IBM Developer
SKILLS NETWORK

Winning Space Race with Data Science

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<25/01/24>

Outline

- Executive Summary
- Introduction
- Methodology
- Results
- Conclusion
- Appendix

Executive Summary

- Summary of methodologies
  - Data collection: SpaceX-API + Webscraping of SpaceX Wikipedia page
  - Data Wrangling: Missing Values replaced by mean values
  - Exploratory Data Analysis:
    - Analyze outcome by orbit type
    - Analyze outcome by payload mass and booster versions with SQL
    - Visual Analysis with charts by payload mass, time, orbit type and launch site
    - Visual Analysis with map by site
  - Interactive Dashboard: Analysis by Site, Payload and booster version
  - Predictive Analysis Using Classification: Logistic Regression, SVM, Decision Tree, KNN

- Summary of all results
  - Launch success rate increases over time
  - Higher success rate for higher orbits
  - Higher success rate for higher payload mass
  - Low success rate for booster versions v1.0, v1.1, high success rate for FT, B4, B5
  - Higher success rate for Kennedy Space center and recent starts at Cape Canaveral

Introduction

- Project background and context
  - SpaceX advertises low-cost Falcon 9 rocket launches (average of $62m vs. $165m of competitors
  - This success is because of the reusability of the first stage

- Problems we want to find answers
  - If we can determine if 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.

Section 1

Methodology

Methodology

Executive Summary

- Data collection methodology:
  - SpaceX-API
  - Webscraping of SpaceX Wikipedia page
- Perform data wrangling
  - Missing Values replaced by mean values (Payload Mass)
- Perform exploratory data analysis (EDA) using visualization and SQL
  - Analyze outcome by orbit type
  - Analyze outcome by payload mass and booster versions with SQL
  - Visual Analysis with charts by payload mass, time, orbit type and launch site
- Perform interactive visual analytics using Folium and Plotly Dash
  - Visual Analysis with map by site
  - Interactive Dashboard: Analysis by Site, Payload and booster version
- Perform predictive analysis using classification models
  - Logistic Regression, SVM, Decision Tree, KNN
  - Parameter Tuning with Grid Search

Data Collection

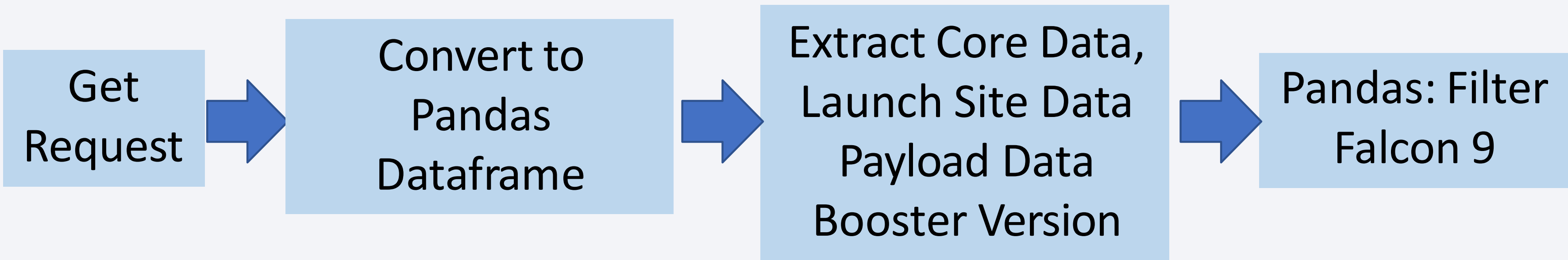
- SpaceX REST API
  - RESTful Interface
  - Get Core Data
  - Get Booster Version
  - Get Launch Site Data
  - Get Payload Data

- Webscraping of SpaceX Wikipedia Page
  - HTML Requests (HTTP-Get)
  - Python / BeautifulSoup (Package for Webscraping)
  - Extract Column Names from HTML table header

- Data Collection Jupyter Notebook

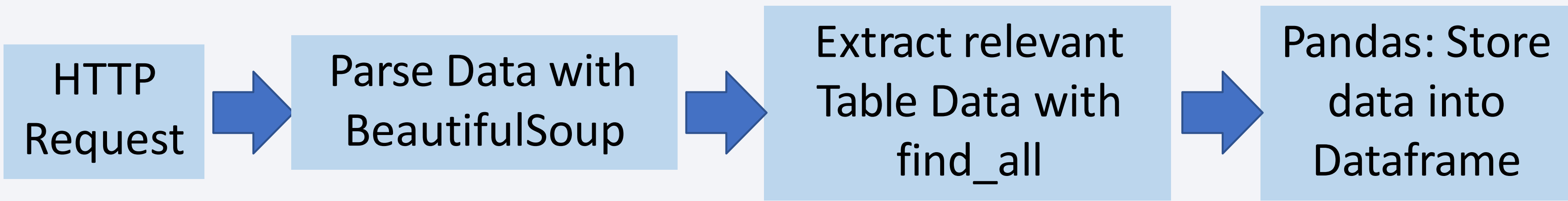
Data Collection - SpaceX API

- Send Get Request to SpaceX API interface website
- Parse data into Pandas dataframe
- Extract data with specific functions for:
  - Core data
  - Launch Site Data
  - Payload Mass
  - Booster Version
- Since Data contains other than Falcon 9 data, we filter for Falcon 9 data only
- [Data Collection (RESTful API)]



Data Collection - Scraping

- Send HTTP Request to SpaceX Wikipedia website
- Parse data into Pandas dataframe with BeautifulSoup Webscraper
- Extract data with find_all method
- Store data into Pandas dataframe for further use
- Data Collection (Webscraping)



Data Wrangling

- Dealing with missing values: The column for payload mass had a handful of missing values. We replaced them with the mean value (standard in Analysis / ML)

- Data Wrangling

EDA with Data Visualization

- Charts:
  - Payload mass vs. Flight number vs. Success rate: This shows us the development of the payload mass and the success rate over time
  - Launch site vs. Flight number vs. Success rate: This shows us the success rate of each launch site over time
  - Launch site vs. Payload mass vs. Success rate: This shows us which payload is best to have success at a specific launch site
  - Orbit type vs. Success rate: This can give us a hint which orbit types have the highest success rates
  - Orbit type vs. Flight number vs. Success rate: This shows us the development of orbit types over time
  - Orbit type vs. Payload mass vs. Success rate: Shows us the success rate for specific orbit type / payload mass clusters
  - Success rate vs. Year: Shows the success development over time
- Data Exploration

EDA with SQL

- SQL queries
  - Extract a list of all launch sites
  - Display 5 records where launch sites begin with the string 'CCA'
  - Display the total payload mass carried by boosters launched by NASA (CRS)
  - Display average payload mass carried by booster version F9 v1.1
  - List the date when the first successful landing outcome in ground pad was achieved
  - List the names of the boosters which have success in drone ship and have payload mass greater than 4000 but less than 6000
  - List the total number of successful and failure mission outcomes
  - List the names of the booster_versions which carried the maximum payload mass
  - List the failed landing_outcomes in drone ship, their booster versions, and launch site names for in year 2015
  - 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
- [Data Analysis with SQL]()

Build an Interactive Map with Folium

- Map Objects
  - Edged Circles (radius 1000m): Space launch sites
  - Markers: for labeling all objects
  - MarkerCluster: for creating a bunch of markers around space launch sites to indicate success (green) or failure (red) of the landing of the rocket's first stage
  - Lines: Measure the distince between the launch site and the next coast or next city

- [Interactive Map with Folium]

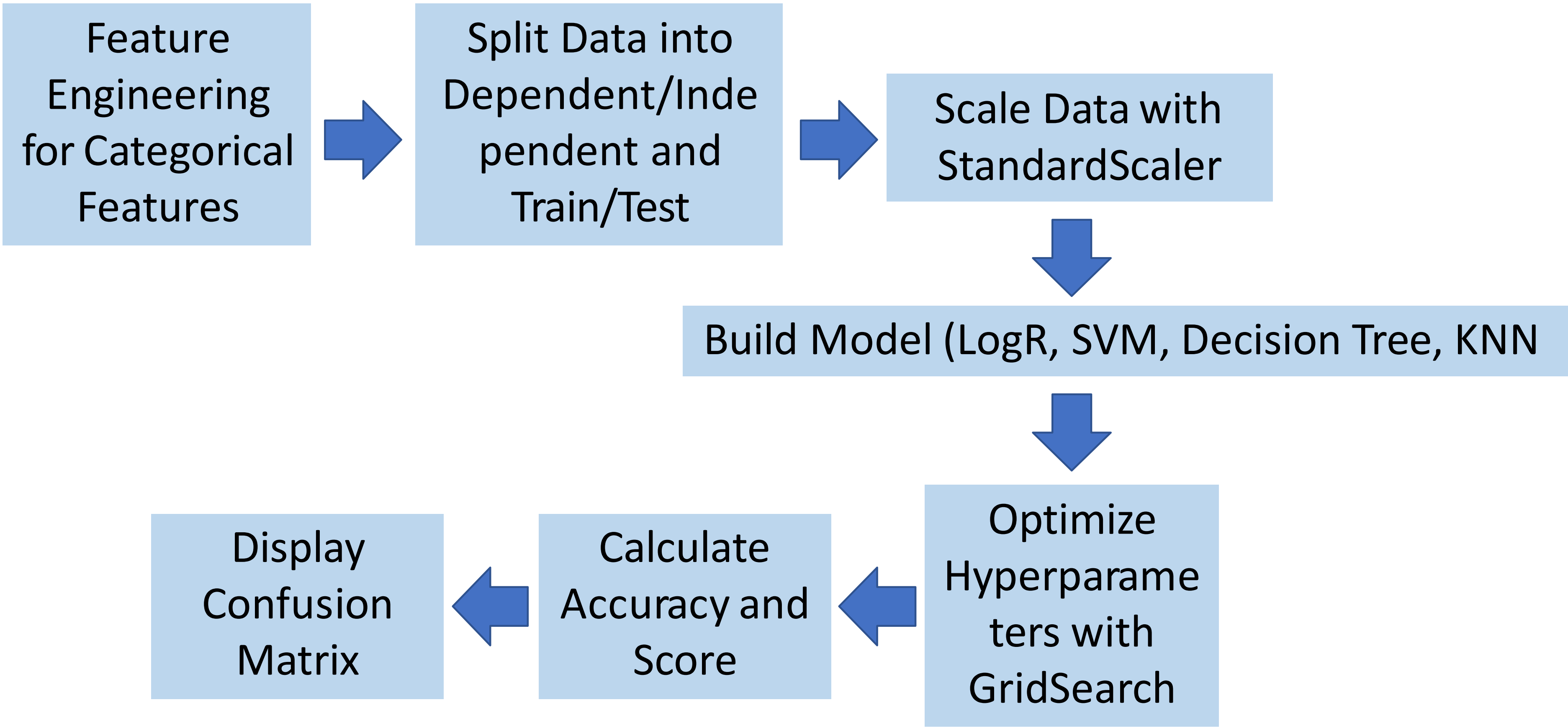
Build a Dashboard with Plotly Dash

- Input Elements:
  - Dropdown list for the launch site (with option to select all)
  - RangeSlider for selecting the payload mass
- Output Elements:
  - PieChart: for showing the success rate of each launch site, or (if all sites are selected) showing the number of successful landing outcomess
  - Scatterplot: Show success/failure by payload and booster version
- Interactive Dashboard with Plotly

Predictive Analysis (Classification)

- Preprocessing
  - One-Hot-Encoding for Categorical Features
  - Split data into dependent/independent variables and train/test data
  - Scale Data with StandardScaler
- Model Building for each Method
  - Logistic Regression
  - Support Vector Machine
  - Decision Tree
  - K-Nearest Neighbor
- Optimization
  - Use Gridsearch for optimizing the models based on their hyperparameters
- Evaluation
  - Use Accuracy of Gridsearch for selecting the best parameter
  - Use Score to compare each classification method
- Machine Learning Prediction

Predictive Analysis (Classification)



Results

- Exploratory data analysis results
  - Launch success rate increases over time
  - Higher success rate for higher orbits

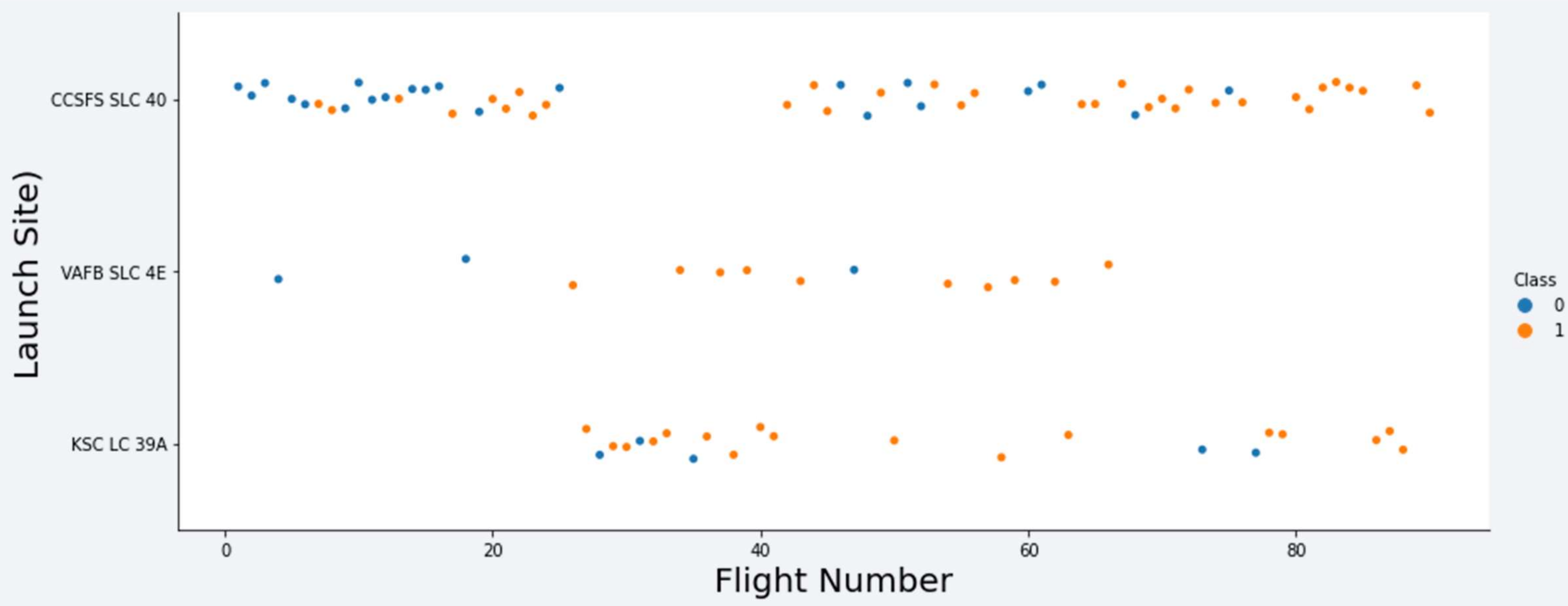
- Interactive analytics demo in screenshots
  - Higher success rate for higher payload mass
  - Low success rate for booster versions v1.0, v1.1, high success rate for FT, B4, B5
  - Higher success rate for Kennedy Space center and recent starts at Cape Canaveral

- Predictive analysis results
  - Best prediction results with Logistic Regression and Support Vector Machine

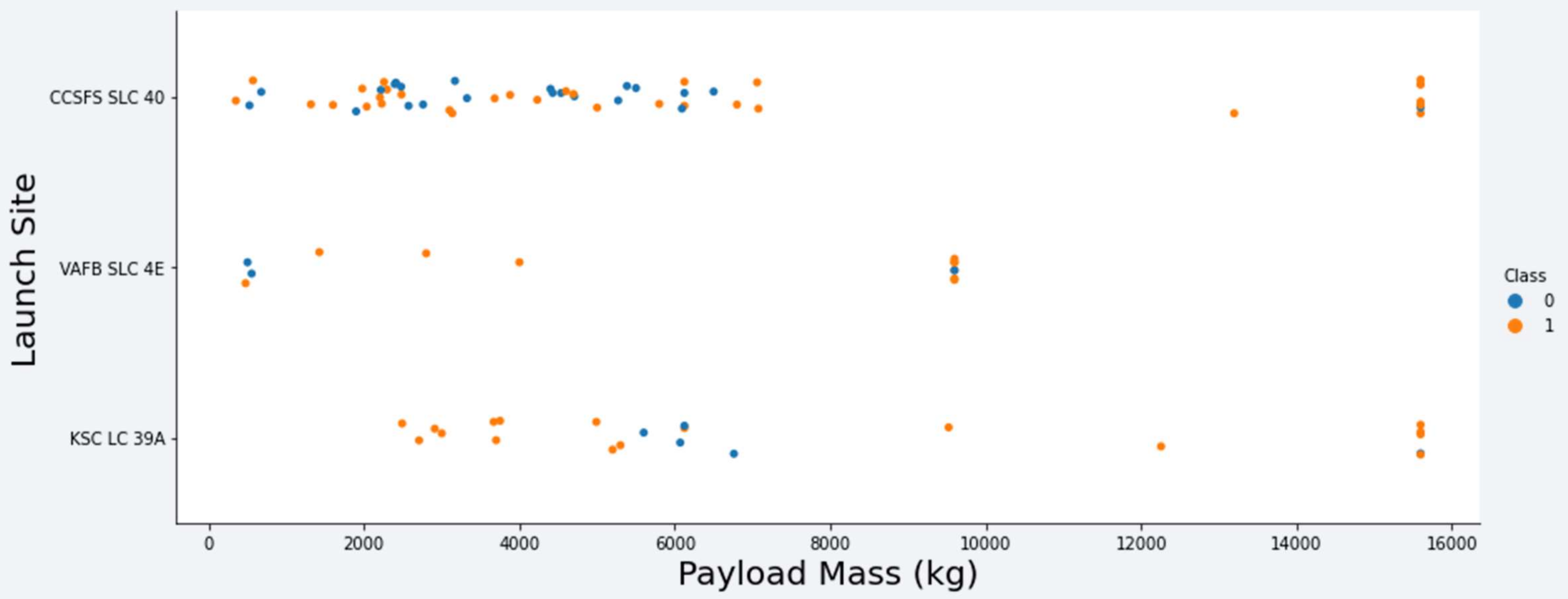
Section 2

Insights drawn from EDA

Flight Number vs. Launch Site

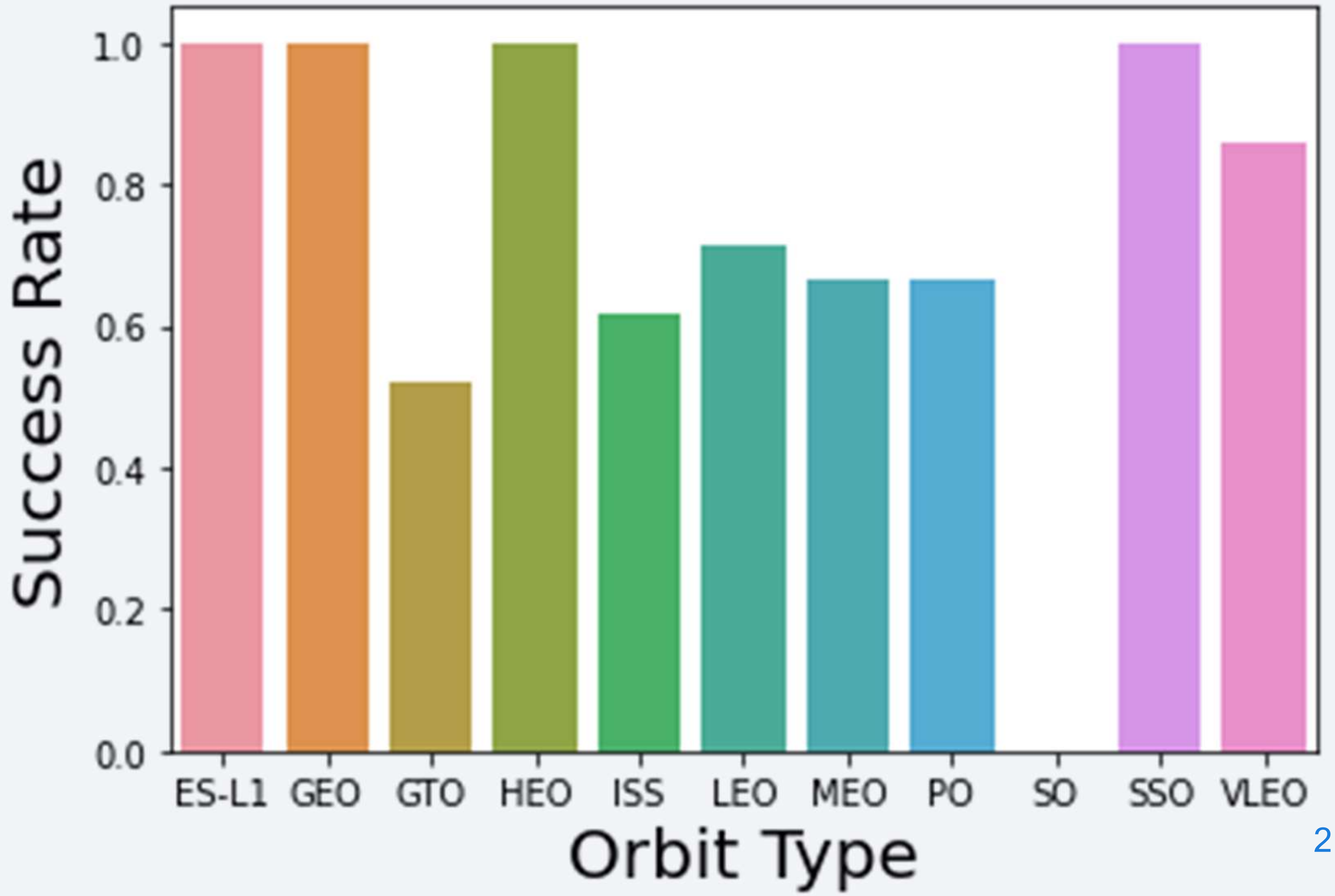


Payload vs. Launch Site



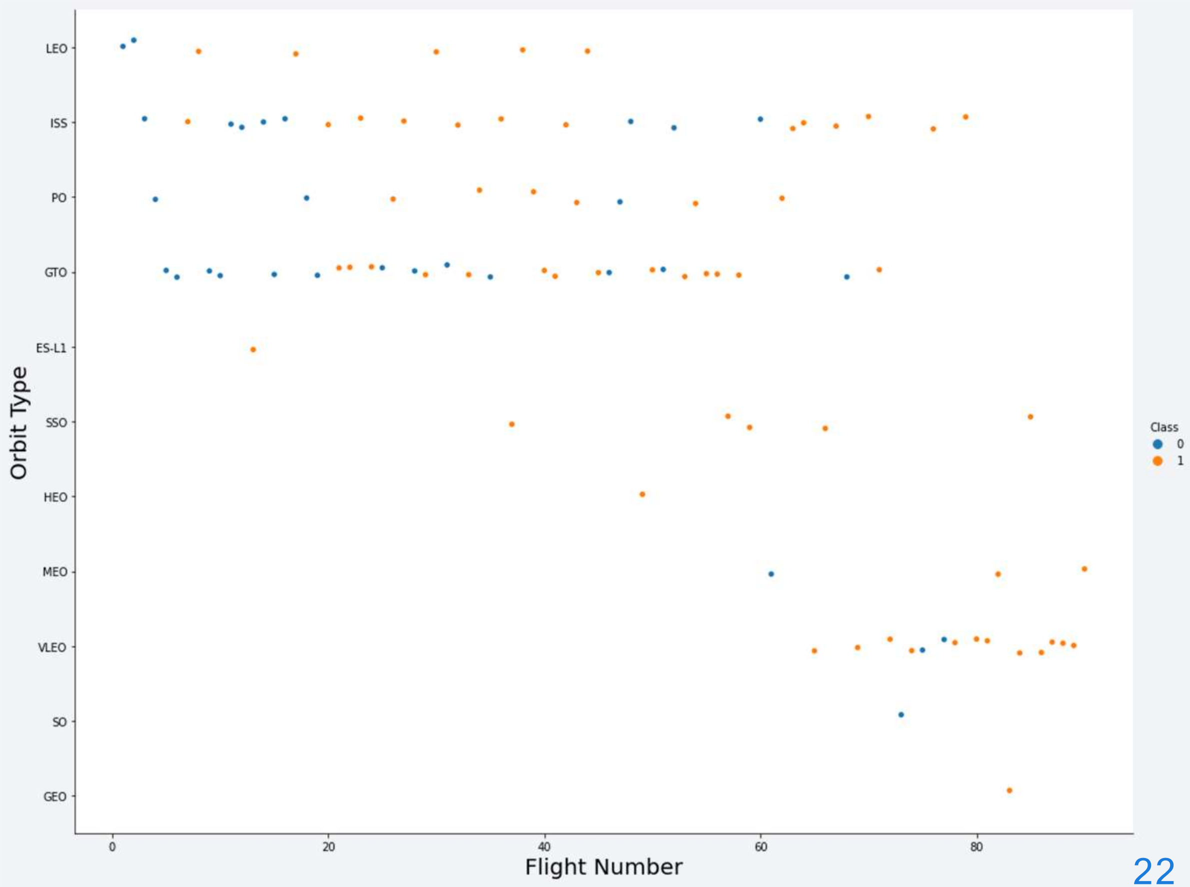
Success Rate vs. Orbit Type

- Low Earth Orbits
  - GTO
  - ISS
  - LEO
  - MEO
  - PO
  - VLEO
- High Earth Orbits
  - ES-L1
  - GEO
  - HEO
  - SSO

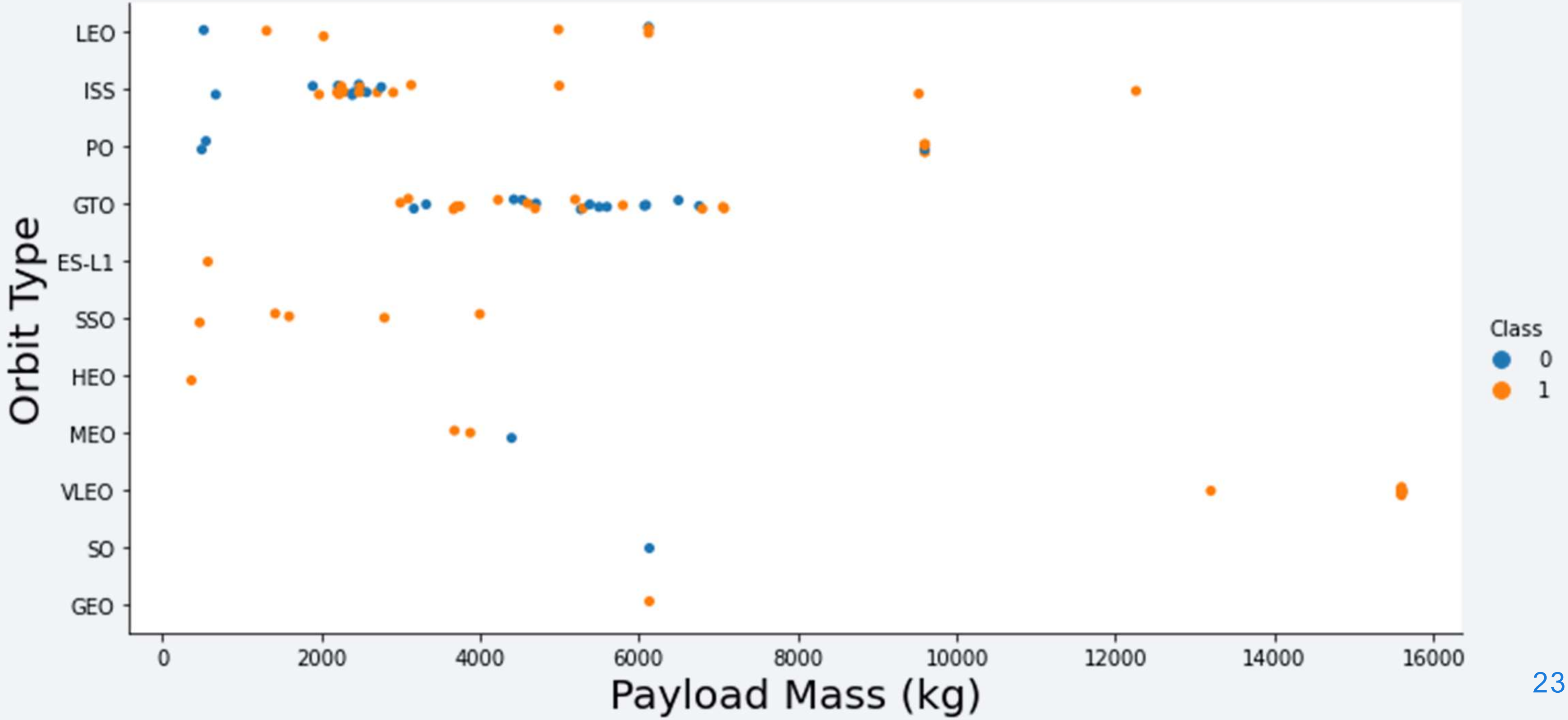


Flight Number vs. Orbit Type

- The predominant orbit types have changed over time. Success rate has increased over time for all orbit types.

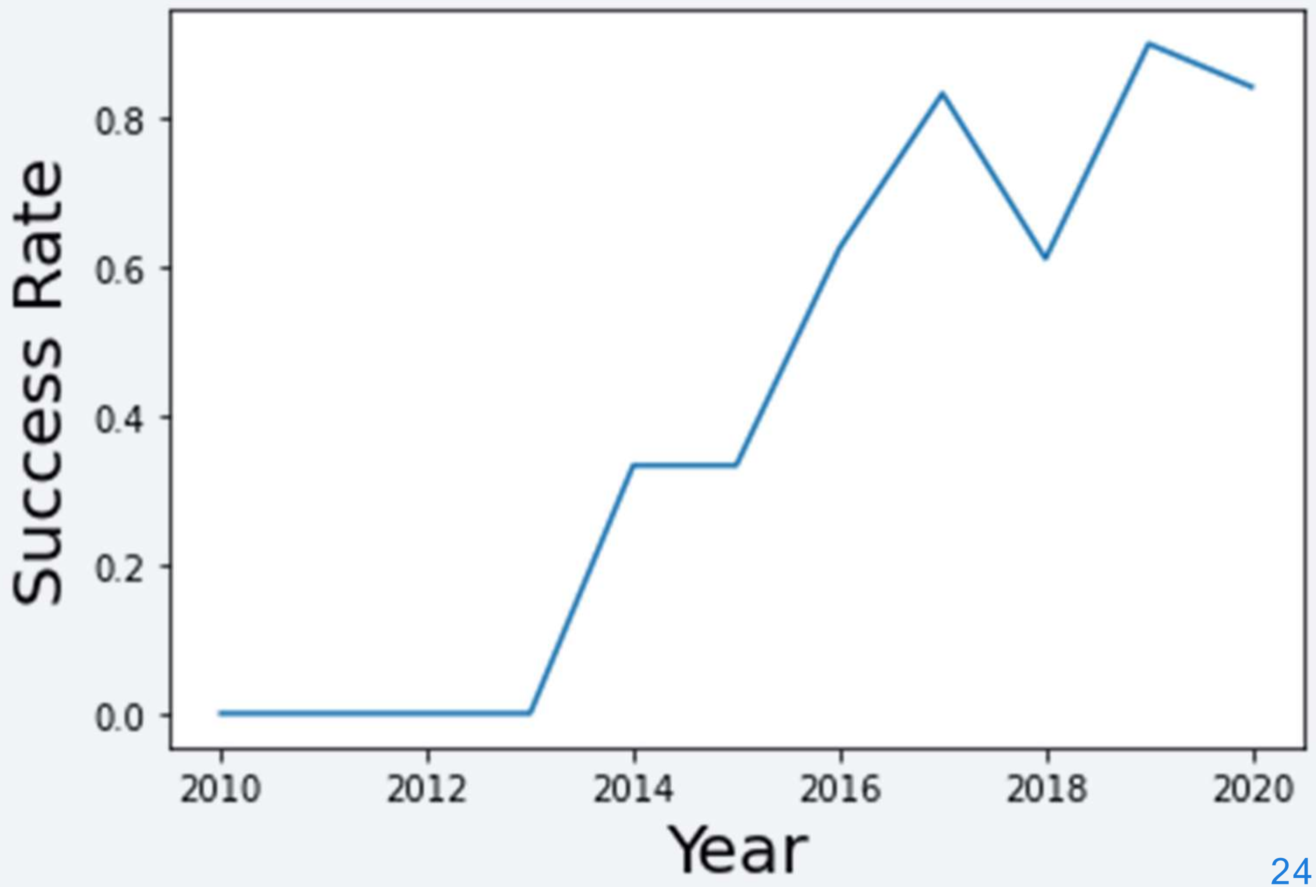


Payload vs. Orbit Type



Launch Success Yearly Trend

- Launch success has increased over the years



All Launch Site Names

- KSC: Kennedy Space Center
- CCA...: Cape Canaveral Launch Center
- VAFB: Vandenburg Air Force Base

	Launch_Site
0	CCAFS LC-40
1	VAFB SLC-4E
2	KSC LC-39A
3	CCAFS SLC-40

Launch Site Names Begin with 'CCA'

- Some sample records for starts at Cape Canaveral Space Center

Date	Time_(UTC)	Booster_Version	Launch_Site	Payload	PAYLOAD_MASS__KG_	Orbit	Customer	Mission_C
2010-06-04 00:00:00	18:45:00	F9 v1.0 B0003	CCAFS LC-40	Dragon Spacecraft Qualification Unit	0	LEO	SpaceX	Success
2010-12-08 00:00:00	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
2012-05-22 00:00:00	07:44:00	F9 v1.0 B0005	CCAFS LC-40	Dragon demo flight C2	525	LEO (ISS)	NASA (COTS)	Success
2012-10-08 00:00:00	00:35:00	F9 v1.0 B0006	CCAFS LC-40	SpaceX CRS-1	500	LEO (ISS)	NASA (CRS)	Success
2013-03-01 00:00:00	15:10:00	F9 v1.0 B0007	CCAFS LC-40	SpaceX CRS-2	677	LEO (ISS)	NASA (CRS)	Success

Total Payload Mass

- Total payload carried by boosters from NASA

sum(PAYLOAD_MASS__KG_)
45596

Average Payload Mass by F9 v1.1

- Average payload mass carried by booster version F9 v1.1

	avg(PAYLOAD_MASS__KG_)
0	2928.4

First Successful Ground Landing Date

- Date of the first successful landing outcome on ground pad

min(Date)
2015-12-22

Successful Drone Ship Landing with Payload between 4000 and 6000

- Names of boosters which have successfully landed on drone ship and had payload mass greater than 4000 but less than 6000

	Booster_Version
0	F9 FT B1022
1	F9 FT B1026
2	F9 FT B1021.2
3	F9 FT B1031.2

Total Number of Successful and Failure Mission Outcomes

- Total number of successful and failure mission outcomes (not to be confused with the outcome of the stage-1 landing)

Mission_Outcome	count(*)
Failure	1
Success	100

Boosters Carried Maximum Payload

- Names of the booster which have carried the maximum payload mass

	Booster_Version
0	F9 B5 B1048.4
1	F9 B5 B1049.4
2	F9 B5 B1051.3
3	F9 B5 B1056.4
4	F9 B5 B1048.5
5	F9 B5 B1051.4
6	F9 B5 B1049.5
7	F9 B5 B1060.2
8	F9 B5 B1058.3
9	F9 B5 B1051.6
10	F9 B5 B1060.3
11	F9 B5 B1049.7

2015 Launch Records

- List of failed landing outcomes in drone ship, their booster versions, and launch site names for in year 2015

Landing_Outcome	Booster_Version	Launch_Site
Failure (drone ship)	F9 v1.1 B1012	CCAFS LC-40
Failure (drone ship)	F9 v1.1 B1015	CCAFS LC-40
Failure (drone ship)	F9 v1.1 B1017	VAFB SLC-4E
Failure (drone ship)	F9 FT B1020	CCAFS LC-40
Failure (drone ship)	F9 FT B1024	CCAFS LC-40

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

- Rank of 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

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

Section 3

Launch Sites Proximities Analysis

Folium Map: Launch Sites

- Launch sites are at the East and West coast, near the southernmost U.S. mainland area, which is Florida and California

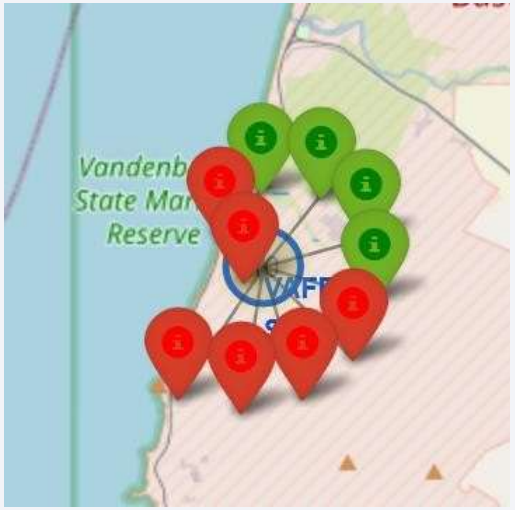
Folium Map: Proximity Vandenburg AFB

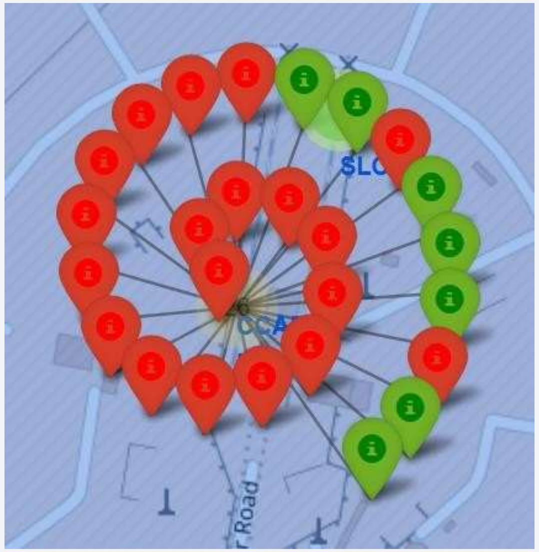
- Close to the Vandenburg AFB is the town of Lompoc. This might be an issue, if the stage-1 landing cannot be controlled, since rockets would usually start towards Eastern direction

Folium Map: Proximity Kennedy SC / Cape Canaveral

- No city towards the Eastern Direction, ideal place for testing rocket launches

Folium Map: Stage-1 Landing Success by Launch Site





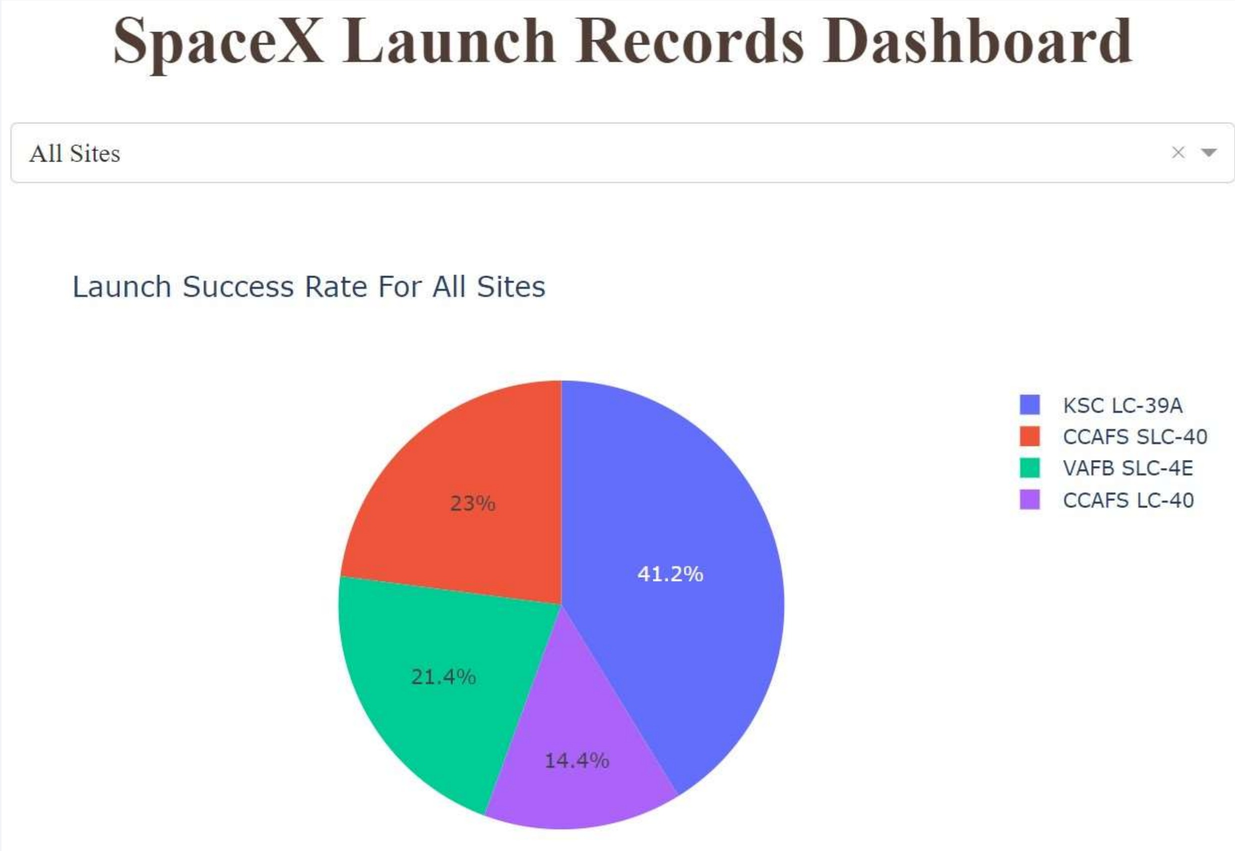
- Vandenburg AFB
- Kennedy Space Center
- Cape Canaveral

Section 4

Build a Dashboard with Plotly Dash

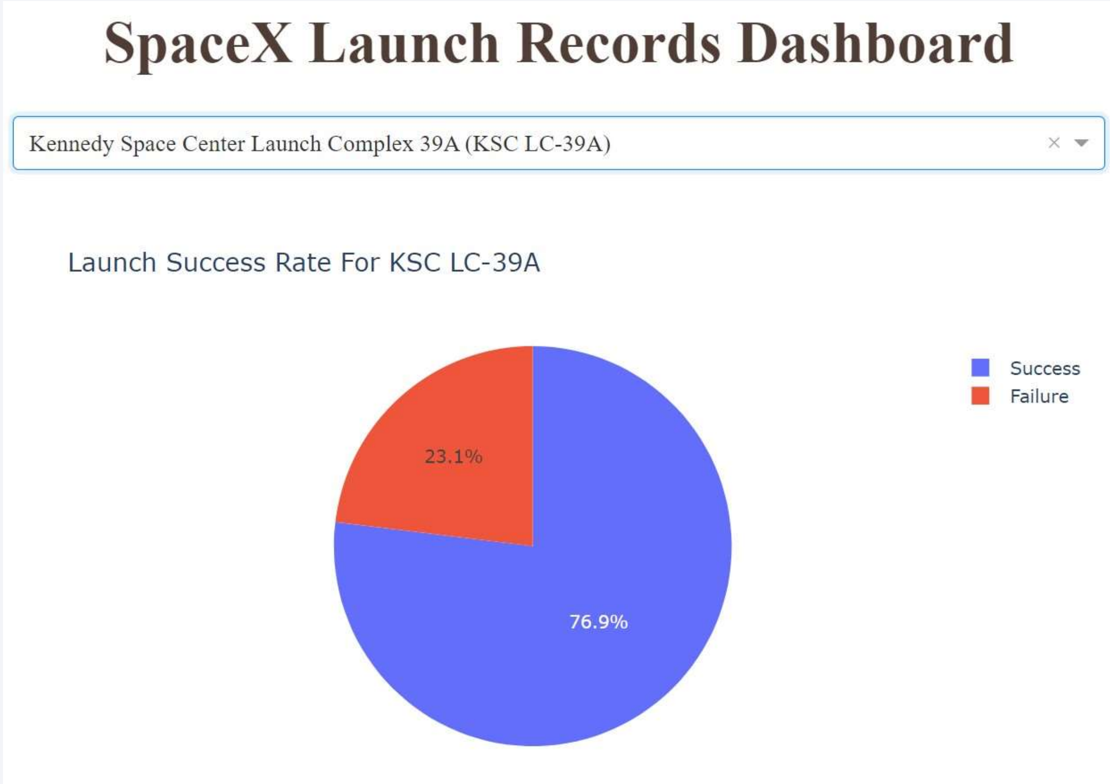
Dashboard: Launch Success Count For All Sites

- Kennedy Space Center (KSC LC-39A) hast the most successful stage-1 landings
- Vandenberg Air Force Base (VAFB SLC-4E) has the least number of successful stage-1 landings



Dashboard: Success Rate Kennedy Space Center

- More than 3 of 4 landings have been successful at Kennedy Space Center



Dashboard: Booster Versions V1.0, V1.1

- Success rate forBooster versions v1.0 and v1.1 is quite small in the payload range to 10000kg

Dashboard: Booster Versions V1.0, V1.1

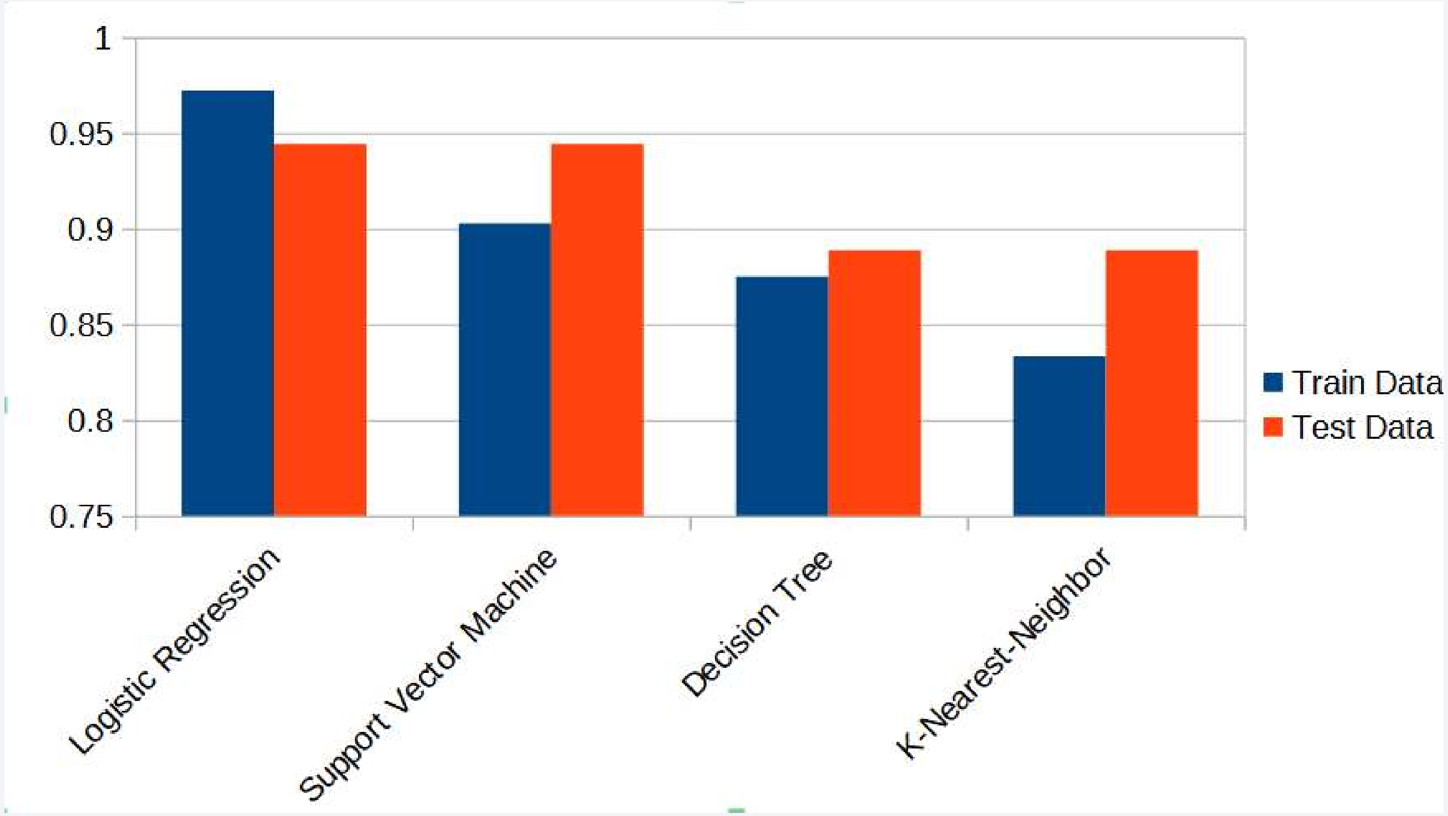
- Success rate forBooster versions FT, B4 and B5 is better in the payload range to 10000kg

Section 5

Predictive Analysis (Classification)

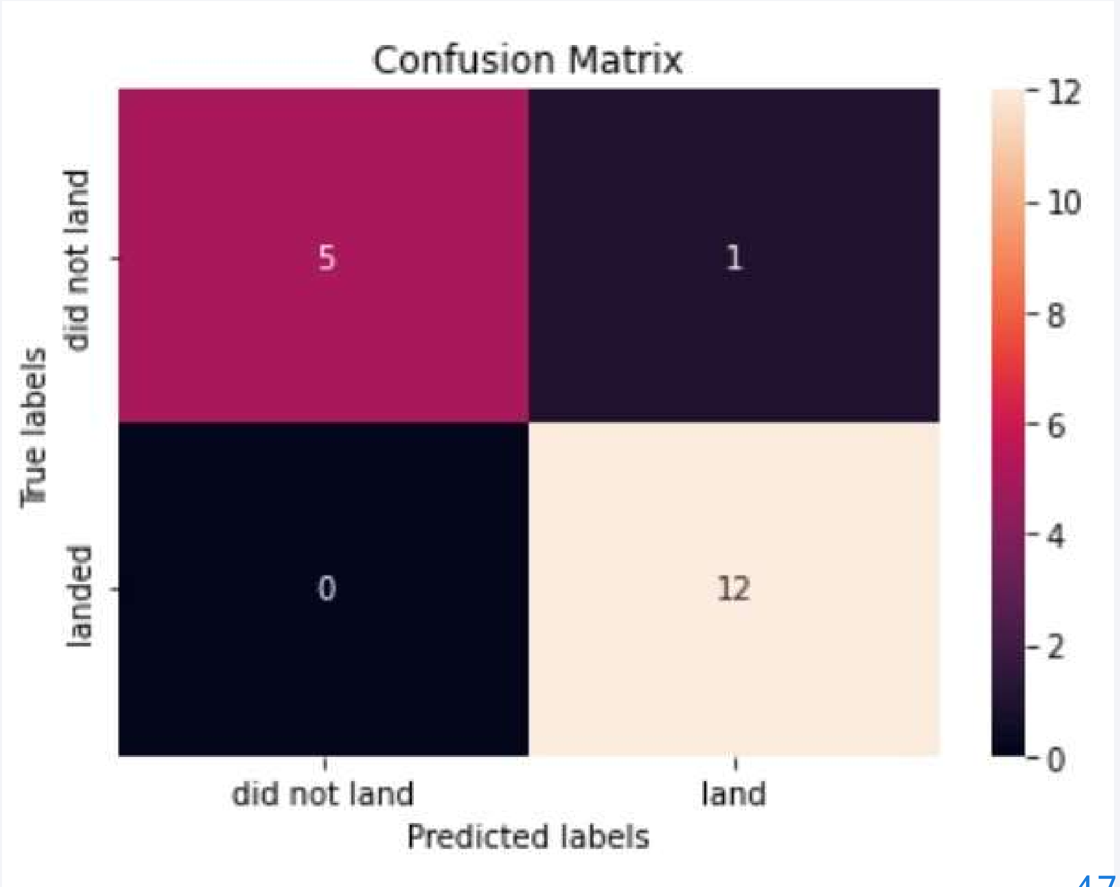
Classification Accuracy

- Logistic Regression has the best result for train data
- Logistic Regression and Support Vector Machines have the best results on test data



Confusion Matrix

- True Positives: 12
- True Negatives: 5
- False Positives: 1
- False Negatives: 0



Conclusions

- Prediction with Logistic Regression is quite accurate
- Support Vector Machine also provide a good result for predicting the landing outcome
- None of the models had false negatives
- All models had at least one false positive

Appendix

- All Python code and SQL can be inspected from the following links
  - GIT Hub


Thank you!