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OPTIMIZATION OF AIRCRAFT MAINTENANCE DOWNTIME BY HARMONIZING LIFE OF COMPONENTS DURING MAJOR OVERHAUL

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ABSTRACT

A considerable amount of valuable operational life of an frontline aircraft can be conserved and effectively utilized for routine operational requirements, if component replacement downtime can be avoided during the operational cycle of an frontline aircraft. Component replacement downtime compounds to the existing scheduled routine maintenance downtimes and at times it extends much longer as certain critical components replacements warrants for a series of post replacement checks during flying prior declaring aircraft fit for routine operational commitments without restrictions. Hence optimal scheduling of the component replacement periodicity or avoiding component replacement during aircraft operational life always contribute to the increase in the operational exploitation of an frontline aircraft. This paper discusses the various downtime associated with the routine aircraft inspections during the operational cycle of aircraft. The paper also provides a brief on the various methods and tools prescribed in Maintenance Repair and Overhaul agencies undertaking major overhaul / inspection of aircraft in scheduling the component life, with an aim to achieve increased operational exploitation time during frontline exploitation.

KEYWORDS: Frontline Squadron, Routine Inspection, Maintenance, Downtime, Inventory, Scheduling, Supervisor, Tradesman, Line Replacement Unit(LRU).

Abbreviations

AE	Air Engineering
AL	Air Electrical
AR	Air Radio
AW	Air Weapon
ATO	Air Technical Officer
CTF	Check Test Flight
CM	Corrective Maintenance
DI	Defect Investigation
DR	Defect Rectification
FSI	Flight Safety Inspector
LRU	Line Replacement Unit
OEM	Original Equipment Manufacturer
PM	Predictive Maintenance
MFOP	Maintenance Free Operational Period

I. INTRODUCTION

An air squadron[14,15] is a place where a number of similar types of aircraft are operated for meeting specific mission requirements. Squadrons are normally provided with adequate manpower and mandatory facilities to carry out routine servicing of the aircraft. However squadrons possess very limited facility to undertake repairs and maintenance of the aircraft. Aircraft needs to be transferred to appropriate maintenance agencies[16] or

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assistance of qualified personnel[19] / equipment are to be sought to undertake major maintenance / repair in frontline squadrons[15]. Post utilization of the aircraft in frontline squadrons for a specified period, the aircraft are mandatorily transferred to appropriate maintenance lines[16] for undertaking mandatory inspections and repairs which warrants considerable down time[9]. Thus the main aim of the frontline squadron is to utilize the allotted aircraft to the maximum for its operational requirements with limited time for maintenance.

The major contributing factors towards aircraft downtime are calendar / hourly based inspections[17],component replacement[13], post checks after inspections, unscheduled defects and defect identification sorties. At times defects due to ground accidents and improper maintenance also contribute to the downtime of aircraft operating from a frontline squadron[15].

Effective inventory management[8,10-13] to augment with the routine maintenance[15,17] and defect rectifications would help in achieving phenomenal reduction in aircraft downtime and inventory management cost[18].

II. FRONTLINE AND OTHER AIRCRAFT MAINTENANCE LINES

A frontline[14,15] air squadron is a place where a group of similar variants of aircraft is operated to meet laid down or specific operational requirements. The number of aircraft, maintenance personnel and the support facility allotted to the frontline squadron depends on the operational requirements and the same varies from squadron to squadron.

The main aim of the frontline squadron is to accomplish the scheduled tasking and the allotted mission by maintaining a maximum aircraft serviceability state[9] at all times.
Downtime arising out of calendar / hourly based routine inspections and checks promulgated by OEM [11] and other agencies to reinstate quality and safe flying is inevitable and is to be strictly adhered to. However, since it is very difficult to exercise positive control over the downtime arising due to unforeseen defects, proper monitoring and timely provisioning of expertise assistance for DI/DR would help in reducing the aircraft inspection downtime in a frontline air squadron.

Aircraft are normally transferred to other appropriate maintenance lines[16] if maintenance downtime for certain inspection or defect rectification is phenomenal. Maintenance lines based on its depth are equipped with specialist tools and equipments along with qualified personnel to carry out tasks on a particular variant of aircraft.

III. ROUTINE INSPECTIONS AND MAINTENANCE ON AIRCRAFT

Every Maintenance Action [1,6] in frontline aircraft can be broadly categorized as one of the following four types as indicated in Figure 1:-

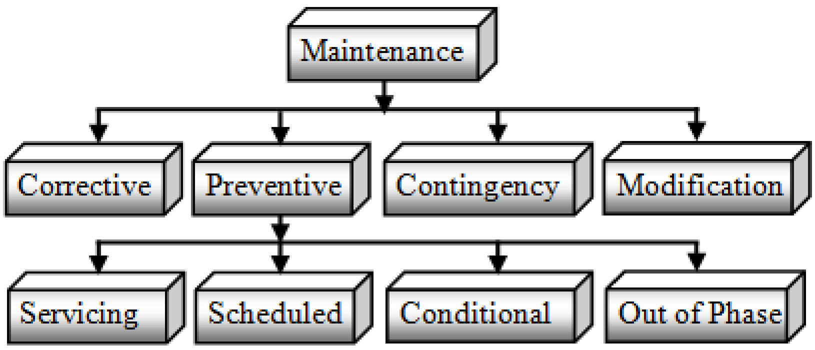

Fig 1. Types of Aircraft Maintenance

Corrective Maintenance: It is used to restore a system after failure to initial status so as to make it serviceable for continued exploitation.

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Preventive Maintenance: It is used to restore a system to initial state before failure, based on the inspection results.

Contingency Maintenance: It is a type of preventive maintenance carried out during war / war like scenario with certain relaxed maintenance standards like suspension of scheduled and condition-based maintenance.

Modification: Modifications are carried out as per requirements to acquire new technology or to seek remedy to a design fault as per recommendations.

Servicing: Inspection carried out prior and post flying to check signs of unserviceability and to replenish fuel, oil and air.

Scheduled Maintenance: Inspection carried out at regular and predetermined intervals to reduce faults and to maintain aircraft in the desired condition.

Condition Based Maintenance: Inspection carried out at intervals and corrective maintenance action is undertaken based on condition of the item.

Out-of-Phase Maintenance*:* Scheduled or condition-based maintenance which mandates at intervals which do not fit on the routine maintenance cycle are termed as out-of-phase inspections or maintenance.

Routine Inspections[1,6] are inspection which are scheduled to be undertaken mandatorily at certain specified intervals. Routine inspection may be of hourly based or calendar based inspections as promulgated by the OEM based on certain predefined requirements of the specific aircraft. In routine inspections there will be a list of scheduled inspections followed by mandatory spares, LRU[4] or component replacements[5,6] enabling the system to undertake necessary course correction[5] and restore back to its initial serviceable state.

The LRU replacements may be mandatory undertaken as per the condition of the LRU / criticality decided by the OEM based on the past Failure Trend[1].If X(t) is the total breakdown of a system at time t and Lg is the failure threshold of a system. The failure threshold[6] of a system under breakdown maintenance and scheduled maintenance is indicated in Figure 2(a) and 2(b):-

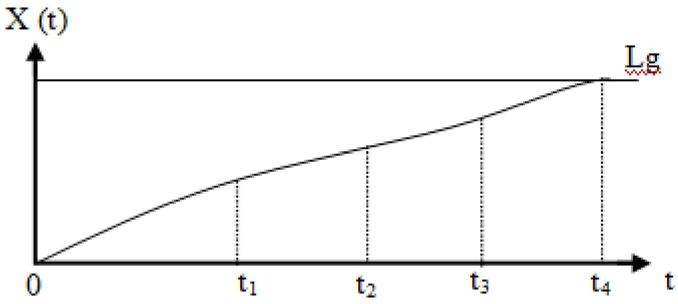

Fig 2(a). Failure threshold of systems without continuous monitoring

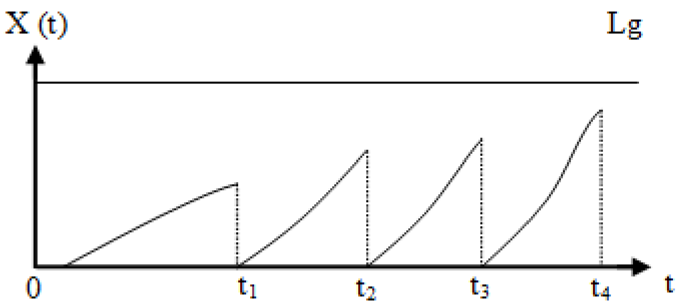

Fig 2(b). Failure threshold of systems with continuous monitoring

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Lists of calendar and hourly based inspections on a particular type of aircraft and the respective downtime of inspections are illustrated on Table I. It may be noted that each calendar and hourly based inspections will be having specific set of checks which could be different and thereby require separate downtimes.

Table I. Illustration of routine inspection of an aircraft

Sr	Hourly Inspection	Downtime (Days)	Calendar Inspection	Downtime (Days)
1	25 Hourly	X	5 Weekly	X
2	50 Hourly	X+1	10 Weekly	X
3	100 Hourly	2X+1	15 Weekly	3X+1
4	200 Hourly	4X	30 Weekly	4X
5	400 Hourly	7X	60 Weekly	17X+1
6	800 Hourly	10X+1	Ac Transfer for Major Overhaul	

Where, "X" is Downtime in days.

It is inevitable that aircraft needs to be placed unserviceable every 25 flying hours of flying and in a gap of 5 weeks in its operational life[2] to ensure completion of the laid down routine inspections. As the flying hours and calendar duration increases the associated downtime also increases due to increase in the number of mandatory checks.

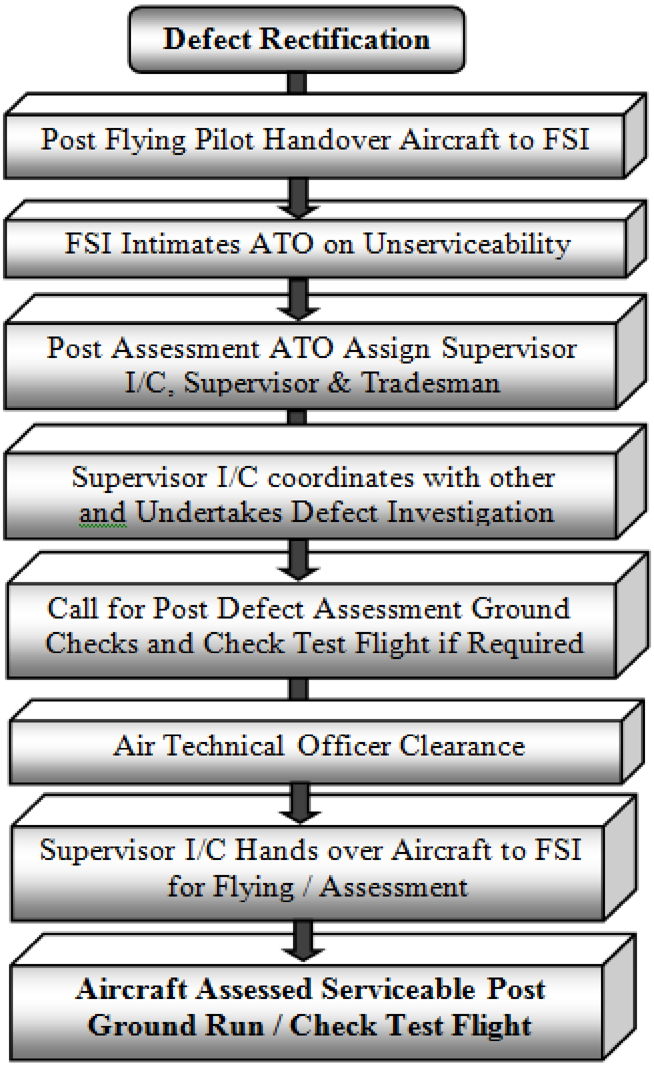

Fig 3. Aircraft Defect Investigation Sequence

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It may be noted that while undertaking every higher routine inspection like 400 Hourly or 60 weekly inspections, multiples of the other smaller inspections which falling due at that time are to be carried out since, mandatory checks mentioned on those inspections may be different. The indicated downtime[9] for every higher inspection is provided in such a way that it caters for the time to complete the smaller inspection also simultaneously. The series of activities undertaken while carrying out defect investigation and rectification actions on a frontline aircraft is enumerated in Figure 3.

The probability of aircraft remaining idle with a particular maintainer for a long time while undertaking defect investigations cannot be ruled out. This may be because of various factors like prolonged DI, non availability of specific tool / test equipment /LRU, support lapse, non availability of qualified personnel. Hence, constant follow up and provision of necessary and timely assistance from the expertise on the specific field is required to expedite the defect investigation and rectification action of a frontline aircraft.

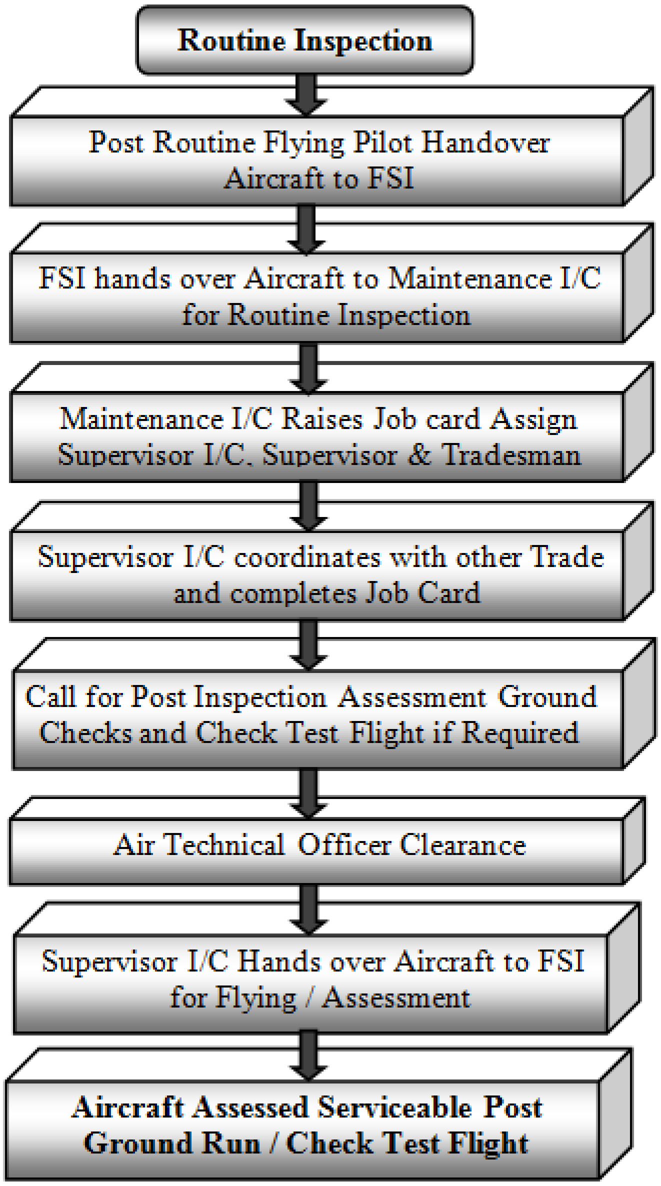

Fig 4. Routine Aircraft Maintenance Sequence

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Post flying aircraft is handed over back to FSI by the pilot. FSI initiates the AFS inspection[17] which is done to assess unserviceability post flying and to carry out replenishment of fuel, oil and air. If unserviceability is reported during flight servicing inspection, then aircraft undergoes defect investigation and corrective maintenance. If no unserviceability is reported and if aircraft is due for calendar / hourly routine inspection , immediately the aircraft is placed unserviceable and handed over to the maintenance in charge. The series of activities undertaken by the maintenance personnel while undertaking routine inspection in a frontline operational aircraft is enumerated in Figure 4.

IV. SPARE REQUIREMENTS OF AIRCRAFT

Downtime arising from routine inspections contribute to the major share of the downtime of frontline operational aircraft and downtime due to unforeseen defects ranks to the next highest contributor of downtime. In addition to the inevitable downtime arising from the routine inspections and defects, on rare occasions ground accident and improper maintenance also contribute to the downtime of operational aircraft which on most of the occasions are avoidable.

As the routine inspections are planned and forecasted after certain flying hours or time period and the mandatory requirement of spares is also predefined, the time lost in spare management while undertaking a routine inspection is minimal. However spare requirements due to unforeseen defects is more cumbersome as it provides only very time for provisioning of spares, which eventually add up to the aircraft downtime. Hence timely and superior planning is required to provision spares[12,13] for unforeseen defect rectifications. Spare management within short notice for defect rectifications can contribute to the following:-

Spare Transportation Cost: If required spares are not available at a particular location , reserve spare needs to be transported from other locations by quickest means to avoid unnecessary downtime. Depending upon the volume of spare and the distance from where the critical spare is transported for the specific unplanned task contribute to the maintenance and operating cost of the aircraft.

Abroad Procurement Cost: Most of the critical aircraft components are to be provisioned from the OEM to maintain the required standards. OEM's charge high for ordering small quantity of items with less lead time for supply than ordering bulk spares with comfortable lead time for production and transportation. Hence abroad procurement for defect rectification will always cost high as the supply lead time provided is less.

Cannibalization of Components: The scenario in which Aircraft remains unserviceable on ground for want of critical spares is termed as AOG (Aircraft on Ground) situation. To reduce the downtime arising out of AOG situation components are often cannibalized from other aircraft to make the primary aircraft serviceable. Cannibalization doubles the requirement of mandatory spares for installation of a component.

Storage of Critical Spares: A set of critical aircraft spares are stored as reserve aircraft spares to meet the contingencies arising from unforeseen defects and component failures. Maintaining critical aircraft spares is a must to reduce the downtime of aircraft during the critical operational junctures to reduce "Aircraft on Ground" situations. However stockpiling of aircraft inventory without proper study increases the aircraft operating cost.

V. BACKGROUND TO BARCODE AND RFID READERS

Barcode Identity identification[24] has emerged as a business process improvement driver in a range of industries. Barcode Identity is a wireless automatic identification and data capture technology, consisting of three hardware components in it barcode identity tags, edge ware or Barcode Identity reader or optical reader, and middleware (software application to filter data). Barcode Identification technology has its own unique characteristics. First, Barcode Identity tags can be manufactured at a very minimal initial investment as it does not have any complicated electronic components. Second, scanning the Barcode Identity to decode the data will take around less than an second. Third, Barcode Identity tags cannot be read by everybody, it requires optical reader positioned in line with the tag to read the encrypted data thereby ensures the security of the sensitive data. Finally, Barcode Identity tags are use and throw disposable tags[29] which can be manufactured by limited skilled personnel at cheap cost.

RFID[21-23] has replaced Barcode Identity in various commercial fields like component identification[22] and supply chain inventory management and retail outlets due to its unique advantages[23] like data acquisition speed ie, less than a second, simultaneous data acquisition[23] and the ability to acquire data from a distance as compared to Barcode Identities. However due to the high initial setting up cost and manufacture cost incurred in setting up RFID in-house in the maintenance unit or retail outlet RFID utility is restricted by users. In addition, RFID scanner[17] can read the components far from certain distance and there is no requirement for RFID reader to be in line with component and thereby increasing the RFID scanning speed making it fit for commercial use and less preferred for military usage where data security is of paramount importance.

VI. MAINTENANCE REPAIR AND OVERHAUL FACILITY

Aircraft is transferred to the appropriate Maintenance Repair and Overhaul Facility[20] for major overhaul/inspection post completion of the planned calendar life in the frontline squadrons. In the MRO facility the components are subjected to conditional monitoring[2] and corrective maintenance[5] as per requirement in order to restore the aircraft system back to the original designed stature. Aircraft structure, LRUs and critical components[4] are subjected to various checks as per a predefined schedule using the expertise of various aircraft maintenance trades[19]. In specific, the components with life are classified as indicated in figure 5 and the components are replaced or restored back to its original state by undertaking corrective maintenance.[5]
Let us consider a aircraft fleet with 20 aircraft. At any point of time 12 aircraft will be operational and positioned in frontline squadron for routine operational commitments. Balance 8 aircraft will be undergoing routine major aircraft conditional monitoring inspection. For easy identification the aircraft are numbered as AC1, AC 2, AC 3….. AC 20.These 20 aircraft are supported with adequate number of additional critical components like engine as spare, since these components turnaround will be laborious and time-consuming in case of repair.

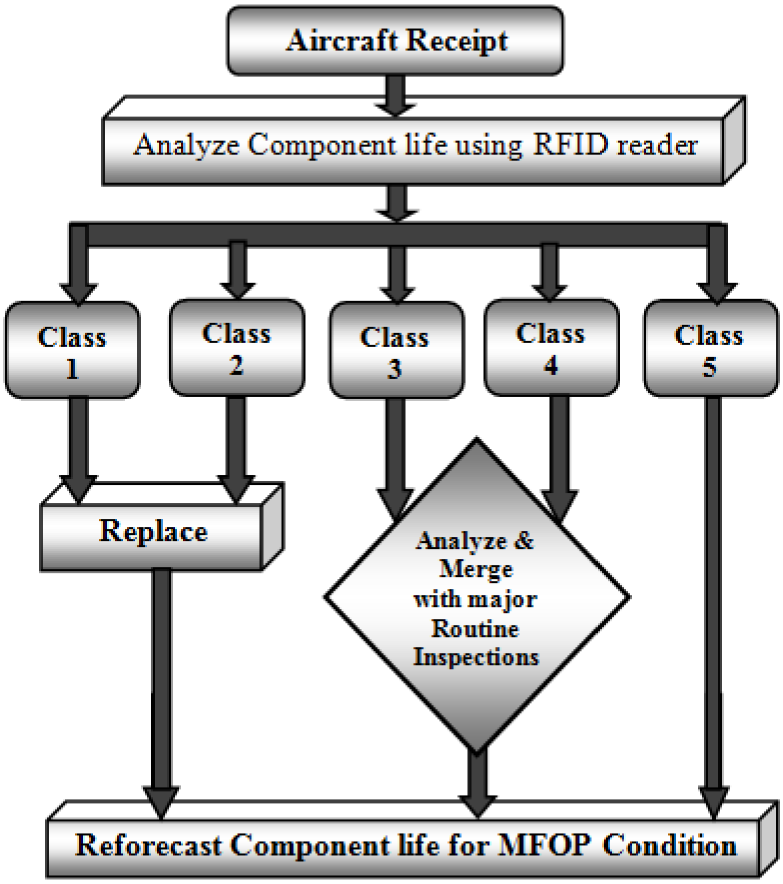

Fig 5. Aircraft Component Life Harmonizing Sequence

The main aim of component life harmonizing is to achieve Maintenance Free Operational Period (MFOP)[4] in the frontline squadron. Hence immediately on receipt of a aircraft in the MRO facility. All components installed on the aircraft with specified service life are analyzed using RFID[7] or Optical Barcode readers[24] and the components[3] are classified into five classes as elaborated below:-

Class 1:- Component due for routine Servicing or Overhaul.

Class 2:- Component with operational life less than 10% of aircraft operational life.

Class 3:- Component due for routine Servicing or Overhaul within 10-50% of aircraft operational life.

Class 4:- Component due for routine Servicing or Overhaul within 50-90% of aircraft operational life.

Class 5:- Component with 90 % of aircraft operational life or due for routine Servicing or Overhaul after 90% of aircraft operational life[4].

Component under class 1 and 2 are replaced with other serviceable alternative with optimal life. Components under class 3 and 4 are checked for their functionality[3] and replacement is forecasted along with major routine inspections i.e Hourly or Calendar inspections. Components falling under class 5 are forecasted along with next Major Overhaul post according optimal extension. The following factors are also additionally taken into consideration prior harmonizing the component life during major overhaul of the aircraft,

- Criticality of the component.
- Past failure trend analysis.
- Effect of component on mission requirements.

Availability of expertise in the area of operation

VII. RESULTS AND DISCUSSION

At any particular point of time, MRO facility of the above discussed variant of aircraft will have access to the components of aircraft undergoing major inspections and additional components undergoing repair or reconditioning at the component repair facility. Hence harmonization of the component life[4] at par with the aircraft operational life[4] can be implemented effectively in the MRO facility

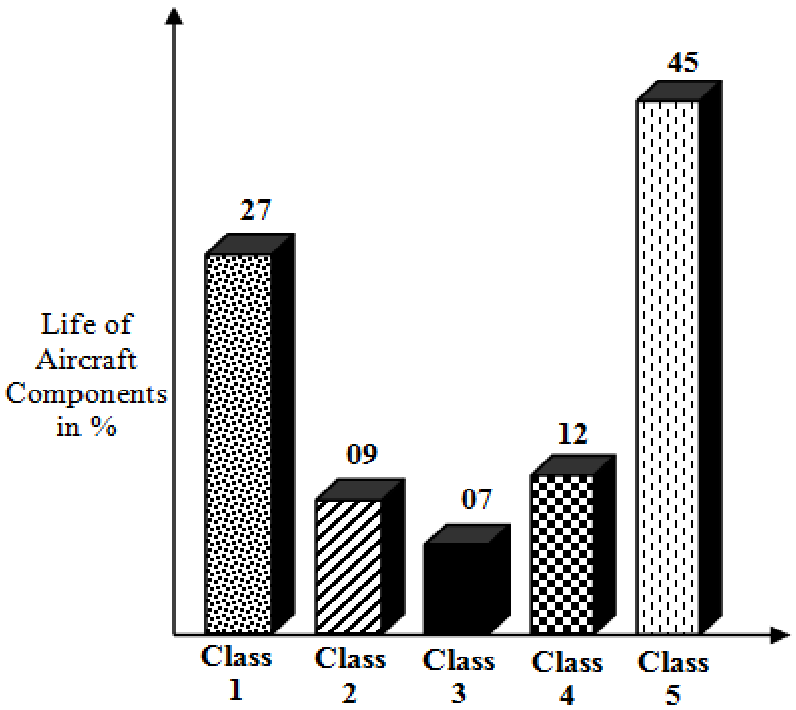

Fig. 8 Dispersion of Aircraft Components

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Let us consider the effect of component life harmonization in the above discussed example ie, for a fleet of 20 aircraft. Post receipt of an aircraft and after completion of the component life survey using automatic identification techniques (RFID or Barcode reader) the dispersion of the component life of a particular aircraft is indicated in figure 8 above.

A total of 36 percent (Class 1 and 2) of the aircraft components were replaced during major inspection at the MRO facility. Component life re-forecasting post harmonizing with aircraft operational life is undertaken for 19 percent (Class 3 and 4) of aircraft components. Balance 45 percent (Class 5) components are retained in the aircraft post satisfactory serviceability checks and appropriate component life extensions for exploitation till completion of next aircraft operational cycle.

Additional 9 percent (Class 2) of components discarded at MRO facility[12] for reconditioning and the 19 percent of (Class 3 and 4) components and merged with major routine inspections post re-forecasting contribute immensely towards achieving MFOP condition[4] in frontline squadron. In normal circumstances the replacement of the 28 percent (Class 2,3 and 4) of aircraft components would have fallen due during the operational cycle of aircraft contributing to the unwarranted aircraft downtime. Aircraft component life time harmonization has reduced the aircraft downtime associated with the replacement of 28 percent of components with life scattered through the operational life of aircraft.

Also, post aircraft component life harmonization since the replacement downtime is concurrently scheduled along with major routine inspection downtime a phenomenal reduction in aircraft downtime during routine operational life[4] of aircraft can be achieved which directly contributes to the operational availability[9] of the aircraft.

VIII. CONCLUSION

Reduction in downtime of frontline aircraft is an direct indicator of increase in aircraft availability or aircraft operational availability. Aircraft maintenance and utilization plan of frontline squadrons are always aimed at achieving the Maintenance Free Operational Period (MFOP) condition in aircraft utilization. Hence the effective implementation of aircraft component life harmonization in aircraft MRO facility during major overhaul of aircraft will help frontline squadrons to achieve MFOP condition by reducing considerable amount of aircraft downtime associated with component replacement during operational life cycle of frontline aircraft.

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