

Systematization and optimization of Fokker 100's Maintenance Plan

Pedro Miguel Sena Martins

Instituto Superior Técnico, Av. Rovisco Pais 1049-001 Lisboa, Portugal

Abstract

The strategies pursued by airline companies are based on strong plans for drastic cost containment. The aviation industry has become increasingly challenging, and the maintenance costs and reliability control are two main points that contribute strongly to the success of an airline company. The concept of optimization is present in all sectors of this industry and is closely related to the systematization concept of the *Aircraft Maintenance Plan* (AMP).

This work aims to study the effects of the inclusion of inspections provided within an interval of 4000 Flight Hours in the *A Check* and afterwards, proceeding with the equalization of this new AMP applied to the Fokker 100 aircraft. For this purpose, this study was integrated in *Portugália Airlines* company.

This project started with a complete review and organization of the database regarding the Fokker 100's AMP, including missing information concerning the aircraft tools and materials needed to perform maintenance tasks. Subsequently, after the analysis of the several variables, an application based on *Visual Basic for Applications* programming language was developed. The methodology used was based on the following assumption: combining the largest number of tasks with similar intervals and, when possible, collecting them based on shared common access panels.

From a temporal point of view, the results were reasonable, reflecting a benefit simultaneously on the implementation of the two inspection types presented above, with a 2,5% time gain, as well as the optimization of time generated regarding the ground time of the aircraft through the equalization of the AMP.

Keywords: Maintenance Plan; Optimization; Fokker 100; Equalization; *Portugália Airlines*

1. Introduction

Airlines' profitability is closely tied to economic growth and trade. The global crisis that currently surrounds us in an uncomfortable economic environment implies a great effort in terms of lowering costs since the years 2000s. The crisis that began in the United States of America is considered by many economists as the worst financial crisis in recent years [1]. Because of this, the strategies followed by

airlines are based on strong plans to reduce human resources and also based on drastic costs containment. The commercial aviation industry is becoming increasingly demanding, being the maintenance costs and reliability control the key success factors of airline industry [2].

It is in this context that *Portugália Airlines* - PGA used this opportunity to identify cost savings in the development of maintenance activity, as well as the possibility of increased

turnover of the airline, which results in a greater availability of the m 100 aircraft, obviously never neglecting the issue of reliability and always trying to achieve the highest levels of efficiency. Based on these assumptions, this paper aims to study the feasibility of including inspections "DRF 4000 Flight Hours (FH)" on A Checks and proceeds to equalize the respective Aircraft Maintenance Plan (AMP), in order to reduce the total time of the maintenance plan and, therefore, reducing costs. This paper starts with the presentation of Fokker 100's current maintenance plan, adopted by PGA, revealing its main features. Afterwards, the used methodology and developed numerical application will be explained and will be performed the analysis results.

2. Maintenance Steering Group

The issue of the effects of corrosion on the structural integrity of aircrafts has been a question of concern for some time. The Maintenance Steering Group (MSG) system has evolved from many years of corporate knowledge. The first generation of formal air carrier maintenance programs was based on the belief that each part on an aircraft required periodic overhaul [3]. As experience was gained, it became apparent that some components did not require as much attention as others and new methods of maintenance control were developed.

The B747 Maintenance Steering Group (MSG) created a new analytic approach to maintenance, using three control processes:

- *Hard Time limit*: Maximum interval for performing maintenance tasks on a part or unit. Such intervals apply to overhaul, but also to the total life of the part or unit.
- *On-Condition*: Repetitive inspections or tests to determine the condition of units or systems, comprising servicing, inspecting, testing, calibrating and replacement.
- *Conditioning Monitoring*: Applies to items that have neither Hard Time limits nor On Condition maintenance as their primary maintenance policies [3].

2.1 MSG-3

The MSG system has now evolved considerably. The experience gained with MSG-1 was used to update its decision logic and create a more universal document for application to other aircraft and power plants. This methodology requires the Systems and Power plant design to be divided into convenient sized items for the purpose of analysis and the aeroplane is divided into major functional areas – ATA systems and subsystems. It helps to improve safety by addressing hidden functional failures. MSG-3 also helps improve maintenance efficiency, by eliminating redundant and ineffective tasks. There is usually a substantial cost reduction in hard time component removal and replacement [4].

3. Airline Case Study – Fokker 100 Maintenance Plan

By analysing environmental considerations, seasonal restrictions, fleet size and other factors, it is possible to package an aircraft's maintenance program by making the maximum use of the parameters: Flight Hours (FH), Flight Cycles (FC) and Calendar Time as specified in the Maintenance Planning Document (MPD), the document which provides the necessary maintenance planning information for an operator to develop a customized scheduled maintenance program. In this paper, the following approximation is made: the maintenance plan consists of the sum of three parts, AMTOSS tasks' time, Opening / Closing Access Panels' time and Additional Tasks' time.

Some important terms included in this work are:

AMTOSS: Aircraft Maintenance Task Oriented Support System numbering system is used to generate the reference number at the Maintenance Review Board (MRB) and is also used as a cross-reference between the MRB and the Aircraft Maintenance Manual [5].

Maintenance Review Board Report is a document intended for use by air carriers. It contains the initial minimum scheduled maintenance and inspection requirements for a particular transport category aircraft.

Additional Tasks are specific procedures that can be executed before or after some

maintenance tasks. An example of two additional tasks can be to lift and lower the aircraft with jacks [6].

DRF 4000 refers to all maintenance items with 4000 FH interval or similar potential.

“A” Check refers to routine light maintenance and tasks with 500 FH interval, as well as others with similar potential. This check consists of six packages, as can be seen in Table 1:

Check	Interval (FH)
1A	500
2A	1000
3A	1500
4A	2000
6A	3000
12A	6000

Table 1 – “A” Check

“C” Check refers to maintenance tasks with 5000 FH interval, as well as others with similar potential. This check consists of two packages, as can be seen in Table 2:

Check	Interval (FH)
1C	5000
2C	10000

Table 2 – “C” Check

“D” Check refers to maintenance tasks with 12000 FH interval or six years, whichever occurs first, as well as others with similar potential. This check consists of two packages, as can be seen in Table 3:

Check	Interval (FH)
1D	12000
2D	24000

Table 3 – “D” Check

The next section will address the effects of the inclusion of inspections provided with an interval of 4000 Flight Hours in the Block “A” Check.

3.1 Current Scenario

For the 165 AMTOSS tasks that compose the 12 block “A” check, there is a remarkable discrepancy in terms of execution time of each package, as can be seen in Figure 1.

Block “A” Check

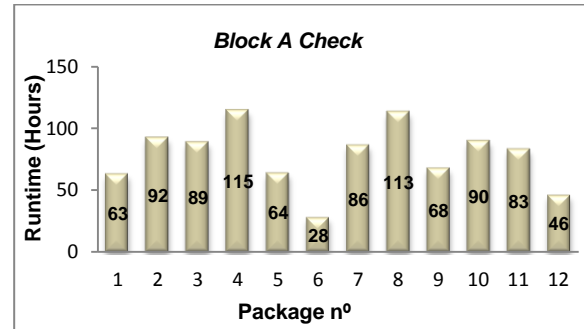


Figure 1 – Block “A” Check maintenance execution time plan

The total time of *Block “A” Check* is 937 hours, being the A4 package the one which presents the longest execution time. On the other hand, the A6 package provides a value of 28 hours.

For the present study and taking into account that additional tasks represent an insignificant fraction of the total maintenance check time, this component is neglected, accounting only the opening / closing access panels’ time and AMTOSS tasks’ time.

DRF 4000

As shown in Figure 2, the impact of additional tasks’ time and the opening / closing access panels’ time is much higher in relation to AMTOSS tasks’ time.

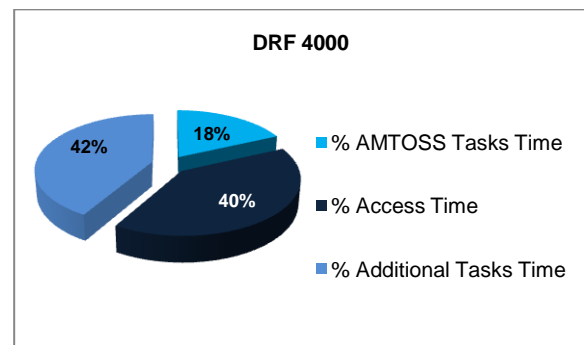


Figure 2 – Partial contribution of the three constituent parts of “DRF 4000” Check

4. Developed methodology

Apart from grouping tasks together by only using the task interval property, other properties can be considered. By considering tasks that share the same set-up activities (e.g. the same access area or access panels, aircraft preparation), tasks can be clustered together. But by considering that, such tasks may bear different maintenance intervals, the maintenance interval should also be considered.

The methodology applied can be seen in Figure 3 and it consists in transferring access panels from a maintenance package to another one in an inferior level, thus transferring the tasks associated with such access. The logic is to take what has been done in the previous level and not to have to make it again, starting preferably by the access panel with an opening / closing higher time, thereby increasing the chances of optimization.

To achieve the objective, the first step is to create a maintenance plan called the "Current Plan". The Current Plan is created based on information provided in PGA database, which reflects the philosophy of AMP Fokker 100. This plan is made up of AMTOSS tasks characterized by an ID, time and offset, as well as their multiple accesses. A copy of the current plan is also created, which is known as the "Copy Plan". It is in this plan that tasks and associated access panels exchanges are made and tested to other maintenance packages.

The study begins in the package 12, finishing in the package 2, due to the fact that in package 1 there cannot be any exchanges. Through the Copy Plan, the access panels' list of all tasks in package 12 is extracted and then creates a list of common access for the next lower package, the package 11, and this list is subsequently analyzed. To a better understanding of the problem, the methodology will be applied between the package 12 and the package 11.

From the list of common access between the package 12 and 11, the application identifies all the tasks in the package 12 that uses this access and transfers the tasks to the package 11. This transfer is then tested by the "Cost Function", comparing the total time of the two plans. Two hypothesis may occur:

- a) In case of having achieved an improvement (Copy Plan Cost < Current

Plan Cost), the Current Plan is substituted by the Copy Plan, the cycle re-begins in package 12 applying the methodology described above to the next Access Panel.

- b) Otherwise, if this change causes an increase of the maintenance's plan, the following steps have to be taken:

1. The Access Panels and the Tasks return to its initial position and other hypothesis will be tested, that is, based on the list containing all the tasks designated by (A, B, C), shown in the flowchart, sharing the access panel "1st access", a new Access List is created: "Access List 2";

2. From the "Access List 2", the process of filtering only the common access panels between Package 12 and Package 11 is repeated, "Access Filtered List 2" and then a new list is created, named (**D, E**). This new list shares the same access panels with Package 12 and Package 11.

3. Taking into account another Access Panel, its associated tasks are once again transferred, tested, and if improvements are detected, the system returns once again to Package 12. If there an improvement is not detected, the procedures to be taken are analogous to those described in a).

The end of this cycle is determined when no spread Access Panels is detected, that is, when a Task fails to bring more Access Panels associated with it, being all the methodology described above applied to the next Access Panel, since its beginning.

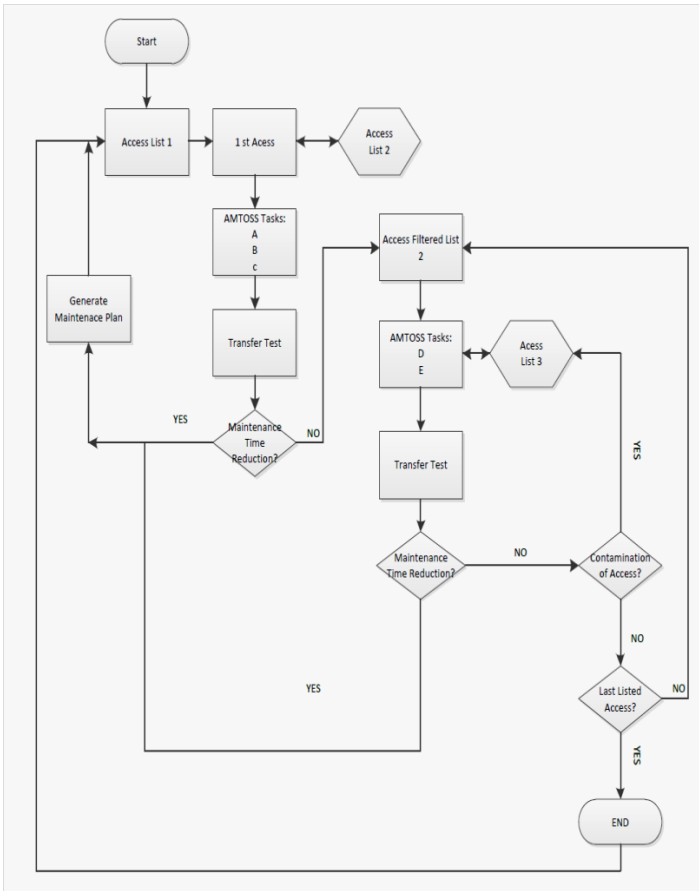


Figure 3 – Flow chart - Developed Methodology

5. Analysis of the Results

5.1 Block "A" Check and DRF 4000 Check

Regarding the new restructured Block "A" Check with the DRF 4000 tasks included, the values corresponding to each of these contributions can be seen in Figure 4, as well as the approaches considered.

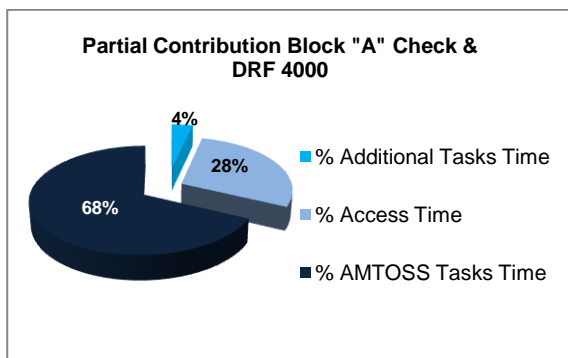


Figure 4 – Partial Contribution Check A & DRF 4000

It can be easily seen that the significance of the additional task execution time component in

relation to the other two is irrelevant and, if that same component is discarded, the Figure 5 is obtained.

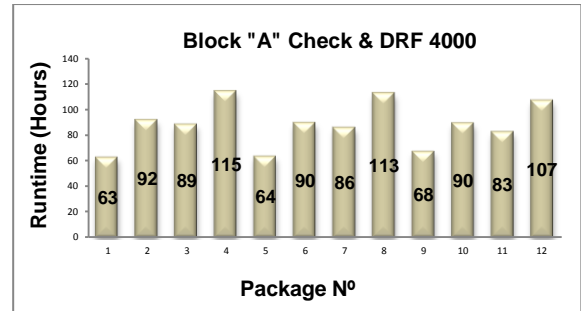


Figure 5 – Block "A" Check & DRF 4000

After analysing the graph, the A1 package presents as the less lengthy in time, translating in a 63h maintenance time. On the other hand, the A4 package is the longest: 115h. The total maintenance time of the PMA now totals **1060** hours. By performing the Check A and Check DRF 4000 separately, the total maintenance time would be **1087** hours, resulting in a time gain of approximately 2,5% with this change.

The advantage of grouping tasks through common accesses panels now takes on a whole new meaning, whether in packet A6 or A12, due to the fact that, by inserting the DRF 4000 tasks in these 2 packages, there are 24 shared accesses panels to distinct tasks between these 2 Checks. Table 4 presents the time and percentual gain in the afore mentioned packages. By inserting the DRF 4000 tasks in package A6, there are 41 common accesses panels, which leads to a time gain of 13 hours of maintenance and a perceptual gain of 12,6%. Concerning package A12, this sharing of common accesses panels results in a time gain of 14 hours of maintenance and a percentual gain of about 11.6%.

Package	Time without sharing access (hours)	Time-sharing access (hours)	Time Gain (hours)	Number of Shared Access	Percentual Gain
A6	103	90	13	41	12,6 %
A12	121	107	14	44	11,6 %

Table 4 – Time and percentual gain obtained in Block "A" Check & DRF 4000

To calculate the dispersion between the different packages in this new restructured maintenance plan, one of the most common

statistical dispersion parameters was used the standard deviation. Comparing the before and after of the application of the implemented methodology, based on Equation 1, the result shown in Table 2 is obtained.

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2} \quad (1)$$

Block "A" Check & DRF 4000	Standard Deviation
Before the Equalization's Process	17,5

Table 2 – Standard Deviation before the equalization's process

5. Equalization of the New AMP

Using the application developed, it was possible to equalize some of the temporal discrepancies observed between the 12 maintenance packages of the new AMP; in this manner it was possible to minimize the aircraft downtime. as can be seen in Figure 6.

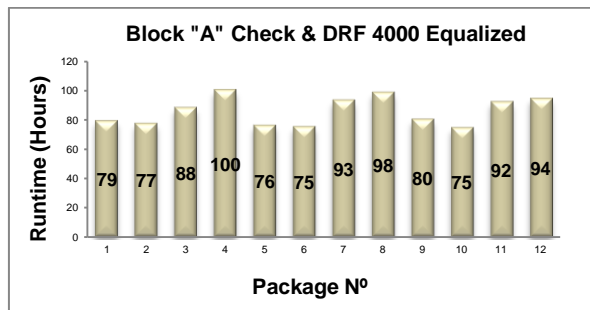


Figure 6 – Block "A" Check & DRF 4000 Equalized

One of the imposed changes was with package A12, where formerly the 2A interval tasks were performed, and which are now being performed in packages 1A, 3A, 5A, 7A, 9A and 11A. With this change it was possible to make the packages more homogeneous in relation to time, as reflected by the temporal deviation calculated in this case: **9.5**, which translates the success of the equalization of the respective maintenance plan as reflected in a time gain of 5.8%, as is documented in Table 5, as well as other relevant results. Besides the mentioned change, and through the application, which dislocated some of the tasks from their original location to other packages, it can be seen a

greater sharing of accesses, which also leads to an optimization of the total AMP time.

	AMP (Hours)	Gain (%)	Satandard Deviation
Base	1087	0	-
A Check + DRF 4000	1060	2.5	17.5
Equalization	1025	5.8	9.5

Table 5 – Main results obtained

6. Conclusions and Recommendations for further Research

The viability of the maintenance plan must be closely studied, as there are a great number of variables subjacent to this change, as is the case of available work teams, tools and materials used, space compatibility in terms of the different inspection types, among others. In this particular study, this issue was not extensively evaluated due to lack of additional information, but some pertinent questions will be raised that, in case of a AMP alteration, should be analysed.

In this study, the fact that there was no access panel to the original maximum period of the tasks before they were optimized was a limiting factor. Probably many of the tasks with which we worked with, due to optimization issues, were subject to original interval reduction and this fact, if indeed true, may greatly restrict obtaining better results. The starting point of this project was already partially optimized, which restricted significantly other possible solutions. In more complex spaces better solutions could be obtained, or at least a greater number of solutions, that is to say, if we were working with a larger universe, including the "C" Check and "D" Check tasks, the opportunity and probability for optimization would be far greater.

In the restructuring of the aircraft maintenance plan, a limitation was felt due to the fact that the number of tasks and accesses panels was reduced. However, the development of the application allowed the equalization of the AMP and also to reach the following very interesting conclusions:

- Relatively to the primary end-point, from a temporal point of view, an improvement was observed when the

DRF 4000 tasks were inserted in Check A, which translated in a temporal gain of approximately 2.5%. It can be concluded, therefore, that there is an advantage in including these two distinct Checks, in only one Check.

- Concerning the secondary objective, the analysis of the standard deviation, which changed from 17.5 to 9.5 translates the success of the equalization of the respective maintenance plan as reflected in a time gain of 5.8%; in this manner, it was possible to optimize the aircraft downtime.

Some of the proposals for future developments, together with this study, may result in a more consistent analysis, and consequently in an asset for the airline company Portugália. We list some of these proposals:

- To analyse the viability of the maintenance tasks, in what concerns the physical space that exists in each access panel.
- To evaluate all maintenance Checks from an economical point of view, performing a cost analysis of all direct and indirect costs.
- To perform a time (h) versus cost (€) analysis, thereby detecting all cases in which a loss of potential or maintenance interval reduction is justified and singling out the cases in which a task implies the removal of high cost material and if, simultaneously, the time it takes to perform it is reduced.
- To study the viability of fragmenting the Type C Check (5000 FH), even if it means a very high time cost, and including it in a Type A Check.
- To implement a solution for managing the mobility of teams, whether internal or external, to run the service maintenance orders. To implement an optimizer that would allow an integrated management of work, resources, competences and availabilities, in order to minimize the aircraft downtime.

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