POLITECNICO
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Executive Summary of the Thesis

# From Paper to Blockchain: A Proof of Concept for Storing Aviation Mainentance Documents

Laurea Magistrale in Aeronaurical Engineering - Ingegneria Aeronautica

**Author:** Nader Mohamed

**Advisor:** Prof. Francesco Bruschi

**Academic year:** 2021-2022

## 1. Abstract

**The purpose of this paper is to explore the use of blockchain technology as a solution for the storage of aviation maintenance documents. Currently, the aviation industry relies on centralized systems that are susceptible to data breaches, errors, obsolescence (documents that become unavailable) and inefficiencies. We examine whether, by leveraging blockchain technology, the industry can achieve greater security, availability, transparency, and accountability in the management of maintenance records. This paper experiments with a reference solution using Hyperledger Fabric, a permissioned blockchain platform. While on the one hand this platform allows you to natively address the issue of data access control and privacy, the lack of decentralization implies a compromise in interoperability and guarantees of future availability. More decentralized solutions are therefore considered, and the problem of data access control is addressed in perspective. The proposed analysis outlines how aviation maintenance companies, airlines, and regulatory bodies (EASA & FAA) can benefit from using a blockchain-based system for the management of maintenance documents.**

## 2. Introduction

The aviation industry is one of the most heavily regulated industries in the world, with strict standards and procedures in place to ensure the safety of passengers, crew, and equipment. A critical component of this is the maintenance and repair of aircrafts, which requires accurate and timely recording of maintenance records and documents. These records contain information about the maintenance history, performance, and compliance of the aircraft and play a crucial role in ensuring their safe and efficient operation.

However, traditional methods of storing these records, such as paper-based systems or centralized electronic databases, are susceptible to a range of limitations, including availability issues, data breaches, and the risk of data loss due to human error or malicious intent. [15] With the increasing demand for secure and reliable storage of aviation maintenance records, the application of blockchain technology in this area has become an interesting possibility.

In this paper, we explore the potential advantages of decentralized systems for secure storage of aviation maintenance records. We practice with a reference implementation using Hyperledger Fabric, a widely adopted open-source distributed ledger platform. We will discuss the advantages and challenges of using a distributed ledger in this context and provide an overview of the proposed solution. We will then highlight the trade offs with respect with more decentralized solutions. The paper will conclude with a discussion of the future direction of the application of blockchain technology in aviation maintenance document storage and the potential impact it could have on the industry.

## 3. State of the Art

A blockchain is a decentralized and distributed digital ledger that records transactions, proposed by the users and ordered by a set of validators, following a consensus protocol. The set of validators can be closed and determined from the start of operations in *permissioned* networks, or it can be open to anyone who wants to participate in *permissionless* networks. Transactions can be considered as proposals for updating the state of an overall processing system. A blockchain can therefore be seen as a processor in which the computation takes place in a directly observable way by a set of subjects, and in which part of the control of code execution is distributed over the validators. This implies that, compared to "classical" processing systems, there is no subject that can arbitrarily control the contents of the memory, altering the running code or the state, with clear implications on the credibility and reliability of the process. [1] In the aviation industry, the safe storage of maintenance records is a critical concern. Currently, several non-blockchain solutions are being used to address this challenge, including paper-based systems and centralized electronic databases. However, these solutions are often plagued by several limitations, including accessibility issues, data breaches, and the risk of data loss due to human error or malicious intent. [18] As we shall see, the decentralized nature of blockchain technology ensures that the recorded data is accessible to all parties involved, providing greater transparency and accountability. This ensures that all parties involved in the maintenance process have access to the most up-to-date and accurate information, allowing them to make informed decisions and take timely action when necessary. Furthermore, blockchain technology offers improved **scalability** and **cost-effectiveness** compared to traditional centralized electronic databases. The decentralized nature of blockchain technology eliminates the need for a centralized database administrator, reducing the operational costs associated with maintaining a centralized database.
The use of blockchain technology in record storage offers several key benefits over traditional non-blockchain solutions. The decentralized and distributed nature of blockchain technology provides a secure and transparent solution for record storage that is resistant to data breaches, hacking, and data loss. The decentralized nature of blockchain technology also ensures that all parties involved in the maintenance process have access to the most up-to-date and accurate information, providing greater transparency and accountability. The improved scalability and cost-effectiveness of blockchain technology make it a promising solution for secure record storage in the aviation industry.

Let's imagine a typical scenario in the aviation industry, with the following stakeholders: the aircraft manufacturer, the airline, and the maintenance provider.
The typical process for managing aviation maintenance documents involved a lot of paper-based documentation. For instance, when the manufacturer produced an aircraft, they would provide a paper manual detailing all the maintenance requirements, which would be provided to the airline. The airline would then assign a maintenance provider to carry out the necessary work on the aircraft, and the maintenance provider would keep a paper record of all the maintenance activities that were performed on the aircraft.

This paper-based process often led to several problems and errors, which could result in safety issues and financial losses. For instance, paper-based records were easily lost or misplaced, which could lead to maintenance being

carried out incorrectly or not at all. This, in turn, could lead to safety issues and potential accidents, as well as financial losses due to grounded aircraft and delayed flights.

In addition, the paper-based process was often time-consuming and inefficient. There was a significant delay between the time maintenance was carried out and the time the records were updated. This delay could result in maintenance being performed twice or not at all, which could also lead to safety issues and financial losses.
Digitization can obviously lower the costs of the process, but some structural problems, related to the priorities of the various stakeholders, remain. For example, it is critical that the original document remains available to both the airline and the maintenance provider. Moreover, updates to the manual by the manufacturer should be promptly communicated. But to whom? If the manufacturer has a relationship only with the the airline that bought the aircraft, the latter should in turn forward the update to the maintenance company. This double-step is expensive and error-prone. Alternatively, the company could provide the maintainer with a reference to the document, provided by the manufacturer. Subsequent updates to the document would then be automatically notified to the maintainer. In this case, the availability of the documents would be in the producer's responsibility. However, note in this case a possible misalignment of the objectives: while the company has every interest in keeping the manuals available for as long as it will use that particular aircraft model, for the manufacturer this could become less of a priority as time goes on.

Some features of blockchain-based systems can help to face these issues. Stakeholders can agree in advance on a system for publishing a document, which allows for the creation of a single and stable reference (resource locator) over time. The document can be initially published by the maintainer, generating a symbolic reference, which is translated into a reference to the actual document by a smart contract. The document can be stored on a distributed system, where anyone can contribute to the availability. An example of a system of this type is the InterPlanetary File System (IPFS)[**?** ], in which anyone can decide "to pin it", i.e. to replicate a file and make it available to other users. Importantly, the availability of the document is the disjunction (the or) of the availability of all the document "suppliers". Therefore, even a single supplier, which can also change over time, is enough to guarantee the availability of the document. The document can be updated over time, for example by the maintainer, by updating the translation between the resource locator and the actual document. The conditions under which an update can be performed can be represented in a smart contract (e.g.: who can do the update? Is an approved revision required?)

These considerations show how blockchain technology can contribute to streamline document processing and make it more efficient. By using a shared register, all stakeholders can have access to the same up-to-date records in real-time, which reduces the risk of errors and improves safety. The immutable nature of blockchain technology also ensures that records cannot be tampered with or deleted, which further enhances safety and reduces the risk of financial losses.

The real-time nature of the blockchain also reduces the time it takes to update and access maintenance records, which can improve operational efficiency and reduce costs.

## 4. Proof of Concept

The aviation industry requires a secure, transparent, and accessible solution for the storage of maintenance records. To address this challenge, we propose the implementation of a Hyperledger Fabric-based blockchain solution. [6] Hyperledger Fabric is an open-source blockchain platform that provides a modular architecture for building and deploying permissioned blockchain applications. Its extensive documentation, language agnosticism, and other benefits make it a suitable platform for developing the Proof-of-Concept. [11] [12]

The proposed blockchain solution will consist of a consortium of authorized participants, including aviation maintenance companies,

airlines, and regulatory bodies such as EASA [7] or FAA. These participants will have the ability to validate transactions, view the ledger, and update the ledger with the most up-to-date maintenance records. [10]

The maintenance records will be stored in the form of smart contracts on the blockchain. A smart contract is a self-executing contract with the terms of the agreement between buyer and seller being directly written into lines of code. The smart contracts will contain all relevant information related to the maintenance of aircraft, including: the type of maintenance performed, the date of maintenance, and the components involved. This information will be accessible to all consortium members in real-time, providing greater transparency and accountability in the maintenance process.

In the proposed solution, the **validators** would be all the stakeholders involved in the maintenance process. This includes airlines, EASA (European Union Aviation Safety Agency), and maintenance companies. Each of these stakeholders would have a node in the network that acts as a **peer**, allowing them to access and update the maintenance documents as needed. The **orderers**, on the other hand, would be a consortium of these stakeholders responsible for maintaining the integrity of the network and ensuring that all transactions are properly recorded and validated. By using a consortium of stakeholders as orderers, the network can maintain a high level of trust and transparency while also ensuring that all stakeholders have a say in how the network operates.

## 5. Experiments and Deployment

To demonstrate the feasibility of using Hyperledger Fabric to store aviation maintenance documents, a proof-of-concept (PoC) was developed using the Hyperledger Fabric framework and the Java SDK. The PoC was designed to show the interaction between different stakeholders, including aircraft maintenance companies, airlines, and regulatory bodies, in a simulated environment.
One key aspect of the system was to allow each stakeholder to have their own unique user identity on the network. This was achieved by using Hyperledger Fabric's certificate authority (CA) to issue digital certificates to each stakeholder, which were then used for authentication when accessing the network.
To demonstrate the interaction between the stakeholders, we wrote code snippets to show how each stakeholder can perform specific actions on the network.

Let's imagine a typical use scenario where an **aircraft maintenance company** uploads its maintenance information to the network, by interacting with an User Interface the invoked smart contract would generally be:

```
// Submit the document to the network
channel.sendTransaction(tx -> {
    Contract.SubmitMaintenanceDocument
    contract = new
    Contract.SubmitMaintenanceDocument();
    contract.setDocumentName(documentName);
    contract.setDocumentType(documentType);
    contract.setAircraftId(aircraftId);
    contract.setMaintenanceDate(maintenanceDate);

    tx.submit(contract);
});
```

This document will need to be reviewed by the **regulatory body** simply by invoking its smart contract:

```
// Review document and set approval status
channel.sendTransaction(tx -> {
 Contract.ReviewMaintenanceDocument
  contract = new
 Contract.ReviewMaintenanceDocument();
 contract.setDocumentId(documentId);
 contract.setApprovalStatus(approvalStatus);
 contract.setReviewNotes(reviewNotes);

    tx.submit(contract);
});
```

**Airlines** can also access these documents to view the history of maintenance performed on their aircraft.

```
// Retrieve the history for an aircraft
channel.queryByChaincode(
new Contract.GetMaintenanceHistory(),
aircraftId)
```

```
.thenAccept(history -> {
// Access the history for the aircraft
    System.out.println("Maintenance History "
    + aircraftId + ": " + history);
    });
```

These are just a few examples of how different stakeholders can interact with the network and access the data stored in the ledger state. In a real-world scenario, these functions would likely be more complex and include additional validation and security checks.

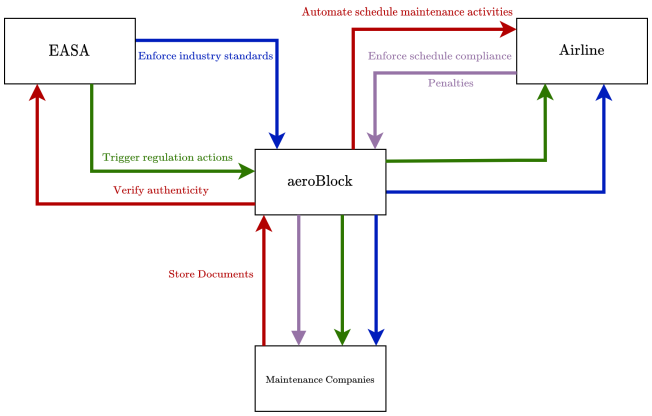


Figure 1: Stakeholders interacting with the chain

## 6. Conclusions

The aim of this paper was demonstrate the potential of using blockchain technology, specifically Hyperledger Fabric, to securely store and manage aviation maintenance documents. The solution proposed in this paper is valid and has shown positive outcomes in terms of data integrity, reliability and secure access to authorized stakeholders.

By using a permissioned blockchain, this solution ensures that only authorized entities such as aircraft maintenance companies, airlines and regulatory bodies can access and modify the data stored in the network. This solution provides a centralized repository for all maintenance documentation, reducing the risk of data loss or manipulation and providing a tamper-proof record of all maintenance activities.

This solution offers the potential for further development and integration with public blockchains in the future. By exploiting layer 2 solutions, it is possible to increase the efficiency and scalability of the network while ensuring the security of the data sent by the aircraft to the blockchain.
Using the proposed technology has the potential to revolutionize the way aviation maintenance documents are managed, providing a secure and efficient means of recording, storing and accessing this critical information. This has the potential to significantly improve the safety and efficiency of the aviation industry, as well as ensuring regulatory compliance.

## References


[1] Supply Chain permissioned vs permissionless, August 2019.

[2] Secure Aircraft Maintenance Recor aft Maintenance Records Using Block ds Using Blockchain (SAMR), October 2020.

[3] 2014-ADSB-SITF13, December 2022.

[4] Acceptable Means of Compliance (AMC) and Guidance Material (GM) | EASA, November 2022.

[5] eCFR :: 14 CFR 91.225 – Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment and use., December 2022.

[6] Hyperledger – Open Source Blockchain Technologies, December 2022.

[7] International Maintenance Review Board Policy Board (IMRBPB) | EASA, October 2022.

[8] It's Time to Take Another Look at Blockchain, December 2022.

[9] Repair Station Operators (Part 145) | Federal Aviation Administration, November 2022.

[10] The Use of Blockchain in Aviation | GTG Advocates, November 2022.

[11] Vicky Achmad. Implementation of computerized maintenance management systems for aircrafts, June 2013, October 2022.

[12] P. Ayeni. *Enhancing competitive advantage through successful lean realisation within*

*the Aviation Maintenance Repair and Overhaul (MRO) industry*. PhD thesis, Cranfield University, October 2015.

[13] D. P. Hanley. Aircraft operating leasing: a legal and practical analysis in the context of public and private international air law, November 2011.

[14] C. W. Johnson. Preparing for cyber-attacks on Air Traffic Management infrastructures: Cyber-safety scenario generation. *ResearchGate*, pages 1–6, January 2012.

[15] Khairy A. H. Kobbacy and D. N. Prabhakar Murthy. *Complex System Maintenance Handbook*. Springer, New York, NY, USA, 2008.

[16] Kari T. Koskinen, Seppo Virtanen, Helena Kortelainen, and Joseph Matthew. Foreword: Proceedings of the 10th World Congress on Engineering Asset Management. In *Proceedings of the 10th World Congress on Engineering Asset Management (WCEAM 2015)*, pages v–x. Springer, Berlin, Germany, 2016.

[17] Moreno Marzolla, Stefano Ferretti, and Gabriele D'Angelo. Dynamic resource provisioning for cloud-based gaming infrastructures. *Comput. Entertain.*, 10(1):1–20, December 2012.

[18] P. Phillips, D. Diston, A. Starr, J. Payne, and S. Pandya. A review on the optimisation of aircraft maintenance with application to landing gears. In *Engineering Asset Lifecycle Management - Proceedings of the 4th World Congress on Engineering Asset Management, WCEAM 2009|Eng. Asset Lifecycle Manage. - Proc. World Congr. Eng. Asset Manage., WCEAM*, pages 68–76. 2009.