Tunisian Republic
Private Higher School of
Aeronautics and Technologies

الجمهورية التونسية
المدرسة العليا الخاصة للطيران
و التكنولوجيا

END OF STUDY PROJECT DISSERTATION
FOR THE OBTENTION OF THE NATIONAL DIPLOMA OF AERONAUTICAL ENGINEER

Reliability and failure analysis for the FCDU equipped on the fleet of A320 and A330

- *Tunisair Technics*
- *Avionic overhaul department*

Realized by:

IHEB KADRI

Supervised by:

Academic supervisor: MRS ABIR LASSOUED
Professional supervisor: MR ANIS HAMMEMI

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A work is never the result of a single person's effort

I would like to express my gratitude to all the people who contributed to its realization.

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Dedication

I want to dedicate this project for all those who have accorded their support

More precisely;

For my parents for their unconditional support and belief.

For all professors who have contributed in my academic evolution.

For all friends,

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Glossary of terms

- **FCDU:** Full Color Display Unit
- **Nav/Com:** Radio-Navigation and Communication workshop
- **AMASIS:** Aircraft Maintenance And Spares Information System
- **ATEC:** Automatic Test Equipment Complex
- **MRO:** Maintenance, Repair and Overhaul
- **FCGC:** Flight Control and Guidance Computer
- **FCSC:** Flight Control Secondary Computer
- **ACR:** Avionics Communication Router
- **ADIRU:** Air Data Inertial Reference Unit
- **CDIS:** Cabin Data Intercommunication System
- **EEC:** Engine Electronic Control
- **AC:** Air Conditioning
- **FM:** Flight Management
- **IPCU:** Ice Protection Control Unit
- **IRDC:** Intelligent Remote Data Concentrator
- **LG:** Landing Gear
- **AOG:** Aircraft on Ground
- **EASA:** European Union Aviation Safety Agency
- **DMC:** Data Management Computer
- **EIS:** Electronic Instrument System
- **EFIS:** Electronic Flight Instrument System
- **ECAM:** Electronic Centralized Aircraft Monito
- **ND:** Navigation Display
- **PFD:** Primary Flight Display
- **CRT:** Cathode Ray Tube
- **SG:** Symbol Generator
- **LVPS:** Low Voltage Power Supply Board
- **GMS:** Global Systems Mobile
- **MTBR:** Mean Time Between Removals
- **MTBF:** Mean Time Between Failure
- **MTBUR:** Mean Time Between Unscheduled Removals
- **Amdt:** Amendment
- **CMM:** Component Maintenance Manual
- **TPS:** Test Program Set
- **SB:** Service Bulletin

General Introduction

In the transportation market, aeronautics are still expanding, with ever-renewed objectives and challenges related to productivity, quality and safety. Moreover, the need of enhancing the reliability of the airplane has become an undisputed priority in order to maximize the safety of the aircraft and the gain of the airline. As a results, one of the never-ending objectives of the maintenance, repair and overhaul center is maintaining the airworthiness of the aircraft and its components.

In that sense, the importance of maintenance activity has increased due to its key role on improving system availability, efficiency, safety and reliability as maintenance-related failures have been associated with up to 15% of major aircraft accidents. Despite this seemingly small percentage, but the European Union Aviation Safety Agency (EASA) found that maintenance related failures are the second leading cause of fatal accidents in aviation exceeded only by pilot error.

As a result, in order to improve avionics considerations in general, maintenance managers should take decisions about the maintenance strategies to be implemented as well as the necessary resources to satisfy avionics system performances.

It is in this context that we conducted this final year project entitled “study of the reliability of equipment FCDU and solution proposition" within the avionic overhaul department of the company of Tunisair Technics a subsidiary of TUNISAIR.

The MRO center evaluated that nearly 30% to 50% of Aircraft on Ground incidents were related to avionics systems more particularly related to communication and displaying systems.

Moreover, our main objectives are the reduction of the failure rate and increase the reliability of the equipment mounted on their fleets in order to avoid considerable losses due to the overcasts of the unreliability of the equipment, the detection of the defects and the reduction of their frequency.

In order to achieve these tasks, we aim to divide this manuscript into 3 major chapters through which we aim to find some solution for the high failure rate of the full color display unit;

In the first chapter, we intend to present the host company, the context of this project as well as a bibliographical study on the approach related to the maintenance strategy.

In the second chapter, firstly, we aim to break down the full color display unit and highline the different functionality presented by this equipment as well its different components in order to relate the role of each component in the overall performance of unit. Secondly, we aim to establish an analysis of the current state of the equipment through a reliability study of the full color display unit in order to evaluate the FCDU.

The third and last chapter will be devoted to specify the specification of the equipment failures using a failure mode and effect analysis through which we aim to propose solutions to enhance the performance of the full color display unit. I will finish this report by the conclusion and the perspectives.

chapter 1 general context and objectives

1. Introduction

In this chapter, we aim to firstly familiarize the general framework by presenting the establishment in which we had our internship generally and the overhaul department precisely. In which secondly, we aim to present the problematic faced in this paper as well the purpose of this study by highlighting the importance of avionic systems as well the objectives of the overhaul department.

2. General presentation of Tunisair

2.1 Creation history and key data

The Tunisian Air Company, also called Tunisair, was officially created in the 21 of October, 1948 as the airline company of Tunisia. It was issued with a capital of 60 million French Francs in which the Tunisian government, Air France and private shareholders all participated in. However, the Tunisair hasn’t officially started operating not until April the following year using planes chartered by Air France. [1]

Towards the end of the 60's Tunisair established a nationalization program of the employees, the civil aviation services and meteorological services hence it became totally Tunisian from 1968 onwards. Since its establishment after the second world war Tunisair was one of the most responsive towards the need for air links between north Africa and the European continent

The main activity of the air transport is carried out through a network of lines extending on the main tourist markets of Tunisia particularly and Western Europe especially with an annual average of about 1600 flight hours according to the indicators for the first quarter of 2022 published by the Tunisian airline company in which it presents a huge development in total number of incomes by a 178% increase to 216 MTD, against 77.7 MTD during the same quarter of previous year. The company noted an improvement in the productivity of the aircraft following the increase in the daily use of the fleet as well, which reached 7.06 hours per day per aircraft on March 31, 2022 against 3.10 in the same period of 2021. [2]

2.2 Tunisair fleet

The main objective of Tunisair is to link between north Africa and the European continent which implicates the short flight range, destinations are close and the course of flight is brief. This strategy occurs more precisely in the choice of aircrafts in the fleet of Tunisair. Thus, all airplanes are dedicated for short courses [1]

In fact, Tunisair have 27 aircrafts in which 22 Airbus and 5 Boeing; furthermore, 2 type A330, 16 type A320, 4 type A319 and 5 from the B373-600 type.

We present below the list of all aircraft in the fleet as well as their matriculation and commissioning date.

Table 1: Tunisair aircraft fleet

Aircraft type	Matriculation	Date of commission	Aircraft type	Matriculation	Date of commission
Airbus A330	IFM	08/06/2015	Airbus A320	IMR	24/06/2010
Airbus A330	IFN	23/08/2015	Airbus A320	IMS	06/05/2011
Airbus A320	IMF	20/11/1992	Airbus A320	IMT	13/07/2012
Airbus A320	IMG	29/03/1994	Airbus A320	IMU	12/02/2013
Airbus A320	IMH	16/04/1994	Airbus A320	IMV	30/04/2013
Airbus A320	IMI	25/03/1995	Airbus A320	IMW	28/11/2014
Airbus A319	IMJ	28/07/1998	Airbus A320 NEO	IMX	23/12/2021
Airbus A319	IMK	15/09/1998	Airbus A320 NEO	IMY	07/02/2022
Airbus A320	IML	02/03/1999	BOEING 737-600	IOK	25/05/1999
Airbus A320	IMM	26/03/1999	BOEING 737-600	IOL	28/05/1999
Airbus A320	IMN	30/03/2000	BOEING 737-600	ION	09/07/2000
Airbus A319	IMO	18/04/2001	BOEING 737-600	IOP	09/03/1995
Airbus A320	IMP	03/06/2002	BOEING 737-600	IOR	13/04/2001
Airbus A319	IMQ	10/04/2007	BOEING 737-600	IOQ	25/05/2000

[1]**Table 2: Aircraft information**

Type of aircraft	Number	Number of passengers	Maximum take-off weight (tons)	Cruising speed
Airbus A330	2	28C/235Y	165	0,82 Mach
Airbus A320	16	25C/120Y or 174 Y	73,5	0,79 Mach
Airbus A319	4	144Y	70	0,79 Mach
Boeing B737-600	5	126Y	65.09	0,785 Mach

[1] Y= economic class |C= comfort class

2.3 Tunisair technics and flowchart of the maintenance center departments

Tunisair Technics is a subsidiary of the Tunisair. It was created in January 2006 and is fully owned by the latter. It is a maintenance center whose main mission is to maintain the airworthiness of all aircrafts in the fleet of Tunisair.

On another hand, one of the main objectives of the creation of this subsidiary is to reduce the cost of maintenance by eliminating the expedition of broken-down equipment.

In order to operate and maintaining its main objective, Tunisair Technics is certified PART 145 which is the certificate of airworthiness which allows the employees of Tunisair Technics to maintain the different versions of both AIRBUS and BOEING as well as ATR and CRJ airplanes

The maintenance center of Tunisair Technics role is to ensure firstly online maintenance and repair for all foreign or local aircrafts, secondly to overhaul and repair of aircraft equipment and accessories; for instance, hydraulic, mechanical and avionics systems and equipment as well as tires and brakes systems [1]. Last but not least, establish non-destructive control and calibration of tooling and test stands.

In order to maintain this multifariousness of tasks, Tunisair has distributed different assignment for each department within the maintenance center. Moreover, every department have a variety of workshops each one has a specific task.

In this diagram in the figure 1, we present the flowchart of the maintenance center departments however we focus more specifically on the workshops of the avionics revision department in which we establish our internship

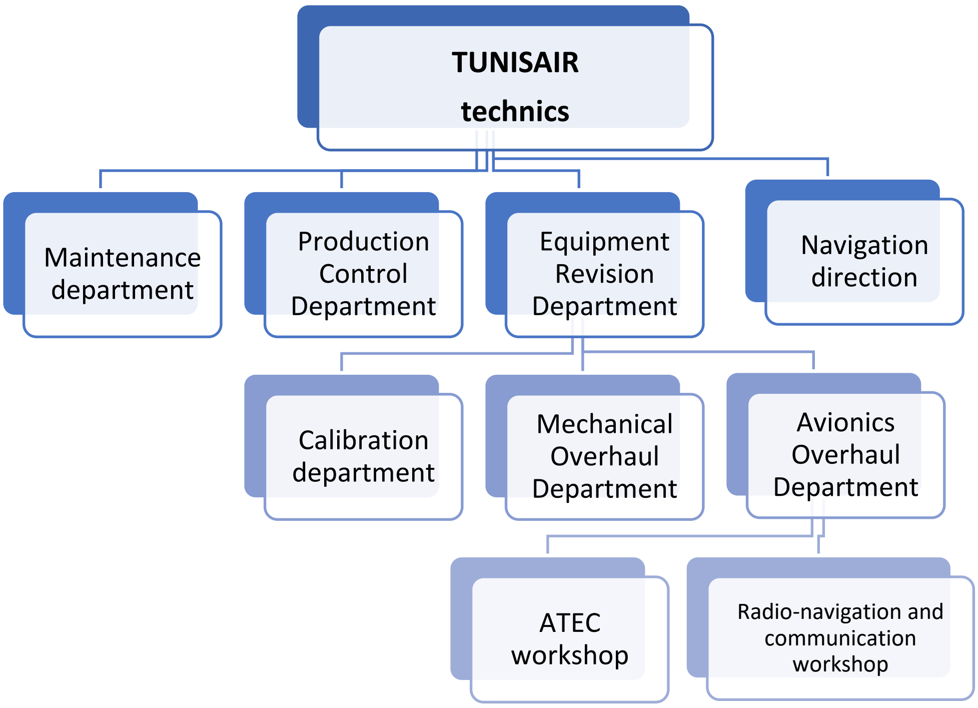


Figure 1: Tunisair Technics flowchart

3. Avionic systems and overhaul department

3.1 Avionic overhaul department objective

As mentioned in the flowchart, the avionic overhaul department is an important organ of the structure of the Tunisair Technics. Furthermore, this department is based on maintaining all avionic system used in all the Tunisair fleet as well as establishing the necessaire repair, modification and overhaul of all avionic equipment. This department is sub-devised into 2 major workshops related to this study.

3.1.1 Radio-navigation and communication workshop

Radio-navigation and communication workshop, also known as NAV/COM workshop, is responsible of the repair, compensation and restoration of the avionic equipment in the aircraft.

Furthermore, the workshop focuses more precisely on navigation system and equipment such as control display unit, instrument landing system, automatic direction finder, very high frequency Oni-directional range, etc., and on communication system and equipment for instance very high frequency, high frequency, cockpit voice recorder etc. [3].

The workshop guarantees the maintain of navigability of all equipment of navigation and communication systems in a safe and efficient manner.

This workshop operates using AMASIS (AIRCRAFT MAINTAINANCE AND SPARES INFORMATION SYSTEM) system which is a storage and management system for various data circulating from the technical complex, the stopovers and the head office of Tunisair.

AMASIS system have 4 major functions sited as;

- To ensure the complete follow-up of all aeronautical stocks in multi-site management with traceability adapted to each type of consumable to serialized equipment
- To monitor the line maintenance of aircraft based on technical data from completed flights, crew complaints handled or put on hold and related equipment removals. This daily data is also used to produce reliability reports for avionic equipment
- To enable the management of official documents from authorities, manufacturers and suppliers.
- To record and maintain manufacturers' maintenance protocols.

3.1.2 ATEC workshop

The test of the equipment is reproduced at the ATEC workshop during the occurrence of real problems that can be encountered during a cruise flight, a hard landing, a flight in a turbulent area, a take-off.

Furthermore, The ATEC 7000 is a programmable aerospace test bench used by a large proportion of airlines and MROs (maintenance, repair and overhaul), mainly for testing avionic equipment on aircraft both Airbus and Boeing as well as for ensuring the repair of these components.

The ATEC 7000 station has 3 major functions:

- Ensuring the storage of data and results automatically
- Instrumentation function which is based on 3 sub-functions;
    - Generating analog tension both in the form of alternative and continued tension
    - Measuring every equipment information and measurements through sensor such as tension and frequencies in the equipment
    - Simulating the real-life conditions automatically through a screen that displays test results
- Communicating function which main purpose is to link and channel signals between the instrumentation function and the equipment under test.

3.2 Purpose and importance of avionic systems

The avionics industry is now a major multi-billion-dollar industry world-wide and the avionics equipment on a modern military or civil aircraft can account for around 30% of the total amount that an aircraft cost. [3]

In fact, the avionic systems are essentials to enable the flight crew to carry on the aircraft mission safely and efficiently. Whether the mission is the carrying of passengers for their destination for the case of civil aviation or the even the case of military aircraft.

The major driver for the development and establishment of avionics systems has been the need to meet the assigned task required with minimum flight crew. To elaborate, this means for instance a crew of only two namely the first and second pilot can still guarantee the operation of the aircraft safely and efficiently.

This is only made possible by automating the tasks used to be carried out by the navigator and the flight engineer. The achievement of safe two crew operation had very considerable benefits for the airline with the consequent of saving crew salaries, expenses and training costs as well as the reduction in weight which contributes to more passengers and les used fuel.

As a results, the development of avionics systems and sub-systems as well as maintaining their function in safe and efficient manner has been a priority for most airlines world-wide due the major effect of avionics systems have.

In fact, there is a fundamental link between the avionic system of the aircraft and the enable of new technologies and technics. Furthermore, the new development of technologies and technics have an impeccable impact on the avionic systems as the modern implementation of new improvement of performance, mass, safety and availability tend to be applied in the aeronautical market all in favor of improving aviation and airline performance. [4]

The figure 2 below shows the interrelationship between avionics systems in the aircraft and new technologies.

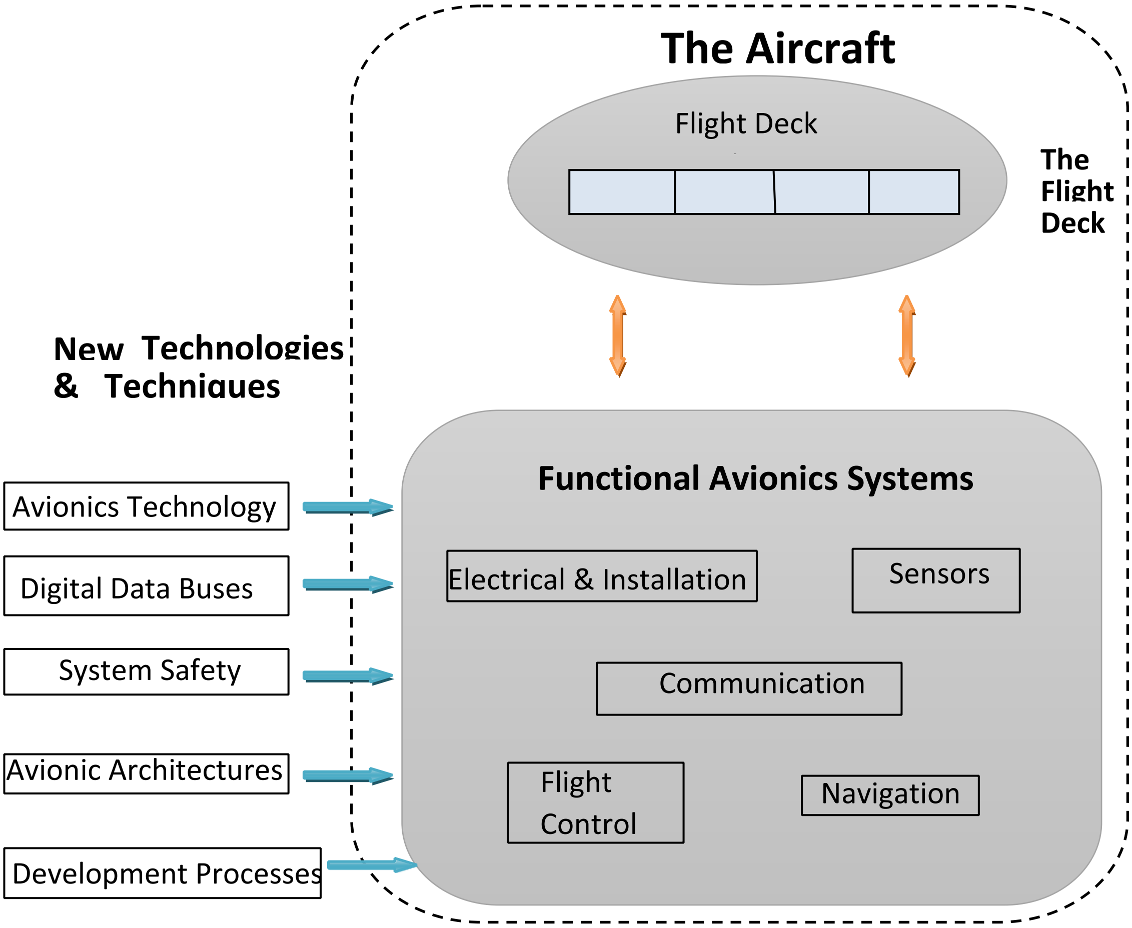


Figure 2: Interrelationship between avionic systems and technology development

3.3 Hierarchy of Avionics System

To clearly describe the avionics maintenance strategy decision problem, we first define avionics system hierarchy structure. Avionics System can be divided into three system levels, system, subsystem and component, which are involved in this paper.

The three system levels can be defined as follows; a system is a combination of subsystems that complete a task together, a subsystem consists of components, which can perform a specific function of the system, and a component is an operating part of the subsystem. [4]

Taken domestic avionics as an example, as shown in the flowchart below, the avionics system can be divided into six subsystems according to their functions and operational characteristics, which is made up of subsystems including flight control subsystem, engine control subsystem, cockpit control-display subsystem, energy control subsystem, fuel and landing gear control subsystem, cabin control subsystem.

These subsystems can be further broken down to components illustrated in the flowchart in the figure 3 below.

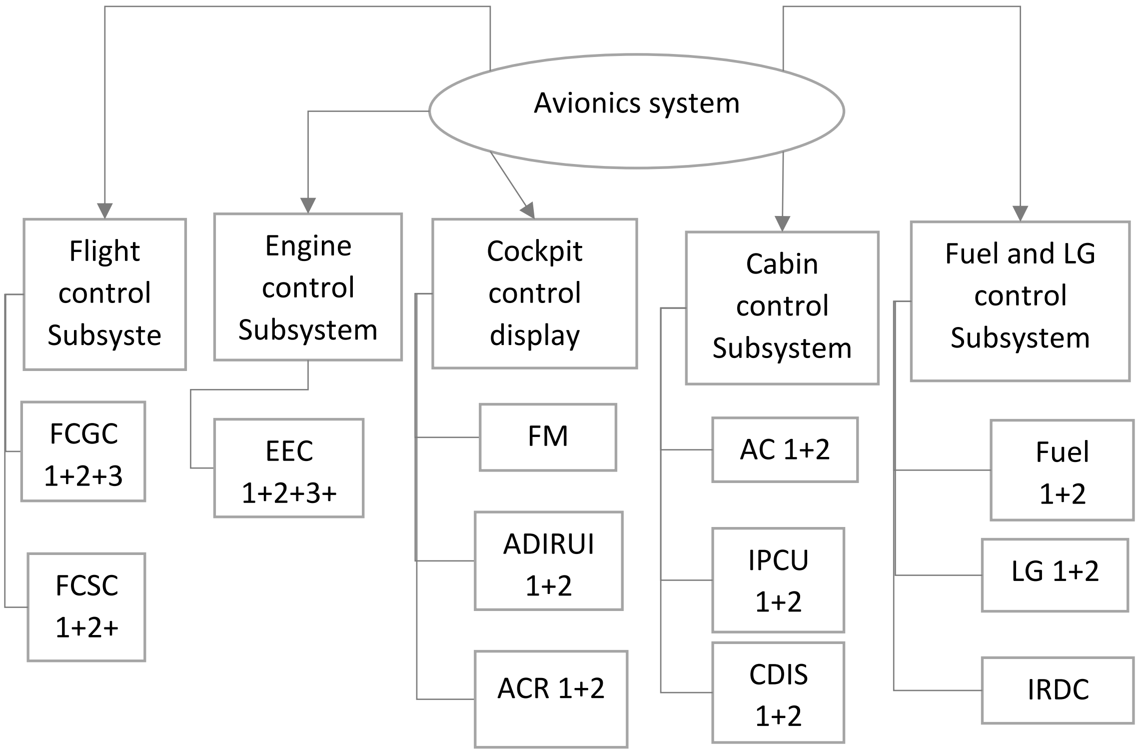


Figure 3: Flowchart of aircraft avionic system

- FCGC: flight control and guidance computer
- FCSC: flight control secondary computer
- ACR: Avionics Communication Router
- ADIRU: Air Data Inertial Reference Unit
- CDIS: Cabin Data Intercommunication System
- EEC: Engine Electronic Control
- AC: Air conditioning
- FM: Flight Management
- IPCU: Ice Protection Control Unit
- IRDC: Intelligent Remote Data Concentrator
- LG: Landing gear

Due to the complexity, the avionics contractor usually subcontracts the avionic subsystems and even components to several subcontractors for further design and manufacturing

3.4 Maintenance strategy for avionic systems

The cost of avionics maintenance is extremely high for modern aircraft. It can be as high as 30% of the aircraft maintenance cost. A great impact on the cost of avionics maintenance is provided by a high level of No Fault Found events (NFF). The NFF rate for avionics systems is between 20% and 50% according to a study made by the National aviation University of Kiev, Ukraine in 2018. [3]

As a results, the practice of avionics operation and maintenance confirms the relevance of assessing the impact of intermittent faults on the maintenance cost and the choice of such option of the maintenance management, in which the negative impact of the intermittent faults is minimized.

In fact, the avionic overhaul department in Tunisair Technics has no different intention and have a specific strategic approach in which firstly to minimize the cost in maintenance and repair of avionic equipment and systems, secondly to maintain all systems in an operative safe and efficient manner and finally to improve the no fault found events rate.

3.4.1 Impact of avionic system failure on the airline performance

Avionics system is an important part of aircraft, being safe, fast and environmentally friendly, whose failures are among the top five reasons that caused aircraft on ground (AOG). Tunisair claims that nearly 30% to 50% of Aircraft on Ground incidents were related to avionics systems more particularly related to interconnected equipment and displaying system.

Broadly speaking, maintenance-related failures have been associated with up to 15% of major aircraft accidents. Despite this seemingly small percentage, but the European Union Aviation Safety Agency (EASA) found that maintenance related failures are the second leading cause of fatal accidents in aviation exceeded only by pilot error.

In that sense, the importance of maintenance activity has increased due to its key role on improving system availability, performance efficiency, safety and reliability. Thus, in order to improve avionics considerations in general, maintenance managers should take decisions about the maintenance strategies to be implemented as well as the necessary resources to satisfy avionics system performances and requirements.

Satisfactory performance of an aircraft depends up on the continued reliability, security, features enhancements of avionics system. Reliability is proportional to amount of maintenance received and knowledge of men who performed such maintenance.

Now, an avionics system may comprise a large number of components, and efficient maintenance strategy is required to improve the reliability of relevant functions for a long time, both home and abroad. The avionic overhaul department have to take preventive tests and routine maintenance to ensure the safe operation of avionics system as well as to reduce high maintenance cost.[4]

3.4.2 Flowchart of maintenance strategy decision of the department

The maintenance policy decision for avionics system based on cognitive uncertainty information processing can be descripted as follows, the implementing process of this approach is shown by flow chart in the figure below and details process are given here after.

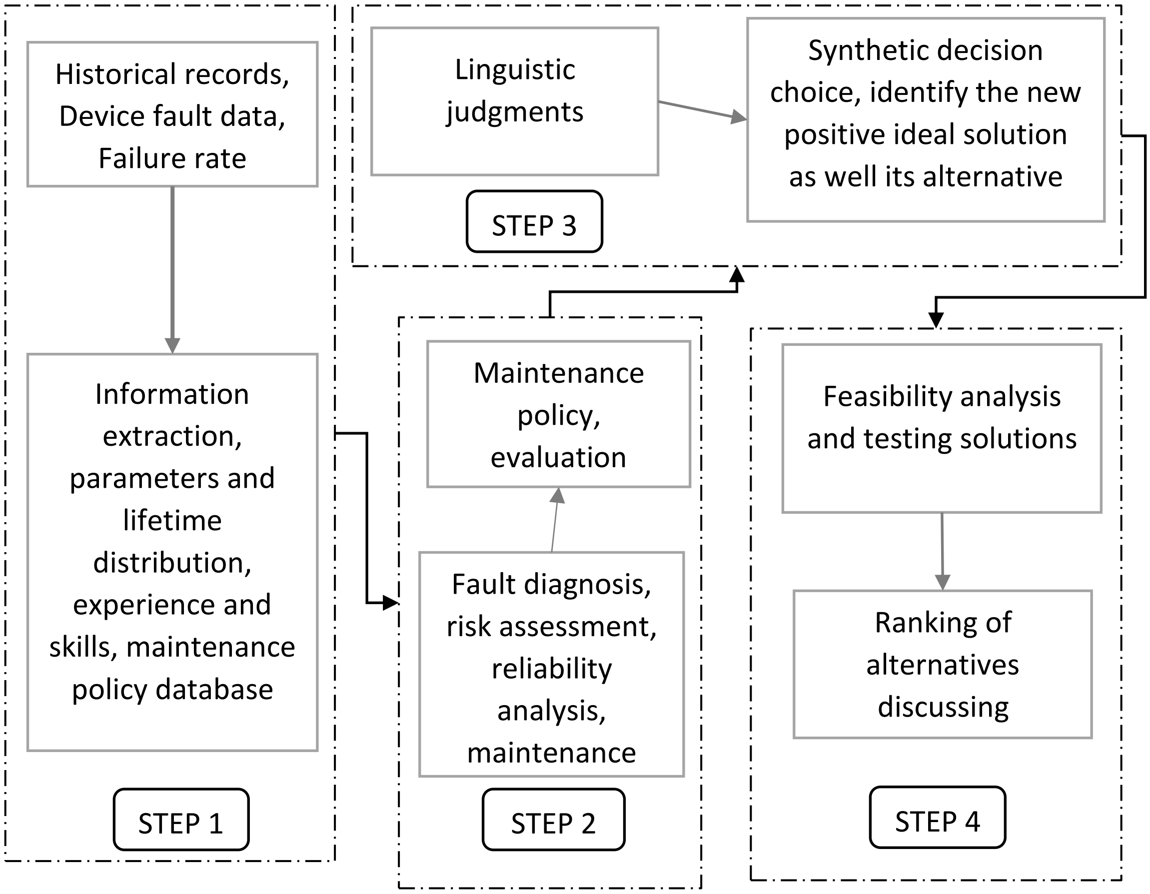


Figure 4: Flowchart of maintenance strategy

3.4.2.1 Step 1: Collected the maintenance records and historic failure data

First step of this approach is the information extraction phase in which information is extracted from various sources. Information in the form of system components' failure rates and repair times are extracted from various sources such as historical maintenance records, reliability databases, system reliability expert opinion, etc.

In decision-making process, based on the fault information provided by the diagnosis and prediction program, the decision is made according to if the faulty equipment is needed to be repaired and when to be repaired, and analysis accounting about maintenance costs and repair working time calculation.

3.4.2.2 Step 2: ascertain the range of attribute weights

Decision making problem in avionics system equipment maintenance, occurs in maintenance experts because they often rely on their own maintenance experience and skills, for maintenance scheme under different criteria values are formed certain risk forecast, such expectations can be considered as maintenance decision makers with reference to the risk behavior characteristics of the formation of the reference point, so the maintenance plan is called a reference.

3.4.2.3 Step 3: Express the corresponding for each maintenance policy solution

Maintenance mangers give their judgments on criteria of alternatives in linguistic terms. They identify the best ideal solution for maintenance policy as well the worst ideal solution presented by the first steps of approach.

3.4.2.4 Step 4: Feasibility analysis Maintenance plan decision

In order to validate the proposed based on the cognition of uncertain information processing the feasibility and effectiveness of equipment maintenance in front of the parking preventive test for the maintenance scheme decision-making system equipment. In order to guarantee the correctness of the decision, before the decision by the engineering and maintenance personnel for each equipment testing and reliability evaluation system, check the equipment operation records report.

4. Technical background and problem statement

As mentioned in the flowchart of maintenance strategy decision, it is upon the avionic overhaul department to establish its tasks through these proceedings to improve the efficiency of all equipment and establish the desired tasks of the hole departments as well as overcoming every day obstacles.

Each year, the avionic department take it upon its technician to follow the maintenance strategy which manifest in the first step of the strategy. It began with a study of reliability of each avionic equipment for every year in order to enhance the functionality of the equipment as well as overcoming its problems.

Furthermore, the department collects information and keep the maintenance history of each equipment precisely the failure data. It is with intension to reduce the failure rate as well as preventing the increase of maintenance and repair cost.

However, for the past 5 years, the department has been facing some critical challenges which prevented the maintain of navigability of some fundamental aircraft equipment. This is due to some backlog unsolved problems and not following the strategy of maintenance yearly.

This also the case the full color display unit which is an essential avionic system in the aircraft. This equipment has shown for the past 5 years a high failure rate as well as enormous repair cost which leaded the department to face the risk of not being able to maintain the navigability of this essential equipment and causing the aircraft unnavigability.

this was the case of this problematic as we intend to overcome the obstacle of multiple failures for this specific equipment the full color display unit in which we need to distinguish different manner of failures as well as each cause. This study is in the purpose of limiting the failure rate as well finding a solution in order to improve the efficiency of this equipment and its reliability.

In order to follow the avionic overhaul department proceedings and achieve to propose a solution with the intention to overcome this problematic, we aim firstly to break-down the FCDU with the intention to determinate the different function of its components. Then, secondly, we intend to establish a reliability study in order to evaluate the efficiency rate of the full color display unit as determinate the failure rate.

Thirdly, we focus on establishing a failure mode and effect analysis in order to determinate the multiples cause of the full color display unit failures as well as the cause of these continues disfunction events.

Finally, based on these studies, we aim to find solution in order to decrease the failure rate of this equipment as well as enhancing the maintain of its navigability.

To summarize, we intend to follow this Gantt chart presented below in the figure 5 in order to illustrate the desired accomplishments during this internship in the Tunisair Technics.

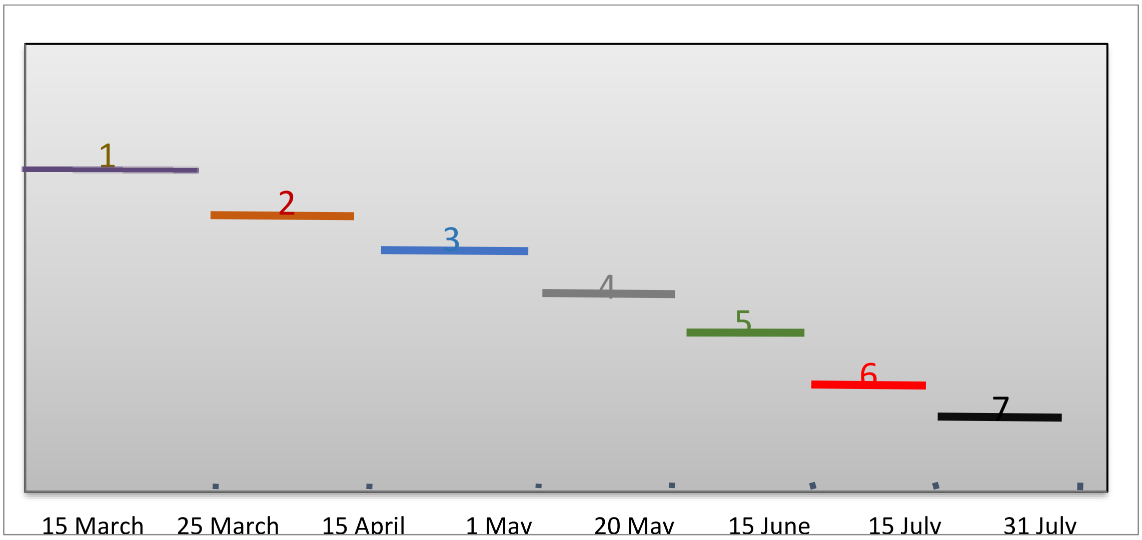


Figure 5: Gantt chart

Furthermore, we intend to explain the desired steps of Gantt diagram through the table 3 below,

Table 3: Gantt chart steps

1	Familiarize the workshop and understanding the tasks required
2	Study of the full color display unit
3	Reliability study
4	Identification of the full color display failure modes
5	Identification of cause of every failure
6	Failure mode and effect analysis
7	Identification of the problem and proposal for a solution

5. Conclusion

Avionics system is an important part of the aircraft, being safe, fast and navigable which presents the essentiality of maintaining all avionic equipment in a proper functional state. However due to their high cost of maintenance and repair, the avionic department aims enhance its reliability by decreasing their failure rate and keep them in a navigable state.

In order to determinate the failure rate of the full color display unit, it is essential to establish a reliability study in order to comprehend the functionality of this equipment as well its failure rate

chapter 2 Technical overview and reliability study

1. Introduction

In this chapter, we aim to fully present the full color display unit as well its specific components in order to identify the equipment functionality and decompose the unit into several multifunctional component.

This study will allow us to secondly study the failure rate of the equipment through the years 2017 up 2021 through a reliability study which presents an efficient method to study the performance of the full color display unit

2. Full Color Display Unit:

2.1 FCDU presentation

2.1.1 Purpose of the FCDU

The Full Color Display unit (FCDU) is designed for installation on and aircraft instrument panel. It displays color piloting and navigation aid data as well as system and warning parameters to the captain and the second officer.

Each display is controlled by a Data Management Computer (DMC) which collects and processes data from other aircraft systems and generates appropriate data for the display image [5]. This data is tele-loaded into the FCDU using dedicated Serial Data Link.

The FCDU contains 6 displays; 2 primary flight displays, 2 navigation displays and 1 ECAM divided into upper and lower as shown in the figure 6 below.

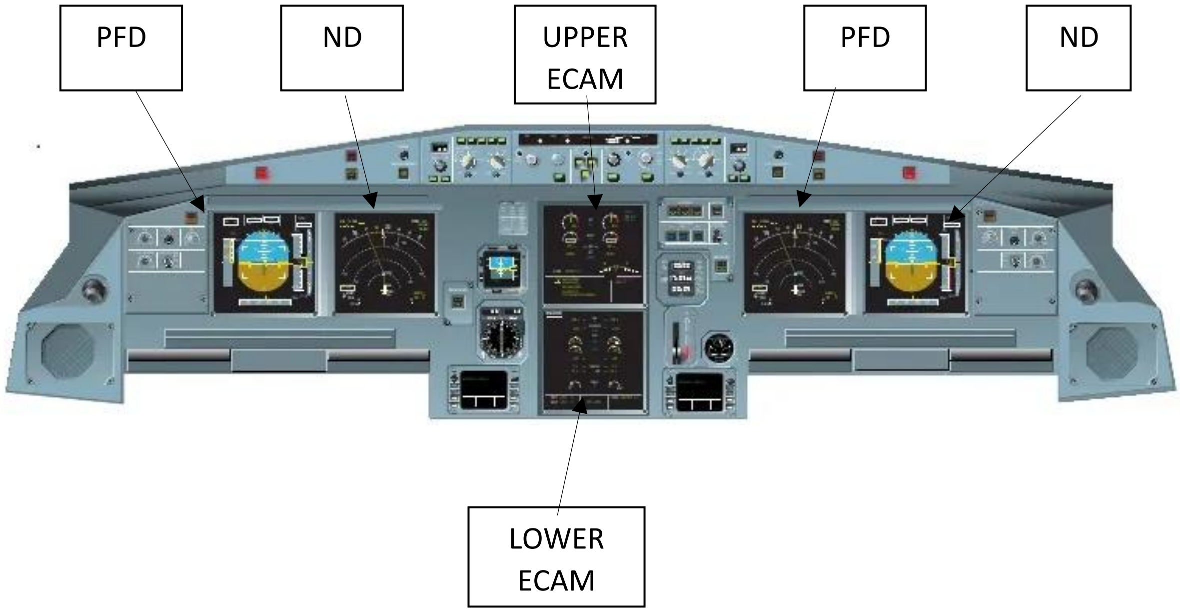


Figure 6: Full color display unit

2.1.2 Functions of the FCDU

The FCDU is used in the Electronic Instrument System (EIS). This system is connected with most of the aircraft systems to carry out the two following main display functions through the following systems;

The Electronic Flight Instrument System (EFIS) which is responsible of the flight and navigation information for the crew and the Electronic Centralized Aircraft Monitor

(ECAM) which indicates information concerning normal and abnormal stated of the aircraft systems.

Both EFIS and ECAM combined forms the Full Color Display Unit. We illustrated both in the figure 7 below.

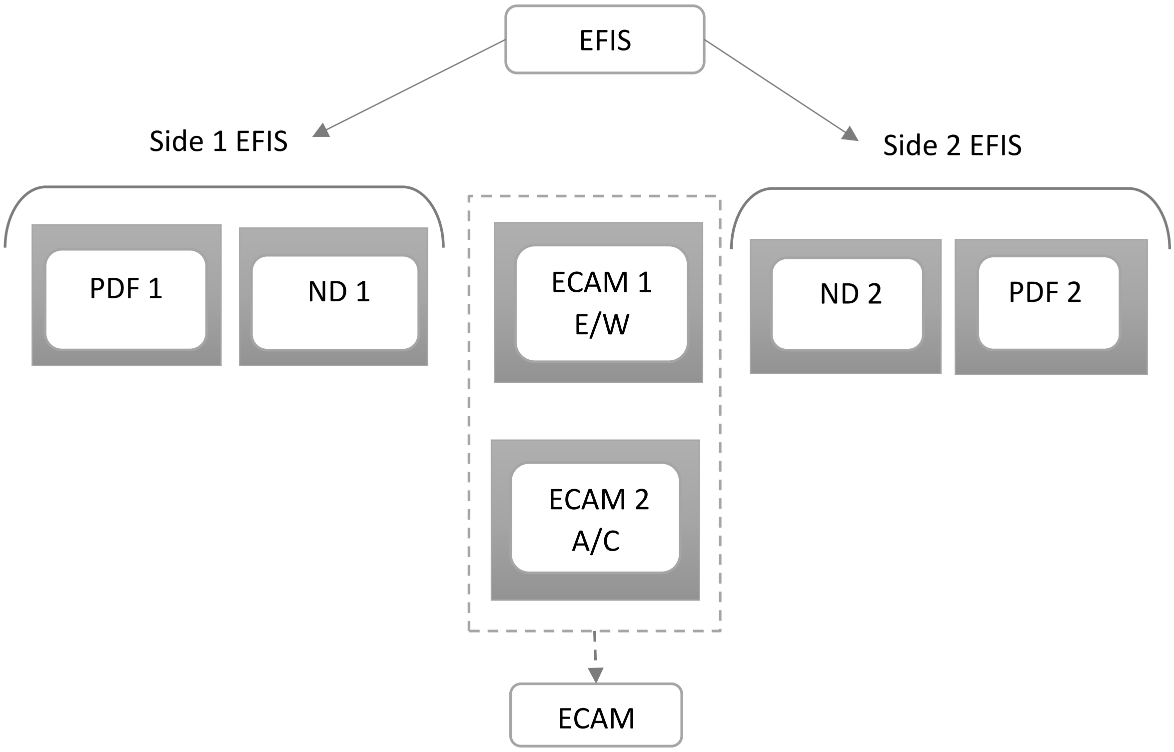


Figure 7: FCDU Function components

The FCDU is used in the Electronic Instrument System (EIS). This system is connected with most of the aircraft systems to carry out the two following main display functions:

- The Electronic Flight Instrument System (EFIS): Flight and navigation information for the crew

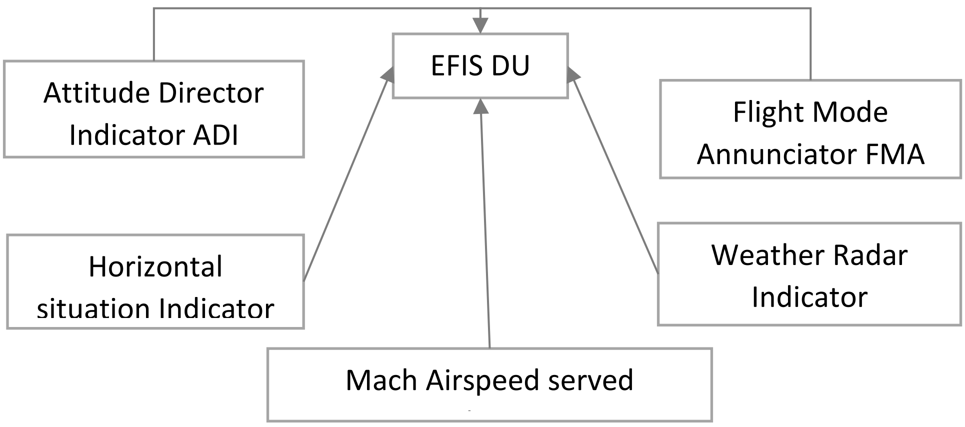


Figure 8: EFIS functions chart

- The Electronic Centralized Aircraft Monitor (ECAM): information concerning normal and abnormal stated of the aircraft systems. In fact, the UPPER ECAM is responsible of the engine and warning data and the LOWER ECAM shows system and status of the aircraft.

2.1.3 FCDU identification

The display Unit is identified on the rear panel by an identification label illustrated in the figure 9 below.

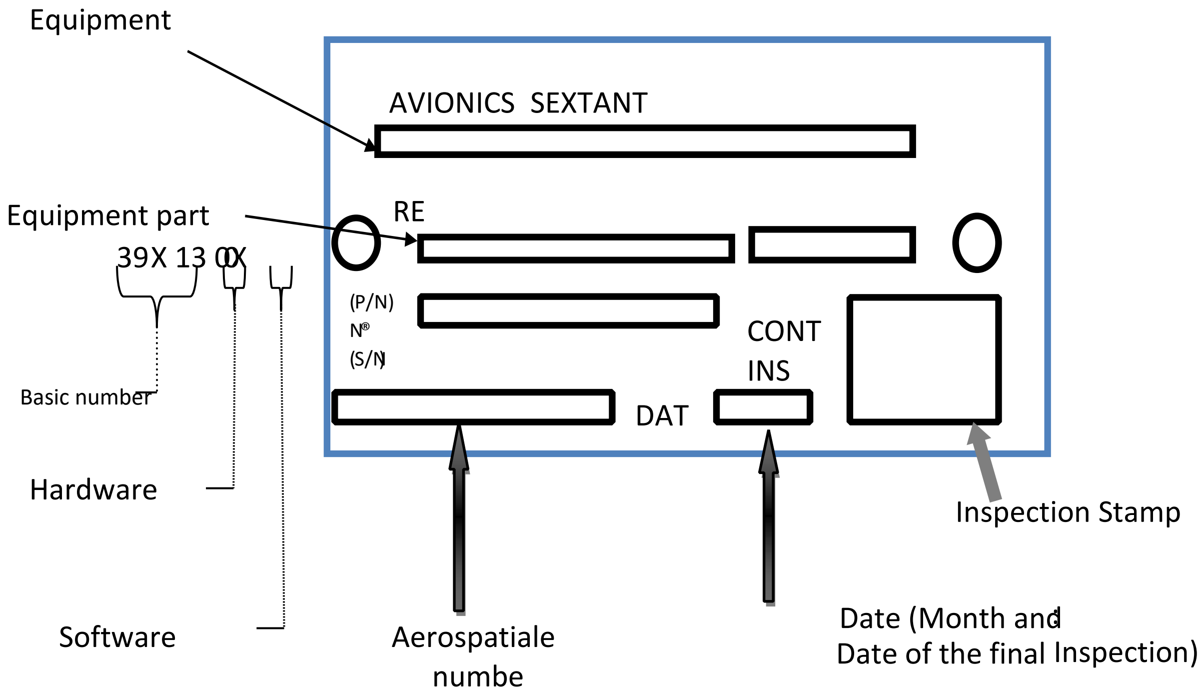


Figure 9:Identification label of the FCDU

We identify every FCDU equipment presented in the workshop by a part number and a serial number. Every equipment should have a specific serial number of determined part number. More precisely, two different equipment can have the same part number but cannot have the same serial number. [6]

In the Radio-navigation and communication workshop we have 4-part-numbers for the FCDU each part number have different number of serial-numbers stated as below;

Table 4: Part numbers of the FCDU

3906130302	3906130402	3907130302	3907140302
46 serial-number	7 serial-number	1 serial-number	49 serial-number

2.2 System configuration

Safety during flight is a fundamental need, thus like every avionic system the full color display unit have a specific configuration in which the captain can modify it due to any modification during the flight [5]. The figure 10 below illustrates different links and connection between the displays and systems of the FCDU.

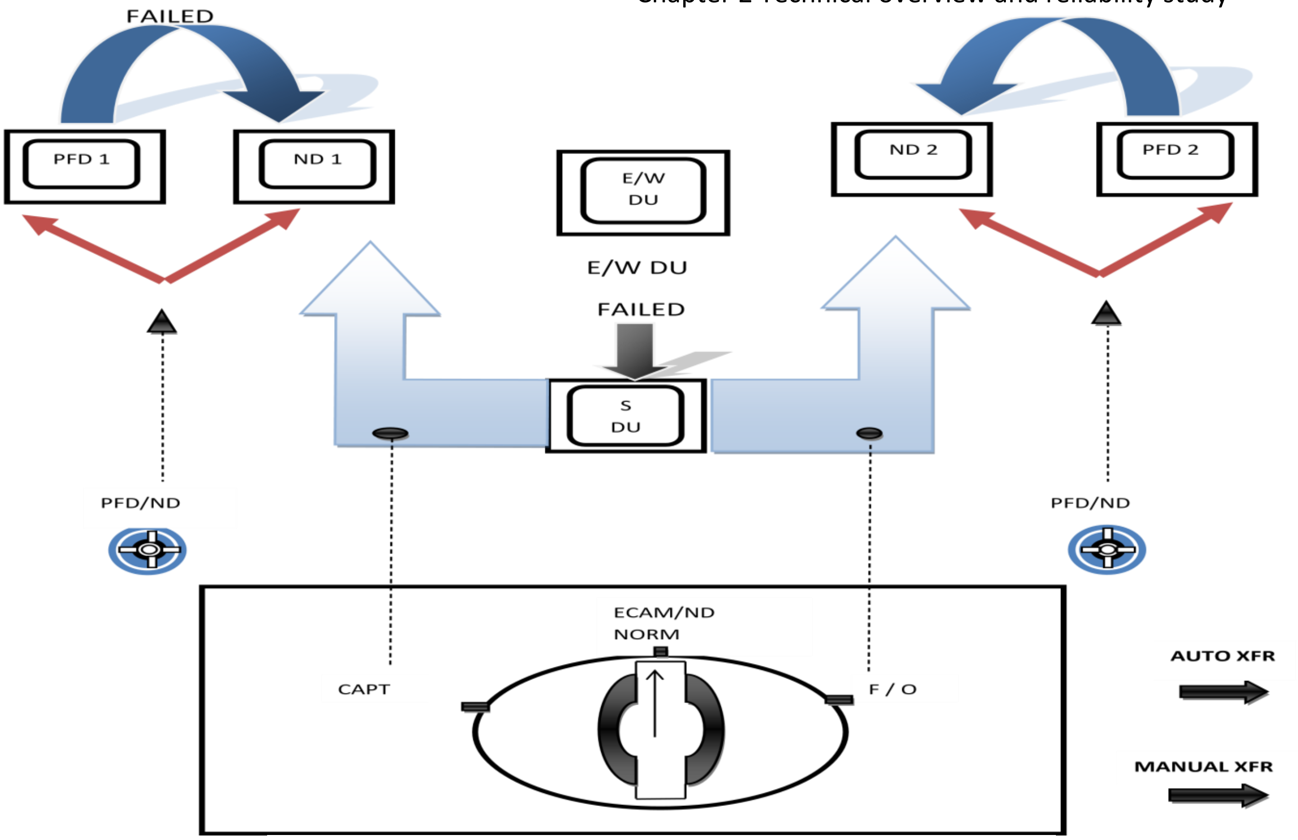


Figure 10: FCDU system configuration

2.2.1 Normal configuration mode

In normal flight condition, the data management computer drives its corresponding displays through their normal input. Additional, one data management computer is in standby for the case in which one of the DMC 1 or 2 fails.

Furthermore,

- the DMC 1 drives the PFD 1, ND 1, UPPER ECAM through their normal input N
- the DMC 2 drives the PFD 2, ND2, LOWER ECAM through their normal input N
- DMC 3 is in standby

2.2.2 Failure configuration mode

If one of display unit fails during flight, the full color display unit allows the captain as well the second officer to switch between displays through a link. This transfer of data can be activated either automatically in case of detected failure or manually by the pilot. Every case of failure will be broken down in details. [7]

2.2.2.1 PFD failure

In case of detected failure of the display normally showing the PFD image, there will be an automatic PFD-ND transfer. The PFD will be presented on the display normally showing the ND image. This transfer will be automatically by means of a direct signal generated by the DMC upon recognition of the failure. Furthermore, the PFD-ND transfer can be manually by pressing the PFD-ND XFR push-button as shown in the configuration figure. This action will cross-change the images between the PFD and ND.

There is an inversion between the two images: the one which was displayed on the left display unit will be displayed on the right one and vice versa.

2.2.2.2 ND failure

In case of failure of the display normally showing the navigation display, the pilot can recover the display of the ND image on the remaining display normally showing the PFD image, by means of the PFD-ND transfer push-button

2.2.2.3 ECAM failure

In the event of UPPER ECAM display unit failure, the Engine/Warning display image will be displayed on the LOWER ECAM display unit instead of the system page or status message. This switching will be automatic: upon reception of the UPPER ECAM anomaly signal through the feedback bus, the DMC 2 ECAM channel processor will switch to an ECAM signal display configuration which will privilege the E/W processing. The LOWER ECAM display unit will receive the E/W image from the DMC 2.

Additionally, the FCDU have an ECAM-ND transfer XFR selector which each pilot can switch his ND display with the LOWER ECAM of system and status image. Obviously, he can at any time get his ND image back by setting the selector back to NORM.

In the event of failure of both upper and lower ECAM displays, each pilot can recover the E/W image on his ND by means of the ECAM-ND transfer selector. In this case, the pilot having the E/W image on his side can temporarily replace it by A/C system and status image by keeping the related push-button on the ECAM CAPT.

2.3 Display unit characteristics

The display unit is identical for each display either it is PFD or ND or ECAM display. In fact, the FCDU consist of 6 identical full color displays which have the following characteristics [6]. The figure number 11 below shows a 3D picture illustrating the presented dimension of the display unit.

- Dimensions:
  - Unit: 184mm × 184mm × 355mm
  - Screen: 147mm × 147mm with a diagonal of 197mm
  - Working area: 143mm × 143mm with a diagonal of 192mm
- Weight: 10 kg (22lbs)
- Consumption: 160 watts MAX

Figure 11: Display unit in 3D dimension [7]

2.4 Unit breakdown

The display unit is composed of several components in which each one has a specific role. In order to fully understand the display unit, we need to breakdown its components and identify its functionality.

We illustrated the figure below of the display unit functional breakdown the connection between different components which we will breakdown in detail in the following figure 12 below.

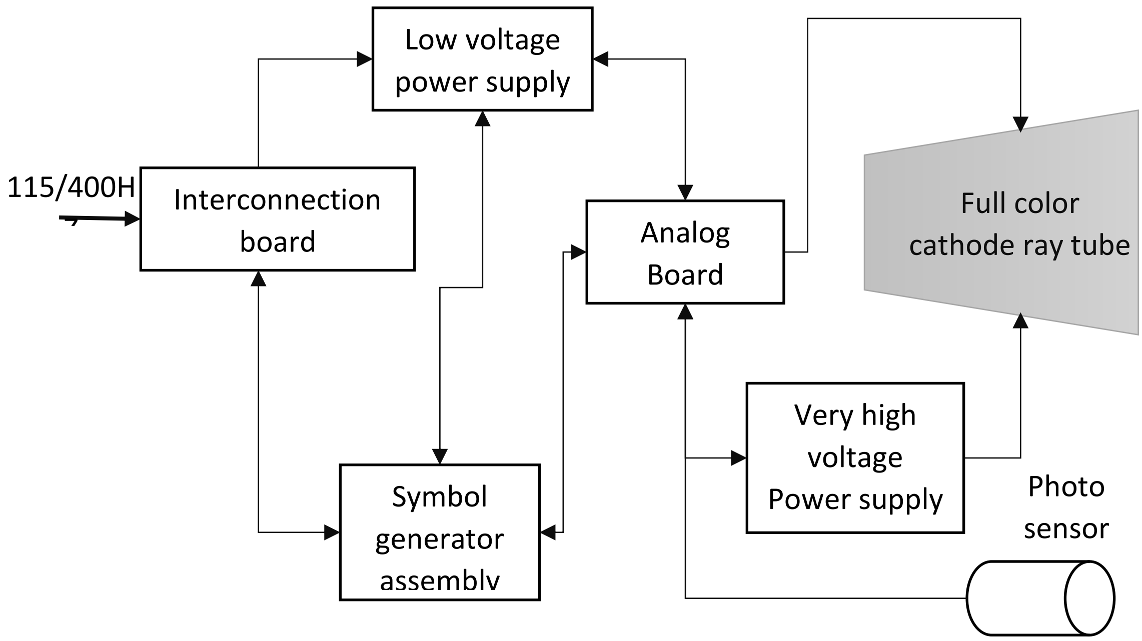


Figure 12: Display unit breakdown

2.4.1 Shadow-mask color Cathode ray tube

The CRT assembly is made up of a high-resolution shadow mask CRT with high contrast black matrix screen, a degaussing oil, deflection coils and beam benders. It is constituted with prevision in line and self-convergent design to reduce the number of static and dynamic convergence adjustments and increase color purity. It has been designed to operate under difficult conditions with particular regard to vibration, temperature and humidity.

The CRT is linked to the equipped structure with a metallic clip to keep a mechanical reference and is provided of all voltages required by the very high voltage power supply board (VHVPS) which located on the lower part of the display unit.

2.4.2 The low voltage power supply board (LVPS)

It generates from the aircraft 115V A/C 400Hz supply, all low voltage power supplies for the full color display unit. We identify all voltages and its uses in the table below:

Table 5: Low voltages in the power supply board in the FCDU

Cathode amplifier	THT	Digital board	Analogic circuit	Memory protection	Derivation amplifiers
+100 V	+25V	+5V	+15V/-15V	+5V	+34V/+17V/-17V

2.4.3 The symbol generator board (SG)

There are two symbol generator versions which can be installed on the equipment, either the V05 or the V03 version.

- The V03 version contains two major parts:

Firstly, we have the symbol generator memory board (SGMB) which contains the main memory, the position and color conversion circuits, the dedicated serial data link (DSDL) liaison and is responsible for the management of masks and radar function.

Secondly, we have symbol generator board (SGB) which contains an interpolator, a clock, graphic CPU and color economizer management circuits.

Globally, the symbol generator memory board acts as the mother-board on which is mounted the symbol generator board.

- The V05 version contains three main parts:

Firstly, we have a DMC interface block based on a dedicated derail data link function and a radar function.

Secondly, we have a symbol generator block based a global systems mobile (GSM) memory function

Finally, we have a video-deflection block.

2.4.4 The analog board

The analog board controls the operation of a shadow mask type CRT in conjunction with signals from the symbol generator. It includes furthermore;

- Deflection circuits for correction and amplification
- Video circuits containing a CRT cathode amplifiers
- Convergence correction circuits
- Brightness and defocusing controls

Monitoring and protection circuits for input monitoring, generation of orbiting signals, generation of a test patter, CRT protection and analog anomaly detection.

2.4.5 Interconnection board

There are two type of interconnection board. The first one provides the electrical link between

- Interconnection board, low voltages power supply board, the symbol generator and the analog board
- Rear equipment connector and equipment board

And the second one provides the lightning protection of the 115V/400Hz generated by the low voltage power supply and display unit. The two types of interconnection board are interchangeable and have the same mechanical and electrical interfaces.

3. Reliability study

3.1 Use and purpose of reliability study

System reliability is an important non-functional requirement whose satisfaction is even crucial for mission critical systems. However, the increase in both system complexity and accuracy required in the reliability analyses often makes inadequate traditional techniques which are mainly based on statistical and probabilistic tools and on the hierarchical decomposition of the system in terms of its components.

In the aviation industry, the delay in maintaining or recovering aircrafts heavily impacts the profit of an airline company. Consequently, the maintenance actions identification and planning of aircrafts is crucial [8]. However, due to the complexity of the domain in terms of data sources, distributed systems and information availability, it is hard to provide automatic maintenance support. As a results, the use of reliability and validity are common in quantitative research in order to evaluate the maintenance strategic plan thus it is reconsidered in the avionic field as one of the supreme tools to evaluate the function of an equipment.

3.2 Study approach

In aerospace industry, MTBR (Mean Time Between Removals), MTBF (Mean Time Between Failure) and MTBUR (Mean Time Between Unscheduled Removals) are generally used for reliability analysis. This is also the case of the avionic overhaul department in which we use these parameters to evaluate the reliability of an equipment.[9]

3.2.1 MTBR, MTBF and MTBUR definitions

The Mean time between repair (MTBR) is one of several related metrics that helps to provide information on operating reliability for avionic products and systems. MTBR is often defined as the average operating calendar time between required repairs for a given product or set of products.

In the other hand, MTBF (Mean Time Between Failures) is an important indicator when it comes to availability of an application. It is a metric that concerns the average time elapsed between a failure and the next time it occurs. These lapses of time can be calculated by using a formula. However, MTBUR (Mean Time Between Unscheduled Removals) concerns the average time elapsed between two unscheduled removals in which the failure is not yet confirmed.

3.2.2 The difference between MTBR, MTBUR and MTBF

For MTBR specifically, the protocol for this measurement seems to be counting the necessary instances of repairs during a given time period and dividing the latter number by the former mean time between repairs differs from MTBF. Whereas the MTBF typically counts only how long a product operates before failure, whereas MTBR would inherently include the time spent on repair, which can make a big difference in the final outcome. In the other hand, the mean time between unscheduled removals focus on all unscheduled removals without indicating either the cause of this removals is a confirmed failure or not. However, the mean time between failures only takes in consideration confirmed failure.[10]

Furthermore, the removals can be caused by a failure however the equipment is functional with no errors on the testing machine. This is due the difference between real life flight condition and the testing machine. This limitation is taken on consideration which stipulates the use of all three metrics in order to guarantee a complete analysis on the reliability of the full color display unit.

3.3 Reliability analysis calculation

This study is based on the 4 part-numbers of the full color display unit presented in the avionic overhaul department for the years from 2017 up until 2021.

In order to establish this analysis, we need to determinate several variables such as the amount of equipment in the aircraft, flight hours and number of FCDU removals in each year. Using AMASIS (aircraft maintenance and spares information system) we can access the data base of each aircraft as well each avionic equipment using its part-number and serial-number.

3.3.1 Determination of flight hours for the studied aircraft fleet

As mentioned previously, in this paper we only focus on the fleet of Tunisair of Airbus aircraft only which is composed of 17 A320 and 2 A330. Using AMASIS, we were able to determinate the flight hours of each aircraft presented in the annexes number 1. Using this data presented in the annexes number 1, we were able to determinate the average flight hours per aircraft for each year as well total flight hours per aircraft for total studied years. We present calculated results through the table 6 below;

Table 6: Average flight hours calculation

Aircraft fleet =19	2017	2018	2019	2020	2021	2022
Average Flight Hours Per Fleet	586636,4	630657	672277,7	715905,8	749000	784606
Average Flight Hours Per Aircraft	30875,6	33192,5	35383,04	37679,2	39421	41295
Annual Average Flight Hours Per Aircraft	2017	2018	2019	2020	2021	
	2316,92	2190,52	2296,21	1741,78	1874	

3.3.2 Removals determination for the FCDU

The maintenance schedule in the aviation industry is very precise and determined in which for each equipment we can elaborate 2 types of removals for any equipment;

- Programmed removals: these removals are determined by the maintenance schedule of aircraft in which we have the exact time of removals as well as the precise task to elaborate for the equipment by a determined qualified technician. This type of removals is a precaution test determined by the constrictor in which the airline should follow according to a suited schedule.
- Non-programmed removals: these removals are not schedule nor expected it can be during flight or during the pre-flight check. Furthermore, we have two-types of non-programmed removals in which; confirmed failure or non-confirmed removals.

Facing a non-programmed removal for an equipment, the avionic overhaul department receive the failed equipment and run it through test to determinate the exact problem and repair the problem. If the test can determinate the exact problem than this removal is called a confirmed removal or failure. However, if the testing bench cannot determinate the exact problem of an equipment it is called a non-confirmed removal. This is due to difference between the real flight conditions and the testing bench. Some unexpected failures can only be determined through real live flight condition. We managed to extract the history of non-confirmed removals presented in the annexes number 2.

In order to have a precise analysis of reliability for the FCDU, we need to take all these types of removals into consideration and determinate the different number of all removal's types. Using AMSIS we were able to access the date base of each full color display unit in which we have different part-numbers and 103 different serial-numbers We were able to determinate the removals history of each FCDU for the studied years from 2017 to 2022. We mentioned obtained results in the annexes number 3 and we summarized the total number of removals through the table below.

Table 7: Number of every type of removals for each studied year

2017	Total removal number	Scheduled removal	Unscheduled removal	confirmed removals	NON-Confirmed removals
	31	6	25	24	1
2018	Total removal number	Scheduled removal	Unscheduled removal	confirmed removals	NON-Confirmed removals
	36	10	26	24	2
2019	Total removal number	Scheduled removal	Unscheduled removal	confirmed removals	NON-Confirmed removals
	38	16	22	22	0
2020	Total removal number	Scheduled removal	Unscheduled removal	confirmed removals	NON-Confirmed removals
	18	6	12	12	0
2021	Total removal number	Scheduled removal	Unscheduled removal	confirmed removals	NON-Confirmed removals
	3	1	2	2	0

3.3.3 Reliability calculus for each year

- For the year 2017 we have;

Table 8: Variables of the year 2017

Annual average flight hours per aircraft	Amount of equipment per aircraft	Total removal number	Scheduled removals	Unscheduled removals	confirmed removals	NON-Confirmed removals
2316,92	6	31	6	25	24	1

Using the following formula for each reliability metrics, we have;

- MTBR = mean time between removals

$$MTBR = \frac{AC\ hrs \times Qt}{TNR} = \frac{(2316{,}92 * \ 6)}{31} = 448.4361$$

- MTBUR = mean time between unscheduled removals

$$MTBUR = \frac{AC\ hrs \times Qt}{NUR} = \frac{(2316{,}92 * 6)}{25} = 556.0603$$

- MTBF= mean time between failure

$$MTBF = \frac{AC\ hrs \times Qt}{CR} = \frac{(2316{,}92 * 6)}{24} = 579.23$$

- For the year 2018 we have;

Table 9: Variables of the year 2018

Annual average flight hours per aircraft	Amount of equipment per aircraft	Total removal number	Scheduled removals	Unscheduled removals	confirmed removals	NON-Confirmed removals
2190,52	6	36	10	26	24	2

Using the following formula for each reliability metrics, we have;

- MTBR = mean time between removals

$$MTBR = \frac{AC\ hrs \times Qt}{TNR} = \frac{(2190{,}52 * 6)}{36} = 365.0866$$

- MTBUR = mean time between unscheduled removals

$$MTBUR = \frac{AC\ hrs \times Qt}{NUR} = \frac{(2190{,}52 * 6)}{26} = 505.5046$$

- MTBF= mean time between failure

$$MTBF = \frac{AC\ hrs \times Qt}{CR} = \frac{(2190{,}52 * 6)}{24} = 547{,}63$$

- For the year 2019 we have;

Table 10: Variables of the year 2019

Annual average flight hours per aircraft	Amount of equipment per aircraft	Total removal number	Scheduled removals	Unscheduled removals	confirmed removals	NON-Confirmed removals
2296,21	6	38	16	22	22	0

Using the following formula for each reliability metrics, we have;

- MTBR = mean time between removals

$$MTBR = \frac{AC\ hrs \times Qt}{TNR} = \frac{(2296{,}21 * 6)}{38} = 362.5594$$

- MTBUR = mean time between unscheduled removals

$$MTBUR = \frac{AC\ hrs \times Qt}{NUR} = \frac{(2296{,}21 * 6)}{22} = 626.2390$$

- MTBF= mean time between failure

$$MTBF = \frac{AC\ hrs \times Qt}{CR} = \frac{(2296{,}21 *\ 6)}{22} = \ 626.2390$$

- For the year 2020 we have:

Table 11: Variables of the year 2020

Annual average flight hours per aircraft	Amount of equipment per aircraft	Total removal number	Scheduled removals	Unscheduled removals	confirmed removals	NON-Confirmed removals
1741,78	6	18	6	12	12	0

Using the following formula for each reliability metrics, we have;

- MTBR = mean time between removals

$$MTBR = \frac{AC\ hrs \times Qt}{TNR} = \frac{1741{,}78 *\ 6}{18} = 580.5933$$

- MTBUR = mean time between unscheduled removals

$$MTBUR = \frac{AC\ hrs \times Qt}{NUR} = \frac{1741{,}78 *\ 6}{12} = 870.89$$

- MTBF=mean time between failure

$$MTBF = \frac{AC\ hrs \times Qt}{CR} = \frac{1741{,}78 *\ 6}{12} = \ 870.89$$

- For the year 2021 we have;

Table 12: Variables of the year 2021

Annual average flight hours per aircraft	Amount of equipment per aircraft	Total removal number	Scheduled removals	Unscheduled removals	confirmed removals	NON-Confirmed removals
1874,00	6	3	1	2	2	0

Using the following formula for each reliability metrics, we have;

- **MTBR = mean time between removals**

$$MTBR = \frac{AC\ hrs \times Qt}{TNR} = \frac{1874{,}00 *\ 6}{3} = 3748$$

- **MTBUR = mean time between unscheduled removals**

$$MTBUR = \frac{AC\ hrs \times Qt}{NUR} = \frac{1874{,}00 *\ 6}{2} = 5622$$

- **MTBF= mean time between failure**

$$MTBF = \frac{AC\ hrs \times Qt}{CR} = \frac{1874{,}00 *\ 6}{2} = 5622$$

3.3.4 Reliability results and interpretation

We were able to summarize the calculated results of the 3 reliability indicators through the table below and the evolution of each indicator through the studied years;

Table 13: Reliability indicator results

Reliability Indicator	2017	2018	2019	2020	2021
MTBR	448,436	365,087	362,559	580,593	3748,000
MTBUR	556,060	505,505	626,239	870,890	5622,000
MTBF	579,230	547.63	626,239	870,890	5622,000

Furthermore, we illustrated the evolution of each calculated reliability indicator through the studied years through graphs below;

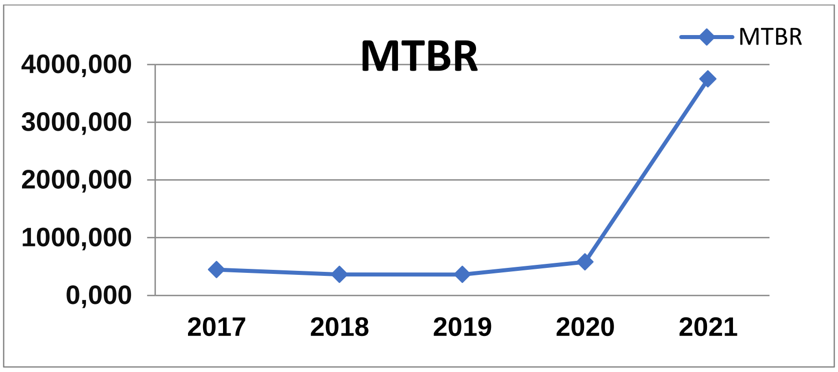


Figure 13: MTBR evolution from 2017 to 2021

In fact, the figure 13 illustrate the evolution of the MTBR from the year 2017 to the year 2021 in which we can relate that the MTBR was continuously constant for the first 4 years from 2017 up to 2020 in which we can determinate the lowest MTBR rate of 365.087. this is the consequence of having the highest number of removals in 2018 of 36 total removals in a single year.

Contrary to 2018, the year 2021 represents the highest MTBR rate of 3748 which indicates a sudden increase of proximally 6,5 times from the previous year. This due the low number of total removals in the year 2021 of only 3 removals.

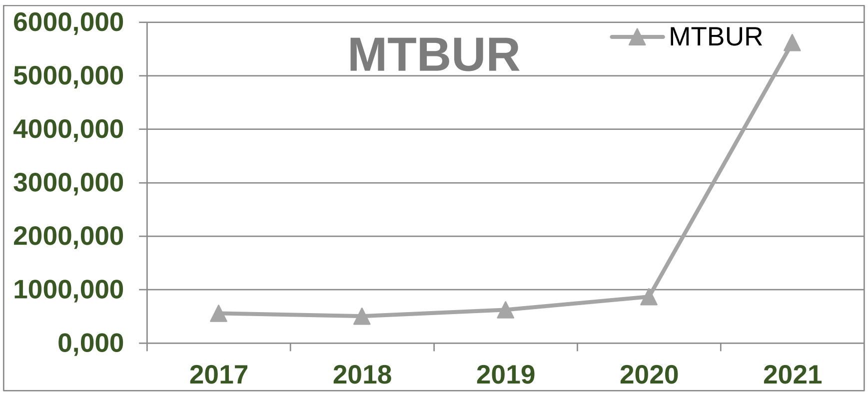


Figure 14: MTBUR evolution from 2017 to 2021

As well, in the figure 14 which indicates the evolution of the MTBUR from the year 2017 to the year 2021 in which we can relate that the MTBUR was continuously constant for the first 4 years from 2017 up to 2020.

Furthermore, we can determinate the lowest MTBUR rate of 505,5050 in the year 2018. this is the consequence of having the highest number of unscheduled removals in 2018 of 26 unscheduled removals from a total 36 removals.

Contrary, the year 2021 represents the highest MTBUR rate of 5622 which indicates a sudden increase of proximally 6,5 times from the previous year. This due the low number of total removals in the year 2021 of only 2 unscheduled removals from a total of 3 removals.

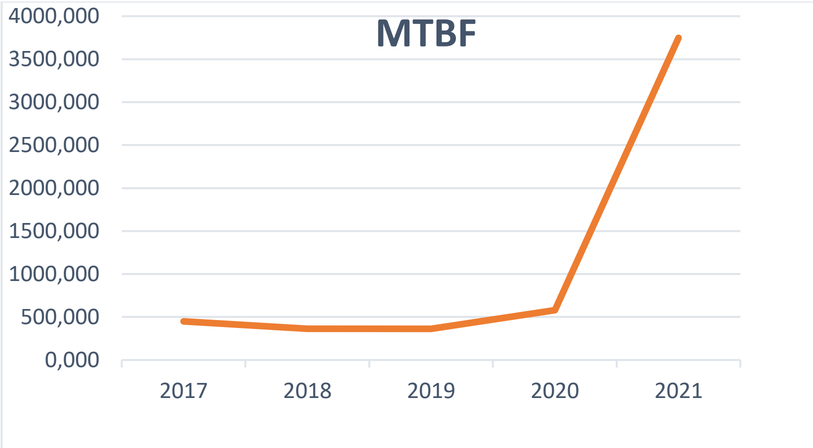


Figure 15: MTBF evolution from 2017 to 2021

Additionally, the figure 15 represents also the evolution of the MTBF through the studied years from 2017 up to 2021 in which we can relate that the MTBUR was continuously constant for the first 4 years from 2017 up to 2020.

Furthermore, we can determinate the lowest MTBF rate of 547.63 in the year 2018 contrary to the MTBR and MTBUR evolution graph. Despite having equal number of confirmed removals of 24 confirmed failure in 2017 and 2018. However, the lowest rate was in 2018 due to difference of the flight hours where it is less in 2018 for only 126,4 hours. From the year 2019 up to year 2021, we can notice that the MTBUR and the MTBF graph are exactly equals. This is the consequence of the number of non-confirmed removals in which have none from the year 2019 up to 2021.

3.3.5 Results evaluation

Each year, the constrictor of every avionic equipment fixes reliability references for the mean time between unscheduled removals in which every maintenance center should compare the yearly calculated MTBUR in order to compare it to the reference value. In our case, AIRBUS has fixed MTBUR for the studied years which we extracted from AIRBUS reliability annual report and illustrated in the table below;

Table 14: Worldwide fleet MTBUR from the years 2017 to 2021

WWF MTBUR 2017	WWF MTBUR 2018	WWF MTBUR 2019	WWF MTBUR 2020	WWF MTBUR 2021
18372	19962	23126	26372	27258

Every year, we have three different type of cases which we presented through the table below.

Table 15: WWF MTBUR results cases

MTBUR equal or superior to WWF	**FCDU is either new or highly maintained in a superb navigable state**
MTBUR near to WWF	**FCDU is highly used but still reliable**
MTBUR below WWF	**FCDU is not reliable and must be examined or changed**

In comparison with the WWF, we have that calculated MTBUR for each studied year is much less than desired references values. Calculated results shows that FCDU is not a reliable equipment despite some of the studied equipment are brand new.

$$\text{MTBUR} << \text{WWF}$$

Based on the worldwide fleet results, it is clear that the full color display unit has presented unreliability during the studied year from 2017 to 2021.

4. Conclusion

In this chapter, we presented the major composing elements of the full color display unit by breaking down every component which allowed us to comprehend the functionality and important role played during everyday flight. However, this equipment has shown a high failure rate which caused many aircraft on ground events. Furthermore, the study clearly shows the unreliability of this equipment during the years from 2017 to 2021 which presents a major problem for the firm and the avionic overhaul department more precisely.

chapter 3 Failure mode and effect analysis and solution proposition

1. Introduction

In this chapter, we aim to establish a failure mode and effect analysis with the intension to determinate the cause of the unreliability of the full color display unit calculated in the chapter 2.

Based on this analysis we aim to priories the failures and trat the major problems with the purpose to find efficient solutions to overcome this problem and enhance the reliability of this equipment.

2. Failure Mode and Effect Analysis

2.1 Use and purpose of FMEA

FMEA titled Procedures for Performing a Failure Mode, Effects and Criticality Analysis, is a systematic method of identifying and preventing system, product and process problems before they occur. It focusses on preventing problems, enhancing safety, and increasing customer satisfaction.

The purpose of the FMEA is to develop, evaluate and enhance the design, development and testing methodologies to achieve the elimination of failures and thus obtain world-class competitive products [11]. As a result, the FMEA method contributes in the reduction of costs, with a critical impact on warranty returns, the reduction of the time needed from the project phase to the market launch and the improvement of the quality and reliability of the products, while increasing the safety of their operation.

As a conclusion, the ultimate goal for attaining these benefits is the increase of customer satisfaction, which assures the growth of the organization's competitively and the improvement of the image on the market.

2.2 Different types of FMEA

FMEA can be classified based on the nature of application. We have 3 types of applications for the FMEA study. Ideally, the analysis begins during the earliest conceptual stages of design and continues throughout the life of the product or service. On the other hand, it can be used during the design stage with an aim to avoid future failures. Later it is used for process control, before and during on-going operation of the process. We break down these 3 types into the three basic types as shown in the diagram in the figure number 16 below.[12]

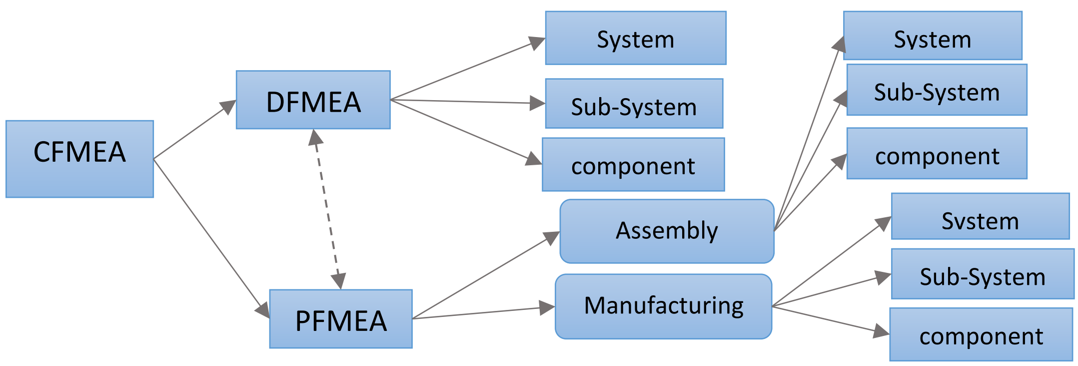


Figure 16: FMEA types of application

2.2.1 Concept FMEA (CFMEA)

The concept FMEA is used to analyze concept in the early stages before hardware is defined (most often at system and subsystem level). It focuses on potential failure modes associated with the proposed functions of a concept proposal.
This type of FMEA includes the interaction of multiple systems and interaction between the elements of a system at the concept stages.

2.2.2 Design FMEA (DFMEA)

This type of FMEA has the purpose of identification and prevention of failure modes of products, which are related to their design, in order to validate the established design parameters for a specific functional performance level, at system, subsystem or component level.

The most important function of this type of FMEA is the identification in the early stages of design development of the potential failure modes in order to eliminate their effects, select the optimal design variant and develop a documentary base to support future designs in order to minimize the risks that faulty products reach the customers.

2.2.3 Process FMEA (PFMEA)

This type of FMEA focuses on potential failure modes of the process that are caused by manufacturing or assembly process deficiencies. Process FMEA is of two types are Manufacturing FMEA, and Assembly FMEA. In Manufacturing FMEA the failure modes are generally dimensional or visual. While in Assembly FMEA these are generally relational dimensions, missing parts, parts assembled incorrectly.

2.3 FMEA process approach

Failure Mode and effect analysis is based on the approach shown in the diagram of the figure below.

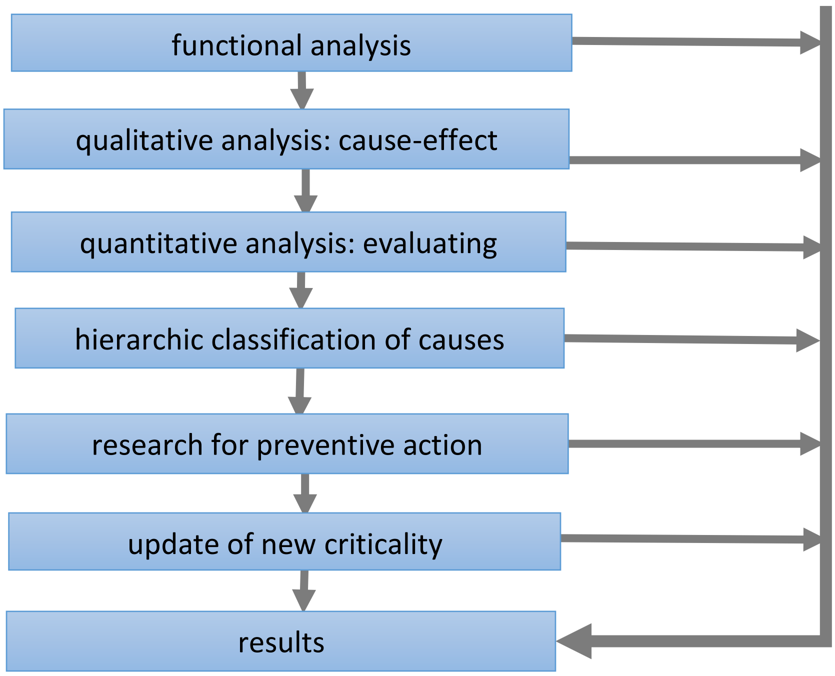


Figure 17: FMEA steps approach

3. FMEA study

3.1 Functional analysis:

A failure is the degradation or disappearance of a function of a product. Functional analysis identifies the main functions of the product as well as constrained and elementary functions.

The functional analysis is divided into 3 phases:

Firstly, we clearly define the requirement. Secondly, Define the functions of the system. Finally, establish the function tree. This is a set of main functions, sub-functions.

3.1.1 analysis of values

This diagram in the figure below aims to answer 3 main questions:

- Who/what does the product serve?
- On whom/what does it act?
- For what purpose?

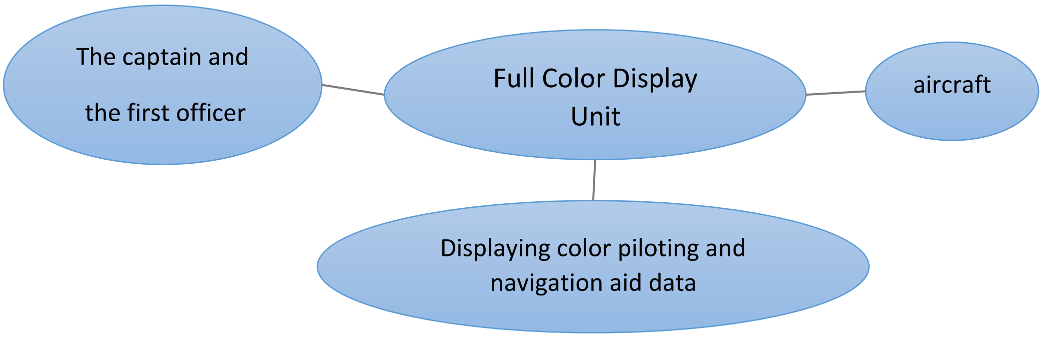


Figure 18: Chart of analysis of values

3.1.2 Functionality Tree of the FCDU

The flowchart below in the figure 19 aims to illustrate the different functions of the full color display unit through the functionality tree;

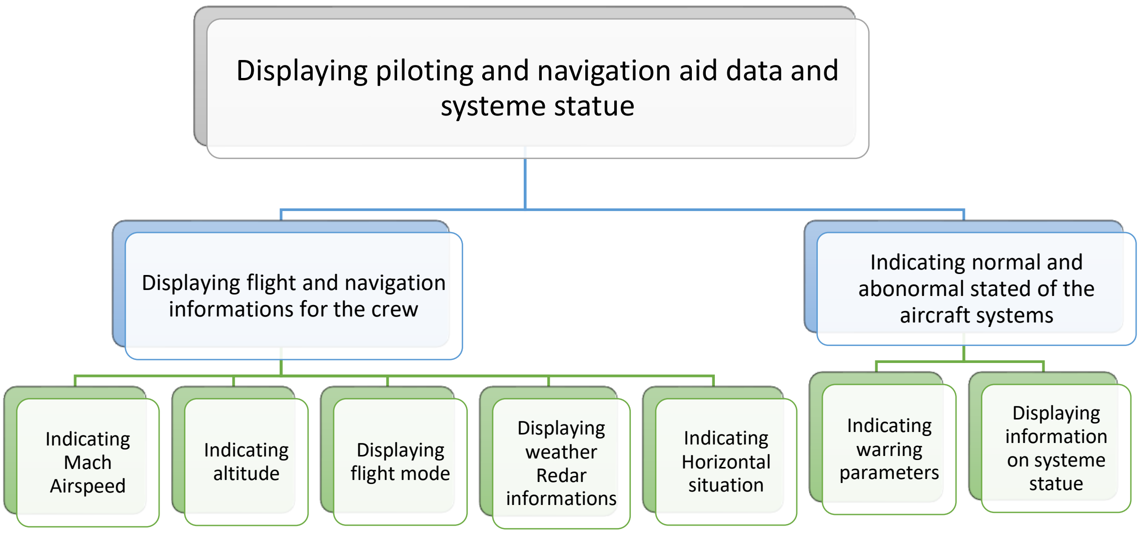


Figure 19: Functionality tree of the FCDU

3.2 Qualitative study of failures

This study consists of identifying all possible failures, determining the failure modes, identifying the effects, analyzing and determining the possible or probable causes. Using AMASIS, we were able to access the data base; presented in the annexes 3; of all the failure that occurred for each FCDU and the repair made. We extracted 76-serial numbers for 4-part numbers registered for the full color display unit.

In order to identify the cause of every failure we used AMASIS to check for every procedure of repair done for each serial number of the FCDU. Thus, we determined the spare part and replacement equipment for each emplacement of failure in the full system. We illustrated the cause of every failure in the table 16 below;

Table 16: FCDU failure causes

Failure	cause of failure
CRT Failure	Embossed display: high intensity that makes the display branded. Flight hours: If flight hours are between 12000 hours and 20000 which is responsible of drop-in the quality of the image. If flight hours are higher than 20000 then it should be replaced according to the constructor
Inter-communication card failure	electrical short circuit between the mother-board and the inter-communication card
Power supply board Failure	2,5 A fuse disfunction / variable resistor failure / 35V current disconnect / 5V failure
SG card Failure	software failure / can't access to the data from the DMC
Analogue card Failure	Brightness problem: set the brightness for maximum levels for a long period of time or constantly switching from day to night mode and vice versa. Colors problem: the colors fade after a flight hour. Life expectancy has been reached.
THT Failure	electrical short circuit

3.3 Quantitative study

This analysis is an estimate of the criticality index of the triplet cause-mode-effect of the failure under consideration. Different criteria can be used to determine the criticality index. Generally, the failure is considered more important if:

- its consequences are severe
- the frequency is high
- the problem occurs and there is a risk that it will not be detected.

As a results, we assign 3 criteria below;

- G for Gravity of the failure
- O for the number of occurrences of the failure
- D for the non-detection of the failure

The criticality index C is obtained by multiplying the 3 criteria.

$$C = G \times O \times D$$

3.3.1 Gravity of failure

We assign for every possible cause of failure a number between 1 up to 10 in which we describe the gravity of the failure based on the consequence and the effect of the failure.

We illustrated the gravity of each failure through the table 17 below;

Table 17: Gravity of each cause of failure

Possible cause of failure	G
Embossed display: high intensity that makes the display branded.	7
If flight hours are between 12000 hours and 20000 which is responsible of drop-in the quality of the image. If flight hours are higher than 20000 then it should be replaced according to the constructor.	10
electrical short circuit between the mother-board and the inter-communication card.	10
2.5A fuse disfunction.	10
Variable resistance failure.	10
35V current disconnection / 5V cutoff.	10
software failure.	5
can't access to the data from the DMC.	5
Brightness problem: set the brightness for maximum levels for a long period of time or constantly switching from day to night mode and vice versa.	7
colors problem: colors fade after a high number of flight hours.	7
Life expectancy has been reached.	3
electrical short circuit.	7

3.3.2 Occurrence of each failure:

Using AMSIS we were able to extract the history of failures presented in the annexes 4 in which we were able to determine the occurrence of each failure.

Table 18: Occurrence for each failure

Failure mode	CRT	Intercommunication card	Power supply board	SG card	Analogue card	THT
failure occurrence	18	6	20	8	20	4

We assignee for each failure a number from 1 to 10 based on the level of occurrence of each failure. We present the level of occurrence of each failure through the table below

Table 19: Assigned levels of occurrences

[4;6[	[6;8[	[8;10[	[10;12[	[12;14[	[14;16[	[16;18[	[18;20[	[20;22[
2	3	4	5	6	7	8	9	10

3.3.3 Detection of Failure

The detection of the failure is guaranteed once we run the system on the ATEC machine which provides a full detailed diagnosis for the equipment as well as indicating the emplacement of the failure.

Thus, the possibility of non-detection is zero. As a result, we assign D=1 for all failures.

3.4 FMEA results

To summarize all calculation explained previously, we intend to illustrate each detected failure with its following effect as well as its possible cause in the table number 20 below which we aim to mention the calculated criticality of each cause of failure.

As shown in the table of failure mode and effect analysis for each failure we have a variable effect number and for the same effect we may have different cause. Due to this diversity of failure yet similarity of effect it is impossible to treat every failure presented.

Thus, using the criticality metric in order to priories which failure should be treated first. As a results, in this paper we only intend to treat failures which criticality is more than 50 which We illustrated in the figure below

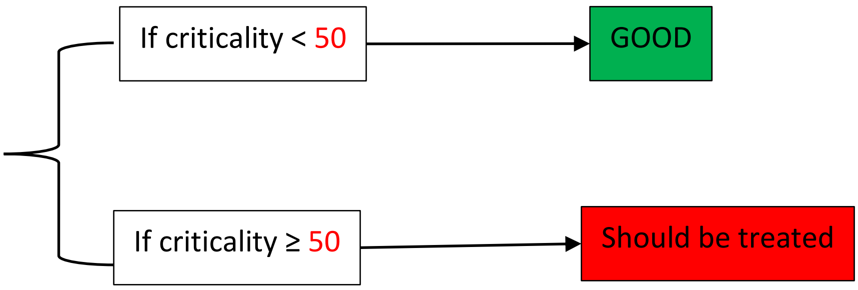


Figure 20: Criticality reference

In order to fully understand the origin of problem, we aim to fully diagnoses the modification history of the full color display unit by determining the service bulletin advised by the manufacture in order to specify the unapplied modification which have direct influence on the dysfunctionality of the equipment.

Table 20: FMEA table

Potential failure mode	Effect of Failure	Possible cause of Failure	Evaluation			
			Detection	Occurrence	Gravity	Criticality
CRT Failure	Brightness out of limit /works intermittently / Color Fail / Blurry image	Embossed display: high intensity that makes the display branded.	1	9	7	63
		If flight hours are between 12000 hours and 20000 which is responsible of drop-in the quality of the image If flight hours are higher than 20000 then it should be replaced according to the constructor	1	9	10	90
Intercommunication card Failure	Full Failure/ DU Failure/ ECAM Failure	electrical short circuit between the mother-board and the inter-communication card	1	3	10	30
Power supply board Failure	Full Failure/ DU Failure/ ECAM Failure/Brightness out of limit /works intermittently	2.5A fuse disfunction	1	10	10	100
		Variable fuse failure	1	10	10	100
		35V current disconnection / 5V cutoff.	1	10	10	100
SG card Failure	Full Failure/ DU Failure/ ECAM Failure	Software Failure	1	4	5	20
		can't access to the data from the DMC	1	4	7	28
Analogue card Failure	Brightness out of limit /works intermittently / Color Fail / Blurry image	Brightness problem: set the brightness for maximum levels for a long period of time or constantly switching from day to night mode and vice versa	1	10	7	70
		colors problem: colors fade after a high number of flight hours	1	10	7	70
		Life expectancy has been reached.	1	10	3	30
THT Failure	Full Failure/ DU Failure/ ECAM Failure	electrical short circuit	1	2	7	14

4. Service bulletin

4.1 Definition of service bulletin

A Service Bulletin (SB) is the document used by manufacturers of aircraft, their engines or their components to communicate details of modifications which can be embodied in aircraft.

If an available modification is judged by the manufacturer to be a matter of safety rather than simply product improvement, then these would be issued as an Alert SB in which case a corresponding Airworthiness Directive (AD).

4.2 Service bulletin history for the FCDU

Using the CMM of the full color display unit under the reference of 31-63-22-31 issued 2019, we were able to determinate a number of 58 SB for the part number 390613-31 issued from the year 1993 till the year of 2013. However, we identified 13 SB for the part number 390713-31 issued from the year 2000 to the year 2004.

This Service bulletin list presents multiple changes and modification advised by the manufacture in order to enhance the performance and functionality of the full color display unit. However, a great number of the SB list is not either launched by the engineering department nor applied by the avionic overhaul department. We present the full list of service bulletin in the annexes number 4.

4.2.1 Unlaunched service bulletin

In order to identify the non-launched SB, we used AMASIS presented in annexes 5, in order to determinate the history of the modification in which we have identified a number of 14 SB for the part number 390613-31 and only 1 SB for the part number 390713-31.

We illustrated the list of the unlaunched service bulletin for both part number in the tables presented in the annexes number 4 highlighted in red.

As we mentioned, for a total number of 71 service bulletin for the full color display unit, the engineering department hasn't launched a total of 15 SB which presents 21.126%. as shown is both tables all these modifications are linked to the power supply board, SG card, inter-communication card and analogue card. All this FCDU component have shown some major failures presented in the FMEA.

4.2.2 Unapplied service bulletin

Unfortunately, none of the launched service bulletin was applied by the avionic overhaul department which explains the important failure rate of the full color display unit.

In order to overcome this major problem, we aim to link the unapplied service bulletin to possible cause of failure presented in the FMEA study since the non-application of this modification presented by the manufactures may be an essential part of the cause of failures.

Table 21: List of unapplied SB linked to failures of FMEA study

Failure mode	unapplied SB
CRT Failure	Service Bulletin 390613-31-: -001 -006REV1 -007REV2 -008REV1 -009REV1 -019REV2 -023REV1 -024REV1
	Service Bulletin 390713-31-: -013
Power supply board Failure	Service Bulletin 390613-31-: -008REV2 -012REV2 -014 REV1
Analogue card Failure	Service Bulletin 390613-31-: -015REV2 -030 -033REV3 -036REV1 -038 -052 -056 -57REV1
	Service Bulletin 390713-31-: -009
SG card Failure	Service Bulletin 390613-31-: -004 -018 -025 -027 -027REV1 -028REV2 -029REV3 -035REV1 -050 -051 -053 -058 -059
	Service Bulletin 390713-31-: -001 -004 -005 -006REV1 -007REV1 -010 -011
Intercommunication card	Service Bulletin 390613-31-: -022REV2 -039REV2 -004

5. Solution proposition

5.1 Service bulletin application

Obviously, the full color display unit low performance rate is due to the lack of application of service bulletin advised by the manufacture which explains the non-reliability of the equipment showed chapter 2. In order to enhance the performance of the full color display unit, we oat to apply the unapplied service bulletin which can prevent a great number of failures occurred in the different component of the FCDU. Furthermore, the application of all service bulletin will improve the functionality and performance of all unit component as one SB can affect multiple component which will prevent as a result multiple causes of failures and reduce occurred failure effect.

However, the application of a total of 51 SB will take a great amount of time and cost a high price which may cause the firm some problems and more precisely the avionic overhaul department. In order to overcome this major problem, we advise the immediate application firstly of the service bulletin linked to the most occurred failures identified by the FMEA study and presented in the table 24 with the purpose of decreasing the failure rate of the FCDU in its most occurred major component failures. Thus, we intend to break down the SB list presented in table 24 in order to present the purpose of these applications.

5.1.1 CRT

For instance, the application of service bulletin related to the CRT failure will improve the performance of the full unit as well decrease the failure rate of the CRT precisely and the full unit globally.

Furthermore, the application of the SB 390613-31-006REV1 will enhance the quality of the image and improve the scanning rate of the frame presented by unit. additionally, the application of the SB 390613-31-007REV1 will improve the stability of the image by preventing the flicking problem on certain vectors as well as an improvement of the green and red lights adjustments.

In the other hand, the application of the list of SB 390613-31-008REV1 -009REV1 -019REV2 -023REV1 -024REV1 will reduce the failure as all this modification has improved the life expectancy of the full color display unit by reducing the electrical constraint affecting the life-time of the cathode ray tube and improving the setting circuits of the CRT. These modifications will instantly decrease the failure rate by resulting the occurred problems faced by the CRT.

5.1.2 Power supply board

The application of Service Bulletin 390613-31-: -008REV2 -012REV2 -014 REV1 related to the power supply board will improve the short power-interruption monitoring circuit and enhance the detection of the red gun detection circuit.

These modifications will secure all the full color display unit component related to the power supply board as the functionality of several component depends on the alimentation provided by the power supply board which will prevent several failing effects most importantly the intermediately functionality of display unit as well as several brightness failures cases.

5.1.3 Analogue card

The application of Service Bulletin 390613-31-: -015REV2 -030 and-056 will enhance the performance on the lighting and brightness level in which these SB presents new brightness laws as well as a new protection against lightning. In the other hand the application of Service Bulletin 390613-31-: -033REV3 -038-036REV1 -052 -056 -57REV1 introduces a new analogue card as well an improvement of the 5V filter in the analogue board.

These modifications will have an enormous impact as the effect of brightness failure presents a total of 146 failure of a total of 895 failures calculated in from the year 2017 up to 2021, this failure rate of 16,31% represents the fourth most rate of failure of the full color display unit.

5.1.4 SG card

The application of Service Bulletin 390613-31-: -004 -018 -025 -027 -027REV1 -028REV2 -029REV3 -035REV1 -050 -051 -053 -058 -059 as well as 390713-31-: -001 -004 -005 -006REV1 -007REV1 -010 -011 which presents an improvement on the performance by enhancing the compatibility, the VHF1 radio as well as introducing several new components with a high performance and compatibility such as a new U32 and DAC ADV101 component on the V05 Symbol generator. These modifications will reduce the failure rate of the FCDU failure which presents a total of 434 case of a total 895 which is the most failure rate of 48.49% in the studied years from 2017 to 2021.

Additionally, this application will prevent the action of the working intermediately which has occurred a total of 88 case.

5.1.5 Intercommunication card

The application of Service Bulletin 390613-31-: -022REV2 -039REV2 -004 which presents an improvement in the electrical communication heatsink and the analogue card as well introducing a new improved intercommunication card.

These modifications will reduce the rate of failure of working intermediately which occurred 88 times as well image failures which presents a total of 169 case of a total of 895 failures in the studied years of 2017 up to 2021. These two failures present respectively a rate of 9,832% and 18,88%.

5.2 Test Program Set version update

In order, to fully enhance the testing program of the full color display unit with the purpose to fully diagnosis the failed equipment we diagnosed the test program set which still operating with the version number m22c-04-1 issued 15 October of the year 2009. Thus, we oat update the operating system to the new version m22c-05-1 issued the 26 of July 2018.

Furthermore, in order to establish this update, we need to follow the TPS service bulletin with the reference SB6-m22c-05-1 which is related to all studied full color display unit part numbers of 3906130302, 3906130402, 3907130302 and 3907130402. This updated program runs on the ATEC series 6 with operating system of the windows XP only and a coding language of ATLAS. It uses the following standard TPS library of the reference CL45T45.

This application of TPS service bulletin related to the update of the program can save an enormous time waited on equipment testing in which the m22c-04-1 version will treat a unit under test (UUT) in an estimated time of 45 minutes whereas the new updated version of m22c-05-1 will treat the same unit in less than 5 minutes according to the followed Service bulletin referenced SB6-m22c-05-1.

5.3 Mandatory of calibration in every maintenance operation

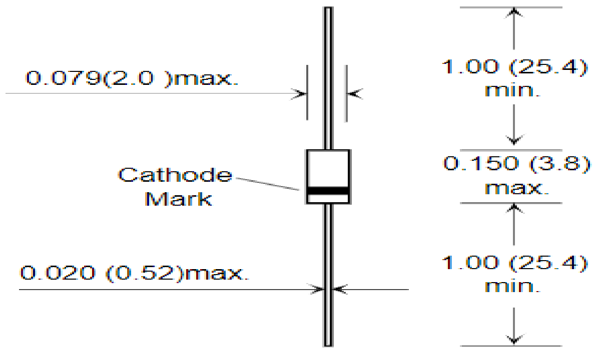
Unfortunately, the calibration of the full color display unit is only proceeded in case of brightness failure or flicking image which doesn’t follow up to the advised procedures presented by the manufacture. Thus, we aim to follow the following two service bulletin with the references of SB6-MB1B-05 and sb6-mb2c-04-2 respectively for the part numbers of 930613-31 and 390713-31.

This modification will prevent all failures linked to brightness problems, blurry image problems and color fails since both Service bulletin treats DU luminance measurements by checking the availability of the luminance meter color correction coefficient, (for green, blue, red color), as it should be mentioned in the calibration report attached to the luminance meter documentation.

5.4 Change of diode in the power supply board

Currently the used diode in the low voltages power supply unit is with the reference A1186862 which have presented a major number of failures which caused the failure of the low voltages power supply more precisely in the deliverance of the memory voltages of 5V and caused as result the full failure of the full color display unit.

In order to overcome this problem, we intend to present this equivalent diode with the reference of ZPD7 which have the following dimension presented in the figures below number 20.



Dimensions in inches and (millimeters)

Figure 21: Diode ZPD7 dimensions [13]

Additionally, we present the diode ZPD7 characteristic in comparison with the old used diode illustrated in the table number 26 below.

Table 22: Diode ZPD7 characteristics

	ZPD7	A1186862
Type of diode	Zener	Regular
Power dissipation	0.5W	0.5W
Zener voltage	7.5V	5V
impedance	4 Ohms	4 ohms
Tolerance	±5%	±5%
Manufacturer	DIOTEC SEMICONDUCTOR	BEARING
Price	$683 for every 30 unit	$529 for every 10 unit

6. Benefit

Clearly, the application of one SB can affect the performance of the full color display unit on several component hence overall improvement which presents the mandatory of application of all service bulletin list in order to guarantee the reduction of failures occurrences as well as enhance the reliability of the equipment.

6.1 Reduction of failure rate

As shown in FMEA study it is clear that same effect can have multiple cause of failures as a result, as the application of the list the service bulletin will reduce the presented effect of failure such as brightness out of limit, blurry image or loss of color etc.

Each modification will no longer affect the only related cause however the multiple effects of failures studied both in chapter 2 through reliability study or in chapter 3 through FMEA study.

To summarize, we intend to illustrate through these tables bellows the benefit of application the list of service bulletin on the both levels of non-functionality cause and effect of failure.

In this table number 26, we introduce the link between cause and effect of failure as well the amount of both human and financial resources dedicated to repair.

Table 23: Cause and effect link to dedicated human and financial resources

Failure	failure effect	Hours dedicated on repair per technician per unit	Price of repair
CRT Failure	brightness out of limit /works intermittently / Color Fail / Blurry image	1073,33	78756,3 + 7,95% since 2020
Inter-communication card failure	Full Failure/ D U Failure/ ECAM Failure	978,56	49782,2 + 7.4% since 2020
Power supply board Failure	Full Failure/ D U Failure/ ECAM Failure/brightness out of limit /works intermittently	316,3	50044,5 + 5.87% since 2020
SG card Failure	Full Failure/ D U Failure/ ECAM Failure	145,19	71591,64
Analogue card Failure	brightness out of limit /works intermittently / Color Fail / Blurry image	647,9	20345,1

Using the table presented in annexes number 3, we were able to determinate in the table below number 27 the occurrence of each detected effect of failure associated for each part-number. As the service bulletin list include both series of part-number 3906130- and 3907130- thus the modification presented the applied SB list will reduce the high number of occurrences for each effect either by an improvement in a specific unit component which will affect the detected effect or by directly improving the detected effect by a new functionality low.

Additionally, using Amasis data presented in both the annexes number 2 and 3, we were able also to determinate the rate of removals presented in form of either failure, sampling, modification and maintenance in which the failure and the sampling rate takes the vast majority of these removals.

Table 24: Occurrence of detected effect of failure for each part-number during the studied period

Detected Failure		P/N				TOTAL Failure
		3906130302	3906130402	3907130302	3907130402	
Brightness out of limit		59	11	0	56	**126**
Works intermittently		47	5	0	32	**84**
Image Failure	Image Flicking	25	0	0	8	**33**
	Blurry Image	18	3	0	22	**43**
	Color Fail	60	3	0	30	**93**
FCDU Failure	Display Unit Failure	91	22	0	77	**190**
	ECAM Failure	36	3	0	31	**70**
	Full Failure	69	10	3	92	**174**
Broken display	Broken Glass	9	0	0	9	**18**
	Fixing Problem	0	0	0	3	**3**
Shop check		32	4	1	24	**61**
Total number of S/N		**49**	**7**	**1**	**49**	**895**

Furthermore, the sampling action is a consequence of a detected action of failure as a result both the failure and sampling rate could be considered as non-functional event.

Currently, the failure rate represents a 72% of the total number of removals during the studied period of 5 years from 2017 up to 2021 in the other hand the modification rate of the full color display unit only represents 5%. We illustrate the removal rate in the graph presented in the figure below.

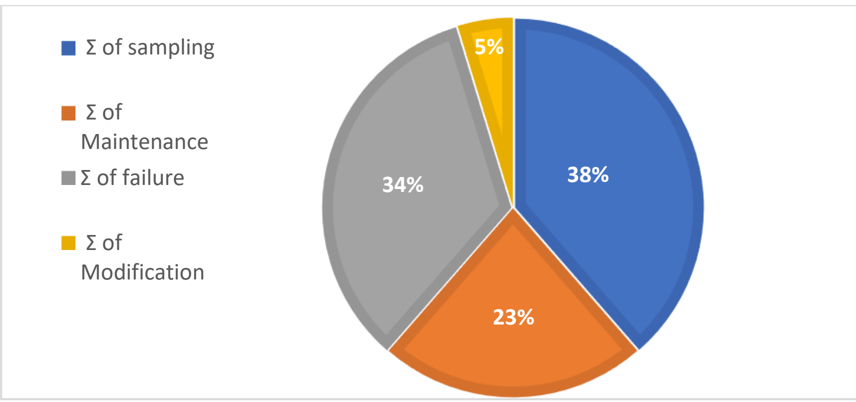


Figure 22: Current removals rates

The application of these modifications presented in the list of service bulletin will automatically increase the modification rate annually which will have a direct impact on the reduction of failure rate as well as the sampling rate.

6.2 Reduction of the cost of repair

Using the magazine data, we were able to track the estimated price of repair for each component for each year in which we intend to calculate the yearly money spent on repair for each specific component as we already determined the number of occurrences for each component failure in the FMEA study.

The avionic overhaul department put both precious and tremendous human and financial resources in order to repair these failures in which we illustrated in the figure 22 below; as it presents the price evolution during the studied period of 5 years for each component of the full color display unit in which we can illustrate high financial resources lost in the process of covering the repair of a high failure rate.

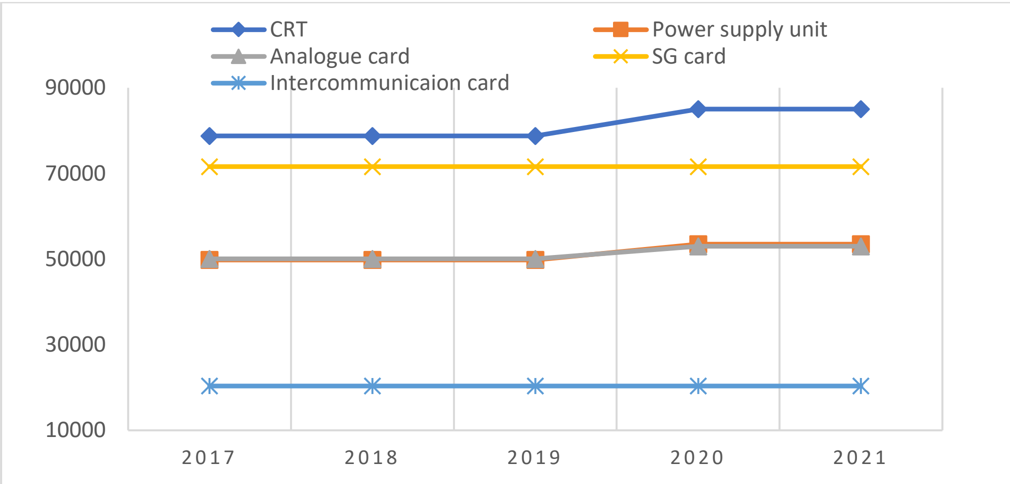


Figure 23: Evolution of unit component cost during studied 5 years

We illustrated the calculated results through the table 28 below in which we present the link between the failure and total estimated cost from 2017 up to 2021.

Table 25: Cost of repair in the studied period of 5 years

Failure	cost of repair	failure occurrence	Estimated total repair cost during 5 years
CRT	78756,3 + 7,95% since 2020	18	1 417 613,4DT
Power supply board Failure	49782,2+ 7.4% since 2020	20	995 644DT
Analogue card	50044,5+ 5.87% since 2020	8	400 356DT
SG card	71591,64	20	1 431 832,8DT
Inter-communication card	20345,1	6	122 070,6DT

As shown in the table, the total estimated cost of repair for the full color display unit is a minimum total of a 4 367 515,4DT which conclude the high amount of financial resource the avionic overhaul department put through in order to cover up the high failure.

Obviously, as the failure rate will decrease with application of the service bulletin list as well other presented modification and unit update the cost of repair will decrease even with the increase of repair cost in different unit component which is the result of covid-19.

As the figure 23 below shows the evolution of the cost of repair through the studied years, we can determinate that even that the cost of repair per unit increases from 2020 due to covid-19 however the total yearly cost is higher in the first 3 years due the high rate of failure from 2017 up to 2019 with a yearly reduction in both 2020 and 2021.

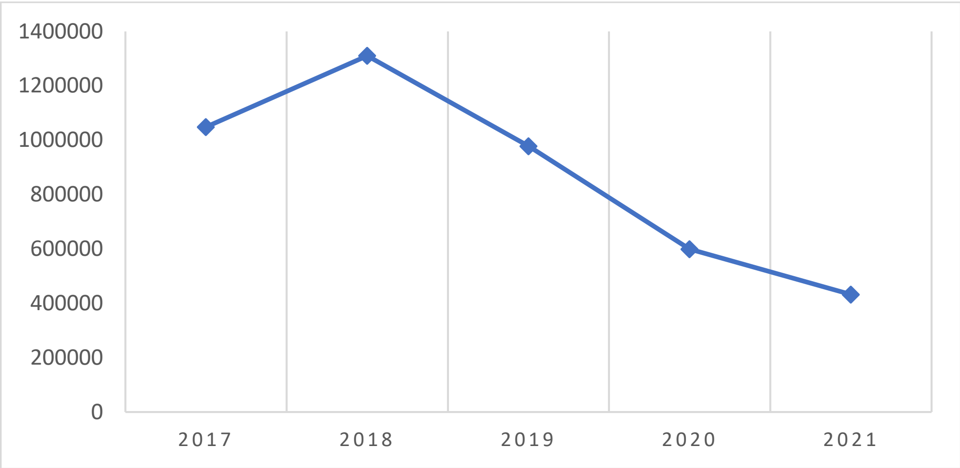


Figure 24: Evolution of yearly cost in the studied period

As shown in the figure 23, the failure rate of full color display unit has the major impact on the total yearly cost for repair despite the increase in cost of repair of several component from 2020 due to covid-19.

furthermore, this can be explained that covid-19 also affected the yearly flight hours as a result this has a direct impact on the decrease of the failure rate on both 2020 and 2021. However, since the aeronautical field was able to overcome this worldwide problem which will contribute to an increase the upcoming yearly flight hours auditioned with the increase in the cost of repair which will cause a tremendous increase yearly cost of repair.

As a result, despite the increase of the cost of repair per unit from 2020 and even estimated continues increase for the following years, the yearly cost of repair for the full color display unit will not increase. The decrease of the failure rate of the equipment will contribute to a decrease in the total yearly cost of repair dedicated for the unit in comparison of the first 3 years.

6.3 Reduction in time and human resources

Additionally, the avionic overhaul department also put tremendous human resources in order to cover up the high number of hours dedicated in the repair of every full color display unit. We intend to break down the different hours dedicated in the repair according to every component failure through the figure 24 below.

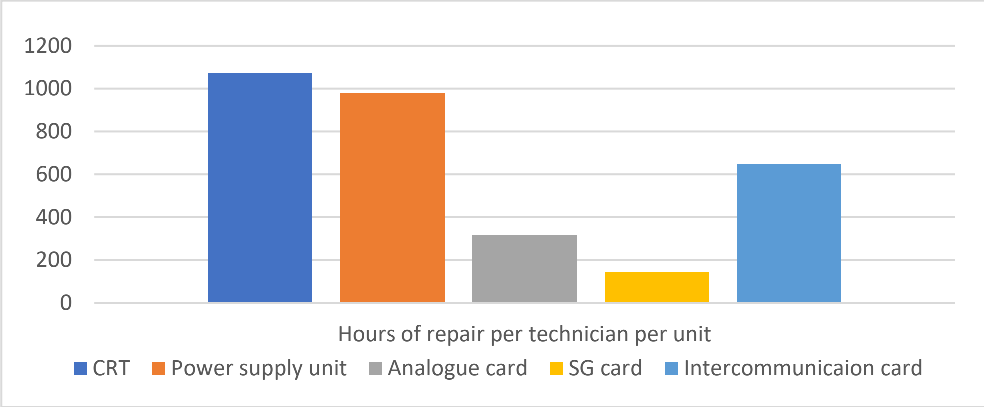


Figure 25: Hours dedicated for repair per technician per unit

As a conclusion, it is obvious that the application of the SB list related to the full color display unit or its testing set up will both reduce the tremendous amount of human and financial resources dedicated by the avionic overhaul department to cover up the high number of occurrences of detected failure effect or the causing component. As a result, this reduction in failure rate will directly impact the amount of both human and financial resources dedicated to cover up the lack of the reliability of the equipment.

7. Conclusion

In this chapter, the failure mode and effect analysis allowed us to break down every failure mode faced by the full color display unit, its effect and more importantly the cause of the failure.

This analysis was with purpose of finding some major solution in order to enhance the reliability of this equipment. We aimed to fully cover all parts of the FCDU by proposing solution linked to the unit itself, to the ATEC station with the intention the maximize the testing procedure and for the major problems and failures for the unit components.

General conclusion

The airworthiness of the aircraft depends on the efficiency and navigability of its avionic systems. In fact, the Full Color Display Unit plays an undisputed role during the flight as it displays color piloting and navigation aid data as well as system and warning parameters to the captain and the second officer.

In order to fully evaluate the full color display unit performance during the last 5 years, we intended firstly to break down its constituent 6 displaying unit in order to determinate the different functions of its components. This study highlighted the major link between manifested failures effects and different responsible components.

Due to the complexity of the domain in terms of data sources and information availability, we established secondly a reliability study for the years from 2017 to 2021 using 3 different metrics; the MTBR, MTBUR and the MTBF commonly known in quantitative research in order to evaluate the efficiency of the equipment.

Furthermore, the reliability study was a supreme tool to evaluate the efficiency of the full color display unit as the calculated results determinates the major unreliability of the equipment for the past 5 years. This study explains the high failure rate of the full color display unit as it failed for a total of 895 times in the studied period which its vast majority were rehearsed events.

In order to overcome the non-reliability of the FCDU, we used a Failure Mode and Effect Analysis with the intention to break down different causes of each failure. This study allowed us to determinate major causes of each manifested failure as well as hierarchize causes according to its criticality. This classification allowed us to focus on the major critical causes which we managed to treat by the application of the service bulletin as well as some modification advised by the manufacture which will decrease high resources dedicated for repair such as repair time as well as human and financial resources.

In conclusion, the application of this scheme not only affects the reliability of the equipment, but also directly affects the calculation results in the FMEA study. Indeed, the proposed modifications will decrease the gravity and occurrence of each perceived failure, thereby reducing the overall criticality. As a result, these new findings will require a new hierarchy of causes and extroverted treatments.

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Annexes

ANNEXE 1: Flight hours for the studied aircrafts

Aircraft Registration	Flight Hours					
	01/01/ 2017	01/01/ 2018	01/01/ 2019	01/01/ 2020	01/01/ 2021	01/01/ 2022
IMF	56797,55	58441,69	60085,83	61729,97	63374,11	65013,12
IMG	53405,87	54827,14	56248,41	57669,68	59090,95	61933,50
IMH	53502,48	55297,09	57091,70	58886,31	60680,92	62475,57
IMI	52730,68	53778,67	54826,66	55874,65	56922,64	57970,63
IMJ	38321,83	38862,29	39802,75	40524,15	40524,15	40524,15
IML	45870,32	47427,46	48984,60	50541,74	52098,88	53655,98
IMM	40750,20	43227,40	43936,37	46912,33	47512,46	48048,65
IMN	39207,05	41091,06	43257,56	45094,43	47684,87	48627,00
IMO	44791,72	46725,68	48337,21	49868,22	51479,81	52849,67
IMP	37538,80	39584,98	41375,38	43680,53	44785,68	46064,52
IMQ	32948,12	35039,39	37882,12	40393,98	42636,71	44161,80
IMR	20431,02	23968,27	26032,58	30615,32	32041,61	34980,05
IMS	18643,98	21345,62	23766,57	26542,23	28632,15	30748,73
IMT	14914,27	18216,20	22178,51	25480,45	28772,95	31432,95
IMU	12926,40	16042,96	19319,17	22144,67	24820,28	27794,25
IMV	12033,07	15906,36	19019,56	22651,30	24623,82	27885,97
IMW	6402,22	10036,42	13584,22	16776,86	19170,03	22362,25
IFM	3117,75	5760,27	8616,97	11258,30	12856,49	13996,13
IFN	2303,15	5078,93	7931,58	9260,66	11291,09	14080,75

Annexes 2: Detected failure for each part-number

2017			
	S/N	Detected Failure	Established Work
P/N 3906130302	1201	INOP	OK
	1268	EWD INOP	Repaired: Repaired according CMM 31-63-22D Rev28 of21/03/2017 Test program: 6-M22C, Rel 05
	1310	D U Failure	Open
	2324	Curved line	Repaired: Repaired according CMM 31-63-22D Rev28 of17/03/2017 Test program: 6-M22C, Rel 05
	3890	Lower display unit unreadable	Repaired: Repaired according CMM 31-63-22D Rev28 of17/03/2017 Test program: 6-M22C, Rel 05
P/N 3906130402	1353	INOP	OK
P/N 3907130302			
P/N 3907130402	6852	Alimentation error Chapter 1	Repaired
non confirmed removals			2

2018			
	S/N	Detected Failure	Established Work
P/N 3906130302	1138	Maintenance Following SD: AB00110318	Repaired: Repaired according CMM 31-63-22D Rev 30 of30/01/2018 Test program: 6-M22C Rel 05
	1277	INOP	OK
	1355	Nav WXR RDR display on NDI flicking	Repaired: Repaired according CMM 31-63-22D Rev 30 of01/03/2018 Test program: 6-M22C, Rel 05
	177	INOP	Repaired: Repaired according CMM 31-63-22D Rev 31 of21/03/2018 Test program: 6-M22C, Rel 05
	1832	INOP	Repaired: Repaired according CMM 31-63-22D Rev 31 of21/03/2018 Test program: 6-M22C, Rel 05
P/N 3906130402			
P/N 3907130302	3058	Brightness out of limit	Inspected, repaired and tested according to CMM 31-63-22C Rev30 of 15/03/2018 Test program 6-M22C Rel04
P/N 3907130402	FCDMK 1011541	"E/S" display SD flashing Now and then	OPEN: THT Failure
	6181	Indication System during Preflight shows that UPDFU is INOP	OPEN
	6337	INOP	OK
	6477	alimentation error in chapter 1	OPEN
	6577	INOP	OK
non confirmed removals			**3**

2019			
P/N 3906130302	S/N	Detected Failure	Established Work
	2787	PFD colored only in black and white	OPEN
	3131	INOP	OPEN
	3890	lower Display Unit Unreadable	Repaired according to CMM31-63-22 D Rev 31 21/03/2019
	535	Brightness Fail	OPEN
P/N 3906130402	1006	INOP	OK
P/N 3907130302			
P/N 3907130402	FCDM 1008390	CAPT ND glass is broken	Repaired according to CMM31-63-22 of 17/09/2019
	6181	INOP	OK
	6252	Brightness out of limit	OPEN
	7852	FCDU Brightness out of limit	CRT repaired
	8037	INOP	Alimentation error chapter1
non confirmed removals			2

2020			
P/N 3906130302	S/N	Detected Failure	Established Work
	177	INOP	Repaired and tested according to CMM 31-63-22 Rev 31 of 21/09/2019
	1832	INOP	Repaired and tested according to CMM 31-63-22 Rev 31 of 21/09/2019
	2651	INOP	OK
P/N 3906130402	1006	INOP	OK
P/N 3907130302			
P/N 3907130402	6163	Brightness out of limit	Repaired according to CMM 3155-44 Rev 31 of 21/03/2018
	6181	INOP	OPEN
	6609	INOP	OK
	6282	Maintenance following PF found (PFD INOP)	OPEN
	6577	INOP	OK
non confirmed removals			4

	2021				2022	
	S/N	Detected Failure	Established Work	S/N	Detected Failure	Established Work
P/N 3906130302	1832	Works intermit-entry	OK	7887	UPPER ECAM brightness out of limit	Repaired according to CMM 31-63-22 Rev 30 of 03/01/2022
P/N 3906130402	3940	Abnormal Color	Repaired according to CMM 31-63-22 Rev 31 of 18/03/2021			
P/N 3907130302						
P/N 3907130402						
non confirmed removals			1	0		

Annexes 3: Total failure occurrence during last 5 years for each part-number

Detected Failure		P/N			
		3906130302	3906130402	3907130302	3907130402
Brightness out of limit		59	11	0	56
Works intermittently		47	5	0	32
Image Failure	Image Flicking	25	0	0	8
	Blurry Image	18	3	0	22
	Color Fail	60	3	0	30
FCDU Failure	Display Unit Failure	91	22	0	77
	ECAM Failure	36	3	0	31
	Full Failure	69	10	3	92
Broken display	Broken Glass	9	0	0	9
	Fixing Problem	0	0	0	3
Shop check		32	4	1	24

Annexes 4: Service Bulletin list for the FCDU

Service Bulletin 390613-31-	Mode	Date	Subject
_001	Amdt A	April 1988	To correct problems experienced in Radar Image
_002 REV1	NONE	October 1996	To replace certain capacitors for those of an improve manufactures
_003	NONE	March 1989	To reduce offset between clock signals in SG assembly
_004	Amdt B	August 1989	To improve compatibility with VHF 1 radio
_005 REV 1	NONE	October 1996	To improve frame scan and improve cushion correction
_006 REV 2	Amdt C	October 1996	To improve image quality
_007 REV 2	Amdt D	November 1996	Prevention of flicker on certain vectors
_008 REV 1	Amdt E	November 1991	Replacement of PAL circuit
_009 REV 1	NONE	October 1996	To improve the tube protection circuit
_010 REV 3	NONE	October 1996	An improvement in reliability
_011 REV 2	NONE	October 1996	Addition of protection circuitry
_012 REV 2	NONE	October 1996	Improvement of red gun failure detection circuit
_013 REV 2	NONE	March 1993	Protection against serious memory writing
_014 REV 1	Amdt F	November 1992	Improvement of short power-interrupt monitoring circuit
_015 REV 1	Amdt G	November 1992	Protection against lightning
_016	Amdt H	January 1993	Introduction of a new VHV
_017 REV 1	Amdt J	October 1993	Display improvement and protection against serious memory writing
_018	Amdt K	March 1993	Replacement of PROM MN 324 on symbol generator unit
_019 REV 1	NONE	October 1996	Improvement of setting circuits of the CRT
_020 REV 1	Amdt L	October 1993	Display improvement and protection against serious memory writing
_021 REV 1	NONE	July 2011	Insulation improvement
_022 REV 2	NONE	October 1996	Improvement of the electrical connection between heatsink and analog board
_023 REV 1	Amdt P	October 1994	To reduce the electrical constraint affecting the life-time of the tube
_024 REV 1	NONE	June 1996	Adjustment of blue light in case of tube replacement
_025	NONE	March 1994	New fitting of C301 on the SG assembly (No effect on CMM)

_026	Amdt M Regrouping SB: 01-06-07-08-10-12-13-14-17-18-19-20-21 and22	March 1994	Grouping of several Improvement under one new amendment
_027	Amdt N	March 1994	Replacement of PAL MN319 on the Symbol Generator Assembly
_027 REV1	Amdt O	August 1994	Replacement of PAL MN319 on the Symbol Generator Assembly
_028 REV2	NONE	March 2002	Improvement of the symbol Generator Assembly
_029 REV3	Amdt R	March 2002	Improvement of the symbol Generator Assembly
_030	Amdt S	August 1995	Introduction of a new Analog Board
_031 REV1	Amdt T	January 1996	In Service Evaluation in UNITED AIRLINES
_032 REV1	NONE	October 1996	Improvement of green and red lights adjustment
_033 REV3	NONE	March 2004	New brightness law
_034 REV1	Amdt U	July 2011	Put the units with Amdt T back to the initial condition
_035 REV1	Amdt V	March 2002	H4 clock improvement on Symbol Generator Assembly
_036 REV1	NONE	October 1998	Analog board manufacturing improvement
_037	NONE	November 1996	Improvement of the 36V filter on the LVPS board
_038	NONE	September 1997	Improvement of 5V filter on the Analog board
_039 REV2	NONE	March 1997	Introduction of a new interconnection board
_040 REV1	NONE	February 2000	Improvement of VHV Assy Protection circuitry
_041	Amdt W	January 2000	Introduction of a new Symbol Generator Board
_043	Amdt Y	March 1998	Improvement of the FCD behavior upon short power supply switching
_044	NONE	August 2000	Replacement of obsolete diodes on the Power Supply Board
_045 REV2	NONE	May 2002	Prevention of Brightness variations
_046	NONE	August 2000	Hardware improvement
_047	NONE	March 2000	Replacement of the LV (BT) Board
_048 REV1	NONE	February 2001	Improvement of the adjustment procedure
_050	NONE	August 2001	Replacement of the U32 component on the SG V05 board
_051	NONE	October 2001	Replacement of obsolete DAC ADV101 on the V05 Symbol Generator

_052	Amdt Z	March 2003	Replacement of obsolete T03 case transistor on the Analog board
_053	NONE	August 2003	Replacement of obsolete DAC AD9713 on the V05 Symbol Generator board
_054	W Amdt Y	June 2003	Introduction of a new Symbol Generator Board
_055	NONE	January 2003	To deactivate unused degaussing function
_056	NONE	April 2004	Replacement of a no longer manufactured microcircuit and new brightness law
_057 REV1	NONE	September 2013	Replacement of o no longer manufactured microcircuit on ANA board
_058	NONE	December 2004	Introduction of a second source of digital analogic converters on V05 Symbol generator
_059	Amdt AA	December 2004	Replacement of a no longer manufactured on V05 Symbol generator

Service Bulletin 390713-31-001	Mode	Date	Subject
_001	NONE	March 2000	Replacement of a no longer manufactured basic on V05 symbol generator
_002 REV 01	NONE	February 2001	Improvement of the adjustment procedure (Close connection with SB 390613-31-048)
_004	NONE	August 2001	Replacement of the U32 component on the SG V05 board
_005	NONE	October 2001	Replacement of the U4 component on the SG V05 board
_006 REV 01	Amdt Z	October 2004	Replacement of obsolete DAC AD9713 on the V05 Symbol Generator board
_007 REV 01	NONE	December 2004	Introduction of a new Symbol Generator board
_008	W and Y	June 2003	Improvement of the interconnection board reliability
_009	NONE	March2003	Replacement of a no longer manufactured microcircuit on ANA board
_010	NONE	May 2004	Introduction of a second source of digital analogic converters on V05 symbol generator
_011	NONE	December 2004	Replacement of a no longer manufactured basic on V05 symbol generator
_012	Amdt AA	December 2004	Replacement of a no longer manufactured microcircuit and new brightness law
_013	NONE	April 2004	Blemishes on CRT display

ABSTRACT

The full color display unit is an undisputed equipment during flight that allows the pilot to display color piloting and navigation aid data as well as system and warning. However, it is facing a high failure rate for the past years which results in several aircraft on ground events for the Tunisair
airline. In order to overcome this major challenge, we aim to enhance the performance efficacity of the equipment.
Thus, we managed first to break-down its components to highlight their different functions.
Secondly, we intend to establish a reliability study for the equipment for the last period of 5 years from 2017 to 2021 in order to evaluate the efficiency of the full color display unit using 3 different reliability indicators.
Additionally, for the purpose to determinate the related cause of each manifested failure of the equipment we established a failure mode and effect analysis as it is a supreme tool to hierarchize the potential causes of each failure.
Based on these studies, we managed to evaluate the equipment reliability and determinate the different causes of failure which allowed us to propose solutions with the intention to reduce its failure rate and reduce its repair costs.

Key words: *Avionic systems, Full color display unit, Reliability study, Failure Mode and effect analysis, Service bulletin, Maintenance,..*

RESUME

Le FCDU est un équipement indispensable à bord de l'avion. Il permet au pilote d'afficher les données d'aide au pilotage et à la navigation ainsi que les systèmes et les alertes. Cependant, il est caractérisé par à un taux de défaillance élevé pendant ces dernières années, ce qui provoque plusieurs événements d'avions au sol pour la compagnie aérienne Tunisair.
Afin de surmonter ce défi majeur, nous visons à améliorer l'efficacité de l'équipement.
Ainsi, nous avons étudié dans un premier temps cet équipement en identifiant ses composants pour mettre en évidence leurs différentes fonctions.
Ensuite, nous avons établi l'étude de fiabilité du FCDU durant la période de 5 ans de 2017 à 2021 afin d'évaluer son efficacité en utilisant 3 indicateurs de fiabilité différents.
De plus, afin de déterminer la cause de chaque défaillance, nous avons établi une analyse des modes de défaillance et de leurs effets (AMDEC), qui nous a permis de hiérarchiser les causes potentielles de chaque défaillance.
En se basant sur ces études, nous avons identifié les différentes causes de défaillance possibles, ce qui nous a permis de proposer des solutions dans le but de réduire son taux de défaillance et ses coûts de réparation.

Mots clés *: Systèmes avioniques, Full color display unit, Fiabilité, Analyse des modes de défaillance et des effets, Bulletin de service, Maintenance.*