IATA

Best Practices for Component Maintenance Cost Management

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NOTICE

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Best Practices for Component Maintenance Cost Management
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Section 1–Introduction

Component maintenance costs (CMC) are a major issue for maintenance departments in airlines all over the world. According to the *Airline Maintenance Cost Executive Summary* for fiscal year 2014 published by the IATA, components make up the second largest portion (24%) of airlines' direct maintenance costs (DMC).

Compared to the impact of CMC on overall maintenance spend, little effort has been made so far to standardize methods to break them down into subcategories suitable for benchmarks. Best practices on how to deal with weaknesses in existing arrangements with suppliers and/or Original Equipment Manufacturers (OEMs) are also difficult to find.

The purpose of this paper is to propose a breakdown method of CMC. For each category of CMC, we provide a short description and "best practice" examples on how to deal with the most common issues regarding component maintenance.

These best practices are based on the experience of the individuals and airlines involved in this project, they are not exhaustive. This paper intends to push discussions forward and provide airlines with insight to better manage CMC and negotiate contracts with suppliers.

In the future, we plan to update this document with all the best practices we will gather. We encourage you to contact us at mctf@iata.org if you would like to contribute and share your experience.

Section 2—Background

For many airlines, component maintenance and associated repair and overhaul represent a complex management challenge.

Many factors contribute to this complexity, including aircraft configuration control with multiple fleet types, common aircraft models with multiple configurations, aircraft ageing, modifications via mandatory directives and service bulletins, parts availability and repair cycle inconsistencies. Additionally, commercial agreements such as leasing requirements and component pooling arrangements add more complexity in managing the costs of component maintenance.

Controlling CMC is therefore a significant leverage in order for airlines to ensure transparencies to extremely intricate management processes.

The *Airline Maintenance Cost Executive Summary*, published by IATA for fiscal year 2014, illustrates that CMC make up 24% of airlines' Direct Maintenance Costs (DMC) per Flight Hour (FH). (Fig 1)

Between 2010 and 2014, the average cost per FH for component maintenance increased by 25%.

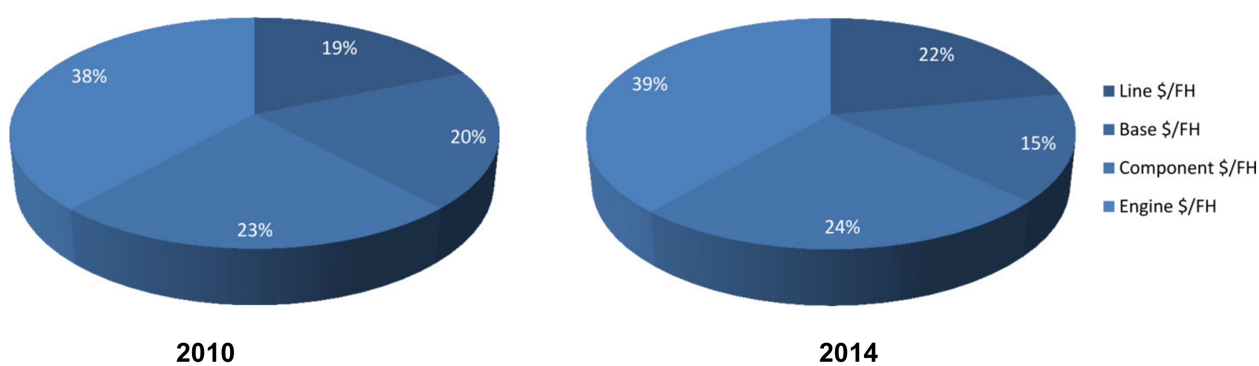


Figure 1. Direct Maintenance Cost Structure by Segment; Evolution 2010-2014

Costs drivers and the complexities related to maintaining oversight are discussed in the following sections. They are compiled to enable operators to eliminate missed opportunities and maintain control over component maintenance costs.

Section 3—Component Maintenance Costs

Before navigating into the analysis of component maintenance costs, it is prudent to define the term "aircraft component".

In aircraft maintenance, a component is defined as any self-contained part, combination of parts, subassemblies or units, which perform a distinctive function necessary to the operation of a system[1]. Maintenance costs associated with this rotable or repairable part can be classified into the following categories illustrated in Figure 2 at Line Replaceable Unit (LRU) level for the airline.

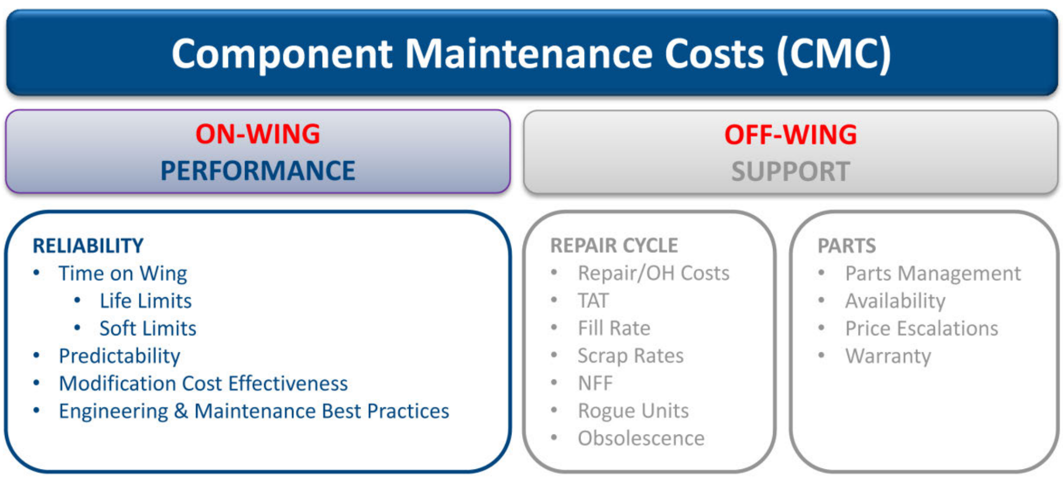


Figure 2. Component Maintenance Costs Categories

On-wing performance and off-wing support are the main categories discussed in Sections 4 and 5 of this document. For airlines based far from component suppliers, freight and overhead costs can be a significant part of component maintenance costs. They may not be aware of these costs because they are embedded in the total costs. Transportation costs can account for a significant amount, especially when airlines are not well covered for Aircraft On Ground (AOG) situations and have to rely on expediting shipments.

Capital cost or leasing cost to ensure access to a pool of units is another driver as well as an area of risk. Component maintenance costs are directly related to the expenses that occur during the annual accounting cycle. However, certain capital expenses may be required to ensure proper operation; they include investments in tools, spare parts/inventory, training and even facilities enhancements.

[1] World Airlines Technical Operations Glossary (WATOG) definition from 'Compendium of International Civil Aviation' by Adrianus D. Groenewege, IATA, Second Edition - 1998-1999

Section 4—On-Wing Performance – Reliability

On-wing performance addresses the performance of the different components used on a certain aircraft. The longer the on-wing life of a component, the lower the impact on related costs, since repair and replacement costs are lower. Therefore, reliability of the components belongs to the on-wing performance category.

The airline's reliability program provides the means to determine the effectiveness of the existing maintenance program. The reliability program is also the basis for optimizing the maintenance program tailored to operating and environmental conditions.

The reliability process allows an airline to explore reliability information for its airplanes and their components during a specific period of time. An airline can compare its reliability to the overall fleet reliability, understand the cost of schedule interruptions, analyze solutions, and prioritize service bulletins based on the impact to its fleet.

By combining fleet reliability data with service interruption data and available improvements, an airline can create a customized and prioritized list of improvements.

There are multiple factors that impact the reliability of components and, consequently, the costs associated with component maintenance. The following factors are detailed below and elaborated upon in the subsequent paragraphs belong in the following categories:

- Time-on-wing
- Predictability
- Modification effectiveness

An effective fault identification by line mechanic is a prerequisite. Only confirmed failure should be included. No Fault Found (NFF) is a major issue causing high administrative burden and wasted expenditure.

4.1 Time-On-Wing

A number of airlines use mean time between unscheduled removals (MTBUR) and mean time between failures (MTBF) as metrics for reliability compared to industry or airline historical data. These numbers can be misleading due to operations, delivery schedule, etc. A better metric to use when tracking component performance is time-on-wing (TOW). Time-on-wing is either Time Since New (TSN) or Time Since Installation (TSI).

Component maintenance costs are largely influenced by time-on-wing. In general, the longer a component remains on wing, the lower the life cycle costs of the component with fewer repair cycles in the life of the component.

However, maximization of life-usage of a part number on the aircraft doesn't always lead to optimal costs for the airline, as a failure of a part during operation can lead to opportunity costs related to out-of-service times or AOG costs. It is based on the assumption that the total repair cost of such a scheduled removal is usually much lower than the cost of a severe unscheduled breakdown. Each individual operator has to find its own optimum, considering which part numbers should be treated on condition or with a soft-time limit.

If a component needs to be sent to the shop, there are two possible ways. Firstly, "life limits" or "soft-time limits" classified components may be replaced at intervals defined by the operator (hard-time limits are mostly determined by the manufacturer). Secondly, components classified as "on condition" are replaced when the component itself fails or parameters are exceeded.

Time-on-wing is also determined by OEM/vendor-mandated life limits, and operator-introduced soft-time. In some cases, airlines can extend life limits, provided they have supporting data through either their own engineering team or an external partner, e.g. an MRO.

4.1.1 Life Limits

The operator's maintenance program includes a schedule for Life Limited Parts (LLPs) fitted to the aircraft and operated under their Air Operators Certificate (AOC). These LLPs are mandated by Instructions for Continued Airworthiness (ICA) that specify the life-on-wing of components identified by part description, part number, serial number, location and life limiting schedules (hours, cycles, calendar days or a combination thereof).

For components with mandated life limits, the efficient utilization of the given interval is an important issue. To contain costs, an operator needs to maximize the interval utilization and avoid removing and replacing life-limited components too early. Making the most out of the interval influences the associated maintenance costs in a positive way for the airline. The planning department needs to work closely with the supply chain department and fix a target to maximize life.

4.1.2 Soft-time Limits

Based on the operator's experience, it may be beneficial to introduce a soft time limit for a component that triggers the removal before a failure is expected. Preventive maintenance can reduce the overall cost and operational risk of failure.

Data analysis using operator time-on-wing and industry standard statistical tools, such as Weibull statistical analysis, can be used to determine cost-effective soft-time intervals.

Using statistical analysis tools such as Life Data Analysis (Weibull Analysis) can aid in making predictions about the characteristics of the component (e.g. reliability or probability of failure, mean life or failure rate).

In the example below (Fig 3 and 4), a Weibull statistical analysis is utilized by an operator to estimate the probability of failure of a Pitot tube.

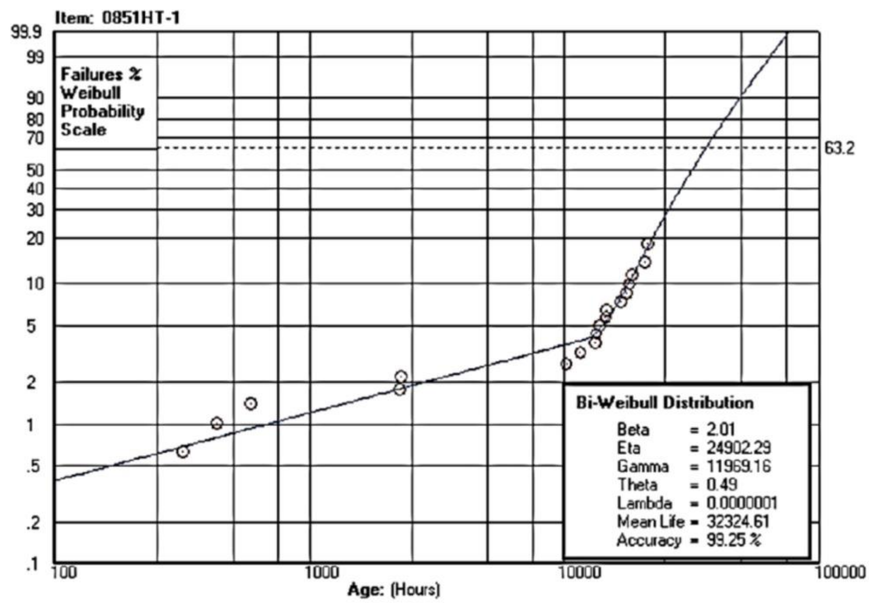
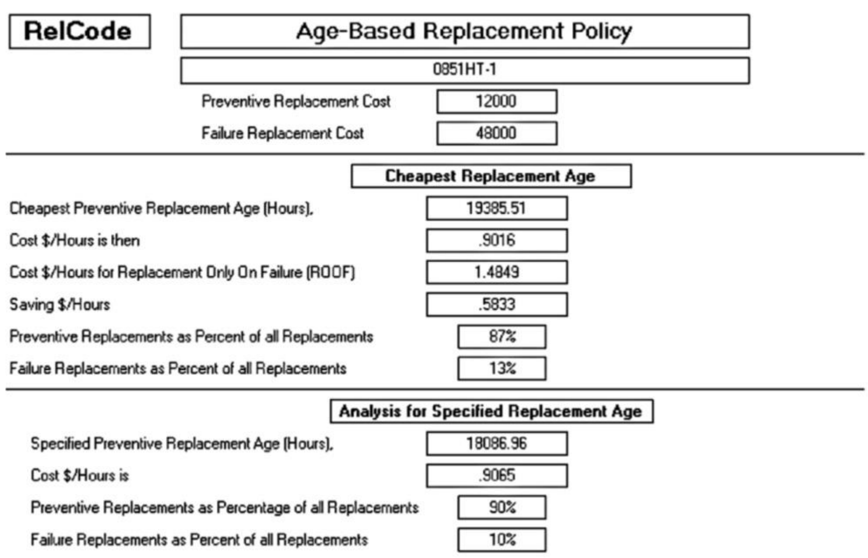


Figure 3. Weibull Statistical Analysis



RelCode

Age-Based Replacement Policy

0851HT-1

Preventive Replacement Cost	12000
Failure Replacement Cost	48000

Cheapest Replacement Age

Cheapest Preventive Replacement Age (Hours).	19385.51
Cost $/Hours is then	.9016
Cost $/Hours for Replacement Only On Failure (ROOF)	1.4849
Saving $/Hours	.5833
Preventive Replacements as Percent of all Replacements	87%
Failure Replacements as Percent of all Replacements	13%

Analysis for Specified Replacement Age

Specified Preventive Replacement Age (Hours).	18086.96
Cost $/Hours is	.9065
Preventive Replacements as Percentage of all Replacements	90%
Failure Replacements as Percent of all Replacements	10%

Figure 4. Age-Based Replacement Policy

The distribution of failure points is concentrated in the +10,000 FH range, although the graph illustrates some low-time failures.

The statistical analysis enables the operator to make an age-based replacement policy decision on the most cost-effective interval to initiate a soft-time interval based on the probability of failure data.

The statistical analysis also indicates the specified preventive replacement age (hours), i.e. the most effective interval at which 90% of the on-wing failures would be prevented.

In considering implementing a soft-time interval, an operator must consider its operational constraints and disruption impact from on-wing failures. In the example of the Pitot tube failure, the operator may consider aircraft out-of-service time if an elevator Pitot tube fails in a location with no access to ground service equipment (GSE) or high lift platforms for replacing the elevator Pitot tube.

Another question in this respect is whether the maintenance of a certain part is performed under predefined limit or “on attrition”. Clearly, life limits will lead to higher costs in the first place, since they restrict the life of a part on the aircraft to a certain extent.

Yet, time limits can be advantageous if overall costs are considered. Since waiting for a failure of a part will have operational consequences in the form of out-of-service aircraft.

4.2 Predictability

Predictive maintenance tools can help operators to cut costs and reduce downtime. Airlines can take better advantage of the increasing amount of aircraft operational data available to support decisions and adjust maintenance planning.

Several OEMs offer predictive maintenance tools. Airbus Time Health Monitoring (AiRTHM), Boeing’s Airplane Health Management (AHM), Honeywell’s Predictive Trend Monitoring & Diagnostics (PTMD) and Pratt & Whitney’s Advanced Diagnostics & Engine Management (ADEM) are only a few examples. These tools use real-time access to aircraft data to provide enhanced fault forwarding, troubleshooting, and historical maintenance information. They allow operators to analyze data remotely, anticipate failures and procure spares.

Predictive maintenance processes can also result in higher No Fault Found[2] (NFF) rates, since a higher number of components are introduced into the repair/overhaul cycle based on predictions of impending failure of the component.

However, once bench-tested in the shop as part of the repair cycle, the component may not demonstrate failure modes in the bench test procedures as when installed in the dynamic on-wing conditions resulting in a NFF score. The component is returned to the operator’s inventory along with the invoice for repair shop testing of the component.

Operators should therefore consider NFF costs as an important factor in the predictive maintenance strategy.

[2] NFF issues and sample events are further discussed in the Section 5.1.4 of this document.

Additionally, equally important consideration should be given to the possibility of a low-time failure if the component that tested NFF in the repair shop is re-installed on-wing and is subject to dynamic or extreme conditions that could not be replicated on the repair shop test bench. Some airlines may consider going beyond Component Maintenance Manual (CMM) requirements.

4.3 Modification Cost Effectiveness

In order to improve reliability of the parts, certain modifications are being introduced by OEMs. Unless policy or commercial clauses exist (component pooling agreements, leasing requirements, etc.), these modifications are not mandatory. In this respect, every single airline needs to adapt its own policy regarding the calculation of the benefit of a modification. Since it clearly depends on the environment in which each airline is operating, different business models and cost structures require different approaches to this matter.

Operators generally calculate modification costs based on modification implementation cost data provided in the technical service literature documentation (e.g. service bulletins, service letters). Typically, OEM/vendor data related to the modification implementation cover man-hour requirements, upgrade kit costs, warranty and downtime requirements to implement the modification.

Cost benefit and risk analyses are common methodologies for justifying a modification implementation.

Under certain conditions of reliability performance or improvement upgrades, vendors or OEMs provide operators with free-of-charge (FOC) component upgrades or modifications issued via service bulletins or service letters.

When evaluating the FOC modification, the operator should also consider consequential costs associated with implementing the free-of-charge modifications.

FOC upgrades do not cover the operator’s man-hour costs for the removal/installation of the component (unless specified in service bulletin/service letter) or transportation costs.

When evaluating the FOC modification implementation, the operator should also estimate repair cost when the component is in the shop for the FOC upgrade. The repair or overhaul costs may be added onto invoices for repairs carried out on the piece-part exposure of the component undergoing the FOC modification.

In summary, FOC labelled modifications are not always free; the operator may incur costs that may not have been calculated in the cost benefit analysis of the modification. Possible repair costs or, in some cases, overhaul costs in addition to man-hour and transportation costs must be considered when deciding to implement FOC vendor modifications on campaign or on attrition basis.

4.4 Engineering and Maintenance Best Practices

Maintenance practices are yet another important contributor to component maintenance costs.

Robust troubleshooting and fault isolation combined with skilled, knowledgeable and experienced personnel can greatly reduce unnecessary costs associated with maintenance practices.

If a maintenance action results in a part removal off aircraft due to an existing system or component diagnostic fault, the repair/overhaul process did not validate the fault resulting in the replacement of the part as not technically justified. This condition is called NFF (No Fault Found) and should be avoided in order to minimize the maintenance cost.

Best practices to enhance on-wing performance

- Concentrate on a good modification policy, try to adopt a model which considers the economic environment and the business model of your airline
- Choose wisely between running component on condition or using soft-time and hard-time limits. Consider opportunity costs like AOG costs
- Optimize task intervals if escalations are permitted; sometimes, a de-escalation may be appropriate
- Optimize intervals; do not throw away residual interval if it does not influence your operation
- Optimize your troubleshooting, learn from experience and share best practices with other airlines in order to get better results
- Be aware of commercial agreements and their, e.g. vendor warranties, component pooling agreements, aircraft leasing contracts, etc.
- Ensure accurate and maintainable reporting by line mechanics
- Track cost effectiveness
- Track high NFF components, issue maintenance tips to avoid re-occurrences
- Use intensively On-board Maintenance System (OMS) to reduce NFF
- Use Maintenance Control for technical support
- Educate cockpit crew on specific items to better understand what affects components' life-on-wing, e.g. heavy landing's impact on landing gear life; high speed taxiing's impact of wheels and brakes; sharp steering angle's impact on wheels, etc. Writing up detail defect information in the logbook may help line mechanics to fix problems more efficiently.
- Provide feedback to training departments in order for them to revise course content

Section 5—Off-Wing Management

In the previous chapter of this document, we focused on on-wing performance with emphasis on reliability of the components to reduce associated costs. Once the component is removed from the aircraft and routed to the shop for repair, overhaul or modification, the focus shifts to the repair shop cycle and costs associated with this process.

Operators that have well-defined supply chain and inventory management procedures in place to manage processes relative to logistics and transportation, turnaround time (TAT), repair costs, shop reporting and receipt/inspection are best placed to retain control over component-related costs.

This chapter addresses (but is not limited to) the factors that define the component costs linked to the repair cycle and part management.

5.1 Repair Cycle

The repair cycle of a component is further classified into the following categories:

- Repair costs & overhaul costs
- Turnaround time
- Fill rate
- Scrap rates
- No Fault Found (NFF)
- Rogue units
- Systems Obsolescence

5.1.1 Repair Costs & Overhaul Costs

Repair costs & overhaul costs need to be defined for the context of the following considerations. Repair means making an item serviceable by replacing or processing failed or damaged parts[3]. Overhaul means returning an item to the highest standard specified in the relevant manual.

[3] World Airlines Technical Operations Glossary (WATOG) definitions from 'Compendium of International Civil Aviation' by Adrianus D. Groenewege, IATA, Second Edition - 1998-1999

As an example, consider a part that consists of many different tubes. Assume that one of these tubes has a leak and needs to be fixed. In an overhaul process, not only will the tube be changed, but the other tubes will also be checked for leaks and possible wear and tear. In this context, repair describes only the rectification of the source problem, i.e. only the replacement of the leaking tube.

Deciding whether to repair or to overhaul a part is a strategic decision for the operator. An overhaul, by definition, will always be the most expensive solution, since the work scope will always be higher or equal to a repair. However, an overhaul may prevent future events by finding problems earlier.

In our example, during the overhaul, another tube may already show signs of heavy wear and tear, and will then be replaced as well. In the event of a repair, this tube may be overseen and demonstrate a leak shortly after the repair event of the first tube. This will lead to another maintenance event, which creates new costs.

Two additional issues need to be considered during the repair cycle:

- Costs are driven by the cost for the overhaul or repair event itself. This is impacted by the local conditions such as material/labor costs of the repair shop location (region) and by the required turn-around-time.
- Assuming that the material and labor costs cannot be influenced, the focus should be on a reasonable demand for a shortened TAT.

5.1.2 Turnaround Time

By definition, TAT is the elapsed time (usually an average, expressed in days) between the induction of a component, engine or aircraft into the repair shop process and the time at which the repair/overhaul is completed and the unit certified and released for service from the repair shop facility. This TAT definition serves well the repair facility (usually after passing a bench test represented in step “Repair/Overhaul” shown in the figure below).

From an airline’s perspective, TAT is defined as the elapsed time between the removal of the component from the aircraft and its return to the operator’s premises as serviceable. With this approach, the operator needs to provision, not only for the time the part is in the repair shop, but also for transportation, customs clearances and other times consumed before the part reaches the repair shop or after it leaves the shop in transit to the airline. Considering shop TAT instead of total TAT is a common pitfall.

Depending on the agreement with the repair provider, TAT can be minimized through an “exchange” program. In such a case, the operator receives a serviceable unit in exchange for its unserviceable one within a certain time frame. There is great variety of such programs as operators and providers try to match needs and requirements with customized offerings.

The following figure illustrates the ideal component repair cycle. It is applicable to all rotables except LLPs.

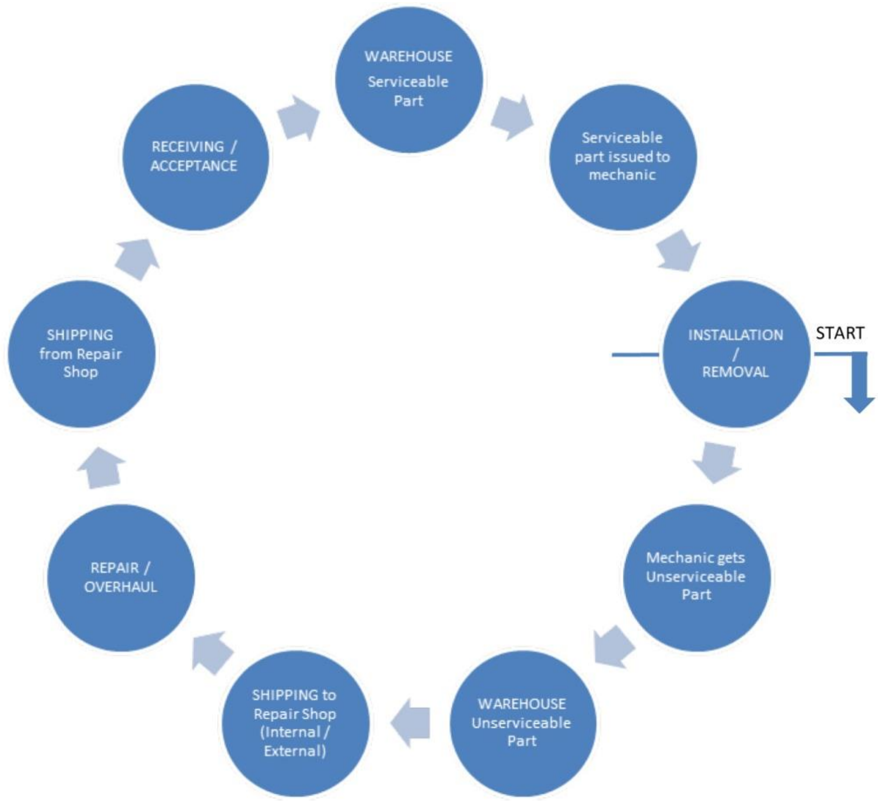


Figure 5. Ideal Component Repair Cycle; Airline TAT

Synchronizing paper work (job cards with “dirty finger prints”) and computerized record system can introduce delays in the cycle. Paperless operations will improve this process and reduce these potential delays.

Each element of the Repair Cycle holds opportunities for cost reduction. Operators should review each of them to estimate their potential. For example, in “Repair/Overhaul”, there are opportunities to implement FOC modifications service bulletins (SB) and engineering orders (EO).

TAT has an impact on the repair or overhaul costs based on efficiency costs. However, there is also consequent consideration of impact to the operator’s inventory spares holdings to cover the components that are in the repair cycle. The operator has to decide if guaranteed TAT costs are an economic offset against costs related to higher spare parts inventory holdings.

5.1.3 Fill Rate

Though TAT is important, fill rate is to be carefully monitored. For example, TAT calculated statistically will determine stocking levels. However, if the airline experiences multiple failures inside a specified time frame, it will result in stock shortages. To avoid this kind of situation, airlines may elect to increase their capital spending (increase spare parts provisioning or contract with a third party).

Airlines should push for closer links with MROs. Life-limited components should be sole sourced and contracted based upon a fill rate demand, not solely TAT. This is due to TSN timing often being very similar for multiple numbers of the same component.

5.1.4 Scrap Rates (Beyond Economical Repair)

Upon removal dictated by an unscheduled or scheduled maintenance event, the component is routed to the shop for repair or overhaul.

Under certain conditions, the cost of rectification of a part is nearly as high as the residual value of the part itself. In such cases, it is common operator policy to “scrap” or discard the component, since it is beyond economic repair (BER).

BER is defined as the ratio of repair cost to the value of the part at which a part is scrapped or repaired. If this ratio exceeds a predefined value, the part is considered as BER and will be scrapped.

A typical value for this threshold is set at 60-70% of the cost for replacement (i.e. catalog list price); each organization has to figure out its own threshold or work on a case-by-case basis. An industry practice is to scrap a part as long as it is BER.

Again, this BER value must be well understood and selected intelligently in terms of needs and circumstances of the individual organization.

Repair facilities often provide a value in their repair quotations that expresses the repair cost compared to the catalogue new price. This value can be misleading. The operator needs to take further aspects into account such as:

- Actual cost for a replacement which can vary in both directions due to additional costs (i.e. transportation, scrap fee for the old part, etc.). Are cheaper options available on the surplus market? Is the airline able to benefit from discounts from the catalogue price?
- Long lead times: in some instances where the opportunity cost of not having a component available due to long lead times for a scrap replacement leads, it makes sense to accept repair cost above the BER threshold and avoid loan or exchange fees. It is therefore recommended to perform a “sanity check” of the BER threshold, especially when the value is very close to the limit or time may play a critical role. Unavailability of a part may force a repair.
- Not all parts are restored as brand new: the useful life (time-on-wing) of the repaired part may not last as long as brand new one.

5.1.5 No Fault Found (NFF)

The problem of intermittent failures in aircraft electronic equipment has long plagued operators, who receive questionable components back from avionics shops labeled “NFF”. NFF occurs when a component that apparently failed in flight is sent to a repair station or OEM for testing, but no failure is found during a bench test.

This NFF is a major problem that is not new. Many believe it is getting worse, in part because today's highly complex aircraft are equipped with more and more electronic sensors, computers, control functions and wires; not all conditions can be replicated on a test bench.

Many factors can cause an NFF. Here are just a few examples[4]:

- Inaccurate in-flight or line maintenance diagnosis
- Multiple component removals to address a single failure
- Inaccurate or incomplete bench testing at repair stations or by the equipment OEMs
- Inability to accurately duplicate the circumstance in which a component fails
- Rogue units – a specific serial number that produces the same fault within a short timeframe when installed on wing.

NFF Sample Demonstration

To accentuate the issue and associated cost implications of NFF, consider the graphic demonstration of a component NFF impact from an operator sample set.

Part: Generator Control Unit P/N 1701321D

Data Sample: Unscheduled Removals (UR) over the last 12 months (L12M)

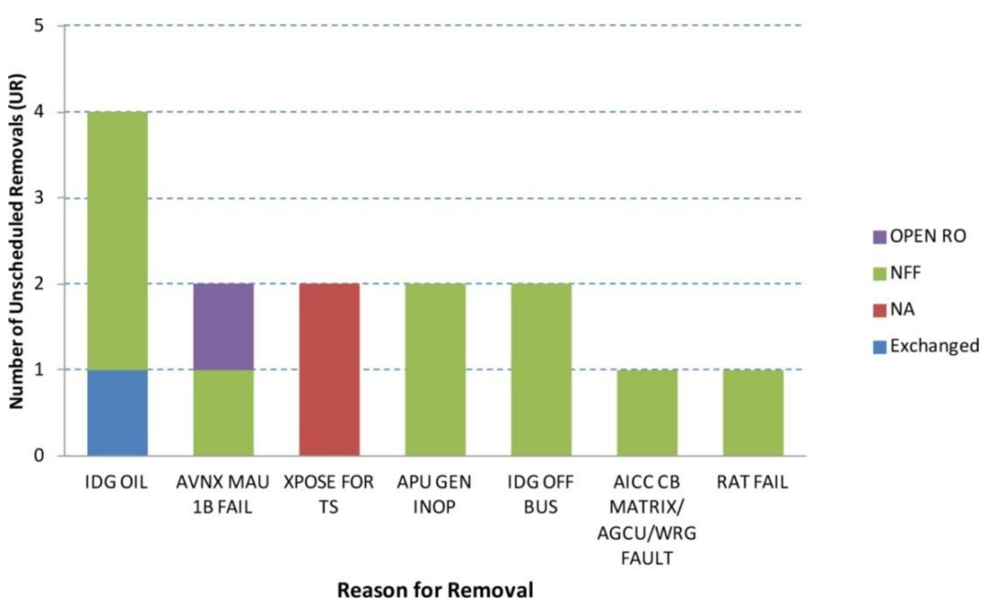


Figure 6. Reasons for Unscheduled Removals

In summary, there have been 14 unscheduled removals for this operator in a 12-month period. The top reason for removal is the "IDG OIL CAS" message.

[4] Aviation Today "Special Report: Avoiding NFF" 2005

Out of 14 removals, 10 have been returned from shop to the operator tagged “NFF” giving a NFF rate of 71%. Of the 14 removals, 8 of the removals were initiated by Predictive Maintenance, and 6 were defect related removals.

The data suggests that the NFF costs associated with shipping, repair, testing and certification are quite substantial, and this applies to one component only.

It is important to note that there should be ongoing communication with the OEM on updating the Fault Isolation Manual (FIM) to address the troubleshooting steps when encountering the fault codes displayed by the component. Also, a solution may be available via modification for which a service bulletin is expected to be released shortly.

The best way to avoid high NFF rates is effective troubleshooting, using your own or other airline’s experience in order to optimize certain troubleshooting steps.

For example, consider a simplified problem with a two-step troubleshooting, both involving the replacement of a certain part number. The part number, which has to be replaced in the first step, shows a very high NFF rate, the second part number shows a high rate of confirmed failures. It is crucial to implement processes that make sure that future troubleshootings start with the second troubleshooting step and the replacement of the second part number. A link needs to be created between the repair organization and the line or base maintenance organization that shares the experience. On one hand, the troubleshooting will be improved, and problems will be solved in a more effective way. On the other hand, unnecessary repair or overhaul events will be avoided. The more data the airline has, the more sophisticated the decisions will be, so it makes sense to share experiences with other airlines in order to improve data quality. If component maintenance is outsourced to a service provider, it is important to have a feedback loop with the line or base maintenance provider and to cover these improvements in contract negotiations or tenders.

Ship or Shelf (SOS) Policy

Removing a component, sending it for test and discovering that no failure was found is definitively a waste of time and money.

In the process of troubleshooting an aircraft system problem, certain airframe, engine or avionics components are replaced. In some instances, the first component change does not correct the problem.

Some airlines implement a Ship Or Shelf (SOS) policy, which is designed to reduce excessive shop costs of components removed for troubleshooting that do not correct the problem and are not physically damaged. A unit determined to be in this category may be classified as serviceable and retained at the maintenance station for future use.

The policy consists in placing a removed unit (eligible for SOS policy) in the SOS quarantine and monitoring the aircraft behavior during a few flights:

- If the fault does not re-appear, the unit replacement corrected the problem. The removed unit is then declared unserviceable and shipped for test/repair.
- If the fault re-occurs, the removed unit is declared serviceable pending results of a physical inspection.

Detailed procedures related to the SOS policy must be described in the Maintenance Policies & Procedures document. The procedures should list the components that are not eligible for SOS policy. Full approval from the Local Airworthiness Authorities is required.

5.1.6 Rogue Units

A rogue unit is a component that repeatedly experiences short service periods.

Airline Technical Operations should implement a tracking program to easily identify rogue units, which encompasses the following:

- Scope & objectives of the tracking program
- Definition(s) of a rogue component
- Well documented processes to support the tracking program
- Implementation of an automated tracking system

The main objectives of the tracking program are to capture components by serial number that have frequent removal records with short service period, to analyse the causes of short life service and to take corrective actions in the aim of:

- Reducing impact on schedule
- Reducing maintenance burden & costs
- Complying with Supplier Support Conditions (SSC) clauses

The corrective actions are usually:

- Taking the issue to the supplier for solutions as envisaged in the SSC with the respective aircraft manufacturer
- Removing the part from stock
- Scrapping the part when declared BER after repeated repair attempts that have not improved its life

5.1.7 Systems Obsolescence

Systems obsolescence[5] refers to an entire line replaceable unit (LRU) being declared that it has reached end of life (EOL) by its manufacturer. The manufacturer has made a business decision to discontinue it because recovery action is either not technically feasible or not profitable anymore due to declining demand.

[5] Source: FAA Draft Document on Obsolescence and Life Cycle Management for Avionics. Limited Release Document dated 24 September 2013.
https://www.faa.gov/aircraft/air_cert/design_approvals/air_software/media/ObsolescenceFinalReport.pdf

Avionics suppliers generally notify customers and end users that a product has reached EOL by means of Service Information Letters (SIL) or Service Bulletins (SB).

Obsolescence is an inevitable occurrence; therefore operators should consider processes for management of systems obsolescence, to minimize the recurring cost impacts within the repair cycle whilst maintaining continued airworthiness and regulatory compliance. The main goal of obsolescence management is to minimize life cycle cost, i.e. enact the most cost-effective solution in terms of component cost.

Operators need to be aware of the terms in their component management contracts in regards to obsolescence. Cost of obsolescence can have significant impact on DOC. In most cases, vendors will seek full cost recovery based on a "time and material" basis if an item cannot be repaired due to obsolescence and has to be replaced with an upgraded version.

5.1.8 Best Practices to Reduce Overhaul and Repair Costs

- Optimize TAT in terms of "Overhaul and Repair costs" but always consider the effects on minimum stock level of the single part number; if there is stock in hand and the fill rate is optimized and met, there is no reason to insist on a short TAT that will drive up the costs.
- Choose wisely whether to repair or overhaul a part. Bear in mind that a repair can lead to more single events in the long run. Also, evaluate if the lead time to get a new part meets the operational requirement.
- Minimize NFF rates and pay attention to the NFF fees in the contracts
- Establish an optimum for your own BER ratio; determine if the BER policy applies and considers allowing flexibility depending on certain cases (e.g. unavailable new part)
- List down the priority items which cause the majority of the costs. Use the categories to find weak points and involve suppliers
- For all commercial agreements, consider total TAT of the part in question. Looking only at the shop's TAT will leave the airline exposed for the time that the part is in transit anywhere between the airline and the outside repair shop.
- Use fill rate in addition to TAT
- Rationalize the supply chain management policy: either pick and choose OEMs individually (this may create overhead costs) or consolidate in a one-stop provider
- Carefully evaluate all implications before using non-OEM products, repairs and new technologies during the term of lease: they may minimize costs but may cause problems at redelivery.
- Consider all costs, i.e. holding cost of inventory, cost of administrative overhead, repair cost, reliability or TOW, freight

- Implement Six Sigma methodologies to minimize overhaul and repair costs: use DMAIC[6] to reduce NFF rate for components with the highest NFF rates (e.g. batteries, emergency transmitter packs, etc.) or reduce TAT.
  - Define the most critical P/N that have unreasonably long TAT
  - Measure the effects on inventory level and AOG requests
  - Analyze the reasons for long TAT (logistics issues, bad contract conditions with repair stations, etc.)
  - Improve on parameters that lead to long TAT
  - Control implementation by monitoring TAT

5.2 Parts Management

This section addresses the various costs associated with parts, the cost of ownership and provisioning (spare part costs) for components as well as escalation rates. These costs are grouped under the following categories:

- Ownership costs
- Component pooling
- Fleet configuration
- Price escalations
- Warranty
- Surplus parts or repair

For more details, please refer to IATA's Guidance Material and Best Practices for Inventory Management, 2nd edition (2015).[7]

5.2.1 Ownership Costs

Each organization's underlying accounting standards, which also account for repaired parts, are a decisive factor for the cost of ownership. This section provides a brief overview of which general items have to be considered when managing component maintenance costs. A more in-depth analysis of the effects and possibilities of accounting methods is not within the scope of this paper.

[6] DMAIC (Define, Measure, Analyse, Improve, Control) is a data-driven methodology to improve, optimize and stabilize processes.

[7] IATA's Guidance Material and Best Practices for Inventory Management, 2nd edition (2015) - ISBN 978-92-9252-741-9 Free download on www.iata.org/mctf

Spare part costs also depend on this obvious decision: which components to stock, in what quantity and where? The question whether a component is directly stocked or not relates to the amount of risk an airline is willing to take on its daily operation.

Stock Optimization using in-service component reliability and operational data

Initial provisioning is a process by which an airline defines the range and depth of spare parts that are considered as necessary for:

- Supporting a new aircraft fleet for an initial period of operation
- Maintaining and repairing a fleet of aircraft, engines, end items, support equipment and related component parts

The selection and initial procurement of spares for a new fleet or another end product is based on a mathematical formula that uses several parameters, among which the MTBUR defined by the manufacturer on the basis of fleet-wide achieved figures.

Revisions of and enhancements to the initial provisioning data are often required when:

- Airline route structures or fleet structures are altered
- Maintenance plans are altered
- Actual removal rates differ significantly from the IP data

The objective of this review is ultimately to assess the main base and station inventories for surplus or deficiencies in light of new requirements. Any component exhibiting poor reliability in comparison to the initial provisioning data usually requires an in-depth engineering investigation and cost-benefit analysis to assess the opportunity of upgrading the component rather than re-provisioning or vice-versa.

Rather than investing in a large amount of inventory, many airlines choose to permanently lease in a certain amount of material from external providers, thus reducing the capital expense.

In terms of operations, a riskier alternative than putting a component on stock is to lease it in case of an emergency. This implies certain lease costs and the cost of the time needed to get access to a part from the market. These costs have to be compared to the cost of ownership of parts you put on your own stock, including opportunity cost, depreciation and storage related costs. Pooling contracts are widely known and further reduce the amount of inventory (capital investment) needed to supply the operation. Under a pooling concept, the airline pays a fee to get access to a pool of components from a certain supplier. Different from the closed-loop repair concept of owned material, a pool concept typically works on an “open-loop” basis and reduces the TAT of repairs – therefore increasing part availability.

In order to get an optimum allocation of which component is made available through one of these channels, all specific circumstances of each airline have to be considered. A smart approach is needed to determine which parts should be sourced through which channel. Some of the cost contributing factors that need to be considered in pooling arrangements are briefly discussed in the following section.

It is important that the airline addresses thoroughly the issue of spares provisioning and how much risk is involved when a spare part is not owned and not pooled. In these cases, it is recommended that the airline has some arrangement in advance with a provider in order to avoid the excessively high emergency “AOG” fees.

5.2.2 Component Pooling

Component pooling arrangements can be beneficial and efficient. They can support multiple operators with less total capital than if each operator owned their own parts. This results from the slow inventory turnover of many aircraft parts, especially when small fleets and multiple stations are involved.

An operator that is considering entering into a component pooling arrangement with a service provider should also review the impact of existing modification policy and reliability-initiated programs that were in place prior to the component pooling arrangement. In case of leased aircraft, the operator should carefully examine the underlying clauses of the status of components during redelivery of the aircraft.

Modification Standard

The operator must specify the minimum modification status for components within the pool. This will ensure that the modification status of a component returned to the operator from the pool meets the standard set by the modification policy or decision for that specific component.

Reliability Standard

Similarly, if the operator has specified reliability-initiated soft-time limits for certain part numbers, it must ensure that a part number removed for soft-time limit as part of a campaign replacement is not exchanged with a part number without a minimum or acceptable remaining life-on-wing.

To further elaborate this discussion, consider a soft-time limit of TSN 25,000 FH set by the operator due to reliability-driven decision. When this part is removed and sent to the pool for an overhaul, the pool provider typically exchanges a similar or interchangeable part number back to the operator inventory. However, if this exchanged part number has a TSN of 20,000 FH, the operator’s maintenance program will schedule removal within 5,000 FH due to the operator set soft-time limit of TSN 25,000 FH. This will result in additional maintenance requirements in labor costs associated with removal and replacement.

5.2.3 Fleet Configuration

Fleet configuration and commonality across the aircraft type are factors that impact the cost of spare part provisioning.

Even though aircraft manufacturers have established aircraft families with common part numbers on several different aircraft types, there are many obstacles that can turn material provisioning into a financial complexity. Similar aircraft models can have an array of specific part numbers due to different configurations, deviations from their modification status, and the evolution of aircraft systems during the lifecycle of an aircraft type.

Aircraft are constantly delivered to operators with upgraded or modified components from specific production line numbers that are one-way or two-way interchangeable with existing part numbers. A full understanding of these configuration changes and updates to inventory data is key to successful inventory management and cost control.

Phase-in of used aircraft enhances the complexity of mixed fleet configuration and can greatly increase inventory costs.

It is beneficial for an operator to maintain fleet commonality as much as possible, define a common modification standard, and make selective decisions on where to base aircraft. If there are deviations in the configuration of an aircraft type within the fleet, it is recommended to establish sub-fleets, grouping aircraft with common features at one location (e.g. keep a sub-fleet of aircraft with a certain engine type at a common home base).

When purchasing new aircraft of the same type but different configuration, it is advantageous to consider retrofitting current aircraft as part of the purchase contract. This may be in the form of reduced price or FOC assuming the aircraft seller can reuse such equipment. The length of time the aircraft is due to remain in ownership should also be taken into consideration, in essence the pay back period.

Components assigned to certain fleets based on commonality of the part numbers and modification status could therefore be inventoried at these grouping locations in order to reduce shipping costs. Availability of components at these grouping locations also reduces time for fault rectification and returning aircraft to service if the required part number component and modification status are at the right place at the right time. For certain locations, an airline should look at the availability of other parts from other airlines or providers and consider participating in pools for specific aircraft types and parts on a loan basis. The International Airlines Technical Pool[8] has established a long history of providing certain parts coverage.

5.2.4 Price Escalations

The annual escalation of list prices of parts can lead to hidden costs and has to be considered while negotiating contracts in terms of long-term purchase pooling or repair agreements.

Most of the escalation is driven by the OEM itself, and there is no unique methodology to justify the increase. Component price sometimes grow by over 5% each year. In certain cases, the OEM claims that

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[8] The International Airlines Technical Pool (IATP) is a convention of airlines sharing technical resources to generate economic savings and to achieve on-time dispatch reliability and safe operation at the line stations.

The IATP is a not for profit, independent, non-political global organization based on a democratic culture with equal opportunities for all member airlines and their delegates.

For more information, please visit www.iatp.com such escalations, much higher than inflation, are justified by the OEM model: providing the unit at or below cost and making profit from the aftermarket. This argument is not necessarily true as OEM profits are consistently much higher than airline margins. Additionally, raw material costs and the quest for low labor cost facilities have made this argument very weak.

Establishing escalation clauses or catalog price discounts may initiate a cap on price escalations and should be considered as part of the contract negotiation. It is necessary to determine these escalation clauses in advance on the long-term pricing of contracts.

5.2.5 Warranty

Warranties can be seen as an insurance for the operator. They can also contribute in reducing maintenance cost in general and, specifically, component maintenance cost.

The importance of warranties comes from product performance uncertainties associated with a new product and protect the user from any design or manufacturing related defects, including unreasonable wear and tear. Additionally, warranties exist not only on new parts but also on parts being repaired or overhauled by repair shops.

Generally, operators would like to preserve the first few years of operations from risks associated with component maintenance: this is the case when the operator procures a component or a new aircraft with installed components. The operator commonly expects to mitigate the risk associated with component repair for a contracted initial duration of either calendar time, flying hours or cycles, or a combination of those. Herein the operator seeks and expects an OEM or an MRO to take the responsibility and bear the costs of a defected part and workmanship, knowing that the OEM/MRO knows the product and have the intelligence on the product behavior.

There are two types of warranties, the implied and the expressed. The implied warranties are governed by law, where the OEM holds the responsibility to meet certain quality levels of sold or installed component by providing correct and accurate information on the sold component. The implied warranties usually are not linked to component repair or service agreement.

These warranties come along with the OEM/MRO sales strategy to assure and to build the operator/lessor’s confidence, as they guarantee that their aircraft/engine/component will operate according to the agreed terms.

In general, the OEM passes on their warranties to the operator, and in case of a leased asset, the warranties are passed on to the lessor who passes them to the operator. Herein, the warranties can take a number of forms to protect the operator from any lien associated with the sale and protecting the right of the operator to take benefit from the implied and expressed warranties that are related to the OEM liability on the component quality and any unforeseen defect for the contracted timeframe.

The expressed warranties are a written statement in the agreement ranging from stating the exact description of the component with its part number and, in specific cases, the serial numbers, to specific figures limitation on components operational promised threshold and minimum hours/cycles, or months on wing. The warranties address the operational defect due to component manufacturing or repair quality (parts and workmanship).

Airlines have to be fully aware of contractual language about warranties. In the agreement, warranties must be written in a clear format, and easy to monitor. In some cases, an example on how to measure the trigger of warranties can be a good method to illustrate and to document the seller's obligation and liability towards the buyer/operator. Also, in order to clarify the relationship between the OEM/MRO and operator, it is highly recommended to document how to claim and to settle warranties and designate who will act as a focal point of contact from each side.

Parties, especially the operator, may assign warranty management to a third party, where the third party holds the management of claims and warranty settlement on behalf of the operator. This case is common when the operator assigns warranty management to its contracted MRO to claim the stated OEM warranties.

When the aircraft/component is leased, the lessor will designate the operator as the beneficiary of any implied or expressed warranties that are associated with the leased asset. During the lease, the operator will manage and get the benefit of any warranties that were given by the OEM/MRO to the lessor.

In the agreement, it is highly recommended to state how the defect of a component will be rectified, depending on whether the defective component can be rectified without being removed or the defect requires to the removal and transportation of the component. In that case, it is also important to state who will be responsible for the cost and risk/insurance of transporting the component to the site where the OEM/MRO can perform its duties.

Warranty management[9] requires compiling information such as matching serial numbers, previous date and scope of service, and contracted warranty terms for different sources. Airlines have limited resources to deal with warranties and tracking mechanisms are usually not in place. It is recommended to designate a warranty manager within the airline (or subcontract to an experienced external provider) to systematically check the warranty status of components to be repaired and set alerts for warranty expiration in the airline maintenance system. It is also important to monitor the warranty savings by tracking the warranty money to be collected and the success percentage. This applies to warranties on both new components and components that have been overhauled/repaired by an MRO provider.

5.2.6 Surplus Parts or Repair

Opting for surplus parts or repair depends on the platform type and the demand of the market.

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[9] Source: Section 5.5.6.3.2 of IATA's Guidance Material & Best Practices for Airline Operational Cost Management ("AOCM Book"), 2nd edition ISBN 978-92-9233-985-2

Airlines and service providers need to have their fingers on the pulse of the market shifts on a daily basis. Different platforms have different saturation points after a period of time in operation. The saturation refers to the level of available surplus material floating about in the market. For example, there are a lot of 737 or A320 aircraft flying and retiring for breakdown, and inventory levels on rotable components are very high. With such a huge supply, prices for serviceable or overhauled material are driven down, sometimes making it more cost effective to simply buy a repaired component instead of sending one out into the MRO supply chain. In certain scenarios, it is possible to buy three overhauled units as a package for the same price as the piece parts needed to perform just one overhaul. Understanding these situations is an essential driver in maintaining the cost effectiveness of flying a mature fleet.

For more information on alternate parts, please refer to IATA's Guidance Material and Best Practices for Alternate Parts (PMA) and Approved (non-OEM) Repairs (DER).[10]

5.2.7 Best Practices for Parts Management

- Develop a model considering all circumstances in the operation of your airline in order to decide whether you own or subcontract all, some or none of the parts management activities through "loan and borrow".
- Avoid as much as possible entering into contracts during emergency situations such as an AOG; have these contracts in place before an AOG happens
- Evaluate foreign exchange exposure and identify mechanisms to mitigate currency fluctuations; consider including them in your contract(s).
- Control escalation fees in your contracts; consider including caps.
- Ensure that there are caps to escalations and link escalations to well-known indices that are related to your operations rather than the OEMs or the MROs
- Participate in industry benchmarks to ensure transparency on escalation rates
- Establish a configuration standard and consider sub-fleets when positioning aircraft
- Determine the optimal mix of own material vs. leased material
- Survey inventory/spares of other airlines and providers at certain locations/stations; there may be a "pooling" opportunity.
- Establish a robust and effective warranty procedure to assess, submit and manage warranty claims
- Make sure that warranty-claimable costs are identified and recovered within contractual timeframes
    - Incorporation of service literature – e.g. SBs and SIL – including claims for material and/or labor
    - Warranty for failed modifications that lead to degradation from pre-modification condition

[10] Guidance Material and Best Practices for Alternate Parts (PMA) and Approved (non-OEM) Repairs (DER) - 2nd Edition (March 2015) - ISBN 978-92-9252-611-5
Free download on www.iata.org/mctf

- Business costs incurred as a consequence of OEM products not performing to specification or an agreed maintenance guarantee
- Specific terms and conditions of OEM Product Support Agreements (PSAs) and Aircraft/Engine purchase contracts which may include claims for material, labour and/or freight costs related to component warranty repair activity or other warranty rectification activity
- Material consumption of airframe maintenance activity during heavy checks. For example, some aircraft OEMs provide a standard consumable allowance in excess of the cost of each check.
- Follow-up of disputed & open claims where waranted, and establish effective reporting of warranty recoveries

Section 6—Summary

We have discussed the complexities and contributing factors associated with the management of aircraft component costs.

Components' on-wing performance is mainly driven by their reliability. The longer a part is installed on-wing, the less replacement and repair costs it generates. Modifications and software or hardware upgrades are designed to increase the time-on-wing. However, the effectiveness of these modifications needs to be weighed against the cost of implementing them through a cost-benefit analysis. A combination of OEM and aftermarket parts may provide the most reliable and cost optimum solution.

Component Life Limits or Soft Limits imposed by operators will result in the part removal off the aircraft.

Predictive maintenance can reduce aircraft out-of-service costs by removing parts before they fail on-wing. However, this policy generates costs by increasing the repair cycle costs. The significance of No Fault Found costs must also be considered. Similarly, established maintenance practices and accurate fault isolation will enhance time-on-wing and reduce the maintenance cost burden of removing components with no hard faults for troubleshooting.

In the section on Off Wing Management, we discussed the Repair Cycle with clear emphasis on maintaining transparency of the repair cycle processes. Operators need to be aware of NFF rates, FOC modifications as well as best practices in establishing guaranteed TAT and thresholds for BER rates. Certain commercial agreements resulting from OEM practices, parts pooling or aircraft leasing, should also be considered. Not all OEM advisory modifications or life limits improve reliability. They should be carefully reviewed before implementation through cost benefit analysis.

In the Parts Management section, we reviewed the financial implications, including ownership costs and pricing escalations, all of which sometimes result in exponential costs for the operator. Common fleet configuration and component pooling can have a positive influence on component costs. In addition, contract management, including warranty clauses, is fundamental to control component maintenance costs.

Based on all the points addressed in this paper, it may be beneficial to compile a Top 50 list of part numbers that generate the highest cost within your operation, in terms of repairs, overhaul or maintenance. This will create a starting point for optimization programs that could be put in place to address the "low hanging fruits" and initiate reductions in component maintenance costs. The costs should include transactional cost, e.g. technical records, purchasing, freight, etc.

Finally, component maintenance costs are a significant contributor to direct maintenance costs, therefore it is sensible to establish policies, procedures and oversight for efficient component management either on-wing or during the off-wing repair cycle.

This document is just a starting point. We intend to update and augment it with all the best practices we will gather in the future. If you would like to contribute, please contact us at mctf@iata.org.

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Section 8—Glossary

ADEM	Advanced Diagnostics & Engine Management
AHM	Airplane Health Management
AiRTHM	Airbus Time Health Monitoring
AOC	Air Operator Certificate
AOG	Aircraft On Ground
APU	Auxiliary Power Unit
BER	Beyond Economic Repair
CMC	Component Maintenance Costs
CMM	Component Maintenance Manual
DER	Designated Engineering Representative
DMAIC	Define, Measure, Analyze, Improve, Control
DMC	Direct Maintenance Costs
DOC	Direct Operating Costs
EOL	End Of Life
FC	Flight Cycle(s)
FH	Flight Hour(s)
FIM	Fault Isolation Manual
FMV	Fair Market Value
FOC	Free Of Charge
GSE	Ground Service Equipment
IATP	International Airlines Technical Pool
IDG	Internal Drive Generator
LLP	Life Limited Part(s)
LRU	Line Replaceable Unit
MRO	Maintenance, Repair and Overhaul
MTBUR	Mean Time Between Unscheduled Removals
NFF	No Fault Found
OEM	Original Equipment Manufacturer
PMA	Part Manufacturer Approval
PSA	Product Support Agreement
PTMD	Predictive Trend Monitoring & Diagnostics
SB	Service Bulletin

SIL	Service Information Letter
SOS	Ship Or Shelf
SSC	Supplier Support Conditions
TAT	Turn Around Time
TOW	Time On Wing
TSI	Time Since Installation
TSN	Time Since New
WATOG	World Airlines Technical Operations Glossary

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