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MAINTENANCE OF AN AIRCRAFT DURING PROTOTYPING PHASE

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ABSTRACT

In this bulletin, the importance of maintenance and repair of a trainer aircraft during the development phase is presented. Necessity of considering maintenance concept beginning from design activities is emphasized. After explaining restrictions on aircraft maintenance, a method, which was developed for periodic aircraft /equipment maintenance by TAI is presented. This method is based on a two-step approach: The first step consists of setting up maintenance requirements during design activities. The second step consists of preparing an initial maintenance plan, in which all calendar-based maintenance actions (CBMAs) and usage-based maintenance actions (UBMAs) are timed to be performed in accordance with the schedule of manufacturing, ground tests and company flights of the aircraft. Later on, the initial plan is optimized. In this paper, maintenance parameters like tool, equipment, spare parts, consumables, material, facilities and documentation are evaluated. Preparation and implementation of maintenance cards are explained. Finally, benefit of these practises are listed.

Keywords: Manufactring, Modernization, Maintenance, Optimization, Precedence,

1. INTRODUCTION

Maintenance can be defined as the total of the activities, which are conducted by service, repair, modification, revison, control and status determination to keep a system's life long violable characteristics at the pre defined quality and quantity or to restore and keep a product at the running situation.

Not any maintenance eliminates failure possibility completely; the results of failure is to be taken care. Since defining maintainability, reliability and accessibility requirements are important for an aircraft, these issues must be considered during development process starting from conceptual design phase (Figure 1).

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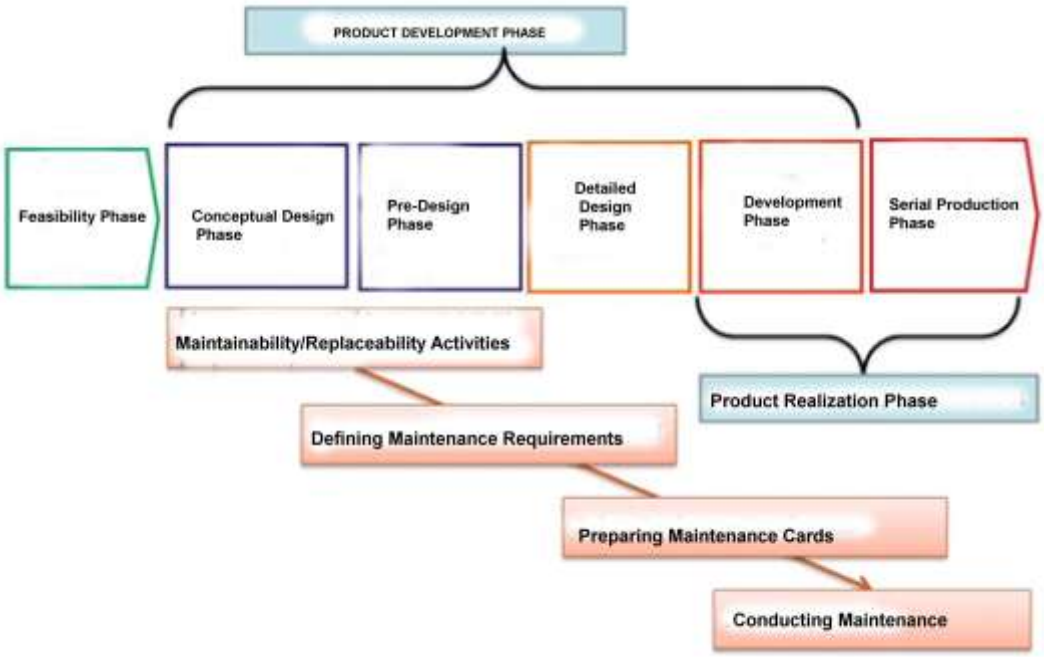

Figure 1: Maintenance Related Activities During Aircraft Prototyping Stages[1].

Maintenance scheduling, which must have ability to prevent catastrophic failures and manufacturing/testing/flying interruptions rather than reacting them after occuring, is typically subjected to a large number of constraints. Among them are maintenance rules, capacities of maintenance facilities, skills of maintenance workers, and flight plans[1]. Performing scheduled or unscheduled maintenance of a newly developed aircraft up to delivery requires a precise organization depending on these restrictions [3].

This organization, which must provide information flow, is more important at the beginning of the product life, because as experiences prove, scheduled and unscheduled maintenance requirements are too high at this phase (Figure 2).

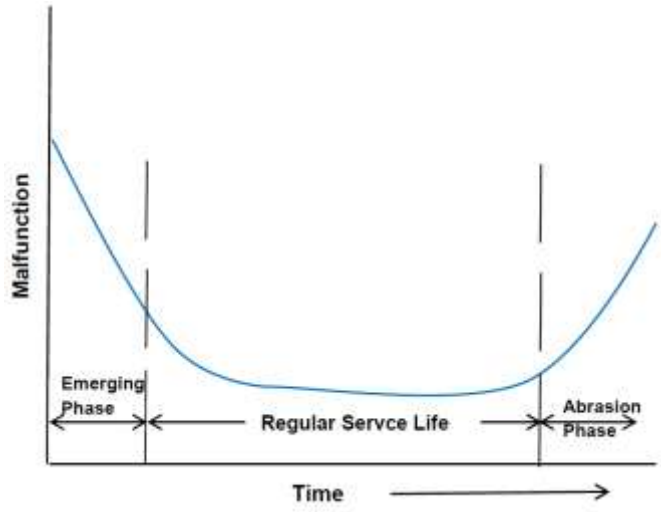

Figure 2: Incidence Frequency During Life of an Aircraft [2].

2. DEFINING MAINTENANCE REQUIREMENTS

Maintenance properties of an aircraft is an important engineering activity to be considered and worked on during design phase. Because the maintenance costs are very high, maintenance features effects aircraft design deeply. Activities to constitute a cost effective maintenance, which will assure reliability

of an aircraft during its service life starts during development phase before production of the aircraft by the maintenance engineers of the manufacturer or user company[4]. Three different approachs are to be mentioned:

a) To continue using the expensive parts, which are not any impact on the safety, until a damage occurs.
b) To check and replace parts in accordance with the intervals incorporated to the manuals (Standard maintenance, which is also called 'on-condition' maintenance).
c) To conduct dynamic maintenance, where the intervals of the checks depend on the situation of the parts. This type of maintenance is rarely applied [5].

For the maintenance of our training aircraft and its equipment, which is developed by regarding these significant topics in terms of maintenance, the following factors are evaluated: maintainability and supportability, capacity analysis, maintenance procedure, document, computer resources (software, hardware, firmware etc.), tool, ground support equipment, duration for each maintenance task, manpower for relevant tasks, training, cost, required provisioning parts (repairable, consumable, expandable, life limited etc.) for each maintenance task [6].

Because the structural, mechanical, electrical and avionic system characteristics of the prototype aircraft are not dominated at this stage yet, it has some parameters to be validated during the first flight campaign. This situation entails some limitations. Maintenance requirements include checks also, which are performed in terms of time or based on the flight hours to monitor the conditions creating these limitations.

2.1. Design Level Activities

Reliability is a character, which is defined by design properties. To ensure this, maintenance steering group (MSG-3) and graphical support analysis (GSA) based on Digital Mock-Up (DMU) methods are utilized during design phase of the trainer aircraft (Figure 3) [7].

Figure 3: Digital Mock-Up for Inspection of an Equipment Using a Mirror by Maintenance Person [1].

Maintenance task analyses are performed to define the maintenence requirements. Equipment maintenance levels with source, maintenance, recoverability (SM&R) codes are defined; logistic support analyze (LDA), level of repair analysis (LORA) are completed and maintenance allocation chart (MAC) is prepared.

Optimization is achieved at this level through allocation of functions and tasks to specific maintenance levels, repair versus discard analyses, reliability centered maintenance (RCM) analyses and formulating design recommendations to optimize maintenance times logistic support resource requirements[7].

Organizational level ("O" level) and depot level ("D" level) maintenance concepts are defined and maintenance allocation table is prepared accordingly. Organizational level maintenance contains defining and replacing of failed devices by means of built in test- BIT, limited repair of electrical harnesses, limited structural repair, inspection, service, preventation and adjustment, while depot level maintenance include repair of shop replacable units-SRU, extensive structural control, repair, modification, calibration of engine, propeller, oil, fuel, hydraulic and other systems.

2.2. Maintenance Facility

It is preferred to accomplish maintenance in a hangar protected against outer factors. This hangar must also have pressured air, water, electricity, electrical grounding and evacuation means in an emergency[8]. Since the aircraft is in the assembly line during the mate through and in-house ground tests phase, these conditions are provided. But a controlled, safe hangar, which has shop resources like pressured air, electrical grounding, emergency evacuation is required during the flight line activities (Figure 4)

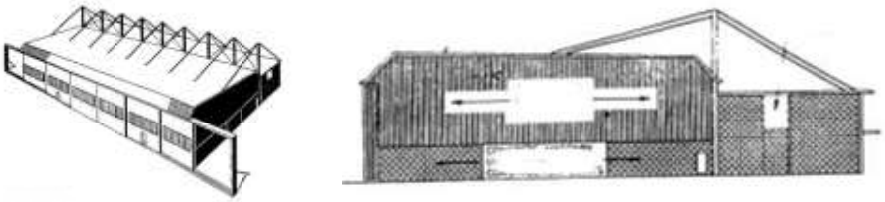

Figure 4: A Typical Maintenence Hangar [8].

Also suitable buildings are utilized to meet the engine revision, manufacturing, repair, part maintenance (avionic, hydraulic, mechanic) and paint shop requirement.

2.3. Spare Part and Material Requirement

Establishing an effective spares inventory without impairing the goal of the training aircraft program is a major objective for our maintenance organization. Scheduled and unscheduled maintenance spare parts, consumables and expendables are defined on

terms of systems (ATA chapters) by a predictive maintenance approach and requirements for them are created in enterprise source planning (ERP) to be purchased. Vendor provided 'O' level spare part lists are used for some components and systems like engine, propeller or landing gear. Estimated material list is prepared for long lead material, which can not be purchased in short term.

2.4. Tool and Equipment Requirements

It is necessary to obtain equipment, tools and devices for each systems timelyr. Especially key equipment with no backup may have a negative impact on maintenance. Needed tools and equipment, which must be kept within specified limits by calibrating regularly, can be classifed per their functions as carrying equipment, maintenance equipment/tool, measurement devices, ground power unit(GPU) (Figure 5).

Figure 5: Ground Support Equipment [1].

2.5. Preparing and Configuring Engineering Document

Data package, which is to be created within the scope of project ‘statement of work’ is categorized in two main class:

-Engineering and production technical data package (Drawings, operation cards, Maintenance Cards),
-Integrated Logistic Support (ILS) (Flight Manual, Maintenance Manual, Structural Repair Manual) [9].

Checks and repairs are defined on the basis of time intervals (calender limited) or flight hours(cycle/flight hour limited) on the maintenance documents (Figure 6).

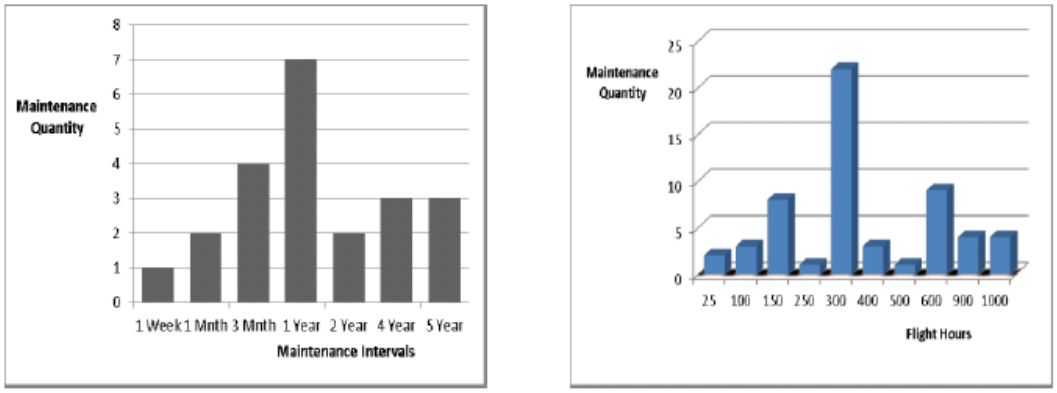

Figure 6: Example of Time and Flight Hours Limited Maintenance Intervals[1].

A configuration management system is used to control TAI and vendor originated maintenance documents. Also airworthiness directives (AD), service bulletins (SB), service letters (SL), which are released by vendor or aviation authorities for relevant equipment are incorporated to the maintenance documents through this system (Figure 7).

Figure 7. An Example of Service Bulletin [1].

3. GENERATING MAINTENANCE CARDS

Manufacturing engineers prepared and released maintenance cards in accordance with source documents to ensure every maintenance task to be conducted and recorded timely. These maintenance cards are created, kept and updated in TAI visual planning system (TVPS), which is developed in TAI (Figure 8).

Figure 8. TVPS User Interface [1].

While engineering documents unique to the aircraft is used to prepare structural maintenance cards, component maintenance manuals are used to to prepare the maintenance cards of equipment like engine, propeller, landing gear. Reliability driven modifications, retrofits, redesign or changes are incorporated to the maintenance documents in a timely manner, thanks to the change management system.

Traceability is a major issue in aviation and a significant factor in maintenance especially to improve the relaibility of the critical systems. Inspections and replacemants of damage tolerant and safe life items within defined periods and according to procedures are guarenteedd by recording on maintenance operation cards.
Preflight, thruflight and postflight check cards are prepared to be used during company flight test campaign.

It is important to record removed parts during maintenance tasks. For this purpose, break of inspection log is used and removed parts are sent to the store by attaching identification tag, to be kept until reinstallation.

Also we established a troubleshooting process for the elimination of the unexpected failures encountered during post maintenance tests. Since some systems tend tofail at the beginning too often, troubleshooting is more important (Figure 9).

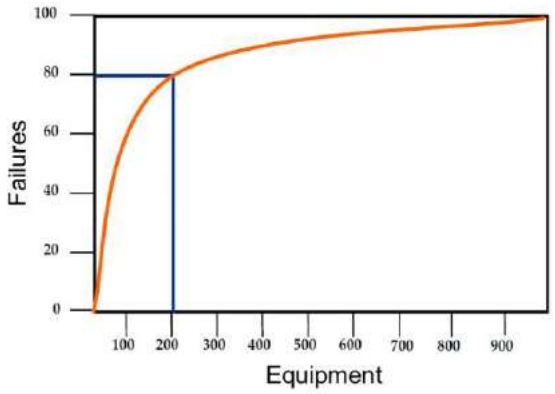

Figure 9: Failure Possibility Depending On Service Life [10].

4. TECHNICIAN AND INSPECTOR ASSIGNMENT

Manpower utilization is a key to maintenance effectiveness. At any time, in many factories, machines are idle for repair or maintenance. A large percentage of these machines are not being repaired because maintenance specialists are already busily working on other machines. Paradoxically, potentially repairmen (the operators of the shut-down machine or cell) are standing idle by, waiting for the machine to be repaired [11].

But it is differant for aircraft protoyping phase. Since human factor is considered vital from maintenance point of view, the quality of workmanship at aircraft maintenance should be at par or even better than manufacturing standards. Repair and maintenance of the new aircraft is accomplished by experienced and competent

technicians and inspectors familiar to the aircraft systems because of working on the manufacturing of that aircraft. By this way; qualified, safe and low cost job is obtained while consistent manpower is guaranteed.

5. CONDUCTING OF MAINTENANCE

Maintenance is achived in preventive, corrective and improvement forms. After engineering documents are converted to the maintenance cards, they are released to the shop floor and maintenance tasks, which are classifed as structural, system and zonal and accomplished in established intervals (Figure 10).

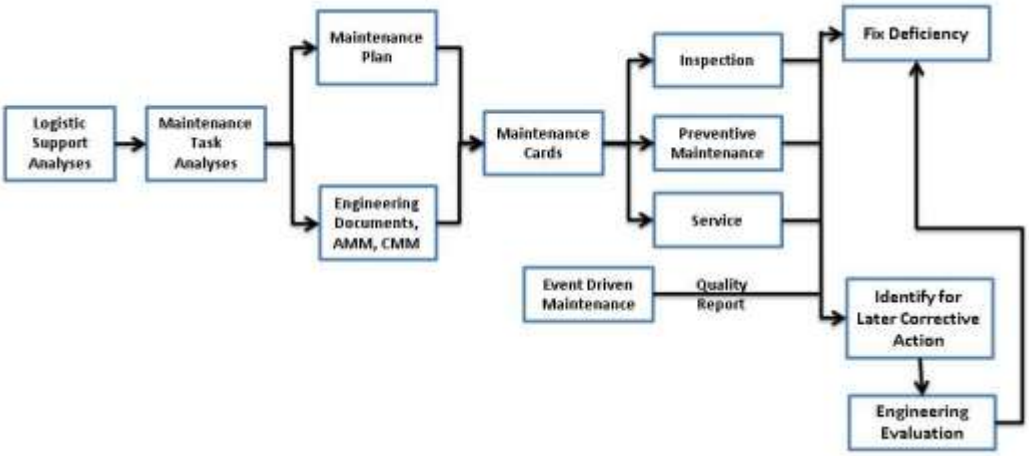

Figure 10: A Typical Workflow for Prototype Aircraft Maintenance[3].

Since the the aircraft is not always available for preventive maintenance, coordination should be a cooperative attitude. By means of this coordination and precedence charts, a balance of workload between manufacturing and maintenance is provided.
Some of the maintenance tasks are as below:
Structural: General visual inspection of forward fuselage, engine cowlings; detail visual inspection of forward fuselage, engine truss structure and attachments, Internal structure.
System: Visual inspection of system equipment, leakage checks, fresh (ambient) air ventilation checks, inspection of main battery, detailed visual inspection of the aileron/rudder/elevator control system, control surfaces functional checks, engine oil check, engine examination with borescope, fuel check for water contamination.

Zonal: General visual Inspection of cockpit, avionics bay and door, control surfaces, propeller.

6. RESULTS

Maintenence during development phase, which has different dynamics from the maintenance of operational aircraft is an issue to be improved depending on the both manufacturing and maintenance technologies. Below results are achieved on this subject by company-specific appliacations in TAI:

- Since the maintenance requirements are established during conceptual design phase, preparations have been carried out appropriately parallel to the maturation of component designs and maintenance activities started as required in terms of time and resources.

- Provision of material and part, which are very significant input of the maintenance started earlier in accordance with priority of the maintenance tasks and this resulted minimum shortage status for maintenance. An effective material stock supporting the maintenance is established.

- Precedence charts of the maintenance are generated to detect the criticial paths in relation with the manufacturing and test operations.

- The experiance obtained during operation, maintenance and observation made it possible to develop a continuous improvement methodology

- Document revisions are incorporated to the maintenance quickly through change management system.

- Suitable conditions for safe flight are ensured by performing 'what-if-analyses' and reducing estimated risks.

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