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
  - Data Collection – SpaceX API
  - Data Scraping
  - Data Wrangling
  - EDA with Data Visualization
  - EDA with SQL
  - Dashboard with Plotly Dash
  - Predictive Analysis (Classification)

- Summary of all results
  - Overall there is a **consistent improvement** in the success rate of all missions over time.
  - **KSC LC-39** had the best success rate of all sites
  - Success is best with **Falcon9 booster version B5** with payloads between **2000-5500kg**
  - Launch site are located **near railway, highway and ports**, but **away from cities**
  - The **Decision Tree Classifie**r performed best as a predictive model.

Introduction

- Project background and context:
  - In the current commercial space travel environment SpaceX is the leading player. They provide a relatively inexpensive rockets compared to the conventional rockets used by NASA and other space agencies.
  - SpaceX's latest rocket is the Falcon 9. It can be reused and therefore significantly reduces the cost of operation.
  - What determines reusage is whether the first stage lands successfully.
- Problems you want to find answers:
  - We are a new space company embarking on a quest to provide a safe commercial space travel, with low cost, to compete with Space X
  - If we use data from the Falcon 9 project, we can generate a model that would predict whether our rocket would successfully land, and what factors go into said success.

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - The data was collected with SpaceX API using GET requests.
  - Additional data for Falcon 9 was collected using Web Scraping.
- Perform data wrangling
  - Data was cleaned and outcome labels were converted to 1 (success) and 0 (failure).
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models
  - Data was split. GridSearch performed. Models were evaluated for best accuracy score.

Data Collection

1. **SpaceX launch** data was collected using **SpaceX API:**
   - Data collected included:
     - Booster versions
     - Launch sites
     - Payload data
     - Core date
   - Data was filtered to include only Falcon 9 launches
   - Data was then cleaned and wrangled
2. Data for historic **Falcon 9 launches** were collected from the web using **Web Scrapping**
   - Data taken as HTML table and then converted to a dataframe with **BeautifulSoup**

Data Collection – SpaceX API

Link to notebook on GitHub

- GET Request to gather data using the API

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

response = requests.get(spacex_url)
```

- Decode the JSON data and turning it into a dataframe

```
r1 = response.json()

data = pd.json_normalize(r1)
```

- Gathering and storing values using custom functions

```
# Call getLaunchSite
getLaunchSite(data)

# Call getPayloadData
getPayloadData(data)

# Call getCoreData
getCoreData(data)
```

```
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}
```

- Filtering for the Falcon 9 only

```
data_falcon9 = launch_data[launch_data['BoosterVersion']!='Falcon 1']
```

FlightNumber	Date	BoosterVersion	PayloadMass	Orbit
1	2010-06-04	Falcon 9	NaN	LEO
2	2012-05-22	Falcon 9	525.0	LEO
3	2013-03-01	Falcon 9	677.0	ISS
4	2013-09-29	Falcon 9	500.0	PO
5	2013-12-03	Falcon 9	3170.0	GTO

Data Collection - Scraping

Link to notebook on GitHub

- Request Falcon 9 Launch wiki page

```
# use requests.get() method with the provided static_url
response = requests.get(static_url).text
```

- Create BeautifulSoup Object

```
soup = BeautifulSoup(response, 'html.parser')
```

- Extract all columns from HTML tables

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

```
column_names = []

for row in first_launch_table.find_all('th'):
    name = extract_column_from_header(row)
    if name is not None and len(name) > 0:
        column_names.append(name)
```

- Create a dataframe by parsing HTML tables

```
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({ key:pd.Series(value) for key, value in launch_dict.items() })
```

Data Wrangling

Link to notebook on GitHub

- Calculating number of launches at each site

```
df['LaunchSite'].value_counts()
```

```
CCAFS SLC 40    55
KSC LC 39A      22
VAFB SLC 4E     13
```

- Calculating number and occurrence of each orbit

```
df['Orbit'].value_counts()
```

```
GTO      27
ISS      21
VLEO     14
PO        9
LEO       7
SSO       5
MEO       3
HEO       1
SO        1
ES-L1     1
GEO       1
```

- Mission outcome per orbit type

```
landing_outcomes = df['Outcome'].value_counts()
print(landing_outcomes)
```

```
True ASDS      41
None None      19
True RTLS      14
False ASDS      6
True Ocean      5
None ASDS       2
False Ocean     2
False RTLS      1
```

- Create landing outcome labels

```
for i,outcome in enumerate(landing_outcomes.keys()):
    print(i,outcome)
```

```
0 True ASDS
1 None None
2 True RTLS
3 False ASDS
4 True Ocean
5 None ASDS
6 False Ocean
7 False RTLS
```

Bad outcomes

```
bad_outcomes=set(landing_outcomes.keys()[[1,3,5,6,7]])
bad_outcomes
```

```
{'False ASDS', 'False Ocean', 'False RTLS', 'None ASDS', 'None None'}
```

Data Wrangling

Link to notebook on GitHub

- Labeling all outcomes as either good or bad

```
landing_class = []

for outcome in df['Outcome']:
    if outcome in bad_outcomes:
        landing_class.append(0)
    else:
        landing_class.append(1)

print(landing_class)
# landing_class = 0 if bad_outcome
# landing_class = 1 otherwise
```

- Creating a new column for the outcomes

```
df['Class']=landing_class
df[['Class']].head(8)
```

	Class
0	0
1	0
2	0
3	0
4	0
5	0
6	1
7	1

- We then determine the success rate

```
df["Class"].mean()
```

```
0.6666666666666666
```

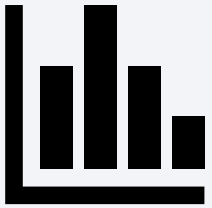
- Now we have a clean dataset that we can use for our analysis.

EDA with Data Visualization

Link to notebook on GitHub

- Scatter plots and bar graphs used to analyze:
  - Flight Number and Launch Site
  - Payload and Launch Site
  - Success Rate of each Orbit Type
  - Flight Number and Orbit type
  - Payload and Orbit type

See results on slides 19-24



- Launch success yearly trend was also visualized
  - Showed a consistent increase

- **Feature Engineering**: one-hot encoding

EDA with SQL

Link to notebook on GitHub

The following SQL queries were called:

1. Display 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 average payload mass carried by booster version F9 v1.1
5. List the date when the first successful landing outcome in ground pad was achieved.
6. List the names of the boosters which have success in drone ship and have 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 which have carried the maximum payload mass. Use a subquery
9. List the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015
10. 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

See results on slides 26-35

Build an Interactive Map with Folium ➡ Link to notebook on GitHub

- To **mark all launch sites** on a map we used:
  - **Circle** objects to highlight the location on a global map
  - **MarkerCluster** to better view multiple launches at a single location
- To **mark the success/failed** launches for each site on the map we used:
  - **MarkerCluster** were labelled **green** for success and **red** for failure
- To **calculate the distances** between a launch site to its proximities we used:
  - **MousePosition** to find the coordiantes of the two locations.
  - **Line** and **distance function** to measure and visualise the distance.

With this visualization we were able to answer the following **questions**:

- Are launch sites in close proximity to **railways** and **highways**?

  Yes, to ease transportation of goods and equipment.

- Are launch sites in close proximity to **coastline**?

  Yes, to have port access.

- Do launch sites keep certain distance **away from cities**?

  Yes, to reduce the amount of noise for people living in the cities.

Build a Dashboard with Plotly Dash ➡ Link to notebook on GitHub

- Created a **Pie Chart** to represent the proportion of **successful** launches **from all launch sit**e.
- Created **a drop down list** to produce a separate **Pie Chart** for each **launch site** showing its **success rate**.
- Created a **range scale** for **Payload Mass** to showcase its relationship with **Booster Version**, and **Successes/Failures**.
- Launched a **Plotly Dash** that contained all the above elements.

We were able to gain **insight** that helped us answer the flowing questions:

- Which site has the largest successful launches? **KSC LC-39A**
- Which site has the highest launch success rate? **KSC LC-39A**
- Which payload range(s) has the highest launch success rate? **2000-5500kg**
- Which payload range(s) has the lowest launch success rate? **under 1500 and 5500 to 7000**
- Which F9 Booster version (v1.0, v1.1, FT, B4, B5, etc.) has the highest launch success rate? **B5**

Predictive Analysis (Classification) ➡ **Link to notebook on GitHub**

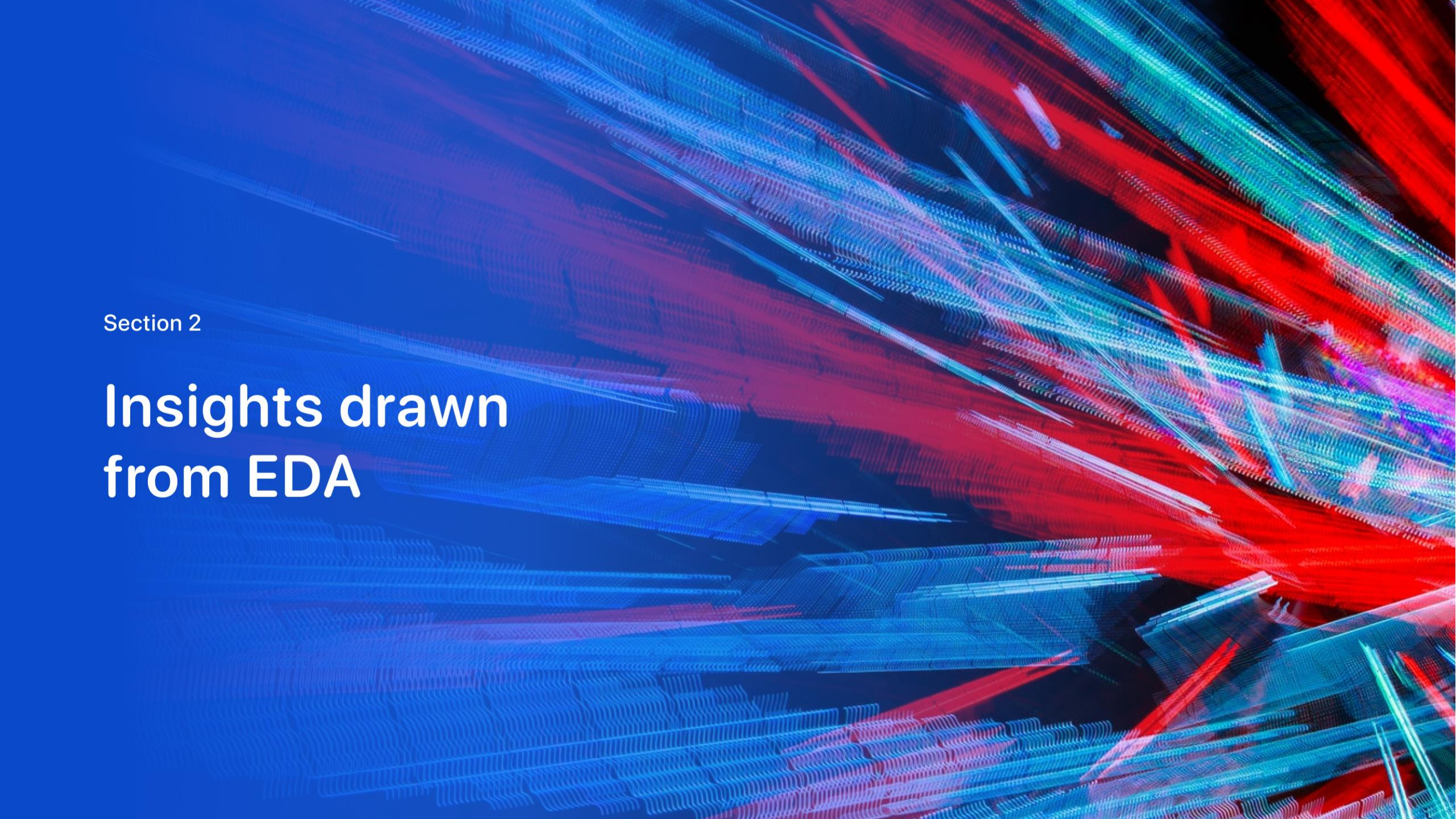
- To build the best model we followed the following steps:
  1. Standardize the data using **StandardScaler()**
  2. **Split the data** into **training** group and **testing** group
  3. Use **GridSearch()** to find the **best hyperparameters** for our model
  4. **Fit the model** and find **accuracy score** on the test data
  5. Create a **Confusion Matrix** to show the accuracy of the model
  6. **Steps 3-5** were each applied to the **following model types**:
     - Logistic Regression
     - Support Vector Machine (SVM)
     - **Decision Tree Classifier (was found to be the best model)**
     - K Nearest Neighbor

Results

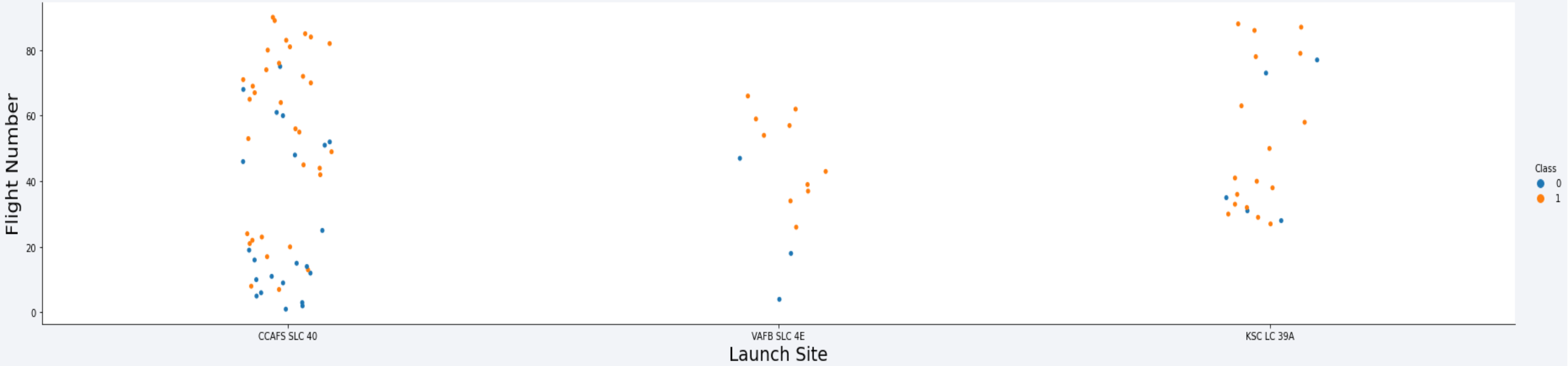
- Exploratory data analysis results
- Interactive analytics demo in screenshots
- Predictive analysis results

Section 2

Insights drawn from EDA

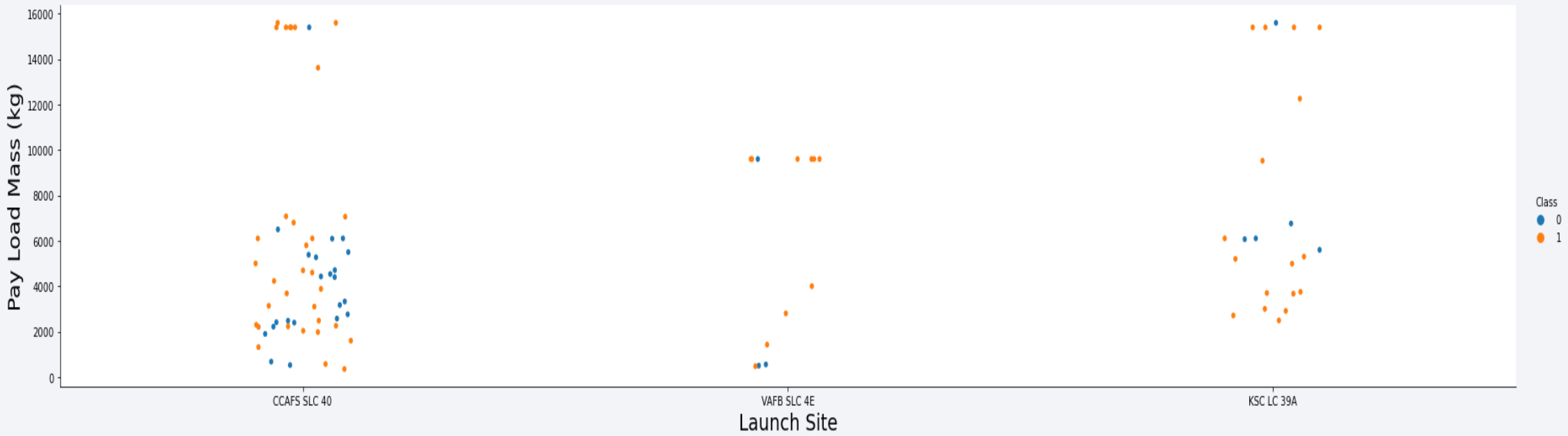


Flight Number vs. Launch Site



- Early flights had lower success rate than later flights, with the bulk launching from CCAFS SLC 40
- KSC LC 39A had the best overall performance

Payload vs. Launch Site

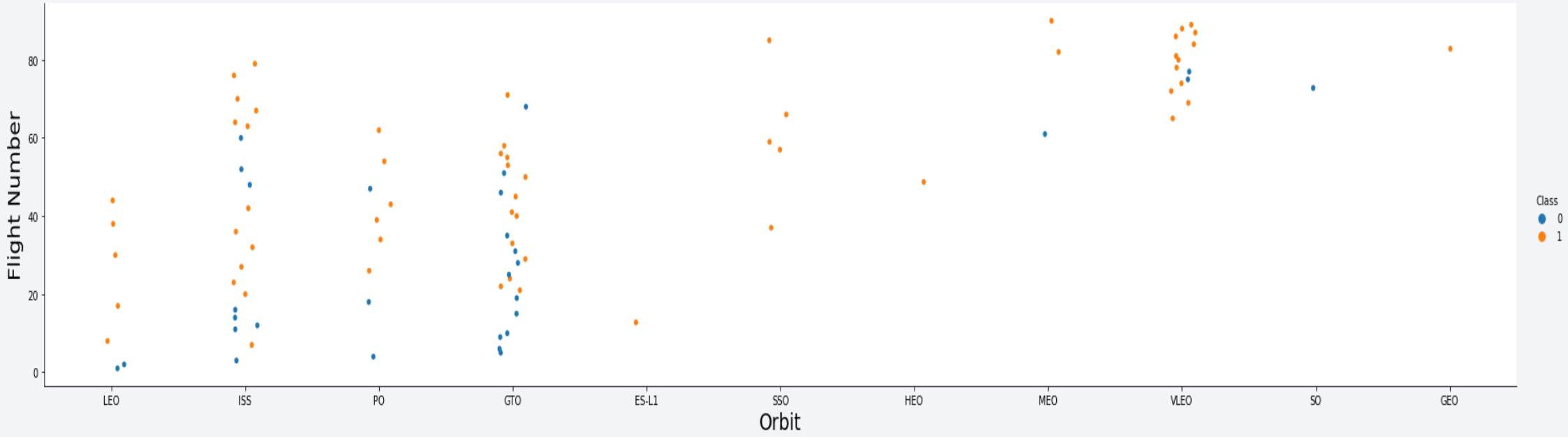


- CAFS LC-40 had the bulk of the light payloads corresponding to the early flights.
- CAFS LC-40 and VAFB SLC 4E had a better success rate as the payload mass increased.
- KSC LC-39A had a perfect success rate at lower payload. It also had an improved success rate as the weight increased beyond 8000kg.

Success Rate vs. Orbit Type

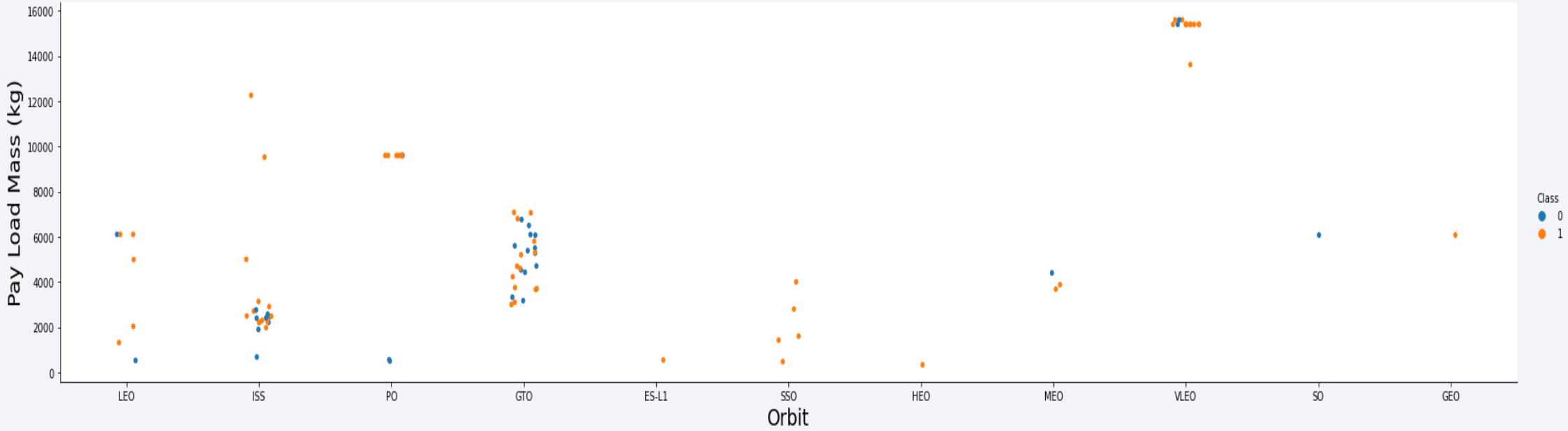
- ESL1, GEO, HEO, and SSO all had a 100% success rate.

Flight Number vs. Orbit Type



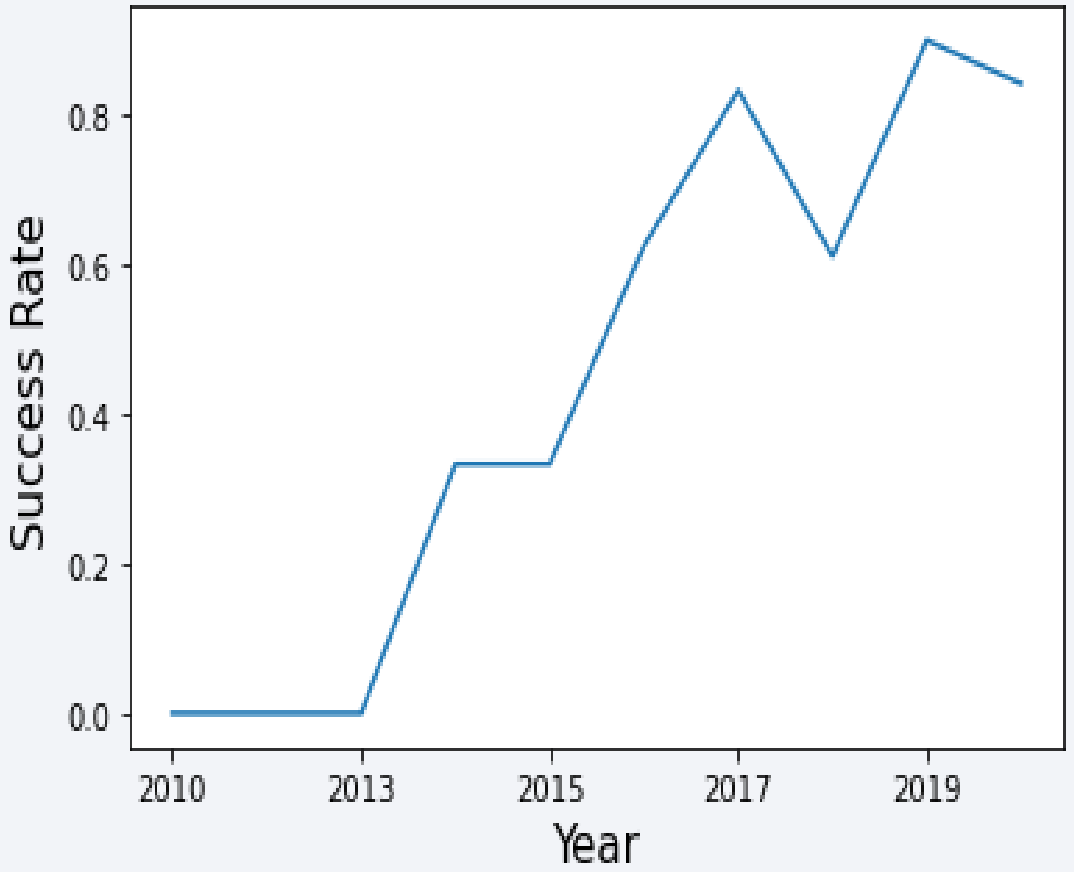
- LEO showed improvement in success rate as the Flight Number increased.
- There seems to be no relationship between flight number in GTO orbit.
- Generally speaking as more launches were conducted the rocket was able to reach farther earth orbits.

Payload vs. Orbit Type



- PO, LEO, ISS orbits saw better success rate as the payload increased.
- GTO orbit saw lower success rates as the payload increased.

Launch Success Yearly Trend



- Since 2013 there has been a steady increase in success rate approaching 100%

EDA with SQL Results

All Launch Site Names

SQL Query:

```
select DISTINCT launch_site FROM spacextbl
```

SQL Explanation:

Query recall all unique launch sites. The use of DISTINCT ensures that no repetition occurs in the launch site names.

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

Launch Site Names Begin with 'CCA'

SQL Query:

```
select * FROM spacextbl WHERE launch_site
LIKE 'CCA%' LIMIT 5
```

SQL Explanation:

Query recall 5 launches from CCAFS LC-40 by using LIKE 'CCA%'. Limiting the response to 5 rows using LIMIT 5.

DATE	time__utc_	booster_version	launch_site	payload	payload_mass__kg_	orbit	customer	mission_outcome	landing__outcome
2010-06-04	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-12-08	15:43:00	F9 v1.0 B0004	CCAFS LC-40	Dragon demo flight C1, two CubeSats, barrel of Brouere cheese	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2012-05-22	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-03-01	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

Total Payload Mass

SQL Query:

```
select SUM(payload_mass__kg_)
AS total_paylaod FROM spacextbl
WHERE customer = 'NASA (CRS)'
```

total_payload_by_nasa
45596

SQL Explanation:

Using SUM() to display the total payload mass carried by boosters that were launched by NASA(CRS)

Average Payload Mass by F9 v1.1

SQL Query:

```
select AVG(payload_mass__kg_)
AS Average_payload FROM spacextbl
WHERE booster_version = 'F9 v1.1'
```

SQL Explanation:

Using AVG() to display the average payload mass carried by booster F9 v1.1

average_payload
2928

First Successful Ground Landing Date

SQL Query:

```
select MIN(date) AS first_successful_landing
FROM spacextbl
WHERE landing_outcome = 'Success (ground pad)'
```

SQL Explanation:

Using MIN(date) to display the first (earliest) successful landinng.

first_successful_landing
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

SQL Query:

```
select booster_version, payload_mass__kg_
FROM spacextbl
WHERE landing__outcome = 'Success (drone
ship)' AND payload_mass__kg_ BETWEEN 4000 and
6000
```

SQL Explanation:

Using BETWEEN to display succeeful drone ship landing with a payload range of 4000-6000 kg

booster_version	payload_mass__kg_
F9 FT B1022	4696
F9 FT B1026	4600
F9 FT B1021.2	5300
F9 FT B1031.2	5200

Total Number of Successful and Failure Mission Outcomes

SQL Query:

```
SELECT mission_outcome, COUNT(*) AS total FROM
spacextbl GROUP BY mission_outcome
```

SQL Explanation:

Using COUNT to display the total successful and failed mission outcomes

mission_outcome	total
Failure (in flight)	1
Success	99
Success (payload status unclear)	1

Boosters Carried Maximum Payload

SQL Query:

```
SELECT booster_version, payload_mass__kg_
FROM spacextbl
WHERE payload_mass__kg_ =
(SELECT MAX(payload_mass__kg_) FROM spacextbl)
```

SQL Explanation:

Using a subquery with MAX() to find the boosters that have carried the maximum payload mass.

booster_version	payload_mass__kg_
F9 B5 B1048.4	15600
F9 B5 B1049.4	15600
F9 B5 B1051.3	15600
F9 B5 B1056.4	15600
F9 B5 B1048.5	15600
F9 B5 B1051.4	15600
F9 B5 B1049.5	15600
F9 B5 B1060.2	15600
F9 B5 B1058.3	15600
F9 B5 B1051.6	15600
F9 B5 B1060.3	15600
F9 B5 B1049.7	15600

2015 Launch Records

SQL Query:

```
SELECT landing__outcome, booster_version,
launch_site, date
FROM spacextbl
WHERE landing__outcome = 'Failure (drone
ship)' AND date LIKE '2015%'
```

SQL Explanation:

Using WHERE clause and LIKE '2015%' to find all failed drone ship landing in the year 2015.

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

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

SQL Query:

```
SELECT landing__outcome, count(*) AS total
FROM spacextbl WHERE date
BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY landing__outcome ORDER BY total DESC
```

SQL Explanation:

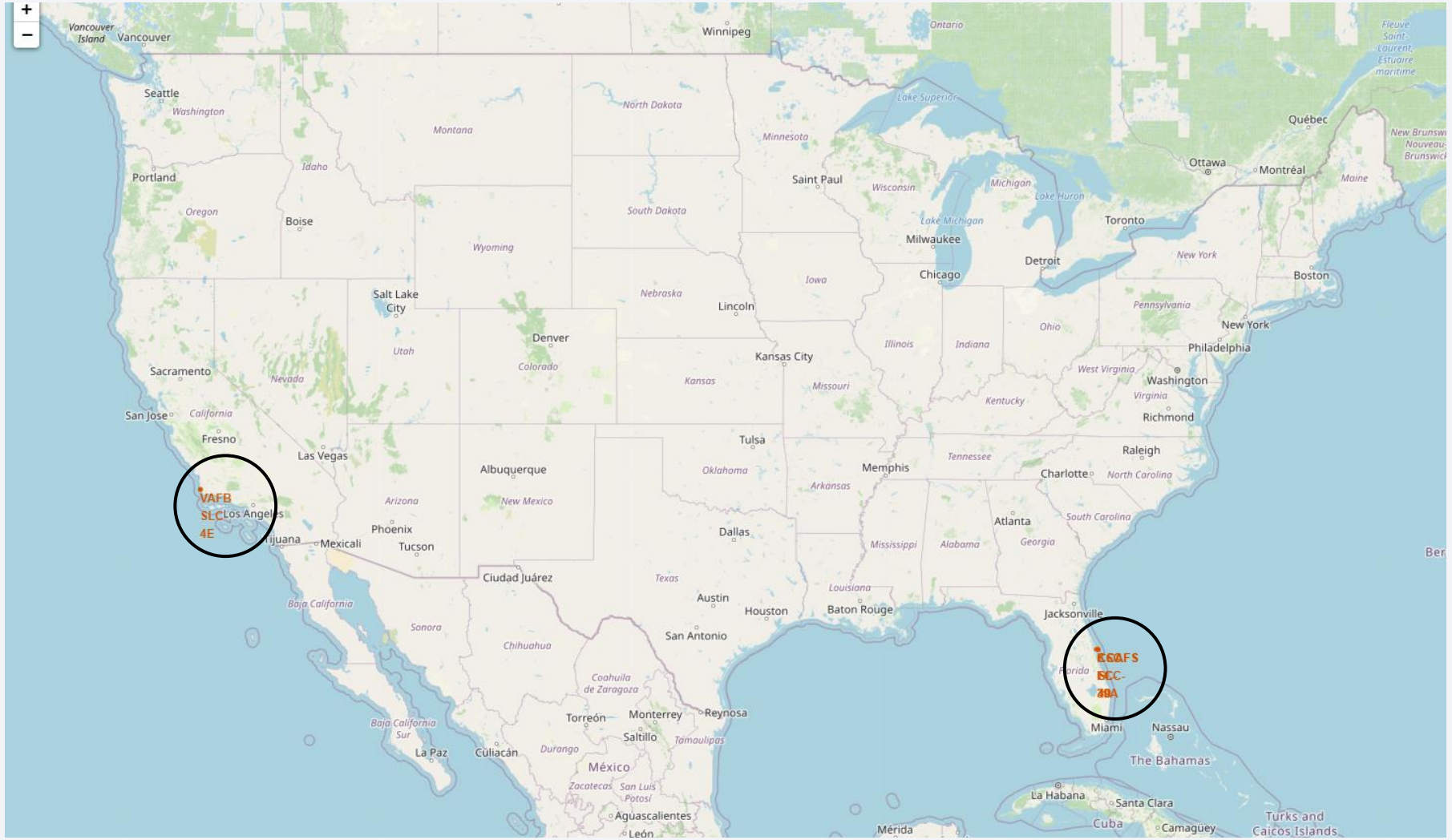
Using GROUP BY and ORDER BY with DESC to list and rank all landing outcomes between 2010-06-04 and 2017-03-20

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

Section 4

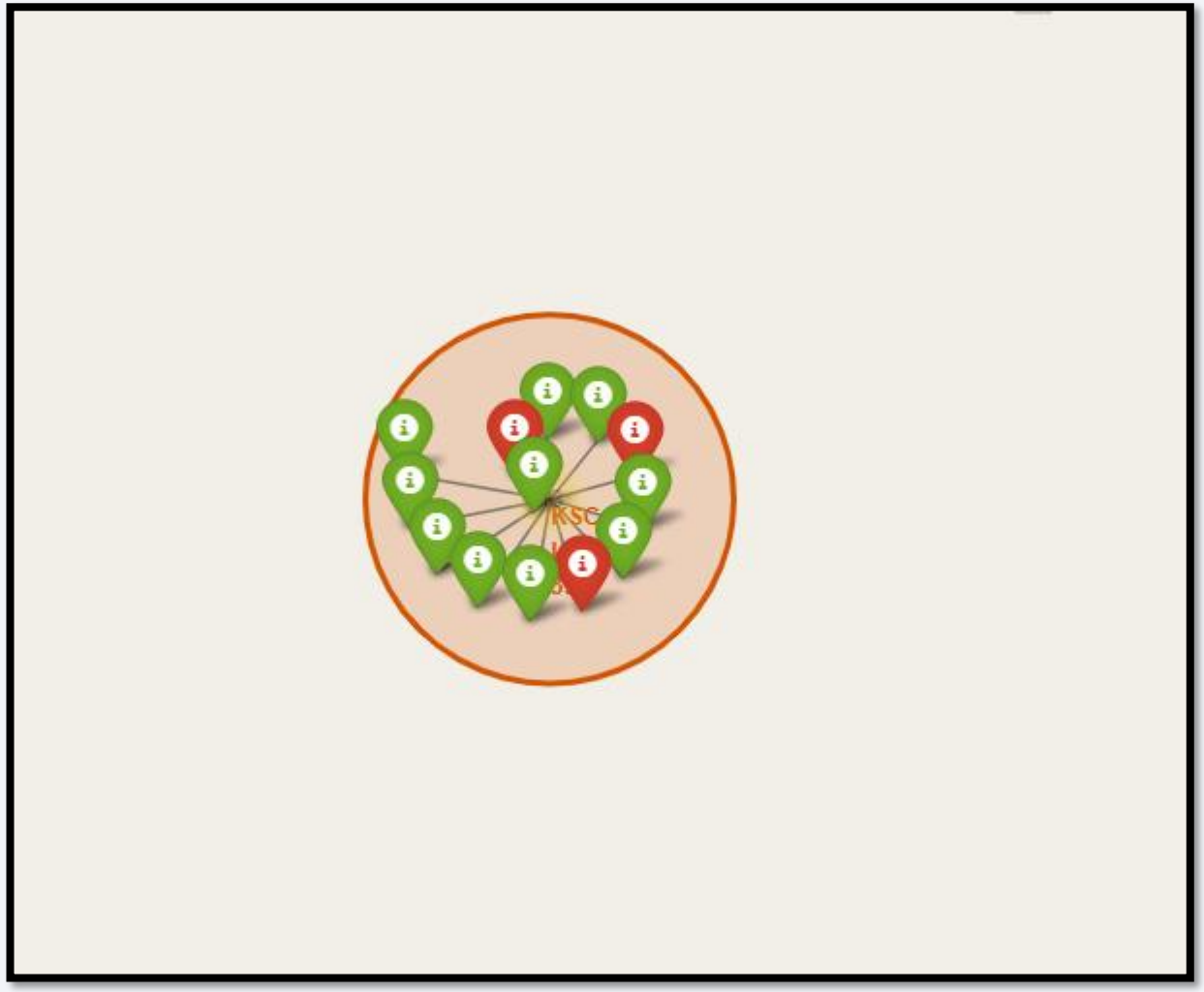
Launch Sites Proximities Analysis

Launch Locations Globally



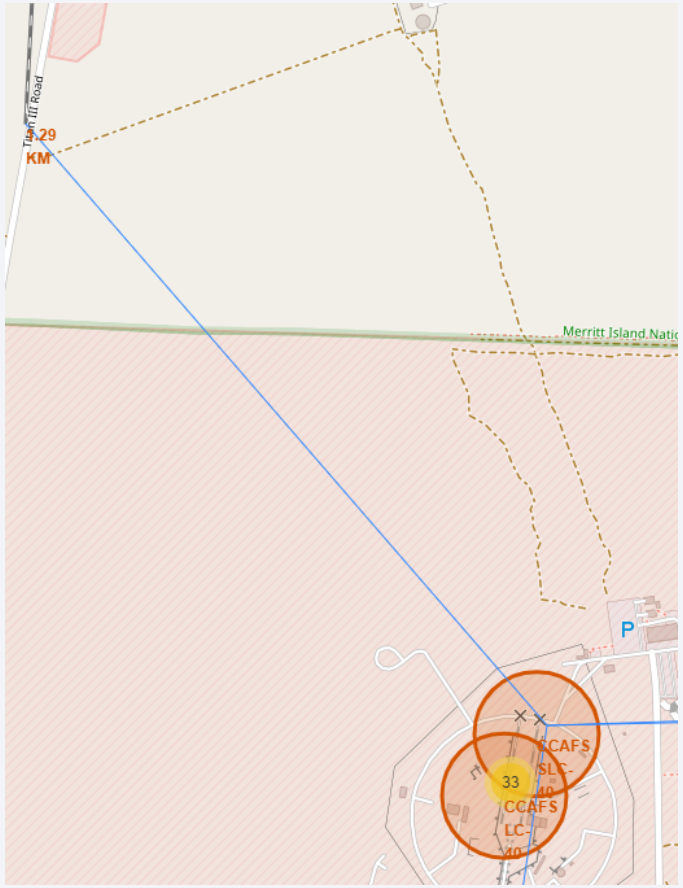
Launch sites are located on the **east coast** and **west coast** of the continental **United States.**

Visualizing Launch Outcomes for KSC LC-39A



- **Folium markers** represent each **launch outcome.**
- **Successes** are labelled **green**
- **Failures** are labelled **red**

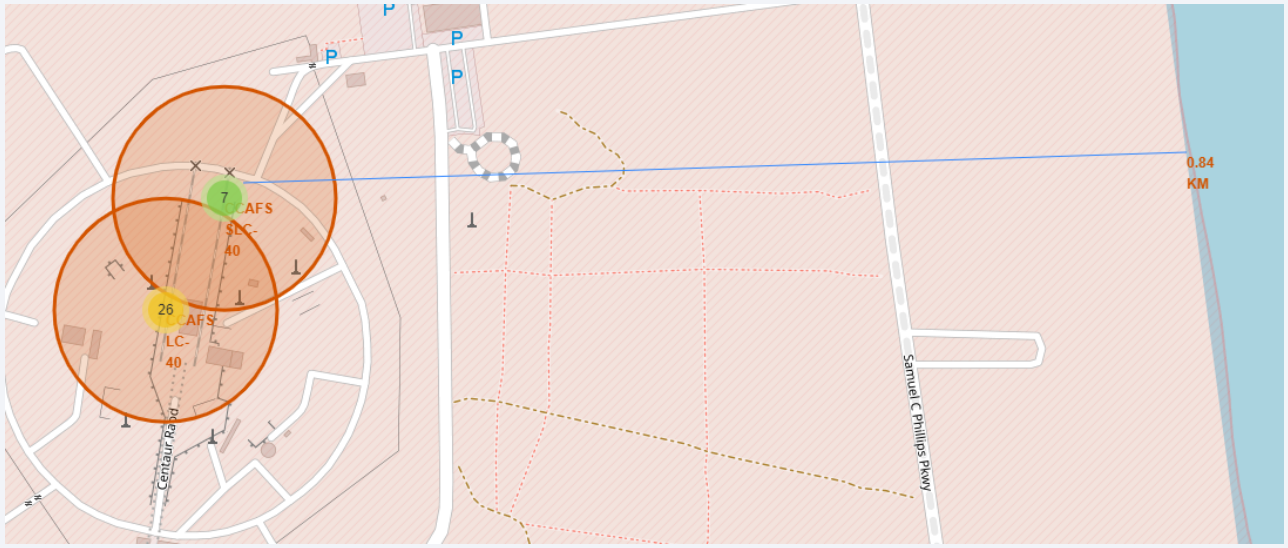
Distances To Features Near Launch Locations



Distance to railway

Distance to highway

Distances To Features Near Launch Locations



Distance to coastline

Distance to a city

Distances To Features Near Launch Locations

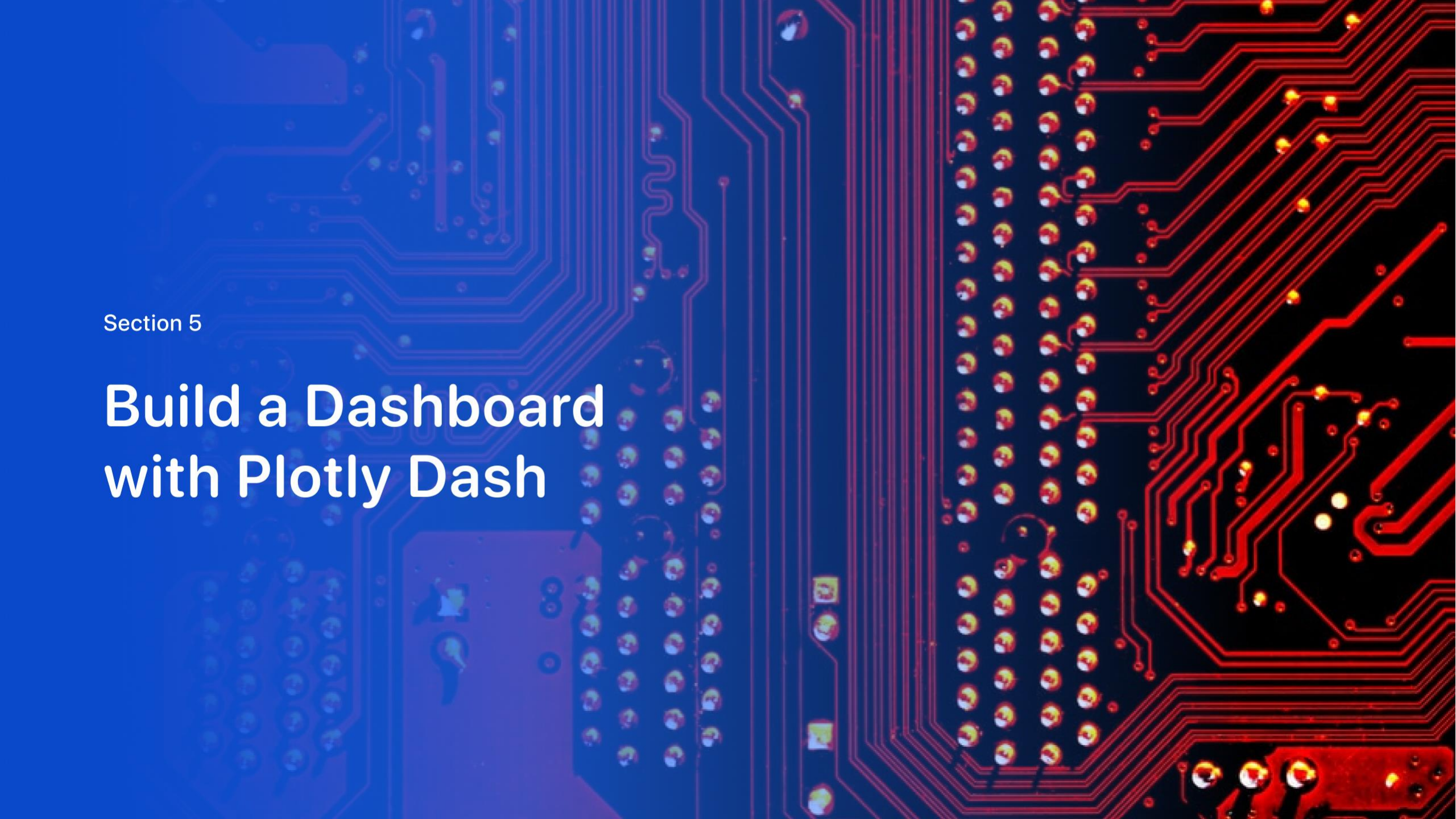
In Summary:

Feature	Distance(KM)
Railway	1.29
Highway	0.57
Coastline	0.84
City	18.18

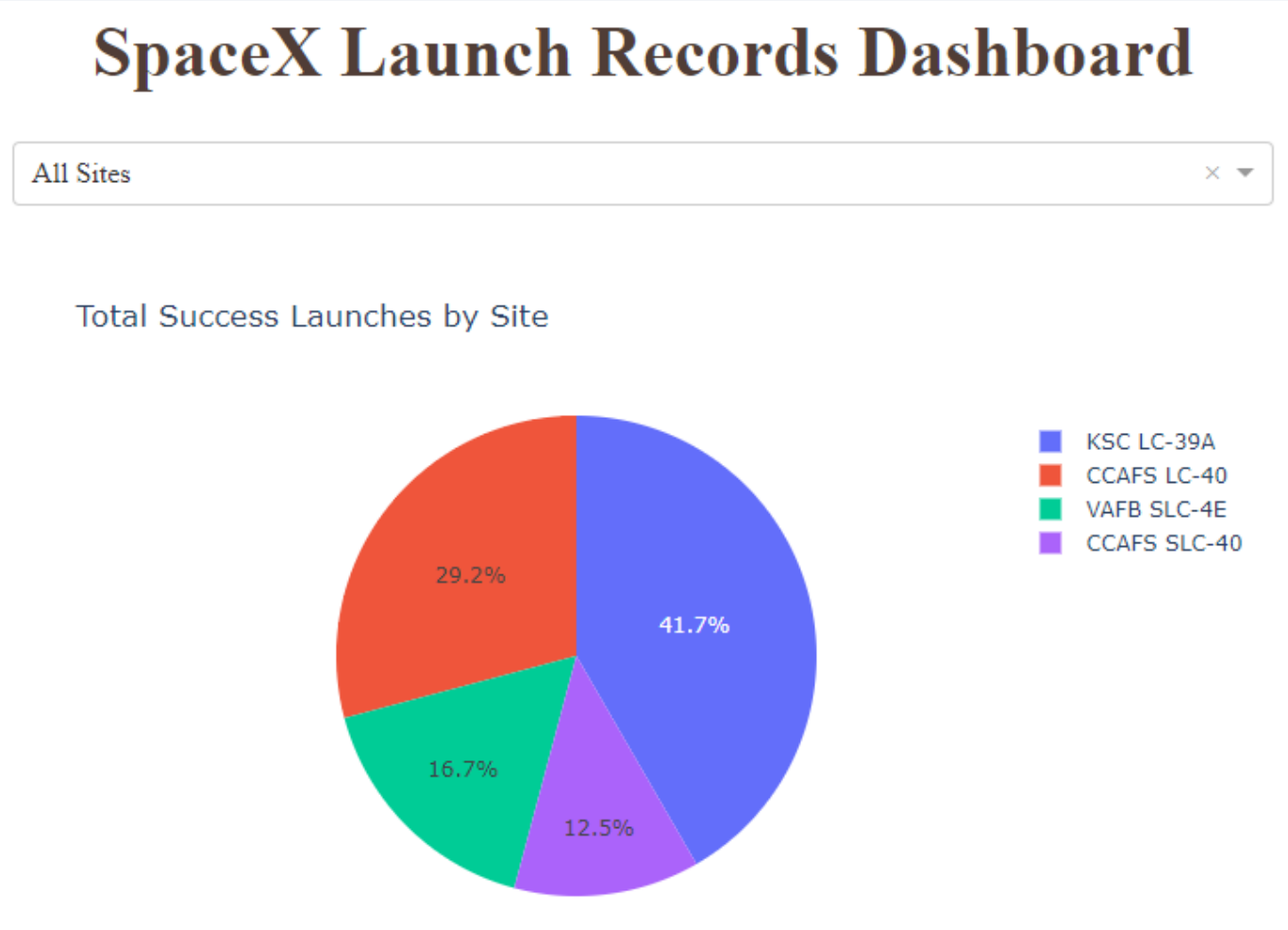
- Launch locations are selected close to railway and highways
- Launch locations are located close to coastlines
- Launch locations are located far from major cities

Section 5

Build a Dashboard with Plotly Dash

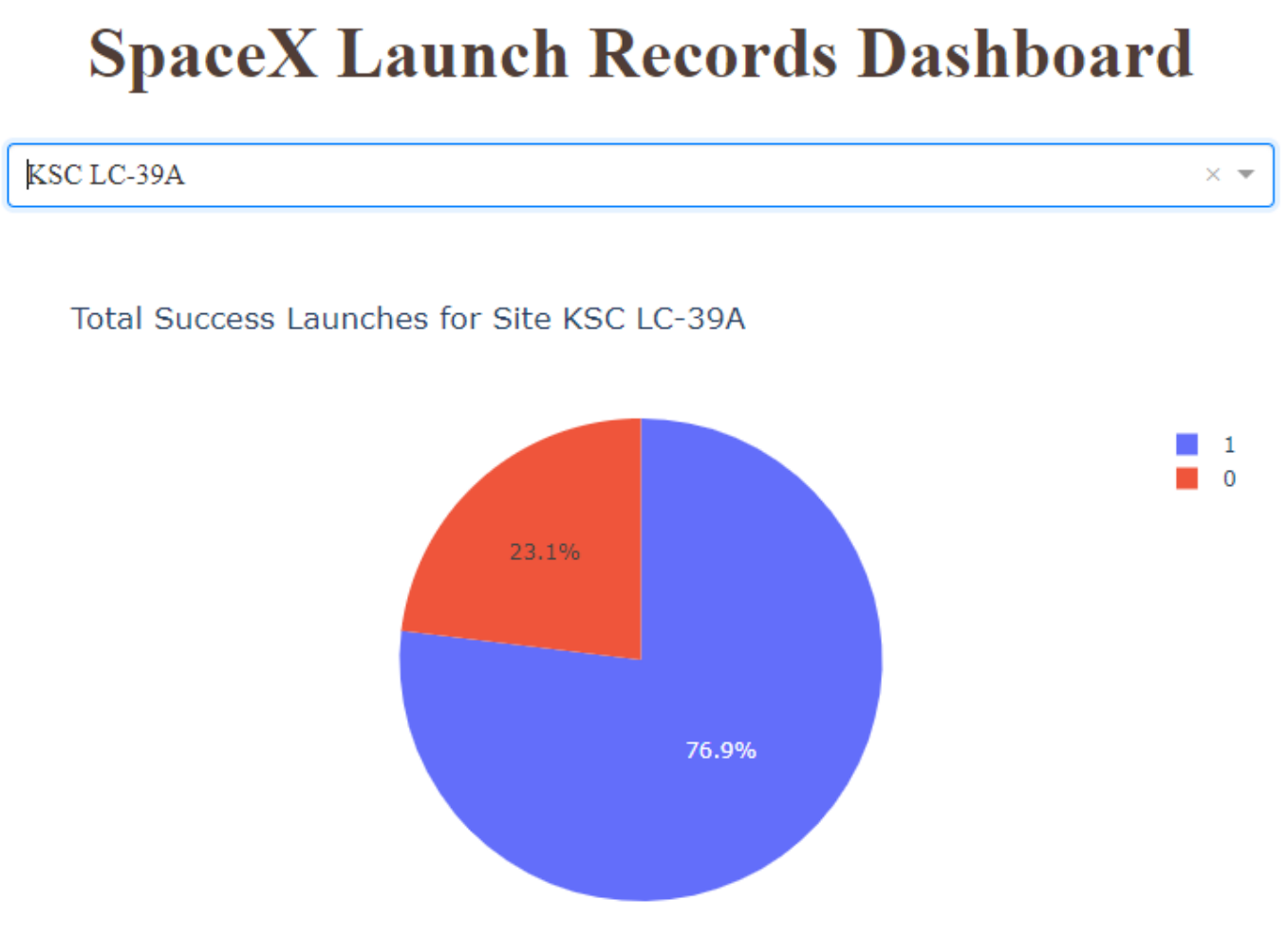


Launch Success Count (For all sites)



- **Kennedy Space Center Launch Complex 39** (KSC LC-39A) had the **most success count** at **41.7%** of total launches.
- **Vandenberg Space Launch Complex 4** (VAFB SLC-4E) had the **lowest success count** at **12.5%** of total launches.

Success Ratio at Kennedy Space Center Launch Complex 39



- **Kennedy Space Center Launch Complex 39** (KSC LC-39A) had the **highest success rate** at **76.9%** of total launches.

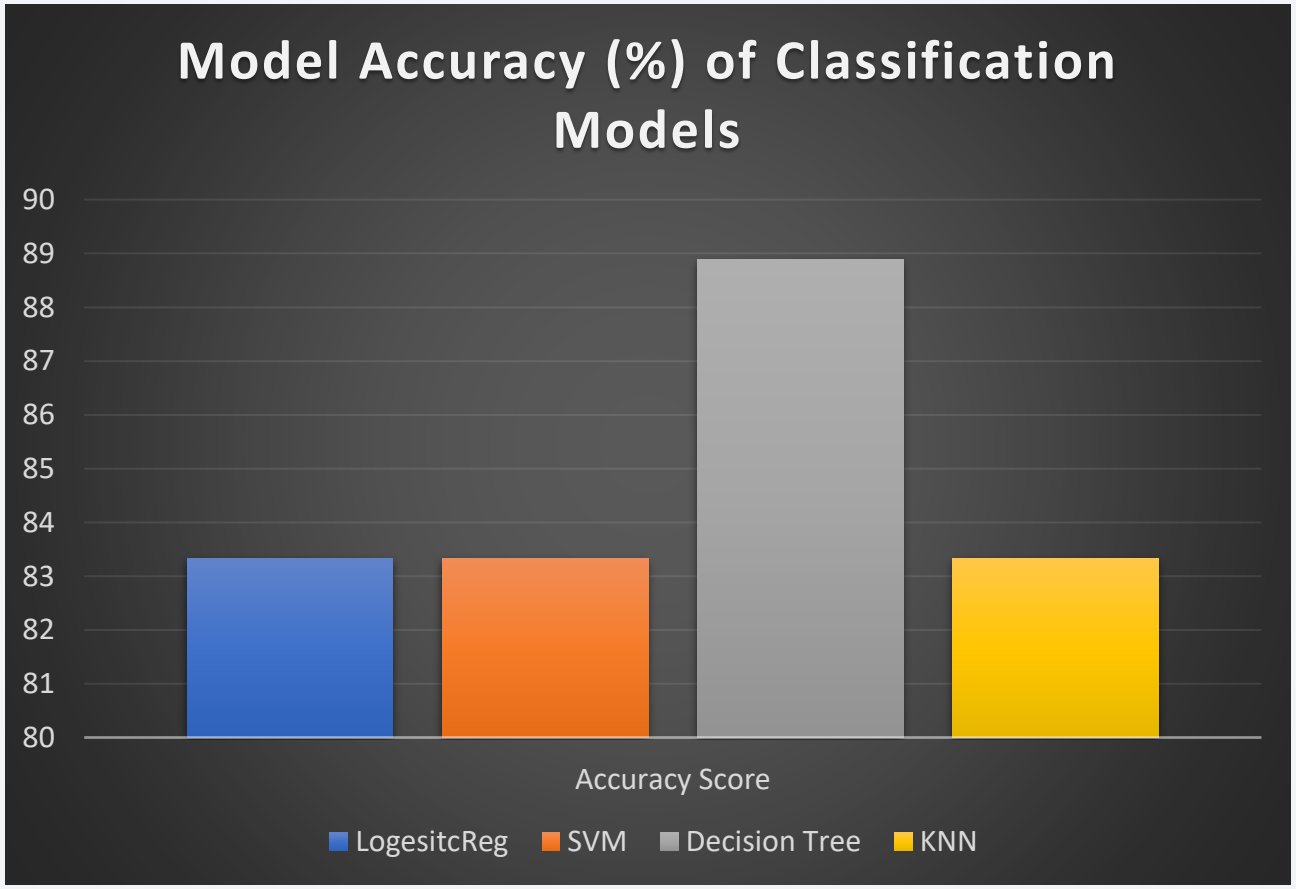
Payload vs. Launch Outcome For All Sites

- **Best success rate** occurs at weight range of **2000-5500kg**
- The **booster version** with the **highest success** rate is **B5**

Section 6

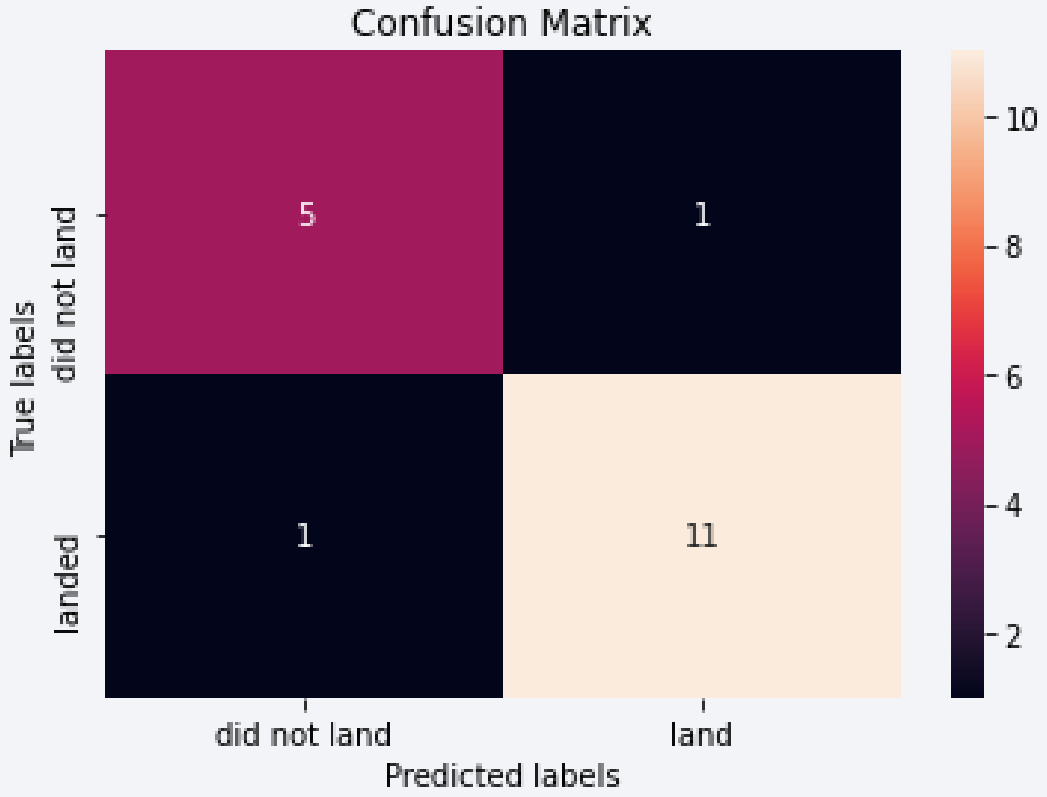
Predictive Analysis (Classification)

Classification Accuracy



- The **Decision Tree** classification model had the **highest accuracy** at **88.888%.**

Confusion Matrix of the Decision Tree Model



- The Confusion Matrix clearly demonstrates the high accuracy of the Decision Tree Mode.
- Only a single case each of false positive and false negative.

Conclusions

- Overall there is a **consistent improvement** in the success rate of all missions over time.
- **KSC LC-39** had the best success rate of all sites
- Success is best with **Falcon9 booster version B5** with payloads between **2000-5500kg**
- Launch site are located **near railway, highway and ports**, but **away from cities**
- The **Decision Tree Classifie**r performed best as a predictive model.

Thank you!