MRO Industry Fundamentals

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Authors: Dr. Michael Frank, Jonas Fornaçon

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I. Purpose of this Document

The purpose of this document is the documentation of the status quo of business processes around aircraft maintenance documentation.
The reader even if he has little or no knowledge of the airline maintenance industry should be able to understand why and when aircraft part repairs need documentation and how that is done in most of the industry in 2021. This introduction document is finished with some examples of these documentations.
As a side effect the document describes the basic principles of the airline maintenance, repair and overhaul market. This is necessary to understand the context of the described business processes.

1. Aviation and MRO General Introduction

1.1. Aircraft Structure Overview

Modern commercial aircrafts are built of around 3 million parts. From a maintenance point of view a certain classification of these parts is standard. Most of these parts are consumables and expendables (C&E or CUE). These are screws, bolds, sealing rings and the like as well as smaller devices that are usually not repaired due to their low value. The next bigger part group is the engine. Blades and all parts of the turbine belong to that group.
Obviously visible from the outside are the airframe parts. Another group of parts is defined by the landing gear. And finally, a diverse group called components. From the seat, the entertainment system, the board computer or the auxiliary power unit everything is a component. Within the components there are sub-groups such as line replaceable units (LRU) and airframe related components (ARC). LRU are parts that can be replaced mostly without tools on the spot. Airframe related components are parts that are linked to the outer haul but not directly a part of it. In example an engine mount.

1.2. Reasons and Goals for Maintenance, Repair and Overhaul

In aviation, there are various goals and reasons to perform Maintenance, Repair and Overhaul (MRO) measures on an aircraft or its components. The most significant reasons are

- Safety and airworthiness,
- Reliability,
- Economic optimization and
- Passenger comfort and appearance.

1.2.1. Safety and Airworthiness

Safety and airworthiness are the most obvious and classical reasons to carry out MRO measures. As the aviation industry is very sensitive to safety due to passengers lives at stake in case of an accident, a high level of safety regulations exists regarding operating and continuously maintaining the entire aircraft.
An aircraft or component is only allowed by aviation authorities to operate, if it is in a safe technical condition and therefore demonstrates its so-called airworthiness, which is confirmed and documented by the receipt of a valid current airworthiness certificate.
This results in the need to continuously perform MRO tasks on your entire aircraft and components. Starting after delivery to an aircraft operator (with an initial airworthiness) and first flight, an aircraft then continuously receives MRO measures in order to be always in a safe technical condition and uphold its airworthiness status. Without this airworthiness status, an aircraft is not allowed to legally operate. The following chapters will go more in detail about the roles and responsibilities regarding MRO measures of manufacturers, aircraft operators, MRO providers, international organizations and authorities.

1.2.2. Reliability

Secondly, reliability is a major reason as why airline operators are performing MRO measures. While safety and airworthiness focus on the aircraft making a safe overall journey, the focus when addressing reliability of an aircraft mostly concerns the dispatch of an aircraft (time before taking flight). Without a reliable aircraft, airlines must deal with cancellations and delays due to arising technical issues. This influences many aspects of their business, i.e., on their operations (on-time performance/ punctuality, flight plans, aircraft and crew rotations, etc.) or their economics (revenue loss due to passenger compensations, higher costs for unforeseen and emergency MRO measures - referred to as “aircraft on ground” (AOG), etc.). Therefore, most airlines have an extensive aircraft reliability program in place to ensure aircraft technical dependability and to achieve the highest level of aircraft dispatch reliability.

1.2.3. Economic Optimization

The third mentioned reason for MRO measures is economic optimization. A planned maintenance task usually leads to overall less economic costs than an unplanned, unexpected emergency task resulting in the worst case in an AOG (see above paragraph “reliability”). An optimized plan of MRO measures, referred to as an airline’s maintenance program, can drive maintenance costs down for example by avoiding high-cost repairs before a component or structure becomes severely damaged (or in the worst-case scrap) or by planning MRO measures long term and thus driving purchasing or sourcing costs down. On the other hand, MRO tasks performed too early or more often than actually necessary lead to overall higher costs. With this is in mind, the design of a maintenance program is a complex undertaking for which engineers are trying to find an optimal solution under technical and economic aspects. Consequently, a sophisticated maintenance program can give an airline an economic advantage against its competitors.

1.1.1. Passenger Comfort and Appearance

Passenger comfort and appearance are also a reason why airlines perform MRO measures. The external appearance of the aircraft, the comfort offered to passengers and the perceived technical condition shape the reputation of a company and hence, to a certain extent, its economic success.

1.2. Definition of Maintenance, Repair and Overhaul

1.2.1. Maintenance

Maintenance can be defined as the preservation of the aircraft's operational capability until the next overhaul event. (Hüttig, 2009, p. 47). This includes measures such as inspections/ checks as well as for example refilling of hydraulic fluids or application of lubricants. Repairs, overhauls and modifications are outside this maintenance definition.

1.2.2. Repair

The purpose of a repair is to restore the serviceability of a component or structure that has become defective. The serviceable condition can be restored by direct machining of the defective structure of the aircraft or component or by the replacement or exchange of subunits within a component (Hüttig, 2009, p. 48).

1.2.3. Component Change

Due to the modular structure of many aircraft systems, it is possible to remove and reinstall certain equipment, assemblies or parts. The replacement of defect/ unserviceable components is called a component change. This procedure is particularly important in aircraft maintenance because it can be carried out quickly and the aircraft is ready for operation again within a short time (Hüttig, 2009, p. 48). The defect parts that were removed can then be send to a workshop for repair, which can be carried out with extra aircraft downtime.

1.2.4. Overhaul

An overhaul pursues the goal of creating an approximately as-new condition of the object being worked on. In aircraft maintenance, the term is a combination of the previously listed terms maintenance, repairs and component changes and can even include modification measures. Overhauls play an important role in maintenance and in this process, parts of systems are disassembled, and a near-new condition is produced under high labor intensity.

In comparison, the FAA defines an overhaul as “The disassembly, cleaning, inspection, necessary replacement or repair of parts, reassembly, adjustment, and testing of an item or equipment in accordance with recommended procedures.” (Federal Aviation Administration, 2021b).

1.2.5. Modification

Modifications are changes and retrofits made to improve the technical characteristics of an aircraft, as well as to maintain its airworthiness. They are usually instructed by the aviation authority or the manufacturer and can be carried out by the manufacturer itself or by approved maintenance organizations. Modification instructions are for example issued by:

- Service Bulletins (SB)
- Engineering Orders (EO)
- Airworthiness Directives (AD)

Special cases of modifications are so called “VIP Completions”. These modifications do not aim at technical improvements of the aircraft, but focus i.e., on military/ government, scientific or cabin (comfort, design) modifications. Every modification must be approved by the respective authority and must be documented.

1.3. Maintenance Approaches

There are two principal forms of maintenance approaches that can be differentiated. These are the scheduled (preventive) maintenance and the unscheduled (corrective) maintenance.

1.3.1. Scheduled (preventive) Maintenance

The scheduled (preventive) maintenance approach can also be referred to as "Hard Time Maintenance". At the core of this approach are fixed intervals based on different indicators after that a preventive maintenance measure is carried out. The part or component shows no sign of defect at the point when the maintenance task is performed. It is a planned, preventive measure. The time between these maintenance measures is also referred to as "time between overhaul" (TBO).

Aircraft parts that underly the preventive maintenance approach (and therefore have a so called "hard time limit") are often critical for the overall safety of the aircraft or are parts where a defect leads to significant costs. The measure can range from maintenance tasks to a complete change of a component or system (see section 1.2 for definitions). If there is a mandatory replacement period for a part set by the OEM or through other regulations, these parts are referred to as "**Life-Limited Parts**" (LLPs) and naturally are subject to scheduled maintenance as well.

The IATA Aircraft Leasing Technical Group describes these parts as follows:

"An LLP is a part with a hard limitation. LLPs can be found on aircraft or on engines. At the time the aircraft or engine was designed, the design approval applicant identified certain parts as having limits, and those limits were approved by the certifying authority. When the LLP has reached its limit, the part may no longer be used (absent a change, such as a life-extension program)." (IATA Aircraft Leasing Technical Group, 2020)

There are three main indicators that are used to define the preventive maintenance intervals.

The first indicator is based on **calendar time** which means that a certain maintenance measure must take place after a certain amount of calendar days.

This indicator is often used in planning when a constant aircraft utilization can be predicted and the wear of the entire aircraft follows homogeneous patterns (e.g., a narrow body aircraft, such as an A320, performs nearly the same amount and equally long short flights each day or each week). Another case are structures or components that consist of certain materials for which the wear can be approximated well and that are not subject to other influencing factors (e.g., larger metal structure or evacuation slides - latter ones are subject to a hard time limit and need to undergo preventive maintenance, even though they are not used, to check that their packaging does not show any sign of wear and to switch the canister of compressed gas that boost the initial inflation process).

The second indicator are **flight hours** which simply means the time an aircraft spent in the air flying. These are relevant for instance on engine parts that are only operating and in use during flight.

The third indicator are the number of take offs and landings, a pair of which is referred to as a "cycle". The **cycles** are a relevant indicator for maintenance measures especially for parts that are heavily under load/ used during a start or a landing (e.g., a thrust reverser or a landing gear is not under load during flight but must withstand during landing or at the point of touch down a sudden spike in high load).

Often the flight hours and cycles both apply together as many parts are affected by both (e.g., an engine is under its maximum operational capability during take-off and thereafter operates mostly at cruising speed during flight. Once the aircraft is on ground, no significant usage takes place). The term "times and cycles" often used in relation to components refers mostly to this combination of flight hours and cycles.

Although the scheduled (preventive) maintenance approach shows a very good plannability and fault resistance, the number of hard time components and the share of scheduled maintenance tasks has over time in general decreased due to inflexibility in maintenance planning as well as the higher costs involved.

1.3.2. Unscheduled (corrective) Maintenance

The unscheduled (corrective) maintenance approach is commonly referred to as "on condition" maintenance. Errors, faults and even failures of components are accepted with this approach. The defective parts will be added to the work to be performed at the next fixed maintenance event. This maintenance approach of course can only be applied to components or systems that have no effect to airworthiness and/or have multiple redundant backup components or systems and thus have no flight critical effect if a failure occurs.

The maintenance event thus takes place only after an error, fault or failure has occurred. The differences to the scheduled (preventive) maintenance approach are less fixed intervals and less planned work. This leads to generally lower maintenance costs as well. Adverse effects are potentially higher repair or overhaul costs once a component shows a defect. For these parts it is essential to make a data driven decision on the optimal maintenance point of time.

This leads to an industry practice referred to as "condition monitoring". It's a method that evaluates continuously technical parameters of a designated component or system. The condition monitoring of engines is a prime example for this method. During flight, most of the engine's components are monitored and provide live data. This enables the airline to initiate maintenance events already during a flight so that a component that shows a malfunction, defect, or seems to be close to becoming defective can be replaced at the next airport – if necessary.

A special case regarding unscheduled maintenance is the "Aircraft On Ground" (AOG), which can be defined as an unplanned technical grounding that causes a delay or even makes it necessary to change an aircraft (IATA, 2018, p. 14). This is the case if a component or system becomes defective that affects the airworthiness of an aircraft. The effect is shown in the following illustration:

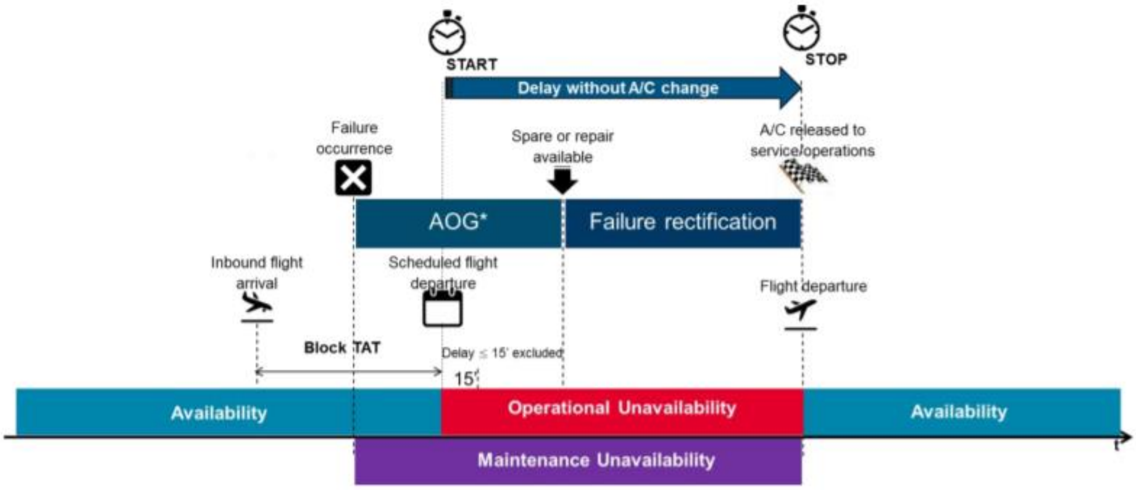

Figure 1: Unplanned technical grounding – Delay without A/C Change (IATA, 2018, p. 14)

The costs involved and the resulting complexity of an AOG can be quite high. The obvious costs are potentially higher repair costs or additional costs for a acquiring a spare part or for the repair, compensations to customers due to delay, in the worst case even costs for changing the aircraft and costs that occur in the operational planning (i.e., necessary crew rotations due to working time restrictions, following delays of flights if the AOG flight is a feeder for a long-distance flight, aircraft rotational planning adjustments, parking or airport slot fees, etc.). Due to these effects, a lot of airlines rely on the scheduled (preventive) maintenance approach to avoid the high complexity and opportunity costs of an AOG.

1.4. MRO Players and relevant Organizations

The maintenance sector of the airline industry is big business. According to published statistics the hole sector was 81.9 B$ (see IATA) before the COVID crises.

1.4.1. MRO Providers

1.4.1.1. OEMs

The original equipment manufacturer (OEM) is an abbreviation used for the developer and constructor of a part. It is used for companies like Boeing and Airbus as constructors of the complete aircraft body. GE and Rolls Royce are developing and constructing engines and therefor OEM. The term is neither limited to a specific part of the aircraft nor does it require that a minimum number of different parts are developed by the company called OEM. When it comes to maintenance most OEMs are limited to the delivery of replacement material in condition New.

1.4.1.2. MRO companies

MRO are the once solemnly focused on the maintenance. They can be divided into full-service providers and repair shops. The full-service providers like Lufthansa Technik in Germany over the full spectrum of maintenance tasks. They offer line and base maintenance, repair engines, components and all other parts of the aircraft. In many cases they of an engineering department to develop repair procedures and replacement materials

on their own. Airlines contracting the full service of these providers only need a minimal staff in the maintenance area focusing on contracting, audits and documentation.
The full-service providers are not only attractive due to their service portfolio. There are significant cost scaling effects with each aircraft under contract. In order to achieve a cost-effective maintenance operation a certain fleet size is required.
Besides the full-service providers there are many shops focusing on various parts of the business. Many MRO companies focus on a specific part spectrum to perform repairs. There are companies just for the engine side or just for components.

1.4.2. MRO Customers

1.4.2.1. Airlines

As the airline industry started after World War 2 most airlines bought the planes and organized the maintenance on their own. With more complex aircrafts and more and more heterogeneous fleets this model needed to change. Today most airlines only operate the aircraft and trust the maintenance with a full-service provider. Since the regulations for an aircraft operator certificate (AOC) still requires a postholder maintenance whose responsibility is the airworthiness of the aircrafts a small group of people inside the airline remain entrusted with maintenance. They often only negotiate contracts, perform audits and monitor documentation.

1.4.2.2. Lessors

Many airlines to not own the aircraft that they are operating. Instead, the aircraft are leased from lessors. It depends on the contract between the airline and the lessor if this has an impact on maintenance. Many contracts do at least give certain restrictions for the maintenance procedures. Sometimes the lessor itself organizes the maintenance.

1.4.2.3. Parts Trader

There are numerous part traders in the industry. Everything from the small shop with a garage as storage in the backyard to big trading company with a billion-revenue figure falls in this category. There are companies just founded to market the material from an aircraft tear down to vendors that exclusively operate for certain airlines.
Buying and selling aircraft material is still a very old-fashioned business. There is still today no amazon like internet-based platform. Parts are marketed mainly to a platform called ILsmart that just lists items with contact information. Deals are still closed via phone and email. That triggers a lot of these traders to list material they do not have but will try to get in case a request comes in.
Another common problem in the industry are gold diggers. These traders just hold a few parts that are rarely needed. Trusting that nobody else has the material they are waiting for the right moment – usually an AOG situation – to sell the parts with outrages margins.

1.4.3. Organizations

1.4.3.1. ICAO

The International Civil Aviation Organization (ICAO) is located in Montreal and is a United Nations specialized agency. It is funded by 193 nations to support diplomacy and cooperation in air transport among them. Its main tasks are to support the “[...] diplomatic interactions, and to research new air transport policy and standardization innovations” (ICAO, 2021). Once policies or standards for innovations reach a consensus among all countries, it is not directly binding law but has to be adopted by the national lawmaking authorities.

1.4.3.2. IATA

"The International Air Transport Association (IATA) is the trade association for the world's airlines, representing some 290 airlines or 83% of total air traffic" (IATA, 2021). IATA's mission is to foster an understanding of the air traffic industry among decision makers, regulators and governments, advocate for the interests of the airline industry regarding rules, charges or regulation, develop global commercial standards and provide professional support.

1.4.3.3. EASA

The European Union Aviation Safety Agency (EASA) is the aviation regulatory authority of the European Union. The agency was established in 2002, is headquartered in Cologne and has 31 member states (EU + Switzerland, Norway, Iceland, Liechtenstein). The main tasks of the agency are stated as follows (EASA, 2021b):

- "Draft implementing rules in all fields pertinent to the EASA mission
- Certify & approve products and organizations, in fields where EASA has exclusive competence (e.g. airworthiness)
- Provide oversight and support to Member States in fields where EASA has shared competence (e.g. Air Operations , Air Traffic Management)
- Promote the use of European and worldwide standards
- Cooperate with international actors in order to achieve the highest safety level for EU citizens globally (e.g. EU safety list, Third Country Operators authorizations)"

EASA's implementing rules and policies represent general European law and are directly applicable in all member states. The national civil aviation authorities, such as the Luftfahrt-Bundesamt (LBA) in Germany, are then responsible to implement the rules, to ensure supervision and even carry out certain tasks on behalf of the EASA.

1.4.3.4. Luftfahrt-Bundesamt (LBA)

The LBA is the Federal Aviation Office with headquarters in Braunschweig. It was founded in 1954 and is - among other tasks - responsible for

- the approval and supervision of the aviation industry in Germany (limited to design, manufacturing and maintenance organizations),
- for approvals and oversight of commercial operators and their aircrafts in operation,
- for licensing of airline transport pilots. (Luftfahrt-Bundesamt, 2021)

The LBA also participates in the further development of aviation regulations on national level that are in then enacted by the Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur).

1.4.3.5. Federal Aviation Administration (FAA)

The FAA is the US aviation authority and the counterpart to EASA and the LBA. Their mission is to "provide the safest, most efficient aerospace system in the world" (Federal Aviation Administration, 2021c). In that regard, the FAA regulation is worldwide often standard setting and many other national aviation authorities adopt rules and regulations from the FAA. Regarding EASA and the FAA, both strive for a tight alignment and collaboration as there is a close connection between the EU and US due to the air traffic and trade volumes. In the context of aviation rules and regulations, the FAA will be often mentioned and referred to in addition to EASA. Both are the most influential and important agencies for the aviation industry.

2. MRO Process Overview

The following sections provide an introduction on how MRO events are structured and how repairs or overhauls are carried out in the industry. First, the concepts of Line and Base Maintenance are explained followed by an overview of component change, repair and overhaul processes.

2.1. Line and base Maintenance

In the aviation industry, maintenance of aircraft is split into two terms referred to as line and base Maintenance. When looking at their complexity for instance, line maintenance events are less complex in nature than base maintenance. The aim of line maintenance events is usually the preservation of the target technical state of an aircraft and includes maintenance tasks while the aircraft is still scheduled for operation.

EASA's Acceptable Means of Compliance (AMC) documentation 145.A.10 defines **Line Maintenance** as follows (EASA, 2015):

> "Line Maintenance should be understood as any maintenance that is carried out before flight to ensure that the aircraft is fit for the intended flight.
>
> Line Maintenance may include:
>
> — Trouble shooting.
>
> — Defect rectification.
>
> — Component replacement with use of external test equipment if required. Component replacement may include components such as engines and propellers.
>
> — Scheduled maintenance and/or checks including visual inspections that will detect obvious unsatisfactory conditions/discrepancies but do not require extensive in depth inspection. It may also include internal structure, systems and powerplant items which are visible through quick opening access panels/doors.
>
> — Minor repairs and modifications which do not require extensive disassembly and can be accomplished by simple means."

For **Base Maintenance** tasks, an aircraft is taken out of the rotational planning of an airline undergoing substantial measures to restore the target technical state. The amount and depth of work, duration of the event and qualification requirements for mechanics in base maintenance are therefore much higher than in line maintenance.

Line and Base Maintenance events are structured into so called “letter checks”. The following example provides a comparison of letter checks for a wide body aircraft (Hinsch, 2019, p. 223):

Table 1: Wide Body Aircraft Letter Checks

Check	Interval	Man hours	Duration
Line Maintenance			
S-Check	Weekly	10 – 50	3 – 5 hours
A-Check	Every 4 - 8 weeks	50 – 250	Approx. 12 hours
Base Maintenance			
C-Check	Approx. every 18 months	2000 – 5000	1 – 2 weeks
D-Check	Every 6 – 10 years	30.000 – 50.000	4 – 8 weeks

2.1.1. Line Maintenance Procedures

Line Maintenance procedures start to take place once the aircraft has landed and reached its parking position at the designated terminal, hangar or ramp. As the times for line maintenance events are short and the aircraft is designated to return to its operational service, not all defects are rectified if not necessary. These defects will be rectified when the next larger maintenance event takes place and are referred to as “Deferred Defects”. In case a defect cannot be deferred, and the aircrafts airworthiness is at risk, the aircraft has the status “Aircraft on Ground” (AOG) and the defect needs to be rectified as quickly as possible to avoid long delays.

Once all necessary tasks of a Line Maintenance event are performed or deferred, a mechanic with the respective qualification level must issue a so called “**Certificate of Release to Service” (CRS)** document. With that CRS document, the aircraft is ready to return to operations and start its next flight.

CERTIFICATE OF RELEASE TO SERVICE

[APPROVED PRODUCTION ORGANISATION NAME]

Production organisation approval Reference:

Certificate of release to service in accordance with 21A.163(d).

Aircraft: .... Type: .... Constructor No/Registration: ....

has been maintained as specified in Work Order: ....

Brief description of work performed:

Certifies that the work specified was carried out in accordance with 21A.163(d) and in respect to that work the aircraft is considered ready for release to service and therefore is in a condition for safe operation.

Certifying Staff (name):

(signature):

Location:

Date: .. - .. - .... (day, month, year).

EASA Form 53

Figure 2: Certificate of Release to Service - EASA Form 53 (European Commission, 2012)

2.1.2. Base Maintenance Procedures

Base Maintenance is often also referred to as “heavy maintenance” because the technical depth of work performed is much deeper and more complex than in Line Maintenance. As an example, during a Base Maintenance event the engines, landing gears, complete cabin equipment (Chairs, galleys (kitchens), entertainment system, overhead bins, etc.), and further components (avionics, hydraulics, etc.) are usually removed and either replaced or repaired/ overhauled. The aircraft will be docked in a hangar so that these tasks can be performed. Due to this complexity, a Base Maintenance event needs thorough planning and preparation in advance to manage all scheduled tasks:

- preparation and coordination of job cards/ sequence of maintenance tasks performed,
- ensuring qualified and sufficient personnel is available,
- procurement of material/ Spare components in advance,
- ensuring all equipment (docking, tooling, engine stands, etc.) needed is in place.

Once the aircraft arrived in the hanger, it is jacked up and docking platforms and scaffolds are put in place so that all performed work can begin. The so-called **routine work** (tasks that were known beforehand during the planning phase that need to be performed) as well as inspections start. Inspections always discover additional defects or tasks that need to be performed. These are called **non-routine work** and MRO providers try to identify these as early as possible because they can lead to additional material needed, long repair or overhaul times or additional qualified staff or tooling needed. All these can have a significant effect on the duration and total costs of the Base Maintenance event.

Once all defects are identified, rectified and all removed parts come back repaired/ overhauled from the shop or the replacement part is available, everything is put back together with respective quality assurances. Every repair performed on the aircraft and every part that is installed back on the aircraft must be installed correctly as well as show the relevant documentation where necessary. Finally, the Base Maintenance event ends again with the issuance of a CRS and the handover of the aircraft back to the customer.

2.2. Component Change (New Parts / Surplus)

As described in section 1.2.3, component changes play a significant role in aircraft maintenance. Instead of performing a repair on an installed component that is still in the aircraft, it is from an economic perspective often better to remove the unserviceable component and replace it with a serviceable one. The duration of the aircraft's ground time is often highly reduced this way.

When changing a component, the replacing part can be an Original Equipment Manufacturer (OEM) new part, a "Part Manufacturer Approval" (PMA) new part or a surplus part.

Component Sources

OEM parts are parts, which comprise the initial (original) equipment when first designing an aircraft. As Airbus or Boeing act as integrators, their aircrafts original equipment is not only designed or manufactured by themselves, but also second tier OEMs (e.g. GE, MTU, Bombardier, Safran, …) supply components or whole assemblies, such as the engines.

PMA is defined by the FAA as "[…] a combined design and production approval for modification and replacement articles. It allows a manufacturer to produce and sell these articles for installation on type certificated products. […]" (Federal Aviation Administration, 2021a). The manufacturer can supply parts that are not original equipment but fulfill all requirements. Economically, these are often much less expensive compared to OEM parts.

Surplus parts are components that were pre-owned and, in most cases, have been installed and in use on an aircraft. They can be OEM or PMA parts. Surplus part conditions are mostly stated as follows:

- As removed:
  Without any test or inspection performed after removal from an aircraft. Also referred to "as-is".
- Serviceable:
  Part is in a condition to be installed on the aircraft with the respective necessary documentation. What maintenance measure has been performed (test/ inspect, repair, overhaul) is not specified. All following conditions are to be considered "serviceable" parts and provide only more detail on the performed maintenance measure.
- Repaired
- Overhauled
- New Condition/ New Surplus:
  A part that was not in use yet, but does not come directly from the OEM. This applies often to parts that are traded by component distributors / part traders or that were in an airline's inventory but never were in use.

The value of a surplus component is closely correlated to its condition. As removed parts show the lowest costs but bear the risk of high-cost repairs or could even be scrap. Also, an overhaul is usually superior to a repair because it restores a near-new condition.
Other parameters, such as flight hours, cycles, hard times, a part's repair/ overhaul history, operating airline, area of operation (e.g., "hot and sandy" in desert regions), also affect the value of surplus parts and have to be considered in the purchasing process.

Component Change Process

Within the component change process, two ways can be differentiated: "Closed Loop" and "Open Loop".

Within a **closed loop** component change process, the aircraft receives again the same component that was removed from the aircraft after the maintenance measure. After removal from the aircraft, the component is sent to a workshop for a repair or overhaul event. Once the component was successfully repaired or overhauled, it is sent back to the aircraft for installation. Hence the name closed loop.

As this process involves a lot of waiting time for the aircraft (removal, transport to workshop, time in workshop, transport to aircraft, installation), the closed loop process usually takes places only when the aircraft is in a longer or heavy maintenance event and therefore is not in operation for a prolonged time that allows the component to go through the closed loop and come back in time for the relevant installation job.

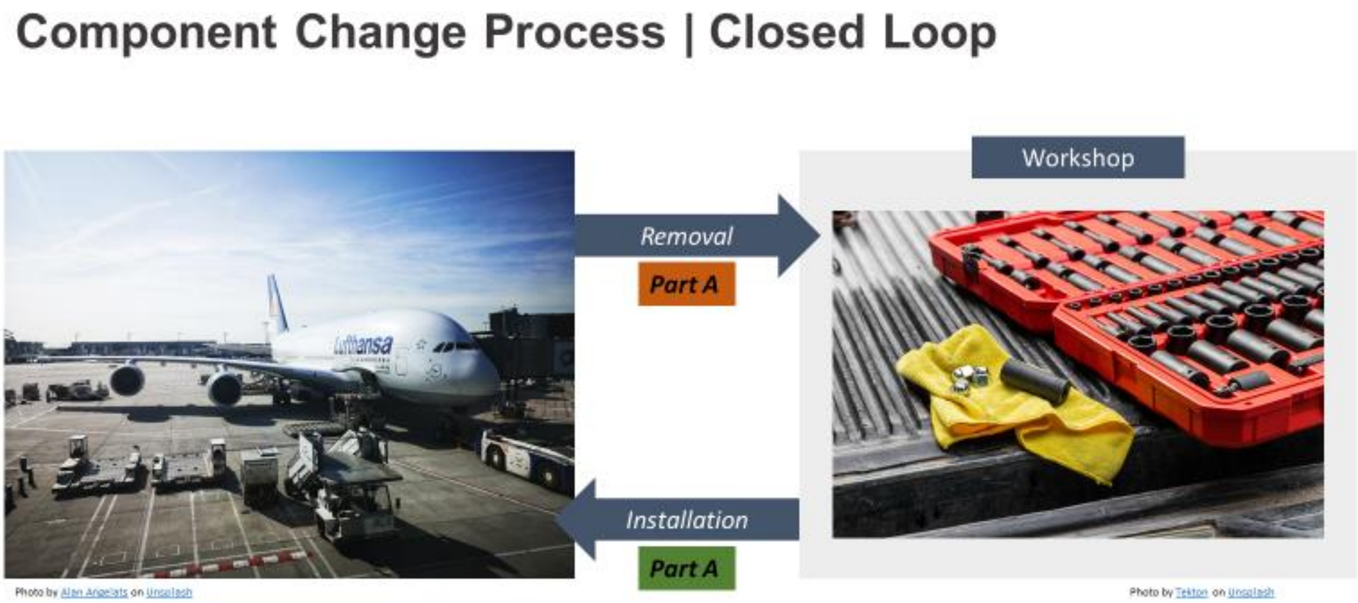

Figure 3: Component Change Process | Closed Loop

The **open loop** process addresses the issue of the closed loop process regarding the waiting time. In an open loop, a component or part A is removed from an aircraft and another part B is installed. This is done in sequence usually by the same mechanic removing part A and then immediately installing part B. The aircraft is operational within a short period of time again and part A can be induced to the workshop without any time pressure.

A prerequisite for the open loop process is either an internal component inventory or an external component pool provider.

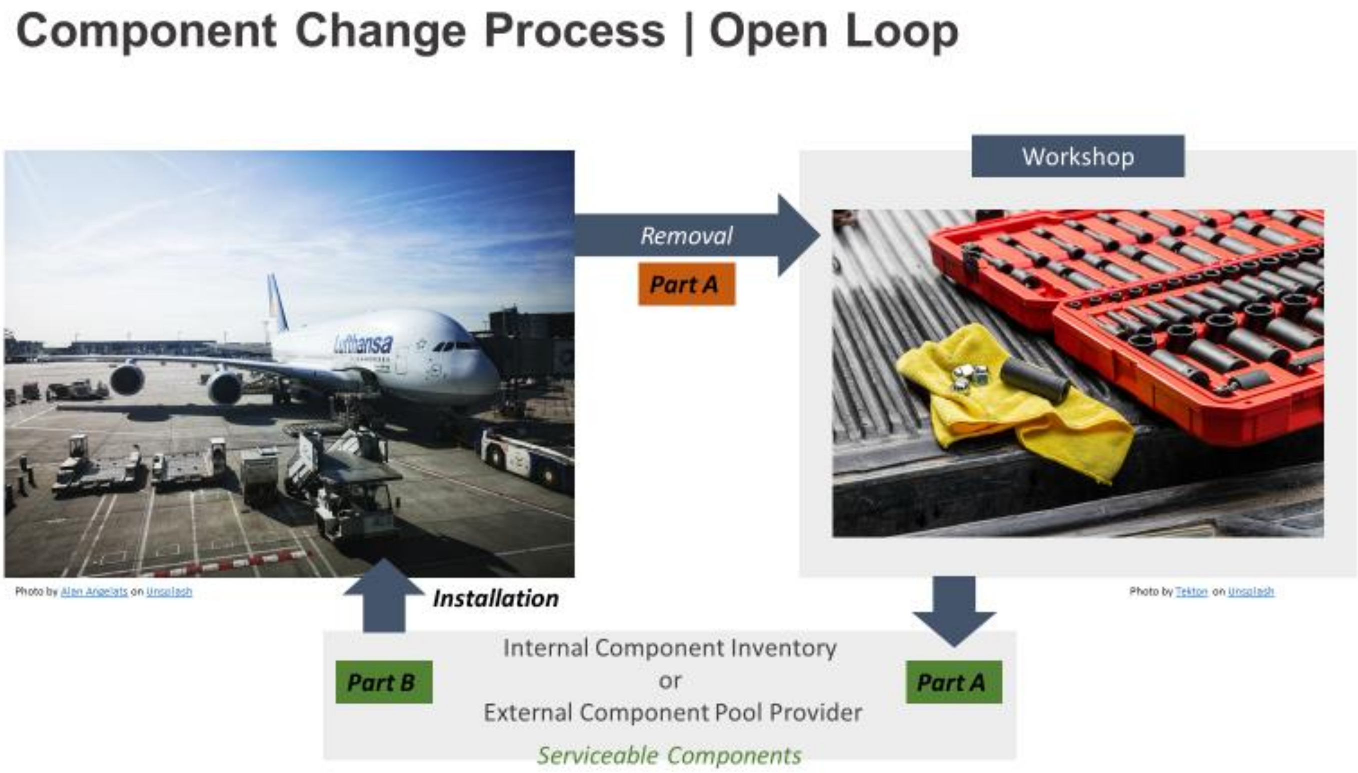

Figure 4: Component Change Process | Open Loop

External component pool providers operate large aircraft component pools, making use of significant economies of scale. Geographically, the material is stored in warehouses worldwide so that it can reach customers within a defined timespan. The material selection for the pool, stock levels, regional distribution, logistics and maintenance of all pool components are all managed by the pool provider.

Customers can buy access to these pools and various service levels exist. The full-service levels usually include 24/7 access to all types of components and worldwide material stocks, transportation and delivery within a pre-determined timespan and further options such as home base stocks (dedicated customer material stocks at their preferred or main airports or location, thus “home base”) or AOG component support. From an IT perspective, these component pools can be compared to cloud computing with its different IaaS, PaaS or SaaS products, being a “component as a service”. Customer benefits are very similar to cloud products, mainly being predictable and less costs, investment and complexity by outsourcing of their material inventory.

Instead of purchasing a component pool contract, products from material providers for a single exchange or loan of a component exist. In case of an **exchange**, the unserviceable component is exchanged for a serviceable component that can be installed on the aircraft. The material provider (often also pool providers) keeps the unserviceable component and either repairs it or scraps it. In case of a **loan**, the component is delivered to the aircraft and installs. When a replacement component is available, the loaned component is removed and sent back to the material provider in unserviceable condition (Mensen, 2012, p. 738).

2.3. Repair and Overhaul Processes

Where Line and Base Maintenance have the entire aircraft as subject, repairs and overhauls also take place for aircraft systems, parts, or single components. These processes are often comparable to a base maintenance event, but are on a smaller scale and are less complex (think of a Base Maintenance event being comprised of hundreds of these smaller component repair events). This section looks at component repair and overhaul processes as well as engine / landing gear repair and overhaul processes as these are their own domains due to their technical complexity.

2.3.1. Components

Repair of components can take place on the aircraft, or often so-called “on-wing”. As this is a less complex case and usually can only be done for simpler repairs, the removal and repair process in a workshop of a component is in the following described.

In a workshop, specially qualified mechanics, testing, tooling and other equipment are available. Usually there is a differentiation between avionic and mechanic workshops. Also, Landing Gears and Engines have in general their own shops.

The first step in the repair/ overhaul process is the removal of a component from the aircraft. Directly upon removal, the component has to be marked with an unserviceable tag and shall be separated from serviceable components during storage and transport.

After arrival in the workshop, the defect component is loaded into the workshop and incoming inspections are performed to determine the cause of the defect. Performed inspections depend on the component and range from electronical tests, non-destructive testing (NDT, i.e. ultrasonic, x-ray, fluorescent liquids, etc.) to mechanical tests.

With the results of the inspection, the actual repair or overhaul can take place (for a differentiation of repairs and overhaul, see section 1.2.2 and 1.2.4). In case the inspection result shows that a repair or overhaul is either technically not possible or economically not reasonable, the component will be scrapped with subparts of it to be utilized or recycled.

The needed tasks to repair or overhaul a component have to be carried out in accordance to the **Component Maintenance Manual** (CMM). This is a document issued by the manufacturer of the component with detailed technical instructions for the mechanic to carry out maintenance measures. Once the repair or overhaul measures are performed, necessary final tests are performed to ensure the unit is fully functional. If all tests have a positive result, the mechanic can release the component back to service with an airworthy status and necessary documentation.

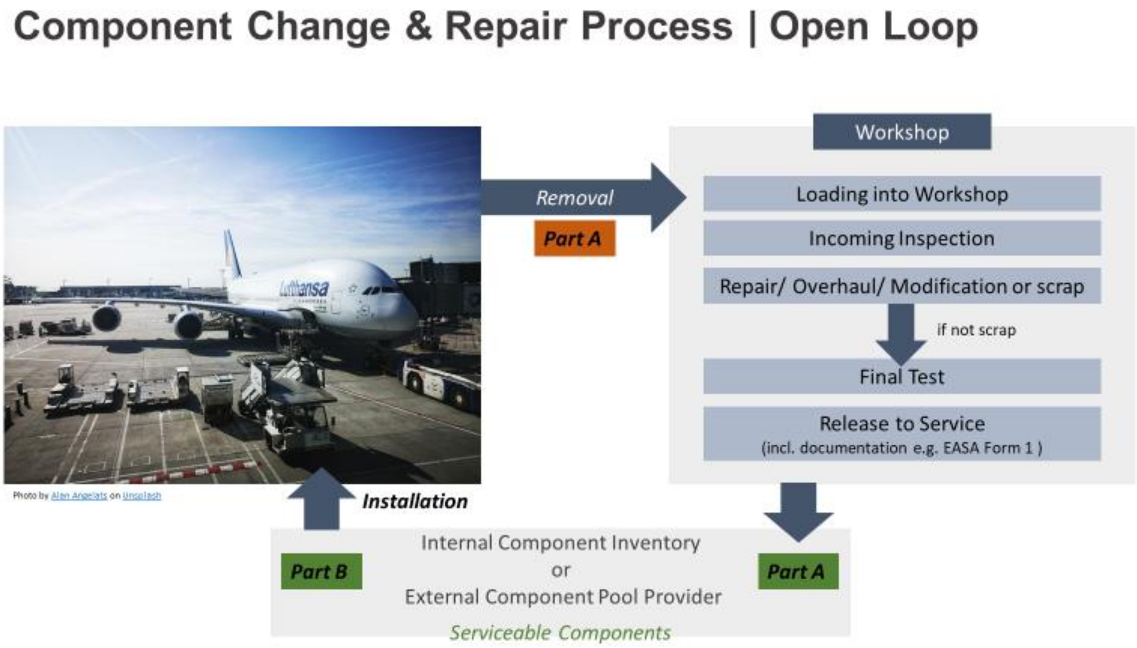

Figure 5: Component Change & Repair Process

Necessary release documentation depends on the airworthiness authority and their respective document requirements. The most common documents are:

- **Europe: EASA Form 1**
- **USA: FAA 8130-3**
- **China: CAAC AAC-038**

An MRO Provider needs the approval from the respective authority to be allowed to issue the relevant documentation. If a MRO provider has approvals for instance from the CAAC, FAA and EASA and can issue all these forms to a repaired or overhauled component, the component can be universally installed on aircrafts operating under either authority. Especially for component pool providers, it is essential to be able to issue the most common certificates so that as many different customers as possible can be supplied with their pool units.

2.3.2. Engines and Landing Gears

Engines are the most complex components of an aircraft. Their repair and overhaul processes are therefore separated from component maintenance and MRO providers need a dedicated authority approval (B-Rating) to be eligible to perform maintenance on engines.

Landing Gears do not have a dedicated authority approval of their own (they fall under the C-Rating), but they consist also of thousands of parts. For instance, "2.100 parts have to be cleaned, repaired and overhauled for the landing gear overhaul of an A320." (Lufthansa Technik AG, 2021). As their repair processes are on a high level similar to those of engines, they follow in general the same steps.

For both assets, the following steps are applicable:

1. Removal from aircraft
2. Loading into workshop

3. Disassembly (components/ modules)
4. Cleaning
5. Inspection (especially for cracks) & Testing
6. Repair/ change of components or modules
7. Assembly
8. Test run / Final test
9. Delivery to customer or aircraft

In case of an engine maintenance event, all repairs need to follow the Engine Maintenance Manual (EMM) and for the components or modules the relevant CMMs. The release to service is valid with i.e. an EASA Form 1 or other document.

3. Certification Requirements

Certification requirements exist on various levels for performing MRO measures. On the highest level, the whole organization needs to be a certified MRO provider before they are eligible to perform any MRO work (the same applies for Design, Production and Continuing Airworthiness Management Organizations).
Secondly, the staff performing the work needs to be certified. There exists various certifications and ratings for mechanics that allow them to perform certain repairs or release an aircraft or component by issuing the relevant documents.
Lastly, the asset or work needs to be certified. This ranges from release certification on a complete aircraft to (sub-)systems, such as engines installed on an aircraft, down to the part and component level where relevant release certificates need to be in place.

Any component is from a legal point of view only eligible to be installed on an aircraft when the manufacturing or MRO organization, the staff and the component itself all can produce the appropriate certification.

This section first provides an overview on the legal basis and further describes the requirements and certification needs per level closer.

3.1. Legal Basis Overview

Within the European Union, the European Union Aviation Safety Agency (EASA) is responsible for drafting rules regarding design, manufacturing and maintenance & operations of aircrafts and aviation products. These rules then pass through the EU legislative process and in the end become legally binding as Regulations in European law.

The Basic Regulation (EC) No 2018/1139 provides the overarching foundation for all the following rules and regulations by defining the overall structure of the rules and regulations and establishes the general setup of the EASA.

Besides this Basic Regulation (EC) No 2018/1139, two Implementing Rules exist that are most relevant for the MRO industry:

1. Initial Airworthiness - Regulation (EU) No 748/2012:
   "laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations" (European Commission, 2012)

2. Continuing Airworthiness - Regulation (EU) No 1321/2014:
   "on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organisations and personnel involved in these tasks" (European Commission, 2014)

These two Implementing Rules are further subdivided into parts, sections and subparts. The following figures shows an excerpt of the structure with the most relevant parts and subparts for certification requirements on organizational level that also affects personnel / staff and asset certification requirements:

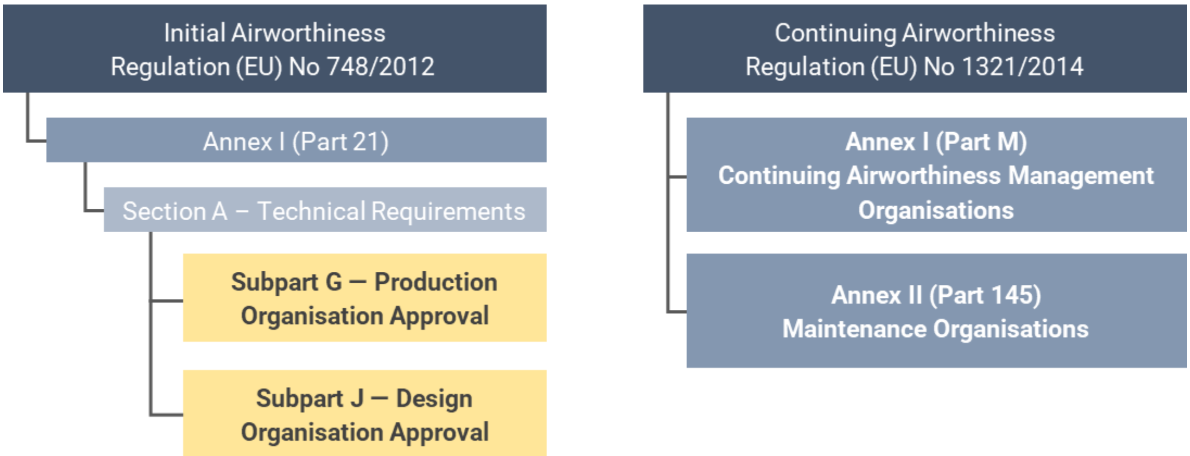

Figure 6: Implementing Rules - relevant parts and subsections

3.2. Organization Certification Requirements

Within the EASA Organization Certifications, four different types of approvals exist:

- Design Organisation,
- Production Organisation,
- Maintenance Organisation and
- Continuing Airworthiness Management Organisation (CAMO.

The definition of these organisations is provided in the following sections. The application process, scope of the approvals and other details are not covered here, but can be found on the EASA website (responsible for all Design Organisation approvals) or the respective National Aviation Authorities websites (responsible for all other organisation approvals with the respective country).

3.2.1. Part 21/J – Design Organisation

Article 8, Paragraph 1 of Commission Regulation (EU) No 748/2021 defines a Design Organisation as follows and establishes the need for an approval and certification:

"1. An organisation responsible for the design of products, parts and appliances or for changes or repairs thereto shall demonstrate its capability in accordance with Annex I (Part 21)." (European Commission, 2012)

After being approved and certified by EASA as a Design Organisation, the organization is then allowed to create or modify as an example construction documents and repair procedures for aviation products or operating and maintenance manuals. Design Organisation are Aircraft OEMs such as Airbus or Boeing, but also Suppliers of aircraft parts need to have an design organisation approval and even MROs such as Lufthansa Technik have a design approval to be able to develop their own repair procedures.

For further information of the scope of a Design Approval, Section "21.A.263 Privileges" of Subpart J can be referred to.

3.2.2. Part 21/G – Production Organisation

A Production Organisation is defined in Article 9, Paragraph 1 of Commission Regulation (EU) No 748/2021 as an "organisation responsible for the manufacture of products, parts and appliances […]" (European Commission, 2012).

Subpart G for Production Organisation Approvals within Commission Regulation (EU) No 748/2021, establishes

"(a) the procedure for the issuance of a production organisation approval for a production organisation showing conformity of products, parts and appliances with the applicable design data;

(b) the rules governing the rights and obligations of the applicant for, and holders of, such approvals." (European Commission, 2012)

Every OEM, Supplier or MRO need to have a Production Organisation approval if they are manufacturing any aviation product, part or appliance/ equipment (which will be certified in the end with an EASA Form 1 "birth certificate" – see Chapter "3.4 Component Certification Requirements").

3.2.3. Part 145 – Maintenance Organisation

In regards to MRO processes, the Maintenance Organisation Approval is the most relevant organizational certification for the scope of this paper. Maintenance Organisation Approvals are legally defined by Article 4 of Commission Regulation (EU) No 1321/2014 which states that "Organisations involved in the maintenance of large aircraft or of aircraft used for commercial air transport, and components intended for fitment thereto, shall be approved in accordance with the provisions of Annex II (Part-145)".

Part-145 includes the following sections that need to be complied with and demonstrated to the authorities in order to receive a Maintenance Organisation Approval and to be eligible to perform MRO work:

Section	***Title***	***Description***
145.A.15	Application	Defines the submission of an application through an EASA Form 2
145.A.20	Terms of approval	The scope of the approval needs to be defined (different approval classes and ratings exists - see Table below)
145.A.25	Facility requirements	Establishes i.e. that appropriate working environment requirements (facilities, tooling, temperature, lightning, etc.) are adhered to
145.A.30	Personnel requirements	Includes establishment of certain roles and nomination of employees to these roles, planning of sufficient personnel as well as other personnel requirements that are further detailed by Part-66 (see chapter 3.3 Staff Certification Requirements)
145.A.35	Certifying staff and support staff	Addresses qualification and training of staff
145.A.36	Records of airworthiness review staff	Recording of staff qualifications and maintenance of a current list of all airworthiness review staff
145.A.40	Equipment and tools	Ensures availability and usage of appropriate tooling and equipment
145.A.42	Components	Defines rules on component classification
145.A.45	Maintenance data	Defines that the Maintenance Organisation needs to work on basis of approved Maintenance Data (i.e. Aircraft Maintenance Manual, Component Maintenace Manual, etc.) and establishes a work card / worksheet system to perform work
145.A.47	Production planning	Establishes that an appropriate production planning system needs to be in place
145.A.48	Performance of maintenance	Establishes necessary procedures (verification, error handling, damage)
145.A.50	Certification of maintenance	Defines processes regarding release to service by staff and exceptions

145.A.55	Maintenance and airworthiness review records	Defines how a maintenance organisation needs to record all maintenance records
145.A.60	Occurance reporting	Establishes rules on reporting of any unsafe conditions and possible implications
145.A.65	Safety and quality policy, maintenance procedures and quality system	Defines a safety and quality measures and establishment of a quality system
145.A.70	Maintenance organisation exposure	The maintenance organisation needs to provide the authority with a document or documents that contains a summary with specified details

Once an organization fulfills all the requirements and demonstrates to the relevant authority compliance in all points, the application process ends with the issuance of a Maintenance Organisation Approval. MRO tasks according to the class and rating can then be performed.

The class and rating system for approval of Maintenance Organisations is defined in Annex I Appendix IV within the Continuing Airworthiness Regulation (EU) No 1321/2014) (European Commission, 2014). Four classes - Aircraft, Engines, Compontents and Special Services – are differentiated with respective A, B, C or D ratings for which a maintenance provider must apply:

CLASS	RATING	LIMITATION	BASE	LINE
AIRCRAFT	A1 Aeroplanes above 5 700 kg	[Rating reserved to Maintenance Organisations approved in accordance with Annex II (Part-145)] [Shall state aeroplane manufacturer or group or series or type and/or the maintenance tasks] *Example: Airbus A320 Series*	[YES/NO] (*)	[YES/NO] (*)
	A2 Aeroplanes 5 700 kg and below	[Shall state aeroplane manufacturer or group or series or type and/or the maintenance tasks] *Example: DHC-6 Twin Otter Series* State whether the issue of airworthiness review certificates is authorised or not	[YES/NO] (*)	[YES/NO] (*)
	A3 Helicopters	[Shall state helicopter manufacturer or group or series or type and/or the maintenance task(s)] *Example: Robinson R44*	[YES/NO] (*)	[YES/NO] (*)

	A4 Aircraft other than A1, A2 and A3	[Shall state aircraft category (sailplane, balloon, airship, etc.), manufacturer or group or series or type and/or the maintenance task(s)] State whether the issue of airworthiness review certificates is authorised or not	[YES/NO] (*)	[YES/NO] (*)
ENGINES	B1 Turbine	[Shall state engine series or type and/or the maintenance task(s)] *Example: PT6A Series*		
	B2 Piston	[Shall state engine manufacturer or group or series or type and/or the maintenance task(s)]		
	B3 APU	[Shall state engine manufacturer or series or type and/or the maintenance task(s)]		
COMPONENTS OTHER THAN COMPLETE ENGINES OR APUs	C1 Air Cond & Press	[Shall state aircraft type or aircraft manufacturer or component manufacturer or the particular component and/or cross refer to a capability list in the exposition and/or the maintenance task(s).] *Example: PT6A Fuel Control*		
	C2 Auto Flight			
	C3 Comms and Nav			
	C4 Doors — Hatches			
	C5 Electrical Power & Lights			
	C6 Equipment			
	C7 Engine — APU			
	C8 Flight Controls			
	C9 Fuel			
	C10 Helicopter — Rotors			
	C11 Helicopter — Trans			
	C12 Hydraulic Power			
	C13 Indicating — recording system			
	C14 Landing Gear			
	C15 Oxygen			
	C16 Propellers			
	C17 Pneumatic & Vacuum			
	C18 Protection ice/rain/fire			
	C19 Windows			
	C20 Structural			
	C21 Water ballast			
	C22 Propulsion Augmentation			
SPECIALISED SERVICES	D1 Non Destructive Testing	[Shall state particular NDT method(s)]		
(*) Delete as appropriate				

3.2.4. Part M – Continuing Airworthiness Management Organisation (CAMO)

In Part-M of Regulation (EU) No 1321/2014 is defined what requirements an operator of an aircraft (such as an airline) needs to fulfill to continuously ensure the airworthiness of its aircrafts. Within Part-M - Subpart G, the establishment of a seperate Continuing Airworthiness Maintenance Organisation (CAMO) is defined and requirements regarding the CAMO are listed and its responsibilities and tasks described. The CAMO for instance has the right to perform airworthiness reviews to ensure the airworthiness of aircrafts. With its responsibilities and tasks, the CAMO can be seen as a connector between maintenance organizations and operators.

3.3. Staff Certification Requirements

The second layer regarding certifications when performing MRO measures concerns the staff of the MRO organization. Requirements are defined in Regulation (EU) No 1321/2014 Annex III Part-66 that further specifies more general definitions of Part-145. In principle, the number of personnel must be sufficient for the tasks to be performed. In addition to the mechanics carrying out the maintenance measures, this also includes, for example, personnel for planning, monitoring and quality assurance. For all staff, an appropriate system must be established to ensure qualification requirements and documentation of qualification/ certification. The certifying/ releasing staff relevant to the research subject are also entered in this system and certifications are monitored. The various certification levels (e.g. A, B1, B2, etc.), the requirements for these levels and the associated authorizations are described in detail in Part-66.
Only an appropriately certified mechanic may release the corresponding Authorized Release Certificates. On the EASA Form 1, therefore, the releasing mechanic is always recorded with the following data, for example:

- Block 14b "Authorized Signature": Signature of the releasing mechanic. Only persons who are authorized to do so in accordance with the regulations and guidelines of the competent authority may sign this block.
- Block 14c "Certificate/Approval Ref. No.": Unique reference number of the mechanic assigned by the competent authority in the certification process to the personnel.
- Field 14d "Name": The name of the releasing mechanic must be entered in plain text on the EASA Form1.

The responsible competent authority for issuance of an aircraft maintenance license is defined in Part-66. A competent authority in this case may be a ministry, a national aviation authority or any aviation body designated by the Member State and located within that Member State that is responsible for the certification of aviation staff in the respective country (EASA, 2022).

When fulfilling all requirements and after obtaining an aircraft maintenance certification, the mechanic now has certain privileges that are defined by Part-66.A.20. In the following, the first three ratings or categories of an aircraft maintenance license are listed as an example:

“(a) the following privileges shall apply:

1. A category A aircraft maintenance licence permits the holder to issue certificates of release to service following minor scheduled line maintenance and simple defect rectification within the limits of tasks specifically endorsed on the certification authorisation referred to in point 145.A.35 of Annex II (Part-145). The certification privileges shall be restricted to work that the licence holder has personally performed in the maintenance organisation that issued the certification authorisation.

2. A category B1 aircraft maintenance licence shall permit the holder to issue certificates of release to service and to act as B1 support staff following:
   - maintenance performed on aircraft structure, powerplant and mechanical and electrical systems,
   - work on avionic systems requiring only simple tests to prove their serviceability and not requiring troubleshooting

Category B1 includes the corresponding A subcategory.

3. A category B2 aircraft maintenance licence shall permit the holder:
   (i) to issue certificates of release to service and to act as B2 support staff for following:
   - maintenance performed on avionic and electrical systems, and
   - electrical and avionics tasks within powerplant and mechanical systems, requiring only simple tests to prove their serviceability; and

   (ii) to issue certificates of release to service following minor scheduled line maintenance and simple defect rectification within the limits of tasks specifically endorsed on the certification authorisation referred to in point 145.A.35 of Annex II (Part-145). This certification privilege shall be restricted to work that the licence holder has personally performed in the maintenance organisation which issued the certification authorisation and limited to the ratings already endorsed in the B2 licence.

   The category B2 licence does not include any A subcategory. […]”

Further information on basic experience requirements, validity of certifications and other aspects are further described and defined in Part-66.

3.4. Component Certification Requirements

Certification requirements for components depend first of all on the classification of a technical part. CAMO Part M Subpart E - M.A.501 provides legal guidance on that topic, stating that all components on an aircraft shall be classified into one of the following categories (European Commission, 2014):

1. All components shall be classified into the following categories:

(1) **Components** which are in a satisfactory condition, **released on an EASA Form 1 or equivalent** […].
(2) **Unserviceable components** which shall be maintained in accordance with this Regulation.
(3) **Components** categorised as **unsalvageable** because they have reached their mandatory life limitation or contain a non-repairable defect.
(4) **Standard parts** used on an aircraft, engine, propeller or other aircraft component […] accompanied by evidence of conformity […].
(5) **Material** both **raw and consumable** used in the course of maintenance […] accompanied by documentation […].

2. Components, standard parts and material **shall only be installed on an aircraft** or a component **when they are in a satisfactory condition, belong to one of the categories** listed in point (a) and the applicable maintenance data specifies the particular component, standard part or material.

Excursus:

Which parts fall into the respective category is determined during the design process of an aircraft. In short, the manufacturer published a Maintenance-Review-Board-Report (MRBR) that is the central basic MRO document for an aircraft and provides guidelines on minimal requirements for maintenance on an aircraft. Within the creation process of that report, working groups follow a concept called Maintenance Steering Group 3 (MSG-3) analysis that identifies and categorizes components into Maintenance Significant Items (MSI) and Structural Significant Items (SSI). For these, maintenance points of time, measures and intervals are defined. For further information the following article provides an introduction:

"Maintenance Steering Group Introduction, Overview, and Evolution" (Klein, 2021)

For the context of the RAPADO project, most relevant from the categorization above is the category number (1) for components as it establishes the legal basis and requirements for certification. A component can only be installed on an aircraft, if it is released with an EASA Form 1 or equivalent. Equivalent in this case can mean certification from another agency or authority that is acceptable by EASA standards, i.e. FAA or CAAC certification.

Subpart Q of Annex I (Part-21) to Regulation (EU) No 748/2012 (European Commission, 2012) defines the obligatory features of an EASA Form 1 (compare section 3.4.2 EASA Form 1 - Figure 8: Authorised Release Certificate — EASA Form 1).

3.4.1. Life Limited Parts (LLPs)

Dedicated requirements exist regarding Life Limited Parts (see description in 1.3.1 Scheduled (preventive) Maintenance) that are established in EASA Guidance Material (GM) M.A 305 (c):

“A ‘life-limited part’ is a part for which the maintenance schedule of the aircraft maintenance programme requires the permanent removal from service when, or before, the specified mandatory life limitation in accordance with Commission Regulation (EU) No 748/2012 if any of the applicable parameters is reached.” (EASA, 2021a)

This leads to further documentation and certification needs or “Traceability”. For example., it is necessary to track LLPs seamlessly back to their first appearance or “birth” when first manufactured and installed on an aircraft, engine or other subassembly. The term therefore is called Back-to-Birth (BTB) documentation.

An example and draft template for standardizing the LLP BTB Traceability by the IATA Aircraft Leasing Technical Group (IATA ALTG) is shown in Figure 7: Template (Life-Limited Part Movement History Sheet) .

Within that template, the dedicated part is uniquely identified by the header items consisting of part and serial number. A description is also part of the header for better understanding.

In the main section of the LLP Movement History Sheet, the operator, installed aircraft, installed assembly, further data on the part, supporting documents and finally handover columns have to be filled.

Especially the TSN (“Time Since New” in flight hours), CSN (“Cycles Since New” in cycles) and from these derived “HOURS & CYCLES REMAINING” have the highest importance for the traceability and define the limit until which a part can be in operation.

In the example from the template, the part to track is a Fan Disk that was manufactured by IAE with a Life Limit of 20.000 Cycles. Flight hours were not an applicable limit for this type of Fan Disk and are therefore not applicable. The Fan Disk was initially released with a FAA 8130 release certificate (Supporting Document Section, line 1). It was then first installed on an US Airways A320-231 aircraft in a V2500A1 engine with Serial Number V0086 (Installed Assembly Section, line 2). The TSN and CSN in this section are recorded for the complete engine. For this initial installation, the part naturally shows 0 TSN and 0 CSN. The “DATE ON WING” field should have been filled in an actual document, but is in the template left out. The third line is a removal event and between installation and removal 4.596 cycles were completed by the aircraft. This means, that the Life Limit for this Fan Disk now is at (20.000 – 4.596 cycles) 15.404 remaining cycles before an overhaul or replacement becomes necessary. The following entries respectively affect the Life Limit. For parts with a longer history, an overhaul event can occur that resets the limits and the counter starts from 0 again.

IATA

5.3 Template (Life-Limited Part Movement History Sheet)

LIFE LIMITED PART (LLP) MOVEMENT HISTORY SHEET

PART NUMBER : 5A1757

Serial Number RSTDK33910

PART DESCRIPTION : FAN DISK

OPERATOR	INSTALLED AIRCRAFT				INSTALLED ASSEMBLY						PART									SUPPORTING DOCUMENT		HANDOVER
OPERATOR	TYPE AND MODEL	AC REG	MSN	MTOW	DATE	TYPE	THRUST RATING	S/N	TSN	CSN	DATE ON WING	DATE OFF WING	P/N	TSN	CSN	LIFE LIMIT		HOURS & CYCLES REMAINING		REASON FOR RECORD ENTRY	REFERENCE	ID
																HOURS	CYCLES	HOURS	CYCLES			
IAE													5A1757	0.0	0		20,000 C	N/A	20,000 C	Production	8130	John Robinson
US AIRWAYS	A320-231	N637AW	99	250,000	29/06/2005	V2500A1	27,000 lbs	V0086	44,565 H	19,956 C	dd-mm-yyyy	dd-mm-yyyy	5A1757	0.0	0	0 H	20,000 C	N/A	20,000 C	Installation		
US AIRWAYS	A320-231	N637AW	99	250,000	15/09/2008	V2500A1	27,000 lbs	V0086	55,103 H	24,552 C	dd-mm-yyyy	dd-mm-yyyy	5A1757	10,538.0	4,596	0 H	20,000 C	N/A	15,404 C	Removal		
US AIRWAYS	A320-231	N622AW	54	250,000	16/04/2009	V2500A1	27,000 lbs	V0086	55,103 H	24,552 C	dd-mm-yyyy	dd-mm-yyyy	5A1757	10,538.0	4,596	0 H	20,000 C	N/A	15,404 C	Installation		
US AIRWAYS	A320-231	N622AW	54	250,000	24/02/2010	V2500A1	27,000 lbs	V0086	57,413 H	25,594 C	dd-mm-yyyy	dd-mm-yyyy	5A1757	12,848.0	5,638	0 H	20,000 C	N/A	14,362 C	Removal		
US AIRWAYS	A320-231	N622AW	54	250,000	13/03/2011	V2500A1	27,000 lbs	V0086	57,413 H	25,594 C	dd-mm-yyyy	dd-mm-yyyy	5A1757	15,158.0	5,638	0 H	20,000 C	N/A	14,362 C	Installation		
US AIRWAYS	A320-231	N622AW	54	250,000	20/08/2013	V2500A1	27,000 lbs	V0086	64,615 H	28,989 C	dd-mm-yyyy	dd-mm-yyyy	5A1757	22,360.0	9,033	0 H	22,000 C	N/A	12,967 C	Change in operational parameters	8130	
US AIRWAYS	A320-231	N633AW	82	250,000	15/11/2013	V2500A1	27,000 lbs	V0086	64,615 H	28,989 C	dd-mm-yyyy	dd-mm-yyyy	5A1757	29,562.0	12,428	0 H	22,000 C	N/A	9,572 C	Installation		
US AIRWAYS	A320-231	N633AW	82	250,000	15/01/2015	V2500A1	27,000 lbs	V0086	66,103 H	29,887 C	dd-mm-yyyy	dd-mm-yyyy	5A1757	31,050.0	13,326	0 H	22,000 C	N/A	8,674 C	Removal		Jim Bicknell
AERCAP	A320-231	N633AW	82	250,000	15/01/2015	V2500A1	27,000 lbs	V0086	66,102 H	29,887 C	dd-mm-yyyy	dd-mm-yyyy	5A1757	32,537.0	13,326	0 H	22,000 C	N/A	8,674 C	Change of operator		Ed Fanning

Key

Items encircled in light green are referred to as "LLP Movement History Sheet Header Items".

Items encircled in light blue are referred to as "LLP Movement History Sheet Items".

Item encircled in brown is referred to as "LLP Movement History Sheet Supporting Documentation Section".

Item encircled in dark blue is referred to as "LLP Movement History Sheet Handover Section".

Figure 7: Template (Life-Limited Part Movement History Sheet) (IATA Aircraft Leasing Technical Group, 2020)

3.4.2. EASA Form 1

While the Certificate of Release to Service (CRS) is the release certificate for the entire aircraft within EASA's jurisdiction on the highest level, the EASA Form 1 is the release certificate for components and is used in manufacturing as well as in maintenance.

In general, any component can only be installed on an aircraft if it has a release certificate EASA Form 1. Only manufacturers or maintenance organizations with a respective approval from EASA (for manufacturers Part 21/G and for maintenance organisations Part-145 approvals – see Figure 6: Implementing Rules - relevant parts and subsections) are eligible to issue an EASA Form 1.

Detailed information on the purpose and use, general format, how to handle errors on an EASA Form 1 as well as on **the completion of the certificate** by the originator can be found in Appendix II to Annex I (Part-M) - Authorized Release Certificate - EASA Form 1 (European Commission, 2014).

For each block on the EASA Form 1, a description is provided on how to fill out the block as well as what information needs to be included or can be filled in. As an example, for Block 11 "Status/Work" the Appendix entry looks as follows:

"***Block 11 Status/Work***

The following describes the permissible entries for block 11. Enter only one of these terms — where more than one may be applicable, use the one that most accurately describes the majority of the work performed and/or the status of the article.

(i)	Overhauled	.	Means a process that ensures the item is in complete conformity with all the applicable service tolerances specified in the type certificate holder's, or equipment manufacturer's instructions for continued airworthiness, or in the data which is approved or accepted by the Authority. The item will be at least disassembled, cleaned, inspected, repaired as necessary, reassembled and tested in accordance with the above specified data.
(ii)	Repaired	.	Rectification of defect(s) using an applicable standard (1).
(iii)	Inspected/Tested	.	Examination, measurement, etc. in accordance with an applicable standard (1) (e.g. visual inspection, functional testing, bench testing etc.).
(iv)	Modified	.	Alteration of an item to conform to an applicable standard (1).

" (European Commission, 2014)

The template for an EASA Form 1 is shown on the following page.

<table>
<tr><td colspan="2">1. Approving Competent Authority/Country</td><td colspan="3">2. AUTHORISED RELEASE CERTIFICATE
EASA FORM 1</td><td>3. Form Tracking Number</td></tr>
<tr><td colspan="5">4. Organisation Name and Address:</td><td>5. Work Order/Contract/Invoice</td></tr>
<tr><td>6. Item</td><td>7. Description</td><td>8. Part No</td><td>9. Qty.</td><td>10. Serial No</td><td>11. Status/Work</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">12. Remarks</td></tr>
<tr><td colspan="3">13a. Certifies that the items identified above were manufactured in conformity to:
☐ approved design data and are in a condition for safe operation
☐ non-approved design data specified in block 12</td><td colspan="3">14a. ☐ Part 145.A.50 Release to Service ☐ Other regulation specified in block 12
Certifies that unless otherwise specified in block 12, the work identified in block 11 and described in block 12, was accomplished in accordance with Part 145 and in respect to that work the items are considered ready for release to service.</td></tr>
<tr><td colspan="2">13b. Authorised Signature</td><td>13c. Approval/ Authorisation Number</td><td colspan="2">14b. Authorised Signature</td><td>14c. Certificate/Approval Ref. No</td></tr>
<tr><td colspan="2">13d. Name</td><td>13e. Date (dd mmm yyyy)</td><td colspan="2">14d. Name</td><td>14e. Date (dd mmm yyyy)</td></tr>
<tr><td colspan="6">USER/INSTALLER RESPONSIBILITIES
This certificate does not automatically constitute authority to install the item(s).
Where the user/installer performs work in accordance with regulations of an airworthiness authority different than the airworthiness authority specified in block 1, it is essential that the user/installer ensures that his/her airworthiness authority accepts items from the airworthiness authority specified in block 1.
Statements in blocks 13a and 14a do not constitute installation certification. In all cases aircraft maintenance records must contain an installation certification issued in accordance with the national regulations by the user/installer before the aircraft may be flown.</td></tr>
</table>

EASA Form 1-21 Issue 2.

Figure 8: Authorised Release Certificate — EASA Form 1 (European Commission, 2012)

3.4.3. FAA 8130-3

Next to the EASA Form 1, which is the release certificate for countries following EASA rules, several further release certificates exist. In the US, the counterpart to the EASA Form 1 is the FAA Form 8130-3.

For the FAA 8130-3 as well as other certain national release certificates, an agreement exists between the two respective aviation authorities about the recognition of the other certificate. These agreements allow the installation of components with the foreign release certificate in an aircraft.

The FAA Form 8130-3 and the EASA Form 1 are very similar regarding the layout as well as the information to be recorded

The template for the FAA Form 8130-3 is shown on the following page (Federal Aviation Authority, 2022).

1. Approving Civil Aviation Authority/Country: FAA/United States	2. **AUTHORIZED RELEASE CERTIFICATE** FAA Form 8130–3, AIRWORTHINESS APPROVAL TAG	3. Form Tracking Number:
4. Organization Name and Address:		5. Work Order/Contract/Invoice Number:

6. Item:	7. Description:	8. Part Number:	9. Quantity:	10. Serial Number:	11. Status/Work:

12. Remarks:

13a. Certifies the items identified above were manufactured in conformity to: ☐ Approved design data and are in a condition for safe operation. ☐ Non-approved design data specified in Block 12.		14a. ☐ 14 CFR 43.9 Return to Service ☐ Other regulation specified in Block 12. Certifies that unless otherwise specified in Block 12, the work identified in Block 11 and described in Block 12 was accomplished in accordance with Title 14, Code of Federal Regulations, part 43 and in respect to that work, the items are approved for return to service.	
13b. Authorized Signature:	13c. Approval/Authorization No.:	14b. Authorized Signature:	14c. Approval/Certificate No.:
13d. Name (Typed or Printed):	13e. Date (dd/mmm/yyyy):	14d. Name (Typed or Printed):	14e. Date (dd/mmm/yyyy):

User/Installer Responsibilities

It is important to understand that the existence of this document alone does not automatically constitute authority to install the aircraft engine/propeller/article.

Where the user/installer performs work in accordance with the national regulations of an airworthiness authority different than the airworthiness authority of the country specified in Block 1, it is essential that the user/installer ensures that his/her airworthiness authority accepts aircraft engine(s)/propeller(s)/article(s) from the airworthiness authority of the country specified in Block 1.

Statements in Blocks 13a and 14a do not constitute installation certification. In all cases, aircraft maintenance records must contain an installation certification issued in accordance with the national regulations by the user/installer before the aircraft may be flown.

FAA Form 8130–3 (02–14) NSN: 0052-00-012-9005

Figure 9: Authorized Release Certificate - FAA Form 8130-3 (Federal Aviation Authority, 2022)

3.4.4. CAAC AAC-038

Regarding the People's Republic of China, documentation relevant regulations are provided by the authority CAAC and Certification Regulations Decree No.152 (CAAC, 2005). The relevant form for certifying aircraft material is the AAC-038. Further information can be found in the Decree No. 152, but further Chinese aviation law specific regulations exists and are out of scope of this paper.

3.4.5. Transport Canada Civil Aviation (TCCA) Form One

The TCCA is the Canadian Aviation Authority and the TCCA's Form One is the respective Authorized Release Certificate and replaced the former Form 24-0078 (Transport Canada, 2022). It also follows very closely the design of an EASA Form 1 or an FAA 8130. The current version can be downloaded here: link.

4. Documentation Overview

Next to the documentation already described in previous chapters in this document, such as CMMs, EMMs or the component certificates (e.g. EASA Form 1, FAA 8130), a lot of other documents exists in the aviation industry. The following table provides an overview and categorization:

Document Category	Document Types
Manufacturing / Design Documents	- Design Documents (,i.e. Drawings, Specifications, Layouts, Drafts, Schematics, Circuit Diagrams, System or Component Descriptions, List of Material, Process Descriptions, Procedures, Manufacturing Techniques, Test Programs & Instructions) - Compliance Documents (Compliance Statement, Checklist, Summary Reports, Inspection Reports, Tests & Simulations, Substantiation Reports, Supporting Engineering Data)
Maintenance & Operations Instructions and Documents	- Aircraft Maintenance Manual (AMM) - Engine Maintenance Manual (EMM) - Component Maintenance Manual (CMM) - Maintenance Instructions - Maintenance Planning Document (MPD) - Structure Repair Manual (SRM) - Illustrated Parts Catalogue (IPC) - Minimum Equipment List (MEL) - Wiring Diagram Manual (WDM) - Standard Practices Manual (SPM) - Airworthiness Limitations - MRB Report

	- A/C Flight Manual - ETOPS Manual - Weight and Balance Manual - Flight Crew Operation Manual (FCOM) - Trouble Shooting Manual (TSM) - Cabin Interior Manual (CIM)
Verification and Compliance Documents	- Type Certificate (TC) - Supplemental Type Certificate (STC) - Change of Type Certificate - Repair Approvals - Certificate of Airworthiness - Certificate of Conformity - Certificate of Registration
Commercial Documentation	- Purchase Orders - Customer Invoices - Bill of Sale - Shipping Documentation - Packing Slips - Non Incident Statements (NIS) - Incident/ Accident Clearance Statement (ICS) - ATA Specification 106 - Aircraft Lease Documentation
Authority and Manufacturer Notices	- Airworthiness Directives (AD) - Alternative Method of Compliance (AMOC) - Safety Information Bulletins (SIB) - Service Bulletins (SB)
Maintenance & Airworthiness Compliance Documents	- Engineering Orders (EO) - Work Orders - Work Packages - Job/ Task Cards - Job/ Tasks Summary Sheet - Shop Reports - Removal/ Serviceable Tags - Installation/ Removal Records - Preservation Records - Test Reports/ Results - Inspection Reports - Dent and Buckle Report - Authorized Release Certificates (EASA Form 1, FAA 8130) - Maintenance Review Board Report (MRBR) - AD/SB Status - Modification Status - LLP Status - Aircraft Inspection Report

In the following, some of these document types will be described further due to their relevance within the aviation industry and the context of this paper.

4.1. Non Incident Statements (NIS)

Non Incident Statements have been popular in the aviation industry as they were regarded as a document that gave more security whether an aircraft or component was involved in an incident. The intention from the buyer's side to be provided with such a statement can be compared to the case when buying a car where the buyer wants to know if the car was involved in an accident. This would potentially have an effect on the safety of driving the car and ultimately on the price that the buyer would be willing to pay. The NIS can therefore be seen as commercial relevant document, but with no regulatory necessity existing.

As there was no industry standard existing, the content and format of Non Incident Statements have varied widely. As the aviation industry also differentiates between incidents and accidents with substantial damage and definitions for these are established in Annex 13 of the Chicago convention, the relevance of the NIS was more and more questionable. As an example, an accident is defined by the Annex 13 as follows (ICAO, 2001):

"**Accident.** An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:

a) a person is fatally or seriously injured as a result of:

   — being in the aircraft, or
   — direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
   — direct exposure to jet blast,

   except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or

b) the aircraft sustains damage or structural failure which:

   — adversely affects the structural strength, performance or flight characteristics of the aircraft, and
   — would normally require major repair or replacement of the affected component,

   except for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage limited to propellers, wing tips, antennas, tires, brakes, fairings, small dents or puncture holes in the aircraft skin; or

c) the aircraft is missing or is completely inaccessible."

An incident would not cover case b) of the accident definition, so the aircraft could have been involved in an accident, but still have a Non Incidence Statement issued as this accident is per definition not an incident. An incident on the other hand is defined simply as follows in Annex 13:

"**Incident**. An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation."

The definition of an incident leaves room for interpretation and cases such as minor damage (smaller scratches, dents) to the aircraft, e.g. from lavatory, baggage or fuel trucks, fall in the incident category. This led the IATA to provide the Incident/ Accident Clearance Statement that further detailed the technical condition and provides a standardized format and content (see the following chapter "4.2 Incident/ Accident Clearance Statement (CIS)").

The following shows an example of a NIS (Blue Air, 2022).

Blue Air
smart flying

Blue Air Airline Management Solutions SRL
Sediu Social: Bucuresti, Sector 1,
Str. Teheran, Nr. 17, Et.1, Ap.2
Reg. Com. J40/5103/2013, RO31525574
Telefon: 0040-21-208 86.86
Fax: 0040-21-208 86.13
e-mail: office@blue-air.ro
Website: blueairweb.com

NON-INCIDENT STATEMENT #20041808

Description: **MAIN LANDING GEAR RH**

Part Number: **162A1100-24**

Serial Number: **MAL00268Y0132**

Was removed from the aircraft with tail no. YR BMH S/N: 27989 and has not been subjected to any incidents, damages , impacts, severe stress or heat and/or other adverse operating conditions during the period it was installed on the aircraft and the aircraft was operated by Blue Air.
The unit was operated and maintained in accordance with the applicable approved manuals.
This statement is based on all technical records available at Blue Air, at the date of its release

Blue Air - A.M.S. SRL
EASA Part - 145 - Approval Certificate RO.145.050

NOTE: The unit is not from any military source or government surplus.

Punct de lucru: Sos. Bucuresti - Ploiesti Nr. 40, Bucuresti Sector 1, Romania. telefon: 0040 - 21 - 208 0005.
fax: 0040 - 21 - 208 0014, Website: blueairweb.com

Figure 10: Non Incident Statement Example

4.2. Incident/ Accident Clearance Statement (ICS)

As described previously in the context of the NIS, the Incident/ Accident Clearance Statement (ICS) is a further development and standardization of the NIS and is issued by IATA. In the guidelines related to the ICS, the reasons are lined out (IATA, 2022):

“The purpose of this incident/accident clearance statement is to remove the focus from whether or not an aircraft/engine/part has been subjected to an accident or incident and instead declare that the aircraft/engine/part has been deemed acceptable for continued use.

[…] Specifically with regard to the definition of incident, it is highly subjective and subject to various interpretations by different regulatory authorities as to what affects or could affect the safety of operation.”

The ICS has also no regulatory necessity, but due to its more detailed format and content and standardization, it has become a relevant and often used commercial document.

The ICS template is shown on the following page (IATA, 2022):

(ON COMPANY LETTERHEAD)

Date

Incident/Accident Clearance Statement

To Whom It May Concern:

Aircraft [enter registration], details of which are specified below, has been operated by [insert company name] during the period from [enter delivery date] to [enter redelivery date]. The aircraft has a valid Certificate of Airworthiness from [insert country of registration] as of the date of this statement.

Configuration details as of date of this statement;

Description	Type/Part No.	Serial No.	TSN	CSN
Aircraft				
Engine				
Engine				
Propeller				
Propeller				

I hereby certify that, to the best of my knowledge, during the period stated above:

1. Neither the aircraft, nor any part installed have been;

    a. damaged during, or identified as the root cause of, a reportable incident or accident as defined by Annex 13 to the Chicago Convention, or

    b. subjected to severe stress or heat (such as in a major engine failure, accident, or fire) or has been submersed in salt water,

    unless its airworthiness status was re-established by an approved maintenance organisation in accordance with the applicable airworthiness regulations and instructions of the type certificate holder and/or supplemental type certificate holder and/or OEM of the part, and supported by an authorised airworthiness release certificate.

2. No part has been installed on the aircraft which was obtained from a military source or was previously fitted to a state aircraft as deemed by Article 3 of the Chicago Convention.

Authorised Airline Representative

Signature: ______________________

Name: ______________________

Position: ______________________

Note: Please see also the Guidelines for understanding the Incident / Accident Clearance Statement (ICS) associated with this form.

Figure 11: Incident/ Accident Clearance Statement

4.3. ATA Specification 106 Form

The ATA Specification 106 was initially created by the Air Transport Association (ATA) and "outlines and identifies some procedures that the airlines and/or suppliers, buyers and quality assurance/control inspectors could follow in approved parts quality assurance programs" (Airlines for America, 2022). The Air Transport Association was founded 1936 in Chicago by 14 US airlines and acts as a US airline trade association and lobbying group. It is named today "Airlines for America" (A4A) (Wikipedia, 2022).

In these procedures, the "ATA Specification 106 Form" is provided as a sample form for part or material commercial certification. (Aviation Suppliers Association, 2010). Therefore, the document is used as commercial trace document, which is not mandatory and has no legal foundation in aviation law context, such as a release certificate EASA Form 1 or an FAA 8130-3. It does have a commercially binding and thus legal aspect though and is therefore often still requested in the aviation component aftermarket. False and misleading information on the statement can have legal commercial consequences. As a result, the document is often seen or used as an additional commercial "security" by the buyer against the seller of a component.

The creation in 1993 and the last revision of the document in 2001 date back more than 20 years and have been driven by the ATA. The document is often referred to as "ATA Spec 106" / "Spec 106" or "ATA 106", but the official declaration is "Specification 106: Sources and Approved Parts Qualification Guidelines" (Airlines for America, 2022).

As the last revision is over 20 years old and it has no legally binding character, a lot of airlines adopted their own variations of the form and deviate from the template. Also, the organization or person signing the document do not need to hold an official aviation authority certificate (i.e. from FAA or EASA).

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