Master's Thesis

New Space Revolution: Prospective Launchers for Small Satellites, Challenges for the Micro Launch Industry and its Implications for SmallSat Manufacturers

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New Space Revolution: Prospective Launchers for Small Satellites, Challenges for the Micro Launch Industry and its Implications for SmallSat Manufacturers

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TU Delft

Our two greatest problems are gravity and paperwork. We can lick gravity, but sometimes the paperwork is overwhelming.

Wernher Von Braun

Preface

It all started when a new generation of *Astroprenerus* dreamt about going to space and democratizing it for everyone. They built innovative start-ups, with far-reaching vision and revolutionary business models, challenging the status quo and old ways of working in a space industry dominated by incumbent giants and their slow bureaucracy. This changed the face of the industry, launching a *New Space Revolution: When the Heavens Went on Sale ...*

As I delved into this transformative era of space exploration, I was captivated and inspired by the boldness and vision of these modern pioneers. Their relentless pursuit of innovation and courage to challenge established norms resonated deeply with my aspirations. This thesis is not just an academic endeavour; it reflects my passion for space and belief in the boundless possibilities beyond our atmosphere.

I hope this thesis provides entrepreneurs in the space sector with a better understanding of their challenges and offers a foundation for other researchers intrigued by the New Space Industry. This work is my modest contribution to the ongoing conversation in the space industry. I hope it is a valuable resource for industry professionals and academic scholars.

The journey to completing this thesis has been both challenging and rewarding. The topic presented numerous challenges, from locating scarce literature to the difficulty of finding subject matter experts, all within a short time frame. Despite these challenges, the support and encouragement I received from my mentors, colleagues, and loved ones have been invaluable.

I want to express my deepest gratitude to the members of my Graduation committee, whose insights and expertise have been instrumental in shaping this research. During pivotal meetings, Dr. Victor Scholten provided crucial insights that deepened my understanding of the topic. My first supervisor, Dr. Laurens Rook, offered detailed analysis and feedback that were vital in forming my thesis. Lastly, I would like to thank Daniela Hallak for her unwavering support throughout the process and for making me feel welcome in her office. I would also like to extend my thanks to TU Delft for the Justus and Louise Van Effen Master's Scholarship and for the numerous opportunities that have enriched my educational journey.

I want to dedicate this work to my parents. Their belief in my potential and their constant encouragement have been my greatest sources of strength.

And finally, to all my people, I want to thank you. If you were there with me throughout this journey, if you met me along the way, or even if we've said goodbyes—thank you. Thank you for laughing with me on weekends, for preparing wonderful dinners, for those amazing parties, and for the incredible trips. During difficult times, thank you for hearing my struggles and helping me find my way through them. In the end, if you find yourself in these words, please accept my gratitude. *I wish you everything this world has to offer and beyond ...*

Deepesh Bhalodia
Delft, August 2024

Executive Summary

Background

The evolution of the global space sector, termed "New Space," signifies a shift from traditional, centralized, and bureaucratic operations to a more dynamic, commercial, and innovative industry. This transition is characterized by the emergence of small satellites (SmallSats) and micro launch vehicles, driven primarily by private investment and customer-centric approaches. The New Space paradigm emphasizes new business models, increased risk acceptance, and market-driven strategies, challenging the established norms of the traditional space industry. This transformation creates a vibrant ecosystem where various actors, including satellite manufacturers, launch service providers, and end-users, collaborate to drive innovation and ensure sustainable growth.

Problem Statement

The micro launch industry, despite its promise of providing affordable and accessible rides to space, is currently under scrutiny due to high-profile bankruptcies and developmental delays among several launchers. This raises questions about the industry's future and whether its previously proposed value propositions still hold against competitive strategies. This uncertainty significantly impacts small satellite (SmallSat) manufacturers, as launch costs heavily influence satellite design and capabilities.

Research Objectives

The primary aim of this thesis was to analyze and elucidate the current trends in the micro launch industry and their implications for the small satellite manufacturing sector. This included:

- Examining the factors contributing to the perceived market bubble within the micro launch industry.
- Identifying key drivers and challenges faced by industry players.
- Benchmarking micro launchers' value propositions against competitive strategies.
- Assessing the impact of these trends on investment decisions in research and development (R&D) for mass optimization among SmallSat manufacturers.

Methodology

This thesis employed a qualitative methodology, combining literature review, desk research, and semi-structured interviews to gather comprehensive insights into the micro launch industry. Additionally, a case study approach was used to provide an in-depth analysis of the micro launch industry set in the broader environment of the SmallSat launch industry. The literature review established the theoretical framework and identified key concepts, while desk research provided relevant current industry data. Semi-structured interviews with industry experts offered practical perspectives and developed insights. This multi-method approach ensured a robust analysis of the factors influencing the micro launch market and its implications for SmallSat manufacturers.

Key Findings

- **Market Bubble Factors**: The micro launch industry's market bubble was driven by an influx of liquidity from private investments, speculative investor behaviour, cognitive biases, and information asymmetry, leading to inflated asset prices and unrealistic market expectations.
- **Growth Drivers**: Key drivers included democratized access to space, which enabled a wider range of applications for small satellites, and substantial institutional support from government and defence applications.
- **Challenges**: Significant challenges included high entry barriers due to substantial capital requirements for R&D and regulatory compliance, competition from established players, and alternative launch strategies such as rideshare and orbital transfer vehicles. These challenges necessitated continuous innovation and strategic agility among micro launch companies.

Implications

- **For SmallSat Manufacturers**: The evolving trends in the micro launch industry have profound implications. Reduced launch costs and increased access to space shift the focus from minimizing satellite mass to optimizing mission performance and reliability. However, the uncertainty surrounding the micro launch sector underscores the importance of strategic planning and diversification.
- **For Industry Stakeholders**: Continuous innovation and strategic agility are necessary to maintain competitiveness and sustainability in the face of high entry barriers and intense competition.
- **For Policymakers**: Effective policy frameworks are crucial for addressing the dynamic nature of the micro-launch industry. Recommendations include streamlining regulatory processes, providing financial support and initiatives, investing in infrastructure and human resource development, and enforcing environmental and safety regulations. This will encourage innovation, reduce barriers to entry, and promote sustainable growth in the space sector.
- **Theoretical Implications**: The findings contribute to the broader understanding of market dynamics within high-tech industries. This research extends theoretical frameworks in the New Space, space policy, economics, applied science and technology, economics, entrepreneurship, and marketing. This research highlights the factors contributing to market bubbles in emerging sectors, the importance of sustainable business models, and the need for strategic foresight in rapidly evolving industries.

Conclusions

The research underscores that while the micro launch industry faces significant challenges, its growth is fueled by key drivers and the increasing demand for small satellite launches. Strategic planning, continuous innovation, and collaborative efforts among industry stakeholders are essential for navigating the complexities of the launch market and leveraging emerging opportunities. The findings provide a comprehensive understanding of the current state and prospects of the micro-launch sector, offering strategic guidance for both micro launch companies and SmallSat manufacturers.

Contents

List of Figures

List of Tables

Nomenclature

Abbreviations

AIAA	American Institute of Aeronautics and Astronautics
ARC	Ames Research Center
B2C	Business-to-Consumer
B2G	Business-to-Government
COTS	Commercial Off-The-Shelf
CubeSat	Cube Satellite
ESA	European Space Agency
EU	European Union
ICBM	Intercontinental Ballistic Missile
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
ISRO	Indian Space Research Organization
LEO	Low Earth Orbit
LV	Launch Vehicle
NASA	National Aeronautics and Space Administration
NTRS	NASA Technical Reports Server
OTV	Orbital Transfer Vehicle
PSLV	Polar Satellite Launch Vehicle
R&D	Research and Development
SmallSat	Small Satellite
SpaceX	Space Exploration Technologies Corp.
US	United States
USD	United States Dollar

Terminology

Throughout this report, we adopt the following classification for launch vehicles and small satellites (refer chapter 4):

Launch Vehicles

- **Sounding Rocket**: Capable only of suborbital flights, cannot deliver payloads to Earth orbit (suborbital only).
- **Micro Launcher Vehicle**: Able to place less than 500 kg into Low Earth Orbit (LEO).
- **Small-Lift Launch Vehicle**: Also known as "small launcher" or "light launcher", can lift between 500 and 2000 kg into LEO.
- **Medium-Lift Launch Vehicle**: Capable of lifting between 2000 and 20,000 kg into LEO.
- **Heavy-Lift Launch Vehicle**: Can lift between 20,000 and 50,000 kg into LEO, also known as "heavy launcher".
- **Super-Heavy-Lift Vehicle**: Capable of lifting more than 50,000 kg into LEO.

Small Satellites

- **Small Satellites**: General category for satellites under 500 kg.
- **Minisatellites**: Weigh between 100 kg and 500 kg.
- **Microsatellites**: Weigh between 10 kg and 100 kg.
- **Nanosatellites**: Weigh under 10 kg.

These classifications help in understanding the different categories of launch vehicles and small satellites, providing a framework for analyzing their capabilities and performance in the context of the micro launch industry and small satellite manufacturing. This classification is further detailed in chapter 4, but is mentioned here to aid the readers. '

Disclaimer

It is important to note that some literature sources and experts also refer to "small launchers" or "small launch vehicles" as those capable of carrying payloads up to 1500 kg or even 2000 kg. This variation in classification is acceptable due to the significant magnitude difference between other launcher categories, such as medium, heavy, and super-heavy, compared to small and micro launchers. The definitions adopted in this report aim to provide clarity and consistency for the purposes of our analysis.

1

Introduction

Old Space (...) is slow, bureaucratic, government-directed, completely top-down. Old Space is NASA, cautious and halting, supervising every project to the last thousand-dollar widget. Old Space is Boeing, Lockheed, and Northrop Grumman. Old Space coasts on the glory of the Apollo era and isn't entirely sure what to do next.
New Space is the opposite of all that. It's wild. It's commercial, bootstrapping, imaginative, right up to the point of being (...) delusional.

Joel Achenbach
(Achenbach, 2013)

1.1. Background and Challenging the Status Quo

The evolution of the global space sector, termed "New Space", signifies a shift from the space industry's traditional, centralized, slow, and bureaucratic operations. Although there is no standard definition of New Space, it has been interpreted differently by various researchers (Golkar & Salado, 2021). Some have focused on the incorporation of cutting-edge miniaturized technologies and novel approaches to project management and research and development, while others have emphasized the role of entrepreneurship, new financing methods, and the commercialization of space (see for example Hay et al., 2009; Peeters, 2018; Autry, 2013; McCurdy, 2019; Frischauf et al., 2017; Davidian, 2020).

At the organizational level, it has been observed that New Space companies tend to adopt flatter organizational structures and are more adaptable, customer-focused, innovative, and risk-taking. These companies are also more inclined towards new technological solutions. In contrast, traditional space companies, which are typically more hierarchical, place a greater emphasis on established business lines and rely heavily on government contracts. These companies often operate in industries characterized by low sales volume, low growth, and high-value offerings (Hay et al., 2009).

The concept of New Space was later expanded to include new services, new frontiers, and explorations. The evolution of New Space was described as the emergence of a "new ecosystem", viewed as a network of interconnected parts rather than a single entity. Furthermore, this transition from "Old" to "New" involves changes in several elements and their connections and interactions (Paikowsky, 2017).

To build on the ideology of the ecosystem, approaching the New Space Ecosystem from an entrepreneurial perspective helps distinguish between commercial space and new space. This perspective elucidates that the commercial application of space technology is not a new phenomenon, primarily as a spin-off process from public space projects between 1970 and 2010 (Peeters, 2018). However, the emergence of new space dynamics has led to a strong desire to develop new space applications independently of government motivations, with financing from private entities becoming the main differentiating factor. This shift was also noted by Christensen et al. (2016), who identified an increase in funding by angel investors and venture capital firms from 2000 onwards and the formation of space startups.

From a business model perspective, new market entrants introduce new business models and set new objectives for traditional space agencies. This shifts the ecosystem towards a demand-pull model of technological innovation, contrasting with the technology push model prevalent in the conventional space industry for downstream applications. Thus, the transformation from traditional to New Space represents a Paradigm shift in the space industry, driven by technological advancements, novel business models, and changing financial infrastructure (Frischauf et al., 2017; Parrella et al., 2022; Bousedra, 2023).

This New Space Paradigm created newer business models focused on market and consumer-centric products and services. Frischauf et al. (2017) identifies at least 4 intrinsic factors for a New Space ecosystem to create market-driven products and services. These factors are related to:

- **Business Philosophy**: creating and living an entrepreneurial spirit.
- **Financing**: increased access to early-stage risk capital and increased venture capital funding.
- **Technology Management**: focus on spinning-in technologies and ICT processes; and
- **Framework Conditions**: favourable political and legal conditions supporting commercialization.

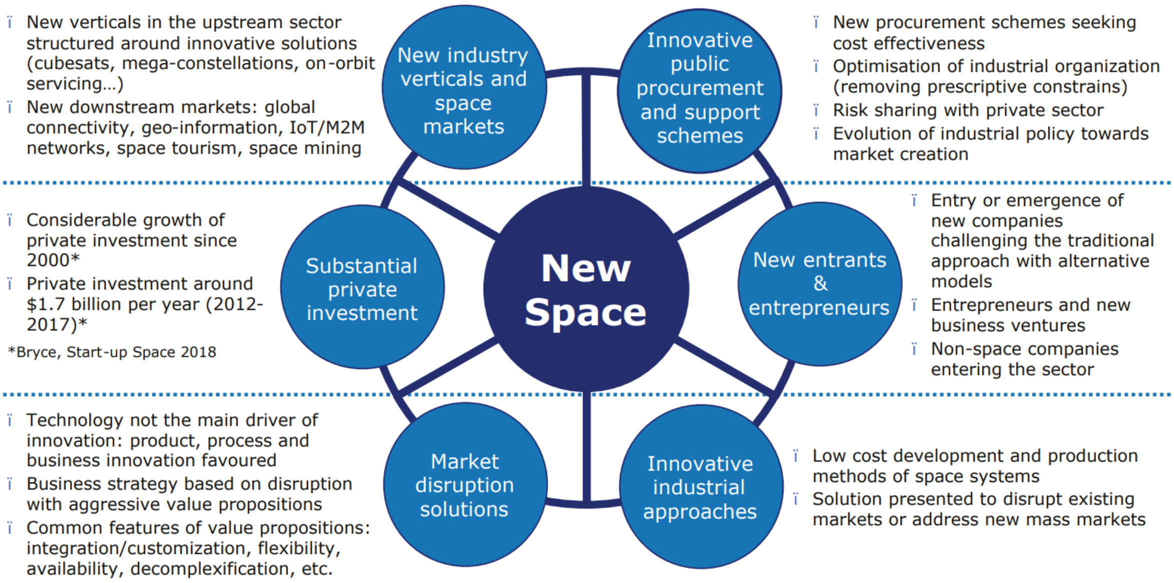

Figure 1.1: Key Trends of New Space Paradigm (Iacomino, 2019).

Furthermore, these factors are embedded in the key trends of the New Space Paradigm (refer figure 1.1).

- **Innovative public procurement and support schemes:** Public ventures started to adopt new procurement schemes for their need for increased cost-effectiveness (e.g. reliance on Falcon 9 rockets for human and cargo transfer to ISS) lead by favourable framework conditions, risk sharing with the private sector and lesser constraints.
- **New entrants & entrepreneurs:** The new business philosophy combined with increased financing opportunity and risk-taking appetite brings new entrants to the ecosystem.
- **Innovative industrial approaches:** Lowering the cost of production using new methods and Commercial Off-the-Self (COTS) components.
- **Disruptive market solutions:** Aggressive and consumer-centric value proposition.
- **Substantial private investment:** Increased Private Investment since 2000 from the private sector.
- **New industry verticals and space markets:** Vertical Integration in the upstream sector and new markets for satellite applications, SmallSat, and CubeSat applications have been prominent.

1.1.1. Emergence of SmallSat Ecosystem

The Drivers behind the New Space Paradigm and the increased affordability and accessibility offered by the initiatives within have catalyzed the growth of a vibrant smallsat ecosystem. Furthermore, small satellites have played an important role in democratizing space exploration and enabling a wide range of applications, from scientific research to commercial services (Venkatesan et al., 2020; Behrens and Lal, 2019). These trends lead to ecosystems where value proposition gradually converges towards a more commercially attractive value proposition that is customer-centric with significant economic benefits (Song et al., 2024).

For this emerging smallsat ecosystem; multilateral interdependence, nongeneric complementary (or specialized investments by actors), collective value creation, and value proposition are essential. Multilateral interdependence suggests that the ecosystem can be divided into actors and actives. This interdependence affects the whole ecosystem when the core actors make non-generic complementary investments and help create value for each other and fulfil the common goal of collective value creation (Song et al., 2024).

The actors in this ecosystem comprise the following:

- **Focal Technology Producers**: The satellite manufacturers design and build the small satellites.
- **Customers**: Satellite operators who use satellites for various purposes such as communication, earth observation, scientific research, etc.
- **Component Providers**: These include satellite bus and payload suppliers who provide the necessary components for building the satellites.
- **Complementors**: These are crucial for the value proposition of the small satellites. They include:
  - **Launch Vehicle Providers**: Launch Vehicles (LV) or launch rocket providers provide the vehicles that launch the satellites into space.
  - **Ground Equipment Providers**: They provide ground equipment for satellite operations.

These actors work together to create a thriving small satellite ecosystem. The success of this ecosystem depends on the collaboration and interplay between these actors (Nightingale et al., 2015; Song et al., 2023; Song et al., 2024)

Due to the interdependence between the actors, the developing value propositions in each of these sectors affect each other and vice versa. Therefore, It is important to analyze how the value proposition develops among the constituent actors and complementors.

1.1.2. Launchers for Small Satellites and Micro Launch Initiatives

The small satellite ecosystem has seen a remarkable evolution over the years, marked by significant contributions from researchers and industry players. In the 90s and early 2000s, pioneers like Naumann (1995) and Foust (2003) laid the groundwork with their research on small satellite launchers, setting the stage for future advancements. As the industry progressed, Niederstrasser's surveys from 2015 onwards provided valuable insights into the development of small launchers, highlighting the critical need for novel capabilities in response to the burgeoning smallsat revolution (C. Niederstrasser and Frick, 2015; C. Niederstrasser and Madry, 2020; C. G. Niederstrasser, 2022).

By 2017, dedicated launch options for SmallSats were limited, yet a notable increase in Micro Launch Vehicles (LVs) is still in development. This surge in micro launcher initiatives was primarily driven by factors categorized by Tugnoli et al. (2019b) as "Institutional and Commercial Drivers."

- **Commercial Drivers**: These include the growing demand for small satellite launches *(Anticipated Business Opportunity)*, the need for dedicated and flexible launch services, and the potential for new business opportunities within the small satellite market (Favorable Business Conditions).
- **Institutional Drivers**: These encompass government and defence applications, scientific research, and educational missions *(Military Operational Response Capabilities)*. Institutions value the ability to deploy small satellites for various purposes, such as reconnaissance, communication, and technology demonstration *(Independent Access to Space)*.

Tugnoli et al. (2019c) also emphasized the necessity of developing micro launch initiatives to enhance European access to space. They highlighted these initiatives' value proposition for the emerging small satellite ecosystem in Europe, reinforcing the strategic importance of micro launch capabilities.

Globally, the Electron, developed by Rocket Lab, was predicted to become a game-changer for small satellite operators. Its design specifically catered to the needs of this market segment, offering solutions to challenges like long lead times and the necessity for precise orbits. Rocket Lab's predicted frequent launches and cost reduction strategies were instrumental in addressing these issues (Bailey, 2020). However, the Electron's launch cadence remains dependent on market demand, with the potential for increased frequency, if required by the market (Kulu, 2023a).

This continuously changing landscape is accompanied by new companies like SpaceX and Blue Origin, alongside established providers such as ISRO and Ariane. The introduction of dedicated rideshares on other launchers and Orbital transfer vehicles (OTVs) further diversified the market (Pelton & Madry, 2019). Especially, SpaceX Falcon 9 exemplifies the evolution of medium-to-high-lift and reusable launch vehicles[1]. These advancements have made space more accessible to smallsat operators by reducing costs and time to market. The Falcon's reusability and larger payload fairings have been particularly beneficial, leading to a shift in operator preferences and a supportive role for heavy-lift vehicles in the smallsat industry. The Transporter missions on Falcon 9 are a testament to this development (Mowry & Grasso, 2020).

The rise of ridesharing has also been pivotal, allowing small satellites launched in large constellations to reach orbit more efficiently. This has given birth to a new business model managed by "smallsat launch aggregators" such as SPACEFLIGHT, EXOLAUNCH, and ISISPACE, who handle all aspects from manufacturing to regulatory compliance, driven by the New Space characteristic trend for Vertical Integration (Madry, 2020).

1.2. Problem Statement

The Micro Launch Industry with all promises of providing affordable and accessible rides to space, is recently under scepticism, with high profile Bankruptcies like Virgin Orbit, Vector, and SpaceRyde (Sheetz, 2023) and delays in the development of several launchers, raises questions about the future of the micro launch industry. Several researchers have raised concerns about a hype bubble in the industry (Kulu, 2023a). Many small and micro launch companies have started making larger launch vehicles, as seen in figure 1.2. Furthermore, Motta et al. (2024), in their recent paper indicated that " To some governments investing in micro-LVs is important, not only as a way of creating high-quality jobs and technologies but also for strategic reasons, but there is no indication that micro-LVs will be able to commercially compete with larger LVs in terms of cost of launch ". This raises a question: *Does the value proposition of micro launchers proposed previously still hold or do competitive solutions have a better standing?*

Furthermore, within the smallsat ecosystem, SmallSat manufacturers are an important element and these developments are important for them as launch cost significantly impacts their satellite design (Nightingale et al., 2015). Over the years the mass of satellites has been dramatically affected by the decrease in launch costs. Reduced expenses relieve some pressure to keep satellite mass to a minimum, historically, which has been a key consideration in manufacturing and design because of high launch costs (Jones, 2018b). This implies that more reliable and well-tested commercial off-the-shelf (COTS) systems—which are frequently heavier but offer increased dependability—can be incorporated into the design of satellites (Jones, 2018a).

Larger or multiple satellites are launched in a single launch due to the cost reduction. For instance, with SpaceX's Falcon 9, the cost of launch to Low Earth Orbit (LEO) is approximately \$5000/kg, compared to \$54,500/kg with the space shuttle (Jones, 2018b). Because of this sharp decline, satellite manufacturers can now pack their spacecraft with more mass for extra instruments, more fuel for extended missions, or even redundancy systems to increase mission dependability. Essentially, the reduced launch costs are making it possible for the satellite design philosophy to change from merely minimising mass to optimising for the longevity and success of the mission (Jones, 2018a).

[1]SpaceX's Transporter missions are rideshare missions that allow multiple smaller payloads to be launched together on a single rocket. Up-to-date SpaceX has launched Ten dedicated small satellite rideshare on their Falcon 9.

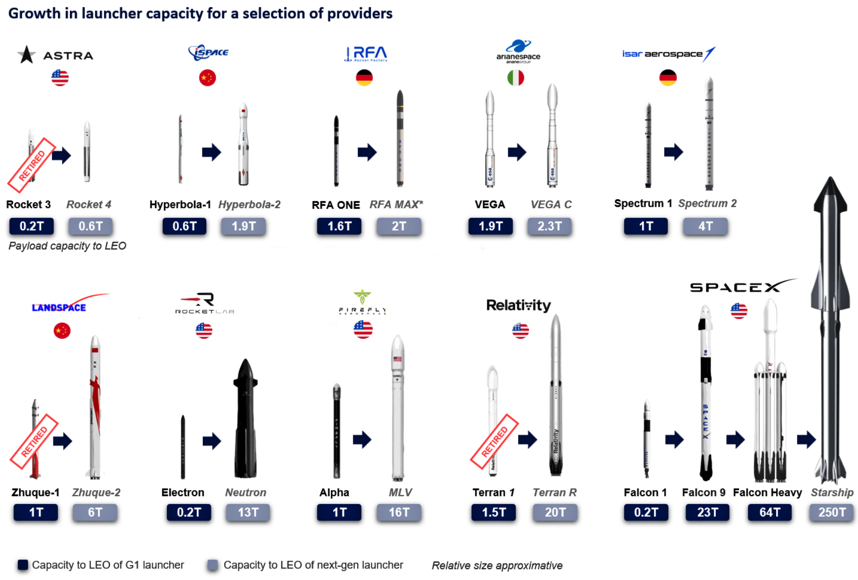

Figure 1.2: Micro/Small Launch Companies sifting to Larger Vehicles (Deville, 2024).

With the successful launch of Starship in March 2024, Marino Fragnito, senior vice president and head of the Vega business unit at Arianespace said that "Starship for sure will disrupt further the launch business and the space business in general" (Foust, 2024c). With all the above movements and trends in the ecosystem embedded within the New Space Paradigm. This raises a question: *What do the trends in the launch market mean for the micro launch industry and how do they impact SmallSat manufacturers like ISISPACE?*

1.3. Research Objective

The primary aim of this study is to analyze and elucidate the current trends in the micro launch industry and their implications for the small satellite manufacturing sector. This involves a comprehensive examination of the factors contributing to the perceived market bubble within the micro launch industry, identification of the key drivers and challenges faced by industry players, benchmarking of micro launchers' value propositions against competitive solutions, and an assessment of how these trends influence investment decisions in research and development (R&D) for mass optimization among SmallSat manufacturers.

1.4. Research Questions

Following up on the research objectives, the next stage is to develop concise research questions. These questions should summarise the main problems this study attempts to solve and offer direction in reaching our goals (Johnson et al., 2020). They need to strike a balance between being detailed enough to provide clear guidance and comprehensive enough to cover all the micro launch industry's aspects and its impact on SmallSat manufacturing.

> ***Main Research Question: What are the current trends in the micro launch industry, and what is the implication of these trends for the small satellite manufacturing industry?***

Given the multiple concepts and intermediate steps involved, the following sub-research questions break down the processes sequentially.

> *Sub-Research Question 1: What are the main factors behind the micro launch industry's market bubble?*

The first sub-research question aids in understanding the underlying factors contributing to the perceived market bubble—such as overvaluation, excessive optimism, or misalignment of capabilities and market needs—and will provide critical insights into the industry's current state and future outlook.

> *Sub-Research Question 2: What are the key drivers and challenges in the micro launch industry?*

Next, identifying the primary drivers and challenges within the micro launch sector is essential for comprehending its growth trajectory and operational hurdles. Factors such as technological advancements, funding availability, regulatory environments, and market demand play pivotal roles. This question dissects these elements to reveal opportunities and threats that shape the industry's landscape.

> *Sub-Research Question 3: How does the value proposition for micro launchers benchmark against competitive solutions amid the current trends in the industry?*

Furthermore, with increasing competition from larger launch vehicles and innovative launch solutions like ridesharing and orbital transfer vehicles, it is crucial to assess the competitiveness of micro launchers. This question will benchmark micro launchers against alternative solutions, focusing on aspects such as cost, flexibility, reliability, and market fit, thereby highlighting their strengths and weaknesses.

> *Sub-Research Question 4: How does the current trends affect SmallSat manufacturers' investment decisions in R&D for mass optimization of their products (e.g., CubeSat dispensers)?*

Finally, the trends in launch costs, vehicle availability, and technological advancements directly impact SmallSat manufacturers' strategies, particularly in R&D investments to optimise mass and enhance payload capabilities. This question seeks to understand how these external trends influence internal strategic decisions, affecting small satellites' design, development, and deployment.

1.5. Summary

The introduction chapter of this thesis provides an in-depth overview of the transformation occurring in the global space sector, focusing on the shift from traditional, bureaucratic operations to the innovative and commercial-oriented Paradigm known as "New Space." This chapter is structured into several sections that collectively establish the foundation for the research.

The chapter begins by describing the evolution of the global space sector from "Old Space"—characterized by centralized, slow, and government-directed operations—to "New Space," which emphasizes entrepreneurship, commercial ventures, and rapid technological innovation (refer section 1.1). Researchers interpret New Space differently, but common themes include adopting cutting-edge technologies, new business models, and increased private sector involvement. The chapter highlights the flatter organizational structures, customer-centric approaches, and increased risk-taking inherent in New Space companies compared to their traditional counterparts.

Next, in subsection 1.1.1, the chapter explores the drivers behind the New Space Paradigm, particularly the rise of small satellite (SmallSat) ecosystems. SmallSats have democratized space exploration by making it more affordable and accessible, leading to a surge in applications ranging from scientific research to commercial services. Key factors contributing to the growth of the SmallSat ecosystem include multilateral interdependence, specialized investments by core actors, and collective value creation among ecosystem participants. The actors within this ecosystem include satellite manufacturers, satellite operators, component providers, and complementors such as launch vehicles and ground equipment providers.

The chapter then delves into the evolution of launch solutions for SmallSats, highlighting the development of dedicated micro launch vehicles driven by commercial and institutional factors (refer subsection 1.1.2). Pioneers in the 1990s and 2000s laid the groundwork for today's advancements, further propelled by market demand for flexible and dedicated launch services. The rise of companies like Rocket Lab, SpaceX, and others has significantly impacted the industry, introducing new business models such as rideshare missions and vertical integration by smallsat launch aggregators.

Despite the promising developments, the micro launch industry faces scepticism due to high-profile bankruptcies and concerns over a market bubble (refer section 1.2). The chapter identifies a crucial question: whether the value proposition of micro launchers still holds or if competitive solutions offer better alternatives. This uncertainty is significant for SmallSat manufacturers, as launch costs directly impact satellite design and overall mission feasibility. The chapter also highlights the implications of reduced launch costs on satellite design philosophy, emphasizing the shift towards optimizing for mission longevity and success.

The study's primary aim is to analyze current trends in the micro launch industry and their implications for the small satellite manufacturing sector (refer section 1.3). The research objectives include investigating the factors behind the market bubble, identifying key drivers and challenges, benchmarking micro launchers' value propositions against competitive solutions, and assessing the impact of these trends on SmallSat manufacturers' R&D investment decisions.

The main research question guiding this study is: "What are the current trends in the micro launch industry, and what are the implications of these trends for the small satellite manufacturing industry?" Sub-research questions further explore the factors behind the market bubble, the drivers and challenges in the industry, the competitive benchmarking of micro launchers, and the impact on SmallSat manufacturers' R&D decisions.

This comprehensive introduction sets the stage for the detailed analysis and discussions in the subsequent chapters, providing a robust framework for understanding the evolving landscape of the micro-launch industry and its broader implications.

1.6. Structure of the Report

The rest of the document is structured into several chapters to comprehensively address the research objectives and questions, as can be seen in the figure 1.3:

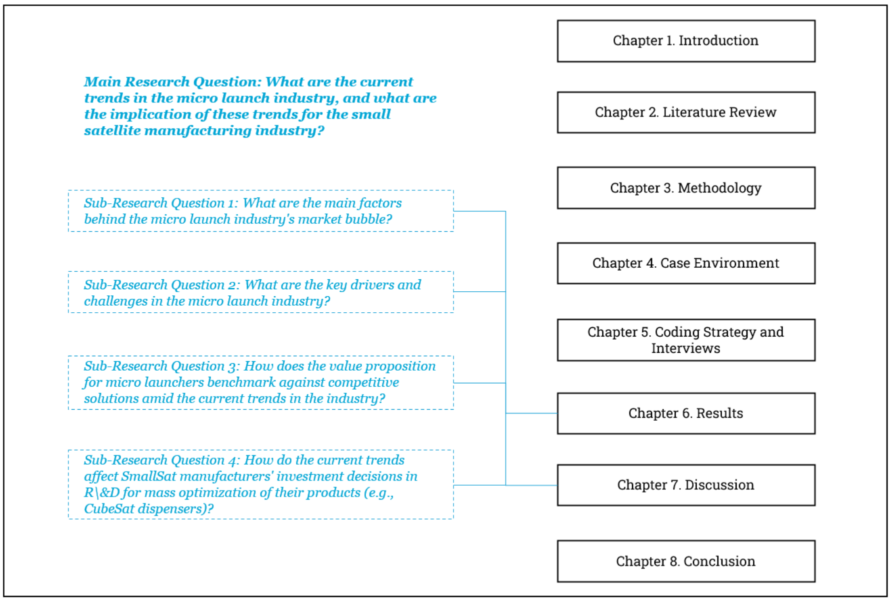

Figure 1.3: Structure of the Report.

Firstly, chapter 2 presents a literature review, examining relevant theories and previous research on market bubbles, New Space startups, and business model frameworks. Chapter 3 outlines the methodology used in this study, detailing the research philosophy, data collection methods, and analysis strategies.

Furthermore, chapter 4 describes the case environment, including the classification of launch vehicles and the segmentation of the small satellite market. Chapter 5 presents the detailed coding strategy and interview summaries.

The findings from the qualitative data analysis are presented in chapter 6, which assists in addressing the first and second sub-research questions. Following this, chapter 7 provides a discussion that benchmarks the value propositions of micro launchers, and examines the implications for SmallSat manufacturers and policymakers, thereby contributing to answering the third and fourth sub-research questions. It also discusses contributions to the literature, addresses the study's limitations and future research directions, and provides the researcher with a reflection on the management of the technology study program.

Finally, chapter 8 offers the conclusion of the thesis, synthesizing the key insights and providing strategic recommendations for stakeholders in the New Space Paradigm.

2

Literature Review

The whole [scientific] process resembles biological evolution. A problem is like an ecological niche, and a theory is like a gene or a species being tested for viability in that niche.

David Deutsch, FRS
Quantum Physicists

This chapter explores the dynamics of market bubbles and the challenges new space startups face, focusing on the Micro Launch Industry. Creation of Market Bubbles (section 2.1) examined broader literature to identify common contributing factors like liquidity abundance, herding behaviour, cognitive biases, and information asymmetry. The section on New Space Startups and their Challenges (section 2.2) highlights high entry barriers, regulatory and geopolitical obstacles, talent acquisition difficulties, rapid innovation needs, and financial management concerns, emphasizing sustainable business models and tailored value propositions. Additionally, Business Model Frameworks (section 2.3) are introduced to analyze and benchmark the competitive landscape, aiding in developing effective business strategies for micro launchers.

2.1. Creation of Market Bubbles

To answer the research questions, a review of the literature is essential. From section 1.2, the potential for a bubble in the Micro Launch Industry emerges. Several researchers have noted this possibility, but there remains a limited understanding of the underlying factors that have contributed to this bubble (Foust, 2019; Kulu, 2021). To understand the factors contributing to a bubble in the Micro Launch Industry from a theoretical perspective, broader literature on the *Creation of Market Bubbles* is studied.

A bubble can be defined as “a sharp rise in the price of an asset or a range of assets in a continuous process, with the initial rise generating expectations of further rises and attracting new buyers”. The first known bubble, the Tulip Mania, happened in the 17th century. Since then, numerous bubbles have been observed, each with its unique characteristics but also with various common underlying factors (Garber, 1990). Many academic fields, including economics, finance, psychology, and sociology, have produced literature on market bubbles (FasterCapital, 2024).

A common theme across the different examples of historic Bubbles is an ***Abundance of Liquidity*** in the market, which leads to excessive borrowing and investing, often in speculative assets, contributing to bubble formation (Andraszewicz, 2020). This is further exacerbated by investors’ tendency to buy overvalued assets with the expectation of selling them at even higher prices. The psychological tendency of individuals to mimic the actions of a larger group, known as ***Herding Behavior*** (Rook, 2006), leads to a collective movement that can inflate asset prices (Avery & Zemsky, 1998).

Investors’ Overestimation of their knowledge and underestimation of risks can result in inflated asset valuations. Various ***Cognitive Biases***, such as confirmation bias and anchoring, can distort investors’ perceptions and decisions, further fueling the bubble (Vogel, 2021). On the other hand, when there is an inherent ***Information Asymmetry*** in the market, some market participants have better or worse information than others, it can also lead to mispricing and bubbles (Brunnermeier, 2016).

New technologies can create excitement and hype, leading to over-investment and bubble dynamics. Inadequate regulation can fail to curb excessive risk-taking and leverage, contributing to the formation of bubbles. This excitement and hype resulting in ***High Expectations for Economic Growth*** can lead to over-optimistic valuations of assets. The overall mood and sentiment of the market can greatly influence asset prices and is often detached from underlying fundamentals (Chang et al., 2016).

Therefore, the literature suggests that the creation of market bubbles is a complex phenomenon driven by various factors, including behavioural tendencies, economic conditions, and market dynamics. Due to the unique characteristics of the space industry, such as long development times, high capital expenditure, and the high technical complexity of space missions, further investigation into the contributing factors specific to the launch Industry is needed.

2.2. New Space Startups and their Challenges: Entrepreneurial and Marketing Perspective

An additional noteworthy element of a bubble is the imminent financial crisis that ensues (Kindleberger, 1991). This presents several difficulties for businesses and start-ups in the industries. Lamine et al. (2021) define space start-ups as *"a new business entity that provides space technologies, products or services, specifically one that manufactures satellites, launch vehicles, manufactures satellite ground equipment, provides services that rely on space systems and analytic services based on data collected extensively from space-based systems either alone or in combination with terrestrial systems"*. Since Micro Launch companies are relatively new, they can be safely classified as High-Tech Start-ups due to their New Space characteristics (refer chapter 1), which include innovative industrial approaches, disruptive market solutions, substantial private investment, extensive R&D, new industry verticals and space markets, and new business models (Skala, 2019; Romasanta et al., 2021; Bala Subrahmanya, 2022; Wainscott-Sargent, 2022). When SCOPUS is searched for keywords "challenges AND micro AND launch AND startups" it provides zero relevant results. Therefore, a review of the broader ***Entrepreneurship and Space Policy Literature*** on the challenges faced by high-tech start-ups in the aerospace industry is necessary to comprehend the difficulties faced by the companies in the micro launch industry.

2.2.1. Entrepreneurial Perspective

Recently, the term ***"Astroprenuer"*** has been coined for entrepreneurs operating in the New Space Era (Vernile, 2018). The prefix *"Astro-"* refers to *"stars or celestial bodies"* that exist beyond Earth's atmosphere and the suffix *"-preneur" refers to a "taker"* someone who establishes and manages a business (Basar, 2018; Higgins et al., 2017). Furthermore, the importance of this terminology is emphasized by its use in various organizations such as the European Union-funded "Astroprenuer" Space Start-up Accelerator ("Astropreneurs – Space Startup Accelerator", 2020).

Many of the challenges New Space Astroprenuer and their startups face are the same as other entrepreneurs but with various subtle differences due to their complex and competitive industry (Gonzalez, 2023). The ***Competition and Entry into the market*** are two of the main obstacles. Factors contributing to the ***Significant Barriers to Entry*** include *High costs of technology development, strict regulations, and competition from established players* (Wainscott-Sargent, 2022 and Berger, 2023). These startups struggle with market entry and with ***Regulatory and Geopolitical Obstacles***. The aerospace sector is subject to intricate, frequently global regulations. Adhering to these regulations can involve managing a complex network of certifications and safety requirements, which can be expensive and time-consuming (Lamine et al., 2021).

Talent Acquisition is also a challenge for these aerospace companies as they need highly skilled engineers and specialists, which are rare due to the extensive qualifications they require. This makes hiring competitive and difficult contributing to higher Operational costs. ***Rapid Innovation and Technology Development*** present another significant challenge. For startups to stay competitive, they must constantly innovate due to the aerospace industry's rapid pace of technological advancements, this includes taking on *Capital Intensive R&D* or handling the possibility of technology obsolescence.

Therefore, these startups must obtain large financial investments and form strategic alliances to overcome these obstacles and maintain healthy relationships with their partners in the value chain (Okhrimchuk, 2019). ***Financial management and Funding*** constitute yet another crucial area of concern. Maintaining financial support for long-term projects is even more difficult than securing initial venture capital. This is made worse by the requirement to set up a dependable manufacturing and supply chain, which is necessary but difficult because suppliers are dispersed worldwide and aerospace components are highly specialised and expensive ("Bridging the Financing Gap Europe's Space Sector", 2024).

Furthermore, due to the increase in space debris and ethical implications of space explorations, ***Environmental Regulations*** become more and more important, aerospace startups need to think about how their operations and products will affect the environment and their business models become even more intricate as a result ("Space Tech Challenges and Opportunities", 2022). The literature stresses how crucial it is to create a ***Sustainable Business Model*** (Higgins et al., 2017). To achieve that, these startups must not only offer ***Unique Value Propositions*** that meet customer demands but also engage in *Value Co-creation* with partners and customers to thrive (Gonzalez, 2023).

To define this unique value proposition, Companies need to determine which end consumer markets they will be catering to (business-to-consumer or B2C), other businesses (business-to-business or B2B), or government or institutional actors (business-to-government or B2G) or a combination of the following. Space Launch Companies, for example, could tailored to both B2B and B2G customers, while downstream services could be offered to both B2C and B2B customers (refer figure B.1 and figure B.2). Startups need to make a conscious decision about which customer segments and markets they can realistically reach and target using their business model and may need to adopt multiple business models. Higgins et al. (2017) emphasises the importance of ***Segmenting Customers*** "as finely as possible according to the most distinctive criteria such as market, needs, revenue, size, geographical region, and sales channels". This will help businesses define their value proposition as precisely as possible. They should also build relationships with their customers to understand their needs and use interactive marketing strategies such as customer co-creation (Prahalad & Ramaswamy, 2004).

2.2.2. Marketing Perspective

From a Marketing perspective, Building relationships with customers is about understanding their needs and values and creating a bond beyond the business's transactional nature. This is where the concept of relationship marketing comes into play. Relationship marketing is designed to foster customer loyalty, interaction and long-term engagement. It is designed to develop strong connections with customers by providing information directly suited to their needs and interests and promoting open communication (Palmatier, 2008). This approach often results in increased word-of-mouth activity, repeat business, and a willingness on the customer's part to provide information to the organization (Kim et al., 2001). Therefore, it is a crucial strategy for micro launchers navigating the competitive aerospace industry.

Understanding customer values is at the heart of relationship marketing. It involves recognizing what is most important to your customers and aligning your offerings with those values (Payne & Holt, 2001). For micro launchers, this could mean understanding the importance of reliability, flexibility, convenience and price-effectiveness (refer subsection 4.2.4), and ensuring that these values are reflected in their products and services. Moreover, relationship marketing is not just about understanding customer values, but also about demonstrating them. This means telling customers about your values and showing them through your actions. For example, suppose flexibility is a key value for your customers. In that case, it should be a key focus in your product development process and something that you highlight in your marketing efforts and keep on that promise.

Therefore, as observed from the previous sections, conducting a comprehensive analysis of the micro launcher industry's business environment is essential. This involves examining the market's key elements, identifying the competition they face in this competitive sector, and understanding the needs and priorities of micro launch clients (refer chapter 4). Such an analysis will aid in accessing the challenges they face in this competitive industry and the competitive fit of their value proposition (refer chapter 7).

2.3. Understanding the Business Model Frameworks

Before delving into a detailed analysis of the industry and benchmarking competing launch strategies and the value proposition of micro launchers, it is beneficial to apply established frameworks to understand business models and the industry's competitive dynamics. To this end, Tugnoli et al. (2019a) adopted the Value Proposition Design (VPD) and Business Model Generation (BMG) frameworks developed by Osterwalder and Pigneur (2010) to analyse several factors, such as business models, the competitive environment, potential markets, and technological and regulatory trends, which should be closely examined to identify and assess the developing micro launcher based services.

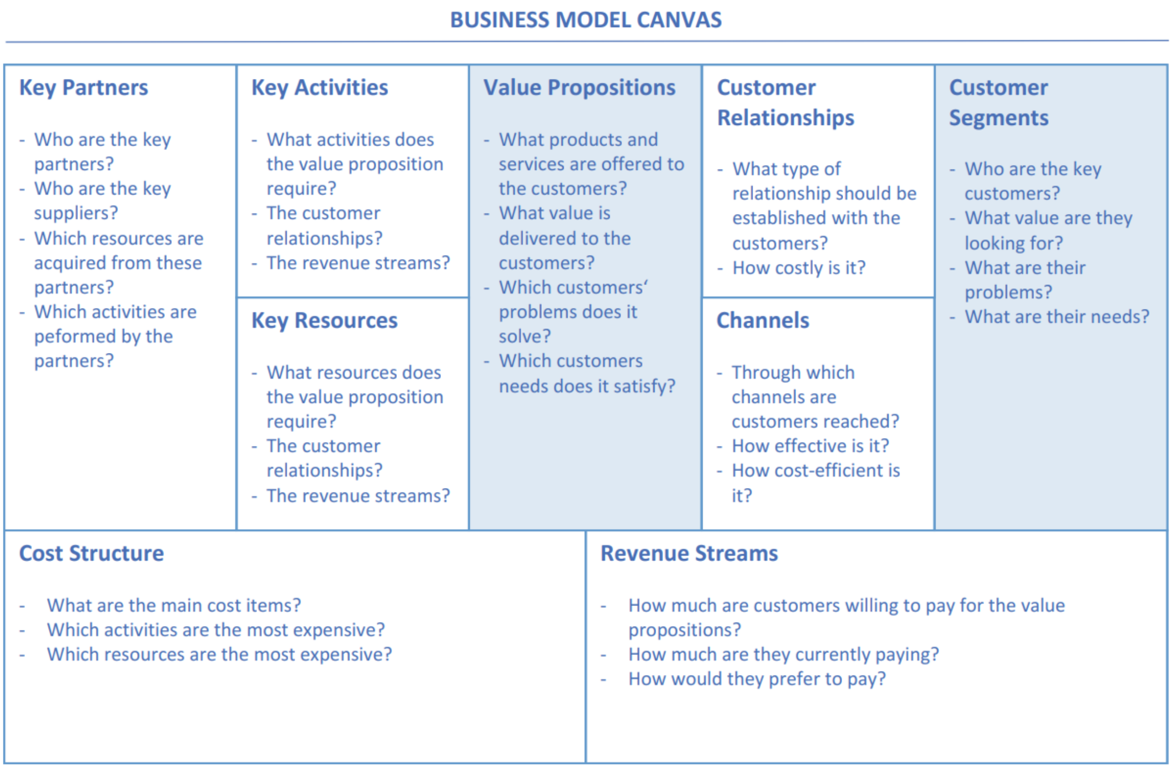

Figure 2.1: Business Model Canvas ("Strategyzer", 2024).

Within the scope of this research (refer chapter 1), the aim is not to develop a universal business model for micro launcher enterprises due to the variety of structures used by different firms and the challenge of obtaining the strategic corporate data necessary to create such a model, for example, Lao Rosell (2024) analyses Blue Origins New Glenn reusable launch vehicle in detail using the business model generation framework and analyses the business model components and value proposition in detail, represented by the Business Model Canvas, a much-used ontology and tool to describe a business model, as can be seen in figure 2.1. Instead, this analysis concentrated on two other aspects of the methodological framework: The Value Proposition and the analysis of the Business Environment, similar to the methodology adopted by Tugnoli et al. (2019a).

The Value Proposition, defined as the worth of the services and products a business offers its clients, is depicted in the value proposition canvas, as seen in figure 2.2. The Value Proposition Canvas is an ontology and tool that helps ensure the business's offerings align with the customer's needs and wants, leading to a product-market fit. The main components of Value Proposition Canvas are

- Customer (Segments) Profile, which helps identify each customer segment and their pains (the negative experiences, emotions and risks that the customer experiences in the process of getting the job done) and gains (the benefits which the customer expects and needs, what would delight customers and the things which may increase the likelihood of adopting a value proposition).
- Value (Proposition) Map shows how products and services create value for customers and relieve

their pains.

- Achieving fit between the value proposition and customer profile.

For this study, the analysis focuses on the description of the *Current Needs of Target Customer Segments*, allowing for an examination of whether or not micro launcher-based services provide a solution to these needs.

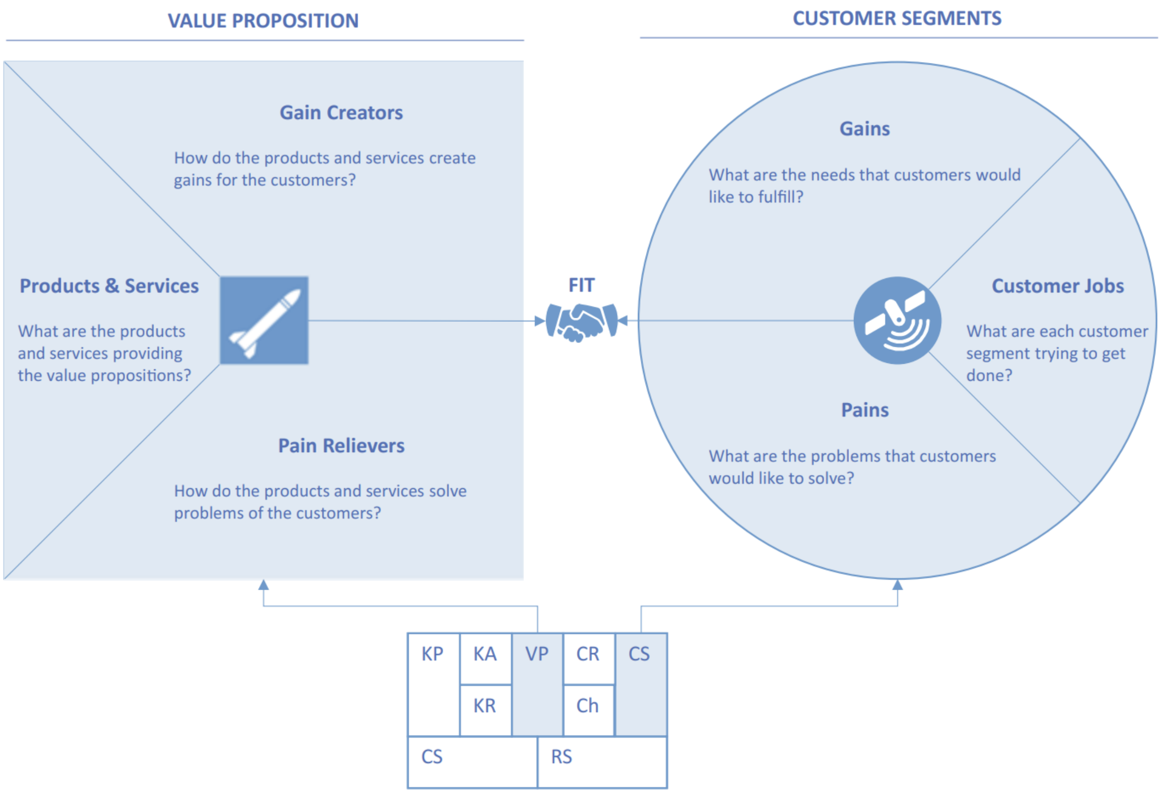

Figure 2.2: Value Proposition Canvas ("Strategyzer", 2024).

The Business Model Environment (as can be seen in figure 2.3) consists of four major components (the Market Forces, the Key Trends, the Industry Forces, and the Macroeconomic Forces):

- **Market Forces:** These include market issues, segments, needs and demands, switching costs, and revenue attractiveness. They are used to understand the customer landscape and the dynamics that affect the market.
- **Industry Forces:** This covers competitors (incumbents and new entrants), substitute products and services, stakeholders, and value chain actors. They help identify the key players and influences in the industry that impact the business model.
- **Key Trends:** These are technology, regulatory, societal, cultural, and socioeconomic trends. They are important for recognizing external changes that could influence the business model.
- **Macroeconomic Forces:** This includes global market conditions, capital markets, commodities and other resources, and economic infrastructure. They provide a macroeconomic perspective that can affect the business model.

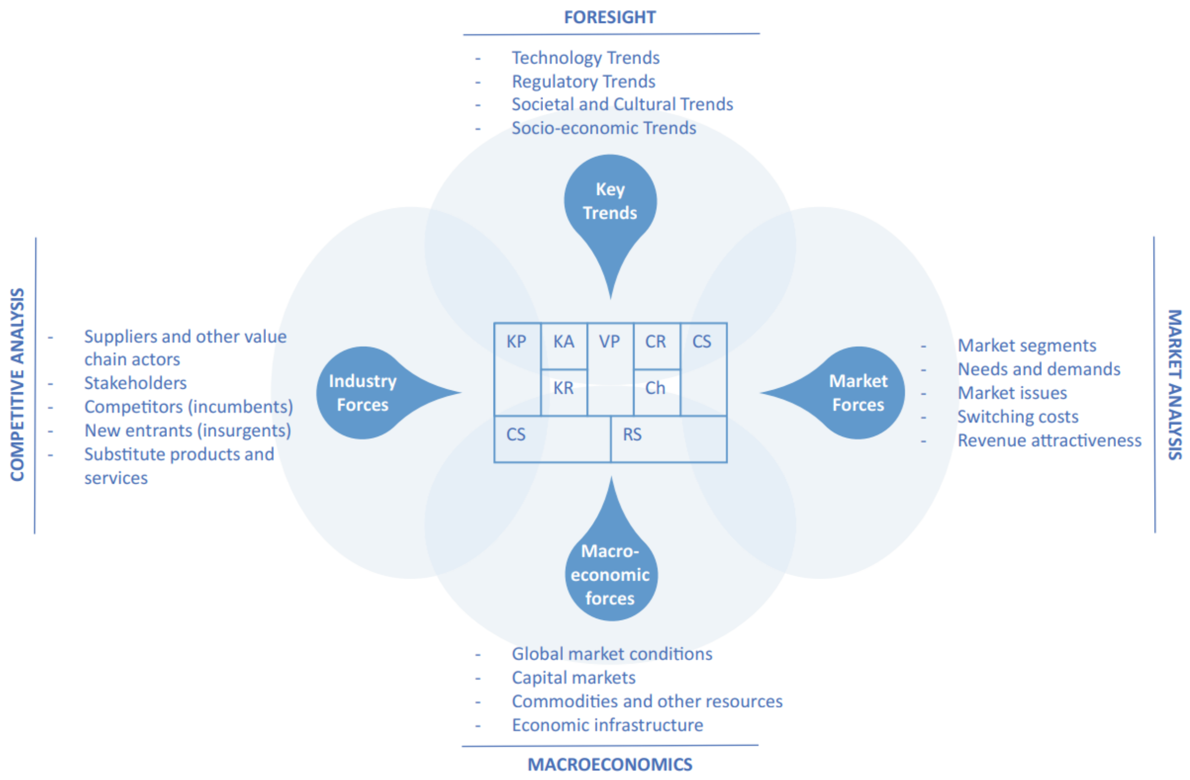

Figure 2.3: Business Model Environment ("Strategyzer", 2024).

In the frame of this study, the business environment analysis has focused on *Market Forces and Competitive Forces*. It is also used to access the potential market for micro launchers, broader macroeconomic conditions and technology and regulatory trends, wherever necessary.

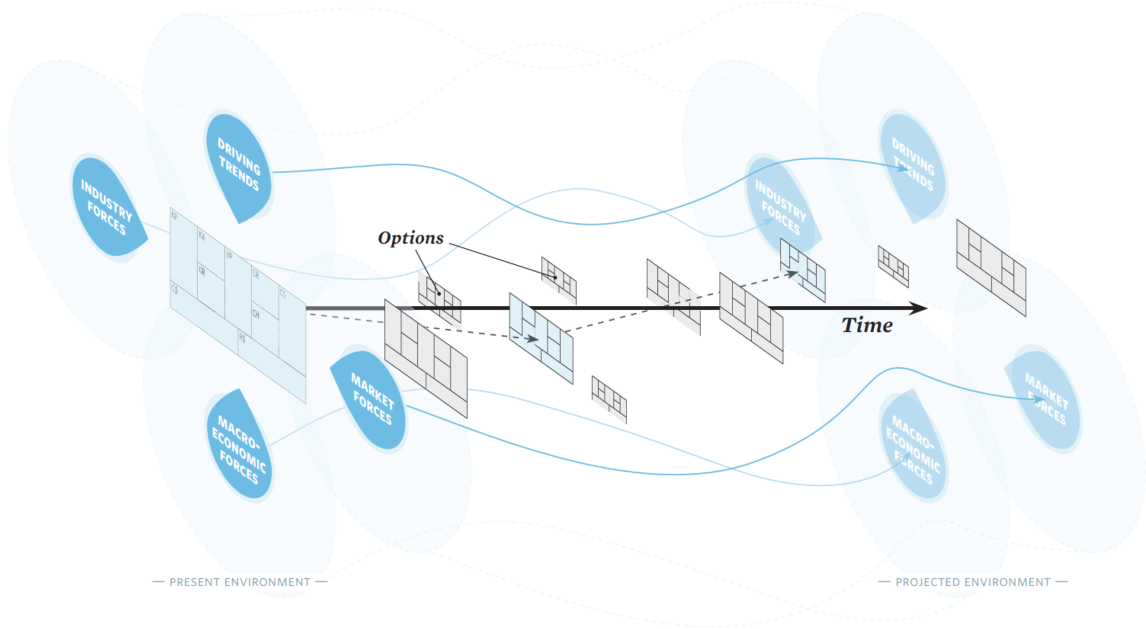

Figure 2.4: Changing Business Environment Through Time ("Strategyzer", 2024).

It is important to scan the business model environment regularly as it constantly changes, bringing new requirements for adapting and reinventing the businesses to maintain competitiveness in the industry (as seen in figure 2.4). This gives us one of the rationale for this study, since the Business Landscape of the Micro launch Industry has changed considerably since 2018, when Tugnoli et al. (2019a) conducted their survey on Business Perspective on Micro Launchers, it's important to scan the business environment in detail.

In conclusion, the Business Model Generation and Value Proposition Design frameworks are used for the following:

- Classify important investigation domains and help develop interview protocol combined with the literature review.
- Examine various internal and external elements of the micro launcher industry.
- Compile the research and analysis findings into a structured data and information set.
- Benchmark micro launchers with other solutions in the market and determine the competitive fit of their value proposition.
- Determine the primary challenges for micro launcher businesses based on the outcomes.

2.4. Summary

The literature review provides critical insights into the creation of market bubbles and the challenges new space startups face. In the Creation of Market Bubbles (section 2.1), it is highlighted that a combination of factors including liquidity abundance, herding behaviour, cognitive biases, and information asymmetry drives market bubbles. These elements lead to speculative investments and inflated asset prices. The review suggests that the Micro Launch Industry, with its unique characteristics, warrants a detailed investigation to understand these bubble dynamics better.

In the section on New Space Startups and their Challenges (section 2.2), significant challenges from an entrepreneurial perspective are identified, such as high entry barriers, complex regulatory and geopolitical landscapes, talent acquisition difficulties, the need for continuous innovation, and the importance of effective financial management. From a marketing perspective, building strong customer relationships and understanding customer values are pivotal for crafting compelling value propositions. The review stresses the need for startups to adopt sustainable business models and engage in value co-creation with customers and partners.

The application of Business Model Frameworks (section 2.3) provides a comprehensive method for analyzing the micro launcher industry's business environment. These frameworks help identify customer needs, understand market dynamics, assess competitive forces, and recognise key industry and macroeconomic trends. This structured analysis aids in developing robust business understanding and benchmarking micro launchers against market competitors.

In conclusion, the literature review emphasizes the complex interplay of factors leading to market bubbles, the multifaceted challenges new space startups face, and the utility of established business model frameworks in navigating the evolving micro launcher industry landscape.

3 Methodology

Science may be described as the art of systematic oversimplification.

Sir Karl Popper, FRS
Theorist and Philosopher

This chapter presents a detailed discussion of the research approach, philosophies, methodology, and strategy to answer the research questions. The approach was based on the Research Onion, developed by Saunders and Bristow (2023), represented in figure 3.1.

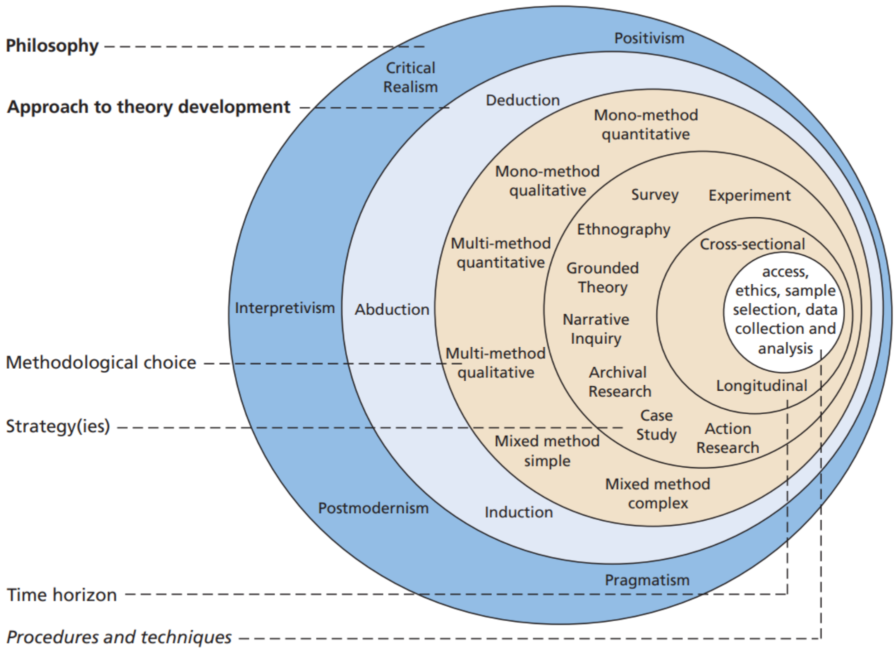

Figure 3.1: Research Onion (Saunders & Bristow, 2023).

3.1. Research Philosophy and Approach

This section of the thesis discusses the research philosophy and approach. These first two layers of the Research Onion reflect how researchers view the subject and the important assumptions they make along the way (Saunders & Bristow, 2023).

This thesis focused on the practical and real-world challenges of the micro launch industry and its implications for SmallSat manufacturers; therefore, it adopted a ***Pragmatic Approach***. Pragmatism prioritized practical outcomes and real-world applications, making it well-suited for understanding the dynamic and evolving micro launch sector. This philosophy allowed for methodological flexibility, enabling the integration of multiple qualitative data sources, namely literature, desk research, and semi-structured interviews. This approach allowed for flexibility in methodology and acknowledged the dynamic nature of the New Space industry.

For the research approach, data was gathered from literature, desk research, and semi-structured interviews to help understand the industry in detail and induce theoretical perspectives. For this purpose, an ***Inductive Approach*** was suitable.

3.2. Research Methodology and Strategy

This section provides a detailed overview of the research methodology and strategy to answer the research questions. Saunders and Bristow (2023) classified research into three kinds of studies to understand the purpose of the research and how research questions are framed: *Exploratory, Descriptive, and Explanatory studies*. This thesis aims to explore the current trends in the small satellite launch industry, determine drivers and challenges for the emerging micro launch sector, and its implications for small satellite manufacturers, involving a broader sense of the phenomenon. Hence, an ***Exploratory Study*** was adopted.

As for the research strategy, a ***Case Study*** was a suitable choice, as it allowed for understanding a case or phenomenon in-depth, and for the development of novel, testable, and empirically valid theory (Eisenhardt, 1989; Yin, 2009). It was apt for developing insight from literature and semi-structured interviews combined with further observation and analysis to form a theory. The context of this research was the broader environment or setting in which the phenomenon being studied was situated. In this case, the context was set in the broader SmallSat launch industry, focusing on the Micro Launch Sector. This included the industry's technological, economic, regulatory, and competitive environment.

The unit of analysis was the major entity analyzed in the study. It was the 'what' or 'who' being studied. In this research, the units of analysis were the views of experts on the SmallSat launch market, drivers and challenges faced by the micro launch companies, the value propositions of micro launchers, the impact of new entrants and trends on the market, and implications for SmallSat manufacturers. This detailed analysis formed a crucial part of the methodology of this research.

In addition to the above research strategy, Saunders and Bristow (2023) recommended defining the methodological choice. It referred to the investigator's selection between a mono data collection and analysis method and multiple methods. Due to the exploratory nature of the thesis and the aim to gather data from literature review (primary sources), desk research (secondary sources), and semi-structured interviews, a ***Qualitative Multi-Method Approach*** was the most suitable. This method involved using multiple data sources and corresponding analysis techniques to conduct the research and gain an in-depth understanding of phenomena (Easterby-Smith et al., 2021; Saunders and Bristow, 2023).

The fifth layer of the research onion was time horizons or the time dedicated to conducting an investigation. It was classified into cross-sectional and longitudinal (refer figure 3.1). Cross-sectional studies involved studying a particular phenomenon (or phenomena) at a specific point in time, whereas a longitudinal study was applied when an investigator needed to study change and development by collecting data over a long period (Saunders & Bristow, 2023).

Since the current research focused on understanding the SmallSat launch industry, drivers and challenges for micro launch companies, and the implications for SmallSat manufacturers, the research had the required time constraints and was for academic purposes. Therefore, a ***Cross-sectional*** study was the best option.

3.3. Data Collection

Due to the exploratory nature of the research questions, this research took a qualitative approach. Historically, little research has been done on micro launchers and their value proposition, and even less on their implications for SmallSat manufacturers. Therefore, the data was collected through multiple methods, including literature review, desk research, and semi-structured interviews.

3.3.1. Literature Review

The literature review aimed to provide an academic understanding of the problem and its related theories (refer chapter 2). This procedure assisted in streamlining the material and offering a foundation for comprehending important ideas, which, coupled with desk research, supplied interviewees with questions to address the sub-research questions. Regarding information sources, the main focus was looking through articles, books, thesis reports, and other materials from places like Google Scholar, conference proceedings, university repositories, ProQuest, and SCOPUS searches. Terms such as "New Space", "New Space Business Models", "Smallsat ecosystem", "Micro Launch Vehicles and Value Proposition", "Astropreneur", "New Space Startups", "Value and Value Proposition", "Challenges and Micro Launch Startups" and so on were primarily used.

3.3.2. Desk Research

Desk research involved the collection and analysis of existing information from various sources such as professional journals (e.g., Harvard Business Review), company reports (e.g., BryceTech Reports), and online databases (e.g., NewSpaceIndex). This report used this method in association with the data gathered through literature review and semi-structured interviews to develop an academic understanding of the micro launch industry, its challenges, trends, and implications for SmallSat manufacturers. It provided a basis for understanding the business environment of the micro launch industry (refer chapter 4), which included insights into industry trends, competitive forces, and customer expectations. This review was also crucial for benchmarking the value proposition of micro launchers against competitive solutions in the market and aiding in developing the interview protocol.

3.3.3. Semi-Structured Interviews

Semi-structured interview was another primary method of data collection. They provided two main benefits: they asked important (broad) questions and guaranteed comparability across the various interviews by focusing on the factors outlined in the interview protocol developed in the literature review. In addition, they permitted pertinent detours from the primary line of inquiry (Grossoehme, 2014). The semi-structured interview participants were contacted, and the interviews were arranged largely by guidelines set up by (Adams, 2015), detailed in the following paragraphs.

Human Research Ethics Committee (HREC) Approval

Ensuring compliance with ethical standards, the research study received approval from the Human Research Ethics Committee (HREC) at TU Delft[1]. The ethical approval process involved a thorough review of the research proposal to ensure that the participants' rights, privacy, and well-being were safeguarded. This review process included evaluating the research design, the recruitment strategies, and the consent procedures.

Participants were provided with an informed consent form, detailing the purpose of the research, the nature of their involvement, and their rights as participants, including the right to withdraw from the study at any time without penalty. The consent form also outlined how confidentiality and anonymity would be maintained, and how the data would be used, stored, and eventually disposed of in compliance with HREC guidelines.

The data collection methods, including the semi-structured interviews, were designed to minimize potential harm or discomfort to the participants. Both online and in-person interviews adhered to the ethical principles set forth by the HREC, ensuring a consistent and respectful approach throughout the data collection process. Additionally, the participants were debriefed post-interview to address any concerns or questions they might have had, further ensuring their well-being and comfort.

The HREC approval underscored the commitment to ethical research practices, providing a framework for conducting the research. This ethical oversight not only enhanced the credibility of the research but also ensured that the study upheld the highest standards of academic integrity and respect for participant autonomy.

[1] Refer TU Delft HREC website for additional information.

Interview Set-up and Protocol

Due to the nature of the research topic and limitations imposed by time and geographical constraints of the study, purposive sampling was adopted. Purposive sampling was a non-random sampling technique in which the researcher chose participants based on predetermined standards, like their experience level or expertise in the field (Campbell et al., 2020). The research project participants were directly linked to the aerospace, micro-launch, and small satellite manufacturing industries. They were contacted via email and informed about the informed consent form, approved by the Human Research Ethics Committee (HREC) TU Delft by their guidelines.

The interviews were conducted under uniform conditions wherever feasible, either online or in person, based on the interviewees' preferences. Online interviews utilized Microsoft Teams, the official platform supported by TU Delft, while in-person interviews took place in Delft, Netherlands, at locations convenient for the participants. Seven targeted interviews were conducted with aerospace industry experts, encompassing experts on new space literature and launch vehicles, industry analysts, small satellite manufacturing executives, launch strategy development experts, and launch vehicle startup executives. These experts hailed from four countries across three continents, as shown in table 3.1, five out of seven experts were based in Europe, with all participants from the Western Hemisphere. Consequently, the findings were particularly relevant to the Western context, especially Europe. This limitation was acknowledged in section 7.3 and section 7.5.

Interview Number	Position	Country
Expert 1	Founder Satellite Start-up & Industry Expert	Estonia
Expert 2	Professor & Advisor in Ministry of Defence	Brazil
Expert 3	Management Professional and Satellite Systems Engineer	South Africa
Expert 4	Co-founder & Executive Small Satellite Manufacturing Firm	Netherlands
Expert 5	Experienced Launch Program Strategist	Netherlands
Expert 6	Co-founder & Executive Micro Launch Firm 1	Netherlands
Expert 7	Executive Micro Launch Firm 2	UK

Table 3.1: List of Expert Interviews.

The interviews lasted an average of one hour, which was considered appropriate to prevent interviewee and interviewer fatigue (Adams, 2015). Certain conditions could be altered at the interviewee's request, and some interviews had shorter durations than others. The primary language spoken by each interviewee was English. A neutral stance and tone were maintained throughout to avoid interjecting the interviewer's personal opinions. Opinions were only shared in response to the interviewee's request, clearly stating that they were the interviewer's personal opinions, solely to move the discussion forward and maintain decorum.

Furthermore, appendix A contains the required interview protocol used to guide the interviews. Due to the semi-structured nature of the interviews, interviewees were allowed to introduce new themes if they thought it was necessary. Also, section 5.2 contains anonymized summaries of the interviews and the main thesis body includes anonymized quotations. All other interview data, including audio recordings, personally identifiable information, and transcripts, were deleted after the end of the research period by HREC guidelines.

3.3.4. Justification for Data Collection Methods per Research Question

Each sub-research question was addressed using a combination of the data collection methods, ensuring a robust and comprehensive analysis, as can be seen in table 3.2:

Sub-Research Question	Data Collection Method	Justification
1. What are the main factors behind the micro launch industry's market bubble?	Literature Review, Desk Research, Semi-Structured Interviews.	The literature review and desk research provided historical context and theoretical perspectives on market bubbles. Semi-structured interviews offered contemporary insights from industry experts, helping to identify specific factors relevant to the micro launch industry.
2. What are the key drivers and challenges in the micro launch industry?	Literature Review, Desk Research, Semi-Structured Interviews.	Literature review and desk research identified general trends and theoretical frameworks. Interviews with industry experts provided detailed, real-world examples and insights on the drivers and challenges in the micro launch companies.
3. How does the value proposition for micro launchers benchmark against competitive solutions amid the current trends in the industry?	Literature Review, Desk Research, Semi-Structured Interviews.	Literature review establishes the importance of developing a unique value proposition and desk research helped establish benchmarks and comparative metrics. Semi-structured interviews allowed for the collection of specific insights on competitive solutions and how micro launchers differentiate themselves.
4. How do current trends affect SmallSat manufacturers' investment decisions in R&D for mass optimization of their products (e.g., CubeSat dispensers)?	Desk Research, Semi-Structured Interviews.	Desk research provided background information on market trends and available launch solutions. Semi-structured interviews offered nuanced perspectives from experts for SmallSat manufacturers, highlighting the impact of market trends on their decisions.

Table 3.2: Research Questions, Data Collection Methods, and Justifications

3.4. Data Analysis

The data analysis process began with the transcription of interviews conducted with subject matter experts from the aerospace industry. These interviews were either conducted online via Microsoft Teams or in person, depending on the preference of the interviewees. Once transcribed using TU Delft-supported software like MS Office and Atlas.ti, the transcripts were meticulously cleaned to ensure accuracy. This step was crucial as it allowed for a smoother thematic analysis, which involved identifying and organizing significant themes that aligned with the research objectives. These themes provided a framework for further categorizing the data into more specific sub-themes derived from the literature review, aiding in a nuanced understanding of each theme in greater detail.

The thematic analysis employed an iterative coding process, starting with open coding where the data was broken down into discrete parts and labelled with initial codes to capture key ideas and concepts (Fereday & Muir-Cochrane, 2006). This process involved reading and re-reading the transcripts to identify patterns and similarities. The initial codes were then organized into sub-themes through axial coding, which helped establish connections between the codes, forming a more cohesive understanding of the data. For instance, challenges in the micro-launch industry were categorized under sub-themes like developing a sustainable business model, geopolitical factors, regulatory challenges, technological hurdles, and talent acquisition. This structured approach facilitated a detailed analysis of the qualitative data, ensuring that all relevant factors were considered.

The final stage of the coding process, selective coding, involved integrating and refining the themes and sub-themes to develop a central narrative addressing the research questions. This phase included synthesizing the coded data to provide a coherent narrative in the results section, which was supported by direct quotations from the interviews to add depth and credibility to the analysis. This methodical approach ensured that the findings were well-supported by the data and aligned with existing research and theories, providing a comprehensive and contextualized understanding of the micro-launch industry. The iterative nature of the analysis allowed for continuous refinement of codes and themes, accommodating new insights and emerging patterns throughout the process. Section 5.1 provides further details of this process.

3.4.1. Capabilities of Atlas.ti

Atlas.ti is a powerful qualitative data analysis software that facilitates the systematic examination of large volumes of text, audio, and visual data. In this report, Atlas.ti was utilized for its robust capabilities in coding, organizing, and analyzing the data collected from semi-structured interviews and other sources. One of the key features of Atlas.ti is its support for *groundedness analysis*, which helps in assessing the frequency and distribution of codes and themes within the data. This feature was particularly useful in this study for evaluating the representativeness of expert opinions. *Groundedness analysis* involves quantifying how often specific themes and concepts appear across different interviews, thereby providing a measure of how representative these themes are of the overall dataset (refer chapter 6). By using Atlas.ti, the researcher was able to systematically identify and organize significant themes, enhance the rigour of the data analysis, and ensure that the findings were well-supported by the empirical evidence gathered from the experts.

3.5. Validity Considerations

Finally, it is pertinent to discuss the limitations associated with the chosen methodology for this research. Qualitative case study research, while rich in contextual detail, has been criticized for several weaknesses, particularly regarding construct, internal, and external validity. Eisenhardt (1989) notes that qualitative case studies often struggle with generalizability due to their small sample sizes, thereby limiting external validity. This issue is compounded by the subjective nature of data interpretation, which can introduce researcher bias and affect internal validity. Yin (2009) highlights the challenge of maintaining rigorous methodological standards to ensure the reliability and replicability of findings, crucial for construct validity. Furthermore, the integration of rival explanations is essential to bolster the credibility of case studies, addressing internal validity concerns. The complex and voluminous data typical of qualitative research necessitates systematic approaches to avoid biases and ensure comprehensive analysis, thereby enhancing construct validity. Overall, addressing these weaknesses through methodological rigour and careful design can improve the validity and robustness of qualitative case study research.

In this qualitative case study, various strategies were employed to address construct, internal, and external validity, ensuring the research's rigour and trustworthiness. Table 3.3 below summarizes the key strategies used to enhance each type of validity and the relevant sections of the study where these strategies are detailed.

Type of Validity	Strategies Deployed	Sections
Construct Validity	Utilise established theoretical frameworks (e.g., Business Model Generation, Value Proposition Design).	chapter 2
	Aligned research questions and interview protocols with literature and extensive desk research.	section 3.3
Internal Validity	Performed groundedness analysis to show the representativeness of the data.	section 3.4
	Employed methodological triangulation to cross-verify data.	section 3.3
	Conducted iterative data analysis (open, axial, selective coding).	chapter 5
External Validity	Provided detailed contextual descriptions of the micro-launch industry and its business environment.	chapter 1, chapter 4
	Used semi-structured interviews with experts from different countries to reflect broader industry trends.	section 3.3
	Ensured transparency in the research process for transferability.	chapter 3
	acknowledged study limitations and boundaries.	section 7.5

Table 3.3: Key Strategies to Enhance Validity

3.6. Summary

This chapter provides a comprehensive overview of the research methodology used to address the research questions concerning the micro launch sector within the broader SmallSat launch industry. The approach was based on the Research Onion model by Saunders and Bristow (2023), guiding the selection of research philosophies, methodologies, and strategies.

In the Research Philosophy and Approach (refer section 3.1), the research adopted a Pragmatic Approach, emphasizing practical outcomes and real-world applications, suitable for the dynamic micro launch sector. An Inductive Approach was used, allowing theory development based on data gathered from literature, desk research, and semi-structured interviews.

The Research Methodology and Strategy (refer section 3.2), detailed the choice of an Exploratory Study to investigate current trends, drivers, and challenges in the small satellite launch industry. The Case Study strategy was employed to gain in-depth insights into the micro launch sector, leveraging literature and interviews for theory development. The Qualitative Multi-Method Approach integrated data from various sources, ensuring a thorough analysis. This section also discussed the time horizon, justifying the selection of a Cross-sectional study due to time constraints and the academic nature of the research, focusing on understanding the industry at a specific point in time.

The Data Collection (refer section 3.3), outlined the methods used: a Literature Review to provide academic context and streamline interview questions; Desk Research to gather information from professional journals, company reports, and online databases; and Semi-Structured Interviews conducted with industry experts to obtain contemporary insights.

The Data Analysis (refer section 3.4), described the thematic analysis process, using open, axial, and selective coding to organize and interpret interview transcripts. This process, supported by Atlas.ti software, involved groundedness analysis to assess the frequency and representativeness of themes across experts, ensuring a comprehensive understanding of the micro-launch industry's challenges and trends.

The Validity Considerations (refer section 3.5), addressed the potential weaknesses of qualitative case study research, particularly regarding construct, internal, and external validity. Strategies to enhance validity included using established theoretical frameworks, methodological triangulation, and detailed contextual descriptions. These efforts ensured the research's rigour and trustworthiness, making the findings relevant and applicable, especially within the Western context, as noted in the sections on implications and limitations.

Overall, the chapter detailed the methodical approach taken to explore the micro-launch industry, highlighting the rationale behind the chosen methodologies and their application in addressing the research objectives.

4 Case Environment

Your most unhappy customers are your greatest source of learning.

Bill Gates
Founder, Microsoft

Chapter 4 provides a comprehensive understanding of the micro launch industry's business environment, primarily through an extensive desk research study that offers a detailed examination of the small satellite launch market as a whole, as well as its segmentation according to customer typology, mission, and expectations (refer section 4.2). This chapter also includes a competitive analysis of current and future small satellite launch strategies. The foundation of customer expectations for smallsat launch strategies is laid by these analyses, which also enable the identification of the strengths and weaknesses of micro launcher companies, the obstacles they face in this cutthroat market, and, ultimately, the competitive fit of their value proposition (refer chapter 6).

4.1. Classification of Launch Vehicles

Building on the BMG and VPD frameworks (refer chapter 2), for this thesis, it is important to classify the types of launch vehicles present, to concur the boundary conditions of the research. Throughout the years, this classification has evolved, NASA (2010) classified Launch vehicles in four categories Small, Medium, Heavy and Super Heavy, while the FAA classification of small launcher class was (≤2268 kg), but since the classification is old, it does not include any specific differentiation for the dedicated class of launchers that launch small payloads micro launchers (Botelho & Xavier, 2019). This class was included by Wekerle et al. (2017) in their survey publication but then they missed the Super-heavy classification.

Launch Vehicles are classification for the purpose of this report is according to table 4.1, and have elements adopted from Motta et al. (2024) and Villas Boas et al. (2023):

Launch Vehicle (LV)	Payload in LEO (kg)	Typical LVs	Cost per kilogram (U$/kg)
Micro-LV	≤500	Electron, Kuaizhou-1A, Pegasus XL	23,100
Small-LV	501–2000	Vega, ISAR Spectrum, RFA One	20,000
Medium-LV	2001–20,000	Atlas V (Retired), Falcon 9, Antares 230+, PSLV, LVM-3, Soyuz	2,600
Heavy-LV	20,001–50,000	Operational: Long March 5, Proton-M, H2, Long March 5B	7,900
		In development: New Glenn, Ariane 6, Vulcan Centaur, H3	
Super Heavy-LV	>50,000	Operational: SpaceX Falcon Heavy	1,500
		In development: SpaceX Starship	100-1,000

Table 4.1: Classification of Launch Vehicles

4.2. Small Satellite Market and Segmentation

To understand the customer values and value proposition, it is important to segment and characterise small satellites market, mission and customer typologies, and customer expectations. It is also important to analyse the competitive solution for dedicated micro launchers since the value proposition of micro launchers will be benchmarked against them. However, first, the classification of small satellites is required to understand the boundary conditions further.

4.2.1. Classification of Small Satellites

The SmallSat revolution saw the increased use of smaller and lighter satellites as the technological advancements could perform the same functions in a smaller form factor. Botelho and Xavier (2019) Present a review of how the classification has evolved through the years and present the 5 classes of classifications of small satellites (Mini, Micro, Nanosatellites can further be classified into Pico (0.1 – 1) kg and Femto (≤ 0.1 kg)). For this report the following classification is adopted represented in table 4.2.

Classification of small satellites (mass under 500 kg)	
Minisatellite	100–500 kg
Microsatellite	10–100 kg
Nanosatellite	Less than 10 kg

Table 4.2: Classifiaction of Small Satellites

This can be further classified based on form-factor into CubeSats, a class of Micro and Nanosatellites, uses standard form factor and sizes of "one unit" or 1U, where 1U refers 10cm x 10 cm x 10 cm (Heidt et al., 2000; Kulu, 2018) discusses the different dimension classification of CubeSats as adopted form CubeSat Design Specification (CSD):

- 1U CubeSat is 10 cm × 10 cm × 11.35 cm.
- 2U CubeSat is 10 cm × 10 cm × 22.70 cm.
- 6U CubeSat is 20 cm × 10 cm × 34.05 cm.
- 12U CubeSat is 20 cm × 20 cm × 34.05 cm.
- The Smallest existing CubeSat design is 0.25U and the largest is 27U

4.2.2. Mission Typologies

Furthermore, the classification can be extended into mission typologies, Missions can be classified into constellation deployment and single mission based on application ("Prospects for the Small Satellite Market, 9th edition", 2023):

Large Constellations

These can be classify as Remote Sensing and Communication and are further described in the following:

1. **Earth Observation:** Satellites used for electro-optical and radar observations of the Earth and meteorology for operational and scientific purposes. It also includes GPS radio occultation (GNSS-RO). Large constellations of satellites are frequently used for comprehensive Earth observation and meteorology (Robert et al., 2020).
2. **Information:** SmallSat providing narrowband communications services (IoT & M2M) and data collection from ground, aerial and atmospheric sensors often form large constellations for global coverage.
3. **Satcom and telecommunication:** Satcom satellite systems funded by civil or defence government and private companies agencies for broadband and MSS communications services including internet, broadcasting (Henri, 2020; Laverty et al., 2019). Satcom satellite systems, especially those providing broadband services, are typically deployed as large constellations.

Single Missions

They can be bunched into five major categories:

- **Science & Exploration:** These missions, such as those for astrophysics, astronomy, and planetary science, are often single missions due to their specific and unique objectives (Martinez, 2020).
- **Security:** Satellites for space surveillance and tracking, missile early warning, near-Earth object monitoring, electrical intelligence (ELINT), and space weather. While some security applications may use constellations for comprehensive coverage, others like missile early warning or near-Earth object monitoring could be single missions (Hitchens, 2019)
- **Space Logistics:** Tasks like In-Orbit Servicing (IOS), Debris Removal, and In-Orbit Manufacturing (IOM) are typically single missions due to their specific targets and objectives (Kulu, 2023a).
- **R&D and Technology:** Technology development satellites are often single missions designed to test new technologies or platform/payload components.
- **Replenishment:** Satellite replenishment at the end of life, the way small sat operators conduct replenishment missions also depends on the class of constellations, for example, a 3U or 6U CubeSat constellations would be replenished differently than SpaceX and OneWebs 150-200kg spacecraft (Cappaert, 2020).

This is a general classification of missions based on seven primary satellite applications and types of missions launched. However, specific missions may vary based on the objectives and resources of the space agency or company. This classification is important because different mission types require or prefer different launch solutions. Large constellations are economically restricted to maintain a low launch price per satellite; otherwise, their finances may not prove commercially viable (Hertzfeld and Pelton, 2020; Motta et al., 2024). On the other hand, security missions, mostly operated by the military, have strict orbital constraints and high financial capabilities. Therefore, it is important to classify mission typologies and track their developments.

4.2.3. Customer typologies

To understand the Smallsat market better it is important to identify the types of customers that use or operate small satellites and in-turn become end-consumers for the launch industry as each customer segment has different values and preferences. The customer typologies can be classified into four major categories (“BryceTech - Reports”, 2024; “Prospects for the Small Satellite Market, 9th edition”, 2023) :

- **Commercial:** Over the years, Commercial players have launched smallsats on various mission mentioned, starting from Earth observation to telecommunications satellites, where large constellations of small satellite constellation by SpaceX and OneWeb dominate, but also Science and Technology demonstrator missions. Recently there has been a huge input of cash into in-space manufacturing, with a successful experiment by a UK-based start-up in 2023 there is potential in the idea (Clark, 2023). Indeed, the commercial sector has dominated over the years and will be the driving force in the market.
- **Civil government:** The civilian government organizations have been launching smallsats for various purposes ranging from large constellations of earth observation and meteorology missions to single missions for science and exploration missions (Blackwell et al., 2018).
- **Defense:** In recent years, the defence sector has recognised the importance of smallsats. The most space-faring nations like the U.S. have observed that launching hundreds of smaller satellites more frequently is better than purchasing large and expensive satellites in longer time intervals, risking reliance on just a few satellites (Werner, 2024).
- **Academic:** The academic customer segments are comprised of research and education institutes such as universities and amateur projects. It can also be considered a subset of the Civil government customer segment since a lot of the university projects are primarily government-funded, but this differentiation is required as it helps highlight a key requirement of this customer segment is Low Prices and most satellite launchers by this segments fall in the small-micro satellite range, among which the CubeSat form-factor is the most used (Serra et al., 2013).

4.2.4. Customer Expectations

An important part of market segmentation and identifying market forces and their implications is the in-depth characterization of customer expectations. This analysis provides insight into what attributes or factors are important when a customer selects a launch solution. This provides perspective from the demand side of the industry and helps understand if micro launchers can fulfil the customers' needs. Identifying these factors or attributes will aid in benchmarking different launch solutions based on the following characteristic expectations. These characteristics are important for launch providers and SmallSat manufacturers as they are part of the same value chain and serve the same end consumer.

In literature, the customer expectations and valuable attributes of micro launchers are characterized in various ways throughout the years. Naumann (1995) classified the expectations into the following categories Launch price, Launcher reliability, Credibility of the project, Orbit injection accuracy, Vibrational environment, and Launch campaign services. Later, Serra et al. (2013) classified the valuable attributes that customers look for in a launcher into Functionality, Reliability, Convenience, Price. Tugnoli et al. (2019a) characterised the expectations of customers in four main categories Slot Availability, Schedule Reliability, Price-effectiveness, and Flexibility. Furthermore, Falduto and Peeters (2023) conducted an extensive expert survey and identified and ranked the following parameters Orbit selection, Launch price, Reliability of the launcher, Timing of the launcher and Location of the launchpad.

For this report, the main factors for bench-marking include:

- **Flexibility:** Different mission types have different orbital requirements and the ability of the launch service provider to accommodate these mission requirements regarding orbital parameters (payload capacity, orbit altitude and orbit inclination) is defined as Flexibility.
- **Price-effectiveness:** Price is an important consideration while launching a smallsat as it forms a significant portion of the costs. Price-effectiveness represents the value for money a customer receives while adopting a Launch approach.
- **Convenience:** This attribute refers to the availability of the launch vehicle to launch readily in short lead times (responsiveness). High responsiveness is valuable for a launch vehicle company (Foust, 2024a).
- **Reliability:** The reliability of a launch vehicle is a critical factor that significantly influences the overall risk of satellite and spacecraft missions. It refers to the probability that the launch vehicle will perform its intended function under specified conditions for a designated period without failure. This includes a variety of factors, including calculation of the risk of manifest delays due to the domino effect after a failure (Guarro, 2013).

The satellite launch process is complex and necessitates a more detailed strategy for each case, so the above criteria serve as a broad guide for assessing the alignment between a launch service provider's offerings and the customer's requirements.

4.3. Competitive Analysis of Launch Strategies

Competitive analysis of launch strategies is conducted to benchmark launch strategies against each other. Each Section starts with the definition of launch strategy, historical significance (if any), advantages and disadvantages and future outlook.

4.3.1. Piggyback

A piggyback launch in the context of space transportation refers to a method where a smaller satellite or spacecraft (secondary payload) is launched into space aboard the same launch vehicle as a larger primary payload. This approach allows the smaller satellite to "hitch a ride" with the primary payload, which can be more cost-effective and efficient than arranging a separate launch.

The history of piggyback launches can be traced back to decommissioned military ballistic missiles ("Riding Piggyback on an ICBM", 2015). Many CubeSats were initially launched on decommissioned Russian rockets through companies like Eurockot and Kosmotras. Kosmotras was founded in 1997 to use the Ukrainian Dnepr rocket launch systems, based on the SS-18 ICBM rocket that was no longer in military service due to international missile treaties. This vehicle was a commercial satellite launch vehicle for many years and at a meager cost ("International Space Company Kosmotras - space-companies.com", 2022). A prime example of the success of the Piggyback launch is India's PSLV. With its First Successful launch in 1994 on its PSLV-D1 mission, PSLV-C2 became the first Indian Launch Vehicle to place 3 spacecraft with IRS-P4(OCEANSAT) Weight 1050 kg, KITSAT-3 and DLR-TUBSAT weight 107 kg and 45 kg respectively in orbit (ISRO, 1999). In 2017, PSLV launched record 104 satellites, consisting of 103 nanosatellites as secondary payloads (Dalmia, 2017).

However, there are four main drawbacks of piggyback launching as identified in the studies by (Peeters et al., 2020; Falduto and Peeters, 2023)

- **Scheduling Issues:** In piggyback launches, the main payload sets the timetable. This means that operators of smaller payloads must modify their schedules and launch windows to match the primary one.
- **Orbit Adjustments:** The launch's orbital path is planned around the main payload. This requires secondary payloads to alter their orbits based on the primary payload, which might necessitate additional manoeuvres and extra fuel.
- **Launch Delays:** If the main payload's delivery schedule is delayed, secondary payloads hitching a ride will also be affected.
- **Risk of Contamination:** There's a chance of resource contamination during a traditional piggyback launch. The secondary payload must adhere to the precautions set by the primary payload to prevent interference and contamination.

As larger rockets get cheaper, the piggyback costs decrease. As more all types of launchers enter operational status, the competition and the number of opportunities for piggyback will also increase. Many larger and reusable small launchers are aiming for weekly launches. This development shows the growing importance and potential of piggyback launches in the future of space exploration.

4.3.2. Dedicated Rideshare

Rideshare launching is a strategy where multiple payloads, owned by one or more customers, share a single launch vehicle to a mutually agreeable orbit. This approach is becoming increasingly relevant for companies entering the small satellite (smallsat) large constellation segment, where timing is crucial for delivering services and generating revenue (Madry, 2020).

Historically, rideshare launches have been used to deploy satellite constellations, where multiple satellites of similar form or specification require transportation to the same orbit for deployment. For instance, SpaceX launched its first dedicated rideshare mission called Transporter-1 with 143 satellites deployed on a single launch in January 2021. This broke the previous record of 104 set by PSLV in February 2017 (Foust, 2024b).

The most evident advantage of rideshare launching is the greater flexibility in selecting the orbit parameters and schedule offered compared to a piggyback solution. Multiple customers can agree on the orbital parameters of a certain launch. However, due to the multiple-manifestation of payloads, the launch date is subject to the proposed development schedule of all the payloads. It can be affected by delays from multiple sources. The satellite operators will also determine the destination orbit, likely resulting in a non-optimal inclination and altitude for all the payloads (Serra et al., 2013).

As launch vehicles develop ever more refined capabilities to launch multiple small through dedicated adapters and dispensers, rideshare launching will constitute an important new strategy for orbital smallsat delivery. Companies such as Northrop Grumman, Spaceflight, D-Orbit, and Momentus propose orbital transfer vehicle services to smallsat operators to launch their products into custom orbital trajectories. This indicates a promising future for rideshare launching as it continues to evolve and adapt to the needs of the growing smallsat market (Villas Boas et al., 2023).

4.3.3. Orbital Transfer Vehicles

An Orbital Transfer Vehicle (OTV), a space tug, is a spacecraft equipped with propulsion, avionics, an energy supply system, and SmallSat deployers. After being placed on a given orbit, an OTV moves around and distributes the SmallSats that it carries on their orbits (Yost & Weston, 2024).

The OTV is a recently introduced solution, with many proposed systems but few with any historical flight heritage. The first Firefly Elytra mission will launch a National Reconnaissance Office (NRO) mission aboard the Firefly Alpha LV. The first LEO Chimera system was launched in January of 2023 aboard a SpaceX Transporter and is currently operational. The D-Orbit ION system is one of the most used OTV platforms. The system was first used in 2020 to deploy Planet Labs constellation satellites (Villas Boas et al., 2023; Yost and Weston, 2024).

Orbital Transfer Vehicles (OTVs) offer significant advantages such as flexibility, allowing secondary spacecraft to manoeuvre much closer to their desired orbits. An OTV can place different SmallSats at different altitudes. Besides altitude, OTV systems can change the orbital inclination and perform orbital phasing of SmallSats' constellations, decreasing the beginning of their commercial operational time significantly (Villas Boas et al., 2023). They are generally more propulsion-capable, but OTVs may also offer hosted systems more in terms of power, pointing, and communications. This emerging technology provides a significant capability to reach destinations not previously achievable with systems of this scale. However, there are also drawbacks to consider. The development, build, and launch costs of OTVs will be added to the satellite costs, which can be high. Space tugs, a relatively new competition to micro launch vehicles, have been enabled by decreasing the costs of rideshare missions. But there isn't much room in the industry for many dedicated space tug providers, thus consolidation can be expected (Kulu, 2021). Despite these challenges, developing in-space transportation services, to move satellites dropped off on rideshare missions to desired orbits, negates some of the advantages of micro launchers. As technologies evolve, the satellite's final orbital insertion is no longer dependent only on the LV. This makes OTVs a promising solution for future space missions (Motta et al., 2024).

4.3.4. On-Board Propulsion

On-board propulsion refers to the autonomous displacement of satellites, meaning satellites which contain their personal propulsion system. It is any method used to accelerate spacecraft and artificial satellites. All space systems require onboard propulsion for various functions, including station-keeping and drag makeup, apogee motors, and delivery and return (Yost & Weston, 2024).

Most operational constellation spacecraft prefer on-board propulsion for collision avoidance, station-keeping, and de-orbiting. This is evident in the operations of Starlink [1] and OneWeb satellites [2], which have been increasing their orbit altitudes after deployment from the rocket using electric propulsion. Kineis, for instance, booked Rocket Lab's Electron to deploy 25 IoT satellites across five dedicated missions. The Kick Stage of the ELectron LV acted as an OTV to deliver each satellite to precise orbital planes at a 650km altitude, allowing Kineis to avoid sacrificing spacecraft mass for propulsion and to begin operational service as quickly as possible. In general, they are paying about $ 1M per spacecraft in launch costs, and on-board propulsion modules can be much less (Kulu, 2021).

On-board propulsion offers several advantages such as lower cost, rapid concept development-to-launch process, greater flexibility in mission concept design (such as constellations for greater coverage), and the capability to advance new technologies. However, the current disadvantage of on-board propulsion is its shallow thrust level, which is related to the power source limitation and extra wait time for the satellites to get into desired orbit (Motta et al., 2024).

4.3.5. Dedicated Launch in Micro launchers

Micro-launchers, or micro-LVs, are specialized launch vehicles that transport small satellites, known as SmallSats, into space. These vehicles have been integral since the inception of the Space Era, enabling countries like the US (1958), France (1965), China (1970), Japan (1970), India (1980), and Israel (1988) to become space-faring nations. However, these were eventually replaced by larger launch vehicles (Jones, 2018b). With the advent of the New Space Paradigm and the drivers within, micro-launchers' development has seen a significant increase. As of 2024, there are 68 micro-launcher

[1] Starlink is a satellite constellation operated by SpaceX, providing broadband-level internet access to users worldwide. As of early March 2024, SpaceX's Starlink constellation consists of over 6,000 mass-produced small satellites in low Earth orbit (LEO). These satellites communicate with designated ground transceivers. The ambitious plan is to deploy nearly 12,000 satellites, with a potential later extension to 34,400.

[2] Eutelsat OneWeb is a joint venture between Eutelsat and OneWeb backed by Amazon, offering low Earth orbit (LEO) satellite services for carrier, enterprise, government, maritime, aviation, and land mobility. OneWeb aims to deploy a constellation of 7000 low Earth orbit (LEO) satellites.

initiatives in progress, a substantial growth from 42 in 2022 (Motta et al., 2024).

Micro-launchers offer several advantages, including selecting the orbit, setting the launch date, and dedicating resources exclusively to SmallSats. However, they also have their drawbacks. They are currently the least cost-effective option on the market, and most are still under development. In terms of reliability, apart from Rocket Labs' Electron, which has had 50 launches and among them 4 failures as of June 2024, the reliability of other micro-launchers remains to be proven, as most of them have yet to make their first orbital flights (Kulu, 2023b).

4.4. Summary

This chapter provides a detailed analysis of the micro launch industry's business environment, emphasizing the importance of market segmentation and customer expectations. The Classification of Launch Vehicles (refer section 4.1) into categories such as Micro-LV, Small-LV, Medium-LV, Heavy-LV, and Super Heavy-LV helps define the scope of the research, setting boundary conditions based on payload capacity.

The Small Satellite Market and Segmentation (refer section 4.2) is explored by satellite size, mission typologies, and customer typologies, which helps in identifying the diverse needs and expectations of different customer groups including commercial entities, civil government, defence, and academic institutions. This segmentation is crucial for tailoring value propositions and competitive strategies. Customer Expectations (refer subsection 4.2.4) are characterized by key factors such as flexibility, price-effectiveness, convenience, and reliability. These attributes are essential for benchmarking launch solutions and understanding how micro launchers can meet the needs of their customers, providing a demand-side perspective that highlights the critical attributes customers consider when selecting a launch service.

The Competitive Analysis of Launch Strategies (refer section 4.3) examines various launch strategies including piggyback launches, dedicated rideshare, orbital transfer vehicles (OTVs), on-board propulsion, and dedicated micro launchers. This comparative analysis helps identify the strengths and weaknesses of each strategy, guiding micro launcher companies in refining their value propositions and competitive positioning.

Overall, this chapter provides a comprehensive understanding of the business environment in the micro launch industry, laying the foundation for identifying the competitive fit of micro launcher companies' value propositions. The insights gained from market segmentation, customer expectations, and competitive analysis are critical for developing effective business understandings and addressing the challenges faced by micro launchers in this dynamic industry.

5

Coding Strategy and Interviews

The only source of knowledge is experience.

Albert Einstein
Physicist and Noble Laureate

This chapter provides a comprehensive overview of the methodology employed for the qualitative analysis of interview transcripts. The section 5.1 delves into the detailed coding strategy adopted for this study, elucidating the systematic approach used to identify, categorize, and interpret patterns and themes within the qualitative data. This ensures a robust and evidence-based understanding of the research questions. The section 5.2 presents anonymized summaries of the interviews conducted with subject matter experts. These summaries offer readers a nuanced perspective on the insights and viewpoints shared by the experts, enhancing the contextual understanding of the study's findings.

5.1. Data Analysis Strategy

This section outlines the coding strategy used to analyze the interview transcripts for this study. The approach systematically identifies, categorizes, and interprets patterns and themes within the qualitative data, ensuring a thorough and evidence-based understanding of the research questions. The primary method employed is ***Thematic Analysis***, which involves identifying and organizing themes relevant to the research questions and objectives. The thematic analysis process in this study can be broken down into several stages, as explained in the following sections.

5.1.1. Theme Identification

The first step in the coding strategy is to identify major ***Themes*** that align with the research questions and objectives of the study (refer chapter 1). Themes are broad categories that capture significant patterns in the data. For this study, some of the major themes identified include:

- Market Bubble in the Micro Launch Industry
- Perception of Current Market Trends
- Drivers in the Micro Launch Industry
- Challenges in the Micro Launch Industry
- Value Proposition and Competitive Benchmarking
- Implications for Small Satellite Manufacturers

These themes provide a basic framework for organizing the data and guiding the subsequent stages of analysis. The data is further categorized within each major theme into ***Sub-Themes***. These sub-themes are derived from the relevant literature review (refer chapter 2) and help understand specific aspects of each theme in greater detail. For example, under the theme "Challenges in the Micro Launch Industry," we identified several sub-themes, including:

- Developing a Sustainable Business Model
- Geopolitical Factors
- Regulatory Challenges
- Technological Hurdles
- Barrier to Entry
- Financial Management and Funding
- Talent Acquisition

Each sub-theme represents a distinct dimension of the broader theme, allowing for a nuanced data analysis.

5.1.2. Code Development Process

Due to the exploratory nature of the study and the semi-structured nature of the interviews, an ***open coding*** approach to code development was adopted, in which the researcher reads and re-reads the cleaned transcripts. The data is broken down into discrete parts and examined for similarities and differences during this process. This involves labelling segments of the data with initial codes that capture key ideas and concepts, for example:

- **Transcript Segment:** *"It's really hard to make a space company profitable at all. If you want to build hardware that is profitable in other space companies, then it's even harder with the launch industry because rockets cost a lot and like smaller rockets still need many of the components that big rockets have. So, there is like a limit of how cheap you can go unless you manufacture a lot of them and propellant is cheap."*
- **Open Codes:** High Technological Challenge, Low Profitability of Space Companies, Challenges of Economies of Scale

During open coding, the researcher identified numerous initial codes that reflect various aspects of the micro launch industry, such as "Low Profitability of Space Companies," "Challenging Operational Execution," "Importance of Government Support," and "Challenges of Economies of Scale."

The next stage of the development process is ***axial coding***, where the researcher relates the initial codes to each other by organizing them into sub-themes. This process helps to refine and differentiate the codes, establishing connections between them to form a more cohesive understanding of the data, for example:

- **Sub-Themes:** Developing a Sustainable Business Model
- **Codes:** High Technological Challenge, Low Profitability of Space Companies, Competing Against Economies of Scale

The researcher grouped related codes under sub-themes in this stage, facilitating a structured and detailed data analysis. ***Selective coding*** is the final stage. In this stage, the researcher integrates and refines the themes and sub-themes to develop a central narrative that addresses the research questions. This involves identifying the core themes and selectively coding data that support these themes to construct a coherent story, for example:

- **Core Theme:** Market Bubble in the Micro Launch Industry
- **Sub-Theme:** Factors Contributing to the Market Bubble
- **Codes:** Abundance of Liquidity, Herding Behaviour, Hyped Micro Launch Market Predictions, Hyped SmallSat Market Predictions, Inaccurate SOM Predictions: Micro Launchers, New Investors and Insufficient Due Diligence, New Technological Hype

Selective coding allows the researcher to focus on the most relevant data, ensuring the analysis is comprehensive and aligned with the research objectives. Furthermore, while analyzing the codes, the researcher keeps an open mind to identify new relevant themes and sub-themes that can emerge from the coding process, for example:

- **Transcript Segment:** *"I think it depends on where in the value chain you are (...) So I think that is a very attractive proposition for talented individuals, like there is this flexibility and always there is room to grow one way or the other whereas if that opportunity is not there. Then I think it's much harder to retain talent."*
- **Open Code:** Talent Retention of Skilled Workforce

This does not fit inside the "Talent Acquisition" sub-theme as proposed in the literature review. Therefore, the open codes "Talent Acquisition of Skilled Workforce" and "Talent Retention of Skilled Workforce" are merged into a new sub-theme ***"Human Resources"***.

5.1.3. Deriving Insights

A critical component of the coding strategy is the integration of direct quotations from the experts interviewed. These quotations provide concrete evidence to support each code and sub-theme, adding depth and credibility to the analysis, for example:

> *Small rockets don't scale well cost-wise...* - Expert 1

> *Public contracts are essential for these companies to survive...* - Expert 2

These quotations are carefully selected during the coding process to illustrate specific points and provide insight into the challenges and dynamic nature of the micro launch industry.

Results Synthesis

The coding and thematic analysis are primarily informed by the literature review and case environment sections of our thesis. By aligning our findings with existing research and theories, we provide a comprehensive and contextualized understanding of the topic, for example:

- **Literature Insight:** The literature emphasizes the importance of developing a sustainable business model in maintaining competitive advantage within the micro launch industry.
- **Application:** This insight informed our coding strategy, where we identified and grouped codes related to "Challenging Operational Execution," "Importance of a Sustainable Business Model," "Importance of Reusability," "Limitations of High Launch Cadence Business Model," and so on. This alignment ensures that our analysis is grounded in existing research and highlights the critical role of strategically developing their business model for long-term sustainability in the industry.

The final stage of the coding strategy involves synthesizing the coded data to answer the research questions. The themes and sub-themes are used to structure the results section, providing a coherent narrative that addresses the study's objectives. For example, in discussing the future bankruptcies in the micro launch industry, we draw on the theme "Market Bubble in the Micro Launch Industry" and the sub-theme "Future Bankruptcies," supported by expert quotations and literature. This approach ensures that our analysis is both comprehensive and evidence-based.

Iterative Process

An important aspect of the coding strategy is its iterative nature, meaning that the researcher refines codes and themes as they progress through the analysis. This iterative approach ensures the analysis remains relevant and accurate, accommodating new insights and emerging patterns.

To conclude, the coding strategy employed in this study involves a detailed thematic analysis supported by open, axial, and selective coding techniques. This systematic and evidence-based approach ensures that our findings are well-supported and aligned with the literature review and the research questions. By integrating existing research and systematically organizing the data, we comprehensively analyse the micro launch industry, highlighting key drivers, challenges, and future trends.

5.2. Interview Summaries

This section includes summaries of the interviews generated from Atlas.ti software. The summaries will help the readers understand the nuanced perspective of each expert. It also contains a detailed list of interview participants presented in table 3.1, which is useful in differentiating between experts and helps understand their professional backgrounds.

5.2.1. Interview - Expert 1

The interviewer and interviewee discuss the small satellite launcher market, challenges, implications for manufacturers, and trends in the industry. They touch upon factors like market demand, government investments, bankruptcies, cancelled constellations, and the impact of larger launch vehicles like Starship. The interviewee emphasizes the importance of orbit selection, cost-effectiveness, and customer value propositions in the evolving market.

The discussion highlights the impact of evolving launch technologies on the satellite industry, especially focusing on the challenges and potential strategies for small satellite manufacturers. Trends indicate a shift towards larger satellites, driven by cost and demand factors, while smaller satellites continue to be relevant for educational and specific applications. Strategies include optimizing mass using cost-effective materials in response to evolving launch options and price points. They also discuss the challenges micro launch companies face, including technological, market uncertainty, financial issues, and regulatory changes. They explore the potential impacts of larger rockets like Starship on the micro launch market in the future. Additionally, they touch on environmental concerns related to rocket emissions and the importance of considering sustainable practices in the space industry.

The discussion covers various trends and considerations in the space industry related to micro-satellites and CubeSats, including the balance between miniaturization and using larger satellites, the impact of cheaper materials on cost and weight, the role of technology advancement in pushing boundaries, considerations for deployers and separation rings, the potential influence of larger rockets like Starship on micro launch companies, regulatory challenges, environmental concerns, and the importance of continuous innovation and adaptation in the industry.

5.2.2. Interview - Expert 2

The interviewee discusses the challenges and developments in the micro-launcher industry, focusing on satellite sizes, technology incorporation, Elon Musk's impact, and micro-launch vehicles' market viability. They highlight the complexities and misconceptions surrounding space innovation and the commercial prospects for micro-launch vehicles.

The interview discusses various topics related to the space sector, including the commercial viability of space projects, the role of governments in funding and supporting space initiatives, the influence of key players like Elon Musk and SpaceX, and the importance of political relationships in space exploration. It highlights the complexities and challenges companies and governments face in the space industry, emphasizing the need for a nuanced understanding of the different factors at play.

The conversation discusses the changing landscape of space technology, including the shift towards electric propulsion and the use of orbital transfer vehicles. It also touches on the role of governments in funding space initiatives and the challenges faced by private companies in the space industry. The speaker emphasizes the importance of government support in space exploration and notes the military origins of many space programs. The conversation ends with the speaker offering additional resources and support to the listener as they navigate their research in the space industry.

5.2.3. Interview - Expert 3

The interview discusses the small satellite launch market, SpaceX's influence, the hype around investments, bankruptcies, shifts to larger rockets, and the value proposition of micro launches compared to other transport options like rideshare and orbital transport vehicles. The conversation also touches on the competition in the market and the potential impact of SpaceX's Starship on small satellite launches.

The discussion covered various topics related to the micro launch industry, including the impact of environmental regulations, reusability, market consolidation, government contracts, and geopolitical factors. The key points highlighted the importance of balancing promises with realistic delivery, the need for government contracts alongside commercial demand for sustainability, and the significance of adapting manufacturing strategies to cater to evolving launch vehicle requirements like those offered by Starship. Ultimately, staying competitive in the micro launch industry requires a strategic approach considering market trends and technological advancements.

The discussion covers two growth approaches in the space industry, one involving modular nanosatellites like cube satellites, while the other focuses on custom-built satellites with their bus. Considerations include customer demands, standardization, payload size, and deployer options. The micro launch industry faces challenges delivering on promised launch cadences due to technical difficulties, cost issues, and customer demand fluctuations impacting business models. Government support for micro launch companies, including regulatory frameworks and investments, is crucial for industry advancement. There are concerns over the imbalanced state of the industry, with examples like SpaceX dominating the market and the sustainability of industry competition.

5.2.4. Interview - Expert 4

The interviewer and interviewee discuss the trends and challenges in the micro launch industry, focusing on small satellite manufacturers. They discuss ethical regulations, product design, competition, value proposition, and regulatory factors influencing the industry. The conversation touches on past hype, bankruptcies in the sector, shifting towards larger rockets, the value propositions of micro launchers, and the sustainability of demand amid competition from medium and heavy launch vehicles. Ultimately, the success of micro-launch companies may depend on organizational efficiency and customer-oriented approaches rather than just technical capabilities.

Discussions touch on the importance of timely paperwork for launch vehicle providers and the potential impact of Starship on the smallsat launch market, particularly concerning micro launchers and satellite deployments. Considerations include technical capabilities, regulatory challenges, geopolitical factors, and balancing commercial and government roles supporting the micro launch industry. The trend towards lower launch costs and standardization of small satellites may influence manufacturing and design decisions, affecting R&D strategies. Recommendations for thesis topics include exploring micro-satellite standardisation and incentivizing adherence to virtual bounding boxes for optimal satellite deployment.

5.2.5. Interview - Expert 5

The interview discussed challenges and trends in the small satellite launch industry, emphasizing key points such as the shift towards smaller and more efficient satellites, recent bankruptcies, competition from larger rocket companies, and the value proposition and challenges micro launchers face. The expert highlighted the potential impact of regulations and geopolitics on the industry, including the possibilities of further consolidations and bankruptcies. Government support was deemed crucial for ensuring commercial sustainability.

The conversation also explored potential opportunities for micro launch providers due to geopolitical factors, suggesting that lobbying and forming partnerships with European companies could be beneficial. The need for standardization in form factors and maximizing ride-share opportunities was emphasized, with ride-sharing with companies like SpaceX seen as a dominant market trend.

The discussion addressed the challenges companies face in the small satellite launch industry due to limited satellite customers for micro launch vehicles, indicating that a few commercially operated launch vehicles could adequately cover the EU market. The impact of trends on small satellite manufacturing, such as combining payloads and increasing capabilities, was also highlighted. Decision-making for mass optimization in small satellite manufacturing involves considering mission type and satellite lifetime to choose between heavier, cheaper materials or lighter, costly ones. Standardization and innovation in deployer systems were recommended to enhance flexibility and efficiency in satellite integration. Overall, government support for small launchers was seen as essential.

5.2.6. Interview - Expert 6

The interview participants discuss the challenges, value propositions, competition, regulatory aspects, and opportunities in the micro launch industry. They discuss the current state of the small satellite launch market, the hype and investments in the sector, recent bankruptcies of companies like Virgin Orbit, and the value propositions of micro launchers compared to competitions like ride-share programs. They also touch on the shift of some companies to medium and heavy launchers due to evolving demands for larger payloads.

The operational and regulatory aspects of launching rockets, such as airspace and sea clearance, do not scale much with the size of the rocket regardless of payload, making larger rockets more cost-effective. SpaceX's Starship could disrupt the micro-launcher market due to its significantly lower cost per kilogram to orbit. Reusability is crucial for lowering costs in the launch industry. High launch cadence business models for micro-launchers face challenges due to regulatory restrictions, cost inefficiencies, and environmental concerns. Geopolitical factors could provide opportunities for small launch companies to gain sovereign capability, offering alternatives and maintaining market diversity. Trends favour larger satellite manufacturing to potentially reduce costs and challenges associated with miniaturization.

The cost of components doesn't decrease significantly with scale. Shrinking component size can make launches cheaper, but launch costs are becoming a smaller portion of total expenses. Performance metrics improve with larger satellites due to factors like payload per kilogram. High launch costs primarily drove the trend towards miniaturization. However, CubeSats still offers advantages in launch flexibility and standardized payloads. The space industry is considered tough due to hardware development and delivery challenges. Therefore start-ups face challenges like financial risks and talent acquisition. Governments could support the industry by specifying demand rather than solutions. Startups should innovate and avoid replicating existing models like Rocket Lab.

5.2.7. Interview - Expert 7

The interview discussed the challenges, competition, value propositions, and regulatory aspects of the small satellite launch industry. They highlighted the underserved market, the trend towards larger and more capable satellites, and the need for specific orbits for revenue-generating services. They also touched on market consolidation, the importance of a sound business case, and the role of investors in the success of companies. The conversation also covered the competition from rideshare, OTV, and self-propulsion methods and the impact of upcoming medium, heavy and super-heavy launchers like SpaceX's Starship on the market.

The discussion covers various topics related to the challenges and potential future developments in the launch industry, particularly focusing on the environmental impacts of rocket launches, regulatory challenges, government support for micro launch companies, geopolitical influences, and strategies for companies to stay competitive. Key points include the significance of aligning business interest with operational feasibility, the increasing importance of environmental regulations, the role of government support in securing contracts and subsidies for startups, the need for long-term business sustainability, and the importance of collaboration with agencies and maximizing existing resources. Additionally, historical perspectives on the evolution of the space industry and the value of talent and infrastructure are highlighted. The overall discussion provides insights into the complex dynamics and considerations shaping the future of the launch industry.

5.3. Summary

This chapter provides a comprehensive overview of the methodologies employed for the qualitative analysis of interview transcripts. The Data Analysis Strategy (refer section 5.1) is outlined in detail, describing a systematic approach that includes thematic analysis to identify, categorize, and interpret patterns and themes within the qualitative data. The process involves open, axial, and selective coding to develop a robust understanding of the research questions. Major themes identified include market bubbles in the micro launch industry, perception of current market trends, drivers and challenges in the micro launch industry, value proposition and competitive benchmarking, and the impact on small satellite manufacturers.

The Theme Identification sub-section describes the utilization of chapter 1 and chapter 2 for identifying major themes such as market bubbles, industry drivers, and challenges. These themes are further categorized into sub-themes, which allow for a more nuanced analysis. For instance, challenges in the micro launch industry are divided into sub-themes like developing a sustainable business model, geopolitical factors, regulatory challenges, technological hurdles, barriers to entry, financial management and funding, and talent acquisition.

The chapter also describes the Code Development process, where open coding breaks down the data into discrete parts and labels them with initial codes that capture key ideas and concepts. Axial coding organizes these initial codes into sub-themes, while selective coding integrates and refines themes and sub-themes to develop a central narrative addressing the research questions.

Deriving Insights sub-section involves the integration of direct quotations from interviewees to provide concrete evidence supporting each code and sub-theme, enhancing the depth and credibility of the analysis. This approach ensures that the findings are grounded in the qualitative data collected.

Finally, Interview Summaries (refer section 5.2) present anonymized summaries of interviews with subject matter experts, offering nuanced perspectives on the insights and viewpoints shared. These summaries contextualise the study's findings and highlight key trends and challenges in the micro launch industry.

This chapter outlines a systematic approach to qualitative data analysis, ensuring the findings are comprehensive and evidence-based. By systematically coding and analyzing interview transcripts, the research provides a detailed understanding of the micro launch industry, addressing key drivers, challenges, future trends and implications for SmallSat manufacturers.

6 Results

The small launch industry is brutal—yes, even more than you thought

Erik Berger
Author of Liftoff and Re-entry

This chapter presents the detailed analysis and interpretation of the results obtained from semi-structured interviews with industry experts supported by extensive desk research and literature review. It explores various aspects of the micro-launch industry, section 6.1 provides a framework to help answer the first sub-research question on the factors contributing to bubble in the micro launch industry:

> *Sub-Research Question 1: What are the main factors behind the micro launch industry's market bubble?*

Furthermore, section 6.2 and section 6.3 examines the drivers and challenges in the micro-launch industry, aiding in answering the second sub-research question:

> *Sub-Research Question 2: What are the key drivers and challenges in the micro launch industry?*

The insights provided in this chapter aim to offer a comprehensive understanding of the current state and prospects of the micro-launch sector, setting the stage for further discussion on the topic. Additionally, each section includes tables that present the groundedness of the factors discussed, with cross-referencing to aid in understanding the groundedness analysis of each factor. The totals in these tables reflect the groundedness of factors and experts, enhancing the clarity and depth of the analysis.

6.1. Market Bubble in the Micro Launch Industry

To address the first sub-research question, this section explore the factors contributing to the phenomena of hype bubbles within the micro-launch industry. This phenomenon can be attributed to several interconnected elements, as explained by various industry experts. Key factors include the abundance of liquidity, herding behavior among investors, hyped market predictions, the presence of new investors with insufficient due diligence, high expectations of economic growth, and the hype surrounding new technology. Furthermore, following the market bubble its impact on the industry is discussed.

6.1.1. Factors Explaining the Market Bubble

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Totals
Abundance of Liquidity Gr=3	1	0	0	1	0	1	0	3
Herding Behaviour Gr=5	1	1	1	1	0	1	0	5
Hyped Micro Launch Market Predictions Gr=8	2	1	1	2	1	1	0	8
Hyped SmallSat Market Predictions Gr=5	2	1	0	1	1	0	0	5
New Investors and Insufficient Due Diligence Gr=4	1	0	1	1	0	0	1	4
New Technological Hype Gr=7	1	2	1	2	0	1	0	7
Totals	8	5	4	8	2	4	1	32

Table 6.1: Groundedness Analysis Table for Market Bubble Factors.

Abundance of Liquidity

One of the primary factors contributing to the hype bubble in the micro launch market was the influx of capital from both public and private sources. This created an environment ripe for over-investment.

> *I think the hype was primarily driven by a trust of the public money combined with with private money being pumped into launch vehicles ...* - Expert 4

> *I think there was of course a bit of a speculative element. There was definitely a lot of hype and too much hype, I think in general and in the periods between, let's say 2016 and 2022, a lot of things in the economy and startup world in general were overhyped, all the things were overvalued and anywhere from tech startups to real estate, everything was overvalued in the era of 0% interest. But, what made the launch one so interesting that it was so overhyped. If you look at, what is kind of the division of total value of the space industry, Launch only represents a very small part of it. And then if you look, during that period of hype, at all the investment money that flew into space, that ratio is almost the opposite, you'll observe that the vast, vast majority went into launch. Even though, that's only a very small part of of the entire industry ...* - Expert 6

The low-interest-rate environment, described as "the era of 0% interest," facilitated easy access to capital, which was pumped into the satellite business with little restraint (Expert 6). This scenario is reminiscent of historical financial bubbles where excessive liquidity leads to speculative investment and inflated valuations (Andraszewicz, 2020). This factor has a groundedness score of 3, with mentions by Experts 1, 4, and 6 (refer table 6.1). This indicates that the influx of capital and the low-interest-rate environment played a significant role in the market bubble.

Herding Behavior

Herding behavior among investors significantly contributed to the bubble. As Expert 1 noted, the initial hype was driven by investors "investing because others were investing," akin to the Tulip Mania. This collective behavior led to investments based more on the actions of others than on sound financial analysis and solid fundamentals .

> *I think what explains the initial hype was mostly like, pure hype, like Tulip Mania. Investors investing because others were investing, they believe the claims in pitch decks and didn't really do good due diligence and there's so much hype about market predictions as well.* - Expert 1

> *Part of it has to do with what I would call the "Elon Musk Effect" combined with the SmallSat fever. While 863 SmallSats were launched between 1995 and 2014, Euroconsult predicts the launch of 26,104 SmallSats to be launched between 2023 and 2032, but there was no definite indication that SmallSats owners will choose dedicated flights on Micro-LVs over cheaper rideshare flights on larger vehicles.* - Expert 2

The "Elon Musk Effect" as coined by Expert 2, where the success of high-profile figures like Musk inspired others to follow suit without adequate market understanding, further exemplifies this behavior.

Furthermore, with a groundedness score of 5, this factor is supported by Experts 1, 2, 3, 4 and 6 (refer table 6.1). The analysis highlights how investor behavior, influenced by high-profile figures and speculative trends, contributed to the bubble.

Hyped SmallSat Market Predictions

Incorrect market forecasts, particularly the Serviceable Obtainable Market (SOM) for micro launchers, further inflated the bubble[1]. The assumption that a large number of micro launch companies could achieve market success looked fundamentally flawed, Expert 5's observation that only few out of over 30 or more proposed satellite constellations were launched and others never made it beyond proposals or demonstration mission. This underscores the disconnect between market reality and investor expectations.

> *So indeed, the amount of satellites that were waiting to be launched or like the low earth (satellite) constellations, which were stating that we would be launching 100 satellites next year or something. When in fact, except from the Planet, I cannot tell that there are any other satellite company doing the satellite launches in the same amounts and there were a lot before at least almost 20 or 30 of them or more.* - Expert 5

> *Many (satellite) constellations are actually not happening. I have a long list of constellations, but most of the time they have done maybe a demonstration. But how many of them are actually like actively deploying some satellites? Not many, and then the ones who are like SpaceX or Oneweb, they are not customers to small rockets. They shouldn't be part of the obtainable market estimation, so it's like they're not obtainable, accessible market.* - Expert 1

Additionally, Expert 1 agrees with Expert 5 and further states that these constellations should not be a part of the Obtainable Market, which in-turn reduces the addressable market and also makes it harder for the companies to access those customers. With a groundedness score of 5, this factor is supported by Experts 1, 2, 4, and 5 (refer table 6.1). The analysis emphasizes the role of unrealistic market predictions in inflating the bubble.

Hyped Micro Launch Market Predictions

Market predictions for both the Micro Launch and SmallSat markets played a crucial role in fueling the hype. Predictions such as the launch of "26,104 SmallSats between 2023 and 2032" created an overestimated sense of demand for dedicated micro launch vehicles (Expert 2).

> *I think, before all that hype with the micro launches started, there was a serious increase in launch services demand from the Cubesat industry and smallsat customers. Then, indeed SpaceX changed the Rules of the Games there, because before in fact, it was only Soyuz and PSLV rockets, mostly available for the launches for the cubesats. So indeed, market felt some potential there with the growing small satellite market, where you can utilize that capacity present. At some point in time, I've calculated the number small rocket startups coming to the market and I just stopped counting when it was more than 100 names in my list. Which apparently, of course, only maybe like a fraction, maybe few percent of those, in fact, would have made it to the real market on time and that's exactly what's happening.* - Expert 5

> *... In this case, it is behind the satellites and what we definitely saw in the certain cases is that the venture capitalists for instance, who were pumping money into the satellite busines also noticed that, ' hey, this whole launch business is an interlinked item and if I first started with satellites, If I invest, I can earn money there. Then I can also do that on the launch side and quite quickly this growing into something where you see that the one cannot really go without the other.' And that is where that hype of launch vehicles definitely follow the hype of the small satellite to increase in demand.* - Expert 4

However, as highlighted, "SpaceX changed the Rules of the Games", this suggest that the market forecasts were overly optimistic and not grounded in actual customer preferences (Expert 5). Their is also a caveat to these forecasts that is neglected a lot of the time, among the total number of the

[1] Refer Chi (2023) for more detailed explanation on business terminologies such as TAM, SAM and SOM.

satellites to be launched a large portion is consisted of SpaceX Starlinks and Amazons OneWebs, while others mostly did not happen, which brings us to our next theme about inaccurate SOM predictions for micro launch market. This factor shows the highest groundedness score of 8, mentioned by Experts 1, 2, 4, 5, and 6 (refer table 6.1). It reflects the widespread impact of overly optimistic market forecasts on the micro launch industry.

New Investors and Insufficient Due Diligence

New investors entering the market often lacked the technical expertise necessary for thorough due diligence. As Expert 3 pointed out, investors were sometimes swayed by "over-optimistic market predictions" without performing the required background checks and fundamental financial analysis. This lack of due diligence led to significant investments in companies that did not have viable technological or business models.

> *Maybe they (Investors) would be presented a company, which said we can launch this many satellites. We can have this percentage of the market in this time, completely over-optimistic and then people would buy it and invest a lot of money. Maybe they didn't do their due diligence and made proper the background checks. I don't like the hype. I think that type of oscillation in the market is very bad for everybody.* - Expert 3

> *... They (Investors) were already their with the Satellite part, But I'm quite confident that for the launch vehicle part, that it was maybe even worse, where people would just see the sexiness of investing in a launch rocket. It's rocket science and of course the business people not always telling them what the real gist is of what needs to be done and what the real challenge is. You know that, only if you are in this field and you work with the launch vehicles...* - Expert 4

Furthermore, as previously describes by Expert 4, this lead to scenario where venture capitalists saw opportunities in the satellite business and subsequently expanded their interests into the launch vehicle sector. This interconnected investment approach fueled the hype around micro launch vehicles and set high expectation for economic growth. This factor has a groundedness score of 4, with mentions by Experts 1, 3, 4, and 7 (refer table 6.1). It highlights the challenges faced by new investors lacking the technical expertise for thorough due diligence.

New Technological Hype and High Expectations for Economic Growth

This high expectation of economic growth combined with allure of new technology also played a significant role in driving the hype. The concept of investing "rocket science" and the development of micro launch vehicles were seen as sexy and innovative, attracting investment despite the inherent technical challenges (Expert 4). This technological hype often overshadowed practical considerations and realistic timelines for development and deployment.

> *... You know that, If you are in this field and you work with the launch vehicles. Then everybody knows that anybody can't say anything about status, up until you've had that moment of your first successful engine test. For instance, your schedule is nowhere. You can say I launch next year, but if you don't have your engine test done and checked off, you can't launch. And at the same time every engineer in this field also knows that, once you've done that engine test, it takes more than three months to actually get to flight...* - Expert 4

> *... What I find even more puzzling is that, if you look, at some point I think there are almost 100 small launch companies, various levels of seriousness, but I think if you look at the ones who are really serious (..) let's say there were 35, at least 30 of them we're just copies of Rocket Lab. Like there was no thing they try to do different than Rocket lab. I think they reached orbit the first time in 2019. Then if you look between 2019 and 2022, and find how many other launch companies still successfully raise some enormous amount of money, its a lot. Even though the value proposition is, we're going to be a copy of Rocket Lab, and we're going to be 4 years late to the party at best. That I found very strange.* - Expert 6

Additionally, Expert 6 highlighted that many companies were essentially "copies of Rocket Lab," indicating a lack of innovation and a misjudgment of the market's capacity to support so many similar ventures in the already fiercely competitive market. This factor has a groundedness score of 7, mentioned by Experts 1, 2, 3, 4, and 6. The analysis underscores the allure of new technology and high expectations for economic growth as major contributors to the hype bubble.

Therefore, the hype bubble in the micro launch market was driven by a complex interplay of excessive liquidity, herding behavior, overhyped market predictions, and a lack of due diligence among new investors. Technological allure and incorrect market forecasts further exacerbated the situation. Furthermore, arising from the bubble is an imminent financial crisis that ensues, with expert insights indicating a looming wave of bankruptcies that could potentially come in the future. Overall, the groundedness analysis reveals that the factors contributing to the market bubble are well-supported by the data, with a total groundedness of 32 occurrences across various factors (refer table 6.1). This high groundedness score underscores the significance and prevalence of these themes in understanding the market bubble in the micro launch industry. The analysis confirms the robustness of the identified factors and their critical roles in shaping the market dynamics.

6.1.2. Impact of Market bubble

As observed from the previous section experts highlight that the initial hype and overestimation of market demand have led to a saturated and unsustainable market. Expert 1 predicts that "we'll see a lot and lot of bankruptcies" as the market corrects itself. Furthermore, Expert 3 draws a parallel with the early aviation industry, where initial hype led to a proliferation of companies, followed by significant consolidation. The micro launch market is experiencing a similar pattern, driven by economic realities and competitive pressures.

> *If you can't make your company profitable and if you can't raise more rounds like that's it, I guess either someone buys you or you go bankrupt. I think we'll see a lot and a lot of bankruptcies. But, I think the bankruptcies are being delayed by those more government and national investments* - Expert 1

> *Consolidation has already been triggered by the laws of physics, which establish that propellants (fuel and oxidizer) represent more than 90% of the mass of an orbital LV but less than 1% of the launch cost. As of today, no one has produced a really "cheap" micro-LV. Since their prices are much higher, the laws of capitalism come into play and determine that their market is quite limited.* - Expert 2

> *So maybe, something like that also happened with airplanes. At the beginning it hyped up, and then then they consolidate just to two. So we are seeing something similar, maybe now the launches rockets market (....) Yeah, I think it will be a curve. You will see a large number of increase and then you'll see some reaching first launch. And the number reaching second Launch will be much less and then the number reaching third launch even lesser.* - Expert 3

> *Yes, definitely, their would be further bankruptcies. To which I would say, if Government here or specifically the European Government. If the country governments are not supporting those launch Companies like (...) or (...), if they're not supporting them and not even subsidizing their launch at the least. It's really hard to imagine that they can be commercially sustainable for long term.* - Expert 5

Experts emphasize that the initial hype and overestimation of market demand have led to a saturated and unsustainable market. Expert 1 predicts a wave of bankruptcies as the market corrects itself. Expert 3 draws parallels with the early aviation industry, highlighting the pattern of initial hype followed by consolidation. Expert 5 adds that government support is crucial for companies' sustainability in the near and long term. This view is echoed by Expert 1, who notes that government and national investments are delaying the expected bankruptcies.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Totals
Impact of Market Bubble Gr=12	3	1	2	2	2	1	1	12
Totals	3	1	2	2	2	1	1	12

Table 6.2: Groundedness Analysis Table for Impact of Market Bubble.

Overall, the groundedness analysis shows that the impact of the market bubble sub-theme is well-supported by the data, with a total groundedness of 12 occurrences spread across four main factors (refer table 6.2). This confirms the prevalence and significance of these insights across multiple expert interviews. This comprehensive understanding underscores these themes' critical role in shaping the micro launch industry's current and future dynamics. Two experts who mention this theme are executives from Micro Launch Companies, while the other two have worked closely with launch companies throughout their careers.

6.2. Drivers for the Micro Launch Industry

Following the discussion on the market bubble in the micro launch industry, as identified by Tugnoli et al. (2019b), the drivers behind micro launchers are embedded in New Space trends (refer chapter 1). These trends emphasize commercial space activities driven by private entities, technological advancements, increased accessibility to space, and institutional activities driven by the need for independent access to space and military operational response capabilities. The micro launch industry is an integral part of these trends and faces a complex landscape shaped by a combination of drivers and challenges. This section delves into these factors, drawing from expert interviews and relevant literature to provide a comprehensive analysis and aid in answering the second sub-research question.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Totals
Current Institutinoal Driver Micro Launchers Gr=21	4	5	2	3	2	1	4	21
Current Commercial Driver Micro Launchers Gr=16	2	4	1	2	3	3	1	16
Totals	6	9	3	5	5	4	5	37

Table 6.3: Groundedness Analysis Table for Drivers and Challenges.

6.2.1. Institutional Drivers

Institutional drivers play a significant role in developing the micro launch industry in the current environment. Government and defence applications, scientific research, and educational missions are primary institutional drivers. These institutions value the capability to deploy small satellites for various purposes, such as reconnaissance, communication, and technology demonstration, thereby ensuring independent access to space. Due to these factors, governments are increasingly investing in these companies, as observed by Expert 1.

> *... So the government investments are skewing the market a lot also, ... therefore, we see a lot of scenarios like Australia's both government and investors supporting their own rockets. We see the same UK government and the UK investors, and the same with France. So I think that is skewing from governmental institutions, stopping pure commercial fundraising that the companies would get purely by market demand* - Expert 1.

> *You see huge movements in the continental level as well. Making sure that we have at least a few European vehicles here that are capable of bringing up satellites and the fact that it costs 2-3 times, maybe four times more. Then will turn out to be acceptable also from an economic point of view, you should also make sure that there are jobs being created. Then we don't lose the knowledge if you make yourself dependent on completely another continent or nation.* - Expert 4

Expert 2 adds another dimension to this explanation, where governments also see strategic interest in creating high-quality jobs and keeping human capital and intellectual knowledge within the country by funding these companies. The underlying reasons behind this current driving force are discussed in the Geopolitical Factors sub-subheading in section 6.3. Furthermore, this institutional support is also necessary for the survival of these companies, as observed by several experts.

> *But purely surviving from micro launch, I think that's very, very difficult. And without any government support or government subsidies, it's even more difficult.* - Expert 1

> *Purely commercial would be a very tough game and that's dependent on what SpaceX does. If they keep on doing what they do now, or even if they would increase the price,*

> *even then I believe that you also need your governmental military.* - Expert 3

> *Public contracts are essential for these companies to survive. No company will survive producing small launch vehicles without government support.* - Expert 2

Expert 4 pointed out that this is not a particular inadequacy of micro launch companies. In the early years of SpaceX, NASA's Commercial Orbital Transportation Services (COTS) Program played a crucial role in the survival of the company when it was developing its Falcon 1[2].

> *Then really you can even ask the same question for SpaceX, on commercial part in the sense that if they haven't gotten that earlier contract for so many launches from the U.S. government, would they have been able to grow to the level where they are! I think It's a mix of both touching on my earlier remark. If the market really turns into that commodity-driven thing, then yeah, there will be a strong commercial aspect. But at the moment, the government's support is needed.* - Expert 4

> *Initially, it's crucial because developing a launcher requires substantial capital investment. Beyond mere capability, securing funding involves attracting investors. Investors often seek a pipeline, and having a strong anchor tenant further encourages investment. While subsidies aren't always necessary, consider SpaceX's success—they secured NASA contracts, providing that essential anchor. As a launch provider, having backing from a national or international agency, such as the European Space Agency or the European Commission, simplifies attracting private investment. So, while key, ongoing subsidies signal that it's not purely a commercial venture.* - Expert 7

Expert 7 also referred to SpaceX's success and the importance of NASA's COTS program in that success. Furthermore, Expert 7 mentioned the importance of this support in signalling demand, which plays an important role. Further, this role is discussed in the following section 6.4.

The groundedness analysis for institutional drivers reveals that the data strongly supports these drivers, with a total groundedness of 21 occurrences across 7 experts (refer table 6.3). This indicates a high level of agreement among the experts about the significance of institutional support for the micro launch industry. The recurring themes include government investments, the strategic interest in job creation, and maintaining national independence in space capabilities. The widespread acknowledgement of these factors underscores their critical role in the survival and growth of micro launch companies.

6.2.2. Commercial Drivers

The commercial drivers in the smallsat launch market are heavily influenced by the **Current Atypical Market Conditions**. Despite an apparent oversupply of launch service providers developing launchers, the market remains constrained due to slow execution, technical problems, and geopolitical issues. Industry experts best explain this paradoxical situation.

> *Yeah, it's a very tricky one to answer. Because, launch in general at the moment is in a really strange position where on the one hand, if you look at the amount of companies working on launch vehicles, you have the feeling the market is completely flooded. There's way too much supply compared to the demand that there is in the market, but at the same time, due to a variety of reasons like slow execution, technical problems, what not. Already for years, there is in fact still a constraint in supply.* - Expert 6

Expert 6 highlights that the market appears flooded with many companies working on launch vehicles. However, slow market entry, disappointing performance from established players like Arianne, and the impact of COVID-19 have constrained supply. Furthermore, geopolitical issues have removed Russian and Chinese launchers from the market, leaving SpaceX as the dominant player.

> *We went on lockdown during COVID, which still has a bit of a hangover in the market. And then, because of the geopolitical climate, Russian and Chinese launchers no longer be*

[2]Under the COTS Program from 2006 to 2013, NASA acted as an investor and advisor with three different, distinct companies in the space transportation industry to promote the development of U.S. space transportation capabilities on the frontier of human exploration. Refer NASA's Websitefor more information.

> *available for most of the market basically means right now, there's only SpaceX.* - Expert 6

This dominance by SpaceX creates a unique challenge for smallsat customers. SpaceX prioritizes its projects like Starlink and U.S. government business over smaller commercial launches, placing smallsat customers at the bottom of the priority list.

> *On the one hand launches a lot and gives decent service and gets people where they need to be. On the other hand, they also only launch when they want to on their own, and especially when you look at the context of small satellites. I think in order of importance for SpaceX will be Starlink, U.S. government business and only then any day and then maybe large commercial and then small cells, so like small cells are really at the bottom of the food chain here.* - Expert 6

This situation forces many smallsat customers to lock in their launches years in advance to secure a slot, as noted by Expert 6.

> *We have many of our customers on the propulsion side who have to lock in their launches like two years in advance by now, almost. Otherwise they simply don't have a slot.* - Expert 6

Expert 7 explains the undeserved nature of the small-sat launch market and the specific needs of certain organizations for precise orbit injections, which are essential for revenue-generating services. This underscores the demand for dedicated launch services that can meet these exact requirements.

> *So, I would say at the moment, it's an underserved market for sure. The only game in town seems to be SpaceX rideshare particularly. So what we're seeing is there's a lot of demand from those organizations, particularly in Europe, who don't necessarily or not necessarily keen to go to the US to do their launches. Particularly around launches which give them specific advantages from the point of view of orbit injection. So particularly inclinations alternans. When you bring up a constellation, you want those satellites in particular locations.* - Expert 7

> *We're also seeing that where in the past maybe CubeSats were small and mainly used for IoD ion missions. Now they're getting a bit larger and used for proper revenue-generating services. Therefore, those requirements for injection in particular orbits are important because it's related to the revenue of the organizations.* - Expert 7

Additionally, Expert 3 provides insights into the influence of SpaceX on the market dynamics. SpaceX's substantial progress and rapid development capabilities have positioned them as a dominant force in the small satellite market. However, their focus tends to be more on microsatellites rather than nanosatellites.

> *We briefly discussed SpaceX. When SpaceX announced their transportation services, they claimed it would change the market, and I believe it truly did. ... , we can observe significant growth. Many of the answers to your questions relate to how SpaceX has grown the market and their plans for future growth. If they control 80% of the market, their decisions will significantly impact the direction of the industry. They may even have more market share than that.*

> *From what I've seen, SpaceX is making substantial progress. They are rapidly building and launching rockets, which gives them the capacity to handle a large portion of the small satellite market annually. However, the question remains: what does SpaceX consider as the small satellite market? My impression is that they are more focused on microsatellites rather than nanosatellites. While they do launch nanosatellites, I don't believe that is their primary focus. They are more interested in microsatellites and prefer customers who align with their stringent operational standards and are willing to pay for their services. They maintain a strict method of operation, and if a customer doesn't fit within that framework, they have to look elsewhere.*

> *This leads to the niche market left for micro launchers. Other than SpaceX, the agile space market and governmental markets, which desire more control, are potential areas*

> *of growth. SpaceX prioritizes their commercial interests, which might not align with some countries' needs or budgets. Consequently, certain countries either cannot or choose not to launch with SpaceX. In conclusion, the remaining market for small satellite launches, outside of SpaceX, lies in specific commercial and governmental sectors. Some of this market has significant value, but it is definitely less than what we expect in the next five years.*
> - Expert 3

Expert 4 also emphasizes the slower-than-expected market growth and the resulting need for multiple developments across continents, driven by geopolitical situations and the need for government independence.

> *Of course, they've been around for quite some time already. So it's actually, if you look at it from that point of view, it's a very valid question because people can ask themselves like, why is it taking people so long to get there? There's only very few who actually made it so far. With I guess Rocket Lab, they left from being the one example that actually did make it in that category. So how do I look at that part? Well, the development why they came about is understandable. But making sure that there is a more on-demand scheme. Whether that justifies that there are, I don't know, about 130. Development is at the moment there is a very big second question we can touch on a few of our aspects there and later I guess.*
>
> *Market has been slower. Definitely, slower than people anticipated a couple of years ago, although it looks different. But as we've mentioned already, we've had that hype and then a bit of a lower again, people were starting to become reluctant to put in so much money. May see that slightly different now again with also driven by geopolitical situations and the need for independence for governments to have their own nation.*
>
> *And that is what we do see if we look at the trends in our market, everything turns to be a bit bigger again. If you look at the US, it's typically always two years ahead of what we do in Europe, they are only building small microsatellites. Hardly any CubeSats for the real applications anymore, so that definitely is a trend that also follows it opportunity of small launch vehicles.* - Expert 4

The market's atypical situation, characterized by a paradox of oversupply and constrained access, creates unique commercial drivers. There is a growing need for reliable and flexible launch services that can accommodate the specific needs of smallsat customers, particularly those requiring precise orbital insertions at an economical price point. Despite the current market constraints, this demand highlights significant business opportunities within the smallsat launch market.

The groundedness analysis for commercial drivers shows a total groundedness of 16 occurrences across seven experts (refer table 6.3). This indicates a robust but slightly less pervasive consensus compared to institutional drivers. The key themes identified include the paradox of market oversupply and constrained access, the dominance of SpaceX, and the specific needs of smallsat customers for precise orbital insertions. Despite the current market constraints, there is a clear recognition of significant business opportunities within the smallsat launch market.

6.3. Challenges for Micro Launch Industry

The micro launch industry faces numerous challenges in the current atypical market condition. These challenges are multifaceted and span various domains, such as business models, regulatory issues, technological hurdles, financial constraints, and human resources. The following section details these challenges, supported by insights from industry experts and aids in answering the second sub-research question.

6.3.1. Developing a Sustainable Business Model

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Totals
Importance of a Sustainable Business Model Gr=12	3	1	0	3	1	1	3	12
Limitations of High Launch Cadence Business Model Gr=14	3	4	1	2	1	2	1	14
Challenging Operational Execution Gr=3	0	0	1	0	0	1	1	3
Totals	6	5	1	6	2	4	5	29

Table 6.4: Groundedness Analysis Table for Developing a Sustainable Business Model.

Importance of a Sustainable Business Model

Developing a sustainable business model for micro launch companies is a significant challenge. The high costs of launching small rockets and the limited revenue generation potential make it difficult to achieve long-term sustainability. Without a sustainable model, these companies struggle to attract investment and achieve profitability.

Expert 1 discusses the scalability challenges:

> *Small rockets don't scale well cost-wise ... Smaller rockets still need a lot of the components that big rockets have. So, there is a limit to how cheap you can go unless you manufacture a lot of them and propellant is cheap.* - Expert 1

> *If you want to be a bigger company, you either need to launch hundreds of times or launch less for a larger cost price ... So if you talk about long-term sustainability, probably not easy.* - Expert 1

To continue this reasoning for economies of scale, Expert 4 mentions why some companies are shifting to make larger rockets:

> *Economies of scale! Because very simply put. The vehicles that they have developed were based on the situation that probably was from 5 to 10 years ago and the market developed faster in that sense than when you look at the growth of the satellites. Making the microbes, rather than the cubesats. Then if you have any electron vehicle that can do 100 - 150 kilogram to. Yeah, that's that's no longer enough that you want to scale that up to being able to to have a couple of microsatellites on board. And that is where the and that combined with the performance of the vehicle also scaling with the size. Is this the sweet spot? Is not at the very low. Its somewhere in the middle. Basically again, How larger bus do you need to to move? What number of people?* - Expert 4

Expert 7 elaborates on the importance of having a balanced approach:

> *For a micro launcher, you have to be acutely aware that your payload capacity is limited and hence your revenue generation potential is limited. You cannot create an organization beyond a certain scale that can be supported by a sound business model.* - Expert 7

Expert 7 also discusses the importance of having a diversified business model to ensure long-term sustainability:

> *The balance between large and small launch gives you resilience. Having more products gives you resilience, and I think they [Rocket Lab] played that very well.* - Expert 7

The groundedness analysis for “Importance of a Sustainable Business Model” shows a total groundedness of 12 occurrences across six experts (refer table 6.4). This indicates a strong consensus among the experts about the critical importance of developing a sustainable business model for long-term success. Key themes include scalability challenges, the need for a balanced approach, and the diversification of business models. The high groundedness score underscores the significance of this factor in ensuring the viability and growth of micro launch companies.

Limitations of High Launch Cadence Business Model

The expectation of a high launch cadence[3] is often unrealistic for micro launch companies. Achieving the necessary frequency of launches to maintain a sustainable business model is challenging due to several factors, including market demand, operational complexities, and financial constraints.

Expert 2 comments on unrealistic launch goals:

> *Chris Kemp[4] intended to launch a rocket a day, but his prediction was out of touch with reality.* - Expert 2

> *A key aspect in making a LV company financially viable is launch cadence. Even Rocket Lab's Electron is under risk. It performed 49 flights between May 25th, 2017, and June 5th, 2024. On average, there were 7 launches per year. Initially, Rocket Lab predicted launching 52 rockets per year!* - Expert 2

> *Micro-LVs are the best option if there is an urgency to launch a SmallSat, either for commercial or military reasons; however, the resulting low launch cadence may provide profitable business to only a few micro-LV providers.* - Expert 2

Expert 5 also weighs in on the difficulties of achieving high launch frequencies:

> *Sort of whatever the small launch vehicle companies say that they're planning to launch hundreds of rockets per year, it's like, good luck. First of all, even if you would have been able to physically build, test, and successfully launch 100 rockets per year, it would be almost impossible to find the customers in that quantity.* - Expert 5

Experts 6 additional perspectives on the limitations and challenges associated with achieving a high launch cadence and elaborates on the financial and operational inefficiencies of a high launch cadence model:

> *You have to evacuate the air and sea space over which you fly, which is expensive. A rocket with a 100-kilogram payload mass will have almost the same operational cost as one that can launch 1,000 kilograms, but you need to amortize that cost over a smaller payload.* - Expert 6

> *If you want to be a bigger company, you either need to launch hundreds of times or launch less for a larger cost price. From a business point of view, this is very difficult.* - Expert 6

Expert 6 further discusses the financial challenges:

> *Endless amounts of venture capital made that easier, but now that those amounts are less endless than they seem. For the micro launcher, you have to be acutely aware that your payload capacity is limited and hence your revenue generation potential is limited.* - Expert 6

The groundedness analysis for "Limitations of High Launch Cadence Business Model" reveals a total groundedness of 14 occurrences across seven experts (refer table 6.4). This indicates a broad agreement among the experts about the unrealistic nature of achieving high launch frequencies. Key challenges mentioned include market demand, operational complexities, and financial constraints. The high number of occurrences reflects the widespread recognition of the difficulties associated with maintaining a high launch cadence and its implications for the business models of micro launch companies.

Challenging Operational Execution

As mentioned by Expert 1, there are scalability challenges, and if you want to make a company bigger, it's hard to scale. Expert 3 provides insight into the complicated nature of the business model, making it harder to achieve operational efficiency.

> *You need a business model which can be forced once a week or once a month. Or wait for the next customer. That's a complicated business model. That's a lot of complications in manufacturing.* - Expert 3

[3] Launch Cadence is the aerospace terminology for number or launches or launch frequency.
[4] Chris Kemp is the Founder, Chairman and CEO of Astra, refer (https://astra.com/team/kemp/) for more information.

Furthermore, Expert 6 emphasizes the environmental and operational costs associated with small rockets:

> *It's also not very sustainable because, when you launch, you're dumping metal, plastics, residual fuel, and hydraulic fluid into the ocean. If this were to happen frequently, it would not be acceptable. The New Zealand Government, for instance, wouldn't allow Rocket Lab to dump at such a rate.* - Expert 6

The groundedness analysis for “Challenging Operational Execution” reveals that this factor is supported by 3 occurrences across three experts (refer table 6.4). This indicates that a few experts have highlighted the difficulties associated with the operational execution of micro launch companies. The challenges mentioned include high costs, limited scalability, and environmental impacts. While the number of occurrences is relatively low, the insights provided are critical in understanding the operational hurdles these companies face.

Overall, The groundedness analysis shows that the factors discussed in all subsections are well-supported by the data (refer table 6.4). Six experts strongly emphasize the importance of developing a sustainable business model, indicating a high level of agreement on this issue.

6.3.2. Regulatory Hurdles

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Totals
Considering Environmental Regulations Crucial Gr=3	0	0	0	1	0	1	1	3
Environmental Regulations: Far Future Gr=3	1	0	0	1	0	0	1	3
Environmental Regulations: Near Future Gr=2	0	0	1	0	1	0	0	2
Regulatory Challenges for Operartions Gr=3	0	0	0	1	0	1	1	3
Totals	1	0	1	3	1	2	3	11

Table 6.5: Groundedness Analysis Table for Regulatory Hurdles.

Regulatory Challenges for Operations

As discussed in the previous section, achieving operational efficiency is a persistent challenge. Expert 6 elaborates on the operational and financial burdens of regulatory compliance:

> *If you launch a rocket, you have to evacuate the air and sea space over which you fly. This is expensive and doesn't scale with the size of the rocket. A rocket with a 100-kilogram payload mass will have almost the same operational cost as one that can launch 1,000 kilograms, but you need to amortize that cost over a smaller payload.* - Expert 6

Expert 4 underscores the need for streamlined regulations to improve operational efficiency:

> *Making sure that regulations are streamlined, for instance, let's take Andøya*[5] *and making sure that we can launch from there. Even those little things can be a pickup already in the process and those really need to be streamlined.* - Expert 4

The complexity of regulatory requirements can also create significant operational delays, as noted by Expert 6:

> *The operational side and regulatory side are often not talked about. For every launch, you have to ensure that air and sea spaces are clear, which is expensive and doesn't scale with the rocket size. This is a significant operational cost that must be amortized over the payload.* - Expert 6

The groundedness analysis for “Regulatory Challenges for Operations” reveals that this factor is supported by 3 occurrences across three experts 4, 6, and 7 (refer table 6.5). This indicates that a few experts have highlighted the difficulties associated with the operational execution of micro launch companies. The challenges mentioned include high costs, limited scalability, and environmental impacts.

[5] Andøya spaceport in Norway is developed to be the first operational orbital spaceport in Europe. Historically, Europe's institutional and other launches take place from Kourou, French Guiana, on South America's Atlantic coast.

While the number of occurrences is relatively low, the insights provided are critical in understanding these companies' operational hurdles.

Environmental Regulations: Near Future

While environmental regulations were not crucial to consider while developing a launch vehicle in the past, they will increasingly become relevant in the coming years. Expert 3 and Expert 5 discuss the trend towards stricter environmental regulations based on past developments (particularly around the concern of *Space Debris*) in the near future:

> *Less than five years ago, they were talking about regulating the time your satellite spends in orbit and proving that it will deorbit. Now, that's already being applied. Looking at how much gas your launch puts out and proving how you're offsetting that impact is coming up in the next 5 to 10 years.* - Expert 3

> *The environmental impact would be indeed the Issue which now, FAA is raising about the lifetime of the satellite Orbit. So they want to reduce it to the five years before the end of the duration and having their active deorbiting, you can use on board, and get as much less impact on the space in terms of the Space debris as possible would be indeed one of the priorities for the small launch vehicles.* - Expert 5

The groundedness analysis for "Environmental Regulations: Near Future" indicates that this factor is supported by 2 occurrences across two experts 3 and 5 (refer table 6.5). This suggests that there is a recognition among experts that near-term environmental regulations are beginning to take shape, particularly concerning space debris and the environmental impact of satellite launches. The insights provided highlight the growing importance of these regulations in the industry's immediate future.

Environmental Regulations: Far Future

While other experts are sceptical about immediate regulatory impacts, there is consensus on long-term changes. Expert 4 remains cynical about immediate regulatory influence but acknowledges future impacts:

> *I don't think that environmental regulations will have a very big influence anytime soon from a regulatory aspect. That's because we will not be able to figure out whose sovereignty that part of the atmosphere actually is.* - Expert 4

Expert 1 suggests that significant environmental regulations may not be imminent but are inevitable in the long run:

> *I don't think environmental regulations are coming in the next five years and maybe further even.* - Expert 1

The groundedness analysis for "Environmental Regulations: Far Future" shows 3 occurrences across three experts 1, 4, and 7 (refer table 6.5), indicating that while there is some scepticism about the immediate impact, there is a consensus on the inevitability of future environmental regulations. These insights emphasize the need for the industry to prepare for long-term changes in environmental regulations to ensure sustainable operations.

Considering Environmental Regulations Crucial

Despite the difference in the expected timeline of environmental regulations by experts, it is crucial to consider them, a well-known example of this is the recent collapse of Canadian space start-up SpaceRyde, which filed for bankruptcy after a cascade of events due to not following proper regulations and had to shut down after noise-complaints from neighbours (Rainbow, 2023). Based on similar examples[6], Expert 4 emphasizes the impact of environmental regulations on development timelines and the necessity for thoughtful implementation:

> *What you've seen in the launch site in northern Scotland are quite a few challenges to get licenses there. It's understandable if people were to build alongside my backyard, I'd ask about pollution levels. We should ensure we don't just wipe out nature reserves. Environ-*

[6] refer Foust (2023)

mental reports are crucial and will definitely impact and potentially delay developments. - Expert 4

Expert 7 highlights the long-term necessity of a regulatory framework to address environmental concerns. They emphasize that while the current number of launches has minimal impact, increasing the frequency tenfold will make it a dominant factor that national agencies will eventually need to study and address, particularly for vehicles like Starship using methane.

> *With the current number of launches, the impact is minimal, but if you want to do 10 times the launches, it will become the dominant factor. National agencies will need to study and address this eventually.* - Expert 7

> *Eventually, the impact of launches, especially from vehicles like Starship using methane, will necessitate a regulatory framework. I can't see the space business existing without such a framework being established in the next 20 years.* - Expert 7

The groundedness analysis for "Considering Environmental Regulations Crucial" indicates that this factor is supported by 3 occurrences across three experts 4, 5, and 7 (refer table 6.5). This demonstrates that several experts recognize the increasing importance of environmental regulations in the near future. Key insights include the necessity for thorough environmental impact assessments, the trend towards stricter regulations, and the anticipated long-term need for a regulatory framework to address environmental concerns. While the current number of occurrences is relatively low, the experts' insights highlight the critical need for the micro launch industry to adapt to evolving environmental regulatory requirements to ensure sustainable operations.

In summary, a total of 11 occurrences were noted across several factors, including the crucial importance of environmental regulations, both in the near and far future, and the operational challenges posed by regulatory requirements (refer table 6.5). The analysis underscores the need for the industry to adapt to evolving regulatory landscapes to ensure sustainable operations and long-term success.

6.3.3. Barrier to Entry

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Totals
Niche Market for Micro Launchers Gr=6	2	1	2	0	1	0	0	6
Competition from other Miro Launchers Gr=2	0	0	0	0	1	0	1	2
High Technological Challenges Gr=8	1	1	1	1	0	1	3	8
Competition form Larger LVs Gr=17	6	5	1	2	1	2	0	17
Competition from Starship Gr=14	4	1	2	2	0	3	2	14
Totals	13	8	6	5	3	6	6	47

Table 6.6: Groundedness Analysis Table for Barrier to Entry.

Niche Market for Micro Launchers

Micro launchers primarily serve a niche market, targeting specific customer needs such as rapid deployment and precise orbital insertion. This niche focus limits the overall market size and the number of potential customers.

Expert 1 emphasizes the limited market:

> *Yeah, it's still like a niche, so that's the market we see with Rocket Lab.* - Expert 1

Expert 5 elaborates on the niche aspect of the market:

> *So one of the reasons why small launch vehicles were seen as super attractive to the customer was because they can place the satellite in the exact orbit at the exact time. But for the vast majority of customers, there is no benefit there.* - Expert 5

The analysis shows a total groundedness of 6 occurrences across three experts 1, 2, and 5 (refer table 6.6). This indicates a moderate recognition of the niche nature of the micro launch market, emphasizing the limited market size and specialized customer needs.

Competition from Other Micro Launchers

The micro launch market is becoming increasingly crowded, with numerous companies entering the field, each vying for a limited number of launch opportunities. This saturation creates significant barriers to entry, making it difficult for new entrants to establish themselves and gain a foothold in the market.

Expert 5 highlights the competitive landscape:

> *I've calculated the number small rocket startups coming to the market and I just stopped counting when it was more than 100 names in my list ...* - Expert 5

Expert 7 also notes the intense competition and the potential for market consolidation:

> *There are a number of new players that entered the market, and not all of those will succeed. It might be better with market consolidation over a period of time.* - Expert 7

The analysis shows a groundedness of 2 occurrences across two experts 5 and 7 (refer table 6.6). This indicates a lower frequency of mention but when seen in combination with the previous theme of “Niche Market for Micro Launchers” highlights the significant competitive pressure within the micro launch market from numerous entrants in a niche market.

Competition from Larger Launch Vehicles

Micro launch companies face significant competition from larger launch vehicles, which can offer more cost-effective solutions due to economies of scale. Larger vehicles like SpaceX’s Falcon 9 and the upcoming vehicles like Neutron, Terran R, and Starship can reduce the cost per kilogram significantly, making it difficult for micro launchers to compete[7].

Expert 2 discusses the cost advantages of larger launch vehicles:

> *The much lower cost per kilogram to launch on larger vehicles is the driving force. We are typically talking about U$25,000/kg on an Electron Micro-LV, about five-ten times higher compared to the Medium-LV Falcon 9.* - Expert 2

Expert 1 highlights the impact of larger launch vehicles on market dynamics:

> *In the second half of the 2020s, the competition will drive prices down temporarily, but achieving profitability will be tough with low prices. This temporary phase will stabilize the market price, allowing some companies to become profitable.* - Expert 1

> *They are a lot of delays [for Micro-Lvs] and maybe what what will impact more than Starship is all the other bigger rockets, medium and heavy launchers. So like if you see neutron, if you see Terran like, they also need customers. So we'll have bigger rockets launching. I don't know, maybe every week from many companies, so I think that will be the impact to small rockets. And I'm sure some of those bigger rockets will also go to different orbits, then perhaps, that will probably be the bigger impact in the next five years and then five plus will be a Starship will impact both small launchers and OTVs.* - Expert 1

Furthermore, Expert 1 adds that the upcoming medium-heavy launchers will be the primary concern for the micro and small launchers in the near future, rather than Starship, which will have a significant impact later on for both micro launchers and OTVs. This leads us to our next section on competition from starship.

The analysis shows the highest groundedness with 17 occurrences across six experts 1, 2, 3, 4, 5, and 6 (refer table 6.6). This indicates a broad and strong recognition of the intense competition from larger launch vehicles, which can offer more cost-effective solutions due to economies of scale.

[7] Upcoming medium, heavy, and super heavy launch vehicles include Neutron, Terran R, New Glenn, and Starship. Neutron is being developed by Rocket Lab (https://www.rocketlabusa.com/), Terran R by Relativity Space (https://www.relativityspace.com/), New Glenn by Blue Origin (https://www.blueorigin.com/), and Starship by SpaceX (https://www.spacex.com/).

Competition from Starship

In the near term, SpaceX's Starship is not expected to significantly lower launch prices. The complexities involved in developing, testing, and operationalizing such a massive and advanced vehicle mean that cost reductions will not be immediate.

Expert 1 emphasizes this delay in cost reduction:

> *I think it will take many, many years for Starship to regularly launch and actually see those cost decreases into launch.* - Expert 1

Expert 7 highlights the operational and logistical challenges that contribute to this:

> *Coordinating the effort of getting a large number of satellites in line for launch and integrating them properly is a significant challenge, making it hard to believe the costs could be as low as projected anytime soon.* - Expert 7

In the long term, however, Starship has the potential to reduce launch costs drastically. As the technology matures and SpaceX optimizes its operations, the economies of scale and reusability could lead to significant price drops.

Expert 1 acknowledges the eventual benefits:

> *Starship won't automatically lower the prices, but eventually, yes, of course, it will make OTV cheaper to launch and then OTV competition will be stronger against dedicated launchers.* - Expert 1

Expert 2 emphasizes the transformative potential of Starship:

> *SpaceX's Super Heavy-LV Starship, to be fully recoverable and reusable, will represent the real revolution in the LV industry.* - Expert 2

As Starship achieves lower prices and higher launch frequencies, it will pose a significant threat to micro launchers. The ability to launch larger payloads at reduced costs will make it difficult for smaller rockets to compete.

Expert 6 points out the potential market disruption:

> *If Starship becomes 600 instead of 6000 per kilogram, barely anyone will be willing to pay the premium for smaller launches. It will be very difficult for small launchers, especially anything expendable, to have a future.* - Expert 6

Expert 7 also sees a substantial impact on micro launchers:

> *It will lower the price point even more and establish a monopoly, potentially wiping out most small launch providers.* - Expert 7

Starship's capabilities will enhance the value proposition of Orbital Transfer Vehicles (OTVs). By providing cheaper and more frequent launches, Starship will make it feasible for OTVs to offer more flexible and cost-effective solutions for satellite deployment.

Expert 1 highlights this potential:

> *Starship won't automatically lower the prices, but eventually, it will make OTV cheaper to launch, strengthening OTV competition against dedicated launchers.* - Expert 1

Expert 4 discusses the strategic implications:

> *People are looking at making very big satellites because if you can pay for a couple of thousand kilograms, you can have a delta V that is humongous and get your OTV delivering satellites where they need to go faster.* - Expert 4

While Starship itself may not lower prices immediately, the ability to piggyback on its missions could offer cost-effective opportunities for smaller payloads, enhancing accessibility for various stakeholders.

Expert 3 notes the potential for piggybacking:

> *Maybe piggybacking on Starship, but rideshare dedicated, no.* - Expert 3

Starship's rideshare missions could intensify competition for micro launchers by offering significantly lower costs and more frequent launch opportunities, making it harder for smaller rockets to justify their premium prices.

Expert 3 discusses the competitive threat:

> *If you have the transporter on the Falcon, with three or four launches, you take a large portion of the new space market.* - Expert 3

Expert 6 elaborates on the competitive dynamics:

> *If Starship's costs drop significantly, it will be difficult for small launchers to compete, especially for those offering expendable rockets.* - Expert 6

The analysis shows a groundedness of 14 occurrences across five experts 1, 2, 3, 4, 6, and 7 (refer table 6.6). This indicates a significant concern about the future competitive threat posed by SpaceX's Starship, which has the potential to drastically lower launch costs and disrupt the micro launch market.

High Technological Challenges

The high costs and technical expertise required to enter the micro launch market are significant barriers to new entrants. Established companies benefit from economies of scale and more substantial financial backing, making it difficult for new startups to compete.

Expert 6 highlights the cost dynamics:

> *You have the cost of the vehicle. Now that scales with size, not linearly. So it's already the case that per unit of payload mass, a larger launch vehicle will be cheaper to build than a small one.* - Expert 6

Expert 7 discusses the challenges of maintaining technological and financial balance:

> *It's not going to be a fight-ready vehicle just around the corner, meaning they will be able to underpin it with a business case on Electron.* - Expert 7

The technological demands of developing a reliable launch vehicle are immense. High costs and technical complexities make it difficult for new companies to achieve the required level of performance and reliability. Developing reliable and efficient launch vehicles is a significant technological challenge. Constant innovation and ensuring safety and reliability add to the complexity and cost of operations.

Expert 4 points out the evolving market dynamics:

> *Economies of scale don't work along with your business case. The vehicles that they have developed were based on the situation that probably was from 5 to 10 years ago and the market developed faster in that sense than when you look at the growth of the satellites.* - Expert 4

Expert 6 emphasizes the need for reusability:

> *Reusability is very required. You want to get the cost basis down because you can't maintain 40,000 kilo prices if the going rate on Starship will be 600, So you need to go down in your price.* - Expert 6

Expert 1 underscores the inherent technological challenges:

> *If you want to build hardware which is profitable in other space companies, it's even harder with the launch industry because rockets cost a lot. Smaller rockets still need many of the components that big rockets have, so there is a limit to how cheap you can go.* - Expert 1

Expert 7 discusses the technological failures and the need for resilience:

> *The proof is being able to handle failures because there are not many launches that exist that haven't had a failure at some time. You need to be able to work out how you absorb that as a business.* - Expert 7

Achieving resilience in the face of technological hurdles is crucial for the survival and growth of micro launch companies. This involves not only overcoming initial development challenges but also ensuring long-term operational viability.

Expert 7 emphasizes the importance of resilience and strategic planning:

> *It's making sure you can cope with failure. It's making sure that you do have an anchor customer. It's making sure your business model works and looking to the future to ensure you still have an effective business in five years' time.* - Expert 7

The analysis for "High Technological Challenege" shows a groundedness of 8 occurrences across five experts 1, 2, 3, 4, 6, and 7 (refer table 6.6). This indicates a strong consensus on the substantial technological barriers to entry, including high costs and technical expertise required for developing reliable launch vehicles.

Overall, the groundedness analysis highlights that the most critical barriers to entry in the micro launch industry are the competition from larger launch vehicles and the high technological challenges, followed closely by the emerging threat from SpaceX's Starship (refer table 6.6). The niche market focus and competition from other micro launchers are also important but comparatively less frequently mentioned barriers.

6.3.4. Financial Management and Funding

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Totals
Low Profitability of Space Companies Gr=2	1	0	0	0	0	1	0	2
Cash Flow Management Gr=1	0	0	0	0	0	0	1	1
Continuosly Raising Capital Gr=3	1	0	0	1	0	1	0	3
Future Bankruptcies Gr=8	2	1	2	1	1	1	0	8
Negative Market Outlook: Micro Launchers Gr=8	1	3	2	1	1	0	0	8
Totals	5	4	4	3	2	3	1	22

Table 6.7: Groundedness Analysis Table for Financial Management and Funding.

Low Profitability of Space Companies

Achieving profitability in the space industry is notoriously difficult. The high costs associated with developing and launching rockets, combined with competitive pressures to lower prices, result in thin margins and financial instability for many companies.

Expert 1 highlights the profitability challenge:

> *It's really hard to make a space company profitable at all. If you want to build hardware which is profitable in other space companies and then it's even harder with launch industry because rockets cost a lot and like smaller rockets still needs a lot of the components that big rockets have.* - Expert 1

The analysis shows a groundedness of 2 occurrences from two experts 1 and 6 (refer table 6.7). This highlights the challenge of achieving profitability in the space industry due to high costs and competitive pressures to lower prices.

Cash Flow Management

Managing cash flow effectively is critical for micro launch companies, given the high costs and extended timelines associated with developing and launching rockets. Continuous investment is necessary to sustain operations until revenue can be generated from successful launches. Expert 6 elaborates on the financial challenges:

Expert 7 highlights the importance of a sound business plan and managing cash flow:

> *We need to establish a business plan on the basis of sound and actual assumptions that can be executed. Fail fast in development and don't run out of cash.* - Expert 7

The analysis shows a total groundedness of 1 occurrence from Expert 7 (refer table 6.7). This indicates a limited mention but combining it with the other sections underscores the critical importance of effective cash flow management for micro launch companies to sustain operations until revenue generation.

Continuously Raising Capital

Given the capital-intensive nature of the space industry, micro launch companies must continually raise funds to cover operational expenses, research and development, and unexpected delays. The ability to secure ongoing investment is crucial for survival.

Expert 1 underscores the importance of raising capital:

> *If you can't make your company profitable and if you can't raise more rounds like that's it, I guess either someone buys you or you go bankrupt. I think we'll see a lot and lot of bankruptcies.* - Expert 1

Securing venture capital and maintaining long-term financial support are critical challenges. The high risks and long development timelines associated with the micro launch industry make it difficult to attract and retain investors.

> *On the financial side, I would have thought this is a very challenging business case to say we need to invest between 8 and 10 years before the first revenue was made.* - Expert 6

Expert 4 highlights the necessity of financial support for long-term sustainability:

> *Without support, and having that longer-term sustainability in place like SpaceX did, investors may not be as willing to invest because it's purely based on varying factors.* - Expert 4

The analysis shows a groundedness of 3 occurrences across three experts 1, 4, and 6 (refer table 6.7). This highlights the significant challenge of securing ongoing investment, which is crucial for covering operational expenses, research, and development

Future Bankruptcies

The combination of high costs, long development timelines, and intense competition makes future bankruptcies likely within the micro launch industry. Companies that cannot secure sufficient funding or achieve profitability will struggle to survive.

Expert 5 predicts further bankruptcies:

> *Yes, definitely, there would be further bankruptcies.* - Expert 5

Expert 3 also emphasizes the expected market shakeout:

> *So for sure, I think not all of those will survive and also realistically, there's not enough market.* - Expert 3

Expert 2 notes the limited market potential:

> *Micro-LVs are the best option if there is an urgency to launch a SmallSat, either for commercial or military reasons; however, the resulting low launch cadence may provide profitable business to only a few micro-LV providers.* - Expert 2

The analysis shows a groundedness of 8 occurrences across six experts 1, 2, 3, 4, 5, and 6 (refer table 6.7). This indicates a strong consensus on the likelihood of future bankruptcies due to high costs, long development timelines, and intense competition. The high number of occurrences reflects widespread concern about financial stability within the industry.

Negative Market Outlook for Micro Launchers

The overall market outlook for micro launchers is negative due to limited demand and intense competition from larger launch vehicles and established players like SpaceX. The market size is not sufficient to support a large number of micro launch companies.

Expert 1 discusses the market limitations:

> *Perhaps, it's still not like a billion-dollar market that was claimed by many of the pitch decks and yeah, I don't think there is room for, too many players. Maybe there is room for one or two players in the Western world, and one or two in in China.* - Expert 1

Expert 2 and Expert 5 also comments on the market constraints:

> *There are studies done in 2022, which predict there will not be market for more than five Micro-LVs.* - Expert 2

> *Up to 10. Because It's not even the question of individual surviving of the small launch vehicles companies, it's the question that in general there is not much satellite customers for that niche. You can have 20 small launches ready to launch tomorrow, but we don't have 20 customers. So, there's just not demand there.* - Expert 5

The analysis shows a groundedness of 8 occurrences across five experts 1, 2, 3, 4, and 5 (refer table 6.7). This indicates a significant concern about the limited market demand and intense competition from larger launch vehicles, which constrains the market size for micro launch companies.

Overall, the groundedness analysis indicates that the most critical financial management and funding challenges in the micro launch industry are the continuous need for raising capital and the negative market outlook (refer table 6.7). There is also a strong consensus on the potential for future bankruptcies and the low profitability of space companies. Cash flow management, while less frequently mentioned, remains a critical factor for sustaining operations.

6.3.5. Challenges of Human Resources

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Totals
Burnout In Launch Industry Gr=1	0	0	1	0	0	0	0	1
Talent Acquisition of Skilled Workforce Gr=2	0	0	0	1	0	0	1	2
Talent Retention of Skilled Workforce Gr=1	0	0	0	0	0	1	0	1
Totals	0	0	1	1	0	1	1	4

Table 6.8: Groundedness Analysis Table for Geopolitical Factors.

Talent Acquisition of Skilled Workforce

Attracting skilled talent is a significant challenge in the launch industry. The sector requires highly specialized skills in engineering, aerodynamics, propulsion, and other technical areas, making it difficult to find qualified candidates. The competition for top talent is fierce, with companies vying to attract and retain the best engineers and scientists This factor has a groundedness score of 2, with insights from Experts 4 and 7.

Expert 4 discusses the difficulty in hiring skilled personnel:

> *The lack of experienced people to hire to actually do the operations is even bigger than the engineering part right now. We see people fighting each other for the knowledgeable engineers who are the best in the field of aerodynamics, propulsion, and other parts.* - Expert 4

Expert 7 notes the importance of adequate facilities and support:

> *Talent is a big factor in this, but the facilities are an area where you need an inordinate amount of cash to get just the basic capability.* - Expert 7

Burnout in the Launch Industry

The launch industry is known for its intense work environment, which can lead to high-stress levels and burnout among employees. The demanding nature of the job, coupled with tight deadlines and high stakes, often results in employees experiencing fatigue and job dissatisfaction. With a groundedness score of 1, this factor is supported by Expert 3 (refer table 6.8).

> *Typically they also burn out quite quickly and stop doing it or go to another industry because it's just too much in the Launch industries. We have heard. It's tough.* - Expert 3

Talent Retention of Skilled Workforce

Once skilled workers are hired, retaining them becomes another significant challenge. The high-pressure environment and demanding work schedules can lead to job dissatisfaction and high turnover rates. Companies must provide a supportive work environment and opportunities for growth to keep their employees engaged and committed. This factor also has a groundedness score of 1, supported by Expert 6.

Expert 6 emphasizes the importance of career growth opportunities:

> *If there is flexibility and room to grow one way or the other, it's much easier to retain talent. If that opportunity is not there, then I think it's much harder to retain talent.* - Expert 6

Overall, the groundedness analysis reveals that human resource challenges in the micro launch industry are primarily focused on attracting and retaining skilled talent while managing the high-stress environment that can lead to burnout. Despite the low total groundedness score of 4 across these factors, considering the experts' backgrounds (refer to table 3.1) helps understand the emphasis on this theme. Two experts who mentioned these challenges are executives from micro launch companies, while the other two have extensive experience working closely with launch companies throughout their careers.

6.3.6. Geopolitical Factors

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Totals
Geopolitcs: Opportunites for Micro LV Gr=9	0	1	1	3	1	1	2	9
Geopolitical Factors change SOM Gr=2	0	1	0	1	0	0	1	3
National Security and Sovereignty Drive Investments Gr=6	1	1	1	1	0	1	1	6
Totals	1	3	2	5	1	2	4	18

Table 6.9: Groundedness Analysis Table for Geopolitical Factors.

Geopolitical Factors Change SOM

Geopolitical factors significantly impact the Serviceable Obtainable Market (SOM) for micro launch vehicles (LVs). These factors can pose challenges to the market, altering demand dynamics and influencing the viability of various players in the industry. Political tensions, national security concerns, and shifts in international relations can all affect market access and competitive landscapes.

> *And regarding geopolitics, the current global situation has a significant impct. While it ensures enough budget for defence applications and increases interest in that sector, the delicate international relations make it unpredictable for commercial ventures. Companies cannot be certain about the stability of international relationships over the next decade, which poses a major threat. This unpredictability necessitates substantial support at the national level rather than relying solely on international agreements. Political support is essential, with government representatives needing to engage in dialogue to resolve these issues.* - Expert 4

> *Brazilian governments satellites, they call it ... , they are launched from China, by Chinese Long March launchers. It's a political thing, you see. It's not commercial, so the Chinese Government and the Brazilian government, they have the interest of developing like relationship among them, So it doesn't matter too much to be quite honest about the quality and the consequences of that project.* - Expert 2

This factor has a groundedness score of 3, with mentions by Experts 2, 7 and 4, highlighting the impact of geopolitical factors on the market dynamics for micro launch vehicles (refer table 6.9).

Geopolitics: Opportunities for Micro LVs

Despite the challenges, geopolitical factors also present significant opportunities for micro launchers. National security concerns and the desire for sovereign launch capabilities drive investments in micro LVs. Governments are increasingly willing to fund and support domestic launch capabilities to ensure access to space, which creates opportunities for micro launchers to secure contracts and subsidies.

Expert 6 underscores this dual nature of geopolitical factors:

> *Yeah, I think geopolitics is both a challenge and an opportunity because the whole region of existence of many of these initiatives is to provide a sovereign alternative. In the last year or two, there has been more government interest in various small launch companies.* - Expert 6

Furthermore, Expert 2 emphasizes the importance of considering geopolitical factors:

> *... So apparently Europe has already realized the danger that is right now in relying too much on the Americans. You can imagine what would happened if, Donald Trump, is elected and there is the risk that will be elected or re-elected in the US, so this the political thing. It's very, very, very important to consider. It might happen that you conclude that there is no commercial viability for micro launch vehicle in Europe, but in terms of, sovereignty and the politics, it's essential that, Europe has its own satellite launchers.* - Expert 2

This factor has a groundedness score of 9, with mentions by Experts 2, 3, 4, 5, 6, and 7, indicating the significant opportunities presented by geopolitical factors for the micro launch industry (refer table 6.9).

National Security and Sovereignty Drive Investments

National security and sovereignty concerns are major drivers of investments in the micro launch industry. Countries seek to develop independent space capabilities to reduce reliance on foreign providers, which can be critical in times of geopolitical tension. This drive for self-sufficiency often translates into governmental support and funding for domestic launch providers.

Expert 4 explains the importance of national security in driving investments:

> *You see huge movements in that continental level as well. Making sure that we have at least a few European vehicles capable of bringing up satellites. The fact that it costs like 2 - 3 times, maybe four times more, then will turn out to be acceptable also from an economic point of view, to ensure jobs and maintain knowledge.* - Expert 4

Expert 5 provides further insight into the strategic importance of national capabilities:

> *If they (Micro LVs) provide offerings close to the pricing of SpaceX with their launch fees, they would potentially have their own client base here, for example, in Europe.* - Expert 5

Furthermore, this factor has a groundedness score of 6, with mentions by Experts 1, 2, 3, 4, 6, and 7, highlighting the crucial role of national security and sovereignty in driving investments in the micro launch sector (refer table 6.9).

Overall, the groundedness analysis for geopolitical factors reveals a total groundedness of 18 occurrences across three main themes (refer table 6.9). This indicates the significant impact of geopolitical considerations on the micro launch market, both in terms of challenges and opportunities. The analysis underscores the importance of national security and sovereignty in driving investments and highlights the dual nature of geopolitical factors as both challenges and opportunities for the industry.

6.3.7. Section Summary

To conclude this section, the challenges faced by micro launch companies in the current market are both complex and multifaceted. Overcoming these obstacles necessitates innovative solutions, strategic investments, and a profound understanding of market dynamics. The table 6.10 provides a comprehensive summary of the key challenges encountered by the micro launch industry, along with the specific factors contributing to each challenge.

Challenges	Factors Contributing to Challenges
Barrier to Entry	- Niche Market for Micro Launchers - Competition from Other Micro Launchers - High Technological Challenges - Competition from Larger LVs - Competition from Starship
Developing a Sustainable Business Model	- Challenging Operational Execution - Importance of a Sustainable Business Model - Limitations of High Launch Cadence
Financial Management and Funding	- Cash Flow Management - Continuously Raising Capital - Future Bankruptcies - Low Profitability of Space Companies - Negative Market Outlook for Micro Launchers
Regulatory Hurdles	- Considering Environmental Regulations Crucial - Environmental Regulations: Far Future - Environmental Regulations: Near Future - Regulatory Challenges for Operations
Human Resources	- Burnout in Launch Industry - Talent Acquisition of Skilled Workforce - Talent Retention of Skilled Workforce
Geopolitical Factors	- Geopolitical Factors Change SOM - Geopolitics: Opportunities for Micro LVs - National Security and Sovereignty Drive Investments

Table 6.10: Summary of Challenges and Factors in the Micro Launch Industry.

6.4. Recommendations from Experts

The previous sections outlined the significant challenges micro launch companies face, including business model limitations, financial management issues, and human resource difficulties. The following expert recommendations provide strategic insights on navigating these obstacles to establish a sustainable presence in the market.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Totals
Diversify Offerings and Adopt Reusability Gr=7	1	0	1	0	0	4	1	7
Change Launcher Segments Gr=4	1	1	0	0	0	1	1	4
Governments as Anchor Customer Gr=4	0	0	0	0	0	3	3	6
Standardization of Microsatellites and Compliance Gr=5	1	0	0	2	0	2	0	5
Strategically Lobby Governments Gr=2	0	0	0	0	1	0	1	2
Totals	3	1	1	2	1	8	6	24

Table 6.11: Groundedness Analysis Table for Geopolitical Factors.

Diversify Offerings and Adopt Reusability

Diversifying offerings beyond just launch services can provide additional revenue streams and resilience against market fluctuations. This could include developing related technologies or services that leverage the expertise gained from launch vehicle development.

Expert 7 highlights the benefits of diversification:

> *Having more products gives you resilience. The balance between large and small launch vehicles provides the same type of resilience.* - Expert 7

Expert 6 stresses the importance of reusability

> *Reusability is very required. I think that is 100% required to get that cost basis down. especially if you want to get the cost basis down because like you can't maintain 40,000 kilo prices if the going rate on Starship will be 600 or whatever it is, let's say below 1000, that is what they're aiming for. You can't maintain such a huge difference, so you need to go down in your price. Which in the field to economically survive, that means your cost also has to come down and you can't get your cost down if you're doing everything the old way.* - Expert 6

The recommendation to diversify offerings and adopt reusability was the most frequently mentioned, with a groundedness score of 7 (refer table 6.11). Experts 1, 3, 6, and 7 emphasized the importance of developing multiple revenue streams and implementing reusable technology to reduce costs and increase competitiveness

Change Launcher Segments

Experts suggest that micro launch companies should consider transitioning to developing larger launch vehicles. As the market for micro launch vehicles becomes increasingly saturated and competitive, shifting focus to medium or large launch vehicles can provide a more sustainable business model.

Expert 2 recommends leveraging know-how to develop larger launch vehicles:

> *The only thing they can do is to use the technical and commercial know-how, acquired by developing Micro-LVs, to the development of larger LVs.* - Expert 2

Expert 6 underscores the importance of this change as the trends set by bigger players in the utilization of microsatellites are increasing, particularly those set by major space market players like the US military.

> *I guess the trend is that balance shifts upwards towards the middle category somewhere. And that might then also be a thing that there has been some more standardization on interface for larger satellites as well. Then also you probably want to be able to be compliant with those standards. So when especially the US military rolled out a lot of new projects around ESPA and SPA grounding standards. Then as a launch vehicle, you want to be able to launch at least one of those because, the US is like 60-70% of the global space market. U.S. government is the majority of the US market. So you can't really afford to miss out on that and not be compatible with that.* - Expert 6

The suggestion to change launcher segments, particularly transitioning to larger launch vehicles, received a groundedness score of 4 (refer table 6.11). This recommendation was supported by Experts 1, 2, 6, and 7, indicating a strategic shift towards more sustainable market segments.

Microsatellite Standardization and Compliance

Expert 4 recommends setting an international standard or agreement for the virtual bounding box of microsatellites. This standardization is crucial to prevent inefficiencies and conflicts in space utilization caused by varied satellite designs.

> *How can we set an international standard or agreement on what would be a virtual bounding box for microsatellites because as soon as you leave the box, people will start engineering in a way that... you're taking up more real estate... It's not the mass issue anymore but a volume issue.* - Expert 4

> *Compliance to Larger satellites. I mean, if there is another segment, the micro launcher could launch are microsatellite and then if there is a regulation that standardizes it, then this could change as well.* - Expert 6

To incentivize adherence to the bounding box, Expert 4 suggests a pricing strategy where customers pay less if they stay within the box and more if they exceed it. This could prevent larger microsatellites from encroaching on the space needed for others.

> *If you stay within this box, this is your price. If you go outside of that box, pay a penalty for taking up space that is not yours.* - Expert 4

Standardizing microsatellites and ensuring compliance was highlighted by Experts 4 and 6, resulting in a groundedness score of 5 (refer table 6.11). This recommendation underscores the need for international standards to optimize space utilization and regulatory adherence.

Strategically Lobby Governments

One of the key strategies experts suggest is for micro launch companies to lobby governments to secure contracts and subsidies actively. Given the importance of national security and sovereignty, governments are often willing to support domestic launch capabilities to ensure access to space. This support can be critical for micro launchers to gain a foothold in the market.

Expert 5 emphasizes the importance of strategic lobbying:

> *They could probably lobby a little bit. They can lobby the customers and the governments in a way that, for example, payloads developed and payloads made in the EU should have the first launch within the European launch vehicles.* - Expert 5

Strategically lobbying governments to secure contracts and subsidies was mentioned by Experts 5 and 7, achieving a groundedness score of 2 (refer table 6.11). This approach is seen as crucial for gaining governmental support and fostering a favourable regulatory environment.

Governments as Anchor Customer

Securing a government as an anchor customer can significantly enhance a micro-launch company's credibility and attract private investment. Government contracts provide a reliable revenue stream and demonstrate the company's capability to deliver critical services. This strategic approach can create a more stable and supportive environment for the nascent space industry, encouraging innovation and competition.

Expert 6 suggests that governments need to evolve their policies to support the dynamic nature of the New Space ecosystem. Historically, governments have often chosen winners before the race, funding specific companies without proven capabilities. This practice can stifle competition and innovation.

> *Yeah, I think what is problematic with governments is that, especially historically, they don't just specify their demand. They kind of pick the winner before the race even starts. Even recently, when governments started to support some of these small launch companies, no one had proven anything yet, but they still decided to fund specific companies.* - Expert 6

Expert 6 proposes a strategic shift where governments specify their demand without dictating the solution to address this. By creating a schedule for launches and allowing companies to bid for these opportunities, the market can become more competitive and innovation-driven.

> *Is it better for the government to—you know, we all talk about commercial space, but at the end of the value chain, there's often a government involved. Look at Copernicus or other projects. Just thinking hypothetically here, let's say in the next 10 years we have 100 medium to large satellites and another hundred CubeSats and Microsats to launch. The government could create a schedule for these launches and allow companies to bid. Those who offer the best conditions would win the bid, but they would only be paid upon delivery. This way, the winners aren't picked before the race even starts, but a strong demand signal is still created.* - Expert 6

This approach would enable companies to leverage government contracts to attract private investment, reducing economic risk and focusing on technical execution.

> *A company could then go to an investor and say, "Look, there's this contract, and all that stands between us and winning that deal is proving we can do it. So invest." This approach would remove the economic risk for the investor, leaving only the technical risk. I think this is the role governments should play, but historically they haven't. Whenever they fund anything in launch, it's typically by subsidizing a player that hasn't proven anything yet, so the other companies don't even get a chance. Specify the demand, don't specify the solution.* - Expert 6

Expert 7 underscores the importance of having an anchor customer to secure private investment and enhance business credibility.

> *Initially, it's crucial because developing a launcher requires substantial capital investment. Beyond mere capability, securing funding involves attracting investors. Investors often seek a pipeline, and having a strong anchor tenant further encourages investment. While subsidies aren't always necessary, consider SpaceX's success—they secured NASA contracts, providing that essential anchor. As a launch provider, having backing from a national or international agency, such as the European Space Agency or the European Commission, simplifies attracting private investment. So, while key, ongoing subsidies signal that it's not purely a commercial venture.* - Expert 7

Furthermore, fostering a regulatory environment that encourages innovation and competition is vital. Expert 7 highlights the European Space Agency's (ESA) efforts to break monopoly and encourage commercial providers (Parsonson, 2023).

> *I think governments could improve. I think ESA is moving that way gradually. They broke the monopoly with ArianeGroup* [8] *and announced this European Launch Challenge to encourage commercial providers to enter the field, similar to NASA's COTS program. If they can guarantee a baseline amount of work, these companies can become commercially successful while being competitive on a global level.* - Expert 7

Moreover, governments should provide strategic support to demonstrate national interest and attract private funding.

> *So it's very much about demonstrating national interests or strategic support from institutional partners to attract private funding. If you approach this with no institutional or governmental support, the business case is simply more difficult to close.* - Expert 7

Finally, securing governments as anchor customers was emphasized by Experts 6 and 7, with a groundedness score of 6 (refer table 6.11). This strategy is critical for stabilizing revenue, attracting private investment, and enhancing business credibility through reliable government contracts.

Overall, the groundedness analysis for the recommendations section shows 24 occurrences across various sub-themes, indicating strong support from the experts. This high level of groundedness underscores the relevance and importance of these recommendations in addressing the challenges micro launch companies face.

6.5. Summary

The results of this study provide a comprehensive analysis of the micro-launch industry's current state, challenges, and opportunities. Several key insights emerged through semi-structured interviews with industry experts, extensive desk research, and a literature review. One significant finding is identifying factors contributing to the market bubble within the micro-launch industry (refer section 6.1). These include an abundance of liquidity, herding behaviour among investors, hyped market predictions, new investors with insufficient due diligence, and the allure of new technological advancements. The study highlights how these factors collectively fueled a speculative investment environment, leading to inflated valuations and market saturation.

Additionally, the impact of the market bubble on the industry is profound. Experts predict a wave of bankruptcies as the market corrects itself, drawing parallels with historical financial bubbles and emphasizing the unsustainable nature of the current market dynamics (refer subsection 6.1.2). The groundedness analysis confirms that these themes are well-supported by the data, underscoring these factors' significance in understanding the micro-launch industry's market bubble.

The study also delves into the drivers and challenges within the micro-launch industry. Institutional drivers, such as government investments and national security concerns, play a crucial role in the industry's development. Governments are increasingly supporting micro-launch companies to ensure independent access to space and create high-quality jobs, highlighting the strategic importance of these

[8] ArianeGroup is European Unions primary launch provider.

investments. However, the commercial drivers are influenced by unique market conditions, including the dominance of SpaceX and the constrained supply of launch services due to slow market entry and geopolitical issues (refer section 6.2).

Furthermore, the micro-launch industry faces numerous challenges (refer section 6.3). Given the high costs and limited revenue generation potential, developing a sustainable business model is a significant hurdle. The expectation of a high launch cadence is often unrealistic, and the operational complexities and financial constraints further exacerbate the difficulties. Regulatory hurdles, particularly environmental regulations, are becoming increasingly relevant, with future compliance expected to impact the industry's operations significantly. Geopolitical factors also pose challenges and opportunities, influencing the Serviceable Obtainable Market (SOM) and driving investments in domestic launch capabilities.

The financial management and funding landscape for micro-launch companies is fraught with difficulties. Achieving profitability is challenging due to high costs, long development timelines, and intense competition. The necessity for continuous capital raising and effective cash flow management underscores the precarious financial position of many companies in the sector. Moreover, human resource challenges, including talent acquisition and retention, are critical issues that impact the industry's operational efficiency and innovation potential.

Based on these findings, several strategic recommendations were provided by industry experts (refer section 6.4. Diversifying offerings and adopting reusability were emphasized as crucial for reducing costs and increasing competitiveness. Transitioning to larger launch vehicle segments was suggested to mitigate the saturation in the micro-launch market and tap into more sustainable business models. Standardizing microsatellites and ensuring compliance with international standards were highlighted as essential for optimizing space utilization and regulatory adherence. Additionally, strategically lobbying governments to secure contracts and subsidies, and positioning governments as anchor customers were recommended to enhance credibility and attract private investment.

In conclusion, the micro-launch industry is at a critical juncture, with significant challenges and opportunities shaping its future trajectory. The insights provided in this study offer a comprehensive understanding of the current state and prospects of the micro-launch sector, setting the stage for further discussion and strategic planning. The groundedness analysis reaffirms the robustness of the identified factors, emphasizing their critical roles in shaping the market dynamics and guiding industry stakeholders towards sustainable growth and innovation.

7 Discussion

Good ideas are always crazy until they're not.

Elon Musk
Founder and CEO of SpaceX

This chapter delves into the analysis and interpretation of the research findings, exploring their implications for the micro launch sector within the SmallSat launch industry. Each section addresses different aspects of the study, providing a comprehensive understanding of the subject matter. The section 7.1 helps to answer the third sub-research question:

> *Sub-Research Question 3: How does the value proposition for micro launchers benchmark against competitive solutions amid the current trends in the industry?*

Furthermore, section 7.2 aids in understanding the implication for small satellite manufacturers and answer the fourth sub-research question:

> *Sub-Research Question 4: How does the current trends affect SmallSat manufacturer's investment decisions in R&D for mass optimization of their products (e.g. CubeSat dispensers)?*

Additionally, section 7.3 discusses policy implications of this study, section 7.4 explores implications for theory and contribution to literature, and section 7.6 provides researchers' reflection on the management of technology study program. Lastly, section 7.5 on limitations and future recommendations help conclude the discussions for this study.

7.1. Benchmarking Launch Strategies, Value Proposition and Key Considerations for Micro Launchers

This section benchmarks various launch strategies for small satellites based on customer expectations and discusses the value proposition and key considerations for micro-launch companies.

7.1.1. Benchmarking Launch Strategies based on Customer Expectations

Benchmarking launch solutions is critical for updating and validating existing benchmarks, as explored in studies by Tugnoli et al. (2019a) and Falduto and Peeters (2023). This section benchmarks various launch strategies for small satellites based on key customer expectations: flexibility, price-effectiveness, convenience, and reliability (refer subsection 4.2.4). The launch strategies analyzed include Piggyback, Rideshare, Orbital Transfer Vehicles, On-board Propulsion, and Dedicated Launch on a Micro Launcher (refer section 4.3).

In this analysis, each factor is qualitatively assessed concerning the performance of different orbital launch strategies for a typical small satellite mission profile. The assessment is presented on a relative scale ranging from "very low" to "very high," facilitating a clear comparison of each strategy's strengths and weaknesses (as can be seen in table 7.1). The evaluation is based on a comprehensive approach that includes interviews with industry stakeholders, reviewing relevant literature, historical data, and launch service manuals. This multi-faceted methodology ensures a robust and informed benchmarking process.

It is important to emphasize that OTVs and On-board Propulsion strategies are relatively new approaches in the launch services market. Consequently, this assessment relies heavily on available information from Desk research and Interview Insights. As these approaches evolve, ongoing updates to benchmarks will be necessary to reflect the latest industry advancements and emerging trends.

	Piggyback	Rideshare	Orbital Transfer Vehicles	On-board Propulsion	Dedicated Micro Launches
Flexibility	Low	Medium	High	High	Very High
Price-effectiveness	Very High	High-Very High	Medium	Medium-High	Low
Convenience	Low	Medium	Medium-High	Medium	High-Very High
Reliability	High	High	Medium	Medium-High	Medium-High

Table 7.1: Assessment of current and emerging space launch strategies for smallsats concerning customer expectations subsection 4.2.4.

Regarding ***Flexibility***, the benchmarking reveals that Piggyback launches score low as the primary payload dictates the launch schedule and orbit, limiting the secondary payloads' flexibility. Rideshare options offer medium flexibility, distributing costs among multiple payloads but restricting orbits to predefined paths. Orbital Transfer Vehicles (OTVs) provide high flexibility as they can transfer payloads to specific orbits post-launch, allowing for more tailored mission profiles. On-board propulsion systems also offer high flexibility by enabling some orbit adjustment capability, although they require additional planning. Dedicated launches on micro launchers provide the highest flexibility, granting complete control over both the launch schedule and orbit, which is particularly valuable for missions with specific timing or orbital requirements.

The ***Price-effectiveness*** analysis shows that Piggyback launches are very highly cost-effectiveness due to shared costs with the primary payload. Rideshare options also score high-very high, as costs are distributed among multiple payloads. OTVs have medium cost-effectiveness, balancing additional costs for the transfer vehicle with the benefits of increased flexibility. On-board propulsion systems score medium-high in this category due to the extra functions you can get throughout the lifetime, for example, propulsion can be used for orbit manoeuvring and clash avoidance. Dedicated launches on micro launchers rank lowest in price-effectiveness, as the exclusive use of the launcher comes with significantly higher costs. However, the premium cost can be justified for missions prioritising specific launch conditions and timing.

When evaluating ***Convenience***, Piggyback launches score low because secondary payloads depend on the primary payload's schedule, leading to potential delays and coordination issues. Rideshare options offer medium convenience by being more flexible than piggyback arrangements but still limited by the needs of other payloads. OTVs provide medium-high convenience by offering post-launch flexibility, allowing payloads to reach their desired orbits without the constraints of the primary launch vehicle. On-board propulsion systems also score medium in convenience, offering some flexibility but requiring additional planning and coordination. Dedicated launches on micro launchers rank high in convenience, providing maximum ease of use through tailored launch schedules and direct control over mission parameters given that all the regulatory issues are settled-off beforehand.

Regarding ***Reliability***, Piggyback launches are rated High as they use established rockets but are subject to changes in the primary mission, which can affect the secondary payloads. Rideshare options are highly reliable, benefiting from the shared use of proven launch vehicles while distributing the risk across multiple payloads. OTVs score medium in reliability, as the additional stage introduces potential failure points despite their operational benefits. On-board propulsion systems are rated medium-high for reliability, leveraging its increasingly proven technology but still depending on the primary launch. Dedicated micro launches have a medium-high reliability, reflecting emerging technology with increasing reliability as more successful missions are conducted. Although not yet matching the long-established reliability of larger, traditional rockets, dedicated micro launches reduce risks associated with carrying multiple payloads, enhancing the focus on mission success.

In conclusion, while each launch strategy has its strengths and weaknesses (as seen in figure 7.1),

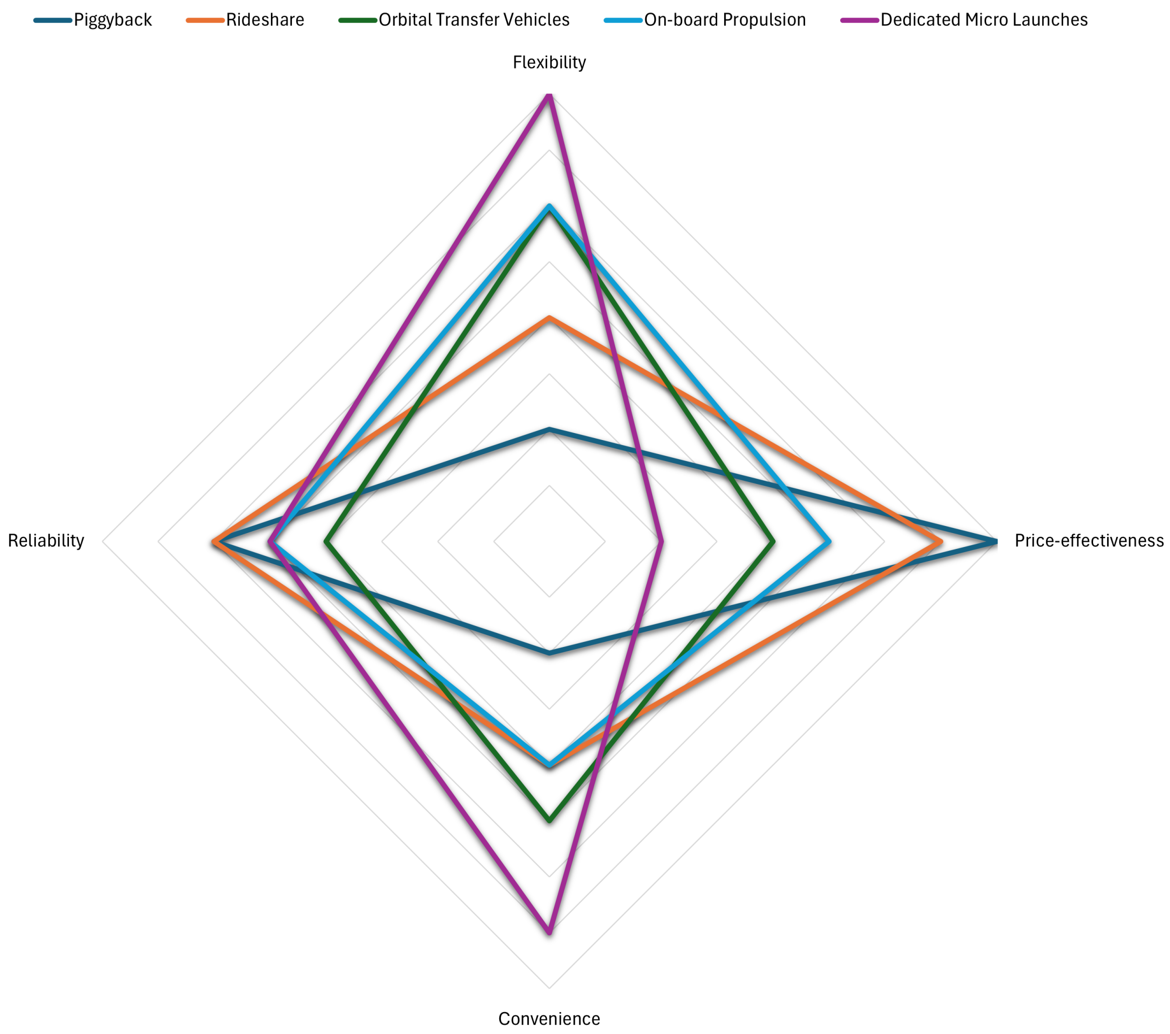

Figure 7.1: Benchmarking on launch strategies for smallsats according to the four criteria outlined in table 7.1.

the dedicated launch on a micro launcher stands out for its high flexibility and convenience, albeit at a higher cost. As more players enter the market and successfully launch smallsats, reliability is expected to improve, making micro launches an attractive option for small satellite operators who prioritize control over their launch conditions and are willing to invest in a dedicated service. Other strategies, such as piggyback and rideshare, offer more cost-effective solutions but come with trade-offs in flexibility and convenience. Orbital transfer vehicles and on-board propulsion provide intermediate options that balance flexibility and cost to varying degrees.

However, choosing a specific launch solution ultimately depends on the relative weight that different customers assign to the various benchmarked criteria. For instance, a university CubeSat project will have priorities and resources different from those of a mega-constellation operator. More specifically, a commercial company might prioritize rapid deployment of its constellation to generate revenue quickly while keeping costs reasonable. In contrast, scientific research satellites may not require rapid deployment but have specific orbital injection requirements. Universities typically seek the cheapest solution, prioritizing low prices over other factors. Governmental agencies would prefer to launch with launch providers who are better for their national sovereignty, as they can afford higher price points. For military customers, the focus will be on fulfilling all mission objectives, including reaching the target orbit promptly, regardless of launch costs. Therefore, understanding each customer's specific needs and priorities is crucial in selecting the most suitable launch strategy.

7.1.2. Value Proposition of Micro Launchers

The value proposition offered by micro launchers is, in principle, compelling. Micro launchers propose a launch service that is perfectly suited to the customer, featuring an on-demand schedule with numerous launches per year dedicated exclusively to small satellites. This level of service provides total control over mission parameters, which is a significant advantage for small satellite developers. The aim is not only to fill the gaps in current access to space solutions but also to open up new possibilities for space activities that small satellite developers can exploit. This can be achieved given that challenges discussed in section 6.3 are overcome.

Historically, price per kilogram[1] to orbit is inversely proportional to the capacity of the launcher itself. Although the technological landscape for rocket manufacturing has evolved significantly over the past thirty years, the cost-effectiveness of micro launchers remains a critical challenge. As highlighted by Tugnoli et al. (2019a), the first micro launchers, like the air-launched Orbital ATK Pegasus, were among the most expensive vehicles in price per kilogram to orbit. Despite the advancements in technology, processes, and engineering approaches, reducing the price per kilogram for micro launchers remains an ongoing challenge.

Micro launchers must achieve extremely cost-effective production, integration, and testing of the launch vehicle and its subsystems to reduce the cost of launches in absolute terms. According to Falduto and Peeters (2023), most micro launcher companies advertise prices between $20,000 and $40,000 per kilogram, significantly lower than the previous generation of micro launchers. However, these prices are based on optimistic baselines where the full capacity of the rocket is employed, often ignoring fairing optimization.

To achieve the advertised prices, a very high launch cadence[2] is necessary to generate the economies of scale required to recover and amortize development costs. As noted by Motta et al. (2024), materials and fabrication costs account for 40% of the total cost of the launch vehicle, making reusability a crucial factor to consider. Reusability can alleviate some pressure to achieve the high launch frequencies needed to justify the business case for micro launchers. Rocket Lab's development of technologies to recover the first stage of their Electron launcher, a significant shift from CEO Peter Beck's earlier views on reusability, underscores its importance in this industry (Sheetz, 2021). The success of micro launchers will heavily depend on maintaining low launch prices, realizing the anticipated growth in the small satellite market, and navigating competition from existing and upcoming medium-heavy and super-heavy launchers.

7.1.3. Key Considerations for Micro Launchers

The unique value proposition of micro launchers includes several key advantages and challenges:

Timely Access to Space and Specific Orbits:

Micro launchers offer timely access to space and the flexibility to reach specific orbits, which customers highly value with stringent mission requirements. This capability is particularly relevant for defence-oriented spacecraft and commercial missions that require precise orbital parameters.

Economic Viability and Frequency of Launches:

The economic viability of micro launchers is closely tied to their ability to maintain a high launch frequency. The ability to generate economies of scale through frequent launches is crucial for reducing the price per kilogram to orbit and ensuring competitive pricing in the market. To achieve this, companies must tackle operational and regulatory challenges while maintaining a lean and efficient organization.

Market Segmentation:

Micro launchers are well-suited for niche market segments, such as replenishing small satellite constellations, defence missions, and scientific or technology demonstrator spacecraft. However, rideshare solutions on medium to heavy-sized rockets are generally more efficient and cost-effective for large-scale deployments of small satellite constellations.

[1]The price of a satellite launch can be classified in two primary ways: *Price per Kilogram (Price per Kg)*, which measures the cost to launch one kilogram of payload into space, and *Absolute Price per Launch*, which is the total cost for the entire launch mission regardless of the payload's mass.

[2]Launch Cadence is the aerospace terminology for number of launches or launch frequency

Competition and Complementarity with Other Launch Strategies:

While micro launchers face competition from rideshare and piggyback options, they also complement these strategies by offering dedicated services that provide higher flexibility and control over mission parameters specifically e.g. replenishment mission (refer section 4.2). The ability to quickly and responsively access space positions micro launchers as valuable players in the small satellite launch market.

Technological Advancements and Cost Reductions:

Ongoing technological advancements in rocket manufacturing and engineering processes are essential for reducing the cost per kilogram to orbit for micro launchers. Innovations in reusable launch systems, efficient production methods, and integration processes will play a pivotal role in enhancing the value proposition of micro launchers.

In conclusion, Benchmarking reveals the strengths and weaknesses of different launch strategies. Dedicated launches on micro launchers offer high flexibility and convenience but come at a higher cost. The value proposition of micro launchers lies in their ability to provide dedicated, flexible, and timely access to space for small satellite operators. While they face significant challenges in terms of economic viability and competition from other launch strategies, their unique advantages make them a critical component of the evolving small satellite launch market. The ability to offer tailored launch services that meet specific customer requirements positions micro launchers as valuable partners for small satellite developers seeking precise and responsive access to space. The success of micro launchers will depend on their ability to maintain competitive pricing, achieve high launch frequencies, and leverage technological advancements to reduce costs and enhance reliability.

7.2. Implications of Trends in the Launch Market on SmallSat manufacturers

The evolving trends in the launch market have significant implications for SmallSat manufacturers, particularly with the shift towards larger satellites. Historically, small satellites, especially CubeSats, were designed to be as lightweight as possible to minimize launch costs. However, with decreasing launch prices and the emergence of more affordable rideshare opportunities, the emphasis on miniaturization is diminishing. Economic and technical factors, such as cheaper rideshare prices and the demand for constellation deployments, encourage manufacturers to increase their satellites' size. This shift allows for integrating more sophisticated payloads and enhanced mission capabilities, making larger satellites increasingly feasible and attractive for manufacturers.

Moreover, the trend towards using cheaper materials in small satellite manufacturing is also notable. As the pressure to minimize mass decreases, manufacturers are exploring cost-effective materials that may not be as lightweight but are less expensive. This shift can lead to reduced production costs and potentially lower prices for end customers. Companies are thus optimizing for total costs rather than solely focusing on mass optimization. With launch prices decreasing, investing in lighter but more expensive materials is likely the wrong strategy. Instead, manufacturers should optimize for lower costs in both hardware and operations.

The implications of these trends on customer expectations are profound. The shift towards larger satellites and using more affordable materials align with the needs of various customer typologies, including commercial, defence, and academic sectors. For commercial customers, the ability to deploy larger, more capable satellites at a lower cost can enhance service offerings and competitiveness. Defence customers benefit from the increased payload capacity and the ability to carry more sophisticated instruments. Academic and research institutions, while traditionally budget-sensitive, can also take advantage of these trends by accessing more powerful and versatile satellite platforms.

7.2.1. Scenarios for R&D Consideration in CubeSat Dispensers

Given the current trends, SmallSat manufacturers must carefully consider their R&D strategies, especially when designing products like CubeSat dispensers. Two potential scenarios emerge: focusing on making heavier products with cheaper materials or developing lighter products with more expensive materials.

Scenario 1: Heavier Products with Cheaper Materials

The pros and cons of scenario 1 are as follows:

Pros:

- **Cost Reduction:** Using cheaper materials can significantly lower production costs, making the products more affordable for customers. This is particularly important as launch prices decrease, and the emphasis shifts from minimizing mass to optimizing cost.
- **Increased Durability:** Heavier materials may offer greater durability and resistance to the harsh conditions of space, potentially enhancing the reliability and lifespan of the dispensers.

Cons:

- **Mass Constraints:** While launch costs are decreasing, mass still plays a role in overall mission planning. Excessive mass can limit the number of satellites deployed in a single launch, particularly for missions requiring precise orbital adjustments.
- **Performance Trade-offs:** Heavier materials may not offer the same performance benefits as lighter, more advanced materials. This could impact the efficiency and effectiveness of the dispenser in deploying satellites.
- **Reliance on Larger Vehicles:** Relying too much on larger vehicles like Starship for launches could limit options and flexibility, making it harder to adapt to other launch opportunities if they become more cost-effective or are preferred by some customers.

Scenario 2: Lighter Products with More Expensive Materials

The pros and cons of scenario 2 are as follows:

Pros:

- **Mass Efficiency:** Using lighter, more advanced materials can optimize the mass of the dispenser, allowing for more satellites to be deployed in a single launch. This is particularly advantageous for missions with stringent mass constraints.
- **Enhanced Performance:** Advanced materials can offer superior performance characteristics, such as better thermal resistance, higher strength-to-weight ratios, and improved reliability.
- **Flexibility in Launch Options:** Lighter products can be more versatile, allowing for a wider range of launch vehicle options. This flexibility can be crucial if larger vehicles like Starship are unavailable or less cost-effective.

Cons:

- **Higher Costs:** Advanced materials are typically more expensive, leading to higher production costs. This can make the dispensers more expensive for customers, which could be a drawback in a market where cost reduction is a priority.
- **Complex Manufacturing:** Advanced materials may require more complex and specialized manufacturing processes, potentially increasing production time and costs.

Strategically, targeting niche markets with specific needs can justify the higher costs associated with advanced materials. Staying light might mean a more expensive production process, but this can be balanced by appealing to customers with bigger budgets willing to pay for the enhanced capabilities and efficiencies.

To conclude this section, the evolving trends in the launch market, particularly the shift towards larger satellites and the use of cheaper materials, have significant implications for SmallSat manufacturers. These trends reshape customer expectations and drive manufacturers to adapt their R&D strategies. For products like CubeSat dispensers, manufacturers must carefully weigh the pros and cons of using heavier, cheaper materials versus lighter, more expensive materials. By aligning their strategies with market trends and customer needs, SmallSat manufacturers can enhance their competitiveness and better meet the demands of the growing small satellite market.

7.3. Implications for Policymakers

As highlighted in this study, the evolution and dynamic nature of the micro-launch industry present several critical implications for policymakers. Effective policy frameworks are essential to support the industry's sustainable growth, ensure regulatory compliance and foster innovation. The following recommendations aim to help policymakers address the challenges and opportunities within the micro-launch sector. These policy recommendations are geared towards the Western Geopolitical Block, in particular Europe. However, other countries and contexts can also benefit from these insights. The reasoning behind this focus is discussed in section 7.5 and section 3.3. Furthermore, these implications are coherent with the insights developed from chapter 6.

Streamlining Regulatory Frameworks

Simplification and Harmonization:

Policymakers should prioritize simplifying and harmonizing regulatory frameworks to facilitate smoother operations for micro launch companies. This includes reducing bureaucratic hurdles and ensuring consistent regulations across different jurisdictions. Such regulatory streamlining can significantly lower start-up and small companies' entry barriers and operational costs.

Financial Support and Initiatives

Tax Incentives and Subsidies:

Tax incentives and subsidies for research and development activities can encourage innovation and reduce the financial burden on emerging micro-launch companies. These incentives should target key areas such as reusable launch technologies and advanced manufacturing processes.

Grant Programs and Public Funding:

Establishing grant programs and increasing public funding for space-related research can stimulate growth in the micro-launch industry. Financial support can help bridge the gap between initial startup phases and long-term sustainability, which is critical for the early stages of micro-launch ventures.

Anchor Customer Initiatives:

Governments can act as anchor customers for micro-launch services, providing a stable demand base that helps companies achieve economies of scale and financial stability. This support is crucial for the commercial viability of new and existing micro-launch providers.

Infrastructure and Human Resource Development

Investment in Spaceport Facilities and Supportive Logistics and Supply Chains:

Developing and enhancing spaceport facilities to support the specific needs of micro-launch vehicles is essential. Policymakers should ensure these facilities have the necessary infrastructure for launch operations, integration, and testing. Additionally, enhancing logistics and supply chain networks can provide the timely availability of critical components and materials.

Promotion of STEM Education:

Investing in science, technology, engineering, and mathematics (STEM) education is vital to developing a skilled workforce for the space industry. Policymakers should promote educational initiatives and programs encouraging young talent to pursue careers in aerospace and related fields.

Environmental and Safety Regulations

Environmental Standards:

Implementing stringent environmental standards is crucial to minimizing the ecological impact of launch activities. Policymakers should enforce regulations that promote sustainable practices and the responsible use of space resources, considering the different capacities of smaller firms compared to larger competitors.

Safety Protocols and Space Debris Management:

Developing comprehensive safety protocols and promoting space debris management initiatives are essential for ensuring the long-term sustainability of space operations. Policymakers should prioritize creating and enforcing guidelines that mitigate risks associated with space debris.

Policymakers play a critical role in shaping the future of the micro-launch industry. By addressing these key areas, they can create a supportive environment that encourages innovation, reduces barriers to entry, and promotes sustainable growth. These efforts will benefit the micro-launch sector and contribute to the broader objectives of space exploration and technological advancement. The strategic recommendations provided in this section are designed to guide policymakers in fostering a resilient and competitive micro-launch industry, ensuring its long-term viability and success.

7.4. Implications for Theory

The research conducted in this study provides significant contributions to several theoretical frameworks and bodies of literature, including the New Space, Space Policy, Applied Science and Technology, Economics, Entrepreneurship, and Marketing. This section discusses these contributions and their implications in detail.

7.4.1. New Space

This study reinforces and extends the understanding of the New Space Paradigm. Golkar and Salado (2021) characterize New Space by customer focus, innovative product development approaches, and new business models driven primarily by private investment. This research supports these characteristics by highlighting the rise of micro launchers, which rely heavily on private funding to develop new business models and adopt a customer-centric approach in the small satellite launch industry.

Additionally, the findings challenge the notion that New Space is solely about miniaturising technologies such as CubeSats. Instead, New Space encompasses a broader range of innovations, including new business models, increased acceptance of risk, and market-driven strategies. This aligns with Golkar and Salado (2021) argument that the essence of New Space lies not in technology miniaturization but in the shift towards new business models and customer-driven innovation.

The study also contributes to the literature on the smallsat innovation ecosystem within this New Space Paradigm. It emphasizes the interdependence of various actors within this ecosystem, such as satellite manufacturers, launch service providers, and end-users (refer chapter 1). This interdependence is critical for fostering innovation and ensuring sustainable ecosystem growth. The findings highlight the importance of collaboration and integration among these actors to create a value proposition that responds to market demands (Song et al., 2023).

Moreover, the research underscores the shift from a technology-push to a market-pull approach in the SmallSat ecosystem. This transition is driven by the increasing demand for tailored and cost-effective solutions and the need for timely and reliable access to space. The study provides empirical evidence that market demand significantly influences technological development and innovation in the SmallSat industry.

7.4.2. Space Policy, Economics, and Applied Science and Technology

The implications for space policy are substantial. The study suggests that governments must play a more active role in supporting the New Space economy. This involves providing funding and creating a regulatory environment that fosters innovation and competition. The research aligns with Song et al. (2024), who argue that governmental policies should evolve to support the dynamic nature of the smallsat ecosystem and the increasing involvement of private enterprises, especially when the private sector lacks economic incentives to specialize during the emerging and nascent periods. The research also contributes to Autry (2013)'s work, where he emphasizes the importance of government involvement in the emergence of new organizational communities, particularly in high-technology sectors like New Space. This thesis aligns with this by suggesting that governments need to evolve their policies to support the dynamic nature of the New Space Paradigm. This involves funding and fostering a regulatory environment that encourages innovation and competition.

Additionally, Autry (2013) calls for longitudinal studies to understand the long-term impacts of governmental policies on new industries, suggesting that such studies could provide valuable insights for policymakers. This thesis extends this by providing empirical evidence from the current state of the micro launcher market, illustrating how specific policies have either supported or hindered industry growth. This practical example helps validate theoretical models and suggests actionable policy adjustments.

Furthermore, this thesis extends the work done by other authors in analyzing the small satellite launch industry. This long-held tradition includes works by Naumann (1995), Foust and Smith (2004), Wekerle et al. (2017), Tugnoli et al. (2019a), C. Niederstrasser and Madry (2020), Kulu (2023a), Motta et al. (2024) and others. Consequently, Tugnoli et al. (2019b) and Falduto and Peeters (2023) have explored various launch strategies and their implications. This study builds on their benchmarks, providing updated and validated comparisons of launch strategies based on flexibility, price effectiveness, convenience, and reliability. These benchmarks are crucial for understanding the launch market's evolving dynamics and micro launchers' role.

From an economic perspective, this study provides a practical example illustrating the creation of market bubbles and the factors related to them (Vogel, 2021). The study identifies key indicators of such bubbles, including excessive capital influx without sustainable business models, market hype, and unrealistic growth expectations. It demonstrates how speculative behaviour can lead to unsustainable growth patterns, resulting in market corrections. This contribution is precious for policymakers and investors who need to navigate the complexities of the emerging space economy.

This thesis extends Jones (2018a)'s work, by the analysis of market trends, including the decreasing importance of miniaturization and the focus on cost optimization rather than solely on mass optimization, provides a nuanced view of economic considerations in satellite manufacturing. The section 7.2 also addresses the economic viability of different R&D strategies for CubeSat dispensers, balancing cost and performance. By examining how economic factors influence manufacturing decisions in the satellite industry, this study adds to the literature on space economics by offering a comprehensive analysis of cost-benefit scenarios in satellite component manufacturing. This detailed examination is critical for economic modelling and strategic planning in the space sector.

Furthermore, the discussion on using heavier, cheaper materials versus lighter, more expensive materials for CubeSat dispensers highlights the trade-offs manufacturers face. This analysis is crucial for understanding the implications of material choices on production costs, durability, performance, and overall mission success. The section contributes to the literature on manufacturing strategies and material science by providing a strategic framework for evaluating material choices in satellite manufacturing. Incorporating expert opinions and real-world trends, it is a valuable reference for future research and development in satellite manufacturing strategies.

7.4.3. Entrepreneurship and Marketing

Regarding entrepreneurship, the research highlights the unique challenges and opportunities encountered by startups in the context of the micro launch industry, building upon the work of Okhrimchuk (2019). It identifies key success factors, including innovating, adapting to market demands, and managing costs effectively. Additionally, the study underscores the importance of strategic partnerships and collaborations in overcoming these challenges and achieving sustainable growth.

In marketing, the study reveals that different customer segments have varying priorities and needs, necessitating a tailored approach to marketing and service delivery. For instance, commercial customers may prioritize rapid deployment and cost-effectiveness, while defence customers may focus on reliability and mission-specific requirements. This segmentation is crucial for developing effective marketing strategies and value propositions that resonate with different customer groups.

Expert recommendations in this study highlight the importance of increasing lobbying efforts, which relates to the Business-to-Government (B2G) relationship marketing literature (Santalainen, 2012; Josephson et al., 2019). Maintaining robust B2G relationships is essential for New Space industries, as evidenced by Santalainen (2012), who discusses the strategic use of political ties and lobbying to enhance business performance in the B2G market.

B2G relationships are unique due to high regulation, stringent relationship oversight, and asset specificity in government procurement processes. Effective B2G relationship marketing involves understanding the regulatory environment, engaging in strategic lobbying, and building long-term relationships with government stakeholders (Josephson et al., 2019). This study suggests that micro launcher companies and other New Space entities should invest in political marketing strategies to navigate regulatory challenges and secure government contracts.

7.4.4. Contributions to Literature

The study makes several contributions to the existing literature:

1. **Extension of New Space Paradigm**: It extends the definition of New Space by providing empirical evidence on the role of new business models, private investment and customer-centric approaches in driving innovation and growth in the small satellite launch industry.
2. **Integration of Ecosystem Perspectives**: It integrates the perspectives of various actors within the SmallSat innovation ecosystem, highlighting their interdependence and the importance of collaboration in fostering innovation.
3. **Practical Examples of Market Bubbles**: It incorporates practical examples of market bubbles in the launch industry to illustrate the economic phenomena associated with speculative investments and eventual market fluctuations in the space industry.
4. **Entrepreneurial Challenges and Success Factors**: It identifies the unique challenges and success factors for startups in the micro launch industry, contributing to the literature on space entrepreneurship and innovation management.
5. **Market Segmentation and Customer Needs**: It offers a nuanced understanding of market segmentation and customer needs in the small satellite launch market, contributing to the literature on marketing and service delivery in the space industry.
6. **B2G Relationship Marketing**: It adds to the B2G relationship marketing literature by emphasizing the importance of political ties, strategic lobbying, and understanding government procurement processes in the New Space industry.
7. **Validation of Benchmarks**: The study updates and validates existing benchmarks from Tugnoli et al. (2019b) and Falduto and Peeters (2023), providing a comprehensive evaluation of various launch strategies and their performance relative to key customer expectations.

In conclusion, this research provides a comprehensive analysis of the New Space Paradigm, the SmallSat innovation ecosystem, and the economic and entrepreneurial dynamics of the micro launch industry. It offers valuable insights for academics, policymakers, and industry practitioners, setting the stage for future research on space commercialisation and the space industry's evolving landscape.

7.5. Limitations and Future Recommendations

The research presented in this thesis significantly contributes to our understanding of the New Space economy, particularly the micro launch industry and its implications for small satellite manufacturers. However, like any study, its limitations need to be acknowledged. Recognizing these limitations provides context for interpreting the findings and offers directions for future research.

One major limitation of this study is its scope, which primarily focuses on the micro launcher segment within the small satellite launch industry. This niche focus, while providing detailed insights, may not fully capture the challenges and opportunities present across other segments, such as medium and heavy launchers. This narrower scope could potentially limit the general applicability of the findings across the entire industry. Additionally, the sample size and selection could pose another limitation. The research relies on semi-structured interviews with seven subject matter experts from the aerospace industry. Although the interview participants were highly experienced and covered various aspects needed for this study, the small sample size may still limit the extended generalizability of the findings. Furthermore, the purposive sampling method, though appropriate for this exploratory study, might introduce selection bias, as the chosen experts may have perspectives that do not fully represent the diversity of views within the industry.

The study's geographic and market focus is another limitation. The research context is primarily based on the Western space industry, particularly European and North American space industries, meaning that the findings may not fully apply to other regions with different market dynamics, regulatory environments, and technological advancements. The researcher attempted to mitigate this limitation by incorporating experts from four countries and three continents in the Western Hemisphere (refer section 3.3). However, this geographic focus may still limit the global applicability of the conclusions drawn. Moreover, the rapid evolution of the New Space industry poses a challenge. The data collected and analyzed in this study represent a snapshot in time, although the researcher tried to incorporate as many upcoming movements in the industry as possible. Some findings may become outdated as the industry evolves, necessitating continuous monitoring and updates to maintain relevance.

Another limitation is the treatment of regulatory and policy considerations. While the study touches on the role of government policies in shaping the micro launch industry, it does not delve deeply into the complex regulatory landscapes across different countries. Regulatory changes in other contexts can significantly impact the industry, and future studies should consider a more detailed analysis of these factors. Additionally, while insightful, the economic analysis provided in this research is not exhaustive. Future research could benefit from a more rigorous quantitative analysis to complement the qualitative insights provided here.

Future research should expand beyond the micro launcher segment to address these limitations to include medium and heavy launch vehicles. Comparing and contrasting the challenges and opportunities across these segments could provide a more comprehensive understanding of the small satellite launch industry. Increasing the sample size and diversity of interview participants could enhance the robustness and generalizability of the findings. Including perspectives from different stakeholders in different contexts, such as policymakers, investors, and end-users, would provide a more holistic view of the industry.

Extending the geographic scope of the study to include regions like Asia, South America, and Africa would help capture a more diverse range of market dynamics and regulatory environments, enhancing the global applicability of the research findings. Conducting longitudinal studies to track the evolution of the micro launch industry over time would provide valuable insights into how technological advancements, market trends, and policy changes impact the sector. This approach would help identify long-term patterns and trends.

Future studies should also undertake a more detailed examination of the regulatory landscapes in different countries and contexts. Understanding how regulations facilitate or hinder the growth of the micro launch industry can provide actionable insights for policymakers and industry stakeholders. Incorporating quantitative methods, such as economic modelling and financial analysis, can complement the qualitative insights and provide a more comprehensive understanding of the micro launch industry's economic viability and financial health. This could include cost-benefit analyses, market forecasts, and investment risk assessments.

Exploring the impact of emerging technologies, such as multi-purpose reusable launch systems, advanced propulsion methods (electric-ion propulsion), and 3D rapid-prototyping of aerospace components, on the micro launch industry would provide valuable insights into future technological trends and their implications for small satellite manufacturers. Additionally, investigating the environmental impact of micro launchers and the sustainability of different launch strategies could contribute to the growing body of literature on sustainable space activities. This includes assessing the life-cycle environmental impact of launch vehicles and the potential for developing greener technologies.

Furthermore, experts recommended research to establish an international standard or agreement for the virtual bounding box of microsatellites. This would be an addition or complement to similar standards developed by Puig-Suari et al. (2001) in the CubeSat domain. This standardization is crucial to prevent inefficiencies and conflicts in space utilization caused by varied satellite designs. Establishing such a standard would help optimise the design and deployment of microsatellites, ensuring they adhere to specific size and volume constraints. Developing a pricing strategy, where customers are incentivized to stay within the bounding box and penalized for exceeding it, is also suggested. This approach would regulate the physical dimensions of satellites and contribute to a more structured and efficient use of space, promoting fair competition and innovation within the industry.

By addressing these limitations and pursuing the suggested future research directions, scholars and industry practitioners can build on the findings of this study to further advance our understanding of the

New Space Paradigm and its dynamic landscape.

7.6. Reflection on Management of Technology Study Program

Reflecting on the Management of Technology (MoT) study program at Delft University of Technology[3], this research exemplifies the application of the program's principles. The MoT program aims to provide students with a strategic understanding of leveraging technology to enhance customer satisfaction, corporate productivity, profitability, and competitiveness. This study encapsulates these objectives by examining the rapidly evolving micro-launch sector and its impact on the broader New Space Paradigm.

The thesis aligns with the MoT program's core objective of understanding technology as a critical corporate resource by exploring how technological advancements and innovative business models within the micro-launch sector drive competitiveness and profitability. Employing robust qualitative research methods ensures that the study meets the MoT requirement of conducting scientific research within a technological context. This methodological rigour also reflects the MoT curriculum's emphasis on using scientific methods to address real-world problems.

Moreover, the research findings have significant implications for SmallSat manufacturers, industry players, and policymakers. The study underscores the necessity of strategic planning, continuous innovation, and effective policy frameworks to enhance competitiveness and ensure sustainable growth. These insights align with the MoT program's goal of improving corporate outcomes through the strategic management of technology. By addressing key industry challenges and identifying future opportunities, the thesis demonstrates the practical application of MoT principles in fostering innovation and driving business success within the New Space Paradigm.

7.7. Summary

In conclusion, the chapter provides a detailed discussion on the benchmarking of launch strategies (refer section 7.1), implications of market trends on SmallSat manufacturers (refer section 7.2), implications for policymakers (refer section 7.3, contributions to theory (refer section 7.4), acknowledges the study's limitations while suggesting future research directions (refer section 7.5) and provides reflection on management of technology study program (refer section 7.6). The findings underscore the dynamic and evolving nature of the micro launch sector and its significant impact on the broader SmallSat launch industry and the New Space Paradigm.

[3] Refer TU Delft | MSc Management of Technology website for more information on the study program.

8 Conclusion

There's plenty of room at bottom.

Richard Feynman
Teacher and Professor of Physics

8.1. Conclusion

The research presented in this thesis provides a comprehensive analysis of the micro launch industry, shedding light on the factors contributing to its market bubble, the key drivers and challenges industry players face, and the broader implications for SmallSat manufacturers. This conclusion synthesizes the findings, offering insights into the evolving landscape of the micro launch sector and its impact on the satellite manufacturing industry.

The investigation into the market bubble within the micro launch industry reveals several contributing factors. The influx of liquidity, driven by increased private investment and venture capital, has led to speculative investments in micro launch companies. Herding behaviour among investors, coupled with cognitive biases and information asymmetry, has exacerbated the situation, inflating asset prices and creating unrealistic market expectations. This environment, coupled with high-profile bankruptcies, casts doubt on the long-term sustainability of the micro launch sector, and rightfully so.

Despite these challenges, several key drivers are fueling the growth of micro launch companies. Democratized access to space enables a wider range of applications for small satellites. Additionally, government and defence applications could provide substantial institutional support for the industry. However, the industry faces significant challenges, including high entry barriers that require substantial capital for R&D and regulatory compliance. The competitive landscape is further complicated by the presence of established players and the emergence of alternative launch solutions, such as rideshare and orbital transfer vehicles. These factors necessitate continuous innovation and strategic agility among micro launch companies.

The evolving trends in the micro launch industry have profound implications for SmallSat manufacturers. Reduced launch costs and increased access to space have shifted the focus from minimizing satellite mass to optimizing mission performance and reliability. Manufacturers can now incorporate more robust and versatile components into their designs, enhancing their satellites' operational capabilities and lifespan. However, the uncertainty surrounding the micro launch sector underscores the importance of strategic planning and diversification. SmallSat manufacturers should cultivate partnerships with multiple launch providers to mitigate risks and ensure consistent access to launch services. Additionally, continuous investment in R&D is crucial to stay ahead of technological advancements and maintain competitiveness in the market.

This study also discusses several implications for policymakers, particularly in Europe. The evolution and dynamic nature of the micro-launch industry present critical challenges and opportunities that require effective policy frameworks. Streamlining regulatory frameworks, providing financial support and initiatives, investing in infrastructure and human resource development, and enforcing environmental and safety regulations are essential. These steps will create a supportive environment that encourages innovation, reduces barriers to entry, and promotes sustainable growth, ultimately benefiting the broader objectives of space exploration and technological advancement.

Furthermore, this research contributes significantly to several theoretical frameworks and bodies of literature, including New Space, space policy, applied science and technology, economics, entrepreneurship, and marketing. It extends the understanding of the New Space Paradigm by highlighting private investment and customer-centric approaches. The study also underscores the interdependence of actors within the SmallSat innovation ecosystem and supports a market-pull approach driven by demand for tailored solutions. Furthermore, it offers practical examples of market bubbles, and identifies entrepreneurial challenges and success factors, contributing to the literature on space policy, entrepreneurship, and marketing.

In conclusion, while facing significant challenges, the micro launch industry can rise to these challenges due to its key drivers and the growing demand for small satellite launches, provided they take into account the insights and recommendations offered by the experts. The insights gained from this research underscore the importance of strategic planning, continuous innovation, and collaborative efforts among industry stakeholders. As the New Space revolution progresses, the ability to navigate the complexities of the launch market and leverage emerging opportunities will determine the future success of both micro launch companies and SmallSat manufacturers. This study provides a crucial foundation for understanding the dynamics of the micro launch industry and offers strategic guidance for navigating it's evolving landscape.

Space, the final frontier, (...) to explore strange new worlds, to seek out new life and new civilizations, to boldly go where no man has gone before ...

Captain Kirk

References

Achenbach, J. (2013). Which way to space? Does the future of space travel lie with NASA or space entrepreneurs? Retrieved May 26, 2024, from http://www.washingtonpost.com/sf/national/2013/11/23/which-way-to-space/

Adams, W. C. (2015). Conducting Semi-Structured Interviews. In *Handbook of Practical Program Evaluation* (pp. 492–505). John Wiley & Sons, Ltd. Retrieved June 5, 2024, from https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119171386.ch19

Andraszewicz, S. (2020). Stock Markets, Market Crashes, and Market Bubbles. In T. Zaleskiewicz & J. Traczyk (Eds.), *Psychological Perspectives on Financial Decision Making* (pp. 205–231). Springer International Publishing. https://doi.org/10.1007/978-3-030-45500-2_10

Astropreneurs – Space Startup Accelerator. (2020, December). Retrieved June 19, 2024, from https://astropreneurs.eu/

Autry, G. (2013). *Exploring New Space: Governmental Roles in the Emergence of New Communities of High-Technology Organizations* [Ph.D.]. University of California, Irvine [ISBN: 9781303420528 Publication Title: ProQuest Dissertations and Theses]. Retrieved May 27, 2024, from https://www.proquest.com/docview/1446517881/abstract/46D56214B4CA4504PQ/2

Avery, C., & Zemsky, P. (1998). Multidimensional Uncertainty and Herd Behavior in Financial Markets [Publisher: American Economic Association]. *The American Economic Review*, *88*(4), 724–748. Retrieved June 17, 2024, from https://www.jstor.org/stable/117003

Bailey, M. (2020). Frequent and Reliable Launch for Small Satellites: Rocket Lab's Electron Launch Vehicle and Photon Spacecraft. In J. N. Pelton (Ed.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 1–17). Springer International Publishing. https://doi.org/10.1007/978-3-030-20707-6_91-1

Bala Subrahmanya, M. H. (2022). Competitiveness of High-Tech Start-Ups and Entrepreneurial Ecosystems: An Overview. *International Journal of Global Business and Competitiveness*, *17*(1), 1–10. https://doi.org/10.1007/s42943-022-00056-w

Basar, P. (2018). Astropreneurship. *5*, 156–164. https://doi.org/10.30845/jbep.v5n4p16

Behrens, J. R., & Lal, B. (2019). Exploring Trends in the Global Small Satellite Ecosystem [Publisher: Mary Ann Liebert, Inc., publishers]. *New Space*, *7*(3), 126–136. https://doi.org/10.1089/space.2018.0017

Berger, E. (2023, March). The small launch industry is brutal—yes, even more than you thought. Retrieved April 29, 2024, from https://arstechnica.com/science/2023/03/the-small-launch-industry-is-brutal-yes-even-more-than-you-thought/

Blackwell, W. J., Braun, S., Bennartz, R., Velden, C., DeMaria, M., Atlas, R., Dunion, J., Marks, F., Rogers, R., Annane, B., & Leslie, R. V. (2018). An overview of the TROPICS NASA Earth Venture Mission. *Quarterly Journal of the Royal Meteorological Society*, *144*(S1), 16–26. https://doi.org/10.1002/qj.3290

Botelho, R., & Xavier, A. (2019). A Unified Satellite Taxonomy Proposal Based on Mass and Size. *04*, 57–73. https://doi.org/10.4236/aast.2019.44005

Bousedra, K. (2023). Downstream Space Activities in the New Space Era: Paradigm Shift and Evaluation Challenges. *Space Policy*, *64*, 101553. https://doi.org/10.1016/j.spacepol.2023.101553

Bridging the Financing Gap Europe's Space Sector. (2024, March). Retrieved June 17, 2024, from https://www.espi.or.at/reports/bridging-the-financing-gap-in-the-european-space-sector-alternative-funding-pathways-in-tightening-markets/

Brunnermeier, M. K. (2016). Bubbles. In G. Jones (Ed.), *Banking Crises: Perspectives from The New Palgrave Dictionary* (pp. 28–36). Palgrave Macmillan UK. https://doi.org/10.1057/9781137553799_5

BryceTech - Reports. (2024). Retrieved May 14, 2024, from https://brycetech.com/reports

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D., & Walker, K. (2020). Purposive sampling: Complex or simple? Research case examples [Publisher: SAGE

Publications Ltd]. *Journal of Research in Nursing*, *25*(8), 652–661. https://doi.org/10.1177/1744987120927206

Cappaert, J. (2020). The Spire Small Satellite Network. In J. N. Pelton & S. Madry (Eds.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 1–21). Springer International Publishing. https://doi.org/10.1007/978-3-030-20707-6_93-1

Chang, V., Newman, R., Walters, R. J., & Wills, G. B. (2016). Review of economic bubbles. *International Journal of Information Management*, *36*(4), 497–506. https://doi.org/10.1016/j.ijinfomgt.2016.02.007

Chi, C. (2023, January). TAM SAM SOM: What Do They Mean & How Do You Calculate Them? Retrieved May 28, 2024, from https://blog.hubspot.com/marketing/tam-sam-som

Christensen, C. B., Armstrong, K., & Perrino, R. (2016, September). Start-Up Space: Rising Investment in Commercial Space Ventures. In *AIAA SPACE 2016*. American Institute of Aeronautics; Astronautics. https://doi.org/10.2514/6.2016-5233

Clark, S. (2023, July). In-space manufacturing startup aces pharma experiment in orbit. Retrieved May 16, 2024, from https://arstechnica.com/space/2023/07/in-space-manufacturing-startup-aces-pharma-experiment-in-orbit/

Dalmia, N. (2017). ISRO sends 104 satellites in one go, breaks Russia's record. *The Economic Times*. Retrieved May 23, 2024, from https://economictimes.indiatimes.com/news/science/isro-sends-104-satellites-in-one-go-breaks-russias-record/articleshow/57159365.cms?from=mdr

Davidian, K. (2020). Definition of NewSpace [Publisher: Mary Ann Liebert, Inc., publishers]. *New Space*, *8*(2), 53–55. https://doi.org/10.1089/space.2020.29027.kda

Deville, G. (2024). Small launchers: Limits of a high launch rate model and the race to heavy follow-ons. Retrieved May 15, 2024, from https://www.euroconsult-ec.com/in-the-loop/small-launchers-limits-of-a-high-launch-rate-model-the-race-to-heavy-follow-ons/

Easterby-Smith, M., Jaspersen, L. J., Thorpe, R., & Valizade, D. (2021, April). *Management and Business Research* [Google-Books-ID: IYskEAAAQBAJ]. SAGE. https://books.google.nl/books?id=IYskEAAAQBAJ

Eisenhardt, K. M. (1989). Building Theories from Case Study Research [Publisher: Academy of Management]. *The Academy of Management Review*, *14*(4), 532–550. https://doi.org/10.2307/258557

Falduto, M., & Peeters, W. (2023). Trade-Off Approach for Launching Smallsats [Publisher: Mary Ann Liebert, Inc., publishers]. *New Space*, *11*(2), 71–81. https://doi.org/10.1089/space.2022.0003

FasterCapital. (2024). Bubble Theory Debunked: Breaking the Bubble Theory Myth: Fact or Fiction. Retrieved June 17, 2024, from https://fastercapital.com/content/Bubble-Theory-Debunked--Breaking-the-Bubble-Theory-Myth--Fact-or-Fiction.html

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, *5*, 1–11. https://doi.org/10.1177/160940690600500107

Foust, J. (2003). Prospects for Affordable Access to Space for Small Payloads, 2003-2012. Retrieved April 15, 2024, from https://www.semanticscholar.org/paper/Prospects-for-Affordable-Access-to-Space-for-Small-Foust/8493063baf767520db61e50ac7188dfdb1a37304#cited-papers

Foust, J. (2019, March). How the space industry learned to stop worrying and love the bubble. Retrieved June 17, 2024, from https://spacenews.com/how-the-space-industry-learned-to-stop-worrying-and-love-the-bubble/

Foust, J. (2023, May). Construction starts on Orbex Scottish launch site. Retrieved July 24, 2024, from https://spacenews.com/construction-starts-on-orbex-scottish-launch-site/

Foust, J. (2024a, February). Firefly to continue responsive launch operations for future Alpha missions. Retrieved April 15, 2024, from https://spacenews.com/firefly-to-continue-responsive-launch-operations-for-future-alpha-missions/

Foust, J. (2024b, March). SpaceX launches tenth Transporter rideshare mission. Retrieved April 15, 2024, from https://spacenews.com/spacex-launches-tenth-transporter-rideshare-mission/

Foust, J. (2024c, March). Starship could have a big impact on small launch vehicles. Retrieved April 18, 2024, from https://spacenews.com/starship-could-have-a-big-impact-on-small-launch-vehicles/

Foust, J., & Smith, P. (2004, September). Small Launch Vehicle Services: Supply and Demand Through 2010. In *Space 2004 Conference and Exhibit*. American Institute of Aeronautics; Astronautics. https://doi.org/10.2514/6.2004-6000

Frischauf, N., Horn, R., Kauerhoff, T., Wittig, M., Baumann, I., Pellander, E., & Koudelka, O. (2017). NewSpace: New Business Models at the Interface of Space and Digital Economy: Chances in an Interconnected World. *New Space*, *6*. https://doi.org/10.1089/space.2017.0028

Garber, P. M. (1990). Famous First Bubbles. *Journal of Economic Perspectives*, *4*(2), 35–54. https://doi.org/10.1257/jep.4.2.35

Golkar, A., & Salado, A. (2021). Definition of New Space—Expert Survey Results and Key Technology Trends [Conference Name: IEEE Journal on Miniaturization for Air and Space Systems]. *IEEE Journal on Miniaturization for Air and Space Systems*, *2*(1), 2–9. https://doi.org/10.1109/JMASS.2020.3045851

Gonzalez, S. (2023). The Astropreneurial Co-creation of the New Space Economy. *Space Policy*, *64*, 101552. https://doi.org/10.1016/j.spacepol.2023.101552

Grossoehme, D. H. (2014). Research MethodologyOverview of Qualitative Research. *Journal of health care chaplaincy*, *20*(3), 109–122. https://doi.org/10.1080/08854726.2014.925660

Guarro, S. (2013). On the estimation of space launch vehicle reliability. *9*, 619–631.

Hay, J., Guthrie, P., Mullins, C., Gresham, E., & Christensen, C. (2009, September). Global Space Industry: Refining the Definition of ”New Space”. In *AIAA SPACE 2009 Conference & Exposition*. American Institute of Aeronautics; Astronautics. https://doi.org/10.2514/6.2009-6400

Heidt, H., Puig-Suari, J., Moore, A., Nakasuka, S., & Twiggs, R. (2000). CubeSat: A New Generation of Picosatellite for Education and Industry Low-Cost Space Experimentation. Retrieved May 26, 2024, from https://www.semanticscholar.org/paper/CubeSat%3A-A-New-Generation-of-Picosatellite-for-and-Heidt-Puig-Suari/d864509011b2c5ffbfc41647774aba25b40d2beb

Henri, Y. (2020). The OneWeb Satellite System. In J. N. Pelton (Ed.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 1–10). Springer International Publishing. https://doi.org/10.1007/978-3-030-20707-6_67-1

Hertzfeld, H., & Pelton, J. N. (2020). Financial Models and Economic Analysis for Small Satellite Systems. In J. N. Pelton & S. Madry (Eds.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 1209–1229). Springer International Publishing. https://doi.org/10.1007/978-3-030-36308-6_69

Higgins, N., Gaset, M., Antonio, E., Mckellar, M., Milza, F., Coelho, P., Ramirez, B., Elkins, A., Parks, A., Kotwal, C., Chao, C., Raurell, D., Calnan, G., Wexler, H., Wang, H., Grzesiak, K., Liu, K., Zhang, M., Clanton, M., & Ni, Z. (2017, September). *The Galactic Guide to Space Entrepreneurship*.

Hitchens, T. (2019). Small Satellites, Safety Challenges, and Reforms Related to Strategic Space Defense Systems. In J. N. Pelton (Ed.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 1–14). Springer International Publishing. https://doi.org/10.1007/978-3-030-20707-6_49-1

Iacomino, C. (2019). The Evolving Role of Private Actors in Space Exploration. In C. Iacomino (Ed.), *Commercial Space Exploration: Potential Contributions of Private Actors to Space Exploration Programmes* (pp. 35–74). Springer International Publishing. https://doi.org/10.1007/978-3-030-15751-7_3

International Space Company Kosmotras - space-companies.com. (2022, July). Retrieved May 23, 2024, from https://space-companies.com/international-space-company-kosmotras/

Johnson, J. L., Adkins, D., & Chauvin, S. (2020). A Review of the Quality Indicators of Rigor in Qualitative Research. *American Journal of Pharmaceutical Education*, *84*(1), 7120. https://doi.org/10.5688/ajpe7120

Jones, H. W. (2018a). The Future Impact of Much Lower Launch Cost [NTRS Author Affiliations: NASA Ames Research Center NTRS Report/Patent Number: ARC-E-DAA-TN56846 NTRS Document ID: 20200001091 NTRS Research Center: Ames Research Center (ARC)]. Retrieved May 24, 2024, from https://ntrs.nasa.gov/citations/20200001091

Jones, H. W. (2018b). The Recent Large Reduction in Space Launch Cost. Retrieved April 29, 2024, from https://www.semanticscholar.org/paper/The-Recent-Large-Reduction-in-Space-Launch-Cost-Jones/1a4659bc1320f193ae0965811e78425985f58055?sort=relevance&page=10

Josephson, B. W., Lee, J.-Y., Mariadoss, B. J., & Johnson, J. L. (2019). Uncle Sam Rising: Performance Implications of Business-to-Government Relationships [Publisher: SAGE Publications Inc]. *Journal of Marketing*, *83*(1), 51–72. https://doi.org/10.1177/0022242918814254

Kim, W. G., Han, J. S., & Lee, E. (2001). Effects of Relationship Marketing on Repeat Purchase and Word of Mouth [Publisher: SAGE Publications Inc]. *Journal of Hospitality & Tourism Research*, *25*(3), 272–288. https://doi.org/10.1177/109634800102500303

Kindleberger, C. P. (1991). Bubbles. In J. Eatwell, M. Milgate, & P. Newman (Eds.), *The World of Economics* (pp. 20–22). Palgrave Macmillan UK. https://doi.org/10.1007/978-1-349-21315-3_3

Kulu, E. (2018). What is a CubeSat? Retrieved May 13, 2024, from https://www.nanosats.eu/cubesat.html

Kulu, E. (2021, October). *Small Launchers - 2021 Industry Survey and Market Analysis*.

Kulu, E. (2023a, March). *In-Space Manufacturing of Semiconductors - History and Future Vision*. https://doi.org/10.13140/RG.2.2.31407.20649

Kulu, E. (2023b, October). *Small Launchers - 2023 Industry Survey and Market Analysis*.

Lamine, W., Anderson, A., Jack, S. L., & Fayolle, A. (2021). Entrepreneurial space and the freedom for entrepreneurship: Institutional settings, policy, and action in the space industry [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/sej.1392]. *Strategic Entrepreneurship Journal*, *15*(2), 309–340. https://doi.org/10.1002/sej.1392

Lao Rosell, G. (2024, January). *Study of commercial reusable launch vehicles business model: Case study of New Glenn from Blue Origin* [Bachelor thesis]. Universitat Politècnica de Catalunya [Accepted: 2024-02-23T13:34:47Z]. Retrieved May 28, 2024, from https://upcommons.upc.edu/handle/2117/403049

Laverty, S., Chong, W. C., Osborne, J., Mitry, M., & Lewis, V. (2019). The Kepler Satellite System. In J. N. Pelton (Ed.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 1–16). Springer International Publishing. https://doi.org/10.1007/978-3-030-20707-6_65-1

Madry, S. (2020). Smallsat Rideshares and Launch Aggregators. In J. N. Pelton & S. Madry (Eds.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 437–451). Springer International Publishing. https://doi.org/10.1007/978-3-030-36308-6_98

Martinez, P. (2020). Small Satellites for Science. In J. N. Pelton & S. Madry (Eds.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 1–25). Springer International Publishing. https://doi.org/10.1007/978-3-030-20707-6_36-1

McCurdy, H. E. (2019). *Financing the New Space Industry: Breaking Free of Gravity and Government Support*. Springer International Publishing. https://doi.org/10.1007/978-3-030-32292-2

Motta, F., Pessoa Filho, J. B., & de Oliveira Moraes, A. (2024). Is there a market for micro-launch vehicles? *Space Policy*, 101629. https://doi.org/10.1016/j.spacepol.2024.101629

Mowry, C., & Grasso, M. (2020). The Evolution of Medium-/Heavy-lift and Reusable Launch Vehicles and Its Implications for Smallsat Access to Space. In J. N. Pelton & S. Madry (Eds.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 1–9). Springer International Publishing. https://doi.org/10.1007/978-3-030-20707-6_92-1

Naumann, W. G. (1995). Small launchers in the future, a global overview of their features and prospects. *Acta Astronautica*, *37*, 471–486. https://doi.org/10.1016/0094-5765(95)00086-F

Niederstrasser, C., & Frick, W. (2015). Small Launch Vehicles - A 2017 State of the Industry Survey. Retrieved May 27, 2024, from https://www.semanticscholar.org/paper/Small-Launch-Vehicles-A-2017-State-of-the-Industry-Niederstrasser-Frick/2e0bcbee9abb7bd98c5ae6d6013be72b0e2b67a8

Niederstrasser, C., & Madry, S. (2020). New Launchers for Small Satellite Systems. In J. N. Pelton (Ed.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 1–14). Springer International Publishing. https://doi.org/10.1007/978-3-030-20707-6_21-1

Niederstrasser, C. G. (2022). The small launch vehicle survey a 2021 update (The rockets are flying). *Journal of Space Safety Engineering*, *9*(3), 341–354. https://doi.org/10.1016/j.jsse.2022.07.003

Nightingale, E. S., Pratt, L. M., & Balakrishnan, A. (2015). *The CubeSat Ecosystem: Examining the Launch Niche (Paper and Presentation)* (tech. rep.). Institute for Defense Analyses. Retrieved April 30, 2024, from https://www.jstor.org/stable/resrep22752

Okhrimchuk, I. (2019). Opportunities and Challenges for Start-up Entrepreneurship in the Space Industry of Finland [Accepted: 2019-03-26T10:56:15Z]. Retrieved June 17, 2024, from http://www.theseus.fi/handle/10024/161709

Osterwalder, A., & Pigneur, Y. (2010, July). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers* [Google-Books-ID: UzuTAwAAQBAJ]. John Wiley & Sons. https://books.google.nl/books?id=UzuTAwAAQBAJ

Paikowsky, D. (2017). What Is New Space? The Changing Ecosystem of Global Space Activity. *New Space*, *20*. https://doi.org/10.1089/space.2016.0027

Palmatier, R. W. (2008). *Relationship Marketing* [Google-Books-ID: QwJtPgAACAAJ]. Marketing Science Institute.

Paravano, A., Locatelli, G., & Trucco, P. (2023). What is value in the New Space Economy? The end-users' perspective on satellite data and solutions. *Acta Astronautica*, *210*, 554–563. https://doi.org/10.1016/j.actaastro.2023.05.001

Parrella, R. M., Spirito, G., Cirina, C., & Falvella, M. C. (2022). The New Space Economy and New Business Models [Publisher: Mary Ann Liebert, Inc., publishers]. *New Space*, *10*(4), 291–297. https://doi.org/10.1089/space.2021.0020

Parsonson, A. (2023, November). Avio and Arianespace Finalize Divorce Terms. Retrieved July 25, 2024, from https://europeanspaceflight.com/avio-and-arianespace-finalize-divorce-terms/

Payne, A., & Holt, S. (2001). Diagnosing Customer Value: Integrating the Value Process and Relationship Marketing [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/1467-8551.00192]. *British Journal of Management*, *12*(2), 159–182. https://doi.org/10.1111/1467-8551.00192

Peeters, W. (2018). Towards a definition of New Space? The entrepreneurial perspective. New Space Vol 6(3) (2018), pp. 187-190.

Peeters, W., Damp, L., & Williams, P. (2020). Launching Smallsats: The Example of Southern Launch [Publisher: Mary Ann Liebert, Inc., publishers]. *New Space*, *8*(4), 201–212. https://doi.org/10.1089/space.2020.0034

Pelton, J. N., & Madry, S. (2019). Global Launch Vehicle Systems for Potential Small Satellite Deployment. In J. N. Pelton (Ed.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 1–47). Springer International Publishing. https://doi.org/10.1007/978-3-030-20707-6_82-1

Prahalad, C. K., & Ramaswamy, V. (2004). Co-creation experiences: The next practice in value creation. *Journal of Interactive Marketing*, *18*(3), 5–14. https://doi.org/10.1002/dir.20015

Prospects for the Small Satellite Market, 9th edition. (2023). Retrieved May 13, 2024, from https://digital-platform.euroconsult-ec.com/product/prospects-for-the-small-satellite-market/

Puig-Suari, J., Turner, C., & Ahlgren, W. (2001). Development of the standard CubeSat deployer and a CubeSat class PicoSatellite. *2001 IEEE Aerospace Conference Proceedings (Cat. No.01TH8542)*, *1*, 1/347–1/353 vol.1. https://doi.org/10.1109/AERO.2001.931726

Rainbow, J. (2023, February). Noise complaints help bring down launch startup SpaceRyde. Retrieved July 22, 2024, from https://spacenews.com/noise-complaints-help-bring-down-launch-startup-spaceryde/

Riding Piggyback on an ICBM. (2015, January). Retrieved May 23, 2024, from https://www.drewexmachina.com/2015/01/21/riding-piggyback-on-an-icbm/

Robert, F. A., Puteaux, M., & Najjar, A. (2020). Small Satellites Market Growth Patterns and Related Technologies. In J. N. Pelton & S. Madry (Eds.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 1–41). Springer International Publishing. https://doi.org/10.1007/978-3-030-20707-6_109-2

Romasanta, A., Ahmadova, G., Wareham, J. D., & Pujol Priego, L. (2021, August). Deep Tech: Unveiling the Foundations. https://doi.org/10.2139/ssrn.4009164

Rook, L. (2006). An Economic Psychological Approach to Herd Behavior [Publisher: Routledge _eprint: https://doi.org/10.1080/00213624.2006.11506883]. *Journal of Economic Issues*, *40*(1), 75–95. https://doi.org/10.1080/00213624.2006.11506883

Santalainen, J. (2012). The untapped value of strategic CSR in contemporary business to government relationship marketing. Case: Industrial B2G Environment in the EU. Retrieved July 26, 2024, from https://aaltodoc.aalto.fi/handle/123456789/3540

Saunders, M., & Bristow, A. (2023, February). 2023 Research Methods for Business Students Preface and Chapter 4.

Serra, L. P., Barrera, J., & Solanilla, J. S. (2013). MICROSATELLITES AND MICROLAUNCHERS: THE TANDEM THAT WILL DISRUPT THE SATELLITE INDUSTRY. Retrieved April 19, 2024, from https://www.semanticscholar.org/paper/MICROSATELLITES-AND-MICROLAUNCHERS%3A-THE-TANDEM-THAT-Serra-Barrera/4bb8d234f68354e54353d006b816e4127a3eb3dd

Sheetz, M. (2021, November). Rocket Lab CEO says companies not reusing rockets are making 'a dead-end product'. Retrieved May 2, 2024, from https://www.cnbc.com/2021/11/23/rocket-lab-ceo-not-reusing-rockets-is-a-dead-end-product.html

Sheetz, M. (2023, May). Virgin Orbit shuts down after bankruptcy sales. Retrieved April 15, 2024, from https://www.cnbc.com/2023/05/23/virgin-orbit-bankruptcy-sale-rocket-lab-stratolaunch-vasts-launcher.html

Skala, A. (2019). Characteristics of Startups. In A. Skala (Ed.), *Digital Startups in Transition Economies: Challenges for Management, Entrepreneurship and Education* (pp. 41–91). Springer International Publishing. https://doi.org/10.1007/978-3-030-01500-8_2

Song, Y., Gnyawali, D., & Qian, L. (2024). From early curiosity to space wide web: The emergence of the small satellite innovation ecosystem. *Research Policy*, *53*(2), 104932. https://doi.org/10.1016/j.respol.2023.104932

Song, Y., Zhou, Y. M., & Zhao, X. (2023). Ecosystems in Transition: Managing Complementor Bottlenecks with Disruptive Innovation [Publisher: Academy of Management]. *Academy of Management Proceedings*, *2023*(1), 16865. https://doi.org/10.5465/AMPROC.2023.184bp

Space Tech Challenges and Opportunities. (2022, December). Retrieved June 17, 2024, from https://www.cliffordchance.com/content/cliffordchance/insights/resources/blogs/talking-tech/en/articles/2022/12/space-tech-challenges-and-opportunities.html

Strategyzer. (2024, July). Retrieved July 2, 2024, from https://www.strategyzer.com/

Tugnoli, M., Sarret, M., & Aliberti, M. (2019a). Business Perspectives for Micro Launchers. In M. Tugnoli, M. Sarret, & M. Aliberti (Eds.), *European Access to Space: Business and Policy Perspectives on Micro Launchers* (pp. 29–66). Springer International Publishing. https://doi.org/10.1007/978-3-319-78960-6_3

Tugnoli, M., Sarret, M., & Aliberti, M. (2019b). Overview on Micro Launchers. In M. Tugnoli, M. Sarret, & M. Aliberti (Eds.), *European Access to Space: Business and Policy Perspectives on Micro Launchers* (pp. 5–28). Springer International Publishing. https://doi.org/10.1007/978-3-319-78960-6_2

Tugnoli, M., Sarret, M., & Aliberti, M. (2019c). Policy Perspectives for Europe. In M. Tugnoli, M. Sarret, & M. Aliberti (Eds.), *European Access to Space: Business and Policy Perspectives on Micro Launchers* (pp. 67–90). Springer International Publishing. https://doi.org/10.1007/978-3-319-78960-6_4

Venkatesan, A., Lowenthal, J., Prem, P., & Vidaurri, M. (2020). The impact of satellite constellations on space as an ancestral global commons [Publisher: Nature Publishing Group]. *Nature Astronomy*, *4*(11), 1043–1048. https://doi.org/10.1038/s41550-020-01238-3

Vernile, A. (2018). *The Rise of Private Actors in the Space Sector*. Springer International Publishing. https://doi.org/10.1007/978-3-319-73802-4

Villas Boas, D. J. F., Pessoa Filho, J. B., Moraes, A. d. O., & Melo Souza, C. H. (2023, January). 17 - Innovative and low-cost launch systems. In F. Branz, C. Cappelletti, A. J. Ricco, & J. W. Hines (Eds.), *Next Generation CubeSats and SmallSats* (pp. 403–419). Elsevier. https://doi.org/10.1016/B978-0-12-824541-5.00005-4

Vogel, H. L. (2021). *Financial Market Bubbles and Crashes: Features, Causes, and Effects*. Springer International Publishing. https://doi.org/10.1007/978-3-030-79182-7

Wainscott-Sargent, A. (2022, January). January/February 2022 - Today's Global Microlaunch Mindset: Flexible, Greener, Cheaper, and Safer | Via Satellite. Retrieved May 2, 2024, from https://interactive.satellitetoday.com/via/january-february-2022/todays-global-microlaunch-mindset-flexible-greener-cheaper-and-safer/

Wekerle, T., Filho, J. B. P., Costa, L. E. V. L. d., & Trabasso, L. G. (2017). Status and Trends of Smallsats and their Launch Vehicles — An Up-to-date Review [Number: 3]. *Journal of Aerospace Technology and Management*, *9*(3), 269–286. Retrieved April 30, 2024, from https://jatm.com.br/jatm/article/view/853

Werner, S. E., Debra. (2024, April). Suppliers struggle as military embraces small satellites. Retrieved May 16, 2024, from https://spacenews.com/suppliers-struggle-as-military-embraces-small-satellites/

Yin, R. K. (2009). *Case Study Research: Design and Methods* [Google-Books-ID: FzawIAdilHkC]. SAGE. https://books.google.nl/books?id=FzawIAdilHkC

Yost, B., & Weston, S. (2024, February). State-of-the-Art Small Spacecraft Technology [NTRS Author Affiliations: Ames Research Center, Millennium Engineering and Integration (United States) NTRS Report/Patent Number: NASA/TP-20240001462 NTRS Document ID: 20240001462 NTRS Research Center: Ames Research Center (ARC)]. Retrieved May 14, 2024, from https://ntrs.nasa.gov/citations/20240001462

A

Appendix A

A.1. Interview Protocol

The questions for all the interviewees are based on the same context but framed differently, due to the sensitivity of the topic.

Questions for Experts:

Basic Question:

- I hope you have gone through the inform consent form, and with your permission I would like to start the transcription of this Interview?

Main Questions:

1. What are your views on the overall SmallSat launcher market? How does the future look for this market?
2. Can you explain the past hype around public and private investment in micro launcher projects? What about the recent bankruptcies, such as Astra considering filing for bankruptcy again in April 2024?
3. Several micro launcher companies have shifted towards making larger rockets or different categories. What do you think is driving this trend?
4. How do the value propositions of micro launchers compare with those of rideshare, piggyback, OTV and Self Propulsion?
5. One of the value propositions of micro launchers is on-demand launching/high responsiveness. But with several other medium/heavy LVs players offering more rideshare options, will the demand be able to sustain the many micro launch companies currently in operation?
6. What could be the impact of SpaceX's Starship on the Small Satellite launch market, particularly on micro launchers? Considering the propositions about the use of the Starlink bus, as SpaceX has figured out how to place Starlink V2s on the Starship, could two or three Starlink slots be filled with a bus carrying smallsats, i.e., piggybacking?
7. Do Orbital Transfer Vehicles pose competition to Micro launcher solutions? If so, how? And does the emergence of Starship provide some significance to this solution?
8. Do you believe there will be further consolidation in the micro-launch industry, and if so, what might trigger it?
9. What challenges and opportunities do Regulations and Geopolitics provide for the micro launch Industry?
10. What strategies can micro-launch companies employ to stay competitive in the face of evolving industry trends?

11. How important do you think government or institutional support is for micro-launchers?
12. Since launch costs are a key factor while designing a smallsat, and in the future, launch prices with MLV, HLV, and SHLV are predicted to be lower. How do you see these trends impacting the small satellite manufacturing industry in the design choices they make?
13. How can smallsat manufacturers adapt their strategies? For example, should they invest in R&D for mass optimization of their products (e.g. Cubesat Dispensers) ? i.e., should they make their products with cheaper but heavier material OR choose to go even lighter than currently available but with more costly materials?

Miscellaneous:

- Are there questions I haven't asked but you expected to be asked regarding this topic?
- Do you have any remaining remarks or questions?

B Appendix B

Figure B.1: Literature overview of new space startup context and markets (Gonzalez, 2023)

Literature overview of new space startup context and markets.

Source	Context for Space startup	Market Grouping & Segments
Lamine, Anderson, Jack Fayolle [14] (Based upon Bryce Tech) [4,28]	• A new business entity that provides space technologies, products, or services • Has received and reported seed funding or venture capital	• Manufactures: o Satellites o Launch vehicles o Other space-based systems o Satellite ground equipment • Provides services that rely on space systems • Provides analytic services based on data collected extensively from space-based systems either alone or in combination with terrestrial systems
Moranta and Donati [29] (Based on Seraphim Capital) [31]	• Company younger than 10 years • Business tends to feature innovative concepts and models • Not yet reached business maturity • Context differentiates between upstream, downstream, and beyond Earth o Upstream: Build, launch, data. o **Downstream**: Downlink, analyze, store, product. o Beyond **Earth**	**Upstream:** • Build: Space Hardware (Satellite manufacturers, propulsion, and modules), other componentry, and engineering • Launch: Launchers, launch services, flight and delivery; space tugs • Data: Satellites, Drones, and UAV **Downstream:** • Downlink: Communications, ground terminals, security, an storage • Analyze: Satellites, drones, and UAV • Product: Data platforms, location, and mapping **Beyond Earth:** • Space exploration and resources, space infrastructure, space research
Matt Weinzierl and Mehak Sarang [32]	• Context differentiates between a space-based or earth-based economy o Space-**for-earth Economy**—Goods or services produced in space for use on earth o **Space-for-Space Economy**—Goods and services produced in space for use in space	**Space-for-earth economy:** o Telecommunications and Internet infrastructure on Earth observation o National security satellites **Space-for-space economy:** o Mining the moon or asteroids on in-space habitats o Refueling depots
Walter Peeters [33,34]	• Private companies, which act independent of governmental space policies and funding, • Target equity funding and promote affordable access to space and novel space applications. • Potentially leverages the transfer of space technologies	• Tourism • Solar power stations • Tele-operated satellite repair robots • Satellite & space transfer services • Space business parks • Industrial platforms • Asteroid mining • Lunar & Mars research stations

Figure B.2: The New Space Economy Value Chain (Paravano et al., 2023)