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DIGITAL TWIN CONCEPT FOR AIRCRAFT COMPONENTS

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Abstract

Digital twins are one way to develop future intelligent systems. Aviation brings along very special circumstances, since the majority of the components do not remain in the first aircraft (A/C) over the life cycle and are constantly changing as they belong to other systems. Due to the high values of these assets, many of them are subjected to a maintenance process and then mounted to another aircraft. In this paper, a digital twin concept is developed for these components. For this purpose, requirements from different areas are derived and merged to the new concept. First, the stakeholders of the aviation maintenance ecosystem are considered. Then the concept of digital twin or digital twin web is explained. In order to enable the identification of the data sets in the digital twin, unique identifiers must be introduced before the specifics of aviation components and their processes are discussed. At the end the new concept is described. The various identifiers, the distributed system and the roles of the stakeholders in the ecosystem are discussed.

Keywords: digital twin; maintenance; components; identifier; integrated vehicle health management

A/C *Aircraft*
AMM *Aircraft Maintenance Manual*
CAGE *Commercial And Government Entity*
CAMO *Contiuos Airworthiness Organisation*
CLB *Cabin Log Book*
CMM *Component Maintenance Manual*
CRS *Certificate of Release to Service*
DLA *Defence Logistic Architecture*
DLR *German Aerospace Center*
DT *Digital Twin*
EASA *European Union Aviation Safety Agency*
ETSO *European Technical Standard Order*
FAA *Federal Aviation Administration*
GADIT *Git-based Architecture for Digital Twins*
GLB *Ground Log Book*
IATA *International Air Transport Association*
IBAN *International BAnk Account Number*
ICAO *International Civil Aviation Organiztion*
ID *Identifier*
IVHM *Integrated Vehicle Health Management*
LRU *Line Replaceable Unit*
MAC *Media Access Control*
MPD *Maintenance Planning Document*
MRO *Maintenance and Repair Organisation*
OEM *Original Equipment Manufacturer*
RFID *Radio Frequency Identification*
SRU *Shop Replaceable Unit*
TLB *Technical Log Book*
UID *Unique Identification*
USN *Universal Serial Number*
UUID *Universally Unique Identifier*
VIN *Vehicle Identification Number*

1. Introduction

Due to the increase in digitalization, the concept of digital twins is becoming more widespread. Especially in the aviation industry, where there are high demands on the traceability and documentation of activities, but also increasing pressure on maintenance costs, digital twins are required to enable condition-based maintenance, predictive and prescriptive maintenance. In contrast to consumer products, for example, the physical assets in aviation are composed of a large number of components that change their affiliation to a higher physical asset or change the owner several

times during their lifetime. In the aviation sector, there are therefore several initiatives for digital representations that were initiated by different stakeholders [1] [2] [3] and thus only meet the respective requirements. This makes it particularly difficult to exchange relevant data that has been generated, for example, in other companies or in other instances. First research in the field of digital twins in distributed systems [4] and digital twin web [5] is already being performed. However, the transformation to the aviation ecosystem is still missing.
Especially in the aircraft (A/C) component market, business models have shifted from providing tangible products to providing intangible product-related services like component pools, component availability or total component supply. [6] [7] In order to support this shift towards data-driven maintenance, digital twins over the whole life cycle of the components are needed.

2. Stakeholder

The stakeholders in an Integrated Vehicle Health Management (IVHM) system have already been described in [8]. These largely coincide with the stakeholders from [9]. Only the crew is seen as part of the workforce, which in turn is part of the population. In Figure 1, the stakeholders are shown in an IVHM system. The IVHM system can be interpreted as a customer of the digital twin or the digital twin as a prerequisite for an effective IVHM. Therefore, the stakeholder remains the same between these two approaches.

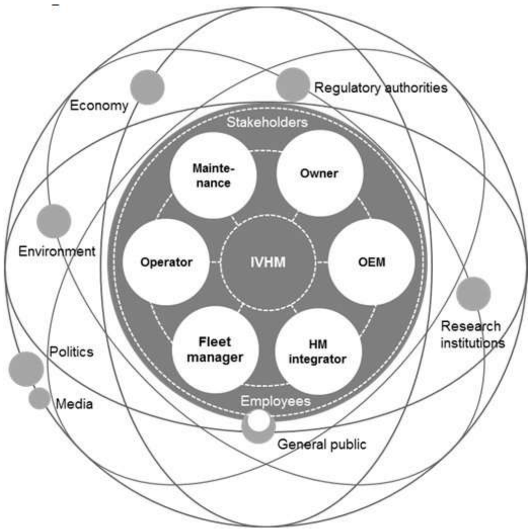

Figure 1: Stakeholder for an IVHM [8]

In the component change process, the logistics companies are an additional stakeholder. The European aviation law regulates the rights and obligations of most stakeholders with regard to air traffic. The operator / CAMO, MRO, OEM, design organization and staff require appropriate licenses, certificates and authorizations. The tasks of the authorities are also anchored in the laws such as Continuing Airworthiness (Regulation (EU) No 1321/2014) or Basic Regulation (Regulation (EU) 2018/1139). The airline is usually the operator of the asset. The airline can be the owner of the asset and makes the operational decisions. But other owners like lessors or finance companies are possible. MRO is the maintenance organization, which can repair either the top-level asset, the component or the sub-component. Several MROs can be involved in the repair of a component. MRO 1 removes the component from the asset. MRO 2 repairs the component and breaks it down into sub-components and MRO 3 repairs the sub-components. However, all work can also take place at one MRO if authorizations are available.

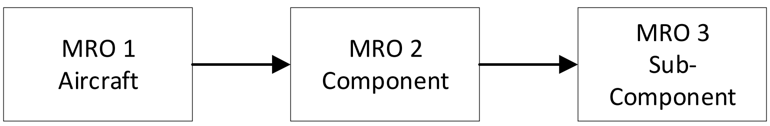

Figure 2: Hierarchical Example Stakeholder MRO

The OEM is the manufacturer. The subdivision can be similar to that for MRO. There is a manufacturer for the asset (or system integrator), one for the component and one for the sub-component. There can also be an OEM that covers several levels. [10] As a stakeholder in the component change process, logistics is responsible for all logistical tasks inside and outside the company. Various logistics companies can be involved in the overall process. In addition to the actual transport task, the companies can also be responsible for customs clearance and warehousing. Various authorities are also involved as stakeholders. These can be various aviation authorities, but also, customs or ministries. In the case of components for aircraft in particular, there are often so-called dual release procedures in which the airworthiness is certified for several authorities, since the future installation location is not yet known when the component leaves the workshop. The last stakeholder to be mentioned is the staff involved in the overall process. In many areas of aviation, but also in logistics, the personnel numbers are stored as part of the certificates and delivery documents.

Requirement 1:	Access to digital twin for different stakeholder with different user rights.

3. Digital Twin

Kritzinger et al. [11] define the digital twin for digital objects that are connected to the physical object with a bi-directional data flow (see Figure 3). This matches to the data link specification defined by van der Falk et al. [12]. The definition by DLR [13] corresponds to the eight dimensions that were developed on the basis of the literature review [12]. The dimensions cover, for example, the data link, the interface, the purpose and the data input. This Paper concentrates on the virtual space of the digital twin.

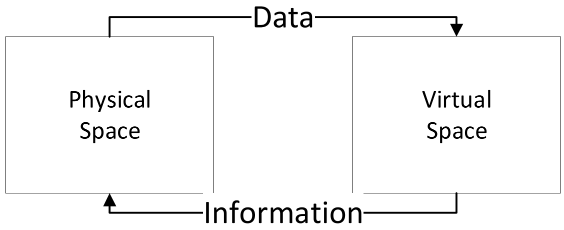

Figure 3: Basic Digital Twin

An important elaboration in the definition of DLR is the relationship of several digital twins. A digital twin (DT) represents an individual object. Since aircrafts are assembled from different objects, the digital twins must also consider these relationships and the composition of different assemblies of DTs. Consequently, mother/child connections are needed (ref to. Figure 4).
The digital twin consists of the digital thread for a physical object, the simulations and programs and the links between these elements. In [13] we defined the digital thread as a concept that represents a chronological storage of information and data for one asset across product life cycles. A major differentiation from the digital thread or digital shadow is the bi-directional data flow mentioned above. This paper refers to the digital twin, because the benefits of a digital thread can only be achieved by establishing a bi-directional link. In the operation the link from the physical space to the virtual space are the operational and maintenance data, while the return link is the maintenance action determined by e.g. predictive maintenance applications. Before these applications can work with digital twins over the lifecycle, the digital thread must be established. Therefore, this paper is focused on the data consistency over the entire life cycle.

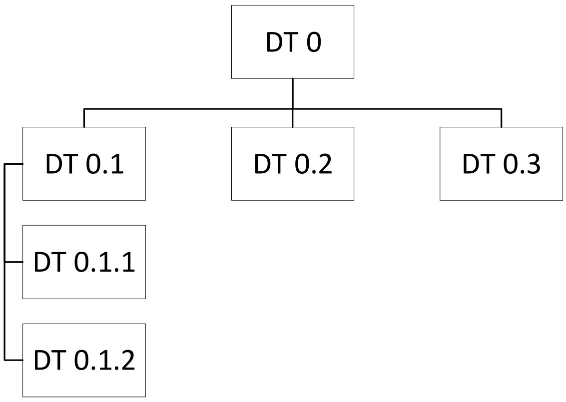

Figure 4: Hierarchical DT

Requirement 2:	A hierarchical digital twin concept is needed.
Requirement 3:	Bi-directional data flow is needed.

3.1 Data Storage Concept

One possibility of data storage is the central storage of data. This would mean that all stakeholders are obliged to transmit their data to the central entity. Since in aviation the manufacturers of engines or aircraft are increasingly entering the aftermarket, the other process participants are not interested in sharing their data. This would result in the minimally required data being transmitted and would consequently lead to less data being shared.

An alternative approach is the isolated data storage concept: Every stakeholder saves its individual data, which they generate themselves, locally. This is the current state of the system. This prevents lifecycle-wide applications. An exchange of data does not take place directly between the different stakeholders. Limited data can be extracted from invoices and documents. There would be no access to time series or test stand data of other stakeholders.

Another option would be to save the data directly on the respective assets. This brings the risk that the data could be changed by anyone with physical access. At the same time, the data would be lost with the component, which does not comply with legal requirements and would make accident investigations impossible.

The last possibility is a distributed data system by connecting the local data storages of the different stakeholders. As a consequence, a high demand for standardization over all stakeholders is needed, which includes interfaces, ontologies, data formats, provenance information and variables.

Based on the experience in aviation maintenance, the sharing of data over different stakeholders is very unlikely. In addition, the interests of employees (e.g. pilots [14]) need to be addressed and included in the overall DT architecture. A study about the acceptance by commercial pilots of using flight data for predictive maintenance shows, that the majority of pilots trust their airline most compared to other stakeholders of the aviation ecosystem. [14] This would require a distributed data system.

Requirement 4:	A distributed digital twin concept is needed.
Requirement 5:	Standardization for digital twin in aviation maintenance is needed.

3.2 The Digital Twin Web / Registry

There are first concepts for central registers for digital twins [5]. The creator of a digital twin enters the ID of the component into a register. In addition to the ID, this register also contains the storage location of the digital representations and provides the reference for the data records. The Digital Twin Web consists of the document servers on which the associated documents are stored, the DT identifier registries that create the link, and the libraries and interfaces for automatic or human use. Due to the implementation on GADIT / git systems, the owner of the digital twin is also the owner of the server, registry and the content on the individual servers. Even if the concept of [5] does not include the complexity of the aviation maintenance ecosystem, the authors are aware of the interaction of digital twins on the meta-data level. [5]

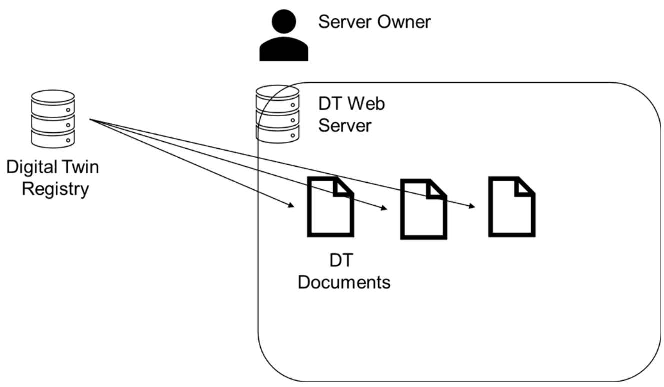

Figure 5: Concept of the Digital Twin Registry based on [5]

Requirement 6:	A registry for distributed digital twins is needed.

4. Identifier

In this chapter, different identifiers for hard-/software are discussed. At the beginning general known identifiers are presented. In the second sub-chapter, the identification of aircraft components is explained. In a last step, different identifier technologies are presented.

4.1 Various Identifiers

Various identifiers have been established in many different areas and industries. This chapter reflects on some identifiers for different applications.

A well-known identifier is the Media Access Control (MAC) address. The MAC address is the hardware address of each individual network adapter, which serves as a unique identifier on a network. It is also often referred to as the physical address. The structure of the identifier is specified in IEEE standards like EUI-48 and EUI64 for IEEE 802 universally unique MAC addresses. A part of the identifier is assigned by the IEEE to the manufacturer identifier and it can be viewed in a central database. [15] The manufacturers can assign the individual MAC addresses to their produced network adapters in the assigned MAC address block.

Another unique identifier is the vehicle identification number (VIN). This number is standardized in the EU by the ISO standard 3779. The structure already contains various information about the vehicle itself, such as the manufacturer, vehicle description and a sequential number, which can also contain information such as the year of construction or the year of manufacture. The VIN shall be unique and thus, it ensures the traceability of the vehicle over a period of 30 years. [16] In some countries, registration in a central vehicle register is mandatory. [17]

A common identifier is also the International Bank Account Number (IBAN), which is the standard for bank accounts. The IBAN is defined in ISO norm 13616-1:2020. The first two digits reflect the country code, the next two following are a check sum and the rest of the number is a max 30-digit account identification. In some countries, the IBAN includes information about the corresponding bank.

The Universally Unique Identifier (UUID) is used to identify information in computer systems. It can exist in different versions using different creation methods. The UUID consists of 128 bits. In the randomly generated version 4, a total of 2^{122} different combinations are possible. This does not guarantee uniqueness, but the coincidence is very unlikely. The advantage is that no central control body or legislation is required. [18]

4.2 Identifier in Aviation

In aviation, components and parts must be marked with the company name, the component number and, for critical components, the serial number. The part number must match the original design data of the OEM. Components which are manufactured according to the European Technical Standard Order (ETSO) must indicate the name and address of the manufacturer, the part description (name, part number), the serial number or the date of manufacture and the ETSO number. [19]

Therefore, components are clearly identified by the combination of part no., serial no. and Manufacturer ID identified on a nameplate. The part number can be an alphanumeric combination including special characters of any length. Likewise, serial numbers are manufacturer-specified combinations and they can range from simple numbers to alphanumeric combinations. The manufacturer identification is defined in aviation as a so-called CAGE code. The manufacturer codes can be found in the respective documentation. The Commercial and Government Entity (CAGE) Code is a five-digit number used extensively within the U.S. federal government, assigned by the Department of Defense's Defense Logistics Agency (DLA). The manufacturer's name can also appear on the components themselves. The cage code contains syntax information on the country in which the requested entity is located. This syntax is defined by the NATO AC/135 Committee and defines either the first or last character as a specific letter. For Germany this results in cage codes that start with C or D and end with a number. As an example, Lufthansa Technik has the CAGE Code C1008. In the latest version of [20], a new Universal Serial Number (USN) is added, which is composed by the cage code and a 15-character serial number given by the manufacturer. The U.S. Department of Defense also established a Military Unique Identification (UID) standard. There the manufacturer and the serial number are embedded by a wrapper which follows the ISO/IEC 15434.

Requirement 7:	Unique identifiers for A/C components indicated on the component are needed.

4.3 Identifier Technologies

In aviation, several technologies for the identification are used. A placard with the information described above is mandatory. However, there are other possibilities to transfer the Component ID to the electronic system. For cabin equipment, RFID is used for the identification and the tracking of equipment. [21] [22]

In [20] the different technologies and how they are used within an aviation standard are described. This includes:

- Type Placard
- Barcode / 2-D Data Matrix
- RFID

If an additional identifier is used, the information must be included in the different identifier standards in order to enable seamless interactions with digital twins of the assets. Regarding RFID identifiers, it is possible to store the part's history on the tag itself. This would reduce the efforts for maintenance organizations but would not fulfill the aviation law in reference to the documentation aspects.

5. Aviation Maintenance Component Process

In aviation, a significant part of maintenance is carried out on a component level. In contrast to consumer products, many of the components are made airworthy again by means of a repair and recertification process so that they can be returned to the aviation ecosystem. In the context of the DT requirements, a distinction can be made between component change and component repair processes.

5.1 Component Change Process

The replacement of components can be either a scheduled or an unscheduled event. In the planned event, the time of removal of a component is controlled by the maintenance plan of the parent asset. The component can go into an overhaul process or it can be scrapped and replaced with a new part. In an unplanned event, the component is damaged/degraded due to utilization. The damage is detected during an inspection, potentially triggered by an incident, or due to consequential errors or malfunctions. Depending on the degree of damage or the historical damages and repairs of the components, a decision is made as to whether the component will be repaired or replaced with a new part. Some components are installed in the process as sub-components (shop replaceable unit SRU) in a line replaceable unit (LRU), which as such is installed in an aircraft.

When a component is repaired, appropriate logistics and repair processes are necessary. A distinction can be made between closed-loop, open-loop and pool processes. In closed-loop processes, the component is removed, repaired and finally reinstalled in the same asset (ref. to Figure 6). In the open-loop or pool processes, the component is replaced with a component that has already been repaired and the repair process takes place independently of the repair of the aircraft (ref. to Figure 7). This drives the requirement for the digital twin to add and remove components to aircraft.

Figure 6: Closed-loop process: Part A is removed and installed in the original aircraft

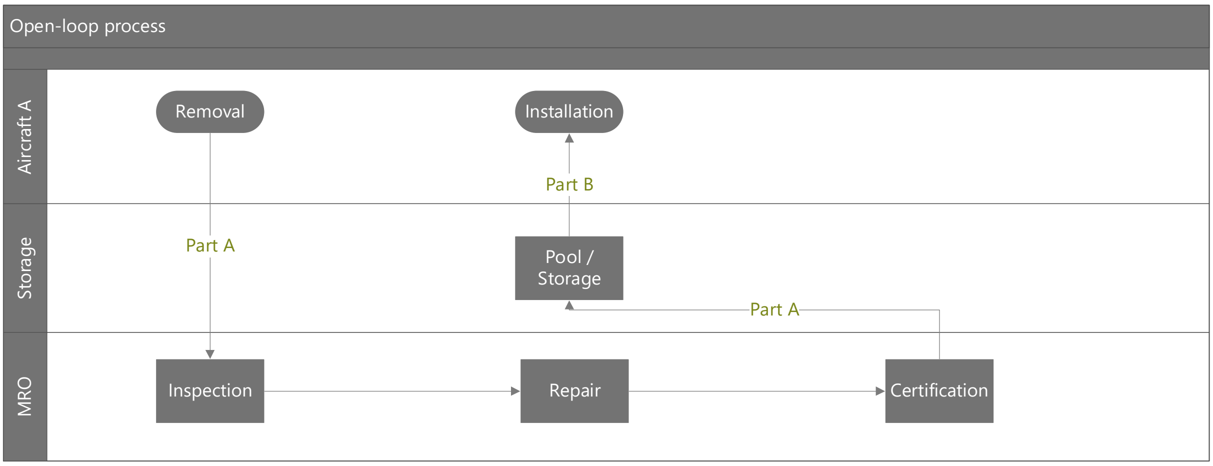

Figure 7: Open-loop process: After the removal of part A, the object is replaced by another part B

When the component is planned to be removed, the removal of the component is triggered by a job card. The job card usually includes the information of the source of the assignment, which is a planning document such as the maintenance plan/MPD. In the case of an unplanned damage, it is documented by a finding that was entered either in a Ground Log Book (GLB) or in the Technical / Cabin Log Book (TLB/CLB). The description of the removal/installation procedure can be found in the associated documentation such as the Aircraft Maintenance Manual (AMM) or Component Maintenance Manual (CMM).

Requirement 8: Removal and integration capability of component Digital Twins from the next higher assembly (e.g. engine/aircraft) is needed.

5.2 Component Repair Process

The component repair process of a composite part is described in [23]. As most of the state-of-the-art repair processes are manually performed by workers, the potential of digitization is very high on one side. On the other side, this drives the requirements for aviation digital twins to integrate stakeholders, workshops and processes with different digitalization level from simple computerization towards full digital systems.

The beforementioned paper also names difficulties in transferring damage with regard to the unit of measure and the reference geometries. In order to transfer damage, deviations or technical information, a high level of standardization with regard to the units of measurement, ontologies and data resolutions / errors / tolerances is required. [23]

In addition, it was identified that beside part identifiers also identifiers for damages/events, processes and data sets which are involved in the maintenance process are needed. At a full digital expansion stage, interactions with the digital twins of non-aviation machines and processes could be useful. This would require an interaction of IDs and data sets of multi economic systems. [23]

Requirement 9: Access for stakeholder to the DT with different digitalization level are needed.
Requirement 10: A high level of standardization with other economic systems is needed.
Requirement 11: Additionally, data, process and damage/event identifiers are needed.

5.3 Maintenance Records

Aviation law defines which data a maintenance company must record, provide and archive about the measures carried out. It must be noted that the responsibility lies with the EASA Part-M (CAMO) organization. Here, the data is usually transferred from the MRO to the CAMO (ref to. Figure 8). If necessary or during checks, this data must be submitted to the competent authority. For certain components, the data includes the:

- In-service history
- Certificate of release to service (CRS)
- Detailed maintenance records for the last 36 months

This data must be archived by the respective CAMO at aircraft level. This contributes to the

Requirement 01. Additional requirements for time history and certificates are needed:

> Requirement 12: Access for time history data is needed
> Requirement 13: Possibility of certificate collections should be provided.

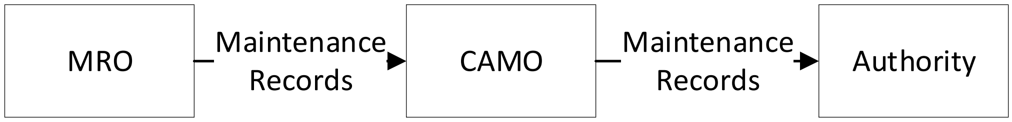

Figure 8: Data Transfer between MRO/CAMO/Authority

6. Proposed Concept

In this chapter, the overall requirements are analyzed and transferred into an architecture for distributed digital twins independent from stakeholders. The architecture is transferred to an example process.

6.1 Requirements

In the previous chapters, different aspects are considered from different perspectives. This results in a list of requirements that such a system has to meet. In this work, these requirements are the top-level requirements for a system of distributed digital twin. Of course, further technical, organizational and legal requirements must be defined for the implementation of such a system. The following requirements are identified:

Requirement 01	Access to digital twin for different Stakeholder with different user rights.
Requirement 02	A hierachical digital twin concept
Requirement 03	Bidirectional data flow
Requirement 04	A distributed digital twin concept.
Requirement 05	Standardization for digital twin in aviation maintenance
Requirement 06	A registry for distributed digital twins is needed.
Requirement 07	Unique identifiers for aircraft components on the component are needed.
Requirement 08	Removal and integration capability of component Digital Twins from the next higher assembly (e.g. engine/aircraft)
Requirement 09	Access for stakeholder to the DT with different digitalization level.
Requirement 10	High level of standardization with other economic systems is needed
Requirement 11	Additionally data, process and damage/event identifier are needed.
Requirement 12	Access for time history data.
Requirement 13	Possibility of certificate collection should be provided.

Most of the top-level requirements are necessary for the creation of a basic architecture or for a usage concept. The areas of cyber security, data security and the immutability of the individual data sets are not considered in this paper, but are essential points for the implementation of a digital twin concept.

6.2 Architecture

The digital thread of the aircraft or component is a collection of unique identifiers (UID) of the individual subsystems and components combined with the associated meta data and the system parameters belonging to the aircraft.

The information about the location of the component DT can then be called up in a digital twin registry by means of the UIDs of the individual components and aircraft. The entries for the respective addresses of the stored data records and the associated meta data are in the registry for each stakeholder. Individual data should always be shared in the digital twins, such as flight hours and flight cycles, which are relevant for all stakeholders.

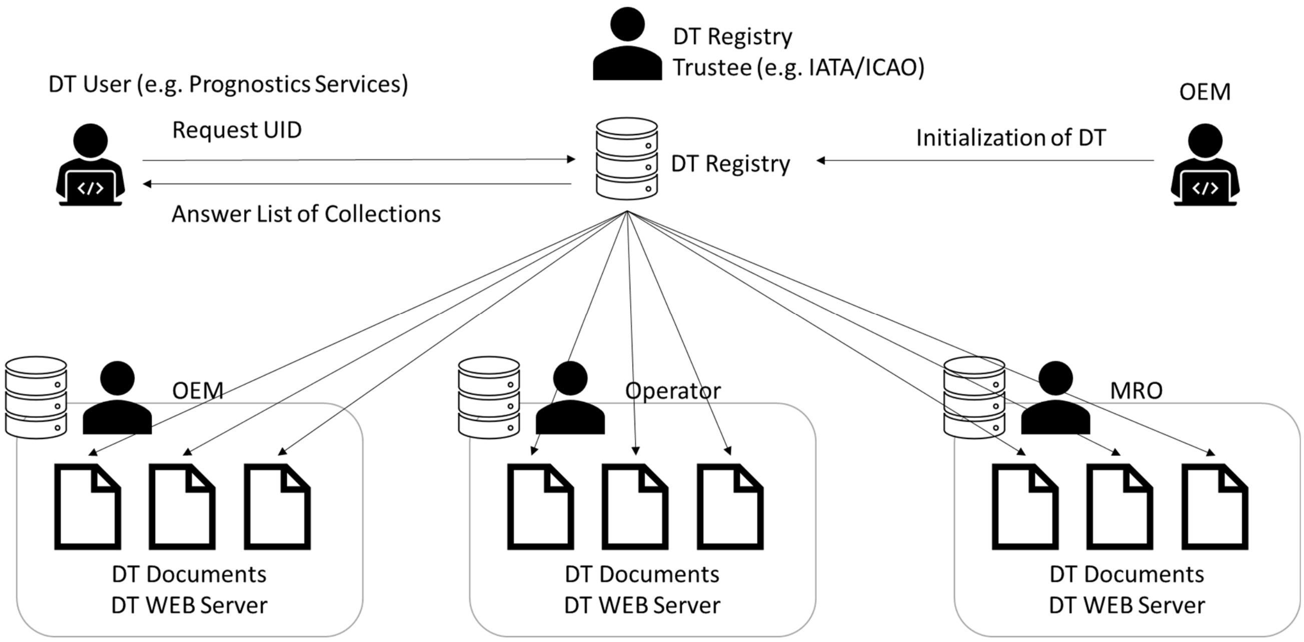

Figure 9: Proposed overall DT architecture

Figure 9 is the conceptual representation of a DT architecture. There are four basic roles reserved in the architecture. The “owner” of the digital twin registry operates the hardware and software for displaying the links between the individual documents and data on the individual stakeholders for each individual asset in the air transport system. Since the mapping of the last maintenance measures is part of aviation law, this registry should be managed by a trustee. Either the international aviation organizations (ICAO, IATA), the major aviation authorities (FAA, EASA) or a specially founded organization should be responsible.

The second role is that of the individual DT server owner. Each stakeholder in the air transport system (operators, OEMs, MROs,…) would operate their own server, on which only the data creators themselves have full access. Access from other stakeholders would be subject to the restrictions described below. Of course, the data storage within the digital twins need to be mandatory. Also, each stakeholder would need an accredited server with a static IP address over the entire life cycle.

The third role is the initiator of the digital twin. Basically, it should be the manufacturer (OEM) of the asset. However, it may well be necessary for another stakeholder to initiate the digital twin, e.g. after a modification or for the insertion of a component that is already in circulation. As every stakeholder needs access to the digital twin, the OEM is also responsible for marking the physical asset with the identifier used for the digital twin.

The last role is the DT User. Every stakeholder can be a user as well. The user can request data from the respective digital twin. To find all data collections corresponding to a physical asset, the user transfers the ID to the DT Registry, which returns the list of collections to the user. This list includes the IP’s of the DT Web Server and the ID’s of the Collections on the Servers. Additionally, some meta data would be transferred like the data of the last modification of the collection and the type of data within the collection.

These roles lead to the required two different server architectures. At first the DT registry is required in which each physical component is registered. The registry serves as an "address book" and contains the addresses of the relevant DT web servers for the respective components. This allows all storage locations of data for an asset to be identified. The registry should include the address, data type, involved stakeholder, data set identifier and date. The second hardware element is the DT web server. There is one for each stakeholder in the overall system. The real data sets, such as design data, operating data or maintenance data, are stored on this. Whenever a new data set is created, it must be registered in the DT Registry.

For safety reasons, the aviation market is very heavily regulated. This also includes the specifications for the stakeholders involved in the air transport system in addition to many specifications for the design or the execution of flights. All key stakeholders require certification for their role within aviation. It is also possible to take on several roles in one company. In the field of maintenance, the component area goes down to the capability list level, which describes exactly for which part number the company is authorized to carry out maintenance. This enables a simple access right implementation. A maintenance company can then receive the access according to their capability list.

In order to enable data-driven maintenance, not only the access rights between the companies have to be regulated, but also the remuneration for the use of data or digital services. A four-part approach would be conceivable:

1. Data that can be used free of charge by any stakeholder.
2. Data that can be used free of charge by the relevant stakeholders (e.g. maintenance data can be used by the MRO).
3. Data usable for data usage fees.
4. Data that cannot be used but belongs to the digital twin for completeness.

The first category encompasses all meta data for the data sets stored in the digital twin. With this data it is possible to map the digital thread of an asset. However, it does not contain any operational data or parameters. All aviation law certificates are stored as a data record. This allows the life of an asset relevant to aviation law to be mapped.

The second category entails data that is necessary for the relevant stakeholders to carry out their activities. For logistics companies, for example, this could be the data relevant to transport. For the MRO it could be the manufacturer’s documentation and the damage history of a component. Overall, this category would contain data that associations (IATA, ICAO) or authorities (EASA, FAA) consider necessary to enable the most efficient possible air transport system. There will be data in this category that can also be obtained from other data sources, such as trajectories or weather data bases. It is very likely that in the proceeding field of prescriptive and predictive maintenance more data will be released on a mandatory basis.

The next category includes data that does not fall into the second category and it is allowed to be monetized by the various stakeholders. This can be paid design data or test bench data or time series. By this means other stakeholders can then offer digital services or products for the physical assets. Different payment models would be conceivable, such as a flat rate between two stakeholders, pay per use, or pay per data set. The data market for the digital twin should keep various options open to support individual models.

In the last category there is data that is generally not offered on the data market in order to protect the respective business models of those involved. This can be very specific detailed design data, test data or process data over the entire life cycle. However, changes in the respective legislation may result in data being shifted to other categories. An example could be the ecological process data.

In addition to the identifier for the asset, each entry in the Digital Twin Registry contains the identifier of the data set, the address of the data set and the description of the data set. Every time a new data set for an asset is generated by a stakeholder, a new entry must be created in the Digital Twin Registry. This could also be after the interaction with the component is finished. As an example, after all maintenance actions are performed, all data accumulated during maintenance is stored. At the same time, the hierarchical relationship between assets must be mapped. This includes the mother-child relationships but also the formation of assemblies.

Preference would be given to identifiers that would not be able to query mass data from the distributed digital twin. If individual UUIDs are used for the components, it is very unlikely that one could call a specific component. Only the manufacturer of the component, who creates the digital twin for the first time, could then call up "his" components in a targeted manner. All other stakeholders would only come into possession of the ID upon receipt of the physical component and, due to the large number of random combinations, would only then have access to the component data. Accordingly, it would be necessary to physically link each component with the respective UUID. The new UUID needs to be included on the nameplates.

6.3 Digital Twin Example

When a component is manufactured, the manufacturer of the component creates the initial entry in the DT registry. The ID (in this example the proposed UUID) needs also to be physically added to the component ideally machine readable with an RFID tag or a bar code. For example, the entry in the registry could look like this (all entries are examples):

```
UUID Component:                 de710a84-46bb-47a0-a563-06eb6266155f
UUID Data Set:                  ec2cba2b-705a-4f81-b772-df934efb9f19
IP Address first Data Set:      126.58.78.219
Data Type:                      Design Data
Stakeholder:                    Design Company
Date:                           24.05.2020
```

This information would now point to the first DT document in the Design Company's DT Web Server. The following data could be available there, for example:

```
UUID Component:                 de710a84-46bb-47a0-a563-06eb6266155f
UUID Data Set:                  ec2cba2b-705a-4f81-b772-df934efb9f19
Part Number:                    PN1234
Serial Number:                  S123
Name:                           Asset 1
Date of MFR:                    24.05.2020
Design Document:                PN1234.cad
…
```

The minimum requirements for the data must be defined via standardization and the needs of the stakeholders. Once manufactured, the component is installed on an aircraft. This is done at an MRO. For this purpose, another entry is created in the DT registry under the same UUID.

```
UUID Component:                 de710a84-46bb-47a0-a563-06eb6266155f
UUID Data Set:                  c6829bcf-8053-4b76-8052-4eac8681b3b9
IP Address first Data Set:      150.85.153.135
Data Type:                      Maintenance
Stakeholder:                    MRO1
Date:                           24.06.2020
```

This entry points to a new record:

```
UUID Component:                 de710a84-46bb-47a0-a563-06eb6266155f
UUID Data Set:                  c6829bcf-8053-4b76-8052-4eac8681b3b9
Part Number:                    PN1234
Serial Number:                  S123
Name:                           Asset 1
Date:                           24.06.2020
UUID Parent:                    e120dcb8-64f9-4b04-ac2f-184d4d7d012c
Document:                       EASA Form One.pdf
…
```

This procedure is repeated for each additional data record that is created in the life cycle of the component. At the same time, other digital twins can be referenced. In this way, for example, the operating data about the aircraft can be called up.

7. Conclusion and Outlook

A digital twin can only be successful if it considers the needs of the individual stakeholders of the aviation system. In doing so, the balance between open data and interfaces must be maintained in relation to the protection of business models and security. In this paper, 13 basic requirements for a future system of digital twins were developed. An architecture based on a distributed digital twin web was then developed. The peculiarities of aviation maintenance were presented. Since aviation as such is very limited and there are laws, requirements and standards for many areas, this must also be developed for the digital twin. This is the only way to ensure that a new system can take over the existing tasks and that new functions can be implemented with security in mind. The use of digital twins supports the development of new digital business models / services and further develops the change to intangible goods in the component area. Important points for further development are, in particular, the standardization of digitalization and the entire issue of security. This not only includes dealing with external threats, but must also include dealing with missing or incorrect data entries. It must also be ensured that the data cannot be changed later.

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10. Copyright Statement

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