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STATISTICAL ANALYSIS OF SPACESHIP LAUNCH SUCCESS RATE

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Abstrak — *This research aims to determine and prove the role of international policies and government programs in influencing technical decisions and the impact of successful launches on costs and risk reduction. In recent decades, spacecraft launch success rates have become a critical topic for analyzing the efficiency and technological advancements within the aerospace industry. This study explores historical data regarding spacecraft launch success rates, considering the influence of technical factors, government policies, and advancements in rocket design. By utilizing launch data from various space agencies such as NASA, SpaceX, and Roscosmos, the analysis highlights significant trends in increasing success rates, which align with innovations in technology and policies that support safer and more efficient space exploration. Additionally, this research examines the role of international policies and government programs in influencing technical decisions and the impact of successful launches on cost reduction and risk mitigation. Through statistical analysis and historical data modeling, this study provides in-depth insights into how technology and policy can shape higher success rates in future launches.*

Keywords: *Launch Success Rate, Launch Data Statistics, Rocket Technology, Space Policy, Statistical Analysis*

1. *INTRODUCTION*

Spacecraft launch is one of the most crucial aspects of space exploration, with launch success rates serving as a key benchmark for assessing the efficiency of the space industry. Launch success is highlydepen dent on various factors, including rocket design, launch technology, and policies that support and regulate the space sector. A NASA report indicates that since the early 2000s, space craft launch success rates have increased significantly thanks to technological develop ments and innova tions in rocket design. Spacecraft launch is one of the most critical stages of a space mission, with launch success rates often used as a key indicator for assessing technological reliability, launch system efficiency, and the overall maturity of the space industry. Launch success is significantly influenced by various factors, including launch vehicle design, propulsion systems, operational procedures, and the policy frameworks governing space activities at the national and international levels. As technology advances, historical data shows a trend of increasing launch success rates over the past two decades, driven not only by advances in rocket design but also by improved risk analysis methodologies and the implemen tation of stricter safety standards. Therefore, statistical analysis of launch data is a crucial approach for identifying success and failure patterns and evaluating the dominant factors influencing launch system perfor mance. Furthermore, international policies and government support through various space programs also influence the develop

ment of rocket technology and design. International space programs such as those launched by NASA, ESA, and Roscosmos play a crucial role in driving innovation and ensuring the safe and efficient conduct of space missions. Therefore, analyzing hist orical launch data is crucial for under standing these patterns and the factors underlying launch success.

2. METHODOLOGY

2.1 Data Collection and Sources

The data used in this study was compiled from various primary sources, including annual reports and documentation from NASA, SpaceX, Roscosmos, ESA, and JAXA. Additionally, commercial and military rocket launch data were reviewed to gain a broader picture of global launch success. The data spans the past two decades and encom passes various missions conducted by leading space agencies. The analysis included data from various rocket genera tions, including the Falcon 9, Saturn V, and Soyuz. The use of historical data from various international space agencies allows for a comprehensive analysis of launch success rates that is representative of the global state of the space industry (McDowell, 2023). Data spanning multiple generations of launch vehicles provides a strong basis for compa ring the performance of conventional and modern technologies, including reusable rockets. In addition, integrating data from com mercial and government missions is important to capture the impact of the space industry paradigm shift, particularly in the context of the increasing role of the private sector in launch system development.

2.2 Data Analysis Techniques

Statistical analysis was conducted to identify trends in launch success rates over time. Linear regression methods were used to model the relationship between various technical factors, policies, and launch success. The collected data were analyzed to identify factors that significantly contribute to success. The analysis was conducted by visualizing launch success trends across various rocket types used over the past few decades. Statistical analysis approaches are widely used in launch system reliability studies to identify long-term trends and evaluate the contribution of technical factors to launch success rates. Regression and trend modeling methods allow for quantitative and systematic analysis of the relationships between technological variables, policies, and launch performance. This type of analysis also plays a role in supporting design and policy decisions by providing an empirical basis for the risk and reliability of space launch systems NASA Office of Safety and Mission Assurance.

3. RESULTS AND DISCUSSION

3.1 Launch Success Trends by Rocket Type

Analysis of historical data shows a significant trend in increasing spacecraft launch success rates, particularly with newer generation rockets. One striking example is the SpaceX Falcon 9 rocket, which has recorded a launch success rate of over 98%. This figure is significantly higher than previous rockets, such as the Space Shuttle, which had a success rate of around 80% from the 1980s to 2011. This suggests that the adoption of reusable rocket technology, which allows for repeated launches at lower costs, has significantly impacted launch success. Figure 1 below shows a graph of launch success rates by rocket type, specifically those manufactured by SpaceX.

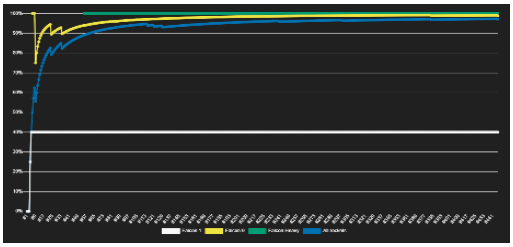


Figure 1. Rocket Launch Success Rate (White = Falcon 1; Yellow = Falcon 9; Green = Falcon Heavy; Blue = all rockets) Source: SpaceX (2023)

Besides SpaceX, the Soyuz rocket used by Roscosmos has also demonstrated a relati vely high success rate, although it is still slightly lower than that of the Falcon 9. Over the past few decades, the Soyuz has been the backbone of the Russian space program, with a success rate exceeding 95% in recent years. However, while the Soyuz rocket has a proven track record, the use of new, more efficient technologies, such as those

implemented in the Falcon 9 rocket, shows potential for greater improvement in the future. This improved success rate is also seen in other rockets, such as the Atlas V and Delta IV, which, despite lacking reusable technology, have demonstrated advances in reliability and efficiency. With success rates reaching around 95%, these rockets have become a mainstay for NASA and other private space contractors. This also under scores the importance of continuous impro vement in rocket design and enhanced, more stringent launch procedures. In general, rockets that integrate more modern, program mable launch systems with advanced automa tion, such as the Falcon 9, have higher success rates.The increased launch success rates observed with the latest generation of rockets align with the findings of various studies showing that modernization of propul sion systems, automation of the launch pro cess, and the adoption of reusable launch vehicle concepts contribute significantly to increased launch reliability. Previous statis tical studies have also shown that launch vehicles with more intensive testing and validation cycles tend to have lower failure rates in the long term.

3.2 Impact of Policy on Launch Success

In addition to technological advances, government policies and international agen cies also play a significant role in influencing the success of spacecraft launches. One clear example is the United States government's policy of supporting the development of reusable rockets through NASA programs and commercial contracts with companies like SpaceX. Programs like the Commercial Crew Program, launched in the 2010s, aimed at facilitating sustainable access to the Interna tional Space Station (ISS) using reusable rockets, have been shown to boost launch success rates.



Figure 2. Boeing CST-100 "Starliner" at Cape Canaveral Launch Complex, as part of the Commercial Crew Program Source: NASA (2020)

The program also includes collaboration between NASA and private companies, which have designed the Falcon 9 rocket and Dragon capsule, which have successfully conducted multiple repeat launches without major failures. This success not only reduced launch costs but also demonstrated how policies that support technological advan cement can lead to remarkable achievements in space exploration. These policies provided an incentive for SpaceX to develop more efficient technologies, which in turn helped other companies in the industry improve the reliability and efficiency of their launches. In addition to the United States, international agencies such as the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA) also play a key role in increasing launch success globally. ESA, for example, has a highly successful rocket launch program, such as the Ariane 5 rocket, which has a success rate of over 98%. This success is driven by policies that promote international cooperation and the development of more advanced techno logies in spacecraft launch. On the other hand, JAXA has collaborated with NASA and other space agencies to develop more efficient rockets, such as the H-IIA and H-IIB, which have achieved high success rates in various space missions, whether satellite missions or cargo deliveries to the ISS. For example, an analysis by SpaceX (SpaceX, 2023) revealed that government policies related to funding and tax incentives for companies developing reusable rockets have accelerated the adoption of this technology, contributing to increased launch success rates. The govern ment has also collaborated with international

institutions such as the International Telecommunication Union (ITU) to regulate satellite launch and operation frequencies, significantly suppor ting efforts to reduce technical failures due to frequency interference. Figure 3 below shows an exam ple of frequency interference mapping around the European continent in decibels milliwatts (dBm), where the horizontal and vertical axes represent the Earth's longitude and latitude.

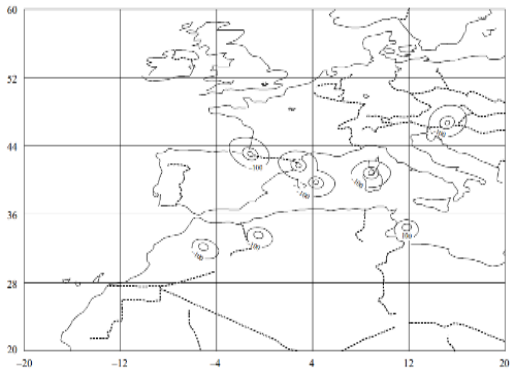


Figure 3. Frequency Interference Level Mapping Source: ITU (2022)

Closer international cooperation between space agencies and more coordinated poli cies at the global level have accelerated the development of safer and more efficient launch technologies. These international programs have helped introduce stricter safety standards and more transparent sharing of success data, which in turn strengthens the collective knowledge base and improves launch success rates. Govern ment policies and international regula tory frameworks play a strategic role in shaping the direction of space launch techno logy development, particularly through research funding, public-private partnerships, and the establishment of safety standards. Collabora tive programs between space agencies and the commercial sector have been shown to improve the efficiency of launch system development and accelerate the adoption of new, more reliable technolo gies. International regulatory coordination, including frequency spectrum manage ment and operational standards, also contri butes to reducing the risk of technical failures stemming from non-technical external factors.

3.3 Analysis of Launch Failure and Its Causative Factors

Although launch success rates have improved significantly in recent decades, data still suggests that some spacecraft launches have failed. Prominent examples include the Space Shuttle failures in 1986 (Challenger Disaster) and 2003 (Columbia Disaster, STS-107 mission), highlighting the importance of safety in rocket design and launch procedures. Although the Space Shuttle was designed for multiple launches, technical and human factors issues in its design and execution have led to significant failures that have impacted public confidence in the safety of space launches.



Figure 4. Space Shuttle "Columbia" at Liftoff on Mission STS-10, Source: NASA (2023)

Factors contributing to launch failure are often technical issues, such as material failure, control system errors, and unforeseen weather conditions at launch. Furthermore, communication failures between launch teams can also lead to unsafe launches. Therefore, modern programs, such as those implemented by SpaceX and other companies, prioritize more in-depth technical inspections and more rigorous testing sys tems to minimize these risks. Figure 5 below shows some of the factors contributing to launch failure.

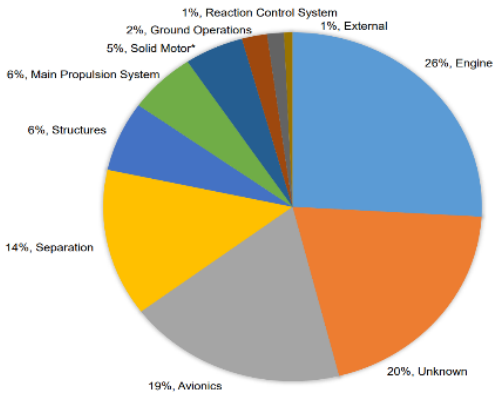


Figure 5. Factors Causing Rocket Launch Failure Source: NASA (2023)

Launch failure analysis is a critical element in improving launch system reliability, as it provides direct insights into design weaknes ses, operational procedures, and risk manage ment. Previous studies have shown that most launch failures are caused by a combination of technical and organizational factors, necessitating a holistic approach to risk mitiga tion (NASA Office of Safety and Mission Assurance' Space Data Corporatio.

4. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

- *The study revealed that the global spacecraft launch success rate shows a significant positive trend, largely driven by technological advances in propulsion systems and the adoption of reusable rockets. One of the biggest innovations is the success of SpaceX's Falcon 9 rocket, which has dramatically improved launch success.*

- *This technology has reduced launch costs, increased launch frequency, and minimized technical errors that lead to failures. Overall, while challenges remain, such as the failure of NASA's Artemis program or the early launch of new rockets, the study shows that space craft launch success rates continue to improve thanks to technological advan cements, policy support, and investment in technology development.*

- *The crucial role of international space programs, such as those launched by NASA, ESA, and Roscosmos, is to foster innovation and ensure that space missions can be conducted safely and efficiently.*

- *The results of this research analysis demonstrate that historical launch data is crucial for understanding existing patterns and the factors underlying launch success.*

4.2. Recommendations

Suggestions for Further Research is:

- *Reusable Rocket Development: Further research is needed to improve the effi ciency of reusable rockets and expand their application for long-duration space mis sions.*

- *Influence of International Policy: Further research into the influence of international policy on launch success would be inva luable for global policy planning*

- *Launch Risk Analysis: Modeling the risks of spacecraft launches can help predict poten tial failures and design strategies to miti gate those risks.*

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