UNIVERSIDADE DA BEIRA INTERIOR
Engenharia

MRO and Fleet Reliability Implementation and Improvements

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Dissertação para obtenção de Grau de Mestre em
Engenharia Aeronáutica
(ciclo de estudos integrado)

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> ”New thinking is required to bring about the improvement required.”
>
> *IATA ECONOMICS BRIEFING No 10*

Dedicated To

My parents, my brother and my beloved family.

Acknowledgements

I would like to show my gratefulness about being able to perform this (MSc) Thesis with Universidade da Beira Interior (UBI) and Indústria Aeronáutica de Portugal, S.A. (OGMA), simultaneously. Surely it is a profitable situation, both for academic and for professional purposes.

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To my dad who thought me the wrongs and rights in life, the one who constantly thought me that exceptional results only come from hard work. To my mum who was, still is and will be my support in everyday life adventures. To my brother who is the example and the one who kindly brought me to see the world with a unique vision.

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Because nothing is achieved only by our own, thank you everyone.

Sincerely grateful,
Adriano Carvalho Andrade

Resumo

É com o constante desenvolvimento na área da aviação que se procura uma maior disponibilidade das aeronaves, bem como a diminuição de custos relacionados com a manutenção, que estão a levar operadoras e centros de manutenção a inserir programas de fiabilidade.

De uma forma geral, excluindo operações de teste e outras mais específicas, a aviação civil está implementada por forma a realizar voos de transporte, com passageiros, correio ou cargas específicas. Por outro lado, a aviação militar está desenhada para realizar operações de combate aéreo, suporte de transporte logístico, voos de vigilância ou reconhecimento, entre outros de carácter operacional especial. Assim sendo, a aviação civil está direcionada para transporte aéreo repetitivo e sistemático e a aviação militar para operações pontuais e particulares.

O sucesso do uso de Programas de Fiabilidade na aviação civil faz aumentar a fiabilidade das aeronaves relativamente ao rendimento dos custos de manutenção das aeronaves, bem como a disponibilidade das mesmas. Este sucesso tem cativado, a pouco e pouco, o interesse por parte da aviação militar.

Devido ao tipo de manutenção (MRO) que a OGMA é responsável, e em paralela decisão com o Operador (cliente), foi acordado a implementação de um Programa de Fiabilidade, como projeto de melhoria contínua inicial, com vista em aumentar a fiabilidade de componentes rotáveis e das próprias aeronaves de uma frota militar de carga.

Desta forma, esta dissertação de mestrado foca-se na validação, implementação e aplicação de um Programa de Fiabilidade de Aeronaves, cálculo de métricas de fiabilidade, geração de alertas, implementação de análises de modos de falha e efeitos direcionados para processos e desenho/projeto de componentes, pesquisa de causas raiz e modos de falha, implementação de ações corretivas e sua monitorização.

São abordados temas como dados de manutenção usados, o cálculo de métricas de fiabilidade, a análise de níveis de alerta, a investigação de causas raiz, a implementação de ações corretivas e sua monitorização.

Palavras-chave

Componentes Rotáveis; Fiabilidade; Frota de Aeronaves de Carga Militar; Manutenção, Reparação e Operações (MRO); Melhoria Contínua; Programa de Fiabilidade de Aeronaves (ARP).

Abstract

With the constant development in the aviation area, it is the search for a greater availability of the aircraft as well as the reduction of costs related to the maintenance that are leading operators and maintenance centers to implement reliability programs.

In general, excluding test operations and other specific operations, civil aviation is designed in order to carry transport flights with passengers, mail or specific cargo. While military aviation is designed to carry out aerial combat operations, logistical transport support, surveillance or reconnaissance flights, among others special operations. Thus, civil aviation is aimed for repetitive and systematic air transport and military aviation for punctual and particular operations.

The success of the use of Reliability Programs in civil aviation increases the reliability of the aircrafts related to maintenance costs and availability. This success has, step by step, seduced the interest in military aviation.

Due to the type of maintenance (MRO) that OGMA is responsible for and in parallel decision with the Operator (costumer), it was agreed to implement a Reliability Program, as a continuous improvement project, with the goal of increasing the reliability of rotable components as well as of the self military cargo aircrafts of the fleet.

By this, this MSc Thesis is focused on the validation, implementation and application of an Aircraft Reliability Program, calculation of reliability metrics, generation of alerts, root cause search and failure modes, implementation of a failure mode and analysis related to design and processes as well as corrective actions and their monitoring.

Issues such as maintenance data, metrics calculation, alert levels analysis, root causes investigation, corrective actions implementation and monitoring processes are addressed.

Keywords

Aircraft Reliability Program (ARP); Continuous Improvement; Maintenance, Repair and Overhaul (MRO); Military Cargo Aircraft Fleet; Reliability; Rotable Components.

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List of Acronyms

A/C	Aircraft
AAIP	Approved Aircraft Inspection Program
AD	Airworthiness Directive
AHM	Airplane Health Management
AMM	Aircraft Maintenance Manual
AMP	Aircraft Maintenance Program
AOG	Aircraft On Ground
ARP	Aircraft Reliability Programme
ATA	Air Transportation Association
CAMO	Continuing Airworthiness Management Organization
CM	Condition Monitoring
CMM	Component Maintenance Manual
CND	Could Not Duplicate
CRS	Certificate of Release to Service
CSI	Cycles Since Installation
CSN	Cycles Since New
CSO	Cycles Since Overhaul
DCA	*Departamento de Ciências Aeroespaciais*
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FAP	Portuguese Air Force
FC	Flight Cycles
FH	Flight Hours
FMEA	Failure Mode and Effects Analysis
FMECA	Failure mode and Effects Criticality Analysis
FMS	Fleet Management System
FR	Failure Rate
HT	Hard-Time
IAW	In Accordance With
ICAO	International Civil Aviation Organization
LM	Lockheed Martin
MCBF	Mean Cycles Between Failures
MCBR	Mean Cycles Between Removals
MCBUR	Mean Time Between Unscheduled Removals
MCTF	Mean Cycles to Failure
MMEL	Master Minimum Equipment List
MRO	Maintenance, Repair and Overhaul
MSc	Master of Science (equivalent to MEng, Master of Engineering)
MSG	Maintenance Steering Group
MTBF	Mean Cycles Between Failures
MTBR	Mean Time Between Removals
MTBUR	Mean Cycles Between Unscheduled Removals
MTTF	Mean Time to Failure
NASA	National Aeronautics and Space Administration
NFF	No Fault Found
OC	On-Condition

OGMA	***Indústria Aeronáutica de Portugal*, S.A.**
P/N	Part Number
QEC	Quick Engine Check
RBM	Reliability Board Meeting
ROTI	Repair, Overhaul, Test and Inspection (procedures)
SB	Service Bulleting
SIGMA	*Sistema de Informação e Gestão da OGMA*
SL	Service Letter
S/N	Serial Number
TAT	Turn Around Time
TD	Temperature Datum
TM	Technical Manual
TO	Technical Operations
TSI	Time Since Installation
TSN	Time Since New
TSO	Time Since Overhaul
UBI	University of Beira Interior
VHF	Very High Frequency

Chapter 1

Introduction

The search for a safer, airworthy, trustful and low cost operation/maintenance in an aircraft fleet is achieved by the correct implementation and usage of several powerful tools, one of them is known as the Aircraft Reliability Program. If correctly analyzed and implemented, it owns a particular ability to improve, in detail, a system, a component or even a process. The data retrieved from reliability is able to give greater benefits to the operator, manufacturer or aircraft/components maintenance centers if all of these cooperate with each other in a constant and continuous manner.

The implementation of a mandatory Reliability Programme by EASA (European Aviation Safety Agency) and FAA (Federal Aviation Administration) is aimed for CAMO (Continuing Airworthiness Management Organization) of PART-M, Subpart-G Organization. Such requirement was established as mandatory for civil aviation in accordance with specific parameters related to the aircraft and fleet size. Even though this requirement is not mandatory for military aviation, Civil Aircraft Reliability Program benefits and results have been catching the Military's attention. Thus, its implementation is considered of great importance.

This thesis holds information about analysis, research and implementation of corrective and/or preventive actions. Such actions aim to improve and optimize rotable components reliability and MRO processes. As the customer service is paid by flight hours, the more hours of flight the fleet has (more availability and less maintenance procedures) the greater OGMA's income is. It is specifically focused in a military cargo aircraft fleet (Lockheed Martin C-130 Hercules), **Figure 1.1**.

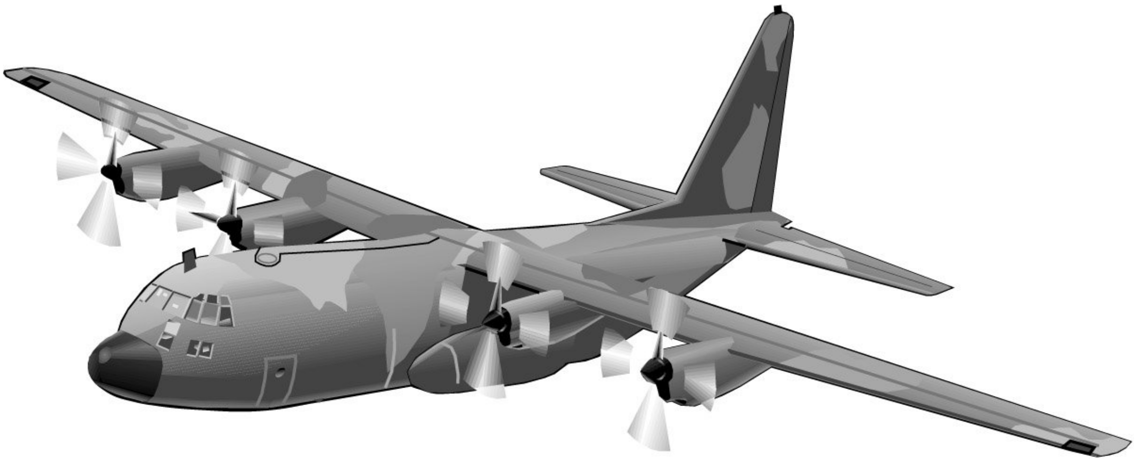


Figure 1.1: Lockheed Martin C-130 Hercules [1].

All data related to the Aircraft, Components and Operator are confidential and might not show eligible or readable due to agreements/policies of privacy and data protection between the Operator and OGMA Services and Maintenance Center.

1.1 Background

This research was triggered by the need of understanding and improving reliability of rotable components and its process. OGMA is the main responsible for these components in all their life stages, from the moment it is removed from an aircraft due to a maintenance task, until their installation (operation is excluded). To sum up, OGMA is responsible for the majority of maintenance, repair and overhaul procedures for the safe and airworthy aircraft components' operation.

With almost one century of historical achievements and experience, OGMA is not only oriented to the Aerospace MRO Industry but also an important player in the Manufacturing Business. Its range of operational approvals is widely known as well as the quality service provided. Such commitment has granted its costumers confidence.

OGMA has been a Lockheed Martin Authorized Service Center for the C-130 Hercules Aircraft Since 1970 and has also joined the few worldwide aviation maintenance companies that carry out extremely complex upgrades and modification programs for military aircrafts.

In the last years, OGMA has been growing rapidly due to the implementation of continuous improvement processes. Under these developments, services availability and quality are getting better.

This project was born by the necessity of understanding the rotable components complexity form of operation. Thus, creating new reliability methods, improving MRO processes and components reliability was a way to improve their costumer's trust and consequently improving the financial income.

1.2 Motivation

The intrinsic motivation inherent to the elaboration of this Masters Thesis comes from the enthusiasm and passion for maintenance and management areas. From research to root problem identification with consequent continuous improvement solutions being a personal concern.

Beyond the interest in the case study and in order to avoid the Masters Thesis to be focused exclusively in academic research, this project reconciles academic knowledge with professional and real life situations, therefore, being profitable for both sides.

Having both academic and professional background in Rotable Components and Aircraft Reliability areas, the present Aeronautical Engineering MSc Thesis project is a growth and a continuity of this same experience.

1.3 Goals and Objectives

The thesis main goal is to improve and define the reliability in rotable components in a military cargo aircraft fleet. This goal was born from an abnormal high number of failures in operation and maintenance procedures from known components. Thus, the thrive for continuous improvement in reliability as well as making it correctly standardized will allow a harmonization of data and corrective procedures for discussion in MRBM (Maintenance Reliability Board Meeting). Hence, preventive and corrective procedures will be possible to implement, aiming to improve rotable components reliability.

To achieve the main goal purposed, specific objectives were created:

- Standardization of Definitions and Data from Components, Reliability and respective Events in a Reliability Manual;
- Description and Standardization of the Reliability Metrics Process and Calculation;
- Detailed programs and user guides for Root Causes Investigation and Failure Modes and Effects Analysis (FMEA);
- Preventive and Corrective Actions proposals implementation and Monitoring.

1.4 Thesis Structure

For a better reading and easier understanding, this thesis is divided by chapters with the objective of showing the project in a continuous way, and also to give the reader a better line of thought. In order to help readers to search topics of interest, this section is useful as it provides an easy and direct access to main topics of information from each chapter.

- **Chapter 1** has a brief project introduction, its background, motivation, objectives and structure.
- **Chapter 2**, named Literature Review is oriented for a literature revision of the up to date state of the art in Aircraft Maintenance and Components in general, Reliability applied in Maintenance and the Continuous Improvement process involved.
- **Chapter 3** talks about ARP, that includes detail information about the process of reliability metric calculations as well as their definitions from the initial data. It also contains information related to root cause investigation, corrective actions, improvements implementation and follow-up monitoring. Every step responsibility is mentioned as well.
- **Chapter 4** has examples of the case study performed, with initial data about the component and the investigation performed. Crucial information about corrective actions proposals are specified in the end of each case study, as well as available results.
- **Chapter 5** has a synthesis about the performed work, improvement proposals and possible future projects for the continuous improvement of the rotable components and fleet reliability.

Chapter 2

Literature Review

An updated overview of Aviation Industry is described in this chapter, as well as, the state of the art and further literature review in Aircraft and Components Maintenance, in Reliability and in Improvement Actions designated as objectives for this project.

2.1 Aviation Industry

Aviation is the activity held by scientific, technological and transportation purposes. Its objective is to develop aircrafts and other aerial vehicles and explore their capacities within their environment.

Between Aerospace, Aerostation and Aeronautics, the last one is he most active area in the industry. Aeronautics is the activity responsible for the aerial movement inside the Hearth’s Atmosphere for aircrafted wings (with or without propulsion). Nowadays and within all these areas, there are common subjects, those are the Design, Manufacturing, Operation, Maintenance, etc. But in the early aviation days, these same areas were archaic and outdated comparing to what they are today due to engineering and safety standards.

”Aviation” word was initially pronounced in 1863 by Gabriel La Landelle [2] from the French navy, however it was not the story frame of the initial aviation activities, there were several early non-confirmed reports of flying machines by then. Back at 1709, *Bartolomeu de Gusmão* flew the first airship that was named *Passarola*, in Figure 2.1. It is still considered as a myth due to the non-existence of any public and written evidence.

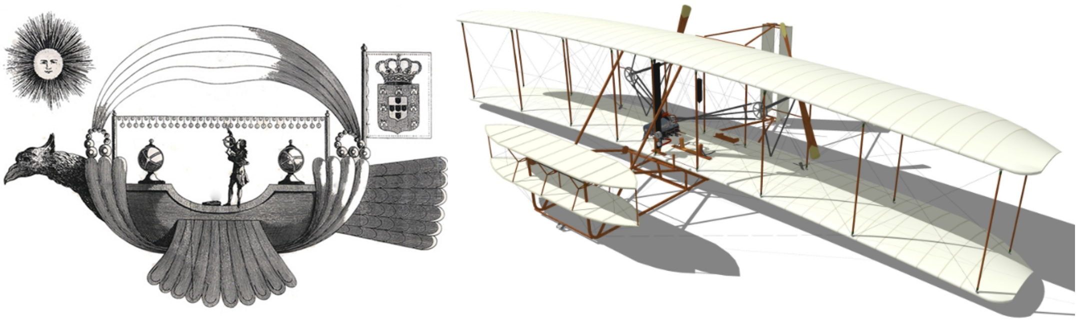


Figure 2.1: *Passarola*’s adapted illustration from 18th century [3] and Brothers Wright Aircraft illustration [4], respectively (pictures not in scale).

It was several years from then that Henri Giffard, in 1852 (France, Paris), flew the first public aerostat (balloon).

After all the flying tries of Otto Lilienthal near 1880, the Wright brothers flew the first wing propelled machine in 1903, in Figure 2.1. This was considered the main Aviation Milestone of all known and active airplanes.

Evolution in technology had its boom in the World War I and World War II [5], by developing lighter aircrafts made with better structural designs and better materials, as well as developing faster aircrafts with the creation of jet engines. Depending on the type of aircraft, cargo capacity was also increased.

At the moment, Aviation is a complex Industry that starts with Aircraft Design, Manufacturing and Tests, it is sustained by Operation, Maintenance, Safety and Management, and ends when the financial and operational plans go wrong, when safety is compromised or simply when aircrafts reach their life limit.

2.1.1 Civil and Military Aviation

Taking into consideration the aircraft operations and excluding Air Safety, Aviation is divided in two main areas, the Civil Aviation and the Military Aviation.

Civil Aviation relies on commercial purposes. The purposes of commercial activities are to satisfy customers on two simple objectives of [6] a freighter:

- **Ferrying Passengers** - repetitive passengers transportation from one place to another, aircraft example in the left side of Figure 2.2;
- **Cargo** - high volume, heavy or special cargo transportation (supplies, goods, etc.), aircraft example in the right side of Figure 2.2;

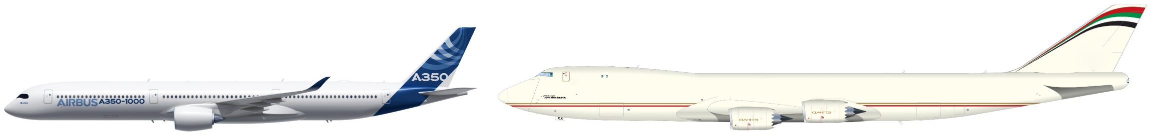


Figure 2.2: Airbus A350-1000 passenger aircraft [7] and Being 747-8 cargo aircraft [8], respectively (pictures not in scale).

Military Aviation exploits the latest developments in technology (prototypes) where the services are confidential to each Air Force or Naval/Army Groups and require tactical and technical tradeoffs. Some of the military missions are [9]:

- **Experimental Aircrafts** - manufactured for design improvements and data research;
- **Ground-Attack** - mainly helicopters but also turbo-prop aircrafts that are able to ground-attack due to their relatively low speed and control;
- **Multirole Combat** - aircrafts capable of being both bomber and attacker;
- **Reconnaissance or Surveillance** - aircrafts used to retrieve crucial and specific intelligence data;
- **Bomb carriers** - aircrafts able to carry large payloads of bombs and specific attack cargo, example in left side of Figure 2.3;

- **Fighters** - known for air-to-air attack, example in the middle of Figure 2.3;
- **Training** - aircrafts used to train new pilots and recruits for several purposes, example from FAP (Portuguese Air Force) in the right side of Figure 2.3;

Figure 2.3: Rockwell B-1B Lancer bomb carrier [10], General Dynamics F-16 Fighting Falcon [11], De Havilland Canada DHC-1 Chipmunk training aircraft [12], respectively (pictures not in scale).

- **Transport** - aircrafts that use their high capability of lifting for high size or heavy transport/cargo, example in Figure 2.4;

Figure 2.4: Lockheed C-130 Hercules cargo aircraft [13].

If management is performed correctly, the revenue in Civil Aviation might be bigger and faster than the Military services, not only due to the simplicity of design and payment from customers from the Civil side, but also from nonprofit goals and the high operational costs and high maintainability needed in Military side. Hence, Civil Aviation is focused on transportation and Military on Defense and Development.

As mentioned before, the type of Aircraft studied in this Thesis is the Military Transportation/Cargo, more precisely the Lockheed C-130 Hercules cargo aircraft.

2.1.2 Civil and Military Airworthiness

Since civil regulation itself have common rules and different levels of compliance at an international level. And military aviation works in the umbrella of each individual Air Force, country or Naval/Army groups, it is hard to establish an accordance and easy collaboration between them. Even though both of the worlds have the same flight purposes, they work separately as singular or particular collaborative frames (involved Nations agreements).

Although regulations divide civil and military responsibilities, a possible collaboration between both is not excluded.

The Chicago Convention on International Aviation document, article 3, 7300/9 [14], stated that military aircraft were excluded from that same convention.

> Quote:
>
> - *Civil and State Aircraft:*
>
> *a) This convention shall be applicable only to civil aircraft, and shall not be applicable to state aircraft.*
>
> *b) Aircraft used in military customs and police services shall be deemed to state aircraft.*

In compliance with International Civil Aviation Organization (ICAO), and EASA's Basic Regulation [15], it was defined that:

> Quote:
>
> - *This Regulation shall not apply to:*
>
> *(A) Products, parts, appliances, personnel and organizations referred to in paragraph 1(a) and (b) while carrying out military, customs, police, search and rescue, firefighting, coastguard or similar activities or services.*

Knowing that paragraph 1(a) and (b) refer to civil aviation, this means that military conditions are not applicable, but also not forbidden. A perfect example is the FAA Military Certification Office [16] and the Advisory Circular [17].

In Europe, military authorities recognized the need of an update to the civil estate models [18], because it has financial, operational and airworthy advantages. Thus, harmonizing both Civil and Military Aviation at the same time is needed by updating Military Airworthiness and Maintenance procedures. This might bring considerable costs in the beginning due to changes, but it is expected to reduce as updates finish and procedures stabilize.

The total maintenance cost includes military spending as the largest proportion of a MRO activity. As example, the report [19] from John Borkowski states further data on maintenance costs, as shown in Figure 2.5.

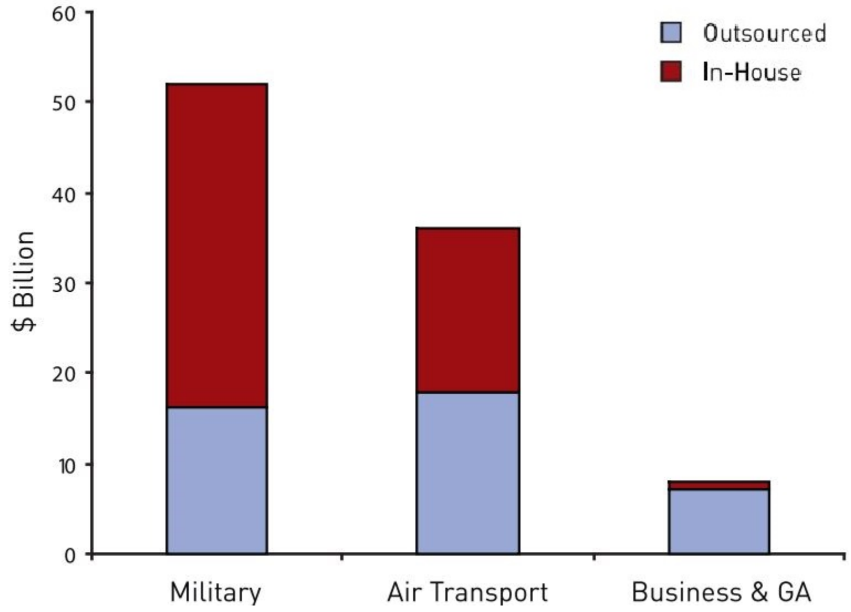


Figure 2.5: 2004 Global Aircraft MRO Spending [19].

Military maintenance is, as previously stated, the most financial demanding service. To comply this information, the following Figure 2.6 [19] also confirms that the components category is valuable in which engines are the only ones to be financially greater.

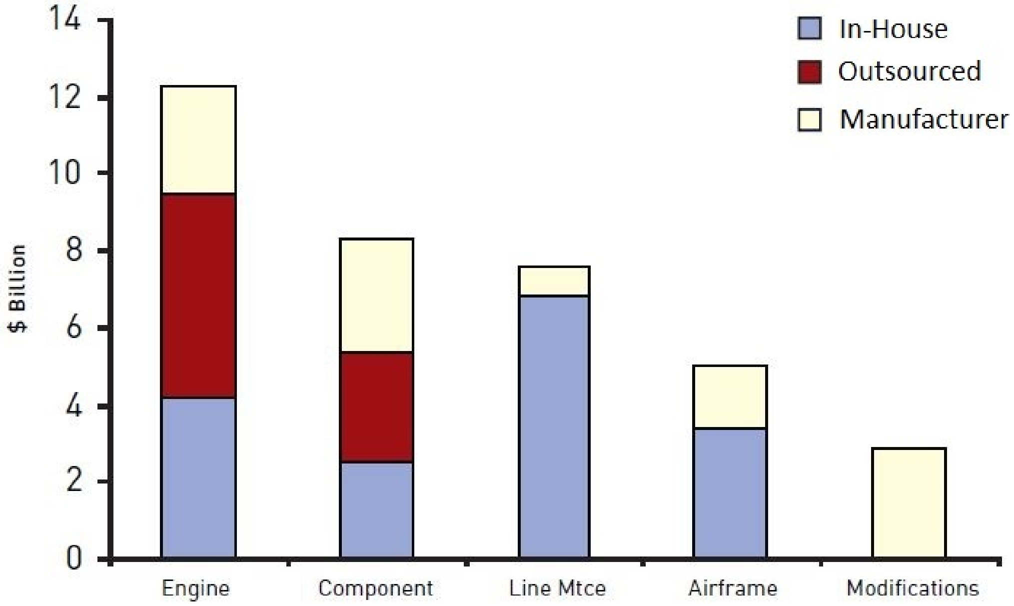


Figure 2.6: Global MRO Segments by Supplier Type [19].

Thus, equally to this project, improvements in Military and Components Maintenance Reliability in order to decrease costs is financially valuable.

2.2 Maintenance

Maintenance is the action of performing procedures to maintain a component or system serviceable and airworthy. In aviation, as per Part M [20]:

> Quote:
>
> *"Maintenance" means any one or combination of overhaul, repair, inspection, replacement, modification or defect rectification of an aircraft or component, with the exception of pre-flight inspection.*

In and ideal world, every machine should be capable of operating within an infinite time frame without compromising its overall performance. However, this is not the reality as machines and components undergo wear, degradation and failure. This is the main reason for the maintenance existence.

Maintenance has the purpose of reestablishing and refreshing a component status into a serviceable and right operational status. Maintenance measurements are performed to monitor aerodynamic forces, structure stresses, landing cycles, pressure and temperature changes, vibrations/flutter, environmental conditions, etc. These measurements of maintaining an item in operational conditions allow an appropriate functional condition for airworthy levels.

2.2.1 Maintenance Processes

In the middle of the XX century, aeronautical industry was supported by strict maintenance process that resulted in high financial costs. This type of maintenance was systemic and process oriented. Near 1960, some performed studies concluded that some components' reliability were not directly affected with age [21], thus, preventive maintenance was not suitable. So, Condition Monitoring was implemented.

The decision procedures for the maintenance programs was then created into a document named "Handbook MSG-1, Maintenance and Program Development", MSG-1 (Maintenance Steering Group). MSG-1 was able to improve safety standards, reliability and reduce maintenance costs.

This document was considered a success and it was subsequently applied in several fleets and improved into what was called "Airline/Manufacturer Maintenance Program Planning Document, MSG-2". This file was initially used in maintenance programs of the Lockheed L-1011 and McDonnell-Douglas DC-10 at 1970 [22]. MSG-2 was a distinctive program as it introduced ATA chapters for an improved maintenance management.

Both MSG-1 and MSG-2 were process oriented and there was the need to improve it. This was where MSG-3 was born as a task oriented maintenance program. As "top-down" and/or "consequence of failure" were the topics for the reason of its creation. These consist in a failure analysis of different levels, within the aircraft or component categories. Resulting in a Safety, Operational or Financial impact.

MSG-3 was and is still used as it maintains a high operational and safety standard, with high reliability values and low maintenance costs. This program introduced A, B, C and D Checks as it also improved aircraft availability, reduced maintenance times (TAT) and improved the aircraft maintenance monitoring.

Line Maintenance and Base Maintenance were also standardized. Line maintenance includes every procedure whenever an aircraft has a flight, as per:

- Pre-flight Inspection;
- Daily Checks;
- Weekly Checks;
- Failure verification and repair;
- Preventive Maintenance and Modifications.

Base maintenance includes every procedure that the Line maintenance is not able to perform due to its nature. Depending on each aircraft, manufacturer and operator, base maintenance include:

- **A Checks** - refurbishments, some failures and on condition items are repaired;
- **B Checks** - incorporation of successive A checks;

- **C Checks** - heavier maintenance procedures carried;
- **D Checks** - most demanding and expensive check for an airplane, as engines and fuselage/structure inspections are performed.

2.2.2 Regulations

Related with this project are Part M and Part 145, from EASA Regulations [23].

Part M establishes the administrative conditions and criteria to be implemented by operators to make sure that the aircraft airworthiness is maintained within its operation.

This is where Reliability appears. The use of a Reliability Program is mandatory for a CAMO, Part-M Organization.

Main responsibilities for a Part-M organization:

- Airworthiness review and audits to certify that an aircraft and maintenance procedures are maintained in an airworthy condition;
- Capacity to issue CRS (certificate of release to service);
- Capacity to issue Airworthiness Certificate due to aircraft maintenance performance in accordance with an Aircraft Maintenance Program (AMP);
- Continuing Airworthiness Management Exposition.

For Reliability purposes in Civil Aviation, an Aircraft Reliability Program, inserted in an AMP from the AMC M.A. 302 (also point 6) [24], the FAA Advisory Circular [25] and Chapter 40 from the Safety Assurance System [26] shall be performed.

Part 145 establishes the requirements and procedure that are necessary for the approval of maintenance organizations. In accordance with Part-M, it is mandatory that every maintenance procedure is performed by an approved maintenance organization. This is where Line and Base Maintenance are taken.

Therefore, every procedure taken from a Part 145 center is registered in a Part M organization and this data registry is used for reliability purposes.

2.2.3 OGMA Services

OGMA, Figure 2.7, is known for their extensive MRO services [27].

Figure 2.7: *Indústria Aeronáutica de Portugal, S.A.* [28]

OGMA Maintenance Center for Civil and Military Aircrafts is based in *Alverca*, Lisbon. Related to this project, OGMA has additional maintenance centers in two other areas, those are *Bricy* (France) and *Djamena* (Tchad).

For the Defense Aviation, as a certified Lockheed Martin maintenance center, the service capabilities are:

- Aircraft Maintenance (Basic, Intermediate and Depot Level);
- Avionics Upgrades;
- Major Structural;
- Aircraft Painting;
- Field Work Teams;
- Aircraft Recovery (Logistic Support Worldwide);
- Fleet Management;
- Training;
- Component Repair and Overhaul;
- Engineering Services;
- Non Destructive Tests/Inspections (NDT or NDI);
- Airworthiness Management (CAMO).

The LM C-130 Engines are maintained by OGMA's services:

- Engine and Engines Module Overhaul;
- Quick Engine Checks (QEC) Maintenance and Repair;
- Engine Test (test cell or on-wing);
- Engineering Support and Fleet Management Services;

- Repair and Overhaul of propellers, valve and pup housings, generators, fuel systems, hydraulic and pneumatic systems, etc.

For Components and the aircraft in which this thesis focuses on, OGMA offers maintenance services for the following components:

- Electrical items and Avionic Components;
- Hydraulic and Fuel Systems;
- Dynamic and Mechanical Items;
- Propellers;
- Others (as well as outsourced services).

2.3 Components

A component, also designated as item or system, comprises a specific purpose for operation and reliability. From its own design to its disposal, a component has several life cycle stages. This section, the maintenance processes, repair and failures are described.

2.3.1 Primary Maintenance Types

There are several types of maintenance in accordance with, the respective event origin. Maintenance occurs whenever there is the need (as obligation or as prevention) to maintain a certain level of serviceability of a component, system or group of systems.

The next Figure 2.8 shows the relationship between Maintenance and Component Maintenance types:

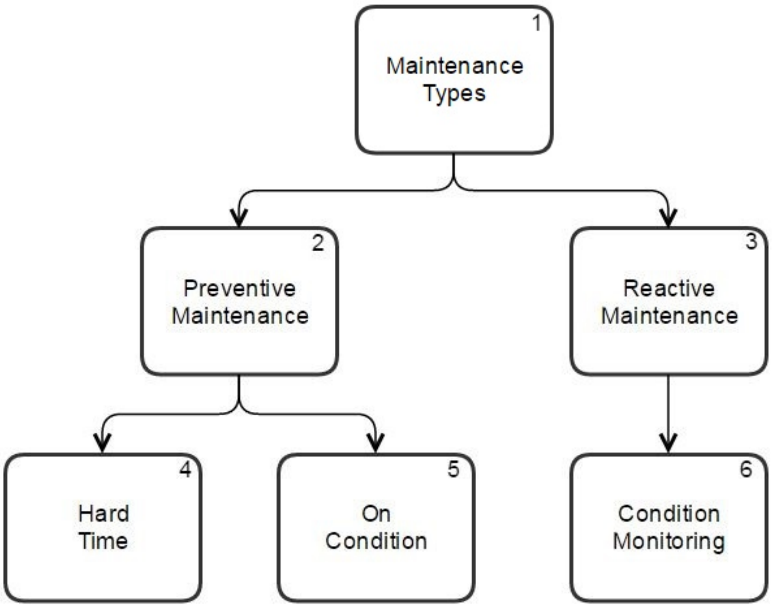


Figure 2.8: Maintenance Types Diagram, adapted from [29] and [30].

The following bullets describe/define each part of the boxes:

- **1st box - Maintenance Types**: as previously mentioned, maintenance procedures are used to maintain a component or system serviceability with inspection, modification, replacement or overhaul in order to avoid failure (in case of a preventive maintenance) or to replace or repair if a fault was found (in case of a reactive maintenance).
- **2nd box - Preventive Maintenance**: also known by scheduled maintenance tasks (tasks performed by predetermined time or cycles or a condition level), it is a type of maintenance procedures accomplished in order to avoid component failures that compromise the aircraft operation and safety. It is the common way to maintain an aircraft airworthiness [31].
- **3rd box - Reactive Maintenance**: also known by unscheduled maintenance tasks, it is a type of maintenance that uses procedures to fix a component that already failed. It causes delays and serious safety problems if the component is specified as crucial for the aircraft airworthiness. It is considered as a preventive maintenance due to the maintenance procedures to repair or overhaul components, that are already determined in manuals, but named as Reactive due to the non prediction of failure [32].
- **4th box - Hard-Time (HT)**: as the name says, HT maintenance procedure uses serviceable time or cycles as the main reason for being removed. This is a preventive and primary maintenance process [33]. It requires that a part to be periodically overhauled, refurbished, bench checked, etc. in accordance with the carrier's Approved Aircraft Inspection Program (AAIP) and the manufacturers recommendations or to be removed from service if the life-limit of the component is achieved.
- **5th box - On Condition (OC)**: OC is also a preventive primary maintenance process that requires a system, component, or item to be inspected periodically or checked against operational standards to determine if it can continue in service. This type of maintenance procedure ensures that the unit is removed from service when it reaches the removal criteria or an high probability stage of failure, avoiding possible critical in-service moments. These standards may be adjusted based on operating experience or tests, as appropriate, in accordance with a carrier's Approved Aircraft Inspection Program (AAIP). A usual OC example are brakes, that use visual inspection pins or tires, which are removed when worned out or when tires have cuts.
- **6th box - Condition Monitoring (CM)**: CM is a maintenance procedure that is applied in components or systems that do not use HT or OC as the primary process (preventive maintenance). In other words, it is a reactive maintenance (also known as fly-to-failure) procedure due to failure or near fault detection. CM is not used in components that might put in danger the flight safety. If there is interest, the operator can control the reliability of these components based on reliability analysis or previous earned knowledge using fleet flight data. If so, these components might be inserted in preventive maintenance procedures.

Also, but not mentioned in Figure 2.8, Predictive Maintenance is a new type of maintenance being developed by several companies. It consists of the idea that the more information the maintenance department has about a component/system in real time, the more accurate will be the preventive maintenance tasks. Thus, reactive maintenance will decrease and serviceability/availability will increase.

This type of maintenance was created by Boeing, named Airplane Health Management (AHM) and it is expected to increase the fleet availability up to 35% and reduce maintenance budgets by 30-40% [34].

2.3.2 Rotable Components

There are several components in an Aircraft depending on its maintenance type. In this project, the ones in analysis are the rotable components. These are components that have a considerable life-service since repairs and overhauls are used to maintain their serviceability.

Rotable Components life cycle/stages [35] (after manufacturing) are described in Figure 2.9:

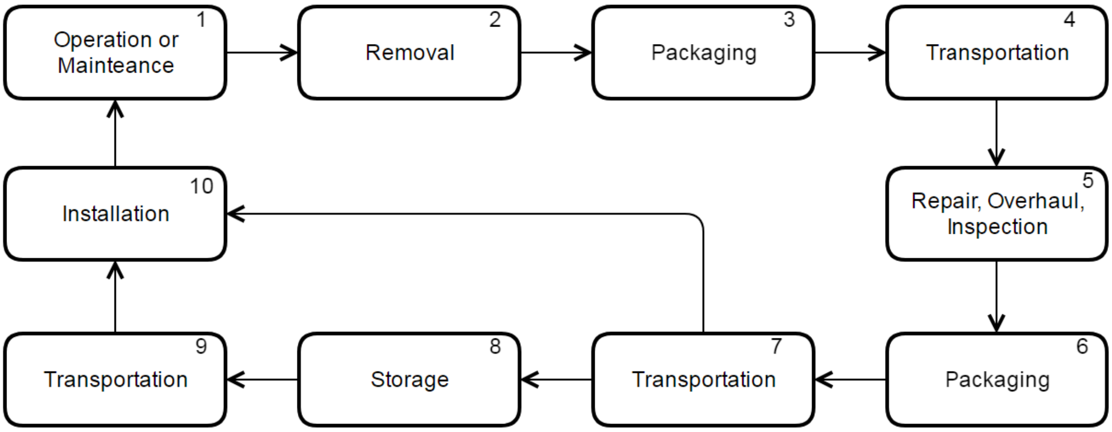


Figure 2.9: Rotable Components life stages in a MRO [35].

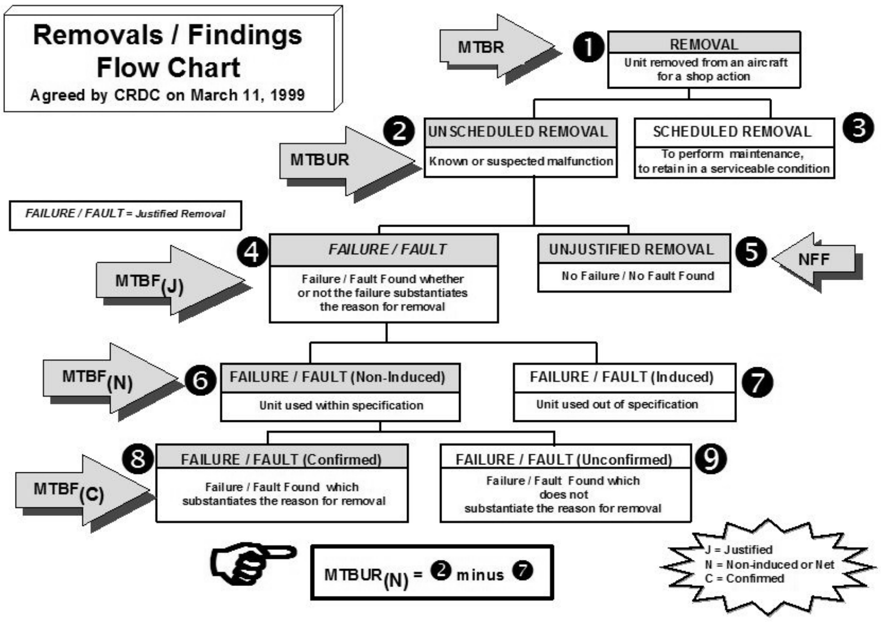
The diagram in Figure 2.9 represents the life stages of a common rotable component.

Usually a component is created and installed in an aircraft as an initial install, it remains in operation until it requires any maintenance intervention. A maintenance procedure from the Repair Shop might be a Repair, Overhaul, Tests, Inspection (ROTI) or even to discard if it is no longer serviceable. Between a removal and an installation, a component passes through at least 2 stages, those are the packaging and the transportation.

2.3.3 Removal Reason

A component has a wide list of removal causes. The following Figure 2.10 from ATA Specification 2000 [36] describes the removal reasons from aircraft's component removals.

Also and in terms of Removal Reasons, the following list explains the same figure.



Note : one category of removal has been voluntarily omitted : " OTHER " (may be used for convenience, robbery, ...)

Figure 2.10: Removal Reason with Metrics overview [36].

- 1st **box - Removal** - any kind of component that is removed from an aircraft;
- 2nd **box - Unscheduled Removal** - a type of component removal that is performed by unscheduled reasons (usually by premature failure or predictive failure);
- 3rd **box - Scheduled Removal** - a type of component removal that is performed by scheduled reasons (scheduled work orders);
- 4th **box - Unscheduled Removal by Failure/Fault** - type of component removal that is performed due to failure of an item;
- 5th **box - Unjustified Removal** - type of component removal that is performed without any kind of failure reported, those might be by swap, switch, cannibalization, access, could not duplicate (CND), etc.;
- 6th **box - Unscheduled Removal by Non-Induced Failure/Fault** - type of component removal that is performed due to non-induced failure of an item, in other words, the component fails due to usual wear or operation;
- 7th **box - Unscheduled Removal by Induced Failure/Fault** - type of component removal that is performed due to induced failure of an item, in other words, the component fails due to a bad operation or fast wear (associated with several problems);
- 8th **box - Unscheduled Removal by Confirmed Failure/Fault** - type of component removal that is performed due to a confirmation of an item failure;
- 9th **box - Unscheduled Removal by Unconfirmed Failure/Fault** - type of component removal that is performed due a unconfirmed failure, this means that the removal was performed due to failure but does not compromise the serviceability of the component.

These type of removal reasons are associated with metrics, which are overviewed in section 2.4.1.

2.3.4 Failure

Every system or component is serviceable until it is unable to perform its objective in operation. Therefore, there are several reasons for a failure occurrence. Most of the times, failure has 6 types/patterns, as Philip Frohne mentioned [37], those are shown in Figure 2.11;

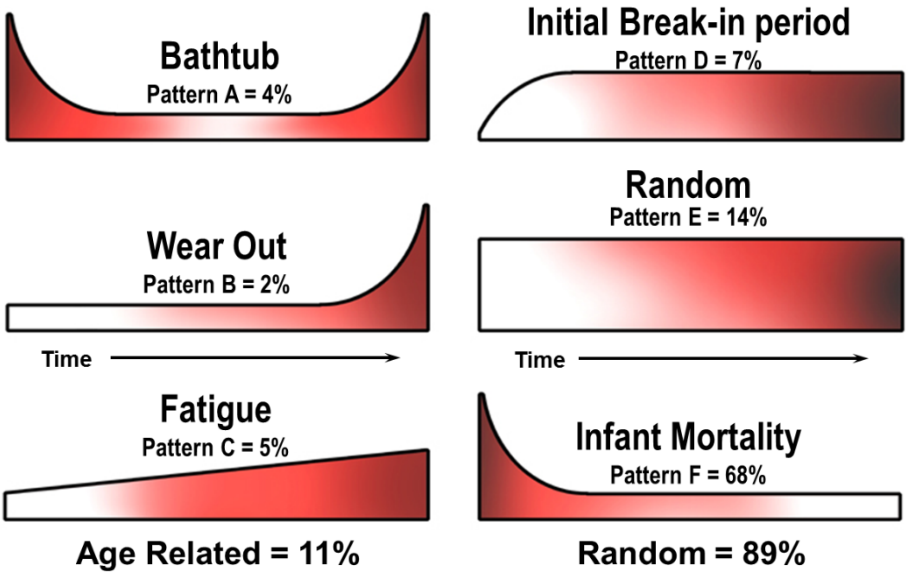


Figure 2.11: Different Failure Patterns present in components life [37].

In order to understand the Figure 2.11, the following bullets explain each pattern in detail [38]:

- **Bathtub (pattern A)** - This pattern shows that in the component's initial operation, it has a high failure probability (infant mortality), by this the failure probability will decrease until it reaches a constant value, at the end of the components life, it will increase once again (rapid wear out phase);
- **Wear Out (pattern B)** - This pattern has a constant and relatively low failure probability during its serviceable life time. However at the end of its life-service, it gains a rapid wear (out phase);
- **Fatigue (pattern C)** - Fatigue represents a component that has an increasing failure probability during its serviceable life, as the probability increases by time;
- **Initial Break-in Period (pattern D)** - The component is relatively well designed for a short period of time, but as it is being used (long term) the probability of failure increases to a constant value;
- **Random (pattern E)** - this pattern shows that there is no tendency and the component fails at a constant and unpredictable way over its entire life;
- **Infant Mortality (pattern F)** - infant mortality pattern has a high failure probability in the beginning, but it decreases rapidly until it reaches a constant value.

These are ways of predicting a failure probability in a component, where the most probable is the infant probability (pattern F). This happens because a component might have problems due to its initial design, but as soon as maintenance and repair operations report problems or report improvement proposals, these items will increase their serviceability and decrease their failure probability. This is also achieved by performing overhauls instead of repairs, because repairs only fix certain points in a system/item/component and an overhaul restores the same item to its full operating level.

A failure might happen [39] due to:

- Computing Error, Human or Operational Error;
- Environmental Factors;
- Lack or redundancy;
- Under design of component specifications;
- Faulty or lack of maintenance;
- Inadequate component tolerances or Others.

To perform the investigation of this project, we will take into consideration various types of failure and identify each one as a separated situation. This procedure will increase the probability of finding the root cause of the problem. Definition of this procedure is included in Chapter 3.

2.3.5 Cause and Effect

In order to find and identify root problem causes due to failure, a Continuous Improvement tool has been used [40]. The known Cause and Effect Diagram, also known as Fishbone, was developed.

Fishbone diagram uses different information from a diversified world and converge them into a problem, in other words, this diagram identifies many possible causes for an effect. It is used in brainstorm sessions, as it is useful to find ideas and create solutions in discussions.

The diagram was created taking into consideration OGMA's areas and Aircraft Operation as is shown in Figure 2.12;

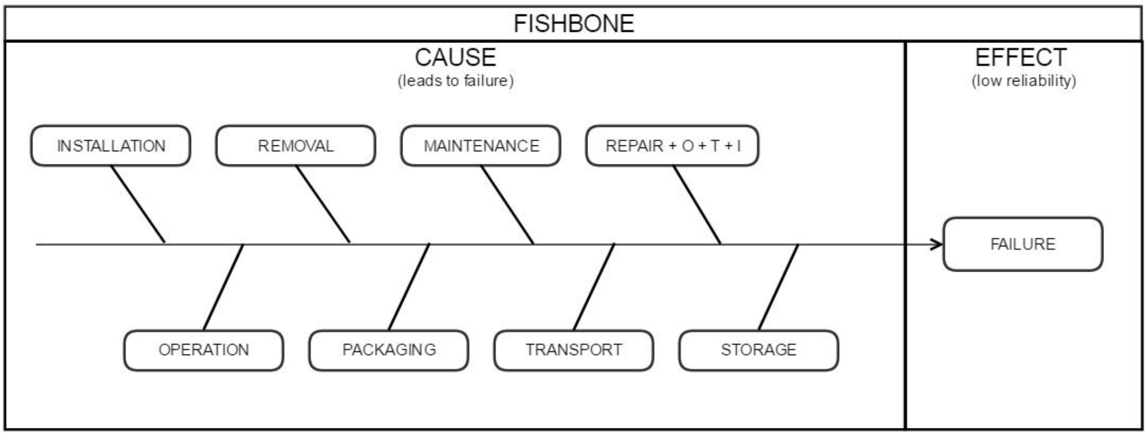


Figure 2.12: Cause and Effect Diagram (Fishbone).

This diagram shows all areas where the root cause for a component failure might happen. Those areas are described in Table 3.5. As mentioned before this diagram, these areas involve OGMA's service and the costumer's operation.

2.4 Reliability

After getting to know what Maintenance is in Military Aviation and their components, reliability takes place to improve the overall availability, airworthiness and fleet satisfaction.

Reliability is the probability of a component performing its duty in a satisfactorily way, within a period of time and specified conditions. It is associated with the words consistency and durability. In order for a system to have a high value of Reliability, it needs to have a high durability and high time of operation and, in the mean time, it needs to have a low number of faults and low decrease of operational performance.

Reliability is a useful tool if it is well performed, in other words, a simple reliability analysis based on its values and probabilities does not bring space for improvement. Thus, implementing it with a system of improvements is as important as the metric calculation and analysis.

The main steps included are, as Figure 3.1 in Chapter 3:

- Data Processing;
- Metric Calculation;
- Analysis and Research or Failure Mode investigation;
- Corrective action (followed by its monitoring).

It is applicable in a group of items, or group of systems. In this project, it is applicable to all rotable components of the fleet.

Once again, it is important to note that information about components operational and maintenance life needs to be correctly inserted, clear and detailed into groups of similar information. If data is randomly inserted, reliability process will be hard to implement.

2.4.1 Metrics Overview

Reliability Metrics are used to trigger an analysis or investigation by values comparison. If an item's metric has a higher or lower value in comparison between several other items, it means that the reliability of that same item is different than the others and a study must be performed in other to understand the change of the value.

In order to understand Reliability Metrics and their definition, the Figure 2.10 summarizes the following metrics that can be calculated:

- **MTBR or MCBR (box 1)** - mean time/cycles between removals gives us the information about the mean time or mean number of cycles a component, within a group of components from a fleet, is in service until it is removed; equation (2.1) and (2.2), respectively;

$$MTBR = \frac{H \times n_{A/C}}{R} \quad (2.1)$$

$$MCBR = \frac{C \times n_{A/C}}{R} \qquad (2.2)$$

- **MTBUR or MCBUR (box 2)** - mean time/cycles between unscheduled removals gives us the information about the mean time or mean number of cycles a component, within a group of components from a fleet, is removed due to unscheduled reasons; equation (2.3) and (2.4), respectively;

$$MTBUR = \frac{H \times n_{A/C}}{UR} \qquad (2.3)$$

$$MCBUR = \frac{C \times n_{A/C}}{UR} \qquad (2.4)$$

- **MTBF or MCBF (box 4)** - mean time/cycles between failures gives us the information about the mean time or mean number of cycles a component, within a group of components from a fleet, is removed due to failure; equation (2.5) and (2.6), respectively;

$$MTBF = \frac{H \times n_{A/C}}{F} \qquad (2.5)$$

$$MCBF = \frac{C \times n_{A/C}}{F} \qquad (2.6)$$

- **Justified, Non-induced and Confirmed failures (boxes 4, 6, 7, 8 and 9** - these are data that come from failure modes and respective research into the repair/overhaul and inspection documents;
- **NFF or Others (box 5)** - these are the number of no fault found and other removal reasons that does only apply to still serviceable components.
- **FR** - Failure rate is a metric related to MTBF, it represents the rate of failure a component has per unscheduled removals by time or cycles, in equation (2.7). The lower the FR value, the better; for the metrics above, the higher the better, because it means they have more time in service and less failures.

$$FR = \frac{H \times n_{A/C}}{F} = \frac{1}{MTBF} \qquad (2.7)$$

Where in Table 2.1 each variable is defined by:

Table 2.1: Variables.

VARIABLE	DEFINITION
H	Hours
C	Cycles
n	Number of Components per Aircraft per number of Aircrafts in the Fleet
R	Removals
UR	Unscheduled Removals
F	Failures

All these reliability metrics are based on a time/cycles window frame for comparison purposes with the manufacturer and operator; this means that they might be calculated in a 1, 3, 6, 12, 24 or more months (time frame). Usually, they are compared with a metric named Basic Value (BV - equation (2.8)), that is the mean value of all MTBF or FR, then these values will be compared to give information if reliability is or is not inside normalized values with the layout of Alert Levels (AL).

$$BV = \frac{\sum MTBF}{n} = \frac{\sum FR}{n} \quad (2.8)$$

Thought, there are further ways of retrieving Alert Levels. Besides the use of Basic Values, the identification of Maintenance Significant Items (MSI) is also used, depending on the environment.

MSI method [41] uses the identification of different levels of operation, performance, maintenance and operation costs, component's costs, etc. to retrieve component's significance. This method will not be used in this project because it is not consistent for Military Aviation due to high operational and maintainability costs.

The method used and adapted to this project for Alert Levels output will be mentioned in Chapter 3.

There is no metric related to scheduled removal because there is no regular way to improve the mean time for scheduled removal by reliability improvements, though, the aircraft maintenance plan can and should be improved before implementation, in order to offer the best aircraft availability possible; i.e. a component that is being schedule removed several and successively times before its needs (it does not fail, its performance is not compromised and the operation time can be extended), a documentation and maintenance plan update.

2.4.2 Failure Mode and Effects Analysis

Failure Mode and Effects Analysis (FMEA) or Failure mode and Effects Criticality Analysis (FMECA), are analysis techniques which details potential problems in a component design or process by examining the effects of different levels of failure. Corrective actions are then implemented to lower the risk of repetitive problems, consequently improving the reliability values and aircraft reliability. FMECA is a FMEA but with a failure criticality analysis.

As per Carl S. Carlson [42], the use of a FMEA had its purpose on:

- Identifying and fully understanding potential failure modes and their causes, and also the effects of failure on the system, for a given product or process;
- Assessing the risk associated with the identified failure modes, effects and causes, and prioritize issues for corrective action;
- Identify and carry out corrective actions to address the most critical issues.

Not forgetting that this process is able to identify safety hazards, minimize loss of product performance or degradation, improve test and verification plans, improve process control plans, propose changes in product's design, identify poor or great product characteristics and improve the preventive maintenance plans.

A FMEA performs the following order of actions, in Figure 2.13, as per NASA FMEA [43]:

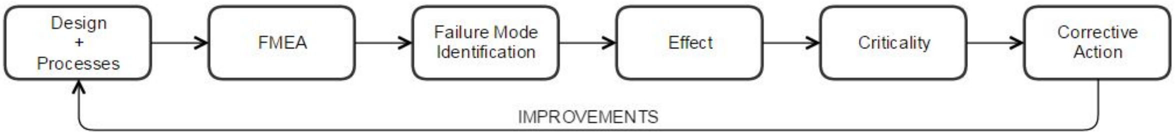


Figure 2.13: Failure Mode and Effects Analysis oriented for Design and Process [43].

Comparing the FMEA in Figure 2.13 with the Carl's Literature [42], the main steps to perform a FMEA are:

- **1**st - Define all the functions and definitions for the items in analysis;
- **2**nd - Start FMEA process by entering all the failure modes;
- **3**rd - Enter all the information needed for Failure Mode identification, effects and criticality;
- **4**th - Link all the failure modes to their effect severities;
- **5**th - Enter information about Risk Priority Numbers (RPNs), that might be by number of failures or probability of failure significance due to the criticality/severity;
- **6**th - Review proposed corrective actions to high severities and criticalities if needed;
- **7**th - Apply recommended corrective actions and proceed to their monitoring.

There are several types of FMEA to be used, in this project, it focuses on the following ones:

- Design FMEA focuses on product design at a subsystem or component level. This FMEA type has the objective of improving the design and ensuring a better product operation during the component's service life.
- Process FMEA focuses on the operation processes, it ensures that they are performed within the design requirements in a safe way. This includes manufacturing, assembly operations, shipping, incoming parts, transportation, storage, conveyors, tool maintenance, labeling, etc.

It is important to mention that a FMEA process is ideal for Reliability purposes and also that it is somehow ideal in a MRO service since the information retrieved within operation and maintenance is available.

In this project, a FMECA with a design and processes orientation will be created, guided by failure mode criticality, thus making the investigation and analysis on root causes easier for corrective actions implementation. This implementation is based on MIL-P-1629A [44] and MIL-STD-2173 [45] as well.

2.4.3 Corrective Actions

Whenever a discrepancy is detected and the root cause is identified, there is the possibility of introducing a corrective or preventive action in order to solve or minimize a problem.

In other to improve an item reliability, the following concepts shall be implemented:

- Design improvement;
- Increase redundancy;
- Maintenance plan improvement;
- Repair and Overhaul improvements;
- Item homologation;
- Other process improvements.

In OGMA's type of working, any corrective action has two types, and depending on their magnitude, they are also divided in two status. These are:

- **Preventive (type)** - the preventive action is performed in order to prevent or avoid further problems; this type of corrective action does not mitigate a root cause problem completely, but it prevents it by lowering its probability to happen.
- **Corrective (type)** - this type of action is performed to exclude the appearance of a problem or error. It is used whenever the root cause and failure mode is entirely identified.
- **Permanent (status)** - a permanent corrective action has the purpose of being implemented in order to mitigate a failure appearance at a long term. Usually, this corrective action status is tested as temporarily in order to check for its effectiveness.
- **Temporary (status)** - this type of corrective action has the objective of being implemented in order to verify its effectiveness at a short time. If there is a low percentage of improvement or no improvement at all, another type of corrective action shall be implemented. If it has a great capability of effectiveness, it shall be considered as a permanent corrective action.

Corrective actions need to have a follow-up monitoring process in order to confirm their effectiveness in reliability improvement. Usually, these follow-up processes are performed using check-lists and monitoring values.

Chapter 3

Aircraft Reliability Program

Aircraft Reliability Program (applied to the Lockheed Martin's C-130 Hercules fleet) is the main program related to reliability, research and improvement procedures for fleets in general at OGMA. ARP has data registry/processing, reliability metric calculation, metric analysis, alert levels, root causes analysis and research, respective preventive and corrective actions (improvement proposals) and a monitoring plant to ensure its successful implementation (Annex A.1). The ARP process is described in Figure 3.1;

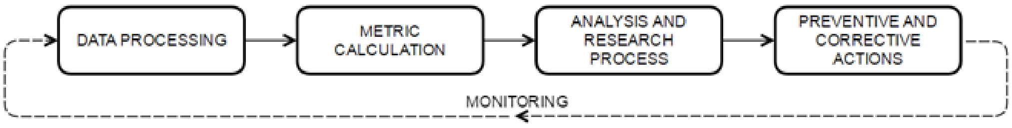


Figure 3.1: Summary of the Reliability Program Workflow [46].

The Aircraft Reliability Program describes and contains all the information related to Reliability data and its improvement processes, as well as related Maintenance and Operation information from OGMA's Services and its client's fleet.

The creation of a Reliability Manual, will improve the components, aircraft and fleet reliability, availability, client's trust and OGMA's financial income, as well as its public image.

The expected improvements and benefits of this ARP implementation are in the following subjects and areas:

- The Approved Aircraft Inspection Program (AAIP);
- Components Design, Performance and Reliability;
- Aircraft and Components Availability;
- Internal procedures, documents and tools;
- Training both OGMA's contracted and subcontracted Personnel;
- Financial, reliance and experience;
- No Fault Found (NFF) or Could Not Duplicate (CND) events reduction;
- Assessments and Turn Around Times (TAT) reduction;
- Components Failure and repetitive failure events reduction;
- Component's Transport and Packaging;
- Minimize life cycle costs and downtime that promote high reliability and extended life service;
- Others.

3.1 Maintenance Organization Responsibilities

The implementation of an ARP and related documents are part of the Maintenance Reliability Team responsibility. The approval of the same program and documents are made in accordance with the Aircraft Maintenance & Engineering Department and the Quality Department.

All documents related to the creation of this Aircraft Reliability Program and processes are certified by OGMA Normative System (ONS).

The Maintenance Reliability Board Meeting (MRBM) is the main meeting to show the overall Fleet Reliability, where subjects as metrics, alert levels, failures, repetitive events, corrective actions and monitoring are discussed. The following personnel take part in this meeting:

- Maintenance and Reliability Team;
- Maintenance and Engineering Director;
- Component Engineering Coordinator;
- Aircraft Fleet Manager;
- Maintenance Technician Representative(s) (by invitation);
- Components Chief;
- Components Technician Representative(s) (by invitation);
- Quality Department Coordinator;
- Pilot or Pilot Engineer (by invitation; if requested).

To conclude, MRT is the main responsible for every procedure in the ARP. Every decision and approval must be agreed in the MRBM.

Any kind of improvement procedure or corrective action shall be approved and performed in the area to which it will be applied.

3.2 Reliability Elements

In order to have an effective and useful Aircraft Reliability Program, it is important not only to have data, but also to know how to treat it. Therefore, the following steps must be performed:

- Filter Aircraft/Components useful data;
- Create a Reliability Report based on metrics and alert levels;
- Identify possible root causes with a FMEA and perform the troubleshooting with the cooperation of the Maintenance of Components (MCO) and Maintenance of Military Aircraft (MMA) departments;
- Propose Corrective Actions;

- Implement improvements and follow-up the results;
- Repeat the Reliability Process.

In order to start the initial Reliability Program, there is the need to create a starting point/process. This initial process will give MRT the needed feedback to evaluate the effectiveness of the process and evolve it to a routine and stable one. The initial process is described in Figure 3.2;

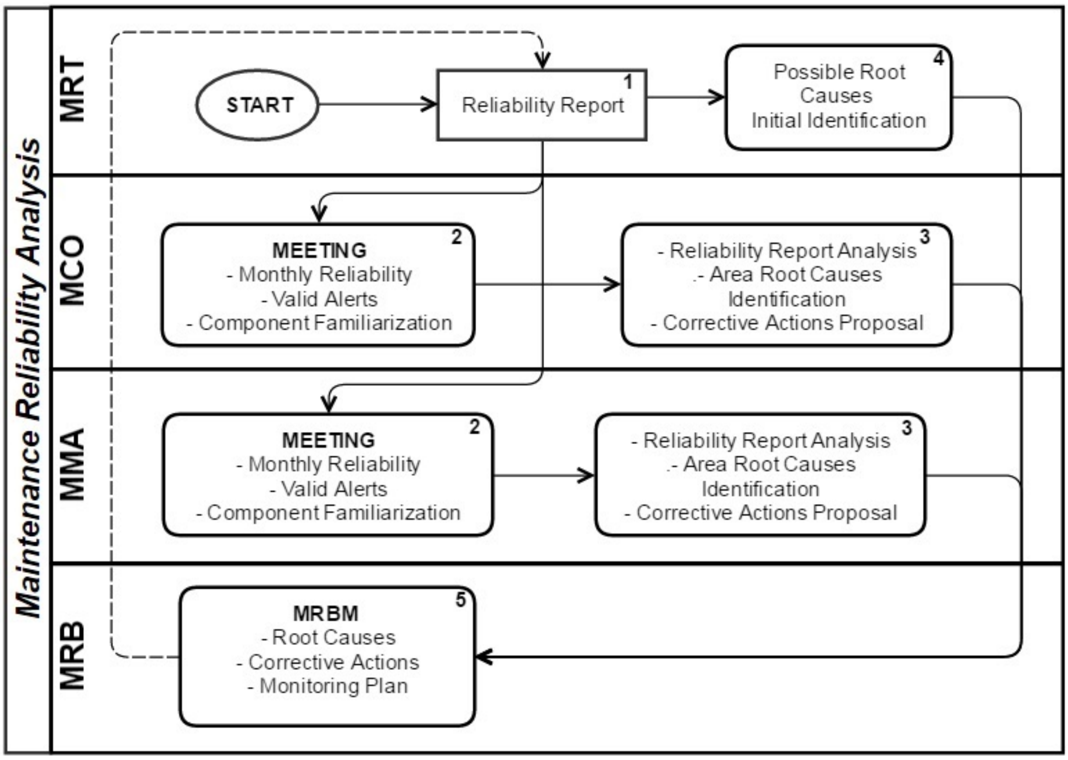


Figure 3.2: Initial Maintenance Reliability Analysis, created and adapted from [47].

This flow-chart, in Figure 3.2, is divided in 4 areas. The Maintenance Reliability Team (MRT) that is the responsible for the reliability process; the Maintenance of Components (MCO) that are responsible of maintaining the serviceability of a component, since inspection/test to repair/overhaul; (MMA) that are responsible for the line and base maintenance; and Maintenance Reliability Board (MRB) that consists in the valuable personnel for the reliability subject discussion.

- **1st box:** The process starts with the creation and presentation of the Reliability Report, these include the Item-ATAs in alert (Alert Levels - AL);
- **2nd box(es):** The presentation of the items is performed to MCO and MMA to familiarize with the reliability status;
- **3rd box(es):** After the initial meeting, MRT, MCO and MMA perform troubleshooting to identify probable root causes and propose corrective actions (Process FMEA) in the Maintenance Reliability Board Meeting (MRBM);
- **4th box:** Design FMEA in accordance with information from Failures, Repair and Overhaul, Removal and Installation documents (initial identification of possible root causes) is performed;

- **5^{th} box**: Last discussion for root causes identification, corrective actions implementation and monitoring plans; which are presented and approved in the MRBM.

3.3 Data Processing

The acquisition and inputs of standardized data are crucial for a trustworthy reliability analysis. In order to provide a correct data insertion, the creation of a procedure with detailed and standardized procedures is needed.

The collected data is based in the fleet and components information; those are:

- Fleet Status and Flight Hours/Cycles (FH/FC);
- Components Position, Installation, Removals, etc.;
- Scheduled and Unscheduled Maintenance;
- Failures and Maintenance findings;
- Accidents and Incidents data;
- Internal and External audits;
- Aerospace Agencies and Manufacturers data.

The previous list of data is inserted in SIGMA and FMS. Afterwards and for reliability calculation purposes, all the information is retrieved from an export that comes with the following layout, present in the Table 3.1:

Table 3.1: Layout of FMS Exported Data.

A/C Tail	(1)
S/N	(2)
P/N	(3)
Date	(4)
Event	(5)
Corrective Action	(6)
Position	(7)
TSI	(8)
TSO	(9)
TSN	(10)
OT	(11)
Reason	(12)
Project	(13)
Form	(14)
Item-ATA	(15)

- **A/C Tail (1)** - Aircraft Tail or S/N Parent, is the source of the Item-ATA in analysis, either coming from an aircraft, engine or APU (Auxiliary Power Unit);
- **S/N (2)** - Component's Serial Number;
- **P/N (3)** - Specific Part Number from a group of Serial Numbers;

- **Date (4)** - Date of the event;
- **Event (5)** - Event of the component, as being an installation, repair, inspection, overhaul, etc.;
- **Corrective Action (6)** - Corrective action, repair or overhaul performed if applicable;
- **Position (7)** - Component's position;
- **TSI (8)** - Component's time since installation, or CSI cycles since installation;
- **TSO (9)** - Component's time since overhaul, or CSO cycles since overhaul;
- **TSN (10)** - Component's time since new (initial installation), or CSN cycles since new;
- **OT (11)** - Operational time represents the time in service before the component's failure or overhaul; it might include removals and installations in between due to convenience/cannibalization/swap reasons;
- **Reason (12)** - Event reason;
- **Project (13)** - Additional document or documents related to the component's event;
- **Form (14)** - Component's Form-1 or related;
- **Item-ATA (15)** - Component's designated Item-ATA.

The table has the information required for future file research and initial information for root cause investigation.

As mentioned in Chapter 2, Figure 2.10 explains the removal reasons from each component removal. But in order to understand and to know the component and the reason behind of its removal, ATA chapters must be used, as well as Item-ATAs (specific components in an ATA chapter).

The Table 3.2, describes each ATA Chapter from the LM C-130 fleet:

Table 3.2: ATA Chapters Descriptions available for reliability.

ATA	DESCRIPTION	ATA	DESCRIPTION
21	Air Conditioning	36	Pneumatic
22	Auto-Flight	49	Airborn Auxiliary Power
23	Communications	52	Doors
24	Electrical Power	53	Fuselage
25	Equipment/Furnishings	57	Wings
26	Fire Protection	61	Propellers/Propulsors
27	Flight Controls	71	Power Plant
28	Fuel	72	Turbine/Turboprop Engine
29	Hydraulic Power	73	Engine Fuel and Control
30	Ice and Rain Protection	74	Ignition
31	Instruments	75	Air
32	Landing Gear	77	Engine Indicating
33	Lights	79	Engine Oil
34	Navigation	80	Starting
35	Oxygen	99	Others[1]

The ATA number 99, Others[1]., is a new chapter created to assemble every Item-ATA that was not standardized in the official ATA Chapters from the aircraft in study. This new chapter makes the introduction of undefined items' data into SIGMA easier.

All information retrieved is introduced in the Fleet Management System (FMS) and in *Sistema de Informação e Gestão da* OGMA (SIGMA).

3.4 Metrics and Indicators

The metrics presented in Chapter 2 are used to get Indicators (Alert Levels), these shall inform the MRT about possible deviations in components' reliability. To retrieve these alerts, the following flow-chart is considered (Figure 3.3):

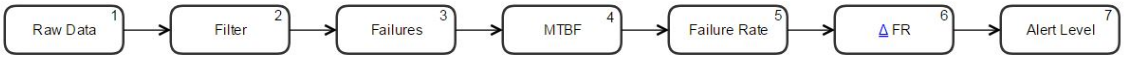


Figure 3.3: Alerts Calculation flow-chart.

This process, as described in the following bullets, is also described in an OGMA User Guide (Annex A.2).

- **1st box - Raw Data**: The data source comes from the Export in FMS;
- **2nd box - Filter**: All filters are selected in accordance with the case study;
- **3rd box - Failures**: Only failures are selected;
- **4th box - MTBF**: Mean Time Between Failure is calculated after the retrievement of failures and time/cycles (1, 3 and 12 months time frame);
- **5th box - Failure Rate**: Failure Rate is also calculated within the same time frame;
- **6th box - $\triangle$FR**: The variation of Failure Rate is calculated in order to identify AL;
- **7th box - Alert Level**: For every alert level, there are several filters; these are explained in the following Figure 3.4, Figure 3.5, Figure 3.6 and Figure 3.7.

Following the Alert Level output, there are several levels designated taking into consideration their significance and reliability magnitude. The explanation of the different AL and decision filters are shown after the following figures and present in Table 3.3.

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[1] Created Chapter to designate undefined Item-ATAs

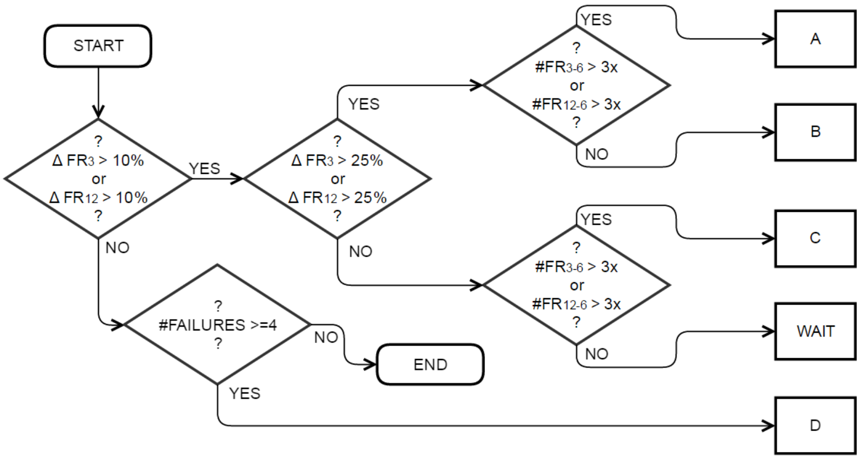

Figure 3.4: The less restrictive decision filter with FR(12) or FR(3).

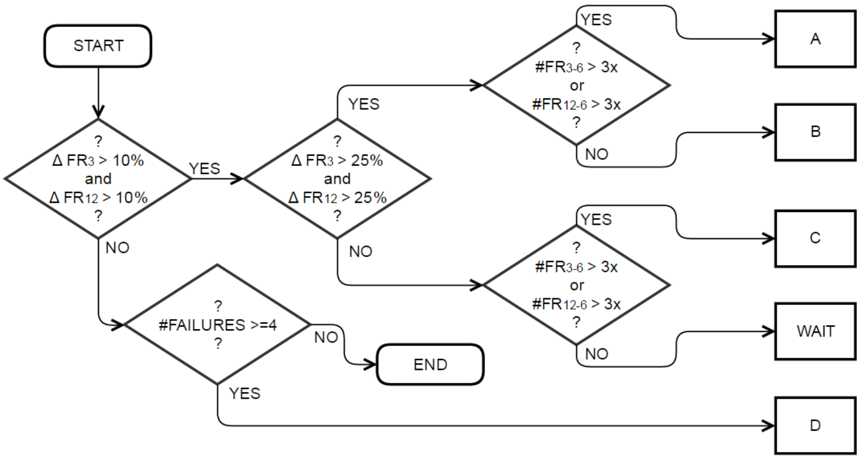

Figure 3.5: The most restrictive decision filter with FR(12) and FR(3).

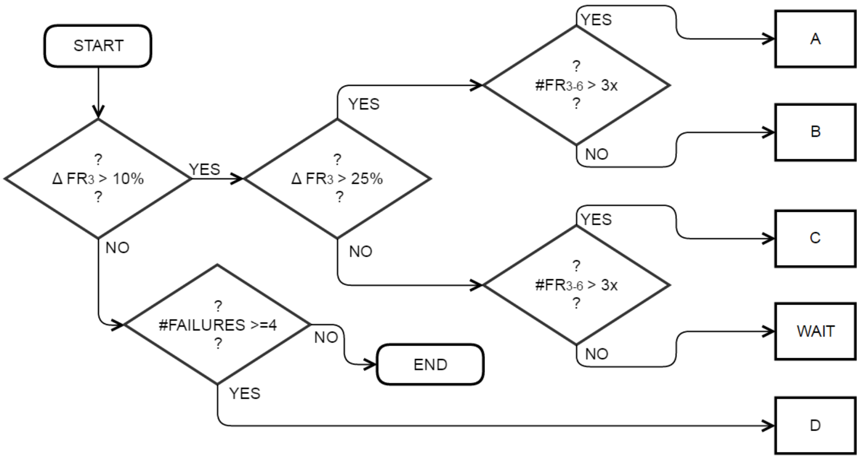

Figure 3.6: Close term decision filter with FR(3).

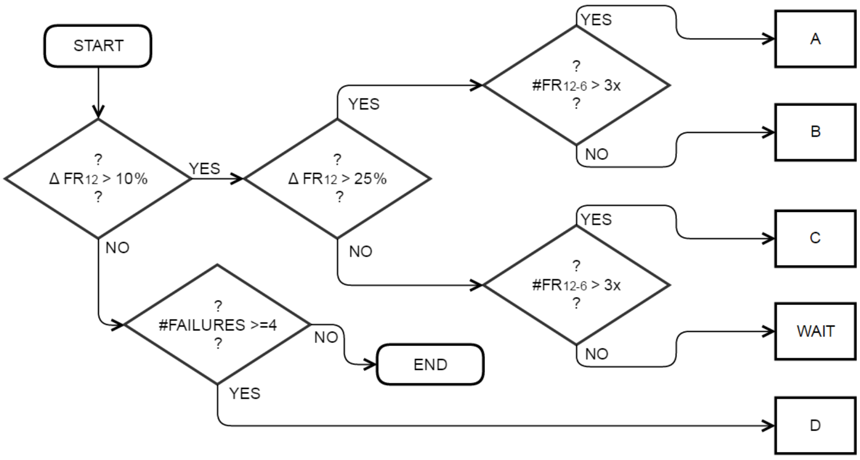

Figure 3.7: Long term decision filter with FR(12).

Taking into consideration and using Figure 3.4 as an example; a component requires to have a ΔFR (either from 3 or 12 month) superior than 10% to proceed into the next level. If the same value is higher than 25%, the level A or B is deployed regarding the number of alerts in the last 6 months being higher than 3. If the ΔFR is inferior than 25%, C or WAIT levels are deployed. D level is deployed only if the number of failures is superior than 4 and ΔFR inferior than 10%.

All the Figures related to decision filters have a different level of approach, depending on the interest of the case study. Usually, the decision filter used by default is the most restrictive one represented in the Figure 3.5, with Failure Rate of 12 and 3 months, every other decision filter is used for investigation purposes. Given these points, an example of the outputs of the metric calculation process is present in the following Table 3.3.

Table 3.3: Alert Priority Ranking or Alert Levels output from reliability metric calculation.

ALERT LEVEL				
A	**B**	**C**	**D**	**WAIT**
XX-YY-ZZ[2]	*XX-YY-ZZ*[2]	*XX-YY-ZZ*[2]	*XX-YY-ZZ*[2]	*XX-YY-ZZ*[2]
	XX-YY-ZZ[2]	*XX-YY-ZZ*[2]	*XX-YY-ZZ*[2]	
	XX-YY-ZZ[2]			
	XX-YY-ZZ[2]			

Using the information above, this table shows the different Alert Levels with several Item-ATAs (XX-YY-ZZ[2]) as examples of the table automatic fill-up.

- **A** - Major/Substantial and consecutive reliability fall trend alert even the last months;
- **B** - Overall reliability fall trend;
- **C** - Reliability fall trend alert over the last few months;
- **D** - Many consecutive failures in the last few months that do not produce a significant change in the component FR;
- **WAIT** - Low reliability fall trend. It shall remain under surveillance until a more significant fall is detected.

---

[2] XX-YY-ZZ is an example used to name a random Item-ATA.

The previous Alert Levels depend on the decision filter having as main criteria a short and long term vision of the reliability trend as well as a more or less restrictive decision filter. Inherent to the alarming level is the severity condition, where ”A” is the higher severity level and by way of contrast ”WAIT” is the less severe level; this method was adapted from [48].

The justification behind the disposal of the Basic Value method is because of the values retrieved comparing MTBF with BV. In this particular case, the Military Cargo Fleet depend on the usage of the aircrafts and also depends on the flight hours/cycles. If these values get lower, all alert levels would be showing, instead, the one used in this thesis is less vulnerable to this case and it allows a wide range of filters for reliability research purposes.

3.5 Reliability Output

In order to properly inform MCO, MMA and the Quality Department, an easy read and analysis output must be performed. This is achieved through the use of a written report and a presentation to be shared in MRBM.

The report and presentation slides must have the following bullets (example in Annex A.3):

- **1.** Month in study;
- **2.** Fleet flight Hours + Cycles;
- **3.** Current Availability (A/C in Maintenance and Operation);
- **4.** Removals (Unscheduled Removals by month and ATA, top 20);
- **5.** Maintenance and Run-Up Findings;
- **6.** Repetitive Events (NFFs and Failures);
- **7.** TOP 20 MTBF;
- **8.** Alert Levels (with 4 decision filters);
- **9.** Previous Alert Levels, Claims and Repetitive Events (introduction);
- **10.** Investigations Performed;
- **11.** Investigations to be Performed;
- **12.** Implemented Corrective Actions and Monitoring procedures;
- **13.** Further Topics (if needed).

Hereafter, all the information required to deploy an investigation process is available. MRT, MCO and MMA are able to develop troubleshooting procedures and meetings in order to retrieve answers and improve the components reliability either by Process or Component’s Design.

3.6 Investigation Process

An investigation process is triggered either by an Alert Level deployment, Repetitive Events (NFF or repetitive Failures) or Claim/Tickets (by request).

Alert Levels come from the reliability metric calculation, Repetitive Events come from high number of Failures or No Fault Founds from a specific Item-ATA in a limited time frame and Claims/Tickets come from special requests, either by customers, either by the Quality Department.

Taking into consideration OGMA's work environment and the project performed by Pedro, Filipe [47], in Figure 3.8 we can see the final flow-chart for the Maintenance Reliability Surveillance Process.

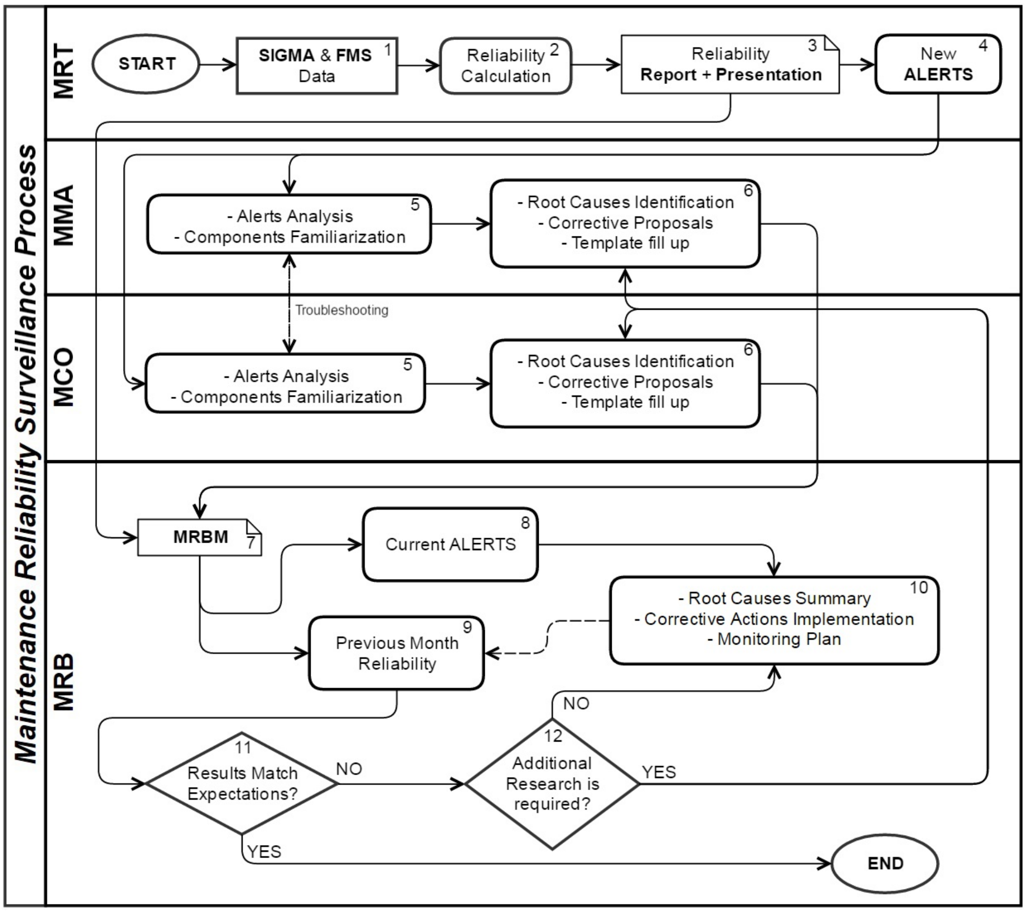

Figure 3.8: Maintenance Reliability Surveillance Process, addapted from [47].

- **1st box - SIGMA and FMS**: Database of all retrieved data for reliability purposes;
- **2nd box - Reliability Calculation**: Process of the reliability calculation performed by MRT;
- **3rd box - Report + Presentation**: MRT information output as a report and presentation to be shared at the MRBM;
- **4th box - New Alerts**: Alert Levels deployed in the month of study;
- **5th box - Initial Analysis**: First MCO and MMA touch into components under investigation;

- **6th box - Troubleshooting Results**: After both teams troubleshooting is performed, results from root causes identification and corrective actions proposals shall be found;
- **7th box - Maintenance Reliability Board Meeting (MRBM)**: The general Maintenance and Reliability Board Meeting takes place to inform both past and present reliability status;
- **8th box - Current Alerts**: Current alerts are shared;
- **9th box - Previous Month Reliability**: Previous studies and investigations are shared in order to inform the performed work in detail;
- **10th box - Solutions**: Solutions for Failure Mode and Effects Analysis are shared;
- **11th box - 1st Stage Monitoring**: First stage of results monitoring;
- **12th box - 2nd Stage Monitoring**: Second and final stage of results monitoring; both stages are used to ensure that the corrective actions reach the expected results.

3.7 Failure Mode and Effects Analysis

A Failure Mode and Effects Analysis is performed whenever an Alert Level or Repetitive Event is deployed. This means a Serial Number (singular item) investigation is not applicable in this situation because a FMEA requires the use of several information (from S/N) in order to be effective. Thus, a FMEA is started by Item-ATAs or Part Numbers.

With this in mind, a Design oriented FMEA requires the following steps:

- **1st**: Define each failure mode for the Item-ATA or P/N;
- **2nd**: Associate each repair and overhaul procedure to the previous Failure Modes;
- **3rd**: Define a RPN for each Failure Mode, by identifying the number of occurrences;
- **4th**: Apply corrective actions for the top RPN.

A Design FMEA (MRT responsibility) is always performed in parallel with a Process FMEA (from MCO, MMA, MRT and the Quality Department).

3.7.1 Root Cause Identification

In the other hand, a report that requires mapping information of a Process oriented FMEA must be written (Annex A.4).

On the Table 3.4 is presented the probable root causes of failure and/or deficient processes that lead to inaccurate failure determination (example A) or failure itself (example D or E).

Table 3.4: Probable Root Causes for component failures.

	PROBABLE ROOT CAUSE
A	Inaccurate Troubleshooting
B	Outdated CMM or AMM
C	Lack of Training
D	Deficient Installation
E	Deficient Removal
F	Deficient Adjustment or Test
G	Customer Operation (weak product design)
H	Abnormal Usage from Customer
I	Maintenance Operation Tasks
J	Humidity, Debris, Dents, etc.
K	Abnormal Maintenance Handling
L	Abnormal Repair Shop Tasks

Having the probable root causes identified, there is the need to also identify the affected area.

3.7.2 Affected Area

The affected area is the main area in which the root cause has its origin or where it has failed the most. The list of these areas are shown in the Table 3.5:

Table 3.5: Affected Areas in which the component has failed and the root cause has been identified.

	AFFECTED AREA
1	Maintenance (Installation + Removal + Test + Inspection)
2	Repair Shop (Repair + Overhaul + Test + Inspection)
3	Operation (Customer)
4	Logistics (Packaging + Transportation + Storage)

Having both Root Causes and Affected Areas, we can now proceed into the improvement process, Corrective Actions Implementation.

3.7.3 Corrective Action Implementation

The MRO oriented Corrective Actions are shown in the Table 3.6.

Table 3.6: Corrective actions to implement in the affected areas due to root cause identification.

	CORRECTIVE ACTION
I	Update Documents
II	Personnel Training
III	Repair Shop Procedures
IV	Internal Procedures
V	Maintenance Procedures
VI	Design Improvements (test equipment and components)
VII	AMP Improvements
VIII	Logistics Procedures

For an easy mapping of corrective actions to implement, the Root Causes, Affected Areas and Corrective Actions table was created (Annex A.5).

The overall process of a FMEA Mapping investigation is as shown in Figure 3.9.

This Mapping Research is used to complete the investigation and to decide the best corrective action to implement, either as temporary or permanent, either corrective or preventive.

The corrective action monitoring plan depends on the improvement process itself. From tasks to their values or from processes to their verification. To ensure that reliability is improved, the follow-up procedures are performed both by MRT and Quality Department.

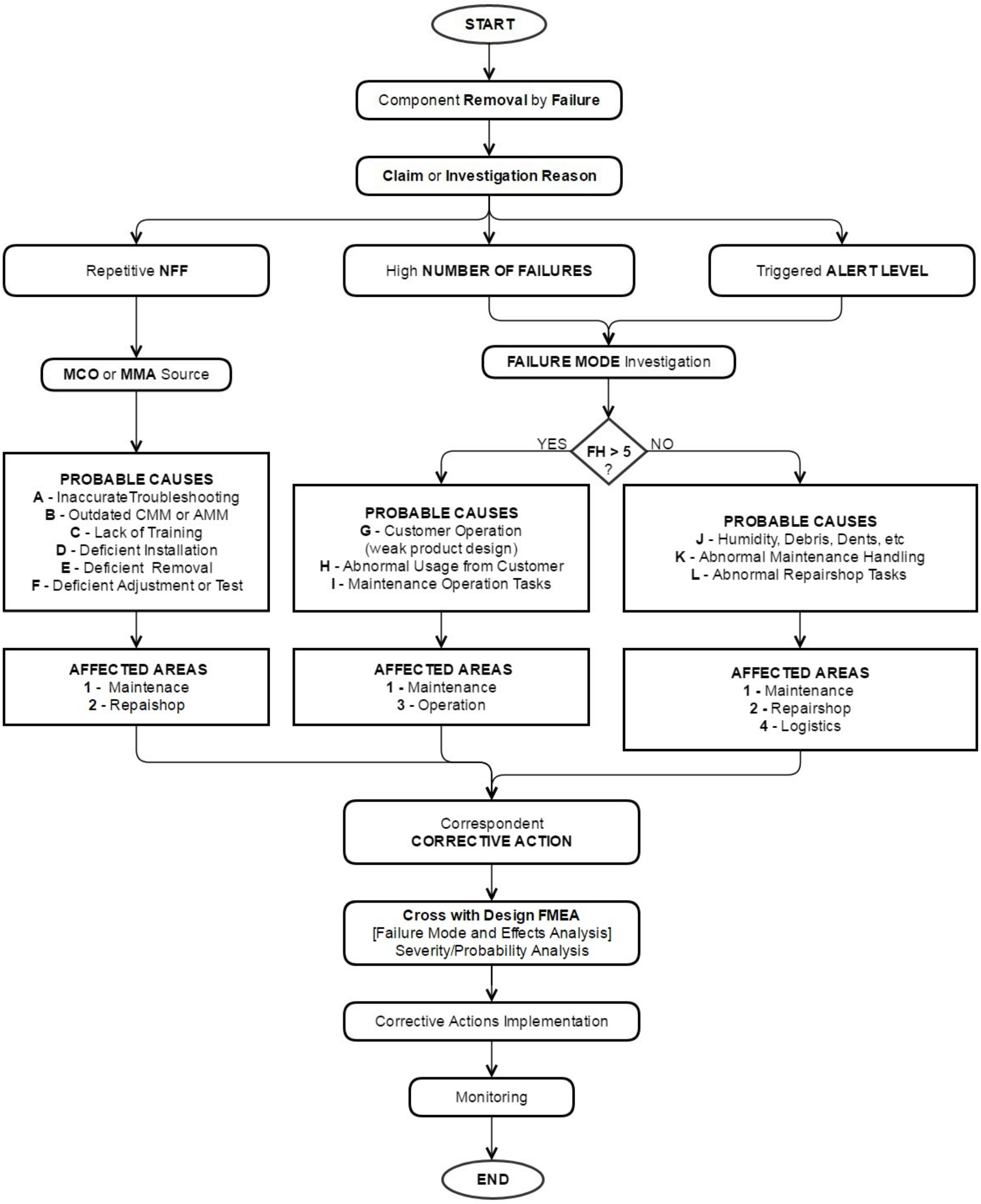

Figure 3.9: Design and Process FMEA Mapping Research [46].

Chapter 4

Case Study

This chapter focuses on the implementation of the Aircraft Reliability Program. This implementation is expected to produce reliability improvements as well as improvements to the program itself by adapting it to each particular or overall situations.

For the purpose of improving the aircraft reliability and the MRO related processes and as mentioned in the previous chapter regarding the investigation deployment, the following case studies are triggered either by Alert Levels, Claims/Tickets or Repetitive Events.

The following items will be investigated in order to determine the root causes of the reported failures and consequently improve reliability:

- **Bleed Air Valve** - this investigation started with a ticket sent by the Quality Department since it was a singular item that was not being triggered by any Alert Level and it was not operational after several inspections/repairs/overhauls.

- **TD Amplifier** - the Temperature Datum Amplifier investigation started with a ticket sent by the Quality Department to understand the repetitive NFF condition reported.

- **Gyroscope** - this item is one of the most critical components since the number of failures are above every other item. As show in the Table 4.1, the Item-ATA 34-*YY-ZZ* from rank one corresponds to the Navigational Chapter, more specifically to the Directional Gyroscope.

Table 4.1: Top 10 Failures per Item-ATA from January 2008 to May 2017.

RANK	ITEM-ATA	FAILURES
1	34-*YY-ZZ*	299
2	61-*YY-ZZ*	257
3	32-*YY-ZZ*	224
4	32-*YY-ZZ*	217
5	79-*YY-ZZ*	205
6	23-*YY-ZZ*	174
7	61-*YY-ZZ*	173
8	34-*YY-ZZ*	157
9	23-*YY-ZZ*	146
10	79-*YY-ZZ*	128

- **VHF Transceiver** - this very high frequency device's investigation was triggered both by an Alert Level (the most restrictive filter in the Table 4.2) as by ticket from the Quality Department. The Item-ATA 23-*YY-ZZ* corresponds to the Navigational Chapter and in this case, to a VHF Transceiver (transmitter and receiver).

Table 4.2: Alert Levels from March 2017.

ALERT LEVEL [MARCH 2017]				
A	**B**	**C**	**D**	**WAIT**
	21-*YY-ZZ*		32-*YY-ZZ*	21-*YY-ZZ*
	22-*YY-ZZ*		34-*YY-ZZ*	23-*YY-ZZ*
	24-*YY-ZZ*			24-*YY-ZZ*
	27-*YY-ZZ*			28-*YY-ZZ*
	30-*YY-ZZ*			33-*YY-ZZ*
	32-*YY-ZZ*			49-*YY-ZZ*
	34-*YY-ZZ*			
	49-*YY-ZZ*			
	52-*YY-ZZ*			

The following sections are going to describe each item procedure and analysis performed.

4.1 Bleed Air Valve

Bleed Air Valve is a compressed air regulation valve responsible for either starting an engine with compressed air, to serve as anti-icing system for aerodynamic leading edges or to feed the cabin with pressurized or/and breathable air.

This particular component is used in 3 main stages in an engine/aircraft operation (the next figures are taken from Part-145 Training presentation files, thus not mentioned in the bibliography):

- **OFF** - the valve is completely shut and compressed air cannot go through any gate. This stage is used in order to have a complete and no loss of energy in the turboprop engine. Usually, it is used during take off and extreme cases where maximum thrust is needed (Figure 4.1);

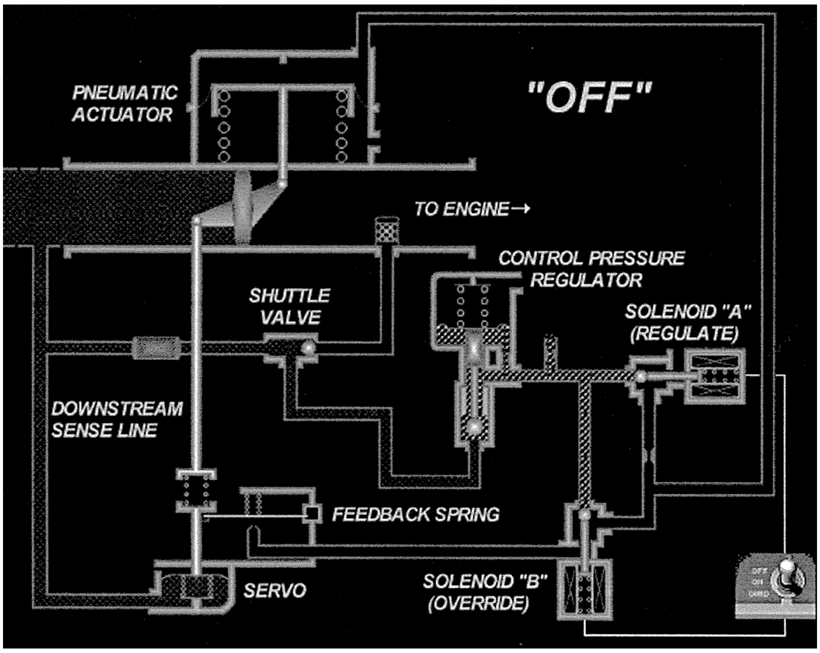

Figure 4.1: Engine Bleed Air Valve OFF stage configuration [49].

- **ON** - the valve is opened and the flow moves in a single direction (from the engine compressor to the cabin) in order to provide the denominated bleed compressed air. It is being regulated with a pressure regulator that opens or closes solenoids. This stage will then feed the cabin and the cargo deck with conditioned/pressurized air and feed the anti-icing system (Figure 4.2);

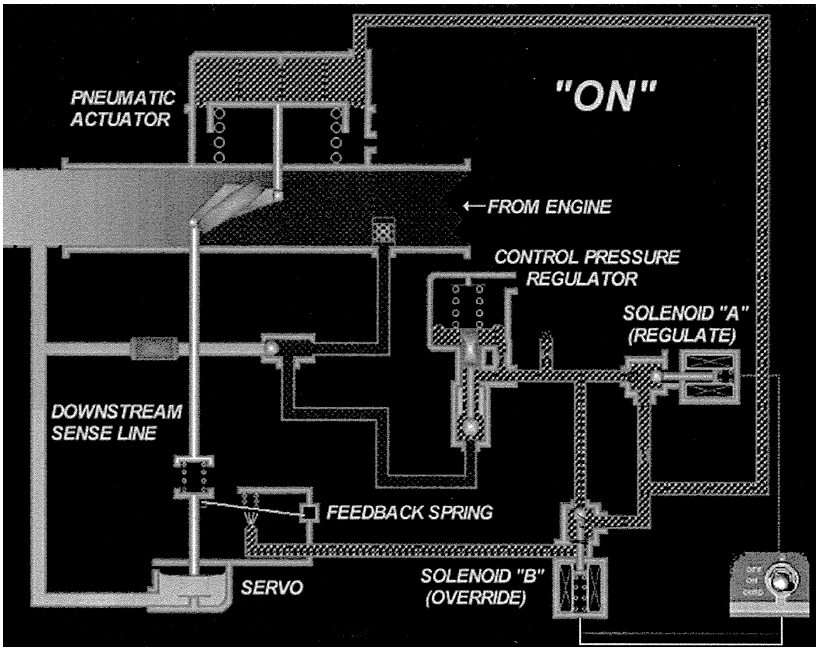

Figure 4.2: Engine Bleed Air Valve ON stage configuration [49].

- **OVERRIDE** - the valve is opened and the flow moves in a single direction, but this time the compressed air comes from the APU and goes to the engine compressor as it will help to start the turboprop engine (Figure 4.3).

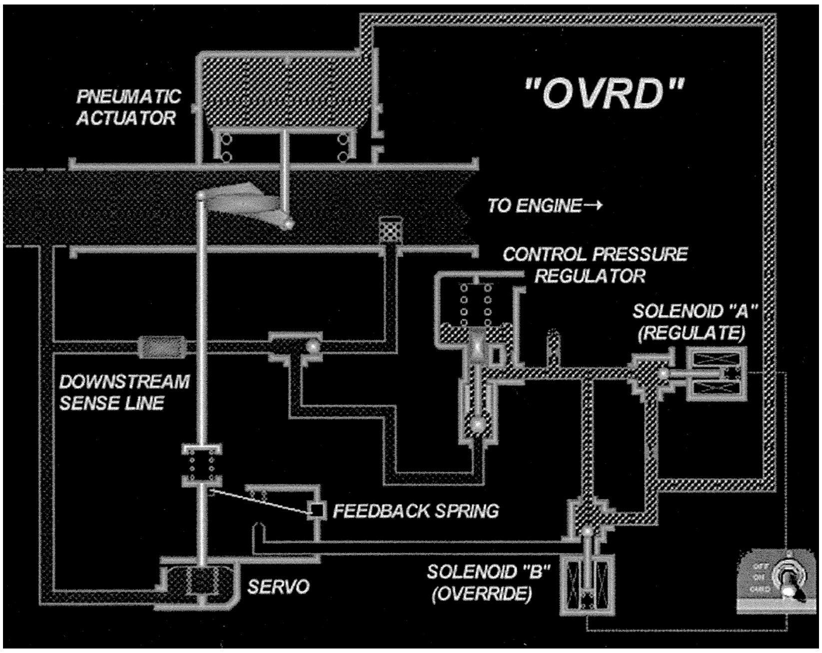

Figure 4.3: Engine Bleed Air Valve OVERRIDE stage configuration [49].

This investigation was deployed because a tested/repaired (serviceable) component was constantly being provided with an operational status and after its installation in the aircraft, it was not working. This situation happened three consecutive times, as the component was reported without any failure in the Repair Shop but it was pronounced as inoperational in the aircraft.

4.1.1 Investigation Process

As the Bleed Air Valve is a specific serial number (SN) investigation, a Design FMEA is not deployed. Likewise, a Process FMEA is started to find the eventual deviation or root cause.

The Maintenance Reliability Surveillance Process is triggered and both MMA and MCO are informed about the problematic item.

The main maintenance history of the Bleed Air Valve can be described as follows:

- Overhaul in December 2015 in accordance with (IAW) the CMM;
- The item was installed and did not pass operation checkout test in accordance with the Technical Manual, TM (often installation in the aircraft);
- Valve was sent to warranty and was returned serviceable. The reported item did not pass the operation checkout test in accordance with TM;
- For the 3^{rd} and last time, after an inspection/test, the item did not pass operational condition in accordance with TM. OGMA Investigation was deployed.

To find the possible root cause after all the information retrieved, further tests in accordance with the Technical Operations Manual (TO) were held, from which the following results were retrieved:

- Test under ON configuration - PASSED;
- Test under OVERRIDE configuration - DID NOT PASS.

These results were considered and discussed with both MRT, MCO, MMA and with the Quality Department, in MRBM, following the Maintenance Reliability Surveillance Process in Figure 3.8.

The conclusion of the investigation stated that the Bleed Air Valve did not open during reverse flow or unregulated flow check, as the main root cause of the component reliability was a sticking ball in a shuttle valve (Figure 4.4), as mentioned in the TO Troubleshooting table.

4.1.2 Improvement Proposal

As the Reliability Investigation Report was being carried out (Annex A.6), the corrective action proposed was the overhaul of the pressurized air conducts and the repair of the sticking ball in the shuttle valve.

Afterwards, the Bleed Air Valve was reported to the warranty services.

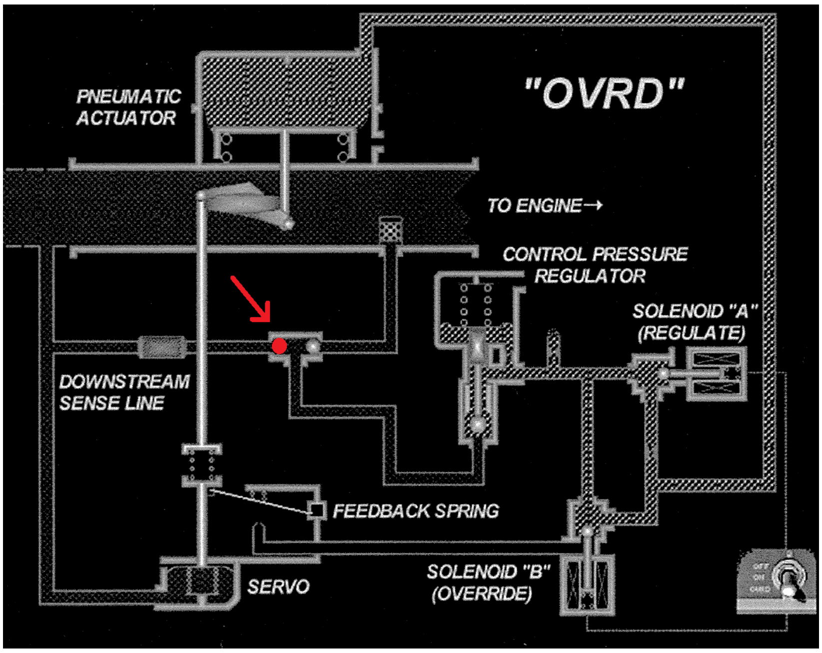

Figure 4.4: Sticking ball identified in OVERRIDE configuration, adapted from [49].

4.2 TD Amplifier

TD Amplifier is a Temperature Datum Amplifier system with the only objective of electronically trim the fuel that goes to the turboprop engine by using temperature data.

This TD Amplifier provides an over-temperature projection during start and in-flight to maintain a selected temperature inside the combustion chamber. This component is presented in (Figure 4.5).

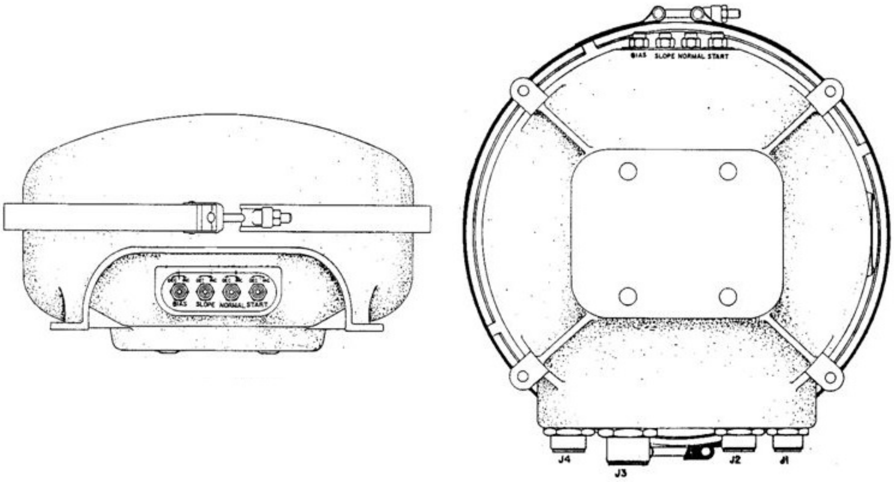

Figure 4.5: Temperature Datum Amplifier [50].

The TD Amplifier was investigated due to a failure detected in the Aircraft and a posterior determined NFF in the Repair Shop. In other words, the test equipment LED (Light Emitting Diode) power signal would not turn on in the initial test setup in accordance with the MMA.

This failure happened every time it was being tested/inspected in the Aircraft and both investigation interventions and troubleshootings did not find any failure in the Repair Shop, in accordance with the TO.

4.2.1 Investigation Process

The investigation process was triggered with both MCO and MMA personnel. Where both managed to better understand the mechanical and electronical functionality.

In the developed paperwork schematics (Annex A.7), the purpose of the initial test focused on the need to understand which electrical signals were provided by the test equipment and which pins in the TD amplifier plug were receiving such signals. By doing this, it was possible to develop a schematic diagram where one could track the signals provided by the equipment and the feedback required from the TD amplifier in order to turn on the LED. In other words, the objective was to create a troubleshooting procedure to find if every electric junction between the equipment test and the Amplifier were working. Both were found as properly connected.

The next step was to perform the same measurement in the TD Amplifier component. This test was where the root cause of the failure was found.

From the TD Amplifier plugs, the connection between Pin G (J3) with Pin D (T3) were not giving any signal in the multimeter, as shown in the Figure 4.6. The failure between these two pins was interrupting the electrical connection signal, as the test equipment LED signal was not being turned on, thus failing in the Aircraft Tests.

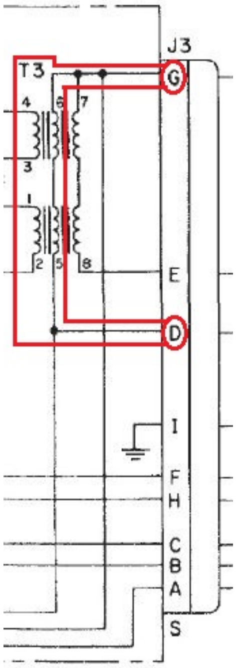

Figure 4.6: Failed internal electric connection in the TD Amplifier, adapted from TO.

4.2.2 Improvement Proposal

The temporary corrective action proposed was to create a secondary task which a multimeter is used to confirm that the electric junction between the pins mentioned earlier is in good condition.

As a permanent corrective action, a proposal to adapt the test equipment was sent to the manufacturer in order to systematize a new and official task to verify the good condition of the electric junctions.

As monitoring plan, a two week compliance check was followed and ensured the corrective action effectiveness.

4.3 Gyroscope

The Directional Gyroscope, Figure 4.7, also known as heading indicator displays the aircraft's direction, comparing its orientation with the magnetic north.

Bearing friction inside the instrument, bad transportation/installation and even hard landings create drift errors in the gyroscope. These problems will then create several failures when reading the indicator measurements. Thus, recalibrating the instrument is needed.

Figure 4.7: Directional Gyroscope [51].

It is not reliable to have such a weak/fragile component when operating. The need of repairs and overhauls is then requested, making this component one with the most failures in the fleet as stated in Table 4.1.

4.3.1 Investigation Process

As this component was triggered due to the high number of failures, a Design FMEA can be performed.

Failure Modes per S/N were determined, as well as the connection to their repair/overhaul procedures. When defining the RPN (Risk Priority Number) within the Process FMEA, the failure modes with the most occurrences were (Table 4.3):

Table 4.3: Design and Process FMEA Mapping Research.

RPN	FAILURE MODE	PROBABLE ROOT CAUSE	AFFECTED AREA	CORRECTIVE ACTION
1	Worn	- Customer Operation - Abnormal Usage	- Operation	- Personnel Training - Design Improvements
2	Dents	- Humidity, Debris, Dents, etc.	- Installation - Removal - Packaging - Transportation - Storage	- Internal Procedures - Personnel Training - M.T.I. Procedures - Transport and Logistics
3	- Lack of Adjustment	- Abnormal R.O.T.I. Tasks - Abnormal Usage	- Maintenance - R.O.T.I. - Operation	- M.T.I. Procedures - R.O.T.I. Procedures - Personnel Training - Design Improvements

The Process FMEA was crossed with the information from the previous results, as the High Number of Failures achieved were from the Directional Gyroscope Under/Weak Design; also because the component was not being properly operated and calibrated during the installation procedure in the aircraft before its operation (Customer Operation).

4.3.2 Improvement Proposal

The improvement proposal established for this component was to perform a data information study about calibration values (values from MCO and A/C). Because whenever this item is installed in the aircraft, the Bias needs to be adjusted and previous conclusions stated that due to the difficult access, occasionally this adjustment is not accomplished, leading to operation probable root causes (Annex A.8).

Previous research procedures in this component, resulted in Logistics improvements, because the component Packaging and Transportation were not being properly implemented. The conclusion was retrieved due to a stability test inside the package of the Gyroscope.

When being packaged, the item had an ink stabilizer inside; whenever the item was being delivered in the Maintenance Center, this same ink stabilizer was fully corrupted. Hence, corrective actions about improving packaging and transportation were performed.

4.4 VHF Transceiver

VHF Transceiver stands for Very High Frequency Transceiver (Figure 4.8). This item [52] is a radio device that uses a transmitter and a receiver. This Transceiver is a digitally controlled radio, it provides an extended frequency range.

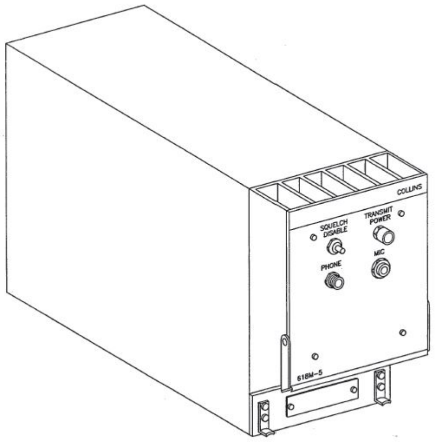

Figure 4.8: VHF Transceiver [53].

4.4.1 Investigation Process

The component's investigation was started due to similar anomalies reported by the Repair Shop. These anomalies were exactly the same every time this item was being repaired/overhauled. As a result, the investigation was triggered both by Alert Level and Ticket/Claim.

As it is an item (group of components, P/N or Item-ATA) and not a singular component (particular component or S/N), a Design FMEA can be performed.

In similarity with the Gyroscope Investigation, the following top RPN were announced:

- **1**st - Equipment Inoperational;
- **2**nd - Weak Transmitter;
- **3**rd - Leaking Capacitors.

There is an important remark to be stated, as this particular Item suffered modifications that came from previous SB; this post modifications triggered a high number of failures followed by a low item reliability (information in Annex A.9).

Following both Design and Process FMEA, in Figure 3.9, it was clear that the probable causes were coming from a weak product design, where the Operation was the main affected area. This statement provided information that a Design Improvement was needed.

The next step was to enter in contact with the manufacturer about the reported failures and problems with the VHF Transceiver.

4.4.2 Improvement Proposal

The corrective action proposed for this component was to send a informative Tear Down Report to the manufacturer, with the following questions:

- *Is the Manufacturer aware of the anomalies reported in RPN 1, 2 and 3?*

- *Do you have any perception if these anomalies are common to other fleets equipped with this radio?*
- *What could be the root causes of the anomalies stated in the different RPN? Can they be related to the SB modification?*
- *What can be done in order to avoid/eliminate the root causes described in the previous question?*

As MRT is waiting for the answers from the manufacturer (regarding the report) and MCO (regarding theoretical analysis and further investigations), the expected results are the enhancement in the VHF Transceiver Design and consecutive improvements in the component's operation. As it will fail less times and continue to increase its reliability.

An Airworthiness Directive (AD), SB or Service Letter (SL) might have to be implemented.
A monitoring plan is not mentioned due to the waiting of the manufacturer answers with this investigated item.

Chapter 5

Conclusion

In this chapter is presented the overall conclusions of the thesis, as well as proposals for the continuous improvement of the project and future research.

5.1 Summary

The implementation of an Aircraft Reliability Program was conducted. The application of reliability procedures improved and assisted to understand vital issues, consequently, corrective actions solved these problems.

The standardization of definitions and data from components, reliability and respective events in a Reliability Manual was accomplished.

The description and standardization of the reliability metrics calculation and process was executed.

Detailed programs and user guides for root causes investigations and Failure Mode and Effects Analysis was partially concluded. As the User Guide for the process was started but not possible to finish.

Preventive and Corrective Actions implementation and respective Monitoring plans were performed whenever possible.

The main objective of the project of making the fleet more available and rotable components more reliable was accomplished. Even thought data is not yet available for comparison, positive results are expected.

5.2 Key Points

It is important to mention this project can be adapted and consequently used in other OGMA's military fleets or similar MROs.

After the improvements procedures, reliability results were not available due to the time frame of the same corrective actions procedures. This means that solid data for results comparison are expected to appear within 6 to 12 months (or more) after the corrective actions being applied.

By the time the Initial Maintenance Reliability Analysis was being applied, it was already being updated due to previous and current investigations. As the Maintenance Reliability Surveillance Process was closed and approved in the Reliability Manual, it was clear that with future investigations, it was going to be updated and improved. This same conclusion is expected in the future, as the reliability process will improve with experience.

Taking into consideration the reliability calculation process, the one currently in use is more reliable than with the use of Basic Values (metrics since the initial aircraft flights), due to the fleet type of operation and changeable time hours/cycles. The customers contract is a ”Pay by Flight Hours”, thus, the more a fleet flies, the better for OGMA financial status is. However, the main problem is that some of the maintenance tasks of the Lockheed Martin C-130 fleet has to be performed by a month or year frame and not only due to flight hours/cycles. This type of maintenance procedures might disrupt the reliability values if basic values are used.

The availability of the four types of alert level filters made a better understanding of the reliability condition possible, allowing users to keep track of the reliability trend taking into account a short and long term view.

The Maintenance Reliability Surveillance Process and the Design and Process FMEA Mapping Research proved to be worthy, as the steps taken to accomplish the expected results were achieved.

5.3 Improvement Proposals

The most important improvement proposal in OGMA is the Personnel Training concerning Reliability. If the area of study is understood by everyone that might take part of it, then people will certainly improve their way of work and pay attention to information and procedures that might compromise a component or even the aircraft reliability and availability.

There was some problematic findings when searching for information in SIGMA and FMS, because such information was sometimes not correctly inserted. By this, one of the greater areas of improvement in the reliability area is the standardization of information retrieved from the components and aircraft management. Thus, the use of standard data for the reliability metric calculation is considered important. If correctly executed, the process is easier and it does not require much effort and working hours from the Maintenance Reliability Team.

Even though the reliability calculation process developed in Excel has improved the overall reliability process, it can also be improved by creating a new procedure into the computerized program where it is expected to retrieve metrics and alert levels automatically.

At last, the Aircraft Reliability Program needs to be performed more times in order to be more effective and effortless.

The proposed future projects for OGMA are:

- Standardization of Information into the SIGMA and FMS (dropdown lists, checkboxes, unlocked/locked information boxes, etc.);
- Automatic Program for Reliability Outputs Reports and Presentations (Data, Graphics, Alerts, etc.).

5.4 Future Research

Besides existing documentation, it is known that the standardization of military aviation regulations is needed, thus, creating normative documents for the same purpose for both Civil and Military is required.

There is the need to standardize the Reliability Processes for Civil and consequent Military Aviation. Nowadays, these processes are dependent of the Operator, Manufacturer and Maintenance Centers, as cooperation/partnerships between them are made to proceed into Reliability Studies. Hence, a unification of data, metrics and improvement processes are a possible future project.

In sum:

- Use Civil Regulations in Military Aviation by creating common and mandatory rules;
- Standardize Reliability Analysis and Procedures processes for Aviation in order to maximize its efficiency.

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Appendix A

Annexes

A.1 Annex 1

OGMA	RELIABILITY MANUAL

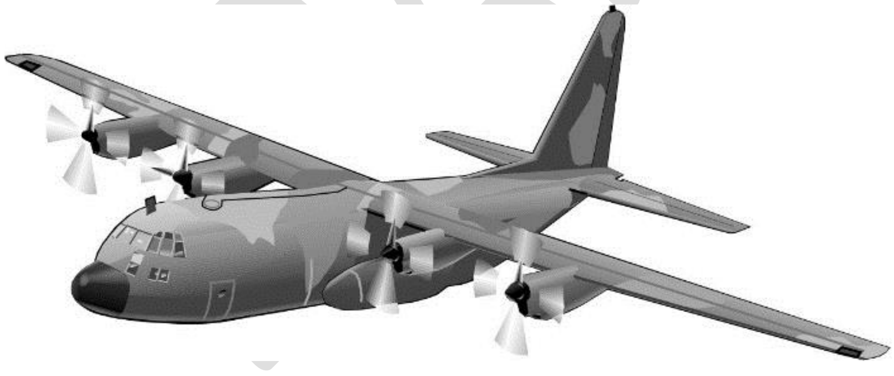
OGMA #

RELIABILITY MANUAL

Reliability Calculation

Research and Analysis Procedures

Improvements Implementation and Monitoring Plan



Lockheed Martin C-130 Hercules Fleet

*********** [###]**

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ACRONYMS

AD – Airworthiness Directive
AL – Alert Level
AMP – Aircraft Maintenance Plan
ATA – Air Transportation Association
CND – Could not Duplicate
FMS – Fleet Management System
FR – Failure Rate
MCBF – Mean Cycles Between Failures
MCO – Maintenance of Components
MMA – Maintenance of Military Aircraft
MRB – Maintenance Reliability Board
MRBM – Maintenance Reliability Board Meeting
MRO – Maintenance, Repair and Overhaul
MRT – Maintenance Reliability Team
MSG – Maintenance Steering Group
MTBF – Mean Time Between Failures
MTBR – Mean Time Between Removals
MTBUR – Mean Time Between Unscheduled Removals
NFF – No Fault Found
OGMA – *OGMA* Indústria Aeronáutica de Portugal, S.A.
ONS – OGMA Normative System
OT – Operational Time
P/N – Part Number
RCM – Reliability Centered Maintenance
S/N – Serial Number
SB – Service Bulletin
SIGMA – *Sistema de Informação e Gestão da OGMA*
SL – Service Letter
TAT – Turn Around Time
TSI – Time Since Installation
TSN – Time Since New
TSO – Time Since Overhaul

PART I - RESUME

Reliability Manual is the main document related to reliability, research and improvement procedures for the to Lockheed Martin's C-130 Hercules Aircrafts from the ********* (###) fleet. This document has data registry, data processing, reliability metric calculation, metric analysis, alert levels, analysis and research of root causes, respective preventive and corrective actions and their monitoring to guarantee success in their implementation by the Maintenance Reliability Team (MRT) and the Quality Department.

I.1. Purpose

This Manual describes and contains all the information related to Reliability and its Improvement processes, as well as related processes associated to Lockheed Martin's C-130 Hercules Aircrafts from the **********, which are # units of C-130H and # units of C-130H30 (see Table 3). This manual will improve the components, aircraft and fleet reliability, availability, client's trust and OGMA's income.

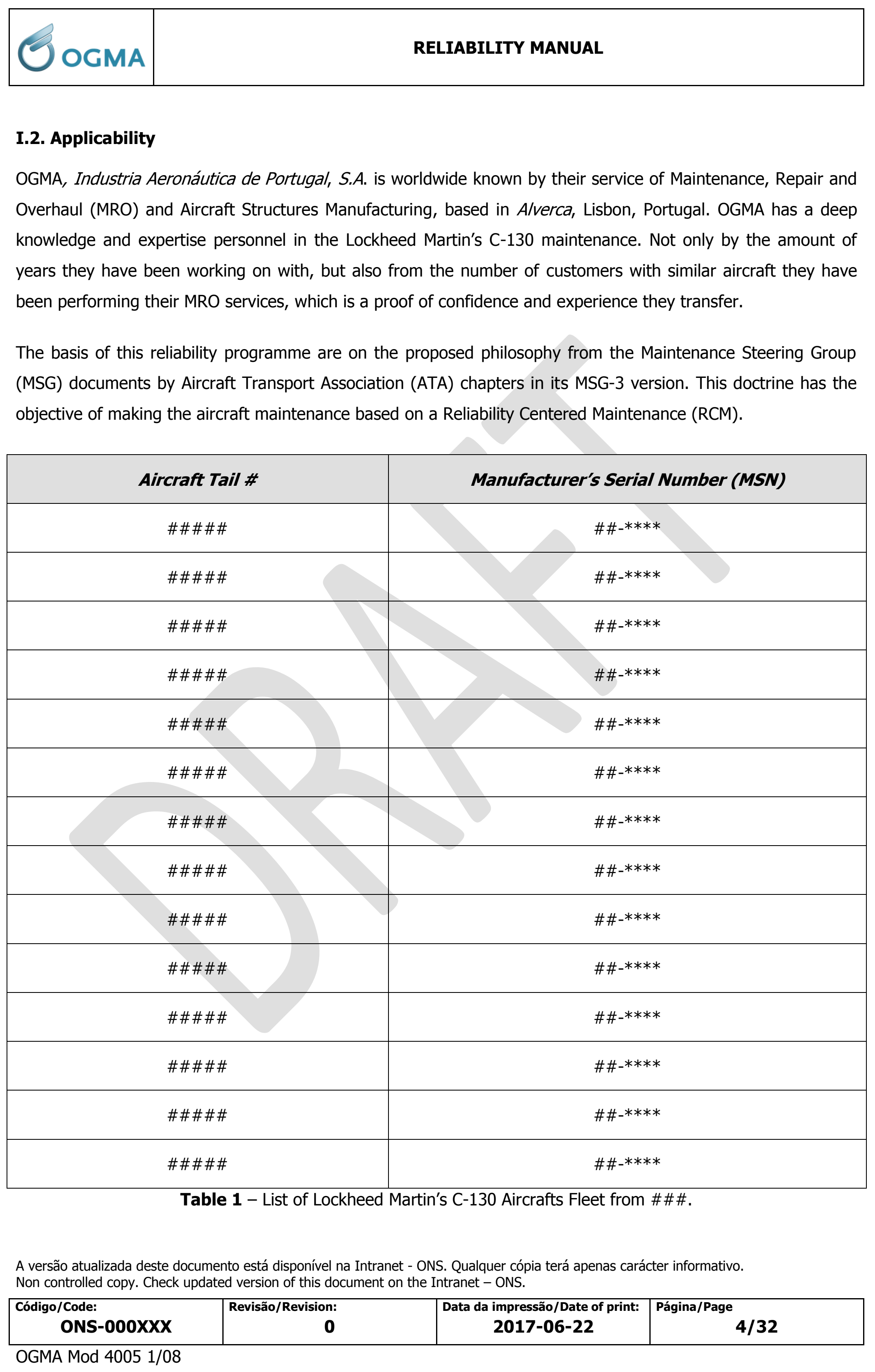
The Reliability Manual consists in data processing, metrics calculation, components understanding, root causes research and improvement actions, also known as corrective actions.

The evaluation of the reliability data results in improvement actions, as mentioned above, those are:

- Improvements in the Approved Aircraft Inspection Program;
- Improvements in Components Performance and Reliability;
- Improvements in Aircraft Reliability and Availability;
- Improvements in internal procedures, documents and tools;
- Improvements by training OGMA's and subcontracted Personnel;
- Financial, reliance and experience improvements;
- Others.

These improvements will bring predictable benefits, those are:

- Components and respective Aircraft availability;
- Reduction in No Fault Found (NFF) or Could Not Duplicate (CND) events;
- Reduction in Assessments and Turn Around Times (TAT);
- Reduction in Components Failure and repetitive failure events;
- Reduction and improvements in component's Transport and Packaging;
- Increase in life and serviceability of the components;
- Others.



I.2. Applicability

OGMA*, Industria Aeronáutica de Portugal*, *S.A*. is worldwide known by their service of Maintenance, Repair and Overhaul (MRO) and Aircraft Structures Manufacturing, based in *Alverca*, Lisbon, Portugal. OGMA has a deep knowledge and expertise personnel in the Lockheed Martin's C-130 maintenance. Not only by the amount of years they have been working on with, but also from the number of customers with similar aircraft they have been performing their MRO services, which is a proof of confidence and experience they transfer.

The basis of this reliability programme are on the proposed philosophy from the Maintenance Steering Group (MSG) documents by Aircraft Transport Association (ATA) chapters in its MSG-3 version. This doctrine has the objective of making the aircraft maintenance based on a Reliability Centered Maintenance (RCM).

Aircraft Tail #	***Manufacturer's Serial Number (MSN)***
#####	##-****
#####	##-****
#####	##-****
#####	##-****
#####	##-****
#####	##-****
#####	##-****
#####	##-****
#####	##-****
#####	##-****
#####	##-****
#####	##-****
#####	##-****
#####	##-****

Table 1 – List of Lockheed Martin's C-130 Aircrafts Fleet from ###.

I.3. References

References and related Documents are stated above:

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- ATA Specification 2200, iSpec 2200, "Information Standards or Aviation Maintenance", 2007.

I.4. Responsibilities

The present document is in the responsibility of the Maintenance Reliability Team, the personnel from Aircraft Maintenance & Engineering Departments and from the Quality Department.

All the Documents present and referred in this manual are certified by the OGMA Normative System (ONS) and monitored by the Quality Department.

The Maintenance Reliability Board Meeting (MRBM) known and present in Maintenance Reliability Board Meetings (MRBM) are the following ones:

- Maintenance Reliability Team;
- Maintenance & Engineering Director;
- Component Engineering Coordinator;
- Aircraft Fleet Manager;
- Maintenance Technician Representative (by invite);
- Components Chief;
- Component Technician Representative (by invite);
- Quality Department Coordinator;
- Pilot or Pilot Engineer (by invite, if available).

The Maintenance Reliability Team is only responsible for the Reliability Calculation and Analysis, as well as scheduling meetings for MRBM, it is responsible for the documents fill up. Data processing and research and analysis for corrective actions are MRBM responsibility.

Quality Department of the Components & Engines Area team is responsible for the implementation of the corrective actions and for its follow-up monitoring.

The Engines & Components Area Responsible is in charge of guaranteeing the correct use of reliability and all processes involved.

I.5. Useful Information

Any improvement in the Manual, Data Processing, Metric Calculation, Analysis and Claim Research or in the Implementing of Corrective Actions and Monitoring need be both proposed to MRT and Quality Department before being implemented.

PART II - THEORETICAL CONCEPTS

II.1. Reliability

Reliability is a concept based in durability and consistency and it usually refers to a successful and non-faulty operation. It refers to the probability of a system/component of accomplishing its purpose in specific conditions during a pre-defined time without failing. As a summary, reliability is an organ than checks if a specific component or system works and lasts as long as it was designed for.

Reliability is, as a simple equation, the sum of success percentage, failure percentage, as shown bellow, where *n* is the number of failures, and *t* is the window time:

$$f(n,t) = 1$$

$$f(n,t) = S + N$$

$$S(n,t) + F(n,t) = 1$$

This equation shows that the reliability of a system or a component or even the aircraft/fleet is related between success and failure of them. The more failures they might have, the less successful they will be due to unavailability. This is a mirrored view of reliability due to the internal failures in the bigger systems (components).

If applied correctly, Reliability will not assure the 100% of success of a specific component/system in time and operation. If something is 100% reliable, it means we have a perfect component/system due to its perfect operation and zero occurrences of failure. By this, reliability optimizes the operation and lowers the number of failures and problems taking into consideration that it has an improvement process in its basis by being the reason of its existence.

Nowadays, systems and components are taken into their limits of operation due to their high requirements and lowered production costs. Even though they need to be certified before being installed and used, there needs to be a correlation between operation/maintenance costs and design and production costs, this is shown in Figure 1. It is achieved by using an optimal component and aircraft management focused in reliability (MSG-3 type). These costs are shown in Figure 2.

As a resume: Reliability will be expensive to implement due to improvement procedures; the greater the Reliability Requirements are, the greater will be their cost related to the processes of level obtaining; the best reliability level is achieved when total related costs are at their minimum.

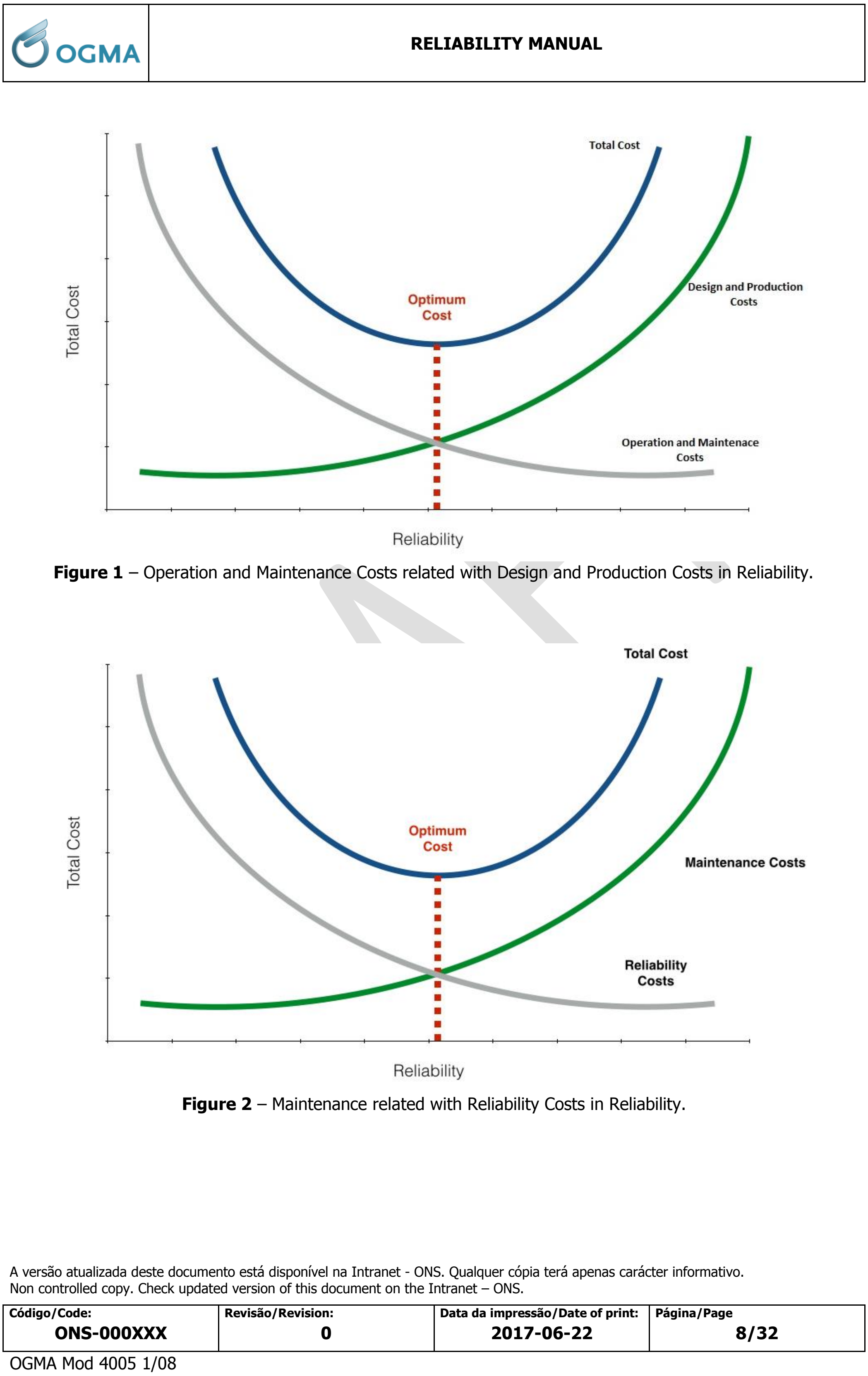

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Figure 1 – Operation and Maintenance Costs related with Design and Production Costs in Reliability.

Figure 2 – Maintenance related with Reliability Costs in Reliability.

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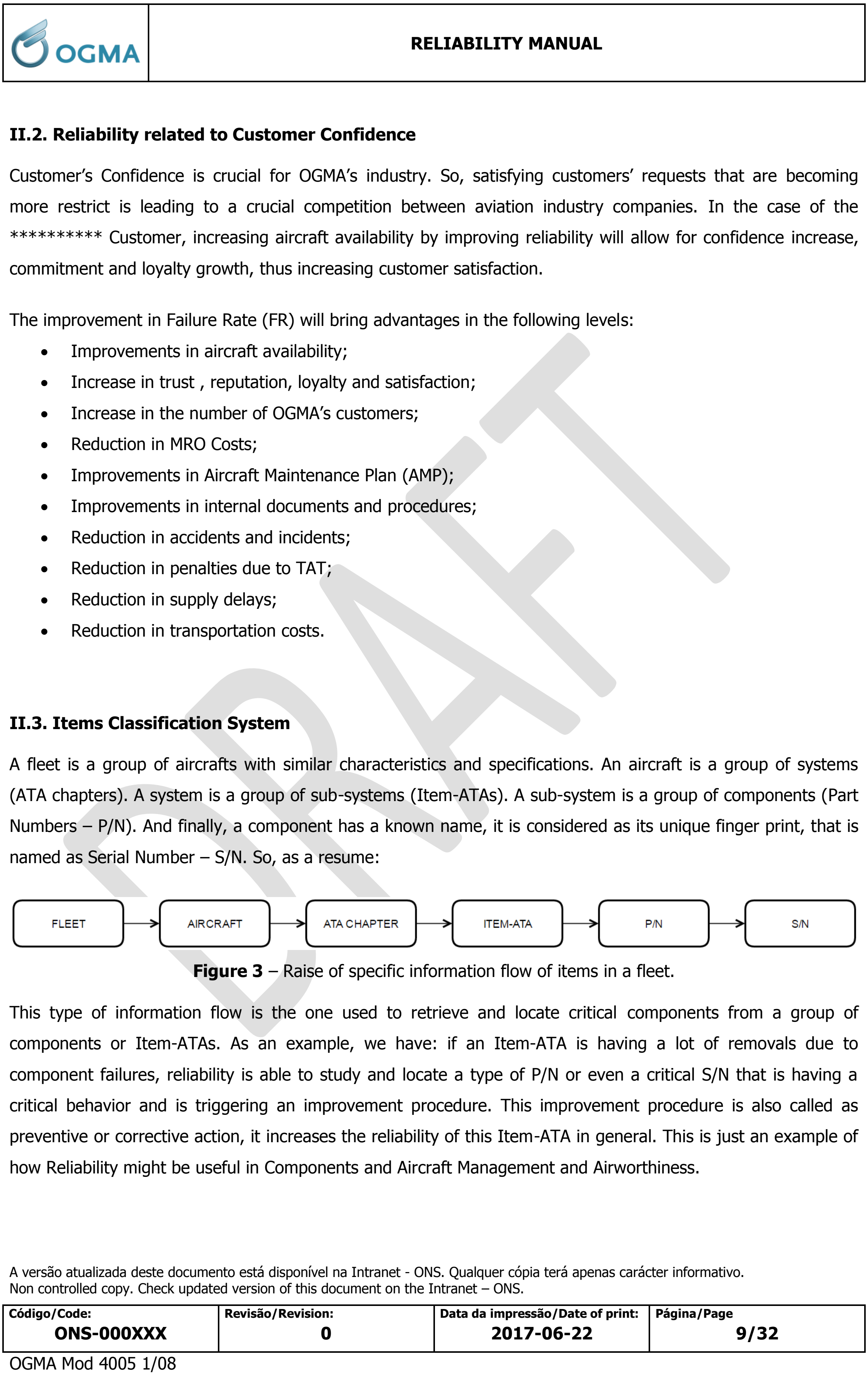

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II.2. Reliability related to Customer Confidence

Customer's Confidence is crucial for OGMA's industry. So, satisfying customers' requests that are becoming more restrict is leading to a crucial competition between aviation industry companies. In the case of the ********** Customer, increasing aircraft availability by improving reliability will allow for confidence increase, commitment and loyalty growth, thus increasing customer satisfaction.

The improvement in Failure Rate (FR) will bring advantages in the following levels:

- Improvements in aircraft availability;
- Increase in trust , reputation, loyalty and satisfaction;
- Increase in the number of OGMA's customers;
- Reduction in MRO Costs;
- Improvements in Aircraft Maintenance Plan (AMP);
- Improvements in internal documents and procedures;
- Reduction in accidents and incidents;
- Reduction in penalties due to TAT;
- Reduction in supply delays;
- Reduction in transportation costs.

II.3. Items Classification System

A fleet is a group of aircrafts with similar characteristics and specifications. An aircraft is a group of systems (ATA chapters). A system is a group of sub-systems (Item-ATAs). A sub-system is a group of components (Part Numbers – P/N). And finally, a component has a known name, it is considered as its unique finger print, that is named as Serial Number – S/N. So, as a resume:

FLEET → AIRCRAFT → ATA CHAPTER → ITEM-ATA → P/N → S/N

Figure 3 – Raise of specific information flow of items in a fleet.

This type of information flow is the one used to retrieve and locate critical components from a group of components or Item-ATAs. As an example, we have: if an Item-ATA is having a lot of removals due to component failures, reliability is able to study and locate a type of P/N or even a critical S/N that is having a critical behavior and is triggering an improvement procedure. This improvement procedure is also called as preventive or corrective action, it increases the reliability of this Item-ATA in general. This is just an example of how Reliability might be useful in Components and Aircraft Management and Airworthiness.

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The following table describes each ATA chapter from the C-130 ### fleet:

ATA Chapter	***Description***	***ATA Chapter***	***Description***
21	Air Conditioning	36	Pneumatic
22	Auto-Flight	49	Airborne Auxiliary Power
23	Communications	52	Doors
24	Electrical Power	53	Fuselage
25	Equipment/Furnishings	57	Wings
26	Fire Protection	61	Propellers/Propulsors
27	Flight Controls	71	Power Plant
28	Fuel	72	Turbine/Turboprop Engine
29	Hydraulic Power	73	Engine Fuel and Control
30	Ice and Rain Protection	74	Ignition
31	Instruments	75	Air
32	Landing Gear	77	Engine Indicating
33	Lights	79	Engine Oil
34	Navigation	80	Starting
35	Oxygen	99	*Others**

Table 2 – Description from the list of ATA-100 Chapters.

*This chapter is for OGMA purposes only. It is a chapter created due to no connection or non-alternatives from other ATA chapters.

Further information is available at the following webpage:

https://www.aviationmaintenancejobs.aero/aircraft-ata-chapters-list

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II.4. Maintenance Removals Reasons

Components Reliability ends in their removal data. Usually, components are removed due to maintenance operations, mainly due to scheduled (preventive maintenance) events but also from unscheduled (reactive maintenance) events. Scheduled removals come from AMP, where manufacturers specify the time/cycles or even condition of components/systems and from the operator due to their operation requirements.

In Figure 3 we can see the Removal/Finding Flow Chart from 1999 and included in ATA iSpec 2000. This Flow chart describes detailed data for removal reasons (where cycles are also applicable).

Summarizing, we have:

- **MTBR** – mean time between removals is achieved with data from box 1 [Removal];
- **MTBUR** – mean time between unscheduled removals is achieved with data from box 2 [Unscheduled Removal], where it is a sum of failures and NFF;
- **MTBF** – mean time between failures is achieved with data from box 4 [Failure/Fault], it represents all failures from a component;
- **Justified**, **Non-Induced** and **Confirmed** data comes from failure modes and respective research;
- The category **OTHER** is assumed to be in box 5 [NFF] due to not having any kind of fault.

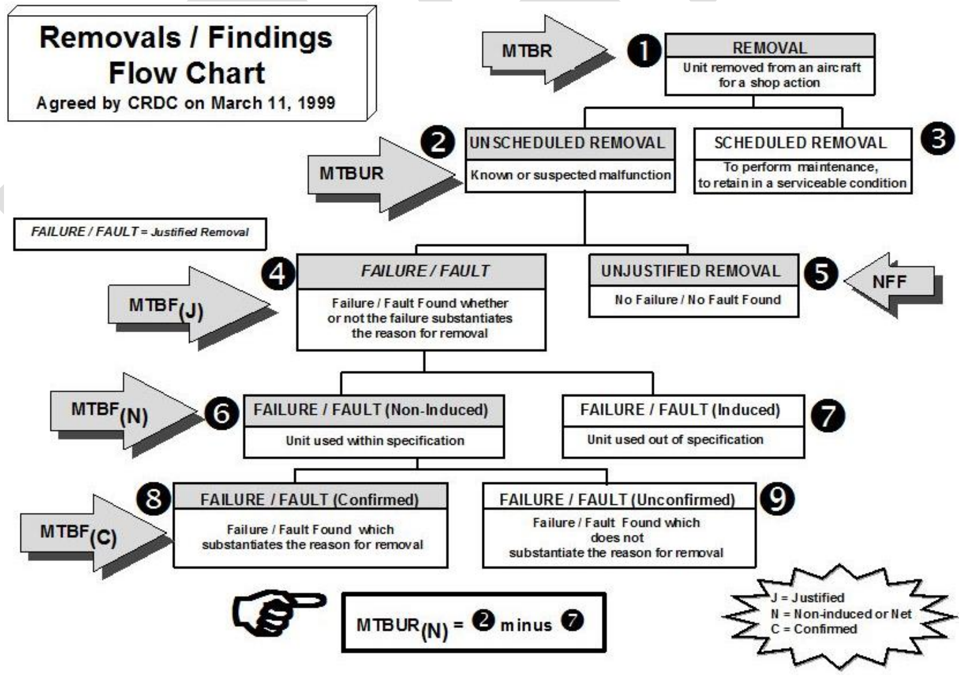


Figure 4 – Component Removal by Reactive or Preventive Maintenance procedures.

II.5. Failure

Knowing the Failure definition is the basis for understanding the Reliability concept. Thus, we have the following definitions for different type of failures:

- **Failure** – Incapacity of a part to perform its specified functional activity;
- **Primary Failure (independent)** – Failure that came from the failed part;
- **Secondary Failure (dependent)** – Failure cause by part malfunction or by other associated failures;
- **Intermittent Failure** – Failure pattern not directly connected to the overage of a part. It usually happens in random time windows;
- **Age related Failure** – Constant failure pattern over the serviceable time. It is connected to the overage of a component/system.

The Failure Rate is the most used reliability metric in aviation, right after MTBF/MCBF. Depending on the use, FR gives the user the rate of failure of a component or system by dividing the number of failures by the hours/cycles of flight times the number of components in each aircraft.

PART III - RELIABILITY PROGRAMME

The Reliability Programme aims for evaluation, control, improvement and permanent monitoring of the Lockheed Martin C-130 Hercules Aircraft Fleet from ********** Customer and their respective components. This project has 4 main steps:

- Input and Processing of Collected Data [*DATA PROCESSING*];
- Reliability Metrics Calculation [*METRIC CALCULATION*]
- Alerts and Claims Research [*ANALYSIS AND RESEARCH PROCESS*];
- Implementation of Corrective Actions and Monitoring [*PREVENTIVE AND CORRECTIVE ACTIONS*].

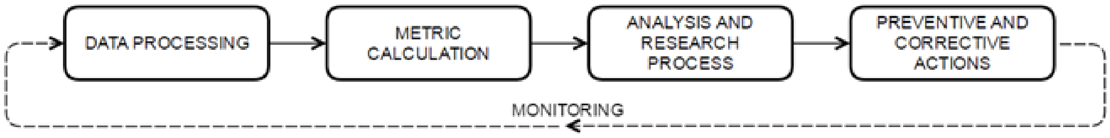


Figure 5 – Summary of the Reliability Programme Workflow.

III.1. Input and Processing of Collected Data

The collected data is based in the fleet and components information. It gives us:

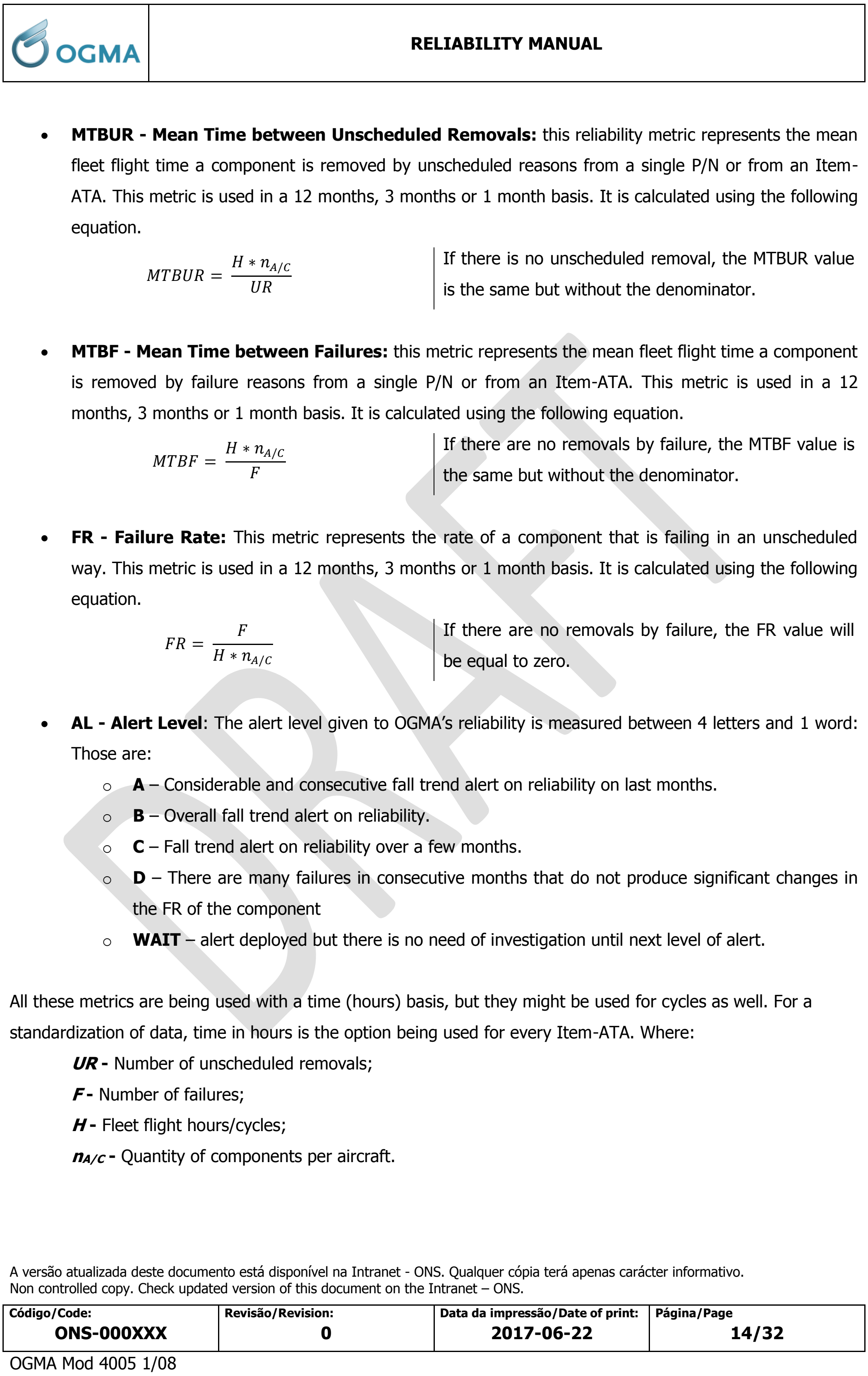
- Fleet Status;
- Components removals;
- Scheduled and Unscheduled Maintenance;
- Failures and Maintenance findings;
- Accidents and Incidents data;
- Internal and External Audits;
- Data from Aeronautical Agencies and Manufacturers.

All this information will be introduced in the Fleet Management System (FMS) and *Sistema de Informação e Gestão da OGMA* (SIGMA).

III.2. Reliability Metrics Calculation

This section refers that for reliability purposes there is the need of creating a metric calculation program for alert levels. These alert levels are the reason key-point for starting a new investigation.

Data processing is performed with the objective of calculating reliability alerts from the fleet in analysis. The main metrics are:



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- **MTBUR - Mean Time between Unscheduled Removals:** this reliability metric represents the mean fleet flight time a component is removed by unscheduled reasons from a single P/N or from an Item-ATA. This metric is used in a 12 months, 3 months or 1 month basis. It is calculated using the following equation.

$$MTBUR = \frac{H * n_{A/C}}{UR}$$

If there is no unscheduled removal, the MTBUR value is the same but without the denominator.

- **MTBF - Mean Time between Failures:** this metric represents the mean fleet flight time a component is removed by failure reasons from a single P/N or from an Item-ATA. This metric is used in a 12 months, 3 months or 1 month basis. It is calculated using the following equation.

$$MTBF = \frac{H * n_{A/C}}{F}$$

If there are no removals by failure, the MTBF value is the same but without the denominator.

- **FR - Failure Rate:** This metric represents the rate of a component that is failing in an unscheduled way. This metric is used in a 12 months, 3 months or 1 month basis. It is calculated using the following equation.

$$FR = \frac{F}{H * n_{A/C}}$$

If there are no removals by failure, the FR value will be equal to zero.

- **AL - Alert Level**: The alert level given to OGMA's reliability is measured between 4 letters and 1 word: Those are:
  - **A** – Considerable and consecutive fall trend alert on reliability on last months.
  - **B** – Overall fall trend alert on reliability.
  - **C** – Fall trend alert on reliability over a few months.
  - **D** – There are many failures in consecutive months that do not produce significant changes in the FR of the component
  - **WAIT** – alert deployed but there is no need of investigation until next level of alert.

All these metrics are being used with a time (hours) basis, but they might be used for cycles as well. For a standardization of data, time in hours is the option being used for every Item-ATA. Where:

***UR* -** Number of unscheduled removals;
***F* -** Number of failures;
***H* -** Fleet flight hours/cycles;
$n_{A/C}$ - Quantity of components per aircraft.

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III.3. Alerts and Claims Research

To trigger an investigation, there is the need to have a quite important alert, claim or investigation ticket. In this case, alerts are found after the metrics calculation, claims come from requests and investigation tickets are due to repetitive removals by failure from a specific Item-ATA and from repetitive or singular NFF item, as well.

In a simple representation, the research starts with an investigation for root causes of the problem or problems. After the analysis is done, there is a meeting with representatives from each area where they will discuss and identify problems.

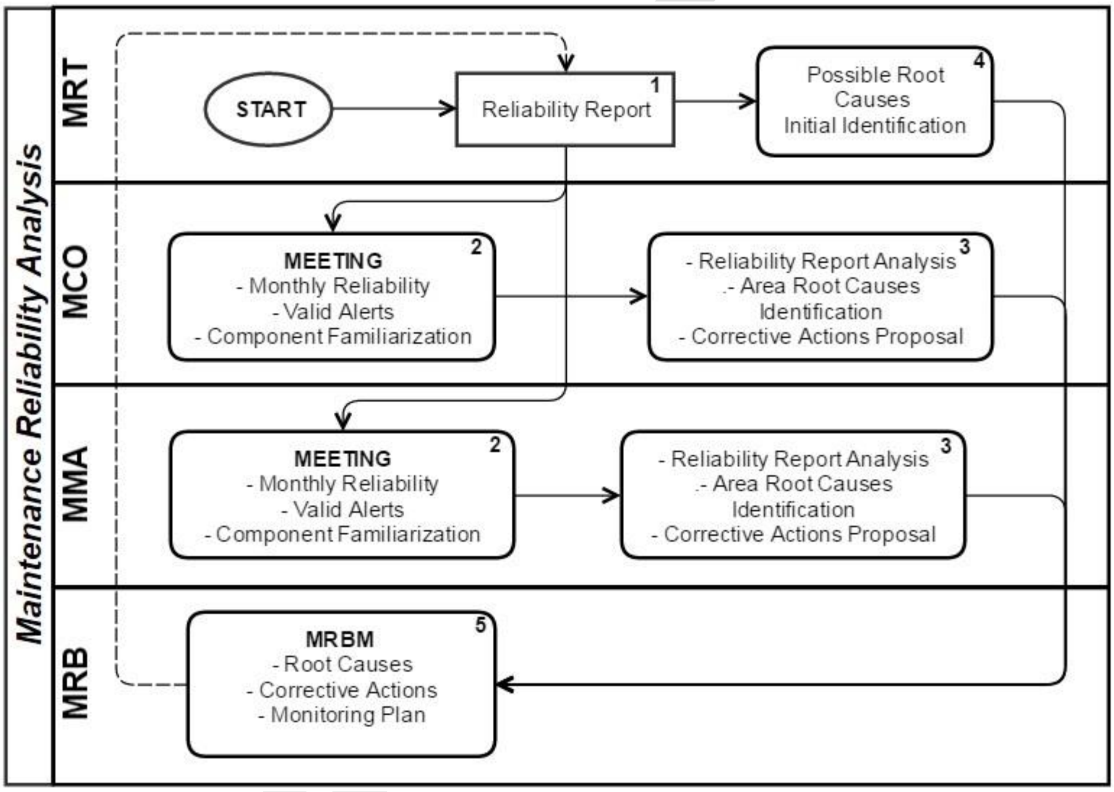


Figure 6 – Initial Maintenance Reliability Analysis.

The flowchart starts with:

- the Reliability Report [box 1], made by the Maintenance Reliability Team – MRT;
- MRT will then share information with Maintenance of Components and Maintenance of Military Aircrafts for alerts and claims [box 2];
- After both meetings, MCO and MMA will help MRT with identification of root causes and proposed corrective actions [box 3];

- MRT will also try to identify primary probable causes out of MCO and MMA [box 4];
- After collecting all information for root causes identification and corrective actions proposals, there will be a last discussion in Maintenance Reliability Board – MRB about how to implement them and the respective monitoring [box 5].

III.4. Implementation of Corrective Actions and Monitoring

The implementation of corrective actions is the responsibility of MRT and Quality Department. After the all the process since the input data for FMS and SIGMA, until the research of root causes, corrective actions and their implementation is last step before monitoring them. At the company level, there are quite a few actions available to improve reliability of a rotable component as well as in its own maintenance process.

#	CORRECTIVE ACTIONS
I	Update Documents
II	Personnel Training
III	Repairshop Procedures
IV	Internal Procedures
V	Maintenance Procedures
VI	Design Improvements
VII	AMP Improvements
VIII	Transport & Packaging

Table 3 – Preventive and Corrective actions to increase components reliability.

PART IV - DATA PROCESSING

The first statement is that Data Processing is the main process of any Reliability Programme. The reason behind its importance is that the source of reliability data needs to be reliable.

The source of data comes from:

- Fleet Status;
- Line and Base Maintenance;
- Flight;
- Manufacturer ADs, SBs, SLs;
- Findings.

For rotable components reliability purposes, the main source comes from the periodic number of the fleet flight hours, number of cycles and general availability. Repair/Overhaul/Inspection reports with detected anomalies and repairs; as well as removal reports with historical data from each S/N with removal reasons, number of hours and cycles, number of the project, etc.

All this information will be manually inserted into FMS and SIGMA. This is performed by users from the Fleet Management. Removal data needs a special attention to avoid the probability of retrieving wrong data from the following process or metric calculation.

The following removal data is in Figure 4, from chapter 7- b.

The objective is to categorize scheduled removals. So, maintenance plans are guided by:

- Limit of operation;
- Customer request;
- AD or SB OR SL.

Any other removal is due to unscheduled behavior, so they are out of the initial maintenance plans and they represent a lack of availability in the operator and consequent unscheduled events into operation and MRO services; for the line/base maintenance, they represent a reactive maintenance, so there is the need of a non prepared maintenance procedure.

There is also removals that does not comply with a failure or scheduled tasks from preventive maintenance. These are known as Others:

- Access
- Convenience
- Swap
- Troubleshooting

The stranger type of removal is the No Fault Found (NFF) or Could Not Duplicate (CND). These removals come from failure reports in operation or line/base maintenance and at the end of a first inspection outside the airplane (MCO), these components are serviceable. This type of removal is problematic because it does not let the operator or maintenance center to know what was the failure/fault and what was going on with the part.

Cannibalizations are also problematic, but a solution for a lowered storage design. As an example, it lets the maintenance center and the operator to have less components held in storage (less money), but it decreases maintenance efficiency due to having components traveling from other airplanes within the fleet and increasing the Turn Around Time (TAT) due to mandatory inspection procedures of the operator.

Troubleshooting by swap is a process where the maintenance center switches positions of the airplane components as mandatory maintenance procedures to search for failures.

Apart from how a removal is described, the following table describes the information needed in reliability.

A/C Tail	S/N	P/N	Date	Event	Correct. Action	Position	TSI	TSO	TSN	OT	Reason	Project	Form	Item ATA
1	2	3	4	5	6	7	8	9	10	11*	12	13	14	15

Table 4 – Exported data from FMS.

The following points explain what each block of information from the exported data are:

1. **A/C Tail**: Aircraft Tail or SN_Parent is the source of the Item-ATA in analysis. Ex: the most common and talked parent is the Aircraft, after that comes the Engines and APU. Engines and APUs use to migrate/change from airplanes and since they are removed/installed as a full system, data from the components installed use to be together;
2. **S/N**: Serial Number of a component;
3. **P/N**: Group of SNs;
4. **Date**: date of the event as a Database input;
5. **Event**: This box has the name of the event. Usually, they are Installation, Repair, Inspection, Overhaul, etc.;
6. **Corrective Action**: Corrective action performed if applicable;
7. **Position**: Position of the component in the aircraft;
8. **TSI**: Time the component has since it was installed;
9. **TSO**: Time the component has since it was overhauled;
10. **TSN**: Time the component has since it was new;
11. **OT**: operational time/cycles: represents the time in service before failure, it might include removals and installations in between due to convenience/cannibalization/swap;

12. **Reason**: Removal Reason is the reason behind the removal of the component. This box should only have the removal reasons available in ATA iSpec 2000 list;
13. **Project**: Additional files for justifying the event;
14. **Form**: Form of the event;
15. **Item-ATA**: Item-ATA is represented as AA-BB-CC, it has the ATA chapter [AA], the section from the ATA [BB], the component type in the section ATA [CC]. It is used to group a certain amount of components by different P/N but that are alternatives between them or only replaceable.

PART V - METRIC CALCULATION

To better understand the component reliability, there is the need to calculate reliability metrics. At the moment, this is performed by a semi-automatic procedure with Microsoft Excel. This program uses the following data calculation flow-chart:

Figure 7 – Alerts Calculation flow-chart.

As show in figure 7, the next bullets will explain each box for an easier understanding:

- **RAW DATA** – This is the export that comes from the FMS, it has all the information coming from each removal, repair, overhaul, inspection, installation, etc. about each component. There is also information that is not needed for reliability calculation;
- **FILTER NEEDS** – After the export, there is the need to filter data that will be used for metrics, these are:
  - all **ITEM-ATA**s that are being used in the fleet;
  - all removals by **FAILURE** and **INDUCED FAILURE**;
  - and the fleet flight **HOURS** per airplane in months.
- **FAILURES** – Only failures are selected;
- **MTBF** – After all the filtering performed, MTBF is a metric that is calculated, but the most important for the next step are the FAILURES;
- **FAILURE RATE** – Failure Rate is also calculated to perform the next step;
- **Δ FR** – This performed step seeks to find a strong and different percentage of removal during a period of time (month, 3 months, 12 months), because if there is a considerable difference in Failure Rate, there might be a situation with the Item-ATA in study;
- **ALERT LEVEL** – This is the last step before retrieving all the graphics and tables to insert in reports and presentations; Alerts are created using a filter type that described in the following letters.
  - **A** – Considerable and consecutive fall trend alert on reliability on last months.
  - **B** – Overall fall trend alert on reliability.
  - **C** – Fall trend alert on reliability over a few months.
  - **D** – There are many failures in consecutive months that do not produce significant changes in the FR of the component
  - **WAIT** – alert deployed but there is no need of investigation until next level of alert.

The following images describe the filters used to get to know the significance of the alert; they have different levels of data filtering.

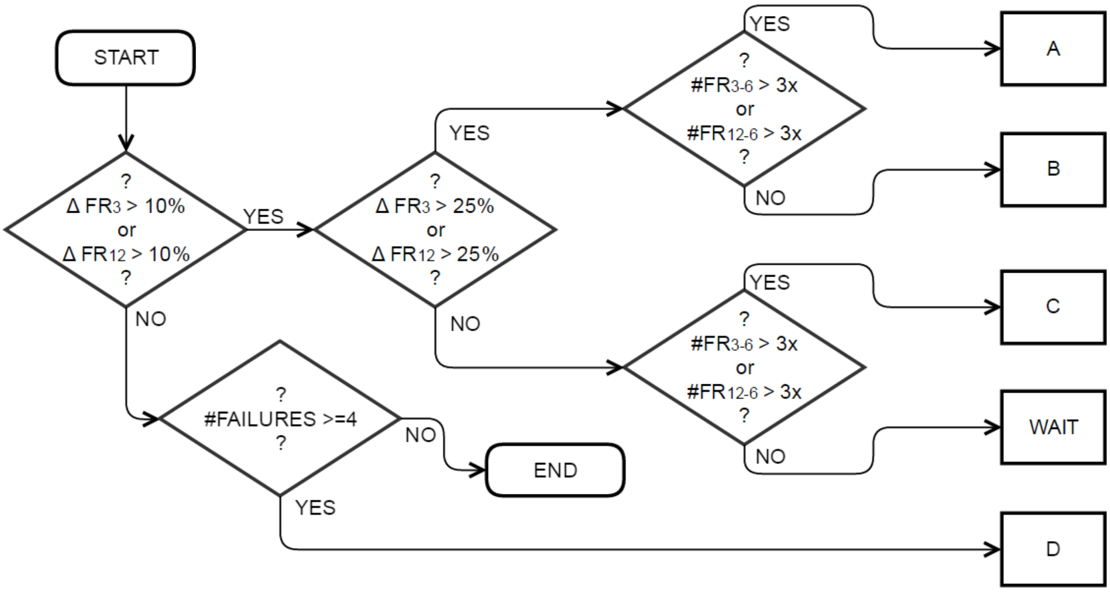


Figure 8 – Decision filter with FR_{12} and FR_3.

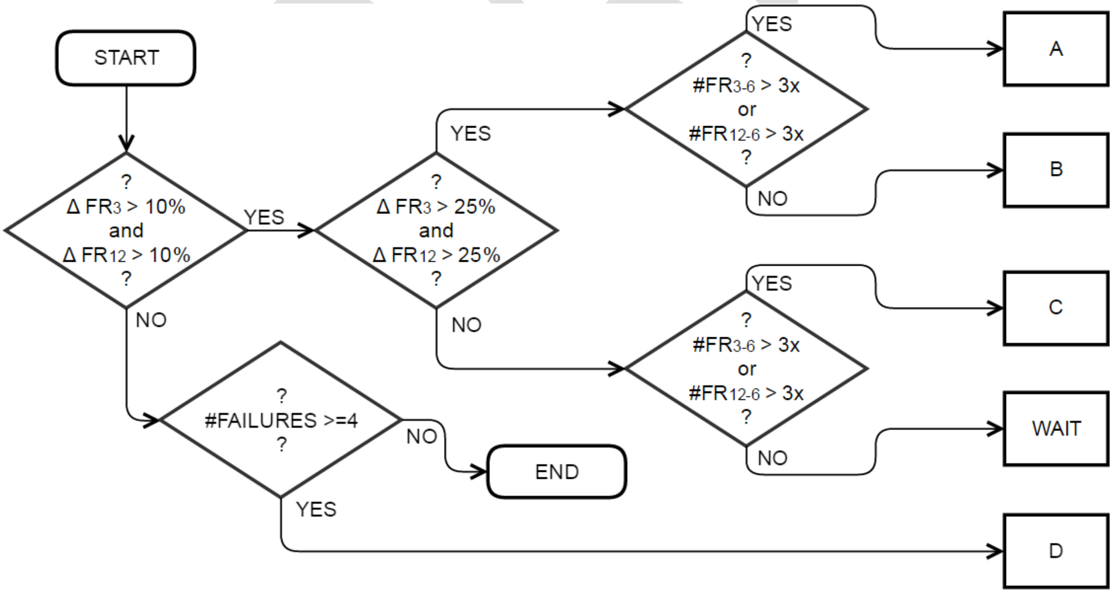


Figure 9 – Decision filter with FR_{12} or FR_3.

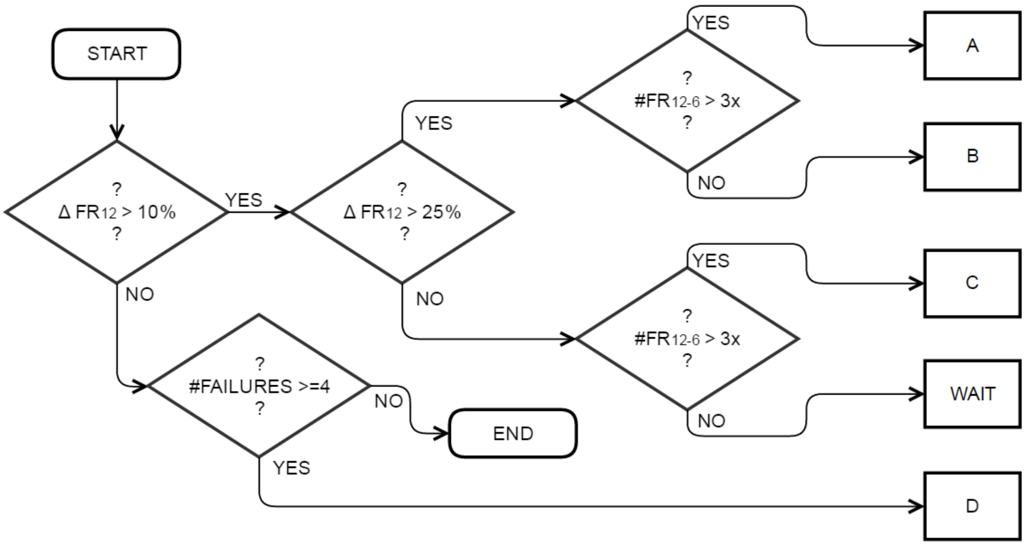


Figure 10 – Decision filter with FR_{12}.

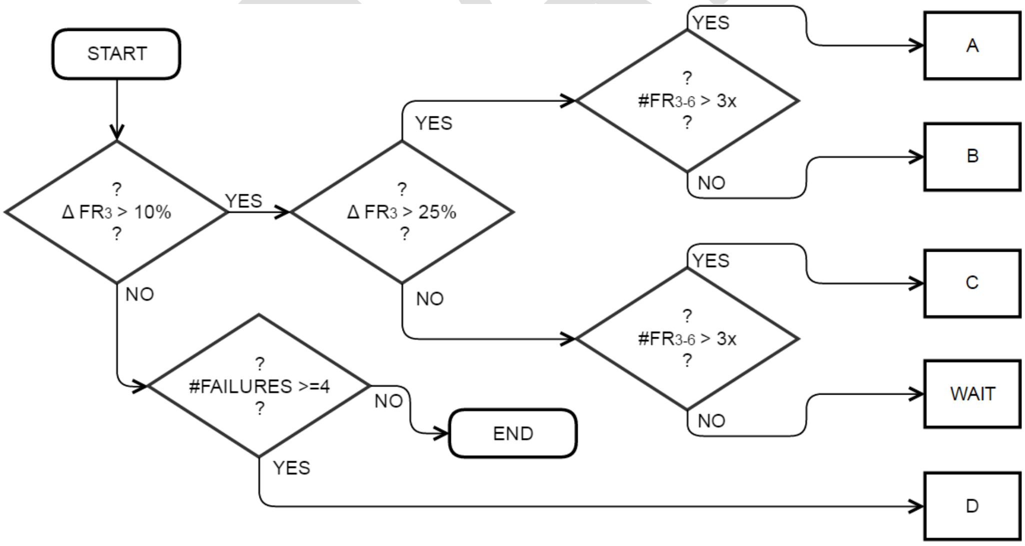
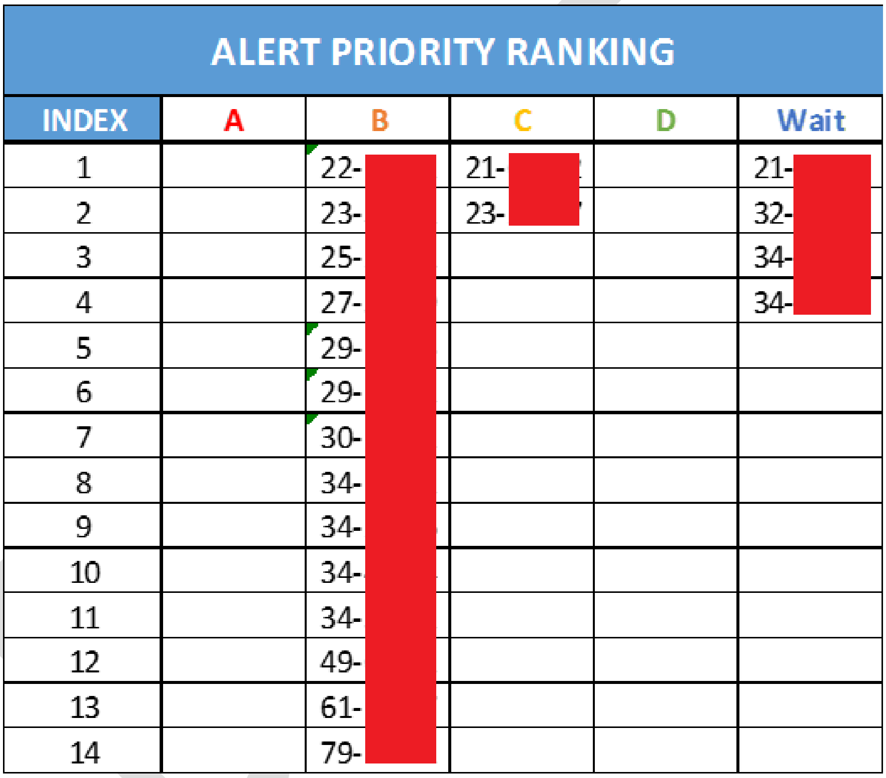


Figure 11 – Decision filter with FR_3.

Depending on the analysis, the four figures represent:

- **FR_{12} or FR_3**: it is the less restrictive filter, the one that has less alerts [Figure 8];
- **FR_{12} and FR_3**: it the most restrictive filter; the one that has more alerts [Figure 9];
- **FR_{12}**: this filter shows the alerts at a long term [Figure 10];
- **FR_{12}**: this filter shows the alerts at a long term [Figure 11].

After all the calculations and decision makers, the following figure is an example of the output from the Excel Reliability Program:



ALERT PRIORITY RANKING

INDEX	A	B	C	D	Wait
1		22- [redacted]	21- [redacted]		21- [redacted]
2		23- [redacted]	23- [redacted]		32- [redacted]
3		25- [redacted]			34- [redacted]
4		27- [redacted]			34- [redacted]
5		29- [redacted]			
6		29- [redacted]			
7		30- [redacted]			
8		34- [redacted]			
9		34- [redacted]			
10		34- [redacted]			
11		34- [redacted]			
12		49- [redacted]			
13		61- [redacted]			
14		79- [redacted]			

Figure 12 – Example of the Alert Levels Table with alerts from a random month.

The calculation process is described in the Metric Calculation User Guide.

OGMA	**RELIABILITY MANUAL**

PART VI - ANALYSIS AND RESEARCH PROCESS

The 3 main reasons to deploy an investigation are the Alert Levels (retrieved from the Metric Calculation), the Repetitive Events (either if they are NFF or repetitive Failures) and the Claims/Tickets.

In this chapter there is a brief explanation of how the Analysis and research process is lead.

VI.1. Affected Areas & Probable Causes

To understand where and how we can find problems in order to implement corrective actions to prevent and fix these problems in the future, the following diagram was created.

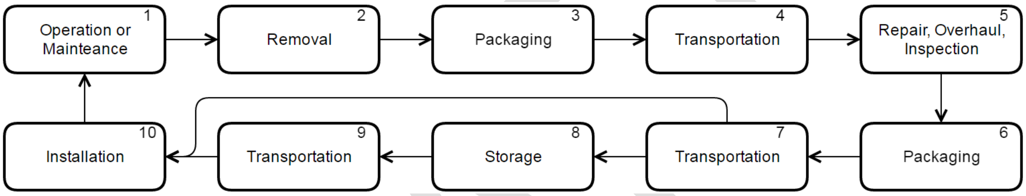


Figure 13 – Life cycle of a rotable component.

From Figure 13, we can see that problems might come form:

- **Operation**: in box 1, where it might be a removal from normal, abnormal or abusive operation;
- **Maintenance (Installation + Removal)**: in boxes 10, 1, and 2, where if might be problems in troubleshooting, problems in maintenance tasks and problems in installation/removals;
- **Transportation**: problems in boxes 4, 7 and 9;
- **Repair/Overhaul/Inspection**: in box 5, overall repair problems;
- **Packaging**: problems in boxes 3 an 6.

Overall, there are 8 affected areas where problems and root causes might be located. These areas are separated to facilitate the investigation troubleshooting. The affected areas are show in the following table:

#	AFFECTED AREAS
1	Maintenance (Installation + Removal + Test + Inspection)
2	Repair Shop (Repair + Overhaul + Test + Inspection)
3	Operation (Customer)

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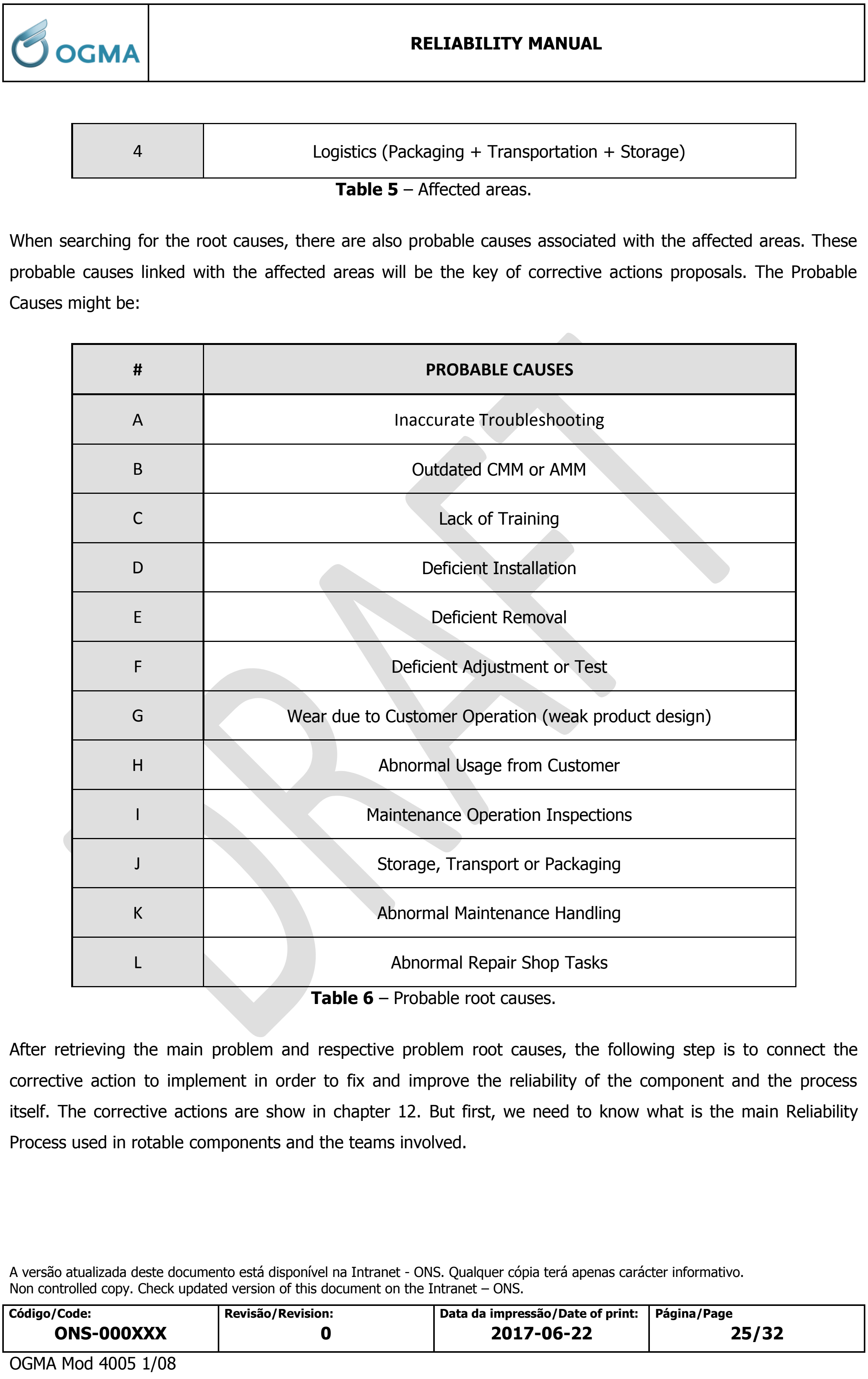


4	Logistics (Packaging + Transportation + Storage)

Table 5 – Affected areas.

When searching for the root causes, there are also probable causes associated with the affected areas. These probable causes linked with the affected areas will be the key of corrective actions proposals. The Probable Causes might be:

#	PROBABLE CAUSES
A	Inaccurate Troubleshooting
B	Outdated CMM or AMM
C	Lack of Training
D	Deficient Installation
E	Deficient Removal
F	Deficient Adjustment or Test
G	Wear due to Customer Operation (weak product design)
H	Abnormal Usage from Customer
I	Maintenance Operation Inspections
J	Storage, Transport or Packaging
K	Abnormal Maintenance Handling
L	Abnormal Repair Shop Tasks

Table 6 – Probable root causes.

After retrieving the main problem and respective problem root causes, the following step is to connect the corrective action to implement in order to fix and improve the reliability of the component and the process itself. The corrective actions are show in chapter 12. But first, we need to know what is the main Reliability Process used in rotable components and the teams involved.

VI.2. Process

The process of root cause research and corrective actions implementation start at the Maintenance Reliability Board Meeting (MRBM). The first flow-chart is designated to let the teams to get used to the process. This starting process is present in Figure 6. All teams involved should get used to the process at a close time range, and the second stage of the research process can be implemented (Figure 14).

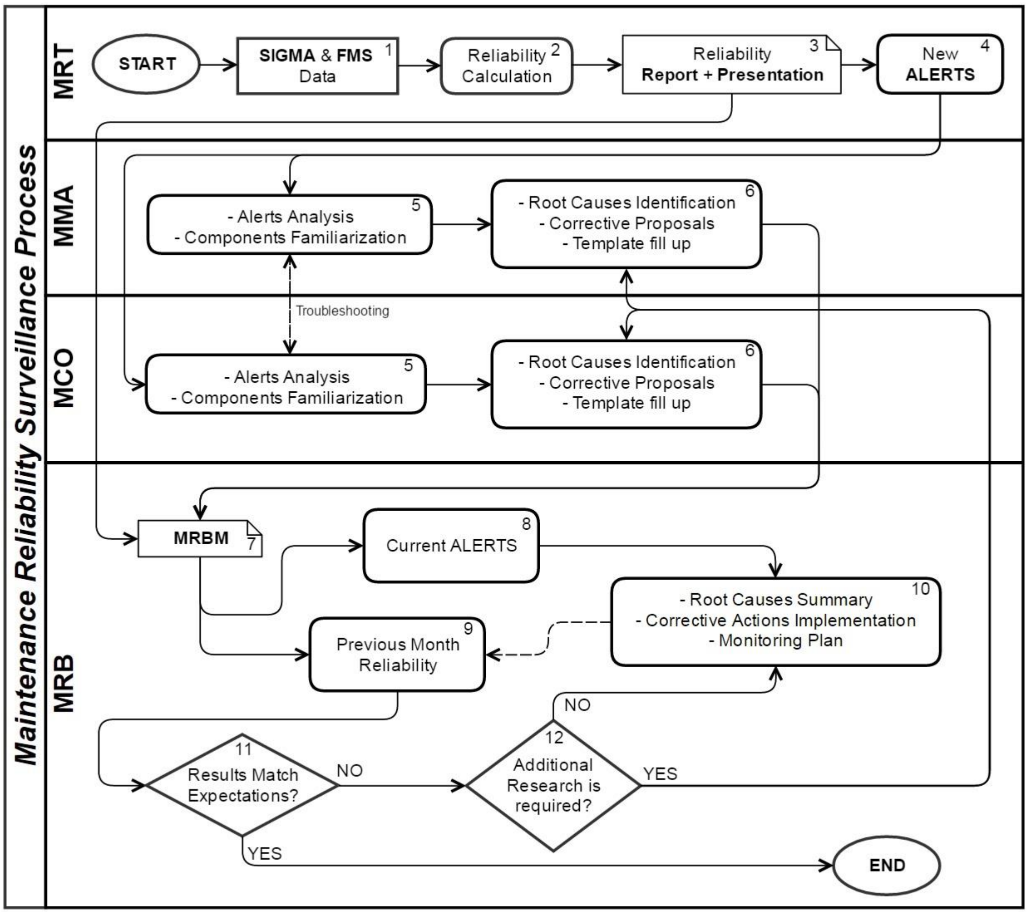


Figure 14 – Final Maintenance Reliability Surveillance Process.

Figure 15 is the purpose of this reliability manual because, in a large scale, it represents the reliability process and its continuous improvement. To understand the process, we have:

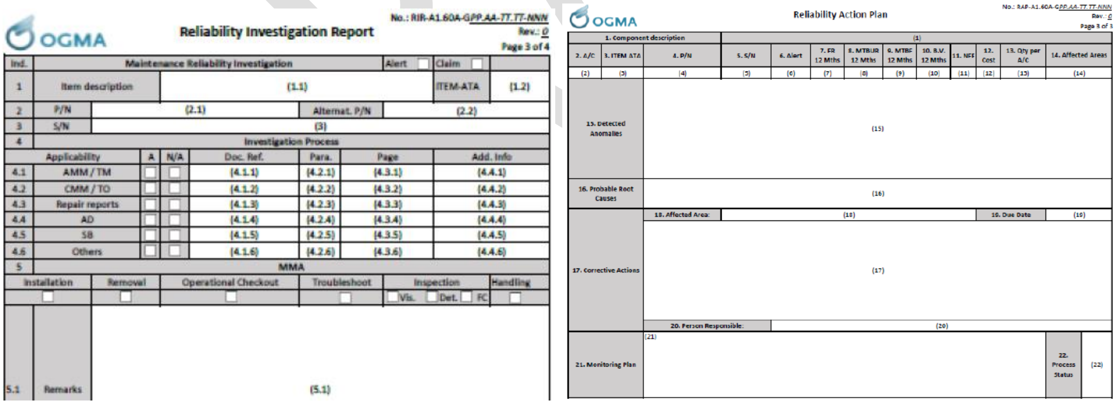
1. **SIGMA & FMS Data** - It is the main process of retrieving data for reliability calculation;
2. **Reliability Calculation** - Process of reliability metric calculation;

3. **Reliability Report + Presentation** - MRT output with Report and Presentation;
4. **New Alerts** - Alerts/Claims/Repetitive Events are pointed to investigation;
5. **Analysis and Familiarization** - First Alerts touch from teams to perform investigation;
6. **Root Causes and Corrective Proposals Template Fill-Up** - MRT template fill-up to retain critical information about components probable causes and future corrective actions proposals;
7. **MRBM** - General Maintenance Reliability Board Meeting;
8. **Current Alerts** - Current month alerts to investigate;
9. **Previous Month Reliability** - Previous information of the corrective actions implemented and monitoring process;
10. **Summary of Root Causes + Corrective Actions + Monitoring** - This meeting chapter will be the start of corrective actions implementation and monitoring plan to perform;
11. **Monitoring Check 1** - Phase 1 of monitoring process;
12. **Monitoring Check 2** - Phase 2 of monitoring process.

There is the need of saving the information from all the teams and alerts. The MRT Template is the Excel file to use in this process.

VI.3. MRT Investigation Template

Before implementing a FMEA (Failure Mode and Effects Analysis), the following template is the one to be used.



OGMA

Reliability Investigation Report

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Ind.	Maintenance Reliability Investigation				Alert ☐	Claim ☐	
1	Item description	(1.1)				ITEM-ATA	(1.2)
2	P/N	(2.1)			Alternat. P/N	(2.2)	
3	S/N	(3)					
4	Investigation Process						
	Applicability	A	N/A	Doc. Ref.	Para.	Page	Add. Info
4.1	AMM / TM	☐	☐	(4.1.1)	(4.2.1)	(4.3.1)	(4.4.1)
4.2	CMM / TO	☐	☐	(4.1.2)	(4.2.2)	(4.3.2)	(4.4.2)
4.3	Repair reports	☐	☐	(4.1.3)	(4.2.3)	(4.3.3)	(4.4.3)
4.4	AD	☐	☐	(4.1.4)	(4.2.4)	(4.3.4)	(4.4.4)
4.5	SB	☐	☐	(4.1.5)	(4.2.5)	(4.3.5)	(4.4.5)
4.6	Others	☐	☐	(4.1.6)	(4.2.6)	(4.3.6)	(4.4.6)
5	MMA						

Installation	Removal	Operational Checkout	Troubleshoot	Inspection	Handling
☐	☐	☐	☐	☐ Vis. ☐ Det. ☐ FC	☐

5.1	Remarks	(5.1)

OGMA

Reliability Action Plan

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1. Component description			(1)										
2. A/C	3. ITEM ATA	4. P/N	5. S/N	6. Alert	7. FR 12 Mths	8. MTBUR 12 Mths	9. MTBF 12 Mths	10. B.V. 12 Mths	11. NFF	12. Cost	13. Qty per A/C	14. Affected Areas	
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	

15. Detected Anomalies	(15)		
16. Probable Root Causes	(16)		
17. Corrective Actions	18. Affected Area: (18)	19. Due Date	(19)
	(17)		
	20. Person Responsible: (20)		
21. Monitoring Plan	(21)	22. Process Status	(22)

Figure 15 – RIP and RAP Templates.

The investigation template is defined by MRT and is based on the following flow-chart:

OGMA	**RELIABILITY MANUAL**

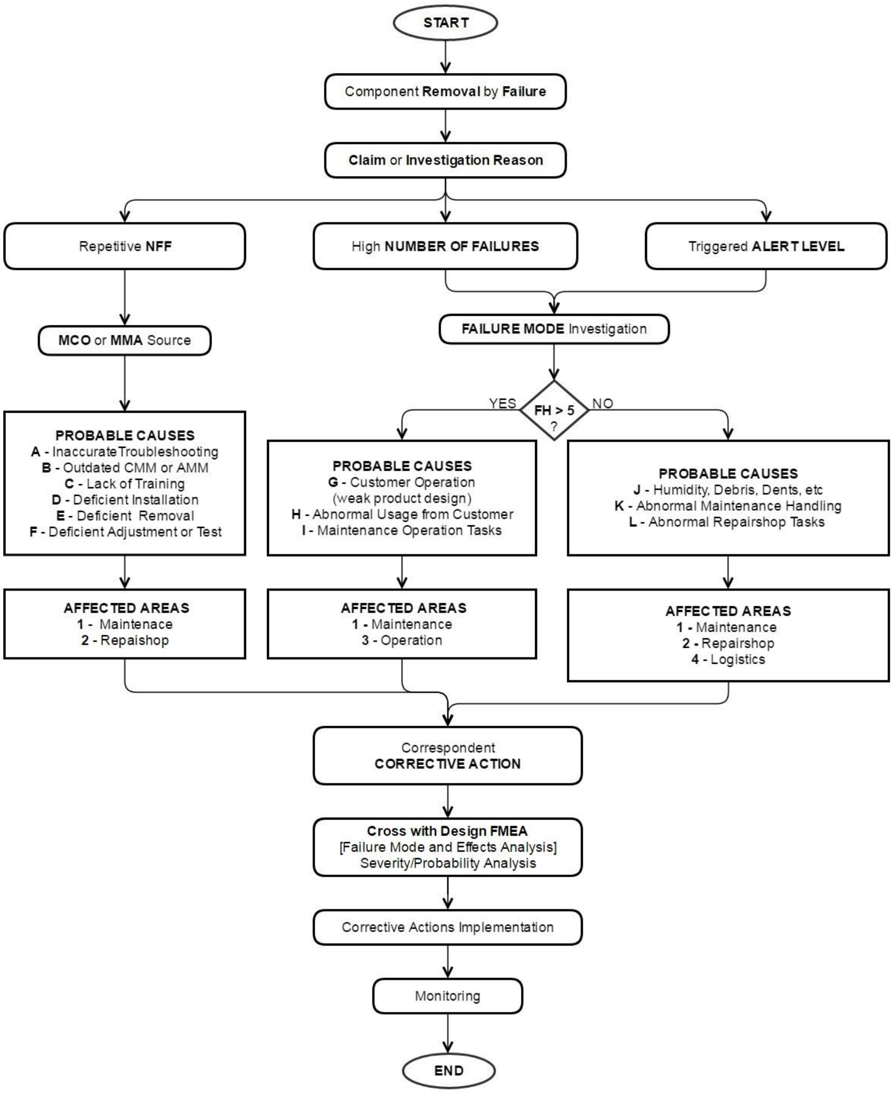

Figure 16 – Failure Mode and Affected Areas Mapping Improvements Research.

This flow-chart is a resume of the Root Cause Search for improvements proposal.

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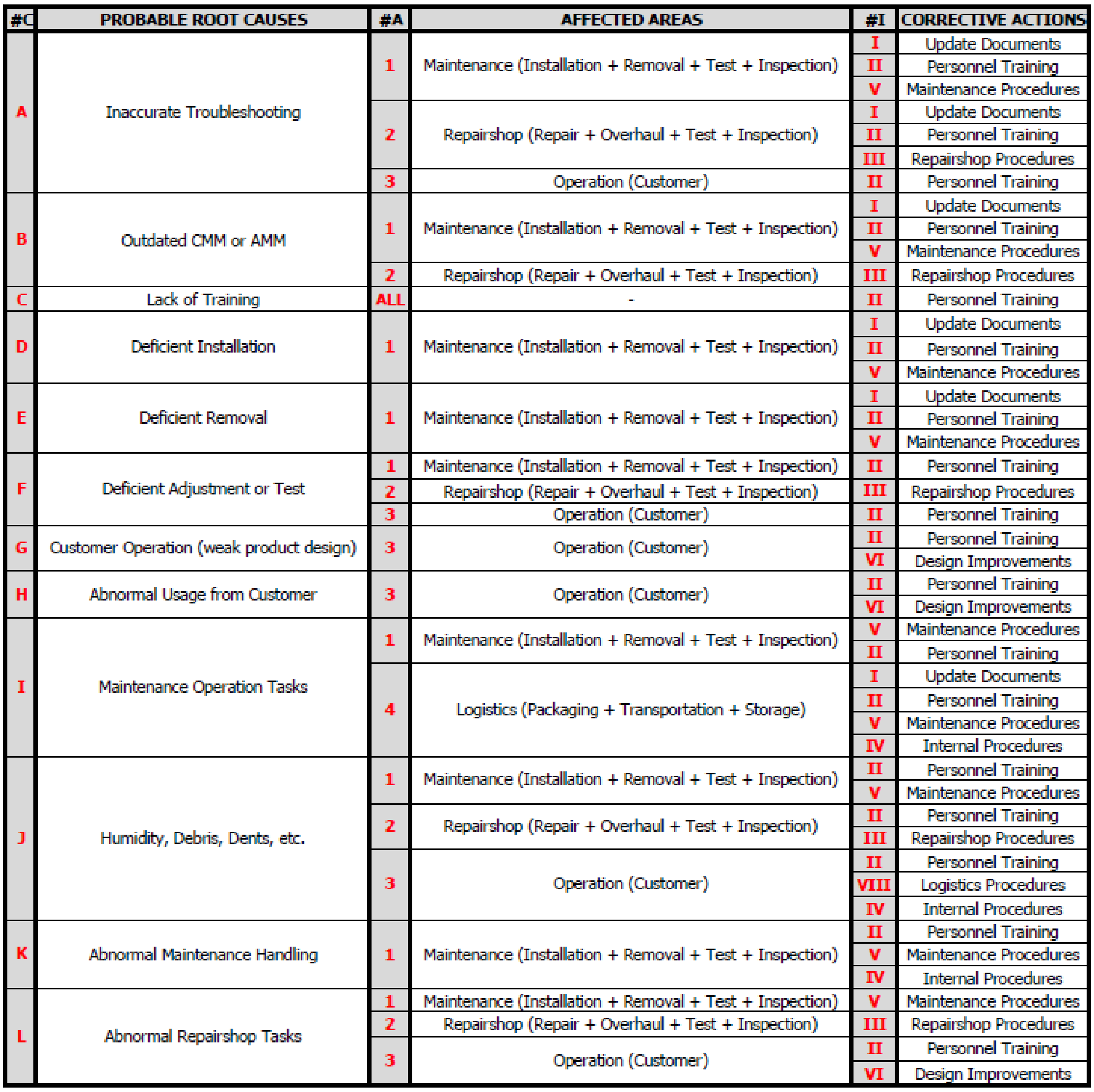
PART VII - PREVENTIVE AND CORRECTIVE ACTIONS

The corrective actions shown in chapter 8 - d. And the following table shows the connection of root causes, affected areas and the corrective actions themselves.



#C	PROBABLE ROOT CAUSES	#A	AFFECTED AREAS	#I	CORRECTIVE ACTIONS
A	Inaccurate Troubleshooting	1	Maintenance (Installation + Removal + Test + Inspection)	I	Update Documents
				II	Personnel Training
				V	Maintenance Procedures
		2	Repairshop (Repair + Overhaul + Test + Inspection)	I	Update Documents
				II	Personnel Training
				III	Repairshop Procedures
		3	Operation (Customer)	II	Personnel Training
B	Outdated CMM or AMM	1	Maintenance (Installation + Removal + Test + Inspection)	I	Update Documents
				II	Personnel Training
				V	Maintenance Procedures
		2	Repairshop (Repair + Overhaul + Test + Inspection)	III	Repairshop Procedures
C	Lack of Training	ALL	-	II	Personnel Training
D	Deficient Installation	1	Maintenance (Installation + Removal + Test + Inspection)	I	Update Documents
				II	Personnel Training
				V	Maintenance Procedures
E	Deficient Removal	1	Maintenance (Installation + Removal + Test + Inspection)	I	Update Documents
				II	Personnel Training
				V	Maintenance Procedures
F	Deficient Adjustment or Test	1	Maintenance (Installation + Removal + Test + Inspection)	II	Personnel Training
		2	Repairshop (Repair + Overhaul + Test + Inspection)	III	Repairshop Procedures
		3	Operation (Customer)	II	Personnel Training
G	Customer Operation (weak product design)	3	Operation (Customer)	II	Personnel Training
				VI	Design Improvements
H	Abnormal Usage from Customer	3	Operation (Customer)	II	Personnel Training
				VI	Design Improvements
I	Maintenance Operation Tasks	1	Maintenance (Installation + Removal + Test + Inspection)	V	Maintenance Procedures
				II	Personnel Training
		4	Logistics (Packaging + Transportation + Storage)	I	Update Documents
				II	Personnel Training
				V	Maintenance Procedures
				IV	Internal Procedures
J	Humidity, Debris, Dents, etc.	1	Maintenance (Installation + Removal + Test + Inspection)	II	Personnel Training
				V	Maintenance Procedures
		2	Repairshop (Repair + Overhaul + Test + Inspection)	II	Personnel Training
				III	Repairshop Procedures
		3	Operation (Customer)	II	Personnel Training
				VIII	Logistics Procedures
				IV	Internal Procedures
K	Abnormal Maintenance Handling	1	Maintenance (Installation + Removal + Test + Inspection)	II	Personnel Training
				V	Maintenance Procedures
				IV	Internal Procedures
L	Abnormal Repairshop Tasks	1	Maintenance (Installation + Removal + Test + Inspection)	V	Maintenance Procedures
		2	Repairshop (Repair + Overhaul + Test + Inspection)	III	Repairshop Procedures
		3	Operation (Customer)	II	Personnel Training
				VI	Design Improvements

Table 7 – Probable root causes.

VII.1. Implementation & Monitoring

Implementation of the Corrective Actions should follow the last process described in chapter 11 - c. To perform these implementations, MRT and Quality Department should work together to improve the capability and success of improving a component's reliability. These teams are also responsible for it's monitoring.

PART VIII - REPORT AND PRESENTATION LAYOUT

In this section, it shows the topics and a small description on how each topic will be discussed. If needed, there is the possibility of adding more information.

VIII.1. Report Chapters

1. Month in study;
2. Fleet Flight Hours + Cycles;
3. Availability;
    - Aircrafts in Operation + in Maintenance;
4. Removals;
    - Unscheduled Removals by month;
    - Unscheduled Removals by ATA [TOP 20];
5. Maintenance Findings;
6. Repetitive Events;
    - NFFs;
    - Failures;
7. TOP 20 MTBF;
8. Alerts Table;
    - FR_{12};
    - FR_3;
    - FR_{12} or FR_3;
    - FR_{12} and FR_3;
9. Previous Claims;
10. Investigations Performed;
11. Investigations to Perform;
12. Implemented Corrective Actions;
13. Others.

For the Report, there is a layout to be used. All information will need to be updated when being filled up.

VIII.2. Presentation Slides

The Presentation Slides to present in Maintenance Reliability Board Meeting are the same as the Report Chapters, but only tables and lists are shown.

A.2 Annex 2

OGMA	**METRIC CAILCULATION USERGUIDE**

01 - RESUME

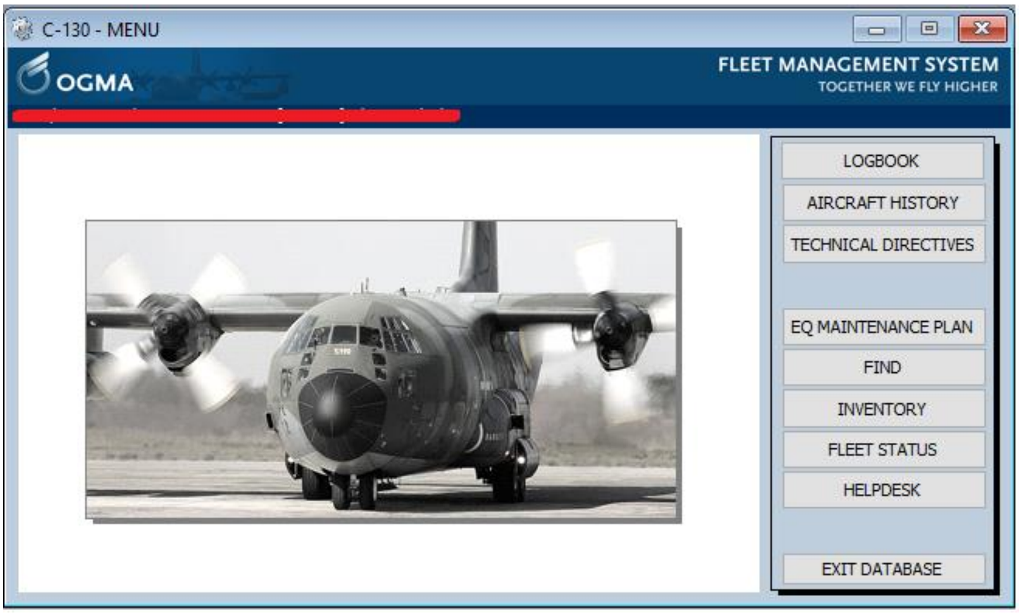
This Annex is mean to explain the detailed procedures for the Metric Calculation.

02 - PROCEDURES

1. EXPORT & UPDATE *AIRCRAFT LOGBOOK* DATA:
   - **a.** Open FMS-CMFAF application by double clicking the following icon available on your desktop { C:\Users\user.name\Desktop\ }:

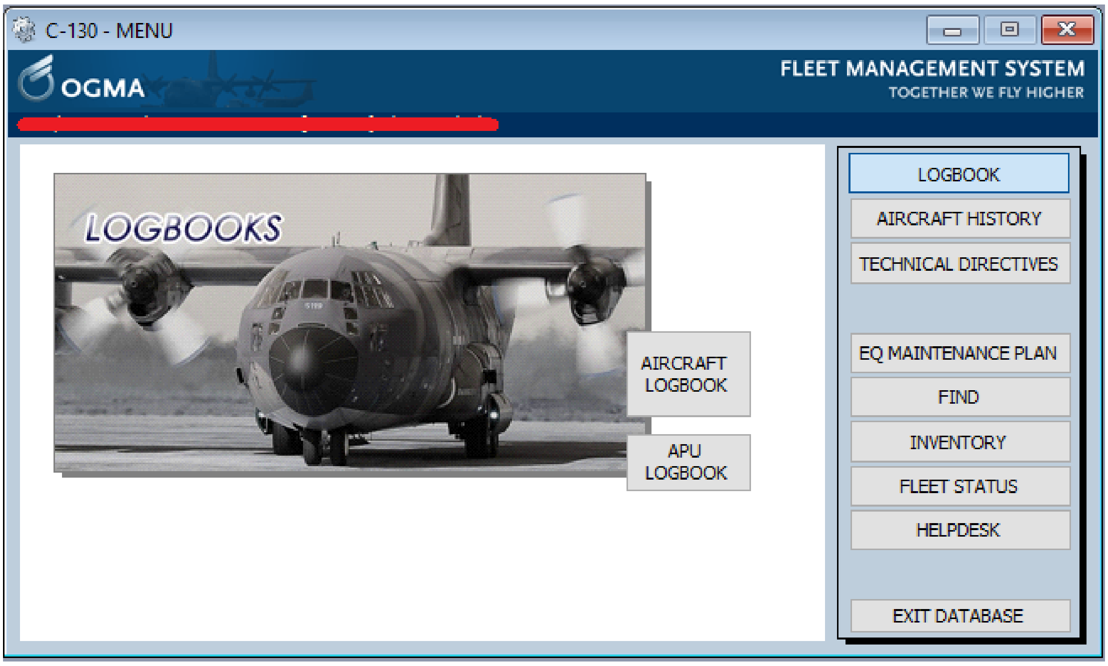
     FMS -

     The following window should appear:

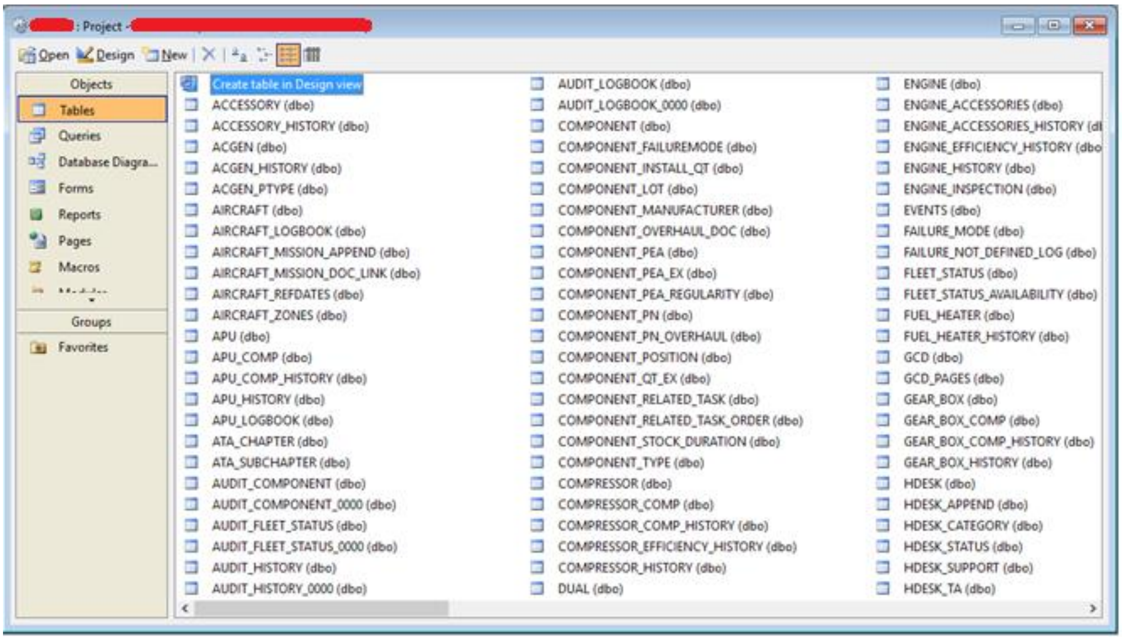


This is the Fleet Management System Application used to monitor the *** C-130 Fleet;

b. Go to Logbook by pressing ***LOGBOOK*** button;

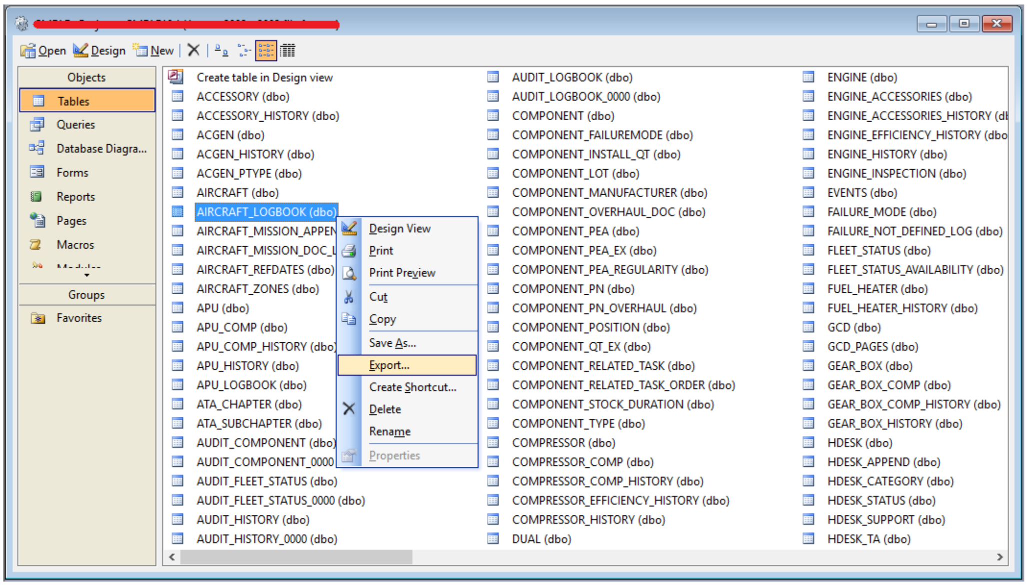


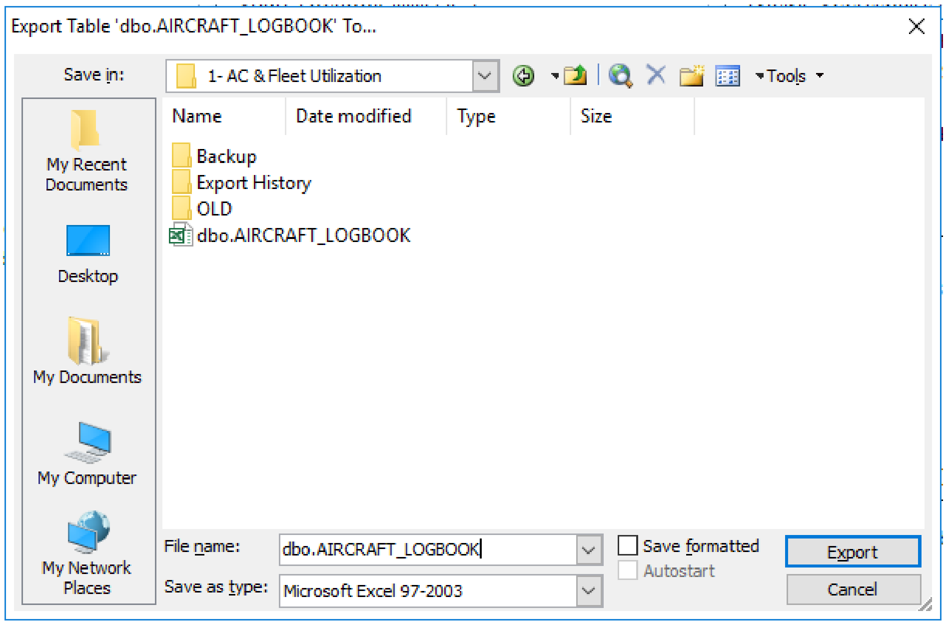
c. Press ***F11*** (keyboard) and go to Tables bookmark;



Create table in Design view
ACCESSORY (dbo)
ACCESSORY_HISTORY (dbo)
ACGEN (dbo)
ACGEN_HISTORY (dbo)
ACGEN_PTYPE (dbo)
AIRCRAFT (dbo)
AIRCRAFT_LOGBOOK (dbo)
AIRCRAFT_MISSION_APPEND (dbo)
AIRCRAFT_MISSION_DOC_LINK (dbo)
AIRCRAFT_REFDATES (dbo)
AIRCRAFT_ZONES (dbo)
APU (dbo)
APU_COMP (dbo)
APU_COMP_HISTORY (dbo)
APU_HISTORY (dbo)
APU_LOGBOOK (dbo)
ATA_CHAPTER (dbo)
ATA_SUBCHAPTER (dbo)
AUDIT_COMPONENT (dbo)
AUDIT_COMPONENT_0000 (dbo)
AUDIT_FLEET_STATUS (dbo)
AUDIT_FLEET_STATUS_0000 (dbo)
AUDIT_HISTORY (dbo)
AUDIT_HISTORY_0000 (dbo)
AUDIT_LOGBOOK (dbo)
AUDIT_LOGBOOK_0000 (dbo)
COMPONENT (dbo)
COMPONENT_FAILUREMODE (dbo)
COMPONENT_INSTALL_QT (dbo)
COMPONENT_LOT (dbo)
COMPONENT_MANUFACTURER (dbo)
COMPONENT_OVERHAUL_DOC (dbo)
COMPONENT_PEA (dbo)
COMPONENT_PEA_EX (dbo)
COMPONENT_PEA_REGULARITY (dbo)
COMPONENT_PN (dbo)
COMPONENT_PN_OVERHAUL (dbo)
COMPONENT_POSITION (dbo)
COMPONENT_QT_EX (dbo)
COMPONENT_RELATED_TASK (dbo)
COMPONENT_RELATED_TASK_ORDER (dbo)
COMPONENT_STOCK_DURATION (dbo)
COMPONENT_TYPE (dbo)
COMPRESSOR (dbo)
COMPRESSOR_COMP (dbo)
COMPRESSOR_COMP_HISTORY (dbo)
COMPRESSOR_EFFICIENCY_HISTORY (dbo)
COMPRESSOR_HISTORY (dbo)
DUAL (dbo)
ENGINE (dbo)
ENGINE_ACCESSORIES (dbo)
ENGINE_ACCESSORIES_HISTORY (d
ENGINE_EFFICIENCY_HISTORY (dbo
ENGINE_HISTORY (dbo)
ENGINE_INSPECTION (dbo)
EVENTS (dbo)
FAILURE_MODE (dbo)
FAILURE_NOT_DEFINED_LOG (dbo)
FLEET_STATUS (dbo)
FLEET_STATUS_AVAILABILITY (dbo)
FUEL_HEATER (dbo)
FUEL_HEATER_HISTORY (dbo)
GCD (dbo)
GCD_PAGES (dbo)
GEAR_BOX (dbo)
GEAR_BOX_COMP (dbo)
GEAR_BOX_COMP_HISTORY (dbo)
GEAR_BOX_HISTORY (dbo)
HDESK (dbo)
HDESK_APPEND (dbo)
HDESK_CATEGORY (dbo)
HDESK_STATUS (dbo)
HDESK_SUPPORT (dbo)
HDESK_TA (dbo)

d. Press the right mouse button and Export *AIRCRAFT_LOGBOK(dbo)* file with Microsoft Excel 97-2003 type into folder { G:\## - *********\# - ******\## - *********\1- AC & Fleet Utilization };


[redacted]


Export Table 'dbo.AIRCRAFT_LOGBOOK' To...

Save in: 1- AC & Fleet Utilization

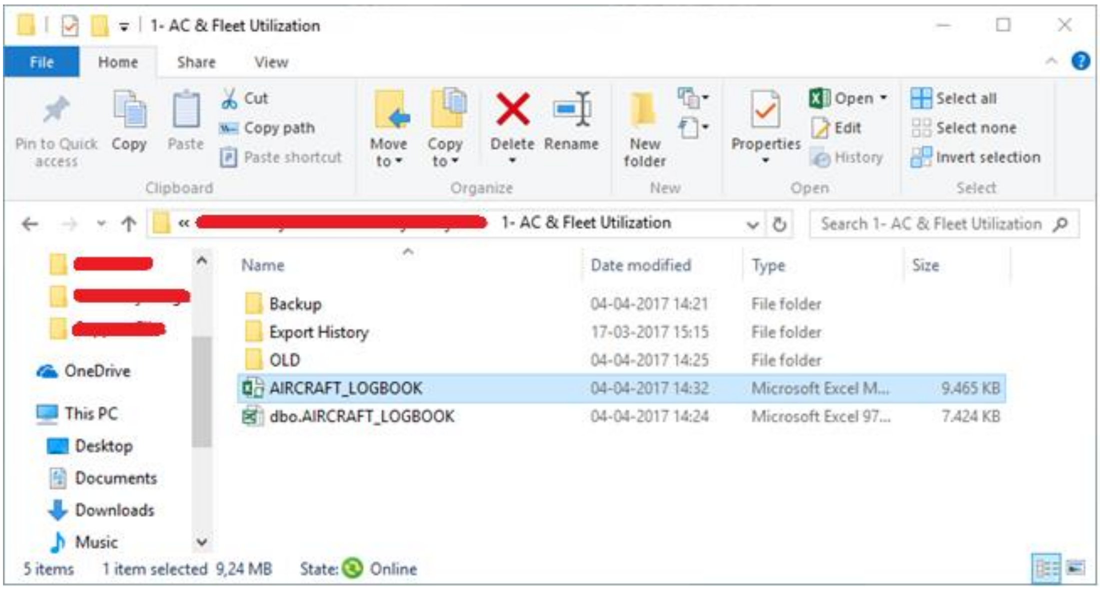
File name: dbo.AIRCRAFT_LOGBOOK

Save as type: Microsoft Excel 97-2003

☐ Save formatted

☐ Autostart

e. Open the Excel file *AIRCRAFT_LOGBOOK* that is in the same folder;



Name	Date modified	Type	Size
Backup	04-04-2017 14:21	File folder	
Export History	17-03-2017 15:15	File folder	
OLD	04-04-2017 14:25	File folder	
AIRCRAFT_LOGBOOK	04-04-2017 14:32	Microsoft Excel M...	9.465 KB
dbo.AIRCRAFT_LOGBOOK	04-04-2017 14:24	Microsoft Excel 97...	7.424 KB

f. Go to "Export" Sheet and press the hotkey ***IMPORT HOURS*** button;

IMPORT HOURS

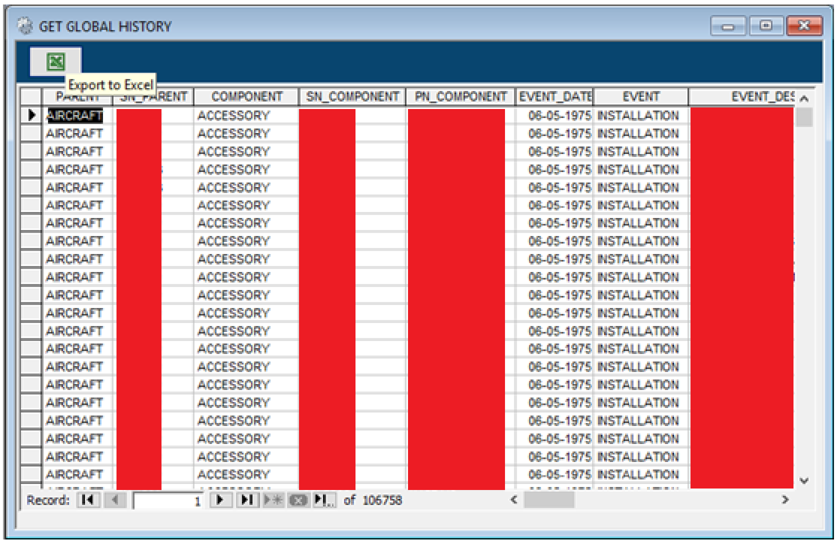
g. Check for table updates (if correctly performed) and save the file.

2. *Export & Update Global History Data*:

   a. Open FMS-CMFAF application by double clicking the following icon available on your desktop { C:\Users\user.name\Desktop\ };

   b. Press ***AIRCRAFT HISTORY*** button;

   c. Press ***(global history)*** button and click the ***Export to Excel*** button;



PARENT	SN_PARENT	COMPONENT	SN_COMPONENT	PN_COMPONENT	EVENT_DATE	EVENT	EVENT_DES
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]
AIRCRAFT	[redacted]	ACCESSORY	[redacted]	[redacted]	06-05-1975	INSTALLATION	[redacted]

Record: 1 of 106758

d. Save the file as *GH EXP* in folder { G:\ ## - *********\# - ******\## - *********\2-Export History };

e. Open *Reliability (Fails)* Excel File from { ## - *********\# - ******\## - *********\2-Global History };

f. Go to "Export" Sheet and press ***Import GH EXP*** button in cell A1;

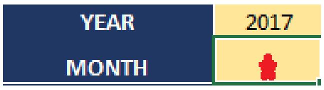
g. Check for table updates (if correctly performed);

h. Open ***AIRCRAFT_LOGBOOK*** previous file and with the Hours data values in FLEET UTILIZATION (Flight Hours) table, update the "Item-ATA Monthly" Sheet on FH TIME FORMAT table until the month in study;

i. Check if the "Item-ATA 3 Months" and "Item-ATA 12 Months" were updated (if correctly performed);

j. [OPTIONAL] Update "BV" Sheet if desired for future research/usage.

k. In "ALERT" Sheet, update to the month in study.

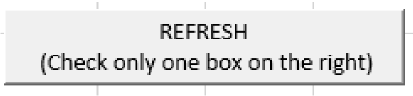


YEAR	2017
MONTH	

3. *UPDATE ALERTS TABLE*:

a. Open *Reliability (Fails)* Excel File from { ## - *********\# - ******\## - *********\2-Global History };

b. Go to "AL SUMMARY" Sheet, select the desired filter as mentioned in the Reliability Manual and press REFRESH Button.



c. Save the file.

4. Retrieve *Repetitive Failures* – last 12 months:
    a. Open *Reliability (Fails)* Excel File from { ## - **********\# - *******\## - **********\2-Global History };
    b. Go to "Item-ATA 12 Months" Sheet and check the last column in study for the highest TOP 10 number of failures;
    c. Create a table in a separate file.
    d. [NOTE] This methodology for Repetitive Failures will be improved as soon as possible.

5. Retrieve *Repetitive No Fault Found (NFF)* – last 12 months:
    a. Open *Reliability (Fails)* Excel File from { ## - **********\# - *******\## - **********\2-Global History };
    b. Go to "Failure 2" Sheet and use the NFF filter;
    c. Create a table in a spate file.
    d. [NOTE] This methodology for Repetitive NFFs will be improved as soon as possible.

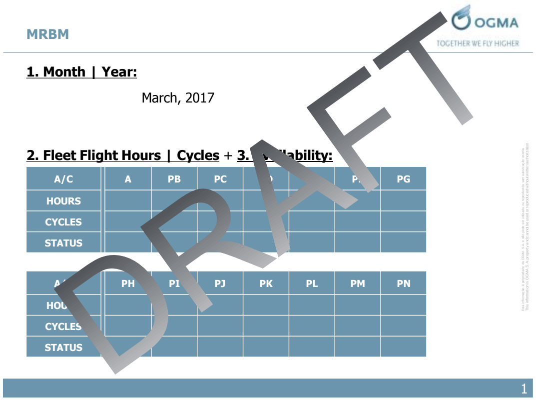
A.3 Annex 3

OGMA

Maintenance Reliability Board Meeting

C-130 XYZ Fleet

April 1st 2017



MRBM

OGMA TOGETHER WE FLY HIGHER

1. Month | Year:

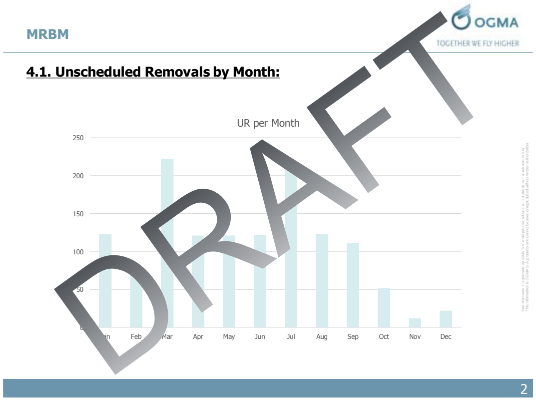
March, 2017

2. Fleet Flight Hours | Cycles + **3. [illegible]lability:**

A/C	A	PB	PC	[illegible]	[illegible]	P	PG
HOURS							
CYCLES							
STATUS							

A/	PH	PI	PJ	PK	PL	PM	PN
HOU							
CYCLES							
STATUS							

1

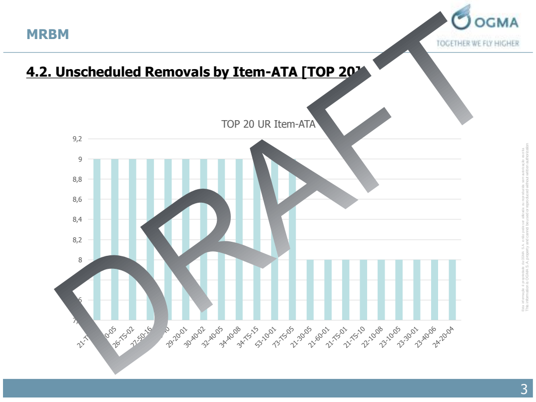


MRBM

OGMA TOGETHER WE FLY HIGHER

4.1. Unscheduled Removals by Month:

2



MRBM

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4.2. Unscheduled Removals by Item-ATA [TOP 20]

3

MRBM

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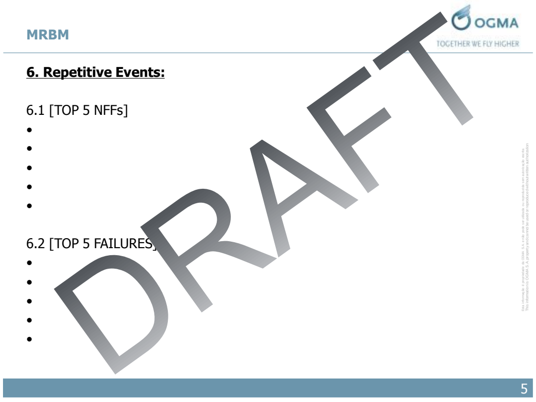
5. Maintenance Findings:

-
-
-
-
-
-
-

4



MRBM

OGMA TOGETHER WE FLY HIGHER

6. Repetitive Events:

6.1 [TOP 5 NFFs]

-
-
-
-
-

6.2 [TOP 5 FAILURES]

-
-
-
-
-

5

MRBM

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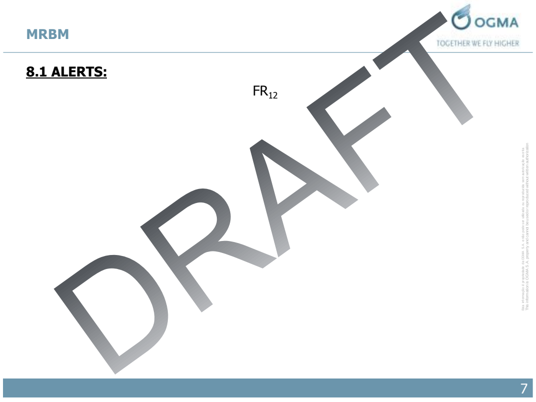
7. TOP 20 MTBF:



MRBM

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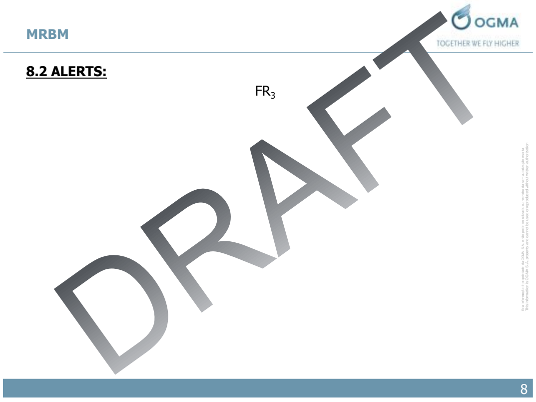
8.1 ALERTS:

FR_{12}



MRBM

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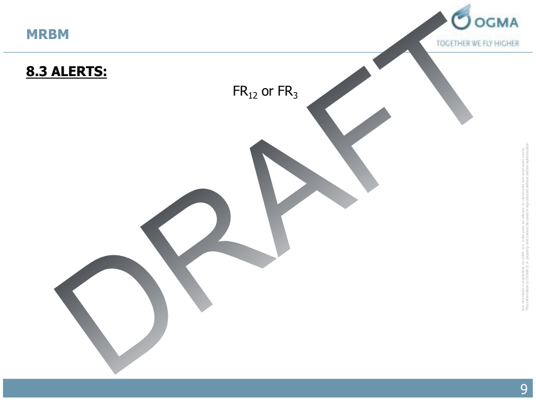
8.2 ALERTS:

FR_3



MRBM

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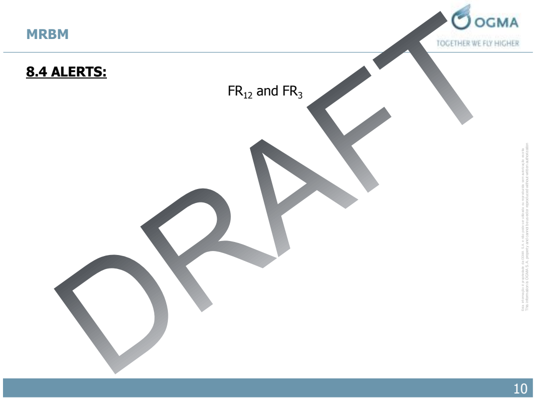
8.3 ALERTS:

FR_{12} or FR_3



MRBM

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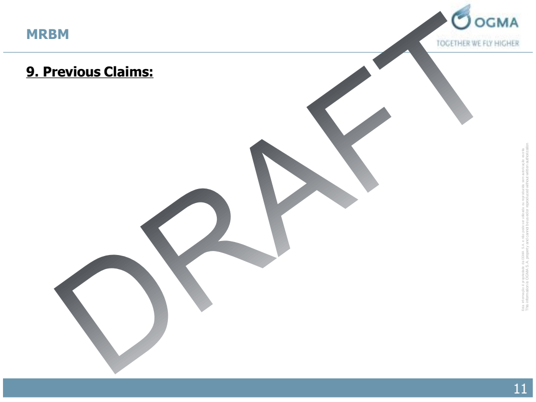
8.4 ALERTS:

FR_{12} and FR_3



MRBM

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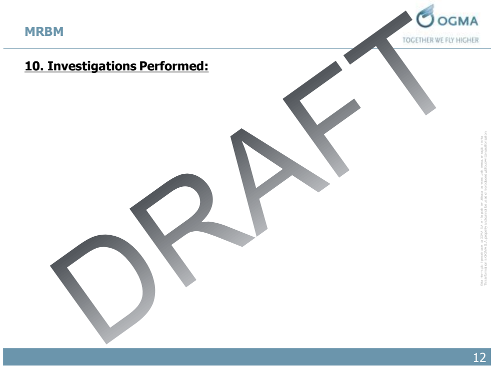
9. Previous Claims:



MRBM

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10. Investigations Performed:

MRBM

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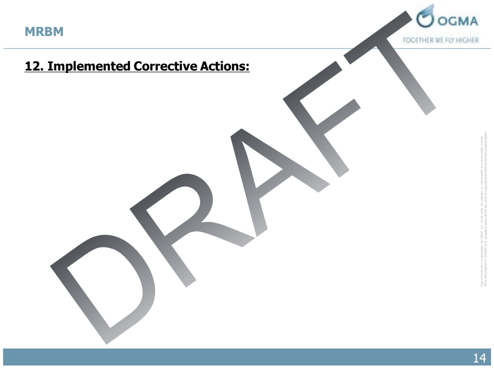
TOGETHER WE FLY HIGHER

11. Investigations to Perform:



MRBM

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12. Implemented Corrective Actions:

MRBM

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13. Others:

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A.4 Annex 4

ABNORMAL FAILURE INVESTIGATION

DESCRIPTION	P/N	S/N	ITEM-ATA
(1)	(2)	(3)	(4)

FAILURE	PROBABLE CAUSES		AFFECTED AREAS			CORRECTIVE ACTION	
DESCRIPTION (MRT 6.)	**IND.**	**DESCRIPTION**	**IND.**	**DESCRIPTION**	**AFF.**	**DESCRIPTION**	**APP.**
(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

OGMA

Reliability Investigation Report

No.: RIR-A1.60A-G*PP.AA-TT.TT-NNN*
Rev.: *0*
Page 1 of 4

TITLE: (A)

DOCUMENT: (B)

PREPARED BY:

[NAME] (C)	(E)	(F)
(D) [POSITION]	**SIGNATURE**	**DATE**

APPROVED BY:

[NAME] (G)	(I)	(J)
(H) [POSITION]	**SIGNATURE**	**DATE**

OGMA **Reliability Investigation Report**

No.: RIR-A1.60A-G*PP.AA-TT.TT-NNN*
Rev.: *0*
Page 2 of 4

RECORD OF REVISIONS:

REV.:	**DATE:**	**DESCRIPTION:**
(K)	(L)	(M)

OGMA - *XXXXXXX*

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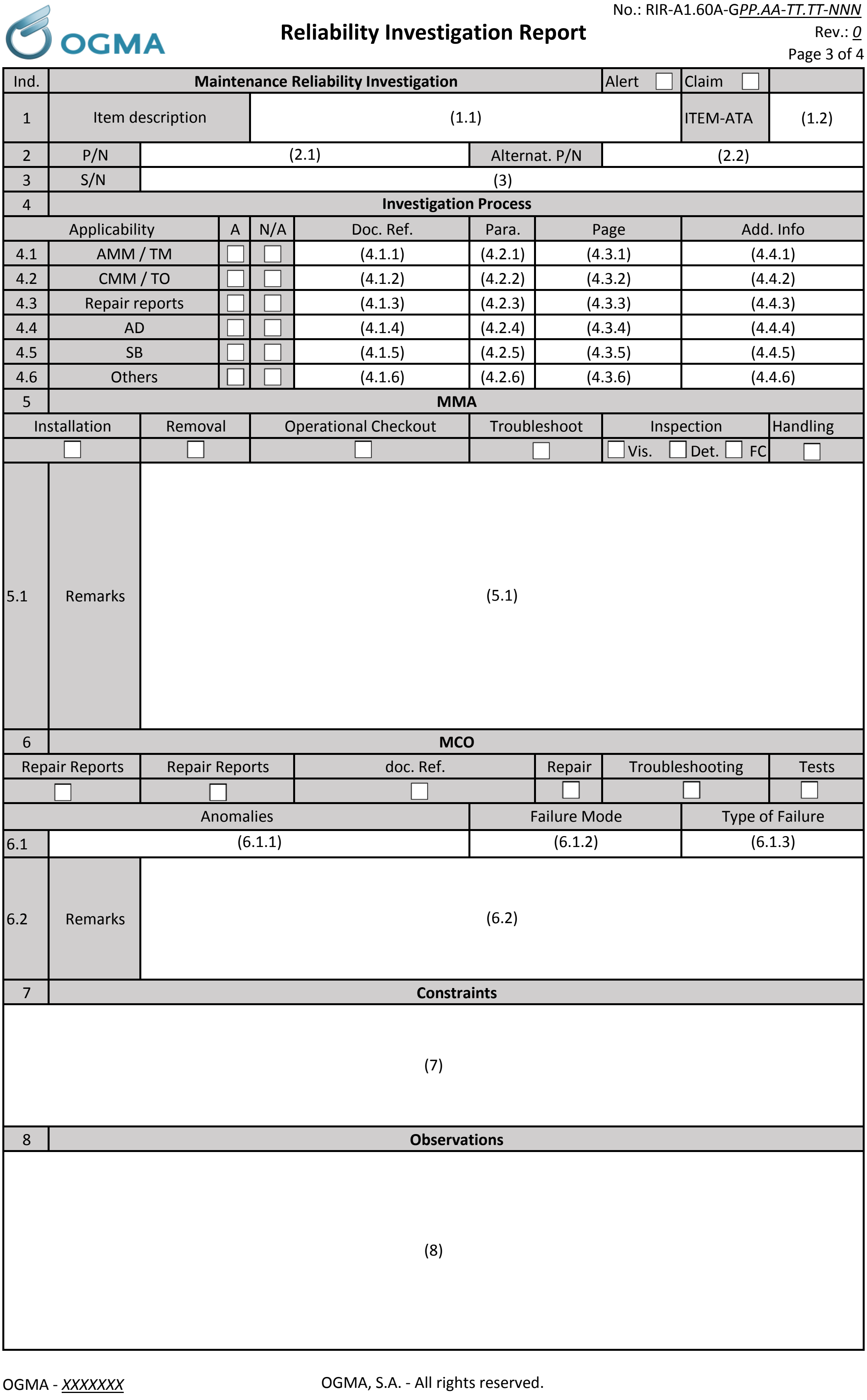


No.: RIR-A1.60A-G*PP.AA-TT.TT-NNN*
Rev.: *0*
Page 3 of 4

Reliability Investigation Report

Ind.	**Maintenance Reliability Investigation**	Alert ☐	Claim ☐	
1	Item description	(1.1)	ITEM-ATA	(1.2)
2	P/N	(2.1)	Alternat. P/N	(2.2)
3	S/N	(3)		

4	**Investigation Process**						
Applicability		A	N/A	Doc. Ref.	Para.	Page	Add. Info
4.1	AMM / TM	☐	☐	(4.1.1)	(4.2.1)	(4.3.1)	(4.4.1)
4.2	CMM / TO	☐	☐	(4.1.2)	(4.2.2)	(4.3.2)	(4.4.2)
4.3	Repair reports	☐	☐	(4.1.3)	(4.2.3)	(4.3.3)	(4.4.3)
4.4	AD	☐	☐	(4.1.4)	(4.2.4)	(4.3.4)	(4.4.4)
4.5	SB	☐	☐	(4.1.5)	(4.2.5)	(4.3.5)	(4.4.5)
4.6	Others	☐	☐	(4.1.6)	(4.2.6)	(4.3.6)	(4.4.6)

5	**MMA**				
Installation	Removal	Operational Checkout	Troubleshoot	Inspection	Handling
☐	☐	☐	☐	☐ Vis. ☐ Det. ☐ FC	☐
5.1	Remarks	(5.1)			

6	**MCO**				
Repair Reports	Repair Reports	doc. Ref.	Repair	Troubleshooting	Tests
☐	☐	☐	☐	☐	☐

Anomalies		Failure Mode	Type of Failure
6.1	(6.1.1)	(6.1.2)	(6.1.3)
6.2	Remarks	(6.2)	

7	**Constraints**
(7)	
8	**Observations**
(8)	

OGMA - *XXXXXXX*

No.: RIR-A1.60A-G*PP.AA-TT.TT-NNN*
Rev.: *0*
Page 4 of 4

Reliability Investigation Report

9	**Probable Root Causes**		
	(9)		
10	**Corrective actions**		
	(10)		
11	**Action Plan Issued (OGMA - *XXXXXXX*)**	**Yes** ☐	**No** ☐

OGMA

Reliability Action Plan

No.: RAP-A1.60A-G*PP.AA-TT.TT-NNN*
Rev.: *0*
Page 1 of 3

TITLE: (A)

DOCUMENT: (B)

PREPARED BY:

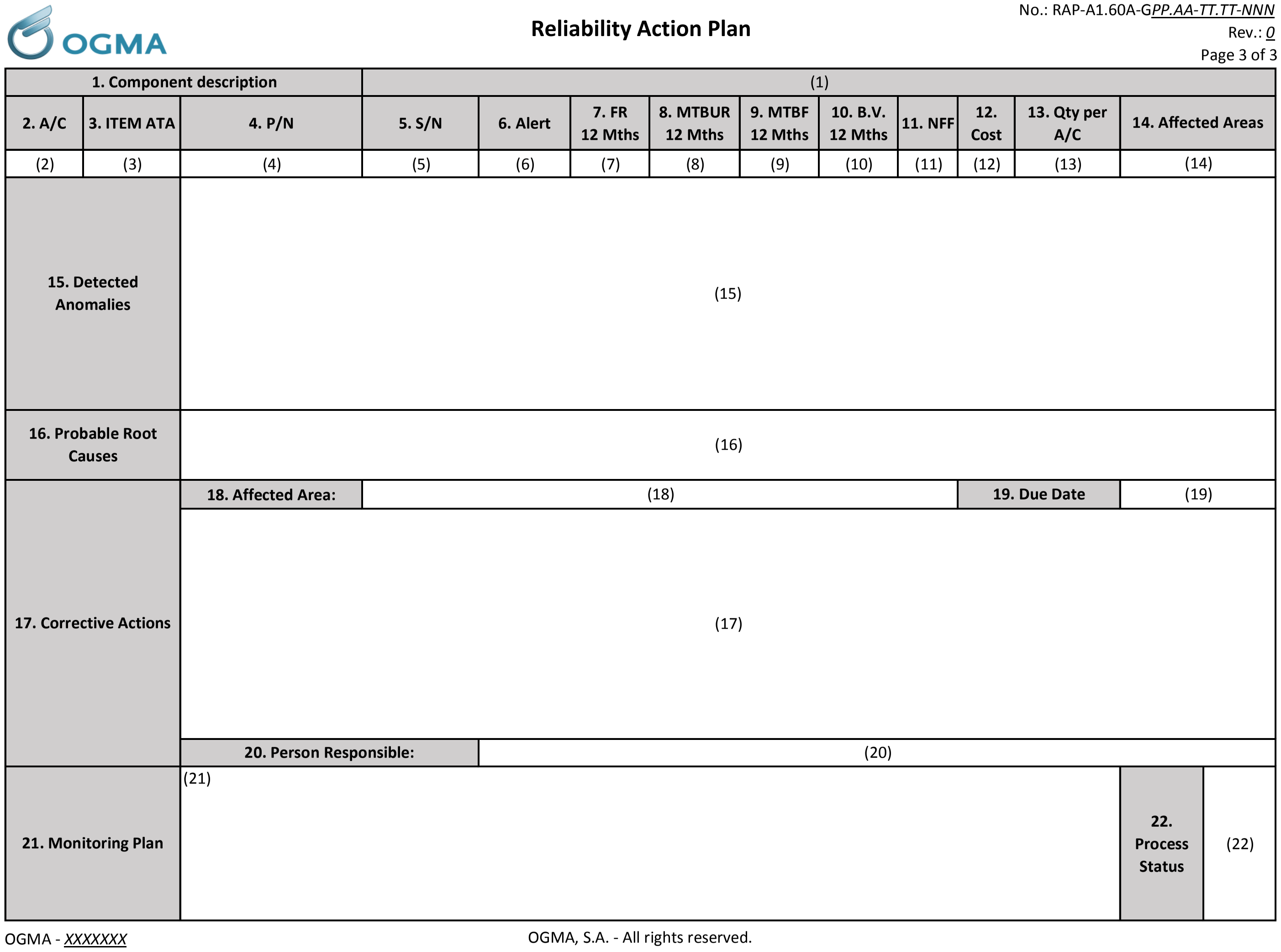
[NAME] (C)	(E)	(F)
(D) [POSITION]	**SIGNATURE**	**DATE**

APPROVED BY:

[NAME] (G)	(I)	(J)
(H) [POSITION]	**SIGNATURE**	**DATE**

RECORD OF REVISIONS:

REV.:	**DATE:**	**DESCRIPTION:**
(K)	(L)	(M)



No.: RAP-A1.60A-G*PP.AA-TT.TT-NNN*
Rev.: *0*
Page 3 of 3

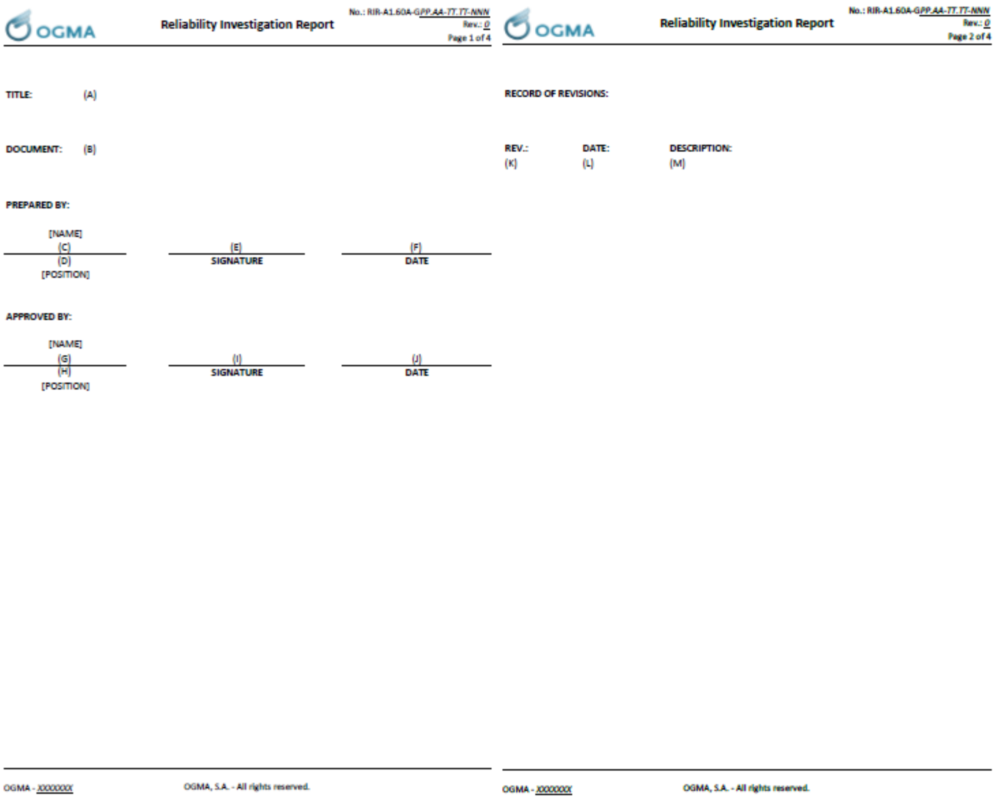
Reliability Action Plan

<table>
<tr><td colspan="3">1. Component description</td><td colspan="11">(1)</td></tr>
<tr><td>2. A/C</td><td>3. ITEM ATA</td><td>4. P/N</td><td>5. S/N</td><td>6. Alert</td><td>7. FR 12 Mths</td><td>8. MTBUR 12 Mths</td><td>9. MTBF 12 Mths</td><td>10. B.V. 12 Mths</td><td>11. NFF</td><td>12. Cost</td><td>13. Qty per A/C</td><td colspan="2">14. Affected Areas</td></tr>
<tr><td>(2)</td><td>(3)</td><td>(4)</td><td>(5)</td><td>(6)</td><td>(7)</td><td>(8)</td><td>(9)</td><td>(10)</td><td>(11)</td><td>(12)</td><td>(13)</td><td colspan="2">(14)</td></tr>
<tr><td colspan="2">15. Detected Anomalies</td><td colspan="12">(15)</td></tr>
<tr><td colspan="2">16. Probable Root Causes</td><td colspan="12">(16)</td></tr>
<tr><td colspan="2" rowspan="3">17. Corrective Actions</td><td>18. Affected Area:</td><td colspan="7">(18)</td><td colspan="2">19. Due Date</td><td colspan="2">(19)</td></tr>
<tr><td colspan="12">(17)</td></tr>
<tr><td colspan="2">20. Person Responsible:</td><td colspan="10">(20)</td></tr>
<tr><td colspan="2">21. Monitoring Plan</td><td colspan="10">(21)</td><td>22. Process Status</td><td>(22)</td></tr>
</table>

OGMA - *XXXXXXX*

1 – Reliability Investigation Report

The investigation report is filled by MRT and the following Images 1, 2 and 3 are shown to better understand each blank space to fill properly (table 1 and 2).



OGMA
Reliability Investigation Report
No.: RIR-A1.60A-GPP.AA-TT.TT-NNN
Rev.: 0
Page 1 of 4

TITLE: (A)

DOCUMENT: (B)

PREPARED BY:

[NAME]
(C)
(D)
[POSITION]

(E)
SIGNATURE

(F)
DATE

APPROVED BY:

[NAME]
(G)
(H)
[POSITION]

(I)
SIGNATURE

(J)
DATE

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Reliability Investigation Report
No.: RIR-A1.60A-GPP.AA-TT.TT-NNN
Rev.: 0
Page 2 of 4

RECORD OF REVISIONS:

REV.:	DATE:	DESCRIPTION:
(K)	(L)	(M)

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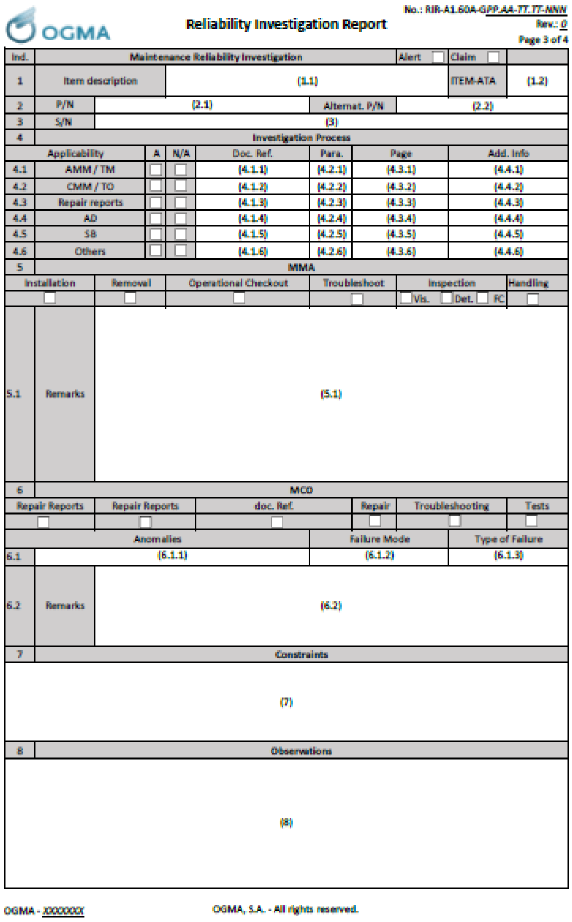
Image 1 – 1st and 2nd pages of Reliability Investigation Report, with creation, approval and revision data.



OGMA **Reliability Investigation Report**

No.: RIR-A1.60A-GPP.AA-TT.TT-NNW
Rev.: 0
Page 3 of 4

Ind.	Maintenance Reliability Investigation				Alert ☐	Claim ☐
1	Item description	(1.1)			ITEM-ATA	(1.2)
2	P/N	(2.1)		Alternat. P/N	(2.2)	
3	S/N	(3)				
4	Investigation Process					

Ind.	Applicability	A	N/A	Doc. Ref.	Para.	Page	Add. Info
4.1	AMM / TM	☐	☐	(4.1.1)	(4.2.1)	(4.3.1)	(4.4.1)
4.2	CMM / TO	☐	☐	(4.1.2)	(4.2.2)	(4.3.2)	(4.4.2)
4.3	Repair reports	☐	☐	(4.1.3)	(4.2.3)	(4.3.3)	(4.4.3)
4.4	AD	☐	☐	(4.1.4)	(4.2.4)	(4.3.4)	(4.4.4)
4.5	SB	☐	☐	(4.1.5)	(4.2.5)	(4.3.5)	(4.4.5)
4.6	Others	☐	☐	(4.1.6)	(4.2.6)	(4.3.6)	(4.4.6)

5 MMA

Installation	Removal	Operational Checkout	Troubleshoot	Inspection	Handling
☐	☐	☐	☐	☐ Vis. ☐ Det. ☐ FC	☐

5.1	Remarks	(5.1)

6 MCO

Repair Reports	Repair Reports	doc. Ref.	Repair	Troubleshooting	Tests
☐	☐	☐	☐	☐	☐

	Anomalies	Failure Mode	Type of Failure
6.1	(6.1.1)	(6.1.2)	(6.1.3)

6.2	Remarks	(6.2)

7 Constraints

(7)

8 Observations

(8)

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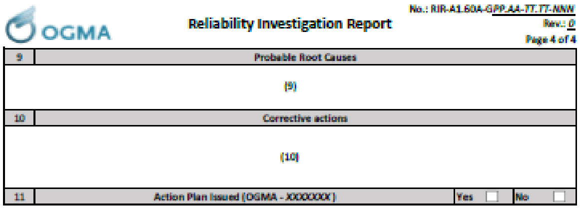
Image 2 – 3rd page of Reliability Investigation Report, with investigation data.



OGMA **Reliability Investigation Report**

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Page 4 of 4

9 Probable Root Causes

(9)

10 Corrective actions

(10)

11 Action Plan Issued (OGMA - XXXXXXX) Yes ☐ No ☐

Image 3 – 4th page of Reliability Investigation Report, with investigation data.

No.	Field	Description
A	Title	Title of the document.
B	Document	Document description.
C	Name	Content creator's Name.
D	Position	Position in OGMA.
E	Signature	Hand Signature of the (C).
F	Date	Date of document Creation.
G	Name	Approval's Name.
H	Position	Position in OGMA.
I	Signature	Hand Signature of the (G).
J	Date	Date of document Approval.
K	Revision	Number of the Revision (initial is 0, "zero").
L	Date	Date of document Approval, same as (J).
M	Description	Brief document revision description.

Table 1 – Reliability Investigation Report fields description, for pages 1 and 2.

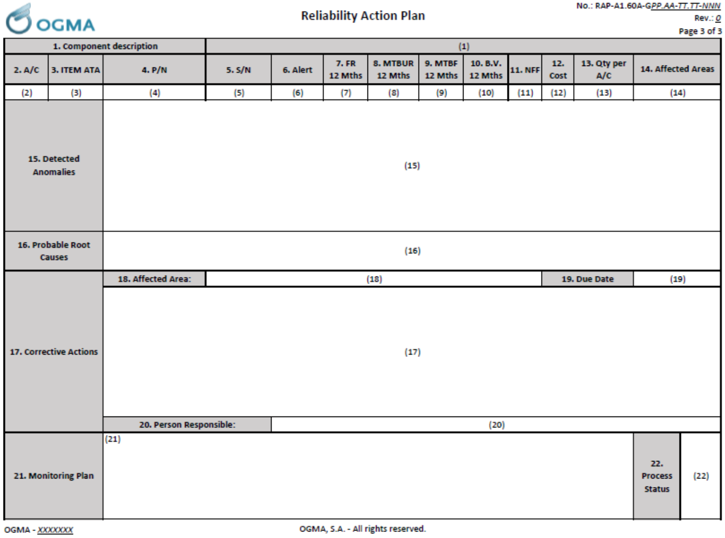
No.	Field	Description
1.1	Item Description	Item Description is filled automatically.
1.2	ITEM-ATA	ITEM-ATA in study.
2.1	P/N	P/N in study.
2.2	P/N Alternatives	Alternative P/Ns in study.
3.1	S/N	S/N for investigation (fill-up with all S/N if investigation is triggered from Alert).
4.1	Aircraft Maintenance Manual	Document Reference, Paragraph, Page and Additional information from the AMM/TM.
4.2	Component Maintenance Manual	Document Reference, Paragraph, Page and Additional information from the CMM/TO.
4.3	Repair Reports	Document Reference, Paragraph, Page and Additional information from the Repair Reports.
4.4	Airworthiness Directive	Document Reference, Paragraph, Page and Additional information from Ads.
4.5	Service Bulletin	Document Reference, Paragraph, Page and Additional information from SBs.
4.6	Other Files	Document Reference, Paragraph, Page and Additional information from further files.
5.1	Maintenance of Military Aircrafts	Failure condition description (when, where and how), equipment and maintenance manual documentation used.
6.1.1	Anomalies	Anomaly description.
6.1.2	Failure Mode	Only used when there is a failure reported in (6.1.1); probable causes for anomaly reported.
6.1.3	Type of Failure	Drop-down list IAW failure mode (6.1.2); determined by MCO.
6.2	Maintenance of Components	Failure condition description, equipment and maintenance manual documentation used (procedures and results IAM MCO).
7	Constraints	Problems or deviations found during investigation.
8	Observations	Investigation reasons; Investigation Analysis Summary; Other notes.

9	Probable Root Causes	Root Cause(s) detailed information.
10	Corrective Actions	Corrective actions to implement or/and to propose.
Check Boxes	"All file"	All check boxes shall be pinned in accordance with the investigation.

Table 2 – Reliability Investigation Report fields description, for pages 3 and 4.

2 – Action Plan Report

The Reliability Action Plan is filled by MRT and the following Image 4 is shown to better understand each blank space to fill properly (table 3).



Reliability Action Plan

No.: RAP-A1.60A-GPP.AA-TT.TT-NNN
Rev.: 0
Page 3 of 3

1. Component description			(1)										
2. A/C	3. ITEM ATA	4. P/N	5. S/N	6. Alert	7. FR 12 Mths	8. MTBUR 12 Mths	9. MTBF 12 Mths	10. B.V. 12 Mths	11. NFF	12. Cost	13. Qty per A/C	14. Affected Areas
(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)

15. Detected Anomalies	(15)			
16. Probable Root Causes	(16)			
17. Corrective Actions	18. Affected Area:	(18)	19. Due Date	(19)
	(17)			
	20. Person Responsible:	(20)		
21. Monitoring Plan	(21)		22. Process Status	(22)

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Image 4 – 3rd page of Reliability Action Plan, with a resume of investigation data.

The fill up procedure for both 1st and 2nd pages are the same as stated above in **2 – Investigation Report, Table 3**, because they are equal.

No.	Field	Description
1	Component Description	Component's description is filled automatically since it retrieves data from Investigation Report Sheet.
2	A/C	Aircraft Tail or SN_Parent.
3	ITEM-ATA	Represented as AA-BB-CC, it has the ATA chapter [AA], the section from the ATA [BB], the component type in the section ATA [CC]. It is used to group a certain amount of components by different P/N but that are alternatives between them or only replaceable.

4	P/N	Part-Number.
5	S/N	Serian Number.
6	ALERT	Alert level.
7	FR 12 Mths	Failure Rate from the last 12 months.
8	MTBUR 12 Mths	Mean Time Between Unscheduled Removal from the last 12 months.
9	MTBF 12 Mths	Mean Time Between Failure from the last 12 months.
10	BV 12 Mths	Basic Value from the last 12 months.
11	NFF	No Fault Founds
12	Cost	Cost of the item.
13	Qty per A/C	Quantity of items per a single aircraft.
14	Affected Areas	Affected Areas (MMA, MCO, Operation, Packaging, Transport or Storage).
15	Detected Anomalies	Detected anomalies from the item.
16	Probable Causes	Probable causes for the anomalies found.
17	Corrective Actions	Corrective Actions proposal.
18	Affected Areas	Affected areas on which the corrective action will take place.
19	Due Date	Final date on which the corrective action will need to be implemented.
20	Person Responsible	Person Responsible for the corrective action implementation.
21	Monitoring Plan	Follow-up procedures for the corrective action implementation.
22	Process Status	Overall process status since updates.

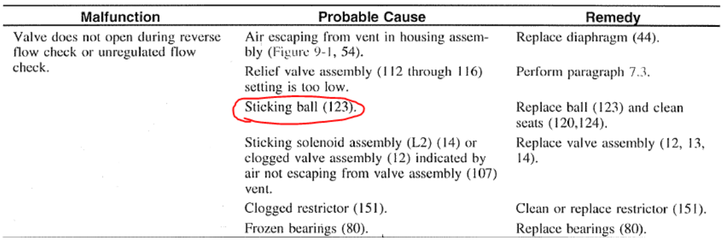
Table 3 – Reliability Action Plan fields description, for page 3.

A.5 Annex 5

#C	PROBABLE ROOT CAUSES	#A	AFFECTED AREAS	#I	CORRECTIVE ACTIONS
A	Inaccurate Troubleshooting	1	Maintenance (Installation + Removal + Test + Inspection)	I	Update Documents
				II	Personnel Training
				V	Maintenance Procedures
		2	Repair Shop (Repair + Overhaul + Test + Inspection)	I	Update Documents
				II	Personnel Training
				III	Repair Shop Procedures
		3	Operation (Customer)	II	Personnel Training
B	Outdated CMM or AMM	1	Maintenance (Installation + Removal + Test + Inspection)	I	Update Documents
				II	Personnel Training
				V	Maintenance Procedures
		2	Repair Shop (Repair + Overhaul + Test + Inspection)	III	Repair Shop Procedures
C	Lack of Training	ALL	-	II	Personnel Training
D	Deficient Installation	1	Maintenance (Installation + Removal + Test + Inspection)	I	Update Documents
				II	Personnel Training
				V	Maintenance Procedures
E	Deficient Removal	1	Maintenance (Installation + Removal + Test + Inspection)	I	Update Documents
				II	Personnel Training
				V	Maintenance Procedures
F	Deficient Adjustment or Test	1	Maintenance (Installation + Removal + Test + Inspection)	II	Personnel Training
		2	Repair Shop (Repair + Overhaul + Test + Inspection)	III	Repair Shop Procedures
		3	Operation (Customer)	II	Personnel Training
G	Customer Operation (weak product design)	3	Operation (Customer)	II	Personnel Training
				VI	Design Improvements
H	Abnormal Usage from Customer	3	Operation (Customer)	II	Personnel Training
				VI	Design Improvements
I	Maintenance Operation Tasks	1	Maintenance (Installation + Removal + Test + Inspection)	V	Maintenance Procedures
				II	Personnel Training
		4	Logistics (Packaging + Transportation + Storage)	I	Update Documents
				II	Personnel Training
				V	Maintenance Procedures
				IV	Internal Procedures
J	Humidity, Debris, Dents, etc.	1	Maintenance (Installation + Removal + Test + Inspection)	II	Personnel Training
				V	Maintenance Procedures
		2	Repair Shop (Repair + Overhaul + Test + Inspection)	II	Personnel Training
				III	Repair Shop Procedures
		3	Operation (Customer)	II	Personnel Training
				VIII	Logistics Procedures
				IV	Internal Procedures
K	Abnormal Maintenance Handling	1	Maintenance (Installation + Removal + Test + Inspection)	II	Personnel Training
				V	Maintenance Procedures
				IV	Internal Procedures
L	Abnormal Repair Shop Tasks	1	Maintenance (Installation + Removal + Test + Inspection)	V	Maintenance Procedures
		2	Repair Shop (Repair + Overhaul + Test + Inspection)	III	Repair Shop Procedures
		3	Operation (Customer)	II	Personnel Training
				VI	Design Improvements

A.6 Annex 6

WARRANTY CLAIM SUPPORT COMPONENT ANALYSIS BY P/N

Description	BLEED AIR REGULATOR AND SHUT-OFF VALVE (MANIFOLD)						
Aircraft/Fleet	**ITEM-ATA**	**P/N**		**S/N**	**TSI**	**TSO**	**OT**
Fleet	36-YY-ZZ	*****		***	0	0	0
1st Repair	**1st Claim**	**2nd Claim**	**NFF**	**Cost**	**Qty (AC)**	**Qty (fleet)**	**Afected Areas**
March 2015	07-10-2015	25-03-2016	2	Warranty	4	N/A	N/A
Detected Anomalies	**BLEED AIR VALVE FAILS TO OPEN**						
Component Repair History	**1. Bleed Air Valve P/N *****, S/N *** was sent to repair for the first time on Marh 2015. Corrective Action:** Overhauled performed on 26th of June 2015 IAW CMM ***** **2. Bleed Air Valve Received at OGMA facilities and Installed IAW TM *****. Operational checkout performed IAW TM ***** paragraph *****, valve did not pass condition on paragraph *****(#), (Valve should be open after Engine Bleed Air switch placed to the OVRD position) .Warranty Claim Issued on 07-10-2015.** **Corrective Action:** Repair report does not show any findings. Valve passed all tests performed. **3. Bleed Air Valve Received at OGMA facilities and Installed IAW TM *****. Operational checkout performed IAW TM ***** paragraph ****, valve did not pass again condition on paragraph ***** (#). Valve returned under Warranty Claim on 25-03-2016.** **Corrective Action:** Repair Services Claims that unit appears to have been tampered as solenoid position was incorrect. Solenoid was properly positioned on valve and adjusted. Unit was then pre-tested and passed all aspects of functional testing. No fault found outside of Tampered/altered solenoid. Military Release Certificate issued on 26-04-2016. **4. Bleed Air Valve Received at OGMA facilities and Installed IAW TM *****. Operational checkout performed IAW TM ***** paragraph *****, valve did not pass again condition on paragraph ***** (#). This is the 3rd time the valve is returned under warranty claim due to the same failure.**						
Investigation Process	Taking into account the number of times the valve was sent to repair and has been returned claiming no fault found, OGMA has decided to test the valve in question in two different aircraft IAW TM *****. Bleed Air Valve S/N ***** continues to fail condition on paragraph ***** (#) on both aircraft. Valve was then removed IAW TM ***** and tested IAW T.O. *****. **Findings:** **1st Test:** Valve did not pass reverse flow check IAW T.O. ***** paragraph #, corresponding to Engine Bleed Air switch placed to the OVRD position on Aircraft. **2nd Test:** Valve passed flow check (with regulating valve arrow set in the same direction as the induced flow), corresponding to Engine Bleed Air switch placed to the ON position on Aircraft.						
Report	Taking into account the results of both tests and IAW the troubleshooting process stated in T.O. *****, Table #, page #, the probable cause regarding the malfunction reported in Table #., "Valve does not open during reverse flow check or unregulated flow check", is "Sticking ball (123)".						
Observations							

Malfunction	Probable Cause	Remedy
Valve does not open during reverse flow check or unregulated flow check.	Air escaping from vent in housing assembly (Figure 9-1, 54).	Replace diaphragm (44).
	Relief valve assembly (112 through 116) setting is too low.	Perform paragraph 7.3.
	Sticking ball (123).	Replace ball (123) and clean seats (120,124).
	Sticking solenoid assembly (L2) (14) or clogged valve assembly (12) indicated by air not escaping from valve assembly (107) vent.	Replace valve assembly (12, 13, 14).
	Clogged restrictor (151).	Clean or replace restrictor (151).
	Frozen bearings (80).	Replace bearings (80).

A.7 Annex 7

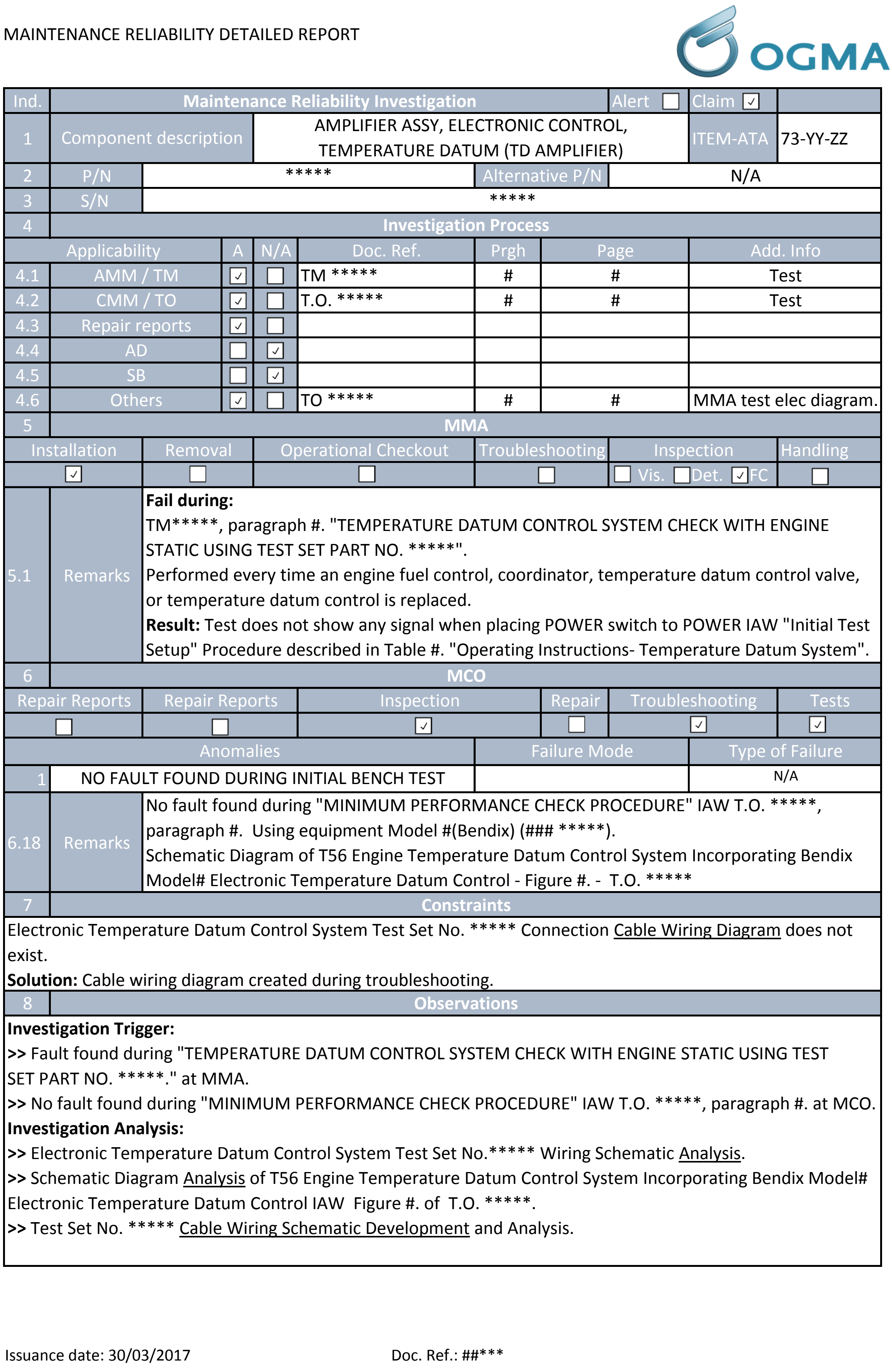
<table>
<tr><th colspan="3">Component description</th><th colspan="10">AMPLIFIER ASSY, ELECTRONIC CONTROL, TEMPERATURE DATUM (TD AMPLIFIER)</th></tr>
<tr><th>Aircraft</th><th>ITEM-ATA Chapter</th><th>P/N</th><th>S/N</th><th>Alert</th><th>FR 12 Mths</th><th>MTBUR 12 Mths</th><th>MTBF 12 Mths</th><th>B.V. 12 Mths</th><th>NFF</th><th>Cost</th><th>Qty AC</th><th>Affected Areas</th></tr>
<tr><td>N/A</td><td>73-YY-ZZ</td><td>*****</td><td>R-6944</td><td>Claim</td><td>0.86</td><td>N/A</td><td>1164</td><td>5201.23</td><td>N/A</td><td>N/A</td><td>4</td><td>MCO</td></tr>
<tr><td colspan="2">Detected anomalies</td><td colspan="11">>> Fault found during "TEMPERATURE DATUM CONTROL SYSTEM CHECK WITH ENGINE STATIC USING TEST SET PART NO. ******." at MMA.
>> No fault found during "MINIMUM PERFORMANCE CHECK PROCEDURE" IAW T.O. *****, paragraph #. at MCO.

Troubleshooting:
<u>Theory:</u>
Pin G - B: Signal
Pin G - E: Signal
Pin G - D: Signal
<u>Reality:</u>
Pin G - B: Signal
Pin G - E: Signal
Pin G - D: <u>No Signal</u></td></tr>
<tr><td colspan="2">Probable Root causes</td><td colspan="11">Electric junction connecting Pin D of J3 to Pin 5 of T3 should be damaged.</td></tr>
<tr><td colspan="2" rowspan="2">Corrective Actions</td><td colspan="9">Repair/Overhaul/Inspection</td><td colspan="2">Doc Ref.</td></tr>
<tr><td colspan="11">Temporary Corrective Action:
>> Create and place a warning sheet next to the equipment test at MCO in order to remind users to check electric junction referred in Ind. 9 of this form.
>> Test Equipment: Multimeter Simpson Model #
>> Procedure: Use the multimeter to measure the resistances between Pin G and D of J3, multimeter must show a value different than zero in order to confirm the good condition of the electric junction.

Permanent Corrective Action:
>> Proposals: Adapt the test equipment used for testing the component at MCO in order to include the electric junction test referred in Ind.9.
>> Test equipment: Model #(Bendix) (## *******).</td></tr>
<tr><td colspan="2">Monitoring Plan</td><td colspan="9">In 20 days, 17th of April, check the compliance status of temporary corrective actions.</td><td>Process Status</td><td>OPEN</td></tr>
</table>

Issuance Date: 30/03/2017

Doc. Ref.: ###***



MAINTENANCE RELIABILITY DETAILED REPORT

OGMA

Ind.	Maintenance Reliability Investigation	Alert ☐	Claim ☑	
1	Component description	AMPLIFIER ASSY, ELECTRONIC CONTROL, TEMPERATURE DATUM (TD AMPLIFIER)	ITEM-ATA	73-YY-ZZ
2	P/N	*****	Alternative P/N	N/A
3	S/N	*****		
4	Investigation Process			

	Applicability	A	N/A	Doc. Ref.	Prgh	Page	Add. Info
4.1	AMM / TM	☑	☐	TM *****	#	#	Test
4.2	CMM / TO	☑	☐	T.O. *****	#	#	Test
4.3	Repair reports	☑	☐				
4.4	AD	☐	☑				
4.5	SB	☐	☑				
4.6	Others	☑	☐	TO *****	#	#	MMA test elec diagram.

5	MMA				
Installation	Removal	Operational Checkout	Troubleshooting	Inspection	Handling
☑	☐	☐	☐	☐ Vis. ☐ Det. ☑ FC	☐

5.1 Remarks

Fail during:
TM*****, paragraph #. "TEMPERATURE DATUM CONTROL SYSTEM CHECK WITH ENGINE STATIC USING TEST SET PART NO. *****".
Performed every time an engine fuel control, coordinator, temperature datum control valve, or temperature datum control is replaced.
Result: Test does not show any signal when placing POWER switch to POWER IAW "Initial Test Setup" Procedure described in Table #. "Operating Instructions- Temperature Datum System".

6	MCO				
Repair Reports	Repair Reports	Inspection	Repair	Troubleshooting	Tests
☐	☐	☑	☐	☑	☑

	Anomalies	Failure Mode	Type of Failure
1	NO FAULT FOUND DURING INITIAL BENCH TEST		N/A

6.18 Remarks

No fault found during "MINIMUM PERFORMANCE CHECK PROCEDURE" IAW T.O. *****, paragraph #. Using equipment Model #(Bendix) (### *****).
Schematic Diagram of T56 Engine Temperature Datum Control System Incorporating Bendix Model# Electronic Temperature Datum Control - Figure #. - T.O. *****

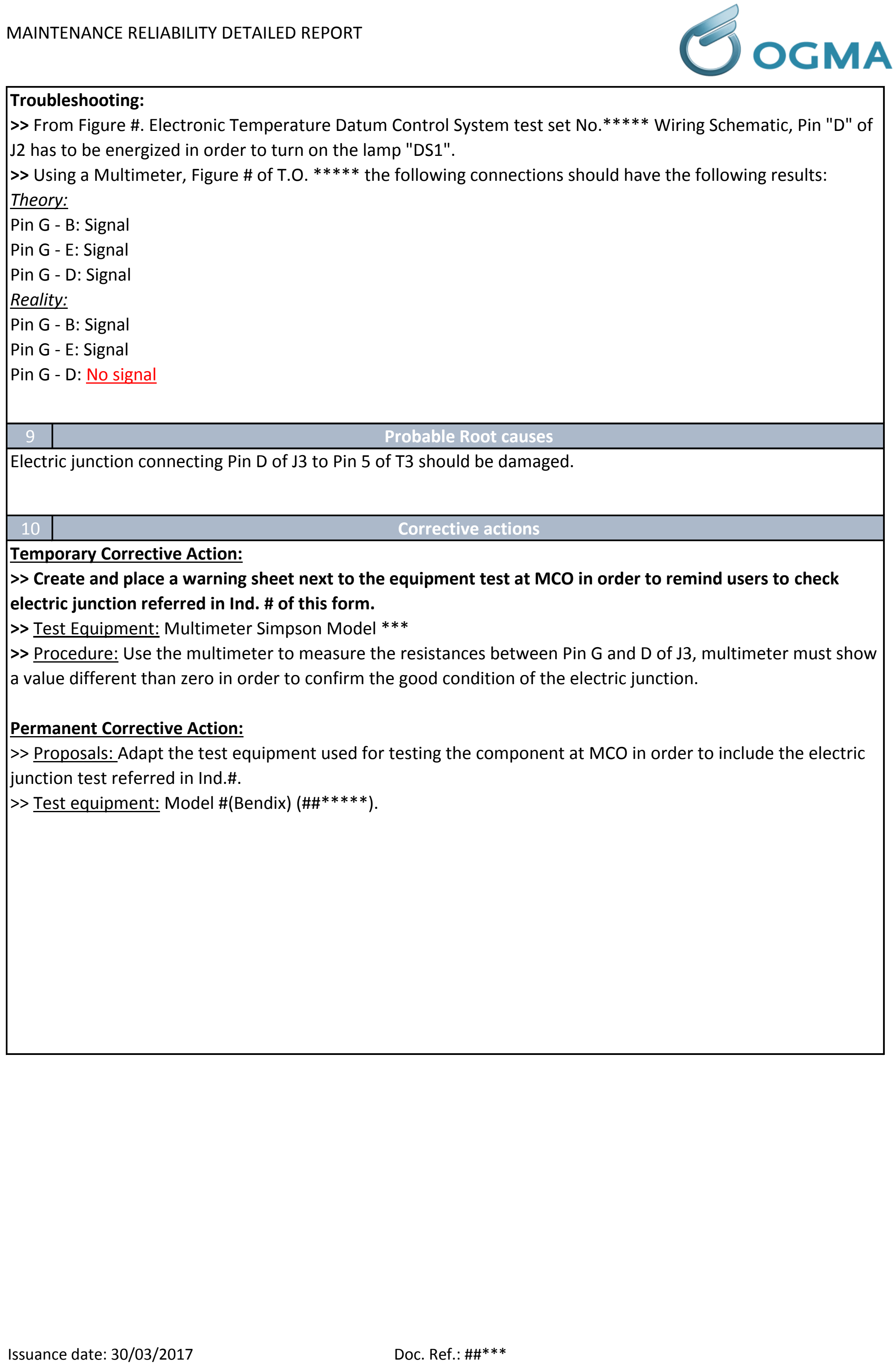
7 Constraints

Electronic Temperature Datum Control System Test Set No. ***** Connection Cable Wiring Diagram does not exist.
Solution: Cable wiring diagram created during troubleshooting.

8 Observations

Investigation Trigger:
>> Fault found during "TEMPERATURE DATUM CONTROL SYSTEM CHECK WITH ENGINE STATIC USING TEST SET PART NO. *****." at MMA.
>> No fault found during "MINIMUM PERFORMANCE CHECK PROCEDURE" IAW T.O. *****, paragraph #. at MCO.
Investigation Analysis:
>> Electronic Temperature Datum Control System Test Set No.***** Wiring Schematic Analysis.
>> Schematic Diagram Analysis of T56 Engine Temperature Datum Control System Incorporating Bendix Model# Electronic Temperature Datum Control IAW Figure #. of T.O. *****.
>> Test Set No. ***** Cable Wiring Schematic Development and Analysis.

Issuance date: 30/03/2017 Doc. Ref.: ##***



MAINTENANCE RELIABILITY DETAILED REPORT

Troubleshooting:

>> From Figure #. Electronic Temperature Datum Control System test set No.***** Wiring Schematic, Pin "D" of J2 has to be energized in order to turn on the lamp "DS1".

>> Using a Multimeter, Figure # of T.O. ***** the following connections should have the following results:

Theory:

Pin G - B: Signal
Pin G - E: Signal
Pin G - D: Signal

Reality:

Pin G - B: Signal
Pin G - E: Signal
Pin G - D: No signal

9	**Probable Root causes**

Electric junction connecting Pin D of J3 to Pin 5 of T3 should be damaged.

10	**Corrective actions**

Temporary Corrective Action:

>> Create and place a warning sheet next to the equipment test at MCO in order to remind users to check electric junction referred in Ind. # of this form.

>> Test Equipment: Multimeter Simpson Model ***

>> Procedure: Use the multimeter to measure the resistances between Pin G and D of J3, multimeter must show a value different than zero in order to confirm the good condition of the electric junction.

Permanent Corrective Action:

>> Proposals: Adapt the test equipment used for testing the component at MCO in order to include the electric junction test referred in Ind.#.

>> Test equipment: Model #(Bendix) (##*****).

Issuance date: 30/03/2017 Doc. Ref.: ##***

ABNORMAL FAILURE INVESTIGATION

DESCRIPTION	P/N	S/N	ITEM-ATA
AMPLIFIER ASSY, ELECTRONIC CONTROL, TEMPERATURE DATUM (TD AMPLIFIER)	****	***	73-YY-ZZ

FAILURE	PROBABLE CAUSES		AFFECTED AREAS			CORRECTIVE ACTION	
DESCRIPTION (MRT 6.)	IND.	DESCRIPTION	IND.	DESCRIPTION	AFF.	DESCRIPTION	APP.
Electric junction connecting Pin D of J3 to Pin 5 of T3 should be damaged.	F.	Deficient Adjustment or Test	4	Repair/Overhaul/Inspection	YES	M.I PROC. IMP.	YES

Linked to Doc. Ref.: MRT***

T.O. [redacted]

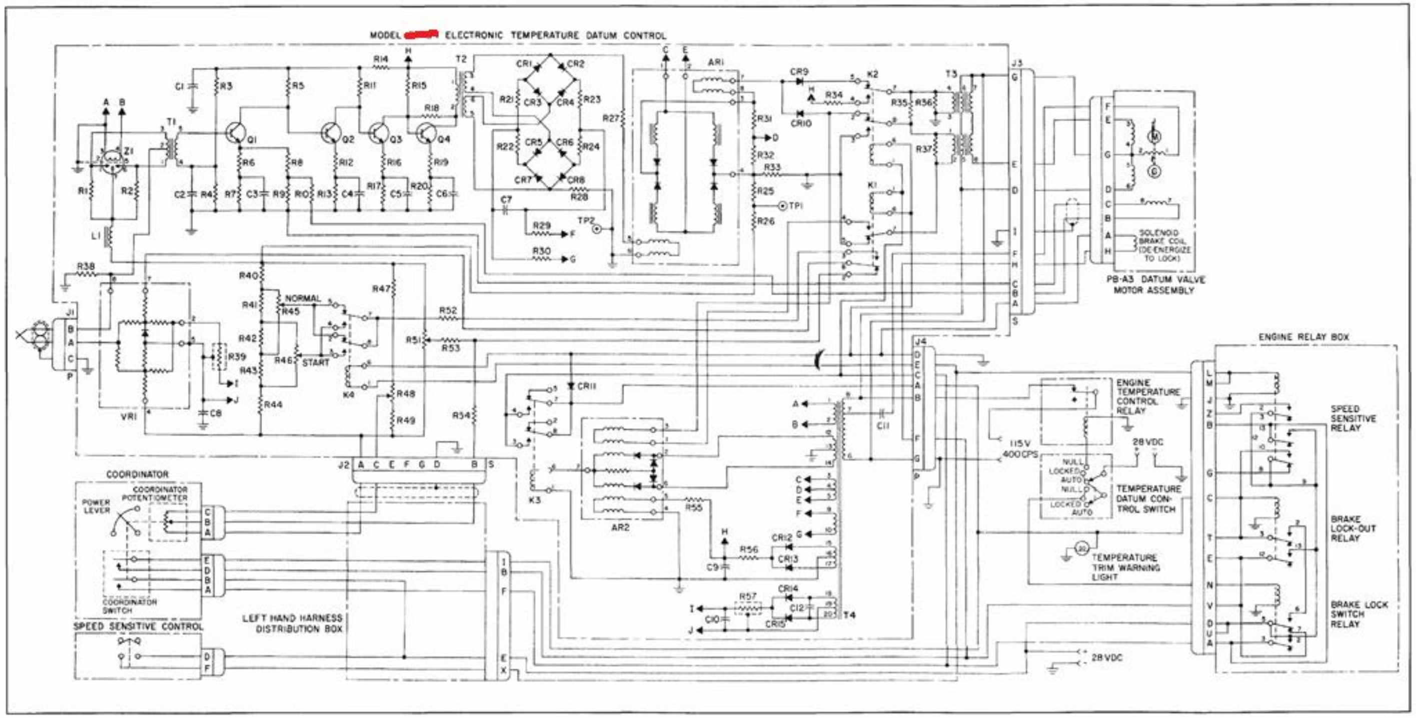
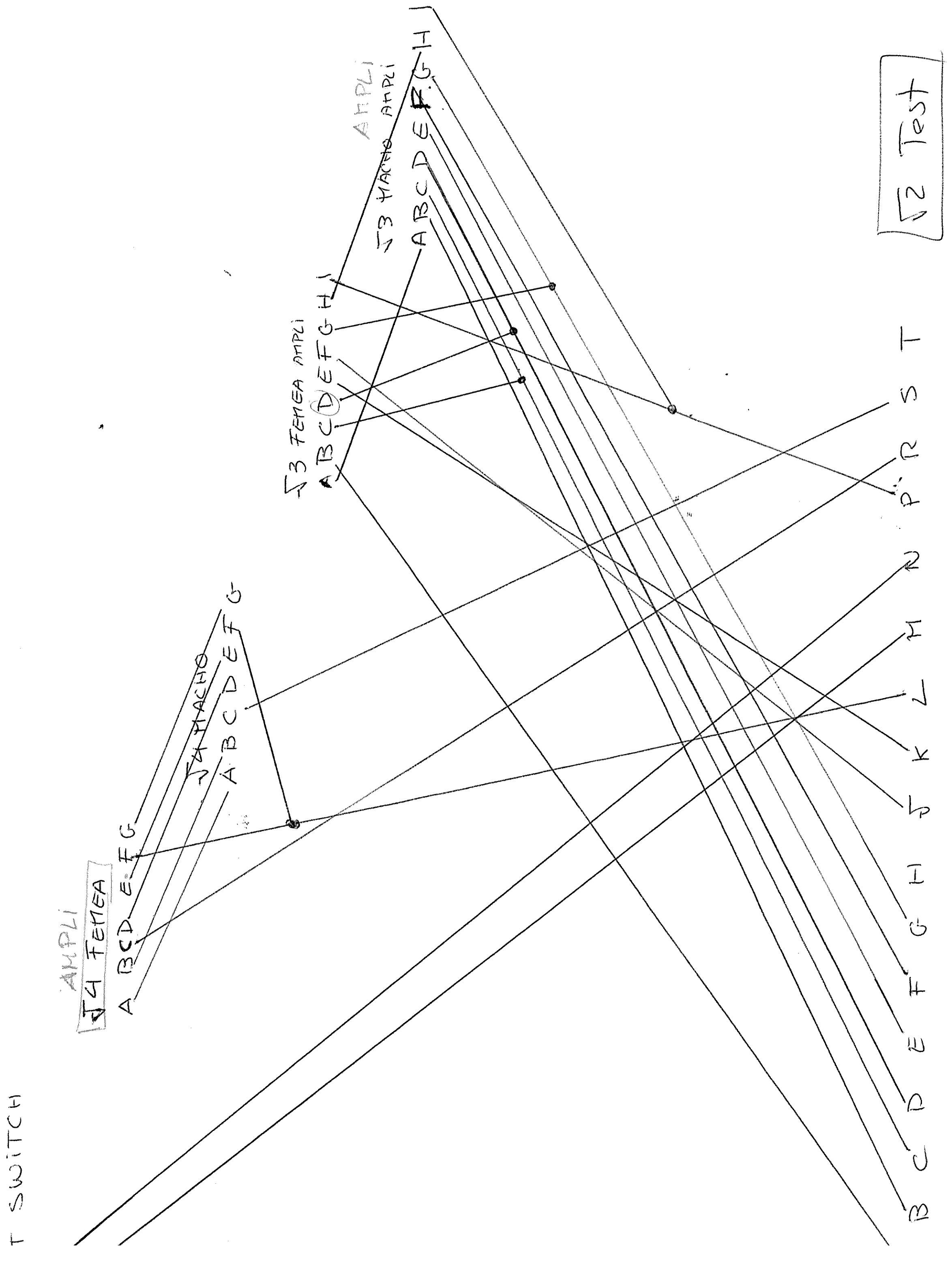


Figure 1-3. Schematic Diagram of T56 Engine Temperature Datum Control System Incorporating Bendix Model [redacted] Electronic Temperature Datum Control, Part No. [redacted] (Sheet 1 of 2)

1-3/(1-4 blank)


T SWITCH
AMPLI
J4 FEMEA
A B C D E F G
J4 MACHO
A B C D E F G
J3 FEMEA AMPLI
A B C D E F G H
AMPLI
J3 MACHO AMPLI
A B C D E F G H
J2 Test
B C D E F G H J K L M N P R S T

TO [redacted]

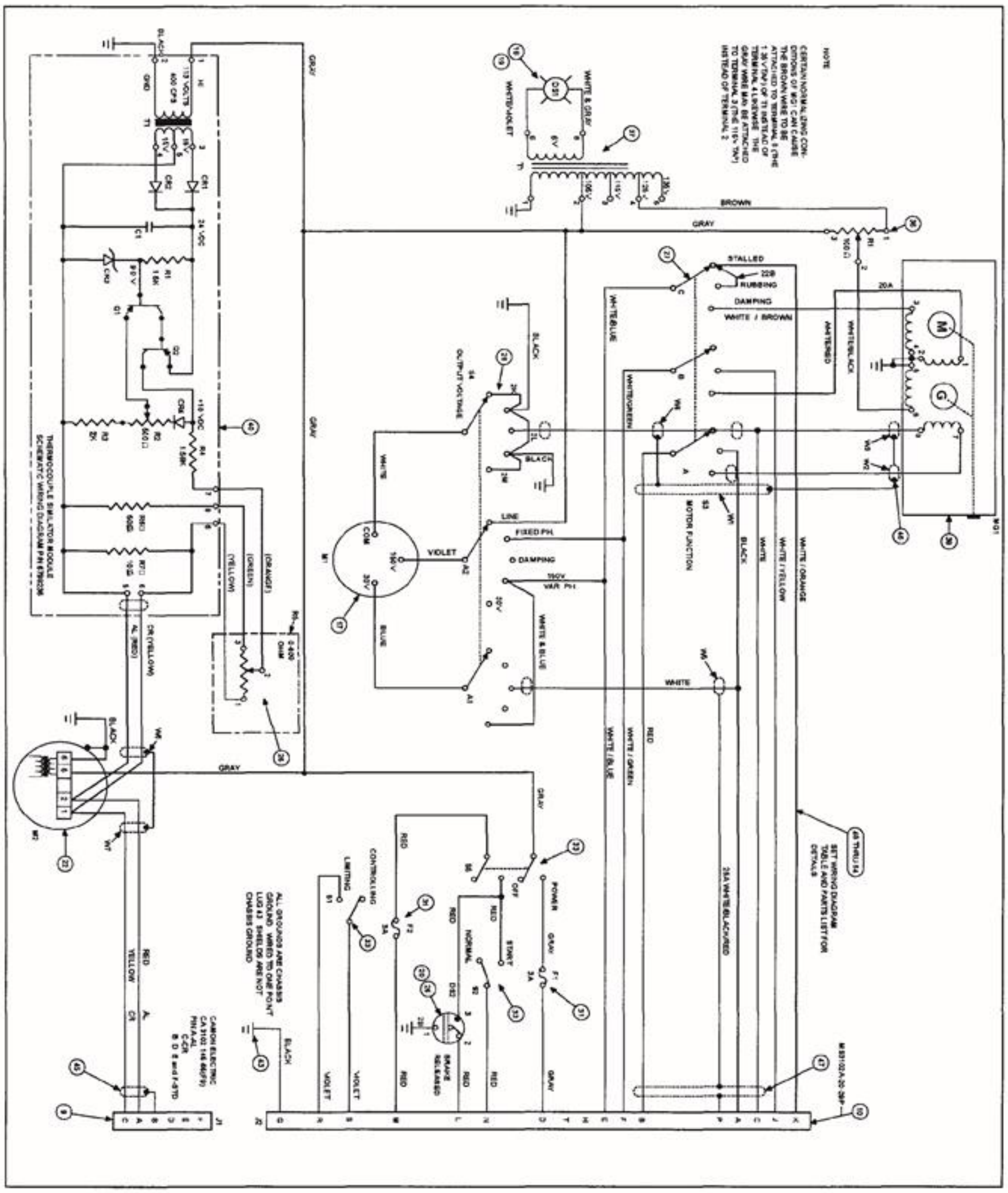


Figure 6-1. Electronic Temperature Datum Control System Test Set No.[redacted] Wiring Schematic

[redacted]

A.8 Annex 8

Doc. Ref.:
MRT-****

Ind.	Maintenance Reliability Investigation		Alert ☑	Claim ☐
1	Component description	GYROSCOPE, DIRECTIONAL	ITEM-ATA	34-YY-ZZ
2	P/N	*****	Alternative P/N	N/A
3	S/N	*****		
4	Investigation Process			

	Applicability	A	N/A	Doc. Ref.	Ed.	Rev.	Additional information		
4.1	AMM / TM	☑	☐	TM *****			#		
4.2	CMM / TO	☑	☐	T.O. *****			#		
4.3	Repair reports	☑	☐						
4.4	AD	☐	☑						
4.5	SB	☐	☑						
4.6	Others	☐	☐						

5	MMA				
Installation	Removal	Operational Checkout	Troubleshooting	Inspection	
☐	☐	☐	☐	☐ Vis. ☐ Det. ☐ FC	
5.1	Remarks				

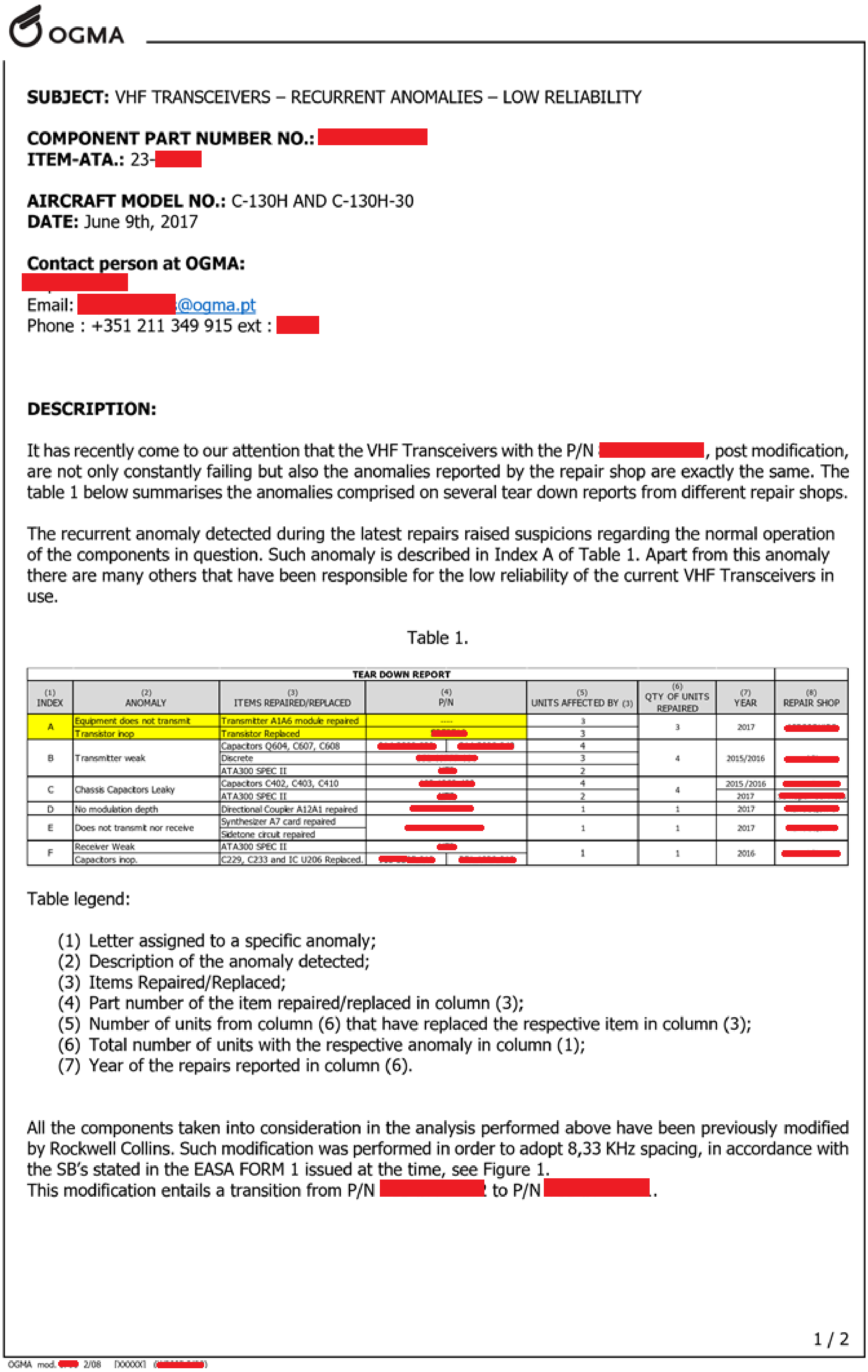
6	MCO				
	Repair Reports	Inspection	Repair	Troubleshooting	Tests
	☑	☐	☑	☐	☐

	Anomalies	Failure Mode	Type of Failure
1	Gyro Unit Fails at Turn On	N/A	N/A
2	Gyro doesn't spin	N/A	N/A
3	Gyro bearings stuck	Worn (heat, lubrication..)	Normal
4	Rotor race bearings with hard points	Worn	Normal
		Dents (Strong Impact)	Abnormal
5	Internal wiring damaged	Worn	Normal
6	Damaged nut and stator	Worn	Normal
7	Excessive drift	Worn	Normal
		Lack of adjustment	Abnormal
8	Internal wiring from levels switch burned	Worn	Normal
9	Unit fails for acceptance test	N/A	N/A
10	Gimbal bearings with hard points	Worn	Normal
		Dents (Strong Impact)	Abnormal
11	Gyro bearing seats damaged	Worn	Normal
12	Gyro bearings damaged	Worn	Normal
		Dents (Strong Impact)	Abnormal
13	The endplay of gyro unit needs adjustment.		
14	Rotor race bearings stuck	Worn	Normal
15	Gyro nuts damaged	Worn	Normal
16	Gyro locks damaged	Worn	Normal

Doc. Ref.:
MRT-****

17	Gyro bearings with hard points	Worn	Normal
		Dents (Strong Impact)	Abnormal
6.18	Remarks	- Many NFFs detected, registered as Failure. - Hard points are related to normal wear caused by the operation or due to an unexpected impact. - Parts stuck are usually related to normal wear (lack of lubrication caused by the heat), etc..	
7	**Constraints**		
8	**Observations**		
9	**Probable Root causes**		
10	**Corrective actions**		
Correct NFF reported as Failure in FMS. Develop and implement excel file in order to monitor the BIAS adjustement when the compoenent enters and leaves COM.			

A.9 Annex 9



OGMA

SUBJECT: VHF TRANSCEIVERS – RECURRENT ANOMALIES – LOW RELIABILITY

COMPONENT PART NUMBER NO.: [redacted]
ITEM-ATA.: 23-[redacted]

AIRCRAFT MODEL NO.: C-130H AND C-130H-30
DATE: June 9th, 2017

Contact person at OGMA:
[redacted]
Email: [redacted]@ogma.pt
Phone : +351 211 349 915 ext : [redacted]

DESCRIPTION:

It has recently come to our attention that the VHF Transceivers with the P/N [redacted], post modification, are not only constantly failing but also the anomalies reported by the repair shop are exactly the same. The table 1 below summarises the anomalies comprised on several tear down reports from different repair shops.

The recurrent anomaly detected during the latest repairs raised suspicions regarding the normal operation of the components in question. Such anomaly is described in Index A of Table 1. Apart from this anomaly there are many others that have been responsible for the low reliability of the current VHF Transceivers in use.

Table 1.

TEAR DOWN REPORT

(1) INDEX	(2) ANOMALY	(3) ITEMS REPAIRED/REPLACED	(4) P/N	(5) UNITS AFFECTED BY (3)	(6) QTY OF UNITS REPAIRED	(7) YEAR	(8) REPAIR SHOP
A	Equipment does not transmit	Transmitter A1A6 module repaired	----	3	3	2017	[redacted]
	Transistor inop	Transistor Replaced	[redacted]	3			
B	Transmitter weak	Capacitors Q604, C607, C608	[redacted] [redacted]	4	4	2015/2016	[redacted]
		Discrete	[redacted]	3			
		ATA300 SPEC II	[redacted]	2			
C	Chassis Capacitors Leaky	Capacitors C402, C403, C410	[redacted]	4	4	2015 /2016	[redacted]
		ATA300 SPEC II	[redacted]	2		2017	[redacted]
D	No modulation depth	Directional Coupler A12A1 repaired	[redacted]	1	1	2017	[redacted]
E	Does not transmit nor receive	Synthesizer A7 card repaired	[redacted]	1	1	2017	[redacted]
		Sidetone circuit repaired					
F	Receiver Weak	ATA300 SPEC II	[redacted]	1	1	2016	[redacted]
	Capacitors inop.	C229, C233 and IC U206 Replaced.	[redacted] [redacted]				

Table legend:

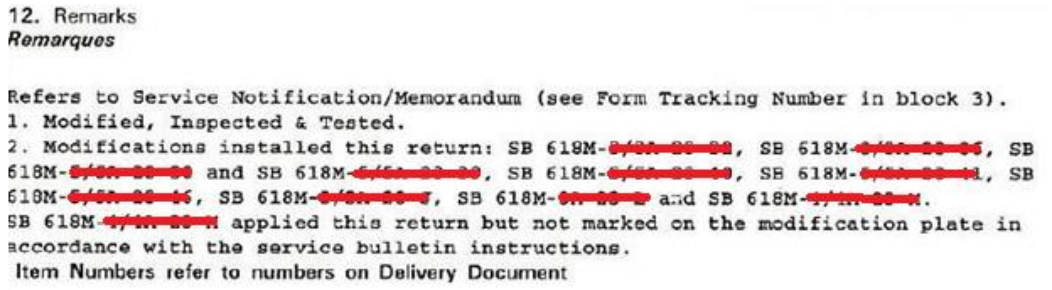
(1) Letter assigned to a specific anomaly;
(2) Description of the anomaly detected;
(3) Items Repaired/Replaced;
(4) Part number of the item repaired/replaced in column (3);
(5) Number of units from column (6) that have replaced the respective item in column (3);
(6) Total number of units with the respective anomaly in column (1);
(7) Year of the repairs reported in column (6).

All the components taken into consideration in the analysis performed above have been previously modified by Rockwell Collins. Such modification was performed in order to adopt 8,33 KHz spacing, in accordance with the SB's stated in the EASA FORM 1 issued at the time, see Figure 1.
This modification entails a transition from P/N [redacted] to P/N [redacted].

1 / 2

OGMA mod. [redacted] 2/08 [XXXXX] ([redacted])

Figure 1.



12. Remarks
Remarques

Refers to Service Notification/Memorandum (see Form Tracking Number in block 3).
1. Modified, Inspected & Tested.
2. Modifications installed this return: SB 618M-[redacted], SB 618M-[redacted], SB 618M-[redacted] and SB 618M-[redacted], SB 618M-[redacted], SB 618M-[redacted], SB 618M-[redacted], SB 618M-[redacted], SB 618M-[redacted] and SB 618M-[redacted].
SB 618M-[redacted] applied this return but not marked on the modification plate in accordance with the service bulletin instructions.
Item Numbers refer to numbers on Delivery Document

It would be much appreciated if you could support us by answering the following questions:

(1) Is Rockwell Collins already aware of the anomalies reported in INDEX A, B and C of Table 1?

(2) Do you have any perception if these anomalies are common to other fleets/aircraft equiped with this radio?

(3) What could be the probable causes of the anomalies stated in INDEX A, B and C of Table 1 and can they be related to the modification mentioned in Figure 1?

(4) What can be done in order to avoid/eliminate the probable causes described in the answer to question (3)?