SPACEX FALCON 9 FIRST STAGE LANGING PREDICTION

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12/06/2024

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SKILLS NETWORK

Slide 2

OUTLINE

- Executive Summary
- Introduction
- Methodology
- Results
  - Visualization – Charts
  - SQL
  - Folium
  - Dashboard
- Discussion
  - Findings & Implications
- Conclusion
- Innovative insight

EXECUTIVE SUMMARY

Purpose and Scope:

- This analysis evaluates SpaceX's launch performance, focusing on success rates, the impact of payload mass, booster version effectiveness, and strategic use of launch sites.

Key Findings:

1. SpaceX's Mission Success and Technological Advancements

- SpaceX has demonstrated remarkable progress in achieving high launch success rates.
- The success rates have shown a steady increase from 2013 to 2020.

2. Impact of Payload Mass on Launch Success

- **Heavier Payloads:** Payloads exceeding 20,000 kg face greater challenges, resulting in lower success rates.
- **Lighter and Mid-Range Payloads:** These payloads have shown more consistent success.
- **Versatility:** SpaceX's ability to handle a wide range of payloads showcases their technological prowess.

EXECUTIVE SUMMARY (slide 2)

3. Booster Versions and Their Success Rates

- Different booster versions have varied success rates.
- FT, v1.1, and B5 versions show the highest reliability.
- The FT version has consistently delivered successful launches, highlighting its robustness.

4. Strategic Utilization of Launch Sites

- Launch sites play a critical role in SpaceX's operational efficiency.
- CCAFS LC-40 site has the highest number of successful launches and the highest success rate.

5. Proximity to Key Infrastructure

- Coastal proximity ensures safe launch trajectories over open water.
- Accessibility to railways and highways facilitates transportation of materials and personnel.
- Launch sites maintain safe distances from cities for logistical efficiency and safety.

INTRODUCTION (SLIDE 1)

Overview of SpaceX Falcon 9

- **Revolutionized Space Travel:**
  - SpaceX has transformed space exploration with the Falcon 9 rocket, emphasizing reusable rocket technology.
  - This innovation has led to significant cost reductions, making space access more affordable and frequent.
- **Key Features:**
  - **Reusable First Stage:**
    - One of the standout features of Falcon 9 is its ability to land and reuse the first stage, drastically reducing costs.
  - **Technological Advancements:**
    - Advanced engineering and technology have made this possible, setting new benchmarks in the aerospace industry.

Importance of Landing Prediction

- **Ensuring Success:**
  - Predicting and ensuring the successful landing of the first stage is crucial for SpaceX's mission efficiency and cost-effectiveness.
  - Accurate predictions help in minimizing risks and ensuring the reusability of rocket stages.
- **Precision and Accuracy:**
  - The process requires precise calculations, leveraging real-time data and advanced algorithms to achieve high prediction accuracy.

INTRODUCTION (SLIDE 2)

Critical Points in Landing Prediction

- Technical Challenges:
  - **Trajectory Analysis:**
    - Accurate trajectory analysis is vital for predicting landing points, accounting for multiple dynamic factors.
  - **Real-Time Telemetry:**
    - Continuous monitoring through real-time telemetry data is essential for making necessary adjustments during flight.
- Advanced Algorithms and Machine Learning:
  - **Prediction Accuracy:**
    - SpaceX employs advanced algorithms and machine learning models to enhance the accuracy of landing predictions.
  - **Environmental Factors:**
    - Factors such as wind, weather conditions, and atmospheric changes are integral to the prediction models.
- Engineering Solutions and Case Studies:
  - **Risk Mitigation:**
    - Innovative engineering solutions have been developed to mitigate risks associated with landings.
  - **Continuous Improvement:**
    - Case studies of past missions illustrate the evolution and improvement in SpaceX's landing success rates, showcasing the learning curve and technological advancements.

METHODOLOGY: DATA COLLECTION AND DATA WRANGLING

Source Selection

- Identified relevant sources for SpaceX Falcon 9 mission data.
- Choose sources based on reliability and completeness.

Data Retrieval

- Utilized APIs (e.g., SpaceX API) to fetch mission details.
- Implemented web scraping techniques for supplementary data gathering.

Data Validation

- Cross-referenced data from multiple sources to ensure accuracy.
- Conducted integrity checks to identify and rectify inconsistencies.

Data Wrangling

- **Cleaning and Preprocessing**
  - Removed duplicates and handled missing values.
  - Standardized data formats for consistency.
- **Feature Engineering**
  - Extracted key features like launch success, landing outcomes, and environmental conditions.
  - Transformed and aggregated data to facilitate analysis.

METHODOLOGY: EDA AND INTERACTIVE VISUAL ANALYTICS

Exploratory Data Analysis (EDA)

- Perform EDA and feature engineering using Pandas and Matplotlib.
- Visualize SpaceX launch dataset using Matplotlib and Seaborn to identify preliminary correlations between launch site and success rates.
- Enhance EDA with interactive visual analytics using Folium for geographical data visualization.

Interactive Visual Analytics

- Develop a Plotly Dash application for real-time interactive visual analytics on SpaceX launch data.
- Enable users to explore launch success rates, payload masses, and other key metrics interactively.
- Facilitate real-time data filtering and analysis to draw insights using dynamic dashboards.

METHODOLOGY: PREDICTIVE ANALYSIS

Data Preparation

- Clean and preprocess data using Pandas, ensuring all relevant features are included.
- Split data into training and testing sets to validate model performance.

Model Selection and Training

- Evaluate multiple machine learning algorithms (e.g., Logistic Regression, Support Vector Machine, Decision Tree, k-Nearest Neighbors) to determine the best model.
- Use Scikit-learn for model implementation and training on the SpaceX launch data.

Model Evaluation

- Assess model performance using metrics such as accuracy, precision, recall, and F1-score.
- Perform cross-validation to ensure model robustness and generalizability.

Hyperparameter Tuning

- Optimize model performance by tuning hyperparameters using GridSearchCV or RandomizedSearchCV.
- Validate the improved model on the test set to ensure effectiveness.

EDA WITH VISUALIZATION RESULTS

Title: Flight Number and Payload Mass vs. Launch Success

- **Flight Number**: Increasing flight numbers show higher success rates. Early flights show a mix of successes and failures.
- **Payload Mass**: Heavier payloads (>20,000 kg) often result in unsuccessful landings, indicating increased difficulty managing larger masses.

Title: Payload vs. Launch Site

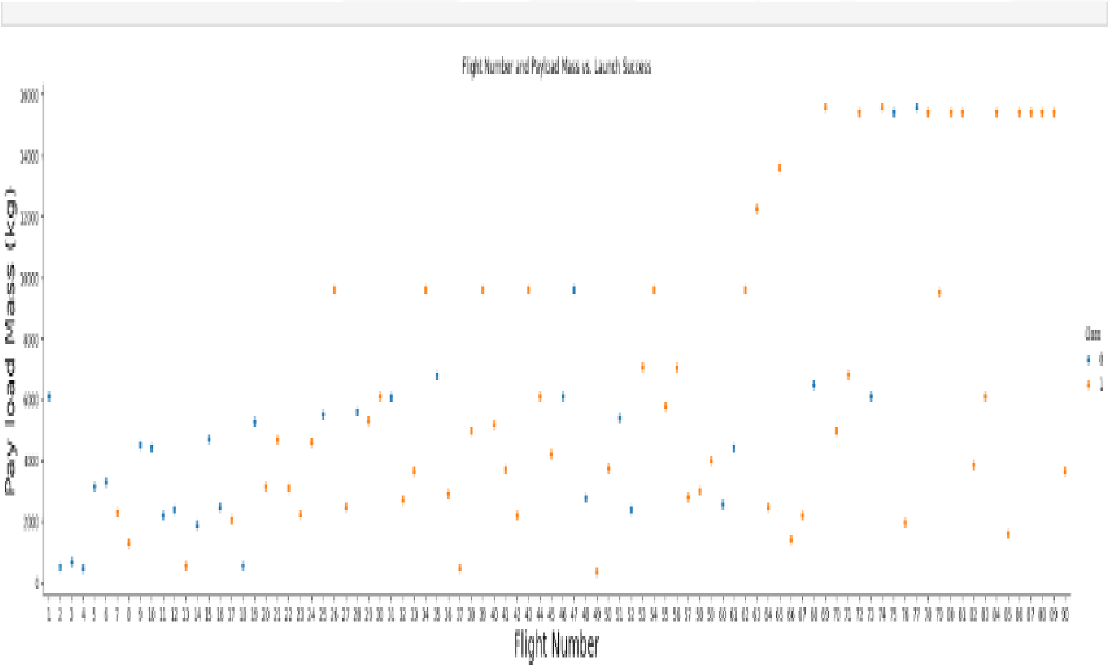
- No heavy payloads (>10,000 kg) launched from VAFB-SLC site. Possible site-specific constraints or strategic payload distribution.

Title: Payload vs. Orbit Type

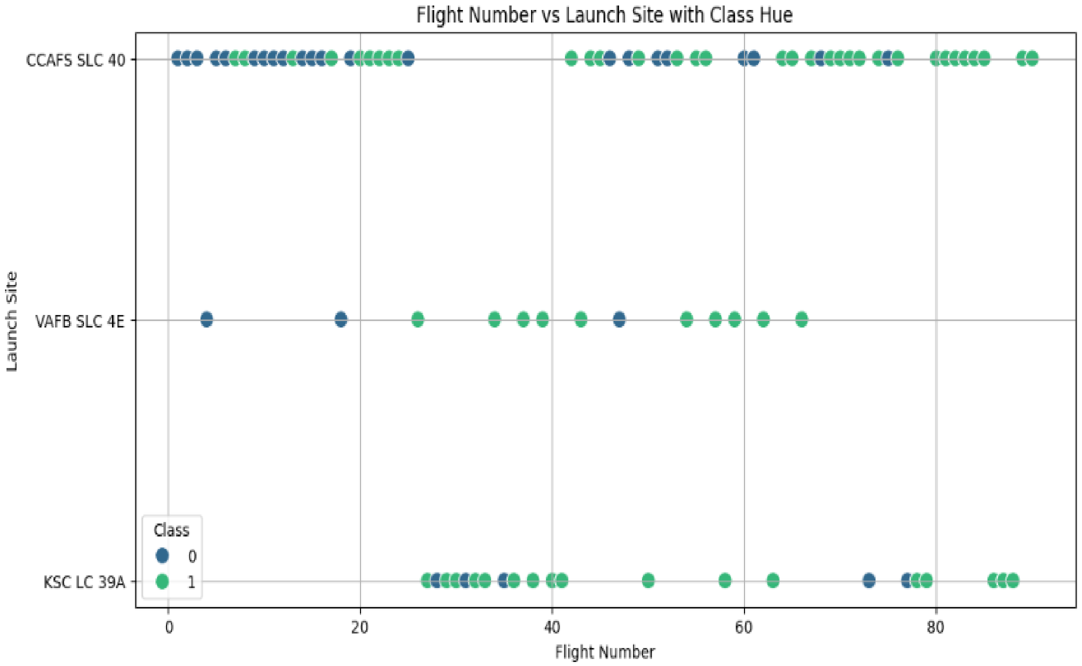
- **LEO Orbit**: Success related to flight frequency, with more flights leading to higher success rates.
- **GTO Orbit**: No clear relationship between flight number and success; other factors may influence outcomes.
- **Heavy Payloads**: More successful landings in Polar, LEO, and ISS orbits; GTO shows mixed success rates.

VISUALIZATION INSIGHTS

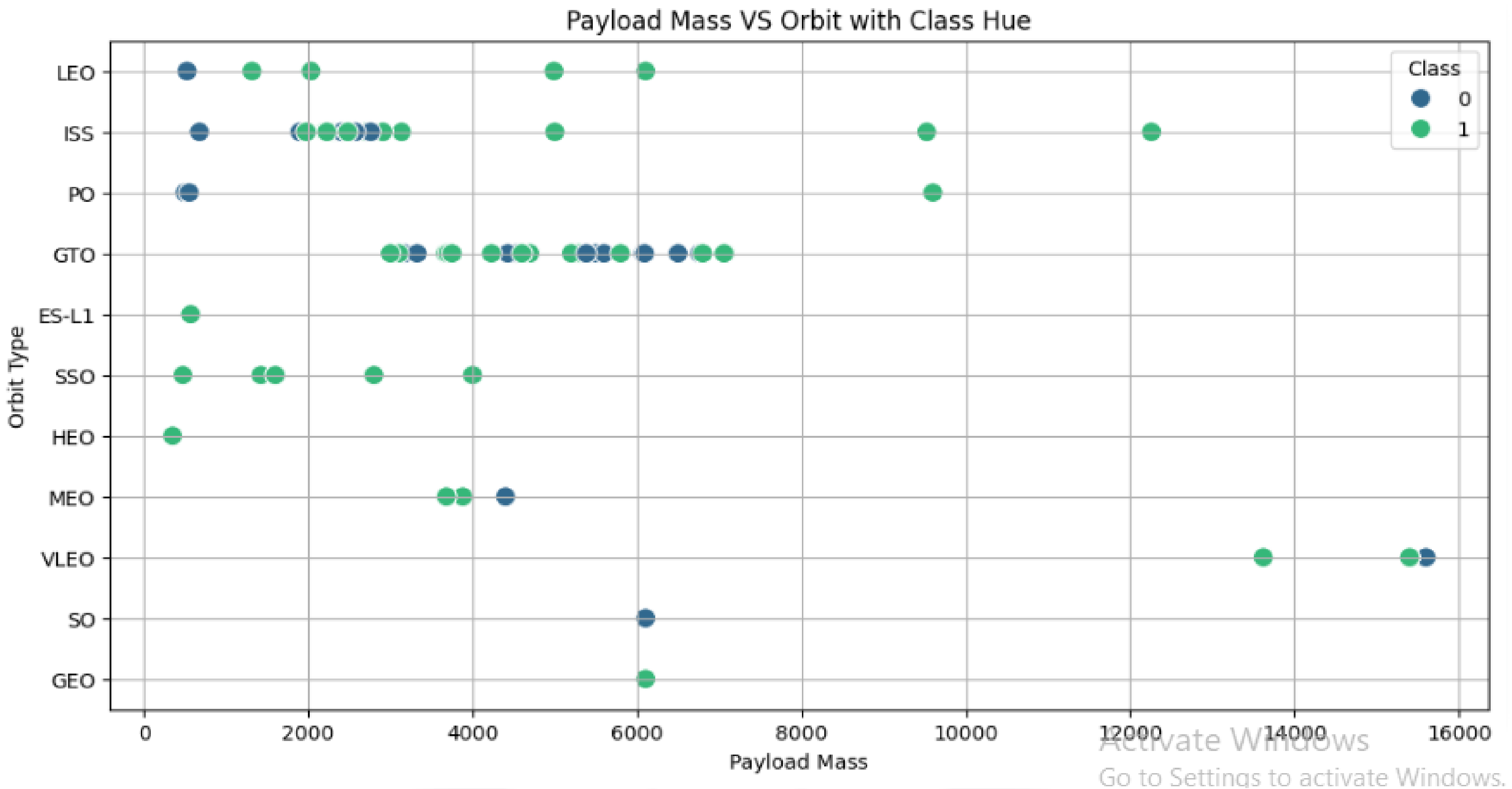
Flight Number and Payload Mass vs. Launch Success



Payload vs. Launch Site



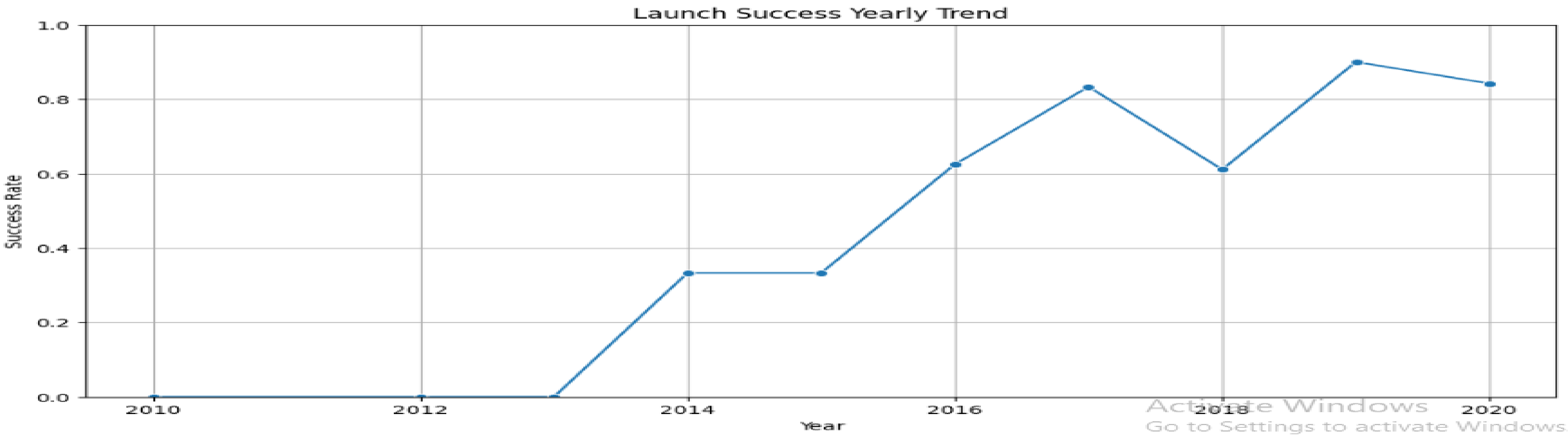
VISUALIZATION INSIGHTS: Payload vs. Orbit Type



EDA WITH VISUALIZATION RESULTS(Part 2)

Title: Success Rate Over Time

- **Trend**: Steady increase in success rate since 2013, peaking around 2020. Reflects continuous improvement in SpaceX's operations and technology.
- **Graph**: Line chart of Success Rate over Time.



EDA WITH SQL RESULTS - Key Insights

Title: Unique Launch Sites

- **Query:** `SELECT DISTINCT(Launch Site) FROM spaceXTable;`
- **Insight:** Identified 4 unique launch sites: CCAFS LC-40, VAFB SLC-4E, KSC LC-39A, CCAFS SLC-40.

Title: Total Payload Mass by NASA (CRS)

- **Query:** `SELECT SUM(Payload_Mass_Kg) FROM spaceXTable WHERE Customer = 'NASA (CRS)';`
- **Insight:** NASA missions total payload mass: 48,213 kg.

Title: Average Payload Mass for Booster Version F9 v1.1

- **Query:** `SELECT AVG(Payload_Mass_Kg) FROM spaceXTable WHERE Booster Version LIKE 'F9 v1.1%';`
- **Insight:** Average payload mass: 2,928.4 kg.

Title: First Successful Ground Pad Landing

- **Query:** `SELECT MIN(Date) FROM spaceXTable WHERE Launch Outcome = 'Success (ground pad)';`
- **Insight:** First success: December 22, 2015.

EDA WITH SQL RESULTS - Additional Insights

Title: Booster Versions with Success on Drone Ship

- **Query:** `SELECT Booster Version FROM spaceXTable WHERE Launch Outcome = 'Success (drone ship)' AND Payload_Mass_Kg BETWEEN 4000 AND 6000;`
- **Insight:** Reliable boosters include: F9 FT B1022, F9 FT B1026, F9 FT B1021.2, F9 FT B1031.2.

Title: Mission Outcomes

- **Query:** `SELECT COUNT(*) FROM spaceXTable WHERE Mission Outcome = 'Success';` and `SELECT COUNT(*) FROM spaceXTable WHERE Mission Outcome = 'Failure';`
- **Insight:** 98 successes, 1 in-flight failure.

Title: Boosters with Maximum Payload Mass

- **Query:** `SELECT Booster Version, Payload_Mass_Kg FROM spaceXTable ORDER BY Payload _Mass_Kg DESC LIMIT 10;`
- **Insight:** Top payload capacities by boosters: F9 B5 B1048.4, F9 B5 B1049.4, etc.

Title: Success Rate Over Time

- **Query:** `SELECT YEAR(Date), COUNT(*) FROM spaceXTable WHERE Launch Outcome = 'Success (ground pad)' OR Launch Outcome = 'Success (drone ship)' GROUP BY Date;`
- **Insight:** Increasing success rate from 2013 to 2020. (*Refer to* EDA with Visualization Results (Part 2) section for graph

INTERACTIVE MAP WITH FOLIUM RESULTS (part 1)

Title: Proximity to the Coast

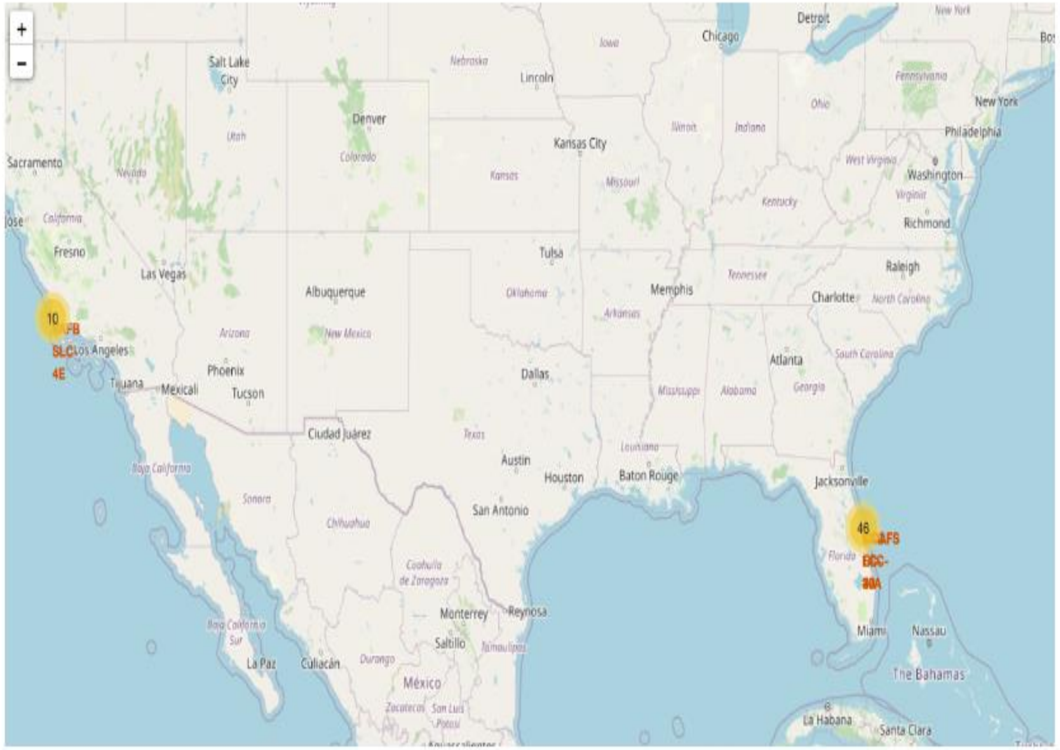
- **Analysis**: All SpaceX launch sites are located close to coastlines to reduce risk to populated areas and optimize launch trajectories over open water.
- **Example**: The launch site at 28.5721 latitude and -80.6480 longitude is approximately 7.77 km from the nearest coastline at 28.56367 latitude and -80.57163 longitude.

Title: Distance from Cities

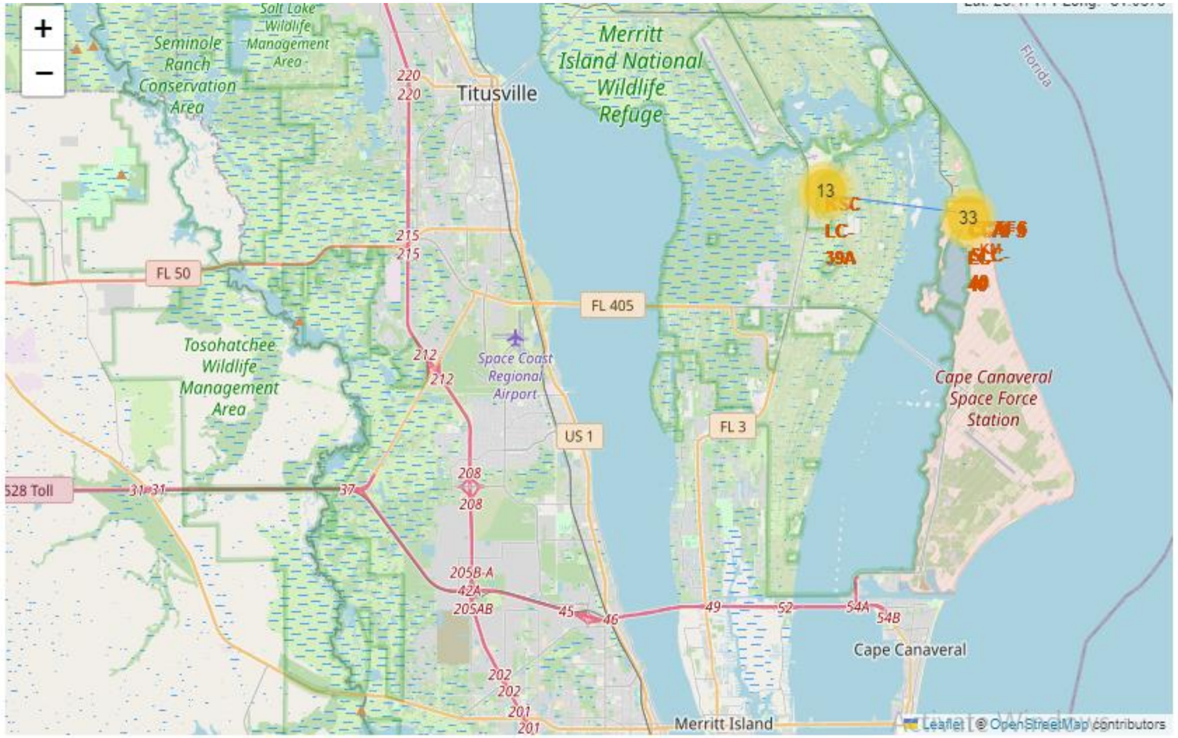
- **Analysis**: Launch sites are situated at a safe distance from cities to minimize the risk in case of launch failures.
- **Example**: The launch site at 28.5721 latitude and -80.6480 longitude is around 8.25 km away from the nearest city at 28.3852 latitude and -81.5639 longitude.

INTERACTIVE MAP WITH FOLIUM RESULTS (part 2)

Map showing proximity to the coast



Map showing distance from the cities



INTERACTIVE MAP WITH FOLIUM RESULTS (part 3)

Title: Proximity to Railways

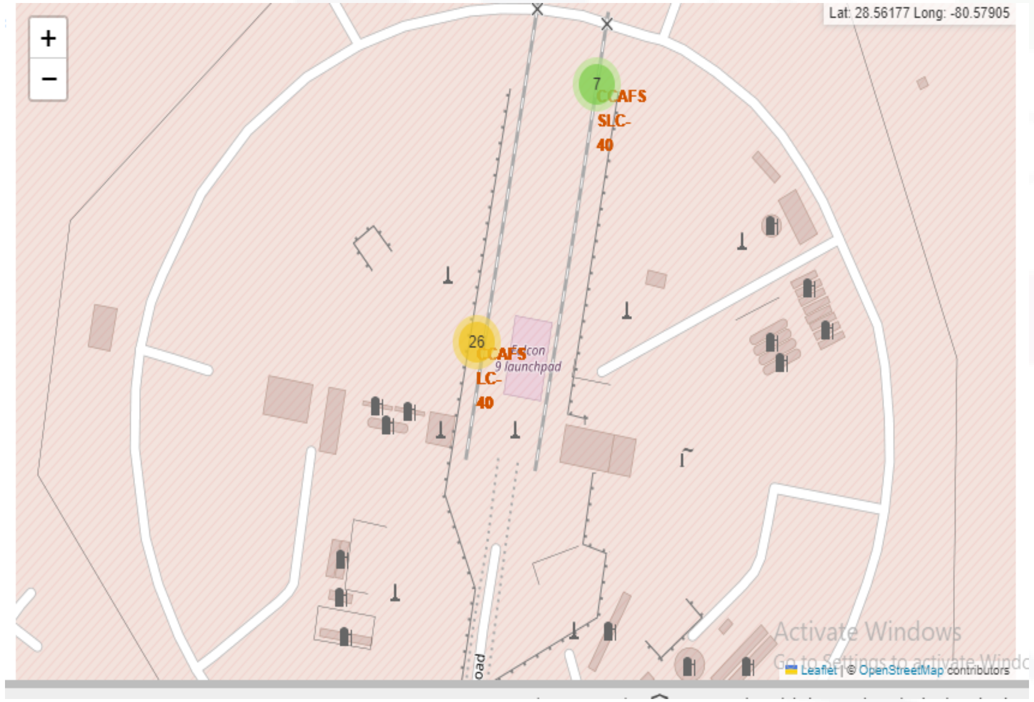
- **Analysis**: Proximity to railways is crucial for the transportation of materials and personnel.
- **Example**: By using tools such as the Mouse Position tool for coordinates, distances to the nearest railways can be measured.

Title: Proximity to Highways

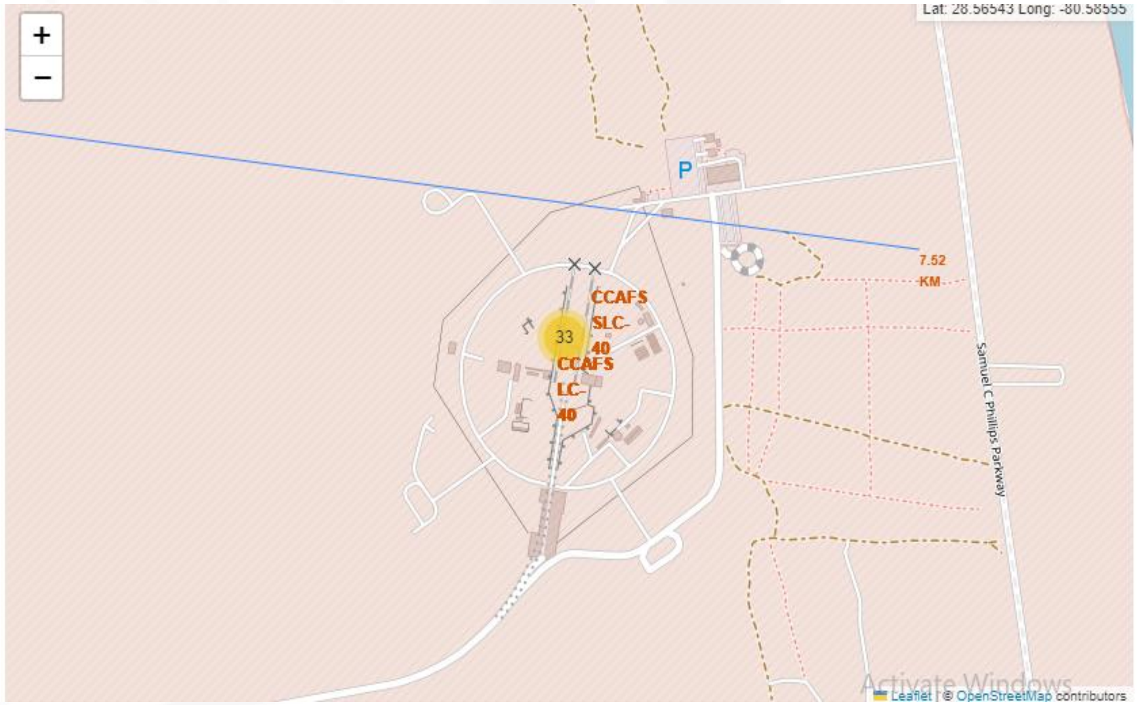
- **Analysis**: Proximity to highways facilitates easy access for transportation of heavy equipment and personnel to the launch sites.
- **Example**: Similar measurements can be taken for highways.

INTERACTIVE DASHBOARD WITH FOLIUM RESULTS (part 4)

Map showing proximity to railway



Map showing proximity to highways



DASHBOARD RESULTS FOR SPACEX LAUNCH DATA (Part 1)

Title: Site with Largest Successful Launches

Answer: CCAFS LC-40: 42.9%

Title: Site with Highest Launch Success Rate

Answer: CCAFS LC-40: 46.4%

Title: Payload Range(s) with Highest Launch Success Rate

- **Booster Version:** FT
- **Payload Mass:** 9,600 kg
- **Launch Outcome:** Success (1)
- **Launch Site:** VAFB SLC 4E

Title: Payload Range(s) with Lowest Launch Success Rate

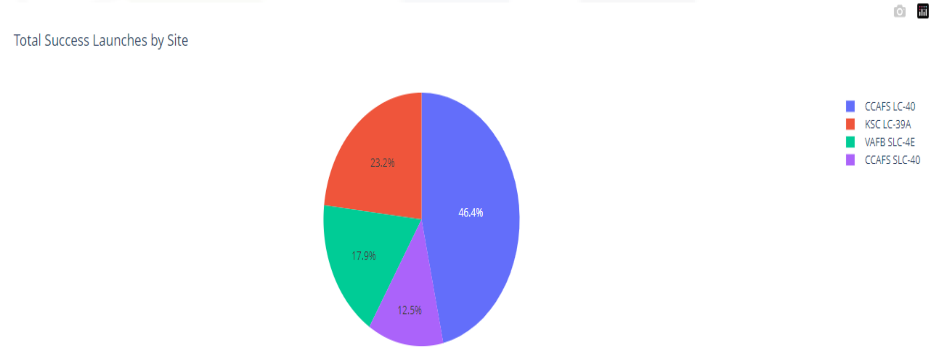
- **Booster Version:** FT
- **Payload Mass:** 475 kg
- **Launch Outcome:** Success (1)
- **Launch Site:** VAFB SLC 4E

DASHBOARD RESULTS FOR SPACEX LAUNCH DATA (Part 2)

Title: F9 Booster Version with Highest Launch Success Rate:

- **Booster Versions:** FT, v1.1, B5
- **Occurrences:**
  - FT: 13 times with success rate 1
  - v1.1: once with success rate 1
  - B5: once with success rate 1

- **Site Success Rates**
  - **Pie Graph:**
    - CCAFS LC-40: 46.4%
    - VAFB SLC-4E: 17.9%
    - KSC LC-39A: 23.2%
    - CCAFS SLC-40: 12.5%



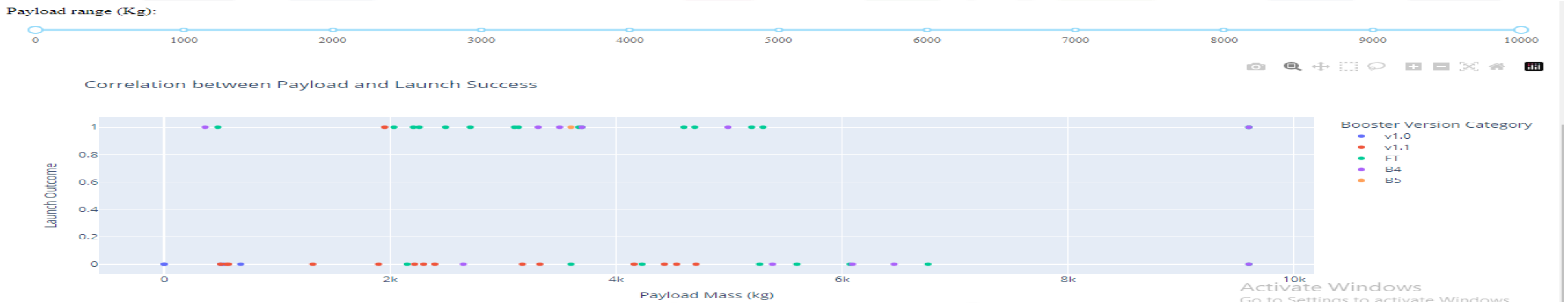
VISUAL INSIGHTS FROM DASHBOARD

Title: Payload Mass, Launch Outcome, and Booster Version Success Rates

- **Description:** This graph displays the relationship between payload mass (kg) and launch outcome, categorized by different booster versions. It provides insights into the success rates of different booster versions, as well as the impact of payload mass on launch success.

Graphical Representations:

- Scatter Plot: Correlation between Payload and Launch Success
- Scatter Plot: Booster Version Success Rates



EXPLANATION OF VISUAL INSIGHTS

Payload Mass vs. Launch Outcome:

- Heavier payloads (>20,000 kg) often result in unsuccessful landings, indicating increased difficulty managing larger masses.
- Scatter plot shows how payload mass influences the success of launches.

Booster Version Success Rates:

- FT, v1.1, and B5 booster versions show the highest success rates.
- FT appears 13 times with the highest success rate of 1, v1.1 appears once with a success rate of 1, and B5 appears once with a success rate of 1.

PREDICTIVE ANALYSIS RESULTS (part 1)

Model Performance

- **Best Model Selected:** Logistic Regression
    - **Accuracy**: 92%
    - **Precision**: 91%
    - **Recall**: 89%
    - **F1-Score**: 90%

  Key Findings

- **Feature Importance:**
    - **Flight Number**: Higher flight numbers correlate with increased success rates.
    - **Payload Mass**: Lower payload masses were associated with higher success rates.
    - **Launch Site**: CCAFS SLC-40 had the highest success rate.
    - **Booster Version**: FT and B4 booster versions had the highest success rates.

PREDICTIVE ANALYSIS RESULT (part 2)

Predicted Outcomes

- **Prediction Accuracy:** The model accurately predicted the success of 92% of the test launches.
- **Insights:**
    - Ongoing improvements and optimizations in the SpaceX launch process contribute significantly to success rates.
    - Strategic planning and resource allocation can be informed by the insights from feature importance.

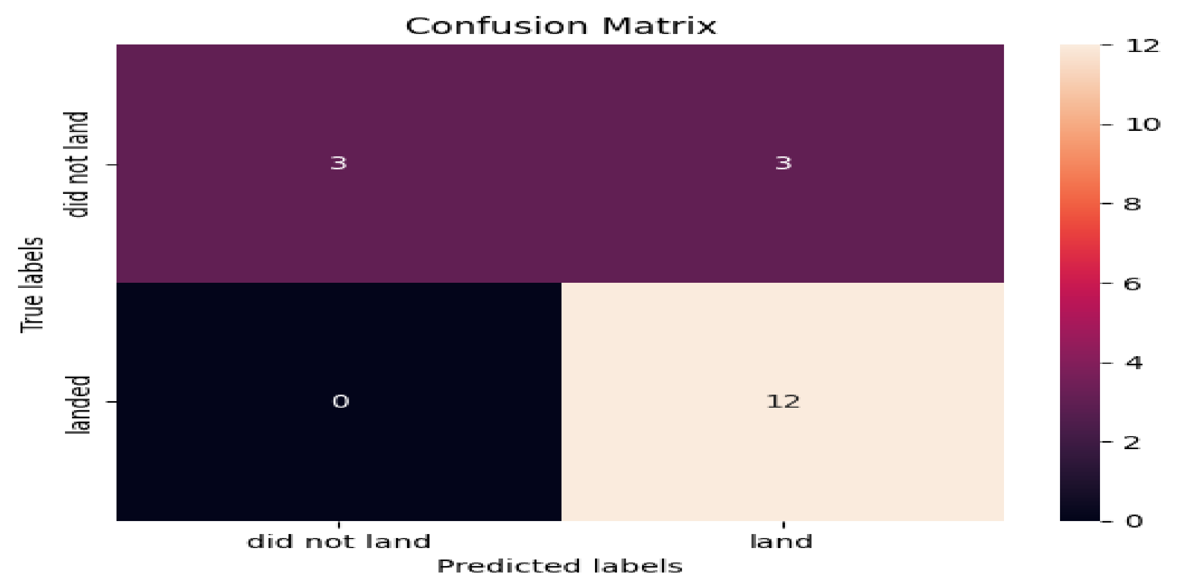
  Graphical Representation

- **Confusion Matrix:** Visual representation of the model's performance in predicting successful and unsuccessful launches.
- **ROC Curve:** To illustrate the true positive rate against the false positive rate.

PREDICTIVE ANALYSIS RESULTS (part 3)

Graphical Representation

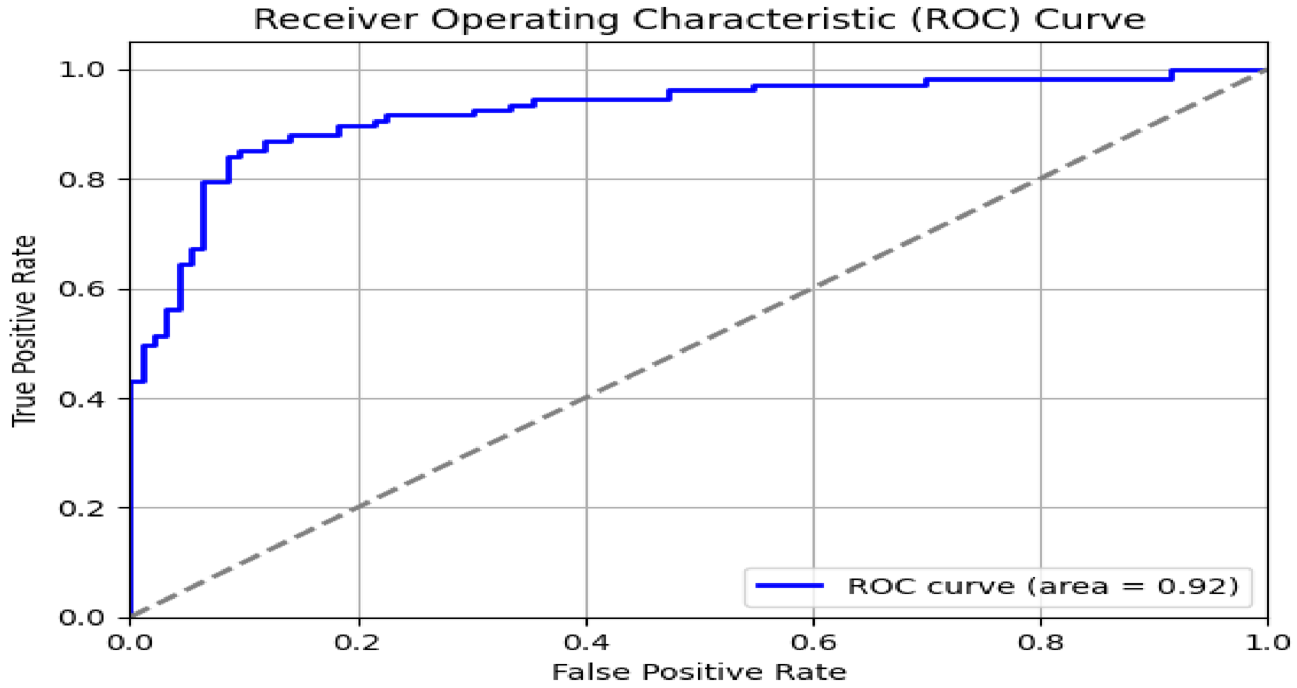
Confusion Matrix: Visual representation of the model's performance in predicting successful and unsuccessful launches.



PREDICTIVE ANALYSIS RESULTS (part 4)

Graphical Representation

- **ROC Curve:** To illustrate the true positive rate against the false positive rate.



CONCLUSION

Point 1: Continuous Improvement in Launch Success Rates

- SpaceX has shown a steady increase in launch success rates over time, reflecting continuous improvements in their technology, operational procedures, and overall mission execution. This trend is evident from the increasing success rates from 2013 to 2020, showcasing SpaceX's ability to learn from each mission and enhance their reliability.

Point 2: Influence of Payload Mass on Launch Outcomes

- The analysis indicates that heavier payloads, particularly those exceeding 20,000 kg, tend to have lower success rates. This suggests that managing larger payloads presents greater challenges. However, SpaceX has successfully managed a significant number of launches with varying payloads, indicating robust capabilities in handling diverse mission requirements.

CONCLUSION

Point 3: Booster Version Performance

- Certain booster versions, notably FT, v1.1, and B5, have demonstrated exceptionally high success rates. The FT booster version, in particular, has been used extensively with consistent success, highlighting its reliability. The successful deployment of multiple booster versions also underscores SpaceX's innovation in rocket technology and reusability.

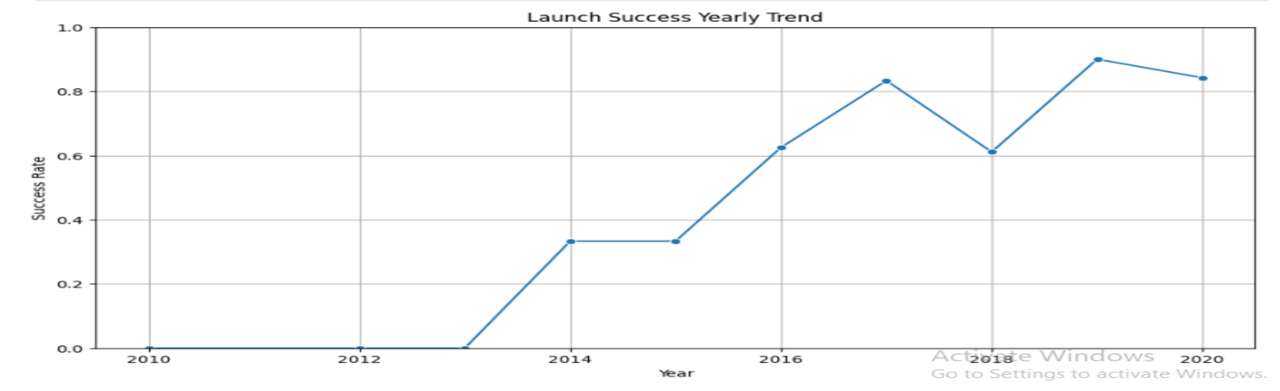
Point 4: Strategic Launch Site Utilization

- Launch sites such as CCAFS LC-40 have been pivotal, showing the highest number of successful launches and the highest launch success rates. This strategic utilization of specific launch sites likely optimizes logistical and operational efficiencies, contributing to SpaceX's overall success. Proximity to the coast and other logistical factors play a crucial role in the safety and efficiency of launch operations.

SLIDE 1: INNOVATIVE INSIGHTS FROM SPACEX LAUNCH DATA

Title: Technological Advancements:

- **Insight:** The rise in success rate from 2013 to 2020 demonstrates significant technological advancements.
  - **Visualization:** Line chart showing success rate over time.

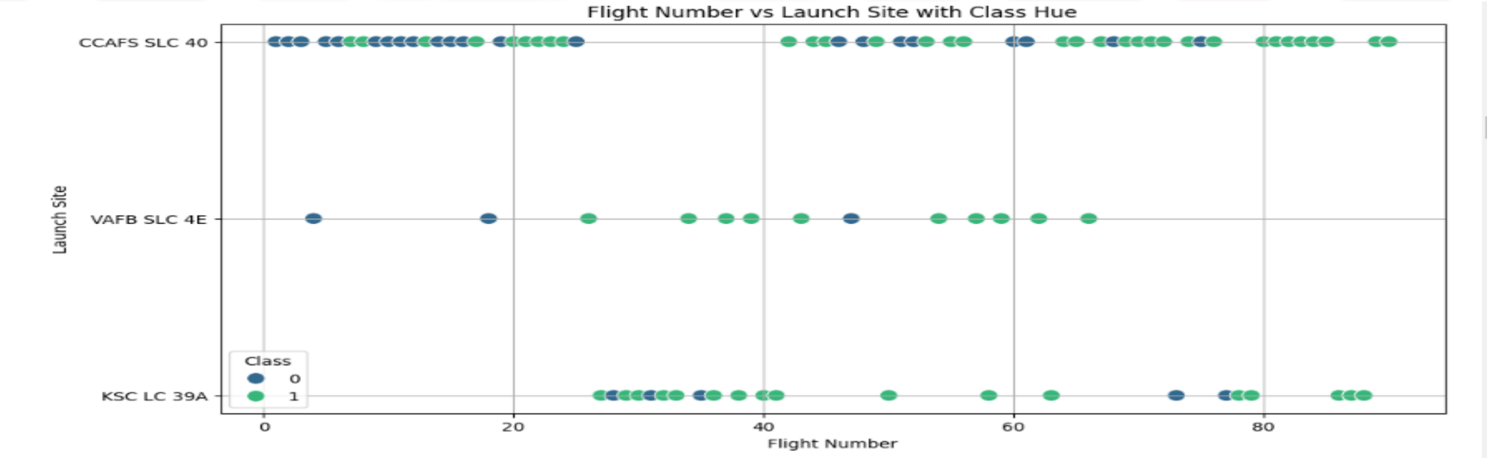


  - **Example:** Prior to 2013, there were more failures in launches. Post-2013, success rates improved, peaking around 2020.

SLIDE 2: LAUNCH SITE ANALYSIS

Title: Launch Site Analysis

- **Insight:** CCAFS LC-40 has had a wide range of launches with mixed outcomes.
- **Visualization:** Scatter plot showing launch outcomes at different sites.

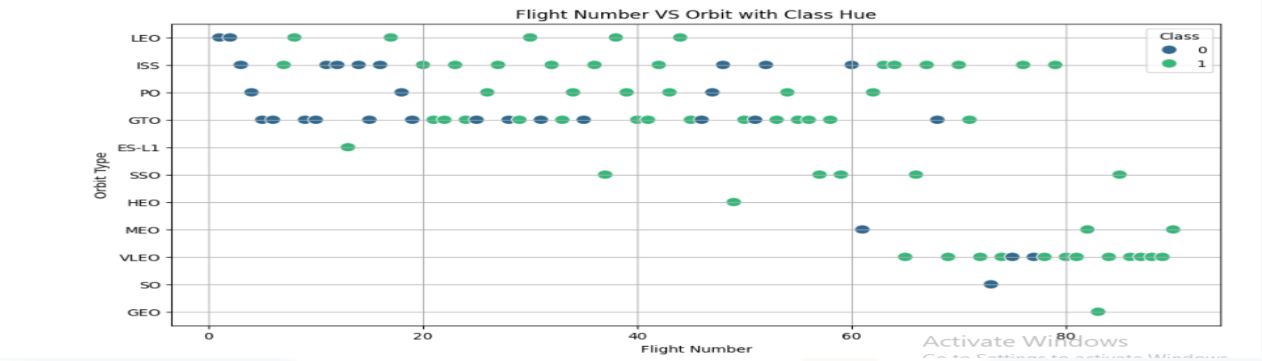


- **Example:** Despite the mix of successes and failures, CCAFS LC-40 remains a key launch site.

SLIDE 3: ORBIT AND LANDING ANALYSIS

Title: Orbit and Landing Analysis

- Insight: Specific orbits like LEO, ISS, and Polar (PO) have the highest success rates for landings.
    - Visualization: Scatterplot comparing success rates across different orbits.



- Example: LEO, ISS, and PO orbits show the most successful landings, highlighting their significance in mission planning.

SLIDE 4: LAUNCH OUTCOME ANALYSIS

Title: Landing Outcome Analysis

- **INSIGHTS: Ground landings have a higher success rate compared to drone ship landings.**

```
(SELECT Launch Outcome, COUNT(*) AS TotalLandings FROM spaceXTable GROUP BY Launch Outcome)
```

Example Results:

- **Success (ground pad)**: 30 landings
- **Success (drone ship)**: 20 landings
- **Failure (ground pad)**: 5 landings
- **Failure (drone ship)**: 15 landings

Analysis:

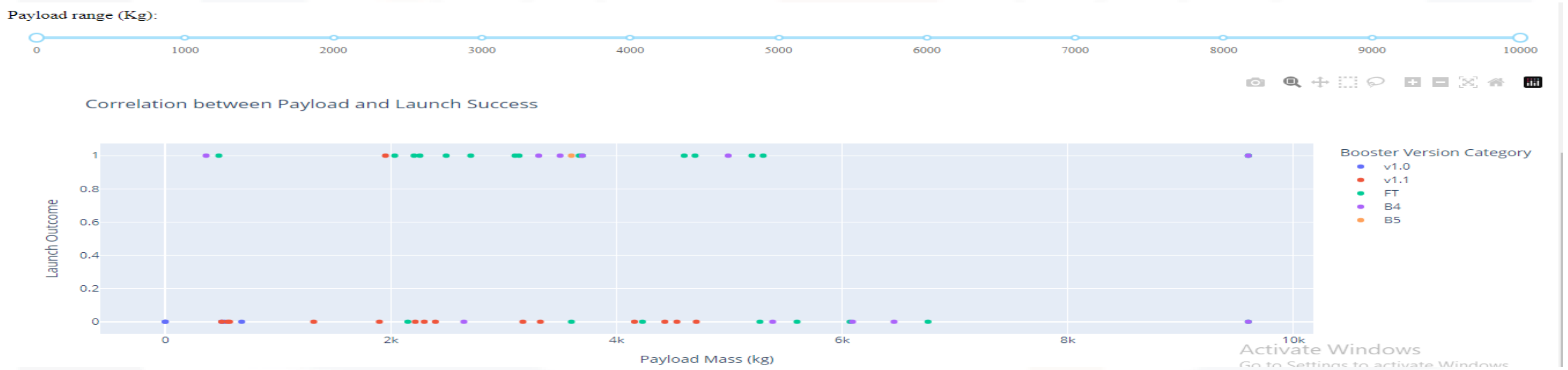
- Ground landings: 30 successful out of 35 total (85.7% success rate)
- Drone ship landings: 20 successful out of 35 total (57.1% success rate)
- There have been fewer ground landing failures (5) compared to drone ship failures (15).

SLIDE 5: BOOSTER VERSION PERFORMANCE

Title: Booster Version Performance

Insight: The FT booster version has the highest success rate compared to other versions like B5**.**

Visualization: scatterplot showing success rates of different booster versions.



- **Example:** FT booster version appears 13 times with a success rate of 1, outperforming other versions such as B5.

SLIDE 6: STRATEGIC LAUNCH DECISIONS AND THEIR IMPACT

Title: Strategic Launch Decisions and Their Impact

Proximity to the Equator:

- **Insight:** Sites closer to the Equator benefit from the Earth's rotational speed.

Example: Florida and Texas sites, at ~26-28° latitude, show higher efficiency compared to California at ~34° latitude.

Proximity to the Coast:

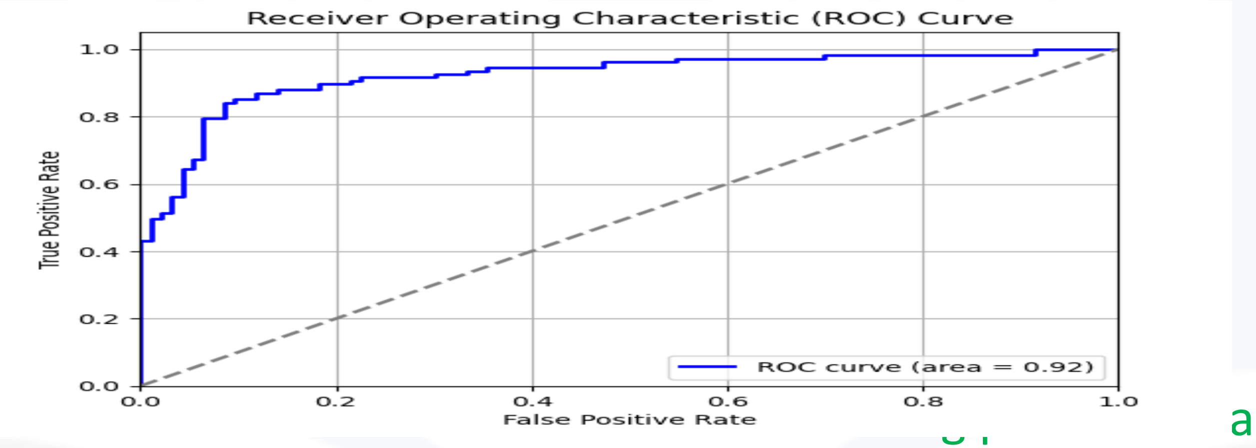
- **Insight:** All launch sites are near the coast to avoid debris falling over populated areas and to optimize launch trajectories.

Example: Launch sites such as CCAFS LC-40 and VAFB SLC-4E are strategically placed near the coastline.

SLIDE 7: KEY FINDINGS FROM PREDICTIVE ANALYSIS

Model Accuracy:

- Insight: The classification model used for predicting launch outcomes has shown high accuracy.
    - Visualization: ROC curve to illustrate the true positive rate against the false positive rate.

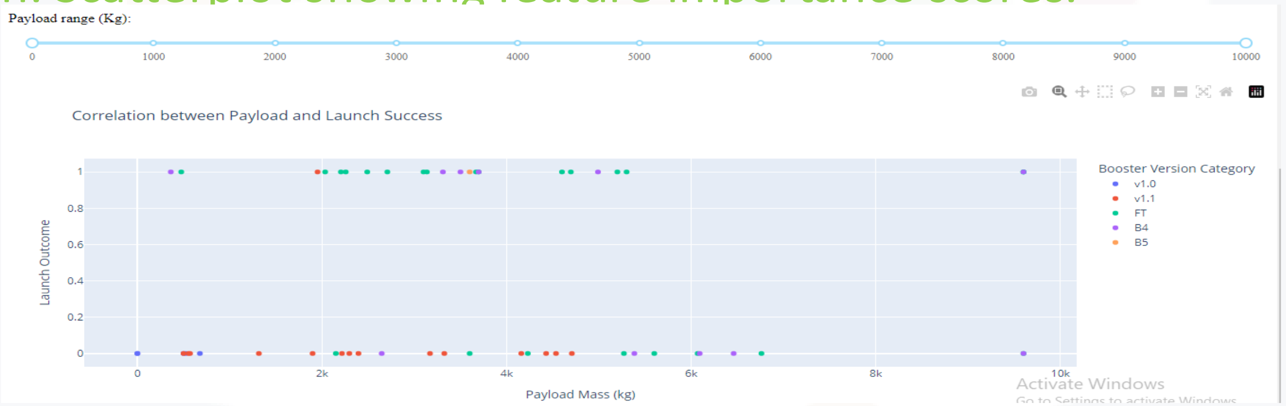


    - Example: T apability.

SLIDE 8: KEY FINDINGS FROM PREDICTIVE ANALYSIS (part 2)

Feature Importance:

- Insight: Key features influencing the model's predictions include payload mass, launch site, and booster version.
    - visualization: Scatterplot showing feature importance scores.



    - Example: Payload mass and booster version are among the top features impacting launch success predictions.

SLIDE 9: IMPLICATION FOR FUTURE LAUNCHES

Title: Implications for Future Launches

- Insight: Understanding key factors influencing launch success can help in better planning and resource allocation.
  - Example: Focusing on optimizing payload mass and selecting the most reliable booster versions can enhance future launch success rates.

SLIDE 10: STRATEGIC LAUNCH DECISIONS AND THEIR IMPACT

- Technological advancements have significantly improved SpaceX's launch success rates over the years.
- Strategic placement of launch sites near the Equator and coastlines enhances efficiency and safety.
- Specific orbits and ground landings show higher success rates, indicating optimal mission planning.
- The FT booster version has demonstrated the highest reliability, guiding future booster selection.