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Secure and Transparent Framework for Aviation Quality Data Exchange

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Abstract: The aviation industry encounters difficulties with quality and safety because of fragmented and manual data management systems. This survey examines issues related to aviation data sharing within the aviation ecosystem. Data silos, transparency gaps, and security risks are discussed, along with issues concerning traceability. Blockchain and Distributed Ledger Technology (DLT) are reviewed as possible solutions. The review considers how these technologies enable secure, transparent, and permanent data exchange within the aviation ecosystem. Benefits include simpler regulatory compliance, improved supply chain traceability, and better trust among stakeholders. The paper also points out challenges like regulatory acceptance, interoperability, and scalability. Future research directions for a robust aviation quality data-sharing platform are outlined.

Keywords: Aviation safety, supply chain, traceability, data sharing, cybersecurity, Blockchain, DLT

INTRODUCTION

The global aviation industry is built on a strong commitment to the values of safety and quality.This commitment is underpinned by a complex network of stakeholders, including airlines, Maintenance, Repair, and Overhaul (MRO) providers, Original Equipment Manufacturers (OEMs), and regulatory bodies.The effective and timely exchange of quality data—such as maintenance logs, part certification documents, and operational reports—is paramount to ensuring airworthiness and operational efficiency.However, the existing data management infrastructure, often characterized by fragmented, siloed systems and a reliance on manual, paper-based processes, is ill-equipped to meet the demands of modern aviation.

There are several major problems in the current system. Data silos make it hard for different organizations to share information [11], [8]. For instance, an airline might keep its own records, but these are not always easy or safe for an MRO or OEM to access when needed. This separation causes delays, inefficiencies, and can even create safety risks. Another issue is the lack of a clear, unchangeable record, which makes it hard to confirm where aviation parts come from or if maintenance records are genuine [12],[14].Counterfeit parts or fake records can seriously threaten safety[9],[10].Centralized databases can also fail or be tampered with, which reduces trust among everyone involved[5],[6].

Modern aircraft generate huge amounts of data, from engine sensors to flight performance details, which calls for stronger and more flexible solutions[17]. The industry needs a platform that can manage this data securely and in real time, while keeping it accurate and private. Standards like AIDX and GADM have helped by standardizing formats and sharing some types of data, but they do not fully solve the need for a decentralized and trustworthy way to exchange sensitive, high-value information, especially for tracking parts and maintenance records[10],[9].

This paper reviews the development of secure and transparent platforms for sharing aviation quality data. It looks at research from academic journals and industry reports to give a clear overview of the main challenges and new technology solutions. The main focus is on blockchain and other distributed ledger technologies, which are being used more because they are decentralized, unchangeable, and secure[3],[6],[13]. The review examines how these technologies can create reliable, tamper- proof records for an aircraft's entire life, from manufacturing to disposal[9],[12].By studying prototypes, research, and case studies, the paper brings together current knowledge, highlights the benefits of blockchain, and points out the technical and organizational challenges that remain[16],[6].These findings aim to help researchers and industry professionals improve the digitalization and security of aviation data management.

Supply chain quality management

Effective supply chain quality management is important to the reliability of aviation data, since suppliers, MROs, and OEMs each generate and hold records that must remain trustworthy across the entire chain[15].Sound quality management includes choosing reliable suppliers, overseeing production, managing logistics, and ensuring consistent delivery. Key practices include supplier audits, standard processes, inventory control, and monitoring data to spot issues early and promote ongoing improvement.Strong quality management builds trust with partners and customers, lowers costs, minimizes waste, and strengthens operations[15].Poor quality can lead to recalls, damage to reputation,and loss of customers.Major challenges include limited visibility, managing global networks, and responding to changing customer demands — challenges that mirror the data-sharing problems this survey addresses, and that a shared, tamper-proof ledger could help resolve[14].

LITERATURE SURVEY

The aviation industry is a complex ecosystem where data integrity, security, and traceability are paramount for safety and operational efficiency.Traditional data management systems, characterized by siloed databases and manual processes, are proving inadequate to meet the demands of modern aviation. This has led to significant research into novel platforms, with a strong focus on blockchain and distributed ledger technology (DLT), to create a secure, transparent, and immutable record of aviation data[3],[6],[16],[13].This survey analyzes recent research to compare different approaches and highlight key findings. Table 1 presents a comparative analysis of the key studies reviewed, summarizing their methodologies, contributions, and limitations.

Challenges in Aviation Data Sharing

- **Data Silos**: Information is often confined to individual organizations (e.g., airlines, MROs, OEMs), resulting in fragmentation and a lack of a single source of truth.
- **Lack of Transparency and Trust**: It is challenging to verify the authenticity of parts and maintenance records, which creates opportunities for counterfeit goods and fraud.
- **Security Vulnerabilities**: Centralized databases are susceptible to cyberattacks, single points of failure, and unauthorized data manipulation.
- **Traceability Issues:** The manual, paper-based tracking of aircraft parts and components makes it difficult and time-consuming to trace their full lifecycle.

Table 1: Comparative Analysis

Paper	Methodology	Contribution	Limitations / Challenges
Cao & Duan (2023) [11]	Proposes a permissioned blockchain using Hyperledger Fabric to manage supplier manufacturing quality data.	Enables secure data sharing among suppliers, improving transparency, traceability, and reducing data silos.	Limited to supplier processes; scalability for the entire aviation ecosystem may be challenging.
J. Li et al. (2025) [8]	Designs a multi-layer secure framework for aviation big data sharing, leveraging blockchain with encryption and access control.	Addresses diverse aviation data and security needs; enables trusted and secure data sharing.	Complex architecture; interoperability and computational overhead may limit real-time implementation.
A. W. S. Ho et al. (2024) [10]	Uses blockchain to manage aircraft spare parts inventory and track history through an immutable ledger.	Enhances traceability, prevents counterfeit parts, and streamlines inventory management.	Focused only on spare parts; does not cover broader quality data such as maintenance records or operational data.
M. O. I. Saliu et al. (2023) [9]	Explores blockchain for secure, tamper-proof digital aircraft maintenance records.	Creates a unified source of truth for maintenance logs, simplifies audits, and builds trust among airlines, MROs, and regulators.	Integration with legacy MRO systems and full adoption by maintenance staff is challenging.
A. D. Ivanov (2024) [16]	Broad review of blockchain in aerospace supply chain, including smart contracts, traceability, and data integrity.	Highlights blockchain benefits for reducing fraud, improving efficiency, and strengthening stakeholder relationships.	Review only; no new technical solution proposed.

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Paper	Methodology	Contribution	Limitations / Challenges
Y. Sun et al. (2025) [17]	Integrates blockchain with IoT sensors to collect, transmit, and store aircraft component data using hybrid on-chain/off-chain storage.	Ensures secure IoT data for predictive maintenance while addressing low-power IoT device constraints.	Hybrid storage adds complexity; scalability for massive IoT data is a challenge.

PROPOSAL SYSTEM

Data Sharing for The Proposal Platform

A blockchain-based aviation supplier process quality data-sharing platform is built on the core principles of blockchain and the integration of enterprise and supplier product management systems, as illustrated in Figure 1. The platform is organized into five sections: the supplier manufacturing data collection layer, the data collection layer, the storage layer, the blockchain data layer, the blockchain business layer, and the application layer. Based on aviation production management, transform, optimize, and extend to satisfy the engineering demands of aviation supplier data-gathering activities.

Data Acquisition Layer

Continuous data collection is crucial for traceability in aviation manufacturing. This can happen through manual sampling, where inspectors use tools like calipers and micrometers to take measurements, or through automatic inspection, where machine sensors capture data in real time. RFID technology helps read and manage process data on-site [1].

Data Structure Layer

To manage large-scale, diverse, and varying process quality data, we developed a structured procedure. We classify product quality factors into six categories: human, equipment, raw materials, process, environment, and testing [2]. The aviation company tracks these factors to effectively oversee supplier process quality. The six-element approach further splits quality characteristics into static and dynamic data. Static data includes predefined specifications such as manufacturing tasks, process requirements, geometric tolerances, and control techniques. Dynamic data, which comes from static data, shows real-time product quality and process status, including evaluation and analysis information.We organize this data hierarchically and store it in a database. Supplier process data and shared information are managed using smart contracts to ensure efficient blockchain integration [2].

Block Data Layer

The blockchain for aviation data sharing uses a classic block structure that includes a block header and a block body [3]. The block header contains the previous block hash, a timestamp, the Merkle root, SM2 encryption, and a random number. The block body has a Merkle tree of shared data. The real data is stored locally by the owner. Each supplier's participation is recorded as a transaction with its ID, a data summary, type, and size. The combination of the Hash algorithm and Merkle tree ensures data integrity and prevents tampering, while the hierarchical Merkle structure allows for traceability. Timestamps in each block provide authentication and improve data credibility [3].

Blockchain Layer

The blockchain framework consists of three main layers: network, consensus, and contract. The network layer uses P2P technology to securely transmit data, which improves fault tolerance when compared to centralized networks [4], [5]. The consensus layer makes sure that data is consistent and valid among supplier nodes. It prevents data distortion or fraud through methods such as PoW, PoS, DPoS, and PBFT [6], [7].

Application Layer

The functions of this layer are for the convenience of aviation companies to visually display and analyze the process quality data of suppliers through the platform, and support the acquisition of corresponding test reports on demand**.**

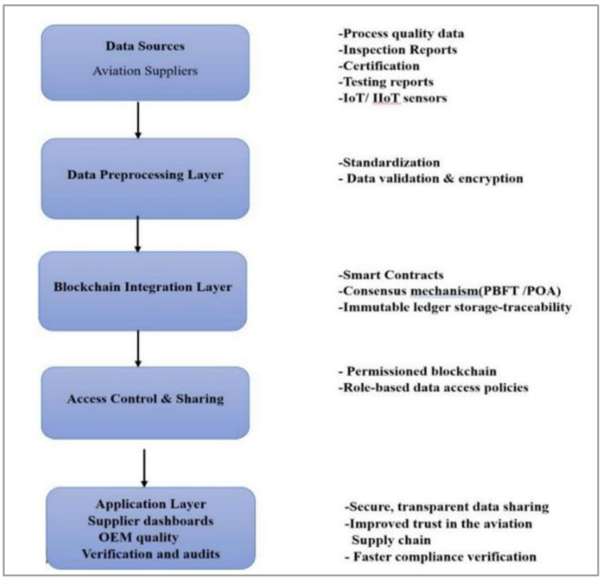

Fig. 1. Blockchain-based intelligent sharing platform of process quality data for aviation suppliers.

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CONCLUSION AND FUTURE WORK

The aviation industry stands at a critical juncture, with an urgent need to modernize its data management infrastructure to uphold and enhance its stringent safety and quality standards. This survey has explored the significant challenges posed by fragmented data silos, a lack of transparency, and security vulnerabilities within the current system. These issues not only create operational inefficiencies and elevate costs but, more critically, introduce risks to the integrity of the aviation supply chain and overall airworthiness. The surveyed literature provides compelling evidence that blockchain technology offers a robust and transformative solution to these persistent problems.

Recent research shows a shift from theory to practical, implementation-focused frameworks. Permissioned blockchain networks in aviation provide a secure, immutable, and transparent platform for stakeholders, including suppliers, MROs, airlines, and regulators. Blockchain provides real-time access to critical data, including part certifications, maintenance logs, and operational records. These advances enable faster data verification, reduce administrative overhead, enhance traceability, curb counterfeit risks, and streamline regulatory compliance through an auditable digital record.

Although blockchain offers many benefits, there are still challenges to overcome. Integrating new platforms with existing IT systems and ensuring they can handle large amounts of data are major concerns. Additionally, the reliable and tamper-proof audit trail provided by blockchain enhances safety and quality. The industry also needs updated regulations for digital records. However, current research and pilot projects show strong support for these changes. Transitioning to blockchain-based data management is a crucial step toward a safer and more efficient future for air travel.

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