

GOVERNANCE AND RISK MANAGEMENT IN U.S. PUBLIC PRIVATE COLLABORATIONS FOR SPACE TECHNOLOGY DEVELOPMENT

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Copyright @Author**Corresponding Author: *****Anmole Jamshaid****Abstract**

This study discussed project management practices as well as the dynamics of governance and risk-sharing in U.S. public-private collaborations (PPCs) in the space-technology industry. Based on a systematic secondary research design, the analysis incorporates the GAO and NASA OIG audit, peer-reviewed literature and visual analytical modelling with risk matrices, subsystem interface mapping and Monte Carlo schedules simulation. The results indicate that multilevel governance structures are associated with formal clarity, although they do not tend to be adaptive to high-uncertainty aerospace. The weaknesses of leadership in systems-integration points increases the technical and schedule risk, whereas the contractual misalignment generates residual risk concentrations, especially among lower-tier suppliers. Systemic schedule volatility and the inability to plan deterministically is further proven by simulation evidence. The study provides a sophisticated insight into the drivers of PPC performance and comes with recommendations regarding the importance of governance reform and adaptive contracting, as well as risk-sensitive decision-making. Some of the proposed recommendations are strengthening integrative leadership, probabilistic scheduling approach, and enhance real time coordination mechanisms across NASA-industry interfaces.

INTRODUCTION

The space technology sector in the U.S has experienced a paradigm shift over the last 20-years in that it has ceased to be a government-dominated sector rather a complex ecosystem of public and private sectors. Conventionally monopolized by NASA since its inception in 1958, the U.S. space endeavors were planned centrally, of high cost, and vertically integrated (Dick, 2010). The Artemis missions by NASA are estimated to cost 86 billion USD by the FY 2025, thus it is the most ambitious and expensive ongoing program by the Agency (NASA, 2021). The emergence of commercial space players, the

most notable of which are SpaceX, Blue Origin, Boeing, and Sierra Space, has transformed the technological, operational, and managerial environment (MacDonald et al., 2024). According to the announcement of Space Foundation (2023), The Space Report Q2 2023, the space economy in the world increased 8 per cent to reach US 546 billion.

As demonstrated in Figure, venture capital firms are now the overwhelmingly preferred source of financing in space-tech, both in the percent of all investors (2012-2022 58% to 2022 74%) and the shares of other sources of investor-capital such as

angel investors, corporations, banks, and the public markets have decreased (BryceTech, 2025) (Fig. 1). At this growing commercial involvement, public-private collaboration (PPC) has become the model of operation of U.S. space programs,

especially in the field of crew transportation, satellite launch, missions to the moon, and in new space sectors, such as in-space manufacturing.

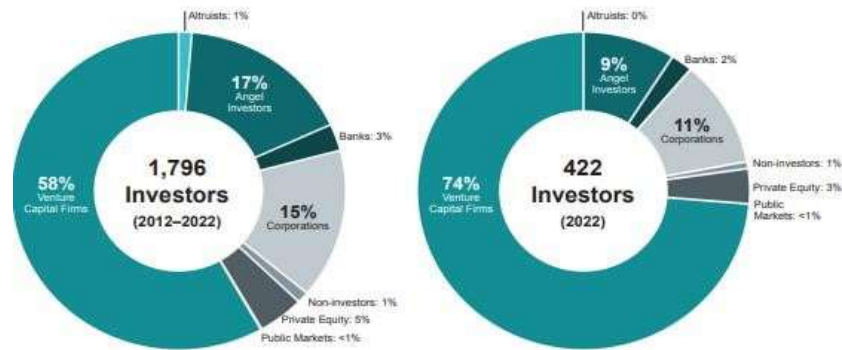


Figure 1: Comparison of investor composition in the space-technology sector (Source BryceTech, 2023)

Previously, the government had been a central figure, however, the recurrent overruns in costs, timelines, and bureaucracies enabled NASA to consider partnership models. The initial significant change in the direction of shared development costs, performance-based contracting, and milestone-based oversight was the Commercial Orbital Transportation Services (COTS) program (2006) and the Commercial Crew Program (CCP) (2010). Although these programs brought about significant achievements, including SpaceX Crew Dragon, they also brought to the fore structural management issues. Chronic risk allocation problems, milestone checking, configuration management, engineering culture conflict, and

communication failure were also reported by multiple GAO reports (GAO, 2019; GAO, 2023).

However, the overall situation under NASA oversight has not changed much: based on the latest annual analysis of its large projects, total cost overruns of NASA large projects have been estimated to be about 4.4 billion in 2024 (compared to 7.6 billion in 2023) (Fig. 2), and schedule overruns have also declined, although major projects (mostly These failures point out the idea that technological excellence is not enough to achieve success in PPC environments; the quality of project management is also of high concern.

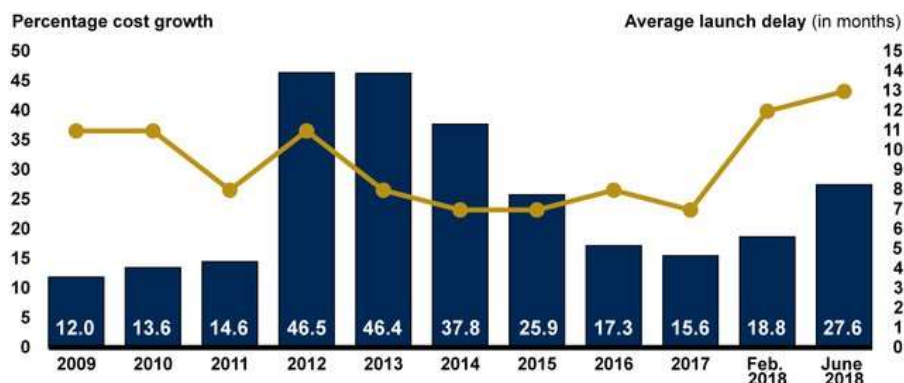


Figure 2: GAO analysis of Space Administration and National Aeronautics (Source: GAO, 2024)

In spite of huge federal spending and commercial innovation never before seen in the industry, mission slippage (e.g. Boeing Starliner, Lunar Gateway modules), fragmented governance, and inappropriate distributions of risks are persistent sources of poor performance. Available theories of project management, developed in relation to traditional government projects, are inadequately suited to the technological ambiguity, asymmetric strengths and hybrid government frameworks of space PPCs. No project management framework is built-in that entirely indicates these complexities or dynamics of the relationship between NASA and private partners. This study fills this important void.

This study aims to review the project management practices, challenges, and success factors in U.S. public-private collaborations within the space technology sector. In addition to

this objective of the study include to review the governance, leadership, risk-sharing, and performance, to synthesize secondary data to evaluate PPC outcomes and to propose improved PM/governance framework.

U.S. competitiveness in the global space race depends on the efficiency of public-private project delivery. NASA (2021) has spent \$37.2 billion to date (FY 2012–2020) on Artemis-related activities, with major elements such as the SLS and Orion experiencing multiyear schedule delays and billions in cumulative cost growth (Figure 3). An investigation based on project management will offer practical data to policymakers, program managers, and commercial contractors to improve mission reliability, decrease cost and schedule overruns, and improves U.S. space leadership.

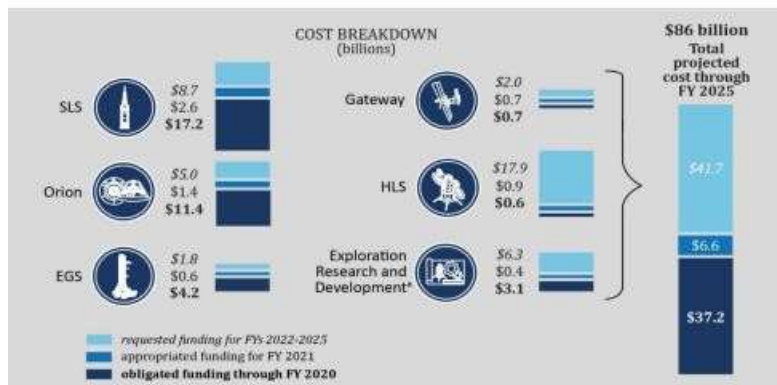


Figure 3: Cost breakdown of NASA’s Artemis program components through FY 2025 (Source: NASA, 2021)

1. Literature Review

1.1 Governance Quality in Public-Private Project Collaborations

PPCs are understood as contractual arrangements and multilayered governance systems necessitate strategic supervision, operational co-ordination and inter-organisational trust. Klijn and Teisman (2003) state that the best PPC governance balances between autonomy and interdependence whereby actors are able to coordinate in high uncertainty-condition which is rife in space-technology projects where subsystems play a significant role where technical interdependence exists, and the flow of

information is essential. The need for robust institutional structures is reinforced by Rouboutsos (2016), who highlights that PPCs demand clear frameworks to guide decision-making and risk distribution. Governance quality is also linked to how structures support uncertainty management, knowledge flows and cross-boundary integration; Samset and Volden (2016) emphasise that adaptable and transparent decision-making reduces project-level risks. Similarly, van Marrewijk et al. (2008) show that reflexive governance, capable of responding to emergent technological or organisational challenges, is essential in megaproject contexts.

The major governance challenge is still coordination failure. Davies and Mackenzie (2014) prove that integrative governance processes are essential to linking contractors, subsystems and organisational interfaces in the high risks technologies. In case of poor such mechanisms, projects become relatively susceptible to schedule slips, design fragmentation and increasing costs. The institutional logics are also not always compatible with governance since the private firms have the propensity towards innovation and efficiency whereas the government agencies focus on the procedural conformity and safety (Osborne, 2006). These tensions may impede the decision-making process and destabilize the systems of control as Geraldi, Maylor and Williams (2011) demonstrate that the incompatibility between cultures disrupts cooperation and compromises governance. Another pillar of governance is trust, according to Olander et al. (2010) trust-based governance cuts on transaction cost and fastens problem solving. However, the opportunity to avoid opportunism cannot be limited to trust, and additional accountability tools are necessary (Hodge and Greve, 2017; Wang et al., 2018).

2.2. Risk-Sharing and Contractual Alignment

Contractual design and risk-sharing have a major influence on the result of PPC. According to Goldthau (2014), in the context of technologically complex environments, the distribution of risks and performance incentives should be balanced with the help of hybrid contracting structures. Moral hazard and opportunistic behaviour are also common in poor contracts and serve to add to cost escalation (Winch, 2012). This is always cited by the global megaproject research as a leading contributor to overruns, especially in cases of excessive risk transfer to non-governmental actors without adequate flexibility or compensation (Flyvbjerg, 2014; Flyvbjerg and Gardner, 2021). On the other hand, hard fixed-price contracts do not work well in high-uncertainty, innovation-based projects, which is demonstrated by the findings by Lenfle and Loch (2010) who state that adaptive arrangements are more flexible to

emergent risks. Shared risk-management processes such as common risk registers and shared decision committees have been found to be mediating performance results (Sharif et al., 2020). Incentive alignment is also very important, as shown by Hartmann, Roehrich and Davies (2014), well-designed incentives promote innovation and efficiency whilst poorly designed incentives promote gaming. Risk distribution is improved with partner capabilities which promote innovation and general reliability (Roumboutsos and Pantelias, 2015).

2.3. Project Performance in High-Risk, High-Technology PPCs

The cost, schedule, quality and safety of project performance are a typical measure in PPCs and the aerospace projects also demand technological maturity, integration success and long-term operability (Shenhar and Dvir, 2007). These outcomes are dynamic interrelations between governance and risk-sharing mechanisms. Roehrich, Lewis and George (2014) demonstrate the moderating impact of quality of governance in strengthening effectiveness of risk-sharing through provision of clarity and accountability and collaborative efforts and equitable allocation of risks on strengthening governance through minimising conflict and enhancing joint problem-solving.

2.4. Gaps in Existing Research

Several research based on governance mechanisms in PPCs (Klijn and Teisman, 2003; van Marrewijk et al., 2008), the available literature concentrates more on general infrastructure or even transportation projects, and has little information upon the high-technological, uncertainty-intensive projects like space systems. Similarly, although there has been extensive theoretical literature on the concept of contractual alignment and risk-sharing (Goldthau, 2014; Winch, 2012; Lenfle and Loch, 2010), there is a dearth of empirical research on the connection between the two mechanisms and project performance in aerospace PPCs. Furthermore, previous research is more likely to examine Governance and Risk allocation

independently without evaluating how they affect the performance results together (Roehrich et al., 2014).

2. Methodology

This study adopts a systematic secondary-data research design (Johnston, 2014), appropriate for analysing governance and risk-sharing mechanisms in U.S. space-technology PPCs where much of the relevant information is contained in publicly available government audits, industry reports, and peer-reviewed studies. Secondary-data designs are widely recommended for studying megaproject governance because they allow researchers to integrate multiple authoritative sources across long project timelines (Qiu et al., 2019). This approach is particularly suitable for the U.S. space sector, where access to primary participants is restricted due to security classifications and organisational confidentiality.

According to Rethlefsen et al. (2024), the systematic method of search was employed to achieve transparency and replicability. The search was performed in Scopus, Web of science, ScienceDirect, Google scholar and publicly open archives including the U.S. Government Accountability Office (GAO), and NASA Office of Inspector General (OIG). Key terms included governance, risk-sharing, contracting, PPC, PPPs, aerospace, NASA, and project performance. Searches covered the period 2000–2024 to capture both legacy NASA programs and contemporary commercial partnerships.

Inclusion criteria were: (1) peer-reviewed articles on PPC governance, risk allocation, or megaproject performance; (2) government audit reports containing empirical data on cost, schedule, or governance failures; and (3) industry publications offering validated statistics (e.g., BryceTech). Exclusion criteria removed news articles, opinion pieces, non-technical blogs, and sources lacking methodological credibility.

Data were extracted and synthesised through secondary sources, following Terry et al. (2017) recommended approach of coding documents for recurrent themes such as role clarity, coordination mechanisms, risk-allocation models, incentive structures, and performance outcomes. Different charts and framework developed using Google Colab.

3. Findings

This section critically evaluates the governance practices, leadership dynamics, risk-sharing structures, and performance outcomes of U.S. space PPCs, using on secondary literature.

4.1. Governance Structures and Their Influence on Project Performance

Project management in U.S. space PPCs is critically shaped by formal governance architectures that determine authority, escalation paths, and verification gates (Guerrero, 2024). Where program governance is multi-layered (agency program office, prime contractor PMO, system integrator boards) but poorly aligned, project managers lack clear decision rights and timely authority to remediate risks – a recurring cause of schedule slippage and rework. The NASA–industry governance flow (Figure 1) demonstrates a multi-layered hierarchy where strategic oversight (NASA HQ and Program Office), contractual administration (Prime Contractor PMO), and technical execution (Subsystem Providers, Integration & Testing) must function in tightly coordinated cycles. This aligns with the conceptualisation of multilevel governance found in Klijn & Teisman (2003), who argue that complex, innovation-intensive PPP environments require strong inter-organisational interfaces and collaborative decision systems. Figure 4 visualises this dependence by showing how decision authority narrows from wide strategic oversight to tightly concentrated technical integration.

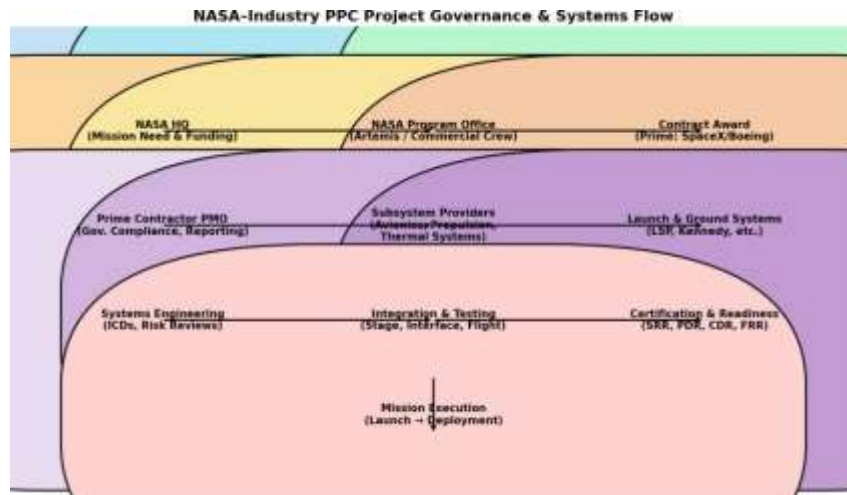


Figure 4: NASA-Industry PPC Project Governance & System Flow

Evidence from GAO’s annual Assessments of Major NASA Projects confirms that governance bottlenecks routinely correlate with schedule slips and cost escalation, especially where communication failures between NASA program managers and private contractors delay integration decisions (GAO, 2024). This supports the idea that performance is not only a function of technical maturity, but of how effectively governance actors synchronise decisions across organisational boundaries.

Critically, while the structural model in Figure 4 appears rational, existing literature warns that formal governance mechanisms can create illusionary control when technical uncertainty exceeds the program’s oversight bandwidth (Samset and Volden, 2016). Thus, a key finding is that governance effectiveness in PPCs depends

on both structural clarity (as depicted) and adaptive capacity—yet NASA audits show the latter remains inconsistent across projects.

4.2. Leadership and Coordination Breakdown at the Integration Node

Integration is the dominant driver of risk in aerospace megaprojects (Crosby, 2017). NASA OIG (2023) and GAO (2024) consistently identify late-stage integration failures as the primary cause of slips in the Commercial Crew Program and Artemis missions. The Subsystem Interface Risk Map (Figure 5) reveals that all major technical subsystems—avionics, propulsion, power, thermal, guidance, software, and structures, converge at a single critical point: Systems Integration.

Subsystem Interface Risk Map (High Risk at Integration Point)

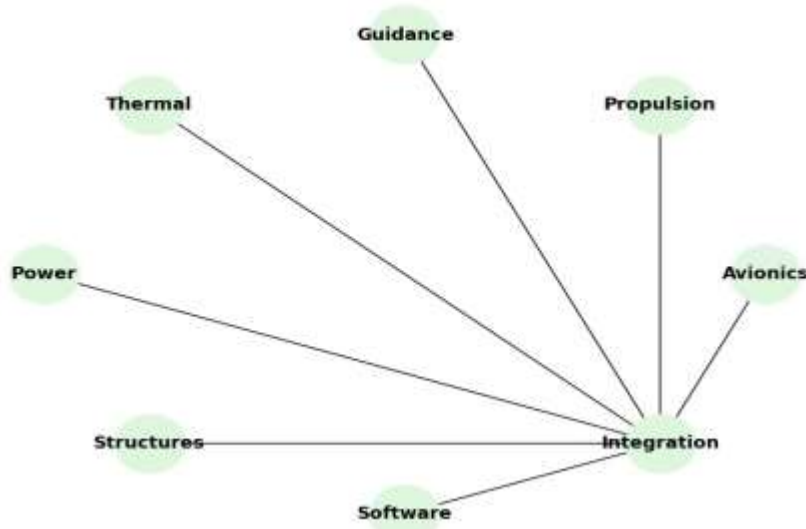


Figure 5: Subsystem Interface Risk Map

Leadership relevance becomes clear here. As per Harris (2012), PPC leadership is distributed across NASA program directors, contractor project managers, and subsystem leads. However, distributed leadership only succeeds when there is strong integration leadership capable of

orchestrating multidisciplinary teams—otherwise risks accumulate at the interfaces (Davies & MacKenzie, 2014). The concentration of edges in Figure 6 illustrates the leadership challenge: weak leadership at the integration layer affects every subsystem simultaneously.

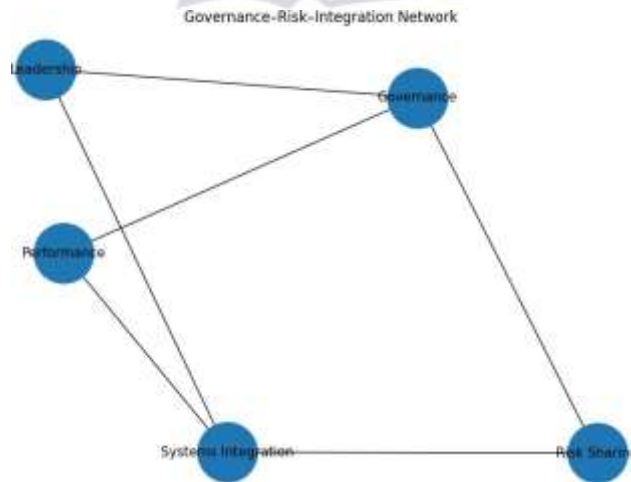


Figure 6: Governance, risk integration Network

Based on the findings, it can be stated that leadership failures (especially around risk communication, schedule realism, and cross-functional negotiation), intensify the technical risks clustered in PPCs. Supporting this, Gerald,

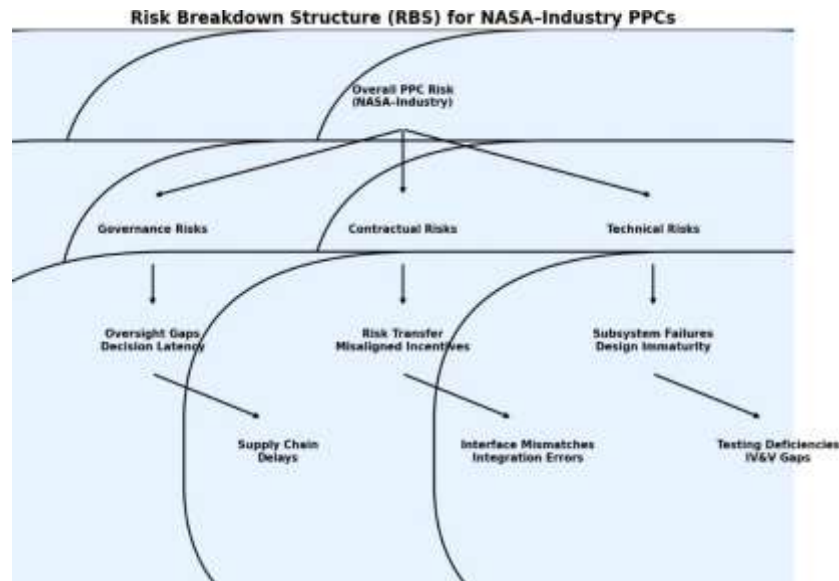
Maylor and Williams (2011), who argue that cultural and managerial misalignment can undermine governance controls and slow decision cycles.

4.3. Risk-Sharing Patterns and Contractual Misalignment

The risk patterns illustrated in NASA’s Artemis, Commercial Crew, and COTS programmes strongly support the categories depicted in this RBS, where governance, contractual, and technical failures intersect and reinforce one another. GAO’s assessments of Artemis repeatedly show that governance risks (such as oversight gaps, fragmented authority, and delayed decision-making) directly contributed to multi-year overruns in the SLS and Orion development cycles (GAO, 2023; GAO, 2024). These governance shortfalls in turn intensified contractual risks: NASA OIG (2022) found that milestone-based fixed-price contracts in Commercial Crew pushed Boeing into premature testing, creating misaligned incentives and

transferring excessive integration risk to the contractor (Roy, 2025).

Moreover, technical failures, including subsystem immaturity, interface mismatches, and inadequate IV&V testing, are widely documented across NASA’s high-technology programmes, with late-stage anomalies such as Starliner’s propulsion faults and Artemis I’s engine controller failures demonstrating the fragility of subsystem integration (NASA OIG, 2022). Hu et al. (2023) also confirm that megaprojects operating under PPC models exhibit compounding risk behaviour, whereby governance deficiencies heighten contractual tensions and ultimately magnify technical failures. Taken together, Figure 7 directly validates the structure of our developed RBS, in which governance, contractual, and technical risks are interconnected drivers of overall NASA–industry PPC vulnerability.



• Figure 7: RBS for NASA-industry PPCs

The Risk-Sharing & Contractual Alignment Model (Figure 8) depicts how PPC risk is divided among NASA (public/accountability risks), prime contractors (shared integration risks), and subsystem suppliers (private schedule and cost

risks). This tri-partite model corresponds closely with empirical PPP evidence (Roehrich et al., 2014), which emphasises that risk-sharing must reflect each actor’s capability to manage uncertainty.

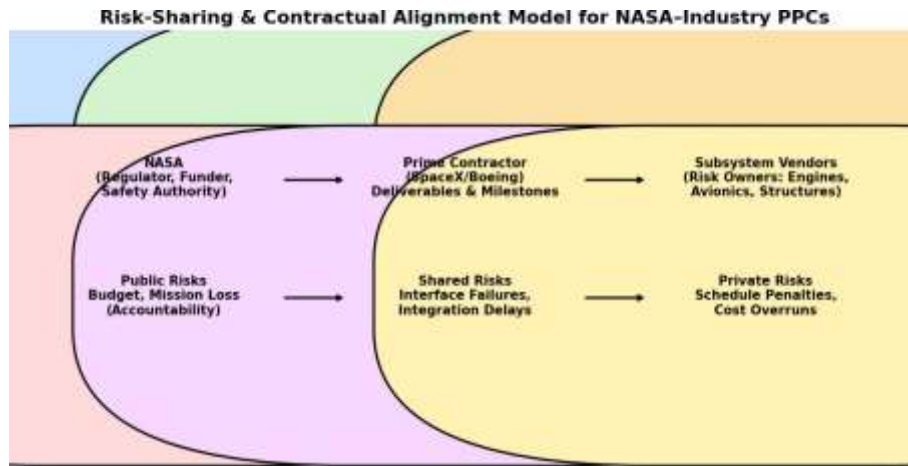


Figure 8: Risk-Sharing & Contractual Alignment Model

However, the Probability × Impact Risk Matrix (Figure 9) shows that contract misalignment and interface failures fall within the high-risk zone, both “likely” and “critical” in impact. This confirms the findings of Flyvbjerg & Gardner

(2021), who observe that megaprojects often suffer from misallocated risk, especially when fixed-price or rigid milestone contracts push private contractors to under-resource complex integration tasks.

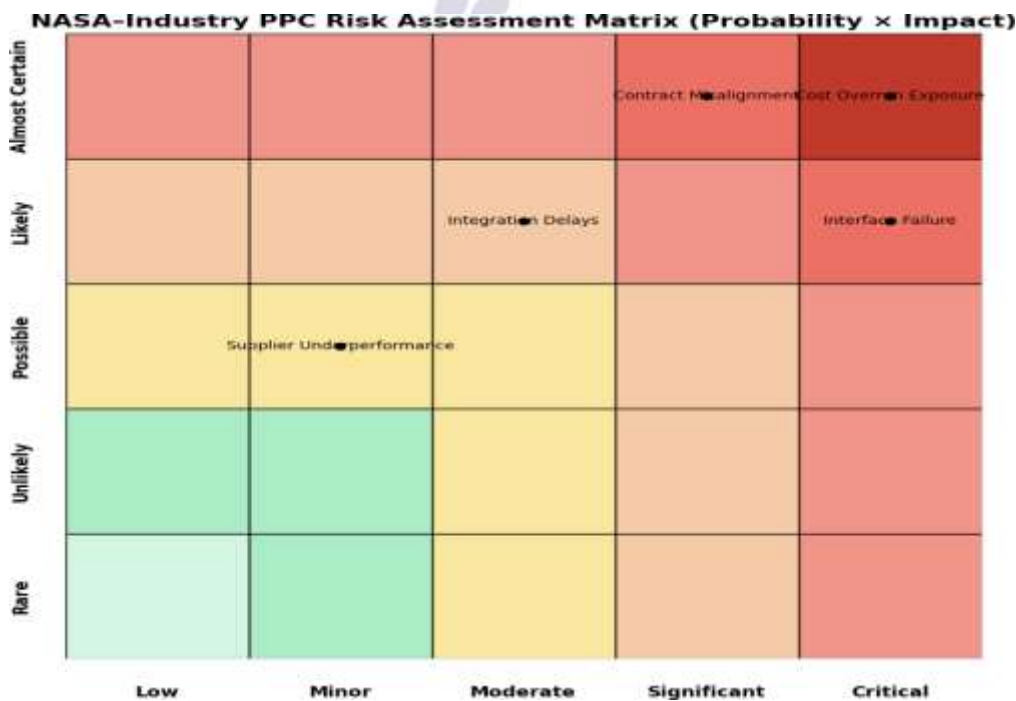


Figure 9: Risk Assessment Matrix for NADA-industry PPC

Complex aerospace projects are especially vulnerable to interface mismatches and coordination failures across suppliers, with

integration delays (Gurumayum, n.d.) and technical incompatibilities (Morandini et al., 2025) identified as dominant predictors of cost

and schedule overrun. Critically, the matrix indicates that supplier underperformance is “possible”, not rare— consistent with public reports involving Boeing’s CST-100 Starliner emergencies, heat shield anomalies, and thruster issues (GAO, 2024). These data points suggest that risk transfer to lower-tier suppliers remains structurally risky in space PPCs. Thus, PPCs exhibit hybrid but imperfect risk-sharing, with significant residual risks clustering at the integration and contractual boundaries.

4.4. Schedule Performance: Simulation Evidence vs. Real-World Observations

Many years of schedule slips in Artemis, SLS, and Commercial Crew (e.g., Artemis and SLS had

multi-year launch and delivery schedule slips; Commercial Crew certification dates were slips by two or more years), reflect significant right-tail schedule risk in NASA-industry PPCs (NASA OIG IG-23-015; NASA OIG IG-24-011; GAO, 2024). Monte Carlo distribution and CDF curve (Figure 10) indicate that the P50 project duration is 36 months and P90 is approximately 40 months. This distribution is similar to the empirically observed distribution in aerospace megaprojects in which median planning estimates are biased to understate tail risk.

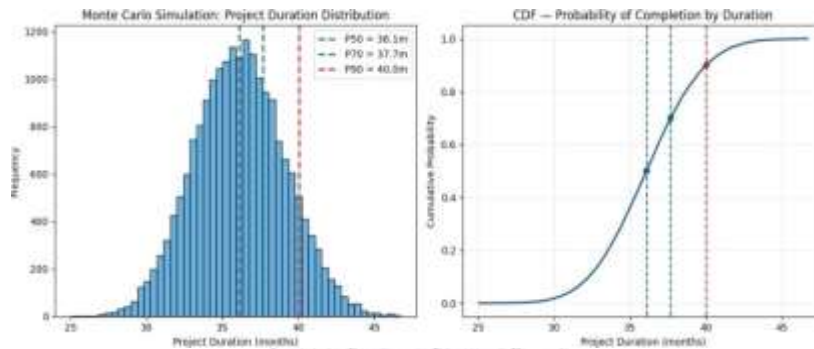


Figure 10: Monto Carlo Simulation for NASA-industry PPCs

The burn-down chart (Figure 11) idealises how risk should decrease from SRR to Launch. Yet GAO (2024) shows that several programmes fail to achieve expected burn-down because subsystem maturity does not progress at planned rates. This supports Lenfle and Loch’s (2010)

critique that overly linear PM models underestimate emergent uncertainty in high-technology environments. The Monte Carlo results therefore strengthen the argument for probabilistic PM practices, showing that PPC performance cannot be managed effectively using deterministic scheduling alone.

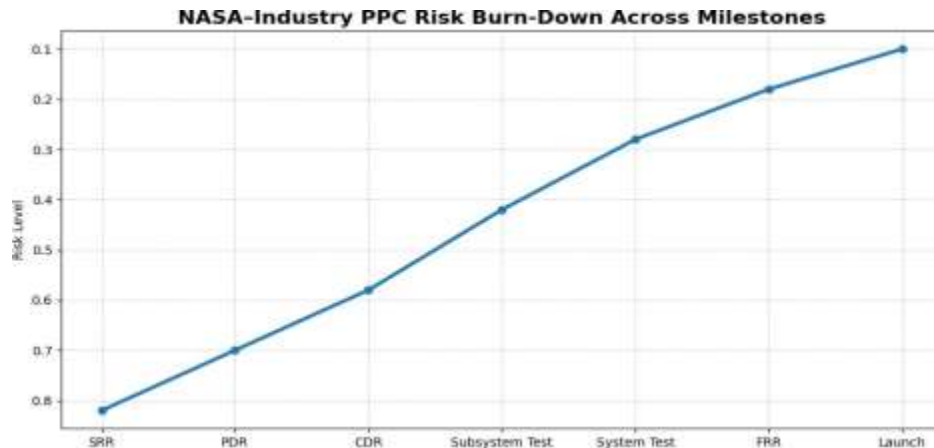


Figure 11: Burn-down chart

4. Discussion

The findings of this research confirm that governance structures, leadership capability, and risk-sharing mechanisms substantially shape performance in U.S. space PPCs; however, several results challenge prevailing assumptions in the literature. First, while the study affirms that structured governance enhances coordination (consistent with insights from Ebers and Oerlemans (2016), who emphasize governance frameworks in complex projects), the analyses reveal that rigid hierarchies may struggle under high technological volatility. project outcomes in U.S. space Performance-Based Partnerships/Contracts (PPCs) are strongly influenced by how governance is designed, how leadership functions, and how risks are allocated among partners. Although the findings align with some academic expectations, they also contradict common beliefs in PPC and project governance research. This sets up the argument that the study contributes new insights or exposes limitations in existing frameworks. This contrasts with expectations in traditional public-sector project governance, where formalization improves predictability. In space PPCs, governance rigidity appears to limit responsiveness, suggesting the need for adaptive rather than purely procedural oversight.

Similarly, although leadership is widely assumed to benefit from distributed arrangements, the subsystem integration map (Figure 2) suggests

that dispersed authority without strong central integration leadership can exacerbate risk. This finding diverges from the collaborative leadership perspectives advocated by Jia et al. (2024), who argue that shared leadership improves project outcomes in innovation-intensive environments. Instead, this study indicates that PPCs may require hybrid leadership models combining distributed expertise with strong integrative authority.

Risk sharing also does not support the optimistic performance-based contracting performance. Although the current literature emphasizes the importance of incentive-based contracts, the simulation analysis, as well as the risk matrix suggests that incentive-based contractual approaches cannot address the technical uncertainty and the immaturity of suppliers. This is more in keeping with Abd Karim (2011) who suggest that PPP/PPC risk-sharing should not be predetermined at the project lifecycle but should be re-calibrated on a regular basis.

The study's findings indicate that risk-sharing arrangements do not produce the optimistic performance improvements often claimed in the performance-based contracting literature. Many scholars argue that incentive-based contracts where contractors are rewarded for meeting performance outcomes rather than merely delivering inputs—can motivate suppliers, drive innovation, and ultimately enhance project success. This logic assumes that by allocating

more risk to contractors, particularly performance and technical risks, firms will be incentivized to perform efficiently, invest in capability, and proactively manage uncertainty.

However, the simulation analysis and the results derived from the risk matrix challenge this assumption. In practice, incentive-based contractual mechanisms appear insufficient when projects operate under high levels of technical uncertainty or involve suppliers whose capabilities are still immature.

Two key challenges emerge, First, the technical uncertainty remains beyond the contractor's manageable control. In complex space projects, many technical risks stem from scientific unknowns, rapid technological evolution, and integration challenges that no contractual incentive can fully mitigate. When the nature, timing, or magnitude of technical risks cannot be accurately predicted, allocating those risks to a contractor simply increases exposure without enabling better risk management. This eventually leads to cost overruns, schedule delays, or contractual disputes.

Second, supplier immaturity undermines the effectiveness of performance incentives. Incentive-based contracts assume that suppliers have the capability, expertise, and internal processes necessary to respond effectively to risk and performance demands. But when suppliers—especially new entrants or firms engaging with novel technologies—lack sufficient maturity, they cannot meaningfully convert incentives into improved performance. Instead, excessive risk allocation may discourage participation, distort behavior (e.g., overly conservative or overly risky decisions), or generate hidden failures at subsystem interfaces.

Together, these dynamics show that risk sharing is not a static mechanism, nor can it be treated as a one-time contractual allocation. Instead, risk distribution must evolve as technical knowledge improves and supplier capability develops. This finding aligns closely with the arguments of Abd Karim (2011), who contends that risk-sharing in PPP and PPC arrangements should not be predetermined and fixed at the beginning of the project lifecycle. Because risks evolve

continuously especially in innovation-intensive, long-duration projects contracts should include mechanisms for ongoing recalibration, enabling partners to adjust responsibilities, incentives, and risk allocations as the project progresses.

Thus, the study reinforces the argument that risk-sharing must be adaptive, not fixed, in order to reflect real-world conditions. It also suggests that performance-based contracting in the space sector may overestimate the ability of incentive structures to manage uncertainty, and therefore must be complemented with learning-oriented, flexible, and relational governance mechanisms.

It also implies that probabilistic scheduling, dynamic risk-sharing models, enhanced integration leadership, and governance arrangements, which involve real-time technical feedback, are required. Limitations are associated with the fact that the secondary data was used exclusively and did not allow gaining access to confidential organisational behaviour; the simulation model is abstraction of the true complexity of projects. Longitudinal case studies, joint interviews between contractors and NASA, or system dynamics modelling might be applied in future studies to verify these findings and rectify such conclusions.

5. Conclusion

This study found the effects of technological capability or capacity on project performance in the U.S. space PPC are less influential than are the aspects of governance, integration of leadership, and risk-sharing systems. The generation of secondary evidence and modelling products proves that formal governance arrangements, despite being highly structured, do not have the dynamism that they require to deal with fast changing technical risks. The problem of leadership within the subsystem interfaces also limits the coordination, whereas the long-lasting contractual misalignment prevents the efficient distribution of risks. Therefore, the paper indicates that to enhance the results of PPC, governance frameworks based on the integration of adaptive oversight, dynamic risk distribution, and empowered integration leadership are needed. Coordination is further constrained by

leadership gaps at subsystem interfaces, where the absence of a strong integrative authority undermines cross-component alignment. At the same time, persistent contractual misalignments impede the timely and efficient redistribution of risks across partners.

Taken together, these findings suggest that improving PPC performance will require governance architectures that combine adaptive oversight, flexible and continually updated risk-allocation practices, and empowered integrative leadership capable of managing system-level dependencies. While the study is constrained by its reliance on secondary data, it provides a robust conceptual basis for future empirical investigation and offers actionable insights for policymakers, program managers, and commercial partners seeking to improve mission reliability and operational performance. Even though the study is limited due to its use of secondary data, it is a solid ground to conduct future empirical research and can be used practically by the policymakers, program managers and commercial partners aiming at enhancing mission reliability and performance.

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