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Evolving governance in the space sector: From Legacy Space to New Space models

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ABSTRACT

The space sector is evolving from the "Legacy Space" to the "New Space". Along with the space sector, space program governance is transitioning to support an environment where legacy and New Space actors co-exist. The aforementioned transitions and the entry of New Space players result in new governance models, as space agencies aim to exploit contributions from non-space sectors, leveraging on collaborative opportunities.

Public-private partnerships (PPPs) become a new golden rule, disclosing unprecedented achievements.

However, the existing body of knowledge lacks a framing of models of space program governance, covering both Legacy Space programs and New Space ones. It is not clear how the roles and responsibilities of stakeholders change from the Legacy Space to the New Space, alongside the related changes in contract structures and the practices space agencies favour in current space programs and projects. Therefore, our paper aims to investigate how space program governance evolved.

We performed a single-case study on NASA-led space exploration programs to investigate the transition of space program governance and its actual state-of-the-art. We co-developed and validated three governance models for space programs through semi-structured interviews with senior experts. Furthermore, we present key drivers and barriers behind the evolution towards New Space governance models.

We found and discussed three program governance models corresponding to the evolutionary stages of space exploration programs. In the Legacy Space model, the government owns space infrastructures to demonstrate technological supremacy. In the Transitional model, lumpsum contracts, transitioning between cost-plus and fixed-price, replace the legacy EPC (Engineering, Production, Construction) ones. In the New Space model, collaborative efforts and PPPs enable alignment between public and private expertise. Finally, we examine the factors that promote and impede the evolution of space governance, leading to the emergence of a polycentric governance structure observed in current space programs.

The three models enable managers to visualize space programs from a governance perspective, where stakeholders' roles and responsibilities in PPPs are clearly identified. Moreover, managers can leverage and innovate existing practices for transitioning across different models of governance in space programs and projects.

We contribute to research by introducing a transitional governance model that enables the smooth transition between the Legacy Space and the New Space paradigms. We justify the concurrent adoption of multiple governance models within the same space program, as in the current Artemis program.

1. Introduction

The space sector is unveiling an unprecedented magnitude of benefits.

The revenues the space sector generated in 2023 reached US$400 billion [1]. Such an outcome followed several previous years of steady growth; the global space industry accounted for US$322.7 billion in 2014 [2] and US$335.3 billion in 2015 [3]. The last years display the most substantial growth; US$371 billion in revenues was generated in 2020 [4], US$386 billion in revenues was reached in 2021 [5], and US $384 billion in 2022 [6]. The commercial satellite sector maintains a dominant position in the space economy. Specifically, it accounted for

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74 % of total revenues in 2020 [4], 72 % in 2021 [5], 73 % in 2022 [6], and 71 % in 2023 [1]. The space economy, indeed, is primarily steered by commercial and private entities taking advantage of diminishing entry barriers into the space industry. Table 1summarizes the revenues of the space sector, with the percentage of the commercial satellite sector, from 2014 to 2023. .

The outlook for the future appears promising as well: SIA [5] forecasts that the global space economy will grow by 55 % over the next 10 years and Morgan Stanley confirmed such a projection, estimating that the space economy will achieve a value of $1 trillion by the year 2040 [7].

The positive outcomes and future projections fuel increasing curiosity in space activities, services, and applications. Numerous nations, both established in the space sector and new entrants, formulate space plans, strategies, and policies [8]. It is the case of the recent UK National Space Strategy in Action [9], New Zealand's National Space Policy [10], and the Indian Space Policy and Program [11]. Numerous new entrants, moreover, endorse the Artemis Accords to attain ambitious space objectives and goals collaboratively, the last nations being Lithuania (May 2024), Peru (May 2024), Slovakia (May 2024), and Armenia (June 2024) [12].

All of this is unfolding within what is commonly referred to as the "Space Economy". The Space Economy is described as "*the full range of activities and the use of resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing, and utilizing space*" [13]. The emergence of a Space Economy centred on the exploitation of space-based assets for societal benefit marks the beginning of a New Space era in the industry, where space exploration becomes increasingly commercialized [14]. This contrasts with the Legacy Space paradigm, exemplified by the Apollo program, where technological supremacy and national sovereignty were primary drivers, and government-led initiatives dominated the sector [15]. The New Space industry is characterized by a dynamic ecosystem of actors, many with origins from non-space sectors. Reduced entry barriers facilitate the influx of these newcomers, making it accessible for them to provide products, services, and applications. Moreover, by integrating cost-effective components, materials, and solutions [16,17], these new entrants contribute to further lower barriers to entry, stimulating and accelerating market development [18,19]. This phenomenon is mutually reinforcing, as the influx of diverse expertise contributes to a more innovative and dynamic industry landscape [20]. Commercial-off-the-shelf components (COTS), technological spin-ins and transfers from other sectors, satellite miniaturization, advanced propulsion technologies, and innovative manufacturing materials [8] have contributed to such a reduction in the barriers to space access [21]. Further contributions are provided by commercially driven activities, such as resource extraction and in-orbit services. This paradigm shift has attracted significant private investment, a departure from the Legacy Space paradigm. The global trend of investments in space start-ups experienced steady growth from 2000 to 2021: in such a period, a total of US$52.2 billion was invested, with a relevant US$15.4 billion peak in 2021 [22,23]. In contrast, venture investments decreased in 2022 (US$8 billion), marking a 46 % decrease from 2021 [24]. A tightening monetary policy environment impacted venture capital investment globally [24]. Nonetheless, startup space investment in 2022, while below the unprecedented 2021 peak, surpassed previous year levels [24]. Such a pattern is positively judged by investors; multiple sources of investment offset the decline in governments' budgets [25]. First, high-profile entrepreneurs employ their wealth to access the space sector. Second, there is a surge in the number of venture capital investments and the availability of seeds, prizes, and grants supporting emerging space initiatives [23,26]. The primary investor categories in the New Space ecosystem encompass angel investors, venture capital firms, and private equity firms [14]. There is, indeed, growing recognition of the commercial potential of space-derived products, services, and applications. Earth Observation (EO), as an example, targets a growing range of applicative contexts [27,28], and, in conjunction with Global Navigation Satellite Systems (GNSS), positively contributes to the advancement of nearly 40 % of the SDGs [29].

Last, a renewed interest in space exploration is currently underway, driven by NASA's Artemis Program. Legacy and new players converge within an enlarged space environment to attain shared objectives. Roles and responsibilities are reshaped and partnerships between the public and private sectors are prioritized.

Established governance models already proved indispensable in conventional space program and project management, aiding in setting guidelines for the delineation of roles and responsibilities of stakeholders, as well as optimizing decision-making processes [30–32]. Legacy Space actors, i.e. those originating within the context of legacy space exploration programs (e.g., during the Apollo and Soyuz programs), pioneered first-of-a-kind infrastructures and solutions under the guidance and oversight of space agencies [33]. As an example, during the Apollo Program, a multiplicity of perspectives existed among project stakeholders regarding the optimal approach to mission accomplishment [34]. In response to this challenge, NASA established a program office with centralized authority encompassing design, engineering, procurement, testing, construction, manufacturing, spare parts, logistics, training, and operational functions [34]. This enabled the space agency to maintain centralized control at the HQ for the management of the program [34]. In the current New Space paradigm, legacy organizations support collaborative partnerships with New Space actors, while adapting to innovative guidelines from space agencies [35]. In such a fast-evolving context, governance models and space procurement practices are undergoing significant changes given the limited applicability of established models to New Space programs and projects.

Notwithstanding, the inclination and quest towards collaboration still lacks a well-documented comprehension of how actors engage in cooperative efforts to shape New Space programs and to pool knowledge and expertise [36]. Besides, governance structure in space programs and projects is still relatively underexplored in the scientific literature. Beyond governance procedural guidelines established by space agencies, a clear conceptual framework delineating the role of owner, sponsor, and client within space programs and projects is absent [37]. Furthermore, the dynamic nature of governance models in response to changing operational environments, such as Legacy or New Space contexts, requires further investigation.

In response to the quest for research put forth by Denicol et al. (2020) [38] for research on new governance models for megaprojects, this paper aims to investigate how the governance of space programs and projects evolved from a "Legacy Space" setting to the "New Space" one. Particular emphasis is given to the evolving dynamics between public and private space organizations and their role in influencing new models of governance in the space sector.

We address two research questions (RQs).

RQ1. How the governance of space programs is evolving in the transition from Legacy to New Space?

Table 1
Data from satellite industry Association (SIA, 2015–2024).

YEAR	TOTAL REVENUES (US$ billion)	% OF COMMERCIAL SATELLITE REVENUES
2014	322.7	63 %
2015	335.3	62 %
2016	339.1	77 %
2017	348	79 %
2018	360	77 %
2019	366	74 %
2020	371	74 %
2021	386	72 %
2022	384	73 %
2023	400	71 %

RQ2. Why the governance of space programs is evolving in the transition from Legacy to New Space?

We answer these research questions through an in-depth single case study of NASA-led space exploration programs, with particular attention to NASA Artemis Program. NASA Artemis program was purposely selected [39] to support a comprehensive analysis of the evolution of space governance towards PPPs and the coexistence of diverse governance models within a unique program.

2. Background knowledge

2.1. Governance in program and project management

The likelihood of achieving successful program implementation is increased when a detailed governance structure effectively coordinates the activities and actors involved [38]; superior performance in terms of benefits, costs, and sustainability may be attained [40].

Given the "*turbulent, unpredictable, and dynamic environment*" [41] where programs and projects are initiated, there is the necessity to implement a clear governance structure to specify authorities, responsibilities, and boundaries straightforwardly [38], and to allocate accountability towards the involved stakeholders [42]. When dealing with megaprojects, defined as collaborative efforts among multiple parties working on interconnected projects organized as larger programs, it is crucial to tackle critical decisions at the outset of projects [38]. Specifically, it is important to establish clear definitions for the roles and responsibilities of the sponsor, client/customer, owner, and operator [38]. Although the specific roles and responsibilities may vary across organizations and industries, a general understanding of these terms within the context of program and project management identifies the following characteristics. The owner stands as the ultimate decision-maker, holding accountability for the success and/or failure of the program/project [43]. Additionally, the owner is requested to provide strategic direction of the program/project objectives, alongside alignment with the organizational goals [43]. The sponsor provides support and resource allocation, ensuring the program/project aligns with business objectives [43]. The client receives the overall benefits of the program/project, defining requirements and expectations to be attained, and eventually providing funds and resources [43] Roles and responsibilities are outlined in the governance framework, which "*provides the project manager and the team with structure, processes, decision-making models and tools for managing the project, while supporting and controlling the project for successful delivery*" [44]. This is key for the identification of power and legitimacy dynamics among program and project stakeholders, something the stakeholder management literature extensively supports [45,46]. In the realm of megaprojects, numerous parties pool resources and establish an array of contractual agreements to participate in inter-related projects; mapping such entities' roles and responsibilities enables the correct identification of the whole system [32]. Additionally, the delivery model strategy, intended as a combination of parties' capabilities adding value along the project lifecycle [32] and the approach and methodology used to execute a program/project, should be delineated for achieving the desired projects' outputs and outcomes [38]. A clear delivery model strategy is key to setting a common understanding of how the project will be structured, managed, and delivered to meet its objectives. It becomes therefore crucial to further enhance the project's success, as it influences the cost, time, quality (i.e., the project's iron triangle), and stakeholder satisfaction [43,47].

As projects' requirements change and programs transform, governance models may necessitate a re-design [32].

2.2. Polycentric governance structure

As put forth by Denicol & Davies, (2022) [48] a novel paradigm in project management is on the rise. Accordingly, flexibility and adaptability of project practices allow stakeholders to integrate greater value from megaprojects [48]. To encourage collaboration and the voluntary pooling of complementary assets, diverse and interconnected decision-making groups should be promoted [49]. While organizational high-level decisions reduce the complexity of enlarged ecosystems, a polycentric governance structure empowers local decision-making authority and facilitates the integration of local knowledge and resources [49]. The incorporation of flexibility within established models may ultimately lead to greater effectiveness and efficiency in the execution of projects [50]. Decentralization and autonomy have the potential to yield advantages not only for governance itself but also for governmentality, namely the diverse range of approaches individuals employ when dealing with governance tasks [50].

A transition towards enhanced flexibility is taking place in the realm of the space industry as well. Diverse projects require diverse levels of governance and diverse governance models [51]. Decreasing barriers to entering space [21] encourage innovations and displaced decision-making centres to promote agility and fast-paced technological changes [51]. Decentralization facilitates the accumulation of experience, and although soft standards and oversight bodies retain major influence, a stringent, centralized authority leaves room for adaptability [51].

2.3. Public-private partnerships (PPPs)

Under this perspective, public-private partnerships (PPPs) serve to facilitate the generation, utilization, and recombination of capabilities distributed across a collaborative network of partners [48]. As put forth by Evans, (1996, p. 1119) [52], "*state-society synergy can be a catalyst for development*". In numerous areas, governments provide assets that enhance and work alongside contributions and inputs from the private sector [52]. The private sector brings forth local knowledge, expertise, and learning from previous endeavours that would be expensive for the public sector to differently attain [48,52].

PPPs are encouraged as they bring advantages to both the public and the private sectors; the two sectors combine their qualities, and the final outcome surpasses the results of individual, separate endeavours [53]. Through collaborative assets and services development, PPPs facilitate the distribution of risks, costs, and resources [53]. Consequently, this leads to reduced strain on government budgets and enhanced cost-effectiveness in final infrastructures [53]. In PPPs, the pivotal aspect is the reconfiguration of risk distribution among project stakeholders; rather than a complete transfer of risk to the private sector, the emphasis lies in the exploration of proper allocation and risk management methodologies [54]. However, this leads to roles and responsibilities within project management becoming blurred and unclear [42]. First, it becomes challenging to properly define the roles of owner, sponsor, and client in specific projects [42]. Second, it is difficult to understand how these roles evolve throughout the lifecycle [42].

In the realm of PPPs, the public sector delegates either complete or partial control to private entities [42]. As a result, power dynamics among participants transform; the ownership usually remains within the public sector, while the private one progressively facilitates assets' realization [42]. PPPs amplify the complexity of projects' ecosystem; the nature of projects becomes more dynamic, and there is an evident introduction of challenges in effectively appointing responsibilities [42].

In the realm of the space industry, the shift towards increased collaboration with the private sector commenced several years ago. Following the Commercial Orbital Transportation Services (COTS) of 2005 and the Commercial Resupply Services (CRS) of 2008, NASA issued in 2010 a formal mandate advocating collaboration with the private sector. PPPs across a diverse range of space-related capabilities enable NASA to attain its mission goals while fostering both US competitiveness and economic growth [55]. Earth Observation (EO)

stands among the space-capability areas benefitting from PPPs. As NASA shares EO data with the private sector and leverages rooted expertise in data collection and processing, partnering with data analytics companies enables the effective development of commercial applications [55].

2.4. Space program and project governance

NASA Program and Project Management Handbook provides guidelines for establishing a well-defined governance structure for the space agency [30]. NASA's governance structure is designed to optimize efficiency, accountability, and effectiveness in space program management. Key principles include the adoption of lean methodologies to streamline decision-making and reduce bureaucratic processes. By clearly delineating roles, responsibilities, and authorities among program and project stakeholders, the space agency aims to foster an accountable operational environment. Similarly, the European Space Agency (ESA) characterizes its governance structure as a complex system involving member states, councils, and committees [31]. This framework is designed to facilitate intergovernmental cooperation among member states through consensus-based decision-making.

Within the realm of space program and project governance, the predominant model entails government provision of financial resources coupled with space agencies retaining ownership of project deliverables. This structure is characterized by stringent oversight and monitoring of contractors [25,56]. The roles of governments and space agencies evolved from what authors refer to as an "Old Space" perspective to a "New Space" one [25]. In the Old Space, programs and projects are financed and dictated by governments, aiming at supporting respective national sovereignty and strategic position in space [19,25,26]. NASA is identified as a prime contractor, i.e. the one designing and developing space technologies from scratch, and exclusive customer of space technologies and assets [25,57], retaining full ownership and control of these [25]. To develop crucial space technologies and infrastructures, space agencies maintain tight and centralized control over contractors [57] through the definition of strict requirements to be attained [25] and a command-and-control policy [26,56]. When the Space Race comes to an end, partnerships and a space exploration "commercial phase" [18] emerge. Space programs and projects become collaborative between space agencies and private actors [19]. Governments provide limited funds and resources [18] and space agencies learn how to cooperate with external partners to face the limited budgets allocated [19]. Public-private partnerships (PPPs) gain centrality; decreasing public funds are partly balanced by private ones and private companies introduce innovative solutions while sharing a portion of associated risks and responsibilities [18]. Recent programs and projects in the space industry are characterized by a drastic decrease in governmental funds and by a replacement of cost-plus contracts with fixed-price payments [25]. Space agencies contract New Space companies and pay for the milestones they achieve [25]. The space agency becomes therefore customer and partner of private contractors [26]. New commercial partners are instrumental in securing funding for space programs and projects; numerous entrepreneurs leverage their wealth to overcome space fixed-cost barriers [26]. Partnerships between nations, governments, industry, and academia are prioritized to enhance capabilities and expertise enhancement [51].

The literature falls short in providing a detailed outline of the roles and responsibilities across diverse project participant groups, extending beyond the internal governance structures of space agencies. A comprehensive delivery model strategy that accounts for the value-added contributions of all participants is therefore absent, and the trajectory of roles and responsibilities in the transition from Legacy to New Space is insufficiently articulated. This knowledge gap hinders the reconstruction of the evolutionary path toward the adoption of Public-Private Partnerships (PPPs) in space programs, a critical endeavour given the escalating complexity of space activities and the growing involvement of private sector entities. Space agencies confront significant challenges in this context, including balancing innovation with risk mitigation, integrating private sector stakeholders into governance structures, and managing the increasing complexity of space programs.

Additionally, tangible advantages of collaborative efforts within PPPs are in this way obscured. Addressing this gap necessitates a comprehensive understanding of the contributions and actions of stakeholders within novel space programs, in a scenario where cooperation becomes the new golden rule. To solve these gaps, we used as in-depth case study NASA-led space exploration programs, to understand how the governance of space programs and projects evolved over time and to deep dive into the gradual introduction of PPPs.

3. Methodology

To answer the RQs, we conducted an in-depth single case study, enabling the investigation from a "real-life context" [58]. Our paper focuses on NASA-led space exploration at an organizational level of analysis (e.g., the space agency), and with a focus on the governance models for the management of the Apollo, ISS, and Artemis Programs. NASA Artemis program was purposely selected [39] to answer RQ2 since it enables a comprehensive analysis of the space governance evolution towards public-private partnerships. To collect primary data on NASA-led space exploration programs, we performed semi-structured interviews with domain experts and managers. We triangulated the primary data with secondary data (e.g., e.g., academic records on program and project management, space governance models, and grey literature encompassing reports, press articles, and documentation from space agencies).

Through a back-and-forth approach between primary and secondary data, and abductive reasoning joining initial theoretical arguments and empirical findings, we derived, co-developed, and validated a theoretical framework [59]. Starting from the framework proposed by Paravano et al. (2023) [60] on space governance, we present the governance transition from a Legacy Space, to a Transitional Space and a New Space. We subsequently apply the space governance framework to investigate the governance of selected Artemis projects. By examining the factors influencing the evolution of space governance, we illustrate the polycentric governance structure within the Artemis program.

3.1. Data collection and sampling

Following a purposive sampling of interviewees [61], we identified a sample of informants knowledgeable and experienced about the phenomena of interest. Favouring a qualitative sample, we identified six space senior experts, providing us with the perspective of ESA, New Space start-ups, space incumbents, NASA, and JAXA. Table 2 displays the sample of informants. The semi-structured interview protocol was organized to confirm/disconfirm the propositions from the background knowledge [62], and to gather insights regarding the collaboration between space stakeholders in past and present space programs. Semi-structured interviews consisted of open-ended questions, typically implemented for qualitative case studies [61]. Questions were reviewed by academics and practitioners, and they were adjusted based on the feedback received. Finally, primary data were complemented with

Table 2
Profiles of the interviewees.

#	Organization	Job role	Experience
Int. #1	ESA	Program manager	30 years
Int. #2	JAXA	Program manager	33 years
Int. #3	Space incumbent company	Senior manager	29 years
Int. #4	New Space start-up	Portfolio manager	3 years
Int. #5	NASA	Program manager	40 years
Int. #6	New Space company	CEO	15 years

public documentation to corroborate and augment evidence [63]; websites, reports, and other public sources enabled the gathering of additional information on the Artemis program.

3.2. Data analysis

With a comprehensive set of data at our disposal, we performed abductive thematic analysis [64]. As a starting point, we adopted the framework introduced by Paravano et al. (2023) [60] and, during the search for recurrent patterns, we structured three governance models; the Legacy Space, the Transitional Space, and the New Space. We collected and unveiled the main drivers and barriers guiding the increased pace of space collaborations and partnerships.

3.3. Model refinement

The thematic analysis of primary and secondary data resulted in the development of two frameworks. The first framework summarizes the characteristics of space governance by categorizing the findings into three governance models, each accompanied by the respective primary characteristics and features. In the second framework, we present the main drivers and barriers driving the diffusion of a polycentric governance structure, drawing insights from the Artemis Program.

4. Findings

The Space Governance framework (Table 3) displays three governance models; the Legacy Space model, the Transitional Space model, and the New Space one. For each model, we present the timeframe of development following Denicol et al. (2021) [32]: the owner of space infrastructures and assets; the sponsor providing financial resources; the client commissioning space products/services; the main contract(s) and contractual partnership(s) implemented; the delivery model; the actor (s) setting requirements; the stakeholders bearing the risks; the relevance of revenues; and the cost structure.

The second framework (Table 4) delves into the factors that drive and impede the evolution of space governance towards a New Space governance model. Examining Artemis projects through a governance lens and analysing the drivers and barriers offer insights into the polycentric governance structure that shapes the Artemis program.

5. Discussion

5.1. Evolution of governance models in space exploration programs

In the Legacy Space Model, the government is the owner, different from what Heracleous et al. (2018) [25] and Tugnoli & Wells (2019) [19] propose; governments, rather than space agencies, retain rights

Table 3
Space governance models in space exploration programs.

	Legacy Space Model	Transitional Space Model	New Space Model
Timing	1957–1975	1975–2005	2005-present
Owner	Government	Space agency	Space agency and private organizations
Quote (interviewee #5): *"What changes is what the government is buying. In a traditional model, the government is buying the end vehicle, like the Orion spacecraft, to be owned and used. In a new model, the public sector is not buying the product but the service, there is no ownership in their hands, contractors retain ownership. For example, in the case of the HLS selected by NASA, SpaceX is later going to sell Starship services to other customers and retaining therefore the ownership."*			
Sponsor	Government	Government	Government and private organizations
Quote (interviewee #3): *"During the Apollo program, the government wanted to achieve its strategic goal and reach the moon as soon as possible. The quickest way is to fully fund a specific program, to do a specific thing, and to get there."*			
Quote (interviewee #2): *"The funding depends on the goal. How to get money for space exploration? Is it a scientific target? Then in this case the main role will be in the hands of the public sector. If the issue is some minerals or resources and that becomes a commercial thing, then the private sector and public sector will participate both in the funding mechanism."*			
Client	Space agency	Space agency	Space agency and private organizations
Quote (interviewee #6): *"The public sector keeps being the primary client even when the ownership is in the hands of private companies. The initial commissioning still comes from public actors, then private companies commission as well."*			
Quote (interviewee #1): *"The space agency is the traditional client, like in the commissioning of the ISS sub-systems. In the new paradigm, it is still the customer, but* commercial *contractors can then open to other customers."*			
Contract	Cost-plus	Cost-plus and Fixed-price	Fixed-price within PPPs
Quote (interviewee #5): *"In the traditional model the risk was higher, so government bears risks through cost-plus, they pay for everything, own everything, all the rights. This was the Apollo model. In a new model, we support fixed-price, and risk is evenly balanced. Privatization means the public sector is not owning everything and not paying for everything."*			
Quote (interviewee #1): *"ESA is shifting towards full fixed-price, to delegate activities to private partners and to reduce time and cost. The space agency pays for the concept, the private partner comes up with the solution and receives milestone payments."*			
Delivery Model	EPC contract	EPC and PPP contract	PPP, Open Innovation, Co-design
Quote (interviewee #3): *"As public budgets got tighter at the end of the Apollo program, and the space industry got more mature, space agencies looked for how to do more with less money. Budgets are flat to decreasing over time. There is a lot of tension behind it. There have always been public-private partnerships for the last 30–40 years probably, but there is pressure to adopt them when public budgets decrease."*			
Requirements	Space agency defines detailed *What*	Space agency defines *When*, *What*, and *How*	Space agency defines *What* and *when*; Private organizations define *How*
Quote (interviewee #5): *"In a traditional model, thousands of requirements were given by space agencies to contractors. Like in the case of Orion, requirements were given from a very high level to very fine detail, from exactly the spacecraft to achieve, to the performance and crew characteristics. In the new servitization approach, we are not telling the fine details, we are buying a service. Like in the case of the Human Landing System, we provide safety margins and requirements but no requirements on the performance. We specify goals and services but not precisely how to develop assets."*			
Quote (interviewee #3): *"It used to be that NASA would tell the contractors exactly what to do and give them money to do it. And if NASA made a change, then they would give them more money. Now NASA is trying to create a system where contractors have what they call "skill in the game". So the contractors spend some of their own money. And NASA gives them fewer requirements. Tell them less what to do."*			
Risks and costs	Space agency incurs total risks and costs	Space agency incurs total risk and costs if cost-plus, shared risk if fixed-price	Shared risk and costs between space agency and private organizations
Quote (interviewee #3): *"In the traditional way, space agency used to bear all the risks and costs to achieve its objectives. It was expensive. But it was exactly the way to achieve what it wanted, plus more. Now with the new paradigm risks and costs are shared. It can cost less money and be faster because at the basis there are fewer requirements given by the space agency."*			
Quote (interviewee #2): *"Even in the new model, small companies cannot take all the risks and costs. In the new model, a small company is required to take more risks and costs with the development and investment, but they are still balanced."*			
Revenues	Secondary importance	Secondary importance	Secondary and primary importance
Quote (interviewee #3): *"In all the cases of national prestige and strategic leadership in space, the government's goal is not to be efficient. I don't think anyone in the Apollo program said, how many entrepreneurs did we get? How much did this help the GDP? Nobody looked at any of those economic factors. But now the objective is to help the economy, to help businesses, now that's completely the measure."*			

Table 4
Drivers and barriers for different governance models.

DRIVERS	
QUOTE(S)	DRIVER
Interviewee #1: *"I think the main driver behind a paradigm evolution is the search for efficiency. The implementation of fixed-price contracts lowers the costs, and the agency gets back more money from the money it invests, normally if the privatization model is led in a good way."* **Interviewee #6**: *"The Apollo program was too expensive. With the new model, the government and space agency must not own everything. They have now to be sustainable, to keep costs low, that's why they are trying a new approach."* **Interviewee #2**: *"The private sector seems to be more efficient than the government organization. So the public sector partners with the private sector, promotes participation from private companies, and space agencies buy services. Then mission costs will be lower."*	Cost efficiency
Interviewee #2: *"Of course the technological skill of the private sector is different. In the case of space exploration the space agency and old space companies have proven technologies. But when it comes to earth technologies you need to collaborate with New Space companies for their innovative solutions and with non-space partners that have skills on earth technologies."* **Interviewee #3**: *"The main benefit of partnerships with private sector and generally of privatization I think is entrepreneurism. It allows more creative solutions, more interesting solutions, and more ways to reach them. I'm not sure that in 50 years of space exploration with old models, we've made 50 years of progress. The magic behind New Space companies is the operational procedure. They take a known technology others have done a couple of times, and they operationalize it better. They are really able to do it over and over again and with quality. Sometimes even without technological breakthroughs, and that's a different culture and core competency. Overall, I think the broad tent of Artemis has helped us think about different things and different ways to do them. And that forced us to look and say, can we try something new and can we be successful?"* **Interviewee #4:** *"We enable new models. We launch things when they are not yet at full capacity to test them. For space agencies it is now convenient to externalize production, for the competency and flexibility the industry offers."*	Innovative technologies and business practices
BARRIERS	
QUOTE(S)	BARRIER
Interviewee #1: *"It's not just a matter of promoting efficiency. The organization of the company which is on the other end of the cooperative model must reflect the new paradigm. You need to have an industry that plays this new paradigm."* **Interviewee #5:** *"Publicly traded companies have to achieve corporate goals. They assess whether new models and servitization help them achieve corporate goals. Established space companies are reluctant to embrace new space approaches, it is challenging to switch the contract type for them."* **Interviewee #3**: *"We are a very traditional company, and it is hard for us. We are used to having the government give us the money for the development. We have trouble changing our culture for the new place. Culture is really hard and it's probably not a lot of engineering stuff, but innovation culture, operational culture, quality culture. That's the biggest challenge we have, nobody knows if the new system will work. And also, as you get to become a big company you layer on different processes that if you are a new company. They are faster and leaner."*	Organizational culture and business model
Interviewee #1: *"I think in Europe even if we had the crewed capability we probably don't have the market like in the US. We have a much smaller market, I'm not sure we have a lot of billionaires in Europe. We want to go to space, I don't know. So maybe the problem for us is also to which field we should apply a new space paradigm. Because human Space Flight is a temptation. But is it something that justifies, which has the volume to justify the interest of the new space players? You need a reasonable market for the agency to accept a new paradigm and for the industry to play it."*	National context
Interviewee #3: *"New models can cost less money and be faster because there are fewer requirements, but you can end up with not what you want. Let's take Mars as an example. NASA does all the traditional ways of getting there. New models work great for LEO. But can you translate that to science? Can you translate that to the Moon and Mars with all the high-risk? Like in our company, we like fixed-price if we know it's something we have done before. But you have to figure out, how to cost risk in a very risky program you have never done before? We would better be more conservative."* **Interviewee #5:** *"Oversight and insight are chosen according to the perceived risk of development. With safer products with low development risk, we favour insight approach, but oversight is preferred with very high risk and new development. Usually, never all the parts of a program are high risk, only some new technologies are used. It depends on the technology readiness level, for low TRL we prefer oversight and control, detailed plans of development, and tasks to be demonstrated, with risk mitigation plans and backup plans."* **Interviewee #1**: *"I would say Orion is really old-fashioned, it's really the old paradigm, and it's probably the same for the SLS, for the risks behind them. In Artemis however you can see the new paradigm in the contributions attributed to SpaceX, like the HLS, but you don't see the new paradigm on historical risky programs."*	Projects' risks

derived from space programs and initiatives. The primary objectives within this model are to enhance political, ideological, and national standing. The government acts in the Legacy Space as the full sponsor of space programs and projects, allocating the necessary funding to fully support space companies [18,25,26,56]. The client of the Legacy Space Model is the space agency; once it receives the institutional objectives to achieve, it engages in cost-plus contracts with contractors to develop space products and components [19,25,57]. The risky nature of space programs and projects requires space agencies to deploy cost-plus contracts [25,57]. However, contrary to what Tugnoli & Wells (2019) [19] sustain, cost-plus contracts are not entirely inefficient at this point. During the Apollo program, such contracts enabled the development of know-how, expertise, and capabilities within an industry that was still in the early stages of space exploration technology and asset readiness. The space agency bears full responsibility for the risks involved and completely centralizes the delivery model under its control [26], in a technocratic and command-and-control model [56]. Enforcing process compliance is indeed common in organizations characterized by strict forms of governmentality [50] and in high-risk environments. When it comes to space mission requirements, high-level ones are set by the government and not solely by the space agency, contrary to Tugnoli & Wells, (2019) [19]; high-level strategic objectives are set by governments, together with a high-level timeframe (when), and budget (how much). On the contrary, the space agency manages the finest level of

projects and component details, providing contractors with precise instructions on the final output, in line with Davidian, (2021) [56]. The centrality of revenues is not discussed in the literature. The main objective guiding Legacy Space programs is to gain national strategic leadership in space; indeed, *"the space race was clearly government-driven, and not an overwhelming expression of societal demand"* [56]. Therefore, revenues in the Legacy Space Model are of secondary importance.

Between the Legacy Space and the New Space, there is a transitional moment when the space agency becomes the owner and operator of space infrastructures, and the government maintains the role of sponsor. Such a transitional period was characterized, as an example, by the International Space Station (ISS) development. During this program, diverse space agencies collaborated to ensure the successful completion of the ISS while maintaining ownership of the subsystems allocated to them. Following the success of the Apollo program, public funds are limited and NASA must join efforts and resources to balance decreasing budgets [18,19,25]. The space agency is the client; contrary to Peeters, (2022) [18] and Tugnoli & Wells, (2019) [19], new entrants do not yet assume the role of client. Cost-plus contracts are still the predominant typology implemented; space incumbents work under legacy cost-plus contracts with space agencies. Fixed-price payments start however to be introduced; contractors receive fixed payments in milestones, and the remaining extra costs are shouldered by them. While EPC contracts are still largely implemented to exploit space agencies' know-how and expertise, public-private partnerships (PPPs) enable balancing risks and costs [25,65]. Public and private sectors are willing to combine capabilities and expertise through PPPs thanks to the risk-sharing feature such partnerships enable [53]. As a result, the public sector obtains assets, services, and infrastructure with much less pressure on public budgets [53]. To successfully implement the newly introduced collaborative models, the space agency favors decentralization in replacement of the conventional centralized model. The space agency is the one still setting all the requirements to be attained, especially the budget for contractors (how much), and milestones timeline (when); limited oversight from space agencies is not been experienced yet, contrary to what Tugnoli & Wells (2019) [19] suggest. The risks and costs are both in the hands of the space agency through cost-plus contracts, while for fixed-price payments costs and risks are shared between the public and private sectors; contrary to Peeters, (2022) [18], risks are gradually shifted, and the public sector support is still of major relevance. Regarding revenues, they continue to hold a secondary role; space programs and projects are still primarily driven by national prestige, expertise, and capabilities development.

The third and last space governance model is the one starting with the Commercial Orbital Transportation Services (COTS) of 2005 and the Commercial Resupply Services (CRS) of 2008. NASA established relevant partnerships with commercial enterprises to obtain win-win solutions; commercial base stimulation enables enhanced commercial capabilities, decreased domestic launch costs, easier access to space, and shifted focus towards R&D for space agencies [66]. In such a logic shift, the space agency maintains the ownership of legacy infrastructures, contrary to the predominantly private ownership depicted by Peeters, (2022) [18]. Private organizations retain ownership of their innovations and seek opportunities for commercialization through the creation of derivative products and services. A service-dominant logic arises [67]; the space agency buys services from commercial partners rather than conventional products and components, and it gradually transfers asset ownership to commercial collaborators. Cooperation and PPPs play an outstanding role in the New Space model; the development of innovative products and services is the result of joint efforts between the public and private sectors [53]. Heterogenous knowledge and resource pooling are major ingredients of a service innovation model, enabled whenever actors engage in value co-creation [68]. However, as in the case of megaprojects where funding no longer originates from a single source, the delineations of ownership often become unclear [32]. The sponsor is still the government but, following the PPP structure, it provides initial support [18,19]; the remaining funds come from the private sector. Private finance enables the public sector to shift the budget to other priorities [53] and commercial actors to gain independence from governments in goal-setting efforts [56,69]. In the realm of PPPs, fixed-price contracts gain prominence as the preferred choice over less efficient cost-plus contracts; through them, space agencies aim to mitigate delays and cost overruns [66]. EPC contracts are replaced by PPPs; decentralization gains predominance over legacy space centralization and contractors receive limited detailed specifications. To boost collaborative efforts, open innovation, co-design approaches [21], and concurrent engineering and design emerge. While the space agency continues to establish *What* requirements, it replaces a fully command-and-control approach in favour of openness and flexibility. Fostering innovation and concept development among commercial partners, the space agency allows companies to develop capabilities that can be retained and later brought to market, instead of solely being owned and operated by the public sector [66]. In collaborative governance models, indeed, delivery partners are responsible for setting *how* requirements and adding value through innovative approaches and practices [48]. Risks and costs are fully shared between the public and private sectors [19]. Part of the revenues is still of secondary importance, especially when it comes to purely scientific missions. Nonetheless, private organizations place significant importance on revenues as they seek a return and validation of investments and efforts [21].

5.2. Governance models in the New Space: the leading factors

A polycentric governance structure is guiding the current Artemis program. If analysed in consideration of the main drivers and barriers behind space governance evolution, project-specific governance models are adopted to manage projects' risks [54].

The development of the Orion modules, in particular the crew module, happens through legacy cost-plus contracts [70] and therefore through what we identify as a Legacy governance model. Nevertheless, due to the significant expenses and delays associated with its development, there is a growing inclination to embrace a servitization approach in many other Artemis projects. The Human Landing System (HLS), indeed, received significantly fewer performance requirements than Orion [71], since NASA buys services rather than the whole asset. SpaceX holds ownership, and the PPP approach facilitates the commercial partner in securing initial public funding for asset development. Similarly, NASA transitioned from a cost-plus contract for the HALO development in 2020 to a fixed-price contract in 2021 due to the cost inefficiencies and schedule delays encountered under the former contract structure [72].

NASA granted nearly complete autonomy for the development of CubeSats to harness cutting-edge technologies and practices. The Italian Space Agency (ASI) was commissioned with the development of a CubeSat, fully outsourced to an Italian New Space company. Through such an innovative and collaborative approach, ASI enhanced insight over oversight provision and exploited the knowledge and expertise of the New Space company on Artificial Intelligence [73]. Similarly, NASA harnesses the commercial capabilities, technologies, and expertise of Maxar Technologies for the development of the Power and Propulsion Element (PPE), favouring, therefore, a New Space model. The PPP between Maxar Technologies and NASA enables the commercial partner to own and operate the module along the whole contract with NASA [74]. Contrarily, JAXA opted for a conventional approach for the development of the Omotenashi CubeSat. External companies supplied components; however since there were no national partners equipped for handling such innovative technology, JAXA maintained complete centralization of the development process.

The Space Launch System (SLS), whose development started during the Constellation program, is developed through cost-plus contracts [75]. Space incumbents commissioned with the SLS development received detailed requirements and oversight from NASA, despite the

substantial cost and risk associated with such an approach [75]. Contractors manage in such a way to leverage rooted expertise, established practices, and inherited technologies [75]. The companies do not change the design approach [76], and adhere to conventional contractual methods that constrain governance evolution. Firms, indeed, may face challenges in re-shaping organizational routines, as these latter are embedded in rooted and structured knowledge, skills, and individuals [48]. The set of the culture of an organization represents, therefore, a factor shaping the governance and governmentality models adopted by companies [50]. Nevertheless, recent developments in the Space Launch System (SLS) program indicate a potential paradigm shift towards a service-oriented contractual model for subsequent launch vehicles of this category [77]. This shift stems from the escalating budgetary demands associated with SLS development, which compromise the program's long-term sustainability.

Last, the risky nature behind the Orion project and its integration with the SLS required the adoption of a Legacy model; NASA provided precise requirements to be attained, and, to effectively oversee and mitigate risks, contractors operate under cost-plus contracts [70].

6. Conclusion

Space governance models are needed to analyse past and current space programs and to better identify the evolving trend the governance is undergoing in time. What the space sector displays is evident progress towards a New Space governance model; this model is, indeed, positively supported by a vast set of space stakeholders. Nonetheless, it is not applied to all the activities, contexts, and by all the companies and space agencies operating in the New Space. For now, it is still a matter of understanding which field is mature enough to fully embrace this emerging, highly collaborative governance model. This assumption is perfectly in line with the evolution the space ecosystem is undergoing. Some actors are more at ease in changing respective organizational culture. Some nations have more developed markets conducive to the future commercialization of space-based products and services to clients extending beyond the conventional space agency. Some investors feel safe therefore in trusting some national space markets and in providing their financial contribution than in other national contexts. Some space agencies are more eager than others to replace conservative approaches towards partnerships and control decentralization. Nonetheless, a polycentric governance structure will probably characterize the space scenario for many coming years. The private sector introduces technologies and innovations the space agencies necessitate. The public sector is asked to facilitate such an introduction, and PPPs play a significant role; while encouraging innovation and technological advancement, PPPs balance the risks and costs imposed on both Legacy and New Space actors.

Our research implies that space programs and projects should be analysed from a governance perspective; a comprehensive overview of the main stakeholders' roles, responsibilities, and relationships is essential to perform a complete program and project analysis. Space agencies should boost the shift towards the New Space governance model for major technological breakthroughs and external knowledge integration and exploitation. Governments, space agencies, and companies should therefore do their best to support such an evolution. Despite its inherent inefficiencies, centralization is however to be favoured in situations involving high-risk projects, human safety concerns, and in those situations where markets and industrial capability are immature. As demonstrated by Artemis, diverse governance models are implemented and applied across projects, unfolding into a polycentric governance structure of the program. This approach maximizes potential value, balances risk and cost-sharing, and captures all available contributions whenever decentralization, servitization, and privatization can be favoured.

The primary limitations of our research pertain to a thorough examination of ongoing Artemis projects. Additional research into the governance of Artemis projects throughout future Artemis missions should be encouraged to grasp the evolutionary trends in space governance. In our paper, we concentrated on NASA-led space exploration programs due to the availability of an extensive repository of official secondary data from the space agency, which facilitated an in-depth analysis. However, this focus results in a US-centric perspective. Future research should explore space programs and projects through the governance structures, institutional contexts, and frameworks of other space agencies.

CRediT authorship contribution statement

Valentina Zancan: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Alessandro Paravano:** Conceptualization, Supervision, Validation, Writing – review & editing. **Giorgio Locatelli:** Supervision, Validation. **Paolo Trucco:** Resources, Supervision, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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