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Maintenance Optimization of Aircraft in Operating Environment using Automatic Identification Techniques

K. Subash[1], R. Vinu[2] and K. Vijayaraja[3]

[1]Sathyabama University, Chennai – 600119, Tamil Nadu, India; subash_27@rediffmail.com
[2]Department of ECE, Toc H Institute of Science and Technology, Kochi – 682313, Kerala, India; vinur81@gmail.com
[3]Department of Aeronautical Engineering, KCG College of Technology, Hindustan Group, Chennai – 600097, Tamil Nadu, India; subash_27@rediffmail.com

Abstract

Objectives: To reduce maintenance downtime in operational cycle by integrating automatic identification techniques in the existing aircraft maintenance and utilization environment of a frontline squadron is discussed in this paper. **Methods/ Statistical Analysis**: Along with explaining the routine calendar and hourly based aircraft maintenance philosophies of a frontline aircraft usage of an application software to undertake real-time status monitoring of aircraft maintenance and repair in a frontline squadron is discussed in brief. The effective utilization of the optical barcode functions, barcode generation and their unique application in personnel identification and maintenance enhancement in a frontline squadron is discussed in detail. **Findings:** The probable reasons for increase in aircraft downtime of military aircraft during defect rectifications and routine inspections and the facility enhancement envisaged in a frontline squadron due to integration of the maintenance monitoring application in the existing aircraft maintenance and utilization environment is explained in the paper. The reduction in aircraft down time in the operational cycle of a frontline military aircraft is the direct indicator of increase the operational efficiency. **Application/Improvements:** The implementation of an maintenance monitoring application using optical identification technique and the resultant enhancement in the operation efficiency due to aircraft downtime reduction is explained in detail.

Keywords: Barcode, Downtime, Frontline Squadron, Inspection, Maintenance

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
CCTV	Closed Circuit Tele Vision
CTF	Check Test Flight
CM	Corrective Maintenance
DI	Defect Investigation
DR	Defect Rectification
DVR	Digital Video Recorder
FSI	Flight Safety Inspector
LRU	Line Replacement Unit
OEM	Original Equipment Manufacturer
PM	Predictive Maintenance

**Author for correspondence*

1. Introduction

An air squadron[1,2] 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 scheduled servicing and routine maintenance of the aircraft. However squadrons possess very limited facility to undertake major repairs and maintenance of the aircraft as it is constrained with facility and trained manpower. Aircraft needs to be transferred to appropriate maintenance agencies[3] 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[4] 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[5].

The major contributing factors towards aircraft downtime are calendar/hourly based inspections[6-9], post checks after inspections, unscheduled defects[10] and defect identification sorties. At times defects due to ground accidents and improper maintenance also contribute to the downtime of a military aircraft operating from a frontline squadron.

Methodology of achieving reduction in aircraft routine inspection downtime by incorporating individual accountability and effective operational monitoring for a specific variant of military aircraft[9,11] is discussed in this paper. It may be noted that the same methodology if implemented on a civil organization or firm would enhance individual accountability resulting in an increase in productivity.

The basics of the military aircraft maintenance polices adopted in the frontline squadron[1,2] aimed at improving the operational availability has been elaborated in detail. The critical requirement of error free maintenance with reduced aircraft turnaround time for undertaking scheduled inspection and routine maintenance of military aircraft[9,12] has been discussed in brief.

Different methodologies for finding the optimal replacement interval[6-9] of an deteriorating system[11,13] and the effective modes of optimizing the maintenance downtime by eliminating the unwarranted inspection and repetitive maintenance[5,15] has been examined prior to optimizing the routine maintenance of the aircraft under study.

The different lines[4] of aviation maintenance and the specialist trades[3] involved in undertaking military aircraft[14] maintenance based on the quantum and specialist requirement for undertaking maintenance has been touched upon in this paper.

The incorporation of barcode enabled identity[16] in the routine maintenance schedule of a particular variant of frontline military aircraft[1,2] for creating individual accountability of all personnel associated with frontline aircraft maintenance and operation has been studied in detail with an aim to achieve maintenance downtime reduction which directly contribute towards increase in operational efficiency[6,11].

2. Frontline Air Squadron

A frontline[1,2] air squadron is a place where a group of similar military aircraft is operated to meet laid down or specific mission requirements. The number of aircraft, maintenance personnel and the support facility allotted to the frontline squadron depends on the mission 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[12] 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 military air squadron[4].

3. Routine Maintenance on Aircraft

Every Maintenance Action[6-9] in frontline aircraft can be broadly categorized as one of the following three types as indicated in Figure 1.

3.1 Corrective Maintenance

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

3.2 Preventive Maintenance

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

3.3 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.

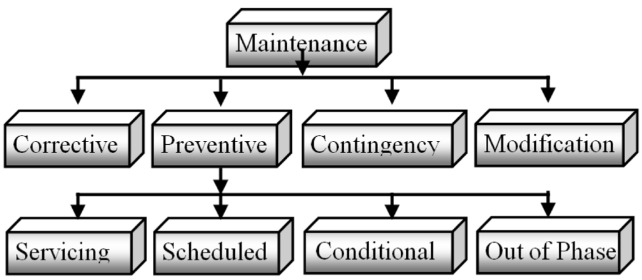

Figure 1. Types of Aircraft Maintenance.

3.4 Modification

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

3.5 Servicing

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

3.6 Scheduled Maintenance

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

3.7 Condition Based Maintenance

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

3.8 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] are inspection which is 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[15] or component replacements enabling the system to undertake necessary course correction[13] 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[15].

Lists of calendar and hourly based inspections on a particular type of aircraft and the respective downtime of inspections are illustrated on Table 1. 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.

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[15] 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.

Table 1. 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	Major Overhaul	Ac Transfer for Overhaul

Where, "X" is Downtime in days.

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 for every higher inspection is provided in such a way that it caters for the time to complete the smaller inspection also simultaneously.

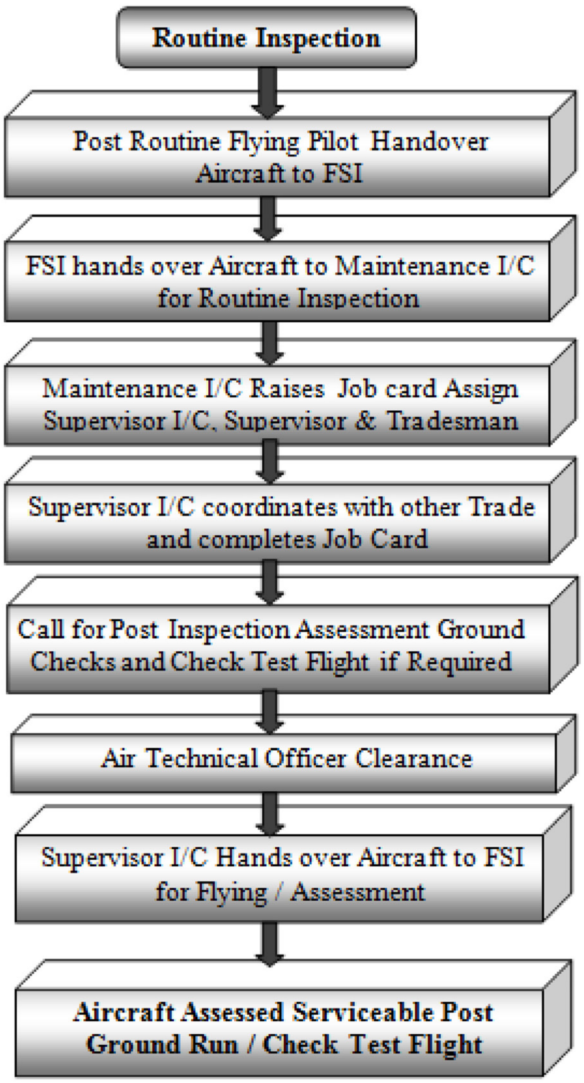

Figure 2. Routine Aircraft Maintenance Sequence.

Post flying aircraft is handed over back to FSI by the pilot. FSI initiates the AFS inspection[1] 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[1] and handed over to the maintenance in charge. The series of activities undertaken by the maintenance personnel while undertaking routine inspection in a frontline military aircraft is enumerated in Figure 2.

4. States of Frontline Military Aircraft

Downtime arising from routine inspections contributes to the major share of the downtime of frontline military aircraft[17]. In addition to the inevitable downtime[12] arising from the routine inspections, on rare occasions ground accident and improper maintenance also contribute to the downtime of military aircraft which on most of the occasions are avoidable.

Based on the mission requirements and the present position of the aircraft, the state of a frontline military aircraft[14] can be broadly classified into the following states:-

4.1 Flying Aircraft

Flying aircraft will be under the responsibility of the senior most aircrew. Any incident, defect or abnormality noticed during flying operation is to be documented and intimated to the ground crew through FSI for further liquidation/rectification.

4.2 Aircraft Parked (Hangar/Dispersal)

Post routine flying and on completion of After Flight Servicing (AFS) inspection aircraft is parked in the hangar to ensure safety/security of aircraft. Prior to planned flying, aircraft is parked in the dispersal after carrying out BFS inspection.

4.3 Aircraft Under Routine Maintenance

Aircraft declared unserviceable will be placed under the custody of nominated supervisor in charge while undergoing routine inspection.

4.4 Aircraft Undergoing washing

Aircraft will be under the custody of nominated supervisor in charge while undergoing washing till handing over back to concerned aircraft supervisor in charge.

4.5 Aircraft Undergoing DI/DR

Aircraft undergoing Defect Investigation/Defect Rectification will be under the custody of the supervisor nominated by the Air Technical Officer.

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[1] like AFS and TRS to assess serviceability post flying. However, the rare probability of serviceable aircraft becoming unserviceable due to improper handling or maintenance cannot be completely ruled out. By enhancing the accountability and increasing the individual responsibility chances of aircraft becoming unserviceable due to improper handling or maintenance can be reduced.

5. Introduction of Barcode Enabled Identities in Aircraft Operational and Maintenance Environment

Provision of barcode identities[16] to all personnel related to the maintenance and operation of military aircraft would enhance in fixing the responsibilities of the personnel with specific timelines. Provision of barcode identities will require optical barcode reader, Tablet PC, Interface software and specific number of barcodes issued to the squadron personnel.

5.1 Optical Barcode Reader

Used for reading the individual barcode identity of squadron personnel and providing necessary input to the Tablet PC for data capturing.

5.2 Individual Barcode Identity

Used for authorizing the squadron personnel ie, Pilot, Observer, Technical officer, Supervisor and Tradesman to undertake the planned task of the respective trades[9].

5.3 Tablet PC

Used for running the application programme for reading the individual barcode identity using the optical reader and creating necessary login/logout record for the squadron personnel.

5.4 Application Programme

Each barcode identity will have a predefined data stored in the computer. The application programme acts as interface between barcode reader and the data stored in the computer.

A symbolic representation of barcode identity issued to the maintenance personnel of various trades and the monitoring staff of a frontline military air squadron is provided in Table 2.

The barcode identity may be endorsed on hard plastic cards with inbuilt provision for enabling easy attachment of the same with the key chains. The same barcode identity can also be used as identity for entering a restricted airbase or squadron if authorized. It may be noted that the additional features like 2D barcode encrypted barcodes or colored barcodes[16] with squadron logo and authorized issuing authority signatures may be incorporated as relevant if requirement exist to increase the security features of barcode identity.

Table 2. List of Authorized Maintainers and Operators

Sr	Description	Strength	Identity	Numbers
1	Pilot	08	**P-300**	001-008
2	Observer	04	**O-300**	009-012
3	Technical Officer	02	**T-300**	013-014
4	Maintenance I/C	02	**M-300**	015 - 016
5	Supervisor AE	12	**SE-300**	017- 028
6	Supervisor AL	10	**SL-300**	029- 038
7	Supervisor AR	06	**SR-300**	039- 044
8	Supervisor AW	06	**SW-300**	045-050
9	Tradesman AE	20	**TE-300**	051 -070
10	Tradesman AL	18	**TL-300**	071-088
11	Tradesman AR	16	**TR-300**	089-104
12	Tradesman AW	14	**TW-300**	105- 118

It may be noted that general visual examination of the barcode identity provided to the squadron personnel will reveal the squadron and trade details only. However, optical reader with the assistance of interface programme loaded on a computer will be required to encrypt the details like name, rank, personnel number, specialist qualification. Symbolic representation of the bar-coded identity is placed in Figure 3.

Figure 3. Sample of Barcode Identity Issued to Squadron Personnel.

6. Enhanced Timeline Monitoring of Defect Investigation and Rectification Using Barcode Identity

Specific timelines are laid down for undertaking the routine inspections[1,15]. Due repetition of inspections and expertise gained over a period of time chances of slipping from the completion date is rare. However, there exist a requirement to undertake a thorough and systematic monitoring of the defect investigation and rectification actions of a frontline aircraft[14] as there is no set timeframe on compliance on most of the occasions and timely completion depends on the individual knowledge and expertise.

The probability of aircraft remaining idle with a particular maintainer[3] 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. The series of activities undertaken while carrying out defect investigation and rectification actions on a frontline aircraft is enumerated in Figure 4.

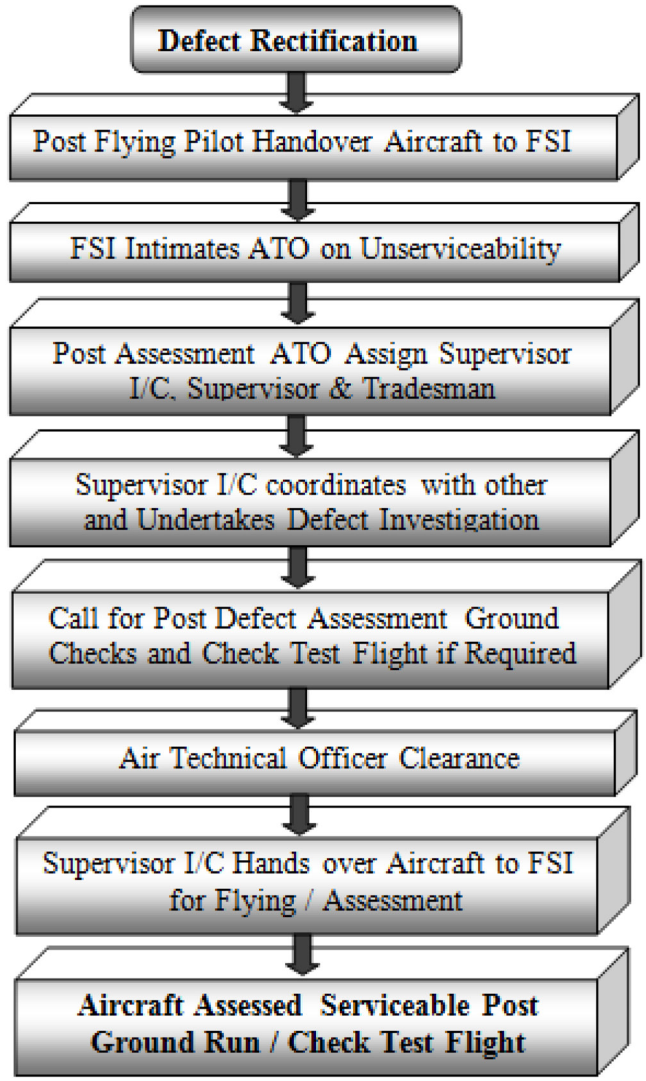

Figure 4. Aircraft Defect Investigation Sequence.

In specific aircraft undergoing inspection, DI/DR, washing or parked in hangar are monitored using CCTV for increasing the accountability of personnel working on the aircraft. The squadron CCTV display unit will have the following output.

- Dispersal Camera Output
- Washing Point Camera Output
- Maintenance Spots Camera Output
- Aircraft NO1 Status and Position
- Aircraft NO2 Status and Position
- Aircraft NO3 Status and Position

All personnel involved in controlling the maintenance and operation[1] of the squadron can view the status of the aircraft at any time from the respective offices. In addition, all personnel including the visitors entering and leaving the squadron aircraft will get recorded in the CCTV control unit hard disc.

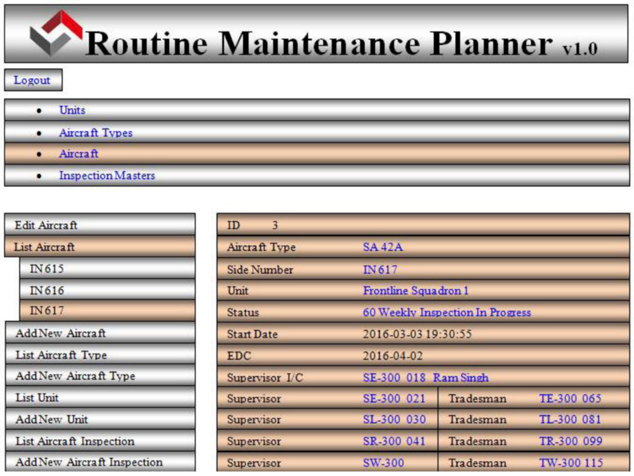

Figure 5. CCTV Display of Routine Aircraft Inspection.

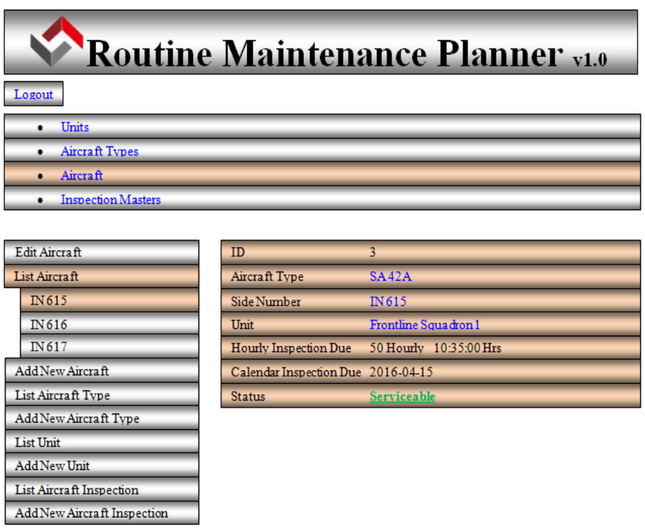

Figure 6. CCTV Display of Serviceable Aircraft.

The data recorded in the hard disc including the aircraft maintenance status data can be used for assisting the investigations contemplated in the event of any incident or accident. The sample output of CCTV display indicating the states of serviceable aircraft ie, aircraft under defect investigation and aircraft undergoing routine inspection is indicated in Figure 5-8.

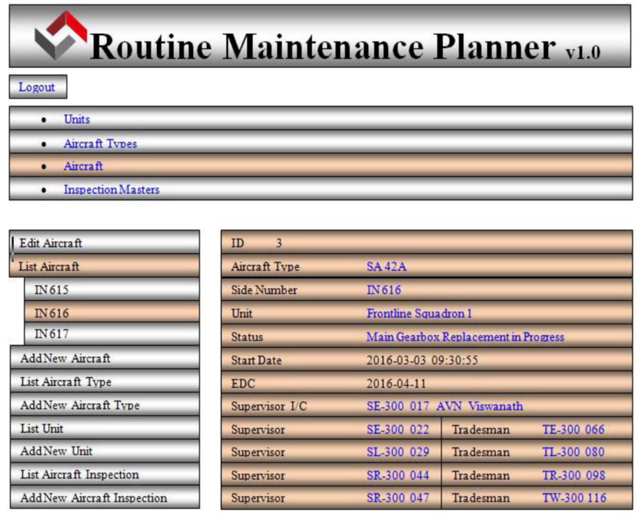

Figure 7. CCTV Display of Aircraft Defect Rectification.

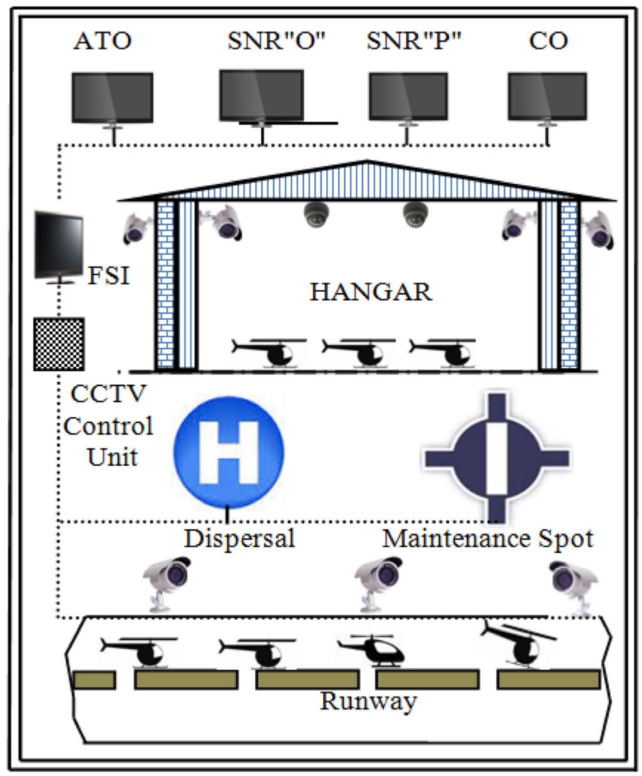

Figure 8. Aircraft Under CCTV Surveillance.

7. Results and Discussion

The implementation of CCTV monitoring along with comprehensive maintenance and maintenance monitoring as discussed above would improve the operational efficiency[15] of a frontline air squadron by reducing the aircraft downtime and by increasing the individual responsibility. In addition, the implementation of the same provides the following advantages:-

The system upkeeps the maintenance data and data pertaining to the personnel visiting the aircraft. This data can be used to assist in investigations at a later stage in the eventuality of an incident or accident.

As the data pertaining to the present position of aircraft and state of maintenance is readily available to the monitoring staff, it helps in timely monitoring to improve the utilization efficiency of aircraft.

Maintenance monitoring staff can seek timely assistance of second line or fourth line[4] expertise by reviewing the progress of DI/DR through the system.

In a training squadron, instructors can correct the errors in aircraft handling/movement by effectively replaying the contents recorded in the DVR of the CCTV control unit.

8. Conclusion

Incorporation of the above operation and maintenance technique in a frontline military air squadron will enhance the operational efficiency of the squadron by reducing the aircraft inspectional and defect rectification downtime by enhancing individual accountability. If the barcode identity issued to the squadron maintainers and operators is extended to the support staff also, then it can be used as an effective tool for monitoring and controlling personnel entering and leaving restricted spaces like military air base and squadrons. The monitoring and accounting tool discussed above, if implemented in a civil production unit will help towards recording reduction in idle time and contribute towards increasing productivity.

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