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Mechanisms of the NewSpace Economy: Signals, Structure, and Sustainability
(A compilation thesis based on three studies)

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A Elena,
ora siamo pari.

A Mamma e Papà,
anche questa va nell’angolo.

Chapter 0: My Personal Journey Through Space and NewSpace

From the very beginning of my career, I have been immersed in the world of space activities, experiencing firsthand the dramatic evolution of the sector and its underlying mechanisms. My professional path has taken me from the heart of traditional space at AVIO (formerly ELV), through the disruptive spirit of NewSpace at Rocket Lab Corp. (formerly Rocket Lab USA), to the frontier of in-orbit servicing at D-Orbit.

My early years at AVIO, working on the Vega launch vehicle, were a direct encounter with the "Old Space" paradigm. In this environment, developing a launch vehicle from scratch was a monumental challenge—one that required deep technical expertise, rigorous safety analysis, and close collaboration with established institutions like ESA and Arianespace. The process was methodical, shaped by decades of accumulated knowledge and regulatory oversight. It was a world where innovation was incremental, risk was tightly managed, and the boundaries of possibility were defined by tradition and institutional support.

The next chapter of my career led me to Rocket Lab in New Zealand, where I experienced the true spirit of NewSpace. Here, I was part of a team that built a launch vehicle from the ground up in a country with virtually no aerospace heritage. The challenge was not only technical but cultural: we had to invent processes, develop new technologies, and construct the Mahia launch site from scratch. As a launch operator, I was responsible for mission analysis and real-time flight safety, interacting directly with NASA and the FAA, trying to merge together the vision of space of such institution, with a different space seen from Rocket Lab. Rocket Lab embodied the essence of NewSpace—rapid iteration, entrepreneurial energy, and the belief that space should be accessible to new players and new ideas. It was a place where the impossible became possible, and where the boundaries of the sector were constantly being redefined.

Today, at D-Orbit, I find myself at the cutting edge of NewSpace, where the paradigm is being pushed to its limits with in-orbit servicing and advanced transportation solutions. My role as VP of Sales Engineering allows me to engage with the full spectrum of the sector—from launch services and microsats to in-orbit relocation and hosted payloads. D-Orbit represents the convergence of innovation, commercial viability, and operational excellence, demonstrating how NewSpace companies can redefine what is possible in space.

The more I became involved in aerospace activities, the more I wanted to understand what lies behind the NewSpace phenomenon. I became fascinated by the mechanisms that drive research and innovation, and by the challenge of building a sustainable business that does not rely solely on institutional or defense contracts. This curiosity and passion ultimately led me to pursue this PhD focused on uncovering the key mechanisms of NewSpace—how innovation, industrial strategy, and sustainability intersect to create a sector that is more open, ambitious, and impactful than ever before.

As I look to the future, I am excited by the possibilities that lie ahead. The journey from Traditional Space to NewSpace has been both challenging and inspiring, and I am eager to see what comes next as the sector continues to evolve and redefine itself.

Non est ad astra mollis e terris via
(L. Annaei Senecae - Hercules Furens, 437)

Chapter 1: Introduction

Over the past two decades, the space sector has undergone a profound transformation. The traditional "Old Space" paradigm, dominated by government agencies and large state-backed contractors, has given way to the entrepreneurial and finance-driven ecosystem known as "NewSpace." This shift is not merely technological or financial; it represents a reimagining of how space activities are conceived, executed, and held accountable. Where Old Space was characterized by centralized control, incremental innovation, and high entry barriers, NewSpace is defined by openness to private investment, rapid iteration, and the emergence of new markets such as satellite constellations, in-orbit servicing, and space tourism. This transition has accelerated innovation and economic growth, but it has also introduced new challenges in sustainability, governance, and market structure. The NewSpace paradigm is more dynamic and globally distributed, yet faces risks related to supply chain immaturity, financial volatility, and the need for robust frameworks to ensure transparency and long-term stewardship of the orbital environment. Within this evolving landscape, three mechanisms jointly shape firm outcomes and system-level dynamics: how innovation is signalled to financiers, how industrial activities are organized across the value chain, and how sustainability and governance pressures are internalized. This thesis integrates three stand-alone studies to examine these mechanisms in concert, asking how signals, structure, and sustainability interact to influence investment flows, industrial readiness, and long-term stewardship.

To clarify the cumulative logic and the overarching research question, the following table summarizes how each paper addresses a specific sub-question and how their findings connect:

Paper / Chapter	**Common Question**	**Sub-question addressed**
Signals from Space	How do firms build, organize, and legitimize competitive advantage in the rapidly evolving NewSpace economy?	Signals: How firms signal value and innovation to attract resources and build trust (through patents, technological cues, and capital).
The Vertical Integration in the NewSpace		Structure: How firms organize and coordinate operational and relational activities (such as vertical integration and value chain management).
Towards Sustainable Space		Sustainability: How firms achieve legitimacy and social acceptance by aligning with sustainability and transparency goals (for example, through SDGs and reporting).

Table 1: Framework connecting the three studies to a single meta-question, with sub-questions, methods, and cumulative links

Taken together, these studies illuminate a coherent arc: investors rely on a broader set of quality signals than patents alone; firms experiment with integration to overcome supply-chain immaturity and coordination gaps; and sustainability reporting remains voluntary and selective, motivating governance innovations. The cumulative logic is clear: when formal intellectual property is an incomplete signal, investors and customers seek operational proofs such as flight heritage and milestone delivery. To generate those proofs at speed, firms internalize critical interfaces through vertical integration, at least temporarily, until markets and standards mature. Integration, in turn, concentrates the levers that determine externalities—emissions, debris, re-entry profiles—yet voluntary reporting under-delivers on accountability, motivating new governance approaches such as a space-specific SDG module. The broader contribution of this thesis lies in connecting these threads to reveal the underlying logic of NewSpace's development. By examining signals, structure, and sustainability together, the work offers a holistic view of how market formation, technological learning, and stewardship are co-evolving. The future of the space economy depends not only on technical breakthroughs or financial flows, but on the capacity of firms and institutions to adapt, coordinate, and build trust at scale. Methodologically, the thesis employs complementary evidence: patent–funding linkages, firm and value-chain mapping with financial staging, and report-level transparency and SDG analysis. This triangulation prioritizes comparability and interpretability, while making explicit the limitations inherent in the available data.

In sum, the research design reflects the very nature of NewSpace itself: dynamic, interdisciplinary, and oriented toward integration. By grounding the analysis in a consistent conceptual framework and employing rigorous, comparative methods, the thesis offers actionable insights for researchers, industry leaders, and policymakers seeking to navigate—and shape—the next era of space activity.

Chapter 2: Signals from Space: Patents, Innovation, and Venture Capital in the NewSpace Economy

Signals from Space: Patents, Innovation, and Venture Capital in the NewSpace Economy[1]

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Abstract

This paper examines the relationship between patent activity and venture capital investment within the rapidly evolving NewSpace sector. As private firms increasingly lead innovation in commercial space exploration, questions arise about whether patents remain a reliable proxy for innovation and a relevant signal to investors. Using a dataset that combines aggregated U.S. patent information with firm-level funding data, we analyze the technological distribution of space-related patents (specifically CPC subclass B64G) and investigate whether a correlation exists between patent intensity and venture capital funding. Our findings indicate a growing internationalization of space innovation and highlight dominant technological domains such as launch systems and propulsion. However, the correlation between patent activity and funding levels is weak, with several prominent NewSpace companies receiving substantial investment despite having little or no patenting activity. These results suggest that investors may rely on alternative indicators of innovation—such as technical complexity, team expertise, or government partnerships—rather than patents alone. The study contributes to a nuanced understanding of how intellectual property fits into broader innovation and investment dynamics in the commercial space economy.

Key Words:

NewSpace, Innovation, Patents, Venture Capital, Intellectual Property, Space Economy, Aerospace Industry

Introduction

Whether patenting activity helps a young venture attract venture capital (VC) has become a central question at the intersection of entrepreneurial finance, innovation strategy, and intellectual property. The intuition is straightforward: early-stage ventures are opaque, their assets are largely intangible, and investors face severe information asymmetries. In such settings, patents are often treated not merely as legal tools but as observable actions that can help investors infer unobservable technological quality and commercialization potential. As Conti, Thursby & Thursby put it unambiguously, “By construction, a patent is an informational mechanism” because it simultaneously discloses technical content and creates an exclusionary right that can (at least in principle) support appropriation of rents. Yet the literature does not converge on a universal positive relationship between patenting and VC. Instead, the accumulated

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evidence suggests that the patent–VC relationship is contingent—studied most intensively in certain industries, varying by financing stage, and moderated by the industry’s appropriation regime.

First, much of the strongest evidence comes from specific empirical contexts—especially biotechnology and other science-driven domains where patents are traditionally considered important. In their early and influential study of VC-seeking biotechnology ventures, Haeussler, Harhoff & Mueller explicitly justify their setting: “The biotechnology industry provides an attractive setting for studying the impact of patents on the VC financing decision,” reflecting high uncertainty, long development cycles, and a strong reliance on intangible assets. Within that context, they document large timing effects: “Having at least one patent application reduces the time to the first VC investment by 76%.” This kind of result has made biotech a canonical example where patenting appears to operate as a meaningful signal in the early resource-assembly phase of venture formation.

However, the same stream of work also shows why simplistic “patent count → VC” stories are incomplete. The patenting process itself generates a sequence of information events (search reports, citations, opposition, grant outcomes) that can update investors’ beliefs. Haeussler, Harhoff & Mueller therefore argue that “the entire examination process should be considered, including information that emerges in the course of patent examination and review,” shifting attention from static patent stocks to dynamic information flows. This mechanism is especially plausible in settings like biotech where third-party evaluation (by examiners and competitors) can be interpreted as credible, structured information that reduces uncertainty for investors.

Second, and critically, the patent–VC relationship depends on the appropriation regime of the industry. Even if patents may function as signals, their economic value and interpretability vary by sector. Haeussler et al. emphasize that “‘patent strength’ varies between industries,” and that in many sectors patents can be less central than other mechanisms such as “mover advantages or secrecy.” Hsu & Ziedonis articulate the same idea through an explicit cross-industry contrast: “patents generally offer stronger product-market advantages in life science and chemical industries than is true in information technology (IT) sectors,”implying that the same patenting action can carry different informational and strategic meaning depending on the market and technological environment. The implication for VC is immediate: if patents are weaker as isolating mechanisms in some sectors, investors may rationally discount both their protective value and their relevance as signals of durable advantage—especially where rapid iteration, tacit know-how, and complementary assets dominate appropriation.

Third, the relationship is consistently shown to be stage-dependent. Patents should matter most where information asymmetry is highest—typically in early rounds—because later rounds bring richer alternative signals (customers, milestones, revenues, manufacturing readiness, regulatory progress). This stage logic is formalized in Hsu & Ziedonis’ predictions: “Increases in patenting activity will induce steeper upward adjustments in valuations of start ups in earlier (versus later) funding rounds.” Zhou et al. arrive at the same conclusion using a different angle—how multiple IP rights work together under staged finance—finding that “the complementarity between patents and trademarks exists only in initial VC funding rounds.” Across both accounts, the shared mechanism is that staged financing is itself a learning process; as the investor’s information set expands, the marginal value of early formal signals diminishes.

Finally, a major reason findings vary across papers is methodological: observed correlations can reflect selection rather than treatment. Ventures that patent may be systematically different before funding occurs, and VCs may be particularly skilled at selecting firms whose patenting already signals commercially viable knowledge. Lahr & Mina address this head-on and summarize their results in unusually strong terms: “Fully accounting for the endogeneity of investment, we find that the effect of VC on patenting is insignificant or negative,” while simultaneously noting that “venture capitalists follow patent signals to invest in companies with commercially viable know-how.” This matters for interpretation: a positive association between patents and VC does not necessarily mean patents cause VC, nor that VC causes more patenting; in some settings, patents may primarily function as screening devices that help investors identify ventures with credible technological trajectories, after which investors may rationalize innovation efforts toward commercialization rather than toward additional patent output.

Taken together, these strands motivate a careful, conditional framing: the patent–VC link has been studied most intensively in biotech and comparable science-driven contexts, but even there it is better understood as an interaction between patents' informational role and the institutional process that generates further information. Beyond biotech, variation in appropriation regimes—the relative importance of patents versus secrecy, lead-time, and complements—means patents can be weaker both as protective instruments and as signals. Across sectors, the financing stage consistently moderates effects, with stronger signaling value expected in early rounds and declining relevance as other performance signals emerge. And across empirical designs, the extent to which researchers control for endogeneity shapes whether patents appear to be a driver of funding, an outcome of investor selection, or both.

Prior Evidence: When Do Patents Matter for VC? Stage and Appropriation Regimes

In a cohort of incubated high-tech start-ups, a 1 % rise in patent filings boosted the probability of receiving VC funding by 46 % (Conti et al., 2013). Later-stage software ventures that hold even a single patent tend to raise more rounds, attract larger cumulative investment, and exit more successfully than their non-patenting peers (Mann & Sager, 2007). Yet the advantage evaporates in the seed phase: qualitative interviews with prerevenue software investors report that patents carry "little or no value" when revenue is still hypothetical (Mann, 2005), and a conjoint experiment with 187 EU/US VCs shows patents are treated mainly as a legal hygiene check—sometimes even a negative signal—rather than proof of technical quality (Hoenig & Henkel, 2015). Adding another twist, patents protecting radical inventions do attract top-tier syndicates at Series A, but the signaling effect fades once richer information about the venture becomes available (Colombo et al., 2023). Table 1 assembles these landmark studies side-by-side, highlighting the swing from strongly positive to neutral—and sometimes negative—findings. In short, whether patents magnetise capital or merely add paperwork hinges as much on when a firm is fundraising and which industry it inhabits as on the mere fact of patenting itself.

Source	Core finding on patent–VC correlation	Industry / stage focus	Key line in the paper
Colombo et al. 2023	Patents generally help, but only *reputable* VCs back radical-invention patents (strong signal + "dark side").	Mixed high-tech, first VC round.	"Patents help young firms obtain VC, **especially in the early stage**, when information asymmetries are more severe"
Hoenig & Henkel 2015	In conjoint experiments patents **do not** work as quality signals once property-right value is netted out.	Early-stage plans across tech sectors (mainly DE/US).	"**Our finding that patents fail to serve as signals of technology quality** is highly interesting in the light of existing studies on patents' signaling value"

Source	**Core finding on patent–VC correlation**	**Industry / stage focus**	**Key line in the paper**
Mann & Sager 2007	For software start-ups, having ≥ 1 patent is **positively correlated** with rounds, total VC and longevity; pre-financing patents ≈ irrelevant.	1 089 US software start-ups, full VC cycle.	“We find **significant and robust positive correlations between patenting and several variables measuring the firm’s performance** (including number of rounds, total investment…)”
Conti et al. 2013	Each +1 % in patents filed ↑ likelihood of VC by 46 %; FFF money matters to angels, not VCs.	117 incubated IT start-ups, US, seed-to-early.	“A **1 % increase in the number of patents filed increases the probability of venture capital funding by 46 %**”
Mann 2005	For pre-revenue software firms patenting has **“minuscule” predictive power** for VC success; enforcement costs too high.	Qualitative interviews + cross-section, US software.	“Patenting practices have at best **a minuscule ability to predict the success of a venture-backed software startup**”
Arts et al. 2018	Methodological article on text matching; **no VC analysis**.	All US patents 1976-2013.	“In this article, we mainly focus on the use of text matching to construct a case–control sample of technologically similar patents …” (no financing content)

Table 2: Empirical findings pull in different directions

Table 3 shows that the impact of patents pivots on a start-up’s place in the financing timeline. In the pre-seed or seed phase investors are still asking whether the venture has any plausible route to product–market fit. Evidence from Mann and Sager (2007) in Table 3 (“no indication… before first financing”) indicates that a patent portfolio offers little reassurance when there is no prototype, revenue, or market data. At this stage angels and micro-VCs read the founding team and an initial proof-of-concept more carefully than they read a patent filing; the patent is essentially paperwork because feasibility is unproven and the firm lacks resources to enforce its rights.

As companies move into Series A and B, information asymmetry peaks: prototypes exist, commercial traction is modest, and technical due-diligence is costly. Here costly, observable signals such as patents on truly radical inventions become valuable. Colombo et al. (2023) capture this in Table 2 with the line that firms holding such patents “match with more reputable VC investors but… [the effect] progressively vanishes.” The patent functions like a classic Spence signal—expensive enough to deter imitators but attainable for teams sitting on genuine breakthrough IP—yet it also flags heightened technical and regulatory risk, which reputable investors mitigate through staged financing and rigorous milestones.

By the growth or late stage, revenue is flowing and hard assets have accumulated, so the investor’s problem shifts from inferring upside to protecting it. Mann and Sager (2007) report in Table 2 that post-financing patent acquisition is “significantly correlated with number of rounds, total investment, and longevity.” At this point patents move from being credibility markers to legal moats that deter copycats, underpin licensing income, and strengthen negotiating leverage in exits. Taken together, Table 3 depicts an inverted-U pattern: the marginal benefit of a patent is low when uncertainty is either too high (nothing yet to protect) or too low (performance data speak for themselves) and highest in the middle when VCs must place large bets under bounded information.

Stage	Typical finding	Illustrative line (paper)
Pre-seed / seed	Patents seldom sway the very first cheque; investors weigh team and prototype instead.	"There was no indication that the existence of patents … before first financing had a positive impact." (*Mann & Sager 2007*)
Series A–B (high uncertainty)	Signals matter most here: patents on radical technology attract reputable syndicates—yet also raise risk flags.	"Firms with patents protecting radical inventions match with more reputable VC investors but this effect progressively vanishes." (*Colombo et al. 2023*)
Growth / late stage	Once revenue or assets appear, patents help cement advantage and underpin bigger rounds.	Patent acquisition is "significantly correlated with number of rounds, total investment, and longevity." (*Mann & Sager 2007*)

Table 3: How the stage changes the story

The economic value—and thus the financing signal—carried by a patent is inseparable from the industry's appropriation regime. In biotechnology and other deep-tech niches, where a single molecule or materials breakthrough can be copied the moment it is disclosed, legal exclusion is essential; patents therefore become a direct source of competitive advantage as well as a credible marker of technological quality. By contrast, most software or digital-service ventures can defend their positions through first-mover scale, network effects, or continuous deployment, making formal IP less critical. Mann and Sager (2007) capture this contrast succinctly, noting that patents "play a different role for biotech start-ups than they do for software start-ups," and even within software they find that product firms extract more value from patents than pure service providers.

The nature of the invention itself adds a second layer of differentiation. Colombo et al. (2023) show that investors react very differently to applications covering genuinely radical technology than to filings that merely refine existing designs: only the former systematically attract top-tier syndicates in early rounds. In incremental cases, a patent's signaling power weakens because rivals can often engineer around the claims or race ahead on complementary assets.

Finally, the presence of alternative information channels further modulates the signal. Hoenig and Henkel (2015) demonstrate that when venture capitalists can observe robust alliances with established firms or assess a founder's prior track record, they down-weight patents as indicators of technology quality. In such settings the patent reverts to a legal checklist rather than a pivotal selection criterion.

Taken together, these findings suggest that the apparent disorder in the patent–VC literature largely reflects shifting industrial ground rules: the stronger the property-rights value of a patent, the more radical the protected invention, and the scarcer alternative signals, the greater the likelihood that patents will tilt investment decisions.

Together, these studies suggest that the patent–funding link is contingent, swinging with (i) the stage of financing and (ii) the industry's appropriation regime.

Once stage and industry are considered jointly, the apparently contradictory findings cohere into a consistent logic. Patents matter only to the extent they ease information frictions and confer enforceable economic rights; both conditions fluctuate with a firm's development phase and technological domain. Aggregated studies that pool very young software apps with late-stage biotech companies are therefore bound to return mixed averages. When the sample is narrowed, the pattern becomes predictable. Early deep-tech start-ups—say, a propulsion company spinning out of a research lab—face acute uncertainty and operate in a field where exclusion through patents is crucial; here a granted claim can signal quality and secure future rents at the same time, making it attractive to venture investors. A seed-stage mobile-app developer, by contrast, competes on speed and user traction; any filing is expensive noise until the product proves itself, so VCs mostly ignore it. Farther along the life-cycle, a growth-stage platform or hardware firm that already earns revenue can use patents as legal armour: the portfolio underpins licensing deals, deters imitators, and justifies higher exit valuations. In short, the value of patenting oscillates across a predictable spectrum, peaking where information asymmetry is high and property rights are strong, and fading where other signals or market evidence dominate.

That contingency is particularly salient in the fast-moving NewSpace arena, where private firms—not states—now drive launch services, in-orbit logistics and downstream applications (Cornet et al., 2023; Gonzalez, 2023). NewSpace ventures face extreme capital intensity and technical uncertainty; patents may simultaneously signal technological credibility, secure bargaining power with incumbents, and reassure outside investors. Yet, precisely because most NewSpace hardware is long-cycle and high-risk, it is unclear whether patents yield the same informational benefits observed in software or biotech.

Against this backdrop, we ask: *To what extent is a firm's patent stock (granted patents) associated with the amount of private equity financing it raises in the NewSpace sector?*

We operationalize "private risk capital" as equity investment from private sources (e.g., venture capital, corporate venture, and growth equity) recorded in discrete funding rounds, and we measure it in two complementary ways: (i) round size (USD) at the time of each financing event, and (ii) cumulative private equity capital raised by the firm up to that event. Our unit of analysis is the firm–round observation, where patent stock is measured as the number of granted patents available up to the year of the round. We include both early-stage startups and later-stage scale-ups—defining "startup" as Seed–Series A and "scale-up" as Series B and beyond—so that we can examine whether the patent–funding association differs across financing stages. By mapping patent portfolios to funding events across a panel of space-sector ventures, this study tests whether patents still function as reliable signals of technological maturity and business viability in an industry where success hinges on both rapid innovation and massive financing.

Importantly, however, generalizing prior evidence on patents as VC signals to the NewSpace start-up context is not straightforward. Much of the empirical literature that finds strong patent–VC effects is rooted in settings such as biotechnology and other science-driven industries, where patents are tightly coupled to appropriability and where third-party examination can reduce technological uncertainty. Conversely, work in software and digital services often reports weaker or stage-contingent effects, consistent with appropriation through speed, secrecy, complements, and network effects rather than formal IP. At first glance, NewSpace might appear to simply "combine" these already-studied features—high uncertainty like biotech, yet fast iteration like software. But the sector also exhibits a distinct configuration of technological, institutional, and market characteristics that can alter the signaling role of patents in ways not captured by those canonical contexts.

In NewSpace, (i) development is capital-intensive and hardware-embedded, but (ii) commercialization is frequently mediated by public procurement, milestone-based contracts, and regulatory regimes that reshape investor learning and firm incentives; (iii) performance signals can emerge through observable operational milestones (test campaigns, launch cadence, flight heritage, mission reliability) that may dominate formal IP as credibility markers; and (iv) competitive advantage may rely on system integration, manufacturing know-how, and tacit process capabilities that are difficult to codify in patents and may be strategically protected via secrecy. Moreover, NewSpace innovations are often dual-use and internationally entangled, raising additional constraints (e.g., export controls, safety certification, and cross-jurisdictional IP strategies) that can discourage disclosure or complicate patent-based measurement. These features imply that patents may be a noisier proxy for innovation and a less central signal to investors than in classic deep-tech settings, even when technological uncertainty remains high. For these reasons, the NewSpace start-up context warrants an explicit, dedicated test rather than an assumption that existing results transfer mechanically across industries.

The NewSpace context

The rise of "NewSpace" is as much a financial re-ordering as a technological one. The turning point came when NASA abandoned cost-plus procurement and adopted milestone contracts; its Commercial Orbital Transportation Services (COTS) scheme "seeded capabilities in the space ecosystem" (Gonzalez 2023). Thanks to that early public push, private actors began pouring money into launchers, small-sat constellations and data services. As WIPO's review notes, "private funding has increased drastically in the 21st century (World intellectual Property). Venture capital followed fast: Gonzalez documents that "investments by the Venture Capital community … saw a 95 % increase from 2018 (US $2 bn) to 2019 (US $4 bn)" (Gonzalez 2023).

Finance instruments have multiplied alongside this maturation. Government remains the first back-stop: the ISS-resupply contracts alone poured "hundreds of millions of dollars for a new launch vehicle" into SpaceX and similar firms. For very small teams, early R&D is still fuelled by programmes such as SBIR, which "provides federally funded research awards to companies with 500 or fewer employees. As prototypes mature, traditional VC steps in; established primes then use their IP and licensing power to stabilise supply-chain partners—Thales Alenia Space, for example, "granted exclusive licences at symbolic prices … and sponsored funding applications by SMEs" (Azzam 2017). Yet colossal outlays are still required before revenues flow. Silvernail reminds us that "rocket launch systems take a vast amount of capital to develop" (Silvernail 2020, a reality that keeps external finance central to NewSpace business models. Against this backdrop, our study asks whether patents ease the path to that finance—or merely add paperwork—in a market that prizes speed, milestone execution and ecosystem partnerships.

Innovation within the NewSpace sector can be broadly defined as the process of generating and applying novel ideas, technologies, and business methods to address complex challenges and create economic and societal value. This includes not only the introduction of breakthrough technologies—such as reusable launch vehicles and miniaturized, high-performance satellites—but also incremental improvements in existing systems, production processes, and commercialization strategies (Silvernail, 2020; Ardito et al., 2022). Moreover, innovation in NewSpace often extends to organizational models and cross-sector partnerships that redefine how space-related services are delivered and monetized.

However, capturing the full scope of innovation in such a fast-moving and diverse industry poses significant measurement challenges. Traditional indicators like R&D expenditures or the number of product launches provide only partial insight into innovative performance (Hsieh et al., 2020).

Patenting activity is one observable indicator related to inventive activity and is widely used in empirical research because it is standardized and comparable across firms (Smith & Funk, 2021; Clancy, 2024). However, this study does not attempt to measure "innovation activity" broadly. Instead, it focuses on patenting activity as an observable strategic behavior and potential signal available to investors in contexts characterized by information asymmetry.

We operationalize patenting activity using the stock of granted patents, since grants reflect externally validated outcomes of the patenting process (Cosmonautics Report, 2025; Hai, 2025). Beyond legal protection, patents may also serve strategic purposes—such as shaping appropriability, monitoring competitors, and communicating technical positioning to external stakeholders. The sharp rise in space-related patent filings since 2011 reflects the increasing emphasis placed on intellectual property rights in the commercial space landscape (Ardito et al., 2022).

VC Financing of NewSpace Startups

Venture capital plays a pivotal role in financing the high-risk, capital-intensive endeavors characteristic of the NewSpace industry. In evaluating potential investments, venture capitalists (VCs) consider multiple factors, including the novelty and scalability of a company's technology, the size and accessibility of its target market, and the strength of its intellectual property portfolio. A central challenge in venture financing is the persistent issue of information asymmetry, where entrepreneurs inherently possess more knowledge about the technical and strategic dimensions of their ventures than external investors. This disparity can give rise to adverse selection and moral hazard, complicating the investment decision-making process.

Patents can serve as a powerful mechanism to reduce this information gap. As a formal, externally validated indicator of innovation, a granted patent provides verifiable evidence of technological novelty and the potential for commercial application (Broderick & Serapiglia, 2023). Research has shown that the approval of a startup's first patent significantly increases its chances of attracting venture capital, highlighting the importance of intellectual property in signaling quality and reducing perceived investment risk (Phero et al., 2022; Giga et al., 2022). In the context of NewSpace—where technological innovation is the cornerstone of competitive advantage and VC funding is essential for growth—the relationship between patent activity and investor engagement is expected to be particularly salient.

Nonetheless, it is essential to recognize the limitations of relying solely on patent data to capture the full spectrum of innovation. Patents primarily document technological innovation and often overlook other critical dimensions such as organizational, business model, or service innovation (Clancy, 2024; Smith & Funk, 2021). Additionally, the decision to patent is strategic and context-dependent—some firms, particularly those in highly competitive or rapidly evolving sectors, may opt to use trade secrets or other forms of IP protection instead. The varying patenting behaviors across firms and industries underscore the need for complementary metrics to construct a more holistic picture of innovation dynamics in NewSpace.

Moreover, patents offer strategic advantages beyond signaling. They create legal barriers to entry, protecting the startup's technological edge from imitation and securing a temporary monopoly that can facilitate market penetration and revenue growth. These protective qualities are especially attractive to venture capitalists, who prioritize high-growth ventures with scalable technologies and defensible competitive positions. As such, intellectual property rights—particularly in the form of well-crafted patent portfolios—are often directly correlated with higher firm valuations, improved negotiation power, and a clearer path to a successful exit through acquisition or IPO (Broderick & Serapiglia, 2023).

Methodology

To examine the relationship between patenting activity and venture capital (VC) investment within the NewSpace sector, this study adopts a quantitative research design. Patenting activity is the focal construct of interest in this paper. While patenting is only one observable indicator related to inventive activity, it provides a standardized and externally recorded outcome that investors can observe and potentially use during screening and due diligence. Accordingly, we test whether higher patenting activity—operationalized as the stock of granted patents available prior to each financing event—is associated with the size and staging of private equity financing rounds.

The analysis centers on a targeted sample of NewSpace firms for which both patent records and venture financing information are available, the selection of the NewSpace companies has been carried out following the definition of NewSpace reported in the Methodology section of "Chapter 4: The Vertical Integration in the NewSpace". Patent data are derived from patents classified under CPC group B64G (space vehicles and related technologies), enabling a consistent identification of space-related patenting activity. These records are used to compute firm-level patent measures (e.g., granted patent stock as of the year of each financing event), rather than attempting to measure innovation broadly. Venture financing data are drawn from publicly available company disclosures and startup intelligence platforms, and are structured at the firm–round level, including round amount and stage where available; qualitative contextual notes are retained to support interpretation.

By focusing on the association between observable patenting activity and venture financing outcomes, the study aims to clarify how capital is allocated in a sector characterized by high technical uncertainty and substantial up-front capital requirements. The methodology follows a multi-stage process of data acquisition, filtering, and structuring based onacquisition, filtering, and structuring based on publicly available datasets and established practices in patent-based research.

The primary dataset was sourced from the PatentsView platform[2], which provides structured, annualized data on U.S. patent grants. This database is widely recognized for its coverage of inventor, assignee, technology classification, and temporal attributes and has been used in prior studies to measure technological trends and knowledge spillovers.

To focus specifically on space-related innovations, the CPC classification data (g_cpc_current.tsv) was obtained from the PatentsView supplementary dataset repository[3]. This dataset allows identification of the technological domain associated with each patent at the time of issuance.

Using a Python-based data processing script, patents were filtered to retain only those classified under CPC group B64G, which corresponds to "Cosmonautics; Vehicles or Equipment Therefor". This classification captures technologies central to the NewSpace sector, including spacecraft systems, launch technologies, and orbital infrastructure. The decision to focus on B64G reflects its alignment with the commercial space domain's innovation priorities, particularly in the context of reusable launch systems and satellite platforms.

The filtered dataset was structured into a patent-level table where each row represents a unique patent. The final dataset includes several key variables for each granted patent. The patent_id serves as the unique identifier for each entry, allowing for accurate cross-referencing and aggregation. The cpc_group indicates the primary Cooperative Patent Classification (CPC) category assigned at the time of issuance, which in this study focuses on B64G, related to space technologies. The assignee field identifies the entity—be it a company, individual, or

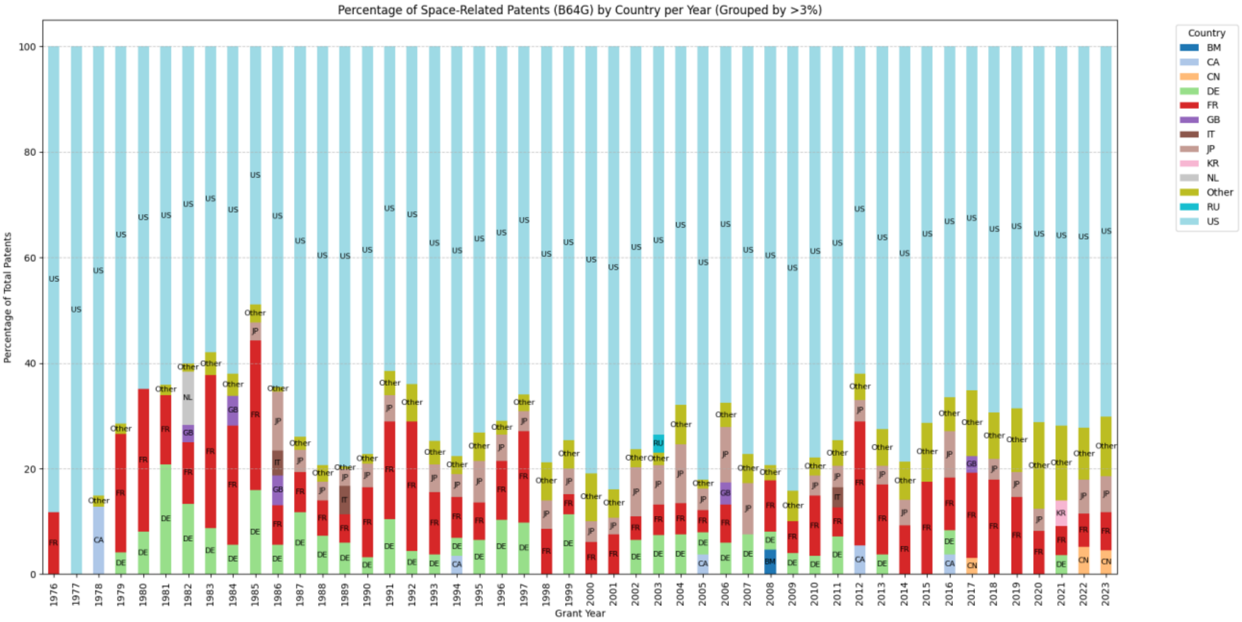

Figure 1: Percentage of Space-Related Patents (B64G) by Country per Year (Grouped by >3%)

institution—to whom the patent was granted. The country variable represents the geographic origin of the assignee, offering insights into the international distribution of space-related innovation. The grant_year specifies the year in which the patent was officially issued. The first_wipo_field_title denotes the primary technology field as classified by the World Intellectual Property Organization (WIPO), while the first_wipo_sector_title provides the broader WIPO sector classification relevant to the patented invention. These variables collectively enable both sector-specific and temporal analysis of innovation trends within the NewSpace domain.

This structure allows for both temporal trend analysis and sectoral mapping.

To complement the patent analysis, a parallel dataset was constructed containing financial and organizational data for a list of major aerospace and NewSpace companies. The dataset on aerospace and NewSpace companies includes several key variables. Company refers to the name of the organization, while Headquarters indicates the geographic location of its main office. Year_Founded captures the year in which the company was established. Ownership_Status classifies the firm as either publicly traded or privately held. Approx_Total_Funding (mUSD) represents the total amount of investment the company has raised, primarily through venture capital or institutional funding. Notes provide additional contextual information, such as details on mergers, spin-offs, or other notable milestones.

Compiling the funding database required a labor-intensive, multi-source approach. For each company, we reconstructed the chronology of investment rounds—along with the corresponding amounts and lead investors—by manually cross-referencing information from Tracxn profiles, official company press releases, and sector-focused news outlets such as TechCrunch, SpaceNews, and Via Satellite.

Results

The research question concerns whether firm-level patenting activity is associated with venture financing outcomes in NewSpace firms. For this reason, we restrict the Results section to analyses that operate at the firm level and that can directly inform the patent–funding relationship. Descriptive analyses of all B64G patents (including those granted to individuals, universities, public agencies, or other non-firm assignees) are informative for understanding the broader technology landscape, but they do not address the research question and can be misleading when interpreted as evidence about NewSpace startups. We therefore remove those patent-landscape results from the main Results and treat them as contextual material

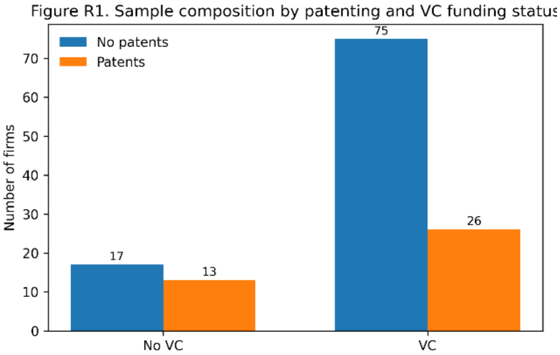

Figure 2: Sample composition by patenting and VC funding status

To address selection bias, we include all NewSpace firms listed in the funding dataset, not only those with observed patents and not only those with observed VC rounds. The resulting sample contains firms with patents but no VC, firms with VC but no patents, firms with both, and firms with neither (Figure 2).

In our data, 39 firms (29.8%) have at least one granted patent and 101 firms (77.1%) have at least one VC funding round; 26 firms (19.8%) have both patents and VC funding, while 17 firms (13.0%) have neither. The largest group is firms with VC funding but no granted patents (75 firms), indicating that patenting is far from universal even among financed NewSpace companies (Table 4).

Metric	Value
N firms	131
Firms with patents (>0)	39
Firms with VC funding (>0)	101
Firms with both patents and VC	26
Firms with neither patents nor VC	17

Table 4: Descriptive data for the expanded sample (including zero–zero firms

We first present a transparent bivariate view that retains firms with zero patents and/or zero VC funding. Figure 3 plots log(1 + total granted patents) against log(1 + total VC funding) for all firms. The dispersion is large: some firms attract substantial funding with little or no patenting activity, while other firms hold patents without raising comparable VC. This reinforces the need for multivariate analysis, because simple scatter plots do not control for confounders such as firm age or (critically) prior funding history. We construct a firm–year panel and estimate regressions that relate funding outcomes in year t to (i) lagged patent stock and (ii) prior funding history, with controls. The dependent variables are:

1. Funding incidence: a dummy equal to 1 if the firm raises a VC round in year t, 0 otherwise.
2. Funding amount: log(1 + VC amount in year t) (unconditional), and log(VC amount) conditional on being funded.

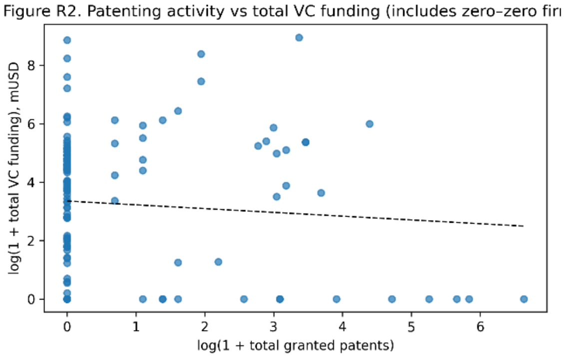

Figure 3: Patenting activity vs total VC funding (includes zero–zero firms)

Key regressors are log(1 + patent stock) lagged (patents accumulated up to year t−1) and log(1 + cumulative VC) lagged (cumulative VC raised up to year t−1), plus firm age. Model 1 estimates funding incidence using a binary dependent variable equal to 1 if a firm raises VC in year t and 0 otherwise (linear probability model with fixed effects). Model 2 estimates funding intensity on the full panel (including zero-funding years) using log(1 + VC amount in year t) as the dependent variable. Model 3 estimates funding intensity conditional on being funded (VC amount > 0) using log(VC amount) as the dependent variable. All models include year fixed effects and country fixed effects[4], with standard errors clustered at the firm level (Table 5).

Table 5 reports three complementary firm–year regression models designed to capture different aspects of venture financing dynamics. All models are estimated on a firm–year panel and use lagged explanatory variables so that patenting activity and prior funding history are measured before the funding outcome occurs. Standard errors are clustered at the firm level, and all specifications include year fixed effects and headquarters-country fixed effects.

Variable[5]	Model 1: Funded (LPM) coef	Model 1: SE	Model 2: log(1+VC amount) coef	Model 2: SE	Model 3: log(VC amount)|funded coef	Model 3: SE
log(1+Patent stock) lag	-0.024**	(0.011)	-0.105***	(0.039)	-0.223	(0.186)
log(1+Cumulative VC) lag	0.024***	(0.008)	0.221***	(0.049)	0.564***	(0.055)
Firm age	-0.002***	(0.000)	-0.003	(0.002)	0.034**	(0.017)
Year FE	Yes		Yes		Yes	
Country FE	Yes		Yes		Yes	
N (firm-years)	1684		1684		303	
Adj. R^2 / R^2	0.066		0.102		0.519	

Table 5: Panel regression results (firm–year), with firm-clustered standard errors.

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[4] with country fixed effects, the coefficient on patent stock is identified by comparing firms within the same country, over time (and also across countries after subtracting each country's baseline).

[5] Notes: Coefficients are reported with firm-clustered standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.10.

Across the multivariate specifications, prior funding history is a strong predictor of both the probability and the magnitude of subsequent funding (positive and highly significant in all models), consistent with the idea that staged finance is a learning process and that past financing is a strong signal of viability. In contrast, lagged patent stock is not a positive predictor of VC outcomes in this dataset. In the funding-incidence model (LPM linear probability model), lagged patent stock is associated with a small negative coefficient (-0.024, $p < 0.05$), while lagged cumulative VC funding is positive (0.024, $p < 0.01$). In the funding-amount model ($\log(1 + \text{VC amount})$), lagged patent stock is also negative (-0.105, $p < 0.01$), while lagged cumulative VC is strongly positive (0.221, $p < 0.01$). In the conditional model (funded firm–years only), lagged patent stock is negative but not statistically significant, while prior cumulative VC remains strongly positive and firm age becomes weakly positive.

These results should be interpreted as associations, not causal effects. They suggest that in NewSpace, observable execution-related signals and funding history may dominate patents as predictors of subsequent VC outcomes. This is consistent with the sector logic discussed earlier: investors may rely on alternative credibility markers (milestones, flight heritage, qualification progress, customer traction, strategic partners) and many firms may protect key know-how through secrecy or integration rather than patent disclosure. Importantly, the inclusion of firms with zero patents and/or zero VC funding is crucial for this conclusion; restricting the analysis only to firms with both patents and VC would mechanically bias inference and overstate any apparent association.

Conclusion

This study set out to investigate whether firm-level patenting activity—operationalized as the stock of granted patents—relates to venture capital (VC) financing outcomes in the NewSpace sector. While patenting is often discussed as an observable indicator related to inventive activity, our empirical objective is specific: to test whether granted patents function as a financing-relevant signal in a sector characterized by high uncertainty and capital intensity.

The revised results support three main conclusions. First, patenting and VC funding are not universal features of NewSpace firm trajectories. By expanding the analytical sample to include firms with zero patents and/or zero VC funding, we avoid selection bias inherent in restricting attention only to firms observed in both patent and funding datasets. This full-sample view reveals substantial heterogeneity: many firms raise VC without holding granted patents, and a non-trivial "zero–zero" group exists that would otherwise be omitted. This matters for inference because the baseline population includes firms that neither patent nor raise VC, as well as firms that pursue one strategy without the other.

Second, descriptive evidence indicates that the relationship between patenting activity and venture financing is weak and highly dispersed when zero–zero firms are retained. The scatter of $\log(1 + \text{patents})$ versus $\log(1 + \text{total VC})$ shows that some firms attract substantial funding with little or no granted patent stock, while other firms accumulate patents without comparable VC outcomes. This dispersion suggests that simple bivariate comparisons are insufficient to explain capital allocation in NewSpace and motivates a multivariate approach that accounts for confounding factors and financing dynamics.

Third—and most importantly—the multivariate longitudinal analysis indicates that patenting activity is not a positive predictor of VC outcomes once prior funding history and fixed effects are introduced. In firm–year regressions, lagged cumulative VC funding is consistently a strong predictor of both the probability of raising funding in a given year and the amount raised, reflecting path dependence and investor learning under staged finance. By contrast, lagged patent stock does not exhibit a robust positive association with subsequent VC outcomes and, in baseline specifications, is estimated with a small negative association in the incidence and unconditional amount models and a non-significant association among funded firm–years. These results should be interpreted as associations rather than causal effects, but they indicate that "more granted patents" is not a general-purpose route to "more VC" in this dataset once the dynamics of repeated financing rounds and cross-country differences are controlled for.

Taken together, the evidence reinforces and nuances the stage-contingency perspective in the innovation–finance literature. Prior work suggests that formal IP can function as a credibility signal in some contexts and stages (Hsu & Ziedonis, 2013; Conti et al., 2019), but it may become less central as alternative information channels (milestones, customer traction, alliances, execution proofs) accumulate. Our results are consistent with this broader interpretation and align with arguments that patent counts are not reliably correlated with scale-up success in settings where secrecy, tacit know-how, and system-level execution dominate value creation (Smith & Funk, 2021). They also align with the NewSpace-specific observation that firms can substitute patents with other credible signals—such as team pedigree, first-mover speed, and government or institutional partnerships—when raising capital (Silvernail, 2020).

These findings carry implications for entrepreneurs, investors, and policymakers. For entrepreneurs, patenting should be treated as one strategic instrument among others, whose value depends on the firm's appropriability regime, architecture, and commercialization pathway rather than as a universally necessary prerequisite for venture funding. For investors, patent metrics are best used as complementary inputs—alongside evidence of execution, milestone delivery, and market traction—rather than as standalone screens. For policymakers seeking to foster commercial space ecosystems, the results suggest that strengthening IP frameworks alone is insufficient: complementary support structures that improve the visibility of execution performance, reduce financing frictions, and enable credible validation of capabilities may matter at least as much as patent accumulation for attracting and sustaining private risk capital.

Limitations and Future Research

While this study contributes valuable insights into the relationship between patent activity and venture capital investment within the NewSpace sector, it is not without limitations.

First, the reliance on U.S. patent data (specifically CPC subclass B64G) limits the scope of analysis to a subset of global innovation activity. Important space innovation efforts occurring under other jurisdictions (e.g., Europe, China, Japan) may be underrepresented, potentially biasing the findings. Future research could expand by incorporating international patent databases such as those from the European Patent Office (EPO) or the World Intellectual Property Organization (WIPO) to provide a more comprehensive global picture.

Second, the study uses patent counts as a primary proxy for innovation without distinguishing between patent quality and impact. Not all patents hold equal technological or commercial value; some may represent incremental improvements rather than major breakthroughs. Future studies could enrich this approach by including patent citation metrics, forward citations, or patent family size to better assess the significance and influence of patented technologies.

Thirdly, the analysis does not fully account for alternative forms of intellectual property protection, such as trade secrets, design rights, or software copyrights, which can be particularly important in space technologies where technical secrecy is a key competitive advantage. Future research could explore the role of non-patent innovation strategies and how they interact with funding decisions.

Ultimately, assembling a more detailed and systematically structured dataset of funding rounds would permit a far more comprehensive statistical investigation, making it possible to detect any underlying correlations with greater confidence.

In summary, future research would benefit from broadening the scope to international datasets, refining measures of innovation quality, differentiating funding stages, incorporating non-patent IP strategies, and adopting longitudinal designs. Such efforts would deepen the understanding of how innovation is signaled, perceived, and financed in the evolving commercial space economy.

Data

The data of this research can be made available on request.

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Declaration of generative ai and ai-assisted technologies in the writing process'

Statement: during the preparation of this work the author(s) used google/gemini in order to increase the readability of the paper, being the main author not an english mothertongue. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication

Ethical approval

This article does not contain any studies with human participants performed by any of the authors. The analysis is based exclusively on secondary data (patent databases and publicly available funding information).

Informed consent

This article does not involve human participants, and therefore informed consent was not required.

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Annex A

The United States has consistently dominated space-related patent activity over the past five decades, accounting for more than 72% of all granted patents in the dataset. This overwhelming share reflects the country's long-standing industrial strength, deep-rooted investment in R&D, and its historical leadership in aerospace and defense innovation (Hai, 2025; Cosmonautics Report, 2025). The early leadership observed in the 1980s and 1990s solidified the U.S. as the foundational innovator in space technology, a trend that has continued into the NewSpace era.

In parallel, countries such as France, Germany, and Japan have maintained a consistent presence in space-related patenting, collectively representing a significant portion of non-U.S. activity. This reflects both their strong national space programs and the role of collaborative initiatives such as the European Space Agency, which has been instrumental in sustaining innovation ecosystems across member states (Radovanovic et al., 2023). Notably, France stands out as the most active European contributor, underscoring its strategic investment in space technologies through both CNES and industrial players like Airbus and Thales Alenia Space.

Over time, the share of patents attributed to countries outside the top four (US, FR, JP, DE)—grouped under "Other"—has steadily increased, now accounting for over 8% of the total. This shift points to a broader diffusion of space innovation capabilities and the growing participation of emerging space nations such as India, South Korea, and Canada. These actors are increasingly carving out specialized niches within the global space economy, whether in launch systems, satellite components, or downstream services.

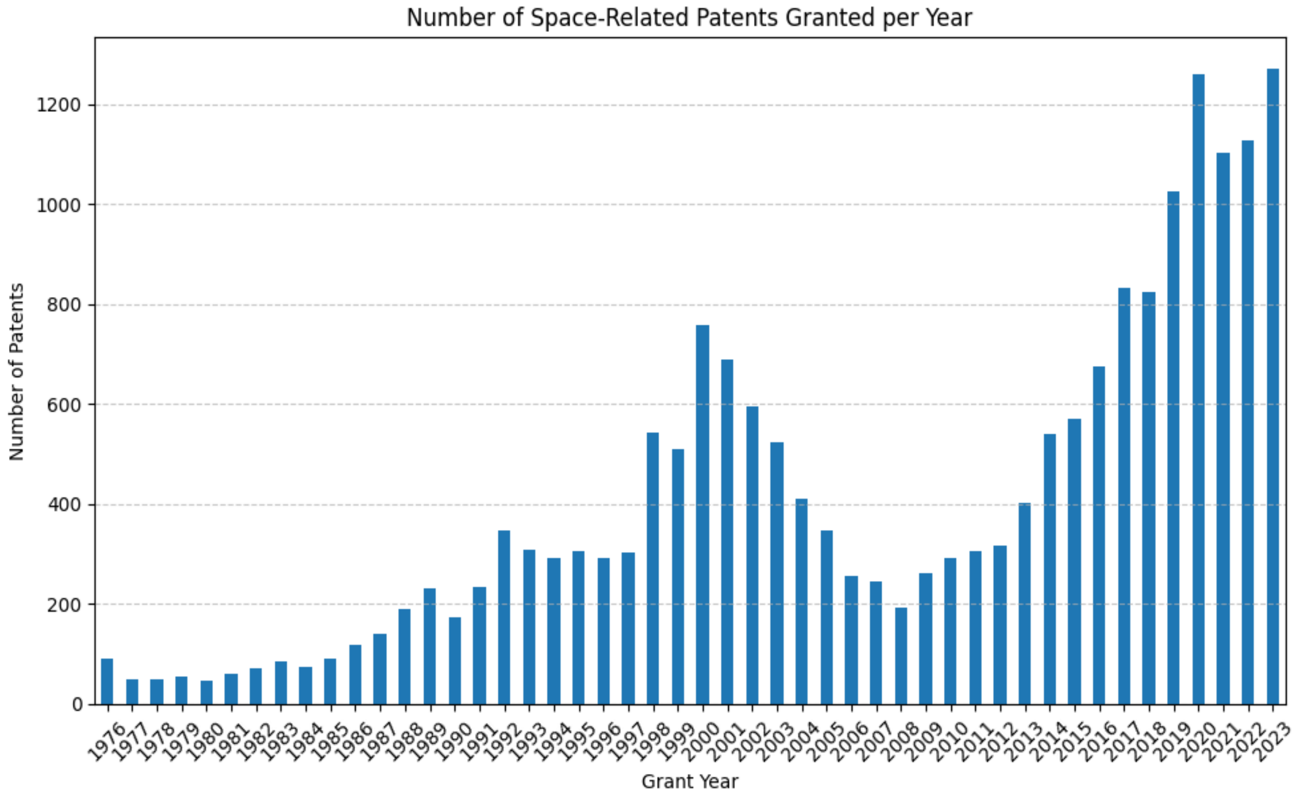

Figure 4: Number of Space-Related Patents Granted

Overall, the long-term trends reveal a landscape that, while historically concentrated, is progressively evolving into a more distributed and collaborative ecosystem. This fragmentation mirrors the strategic interdependence of NewSpace actors, where cross-border partnerships and supply chain alliances play a crucial role in advancing technological development, especially as commercial and civilian applications multiply. The result is a globally networked innovation environment where the United States continues to lead, but not in isolation.

The trajectory of space-related patent activity from 1976 to 2023 reveals a nuanced evolution shaped by shifting technological, institutional, and commercial dynamics (Figure 4). From the late 1970s through the early 2000s, annual patent filings in the space domain remained relatively modest, reflecting a period in which innovation was primarily concentrated within government space agencies and a limited number of aerospace contractors. Notably, a gradual decline in patent activity is observable from the mid-1990s to 2008, likely linked to post-Cold War budget contractions, program consolidation, and reduced commercial incentive for space-focused R&D during that time.

However, beginning around 2009, a new phase of growth emerges. This upward trend coincides with the rising prominence of commercial space players and the institutional shifts that paved the way for the NewSpace movement. The retirement of the U.S. Space Shuttle program, the entrance of private actors such as SpaceX and Blue Origin, and increased public-private partnerships created fertile ground for renewed technological development.

This innovation surge is vividly captured in the data, culminating in a peak of 1,259 granted patents in 2020—a record high. The 2020 peak may be attributed to a convergence of maturing technologies, increased venture capital investment throughout the late 2010s, and a wave of patent filings reaching grant stage following the explosive growth of space startups earlier in the decade.

Following 2020, patent activity stabilizes at a high level but does not continue its exponential rise. This plateau, observed through 2021 to 2023, may reflect broader economic headwinds, supply chain disruptions, and shifting investment priorities in the aftermath of the COVID-19 pandemic.

Nevertheless, the persistence of high patent volumes underscores the resilience and ongoing maturation of the NewSpace sector, which continues to diversify its technological base while attracting both institutional and commercial attention. The overall pattern thus reflects a transition from stagnation to innovation acceleration, mirroring the transformation of the space economy itself.

Based on the extended dataset analysis and the visualization above, we observe distinct patterns in the evolution of key CPC subclasses (Figure 3), each representing a different technological focus within the space sector. These changes reveal how innovation priorities have shifted over time in response to new technical challenges, commercial opportunities, and funding landscapes.

During the late 1990s and early 2000s, CPC subclass B64G1/244—which pertains to support or protection of on-board instruments or payloads—experienced a noticeable surge in relative patenting activity. This peak likely reflects a phase in which satellite miniaturization and onboard instrumentation were rapidly advancing, especially as commercial and military operators looked to enhance payload capabilities for Earth observation and telecommunications. However, this category's prominence sharply declined after 2005. The decline coincides with the broader consolidation of

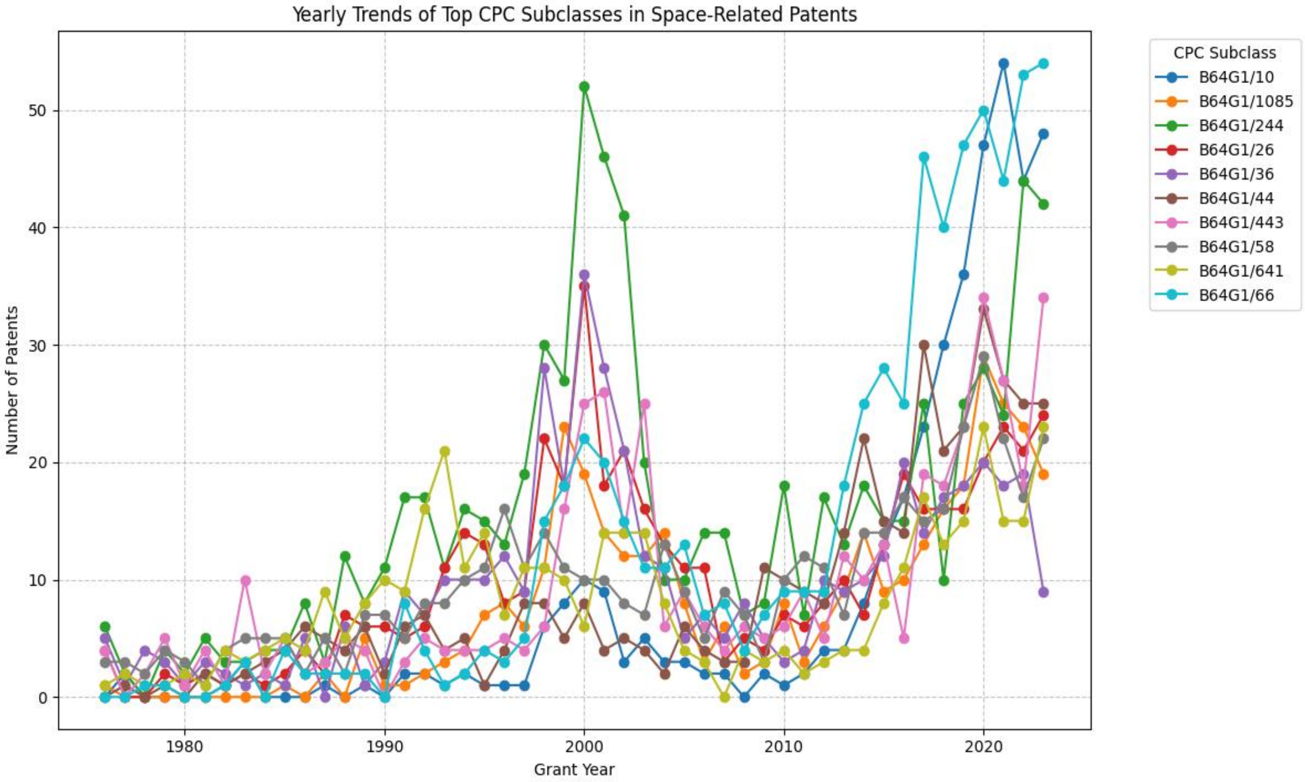

Figure 5: Yearly Trends of Top CPC Subclasses in Space-Related Patents

heritage satellite systems and a temporary contraction in commercial launch activity during the early post-dot-com years and early 2000s, a period marked by slower investment in new satellite constellations and a lull in large-scale innovation funding.

In contrast, B64G1/66, which covers spacecraft orientation or attitude control, has seen a sustained and growing share of patent activity, particularly since the mid-2010s. This growth can be linked to the rise of small satellite constellations and in-orbit servicing missions, both of which require advanced precision in orientation and maneuvering. Companies such as Planet Labs and Starfish Space have prioritized this area to enable more agile, autonomous, and scalable spacecraft operations, aligning with venture funding directed at enabling new mission architectures and satellite servicing capabilities.

Meanwhile, B64G1/10, which concerns propulsion systems specifically adapted for space vehicles, has exhibited a steady rise in importance since the early 2010s. This growth correlates with the entry of private launch providers such as Rocket Lab, Astra, and Firefly Aerospace, who are innovating in propulsion technologies to increase thrust efficiency, support rideshare missions, and reduce cost per kilogram to orbit. The increased patenting in this area reflects both government-supported innovation (e.g., DARPA and NASA SBIR programs) and aggressive venture-backed development of proprietary propulsion platforms, a core differentiator for competitive edge in the launch and mobility segments.

Together, these subclass trends underscore the dynamic nature of technological specialization in the NewSpace economy. The rise and fall of specific CPC categories mirror broader market cycles, funding influxes, and evolving strategic goals of companies seeking to commercialize orbital access and services. These patterns reinforce the idea that patent intensity in particular technological domains can serve as a proxy for emerging innovation themes and guide investment analysis. To further investigate the correlation between patenting and funding round, Figure 6 presented below integrate two complementary data streams contained in the workbook: the chronological ledger of financing events and the register of granted patents. Our analysis is restricted to firms that are represented in both sources; observations for which either a funding event or a patent record is absent are excluded. For each qualifying financing round we compute the stock of patents already granted as of the calendar year in which the round closed. Patents granted thereafter are deliberately omitted, thereby preserving temporal causality and ensuring that the intellectual-property position displayed on the ordinate could have informed the investor's decision at the time of investment.

Free-text descriptions of financing rounds vary widely—ranging from "mega-Series B" through "SBIR Phase II non-dilutive grant" to "De-SPAC business combination". To impose analytical coherence these descriptions are mapped, by means of a deterministic keyword scheme, to the canonical stages of venture finance: Seed, Series A, Series B, Series C, Series D, Series E. This procedure preserves semantic consistency while avoiding subjective re-classification.

In every panel the abscissa records the size of the round, expressed in millions of U.S. dollars and rendered on a logarithmic scale so that micro-seed notes and nine-figure growth financings can be visualised simultaneously. The ordinate reports the contemporaneous stock of granted patents. A simple ordinary-least-squares line is superimposed on each scatter plot; it serves solely as a visual aid, indicating whether the cloud of observations exhibits a positive, negative, or negligible linear tendency. Taken collectively, the plots reveal a coherent narrative. Among Seed rounds, the point cloud ascends, implying that larger early cheques are typically extended to companies possessing more granted patents. At the Series A milestone the pattern flattens, suggesting that investors at this juncture privilege commercial traction over intellectual-property accumulation. The upward tendency re-emerges at Series B, consistent with a renewed emphasis on defensible technological moats. Beyond Series C, however, the dispersion of points broadens and the fitted line often loses a discernible slope, indicating that late-stage and quasi-public financings are influenced predominantly by scale and revenue metrics rather than by patent counts.

This framework—joint consideration of contemporaneous patent stock and log-scaled financing magnitude within harmonised stage buckets—provides a transparent basis for interpreting how intellectual property is capitalised at successive phases of the venture life cycle. From our perspective, it is important to emphasize that these observations are derived from a qualitative interpretation of the plots. We fully acknowledge that a more rigorous statistical analysis will be required to determine whether a measurable correlation exists. However, we also recognize that such an analysis would depend on the availability of a more comprehensive and structured dataset on funding rounds.

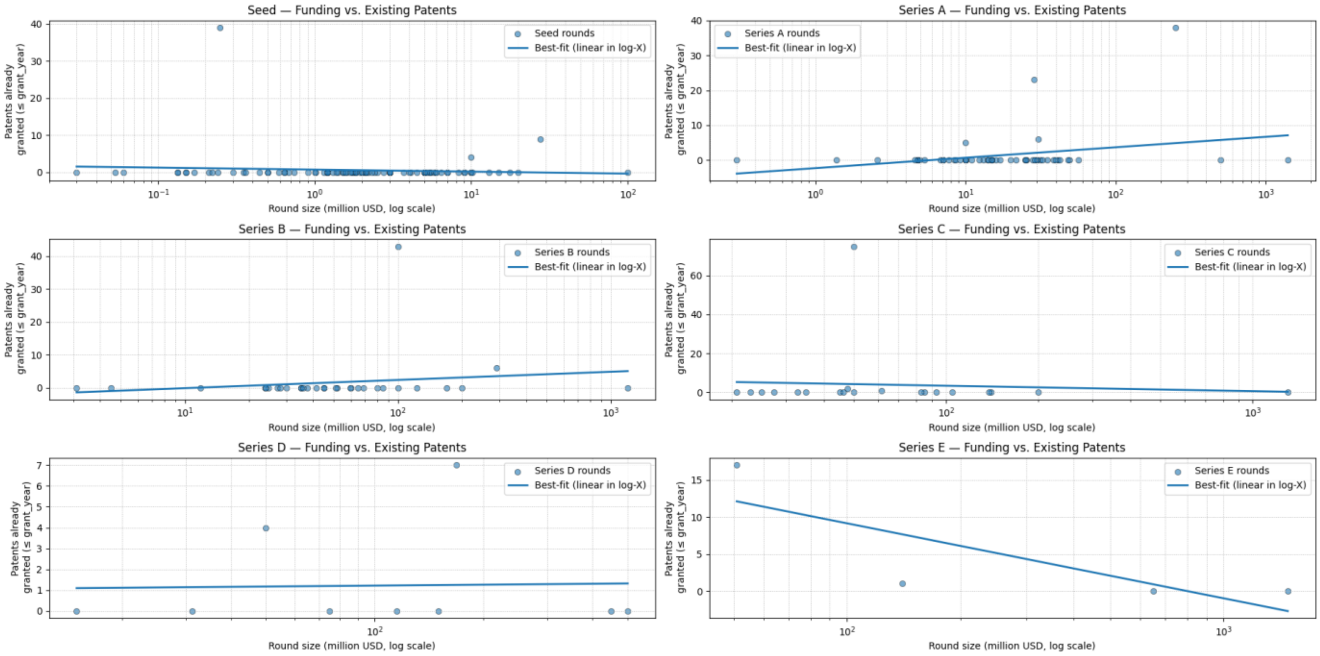

Figure 6: Patent Intensity vs. Funding Levels in NewSpace Companies

Chapter 3: From Innovation Signals to Industrial Structure

In our dataset, the observed patent–VC patterns suggest that high venture funding is not robustly and systematically associated with extensive patent portfolios. Within the limits of our evidence, formal intellectual property does not appear to function as a universal prerequisite for capital allocation across NewSpace firms. A plausible interpretation is that investors often weigh execution-related signals (e.g., milestones, team experience, partnerships, early traction) alongside or in place of patents, especially when information asymmetry is high and due diligence is costly. If any stage pattern exists, it is at most suggestive that patents may matter more in some mid-stages for certain deep-tech firms; however, this interpretation remains tentative and may also reflect selection effects, milestone validation, or appropriability choices (e.g., secrecy or integration).

Taken together, our patent evidence (CPC B64G) and prior signaling research are consistent with the view that patents can be informative only under certain conditions, and that investors may shift attention toward alternative signals as additional information becomes available.

These findings have implications for how industrial organization may evolve in NewSpace. When supplier ecosystems are immature or cannot reliably meet cadence and quality needs, firms may rely more on operational proofs (e.g., control of critical assets/processes) than on formal IP signals to reduce uncertainty for stakeholders. One possible organizational response is greater vertical scope/integration, including internalizing key subsystems (e.g., propulsion, structures, avionics) and co-locating design, manufacturing, and testing to shorten iteration cycles. Reducing physical and contractual distance across interfaces can plausibly lower transaction costs under uncertainty, preserve architectural flexibility, and reduce coordination risks in mission-critical handoffs. Conversely, as specialized vendors emerge, standards stabilize, and learning accelerates, outsourcing can become more attractive, enabling firms to concentrate resources on differentiation (e.g., operations, data products, end-user platforms). This logic is broadly aligned with transaction-cost and resource-based perspectives: greater integration/scope is more likely when coordination is intense, assets are specific, and uncertainty is high, while disintegration/outsourcing becomes more viable as markets mature and vendor reliability improves.

Our mapping of 112 post-2000 firms across Space Access, EO, Navigation, and Communication—and across Upstream, Downstream, and End-User segments—indicates that only a minority span the full value chain. Within the subset of firms that span the full value chain, only two report positive EBITDA; this suggests that profitable full-stream coverage is rare in the available data, but the small cell size prevents broader conclusions about the viability of deeply integrated models. The observed concentration in downstream segments and limited end-user presence are consistent with the interpretation that many firms position where entry barriers are lower and monetization may be faster, whereas fewer firms undertake the complexity and capital intensity of upstream integration.

The link from signaling to organizational structure can be framed as both informational and organizational. When patents are an incomplete or noisy signal, investors and anchor customers may place greater weight on operational proofs (e.g., flight heritage, cadence, qualification throughput, in-house production, integrated delivery) that complement or substitute for patents in decision processes. To deliver such proofs rapidly, firms may internalize key interfaces—synchronizing design, testing, and production, protecting tacit knowledge, and shortening feedback cycles. In this interpretation, vertical integration (or broader value-chain scope) can function as a mechanism to accelerate learning and manage schedules under uncertainty. As supplier ecosystems mature and standards stabilize, some firms may shift toward modular outsourcing—consistent with an ‘integrate to learn, outsource to scale’ logic.

Policy developments may reinforce these dynamics. The shift from cost-plus to milestone-based procurement (e.g., NASA’s COTS/Commercial Crew programs) likely altered incentives by rewarding demonstrated capability rather than effort expended, thereby increasing the salience of execution signals relative to patent portfolios. Venture finance may have adapted in parallel, with expectations often centered on staged technical and commercial progress rather than on IP accumulation alone. Consequently, organizational control over critical-path activities can be an important lever for risk mitigation in NewSpace, although its relative importance likely varies by subsector and firm maturity.

The relevance of vertical integration plausibly varies across streams. In Space Access (launch), hardware intensity, safety, and reliability can make integration more persistent; qualified suppliers may be scarce, reputation is salient, and test infrastructure can represent a strategic asset. In downstream segments (EO, Navigation, Communication), where software, analytics, and customer relationships are often central, firms may leverage partnerships and cloud-native pipelines, making selective outsourcing viable earlier in the lifecycle. The end-user tier appears comparatively underdeveloped in our mapping, which is consistent with an emphasis on upstream/midstream operational proofs prior to expansion into specialized applications.

In summary, the signaling limitations highlighted in the first study motivate a cautious interpretation in the integration analysis: when patents do not consistently correlate with financing outcomes, operational proofs may play a larger role in stakeholder selection, alongside other mechanisms.

To deliver such proofs efficiently, some firms may integrate critical interfaces and later re-modularize as markets, vendors, and standards develop. Accordingly, vertical integration (or broader value-chain scope) can be interpreted not only as a response to production efficiency, but also as a strategy to address coordination challenges, manage uncertainty, and build proprietary capabilities in NewSpace. Conceptually, the thesis moves from symbolic mechanisms of legitimacy to structural mechanisms of organization, consistent with the cumulative logic of the three studies.

Chapter 4: The Vertical Integration in the NewSpace

The Vertical Integration in the NewSpace[6]

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Abstract

The rapid evolution of the NewSpace industry, characterized by increased private sector involvement and technological innovation, has prompted significant changes in how space-related activities are conducted. This paper explores the concept of vertical integration within NewSpace companies, focusing on their involvement across the upstream, midstream, and downstream sectors of the space economy. Using data from 67 NewSpace companies, we assess the extent to which these companies can sustain operations across the entire value chain. Our analysis reveals that while many NewSpace companies have diversified their operations, only a few have achieved full vertical integration, and even fewer possess sustainable business models, as indicated by positive EBITDA figures. The study highlights the potential advantages of vertical integration for reducing costs and improving service efficiency, as demonstrated by companies like SpaceX. However, the industry's early developmental stage, combined with challenges in engaging the end-user market and maintaining financial transparency, suggests that further research is necessary. This paper also outlines areas for future development, including the role of emerging technologies, strategic partnerships, and evolving regulatory frameworks that will shape the future of the NewSpace sector.

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[6] Bartolini, M. The Vertical Integration in the NewSpace. “Aerotecnica Missili e Spazio”. (2025). https://doi.org/10.1007/s42496-025-00271-7
In reference to my publication/citation in "Aerotecnica Missili e Spazio" (AMS), I wanted to provide some brief context on its standing within the aerospace engineering field, as its significance is particularly notable within the Italian and European aerospace community.
"Aerotecnica Missili e Spazio" is the official scientific journal of the Associazione Italiana di Aeronautica e Astronautica (AIDAA) (Source: https://www.aidaa.it/our-journal/). This is the primary Italian professional society for aeronautics and astronautics, serving a role analogous to the AIAA in the United States or the RAeS in the UK. The journal is also one of the oldest in the field; its origins trace back to "L'Aerotecnica," which was founded in 1920 as one of the society's first initiatives (Source: https://www.aidaa.it/our-history/). As a high-quality, peer-reviewed journal, its articles are indexed in major international databases, including Scopus and the Emerging Sources Citation Index (ESCI) by Clarivate, which confirms its academic standards (Source: https://link.springer.com/journal/42496).

Key Words: NewSpace, Vertical Integration, Space Economics, New Space Economy, Commercial Space, Private Sector Involvement, Commercial Space, Aerospace Value Chain

Nomenclature

EO	Earth Observation
IOS	In-Orbit Servicing
PNT	Position, Navigation and Timing

Subscripts

Introduction

Even for someone observing the aerospace sector from a distant perspective, it would be apparent that something has changed over the past twenty years, starting around the early 2000s.

Undoubtedly, there is much more complexity beneath the surface. What may initially appear as a simple dichotomy—how space activities were conducted before 2000 and how they are carried out now—actually conceals a more intricate reality. In this paper, we aim to explore several key points. First, we will provide a brief overview of the recent shift in the aerospace industry, comparing the emerging "NewSpace" paradigm with the traditional "OldSpace" or conventional approach ("Traditional Space")".

The theoretical framework of vertical integration has been significantly enriched by numerous key studies. Perry (1989) provides a thorough analysis by examining vertical integration through the lenses of firm theory, contracts, and markets, highlighting technological economies, transactional economies, and market imperfections as central determinants. Gulbrandsen et al. (2009) contribute to the foundation by investigating the antecedents of vertical integration, utilizing transaction cost economics and resource-based views to deepen the theoretical discussion. Rothaermel et al. (2006) examine the delicate balance between vertical integration and strategic outsourcing, particularly in terms of its effects on product success and firm performance. Furthermore, Li and Tang (2010) explore the influence of vertical integration on innovation performance, demonstrating that while vertical integration may initially stimulate innovation, it can later hinder the acquisition of external knowledge, urging firms to carefully consider the long-term implications of this strategy. Nugent and Hamblin (1996) also stress the need for improved methodologies in vertical integration research, highlighting the complexity of the subject.

Vertical integration has been applied across diverse industries and markets, attracting attention from scholars in various fields, investigating the economic rationale for vertical integration in the technology sector, emphasizing its potential to enhance efficiency and user experience. From a healthcare perspective, Amado et al. (2022) summarize the literature on the impact of vertical integration on quality, access, efficiency, and cost containment. In the food manufacturing industry, Bhuyan (2005) identifies the factors driving forward vertical integration, while Krickx (1995) offers a transaction cost analysis of vertical integration within the computer mainframe industry. Liu (2016) examines the relationship between vertical integration and innovation in the pharmaceutical industry, providing insights into how this strategy influences innovation processes. Zhu et al. (2019) explore vertical integration in the maritime industry, particularly focusing on its implications for port expansion.

Despite the extensive research on vertical integration across various sectors, there remains a significant gap in the literature regarding its application within the emerging New Space industry. This gap becomes even more apparent when considering current industry reports that advocate clearer measurement and categorization of space-related activities (ESA, 2024; OECD, 2022). As these studies underscore, obtaining robust data on space markets and the broader space economy is crucial for aligning investment, policy, and research.

The concept of "New Space" has been frequently referenced, yet there remains no clear consensus on its precise definition or how it differs from what is commonly referred to as Traditional or "Old Space." To illustrate the complexity and ambiguity of this topic, even the term itself is subject to debate. Some scholars, such as Chen et al. (2022), advocate for the use of the single compound word "NewSpace," while others, like Heitor et al. (2024), prefer the two-word version, "New Space." A useful starting point for understanding the evolution of the aerospace industry is Handberg's (2014) theory of the five waves. The industry's growth begins with Wave 1, often referred to as the "post-Cold War" era, which is characterized by a landscape in which federal priorities—particularly those of the U.S. Air Force (USAF) and the National Aeronautics and Space Administration (NASA)—dominated the direction and timing of space activities (Handberg, 2014, p. 5).

The second wave, often termed the "communications revolution," marked the advent of the Internet. This era witnessed the promise of multiple new launch vehicles, most of which failed to materialize. During this time, Iridium boasted the largest satellite constellation, but the provider went bankrupt due to the prohibitive costs involved.

The third wave, referred to as the "X-33 effect," was characterized by the development of reusable launch vehicle prototypes, such as NASA’s X-33, a period primarily focused on research and experimentation.

The fourth wave, the "X-Prize bubble," signified a transformative shift in aerospace players. The "Ansari X-Prize" incentivized non-governmental agencies to enter the space industry, marking what Handberg called the “public birth of NewSpace.”

The fifth and final wave, termed “true commercial space,” emerged in response to NASA's difficulties in replacing the Space Shuttle. As Giannopapa et al. (2022) pointed out, in previous waves, the space sector was dominated by a centralized model where private firms, operating under cost-plus contracts with NASA, were largely insulated from financial risks while having limited opportunities to benefit from the commercial space market. However, in this "NewSpace" era, private companies began sharing both the risks and the rewards of space investments. By 2017, significant strides toward decentralization had been made with the implementation of the NASA Transition and Authorization Act, which allowed private firms to take the lead in space-related economic development. As Madan and Halkias (2020, p. 13) note, this shifted NASA's role from technology developer to a more strategically focused driver, contracting private companies for services such as launch transportation, thereby reducing both costs and risks for the government.

Based on the approach outlined by Frischauf et al. (2017), an additional criterion can be introduced to help define potential NewSpace companies. This will assist in narrowing down viable candidates for use in the data collection process. Specifically, these NewSpace companies should either be currently offering or in the process of commercializing services such as PNT (Positioning, Navigation, and Timing), Earth Observation (EO) constellation deployment, launch vehicle development, IOS (In-Orbit Servicing), manufacturing of components for satellite, communication or space tourism. Merging this services with the view suggested by Paravano et al. (2023), all of these can be allocated into four different streams:

- Space Access involves technologies that enable space exploration, such as rockets, telescopes, and space vehicles (both manned and unmanned), including the International Space Station, space tourism ventures like Virgin Galactic, and Mars rovers.
- Earth Observation refers to the monitoring of the Earth's land, water, and atmosphere using satellite imagery.
- Satellite Navigation allows users with compatible devices to determine their position, velocity, and time by processing signals transmitted from satellites.
- Satellite Communication facilitates data transmission for telecommunications, TV broadcasting, radio, telephone, and, more recently,

internet services.

Moreover for each of this stream it is possible to identify the following stage of each stream:

- Upstream stakeholders include companies and institutions within the space industry that are involved in the research, development, construction, and management of foundational space infrastructures and technologies.
- Downstream stakeholders encompass companies providing digital innovation solutions and services, such as IT providers, system integrators, consulting firms, as well as specialized research centers focused on the development and application of cutting-edge digital technologies, which leverage space-related technologies and data.
- End-users refer to companies and institutions that have a demand for, and interest in, new applications and services arising from the integration of space and digital technologies.

It is important to illustrate how these value streams have evolved across the different aerospace waves described by Handberg. To provide a clear representation of this progression, we referenced Handberg's original image (see Figure **7**) and emphasized the specific segments of the value stream that emerged during each wave.

During the first wave, the primary impact was on launch services and space infrastructure.

Although launch vehicle services are cross-cutting across multiple streams, we emphasized those related to space exploration and Earth observation, as these were the dominant streams during this period. The second wave marked the communications era, with services like Iridium being provided to end users.

The third wave mainly focused on advancements in launch services, particularly with efforts by companies and agencies to improve reusability. Although this is not explicitly highlighted in the visual representation, it can be viewed as a reinforcement of existing launch services.

Wave four corresponds to the X-Prize era, characterized by the growth of space tourism activities.

Finally, wave five represents the current landscape. It is evident that these value streams have not developed uniformly over time or across sectors. The exception is the communications stream, which, despite experiencing a restructuring due to Iridium's initially unsuccessful business plan, has remained consistent.
We employed a color-coding methodology to illustrate, in an incremental manner, the specific contributions each successive wave added to the comprehensive value stream of the NewSpace economy (Figure 7).

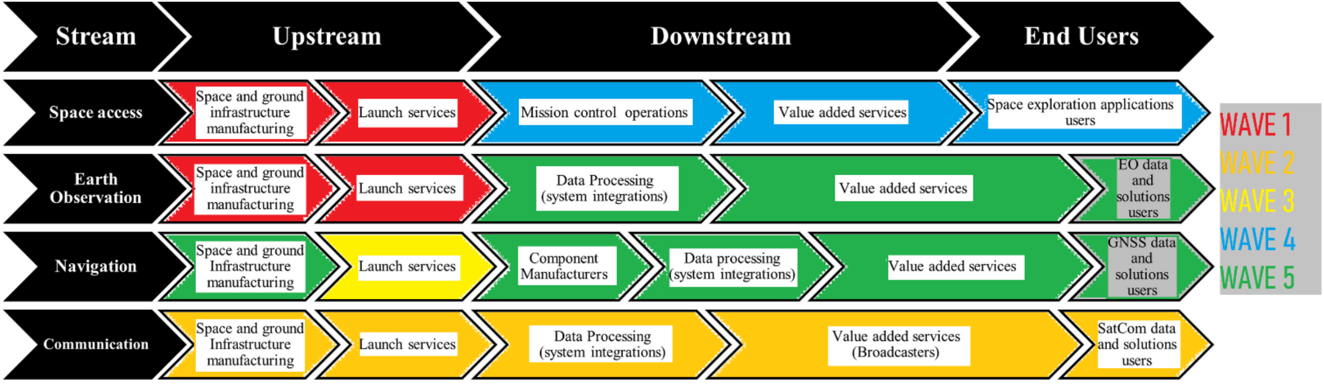

Figure 7: Revisitation The New Space Economy value streams[7]

To summarize, the key criteria for identifying and selecting a NewSpace company for inclusion in our data collection are as follows:

- The company must have been founded

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[7] Space Economy Observatory, Space Economy: La nuova frontiera dell'Innovazione si presenta!, 2020. Milan, Italy.

after the year 2000, in accordance with the fifth wave of space sector development as outlined by Handberg (2014).
- The company's core business operations should correspond with the NewSpace business plan categories defined by Paravano et al. (2023).
- The company must position itself within any of the development stages described by Frischauf et al. (2017).

Building on the literature review and the identified research gap, this paper addresses the following questions:
- Q - 1, we will analyze data on the current landscape of "NewSpace" companies, examining their roles within the broader aerospace sector and identifying their positions across the upstream, midstream, and downstream levels of the value chain. Special attention will be given to the criteria for selecting these companies, the services they offer, and their positioning within the aerospace services chain.
- Q - 2, we aim to assess the readiness of various segments within the aerospace sector's value chain by identifying any gaps or missing elements across different points of the value stream. Additionally, we seek to identify common patterns among these companies to determine whether they demonstrate a tendency towards vertical integration and participation in multiple stages of the aerospace sector.

The motivation behind our investigation into the NewSpace sector and its associated level of vertical integration can be traced to an insightful perspective offered by Weinzierl (2018). Weinzierl posits that "many NewSpace companies have business models that make sense only when other, complementary models are already in place" (p. 184). This observation underscores the interdependence within the sector, which prompted further exploration into the degree of verticalization prevalent among NewSpace companies.

In this section, we aim to examine the different stages of the aerospace sector, including upstream, midstream, and downstream activities. This classification will be essential for the second phase of this study, where we will identify aerospace companies that operate across the entire aerospace supply chain, from upstream to downstream, including end-user applications.

We will construct a data matrix for the selected aerospace companies, assessing their presence in each stream (upstream, midstream, and end-user) and the level at which they participate. This analysis will allow us to determine whether any company is capable of independently sustaining the full value chain. Furthermore, at a broader level, we will evaluate the overall sustainability of these streams, identifying any gaps or missing components that may hinder the viability of the entire value chain. This approach is particularly relevant given recent findings that call for more rigorous frameworks to measure space-related activities (ESA, 2024; OECD, 2022). It also connects to studies like Erkel (2023) that visualize the interplay between satellite manufacturing and launch costs, illustrating the interlinked nature of space services..

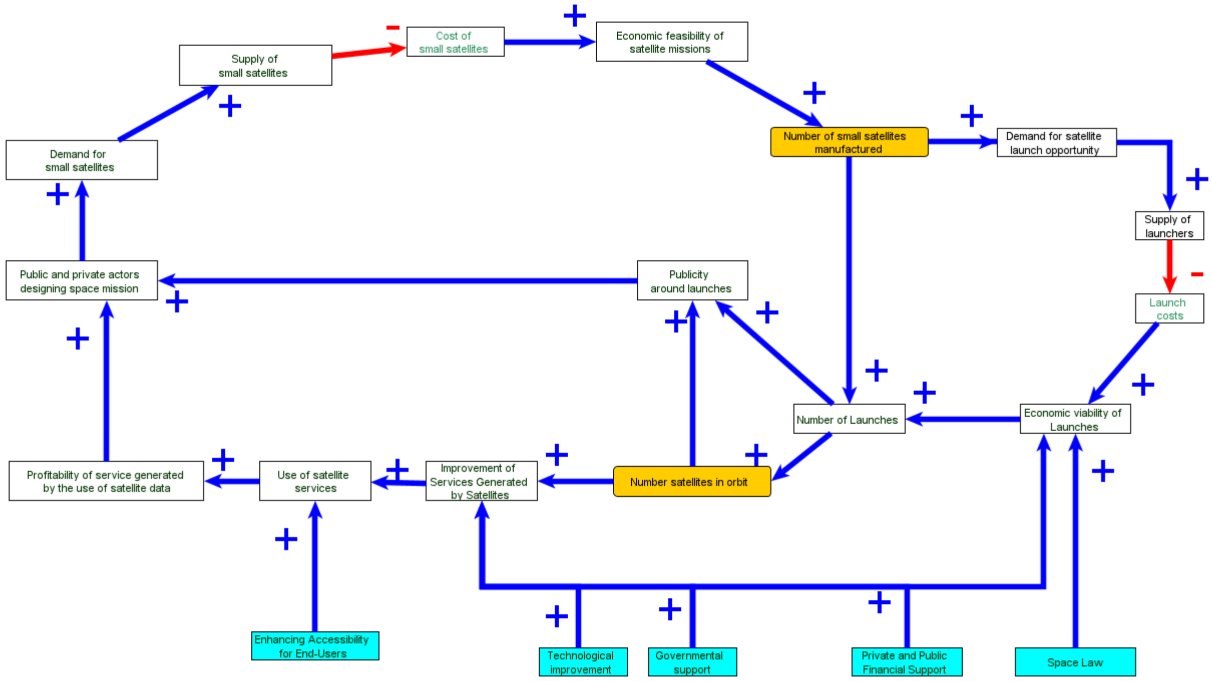

Figure 8: Revisitation of Influence diagram showing the interaction between the number of satellites in orbit and launch costs (Erkel, 2023)

Figure 8 demonstrates that an increase in demand for satellites, albeit with some time lag, leads to an expansion in supply, which subsequently reduces the cost of manufacturing these systems. This growing number of satellites stimulates higher demand for launch services, which in turn drives down launch costs and results in an increase in the overall number of launches.

The framework clearly illustrates the interconnection of several key activities across different streams, including launch services, space manufacturing, ground infrastructure, and component manufacturing. From this perspective, we see an imperative need to make minor adjustments to the diagram to incorporate additional concepts. First, we propose the inclusion of exogenous factors, highlighted in cyan, that are influencing the boundaries of satellite services and launch vehicles. These factors are grouped into broad categories, such as Technological Advancements, Governmental Support (emphasizing favorable and agile policies), and both private and public financial support. Recognizing the inherent safety concerns associated with space launches, a robust Space Law framework can significantly streamline operations for launch service providers. In terms of satellite service utilization, broadening the customer base to include non-traditional aerospace sectors can foster a more balanced and sustainable ecosystem. By drawing on up-to-date guides for measuring the broader space economy (ESA, 2024; OECD, 2022), this paper aims to clarify how vertical integration patterns arise within NewSpace and how they might evolve in tandem with technological and market developments.

Following this introduction, Section 2 details the methodology adopted to select and categorize NewSpace companies, including data collection procedures and analytical techniques. Section 3 presents the results, focusing on the distribution of these companies across the upstream, midstream, and downstream segments and examining the extent of their vertical integration. Section 4 provides a discussion of the key findings and their implications for both industry practitioners and policymakers. Finally, Section 5 offers the paper's conclusions, highlights its limitations, and outlines potential directions for future research.

Methodology

This section describes the data collection and analytical techniques employed to examine vertical integration and the positioning of NewSpace companies in the space value chain. It aims to create a robust dataset of firms that represent the post-2000 "NewSpace" paradigm and to extract insights regarding their strategic, operational, and financial profiles.

We began by sourcing information from Orbis, a database provided by Moody's, focusing on companies with an "Active" status. The initial screening targeted firms classified under NACE Rev. 2 code 3030, corresponding to the "Manufacture of air and spacecraft and related machinery." This classification aligns with standard aerospace definitions from the Statistical Classification of Economic Activities in the European Community. Only companies incorporated after the year 2000 were retained, so as to capture the defining characteristic of "NewSpace" as a post-2000 movement. Further refinement took place by removing companies without known operating revenue and conducting a text search for "Aerospace" (through brand names, descriptions, and other metadata) to catch additional entities that might not have been fully captured under the initial filter.

Branches were then excluded to avoid duplication and ensure that only headquarters remained in the sample. Entities headquartered in China or Russia were removed to maintain a consistent geographic focus. Beyond these filters, we supplemented the dataset with known NewSpace companies not previously identified, together with a group of firms functioning as end users. These latter companies are dependent on space-related data from both upstream and downstream sources and come from categories such as Academic, Quantum-based Application Development, Application Developers, Defense, Enterprise Embedded Systems, and Geospatial Data Manipulation.

Starting with 213 companies, we excluded those operating primarily in aeronautical trade or whose dates of incorporation fell outside the NewSpace timeframe. We further removed Virgin Orbit, which, despite appearing as active on Orbis, filed for bankruptcy in April 2023 and ceased operations by June 2023. The final dataset totaled 112 companies.

A key aspect of the classification involved categorizing each company's business model according to Paravano et al. (2023), using four main streams: Space Access, Earth Observation, Navigation, and Communication. Because some firms engage in multiple streams—such as Space Exploration Technologies Corp. (SpaceX), which operates launch vehicles, satellite constellations, and end-user internet services—we introduced an "All" label to account for multi-stream coverage. The next step required assigning each firm a development stage, drawing on Frischauf et al. (2017) in conjunction with EBITDA data from Orbis. Three stages defined this process: Emerging for companies with no available EBITDA, Started for companies that had negative EBITDA, and Implemented for companies reporting positive EBITDA. These labels align with the progression from early business model conceptualization to revenue optimization and cost management. Finally, each company's activities were mapped across three phases of the space value chain—Upstream, Downstream, and End User—based on official trade descriptions and corporate self-disclosures.

We compiled a master data matrix incorporating each firm's primary stream or streams (Space Access, Earth Observation, Navigation, Communication), development stage (Emerging, Started, Implemented), and value chain positioning (Upstream, Downstream, End User). Simple frequency counts and cross-tabulations illustrated how these criteria overlapped, exposing patterns such as the propensity of certain streams to correlate with specific stages or positions in the chain.

To gauge vertical integration, we measured the extent to which companies took part in more than one value-chain segment. We ranked the firms based on coverage of Upstream, Downstream, and End User activities. This made it possible to compare the degree of integration to each company's financial data. The analysis also included comparing how fully each of the four streams (Space Access, Earth Observation, Navigation, and Communication) was represented in the dataset, and identifying gaps or bottlenecks within the upstream or downstream segments.

We synthesized the results of these analytical steps to answer Q-1 (the distribution of NewSpace firms across the aerospace sector) and Q-2 (the industry's readiness, including any observed vertical integration patterns). By connecting business model categories, financial metrics, and operational coverage, we gained a deeper understanding of the ways in which NewSpace companies operate across the entire aerospace ecosystem. This approach provided a grounded view of both the sustainability of current business models and the constraints that might impede further development.

Results

Referring back to the topic introduced in Q - 1, our focus will be on companies that, regardless of their core business stream, operate at various stages of the aerospace value chain, from Upstream to End User.

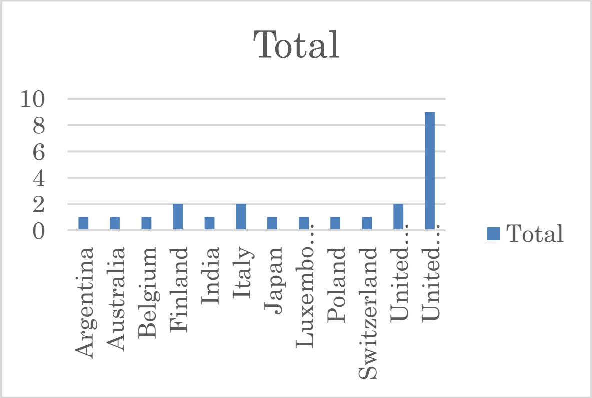

Figure 9: Main country distribution of the companies able to cover the full stream

Of the 112 companies initially selected, 23 (20%) meet this criterion. The distribution of these companies by country is presented in Figure 9

When narrowing down the selection to companies with a sustainable business model, defined by a positive EBITDA, only two remain, both based in Italy. This finding highlights the very limited number of NewSpace companies capable of sustaining operations across the full value chain, from upstream to downstream, at this stage. It is important to note that further analysis may be necessary as more comprehensive data becomes available for other companies currently in earlier development phases. Furthermore, it is important to highlight that both space vehicles and launch vehicles are categorized as upstream activities. However, neither of the two remaining companies with a sustainable business model owns a launch vehicle.

For instance, Space Exploration Technologies Corp. (SpaceX) is not included in this subset due to the unavailability of its EBITDA. Future research could consider exploring alternative data sources beyond Orbis to obtain financial information, especially for companies that are privately held.

The second question under investigation, Q - 2, is less stringent compared to the analysis of the first question. Here, the objective is to assess whether a stream possesses all the necessary components, even if sourced from different companies, that contribute to its sustainability.

The following table provides a summary of the composition of a complete ecosystem for each stream."

	Count - All Companies			**Count - Only EBITDA Positive Companies (Implemented Stage)**		
Stream	**Upstream**	**Downstream**	**EndUser**	**Upstream**	**Downstream**	**EndUser**
Space Access	38	44	3	6	14	1
EO	20	43	28	3	11	9
Navigation	8	31	21	2	10	10
Communication	13	38	9	1	10	2

Table 6: Quantification of the readiness of each stream

Table 6 summarizes the completeness of the NewSpace scenario for each stream. First, we examine the full dataset of companies, which reveals an imbalanced landscape. Most companies are concentrated in the Downstream sector, with a noticeable shortage of services in the EndUser segment. Ideally, these three segments should be balanced to prevent bottlenecks and, at least theoretically, ensure sustainability for all stakeholders at every stage of the stream.

In the second part of the table, we present the same scenario but focus solely on companies that have reached the 'Implemented' stage, meaning they have a deliverable product or service and a viable business plan. While a similar pattern emerges— with more companies focused on Downstream—the EndUser sector remains critically underrepresented, reflecting the current state of the NewSpace industry.

A crucial but often underexplored dimension in the vertical integration debate is the maturity of the supply chain—specifically, the volume, reliability, and mission-criticality of components or subsystems required by NewSpace companies. In many cases, suitable external suppliers or contract manufacturers have yet to emerge for specialized orbital hardware, or they cannot reliably produce at the scale and speed necessary for ambitious space missions (Bhuyan, 2005; Liu, 2016; Zhu et al., 2019). Consequently, firms face a strategic choice: either integrate vertically to secure control over critical parts of the supply chain or rely on limited, and sometimes uncertain, third-party capacities. While vertical integration can alleviate supply bottlenecks and quality concerns (Rothaermel, Hitt, and Jobe, 2006), it also increases capital expenditure and operational complexity (Li and Tang, 2010), a trade-off that smaller startups may find difficult to bear. As the supply chain matures and specialized vendors acquire advanced manufacturing capabilities, some companies may revert to outsourcing, benefiting from economies of scale and more robust vendor reliability.

Closely related to supply chain maturity is the development process a company employs. Highly iterative or agile approaches—which rely on rapid feedback loops and frequent prototyping—generally benefit from in-house control over key subsystems (Giannopapa et al., 2022). When external suppliers cannot match the pace or specificity demanded by these development cycles, vertical integration ensures that design changes, testing protocols, and production schedules remain tightly synchronized. This internal control not only streamlines product development but also reduces the latency caused by external negotiations or rework cycles (Li and Tang, 2010). Thus, companies aiming for continuous innovation or rapid iteration often favor a higher degree of integration to maintain alignment between design engineering, manufacturing, and testing phases.

Taken together, supply chain immaturity and in-house development processes create a compelling impetus for vertical integration in the NewSpace sector. As the industry evolves, these two factors will continue to shape integration strategies. On one hand, a more robust, diversified supply network could encourage a shift toward modular outsourcing—lowering cost barriers for smaller firms. On the other hand, companies pushing the envelope of mission-critical innovation may remain highly integrated to safeguard data integrity, product quality, and timeline stability. Future research could explore in greater depth the tipping points at which in-house development loses its relative advantage, or conversely, when persistent supply chain gaps solidify a long-term commitment to vertical integration. Although the interplay between supply chain maturity, development processes, and vertical integration is undoubtedly influential, it was not investigated exhaustively in this paper due to data limitations. Our primary dataset—derived from publicly accessible financials and corporate descriptions—did not include granular information regarding each firm's supply chain partnerships or development practices. Moreover, conducting in-depth interviews or surveys with individual firms to elucidate their internal processes and supplier networks fell beyond the immediate scope of this study. As a result, while we acknowledge the critical role these factors play in shaping integration decisions, our current analysis focused on more readily measurable indicators such as EBITDA and value-chain positioning.

Conclusion

This study has investigated the evolving landscape of the NewSpace industry—an arena characterized by increased private sector participation and an emphasis on vertical integration across multiple points in the aerospace value chain. The research questions centered on (1) describing how NewSpace companies position themselves within the upstream, midstream, and downstream segments, and (2) assessing whether these segments are prepared to support fully integrated business models. By analyzing both financial and operational data—filtered, cross-referenced, and validated against companies' own trade descriptions—the study design has proven appropriate for examining these questions. The evidence presented, including quantitative indicators (e.g., EBITDA analysis) and value chain mapping, supports the main findings and conclusions.

Our results demonstrate that while many NewSpace firms have diversified their operations beyond traditional single-segment models, only a small subset can currently sustain the entire value chain. Most companies, particularly those lacking a positive EBITDA, focus on downstream services, indicating the early developmental stage of the sector. Nevertheless, vertical integration shows significant promise, with companies such as SpaceX illustrating the benefits of controlling multiple layers of the supply chain. As the industry matures, these integrated models are likely to proliferate, helped by increasing demand for cost-effective and innovative space access.

Despite the growing interest and experimentation with different forms of vertical integration, the NewSpace sector remains reliant on external support and partnerships with both government agencies and private investors. To foster a more robust industry, it is therefore critical that future efforts emphasize system-wide coordination, ensuring that each segment (upstream, midstream, downstream) evolves in tandem. This integrative approach, rather than an isolated optimization of single components, will help the entire sector progress toward financial and operational viability.

Several open questions require deeper investigation, which can further refine how emerging and established companies sustain multi-segment operations:

- **Enhancing Accessibility for End-Users:** While many NewSpace providers address upstream or downstream functions, end-user accessibility to satellite-based services often remains limited. Future work could explore business models that expand availability and affordability, fostering a more balanced, inclusive space ecosystem.
- **Balancing Vertical Integration and Strategic Partnerships:** Although vertical integration can yield efficiency gains, it is not universally optimal. Research might assess how flexible partnerships or outsourcing could offer comparable or greater benefits in specific parts of the value chain.
- **Sustainability and Risk Management**: Expanding across multiple stages of the space sector entails complexities and financial burdens. Investigating effective risk-mitigation strategies (e.g., portfolio diversification, collaborative R&D, supply chain contingency planning)

may clarify how firms can remain profitable and agile.

- **Role of Emerging Technologies:** Automation, AI, and advanced manufacturing could reshape both costs and operational throughput. Studying how and when to integrate these technologies into vertically integrated models can illuminate viable paths to scalability.
- **Government Policy and Regulatory Frameworks**: Evolving international space law and national regulations will shape the boundaries of viable strategies. Understanding policy impacts, as well as potential new legal instruments, will be critical to sustain an equitable, secure, and competitive environment.
- **Global Expansion and Competitiveness**: As India, China, and other emerging space economies mature, multinational NewSpace operations may become the norm. Examining how vertical integration functions in cross-border collaborations could yield insights into evolving global supply chains.
- **Data and Financial Transparency**: The relative scarcity of publicly available financial data remains an obstacle, particularly for private companies. Future research could explore alternative data-collection methods and foster open-data initiatives to address this opacity.

By addressing these issues, subsequent studies will strengthen our understanding of how vertical integration unfolds in different geographic contexts and market conditions. The evidence and analyses presented here demonstrate that the methodology—encompassing both quantitative (EBITDA, company profiles) and qualitative (value chain mapping, strategic positioning) elements—yields results that fully support the conclusions about NewSpace companies' positioning and readiness. Such interdisciplinary approaches will prove instrumental in guiding the industry's next phase of development, ensuring that NewSpace can realize its potential for innovation, cost savings, and broader societal benefit as commercial space activities continue to expand.

Data

The data of this research can be made available on request.

Declaration of Generative AI and AI-assisted technologies in the writing process'

Statement: During the preparation of this work the author(s) used Google/GEMINI in order to increase the readability of the paper, being the main author not an English mothertongue. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication

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Chapter 5: From Industrial Structure to Sustainability and Governance

The sustainability profile of NewSpace is shaped by integration choices and operational cadence, but the strength and direction of these relationships depend on mission mix, technologies, and regulatory context. Higher launch rates, the growth of large LEO constellations, and increasing re-entry activity are plausibly associated with stronger environmental externalities, including greenhouse gas emissions, orbital debris, and the introduction of metal aerosols into the upper atmosphere. While the magnitude of these impacts remains uncertain and scenario-dependent, several projections suggest that—under plausible growth pathways—launch and re-entry particulate loads could rise substantially over the coming decades, with potential implications for ozone chemistry and radiative forcing.

In this context, vertical integration (here understood as broader value-chain scope and/or internalization of critical interfaces) can be viewed as a relevant organizational mechanism, although its implications should not be assumed to be uniformly positive. Firms that control multiple stages of the value chain—from upstream manufacturing to downstream operations and service delivery—may be better positioned to influence sustainability-relevant design and operational decisions. Architectural control can enable more deliberate choices on vehicle design, propulsion, debris mitigation, and end-of-life protocols, and it may facilitate coordination across engineering and operations. At the same time, integration concentrates decision rights and may accelerate deployment, which can amplify externalities if stewardship practices are weak. Accordingly, integration should be treated as a capability that can support sustainability outcomes, not as evidence of sustainability performance by itself.

This connects to the organizational logic developed in the previous chapters: when conventional signals are incomplete, stakeholders may rely more heavily on observable operational proofs, and firms may internalize interfaces to manage uncertainty and execution risk. The same structural choices that can accelerate learning and execution also concentrate the levers that affect externalities. For this reason, the sustainability implications of integration are fundamentally governance-dependent: without credible disclosure and verification, architectural control does not automatically translate into measurable stewardship.

Evidence from sustainability reporting in the NewSpace population underscores this governance challenge. In the available data, most sustainability disclosures are voluntary and heterogeneous in scope, and only a subset of firms publish stand-alone reports. Where reports exist, they often perform well on clarity and presentation and frequently reference the Sustainable Development Goals (SDGs), but methodological transparency, accuracy, and independent assurance are uneven. Because reporting firms are likely systematically different from non-reporting firms (e.g., larger, more visible, or subject to stronger disclosure expectations), these observations should be interpreted as describing reporting practice among observed reporters rather than as a sector-wide baseline.

The governance gap is particularly salient in NewSpace because integrated architectures could, in principle, internalize externalities more effectively than fragmented ones—provided that operators adopt measurable stewardship practices and make them comparable across firms and jurisdictions. If integrated firms shape both upstream design choices and downstream operational behavior, their reporting and verification practices could anchor accountability. However, without standardized metrics and credible oversight, the opportunity to convert design control into demonstrable stewardship is often missed, and incentives may favor visibility over verifiability.

To address this gap, the proposed space-specific SDG module ("SDG 18: Sustainable Space for People and Planet") is presented as a structured way to connect integration choices with sustainability leadership in measurable terms. A pragmatic indicator set—covering debris mitigation, space-traffic practices, life-cycle environmental impacts, equitable access, and governance transparency—could help policymakers and stakeholders link firm-level architectures to system-level outcomes using data that are, at least in part, already collected through space situational awareness networks and regulatory filings. The intent is not to claim that such a framework is immediately adopted, but to outline how it could improve comparability and accountability relative to today's largely voluntary reporting landscape.

From a management perspective, the intersection of integration, cadence, and sustainability in NewSpace therefore presents both challenges and opportunities. The sector's technical and organizational evolution creates the capacity for stronger stewardship, but current disclosure remains selective. Embedding sustainability into integrated operations—through standardized metrics, clearer methodological disclosure, and independent verification where feasible—would strengthen accountability and reduce the risk that the benefits of NewSpace scale at the expense of the orbital environment or broader development objectives.

In summary, the progression from signaling to organizational structure and then to sustainability reflects a cumulative logic: as firms move from symbolic mechanisms of legitimacy to structural mechanisms of control, they gain the capacity to shape both operational and environmental outcomes. The managerial contribution of this chapter is to clarify that vertical integration can be leveraged not only for coordination and execution, but also—under the right governance conditions—for measurable stewardship and long-term accountability in the evolving NewSpace economy.

Chapter 6: Towards Sustainable: Space Assessing the contribution to the SDGs in Aerospace Activities

Towards Sustainable Space: Assessing the contribution to the SDGs in Aerospace Activities[8]

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Abstract

The NewSpace industry represents a paradigm shift in the aerospace sector, transitioning from government-led space activities to a commercialized, innovation-driven market. While this shift has accelerated technological advancements and economic growth, it has also introduced significant sustainability challenges. This study examines the transparency and sustainability reporting practices of NewSpace companies, evaluating their alignment with global sustainability goals and industry best practices.

By analyzing 94 NewSpace companies, this research identifies the limited prevalence of sustainability reporting, with only 16 firms publishing non-financial reports. The findings highlight that companies most frequently address SDGs related to climate action (SDG 13), industry innovation (SDG 9), global partnerships (SDG 17), and clean energy (SDG 7). However, the voluntary nature of sustainability reporting results in inconsistencies in disclosure, clarity, and accuracy, making cross-industry comparisons challenging. Building on this assumption, we further explore whether introducing a new SDG goal specifically tailored to the unique characteristics of aerospace activities would be more effective in evaluating these companies.

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The Journal of Space Safety Engineering is one of the most important publication within aerospace and safety engineering. It is the official journal of the International Association for the Advancement of Space Safety (IAASS), a respected organization dedicated to promoting space safety standards globally. Published by Elsevier, one of the leading academic publishers, the journal ensures rigorous peer review and high scientific standards through its distinguished editorial board.

The journal is indexed in major databases such as Scopus and the Emerging Sources Citation Index (ESCI), which confirms its visibility and credibility in the academic community.

Beyond metrics, the journal serves as a key platform for advancing the science, technology, and practice of space safety. It publishes research on critical topics such as space debris mitigation, safety design, risk assessment, and reliability engineering, fostering communication between industry, academia, and government. This interdisciplinary scope makes it an authoritative source for engineers and researchers working on complex space systems and safety protocols.

For these reasons, references from the Journal of Space Safety Engineering strengthen the technical and scientific foundation of my thesis and align with recognized standards in aerospace engineering research.

Key Words:

NewSpace Industry, Sustainability, Non-financial Reporting, Circular Economy,
Sustainable Development Goals (SDGs), Transparency

Nomenclature

EO	Earth Observation
GNSS	Global Navigation Satellite System
SDGs	SDGs – Sustainable Development Goals
SSR	Space Sustainability Rating

Introduction

The aerospace sector is experiencing significant growth, with the global space economy expanded to US$570 billion in 2023, representing about 7% year-over-year growth rate, in line the predicted five-year compound annual growth rate of 7.3%[9].

Within this context, an important dimension to consider in current research is the sustainability of NewSpace activities. As highlighted by previous literature: "*it is important to consider the positive and negative effects of space activities on sustainable development*" (Cernev et al., 2024, p. 1). Research further emphasizes that "*a sustainable space debris environment will be possible only with adequate and responsible operators following internationally agreed rules of conduct*" (Heinrich et al., 2022, p. 464).

The term NewSpace refers to the recent wave of private-sector–driven space activities that differs fundamentally from the traditional, government-led "OldSpace" paradigm. Whereas OldSpace was characterized by large public agencies and state contractors operating under cost-plus contracts with high levels of risk insulation, NewSpace is defined by entrepreneurial firms, venture financing, and commercial business models that emphasize speed, cost reduction, and scalability. The shift is visible in the growth of small satellite constellations, reusable launch vehicles, and in-orbit services, where private actors now play a leading role. While OldSpace players such as NASA, ESA, Roscosmos, and their prime contractors still account for the bulk of large infrastructure and flagship programs, NewSpace firms have captured a growing share of satellite manufacturing, launch services, and data-driven applications. This rapid growth has positioned NewSpace not as a replacement for OldSpace, but as a complementary and increasingly influential ecosystem whose practices raise new sustainability and governance challenges (Bartolini, 2025).

Furthermore, space activities are increasingly recognized as having implications for the United Nations' Sustainable Development Goals (SDGs) (UN, 2015). Established in 2015 as part of the 2030 Agenda for Sustainable Development, the SDGs consist of 17 interrelated goals designed to address the world's most pressing challenges, including poverty, inequality, climate change, environmental degradation, and global peace and justice. These goals aim to create a sustainable and equitable future for all, leaving no one behind. Unlike previous global initiatives, the SDGs are universal, applying to all nations and recognizing sustainability as a shared responsibility. They emphasize the interconnected nature of development, where progress in one area often facilitates advancements in others, such as how improving education can reduce poverty and foster innovation (UN, 2015).

The reason why we emphasize standardized reporting is because NewSpace firms often cite SDGs in heterogeneous ways, we define standardized reporting here as a minimum set of fields whenever an SDG is referenced: (i) the official indicator ID and unit; (ii) the firm's role (direct—own operations affect the indicator; enabling—products/services help others measure or achieve it); and (iii) evidence sufficient for verification (method, spatial/temporal coverage, and validation/QA). Making these elements explicit improves comparability and aligns with our Clarity and Accuracy criteria used later in the transparency assessment. We evaluate current practice against this minimum and illustrate feasible indicators in Appendix C.

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[9] 2025 Aerospace and Defense Industry Outlook | Deloitte Insights

Previous studies showed how the interaction between space and sustainability can be understood through different dimensions. More specifically, the interrelations between space activities (defined as *"Launching space objects into outer space; operation, control and return of space objects to Earth; as well as other essential activities in this connection*[10]*"*) and sustainability can be categorized into four perspectives based on the origin and target of sustainable development: Earth-to-Earth, Earth-to-Space, Space-to-Earth, and Space-to-Space (Maiwald, 2022). These perspectives outline the boundaries of systems to be developed sustainably. For instance, Earth-to-Earth perspectives involve using space programs to support Earth's sustainable development through the terrestrial application of technologies or scientific findings. Earth-to-Space perspectives describe efforts to sustain space missions from Earth, such as the resupply operations for the International Space Station (ISS). Space-to-Earth perspectives emphasize how space can contribute to Earth's sustainability, such as through satellite-based Earth observation data or communications infrastructure. Finally, Space-to-Space perspectives focus on making space missions sustainable within space itself, such as through the use of renewable resources like solar energy to reduce reliance on Earth's resupply efforts (Maiwald, 2022).

Research highlights the extensive potential of space activities to support the majority of SDGs. As noted by Maiwald (2023, p. 1), this includes setting up satellite infrastructures for communication, fostering business development, and supporting ecosystem protection through Earth observation. However, the integration of sustainability into space activities is not without challenges. Previous literature indeed highlights the "*space sustainability paradox*" describes a situation where the use of space to advance the SDGs on Earth may, paradoxically, lead to unsustainable outcomes for both the Earth and the space environment (Wilson and Vasile, 2023, p. 1). Addressing this paradox requires a nuanced understanding of how space activities can be conducted responsibly to balance their benefits and long-term viability.

One potential solution to the sustainability challenges in space activities lies in adopting circular economy principles. The circular economy aims to optimize the use of materials and resources by emphasizing practices such as reducing, reusing, recycling, recovering, remanufacturing, and redesigning (the 6Rs). As noted by Tan et al. (2023), these principles can be particularly relevant to the upstream segment of the space industry, offering a framework to address sustainability concerns. For instance, adopting circular economy strategies can reduce waste, enhance resource efficiency, and create opportunities for innovation within the aerospace sector.

Emerging concepts continue to strengthen the relationship between sustainability and aerospace activities, with the Space Sustainability Rating (SSR) standing out as a notable example. The Space Sustainability Rating (SSR) promotes responsible space operations by providing measurable sustainability metrics. Developed by a global consortium, it transitioned to an operational phase in 2022, offering certifications for mission operators. By fostering transparency and accountability, the SSR enhances the long-term sustainability of the space environment (Minoo Rathnasabapathy et al., p. 1). However, one of the key limitations of the SSR is that its scope is currently focused on mission-level sustainability assessments—primarily evaluating the design and operational practices of individual space missions—rather than addressing the broader corporate-level sustainability strategies and reporting practices of NewSpace companies. Building upon this context, the focus of this research is to investigate how NewSpace companies practically address sustainability at the organizational level, particularly through their public disclosures and alignment with the Sustainable Development Goals (SDGs). While previous studies have examined non-financial reporting and the integration of Sustainable Development Goals (SDGs) in various industries (Pizzi 2021), there is a notable gap in research concerning these aspects within the NewSpace sector. This gap is particularly significant given the increasing environmental impact of space activities (Fuller 2024), including carbon emissions from rocket launches and space debris accumulation . Addressing sustainability in NewSpace is therefore crucial to ensuring the long-term viability and responsible development of the space industry. Orbital

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[10] Space Activity Definition | Law Insider

activity has undergone a structural shift over the last decade. In 2024, there were 259 orbital launches, with commercial providers accounting for ~70%—a pragmatic proxy for "NewSpace" activity (as distinct from legacy, government-led "OldSpace"). That year ~2,900 spacecraft were deployed, and the number of operational satellites has risen from ~3,371 (2020) to 11,539 (end-2024), driven primarily by commercial LEO constellations[11][12].

These deployment and cadence trends matter environmentally. State-of-the-art modeling suggests that rocket emissions—especially black carbon injected into the stratosphere—and reentry-generated metal aerosols can delay ozone recovery and exert non-negligible radiative forcing: for example, ~0.15% upper-stratospheric O_3 loss after a decade under recent growth, and ~3.9–7.9 mW m^{-2} radiative forcing under plausible scenarios (Tayan et al. 2022). Looking forward, NASA projects that launch and reentry particulates may increase by an order of magnitude by ~2040 as very large LEO constellations mature, with reentry-related particulates rising from ~1,000 t/yr to >30,000 t/yr. While uncertainties remain, the directional trend and NewSpace's outsized contribution to launch/reentry fluxes strengthen the case to analyze sustainability practices in this segment (Sharma 2024).

On the benefits side, Earth-observation and space-based connectivity—both expanded by NewSpace—now directly or indirectly inform SDG indicators across 11 Goals, improving environmental monitoring (e.g., SDGs 6, 13, 14, 15) and enabling inclusion (e.g., 9, 4, 17) through broadband access. We treat these as enabling contributions distinct from firms' direct operational impacts[13]. The sustainability mechanisms we analyze—high-frequency launches and re-entries, large LEO constellations, evolving private reporting practices, new vehicle/propellant choices, and fast operational iteration—map most directly to the commercial-led segment commonly termed "NewSpace," not cleanly to firm size or subsector alone. Put differently, it is this market/operational structure (commercial dominance of launch cadence and constellation scale) that drives the environmental pressures and SDG-enabling pathways we study. For transparency, we use commercial vs. government activity as an operational proxy for NewSpace vs. OldSpace when presenting sector-level trends (Table 7).

Dimension	**OldSpace (legacy/government-led)**	**NewSpace (commercial-led)**
Operational proxy	Government launches/operators	**Commercial** launches/operators
Deployment pattern	Fewer, larger GEO/MEO missions	**High-cadence LEO smallsat constellations** (e.g., thousands of spacecraft)
Key environmental drivers	Lower cadence; solids common on some legacy systems	**Higher cadence & reentries**; hydrocarbon/methane use; reusability; growing **reentry aerosol** flux
SDG benefits channels	Govt science, weather, navigation	**EO for SDG monitoring; broadband inclusion** at scale (millions of users)

Table 7: "NewSpace" vs. "OldSpace" (operational proxy and sustainability relevance) analyzed

This paper makes two main intellectual contributions. First, it provides the first systematic assessment of how NewSpace firms engage with sustainability reporting, combining a transparency checklist with readability metrics and SDG alignment analysis. In doing so, it demonstrates not only the extent of reporting but also the strategic selectivity that shapes what is disclosed. Second, it advances the governance debate by

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[11] Historic Number of Launches Powers Commercial Satellite Industry Growth – Satellite Industry Association Releases the 28th Annual State of the Satellite Industry Report – Satellite Industry Association

[12] Bryce 2024 YinR Briefing FINAL

[13] https://eo4sdg.org/release-of-a-compendium-of-eo-contribution-to-the-sdgs/

evaluating whether the existing SDG framework adequately captures the sustainability challenges of the aerospace sector and by proposing a structured, preliminary case for a dedicated “SDG 18” on space sustainability. Together, these contributions lead to three major conclusions: (i) NewSpace firms emphasize indirect, enabling contributions to the SDGs while underreporting their direct impacts, (ii) reporting remains largely voluntary and thus uneven, privileging visibility over accountability, and (iii) accountability gaps—particularly in accuracy and assurance—underscore the need for stronger frameworks at both national and international levels. These findings position the paper at the intersection of sustainability reporting, space governance, and international development policy, offering evidence-based insights for researchers, regulators, and industry alike.

Theory

Sustainability reporting has become an essential tool for organizations to communicate their environmental, social, and governance (ESG) performance. Non-financial reports, including sustainability reports, increasingly reference the United Nations Sustainable Development Goals (SDGs) to align corporate strategies with global sustainability targets (Pizzi et al., 2022). By disclosing their commitments and progress, companies enhance transparency, which is critical for stakeholders—including investors, regulators, and the public—to assess corporate sustainability efforts (Michelon et al., 2015).

Transparency in corporate reporting refers to the extent to which an organization provides clear, reliable, and comprehensive information about its sustainability performance. Transparent sustainability reports can strengthen corporate accountability, improve decision-making, and foster trust among stakeholders (Hahn & Kühnen, 2013). Moreover, effective stakeholder engagement plays a key role in enhancing transparency. Companies that actively involve stakeholders in the reporting process tend to produce more comprehensive and meaningful sustainability disclosures (Manetti, 2011).

To measure transparency in sustainability reporting, Demartini et al. (2024) propose a framework based on three key dimensions: Disclosure, Clarity, and Accuracy. Disclosure focuses on the availability and relevance of sustainability-related information. It assesses whether reported topics align with financial performance, strategy, and stakeholder interests, ensures consistency over time, evaluates whether reports include both positive and negative performance, and considers whether the information is up-to-date and regularly updated.

Clarity ensures that sustainability reports are understandable and well-structured. It examines how well a report communicates company targets and their relation to strategy, evaluates the use of graphs, tables, and explanations for better comprehension, and assesses whether technical terms, acronyms, and recurring phrases are adequately explained. It also checks for the presence of glossaries, tables of contents, and standardized international metrics to enhance readability.

Accuracy pertains to the trustworthiness and correctness of the reported data. It ensures that data sources and estimation methods are disclosed, assesses whether calculations are replicable, measures whether data aligns with past reports and industry standards, and verifies the presence of independent audits to confirm the reliability of the reports.

By applying this framework, this study evaluates how NewSpace companies integrate sustainability practices into their reporting and whether they align with global transparency standards. The role of stakeholder engagement is also considered, as companies with strong stakeholder interactions tend to provide more transparent and comprehensive sustainability disclosures (Freeman et al., 2020).

Following the presentation of this framework, it is essential to define the research questions guiding this study. The formulation of these questions stems from key gaps identified in the literature on sustainability reporting in the aerospace sector. While previous research has extensively examined non-financial reporting practices and the incorporation of Sustainable Development Goals (SDGs) in various industries, there is a lack of standardized sustainability reporting in the NewSpace sector. Given the increasing role of private space companies in global sustainability efforts, transparency in their sustainability practices remains a critical issue. Moreover, existing SDGs primarily focus on Earth-based sustainability challenges, raising the question of whether an additional SDG dedicated to space sustainability could better address the unique environmental impacts of space activities. In addition to examining existing sustainability disclosures, this study also interrogates whether the current Sustainable Development Goals (SDGs) are sufficient to capture the unique sustainability challenges of aerospace activities. While several goals—such as SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action)—partially address relevant dimensions, none explicitly covers the orbital environment or the governance practices unique to space operations. This raises the possibility of introducing a dedicated "SDG 18" on space sustainability. As past UN discussions have demonstrated (e.g., calls for SDGs on global health security and racial equality), extending the SDG framework is politically complex but can be justified where emerging domains are both critical to human development and insufficiently addressed by existing goals. We therefore treat the question of whether space requires its own SDG not merely as a speculative add-on, but as a substantive research problem connected to our transparency analysis.

Building on this background, our study is guided by two research questions:

1. Do existing SDGs adequately capture the sustainability challenges of the aerospace sector, or is there a need for a dedicated SDG on space sustainability?
2. How do NewSpace firms currently disclose sustainability information, and what does this reveal about the quality, accessibility, and accountability of their reporting?

Addressing these questions allows us to connect firm-level reporting practices with broader governance debates. By examining not only whether companies report but also how and what they disclose, we establish the analytical bridge between corporate incentives and the potential role of international frameworks in closing transparency and accountability gaps.

Methodology

This section describes the methodology used for data collection. The selection of NewSpace companies was conducted using Orbis, a database provided by Moody's. Within our research, we aimed to apply a similar framework to assess the transparency of sustainability reports in NewSpace companies. The identification and selection of companies followed specific criteria to ensure relevance to the research objectives.

First, only companies founded after the year 2000 were considered. This cutoff aligns with the emergence of the fifth wave of space sector development, as described by Handberg (2014), which marks the shift from government-led space exploration to a more commercialized and innovation-driven NewSpace industry. Companies established before this period typically follow a traditional aerospace model and may not fully represent the sustainability practices and transparency standards characteristic of modern NewSpace firms.

Second, the core business operations of each company had to correspond with the NewSpace business plan categories, as defined by Paravano et al. (2023). This criterion was essential to exclude companies that, while operating in the aerospace sector, do not engage in the commercial, decentralized, and privately funded space activities that distinguish NewSpace from traditional aerospace enterprises.

Finally, each company had to fit within one of the development stages described by Frischauf et al. (2017). This classification ensured that selected firms were actively contributing to the advancement of the NewSpace industry, rather than operating as legacy aerospace contractors or state-funded agencies. The inclusion of these development stages also allowed for a comparative analysis of sustainability transparency across companies at different levels of maturity.

By applying these criteria, we ensured that the dataset reflected companies truly representative of the NewSpace sector, focusing on those driving innovation, commercialization, and sustainability initiatives in the modern space economy.

Building upon the existing literature, this study aims to investigate how NewSpace companies are addressing sustainability. To achieve this objective, the research analyzes the transparency of sustainability-related disclosures published by a sample of NewSpace companies. The paper is structured to first provide a comprehensive review of the relevant literature on sustainability in the space sector and the role of SDGs, followed by a description of the methodology used for the analysis. The findings of the analysis are then presented and discussed, leading to concluding remarks and potential avenues for future research.

Our objective is to evaluate firm-level transparency among companies most closely linked to the operational features of the NewSpace wave which we expect to shape both environmental externalities and the way firms cite SDG indicators. Figure 2 summarizes the whole flow.

We began with firms recorded as Active in Orbis in order to exclude dormant or shell entities and focus on companies plausibly producing public disclosures. "Active" status can lag reality, so we cross-checked a subset and corrected obvious misclassifications; for example, Virgin Orbit was removed despite being listed as active, because it ceased operations following bankruptcy in 2023. From this universe, we defined the Main sample by selecting entities coded NACE Rev.2 30.30 (Manufacture of air and spacecraft and related machinery). This frame concentrates on upstream manufacturers and operators, i.e., the part of the market most proximate to the launch/constellation/re-entry mechanisms at the heart of our analysis and the firms most likely to discuss those issues in sustainability reports. A consequence of this choice is that it does not fully capture downstream actors—software and analytics providers, information platforms, and some satellite operators whose primary codes lie outside 30.30. We make this trade-off explicit and treat downstream segments in separate cohorts described below.

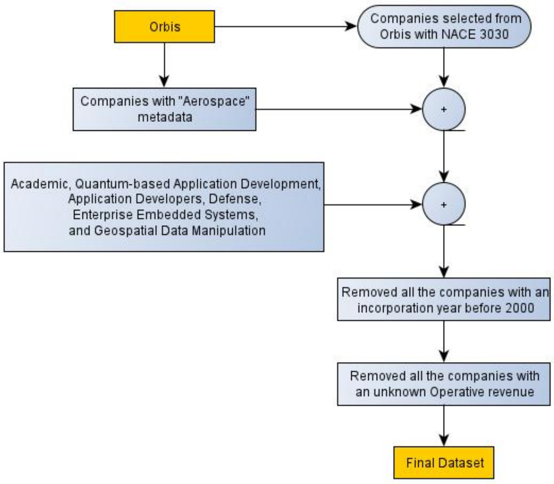

Figure 10: Process describing the flow used to built the final dataset of companies

Because the paper analyzes the commercial NewSpace wave, we restricted the Main sample to firms incorporated in or after 2000. This temporal cut aligns the sample with the period commonly associated with venture-led commercialization and rapid operational iteration. We also retained only firms with known operating revenue. Revenue disclosure is an imperfect but practical screen for economic activity and data sufficiency; it improves comparability (e.g., size bands, materiality) and increases the likelihood that a firm publishes the kinds of evidence our transparency rubric assesses. The cost is a bias toward more established companies and against very early-stage start-ups.

To reduce false negatives due to coding noise, we complemented the classification filter with a targeted text search ("Aerospace") across names, brand descriptions, and overviews, and then collapsed branches and subsidiaries to the headquarters entity so that the unit of analysis matches corporate-level governance and reporting. We further excluded firms headquartered in China or Russia. This decision was driven by comparability and verifiability concerns during the study period: access to filings, disclosure regimes, and sanctions-related constraints complicate systematic data collection and cross-checks. Excluding these jurisdictions introduces a geographic bias that we make explicit; we frame our findings as indicative for the covered jurisdictions and outline how the protocol could be extended.

Because industry codes and automated searches can still miss relevant players, we added a small number of expert-identified firms widely recognized as part of NewSpace, documenting sources and decisions in an audit trail. At this point we also clarified what is not in the Main sample and defined additional cohorts for robustness: satellite telecommunications operators, downstream data processing and information services, software/application developers, and R&D/quantum labs. These cohorts matter for SDG-enabling claims even if they are less proximate to launch and re-entry. Academic institutions and public agencies are mapped to show the ecosystem but are not scored, since our unit of analysis is private firms.

Applying this process produced 213 candidates. After removing in-scope aeronautical traders (whose sustainability drivers and regulatory frameworks differ from space enterprises), correcting "active"-status anomalies, the final dataset comprises 94 companies.

For each of the 94 companies, we searched their websites for publicly available sustainability reports, not only in English but also in their different languages. Since the scarcity of reports, the most recent year of reporting has been considered, without setting a minimum year threshold. However, due to factors such as company size, revenue, and status, not all had such reports accessible. Out of the 94 companies, only 16 had published a sustainability report. The results presented here are based on an analysis of those 16 reports. We prefer not to disclose the names of these companies, but the following table outlines the legal headquarters of each, category size and main aerospace stream.

Company	**Headquarters Country**	**Aerospace Stream**	**Employees**
Company 1	United States of America	EO - Downstream	250-1000
Company 2	United States of America	Navigation - EndUser	250-1000
Company 3	France	Space Access, EO, Communication - Upstream and Downstream	above 5000
Company 4	France	Space Access - Upstream	above 5000
Company 5	Netherlands	EO and Navigation - Downstream	above 5000
Company 6	Denmark	EO, Communication - Upstream	100-250
Company 7	Luxembourg	EO - Downstream	less than 100
Company 8	United States of America	Communication, EO - Upstream and Downstream	above 5000
Company 9	United States of America	EO, Communication - Upstream and Downstream	1000-5000
Company 10	United States of America	Communication - End User	above 5000
Company 11	United States of America	EO and Navigation - End User	above 5000
Company 12	Italy	EO - Downstream	less than 100
Company 13	United States of America	Space Access - Upstream	1000-5000
Company 14	Belgium	Space Access - Upstream	1000-5000
Company 15	Netherlands	Navigation - End User	1000-5000
Company 16	Japan	Navigation - Downstream	1000-5000

Table 8: Headquarter country for each company analyzed

It is important to anticipate that the statistical sample is not sufficiently large to conduct a comprehensive statistical analysis. This limitation was anticipated from the outset for two primary reasons. First, the number of NewSpace companies is relatively small, given the specific definition adopted in this study. Second, from a regulatory standpoint, most of these companies are not legally required to publish sustainability reports, resulting in a limited dataset.

All the sustainability reports have been then read one by one and an answer to the questions of the framework have been extracted and collected within an excel spreadsheet, citing also the source from where the answer was extracted.

Regarding the claiming of SDGs, because firms in the space sector often support societal outcomes indirectly (e.g., by supplying Earth-observation data) as well as directly (e.g., reducing their own emissions), we distinguish two contribution types.

Direct means that the firm demonstrates a quantified change in outcomes inside its own organizational boundary—its operations or controlled assets—that corresponds to an SDG indicator or to a clearly stated, indicator-aligned proxy. Examples include: a manufacturer reporting year-over-year reductions in Scope 1–2 GHG emissions (aligned to SDG 13 targets), energy/water/waste intensity improvements (SDG 12), or occupational safety rates (SDG 8), with methods, boundaries, and units disclosed.

Enabling means the firm provides data, infrastructure, or services that a competent authority or customer uses to measure or achieve an SDG indicator—e.g., satellite imagery used by an environment ministry to compute 6.6.1 (water-related ecosystems),

city-scale $PM_{2.5}$ fields that feed 11.6.2, or connectivity that expands digital inclusion relevant to SDG 9. Enabling claims should name the indicator, define who uses the product (e.g., NSO, agency, NGO), and provide evidence of method/coverage/validation.
For transparency scoring, Direct and Enabling claims are both eligible; what differs is the role label and evidence requirement

A different approach was needed to assess the readability of the paper that required a Gunning Fog index between 12 and 14: we built a non-subjective python script reported in Appendix B to evaluate the Gunning Gog index of each report.

The Gunning Fog Index is a readability test that estimates the years of formal education a person needs to understand a piece of writing on the first reading. It is calculated based on the average length of sentences and the percentage of complex words (words with three or more syllables, excluding proper nouns, compound words, or familiar jargon). This index is considered useful and appropriate for this research as it provides a quantitative measure of the clarity and complexity of language used in sustainability reports. By applying the Gunning Fog Index, we can assess how easily accessible and understandable the sustainability information presented by NewSpace companies is to a broad audience of stakeholders. This is particularly relevant as transparency requires clear and concise communication. While specific applications of the Gunning Fog Index to the sustainability reporting of NewSpace companies might be novel, readability tests, including the Gunning Fog Index, have been employed in other studies to analyze the clarity of corporate communications, financial reports, and even sustainability disclosures in different sectors (Demartini et al. 2024). These studies often aim to identify potential barriers to understanding and assess the overall effectiveness of communication. The Gunning Fog Index can be calculated starting from the following items: the number of words in the document, the number of sentences, the number of complex words (words with three or more syllables, excluding proper nouns, compound words, or familiar jargon) and used within the following formula:

$$\boldsymbol{Gunning\ Fog\ Index = 0.4 \cdot \left(\frac{Words}{Sentences} + \frac{Complex\ Words}{Words} \cdot 100\right)}$$

Equation 1: Gunning Fog Index Formula

A Python script, reported in Appendix B, was used to evaluate the Fog Index automatically relying on the textstat package.
Finally, using the checklist in Appendix A and the Gunning Fog Index procedure described in Appendix B, we evaluated each sustainability report's transparency as follows: for every checklist item in Appendix A, we assigned 1 if the report met the criterion and 0 otherwise; the overall transparency score is the proportion of criteria satisfied, computed as the sum of compliant items divided by the total number of items.
Finally, an assessment has been conducted on the voluntariness of the sustainability report: to indicate whether a report was issued voluntarily or to satisfy a legal requirement, we combined three fields from our dataset: country of the reporting entity, employee headcount, and the report year. We then applied a simple, documented rule-set by jurisdiction:

- European Union (pre-CSRD): Under the Non-Financial Reporting Directive (NFRD), large public-interest entities (PIEs) with >500 employees must include a non-financial statement for financial years in scope; member-state transpositions may set lower thresholds (e.g., Sweden ≥250 employees under the Annual Accounts Act). For FY 2024 and beyond, entities previously captured by NFRD transition to CSRD (reports typically published the following year).
- United Kingdom: TCFD-aligned climate disclosures are mandatory for large companies/LLPs (generally >500 employees and >£500m turnover) for financial years starting on/after 6 April 2022.
- United States: During our observation window (reports dated 2022–2024), there was no federal mandate for a standalone sustainability/ESG report.
- Other jurisdictions in our sample (e.g.,

Japan) had no general statutory requirement for a standalone sustainability report during the window; exchange rules and codes may encourage disclosures but do not convert them into a legal mandate for our purposes.

Operational decisions. If headcount met the relevant statutory threshold for the firm's country in the report year, we labeled the report Required and note the regime (e.g., "Required (NFRD)" for a 2023 report by an EU entity; "Required (CSRD scope from FY2024)" for a 2024 EU report). Where turnover is part of the legal test (UK TCFD), and we did not have turnover in our dataset, we applied a conservative rule: we required the employee threshold to be met and otherwise labeled the report Voluntary. When employee counts were unknown, we did not assume mandate status; those reports are provisionally classified Voluntary with a note that mandate cannot be ruled in or out without additional size information.

Results

The analysis yields three central findings. First, companies overwhelmingly frame their sustainability impact in terms of indirect or enabling contributions to the SDGs rather than direct operational performance. For example, firms highlight how their satellites support climate monitoring or agricultural optimization (SDG 13 and SDG 2), while few report on their own emissions, debris mitigation, or resource use. Second, sustainability reporting in the NewSpace sector remains largely voluntary, with only three of the 16 available reports prepared under a regulatory mandate. This voluntariness helps explain why disclosures are often selective, emphasizing positive narratives while omitting sensitive or costly details. Third, within the transparency checklist, compliance is uneven across categories: Clarity (≈76%) and Disclosure (≈74%) are consistently stronger, while Accuracy/Assurance lags behind (≈61%), reflecting a reluctance to engage with independent verification or replicable methods. These patterns, taken together, illustrate that reporting is not merely incomplete but shaped by strategic incentives, privileging visibility and reputational value over comparability and accountability.

Before analyzing the transparency of the sustainability reports, we first examined the explicit references to Sustainable Development Goals (SDGs) made by aerospace companies. For each report, we systematically identified all SDGs that were mentioned as part of the company's sustainability strategy or commitments. The analysis focused on whether an SDG was explicitly cited in the report, regardless of the number of times it appeared. This approach ensures that we capture which SDGs companies recognize as relevant to their activities, rather than emphasizing mere word frequency, which may not always reflect substantive engagement with a goal.

The Gunning Fog Index across the 16 sustainability reports ranges from 10.42 to 14.82, with a mean of 12.39 and a median of 12.27 (SD = 1.53). Five reports scored below 12, suggesting they are written at a level broadly accessible to secondary school graduates. Seven reports fell within the recommended 12–14 range for professional communications, while four reports exceeded 14, indicating higher complexity. This distribution shows that companies adopt diverse strategies: some opt for highly accessible reports aimed at broad stakeholder engagement, while others produce more technical documents targeted at expert or regulatory audiences.

To quantify the presence of each SDG across the dataset, we calculated its frequency by determining the proportion of reports that referenced it. The frequency was then normalized by dividing the number of reports mentioning a given SDG by the total number of sustainability reports analyzed (16). A value of 100% indicates that an SDG was referenced in every report, while lower percentages highlight SDGs that were mentioned less frequently. A detailed breakdown of these findings is provided in Figure 11, where the relative presence of each SDG is illustrated.

This method allows us to assess which SDGs are most commonly addressed in sustainability reports within the NewSpace industry, providing insights into which aspects of sustainability are prioritized and whether there are significant gaps in SDG coverage.

The four most commonly referenced SDGs are SDG 13 (Climate Action), SDG 9 (Industry, Innovation, and Infrastructure), SDG 17 (Partnerships for the Goals), and SDG 7 (Affordable and Clean Energy).

SDG 13 (Climate Action) focuses on combating climate change by reducing carbon emissions, enhancing resilience, and promoting sustainable policies. Aerospace companies contribute to this goal by developing satellite-based climate monitoring, improving Earth observation for disaster response, and advancing space-based solar power technology.

SDG 9 (Industry, Innovation, and Infrastructure) emphasizes building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation. Space companies drive this goal by advancing satellite communications, pioneering new propulsion technologies, and supporting deep-space exploration, leading to technological breakthroughs with Earth-based applications.

SDG 17 (Partnerships for the Goals) highlights the importance of global collaboration to achieve sustainability. The space industry fosters international cooperation through joint missions, data-sharing agreements, and partnerships for space exploration and climate research, ensuring that nations work together toward common objectives.

SDG 7 (Affordable and Clean Energy) aims to ensure access to reliable and sustainable energy. Space companies contribute by developing space-based solar power concepts, improving energy-efficient satellite systems, and enabling better grid management through advanced satellite data, helping optimize renewable energy use on Earth.

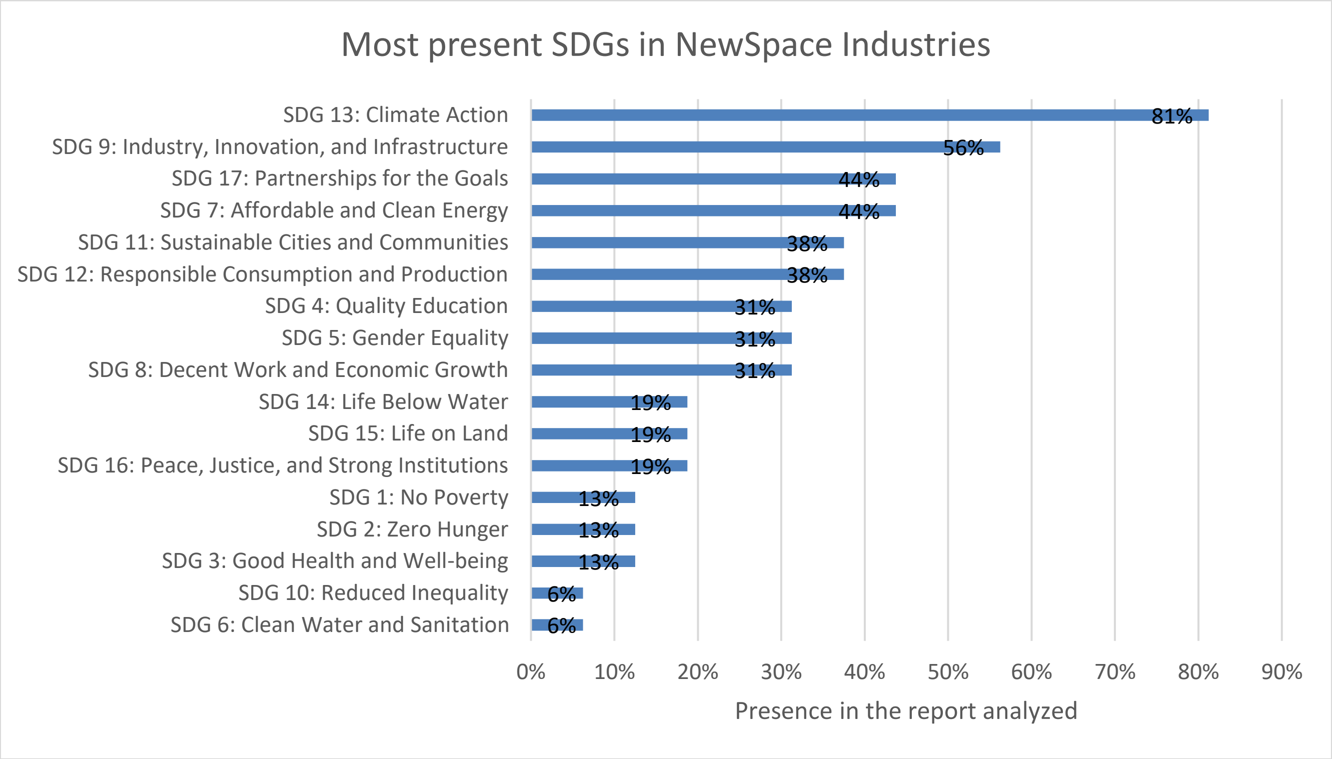

Figure 11: SDG goals presence in the sustainability report analyzed

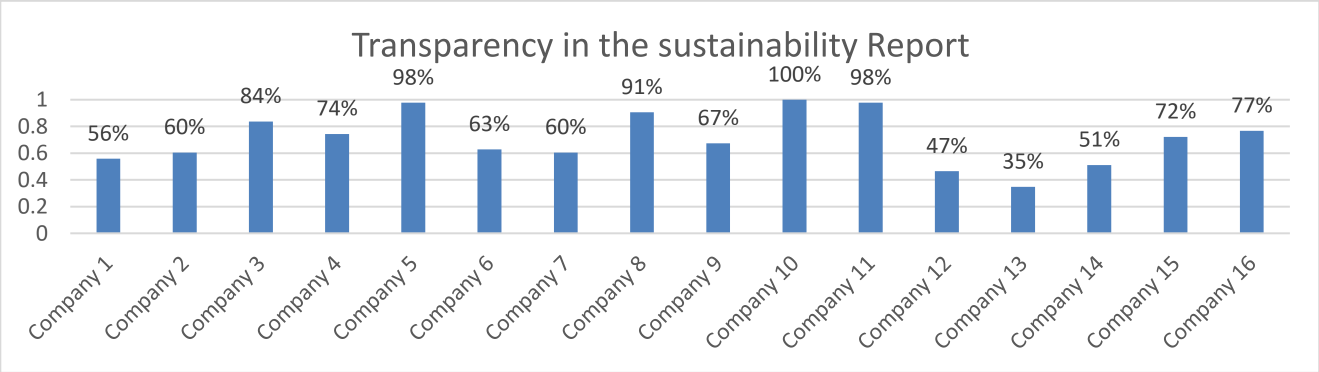

Figure 12: Transparency in the sustainability report

Figure 12 illustrates the distribution of transparency levels observed in the analyzed reports. The average transparency score is 0.7, with values ranging from a minimum of 0.35 to a maximum of 1. Across the 16 reports in our coded sample, the median transparency score (share of checklist criteria met) is 0.698 (min 0.349, max 1.000). The top three are Company 10 (1.000), Company 5 (0.977) and Company 11 (0.977), while the lowest three are Company 14 (0.349), Company 12 (0.465) and Company 14 (0.512). Figure 12 plots the per-company scores whereas Figure 13 shows a company-by-item heatmap (binary items only), making it clear where specific criteria are consistently missed. The most frequently satisfied items include: "Is the data correctly labeled?", "Is it clear to which period the information relates?", and "Does the data relate to the respective chapter/topic?" (all 100% compliance across the 16 reports). Recurrent gaps are: "Is there a glossary to explain technical terms, acronyms, and jargon?" (18.8% compliance), "Does the auditor's report cover the entire report?" (18.8%), and "Is it clear when the information will be updated?" (25.0%).

Regarding the Required/Voluntary status of the report, applying the rules set in the Methodology section we got 3 Required report and 13 Voluntary. The three required are:

- Company 3 (France, 2023) — Required (NFRD);
- Company 15 (Netherlands, 2023) — Required (NFRD);
- Company 5 (Netherlands, 2024) — Required (CSRD scope from FY2024).

The required reports in our sample are concentrated among large, EU-based manufacturers subject to NFRD/CSRD. U.S. reports are voluntary under federal law in our window. Several EU entries are classified as voluntary because the entity-level headcounts in our file sit below the statutory thresholds (or are unknown).

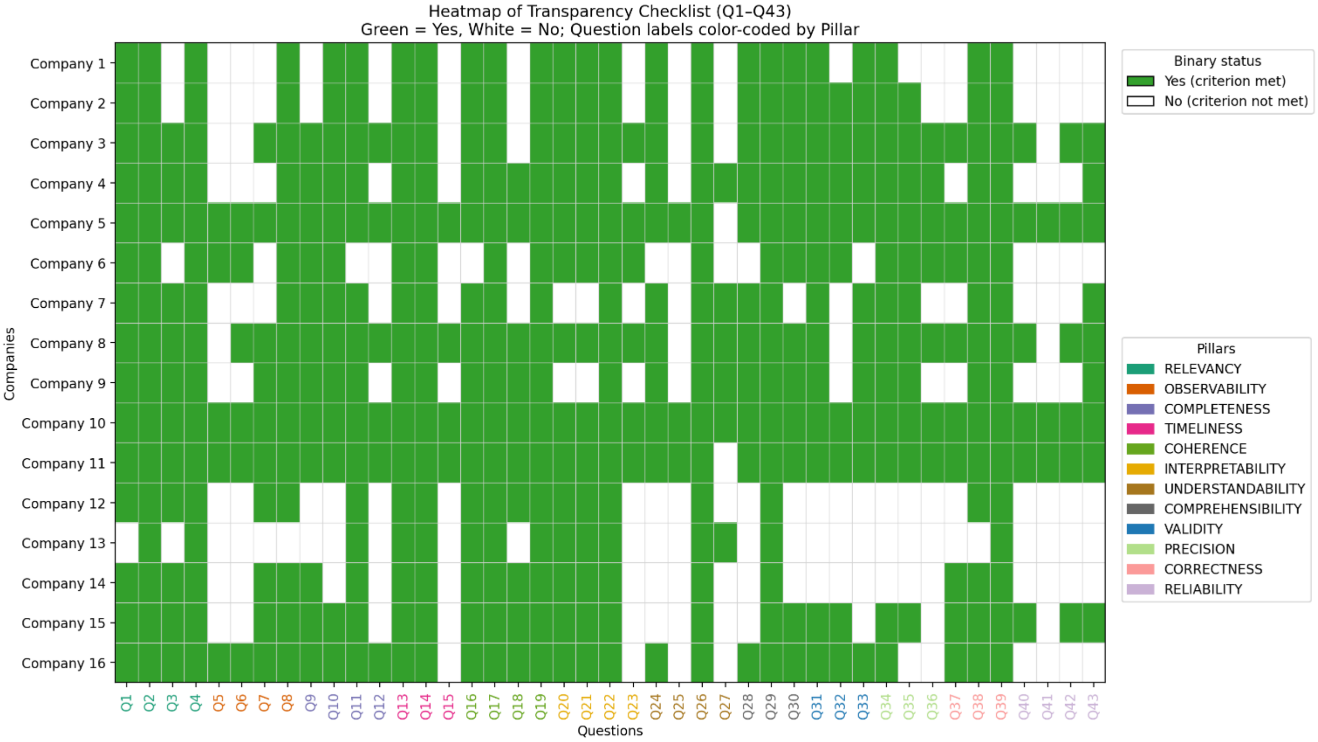

Figure 13: Compliance heatmap – Question code (Q1, Q43 are in Annex A)

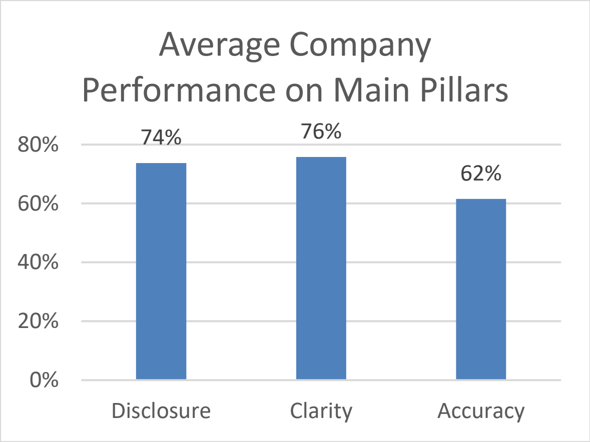

Figure 14: Average Company Performance on Main Pillars

The distribution of checklist compliance is not random. Companies perform strongly on presentational and descriptive elements, such as including figures, tables, and year-to-year comparisons, but systematically underperform on verification and methodological disclosure.

Category-level differences are evident: as shown in Figure 5 and the pillar-level summary, compliance is highest in Clarity (≈76%) and Disclosure (≈74%), but significantly lower in Accuracy/Assurance (≈61%)[14]. This indicates that firms emphasize presentation and basic disclosure while avoiding costly or risky verification.
Looking more closely, systematic omissions emerge. The weakest items across the dataset include "External assurance," "Assurance scope," and "Evidence for assumptions." Very few companies submit their reports to independent auditing or provide the methodological transparency required for replication. This pattern reflects a governance gap: without regulatory mandate, companies rarely invite external scrutiny of their sustainability claims. Instead, sustainability reporting becomes a reputational instrument rather than a robust accountability mechanism.
These outcomes can be explained by strategic incentives. Firms gravitate toward disclosures that are reputationally safe and easy to produce—such as providing figures, graphs, or stating generic targets—but resist those that expose methodological detail or make their claims falsifiable. The asymmetry is consistent with the voluntary character of reporting in the NewSpace sector: companies disclose when it serves investor relations or branding purposes, but withhold when disclosure could reveal operational weaknesses or introduce legal risk.
The implications for governance are clear. NewSpace sustainability reporting remains superficial in critical areas: while transparency on surface-level elements is improving, accountability mechanisms that ensure comparability and verifiability are largely absent. This undermines the potential of ESG reporting to guide investors, regulators, and international coordination efforts. Our findings provide concrete evidence that stronger frameworks—whether through the expansion of EU directives, the harmonization of international standards, or the establishment of a dedicated SDG for space sustainability—are necessary to close this gap. Without such structures, the reporting practices of NewSpace firms will continue to favor visibility over accountability, leaving orbital sustainability as a governance blind spot.

Open Discussion

Taken together, the results reveal a reporting landscape that is highly selective and strategically shaped. The dominance of indirect contributions shows that NewSpace firms prefer to emphasize how their technologies enable sustainability outcomes on Earth, rather than disclosing the direct impacts of their own operations. This reflects both reputational incentives and the difficulty of measuring space-specific externalities such as orbital debris or re-entry emissions. The prevalence of voluntary reporting underscores the absence of regulatory compulsion: without mandates, firms disclose what is safe and beneficial for branding while avoiding areas that could expose weaknesses or create liability. Finally, the systematic weakness in Accuracy/Assurance compared to Disclosure and Clarity highlights a deeper governance

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[14] The match between Clarity, Disclosure and Accuracy is reported in Appendix A. To calculate those alues, we first determined, for each checklist item, the proportion of companies that satisfied the criterion by averaging across all firms. We then grouped these items according to their assigned pillar, and within each pillar we calculated the mean across all items. This provided an overall compliance rate for each pillar.

gap: while companies excel at presentation, they rarely provide the independent verification or methodological detail required for comparability and accountability. Together, these insights suggest that transparency in NewSpace is not just incomplete but structurally biased toward visibility over accountability, reinforcing the need for stronger frameworks to close this gap.
Our analysis highlights two key findings: first, reporting is highly uneven and largely voluntary; second, the SDGs most frequently cited by firms are those easiest to claim through enabling contributions (SDG 9 on innovation, SDG 13 on climate action, SDG 17 on partnerships, and SDG 7 on clean energy). While these observations are important descriptively, the deeper question is why transparency remains fragmented, and what governance gaps this reveals.
The overwhelming predominance of voluntary reporting (81% of the reports) reflects the structural characteristics of the NewSpace sector. Many firms are young, privately financed, and fall below regulatory thresholds such as the EU's Non-Financial Reporting Directive (NFRD). In the U.S. and Japan, no equivalent federal mandate existed during the study period. As a result, sustainability disclosures are shaped less by legal obligation than by strategic calculation: firms disclose selectively, often emphasizing reputational benefits or investor relations rather than providing comprehensive, standardized information.
This voluntariness has two implications. First, it explains the unevenness of transparency scores: where firms face no obligation, reporting tends to highlight positive contributions while omitting negative externalities, such as launch emissions or debris risk. Second, it generates a governance deficit: without harmonized requirements, data cannot be compared reliably across jurisdictions, limiting the usefulness of ESG information for investors, regulators, and policymakers. In a sector where activities have global externalities—orbital crowding, re-entry aerosols, carbon emissions—such gaps undermine accountability.

Readability, as measured by the Gunning Fog Index, interacts with transparency in complex ways. Reports written below the 12–14 benchmark are not necessarily "low quality": easier readability may enhance accessibility for policymakers, NGOs, or the general public, even if technical details are simplified. Conversely, reports above 14 may demonstrate methodological rigor but risk alienating non-specialist stakeholders. The most transparent reports are those that balance clarity with sufficient methodological disclosure, ensuring both accessibility and accuracy. This suggests that readability should be interpreted as a complement to, rather than a substitute for, other transparency dimensions such as disclosure and accuracy.
The concentration of references to SDGs 9, 13, 17, and 7 reflects the pathways most accessible to NewSpace companies. Firms can credibly claim to "enable" societal outcomes by providing Earth observation data, connectivity, or innovation capacity that governments and organizations use to monitor or implement SDGs. Direct, within-boundary contributions—such as reducing emissions or resource use—require investment, measurement capacity, and a willingness to expose trade-offs, which many firms lack. This explains why enabling claims dominate: they are easier to communicate, less risky reputationally, and align with firms' commercial narratives.
Yet, this pattern creates a paradox. Space companies emphasize how they help achieve sustainability goals on Earth, but the sustainability of space itself remains underreported. This asymmetry illustrates both the limits of voluntary ESG frameworks and the inadequacy of the current SDG set for capturing the unique sustainability challenges of space activities.

Existing SDGs partially capture aerospace sustainability: SDG 12 on responsible production can cover life-cycle impacts, SDG 13 on climate action addresses emissions, and SDG 9 on innovation recognizes technological advances. However, none explicitly addresses orbital stewardship, debris mitigation, or space-traffic transparency. Several initiatives outside the SDG framework—COPUOS Long-Term Sustainability Guidelines, ISO 24113, and the Space Sustainability Rating (SSR)—are important but remain voluntary, fragmented, and weakly integrated into national reporting systems.
An SDG dedicated to space sustainability would not duplicate these initiatives but elevate and integrate them within a global accountability framework. Embedding orbital sustainability into the UN's statistical and reporting system would ensure comparability, visibility, and systematic monitoring across

jurisdictions, linking firm-level practices with national responsibility.

The proposed "SDG 18 – Sustainable Space for People and Planet" aims to close this governance gap. The five targets—debris mitigation, space-traffic practices, life-cycle environmental impacts, equitable access, and governance/transparency—were chosen because they balance policy relevance, feasibility, and alignment with existing data streams. Each can be measured today using information from space situational awareness networks, regulatory filings, environmental inventories, or EO open-data policies. Alternative indicators (e.g., propulsion-specific standards or mission-level life-cycle assessments) were considered but excluded due to uneven availability and low comparability. The proposed set therefore represents a pragmatic minimum that could be refined through consensus-building.

Introducing a new SDG is politically complex. Reaching intergovernmental consensus would require reconciling commercial sensitivities, national security concerns, and data harmonization challenges. Measurement capacity is uneven, and duplication with existing efforts must be avoided. Yet precedents exist: proposals for additional SDGs on global health security and racial equality illustrate that when gaps are significant and consequences global, expansion of the framework is possible.

Framed in this way, SDG 18 should be seen not as a fully developed blueprint but as a structured provocation grounded in empirical findings. The predominance of voluntary, selective reporting among NewSpace firms demonstrates the limitations of existing frameworks and the need for stronger, standardized accountability. By integrating orbital sustainability into the SDG framework, the international community could ensure that the benefits of space activities do not come at the expense of their long-term viability.

Proposal for SDG-18: Sustainable Space for People and Planet

The emergence of NewSpace has accelerated innovation and market entry while creating novel sustainability externalities—most notably launch- and constellation-driven emissions, orbital crowding, collision risk, and uneven access to space-enabled services. In our sample, only 16 of 94 firms published a sustainability report, and most of those disclosures are voluntary rather than mandated, with documentation strongest among large EU manufacturers and weakest for smaller firms. Evidence also shows that many SDG claims are enabling (firms provide data/services used by others for SDG measurement) rather than direct (within-boundary outcomes). Current SDGs capture parts of this picture (SDGs 9, 12, 13, 17), but they do not explicitly account for the orbital environment or the upstream practices unique to space operations.

A dedicated SDG would (i) create a country-level accountability frame for preserving the orbital environment, (ii) define operator-level practices expected from public and private actors, and (iii) standardize indicator-quality reporting so that NewSpace firms can disclose consistently across jurisdictions. It would close the present gap where space contributes to many SDGs but the sustainability of space itself is not measured.

The evidence presented here suggests that existing frameworks—whether voluntary corporate ESG reporting or partial alignment with current SDGs—are insufficient to capture the distinctive sustainability challenges of space activities. While initiatives such as the COPUOS Long-Term Sustainability Guidelines or the Space Sustainability Rating provide important benchmarks, they remain voluntary, fragmented, and weakly integrated into national or international reporting systems. An SDG dedicated to space sustainability would address this gap by embedding orbital stewardship within the UN's global development architecture. By defining measurable indicators for debris mitigation, space-traffic management, life-cycle environmental impacts, equitable access, and governance transparency, such a goal would move beyond visibility toward enforceable accountability. In this way, the findings of our analysis do not simply diagnose shortcomings in corporate reporting; they highlight the structural reasons why space sustainability requires integration into a stronger, harmonized, and universally recognized framework.

To capture these objectives in a single, measurable commitment, we propose the goal be stated as: "SDG 18 – Sustainable Space for People and Planet: *Ensure the long-term sustainability, safety, and equitable use of outer space to support sustainable development on Earth".*

To show that a space-focused SDG can be implemented with data already collected today, we outline five practical targets and the indicators and custodians that could support them.

18.1 — Minimize orbital debris and collision risk.

This target would be tracked with two operational metrics: (18.1.1) post-mission disposal compliance in LEO/MEO/GEO—i.e., the share of satellites deorbited, re-orbited, or passivated within guideline timelines—and (18.1.2) the conjunction rate above a defined risk threshold (events per active satellite per year). Data can be compiled from national registries and space-situational-awareness (SSA) networks, coordinated by UNOOSA with technical input from COPUOS/IADC/ISO and national space agencies.

18.2 — Strengthen transparent space-traffic practices.

Here, the emphasis is on behaviours that reduce operational uncertainty. We would monitor (18.2.1) the share of operators publishing precise ephemerides in recognized formats and (18.2.2) the share of launches with pre-filed, publicly documented end-of-life (EOL) plans. Oversight could sit with UNOOSA and the ITU (for notification and spectrum interfaces), alongside national regulators.

18.3 — Reduce life-cycle environmental impacts of missions.

To bring climate and materials into scope, we propose (18.3.1) the share of launches disclosing life-cycle GHGs (with scope, method, and uncertainty) and (18.3.2) a hazardous-substance substitution rate in propulsion and materials (percent of mass meeting defined criteria). UNEP and UNFCCC could steward methods with support from space agencies; implementation would be coordinated with national environment ministries.

18.4 — Ensure equitable access and public-good use of space services.

Indicators include (18.4.1) population in underserved areas reached by satellite connectivity (percent) and (18.4.2) the share of EO missions with open-data policies. The ITU can curate coverage data; UNOOSA/UNSD can track open EO practices.

18.5 — Improve governance and transparency.

Finally, to embed good reporting, we would monitor (18.5.1) the share of firms publishing standardized space-sustainability disclosures (naming indicator IDs, role, and evidence fields) and (18.5.2) the number of states adopting national space-sustainability guidelines. UNOOSA/UNSD could serve as custodians and publish annual summaries.

Together, these targets translate “space sustainability” into measurable, policy-relevant signals that countries and operators can report against now, using existing SSA feeds, regulatory filings, and well-established statistical channels.

Below we describe the institutional route—and its feasibility—for making this goal operational. Near-term, elements of SDG 18 can be piloted as a “space sustainability module” under existing SDGs (primarily 12/13/9/17) and reported in Voluntary National Reviews using data already curated by national space agencies and SSA providers. A formal post-2030 adoption would follow the standard UN route: define targets through an inter-agency expert group led by UNOOSA/UNSD/ITU, test indicators in a 10–12 country pilot, then submit the indicator set for UN Statistical Commission approval and inclusion in the global framework.

A few obstacles are predictable. The first is political consensus: governments and firms must balance security and commercial sensitivities with the transparency a global goal requires. The second is measurement capacity: reliable, comparable indicators depend on access to and harmonization of space-situational-awareness data. A third challenge is operator confidentiality, since precise ephemerides and end-of-life plans can be commercially sensitive. These risks can be managed by beginning with a minimal core of indicators drawn from information already public in catalogs and filings; allowing operator-level reporting through industry associations with aggregation at the national level; providing funding for capacity-building and indicator production—ideally via a UN-administered trust fund; and aligning the indicator set with existing norms (e.g., COPUOS Long-Term Sustainability guidelines and ISO 24113) so adoption builds on practices firms already recognize.

Our analysis suggests that NewSpace firms disclose unevenly, with many sustainability claims framed as enabling rather than direct. This limits accountability and comparability. While existing SDGs capture parts of this picture, they do not address the sustainability of the orbital environment itself. A dedicated SDG—framed here as a preliminary "SDG 18: Sustainable Space for People and Planet"—would elevate space sustainability to the level of global development priorities, provide harmonized indicators for firms and countries, and ensure systematic monitoring of orbital practices.

Conclusion

This study demonstrates that sustainability reporting in the NewSpace sector is both limited and strategically selective. Firms overwhelmingly emphasize indirect, enabling contributions to global sustainability while underreporting the direct impacts of their own operations. Reporting is further shaped by its voluntary character, which allows companies to highlight reputationally beneficial narratives while avoiding disclosures that would require independent verification. The resulting imbalance is clear: while companies perform strongly in Clarity and Disclosure, the persistent weakness in Accuracy/Assurance exposes a structural gap between visibility and accountability. These findings provide more than descriptive statistics—they reveal how firm incentives, regulatory absence, and methodological omissions combine to undermine the comparability and credibility of existing reports. Addressing this governance deficit requires frameworks that go beyond voluntary disclosure and extend into harmonized, mandatory, and internationally visible accountability mechanisms.

To address this gap, we propose the introduction of a dedicated SDG-18 focused on sustainable space, with specific targets and indicators outlined in Section 6. Embedding space sustainability within the global development framework would help ensure the long-term viability and equitable use of outer space.

We acknowledge that creating a new SDG involves political, technical, and institutional hurdles, and that a full treatment could warrant a separate paper. Our intent here is to articulate a feasible indicator set, demonstrate its grounding in existing data practices, and highlight what an SDG framework would uniquely enable: integration into national reporting, comparability across jurisdictions, and long-term accountability for both public and private actors. In this way, the proposal complements rather than duplicates existing initiatives such as the SSR or COPUOS guidelines, while offering a pathway to embed space sustainability within the global development architecture..

Future Research Improvement

While this study provides valuable insights into the sustainability practices of NewSpace companies, several areas remain open for further research and development, and certain limitations should be acknowledged. First, the study was limited to 94 companies, only 16 of which published sustainability reports, making the results less generalizable to the broader NewSpace sector. Future research should aim to expand the dataset by including a wider range of NewSpace firms, particularly those in emerging markets where sustainability regulations are still evolving; it would also be useful to investigate private companies that do not publicly disclose sustainability data to gain a more comprehensive understanding of industry-wide practices.

A comparative analysis with other high-tech or resource-intensive industries, such as aviation, energy, and manufacturing, could help pinpoint best practices and benchmark sustainability performance across sectors. Additionally, a longitudinal approach would allow researchers to track changes in reporting transparency, regulatory adaptation, and corporate sustainability strategies over time, shedding light on whether NewSpace companies are progressing toward more sustainable operations. Future studies should also examine technological innovations that support sustainable space activities—such as in-orbit servicing, debris mitigation systems, reusable launch vehicles, and resource-efficient satellite manufacturing—and assess the feasibility and adoption of these innovations among industry stakeholders.

Investigating the perspectives of investors, policymakers, space agencies, and consumers on sustainability in the NewSpace field would offer a more nuanced view of the incentives and challenges that shape sustainable practices. Lastly, there is a need for further exploration of SDG 18, focused on sustainable space exploration, including the development of specific targets and best practices for tailored reporting that comprehensively address all aspects of space activities. By delving into these areas, future research can help strengthen the policymaking process, improve reporting standards, and drive technological advancements that align the NewSpace industry with long-term sustainability goals.

Data

The data of this research can be made available on request.

Declaration of generative ai and ai-assisted technologies in the writing process

Statement: during the preparation of this work the author(s) used google/gemini in order to increase the readability of the paper, being the main author not an english mothertongue. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication

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Appendix A: Detailed List of Questions

Item	Pillar	Criterion	Question Code
Disclosure	**Relevancy**	[D1] Are the mentioned topics relevant for the firm's financial performance?	Q1
		[D2] Are the sustainable actions relevant for the firm strategy?	Q2
		[D3] Does the report prioritize the different topics?	Q3
		[D4] Does the report state the interests and expectations of stakeholders specifically invested in the organization, such as	Q4
	Observability	[D5] Does the report outline the same topics consistently over equally large periods (3–5 years)?	Q5
		[D6] Do the unit measures stay consistent over the 5-year period?	Q6
		[D7] Does the report refer to progress made in response to promised improvements from the previous report?	Q7
		[D8] Does the presentation of the information in the report allow to see trends in performance on a year-to-year basis?	Q8
	Completeness	[D9] Are both positive and negative performances reported?	Q9
		[D10] Does the report indicate how complete the data is?	Q10
		[D11] Does the report state estimates of future impacts?	Q11
		[D12] Does the company provide explanation for discrepancy between targets and achievements if necessary?	Q12
	Timeliness	[D13] Is it clear to which period the information relates?	Q13
		[D14] Does the disclosed information cover recent events and issues?	Q14
		[D15] Is it clear when the information will be updated?	Q15
C	**Coherence**	[C1] Does the report state the company's targets?	Q16

Item	Pillar	Criterion	Question Code
		[C2] Does the report state how economic, environmental, and/or social topics relate to its strategy, risks, opportunities, and goals?	Q17
		[C3] Are internal goals and actions put into relation with industry standards?	Q18
		[C4] Does the report state the company's achievements?	Q19
	Interpretability	[C5] Are there supporting graphs, tables, and figures?	Q20
		[C6] Are measures and graphics explained?	Q21
		[C7] Does the data relate to the respective chapter/topic?	Q22
		[C8] Does the report state if calculations/labels were adjusted from previous reports?	Q23
	Understandability	[C9] Are taglines and reoccurring phrases explained?	Q24
		[C10] Is there a glossary to explain technical terms, acronyms, and jargon?	Q25
		[C11] Does the reporting organization explain its understanding of sustainable development, using objective measures of sustainable development for the topics covered?	Q26
		[C12] Is the Gunning Fog index between 12 and 14?	Q27
	Comprehensibility	[C13] Does the report define its audience?	Q28
		[C14] Are there tables of content, maps, links, subheadings, or other aids so that stakeholders can find the specific information they want without unreasonable effort?	Q29
		[C15] Does the report use generally accepted international metrics (such as kilograms or liters) and standard conversion factors when compiling, measuring, and presenting information?	Q30

Item	Pillar	Criterion	Question Code
Accuracy	**Validity**	[A1] Does the report indicate how data were obtained and processed?	Q31
		[A2] Does the report indicate which data have been estimated?	Q32
		[A3] Does the report distinguish between the presentation of facts and the company's interpretation of information?	Q33
	Precision	[A4] Are information measurement techniques described?	Q34
		[A5] Are calculations described?	Q35
		[A6] Can the calculations be replicated with similar results?	Q36
	Correctness	[A7] Is the data presented in the current and previous report accurate?	Q37
		[A8] Does the data reported in the text match the data presented in comparative figures?	Q38
		[A9] Is the data correctly labeled?	Q39
	Reliability	[A10] Is the report independently verified?	Q40
		[A11] Does the auditor's report cover the entire report?	Q41
		[A12] Is there a representation available from the original data or does the information owner attest its accuracy within acceptable margins of error?	Q42
		[A13] Can the organization provide evidence to support assumptions or complex calculations?	Q43

Table 9: Criteria catalog for the transparency (Demartini, Maria Chiara, Valentina Beretta, And Anna Larisch. "Does The Transparency Of Sustainability Reports Matter? A Quantitative Assessment.")

Appendix B: Python Code to evaluate the Gunning Fog Index

```python
from pathlib import Path
from textstat import textstat
import glob
# Extract text content from the PDF
from PyPDF2 import PdfReader
import os

# Load the document content
listDocs = glob.glob(os.path.join("allReports","*.pdf"))
#print(listDocs)
for doc in listDocs:

    pdf_reader = PdfReader(doc)
    document_text = ""
    for page in pdf_reader.pages:
        document_text += page.extract_text()

    # Calculate Gunning Fog Index and related metrics
    gunning_fog_index = textstat.gunning_fog(document_text)

    print("\n ###### {:}".format(os.path.split(doc)[-1]))
    print("{:} gunning fog index= {:}".format(os.path.split(doc)[-1],gunning_fog_index))
```

Appendix C: SDG indicators that space firms can legitimately reference

Direct = your own footprint/operations change the indicator.

Enabling = your data/services help a competent authority or customer measure or improve the indicator; avoid claiming outcome achievement unless you operate the intervention.

SDG (ID)	Official indicator name	Role for space firms	Where space fits	What a firm could report (examples)
1.5.1 / 11.5.1 / 13.1.1	Number of deaths, missing persons and directly affected persons attributed to disasters, per 100,000	**Enabling** (hazard mapping, exposure, rapid damage assessment)	EO flood/burn mapping; SAR; GNSS timing for alerting	Product catalog; coverage & latency; users (civil protection/NSOs); accuracy/validation
1.5.2 / 11.5.2	Direct economic loss attributed to disasters in relation to GDP	**Enabling** (damage extent/intensity to support loss models)	EO damage grading; exposure & asset layers	Layers delivered; sectors covered; turnaround time

SDG (ID)	Official indicator name	Role for space firms	Where space fits	What a firm could report (examples)
2.4.1	Proportion of agricultural area under productive and sustainable agriculture	**Enabling** (crop/management, irrigation, soil moisture)	EO crop/field mapping; ET; irrigation detection	Area/regions; update cadence; accuracy vs. ground
3.3.3	Malaria incidence per 1,000 population at risk	**Enabling** (vector habitat risk)	EO water/veg/temp; pop & mobility layers	Risk maps delivered; validation; use in campaigns
3.9.1	Mortality rate attributed to household & ambient air pollution	**Enabling** (PM2.5 exposure)	EO AOD → PM2.5 fusion	City coverage; fusion method; error metrics
6.3.2	Proportion of bodies of water with good ambient water quality	**Enabling** (EO water-quality proxies)	Chl-a, turbidity, temp	Parameters; water bodies monitored; validation
6.4.1	Change in water-use efficiency over time	**Enabling** (inputs to WUE)	ET; irrigated area; biomass proxies	ET products; sector coverage; methods
6.4.2	Level of water stress (withdrawals / available resources)	**Enabling** (availability/use inputs)	Precip/ET; surface water extent	Basins covered; series length; integration with water accounts
6.6.1	Change in the extent of water-related ecosystems	**Enabling**	Water extent; wetlands; mangroves	km² mapped; revisit; QA/QC
7.1.1	Proportion of population with access to electricity	**Enabling** (night-lights; connectivity backhaul)	Night-lights; satellite footprints	Electrification maps; accuracy vs. surveys
9.1.1	Proportion of rural population within 2 km of an all-season road	**Enabling**	EO roads/settlements; travel-time surfaces	Coverage; model & validation; ministry users
9.c.1	Proportion of population covered by a mobile network, by technology	**Enabling** (NTN/backhaul; coverage mapping)	Operator footprints; EO population denominator	Coverage maps; population reached; method
11.1.1	Proportion of urban population in slums/informal/inadequate housing	**Enabling**	Built-up; building footprints; roofing/materials proxies	Cities mapped; method; comparison to UN-Habitat defs

SDG (ID)	Official indicator name	Role for space firms	Where space fits	What a firm could report (examples)
11.2.1	Proportion of population with convenient access to public transport	**Enabling**	Stop/route mapping; GTFS; walkability	Cities covered; stop buffers; population within 500m/1km
11.3.1	Ratio of land consumption rate to population growth rate	**Enabling**	Built-up area change; urban boundaries	Years analyzed; cities; accuracy
11.6.2	Annual mean PM2.5/PM10 in cities (population-weighted)	**Enabling**	EO aerosols; model-monitor fusion	City list; temporal granularity; CV vs. monitors
11.7.1	Share of built-up area that is open space for public use	**Enabling**	Land-use/land-cover; accessibility	Cities mapped; % open space; updates
13.2.2	Total greenhouse gas emissions per year	**Enabling** (MRV support)	EO CO_2/CH_4; hotspot detection; inversions	Regions monitored; accuracy; work with inventories
14.1.1 (a/b)	(a) Index of coastal eutrophication; (b) floating plastic debris density	**Enabling**	Ocean colour; debris detection/tracking	Coastline monitored; revisit; detection limits
14.2.1	Countries using ecosystem-based approaches to manage marine areas	**Enabling**	MSP layers; habitat/pressure maps; S-AIS	Datasets supplied to MSP/ICZM authorities
14.4.1	Proportion of fish stocks within biologically sustainable levels	**Enabling**	S-AIS effort; ocean fronts	Effort analytics; coverage; RFMOs users
14.5.1	Coverage of protected areas in relation to marine areas	**Enabling**	MPA boundary monitoring; S-AIS	MPAs monitored; compliance analytics
15.1.1	Forest area as a proportion of total land area	**Enabling / Direct** (if managing land)	Forest extent & change	Extent datasets; uncertainty; stewardship claims
15.1.2	Important terrestrial/freshwater sites covered by protected areas	**Enabling**	Habitat integrity; KBA coverage/overlap	Protected areas monitored; KBA datasets used
15.2.1	Progress towards sustainable forest management	**Enabling**	Forest extent/biomass; disturbance mapping	Sub-indicators supported; validation

SDG (ID)	Official indicator name	Role for space firms	Where space fits	What a firm could report (examples)
15.3.1	Proportion of land that is degraded over total land area	**Enabling** (EO-based sub-indicators)	Land cover; productivity; SOC proxies	National implementations; datasets delivered; QA
15.4.2	Mountain Green Cover Index & degraded mountain land	**Enabling**	EO land cover/productivity in mountains	MGCI values; trends; methods
1.4.2	Adults with secure tenure rights to land (a) documented, (b) perceive secure	**Enabling** (geospatial evidence for tenure mapping)	Hi-res imagery for parcel delineation; GNSS survey support	Parcels mapped; QA; cadastre/NSO collaboration

Chapter 7: Conclusions

This thesis set out to examine how signals, structure, and sustainability relate to the competitive dynamics and longer-term evolution of the NewSpace economy. Although the three studies employ distinct methods—quantitative, qualitative, and mixed—their common aim is to illuminate how firms build, organize, and legitimize competitive advantage in a rapidly evolving and data-constrained industry context.

The thesis is structured as a cumulative research journey in which each study addresses a distinct mechanism—signals, structure, and sustainability—while collectively contributing to a single integrative question: How do NewSpace firms assemble resources, coordinate complex activities, and sustain legitimacy as the sector scales?

Signals (Study 1) focuses on how NewSpace firms construct visibility and credibility under high uncertainty and information asymmetry. The empirical results are best interpreted as associations: in the available data, patents are not a universal or consistently positive correlate of venture financing outcomes once financing dynamics and other factors are considered. This does not imply that patents are irrelevant; rather, it suggests that their informational role is contingent and may vary with firm stage, technology, and the availability of alternative signals (e.g., milestones, partnerships, execution proof). Importantly, multiple mechanisms could generate the observed patterns—including investor selection, appropriability strategies (e.g., secrecy), and milestone-based validation—so the thesis refrains from attributing the results to a single dominant "signaling" channel.

Structure (Study 2) then examines how firms organize and coordinate activities to manage complexity and uncertainty, with attention to vertical integration. Given the limited observability of internal make–buy boundaries for many private firms, the study operationalizes vertical integration primarily as value-chain scope (participation across multiple stages of the space value chain) rather than as a definitive measure of ownership-based internalization. The descriptive mapping highlights heterogeneity in scope across firms and streams, and it motivates an interpretation in which broader scope can be a strategic response to immature supplier ecosystems, coordination costs, and the need to control mission-critical interfaces. At the same time, the evidence base supports cautious interpretation: certain observations rely on small subsamples (e.g., very few firms simultaneously meet full-stream criteria and report positive EBITDA), so the thesis treats these patterns as indicative of rarity in the available data rather than as general claims about the sustainability or optimality of integration strategies.

Sustainability (Study 3) investigates how firms seek legitimacy by aligning with sustainability goals and transparency expectations. The evidence indicates that sustainability reporting in NewSpace is uneven and frequently voluntary, and that where reports exist they often emphasize visibility (clarity and disclosure) more than verifiability (methodological transparency and assurance). However, because only a subset of firms publish sustainability reports—and reporting firms are likely systematically different from non-reporting firms—the thesis does not treat the observed reporting practices as representative of the entire NewSpace population. Instead, it interprets the findings as describing reporting behavior among observed reporters and as revealing a governance gap: without harmonized metrics and credible verification, reporting can function as a reputational instrument rather than a robust accountability mechanism.

Methodologically, the value of the thesis lies in triangulation rather than single-study identification. By combining patent–funding linkages, value-chain mapping with operational/financial staging proxies, and a report-level transparency assessment, the thesis builds a coherent narrative while explicitly acknowledging data and measurement limits. Across studies, the empirical approach is primarily descriptive and associational; accordingly, the thesis emphasizes careful language, avoids causal claims, and treats results as hypothesis-consistent evidence that motivates further testing rather than as definitive proof of mechanisms.

Taken together, the thesis suggests a cumulative logic that is plausible but not deterministic: as firms navigate information frictions, they may rely on a broader set of signals than formal IP alone; as they pursue execution under uncertainty, they may widen their value-chain scope or internalize critical interfaces; and as activity scales, legitimacy pressures increase while governance and reporting remain uneven. In this framing, visibility, coordination capacity, and legitimacy are mutually reinforcing—yet the strength of each linkage depends on firm heterogeneity (stage, subsector, geography, regulatory exposure) and on the availability and quality of observable data.

The integrative model draws on and contributes to three theoretical lenses. First, the Resource-Based View (RBV) helps frame how firms assemble and deploy distinctive resources and capabilities—while the thesis highlights that the value of these resources often depends on how credibly they are signaled and how effectively they are organized. Second, an innovation-ecosystem perspective clarifies that NewSpace outcomes are shaped by interdependencies among firms, institutions, and infrastructures, making coordination choices and boundary decisions central. Third, institutional theory helps explain how legitimacy and accountability pressures shape sustainability practices, and why voluntary disclosure can drift toward visibility over verification when standardized oversight is limited.

In summary, the thesis argues that competitive advantage in the NewSpace economy is unlikely to be the product of any single mechanism in isolation. Rather, it can be understood as the outcome of an evolving balance between signaling under uncertainty, structuring for execution, and sustaining legitimacy as the sector scales. At the same time, the thesis is explicit about what the evidence can and cannot support: the findings are grounded in substantial data collection and coherent comparative logic, but they are constrained by limited observability, small subsamples in certain comparisons, and the predominantly descriptive character of available measures. For these reasons, the thesis positions its conclusions as carefully bounded, and it identifies clear opportunities for future research—especially designs that model funding incidence as well as amounts, triangulate integration with richer governance indicators, and analyze sustainability disclosure heterogeneity across jurisdictions, firm types, and reporting regimes.

This bounded but integrative perspective provides actionable implications for managers, policymakers, and researchers. For managers, it highlights that patents are one strategic instrument among many, and that execution proofs and coordination choices can be equally salient signals. For policymakers, it suggests that governance and measurement frameworks matter: stronger comparability and verification mechanisms can improve accountability without assuming uniform firm behavior. For researchers, it motivates deeper causal identification, richer measurement of organizational boundaries, and systematic analysis of selection into disclosure. In doing so, the thesis offers a coherent map of signals, structure, and sustainability as interlinked mechanisms shaping the next phase of commercial space activities.

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Declaration of generative ai and ai-assisted technologies in the writing process

Statement: during the preparation of this work the author(s) used google/gemini in order to increase the readability of the paper, being the main author not an english mothertongue. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication

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