IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

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- Results
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Executive Summary

In this project, we wanted to determine if we can predict whether the Falcon 9 first stage will land successfully. SpaceX advertises Falcon 9 rocket launches on its website with a cost of $62M; other providers cost up to $165M each; much of the savings because SpaceX can reuse the first stage.

If we can determine whether 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.

Use of Exploratory Data Analysis and Interactive Visual Analytics resulted in the identification of variables for the classification features data set – such as Launch Site, Payload Mass, Orbit, Booster Version, and Landing Pad

Among the four studied classification models, Decision Tree distinguished best between the different classes, with 83.3% prediction accuracy for ‘landed’ results and ‘did not land’ results

Given the presented SpaceX launch data from 2010-2020, yes, using EDA and Predictive Analysis, we can predict whether the Falcon 9 first stage will land successfully

Introduction

- In this project, we want to determine if we can predict whether the Falcon 9 first stage will land successfully. SpaceX advertises Falcon 9 rocket launches on its website with a cost of $62M; other providers cost up to $165M; much of the savings because SpaceX can reuse the first stage.
- If we can determine whether 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.
- We will obtain launch data from SpaceX and open-source web sites, apply Exploratory Data Analysis and Interactive Visual Analytic methods to develop and refine Feature Sets and Launch Outcome Label Sets, and then predict launch outcomes using Predictive Analysis algorithms.

Section 1

Methodology

Methodology

- Data collection methodology: applied SpaceX REST API, targeting several endpoints to obtain Falcon 9 launch data; used BeautifulSoup to access HTML tables and obtain additional launch data
- Perform data wrangling: processed missing values, performed breakdown of launches by orbit, reviewed different booster landing outcomes to create a landing outcome training label (Y = 0 or 1)
- Perform exploratory data analysis (EDA) using visualization and SQL: identified features that affected landing outcome (e.g., launch site, payload) to include feature interactions
- Perform interactive visual analytics using Folium and Plotly Dash: used Folium to examine launch site proximities to help identify optimum location; used Dash to interactively examine launch site, booster version category, and payload relationships
- Perform predictive analysis using classification models: preprocessed data (e.g., standardized data and split into train and test subsets), used grid search method to find best hyperparameters with four classification algorithms, selected best algorithm prediction accuracy using confusion matrix

Data Collection – SpaceX API

Flowchart of SpaceX API calls

Task 0 - Import Libraries and Define Auxiliary Functions

BoosterVersion - Booster Name

Launch Site - Launch Site Name, Site Latitude, Site Longitude

PayloadData - Payload Mass, Orbit

CoreData - Landing Outcome, Landing Type, Landing Pad, additional fields with landing characteristics

Task 1 - Request and parse the SpaceX launch data using the GET request

Task 2 -Filter the dataframe to only include Falcon 9 launches

Task 3 - Conduct Data Wrangling

Identify fields with missing values

Convert missing Landing Pad values to 'None'

Convert missing PayloadMass values to Average PayloadMass

https://github.com/rjohna/IBM-Capstone-for-DS/blob/master/Data%20Collection%20API.ipynb

Data Collection - Scraping

Flowchart of SpaceX Web Scraping Tasks

Task 0 - Import Required Packages
- Beautifulsoup4
- Requests
- Re, unicodedata, pandas

TASK 1- Request the Falcon9 Launch Wiki page from its URL
- Use the Requests.get method
- Use Beautifulsoup to create a beautiful object from response text content

TASK 2: Extract all column/variable names from the HTML table header
- Search all tables on the wiki page
- Identify relevant table, containing launch records
- Identify relevant column names

TASK 3: Create a data frame by parsing the launch HTML tables
- Create an empty dictionary
- Fill the dictionary with launch records extracted from table rows
- Create a dataframe from the dictionary
- Export the data frame to a csv for subsequent use

https://github.com/rjohna/IBM-Capstone-for-DS/blob/master/Data%20Collection%20-%20Web%20Scraping.ipynb

Data Wrangling

Flowchart of Data Wrangling Tasks

Task 0 - Import Libraries, Define Auxiliary Functions, Conduct Initial Data Analysis

Pandas

Numpy

Initial Data Analysis: create dataframe from csv, check missing values, data types

TASK 1: Calculate the number of launches on each site

TASK 2: Calculate the number and occurrence of each orbit

TASK 3: Calculate the number and occurence of mission outcome per orbit type

TASK 4: Create a landing outcome label from Outcome column

https://github.com/rjohna/IBM-Capstone-for-DS/blob/5848ce40a1c508da620c4bf93e45b1ccc85dfc38/EDA.ipynb

EDA with Data Visualization

Summary of Charts Plotted and Why They Were Used

Scatterplot: Flight # vs Payload Mass, Colored by Launch Outcome
- Is there a relationship between Flight # and Launch Outcome?
- Is there a relationship between Payload Mass and Launch Outcome?
- Is there a relationship between Flight # and Payload Mass with respect to Launch Outcome?

Scatterplot: Flight # vs Launch Site, Colored by Launch Outcome
- Is there a relationship between Launch Site and Launch Outcome?
- Is there a relationship between Flight # and Launch Site with respect to Launch Outcome?

Scatterplot: Payload Mass vs Launch Site, Colored by Launch Outcome
- Is there a relationship between Payload Mass and Launch Site with respect to Launch Outcome?

Barchart: Orbit Type and Mean Launch Outcome
- Which orbits have a high success rate?

Scatterplot: Flight # vs Orbit Type, Colored by Launch Outcome
- Is there a relationship between Orbit type and Launch Outcome?
- Is there a relationship between Flight # and Orbit Type with respect to Launch Outcome?

Scatterplot: Orbit Type vs Payload Mass, Colored by Launch Outcome
- Is there a relationship between Orbit Type and Payload Mass with respect to Launch Outcome?

Linechart: Year vs Mean Launch Outcome
- What is the annual trend for average success rate?

https://github.com/rjohna/IBM-Capstone-for-DS/blob/master/EDA%20with%20Visualization.ipynb

EDA with SQL

For SQL EDA we performed the following queries

- All launch site names
- Cape Canaveral launch sites
- Total payload mass for NASA customers
- Average payload mass for Booster Version F9 v1.1
- First successful ground landing date
- Successful drone ship landing with payload between 4000 and 6000 Kg
- Total number of successful and failure mission outcomes
- Boosters that carried the maximum payload
- 2015 launch records
- Rank landing outcomes between 2010-06-04 and 2017-03-20

Note: in spite of dialogue with Coursera and IBM I was unable to resolve recent Service Credential issues with IBM DB2 (credentials worked for me previously). So, rather than accessing DB2 remotely, I performed these queries by directly accessing DB2. The referenced Jupyter notebook reflects that situation.

https://github.com/rjohna/IBM-Capstone-for-DS/blob/master/EDA%20with%20SQL%20Lite.ipynb

Build an Interactive Map with Folium

We wanted to show maps with circles and labels to identify the launch sites, markers to show launch outcomes, and lines to show proximity to local features such as highways

https://github.com/rjohna/IBM-Capstone-for-DS/blob/master/Visual%20Analytics%20with%20Folium.ipynb

Build a Dashboard with Plotly Dash

Success Pie Chart

We wanted to see which of four launch sites had the largest success count and then its detailed success rate
We developed a success pie chart with a dropdown interaction to look at all sites or selected sites
With dropdown selected to all sites we identified the launch site with the largest percentage of successful launches
Using the dropdown we selected the launch site with the largest percentage of successful launches
Then we checked its detailed success rate (percentage of launches that are successful)

Scatterplot: Payload Mass vs Launch Outcome, Colored by Booster Version

We built a scatter plot with the x axis to be the payload and the y axis to be the launch outcome
Each data point was marked or colored by Booster Version (v1.0, v1.1,FT, B4, B5)
We wanted to visually observe how payload may be correlated to mission outcomes for selected sites
We added a slider interaction that allows us to filter to an interval of payload mass
With this arrangement we could determine payload intervals with highest launch success rate and lowest launch success rate
We could also determine which Falcon 9 Booster Version has the highest launch success rate

Note: another technical difficulty; in spite of dialogue with Coursera I am unable to access the IBM Skills Network Lab and my Plotly Dash project. I routinely use SN Labs and had completed the Dash project a few weeks back. I was able to successfully launch the dashboard, but there was some inconsistency and instability in the launching. So, I wanted to review my code one more time before submitting the Final Report and held off on submitting to GitHub. So, now I do not have a GitHub link for this section.

Predictive Analysis (Classification)

Preparation

Imported Pandas, Numpy, Matplotlib, Seaborn, Sklearn and classification algorithms

Read data into dataframe and review

Created Labels Array (Y), create Features Array (X), and standardized X

Created a Train Set and Test Set

Classification - Logistic Regression

Created a Logistic Regression Object

Fit the model against Train Set data and predicted Yhat against the Test Set data

Applied Cross Validation Grid Search against multiple LR parameters to find the best hyperparameter set

Classification - Remaining Algorithms

Followed similar process with Support Vector, Decision Tree, and K-Nearest Neighbor classification algorithms

Determined which Classification Algorithm performed with best prediction accuracy

Used F1 and Jaccard accuracy statistics

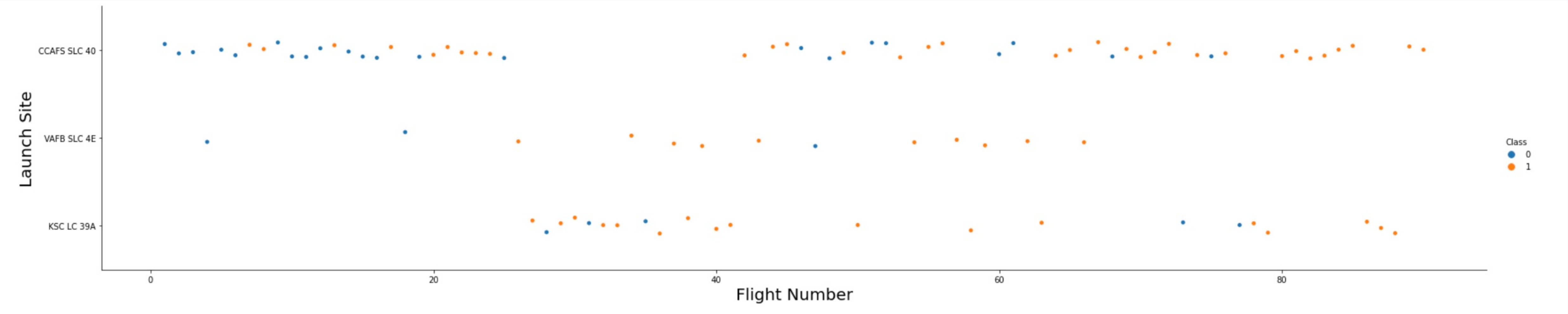
Used Confusion Matrix

https://github.com/rjohna/IBM-Capstone-for-DS/blob/master/Machine%20Learning%20Prediction.ipynb

Section 2

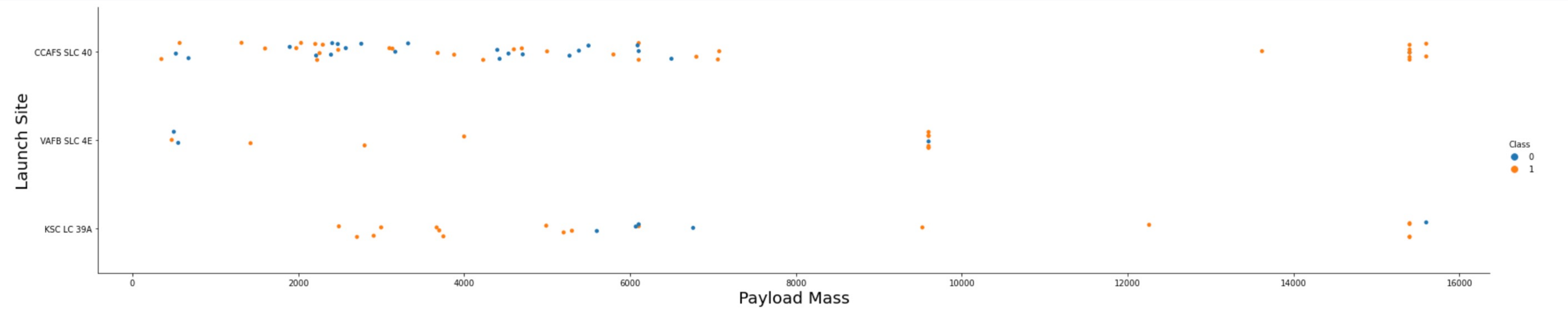
Insights drawn from EDA

Flight Number vs. Launch Site



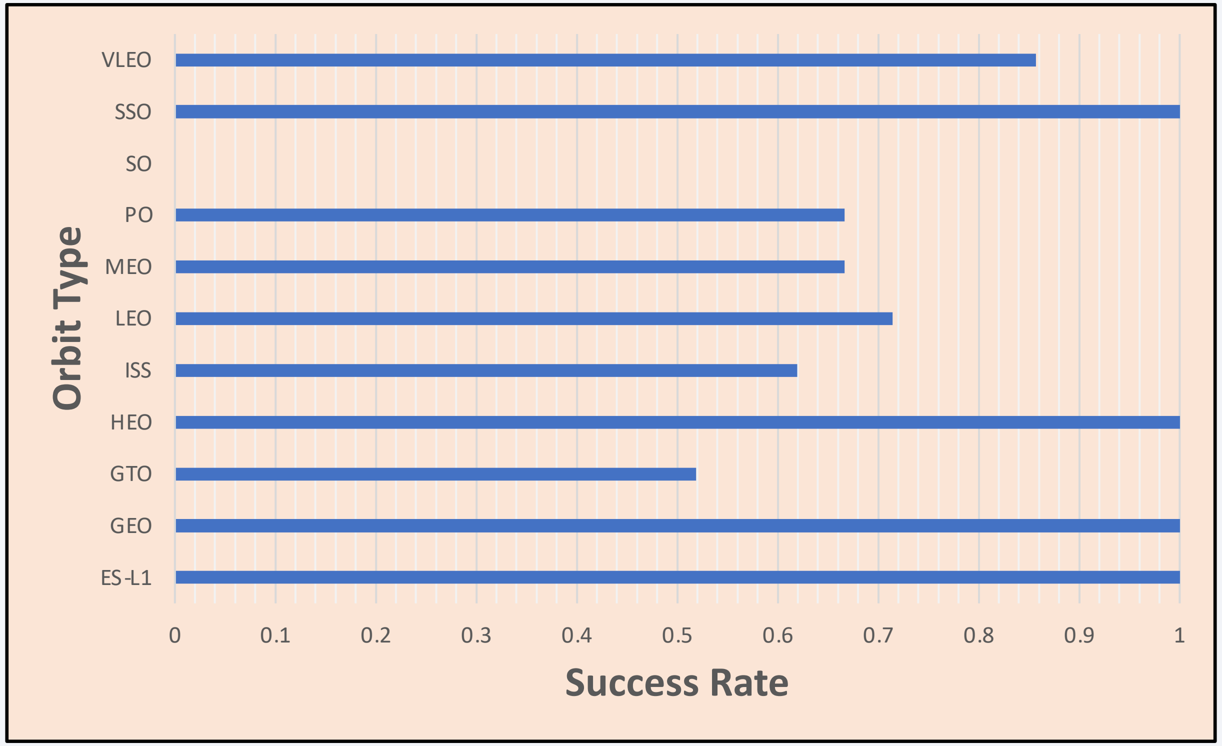
- Cape Canaveral Space Launch Complex 40 had a tight group of launches toward the beginning of the test period with 9 of 23 launches successful (39%); a second tight group toward the end of the test period showed improvement with of 24 of 32 launches successful (75%)
- Vandenberg Space Launch Complex 4 had a lower number of launches generally spread from the beginning thru middle portions of the test period; 10 of 13 launches were successful (77%)
- Kennedy Space Center Launch Complex 39 had 22 launches roughly in the last two thirds of the test period with 17 successful (77%)
- So, success rates generally appear to improve over time with the later group of Cape Canaveral launches, Vandenberg launches, and Kennedy Space Center Launches having a similar success rate (75-77%)

Payload vs. Launch Site



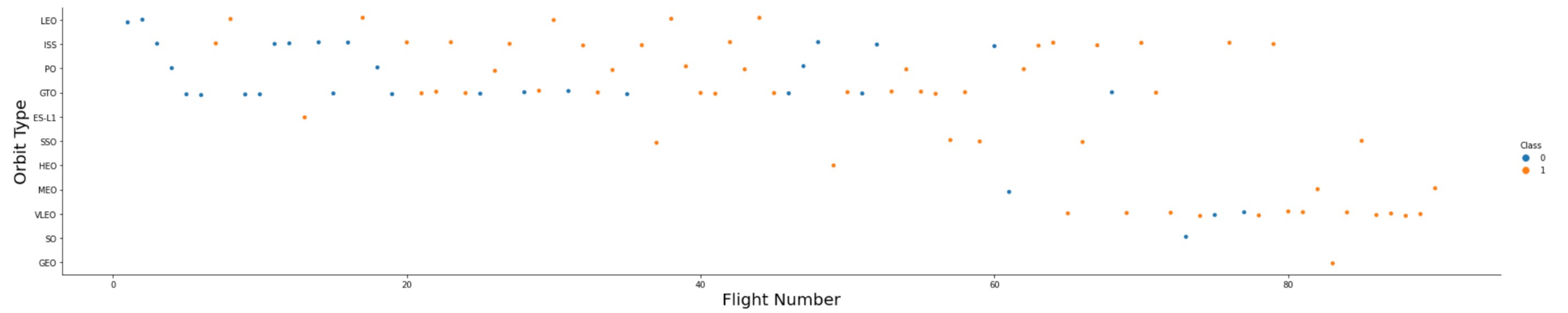
- Cape Canaveral Space Launch Complex 40 had most launches with Payload Mass less than 8,000 Kg with roughly half of these successful; there were 5 launches with Payload Mass greater than 13,000 Kg and all of these were successful
- Vandenberg Space Launch Complex 4 did not have any launches with Payload Mass greater than 10,000 Kg
- Kennedy Space Center Launch Complex 39 had launches with Payload Mass between 2,000 and 16,000 Kg with no particular trend with Payload Mass

Success Rate vs. Orbit Type



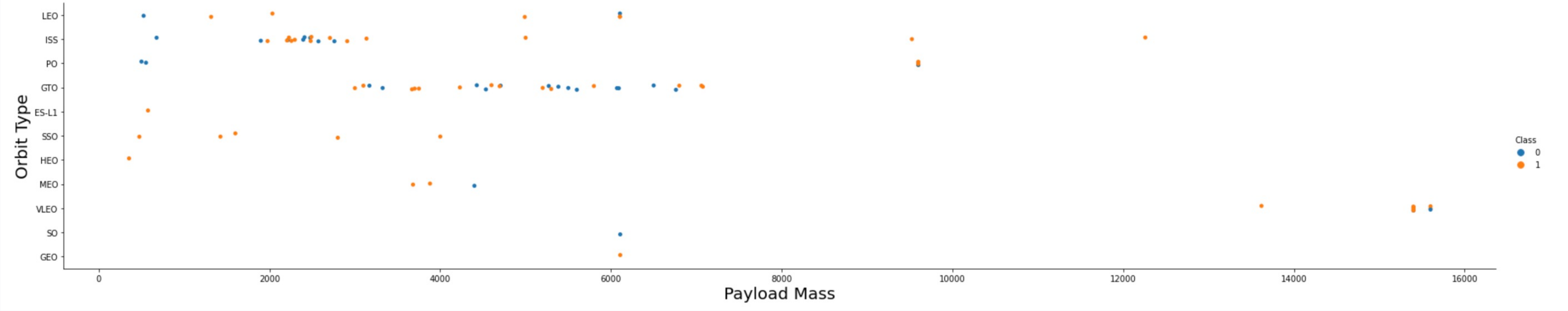
- Use of orbits with the highest success rate include Sun-synchronous Orbit (SSO), Highly Elliptical Orbit (HEO), Circular Geosynchronous Orbit (GEO), and Sun Earth Lagrange Point (ES-L1), all at 100%
- Use of the Very Low Earth Orbit (VLEO) was also relatively highly successful at 86%

Flight Number vs. Orbit Type



- LEO, ISS, PO, and GTO orbits generally were used across the test period
- The use of remaining orbits generally occurred towards the end of the test period
- In 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 and other orbits

Payload vs. Orbit Type



- With heavier Payload Mass the successful landings favor International Space Station (ISS), Polar (PO), and Very Low Earth Orbit (VLEO)
- We do not see a relationship between Orbits and successful launches for the lower Payload Mass

Launch Success Yearly Trend

Average launch success rates have generally improved across the test years

All Launch Site Names

```sql
select distinct launch_site from spacextbl;
```

Result set 1

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

- There are four distinct Launch Sites addressed in this study

Launch Site Names Begin with 'CCA'

```
select date, launch_site, payload from spacextbl where launch_site like 'CCA%' limit 5;
```

Result set 1

DATE	LAUNCH_SITE	PAYLOAD
2010-06-04	CCAFS LC-40	Dragon Spacecraft Qualification Unit
2010-12-08	CCAFS LC-40	Dragon demo flight C1, two CubeSats, barrel of Brouere cheese
2012-05-22	CCAFS LC-40	Dragon demo flight C2
2012-10-08	CCAFS LC-40	SpaceX CRS-1
2013-03-01	CCAFS LC-40	SpaceX CRS-2

SQL shows 5 Cape Canaveral Launch Site records, where Launch Site Names begin with CCA

Total Payload Mass

```sql
select sum (payload_mass__kg_) from spacextbl where customer like '%NASA%';
```

Result set 1
1
107010

SQL code to calculate to total payload mass where the customer field contained NASA

Average Payload Mass by F9 v1.1

```sql
select avg (payload_mass__kg_) from spacextbl where booster_version like 'F9 v1.1%';
```

Result set 1
1
2534

SQL code to calculate average payload mass for booster version F9 v1.1

First Successful Ground Landing Date

```sql
select min (date) from spacextbl where landing__outcome like 'Success (ground pad%';
```

Result set 1
1
2015-12-22

SQL code finds the first or minimum date for successful landing outcomes on ground pads

Successful Drone Ship Landing with Payload between 4000 and 6000

```sql
select booster_version from spacextbl
where landing__outcome like 'Success (drone ship)'
and payload_mass__kg_ between 4000 and 6000;
```

Result set 1

BOOSTER_VERSION
F9 FT B1022
F9 FT B1026
F9 FT B1021.2
F9 FT B1031.2

SQL list the booster version which successfully landed on a drone ship and had payload mass greater than 4000 but less than 6000

Total Number of Successful and Failure Mission Outcomes

```sql
select count (date), Mission_Outcome from spacextbl Group By Mission_Outcome;
```

Result set 1

1	MISSION_OUTCOME
1	Failure (in flight)
99	Success
1	Success (payload status unclear)

SQL code determines total number of successful and failure mission outcomes; would infer 100 successes

Boosters Carried Maximum Payload

```
select max (payload_mass__kg_), Booster_version
from spacextbl
Group By Booster_version
Order by avg(payload_mass__kg_) desc limit 13;
```

SQL code lists max payload for boosters; there are twelve boosters that have carried the max payload of 15,600 kg

Result set 1

1	BOOSTER_VERSION
15600	F9 B5 B1048.4
15600	F9 B5 B1060.3
15600	F9 B5 B1060.2
15600	F9 B5 B1058.3
15600	F9 B5 B1056.4
15600	F9 B5 B1051.6
15600	F9 B5 B1051.4
15600	F9 B5 B1051.3
15600	F9 B5 B1049.7
15600	F9 B5 B1049.5
15600	F9 B5 B1049.4
15600	F9 B5 B1048.5
15440	F9 B5 B1049.6

2015 Launch Records

```
select date, landing__outcome, Booster_version, launch_site
from spacextbl
where date like '2015%'
and landing__outcome like 'Failure (drone ship)';
```

Result set 1

Find

DATE	LANDING__OUTCOME	BOOSTER_VERSION	LAUNCH_SITE
2015-01-10	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
2015-04-14	Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40

SQL code lists failed landing_outcomes in drone ship, their booster versions, and launch site names in year 2015

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

```
select count (launch_site), landing__outcome
from spacextbl
where date between '2010-06-04' and '2017-03-20'
group by landing__outcome
order by count (launch_site) desc;
```

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

SQL code ranks count of landing outcomes between the date 2010-06-04 and 2017-03-20, in descending order

Section 3

Launch Sites Proximities Analysis

All Launch Sites

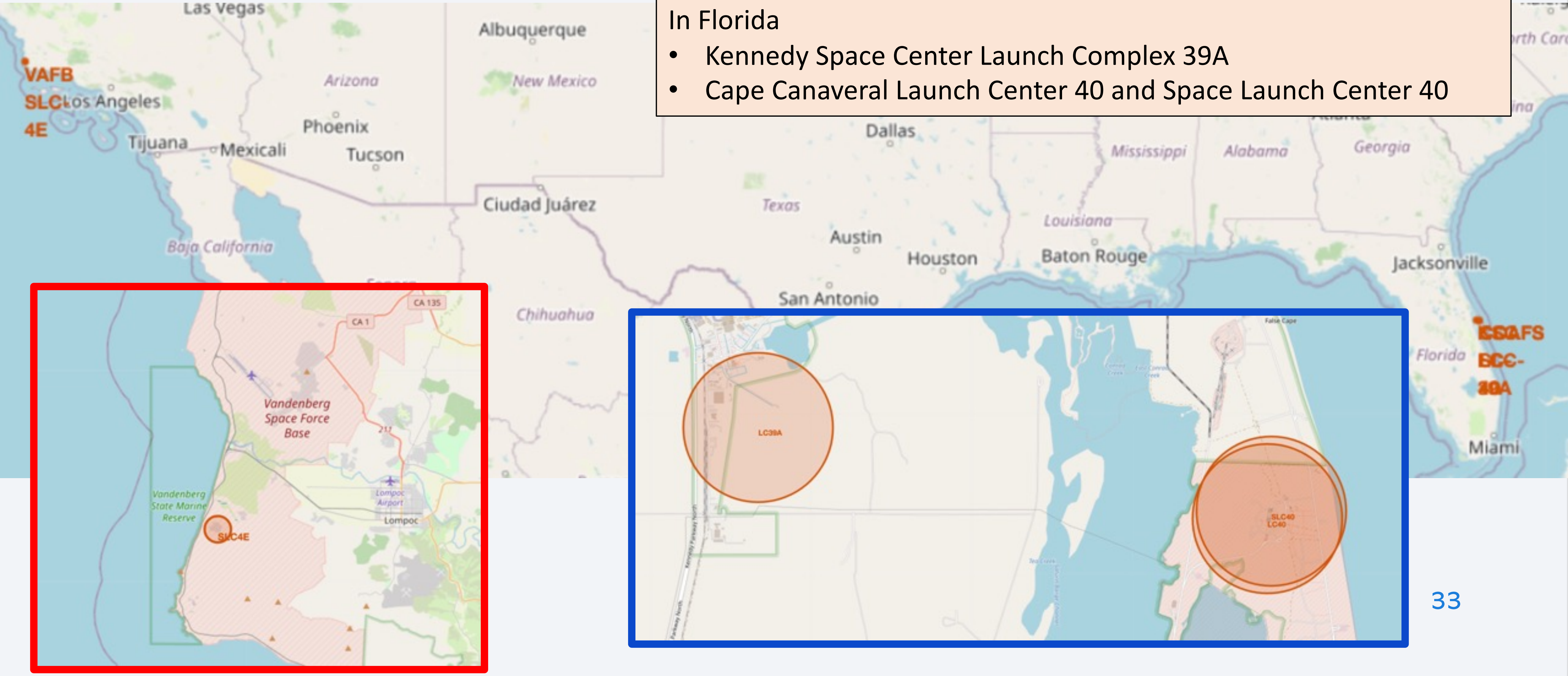
Maps show

In California

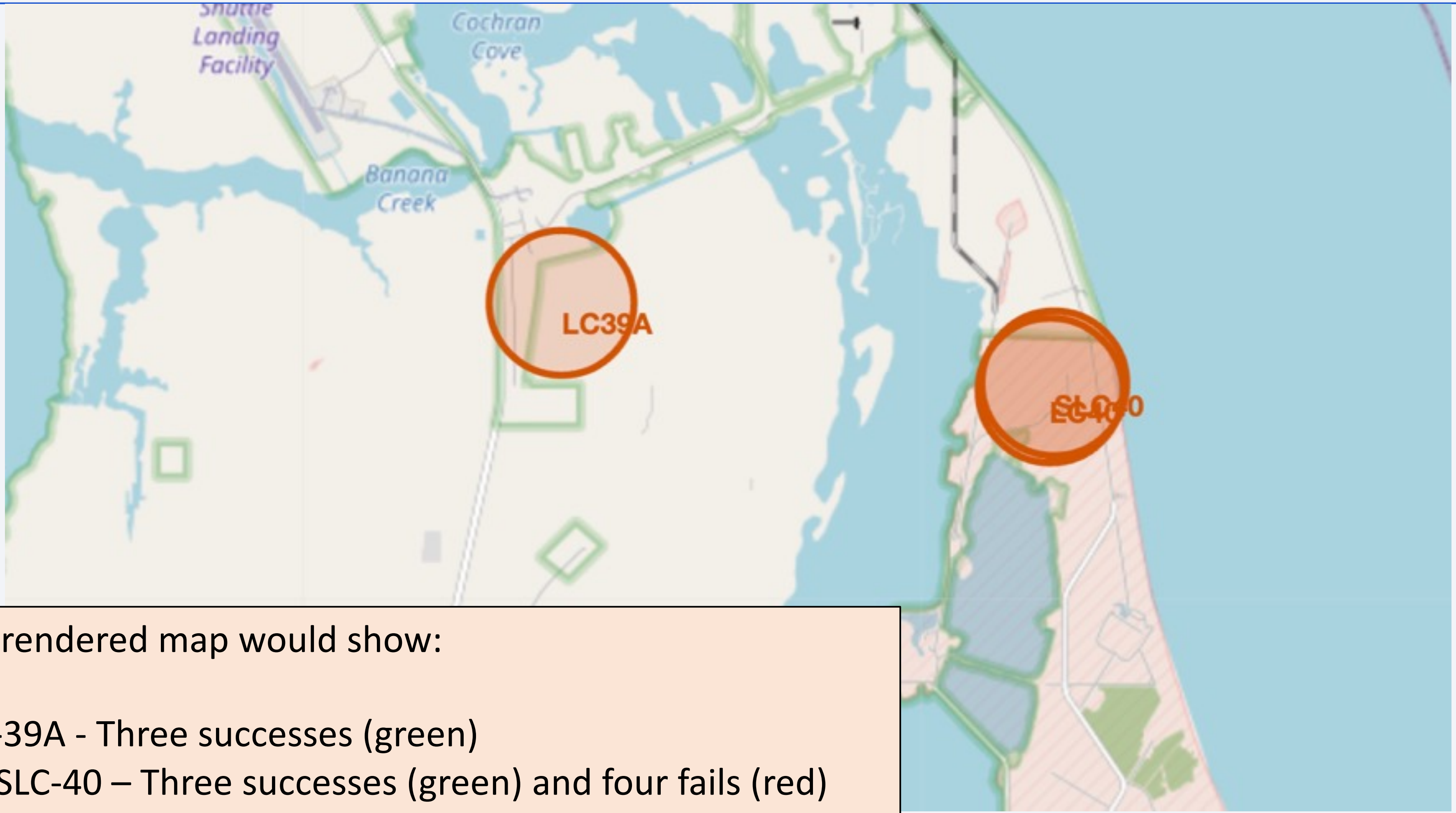
- Vandenberg Space Launch Complex 4E

In Florida

- Kennedy Space Center Launch Complex 39A
- Cape Canaveral Launch Center 40 and Space Launch Center 40



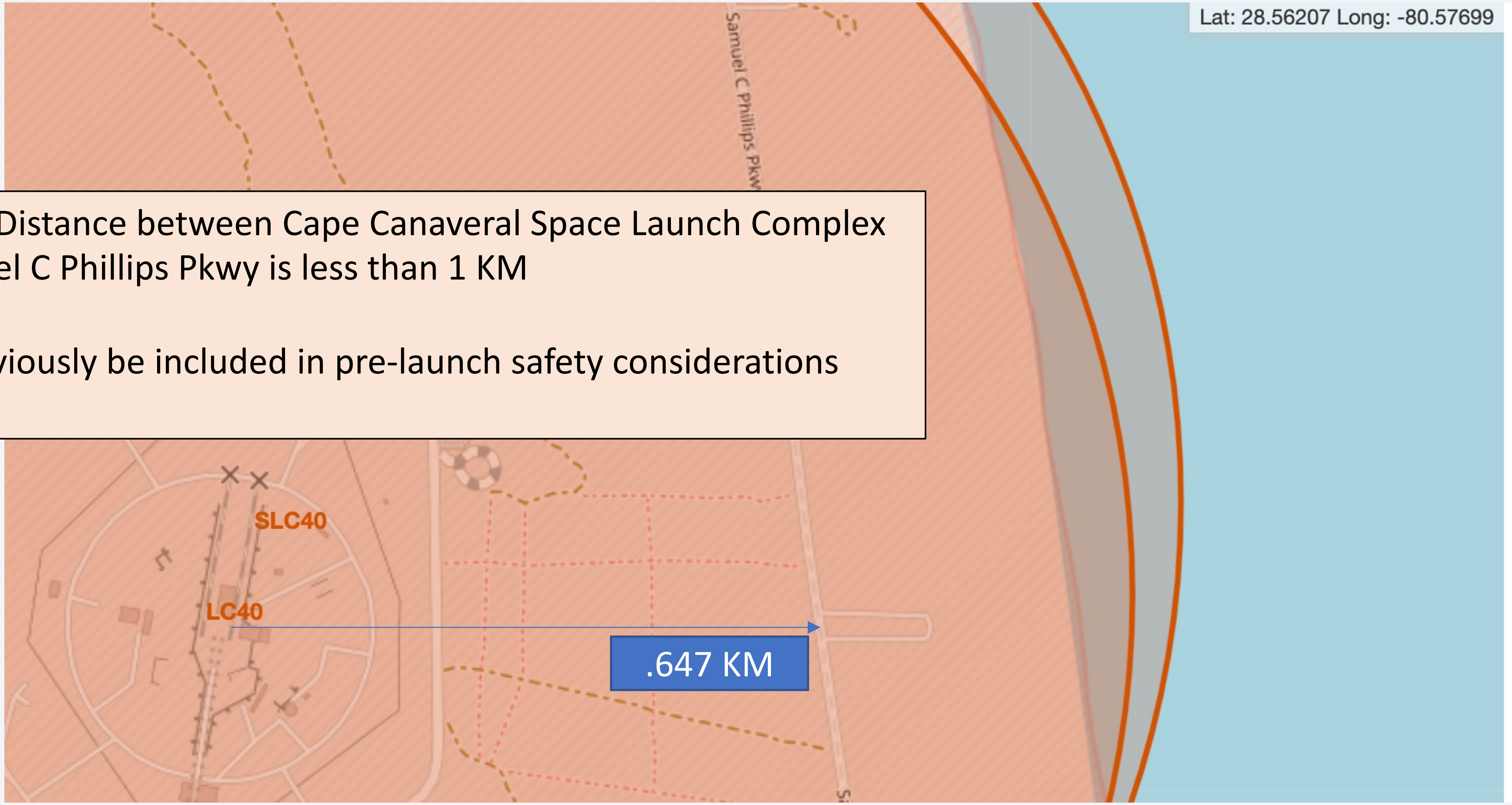
Launch Outcomes



A properly rendered map would show:

For KSC LC-39A - Three successes (green)
For CCAFS SLC-40 – Three successes (green) and four fails (red)

Launch Site Proximities



Straight Line Distance between Cape Canaveral Space Launch Complex 40 and Samuel C Phillips Pkwy is less than 1 KM

This must obviously be included in pre-launch safety considerations

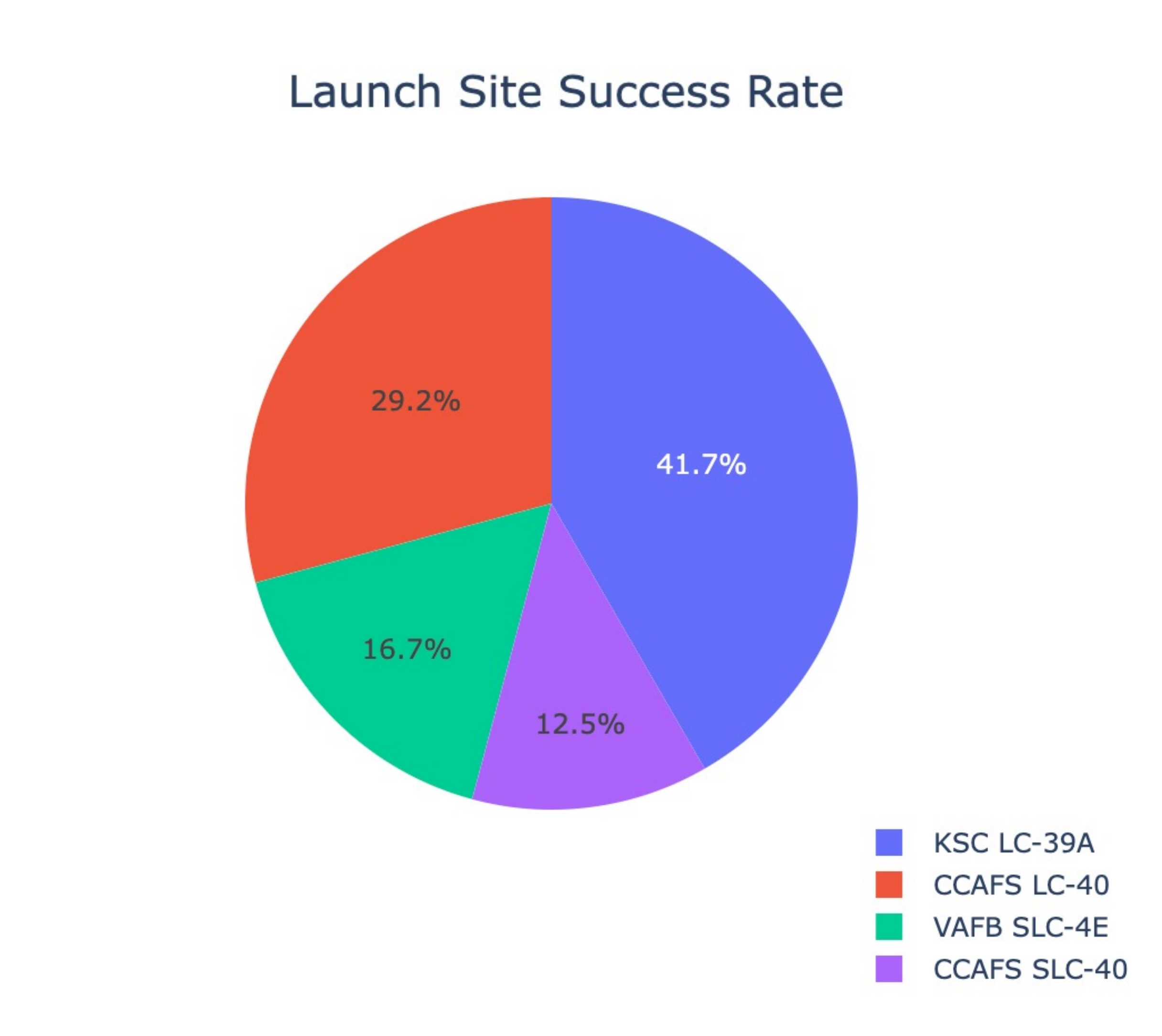
Section 4

Build a Dashboard with Plotly Dash

Launch Site Success Rate for All Sites

This chart examines successful landing outcomes and breaks them down by associated launch sites.

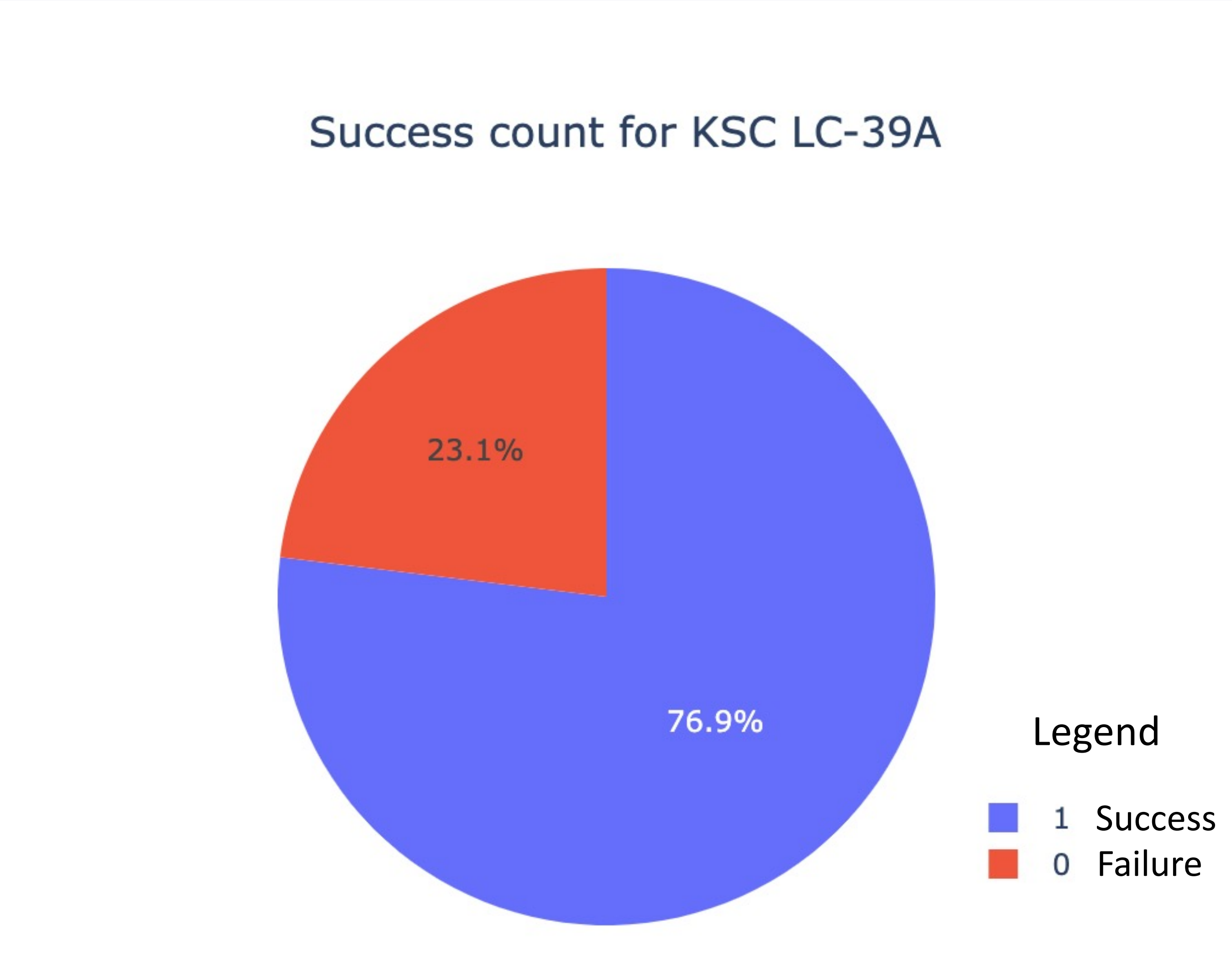
- Kennedy Space Center Launch Complex 39A had the highest percentage of the successful launch outcomes, with 41.7% (10 of 24)
- The lowest percentage of successful launch outcomes was attributed to Cape Canaveral Space Launch Center 40 with 12.5% (3 of 24)



Launch Site with Highest Launch Success Ratio

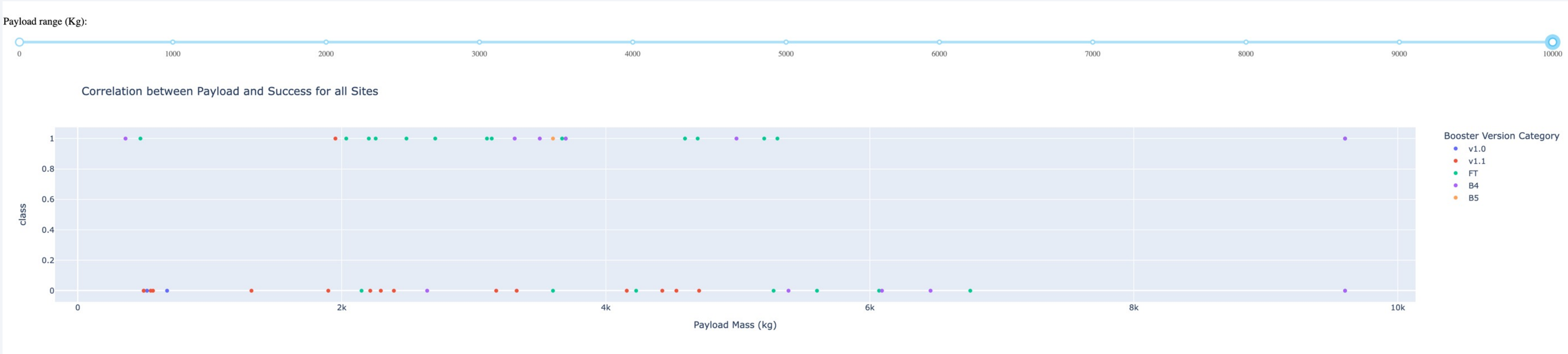
This chart examines launches from Kennedy Space Center Launch Complex 39A and breaks down launch outcomes by Success and Failure.

- The breakout of successful launch outcomes, was 76.9% (10 of 13)
- This resulted in Kennedy Space Center Launch Complex 39A having the highest launch success ratio



Payload vs. Launch Outcome – Overall Findings

This chart accounts for launches from all sites and payload ranges, with each launch labeled with a color-coded Booster Version Category. The x-axis shows the range of Payload Mass in kilograms (kg) and the y-axis shows launch outcomes, where Class of 1 indicates a successful launch outcome and Class of 0 indicates a failed launch outcome.



- Most launches occur with Payload Mass ranging from 500 to 6000 kg
- The majority of successful launch outcomes occur with Payload Mass ranging from 2000 to 6000 kg
- The FT Booster Version Category had the most successful launch outcomes, followed by the B4
- In this Payload Mass range (2000 – 6000 kg) the percentage of launch outcomes that were successful is 53% (17 of 32)

Payload vs. Launch Outcome - Lower Range of Payload Mass

This chart accounts for launches with Payload Mass less than 2000 kg.

- There were ten launches with payloads less than 2000 kg
- Three successful launches included Booster Version Categories of FT, B4 and v1.1
- Seven failed launches included Booster Version Categories of v1.0 and v1.1
- In this Payload Mass range the resulting percentage of launch outcomes that were successful is 30%

Payload vs. Launch Outcome - Higher Range of Payload Mass

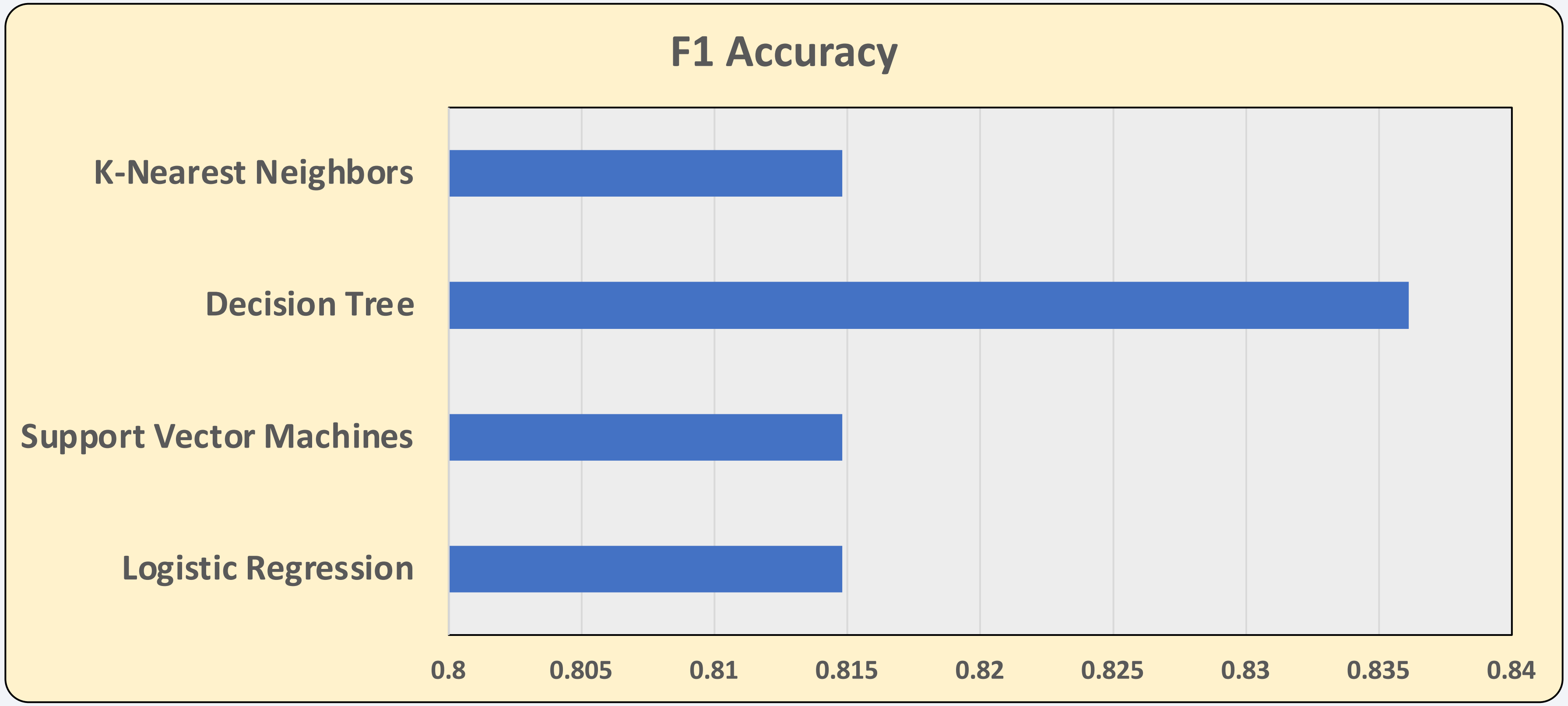
This chart accounts for launches with Payload Mass greater than 6000 kg.

- There were six launches with payloads greater than 6000 kg
- There was one successful launch with a B4 Booster Version Category
- The other five launches failed with Booster Version Categories of B4 and FT
- In this Payload Mass range the resulting percentage of launch outcomes that were successful is 17%

Section 5

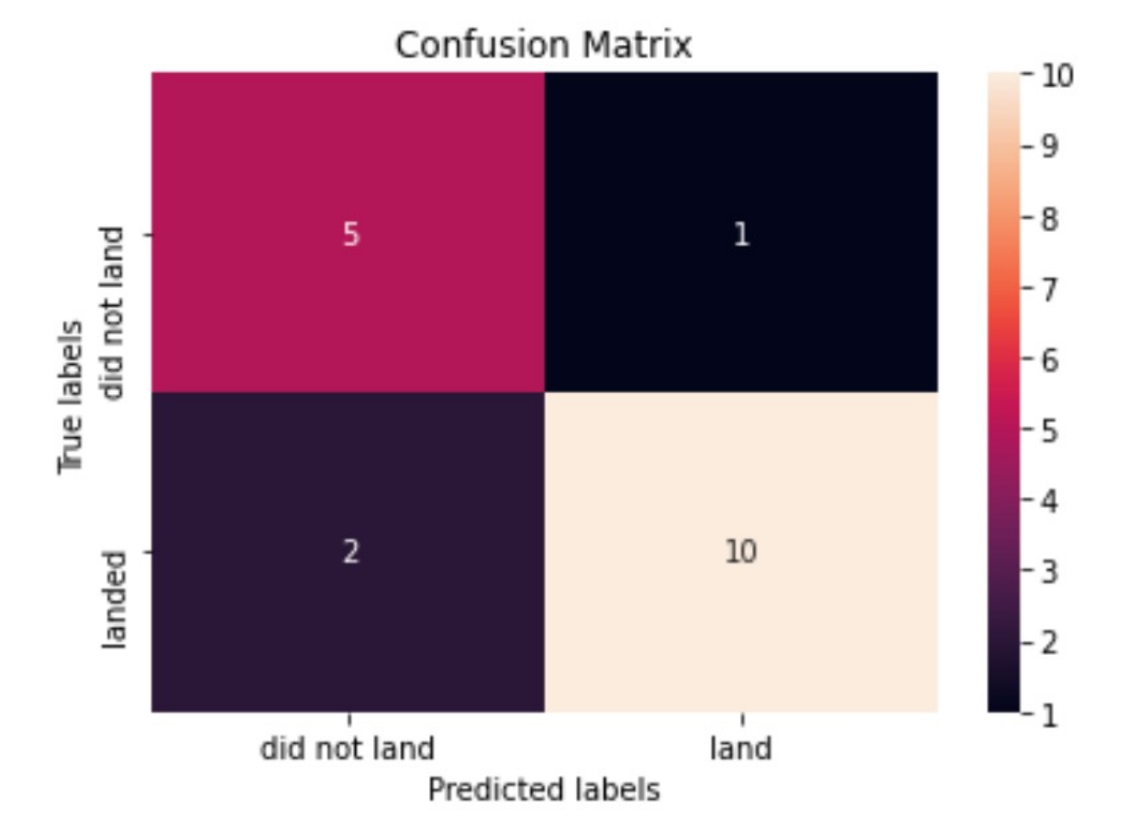
Predictive Analysis (Classification)

Classification Accuracy



- The Decision Tree classification method had the best accuracy
- Decision Tree F1 score of .836 versus a score of .815 for the other three methods

Confusion Matrix From the Decision Tree Model



- The Decision Tree classification method correctly predicted 10 of the 12 ‘landed results’ (83.3%)
- The method correctly predicted 5 of the 6 ‘did not land’ results (83.3%

Results - EDA and Predictive Analysis

- Exploratory data analysis – identified relationships (main effects and interactions) with several variables to help develop the features data set for classification (e.g., Landing Outcomes and Success, Launch Site, Payload, Orbit, Booster Version, Landing Pad); in particular:
  - Orbits with highest launch success include Sun Synchronous Orbit (SSO), Highly Elliptical Orbit (HEO), Geosynchronous Orbit (GEO), and Earth Sun Lagrange Point (ES-L1), all at 100%
  - Launch success generally appears to improve over time between 2010-2020
- Predictive analysis
  - Among the four models, Decision Tree distinguishes best between the different classes, with 83.3% prediction accuracy for 'landed' results and 'did not land' results
  - The other three models had identical prediction results (100% correct 'landed' results, 50% correct 'did not land' results)

Results – Visual Analytics

- Folium visual analytics - launch sites are in close proximity to highways, rail lines and coastlines, but further in distance from cities

- Plotly Dashboard visual analytics
    - Kennedy Space Center Launch Complex 39A had the highest number of successful launches of the four launch sites in study, as well as the highest percentage of launches with successful outcomes
    - Booster Version Category FT had the highest number of successful launches of the five Booster Version categories
    - The majority of successful launch outcomes occur payload mass ranging between 2000 and 6000 Kg

Conclusions

- Use of Exploratory Data Analysis and Interactive Visual Analytics resulted in the identification of variables for the classification features data set – such as Launch Site, Payload Mass, Orbit, Booster Version, and Landing Pad
- Among the four studied classification models, Decision Tree distinguished best between the different classes, with 83.3% prediction accuracy for ‘landed’ results and ‘did not land’ results
- Given the presented launch data, yes, using EDA and Predictive Analysis, we can predict whether the Falcon 9 first stage will land successfully

Appendix

This appendix shows a few relevant assets created during this project (e.g., data sets)

Appendix 1 – Initial Launch Data Set

	FlightNumber	Date	BoosterVersion	PayloadMass	Orbit	LaunchSite	Outcome	Flights	GridFins	Reused	Legs	LandingPad	Block	ReusedCount	Serial	Longitude	Latitude
0	1	2010-06-04	Falcon 9	6104.959412	LEO	CCAFS SLC 40	None None	1	False	False	False	NaN	1.0	0	B0003	-80.577366	28.561857
1	2	2012-05-22	Falcon 9	525.000000	LEO	CCAFS SLC 40	None None	1	False	False	False	NaN	1.0	0	B0005	-80.577366	28.561857
2	3	2013-03-01	Falcon 9	677.000000	ISS	CCAFS SLC 40	None None	1	False	False	False	NaN	1.0	0	B0007	-80.577366	28.561857
3	4	2013-09-29	Falcon 9	500.000000	PO	VAFB SLC 4E	False Ocean	1	False	False	False	NaN	1.0	0	B1003	-120.610829	34.632093
4	5	2013-12-03	Falcon 9	3170.000000	GTO	CCAFS SLC 40	None None	1	False	False	False	NaN	1.0	0	B1004	-80.577366	28.561857
5	6	2014-01-06	Falcon 9	3325.000000	GTO	CCAFS SLC 40	None None	1	False	False	False	NaN	1.0	0	B1005	-80.577366	28.561857
6	7	2014-04-18	Falcon 9	2296.000000	ISS	CCAFS SLC 40	True Ocean	1	False	False	True	NaN	1.0	0	B1006	-80.577366	28.561857
7	8	2014-07-14	Falcon 9	1316.000000	LEO	CCAFS SLC 40	True Ocean	1	False	False	True	NaN	1.0	0	B1007	-80.577366	28.561857
8	9	2014-08-05	Falcon 9	4535.000000	GTO	CCAFS SLC 40	None None	1	False	False	False	NaN	1.0	0	B1008	-80.577366	28.561857
9	10	2014-09-07	Falcon 9	4428.000000	GTO	CCAFS SLC 40	None None	1	False	False	False	NaN	1.0	0	B1011	-80.577366	28.561857

- Shows first 10 records of the initial launch data set prior to data wrangling

Appendix 2 – Launch Site Locations and Success Indicator

	Launch Site	Lat	Long	class	marker_color
46	KSC LC-39A	28.573255	-80.646895	1	green
47	KSC LC-39A	28.573255	-80.646895	1	green
48	KSC LC-39A	28.573255	-80.646895	1	green
49	CCAFS SLC-40	28.563197	-80.576820	1	green
50	CCAFS SLC-40	28.563197	-80.576820	1	green
51	CCAFS SLC-40	28.563197	-80.576820	0	red
52	CCAFS SLC-40	28.563197	-80.576820	0	red
53	CCAFS SLC-40	28.563197	-80.576820	0	red
54	CCAFS SLC-40	28.563197	-80.576820	1	green
55	CCAFS SLC-40	28.563197	-80.576820	0	red

- Shows Launch Site locations, success indicator and color marker for the Folium maps

Appendix 3 – Classification – Features Data Set

```
In [6]: X.columns

Out[6]: Index(['FlightNumber', 'PayloadMass', 'Flights', 'Block', 'ReusedCount',
               'Orbit_ES-L1', 'Orbit_GEO', 'Orbit_GTO', 'Orbit_HEO', 'Orbit_ISS',
               'Orbit_LEO', 'Orbit_MEO', 'Orbit_PO', 'Orbit_SO', 'Orbit_SSO',
               'Orbit_VLEO', 'LaunchSite_CCAFS SLC 40', 'LaunchSite_KSC LC 39A',
               'LaunchSite_VAFB SLC 4E', 'LandingPad_5e9e3032383ecb267a34e7c7',
               'LandingPad_5e9e3032383ecb554034e7c9',
               'LandingPad_5e9e3032383ecb6bb234e7ca',
               'LandingPad_5e9e3032383ecb761634e7cb',
               'LandingPad_5e9e3033383ecbb9e534e7cc', 'Serial_B0003', 'Serial_B0005',
               'Serial_B0007', 'Serial_B1003', 'Serial_B1004', 'Serial_B1005',
               'Serial_B1006', 'Serial_B1007', 'Serial_B1008', 'Serial_B1010',
               'Serial_B1011', 'Serial_B1012', 'Serial_B1013', 'Serial_B1015',
               'Serial_B1016', 'Serial_B1017', 'Serial_B1018', 'Serial_B1019',
               'Serial_B1020', 'Serial_B1021', 'Serial_B1022', 'Serial_B1023',
               'Serial_B1025', 'Serial_B1026', 'Serial_B1028', 'Serial_B1029',
               'Serial_B1030', 'Serial_B1031', 'Serial_B1032', 'Serial_B1034',
               'Serial_B1035', 'Serial_B1036', 'Serial_B1037', 'Serial_B1038',
               'Serial_B1039', 'Serial_B1040', 'Serial_B1041', 'Serial_B1042',
               'Serial_B1043', 'Serial_B1044', 'Serial_B1045', 'Serial_B1046',
               'Serial_B1047', 'Serial_B1048', 'Serial_B1049', 'Serial_B1050',
               'Serial_B1051', 'Serial_B1054', 'Serial_B1056', 'Serial_B1058',
               'Serial_B1059', 'Serial_B1060', 'Serial_B1062', 'GridFins_False',
               'GridFins_True', 'Reused_False', 'Reused_True', 'Legs_False',
               'Legs_True'],
              dtype='object')
```


Shows columns in the features data set for machine learning launch outcome prediction

Thank you!