Space Business

Emerging Theory and Practice

Edited by

Arto Ojala

William W. Baber

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ISBN 978-981-97-3429-0 ISBN 978-981-97-3430-6 (eBook)
https://doi.org/10.1007/978-981-97-3430-6

This Palgrave Macmillan imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Foreword

While we are still in the early stages of the new space economy, there is palpable excitement about its business potential. As of January 2024, the Space Foundation estimates that 91 countries operate in space, and that the size of the space economy is around $546 billion. If projections are to be believed, the future space economy will become at least a trillion-dollar economy. Valuations by prominent financial institutions fuel the enthusiasm: by the 2040s, Morgan Stanley puts the space economy size at around $1.1 trillion, Bank of America at around $2.7 trillion, and Goldman Sachs even beyond that.

Something has changed about space, but what exactly? The popular narrative is that we have moved from an old model of government-led space ventures to a contemporary one dominated by a new generation of private firms and entrepreneurs with their own visions.

These new actors have brought an unprecedented range of technologies and services to the global space economy. A number of conditions favor their rise. Entrepreneurship and equity funding have combined fortuitously to benefit not just their interests but also other space stakeholders in the wider ecosystem. Thanks in large part to the pioneers of reusable rocketry, the costs of launching an object into space are going down; as well, processes of miniaturization are further reducing the size and weight of objects headed to space. Increasingly, space activities also force attention toward value chains based on data rather than just supply chains for assembling physical technologies.

This is among the first books that attempts to move beyond headline news to assess the landscape of new commercial prospects, primarily with a focus on activities in Low Earth Orbit (LEO). It is the business side of things that is of theoretical, substantive, and methodological interest to the collaborators of this volume. Who are the players in the new space realities? What are they making and for whom? What drives them? Who are the customers, and what motivates them?

It is difficult to know which space businesses will eventually thrive and profit. Meanwhile, they continue to draw attention worldwide. Space-related infrastructure, data, and applications are interlinked across civilian, commercial, and military activities. There are rockets that go up but also down, mega-constellations that tackle the digital divide, and small satellites producing big data that intersect with other technology frontiers like AI to enable constant observation of virtually all human activities on a planetary scale. There are of course continuing ventures with a strong element of science and exploration and off-world settlements; in parallel there is the push to harness space-enabled data for all kinds of purposes ranging from disasters to development around us on Earth. The market for space tourism is also gaining ground. While still branded as a luxury space item, the very idea attracts enthusiastic devotees from developed and developing countries alike. As 95 percent of space technologies are dual use, issues of space security and defense also condition profits and prospects for space business.

All governments, along with a wide range of their home commercial entities, are hoping to position themselves in this emerging multi-faceted ecosystem. This book is a valuable informational guide for such endeavors.

Seattle, WA, USA Saadia M. Pekkanen

Saadia M. Pekkanen is the Job and Gertrud Tamaki Endowed Professor at the University of Washington in Seattle. In addition to this appointment in The Henry M. Jackson School of International Studies, she is Adjunct Professor in the Department of Political Science, and Adjunct Professor at the School of Law where she also teaches courses. She earned Master's degrees from Columbia University and Yale Law School, and a doctorate from Harvard University in government. At the University of Washington, she is the founding director of the Space Law, Data, and Policy Program (SPACE LDP), and the founding director of the Qualitative Multi-Method Program (QUAL). She works at the

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Preface

The editors created this book to update understanding of commercial activities of firms acting in space-related industries or utilizing services provided by space technology firms. These commercial activities are largely conceptualized by "New Space" concept where commercial activities in space are mainly taken by private firms, partly replacing the actions of government-resourced space institutions, i.e., "Old Space." New Space refers to business opportunities exploited through small and low-cost satellites and innovative space data services. These services include, for example, precise navigation solutions, satellite imagery and processing, satellite telecommunication, data communication, remote sensing, among others. Further, commercial use of space technologies has created new services, businesses, business models, value chains, and ecosystems. Thus, space-related technologies, activities, and services are nowadays more easily available for entrepreneurs and small businesses. This increasing accessibility has created numerous research opportunities in this field that is known broadly as space business and which includes New Space as well as traditional space activities and business opportunities. Although space technologies and services have attracted growing interest in many technical disciplines, academic studies of space business and management activities among firms acting in New Space or utilizing the services provided by New Space are just emerging.

There are several theoretical insights encompassed in this volume. These include the main influences on space business for the near term such as increasing resilience of space and communication systems, decreasing cost of equipment and launch services, and miniaturization. Taken together, these are likely to drive demand up and cost down. Space business, especially in the context of New Space, forms an ecosystem of much greater complexity and with far more partners than the previous space business could claim. This ecosystem has structures and layers discussed in this book that will guide the evolution of New Space, its business and research, for some time. Space business is now in fact not merely one large ecosystem, but is composed of smaller ecosystems around particular firms, technologies, and regions. Understanding these smaller systems as well as the overall ecosystem will aid business decision makers as the industry develops. Space business is no longer focused on technology as in the past when telecommunications or science projects from Moon landings to deep space exploration dominated. The current era is just beginning to provide services from tourism to services in orbit to development of lunar resources. These are characteristics of space business that are touched upon in this volume but which need more research in the near future.

This book is targeted toward both academic and business readers. In academia, the audience will include researchers, business students, and business educators seeking basic understanding of space business and its characteristics. These audiences will include students and researchers at universities as well as at polytechnics. Educators will assign various chapters for reading. Meanwhile, students in search of up-to-date theory and insights will frequently find these chapters in search results. Policy institutes and think tanks with focus on space will find the book of high interest.

Among businesspeople, the book will provide understanding of business activities, business models, value chains, and ecosystems in the space business. Economists in large multinational firms will be interested in the explication of theory and industry structure contained in the book. The audience further includes consultants, managers working in space-related industries, and entrepreneurs planning to establish space businesses.

Vaasa, Finland — Arto Ojala

Kyoto, Japan — William W. Baber

Acknowledgments The editors gratefully acknowledge the support of their institutions, the volunteer help of reviewers, and the cooperation of the authors. We also are grateful to our families for their patience and understanding during the preparation of this volume.

List of Reviewers

The editors and authors offer their acknowledgment and thanks to the reviewers who contributed time and expertise by making insightful and thorough comments. These comments improved the quality of the chapters and focused the authors on more clearly telling their stories and understandings.

Each chapter was peer-reviewed by two or more academics or practitioners from around the world. The review process was double-blind, except where the editors contributed reviews.

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PART I

Space Business: Theory and State of the Art

New Space Era: Characteristics of the New Space Industry Landscape

William W. Baber and Arto Ojala

1 Introduction

The space age dawned in 1957 with the successful orbiting of Sputnik by the Soviet Union, and it surged forward with the Apollo moon landings, ushering in the era of satellites and deep space probes. This situation in which space business relied on space science probes, space shuttle flights, and satellite launches largely persisted until the decentralization of space exploration began in the years following the 2003 Challenger Shuttle accident. In the subsequent decade, the US space agency, the National Aeronautics and Space Administration (NASA) shifted its focus from engaging in a wide array of space activities to concentrating on lunar, Martian, solar, and other deep space missions.

Nonetheless, historical events accelerated the decentralization trend as the Russian space agency experienced several highly visible launch failures

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_1

from 2010 to 2014. It was evident that a transition from government-led space exploration to private-sector leadership would occur. The questions were how rapidly and effectively the private industry could make this transition. Time was of the essence as NASA canceled the space shuttle program, with its last flight in 2011, and had to depend on Russia's Roscosmos to deliver supplies and crew to the International Space Station (ISS). Even earlier, however, in 2001, the privatization of Intelsat occurred, marking a clear departure from government-dominated space services. The privatization, the move away from human launches by NASA, and similar events were steps toward the New Space era. New Space is understood here as a model where value stems from investor support for entrepreneurial ventures, in contrast to "old space," where value traditionally originated from government sources directed to research institutions and defense contractors (Paikowsky, 2017; Peeters, 2021; Weinzierl, 2018).

The development of New Space saw the establishment of private firms like SpaceX, Virgin Galactic, and Blue Origin in sectors that were previously limited to government activities. First, they took on launch services, and in subsequent years, milestones were frequently achieved, ranging from tests of new rockets to successful dockings at the ISS, the development of reusable rockets, and the emergence of space tourism experiences. These firms, however, also took on new services requiring satellite fleets and ground-based services. They were joined by many new entrepreneurial firms providing various services from satellite manufacturing to management to data analysis. The skills and technologies of these ambitious private firms are maturing, and the exploitation of Low Earth Orbit (LEO)—the region spanning roughly from 150 km to 2,000 km in altitiude (Lawrence et al., 2022)—is now in full swing.

With a decade or more of rapid and profound changes behind it, this field is overdue for a review of its theories and characteristics, especially concerning business activities related to space. The most recent comprehensive assessment of the industry can be found in Gurtuna's (2013) book, "Fundamentals of Space Business and Economics." However, significant developments have occurred in the intervening years. The current book aims to comprehend these changes and establish the theoretical foundations of the rapidly emerging business field known as New Space. This field encompasses commercial LEO space services, trends, and technologies.

This book primarily centers on LEO and New Space; however, the delineation between these topic areas and conventional space business is not distinctly defined. The LEO space business, for instance, shares certain business aspects with higher orbits, contingent on the purpose and flexibility of satellites or fleets, as well as the utilization of ground stations and other services. The established space business, predominantly driven by major science projects and telecommunications, has not vanished; rather, it continues to coexist and, in certain instances, overlaps with New Space businesses and their innovative approaches. Dual use, that is for military and civilian purposes, is less clearly separated than in the past in space activities as seen in the examples of commercial space imagery delivered to support Ukrainian defenders and Starlink internet access exploited by all combatants.

The aim of this introductory chapter is to highlight the characteristics and recent development in space business. We present five propositions supported by literature and in-depth interviews with experts within the space industry. We then synthesize these into tentative theory elements, identifying the feedback loops that illustrate how the propositions interact with current trends and the realities of the industry.

2 Evolution of the Space Business

In his book, Gurtuna (2013) identified seven features of space business before the New Space era. We will now elaborate on these features briefly. Firstly, business cycles in the post-Apollo era were defined by funding announcements or the lack thereof, which led to lengthy decision-making processes. The waning interest in space after the Apollo programs resulted in a lack of projects until satellites for defense and communications were launched. Secondly, long investment horizons were common in space business. At that time, probes might take 2–4 years for approval, followed by additional years for construction and the subsequent launch. For example, the New Horizons mission was discussed in the 1990s, approved in 2001, and eventually launched in 2006. Thirdly, most technological advances were driven by defense needs, while export restrictions made it difficult to provide services internationally. Major firms in the sector, such as Boeing and Lockheed Martin, had both military and civilian space programs with overlapping equipment, technology, and staff. Fourthly, the primary customers in this time period were national governments of developed countries and their agencies. Over time, other customers began to include telecommunications groups. Fifthly, the only destinations for humans after the Apollo program had concluded were space stations, such as Skylab and the ISS. Sixthly, there were very few companies in each category, such as lift services, satellite building, ground station services, components, and more. Internationally, there was limited competition for heavy lift, including Roscosmos, Ariane, and NASA. Lastly, most satellites and space probes were one-off products. Over time, some communication satellites were built on the same platform, allowing for batch production and other limited efficiencies. Altogether, much has changed in the decade since the publication of Gurtuna's list. The Table 1 provides a then-and-now comparison.

Of the seven features, it is clear that six have undergone radical changes. The remaining one, lack of destinations, however, has changed only in that China's space station is now in use. Nonetheless, with various firms discussing plans to construct so-called manufacturing hotels or tourist hotels in orbit, we may see an increase in space-based destinations within a few years or even sooner. Furthermore, the Artemis Accords and separate plans by the USA and China may lead to the establishment of manned posts on the moon within the decade.

Currently, the space business is undergoing significant changes that have emerged over the past decade. Firstly, there has been a remarkable shift in funding. In the past, funding primarily came from governments, often in the form of major space exploration projects. In the private sector, the high costs associated with telecommunications satellites in high orbits were typically funded through stock issuance. However, today, funding is also flowing from conventional loans and, more recently, through venture-style equity investments. This latter practice, in particular, is often referred to as "New Space" (Paikowsky, 2017; Peeters, 2021; Weinzierl, 2018) and has now become a significant part of the space business. Another major shift is found in manufacturing. The smaller size of satellites, rapid developments in 3D printing, use of commercial off the shelf (COTS) components, and miniaturization have allowed satellite manufacturing costs to decrease.

As a result of these changes, new business models are rapidly emerging, offering value propositions in positioning, localization, advanced services, and orbital manufacturing, among others (Davidian, 2020; Frischauf et al., 2018; Madan & Halkias, 2022; Prol et al., 2022). These business models may revolve around novel value chains based on data rather than

Table 1 Space business features, 2013 and 2024

Features identified by Gurtuna (2013)	*Up to 2013*	*Currently*
Business cycle	Long cycles of planning and construction	Shorter, as demand has increased for larger satellites and entirely new demand has emerged for microsatellites used in various applications
Long investment horizon	Very long horizon measured in years	Much shorter cycles of demand, design, and launch for microsatellites, with an increasing number of projects originating from other space agencies (e.g., Japan, India, Israel…)
Defense linkage	Very strong	Less strong than in the past; however, defense spending and funding remain crucial as near real-time data is increasingly in demand
Government as main customer	Few non-government customers other than telecommunications firms	Less so (small and startup services can also be customers)
Destinations limited	Skylab and later ISS	Still very limited, but now space tourism has begun. Orbital manufacturing and orbital tourist hotels are still lacking; the moon is not yet a destination
Limited competition	Few firms involved in assembly. Often depending on the same suppliers	More suppliers and lift options are available. Everything is more cost-effective: SpaceX has reduced launch costs, and there are more rocket builders, ground services, and so on
Curse of single unit of production	Almost all satellites are unique unless a small series was planned	Much less common—mass production of microsatellites, although this still applies to science packages

the traditional models around making and assembling physical components. New Space has also increased resilience through the use of cluster constellations, providing greater flexibility and allowing dual use, military and civilian, of satellites and data. Previously, space services were vulnerable to single points of failure, such as the failure of a satellite or a launch. With the advent of microsatellites and distributed control technologies, the failure of a single node or unit has less impact.

New Space has also opened the door for small and emerging economies to enter the space industry and related business activities. Their emergence has led to the development of new national space agencies and/or private businesses in countries other than major economies, including Finland, South Korea, Israel, Norway, Sweden, the United Arab Emirates, and many others. The increased number of players has created a greater demand for space equipment and services. The trend toward increased firms and countries also differentiates today's space business from the years when Western space programs heavily relied on Russian launch capacity and parts and subassemblies from China (Brennan et al., 2018; Wyne, 2020). This trend to separation is likely to continue, especially in light of the Russian invasion of Ukraine and the challenges of conducting legal business with Russian entities. The de facto decoupling may lead to the independent evolution of technologies which are available within specific groups of countries and have little or no interoperability.

Given the tense global political situation and the re-territorialization of space (Brennan et al., 2018), there is an increasing threat of hacking or terrorist attacks, as malicious actors may plan to target or destroy a satellite or an entire orbital fleet (Crain, 2016). This threat is exacerbated in part because major space-faring countries such as Russia and China appear willing to increase orbital debris to claim orbital territory (Brennan et al., 2018) or as a display of attack capabilities (Patel & Koller, 2022), despite the potential drawbacks to their own operations. Additionally, rogue states, hackers, and political or religious extremists are increasingly equipped to hijack a system (Willbold et al., 2023) which could then be destroyed or sent out of control. Because such tech savvy actors are uninterested in adhering to norms around safety and access, there are no moral or practical limitations on their potential for destruction.

3 Empirical Background

To achieve a better understanding of current development of space business, we interviewed 10 experts working in different positions, tasks, and fields of space business. All the interviews were conducted in face-to-face meetings with interviewees in 2023. Each interview was recorded and transcribed verbatim. During the interviews, we also took notes and if needed, photos. The details of each interviewee and length of the interviews are displayed in Table 2.

Table 2 List of interviewees

Interviewee	*Interview length (hrs)*	*Background and expertise of the interviewees*
Interviewee A	1:00	CEO of a space firm specializing in the development of small spacecraft movement and lifecycle control systems
Interviewee B	1:05	CEO of a technology firm engaged in the development of light sensing and spectroscopy technologies for satellites
Interviewee C	0:40	CEO of a consulting firm offering services in spacecraft engineering, radio technologies, microwave components, etc
Interviewee D	1:00	Director of Space and Defense at one of the oldest space firms in Finland, with a focus on technology design and software development for space projects
Interviewee E	1:00	Chief Strategy Officer and co-founder of a space firm providing earth observation data through their own SAR satellite constellation
Interviewee F	0:55	Director of a space firm offering earth observation data via their own SAR satellite constellation
Interviewee G	0:55	CEO of a space firm providing earth observation services based on a hyperspectral satellite constellation
Interviewee H	1:50	CEO and founder of a space firm specializing in ground station services
Interviewee I	0:55	Chief Business Officer of a firm providing design and development services, with a specialization in small satellites and the space industry
Interviewee J	1:05	Chief Product Officer and founder of a firm providing weather forecasting services based on satellite data

4 Findings and Propositions Development

Conventional theories of business and economics broadly apply to space business and its constituent organizations. Nevertheless, the theory surrounding space business differs from conventional business theory in several aspects. Theory serves various purposes, such as explanation and provocation (Sandberg & Alvesson, 2021), among others. This chapter primarily focuses on theory development to explain observed phenomena. Secondly, the chapter utilizes theory to stimulate changes in thinking and perspective among readers. Theories that provoke should encourage further work to either substantiate or challenge these theoretical points (Sandberg & Alvesson, 2021). With this in mind, the authors present five propositions about space business, which, when considered together, set it apart from other business domains. While the propositions may apply to other business domains, they are of particular importance to space business. Other propositions will certainly emerge, these five are not exhaustive and the authors encourage others to identify more. The salience of the themes in these propositions emerged from recent literature on the space industry and interviews with experts working in the space business.

4.1 Space Business Is in a Phase of Decreasing Costs

At the time of writing, the space business is experiencing an ongoing reduction in costs. This cost reduction is driven by the recent significant decrease in launch expenses, mass production, and further accelerated by miniaturization as has been summarized previously (Bushnell & Moses, 2018; Garzaniti et al., 2021). The cost of launching a kilogram of mass into orbit has substantially decreased with the introduction of reusable rocketry. Spearheaded by SpaceX, the cost per kilogram of launch has seen a remarkable decline with the introduction of reliably reusable rocket bodies. The savings per launch for the customer amount to approximately one-third in the case of the Falcon Heavy rocket according to the company. However, it's essential to note that this substantial price decrease is a one-time occurrence in the industry. We cannot anticipate whether other rocket components can achieve similarly significant cost reductions. Also, inflation is driving up nominal prices (Foust, 2023), though perhaps not as fast as national indices. One of the interviewees explained the cost reduction as follows:

> New Space offers possibilities that did not exist 20 years ago. We can act faster, be more competitive, and more cost-effective while remaining efficient when we bring new services to the market. We are like a low-cost carrier in the space business, and we bring a new type of agility to the market. (Interviewee F)

Consequently, it is the ongoing process of miniaturization that reduces weight and, consequently, lowers the cost of delivery to orbit. Moore's Law states that integrated circuit density doubles about every two years (Moore, 1965). However, Moore's Law does not inherently indicate that costs must decrease, and the low cost of launching smaller components and systems is offset by the high expenses associated with development and production as well as inflation caused by chip shortages. Other factors, including advances in materials, batteries, communication equipment, and so on, enable engineers to create smaller units. The unit size of satellites has shrunk from over 3,000 kilograms for a single Telstar communications satellite in 1995 to about 250 kilograms in 2023 for a Starlink micro-satellite and as small as 1 kilogram for 1U (one unit) CubeSats (Kopacz et al., 2020). Meanwhile miniaturization allows more computing power onboard even small satellites and in-orbit data processing is becoming possible saving time and download bandwidth (Van Camp, 2023), and thus costs. The current generation of microsatellites benefits from lower power consumption, resulting in smaller, lighter electrical systems and batteries, as well as lighter communication equipment (Kopacz et al., 2020); that weight decrease also cuts launch cost per unit. Since satellites are not required to last too long, due to large fleets, COTS components allow further cost reduction. The trend of miniaturization and mass production in electronics is well-established and will continue to benefit the space business for the foreseeable future. As one of our interviewees emphasized:

> Unlike the old model, where developing a single satellite could cost billions and take up to 15 years, the current emphasis is on creating small, cost-effective satellites through mass production. (Interviewee I)

Based on the above, we propose:

Proposition 1 Long-term trends indicate decreasing costs for satellite manufacturing, delivery, and services, particularly for New Space.

4.2 *Resilience Is Greater than Previously in Space Business*

Historically, the space business has been plagued by expensive failures and the high cost of replacement, as well as the high cost of success. For example, the failure of Intelsat 603 in 1990 relied on the owner to pay all costs of rescue or replacement (Burgess, 1992) in order to secure long-term success. While high replacement cost and long lead time remain for geosynchronous communications satellites and other major equipment, in the New Space era, the firms increasingly rely on fleets of smaller, more cost-effective LEO satellites. One of the interviewees highlighted this as follows:

> In such endeavors [old space], failure was not an option, as second chances are not available. However, New Space ventures offer more flexibility, opportunities for duplication and replication of projects, compared to traditional space projects. (Interviewee D)

As LEO satellites collaborate to perform tasks, such as collecting imagery from locations they briefly pass over due to their low-altitude orbits, they form a network. If one satellite fails, another can assume the task. Additionally, these satellites can be reprogrammable and redirected (Tumenjargal et al., 2019), or replaced if necessary. For instance, the Galileo satellite navigation system maintains a fleet of 24 satellites plus spares well above LEO altitudes which are therefore more expensive to reach. In contrast, Starlink is expected to have tens of thousands of satellites, all in low orbits, when completed. Therefore, the emerging space business based on LEO constellations is all but immune to expensive single-node failures. With multiple affordable nodes, downtime is less common and shorter. Additionally, a single catastrophic event, such as a solar storm, collision, or intentional attack, is less likely to completely disrupt the functioning of the system. One of our interviewees expressed this as follows:

> In the New Space paradigm, satellite reform and technology updates in orbit are crucial. This approach allows for continuous updates and deployment of new technology over the service's lifespan. Furthermore, with a cluster constellation, if one satellite fails, the service can continue operating. However, managing fifty satellites poses a greater challenge than a single one. (Interviewee I)

The increased resilience of these systems, thanks to their numerous units, also extends to ground stations. The number of ground stations and access to them through services such as Amazon Web Services and Microsoft's Azure has increased remarkably in recent years (Willbold et al., 2023). Although ground stations may be under control of various firms, they have established procedures for interaction, task sharing, and managing data uplinks and downlinks. Consequently, they too form complex networks with the advantages of being able to reroute around non-functioning units. New technologies will also lead to greater resilience of systems and services, however that discussion is found in the section on illegal activities.

This leads us to the following proposition:

Proposition 2 Space business systems are becoming more resilient in terms of service continuity due to the greater number of interconnected units they include.

4.3 Increasing Regulation for Space Business

The rapid expansion of the space business is accelerating the need for updated governmental regulations (Patel & Koller, 2022). Governments are becoming more aware of the space business, leading to adjustments in policies to support and regulate business activities. Recent implementations include fines in the USA for failing to properly maneuver satellites, imposed by the Federal Communications Commission (FCC, 2023). Governmental awareness and actions encompass providing funding or contracts to support promising technologies through defense organizations like the Space Rapid Capabilities Office and traditional space agencies such as NASA, European Space Agency (ESA), and Japan Aerospace Exploration Agency (JAXA). The growth of orbital debris, items that are not under any control, will likely lead to stricter regulations on satellite design and management in the near future such requirements for fuel availability for end of life maneuvers. Regulations are poised to focus on sustainability issues such as orbital debris, launch pollution, and re-entry pollution. Launches, especially those using solid propellants, have strong negative impact on the ozone layer while re-entry incineration leaves fine metal particulates in the upper atmosphere (Lawrence et al., 2022; McElroy, 2022; Ryan et al., 2022). Increased or internationally harmonized regulations will decrease uncertainty for business managers.

On the other hand, some costs may rise. Interviewees also highlighted the impact of regulations on space business:

> Navigating regulations is a constant concern and there is always a question of how we can act on a global scale. We need to consider what is permissible in Finland, the EU, and the USA, and what types of services we can offer in different locations. (Interviewee G)

> Particularly concerning ground stations, the legislation varies significantly between countries. In Finland, we now have legislation governing ground station activities. However, in other countries like Sweden, there still appears to be no specific legislation in place. This disparity creates challenges for firms operating within this industry. (Interviewee H)

Nevertheless, regulations introduced by advanced economies may play a lesser role in some countries due to the process of decoupling and de-risking. Decoupling and de-risking involve reducing supply chain exposure to risks associated with sanctions, political instability, and similar issues (Baldwin & Freeman, 2022). With diminished benefits from the value chain, countries subject to decoupling and de-risking may have less incentive to comply with international rules and regulations perceived as foreign and of limited benefit. The countries least likely to comply after decoupling and de-risking include China, Russia, and, of course, countries that have traditionally operated outside of international norms, such as Iran and North Korea. Businesses operating in such countries may adhere to different rules than businesses elsewhere. This is summarized in a proposition as follows:

Proposition 3 Regulation related to space business is likely to increase in the near term with impact on space business management and security as well as cost and inconvenience.

4.4 Space Business Can Deliver Unique Benefits to Society

Activities in space have the potential to provide benefits to society and institutions that are unattainable without space-based infrastructure (McElroy, 2022). At the same time, emphasis in space has moved from human progress to value for money (Suzuki, 2007), though this change does not preclude societal benefits, which appear to come in parallel. These benefits can be achieved through the manufacturing of products and the delivery of services. An example of this is satellite telephony, which allows those with receivers to make phone calls worldwide. Rapid dispatch of rescue services to remote areas is also possible through space-based communications, and existing but still developing application (McGarry et al., 2023). More importantly, disasters, including their intensity and boundaries, can be assessed more rapidly and accurately from space. Near real-time services enable satellites to collect imagery at short notice and deliver it within ever shorter timeframes. The results of such speed and flexibility lead to faster responses in emergencies, improved disaster planning, and better assessments of the needs of affected areas and people. Such space-based technologies and services can have a positive effect on delivery of the United Nations Sustainable Development Goals (SDGs) (United Nations Statistics Division, 2020) and the quality of life of people in developing as well as developed economies (Manotti et al., 2023).

Previously space technology was more clearly identifiable for military or non-military purposes. For example, spy satellites and telecommunications satellites had distinctly different orbits and onboard systems. More recently however, constellations of satellites in LEO or Medium Earth Orbit (MEO) may carry a variety of imaging sensors which can be put to dual use for such disparate purposes as disaster response or providing information about military assets; indeed, space technology can be considered fundamentally dual use (Paikowsky, 2017). Debris removal systems, for example, could also be used to remove working satellites (Pražák, 2021). In both use cases, the data can be updated multiple times per day, allowing rapid responses. Since firms may choose to sell raw imagery and processed data to many kinds of customers, sharp delineation between civil and military use can no longer be made.

In manufacturing, despite limited testing, there are signs that drugs and materials with highly valuable properties that are otherwise unattainable may be manufactured in space in ultraclean, microgravity environments at a practical cost and scale (Weinzierl et al., 2022). Various solutions have been tested, such as launching and retrieving manufacturing modules, or proposed, such as multi-use, semi-permanent platforms, commonly referred to as manufacturing hotels, where various manufacturers could produce substances in manned or fully automated settings (McElroy, 2022; Prater et al., 2019; Sowards et al., 2022). Constraints in this context include the cost of launch and the limited cargo sizes that even large rockets can handle. This leads us to the following proposition:

Proposition 4 Various space-based business models offer unique social benefits to humankind; however, military and other negative or even abusive business models may increase.

4.5 Illegal and Irresponsible Business Activities Will Evolve with Space Business

Irresponsible business refers to activities that create injustice or damage in relation to the community, society, and/or business practices (Michailova, 2020). In the space business, these activities include hijacking satellites, appropriating or misusing data, spoofing, creating space debris, stealing or corrupting data, deploying malware, attacking satellites and their control centers, and so on. Irresponsible and illegal activities are not surprising in and of themselves. Rather, what is surprising is that engineers and businesspeople involved in space activities often do not think about and prepare for these challenges. One of the interviewees highlighted this issue as follows:

> There are always possibilities for a war actions or sabotage in space. The ways to do it are interference of radio communication, block usage of GNSS [Global Navigation Satellite System], etc. Or someone can try to impact on ground systems either by using cyber or kinetic affection that is much easier than trying to impact flying objects in space. (Interviewee I)

A study by Willbold et al. (2023) found that space-based assets were vulnerable at the most fundamental levels. They suggest that space engineers and IT professionals might lack awareness of security issues. The lack of basic security on satellites reflects the early days of the internet when security was an afterthought. Similarly, the lack of security in space business provides a foothold for criminal activities, allowing them to establish a presence. With a foothold and a strong motivation to survive, malicious actors are likely to adapt their targets and skills to the evolving virtual ecosystem (Moore, 2016). Each party will adapt to changes implemented by the other. In this race to adapt and survive, it is imperative for business professionals, government regulators, and academics to be aware of threats in order to outmaneuver them as frequently as possible. Various technologies that will boost resilience to hacking appear to be coming into play, such as debris detection and evasion, debris deorbiting, narrow aperture, and laser-based communications, AI-based decision-making in orbit for fleet management, to name a few (Aerospace, 2022; Bailey, 2020; Patel & Koller, 2022; S-ISAC, 2023; Van Camp, 2023). Additionally, legal structures are likely to develop which will aid in deterring and prosecuting malevolent actors (Freeland & Ireland-Piper, 2022; Way & Koller, 2021).

In addition to criminal and irresponsible organizations, space business faces man-made threats such as orbital debris. With 27,000 pieces of debris being tracked and perhaps a million more in orbit, orbital debris poses a serious safety concern as well as a business opportunity. Key events, such as the 2007 Chinese anti-satellite test, the 2009 collision of the Iridium and Kosmos satellites, the 2021 Russian anti-satellite demonstration, and the disintegration of a Kosmos satellite in 2023, have increased the potential for a Kessler Syndrome event (Kessler, et al., 2010). This could result in much of LEO space becoming unusable. Business activities related to global active debris removal are expected to reach a market value of $273 million in 2030 (Patel & Koller, 2022). Firms offering debris collection, removal, tracking, and other services are likely to be in demand. The interviewees explained this as follows:

> The technology we are developing, a plasma brake for de-orbiting, is one solution to this problem. The number of satellites in orbit is growing exponentially, and they need to be de-orbited somehow. Dealing with this increasing amount of space junk presents a significant challenge. Additionally, there is upcoming legislation addressing the retrieval of satellites from orbit. (Interviewee A)

> One negative thing in small satellites is that if you do it really cheaply, it does not include any kind of control or deorbiting system. Then there is no way to control it e.g., when the battery runs out or solar panels' electricity production stop to work. There should be a standard for minimum requirements that should be in the place so that we can bring satellites safety down in the end of its life cycle. (Interviewee I)

Space business may see the arrival of funds supported by insurance firms, industry associations, and national governments that will support technology and missions for deorbiting debris and aging equipment, as has happened in other business areas. Based on this, we propose the following:

Proposition 5 Criminal and irresponsible business practices will evolve in constant dynamic adjustment with legitimate business needs and practices.

5 Conclusion

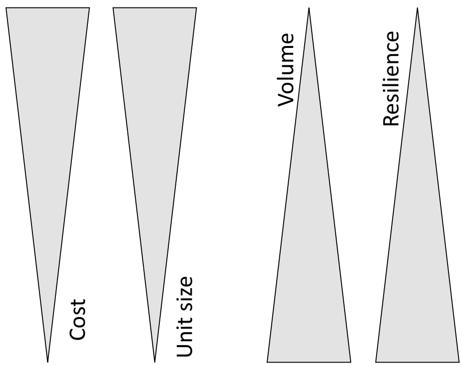
Here follows a brief written and graphical summary of space business theory.

- As unit size decreases, the cost per unit (considering production, delivery to orbit, operating cost, insurance, etc.) decreases;
- As unit cost decreases, the volume of orders and deliveries to orbit increases which also decreases cost per unit;
- As numbers increase and therefore the substitution effect for downed nodes improves, the overall resilience of systems increases.

The above concepts are depicted on sliding scales indicating their relationships in Fig. 1. Further work is required to know the exact mathematical relationships including whether they are linear or non-linear.

Figure 1 shows that cost decreases with the size of the satellites. The main source of the cost decrease is that multiple small units can be launched with one rocket. Full size satellites weighing 500 to 3,000 kilograms, or more, can only be launched a few at the time or individually.

Fig. 1 Key relationships



Other cost gains from small unit size include lower costs of construction, insurance, replacement, and so on. This parallel is shown by downward pointing triangles in Fig. 1. An inverse relationship is shown by upward pointing triangles for volume and resilience. Namely, as cost and size go down, volume and resilience rise. For example, SpaceX is able to launch 50 or more satellites at a time with plans to add several thousand to the roughly 5,000 currently in orbit. This network is so robust that SpaceX can plan the destruction of 100 satellites without diminishing service (Foust, 2024).

The relationships can be depicted with greater detail in a feedback loop diagram such as Fig. 2. Feedback loops can explain and depict factors influencing business model innovation and dynamic change (Ammirato et al., 2021; Pateli & Giaglis, 2005). In this diagram, the impact of one block on others appears as positive reinforcement, labeled R, which increase the next block in the flow. Arrows, labeled B, are balancing forces which decrease the subsequent block. For example, as shown in Fig. 2, the greater the volume of satellites launched, the greater the resilience of space-based networks. At the same time, increases in production and launches mean a decrease in related costs.

Figure 2 shows that as technology improves, the size of satellites becomes smaller, and they are therefore cheaper to build and launch

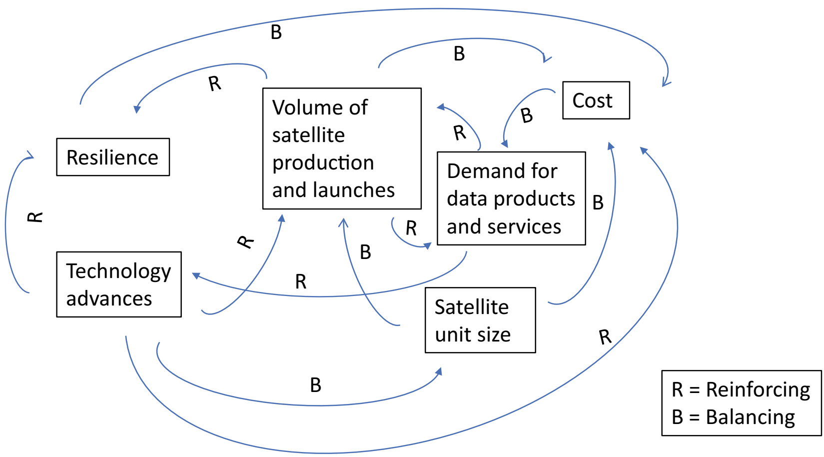


Fig. 2 Theoretical framework as feedback loops

which means more can be launched which in turn makes them more affordable per unit. At the same time, more units in space and the arrival of new technologies mean that systems are more resilient so costs decrease. As costs decrease, demand goes up and as demand goes up, volume increases. In Fig. 2, the block "technology advances" emerges as a key driver of cost reduction and demand growth. Technology advances include, for example, the upcoming wave of reusable rocket services, such as iSpace, Galactic Energy, Deep Blue Aerospace, and others that will challenge the only current reusable rocket firm, SpaceX, on price. For the time being, satellite demand and volume are fixed in a cycle of increase. Further research is needed to unlock precise relationships among these feedback loops.

In conclusion, this chapter has laid out key features of current space business indicating how it has changed over recent years. Further, the chapter has identified elements of theory that help explain how the business is changing and how it will likely proceed in the near future.

Limitations of scope and space prevent integration in this chapter of other potentially important issues such as decoupling from China and the potential separation of space programs into USA, Chinese, and Russian with consequent differentiation of technologies and lack of interoperability. In particular, the impact of decoupling on cost, resilience, regulation, societal benefit, and illegal business is too unclear at this point in time to address. There are, inevitable, more issues in technology, regulation, market demand, and other space business propositions than can be considered.

In general, space business is likely to grow due to the mechanisms of cost and scale described above. New technologies, as well as new challenges, are arriving rapidly while the legal and regulatory environment continues to coevolve alongside the business developments. Meanwhile continued investment, including national initiatives such as Japan's $6 billion space initiative announced in 2023, may further boost growth in New Space.

6 Overview of the Content of This Book

Including the introduction, this book presents 12 chapters. The second chapter, authored by Punnala et al., focuses on the space ecosystem by examining its current status and future prospects. The study presents a systematic literature review of 72 academic publications released between

2018 and 2022 related to the topic. The findings of the chapter enhance understanding of the nuances of the space economy, facilitate informed decision-making, and promote sustainable growth in the space sector.

The third chapter, by Alghani et al., investigates the architecture of the New Space Ecosystem through a systematic literature review method that analyzes 51 articles. This chapter contributes to our current understanding of New Space Ecosystems by identifying key dynamics that shape their architecture, delineating the distinct layers composing the ecosystem, and suggesting further research directions based on parallels drawn with digital platform ecosystems.

The fourth chapter, authored by Hassinen et al., presents a systematic literature review of the commercial aspects of navigation satellites. Through examination of 32 papers, the study identifies six themes and elaborates on their contributions to our understanding of the topic. The research reveals that while there is considerable interest in the technical features of GNSS (Global Navigation Satellite Systems), the commercial dimension of this market is still emerging. This chapter proposes further research directions aimed at better understanding the business models and ecosystems of companies operating in this industry.

In the fifth chapter, Punnala and Ratikainen investigate emerging innovation ecosystems in the realm of New Space. Using qualitative methods and the Kvarken Space Center in Finland as a case study, they offer insights that are applicable to similar New Space Ecosystems worldwide. The findings underscore the significance of collaboration among various ecosystem stakeholders and highlight the potential impact of such synergy on the New Space Economy.

The sixth chapter, authored by Brennan and Utrero-González, examines the recent evolution of the Spanish space sector. The authors demonstrate how the emergence of new businesses in the space industry has been influenced not only by traditional university-industry-government relationships but also by the experience and expertise developed by established "Old Space" companies. The chapter also highlights the emergence of bidirectional relationships between old and new market participants as a distinctive feature of the Spanish sector, which can enhance its competitiveness in the "New Space" scenario.

In the seventh chapter of the book, Baber and Ojala focus on emerging business model value chains in the New Space era. They provide an overview of eight different value chains within the context of space business. The chapter also elaborates on business opportunities within these value chains and offers insights into emerging business model value chains in the New Space industry. Based on these business model value chains, the chapter presents feedback loops that firms can identify and benefit from when planning and implementing value chains.

The eighth chapter, written by Rasila and Ojala, emphasizes ground station regulations and how they vary across 20 different countries worldwide. The chapter highlights that varying regulations for ground stations might inhibit the successful global operations of firms operating such stations. Based on their findings, the chapter elaborates on different regulations and explains their impact on ground station operations. It also underscores the possibilities for foreign operators to establish ground stations in different countries and emphasizes the need for harmonizing regulations globally.

In the ninth chapter of the book, Cordova and Gonzalez-Perez focus on interplanetary supply chains from a business and management perspective, with a particular emphasis on sustainability. By synthesizing insights from existing literature, the chapter contributes to the ongoing discourse on interplanetary supply chains, their potential contributions to the UN Sustainable Development Goals (SDGs), and the multifaceted challenges and opportunities associated with sustainability in interplanetary business. Additionally, the chapter underscores the importance of responsible and sustainable space exploration for the future of humanity.

The tenth chapter, written by Haq, delves into the development of the New Space economy and explores how space data can be leveraged by firms. Employing an opportunity creation and development framework, the study evaluates the availability of space data across various business activities. Drawing from empirical findings, the chapter identifies key parameters to consider before integrating space data into new product development processes.

The eleventh chapter, authored by Jaskari et al., investigates suborbital space tourism. Based on qualitative data and mixed methods that combine face-to-face interviews, previously published interviews, and archival data, the chapter provides insights into the unique circumstances of space travel and the lived experiences of such journeys. It also introduces the concept of "doozy tourism" to illustrate the specific nature of space tourism, characterized here as a niche within luxury tourism. Finally, it delineates how experiences within space tourism can be divided into four phases.

In the twelfth chapter, Yang provides insights into the sociological shaping of space tourism. By integrating insights from institutional and performativity theories, the chapter offers a nuanced sociological analysis of the burgeoning market for space tourism and emphasizes the importance of these theoretical lenses for understanding the social foundations of space tourism. The chapter also argues that a more comprehensive understanding of space tourism, informed by sociological insights, can pave the way for more equitable and sustainable practices that transcend purely commercial or technological achievements.

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The Space Economy: Review of the Current Status and Future Prospects

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1 Introduction

Space, once the final frontier and a symbol of human aspiration, has transitioned from a realm of exploration to an indispensable backbone of our global infrastructure. Since Neil Armstrong's historic lunar step in 1969, our reliance on space has expanded exponentially, permeating every facet of modern life. From satellite-assisted navigation to global communication networks, space systems have become integral to both civilian and military operations. Beyond its immediate applications, the burgeoning space economy stands testament to the increasing commercial and strategic value of space. As we stand on the cusp of a new era, the development and growth of the space economy not only promise unprecedented opportunities but also underscore the need for sustainable

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_2

and responsible utilization of the space domain. Space harbors immense untapped potential to address future crises, stimulate job creation, and foster innovation within the space industry (European Commission, 2016), and it is widely anticipated that, in the forthcoming years, space entrepreneurs offering economical and accessible space strategies will be instrumental in shaping the progression of the space economy (Peeters, 2021). Access to space is invariably viewed as a critical component of sovereignty and autonomy. The metamorphosis of the space sector into the contemporary space economy symbolizes a nascent industry, stemming from regulatory shifts, the influx of novel contenders, and the inception of space agencies partnering with businesses to foster space advancement (Denis et al., 2020; Weinzierl, 2018).

Academic analysis of the economic aspects of space activities has gradually matured into a specialized field, yet the task of comprehensively classifying and as such, understanding the space economy continues to present significant challenges (OECD, 2020, 2022; Weinzierl, 2018). In advanced economies, the complexity of the space economy is becoming ever more evident, and the distinction between activities related to space and those that aren't is progressively diminishing (Profitiliotis & Loizidou, 2019b).

While space economy research has rightfully begun to garner broader academic attention, it still remains fraught with ambiguities and misunderstandings. One of the most significant gaps is the absence of a comprehensive theoretical framework specifically tailored for understanding and classifying the activities of the space economy in terms of international business and their linkage to the broader economy. Existing theories in economics and business, while providing initial scaffolding, seem to not fully encapsulate the unique complexities and multidisciplinary nature of

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space activities. This absence not only hinders nuanced, targeted research but also limits our understanding of various business intricacies within the domain. Moreover, despite the growth in data availability and the maturation of the field, there is a conspicuous absence of standardized metrics and frameworks for assessing the space economy globally. This lack of standardization not only hampers cross-national comparisons but also poses challenges for policymakers and stakeholders in making informed decisions.

Furthermore, previous literature has not adequately addressed several pivotal questions. The establishment of international standards to ensure the comparability of space economy statistics across different countries remains an unresolved issue (OECD, 2022). The role of new entrants, such as business enterprises in space activities, is evolving, but the future industry dynamics are not yet fully understood (Denis et al., 2020; Profitiliotis & Loizidou, 2019b). Policymakers must contemplate how enhanced statistics on the space economy can guide policy decisions and investments in the space sector (Emen, 2020).

There seems to be an urgent need for a unified framework to comprehensively categorize the economic activities within the space economy, considering its multifaceted nature and diverse impacts on the broader economy. Such a framework should ideally integrate international business theories specific to the space economy, providing a structured perspective for examining this emerging field. As this area of study is novel and evolving, our study aims to act as a proof of concept, identifying foundational principles for developing such a framework. We propose using a modified version of the OECD approach as a basis for this framework. This approach, detailed in the OECD Handbook on Measuring the Space Economy, encompasses a broad spectrum of economic activities within the space domain (OECD, 2020).

Using the said approach, our aim for this chapter was to identify key enablers and areas of challenge within the space economy, so that we could gain a better understanding of the macro-level potential and challenges of the domain, while simultaneously testing the feasibility of the proposed framework for such research. In order to achieve a broad coverage of the economic activities within the space economy, we have conducted a systematic literature review meticulously selecting and examining a range of academic sources specifically focused on the space economy. Our approach proved fruitful as we were able to identify a significant number of macro-level trends that have played important roles in the emergence of the space economy and those that may guide its development in the coming years. Ultimately, by providing such a common frame of reference, our goal is to ensure that the benefits of space exploration and commercialization are maximized and responsibly managed for the sustainable growth of the global economy.

2 Methodology

2.1 Selection of Relevant Articles

A systematic literature review was employed as our primary research method. This approach is renowned for its effectiveness in delivering a comprehensive and current understanding of specific themes. It enables an in-depth exploration of the research topic, allowing for a nuanced comparison and contrast of findings from previous studies (Paul & Rialp Criado, 2020). In identifying relevant literature, we adhered to a rigorous process that included systematic search strategies and evaluative criteria, as advocated by Littell et al. (2008) and Palmatier et al. (2018) (Littell et al., 2008; Palmatier et al., 2018; Paul & Rialp Criado, 2020). This method ensured a thorough and unbiased collection of pertinent studies, setting a solid foundation for our research. First, we applied search words to find relevant literature published between 2018 and 2022. The keywords (space economy, satellite account, new space economy, space economic, and space economics) were selected based on the aim of this study, and they should appear within titles, abstracts, or the entire content. The timeframe for the chosen articles is based on the 2nd edition of the OECD Handbook on measuring the space economy, which highlights that the most important space economy literature has been published after 2017. To find relevant literature, we utilized six main databases covering a wide range of publications across different disciplines in business, economics, information systems, engineering, and so on to ensure that we obtained all relevant articles on the topic. The databases employed were SAGE, SCOPUS, IEEE, ABI, EBSCO, and Taylor and Francis. The search was conducted between September 13, 2022, and September 19, 2022, and again between January 6, 2023, and January 8, 2023. To maintain academic quality of the study, we focused on peer-reviewed academic publications and excluded marketing and industry reports. Table 1 demonstrates the inclusion/exclusion criteria for articles found

Table 1 Selection process and criteria for accepted articles

Phase 1	*Phase 2*	*Phase 3*	*Phase 4*	*Phase 5*	*Phase 6*
Database query (13.9.—19.9.2022): SAGE, SCOPUS, IEEE, ABI, EBSCO (Academic Search Elite, Business Source Premier, eBook Collection and Regional Business News) and Taylor and Francis	Titles and abstracts were verified, and selection was made based on them	Only publications written in English were accepted	Articles were read and those that did not deal with the space economy were eliminated	New database query 6.1.-8.1.2023 (articles after the first query to 31.12.2022), phases 2 to 4	Articles were categorized based on the findings in an Excel table
3258 articles	121 articles	117 articles	57 articles	225 articles, from which 15 fulfilling the set criteria	72 articles

in the databases. Altogether, we found 72 articles that fulfilled selection criteria and were accepted for the ultimate analysis.

2.2 Selection of Relevant Articles

The articles found were published in a wide range of journals, varying from publications focused on space-related issues to more general outlets in the economics and management fields. The most relevant articles were found to be published in the core, leading research journals in space politics and policy, technical knowledge and information, international business, international economics, and international management literature.

There was also a great variation in the journals as the recognized articles were published in 45 different journals, of which seven journals have published more than one article examined in this chapter. The most publications were in Acta Astronautica (14), Space Policy (12), Astropolitics (9), and IEEE Access (3), representing 49% of the total number of selected articles. It is also important to note that space economy research has focused more on publications concentrating on space sciences than on those dealing directly with economic/financial/

commercial research. Based on the years of publication (2018, 11; 2019, 9; 2020, 15; 2021, 11 and 2022, 26), it can be argued that for 2022 a significant increase can be observed compared to earlier years. A total of 214 authors contributed to writing the selected articles, of which 8 authors (Almorad, Al-Naffour, Bowen, Dahrouj, Alouini, Li, Loizidou, Profitiliotis, and Saeed) contributed to two different articles. Based on this, it can be claimed that no single author can be identified as a definite leader in space economy research.

When examining the articles from both geographical and organizational perspectives, it is evident that the majority of the research is focused on the United States, followed by China and Europe (EU). In contrast, Russia's role is highlighted more for its historical achievements in space conquest than for its recent innovations in the development of the new space economy. When doing a similar comparison for organizations (companies) studied, the dominant role of SpaceX and other US companies in shaping the development and management of the new space economy is prominent.

In our research, we have adopted the classification of space activities into segments as outlined in the OECD Handbook on Measuring the Space Economy (OECD, 2020). This classification includes eight well-established segments; Satellite Communications, Positioning, Navigation and Timing (PNT), Earth Observation (EO), Space Transportation, Space Exploration, Science, Space Technologies, and Generic Technologies or Components that enable space capabilities. Like some organizations, we categorize "defense" as a distinct application within our framework to clearly differentiate between civilian and military activities in the space sector. Furthermore, our systematic literature review has identified three additional categories that are useful in the classification of economic activities within the space economy. These are:

1. **Co-operation:** This category emphasizes the importance of collaborative efforts and partnerships in the space sector. It includes international, intergovernmental, and commercial collaborations which are pivotal in advancing space exploration and technology.
2. **Legal:** The legal aspect covers the regulatory frameworks and legal considerations necessary for space activities. This includes space law, policies governing space exploration, and the use of outer space.
3. **Satellite Orbit/Constellation/Size:** This category delves into the technical specifics of satellite deployment, including considerations

of orbit types, satellite constellations for various applications, and the size and capabilities of different satellites.

By incorporating these additional categories derived from our literature review into the OECD's framework, our chapter offers a more comprehensive and nuanced understanding of the space economy, reflecting its evolving and multifaceted nature.

3 Findings

3.1 Emergence of a Sustainable Commercial Space Economy

The evolution of the space economy can be traced through three distinct phases: government-driven, industry-driven, and entrepreneur-driven. The first phase was characterized by government institutions such as NASA playing a central role in the sector, procuring from aerospace firms and undertaking major space missions driven by national prestige (Bowen, 2018b; Emen, 2020; Peeters, 2021; Tucker & Alewine, 2022). The launch of Russia's Sputnik I in 1957, which stimulated both the space race and the rapid development of international space law, was further shaped by the competitive dynamics of the Cold War, particularly the "Space Race" between the United States and the Soviet Union (Bashlakov-Nikolaev et al., 2022; Emen, 2020). That is, the ability to launch satellites and send humans to space was seen as a demonstration of technological prowess and economic strength, contributing to a nation's international standing and influence. This prestige factor continues to play a role in the space programs of both established and emerging spacefaring nations (Cvetkovic et al., 2022; Rementeria, 2022).

In the second phase, commercial space applications became prominent, transforming the dynamics of the space industry. Previously dominated by public actors and their prime business contractors, the industry began to attract new commercial entities. Decades of consistent public funding and government backing propelled this transition, allowing space technology to drive expansion in other segments with a more commercial orientation (Profitiliotis & Loizidou, 2019b). The growth of the space economy is mostly enabled by advancements in various space technologies, governmental support, and the strategic importance of these technologies for defense and military purposes. Governmental support has been a critical enabler for the growth of the space economy (Denis et al., 2020;

Lambakis, 2018; López et al., 2018). The ability to monitor and collect data about the Earth's surface and atmosphere from space provides a strategic advantage in terms of situational awareness and intelligence gathering. While space activities were largely state driven, they began to involve private companies as collaborators in space research activities (Emen, 2020).

A surge of entrepreneurial involvement, powered by equity funding, characterizes the third phase, new space. The emergence of disruptive innovations has created new markets and value networks, often initiated by outsiders and entrepreneurs. The space economy has experienced this disruption, leading to significant shifts in established market dynamics (Denis et al., 2020).

3.2 Enablers of a Sustainable Commercial Space Economy

Based on our literature review, we identified seven segments that seem to have acted as enablers for the emergence of a sustainable space economy. Those were defense, PNT, space exploration, space transportation, satellite communications, EO, and science. Among these, the need for defense, PNT, space exploration, and space transportation solutions stand out as the primary drivers for space-related economic activities in the emerging days of the space economy. These four main drivers are elaborated in detail next.

Firstly, defense emerged as a paramount consideration due to historical and sustained investments in space for defense purposes, as elaborated in 31 articles. These investments have led to technological breakthroughs and infrastructure developments fundamental to the growth of the space economy. The genesis and evolution of the space economy were significantly influenced by nations' defense and military imperatives. Discoveries about the vulnerability of space assets prompted a strategic shift toward the importance of space for national security and corresponding investments in space technologies (Bowen, 2018b; Lambakis, 2018). The military focus in space extended beyond merely protecting national interests, evolving into an instrument of geopolitical dominance and reshaping international relations. In this light, the launch of satellites and advanced space weaponry became symbols of global influence, not just military assets (Rementeria, 2022). The private sector's involvement in defense has spurred innovation through public–private partnerships, igniting debates over the commercialization of national security. While these collaborations introduced dual-use solutions and cost efficiencies, they also underscored the need to balance innovation with control over essential military capabilities (Chavy-Macdonald et al., 2021; Lickfold & Jetter, 2019). International rivalries in space, exemplified by milestones like the moon race, intensified this drive, with nations investing heavily in space technology to assert supremacy (Rementeria, 2022; Szocik, 2019). Notably, while many space technologies are developed exclusively for civilian (peaceful) use, innovations such as PNT or satellite communications remain crucial for various defense and security agencies, and their development cannot always be easily categorized easily into strictly military or non-military solutions.

Secondly, PNT services played a central role in driving the growth of the space economy. This was indicated in 26 articles. The significance of these services, which play a key role in a wide variety of applications on Earth, from navigation and logistics to telecommunications and disaster management, is underlined. The demand for dependable PNT services has spurred investment and innovation in the space sector, thereby increasing its growth. The rapid expansion of the space economy is intricately tied to the advancement of PNT technologies, as clearly demonstrated by Global Navigation Satellite Systems (GNSS) such as the US GPS, Chinese Beidou, European Galileo, and Russian GLONASS. These technologies have catalyzed diverse applications, from precision weaponry to financial transactions and agricultural innovations (Bowen, 2018a; Lickfold & Jetter, 2019). The role of governments in the PNT sector has been pivotal as PNT has strategic importance in several domains such as national security, environmental management, and agriculture (Aloini et al., 2022; Bowen, 2018a, 2018b; Chavy-Macdonald et al., 2021; Lambakis, 2018; Oyewole, 2020). Further, PNT infrastructure greatly elevates a nation's international prestige and technological stature (Rementeria, 2022; Weinzierl, 2018).

Thirdly, based on 45 (24 + 21) articles, space exploration and space transportation have also had a crucial influence on the formation of a space economy (Alewine, 2020; Bi et al., 2022; Elvis & Milligan, 2019; Jakhu et al., 2020). These technologies, ranging from launching satellites into orbit to enabling human space travel, have revolutionized various sectors, including defense, finance, agriculture and maritime traffic management, becoming an integral part of our global, wireless, and mobile information infrastructure (Bi et al., 2022; Lambakis, 2018;

Weinzierl, 2018). Simultaneously, these advancements in space transportation systems have played a vital role in broadening access to space, thereby fostering the expansion of the space economy through cheaper and easier delivery methods for hardware, that is essential for providing other space economy-related services (Bi et al., 2022; Chavy-Macdonald et al., 2021; Kumar et al., 2020).

3.3 Present Status of the Space Economy and Its Most Essential Elements

Based on the reviewed literature, the present status of the space economy reflects significant growth, diversification, and commercialization of the industry. The commercial space sector is projected to reach a market value of $2.7 trillion by 2045 and encompasses a wide range of activities ranging from space manufacturing and asteroid mining to colonization efforts to other celestial bodies (Toivonen, 2022; Weinzierl, 2018). Governmental interventions have been pivotal in molding the space economy, as they orchestrate regulations that guide business practices and stimulate expansion across diverse domains, encompassing areas such as direct consumer applications and personal entertainment (Argentiero & Falcone, 2020; Toivonen, 2022). The heavy government interest toward the sector is also unlikely to disappear, due to its high weight in many critical fields. As Jakhu et al. (2020) put it, the space sector acts as a kind of linchpin for numerous industries, with an array of over 2200 satellites originating from more than 80 countries delivering several services across the globe. It could be said that organizations delivering services within the space economy context are primarily enablers for other segments. Next, we present eight key elements of space economy. Satellite orbit and constellation size has not been discussed as a unique theme, as it is covered within other satellite-related factors. Table 2 presents each of the segments in terms of how the analyzed literature sees the segment in terms of developments in the space economy. It is notable that many of the segments are seen both as slowing down the space economy development, while at the same time offering significant potential. This is logical, because if the challenges within the said segments can be overcome, it would offer huge future potential.

Satellite communications have become a cornerstone in the evolving space economy, with their applications permeating various sectors, from telecommunications and broadcasting to remote sensing and the Internet

Table 2 Amount of literature mentioning a specific space economy segment, grouped by narrative presented in the mentioning literature

Segment of the space economy	*Slowing down the development of the space economy*	*Created the basis for space economy growth*	*Requirement for the space economy to develop*	*Future potential for the space economy*
Co-operation			37	8
Defense		31		20
Earth Observation (EO)		16	3	38
Generic technologies or components that may enable space capabilities	18		42	51
Legal	18			
Positioning, navigation and timing (PNT)		26	3	26
Satellite communications		18	3	43
Satellite orbit/ constellation/size			22	55
Science	5	9	4	36
Space exploration		24		45
Space technologies	43		31	53
Space transportation	4	21	25	44
Grand total	**88**	**145**	**170**	**419**

of Things (IoT). As the global space economy approaches a valuation of over $350 billion, satellite services, particularly communications, are poised to account for a significant portion of this growth (Lauer, 2022). The ubiquity of these services, essential for internet connectivity, has expanded their reach to all nations (Lambakis, 2018). The integration of 5G and 6G technologies with satellite systems is heralding a new era in satellite-enabled services, promising reduced communication latencies and enhanced global internet service (Ho-Baillie et al., 2022; Hoyhtya et al., 2022; Jha et al., 2022; Saeed et al., 2021). Mega constellations, exemplified by initiatives like Starlink, are reshaping the satellite communications paradigm, offering ease of deployment and use.

PNT services, including GNSS, are foundational to, e.g., aviation, marine transportation, financial services, and military operations. They ensure precise navigation, timing, and efficient data transmission, highlighting their economic and strategic significance (Bowen, 2018a; Van Camp & Peeters, 2022). The rising demand for PNT services underscores their diverse applications, from aiding accurate navigation in aviation to ensuring transaction timestamp in finance or providing location-based mobile applications. Their military potential is also paramount, bolstered by satellite constellations and private investments, offering strategic advantages in operations and communication (Rementeria, 2022). The blend of governmental and commercial interests in PNT has spurred investments and advancements, but addressing challenges, such as orbital congestion and electromagnetic spectrum saturation, is essential for sustainable growth (Bowen, 2018a; Chavy-Macdonald et al., 2021).

Earth Observation (EO) technologies have become central to the space economy, expanding their capabilities from tracking military maneuvers to monitoring environmental changes. The commercial sector's access to advanced imagery underscores EO's indispensable role in modern society (Bowen, 2018a; Chavy-Macdonald et al., 2021). The pressing environmental challenges of today necessitate innovative satellites and sensors. Reduced costs, rapid technological advancements, and the rise of small satellite manufacturing are beginning to meet this demand. Emerging trends in EO, particularly in low earth orbit (LEO) constellations, are beginning to provide continuous video from space. This, coupled with the development of image analytics services, is opening new markets, and solidifying the importance of EO across traditional sectors such as climate monitoring and defense, but also pushing the services to new sectors such as finance. As technology advances, the role of EO-services continues to grow, promising innovative opportunities in both public and private sector (Denis et al., 2020; Rementeria, 2022).

Space transportation has, especially in the past few years emerged as a pivotal component in the burgeoning space economy, with its trajectory shaped by factors such as cost, delivery time, and technological risk acceptance (Denis et al., 2020; Rementeria, 2022). The influx of new entrants aiming to democratize access to space and reduce launch costs underscores the segment's significance (Friel, 2020). This trend is exemplified by companies such as SpaceX, which have revolutionized the industry with innovations such as reusable rockets and competitive launch systems (Denis et al., 2020). Historically, space transportation was dominated by national entities, with orbital launchers primarily serving military objectives (Denis et al., 2020). However, the contemporary landscape is witnessing a shift characterized by the democratization of space and a burgeoning commercial sector. This is also opening significant opportunities for other parts of the space economy, as the cost of delivering essential payloads to orbit and beyond is dropping rapidly.

Space exploration began in 1957 and has since been a catalyst for technological revolutions culminating in human spaceflight. Historically dominated by state actors, the domain is now witnessing a transformative shift with the entry of commercial and private stakeholders, adding new dimensions to the exploration narrative (Kumar et al., 2020; Marzuki & Newell, 2021). The impetus provided by space exploration has spurred the inception of novel technologies and industries. Establishments such as lunar bases are potential testbeds for cutting-edge technologies that encompass energy generation, water processing, and space robotics. These innovations symbolize the profound knowledge generation intrinsic to the contemporary space sector (Argentiero & Falcone, 2020; Bi et al., 2022). Furthermore, the exploration of celestial bodies, such as Mars, has become a tangible reality, yielding a vast magnitude of data. The diminishing resources on Earth have pivoted attention toward the potential of extraterrestrial resource extraction, marking a transformative phase in space utilization (Bi et al., 2022; Jakhu et al., 2020).

Science encompassing human spaceflight is a pivotal component of the space economy. Such pursuits not only establish a distinct market but also catalyze the inception of innovative technologies, which subsequently find commercial applications. The escalating environmental challenges and the imperatives of climate change have accelerated the development of advanced satellites and sensors, delivering indispensable meteorological and climatic insights (Denis et al., 2020). The cost-effective "CubeSat" satellites are also pivotal for space exploration and scientific missions, aiming to augment our understanding of diverse scientific domains such as astronomy, heliophysics, and planetary science (Saeed et al., 2020). International collaboration in space science and research is intensifying, with nations combining their expertise and resources. The indispensable role of governments in nurturing the space industry cannot be understated. State patronage facilitates the realization of avant-garde space technology and research, subsequently bolstering national defense capabilities (Wu, 2018).

The evolution and proliferation of space technologies have been pivotal in augmenting our understanding of the cosmos and yielding myriad benefits for humanity. The International Space Station (ISS) epitomizes this, serving as a nexus for cutting-edge technology and research, enriching domains from human health to global education and the burgeoning space economy (Emen, 2020). The horizon for space technology applications is vast and ever-expanding. However, the rapid expansion of space technologies has ushered in challenges, notably concerning space sustainability. For instance, the quandary of space debris has emerged as a focal point, with an estimated 300,000 potential satellite-destroying debris fragments in orbit (Emen, 2020). Addressing this conundrum necessitates concerted efforts, encompassing national and international regulations, and innovative solutions such as insurance incentives for debris mitigation (Harrington, 2020). In sum, space technologies, while offering a plethora of opportunities and benefits, also introduce challenges that mandate astute navigation.

The integration of generic technologies and components has been a game changer in the space sector, ushering in unprecedented capabilities and prompting even faster innovation. The incorporation of commercial off-the-shelf (COTS) technologies in satellite production epitomizes this shift, offering a blend of cost-efficiency and streamlined operations (Denis et al., 2020; Weinzierl, 2018). The rise of CubeSats underpinned by COTS components, and the advent of specialized suppliers focusing on cost curtailment through bulk production further accentuate this paradigm shift (Bi et al., 2022; Weinzierl, 2018). Another transformative approach is vertical integration, which combines service operation with satellite manufacturing, bypassing cumbersome contracting and procurement processes, thereby ensuring a seamless supply chain (Weinzierl, 2018). Concurrently, innovative manufacturing methodologies, such as additive manufacturing, are bolstering space capabilities (Bi et al., 2022; Weinzierl, 2018). However, the proliferation of these generic technologies and components is not devoid of challenges. Cybersecurity has emerged as a paramount concern in this context. Addressing these cyber vulnerabilities is imperative to safeguard the integrity and security of space systems (Bi et al., 2022).

3.4 *Future Potential and Key Success Factors of the New Space Economy*

The space economy is undeniably vast and comprises diverse segments, each with its unique potential for growth and impact. Navigating the intricate boundaries that sometimes delineate these segments can be a formidable task. In the following section, we will outline the most promising segments, drawing from our review of the existing literature.

Our analysis reveals that satellite constellations represent pivotal arenas for future growth, underpinned by technological evolution and the mounting demand for satellite services. The proliferation of satellite constellations, the inclination toward compact satellite missions, and the integration of these advancements with terrestrial networks set the stage for transformative economic growth. The management and optimization of satellite deployment in various orbits is a critical aspect of space operations. The future of this segment is tied to the advancement of technologies that enable a more efficient use of orbits and the development of smaller, more capable satellites. Growth in this segment will likely be driven by the increasing demand for satellite services, from communication to Earth Observation (Barry & Alfaro, 2021; Lambakis, 2018). The recent surge in proposed constellations—over a hundred in 2020—signals both the growth and unpredictability of this segment (Letellier & Lizy-Destrez, 2022). While high-orbit satellites predominantly hail from industry giants, LEO constellations expand their reach, catering to diverse environments, including the Arctic (Hoyhtya et al., 2022). The global trend leans toward smaller satellite missions epitomized by projects such as Starlink, which boasts over 2000 satellites. Moreover, the pursuit of small satellite launchers stems from increasing satellite counts and the blossoming of large constellations, which generated $1.2 billion investment between 2000 and 2016 (Ali et al., 2020; Denis et al., 2020). Enhanced electronics miniaturization which reduces satellite size and launch costs, augments this progression without compromising performance. In summary, the future of the space economy seems to hinge on LEO innovations, vast constellations, and compact satellite technologies, promising transformational growth and integration between satellites and terrestrial technologies.

Space technologies encompass a broad range of systems and applications. From satellite technologies to space-based sensors and instruments, these technologies underpin the capabilities of the space economy. Technological advancements and the increasing demand for space-based capabilities will shape the future of this segment (He, 2022; Jakhu et al., 2020). Space technologies are poised for extensive and multifaceted advancements. The industry is transitioning toward more interconnected, decentralized systems of systems (SoS), fueled by the imperative of efficient information integration, which is crucial for mission success (Bi et al., 2022). Industry leaders notably advocate for the integration of space and terrestrial networks, especially for applications like remote 5G backhauling (Denis et al., 2020). With milestones such as SpaceX's Crew-1, the paradigm of space travel is shifting, urging NASA (and other governmental institutions) to adapt its strategies to foster public–private collaborations (McCaffrey, 2021). The US Department of Defense (DoD) continues to leverage commercial procurement, anticipating that this trend will intensify. Private ventures are also eyeing innovative space segments, from Martian research to space tourism, with potential planetary protection implications (Profitiliotis & Loizidou, 2019a, 2019b). Simultaneously, a significant proportion of individuals within the high-income bracket express interest in space tourism (Pásková et al., 2021). Conclusively, as the space sector evolves, it will likely become more interconnected and complex, amplifying the roles of private enterprises, and emphasizing public–private collaborations.

The space economy is poised for considerable growth, fueled by generic technologies that enhance space capabilities. Recent strides in democratizing space access, exemplified by SpaceX's reusable rockets, align with the miniaturization trend seen in satellites such as CubeSats, which are pivotal for global IoT connectivity (Bi et al., 2022; Denis et al., 2020). This transformation integrates space and terrestrial networks, heralding a new era of broadband access, especially in remote areas (Denis et al., 2020). The industry's pivot to satellite constellations demands novel, cost-effective manufacturing methods, championing standardized designs and expedited development (Eugeni et al., 2022; Rementeria, 2022). As lunar bases emerge as testing hubs for nascent technologies, from power generation to waste management, sensing technologies also rise in prominence for both terrestrial and space object tracking applications. With further space explorations, the surging data is bound to underscore the importance of continual space tech innovations (Bi et al., 2022). Fundamentally, propulsion systems, communication modalities, and advancements in materials science serve as the foundation of this booming space economy, driving unparalleled economic growth and fostering innovation (Barry & Alfaro, 2021; Lambakis, 2018).

Space exploration, which encompasses, e.g., human spaceflight, robotic studies, and potential colonization, is a key driver of the future space economy. Companies like Blue Origin and SpaceX, with their ambitious plans, catalyze investments and technological advancements in this domain (Barry & Alfaro, 2021). There is growing attention toward mining resources from celestial bodies such as asteroids and the Moon, underlined by significant private and governmental interest (Feichtner, 2019; Marçal Sanmartí, 2020; Vergaaij et al., 2021). However, under the current framework of international and domestic law, considerable ambiguity exists regarding the legal parameters and guidelines for lunar and asteroid mining activities (Anderson et al., 2019; Steffen, 2022). Satellite technologies play an instrumental role in enabling such ventures, although their economic feasibility remains a subject of debate (Jakhu et al., 2020). The trajectory of this segment is influenced by scientific intrigue, evolving technology, and aspirations to broaden human activities in space (He, 2022; Szocik, 2019). Asteroids could soon bolster astronaut missions in multiple ways. They could serve as resource hubs for deep-space settlements, act as testing grounds for pioneering technologies, and even function as depots or transit vehicles for interstellar journeys (Krolikowski & Elvis, 2019).

Space transportation, which is pivotal to the burgeoning space economy, is driven by cost, delivery time, and technological risks (Denis et al., 2020; Rementeria, 2022). New entrants are reducing launch expenses, and SpaceX's reusable rockets exemplify these advancements. The increasing presence of specialized launch services, such as the deployment of small satellites from the ISS, further underscores this transition (Denis et al., 2020). Countries such as the United States and China have fortified their positions through a blend of government policies and private ventures. The push for commercial launches shows expansive growth in this realm (Pomeroy et al., 2019; Rementeria, 2022). However, despite varied solutions, space transportation remains under significant governmental influence, emphasizing the importance of domestic upstream capabilities. Ultimately, as the segment serves defense, communication and exploration needs, the urgency to advance technology and ensure security grows, underscoring its role in shaping the space economy's future trajectory.

Satellite communications are a segment that has already demonstrated its economic value and is poised for further growth. The demand for reliable and readily available high-speed communication services is growing, and satellite technology is uniquely positioned to meet this demand. The future of this segment will likely be shaped by the development of new technologies and the expansion of services to underserved areas (Jakhu et al., 2020; Lambakis, 2018). Essential to our digital era, these services foster global connectivity, are indispensable to defense, security, and commercial ventures (Lambakis, 2018). Both commercial and defense sectors are increasingly reliant on satellite capabilities (Budning et al., 2021; Lambakis, 2018). The incorporation of 5G/6G into satellite systems signals is a transformative change, offering the benefits of decreased communication delays and an edge over conventional geostationary orbit (GEO) systems (Hoyhtya et al., 2022; Jha et al., 2022; Saeed et al., 2021). Mega constellations such as Starlink further redefine this landscape, complemented by shared ground station networks such as Amazon AWS that centralize data from numerous satellites (Jha et al., 2022). While the potential is immense, this burgeoning reliance calls for heightened security and resilience. Efforts encompass space debris mitigation, secure connectivity systems, and strategies to counteract satellite interference (Hoyhtya et al., 2022; Jha et al., 2022; Lambakis, 2018). The future of satellite communications includes governmental satellite communication solutions, which integrate 5G/6G technologies with security features and quantum solutions (Hoyhtya et al., 2022). Satellite communication's future is vibrant, central to the expanding space economy. Embracing novel technologies, fortifying security, and championing sustainability and regulations will cater to the escalating needs of diverse sectors.

Earth Observation (EO) is a segment with significant future potential. The ability to monitor and collect data on the Earth's physical, chemical, and biological systems have wide-ranging applications, from climate monitoring to disaster management. The growth of this segment is expected to be driven by the increasing demand for data and the advancement of satellite technologies (Argentiero & Falcone, 2020; Budning et al., 2021). The analysis underscores the importance of EO satellites for providing valuable data for various Earth applications, from environmental monitoring to urban planning. Similarly, scientific research in space will continue to lead to numerous technological and scientific advancements, contributing to the growth of the space economy.

4 Conclusion and Further Research Directions

Based on the analyzed literature, it can be noted that the emergence and phenomenal growth of the space economy cannot be attributed to a single or even a few factors. It is rather a complex, multifaceted phenomenon, intricately woven by technological advancements, governmental patronage, and the strategic imperatives of defense applications, that at a later stage have been supported more and more through purely civilian commercial projects. The governmental backbone has been instrumental, providing not only financial but also infrastructural and moral support, catalyzing the sector's growth and ensuring its sustainability. The space economy functions like a self-sustaining reaction, where the demands of one field catalyze the substantial development of others. This interconnectedness makes it challenging to pinpoint a singular cornerstone of the space economy.

In this study, we observed from the literature that defense imperatives, technological advancements, and burgeoning commercial interests are the main catalysts for growth. Historically, the quest for enhanced surveillance, reconnaissance, and communication capabilities has driven nations to invest significantly in space technology and exploration. These early investments, initially spurred by pioneering aspirations and technological curiosity, have matured over time into indispensable tools for national security. This evolution underscores the strategic importance of space within the broader canvas of global geopolitics. At the same time, we are seeing an unprecedented democratization of space, through purely private and civilian initiatives. These mainly commercial activities are taking the previously defense-centric space economy toward new horizons and leading to a transformative evolution of the space economy. However, this journey is interspersed with challenges. The increasing militarization of space, the looming threat of its potential weaponization, and the ever-present concern of space debris necessitate a framework of robust governance, stringent regulation, and international collaboration.

The commercialization of space emerges as a transformative theme in this study. Based on the reviewed literature, transitioning from traditionally government-led initiatives to a more commercial-centric paradigm, the space sector is witnessing a reshaping of its very fabric. At the heart of this commercialization, and the ensuing democratization of space, is the development and proliferation of space-centric products and services tailored for diverse commercial markets, usually entirely outside of the space domain. This evolution is not only reshaping the industry but is also anticipated to ignite competition, foster unparalleled innovation, reduce operational and entry costs, and unveil novel economic growth avenues. The ripple effects of this transformation are profound, with expectations of substantial job creation, a surge in innovation, and a plethora of opportunities for both established businesses and budding entrepreneurs.

Moreover, the space sector is witnessing a technological renaissance. The fusion of space-specific technologies with generic, terrestrial technologies is expanding the realm of possibilities in space. Pioneering innovations, such as the development and deployment of LEO constellations and the rise of small, versatile satellites, are revolutionizing traditional communication and surveillance capabilities. The democratization of space, further propelled by commercialization, promises to catalyze innovation, broaden participation, and amplify the collective benefits of space activities, setting the stage for an era of inclusive, global space exploration.

In light of these developments, the absence of a dedicated theoretical framework for the space economy becomes increasingly conspicuous. While existing theories provide initial scaffolding, they fall short in addressing the unique complexities of space activities, such as technological challenges, ethical considerations, and international regulations. The development of a bespoke theoretical framework is imperative for targeted research and effective policy formulation. This would not only deepen our understanding of business dynamics in the space economy but also facilitate more robust strategies and cross-border collaboration.

As we stand at the crossroads of the future of the space economy, the landscape offers a rich tapestry of opportunities, intricately woven with challenges. As we navigate this multifaceted landscape, a harmonized, collaborative approach is paramount. This approach, which balances both the potential and inherent complexities of space endeavors, co-operation will be instrumental in ensuring the holistic, sustainable, and beneficial evolution of the global space economy.

4.1 Further Research Implications

The space economy, with its vast opportunities contrasted against inherent challenges, offers a fertile domain for both academic and practical exploration. The analysis of the literature reveals a predominant alignment with the definitions presented in the 2nd edition of the OECD

Handbook on measuring the space economy. The importance of understanding the present state and prospects of national space economies, as delineated in the OECD Handbook, cannot be overstated, as it provides a comprehensive overview of a nation's space economy potential.

This article consistently underscores the strategic significance of defense in space. Historically, investments in space, driven by defense imperatives, have been catalysts for technological and infrastructural advancements that have shaped the trajectory of the space economy. Nations' defense and military priorities have deeply influenced the evolution and growth of the space economy. At the same time academic literature seems to see the future potential more in other segments of the space economy, suggesting that a change might be upon us in this regard, and understanding this shift might prove to be crucial. It is notable, that the segments that have defined the space economy since its beginning days, such as defense, PNT or space exploration are not at the forefront of future expectations, even though their importance and potential remain high.

The literature that we have referenced seems to highlight the increasing role of the private sector in space activities. Their involvement has yielded innovative approaches, increased financial commitments, and initiated a shift in the conceptualization and realization of space missions. While, e.g., the domains of space tourism and space mining are not exhaustively explored in this article, the growing engagement of the private sector advocates a promising trajectory for these and other areas. The innumerable benefits that space exploration offers, from scientific advancements to potential space habitation, further highlight the potential of these new kinds of ventures.

While potential avenues for future research are endless, based on our findings the following areas of research seem to be the most urgent for understanding the whole potential and challenges of the space economy:

- What are the foundational principles and theories that can be developed to understand international business in the context of the space economy?
- How has the OECD Handbook on measuring the space economy been implemented in statistical reporting, and are there discernible differences between countries in terms of space industry development and internationalization opportunities?

- What specific barriers to market entry do companies encounter when expanding into various national space economies, and how do these barriers differ across countries?
- How can a multidisciplinary approach, incorporating international economics, provide a more nuanced understanding of the complexities inherent in the space economy?
- What insights can case studies offer into the economic strategies employed by different countries and companies in the space sector?
- How do different national policies and economic strategies in the space sector compare in terms of effectiveness and impact on the global space economy?
- How is the dynamic between defense and security in space, particularly in the context of increasing commercialization developing?
- What is the role and influence of start-ups in driving innovation and competition within the space sector?
- What challenges and opportunities are presented by LEO constellations and the emergence of small satellites?
- How does the integration of terrestrial technologies into space applications affect the broader technology sector?
- What strategies can be developed to enhance international collaboration and ensure the sustainable and collaborative use of space resources?

Moreover, the imperative for research in international economics as it pertains to the space economy is increasingly evident. Topics such as market entry strategies across different national space economies, the implications of international space law on global trade, and the role of international taxation and financing mechanisms are becoming ever more important when assessing the viability and holistic impact of future space endeavors. These economic considerations are integral to understanding how the space economy interfaces with global, non-space-related markets, and regulatory frameworks, thus likewise affecting how space capabilities are developed. A multidisciplinary approach, incorporating especially international economics, is therefore indispensable for a nuanced understanding of the space economy. This focus on international economics not only enriches existing research agendas but also serves as a critical lens through which to explore the complex interplay between space activities and global economic systems.

At a broader scale our findings also emphasize the need for robust regulatory frameworks to ensure sustainable and equitable access to outer space while addressing potential conflicts and resource conservation. The rising prominence of the private sector, the extensive benefits of space exploration, and the imperative for international collaboration are other key themes that resonate throughout the article's narrative.

4.2 Limitations

As this study operates at the cutting edge of economics-focused new space research, we recognize the potential for imperfections in our selection methodology. Our analysis should be perceived more as a broad exploration and synopsis of the factors shaping the growth of a sustainable (new) space economy and its future, rather than a comprehensive listing of all related works. However, the 72 international academic papers ultimately chosen for our literature review epitomize the most pivotal contributions in this academic domain. While our selection was not entirely exhaustive, it encompasses a substantial and highly indicative collection of scholarly efforts, underscoring the growing attention and significance this subject now commands within the global academic sphere.

We also wish to acknowledge the subject's complexity and novelty and emphasize that the framework we have used in this paper to classify activities within the new space domain is not fully exhaustive. Thus, we see an urgent need for developing a framework that better describes the different levels and relationships of activities not only within the space economy, but also the linkages to the broader, global economy. We also acknowledge that a large amount of the used literature was US-based, though this was also to be expected due to the prominence of the US in the space domain and was not an active choice from the authors. Due to the factors mentioned above, it was quite challenging to construct a comprehensive categorization for "new space" activities.

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The New Space Ecosystem: Insights from the Architecture of Digital Platforms

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1 Introduction

The fascination with space-related activities has roots dating back to at least the beginning of the Cold War (Jora et al., 2023). However, for many years, these activities remained beyond the reach of private companies and certainly out of reach for end customers (Vidmar, 2020). While people are familiar with significant events like the Soviet Union's launch of the first satellite into space or the American moon landing (Gupta et al., 2022), these occurrences were distant news read in the media rather than firsthand experiences for people. The dominance of powerful governments played a central role in keeping the space ecosystem a realm

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_3

exclusive to a handful of nations (Gupta et al., 2022), leaving the rest of the world as mere spectators. Over the last two decades, a notable shift occurred with the private sector making significant inroads into the space ecosystem (Bousedra, 2023; Vidmar, 2020; Weinzierl, 2018), challenging established standards and beliefs that previously considered such endeavors as the exclusive domain of governmental entities. This evolution enabled the private sector not only to be part of the space ecosystem but also to directly deliver space-related applications to end customers, paving the way for a new era often denoted as New Space (Di Tullio et al., 2023; Madan & Halkias, 2020; Parrella et al., 2022; Robinson & Mazzucato, 2019).

The integration of digitalization into the space ecosystem has not only transformed the configuration of the ecosystem but has given rise to entirely new paradigms within the New Space Ecosystem (Bousedra, 2023; Vidmar, 2020). However, this transformation might not be solely attributable to digitalization; it extends to the underlying mindset steering this technological shift (Jora et al., 2023). The incursion of the American capitalist mindset, personified by influential figures like Elon Musk, Jeff Bezos, and Richard Branson (Bousedra, 2023; Vidmar, 2020; Weinzierl et al., 2022), has been a defining factor in reshaping the space ecosystem. Accordingly, the integration of these various factors into the dynamics of the New Space introduced new value chains that surpass the traditional distinction between upstream and downstream. The upstream segment, while retaining its fundamental player categories, has undergone substantial advancements with the entry of the private sector (Borroz & Korber, 2023). This is particularly evident in terms of satellite miniaturization and the cost reduction of launch activities (Parrella et al., 2022; Vidmar, 2020). As a result, the upstream advancements have cascaded downstream (Lamine et al., 2021), giving rise to a diverse array of endeavors, particularly applications developed by third-party developers through utilizing the space-related data (Onwudiwe & Newton, 2021). Accordingly, these initiatives have actively played a role in restructuring the downstream segment of the value system. Nevertheless, our understanding of the New Space Ecosystem's architecture remains incomplete.

Our primary objective is to conduct a systematic review to unveil the architectural configuration of the New Space Ecosystem. Accordingly, we aimed to curate a diverse selection of articles that explore distinct value chains, both upstream and downstream, within the overall value system of the New Space. Upon analyzing the selected articles, we observed striking parallels between the architecture of the digital platform ecosystem and that of the New Space. Therefore, following the presentation of the methodology in Sect. 2 and the discussion on the evolution of the space ecosystem in Sect. 3, we uncovered the architecture of the New Space Ecosystem in Sect. 4. Further, in Sect. 5, we proceeded to present the architecture of the digital platform ecosystem, drawing parallels between its structure and that of the New Space Ecosystem. We posit that the literature on digital platforms serves as a valuable starting point to comprehend the intricacies across different layers within the New Space Ecosystem. Accordingly, this study centers around three main contributions. First, we identify the key dynamics that have shaped the architecture of the New Space Ecosystem, namely, the incursion of the private sector, the miniaturization of satellites, and the surge in space data applications. Furthermore, we delineate the distinct layers composing the New Space Ecosystem, which emerges as a layered structure consisting of three primary layers: the infrastructure layer, the data layer, and the application layer. Lastly, we propose a prospective research agenda derived from the parallels drawn with the digital platform ecosystem, mainly centered around the dynamics of network effects within the New Space Ecosystem, the orchestration of the ecosystem, and the applicability of the platform business model within and across the different layers of the New Space Ecosystem.

2 Methodology

To achieve the objective of uncovering the architecture of the New Space Ecosystem, conducting a systematic review emerged as the optimal approach. Accordingly, it was crucial to curate a diverse array of articles that could provide valuable insights into this realm. The initial step entailed the identification of relevant search terms, followed by the establishment of selection criteria, as outlined by Tranfield et al.'s (2003). We required that the selected articles have at least one of the following keywords in their titles: "new space" OR "space econom*" OR "space industr*" OR "space sector*" OR "space ecosystem*" OR "ecosystem of space" OR "space firm*" OR "space business*" OR "space activit*" OR "space innovation*" OR "space technolog*". We utilized Elsevier's Scopus, which is recognized as one of the most effective tools for literature searches (Falagas et al., 2008). Concerning the selection criteria, as depicted in Fig. 1, our emphasis was on the domains of business and management. Specifically, we targeted peer-reviewed journal articles and book chapters published after the year 1999. This timeframe aligns with the private sector's significant involvement in the space ecosystem, as highlighted by Gupta et al. (2022).

The initial search yielded 137 articles; however, three of them were duplicates, resulting in a final count of 134. Furthermore, after an initial screening of titles and/or keywords, we excluded 24 articles that did not specifically focus on New Space. For instance, some focused on "new space" as a physical space, particularly within architectural and real estate contexts. Besides, upon thorough examination of the abstracts and/or the

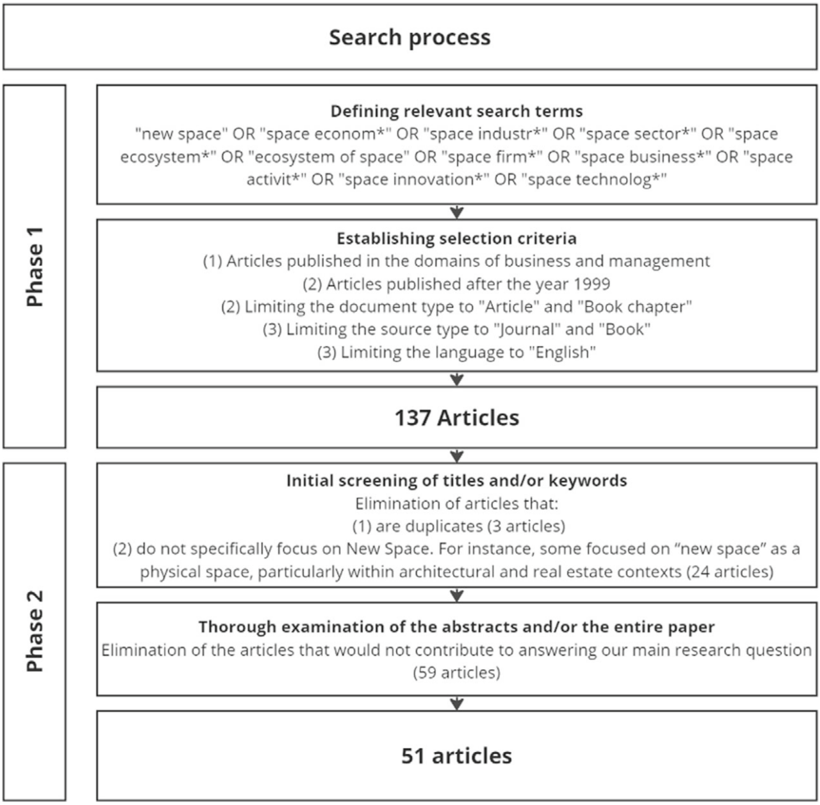


Fig. 1 Search process

entire remaining articles, we excluded 59 articles, as it became apparent that they would not contribute to answering our main research question. Thus, we were left with 51 articles to uncover the architecture of the New Space Ecosystem.

Furthermore, the systematic approach of the review extends beyond the search process to encompass the analysis phase (Spanuth & Urbano, 2023). This entailed a comprehensive analysis of the 51 articles, initially categorizing each as either upstream or downstream, based on the definitions provided by Lamine et al. (2021), OECD (2022), and Onwudiwe and Newton (2021). However, during the categorization process, it became evident that certain articles did not align with either the upstream or downstream segments. Consequently, this approach allowed us to systematically identify the distinct layers constituting the New Space Ecosystem, as illustrated in Sect. 4.

3 From Old Space to New Space: The Evolution of the Space Ecosystem

The economic interest in space began to gain momentum during the Cold War, where the space ecosystem was predominantly monopolized by two major countries, the United States and the Soviet Union (Lee et al., 2021). The Soviet Union launched the world's first satellite, Sputnik, in 1957, followed by the first human to orbit Earth in 1961. On the American side, the Apollo Moon missions involved more complex missions. These missions ultimately lead to the historic moon landing by humans in 1969 (Gupta et al., 2022). Alongside Russia and the US, other participants such as France, Japan, and the United Kingdom entered the scene. However, all of these activities conducted in the first few decades were dominated by state-funded initiatives, commonly referred to as traditional space or old space (Gupta et al., 2022). The primary objective of such early space initiatives was exploration and scientific pursuits (Bousedra, 2023). Nevertheless, in contemporary times, there has been a shift away from the traditional goals of exploration and science toward socio-economic objectives, with a particular focus on innovation and economic performance (Bousedra, 2023). Additionally, during the past few years, the space ecosystem has shifted from being dominated by a handful of leading space nations, mainly through the public sector, to now involving more than 60 countries. These countries, along with their private commercial entities, are actively engaged in the space ecosystem (Robinson & Mazzucato, 2019).

3.1 Unfolding the Evolution: Three Key Phases

Various scholars have categorized the evolution of the space ecosystem into distinct eras or phases. The majority of these classifications typically revolved around three or four different space eras. Robinson and Mazzucato (2019) categorized space waves into four: Space 1.0, encompassing astronomy; Space 2.0, focusing on the space race and the Apollo era; Space 3.0, involving the International Space Station era and integrated international initiatives; and Space 4.0, featuring more nations, diverse types of space players, spin-off, spin-in, and spillover, indicating closer ties to consumers and society. Other scholars, such as Jora et al. (2023), have classified the evolution of the space ecosystem into three distinct time frames. In their classification, the first stage commenced at the beginning of the twentieth century, emphasizing scientists' theoretical research on the potential uses of space. The second stage, spanning from 1950 to 1970, marked the initiation of practical exploration projects, military considerations, and initial economic contemplations related to the cosmos. The third stage, post the 1970s, witnessed a shift toward collaboration between the governmental and commercial sectors in space endeavors (Jora et al., 2023). In a similar vein, Vidmar (2020) outlined three distinct eras: the first phase, spanning the 1960s and 1970s, characterized by the dominance of a few nations, notably the US and the Soviet Union; the second phase, spanning the 1980s and 1990s, marked the commencement of commercialization by large multinational corporations; and the final phase, post the 2000s, represents the democratization of space activities driven by innovation and entrepreneurship. Regardless of the various categorizations offered by different scholars, they can all be distilled into three key phases. The first encompassed the theoretical phase of space activities, preceding the Cold War era. The second phase entailed space activities monopolized by a few nations and distanced from private businesses, consumers, and society, primarily during the Cold War era. And the final phase, predominantly observed in the past two to three decades, witnessed the private sector's increasing involvement in space-related activities. This involvement has reshaped our perceptions of space and the benefits derived from such endeavors. Academically, this last phase is commonly denoted as the New Space era.

3.2 *Defining the Dynamics of the New Space Ecosystem*

In contrast to the old, or traditional, space era, which predominantly originated with the beginning of the Cold War, the New Space era lacks a specific date or event marking its commencement (Gupta et al., 2022). Nevertheless, various events occurring around the 2000s collectively signified the initiation of the New Space era, notably the entry of the private sector into the space ecosystem (Gupta et al., 2022). As a result, space-related activities witnessed a transition from the (dominated) government sector to the private sector, particularly with the advent of the capitalist mindset into the space ecosystem (Jora et al., 2023). Besides, in discussions regarding New Space, SpaceX consistently emerges as a focal point. The company indeed has achieved remarkable milestones in the space ecosystem, notably being the first private company capable of returning a space vehicle from low Earth Orbit. Also, it holds the distinction of being the first private company to successfully deliver a shipment to the International Space Station (Yazici & Darici, 2019). However, the emergence of New Space cannot be solely attributed to the advent of SpaceX and its groundbreaking launch capabilities. Therefore, the New Space Ecosystem has been influenced by various factors, let alone the transformative impact of digitalization (Bousedra, 2023; Vidmar, 2020).

While a universally agreed-upon definition of New Space may currently be lacking, we posit that the emergence of New Space Ecosystem was influenced by at least three major dynamics: (1) the growing interest in the commercial tendering of government practices and the involvement of the private sector in the space ecosystem (Bousedra, 2023; Vidmar, 2020), (2) the miniaturization of satellites (Parrella et al., 2022; Vidmar, 2020), that is, the reduction in both size and weight of the satellite (Bousedra, 2023; Gupta et al., 2022; Vidmar, 2020), and (3) the surge in space data applications propelled by the impact of digitalization (Vidmar, 2020). Besides, when referring to ecosystems, we adhere to Adner's (2017, p. 40) definition, where an ecosystem is described as "*the alignment structure of the multilateral set of partners that need to interact for a focal value proposition to materialize*".

4 The Architecture of the New Space Ecosystem

Researchers commonly classify the space ecosystem into upstream and downstream, e.g., Lamine et al. (2021) and Onwudiwe and Newton (2021). On the one hand, the upstream segment represents the "*scientific and technological foundations of space programmes (e.g., science, R&D, manufacturing and launch)*" OECD (2022, p. 30). On the other hand, the downstream segment encompasses the products and services delivered through the utilization of space infrastructures and the data they provide (Lamine et al., 2021), or what is referred to as the "*Space-derived activities in other sectors*" in the OECD (2022, p. 31). Besides, it is noteworthy to emphasize that the OECD (2022, p. 30) defines the downstream segment as encompassing activities such as the "*Daily operations of space infrastructure and "down-to-earth" activities that directly rely on the provision of a space capacity*".

With the miniaturization of satellites and increase in launcher capacity, there has been a notable increase in the number of satellite launches into space. Consequently, a surge in data generation from these satellites has been observed (Harris & Baumann, 2015). Nevertheless, raw data alone does not yield any economic benefit, requiring substantial practical efforts to harness the economic potential inherent in this data (Harris & Baumann, 2015). For this reason, a data layer has begun to emerge between the upstream and downstream segments. The increased availability of data and enhanced computing power is paving the way for novel commercial opportunities, especially in the fields of data processing and analysis (Vidmar, 2020), as exemplified by entities like SkyWatch, Microsoft Azure, and Amazon Web Services. Accordingly, we propose that the architecture of the New Space Ecosystem can be illustrated as a layered structure, consisting of three primary layers: (1) the infrastructure layer, (2) the data layer, and (3) the application layer.

4.1 The Infrastructure Layer

The infrastructure layer encompasses a spectrum of activities related to the development, manufacturing, launch, and ongoing operations and management of space-bound infrastructure. To a certain extent, this layer is considered mature, subject to extensive regulation by the public sector (Lamine et al., 2021), and characterized by substantial intellectual property protection and a high level of secrecy (Vidmar, 2020). Until recently, the private sector did not significantly influence or contribute substantial value to the various activities within this layer (Vidmar, 2020). However, over the past two decades, this layer has progressively opened up to the private sector, marked by the emergence of public–private partnerships between government entities and private companies like SpaceX led by Elon Musk and Blue Origin founded by Jeff Bezos (Onwudiwe & Newton, 2021). As a result, novel actors became actively engaged in this layer, playing a crucial role in paving the way for the emergence of the New Space phenomenon (Vidmar, 2020). One prominent example in this layer is SpaceX, which is an American company specializing in the design, manufacturing, and launch of advanced rockets and spacecraft.

4.2 The Data Layer

A key outcome of advancements in the infrastructure layer is the heightened flow of data (Vidmar, 2020). A space infrastructure, namely a satellite, has a restricted capacity for carrying data on its payload, which emerges from its instrumentation. Consequently, there is an ongoing necessity to relay the data to an external source (Ellipsis Drive, 2023). However, extracting and acquiring data from the infrastructure layer is anything but straightforward. Transmitting this data to Earth can be slow and costly due to limitations in frequency and bandwidth, as well as the demand for specific IT skills (Gupta et al., 2022). Alternatively, employing space-based cloud networks for data analysis can significantly enhance speed, efficiency, and cost-effectiveness, eliminating the need to download massive amounts of data back to Earth (Gupta et al., 2022). Regardless of the method employed to extract data, it is certain that novel value chains are emerging within the broader space ecosystem. Further, extracting data constitutes just one aspect within the data layer, as the mere provision of raw data does not inherently lead to substantial economic benefits (Bousedra, 2023; Harris & Baumann, 2015). Therefore, a considerable amount of work is essential to unlock the economic potential inherent in this data (Harris & Baumann, 2015). Alongside data extraction and processing, several companies have emerged offering processed data. This data is mainly provided in the form of Application Programming Interfaces (APIs), allowing external parties to develop complementary applications atop the extracted data from the infrastructure layer. Thus, the data layer encompasses all activities related to the space-related data derived from the infrastructure layer, including, but not limited to, extraction, processing, and provision. SkyWatch Space Application exemplifies a company functioning within this layer. The company aggregates remote sensing data from the infrastructure layer, offering customers the tools necessary to maximize the benefits of such data. Simultaneously, SkyWatch provides the infrastructure layer with a remote sensing data distribution solution, facilitating the efficient delivery of data to the market.

4.3 The Application Layer

In contrast to the well-established and regulated nature of the infrastructure layer, the application layer emerges as a dynamic and less structured one (Lamine et al., 2021; Vidmar, 2020). An illustrative example within the application layer involves the first artificial satellite, Sputnik. Upon being launched into Earth's orbit, Sputnik transmitted a series of audible beeps accessible to anyone with a radio receiver. A few years later, with advancements in encryption technologies during the 70s and 80s, broadcasting and telecommunications emerged as the predominant offering in the application layer. This was mainly driven by the minimal processing requirements for the data (Vidmar, 2020). However, with the emergence of the New Space era, a diverse array of data types has emerged, opening up possibilities for the development of various applications built on top of the data layer. A notable example is the utilization of Earth Observation data, which offers a versatile portfolio of offerings spanning industries such as transportation, education, insurance, and banking (Lamine et al., 2021). Another example is the utilization of satellite navigation data, particularly when coupled with smartphones (Reid et al., 2020). Thus, space-based applications are gaining momentum, both in terms of volume and the diversity of offerings being developed (Bousedra, 2023). For instance, the identical dataset extracted from an Earth Observation satellite can be simultaneously employed by various players in the application layer. This allows them to develop diverse offerings across different industries, incurring low or even negligible costs for the firms in the data layer (Bousedra, 2023). Thus, the application layer encompasses a diverse array of offerings crafted for end customers, whether in a business-to-business (B2B) or business-to-consumer (B2C) context. These offerings are built upon space-related data originating from the infrastructure layer and extracted, processed, distributed, and transferred by the data layer. Within this layer, Orbital Insight exemplifies a company that analyzes billions of geospatial data points, providing essential input for strategic business decisions. These decisions span a range of areas, such as cost reduction, time savings, revenue and margin enhancement, improved asset utilization, accelerated due diligence, and more.

4.4 The Layered Structure

The New Space Ecosystem, Fig. 2, emerges as a layered structure, consisting of three primary layers: (1) the infrastructure layer, (2) the data layer, and the (3) application layer. First, the infrastructure layer encompasses all activities related to the manufacturing, launching, and control of space infrastructure. Further, the data layer includes all activities associated with extracting, processing, distributing, and transferring data derived from the infrastructure layer. Lastly, the application layer involves the development of offerings, comprising both products and services, built on top of the data extracted from the infrastructure layer as well as processed and disseminated by the data layer. The infrastructure layer reflects the transformative journey from a government-centric space domain to one characterized by private sector participation, notably exemplified by companies like SpaceX and Blue Origin. The data layer, as a pivotal intermediary, highlights the increased availability of data and computing power, fostering novel opportunities in data processing and analysis. Meanwhile, the application layer embodies the innovative spirit of the New Space era, showcasing the diverse offerings developed by third-party complementors across various industries. Accordingly, this conceptual framework delineates the intricate interplay among the different layers that define the evolving dynamics within the New Space Ecosystem. Nevertheless, these layers are not entirely distinct. While we have provided examples of different players within specific layers, there are firms that extend across two or three layers. An illustrative case is the emergence of Starlink, which is a division of SpaceX. In this instance, the parent company expanded its activities to encompass the diverse layers, offering high-speed internet services to end customers almost anywhere.

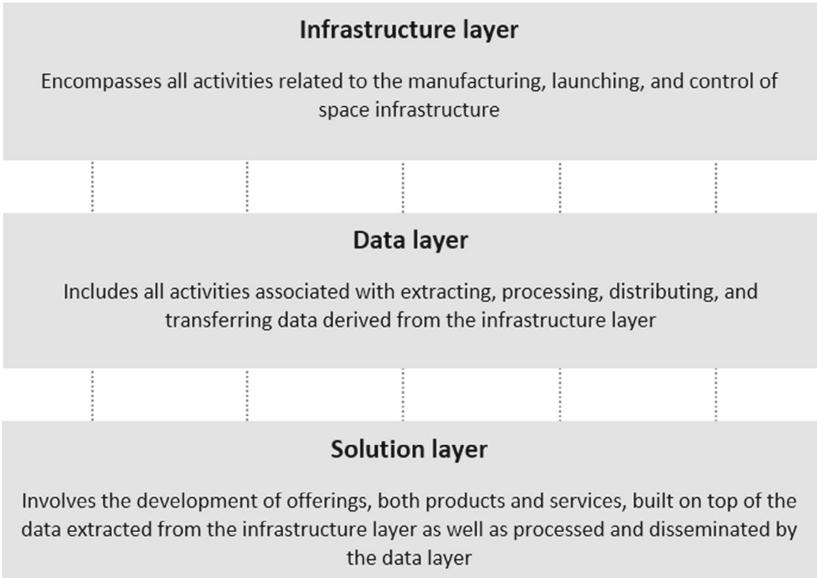


Fig. 2 The layered structure of the New Space Ecosystem

5 The Digital Platform Ecosystem and the New Space Ecosystem

When examining the architecture of the New Space Ecosystem, parallels can be drawn with another digital infrastructure-based ecosystem, namely, the digital platform ecosystem. In Sect. 5.1, we define digital platforms, while in Sect. 5.2, we explore the architecture of the digital platform ecosystem. Further, in Sect. 5.3, we briefly explore the digital threads within the New Space Ecosystem. Accordingly, in Sect. 5.4, we compare and contrast the architectures of the digital platform ecosystem and that of the New Space, elucidating the underlying similarities and differences between these two distinct ecosystems. Finally, in Sect. 5.5, we present certain areas of future research from the lens of the digital platform ecosystem, mainly drawn based on the parallels presented in the previous section, Sect. 5.4.

5.1 Defining Digital Platforms

As we explore the parallels between the architecture of the two ecosystems, it is crucial to define our understanding of digital platforms. The term itself lacks a standardized definition in the literature, and various scholars offer distinct terminologies, definitions, and classifications for digital platforms. In broad terms, one of the clearest and most straightforward categorizations is presented by Cusumano et al. (2019). They have classified technological platforms associated with network effects into two primary categories. On the one hand, there are (1) transaction platforms, which facilitate transactions between different market sides, e.g., Apple App Store. On the other hand, there are (2) innovation platforms, which enable third-party complementors to create complementary innovations on top of the platform through utilizing the extensible codebase provided by the platform owner or the platform provider, e.g., Apple iOS. Furthermore, (3) hybrid platforms are situated between transaction and innovation platforms, blending functions from both types, e.g., Apple. Technological platforms associated with network effects are referred to as industry platforms and defined as "*products, services, or technologies developed by one or more firms, serving as foundations upon which a larger number of firms can build further complementary innovations, potentially generating network effects*" (Gawer & Cusumano, 2014, p. 420). Besides, what distinguishes an industry platform from other types, such as internal, company, product, or supply-chain platforms, is its ability to potentially generate network effects (Gawer & Cusumano, 2014). Network effects occur when the value of the platform increases for one side as the number of parties on the other side increases (Katz & Shapiro, 1985).

Thus, when drawing parallels from the digital platform ecosystem, we are specifically referring to the second type of industry platforms, known as innovation platforms according to the strategic management literature (Gawer, 2021, 2022). Alternatively, innovation platforms are known as digital platforms in the information systems literature and are defined as "*purely technical artifacts where the platform is an extensible codebase, and the ecosystem comprises third-party modules complementing this codebase*" (de Reuver et al., 2018, p. 126). Therefore, regardless of the terminology used, we are referring to technological platforms that: (1) are associated with network effects and (2) provide an extensible codebase.

This codebase enables third-party software developers to create complementary applications atop the platform, primarily facilitated through the provision of APIs (Ghazawneh & Henfridsson, 2013).

5.2 *The Architecture of the Digital Platform Ecosystem*

It is crucial to grasp the architecture of the digital platform ecosystem, akin to the depiction of the layered structure of the New Space Ecosystem. A digital platform ecosystem is typically illustrated as having a core-periphery structure (Modol & Eaton, 2021). The platform owner is situated at the core, surrounded by various actors within the ecosystem, such as producers and consumers. Modol and Eaton (2021) presented a comprehensive analysis spanning a 20-year period, detailing the evolution of the digital infrastructure concept, resulting in the architectural manifestation of a digital platform with a core-periphery structure. Furthermore, as outlined by Baldwin and Woodard (2009), the digital platform ecosystem comprises three distinct elements: (1) a stable core characterized by limited variety, (2) a variable periphery exhibiting high variety, and (3) interfaces in between, defined as "*specifications and design rules that describe how the platform and modules interact and exchange information*" (Tiwana et al., 2010, p. 676). Boundary resources, such as standardized development tools (Miric et al., 2022), software libraries (Fink et al., 2020), and Application Programming Interfaces (Ghazawneh & Henfridsson, 2013), exemplify some of these interfaces. Boundary resources are defined as "*the software tools and regulations that serve as the interface for the arm's-length relationship between the platform owner and the application developer*" (Ghazawneh & Henfridsson, 2013, p. 175). Thus, these boundary resources serve as interfaces between the platform core and its periphery. Further, within this core-periphery structure, or, in other words, within the digital platform ecosystem, four distinct layers exist: (1) the platform owner, who controls the platform and decides on participation eligibility and criteria, such as Google owning Android; (2) the platform provider, who manages the platform interfaces, exemplified by Samsung providing Android; (3) producers, who are software developers creating applications on top of the platform, for instance, applications available in the Samsung App Store, e.g., Angry Birds; and (4) consumers, who purchase or use the developed applications (Van Alstyne et al., 2016).

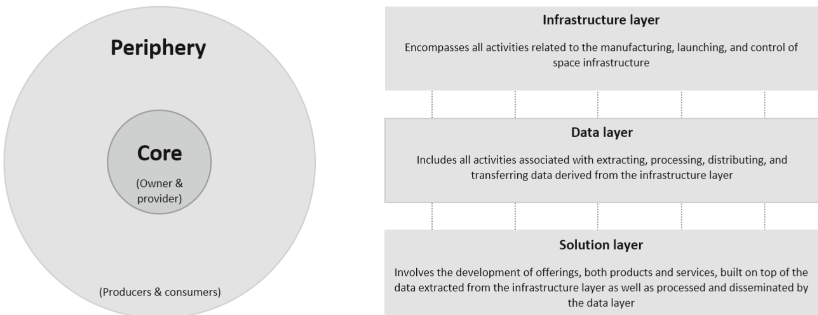
5.3 *Digital Threads in the New Space Ecosystem*

Bousedra (2023, p. 8) contends that "*the incursion of digital technologies into the space sector offers new market opportunities for space data*". The pervasive adoption of digital technologies has brought about significant disruptions across numerous industries. These disruptions include reducing entry barriers, intensifying business dynamics, introducing novel business models, or encompassing all of these aspects. However, digitalization is just one of the factors contributing to the evolution of space-related activities. Earlier, we discussed the penetration of the capitalist mindset into the space sector. To explore further, it is crucial to specify that it is the American capitalist mindset at play (Jora et al., 2023). More precisely, it is embodied by key figures associated with digital giants leading the ongoing space race. This is exemplified by individuals like Jeff Bezos, the founder of Amazon (Blue Origin), and Elon Musk, the founder of PayPal, Amazon, and Tesla (SpaceX) (Bousedra, 2023). These individuals are not only leveraging their economic fortunes but also drawing upon their previous experiences in the Information Technology (IT) sector. Their approach involves advancing innovation and disrupting the status quo (Madan & Halkias, 2020). Consequently, the initiatives led by these figures have primarily penetrated the infrastructure layer, where the upstream innovations have had a downstream ripple effect (Lamine et al., 2021), bringing space-related activities closer to end customers. This is mainly evident through the development of space-related applications. Therefore, whether through the widespread adoption of digital technologies or the initiatives of specific influential figures, such digital threads have actively contributed to reshaping the dynamics within the New Space Ecosystem.

5.4 *Architectural Parallels Between the Digital Platform Ecosystem and the New Space Ecosystem*

A platform is characterized by a core and a periphery, featuring a singular owner positioned at the center of the ecosystem, responsible for orchestrating the diverse ecosystem actors in the periphery (Zeng et al., 2022). Nevertheless, the core-periphery structure does not precisely capture the essence of the New Space Ecosystem, given the absence of a singular actor responsible for orchestrating the diverse actors within the ecosystem, as shown in Fig. 3. Within the infrastructure layer, neither the satellite manufacturer, the satellite owner, nor the launcher bears the responsibility for this orchestration task. Similarly, in the data layer, neither the data extractor, the data processor, nor the provider of processed data shoulders the responsibility for orchestration. This principle is similarly applicable to the application layer. For that reason, the architecture of the New Space Ecosystem is more accurately depicted as a layered structure rather than a core-periphery one, given the absence of a single player responsible for orchestrating the entire ecosystem.

Revisiting the diverse layers within both architectures, parallels can be drawn based on the roles played within the different layers, as shown in Table 1. Whether it is the platform owner layer or the infrastructure layer, both are, in one way or another, responsible for the digital infrastructure that is at the heart of the ecosystem, be it the platform in the case of the digital platform ecosystem or the satellite in the case of the New Space Ecosystem. Thus, the platform owner's ownership of the digital infrastructure, the platform, aligns with the infrastructure layer, representing those players who are directly responsible for the infrastructure, the satellites. Correspondingly, the platform provider layer aligns with the data layer, given that both serve as providers of interfaces, mainly in the form of APIs. Similarly, the producers align with the application layer, analogous to the role of third-party developers creating complementary applications atop the APIs. These APIs are provided by the platform provider in the digital platform ecosystem and by the data layer in the



The core-periphery structure of the digital platform ecosystem

The layered structure of the New Space Ecosystem

Fig. 3 Architectural contrasts: Digital platform ecosystem versus New Space Ecosystem

Table 1 Comparison of roles across the diverse layers: Digital platform ecosystem versus New Space Ecosystem

Digital platform ecosystem		*New space ecosystem*	
Layer	*Role/s*	Layer	*Role/s*
Platform owner	Controls the platform and decides on participation eligibility and criteria, e.g., Google (owning Android)	*Infrastructure layer*	Encompasses all activities related to the manufacturing, launching, and control of space infrastructure, e.g., Space X
Platform provider	Manages the platform interfaces, or, in other words, responsible for the provision of the API's, e.g., Samsung (providing Android)	*Data layer*	Includes all activities associated with extracting, processing, distributing, and transferring data, e.g., API's, derived from the infrastructure layer, e.g., SkyWatch
Producers	Develop complementary applications on top of the API's provided by the platform provider, e.g., Angry Birds	*Application layer*	Develop complementary applications built on top of the data extracted from the infrastructure layer as well as processed and disseminated by the data layer, e.g., Orbital Insight
Consumers	Purchase or use the developed applications	*Consumers*	Purchase or use the developed applications

New Space Ecosystem. Finally, consumers, present in both digital platforms and the New Space, represent individuals or entities benefiting from the applications developed on top of these (digital) infrastructures. Accordingly, as we navigate into the diverse layers of the digital platform ecosystem, a growing convergence of similarities becomes evident when compared to the New Space Ecosystem.

5.5 Implications and Future Directions

Significant parallels emerge between the architectures of the digital platform ecosystem and the New Space Ecosystem, particularly in the distinct layers characterizing each. This observation leads us to assert that exploring the architecture of the digital platform ecosystem can serve as a crucial foundation for a more in-depth exploration of the New Space

Ecosystem, mainly in the reams of: (1) the dynamics of network effects within the ecosystem, (2) the orchestration of the layered New Space Ecosystem, and (3) the adoption of the platform business model within and across the different layers.

5.5.1 The Dynamics of Network Effects Within the New Space Ecosystem

As more satellites join the infrastructure layer, the data layer becomes richer and more diverse, thereby enhancing the overall value for diverse actors in the application layer. Exploring how the growth of the infrastructure layer contributes to positive, or potentially negative, network effects unveils the dynamics within the New Space Ecosystem. The impact of an expanding satellite network on the data and application layers, and consequently on the value proposition for end-users and stakeholders, provides valuable insights into the power of network effects within the New Space Ecosystem. Thus, the literature on digital platform ecosystems serves as a valuable starting point to understand the dynamics of network effects within the New Space Ecosystem, particularly due to the fact that network effects are the main distinguishing factor that sets digital platforms apart from all other types of platforms (Gawer & Cusumano, 2014).

5.5.2 The Adoption of the Platform Business Model Within and Across the Different Layers of the New Space Ecosystem

Throughout this study, our focus has been on the architecture of the digital platform ecosystem rather than on the applicability of the digital platform as a business model. However, when examined as a business model rather than merely an ecosystem, the digital platform business model can be effectively employed across the various layers of the New Space Ecosystem. While the infrastructure layer and the data layer are typically associated with B2B contexts due to their upstream positions, it is worth noting that digital platforms in B2B contexts are not entirely absent, even though the literature has predominantly focused on examining such platforms in B2C and C2C contexts (Abed Alghani et al., 2024; Loux et al., 2020). Moreover, while our focus in this paper has predominantly been on innovation platforms, it is worth noting that another type of industry platforms, namely transaction platforms (Cusumano et al., 2019), could also find application across various layers within the New Space Ecosystem. Thus, whether adopting an innovation or a transaction platform business model, both possess the capability to introduce novel value creation, delivery, and capturing initiatives within the different layers of the New Space Ecosystem.

5.5.3 The Orchestration of the Layered New Space Ecosystem

An essential takeaway from the digital platform ecosystem is the understanding of governance mechanisms responsible for guiding and stimulating innovation within the ecosystem. In broad terms, there is a need to implement rules and regulations to strike a balance between controlling and fostering innovation (Boudreau, 2012; Hagiu & Wright, 2018). This is particularly crucial between the data and application layers, mirroring the governance mechanisms employed by platform owners or providers to orchestrate the behaviors of third-party developers in the digital platform ecosystem (Boudreau, 2017). Digital platforms providing an extensible codebase for external complementors underscore the importance of a regulatory framework that fosters innovation while maintaining an adequate level of control. For instance, through a detailed case study of Apple's iPhone platform, Ghazawneh and Henfridsson (2013) developed a theoretical model to characterize the design and use of boundary resources, centered on two main drivers: resourcing, "*the process by which the scope and diversity of a platform is enhanced*", and securing, "*the process by which the control of a platform and its related services is increased*" Ghazawneh and Henfridsson (2013, p. 176). Ghazawneh and Henfridsson (2013) linked the developed model to process theory, in which causation requires the sequential presence of essential conditions to achieve a specific outcome, and where causation is both contingent and bidirectional. Such insights could provide valuable contributions to the New Space Ecosystem, particularly in the interplay between the data layer and the application layer, by promoting regulatory environments that encourage innovation initiatives while maintaining essential control. Therefore, there is a wealth of knowledge to be acquired from the digital platform literature, covering insights into boundary resources (Eaton et al., 2015; Ghazawneh & Henfridsson, 2013), control mechanisms (Parker & Van Alstyne, 2018), gatekeeping strategies (Zhang et al., 2022), and even the softer governance mechanisms (Foerderer et al., 2021) employed by platform owners to orchestrate diverse actors within the digital platform ecosystem.

6 Conclusion

In brief, the primary objective of this chapter was to unveil the architecture of the New Space Ecosystem. To achieve this, we initially depicted the evolutionary trajectory from the Old Space to the New Space era, emphasizing the three key dynamics that defined the New Space Ecosystem. As we pursue our primary objective of uncovering the diverse layers, namely infrastructure, data, and application layers, we have identified significant parallels between the architectures of the digital platform ecosystem and that of the New Space. Consequently, our aim was to draw parallels between the two ecosystems, extracting insights from the literature on the digital platform ecosystem. Building on these findings, we presented a future research agenda, primarily driven by insights from the literature on digital platforms. We firmly believe that the presented research agenda establishes the groundwork for future research and in-depth investigations into the New Space Ecosystem.

An essential theoretical contribution of this chapter lies in the identification and elucidation of the core dynamics that have shaped the architecture of the New Space Ecosystem. These insights not only enrich our understanding of the New Space Ecosystem but also pave the way for a comprehensive and unified definition, not only for New Space but also for the broader New Space Ecosystem. Further, we explored the architectural intricacies of the New Space Ecosystem, revealing its layered structure. This exploration allowed us to map out the various layers constituting the ecosystem, shedding light on the nuanced relationships and interactions between them. Last but not least, we have laid the groundwork for future research by drawing parallels with the digital platform ecosystem. Accordingly, this has the potential to serve as a valuable starting point for a deeper exploration of the New Space Ecosystem.

On the practical side, this paper serves as a valuable resource for practitioners seeking to grasp the dynamics and architecture of the New Space Ecosystem. It enables them to evaluate whether their organizations can engage with this promising ecosystem, either within a single layer or across the diverse layers. Furthermore, shedding light on the absence of an orchestrator within the New Space Ecosystem, along with outlining its various layers, could serve as a valuable starting point, especially for policymakers. These insights might incentivize legislators to reexamine whether there should be a designated entity responsible for orchestrating this evolving ecosystem and, if so, who should assume the role of the orchestrator. Besides, expanding upon the identified parallels, we proposed the potential application of the platform business model across diverse layers. Such insights offer practitioners a valuable foundation to innovate and develop novel business models within the dynamic landscape of New Space Ecosystem. Lastly, the identification of the application layer highlights that any industry has the opportunity not only to participate in the New Space Ecosystem but also to reap benefits from its involvement. Therefore, we firmly believe that "*Your Company Needs a Space Strategy. Now*" (Weinzierl et al., 2022).

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The Commercial Aspects of Navigation Satellites: A Systematic Literature Review

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1 Introduction

Commercial space activities have been under growing interest during the last two decades (Davidian, 2021; George, 2019; Gurtuna, 2013). In this chapter, we focus on commercial activities within one specific sector (Davidian, 2021)—satellite navigation systems—as these systems are increasingly integrated into daily commercial activities (OECD, 2022). Further, satellite navigation systems have rapidly evolved since the launch

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_4

of the first location-based services (LBS) in the 1990s (Huang et al., 2018). The Global Navigation Satellite System (GNSS) is a key method for LBS and finds application in various industries (Manulis et al., 2021). That is, the commercial use of navigation services now encompasses a wide range of products and value-added services, catering to diverse purposes and industries (see e.g., Paravano et al., 2023).

GNSS-based services are employed at both enterprise and consumer levels. The enterprise market primarily encompasses maritime navigation, agriculture, aviation, driver advisory systems, geomatics, search and rescue, rail, critical infrastructures, among others. The consumer market mainly involves system integrators such as smartphone and automotive companies (Breeman et al., 2022). According to the EU Agency for the Space Programme, the most significant cumulative revenue segments in 2021–2031 are consumer solutions (61.0%), with revenues primarily generated from sensors installed in smartphones and tablets using LBS and applications. This is followed by the road and automotive sector (29.2%), where the majority of revenue comes from devices used for navigation, including emergency assistance, advanced driver-assistance systems, and fleet management applications (EU Agency for the Space Programme, 2022). As space-based activities are highly demanding, and technology is advancing rapidly, companies operating in this sector face several challenges related to technology, organization, and management in their pursuit of success (Xue et al., 2008).

The field of LBS, including the GNSS industry, has been extensively studied across various academic disciplines. However, while GNSS plays an increasingly vital role in our daily lives and has been integrated into numerous commercial products and services, there is limited academic understanding of the commercial usage and application of navigation satellites. By promoting awareness of this field from a commercial perspective, it can provide a foundation for future research on the subject and offer valuable insights for both academic research and business practices. For these reasons, it is essential to investigate the current state of research related to the commercial aspects of navigation satellites.

The objective of this systematic literature review is to compile existing literature, map the current state of knowledge, and suggest new research directions concerning the commercial issues of navigation satellites. Specifically, the aim is to find answers to the following research question: What is the current state of knowledge about the commercial aspects of navigation satellites?

Given the ongoing development of LBS and technological advancements, it is evident that this industry is in a constant state of evolution. In this chapter, our goal is to contribute to the existing literature by providing a deeper understanding of the GNSS market. This article is organized as follows: In Sect. 2, we present the literature search process, the selection criteria for the collected data, and an overview of the data. In Sect. 3, we disclose findings from the literature review by categorizing the articles into six themes. Section 4 discusses further research directions based on the literature review. Finally, in Sect. 5, we conclude by presenting the contributions and acknowledging some limitations of this work.

2 Methodology

2.1 Data Collection

The data collection for this systematic literature review was conducted across five databases: ABI, EBSCO, IEEE, SCOPUS, and Taylor and Francis Online. Data searches were carried out between October 2022 and January 2023. The selected keywords for the search were 'navigation,' 'satellite,' 'GPS,' 'GNSS,' 'business,' 'space economy,' and 'commerc*.' These keywords were chosen because they are associated with the studied phenomenon and are essential for finding relevant articles on the topic.

For the data search, specific criteria were established to guide the collection process. An initial search using the selected keywords, without additional selection criteria, yielded a total of 28,478 results from articles across the five databases. Consequently, it was crucial to carefully apply chosen criteria to identify suitable articles that could address the research questions. To achieve this goal, we focused on publications published in English in scholarly peer-reviewed journals. No restrictions were set on the publication years, allowing us to capture all relevant studies related to this research.

Using the selected terms and criteria, we identified 1,253 articles based on the abstracts. These included 292 articles from ABI Inform Complete (ProQuest), 43 from EBSCO, 13 from IEEE Xplore, 474 from SCOPUS, and 431 from Taylor and Francis Online. The abstract criteria required that they comprehensively describe the topic of this study. Additionally, duplicate publications were excluded at this stage. In total, 153 articles that met the abstract criteria were selected for full-text review.

During the full-text review, it became evident that some of the articles primarily focused on the technical aspects, with the commercial dimension being less prominent in the study. For instance, Prol et al. (2022) surveyed the potential of Low Earth orbits (LEO) for positioning, navigation, and timing (PNT) systems, delving into technical elements while also touching on the commercial prospects of the industry's current and future market. However, this article was omitted from the literature review because it primarily focused on the technical aspects of LEO-PNT, with the commercial dimension being a minor component in relation to the overall content of the article.

Based on the full texts, a total of 32 articles were deemed suitable for inclusion in this systematic literature review. Most of the articles were obtained from Taylor and Francis Online, totaling nine articles, while EBSCO and SCOPUS each contributed eight articles. Additionally, ABI yielded five articles, and IEEE provided two articles. Figure 1 illustrates the process by which data were searched, articles were selected from the database search, and articles were ultimately included in the final analysis. In Table 1, all 32 articles selected for this literature review are listed, presenting the authors, journals, publication year, databases from which they were retrieved, and the research themes covered in these articles.

2.2 *Overview of the Data*

The distribution of the selected studies for this literature review by year is presented in Fig. 2. The articles were published between 2002 and 2022, with the majority in 2021 (3), 2019 (5), 2013 (5), and 2011 (3). The distribution of selected studies by year indicates that researchers have been actively studying and contributing to the understanding and advancement of this field over a significant span of time.

Over the years, as navigation satellite systems have become prevalent in our daily lives, they have sparked interest among researchers. Numerous studies about the industry have been conducted from various perspectives and across multiple disciplines. However, while most of the studies have focused on the technical aspects of navigation satellite systems, there also appears to be a growing interest in commercial and business-oriented research. This broad interest among different disciplines can also be observed in the various journals in which the selected articles are

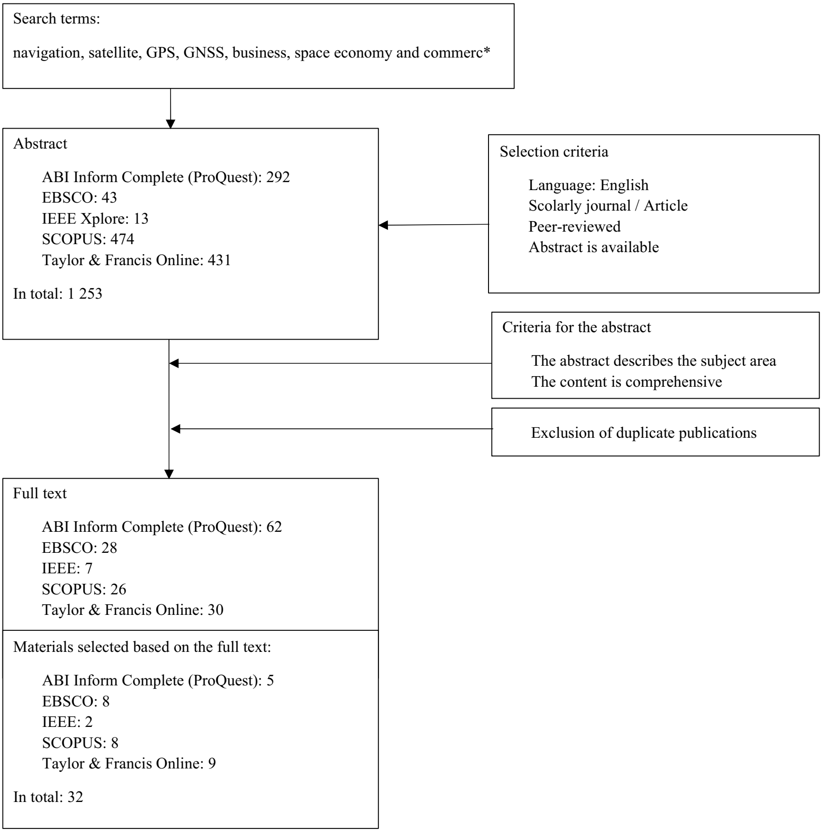

Fig. 1 Search process and selection criteria

published. Table 2 shows the journals and the corresponding number of publications from each. The reviewed articles were published in 26 different journals. The most common journals among the publications were the Journal of Location-Based Services (4), the Journal of Spatial Science (2), Sustainability (2), and Regional Studies (2).

The articles included in this literature review employ a diverse range of research and analytical approaches. The following categories were used to distinguish the different methodologies adopted in the studies:

Table 1 Selected articles

Article title	*Authors*	*Journal*	*Year*	*Database*	*Research themes*
Agent-Based Modeling (ABM): Support for Emphasizing the Air Transport Infrastructure Dependence of Space Systems	Bucovetchi, Georgescu, Badea and Stanciu	Sustainability	2019	ABI	Space systems; modeling; air transport; critical infrastructures; governance
An Organisational Model for a Unified GNSS Reference Station Network for Australia	Higgins	Journal of Spatial Science	2008	SCOPUS	GNSS, reference station networks, precise positioning, RTK, organizational models, business models
Application of Tracking Technologies to the Study of Pedestrian Spatial Behavior	Isaacson and Shoval	The Professional Geographer	2006	Taylor & Francis Online	Pedestrian, spatial activity, tracking
Battles in Space: De facto Standardization of Global Navigation Satellite Systems	Breeman, Grillo, and van de Kaa	Journal of Engineering and Technology Management	2022	SCOPUS	GNSS, Standards battle, Technology battle, De facto standard, Standard dominance
Cyber Security In: Analysis of Threats, Key Enabling Technologies and Challenges	Manulis, Bridges, Harrison, Sekar, and Davis	International Journal of Information Security	2021	ABI	New Space, Cyber security, Satellites, Constellations, COTS
Geographic Information Technologies for Cultural Research: Cultural Mapping and the Prospects of Colliding Epistemologies	Gibson, Brennan-Horley, and Warren	Cultural Trends	2010	EBSCO	Geographic Information Technologies, Geographic Information Systems (GIS), Global Positioning System (GPS), Geoweb, cultural mapping; creative city, cultural planning

Article title	*Authors*	*Journal*	*Year*	*Database*	*Research themes*
Getting into Networks and Clusters: Evidence from the Midi-Pyrenean Global Navigation Satellite Systems (GNSS) Collaboration Network	Vicente, Balland, and Brossard	Regional Studies	2011	Taylor & Francis Online	Knowledge, Networks, Economic geography, Cluster, Global Navigation Satellite Systems (GNSS)
GPS as a Method for Assessing Spatial and Temporal Use Distributions of Nature-Based Tourists	Hallo, Beeco, Goetcheus, McGee, McGehee, and Norman	Journal of Travel Research	2012	SCOPUS	GPS, spatial distributions, visitor use, tracking, time–space
Identification of Preconditions for an Emerging Mobile LBS Market	Khurri and Luukkainen	Journal of Location-Based Services	2009	Taylor & Francis Online	Mobile location-based services; Global Navigation Satellite System; smartphone; value network; value proposition
Identifying Motion and Interest Patterns of Shoppers for Developing Personalized Wayfinding Tools	Millonig and Gartner	Journal of Location-Based Services	2011	Taylor & Francis Online	Spatio-temporal behavior; methods triangulation; wayfinding; clustering; pedestrian typology
Impact of Galileo Commercial Service on Location-Based Service Providers: Business Model Analysis and Policy Implications	de Reuver, Skournetou, and Lohan	Journal of Location-Based Services	2013	Taylor & Francis Online	Galileo; location-based services; business models; satellite technologies; GPS
Interference Localization for Satellite Navigation Systems	Dempster and Cetin	Proceedings of the IEEE	2016	IEEE	Global Navigation Satellite Systems (GNNS) vulnerability; jamming; radio frequency interference

(continued)

Table 1 (continued)

Article title	*Authors*	*Journal*	*Year*	*Database*	*Research themes*
Location-Based Services—The Market: Success Factors and Emerging Trends from an Exploratory Approach	Uphaus, Beringer, Siemens, Ehlers, and Rau	Journal of Location-Based Services	2021	Taylor & Francis Online	Location-Based services; market exploration; content analysis; theoretical sampling; strategic application management
Location-Based Services Deployment and Demand: A Roadmap Model	Petrova and Wang	Electronic Commerce Research	2011	SCOPUS	Mobile services, Location-based services, Location-aware services, LBS, Case study
Managing Knowledge Sharing-Protecting Tensions in Coupled Innovation Projects among Several Competitors	Rouyre and Fernandez	California Management Review	2019	EBSCO	Open innovation, coopetition, management, project management, third-party intervention
Mobile Targeting	Luo, Andrews, Fang, and Phang	Management Science	2014	EBSCO	Mobile commerce; mobile targeting; randomized field experiment
National Positioning Infrastructure: Identifying and Evaluating high-Accuracy GNSS Service Coverage Across Australia	Hausler and Collier	Journal of Spatial Science	2013	SCOPUS	National Positioning Infrastructure (NPI); Continuously Operating Reference Station (CORS); Global Navigation Satellite System (GNSS)
Personal Information Privacy and Emerging Technologies	Conger, Pratt, and Loch	Information Systems Journal	2013	EBSCO	Personal information privacy, data sharing, data leakage, data integration, data collection, emerging technologies

Article title	*Authors*	*Journal*	*Year*	*Database*	*Research themes*
Proximity and the Evolution of Collaboration Networks: Evidence from Research and Development Projects within the Global Navigation Satellite System (GNSS) Industry	Balland	Regional Studies	2012	Taylor & Francis Online	Collaboration networks, Proximity, Economic geography, Dynamic network models, Global Navigation Satellite System (GNSS)
Satellites and the Security Dilemma	Lubojemski	Astropolitics	2019	Taylor & Francis Online	
Semantic Trajectories Modeling and Analysis	Parent, Spaccapietra, Renso, Andrienko, Andrienko, Bogorny, Gkoulalas-Divanis, Macedo, Pelekis, Theodoridis, and Yan	ACM Computing Surveys	2013	EBSCO	Movement, mobility tracks, tracking, mobility data, trajectories, trajectory behavior, semantic enrichment, data mining, activity identification, GPS
Structural and Geographical Patterns of Knowledge Networks in Emerging Technological Standards: Evidence from the European GNSS Industry	Balland, Suire, and Vicente	Economics of Innovation and New Technology	2013	SCOPUS	Economic geography; knowledge networks; social network analysis; EU Framework Programs; technological standards; GNSS
SWOT-AHP Analysis of the Korean Satellite and Space Industry: Strategy Recommendations for Development	Lee, Kim, Kim, Kang	Technological Forecasting and Social Change	2021	SCOPUS	Satellite, Strategy, South Korean space and satellite industry, SWOT-AHP, Topic modeling
Synchronization of Critical Infrastructures Dependent Upon GNSS: Current Vulnerabilities and Protection Provided by New Signals	Falletti, Davide, Marucco, Motella, Nicola, and Pini	IEEE Systems Journal	2019	IEEE	Critical infrastructures, Global Navigation Satellite System (GNSS), spoofing, synchronization, timing

(continued)

Table 1 (continued)

Article title	*Authors*	*Journal*	*Year*	*Database*	*Research themes*
Technology, Security, and policy Implications of Future Transatlantic Partnerships in Space: Lessons from Galileo	Zervos and Siegel	Research Policy	2008	SCOPUS	Public–private partnerships, Security, Technology, Galileo, Transatlantic
The Importance of Coordination in National Technology Policy: Evidence from the Galileo Project	Zervos and Siegel	Prometheus	2005	EBSCO	Galileo; navigation; space; technology policy; transatlantic
The Market Turn in EU Governance—The Emergence of Public–Private Collaboration	Mörth	Governance	2009	EBSCO	
The Price of Convenience: Privacy and Mobile Commerce	Ng-Kruelle, Swatman, Rebne, and Hampe	Quarterly Journal of Electronic Commerce	2002	EBSCO	Privacy, mobile commerce, location-based services, pervasive computing, attitudes, behavior
User Needs for Location-Aware Mobile Services	Kaasinen	Personal and Ubiquitous Computing	2003	ABI	Location-aware services, Mobile services, Usability, User evaluation, User needs
Using Global Positioning Systems as a Marketing Tool: An Analysis of U.S. Consumers' Use and Perceptions	Cobanoglu, Ciccarelli, Nelson, and Demicco	Journal of Hospitality Marketing and Management	2010	Taylor & Francis Online	Global positioning system, GPS, location-based services, marketing, marketing tool, hospitality
Visitor Mobility and Spatial Structure in a Local Urban Tourism Destination: GPS Tracking and Network Analysis	Sugimoto, Ota, and Suzuki	Sustainability	2019	ABI	Visitor mobility; urban tourism; spatial structure; GPS tracking; network analysis; Ueno district

Article title	*Authors*	*Journal*	*Year*	*Database*	*Research themes*
What Drives Users' Intentions to Purchase a GPS Navigation App: The Moderating Role of Perceived Availability of Free Substitutes	Wang, Lin, Wang, Shih, and Wang	Internet Research	2018	ABI	Global positioning system (GPS) navigation app, Innovation diffusion theory (IDT), Mobile applications (apps), Perceived availability of free substitutes (PAFS), Value-based adoption model (VAM)

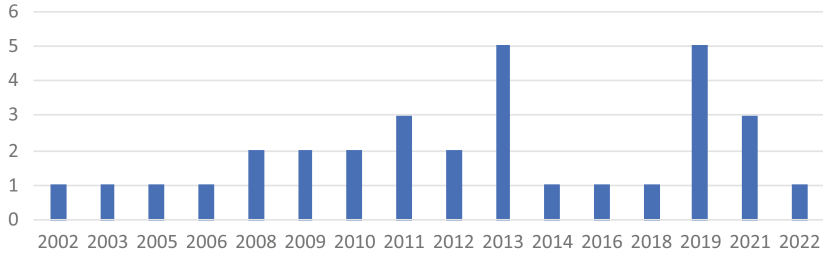

Fig. 2 Distribution of the chosen articles by year

Table 2 Distribution of the chosen articles by journal

List of journals	*Number of articles*
ACM Computing Surveys	1
Astropolitics	1
California Management Review	1
Cultural Trends	1
Economics of Innovation and New Technology	1
Electronic Commerce Research	1
Governance	1
IEEE Systems Journal	1
Information Systems Journal	1
International Journal of Information Security	1
Internet Research	1
Journal of Engineering and Technology Management	1
Journal of Hospitality Marketing and Management	1
Journal of Location-Based Services	4
Journal of Spatial Science	2
Journal of Travel Research	1
Management Science	1
Personal and Ubiquitous Computing	1
Proceedings of the IEEE	1
Prometheus	1
Quarterly Journal of Electronic Commerce	1
Regional Studies	2
Research Policy	1
Sustainability	2
Technological Forecasting and Social Change	1
The Professional Geographer	1

1. Qualitative research
2. Quantitative research
3. Mixed methodology (e.g., both qualitative and quantitative research)
4. Computational methods
5. Literature reviews, overviews, and mapping studies

The distribution of different methodologies is presented in Fig. 3. Due to the nature of the topic, it is common for the studies to involve various domains of research methods. In the business-related literature, it is evident that there are methodologies that combine both business and technical principles.

The majority of the reviewed studies employed empirical research. Quantitative research was the most widely used method, with a total of 13 studies employing this approach. Additionally, the review category, which encompassed overviews and mapping studies, consisted of ten studies. Mixed methodologies, meaning in this context the use of multiple research methodologies, such as a combination of qualitative interviews and quantitative data, were employed in four studies. Additionally, four studies conducted qualitative research. Lastly, one study used a computational method, more precisely, agent-based modeling. Interestingly, five studies applied a case study approach along with the main research method.

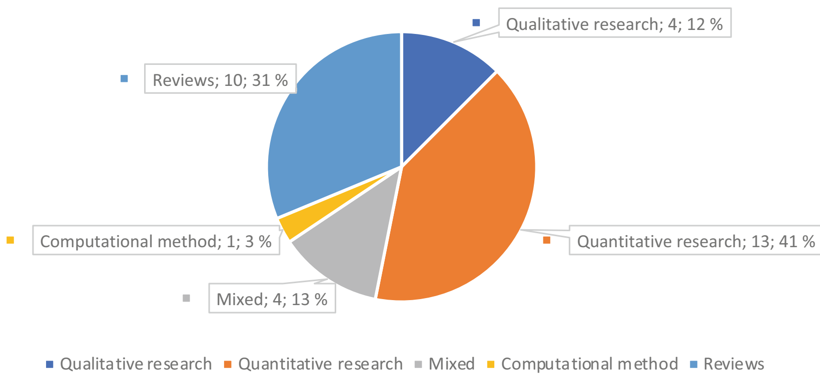

Fig. 3 Distribution of research methods

3 Analysis and Findings

The purpose of the following subsections is to offer an overview of the existing knowledge on the topic and to present six key themes that have emerged from the literature. This will establish a foundation for the subsequent section where we will explore potential directions for future research in this area.

The research topic of commercial aspects of navigation satellite systems has generated interest for studies in various contexts and for various purposes. Given the broad nature of this industry and its engagement with various domains, the research themes are extensive. Based on the systematic literature review, six themes have emerged from the reviewed articles. Table 3 summarizes the themes and the number of publications in each theme.

LBS are an integral part of the utilization of navigation satellite systems, and it was expected that this topic would be discussed in the literature. LBS were discussed in several studies, yet four articles were categorized in this theme group, as they had a prevailing focus on LBS in their research agenda. Mobility and spatial data are also relevant topics concerning commercial aspects of navigation satellite systems, with a total of six studies focusing on these themes in their research. In total, eleven articles covered topics of collaboration, coordination, and knowledge networks while studying navigation satellite systems. The consumer and user point of view were covered by four studies. A popular theme among the studies was security, privacy, and personal information privacy, and

Table 3 Themes observed in the literature

List of themes	*Number of publications*
Location-based services (LBS)	4
Mobility/Spatial data	6
Collaboration/Coordination/Knowledge networks	11
Consumer/User point of view	4
Security/Privacy/Personal information privacy (PIP)	4
Critical infrastructures	3

this category included four articles. Lastly, three articles discussed navigation satellite systems from the critical infrastructures viewpoint. In the following section, the themes are introduced, and the research on each theme is elaborated.

3.1 Location-Based Services

LBS are services that comprise technologies enabling the geographic information of a mobile user's real-time location and provide personalized information for their users (Uphaus et al., 2021). The development and deployment of LBS have been studied by Petrova and Wang (2011) through a case study approach. The focus is on the LBS landscape and reveals that regulatory factors have been crucial for commercial success in the LBS markets, yet innovative business approaches have also played a significant role in generating customer demand. The findings suggest that economies aiming to adopt LBS should prioritize the establishment of a supportive environment that nurtures the development of services tailored to meet the specific needs and requirements of the target customer market.

A recent study by Uphaus et al. (2021) presents a comprehensive overview of the current LBS market. They investigated the existing use cases of LBS and identified the relevant players and value creation models within the market. By analyzing providers, areas of application, functions, and technologies, the study establishes a category system that helps identify success factors in well-established services based on application type, technology, business models, and other characteristics. The research highlights the promising opportunity of using location analytics to improve the user experience in current LBS implementations. Overall, the study introduces a novel framework for future market explorations in this field.

The work by Khurri and Luukkainen (2009) focuses on identifying and analyzing the necessary conditions for the development of a mobile LBS market in its phases of evolution. They found that there are favorable conditions in place to initiate the implementation of LBS. However, the authors indicate several areas that require further research, such as understanding the societal impact, value proposition, and risks related to security and privacy. Additionally, the authors state that creating sustainable business models and establishing a balanced mobile LBS ecosystem that offers equal profit opportunities for all participants is crucial for the success of the LBS market. Additionally, De Reuver et al. (2013) have conducted research on the topic of business models of LBS providers and how these will be impacted by the advantages of Galileo commercial services.

3.2 *Mobility/Spatial Data*

The rapid mobility of people and goods has been facilitated by the widespread availability of ubiquitous computing and LBS. The emergence of GPS and other positioning devices has further enabled the collection of real-time location data for objects moving in geographical space. As a result, vast amounts of tracking data have been generated, opening up new commercial possibilities for innovative applications built upon this movement information. Researchers from various fields, including database management, geographic information systems (GIS), visualization, data mining, and knowledge extraction, have contributed to the development of models and techniques for analyzing mobility patterns and extracting valuable insights from this data (Parent et al., 2013).

The survey conducted by Parent et al. (2013) delves into the fundamentals of mobility data, addressing its definitions and investigating the challenges associated with its management. The study also offers a comprehensive overview of various approaches and techniques for three critical aspects: (1) constructing trajectories from movement tracks, (2) enriching trajectories with semantic information to facilitate meaningful interpretations of movements, and (3) utilizing data mining to analyze semantic trajectories and extract insights, including behavioral patterns of moving objects. Likewise, Isaacson and Shoval (2006) conducted an examination of tracking technologies for gathering data on pedestrian spatial behavior. Their study primarily focuses on two key tracking technologies: satellite navigation systems and land-based navigation systems. In a separate study, Millonig and Gartner (2011) delved into the spatio-temporal behavior of shoppers, investigating the factors that influence their commercial behavior within specific groups. Moreover, research has explored the potential of applying Geographic Information Technologies, such as GPS, in cultural research, as demonstrated by the work of Gibson et al. (2010).

Visitor mobility plays a crucial role in supporting sustainable local economies and effective management in urban tourism destinations. When researching visitor mobility, much attention has been focused on uncovering the underlying patterns and structures of spatial visitor behavior (Sugimoto et al., 2019). Traditional approaches to gathering data on spatial and temporal visitor activity have posed challenges for both survey participants and researchers. However, advancements in geospatial technologies have provided alternative methods for collecting and visually presenting information about activities in specific locations. Among these technologies, GPS has emerged as a valuable tool for data collection related to commercial behavior.

In their study, Hallo et al. (2012) explore the use of GPS technology for tracking nature-based tourists and underscore its benefits compared to traditional tracking methods. Their research revealed that GPS provides numerous advantages, including increased reliability, accuracy, and precision in data collection. By leveraging GPS technology, researchers can examine the actual movements of visitors, yielding valuable insights into visitor use patterns, as opposed to relying solely on self-reported data. In a study conducted by Sugimoto et al. (2019), researchers investigated the connection between visitor mobility and urban spatial structures through an exploratory analysis. They collected data on visitors' movements and characteristics using surveys that combined GPS tracking technologies and questionnaires. Based on these works, it is evident that GPS technology offers several advantages that can be applied for different tourism related businesses.

3.3 Collaboration/Coordination/Knowledge Networks

Balland (2012) has made significant contributions to the literature in the GNSS industry. His highly acclaimed article explores the impact of proximity on the development of the GNSS collaboration network (Balland, 2012). The study's primary focus is to understand how organizations select their partners, with a specific emphasis on proximity or distance. It empirically analyzes how organizations choose their partners based on various dimensions of proximity, including geographical, cognitive, organizational, institutional, and social factors (Balland, 2012). Another study by Balland, conducted in collaboration with Vicente and Brossard, analyzes clusters within collaborative knowledge networks in a specific technological field. It examines the interface between clusters and networks, aiming to enhance our understanding of collaboration across different locations and cognitive domains. The research specifically investigates the Midi-Pyrenean cluster in the GNSS industry, utilizing a relational database constructed from collaborative research and development projects funded at various levels in Europe (Vicente et al., 2011). These collaborative networks are important for commercialization of innovations (Balland, 2012; Balland et al., 2013) Additionally, Balland et al. (2013) have studied how innovation is influenced by specific structural characteristics of knowledge networks and its impact on geographical patterns.

The topic of public–private partnerships (PPPs) has garnered interest among researchers in GNSS literature, particularly concerning the European Galileo case. Mörth (2009) has studied the relationships between the public and private spheres through an analysis of three European collaboration cases involving public and private actors. The study includes cases of the European satellite navigation program (Galileo), the European Investment Bank (EIB), and the European financial market. The article examines the balance between managerial autonomy and democratic accountability in European public–private collaborations, emphasizing the importance of political control for democratic legitimacy, rather than evaluating efficiency.

In their paper, Zervos and Siegel (2008) explore the role of multi-public partnerships in the space industry in promoting commercially viable space programs, addressing market failures, and tackling transatlantic security concerns. The paper specifically focuses on the benefits and policy implications of transatlantic multi-public–private partnerships through a case study of the Galileo space-based navigation system. In another publication by Zervos and Siegel (2005), they examine the advantages of transatlantic collaboration in technology policy, particularly in publicly-funded R&D space projects like Galileo. Using an industrial organization methodology, the research investigates the negative security impacts of unilateral space projects, highlighting the importance of transatlantic coordination in technology policy to enable the space industries to benefit from cross-border strategic research partnerships (SRPs). Rouyre and Fernandez (2019) conducted a case study on Galileo to examine the challenges associated with balancing knowledge sharing and knowledge protection in collaborative innovation projects involving competitors. Additionally, de facto standardization concerning GNSS has also been studied in the literature, with a focus on GPS, GLONASS, and Galileo (Breeman et al., 2022).

Higgins (2008) and Hausler and Collier (2013) studied GNSS coverage and precise positioning in Australia. Both studies address the challenges and opportunities associated with establishing a comprehensive and accessible National Positioning Infrastructure in Australia. They highlight the limited coverage of high-accuracy GNSS services in Australia and identify inefficiencies and factors that have hindered nationwide access to high-accuracy positioning services, such as inefficient investment and lack of coordination. Higgins (2008) introduces a model to identify the distinct roles played by organizations involved in delivering precise positioning services. It emphasizes the importance of governance mechanisms that enable collaboration among partners, ensuring transparency regarding their respective roles and maintaining user confidence in the services provided. In their work, Hausler and Collier (2013) identify organizational business drivers and technical methodologies that have resulted in a lack of nationwide access to high-accuracy positioning services and inefficient investments in Australia. The study by Lee et al. (2021) focuses on analyzing the Korean satellite and space industry and developing strategies for its growth. The researchers utilized the SWOT-AHP method to assess the priorities of various factors and proposed detailed strategies based on their findings.

3.4 Consumer/User Point of View

Given the extensive research conducted on GNSS from various perspectives and domains, it is evident that commercial literature also explores the consumer's or user's viewpoint in relation to the market. Furthermore, there has been an interest in examining the value proposition of GPS and other navigation satellite systems for their users, as well as analyzing their impact at a consumer level.

A paper by Kaasinen (2003) studies location-aware mobile services from the user's point of view and has received significant attention among scholars. In her study, Kaasinen conducts a thorough analysis of user needs in location-aware services through a comprehensive approach encompassing user interviews, laboratory, and field evaluations, as well as expert evaluations. The study identifies key issues and presents user needs across five main themes: topical and comprehensive contents, seamless user interaction, personalized and user-generated contents, cohesive service entities, and privacy concerns.

Luo et al. (2014) study how mobile technologies allow marketers to target consumers based on time and location. Their work examines the effects of different combinations of mobile targeting on consumer responses to mobile promotions. Using a large-scale randomized experiment involving 12,265 mobile users, the researchers draw on contextual marketing theory to formulate hypotheses. Overall, the article emphasizes the importance of understanding the timing, location, and strategies used in mobile targeting.

A study by Wang et al. (2018) explores consumer purchase decisions regarding mobile GPS navigation apps, drawing on the value-based adoption model and innovation diffusion theory. It also examines the moderating role of perceived availability of free substitutes (PAFS) in the relationship between perceived value and purchase intention. For the study, authors' analyzed data from 219 mobile users using the partial least squares approach. With this study, they aimed to contribute to advancing knowledge in mobile internet marketing and analyzed consumer purchase intentions in the mobile GPS navigation app context.

Navigation satellite systems have also raised interest from a marketing perspective. In their research, Cobanoglu et al. (2010) investigate how consumers perceive the possibility of using GPS devices as marketing tools, specifically in the context of services for travelers. It is based on a survey of 200 randomly-selected online consumers, gathering insights into their usage patterns and attitudes toward GPS. The findings suggest that GPS devices are indeed employed as marketing tools, but there is notable resistance among consumers toward businesses reaching out to them through GPS.

3.5 Privacy/Personal Information Privacy (PIP)/Security

When discussing locations and activities that concern individuals' personal lives, such as their residences, workplaces, visited places, and social interactions, this information should be regarded as personal and safeguarded from being shared without authorization. Many countries around the world have established norms and laws to limit the gathering and utilization of personal data. Nevertheless, privacy regulations are unable to fully shield personal information from malicious entities, namely those intentionally seeking unauthorized access to protected data (Parent et al., 2013). In their study, Ng-Kruelle et al. (2002) discuss the hidden aspect of mobile commerce concerning private information, such as personal location, that must be provided for benefits like navigation support; hence, this can be perceived as a significant cost. The authors introduce the concept of the "price of convenience," which addresses how users' privacy is exchanged for convenience. More specifically, the study examines the decision-making process of individuals.

The topics of personal information privacy and security have been studied considerably in navigation satellite systems-related literature. The overall topic of privacy concerning individuals' locational data has received increasing interest among researchers, and it is considered an important aspect related to the industry. A study by Conger et al. (2013) introduces a comprehensive model of personal information privacy (PIP) that goes beyond just collecting transactional data and also considers the sharing of data in interorganizational settings. This study examines how emerging technologies impact the management of PIP. It also explores various research avenues related to privacy, technologies that protect privacy, interorganizational data sharing, and the development of policies in this field. For a better understanding of the motives and traits of adversarial threats, Manulis et al. (2021) examine past instances of security threats and incidents targeting satellites. According to their analysis, ground and radio frequency communications have been the primary targets so far. Yet, with the growth of satellite constellations expected in the near future, there is a need to shift focus toward securing the space segment as well. Lubojemski (2019) contributes to the security discussion by examining the security dilemma linked to satellites. By applying concepts and theories from international relations studies, the dual-use nature of satellites provides valuable insights into understanding their influence on the international system.

3.6 Critical Infrastructures

GNSS, like GPS, is increasingly relied upon in modern infrastructures due to its positioning and timing capabilities, hence making GNSS itself a critical infrastructure. These infrastructures are essential systems that contribute to the operations of the economy, government, and businesses. Moreover, they are essential for maintaining the economical operations, societal functions, well-being, health, safety, and security of citizens and states (Bucovetchi et al., 2019; Dempster & Cetin, 2016). Fields such as finance, telecommunications, and energy distribution use GNSS as a timing source for network synchronization. However, GNSS can face issues by becoming a target of hackers, spoofing attacks, and such, as some of these networks can also be classified as critical infrastructures (Falletti et al., 2019).

The literature review identified three articles that considered critical infrastructures in their research and highlighted the significance of

GNSS's role in the operations of critical infrastructures. Bucovetchi et al. (2019) emphasize the vital role of critical infrastructure. The study showcases a modeling exercise revealing the global air transport infrastructure's reliance on space systems, underscoring the potential impact of disruptions and the necessity for tools to support policy and decision-making in safeguarding and designing infrastructures.

In their study, Falletti et al. (2019) discuss the dependence of critical infrastructures on GNSS and GPS for time synchronization and consider the vulnerability of their receivers to spoofing attacks. It emphasizes the need for increased awareness and potential mitigation strategies to address this vulnerability of GNSS. Similarly, Dempster and Cetin (2016) discuss the increasing reliance on GNSS, specifically GPS, in safety–critical infrastructures. It highlights the vulnerability of GNSS to radio frequency interference (RFI) from intentional (jamming) or unintentional sources, which has become a significant concern. As a result, GNSS itself is now considered critical infrastructure that requires protection and mitigation of its vulnerability to interference. In this study, Dempster and Cetin (2016) present an overview of the existing systems and a comparison of different interference geo-localization techniques based on literature.

4 Future Research Directions

Navigation satellite systems have become an intriguing subject of investigation spanning a wide range of research areas. Beyond their primary applications in technical, engineering, and aerospace sectors, navigation satellite systems have increasingly piqued the interest of the business research community. Nevertheless, there remains a substantial need for a deeper comprehension of the business and economic aspects within this domain. This is primarily because the majority of published papers have been predominantly technically oriented, with limited attention given to entrepreneurial initiatives and business prospects related to GNSS-based services. Consequently, there is ample opportunity for research that delves into these aspects through a business-oriented lens. Some avenues for further studies are presented below.

Based on the existing literature on LBS, it becomes evident that there exists a significant variance in customer requirements concerning these services (Khurri & Luukkainen, 2009; Uphaus et al., 2021). This challenge is underscored by Khurri and Luukkainen (2009, p. 206), who note, "It is not clear how to develop business models that will take into account the interests of different players in the LBS value network ranging from content owners and device vendors to end-users." In order to effectively thrive in markets with such diverse customer needs, there is a compelling necessity for a business model that can be replicated across various use cases, industries, and market segments (Winter & Szulanski, 2001). As such, there is a clear demand for further research to delve into the innovation and development of business models (Karami et al., 2022) within the context of LBS. These studies should explore how to create a versatile business model that is easily customized, while also considering the diverse demands of customers and the specific regulations of different countries.

Prior research underscores the utility of various positioning-based services in data collection and the examination of visitor mobility, encompassing their underlying patterns and structures (Hallo et al., 2012; Sugimoto et al., 2019). Leveraging such data, diverse service types have been developed, including smart-city services for municipal authorities and tracking services for consumers aiming to circumvent traffic congestion, among others. Nonetheless, a noticeable gap exists in linking the development of these services to entrepreneurial aspects that could explore how entrepreneurs innovate novel services using available positioning technologies. An equally intriguing realm lies in indoor positioning, which presents unique challenges due to the limitations of GPS within interior spaces and the need for multifaceted technology solutions (Dedes & Dempster, 2005). Exploring this area would expand positioning-based studies and business prospects from outdoor to indoor settings (Ojala et al., 2024).

We have observed that the existing literature emphasizes networking with partners and other market actors (see Balland, 2012; Zervos & Siegel, 2008). In future research endeavors, we propose a more comprehensive application of network theories to yield in-depth insights into the dynamics of networking and ecosystem initiation among diverse stakeholders in GNSS-based services. For instance, exploring the formation of both weak and strong ties, as outlined by Granovetter (1973), can shed light on how these various types of connections contribute to the creation of a successful business ecosystem (Tiwana, 2015). Furthermore, given the international nature of GNSS-based businesses, there is a compelling need to investigate the establishment of different types of cross-border networks (Ojala, 2009). This research should aim to identify the necessary actions and strategies for integrating the potential requirements of foreign partners and addressing possible bottlenecks in the market into the service (Fraccastoro et al., 2023).

5 Conclusions

In this chapter, we have provided a comprehensive literature review that contributes to the advancement of our understanding regarding the commercial application of navigation satellite systems. Our review indicates the main themes and key findings derived from an analysis of 32 studies within this domain. The outcomes of this systematic literature review reveal that despite its importance, business-related research on the application of navigation satellite systems remains relatively scarce. While the technical features of GNSS have attracted a lot of interest, the commercial side of this market is only emerging. However, there seems to be growing interest in business research related to GNSS. Notably, a substantial portion of the existing business literature concerning GNSS and LBS emerged in the early 2010s, indicating a pressing need for contemporary research that examines the current market dynamics of GNSS and LBS.

In light of these findings, this study provides the following contributions that future research endeavors should focus on in more detail. Firstly, especially in the LBS market, there are diverse customer needs that should be addressed by developing flexible and replicable business models. Secondly, the literature highlights different services and technologies for position-based data collection, but it does not focus on how these services are created and commercialized. Thirdly, we observed that although the industry is highly networked, these networks and how they are formed have not been studied in detail.

It is essential to acknowledge the limitations of this literature review. While it aims to provide an overview of the current literature concerning navigation satellite systems with a focus on commercial aspects, it is important to note that the review is based on a modest sample size of 32 publications. We also acknowledge that some publications might be missing if they are not published within the databases applied or did not include the search words employed. Furthermore, there is always a possibility of mistakes, and the authors are responsible for any potential errors. We also acknowledge that the findings and implications of this study cannot be extrapolated beyond its specific scope. However, the study provides valuable insights into the existing literature within its specified themes and offers new perspectives for further business research on this topic.

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PART II

Evolution of Space Business

An Emerging Innovation Ecosystem for New Space—Kvarken Space Center in Finland

Mikko Punnala and Jari Ratilainen

1 Introduction

Space, a source of inspiration for humanity, has been integral to our lives since the historic moment in 1969 when Neil Armstrong took mankind's first steps on the Moon. However, the pervasive influence of space on our daily lives may not be immediately apparent. From smartphone navigation to air travel, weather forecasting, and financial transactions, we are constantly utilizing space systems. In fact, the absence of these systems would render modern life, particularly in developed nations, virtually

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_5

impossible (Jakhu et al., 2020). Space harbors immense untapped potential to address future crises, stimulate job creation, and foster innovation within the space industry (European Commission, 2016). In the coming years, space entrepreneurs, who provide cost-effective and affordable space solutions, will play a pivotal role in the evolution of the space economy (Peeters, 2021).

In developed economies, the intricacy of the space economy is on the rise, and distinguishing between space-related and unrelated activities is becoming progressively challenging. As the OECD Handbook on Measurement of the Space Economy (OECD, 2022) predicts, measuring the space economy will remain an evolving field as commercial space activities are changing rapidly. There is no explicit definition of space economy, nor is there a clear separation between different sub-areas.

The OECD Handbook on Measurement of the Space Economy defines the space economy as 'the full range of activities and the use of resources that create and provide value and benefits to human beings during exploring, understanding, managing and utilising space.' This includes all public and private actors involved in developing, providing, and using space-related products and services, ranging from research and development, the manufacture and use of space infrastructure (ground stations, launch vehicles, and satellites) to space-enabled applications (navigation equipment, satellite phones, meteorological services, etc.) and the scientific knowledge generated by such activities (OECD, 2022). For comparison, the US Bureau of Economic Analysis (BEA) described the following definition when compiling their Space Economy Satellite Account: 'The space economy consists of space-related goods and services, both public and private. This includes goods and services that are used in space, or directly support those used in space, require direct input from space to function, or directly support those that do, and are associated with studying space' (OECD, 2022).

As Peeters (2021) and Weinzierl (2018) point out, the term New Space lacks a single, specific definition, reflecting its multidimensional nature that goes beyond mere commercial aspects. Various interpretations exist, ranging from the Space Frontier Foundation's view of New Space as a pathway to human settlement through economic development to Martin Sweeting's (Sweeting, 2018) emphasis on a fresh ethos that challenges traditional aerospace methods with entrepreneurial and agile approaches (Denis et al., 2020). Alternative terms such as Alt.space, entrepreneurial space, and commercial space have also been employed

(Pomeroy et al., 2019). These designations not only encapsulate technological innovations but also underscore new business models and organizational structures that focus on collaboration, agility, incremental deployment, and customer-centric design (Denis et al., 2020).

In essence, 'New Space' represents a paradigm shift, characterized by the inclusion of non-traditional actors such as private investors and hybrid public–private organizations, as well as a new approach to space utilization exploration, and commercialization (Peeters, 2021; Weinzierl, 2018). In the past decade, the space sector has seen a rise in initiatives providing open access to a wealth of space-derived data, enabling diverse entities in the field to utilize the rapidly increasing data volume (Aloini et al., 2022).

This chapter aims to provide an in-depth analysis of the emerging innovation ecosystem in the New Space sector, with a specific focus on the Kvarken Space Center. Recognizing the persistent challenges and opportunities in this rapidly evolving field, our purpose is to explore and articulate the key factors driving innovation and growth at the Kvarken Space Center. Through this exploration, we address critical questions such as: 'What are the specific challenges facing the New Space ecosystem?' and 'How is the Kvarken Space Center contributing to overcoming these challenges and fostering innovation?' This approach allows us to delve deeper into the role of the Kvarken Space Center as a pivotal player in shaping the future of the New Space Economy.

2 New Space Economy Ecosystem

2.1 Early-Stage Ecosystems Establishment

An innovation ecosystem can be defined as a network of interconnected actors, formed around a focal firm or a platform (a shared focal point or asset), incorporating production and use side participants, creating and appropriating new value through innovation (Thomas & Autio, 2020). Currently, there is only a limited body of literature and understanding around early-stage ecosystems in the New Space industry. Work more closely linking the nascent organizational processes of ecosystems to the different institutional and inter-organizational environments found in unsettled industry spaces, where the initial circumstances for ecosystem formation are asymmetric, distributed, and dynamic, is still missing (Salenius et al., 2023).

Business ecosystems develop through four life cycle phases: birth, expansion, leadership, and self-renewal (Moore, 1993). In the first stage, entrepreneurs focus on defining what customers want i.e., the value proposition of a new product or service. It is also often beneficial to cooperate during the first stage (Moore, 1993). As early-stage ecosystem collaboration lacks external trust and legitimacy, emerging ecosystems must engage legitimacy building, with agency and coordination to support interaction with the ecosystem participants and those looking to support or join it. Partner alignment, formation of a joint vision, core value proposition, and ecosystem identity are also critical. To pursue the ecosystem's intended value proposition, securing material and intellectual resources is required (Salenius et al., 2023).

The starting point of innovation ecosystems in literature can be defined as an empirically observed trend of non-hierarchical organization of the innovation process among actors that complement each other with non-generic collaboration (Salenius et al., 2023). The actor assuming the ecosystem leader role first engages in governance related actions such as designing the role of other actors and coordinating interactions and initiates, maintains, and develops ecosystem (Dedehayir et al., 2018). Ecosystems are composed of heterogeneous participants in various roles and facilitate an output that is more encompassing than any single participant can deliver alone. There is a great interdependence among its participants which is managed primarily by non-contractual mechanisms of system governance (Thomas & Autio, 2020). One of the most critical features in industry platforms is the potential of network effects (Gawer & Cusumano, 2014).

Innovation management in innovation ecosystems focuses mainly on two perspectives: analysis of innovation management strategies, and value creation and capture in innovation ecosystems (Li, 2019). Leveraging collaboration is the key to value creation through innovation. The innovation ecosystem approach examines the very nature of successful innovation systems and stresses that the system is greater than the sum of its parts. On the surface, many innovation systems contain all the right elements, but still fall short of expected outcome. Innovation ecology is dependent on the presence of several factors, such as talent, companies, institutions, and capital elements and to a great extent on identities, meaning, networking capabilities, culture of trust, and pragmatic cooperation. Smart development of a complex dynamic non-hierarchical system is of key importance. In addition to finding the right compositions of elements, it is important to stimulate their relations and interactions in non-linear and non-hierarchical ways. For the development of innovation ecosystems, the definition of the system and its boundaries is not important but aiding the self-organization of its actors and facilitating the system's emergence from the multiple interactions are (Jucevičius & Grumadaitė, 2014).

2.2 Unveiling the Future: The Ascendance of the New Space Economy

The New Space Economy heralds a significant paradigm shift in the global space sector, increasingly characterized by the burgeoning role of private enterprises alongside groundbreaking technological innovations. This shift represents a departure from the era historically dominated by government agencies, marking the dawn of a new age where private companies are not only democratizing access to space but also pioneering novel business models and services. The term 'New Space' aptly encapsulates this evolution, denoting the emerging trend of innovative private space ventures that autonomously seek business opportunities, liberated from the confines traditionally imposed by governmental space missions (Profitiliotis & Loizidou, 2019).

Moreover, the sustainable growth and economic viability of the space economy are increasingly underpinned by 'New Space' initiatives. Such initiatives, propelled by technological advancements and innovative business models, aim to make space more accessible and beneficial for a wider array of applications. As the space economy continues to evolve, the distinction between governmental and commercial space activities becomes more nuanced, highlighting the critical role of public–private partnerships in advancing space technology and infrastructure (Peeters, 2021).

The current era is marked by a notable surge in commercial satellite launches, space tourism ventures, and private lunar exploration missions, fundamentally transforming the economic landscape of space activities. The comprehensive analysis provided by Greg Sadlier et al. (2019) further illuminates the economic impact of these activities, underscoring the strategic importance of nurturing this burgeoning field.

The narrative of the New Space Economy is one of profound transformation, characterized by the melding of entrepreneurial innovation with strategic economic growth. It is an era defined by the quest for sustainability, the expansion of access to space, and the enhancement of global connectivity, all supported by a collaborative spirit among stakeholders. This narrative offers a multifaceted perspective on the ongoing evolution within the global space sector, showcasing its potential to drive future technological, economic, and societal advancements, enriched by the insights (Gonzalez, 2023; Paravano et al., 2023; Peeters, 2021; Profitiliotis & Loizidou, 2019; Sadlier et al., 2019).

The advent of reusable launch vehicles, SmallSats, and CubeSats has revolutionized space access, making it more cost-effective and inclusive. These innovations have precipitated a significant uptick in spacecraft launches, with SmallSats representing a substantial majority in recent years. Furthermore, the deployment of satellite constellations promises to extend global coverage, facilitating a range of applications from climate monitoring to broadband internet, marking a critical driver for the space market's future trajectory (Aloini et al., 2022; Deloitte Insights, 2023; Denis et al., 2020).

Venture capital and private equity firms have significantly increased their investment in space-related start-ups and technologies, fostering an environment ripe for innovation and competition. This influx of capital has enabled the emergence of new business models, such as mega constellations, and supported ambitious projects by leading companies like SpaceX and Blue Origin, thereby contributing to the sector's expansion and commercialization. The global space economy's growth trajectory underscores the sector's burgeoning strategic importance, with start-up equity investments reaching notable figures and a policy shift catalyzing the establishment of space start-ups, reflecting the entrepreneurial dynamism propelling the industry's growth (Deloitte Insights, 2023; Emen, 2020; McKinsey & Company, 2023).

An increasing reliance on space-based data by government agencies, private companies, and research institutions is driving the demand for space data and related services. This has led to the development of the space data-as-a-service market, where companies offer customized data sets for diverse applications, highlighting the critical role of space data in various industries (Deloitte Insights, 2023).

Projections indicate substantial growth in the sector's value and the number of active satellites, emphasizing the necessity for continued innovation, investment, and collaboration between public and private entities. Addressing emerging challenges, such as supply chain disruptions, regulatory hurdles, and environmental concerns, will be pivotal for the sector's sustained growth and long-term viability (Space Foundation, 2023).

The New Space Economy heralds a novel approach to space exploration and utilization, marked by the increasing role of non-traditional actors, the integration of space activities with ICT, and significant economic expansion. The sector's evolution presents exciting opportunities for interdisciplinary research, technological advancements, and economic development, underpinned by a collaborative spirit among all stakeholders (Aloini et al., 2022; Chavy-Macdonald et al., 2021; Deloitte Insights, 2023; Denis et al., 2020; Emen, 2020; McKinsey & Company, 2023; Pomeroy et al., 2019; Space Foundation, 2023; Weinzierl, 2018).

The European space sector is undergoing a transformative phase, shaped by global trends such as technological innovations, increased private sector investments, and a growing demand for space-based data and services. These trends are not only reshaping the space sector globally but are also manifesting uniquely in Europe, underpinned by strategic EU initiatives, investments, and the burgeoning role of commercial space activities.

Europe has embraced the technological advancements that are driving the New Space Economy forward. Innovations in reusable launch vehicles, SmallSats, and CubeSats, similar to global trends, are making space more accessible and cost-effective. This has led to an increase in spacecraft launches and the development of satellite constellations offering global coverage. European space endeavors are supported by strategic investments aimed at fostering technological advancements and commercial activities within the space sector. The European Union, recognizing the strategic importance of space, has allocated significant funds to its space programs, aiming to strengthen Europe's position in the global space economy and enhance its autonomy in space (Council of the European Union, 2020a, 2020b).

The European space sector is increasingly driven by commercial activities, aligning with the global shift toward a New Space Economy characterized by the involvement of private companies and entrepreneurs. This shift is facilitated by EU policies that encourage the commercialization of space and the success of European space companies in the global market. Initiatives to promote space and provide access to finance for start-ups, expanding businesses, and SMEs are crucial in developing a competitive European space industry (Council of the European Union, 2020a).

The EU's substantial space investments, particularly the €14.4 billion, earmarked for the European Space Programme for 2020–2022(24), underscore its commitment to advancing satellite systems like Galileo, EGNOS, and Copernicus. These investments also aim to nurture space entrepreneurship and innovation, furthering the development of the European space sector. The EU's space policy is designed to meet increasing societal demands for space-based solutions and strengthen Europe's standing in the global space arena (Työ- ja elinkeinoministeriö, 2020).

While the European space sector benefits from the EU's strategic focus and investments, challenges remain in fully tapping into the potential of the New Space Economy. The integration of emerging space companies into significant space projects and the global market poses a formidable challenge. Nonetheless, the European space sector, with its rich history of technological innovation and strategic investments, is well-positioned to navigate these challenges and capitalize on the opportunities presented by the New Space Economy (Council of the European Union, 2020b).

The European Space Economy is at a pivotal juncture, with the EU's strategic initiatives and investments playing a critical role in shaping its future. The transition toward a more commercial and innovative space sector reflects Europe's response to global trends and its ambition to remain a key player in the New Space Economy.

In the evolving landscape of the New Space Economy, Finland's strategic approach and the initiatives at the Kvarken Space Center exemplify the nation's commitment to harnessing the potential of space for economic development, technological innovation, and societal benefits. Positioned within the broader European context, Finland's endeavors in space reflect a concerted effort to align with EU strategies, leverage investments, and capitalize on the burgeoning role of commercial space activities.

Finland has proactively embraced the shift toward a more commercial and private sector-driven space industry. This transition is marked by technological breakthroughs and a significant decrease in the costs associated with space exploration, enabling Finland to explore new business models and state-of-the-art technologies across various sectors (Harri et al., 2020; Piirainen et al., 2022). The Finnish government's reports and policy programs underscore the nation's vision to integrate space activities across sectors, translating space strategies into actionable goals and fostering government-led actions and investment programs to amplify space activities (Harri et al., 2020; Piirainen et al., 2022).

The New Space Economy program, spearheaded by the Finnish Ministry of Employment and the Economy, targets economic growth and employment through innovative business models. Coupled with Business Finland's New Space Economy program (2018–2022), these initiatives position Finland as a key player in the global space economy, emphasizing sustainable space utilization, climate change objectives, and security (Ranne, 2021).

At the heart of Finland's space endeavors lies the Kvarken Space Center, serving as an innovation hub and a beacon for Nordic cooperation in space. The center facilitates stakeholders in the Nordic region to explore new opportunities, enhance the use of satellite technology, data, and applications in various domains, thereby reinforcing Finland's pivotal role in space-related Nordic collaboration. The inception of the Kvarken Space Center, through the KvarkenSpaceEco project supported by the EU Interreg Botnia-Atlantica program, showcases a successful collaboration among universities and research institutions from Finland and Sweden (Kvarken Space Center, 2024).

Despite the promising trajectory, Finland faces regulatory challenges and hurdles related to the decentralized nature of its space sector. Overcoming these obstacles is paramount for Finland to fully leverage the opportunities presented by the New Space Economy (Harri et al., 2020). The Finnish space sector, characterized by a diverse array of companies and a highly educated workforce, stands testament to Finland's capabilities and ambitions in space (Piirainen et al., 2022).

In conclusion, Finland's strategic approach within the European context, bolstered by initiatives like the Kvarken Space Center, illustrates the nation's resolve to be at the forefront of the space revolution. As Finland navigates the complexities of the New Space Economy, its contributions to the global space industry and the Finnish economy's overall development are poised to make significant strides, contributing to the sustainable growth of the space sector.

3 Methodology

3.1 Emergence of a Sustainable Commercial Space Economy

The research was conducted within the framework of the EU Interreg Botnia-Atlantica Kvarken Space Economy project, spanning from 2019 to 2022, with the objective of establishing the Kvarken Space Center.

Situated in the Kvarken region (Fig. 1), which encompasses both Finland and Sweden, the center aims to serve as a catalyst for innovation in regional New Space activities. Its primary mission is to create a sustainable structure for regional economic development, focusing on space-based business and innovation. Additionally, the center seeks to bolster regional businesses by facilitating the development of new opportunities within the New Space Economy and aiding in the commercialization of existing space-based data through the establishment of a regional innovation ecosystem (Kvarken Space Center, 2019).

The concept of open innovation posits that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they advance their technology (Chesbrough, 2006).

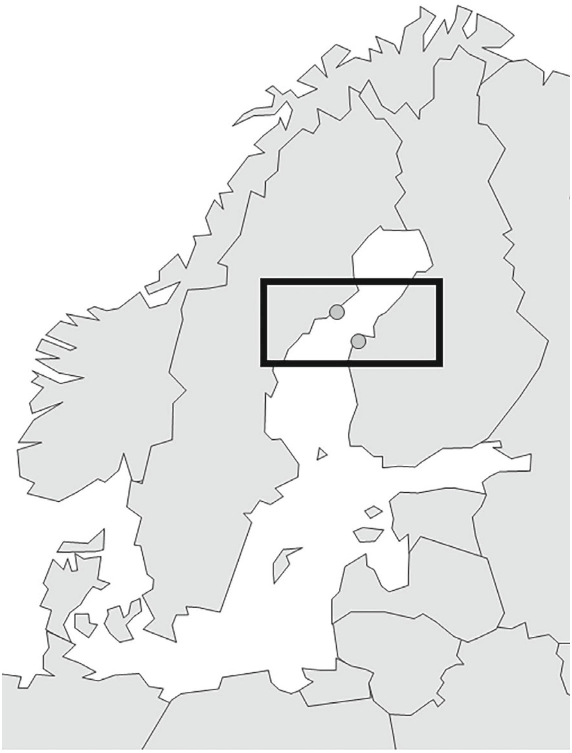

Fig. 1 The Kvarken region between Sweden and Finland

The current body of literature suggests that open innovation thrives under conditions of technological complexity and market uncertainty (Herskovits et al., 2013). This paper delves into the potential of New Space in the Kvarken region in Finland, by scrutinizing the critical aspects and demands for the regional innovation ecosystem landscape. It does so by leveraging insights from industry representatives and examining the manifestation of open innovation within these innovation ecosystems. Our objective is to elucidate the management of the open innovation process within an ecosystem involving multiple participants.

The study of an emerging ecosystem is inherently exploratory, necessitating the use of qualitative case study methods and in-depth interviews. The analysis of how ecosystems emerge is primarily anchored in empirical observation (Salenius et al., 2023). Semi-structured interviews with representatives from diverse sectors within the industry landscape were conducted, both in-person and via video conference calls. These sectors spanned energy, IT, maritime, logistics, land surveying, construction, security, forestry, and waste management. Additionally, subject matter experts involved in the KvarkenSpaceEco project were consulted. The research and establishment activities for the Kvarken Space Center ecosystem were conducted from January 2020 to September 2022, involved 30 interviews, 3 workshops, and several separate consultations and discussions. The aim was to map the landscape of the New Space Economy in the Kvarken region and identify potential opportunities for the innovation ecosystem. The current and potential utilization of space-based data for new product and service development and application for the development of internal business processes were also discussed. The authors of this chapter played a dual role as actor/observer, with the active goal of initiating and supporting the new space innovation ecosystem establishment in the Kvarken region. The research was designed to capture a snapshot of perspectives within a specific timeframe, focusing on the qualitative insights that inform the current state and potential future directions of the sector as related to the Kvarken Space Center in Finland.

The interviewees comprised entrepreneurs, technology and strategy managers, facilitators, coordinators from the business world, as well as experts from universities and research institutes. These individuals were either participating or aspiring to participate in the Kvarken region's space ecosystem. The interviews, which lasted from one to two hours, were documented. An organized approach was employed to analyze the qualitative data gathered from interviews and reports to uncover underlying themes (Appendix: Thematic Culmination Points from the Interviews). Subsequently, we performed a detailed manual analysis to delve deeper into these themes. Additionally, to validate our findings and ensure robustness, we cross-referenced these themes with relevant literature in the field.

Five main questions were developed for the analysis:

1. What type of infrastructure would be needed to support innovation in the Kvarken region?
2. What type of competence, skills, products, or services would companies offer to the ecosystem either as individual offerings or connecting into a part of a value chain?
3. How can the decentralized nature of the space sector in the Kvarken region be effectively managed to enhance efficiency and foster a more coordinated approach?
4. Considering the global space economy, what are the potential areas for scalable business for companies in the Kvarken region, and how can these opportunities be maximized to support the growth of the local space economy ecosystem?
5. What strategies can be employed to improve the understanding and utilization of space-based data in the region?

Furthermore, the material concerning Finland's space economy has been primarily sourced from reports commissioned by the Prime Minister's Office. These reports, which scrutinize and aim to develop Finland's space strategy and space economy, serve as foundational references for the development of the national space economy, including in the Kvarken region. Based on this material, efforts have been made to utilize the nationally approved space strategy measures to ascertain and develop the state of the space economy in the Kvarken region.

4 Findings

In the establishment phase of the KvarkenSpaceEco project's ecosystem, we observe a harmonious alignment with foundational principles delineated in Sect. 2.1 of our literature review. This phase embodies the essence of collaboration, value generation, ecosystem identity, and the strategic amalgamation of essential elements for ongoing development. These facets collectively mirror the theoretical underpinnings and practical examples cited in the scholarly discourse, thereby validating our research findings within the broader context of ecosystem evolution.

During the research and development of the Kvarken Space Center, observations of the New Space innovation ecosystem revealed that open development activities at the ecosystem level really mean finding new ideas together with innovation projects. The findings provide additional evidence that the formation of an innovation ecosystem for New Space is important and for companies that make people meet others and share a common interest in innovation cooperation. The actors emphasized interaction between members, as one company representative formulated: '*The goal of this New Space Economy ecosystem is to get people to talk, meet and know others, and find requirements of common interest*.'

A common platform must provide opportunities for brainstorming, advancing ideas into innovation projects, and creating a sustainable New Space Economy ecosystem. Creation of joint projects, from the bottom up by starting with brainstorming sessions, meetings, and workshops between organizations facilitate emergence of new ideas and incorporate the various views of different parties.

A broad level of interest can also be observed from the industry interviews for new technology, space-based data applications and opportunities utilizing new data layers to support day-to-day business and innovation. Business needs and interest areas of application range extensively. Only a few companies are already integrating space-based data into their processes. Proper understanding of data access, application, and possibilities for data utilization is still on a low level.

A major unanswered question is the viability of satellite remote sensing for local applications as the level of local infrastructure, easy utilization of drones and access to good quality aerial images and ready-made materials provided by public sector actors is commonly and often freely available for diverse applications. For many applications, openly available remote sensing data was considered to have insufficient spatial resolution for many industrial use cases and the cost of commercial imagery product remains expensive (especially for small companies). As a mitigating action cost sharing between several users of commercial imagery products acquisition was identified (e.g., via the Kvarken Space Center, shared project consortiums or actors in the value chains). The value of remote sensing was especially observed for business activities, products, and services delivered to more remote geographical areas. The most utilized space data applications on the local level are connected to Positioning, Navigation, and Timing (PNT); in activities requiring PNT data, and were observed especially in the energy, maritime, security, logistics, and construction planning and engineering related discussions. Also, the value of PNT was identified in many new opportunities for product and service development, for example in combination of geographical information systems and supporting location-specific decision making in e.g., built and urban environments.

From the Business Development workshop (application to Waste Management) key identified issues included how to enhance traceability, developing pre-sorting, resource, and route optimization and how to make the waste value chain more transparent, identify origin and target actions on specific geolocations. In addition, special interest in applying space-based data to developing countries' needs was acknowledged. Current ESA funding calls were also reviewed as an opportunity to pursue further support for potential business applications.

During the Ecosystem Workshop 2022, several representatives of different companies pointed out that remote sensing, PNT data, and telecommunications support applications in the energy industry, logistics, shipping, improving the situational picture and awareness, agriculture, and forestry for change detection, connectivity, and forecasting. Often space-based data offers only a single part in a diverse value chain.

Several university and business representatives drew strong attention to the fact that education and know-how related to the utilization of space must be developed in Finland. The informants agreed that Finnish education is mostly insufficient to meet the challenges of the New Space Economy. One key requirement for the development of the space industry is to invest in the development of competence and know-how comprehensively in accordance with the needs of different sectors. Companies develop the ability to take advantage of emerging opportunities and participate in the New Space Economy as they create and acquire new skills and abilities.

In an interview with a manager of a start-up space data company, a comprehensive view on developing competencies from a business point of view was discussed. He emphasizes the critical need for understanding and effectively utilizing space-based satellite data, such as remote sensing images, across various applications. The manager points out a significant gap in the general awareness and technical know-how among users, particularly in accessing, interpreting, and using raw image data and its associated metadata. This lack of understanding hinders the ability to extract valuable information from these images.

Furthermore, the manager stresses the importance of enhancing machine learning skills. He argues that analyzing satellite data without machine learning tools is too labor-intensive, highlighting the need for teaching the creation of machine learning models. Alongside this, there is a call for increasing data science education to enable structured big data analysis, requiring specialized data processing skills in programming languages like R or Python.

The discussion also extends to the teaching of artificial intelligence (AI) algorithms. The use of various AI models in the processing of space data is deemed crucial for analyzing the material effectively and preparing forecasts. This technical competence is complemented by a need for general business skills in start-ups within the New Space Economy. The manager enumerates roles such as front-end and back-end developers, designers, mobile application developers, and professionals in sales, marketing, partnerships, and fundraising. These roles are essential for a comprehensive understanding of the possibilities within the New Space Economy ecosystem and the interconnections between different actors.

A working model was also created that brings the relevant actors together to create solutions and consider possible project piloting and funding for Business Development Workshops. The proposed format was found to be an excellent approach from the point of view of developing a sustainable New Space Economy ecosystem in the Kvarken region. According to the model, existing funding tools or opportunities are combined with a real business challenge and a group of relevant industry players is ideal to strengthen the development of a New Space Economy ecosystem. The model can also serve as a blueprint for the development of future ecosystem networking opportunities.

Many aspects and needs of the innovation ecosystem were collected with the help of industry feedback:

1. Recognizing the value of the company/organization in the innovation ecosystem and creating added value to develop one's own

operations. As observed in the ecosystem literature, the key question was also, how can the developing innovation ecosystem create value for participating companies and organizations?

2. What kind of activity will the innovation ecosystem have for participating companies and organizations. Ease of use of business incubator services, regular ecosystem member meetings, organizing/providing various events (such as hackathons, webinars, learning opportunities, online courses, training, and short courses on space technology, data, and business), provision of a common online platform or group to share information, facilitating establishment of consortia and project groups for EU space searches were identified as the main needs, as well as the creation of a center for start-up activities to connect the designs of the different sectors interested in the area.
3. Infrastructure, business incubator services, open access to information resources, availability of laboratories also for research and training activities, the creation of collaboration platforms for information exchange, the acquisition of data and equipment required for training activities, the utilization of infrastructure funding and the combination of industry/business know-how, products and services in the region are also needed to support innovations, as well as the current manufacturing possibilities for New Space Economy applications are of paramount importance for the development of a sustainable space economy ecosystem in the Kvarken region.
4. Those who participated in the workshop were asked what kind of expertise, skills, products, or services they would offer to the ecosystem either as individual offers or as part of the value chain. The following components were identified; participation in system design, knowledge, and training of the latest technology, information science for environmental and climate applications, climate solutions utilizing satellite data to measure, monitor, and reduce the carbon footprint of companies, applications of real-time satellite data packages, satellite data application related to climate change, GNSS-controlled automation, application and management of ESA projects, implementation of mapping services, access to international contacts, access to industrial and agricultural information and possible end users of applications, knowledge of battery chemistry and mobile networks and the provision of satellite testing facilities

(vibration and RF) and opportunities to organize joint events with ESA BIC Finland.

5. Based on the discussions and presentations, the Kvarken Space Center should act as an umbrella that connects actors through events and activities as a form of Finnish-Swedish cross-border cooperation. Cooperation opportunities were seen as joint EU funding efforts, project consortia, matchmaking, customer and partner search, offering start-up events and organizing company and group visits, as well as direct promotion across the region.

Several development initiatives were identified across ecosystem actors, structures, activities, and support. The development of the space economy ecosystem will require increasing the awareness and commitment of stakeholders related to the New Space Economy. The establishment and support of a continuous innovation pipeline, the initiation of new space projects, participation in, supporting and promoting the establishment of new project consortiums were seen as important. Supporting industry in the introduction of New Space Economy applications, providing business incubation and mentoring for start-up and spin-off companies, identifying business and funding opportunities, establishing and developing local/regional innovation infrastructure for joint efforts in the New Space innovation ecosystem were identified. Organizing special events on business opportunities, new technology and networking, developing and promoting education in key subject areas (e.g., remote sensing, PNT, satellite communication, and New Space Business), and disseminating information to stakeholders were also recognized as important aspects of development. In Table 1, the key findings are presented categorized by their main themes.

The New Space Center plays a pivotal role in the evolution of the space ecosystem, serving as a linchpin across various key areas outlined in Table 1. Within the realms of education and skills development, the Center spearheads innovative programs and partnerships that bridge the gap between theoretical knowledge and practical application in space sciences. By collaborating with academic institutions and industry leaders, the Center engages in various activities to equip ecosystem members with the necessary expertise and insights. Through the ecosystem members, the Center's contribution extends beyond networking to

Table 1 Enhancing the New Space Economy: the role of the Kvarken Space Center in developing the space ecosystem

Category	*Key findings/insights*
Open development activities	– Open development signifies collaboratively finding new ideas within innovation projects – The significance of establishing an innovation ecosystem for new space – Emphasis on fostering dialogue, meetings, and shared interests
Industry interviews	– Widespread interest in new technology and space-based data applications – Few companies currently integrate space-based data – Limited comprehension of data access and its potential uses
Satellite remote sensing	– The feasibility of satellite remote sensing for local applications remains uncertain – Publicly available data often lacks the necessary resolution – Notable value in remote geographical areas and activities requiring PNT data
Business Development Workshop	– Focus on enhancing traceability in waste management – Interest in applying space-based data to developing nations – Exploration of current ESA funding opportunities
Ecosystem Workshop 2022	– Space-based data often plays a role in a multifaceted value chain – The importance of education and expertise in space utilization in Finland
Skill and competence development	– The need for understanding and utilizing space-based satellite data – The importance of advancing machine learning and data science education – Emphasis on mastering AI algorithms and general business acumen
Working model	– A model that amalgamates relevant stakeholders to devise solutions – Merging funding mechanisms with tangible business challenges

(continued)

Table 1 (continued)

Category	*Key findings/insights*
Industry feedback	– Recognizing a company's value within the ecosystem – The necessity for infrastructure and business incubator services – The expertise, skills, and services offered to the ecosystem
Kvarken Space Center role	– Serving as a nexus that connects various stakeholders – Promoting Finnish-Swedish cross-border collaboration
Development initiatives	– The need to heighten awareness and stakeholder commitment – Advocacy for the New Space Economy – Organizing events centered on business opportunities and novel technology

community engagement, fostering advancements in technology and business opportunities, thereby reinforcing its integral position within the space ecosystem's fabric.

5 Conclusion and Further Research Directions

Several significant empirical findings and implications for the development of a sustainable space innovation ecosystem in the Kvarken region have been identified and several key elements can be underscored. As discussed, coordination efforts to support early-stage ecosystem emergence and development are required, therefore the following should be considered:

1. **Continuous Innovation Pipeline**: Essential for generating new ideas and solutions, the establishment and nurturing of an innovation pipeline is a primary consideration.
2. **New Space Projects and Industry Support**: Crucial for applying theoretical concepts and realizing economic benefits, the introduction and industry support of New Space Economy applications is vital.

3. **Business Incubation and Mentoring**: Providing incubation and mentoring to start-ups and spin-offs is necessary to foster new business growth and entrepreneurial activities in the space economy.
4. **Identification of Business and Funding Opportunities**: This is vital for the financial sustainability of the space innovation ecosystem.
5. **Local/Regional Innovation Infrastructure**: Building and enhancing infrastructure is important for collaboration and resource sharing among different ecosystem actors.
6. **Event Organization**: Focusing events on business opportunities, new technology, and networking is important for knowledge sharing and value creation (e.g., Business Development Workshops).
7. **Stakeholder Awareness and Engagement**: Enhancing awareness, engagement, and commitment toward the New Space Economy is critical for fostering an innovation-supportive environment.

In addition to these elements, the collaborative Business Development Workshop model developed for encouraging involvement of relevant actors in solution creation, potential project piloting, and funding should be further explored. The model represents a practical approach to fostering collaboration and promoting collective efforts in the innovation ecosystem as seen in Fig. 2.

Some significant challenges were also uncovered around capabilities. There is a notable gap in the region regarding the necessary skills and educational opportunities for utilizing space data. Despite the presence of suitable capabilities across almost all areas of the space economy, these resources are not being optimally utilized. Furthermore, sustainable development regarding the new space innovation ecosystem has not been fully realized based on individual actors.

To address these challenges, the Kvarken Space Center has initiated several research, development, and innovation projects in collaboration with local universities and industry representatives. These projects aim to foster a sustainable New Space Economy ecosystem in the region. They have already enhanced awareness, understanding, and utilization of space-based information, leading to the creation of new innovations in the field.

In conclusion, the KvarkenSpaceEco project has established both an invaluable and robust foundation for the sustainable development and evolution of a space innovation ecosystem in the Kvarken region. The project's findings and initiatives serve as a strategic guide for future

Fig. 2 Innovation ecosystem potential overview in the Kvarken region in Finland. The Kvarken Space Center functions as the hub for local and regional activities and gives a single interface to Swedish and international collaboration

advancements in the New Space Economy, while also emphasizing the urgent need for further research. This is particularly salient in the context of early-stage ecosystems in the new space industry, an area currently characterized by a limited body of literature and empirical studies. The challenges and key elements identified by the project offer a fertile ground for future scholarly work in this underexplored domain. Moreover, the project's collaborative model, along with the research, development, and innovation projects it has initiated, represent promising approaches to addressing these challenges. As there is currently limited research available on early-stage ecosystems and their establishment, this paper offers a single case perspective for future research efforts into uncovering rationale and mechanisms for early-stage ecosystem development, especially in the new space industry. Therefore, there is a prevailing need for further studies that delve into the complexities and nuances of early-stage space innovation ecosystems, thereby fostering a more sustainable and robust space innovation ecosystem in the Kvarken region and beyond.

To promote the development of space technology and harness the commercial potential of the emerging space industry, the following policy recommendations are presented:

1. **Facilitating Regional Networking and Collaboration**: Foster and deepen networking among regional stakeholders in the space industry. Encourage collaboration and knowledge exchange among local space-related organizations, universities, and businesses. This recommendation is based on points 1, 2, 3, 4, 5, 6, and 7 in the Conclusions.
2. **Enhancing Public–Private Partnerships**: Foster collaboration between government bodies and private enterprises in the space sector. Encourage joint ventures and public funding in private space initiatives to accelerate technological advancements and commercial viability. This recommendation is based on points 1, 2, 3, 4, and 5 in the Conclusions.
3. **Supporting Education and Workforce Development**: Invest in educational programs and training facilities focused on space technology and research. Promote STEM education to build a skilled workforce equipped to meet the demands of the growing space industry. This recommendation is based on points 1, 2, and 4 in the Conclusions.
4. **Encouraging International Collaboration**: Promote cross-border cooperation, particularly with Sweden, to jointly participate in the New Space Economy, proceed with economic steps toward a new space product and service industry, and to meet the capacity requirements of infrastructure, education, and innovation in the field of commercialization and utilization of space. This recommendation is based on points 2, 4, 5, 6, and 7 in the Conclusions.

Appendix

Thematic culmination points from the interviews:

Interviewee	*Theme*	*Related point to consider*	*Applicability to ecosystem elements*
Informant A: ICT Manager	Smart transport and data integration	Exploring IoT and location data for fleet management and asset tracking	1, 5
Informant B: Business Development Director	Integration of business in development projects	Need for engineers with natural sciences background and business understanding	2, 3
Informant C: Leading Specialist	Digital solutions for data management	Increasing importance of data science and GIS in product and service offerings	1, 2, 4
Informant D: CEO	Collaboration in the ecosystem	Learning about new data opportunities and integrating them into workflows	2, 6, 7
Informant E: Program Manager	The need for multi-talented individuals in future skills	Understanding the interplay between systems and the concept of time	1, 2, 7
Informant F: Area Manager	Solving customer challenges with technology	N/A	2, 3
Informant G: CEO	Interest in measuring technology and analytics in space	Potential in hardware and analytics for upstream and satellites	1, 2, 4
Informant H: Energy and Maritime Director	Material management and seafare optimization	Utilizing container tracking and positioning, voyage optimization challenges	2, 5
Informant I: Program Manager, Energy Distribution	Network monitoring and maritime data utilization	Time synchronization, utilization of wireless and satellite for backup, navigation, and vessel use optimization	1, 4

(continued)

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Interviewee	*Theme*	*Related point to consider*	*Applicability to ecosystem elements*
Informant J: Vice President	Data analytics and ecosystem engagement	Advise on active ecosystem establishment and engagement with companies and students	2, 6, 7
Informant K: Research and Development	Real-time information and infrastructure understanding	Application of satellite imagery in infrastructure and maintenance	2, 4
Informant L: ICT Director	Usability of open-source remote sensing data	Challenges in spatial resolution and data frequency	1, 5
Informant M: Project Manager	Utilization of GIS data and software	Contribution of development activities to commercial products	2, 4
Informant N: Vice President	Introduction to space-based data	Interest in ecosystem providing relevant application information	2, 7
Informant O: CCO	Openness to ecosystem cooperation	Interest in more available information and collaborative activities	1, 2, 7
Informant P: Associate Professor	Importance of start-ups and new ideas	Need for critical mass and collaboration among various stakeholders	1, 3, 4, 7
Informant Q: CEO	Facilitating concrete ecosystem activities	Strategies for creating sustainable business flows within the ecosystem	3, 4, 5
Informant R: Lecturer and Researcher	Trends, capabilities, and collaborative projects	Understanding technology trends, mapping capabilities, and analyzing opportunities for collaboration	1, 3, 5
Informant S: CEO	High-resolution imagery and skill development	Need for high-resolution data, machine learning, and data science skills	3, 4, 5

(continued)

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Interviewee	*Theme*	*Related point to consider*	*Applicability to ecosystem elements*
Informant T: Project Controller	Utilization of space-based data and blockchain	Systems development utilizing space-based data, drone inspections, and interest in hackathons	1, 6

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Evolving Dynamics of the Spanish Space Sector: Institutional Influence in the Spanish New Space Economy

Louis Brennan and Natalia Utrero-González

1 Introduction

On October 25, 2023, the private Spanish company PLD Space launched Europe's first fully private and reusable rocket. The launch has put Spain in the exclusive club of less than a dozen countries that can send objects into space and shows the dynamism of the Spanish space sector. PLD Space is not an isolated case; an increasing number of space start-ups and initiatives have recently emerged in Spain to develop cheaper space systems and new commercial opportunities. Although the United States (U.S.) was home to about two-thirds of worldwide space investors in 2019, 12% of the non-U.S. investments are based in Spain after Japan, the UK, Israel, and Canada (De Concini & Toth, 2019). As has happened in these countries, the new entrants have brought about a structural transformation of the Spanish space sector. Consequently, public agencies are

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_6

adapting to the new scenario to reinforce the industry's competitiveness (*Espacio Magazine*, 2015).

Since the mid-seventies, the Spanish space industry has developed, fostered by public initiatives and contracts (Plataforma Aeroespacial Española, 2020) and participation in European Space Agency (ESA) international collaborative projects. Further, as a dual technology, the Spanish Ministry of Defence has also supported the space industry through national projects and international collaborations (Fiott, 2023). This public commitment has been reinforced by the 2019 National Aerospace Security Strategy and the 2021 National Security Strategy, which define Space as a technological and strategic priority. At the same time, a focus on the commercial success of new companies has altered how traditional space companies operate, based on high technological complexity and long development cycles to ensure reliability and performance (Mazzucato & Robinson, 2018), with public administration and governments as main clients.

Despite the increasing interest of private investors and specialised media in the Spanish space sector, academic research has been nearly nonexistent. This chapter contributes in this respect. In particular, it analyses the role of the institutional context in the recent evolution of the Spanish space sector. We analyse the conditions that influence the market structure, the promotion of entrepreneurship, and the emergence of partnering relationships among different stakeholders.

We show that the Spanish market's characteristics and the institutional environment have created a bidirectional relationship between "New Space" and "Old Space". On the one hand, the leading incumbent firms have developed corporate entrepreneurship capabilities over the years (Covin & Slevin, 1991). This has allowed them to identify ways to participate in the "New Space" revolution, developing new technologies, products, and business collaborations. On the other hand, the evolution of new businesses has been influenced by the traditional triad of university-industry-government relationships (Etzkowitz & Leydesdorff, 2000) and the experience and know-how developed by "Old Space" companies. Further, by cooperating with them, new firms gained resources that would otherwise have been difficult to acquire due to small size and limited resources (a similar pattern has been evidenced in the IT sector [Ojala, 2016]).

This chapter explores the conditions giving rise to increasing ventures and start-up "New Space" initiatives in Spain, particularly relationships with incumbent firms to establish mutual influence and symbiosis. In this respect, we begin by introducing the theoretical framework to demonstrate that institutional settings affect established firms and can facilitate the formation of innovative new companies. Next, the methodology adopted is described in some detail, along with the sources and data examined. We then report the analysis results, followed by a discussion of the evidence found. The last section concludes with implications for policy and practitioners, our research's limitations, and future research directions.

2 Theoretical Background

The institutional environment and its impact on industry dynamics and entrepreneurship have received increased attention (Valdez & Richardson, 2013). Research has examined both the influence of formal and informal institutions, as defined by North (1990). Greif (2006, p. 424) claims that different informal institutional norms may require a diverse formal institutional setting to sustain economic growth and entrepreneurship. Accordingly, some interventions may produce little venturing activity, and many created ventures either do not grow or may displace incumbent firms (Colombelli et al., 2016). Similarly, Davis and Williamson (2016) conclude that formal rules to promote entrepreneurship may only meet with success if local conditions are considered. Put differently, the interaction of formal and informal institutions can enhance or inhibit entrepreneurship to exploit new business opportunities (Lamine et al., 2021).

Existing firms can capitalise on new opportunities as well. This ability to identify new approaches is often called corporate entrepreneurship (Teng, 2007). Traditionally, the space sector has been dominated by large companies affiliated with the defence and aerospace industries, closely linked with public agencies, and reliant on government procurement (OECD, 2022). These firms have also enjoyed public R&D support to develop new projects and products. In contrast, "New Space" actors, big and small, brought funding and innovation strategies from other industries with them (OECD, 2023). Although many of the former are concentrated in the upstream sector and most of the latter blossom in the downstream industry, complementarities and synergies may emerge, creating a new ecosystem (Jacobides et al., 2018). This perspective enriches the analysis by considering the complex, coevolving nature of the actors, conditions, and entrepreneurial initiatives in any given entrepreneurial context (Carter & Pezeshkan, 2023).

The role of universities, together with governments and businesses (the "triple helix"), is considered to be an essential driver of knowledge-based economies and societies (Etzkowitz & Leydesdorff, 2000). It implies that it is necessary to have a relevant critical mass of industry to absorb university research outputs and thus foster growth (Youtie & Shapira, 2008). It suggests that technology transfer is a complex and iterative activity involving multiple stakeholders and expanding to the community ("four-helix model") (Rinaldi et al., 2018). New instruments, such as the technology transfer offices, have been developed to foster innovation and economic progress (D'Este & Perkmann, 2011). The interplay between institutions and actors can be even more relevant for entrepreneurship and developing innovative sectors, as is the case of the space industry.

3 Methods

We employ case study methodology to analyse the evolution of the Spanish space sector. Case study relies on a research strategy of multiple data collection methods to study a phenomenon in its real-life context (Yin, 2009). That is, the detailed empirical information collected over a period allows us to analyse the context and processes involved in it. Case study research offers benefits in terms of process and outcome. The case study will help to focus the research within the confines of space and time. Further, the different kinds of data, such as interviews, documents, observations, surveys, and others, allow an in-depth look at the interactions taking place to deliver a comprehensive understanding of the phenomenon analysed, which can also be applied to gain comprehension of other situations (Schoch, 2019). In addition, it is one of the most extensively used strategies of qualitative social research, and its application has been expanded (Priya, 2021).

Although Yin (2018) claims that case studies can help explain diverse phenomena, case studies have been traditionally used for exploratory and descriptive purposes, especially in scarcely researched topics. This makes them suitable for analysing the impact of institutions on the emergence of entrepreneurship in the Spanish space industry and the bidirectional relationships between "New Space" and "Old Space" that have formed a new ecosystem.

3.1 Data

We use multiple sources of secondary data: information from institutional sources (international and national), companies' web pages, and media articles. In addition, we collect data from speeches and round tables with various commercial experts, established firms' and start-ups' executives and government officials at two specialised summits called "New Space España" held in Vigo (Galicia) in 2018 and 2022. The summits' debates and speeches detail the recent industry evolution and dynamics and signal new players in the traditionally government-linked space sector. The participation of incumbent firm representatives shows the interest of "Old Space" companies and allows us to ascertain their strategies towards new technologies and entrants.

To analyse the content of the summits, we follow a four-step process inspired by Lotzkar and Bottorff (2001), who conducted a systematic thematic analysis of videotaped data. While thematic analysis may not be as established as other qualitative approaches like discourse analysis (Brennan & Vecchi, 2023), it proves more suitable when the goal is to identify patterns within the data (Nowell et al., 2017). While it doesn't explore the relationships between language and power as discourse analysis does, thematic analysis is highly effective in summarising critical features of large datasets. This method encourages a well-structured approach to data handling, facilitating the production of a clear and organised final report (King, 2004).

As our research question is to analyse recurrent themes across the data, we consider thematic analysis more appropriate. We proceeded in four steps. First, we reviewed the videotaped summits to identify and describe themes of interest for incumbents and new firms. Second, we reviewed the recordings and notes to determine how and when different themes emerge. Third, we described differences between themes and actors to understand the distinct opinions. Finally, we constructed a detailed theme description, including the observed interactions' conditions, causes or functions, and consequences. The data analysis is completed with information from other secondary sources. Table 2 in the appendix lists the sources used.

4 Findings

In the process of analysing the data, numerous topics emerged. We organised related topics into distinct theme categories. It is important to note that these first categories were provisional, and as new data was scrutinised, we revised the themes. During this stage, we assessed whether additional information genuinely supported the theme and fit into the context of the data collected. Additionally, we examined the coherence and distinctiveness of each theme to establish clear relationships between themes and sub-themes. As a result of the iterative process, five main themes emerged, namely, legacy and opportunity, institutional support and demand, relationships with universities and research centres, investors and financing, and collaboration between different actors.

4.1 *Legacy and Opportunity*

The Spanish space sector boasts a rich historical legacy. The Instituto Nacional de Técnica Aeroespacial (INTA) was founded in 1942, focusing primarily on aeronautical research. From its inception, INTA embraced international collaborations. During the 1960s, diverse cooperation agreements were signed with NASA to establish tracking stations in Spain to support NASA missions. Consequently, in 1963, the National Space Research Commission (Comisión Nacional de Investigación del Espacio, CONIE) was established to engage in space research and foster enduring partnerships with NASA and other international institutions such as the German Max Planck Institute and the French National Space Studies Centre (CNES). In essence, CONIE has been regarded as the inaugural national long-term space strategy. Along with its collaboration with NASA, Spain became a member of the European Space Research Organization (ESRO), the precursor to the current European Space Agency (ESA). These international collaborations enriched the expertise of the Spanish space sector. By 1970, all NASA monitoring stations came under the management of Spanish personnel. In addition, two survey rockets, INTA 255 and INTA 200 (developed in collaboration with Bristol Aerojet LTD), were launched, and the first fully developed Spanish satellite, INTASAT, appeared in 1974. In 1975, Spain was among the members approving the establishment of ESA (Dorado et al., 2002).

The dual nature of the space sector has played a pivotal role in its advancement. The Spanish government's interest in fostering defence-related technological and industrial capabilities, particularly after the dictatorship, was based on the anticipation that the military demand would drive the development of Spain's high-technology industries, particularly in electronics and aerospace (Molas Gallart, 1998). Notably, INTA is affiliated with the Ministry of Defence, leading to occasional convergence between national space and defence plans.

These sustained efforts at both national and multinational levels have yielded noteworthy outcomes for the Spanish space industry. Firstly, there has been a substantial enhancement in scientific knowledge and expertise, enabling scientific institutions and groups to participate in and lead ESA and European research projects actively. The industry has undergone modernisation, giving rise to internationally competitive companies that have absorbed this knowledge and can now develop products and services that contribute to the nation's prosperity in previously unexplored areas. Consequently, professionals in the industry have elevated their training and expertise to the most advanced technical levels (TEDAE, 2019).

Secondly, Spain is a member of significant space organisations, European (EUMETSAT) and international (International COSPAS-SARSAT Programme and COSPAR). These memberships indicate the presence of a substantial critical mass in Spain's space sector that would only have emerged with Spain's ESA participation (Dorado et al., 2002). In this context, the "New Space revolution" is perceived by "Old Space" companies as an opportunity to leverage accumulated expertise and resources to enhance the competitiveness and position of the Spanish space sector in the global market. This involves embracing new ideas while drawing valuable lessons from recent experiences.

4.2 Institutional Support and Demand

Traditional development costs of space technologies were massive and could only be supported by national governments (Bousedra, 2023) and, in many cases, in cooperation with other countries. Therefore, space activities have been shaped by at least two different factors: on the one hand, the type of international relations that the individual countries engage in, for instance, membership in international organisations or cooperation agreements; on the other, the economic, financial, and technological resources available in the economy. In this setting, national security concerns and defence projects have played a determining role in defining state demand. One interesting feature is that this governmental demand, apart from acting as a pull mechanism, has evolved independently of market constraints. For instance, economic considerations, such as cost reductions derived from the introduction of new technologies, were not the main issue in project development (Mowery, 2010) and have not affected the relationships between governments and companies. Hence, the space industry is a complex group of stakeholders, including different governmental ministries (defence, foreign affairs, research and innovation, and education) and the companies that design and produce the systems (Petroni et al., 2009). One common feature of nearly all countries that carry out space activities is establishing a national public agency responsible for managing the sector and its variety of stakeholders and guiding the choices and the development of the national strategy (Cucit et al., 2004). Yet, Spain, despite its active presence in the space sector, did not have a national space agency or a national space strategy (except for the CONIE antecedent explained previously) until very recently.

The establishment of the Technological and Industrial Development Centre (CDTI) within the Ministry of Industry and Energy in 1986 was geared towards enhancing support to leverage technological capabilities in the space sector (and other industries). CDTI granted financial and consulting support. However, coordination with different governing bodies: the Ministry of Science, the Ministry of Defence, and, at the very least, the Ministry of Foreign Affairs was crucial for two reasons. Firstly, as space stakeholders, all these entities are interested in contributing to the national space strategy. Secondly, the sector's key pillars have been national and international programmes. For instance, Hisdesat, the government satellite operator for defence, security, intelligence, and foreign affairs, exerted significant influence (TEDAE, 2019). International collaborations such as ESA programmes, European Union space initiatives, and cooperation with NASA, CNES, or Roscosmos have also played a vital role in the industry's development. Since 2008, CDTI has operated under the Ministry of Science and Technology to improve coordination between scientific and supportive endeavours. One notable outcome of this particular institutional framework is that the state demand for space-related activities in Spain has not been as extensive as observed in other countries and has conditioned (as we will explain below) the development of the "Old Space" sector.

Establishing a national agency to centralise the action of the diverse institutions and formulating a long-term national strategy for Spanish space has been a long demand from industry and business organisations (Plataforma Aeroespacial Española, 2020). In 2019 TEDAE and the Plataforma Aeroespacial Española (Spanish Aerospace Platform) released their own agenda and strategy to signal the need to establish a common and shared long-term industry vision. The Spanish Space Agency was set up in April 2023. The Space Council, launched a year before to define the Agency's duties and objectives, was composed of the Presidential Cabinet, 11 ministries, and the National Intelligence Center, indicating the necessity of a central institution.

Without a single agency, the development of national space plans had not evolved smoothly, depriving the sector of the necessary continuous investment effort. This can explain the discontinuity of some projects (even abandonment because of lack of funds), especially in the seventies and eighties (Dorado et al., 2002).

Since 2018, Spain has been participating in all ESA Space projects (TEDAE, 2019). It forms part of other international consortia, which suggests that institutional demand has allowed Spanish companies to transform from mere equipment suppliers to integrate complete systems and be capable of leading multinational missions.[1] Despite the positive effects of public support, diverse managers from "Old Space" companies opine that the lack of public investment continuity and ambition has hindered industrial development, which has been less rapid than in other countries.

[1] In the European Space Agency's (ESA) map of 26 technological domains, Spain demonstrates technological leadership in 12 of them. Notably, excellence has been achieved in half of these domains (Space System SW, Space System Control, RF Payload, Mission Operation, Ground Data Systems, Thermal, and Formation Flight) since 2010. Additionally, progress is underway in five other technological domains. Equally significant is the fact that in 2010, capabilities in the remaining technological domains, such as propulsion, optics, life support, or automation and robotics, were virtually nonexistent, and considerable progress has been made in all of them.

As elsewhere, the emergence of Spanish "New Space" companies means that the expansion of the space sector no longer depends solely on state-driven demand but is progressively influenced by market demand for space-based services. Conversely, increasing market demand is necessary for the commercial success of these new entrants. Despite these shifting dynamics of public and private sector involvement (Tucker & Alewine, 2023), the market for space-based services is still in its infancy. To fill this void, the Spanish government is designing different initiatives and policies to support the newcomers. For instance, through government calls to develop technological collaborations and public–private partnerships (PPP) on space-based applications. Another outstanding initiative, the Innovative Public Procurement Plan, is related to these PPPs. The plan aims to modernise the public administration to improve public services and, simultaneously, show the market the strength and possibilities of new space-driven products and services.

4.3 Relationships with University and Research Centres

The Spanish university system has experienced a remarkable evolution in the last fifty years. The number of university centres and students has significantly increased in these decades. In addition, the different scientific and research programmes developed by the government have permitted the Spanish scientific community to improve its technological and scientific knowledge, participate in international research networks successfully, and cooperate with industry.

Spain boasts a higher education attainment rate (39.4%), surpassing the European average of 30.5%. However, the distribution of graduates varies significantly across fields of study. Popular areas include business, administration, and law (19%), and education (17%). In contrast, fields such as information and communication technology (3.9%), mathematics and statistics (0.5%), and manufacturing and processing (0.8%) attract fewer graduates (Cedefop, 2016). This shortage may be related to the persistent gender gap in STEM enrolment.

From 2018 to 2020, women overwhelmingly favoured non-STEM fields, with 78% and 72% enrolling in education and health, respectively. Within STEM, Usart et al. (2022) show that the gender disparity is more pronounced, particularly in technology-related studies (13% women compared to 87% men) and engineering (29% women and 71% men).

Public institutions and business organisations are aware of the need to reduce the shortage of qualified workers to meet the challenges of the knowledge economy. Action has been proposed in two interconnected areas. Firstly, there is a call to increase the enrolment of women in technological subjects. Secondly, closer collaboration between universities and businesses is promoted by aligning education programmes more effectively and offering on-the-job traineeships. In addition, many universities have incorporated entrepreneurial activities and formal courses in their academic curricula to encourage entrepreneurship among students.

In this respect, a vibrant network of technological and science parks associated with universities, more than 50 nowadays, has emerged to enhance the connection between universities, businesses, and society. This network has also strengthened the relationships between academia and industry, with many scientific parks serving as incubators for student-generated business proposals.

The relationships between universities and research centres, and industry in the space sector have always been close. Firms like Alen Space or DasPhotonics originated in research groups. However, the shortage of STEM and technological graduates can lead to future industry challenges. As the demand for space-based applications grows, one potential challenge will be commanding the resources and technology for satellite mass production, that is, to manufacture regularly.

Spain has recently committed to addressing this gap by participating in two European projects: the educational ESA project, ESERO, and Women in Aerospace (WIA-Europe). These initiatives encourage science and engineering careers in space and promote female talent and leadership, respectively. Spain's participation in these projects signifies a commitment to foster greater interest and participation in STEM and space-related fields. However, it also reveals a noteworthy delay in joining such initiatives. Granada Science Park, representing ESERO in Spain, was commissioned only in 2017, while ESA educational activities started in The Netherlands as early as 2005. This tardiness underscores the urgency to promote vocations in the space sector.

The Spanish participation in the Copernicus project, the observation component of the European Union's Space programme, has allowed the

Spanish inclusion in the Copernicus Academy, which connects universities, research institutions, business schools, and private and non-profit organisations. The main goal is to facilitate collaborative research and improve educational and training material to empower the next generation of researchers, scientists, and entrepreneurs. Spain has more than 25 universities and research centres collaborating with this initiative. Further, in Madrid and Barcelona, two ESA Business Incubation Centers (BIC) were established in 2015 and 2017, respectively, as part of the ESA BIC Network, which started in 2003 and is currently in nine countries. In November 2023, there are three other active BICs in Leon, Castellón, and Sevilla. It is expected that all these public initiatives will have a positive impact on talent attraction to the space sector.

4.4 Financing

The dual nature of space activities has allowed for diverse sources of financing, both civil and military. In the case of civilian applications, the national budget allocated to space programmes has lacked continuous commitment, as mentioned earlier. Notably, Spain's contribution to ESA nearly doubled in the 2000s, aligning with the decision to develop Earth observation satellites for both civilian and military use—this double effort aimed to enhance the technological capabilities of national companies. The long-term goal was to increase Spain's ESA contribution to its economic weight proportionally. This is particularly crucial as the ESA's industrial policy comprises the geographical fair return (GFR). Under GFR, a country's share in the weighted value of contracts should align with its share of financial contributions. Despite Spain's efforts, the progress made by other members, led by France and Germany, resulted in a financing contribution of approximately 5% in 2018—falling well short of Spain's 7% GDP representation. It wasn't until 2019, with a former astronaut serving as the Minister of Science, that a formal commitment to achieving the 7% contribution 2020–2025 was announced. However, as of 2023, Spain's ESA contribution of €285.7 M remains below the 7% target, lagging behind the contributions of Germany, France, the UK, and Italy with 1046.8 M€, 1000.9 M€, 609.8 M€, and 580.1 M€, respectively. Additionally, in March 2022, as part of the Spanish government's economic recovery efforts post-COVID-19, the Strategic Project for Aerospace Economic Recovery and Transformation (PERTE) was approved. This initiative aims to mobilise nearly €4.5 billion in both public and private funding to boost research, development, and innovation in the aerospace sector. This double investment effort reinforces the consideration of the space sector as a national strategic priority. It also highlights the preponderance of public support despite increasing private venturing activity.

Related to defence projects, the Special Armament Programs (SAPs) have been used to modernise Spanish Armed Forces equipment since the nineties. The HISDESAT satellites project was essential to these SAPs and significantly impacted the space industry. The 2015 Defence Space System Plan highlighted, however, the need for international cooperation to attain future space capabilities (DGAM, 2015). Consequently, Spain has heightened its involvement in European projects related to security and defence, exemplified by its participation in the EUSatCen, located in Madrid. Spain is also engaged in Permanent Structured Cooperation (PESCO) and European Defence Fund (EDF) capability projects, participating in all four ongoing PESCO space projects. In the 2021 and 2022 EDF calls, 19 and 12 Spanish firms and institutes are involved in seven out of eight and three space-related projects, respectively. While Spain may not coordinate any space projects, these investments are expected to enhance the competitiveness of Spain's technological, scientific, and innovation sectors.

The upstream market still requires significant public investments. More than 60% of the turnover in the ground segments comes from government budgets (TEDAE, 2019). On the contrary, the downstream market (focused on satellite applications and services) has a high volume of private business. In this respect, new supportive mechanisms have been implemented to foster the development and expansion of space start-ups. Two key entities under the Ministry of Industry play a crucial role. Firstly, the National Innovation Enterprise (ENISA) extends financial support to small and medium-sized businesses engaged in innovative entrepreneurial projects. Notably, these funds can complement other potential public or private investment sources. On the other hand, the Technological and Industrial Development Centre (CDTI) has expanded its traditional low-interest loan programmes. CDTI now encompasses initiatives such as creating an investment fund to attract venture capital and private investors for new firms and developing co-ownership models to collaborate with business angels and investment funds in their investment decisions. Overall, these initiatives try to inject dynamism into the Spanish market for private ventures and, particularly in the case of space start-ups, have facilitated the involvement of private investors.

4.5 Collaboration Between Different Actors

The Spanish space ecosystem is vibrant and diverse. TEDAE, the business organisation, identifies 26 prominent space companies within the sector, including "New Space" companies like PLD Space and Satlantis. Moreover, Plataforma Aeroespacial Española (Spanish Aerospace Platform) boasts 41 space associates, with 25 classified as SMEs (small and medium enterprises). Some are also considered "New Space" firms, such as Alen, Emxys, Pangea, or Uarx (Table 3 in the appendix lists the leading Spanish space companies).

The number of "Old Space" companies participating in the "New Space" summits has risen, showing increased interest. Further, "Old Space" managers describe themselves as "Proto-New-Space". There are at least two reasons they claim for this identification. Firstly, nowadays, many of them would be described as start-ups. Secondly, as institutional support had not evolved smoothly, they were used to working with tight budgets; therefore, controlling costs and shortening development timeframes were crucial. Further, they have developed the ability to adapt to the circumstances and be aware of potential changes. Accordingly, they are creating new divisions or branches to participate in developing the "New Space" segment and partnering with newcomers and start-ups. In some cases, these investments have turned to shareholdings and participation in the boards of directors.

"New Space" firms are also affected by "Old Space" companies. Some of the founders and CEOs of the new firms have previous experience in "Old Space" firms and have taken advantage of the experience, knowledge, and networking developed previously. In addition, apart from financing, technological relationships with "Old Space" have also been crucial to obtain valuable resources that would have needed much more time otherwise to acquire. Therefore, the evidence suggests that both types of companies show complementarities and that bidirectional relationships have been developed as each group has exerted influence on the other differently. “Old Space” managers acknowledge this influence by recognising strategic and management decision changes. The companies’ profiles in the TEDAE latest yearbooks also admit newcomers’ impact when they present their expertise in COTS (commercial-off-the-shelf) components’ validation or Low Earth Orbit (LEO) satellites. Overall, “Old Space” companies concede recognition to newcomers as market participants and potential competitors, indicating the emergence of a new space ecosystem.

Further, the cost reduction strategy of “New Space” companies has put focus on the verticalisation of production. Again, these partnerships are bidirectional. For example, PLD Space, the rocket launcher company, was awarded one of the Strategic Project for Aerospace Economic Recovery and Transformation Plan (PERTE) projects in June 2023. An advantage presented by PLD is the incorporation of “Old Space” partners (Airbus, Aciturri, and Deimos) to guarantee the quality and supply of components. Another example of New-Old Space technological partnerships is the case of Sateliot, one of the “New Space” start-ups in which Indra (a leading “Old Space” company) holds a significant stake. Sateliot has signed an alliance with Open Cosmos (a “new space” company started by Spanish Engineers but located in the UK) to construct and develop satellites for a constellation project.

One potential explanation for these bidirectional relationships could be that traditional Spanish companies are not as large as their European counterparts. For example, GMV, the European leader in the ground segment of navigation systems (EGNOS and Galileo), is the 6th industrial group in the European space sector, after Airbus, Thales Alenia, Ariane, Leonardo, and OHB. The “Proto-New-Space” self-identification and size structure may have helped them to be flexible enough to adapt to industry changes and cooperate with new entrants. Figure 1 illustrates the main concepts found in the data on which our thematic analysis of the evolution of the space Spanish market, its participants, and the bidirectional relationships among them were built.

5 Discussion

From our data analysis, five different themes have emerged (see Table 1), and the explanatory power of the triple/quadruple helix model is particularly evident. Further, we have identified some circumstances that could have been improved to better align the context to the needs of the space industry.

1. **Legacy and opportunity**. The government has provided the institutional framework, both national and international, for the space sector to be established and developed. However, the government's support has not been remarkably constant. Further, the absence of a central agency has prevented the sector from having a unique strategy and has caused coordination problems. The situation has

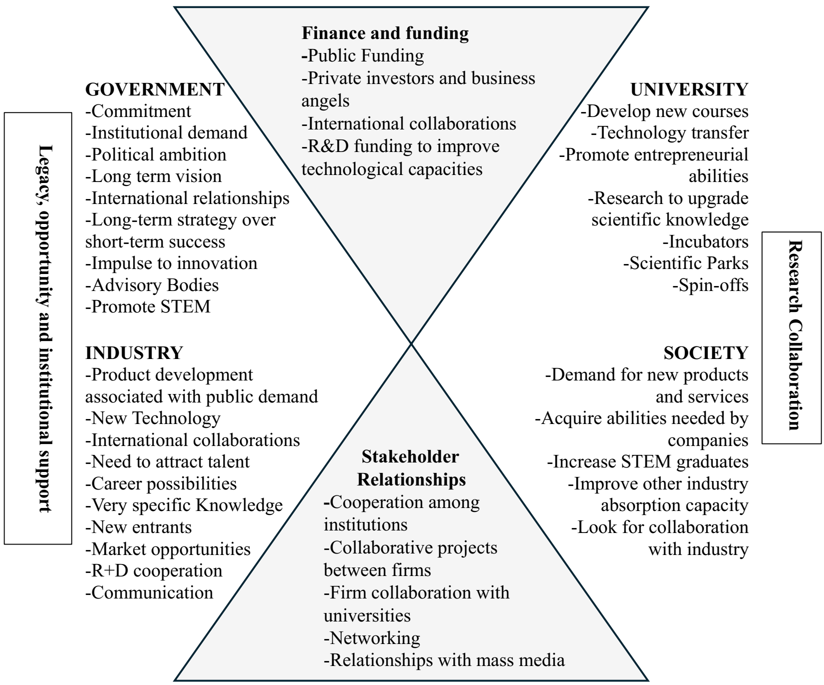

Fig. 1 Summary of main concepts found in the data

Table 1 Themes and the triple/quadruple helix model

Legacy and opportunity	The Spanish space sector has developed over the years, taking advantage of institutional support and market opportunities. The "New Space" firms find a mature industry from which they can learn and partner. The emergence of these new firms is also an opportunity for incumbents to adapt to the new circumstances. A new ecosystem is formed
Institutional support and demand	The government has played a central role in shaping the industry's evolution and promoting new entrants through different activities: international collaboration, R&D industrial strategy, direct financing, and investment in higher education. State demand has boosted incumbent firms, but "New Space" firms need commercial demand to increase to be profitable. The government is also developing initiatives to promote space-based services
Industry relationships with universities and research centres	Investment in higher education has boosted university graduates and Research outcomes. Universities and Research Centres have enjoyed close relationships with the space industry. Recognising the potential demand for STEM and engineering graduates and aiming to strengthen ties with the industry, the government and universities are undertaking various initiatives
Financing	Public finance has been central to industry development. Private capital is funding for new ventures. The government has developed new financial tools to support investors and occasionally become shareholders. The space sector needs to be more transparent to attract finance
Collaboration among different actors	"New" and "Old" companies have exchanged technologies among themselves and also between space and non-space sectors, creating technology synergies. Incumbent firms have been able to exploit their core competencies to explore new opportunities. The space sector must be more transparent to attract talent and private finance

changed recently; coordination among agencies and ministries has been enhanced and will crystallise in the National Space Agency. Newcomers find a solid playground to start operations and develop valuable relationships.

2. **Institutional support and demand**. Government and state demand has allowed the industry to flourish and upgrade its technological expertise. The lack of continuity has, however, caused the industry not to be as prepared as other competitors to increase production since the institutional demand was based on few units. The "New Space" firms are assumed to depend on commercial demand, but that market is still underdeveloped. Therefore, although the

new space ecosystem has reduced the relevance of government demand, it can still complement the commercial demand or even help to create it, as the plans adopted by the Spanish government to promote the development of new services show.

3. **Relationships with universities and research centres**. The research projects developed by the government have enabled a close relationship between the research centres and the space industry. The development of technological parks with its incubator initiatives has also helped to intensify the relationships between firms and the scientific community. It has reinforced the links between the three central actors of regional innovation systems: government, universities, and industry. In addition, entrepreneurial activities, university courses, and consulting have helped disseminate opportunities among students. Despite these efforts, some imbalances should not be overlooked. The shortage of graduates in technological and scientific areas or the low level of women in STEM programmes and industry reveals that public initiatives have not been adequately designed. In addition, the closed perception of the space industry might have acted as a barrier to entry for newcomers. Incorporating Spanish universities into different programmes sponsored by the ESA can resolve this situation by increasing enrolment in technological studies. Moreover, more industry transparency and openness to society could enhance the attraction of new graduates, narrowing the ties between university-research-industry-society.
4. **Financing**. The financial support system has encompassed state demand and institutional aid. The duality of the space industry has profited from the ad-hoc financing associated with the defence special programmes; the pre-financing system designed by the government has permitted the industry to reduce the risks considerably and has acted as a competitive advantage. Further, the state-owned enterprises and agencies designed to boost industry innovation have proven flexible enough to adapt their instruments to the changing ecosystem and its financial needs. Although it is still early to evaluate the effects of the new financial instruments (and it is out of the scope of this chapter), it seems that the government, through its delegated bodies, has understood the necessity to adapt mechanisms and has acted rapidly in reaction to the industry's new demands. In addition, business angels and private investors (national and international) are financing new ventures.

5. **Collaboration between different actors**. The emergence of "New Space" firms has brought about a new space ecosystem where bidirectional relationships between "Old Space" and "New Space" have emerged. Incumbents have incorporated new business models (through subsidiaries or new divisions), showing flexibility to adapt and entrepreneurial corporate culture that has not been so much observed in other European countries (see Lamine et al., 2021). Some of these initiatives are the result of partnering with newcomers. In addition, relationships with universities to discover and support new business ideas and stay closer to potential start-ups are being reinforced. Second, newcomers receive support from incumbents, either as technological or financial partners, to submit proposals for national or international tenders. These business relations rely on complementarities and could be an opportunity to develop the space sector further. However, society is not very conscious of the space potentiality or the multidisciplinarity introduced by "New SpaceNew Space" yet. More transparency by the industry and more fluid communications with universities and business organisations are needed to translate the space possibilities for economic well-being to attract and retain talent and develop a critical mass to absorb the advances and envision the possibilities of space-based markets.

6 Conclusion

In this chapter, we have examined the recent developments of the Spanish space industry and the "New Space" ecosystem in the light of institutional theory. Our interest is to show how institutions and institutional arrangements (or their absence) have shaped the emergence of different types of ventures. We also explore how newcomers have compelled both institutions and incumbents to adapt and how close relationships among market participants have emerged. To achieve this, we applied the three/four-helix theoretical model and conducted a systematic thematic analysis of various secondary information sources.

This chapter contributes to the broader analysis of national and regional space sectors (see, e.g., Brennan and Vecchi [2023], Castelnovo et al. [2023], and Clifton et al. [2011] for the Irish, Italian, and Welsh industries, respectively). We demonstrate the explanatory power of institutional theory and highlight the utility of thematic analysis in identifying patterns and gaining insights into the experiences and perceptions of industry participants. However, like all qualitative studies, ours has its limitations. Thematic analysis, while straightforward, may oversimplify the richness of the data and overlook broader contextual factors. Additionally, exploring aspects such as power dynamics, ideologies, and the relationships between language and meaning among industry participants would have been interesting due to the diverse nature and size of space industry participants.

Nevertheless, our analysis provides novel and valuable findings. The specifics of the Spanish case can be attributed to institutional support and the relationships between the government, universities, industry, and society. The "New Space" revolution has come with the adjustment of traditional players to adapt to the new circumstances and follow the pace of the newcomers. This process has been accompanied by the adaptation of institutional arrangements and support strategies as well. These new supportive measures imply that government demand and public finance are still relevant. Altogether, it suggests that "Old Space" has had the flexibility and speed to *change its skin* to the new circumstances. Further, the data indicates that the evolution and bidirectionality of the relationships among market participants appear crucial for building a competitive space sector. However, the analysis reveals some imbalances underscoring the need to address these to enhance the effectiveness of future political support. This is particularly important for fostering entrepreneurial activity and developing a commercial market for new space-based products and services.

The ongoing activities, events, and initiatives organised by various government bodies, universities, and industry organisations during the writing of this chapter and planned for 2024 reflect the sector's dynamism. They also point to future research opportunities, including exploring power relationships, enhancing contextual understanding, and evaluating recent policy initiatives in response to the evolving landscape.

Appendix

See Tables 2 and 3.

Table 2 Data sources

International Institutional Sources

OECD

Handbook on Measuring the Space Economy. https://doi.org/10.1787/8bfef437-en

Harnessing “New Space” for sustainable growth of the Space Economy. http://www.oecd.org/termsandconditions

European Institutional Sources

European Space Agency

Funding and Budget. https://www.esa.int/About_Us/Business_with_ESA/How_to_do/Industrial_policy_and_geographical_distribution https://www.esa.int/ESA_Multimedia/Images/2023/01/ESA_budget_2023

Educational Projects. https://esero.es

Entrepreneurial Activities. https://www.esa.int/Space_in_Member_States/Spain/Los_viveros_de_empresas_de_la_ESA

European Union

European Space Policy. https://defence-industry-space.ec.europa.eu/eu-space-policy/eu-space-programme_en. https://defence-industry-space.ec.europa.eu/eu-space-policy/eu-space-strategy-security-and-defence_en

Copernicus Academy. https://www.copernicus.eu/es/oportunidades/educacion/academia-copernicus

European Defence Agency. https://eda.europa.eu/what-we-do/capability-development/space

Permanent Structured Cooperation. https://www.pesco.europa.eu/project/defence-of-space-assets-dosa/

European Centre for the Development of Vocational Learning. https://www.cedefop.europa.eu/en/data-insights/spain-mismatch-priority-occupations

Statistical Offices of the EU. https://ec.europa.eu/eurostat/databrowser/view/edat_lfs_9912__custom_9113293/default/table?lang=en

Spanish Institutional Sources

Spanish Government

2015 Space System Plan. https://www.defensa.gob.es/Galerias/dgamdocs/plan-director-sistemas-espaciales.pdf

2019 National Aerospace Defence Strategy. https://www.dsn.gob.es/es/documento/estrategia-seguridad-aeroespacial-nacional-2019

National Space Agency. https://www.aee.gob.es

Strategic Project for Aerospace Economic Recovery and Transformation. https://planderecuperacion.gob.es/como-acceder-a-los-fondos/pertes/perte-aeroespacial

Ministry of Science

Scientific Parks. https://www.ciencia.gob.es/Estrategias-y-Planes/Sistema-de-Informacion-sobre-Ciencia--Tecnologia-e-Innovacion--SICTI-/Red-Espanola-de-Centros-de-I-D-I--RECIDI-.html

(continued)

Table 2 (continued)

Research funding. https://www.ciencia.gob.es/Noticias/2022/Noviembre/El-Ministerio-de-Ciencia-e-Innovacion-aumenta-en-un-20-por-ciento-la-aportacion-de-Espana-a-la-Agencia-Espacial-Europea.html

Ministry of Universities

Data. https://www.universidades.gob.es/catalogo-de-datos/

National Statistical Office

Innovation data. https://www.ine.es/prensa/eie_2022.pdf

National Innovation Enterprise (ENISA)

Successful cases. https://www.enisa.es/es/financia-tu-empresa/casos-de-exito/uarx#

Technological and Industrial Development Centre (CDTI)

https://www.cdti.es/en

Tribunal de Cuentas

Report on Special Armament Programmes. https://www.tcu.es/repositorio/6610226d-f618-45f6-a04d-190de245b9f8/I1155.pdf

Business Organisations

TEDAE

2019 Annual Report. https://tedae.org/es/publicaciones/etiqueta/informe-sectorial

2015 Espacio Magazine. https://tedae.org/es/publicaciones/etiqueta/revista-espacio

Plataforma Aeroespacial Española

Estrategia de investigación, desarrollo e innovación del espacio 2020–2030. https://plataforma-aeroespacial.es/descargas/

Analyst Reports

International Bar Association

Spain—getting ready for the next steps in space exploration. https://www.ibanet.org/spain-getting-ready-for-the-next-steps-in-space-exploration

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New Space España 2018. https://newspaceespana.com/new-space-espana- 2018/

New Space España 2022. https://newspaceespana.com/conferencias-y-mesas-redondas

Media

El País. https://elpais.com

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Spacenews. https://spacenews.com

Infodefensa. https://www.infodefensa.com

Actualidad Aerospacial. https://actualidadaeroespacial.com

Zona Movilidad. https://www.zonamovilidad.es

Escudo Digital. https://www.escudodigital.com

Europa Press. https://www.europapress.es

Other

Individual company and new venture websites

Table 3 Spanish space companies (alphabetical order)

TEDAE space associates	*Members of Plataforma Aeroespacial*	
	Large	*SME*
Aciturri Espacio	Aciturri	Aenium
Aicox. Soluciones	Airbus	Alen
Airbus	Airgroup	Anisopter
Alter	Alestis.Aerospace	Anteral
Arquimea	Alter Technology	Arkadia
Airbus Crisa	Arquimea	CITD
Das Photonics	Crisa	Comet Ing
Deimos	CT ingenieros	Compoxi
GMW	Deimos	Cotesa
GTD	Everis	DHVTech
HisdeSAT	GMV	Emxys
Hispasat	Hisdesat	Fentiss
HV sistemas	Hispasat	Hvsistemas
indra	Indra	Hydra Space
inster	Sener	Indaero
integrasys	Thales	Inventia
inventia.kinetics		MadridSpace
Orbital.Critical Systems		M&Me
PLDSpace		Obuu
Quasar		Pangea
Satlantis		Plata
Sener		PLDSpace
Tecnalia		RGF123
Tecnobit		Satlantis
Telespazio		Uarx
ThalesAleniaSpace		

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Exploring Emerging Business Model Value Chains in New Space

William W. Baber and Arto Ojala

1 Introduction

New Space represents an emerging frontier in the business world. It refers to entrepreneurial activities where risks related to the space business are shared among private business organizations, as opposed to governments and national space agencies (Paikowsky, 2017; Peeters, 2021; Weinzierl, 2018). This shift from national to private also signifies a focus on generating profits rather than achievement of space missions and research objectives.

The burgeoning sector of New Space is characterized by a combination of familiar business activities adapted to new conditions and entirely novel ways of conducting business, necessitating wholly new business models and value chains. Notably, recent developments in New Space have led to various business endeavors, including Low Earth Orbit (LEO) satellites

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_7

for communication, navigation, remote sensing, and more (Prol et al., 2022). In such a dynamic environment, new business models continue to emerge as demand and technology advance (Karami et al., 2022; Ojala, 2016).

A value chain is an important part of a business model (Foss & Saebi, 2017; Magretta, 2002; Osterwalder, 2004). It describes how firms create, capture, and deliver value within the business ecosystem (Al-Debei & Avison, 2010; Osterwalder & Pigneur, 2010). In New Space, value chains are extremely important because a better understanding of different actors, activities, and value creation aids in structuring the industry and identifying business gaps and novel opportunities. This also facilitates different actors within the value chain to improve efficiency, reduce costs, and gain competitive advantages in the market (Osterwalder, 2004).

To gain a comprehensive understanding of this evolving landscape and anticipate future developments in the New Space business, it is crucial to explore the broader business environment and delve into the intricacies of business model value chains in the New Space era. Our aim is to conceptually extend the understanding of this phenomenon by using previous literature, case examples, and expert interviews. The main question we are interested in addressing in this paper is: What are the current and near-future business model value chains of space business in earth orbit? These are explored at the basic level of industries—from basic inputs to final products and services—and in a macro-level aggregated value chain for the whole industry.

2 Literature Review

2.1 Business Models and Value Chains

In academic literature, there are several definitions for the business model concept. These definitions range widely from an explanation of how a business delivers value (Ojala & Baber, 2024), to stories explaining how a business operates (Magretta, 2002) and graphic-textual depictions of business elements and their relationships in an organization (Osterwalder et al., 2005). Business models can focus on single products and services, business units, or complex corporate entities (Wirtz, 2021). A business model can also function as a tool for communication, diagnosis, and innovation (Ojala & Baber, 2024).

Space business is a locus of business model creation, boosted by the connectivity of its ecosystem, new technologies, developing regulation, decreasing costs, and increased demand. Business models develop either through opportunity discovery or creation (Alvarez & Barney, 2007), existing opportunities and models are discovered, novel ones are created. There are also closely related concepts—effectuation and causation—that are presented in the effectuation theory by Sarasvathy (2001, 2008). An important aspect of effectuation that applies to space business is that firms should recognize that they can create new business models in concert with other firms within an ecosystem they inhabit. Such actions firms take in the market can lead to business model innovation (Karami et al., 2022), referring to changes or modifications in a business model (Foss & Saebi, 2017). These innovative processes lead to feedback loops, whether internal or involving other firms, that can be used to make business models more robust and successful (Casadesus-Masanell & Ricart, 2011).

The business model employs the value chain to explain how money is made (Rappa, 2001), thus business model value chains are vital to understand. Further, the value chain is an important part of the business model as it provides a detailed view of creating and delivering value (Porter, 2001). In her work, Magretta (2002) argues that value chains in a business model can be divided into two parts, one involving making things and another encompassing activities related to selling things. In the context of a business model, Osterwalder (2004) includes five primary activities, namely inbound logistics, operation, outbound logistics, marketing & sales, and services as value chain structures. Additional value chains, such as knowledge (Chyi Lee & Yang, 2000), have been proposed in management literature to specify the steps and infrastructure germane to certain business models and activities. In general business model literature, value chains are commonly conceptualized as value creation and delivery networks that describe where the actors are within the value chain and the how the value is delivered among the different actors (see, e.g., Foss & Saebi, 2017; Ojala, 2016; Osterwalder, 2004).

2.2 *Space Business*

Space business refers to a broad range of commercial activities in space and related ground-based services (Baber & Ojala, 2024b). Space operations are seen as reaching from suborbital (up to about 150 km) to LEO

(150 km to 2000 km) to High Earth Orbit (up to and including geosynchronous altitude) and into deep space (beyond geosynchronous, lunar space, and the solar system). In LEO, space business is dominated by commercial activities rather than by government activities although the latter sometimes contract to private businesses. In deep space, business is mainly driven by government contracting for exploration or research.

Space business comprises a complex range of technical products and services that are delivered by a constellation of firms that contribute to value creation. There are few vertically integrated players that dominate their market such as Boeing or SpaceX. Thus firms are commonly interdependent of complex and dense networks that form a business ecosystem (Baber & Ojala, 2024a). Under such conditions, feedback loops may emerge that strengthen or weaken the ecosystem (Baber & Yao, 2022; Fasnacht, 2020). These ecosystems serve as locations for innovation, particularly where they are open and highly interconnected (Fasnacht, 2020).

New Space refers to the recent trend of private businesses sharing risk through tools such as lending and equity investment (Paikowsky, 2017; Peeters, 2021; Weinzierl, 2018). In this model, risk is borne jointly among private business organizations instead of national space agencies shouldering most of the burden. Additionally, the emphasis in New Space is on generating profits rather than solely achieving the successful completion of a space mission. Finally, the focus in New Space is on commercial services rather than exploration and research.

In the context of space business, value chains encompass the enhancement value as various resources, products, and services pass through customers and partners as they culminate in tangible benefits, such as revenue, and intangible benefits, such as brand, relationships, and intellectual property. The complexity of space technologies and services, as well as the need for novel engineering and packages of solutions, means that constellations of value creating and sharing organizations may cooperate to achieve final results.

3 Discussion

In this section, we consider the value chains of the newly developing space business. In previous decades, the primary value chain of the space industry involved the design and construction of hardware such as rockets, satellites, and probes. The initiators of projects were national space agencies and leading space institutes while the funders were national governments. A parallel hardware-oriented value chain formed in the telecoms industry with regard to communications satellites. In addition to these chains of tangible value, there were intangible value chains that built up prestige and scientific knowledge. While these value chains continue to exist, more recent developments have brought about changes to those previous value chains as well as distinct new value chains. The seven value chains discussed below were developed conceptualizing real-life case examples, interviews with 13 business and academic experts working in the industry, and emerging literature on space business. They are linked by their salience to the contemporary realities of the business of New Space. These seven are not proposed as comprehensive, they are however at the forefront of the interest and thinking of the expert interviews conducted for this study. We then consider an eighth value chain for the overall space business industry. Thereafter we discuss opportunities in those value chains, emerging business models, and feedback loops of importance to the space business.

3.1 Value Chains in Space Business

3.1.1 Data Value Chain

The data value chain relies on the generation, transfer, refining, and organizing of data (Fig. 1). Data are the resource that is transformed in various steps from abstract digital form to polished user products. The generation and delivery of data rely on payloads that can be made of technical sensor packages and launch of those packages on a satellite body called a bus. The value chain of that hardware and related services is dealt with later.

The data value chain starts with goals and technical procedures set on Earth. These are issued as commands to satellites which execute them and thereby generate data. The resulting data are sent via ground stations to various kinds of customers. The customers repackage, refine, analyze, and interpret the data converting it into organized information and higher order knowledge. These steps may occur across multiple firms. Final users may include retail users, policymakers, and various kinds of firms. The value chain enables various business models that include part or all of the chain in one or more firms.

As an example, we can follow the data value chain through a firm such as ICEYE (https://www.iceye.com) a space data services company.

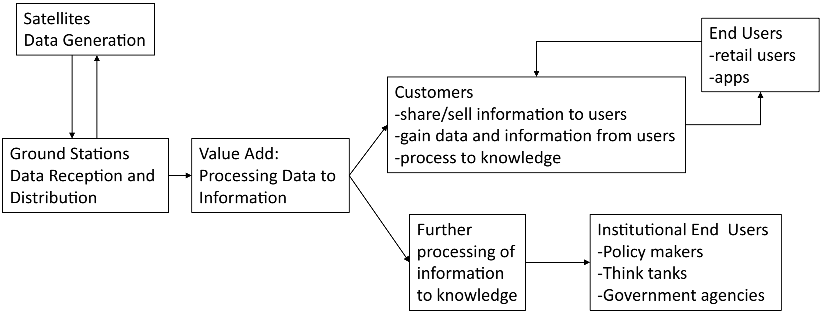

Fig. 1 Data value chain

ICEYE designs, builds, and controls a fleet of earth observation satellites while coordinating launch services with rocket firms and data services with other partners. In ICEYE, data are generated based on the commands issued by ICEYE, those data are processed by ICEYE to create information in various digital formats from maps to analyze of topographical changes. These data products are delivered to a range of paying customers, for example BAE Systems (https://www.iceye.com/blog/utilizing-sar-in-multi-sensor-data-collection). Customers and partners may further process and repackage the data for their own use or into products for sale, such as in the case with ICEYE and Windward AI (https://www.iceye.com/blog/iceye-and-windward-maritime-domain-awareness) or New Light Technologies. These products may also be delivered free of charge as freemium content to firms or governmental organizations making policy and strategic decisions.

3.1.2 Hardware Value Chain

The hardware value chain relates to the equipment needed for commercial exploitation of space (Fig. 2). As such, this value chain is similar to conventional value chains in which value is added successively through manufacturing and assembly after which much of the value is paid for the customers of the equipment while other pieces as capital equipment to generate more value.

The value chain starts with steel, titanium, rocket fuel, and similar basic materials. To these are added various kinds of processing, design, and many sub-assemblies. Services and sub-assemblies, from rocket nozzles to chipsets, arrive typically from smaller firms or business units of larger firms

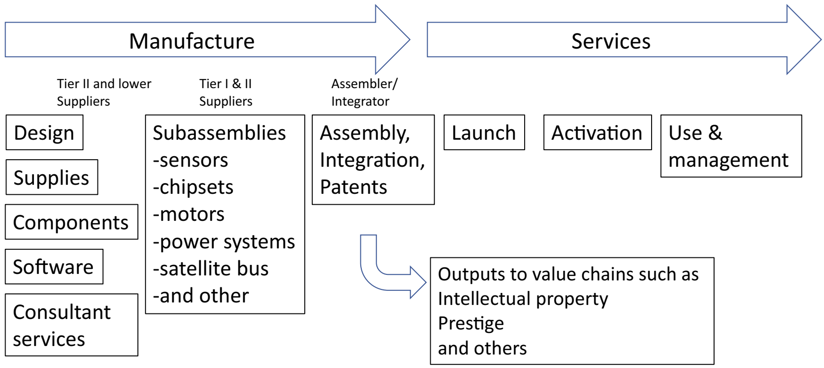

Fig. 2 Hardware value chain

until they are assembled by established firms such as Boeing and Airbus or newcomers such as Blue Origin or Space X. Satellites start similarly with basic materials, sub-assemblies, and services, with an increasing number of builders arriving to challenge major established firms. Generally, the hardware arrives with required software which the recipient firm may add to or revise. The final services include brokering of launches and joint payloads, launch, telemetry, and placement in orbit. Without these final services, the value chain cannot culminate. Thus a failed launch dampens all the value chains of New Space due to increased insurance costs and decreased equipment availability. Use and management is where the hardware value chain overlaps with the data value chain as physical systems are managed to generate and transmit data.

As an example, we can follow the hardware value chain through firms such as Advanced Structural Technologies, IHI, and Boeing that make titanium rocket engine parts to rocket assemblers such as Rocket Lab, CALT, and others. Modern rockets, especially reusable ones, also require complex electronic systems for guidance and control as well as onboard computing. Electronic systems are developed, for example, by rocket makers such as Astrobotic for their own systems as well as by specialist firms for rocket builders. Satellites range from tiny 1U (10 × 10x10cm) to 12U structures (12 times the dimensions of 1U), traditional large satellites that weigh several tons. This value chain finishes with delivery of a satellite to orbit and handover of control to a team or firm that operates it.

3.1.3 Intellectual Property (IP) Value Chain

The value chain of IP in New Space is built on the development of innovative equipment, code, engineering solutions, as well as basic science discoveries (Fig. 3). Two main kinds of actors, firms that make equipment and institutes that conduct research, generate IP which appear as discrete sets of knowledge and solutions that can be bought and sold similar to products for various purposes. Both kinds of actors keep the IP in order to accomplish missions and contracts as well as to patent it. Research institutes also generate new basic knowledge which they publish thus they are seen as fundamental contributor to the value chain (Lipic & Nikitas, 2020). The published research results may eventually be used to create more valuable IP. The value chain is tied to New Space through data collection that result from launched and ground-based systems. The IP value chain is only similar to conventional value chains in that knowledge and research results are upgraded in value as they move through various organizations until the value is realized by a customer.

In the value chain modeled in Fig. 3, data form the raw resource from which IP ultimately is fashioned. Data from institutes first lead to pure research output and knowledge creation which are generated mainly by satellites and processed by organizations such as universities and research institutes. These may be breakthroughs or incremental results that require many years to become IP. Pure research usually leads to

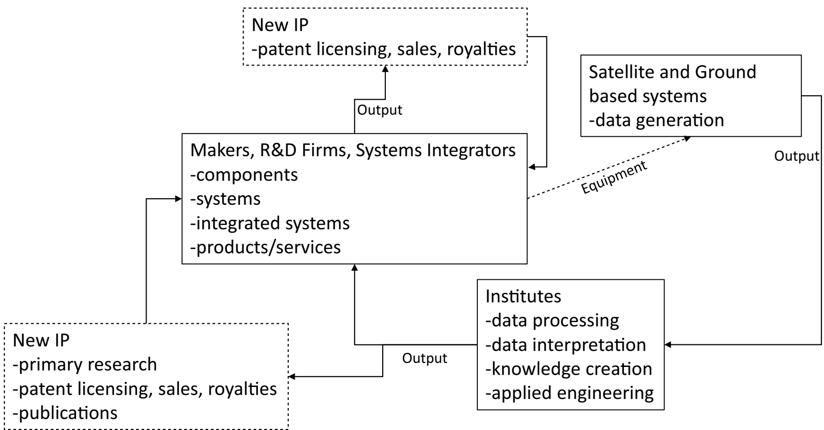

Fig. 3 IP value chain

publications which make no direct profit to the institution. These research results however are transformed later, often by equipment makers through processes of applied research and engineering, to become value creating assets such as equipment or patents which can be sold, licensed, or subject to royalties. Thus, the knowledge created by primary research feeds the IP value chain as a raw resource in need of refining.

An example of the value chain described above can be found in the development by Space Dynamics Laboratory at University of Utah of patents around atomic clocks which are necessary for coordinating space-based assets and communications (Space Dynamics Laboratory, 2020). The basic research behind the patent has been developed at numerous universities in previous decades after which the patent holder conducted applied engineering research to create a product with applications in satellites. A similar example is found in the satellite detumbler which was patented by Airbus in 2023 based on the reaction to the Earth's magnetic field. (Garcia, 2023). The invention was developed with the National Centre for Space Studies and may find buyers even among small satellite makers.

3.1.4 Prestige Value Chain

Since the first days of space research and exploitation, prestige, alongside security, has been a powerful though intangible motivation for investment and action (Cross, 2019). This section examines the building up of prestige, broadly the positive feelings of observers, rather than reputation which may be positive or negative, through its own value chain. In the model of the legacy space industry, prestige belonged to and was sought by the two leading countries, USSR and USA, and their lead space agencies (Curtis, 2018; Gurtuna, 2013; Rementeria, 2022). Other countries, such as Brazil, followed similar motivations as they entered space activities (Nakahodo, 2021). While prestige is still sought on the national level, it has more recently also been sought and captured by private businesses entering space exploration or commercial development (Curtis, 2018).

The Prestige value chain graphic, Fig. 4, tracks the creation and capture of prestige by nations and private firms. The space race of the 1950s–1970s involved only two countries and their national space agencies. Despite competition among firms and institutions within those countries, achievements, mainly creation of new knowledge about the cosmos and Earth as well as attention grabbing firsts, mainly served to boost intangible perceptions about though lead nations. In the New Space model,

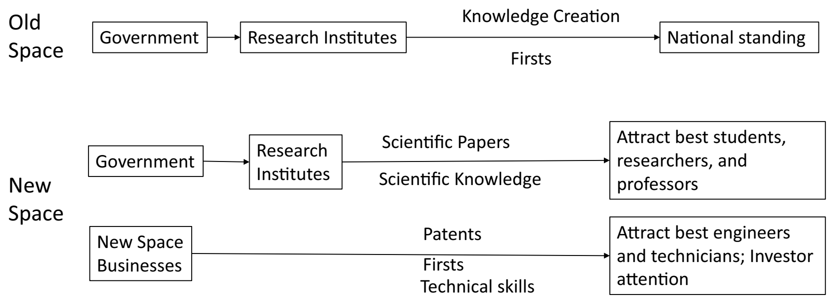

Fig. 4 Prestige value chain

however, prestige serves additional purposes, attracting talent as well as the attention of investors. In the New Space era, the capture of prestige takes two different paths. Governments support research institutes which generate scientific publications and knowledge which helps them attract the best students, researchers, and professors. This is the case in emerging space countries such as Oman, Israel, and India, as well as the USA. Meanwhile private firms also build prestige, mainly through firsts and technical ability, but also through patents. Their prestige helps draw talent into the company and investment whether from funds and wealthy individuals or from retail buyers of stock market shares.

An example of the prestige value chain can be found with Blue Origin, a firm noted for filing space-related patents (Haney, 2020). One reason for Blue Origin to file patents is to announce its technical success and build its prestige, another is to create revenue from patent licensing or sale. The prestige, however, may help to attract leading technologists to the firm (Palomeras & Melero, 2010).

3.1.5 Mission Planning Value Chain

From the start of the space age, mission planning has included a vital set of processes and practices to ensure safety and success. Generally, these practices deal with orbital insertion, telemetry, and control of a satellite but can also include design of the mission from sensors and equipment to movements and disposal at end of life. In the case of the legacy space business launches of science, defense, and communications missions, mission planning resided largely in national space agencies. In New Space, mission planning is a service which may be handled by launch firms or specialized

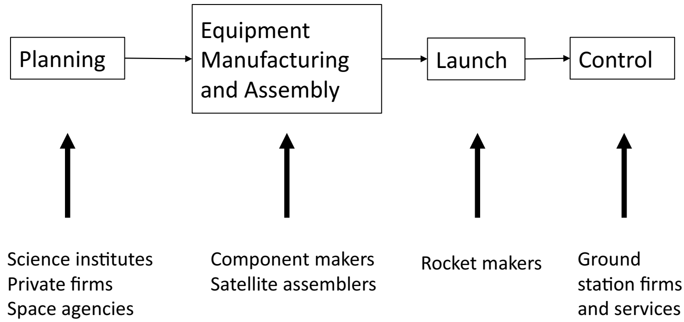

Fig. 5 Mission planning value chain

service providers. Overall, the value chain extends from service designers, whether private firms or scientific research institutes, through to ground station controllers (Fig. 5).

The value chain of mission planning conventionally begins with the creation of goals and proceeds to selection and design of equipment. Specialized equipment must then be created. Meanwhile, New Space relies increasingly on satellites that can be built in advance and used with little or no customization. This means that planning and equipment selection or design can be concurrent. The next step in the value chain is launch, in which value is created by placing the equipment in orbit. Launch and orbit insertion, as well as control thereafter, require the services of ground station operators. Mission planning may include other specifics such as return of reusable equipment. The mission planning value chain of New Space either concludes at this point with value realized or with the passage of satellites to mundane daily control. For commercial LEO payloads, planning may start only a few months before launch whereas in the case of deep space scientific missions, mission planning may commence many years prior to launch and continue for many years afterward involving complex maneuvers around planets.

An example of New Space mission planning begins with, for example, Advanced Space, which specializes in mission planning. The customers of Advanced Space include NASA. After planning certain elements of NASA's CAPSTONE mission, Rocket Lab launched the probe, and operational control returned to Advanced Space. Other firms may use their own systems or complete the mission planning work using services such as Microsoft's Azure or Amazon's AWS. Currently, the range of firms and their offerings in New Space means that any combination of services and firms is possibly including a single vertically integrated firm doing it all.

3.1.6 Tourism Value Chain

The value chain of space tourism starts like conventional tourism with multiple origination points such as the acquisition of tourists, preparation of conveyance, and design of experiences (Fig. 6). Unlike Earth-based tourism, however, space has no destinations other than the International Space Station, the target of a few visits so far. Thus space tourism remains for the moment, experience based. It appears to be technically and financially feasible for relatively low-cost habitations, inflatable ones, for example, to be constructed; however, it is not clear that these would attract visitors. Similar to some examples of experience or adventure tourism, significant training would be part of the value chain.

Like the mission planning value chain, the space tourism value chain starts with mission planning and experience design. This step is an analog to conventional Earth-based tourism in which travel packages are designed and planned. Thereafter marketing specialists and firms acquire the tourists in advance. Because space tourism is relatively expensive, the pool of prospective customers is small. Rigorous physical demands make the pool even smaller as health requirements must be met. At the same time as customer acquisition, specialized equipment may necessarily be designed and built. After confirmation of customers, training is necessary in order for customers to safely operate equipment and react to situations as they arise, including insurance of passengers. Further, evaluation and improvement of health and fitness are likely services to be required.

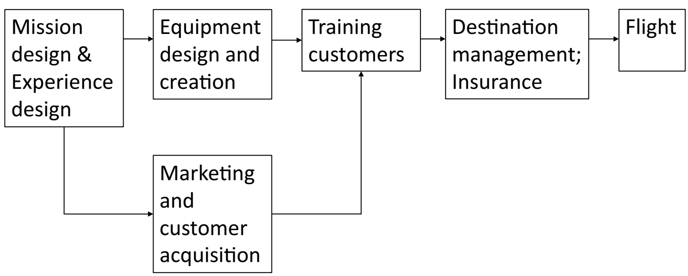

Fig. 6 Tourism value chain

The value chain culminates in the flight and return of the travelers and post-flight health evaluation. Thus the tourism value chain seems likely to add activities before flight, such as pre-flight experience and evaluation, as well as to extend into the space after the flight with services such as documentation and luxury recovery experiences.

In the case of the first space tourist, Dennis Tito, tourism design and planning, was done by Space Adventures, Ltd. while training was completed by NASA and Roscosmos. Blue Origin by contrast is vertically integrated regarding space tourism. The firm takes in interested tourists, trains them at a site they operate, and launches them into space. In another example, Axiom Space takes in-flight customers, trains them for scientific work aboard the International Space Station in conjunction with NASA at NASA facilities, and launches the participants with SpaceX.

3.1.7 In-Orbit-Servicing Value Chain

Space services and the related value chain are an emerging part of the New Space business-scape. The roots of this business area lie in the repairs made to the Hubble Space Telescope in 1993. Since then servicing of satellites and instruments in flight has remained rare and has been largely limited to unique high-value systems epitomized by the Hubble. Currently, tests have been made or are planned to repair, refuel, de-orbit, or park systems in space. Removal of space debris is an area of interest due to the risks of damage to orbiting assets.

Some service needs of satellites can be seen in advance, for example refueling and de-orbiting. A satellite's lifespan is determined in part by its remaining fuel, the last of which is kept for the purpose of de-orbiting or movement to parking orbit where the system can be abandoned. As service missions become cheaper due to decreasing launch costs and automation, reaction to unforeseen issues and even scheduled repairs are poised to become feasible. The value chain begins with the need of the space-based system (Fig. 7), whether foreseen and planned as part of the system's lifecycle or emergent due to debris strike, equipment failure, excessive fuel consumption, sabotage, hijacking, or other reasons. New missions and payloads for service vehicles may require planning in the next step of the value chain. An additional planning step may be needed to link or coordinate the abilities of various firms analogous to managing complex earthbound itineraries. On the other hand, highly automated systems with built in fixtures for grappling and connecting with satellites would minimize or obviate these steps. The next link in the value chain

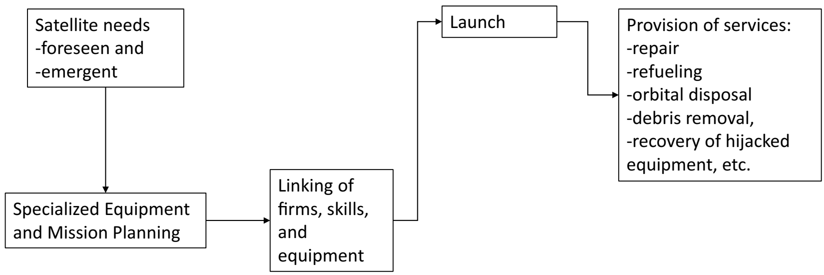

Fig. 7 Space services value chain

is the launch to orbit without which the final value cannot be realized. In space, the final value is realized for customers built on the value creation added and shared in previous steps. Because these kinds of services are not regularly in place, no examples can be offered other than hypotheticals. Only one high profile satellite, the Hubble Space Telescope, has received irregular service visits. In the future however, service units may be pre-positioned to deliver fuel, to de-orbit satellites, or to replace standard sensor or communication modules. These services will mostly likely first develop for larger and more expensive satellites in mid-earth and high-earth orbits rather than for the less expensive fleets of micro and nano satellites typically found in LEO.

3.1.8 Aggregated Value Chain

In summary of value chains in space business, we present the view in Fig. 8. This graphic aggregates the value chains showing approximate value constellations, described as relationships among firms that contribute toward value creation and realization (Normann & Ramirez, 1993), of value creating entities. The number of participants in the value constellation is potentially large, though some firms are currently partly vertically integrated. The aggregate value chain starts with raw inputs from steel to data which feed the creators and deliverers of final products and services who present these to customers. Industrial customers may also present variations of the services and products to retail users initially or as follow-up services.

The aggregated value chain depicts a conventional progression from simple materials, whether raw data from sensors or titanium used in a satellite bus, to creation of final packages of products and services.

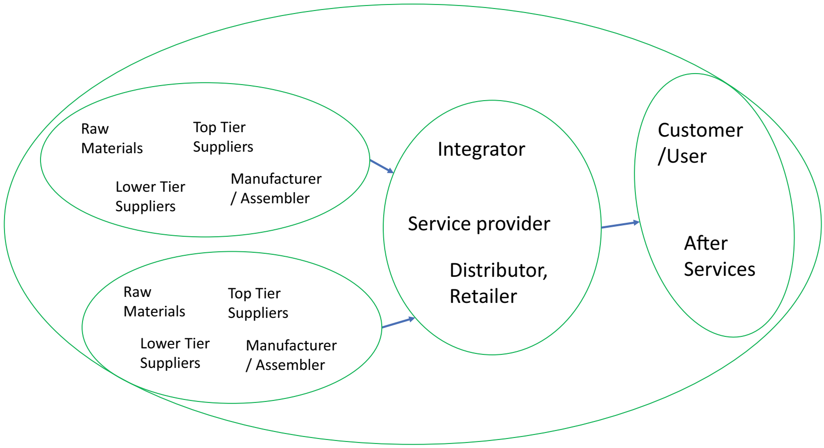

Fig. 8 Aggregated value chain

These upstream processes result in the products and services delivered to firms that undertake the focal activities of New Space and deliver outputs and services downstream (Garzaniti et al., 2021; Prol et al., 2022) to customers. The aggregated value chain may, for example, flow from data that feeds space research, which leads to engineering applications which combine with software to form function launch systems, satellites, and grounds stations which in turn provide data that can be sold raw, processed, or on demand. These data flows may in turn lead to new hardware systems. A concrete example is the NOAA data that fueled developments of Telstar satellites built by SSL which then created data and revenue flows allowing improved satellites. Telstar 19 V was launched by a SpaceX Falcon 9 rocket built of various components made in house and purchased from suppliers. The launch system as well as the satellite includes software as do the ground stations which in turn were built of assembled components and systems by firms such as General Dynamics. While these groups are separated by their activities and position in the flow of value creation, the entire system works together to create, refine, and realize value.

3.2 Apparent Value Chain Opportunities

Business opportunities are based on discovery or creation of opportunities and creation or re-assembly of products, services, and value creation partners to better meet current needs (Alvarez & Barney, 2007). Opportunities potentially can be discovered or created at all points in a value chain and can be filled by new businesses, services, and products. Because the space-related regulation and technology are evolving quickly, there are potentially numerous opportunities that will emerge in the near future. Considering the value chains described above, some gaps in services and products are readily identifiable while others will remain obscure except to visionary leaders.

Regarding creation and delivery of space-based data and services, there remains unknown but emerging demand for novel services. Thus firms can develop business activities driven by demand of customers as well as retail or institutional end users. On Fig. 1, delivery to end users and institutional users currently depends mainly on cellular and Internet infrastructure, even in non-urban parts of developed countries. The launch in late 2023 of direct-to-cell satellites by SpaceX is evidence of interest in this gap. Asset tracking remains largely in the realm of business-to-business services, but could soon devolve to retail customers for tracking their own property, pets, and belongings. Globally, watchdog organizations and government enforcement agencies may become more common business-to-government customers as cost decreases allow faster and more precise monitoring of illegal traffickers operating on seas and highways.

At the start of the data value chain, ground stations direct commands spaceward and receive data from satellites which they redirect to various customers. Location can be important to these ground stations. Due to national regulations regarding data storage, data location, and security, countries may insist on locations within their borders. In order to have frequent contact with a satellite or fleet, they may be placed in polar regions such as the Antarctic continent or even on rigs and barges in international Arctic waters. Emerging Artificial Intelligence tools are speeding the processing of data while adding more value with less cost thereby making it possible for firms to offer specialized niche tools or outputs.

Opportunities in the hardware chain include, above all, lower cost launch services which would allow more entrants to satellite ownership and operation which in turn would increase demand for launches.

Numerous firms are attempting to copy or improve on the reusable rocket success of SpaceX and are likely to achieve technological success in the near future. Other approaches include catapults, e.g., SpinLaunch and even artillery-style guns, both of which are potentially cheaper and less polluting than current rocketry. Another opportunity lies in creating and delivering cost effective and powerful low pollution fuels, for example based on methane, and compatible hardware, such as that being developed by JAXA and Mitsubishi Heavy Industries or in use at SpaceX. Advances in satellites, especially constellation types, onboard processing, and space-based networks seem likely to drive new value chain developments (Kodheli et al., 2021). Further opportunities will constantly arise in the inputs at the beginning of the value chain and onward as technologies around electronics, power supply, and materials improve.

Firms that produce or support production of IP, for example in the form of patents, brands, and novel solutions, will inevitably find openings to deploy their abilities and gain revenues—the space business thrives on new technologies and systems. In addition to accepting new technologies, this value chain in particular can be exploited by firms able to integrate new IP with existing systems. Integrators, central to the value chains as depicted in Fig. 8, are able to bring technologies together to create solutions that are usable by more customers and end users.

The value chains of prestige, mission planning, tourism, and space services are considered briefly next. The prestige value chain can be enhanced by firms that aid in building prestige through patent filing, patent law, public relations, and strategic identification of targetable firsts. The mission planning value chain has gaps for novel or competitor services in each part of the chain. Ride-sharing and payload coordination services have recently grown and further integrated or end-to-end services that link planning to operation may be in demand. Openings in the tourism value chain are particularly under scrutiny currently as this industry appears to be on course to develop quickly. Above all, customer acquisition is important in tourism. The time periods before and after tourist flights could become fertile grounds for services related to preparation, physical and mental well-being, documentation of the experience, and packaging of pre- and post-flight luxury experiences. Space services are currently limited mainly to remote fleet management. As launch costs decrease and key related technologies improve, some services could become regular. These might include refueling, repair, removal from orbit, recovery of control after hacking or a system failure, and similar services.

3.3 Emerging Business Models in Space Business

Some novel business models are under development or already available in limited fashion. These include:

Space cleanup

LEO is increasingly cluttered with dangerous debris. Currently, no business model and related value chains exists that would pay for cleanup. Funding however is likely to come from governments, which already fund this kind of technology development, and or from insurance companies seeking to minimize risk.

Tracking of mobile assets

Various kinds of objects and assets are in motion on the Earth that cannot easily be tracked. Broadly, GPS and similar systems allow tracking of equipment under two preconditions: that there is a transponder and that it is working. Thus illicit activities are easily maintained by removing or switching off transponders on ships, containers, and other assets. One application is anti-smuggling services through combinations of data, especially if interpreted automatically by AI, that could track ships of various sorts and possibly other smaller assets such as vehicles and containers in real time.

Detecting military assets and movements

Real-time tracking and identification of mobile and fixed military equipment, troops, and infrastructure have come to attention especially since the Russian invasion of Ukraine. Quickly arriving images and interpretation of those images have become staples of daily analysis and decision-making.

Planning and assessment of risks and disaster impacts

Business model value chains around planning and assessment of risks and disaster impacts are already in place though developing rapidly. Older models relied on requesting time on defense satellites and overflights to generate imagery. Recently, this model is substituting those data gathering methods with LEO observation satellites which require less advanced planning, less or no maneuvering, and which generate more data faster. The higher flow of data in turn necessitates improving analysis tools but increases the applications and value of the processed data. Tracking services already include dryness, weather, wind, vegetation, and wildfire fuel volumes for applications in agriculture, weather forecasting, insurance risk forecasting, as well as disaster prevention and mitigation.

Systems to replace or supplement GPS/GLONASS signals

Geolocation-based satellite signals are already a high-value service. However, these systems can be jammed locally, and in increasingly large areas, by terrorists or uncooperative governments, as well as for defense against weapons enabled with these navigation aids. Approaches such as space-based laser communication or identification of routes and locations using visual or LIDAR image databases of physical topography and infrastructure would enable supplementary or substitute data for guidance despite jamming of other kinds of signals.

Cybersecurity for space-based assets and space-ground communications

Various existing and emerging software technologies and suites of services could boost reliability of space-based data delivery and prevent hijacking of hardware. As this has become the norm on personal devices, it is likely to become increasingly common on space-based systems.

Pre-positioned orbital supplies

Positioning objects in orbit remains expensive but will become less so in the near and midterm future. While positioning such supplies is a business activity of its own, it would allow more complex services to be created and delivered as discussed above. The variety of things that might be pre-positioned include emergency human habitats, emergency supplies, fuel, rescue systems, orbital junkyards composed of existing dead satellites to be recycled, automated dispensers of parts, robotic tugs, and more.

Shared economy in space

The International Space Station allows commercial experiments to be placed and conducted in space, in effect a shared-economy activity. Such activities could increase with so-called manufacturing hotels in which processing, prototyping, manufacturing, and experimentation could occur. These hotels might include human attendees or be fully automated. Human habitats and hotels or health clinics for special treatments might also exploit shared spaces, though luxury space experiences seem unrealistic for the foreseeable future.

3.4 Key Feedback Loops

Feedback loops are found in value chains when one element in a system inputs to a second element which then increases the strength of the first which therefore increases the input and output of the second. Negative feedback loops, decreasing output loops, are also possible. The first chapter of this book describes feedback loops in the current space business. Business actors may be able to adjust feedback loops to rapidly increase or decrease demand for a service, consumption of products, or ability of a technology to perform. Even if they cannot impact a feedback loop, firms may be able to identify and benefit from these features of value chains.

Key feedback loops to consider for exploitation in space business value chains include:

- Demand for data due to political and climate risk which increases launches which in turn decreases cost of data generation;
- Increases in data generation with decreased cost may raise demand for data services, i.e., just in time data, asset tracking, awareness as a service, and so on;
- Development of advanced algorithms and AI that can automate the structuring of data and compiling of reports may cut cost while increasing quality the combination of which may fuel demand for data services;

- Space debris, a negative feedback loop, may get out of hand and shut down certain kinds of orbits while requiring new launches and new technologies to cope;
- Increased hacking of equipment and data, a negative feedback loop, will increase all costs due to replaced equipment, increased insurance, and requirement for new technologies and cybersecurity services.

Other feedback loops will likely emerge that allow entrepreneurs and established business organizations to discover or create new products and services.

4 Conclusions

In this chapter, we demonstrated eight different business model value chains in New Space business, business opportunities within these value chains, and provided insights into totally new types of business model value chains emerging in the space business. Based on our knowledge, this is among the first studies revealing and explaining business model value chains in New Space business.

The value chains investigated in this study include seven internal to the space business and one general value chain for the space business that aggregates the other seven to provide an overall business model and value chain logic of space business in current times. Of these seven value chains, previous studies have considered the value chains of data, services, hardware, and tourism. To our knowledge however, none of those has been investigated in the context of space business. Moreover, the value chains of IP, prestige, and mission planning have not been considered in academic literature at all. Additionally, this study has considered feedback loops found within the value chains of the space business.

Based on our conceptualizations related to the value chains, further studies are needed to refine and empirically validate the chains. We believe that qualitative case studies work best to get more detailed insights about activities, actors, and processes within value chains. Thereafter, quantitative studies can be used to validate the refined value chains.

This study includes certain managerial implications. Above all, managers should consider the key value chains and investigate how they may claim positions in them and exploit feedback loops to their advantage. Where gaps may appear, executives should handle these as opportunities for discovering or inventing business model innovations.

The value chains of space business models wind through the space business ecosystem offering countless potential interactions to create and realize value.

The authors expect the space business to continue rapid development regarding numbers of participants, new technologies, and new combinations of services and technologies. We hope the readers of this study will expand their businesses and research as they investigate all forms of space business.

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National Regulation of Satellite Ground Stations: A Global Comparison

Tommi Rasila and Arto Ojala

1 Introduction

Satellites and space activities are extensively regulated on both international and national levels, and this is well justified (Spencer, 2010). Satellites operate beyond national boundaries, potentially impacting any location on the planet when issues arise. In contrast, satellite ground stations have encountered comparatively limited regulation. Unlike space objects, they necessitate less international coordination as ground stations remain stationary, primarily affecting radio traffic within neighboring countries.

Nevertheless, satellite ground stations hold a crucial role within the space ecosystem (Elbert, 2008; Prol et al., 2022). Without them the satellites and all the data gathered with their state-of-the art sensors and

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_8

cameras would be unusable. Satellites rely on commands from the ground to maintain their orbital positions and carry out their intended functions. Moreover, the data they gather often requires transmission back to the Earth's surface for processing and application. Consequently, satellite owners and operators require access to one, or ideally multiple, strategically located ground stations worldwide, tailored to accommodate the satellite's orbit and specific characteristics (see, e.g., Schmidt, 2011).

Although many countries have regulations associated with ground stations, either directly or indirectly, only a handful have specific laws dedicated to governing their ownership and operation. Conversely, several countries lack any distinct regulations, with global regulations primarily targeting satellites, consequently exerting an indirect influence on ground stations resulting in an uneven regulatory landscape, posing challenges for competition and offering opportunities to exploit regulatory gaps.

Based on the aforementioned facts, this study primarily focuses on examining the legal framework and regulations governing satellite ground stations. Our objective is to assess and analyze the regulatory landscape surrounding satellite ground stations across various countries worldwide. Consequently, the study aims address the following questions:

1. What types of regulations govern ground station operations globally?
2. How do ground station regulations enable ground station providers to operate in different countries?
3. Is there a necessity for international regulation or harmonization of regulations?

The data collection for this study was conducted using an open-ended qualitative email questionnaire (Dahlin, 2021) with local professionals from 16 countries, supplemented by a desk study of four additional countries. Using empirical data, we present a comparative analysis of regulations across nations, enriching our understanding of global ground station regulation. Moreover, we contribute current thinking by offering insights and recommendations for the potential development of both national and international regulations.

2 Literature Review

In this section, we will give an overview of ground stations and their importance in a space ecosystem. Thereafter, we will discuss the regulation of space activities in general and specific challenges related to the ground station regulations.

2.1 Ground Station as a Technical Device and Part of the Satellite System

The role of ground stations is crucial in both launching and operating satellites as they serve as the primary means of communication between Earth and satellites in orbit. A satellite mission typically spans several years, commencing with the design of the satellite and its payload, which often includes, e.g., cameras or measurement instruments (see, e.g., Gurtuna, 2013). Transporting the satellite into orbit necessitates a launch vehicle, typically a rocket, and a launch pad for lift-off. However, without reliable communication, these efforts would be futile. Communication through ground stations plays an essential role in two critical phases: first, in the launch and early orbit phase (LEOP), and then throughout the entire operational period until the mission concludes (Elbert, 2008).

The needs for ground stations vary significantly based on the purpose and orbit of satellites (Prol et al., 2022; Vasisht & Chandra, 2020). Geostationary (GEO) satellites are often considered relatively straightforward: due to their high orbit, they maintain a fixed position relative to the Earth, potentially covering nearly half of the globe. Therefore, they excel in applications such as broadcasting and communications, given their ability to relay large volumes of information across continents. Establishing a ground station for GEO satellites involves assembling an appropriately sized dish near the data source or destination, pointed toward the satellite's position (Elbert, 2008).

Satellites positioned in geosynchronous orbits (GSOs) or lower orbits, like medium-earth orbit (MEO) or low-earth orbits (LEO), present more challenges due to their constant movement relative to the Earth while in orbit (Prol et al., 2022). Also, the number and proportion of LEO is rising constantly (see, e.g., UNOOSA, 2024a).[1] As an example, the

[1] Additionally, numerous other satellites and space objects require ground communications. However, this study focuses on LEO, MEO, and GEO satellites, which collectively

GPS positioning system relies on MEO satellites, whereas satellite internet utilizes extensive LEO constellations, allowing the nearest visible satellite to provide connectivity to users within its range (Vasisht & Chandra, 2020). As the orbit altitude decreases, the visibility area on the Earth reduces. For instance, a typical LEO satellite orbits at heights between 400 and 1200 km with an orbital period of 90–128 minutes, resulting in a brief visibility window of around 20 minutes or less as it passes over observation points, such as internet clients or ground stations. Clients of these satellites use various types of antennas, such as small fixed antennas, array antennas, or tracking antennas (Fig. 1). For sending commands to the satellite or downloading greater amounts of data, ground stations with tracking systems and hi-directivity radio frequency (RF) antennas or optical links are needed.

Fig. 1 Two distinct types of tracking ground stations

represent most commercial and scientific space objects. As of early 2021, there were 4550 satellites in orbit, with 3790 in LEO, 139 in MEO, and 565 in GEO or GSO (Rome, 2023).

Fig. 1 Two distinct types of tracking ground stations: a VHF/UHF band ground station equipped with yagi antennas (left) and an S/X band station featuring a 3.9-meter paraboloid antenna housed within a weather-protecting radome (© Tommi Rasila, Northbase Oy)

The nature of the orbit impacts not only the number of ground stations required to communicate with a satellite but also their optimal locations (Fuchs & Moll, 2015; Vasisht & Chandra, 2020). Satellites on equatorial orbits necessitate ground stations near the equator, whereas polar orbit satellites benefit from locations near the poles. Moreover, a satellite in a sun-synchronous orbit (SSO) orbits the Earth in sync with the sun, resulting in a different path over the Earth during each 24-hour cycle. In practice, this means that to establish communication with an SSO satellite during each orbit, its operator needs ground stations positioned very close to the North or South Pole. Alternatively, they may require several stations at lower latitudes to sufficiently cover the satellite's path across the globe.

Ground station optimization raises the issue of international cooperation, a common practice in space research and particularly prevalent in the emerging new space economy. In space missions dating back to the 1960s, multiple ground stations were necessary worldwide to maintain constant communication with spacecraft. Likewise, in the new space economy, satellite operators require timely access to their satellites for various purposes: during the LEOP phase, the ability to issue commands for orbital corrections is crucial to prevent loss during the early stages. For remote sensing satellites, frequent, low-latency downloads enable rapid response times, fresher images, and increased download capacity (Prol et al., 2022).

This study will specifically focus on ground stations designed for LEO satellites on sun-synchronous polar orbits, considering that the majority of new satellites fall within this category. Moreover, the evident need for versatile global coverage by ground stations becomes particularly evident within this context. To meet the frequent communication needs of LEO satellite operators, ground station service providers must offer stations across numerous global locations to ensure the necessary low-latency access (Prol et al., 2022; Schmidt, 2011; Vasisht & Chandra, 2020). In theory, a ground station positioned at either the North or South Pole would provide optimal coverage, allowing visibility of the LEO satellite during each orbit. However, practical challenges, including access to electricity, internet connectivity, and maintenance services, render both options unfeasible. Even within the Arctic Circle, suitable ground station locations are limited, further compounded within the Antarctic Circle. Therefore, it becomes evident that diverse locations across various countries are essential for the successful operation of ground station services. However, the regulations for ground stations might vary significantly across countries, which is the topic we will focus on next.

2.2 Regulation of Ground Stations and Space Activities in General

A satellite operator can choose to establish their network of ground stations or utilize services from a ground station service provider (Tubío-Pardavila & Kurahara, 2021). In both scenarios, the network is presumed to cover multiple countries. Consequently, it is important to consider the regulations of all these countries in addition to those of the operator's home country.

There are various regulations governing space objects and ground stations (Spencer, 2010; Vasisht & Chandra, 2020) such as ground station and radio permits, licenses for transferring satellite data, and building permits. The regulations about space objects, like satellites, are more internationally harmonized, given that these objects transcend national boundaries and traverse nearly all countries globally. Consequently, it is crucial to regulate and coordinate aspects such as their uplink and downlink radio frequencies, power levels, orbital characteristics, and to mitigate risks associated with planned or unplanned re-entry into the Earth's atmosphere (see, e.g., Kurahara, 2018).

Despite its importance, there is minimal international coordination among ground stations, resulting in having each nation with its own set of regulations (see UNOOSA, 2024b). These regulations often comprise sporadic collections of laws and guidelines. This lack of uniformity could be attributed to the organic growth of the ground station industry. Similar to many emerging businesses, ground station establishment has occurred somewhat haphazardly across countries, conforming to existing regulations, primarily focused on aspects like radio frequency usage, export restrictions, and civil work regulations, including building permits.

Only recently have certain nations established specific ground station laws, in part to address both past and anticipated issues arising from an unregulated environment. These issues include instances of foreign entities, and even nation-states, constructing and deploying ground stations in countries where their satellite operations might be viewed as potentially hostile. Simultaneously, satellite operators and ground station service providers must navigate vastly differing regulatory landscapes across various countries. This dynamic renders some countries appealing for operations while making others practically impossible to operate within.

3 Research Method

Data for this study was collected by using an open-ended qualitative email questionnaire (Appendix 1). Even though face-to-face interviews would have helped to collect more detailed data, the email approach was selected due to excessive resources needed for traveling and difficulties finding common times for interviews as the interviewees were located around the world. Despite some weaknesses, email interviews can generate more in-depth and lengthier responses (Dahlin, 2021) than face-to-face interviews as respondents have more time to think about how and what to answer. Based on the first author's knowledge of the field, we approached 18 ground station experts in 18 different countries. These experts ranged from founders of a ground station company to people working in a notable position related to ground station activities. Altogether we received answers from 16 experts (see Table 1). Appendix 2 provides a list of participants and their organizations if they chose to provide that information.

A desk study was conducted on four countries—France, Germany, Norway, and Spain—to complement the email interviews covering 16 countries. This increased the total number of countries covered to 20. The literature and other sources used for the desk study are listed in Appendix 3. The validity and relevance of this sample are considered adequate for this study, given the spread of the research objects based on their geographical location, geopolitical position, and the developmental stage of the national space sector.

4 Findings

4.1 Categorization of the Regulations

Based on the empirical findings, the level and intensity of regulation vary greatly. In many countries, regulations are stringent, necessitating ground station operators to adhere to a set of implicit rules regarding

Table 1 Summary of the participants

Interviewee	*Country*	*Expertise*
A	Finland	Executive of a ground station service provider
B	Bulgaria	Executive of a ground station service provider
C	China	Freelance consultant
D	Italy	Executive of a ground station service provider
E	Sweden	Executive of a teleport services provider
F	Tanzania	Executive of a private space company
G	India	Executive of a small sat development company
H	UK	Executive of a ground station service provider
I	Republic of Korea	Executive of a ground station service provider
J	Ukraine	Executive of a ground station service provider
K	USA	Executive of a ground station service provider
L	Czech Republic	Executive of a ground station development company
M	South Africa	Executive of an EO specialist company
N	Japan	Executive of a ground station service provider
O	Kazakhstan	Official in a space research institution
P	Canada	Official in the regulatory body

ownership, technical standards, and security—both physical and cyber—as well as practices such as customer identification for security and geopolitical reasons, among others. These regulations naturally require a certain level of transparency and reporting. Based on this, regulators may impose requirements for logging activities and reporting to the regulatory body.

There are several types of regulations that are implied in ground station operations. Based on the collected data, three categorize emerged from the data:

1. *Specific* regulations, such as ground station laws and RF licensing.
2. *General* regulations, including building permits and export licensing.
3. *Hidden* regulations, such as those related to geopolitics and national security matters.

Only a few countries—such as the USA, and Finland—have *specific* laws pertaining to ground stations. In some countries—such as Canada, France, and Germany—ground operations are specifically addressed within legislation on space operations. In most countries, regulations primarily focus on radio operations. Transmitting from a ground station (transmit (TX), uplink) requires radio permission in all countries, and in some countries, receiving (receive (RX), downlink) also necessitates a license. A notable exception is Norway, which has different rules for mainland Norway compared to Svalbard and Antarctica due to treaties such as the Svalbard Treaty and the Antarctic Treaty. These treaties impose additional restrictions, such as limitations on military use of downloaded data.

In addition to ground station and radio permits, it is natural that *general* national permits required for building structures and operating businesses are also implied. While this group is not the focal point of this study, it should be noted that, broadly, the general permit processes for ground stations appear to be fairly lax. For example, ground stations are largely regarded as technical structures and thus usually do not require a building permit but rather just a notification. While physical security and occupational health issues are naturally observed, a more intriguing set of requirements is formed by cyber or information security, dual-use products, and export permits.

In many countries, specific requirements are set regarding cybersecurity, encryption, and the distribution of data. This is because remote sensing data, such as aerial photographs, can be utilized for malicious purposes. Consequently, there are also requirements to address dual-use and export regulations. Interestingly, while most countries have explicit rules and procedures for this, in some others, satellite data is not considered a dual-use product, and therefore export regulations are not applicable. Nevertheless, the acquired data is generally considered to have the potential to be of a critical nature.

When considering security matters further, the third group of regulations—the *hidden* ones—may come into play. These encompass implicit secondary rules embedded within the regulatory framework, such as policies that allow the regulator or state to make exceptions to the rules based on national security considerations. Additionally, other ministries besides the official regulatory bodies may become involved in regulatory decisions or changes. Situations may evolve with the formation or alteration of global alliances or shifts in international geopolitical conditions. These rules are often not transparently expressed, and their implementation may involve a certain level of secrecy.

This brings us to the nature of the regulating body, which varies greatly. To illustrate this diversity, a few examples are provided in Table 2.

Table 2 Examples of regulating bodies

Country	*Regulating body*
Canada	Global Affairs Canada (Non-Proliferation and Disarmament unit under foreign ministry) for remote sensing space systems and Innovation, Science and Economic Development Canada (federal dept) for ground stations and spectrum management
Finland	Traficom (licensing body of M.o. Transport and Communications) for ground stations and spectrum management and M.o. Economic Affairs and Employment for space objects
France	SGDSN—General Secretariat for Defence and National Security
Germany	BAFA—Federal Office of Economic Affairs and Export Control under Federal Ministry of Economic Affairs and Climate Action (formerly Economic Affairs and Energy)
India	IN-SPACe—Indian National Space Promotion and Authorization Center
USA	FCC, NOAA/DoC—The Federal Telecommunications Authority, along with the weather and ocean research organization within the Department of Commerce

This may result from the same development noted earlier regarding the differing collections of laws and regulations: When the need to regulate space issues first arises, there is no natural place for it. Space may be perceived as an issue of communications, traffic, aviation, science, international affairs, or security. As space becomes more integrated into everyday activities, it is often still regulated by the public body to which it was originally assigned. For example, in Sweden, satellites may fall under the jurisdiction of the Ministry of Education and Research, while ground stations may be overseen by the Post and Telecom Authority. Similarly, in France, space regulation may be managed by the General Secretariat for Defence and National Security.

To add complexity, regulatory bodies may differ for ground stations, frequency permits, and satellites. Additionally, the regulating body may be required to consult other ministries or state departments, and there may be multiple processes and permits that the applicant must navigate. As a result, the licensing process for a ground station can be quite intricate. Due to this complexity, in most countries, the number of applications is presumably very low, leading to potentially high administrative costs and burdens. However, there are also examples of streamlined processes, such as India's establishment of IN-SPACe as a one-stop shop for space permissions. Furthermore, some countries, including the UK, Ukraine, and Spain, only require a TX radio license, sometimes supplemented by notifying the regulatory body about the commencement of ground station operations.

4.1.1 Specific Laws and Regulations for Ground Stations

Less than half of the target countries have specific ground station regulations. For instance, Finland introduced a law on "ground stations and certain kinds of radars" on February 1, 2023, despite the practical non-existence of ground stations as a business. However, the law is forward-looking, as its title suggests: it anticipates future developments beyond traditional RF antennas. Ground stations may increasingly communicate with satellites using various methods, including optical or other advanced technologies.

In countries where ground station operations have been extensively conducted for decades by public and/or private organizations, specific laws and regulatory processes exist. Operators may be required to apply for permits or licenses for their ground stations. For example, in Germany, a license is required for transferring satellite data. Conversely, in Sweden, controlling a satellite is the basis for needing a license, meaning that owning an RX ground station does not require a license. Additionally, the location of the mission control center may determine the need for a ground station permit. For instance, if the control center is based in Canada, a local permit is necessary, and regulations also cover the distribution and security of raw data.

In Japan and the USA, comprehensive regulatory frameworks exist, including processes for validating and auditing ground stations. In South Africa, the permit required is a generic electronic communications service license, while China has its own licensing processes in place. In India, the licensing process is handled by the national one-stop shop space agency.

Apart from specific ground station regulations, a TX permit is needed for the uplink frequency in many countries. Some countries primarily regulate radio licenses and do not have a licensing process specifically for ground stations. For example, in the UK, the Republic of Korea, Ukraine, Bulgaria, Kazakhstan, Spain, and France, only a TX permit is required. Norway follows a similar approach, except that a ground station license is required if the station is located on Svalbard or Antarctica.

In addition, there is a group of countries that do not require a specific ground station license but mandate additional steps alongside the TX permit mentioned earlier. For example, in the Czech Republic, both

RX (downlink) and TX (uplink) require licenses, meaning that a ground station in the Czech Republic always requires a license. Nevertheless, the process is reportedly fast and inexpensive. In Italy, individuals must file a notification to become a tele-operator. This filing takes effect immediately and is free of charge, with annual fees collected only if sales income exceeds €500,000 per annum. Operating in France necessitates an advance notification of the distribution of satellite data. Similarly to some other countries, attention is given to the security of data, which could be harmful if accessed by unauthorized parties.

The differences between countries in the anticipated or estimated speed of the radio permit process, as reported by respondents, were striking, ranging from two days to one year. The shortest estimates came from the UK, where the process has taken as little as two days. However, it's noted that if shared spectrum usage requires consultation with other stakeholders or if the satellite class needs approval by the Ministry of Defence, the process can extend to 2–3 months. At the other end of the spectrum is the USA, where the process may take up to 9–12 months and can involve multiple cycles of application submission and clarification.

It's also observed that announced permit process times are often exceeded in reality. For example, in Italy or South Africa, the official 60-day time frame is rarely met, and the process may extend beyond 6 months. This, of course, introduces uncertainty into the business operations of ground station operators. Additionally, some respondents noted that the process and its progression are "somewhat opaque," further adding uncertainty and undermining the predictability of business operations.

4.1.2 General and Hidden Regulations Affecting Ground Stations

As noted earlier, numerous types of general national and regional regulations that must be taken into consideration when commencing ground station operations. These include obtaining building permits, addressing occupational health considerations, adhering to export restrictions, and ensuring compliance with environmental impact regulations.

Imported equipment must also adhere to trade restrictions and possess necessary certifications, such as the CE mark in the EU, UL certification in the USA, and Great Wall certification in China or the Type Approval required in South Africa for imported devices that transmit a signal. Depending on the country and the project, consultation with aviation, security, or defense authorities may be necessary. This is sometimes linked to hosting equipment for a foreign party. Furthermore, when operating on non-commercial radio-amateur bands, operators are required to obtain a HAREC license.

In summary, general regulations typically do not overly complicate the construction or operation of ground stations, as they are generally predictable and transparent. However, the same cannot be said for the hidden regulations mentioned earlier. These are often neither predictable nor transparent. Delays in the permit processes may indicate security evaluation procedures in connection with the ground station operator or its clients. According to several respondents, other ministries and regulatory bodies may be invited to participate in the process on a case-by-case basis. At its worst, this may result in unfair favoritism toward certain applicants.

At the same time, it's worth noting that opinion letters, decisions, or even participants in these discussions may be classified. Based on the authors' experience, the interviewees' responses, and desk study, there appears to be widespread variation between countries in the stringency of these classification processes. Overall, satellite data is increasingly recognized as a valuable and even strategic asset, the distribution of which must be controlled by nation-states. Nonetheless, this contrasts with the fact that remote sensing satellites do not recognize country borders—they sense remotely wherever they are programmed to and download their data wherever they can, whether it's in their home country or a friendly foreign country.

4.2 Foreign Operators and Foreign Operations

In general, most countries allow foreign entities to own and operate satellite ground stations on their soil, provided they comply with local regulations similar to domestic entities. Only two of the countries inspected, namely China and the Republic of Korea, explicitly block foreign ground station operations within their borders. However, China does allow ground stations for foreign embassies and Non-Governmental Organizations with special permission. In some other countries, such as Japan and South Africa, establishing a local entity for compliance is required, while in others it is merely recommended. Nevertheless, the situation is somewhat unclear in several of the countries studied, as there are no prior cases on this matter. It's worth noting that foreign entities operating inside the USA must pay market access fees, with the highest fees imposed on foreign entities serving foreign satellites.

It should be noted that sharing capacity with peers—or even competitors—in other countries or hosting foreign peers' ground stations in one's "antenna farm" is more or less an industry standard in new space ground station companies. This is much easier for foreign peers than the alternative of acquiring real estate, organizing local maintenance, and navigating regulatory processes in all the target countries, which may be several. These business models—hosting and co-locating—are inherently international, but rules and regulations on these practices are largely underdeveloped.

A local ground station operator may also want to operate ground stations in other countries. This is mostly unregulated in their home country; hence, the main concern is to comply with the local regulations of the target country. Some countries require notifications to be made to the home country regulator. Additionally, in Italy, revenues generated in foreign countries are added to the calculation when revenue-dependent permission fees are calculated. Interestingly, China and the Republic of Korea allow their companies and citizens to operate ground stations in other countries.

It should be noted, however, that some countries do not differentiate whether the actual ground station is located within the home country of the company or elsewhere: as long as the mission control center is in the USA, Canada, Germany, or Sweden, one must obtain a ground station operations permit in the respective country and comply with the regulations when applicable—in addition to adhering to the local regulations of the country where the ground station is situated. Hence, it is possible that the ground station operator does not have any ground stations in its home country but still has to comply with its ground station regulations.

Based on the findings, it seems evident that regulations regarding foreign entities building, owning, or operating satellite ground stations in other countries have room to evolve in the coming years as new kinds of cases needing regulation emerge in various countries.

4.3 Comparing and Harmonizing with Other Countries

When comparing their country to others, some respondents express modesty in their opinions, often stating that they do not know enough about other countries to make a sensible comparison. Additionally, there were misconceptions, such as expecting that all countries have similarly strict rules as the respondent's home country. These findings reveal that the perspective of ground station operatives is often local, without considering global or cross-border factors.

Many of the operators have their own global antenna networks and work more internationally, making them more capable of assessing how their local environment may differ in a global comparison. Nevertheless, regardless of the respondent, there was significant support for global harmonization of regulations, with some caveats and several opportunities identified. The newness of LEO satellites and constellations, coupled with the inexperience of regulators in regulating them, was seen as one of the primary challenges. Therefore, suggestions were made to adjust local regulations and educate regulators to accommodate LEO satellites.

> In the case of small satellites (nanosatellites, CubeSats), regulation is lagging behind with the reality.

> Regulators are not familiar with Satellite RF reality, the pace of launches of small satellites, the needs of satellites and the ground segment-as-a-service business model.

Operating with GEO satellites may be considered a relatively straightforward and "rigid" business, compared with LEO satellites, which are inherently more dynamic. LEO satellites have the capability to obtain remote sensing data from virtually all parts of the world. They do not "honor" the borders, and constellations may grow from small to large over time, while regulated parameters generally remain consistent.

> Regulations must take a global approach as LEO satellites are not restricted to any one geography.

One respondent complains that their country's regulation is loose and partially undetermined, which brings uncertainty to the process. In some other countries, the regulator is more helpful, and regulations are more rigid yet transparent. This may also result in negative regulatory decisions, but even that may be better than not having the decision in a sensible time frame.

> Regulations are lax, but uncertainty does not help operating. … In other countries there's more precision and, even if that might mean getting 'No' as an answer, at least we know why and in a timely manner.

Lengthy process times were also mentioned in some responses, particularly concerning uplink frequency applications, which necessitate filing through the International Telecommunication Union (ITU) process first. Overall, the timeline, coupled with the successive order of the ITU and local permit processes, is seen as problematic.

> It is time to think about a better approach to the ITU frequency coordination process in combination with ground stations.

Part of the responsibility is also assigned to satellite operators themselves.

> I feel that satellite operators sometimes focus on the satellite and overlook the ground side and some regulations. So, I think it is important for GSaaS operators like us to inform them about this.

Based on the responses, the most pressing area for improvement is the regulation of uplink frequencies. While these frequencies are regulated by the ITU on the satellite end, they are regulated nationally on the ground station end. This discrepancy is viewed as a significant challenge, particularly since LEO satellites require consistent data uplink across all countries where they are supported by ground stations.

> Better harmonization of ground space spectrum would help.

> Harmonization should follow in particular for bands usage. It would be great if all would accept the same bands at the same conditions for TT&C.

Recipients also perceive clear risks in harmonizing regulation if not done properly. The goal should be to establish an enabling governance system that prioritizes the efficiency of both operation and administration. Therefore, existing best practices should be identified and utilized as a foundation, with input from the industry being sought from the outset. Merely amalgamating all regulations together would result in additional bureaucracy, potentially undermining many, if not all, nations—a scenario detrimental to the space sector's needs.

> Before harmonization, sharing best practices would be great. Regulators should be open to hear how other countries are doing things.

> Yes, if said harmonization results in more flexibility in setting up and licensing ground station, and not making it difficult!

> While we would like to see standards between countries in ground station regulation, we fear that a 'one size fits all' approach will burden smaller countries with significant red tape.

Permits should not be regarded as a source of income for the government, as the primary purpose of regulation is to prevent interference. Therefore, market entry fees, for example, are viewed as a net negative, potentially resulting in loss of business and distorting market development. Another objective of regulation is, or should be, cybersecurity, which ought to be integrated into all operations.

> Regulators should not look to regulatory fees as a revenue source and should keep them as low as possible to encourage economic development in the space industry. Market access fees for international satellite operators is a net negative.

> Cyber security compliance must be built into the regulations to ensure safe and trustworthy international ground station operations.

Respondents advocate for greater harmonization in ground station regulation and recognize numerous benefits for all parties involved: enhanced resource utilization, reduced interference, fair competition, and decreased compliance costs, among others. The focus should be on creating an enabling environment rather than imposing restrictions, while ensuring the visibility of both national and global rules and benefits.

> Regulations and the costs related to ground station licensing differ greatly from country to country. This has a significant impact on the operation and cost of deployment of satellite constellations, so global harmonization is a key element to expanding the space industry.

> It's a global market with global customers. Think all would gain to get a more harmonizing regulation, with aligned processes and cost procedures. It could potentially also lead to better overall structure and control.

> Efforts to harmonize regulations for satellite ground stations globally hold several key advantages. Standardized rules enhance spectrum efficiency, reduce compliance costs, and encourage the development of seamless global connectivity. This approach facilitates innovation, attracts investment, and mitigates cross-border interference issues. Additionally, global regulations ensure adherence to environmental and safety standards and promote international cooperation in addressing shared challenges. While achieving global harmonization may present challenges, the potential benefits for the satellite industry and its stakeholders are substantial.

In contrast, respondents also express concerns regarding the utilization and sharing of resources. The vast sizes of constellations, gaps in reception coverage, and unhealthy competition stemming from regulatory disparities are identified as potential hazards. These factors may contribute to an unoptimized global system and congestion of frequencies, which are globally limited and scarce resources.

According to the findings of this study, a certain level of harmonization of satellite ground station policies and regulation would be beneficial to the space sector. It would help operatives in getting the required resources and licenses to operate their constellations and thus provide the space community the core ingredient of their services: the data. Harmonization could improve the coordination and use of scarce resources, such as the frequencies and orbit space. When done right, harmonization would also improve the security of the satellites and their data, not forgetting the security needs of participating nations.

5 Discussion and Conclusions

Based on the findings, it is evident that there is support as well as a clear need for global harmonization of regulations governing satellite ground stations across different countries. Best practices should be defined through an open process, shared, and implemented globally. However, it is important to recognize that one size does not necessarily fit all: countries vary greatly in terms of the age, nature, and size of their space sectors.

The nature and resourcing of national regulatory bodies should also be considered. It is essential to assess the key skills required and the objectives given to regulators, especially if they were not initially established for space administration. Creating common regulations and enforcing them through administrative offices ranging from the Ministry of Education to the Ministry of Transportation, and from the Office of Security and Defense to the ITU, may not yield the best results, especially given the current scarcity of resources. However, a multidisciplinary approach may prove fruitful if implemented intentionally.

It should be noted that developing regulation and processes on ITU internationally and harmonizing ground station regulations on national level are two separate issues. The role and importance of the ITU in current regulation and its development are clearly acknowledged. However, changing regulatory frameworks is recognized as a lengthy process, and there is uncertainty about whether all nations would consistently adhere to common rules. Sanctions are typically needed to enforce regulations, but as sanctions do not exist in this context, it is unsurprising that some nation-states have their own rules for international operations.

Given these challenges, a mutually agreed-upon set of recommendations, perhaps with tier levels, might be preferred over applying one strict set of rules universally. Compliance with these recommendations could lead to an ITU speed lane, resulting in a more streamlined regulatory process in participating countries. In addition to aspects regarding satellites and ground stations, these rules should also address cybersecurity issues.

The outcome of this study carries a subtle tone of warning, suggesting that action is needed before the situation becomes uncontrollable. The increasing congestion of orbits, coupled with the uncontrolled creation of space debris, is reminiscent of the development of climate change: it was recognized early on, but action was not taken until its reality forced nations and the international community to act.

The underlying sentiment of respondents appears to advocate for sensible, common regulation to conserve and ration the scarce resource known as space. Specifically, the frequencies required to uplink and downlink data to and from satellites and other spacecraft should not be overutilized in a short-sighted manner, as this would limit their usability in the future. Such conservation efforts would be to the benefit of all parties involved: nations, the world, and space itself.

6 Appendix 1. Email Questionnaire

- Which country are you answering for?

- Which key laws in your country need to be taken in consideration specifically in satellite ground station operation?
- Do you need a permit to own or operate a ground station in your country? If yes, describe the process with few sentences, including cost and timeline.
- Do you need permits for radio TX or RX? If yes, describe the process with few sentences, including cost and timeline.
- Do you need other permits, such as export permits?
- Can foreign parties own and operate ground stations in your country? How are they regulated?
- Can you own satellite ground stations in other countries? How is this regulated by your country?
- How would you compare your country to others as a base for satellite ground stations?
- Do you think we should put effort in harmonizing the regulation in different countries and putting global regulation in place? Please elaborate?
- Any thoughts you would like to share about the topic—regulation of ground stations and space in general in various countries?
- Please give your name, title, and organization.
- We would like to add you to the list of contributors, listing your name, title, and organization. Is this ok for you?

7 Appendix 2. List of Participants

- Bulgaria: Sfera Technologies
- Canada: Estelle Chou, Senior Policy and Licensing Office, Global Affairs Canada, Government of Canada.
- China: Jingdong Xue, freelance Chinese aerospace expert
- Czech Republic: Groundcom.space
- Finland: Dr. Tommi Rasila, Founder and chairman, NorthBase Oy
- India: Kiran Sharma
- Italy: Matteo Cappella, Regulatory Affairs Specialist, Leaf Space
- Japan: Hiromu Inoue, Sales Engineer, Infostellar, Inc.
- Kazakhstan: Identity withheld
- Republic of Korea: Kihwan Choi, Manager, CONTEC Co., Ltd.
- South Africa: Stefan de Klerk, CFO, Pink Matter
- Sweden: Arctic Space Technologies

- UK: Dr. Paul Crawford, Director, Dundee Satellite Station Ltd.
- Ukraine: Identity withheld
- USA: Ronald Faith, President and COO, RBC Signals
- Tanzania: Leonard Shayo, Founder & CEO, Olduvai Space Center (OLSPACE)

8 Appendix 3. Desk Study Material

- Remote Sensing Space Systems Act (CAN): https://laws-lois.justice.gc.ca/eng/acts/R-5.4/FullText.html
- Remote Sensing Space Systems Regulations (CAN): https://laws-lois.justice.gc.ca/eng/regulations/SOR-2007-66/FullText.html
- French Space Operations Act, No. 2008–51 (F): https://www.legifrance.gouv.fr/loda/id/LEGITEXT000018939303/
- LOI N° 2008-518 DU 3 JUIN 2008 RELATIVE AUX OPÉRATIONS SPATIALES: https://www.legifrance.gouv.fr/loda/id/LEGISCTA000045223235
- Act to give Protection against the Security Risk to the Federal Republic of Germany by the Dissemination of High-Grade Earth Remote Sensing Data (D); https://www.unoosa.org/documents/doc/spacelaw/national/germany-satdsigGE.doc
- Dunk, F. (2001). Vikings first in national space law; Other Europeans to follow: https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1038&context=spacelaw
- Updated report on the voluntary implementation of the Guidelines for the Long-term Sustainability of Outer Space Activities in Norway (N): https://www.unoosa.org/res/oosadoc/data/documents/2023/aac_105c_12023crp/aac_105c_12023crp_21_0_html/AC105_C1_2023_CRP21E.pdf
- Royal Decree No. 278/1995 (E): https://www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw/spain/royal_decree_278_1995E.html
- Independent Communications Agency of South Africa (RSA): https://www.icasa.org.za/
- Code of Federal Regulations (USA): https://www.ecfr.gov/current/title-47/chapter-I/subchapter-B/part-25

- Hallituksen esitys eduskunnalle laeiksi maa-asemista ja eräistä tutkista sekä avaruustoiminnasta annetun lain muuttamisesta ja sakon täytäntöönpanosta annetun lain 1 §:n muuttamisesta; https://www.finlex.fi/fi/esitykset/he/2022/20220113

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PART III

Sector Innovation

From Sci-Fi to Reality in the New Space Economy: Unlocking the Potential of Sustainable Interplanetary Supply Chains

Miguel Cordova and *Maria Alejandra Gonzalez-Perez*

We may brave human laws, but we cannot resist natural ones. (Jules Verne)

1 Introduction

Using artificial intelligence-guided manufacturing to build a biomedical device on a planet other than Earth where pressure is stable and more precision would be gained for someone awaiting a surgical intervention in Chicago or Sao Paulo could be possible, but not before using a clean energy powered spaceship and an extraterrestrial commerce route to deliver it. For a long time, science fiction books and movies have pushed our imagination to dream about an integrated space economy across the universe, where distances are shorter, resource synergies are

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_9

efficient, and possibilities endless. We have imagined interstellar distances covered at light speed and spaceships freely carrying cargo and people from one planet to another. However, reality could be more difficult to attain when it comes to interplanetary supply chain management with sustainable development expectations.

Since the twenty-first century started, global supply chain commerce has tripled to more than USD 10 trillion (Alicke et al., 2020). Supply chains are complex networks of interrelated economic activities and structures with many participants (Fontalvo-Herrera et al., 2019). These activities include procurement, warehousing, manufacturing, distribution, and consumption, while those participants could be suppliers, logistic operators, producers, wholesalers, customers, and others. How these activities and participants take their roles over time has depended on the evolutionary stage from logistics management to a more comprehensive and integrative supply chain management (Southern, 2011). The main goal of supply chains is to secure the flow of goods and services to final users or consumers, using materials, capital, and information. Due to their complexity, there are special events and big challenges that could be hard to manage for these supply chains, such as global disruptions as well as global joint efforts. According to this, black swan events could lead to the reconfiguration of participants' location in order to secure procurement and business continuity, despite the higher costs (Perez-Batres & Treviño, 2020).

On the other hand, Stentoft and Mikkelsen (2021) argue that supply chains are difficult contexts in which to operationalize the United Nations' global effort of sustainable development goals (SDGs), and Villena and Gioia (2020) concluded that despite the high commitment of firms toward sustainability, provoking a cascade effect of this same commitment in their suppliers at different levels is extremely complicated for them. Moreover, almost 70% of the respondent firms in a study conducted just after the COVID-19 outbreak said that they do not have detailed maps of their suppliers at those levels (Choi et al., 2020). In addition, Fritz and Cordova (2023) state that achieving comprehensive sustainability along supply chains is highly challenging and would need to use innovative frameworks of assessment. For instance, the Balanced Scorecard in supply chains and the Supply Chain Operations Reference (SCOR) would be assessment models that could incorporate sustainable development at some level of analysis (Cordova & Coronado, 2020; Ntabe et al., 2015).

Therefore, although supply chains on planet Earth are struggling to manage a proper balance between costs efficiency and sustainable practices (Cordova & Gonzalez-Perez, 2019; Leonard & Gonzalez-Perez, 2013; Ntabe et al., 2015), this challenge would be different for supply chains in space. Some of these challenges would refer to how interplanetary supply chains (IPSCs) would need to think about the best positions of the planets and specific spots on them to land and depart, which supply chain processes companies would decide to outsource into space and which not to, how to achieve efficiency through economies of scale during warehousing, manufacturing, or transporting to/from space, and so on. Furthermore, a joint initiative between MIT and NASA is mapping transportation routes, through a special triangulation among Earth, Mars, and the Moon (MIT, n.d.). Thus, these types of projects are paving the way for a better understanding of the new space economy as well as its opportunities and constraints toward sustainable development.

Sustainability in extraterrestrial businesses refers to the ability to maintain economic viability, environmental responsibility, and social equity in IPSCs. It involves ensuring that supply chains are resilient, secure, and transparent, while also minimizing waste and environmental impact. Sustainable interplanetary businesses aim to balance economic growth with the preservation of resources and the well-being of stakeholders, both on Earth and in space.

This chapter aims to identify how IPSCs are becoming real from the business and management standpoint, and to contribute to the current discussion about how extended contemporary supply chains could become, and to the emerging discussion about sustainable business activities in extraterrestrial space. In addition, it discusses to what extent managers would be able to manage sustainability of IPSCs. Therefore, this would be one of the first approaches to highlight how complicated, risky, and sustainable the contemporary space race would be regarding the integration of space into the current global value chains (GVCs) and turning them into interplanetary value chains.

Hence, our chapter builds upon the sustainable supply chain management literature, proposing an extension toward an IPSC field, which in turn should consider new perspectives for the management of sustainability. Therefore, we argue that the concept of IPSCs would need to be extensively analyzed by the business and management fields as well, providing new managerial considerations and novel paths for future research.

2 New Space Economy Background

Many reasons have driven space exploration over time besides human curiosity. For decades it has been the focus of strategic resource extraction for key manufacturing processes (Crawford, 2015), emerging industries such as space tourism (Toivonen, 2022), sustainable planetary protection (Profitiliotis & Loizidou, 2019), and so on.

National governments have conducted space exploration for motives including politics, science, economy, military, and increasing their wealth in the long run (McMahon, 1961). Later, organizational interests in the space economy have progressively changed how participants were involved, from governmental initiatives at the beginning, to large companies' investments after that, and finally to entrepreneurs obtaining equity funds to develop several initiatives at small and medium scale (Peeters, 2021).

While supply chain operations on Earth must be efficient to achieve all stakeholders' expectations, supply chains in outer space would have to be even more efficient, considering the high transaction costs involved, such as transportation back and forth to planet Earth. Lee et al. (2008) argued that it's possible to build models of highly efficient networks of activities in space using already known logistics operations, thus improving resources utilization. In addition, besides efficiency, traceability, and transparency in space mission, generating a reliable record of transactions, operation costs, and how logistic activities are serving stakeholders' needs, by using digital technologies such as blockchain, would be extremely important to develop IPSCs (Rana et al., 2021).

Indeed, securing the availability of reliable data would be instrumental for the development of IPSCs, not only due to their geographical distance from GVCs on Earth, but to potential effects of disruptions or unexpected events. Furthermore, modeling new space routes and incorporating highly advanced technology would bring new considerations for sustainable development outside Earth. Thus, the new space economy will shape itself in accordance with the identified opportunities and the challenges that human beings overcome.

3 Opportunities: Artificial Intelligence and Interplanetary Supply Chains

Artificial Intelligence (AI) has the potential to significantly contribute to IPSCs by enhancing their resilience, sustainability, and efficiency. AI can be utilized to improve supply chain resilience by developing business continuity capabilities (Modgil et al., 2021). It can also enable the creation of sustainable and resilient supply chains, providing optimal solutions for risk mitigation (Naz et al., 2021). Furthermore, AI can aid in predicting supply chain risks through machine learning techniques, thereby improving risk management (Baryannis et al., 2019). Additionally, AI's impact on stimulating financial services for supply chain network activities can be crucial for sustainable supply chain finance (Olan et al., 2021). Hence, IPSCs could achieve resilience as well as develop proper risk management systems after incorporating AI in their logistics operations, supporting the perspective of Perez-Batres and Treviño (2020). Therefore, AI would prevent IPSCs from being unprepared for black swan events or major disruptions.

Moreover, AI can optimize supply chain operations by reducing costs and enhancing customer satisfaction (Calatayud et al., 2019). However, challenges such as lack of trust in AI and the Internet of Things (IoT) may hinder the development of intelligent supply chains (Nozari et al., 2022). Nevertheless, the application of AI and machine learning techniques within supply chains can lead to improved operational efficiency and customer satisfaction (Younis et al., 2021).

Furthermore, AI can aid in interpreting and evaluating alternatives in dynamic supply chain situations, particularly during disruptions (Gupta et al., 2022). In the context of the food supply chain, AI can be integrated vertically to enhance its functions, contributing to the entire food supply and value chain (Bačiulienė et al., 2023). Additionally, the integration of AI in supply chain management can improve demand forecasting, inventory management, decision-making, and operational efficiency (Rickardo & Gladson, 2023). Besides, the use of cognitive heterogeneous wireless networks and AI in supply chains can significantly enhance supply chain control and operation processes (Yuan, 2022). AI and machine learning have the potential to enhance the efficiency and effectiveness of supply chain management by enabling the analysis and interpretation of large datasets, thereby improving environmental performance (Naved, 2022). Moreover, the adoption of AI in food supply chains can address unique challenges related to food safety, quality, and wastage by improving transparency and traceability (Dora et al., 2021).

In sum, AI would generate reliable information for decision-making processes in space, which would be led by AI systems as proposed in movies such as Space Odyssey, Aliens, or The Martian, leveraging the capacity of IPSCs to operationalize new variables and achieve an overall visibility of the participants' roles within (Stentoft & Mikkelsen, 2021; Villena & Gioia, 2020).

4 Challenges: The Relevance of SDGs in Outer Space Operations

How can SDGs, originally formulated for Earth, be adapted for extraterrestrial activities involving humans and AI, considering unique environmental, ethical, and resource challenges in space environments?

To adapt the SDGs for extraterrestrial activities involving humans and AI, it is essential to consider the unique environmental, ethical, and resource challenges in space environments. The SDGs, initially formulated for Earth, can be adapted for space by integrating them with the specific challenges and opportunities presented by space exploration and colonization. The 17 SDGs, established by the United Nations Agenda 2030, provide a global blueprint for peace and prosperity worldwide (Palomares et al., 2021). To adapt these goals for extraterrestrial activities, it is crucial to consider the environmental challenges of space, such as resource scarcity, limited habitable space, and the need for closed-loop life support systems. AI can play a significant role in addressing these challenges by optimizing resource management, life support systems, and environmental sustainability in space environments (Palomares et al., 2021). Furthermore, the ethical considerations of space exploration, including the preservation of celestial bodies and the prevention of contamination, need to be integrated into the SDGs for space activities. AI can be leveraged to address these ethical challenges by developing responsible and sustainable exploration and utilization practices. Additionally, the resource challenges in space, such as energy, water, and food scarcity, can be addressed through AI-driven technologies and innovations, aligning with the SDGs' focus on poverty eradication, economic development, and environmental sustainability (Mabhaudhi et al., 2021). Moreover, the integration of AI in space activities should align with the SDGs' emphasis on innovation, industry, and infrastructure (Mayer-Foulkes et al., 2021).

AI technologies can contribute to the development of sustainable and resilient infrastructure for extraterrestrial habitats, as well as the advancement of space exploration technologies. Furthermore, the SDGs' focus on education and capacity-building can be adapted for space by promoting interdisciplinary research and education in AI, space science, and sustainability to address the unique challenges of space environments (Hansen et al., 2021).

In summary, adapting the SDGs for extraterrestrial activities involving humans and AI requires a comprehensive integration of environmental, ethical, and resource challenges specific to space exploration and colonization. AI can play a pivotal role in addressing these challenges and aligning with the SDGs to ensure sustainable and responsible space activities.

5 Sustainable Interplanetary Supply Chains in New Space Economy

The management of supply chains outside Earth may demand a new set of managerial skills, as well as interdisciplinary approaches, since usual logistic concepts such as location, capacity, economies of scale, lead time, etc., would have to include, for example, an astrophysics perspective in order for supply chain managers to understand how unusual terms in business such as gravity, pressure, planetary translation and rotation periods, among others, affect supply chain activities (Agrawal et al., 2021). According to this, governments and companies would decide which operations would be better to outsource in outer space, and which ones must remain on planet Earth. The latter will open new areas for space entrepreneurs, businesses, and policymaking, introducing intermediaries in between that would take advantage of these newly opened IPSCs. Furthermore, the aforementioned decisions would trigger data registration, traceability, and the need of other several business applications to the new space economy (De Filippi & Leiter, 2021).

In addition, SDGs have to be revisited to understand which IPSC operations would have a positive as well as negative impact on environmental, social and/or economic issues on Earth (Leonard & Gonzalez-Perez, 2013) and possibly in outer space too. Also, this raises the following additional questions: Would it be relevant to begin a conversation about the sustainable development of space as a common area such as has happened with international high seas on Earth) (see David et al., 2021)? Would back and forth transportation meet the minimum requirements of economies of scale and transaction costs to do business? How would new outer space entrepreneurial ventures contribute to expanding or reducing social as well as economic inequalities on Earth? Table 1 exhibits specific examples of the challenges that global supply chains are facing toward the achievement of some of the SDGs on Earth, generating questions for the future about how those challenges may emerge for the management of IPSCs too.

Interplanetary supply chains, which would be essential for sustaining extraterrestrial businesses, must exhibit specific characteristics to ensure sustainability. Firstly, the integration of blockchain technology with decentralized storage systems, such as the Interplanetary File System (an open and verifiable network that connects application-developers, scientists, infrastructure developers, and researchers), is crucial for securely managing data related to the supply chain (Ahmad et al., 2021; Rana et al., 2021; Reza et al., 2022). This integration ensures traceability, transparency, and trustworthiness (Cordova & Nava-Aguirre, 2022), which are vital for sustainable IPSCs. Additionally, the use of blockchain enhances security and reliability in supply chain transactions, contributing to sustainability (Agarwal et al., 2022; Hellani et al., 2021). Furthermore, modeling and simulation of IPSCs using space logistics frameworks provides a quantitative way to evaluate and optimize these supply chains, thereby enhancing their sustainability (Armar & Weck, 2009; Gralla et al., 2006; Lee et al., 2008). These models enable the assessment of life-cycle costs and logistics strategies, which are essential for sustainable interplanetary businesses, addressing the statements of Fritz and Cordova (2023). Moreover, the scalability and efficiency of blockchain-based supply chain systems are crucial for achieving sustainability in extraterrestrial businesses (Hellani et al., 2021).

Finally, the management of IPSCs in the new space economy would have to be strictly guided by international policy-making (Gonzalez-Perez & Cordova, 2024) that may represent a shift from the current international regulations to interplanetary ones, which may consider sharing locations, routes, models, and resources in extraterrestrial space.

6 Discussion and Conclusions

According to our analysis, we argue that interdisciplinary research will be instrumental in the study of IPSCs, since achieving quality in the delivery and operational efficiency would depend not only on managerial

Table 1 Examples of SDG challenges in global supply chains and questions for IPSCs

SDGs	*Global supply chains*	*Interplanetary supply chains*
1. No Poverty	Unexpected crises can dramatically constrain the wages of supply chain low-income participants, such as in commerce or agriculture (Ben Hassen & El Bilali, 2022)	Would low-income level workers be stakeholders of interplanetary supply chains?
2. Zero Hunger	Global disruptions such as pandemics and wars can severely affect the operational continuity of food supply chains (Ben Hassen & El Bilali, 2022)	Which kind of disruptions to links of food supply chains which are located and outsourced in outer space?
3. Good Health and Well-Being	Mining some minerals such as cobalt for electric batteries can cause serious diseases and improper working conditions for people (Da Silva Lima et al., 2022)	Is the design of medical and protection equipment ready for the working conditions of outer space?
4. Quality Education	Digital technology has positively enhanced the training opportunities in maritime supply chains through the use of simulators (Kim et al., 2021)	To what degree have higher education institutions already incorporated interplanetary perspectives in supply chain education?
7. Affordable and Clean Energy	Production of components from raw materials that are useful to supply chains' processes still use fossil fuel (Da Silva Lima et al., 2022)	Would manufacturing processes regarding the support of outer space logistics use fossil fuel?
9. Industry, Innovation and Infrastructure	Innovative disruptions in supply chain operations would generate important trade-offs between sustainable development and firms' strategic decisions (Cordova & Coronado, 2020)	Which new trade-offs would firms face after incorporating space locations in supply chain operations?

(continued)

Table 1 (continued)

SDGs	*Global supply chains*	*Interplanetary supply chains*
12. Responsible Consumption and Production	Technological revolution advances such as Blockchain would provide enough data and traceability of processes to build reliable and efficient supply chains (Cordova & Nava-Aguirre, 2022)	Would having more data, transparency, and traceability in the new space economy create the necessity of more space travel, resource utilization, and/or an unexpected demand?
13. Climate Action	Unexpected rain events cause flood and other related disruptions in critical supply chains such as medical equipment or vaccines (De Boeck et al., 2022)	Which discontinuities and cost overruns in interplanetary supply chains can unexpected climate change outcomes on Earth cause?

Source Authors

skills, but for instance on astrophysics dynamics, technological capabilities, climate phenomena, or industrial chemistry applications. Besides, we state that more research of the new space economy from the business and management fields including an interdisciplinary perspective is needed, since complex international business processes such as global supply chains would become IPSCs over time.

Interplanetary value chains are far more complex networks than GVCs, given the space environment and the highly specialized knowledge needed to operate in them. Nevertheless, IPSCs would continue contributing added value through key supply chain processes such as extracting, procurement, warehousing, manufacturing, distributing, etc., should they decide to operate outside planet Earth. Thus, firms will decide how they would continue participating in IPSCs, on Earth or in space, finding new locations and building new infrastructure for it.

In addition to this, we posit that AI has the potential to revolutionize IPSCs by improving resilience, sustainability, and efficiency. By leveraging AI technologies, supply chains can become more adaptive, responsive, and capable of addressing the unique challenges of interplanetary logistics. However, as human and AI activities expand into space, ethical considerations become crucial. Ethics includes respecting potential extraterrestrial life forms and considering the long-term implications of terraforming activities, which would be related to incorporating a sustainable development perspective toward the new space economy. Also, ethics considerations would mean having AI-driven systems in the form of robots or intelligent software that would help humans to take decisions in space.

Sustainable development challenges add additional complexity to the management of IPSCs. Key to these challenges is the integration of advanced technologies such as blockchain, decentralized storage systems, efficient modeling and simulation frameworks, and scalability tools. These innovations are essential for ensuring traceability, transparency, security, and cost-effectiveness in sustainable IPSCs.

Central to sustainability in extraterrestrial businesses are three core principles: economic viability, environmental responsibility, and social equity. The overarching goal is to minimize waste and reduce environmental impact, creating a balance between exploration and conservation. Minimizing the impact on extraterrestrial environments is a primary concern. Measures include avoiding the contamination of celestial bodies and effectively managing space debris, as guided by NASA's Office of Planetary Protection and its protocols for avoiding biological contamination. This appropriate balance would make us think in a sustainable way for developing the new space economy but also if there were those besides humans who would be able to raise complaints about any transgression, new stakeholders in a new business playground.

Efficient resource utilization is another critical aspect. Utilizing in-situ resources, such as lunar water ice for fuel or Martian soil for construction, is vital to reduce dependence on Earth-based supplies. This approach not only promotes sustainability but also enhances the feasibility of long-term space missions. Indeed, resource extraction in outer space places before humans the need of strong interplanetary regulation in order to steward the resources.

Doubtless, the socio-economic impact of space activities cannot be overlooked. Ensuring equitable resource distribution and preventing the monopolization of space resources are fundamental to maintaining socio-economic balance in space exploration. Otherwise, such issues would substantially increase the social and economic inequalities on Earth.

Besides, sustainability in space technology should focus on longevity, repairability, and adaptability. Hence, designing AI systems and other technologies to be robust and sustainable in the harsh space environment is essential for the success of long-term space missions.

An additional crucial consideration is the role of international collaboration and governance. Developing extraterrestrial SDGs requires a global effort and consensus, similar to the Antarctic Treaty System, to ensure peaceful and sustainable space exploration. Moreover, adaptability and resilience are key in the unpredictable space environment. SDGs for space activities should prioritize these elements to effectively navigate and manage the unknown challenges of space exploration. Hence, gathering the different global standpoints to progress toward combined and holistic regulations for the new space economy is fundamental as well as urgent.

Therefore, would the SDGs framework still be enough to summarize the most important concerns of humanity when including extraterrestrial business? Should new SDGs due to the development of interplanetary value chains be generated? Which other concerns regarding interplanetary sustainability would be relevant to identify and analyze? The extractive activity of natural resources makes it almost impossible to talk about sustainable supply chains. Would the new space economy worsen or improve that?

It is crucial to consider the particular resource, ethical, and environmental difficulties in space environments while adapting the SDGs for extraterrestrial activities involving humans and AI. The SDGs, which were first developed for Earth, can be modified for space by interweaving them with the unique opportunities and problems of space travel and colonization. The United Nations Agenda 2030 developed the 17 SDGs, which offer a global framework for peace and prosperity. However, it is critical to take into account the environmental difficulties of space, such as resource scarcity, restricted habitable space, and the requirement for closed-loop life support systems, in order to modify these aims for extraterrestrial activity.

In sum, even though some supply chain participants could change the location of their activities to space, extending the scope of traditional supply chain management and incorporating an interdisciplinary approach to fully understand the usual requirements of speed, delivery, and cost, these would not be replaced but be supplemented by new ones of traceability, transparency, resiliency, adaptability, and responsivity. In addition, sustainability is a driving force in the realm of space exploration and development. Ongoing research and international discourse are continually shaping our approaches to these complex challenges, ensuring that our ventures into space are conducted responsibly and sustainably.

Acknowledgements In this chapter, we gratefully acknowledge the invaluable assistance of AI tools such as Scite, Grammarly, and ChatGPT, which played a crucial role in enhancing the quality and accuracy of our work.

Competing Interests The authors have no conflicts of interest to declare that are relevant to the content of this chapter.

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How Firms Utilize the Data Provided by Space Firms

Hafiz Haq

1 Introduction

Space firms can be described as firms that are associated with at least one of the space sectors. There are two major space sectors—upstream and downstream. Upstream can be further divided into manufacturers and launchers, while downstream includes communications providers, satellite data providers, and platforms and mapmakers (Weinzierl, 2018). The broader space economy may also include sectors such as space exploration, space infrastructure, and space governance. The shifting focus of space firms toward nanosats has greatly influenced the increased production of satellite products to gather significant amounts of data from the lower earth orbit. There are over 2080 nanosats scheduled to launch from 2022 to 2027 (Nanosats, 2023). This will result in an enormous supply of satellite data including remote sensing, earth observation, and geospatial data, which may enable companies to use the data products to improve the existing business sectors and enter the next chapter in their evolutionary journey.

The existing literature has provided applications of space data in various business sectors including, agriculture to improve water management

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_10

by mapping the field in addition to monitoring crop health and forecast yield (Vuran et al., 2018), allowing insurance firms to evaluate the risk of natural disasters as well as quantify the losses (Ardila et al., 2022; Kuntla, 2021). The infrastructure development and shipping routes trackers benefit from satellite data to improve the performance of transportation (Perboli et al., 2021). Satellite data are also used to monitor mining operations, assess the environmental impacts, and understand land management (Maus et al., 2020). Oil and gas firms can greatly benefit from using satellite data to identify leaks (Guanter et al., 2021). However, the focus of these studies corresponds to application specific and inapplicable on a general level. The most important challenges of integrating satellite data into existing businesses include:

- Value proposition
- Lack of understanding about satellite products
- Lack of innovative solutions

Firms may also require significant government grants and funding to optimize the fundamental economic structure to incorporate satellite data (Weinzierl et al., 2022). Firms compel the designer to focus on customer-centric product development in the new space under the uncertainty of market conditions (Golkar & Salado, 2021; Ojala, 2016). To address these gaps, the aim is to gather insight about space data to integrate with opportunity creation/development theory (Alvarez et al., 2013; Overholm, 2015; Schneider, 2019). In the space data economy, product innovation by means of using space data has not been conceptualized widely in the literature. Therefore, an analysis of how companies have used space data in business activities to improve business performance bring forth insights for space data economy and business literature is needed. The main contribution of this study is to present a theoretical and practical explanation of some of the fundamental questions in space economy. These questions include:

1. How does space data create value for business activities that is unmatched by any other technologies?

2. What types of space data products are available in the market that can be integrated in new product development?
3. How do firms decide whether to use space data or not?

The aim of these research questions is to enable space data practitioners with guiding literature as well as contributing to the continuously evolving literature of space data business. The chapter is organized as follows: the next section lays the foundation of opportunity creation/development theory followed with space data economy. Research methods and findings are presented in the following section. The chapter closes with discussion and conclusions.

2 Literature Review

It is generally agreed among opportunity theorists that opportunity comes from imperfection of a competitive market that can potentially be realized with monetary value (Alvarez et al., 2013; Overholm, 2015; Schneider, 2019). This means that there won't be any opportunities in perfect market conditions. Therefore, opportunities are generated in an economic system when there is room for improvement. Firms tend to focus on product innovation during a certain market condition (Schneider, 2019). Previous studies have broadly debated the role of discovery, which can be caused by an external force that brings forth opportunities (Alvarez & Barney, 2007). This could lead to the creation of new products and services solving existential problems and meet the demand of the market (Korsgaard, 2011; Ojala, 2016). However, Filser et al. (2020) argued recognizing an opportunity requires a few aspects from an entrepreneur or a venture including (1) Personal factor (Education, Knowledge), (2) Organizational factor (Funding potential, Decision-making process), and (3) Environmental factor (Network, Market conditions).

Authors have argued that entrepreneurial education is associated with the performance in creation (Hmieleski et al., 2015). The environmental conditions of a firm play a big role in how the opportunities are recognized (Edelman & Yli-Renko, 2010). Closing the gap between opportunity recognition and action depends on the firm's belief and perception (Barreto, 2012; Shepherd et al., 2014). Karami et al. (2022) emphasized seizing the opportunity with an example case study where firms anticipate change in advance instead of waiting for change to occur in the market, while taking a tolerable risk on product development as well as engaging with business platforms, expanding the value network, and participating in conferences. In this context, firms should proactively recognize opportunities by anticipating the changes in the space data economy. The opportunity theory has widely been established in the literature with respect to the implications on space product innovation. However, there is a gap in integrating opportunity theory with new space to explain how firms can utilize the opportunity from space data in existing businesses.

Space data refers to the data generated by satellites using synthetic aperture radar (SAR), multispectral image, and geolocation information. The context of space data is specifically mentioning these sources of information that can be used by existing firms on the globe. Space data economy can be divided into two major building blocks, which are upstream and downstream shown in Fig. 1. The upstream consists of manufacturers of satellites and ground stations as well as launch activation and operations (OECD, 2022; PWC, 2020). The manufacturers provide hardware equipment, assembly and network capabilities. The launchers bring rockets and services that are necessary to launch satellites into the orbital system. The operations block allocates the capacity of the system and provides system's maintenance in the ground station. Operations are connected to both upstream and downstream blocks to ensure connectivity and downlinking the data (raw data) and enable for further processing (Black et al., 2022; Deloitte, 2019). The downstream segment consists of operations and space data products. The space data products consist of various data products and packages. These products include agriculture, climate, insurance, geo-intelligence, security, maritime, and finance. These packages also include communication, surveillance, RF spectrum monitoring, and emission monitoring. The industry is governed with regulations as a whole.

The space economy in the US and India has been growing in the last decade (Highfill & MacDonald, 2022; Mani et al., 2023). However, the impact on the economy of this expansion is yet to be quantified. The downstream space activities have been expanding in Europe over the last few years compelling enterprises to innovate and capture value from the opportunities presented by the new space paradigm shift (Bousedra, 2023). China aims to explore the possible access for materials and energy resources to fulfill its economic and energy needs by building a solar power station (Goswami, 2018). These activities inspire new power dynamics in the space sector considering that government

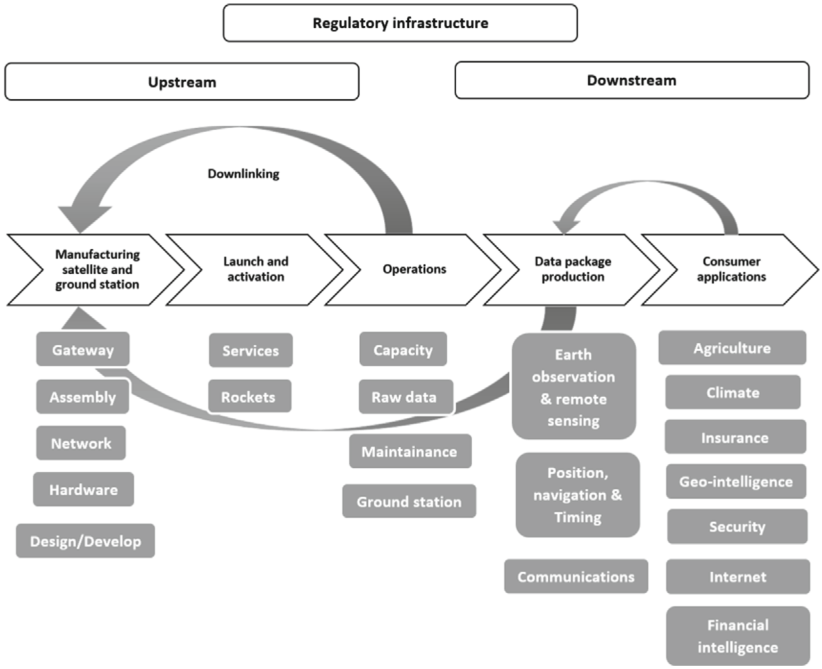

Fig. 1 Representation of space data economy

is not the only agency participating in the development of the space industry (Rementeria, 2022). Nevertheless, democratization of the space sector brings a new structural aspect to the governance of this industry. The uncertainty of space economy and openness also present challenges that may lead to a culture of innovation (Clormann, 2021). The biggest challenge the space sector currently faces is the space debris (Béal et al., 2020). However, the infrastructure for taxation is unclear. The role of policy intervention can be effective when the timing and selection are appropriate to reflect the targeted components of the system in the evolving ecosystem (Carter & Pezeshkan, 2023). The growing numbers of satellites in the orbit system eventually leads to expansion of the space surveillance system to identify illegal objects and understand the nature of space pollution (Wang et al., 2022). Furthermore, secure communication from satellites to devices should be considered in the evolution of the space sector (Bradbury et al., 2020). Space security and surveillance give rise to the construction of space policies that support research and development of new space (Castaño, 2021).

There is a variety of space data products available in the market at various bandwidths with different hardware adding complexity to choosing the right product for a firm's need. Prol et al. (2022) discussed the opportunities and challenges of communication satellites in low earth orbit. The most common commercial application is flood monitoring produced with SAR and multispectral images (Kuntla, 2021). The quantification of disaster caused by flooding has proven to be an important application for insurance providers (Ardila et al., 2022). Remote sensing also allows precision agriculture and mapping greenhouse gas to improve climate change response (Guanter et al., 2021; Vuran et al., 2018). The mining industry has been benefited greatly by remote sensing data (Maus et al., 2020). Moreover, logistics has improved performance by space data adoption (Perboli et al., 2021). Many specific industrial applications have adopted space data to improve the performance of businesses. However, there is still a huge gap among various business sectors using space data in business activities. This study addresses how businesses can identify the opportunity to use space data in product development.

3 Research Method

The study considers gathering valuable insights from an emerging business sector that can be complemented with the literary knowledge provided by previous research studies and facilitate business models toward product development using space data. These tasks were achieved by extracting information from two case studies (Darke et al., 1998; Yin, 2013). The information helped generalize and unfold conclusions that reflect on the research questions and provide a deeper understanding of the research field (Eisenhardt, 1989). The knowledge derived from the case studies help integrate and examine the business model evolution (Hedman & Kalling, 2003).

The case studies selected in this project are all participating in the space sector. The firms also meet the theoretical requirements as prescribed by (Eisenhardt, 1989). These firms met the following criteria: (1) firms involved in the innovation and opportunity creation/development activities in new space, (2) progress of the firms directly related to space data-based services, and (3) firms provided solutions to the observable problems in non-space related businesses. Table 1 shows the materials and various data sources used in the study. There were four interviews and one questionnaire conducted by the author for the purpose of data collection for this study during the year 2023. The first interview was related to the development and progress in the upstream sector conducted through virtual meetings. The intentions were to gather information about space data-based services or products in the industry. It was found that the upstream sector provides the hardware and services to the satellite companies to launch into the respective orbits. The second interview dealt with the downstream activities over virtual meeting. This firm provides space data-based services to conventional businesses. There was only one questionnaire designed for Firm C due to the unavailability of time. Firm C provides weather related services to customers. The third interview was a face-to-face meeting. The interviewee has a lifelong experience in both industry and academic organizations. The topic of the interview was remote sensing and earth observation. The fourth interview was also a face-to-face meeting. The interviewee has a wide range of experience in both industry and academia. The topic of the meeting was global navigation space systems.

The length of the interviews varied between 20–120 min. All interviewees have an in-depth knowledge of the subject area. They talked in-detail about the role of their organizations and the progress of the space industry. They were asked the research questions in many ways, to which interviewees provided detailed answers. The author took notes of the information provided by the interviewees. The qualitative approach

Table 1 Empirical data used in the study

Data source	*Main activity*	*Year*	*Headquarter location*
Interview with the CEO of Firm A	Upstream	2023	Espoo, Finland
Interview with the CEO of Firm B	Downstream	2023	Espoo, Finland
Questionnaire with a senior member of Firm C	Weather related services	2023	Helsinki, Finland
Interview with academic/ industry expert	Remote sensing	2023	Vaasa, Finland
Interview with academic/ industry expert	Global navigation space system	2023	Vaasa, Finland

taken in this study provided the author with the tools to extract data and knowledge in the space industry that are conformed to the research questions (Eisenhardt, 1989).

The data collection also includes visiting websites of space firms and gathering information on products and services shown in Table 2. There are six types of CubeSat constellations identified in the space sector providing services to the existing businesses. These constellations generally provide seven types of products and services that are observable from a satellite. Each of these general products and services may include various solutions addressing specific identifiable problems. There were over twenty-five company web pages found from the internet search. The data collected from companies web pages included different products and services offered to the business to understand how companies have used space data in solving problems. The database used for gathering information on satellite companies is nanosats.eu

This study implements a comprehensive data analysis method, which consisted of three parts (Casterlé et al., 2012; Lester et al., 2020), (1) Data summarization, (2) Data visualization, and (3) Conclusions. In the first part of data analysis, the notes taken from the interviews were organized based on the research questions. The contents were then simplified to adhere with the flow of the study including the business model and opportunity creation/development. The written sources were also used to explain products and services of space businesses recommended by the mixed method research (Leko et al., 2023; Liu, 2022). This process

Table 2 Other written sources

CubeSat constellations	*Number of sources*	*Products and services*
Multispectral and hyperspectral	9	Earth observation and remote sensing
Communication	5	Infrastructure
AIS/ADS-B	3	Surveillance
Weather data	3	Weather forecast
RF spectrum monitoring & geolocation	3	Security, position, navigation and timing
Emissions & greenhouse gas monitoring	2	Monitoring and observation
Quantum key distribution	3	Secure communication and clock synchronization

allows creating summaries reflecting on both qualitative and quantitative data for each research question in chronological order and allowing synchronous links to the subject of this study.

The second part of data analysis includes visualization or representation of the data that are relevant to the subject of this study and answer the research questions. The visualization is accomplished by creating tables to represent a clear understanding of the topic studied. It was noted that the interviewees brought different points of view for the topic at hand. Although, these points are valid in practical aspects of business processes. The most relevant answers are favored and presented in the study. The Tables provided a visualized outcome of the study including the characteristics of space data firms, progress of the industry, and possibility of value creation.

The third part of the data analysis includes conclusions drawn from the various aspects of the industry. The identified key aspects of the case study are elaborated. The key benefits and challenges of the study are highlighted as well as identified patterns are discussed. The outcome of the study is further related with the literature to form a solid understanding of the topic (Leko et al., 2023), and presents knowledge on how firms can benefit from the opportunities in the emerging space data sector.

4 Findings

This section presents the finding of all research questions mentioned in the introduction. Each subsection provides examples from the interviews in tables. The subsections also reflect on the information extracted from the interviews.

4.1 How Does Space Data Create Value for Business Activities that is Unmatched by any Other Technologies?

Space data provides an opportunity to look at the planet in its entirety, which makes it very valuable for various business activities. Any problems occurring on the planet can be detected and seen, giving businesses the opportunity to make better decisions through monitoring natural disasters, detecting environmental change, and providing data regarding the past, present, and likely future. There are separate satellite constellations to provide position, navigation, and timing data. The positioning data is important for the manufacturers because the devices used for positioning send information of its status. A great challenge to this industry is easy access to space due to high cost. Therefore, special considerations have been given to the development of low cost hardware. The life cycle of the satellite is also short, which also contributes to the high cost factor.

There are various business cases of space data implementation. For example, a local company in Finland conducted an analysis of tree height that may disturb electricity distribution lines. In this case, space data is not directly being used for energy distribution but indirectly, for solving a problem. This type of innovative solution is difficult to come by for most firms. Space data have been used in the solar and wind industries to help understand the climate better and predict the weather. Space agencies around the world share data to study various problems including estimation of clouds' effect on solar radiation on long or short timescales as well as price fluctuations. While there is much interesting research related to space industry, commercial applications have a lot of room to fill other than estimating the prices of space data packages. Examples of product development opportunities from the interviews are presented in Table 3.

Table 3 Highlighting product development opportunities for research question 1

Examples from interviews	*Identified opportunities*
"Building forest inventory for Nordic customers requires intensive satellite data usage to create a product of high accuracy to investigate and detect bark beetle attack using data fusion. Remote sensing and artificial intelligence were used to create the product"	Data fusion (remote sensing and artificial intelligence)
"Positioning data is needed for many business sectors. Firms did not use to have information of the devices employed. However, new positioning devices send information of its health as well. This generate interest from various firms to utilize these devices"	Generated interest is value creation
"Sentinel 1 and ICEYE satellites are similar but different in its resolution because Sentinel 1 was designed to view big problems on the planet and ICEYE was not"	Education and skills

Space firms deal with managing big data, which brings its own complexity so they cannot always focus on what can be done with it. For example, Sentinel 2 data packages are images from a camera. How these images can be used to solve problems of social services and inequality through observation is another challenge. Data analysis and problem domain variables determine whether it works for the customers. The goal of the satellite firms also determines the solution it will provide. The firms understand the problems on the planet and the space industry has a better chance to provide relevant solutions. Knowledge gaps have to be closed in space data usage in industries that could solve problems on a large scale. There is value in having platforms that could address the problems on the planet relevant to the space data products. For example, the hardware of satellite and electricity distribution are technically very disparate. Satellite images may be a bridge to the gap between "cutting trees with chainsaws" and space data. The gap is currently wide, as "chainsaw managers" are not looking to incorporate space data in their businesses so a middle entity or a platform would help address the needs of the market and educate about the problem. If there is a common objective between firms on the ground and space firms and a clear value proposition, the solution can become a reality. There are also other tangible limiting factors including resolution, data engineering, downloading and scaling. Not all satellites have the power to produce and expand at the same time.

4.2 What Type of Space Data Products are Available in the Market that Can be Integrated in Product Development?

There are many types of space data products available in the market. Speaking strictly of CubeSat constellations, there are seven categories of space data products (see Table 2). This study categorizes space data products and services into three categories. (1) Earth observation and remote sensing, (2) Position, navigation, timing, and (3) Communication. The first category's products and services include all multispectral, hyperspectral, and SAR data packages. The second type is related to global position and navigation as well as time synchronization. The third group of products and services includes communication. These three categories cover all the space data products available to customers (see Fig. 1). Examples of product development opportunities are shown in Table 4.

Table 4 Highlighting product development opportunities for research question 2

Examples from interviews	*Identified opportunities*
"Leveraging AI and robotics along with space data in the same platform will enable businesses to utilize this industry at maximum extent. A new commercial sector takes time to grow due to the slow technological adoption. Space data is dependent on the hardware that require access to space. This is a supply chain issue. Once this issue is resolved, the suppliers and the contractors will have a better chance to address majority of the problems"	Resolving supply chain through networks
"There are many ways space data can be used to identify and solve problems. Activities related to piracy and oil leaks are responsibility of governments but private contractors can identify these problems as well. As soon as cost and benefits are analyzed, the problem can be resolved"	Funding and value creation
"Firms that serve society and identify climate change problems, they are likely to use space data for study and research. Space data is most suitable for large-scale problems. For example, ICEYE focuses on flood detection problem and not any others"	Problem solving through skills

In the space data economy, object detection plays a key role with optical and SAR data at high resolution. These data can be used to estimate temperatures, number of trees in a region, and for city planning. Space data make an impact when designers leverage robotics and artificial intelligence in the same platform. Incorporating space data can benefit businesses for solving an identifiable problem. The largest users of space data are governments. They assign tasks to various agencies to solve a problem by space data. Firms on the ground are trying to close the gaps between using space data and problem solutions. The technical infrastructure is in place but the lack of skill for using space data is a hurdle for many firms. There are risks associated with adopting space data, however the rewards for incorporating space data for solving problems can be high for firms. If space data is publicly available, firms do not need to manufacture the satellite from scratch and then fill the market demand cost efficiently. Thus, firms that are willing to use space data are already one step ahead in dealing with the complexity of manufacturing the satellite and launching it.

Firms that are tackling climate change problems, biodiversity loss, and pollution are likely to use space data. Space data would benefit the study of this problem, as these are multidimensional problems. For example, a main product of ICEYE is flood detection. The frequency of data production may be a key for solving some problems. It depends on the nature of application and the system's ability to generate data packages. For military applications, high frequency is critical. Forestry and agriculture may not need high frequency. Furthermore, speed is important for pest detection in forestry, natural disaster assessment, and electricity distribution. A local electricity distribution firm used helicopters for inspection of distribution lines. However, the manual inspection can be replaced by space data since "helicopters cannot fly in storms," they explained. The frequency of space data should be determined based on application and the system's capability for producing it. Some applications derive value from high frequency of space data. Space data firms provide simple to use products to firms that implement the data in business activities. Firms pay different prices for different applications. The cost of space data products and services can be determined by the production cost and understanding the customer needs. The cost of space data can be understood better by separating the space data from data analytics and data intelligence. The market will determine the cost by application specific solutions. It also depends on whether a firm is selling space data or analysis of space data, which is an important distinction.

4.3 How Do Firms Decide Whether to Use Space Data or Not?

One of the challenges that firms face when adopting space data is the unknown criteria of which the firm can benefit from. There are efforts made by satellite communities to provide examples for various applications. The value of knowing the problem that can be addressed by space data is existential. However, the solutions remain abstract. There is a need to break down the inquiry from a broader problem to sector level analysis and dispel any abstract solutions. The criteria for a firm to use space data broadly is the replacement of manual inspection outdoors. Furthermore, a business owner would also take into account the cost and benefits as well as timely advantages of space data adoption. These criteria can be evaluated by feasibility study. For example, a local company can hire ten employees for expansion but global expansion may require space data adoption. In this case, geographical scaling is another criterion. Examples of product development opportunities are shown in Table 5.

The firms looking to adopt space data in their business activities can expect particular outcomes from its value chain. These expectations may include (1) better decision-making capabilities, (2) increased revenue, (3) cost reduction, and (4) risk mitigation. There are various investment firms and financial institutions already using space data in investment models and financial models. The decision-making for these firms rely on space data to monitor the performance of a company. Start-ups should be critical in their feasibility analysis. Inaccurate understanding of customer needs can bankrupt a space company. The amount and abilities of space start-ups should justify the demand of space data products.

The infrastructure for space firms is available to support product development. There are many firms providing small platforms using space data. Conventionally, the big firms provide platforms for small firms in communications. Communication satellites provide a platform for companies and remote sensing satellites provide earth observation. The concept of platform is also disturbing to some companies due to the lack of trust. For example, there are four major global navigation systems including GPS,

Table 5 Highlighting product development opportunities for research question 3

Examples from interviews	*Identified opportunities*
"It is important to determine the size of the market for space data solutions. Are there enough customers and what the state of competition in that area is"	Problem solving
"Investment firms use space data for investment and financial modeling"	Problem solving and skills
"Big firms provide platforms for small companies that can be used to create products and services for customers"	Value creation and problem solving

GNSS, GLONASS, and BDS. The existence of different global navigation is proof of distrust among nations. Similarly, firms compete to make a better product than others do, using their own platforms due to distrust and geopolitical reasons. The development of the space data economy is progressing slowly. The reason is that the gap closes in some business activities and not in others. Recently, solving problems with space data can be seen. However, not all areas of business will see the integration of space data. Despite the existence of motor vehicles, between 1890 and 1920, mobility relied mainly on horses before suddenly changing. Similar trends were seen for the adoption of the internet in the 90's. It generally takes one generation for technological adoption.

4.4 *What are Space Data Opportunities for Product Development?*

This section briefly summarizes the outcome of product development opportunities shown in Table 6. The essence of opportunity development related to space data knowledge gathered from the interviews are highlighted in Table 3–5. There are five important aspects of opportunity development presented in Table 6, which include value creation (Alvarez et al., 2013; Schneider, 2019), network (Filser et al., 2020), problem solving (Korsgaard, 2011; Ojala, 2016), skills (Filser et al., 2020), and funding (Filser et al., 2020). There are six key parameters selected from the research questions to justify integration of space data in business activities. These parameters include technological advantage, space data integration, space data platform, space data infrastructure, space data frequency, and space data expected outcome. It was found that funding and networks for space data products and services are available. There were many observable problems being solved by using space data products in various business sectors. Furthermore, there is an enormous gap in many industries that can be bridged by space data products and services leading to value creation. However, there is a mismatch of skills needed to implement space data in business activities. The major reason for this mismatch was the required knowledge needed for various business sectors and identification of problems that could be observed by satellites. In addition, a separate set of skills were required to implement space data in business activities.

Table 6 Available opportunities of space data for product development

Parameters	*Value creation*	*Network*	*Problem solving*	*Skills*	*Funding*
Technological advantage	A	A	A	PA	A
Space data integration	A	A	A	PA	A
Space data Platform	A	A	PA	PA	A
Space data infrastructure	A	A	A	A	A
Space data frequency	PA	A	A	PA	A
Space data expected outcome	A	A	A	PA	A

1. A is for available
2. PA is for partially available

5 Discussion and Conclusions

This study aimed to highlight important questions lingering in the new space. The current research work in this domain is application specific. The biggest challenges hindering the space data economy were found to be unclear value propositions, lack of skills, and need for education. Firms involved in new space require government grants and funding to optimize the business model. To address these challenges, the study investigated three major questions corresponding to value proposition, space data products and services in the market, and the criteria used to adopt space data. It implemented opportunity development theory to identify the key parameters of space data adoption that can benefit a firm. Further, the study found that space data primarily deals with the problems on a large scale that are observable by satellites. These problems may relate to remote sensing, navigation, or communications. Remote sensing provides data from various sensors including multispectral, hyperspectral, and synthetic aperture radar. Navigation data mainly includes positioning information while communications satellite data provide infrastructure. The study also found that the frequency of space data generation is application specific. Some applications can benefit from near real time space data production. The frequency of space data production is also dependent upon the hardware capability and budget, thus frequency data generation would increase the cost significantly.

5.1 Theoretical Implications

This study contributes to business research by combining insights from the new space sector into opportunity development theory. Firstly, opportunity development theory was used as a foundation for the development in the new space. The questions for the interviews were developed using the essence of opportunity development literature. The questions were specifically developed to collect data on value proposition and product development (Alvarez et al., 2013; Schneider, 2019). While space data utilization has always been for defense purposes till now, many new businesses have been taking the opportunity to incorporate the publicly available space data in their business activities to create value. The research questions also reflect on the nature of problem solving in the market (Korsgaard, 2011; Ojala, 2016). Currently, the most successful applications of space data are insurance claims for natural disasters and agricultural monitoring. Space data provides solutions to large-scale problems. Furthermore, the study refers to the skills and resource exploitation of space data (Filser et al., 2020). The applications of space data requires various sets of skills and multidisciplinary approaches.

Secondly, the study provides a theoretical aspect on the progress of space data applications by demonstrating the benefits in the agriculture sector (Vuran et al., 2018). Crop health detection and water management have been the top products in agriculture. However, the cost of incorporating high tech products could be unaffordable for farmers. Insurance and transportation has been at the forefront in the adoption of space data (Ardila et al., 2022; Kuntla, 2021; Perboli et al., 2021). Furthermore, mining and environmental impact assessment are benefitting from space data (Maus et al., 2020), in addition to oil and gas leak detection. Although, space data provides asset monitoring on mining sites and oil leakage in the ocean as added value to the business performance. However, these applications are useful for government law enforcement. The study also emphasized on the importance of space surveillance and avoiding space pollution (Béal et al., 2020; Wang et al., 2022). The future of new space depends on the infrastructure and management of space activities that are highlighted in the study for a sustainable space data adoption.

Finally, the study implements the essence of opportunity development theory to gather key insights of space data availability for product development. The study focused on five essential parameters from opportunity development theory including value creation (Alvarez et al., 2013; Overholm, 2015), funding (Filser et al., 2020), solution to a problem (Korsgaard, 2011), and skills and network (Filser et al., 2020). These parameters were considered to be the foundation of space data integration in business activities. Furthermore, the study provides key indicators of space data availability for adoption in businesses including technological advantage, space data integration, platform, infrastructure, frequency, and expected outcome. The findings of the study enhance our understanding regarding opportunity development by emphasizing the importance of large-scale planetary problems. Problem scale (large or small) is an important factor to be considered in opportunity development when leveraging space data.

5.2 Practical Implications

This study provides a guide for small to medium firms on the opportunities available in the domain of space data utilization for various business activities. The practical aspects of integrating space data can be decoded in three ways. Firstly, firms should focus on how space data create value in their business activities (Schneider, 2019). Value creation does not strictly refer to monetary value. However, a sustainable business proposition requires a monetary aspect. Space data provides technological advantages and eliminates manual inspections from observable problems on the planet (Korsgaard, 2011). Firms should look into the possibility of solving a problem using space data that may not be solved by other technologies. The use of space data also requires skills and knowledge in various disciplines. Firms should be ready for skill development that is necessary to be successful in space data adoption (Filser et al., 2020). There are various funding and growing networks available in Europe for space data related activities. Firms should not try to reinvent the wheel by focusing on the development of satellites from scratch to match their application specific needs, instead they should identify appropriate platforms and infrastructures already available. Firms should try to follow the market development and conduct feasibility studies to facilitate their decision-making for adoption of space data.

Secondly, there are various space data products and services already available in the market for businesses. For example, the Copernicus project provides SAR data, multispectral data, and climate data freely to create data products and services. Firms that are looking for global expansion may consider these products and services to benefit their business performance and practice business model innovation. The space sector can make a great impact on all existing businesses. The ramifications for avoiding space data integration may be higher than one can anticipate. Nonetheless, it is important to make sure the applicability of space data is feasible. The cost of space data plays an important role in its adoption but the risk to reward justify the investment. Firms should also consider the frequency and resolution of space data products and services. Both frequency and resolution depend on scale of application as small-scale applications may require high frequency and vice versa. The best emerging space data practices include:

- Investment firms use space data to create financial models and investment strategies including oil prices and energy prices;
- Space data can be used to track livestock and manage crops;
- Space data is used to monitor tree growth around electrical power lines;
- Firms use space data to detect flooding and calculate insurance claims;
- Agricultural and forest health monitoring has been done using space data.

Finally, firms should consider all the necessary criteria before incorporating space data in business activities. Conventionally, firms jump on the opportunity of available funding without considering the feasibility of space data adoption for their businesses. If a customer is unwilling to pay for a solution based on space data, it is unwise to develop that product or service even when the funding is available. Without a usable product or service, funding will only prolong the failure. So how should firms avoid making this mistake? Firms should consider the key essence of opportunity development theory. The first is value creation, which means customer-centric product development. A customer should be willing to pay for a product made by using space data. The second is problem solving, which means a space data product or service should provide a solution to an existing problem that may have not been solved otherwise. The third is skill and network. Space data products require skills in various disciplines and examples from hands on experience. Firms should consider their own ability to navigate through multiple layers of education and skills before applying for space funding.

5.3 Limitations

This study provides insights into the use of space data in business activities by gathering information through interviews similar to any empirical study. However, the quantity of interviews could be expanded by including more data from other experts in the field. The first shortcoming has to do with information gathering from diverse business sectors to have a concrete understanding before generalization of the subject. The second factor that limits this study is the integration of two separate fields of study including business research and space research. Most of the literature available on the space sector is technologically driven. However, it was challenging to relate these two fields of research. The third limiting factor is that the study provides few parameters to consider before the adoption of space data. However, these criteria could be expanded depending on the nature of the business sector.

Acknowledgements The author would like to thank the participants who delivered valuable information for this study including Kendall Rutledge, Jaakko Yliaho, Rolf Schmitz, Pravin Luthada, and Ali Arslan. The author would also like to thank the editors: Arto Ojala and William W. Baber.

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Suborbital Space Tourism: Doozy Experiences Beyond Earth

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1 Introduction

This chapter focuses on the emerging field of suborbital space tourism, which involves suborbital space flights lasting about two hours, which allow travelers to experience high speed, five to ten minutes of weightlessness, and a view of Earth from space.

Past space tourism studies contribute with knowledge on consumers' motivations (Kim et al., 2023; Laing & Frost, 2019), interests (Gianchino et al., 2021), the role of personal involvement, motivational factors, and risk perceptions (Wang et al., 2021), and public opinion regarding the sustainability of space tourism (Toivonen, 2022). That said, these studies have focused on space tourism by surveying potential travelers or travelers showing an interest in space tourism (e.g., Kim et al., 2023; Olya & Han,

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_11

2023). Despite the contributions of past studies, little is known about the experiences of actual space travelers.

The study presented in this chapter builds on two yet-to-be-understood issues. First, our study adds to the literature of space tourism by focusing on travelers' experiences, including their expectations, hopes, and fears related to space tourism. With a focus on experiences, the underlying premise is that experiences occur in various phases of the entire journey. Past research shows that each of these phases—pre, during, and after—plays a crucial role in shaping the holistic travel experience (Björk & Kauppinen-Räisänen, 2016; Helkkula, 2011; Lemon & Verhoef, 2016). Second, by focusing on a unique sample of individuals—actual space travelers—our study advances the literature by providing insights from firsthand space travelers. To the best of our knowledge, there are few earlier studies focusing on individuals who could genuinely be classified as space travelers. Hence, our study offers valuable insights from a unique cohort of travelers who have demonstrated a genuine commitment to space travel by actually purchasing tickets.

With its roots in prior discussion, this chapter delves into the experiences of actual space travelers, focusing on their experiences along the entire journey.

To meet the study aim, we designed a qualitative study using mixed methods. For exploratory purposes, we conducted in-depth interviews with three space travelers. These interviews are particularly insightful as they encompass a range of experiences, offering a diverse perspective on how travelers experienced the entire journey. To add to these interviews, we analyzed publicly accessible interviews with six space travelers who have participated in suborbital space flights. Then, to validate the findings, we reviewed archival data.

With the selected approach, the study contributes with several insights. First, it contributes with an insightful understanding of the unique circumstances of space travel and the lived experiences of the travelers during the entire journey. We also introduce the concept of "doozy tourism" to illustrate the specific nature of space tourism, which we characterize as being a niche of luxury tourism. At its best, luxury space tourism is built on creativity, excellence, and exclusivity in accordance with the definition by Cristini et al. (2017). Third, the study contributes to the literature of experiences by showing how experiences within space tourism consist of four phases. The first two phases—the signing of the contract and the prolonged waiting period—comprise the pre-phase. The next two are the core flight and the post-return phase. The study also contributes with managerial implications, which attempt to guide further development of space tourism, and the services provided by the luxury tourism sector. This includes crafting unique and memorable travel experiences, taking into consideration the entire space voyage, including its prolonged pre-phase.

The rest of the chapter is organized as follows. First, the theoretical framework is presented. It elaborates on space tourism, existing research on potential space travelers and their interest in undertaking a space flight, and the construct of experiences. It then discusses the study design and presents the findings. The chapter ends with conclusions and suggestions for future research.

2 Space Tourism and Reasons to Travel in Space

2.1 Space Tourism and Its Various Forms

Conquering space has been one of the dreams of humankind. The first milestones in the conquest of space are the flight of a dog (1957), a monkey (1961), a human Yuri Gagarin (1961), and Apollo 11 (1969). Since then, space tourism has evolved to be accessible for both professional and non-professional astronauts (e.g., Futron, 2002). The first paying space traveler was officially announced in 2001, when Dennis Tito crewed together with a professional astronaut and spent a week aboard the International Space Station (ISS) (*Time Magazine*, 2022). 2021 was a landmark year for space tourism with several successful suborbital space flights. Virgin Galactic, Blue Origin, and SpaceX were among the key companies providing more accessible flights marketed to a broader public (Grand View Research, 2023).

A suborbital space flight lasts about two hours, including five to ten minutes in weightlessness, priced at about USD 450,000. While suborbital flights are cheaper than orbital flights to the International Space Station, space travel remains exclusive and the most expensive mode of transportation (Abeyratne, 2013; Hobe, 2007). Despite its prestige pricing, it is predicted that advances in suborbital flight will lead to an increase in space tourism through declining prices and an expansion in accommodation in space (Futron, 2002). The vision is that commercial space tourism will become a reality thanks to technological advancement and a rising trend in individual adventure-seeking even if its sustainability is questioned (Cohen, 2017; Peeters, 2018; Toivonen, 2022). This trend is also seen in market size forecasts. The global space tourism market was valued at USD 695.1 million in 2022 and is expected to reach USD 815.7 million in 2023. It is expected to grow at a compound annual rate of 40.2% from 2023 to 2030 to reach USD 8,669.2 million by 2030 (Grand View Research, 2023). The growth potential is clear: So far, only dozens of travelers have flown to space, but according to Statista (2021), 49% of United States adults would want to travel to space if money was not an issue.

Space tourism can be defined as commercial space travel for leisure and recreation characterized by the experience of weightlessness and celestial observation (Chang, 2017; Cohen & Spector, 2020; Zhang & Wang, 2022, p. 372). Space tourism can take various forms and is typically divided into terrestrial space tourism, atmospheric space tourism, and astrotourism.

Terrestrial space tourism includes activities on the ground and virtual space experiences. For example, Finnish Lapland is a popular destination to witness the Northern Lights and explore the universe using the naked eye. Also, scientific organizations and entertainment businesses, such as the Kennedy Space Centre or Future World at Disneyworld, frequently provide this type of tourism (Wang et al., 2021).

Atmospheric space tourism includes excursions to Earth's atmosphere, such as zero gravity flights or high-altitude flights, while *astrotourism* includes journeys in and beyond Earth's orbit. (Cater, 2019; Crouch, 2001; Toivonen, 2022). Within astrotourism, there are three types of orbital space tourism: *orbital*, *suborbital*, and *beyond orbital*. Orbital journeys have a longer duration, require higher speed, and operate a "few hundred miles above Earth's surface" while being extremely expensive. Extensive weightlessness, a possible stay at a space station, and multiple sunsets and sunrises as the space station orbits the Earth might all be included in this experience. Suborbital space tourism involves short visits to 50–70 miles above Earth, typically above the so-called Kármán line. The experience involves a few minutes of weightlessness and the sight of the Earth against the blackness of space. These journeys require less speed and are less expensive than orbital travel, and will thus be the most prominent area for space tourism in the coming years (Clash, 2022; Kim et al., 2023). Finally, travel beyond orbital space goes even further and may include experiences such as circling the moon or even flights to the Moon and Mars (Crouch, 2001; Toivonen, 2022). While acknowledging the broad scope of potential activities within space tourism, our study limits itself to commercial suborbital space travel.

2.2 Reasons Inspiring Interest in Space Tourism

Research on individuals who could genuinely be classified as space travelers is practically nonexistent. Instead, past studies have focused on potential travelers who are interested in space travel. In doing so, previous empirical studies have identified various traveler segments and not only a range of reasons inspiring potential travelers' interest in space travel, but also reasons hindering interest in such tourism.

Space travel appeals to certain types of individuals. For example, Reddy et al. (2012) identified two distinct types—extreme sports enthusiasts and wealthy leisure travelers—while Kim et al. (2023) characterize various types of travelers interested in orbital and suborbital space tourism. According to them, young, educated, professional males comprise the main target group for orbital space tourism whereas older, married, high-income individuals define the suborbital group. This is unsurprising, given that although both types of space travel demand an adventurous mindset and substantial financial resources, an orbital flight imposes greater physical health requirements. Indeed, Masson-Zwaan and Freeland (2010) suggest that space tourism is tailored for a group of travelers who are willing and able to accept the associated risks. Similarly, Mehran et al. (2023) found that space tourism is particularly appealing to individuals who are drawn to risk-taking and seeking novel experiences. To conclude, past studies highlight the existence of distinct segments: from extreme sports enthusiasts to wealthy leisure travelers, and from young, educated professionals to older, high-income individuals at quite a general level.

Various reasons are found to drive interest in space tourism (e.g., Giachino et al., 2021). First, the "vision of earth from space" appears as the most important reason to potentially travel to space (Futron, 2002; Reddy et al., 2012; Wang et al., 2021). Second, potential travelers are driven by interest in "the experience of weightlessness," or "zero gravity," that is, the physiological sensation associated with space travel. For example, Reddy et al. (2012) found that 44% of the British respondents identified weightlessness as a very important motive to travel to space. Third, potential travelers are motivated to embark on a space journey due to a desire for unique and thrilling adventures. This desire includes exploration of new areas, being at the forefront of new endeavors, accomplishing feats that have never been done before, and experiencing the excitement of the unknown and testing one's own limits (Chang & Chern, 2016; Mehran et al., 2023). In the published studies on potential space travelers, the highlighted motivations for traveling to space include the desire to experience something unique and unusual (Wang et al., 2021), the unusual nature of the experience (Reddy et al., 2012) and the experience of high speed (Reddy et al., 2012). "Uniqueness" may include actions such as "riding a spacecraft" or "being able to walk in space" (Wang et al., 2021). Within the field of space tourism, this uniqueness is combined with adventure and excitement, high risk, and even danger. Typically, potential travelers value "the experience of excitement" or "thrill" (Futron, 2002; Laing & Frost, 2019; Wang et al., 2021) (Table 1).

In addition to issues motivating potential travelers to consider a space flight, research has uncovered what discourages interest in such tourism. Not surprisingly, the main reason limiting interest in this experience is its high price (Chang & Chern, 2016). Another main set of reasons hindering space travel typically consists of danger and safety concerns. For example, Reddy et al. (2012) found that risk is the primary reason why potential tourists would not be willing to travel into space, which is consistent with earlier research (Wang et al., 2021). Indeed, space tourism is intended for a distinct and limited group of individuals who have the means and are willing and able to embrace certain risks, particularly those who are risk-takers and novelty seekers (Giachino et al., 2021; Mehran et al., 2023).

There seems to be a limited number of studies focusing on not only actual space travelers, but also on exploring travelers' experiences, including their expectations, hopes, and fears related to space tourism. The following section attempts to define the multifaceted nature of the construct of experience, and explicitly experiences within tourism.

2.3 The Multifaceted Nature of Tourism Experience

The concept of experience—as gained through travel, for instance—is complex and has many different aspects. Essentially, experiences can be categorized along a spectrum ranging from extraordinary to ordinary (Björk & Kauppinen-Räisänen, 2016). Extraordinary experiences encompass those that are perceived as unusual, distinctive, and novel (Arnould &

Table 1 Summary of the main findings of the earlier research on potential space travelers' motivations to travel to space

Author(s)	*Purpose*	*Empirical context*	*Findings*
Kim et al. (2023)	The study examines what factors make consumers participate in orbital and/or suborbital space tourism	A questionnaire was carried out with respondents who wanted to participate in orbital (n = 332) and suborbital (n = 332) space tourism in the future	Both intrinsic and extrinsic motivation have a positive impact on intention to participate in space travel. The two types of space tourism have very distinct characteristics
Gianchino et al. (2021)	The study investigates the views of younger generations towards space tourism	Combination of qualitative and quantitative data. Northwestern Italy. Focus group, survey, n = 2027	Highlighted an interest in space tourism, although motivated by different reasons, levels of budget and sustainability aspects. Interest in space tourism varies according to the extent to which it is perceived as potential, possible or sustainable, or to people's personal feelings
Wang et al. (2021)	The study investigates factors that affect enthusiasm for becoming a suborbital space tourist among those who are interested in space exploration and, at the same time, are younger and educated	US, online survey, n = 166	Most important motivations: a quest for unique experiences, excitement, seeing the beauty of the Universe, and making a scientific contribution

(continued)

Table 1 (continued)

Author(s)	*Purpose*	*Empirical context*	*Findings*
Olya & Han (2020)	This study investigates the triggers and concerns of behavioral intentions of potential space travelers	Survey, US, online panel, n = 370	Although motivations appeared as sufficient and necessary antecedents, risk antecedents play a dominant role such that risks can diminish the effects of motivations in shaping the desired behavioral intentions of space travelers
Laing and Frost (2019)	The study investigates the motivations of potential space tourists	Qualitative, interviews with four proposed space tourists conducted, as well as an analysis of four published interviews with two individuals who had flown to the ISS as space tourists: Mark Shuttleworth and Greg Olsen	Four types of motivations identified: hedonic motivations (such as thrill-seeking or risk-taking), eudaimonic motivations (such as challenge, curiosity, spirituality, and nostalgia), and extrinsic cases (such as seeking distinction or a desire to motivate and assist others)
Reddy et al. (2012)	The study examines the perceptions of potential space travellers' motivations, behaviour and decision-making	Self-administered survey with quantitative and qualitative questions. Ordinary people, South England, n = 164	Reasons to travel: Vision of Earth from space, zero gravity, unusual experience, high speed experience, scientific contributions. Reasons not to travel: too risky, enough destinations on earth, environmental concern, health problems
Futron (2002)	The survey examines the demand for space tourism	Market research, 450 telephone interviews, survey	80% of respondents are interested in space travel. Reasons to travel: being a pioneer (24%); seeing Earth from space (15%); lifelong dream (12%); space enthusiasm (7%); other (25%). Main reason not to travel was the cost

Price, 1993), while ordinary experiences pertain to those that are considered common, which potentially occur on a regular basis and may even be routine (Carù & Cova, 2008).

The concept of a tourism experience is often described as the interplay between the routine of daily life and the different extraordinary worlds that we encounter while traveling. This interplay or interaction is particularly visible when there are changes in the usual temporal and spatial structures that people are accustomed to (Binkhorst & Den Dekker, 2009). For example, when travelers visit various places, they seek authentic, rewarding, meaningful, multisensory, and even transformative experiences (Hosany et al., 2022). Some researchers point out that people seek experiences for the means of self-fulfillment and self-actualization, such as to fulfill a lifelong dream, sometimes originating from childhood (Futron, 2002; Reddy et al., 2012).

Experiences are multifaceted in nature, as they involve mental, emotional, physical, social, and sensorial factors (Becker & Jaakkola, 2020; Kauppinen-Räisänen et al., 2013). They are also defined to be subjective, situational, and contextual (e.g., Becker & Jaakkola, 2020; Carù & Cova, 2008; Kauppinen-Räisänen et al., 2013). In the context of tourism, this means that travelers' values, beliefs, interests, backgrounds, past experiences, and expectations lead to different experiences of the same tourism offering. It also means that the same traveler may experience an activity differently at various points in time, and also implies that the setting influences how an event or activity is experienced and perceived. This view highlights how experiences are co-created through interaction (Campos et al., 2018; Jaskari, 2023; Kauppinen-Räisänen et al., 2019).

3 Methodology

In order to gain an understanding of committed space travelers' experiences, we designed a qualitative study using mixed methods. Our approach combines three one-to-one interviews, analysis of published interviews with six space travelers, and archival data.

3.1 Data Gathering

Our one-to-one interviews consist of three interviews with space tourism customers who have bought a ticket for a suborbital space flight, thereby demonstrating their commitment and engagement with space travel. All three bought a ticket from Virgin Galactic. One of the participants has completed the flight (Namira Salim, Astronaut 019) and one has been waiting since 2010 and is expected to fly in 2026 (Vesa Heilala, Future Astronaut). Although the third ("Claire") eventually canceled her purchase, our interview with her provided a unique opportunity to explore experiences of the waiting period.

Participants for the study were recruited utilizing personal networks as well as public media channels. The group comprises two females and one male, representing a diverse array of cultures including French, Monégasque-Pakistani, and Finnish. Notably, two participants identify as Monégasques, citing their residency in the Principality of Monaco as a significant aspect of their identity. This diversity ensures that the interviews conducted outside the traditional realm of press and media relations offer a variety of unique perspectives on the experiences associated with space tourism.

The interviews were carried out in the Principality of Monaco and Finland during the autumn of 2023. Each interview session varied in length, lasting anywhere from 30 minutes to an hour. Adopting an open and discursive approach, the interviews primarily centered on the interviewees' personal experiences with space tourism. For the purpose of thorough analysis, each interview was transcribed and translated into English. Notably, Claire, who was reimbursed for her ticket, expressed a wish to remain anonymous and thus a pseudonym is used. She prefers not to leave any personal trace online regarding her space tourism experience. We closely followed the websites of the two other interviewees in order to gain insight: www.namirasalim.com and Vesa Heilala's blog "*The Finnish Astronaut: Dream—Wish—Opportunity*." Table 2 summarizes the background information from the three one-to-one interviews.

Our data also consists of public accounts by six space tourists. Four of them have taken part in Virgin Galactic flights, through Mission: Galactic 02 or 03, and one flew on a SpaceX Crew Dragon. Combined with public websites, their accounts allowed us to gain rich insights into the actual experiences of space travelers in different phases of their journey, while the various sets of data also served a validating purpose. Table 3 summarizes the background information on these six space tourists.

Before conducting the interviews, we participated in a conference held by an international space travel organization in the Principality of Monaco, where we had the opportunity to meet various professionals in the field. During this event, we collected a range of materials

Table 2 Background information from one-to-one interviews

Name / pseudonym	*Gender*	*Country of birth*	*Country of residence*	*Background*	*Type of interview*	*Social media and websites*
Astronaut 019 Namira Salim	Female	Pakistan	Monaco	Bought ticket in 2006. Took part in Spaceflight Galactic 02 on 10 August 2023, being the first Pakistani woman to fly to space	Face-to-face	https://www.namirasalim.com/ https://www.instagram.com/NamiraSalimOfficial/?hl=fr
Future Astronaut FA1 Vesa Heilala	Male	Finland	Finland	Ticket bought in 2010, first expected to fly in 2013, now expecting to fly in 2026	Face-to-face online	www.suomalainenastronautti.fi https://www.facebook.com/SuomalainenAstronauttiVesaHeilala
Former future astronaut Claire (pseudonym)	Female	N/A	N/A	Ticket bought in 2013, cancelled the flight in 2015	Face-to-face	N/A

Table 3 Background information and public accounts use of six actual space tourists

Space travel company	*Name of the astronaut*	*Nationality*	*Background*	*Data sources used*
Virgin Galactic space travelers	Astronaut 011 Jon Goodwin	UK	One of the first to sign up for a space flight. He competed in the 1972 Olympic Games. Flew on Spaceflight Galactic 02 on 10 August 2023	https://www.virgingalactic.com/virgin-galactic-astronauts https://www.ynetnews.com/article/bycrqtm2h
	Astronaut 012 Keisha Schahaff	Antigua & Barbuda	Flew on Spaceflight Galactic 02 on 10 August 2023	https://www.virgingalactic.com/astronaut-bio-keisha-schahaff https://www.bbc.com/travel/article/20230830-whats-it-like-to-win-a-trip-to-space https://www.youtube.com/watch?v=XcrDuHS36Ys
	Astronaut 013 Anastatia Mayers	Antigua & Barbuda	Flew on Spaceflight Galactic 02 on 10 August 2023	https://www.youtube.com/watch?v=XcrDuHS36Ys https://www.virgingalactic.com/astronaut-bio-anastatia-mayers
	Astronaut 014 Ken Baxter	USA	Flew on Spaceflight Galactic 03 on 8 September 2023	https://www.virgingalactic.com/virgin-galactic-astronauts https://www.youtube.com/watch?v=-tb2BUmFsqA

(continued)

Table 3 (continued)

Space travel company	*Name of the astronaut*	*Nationality*	*Background*	*Data sources used*
				https://web.archive.org/web/20080127132016/
Mission SpaceX Axiom	Mark Pathy	Canada	A businessman who travelled to the International Space Station for 10 days	https://www.youtube.com/watch?v=sKOpxBH2XRE https://www.lapresse.ca/actualites/2022-07-02/un-montrealais-dans-l-espace.php
Soyuz TMA-16	Guy Laliberté	Canada	Businessman and founder of Cirque du Soleil. Wanted to be "the first clown in space" Travelled to the International Space Station on 30 September 2009	https://montrealgazette.com/entertainment/theatre/guy-lalibert-docks-safely-at-the-international-space-station https://www.youtube.com/watch?v=Lpe8dkpKK3U

to gain a deeper understanding of the procedural aspects of space tourism. Engaging in face-to-face conversations with space professionals and astronauts, we conducted pilot interviews to comprehensively grasp the context of space tourism. These discussions also helped us gather insights into the process and test the terminology commonly used in the space tourism sector. We also conducted an industry interview with the President of SpaceLand. These experiences significantly bolstered our preparations to collect qualitative international data. Finally, we gathered a diverse set of archival data including, for example, media texts and TV programs about space travel in order to gain deep contextual understanding.

3.2 Data Analysis

The data underwent an abductive qualitative content analysis, adhering to the methods outlined by Miles and Huberman (1994). Initially, the English transcriptions of the interviews were read multiple times to capture the essence of the overall experiences of the interviewees. Each author conducted a preliminary analysis, focusing on the intriguing aspects of the interviewees' experiences and their unique ways of expressing ideas and thoughts. This initial approach allowed us to analyze the data with an open mind, starting from the ground level. Following that, our initial interpretations were discussed collaboratively, leading to a more targeted analysis guided by specific research questions.

First, the interviews were scrutinized with "what" and "how" questions to uncover the nature of the interviewees' experiences and how they explained their thoughts and feelings. This technique enabled us to construct case narratives (Sect. 4.1), where the core elements of each experience are presented in narrative form. The core narratives were compared and enriched by using secondary data from the interviewees' websites. The case narratives have been approved by the interviewees. In the subsequent phase, we expanded our data to encompass public interviews with six space tourists. This data was analyzed with a focus on their lived experiences along the various phases of the journey. This stage of the analysis enabled us to verify the two pre-phases of the four phases encompassing the entire journey (Sect. 4.2).

4 Findings

4.1 Narrative Experiences by Three Space Travelers

In this section, we delve into the narratives of three distinct participants. Each narrative is intended to enable readers to deeply immerse themselves in it and vividly experience the journey. By giving voice to our participants, we highlight the unique aspects of each case, emphasizing the personalized nature of space travel experiences, and thereby enriching the reader's understanding of this extraordinary field. These narratives have been constructed from one-to-one interviews and supplemented by secondary data.

The three narratives reveal that all three share a passion for space that began in childhood and which they have pursued throughout their lives in activities such as their studies and hobbies. For all of them, space travel was a dream that they wanted to turn into reality. This passion for space was also evident to their peers: Families, friends, colleagues, and other people all knew about their passion. Their peers supported their passion wholeheartedly. However, when they made the commitment to travel to space, e.g., they bought their ticket, sometimes their peers were worried about the safety of their loved ones.

4.1.1 The Passionate Astronaut Namira

It was a dream for me. It is my DNA. As a child I was always dreaming of going to space. Then, as a teenager, I was very confident—I told everybody in my family I was gonna go to space, that I would become an astronaut. I didn't know how I'd become an astronaut, but I just believed in it. If you want to make your dreams come true, the most important thing is to believe in them strongly.

My parents always knew that, so when I was 14, my father bought me a telescope. I was the first female member of the first Astronomy Society of Pakistan. Among my other studies, I studied art and used space as my inspiration. Space has been my whole life.

It was in 2005 that I found out that Richard Branson was going to create a spaceline—the first in the world—to take people to space. When I saw the news at home, I immediately called Virgin Galactic and said that I wanted to buy a ticket. I was the first person from Pakistan and the first person from Monaco.

I wanted to keep it private. We didn't do any press releases. But surprisingly, after buying a ticket, I was introduced to the entire Pakistani nation of 230 million people. As Namira Salim, I was the first Pakistani astronaut. So, it's like a major dream come true for a little girl growing up in Pakistan, not in America.

My mother was worried and thought it wasn't safe. My parents wanted to stop me, but I didn't listen to them.

My friends whom I went to school with were so proud of me because I've been on the front page of the news in my country. I couldn't believe it; it was an emotional experience as well. What kind of headlines? In Pakistan, it was "she made history," "she has gone to space," "she actually comes back to space," and "she is safe, she is back," "she took the flight." Everybody, including my family, feels that I made our country proud!

4.1.2 The Expectant Astronaut Vesa

Ever since I was a child, traveling to space has been my dream. My fascination began with the colorful pages of *Avaruusmatka* comics, enthralling episodes of *Star Trek*, and the captivating universe of *Star Wars*. I still vividly remember Christmas when I got a Lego rocket at the age of seven. That was the spark that ignited my lifelong aspiration to journey beyond our atmosphere.

I bought my ticket for a space flight back in 2010. At that time, I was led to believe that my turn would come in 2013. I bought my ticket from the travel agency, and got a lot of publicity. I've been interviewed several times on television and in the newspapers. I remember being interviewed for the first time, and the response was overwhelming. My website, which I had set up to chronicle my journey, got over 100,000 page views in a single day. Messages poured in from friends and strangers alike, some expressing surprise, others offering their support and sharing in my excitement. But my friends—they were not surprised. For them, it wasn't news at all that I was the one to buy the ticket.

Space travel hardly ever sticks to the timetable, and it's the same with my trip. I've used this time not only to feed my curiosity but also to engage in related activities. I've had the opportunity to visit SpacePort America, meet Branson briefly, try a centrifuge, have a beer with an Apollo astronaut, and visit interesting places and meet interesting people. All these experiences have brought me closer to the reality of my dream. I've also been involved in the CanSat project, which allows me to work on miniature satellites—a small-scale version of space exploration.

I'm still waiting for my turn. I've counted that I should be on flight number thirty-five. Despite the delays, my excitement hasn't waned. I look forward to the day when I'll witness the Earth from a perspective few have had the privilege to see—the profound darkness of space, the vibrant colors of our planet, the sensation of speed, and the thrill of the unknown.

4.1.3 The Cautious Astronaut Claire

Ever since I was a child, I've wanted to be an astronaut. I've always had a love of space. I take pictures of stars all the time. I want to see the curve of the Earth. That's what I want to see. The curve of the Earth. Through my own eyes.

I bought a ticket in 2012. And I was supposed to officially fly three years later. I could've been the first one in my country. I could've been the first of my gender and my age. I had the possibility, and it was a good opportunity for people like me who were never able to become professional astronauts.

I went to visit SpacePort America in 2013. There was an official presentation of the shuttle with Branson and all the registered future astronauts. We were all there, almost all the people who were registered. At least a hundred. There were a lot of space lovers, as expected. Of course, they are different kinds of persons: All were space lovers, but like everywhere also there was a little bit of pretentiousness. I realized once I signed up that this could bring me other things. The link with other space lovers and a network, yes, also a business network, of course, as always. I'm still in contact with some of those who are still registered.

Except, that in 2014, the shuttle exploded during the last test phases. Then my family started to get a little scared and I'd always said that if there's someone in my immediate family who doesn't feel comfortable with this, I wasn't going to go there. They were too scared for me. That is why I cancelled.

From the beginning, I didn't want to have anything to do with publicity, I didn't want this to be known. But then my name leaked in the press. It turned into carnage. I had the media calling every day. I found myself on the front page of many newspapers, with conspicuous headlines. It hurts. I was just doing it to pursue my passion. Then death threats were sent to me, my family, and my friends. I had to go back to live with my parents because being all alone in my apartment wasn't safe. It lasted more than six months. I think it was because of my age and maybe my gender. There was another Frenchman who'd sold his house to buy the ticket. He was never bothered.

I love space. There isn't a trip that I take without looking at the phases of the moon to find out if I can take pictures of stars. If tomorrow you were to tell me that we must go spend a week in space, on Mars, I'd leave tomorrow.

4.2 Experiences in Different Phases of Space Travel

Past research stresses that experiences occur in various phases of travel—before the journey, during the core journey, and afterwards—each playing a crucial role in shaping the holistic travel experience (Björk & Kauppinen-Räisänen, 2016; Helkkula, 2011; Lemon & Verhoef, 2016).

In our study, all participants stressed that the pre-phase stage is divided into two phases, one of which is the prolonged waiting period. Hence, our study adds to the existing knowledge on experiences by revealing that they occur in four essential phases which all contribute to the overall travel experience.

4.2.1 The Phase of Contract Signing—Ticket in Hand

The first step in the travel process is characterized by the traveler's signing of the travel agreement, which marks the decision-making point. This step is significant because it demonstrates the traveler's engagement and commitment in the space journey. For early travelers, the decision to buy the ticket seems to be quite straightforward. As Vesa explains: "*In 2010, it was announced that the first trip had been sold. A friend called me, asking if it was me. No, it wasn't. Then I immediately went and bought a ticket. I thought they would sell out. A week later, it was announced that a second trip was sold.*" In a similar vein, Namira acted quickly to pursue her dream: "*I found out that Richard Branson is gonna take people to space. I was in my apartment when I heard about it. I immediately called Virgin Galactic and I said that I want to go to space.*"

This stage involves various emotional reactions from family and friends, but also a number of financial and insurance considerations. For example, Namira's and Claire's families were concerned about their decision, while Vesa's friends merely asked him if he was the holder of the first Finnish ticket. In our data, financial and insurance considerations were mostly discussed in connection with the unfortunate space shuttle accident. To illustrate, the accident caused stress to Claire, as her family became concerned about her safety and her financial advisor suggested that it would be better to invest the money in something else.

4.2.2 The Phase of Waiting—Commitment at Stake

The second phase occurs after the contract has been signed and the ticket purchased—an extended waiting period for the core space flight, experienced by all our study participants. This phase is characterized by the travelers' commitment—on the one hand to the process and on the other hand to the forthcoming flight. In this stage, the travelers visit the site, meet the staff, and get a close-up look at the spacecraft. This stage is susceptible to adjustments due to technical or logistical changes. In essence, this phase embodies a unique and multifaceted aspect of the journey, filled with varying experiences.

A veteran astronaut, Jon, spoke about the long amount of time he spent on the waiting list, highlighting the lengthy and uncertain path to space travel. "*I have been waiting for 18 years,*" he said, illustrating the significant commitment and patience required in the pursuit of this extraordinary venture. For Jon, his health and its potential impact on his space travel became an issue of concern when the waiting time became longer and longer. He revealed a personal health struggle: "*I contracted the disease [Parkinson's], I thought that's the end of me going into space.*" Indeed, health issues can lead to cancellations of purchased tickets during the long waiting period.

Travelers also expressed substantial concerns regarding the technical safety of space travel. Due to the long waiting time, these issues become particularly significant for some. However, another traveler, Mark, was confident and explained how he felt: "*I looked at who the people at Axiom were, what their capabilities were for getting people safely to and from space, and I was impressed. I'm not a daredevil. I'm adventurous but I don't have a death wish. I have a young family and I'm looking forward to seeing them grow up. I wouldn't be doing this if I thought there was a meaningful risk of this not working out.*"

Some travelers stated that the waiting period provides unique and memorable experiences thanks to events and happenings that might not have been held without this long wait. Vesa, who has been waiting since 2010, ponders: "*If this trip had happened in 2013, as I was led to believe, would I have walked 100 km? Would I have entered the Wife Carrying World Championships? Would my rocket car be in this shape? I can't say. And I don't know if I would've met a living Apollo astronaut and had a beer with him. I don't know. Because these things have happened during this waiting period. Plus, I've met many other astronauts and all kinds of things. And read more about these topics.*"

An important aspect is that because space tourism is still in its early stages, it receives significant media interest. Media treatment of these travelers has varied; for some, media attention has felt like an honor, while for others, it has become an emotional burden. Indeed, the uniqueness of space tourism becomes evident in the way the media have shown interest in the space travelers, while the relationship of the travelers with the media seems to vary. To illustrate, once the media found out that Claire had bought a ticket, her house was tagged, and she received insults and even death threats. She had to move out of her house for some time. On the contrary, when the media found out that Namira had bought a ticket, the media celebrated her as a pioneer who was making her country proud. It is evident that at this moment, media and public reactions can have a positive or negative impact on space tourists.

This prolonged pre-phase, a hallmark of space tourism in its current state, goes beyond mere preparation for space travel; it becomes a distinct journey in itself. For many, it is a time of life-changing experiences—personal development, unexpected achievements, and emotional preparation for the upcoming space journey. Indeed, the long waiting period has shaped Namira's, Vesa's, and Claire's experiences in different ways. To begin with, they all visited SpacePort America—this made the wait more exciting, but the waiting period, and the events held during it, in one case even caused them to rethink their commitment to the trip. Public and media reactions during this time also add layers of complexity, ranging from overwhelming support to overbearing scrutiny. Thus, this phase—which is often overshadowed by the space flight itself—plays a crucial role in shaping the space travelers' experiences, revealing the complex and detailed nature of waiting and the different ways it changes the lives of people who are going to space.

4.2.3 The Stage of Pre-launch Activities and the Core Flight

The third stage encompasses the core flight and necessary pre-launch activities, such as getting fitted for suits and attending technical briefings, all of which contribute to mounting excitement as the launch approaches.

Certainly, the astronauts felt a profound sense of excitement and wonder when they received confirmation that they had been selected for an upcoming space journey. To illustrate, Ken recalled his reaction, saying, "*I was blown away when he called me back on his cell phone,*" highlighting the unexpected nature of his selection. Similarly, Sebastien shared his disbelief, exclaiming, "*It was crazy! I couldn't believe it,*" which underscores how surreal he felt when he heard the news.

During the core flight experience, space travelers encountered moments that felt magical and transcendent. Jon, who struggles with severe health conditions, shared his sheer astonishment during the journey: "*It is completely unreal for me to go into space … the experience exceeded my wildest dreams.*" Keisha experienced a profound sense of peace and freedom, reflecting, "*It was just a great escape getting off our planet, a great adventure. To see our Earth just sitting there in this peacefulness, just so Zen—it was just the biggest peace that you can find out there … For me, it was really a place of tranquility, a place of freedom,* *a place of connection.*" Similarly, Ana's first look out of the spacecraft's window was intensely emotional: "*I remember that the first time I turned and looked out the window, I almost panicked. It was just such a huge thing that, for a second, I didn't know how to really process it. It was just unbelievable. My emotions were all over the place. There was no fear, but there was a lot of confusion.*"

The examples above illustrate the overwhelming and transformative nature of their space travel experiences. Only a few of the interviewees mentioned difficulties during the experience, such as sickness. Yet, Mark, who took part in a longer voyage, a 10-day mission to the International Space Station, explains: "*It was difficult, sleeping in space. There are no visual cues to know if it is day or night, so it affects the circadian rhythm …. When we arrived at the station, I was completely disoriented. I wasn't feeling well. I felt sick. For the first few days, I had pain in my back due to microgravity and I had a headache.*" Some of the astronauts were aware of the typical bodily reactions and expected to feel nauseous because "*it is obvious*" (Claire).

Reflecting on their subjective experiences, travelers described their space journeys as spiritual and even transformative. Namira articulated this as involving "*a spiritual connection,*" a sentiment that Keisha deepened by describing space as "*a spiritual place.*" Beyond spirituality, Namira also experienced a sense of romance, while Guy perceived it as "*poetic.*" Anastatia expressed a profound connection and unity with the cosmos, saying, "*I have a place in the universe.*"

The varied expressions highlight the deeply personal impact and growth that resulted from the unique and extraordinary experience of flying to space.

4.2.4 Upon Return—A Traveler Altered Forever

In the final stage—upon landing—the space travelers expressed that they experienced a profound array of emotions, encompassing not only psychological aspects but also physiological ones, signifying a pivotal shift from their remarkable adventure to a transformed daily existence.

Ken, for instance, described his reactions upon landing as "*almost breathtaking,*" highlighting the intense and overwhelming impact of the journey. After the flight, the tourists often found it challenging to articulate the intense emotions they'd experienced, as Ken explained: "*There are no words that can explain looking down at the Earth.*" Similarly, Keisha struggled to express her feelings: "*Beyond. Beyond. I don't have the words about how I actually felt about it. It is just huge.*"

In accordance with the second stage, returning from the space flight also attracted significant public attention and acclaim, resulting in social recognition. To start with, all space travelers and their pictures are presented on the Virgin Galactic website (https://www.virgingalactic.com/virgin-galactic-astronauts) and found on several websites. The experiences of the space travelers are acknowledged and celebrated in the media, marking them as individuals who have accomplished a remarkable feat. Most of the travelers participated in interviews, sharing their stories locally, nationally, internationally, and on digital platforms. This media engagement highlights the importance of their journey in the larger social context. A notable example is Namira, who expressed gratitude for the warm reception and the prestigious civil award she received, highlighting the esteem and recognition bestowed upon her by her country for her space endeavors.

These findings reveal how space travel leaves an indelible impression on the individual, not only through personal transformation but also through social acknowledgment, bridging the gap between individual experience and collective recognition.

5 Discussion—Space Travel as Doozy Tourism

Commercial space tourism companies encapsulate the hallmarks of luxury, positioning themselves firmly within the luxury tourism industry (Kapferer & Valette-Florence, 2018; Toivonen, 2022). Building on Cristini et al.'s (2017) definition of luxury, space tourism can be characterized by its creativity, excellence, and exclusivity. The essence of space tourism, driven by technological progress and innovations, primarily lies in its creativity, fostering a novel perspective on environmental interaction. The fundamental premise of space travel is a comprehensive commitment to excellence, ensuring safety and additional benefits for travelers. Moreover, space tourism is defined by the exclusivity marked by its limited availability and premium cost, restricting access to a distinct group of individuals, which all define luxury (e.g., Cristini et al., 2024; Gummerus et al., 2023; Kapferer & Valette-Florence, 2018).

However, the concept of luxury in space tourism is complex and multifaceted (Christini et al., 2024; Iloranta, 2022). The financial barrier, currently around USD 450,000, means that the experience is out of reach for most people—it is aligned with certain luxury criteria such as quality, aesthetics, and heritage. For instance, the state-of-the-art technology of the spaceships and astronauts' descriptions of the beauty of space add to its luxury appeal. However, our findings illustrate that travelers view their experience not in terms of luxury but as a personal journey of happiness, joy, and self-fulfillment. Also, when they described their experiences, they focused on awesomeness and a sense of personal triumph, highlighting the sense of wonder sparked by these experiences. Moreover, despite its high cost, which indicates prestige, the experience lacks certain luxury elements like comfort and individual attention—it could thus be debated whether it could in fact be classified as a luxury.

Given these unique characteristics and the blurred lines between luxury and space tourism, a new term is justified. This term should encapsulate the exclusive, emotional, and experiential aspects of space travel, as distinct from traditional luxury concepts. Therefore, in this study, we introduce "doozy tourism" as a distinctive term to encapsulate the profound and unparalleled essence of space tourism. This choice is inspired by the consistent description of the experience as incredible, outstanding, and rarely accessible, offering emotions seldom encountered anywhere. While space travel could be considered as unconventional adventure tourism (Cohen, 2017; Iloranta, 2022; Toivonen, 2022), doozy tourism pushes the experience even further combining extraordinary and exclusiveness with risks and danger. Moreover, instead of exhilaration and adrenaline increase, doozy tourism can be about self-development, knowledge and pushing one's limits.

Doozy tourism embodies an awe-inspiring journey that fulfills deep-seated dreams and passions, pushing individuals out of their comfort zones into the realm of unique, unknown experiences. It involves the magical opportunity to witness Earth from an exceptional vantage point and to delve into the mysterious depths of black space. This term captures the transformative nature of the journey, where travelers engage in profound self-discovery and memory-making, and embraces the unspoken emotional magnitude of the experience, marked by its intensity and the lasting impact on personal fulfillment. Furthermore, "doozy" reflects the creativity ignited by this adventure, as many interviewees express a desire to immerse themselves in new space-related projects after their return from the trip.

In essence, the term "doozy" summarizes the space travel experience as amazing, remarkable, unique, and intensely extraordinary, echoing the unanimous sentiment expressed by space tourists.

6 Conclusions

The study reported in this chapter responds to the need for more empirical research on space tourism, as highlighted by Reddy et al. (2012) and Zhang and Wang (2022). Focusing on actual, committed space travelers rather than potential travelers with an interest in space tourism, our research provides in-depth insights through three one-to-one interviews. These interviews, selected to explore the impact of prolonged waiting on travelers' experiences, reveal that fulfilling a childhood dream is a key motivation for these pioneers. Additionally, the interviews shed light on how the extended waiting period influences traveler behavior. The analysis is further enriched by six publicly available interviews and archival data, enhancing our understanding of the actual space experience and the personal, spiritual, and social responses following the flight.

Recognizing the importance of the pre-phase stage as a distinct journey in itself, space tourism companies should focus on enhancing this period for their customers. This prolonged waiting period offers a unique opportunity for companies to delight their customers by engaging with them through personalized experiences, learning opportunities, and exclusive events that build excitement and a sense of community. By investing in these aspects, companies can transform the waiting period from a passive wait into an integral part of the space tourism experience. Additionally, managing public and media interactions carefully during this phase is crucial, as these can significantly impact the travelers' overall experience and perception of the journey.

Our findings reveal how space travelers view their experiences as embodying the essence of doozy tourism—a construct that encapsulates an amazing, remarkable, unique, and intensely breathtaking travel experience. This form of tourism reconciles elements of wonder, extraordinariness, and impressiveness. Doozy tourism is characterized by endless happiness, personal triumph, and a profound sense of joy.

Our study represents the first effort to contribute to a more precise understanding of what doozy tourism entails in the context of space travel. Future research could potentially categorize other exceptional and rare forms of tourism in a similar vein.

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The Sociological Shaping of Space Tourism

Michelle I. C. Yang

1 Introduction

Space tourism, once considered a distant dream, has become a reality in recent decades. Advances in space technology, particularly following the successful excursion of Yuri Gagarin, the first man in space, by Russia in 1961 and Neil Armstrong's moonwalk in 1969, have led to significant changes in the industry. Today, space has become a battleground for countries competing for supremacy in space exploration and commercial development. The potential for business opportunities in various sectors, such as telecommunications and space tourism, has made space an attractive destination for entrepreneurs and investors (Friel, 2020; Loizou, 2006). In 2001, Dennis Tito made history when he became the first "space tourist," initiating a shift in space tourism from scientific exploration to commercialization. With the development of private space companies such as SpaceX and Blue Origin, space tourism is no longer a pipe dream but a reality becoming accessible to more and more consumers through commercialization. These private companies have been instrumental in driving the market development of space tourism, not only

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6_12

through innovations in space technologies but also through collective efforts to bring space tourism into the public discourse.

In tourism scholarship, discussions on space tourism (also discussed as *space travel* and *astrotourism*) began as early as 1990 in the seminal works of Ashford (1990) and Crouch (2001). These works focus on a futuristic perspective toward space tourism (Prideaux & Singer, 2005), outlining the motivations and experiences of space tourists (Cater, 2010), consumer attitudes toward space (Chang, 2017), and the sustainability of space tourism (Peeters, 2018; Toivonen, 2022). While there is growing research fervor on space tourism, the scholarship faces epistemological constraints regarding the availability of empirical data. Many of the published works focus on discursive analysis and conceptualization with limited explorations on the sociological shaping of this emerging market.

This chapter argues that studying the sociological shaping of space tourism will allow us to better understand the nature of this market, the socio-political forces, and the power dynamics that have shaped it. The market for space tourism is constantly evolving, with factors such as technological advancements, government regulations, and public opinion impacting how the market functions and develops. By integrating institutional theory and performativity theory, this paper aims to provide a sociological account of how the space tourism market is shaped.

On the one hand, institutional theory offers a perspective through which we can decipher the complex web of formal and informal rules, norms, and beliefs that shape the behavior of institutional actors in the space tourism ecosystem. Specifically, the regulative, normative, and cultural-cognitive pillars and their interplay provide an important structural foundation for the market (Scott, 1995, 2008). On the other hand, performativity theory (Callon, 1998) which focuses on realizing economic practices through discourse and action, offers valuable insights into how the market for space tourism is constituted and sustained. In space tourism, the performative act of marketing space experiences alongside the technological demonstrations of successful space missions serves to construct and reinforce the market. Taken together, the integrative view serves to contribute to our understanding of space businesses.

2 Theoretical Foundations

2.1 Space Tourism

Space tourism is an up-and-coming field in the tourism industry. As early as the 1980s, with scholarly discussions on the prospects of space tourism. While excursions into space were reserved exclusively for government projects, scientists in the field of tourism have explored the possibility of space becoming a commercial reality (Loizou, 2006). The research and industry enthusiasm for space tourism is largely due to the realization of space fantasies that were once far-fetched, as well as the immense economic gains associated with the development of space tourism. Space tourism represents a novel niche market that has the potential to revolutionize the way people perceive and experience travel. Extant research on space tourism follows three main themes: consumer-related phenomenon; environmental impacts and sustainability issues related to space tourism and legal and policy analysis.

Research on consumer behavior in space tourism focuses on understanding the motivations, attitudes, and decision-making processes of individuals interested in space tourism as a leisure activity (Chang, 2017; Crouch et al., 2009). For example, Chang (2017) examines the relationship between consumer attitudes toward space tourism and the development of technological innovations in space tourism in Taiwan and found that hedonic and social innovations were associated with consumers' positive attitudes toward space tourism. This area of research focuses on factors such as travel motivation and the role of perceived risk and safety concerns on willingness to participate in space tourism. The main practical implications of this research are how it contributes to a better understanding of consumer behavior in space tourism for future marketing strategies.

The second area focuses on the environmental impact and sustainability issues associated with space tourism. Specifically, it deals with carbon emissions from spacecraft launches and space debris. Peeters (2018) argues that "space tourism will not be part of sustainable tourism" as it can exacerbate social and environmental impacts. Similarly, Frost and Frost (2022) discuss the paradox of space tourism. While space tourism operators market space as a natural wonder untouched by human development, this form of travel directly impacts Earth, exacerbating the ethical dilemma of space tourism. The reality of space tourism is that this form of travel, while fascinating, directly reverses the decades of sustainability efforts that the tourism industry has committed to.

Finally, the analysis of the current regulatory framework and legal challenges in space tourism is an essential area of research (Polkowska, 2021). Issues related to the ethical use of space technologies, the environmental impact, and the safety of operations emphasize the need for governance and ongoing policy discussions. Marsh (2006), for example, warns of the medical implications of space tourism. Despite decades of research on the effects of space tourism on the psychological and physiological health of travelers, there still needs to be more understanding of how space tourism can affect the human body. Spector (2020) discusses the acceptable level of risk in space tourism and points to the uncertainty surrounding the industry's development. Given the limited number of space tours undertaken to date, the current regulatory framework for ethical and safety issues is inadequate. The unpredictable nature of space tourism also means that the legal framework is only likely to be updated when disasters occur. Much more research remains to be explored on the liability of space tourism and the various risk factors associated with such an activity.

2.2 Sociological Shaping of Market

Scholarly attempts to understand how markets emerge, transform, change, and sometimes fail are crucial to understanding economies and markets. These studies have helped understand various market dynamics aspects, with two dominant approaches. Economists argue that markets are driven by economic factors such as supply and demand. Sociologists, conversely, argue that markets are deeply embedded in social processes and institutions, and various social forces shape markets (Fligstein & McAdam, 2012). Central to the thesis of the sociological making of markets is the decentralization within a market—from the rationally organized market at the top-down level to the recognition of the multilayered and multifaceted mechanisms that characterize modern markets. In other words, the traditional view of markets as purely economic entities, in which supply and demand are the key factors determining outcomes, has been challenged. Instead, scholars, particularly from economic sociology, have shown that social and cultural factors also play an important role in shaping markets.

Although different terms have been used—market shaping (Nenonen et al., 2021), market emergence (Martin & Schouten, 2014), market development (Wüstenhagen & Bilharz, 2006), and market configuration (Storbacka & Nenonen, 2015)—these works are generally concerned with understanding the sociological structuring of markets. Fundamentally, the sociological shaping of markets is a field of research that looks at how societal forces and social structures influence market dynamics. Previous research has discussed the sociological shaping of markets along five lines: (1) culture, (2) power relations, (3) institutional interplay, (4) social networks and (5) performativity.

To elaborate further, culture shapes economic behavior. The central argument of this approach is that societies have unique cultural values, beliefs, and practices that influence behaviors such as consumer preferences and market demand (Swidler, 1986). In *Economic Lives*, Zelizer (2013) argues that these actions are deeply embedded in socio-cultural contexts and relationships. Adopting a cultural perspective on how markets emerge allows us to capture the nuances that differentiate one market from the other and raises the level of discourse when discussing economies (Guiso et al., 2006).

Secondly, power relations influence how markets are maintained and structured. In capitalist societies, "economic capital is transformed into symbolic capital through the exercise of power" (Bourdieu, 1984). Power relations play a significant role in the sociological shaping of markets through various aspects, such as market competition, pricing strategies, and access to resources. Within capitalist economies, those in power shape how the market works—such as who is permitted to produce, the production of goods, access to resources, the organization of labor, and how goods are marketed and sold (Fligstein, 2017; Reuss, 2020). In many cases, dominant actors or organizations exert their power to control market outcomes. While this approach highlights the influential role of power relations in shaping markets, it does not consider the role of institutions (of different levels) as well as socio-cultural dispositions in shaping market dynamics, which can significantly affect the exercise of power by dominant actors. Additionally, it does not explore the potential for resistance and contestation by actors not in positions of power, which can also shape market outcomes (e.g., Hietanen & Rokka, 2015).

A related area looks at how social network's structure market interactions. Granovetter (1973) introduced the concept of "embeddedness," which states that "social ties act as conduits for information about employment opportunities and lend credibility to claims about products or services." Social networks profoundly impact how markets are shaped by facilitating the flow of information, resources, and opportunities between individuals and organizations (White, 2001). He argues that "the structure of relationships between actors influences their ability to cooperate effectively in the pursuit of mutual gain" (Granovetter, 1985, p. 488). Researchers following this network approach focus on deciphering the social structures within the market and the relational aspects of market interactions, such as resource dependence (Fligstein & Dauter, 2007). The related idea of the market as a "configuration of actors" argues that the market is configured and enacted "through which the actors use their relational power" (Hietanen & Rokka, 2015, p. 1566). Baker and Nenonen (2020) propose the notion of "collective market work," exemplified by the screwcap closure on New Zealand wine, which proceeds through three stages: coalescing, legitimizing, and using market clout. This process gradually empowers and emboldens small groups to influence larger players and market gatekeepers.

Fourth, institutional factors shape the rules and regulations of the market. DiMaggio and Powell (1983) argue that "institutions are the rules of the game in a society, or more formally, the humanly devised constraints that shape behavior." Institutional forces such as governance and regulations, formal and informal norms, and professional standards shape market practices. Fligstein and McAdam (2012) emphasize that institutional processes play a central role in shaping markets by influencing the rules, norms, and cultural practices that govern economic interactions. Neo-institutional theorists focus on how institutional pillars (regulative, normative, and cultural-cognitive) collectively shape, maintain, and sometimes disrupt market dynamics (Lawrence & Suddaby, 2006; Scott, 2003).

The final direction looks at the performativity of economics (Callon, 1998) and views the market as the outcome of deliberate logic and rational calculations to achieve their respective economic interests. While they do not refute the importance of sociology, performativists argue that "sociology's goal should be to understand how they are produced," ultimately, "economics perform the economy" (MacKenzie & Millo, 2003, p. 108). Performativity theorists have criticized the extant sociological work on markets for neglecting how markets are structured by the interaction of economic activity with disruptions such as new technology.

The sociological approach to understanding how markets are formed provides a comprehensive framework beyond the economic determinism of supply and demand. It emphasizes the significance of social structures and processes, cultural norms, power dynamics, institutional frameworks, and the performative aspects of economics in shaping markets. Nevertheless, these are often divergent (though ironically overlapping) approaches, each with their own conceptualizations and beliefs, leading to incomplete narratives about how markets are shaped (Fligstein & Dauter, 2007). An integrated approach that considers both sociological and economic perspectives may offer a more holistic understanding of market dynamics, recognizing the complex interplay between social structures and economic activities in shaping markets. This integrated perspective could better address the limitations of focusing solely on either sociological or economic factors, paving the way for a more nuanced understanding of how markets emerge, transform, and operate within broader societal contexts.

To this end, I consider both institutional and performative approaches to be complementary in exploring the sociological shaping of the space tourism market. Primarily, institutional theory recognizes the temporal aspects of the market, particularly in terms of its historical evolution and technological changes. Parenthetically speaking, institutions are not static concepts; they evolve along with shifts and evolvements within the social context. Nevertheless, institutional theory recognizes that market shaping is an ongoing process influenced by both external pressures and internal organizational responses. Institutions can be both constraining and enabling forces for organizations operating within a market (Lawrence & Suddaby, 2006). External pressures such as technological advancements can disrupt existing market structures, prompting organizations to adapt their strategies and practices.

To the extent that institutions attempt to stabilize a market, the institutional arrangement is seen as temporary and susceptible to disruption and disorientation by technological change. Technological innovations are performative—they are deliberate economic calculations and strategies designed to advance the economic interests of particular, powerful actors. In the financial sector, for example, new financial products such as FinTech challenge the parameters of the traditional financial market and how market actors engage in new institutional processes to stabilize the market (Alt et al., 2018; Fligstein & Dauter, 2007). Introducing new technologies forces market players to adopt isomorphic practices to remain competitive (Du, 2018). Other findings, including work on institutional entrepreneurship, also emphasize how actors challenge the prevailing norms and rules within a market to initiate market change

(Hargadon & Douglas, 2001). Thus, the combination of institutional and performative approaches provides a comprehensive understanding of the sociological shaping of the space tourism market. The following section delves into the emergence of the space tourism market by drawing on neo-institutional theory and performativity perspectives.

3 Emergence of the Space Tourism Market

This chapter argues that the shaping of the space tourism market is an outcome of institutional work and performative economics enacted through the neoliberal market system, where competition and technological advancements influence the institutionalization of the market. By integrating these two perspectives, we can explore the dynamic interplay between economic practices and institutional structures in the formation and evolution of markets. The first part of the analysis focuses on neo-institutional theory, particularly the three institutional pillars: regulative, normative, and cultural-cognitive, and outlines how they institutionalize the space tourism market. The second part introduces the performative aspect of space tourism (Fig. 1).

3.1 Institutionalizing the Space Tourism Market

Neo-institutional theory is a sociological perspective that seeks to explain how institutions shape social behavior and outcomes (Yang et al., 2022). It emphasizes the importance of formal and informal rules, norms, and values in shaping individual and organizational behavior. The theory posits that those three pillars—regulative, normative, and cultural-cognitive—work together to maintain stability and conformity within social systems.

3.1.1 Regulative Pillar

The regulative pillar comprises the formal rules and regulations that govern operations and activities within a particular industry. Actors with authority and legislative powers, such as government agencies, create and enforce these regulations (Scott, 2001). The main purpose of regulations is to ensure compliance with international laws, licensing requirements, and safety standards. In space tourism, for example, regulations are crucial in creating a legal framework for developing, using, and monitoring space technologies. Regulatory frameworks encompass a range of formal rules,

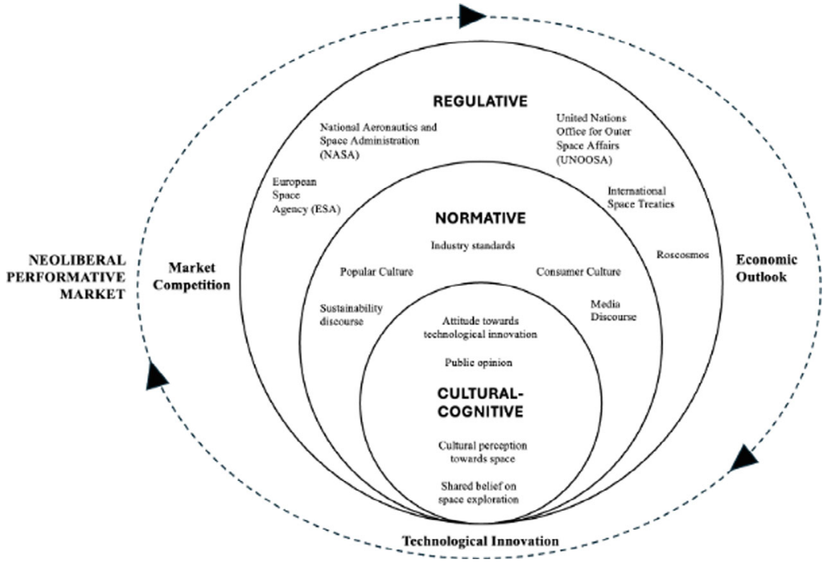

Fig. 1 The sociological shaping of space tourism market

including international treaties and national space laws. The regulation of space, the space economy, and space tourism are a complex web of international treaties, national regulations, and industry standards that ensure that space activities are carried out in the interests of the various stakeholders (see Table 1).

The regulative pillar is a decisive factor in shaping the development and growth of markets. It establishes the regulatory framework that guides companies in their activities, ensuring that they operate within ethical boundaries and that consumers are protected from potential harm. In the space industry, for example, both NASA and the CNSA have the important role of regulating space activities, including commercial ventures, in their respective countries. These agencies are important in determining how commercial space activities can be conducted. They assess the risks and costs associated with such ventures and set guidelines and regulations that industry players must adhere to. They are also empowered to enforce compliance and ensure that all stakeholders, including industry players and consumers, follow the rules. In this way, the regulatory pillar

Table 1 Selected list of governing bodies and space law

International convention	
United Nations Office for Outer Space Affairs	UNOOSA oversees international space law and is responsible for promoting international cooperation in the peaceful use and exploration of outer space
International space laws	
Outer Space Treaty	This treaty establishes that space shall be free for exploration and use by all countries, but no country may claim sovereignty over outer space or celestial bodies
Rescue Agreement	The Rescue Agreement aims to ensure that all possible assistance is provided to astronauts in distress and that there is a framework for the return of astronauts and space objects that land outside the territory of the launching state
Liability Convention	Outlines the liability of launching states for damage caused by their space objects
Registration Convention	Requires states to furnish to the UN a register of objects launched into outer space
National space agencies	
National Aeronautics and Space Act	The United States' space agency, which conducts civil space research and exploration. While NASA primarily focuses on exploration and science, its policies and collaborations also impact space business and tourism
European Space Agency	An intergovernmental organization dedicated to the exploration of space, ESA's activities also influence space policy and business in its member states
China National Space Administration	CNSA is the national space agency of the People's Republic of China, responsible for the planning and development of space activities
Roscosmos	The Russian space agency, which oversees space exploration, research, and development activities in Russia
Industry regulations	
International Astronautical Federation	A leading space advocacy body that fosters dialogue among space agencies, industry, and academia worldwide

(continued)

Table 1 (continued)

Commercial Spaceflight Federation	An industry association representing businesses and organizations working to make commercial human spaceflight a reality. It works on regulatory issues, promotes industry standards, and encourages the development of commercial spaceflight
International Association for the Advancement of Space Safety	Dedicated to promoting space safety standards and practices, IAASS plays a crucial role in ensuring that space tourism and commercial spaceflight activities are conducted safely

ensures a level playing field for all market participants, which promotes fair competition and protects the interests of all stakeholders.

3.1.2 Normative Pillar

The normative pillar in any given social structure is important, as it sheds light on the various social norms and expectations that guide social behaviors and establish standards (DiMaggio & Powell, 1983). While the regulative pillar relies on formal rules and authoritative power to ensure compliance, the normative pillar operates through informal rules and social norms that are not legally binding but can still significantly impact behavior. This is particularly important in the space tourism industry, where standards ensure companies act responsibly and ethically. These norms guide the setting of professional and safety standards, and although they are not legally enforceable, companies are likely to adhere to them to avoid resistance and public backlash. It is worth noting that the normative pillar alone is not always sufficient and, in certain cases, is complemented by the regulatory pillar. Nevertheless, norms can effectively encourage responsible behavior and ensure that social structures operate fairly and equitably.

Some examples of the normative pillar would be industry standards, popular culture, consumer culture, and the sustainability discourse. To illustrate, the rise of the sustainability discourse in tourism (including space) reflects the increasing importance of environmental and ethical considerations in tourism activities. Stakeholders, including customers, governments, and businesses, are increasingly concerned about the environmental impact of space launches, ethical considerations in space exploration, and the equitable distribution of space-related benefits. These normative expectations shape companies' strategies, including their commitment to sustainability, ethical business practices, and social responsibility (Toivonen, 2022).

Similarly, the consumer culture within a society influences how the norms for the production and consumption of space tourism are shaped. In societies with a stronger emphasis on ethical consumption, space tourism can present an ethical conundrum, as space debris and pollution can lead to negative environmental consequences (Hoffman & Ventresca, 2002).

3.1.3 Cultural-Cognitive Pillar

The cultural-cognitive pillar plays a crucial role in shaping public opinion and influencing the behavior of industry stakeholders in the context of space tourism. It is important to note that cultural-cognitive factors can either facilitate or hinder the industry's success. If the cultural narrative around space tourism is predominantly negative, this could lead to a lack of public support and, ultimately, hinder the industry's growth. Conversely, if the cultural narrative emphasizes the potential benefits of space tourism, such as its potential to drive scientific discovery and exploration, it could encourage companies to invest in research and development in these areas, leading to significant advancements in the field.

The cultural-cognitive pillar would also include the cultural perception of space exploration. This perception is influenced by factors such as historical achievements in space exploration, media portrayal, national pride, and personal beliefs about technological innovation. For example, popular movie series such as Star Wars and Star Trek have contributed to the global fascination with space exploration (Ceuterick & Johnson, 2019). These various cultural-cognitive elements can shape consumer demand and influence support for investment in space tourism ventures and general enthusiasm for space-related activities.

Taken together, the three pillars are crucial for shaping the space tourism market. Regulations ensure safety and compliance in the industry, while social norms promote ethical practices and responsible behavior. In addition, understanding cultural-cognitive factors helps businesses cater to different consumer preferences. These institutional pillars work together to institutionalize a viable industry. While these three pillars of institutional theory provide a useful framework for understanding the complex interplay of factors that shape the space tourism industry, they do not consider the performative aspect of any market (Fig. 1).

3.2 *Performativity of the Space Tourism Market*

The concept of performativity implies that economic activities are descriptive and performative. Performativity economics suggests that markets are not naturally occurring phenomena but are actively constructed and shaped through practices and calculations which fulfill certain functions to shape and maintain the market. Technological progress is seen as a performative act planned by market participants to reshape existing markets or create new ones. According to Callon (1998), technological advances reinforce the performative nature of the economy by introducing new opportunities for competition and disrupting existing market dynamics. For example, the rise of online marketplaces such as Amazon has changed consumer behavior and, more importantly, altered the dynamics of traditional retailing and reshaped the retail market. Similarly, technological advancements in smartphones also helped create new gig economies and ways of consuming through Uber and Airbnb (Srnicek, 2017). Performative economics is closely intertwined with technological advancement. Technology shapes economic practices, creates new possibilities, and challenges existing norms.

Performative economics is particularly associated with the neoliberal market mechanism—an economic and political ideology that decentralizes market dynamics from the state to market participants. The most important aspects of neoliberalism include free market mechanisms, competition, and international trade. In order to compete, companies rely on various practices such as investment and technology development. The neoliberal performative market, which includes technological innovation, market competition, and economic prospects, co–evolving with the existing institutional structures to shape the market for space tourism. For example, market competition drives innovation, affects prices, and shapes the variety of space tourism experiences offered to consumers, while economic factors such as fuel prices and production costs influence the development of the market.

3.3 An Integrated View of the Space Tourism Market

The integration of performative economics and institutional theory sheds light on how markets are shaped by the feedback loop between economic performativity and institutional adaptation. Economic theories, when put into practice, can become institutional norms, influencing future economic actions and potentially leading to the creation of new institutional structures. This cyclical process (Fig. 1) illustrates how markets are not fixed entities but are continuously built and reconstructed through the interaction between performative actions and institutional structures.

Furthermore, the temporal and spatial aspects of space tourism require a flexible and dynamic approach to institutional adaptation. For instance, the technology and infrastructure required for space tourism are continuously evolving, and institutional structures must keep up with these changes to ensure the industry's sustainability. Additionally, space tourism is a global industry that involves multiple jurisdictions, and therefore, institutional structures must be adaptive and responsive to the different legal and regulatory environments in which it operates. The integration of performative economics and institutional theory highlights the dynamic and continuously evolving nature of markets, and how institutional adaptation is critical to supporting economic performance.

4 Conclusion

Understanding the sociological shaping of the space tourism market essentially reveals the complex interplay between institutional forces and economic performativity. As discussed in this paper, various institutional pillars such as the regulative, the normative and the cultural-cognitive pillar have intermingled with neoliberal market performativity and shaped the development of space tourism. The emergence of the space tourism market is not a natural phenomenon and does not take place in a vacuum but is continuously shaped by changing social norms and expectations. The future development of space tourism will depend not only on technological possibilities and economic models, but also on how well it can be reconciled with evolving societal benefits. Nevertheless, future space tourism research must also consider the socio-political forces and power dynamics that influence market development. This includes examining the power dynamics within the space tourism market, geopolitical interests, various space laws, and changes in public opinion on space tourism. The power dynamics, particularly between private space companies and regulators and between wealthy consumers and broader societal interests, are critical to the development of future space tourism. Furthermore, with the growing success of space tourism and the portrayal of space tourists in the media, societal reactions and perceptions toward this form of tourism will evolve and require changes to the existing institutional structure.

With the continuous development of space tourism and the commercialization of space, future research could go in two directions. First, the study of ethical consumer behavior in the context of space tourism represents a unique and emerging field where environmental sustainability, social justice, and the moral responsibility of consumers and providers intersect. Future research could, for example, investigate corporate social responsibility in space tourism, such as how companies deal with environmental, social, and ethical issues. Future research could also assess existing CSR practices, examine frameworks for responsible business behavior in unregulated environments such as space, and propose guidelines for sustainable and equitable growth of the space tourism sector. Second, understanding the commercialization of space also means understanding how branding works in the space industry. Research on branding in the space tourism industry could include a multifaceted examination of how space tourism companies cultivate their identity, differentiate themselves in the marketplace, and connect with potential customers.

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A. Ojala and W. W. Baber (eds.), *Space Business*,
https://doi.org/10.1007/978-981-97-3430-6