

Winning Space Race with Data Science

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GitHub:

<https://github.com/anis876/Applied-Data-Science-Capstone>



OUTLINE

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Executive Summary

Methodology Summary

- Data Collection
- Data Wrangling
- EDA with Visualization
- EDA with SQL
- Building an Interactive Map with Folium
- Building a Dashboard with Plotly Dash
- Predictive Analysis (Classification)

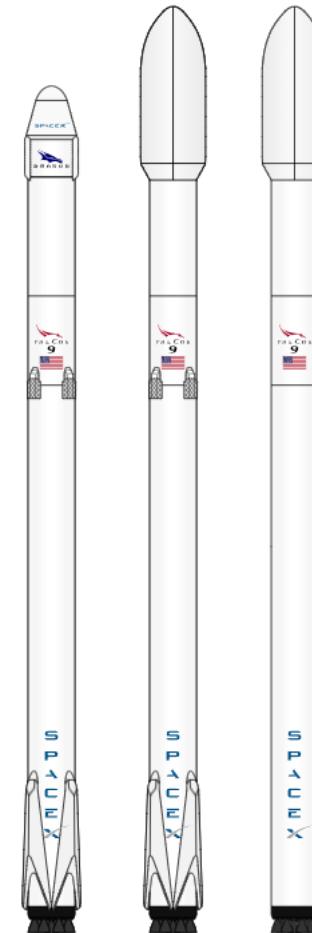
Results Summary

- EDA Results
- Interactive Analytics
- Predictive Analysis

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 unlike other rocket providers, SpaceX's Falcon 9 can reuse the first stage.



Problem to Solve:

If we can determine if the first stage will land, we can determine the cost of a launch. We will train a machine learning model using the previous data of launches of Falcon 9 rocket to predict if the first stage of the SpaceX will land or not.



Section 1

Methodology

Methodology

Data Collection

- SpaceX REST API
- Web Scraping from Wikipedia

Data Wrangling

- Data cleaning (e.g. replacing missing payload mass with its mean; removing irrelevant columns)
- Create a landing outcome label
- Data transformation (One Hot Encoding for categorical features, Standardization of numerical features)

Exploratory Data Analysis (EDA) using Visualization and SQL

Interactive Visual Analytics using Folium and Plotly Dash

Predictive Analysis using Classification Models

- Linear Regression, K Nearest Neighbors, Support Vector Machine, and Decision Tree models have been built and evaluated for the best classifier

Data Collection

SpaceX REST API

- SpaceX launches is gathered from the SpaceX REST API.
- The url starts with `api.spacexdata.com/v4/`
- The information gathered include: the rocket used, payload delivered, launch specifications, landing specifications, and landing outcome.



Web Scraping from Wikipedia

- SpaceX lunches is gathered from Wikipedia:
- https://en.wikipedia.org/wiki/List_of_Falcon_9_and_Falcon_Heavy_launches
- The launch records are stored in a HTML table

Data Collection – SpaceX API

1. Make a request to get rocket launch data

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

response = requests.get(spacex_url)

static_json_url='https://cf-courses-data.s3.us.cloud-object-
response.status_code

200
```

2. Normalize to data frame

```
# Decode the response content as a JSON using .json()
json_data=response.json()

# Convert the json response into a dataframe using .json_normalize()
data = pd.json_normalize(json_data)
```

3. Create a dictionary

```
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}
```

4. Create a Pandas data frame

```
#create a dataframe from launch_dic
data = pd.DataFrame(launch_dict)
```

5. Filter Falcon 9 only

```
# Hint data['BoosterVersion']!='Falcon 1'
data_falcon9= data[data ['BoosterVersion']!='Falcon 1']
```

6. Save to CSV

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

Data Collection – Scraping (Web Scraping from Wikipedia)

1. Get Response from HTML

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

2. Create Beautiful Soup Object

```
content = page.text  
BeautifulSoup = BeautifulSoup(content, 'html.parser')
```

3. Find tables

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

4. Get column names

```
column_names = []  
for i in first_launch_table.find_all('th'):  
    if extract_column_from_header(i)!=None:  
        if len(extract_column_from_header(i))>0:  
            column_names.append(extract_column_from_header(i))
```

5. Create a dictionary

```
launch_dict= dict.fromkeys(column_names)  
del launch_dict['Date and time ()']  
  
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']= []  
launch_dict['Version Booster']=[]  
launch_dict['Booster landing']=[]  
launch_dict['Date']=[]  
launch_dict['Time']=[]
```

6. Append data to keys (e.g. below for Date- refer to notebook for more)

```
#Append the date into launch_dict with key `Date`  
date = datatimelist[0].strip(',')  
launch_dict['Date'].append(date)
```

7. Convert dictionary to dataframe

```
df=pd.DataFrame(launch_dict)
```

8. Save to CSV

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

Data Wrangling

Initially some Exploratory Data Analysis (EDA) was performed:

1. Check and calculate null values

```
df.isnull().sum()/df.shape[0]*100
```

FlightNumber	0.000000
Date	0.000000
BoosterVersion	0.000000
PayloadMass	0.000000

2. Calculate the n of launches on each site

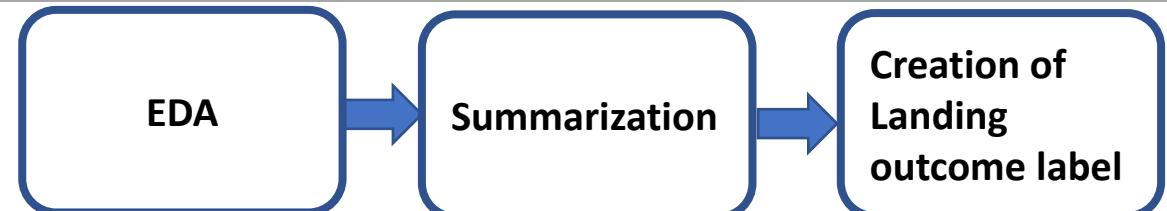
```
df['LaunchSite'].value_counts()
```

CCAFS SLC 40	55
KSC LC 39A	22
VAFB SLC 4E	13
Name: LaunchSite, dtype: int64	

3. Calculate the n and occurrence of each orbit

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

GTO	27
ISS	21
VLEO	14
PO	9



4. Calculate the n and occurrence of outcome per orbit type

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

True ASDS	41
None None	19
True RTLS	14
False ASDS	6

5. Create a landing outcome label from Outcome column

```
def outcome_to_class(outcome_value):  
    if outcome_value in bad_outcomes:  
        return 0  
    else:  
        return 1  
landing_class = df['Outcome'].apply(outcome_to_class)
```

6. Calculate success from Class column

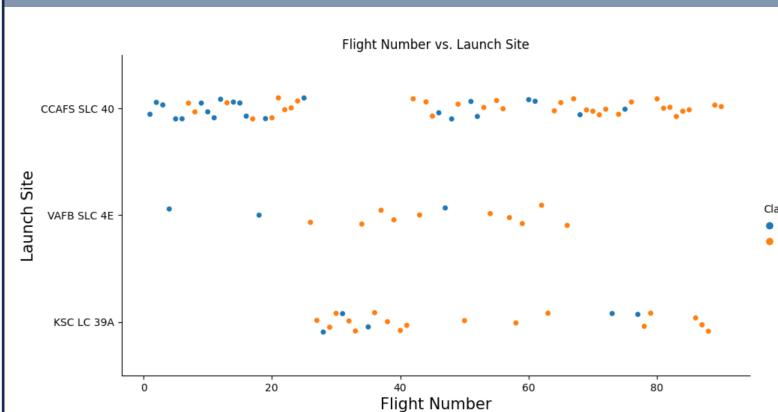
```
df["Class"].mean()
```

0.6666666666666666

EDA with Data Visualization

To explore data, scatterplots, bar plots, were used to visualize the relationship between pair of features.

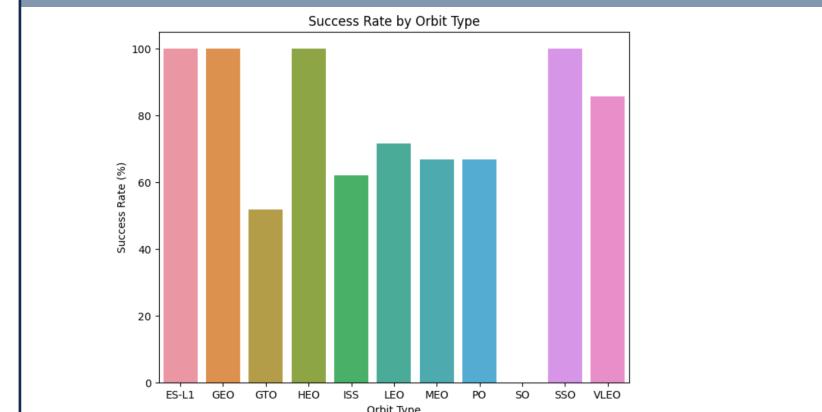
Flight Number and Launch Site



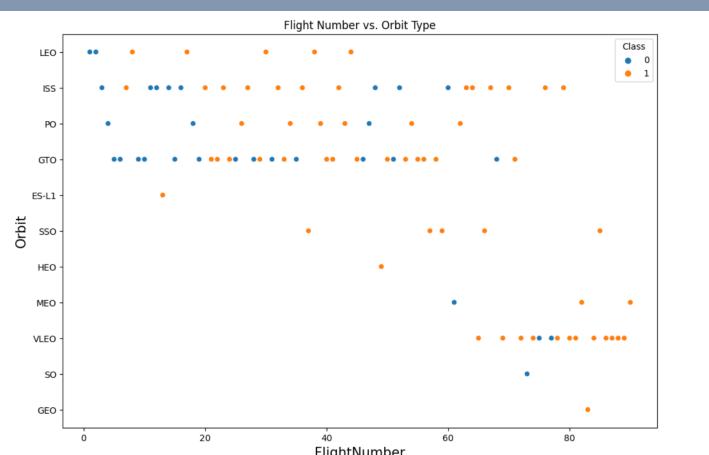
Payload Mass and Launch Site



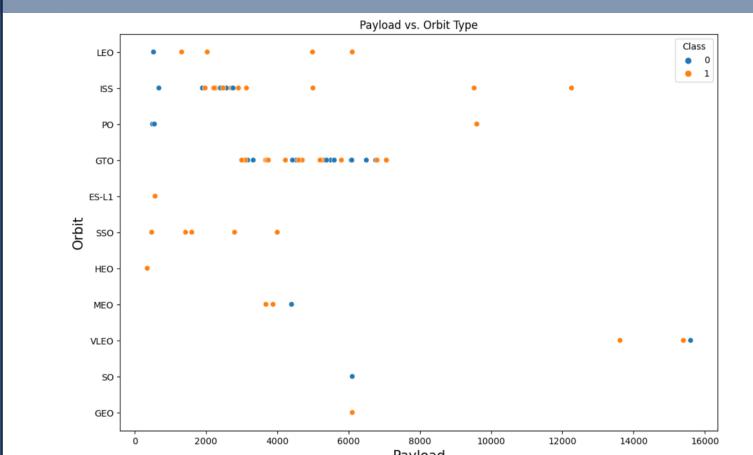
Success Rate and Orbit Type



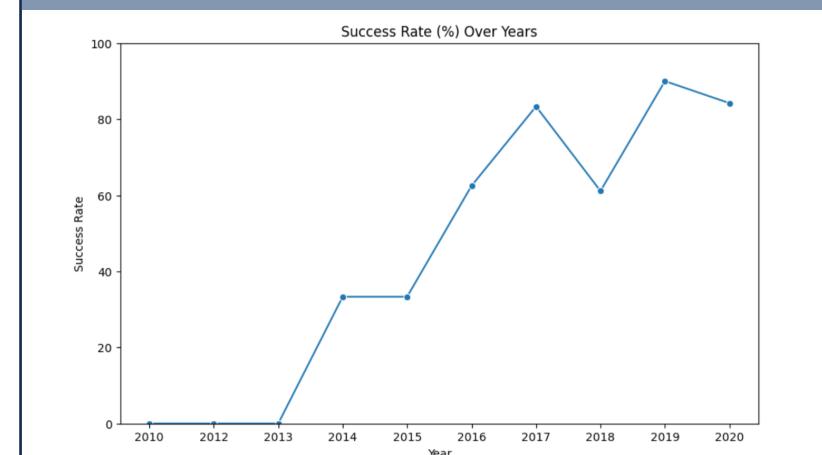
Flight Number and Orbit Type



Payload Mass and Orbit Type



Trend of success over the years



EDA with SQL

- Displaying the names of the unique launch sites in the space mission
- Displaying 5 records where launch sites begin with the string 'KSC'
- Displaying the total payload mass carried by boosters launched by NASA (CRS)
- Displaying average payload mass carried by booster version F9 v1.1
- Listing the date where the successful landing outcome in drone ship was achieved.
- Listing the names of the boosters which have success in ground pad and have payload mass greater than 4000 but less than 6000
- Listing the total number of successful and failure mission outcomes
- Listing the names of the booster versions which have carried the maximum payload mass
- Listing the records which will display the month names, successful landing outcomes in ground pad booster versions, launch site for the months in year 2017
- Ranking the count of successful landing outcomes between the date 2010 06 04 and 2017 03 20 in descending order.

Build an Interactive Map with Folium

- An interactive map offers a dynamic way to visualize and analyze launch site data, facilitating decision-making and insights into the spatial relationships of launch activities. For instance, the success rate may depend on the location and proximities of a launch site, i.e., the initial position of rocket trajectories.

We created three maps for:

- Visualization of **each launch site** in an interactive map.
- Visualization of launch sites on the map based on **fail or success**. This gives us insights into the performance of launch sites.
- Visualization of the geographical context and **proximity** of the launch sites to railway, highway, coastline, etc

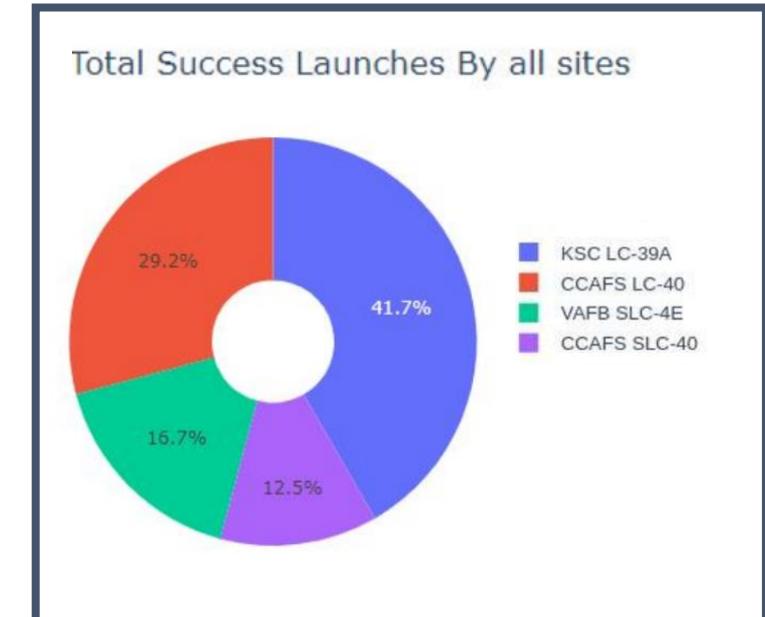


Build a Dashboard with Plotly Dash

- Plotly Dash applications allows us to perform interactive visual analytics on SpaceX lunch data in real time.

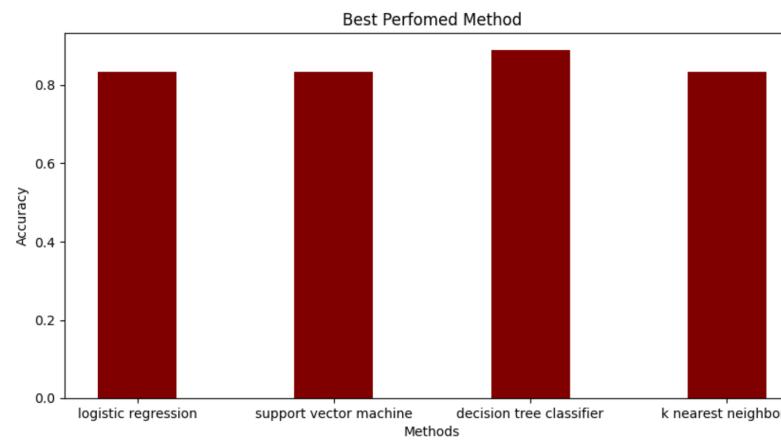
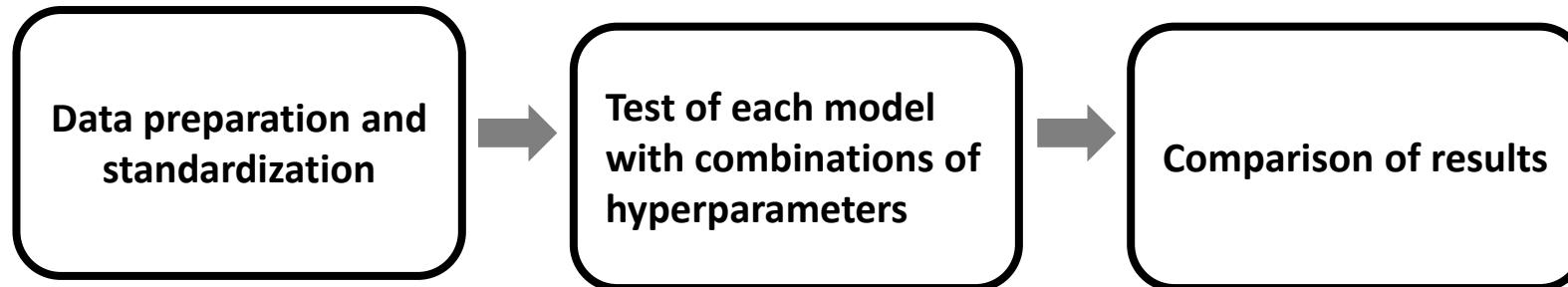
We developed a dashboard that enables us to:

- Visualize a pie chart depicting success based on the selected launch site.
- Explore the correlation between success and payload by utilizing a Range Slider to choose the payload range, presented through a scatter plot.



Predictive Analysis (Classification)

Four classification models including Linear Regression, K Nearest Neighbors, Decision Tree models, and Support Vector Machine, were built and compared.



Results

- The first successful ground pad landing took place on December 22, 2015.
- The success rates for SpaceX launches increased over time (2013-2020).
- The location of launch appears to be a significant contributing factor to the success of missions
- KSC LC-39A has the most successful launches compared to other sites.
- Low weighted payloads perform better than the heavier payloads.
- ES-L1, GEO, HEO, and SSO orbits achieved the highest success rate.
- For heavy payloads, the rates of success are higher for VLO and ISS orbits.
- Decision Tree model is the best in terms of prediction accuracy for this dataset.

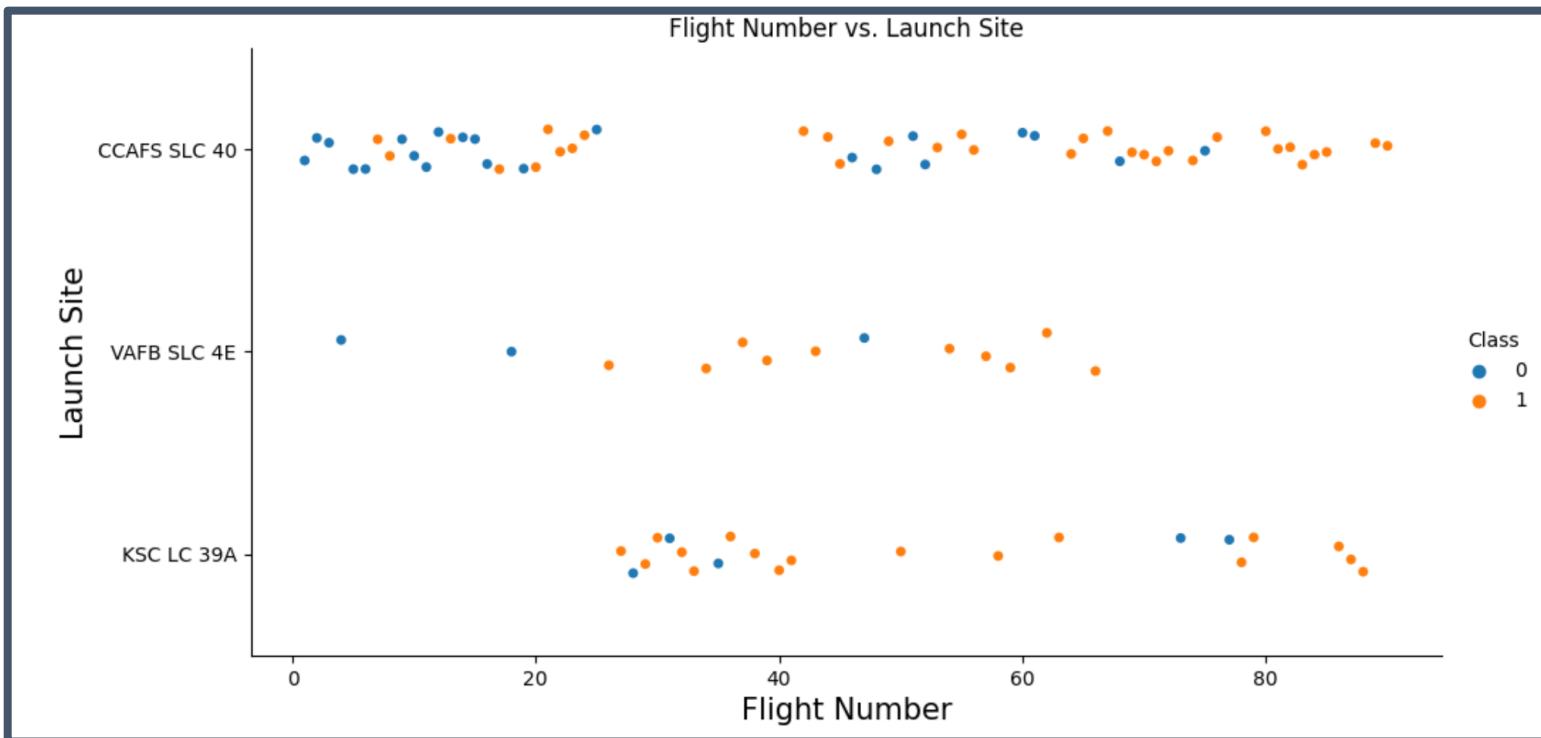
For additional information, refer to slides 18 through 45.

The background of the slide features a complex, abstract digital visualization. It consists of numerous thin, glowing lines that create a sense of depth and motion. The lines are primarily blue and red, with some green and purple highlights. They form a grid-like structure that curves and twists across the frame, resembling a three-dimensional space or a network of data points. The overall effect is futuristic and dynamic.

Section 2

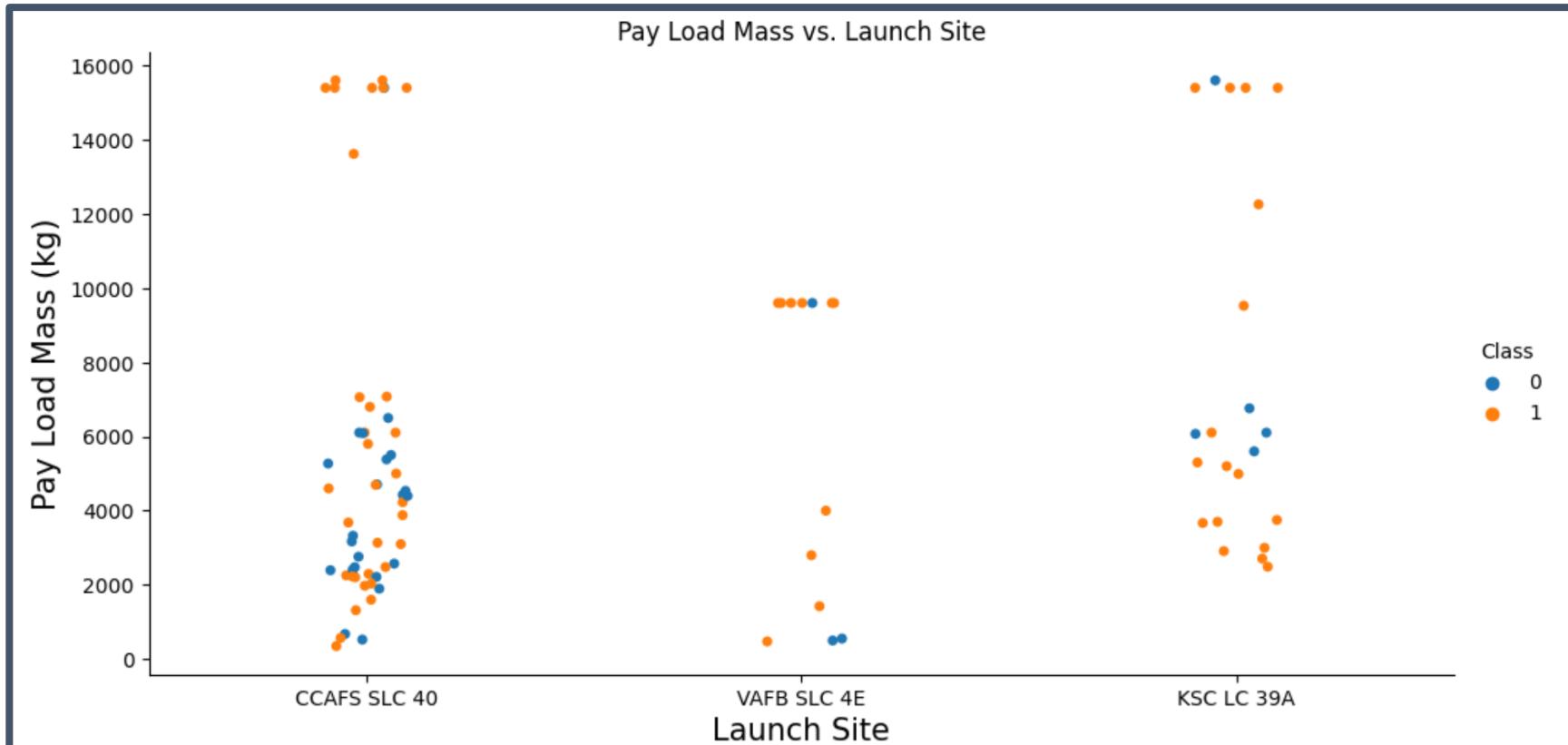
Insights drawn from EDA

Flight Number vs. Launch Site



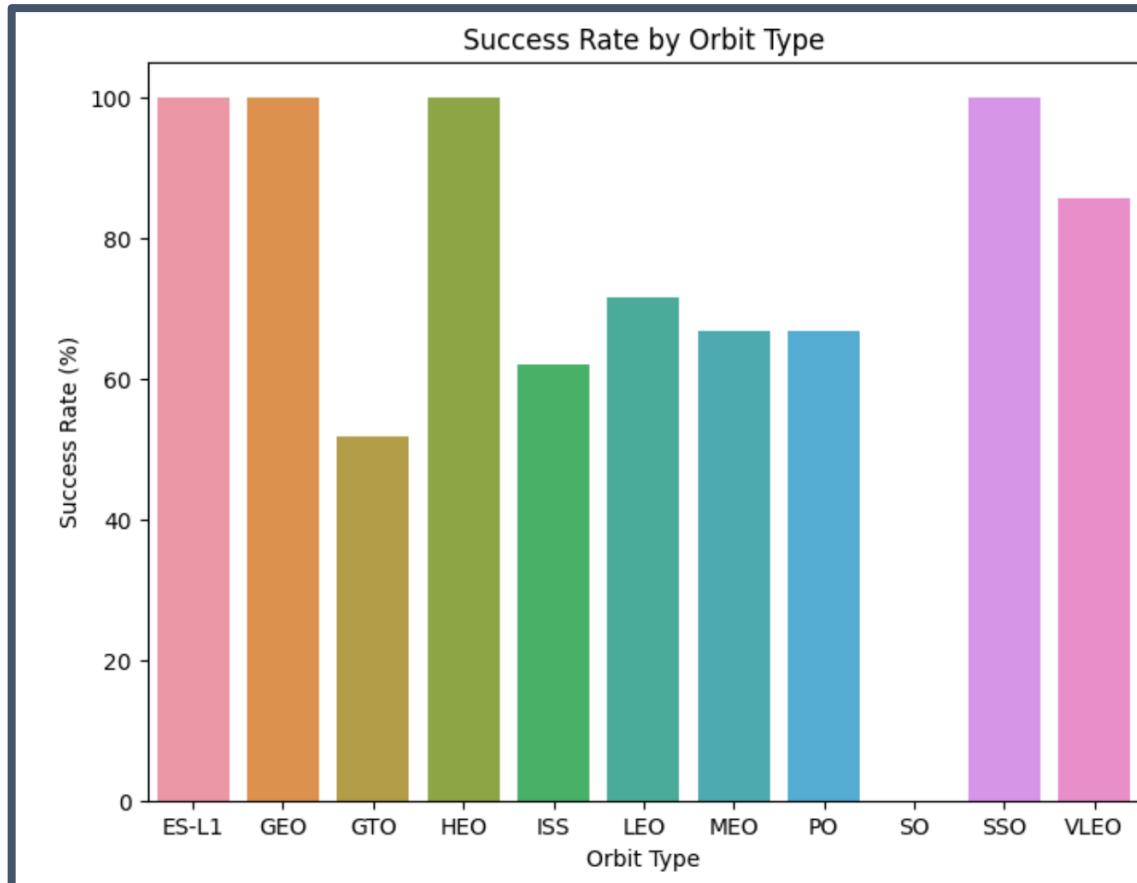
- Most launches took off from CCAFS SLC 40 launch site
- The initial launches were mostly carried out from the CCAFS SLC 40 launch site
- The majority of recent launches from CCAFS SLC 40 resulted in success
- The success rates for all launch sites improved over time.

Payload vs. Launch Site



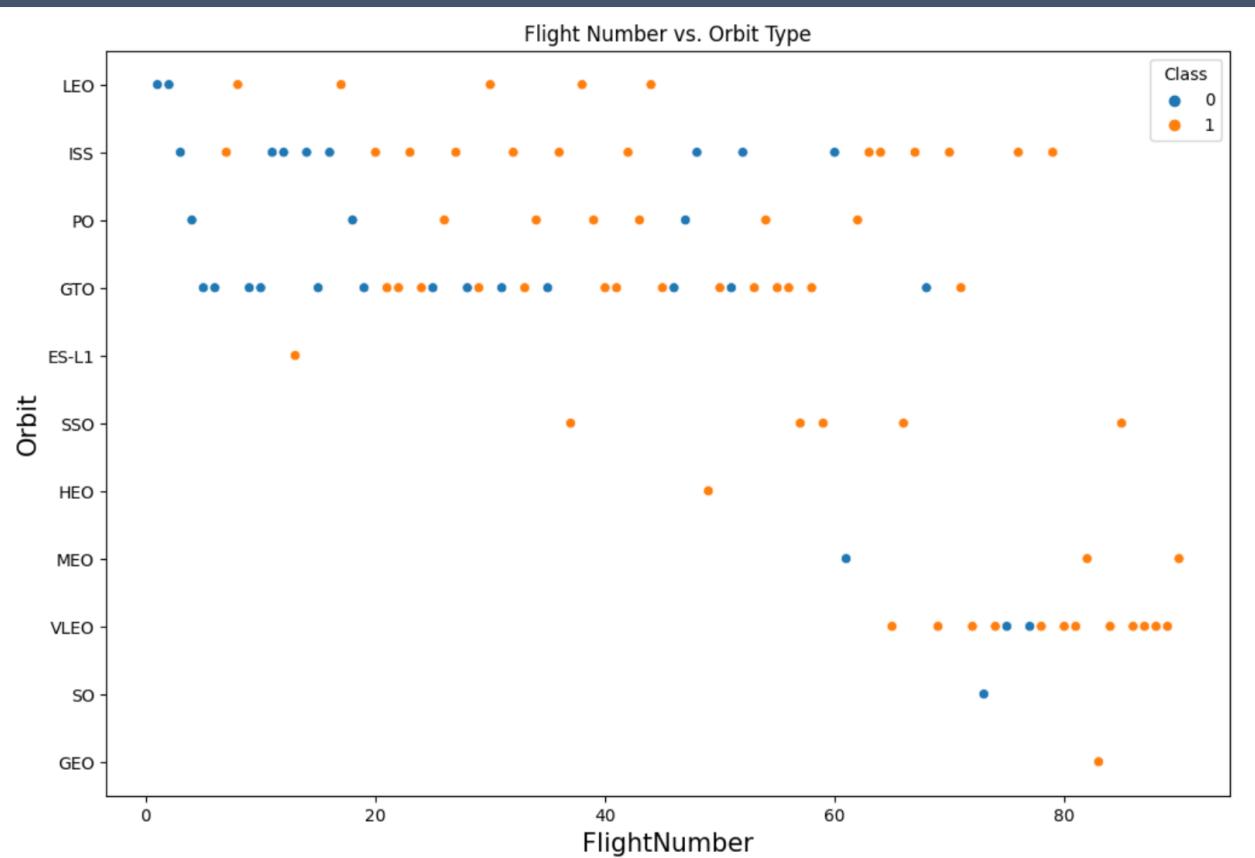
- VAFB SLC 4E launch site conducts launches with lower payloads (zero launches for >10000 kg)
- CCAFS SLC 40 hosts a higher number of launches involving both higher and lower payloads.
- Most payloads weighing over 9000 kg have achieved successful outcomes.

Success Rate vs. Orbit Type



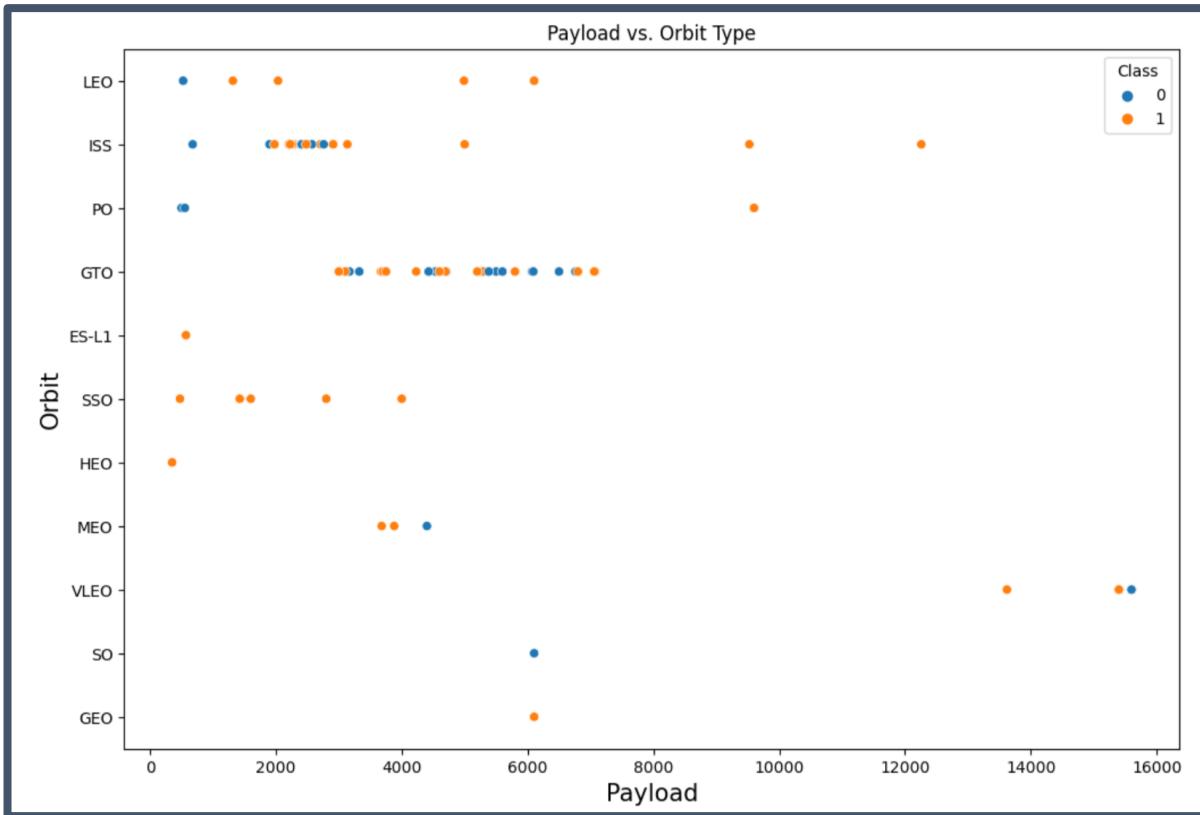
ES-L1, GEO, HEO, and SSO orbits achieved the highest success rate at 100%, followed by VLEO with a success rate >80%, and LEO with a success rate >70%.

Flight Number vs. Orbit Type



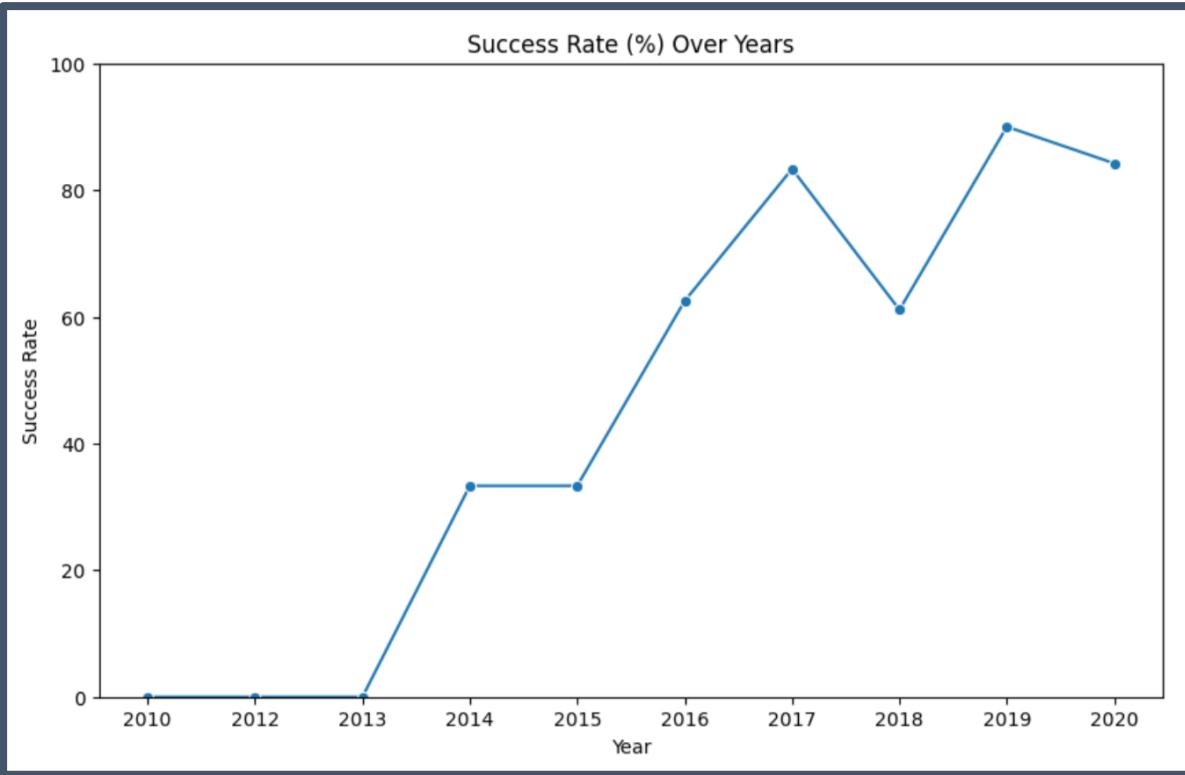
- In the recent years, there has been a transition towards launching missions into Very Low Earth Orbits (VLEO) with a significantly high rate of success.
 - While the GTO orbit experiences a low success rate, there appears to be no discernible relationship between flight number and the rate of success in this orbit.

Payload Mass vs. Orbit Type



- For heavy payloads, the rates of success are higher for VLO and ISS orbits.
- In the case of GTO, there seems no apparent relationship between payload and the rate of success.

Launch Success Yearly Trend



- The rate of success has seen a notable rise since 2013 and continued to rise until 2020, possibly attributed to technological advancements.
- The first three years (2010-2013) seem to have been a phase focused on fine-tuning and technological enhancement.

All Sites Names

- Here are the names of four launch sites in the space mission:

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

- The associated SQL code:

```
%sql SELECT DISTINCT Launch_Site FROM SPACEXTABLE;
```

Launch Site Names Begin with 'CCA'

- Five records where launch sites begin with the 'CCA' are listed below:

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS_KG_	Orbit	Customer	Mission_Outcome	Landing_Outcome
2010-04-06	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-08-12	15:43:00	F9 v1.0 B0004	CCAFS LC-40	Dragon demo flight C1, two CubeSats, barrel of Brouere cheese	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2012-05-22	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-08-10	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-01-03	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

- The associated SQL code:

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

Total Payload Mass

- The total payload carried by boosters from NASA (CRS) is **45596 (kg)**
- The associated SQL code:

```
%sql SELECT SUM(PAYLOAD_MASS__KG_) AS Total_payload_mass FROM SPACEXTABLE WHERE Customer = 'NASA (CRS)';
```

Average Payload Mass by F9 v1.1

- The average payload mass carried by booster version **F9 v1.1** is **2928.4 (kg)**
- The associated SQL code:

```
%sql SELECT AVG(PAYLOAD_MASS__KG_) AS Average_Payload_Mass FROM SPACEXTABLE WHERE Booster_Version = 'F9 v1.1';
```

First Successful Ground Landing Date

- The first successful ground pad landing took place on **December 22, 2015**.
- The associated SQL code:

```
%sql SELECT MIN(DATE) AS First_successful_landing_gound FROM SPACEXTABLE WHERE Landing_Outcome = 'Success (ground pad)';
```

Successful Drone Ship Landing with Payload between 4000 and 6000

- The boosters that have successfully landed on drone ships and carried payloads with a mass exceeding 4000 but below 6000 are as follows:

Booster_Version

F9 FT B1022

F9 FT B1026

F9 FT B1021.2

F9 FT B1031.2

- The associated SQL code:

```
%%sql SELECT Booster_Version  
FROM SPACEXTABLE  
WHERE Landing_Outcome = 'Success (drone ship)' AND PAYLOAD_MASS_KG_>4000 AND PAYLOAD_MASS_KG_<6000;
```

Total Number of Successful and Failure Mission Outcomes

- The total number of 100 mission outcomes, including both successful and unsuccessful results is presented in the following breakdown:

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

- The associated SQL code:

```
%%sql SELECT Mission_Outcome, COUNT(*) AS Total_count  
FROM SPACEXTABLE  
GROUP BY Mission_Outcome;
```

Boosters Carried Maximum Payload

- The boosters which have carried the maximum payload mass include:
- The associate SQL code:

```
%%sql SELECT Booster_Version  
FROM SPACEXTABLE  
WHERE PAYLOAD_MASS__KG_ =  
  (SELECT MAX(PAYLOAD_MASS__KG_)  
   FROM SPACEXTABLE  
)
```

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

- The unsuccessful landing outcomes on drone ships, along with their corresponding booster versions and launch site names, during the year 2015, are provided below:

Month	Failure_Landing_Outcome	Booster_Version	Launch_Site
October	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
April	Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40

- The associated SQL code:

```
%%sql SELECT
CASE
    WHEN Date like '%-01-%' THEN 'January'
    WHEN Date like '%-02-%' THEN 'February'
    WHEN Date like '%-03-%' THEN 'March'
    WHEN Date like '%-04-%' THEN 'April'
    WHEN Date like '%-05-%' THEN 'May'
    WHEN Date like '%-06-%' THEN 'June'
    WHEN Date like '%-07-%' THEN 'July'
    WHEN Date like '%-08-%' THEN 'August'
    WHEN Date like '%-09-%' THEN 'September'
    WHEN Date like '%-10-%' THEN 'October'
    WHEN Date like '%-11-%' THEN 'November'
    WHEN Date like '%-12-%' THEN 'December'
END AS Month,
Landing_Outcome AS Failure_Landing_Outcome,
Booster_Version,
Launch_Site
FROM SPACEXTABLE
WHERE Date like '%2015%' AND Landing_Outcome LIKE 'Failure (drone ship)';
```

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

- The tally of landing results (including Failure on drone ships or Success on ground pads) occurring between June 4, 2010, and March 20, 2017, is presented in a descending order:
- As shown, the highest count among the landing outcomes is attributed to "No attempt", totaling 10. This is followed by "Success (ground pad)", "Success (drone ship)", and "Failure (drone ship)" each occurring 5 times, while "Controlled (ocean)" is observed 3 times.
- The associated SQL code:

```
%sql SELECT Landing_Outcome, COUNT(*) AS Outcome_Count  
FROM SPACEXTABLE  
WHERE Date BETWEEN '2010-06-04' AND '2017-03-20'  
GROUP BY Landing_Outcome  
ORDER BY Outcome_Count DESC;
```

Landing_Outcome	Outcome_Count
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

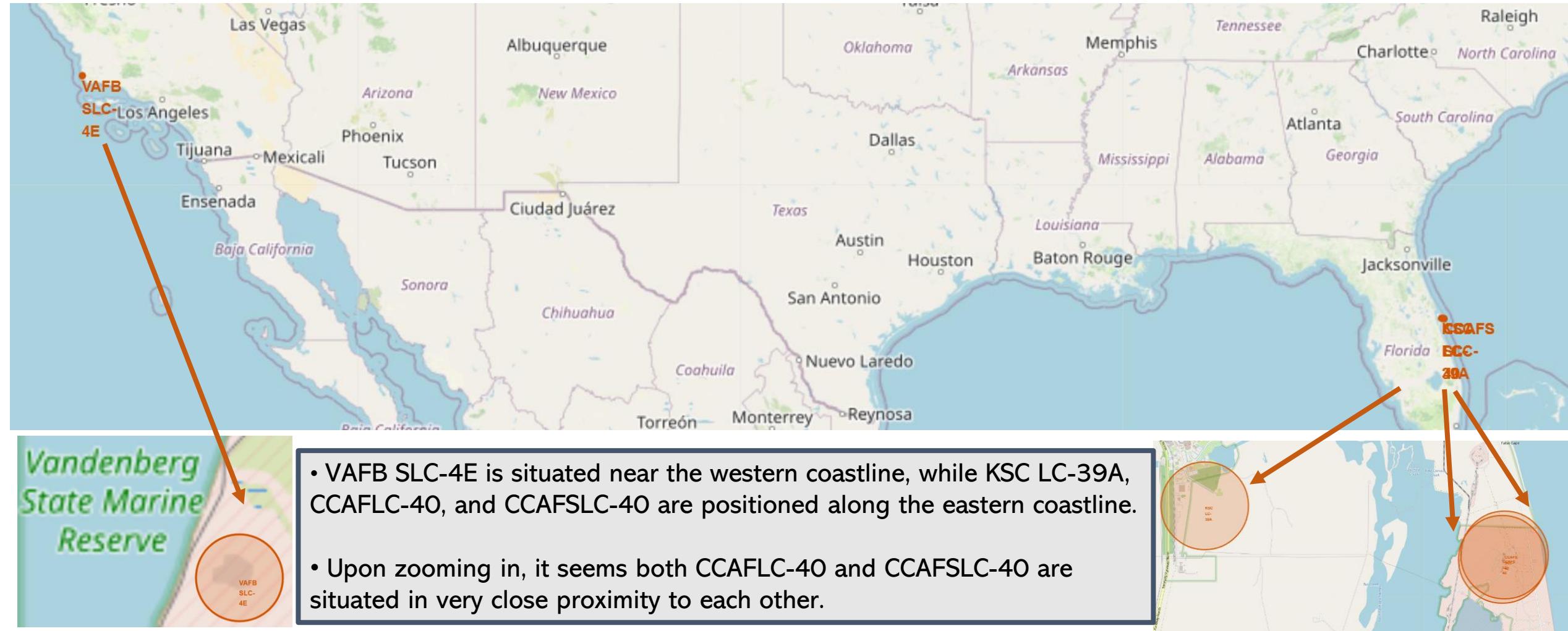
The background of the slide is a photograph taken from space at night. It shows the curvature of the Earth's horizon against a dark blue sky. Numerous glowing yellow and white points represent city lights, concentrated in coastal and urban areas. In the upper right quadrant, there are bright green and yellow bands of light, likely the Aurora Borealis or Australis. The overall atmosphere is dark and mysterious.

Section 3

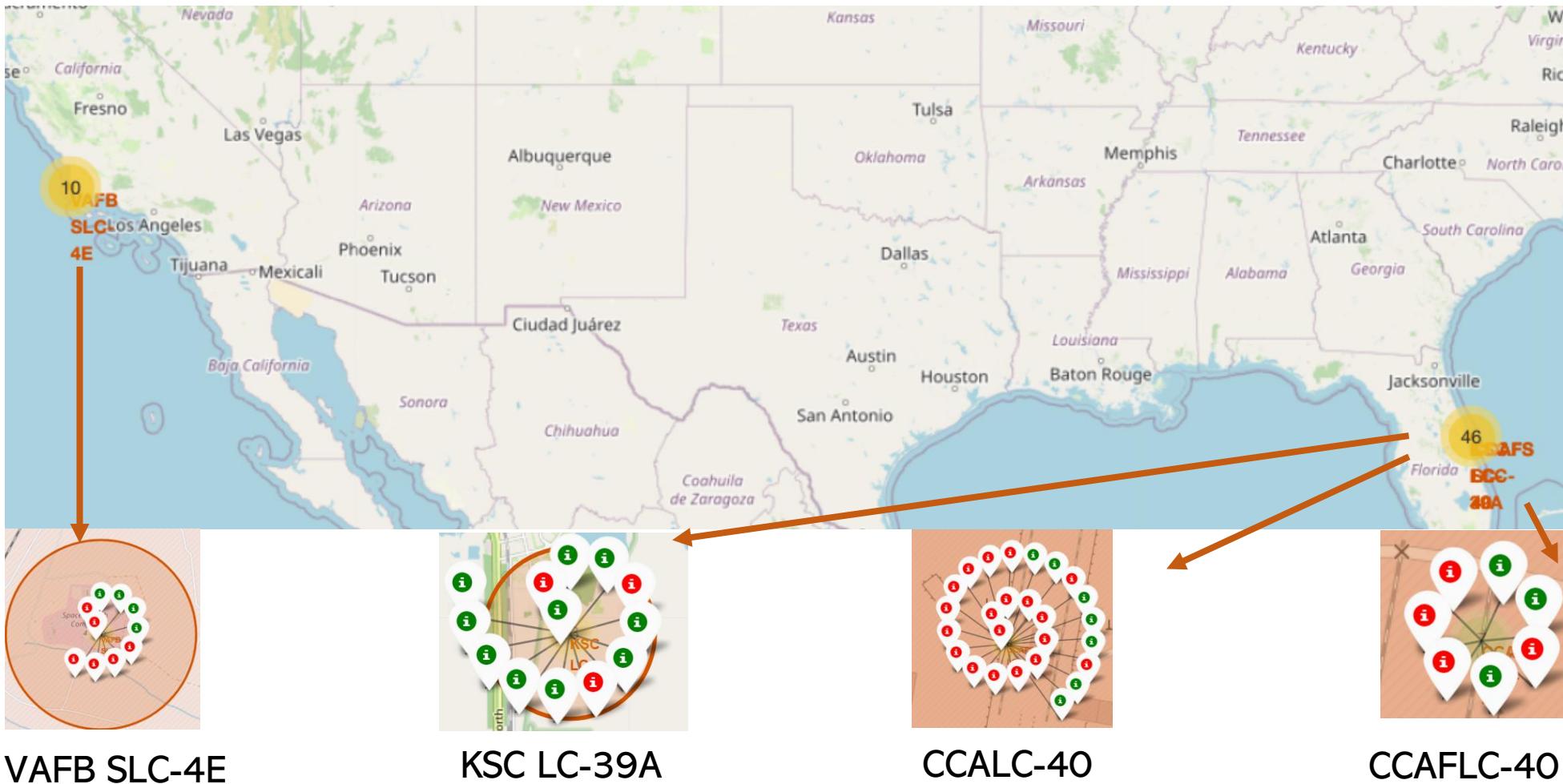
Launch Sites Proximities Analysis

Folium Map Screenshot 1 – Launch Site Locations

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



Folium Map Screenshot 2 – Success/Failed Launches for Launch Sites



VAFB SLC-4E

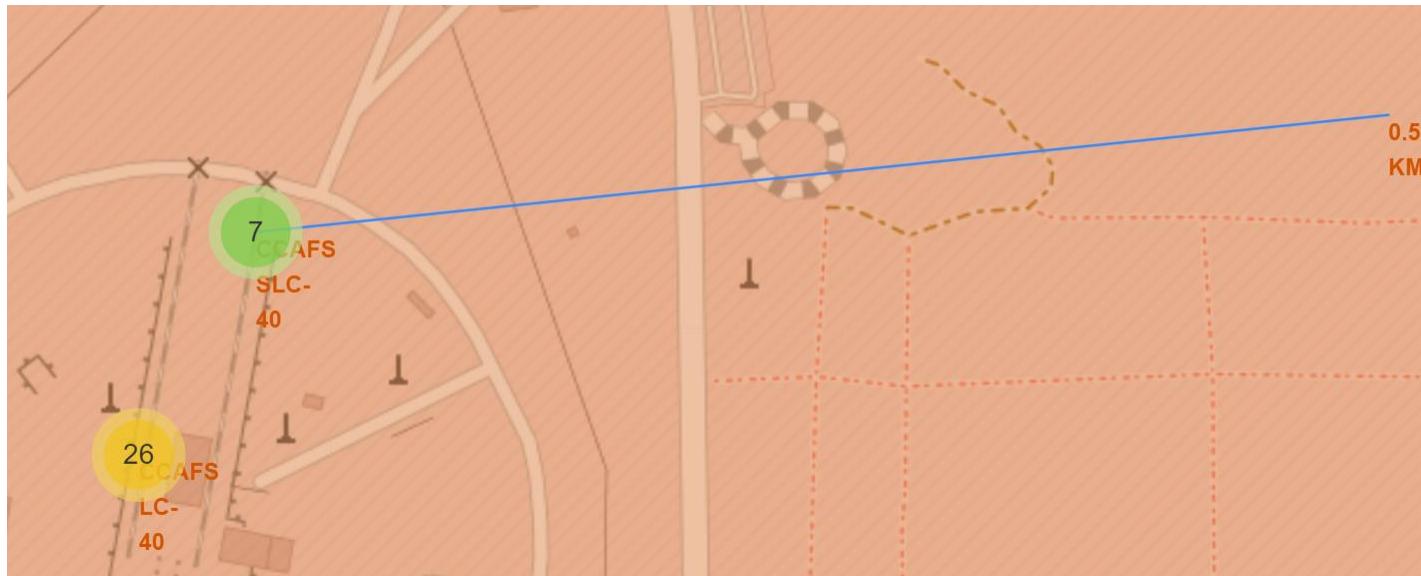
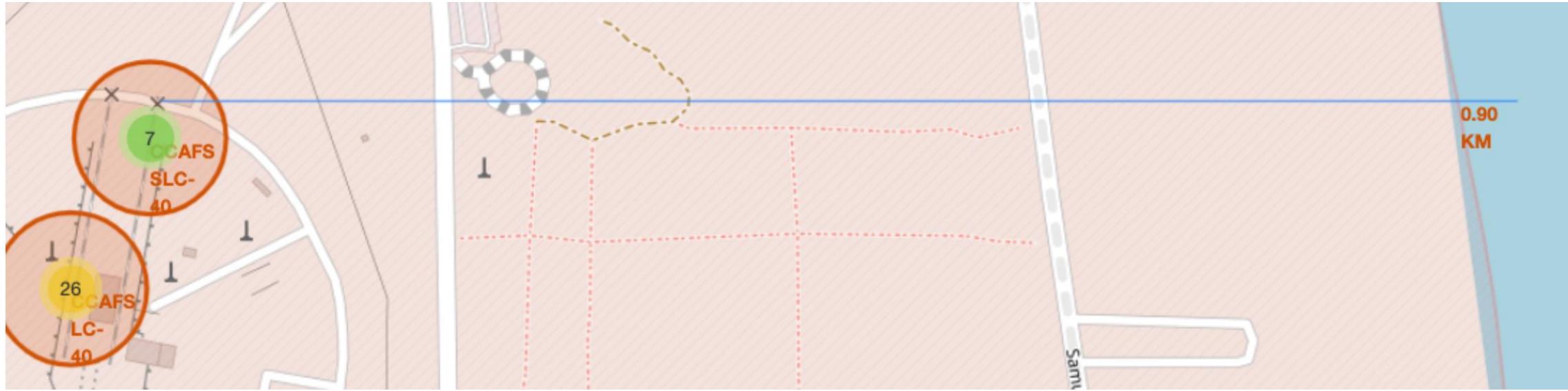
KSC LC-39A

CCALC-40

CCAFLC-40

- Upon zooming in, we can see the success (green) and failure (red) marks for each site.
- Out of 13 launches, KSC LC-39A has achieved the highest success rate with 10 successful missions ($10/13=76.9\%$)

Folium Map Screenshot 3 – Proximity of Launch Sites to Other Areas



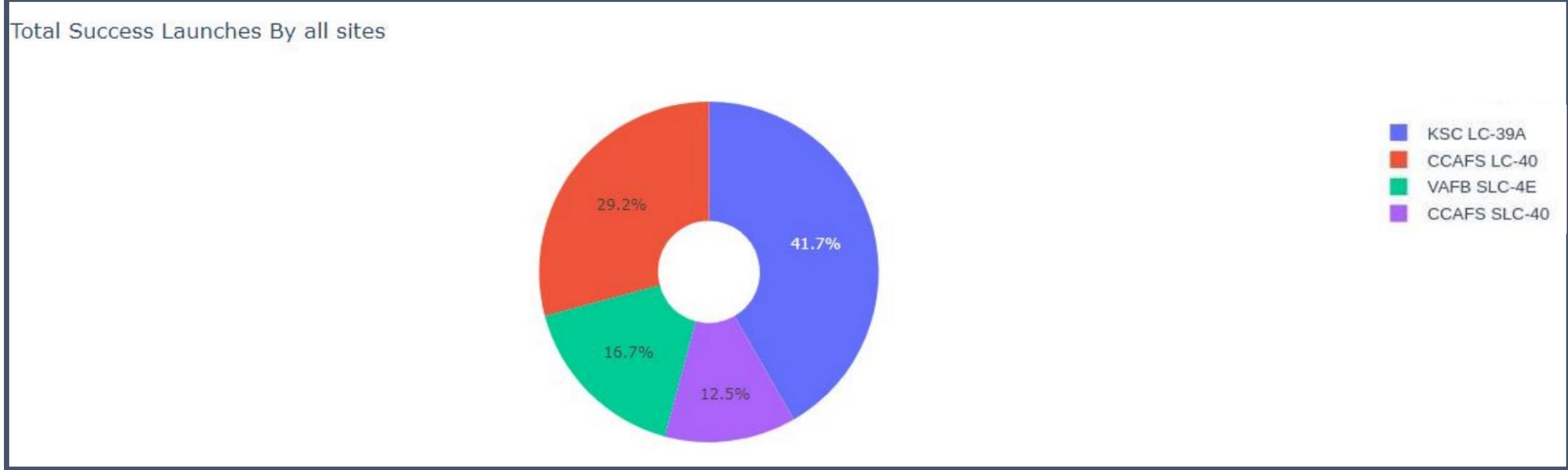
- These figures show a PolyLine between CCAFSLC-40 to the selected coastline point, etc.



Section 4

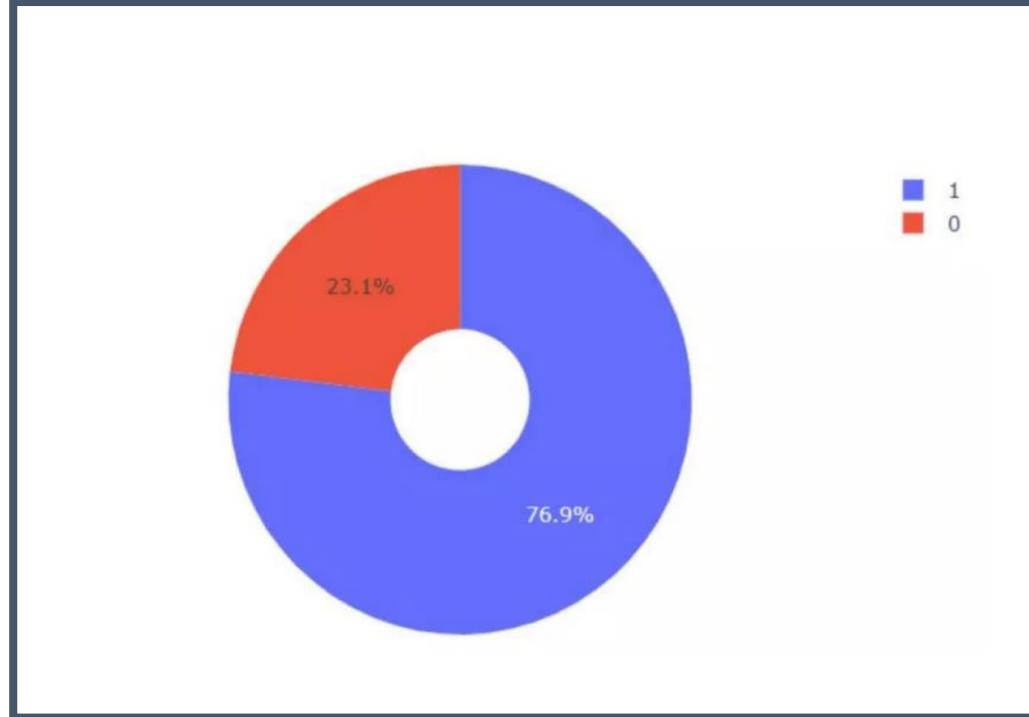
Build a Dashboard with Plotly Dash

Dashboard Screen Shot 1 – Total Success Launches By All Sites



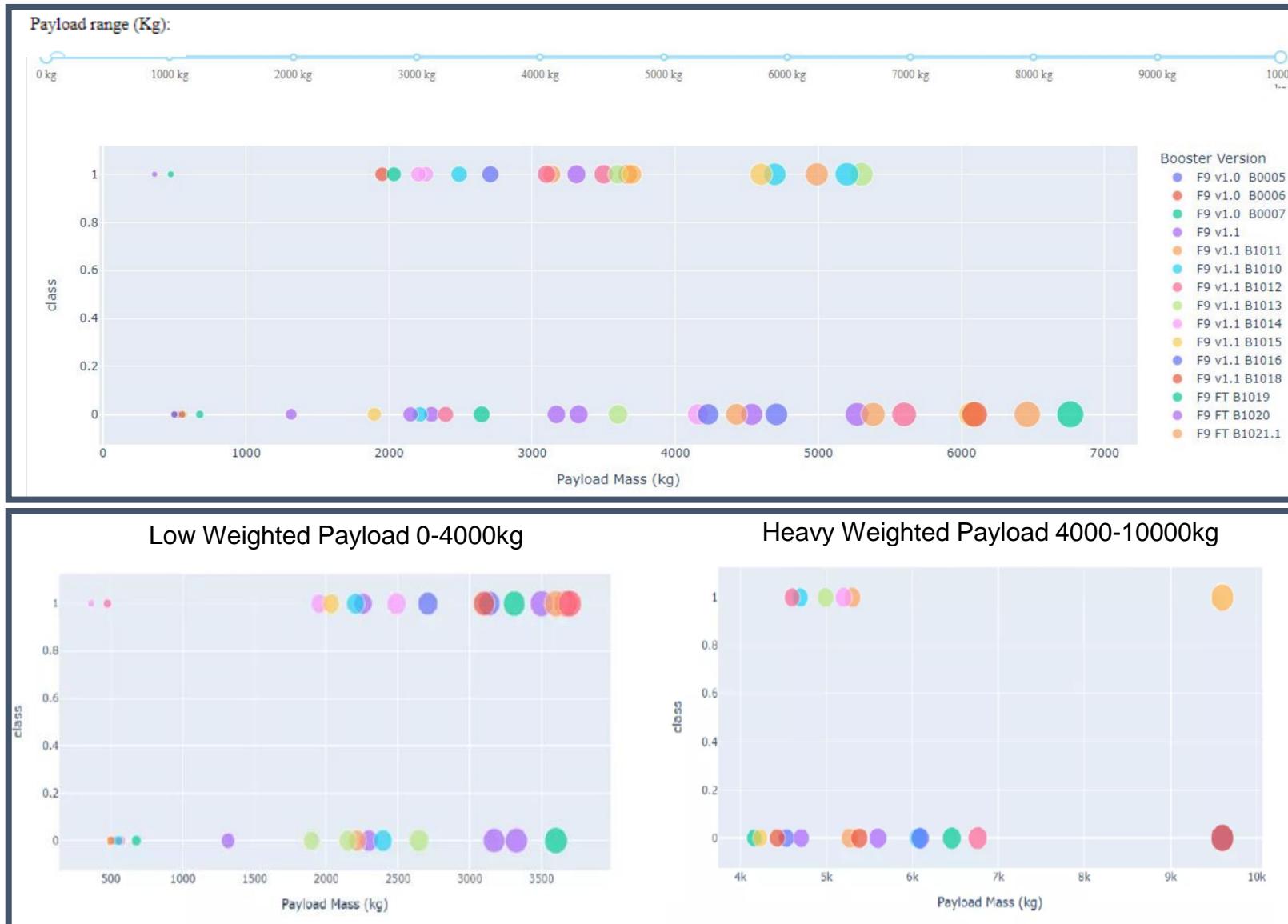
- The location of launch appears to be a significant contributing factor to the success of missions.
- KSC LC-39A has the most successful launches compared to other sites.

Dashboard Screen Shot 2 – Launch Site With Highest Launch Success Ratio



- Using the dropdown menu on the dashboard allows for viewing single site launches.
- At KSC LC-39A, 76.9% of the launches resulted in success, while 23.1% experienced failure.

Dashboard Screen Shot 3 – Payload vs. Launch Outcome



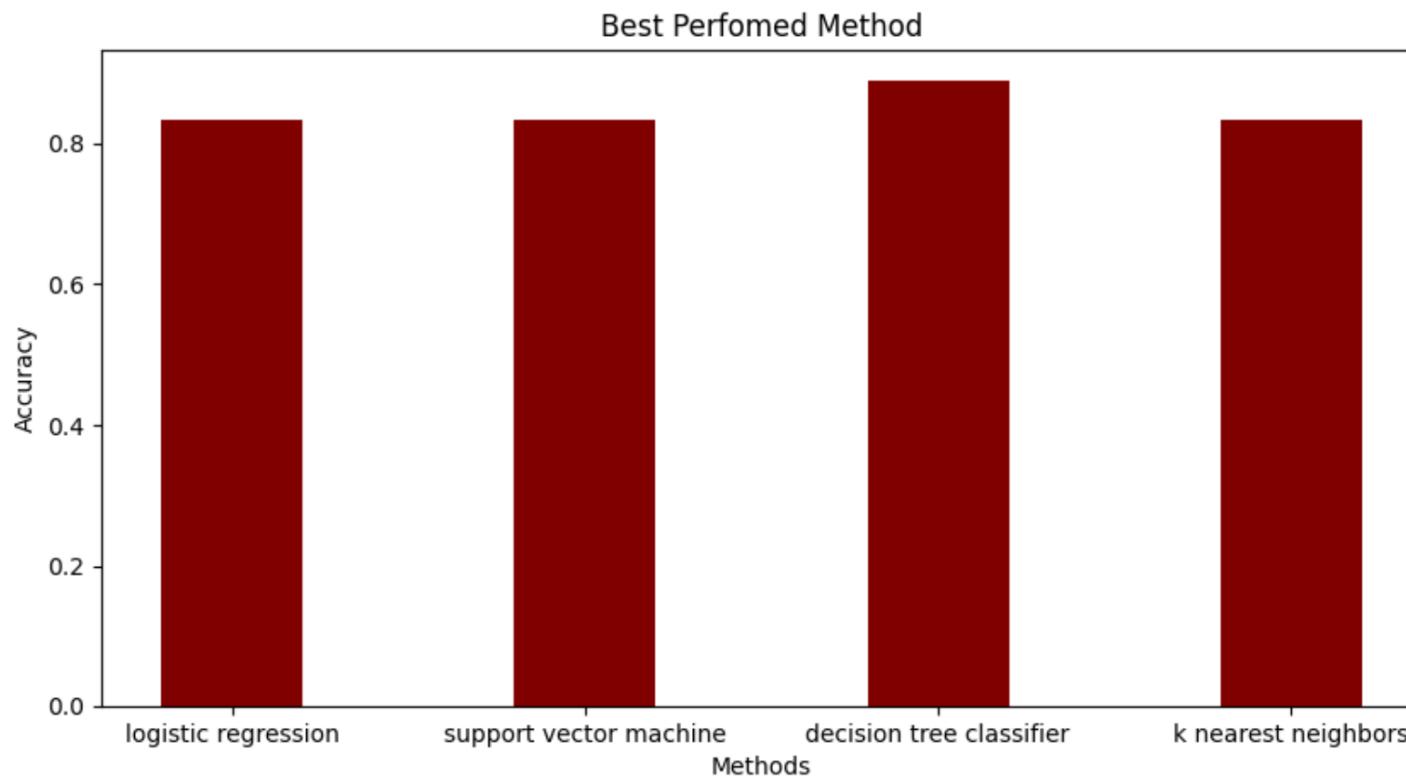
- With the Range Slider, we can observe the outcomes of both successful and failed launches for each booster version, along with the corresponding payload they carried.
- Success rates are higher for lighter payloads compared to heavier ones.

The background of the slide features a dynamic, abstract design. It consists of several thick, curved lines that transition from a bright yellow at the top right to a deep blue at the bottom left. These curves are set against a lighter blue background, creating a sense of motion and depth. In the lower right quadrant, there is a vertical column of solid white space.

Section 5

Predictive Analysis (Classification)

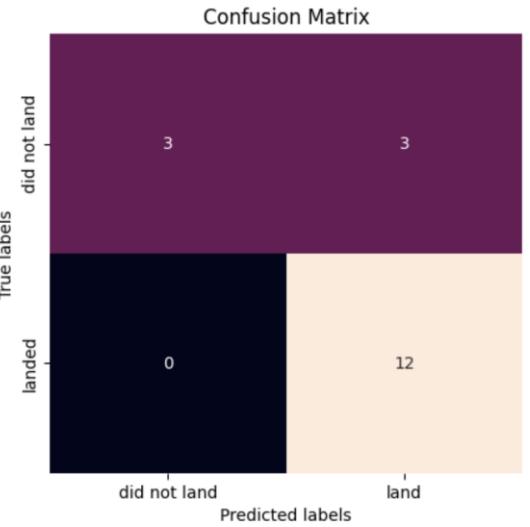
Classification Accuracy:



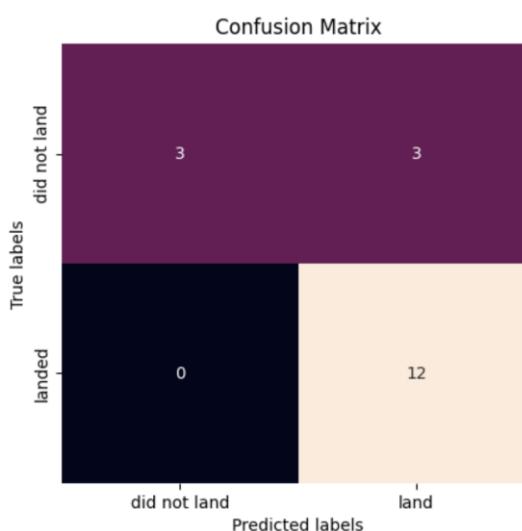
Decision Tree model achieved the highest accuracy at 88 %, while the SVM performs the best in terms of Area Under the Curve at 0.96 (not shown).

Confusion Matrix:

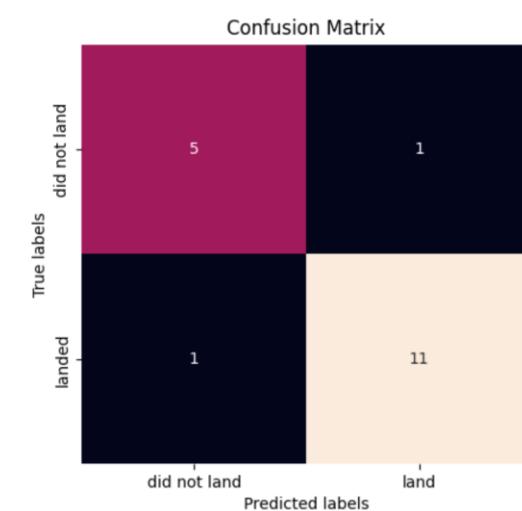
Logistic Regression (LR)



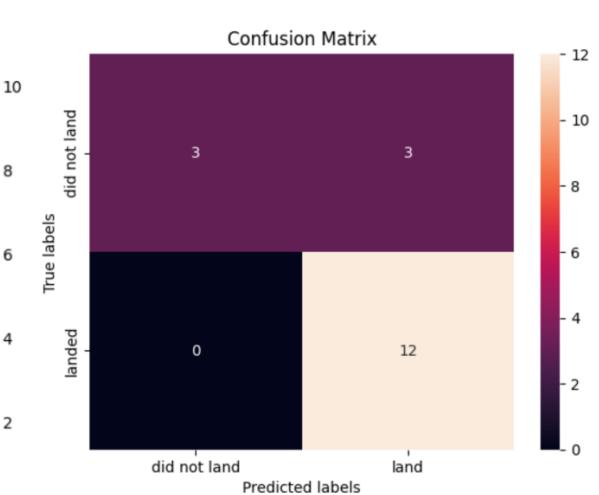
Support Vector Machine (SVM)



Decision Tree (DT)



K Nearest Neighbors (KNN)



- All four models can distinguish between the different classes.
- However, the major problem for LR, SVM, and KNN is False Positives (n=3)
- Decision Tree has the least False Positive (n=1)

ACTUAL VALUES	PREDICTIVE VALUES	
	0 (Negative)	1 (Positive)
0 (Negative)	TN	FP
1 (Positive)	FN	TP

Conclusions:

- The success rates for SpaceX launches increased over time (2013-2020).
- KSC LC-39A has the most successful launches compared to other sites.
- Low weighted payloads perform better than the heavier payloads.
- ES-L1, GEO, HEO, and SSO orbits achieved the highest success rate.
- For heavy payloads, the rates of success are higher for VLO and ISS orbits.
- Decision Tree models are the best in terms of prediction accuracy for this dataset.
- Through the utilization of available data and comprehensive analysis, rocket companies can pinpoint the most effective techniques for diminishing launch expenses. This approach averts the risk of losing clients and ensures they remain competitive in the market.

Thank you!

