The Aircraft Maintenance Program and its importance on Continuing Airworthiness Management

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ABSTRACT

In air transport, besides safety, the economical aspect of operation is the other base element for the success of the aviation industry. Therefore, the concern about economical and operational optimization has a prominent place on the literature. However, with this study it is intended to explore the Aircraft Maintenance Program as an element of Continuing Airworthiness Management (CAM). The objectives are: to present the methodology of AMP construction in accordance with the requirements of Continuing Airworthiness; to present the interrelation between the AMP and the other areas of Continuing Airworthiness; to demonstrate the importance of the AMP for the CAM. As part of this study, it is developed and presents a complete AMP for fleet of Airbus A319 aircraft. The demonstration of the importance of AMP for the CAM is done through the study of aviation accidents occurred between 1980 and 2011. After researching, the accidents on which the causes relate to the AMP where subjected to further study. This study demonstrated the importance of the AMP on the CAM, moreover the interrelation between the AMP and the other areas of CAM is fundamental for its effectiveness.

Keywords: continuing airworthiness, maintenance program, aircraft, EASA, air accident investigation

1. INTRODUCTION

Empirically, the experience reveals that there is a general lack of understanding about the basis or Aircraft Maintenance Program (AMP), specially regarding the formalism required for its development. This is due to the importance and focus given to the economical affairs in Aviation. In air transport, besides Safety, the economics of operations is the other base element for the success of the industry. In accordance with ICAO (International Civil Aviation Organization), maintenance represents an average of 11% of operational costs of air operators up to 25%, depending on fleet size, age and level of utilization (Papakostas, Papachatzakis, Xanthakis, Mourtzis, & Chryssolouris, 2010). These studies focus primarily on operational optimizations within the concept of maintenance management for aviation. However, with this dissertation, it is pretended to explore the AMP as basis for the Continuing Airworthiness, meaning the maintenance of aircraft safety without approaching the associated economics. The following chapter begins by introducing the basic concepts of Continuing Airworthiness, and the standards and laws applicable in the European context.

2. CONTINUING AIRWORTHINESS

Continuing Airworthiness is defined as "all of the processes ensuring that, at any time in its life, an aeroplane complies with the technical conditions fixed to the issue of the Certificate of Airworthiness and is in a condition for safe operation" (ICAO, Document nº9713/ (1998). The rule-making of Continuing Airworthiness is complex because it depends of requirements that change over time, technology developments and the diversity of aircraft and manufacturers. The process of Continuing Airworthiness derives from the initial aircraft *Type-Certificate* (certification given to a manufacturer to confirm that a certain aircraft type abides the design safety or airworthiness requirements). The rules, standards and laws that regulate Continuing Airworthiness are established in two different organizational levels:

- ICAO – International Civil Aviation Organization
  Definition of the responsibilities of member-state.
  Establishment of International standards for Civil Aviation.
- Aviation Authority
  Establishment of rule-making and procedures
  Control of Aviation related activities in general
  Three types of organizations regulated and controlled by Aviation Authority: Air Operators; Aircraft and Systems Design and Production Organizations; Maintenance Organization.

The ultimate responsibility for Continued Airworthiness is assigned in ICAO Annex 8 to the State of Design but the programme to achieve it is a matter for the State of Registry. In Europe, the Aviation Authority in title is EASA (European Aviation Safety Agency), which will be presented in the following paragraphs.

EASA – European Aviation Safety Agency

With the adoption of the Regulation (EC) No. 1592/2002 by the European Parliament and the Council of the European Union (EU) and the subsequent setup of the EASA, a new regulatory framework was created in European aviation. According to this Regulation for EU Member States, national regulations of airworthiness have been replaced by EU Regulation, and certification tasks have been transferred from National Authorities to EASA. Non-EU States maintain their responsibility in all fields (De Florio, 2011). A Non-EU State may also adopt the rules and standards of EASA.

EASA Responsibilities

The main tasks of the Agency currently include (De Florio, 2011):

- Rulemaking: drafting aviation safety legislation and providing technical advice to the European Commission and to the Member States;
- Inspections, training, and standardization programs to ensure uniform implementation of European aviation safety legislation in all Member States;
- Safety and environmental type certification of aircraft, engines, and parts;
- Approval of aircraft design organizations worldwide and of production and maintenance organizations outside the EU;
- Authorization of third-country (non-EU) operators;
- Coordination of the European Community program Safety Assessment of Foreign Aircraft regarding the safety of foreign aircraft using Community airports;
- Data collection, analysis, and research to improve aviation safety.

Main EASA standards

There are three main standards of EASA related to Continuing Airworthiness: Part-21, Part-M, Part-145 that provide the requirements of Certification of aircraft and components, Continuing Airworthiness Organizations and the Approval of Maintenance Organizations, respectively (EASA, 2012).

EASA PART – M

EASA Part-M establishes the requirements and procedures necessary to Continuing Airworthiness Management. In accordance with AMC M.A. 201 of Part-M for commercial air transport, the operator is responsible for the continuing airworthiness of the aircraft it operates and shall ensure that no flight takes place unless:

- The aircraft is maintained in an airworthy condition, and;
- Any operational and emergency equipment fitted is correctly installed and serviceable or clearly identified as unserviceable, and;
- the airworthiness certificate remains valid, and;
- The maintenance of the aircraft is performed in accordance with the approved maintenance programme.

EASA PART – 145

Part-145 establishes the requirements and procedures necessary for the approval of maintenance organizations of aircraft. In accordance with Part-M, all maintenance actions shall be undertake by and approved maintenance organization.

INAC – Instituto Nacional de Aviação Civil

Despite the fact the EASA regulates the safety of aviation in European Union, the responsibility of enforcing its rules is attributed to each Member-State, by designated state organizations. In Portugal, this organization is INAC. INAC an independent organization under the supervision of the Portuguese Government, and it is responsible for the certification and approval of activities, procedures, persons, aircraft, infrastructures, equipments and systems related to civil aviation (INAC, 2012).

3. AIRCRAFT MAINTENANCE PROGRAM

The aircraft maintenance program (AMP) establishes the maintenance tasks to be performed on a certain aircraft, in order to maintain its airworthiness. The maintenance tasks and their interval shall be such that they must enable the maintenance of the aircraft in the same operating and safety condition established by their design, throughout its life, either by the prevention of wear of materials and systems (preventive maintenance) or by the restoration of adequate operation and performance of aircraft and its systems (corrective maintenance). The AMP is a corner stone of Continuing Airworthiness management; therefore it must be developed and evolved bearing in mind safety of aircraft, as well as economical aspects.

The main objectives of the AMP are the following (FAA Part 238, 2011):

1. To ensure realization of the design level of safety and reliability of the equipment;
2. To restore safety and reliability to their design levels when deterioration has occurred;
3. To obtain the information necessary for design improvements of those items whose design reliability proves inadequate; and
4. To accomplish these goals at a minimum total cost, including maintenance costs and the costs of residual failures.

Methodology

The AMP is develop by the Engineering of an operator and it is based on the requirements of the Aviation Authorities, the recommendations of the Type-Certificate holder, the results of the Reliability Program and operational requirements. In general terms, the process of development of an AMP is independent of the type of aircraft or its manufacturer. However, for demonstrational purposes, the Airbus system of documents and concepts shall be used throughout the dissertation in order to introduce the adequate meanings for the following chapters. The process of development of an AMP may be established in accordance with **Error! Reference source not found.**:

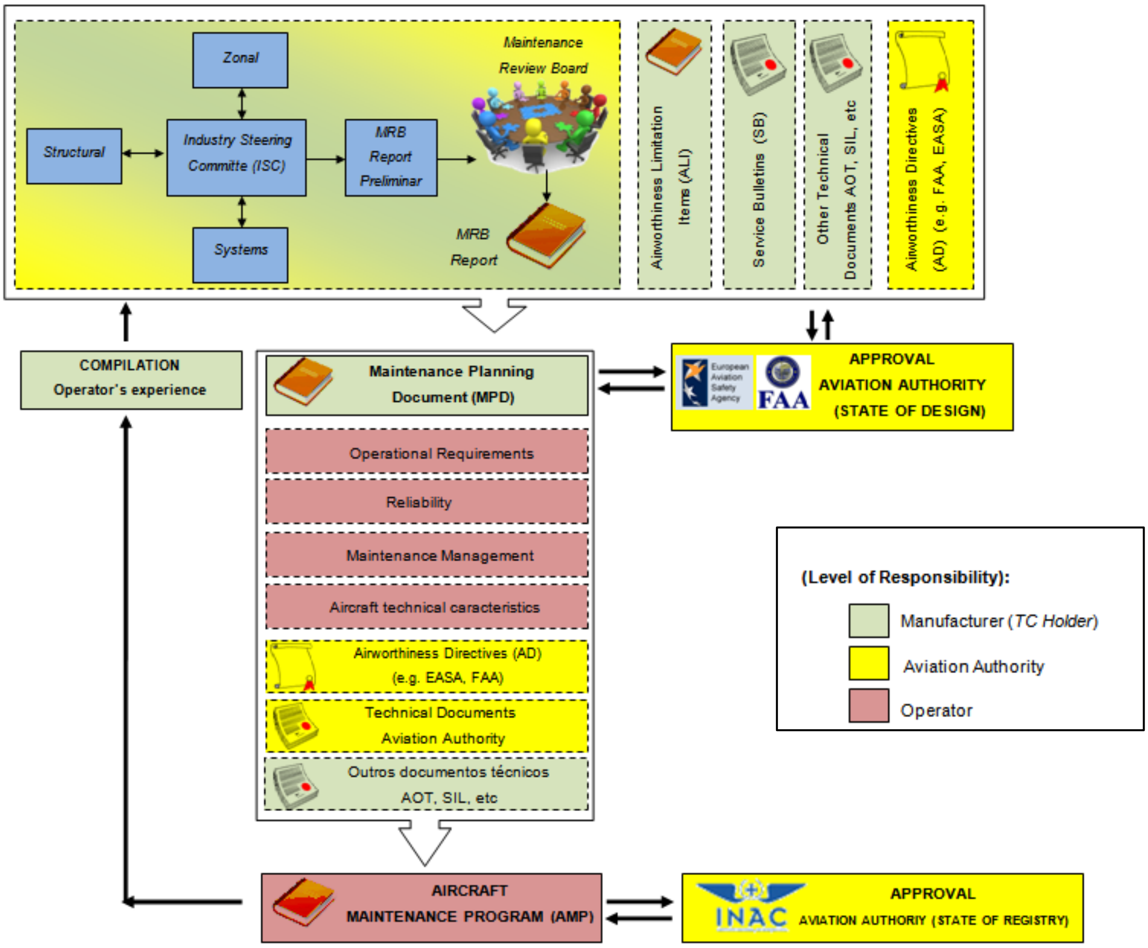

Figure 1: AMP development

The AMP for a fleet of Airbus A319

To demonstrate the AMP and its process of development, a complete AMP for fleet was developed and presented on the present work. Due to confidentiality issues, a fictitious operator and aircraft were created for this purpose. This work culminated in a complete AMP that matches all airworthiness requirements and its content is the result of the same in-depth analysis and development of a real operator with a real fleet. The developed AMP may be accessed by consulting the annexes of the complete dissertation from which the present work relates to.

The AMP was developed with the following assumptions:

- Aircraft type: Airbus A319
- State of Registry: Portugal
- Aviation Authority: INAC, Portugal; under the airworthiness requirements of EASA.
- Operation type: commercial, airline.

The AMP was structured in two parts:

- Part 1 – Definition and description of the maintenance program details.
  Part 1 defines the guidelines for the maintenance program and its baseline assumptions.
- Part 2 – Description of the maintenance tasks applicable to each aircraft.
  Part 2 is the exhaustive list of all maintenance tasks, intervals, description, procedural references and their specific aircraft applicability

4. THE INTERRELATION OF THE MAINTENANCE PROGRAM WITH THE OTHER AREAS OF CONTINUING AIRWORTHINESS

The Continuing Airworthiness Management (CAM) is responsible for the definition and administration of all maintenance actions to be performed on an aircraft in order to maintain its airworthiness, meaning assuring its operational safety. The CAM is complex due to the fact that all its activities must comply with all requirements established by the Aviation Authorities, manufactures and operator's internal procedures and policies. The hardest challenge of the CAM is to assure the airworthiness (of aircraft) while maximizing its availability to operate. The CAM activities also interrelate with other departments of an operator, such as Flight Operations or Quality Assurance. This chapter was developed in order to present the importance of interrelation between the different activities of CAM with the AMP, by detailing how each areas influence the AMP and vice-versa through *inputs* and *outputs.*

Main areas of activity of Continuing Airworthiness Management

The CAM shall assure the performance of control activities in five main areas of actuation:

1. Maintenance Planning (AMP accomplishment);
2. Components Control;
3. Deferred Defects Control;
4. Technical Documents Control;
5. Modifications and repairs Control.

Additionally, besides these five control activities the CAM shall define and develop the following activities:

6. Reliability Program
7. Engine Condition Monitoring (ECM);
8. Engineering;
9. Management of technical documents and manuals;
10. Management of aircraft and components records;

By detailing all inputs and outputs between each of these activities with the aircraft maintenance program, it can be concluded that the interrelation is fundamental for the effectiveness of the CAM. If the level of interaction between these areas and the maintenance program is low, it will strongly impact on the effectiveness of the CAM. The interaction is not limited to the exchange of information, but each and every area should be influence by AMP and vice-versa throughout the performance of their activities. In short, the following effects was identified:

- Accomplishment, Compliance and Control of the AMP.
- Economical optimization of the AMP accomplishment.
- AMP evolution of continuous update and development of preventive maintenance.
- Implementation of repetitive inspections to control defects.
- Reduction of the interval of the preventive maintenance tasks to improve their effectives and the increase of aircraft, engine and component performance levels (perfection).
- Mitigation of errors and mishaps identified during the accomplishment of maintenance tasks
- Update and evolution the AMP with the most recent airworthiness directives and technical data from the aircraft, engines and components manufacturers.
- Constant update and evolution of the AMP to reflect the most up-to-date status of the aircraft, engines and components in respect to implemented modifications and repairs, which may require new or different maintenance or inspection tasks.

5. THE IMPORTANCE OF AIRCRAFT MAINTENANCE PROGRAM FOR CONTINUING AIRWORTHINESS MANAGEMENT

The most adequate method to demonstrate the importance of the AMP for the CAM is by studying cases on which the airworthiness of certain aircraft has been jeopardized due to the ineffectiveness of the AMP or due to failures in the interrelation between the AMP and the CAM. Due to the impossibility of using non-public real data or case studies on this task, mainly due to confidentiality issues, it was considered to obtain such case studies from aircraft accidents. The accidents are caused by failure in maintaining aircraft safety during operation, meaning its airworthy condition; therefore they prove to be the most adequate case studies for such demonstration. Following the previous assumptions the study was elaborated with the following method:

1. To Research and identify the accidents for which the probable cause is the ineffectiveness, totally or partially, of the AMP, due to errors or omissions in its the development or accomplishment. The research would sample among the several accidents happened in an historical timeframe.
2. To present and resume the fact of each case study that are important for the demonstration.
3. To conclude about the importance of AMP for the CAM in relation to each case study.

Accidents and Incidents

Accidents and Incidents distinguish themselves in accordance with the following (ICAO, 2001):
Accident: An occurrence associated with the operation of an aircraft, which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:

- Serious or fatal damage to passenger or crew, or
- The aircraft sustains damage or structural failure, or
- The aircraft is missing or is completely inaccessible

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

The investigation of these events is the responsibility of the State on which it occurs or of the State of Registry of the aircraft, without prejudice of these States being able to delegate such responsibility to other organizations. The investigation is supported by the State of Design (State that has jurisdiction over the organization that designed the aircraft – Type Certificate), State of Manufacture (State that has jurisdiction over the organization responsible for the aircraft final assembly), State of the Operator and State of Registry.

A failure (technical or human) is not sufficient to cause an accident. The accident occurs as a build-up of multiple factors that contribute to the accident. The *Swiss Chesse Model* (SCM) was proposed by Reason (2006) and it serves as a base for accident investigation. The name SCM is just a metaphor for the complex modelling within the scope of Human Factors (HFACS – Human Factors Analysis and Classification System). In the SCM the defences against failure are modelled as a series of barriers represented as slices of cheese. The holes on the slices represent individual weaknesses of each level of the system, and they vary in size and position on each level. The system fails when each hole momentary aligns on every slice of the cheese and therefore allowing the development of an opportunity for an accident to happen.

Sources

For the present study, the investigation reports of three organizations dedicated to accident investigation from three different countries were chosen: Portugal, USA and United Kingdom. The universe of research is defined in accordance with Table 1:

Organization	Country	Universe	
		Total Accidents	Characteristics
NTSB[1]	U.S.A.	120	Formal investigation reports of commercial aviation incidents and accidents, with fixed wing aircraft, dated between 1980 and 2011.
AAIB[2]	United Kingdom	180	
GPIAA[3]	Portugal	206	

Table 1 – Universe of research for the study of civil aviation accidents.

[1] National Transport and Safety Board, U.S.A.
[2] Aircraft Accident Investigation Branch, United Kingdom
[3] Gabinete Prevenção e Investigação de Acidentes com Aeronaves, Portugal

The research has showed that two accidents meet the requirements in supporting the demonstration of the importance of the AMP for the CAM and its interrelation with the different areas of the CAM: the Aloha Airlines flight 243 (1988) and United Airlines flight 811 (1989).

5.1 - ALOHA AIRLINES, FLIGHT 243 (1988)

Introduction

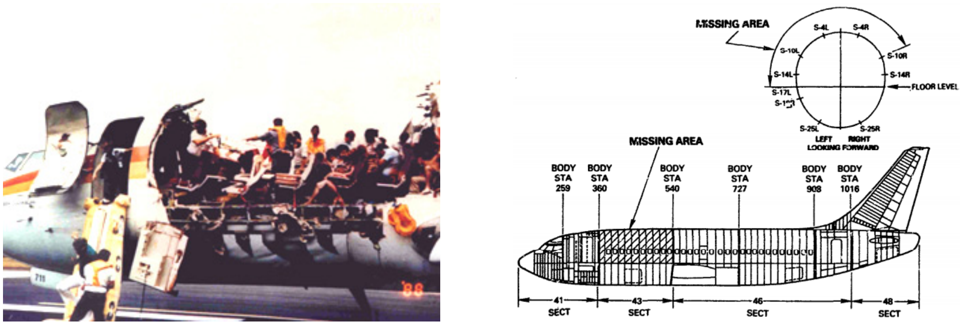

Figure 2 – Aloha Airlines Flight 243: resulting damages of the aircraft after the accident their layout on the aircraft structure (zones, sections and *stringers)* (NTSB, 1989)

In April 1988, a Boeing 737-200 operated by Aloha Airlines (Flight 243) suffered an explosive decompression and catastrophic structural failure at 24,000 feet of altitude when it was flying for Honolulu (Hawaii) with 89 passengers and 6 crew members. The upper panels of the central fuselage, with 7 meters in length separated in-flight. Among the victims there fatality of a flight assistant that was ejected out of the aircraft following the decompression and 7 passengers and other flight attendant were severely injured. The NTSB determined that the probable cause of the accident was the inaptitude of the AMP elaborated by Aloha Airlines to detect the presence of significant disbonding and fatigue damage, which lead the failure of the lap joint at stringer S-10L and the separation of the fuselage. Figure 3 shows the contributing factors to the cause of the accident:

- Inadequate maintenance management practices of Aloha Airlines
- Inadequate oversight of the AMP by the FAA
- Inadequate oversight of the FAA for inspection and Quality control procedures of Aloha Airlines
- FAA failed in the establishment of inspection instructions on the AD 87-21-08, which should mandate the inspection of the lap joints in the same way a Boeing SB Alert.
- Absence of terminating action (by FAA and Boeing) after the finding of production difficulties in the cold bonding process for Boeing 737 lap joint manufacture, which resulted in low durability of the bond, corrosion, and premature cracks due to fatigue.

A thorough analysis of the accident investigation report was made in order to point-out the elements related for the demonstration proposed by the present work.

Conclusions

From the thorough analysis of the accident report of the Aloha Airlines Flight 243, four main discrepancies were found, directly related to the AMP and to the operator's capabilities to manage the Continuing Airworthiness of its fleet:

- <u>Aircraft's high accumulation of FC between structural inspections due to FC to FH proportion</u>
  Boeing MPD was designed for 1,5 FC per FH, while the aircraft operated 3 FC per FH on average.
- <u>Extension of intervals between structural checks (D-Check), allowing the increase of degradation of the cracks and corrosion of the overlapped joint</u>
  Main driver for inspections is FC, however the AMP structural inspections were established by FH.
- <u>Significant phasing of important structural checks (D-Check)</u>
  All 52 jobcards, that compose the D-Check, were planned to be accomplished in different occasions, and maintenance planning had little resources to cope with the aggressive phasing of Job Cards.
- <u>A Corrosion Control Program was not established by the operator</u>.
  Every corrosion finding or its repairs were not duly followed and controlled. Additionally, there the AMP was not adjusted to a maritime operating environment with heavy impact on aircraft corrosion.
- <u>Inexistent operator's Engineering capabilities</u>.
  The technical documentation from manufacturers or airworthiness authorities was not properly analysed by an Engineering department, which leaded to failures in accomplishing the AD 87-21-08.

The Aloha Airlines Flight 243 is an accurate portrait that an accident occurs due to the build-up of failure; in this case the failures were from the FAA, manufacturer and operator. Regarding the operator, the main contribution for the accident was the absence of engineering capabilities, which should study and establish repair procedures, develop contents of maintenance tasks and support the development and evolution of the AMP. The Engineering should also serve as technical support to other departments within the operator and maintenance organizations. Therefore, the non-existence of Engineering affected several activities, which are extremely relevant for the Continuing Airworthiness Management, such as:

- Control of the accomplishment of the AMP (Planning)
- Control of Technical Documentation (AD/SB/etc.)
- Control of Repairs

Among the contributing factors for the accident were the errors of AD elaboration and inadequacy of the AMP for air operation in a maritime environment, making it fundamental the collaboration between the operator's CAM, manufacturers and Aviation Authorities. In general terms, there would be the need for the following implementations on the AMP:

- Creation of Job Cards for monitoring and control of the multiple corrosion findings. The AMP presented for "FlyFicticious" in this work may serve to exemplify the methodology behind Corrosion Prevention and Control Program and the associated tasks.
- Changing the contents or intervals of Job Cards that are associated to the AD in question.
- Changing the planning policy of the AMP, from "phase" to "block".

5.2 - UNITED AIRLINES, FLIGHT 811 (1989)

Introduction

Figure 3 – United Airlines – flight 811: aircraft damage after the accident (NTSB, 1990)

On 24th February 1989, the Flight number 811 between Los Angeles (USA) and Sydney (Australia) operated by United Airlines (UAL) was abruptly interrupted when a Boeing 747-122 suffered an explosive decompression when climbing from 22,000 to 23,000 feet. The aircraft was carrying 3 crew members, 15 flight attendants and 337 passengers. Following this event, the engines nr. 3 and 4 shutdown due to the ingestion of debris. The aircraft was successfully landed at the Honolulu Airport in Hawai. The assessment of the aircraft condition revealed that the forward cargo door separated from the fuselage in-flight causing extensive damage to the fuselage, wings and engine, especially on the structure adjacent to the cargo door. Nine passengers were ejected during flight and considered missing. Fatigue or corrosion damage was not found and the malfunction was due to overstress. NTSB concluded that the probable cause of the accident was the sudden opening of the cargo door latch and subsequent explosive decompression. The contributing factors were the following:

1. Design deficiency of the cargo door mechanisms, which made them vulnerable to damages in operation.
2. Absence of corrective actions by the aircraft manufacturer (Boeing) and the Aviation Authority (FAA) after a previous accident occurred 2 years before involving a Boeing 747 of Pan Am. In this accident, the cargo door was inadvertently open during flight.
3. Improper maintenance and inspection actions performed by UAL.

A thorough analysis of the accident investigation report was made in order to point-out the elements related for the demonstration proposed by the present work.

Conclusions

From the thorough analysis of the accident report of the United Airlines Flight 811, five main discrepancies were found, directly related to the AMP and to the operator's capabilities to manage the Continuing Airworthiness of its fleet:

- Ineffective Reliability Program
  The reliability Program did not proposed corrective actions following several findings of failure and malfunctioning of aircraft's and fleet's the cargo doors, that preceded the accident.

- Postponement of accomplishment terminating action of the AD 88-12-04
  Terminating action of AD 88-12-04 was postponement to later times, even knowing that it was issued by the FAA following similar events on a Pan American Airways flight two years before the accident.
- Partial accomplishment of the AD 88-12-04
  Due to a clerical error, an important action of assuring inspection to the cargo doors following manual operation was omitted and procedure was not implemented.
- Inconsistent records of aircraft modification embodiement

The case study of Aloha Airlines Flight 811 confirms the several opportunities that the aircraft manufacturer, the FAA and the operator had to perform the set of actions to maintain safe operation of the aircraft. Concerning the operator, this case study reinforces the importance of three major activities inherent to the aircraft Continuing Airworthiness:

Reliability Program

Through the aircraft records, 39 defects were reported related to the mal function of cargo doors over the six years that preceded the accident. 10 of the defects involved severe failures like failure in cabin pressurization. In the first 6 months before the accident, 17 defects where reported with special focus on failure in normal operation of the cargo doors. In case the Reliability program was implemented correctly, these defects would have alerted for the need of corrective maintenance actions, triggering the following actions:

- Creation of Job Cards for periodical inspection and follow-up the reported defects, or to implement corrective actions.
- Changing the contents and/or intervals of maintenance tasks related to the door structure and operational check of the mechanisms, therefore enabling the possibility of damage detection and door rigging.

Additionally the Reliability data of the operator could have been shared with the aircraft manufacturer. Sharing information between the operators and manufacturers is very important not only to improve Design but also to introduce improvements to the AMP of all operators through the MRB process.

Control of Technical Documents (AD/SB/etc.)

Despite the fact that UAL abided with the established deadlines by FAA for the accomplishment of AD 88-12-04, the terminating action was push forward in time, and the AMP lacked a periodical inspection to damage on the door mechanisms that should be executed every time the door was operated in manual mode. It is the operator's Engineering responsibility to assess the technical documents (either from manufacturers or aviation authorities) and broadcast the necessary actions for accomplishment to the other areas of CAM. Further attention should be given to the AD in question since it followed a previous similar accident with PanAm, in order to anticipate the accomplishment of the AD's terminating action. To accomplish the assessment and planning of the AD's terminating action, the Engineering would be supported by the Reliability Program findings and the AMP accomplishment intervals.

The control of technical documents has severe impact on the AMP and consequently on aircraft airworthiness condition. The AMP strongly depends on the records of modification embodiment due to the fact that the applicability of most tasks depend on their status. The embodiment of modifications may replace the need of executing certain maintenance tasks or implying the need for additional ones.

Control of Repairs

Before the 6^{th} of September 1988 and the day preceding the accident, 6 defects related with cargo doors were reported of which 2 impelled permanent and temporary repair. A control of structural repairs related to the history of each repair would eventually contribute severely for the effectiveness of the Reliability Program.

6. CONCLUSIONS

The objectives of the present work were accomplished. Throughout this work the elements of an Aircraft Maintenance Program were presented, including its development methodology.

The complete AMP developed and presented in this work for a fleet of Airbus A319 under the airworthiness requirements of EASA showed that, for its development, one must work with information that embraces several and different areas of expertise, with a need of adjusting its assumptions and results to the characteristics of the aircraft, operational requirements of the operator, manufacturer requirements and guidelines, rules and laws of Continuing Airworthiness applicable to the context where the aircraft is Registered and where it will be operated. It is the operator's responsibility of developing and accomplish the AMP. By presenting a complete AMP, based on a real operational scenario was important for the understanding of the details by the reader.

Chapter 4 demonstrates the importance of the AMP for Continuing Airworthiness Management. From the universe of the analysed 506 air accidents, two of them were selected to test and demonstrate the importance of the AMP for the CAM. These accidents were chosen since they meet the requirements of *having as probable cause or contributing factors, the total or partial infectiveness of the AMP, either by errors or omissions in its development or accomplishment*. From the thorough analysis of the selected case studies, the following conclusions may be withdrawn:

- The AMP is among the probable cause or contributing factors.
- The interrelation between the different areas of the CAM and the AMP is among probable cause or contributing factors.
- The adequate development or evolution of the AMP would prevent the accident to happen.
- If there was an adequate interrelation of the AMP with the different areas of CAM, the accident would have been prevented.

Despite the same conclusions may be withdrawn from both case studies, they present one main difference. In the case of Aloha Airlines accident, it is noted that an organized and adequate system of CAM was not implemented. On the contrary, in the case of the United Airlines accident, it is noticed that an organized and adequate system of AMP was established with all areas comprising it, however this system was not effective in preventing the accident. The interrelation between the different areas of the CAM between themselves and as well as with the AMP is fundamental for the effectiveness of the CAM, which was a clear missing element that created the opportunity for the United Airlines accident to occur.

The study could be more robust if there were additional case studies beyond the ones selected. However, in universe of 506 accidents, the research did not reveal more accidents that would serve for the demonstration in question. One should say as well, that also no accident proved the contrary of the demonstration. Other direct causes and contributing factors are found to be very common among the studied universe of accidents: piloting errors and human errors in executing maintenance tasks.

One should suggest that in case a further study is to be developed, the universe of accidents should be broader to include the accidents investigated by other organizations from other countries or continents.

From the research done, it is concluded that the CAM is in constant evolution. Among the air accident reports that were elaborated in different eras, it is notice that the Airworthiness subject is approached and presented in a different way, meaning different vocabulary and concepts. Each of the most important accidents in history helped to shape the airworthiness requirements, standards and laws. The requirements, standards and laws and structure of the CAM that we know today are very different from the ones established in the past.

One final remark regarding this work: the subjects of this work are vast and complex, especially due to the demanding requirements of CAM, therefore, an effort has been made to simplify the presented information in order to synthesise it to increase the easiness of understanding by the reader, regarding the details of the AMP and CAM.

7. REFERENCES

De Florio, F. (2011). *Airworthiness: An Introduction to Aircraft Certification.* Great Britain: Elsevier Ltd.

EASA. (2010). *Continuing Airworthiness Requirements PART-M.* Luxembourg: Publications Office of the European Union.

EASA. (2012). *Regulations Structure.* Retrieved Julho 2012 from easa.europa.eu: http://easa.europa.eu/regulations/regulations-structure.php

FAA. (2011). Appendix E to Part 238 - General Principles of Reliability-Based Maintenance Programs. USA.

ICAO. (2001). Annex 13 - Aircraft Accident and Incident Investigation. *International Standards and Recommended Practices* (9). Montreal, Canada.

ICAO. (2005). Annex 8 to the Convention on International Civil Aviation. *International Standards and Recommended Practices* (10).

ICAO. (1998). Documento nº9713. *International Civil Aviation Vocabulary , 2*(3).

INAC. (2012). *Quem Somos.* Retrieved Julho 2012 from INAC.pt: http://www.inac.pt/vPT/Generico/INAC/QuemSomos/Paginas/QuemSomos.aspx

NTSB. (1990). *Aircraft Accident Report - United Airlines Flight 811.* Washington D.C.

NTSB. (1989). *Aircraft Accident Report Aloha Airlines Flight 243.* Washington D.C.

NTSB. (2012). *History of The National Transportation Safety Board.* Retrieved Julho 2012 from ntsb.gov: http://www.ntsb.gov/about/history.html

Papakostas, N., Papachatzakis, P., Xanthakis, V., Mourtzis, D., & Chryssolouris, G. (2010). An approach to operational aircraft maintenance planning. *Decision Support Systems* , 604-612.

Reason, J., Hollnagel, E., & Paries, J. (2006). *Revisiting the "SWISS CHEESE" MODEL of Acidents.* EUROCONTROL Experimental Centre.