Optimisation of Aircraft Maintenance and Utilisation factor by Implementation of Effective Inventory Management

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***Abstract*—A considerable time is utilized in undertaking routine inspection during the operational cycle of aircraft The routine inspections contribute to the major share of downtime in addition to the downtimes arising due to unscheduled defects and associated inspections. Effective monitoring of the aircraft operations and maintenance and ensuring timely completion within scheduled timelines would enhance the operational availability of frontline aircraft by reducing the aircraft downtime. A large chunk of useful operational life and cost in terms of provisioning of critical spares are at times exhausted to maintain the operational readiness of frontline squadron despite there are various checks and balances in place to effectively manage the critical aircraft inventory. The main aim of the work is to indicate the increase in operational efficiency of aircraft in frontline squadrons and other maintenance lines by incorporation of an application to sort and undertake effective inventory management. In addition to enhancing the operational efficiency of a frontline operational air squadron and reducing maintenance downtime in other maintenance lines, the inventory management technique discussed in this paper would also help in reducing the operating cost and logistics management time associated with aircraft maintenance and operation.**

Keywords—Frontline Squadron, Routine Inspection, Maintenance, Downtime, Inventory, Supervisor, Tradesman, Line Replacement Unit(LRU).

I. INTRODUCTION

An air squadron[6,8] 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 or assistance of qualified personnel / equipment are to be sought to undertake major maintenance / repair in frontline squadrons. Post utilization of the aircraft in frontline squadrons for a specified period, the aircraft are mandatorily transferred to appropriate maintenance lines[7] for undertaking mandatory inspections and repairs which warrants considerable down time. Thus the main aim of the frontline squadron is to utilize the allotted aircraft to the maximum for its mission requirements with limited time for maintenance.

The major contributing factors towards aircraft downtime are calendar / hourly based inspections[9], 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[6].

Effective inventory management[4] to support routine maintenance and defect rectifications would help in achieving phenomenal reduction in aircraft downtime and inventory management cost.

Abbreviations :

AFS	After Flight Servicing
AE	Air Engineering
AL	Air Electrical
AR	Air Radio
AW	Air Weapon
ATO	Air Technical Officer
BFS	Before Flight Servicing
CTF	Check Test Flight
CM	Corrective Maintenance
CO	Senior Officer
DI	Defect Investigation
DR	Defect Rectification
FSI	Flight Safety Inspector
LRU	Line Replacement Unit
OEM	Original Equipment Manufacturer
PM	Predictive Maintenance
SNR"P"	Senior Pilot
SNR"O"	Senior Observer

II. FRONTLINE AND OTHER AIRCRAFT MAINTENANCE LINES

A frontline[6,8] 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 at all times.

Downtime arising out of calendar / hourly based routine inspections and checks promulgated by OEM 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[7] 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 [5,6] in frontline aircraft can be broadly categorized as one of the following three types as indicated in Figure 1:-

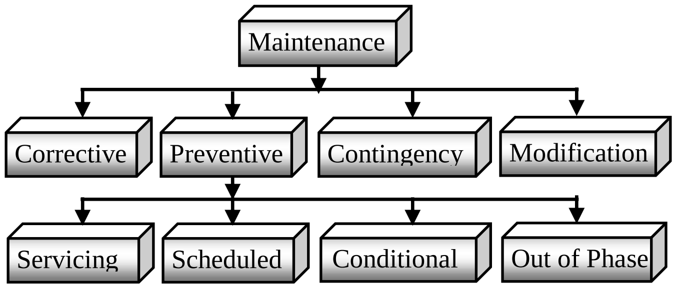


Fig 1. Types of Aircraft Maintenance

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

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[5,6] 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 enabling the system to undertake necessary course correction 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[2].

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.

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[1] 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 2.

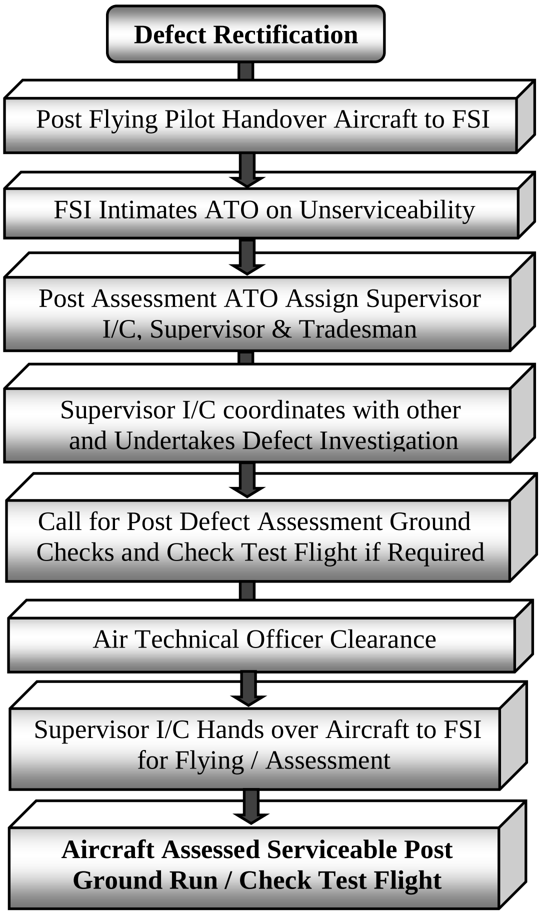


Fig 2. Aircraft Defect Investigation Sequence

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.

Post flying aircraft is handed over back to FSI by the pilot. FSI initiates the AFS inspection[5] 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 in Mod Form 700 [6] 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 3.

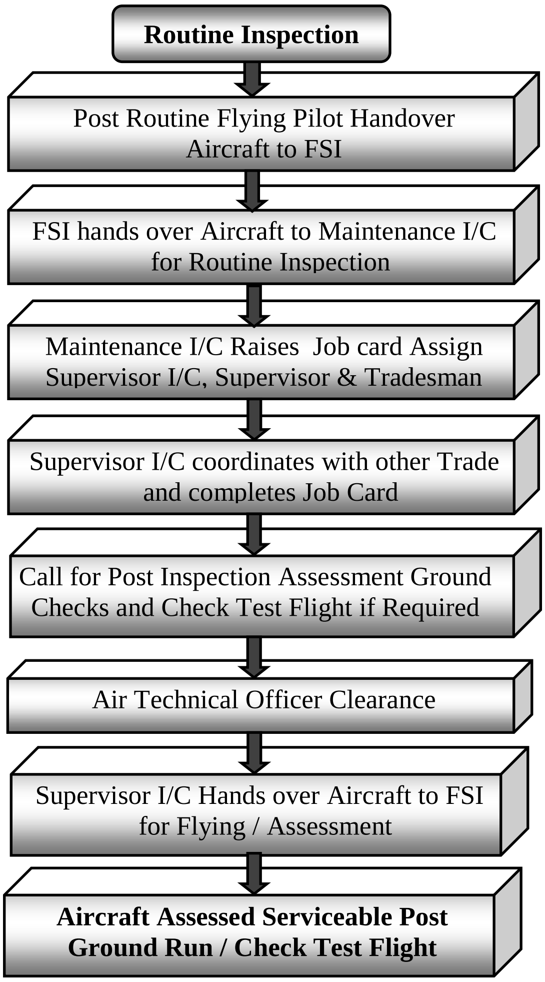


Fig 3. Routine Aircraft Maintenance Sequence

IV. SPARE REQUIREMENTS OF AIRCRAFT

Downtime arising from routine inspections contribute to the major share of the downtime of frontline operational aircraft and downtime arising out of unforeseen defects ranks 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 described 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[2,10] 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.

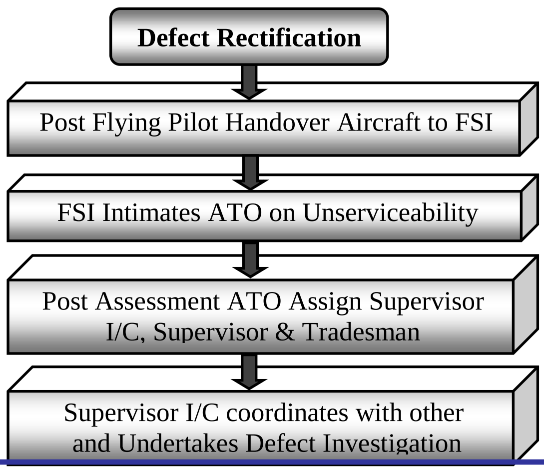
Abroad Procurement Cost: Most of the critical aircraft components are to be provisioned from the OEM to maintain the required standards. OEM's charge high for ordering small quantity of items with less lead time for supply than ordering bulk spares with comfortable lead time for production and transportation. 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. APPLICATION FOR IDENTIFICATION OF ALTERNATE AIRCRAFT INVENTORY

The probability of aircraft components or structure getting damaged or changing from serviceable to unserviceable condition is more during flying operation. Hence, aircraft is subjected to various routine flying checks[5] like AFS and TRS to assess serviceability post flying. Post finalization of the components for replacement post routine inspections or during defect investigations, if the replacement for faulty component is not readily available then the non availability of spare contributes to unnecessary downtime. The comprehensive defect rectification sequence of an aircraft is indicated in figure 4.



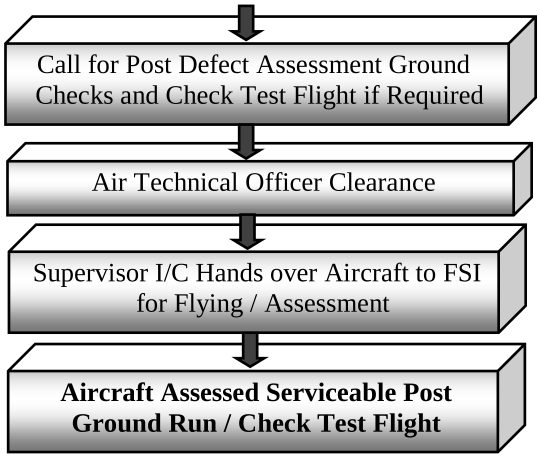


Fig 4. Aircraft Defect Investigation Sequence

Let us consider a fleet operating more than three variants of aircraft from different OEM and countries. Consider the different variants of aircraft as AC1, AC 2, AC 3….. ACn.

The minimal downtime associated with the defect rectification due to failure of a particular components or LRU for a particular aircraft variant is enumerated in figure 5.However the indicated down time may increase depending on the following factors:-

- Co-location of unit with depot.
- Availability of reserve aircraft for cannibalization.
- Availability of LRU repair facility and location
- LRU Procurement time.

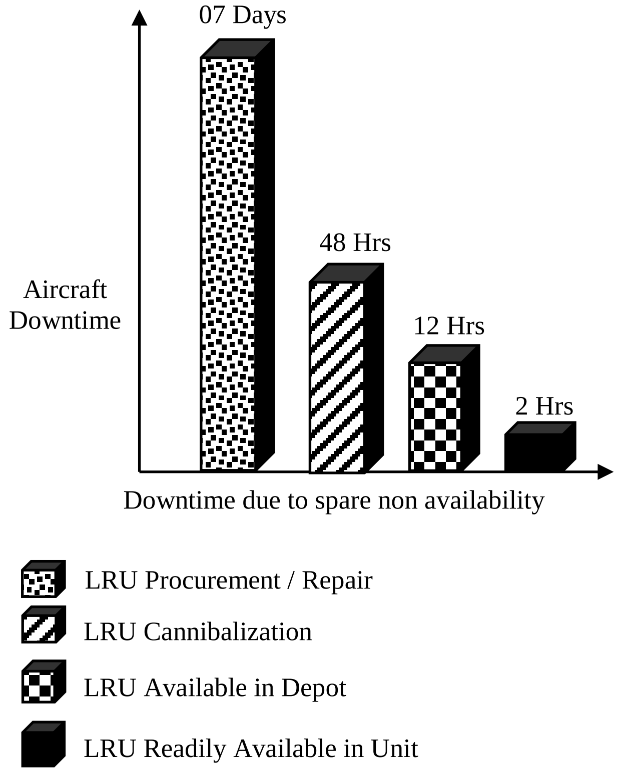


Fig. 5 Comparison Downtime due to spare non availability

In general LRU or components from same aircraft variants are interchangeable and components from different aircraft variants are not interchangeable. However certain general LRU or components of same OEM from different variants of aircraft may match as alternate. The application under discussion is aimed at identifying similar and interchangeable components of different aircraft variants for utilization during spare crisis. The input and output requirements of the alternate spare identifying application is indicated in figure 6.

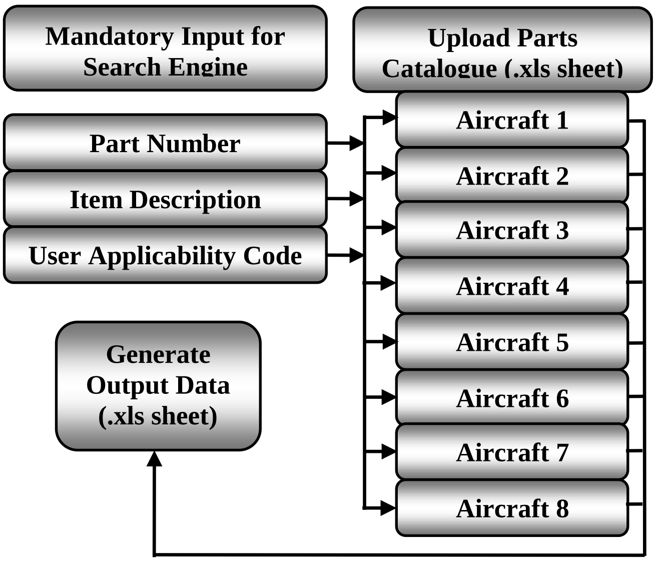


Figure 6. Application for Inventory Matching

In the above application provision is given for searching the parts catalogue of 8 different variants of aircraft. The key behind the search or the input requirements are, item part number, description and user applicability code. Post completion of the input, the parts catalogue from the same OEM of other variants of aircraft are uploaded in .xls format as per requirements for Aircraft from 1 to 8. After successfully uploading the aircraft parts catalogue data, the output is generated in the same .xls format. If requirement exist to search more than 8 variants of aircraft, search pattern may be repeated for aircraft from 9 to 16 and so on. sample output of the application after identification of alternate LRU or component is indicated in figure 7.

List of Probable Alternate Items

Description: Nut Hexagon **Part No:** Part Number 23

Sl	Part Number	Description	Applicability Code of User	Aircraft Code
1	Part Number 1	AC Item 1	Code 1	AC 1
2	Part Number 2	AC Item 2	Code 2	AC 3
3	Part Number 3	AC Item 3	Code 3	AC 5
4	Part Number 4	AC Item 4	Code 4	AC 6
5	Part Number 5	AC Item 5	Code 5	AC 8

Fig 7. Sample Output of Inventory Matching Application

VI. RESULTS AND DISCUSSION

The utilization of the above discussed inventory matching application for a fleet operating more than 3 variants of aircraft with at least 2 variants from the same OEM result in considerable downtime reduction. The various conditions for achieving downtime reduction through implementation of the inventory matching application is enumerated below:-

Condition 1: Let us consider the failure of a LRU or component from aircraft variant AC1 and the LRU is not readily available with the unit or depot. Consider the availability of the LRU in the inventory of one or more of the other aircraft variants ie, AC1, AC 2, AC 3….. ACn.

In this case the LRU can be temporarily issued from the alternate aircraft inventory rater than wasting time in repair, procurement or cannibalization of spare from reserve aircraft. The anticipated downtime is based on the assumption on the LRU availability in condition 1 is indicated in figure 8.

It may be noted that the decision to repair the LRU may take at least 07 days if repair is feasible within maintenance lines[7].Repair abroad or new procurement of LRU may take months together. Hence the case of new procurement and repair abroad is not taken into consideration while comparing the maintenance downtime due to LRU non-availability.

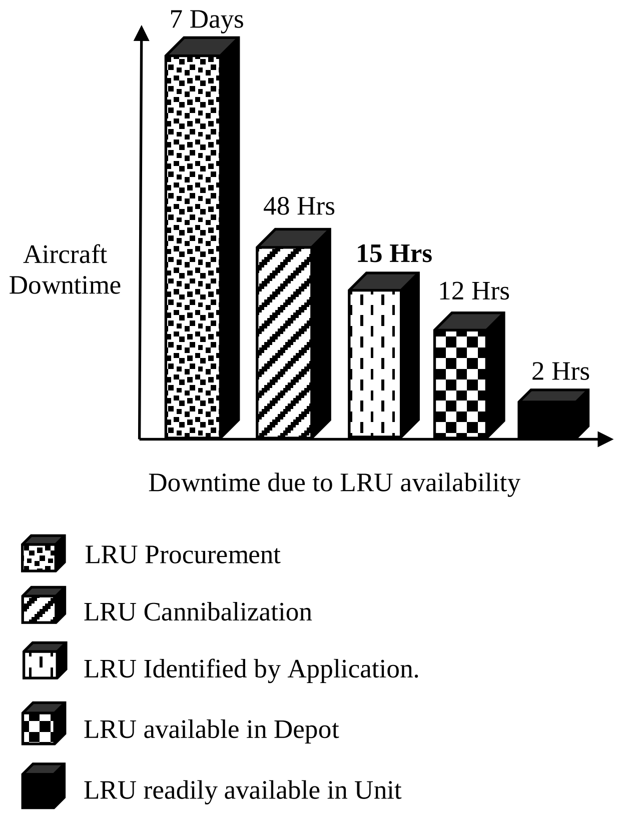


Fig. 8 Comparison Downtime in Condition 1.

Condition 2: Let us consider the failure of a LRU or component from aircraft variant AC1 and the LRU is readily not available with the unit or depot. Consider the availability of the mandatory break down spare of the LRU in the inventory of one or more of the other aircraft variants ie, AC1, AC 2, AC 3….. ACn.

In this case the LRU can be repaired utilizing the alternate break down spare rather than initiating emergency procurement which incur high cost or cannibalization of spare from reserve aircraft. Cannibalization of LRU doubles the requirement of mandatory spares required for installation of LRU. Hence it is always recommended to avoid cannibalization as a good maintenance practice as an aim to avoid unnecessary consumption of mandatory spares.

The anticipated downtime is based on the assumption on availability of alternate break down spares in depot and repair feasibility availability in maintenance lines. The anticipated downtime based on the above assumption for condition 2 is indicated in figure 9.

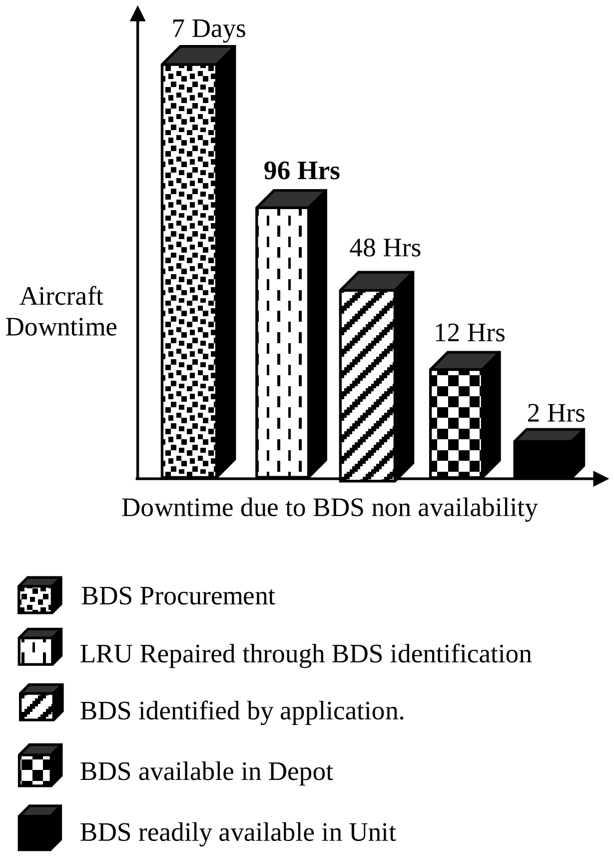


Fig. 9 Comparison Downtime in Condition 2.

Condition 3: Let us consider the drawdown of a particular variant of aircraft due to obsolescence, OEM supportability, high operating cost, inferior efficiency or due to any other reasons. The suitable spares that can be utilized on other aircraft variants can be segregated and merged with the relevant alternate aircraft variant rather than discarding the complete spare as obsolete. In this case the application can be used as a tool to save phenomenal cost as spare procurement cost.

VII. CONCLUSION

In short the effective utilization of the inventory matching application in a fleet operating more than 3 variants of aircraft with at least 2 aircraft from the same OEM can result in cost savings in addition to achieving aircraft maintenance downtime reduction. It increases the spare sorting and identification ability of depot and reduces spare wastage due to unwarranted cannibalization arising due to non availability of critical spares. It also helps in sorting the obsolete spares of aircraft scheduled for draw down for reuse in the aircraft in service.

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