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FROM INTELLIGENT UNMANNED SYSTEMS TO THE DIGITAL ECOSYSTEM OF THE LOW-ALTITUDE ECONOMY

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Abstract

The development of onboard artificial intelligence expands the capabilities of individual unmanned aircraft; however, the large-scale provision of unmanned services requires interaction among independent organizations. Drawing on ecosystem theory and a comparison of the UTM and U-space approaches, the study examines the role of interoperable data in this transition. It substantiates the distinction between vehicle autonomy and the digital coordination of participants, as well as the importance of shared information conditions for applying AI at the level of the low-altitude economy.

Keywords: low-altitude economy, digital ecosystem, artificial intelligence, data interoperability, UTM, U-space, autonomy, coordination, digital infrastructure, data portability, accountability, Uzbekistan.

Introduction

A fleet of intelligent unmanned aircraft does not, in itself, constitute a digital ecosystem. Fulfilling an order requires information about the task, conditions for the use of airspace, available resources, and acceptance criteria. Such information is provided by customers, operators, data providers, and infrastructure service providers. If each participant uses its own object identifiers and incompatible



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formats, technical autonomy coexists with manual reconciliation at organizational boundaries. Therefore, scalability is constrained not only by the capabilities of the aircraft, but also by the cost of interorganizational coordination. The Strategy for the Development of Artificial Intelligence Technologies until 2030, approved by Resolution of the President of the Republic of Uzbekistan No. PP-358 dated 14 October 2024, provides for the development of data-processing infrastructure, competencies, and sector-specific applications of AI [6]. In the context of unmanned services, these priorities are associated with data harmonization and the organization of interaction among independent providers.

Literature Review

In the theory developed by M. Jacobides, C. Cennamo, and A. Gawer, ecosystems are associated with modularity and specific complementarities among the activities of independent organizations [1]. In the context of unmanned services, this means that the output of one specialized function can be incorporated into another. An operator conducts an inspection, an analytics service interprets the resulting materials, and the customer uses the output in its production process. Interoperability supports the division of labor without requiring all functions to be integrated within a single company.

E. Brynjolfsson, D. Rock, and C. Syverson explain the importance of complementary intangible investments in the adoption of general-purpose technologies [5]. In an unmanned-services ecosystem, this perspective makes it possible to distinguish the preparation of interoperable data, workforce capabilities, and system integrations as a separate component of AI adoption. This application of the theory represents an analytical interpretation rather than a measured estimate of sectoral effects.



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A comparison of the two approaches indicates that ecosystem resilience depends simultaneously on the complementarity of services and on the resources invested in organizing their interaction.

Research Methodology

The study uses the scholarly publications and official documents included in the source article. The methods applied include critical review, functional comparison, and comparative analysis of the principles of UTM and U-space. The analysis focuses on information functions and participant roles; the extent of implementation and market profitability are not assessed quantitatively.

Analysis and Results

The U.S. UTM ConOps 2.0 concept describes the cooperative organization of unmanned operations through distributed information exchange among operators, service providers, and the FAA [2]. Information on flight intent and airspace constraints plays a significant role. The conceptual model demonstrates how coordination can rely on interoperating services. Its content should not be interpreted as evidence of universal implementation or of the demonstrated economic efficiency of every mechanism it specifies.

The European U-space model defines the organization of services within designated airspace. EASA identifies flight authorization, geo-awareness, network identification, and traffic information among the mandatory services; the model also provides for certified service providers while retaining operator responsibility [3]. Unlike the conceptual description of UTM, U-space places substantial emphasis on the institutional formalization of roles. Accordingly, the comparison concerns coordination functions and architecture rather than a ranking of national markets.



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Table 1. Comparison of UTM and U-space

Criterion	UTM ConOps 2.0	U-space
Status of the material reviewed	FAA Concept of Operations	Description of the EASA regulatory model
Organization of interaction	Distributed information exchange through services	Certified providers in designated areas
Common function	Information-based coordination	Information-based coordination

Source: compiled by the author based on [2; 3]. A common feature of the two approaches is the provision of harmonized information to participants, while the difference lies in the status of the documents and the degree of formalization of roles.

A common feature of both approaches is that part of the relevant information is maintained outside the individual aircraft. The onboard system perceives the immediate environment, whereas shared services provide information required by multiple participants. This division reflects the distinction between local autonomy and collective coordination. More advanced computer vision does not replace information about operational constraints, and connection to a shared service does not eliminate the technical limitations of a particular UAS. The complementarity of these levels provides a basis for scalability.

The economic significance of interoperability is reflected in lower costs associated with repeated data entry, manual reconciliation, and the onboarding of new participants. The sequential fulfilment of an order requires a link among the task identifier, execution conditions, the operational record, and the accepted result. Such linkage makes it possible to determine which data relate to a specific obligation and to transfer them to the next service provider. A technical flight log that is not linked to the order and its outcome is insufficient for assessing the quality of the service as a whole.



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An interoperable operational history creates the conditions for a second area of AI application: the analysis of processes involving multiple participants. Load forecasting, detection of atypical events, and data-quality assessment belong to this level. Their value depends on the content of the records: a large volume of heterogeneous messages is not equivalent to a suitable training dataset. Differences in timestamps, units of measurement, and task-completion criteria may translate into errors in a shared model. Therefore, harmonization of data semantics precedes the benefits that can be obtained from their joint analysis.

A shared service simultaneously creates benefits and a concentration of risk. An error in, or the unavailability of, such a service affects multiple users, while dependence on a closed operational history increases the cost of switching providers. Documented interfaces, data portability, and traceability of processing versions reduce the corresponding costs. At the same time, shared use does not require open access to all information: the scope of data exchanged is determined by the specific function and the terms of interaction.

The human-centric approach to aviation AI set out in the EASA roadmap [4] emphasizes the importance of trust and justification in the use of technology. For the ecosystem considered here, this implies a distinction among prediction, recommendation, and mandatory constraint. A model may estimate expected workload; however, the status of the decision and the procedure for intervention by the accountable participant must remain clearly defined. Digital coordination does not imply transferring all responsibility to an algorithm.

Conclusions and Recommendations

Thus, the digital ecosystem of the low-altitude economy emerges through repeatable interaction among specialized participants. Onboard AI expands the capabilities for task execution, while the shared environment ensures the



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consistency of information and the use of resulting outputs. The second level of AI becomes economically meaningful when interoperable data, distributed functions, and traceable accountability are in place. For the development of such an ecosystem in Uzbekistan, this conclusion links the advancement of unmanned technologies with the quality of interorganizational interaction and the ability to integrate independent providers.

The scientific proposal is to link the task, execution conditions, the operational record, and the accepted result through harmonized identifiers. Such data organization supports the reuse of services and the traceability of quality while preserving the organizational independence of providers.

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