SpaceX Landing prediction

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Presented to:
Space Y leadership team

OUTLINE

- Executive Summary
- Introduction
- Methodology
- Results
  - Visualization – Charts
  - Dashboard
- Discussion
  - Findings & Implications
- Conclusion
- Appendix

EXECUTIVE SUMMARY

- To win over customers when bidding against Space X, we want competitive pricing
  - SpaceX's bid price depends heavily on if they can reuse the rocket for its launch (for another future launch)
  - Therefore if we can predict their bidding launch's reuse chances, we can get better pricing guess (assuming SpaceX does similar pricing strategy)
- Goal is to answer the question is, "Would SpaceX's new (bidding) launch reuse stage 1 or not?"
- Our best Machine Learning classifier had average accuracy of 83%, which seems usable
- We can likely improve if we have more data points

INTRODUCTION

- We want more customers. SpaceX is our competitor and we need to have competitive advantage.
- One way to compete is **<u>cost</u>**
- If we can estimate SpaceX's bidding price, we can bid for lower price (and win customers)
- Space X's cost of launch heavily depends on reuse success of stage 1 rocket
  - If it can be reused, SpaceX can cut the cost (and therefore the bid price) to ~half
  - If we can predict SpaceX's chances of reuse success, then we have better idea of what their bidding price will be.
- Therefore, the goal is to answer, "**Would SpaceX's new (bidding) launch reuse stage 1 or not?**"
  - Approach is to use Machine Learning (ML) classifier)

METHODOLOGY

- Collecting data
  - Use SpaceX public data & API to collect launch information
- Data wrangling
  - Fix problematic values (e.g. nulls)
  - Use one hot encoding for binary data (as ML feature)
- Data analysis
  - Use SQL for (aggregated) quantitative analysis of data
  - Use visualizations to look for trends & correlations with successful reuse launch
  - Create dashboard for others to explore data
- Building & evaluating ML classifier
  - Test few ML classifiers to predict if a particular launch (or bid) can land 1st stage successfully or not
  - Each classifier will be tested with multiple parameters
  - Accuracy will be used as eval score

RESULTS – Data collection

- Used following SpaceX API endpoints for data collection:
  - https://api.spacexdata.com/v4/launches/past
  - https://api.spacexdata.com/v4/rockets/
  - https://api.spacexdata.com/v4/launchpads/
  - https://api.spacexdata.com/v4/payloads/
  - https://api.spacexdata.com/v4/cores/
- Also pulled data from wikipedia
  - https://en.wikipedia.org/wiki/List_of_Falcon_9_and_Falcon_Heavy_launches

RESULTS – Data wrangling

- Replaced empty 'payload mass' field with average of all
- Created new outcome label for reuse based on landing class field (which is a combination of landing success and where the landing was done/attempted)
- Used one-hot encoding for a few fields
    - 'Orbit','LaunchSite','LandingPad','Serial'

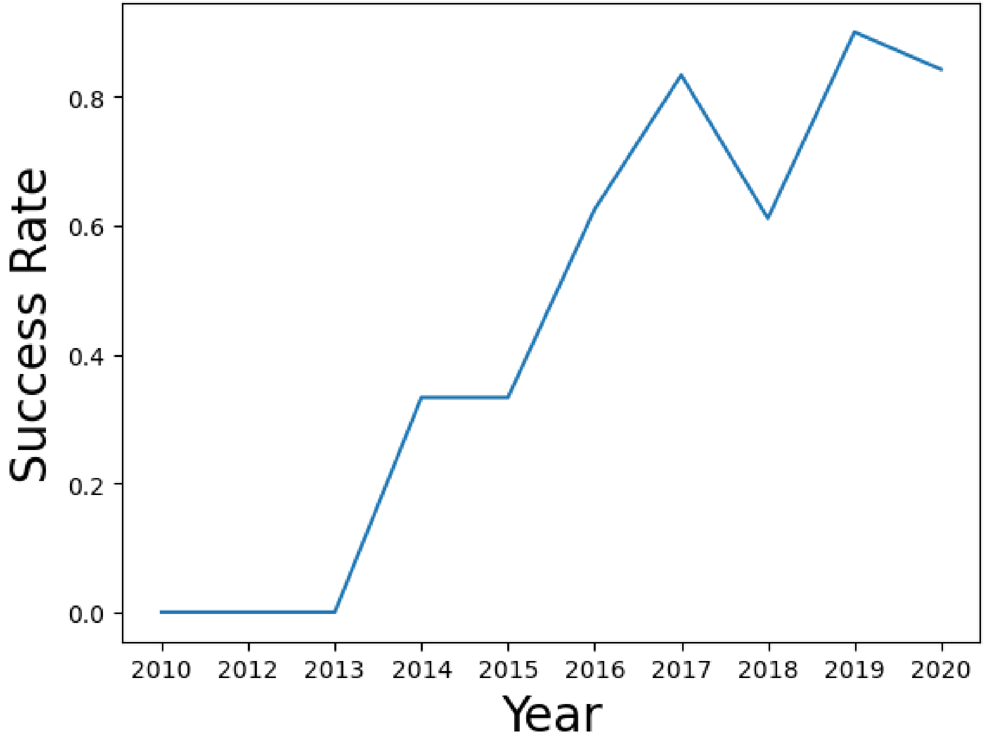
RESULTS - Analysis

Data source Basic stats

- # of launches:
  - 2010 ~ 2020
- Overall success rate:
- Launch attributes:
  - Examples: Launch site, Payload mass, Landing pad

RESULTS - Analysis

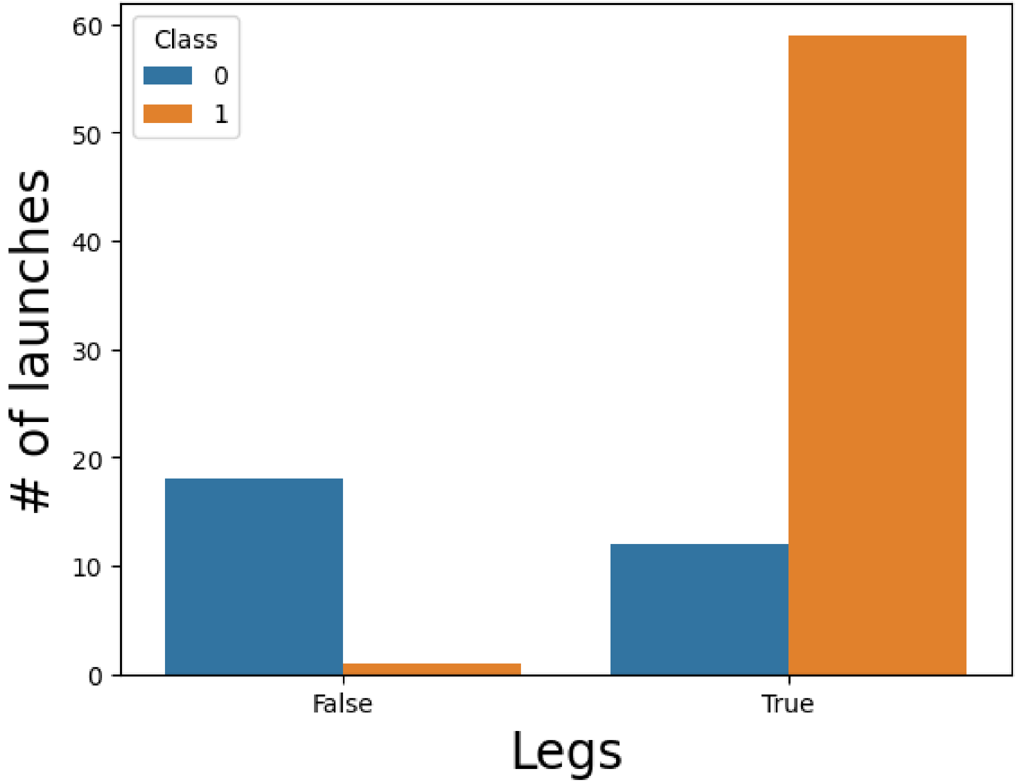
The reuse success rate has been increasing year over year

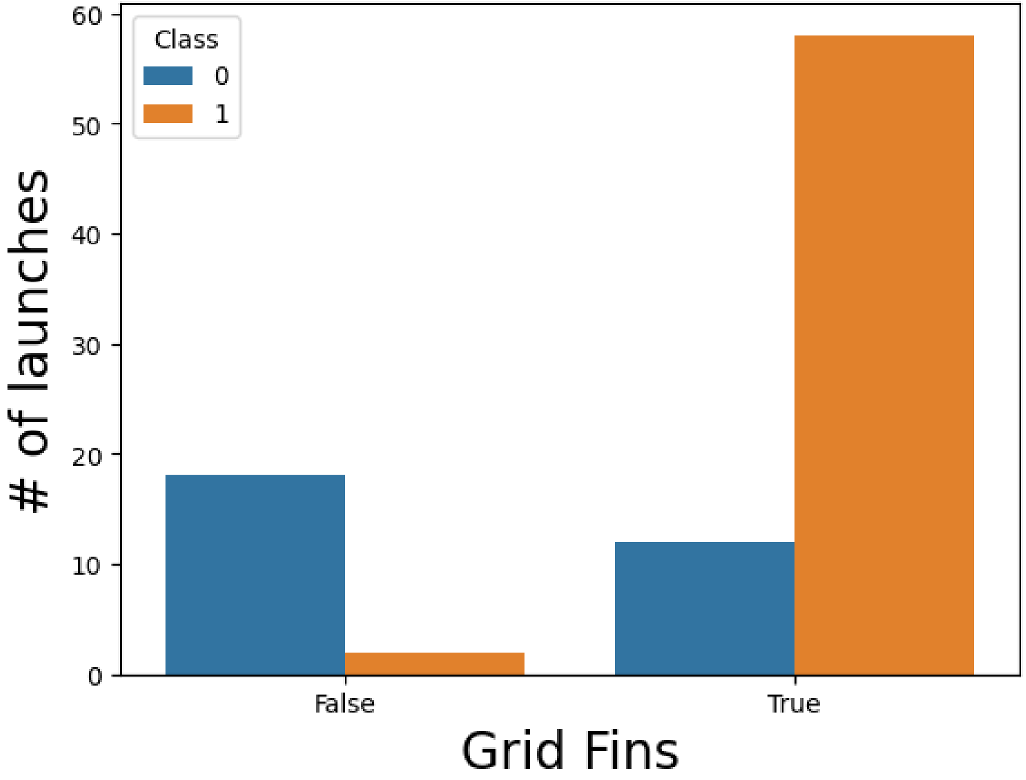


Implication: We should expect the trend of high success rate to continue

RESULTS - Analysis

Having Legs or Grid Fins seems to signal success rate



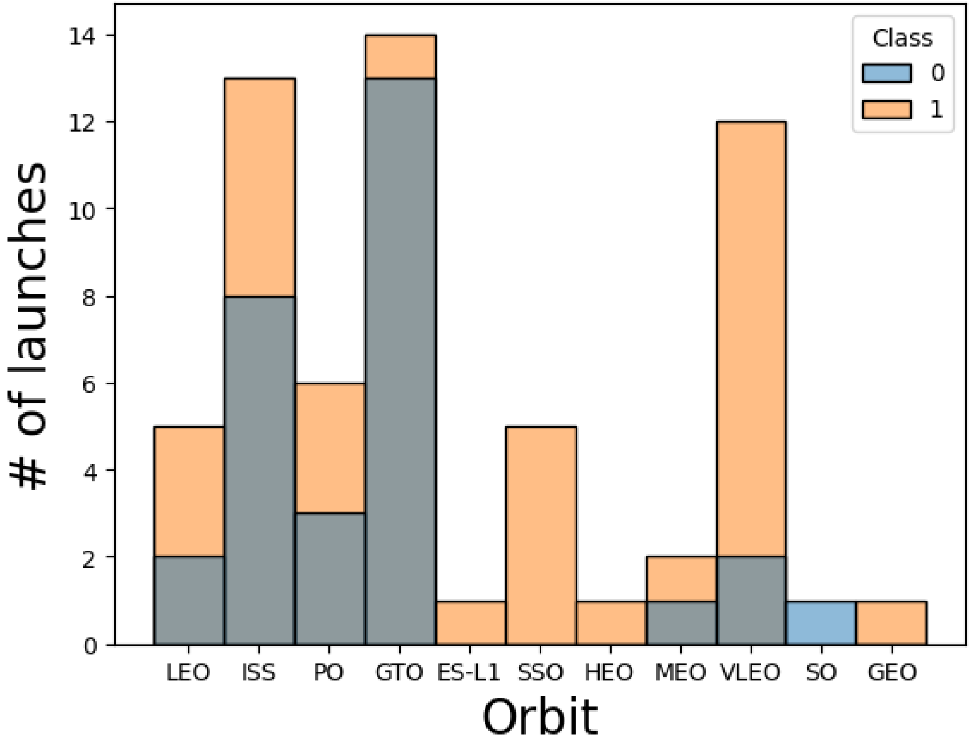


RESULTS - Analysis

Some launch site and orbit types shows noticeable difference in reuse success rate

Launch site (green = reused)

Orbit type (1 = reused)



RESULTS - (SQL) Analysis

First reuse success was in 2015

First_date
2015-12-22

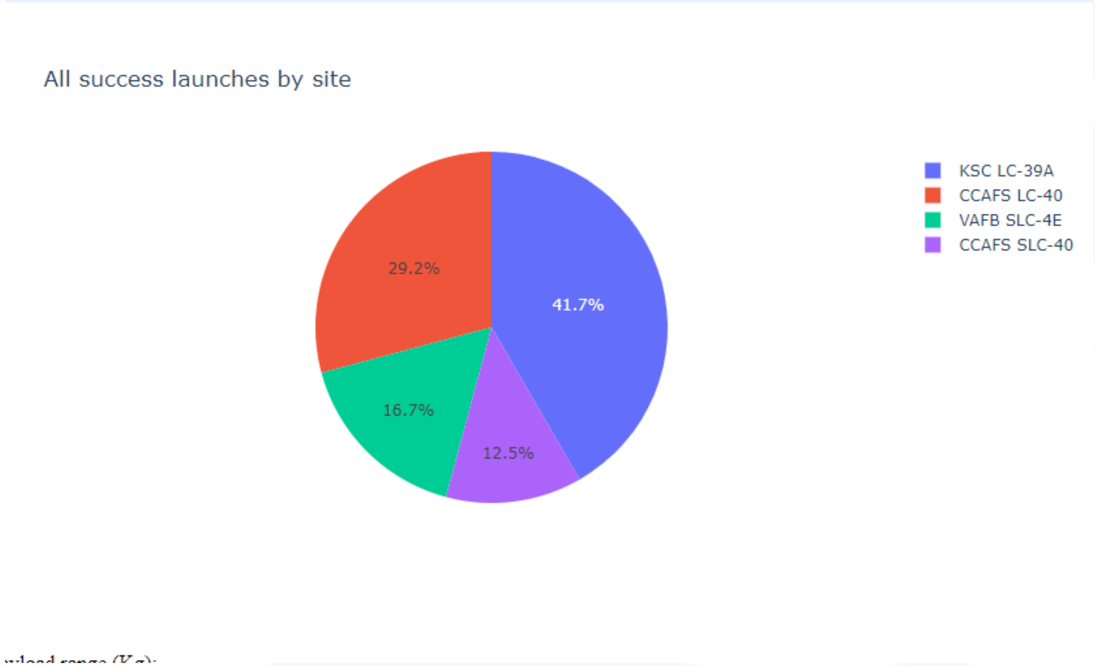
A lot of launches ended as no attempt

Landing_Outcome	count
Success	38
No attempt	21
Success (drone ship)	14
Success (ground pad)	9
Failure (drone ship)	5
Controlled (ocean)	5
Failure	3
Uncontrolled (ocean)	2
Failure (parachute)	2
Precluded (drone ship)	1
No attempt	1

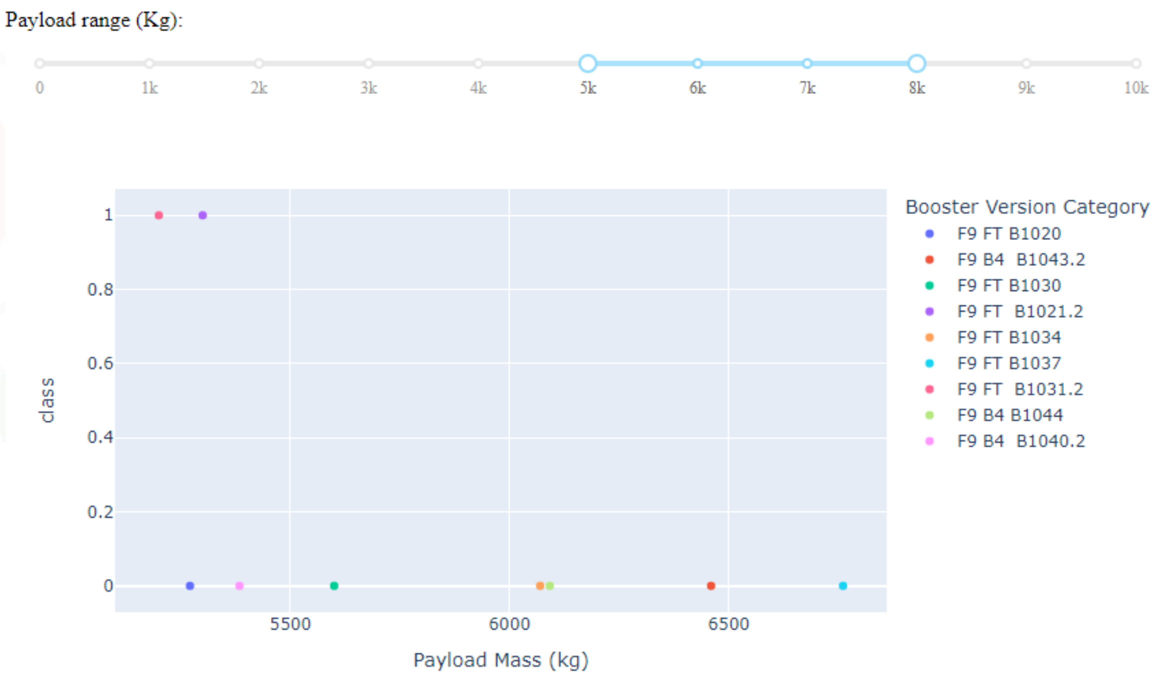
RESULTS: DASHBOARD

Dashboard – All launch sites

Show success by site



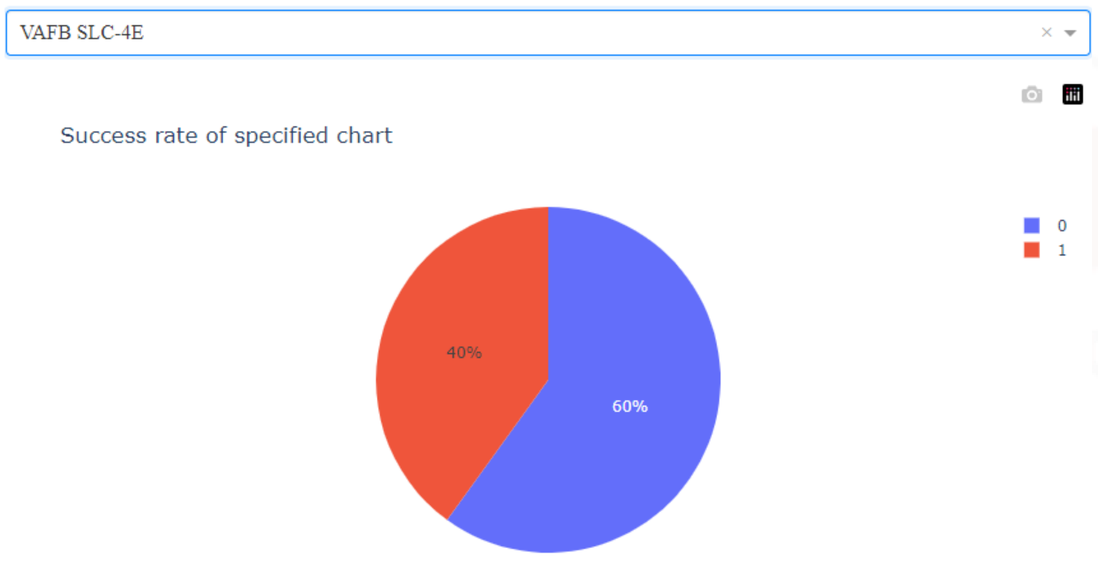
Show relation of site, booster version and success/fail

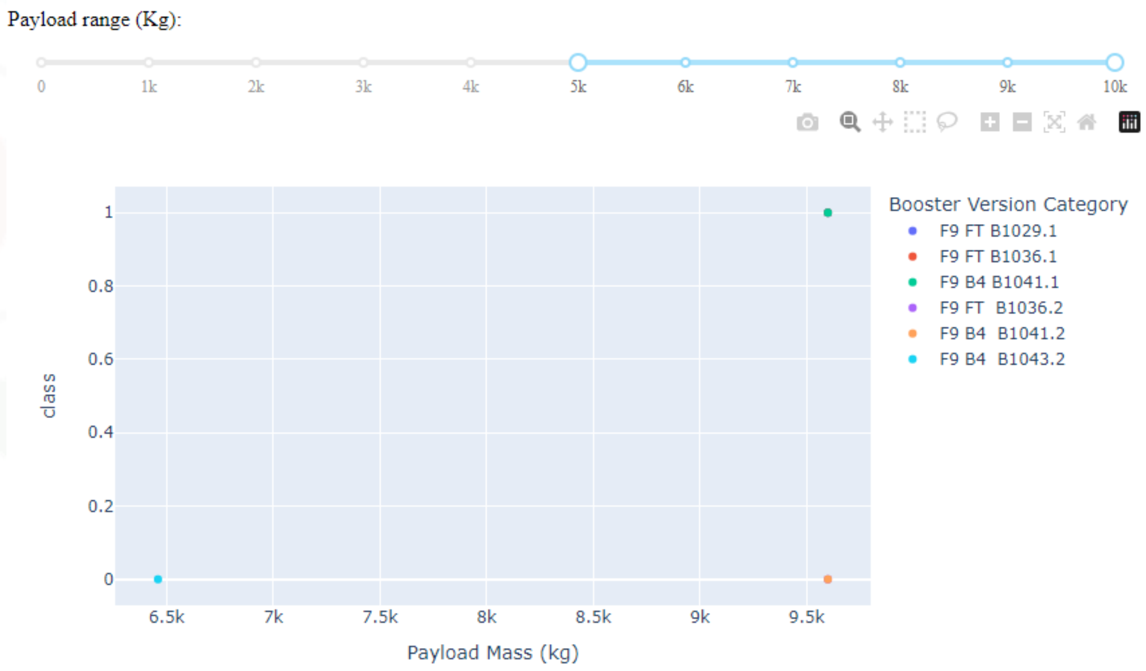


Dashboard - Single site

Success/fail chart

Show relation of chosen site, booster version and success/fail





DISCUSSION

Summary of findings & implications

Major Findings

- Newer flights have higher success
- Few binary variables (e.g. legs, grid fins) have correlation with success rate
- Few categorical variables (landing site, orbit) have correlation with success rate

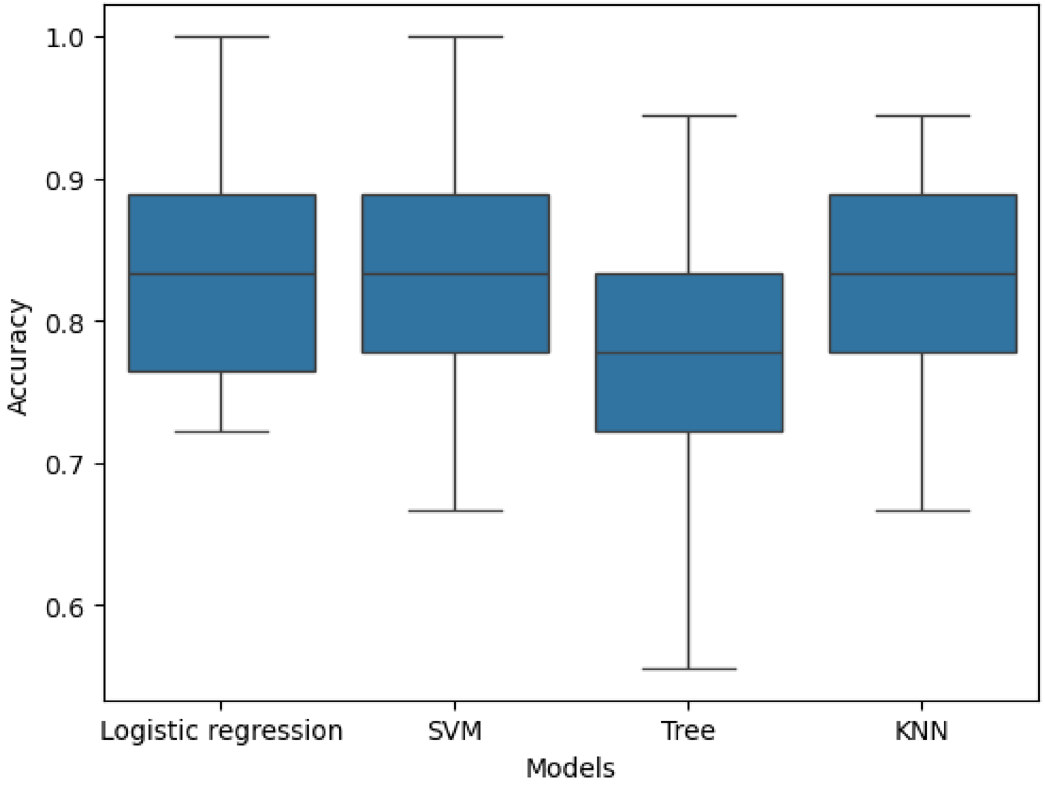
Implications

- While simple ML model may not be enough, it seems feasible to create an ML classifier with sufficient precision using multiple variables

ML Classifier

Best model had accuracy of ~83%

- SVM (sigmoid)
- Tested 20 iterations of random sampling test set
- Confidence Interval (95.0%): (0.79, 0.880)

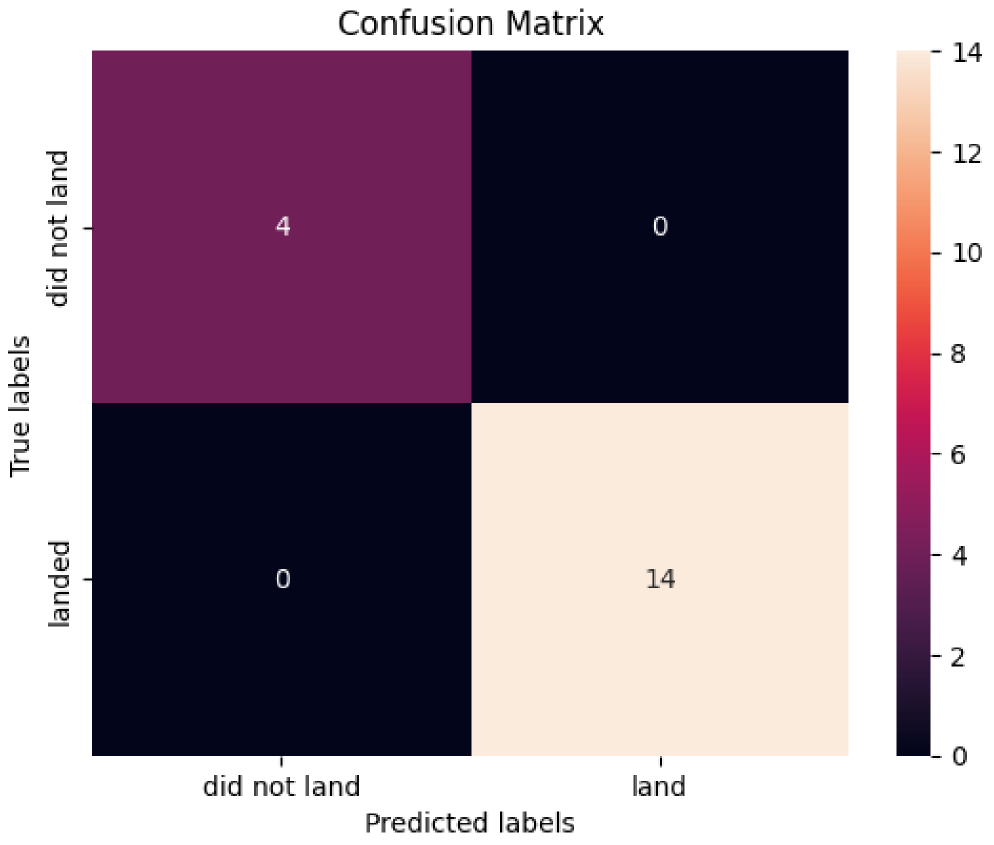


Caveat: Logistic regression, SVM, KNN accuracies are quite similar. Better to tune when there's more data available.

ML Classifier

Best test sample for SVM had 100% accuracy!!!

...however, the sample size is quite small



OVERALL FINDINGS & IMPLICATIONS

Findings

- With feature engineering, best suited model (SVM) had average accuracy of 83%
- Other model accuracies were quite close
- Test (and train) sample size is small

Implications

- We can likely increase the accuracy with more time
- The best way to improve & evaluate the model is have more launch data points

CONCLUSION

- To have competitive pricing when competing with SpaceX, we analyzed SpaceX launch data analysis and build classifier for its launch reuse
- Our best model had average accuracy of 83%
- More fine tuning can be done, however best way to improve will be to have more data points

APPENDIX

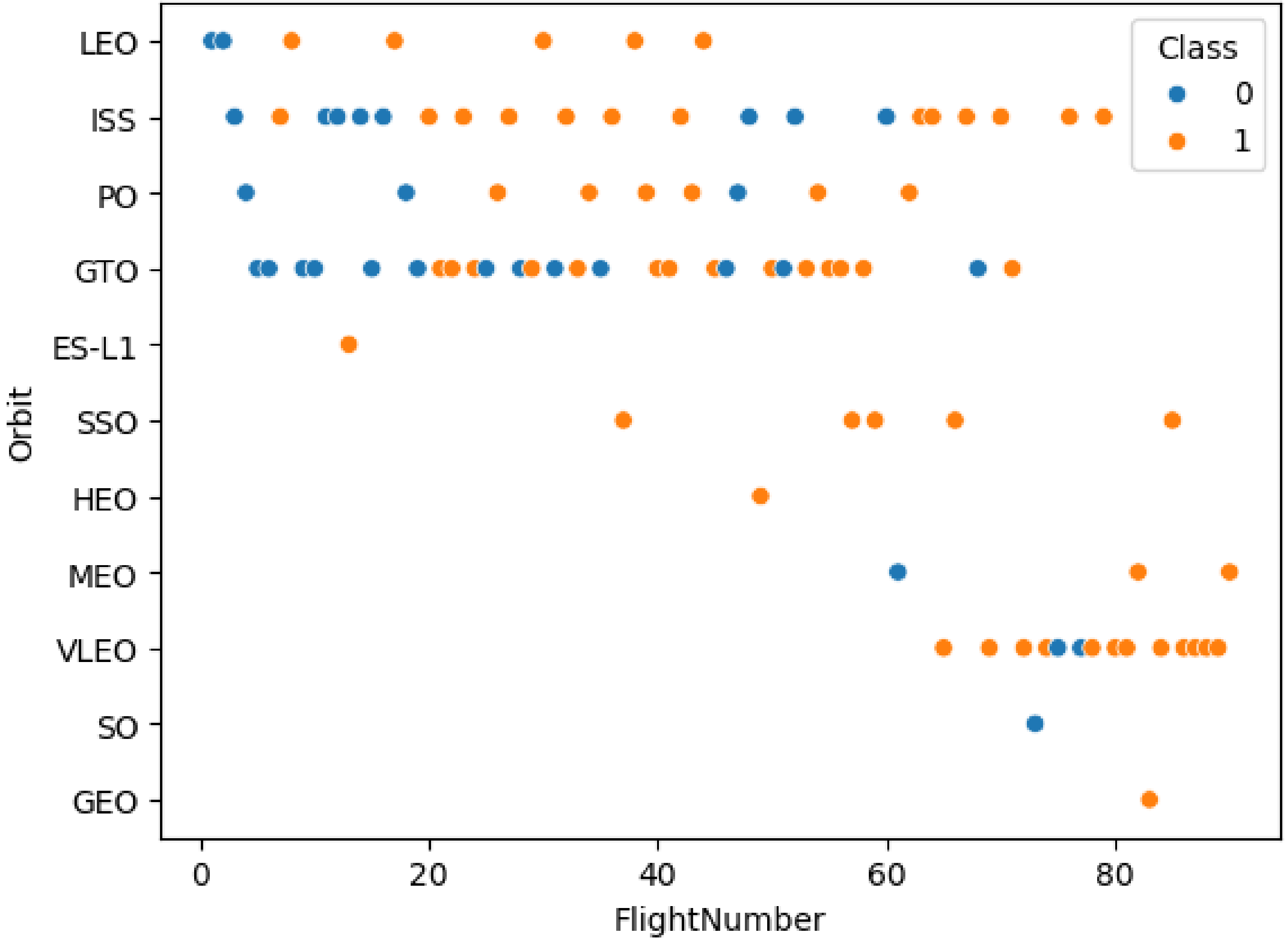
Data scraped from wikipedia

2020 [edit]

In late 2019, Gwynne Shotwell stated that SpaceX hoped for as many as 24 launches for Starlink satellites in 2020,[490] in addition to 14 or 15 non-Starlink launches. At 26 launches, 13 of which for Starlink satellites, Falcon 9 had its most prolific year, and Falcon rockets were second most prolific rocket family of 2020, only behind China's Long March rocket family.[491]

[hide] Flight No.	Date and time (UTC)	Version, Booster[b]	Launch site	Payload[c]	Payload mass	Orbit	Customer	Launch outcome	Booster landing
78	7 January 2020, 02:19:21[492]	F9 B5 ♺ B1049.4	CCAFS, SLC-40	Starlink 2 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Success (drone ship)
	Third large batch and second operational flight of Starlink constellation. One of the 60 satellites included a test coating to make the satellite less reflective, and thus less likely to interfere with ground-based astronomical observations.[493]								
79	19 January 2020, 15:30[494]	F9 B5 ♺ B1046.4	KSC, LC-39A	Crew Dragon in-flight abort test[495] (Dragon C205.1)	12,050 kg (26,570 lb)	Sub-orbital[496]	NASA (CTS)[497]	Success	No attempt
	An atmospheric test of the Dragon 2 abort system after Max Q. The capsule fired its SuperDraco engines, reached an apogee of 40 km (25 mi), deployed parachutes after reentry, and splashed down in the ocean 31 km (19 mi) downrange from the launch site. The test was previously slated to be accomplished with the Crew Dragon Demo-1 capsule;[498] but that test article exploded during a ground test of SuperDraco engines on 20 April 2019.[419] The abort test used the capsule originally intended for the first crewed flight.[499] As expected, the booster was destroyed by aerodynamic forces after the capsule aborted.[500] First flight of a Falcon 9 with only one functional stage — the second stage had a mass simulator in place of its engine.								
80	29 January 2020, 14:07[501]	F9 B5 ♺ B1051.3	CCAFS, SLC-40	Starlink 3 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Success (drone ship)
	Third operational and fourth large batch of Starlink satellites, deployed in a circular 290 km (180 mi) orbit. One of the fairing halves was caught, while the other was fished out of the ocean.[502]								
81	17 February 2020, 15:05[503]	F9 B5 ♺ B1056.4	CCAFS, SLC-40	Starlink 4 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Failure (drone ship)
	Fourth operational and fifth large batch of Starlink satellites. Used a new flight profile which deployed into a 212 km × 386 km (132 mi × 240 mi) elliptical orbit instead of launching into a circular orbit and firing the second stage engine twice. The first stage booster failed to land on the drone ship[504] due to incorrect wind data.[505] This was the first time a flight proven booster failed to land.								
82	7 March 2020, 04:50[506]	F9 B5 ♺ B1059.2	CCAFS, SLC-40	SpaceX CRS-20 (Dragon C112.3 ♺)	1,977 kg (4,359 lb)[507]	LEO (ISS)	NASA (CRS)	Success	Success (ground pad)
	Last launch of phase 1 of the CRS contract. Carries *Bartolomeo*, an ESA platform for hosting external payloads onto ISS.[508] Originally scheduled to launch on 2 March 2020, the launch date was pushed back due to a second stage engine failure. SpaceX decided to swap out the second stage instead of replacing the faulty part.[509] It was SpaceX's 50th successful landing of a first stage booster, the third flight of the Dragon C112 and the last launch of the cargo Dragon spacecraft.								
83	18 March 2020, 12:16[510]	F9 B5 ♺ B1048.5	KSC, LC-39A	Starlink 5 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Failure (drone ship)
	Fifth operational launch of Starlink satellites. It was the first time a first stage booster flew for a fifth time and the second time the fairings were reused (Starlink flight in May 2019).[511] Towards the end of the first stage burn, the booster suffered premature shut down of an engine, the first of a Merlin 1D variant and first since the CRS-1 mission in October 2012. However, the payload still reached the targeted orbit.[512] This was the second Starlink launch booster landing failure in a row, later revealed to be caused by residual cleaning fluid trapped inside a sensor.[513]								
84	22 April 2020, 19:30[514]	F9 B5 ♺ B1051.4	KSC, LC-39A	Starlink 6 v1.0 (60 satellites)	15,600 kg (34,400 lb)[5]	LEO	SpaceX	Success	Success (drone ship)

Comparing orbit type, flight # and success/fail



Space X launch locations