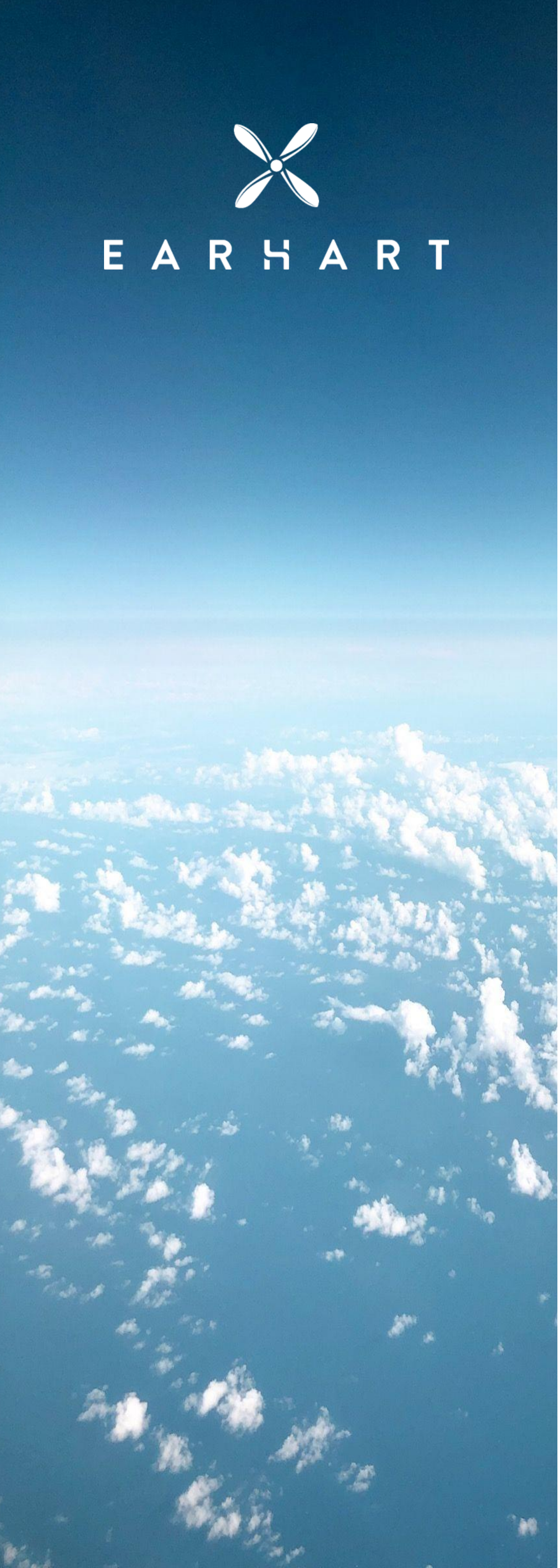
EARHART

THE FUTURE OF AVIATION
HAS ARRIVED

WHITE PAPER V2.0



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ABSTRACT

Earhart is a blockchain powered solution that transforms how the trustworthiness and traceability of aeronautical records is stored and used. A Proof of Airworthiness concept is developed to materialize the fulfilment of all regulation. Earhart also implements an innovative concept of on-chain transactions that allows instant data sharing, monetization, and acquisition.

DISCLAIMER

- This whitepaper describes an ongoing project.
- This whitepaper is not a financial advice.
- This whitepaper describes a validated but not yet regulated process.
- This whitepaper describes the Earhart team goals and not the aviation regulators and/or authority's objectives or future policies.

OVERVIEW

Civil aeronautical industry is one of the most regulated sectors worldwide. Every single aspect of the aircraft and who performs actions on it is regulated. The accomplishment of these regulation relies in a very strict register of individuals, aircraft and companies logs and records.

When every point of the regulations is fulfilled it is said that the aircraft is airworthy. When some point of the regulations is not accomplished it is said that the aircraft is not airworthy, grounded or most common said AOG. When this happens, or the requirement is fulfilled, or a special authorization given by the authority is granted to permit flight. The continuing monitoring of the airworthiness of every aircraft is very hard and time consuming, and frequently involves a lot of resources, mainly human, which leads to one new field of study of Human Factors or Managing Human Errors [1]. The processes automation here proposed will unleash humans from records management and will enhance safety through record keeping and control. It will also help in the liquidity of all aeronautical players releasing resources.

One key point of the regulations is the record keeping. Nowadays, the record keeping is done in centralized ledgers without the ability to communicate with others. Aviation regulators require that record keeping is performed in order to keep the traceability and accountability of every action taken in the industry[1,2]. Since the ledgers don't communicate with each other's, this type of work is made essentially by manpower which give origins of many errors. Besides the time of reassessment of the information is much higher, these errors can put at stake the aircraft safety. The technology used for the centralized ledgers, mainly paper and non-standard software's, can give origin to data lost, wrong data, corrupted, deterioration, or even changed or adulterated. On rare occasions, falsification of licenses is a problem [7,8,9,10,12]. This data management costs to all aviation industry many millions of USD annually.

One specific example is when an aircraft changes owner or operator, a very hard, stressful, and timekeeping process is performed. A lot of resources are deployed to verify the conformity of every single aircraft record. Since aircraft owners or operators use different ways to control the airworthiness of the aircrafts, these processes are not lean to perform and usually take months. Reconstructing the aircraft history is very expensive and

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[1] EASA Requirements: M.A.305, AMC M.A.305(e), M.A.306, M.A.503, M.A.801, M.A.901, CAMO.A.220, CAMO.A.315, CAMO.A.325, 145.A.55, 21.A.55.

[2] FAA Requirements: CFR Part 11, CFR Part 26, CFR 21.2, CFR 21.137, CFR 21.142, CFR 21.2, CFR Part 25, CFR 43.2, CFR 43.9, CFR 43.11, CFR 43.17, CFR 91.417, CFR 91.419, CFR 91.421, CFR 91.1027, CFR 91.1113, CFR 91.1427, CFR 91.1439, CFR 91.1441, CFR 91.1443, CFR 145.12, CFR 91.161, CFR 91.219, CFR Part 249.

time-consuming process, and often requires huge expensive human resources, materials, and aircraft ground time. This is a multimillion-dollar worldwide industry in which considerable savings can be made through a more efficient record keeping processes and interconnecting the individual ledgers. This will highly improve the flow of information, traceability, and accountability in all aviation practises.

When all requirements are fulfilled it is said that exists a Proof of Airworthiness.

ACRONYMS

AI – Artificial Intelligence

AOG – Aircraft on Ground

APU – Auxiliary Power Unit

CAMO – Continuing Airworthiness Management Organization

CFR – Code of Federal Regulations

DOA – Design Organization Approval

EASA – European Aviation Safety Agency

GSE – Ground Support Equipment

FAA – Federal Aviation Administration

IATA – International Air Transport Association

ICAO – International Civil Aviation Organization

LH – Left Hand

MH – Man-Hours

OEM – Original Equipment Manufacturer

SKU – Stock Keeping Units

UI – User Interface

UTC – Universal Time Coordinated

DEFINITIONS

Accountability – The responsibility of every individual and/or organization. By regulations, in the aviation industry every action must have an accountable.

Airworthiness – A generic term implied to define the suitability for a safe flight. The aircraft airworthiness is related to the interaction of many individuals, organizations, OEM's, installed parts and aircraft condition. There is the initial airworthiness which is related to the aircraft design and manufacture. There are then the additional airworthiness specifications and the continuing airworthiness, which is related to the aircraft status and operation. To achieve the airworthy status, an aircraft must fulfil all the requirements given by the OEM's, CAMO's, Authorities and Regulators.

Airworthiness Instructions – An instruction given in order to the aircraft maintain its airworthy status. These instructions can be issued by Authorities, Regulators, OEM's, CAMO's, DOA or Service Centres.

Airworthiness Requirement – All the requirements that an individual, organization or aircraft must fulfil. The requirements are given by Authorities, Regulators, OEM's or CAMO's.

AOG – This term can be used in many frameworks. Here, it means that the aircraft is not able to fly due to not accomplishing at least one airworthiness requirement, or that the aircraft is not airworthy.

Authority – Is a State institution whose mission is to supervise the air industry. The scope of work of each authority is not the same in all States, it depends on the autonomy given by the regulators, which in some situations are the same entities. Their scope of work varies with the license's approvals, maintenance planning supervisions and approval, auditing, and general supervision for the regulation's accomplishment. It can also in some cases issue regulations.

Block – Is the term used to divide every main role of each organization in their scope of work.

Calendar Time – It is the projection of time into a specific unit, such as hours, days, months, etc. This time counting method is usually between installation and removal, or between a finding and its correction. It has no relation with operation time.

CAMO – An organization which is responsible for supervising the aircraft airworthiness. It can employ several dozens of persons to monitor and maintain all the data that are issued and generated by its operation. It's also under their responsibility to monitor the aircraft configuration, reliability and maintenance.

Certifications – Are all individuals, aircraft, organizations, parts, etc. must acquire to be fitted to work, fly, or be installed in an aircraft. There are many types of certifications and entities who issued them. Some are not valid from entity to other entity. Mainly, all certifications are paper issued.

CFR – The FAA code for every regulation.

Flight Cycles – Is a take-off and landing. Example, a take-off and landing is 1 (one) flight cycle. It is a used to measure life of aircraft and components.

Flight Hours – For every calendar hour that aircraft spends flying it counts 1 (one) flight hour. If the aircraft is not flying, i.e., on the ground, this counting is stopped It is a used to measure life of aircraft and components.

Man Hours – The number of working hours carried out by individuals.

OEM – Is the organization that holds the patent for any specific product or part. Some may delegate to third parties the manufacture or assembling, but they are accountable for every designed product.

Operation Time – The time that a certain equipment or part is operating. It is a measure used to acquire parts life in service.

Part number – Is an alphanumeric code which identifies a certain part in the aircraft. There cannot be two identical part numbers that correspond to two different components. The part numbers are given by the OEM's and standard organizations. In most cases the part number can reflect their configuration.

Parts – It is a generic term used to define something that is installed in the aircraft.

Regulations – Are all the rules and requirements issued by the regulators and authorities that must be accomplished to be in an airworthy condition.

Regulator – Are the organizations which create all regulations and/or the airworthiness instructions. Their role is to keep the pace of the evolution and constantly updating their requirements for a safe air travel. The scope of their instructions are individuals, aircraft, aircraft products and services, organizations, and authorities. Their instructions are then accomplished by the applicable ones which are monitored by the authorities.

Serial number – It is generally a unique sequential numerical code that traces the identity of a specific and unique part within all its universe.

Service – Is a term used to tell a type of work accomplished in an aircraft. It can be inspections, repairs, replacements, lubrications, servicing, etc. These services can be accomplished initially by the OEM or during aircraft operation by the service centres/maintenance providers. The instructions that lead to the services are usually given by the CAMOs, but can also be given by the Service Centres, Authorities, OEM's, or Regulators.

Service Centres – Are all the maintenance providers. To be an approved maintenance provided, it must be accomplished all the applicable regulations. A Service Centre can only work on its scope of work, i.e., only on the aircraft's models, parts, engines models, type of work that are certified too.

Traceability – It is the process to trace every installed part or every action taken in the aircraft or process related to an action approval and accomplishment.

Type Ratings – It is usually the specific model of an aircraft, engine, part or specific service or a combination of those. The type ratings are commonly attributed to pilots, engineers, or service centres. Only who holds a specific type rating can carry out actions on the product.

OBJECTIVES

The Earhart challenge is separated into two different and major phases. The first, and more important is to build the blockchain framework where all records and transactions will be made. The second is to develop and incentivise the development of the applications which will run on top of the chain.

The constructions of these digital ledgers with blockchain interface will allow to permanent record every key aspect of aircraft and individuals who perform actions in it. This will help to:

- Connect all aviation centralized ledgers for information/data sharing and monetization.
- Provide trusted and immutable traceability and back to birth for all aircraft and components maintenance data.
- Accelerate the industry digitalization and blockchain adoption.
- Increase the speed and efficiency of record managing and control.
- Provide instant airworthiness status.
- Improve individual, organizational and aircraft licenses and authorizations issuance and tracking.
- Improve individual training records issuance and transparency.
- Provide real time issuance and overview of airworthiness data.
- Provide trusted and immutable records traceability for individuals, companies, and aircrafts.
- Provide trusted and immutable traceability for all airworthiness data.
- Provide trusted and immutable traceability for all aircrafts and components operational and reliability data.
- Provide trust and immutable birth certificates.
- Increase the aeronautical player's liquidity by implementing the process automation and digitalization.

- Improve the turnaround time and effectiveness of aircraft hand over or redeliveries.
- Provide smart contract managing leasing and data access.
- Provide monetization of aircrafts, aircrafts and engines components, data, logs and records, maintenance, and reliability data.
- Improve auditing and compliance processes.
- Improve certification, warranty, and insurance claims response time.
- Provide real time inventory tracking.
- Improve the overhaul industry safety with the decrease of human errors.

COMPLIANCE

Earhart's solution complies with current US regulator, FAA, requirements outlined in CFR Part 11, Part 21, Part 25, Part 26, Part 43, Part 61, Part 91, Part 141, Part 145, Part 147, and Part 249.

Earhart Team has conducted several meetings with the European Regulator EASA. The current regulations are omitting the use of blockchain technology for aviation. EASA has confirmed that Blockchain complies with aviation regulations M.A.305, 145.A.55 and 21.A.55. They also confirmed that the proposed Earhart approach are reliable and consistent to the current aviation framework.

Following this and having into account the analysis made from FAA and EASA regulations, Earhart solution complies with all set of record keeping and transfer, making blockchain a valid choice for aviation records management.

INTRODUCTION

The civil aeronautical industry is highly regulated, which demand very high airworthiness standards. One key point of the airworthiness standards required by the regulators is the records of all phases related to aircraft maintenance, operation, and airworthiness control. The aeronautical records are estimated to weigh up to 50% of an aged aircraft [5], transforming this industry in a multi-million business. Is also important to refer that it is not attractive for nobody acquiring an aircraft with missing or poor records. Which often devalues the aircraft several times.

The aviation industry still relies on paper and nonstandard software records. These can be corrupted, damaged, missing data, wrong data, etc. When the logs of a certain aircraft work are missing, there's an immediate action to perform again that task. With Earhart blockchain powered solutions, all the records will be recorded forever, never lost, adulterated, or even corrupted. This solution will decrease by many factors the price of used aircrafts, since the records will be cheaper and the needs for reworks are near zero, saving large USD millions in aircrafts maintenance per year.

With the Earhart solution implemented, there is the possibility in real time to acquire all the desired airworthiness data. The daily management of aircraft fleets will be highly facilitated. The man-power to perform the aircraft airworthiness control will be highly reduced and the authorities can issue their airworthiness data and immediately perceive their impact. Audits, aircrafts modification status and professionals working time can be conducted in real time [3, 4, 6].

Earhart solution will ease aircraft re-deliveries since everything can easily be monitored, controlled, and automatized. An aircraft redelivery using this technology will reduce the ground time from months to weeks. The cost to do it will be decreased minimum 10x since no reworks or missing data need to be performed [5]. The need to tear down an entire aircraft will no longer be necessary.

Earhart's solution will help the aeronautical industry to optimize and achieve the next level of automation, computerization and digitization of aircraft airworthiness data, information and records. Adopting this solution will save the airlines industry large thousands of aircraft ground time per year. It will increase the airline's liquidity and profits directly because the aircrafts will fly more, and indirectly because since the re-works are reduced, the maintenance costs are also reduced.

This technology will enhance the capabilities and highly benefit the several players in the aeronautical industry. The main stakeholders and OEM's can benefit from services and parts. CAMO's can benefit from real time airworthiness overview; on-chain and reliable data; reliable records; real time airworthiness impact. Service Centres can have access from OEM's and CAMO data in real time, with reliable data and correct configurations; engineering working time and certifications can be recorded and monitored in real time [1,3,4,6].

Operations can benefit from controlling the cockpit and cabin crew working times and certifications as well record all the relevant airworthiness data. Authorities, when grated access, can monitor or audit in real time and as well monitor in real time the airworthiness data. Can also perceive the impact of issued airworthiness requirements in all types of fleets.

Training and certifications tracking can also benefit from Earhart solution, both can be registered and easily accessed to verify the individual and organization certifications, training, and recurrent training needs. In the end, Earhart will control who is working or operating the aircraft and detect who has not the certified training or recurrent training maintain or operate the aircraft.

The key features of Earhart are to design a specific framework process which will facilitate the interface between the centralized ledgers, blockchain and the aeronautical organizations. In the blockchain it will be recorded specific data and, in the software, the more detailed data. The access to the blockchain data will be granted individually or by smart contract. The database solutions will be centralized by the user, entity, or cloud service; or can be decentralized storage solutions.
The industry is demanding decentralized solutions, since every aeronautical management organization tends to use their own process, developed sometimes internally, given no or few changes for external entities to manage and treat the information. When a service is hired externally, the linkage between the platforms is different, arising then difficulties to treat all the huge amounts of information. This airworthiness information is then treated by many people, sometimes with different interpretations, which requires a lot of human resources. Earhart solution will automate

this process, giving full temper proof of the carried-out work, called Proof of Airworthiness which is done in real time.
The generated data can then be shared directly or through a smart contract to improve the airworthiness or reliability data of other players. To incentive users to enrich their airworthiness data, is the possibility to monetize their information by selling to other aeronautical player's relevant data.

Earhart project proposes to develop a software solution which will connect the centralized ledgers
with the blockchain. In the blockchains will be stored the information which will need to be tamper proof, immutable and required as evidence of work and Proof of Airworthiness. Earhart software solution will act like a ledger and will add the remaining information to complete all relevant data required to ensure the airworthiness of every single point for the aircraft operation. Since the amount of data per aircraft can be quite significant, and to improve the blockchains readability, only some key parameters will be recorded on the blockchain, the remaining data will be stored out of the blockchain, in specific ledgers which can be accessed through specific smart contract agreements or granted accesses protocols.

Different Blockchains can interact and have interconnected transactions, i.e. a Blockchain created for an aircraft engine history, can interact, and live along a Blockchain created for the actual aircraft where the engine will be installed. Through cross-chain capabilities, data can travel, if required, in a variety of platforms.

An integrated Blockchain platform, based on common regulated principles, can be used to register, and assert the historic data of aircrafts, aircraft components, aircraft parts, airport activities, aircraft flight personnel activity, aircraft maintenance personnel activity and others (Bonomo et al., 2018; Mandolla et al., 2019; Liu et al., 2020).

HIGH LEVEL FUNCTIONS

Following it is represented and explained the function of the proposed model. To be simpler, it will be divided in several blocks of explanation, every single block represents a part of the process or an aeronautical player. For last, all the process will be explained, with the interaction between all the participants. When everything is accomplished and verified, it will be achieving the status of Proof of Airworthiness.

It is convenient to introduce the definition of all the proposed processes. In the base are the proposed blocks illustrated in figure 1.

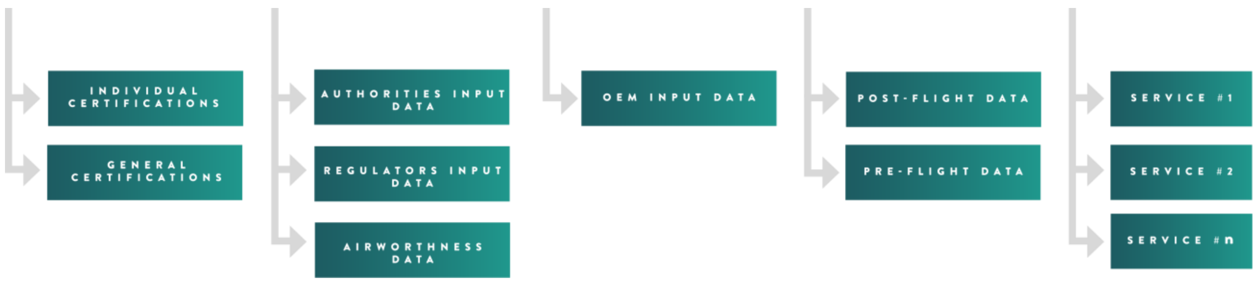

Figure 1 – Blocks.

Each player and respective block have his own functions and responsibilities, but all are interconnected and dependent from each other. The proposed blocks are:

- Individual Certifications.
- General Certifications.
- Authorities Input Data.
- Regulators Input Data.
- Airworthiness Data.
- Pre-Flight Data.
- OEM Input Data.
- Post Flight Data.
- Services Data.

After the blocks is the approval routines.

Figure 2 – Approval Routines.

The purpose of the approval routines is the act of approving some request, document, service, etc. The approval routines can be delegated to other players, for example a pilot license issued by a school and approved by the authority. It can be internal approval procedures such as approval of an airworthiness instruction by the authority, or even by AI or pre-programmed conditions.

Following is the gateway. The gateway verifies and transforms the content from a UI or ledger to the requirements of the blockchain and vice-versa.

Figure 3 – Gateway.

After the gateway comes the blockchains. Here is where it is stored, or time stamped all the data that needs to be immutable. It can be used several types of blockchain, depending on the content or purpose of the data. It can create a mechanism where several blockchains interact by exchanging data.

Figure 4 – Blockchains.

Following the process, it is found the databases, aka ledgers. The access to interchanging data between the ledgers can be given by authentication or by smart contracts. Ledgers can be centralized or decentralized.

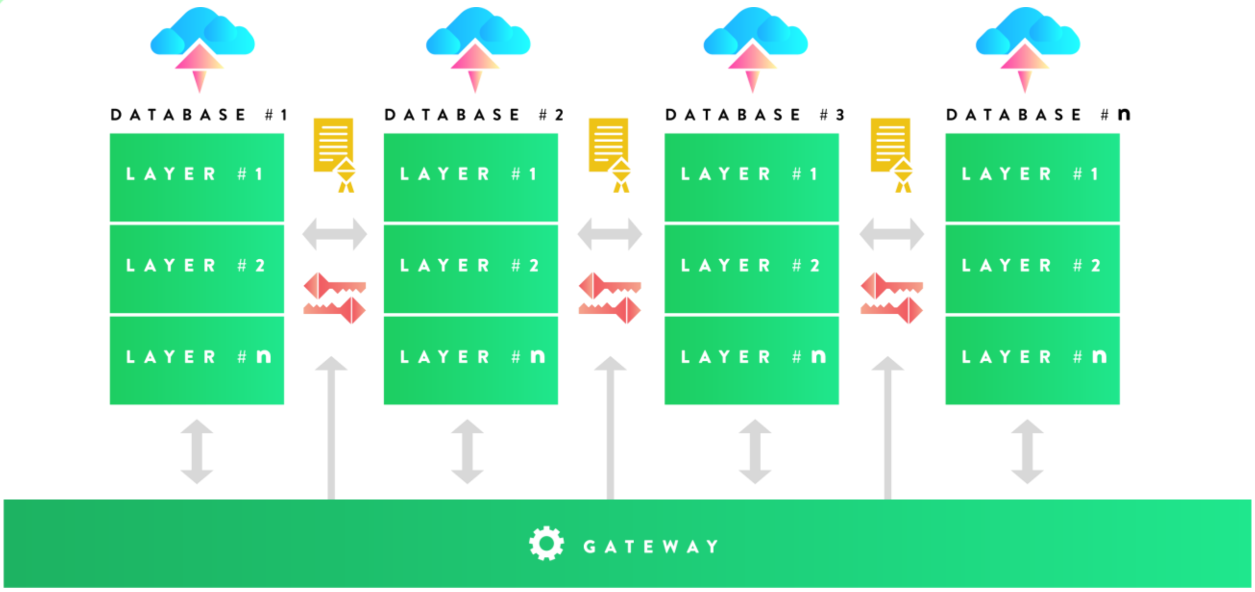

Figure 5 – Databases/ledgers.

On the top of the process is the hyper view, which is where users will browse, check, and verify all the data. The access can be granted by block, by a specific component, a specific instruction, a specific data or by specific aircraft or an entire fleet. This access can be granted by authentication or by smart contract.

Figure 6 – HyperView.

BLOCKS

Following is mentioned the workflow of the several blocks. Is given in detail the role and the competences of each working block.

CERTIFICATIONS BLOCK

In Figure 7 it is represented by the individual and general certifications. In this module, the training, certifications, and type rating of all individuals will be recorded. It is also recorded the certifications of aircrafts and organizations. The components certifications are not part of this module.

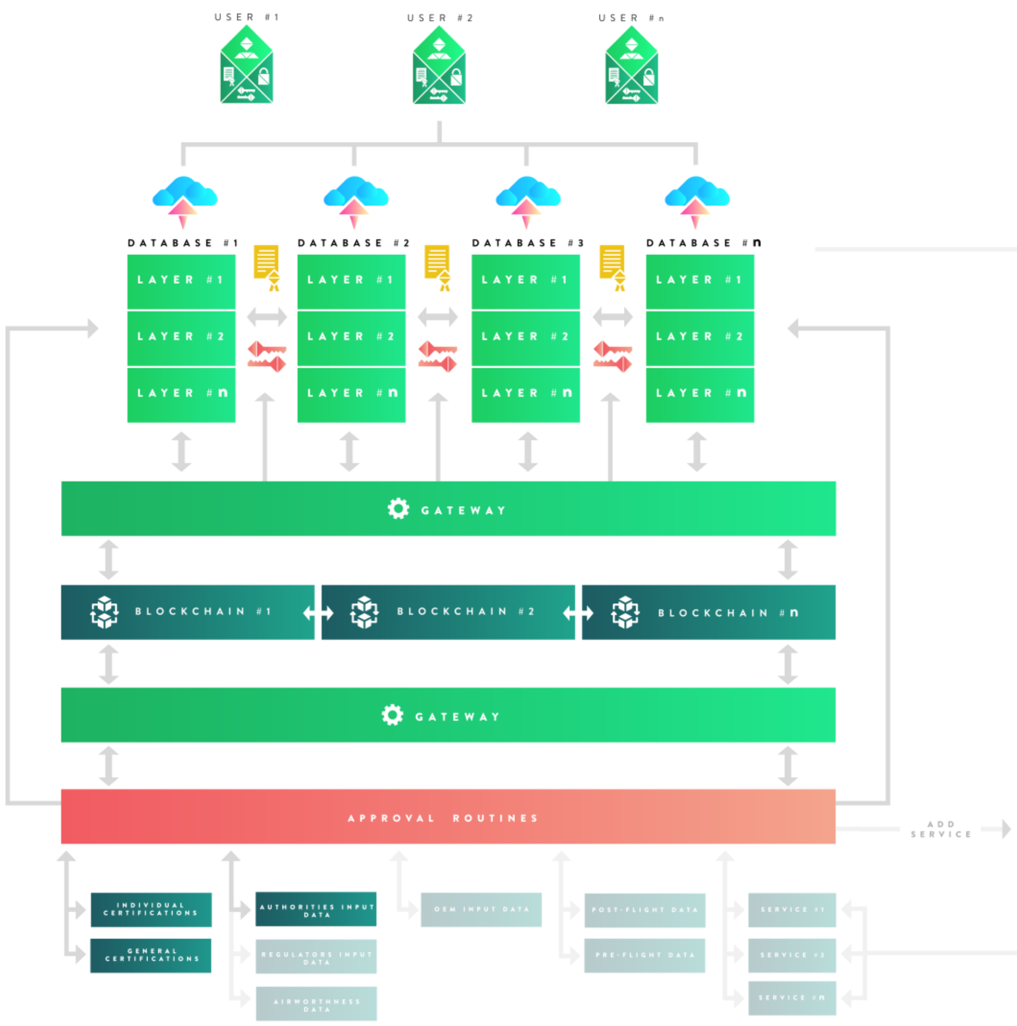

Figure 7 – Training and Certifications Process.

For individual certifications it can be recorded, for example, pilots, maintenance technicians, engineers, cabin crew, etc. Can be recorded as the pilot license and specific aircraft type rating, the aircraft maintenance license per issued authority; medical, technical, and physiological qualifications; the recurrent required training.

For aircrafts and organizations, it can record which part is an organization compliant; in aircraft can record the noise certification, airworthiness certification, insurance, etc. At the end, this module will act like a digital ID for aircrafts, individuals and organizations that interacts with the aircraft.

Example 1:

An individual finishes the pilot license training, the pilot school and/or authority can issue the request for the license. After it goes to approval routines, which is made by the authority or AI in the Authorities block. If the submission accomplishes all the requirements such as flight hours, class modules, exams approval, physical, medical, and psychological fitness, etc. given in the Regulators block, the approval is granted. Then individual data is recorded on the blockchain whose interface is made by a gateway that verifies if all the blockchain requirements are fulfilled. In the blockchain is then recorded the name, license number, type rating, timestamp, operational data (flight hours and flight cycles). In the database/ledger it will record more operational data, such as which flight a pilot has made, its dates, flight duration, etc. If a pilot goes into refresh or simulated training, he follows the same path, i.e., approval routines and blockchain record. The access to the information is only possible through identification or smart contract. Relevant to mention that also ledgers can interact with cloud services.

Example 2:

An aircraft to be allowed to operate requires several certifications, one of those certifications is the noise certification[3,4,5]. The aircraft operator will present to the authority all the requirements for noise evaluation. The authority by individuals or any automation analyses and grant the approval in the Authorities block. This approval is going to the gateway which verifies if all the data and blockchain constraints are fulfilled, if yes then the certification is issued directly on the blockchain. Consulting information or records,

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[3] EASA Requirements: 21.A.165, 21.A.201, 21.A.203, 21.A.204, 21.A.207, 21.A.209, 21.A.210, 21.A.211, M.A.901, CS-25.
[4] ICAO Requirements: Annex 16.
[5] FAA Requirements: CFR Part 21, CFR Part 25, CFR Part 33, CFR Part 36.

only through identification or smart contract. Relevant to mention that also ledgers can interact with cloud services.

AUTHORITIES BLOCK

Authorities play a crucial role in the aeronautical process and overall safety. Through the authority's block is possible to make all the approvals regarding their scope of work. It is possible also to issue airworthiness documentation and immediately see their impact. It can also issue airworthiness instructions that can be implemented in real time, if applicable, minimizing the CAMO analysis and manpower and also improving assertiveness of the instructions.

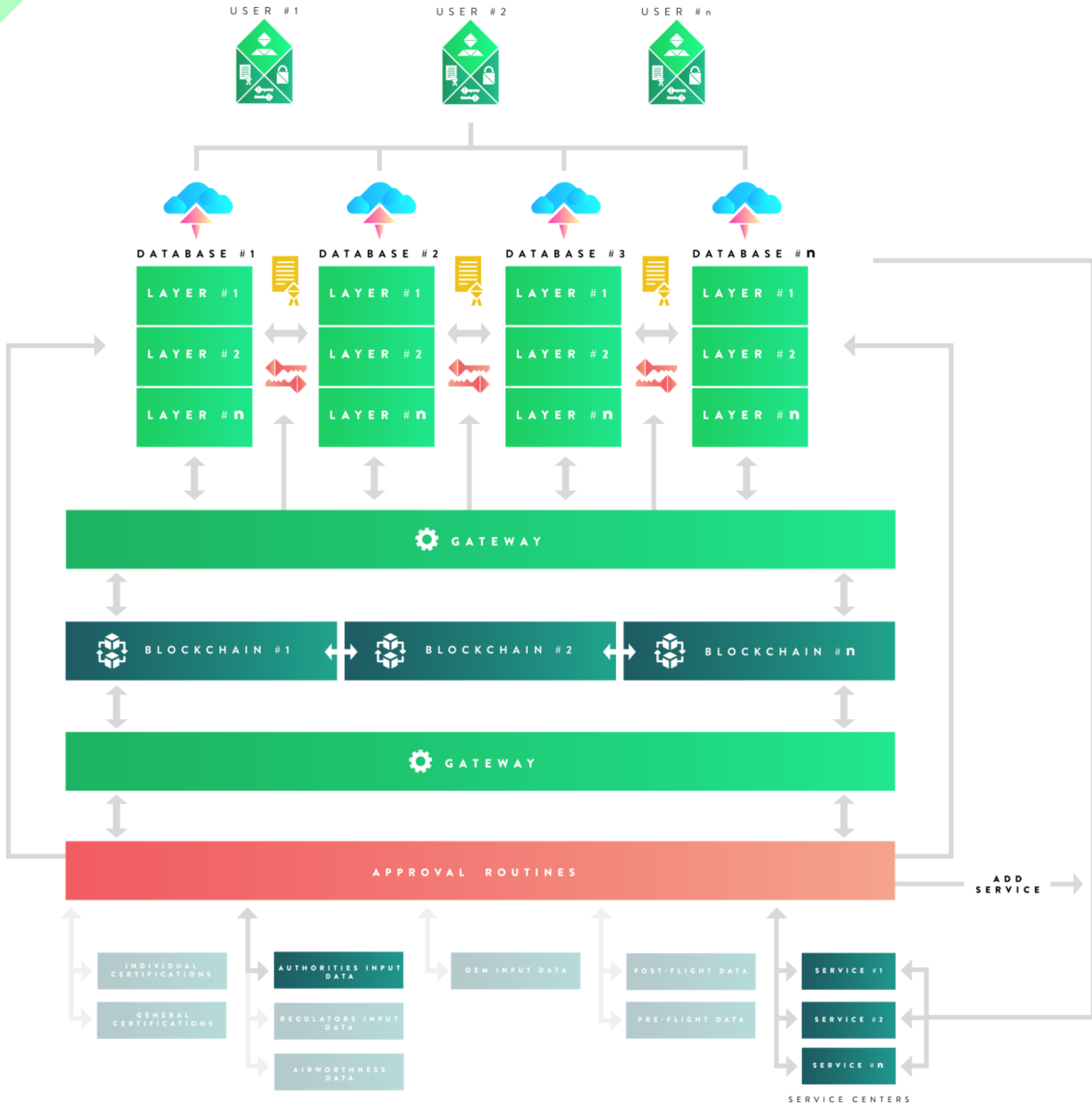

Figure 8 – Authorities Process.

Example 3:

Approve or reject certifications from example 1 and example 2.

Example 4:

Authority issued an airworthiness directive to replace wing structural fitting which is applicable to all Boeing 747-400 which has more than 24000 flight hours and have embodied wing fitting part number "ABC-123" installed.

Currently, the time between the issuance of the airworthiness instructions, the analysis by the CAMO's and the accomplishment by the maintenance service centres is not instant. In some cases, several years can pass between the airworthiness instructions issuance and accomplishment in the aircraft. Also, the authority does not know the full impact and the number of affected aircrafts.

Earhart solution, after the issuance of the airworthiness instruction, is approved by the authority internal routines and records in the blockchain its number, scope and applicability. To the ledger database it will go to the remaining information. The authority can know in real time how many aircrafts and which ones are affected by this airworthiness directive. Then CAMO's and service centres have an instant view of the scope of work for each instruction.

REGULATORS BLOCK

Regulators also play a very important role in this industry. Regulations can be programmed in order to be verified by the applicable intervention. Currently this process is fully manmade and a time-consuming process. With Earhart solution, regulations can be easily programmed on the approval and requirement routines.

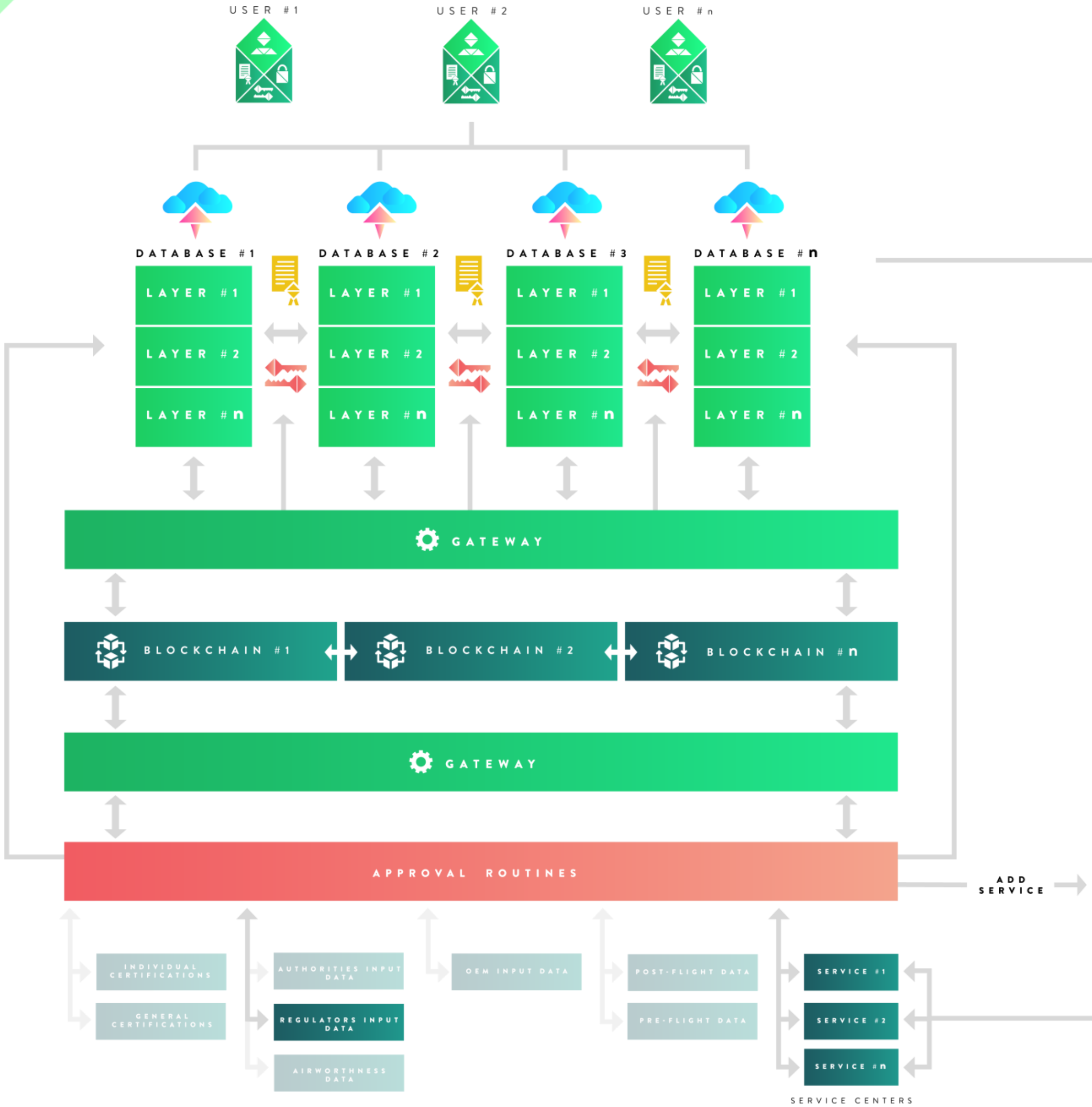

Figure 9 – Regulators.

Example 5:

Regulation: An aircraft pilot must be at least 18 years old and completed the course of airline pilot.

Regulators can program a new directive or alter an existing one that forces the system to comply with the new requirements. When a new application or an amendment is submitted, it will go through the new approval workflow and thus the entire system will be forced to comply with new standards or certifications. For this to happen, the new regulation code will insert key values in the blockchain and in the software ledger.

Where, from Example 1, a pilot applies for certification, this approval routine will immediately verify his age and classification from airline pilot's degree from the Certifications block. If everything is successfully verified, then the certification is approved by the authority. An airline which will want to hire a pilot can verify if their skills and certifications match with his resume or internal requirements.

AIRWORTHINESS BLOCK

CAMOs are the key players in the aircrafts' airworthiness management. It's their responsibility to make sure that all the maintenance and operation requirements are fulfilled[6,7]. It's their responsibility to build an aircraft maintenance plan and issue instructions to keep the aircraft in an airworthy condition.

Nowadays this process requires large teams working around the clock to keep up with all the regulators and authority's requirements. Especially when it's necessary to accomplish actions in third parties, who use different ledgers and methods. This happens because matches between two different systems need to be made.

One area where Earhart solution can intervene is when CAMO teams issue the aircraft maintenance plan. The maintenance plan needs to be approved by an authority[8,9] as explained in Authorities block. Upon approval, the gateway will verify and send its references in the different blockchains and in the database ledger. Anybody who was granted access can check in real time the status of a specific aircraft, as well as its predicted maintenance plan. This is useful for CAMO teams, lessors, auditors, or authorities. The ledger can also be programmed for when certain conditions are met, to emit alerts and issue task cards with service requisitions.

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[6] EASA Requirements: M.A.201, Part-M Subpart F, Part-M Subpart G, Part-CAMO, Part-OPS Subpart OPS.
[7] FAA Requirements: CFR Part 11, CFR Part 26, CFR Part 43, CFR Part 91, CFR Part 249.
[8] EASA Requirements: M.A.302(b).
[9] FAA Requirements: CFR Part 91.1109(3).

Another feature of Earhart is the capability to monitor all the parts installed in the aircraft and engines, if all meet the certification criteria and its digital certificates. Reliability is also one role of the CAMO's teams[10,11]. Using this solution, automatized reliability reports will be generated. These reports can be shared or monetized by the organizations.

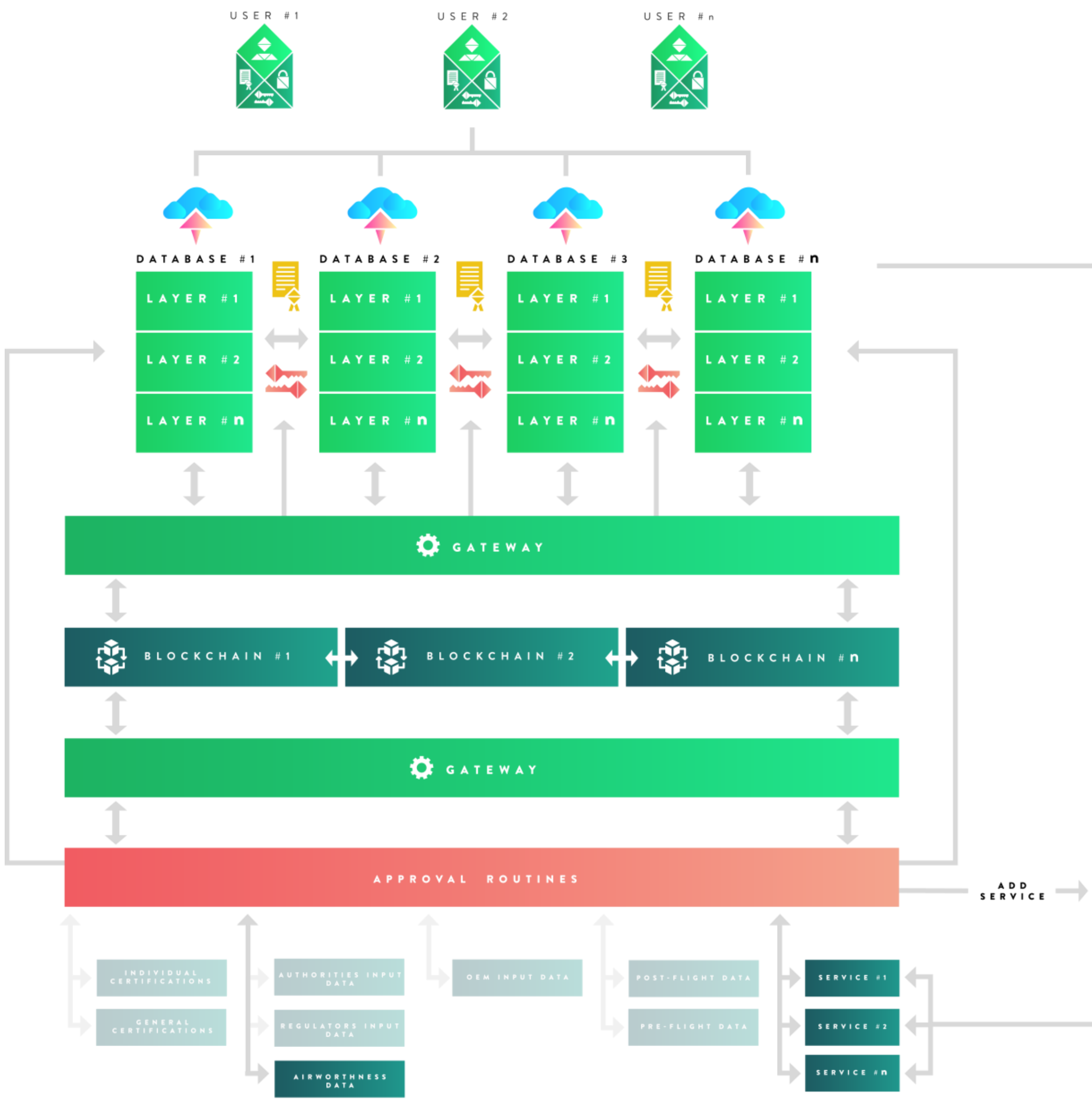

Figure 10 – Airworthiness.

[10] EASA Requirements: M.A.302, M.A.708, M.A.711, CAMO.A.220, CAMO.A.315, CAMO.A.325.
[11] FAA Requirements: CFR Part 91.1415, CFR Part 121.374.

Example 6:

The CAMO team issued an aircraft maintenance plan[12,13]. Then the maintenance plan, composed of many hundreds of maintenance actions, is reviewed by the authority in the Authorities block[14,15], and approved if it meets the Regulators requirements[16,17] block. Through the gateway is then stored in the blockchain the reference and who made the submission and who made the approval, the remaining data will then go to the ledger, such as tasks interval, applicability, task reference, etc. When the conditions approved are meet, ledger will send an alert and issue tasks to be accomplished, such as:

- Service 1 – Engine #1 borescope inspection.
- Service 2 – Inspection pilot windshield.
- Service n – Replace LH Main Landing Gear Actuator.

If from Service 1 is detected that Engine #1 is out of limits, then is added a service to replace Engine #1. This service is also approved by the routines, total time, material and instructions to perform the work need to be submitted and approved.

These services are accomplished and recorded on the blockchain and added to the ledger.

OEM'S BLOCK

OEM's are also one of the key players. They design and manufacture every component and part that are installed in aircrafts. According to current regulations, they are required to keep record[18,19], ensure the serviceability and the performance of every part installed in aircrafts[20,21]. Therefore, they require ever more efficient systems that store and keep track of aircrafts part's data, ensuring regulatory compliance.

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12 EASA Requirements: M.A.302, CAMO.A.220, CAMO.A.315, CAMO.A.325.
13 FAA Requirements: CFR Part 11, CFR Part 26, CFR Part 43, CFR Part 91, CFR Part 249.
14 EASA Requirements: M.A.302(b).
15 FAA Requirements: CFR Part 91.1109(3).
16 EASA Requirements: Part-M, Part-CAMO, Part-145, Part-66, Part-147, Part-21.
17 FAA Requirements: CFR Part 11, CFR Part 26, CFR Part 43, CFR Part 91, CFR Part 249.
18 EASA Requirements: 21.A.55.
19 FAA Requirements: CFR Part CFR Part 21.2, CFR Part 21.137, CFR Part 21.142.
20 EASA Requirements: Certification Specifications, Part-21.
21 FAA Requirements: CFR Part 21.

Earhart can boost current systems, with a more reliable platform. The databases can be initially filled with the information from the OEM's, can be filled by the operators with their service information or can be acquired by monetizing other data.

Furthermore, OEMs by being able to access their parts status in real time, can provide better services to industry players. This is achieved by delivering parts, improving future parts performance, and ensuring safety requirements are being met. In the end, all players will benefit from decreasing aircraft down time, working capital requirements and highly maintained software as well as labour needs.

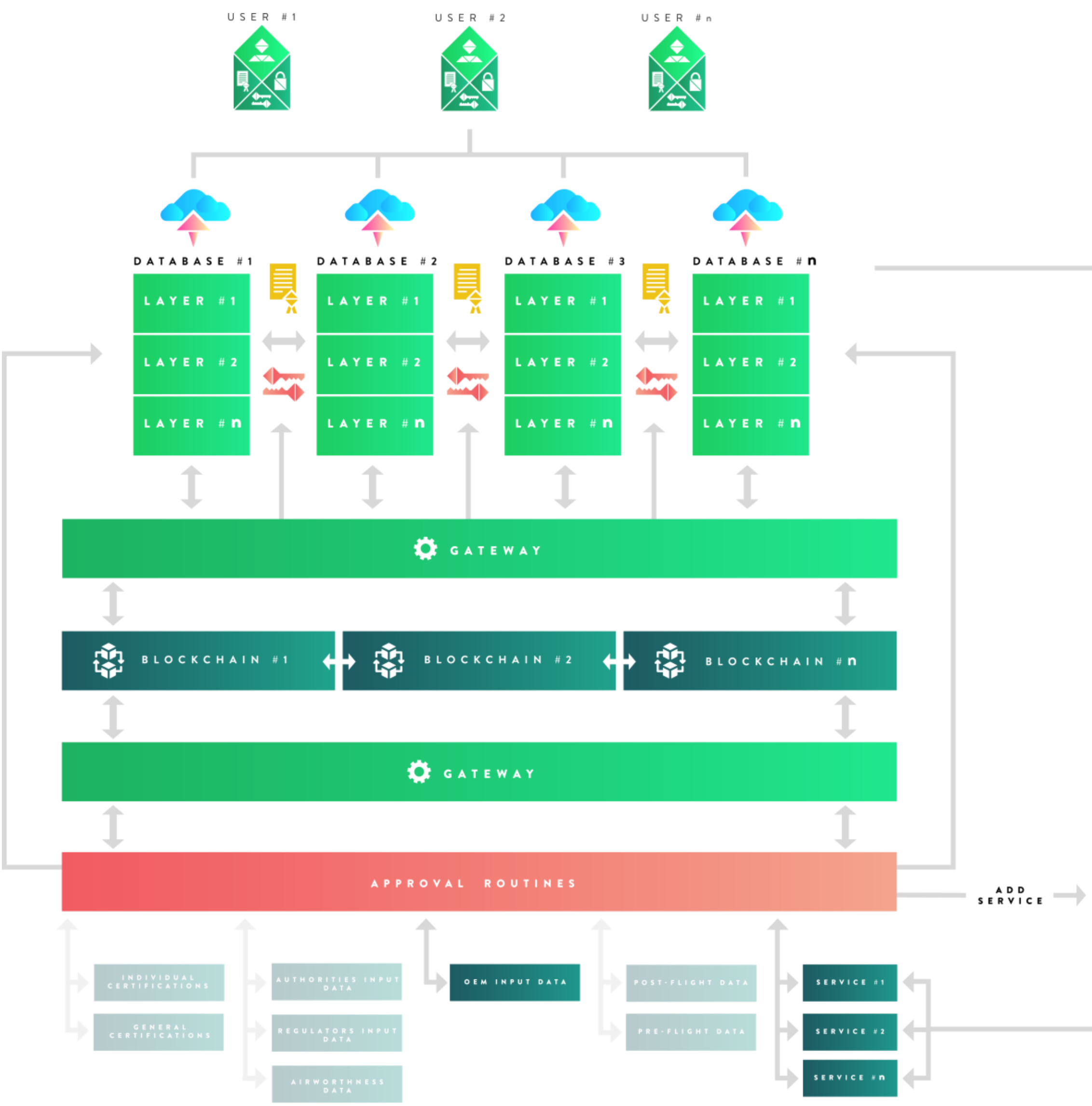

Figure 11 – OEM's.

Example 7:

During the manufacture of a Boeing 747-400 it is necessary to install the LH wing fitting PN ABC123-1 with SN 123 on aircraft SN 00321. Following the approval routines and recording in the blockchain the relevant data a service is generated. Then after service implementation the relevant data such as PN, SN and ID is recorded in the blockchain and databases.

During this process is issued the first parts certificates, also known as birth certificates, which will then be updated during their operating life.

Example 8:

During operation of a Boeing 747-400 SN 00321 a maintenance message is shown. After troubleshooting it is requested help from the OEM to solve the problem. Can be granted to OEM access to information of aircraft SN 00321. OEM can then verify all performed work, aircraft configuration, parts installed, issue new troubleshooting actions, etc. Time between asking and replying will vanish. Reducing the aircraft ground time several times.

OPERATIONS BLOCK

Operations will give important inputs to the aircraft ledgers. Aircrafts are controlled by calendar time, by aircraft flight hours or by aircraft flight cycles. There are other forms of accounting operational data, for example engines flight hours and flight cycles, APU operating hours and landing gear cycles. Individual components life monitoring is mandatory[22,23] since components can be swapped between aircrafts, and when this happens, this individual data must go with it.

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[22] EASA Requirements: M.A.305, AMC M.A.305(e), M.A.306, M.A.503, M.A.801, M.A.901, CAMO.A.220, CAMO.A.315, CAMO.A.325, 145.A.55, 21.A.55.

[23] FAA Requirements: CFR Part 11, CFR 21.2, CFR 21.137, CFR 21.142, CFR 21.2, CFR Part 25, CFR 43.2, CFR 43.9, CFR 43.11, CFR 43.17, CFR 91.417, CFR 91.419, CFR 91.421, CFR 91.1027, CFR 91.1113, CFR 91.1427, CFR 91.1439, CFR 91.1441, CFR 91.1443, CFR 145.12, CFR 91.161, CFR 91.219, CFR Part 249.

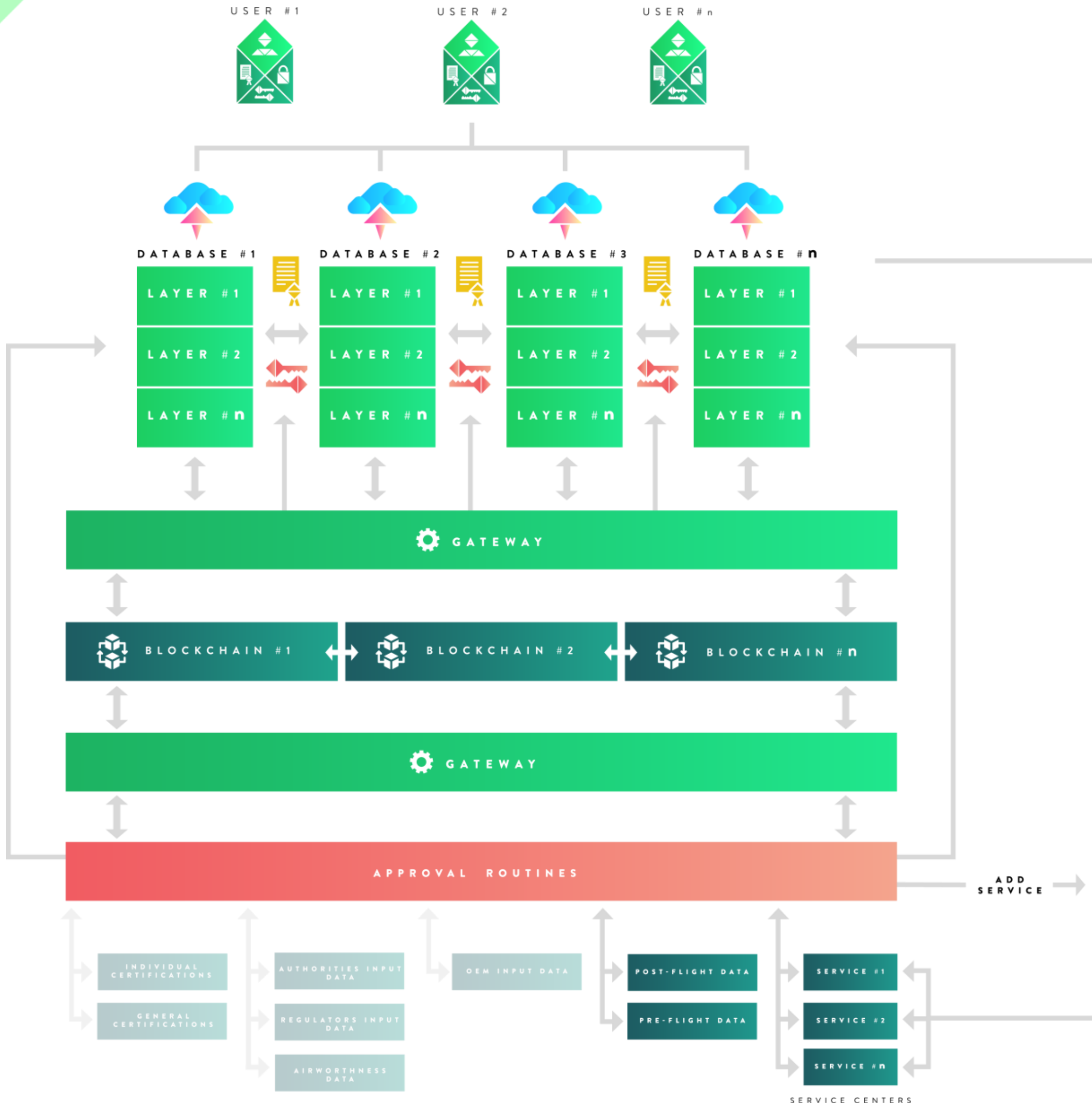

Figure 12 – Flight Operations.

Example 9:

Aircraft registry N00001, a Boeing 747-400 has a programmed flight from New York to London with estimated Departure Time at 12:00 UTC and Arrival 17:00 UTC. This flight has a total of 5 aircraft and engine flight hours and 1 aircraft, engines and landing gears flight cycles.

The cockpit crew is Captain John and First Officer Mike. The cabin crew is Larissa, Joanne, Michael, Peter, Danielle, Abigail and Chloe. The operations submit the programmed flight plan and crew details data, which after approval from the internal routines and gateways will be stored in the ledger. After aircraft flight, crew reported that the Departure Time was 12:01 UTC and Arrival 16:31 UTC, total 4,5 aircraft and engines flight hours and 1 aircraft, engines and landing gears flight cycles. Will then be added 4,5 flight hours to the aircraft and engines and 1 aircraft, engines and landing gears cycles which will be then recorded in the blockchain. It will also be recorded who performed the flight[24,25]. Ledger will then update aircraft, life limit parts and components time and cycles, programmed maintenance plan tasks/services[26,27], cockpit and cabin crew total flown hours and remaining or required rest/off duty time[28,29].

SERVICE CENTERS BLOCK

Service Centres are usually defined as maintenance centres and are where the maintenance technicians are. Service Centres are to accomplish the line and base maintenance tasks, defined in the airworthiness block, given by the CAMO's. During the accomplishment of these maintenance tasks, can arise a non-routine work, or not predicted, aka "Added Service". These added services work need to be carried out to preserve its airworthiness[30,31].

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[24] EASA Requirements: M.A.306, CAMO.A.220, CAMO.A.315, CAMO.A.325.
[25] FAA Requirements: CFR Part 249.
[26] EASA Requirements: M.A.305, AMC M.A.305(e), M.A.306, M.A.503, M.A.801, M.A.901, CAMO.A.220, CAMO.A.315, CAMO.A.325, 145.A.55, 21.A.55.
[27] FAA Requirements: CFR Part 11, CFR 21.2, CFR 21.137, CFR 21.142, CFR 21.2, CFR Part 25, CFR 43.2, CFR 43.9, CFR 43.11, CFR 43.17, CFR 91.417, CFR 91.419, CFR 91.421, CFR 91.1027, CFR 91.1113, CFR 91.1427, CFR 91.1439, CFR 91.1441, CFR 91.1443, CFR 145.12, CFR 91.161, CFR 91.219, CFR Part 249.
[28] EASA Requirements: ORO.FTL.210.
[29] FAA Requirements: CFR Part 117, CFR Part 61.13, CFR Part 61.5, CFR Part 61.189, CFR Part 61.423.
[30] EASA Requirements: M.A.301, M.A.401, M.A.403.
[31] FAA Requirements: CFR part 26, CFR Part 43.

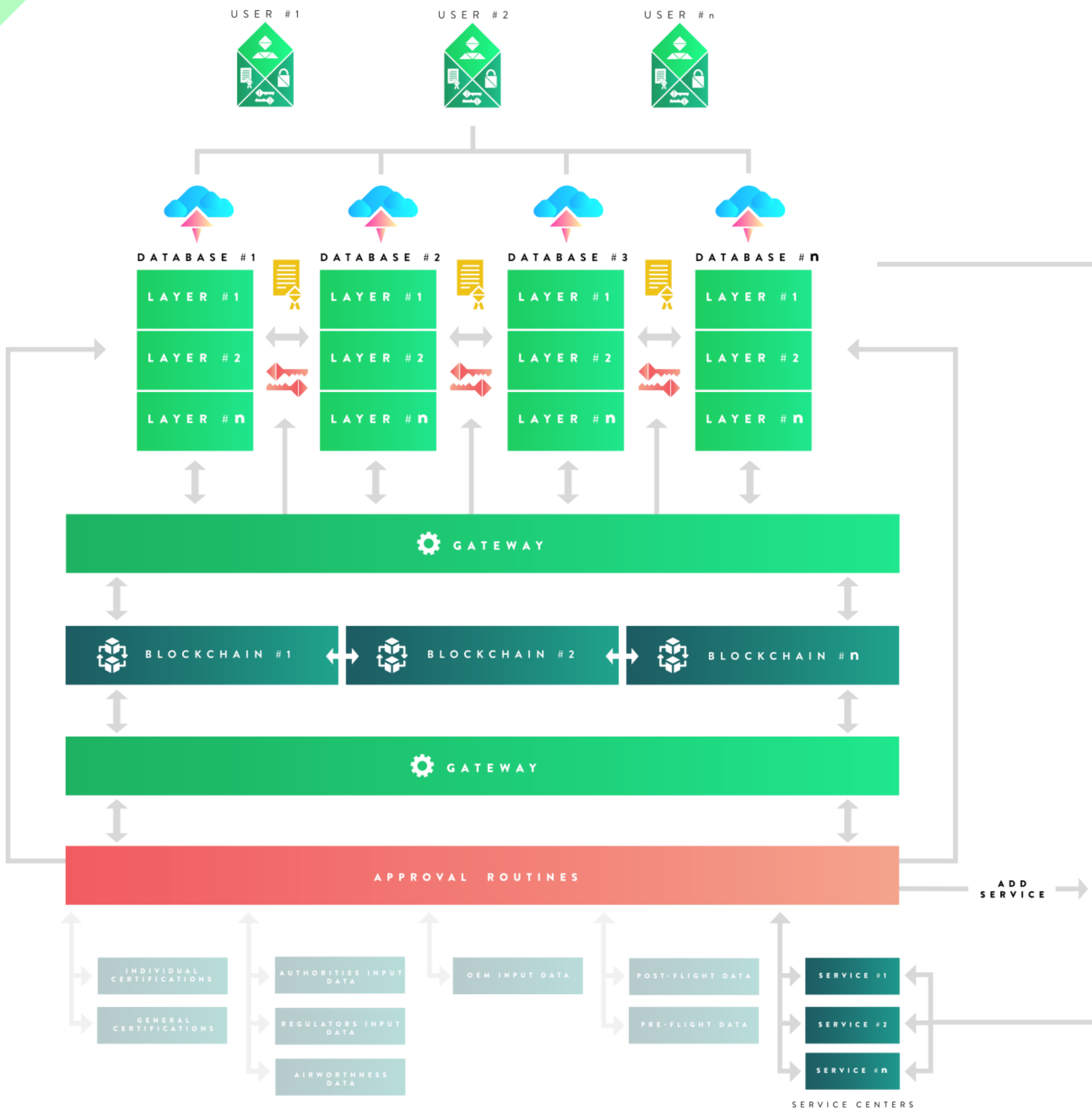

Figure 13 – Service Centers.

Example 10:

Starting to accomplish a maintenance plan, submitted in the Airworthiness block, technicians start to remove, inspect, test, etc. aircraft equipment's. All these accomplishments are blockchain recorded and controlled. When a defect arises from this, an Added Service is generated and recorded in the blockchain. After, a customer or a routine will approve or reject this added work. All this will be recorded in the blockchain to maintain the accountability, traceability and records. The airworthiness block will instantly be updated with the accomplishment of the maintenance tasks.

If ledgers are complete, the installation of a non-approved part number or a component out of certification can be avoided, since the ledger will warn technicians that installing a certain part will make the aircraft lose its Proof of Airworthiness[32,33].

[32] EASA Requirements: M.A.401, M.A.403, M.A.501(b).
[33] FAA Requirements: CFR Part 43.13.

EARHART SOLUTION

In aviation every role relates to others. Analysing every single block is important to understand the individual role but understand the interactions is the key to recognize the true potential of Earhart project.

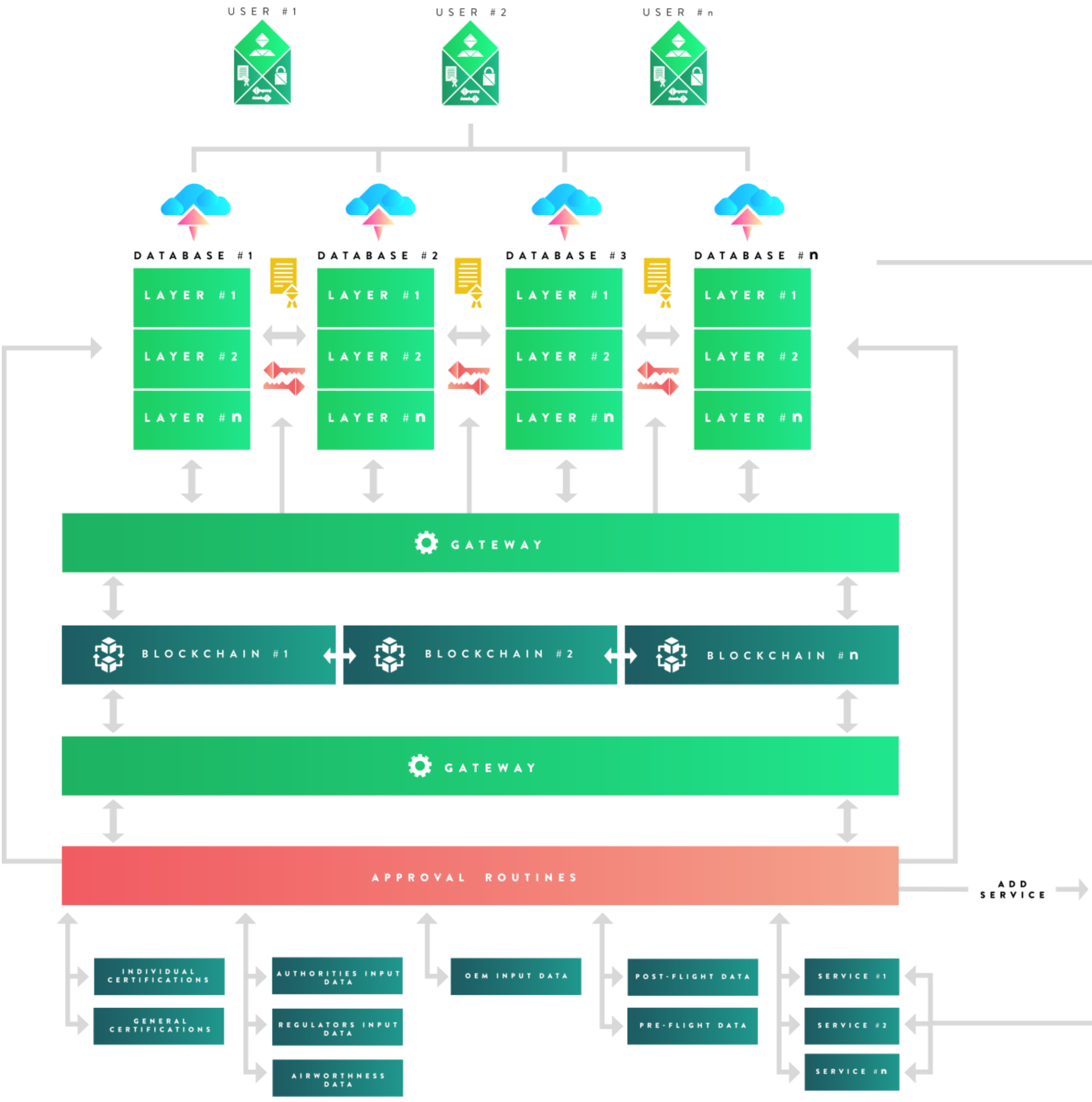

Figure 14 – Earhart.

To understand how Earhart can be deployed, is detailed below the case scenario of an airline that uses Earhart solution. Explained step by step, as the scenario unfolds, what would be requirements, as well as how other players could be involved.

Example 11:

Pre-Requirements: Database/ledger be loaded with at least one aircraft technical information, regarding parts identification.

An airline decides to acquire a used aircraft to one lessor company. The airline CAMO then must develop an aircraft maintenance plan[34,35] aka the block of airworthiness data. From this point there are two options, 1. have manpower to develop one, or 2. use the monetization function to instant acquire one. This will not exclude CAMO from studying, evaluating and periodic reviews per requirements[36,37]. This maintenance plan, with requirements given by the regulators block, is submitted to the approval routines for the authority to approve[38,39]. Once approved, record of submission and the approval is recorded in the blockchain, the maintenance plan is then validated in the ledger. If rejected, it goes back for alterations, also recording this action in the blockchain and ledger.

At the same time the airline needs to acquire the aircraft and company certifications, aka block general certifications with requirements given by the regulators block. After submission to the approval routines, the authority will then review it and if the case, approve the certifications. After the approval, information will be recorded in the blockchain and in the ledger. Otherwise, will return to the issuer with the comments for alterations, also recording this action in the blockchain and ledger.

At this stage, with aircraft and company certifications validated, the next step is to start the operation. For that is required cockpit and cabin crew. After a candidate's appliance,

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[34] EASA Requirements: M.A.302, CAMO.A.220, CAMO.A.315, CAMO.A.325.
[35] FAA Requirements: CFR Part 11, CFR Part 26, CFR Part 43, CFR Part 91, CFR Part 249.
[36] EASA Requirements: M.A.302(h).
[37] FAA Requirements: CFR Part 121, CFR 135.411, CFR Part 91 Subpart K, CFR Part 119.
[38] EASA Requirements: M.A.302(b).
[39] FAA Requirements: CFR Part 91.1109(3).

the airline will validate their licenses, type ratings, and training of the crew which were issued previously in the blockchain. These requirements were given by the regulators block.

Then the aircraft will start to operate, in the block of flight data, operations will update after every single flight the operational data, which then automatically update maintenance data and components time. The flight hours and cycles will also be added to the crew curriculum, and also their duty time. All this information will be recorded in the blockchain and the ledger since is one key airworthiness information.

With the aircraft operation, i.e., the increase in the flight hours and cycles, the continuing airworthiness instructions will start to become active and life limit parts remaining time decreasing its potential[40,41]. The issue of the services will become active through the ledger and services will be added in Service Centres block. Then, the maintenance technician, which has his license and training validated through the individual certifications block with requirements given in the regulators block, accomplish these services. After accomplishment, the service records in the blockchain and ledger the relevant information. If after an inspection, a component needs to be replaced, this added service will be carried out, the installed component is validated through the blockchain, to validate its serviceability and aircraft ledger will update its documentation to reflect this alteration[42,43]. With the component change, which has the flight hours and cycles when was installed and removed, it is possible to perform a reliability analysis. This can be done by a specific component, system or even an entire aircraft.

If during operation is required assistance from any OEM, it can then be granted to help in any required assistance. This is done under the OEM block. Here the OEM can verify and check the relevant data for the analysis and can also issue services to perform. These services are instructions to solve the requested assistance.

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[40] EASA Requirements: M.A.503.
[41] FAA Requirements: CFR Part 33.70.
[42] EASA Requirements: M.A.305, M.A.306, M.A.401, M.A.403, M.A.501, M.A.503, M.A.801, M.A.901, CAMO.A.220, CAMO.A.315, CAMO.A.325.
[43] FAA Requirements: CFR Part 33.70.

If after several inspections from several different aircrafts and operators, many critical defects are found in a single critical component, which the authority has the possibility to see in real time in its block, can issue an airworthiness instruction[44,45]. This airworthiness instruction is validated through internal routines and recorded in the blockchain and ledger. Immediately, the authority knows how many and which aircrafts attend to the requirements. Then the airworthiness data block receives the information and transforms into a service, which after internal approval routines is approved and transformed into a service. Then the service from the airworthiness instruction from the authority is accomplished by a maintenance technician and details recorded in the blockchain and ledger.

The databases, aka ledgers, are segregated, because each block only sees what is encoded in the blockchain and in the respective ledger. Nevertheless, by authentication or by smart contract, can access or interchange information with other ledgers and/or blockchains. A "master user", in the HyperView can see all the information from all the ledgers and blockchains. The access to this information can be filtered by user convenience.

If the aircraft accomplish all the regulations, requirements, and instructions, can be said and given the Proof of Airworthiness.

The final application would be the air traffic control dispatching the aircraft to flight. If in their screen the aircraft is in green colour then the aircraft achieved Proof of airworthiness, which is a go for flight. If it is in red colour, it means that it did not achieve the status of Proof of Airworthiness, then the air traffic control can say it's not authorized to take off. Everything with a real time status.

[44] EASA Requirements: 21.A.265.
[45] FAA Requirements: CFR Part 21, CFR Part 25.

COST SAVINGS ESTIMATION

Maintaining an airworthy fleet is costly. Many man hours of work are carried out by all aeronautical players. Trying to quantify how much is the savings is no easy task. Several approaches need to be made only from the operator point of view.

The total amount of saved man hours is defined as:

$$\sum_{Total_{MH}} = \sum_{Authority_{MH}} + \sum_{Regulators_{MH}} + \sum_{Airworthiness_{MH}} + \sum_{Certifications_{MH}} + \sum_{Service\ Centers_{MH}} + \sum_{OEMMH} + \sum_{OPSMH} \quad (1)$$

The total amount of savings is defined by the sum of all the direct savings plus all the indirect savings. This relation is defined in (2).

$$\sum_{Total\ Savings} = \sum_{Direct\ Savings} + \sum_{Indirect\ Savings} \quad (2)$$

The Direct Savings are easily described as the total man hours saved using Earhart solution plus costs of reworks plus the costs of all traceability. This is defined in (3).

$$\sum_{Direct\ Savings} = \sum_{Total\ MH} + \sum_{Reworks} + \sum_{Traceability} \quad (3)$$

The Indirect Savings is the return of aircraft availability plus the second-hand aircraft market value. This is defined in (4).

$$\sum_{Indirect\ Savings} = \sum_{Aircraft\ Availability} + \sum_{Aircraft\ Market\ Value} \quad (4)$$

Since this process is highly complex, no precise values can be obtained. Nevertheless, and taking only the aircraft CAMO management and Service Centres, a fair approximation can be given when applying equations (2), (3) and (4).

As a keynote the Authorities, Regulators, Certifications, OEM's and Operations savings will not go into account in this approximation but can be estimated as 1 to 5 % of the savings of the combined CAMO and Service Centres.

CAMO management needs a fair average of 3 MH per aircraft of Engineering, Quality, Planning, Logistics and Service Centres Line Maintenance. Total per aircraft is 15 MH.

The amount of MH from the Service Centres is difficult to eliminate since it involves physical work on aircraft. Nevertheless, a rough estimation for optimization processes, and due to Earhart solution with real time automation, 5 MH can be reduced or eliminated.

Regarding base maintenance checks, light and heavy, the amount of man hours is exponentially higher. For a 1000 MH base maintenance check, a 4000 MH is easily achieved with defect rectification. From those 3000 MH, a fair 100 MH of reworks are done due to poor records or loss of certificates. The cost of parts exchange or recertification can be lower estimated as 25k USD per base check. Having this and estimating an average cost of 30 USD per MH, equation (3) can be completed as:

$$\sum_{Direct\ Savings} = (5 \times 365 \times 30) + (100 \times 30) + (25000) = 82750 \text{ USD}$$

Regarding the Indirect Savings calculation, equation (4), the revenue per aircraft availability model is developed by IATA in [11]. The saved amount depends on the aircraft type, for an approximation, can be averaged to an amount of 12k per aircraft per day. Per year it can be estimated that 4 to 10 days of aircraft unavailability mainly due to reworks and overhaul interactions between the several aeronautical players.
For the Aircraft Market Value and having in consideration a second-hand aircraft valued in 40 million USD, when time of doing the redelivery, authors in [5] estimated that the records value proximally 50% of the aircraft value. Poor records devalue the aircrafts since recertifications need to be performed, which corresponds to reworks and traceability in equation (3). Having this, equation (4) can now be computed.

$$\sum_{Indirect\ Savings} = (4 \times 12000) + \frac{(50\% \times 40000000)}{10} = 2048000 \text{ USD}$$

The above equation reflects a savings of 4 downtime days per year, costing 12k per day, and 50% of the aircraft 40 Million market value diluted for example with 10 years' operation time. The result is approximately 2 Million per aircraft per year.
Now, equation (2) can be calculated, giving the total savings per aircraft per year.

$$\sum_{Total\ Savings} = 82750 + 2048000 = 2130750 \text{ USD}$$

An average operator with 50 aircrafts, can catch up savings of more than 100 Million USD per year.

This estimation is not straight forward nor a rule but can easily demonstrate the loss potential that the airline business faces within this scope.

MONETIZATION AND TOKENOMICS

The work behind construction of an aircraft database can be quite laborious. By monetizing it, incentives to their construction can be made.

The airworthiness data can be monetized. Currently if new airworthiness data needs to be constructed, the only solution is to hire a CAMO or specialized and experienced personnel to build this plan. Both these options required a lot of monetary and man-power efforts. An already existing maintenance plan can be tokenized and sold to a third party within minutes. This will not exclude CAMO from studying, evaluating and periodic reviews per requirements[46,47]. The expenses would then be astronomically decreased, the aircraft down time will also be reduced from months to possible hours.

The reliability data can also be tokenized. The reliability is quite important in the development and improving components and maintenance plans. Nevertheless, the OEM's only have access to a small part of the data since the operators are not impelled to provide the required data.

Monetizing the reliability data will impel the operators and maintenance providers to sell their data to the OEM's to improve their design and for the authority's supervision.

The defects found from the inspections and/or tests, represented by the added services can also be monetized. This data is relevant for the OEM's and authorities to know the degree of findings from which programmed task. From this can arise the necessity to change the intervals to adapt to the levels and number of findings. This can optimize the maintenance plans becoming less expensive[48,49]. And so, this data can also be tokenized to be sold to the interested parts.

The logistics behind the aircraft operation or Service Centres are a huge problem. Aircraft readiness can be sacrificed to reduce the available stocked material, or a considerable investment is made in SKU's to increase the material stock. Operators and Service Centres

[46] EASA Requirements: M.A.302(h).
[47] FAA Requirements: CFR Part 121, CFR 135.411 CFR Part 91 Subpart K, CFR Part 119.
[48] EASA Requirements: M.A.302(h).
[49] FAA Requirements: CFR Part 121, CFR 135.411 CFR Part 91 Subpart K, CFR Part 119.

with a considerable backlog can tokenize the approximated required material per aircraft per its stage of life. This will reduce the aircraft ground time and decrease the stoked material.

FOR TOKENOMICS THE PROPOSAL IS:

Name: EHT (Earhart Tokens)
Total tokens: 1 000 000 000 EHT

1) Early development: 100 M (10%)
It is used for community construction and promotion in the early stage.

2) Cornerstone Investment: 100 M (10%)
It is used for the participation of institutions and partners, bringing more resources and institutional partners to the Earhart ecosystem, and promoting the development of the project.

3) Earhart Foundation: 110 M (11%)
It is used for the team development and R&D, as well as the long-term development fund support of and sustainable development of the Earhart project.

4) Marketing: 100 M (10%)
Destined for marketing purposes and exchange listing activities.

5) SCO: 40 M (4%)
For early distribution for the NULS community using the SCO process. This will allow to build up a community organically from the ground up.

6) NULS foundation: 50 M (5%)
Destined for cross promotion activities to help build up both communities organically. Core team direct support, and other activities.

7) Rewards: 500 M (50%)
Rewards and incentives to industry early adopters.

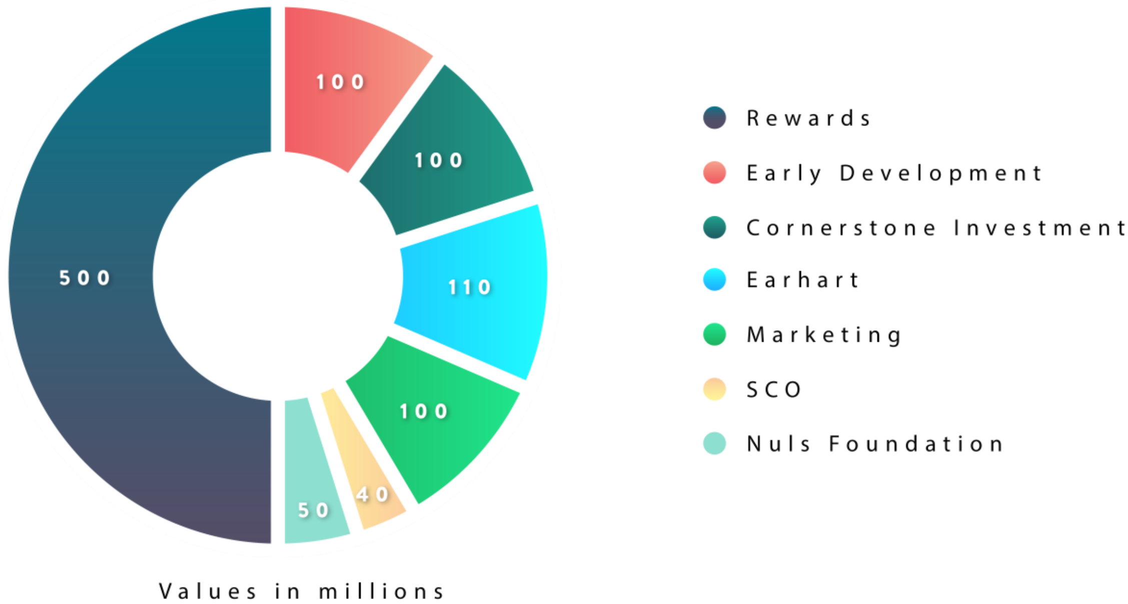

Figure 15 – Token Distribution.

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