

Rethinking State Control of Airspace Sovereignty in Advanced Aerial Mobility

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ABSTRACT

Advanced Aerial Mobility (AAM) is reshaping the future of transportation through the development of air taxis, autonomous aerial systems, and AI-enabled low-altitude operations. While these innovations create new opportunities for urban mobility, they also expose structural weaknesses in existing air law frameworks. Current legal regimes remain largely designed for conventional aviation and are not fully equipped to address fragmented governance, overlapping regulatory authority, and challenges to the operational effectiveness of state control over airspace. This study examines whether the traditional concept of state control over airspace remains operationally and institutionally adequate in the era of AAM and identifies governance reforms needed to respond to AI-enabled and low-altitude air mobility operations. Using a normative legal method, this research analyses international air law principles, selected national regulatory models, and recent policy developments on AAM. The study finds that the main challenge lies not merely in regulatory gaps but in governance gaps caused by dispersed authority, inconsistent standards, and unclear accountability among multiple actors. The article argues that state sovereignty over airspace must be operationalized through a coordinated, state-led but networked governance model based on institutional integration, data interoperability, and real-time oversight. This approach provides a practical pathway for preserving effective state control while enabling responsible innovation in future air mobility.

Introduction

Every state is recognized as having full and exclusive sovereignty over the airspace above its territory under classical international air law (Convention on International Civil Aviation Convention, 1944). This principle is a cornerstone of modern aviation law and establishes that other states must obtain “permission” from the state over which the airspace lies in order to use that airspace. This is the key distinction between airspace and the high seas regime, which recognizes certain freedoms. Through this principle, a state has the authority to determine access to airspace, set safety standards, regulate air navigation, and take legal action against violations. This control model was developed within the context of relatively centralized conventional aviation, where the objects of regulation include traditional aircraft, human pilots, clearly identified operators, and predetermined routes and airports.

The development of Advanced Aerial Mobility (AAM) is beginning to challenge the adequacy of that model. AAM is recognized as a new form of air transportation that includes eVTOLs, air taxis, autonomous aerial systems, vertiports, and low-altitude operations in urban areas (Chen et al., 2025). This technology offers opportunities for faster, more flexible mobility that is integrated with urban transportation systems (Dulia et al., 2022). However, AAM does not merely introduce new types of air vehicles; it also transforms how aviation operations are conducted through the use of artificial intelligence, automation, real-time data connectivity, and digital platforms. AAM governance involves multiple stakeholders, not just governments or civil aviation authorities. AAM operations can involve vehicle manufacturers, platform operators, software developers, AI providers, vertiport operators, telecommunications

regulators, data protection authorities, cybersecurity agencies, local governments, and infrastructure providers. This complexity poses risks of fragmented standards and overlapping jurisdictions (Pons-Prats et al., 2022). Safety and certification matters may fall under the jurisdiction of aviation authorities, but vertiport locations and land-use planning are the responsibility of local governments, while digital connectivity, data, and cybersecurity fall under a different regulatory framework (Koumoutsidi et al., 2022).

This situation raises the question of whether the classic concept of state control of airspace is still sufficient to address the increasingly digital, autonomous, and multi-stakeholder AAM ecosystem. States legally retain sovereignty over airspace, but the effectiveness of their control in practice can be undermined if authority is fragmented, standards are inconsistent, and legal responsibilities are unclear. Thus, the AAM issue cannot be viewed merely as a need to establish new rules, but also as a governance design issue that determines whether the state is still capable of exercising effective control. The primary issue with AAM is not merely a lack of norms, but rather the mismatch between the governance structure and the nature of AAM, which is based on AI, data, and cross-sectoral coordination (Kwon et al., 2022). If AAM is regulated solely through a sectoral approach, fragmentation could actually increase and undermine the effectiveness of state control over airspace. Therefore, a governance model is needed that can integrate authority, standards, data oversight, AI oversight, and multi-stakeholder accountability.

This study examines the shift in focus from regulatory gaps to governance gaps. Many studies on AAM have addressed issues of safety, certification, infrastructure, and regulatory readiness, but have not sufficiently placed them within the framework of the effectiveness of state control over airspace sovereignty. This article argues that state control needs to be redefined as coordinated governance, rather than merely formal authority to grant permits, impose bans, or enforce violations. This issue is critical because AAM is likely to be integrated into urban transportation policies in the near future, while many developing countries lack regulatory frameworks ready to manage the associated legal, technical, and institutional risks.

Literature Review

The existing literature views Advanced Aerial Mobility as a broader transformation of future air transportation, encompassing eVTOL aircraft, air taxis, autonomous systems, vertiports, digital platforms, traffic management systems, and regulatory institutions (Wild, 2024). Much of the literature focuses on safety, certification, infrastructure, and regulatory readiness (Silva & Verhagen, 2025), suggesting that AAM cannot simply be incorporated into existing aviation regulation because its technical features and urban operating environment differ from those of conventional aviation (Stansbury, Richard S, Waleed, 2025). Studies on FAA, EASA, and ICAO initiatives also show growing regulatory awareness, but reveal risks of fragmented standards and uneven international harmonization. (European Union Aviation Safety Agency, n.d., 2025; Federal Aviation Administration, 2023)

However, existing studies remain largely sectoral, addressing operational safety, airworthiness, vertiports, urban planning, or national policy separately. What remains underdeveloped is an integrated legal analysis of how fragmented standards, overlapping authority, algorithmic systems, real-time data flows, and multi-actor governance affect the effectiveness of state control over airspace sovereignty. This study fills that gap by shifting the analysis from regulatory gaps to governance gaps, particularly fragmented standards, regulatory overlap, and accountability deficits in AI-enabled Advanced Aerial Mobility.

Theoretical Framework

This research is grounded in the theory of state sovereignty over airspace, the concept of effective control, and the international governance approach. The principle of state sovereignty over airspace provides the primary legal foundation for understanding a state's authority to regulate, supervise, and enforce rules within its airspace. Article 1 of the Chicago

Convention affirms that every state has “complete and exclusive sovereignty over the airspace above its territory” (Convention on International Civil Aviation Convention, 1944). Under classical international air law, this principle confirms that airspace is not a free domain, but a territorial space subject to the full and exclusive authority of the state. This framework is essential for examining the extent to which states remain legally empowered to regulate Advanced Aerial Mobility.

However, sovereignty alone is insufficient to explain the regulatory challenges created by AI-enabled Advanced Aerial Mobility. AAM has been described as an emerging aviation sector that seeks to provide secure, efficient, and environmentally friendly transportation through eVTOL aircraft, while also requiring integration of operations, infrastructure, connectivity, and ecosystem support (Al-Rubaye et al., 2023). This shows that AAM is not merely a new aircraft category, but a broader operational system that depends on digital infrastructure, data connectivity, and multi-actor coordination. Therefore, this research employs the concept of effective control to distinguish between formal legal authority and actual regulatory capacity. In the AAM context, effective control refers to the state's ability to supervise low-altitude operations, access operational data, oversee AI-based systems, coordinate relevant institutions, and respond to safety and cybersecurity risks.

The research further applies an international governance approach to explain the fragmented and multi-level nature of AAM regulation. Comparative policy studies show that governments are developing AAM policies in different ways, with approaches ranging from “very comprehensive frameworks” to “more general regulation” (Wiedemann & al., 2024). This supports the view that AAM governance may produce fragmented standards when certification, safety, airspace integration, and operational requirements evolve differently across jurisdictions. The governance challenge is also reinforced by the fact that managing eVTOL traffic in congested urban airspace requires high levels of connectivity to support routing information and future mobility operations (Al-Rubaye et al., 2023).

Accordingly, AAM governance involves not only civil aviation authorities, but also local governments, telecommunications regulators, data protection authorities, cybersecurity agencies, infrastructure providers, and private technology actors. This approach helps identify why the current challenge is not merely the absence of specific rules, but the existence of structural governance gaps, including fragmented standards, regulatory overlap, and unclear accountability. Through this theoretical framework, the study argues that state control over airspace must be reconceptualised as coordinated governance rather than merely formal command over territorial airspace.

Methodology

This study employs a normative legal research method to assess the adequacy of the concept of state control of airspace for addressing Advanced Aerial Mobility. The primary focus of the study is to analyze norms, legal concepts, institutional structures, and regulatory developments related to airspace sovereignty, AI-enabled aviation, and AAM governance. This study employs a conceptual approach and a statutory approach. The conceptual approach is used to analyze the concepts of airspace sovereignty, state control, effective control, and airspace governance. Meanwhile, the statutory approach is used to examine relevant international legal instruments and regulations, particularly the principle of state sovereignty in international air law, as well as standards and policies developed by aviation agencies. The legal materials used in this study consist of international air law instruments, aviation standards, and national or regional regulations relevant to AAM. The data analysis was conducted using a qualitative-prescriptive legal analysis approach. First, legal materials were systematically analyzed to examine the relationship between the principle of airspace sovereignty and the need for AAM regulation. Second, a conceptual analysis was conducted to assess whether state control can still be understood in classical terms or needs to be expanded to include control based on coordination, data, and digital surveillance. The analysis results were used

to formulate prescriptive recommendations for a governance model that maintains the effectiveness of state control over airspace without hindering AAM innovation. The research indicates that the challenges facing AAM stem not only from incomplete regulations but also from an inadequate governance framework that fails to effectively integrate state authority, technical standards, digital oversight, and multi-stakeholder accountability.

Results and Discussion

Governance Gaps and The Inadequacy of Conventional State Control in the AAM Era

The concept of state control over airspace in international aviation law is fundamentally based on the conventional aviation model. States exercise their authority through relatively clear mechanisms, such as issuing flight permits, establishing safety standards, regulating air traffic, supervising operators, and enforcing the law against violations. The regulated objects are traditional aircraft operated by specific airlines or operators, piloted by human pilots, and following predetermined routes and passing through designated airports. Consequently, state control has traditionally been understood as administrative and technical control primarily exercised by national civil aviation authorities. However, this model begins to fall short when confronted with the Advanced Aerial Mobility (AAM) ecosystem. AAM not only introduces new aircraft types but also transforms how aviation operations are conducted. Air taxis, eVTOLs, and autonomous aerial systems can operate in low-altitude urban airspace, utilize vertiports, connect to digital systems, and, in some scenarios, incorporate automation or artificial intelligence into operational decision-making. Operations like these do not fully follow the traditional aviation model based on airports, fixed routes, human pilots, and conventional air traffic control. These operational differences pose fundamental challenges for the concept of state control. In conventional aviation, the state can more easily identify the operator, the pilot, the routes used, and the oversight authority. However, in AAM mechanisms, this structure becomes more complex because operations may involve vehicle manufacturers, software developers, navigation system providers, vertiport operators, digital platform operators, communication network providers, and local authorities. Consequently, the point of control no longer lies in a simple relationship between the state, the operator, and the aircraft, but is dispersed across a network of actors and technological systems.

The involvement of AI and autonomous systems also undermines the adequacy of classical control models. If certain operational decisions are influenced by algorithms, sensors, or automated systems, then state oversight cannot be adequately ensured through initial certification or administrative inspections alone. The state must ensure that these systems can be audited, monitored, and controlled in the event of anomalies or safety risks. These things require new capabilities that were not previously a focus of conventional aviation law, such as access to operational data, real-time oversight, algorithmic audits, and integration with cybersecurity systems. Furthermore, AAM operates in urban airspace that is denser and more sensitive than typical commercial aviation airspace. Low-altitude operations over urban areas directly intersect with land use planning, public safety, noise, privacy, and the use of urban infrastructure. State control cannot be exercised solely by civil aviation authorities but also requires coordination with local governments, transportation authorities, data regulators, telecommunications regulators, and cybersecurity agencies. It is here that the primary weakness lies not in the loss of state sovereignty but in the inadequacy of institutional instruments to exercise that sovereignty effectively.

The main problem in the governance of Advanced Aerial Mobility cannot be reduced to a regulatory vacuum alone. While it is true that many aspects of AAM have not yet been fully regulated, the more fundamental issue lies in the fragmentation of governance. AAM operates at the intersection of aviation law, technology regulations, urban planning, data protection, cybersecurity, and transportation policy. Consequently, a single AAM operation may be subject to multiple standards and authorities simultaneously. This situation indicates that the challenges facing AAM are structural, not merely normative. The most prominent issue

regarding AAM operations is the divergence in approaches among countries and regulators in establishing AAM standards, particularly concerning eVTOL certification, autonomous aircraft, air taxis, operational safety, low-altitude airspace management, UTM, and compliance with AI-based systems. These differences risk causing AAM development to proceed inconsistently and hinder cross-jurisdictional interoperability. AAM relies on connectivity between vehicles, operators, navigation systems, vertiports, digital platforms, and data exchange mechanisms. If standards for certification, data exchange, emergency response, and AI oversight differ too widely, safety and legal certainty become difficult to guarantee, and may even encourage regulatory shopping toward jurisdictions with looser standards.

The next issue is regulatory overlap, which refers to the jurisdictions that overlap and each has authority to regulate specific aspects of AAM. Aviation authorities are responsible for safety, navigation, certification, and air operations, while local governments regulate land use, vertiport locations, building permits, and urban impacts. At the same time, telecommunications regulators, data protection authorities, and cybersecurity agencies are also relevant because AAM relies on digital connectivity, data processing, and system security. This overlap of authority is not always problematic, as AAM indeed requires cross-sectoral oversight. Problems arise when there is no clear division of authority, coordination forums, or integrated procedures. As a result, industry players may face inconsistent permits, regulators may pass the buck to one another, and some aspects may go unregulated because they are considered the responsibility of other agencies.

Furthermore, accountability deficits refer to the lack of clarity regarding which party is responsible when an incident occurs during AAM operations. Unlike conventional aviation, where responsibility can generally be traced to the pilot, operator, airline, manufacturer, or regulator, AAM involves a more complex chain of actors, including software developers, AI providers, sensors, communication networks, navigation data providers, vertiport operators, and digital platforms. This situation makes it difficult to determine liability in the event of an accident, route error, delayed response, system failure, or cyberattack. Without a clear accountability framework, victims may struggle to seek compensation, the industry faces legal uncertainty, and the state risks being seen as failing to exercise oversight. Therefore, legal liability in AAM should be directed toward a multi-actor model rather than relying solely on traditional aviation operators.

These three points indicate that the issue with AAM is not merely the absence of specific regulations but the lack of a governance structure capable of unifying standards, authority, and accountability. If regulations are added on a sector-by-sector basis without institutional coordination, fragmentation may actually increase. Within the framework of state control, this is critical because air sovereignty cannot be adequately maintained through formal jurisdictional claims alone. The state must ensure that all AAM actors and systems are integrated into a coordinated oversight framework, as fragmented standards undermine the control of consistency, regulatory overlap weakens institutional effectiveness, and accountability deficits hinder the enforcement of responsibility.

Toward a Coordinated State Control Model for Future Airspace Governance

This article proposes a coordinated state control model to modernize the exercise of state sovereignty over airspace within an AAM ecosystem that is increasingly digital, autonomous, and multi-stakeholder. This model does not replace the principle of state sovereignty, but rather emphasizes that sovereignty must be exercised through more adaptive coordination mechanisms. State control can no longer be understood merely as the authority to grant permits, impose restrictions, issue bans, or enforce violations. The state must also have the capacity to coordinate cross-sectoral agencies, access operational data, oversee AI-based systems, respond to cyber risks, and ensure that all actors are part of a clear chain of accountability. Thus, state control shifts from mere formal authority toward coordinated governance.

First, there needs to be the designation or establishment of a lead authority with a coordinating role, which should be given a clear mandate to liaise between the aviation sector and local governments, telecommunications regulators, data protection authorities, cybersecurity agencies, and transportation agencies. This authority does not need to assume the full jurisdiction of other agencies; rather, it serves as a coordination hub for AAM regulation. The civil aviation authority can remain the lead authority, since AAM essentially operates within the airspace.

Second, there needs to be a clear division of authority among agencies. Aviation safety, vehicle certification, and air traffic management can remain under the authority of the aviation agency. Meanwhile, land use, vertiport locations, and integration with urban transportation fall under the purview of local governments and spatial planning agencies. This division of authority must be codified in a clear legal or policy framework to prevent duplicate permits, jurisdictional conflicts, or gaps in oversight. With a clear division of authority, each agency understands its limits and has coordination mechanisms in place when an AAM issue spans multiple sectors.

Third, AAM relies on real-time data, such as flight data, vehicle locations, system status, low-altitude air traffic, micro-weather conditions, and vertiport operational information. The government will not be able to exercise effective control if this data is scattered among private operators without clear access mechanisms for regulators. Therefore, a coordination model must include secure, proportionate, and auditable data exchange standards. The government's access to data should not be interpreted as unlimited access, but rather as access necessary for safety, incident investigations, law enforcement, and the protection of the public interest.

Furthermore, since AAM may involve automated systems and artificial intelligence in navigation, obstacle detection, risk management, and operational decision-making, the government needs to establish a specific oversight framework for AI use. This oversight could include requirements for algorithmic audits, system documentation, software security testing, standards for explainability within feasible limits, and mechanisms for human intervention when the system exhibits anomalies. The goal is not to hinder the use of AI, but rather to ensure that technology used in public airspace can be monitored, tested, and held legally accountable.

AAM can no longer rely solely on a liability model centered on the pilot or flight operator, as risks can arise from multiple sources within a single operational chain. In AAM operations, failures can stem from vehicle design, software, navigation data, communication systems, vertiport management, AI providers, or platform operator decisions. Therefore, the law must establish a division of liability among operators, manufacturers, software developers, AI providers, infrastructure managers, and other parties that materially affect operational safety. This framework is essential to ensure that victims do not face an excessive burden of proof, while also encouraging every actor to prioritize safety from the design and certification stages through to operations.

Risk-based regulation mechanisms must also accompany the coordinated state control model. Not all AAM operations carry the same level of risk; therefore, limited test operations, light cargo, passenger air taxis, and autonomous passenger transport should not be subject to identical standards. Governments can adopt a phased approach through regulatory testing zones, limited permits, pilot projects, and periodic evaluations before granting full commercial operating permits. This approach is more realistic as it allows innovation to proceed under government oversight. Through this model, state sovereignty is not weakened by embracing AAM innovation, but is actually strengthened when formal authority is translated into institutional coordination, digital oversight, data standards, AI risk management, and multi-stakeholder accountability. Thus, innovation and state control need not be positioned as two conflicting interests. This paper presents a shift from state control as command toward state control as coordinated governance. The state remains the primary actor in regulating airspace, but its approach must be more collaborative, adaptive, and data-driven. If this model is

implemented, AAM can develop within a legal framework that is safer, more certain, and more accountable. Conversely, if the state continues to rely on conventional control instruments without institutional reform, AAM risks creating an airspace that is formally under state sovereignty but practically difficult to control.

Conclusion

The adoption of Advanced Aerial Mobility (AAM) demonstrates that a state's sovereignty over its airspace remains relevant, but conventional control models are no longer sufficient to ensure it. The primary challenges of AAM are not merely regulatory gaps, but also governance gaps, such as fragmented standards and overlapping jurisdictions. Therefore, state control must be understood as coordinated governance, not merely the authority to grant permits, impose bans, or take enforcement actions. Through interagency coordination, data interoperability, AI oversight, cyber response, and multi-stakeholder accountability, the state can maintain effective control over airspace without hindering AAM innovation.

Conflict of Interest

The author declares that no conflict of interest in the paper.

AI Declaration

The author declares that any artificial intelligence (AI) tools were not used during the preparation of the manuscript, including writing assistance, language editing, data processing, image generation, or other related purposes.

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