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Original Article

Mapping the Intellectual Structure and Thematic Evolution of Space Entrepreneurship Ecosystems: A Bibliometric Analysis

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Abstract: *The rapid commercialisation of the global space sector has transformed space activities from government-led programmes into innovation-driven entrepreneurial ecosystems supported by private enterprises, technological advancements, and strategic public–private collaborations. Despite the growing scholarly interest in this emerging domain, research on space entrepreneurship ecosystems remains fragmented across multiple disciplines, limiting a comprehensive understanding of its intellectual structure and thematic evolution. This study aims to systematically map the knowledge landscape of space entrepreneurship ecosystem research through a bibliometric analysis. Bibliographic data comprising 2,722 publications were retrieved from the OpenAlex database and analysed using VOSviewer and Microsoft Excel. The study employed performance analysis and science-mapping techniques, including citation analysis, author productivity, co-authorship analysis, term co-occurrence, network visualization, overlay visualization, and density visualization. The results show a large growth in academic publications after the NewSpace economy trend, reflecting increasing levels of interest among scholars in this area of study. Field conceptual structure is situated around four thematically connected aspects: commercialisation and regulation, innovation and entrepreneurship, business development and organisational evolution. This first overlay visualization demonstrates a slow shift from legal and policy research to innovation, start-ups and entrepreneurship. The analysis also uncovers gaps in the literature on venture capital, incubation and entrepreneurial finance as well as ecosystem governance important opportunities for future research. This study encapsulates the architecture of space entrepreneurship systems, contributing to a nascent body of literature pertaining to commercial space innovation and offering actionable insights for researchers as well as practitioners interested in enhancing entrepreneurial ecosystem performance within the NewSpace economy.*

Keywords: *Space Entrepreneurship, NewSpace, Entrepreneurial Ecosystem, Bibliometric Analysis, OpenAlex, VOSviewer, Commercial Space, Innovation Ecosystem.*

I. INTRODUCTION

The global space sector has undergone a profound transformation over the past two decades, shifting from a predominantly government-led domain to an increasingly commercial and innovation-driven industry. Rapid technological advancements, declining launch costs, private investment, and supportive policy reforms have accelerated the emergence of the NewSpace economy, enabling entrepreneurial firms to participate in satellite manufacturing, launch services, Earth observation, space tourism, in-orbit servicing, and other downstream applications. This transformation has expanded the economic significance of space activities beyond scientific exploration, positioning the commercial space sector as an important contributor to technological innovation, industrial competitiveness, sustainable development, and economic growth. Consequently, governments, private enterprises, investors, and research institutions are increasingly collaborating to strengthen entrepreneurial ecosystems that facilitate the commercialisation of space technologies and the creation of new business opportunities.

The growing commercialisation of space activities has stimulated a rapidly expanding body of scholarly research spanning entrepreneurship, innovation management, aerospace engineering, economics, public policy, sustainability, and technology management. Existing studies have examined diverse themes, including commercial space markets, space policy, technology transfer, public–private partnerships, sustainable space development, venture financing, and innovation ecosystems. However, the research landscape remains fragmented across multiple disciplines, with limited integration of these diverse knowledge streams. The preliminary analysis of the present dataset demonstrates that the literature is primarily concentrated on legal and regulatory issues, orbital infrastructure, commercialisation, and sustainability, while comparatively less attention has been devoted to entrepreneurial ecosystem components such as venture capital, incubators, accelerators, and start-up development. This fragmentation makes it difficult to understand the intellectual foundations, thematic evolution, and collaborative structure of research on space entrepreneurship ecosystems.

Despite the increasing academic and policy interest in commercial space activities, no comprehensive bibliometric study has systematically mapped the intellectual structure of research on space entrepreneurship ecosystems using a large multidisciplinary dataset. Addressing this gap, the present study analyses 2,722 publications retrieved from the OpenAlex

database through a combination of performance analysis and science-mapping techniques using VOSviewer. The study identifies the evolution of scientific publications, influential authors, collaboration networks, citation structures, and thematic clusters while examining the conceptual evolution of the field. By synthesising fragmented research and identifying emerging knowledge gaps, this study provides a comprehensive overview of the development of space entrepreneurship ecosystem research and proposes a future research agenda for scholars, policymakers, entrepreneurs, and industry practitioners.

Accordingly, this study aims to: (i) examine publication trends in space entrepreneurship ecosystem research; (ii) identify influential publications and leading contributors; (iii) analyse collaboration patterns; (iv) map the conceptual structure of the field through science-mapping techniques; and (v) identify emerging research themes and future research directions.

II. LITERATURE REVIEW

A) Evolution of Space Entrepreneurship

Space entrepreneurship has emerged as a significant research domain following the rapid commercialisation of the global space sector. Traditionally, space missions only covered government agencies like NASA, ESA, ISRO and Roscosmos, with private firms taking a little more than the role of contractors. Conversely, recent technology advances and launch cost decreases, combined with high investment from venture capitalists in space and new government policies have expedited the potential of NewSpace economy characterised by a more such as start-ups / private ventures/ commercial investors participation. Modern space entrepreneurship goes far beyond satellite manufacturing and launch services; it includes Earth observation, satellite communications, in-orbit servicing, space tourism, as well as a variety of other data analytics and applications built on top of these assets (Barney 1991; Oh et al., 2016). Consequently, space entrepreneurship is being more commonly perceived as a key driver of innovation, technology production and commercialisation, speed in economic development and enhancing industrial edge (Porel & Singh, 2025; Autry, 2025).

B) Space Entrepreneurship Ecosystems

The entrepreneurial ecosystem perspective holds that venture creation depends on the mutual interaction of not only entrepreneurs but also governments, universities, investors, research institutions, incubators and established firms (Isenberg 2010; Cohen 2006; Malecki 2018; Stam 2015). These interactions matter in the space sector especially because entrepreneurial ventures are conducted under technology-heavy conditions that usually entail high capital requirements, long development cycles and institutionalised regulations. A modelling study on the role of technology transfer mechanisms, supportive policy environments and specialised financial institutions in promoting innovation and commercialization (Spigel, 2017; Audretsch & Belitski, 2017; Brown & Mason, 2017). More generally, ecosystem theory ultimately conceptualises value creation as an interdependent multi-actor process across the entire ecosystem (Moore 1993; Adner 2017; Adner & Kapoor 2010; Stam & Van de Ven,2021). However, studies that examine the ecosystem as an integrated system are far less common than those dealing with specific technological or policy issues (Spigel & Harrison 2018; Wurth et al. 2022).

C) Existing Research Streams

Space entrepreneurship research thus far has evolved out of multiple intertwined literature streams, not as one coherent body. The first stream contains studies which analyse commercial space markets (Martin, 1999; Porel & Singh, 2025), with a focus on industrial development and market opportunities as well as the economic contribution of individual commercial space activities. A second stream looks at space law and policy, including licensing, regulatory frameworks, liability, international treaties governance (Koch 2018 Chrysaki 2020). The third stream studies technology commercialisation and innovation, with a special focus on aspects such as: technology transfer; satellite technologies; reusable launch systems (RLS); additive manufacturing (AM) and digital innovations. Later studies dealt with sustainability focused on orbital debris mitigation, responsible space operations, and sustainable space development more generally (Undseth et al., 2020; Ryan et al., 2022; World Commission on Environment and Development, 1987; Russell & Smorodinskaya, 2018). While these lines of investigation can add up to our knowledge about the commercial space industry, they are still fragmented in entrepreneurship (Tyler et al., 2021), aerospace engineering (Hofmann & Mukhtarov, 2019; Xie et al., 2020), innovation management (Notteboom & Vernimmen, 2008) and economics/public policy context, so there is little advancement toward a systematic body of knowledge on that field.

D) Research Gap

The preliminary bibliometric evidence proves that the contemporary literature tends to be focused on legal and regulatory frameworks, orbital infrastructure, commercialisation, sustainability while comparatively less attention has been paid towards entrepreneurship ecosystem components like venture capital, business incubation, accelerators entrepreneurial networks and startup development (Cavallo et al., 2019; Roundy, 2017; Acs et al., 2014). Moreover, previous review studies typically address narrower technology-, policy- or industrial segment-specific questions, as opposed to offering a broad mapping of the intellectual realm (i.e. research co-citation) and collaboration networks related to space entrepreneurship ecosystem literature evolution patterns for thematic analysis purposes (Martinez Dy & Roberts 2025; Autio & Thomas, 2014). As a result, an understanding of

how the academic culture has developed in this field, who the scholars are driving its development and which themes from research will inform future priorities remains elusive.

E) Positioning of the Present Study

To overcome such limitations, bibliometric techniques can be applied to systematically map the intellectual structure of research on space entrepreneurship ecosystems. Based on 2,722 publications obtained from the OpenAlex database, this study applies performance analysis and science mapping to detect prominent (1) papers; authors; institutions/countries/regions collaboration networks with their corresponding structures of citations across research disciplines along with thematic clusters. The fusion of descriptive performance indicators and visualization techniques identifies both the evolution of this nascent field while also providing future research directions.

III. METHODOLOGY

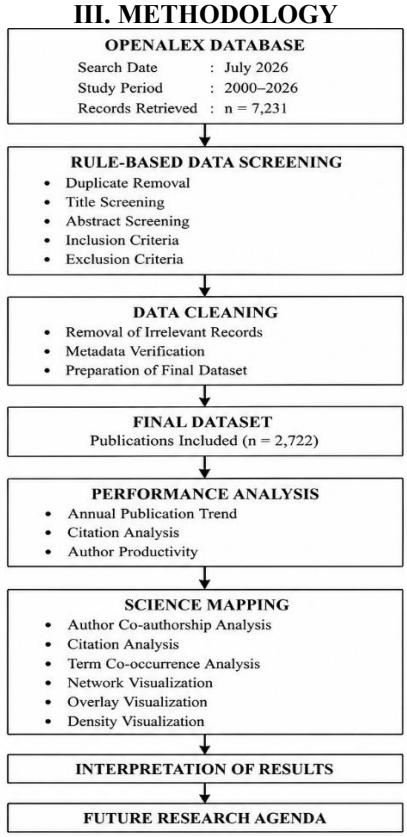

Figure 1. Bibliometric Data Collection and Selection Process

The bibliographic records were retrieved from the OpenAlex database in July 2026, covering the period from 1960 to 2026. An initial search identified 7,231 records, which were screened and cleaned using predefined rule-based criteria, resulting in a final dataset of 2,722 publications for bibliometric analysis. Publication activity before 2000 is sparse and isolated, represented by a small number of early studies such as Martin (1999), which examined the economic dimensions of space activity well ahead of the field's later formalisation. Sustained publication momentum begins around 2000, with the publication trend indicating a slow developmental phase until approximately 2015, followed by accelerated growth after 2020.

A) Research Design

The research follows a structured bibliometric workflow comprising five sequential stages:

1. Bibliographic data retrieval from the OpenAlex database.
2. Data screening and rule-based filtering.
3. Data preparation and cleaning.
4. Performance analysis.
5. Science mapping and interpretation of findings.

This systematic workflow ensures transparency, reproducibility, and consistency throughout the bibliometric analysis.

B) Search Strategy

A comprehensive search strategy was developed using Boolean operators (AND, OR) and phrase searching to retrieve publications relevant to space entrepreneurship ecosystems.

The search incorporated combinations of the following keywords:

- Space entrepreneurship
- Commercial space
- NewSpace
- Space economy
- Space innovation ecosystem
- Space entrepreneurial ecosystem
- Technology commercialisation
- Venture capital
- Public–private partnerships
- Space sustainability

The initial search retrieved 7,231 bibliographic records from the OpenAlex database.

C) Data Screening and Selection

The retrieved records were subjected to a systematic rule-based screening process to ensure that only publications directly relevant to commercial space entrepreneurship were retained for analysis.

The screening process involved the following stages:

a. Stage 1: Keyword Relevance

Publications were required to contain the term "space" within the title or abstract. This initial screening eliminated a substantial number of unrelated publications originating from disciplines such as healthcare, environmental engineering, e-commerce, cloud computing, and regional economics.

b. Stage 2: Rule-Based Exclusion

Publications were excluded when the term "space" referred to contexts unrelated to commercial space activities, including:

- Co-working and office spaces
- Urban and architectural spaces
- Mathematical and computational spaces (e.g., vector space, state space, latent space)
- Pure astronomy and astrophysics
- Pure engineering studies focusing solely on spacecraft design, propulsion systems, heat transfer, reactor technology, nozzle testing, and attitude control without any commercial, entrepreneurial, or policy perspective.

c. Stage 3: Contextual Retention

To minimise false exclusions, publications containing both technical terminology and entrepreneurship- or policy-related concepts were retained. For example, studies addressing commercial propulsion markets, technology commercialisation, space regulation, or private-sector launch services were included despite containing engineering-related terminology.

The rule-based filtering procedure was followed by manual verification of borderline publications to ensure the final dataset accurately represented research on space entrepreneurship ecosystems.

Following screening and data cleaning, 2,722 publications were retained for bibliometric analysis.

The complete screening procedure is presented in Figure 1.

D) Data Preparation

The final bibliographic records were exported from OpenAlex in CSV format.
The dataset was subsequently prepared for bibliometric analysis through:

- Removal of duplicate records,
- Elimination of irrelevant publications,
- Verification of publication metadata,
- Organisation of author information,
- Extraction of title and abstract terms,
- Preparation of citation information.

The cleaned dataset served as the basis for all subsequent analyses.

E) Bibliometric Analysis

Two complementary bibliometric approaches were employed.

a. Performance Analysis

Performance analysis evaluates the scientific productivity and influence of the research field.

The present study includes:

- Annual publication trends
- Highly cited publications
- Author productivity

These indicators provide an overview of the growth and scientific impact of research on space entrepreneurship ecosystems.

b. Science Mapping

Science mapping techniques were employed to examine the intellectual and conceptual structure of the literature.

The analyses include:

- Author co-authorship analysis
- Citation analysis
- Term co-occurrence analysis
- Network visualization
- Overlay visualization
- Density visualization

These techniques facilitate the identification of collaboration patterns, thematic clusters, research hotspots, and the temporal evolution of knowledge within the field.

F) Software Used

The bibliometric analyses were performed using three complementary software applications.

a. OpenAlex

OpenAlex served as the primary source for retrieving bibliographic records and publication metadata.

b. VOSviewer (Version 1.6.21)

VOSviewer was used to construct bibliometric networks and generate science-mapping visualizations, including co-authorship networks, citation networks, term co-occurrence maps, network visualization, overlay visualization, and density visualization.

c. Microsoft Excel

Microsoft Excel was used for data organisation, descriptive statistical analysis, preparation of summary tables, and graphical representation of annual publication trends and citation indicators.

IV. RESULTS

A) Annual Publication Trend

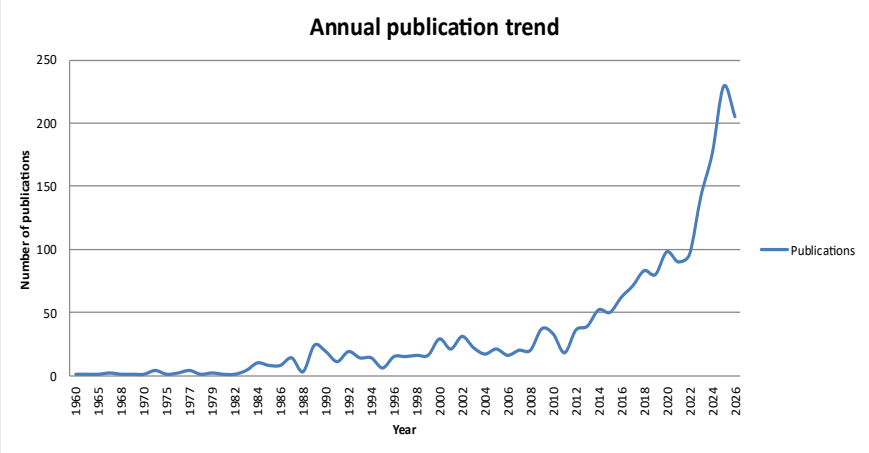

Figure 2. Annual Scientific Production (1960–2026)

The sharp increase after 2020 corresponds with the expansion of commercial launch providers, increased venture capital investment, satellite mega-constellations, and growing government support for NewSpace initiatives. This trend indicates that commercial space has become a rapidly emerging multidisciplinary research domain rather than remaining confined to aerospace engineering.

B) Most Influential Publications

Table 1: Top 20 Most Cited Publications

Rank	Title	Authors	Year	Citation count
1	From new space to big space: How commercial space dream is becoming a reality	Gil Denis |Didier Alary| Xavier Pasco| Nathalie Pisot|D. Texier| Sandrine Toulza	2020	177
2	The environmental impact of emissions from space launches: A comprehensive review	J.A. Dallas| Simit Raval| J.P. Alvarez Gaitan| Serkan Saydam| Andrew G. Dempster	2020	153
3	Cyber security in New Space	Mark Manulis| Christopher Bridges| R. Harrison| Vyas Sekar| Alexander Davis	2020	152
4	The case for robotic on-orbit servicing of spacecraft: Spacecraft reliability is a myth	Alex Ellery| Joerg Kreisel| Bernd Sommer	2008	143
5	Money and the Space Economy	R. L. Martin	1999	122
6	Impact of Rocket Launch and Space Debris Air Pollutant Emissions on Stratospheric Ozone and Global Climate	Robert G. Ryan| Eloïse A. Marais| Chloe J. Balhatchet| Sebastian D. Eastham	2022	118
7	The first decade of commercial space tourism	Yi-Wei Chang	2015	85
8	The long-term scientific benefits of a space economy	Ian Crawford	2016	83
9	Sustainability dimensions in space tourism: the case of Finland	Annette Toivonen	2020	80
10	One giant leap for capitalistkind: private enterprise in outer space	Victor L. Shammas| Tomas B. Holen	2019	79
11	Constellations, clusters, and communication technology: Expanding small satellite access to space	Jennifer L. Alvarez| B. Walls	2016	78
12	Entrepreneurial space and the freedom for entrepreneurship: Institutional settings, policy, and action in the space industry	Wadid Lamine| Alistair R. Anderson| Sarah Jack| Alain Fayolle	2021	76
13	Additive manufacturing in the new space economy: Current achievements and future perspectives	T. Ghidini| Marco Grasso|Johannes Gumpinger| Advenit Makaya| Bianca Maria Colosimo	2023	73
14	The Economic Impacts of the Commercial Space Industry	Kelly George	2021	64
15	A TECHNICAL OVERVIEW OF THE “SUNTOWER” SOLAR POWER SATELLITE CONCEPT	John C. Mankins	2002	61
16	Large satellite constellations and space debris: Exploratory analysis of strategic management of the space commons	Pierre Bernhard| Marc Deschamps| Georges Zaccour	2023	56
17	The Present and Future of the Space Sector: A Business Ecosystem Approach	Alina Orlova| Antônio Roberto Ramos Nogueira| Paula Chimenti	2020	55
18	Affordable, Rapid Bootstrapping of the Space Industry and Solar System Civilization	Philip T. Metzger| Anthony Muscatello| Robert P. Mueller| James Mantovani	2012	52
19	Institutional Framework for the Province of all Mankind: Lessons from the International Seabed Authority for the Governance of Commercial Space Mining	Jonathan Sydney Koch	2018	46
20	Psychology of space tourism marketing, technology, and sustainable development: From a literature review to an integrative framework	Javaneh Mehran| Hossein Olya| Heesup Han	2023	45

Citation analysis identifies the intellectual foundations and influential knowledge base of space entrepreneurship ecosystem research. As shown in Table 1, the most highly cited publication is *From New Space to Big Space: How Commercial Space Dream is Becoming a Reality* (Denis et al., 2020), with 177 citations, highlighting the growing importance of commercial

space activities and the transition towards the NewSpace economy. Other highly cited publications address environmental sustainability, cybersecurity, robotic on-orbit servicing, space tourism, commercial space economics, business ecosystems, and technology commercialisation. The presence of these diverse themes indicates that the field has evolved beyond its traditional engineering focus to encompass entrepreneurship, innovation, sustainability, economics, policy, and strategic management. Overall, the citation analysis demonstrates the multidisciplinary nature of space entrepreneurship ecosystem research and identifies the seminal studies that have shaped its intellectual development.

C) Leading Contributors

Table 2: Leading Contributors' Table

Rank	Author	Publication Count
1	Barbara A. Stone	13
2	Next Move Strategy Consulting*	12
3	Joseph N. Pelton	10
4	Carissa B. Christensen	10
5	NASA*	10
6	OECD*	9
7	Yun Zhao	8
8	Janet K. Tinoco	8
9	Alessandro Paravano	8
10	Lesley Smith	7

***Note:** Corporate or institutional authors indexed in OpenAlex were retained because they represent identifiable contributors to the literature.*

Table 2 presents the most productive contributors to research on space entrepreneurship ecosystems. Barbara A. Stone leads with 13 publications, followed by Joseph N. Pelton and Carissa B. Christensen, each with 10 publications, reflecting their sustained contributions to commercial space activities and the NewSpace economy. The presence of organisational contributors such as Next Move Strategy Consulting, NASA, and the OECD highlights the multidisciplinary and practice-oriented nature of the field, where academic research is complemented by government agencies, international organisations, and industry. This indicates that research on space entrepreneurship ecosystems is driven by a relatively small group of influential contributors, demonstrating the collaborative and interdisciplinary development of the field.

D) Co-authorship Analysis

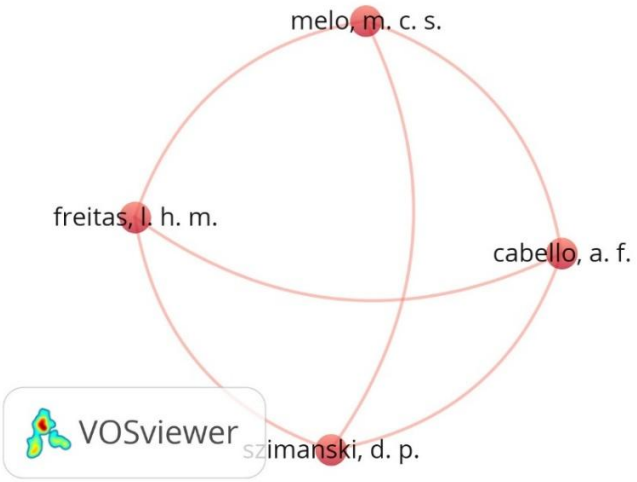

Figure 3. Author Collaboration Network

The co-authorship network (Figure 3) demonstrates a fragmented collaboration structure. Only a limited number of author collaborations were identified, suggesting that research on space entrepreneurship ecosystems remains dispersed across multiple disciplines. Unlike mature research domains characterised by extensive international collaboration, the present field appears to be in an emerging stage where researchers contribute independently or within small collaborative groups. This finding highlights opportunities for stronger interdisciplinary and international research collaboration

E) Overlay Visualization of Leading Contributors

Figure 4. Overlay Visualization of Leading Contributors

Figure 4 illustrates the overlay visualization of leading contributors to space entrepreneurship ecosystem research. The colour gradient represents the average publication year, with darker colours indicating earlier contributions and lighter colours representing more recent research. Earlier influential contributors, including NASA and John C. Mankins, laid the foundation for the field through studies on government-led space programmes and technological development. More recent contributors, such as Walter Peeters, Luca Giraldi, and Yun Zhao, reflect the growing emphasis on commercialisation, innovation, and the NewSpace economy. The visualization demonstrates the evolution of the research community from traditional space agencies towards a more diverse network comprising academic researchers, policy institutions, and industry organisations. It should be noted that Figure 4 selects contributors based on their connectivity within the co-authorship network (link strength), whereas Table 2 ranks contributors by raw publication count; consequently, the two exhibits do not necessarily highlight an identical set of individuals, though NASA appears prominently in both.

F) Network Visualization of Research Themes

Figure 5 presents the network visualization of term co-occurrence generated using VOSviewer. Each node represents a frequently occurring term extracted from the bibliographic records, while the links indicate the frequency with which two terms appear together within the literature. Larger nodes represent terms with higher occurrence frequencies, and colours indicate thematic clusters identified through the VOSviewer clustering algorithm. The network reveals four interconnected research clusters, demonstrating the multidisciplinary nature of research on space entrepreneurship ecosystems.

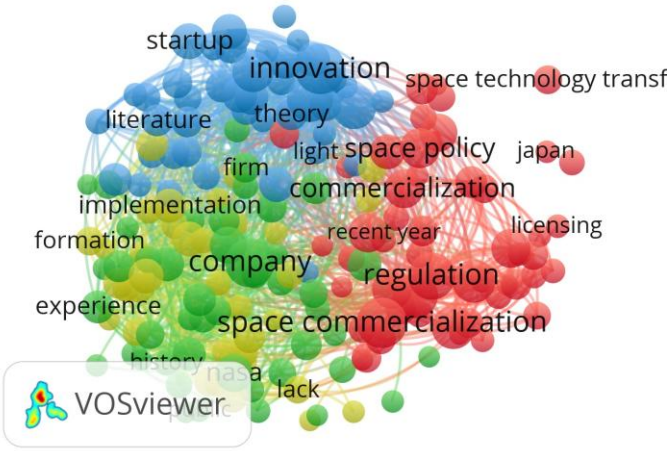

Figure 5. Network Visualization of Term Co-occurrence

a. Cluster 1 (Red): Commercialisation, Regulation and Space Policy

Cluster 1 represents the institutional, regulatory and policy dimension of the space entrepreneurship ecosystem. The highlight of terms like regulation, space commercialization, licensing and space policy suggests that a significant amount of

research relates to the governance structures, legal frameworks or other processes (such as market development) through which governments can support de-nationalized industries in transitioning from government-led towards commercial-driven spatial activities. The associations between these words highlight the tight relationships between commercialisation and regulatory reforms, licensing processes and private–public partnerships in driving engagement of business and investment interest into space.

These results align well with previous studies that highlight the need for policy support, institutional governance and technology transfer to allow further expansion of the NewSpace economy (Chrysaki 2020; Denis et al. 2020; Undseth et al. 2021). The cluster additionally illustrates the surge in significance of sustainability of commercial space endeavours, further reflected by scholars treating environmental externalities and challenge governance for sustainable development (Dallas et al., 2020; Ryan et al., 2022; OECD, 2023). Moreover, the works dealing with technology commercialisation emphasise that converting scientific knowledge into commercially successful products and services is dependent on innovation, knowledge transfer between governments, research institutions and industry (Olivari et al., 2021; Ghidini et al., 2023; Orlova et al., 2020). This cluster identifies regulation, commercialisation and technology transfer as the three institutional pillars to implementing a sustainable global space entrepreneurship ecosystem.

b. Cluster 2 (Blue): Innovation and Entrepreneurship

Cluster 2: The innovation and entrepreneurship dimension within the space entrepreneurship ecosystem. Keywords such as innovation, startup, theory and literature indicate a growing interest from academics in the space-related aspects of entrepreneurship and human creativity, the major processes at work in NewSpace. The interrelation of these terms reveals that innovation-driven entrepreneurship has become a vital driver for the commercialisation processes and new business concepts within space technologies. These results are in line with innovation ecosystem literature that identifies collaboration, value creation and technological interdependence as the most important drivers of innovation (Adner 2006; Adner & Kapoor 2010; Granstrand & Holgersson 2020).

Likewise, research on entrepreneurship ecosystems focuses on the roles of institutions supporting networks and entrepreneurial culture in high-growth firms and innovation-based economic development (Isenberg 2010; Stam 2015; Spigel 2017). Reflecting on more recent studies, the NewSpace economy is increasingly recognised as marked by technology-based start-ups (commercialisation of space tech), private funding and ecosystem innovation providing new areas for commercial entrepreneurship. This cluster is newer and considerably smaller than the regulatory cluster, but its exponential growth suggests that innovation and entrepreneurship may be becoming some of the more exciting themes driving future development in our global space-entrepreneurship ecosystem.

c. Cluster 3 (Green): Firms and Commercial Development

Cluster 3 is about the organisational and commercial development dimension of the space entrepreneurship ecosystem. The terms company, firm and implementation are all indicative of greater academic focus on business strategies, capabilities (firm performance), commercial business models as well as the practical application or actual deployment of space technologies. The close link of these terms with the two clusters on innovation and commercialisation further suggests that firms represent a critical nexus for taking technological innovations, developing them into marketable products as well as distinct services through entrepreneurial innovation and commercial market development. Such findings complement business ecosystem research, which regards inter-firm collaboration as the essential mechanism contributing to value creation and industry performance (Moore 1993; Orlova et al. In this regard, studies on technology commercialisation highlight knowledge transfer from public research to industry and the importance of collaboration between academia and industry partners in promoting innovation that can accelerate commercial outcomes (Olivari et al., 2021; Ghidini et al., 2023). Furthermore, recent studies show that evolving business models and strategic entrepreneurship firms' capabilities have emerged as the most important determinants of competitiveness and market entry in NewSpace (Peeters 2024; Adilov & Alexander 2026; Giraldi & Rossi das-Guimaraes del Angel 2017−2030). In short, this cluster confirms that firms have become key players in innovation, commercialisation and sustainable growth of the global space entrepreneurship ecosystem.

d. Cluster 4 (Yellow): Organisational Development and Experience

Cluster 4 reflects the evolution of history and organisations in the space entrepreneurship ecosystem. The presence of words like formation, experience and history is complemented by the name NASA, which suggests that there is a wide literature assessing transition in the space arena from government-driven exploration programmes to commercial activities based on innovation. This cluster illustrates the pivotal role played by national space agencies, particularly NASA, in establishing technological capabilities, institutional frameworks and infrastructures upon which commercial participation was eventually built. Initial studies concentrated on the economic weight of space endeavours and sellable bases that would play a role in publicly pursued undertakings (Martin, 1999; Mankins, 2002; Metzger et al.,2012). Recent studies began to focus on the employment of findings from these institutional experiences in fostering the NewSpace economy through leveraging

commercial competitiveness, industry-spanning entrepreneurial ecosystems and facilitating public–private partnerships (Denis et al., 2020; Lamine et al., 2021; Ghidini et al., 2023). The dominance of historical and organisational themes is evidence that understanding the history of space institutions is important in explaining developments within contemporary commercial space activity. Overall, this cluster shows that the historical and institutional basis for innovation as well as entrepreneurial activity outside government funds has been built into space entrepreneurship, around which all spheres of global commercial focus based on private developments should develop.

This explains the network visualisation indicating that research on space entrepreneurship ecosystems is structured into four interlinked domains of knowledge: (i) commercialisation, regulation and space policy; (ii) innovation and Entrepreneurship; iii). Firms and Commercial Development; iv) Organisational development and historical evolution. The commercialisation and regulation cluster, located in the centre of these 3 clusters, exemplifies this continued legacy from policy frameworks and governance mechanisms along with technology commercialisation at stake. These tight linkages across the clusters illustrate how innovation, entrepreneurial activity and firm development are not merely about science or technology o! Press Page 3 but very much embedded in a wider institutional/regulatory environment. Moreover, the network suggests an evolutionary transition from classic state-driven space programmes towards innovation-based commercial ecosystems, with private enterprises and start-ups inevitably playing a more substantial role, pointing to new infrastructure business models resulting in further economic impact on NewSpace.

G) Overlay Visualization of Research Themes

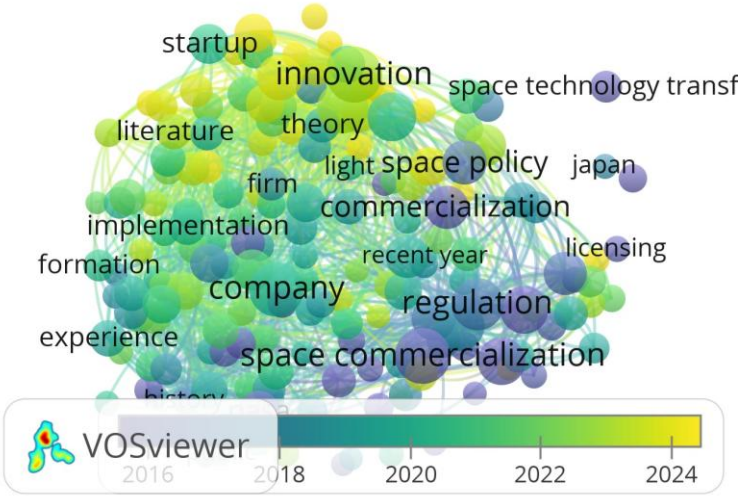

Figure 6. Overlay Visualization of Research Themes

Figure 6 presents the overlay visualization of term co-occurrence, illustrating the temporal evolution of research themes in space entrepreneurship ecosystems. The colour gradient represents the average publication year, ranging from earlier studies (blue and purple) to more recent studies (yellow). Previous studies focused largely on aspects like technology transfer, licensing, regulation and space commercialisation: all essential parts of legal instatement or framework; transitioning from earlier institutional niche policies into firm discussion (Martin 1999; Crawford 2016; Koch et al. With the maturation of the field, research has moved towards company-centred themes such as implementation and commercialisation processes; organisational transformation by innovation project-based networks at a firm level (Denis et al., 2020); business ecosystems(Orlova et al., 2020); market development (Lamine et al., 2021) and technology commercialization (Olivari et al. Recently published studies have focused more on innovation, start-ups and entrepreneurial ecosystems depicting the growth of a NewSpace economy fuelled by private investment, technological innovations and collaborative business models (Ghidini et al., 2023; Peeters, 2024; Autry, 2025; Cavallo et al.) This temporal evolution demonstrates a clear transition from government-led space programmes towards commercially oriented and innovation-driven ecosystems, while also indicating that entrepreneurship research is expanding but remains less mature than the well-established literature on regulation and commercialisation.

H) Density Visualization of Research Themes

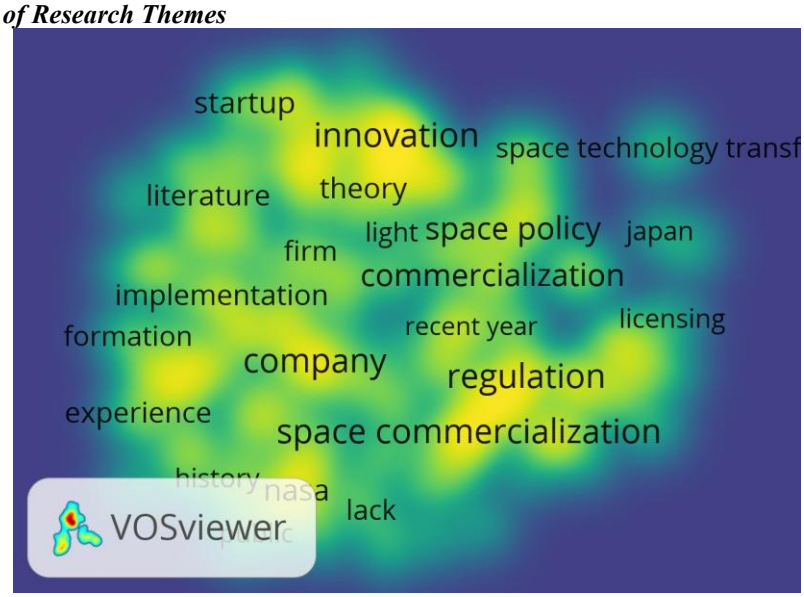

Figure 7. Density Visualization of Research Themes

The density visualization (Figure 7) indicates that the literature is highly concentrated around innovation, regulation, commercialization, and firm-related topics. In contrast, entrepreneurial finance, incubation, accelerators, and venture capital receive comparatively limited attention, suggesting that these themes remain underdeveloped within the broader space entrepreneurship ecosystem literature.

V. DISCUSSION

The present study provides a comprehensive bibliometric assessment of research on space entrepreneurship ecosystems by integrating performance analysis with science-mapping techniques. The findings indicate that scholarly interest in this field has grown substantially over the past decade, particularly after 2020, reflecting the rapid transformation of the global space sector from government-led programmes to commercially driven and innovation-oriented activities. This growth corresponds with the emergence of the NewSpace economy, supported by declining launch costs, private sector participation, technological innovation, and enabling public policies. Consequently, the field of space entrepreneurship has developed into an interdisciplinary area encompassing research in entrepreneurship and innovation management, economics/public policy/sustainability/and aerospace studies.

Key among these findings is the repositioning of commercialisation at the centre of the field with major implications for its intellectual structure. The network and term co-occurrence analyses reveal that existing literature relies on expertise in commercialisation, regulation, technology transfer and space policy interwoven into governance. Instead, the literature does shift away from seeing entrepreneurship as an isolated event and increasingly frames it in terms of a consequence realised through commercialisation whereby technological progress is translated into commercially viable products, services and well-founded business opportunities. Findings show the increasing relevance of public–private partnerships, regulatory reforms and technology transfer in enabling private sector engagement with international space activity.

The results also show a distinct chronological development of research priorities. While earlier research focused on regulation, licensing and institutional development, more recent studies have emphasized innovation, start-ups (entrepreneurs), entrepreneurial ecosystem initiative activities 1, business model generation. This fundamental shift is indicative of the increasing contribution that entrepreneurial firms provide to both technological progress and market development in the NewSpace economy. However, the relatively minor innovation cluster indicates that entrepreneurship oriented research has still a comparatively weak theoretical status compared to policy and commercialisation studies, with strikingly high room for further development both in theory and data.

Nonetheless, the analysis highlights a number of under-explored dimensions characterizing entrepreneurial ecosystems. Venture capital, business incubators and accelerators, as well as entrepreneurial finance aka start-up support mechanisms, are peripheral in the literature's conceptual landscape. This implies that the current research still emphasizes significantly technological and regulatory issues while devoting a relatively lower amount of attention to mechanisms based on financial, institutional or collaborative foundations sustaining entrepreneurial growth. More research is thus needed to explore the role

played by investment ecosystems, incubation programmes, entrepreneurial networks and public–private partnerships in fostering long-term development of commercial space ventures.

Overall, the findings demonstrate that research on space entrepreneurship ecosystems is undergoing a transition from a predominantly policy-oriented perspective towards a broader ecosystem approach that integrates innovation, entrepreneurship, commercialisation, and sustainability. However, important conceptual and empirical gaps remain, particularly regarding entrepreneurial finance, ecosystem governance, and start-up support, providing promising directions for future research.

Methodological Note. This study focuses on mapping the conceptual and intellectual structure of research on space entrepreneurship ecosystems. Accordingly, greater emphasis was placed on science-mapping techniquesincluding term co-occurrence, network visualization, overlay visualization, and density visualization than on geographical productivity indicators. This approach aligns with the study's objective of examining how knowledge within the field is structured, interconnected, and evolving over time.

VI. FUTURE RESEARCH AGENDA

This bibliometric analysis highlights potential directions for future research on space entrepreneurship ecosystems. With first, the course should learn more on functions of entrepreneurial finance such as venture capital, angel investment, private equity or other funding mechanisms, to assist NewSpace ventures in starting up and growing well into being successfully scaled. Because few publications within this literature address the financial ecosystems guiding their work, there is a need for empirical investigations of investment patterns and financing strategies.

Second, this study should be complemented by future studies focusing on both the role of different entrepreneurial support mechanisms incubators incubating start-ups and spin-offs from universities or knowledge-based companies, in fostering technology commercialisation among entrepreneurs at an early stage and how an overarching framework such as for example innovation hubs are implemented into innovative regional ecosystems. Comparative studies between nations and regions might also be used to uncover additional institutional best practices that promote commercial space sustainability.

Third, the field should examine new business models and partnerships involving reusable launch systems, satellite constellations, servicing in orbit at low cost (or even free), space tourism. There are opportunities to observe value creation, competitive advantage and ecosystem dynamics unfold in this rapidly evolving NewSpace economy.

Finally, future studies should adopt empirical and interdisciplinary approaches to examine the relationship between space entrepreneurship, sustainability, and ecosystem performance. Survey research, case studies, social network analysis, and mixed-method designs can provide deeper insights into entrepreneurial behaviour, institutional collaboration, innovation outcomes, and responsible governance in the commercial space sector.

VII. THEORETICAL CONTRIBUTIONS

The present study makes several important theoretical contributions to the emerging literature on space entrepreneurship ecosystems. First, it provides one of the earliest comprehensive bibliometric mappings of this rapidly evolving research domain, thereby establishing a structured overview of its intellectual foundations, conceptual development, and thematic evolution. Although specific areas such as technology development, space policy or sustainability have been reviewed in previous studies the current research consolidates these fragmented streams into a holistic body of knowledge. This enhances the understanding of how space entrepreneurship emerged as an interdisciplinary domain at the nexus between fields such as entrepreneurship, innovation management, public policy/economics and aerospace research.

Second, this study contributes to theory on entrepreneurial ecosystems by providing evidence that commercialisation is the key mechanism through which technological innovation translates into value creation in space entrepreneurship. Overall, the science-mapping analyses illustrate that regulatory governance and technology transfer work in concert with innovation and business development to shape how entrepreneurial ecosystems evolve anchoring successful space entrepreneurship within larger institutional, technological, and policy contexts.

Third, it contributes to the literature of innovation ecosystems by providing a timeline for how research themes on this topic have evolved. The overlay visualisation shows a shift from government focused themes such as regulation, licensing and technology transfer to more recent focus on innovation, start-ups and entrepreneurship development. This temporal evolution builds on existing theoretical eyes of how knowledge structures develop by noting the dynamic relationship between scientific fields, technological advancement, market liberalisation and greater private sector participation within a commercial space industry.

Finally, the paper identifies important theoretical gaps in current literature. The little evidence regarding the themes of venture capital, entrepreneurial finance, incubation and accelerators as well as ecosystem governance indicates that most research is still technology-policy-oriented. It will provide useful theoretical guidance for future entrepreneurs' support mechanism, cross-

boundary coordination and institutional collaboration incentives, financing system improvement structure as well as sustainable space innovative ecosystem.

VIII. PRACTICAL IMPLICATIONS

The results of this study have several implications for policymakers, government agencies and industry practitioners, investors,and academic institutions involved in building commercial space ecosystems. The growing importance of commercialisation and innovation indicates that governments must craft regulatory frameworks to support entrepreneurial endeavours while balancing them with the need for responsible and sustainable use of outer space resources. Some policies can be much more effective, such as simplifying procedures for obtaining licenses to operate in space or improving protection of intellectual property rights and public–private partnerships.

However, for space agencies and policymakers the key take away from this research is to move beyond government player that can only do technologies through major contracts towards collaborative innovation ecosystems that combine universities, research institutions, private enterprises (with their own related business), venture capital firms focused on supporting useful spin-off companies in each country maintaining a creative spirit while being integrated with technology incubators. This enhanced collaborative network will enable tech-transfer, encourage utilising that technology in novel solutions and successful commercialisation of space technologies.

The insights will also be useful for investors and entrepreneurial support organisations. The implication of this limited research attention is that significant room exists to create specialized investment mechanisms suited with the unique characteristics for NewSpace ventures, such as venture capital, incubation and accelerator programmes or horizontal entrepreneurship redescribed in the light of entrepreneurial finance. By lowering the necessary entrance cap for new movers and shakers, at least one pioneering commercial space start-up initiative can become established with dedicated space incubators, innovation hubs or venture capital funds.

Finally, academic institutions and researchers can utilise the findings to identify emerging research priorities and strengthen interdisciplinary collaboration across entrepreneurship, innovation management, aerospace engineering, economics, sustainability, and public policy. The bibliometric evidence presented in this study serves as a strategic roadmap for future research while supporting evidence-based decision-making for organisations seeking to build resilient and globally competitive space entrepreneurship ecosystems.

IX. CONCLUSION

The present study systematically mapped the intellectual structure and thematic evolution of research on space entrepreneurship ecosystems using bibliometric techniques. Based on a dataset of 2,722 publications retrieved from the OpenAlex database, the study combined performance analysis and science-mapping techniques to identify publication trends, influential publications, author productivity, collaboration patterns, and the conceptual development of the field. The findings demonstrate that scholarly interest in space entrepreneurship has increased substantially during the past decade, reflecting the rapid expansion of the commercial space sector and the emergence of the NewSpace economy.

Science-mapping analyses show that the literature is organized around four interrelated knowledge domains: commercialisation and regulation, innovation and entrepreneurship, business model development, and organisational performance. While regulation and commercialisation remain worldview pillars, emerging scholarship reflects an increasing pivot towards innovation-related activities including start-up development and entrepreneurship. Conversely, its limited treatment of themes such as venture capital, incubation and entrepreneurial finance (except with respect to startups) and ecosystem governance exposes several noteworthy gaps in knowledge that warrant greater research focus.

This study enhances the literature through a systematic mapping of research on space entrepreneurship ecosystems and pinpoints recommendations for future studies serving as avenues to explore go-to priorities from various perspectives including academics, policymakers, or industry practitioners. In addition to summarising publication trends, the study shows how reflected conceptual evolution from government space programs toward commercial innovation ecosystems. The findings also provide a foundation for future interdisciplinary research aimed at strengthening entrepreneurial support mechanisms, promoting sustainable commercial space development, and advancing the global NewSpace economy.

Interest Conflicts

The author(s) declare(s) that there is no conflict of interest concerning the publishing of this paper.

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