COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM FOR INDIGENOUSLY DEVELOPED FIGHTER AIRCRAFT INLINE WITH EMERGING TRENDS

Sanjay Kumar Shukla[1], Satish Kumar[1], P. Selvaraj[2] and V. Subba Rao[3]
[1]PV and P/ADA, Bangalore, India
[2]GD (CAD and PLM-PM)/ADA, Bangalore, India
[3]TD (PV and P)/ADA, Bangalore, India
E-Mail: skshukla@jetmail.ada.gov.in

ABSTRACT

The ground and flight tests play a crucial role during proto-vehicle development for any fighter aircraft development program. The objectives of the prototype testing are to assess the aircraft's mission capability in a phased manner. The observations from the field trials are of immense value. In addition to the aircraft performance assessment, the data from field trials facilitate in assessing the Reliability and Maintainability (R and M) of various aircraft components at system level and optimize the maintenance procedures to reduce Turn around Time (TAT). The fleet of proto-vehicles meant for field trials undergoes frequent change in Standard of Preparation (SOP), leading to update of maintenance procedures. This poses a great challenge for the planning of aircraft maintenance activities. This paper brings out a conceptual model of Computerized Aircraft Maintenance Management System (CAMMS), which is relevant to the typical military aircraft flight testing and servicing activities during prototyping and certification phase. An enterprise-wide CAMMS based on Product Lifecycle Management (PLM) would act as a digital thread between designers, maintenance planners, flight test engineers, inspectors and certification agency. CAMMS would enable to track various Line Replaceable Units (LRUs), which constitute of various electro mechanical systems, across various aircraft at fleet level with details such as shelf life, calendar life, maintenance schedule, Pre-Installation (PI) checks, serial part number etc. In addition, maintenance and service documents such as Flight Safety Certificate, LRU log cards, maintenance due list etc. could be generated using CAMMS. CAMMS in association with Failure Reporting Analysis and Corrective Action System (FRACAS) will offer a framework for repair and maintenance studies that can be extended to Performance Based Logistics (PBL) in future.

Keywords: aircraft maintenance, MRO, PLM, FRACAS, PBL.

1. INTRODUCTION

Any development program of a military aircraft goes through the phases of design and development, prototyping, testing, certification and production. Though simulation and analysis techniques enable a quick and cost effective validation of the design, it has to be corroborated with the field data. The ground test and the flight test thus play a crucial role in the development cycle of a military aircraft.

The objectives of the prototype testing are to assess the aircraft's mission capability in a phased manner over a period of time. The observations from the field trials are of immense value to both designers and maintenance planners. The designers need the field data to assess the R and M of various aircraft components at system level and to analyze the system interactions. The maintenance planners require the designers' dispositions over the reported field snags to optimize the maintenance procedures to reduce TAT and Aircraft on Ground (AOG).
The gaps observed during field trials in terms of desired and achieved mission capability may result in multiple iterations of design change and process change through aircraft build change. This also results in increase in number of prototypes, each having different configuration suiting to specific requirement. The maintenance of a fleet of such proto-vehicles with different SOP is a challenging task. As the maintenance procedures of each proto-vehicle also keep changing inline with SOP change, it poses great challenge for the maintenance planner to track the changes and update the aircraft maintenance procedures accordingly.

After the aircraft has successfully completed the rigorous field trials and demonstrated the desired mission capabilities, the product design and processes are frozen, Initial Operation Clearance (IOC) and Final Operation Clearance (FOC) are granted and the series production can commence.

2. THE NECESSITY FOR CAMMS

Final certification of any fighter aircraft depends on meeting the customer requirements in terms of mission capability, performance and reliability. Multiple prototype aircraft with different SOP are required for various flight testing activities. These prototypes also serve as a platform for testing indigenously developed LRUs. The flight data thus collected during trials for different prototypes is analyzed for required performance and may lead to design modifications.

With automated system like CAMMS not in place, the prototype aircraft is managed through disparate systems viz. Product Data Management (PDM), in-house developed flight scheduling tools, Enterprise Resource Planning (ERP), and wherever required paper based and other vintage Maintenance, Repair and Overhaul (MRO)

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systems. The multiple systems in place pose numerous management challenges and as the fleet size grows, the challenges only increase. With the aim to streamline the current practices and lay the foundation for state-of-the-art Integrated Logistics System (ILS) and PBL, CAMMS project has been initiated.

Once fully functional, CAMMS will support all the engineering processes necessary for preparation of aircraft for a flight test and analysis of observations during the sortie. CAMMS infrastructure will enable the following:

- Configuration controlled As-built and As-maintained SOP of each aircraft.
- Aircraft Asset Management and LRU tracking to update the serviceable life of the component, prepare log cards (history of LRU), maintenance schedule, embedded software versions, defects observed and remedial work done.
- Snag reporting and rectification through workflow interfaced with the test flight scheduling software.
- Capture data from Aircraft flight data recorders.
- Dynamic update of Aircraft Maintenance Manual (AMM). AMM evolves as the aircraft undergoes testing and development program.
- Service work card creation from the AMM for maintenance execution.
- Preparation of Maintenance Servicing Schedule (MSS) for periodic maintenance of LRUs and provision for any unscheduled maintenance as required.
- Failure trend analysis using the maintenance history of the aircraft.
- Release of flight related documents for carrying out a test sortie.
- Status of aircraft on a single dashboard.

This paper brings out the conceptual approach to develop such a system and the benefits that it shall incur.

3. OVERVIEW OF CAMMS FRAMEWORK

Figure-1 shows the data exchange at various stages of aircraft development. The derived Bill of Material (BOM) at different stages includes As-Designed, As-Built, As-Planned, As-Maintained and As-Operated. The data captured during operation and maintenance has immense value to both designers and shop technicians. Where designers are trying to understand the system interactions and need the performance data to predict the R and M of aircraft systems, the shop technicians require the dispositions from the designers to carry out the maintenance activity to make the aircraft flight ready. As the product and thus the maintenance procedures are still in development, the technicians have to be in close loop with the designers to service the aircraft. The learning during the maintenance of proto-vehicles is utilized to update the technical publication, a treatise on maintenance philosophy for the aircraft.

4. CAMMS VS. OTHER MRO SOLUTIONS

MRO of an aircraft historically has been handled with paper-based maintenance manuals, service bulletins, engineering drawings, business documents and maintenance technician notes containing a wealth of critical process knowledge. To manage these voluminous aircraft technical publication, a market of one-off content management solutions emerged with a variety of ways of dealing with the vast amounts of documentation. While these solutions based on standards viz. ATA iSpec 2200 and ASD -S- 1000D provided a degree of automated availability, they were rarely integrated into a centralized business system, much less to PLM based engineering and manufacturing systems that could address design/build information, inventory and supply chain management issues [1]. Lacking PLM backbone, the

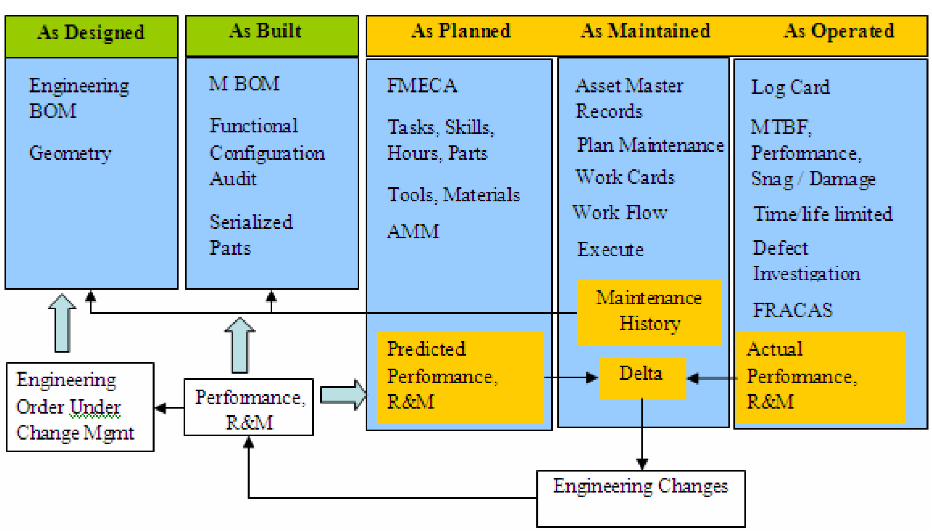

Figure-1. Data exchange during Aircraft Development [2].

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standard MRO solutions have little provisions for design change or designer interaction during the product's service life.

The Asset Management Systems (AMS) are good MRO tools for frozen product but doesn't provide a common platform for the designers and the maintenance planners to collaborate, prolonging the field trials and often resulting in loss of valuable field knowledge which is required by the designers for development activities related to maintainability and availability.

Both standard MRO and AMS solutions are limited in provisions for engineering change management, a crucial requirement for any product in production and deployment phase. Also, as the SOP of the prototypes is changed frequently to maximize the use of the aircraft and shorten the development lead time, it is imperative to track the technical history, embedded software versions, defects, remedial work done on LRUs and other identified components serial number wise and aircraft tail number wise.

CAMMS is being designed and developed for the maintenance and sustenance of the proto-vehicles. Being built on the PLM based software modules; it is differentiated from the MRO/AMS solutions, which mostly support products that have frozen SOP. CAMMS will allow for field information to flow back to the designers enabling them to fine tune the product design for the desired system performance, while monitoring defects, remedial work done and other required details.

The maintenance of the aircraft after the flight and any other planned/unplanned maintenance activity needs an elaborate system to function uninterruptedly. By utilizing the best of PLM, AMS and MRO practices in place, CAMMS will offer a framework to achieve the desired goals.

5. COMPUTERIZED AIRCRAFT MAINTENANCE MANAGEMENT SYSTEM (CAMMS)

CAMMS would be state-of-the-art enterprise aircraft maintenance system that shall act as a digital thread between the key stakeholders, enabling field trials and certification of development aircrafts. It shall further facilitate in reducing the lead time before the start of the production and deployment of the aircraft.

Figure-2 illustrates CAMMS process flow diagram. The field test is initiated when the Flight Test Engineers generate a flight test plan by deriving the test points from the Master Certificate Plan (MCP) prepared by the certifying agency based on the designers' input on the detailed design of the aircraft. The flight test plan may require aircraft with a specific configuration.
CAMMS would aid in preparation of the aircraft

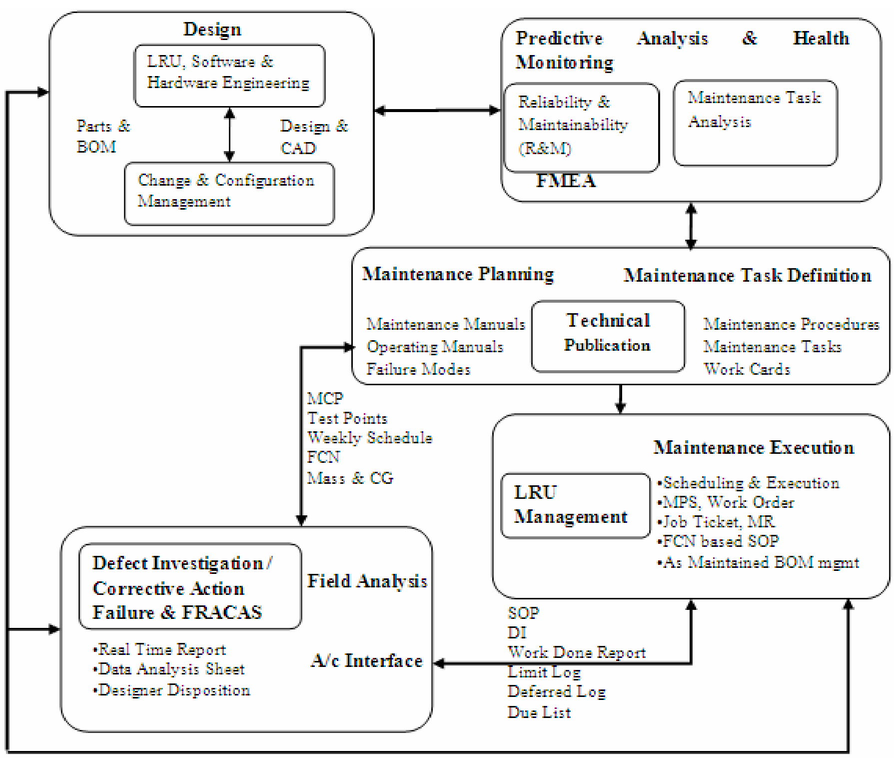

Figure-2. CAMMS process flow diagram.

by identifying the aircraft closest to the desired configuration, identifying the gaps in current and the required configuration, locating the required components and raising either Material Request (MR) if the component is available with the shop floor or cannibalization request if the component is available on the other aircraft.

Once the flight gets over, the snags are reported in the Real Time Monitoring and pilot Hot Debrief/Data

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Debrief. These snags along with the data milked from aircraft's data recorder are analyzed by the designers for rendering their dispositions in concurrence with the Quality group, which leads to the initiation of the snag rectification/maintenance processes through CAMMS.

Once the designer has given the disposition, CAMMS can issue a request for maintenance activity to begin. CAMMS manages the aircraft maintenance related information such as MSS, AMM etc. in its database for maintenance planning and scheduling. The AMM is referred for any unscheduled as well as periodic maintenance activity. CAMMS will keep track of the periodic maintenance dues and raise timely flags to schedule any maintenance activity.

Against the service request, the methods engineer prepares a Maintenance Bill of Material (MBOM), referring to the AMM in CAMMS. The MBOM is further drilled down to work order, route book, job ticket and MR. The work cards summarize the maintenance instructions, the list of consumables, skill set required, jigs and fixtures, their calibration process and other maintenance related details; whereas, the route book details on the flow of maintenance execution across different departments. The job cards and material request is finally issued to the technician to carry out the maintenance activity.

Once the maintenance task gets executed, it will be recorded in CAMMS database. The history of maintenance task viz. balance life of an LRU, cannibalization details, log card, process sheet, deferred log, limit log, Inspection Record Sheet, Work Done Report, data for Flight Safety Certificate (FSC) etc. will be maintained in CAMMS. The data could be utilized for generation of various reports (FSC, Daily Inspection (DI), Ground Handling Equipment (GHE) / Ground Support Equipment (GSE) etc.) for tracking assets/logistics required for maintenance, enhancing communication between the key stakeholders and other purposes. The system would help in expediting the snag rectification and other aircraft maintenance related activities, reducing AOG time and minimizing TAT.

The findings from the test flight, maintenance data and other details rendered while rectification of the snags would be recorded in a structured format in CAMMS using FRACAS framework. The findings from the field trials could be later analyzed to track and update R and M data of an aircraft system. This not only would help in keeping the track on the system performance as the aircraft undergoes various modifications resulting from the field trials but also helps in identifying potential causes of degradation in the performance over the continued field trials.

6. FAILURE MODE AND EFFECT ANALYSIS (FMEA) - FAILURE REPORTING ANALYSIS ANDCORRECTIVE ACTION SYSTEM (FRACAS)

Failure Mode and Effect Analysis (FMEA) is an engineering technique used to define, identify, and eliminate known and/or potential problems, errors, and so on from the system, design, process, and/or service before they reach the customer.

FMEA is a systemic methodology intended to perform the following activities:

i. Identify and recognize potential failures including their causes and effects
ii. Evaluate and prioritize identified failure modes, since failures are not created equal
iii. Identify and suggest actions that can eliminate or reduce the chance of the potential failures from occurring. [3]

FMEA is prepared by the designers of the individual systems during the design phase. During the field trials, the system interactions may lead to failures previously not conceived by the designer. The FRACAS is a framework to record the field failures, analysis done and corrective action taken. FRACAS, commonly referred as a "Closed Loop Reporting System", is instrumental in understanding how an equipment or system is actually performing in the field from R and M perspective.

FRACAS consists of failure identification, failure confirmation, establishing root cause and corrective action. The snags recorded during flight in aircraft's data recorder, observed in telemetry and in hot debrief are analyzed, compared against the failure modes recorded in FMEA for different system of an aircraft and the result of the analysis is input to either a design change or in case of failures that are not severe, the FMEA database is updated with the probable causes and remedial actions.

CAMMS provides a framework for FMEA-FRACAS, enabling correlation to be made between predicted R and M data and actual performance R and M data. This information permits better informed decisions for new designs; reveals when there are potential reliability, maintainability and logistical HOT SPOTS; provide confidence over issues associated with warranties, and extends an opportunity for continuous process improvement through lean or six sigma methodologies.

7. PERFORMANCE BASED LOGISTICS

The military services today require high availability of expensive assets (worth to crores of rupees) with long lifecycle (for example over 20 years) to be mission capable for quick deployment all over the globe which requires an “agile logistics” concept. Traditionally, the after-market support infrastructure has been based on the original equipment manufacturers providing spare parts and data for the maintenance and supply aspects (organizational, intermediate and depot). This led to low mission capable rates, inadequate spare parts for repair and “depot possessed” weapons systems [2].

The "agile logistics" concept requires change in way the customers and manufacturers deal. The war equipments are mostly sold on cost to company basis. The servicing of the same constitutes the major revenue source for the manufacturers. But in recent times, there have been a paradigm shift in the way contracts are drawn. Today's customers are more interested in buying the UPTIME for a product. Under PBL contract, the manufacturer has to deliver not the product but the operational time that the customer can avail. The PBL based contract is way to the future, in which the mission capable rates would be defined at the design phase and would be the obligation of the manufacturer.

The PBL based contract has made the manufacturers of the war equipments to concentrate more on serviceability aspects. Failure scenarios, either analyzed by designers in FMEA charts during design phase or found during the field trials, are the Holy Grail to cut down the serviceability costs. ILS facilitated by Logistics Support Analysis (LSA), methodologies to quantify and measure supportability objectives, enable end to end logistics support required for entire service life of a product. The LSA and ILS in conjunction can enable the manufacturer to deliver the product on PBL, a new trend in procurement and sustenance of war machines.

Based on PLM, CAMMS enables a framework for FMEA and FRACAS. It complies with the military standards pertaining to weapon acquisition and sustenance program and can be extended to ILS and PBL in future.

8. CONCLUSIONS

Product lifecycle data is the lifeblood of any product from initial concept, detail design, build and through life support. CAMMS offers a novel solution to manage the requirements during production and deployment of a military aircraft, with PLM modules pertaining to maintenance aspects. It will not only help to better understand the maintenance activities but also help to streamline the logistics and spares required to support the product till the end of its life.

As compared to MRO/AMS available in the industry, CAMMS would be better suited to track the engineering changes, a crucial requirement during the production and deployment phase. It shall offer the FRACAS framework for R and M studies and could be extended in future to implement PBL, which is an emerging trend in the aircraft acquisition and sustenance. The PBL based contract is way to the future, where the Mission Capable Rates (MICAP) would be defined at the design phase itself and the obligation will lie on the manufacturer to keep the war equipment in the operation ready state.

CAMMS framework once established would help in graduating towards Integrated Logistics System (ILS), facilitate assessment of Life Support Cost (LSC) and streamline the logistics and spares required to support the product till the end of its life. The experience gained with CAMMS implementation will be better utilized for maintenance practices of all future strategic programs.

Nomenclature

AMS	Asset Management System
AMM	Aircraft Maintenance Manual
AQA	Aircraft Quality Assurance
AOG	Aircraft on Ground
BOM	Bill of Material
CAMMS	Computerized Aircraft Maintenance Management System
DI	Daily Inspection
ERP	Enterprise Resource Planning
FCN	Flight Clearance Note
FMEA	Failure Mode and Effect Analysis
FMECA	Failure Mode Effect and Criticality Analysis
FOC	Final Operation Clearance
FRACAS	Failure Reporting Analysis and Corrective Action System
FSC	Flight Safety Certificate
GHE	Ground Handling Equipment
GSE	Ground Support Equipment
ILS	Integrated Logistics System
IOC	Initial Operation Clearance
KPI	Key Performance Indicators
LRU	Line Replaceable Unit
LSA	Logistics Support Analysis
LSC	Life Support Cost
MBOM	Maintenance Bill of Material
MCP	Master Certificate Plan
MICAP	Mission Capable Rates
MR	Material Request
MRO	Maintenance, Repair and Overhaul
MSS	Maintenance Servicing Schedule
MTBF	Mean Time between Failures
PBL	Performance Based Logistics
PDM	Product Data Management
PI	Pre-Installation
PLM	Product Lifecycle Management
RCMA	Regional Center for Military Airworthiness
R and M	Reliability and Maintainability
SOP	Standard of Preparation
TAT	Turn Around Time

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