Winning Space Race with Data Science

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Outline

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

Executive Summary

CRISP Methodology:

1. Determine cost of each launch & whether SpaceX will reuse their first stage.

2. Collect SpaceX data via Wikipedia, Spacex.com

3. Format Data

4. Analyze for insights

5. Predict whether first stage will be reused.

Summary of all results:

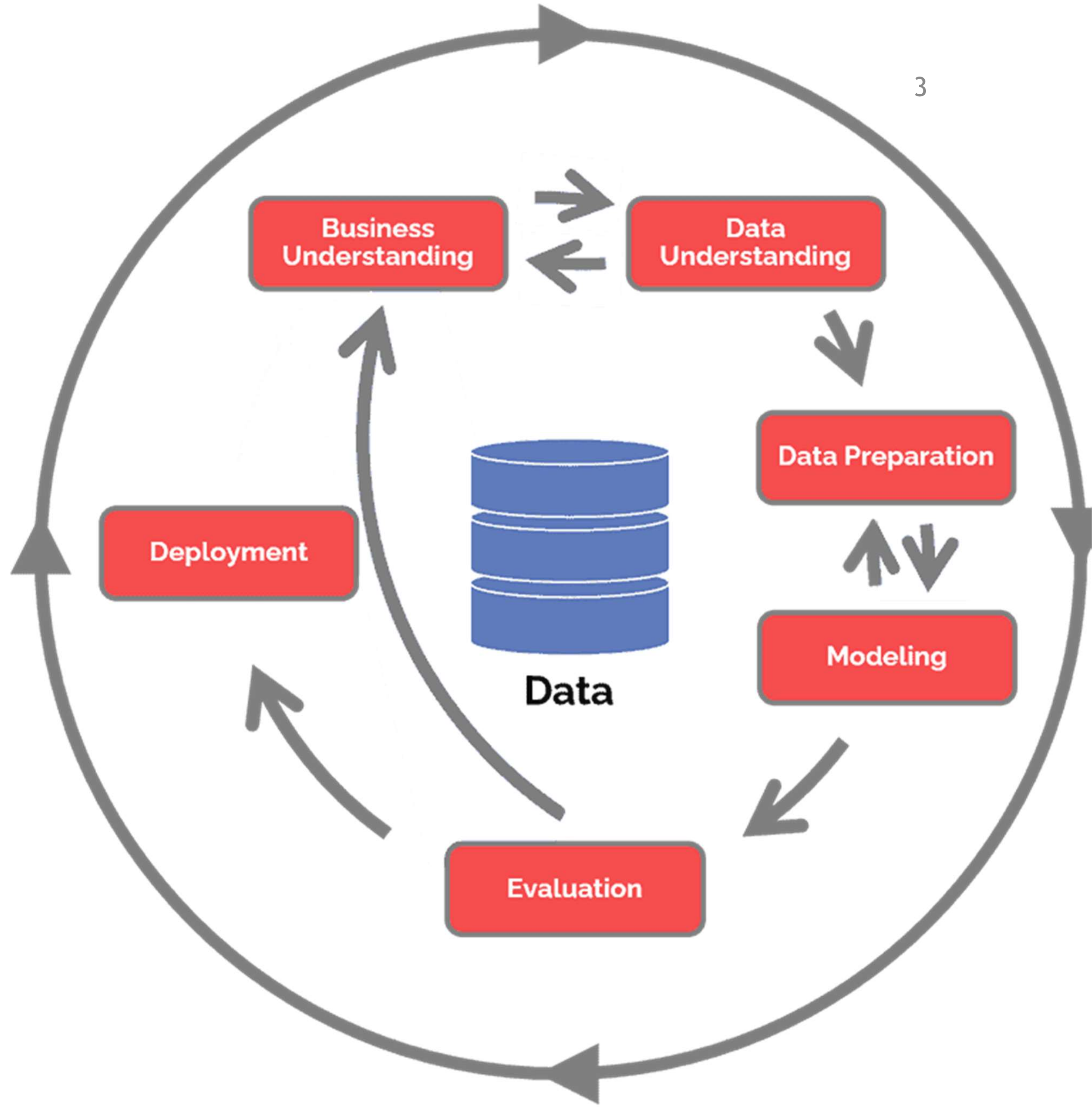
- Cost of launch decreases every reuse.

- SpaceX will reuse their first stage; perhaps, striving to reuse each stage.

- Over 96% of **Successful Landings** utilized

CRISM-DM Diagram: Nick Hotz

Grid-Fins & Legs.



Introduction

- Goal:

  - Company Space Y plans to compete in the Race to Space, our goal is to ***minimize*** the **Cost of Each Launch**

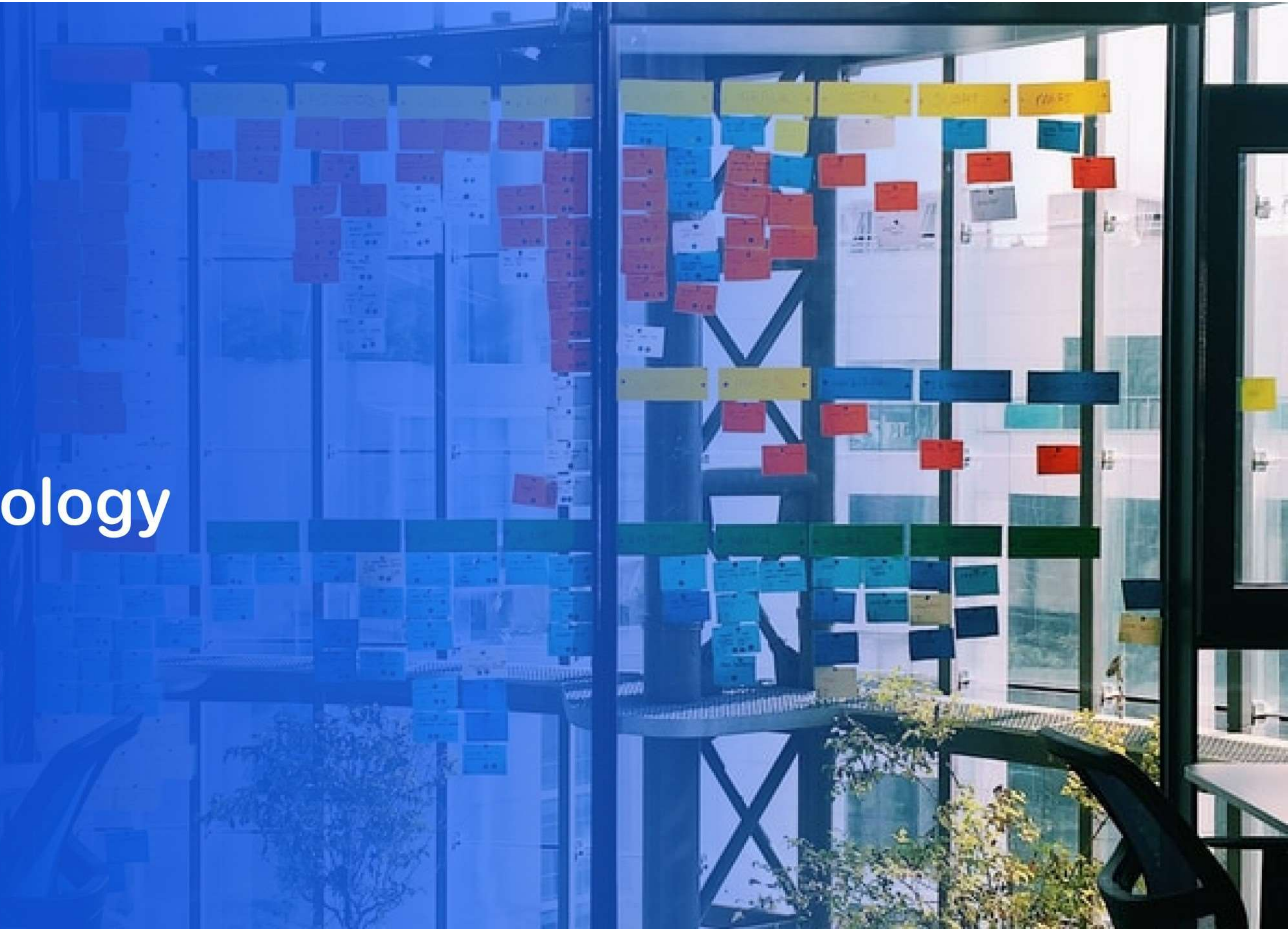
- Problems to Answer:

  - Why do SpaceX competitors spend $165 Million per Launch, relative to SpaceX's $62 million cost per Launch?

  - What variables contribute to a higher Success Rate of Landing, and why?

Section 1

Methodology



Methodology

Executive Summary

- Data collection methodology:
  - SpaceX data was collected via Wikipedia & SpaceX website; data was collected with tools such as, Python and web-scraping HTML.
- Perform data wrangling
  - Collected data started off unstructured; we organized, cleaned, and visualized the collected data to find data-driven insights that lead to business-decisions.
- Perform exploratory data analysis (EDA) using visualization and SQL
- Perform interactive visual analytics using Folium and Plotly Dash
- Perform predictive analysis using classification models

- We build classification models using different variables and use evaluation methods to validate the out-of-sample accuracy of each Data Model.

Data Collection

Proof of work:

- Data collection from SpaceX website

Link

- Data Collection from Wikipedia

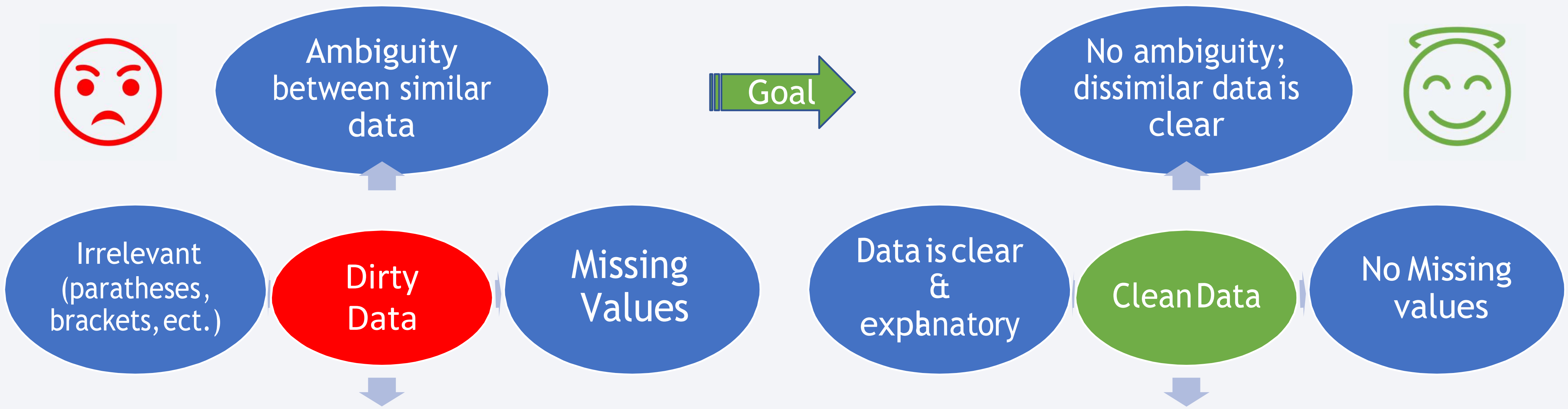
Link

1.


3.
7
Store relevant data to SQL database
2.
Collect Data, ensure its relevance, move on to next year

Data Wrangling

- Proof of Work:
  - [Data Wrangling Notebook]



Unstructured Labels

Clear & Concise Labels

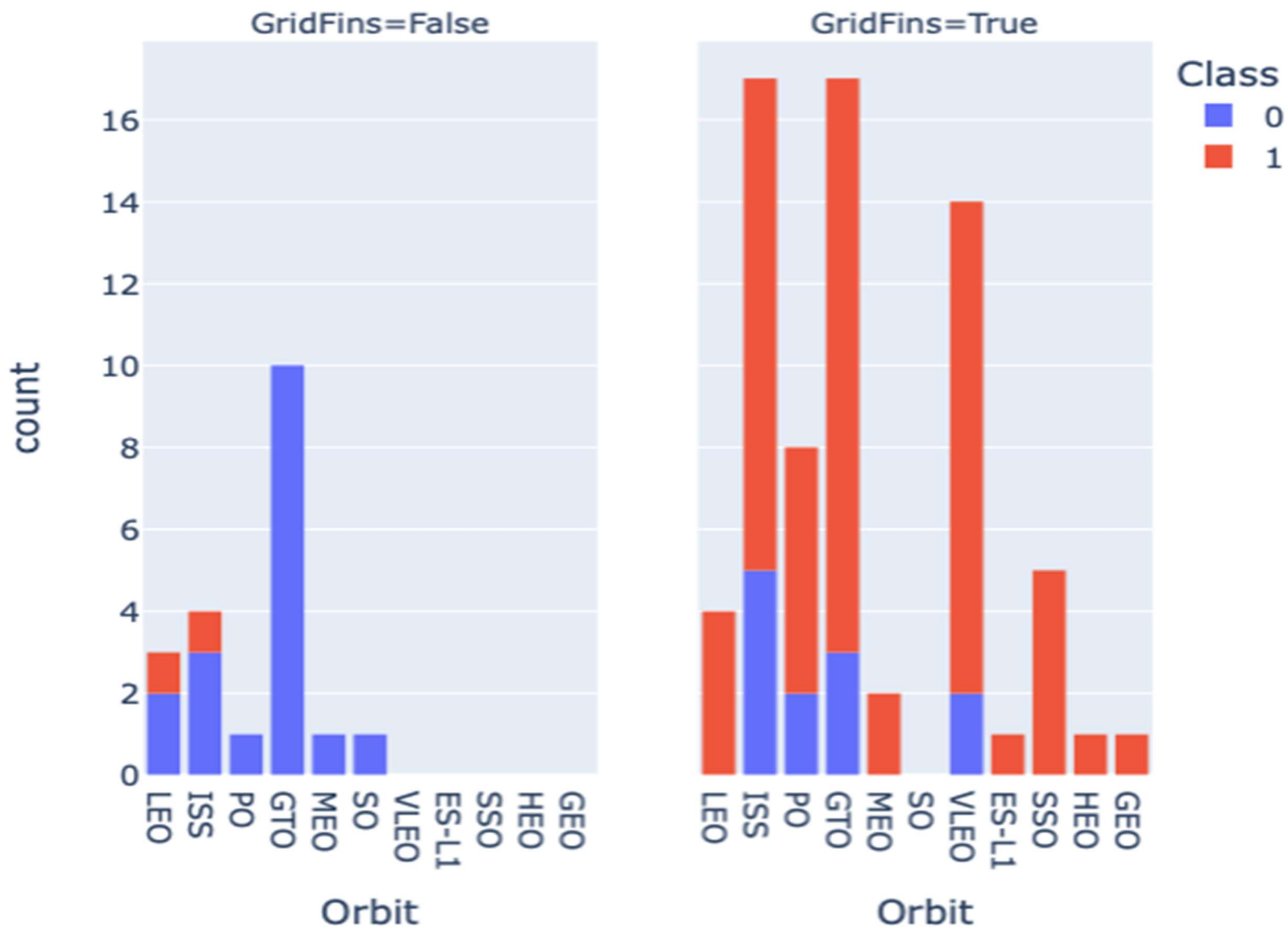
- [Proof of EDA]

EDA with Data Visualization (1)

- **Goal**: DECREASE COST OF LAUNCH

  - Probability of a **successful landing increases** when utilizing **Grid Fins**, allowing for diverse Orbital Missions.

  - A successful landing decreases cost per launch, due to decreased **CAP EX, i.e. First Stage Booster cost**



Relatio nship

Analysis: Orbit & Success Rate vs Grid Fins

EDA with Data Visualization (2)

- **Goal**: Find Optimal Launch Site per Payload Mass

  - Vandenburg has fewer high payload flight attempts over 4,000kg

  - Needs more research before coming to any conclusions

- Proof of EDA

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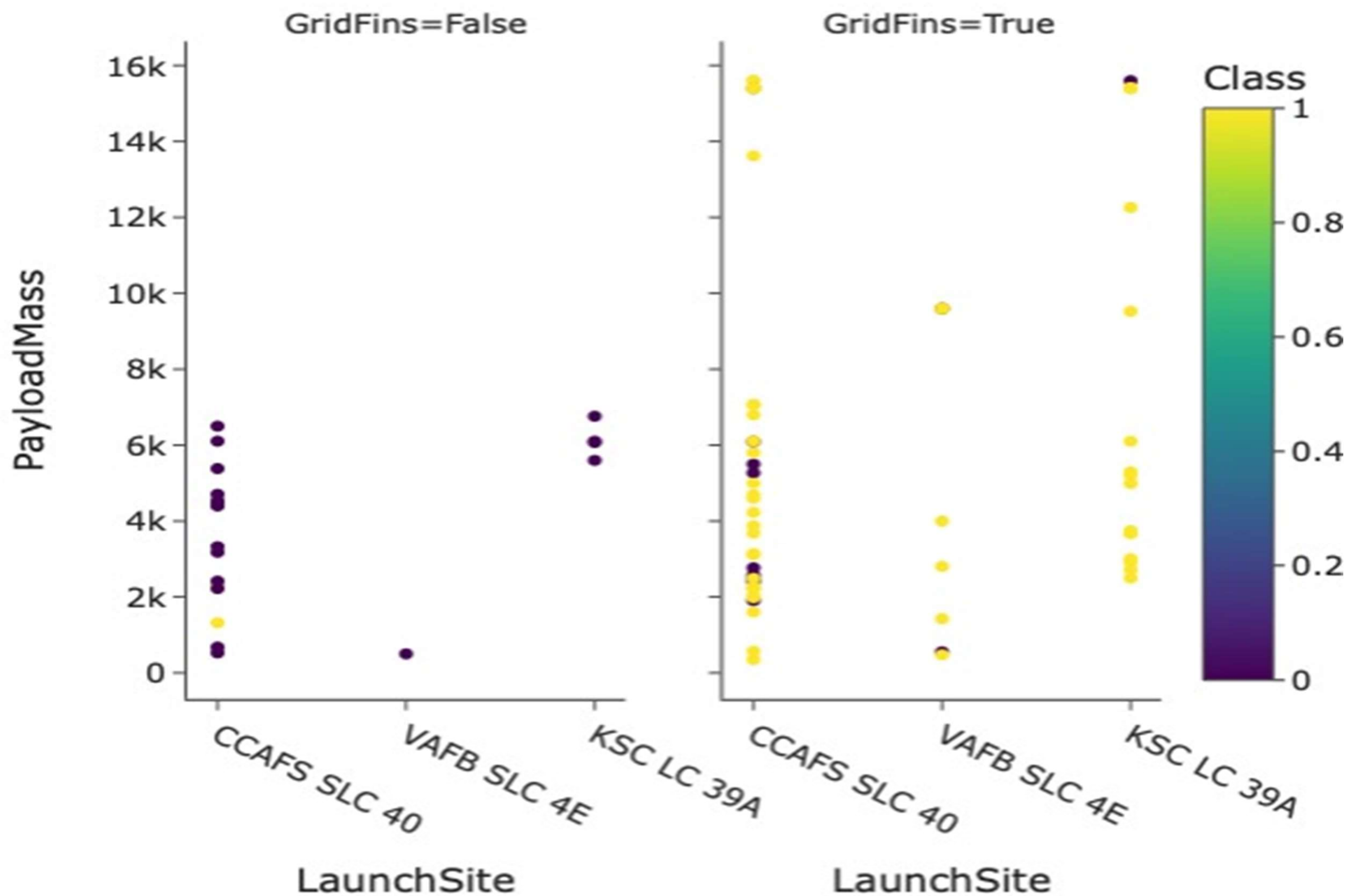
sis:
Payload Mass & Success Rate vs Grid Fins
(per Flight)



EDA with SQL

- **Historical Data Variance by Date:**

  - From 2010 to December of 2020

- **Minimum Payload Mass:**

  - 362 (kg)

- **Total payload mass by Booster Version:**

  - 619,967 (kg)

Build a Dashboard with Plotly Dash

- **Pie charts statistics to showcase the success rate of each launch landing**

  - Kennedy Space Launch Complex (KSC) had a 76.9% success rate, the most successful among other launch sites.

- **Scatterplot to find insights into whether variables Payload Mass and Success per Site had signs of correlation.**

  - Higher success rate per Payload Mass between **2,000 & 5,300 kg.**

  - <u>Pearson Correlation (~ 0.2 Points),</u> data size may be insufficient.

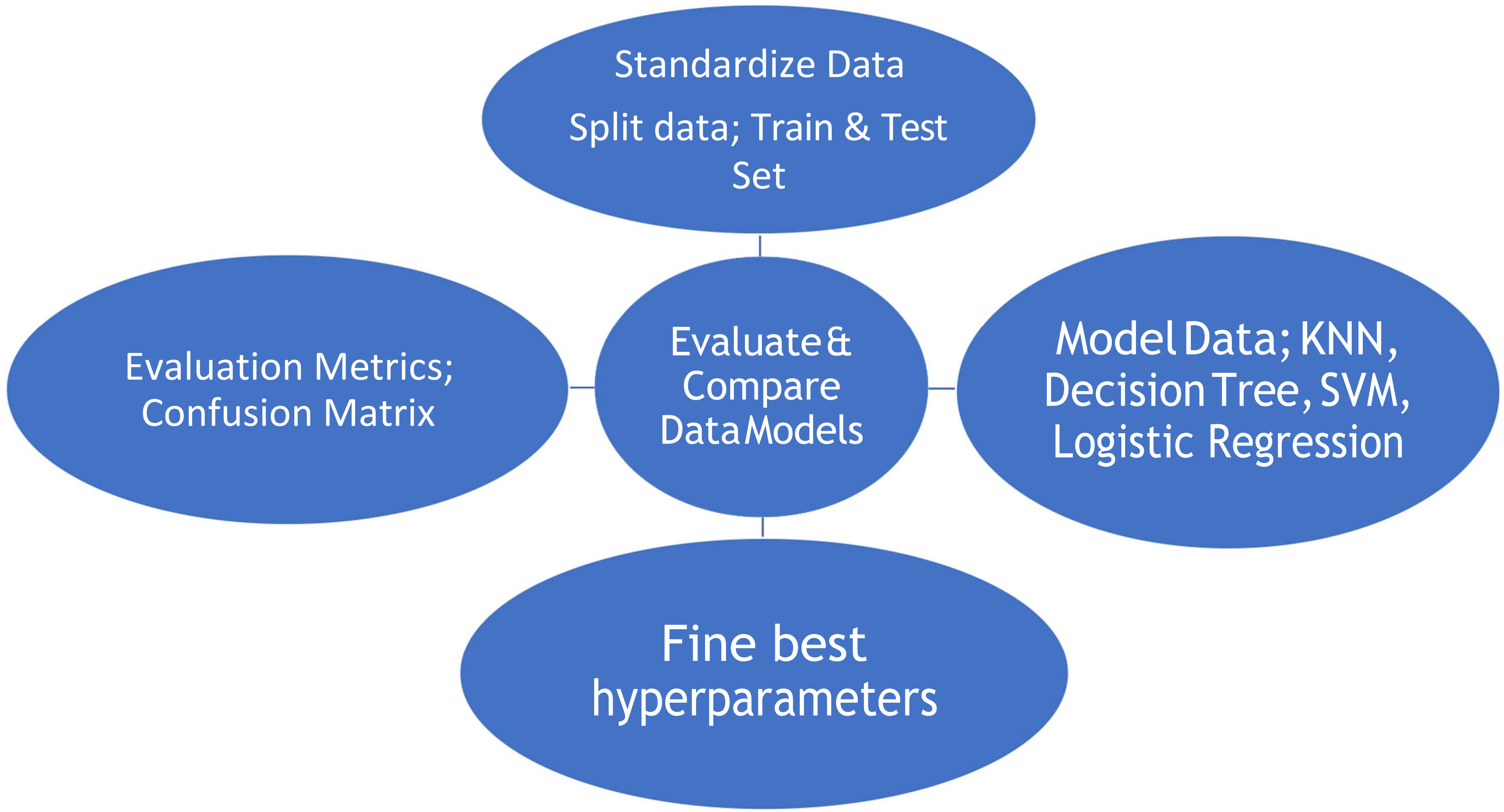
- Dashboard

Predictive Analysis (Classification)

- After tuning hyperparameters, every classification model had an **out-of-sample accuracy of 83%**

- Evaluation Metric: **Confusion Matrix**

- Data Model Notebook



Results (1)

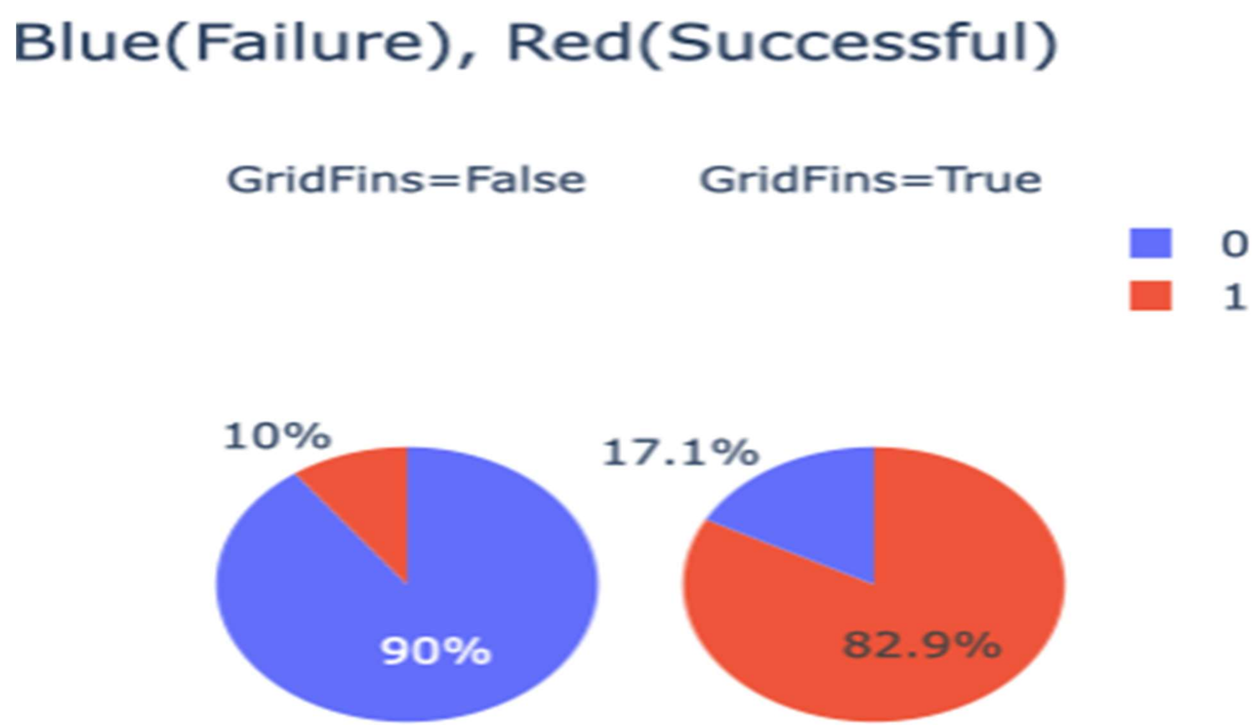
- **EDA: Are there any variables that INCREASE the probability of a SUCCESSFUL LANDING?**

  - Grid Fins and Legs **INCREASE** probability of a **SUCCESSFUL** landings by over 70%

- **Interactive analytics demo: Screenshots (next slide)**

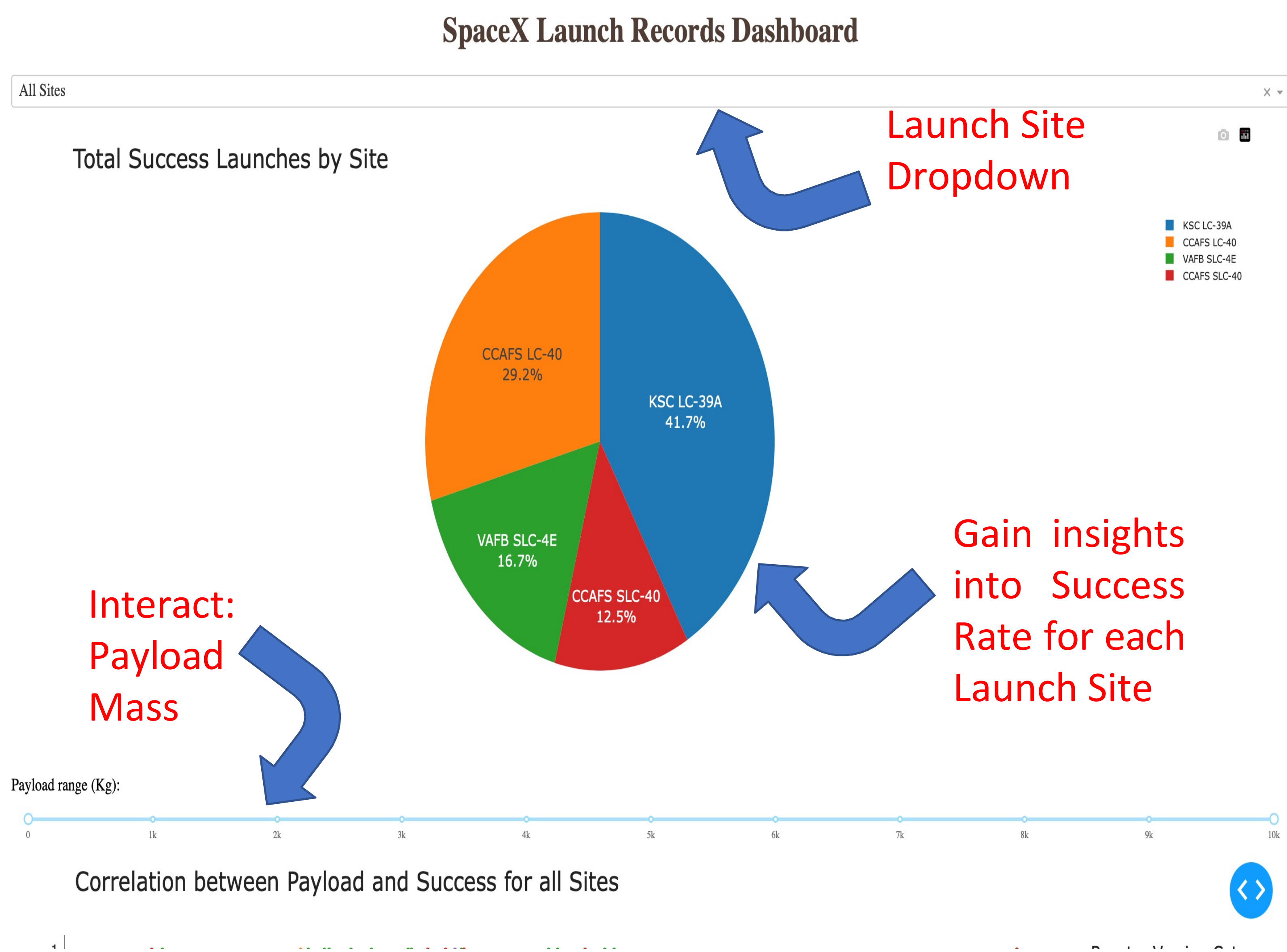
- **Predictive analysis results:**

  - **83% out-of-sample accuracy** (all data models)



Results (2)

- **Interactive analytics demo:**



Section 2

Insights drawn from EDA

Flight Number vs. Launch Site

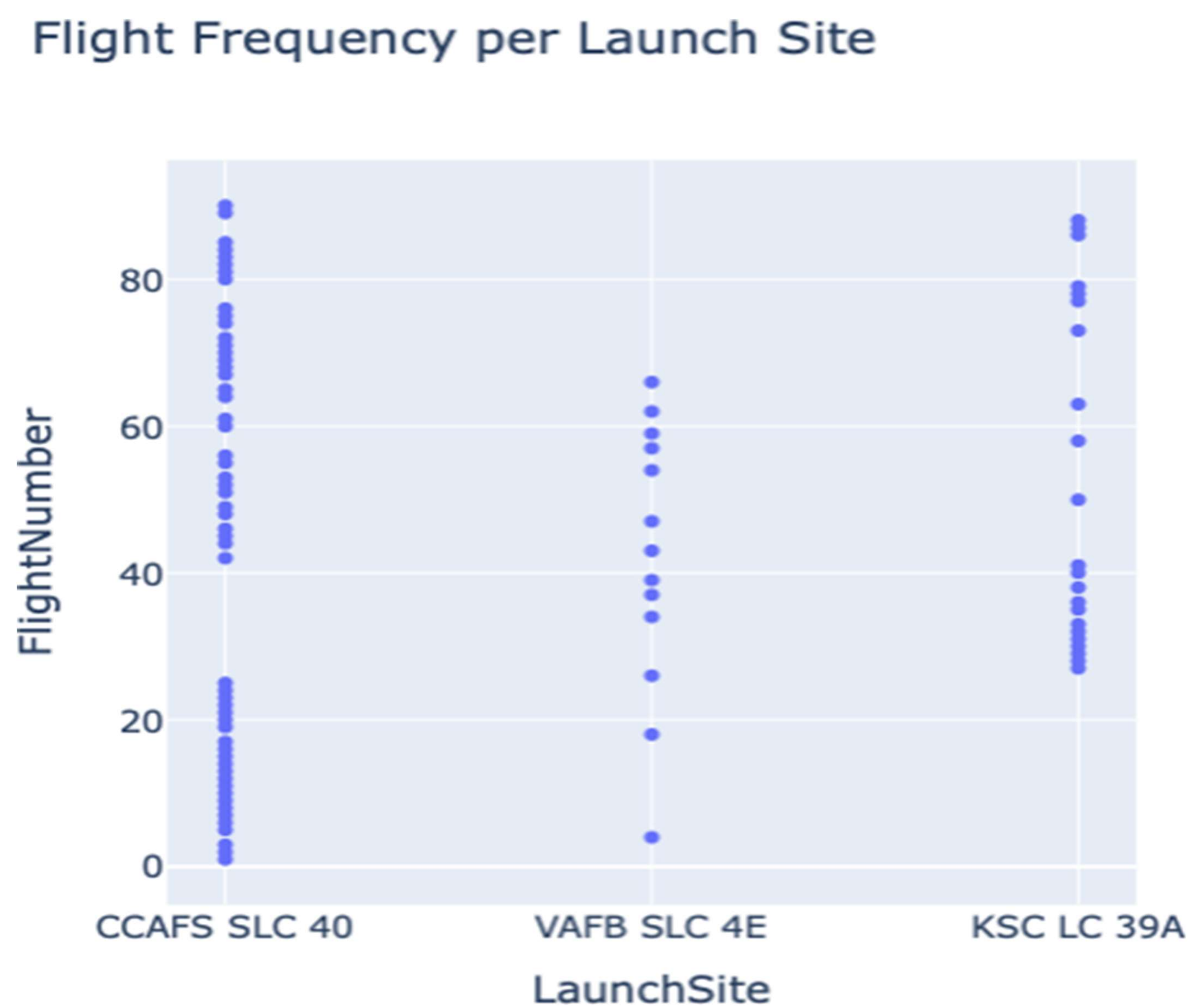
- 90 Flight Attempts (2010-2020)

- KSC accounted for ~25% of **Total Flights**

  - 77% Success Rate

- CCAFS accounted for ~61% of **Total Flights**

  - 60% Success Rate



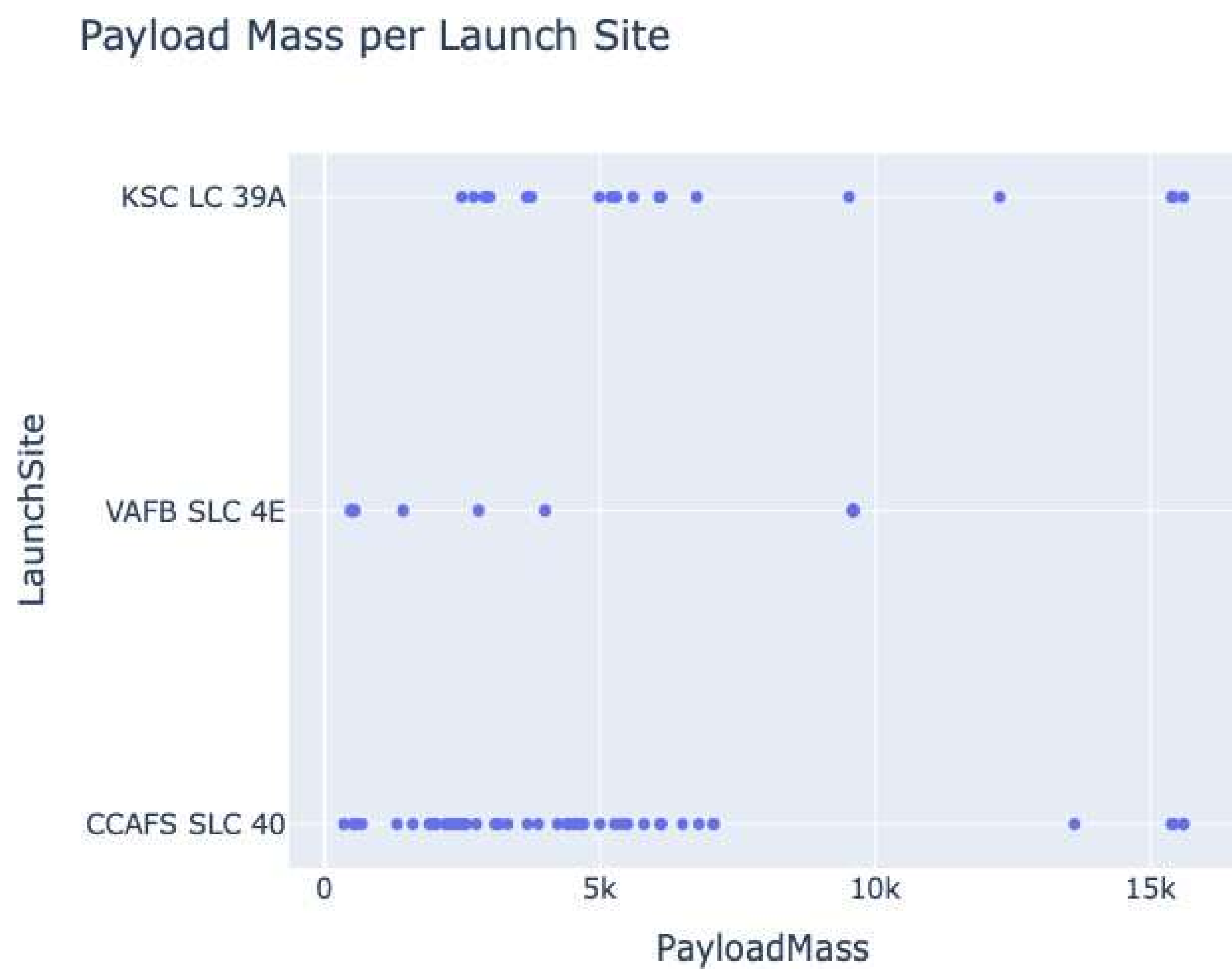
Payload vs. Launch Site

- CCAFS & KSC:

  - Majority of flights between 2500-6500 kg

- VAFB:

  - Majority of flights under 5000 kg



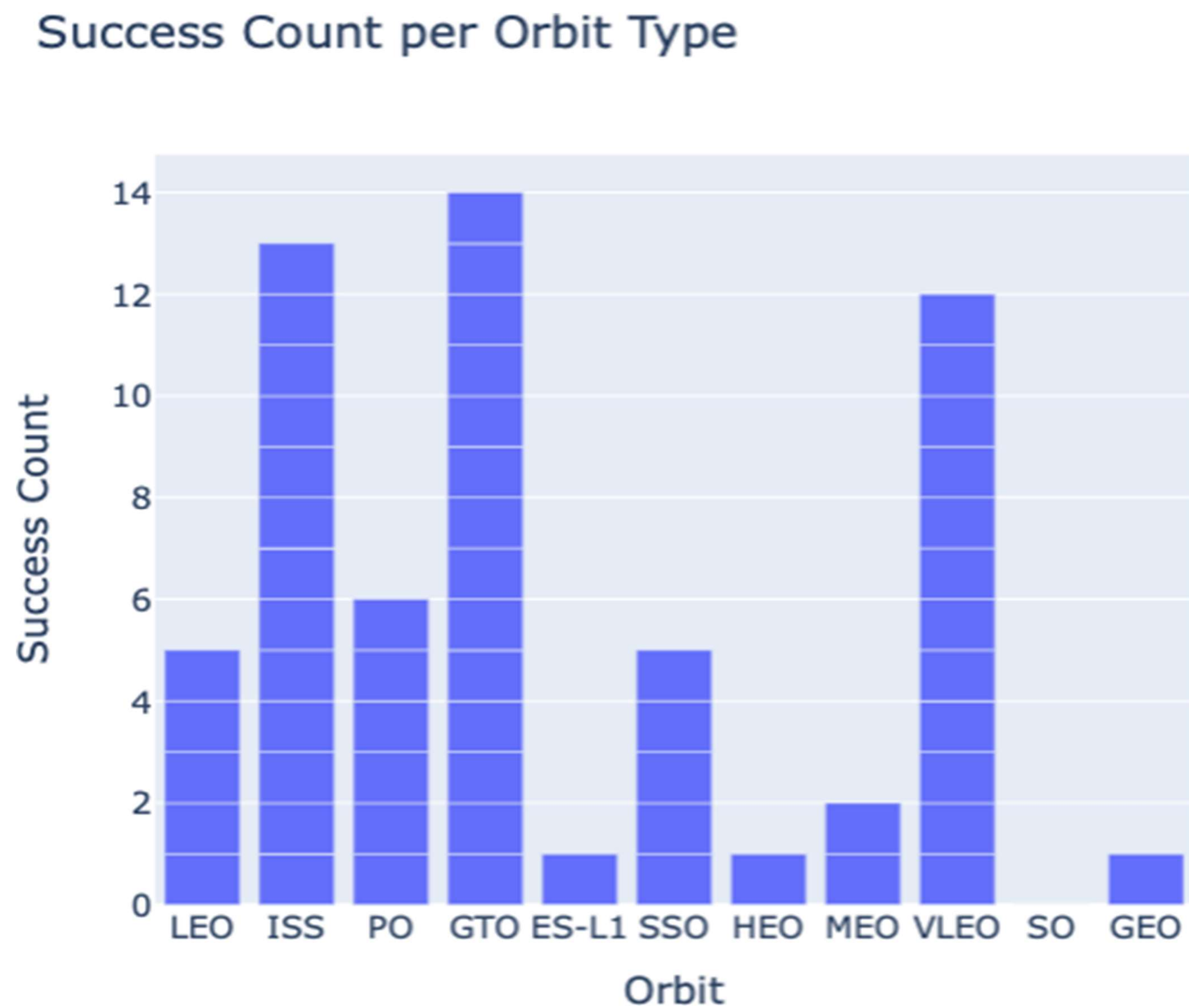
Success Rate vs. Orbit Type

- ISS, GTO, VLEO:

  - Accounted for -
2/3, or ~66% of all successful launches

- ES-L1, HEO, MEO, SO, GEO:

  - Success rate **drops** to nearly **ZERO**

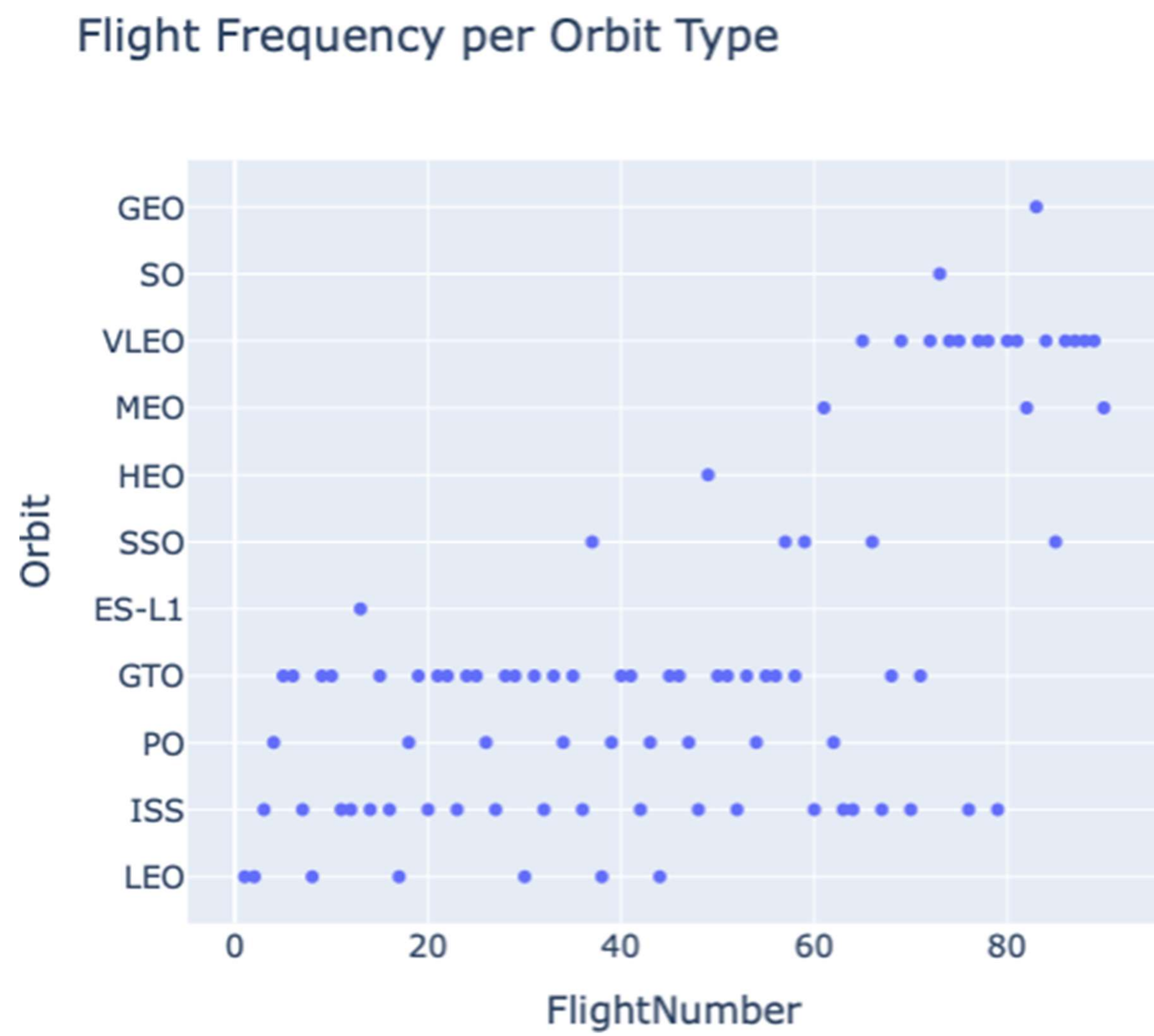


Flight Number vs. Orbit Type

- **Majority** of Flights per Orbit:

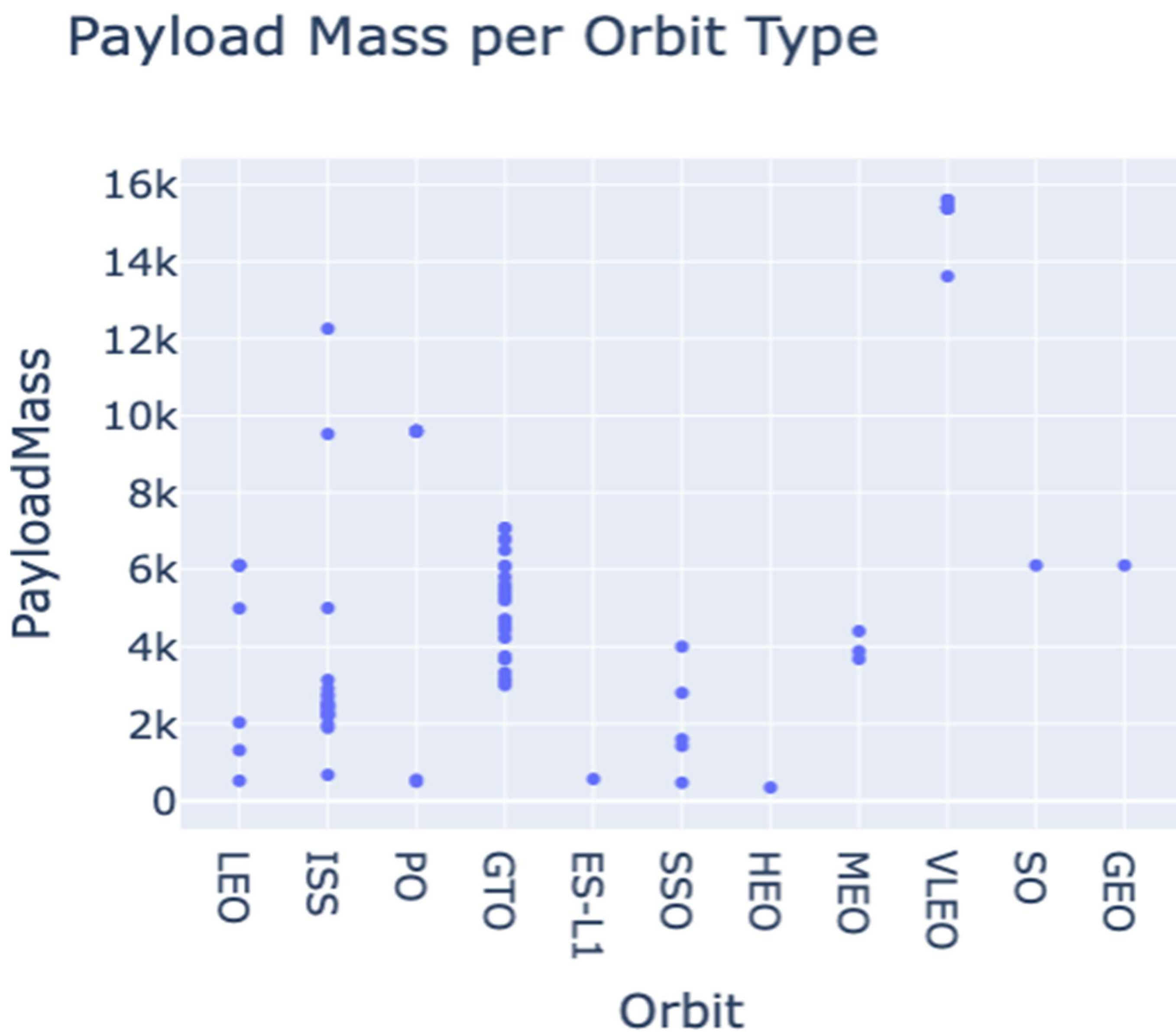
  - ISS, LEO, GTO, VLEO

- **Large** sequence of VLEO orbit attempts started after **Flight #60**



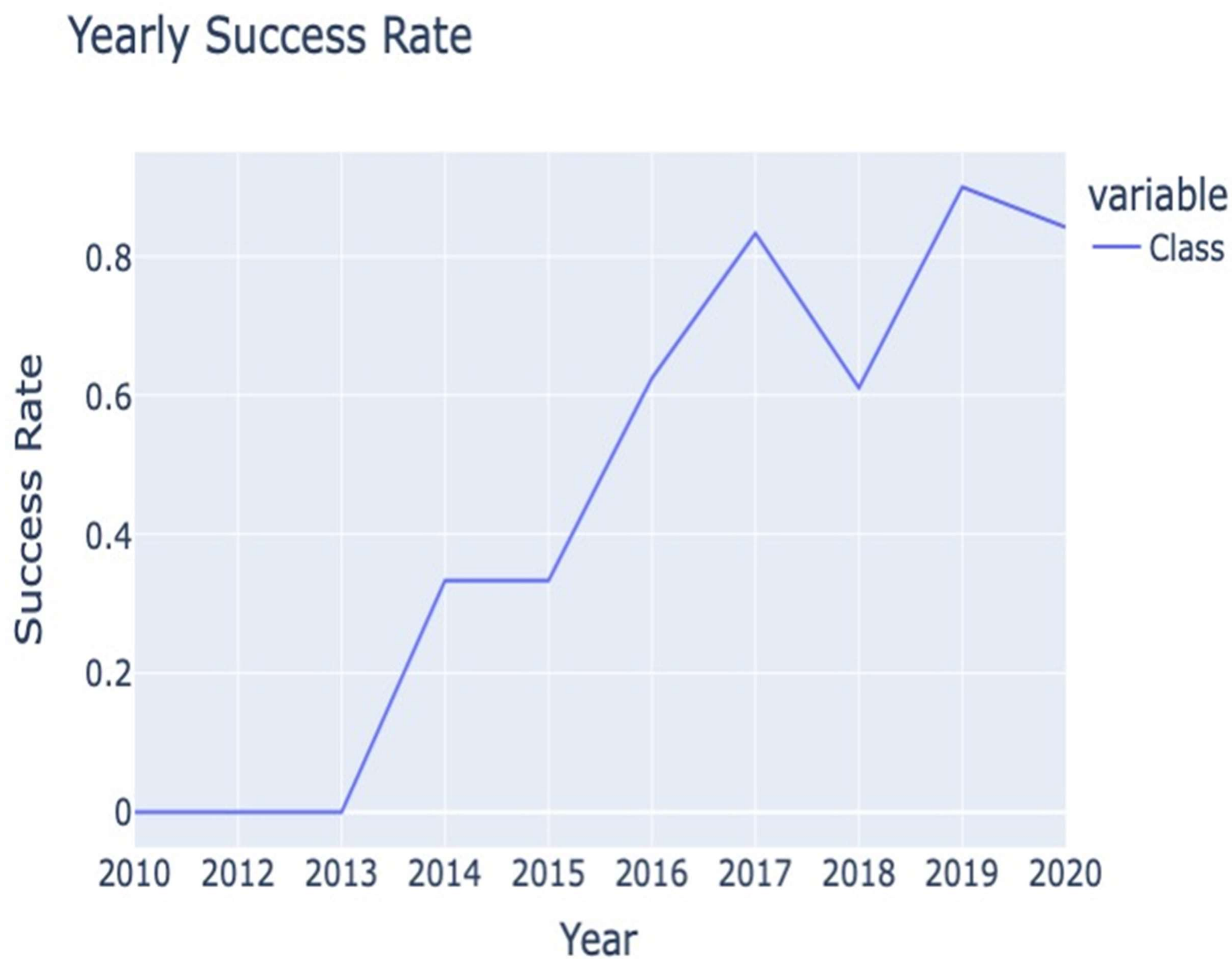
Payload vs. Orbit Type

- Payload Mass distribution **concentrates** below 8,000 kg
- **GTO Payload range** between 3,000 & 7,000 kg



Launch Success Yearly Trend

- Over 80% increase in Success Rate from 2010 to 2020
- **60-90%** Success Rate since **2016**



All Launch Site Names

- Launch Sites:
  - KSC LC-39A
  - CCAFS LC-40
  - VAFB SLC-4E
  - CCAFS SLC-40
- QUERY:

SELECT DISTINCT

LAUNCH_SITE

FROM ‘launchData.spaceX’

Launch Site Names Begin with 'CCA'

- QUERY:

```
SELECT *
FROM `lightning-data-331802.launchData.spaceX`
WHERE LAUNCH_SITE
LIKE 'CCA%’
LIMIT 5
```

- Results:

1	3170	GTO	SES	Success	No attempt
2	3325	GTO	Thaicom	Success	No attempt
3	4535	GTO	AsiaSat	Success	No attempt
4	4428	GTO	AsiaSat	Success	No attempt
5	4159	GTO	ABS Eutelsat	Success	No attempt

Total Payload Mass

- Calculate the total payload carried by boosters from NASA

- QUERY:

```
SELECT SUM(PAYLOAD_MASS__KG_) AS NASA_PAYLOAD
FROM `lightning-data-331802.launchData.spaceX`
WHERE CUSTOMER
LIKE 'NASA%’
```

- RESULTS:

  - 99980 kg

Average Payload Mass by F9 v1.1

- QUERY:

```
SELECT avg(PAYLOAD_MASS__KG_) AS avg_PAYLOAD
FROM `lightning-data-331802.launchData.spaceX`
WHERE BOOSTER_VERSION
LIKE 'F9 v1.1'
```

- Results:

  - Booster Version F9 v1.1 carried a **total payload of 2928.4 kg**

First Successful Ground Landing Date

- QUERY:

```
SELECT
        DATE, Landing_Outcome
FROM `lightning-data-331802.launchData.spaceX`
WHERE LANDING_OUTCOME
LIKE 'Success (ground pad)’
ORDER BY DATE
LIMIT 5
```

- Results:

First successful ground landing took place **December 22, 2015**

Successful Drone Ship Landing with Payload between 4000 and 6000

- QUERY:

```
SELECT DISTINCT
        Booster_Version, Landing__Outcome
FROM `lightning-data-331802.launchData.spaceX`
WHERE Landing__Outcome = 'Success (drone ship)'
        AND PAYLOAD_MASS__KG_ BETWEEN 4000 AND 6000
```

- Results: The only Version Boosters to successfully land on drone ship

Row	Booster_Version	Landing__Outcome
1	F9 FT B1021.2	Success (drone ship)
2	F9 FT B1031.2	Success (drone ship)
3	F9 FT B1022	Success (drone ship)
4	F9 FT B1026	Success (drone ship)

Total Number of Successful and Failure Mission Outcomes

- QUERY:

```
SELECT DISTINCT
        COUNT(Mission_Outcome) AS TOTAL, Mission_Outcome
FROM `lightning-data-331802.launchData.spaceX`
GROUP BY Mission_Outcome
```

- RESULTS: All 101 Mission Outcomes were successful besides **one**

1	98	Success
2	1	Failure (in flight)
3	1	Success (payload status uncle...
4	1	Success

Boosters Carried Maximum Payload

- QUERY:

```
SELECT
        MAX(PAYLOAD_MASS__KG_)
AS MAX_PAYLOAD, Booster_Version
FROM `lightning-data-
        331802.launchData.spaceX`
GROUP BY Booster_Version
ORDER BY MAX_PAYLOAD DESC
```

- Results: **12 Boosters carried the**

Row	MAX_PAYL...	Booster_Version
1	15600	F9 B5 B1048.5
2	15600	F9 B5 B1051.4
3	15600	F9 B5 B1060.2
4	15600	F9 B5 B1058.3
5	15600	F9 B5 B1051.6
6	15600	F9 B5 B1048.4
7	15600	F9 B5 B1049.4
8	15600	F9 B5 B1051.3
9	15600	F9 B5 B1056.4
10	15600	F9 B5 B1049.5
11	15600	F9 B5 B1060.3
12	15600	F9 B5 B1049.7

maximum payload of 15,600 kg

2015 Launch Records

- QUERY:

```
SELECT Booster_Version, Launch_Site, DATE, Landing__Outcome
FROM `lightning-data-331802.launchData.spaceX`
WHERE DATE BETWEEN '2015-01-01' AND '2015-12-31’
        AND Landing__Outcome = 'Failure (drone ship)’
```

- Results: **Two Booster Versions at CCAFS LC-40 failed to land on drone ship (2015)**

Row	Booster_Version	Launch_Site	DATE	Landing_Outcome
1	F9 v1.1 B1012	CCAFS LC-40	2015-01-10	Failure (drone ship)
2	F9 v1.1 B1015	CCAFS LC-40	2015-04-14	Failure (drone ship)

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

- QUERY:

```
SELECT DISTINCT
COUNT(Landing_Outcome) AS
        TOTAL_COUNT,   LANDING__OUTCOME
FROM `lightning-data-331802.launchData.spaceX`
WHERE DATE BETWEEN '2010-06-04' AND '2017-03-20'
GROUP BY Landing__Outcome
ORDER BY TOTAL_COUNT DESC
```

- Results:

    - Majority of landings were **NOT attempted**

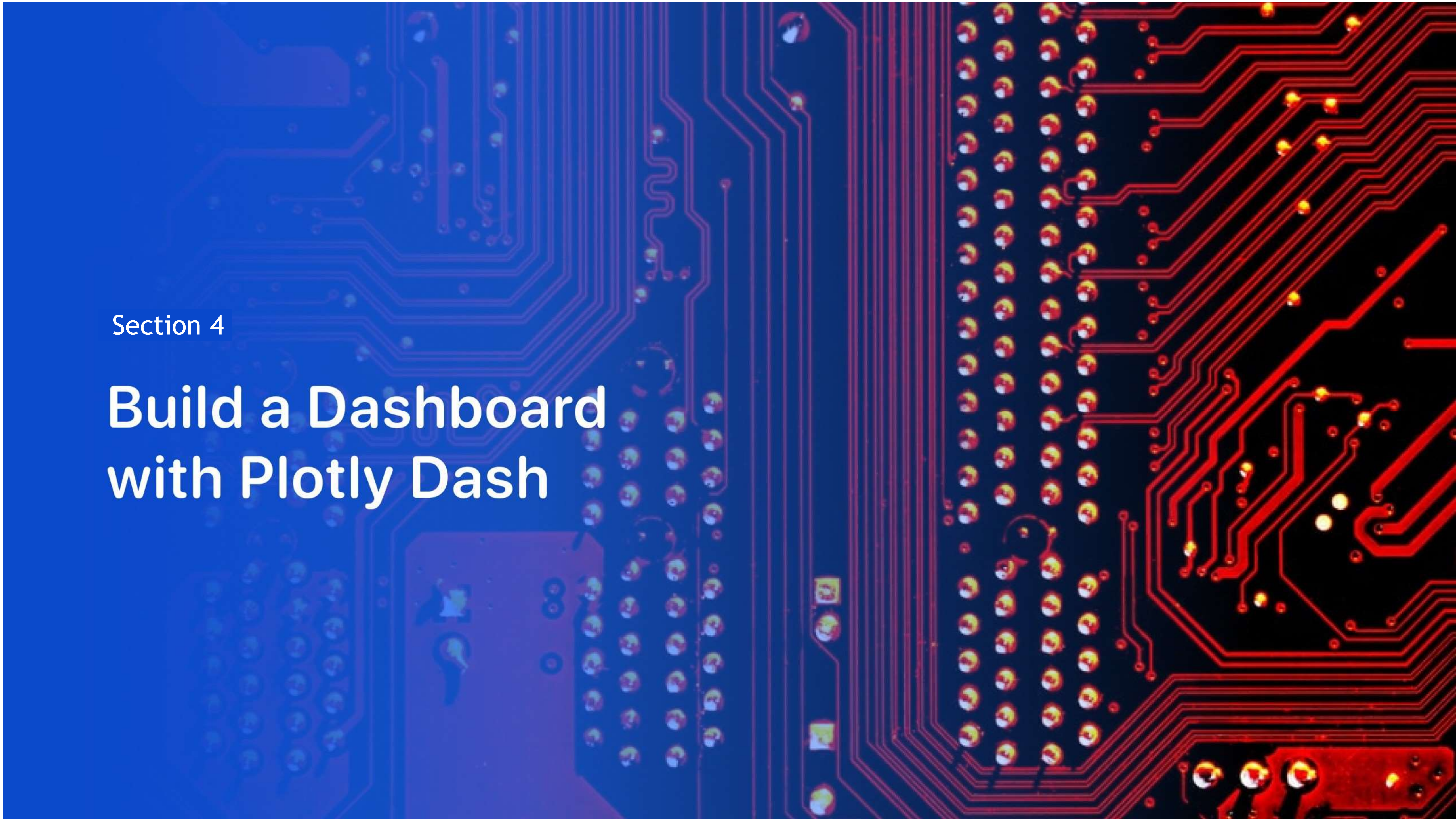
Row	TOTAL_COU...	LANDING__OUTCOME
1	10	No attempt
2	5	Failure (drone ship)
3	5	Success (drone ship)
4	3	Success (ground pad)
5	3	Controlled (ocean)
6	2	Failure (parachute)
7	2	Uncontrolled (ocean)
8	1	Precluded (drone ship)

- 50% Success Rate landing on **drone ship**


Section 3
Launch Sites
Proximities Analysis

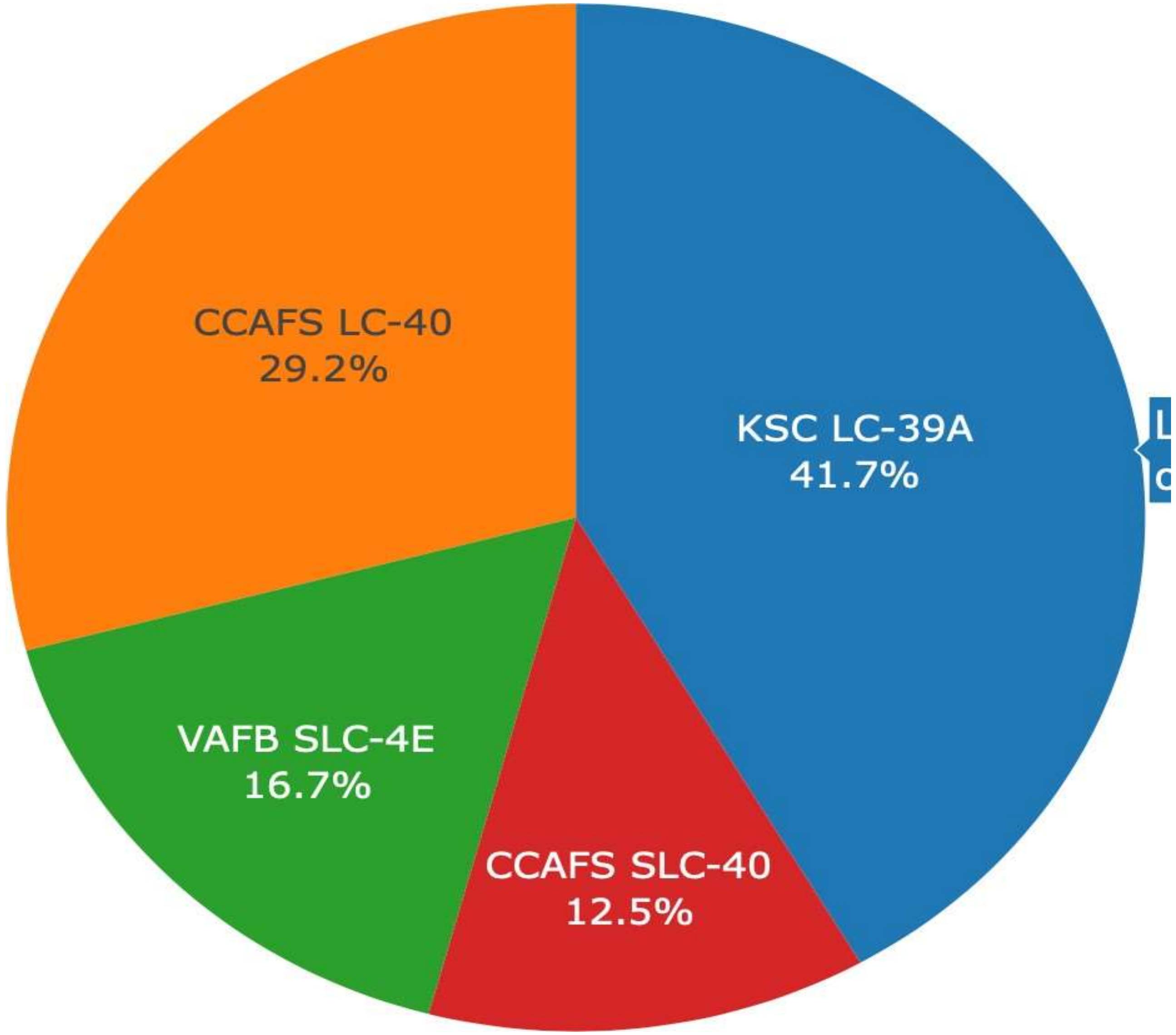
Section 4

Build a Dashboard with Plotly Dash



Success Rate: All Launch Site

- Nearly **42% of Successful Landings** performed at **Kennedy Space Complex**
- **CCAFS SLC-40** performed the **worst**, with a **12.5% Success Rate among other Launch Sites**

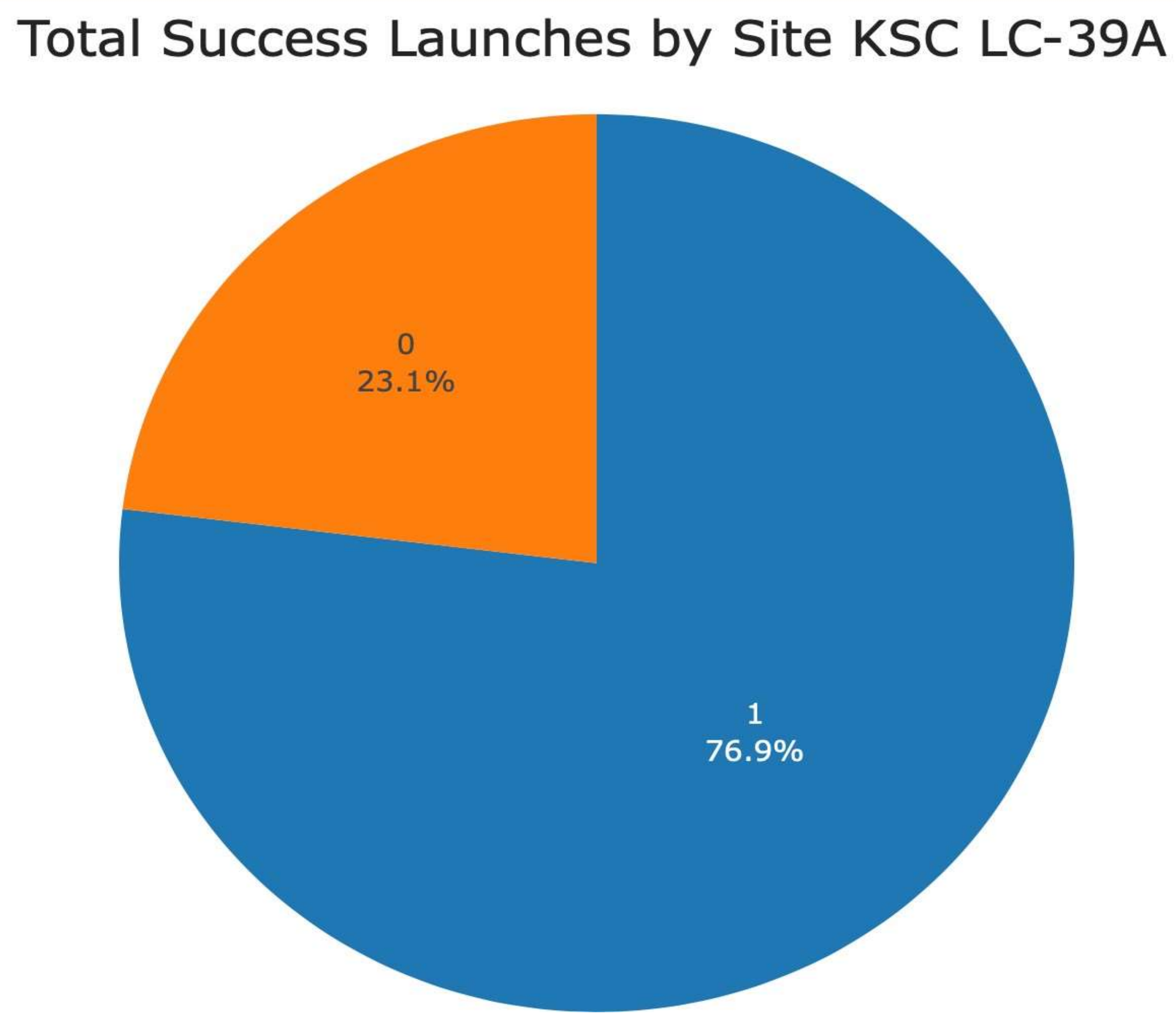


Kennedy Space Complex: Highest Success Ratio

- KSC LC-39A has the **highest Success Ratio**

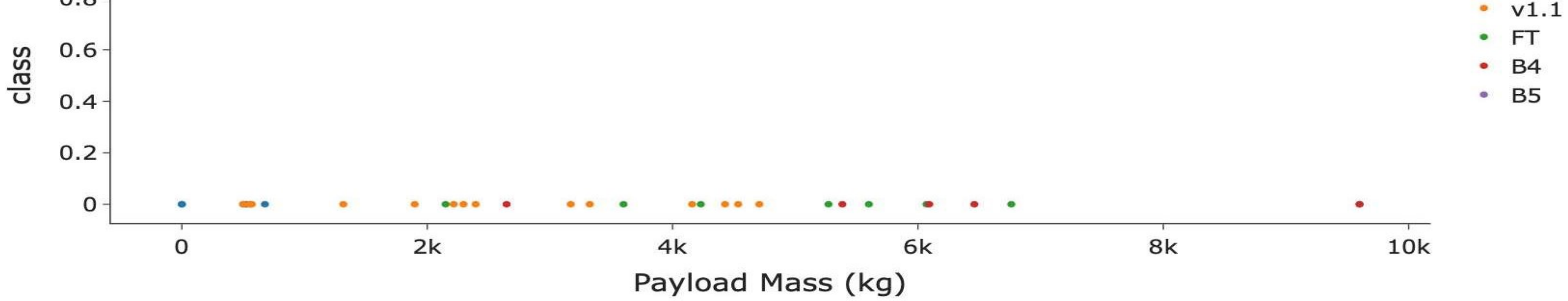
  - 76.9% Success

- **Less** than a **quarter** of launches were **failures**, compared to **VAFB's 60% Failure Ratio**



<Dashboard Screenshot 3>

- **Payload Mass ranges between 2,000 and 6,000 kg have high success**, especially among Booster Version (FT)
- Version Booster (v1.1) has **high failure among Payload Mass ranges between 500 and 5000 kg**


0.6
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Payload Mass (kg)
v1.1
FT
B4
B5

Section 5

Predictive Analysis (Classification)

Classification Accuracy:

- Highest out-of-sample accuracy **(~ 89%)**

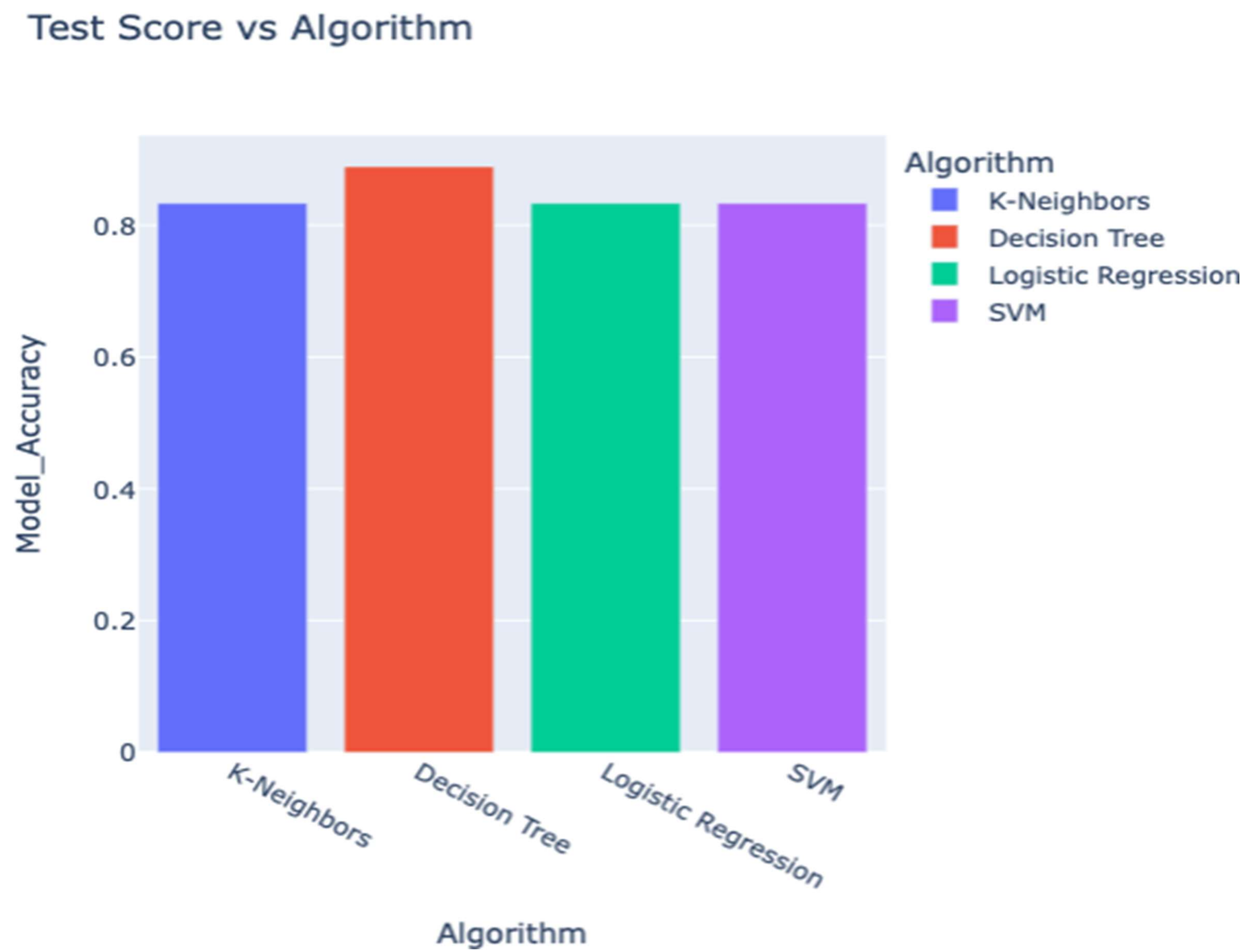
  - **Decision Tree**

- Evaluation Metric:

  - **Accuracy**

- Function**:**

(TP-TN) / (TP+FP+FN+TN)



Confusion Matrix

- Test set contained 18 observations / predictions:

  - Did Land / Did Not Land

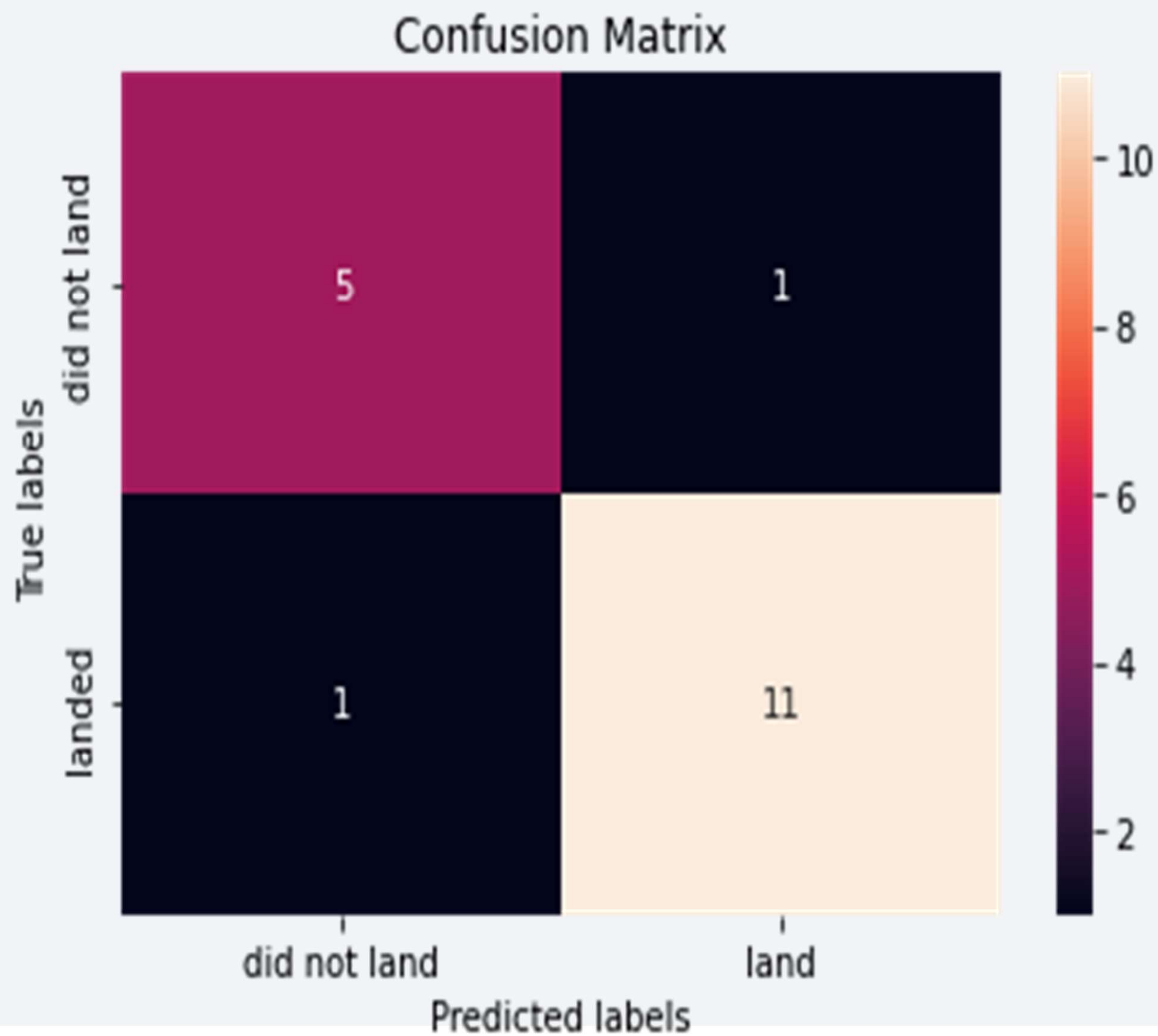
- Land predictions:

  - True Positive (11/12)

  - False Positive (1/12)

- Did Not Land predictions:

  - True Negative (5/6)



- False Negative (1/6)

Conclusions

- **WHY** should SpaceY strive to build a **fully reusable rocket?**

  - Reusing rockets **reduces ALLOY COSTS** by reducing the amount of **alloy needed per launch**

  - Reduces **CAPITAL EXPENDITURES**

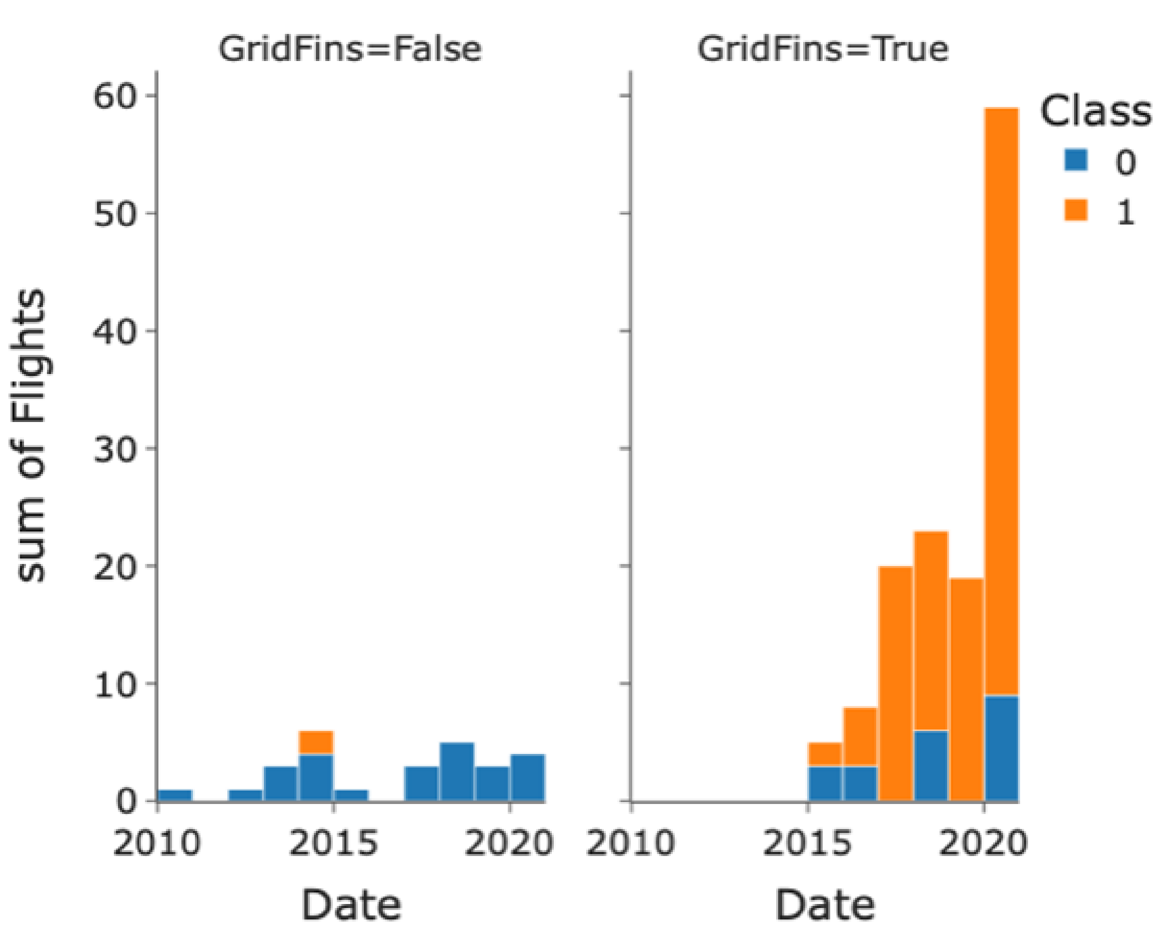
  - Reduces **TIME-TO-BUILD,** allowing for increased **flights per year**

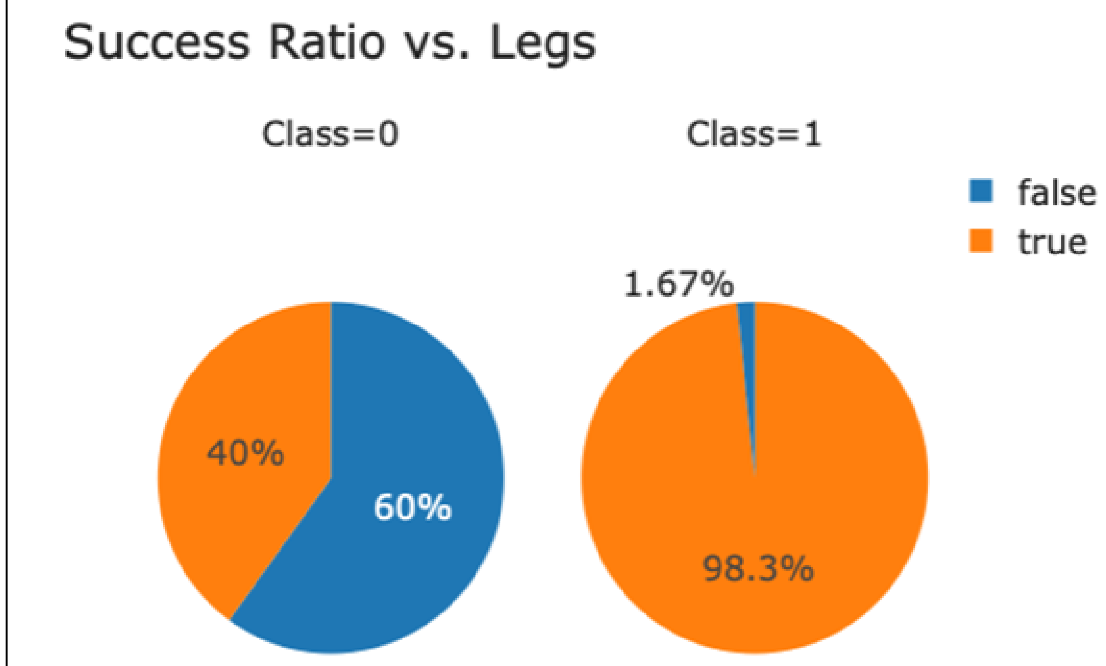
- **HOW** can SpaceY increase the **probability** of a **successful landing**?

  - Introducing **Grid Fins & Legs increased the Success Ratio from 10 - 82.9%**

Appendix

EDA: BARCHART & PIE CHART– **Grid Fins & Legs dramatically INCREASED Success Ratio**






Thank you!