IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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Outline

Executive Summary

- The mission cost for SpaceX launches is materially affected by the likelihood of recovering the Falcon 9 booster during the mission.
- Fortunately, considerable public data are available from and about SpaceX launches and landings that might help predict booster recovery for a mission of known parameters.
- For this project, data were collected from SpaceX and public Internet sources regarding the success in landing the Falcon 9 booster and the mission parameters likely to predict such success
- Data were cleaned, standardized, and coded to support predictive analysis of a simplified success vs. Failure outcome.
- Multiple predictive models were evaluated and results were robust across models indicating a reliable message in the data.
- A wide variety of analyses were performed and reported, but for this executive summary, we focus results on our primary question how likely is booster recovery and how might we predict success.

Executive Summary: Take Home Messages

- SpaceX has become much more capable of recovering the Falcon 9 boosters with experience, and has sustained a success rate of about 80% in recent years
- Several factors are related to success rate including the type of destination orbit, amount of payload, type of booster, and nature of the landing site.
- Landing success may be predicted with about 83% accuracy, and prediction failures tend to take the form of failed landings that were expected to succeed.
- As a potential competitor, SpaceY could apply these results to identify niches in which to compete with SpaceX, develop a competitive pricing model based on customer needs (e.g., payload, orbit, etc.), perform site analysis for operational facilities, and potentially make go-no go decisions about product development based on SpaceY's capacity to exceed SpaceX performance.

Introduction

- SpaceY is a start-up company in the commercial space industry that is evaluating the potential to compete with SpaceX, a current industry leader in commercial space missions.
- SpaceX holds a key competitive advantage in mission costs due to its capacity to recover and reuse its first stage Falcon 9 booster.
- This project was tasked with finding, gathering, and analyzing data related to SpaceX missions and success in landing the Falcon 9 booster.
- The key questions that this project seeks to answer are:
  1. How successful is SpaceX at recovering the Falcon 9 booster?
  2. How well can booster recovery be predicted from mission parameters?
- Secondary goals include creating two data tools for SpaceY users to explore SpaceX information:
  - An interactive dashboard for exploration of operational parameters.
  - An interactive map for exploration of launch sites and nearby resources.

Section 1

Methodology

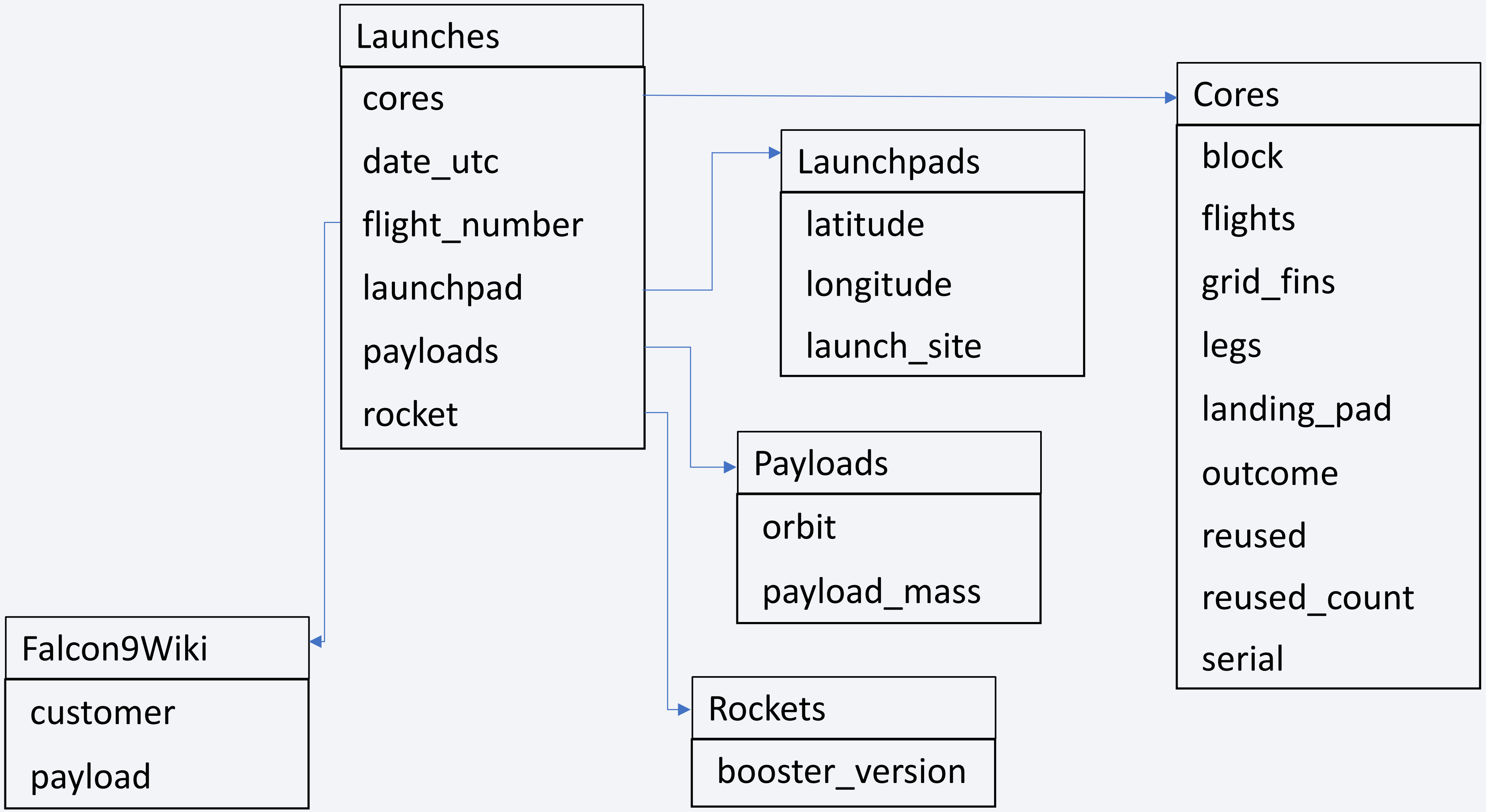
Methodology

- Data collection
    - Data for the project were gathered from the Space X public API and supplemented by a Wikipedia page detailing the Falcon 9 launch history
- Data wrangling
- Exploratory data analysis (EDA) using visualization and SQL
- Interactive visual analytics using Folium and Plotly Dash
- Predictive analysis using classification models

Data Collection

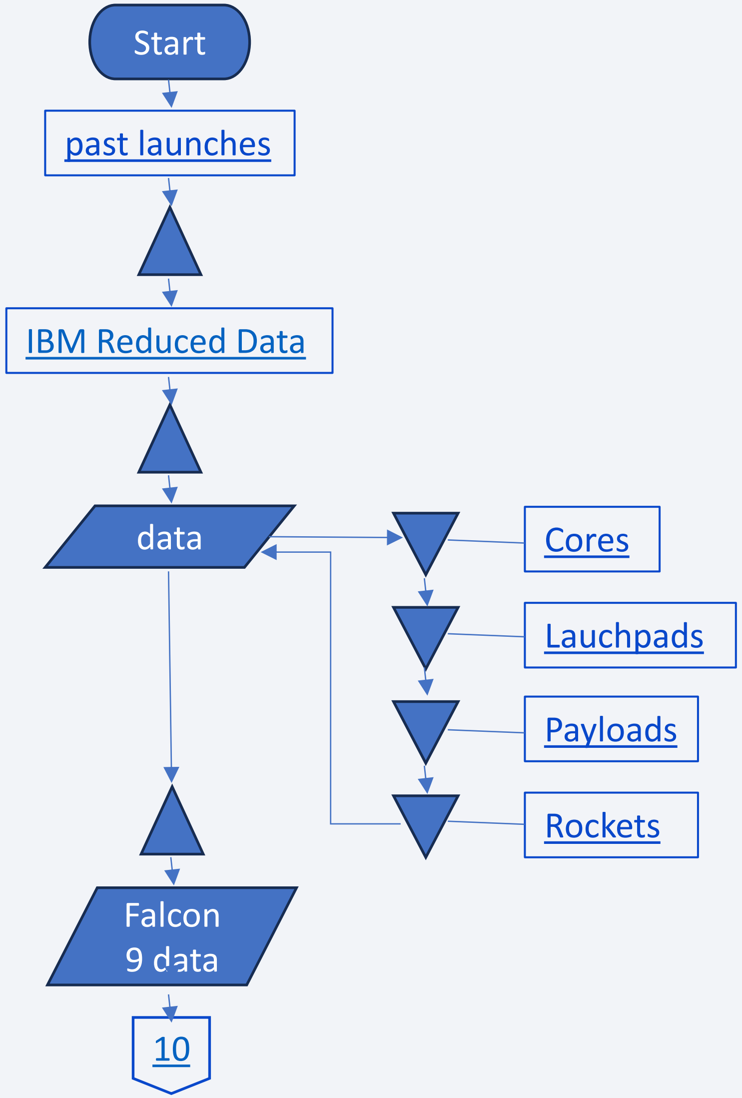
- Multiple data sets were gathered and assembled for this project
  - The primary source was the SpaceX API version 4.
    - The foundational data table was the record of past launches.
    - The launch data were enhanced with additional information from the tables of Cores, Lauchpads, Payloads, and Rockets.
  - Additional supplementary data specific to the Falcon 9 family of rockets were scraped from the Wikipedia page titled List_of_Falcon_9_and_Falcon_Heavy_launches.

Data Collection: Data Source Relations and Fields



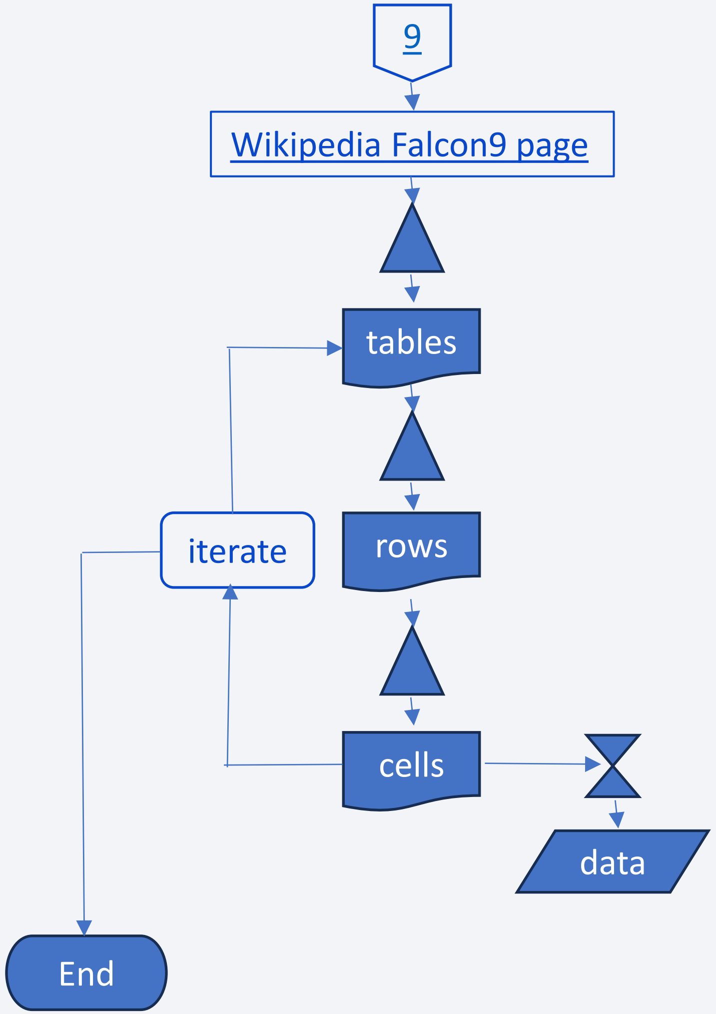
Data Collection – SpaceX API

- Begin data collection with download SpaceX data set of past launches
- Reduce data fields to a standard data set downloaded from IBM Skills Network and normalize.
- Extract fields of interest into foundational data frame.
- Merge fields of interest from api calls to Cores, Lauchpads, Payloads, and Rockets
- Reduce data set by filtering records to only include the Falcon 9 booster version
- View on GitHub



Data Collection - Scraping

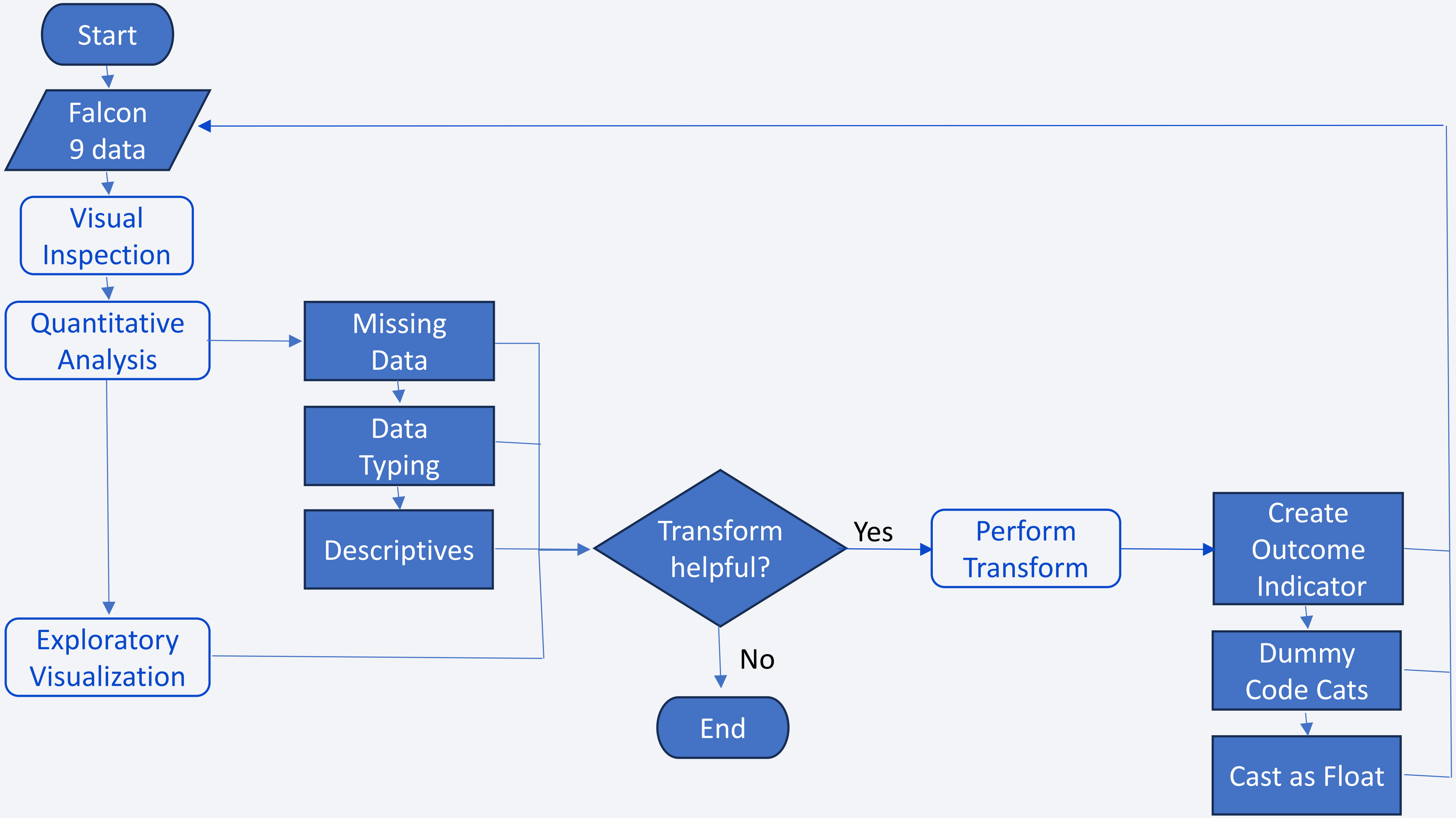
- Begin webscraping with call to [Wikipedia Falcon9 page]
- Use beautiful soup to extract all tables with plain row headers
- Iterate table rows to extract cells (i.e., td elements)
- Transform and collate cells into a dictionary with fields for flight number, launch site, payload, payload mass, orbit, customer, launch outcomes, version booster, booster landing, date, and time
- Represent dictionary as a data frame.
- View on GitHub



Data Wrangling

- Data wrangling began with visual inspection of the data.
- Quantitative analysis and exploratory visualizations were used to consider whether additional coding or transformations were appropriate to the goal of ultimately representing all features as float values.
- Quantitative analysis began with an evaluation of missing data.
  - Landing Pad was the only column containing missing values (~29%).
  - No further action was taken as this was not material to planned analyses.
- Data types were evaluated to identify categorical that quantitative features that might benefit from coding or transformation.
- Descriptive analyses were performed using value counts of categorical variables.
- Additional coding was applied to the *outcome* column, to create a *class* column as a pure indicator of the success (1) vs. failure (0) of the booster landing independent of the target location of the landing.
- View on GitHub

Data Wrangling: Process



EDA with Data Visualization

- A series of data visualizations were created to generate hypotheses about features and interactions that might be related to first stage landing success.
- Examined features were Launch Site, Payload Mass, Type of Destination Orbit, and Launch Experience as indicated by Flight Number or Year of Launch.
- Specific visualizations included:
    - Outcome by Flight Number and Launch Site
    - Outcome by Payload Mass and Launch Site
    - Outcome by Flight Number and Type of Destination Orbit
    - Outcome by Payload Mass and Type of Destination Orbit
    - Landing Success by Type of Destination Orbit
    - Landing Success by Year
- View on GitHub

Build an Interactive Map with Folium

- Geographic visualization began by creating circle markers for each of the four launch sites and placing them on a map based on their latitude and longitude.
- Launches and launch outcomes for each site were represented through the use of a marker cluster. Color coded markers with green indicating a successful launch and red indicating an unsuccessful launch were added to the cluster.
- This strategy displayed a count of the launches within the cluster at low zoom levels and as zoom level increased, launch counts were increasingly differentiated by site up to the point where colored individual launch markers were displayed for each site at a high zoom level.
- Next, a mouse position object was added to allow the user to mouse-over any position on the map and read information about the coordinate.
- Finally, using the Kennedy Space Center launch site as an example, lines (i.e., polyline objects) and text (i.e., marker with div-icon) were added to illustrate the distance between the launch site and the nearest coastline and airport.
- View on GitHub

Build a Dashboard with Plotly Dash

- A dashboard application was developed to enable a user to interactively explore data across all launch sites or for a specific site through two plots:
  1. *Landing outcome* by *launch site* were illustrated with a pie plot.
  2. The interaction of *payload mass, booster version,* and *landing outcome* by *launch site* was illustrated with a scatter plot.
- A slider control was also added to allowed the user to filter the range of the *payload mass* displayed in the scatter plot.
  - This enabled the user to "dial-in" to a specific range of interest and more closely examine the interaction of *launch outcome* and *booster version* for the selected *launch site*(s).
  - For example, if a user is planning a launch with a known *payload mass*, they could more easily inspect *booster version*s that have carried a similar mass, which sites those boosters have launched from, and whether landing success has varied across sites.
- View on GitHub

EDA with SQL

- Additional exploratory analyses were performed using SQL with data loaded into an instance of sqlite.
- The values of the launch site were inspected as were records filtered for specific sets of sites
- Total and average payload mass were examined in relation to multiple features, such as customer and booster version.
- The earliest date of a successful ground landing was determined
- The booster versions were examined to identify those that carried the maximum payload mass, and those that carried a payload mass in a desired range and yet successfully landed on a drone ship.

EDA with SQL

- With respect to outcomes,
  - Overall mission outcomes were examined.
  - Monthly drone ship landing outcomes during 2015 were also examined.
  - A frequency table of landing outcomes for the 6/2010 to 3/2017 period was also prepared.

- View on GitHub

Predictive Analysis (Classification)

- The final feature set used to predict landing success was standardized using StandardScaler class and included:

Continuous Variables
- Payload Mass
- Number of Flights
- Block
- Reused Count

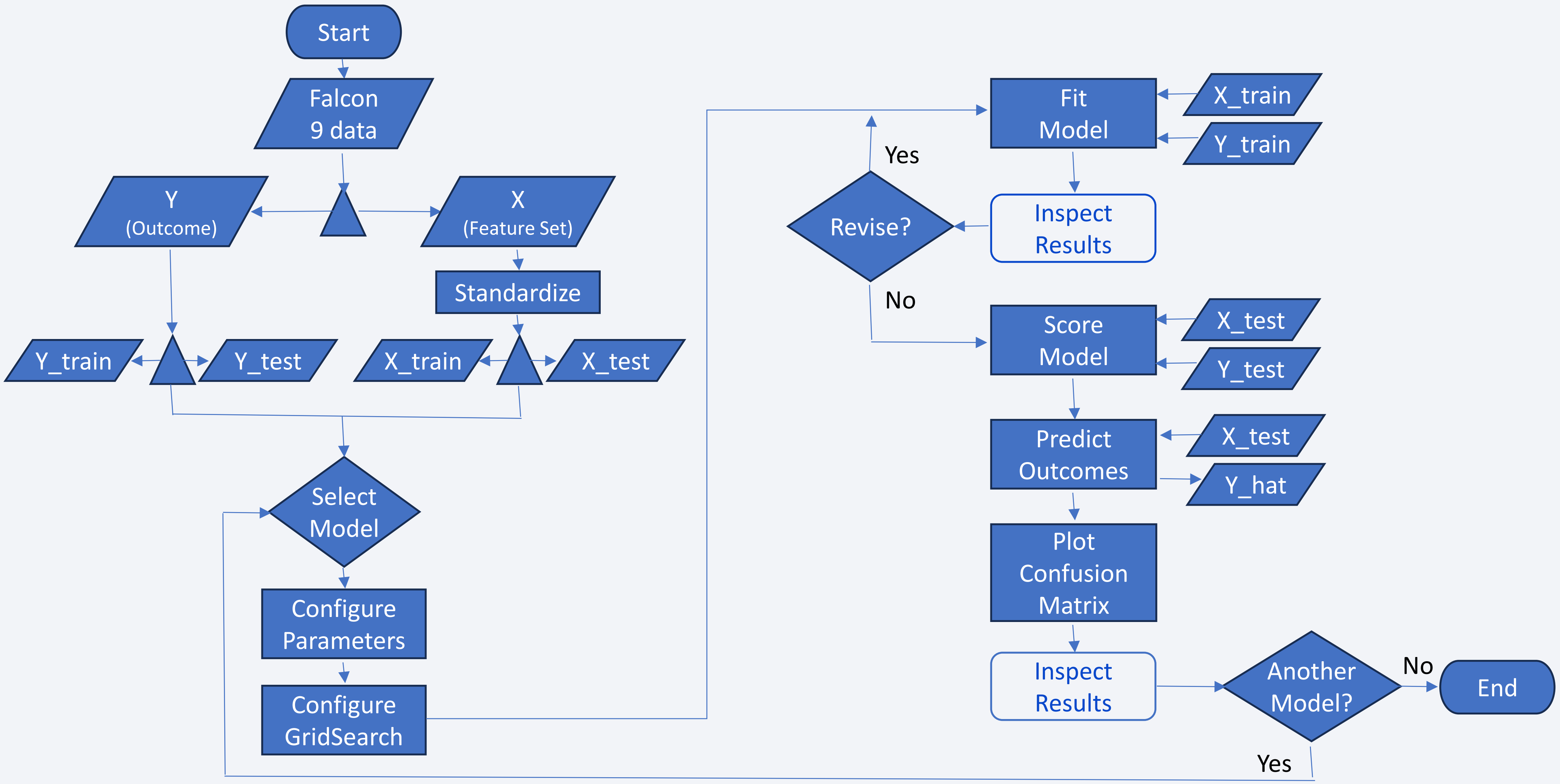
Dummy Coded Categories
- Type of Destination Orbit
- Serial Number
- Grid Fins
- Any Legs
- Any Reuse

- The outcome of interest was landing success (1) or failure (0) [i.e., the class variable]
- The train_test_split function was used to reserve 20% of the data for testing (n = 18 launches), and the remainder was used for training.

Predictive Analysis (Classification)

- The GridSearchCV object with 10 cross validation folds was used to optimize parameter selection for four different predictive models:
    1. logistic regression,
    2. support vector machine,
    3. decision tree classifier, and
    4. K-nearest neighbors classifier
- Each model was fit to the training data, examined for accuracy, and the best parameter set was identified. Then, each model was scored with regard to accuracy on the test data and the confusion matrix was inspected.
- View on GitHub

Predictive Analysis (Classification)



Results

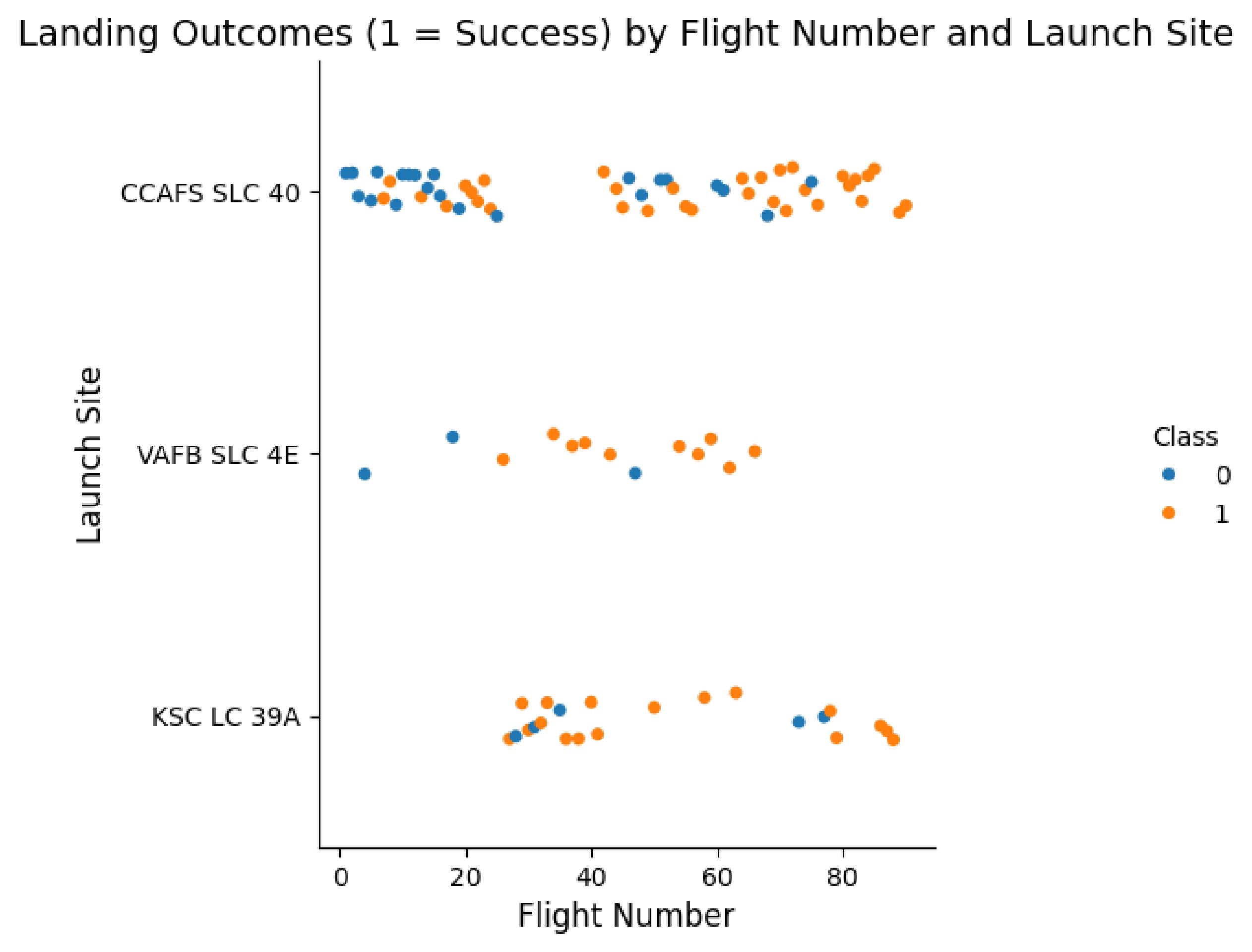
- Exploratory data analysis results
- Interactive analytics demo in screenshots
  - Interactive map for launch site proximity analysis
  - Interactive dashboard for exploration of operational parameters
- Predictive analysis results

Section 2

Insights drawn from EDA

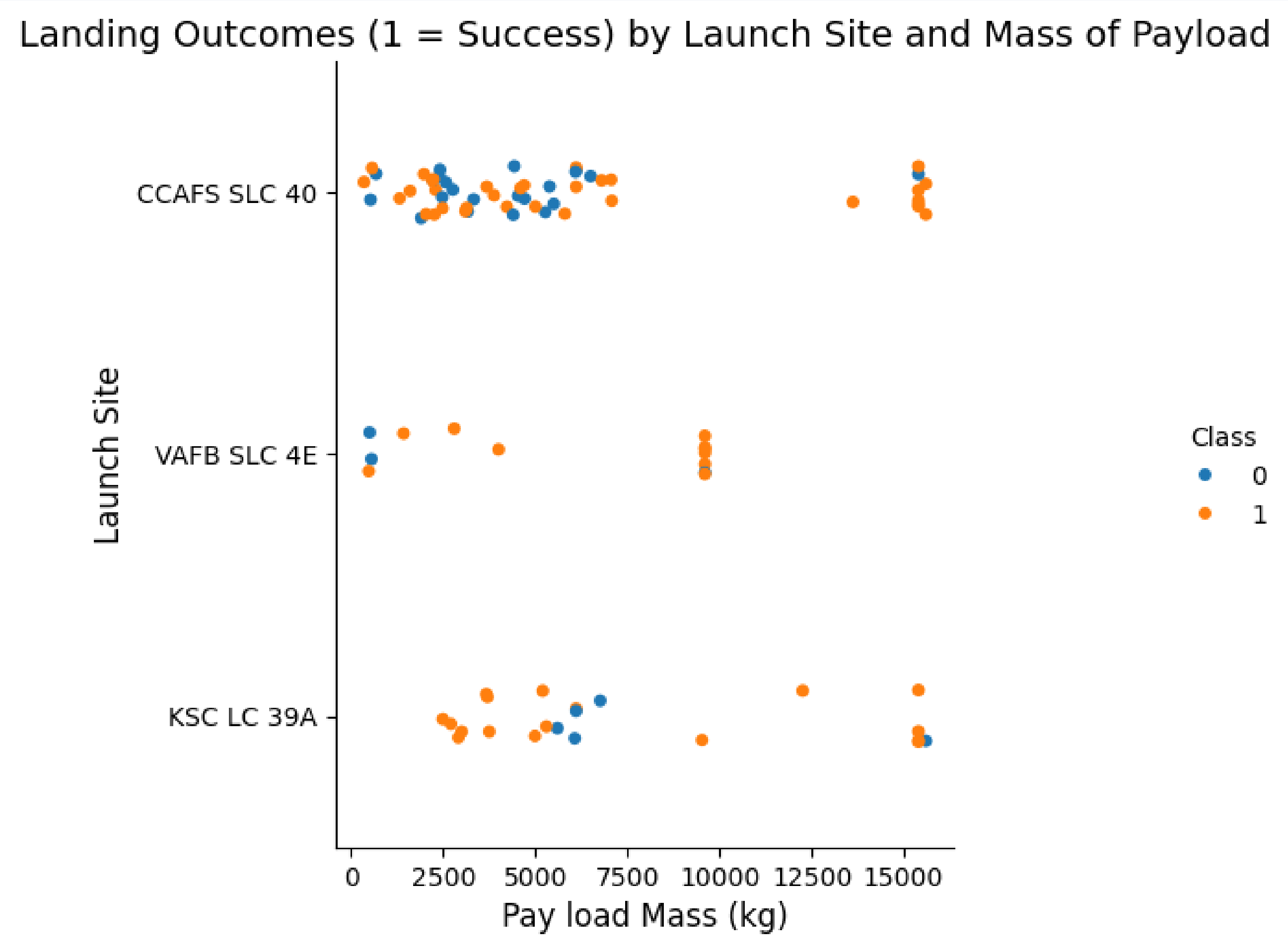
Flight Number vs. Launch Site

- A plot of Outcome by Flight Number and Launch Site indicated that the Falcon 9 launched from 2 sites in FL, Cape Canaveral SLC 40 and Kennedy Space Center LC 39A, and 1 site in CA, Vandenberg SLC4e.
- Canaveral hosted the most flights except for a period of pause for flights 25 – 40, when Kennedy was used more intensively.
- Vanderberg was mostly used during mid-range flight numbers (~20 – 60)
- Landing failure appeared more highly related to flight number than launch site.
  - Failures occurred at all sites.
  - Failures were less frequent with increased experience across sites.



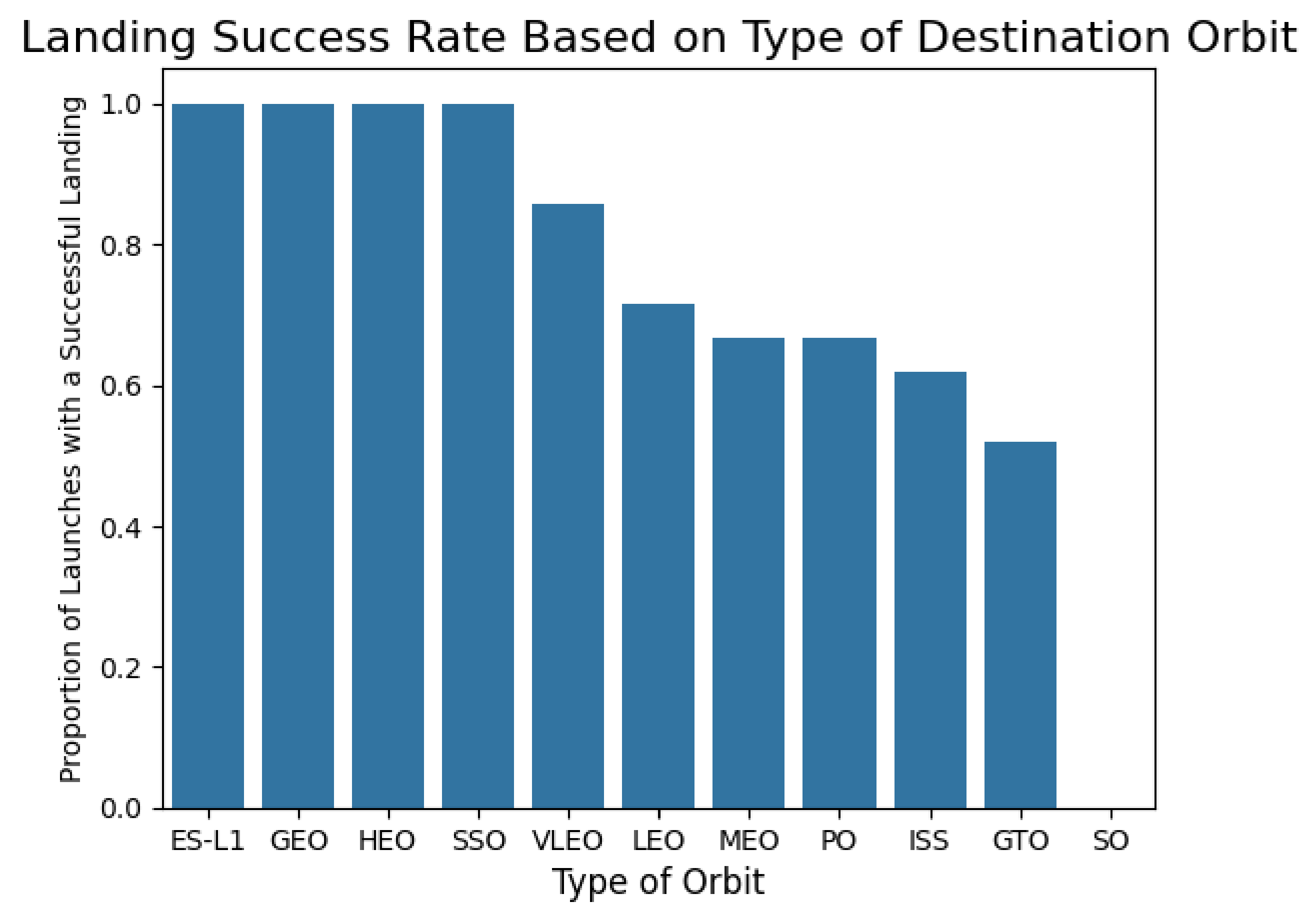
Payload vs. Launch Site

- A plot of Outcome by Payload Mass and Launch Site indicated that most launches were less than 7,500 kg and were launched from each site
- Vandenberg supported payloads up to 10,000 kg, but heavier payloads were launched from Canaveral and Kennedy
- Moderate to heavy payloads had a good success rate.
- More failures were evident for lighter payloads, perhaps due to light payloads being used at lower flight numbers.



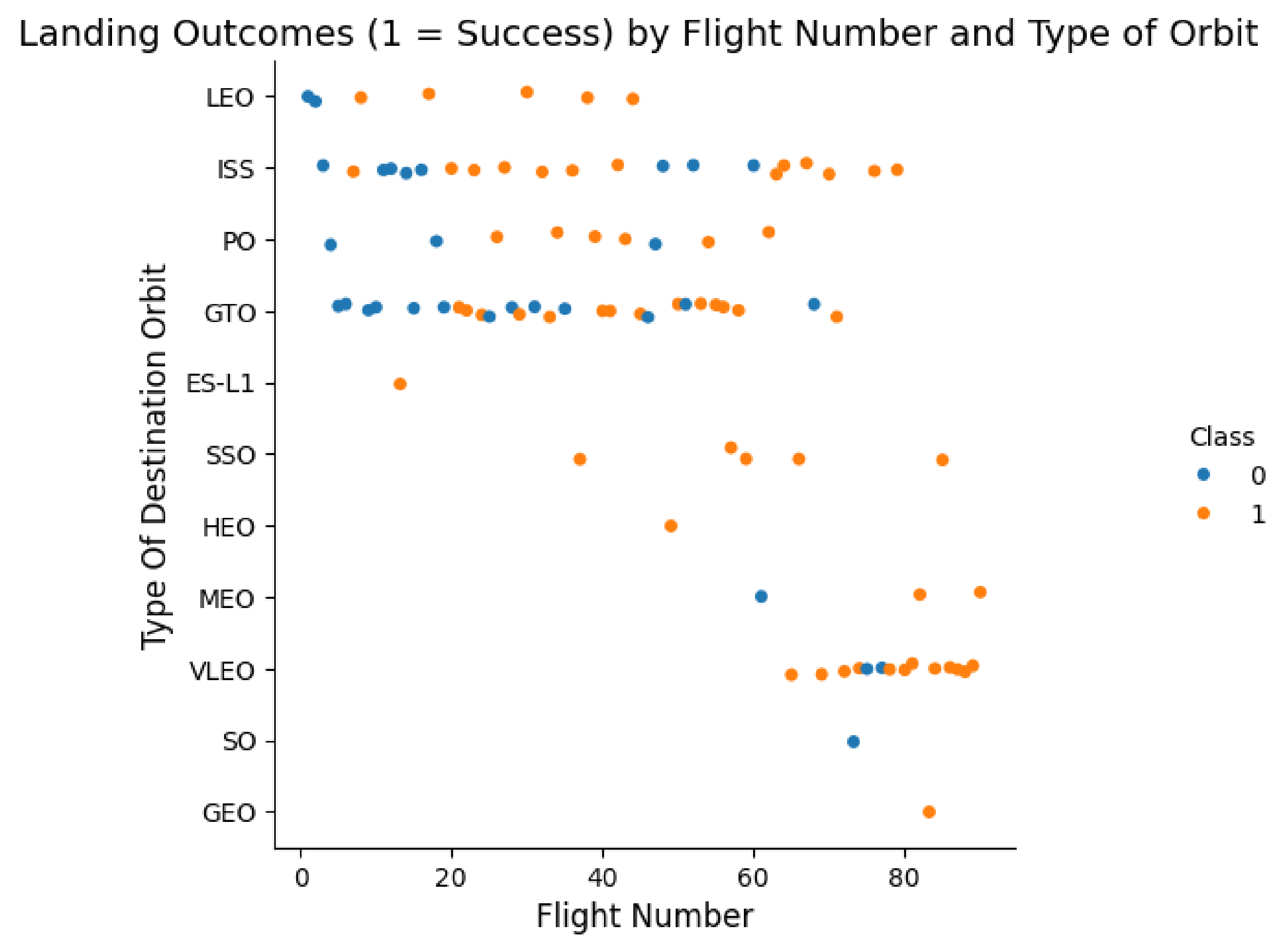
Success Rate vs. Orbit Type

- A plot of Landing Success by Type of Destination Orbit indicated that orbit was related to landing success.
- Some orbits are harder to land from than others, but additional analysis of orbital attributes is needed to generate hypotheses about why this might be the case.



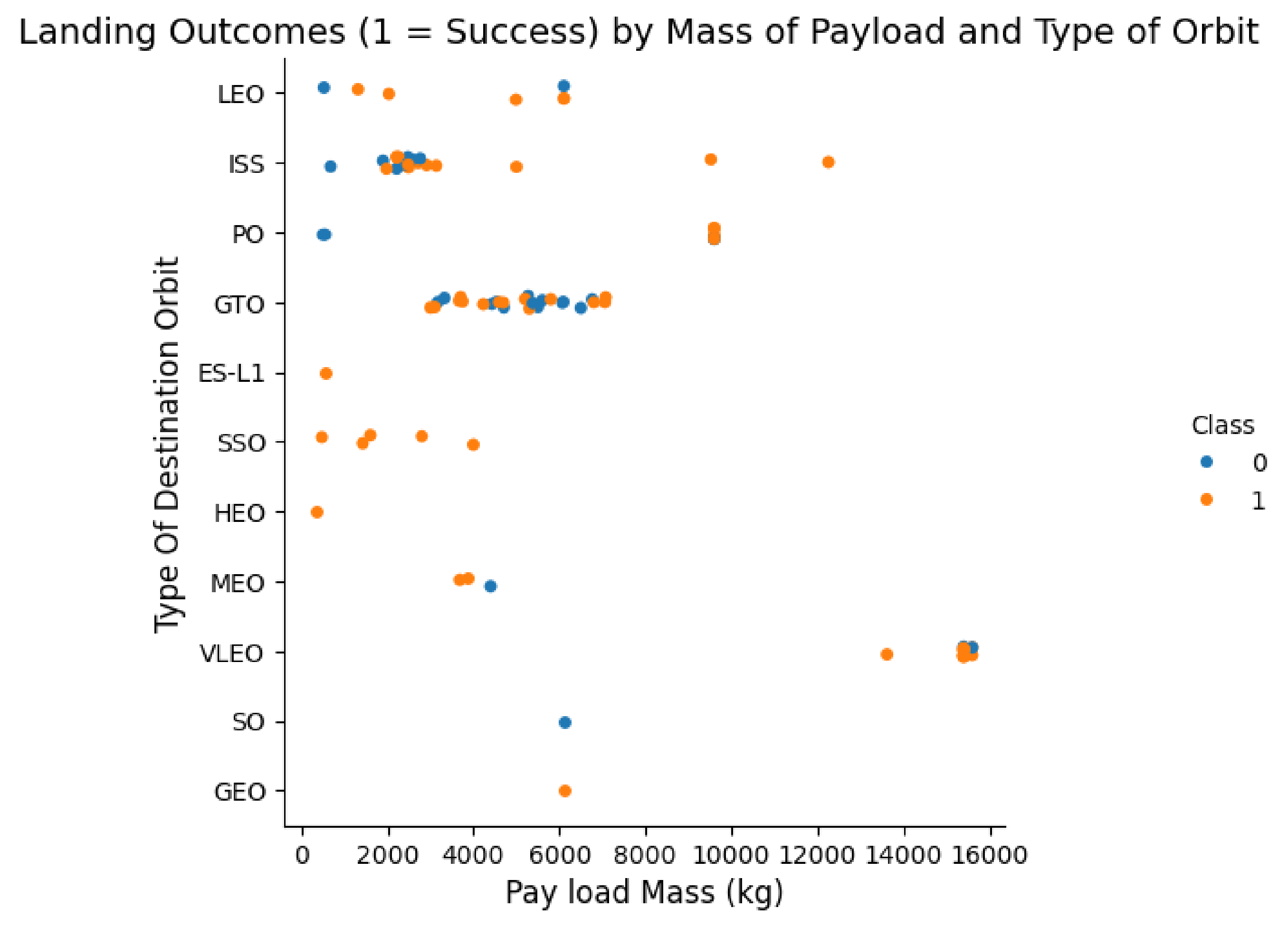
Flight Number vs. Orbit Type

- Outcome by Flight Number and Type of Destination Orbit indicated that launch experience was related to the type of orbit, with many recent flights headed to very low earth orbits.
- Some landing failure occurred at each orbit with more than a few launches excepted for a Sun-synchronous which has an unbroken string of landing success.



Payload vs. Orbit Type

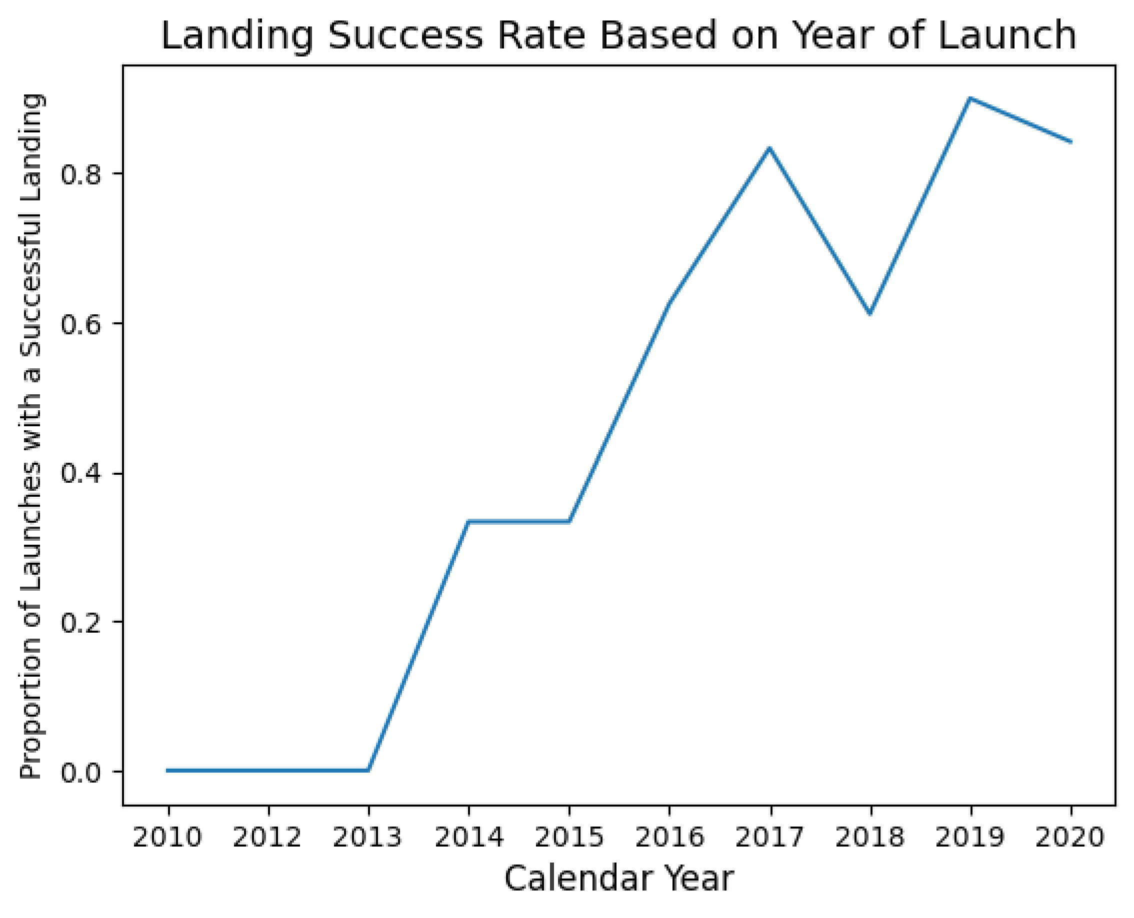
- A plot of Outcome by Payload Mass and Type of Destination Orbit indicated that Light to moderate payloads were destined for a wide variety of orbits.
- Moderately heavy payloads were destined for international space station or polar orbits.
- The heaviest payloads were destined for very low earth orbits.
- LEO, MEO, GEO/GTO, HEO, ES-L1, and SSO/SO orbits were only attempted with payloads less than ~7,500 kg



Launch Success Yearly Trend

- A plot of Landing Success by Year demonstrated a significant overall improvement in booster recovers over the decade from 2010 – 2020.

- A landing success rate above 80% was achieved
  - during calendar years 2019 and 2020, and
  - in 3 of the final 4 years.



All Launch Site Names

- Examination of distinct launch sites by the query, *SELECT DISTINCT Launch_Site FROM SPACEXTBL ORDER BY Launch_Site*, indicated that four sites were coded in the data set:

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

- These codes refer to:

Description	Latitude	Longitude
Cape Canaveral Air Force Station Launch Complex 40	28.562302	-80.577356
Cape Canaveral Air Force Station Space Launch Complex 40	28.563197	-80.576820
Kennedy Space Center Launch Complex 39A	28.573255	-80.646895
Vandenberg Air Force Station Space Launch Complex 4E	34.632834	-120.610745

Launch Site Names Begin with 'CCA'

- The query *SELECT * FROM SPACEXTBL WHERE Launch_Site LIKE 'CCA%' LIMIT 5* was used to return 5 records where launch sites begin with `CCA` (i.e., were from a Cape Canaveral launch site).
- The LIKE 'CCA%' wildcard was used to include records from both the LC-40 and SLC-40 complexes, even though the 5 records actually returned were all from LC-40.
- Results of the query were as follows:

Launch Site Names Begin with 'CCA'

Date	Time (UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_Outcome	Landing_Outcome
2010-06-04	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success	Failure (parachute)
2010-12-08	15:43:00	F9 v1.0 B0004	CCAFS LC-40	Dragon demo flight C1, two CubeSats, barrel of Brouere cheese	0	LEO (ISS)	NASA (COTS) NRO	Success	Failure (parachute)
2012-05-22	7:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success	No attempt
2012-10-08	0:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success	No attempt
2013-03-01	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success	No attempt

Total Payload Mass

- The query *SELECT SUM(PAYLOAD_MASS__KG_) as Total_Payload_Mass FROM SPACEXTBL WHERE Customer = 'NASA (CRS)'* was used to identify the total payload mass all launches under NASA commercial resupply mission contracts.
- During the 2012 – 2020 period, SpaceX supplied 45,596 kilograms of payload across 20 launches to the International Space Station under NASA commercial resupply mission contracts.

Average Payload Mass by F9 v1.1

- Average payload mass was examined for the F9 v1.1 booster specifically (5 launches) and for the F9 v1.1 family of boosters (15 launches including the F9 v1.1 B series).
- The query *SELECT AVG(PAYLOAD_MASS__KG_) as Average_Payload_Mass FROM SPACEXTBL WHERE Booster_Version = 'F9 v1.1'* indicated that launches with the F9 v1.1 booster (5 launches) carried an average payload of 2,928 kg.
- The query *SELECT AVG(PAYLOAD_MASS__KG_) as Average_Payload_Mass FROM SPACEXTBL WHERE Booster_Version LIKE 'F9 v1.1%'* indicated that launches with the F9 v1.1 booster family carried an average payload of 2,535 kg.
- Thus, the average payload was lower for the F9 v1.1 booster family than the *F9 v1.1' booster specifically*

First Successful Ground Landing Date

- The first successful ground landing date was December 22, 2015, as indicated by the query *SELECT MIN(Date) as First_Successful_Ground_Landing FROM SPACEXTBL WHERE Landing_Outcome = 'Success (ground pad)'* .

Successful Drone Ship Landing with Payload between 4000 and 6000

- The query SELECT DISTINCT Booster_Version FROM SPACEXTBL WHERE Landing_Outcome = 'Success (drone ship)' AND PAYLOAD_MASS__KG_ > 4000 AND PAYLOAD_MASS__KG_ < 6000 ORDER BY Booster_Version was used to identify the names of the booster version which have successfully landed on drone ship and had payload mass greater than 4000 kg but less than 6000 kg
- Four booster versions were successfully recovered to drone ships after delivering 4,000 – 6,000 kilograms of payload to orbit:

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

Total Number of Successful and Failure Mission Outcomes

- Only a single mission failure was evident in 101 SpaceX mission launches:

Outcome	Total_N
Failure	1
Success	100

- The query used for this evaluation was

```
SELECT  CASE WHEN Mission_Outcome LIKE 'F%' THEN 'Failure'
                    ELSE 'Success' END AS Outcome,
             Count(*) AS Total_N
FROM SPACEXTBL
GROUP BY CASE WHEN Mission_Outcome LIKE 'F%' THEN 'Failure'
                       ELSE 'Success' END
```

- Further inspection indicated that the payload status was unclear for one of the missions coded as a success.

Boosters Carried Maximum Payload

- 12 booster versions, all in the F9 B5 series, have carried the maximum payload amount of 15,600 kilograms:

- The query used to identify these booster versions was:

```
SELECT DISTINCT Booster_Version
FROM SPACEXTBL
WHERE PAYLOAD_MASS__KG_ = (
        SELECT MAX(PAYLOAD_MASS__KG_)
        FROM SPACEXTBL)
ORDER BY Booster_Version
```

Booster_Version
F9 B5 B1048.4
F9 B5 B1048.5
F9 B5 B1049.4
F9 B5 B1049.5
F9 B5 B1049.7
F9 B5 B1051.3
F9 B5 B1051.4
F9 B5 B1051.6
F9 B5 B1056.4
F9 B5 B1058.3
F9 B5 B1060.2
F9 B5 B1060.3

2015 Launch Records

- During 2015, SpaceX launched 7 Falcon 9's, 2 of which failed to land on a drone ship. Booster F9 v1.1 B1012 failed in January, and F9 v1.1 B1015 failed in April.

Month	Failed_Drone_Ship_Landing	Booster_Version	Launch_Site
01	Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
02		F9 v1.1 B1013	CCAFS LC-40
03		F9 v1.1 B1014	CCAFS LC-40
04	Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40
04		F9 v1.1 B1016	CCAFS LC-40
06		F9 v1.1 B1018	CCAFS LC-40
12		F9 FT B1019	CCAFS LC-40

2015 Launch Records

- The 2015 launches were evaluated with the query:

```
SELECT substr(Date, 6, 2) as Month,
        CASE WHEN Landing_Outcome = 'Failure (drone ship)'
            THEN Landing_Outcome
            ELSE ''
        END AS Failed_Drone_Ship_Landing,
        Booster_Version,
        Launch_Site
FROM SPACEXTBL
WHERE substr(Date, 0, 5)='2015'
ORDER BY Month
```

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

- For the period from June 4, 2010 to March 20, 2017, SpaceX launched 31 Falcon 9s.
- For 10 launches, no landing was attempted, which represented the most common landing outcome.
- Drone ship landings were the next most common landing attempts with success and failure outcomes ranking equal at 5 each. The lowest ranked outcome was a precluded landing on a drone ship.
- Successful ground pad landings and controlled ocean descents ranked at 3 apiece, with uncontrolled ocean and failed parachute landings ranking second last at 2 apiece.

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

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

- The query used to rank landing outcomes was:

```
SELECT  Landing_Outcome, Count(*) AS Total_N
FROM SPACEXTBL
WHERE DATETIME(DATE) BETWEEN DATETIME('2010-06-04') AND
                             DATETIME('2017-03-20')
GROUP BY Landing_Outcome
ORDER BY Count(*) DESC
```

Section 3

Launch Sites Proximities Analysis

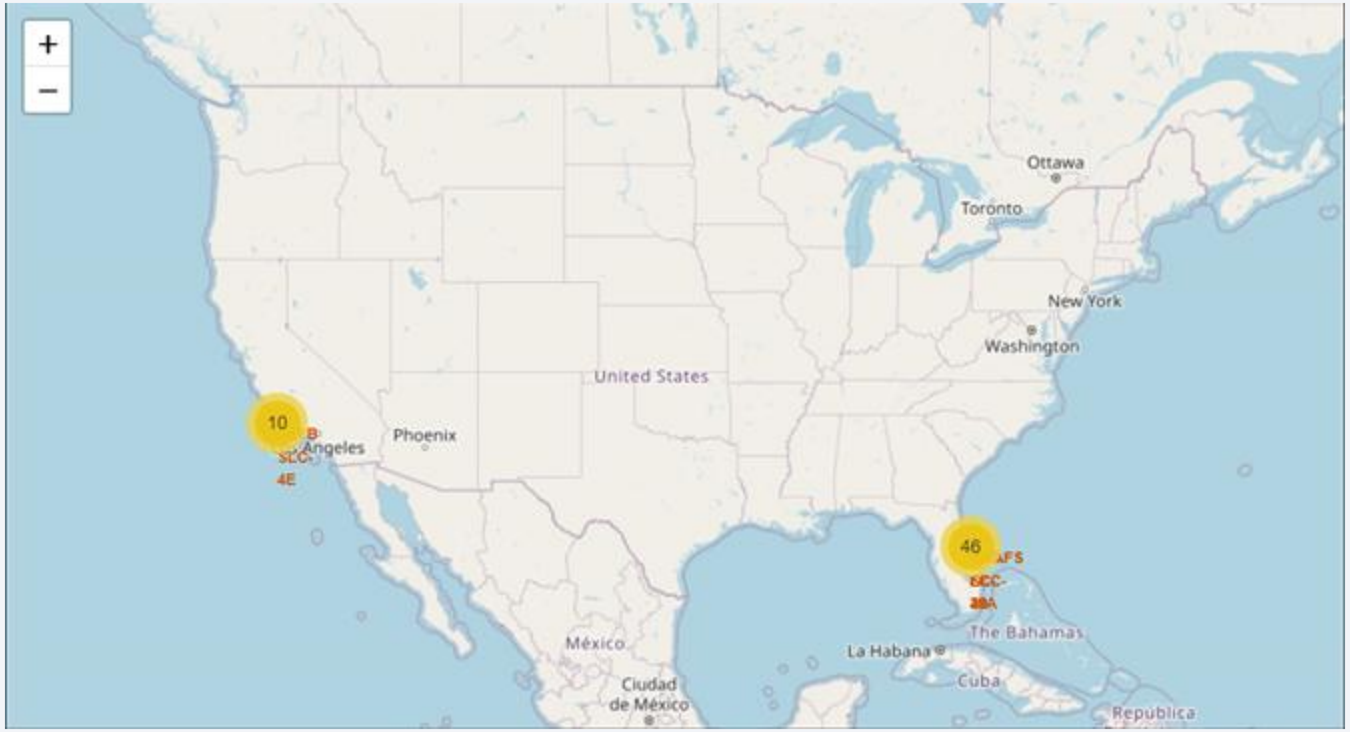
Falcon 9 Launch Site Locations: Global Reference

- Each of the four Falcon 9 launch sites were in the United States of America, with one on the west coast and three on the east coast.

- The east coast sites are within a few miles of each other, so they appear to overlap in this global map.

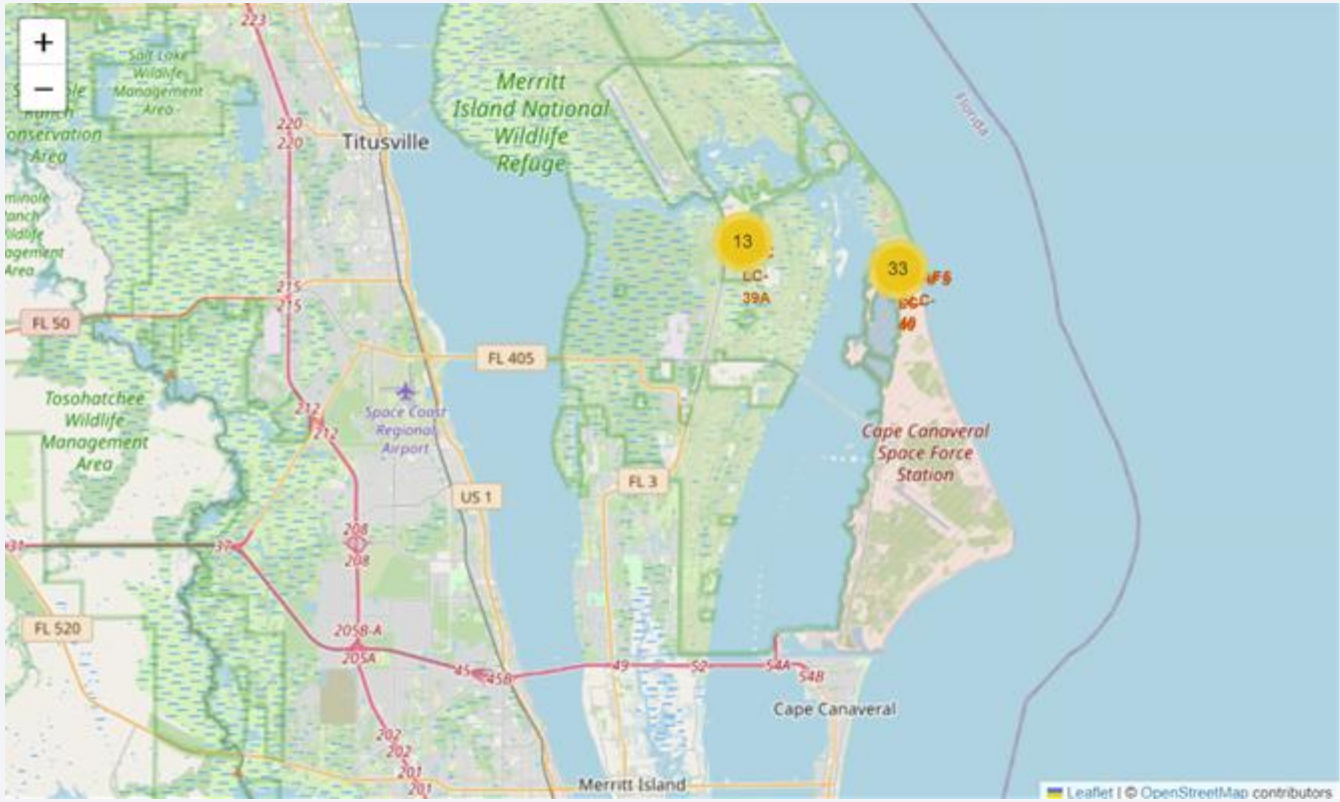
Falcon 9 Launches by Site: USA Reference

- Zooming into the USA, we can see that 56 launches recorded.
- 10 were west coast launches from Vandenberg
- 46 were east coast launches from Kennedy or Cape Canaveral.
- The Florida sites remain clustered and individual indicators of success and failure are not yet visible from this perspective.



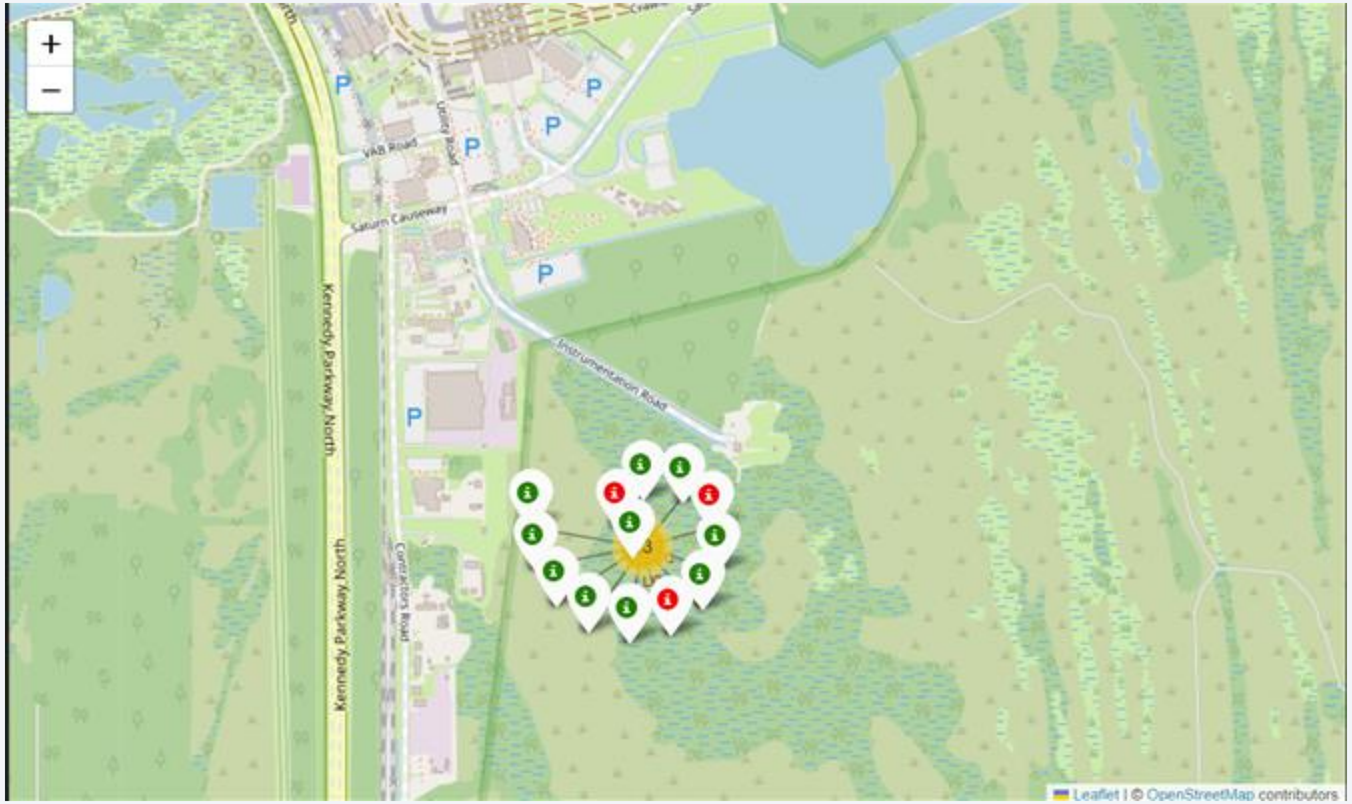
Falcon 9 Launches by Site: FL Space Coast

- Zooming into the Florida Space Coast, we can see that 13 launches were from the Kennedy Space Center, which is on the west side of the Banana river.
- 33 launches were from the Cape Canaveral Space Force Station, which is on the east side of the Banana river.
- The individual launch pads and indicators of success and failure are still not visible from this perspective.



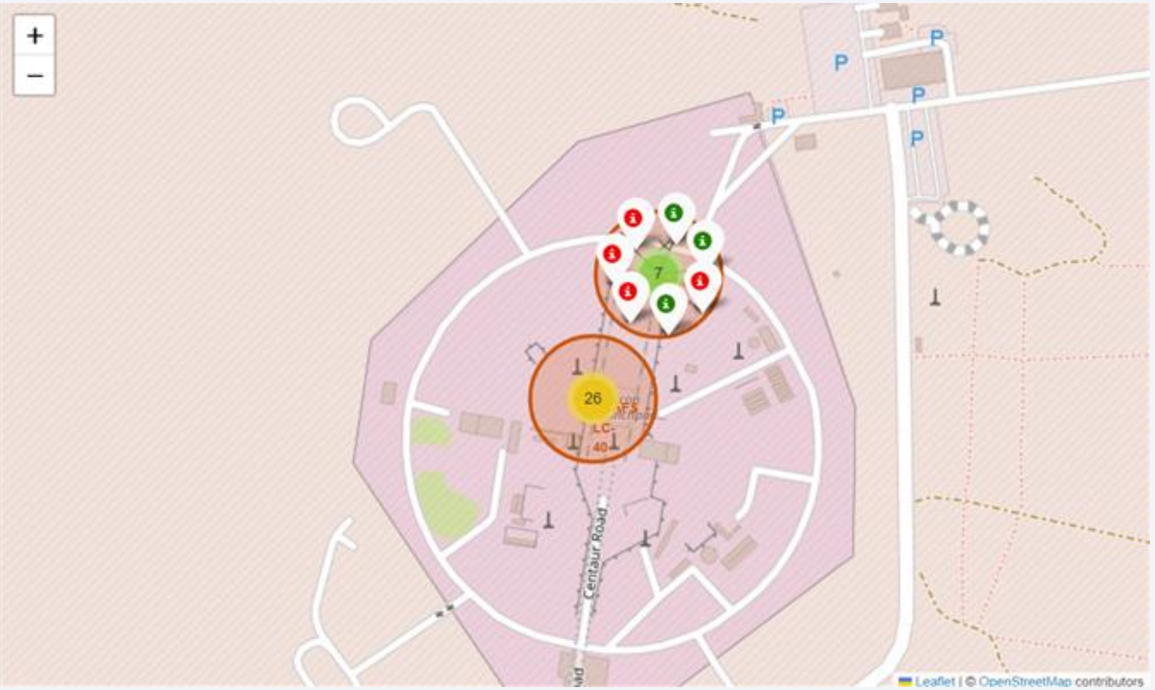
Falcon 9 Launch Success from Kennedy Space Center

- Zooming in on Kennedy Space Center, we can see information about the individual launches from the LC-39A pad in red and green markers, with a green marker indicating a successful landing.
- Specifically, we see that 10 of the 13 launches resulted in successful landings.



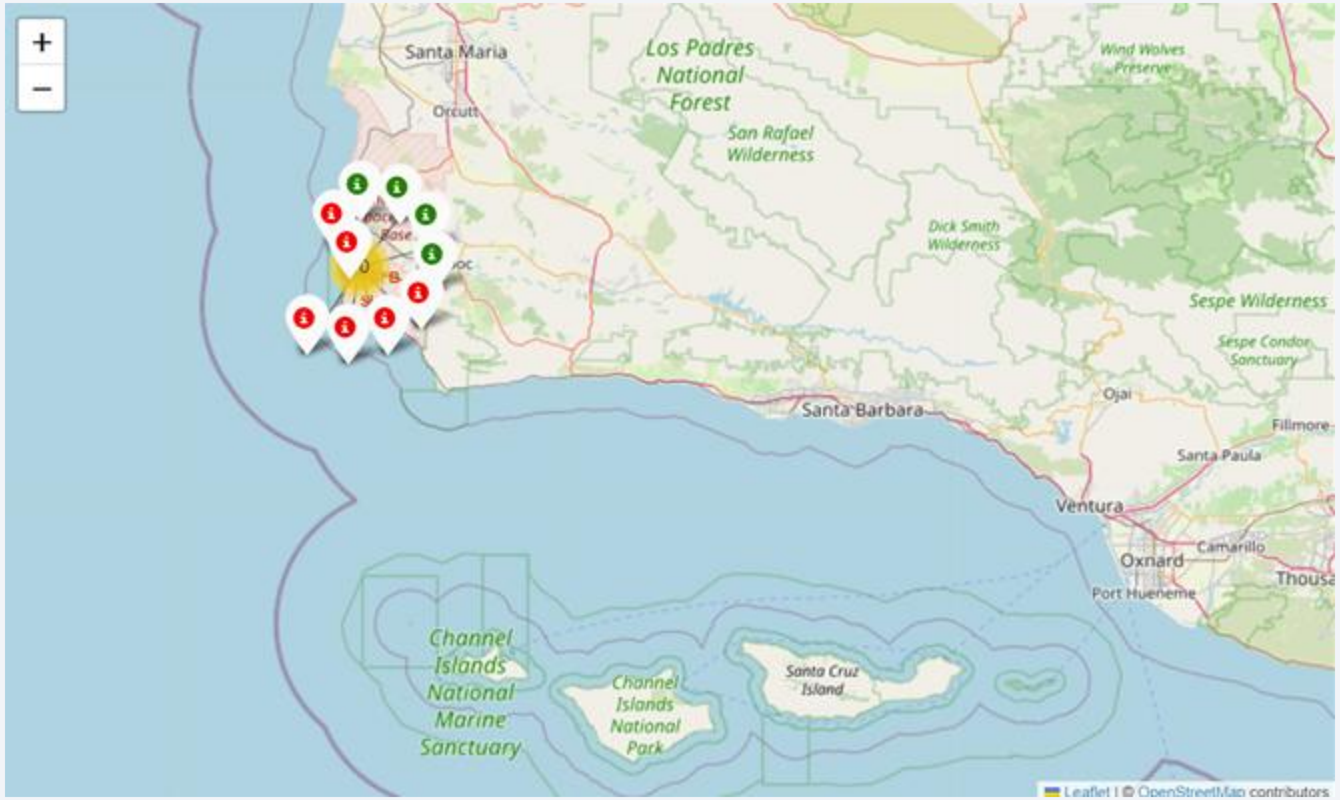
Falcon 9 Launch Success from Cape Canaveral Sites

- Zooming in further on Cape Canaveral, we see the close proximity of the LC-40 and SLC-40 launch pads, and note that the LC-40 pad was used for 26 launches with 7 successful landings, while the SLC-40 pad was used for 7 launches with 3 successful landings.



Falcon 9 Launch Success from Vandenberg

- Zooming in on Vandenberg Space Force Base in southern California, we can see information about the individual launches from the SLC-4E pad.
- Specifically, we see that 4 of the 10 launches resulted in successful landings.



Kennedy Space Center: Nearest Commercial Airport

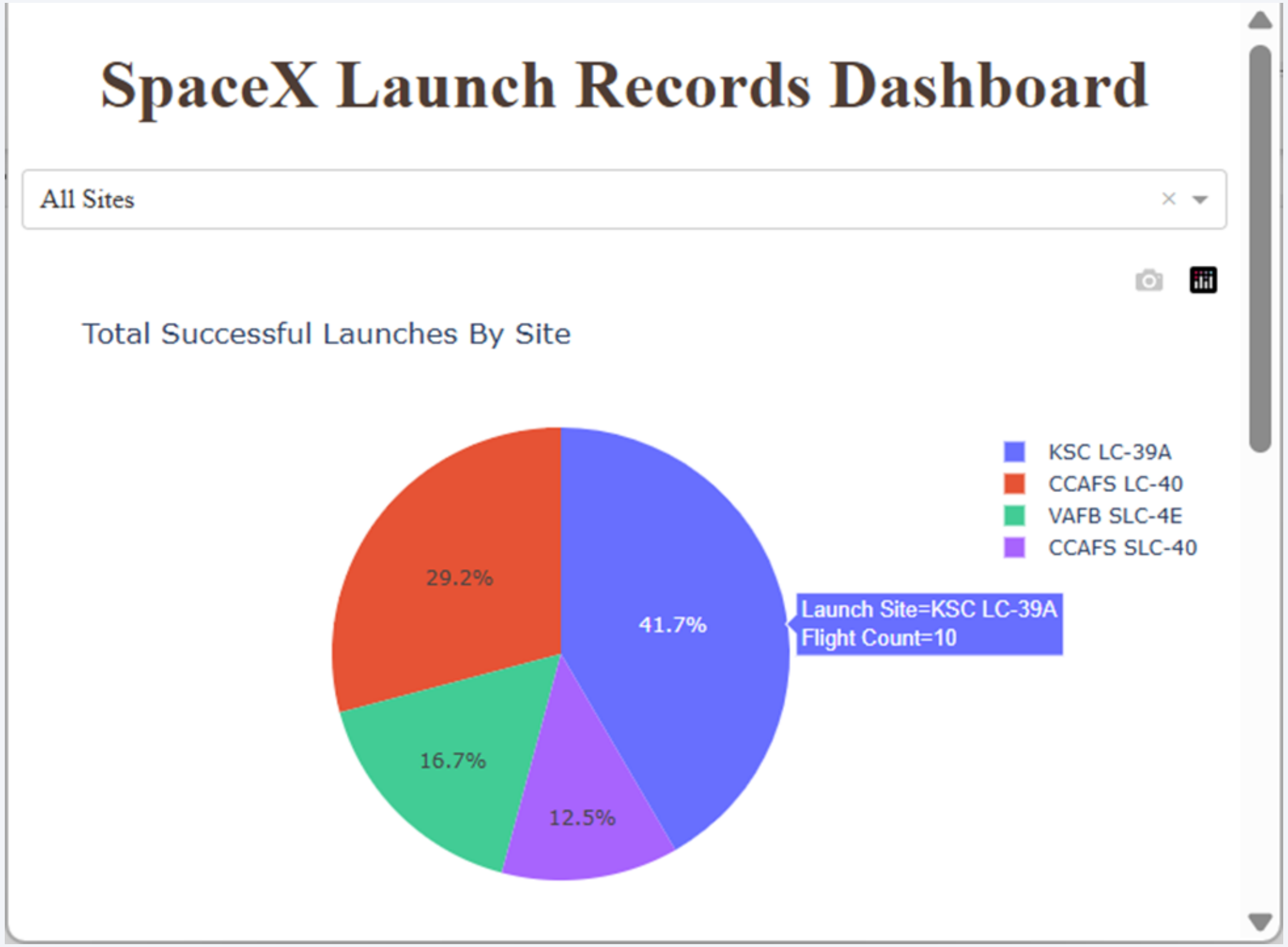
- This map illustrates the location of the Kennedy Space Center (KSC) relative to the nearest airport.
- The Space Coast Regional Airport is located 16.53 kilometers away from the LC-39A pad as the crow flies. The distance by car will be longer as roadways are more limited.
- The launch and landing facility of KSC is visible to the northwest of the of LC-39a pad, but this is not a commercial airport.

Section 4

Build a Dashboard with Plotly Dash

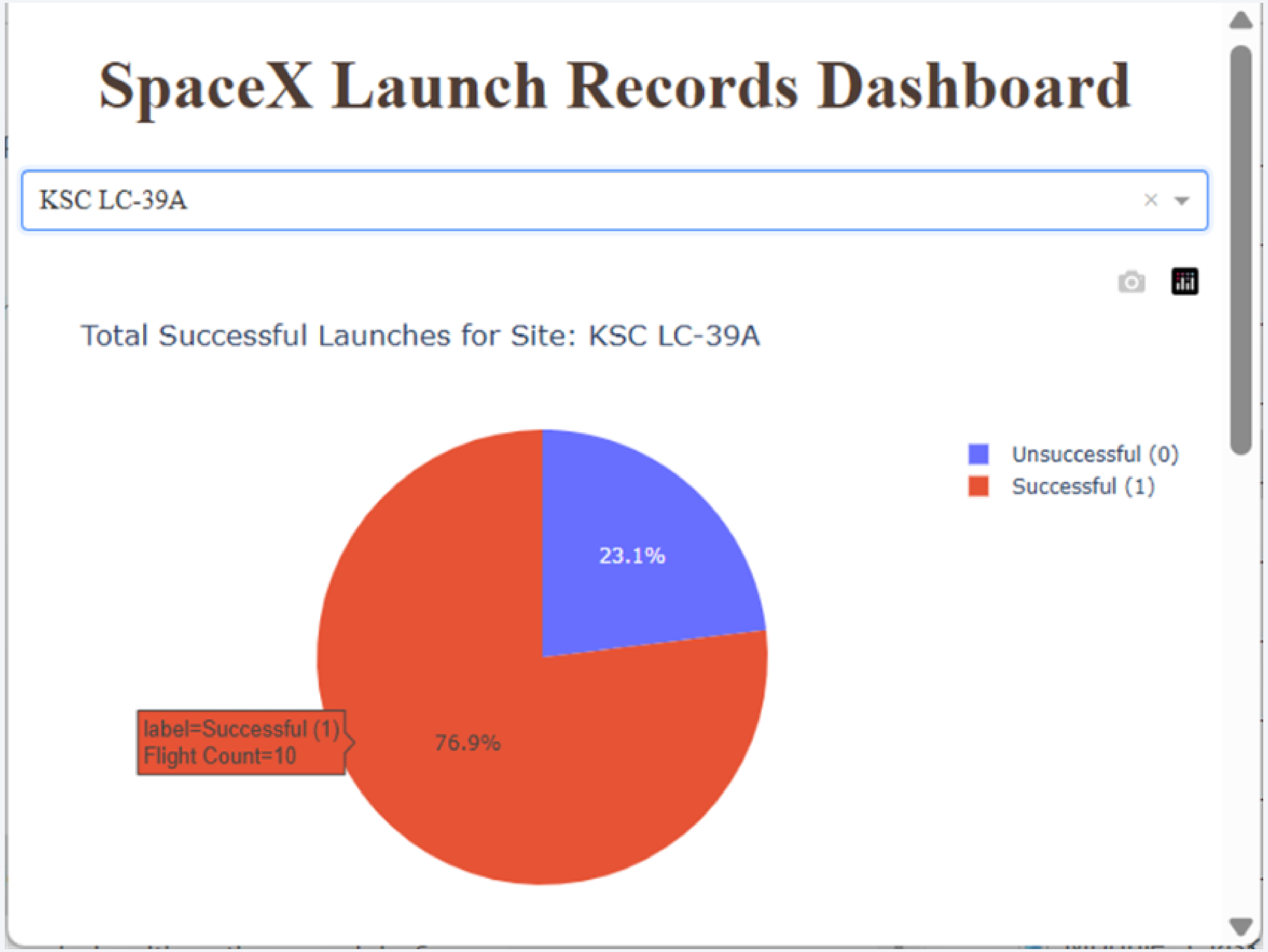
Successful Falcon 9 Launches by Site

- The first dashboard pane allows the user to explore the number and proportion of successful launches by site.
- The default display shows the percent of successful launches by site, and the mouse over allows the user to see the number of successful launches from a site.
- From this view, the user may readily digest the ranking and volume of success by site.
- This view only displays successes. If the user is interested in the relative success (i.e., percent of flights that were successful), then they may select an individual site to see a pie chart displaying both successes and failures at the site.



Launch Site With Highest Success Rate: Kennedy

- Here the user selected the most successful launches: Kennedy Space Center (KSC) site.
- This view illustrates that in addition to the 10 successful launches illustrated in the all site view, 3 additional flights resulted in failure.
- Thus, KSC demonstrated a success rate of %77 (10 of 13 flights), which is the highest of all sites.



Success by Payload, Booster Version, and Site

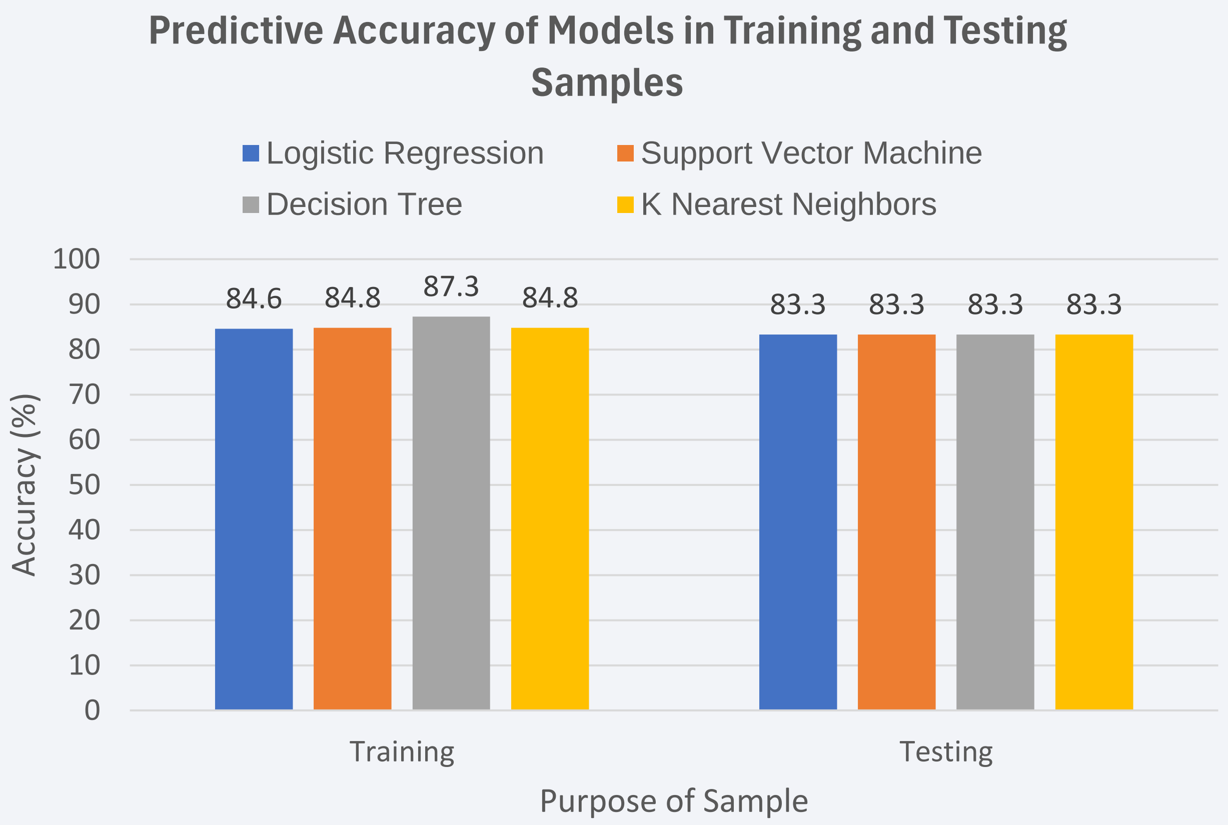
- The second pane allows the user to select a payload range of interest and explore the successful launches by booster version.
- Here, the view shows all sites, but the user may also select a specific site to review.
- The user has selected a payload range of 4,000 to 6,000 kg, and observes that 3 different boosters were used to launch payloads in this range, namely, the v1.1, FT, and B4 versions,
- However, the v1.1 was never successfully landed, whereas the FT has multiple successful landings.
- Payloads at the high end of the range (> ~5,200 kg) have fewer successes.

Section 5

Predictive Analysis (Classification)

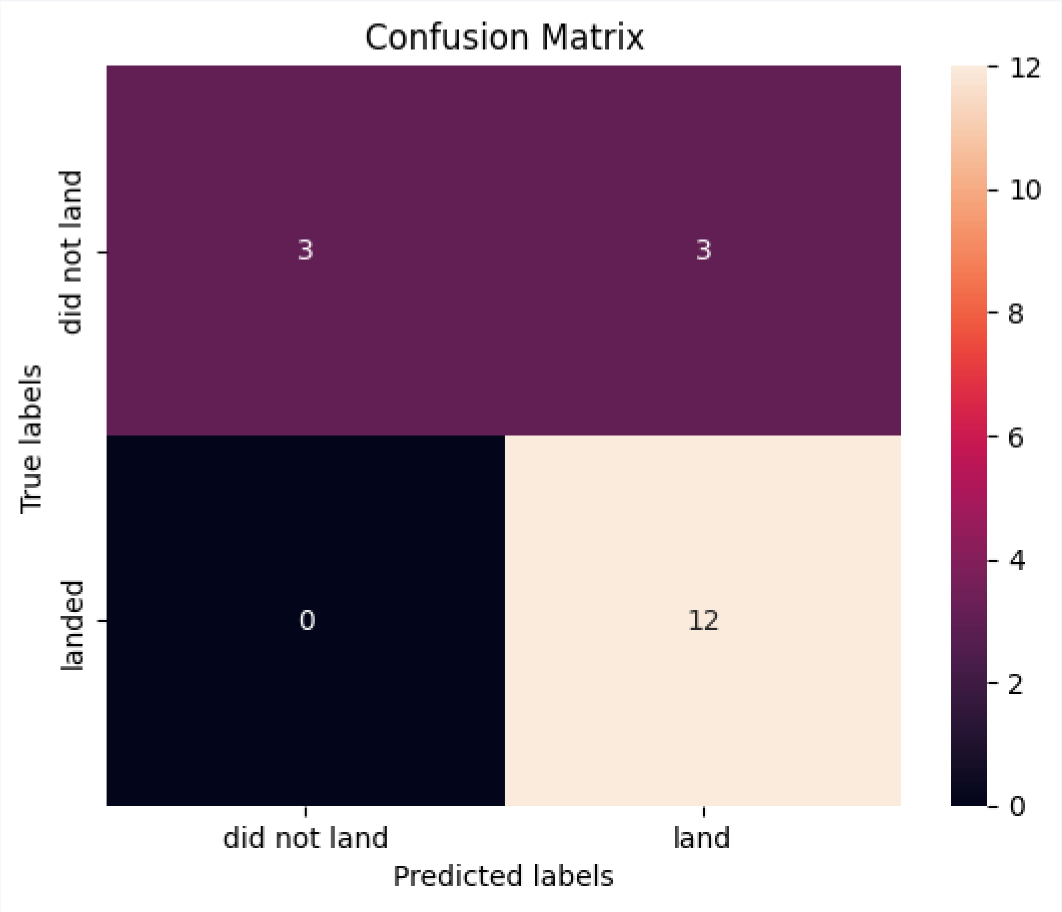
Classification Accuracy

- All models performed equally well when evaluated in the test data with 3 false positive errors.
- On the training data, the decision tree classifier demonstrated a slight advantage with an accuracy of 87% compared to 85% for the other 3 models.
- Additional model tuning might be performed and the inclusion of additional data is recommended for future.



Confusion Matrix

- The confusion matrix for the testing samples, was identical across models.
- Prediction of 15 of the 18 test cases was robust across models, with 12 landing successes accurately predicted and 3 landing failures accurately predicted.
- The consistent error was a tendency to overestimate success and underestimate failure, with 3 landings erroneously predicted to land when in fact they did not land.



Conclusions

- Considerable public data are available from and about SpaceX launches and landings
- SpaceX has become much more capable of recovering the Falcon 9 boosters with experience, and has sustained a success rate of about 80% in recent years
- Several factors are related to success rate including the type of destination orbit, amount of payload, type of booster, and nature of the landing site.
- Landing success may be predicted with about 83% accuracy, and prediction failures tend to take the form of failed landings that were expected to succeed.
- As a potential competitor, SpaceY could apply these results to identify niches in which to compete with SpaceX, develop a competitive pricing model based on customer needs (e.g., payload, orbit, etc.), perform site analysis for operational facilities, and maybe even make go-no go decisions about product development based on capacity to exceed SpaceX performance.

Appendix

- Additional information related to this project is available in a GitHub repository for this project: eric-daleiden/ibm_applied_data_science_capstone: Final project for the IBM Applied Data Science Capstone course.

- Jupyter notebooks containing the procedures are organized into:
  - Data Collection: SpaceX API
  - Data Collection: Web Scraping
  - Data Wrangling
  - Exploratory Data Analysis: Visualization
  - Exploratory Data Analysis: Geographic
  - Exploratory Data Analysis: Tabular
  - Predictive Analytics

- The Python code for the dashboard application is also included in the file: spacex-dash-app_SN.py

Thank you!