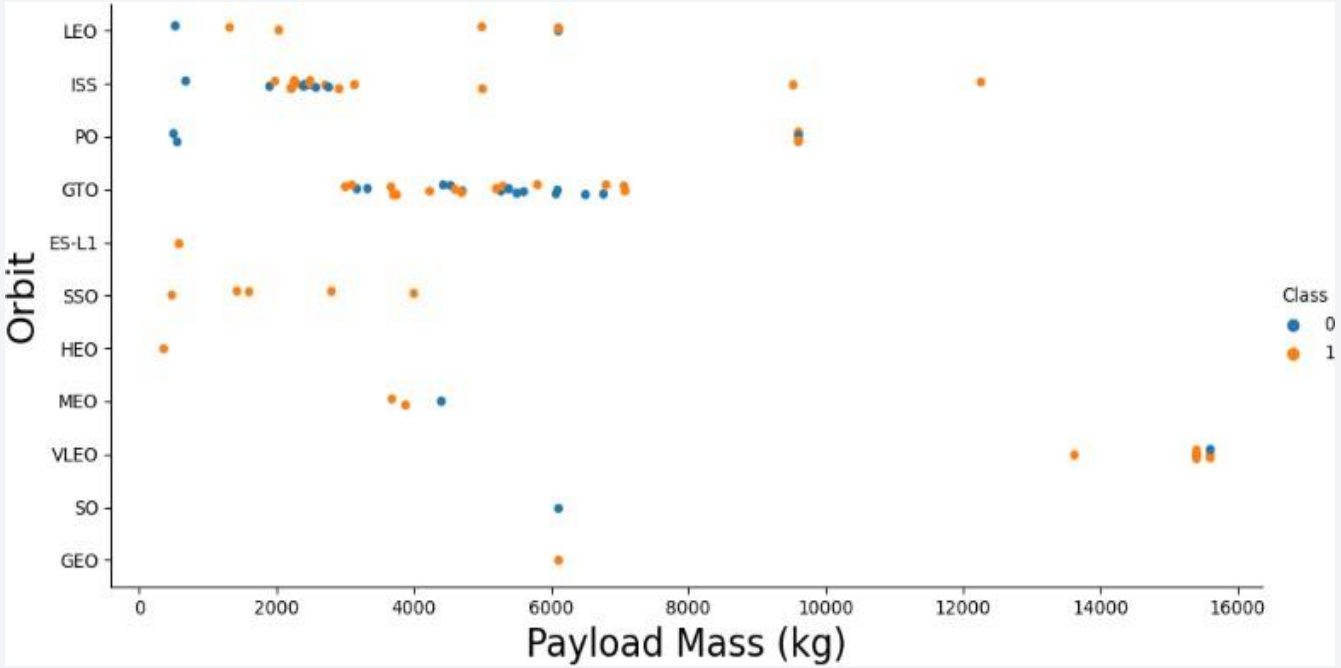
Flight Number vs. Orbit Type

- The success rate typically increases with the number of flights for each orbit
- This relationship is highly apparent for the LEO orbit
- The GTO orbit, however, does not follow this trend



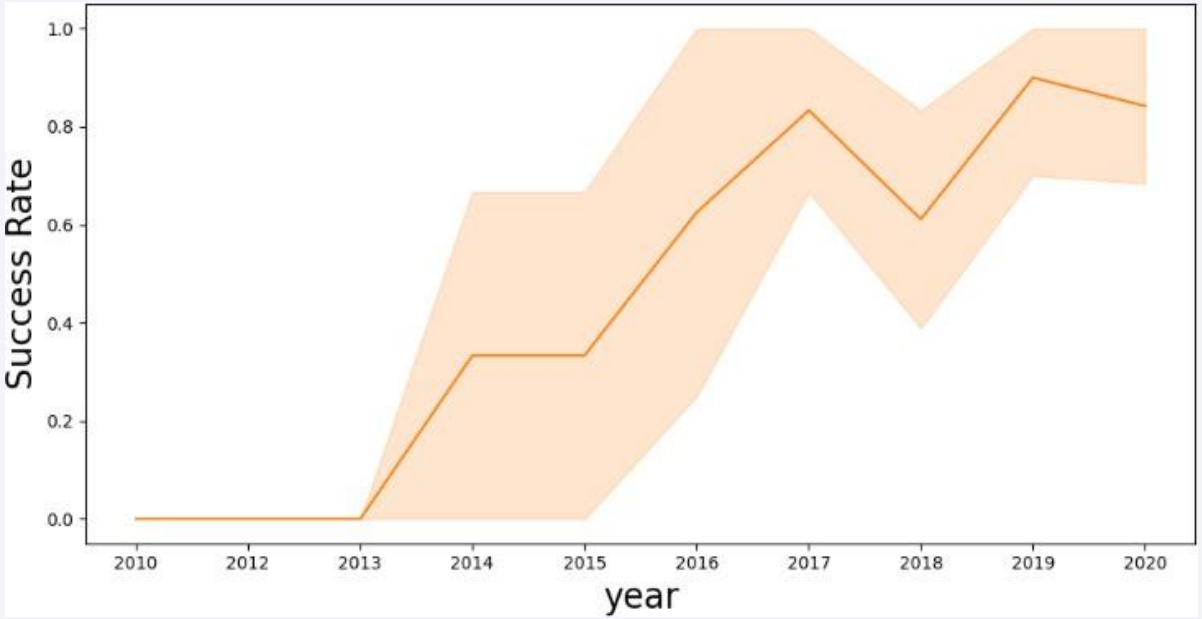
Payload vs. Orbit Type

- Heavy payloads are better with LEO, ISS and PO orbits
- The GTO orbit has mixed success with heavier payloads



Launch Success Yearly Trend

- The success rate improved from 2013-2017 and 2018-2019
- The success rate decreased from 2017-2018 and from 2019-2020
- Overall, the success rate has improved since 2013



All Launch Site Names

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

In [12]:
```
%%sql
SELECT DISTINCT LAUNCH_SITE
FROM SPACEXTBL;
```

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

Out[12]:

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

Launch Site Names Begin with 'CCA'

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

In [13]:
```
%%sql
SELECT LAUNCH_SITE
FROM SPACEXTBL
WHERE LAUNCH_SITE LIKE 'CCA%'
LIMIT 5;
```

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

Out[13]:

Launch_Site
CCAFS LC-40
CCAFS LC-40
CCAFS LC-40
CCAFS LC-40
CCAFS LC-40

Total Payload Mass

Task 3

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

In [14]:
```
%%sql
SELECT SUM(PAYLOAD_MASS__KG_)
FROM SPACEXTBL
WHERE Customer = 'NASA (CRS)';
```

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

Out[14]:

SUM(PAYLOAD_MASS__KG_)
45596

Average Payload Mass by F9 v1.1

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

In [15]:
```
%%sql
SELECT AVG(PAYLOAD_MASS__KG_)
FROM SPACEXTBL
WHERE Booster_Version LIKE 'F9 v1.0%';
```

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

Out[15]:

AVG(PAYLOAD_MASS__KG_)
340.4

First Successful Ground Landing Date

List the date when the first succesful landing outcome in ground pad was acheived.

Hint:Use min function

In [19]:
```
%%sql
SELECT MIN(Date)
FROM SPACEXTBL
WHERE Landing_Outcome = 'Success (ground pad)';
```

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

Out[19]:

MIN(Date)
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 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 [22]:
```
%%sql
SELECT BOOSTER_VERSION
FROM SPACEXTBL
WHERE LANDING_OUTCOME = 'Success (drone ship)'
    AND 4000 < PAYLOAD_MASS__KG_ < 6000;
```

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

Out[22]:

Booster_Version
F9 FT B1021.1
F9 FT B1022
F9 FT B1023.1
F9 FT B1026
F9 FT B1029.1
F9 FT B1021.2
F9 FT B1029.2
F9 FT B1036.1
F9 FT B1038.1
F9 B4 B1041.1
F9 FT B1031.2
F9 B4 B1042.1
F9 B4 B1045.1
F9 B5 B1046.1

Total Number of Successful and Failure Mission Outcomes

List the total number of successful and failure mission outcomes

In [23]:
```
%%sql
SELECT MISSION_OUTCOME, COUNT(MISSION_OUTCOME) AS TOTAL_NUMBER
FROM SPACEXTBL
GROUP BY MISSION_OUTCOME;
```

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

Out[23]:

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

Boosters Carried Maximum Payload

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

In [24]:
```
%%sql
SELECT DISTINCT BOOSTER_VERSION
FROM SPACEXTBL
WHERE PAYLOAD_MASS__KG_ = (
    SELECT MAX(PAYLOAD_MASS__KG_)
    FROM SPACEXTBL);
```

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

Out[24]:

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 records which will display the month names, failure landing_outcomes in drone ship ,booster versions, launch_site for the months in year 2015.

Note: SQLLite does not support monthnames. So you need to use substr(Date, 4, 2) as month to get the months and substr(Date,7,4)='2015' for year.

```
%%sql
SELECT LANDING_OUTCOME, BOOSTER_VERSION, LAUNCH_SITE, DATE
FROM SPACEXTBL
WHERE Landing_Outcome = 'Failure (drone ship)'
AND DATE like '2015%';
```

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

Landing_Outcome	Booster_Version	Launch_Site	Date
Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40	2015-10-01
Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40	2015-04-14

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.

```
%%sql
SELECT LANDING_OUTCOME, COUNT(LANDING_OUTCOME) AS TOTAL_NUMBER
FROM SPACEXTBL
WHERE DATE BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY LANDING_OUTCOME
ORDER BY TOTAL_NUMBER DESC
```

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

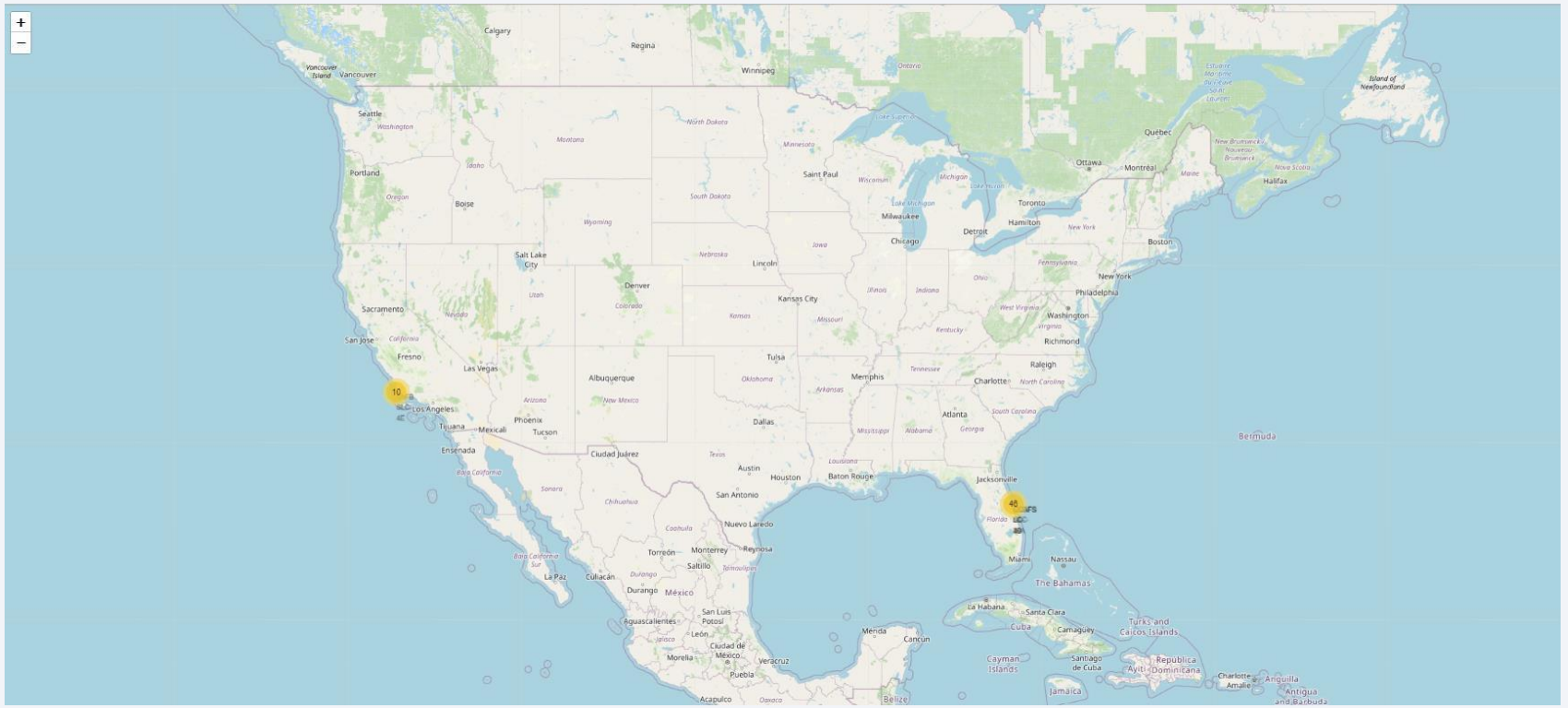
Landing_Outcome	TOTAL_NUMBER
No attempt	10
Success (ground pad)	5
Success (drone ship)	5
Failure (drone ship)	5
Controlled (ocean)	3
Uncontrolled (ocean)	2
Precluded (drone ship)	1
Failure (parachute)	1


Launch Sites
Proximities Analysis

Launch Sites

With Markers

Near Equator: the closer the launch site to the equator, the **easier** it is **to launch** to equatorial orbit, and the more help you get from Earth's rotation for a prograde orbit. Rockets launched from sites near the equator get an **additional natural boost** - due to the rotational speed of earth - that **helps save the cost** of putting in extra fuel and boosters.



Launch Outcomes

At Each Launch Site

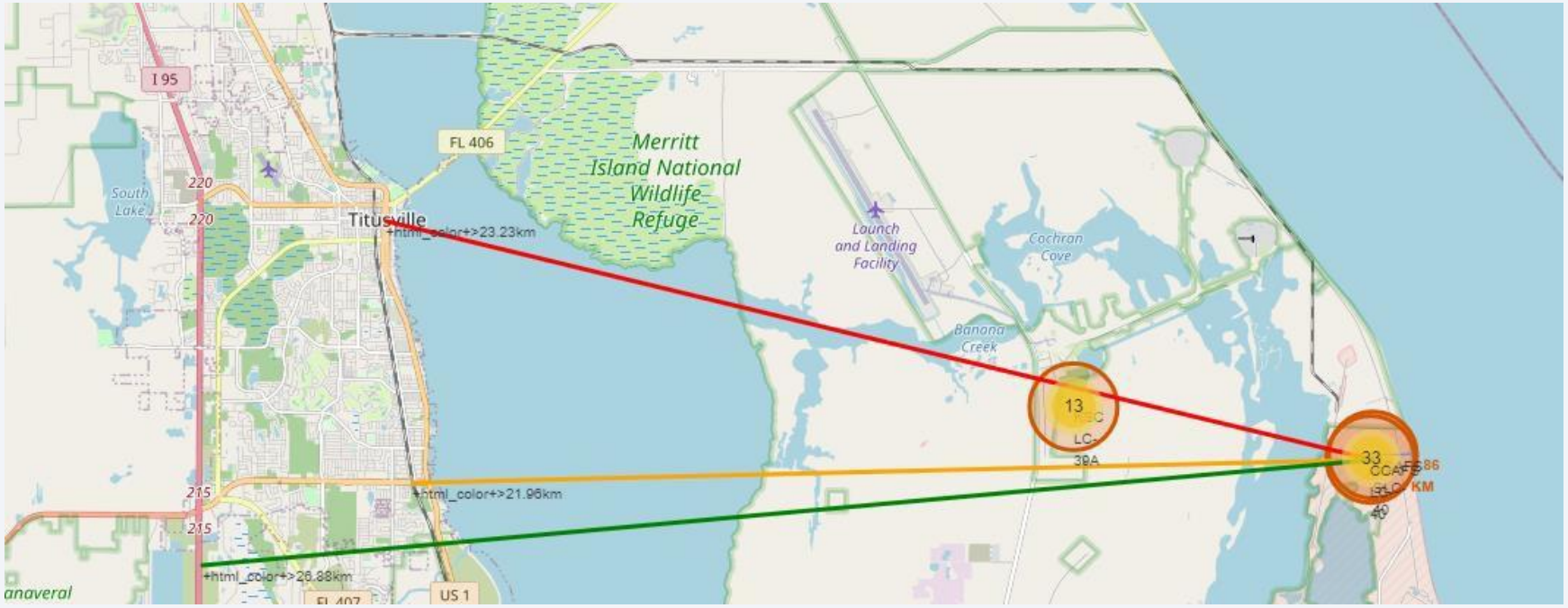
Outcomes:

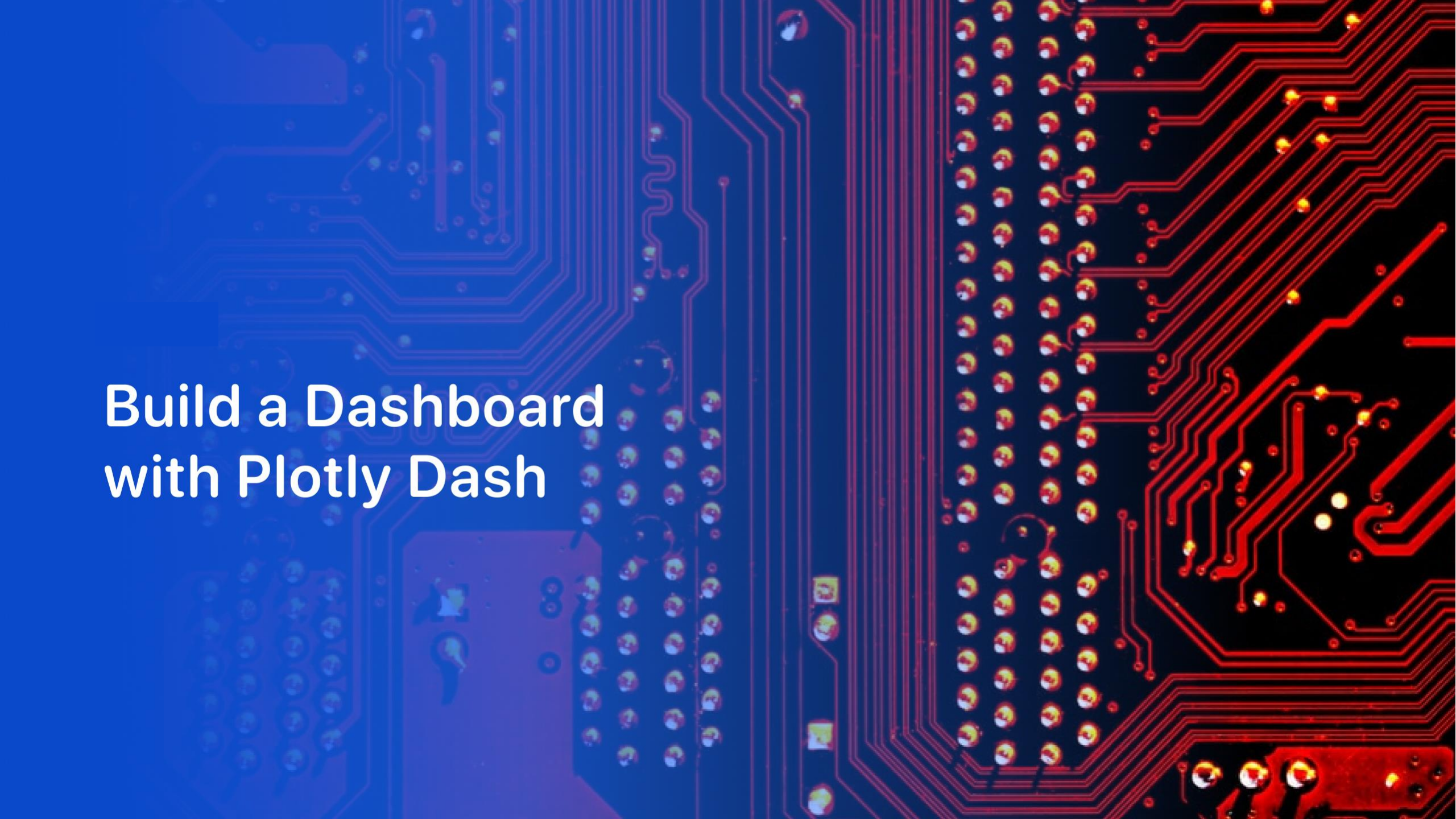
- Green markers for successful launches
- Red markers for unsuccessful launches
- Launch site CCAFS SLC-40 has a 3/7 success rate (42.9%)

Distance to Proximities

CCAFS SLC-40

- .86 km from nearest coastline
- 21.96 km from nearest railway
- 23.23 km from nearest city
- 26.88 km from nearest highway

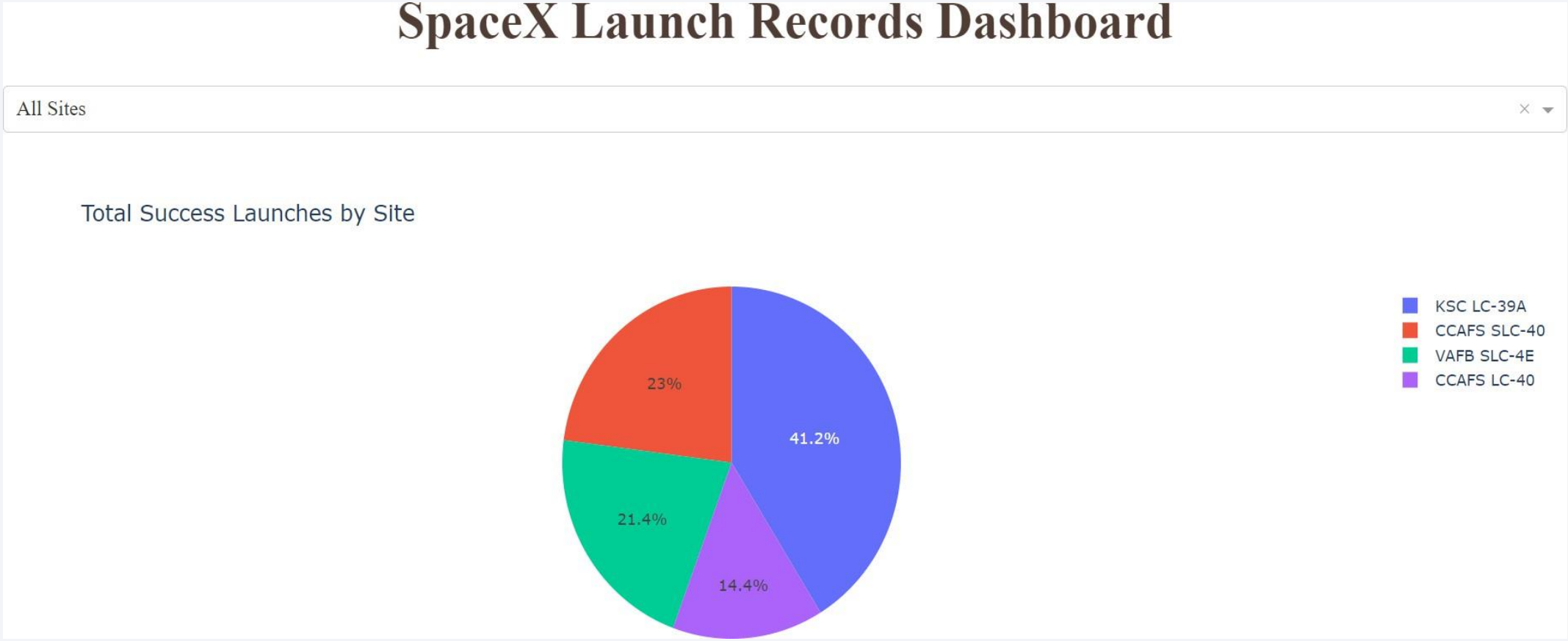



Build a Dashboard
with Plotly Dash

Launch Success by Site

Success as Percent of Total

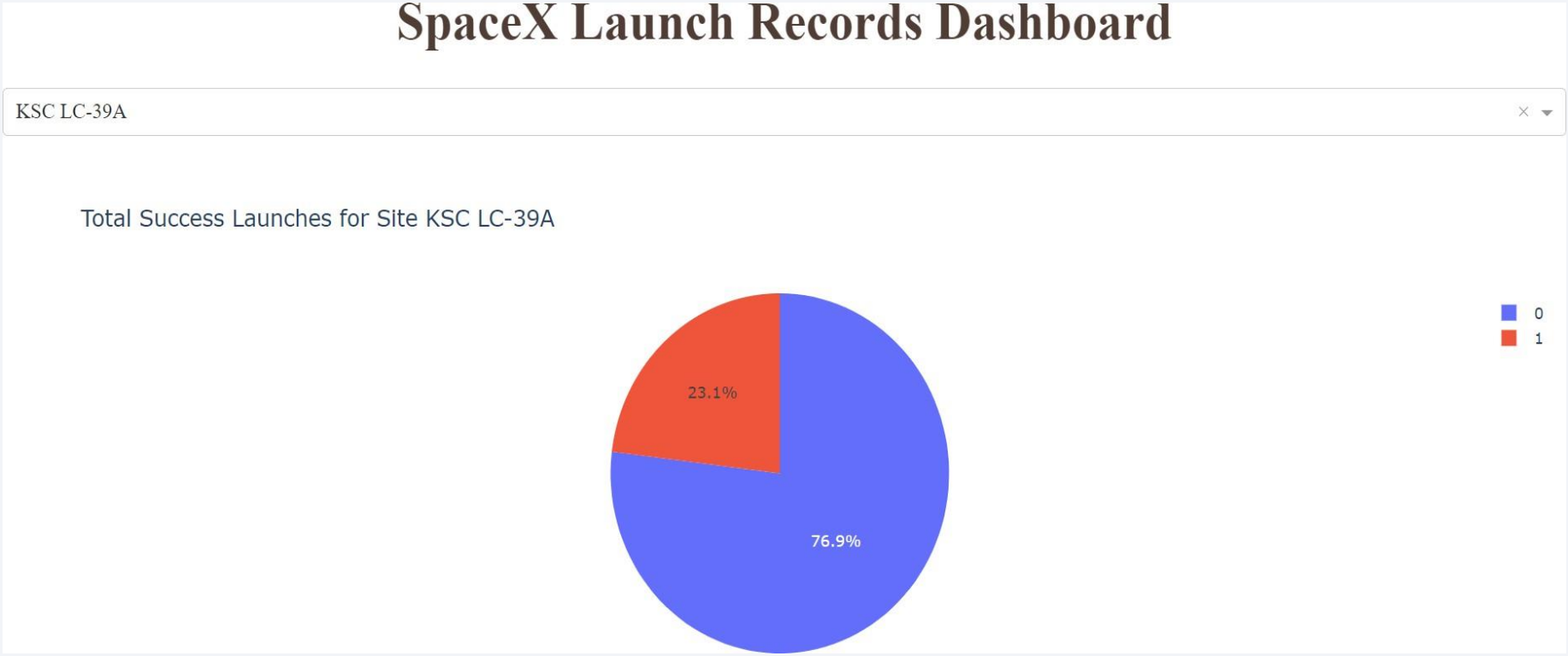
- **KSC LC-39A** has the **most successful launches** amongst launch sites (**41.2%**)



Launch Success (KSC LC-29A)

Success as Percent of Total

- **KSC LC-39A** has the **highest success rate** amongst launch sites (**76.9%**)
- 10 successful launches and 3 failed launches



Payload Mass and Success

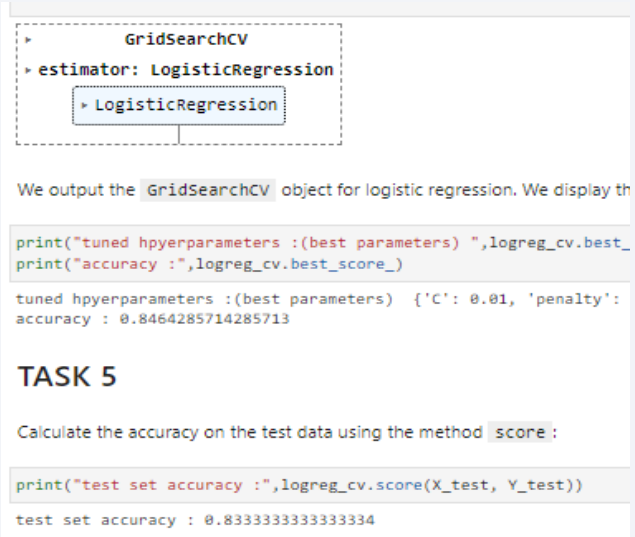
By Booster Version

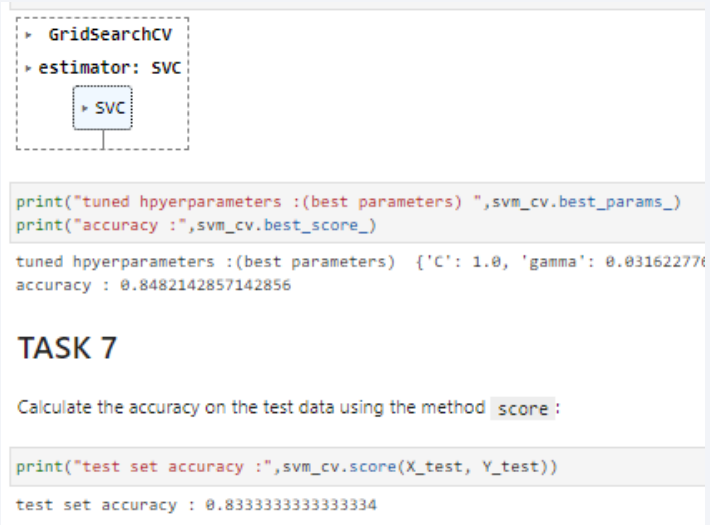
- **Payloads between 2,000 kg** and **5,000 kg** have the **highest success rate**
- 1 indicating successful outcome and 0 indicating an unsuccessful outcome

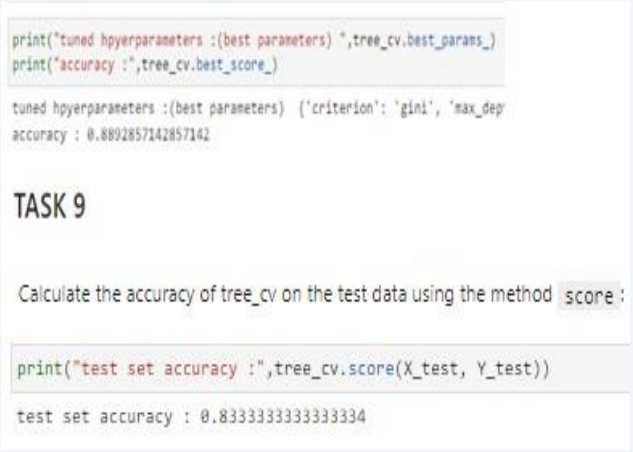
Predictive Analysis (Classification)

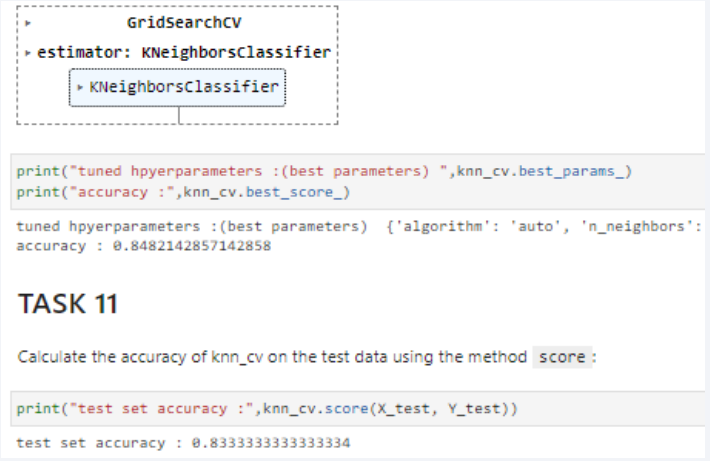
Classification Accuracy

- **All** the **models** performed at about the same level and had the **same scores** and **accuracy**. This is likely due to the **small dataset**.
- The **Decision Tree model slightly outperformed** the rest



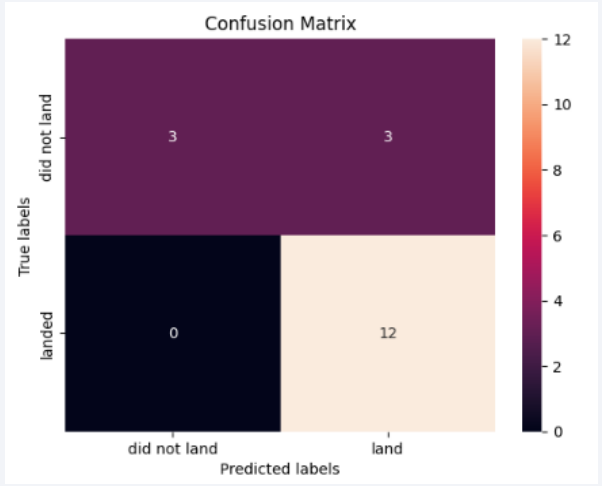


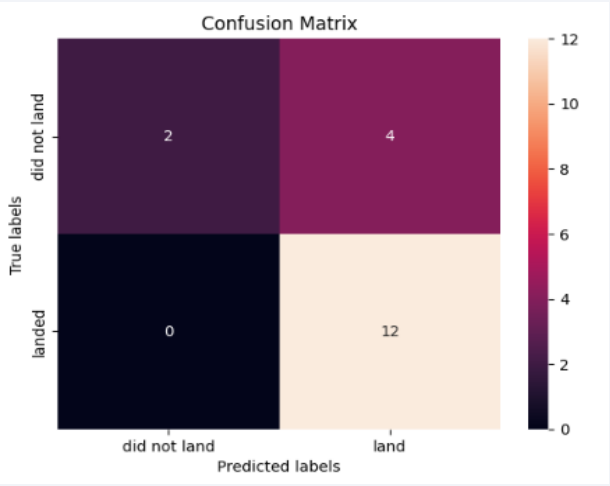


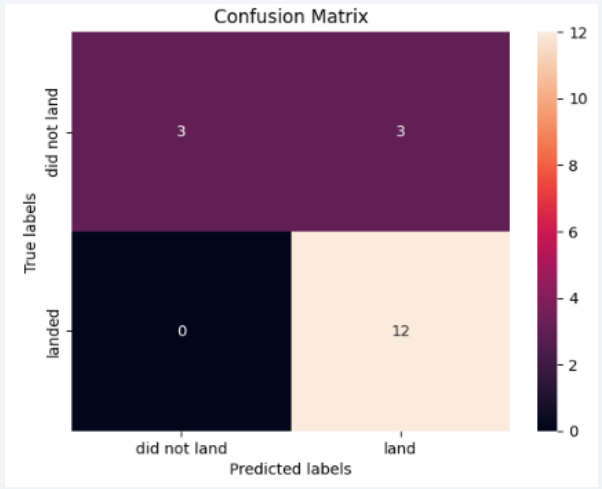


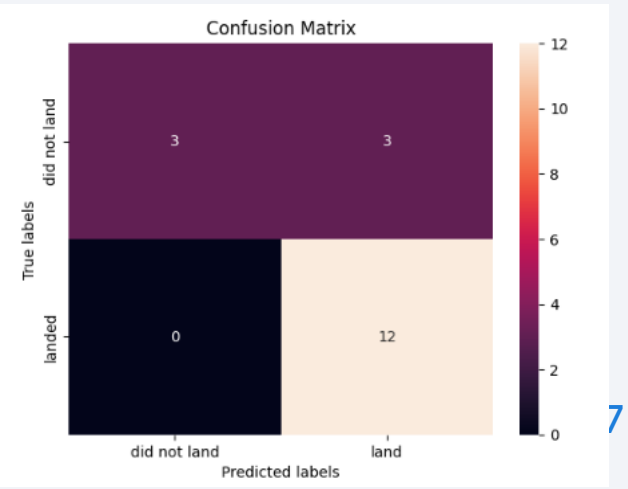
Confusion Matrix

- A **confusion matrix summarizes** the performance of a classification algorithm
- All the confusion matrices were **identical**









Conclusion

Conclusion

- **Model Performance**: The models performed similarly on the test set with the decision tree model slightly outperforming
- **Equator**: Most of the launch sites are near the equator for an additional natural boost - due to the rotational speed of earth - which helps save the cost of putting in extra fuel and boosters
- **Coast**: All the launch sites are close to the coast
- **Launch Success**: Increases over time
- **KSC LC-39A**: Has the highest success rate among launch sites. Has a 100% success rate for launches less than 5,500 kg
- **Orbits**: ES-L1, GEO, HEO, and SSO have a 100% success rate
- **Payload Mass**: Across all launch sites, the higher the payload mass (kg), the higher the success rate

Things to Consider

- **Dataset:** A larger dataset will help build on the predictive analytics results to help understand if the findings can be generalizable to a larger data set
- **Feature Analysis / PCA:** Additional feature analysis or principal component analysis should be conducted to see if it can help improve accuracy

Thank you!