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Reconstructing Engineering Knowledge in the Low-Altitude Economy: The DAT Framework and the Emergence of Low-Altitude Engineering

Yong Ding
Weifang University of Science and Technology

Abstract

The rise of the low-altitude economy signals a fundamental transformation in engineering knowledge rather than a simple expansion of aviation activities. As autonomous aerial systems operate within dense, data-driven, and governance-intensive airspace, traditional aviation engineering paradigms centered on vehicle performance and centralized control become insufficient. This paper proposes Low-Altitude Engineering as an emerging discipline and introduces the DAT framework—Digital Airspace, Autonomous Systems, and Territorial Intelligence—as its core epistemic structure. DAT conceptualizes airspace as a computable governance object, autonomy as algorithmically controlled under Human-on-the-Loop paradigms, and space as an active substrate of engineering cognition. The study further explains how this knowledge transformation is institutionalized through talent systems and governance mechanisms, defining a long-term intellectual agenda for low-altitude economy and intelligent aviation research.

Keywords Low-Altitude Economy; Intelligent Aviation; Engineering Knowledge; DAT Framework; State Capacity

1 Introduction: Why the Low-Altitude Economy Is Redefining Engineering

The rapid rise of the low-altitude economy marks a critical turning point in the evolution of intelligent aviation systems. Unlike previous phases of aviation development, which were primarily driven by incremental improvements in aircraft performance or traffic volume, the current transformation signals a more fundamental disruption: a redefinition of the object, structure, and epistemic foundations of engineering itself. As low-altitude airspace becomes densely populated by autonomous aerial systems, traditional engineering paradigms rooted in classical aviation no longer provide sufficient analytical or institutional support. What is at stake is not merely the expansion of aviation activities, but the emergence of a new engineering domain shaped by digital airspace governance, autonomous systems, and territorially embedded intelligence.

1.1 From Aviation Expansion to Engineering Disruption

The so-called "third aviation revolution" is often described in terms of scale—more aircraft, more missions, and broader commercial applications. Such descriptions, however, obscure the deeper nature of the transformation. The defining feature of this phase is not quantitative expansion, but a qualitative shift in the engineering object itself. In low-altitude environments, airspace is no longer treated as a passive physical container to be controlled through centralized command-and-control mechanisms. Instead, it is increasingly constructed as a digital, computable, and governable space.

This shift entails a transition from traditional air traffic control toward data-driven airspace management systems, such as unmanned traffic management (UTM) and platform-based governance architectures. Airspace thus becomes

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a hybrid entity—simultaneously physical, digital, and institutional—requiring new forms of engineering knowledge that integrate system architecture, algorithmic coordination, and regulatory design. In this sense, the low-altitude economy represents an engineering disruption rather than a mere extension of aviation activity, calling into question the adequacy of existing disciplinary boundaries.

1.2 Talent Shortages as a Structural Symptom, Not the Root Cause

The frequently cited "million-level talent gap" in the low-altitude economy is often interpreted as evidence of insufficient workforce supply. From a structural perspective, however, this shortage should be understood as a symptom rather than a root cause. The problem does not lie primarily in the number of trained personnel, but in the misalignment between emerging engineering demands and legacy disciplinary frameworks.

Conventional aviation education and training systems were designed around stable aircraft platforms, clearly defined operational roles, and hierarchical control structures. By contrast, low-altitude intelligent aviation systems require engineers capable of operating across digital airspace modeling, autonomous system integration, and spatial data interpretation. When existing engineering disciplines fail to accommodate these requirements, talent shortages inevitably emerge—not because individuals are unavailable, but because the prevailing engineering paradigm no longer corresponds to the underlying technological and governance realities.

1.3 Research Question and Contribution

Against this backdrop, this study addresses a central research question: *how does the low-altitude economy reshape engineering knowledge, and through what conceptual and institutional mechanisms can this transformation be understood and operationalized?* To answer this question, the paper makes three interrelated contributions.

First, it proposes *Low-Altitude Engineering* as a distinct emerging engineering discipline, defined by its unique object of inquiry, methodological orientation, and governance embeddedness. Second, it develops the DAT framework—comprising *Digital Airspace*, *Autonomous Systems*, and *Territorial Intelligence*—as an epistemic structure for analyzing the knowledge foundations of low-altitude engineering beyond conventional training or curriculum models. Third, it explains how the reconstruction of engineering knowledge is institutionalized through talent systems and governance mechanisms, thereby linking theoretical transformation with practical implementation.

By reframing talent cultivation as a derived institutional outcome of engineering paradigm shifts, rather than their starting point, this paper seeks to establish a discipline-defining perspective for understanding the low-altitude economy and its long-term implications for intelligent aviation.

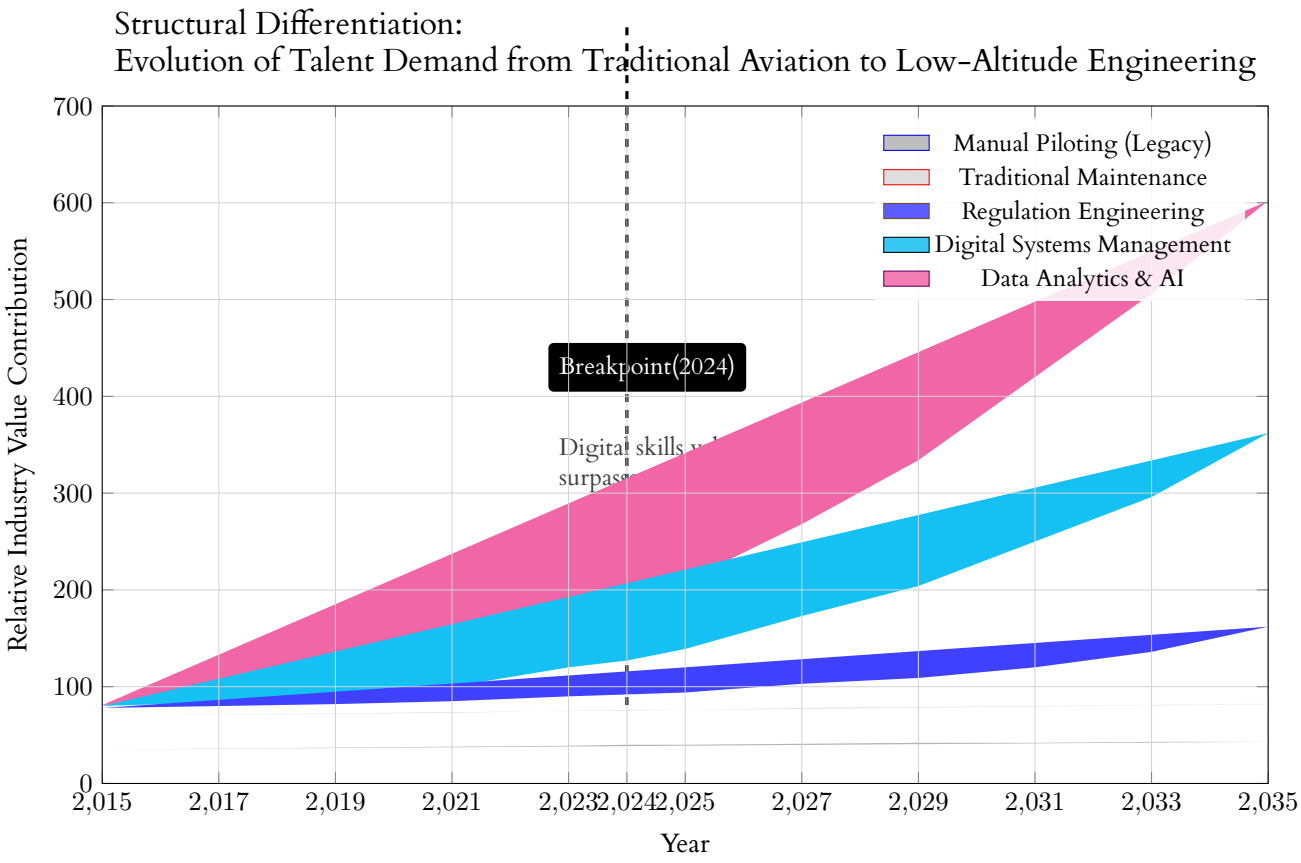
2 Theoretical Background: Engineering Paradigm Shifts in Intelligent Systems

This section positions the study within an international theoretical conversation on how major technological transitions reorganize engineering knowledge. The central claim is that the low-altitude economy is best understood not as a sectoral expansion of aviation, but as a paradigmatic shift in the epistemic foundations of engineering—a shift driven by intelligent, networked, and governance-embedded systems. In this perspective, what changes is not only *what* engineers build (aircraft, infrastructures, services), but *how* engineering problems are formulated, validated, and institutionalized under new conditions of autonomy, datafied environments, and risk-based regulation.

2.1 From Classical Aviation Engineering to Intelligent System Engineering

Classical aviation engineering emerged under conditions in which the aircraft was the primary engineering object and the operational environment was treated as largely exogenous. The dominant epistemic orientation focused on airframe and propulsion design, aerodynamic stability, structural integrity, and safety assurance through deterministic analysis and certification regimes. This tradition produced robust methods for fixed-wing and rotary-wing systems and supported the industrialization of air transport under relatively stable assumptions: controlled airspace, route-based traffic, and human-centered command hierarchies.

The rise of the low-altitude economy challenges these assumptions at multiple levels. First, the engineering object is no longer the aircraft alone, but a coupled *aircraft–airspace–communication–platform* assemblage. Low-altitude operations are intrinsically more heterogeneous (manned/unmanned, diverse mission profiles, mixed operators), more



spatially constrained (urban canyons, terrain, micro-meteorology), and more governance-intensive (dynamic permissions, geofencing, compliance-by-design). Under these conditions, traditional aviation engineering—centered on vehicle performance and deterministic control—is insufficient to explain system outcomes such as scalable safety, coordinated autonomy, or operational legitimacy.

Second, the engineering paradigm shifts from vehicle-centric design toward *system engineering* for distributed autonomy. The relevant unit of analysis becomes the socio-technical system: sensing and communication networks, traffic management architectures, verification layers, and human–machine responsibility allocations. Decisions that once belonged to pilots and controllers increasingly migrate into algorithmic coordination, runtime supervision, and cross-layer optimization. Consequently, the principal engineering problems are redefined: not only "can the vehicle fly safely," but "can a heterogeneous population of vehicles operate safely and efficiently under uncertainty, partial observability, and imperfect communication within a governable airspace regime."

Third, the low-altitude economy accelerates the transition from system engineering to what can be termed *spatial computing engineering*. In low-altitude contexts, engineering performance depends critically on the ability to represent, compute, and govern space: digital airspace models, probabilistic risk maps, dynamic constraints, and real-time allocative decisions. Space is no longer a static background but a computational substrate, continuously produced by data flows and institutional rules. This is why the low-altitude economy cannot be reduced to "aviation + drones" or "aircraft + AI." It entails a distinct engineering orientation in which spatial intelligence, data-driven governance, and autonomy assurance become co-equal foundations of system design.

From this theoretical standpoint, the paper treats the low-altitude economy as an empirical domain in which engineering knowledge is being reconstituted. The key question is therefore epistemic: which knowledge structures and competence architectures are required when engineering objects become intelligent, networked, and governance-embedded? The next subsection extends this argument by linking engineering paradigms to state capacity and governance technologies.

2.2 Engineering Knowledge, State Capacity, and Governance Technologies

A second theoretical lens is required to capture the institutional stakes of engineering paradigms: *engineering knowledge is not merely a technical repertoire; it is a component of state capacity.* In domains where safety, security, and public legitimacy are binding constraints, engineering solutions are inseparable from governance architectures. This is especially true for low-altitude systems, where the operational environment is densely regulated, risk is socially salient, and failures can propagate rapidly across networks and jurisdictions.

The notion of *state capacity* highlights that the feasibility of large-scale technological systems depends not only on innovation supply, but also on the state ' s ability to classify risks, allocate resources, enforce compliance, and coordinate actors. In the low-altitude economy, airspace is both a strategic resource and an allocable factor of production. Its commercialization requires institutional infrastructures: legal definitions of permissible operations, licensing and monitoring systems, accountability rules, data standards, and mechanisms for managing externalities. These are not peripheral administrative details; they shape what kinds of engineering solutions are viable and what kinds of organizations can participate.

Within this frame, *governance technologies* refer to the technical and institutional instruments through which governance becomes operational at scale. Examples include risk-based classification regimes, geofencing and remote identification, digital permitting workflows, auditability requirements for autonomous decision-making, and runtime assurance layers that bridge learning-based control with safety constraints. Importantly, these instruments are simultaneously technical (embedded in systems) and institutional (anchored in rules and enforcement). They therefore demand an engineering epistemology that treats compliance, verification, and accountability as design variables rather than ex post constraints.

This perspective also clarifies why "engineering education" alone cannot explain the low-altitude transformation. The core challenge is not simply training more personnel, but reorganizing engineering knowledge around a new triad: computable airspace governance, autonomous system integration, and territorially embedded intelligence. In other words, the low-altitude economy is a paradigmatic site where engineering knowledge, state capacity, and governance technologies co-evolve. Positioning the study in this theoretical space signals to reviewers that the paper is not a pedagogical reform report. It is a theory-building contribution on how intelligent systems reshape engineering paradigms under governance-intensive conditions.

In the remainder of the paper, this theoretical framing is operationalized through the DAT framework. DAT functions as an epistemic structure that specifies how low-altitude engineering knowledge is organized (Digital Airspace), how autonomy is engineered and assured (Autonomous Systems), and how spatial intelligence becomes a core engineering substrate (Territorial Intelligence). The framework further enables a principled account of how these knowledge domains are institutionalized through talent systems and governance mechanisms, linking paradigm reconstruction to implementable architectures.

3 The DAT Framework: An Epistemic Model for Low-Altitude Engineering

This section develops the DAT framework as the core theoretical contribution of the paper. Rather than a training schema or a curriculum design tool, DAT is proposed as an epistemic model that specifies how engineering knowledge is structured, mobilized, and institutionalized in the low-altitude economy. The framework identifies three irreducible and interdependent knowledge domains—Digital Airspace, Autonomous Systems, and Territorial Intelligence—that together define the intellectual foundations of Low-Altitude Engineering as an emerging discipline.

The analytical value of DAT lies in its capacity to explain why existing engineering paradigms fail to scale in low-altitude environments and how new forms of governance-embedded, computation-intensive engineering knowledge are taking shape. Each component of DAT corresponds to a distinct shift in engineering object, method, and validation logic, while their integration reflects the systemic nature of intelligent aviation.

3.1 Digital Airspace: From Air Traffic Control to Computable Governance

In classical aviation systems, airspace was conceptualized as a controlled physical volume, governed through centralized air traffic control (ATC) and rule-based separation standards. Engineering problems were framed around ensuring safe trajectories for relatively small numbers of certified aircraft operating along predefined routes. Under such conditions, airspace governance functioned primarily as an operational constraint external to engineering design.

The low-altitude economy fundamentally alters this configuration. As heterogeneous aerial systems proliferate in dense, dynamic, and urbanized environments, airspace can no longer be governed solely through centralized human control. Instead, it is increasingly reconstituted as a digital and computable entity, operationalized through unmanned traffic management (UTM), U-space architectures, and platform-based coordination mechanisms. In this context, airspace itself becomes an engineered object—continuously produced through data acquisition, algorithmic allocation, and institutional rule sets.

From an epistemic standpoint, Digital Airspace represents a shift from control-oriented governance to computation-oriented governance. Engineering knowledge must therefore incorporate formal representations of airspace, real-time risk assessment, dynamic constraint resolution, and compliance-by-design mechanisms. Safety and efficiency are no longer guaranteed ex ante through fixed separation rules, but are achieved through continuous computation, monitoring, and adaptive coordination. This transformation requires engineers to engage with governance logic as an intrinsic design parameter, rather than as an external regulatory boundary.

3.2 Autonomous Systems: From Mechanical Stability to Algorithmic Control

A second pillar of the DAT framework concerns the transformation of autonomy in engineering systems. Traditional aviation engineering prioritized mechanical stability, deterministic control, and human-centered decision-making. Aircraft behavior was designed to be predictable under predefined conditions, with pilots and controllers retaining ultimate authority over operational decisions.

In low-altitude intelligent aviation, autonomy is no longer an auxiliary feature but a systemic necessity. Large-scale operations involving diverse vehicles, missions, and environments cannot be coordinated through direct human control alone. Consequently, stability and safety increasingly depend on algorithmic control, learning-based perception, and distributed decision-making architectures. Engineering validation thus shifts from certifying fixed behaviors to assuring acceptable performance under uncertainty and adaptation.

Within this paradigm, the emerging norm is not full autonomy in the sense of human exclusion, but what can be described as *Human-on-the-Loop*. Humans retain supervisory and accountability roles, intervening at the level of system oversight, exception handling, and governance design, rather than continuous manual control. This reconfiguration fundamentally alters engineering competence requirements: engineers must design systems that are not only performant, but also interpretable, auditable, and governable over their operational lifecycle.

Algorithmic control therefore introduces a new epistemic challenge. Engineering knowledge must bridge control theory, artificial intelligence, verification methods, and institutional accountability. The question is no longer whether a system is autonomous, but whether autonomy can be structured, constrained, and governed in ways that sustain public trust and operational legitimacy at scale.

3.3 Territorial Intelligence: From Navigation to Spatial Cognition

The third component of the DAT framework, Territorial Intelligence, addresses the transformation of spatial knowledge in low-altitude engineering. In conventional aviation, navigation focused on route planning and positional accuracy within largely homogeneous airspace. Spatial reasoning was secondary to vehicle performance and procedural compliance.

By contrast, low-altitude operations unfold in territorially complex environments characterized by urban morphology, population density, infrastructure interdependencies, and localized risk profiles. Effective operation therefore depends on the ability to sense, model, and reason about space as a multi-layered socio-technical construct. Navigation alone is insufficient; what is required is spatial cognition embedded in engineering systems.

Territorial Intelligence refers to the engineering capacity to integrate spatial data, environmental sensing, and decision-making processes into operational logic. This includes dynamic geofencing, context-aware routing, probabilistic risk mapping, and the incorporation of social and regulatory constraints into system behavior. Space becomes an active variable in system performance, continuously interpreted and reconstituted through data-driven processes.

Epistemically, this shift elevates spatial knowledge from background context to core engineering substrate. Engineers must work across geographic information systems, sensor fusion, machine learning, and institutional rule sets to produce systems that are territorially responsive and socially acceptable. Territorial Intelligence thus completes the triad by grounding digital airspace governance and autonomous control within concrete spatial realities.

3.4 DAT as an Epistemic Structure Rather Than a Training Model

It is essential to clarify that the DAT framework is not a pedagogical or curricular model. Although it has implications for education and talent cultivation, its primary function is epistemic. DAT specifies how engineering knowledge is differentiated, integrated, and validated in the low-altitude economy.

As an epistemic structure, DAT performs three functions. First, it delineates the knowledge domains that constitute Low-Altitude Engineering, preventing its reduction to existing disciplines such as aviation engineering, robotics, or artificial intelligence. Second, it explains why engineering challenges in low-altitude systems are irreducibly systemic, requiring coordination across governance, autonomy, and spatial intelligence. Third, it provides a conceptual basis for understanding how engineering paradigms are translated into institutional arrangements, including regulatory frameworks, organizational forms, and talent systems.

From this perspective, education and training are downstream processes: they institutionalize an already transformed knowledge structure. Treating DAT as a training model would therefore invert causality and obscure the deeper paradigm shift at work. Recognizing DAT as an epistemic framework allows Low-Altitude Engineering to be articulated as a discipline-defining field, capable of guiding research agendas, governance design, and long-term capacity building in intelligent aviation.

In the following sections, this epistemic model is further connected to institutional mechanisms through which engineering knowledge is operationalized, illustrating how paradigm reconstruction materializes in talent systems and governance practices.

4 The Emergence of Low-Altitude Engineering as a New Discipline

The preceding sections have established the DAT framework as an epistemic structure for understanding engineering knowledge in the low-altitude economy. This section advances the argument by demonstrating that DAT does not merely reorganize existing competencies, but underpins the emergence of *Low-Altitude Engineering* as a distinct engineering discipline. The claim is not that low-altitude applications require additional skills, but that they constitute a qualitatively different object of inquiry, methodological configuration, and disciplinary boundary that cannot be subsumed under existing engineering fields.

4.1 Object, Method, and Boundary of Low-Altitude Engineering

At the core of Low-Altitude Engineering lies a novel engineering object: the *low-altitude digital–physical system*. Unlike classical engineering objects—such as aircraft, vehicles, or infrastructures—this system is inherently hybrid. It integrates physical flight platforms, digital airspace representations, algorithmic coordination mechanisms, and governance rules into a single operational assemblage. Performance, safety, and legitimacy emerge from the interaction among these elements rather than from any component in isolation.

Methodologically, Low-Altitude Engineering is characterized by the systematic integration of three analytical logics. First, it relies on *systems engineering* to manage the interdependencies among heterogeneous components, including vehicles, communication networks, control architectures, and human oversight layers. Second, it incorporates *spatial computing* as a core methodological pillar. Engineering solutions depend on the ability to represent, compute, and dynamically allocate space through digital models, probabilistic risk assessments, and real-time decision processes. Third, Low-Altitude Engineering embeds *governance logic* within technical design. Regulatory constraints, accountability mechanisms, and public risk thresholds are treated as endogenous design variables rather than exogenous limitations.

These methodological commitments distinguish Low-Altitude Engineering from neighboring disciplines. Its boundary is not defined by a specific technology or vehicle type, but by the requirement to engineer operationally viable systems under conditions of dense autonomy, spatial heterogeneity, and governance intensity. In this sense, Low-Altitude Engineering is neither a specialization of aviation engineering nor an application domain of artificial intelligence, but a discipline organized around a distinct class of socio-technical problems.

4.2 Why Low-Altitude Engineering Cannot Be Reduced to Existing Disciplines

A common analytical shortcut is to interpret low-altitude systems as the result of combining aviation engineering with artificial intelligence or robotics. This reductionist view, however, fails to capture the epistemic novelty of the

field. Aviation engineering traditionally prioritizes vehicle-centric performance, certification-based safety assurance, and stable operational environments. Artificial intelligence, by contrast, focuses on algorithmic learning, perception, and optimization, often abstracted from institutional and spatial constraints. Simply juxtaposing the two does not generate the integrated knowledge required to govern low-altitude systems at scale.

Similarly, framing the field as "drone engineering" or "unmanned systems engineering" obscures the systemic nature of the challenge. Vehicle-focused approaches treat airspace, regulation, and social risk as contextual variables, whereas in low-altitude environments these elements are constitutive of system behavior. A technically sophisticated unmanned aircraft is insufficient if it cannot operate within a computable airspace regime, comply with dynamic governance rules, or adapt to territorially specific constraints.

The irreducibility of Low-Altitude Engineering stems from the fact that its central problems arise at the intersection of autonomy, space, and governance. These problems cannot be decomposed into independent subproblems without losing explanatory and operational coherence. Engineering solutions must simultaneously satisfy technical feasibility, spatial rationality, and institutional legitimacy. This triadic constraint structure produces a form of complexity that existing disciplines are not equipped to address in isolation.

Recognizing Low-Altitude Engineering as a distinct discipline is therefore not a matter of academic taxonomy, but of analytical necessity. Without a discipline capable of integrating digital airspace governance, autonomous system assurance, and territorial intelligence, the low-altitude economy risks remaining fragmented, unscalable, or socially contested. By articulating the object, method, and boundary of Low-Altitude Engineering, this section establishes the disciplinary foundation upon which subsequent institutional arrangements—such as talent systems, regulatory frameworks, and organizational forms—can be coherently constructed.

5 Institutionalizing Engineering Knowledge: Talent Systems as a Derived Outcome

Having established Low-Altitude Engineering as a distinct epistemic and disciplinary formation, this section examines how engineering knowledge is translated into institutional arrangements. The central argument is that talent systems do not constitute the starting point of transformation in the low-altitude economy. Rather, they are a derived outcome of deeper paradigm shifts in engineering knowledge and governance. From this perspective, talent cultivation functions as an institutional mechanism through which newly constituted engineering epistemologies are stabilized, reproduced, and scaled.

5.1 Talent Cultivation as Institutional Translation of Engineering Paradigms

In engineering-intensive domains, talent systems operate as a key interface between abstract knowledge structures and practical system performance. However, talent cultivation is often misinterpreted as a matter of curricular design or workforce planning. Such interpretations obscure the more fundamental role of talent systems as institutional translations of engineering paradigms.

Within the framework developed in this paper, the emergence of Low-Altitude Engineering necessitates a corresponding reconfiguration of competence structures. These structures are not defined by isolated skills, but by the capacity to operate across digital airspace governance, autonomous system integration, and territorial intelligence. Talent systems therefore serve to codify, legitimate, and transmit these capacities across organizational and generational boundaries.

From an institutional standpoint, this process involves embedding epistemic priorities into formal arrangements: degree classifications, professional standards, certification regimes, organizational roles, and accountability frameworks. What is being institutionalized is not a "training plan," but a structured understanding of what counts as valid engineering knowledge and responsibility in low-altitude systems. In this sense, talent cultivation reflects the downstream stabilization of an already transformed engineering paradigm.

5.2 China as an Early-Exposure Case of Global Challenges

The relevance of China in the low-altitude economy should not be interpreted through the lens of national exceptionalism. Rather, China functions as an early-exposure case in which global challenges associated with low-altitude intelligent systems become visible at scale. Rapid industrial expansion, dense urban environments, and proactive policy experimentation have accelerated the manifestation of governance, coordination, and capacity constraints that are likely to confront other regions in the near future.

This early exposure has revealed a recurring structural pattern: technological feasibility advances faster than institutional adaptation. As low-altitude operations scale, mismatches emerge between legacy engineering disciplines, regulatory frameworks, and emerging system requirements. Talent shortages, coordination failures, and public risk concerns are not uniquely Chinese phenomena; they are symptoms of a broader transition toward governance-intensive engineering systems.

Analyzing China as an early-exposure case thus provides analytical leverage rather than empirical generalization. It allows researchers to observe how engineering paradigms, talent systems, and governance technologies co-evolve under conditions of accelerated deployment. In this sense, the Chinese experience anticipates, rather than deviates from, the future trajectory of the low-altitude economy globally.

5.3 Illustrative Cases and Institutional Arrangements

To concretize the institutionalization process without conflating conceptual analysis with empirical causality testing, this study employs illustrative cases. These cases are used to demonstrate how engineering paradigms are translated into organizational and regulatory arrangements, rather than to establish statistical relationships or causal effects.

Examples include industry–university collaborations oriented toward system-level engineering competencies, regulatory sandboxes that integrate autonomous operations with dynamic governance constraints, and organizational roles that formalize Human-on-the-Loop responsibilities. Such arrangements illustrate how epistemic structures materialize in practice through institutional design choices.

Methodologically, these cases serve an explanatory function. They clarify mechanisms and pathways by which Low-Altitude Engineering knowledge becomes operational, while avoiding claims of representativeness or causal inference. By explicitly delimiting the role of cases as illustrative, the analysis maintains conceptual rigor and reduces exposure to empirical critique.

Taken together, these institutional arrangements demonstrate that talent systems are best understood as manifestations of engineering paradigm shifts. Their effectiveness depends not on incremental adjustments to training programs, but on the coherence between epistemic structures, governance technologies, and organizational forms. This perspective reinforces the central claim of the paper: that the low-altitude economy compels a rethinking of engineering knowledge first, and talent systems only thereafter.

6 Implications for Engineering Education, Governance, and the Journal's Agenda

The reconstruction of engineering knowledge articulated in this paper has implications that extend beyond a single sector or institutional setting. By conceptualizing Low-Altitude Engineering as an epistemic and disciplinary formation structured by the DAT framework, the analysis provides a set of principles for rethinking engineering education, state capacity, and future research agendas in the low-altitude economy. This section outlines these implications, not as prescriptive recommendations, but as orienting frameworks for sustained inquiry and institutional development.

6.1 Implications for Engineering Education

The emergence of Low-Altitude Engineering calls for a reorientation of engineering education at the level of principles rather than curricula. Traditional engineering education has been organized around stable disciplinary cores, linear skill progression, and clearly bounded professional roles. In governance-intensive and autonomy-driven systems, such assumptions no longer hold.

From the perspective advanced in this paper, engineering education must respond to disciplinary reconstruction by prioritizing epistemic integration over modular skill accumulation. This entails cultivating engineers who can reason across digital governance infrastructures, autonomous system assurance, and spatial intelligence, rather than training specialists confined to isolated technical domains. Educational institutions thus face the challenge of aligning degree structures, evaluation criteria, and professional identities with a redefined understanding of what constitutes engineering competence.

Importantly, this reorientation does not require detailed pedagogical prescriptions. Instead, it requires recognition that educational systems function as institutional mechanisms for stabilizing emerging engineering paradigms. Engineering education becomes effective to the extent that it coherently reflects the underlying epistemic structure of the discipline it serves.

6.2 Implications for State Capacity and Low-Altitude Governance

Beyond education, the DAT framework highlights the intimate relationship between engineering knowledge and state capacity in low-altitude systems. As airspace becomes a strategic and allocable resource, effective governance depends on the state's ability to operationalize technical knowledge through regulatory and institutional instruments.

The DAT capability structure provides a conceptual map for this process. Digital Airspace enables the state to transform airspace governance from rule-based control into data-driven allocation and risk management. Autonomous Systems engineering supports scalable operations by embedding compliance, auditability, and human oversight within system architectures. Territorial Intelligence allows governance mechanisms to account for spatial heterogeneity, local risk profiles, and socially salient constraints.

Taken together, these capabilities illustrate how engineering paradigms underpin governance technologies. Regulation in low-altitude environments is not external to engineering practice; it is co-produced through design choices, validation logics, and operational interfaces. Strengthening state capacity therefore requires investment not only in regulatory institutions, but also in the epistemic foundations that allow engineering systems to function as instruments of governance.

6.3 Implications for Low-Altitude Economy Research

Finally, the analytical framework developed in this paper has implications for the future trajectory of research on the low-altitude economy. Much of the existing literature remains fragmented across technology studies, policy analysis, and sector-specific applications. The DAT framework offers a unifying perspective by situating these strands within a shared epistemic structure.

By framing the low-altitude economy as a site of engineering paradigm reconstruction, the framework shifts attention from isolated innovations to systemic transformations in knowledge, governance, and institutional design. It invites future research to examine how engineering disciplines emerge, how governance technologies co-evolve with autonomy, and how state capacity is reconfigured through computation-intensive infrastructures.

This framework defines the long-term intellectual agenda of low-altitude economy studies. It positions the field not merely as an applied research domain, but as a generative space for advancing theories of engineering, governance, and socio-technical change. In doing so, it establishes a durable foundation for scholarly inquiry and editorial orientation in the years ahead.

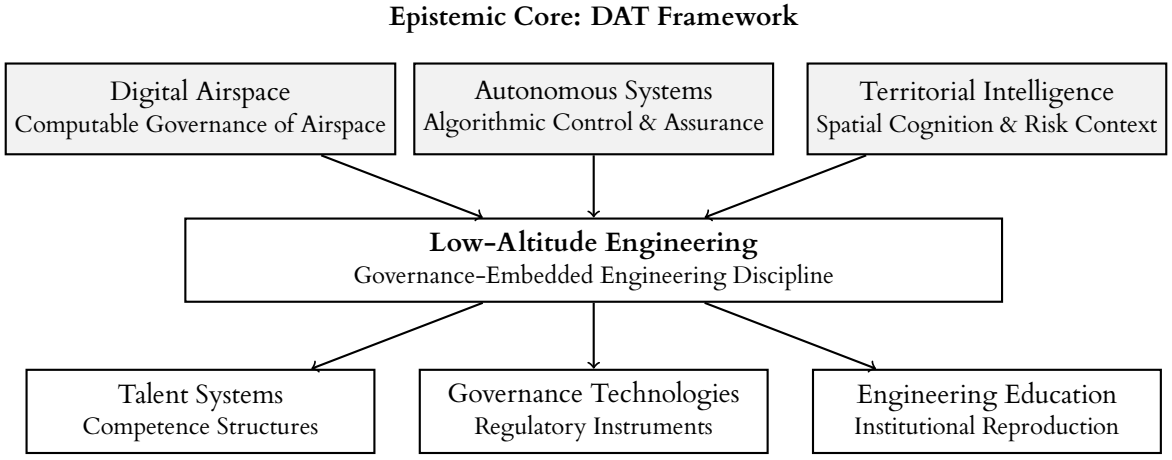


Figure 1: The DAT epistemic structure and the emergence of Low-Altitude Engineering as a governance-embedded discipline

7 Conclusion: Toward a Discipline-Defining Framework for Intelligent Aviation

The analysis presented in this paper has argued that the low-altitude economy should not be understood primarily as an expansion of aviation activities or a proliferation of new aerial applications. Its most consequential challenge lies elsewhere: in the reconstruction of engineering knowledge under conditions of dense autonomy, computable space,

and governance-intensive operation. What is at stake is not simply how low-altitude systems are deployed, but how engineering itself is conceptualized, organized, and institutionalized in the era of intelligent aviation.

By developing the DAT framework—Digital Airspace, Autonomous Systems, and Territorial Intelligence—this study has articulated an epistemic structure capable of capturing this transformation. DAT provides a systematic account of how engineering knowledge is reconfigured when airspace becomes a governable computational resource, when autonomy shifts from mechanical stability to algorithmic control, and when spatial cognition emerges as a core engineering substrate. Importantly, the framework clarifies why these dimensions are irreducible and mutually constitutive, and why attempts to address low-altitude challenges through existing disciplinary lenses remain analytically and operationally insufficient.

On this basis, the paper has advanced Low-Altitude Engineering as a distinct emerging engineering discipline. Its defining feature is not a specific technology or vehicle type, but a class of problems characterized by the integration of autonomy, space, and governance at scale. Recognizing this discipline enables a more coherent understanding of why talent systems, regulatory instruments, and organizational forms must evolve in tandem with engineering paradigms, rather than in isolation. Talent cultivation, in particular, appears not as an antecedent driver but as an institutionalized outcome of deeper epistemic shifts.

The long-term significance of Low-Altitude Engineering lies in its research potential. As intelligent systems increasingly operate in open, contested, and socially sensitive environments, similar paradigm shifts are likely to emerge beyond low-altitude aviation. The conceptual architecture developed here offers a foundation for comparative studies of engineering disciplines under governance-intensive conditions, for analyses of state capacity in datafied infrastructures, and for investigations into how epistemic structures shape the scalability and legitimacy of intelligent technologies.

In this sense, the contribution of the paper extends beyond the low-altitude economy as a sector. It proposes a discipline-defining framework for intelligent aviation that reframes engineering as a field in which technical design, spatial computation, and governance technologies are inseparable. By doing so, it provides a durable intellectual anchor for future scholarship and a coherent orientation for the study of low-altitude systems as a central domain of socio-technical transformation.

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