Extracted From
ALM-35-0323-RB

MAINTENANCE PLANNING

1. Introduction.

a. In this unit of instruction, ***maintenance planning will be defined as the process of determining how maintenance will be performed on a new materiel system***.

b. Maintenance planning is an essential element in the development of acquisition logistics support for a weapon system or weapon support system. It must be accomplished as part of any materiel acquisition effort.

c. Maintenance planning is a necessary sub-process within the overall materiel acquisition process which must be performed to ensure a materiel system can be effectively and economically maintained at the desired level of readiness once it is placed in operation use.

d. This unit of instruction will address how the maintenance planning process is managed and executed.

2. Maintenance.

a. Essential to any discussion of maintenance planning is a baseline definition for maintenance. Maintenance can and has been defined in many slightly different ways. For maintenance planning purposes, ***maintenance is the total set of maintenance tasks required to be performed on a materiel system to retain it in or to restore it to a specified (serviceable) condition***.

b. A materiel system or other item may be considered in a serviceable condition as long as no functional failure is present. ***A functional failure is defined as a failure of an item to perform its normal or characteristic functions within specified limits***. Ideally all maintenance could be performed between the point of potential failure and functional failure. ***Potential failure is defined as a quantifiable failure symptom which indicates a functional failure is likely to occur***.

c. The above definition of maintenance does not consider the aspect of operational maintenance dealing with the upgrade of the functional or physical configuration of an item through the application of modifications. While the application of modifications is a normal function of many maintenance organizations, this activity cannot be planned during the materiel acquisition process since required modifications do not become known until after a materiel system has been placed in operational use and needed upgrades are identified.

d. Also, the above definition of maintenance defines maintenance in terms of "maintenance tasks." For maintenance planning purposes, ***a maintenance task is the basic unit of maintenance planning and represents the smallest, discrete, contiguous work effort into which the overall maintenance work effort will be broken down for maintenance planning purposes***.

3. Variables. The way maintenance is planned for a new materiel system depends on two prime variables. These variables are the -

a. Maintenance characteristics inherent in the design of the new materiel system. Inherent maintenance characteristics of the design include both the inherent reliability and maintainability design characteristics.

b. Maintenance concept for the new materiel system.

4. Maintenance Concept. For maintenance planning purposes, ***the maintenance concept is the way the customer wants maintenance to be planned for a new materiel system***. The maintenance concept is dependent on the mission requirements associated with the new materiel system and the capabilities of the overall support structure the customer expects to have in place when the new materiel system is placed in operational use.

a. The maintenance plan for a new materiel system may be viewed as a finalized version of the maintenance concept which has been progressively refined during the materiel acquisition process when respect is given to the inherent maintenance characteristics of the design as they become known.

(1) In other words, the organizational entity given the responsibility for planning maintenance for a new materiel system will attempt to plan maintenance in accordance with the customers' wishes and will normally only deviate from the customers' desires when the design demands it.

(2) For example, the customer may want to repair circuit boards at the intermediate maintenance level. However, if the boards are multi-layered and conformal coated and the intermediate maintenance level does not have the support equipment required for such sophisticated repair, then the inherent maintenance characteristics of the boards will not allow their repair to be allocated in accordance with the customers' wishes.

b. The maintenance concept should give customer guidance relative to all steps within the maintenance planning process.

5. Maintenance Planning Process. ***The maintenance planning process is composed of the steps required to accomplish the following:***

a. Identify all maintenance tasks to be/must be performed on the new materiel system.

b. Determine the timing and frequency of each identified task.

c. Determine the maintenance level where each identified task will be performed. This step is often referred to as maintenance allocation.

d. Design and document the procedural steps describing how each identified maintenance task will be performed.

e. Identify, describe, and document the resources required to perform each identified maintenance task.

6. Step 1 - Types of Maintenance Tasks.

a. To ensure the organizational entity assigned the responsibility for planning maintenance for a new system identifies the total range of tasks the customer wishes planned as part of the maintenance planning effort, it is essential some common understanding exists as to the types of support tasks which are to be considered maintenance.

b. Although it may be impossible to get universal consensus on the types of maintenance tasks, the following appear to be representative of the types of work efforts performed by maintenance capabilities at the various levels of maintenance:

(1) Determination of equipment status. Traditionally, a task of this type has been considered a "preventive" maintenance task.

(2) Correction of malfunctions before functional failure. Traditionally, a task of this type has been considered a "preventive" maintenance task.

(3) Correction of malfunctions after functional failure. Traditionally, a task of this type has been considered a "corrective" maintenance task.

(4) Replenishment of consumables.

(5) Installation and removal of operational suites.

(6) Return of an item to a prescribed condition.

c. The maintenance concept should clearly address the types of maintenance tasks which are to be identified.

7. On-Equipment and Off-Equipment Maintenance.

a. Before discussing the techniques available to the maintenance planner for identifying maintenance tasks, the concept of on-equipment and off-equipment maintenance must be defined because this concept is used to differentiate between maintenance tasks which have an impact on the availability and safety aspects of the end item and those that don't. The primary measure of effectiveness of any maintenance planning effort should be how well it ensures required availability and sustains inherent levels of safety.

b. On-equipment maintenance is the set of all those maintenance tasks which would cause an end item to be unavailable during their performance and where their performance would have a direct impact on sustaining the inherent level of safety associated with the end item.

c. Off-equipment maintenance is the set of all those maintenance tasks which would not cause the end item to be unavailable since these are normally repair tasks performed on lower indenture components of the end items after these lower indenture items have been removed from the end item and replaced with a like, serviceable item. After the repair tasks are completed on these lower indenture items, the items are returned to stock, not to the end item from which they were removed.

d. The following are examples of on-equipment and off-equipment maintenance tasks:

(1) A scheduled inspection of an attack helicopter would be an on-equipment maintenance task. The helicopter would be unavailable for any operational requirement during the duration of the inspection. Since the helicopter is only unavailable and not necessarily inoperable during the scheduled inspection, if an essential operational demand were to occur, the helicopter could be used by deferring the scheduled inspection task. However, deferring the inspection task can be done only at an increased risk for operational failure and safety hazard.

(2) The remove and replace of a rotor blade on the helicopter after some specified number of operating hours is an on-equipment maintenance task. A "remove and replace" task entails the removal of an unserviceable item and its replacement with a like, serviceable item. Again, the helicopter would be unavailable for any operational requirement during the duration of the remove and replace of the blade. In this case, the helicopter is not only unavailable but also inoperable during performance of the task. If an essential operational demand were known to exist immediately before the scheduled remove and replace was to commence, the helicopter could be used by deferring the scheduled remove and replace. However, deferring the remove and replace can be done only at an increased risk for operational failure and safety hazard.

(3) If a failed hydraulic actuator is removed from the helicopter, taken into the unit level shop, repaired through replacement of lower indenture repair parts, tested for acceptable functionality, and then placed back on the same helicopter from which it was removed, then this is an on-equipment maintenance task. Even though the detailed repair of the hydraulic actuator is done away from the equipment, the hydraulic actuator never lost its association with the end item. It was returned to the helicopter; it came immediately after the repair was completed.

(4) The repair of the rotor blade at the depot level of maintenance is an off-equipment maintenance task. The rotor blade has lost all association with the helicopter from which it was removed. Once repaired at depot, it will be returned to stock.

8. Techniques for Identifying Maintenance Tasks and Timing of Tasks.

a. The results of the Failure Mode, Effects, and Criticality Analysis (FMECA) are going to provide the valid engineering source data needed as the basis for the effort of identifying maintenance task requirements.

(1) The objective of a FMECA is to identify all failure modes within a materiel system design. Its first purpose is to early identification of all catastrophic and critical failure possibilities so they can be eliminated or minimized through design correction at the earliest possible time. Therefore, the FMECA is initiated as soon as preliminary design information is available at the higher system levels and extended to the lower levels as more information becomes available on the items in question.

(2) Although the FMECA is an essential reliability program task, it also provides information for other purposes. Use of the FMECA is called for in maintainability, safety analysis, survivability and vulnerability, failure detection and isolation subsystem design, and in maintenance planning analysis activity.

(3) A FMECA does the following -

(a) Identifies all potential item and interface failure modes and defines their effect on the immediate function or item, on the system, and on the mission to be performed.

(b) Evaluates each failure mode in terms of the worst potential consequences which may result and assigns a severity classification category.

(c) Identifies failure detection methods and compensating provisions for each failure mode.

(d) Identifies corrective design or other actions required to eliminate the failure of control of risk.

(e) Identifies effects of corrective actions or other system attributes, such as requirements for logistic support.

(f) Documents the analysis and summarizes the problems which could not be corrected by design and identifies the special controls which are necessary to reduce failure risk.

b. Simply stated, a direct analysis of the FMECA results will show the failure modes inherent to the system and will support the identification of off-equipment maintenance of the correction after functional failure and return to prescribed condition types.

c. To effectively identify all on-equipment maintenance tasks, the Reliability Centered Maintenance (RCM) analysis process must be used.

(1) The RCM analysis uses a decision logic diagram to identify the best way to perform on-equipment maintenance tasks. Safety, mission criticality, and cost-effectiveness are the determinants for choosing tasks to be performed and when to perform those tasks.
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(2) The on-equipment maintenance portion of the maintenance plan resulting from an RCM analysis effort should ensure the inherent reliability potential of the new materiel system is realized. The objective of RCM is to develop a maintenance plan ensuring the sustainment of the new materiel system's inherent levels of safety and reliability at the lowest cost. RCM is based on the premise that maintenance cannot improve upon the safety or reliability inherent in the design of the system. However, properly planned maintenance can preserve those characteristics.

9. Step 2 - Maintenance Task Timing Approaches.

a. To ensure the organizational entity assigned the responsibility for planning maintenance for a new system applies the maintenance task timing approaches the customer wishes, it is essential some common understanding exists as to the types of timing approaches to be used and the customers' preference relative to the use of those approaches.

b. The following appear to represent the total range of maintenance task timing approaches:

(1) After functional failure.

(2) Calendar-time.

(3) Hard-time.

(4) Event-oriented.

(a) On-condition.

(b) Condition monitoring.

(c) Operational interval.

(d) Arrival.

c. In the "after functional failure" timing approach, a correction after functional failure task is instituted after a functional failure has actually occurred with no attempt made to predict the time of the functional failure or to ascertain the ongoing condition of the item. This type of maintenance timing approach can be used where functional failures would not constitute a serious personnel safety hazard or cause an unacceptable degradation in system effectiveness.

d. In the "calendar-time" timing approach, a maintenance task is instituted based on calendar-time.

(1) When used to schedule correction before functional failure tasks, some effort must have been made to assess the point in time where a particular item begins to malfunction at an increased rate and to determine at what point the increasing malfunction rate represents a functional failure from a cost or mission and safety standpoint. Average usage rates must be used in determining the specific points in time when "calendar-time" correction before functional failure task will be performed. This timing approach is most appropriate for equipment with a fairly stable operational environment or when there is an adverse relationship between age and serviceability (in other words, independent of usage).

(2) When used to schedule equipment status determination tasks, again some effort must have been made to assess the point in time where particular items begin to malfunction at an increased rate and to determine what the best calendar interval is to give the greatest probability of catching these increasing malfunctions between the potential failure and functional failure points. This interval will be determined on a cost or mission and safety basis.

e. In the "hard-time" timing approach, a maintenance task is instituted based on hard-time. Normally, this approach is used to schedule a correction before functional failure task. This means some effort must have been made to determine the point in the operating life of a unit, component, or system when the failure rate begins to increase due to its usage; i.e., the usage-reliability curve takes a decided upturn and enough of the family of these items have survived to this point to warrant taking positive maintenance action.

f. In the "on-condition" timing approach, normally a correction before functional failure task is instituted as the result of a scheduled equipment status determination task. For many years, "on-condition" was considered the only alternative to the "hard-time" timing approach and was used to cover everything where the "hard-time" timing approach was not applicable. Currently, "on-condition" encompasses those items, components, systems, subsystems, etc., which exhibit basically a constant failure rate without the distinct upturn characteristic of the usage-reliability curve of a "hard-time" component. Moreover, these components either by design, location, or often coincidence, permit the use of equipment status determination tasks scheduled at regular intervals to determine the degree of deterioration present, and to ascertain whether or not the item can continue to perform to minimums until the next scheduled equipment status determination task. If no, then the appropriate correction prior to functional failure task is performed. If yes, then the item is permitted to continue in service until its next scheduled test.

(NOTE: The prime distinction between "hard-time" and "on-condition" maintenance is candidates for "hard time" have a predetermined life beyond which failure rates sharply rise while "on-condition" candidates will be inspected or tested on some predetermined interval to determine deterioration and thus continue a useful life with associated correction prior to functional failure tasks dependent on results of the inspect or test activities contained within the regularly scheduled equipment status determination task.)

g. In the "condition monitoring" timing approach, normally a correction before functional failure task or a correction after functional failure task is instituted when the operator or crew detects through continuous monitoring some indication an item is not operating within expected norms. In their continuous monitoring effort, the operator or crew uses the inherent human sensory capabilities and available instrumentation. This timing approach is perhaps the hardest to understand and accept; however, it is potentially rewarding when properly applied. Items which demonstrate a constant or uniform failure rate are candidates for this maintenance timing approach. In this approach, there is no scheduled equipment status determination task. Items are monitored continuously and no maintenance is performed until a potential failure or functional failure is indicated by the monitoring process. Condition monitoring is based on the following premises:

(1) Many items, irrespective of the importance of their function, are unresponsive to hard-time correction before functional failure tasks as a means of ensuring their continued reliability.

(2) Not all functional failures affect safety.

(3) A correction after functional failure task may be less costly than correction before functional failure task where failures are unpredictable and when "infant mortality" and maintenance degradation are also considered.

h. In the "operational interval" timing approach, normally equipment status determination tasks are scheduled either before or after some operational event; e.g., pre-op, post-op.

i. In the "arrival" timing approach, normally correction after functional failure tasks are scheduled at higher maintenance levels on the arrival of a reparable item.

j. Example of scheduling approaches using an automobile as the case.

(1) If you drive your car until it stops and replace your spark plugs after a troubleshooting process has found them defective, this is use of the "after functional failure" timing approach for a correction after functional failure task.

(2) If, because of carbon buildup after 11,000 miles, your spark plugs no longer give proper ignition and you decide to remove and replace them after each 10,000 miles, this is use of the "hard time" timing approach for a correction before functional failure task.

(3) If you decide you average 10,000 miles per year and remove and replace your spark plugs every year on the 30th of June, this is use of the "calendar time" timing approach of a correction before functional failure task.

(4) If every 5,000 miles you remove your spark plugs, inspect them, and replace them only if you determine they will last at least another 5,000 miles, this is an example of a "hard-time" equipment status determination task and an "on-condition" correction before functional failure maintenance task.

(5) If during the course of operating your car, you listen and watch for the indicators of faulty spark plugs and remove and replace them after you sense these indicators, this is use of a "condition monitoring" equipment status determination effort and a correction before functional failure task.

k. The maintenance concept should clearly address the types of timing approaches and the preferred timing approaches relative to the performance of Step 2 of the maintenance planning process.

10. Step 3 - Maintenance Levels.

a. For maintenance planning purposes, it is convenient to consider three maintenance levels. These three maintenance levels are:

(1) Unit.

(2) Intermediate.

(3) Depot.

b. The unit maintenance level represents that maintenance capability possessed by the using unit. The unit maintenance level may be further broken down into lower indenture levels such as crew and organizational.

c. The intermediate maintenance level represents that maintenance capability available in the tactical force structure above the using unit. The intermediate level may be further broken down into lower indenture levels such as intermediate direct support and general support.

d. The depot maintenance level represents that maintenance capability available outside the tactical force structure and closely associated with the industrial base.

e. Step 3 of the maintenance planning process determines which maintenance level is the most appropriate for the performance of an identified maintenance task. Much of this "allocation" activity is performed by using mathematical models which incorporate in their structure the variables and decision rules applicable to maintenance allocation decisions. These models are normally called Level-of-Repair Analysis (LORA) models. Many such models are available and different ones are used by the various U.S. military services. The model that is currently used in the development of Army maintenance programs is the Computerized Optimization Model for Predicting and Analyzing Support Structures (COMPASS). COMPASS will not only recommend a level of maintenance for a repair or replace maintenance task, but it will also make repair versus discard recommendations and contract versus organic repair decisions. The LORA modeling is accomplished at several stages in the development cycle to include the latest cost data, configuration changes, support structure changes, and test equipment availability that would result in a revision to previously determined levels of repair recommendations.

f. The maintenance concept should provide the capabilities of the various maintenance levels used by the customer and give it criteria for assigning a maintenance to a given level of maintenance.

11. Step 4 - Task Design and Documentation.

a. Identified maintenance tasks must be designed to be performed at the maintenance level to which they are allocated. This means the task design effort must take into account all capabilities and constraints that exist at a maintenance level.

b. The design of correction after functional failure maintenance task must be carefully coordinated with the Maintainability Program effort to design these same tasks for purposes of demonstrating attainment of the maintainability requirement, e.g., Mean time to repair, that may be in the program peculiar specifications. In the case of correction after functional failure maintenance tasks, the task design reflected in the maintenance planning documentation should be identical to the Maintainability Program task designs.

c. The writing style and degree of detail to be used in developing the task design documentation should be coordinated with the technical manual and training elements to ensure effective use of this maintenance planning documentation in serving as input source data for the development of technical manuals and training documentation.

d. The maintenance concept should provide any information the customer may consider required relative to the design and documentation of maintenance tasks.

12. Step 5 - Resource Identification and Description.

a. As the maintenance tasks are designed in Step 4 of the maintenance planning process, resource requirements must be identified and described with the minimum number of descriptive data elements needed to ensure the resource requirement remains associated with the task and queues provisioning and cataloging personnel.

b. The contractor identifies the set of data for describing resource requirements associated with maintenance tasks, provides the mechanism for ensuring the relationship between and task and a resource is maintained, and makes the resource requirement visible to provisioners and catalogers.

13. Output from the Maintenance Planning Process. Outputs from the maintenance planning process include the following:

a. Maintenance planning documentation. for example:

(1) Depot Maintenance Support Plan.

(2) Maintenance planning documentation required by operational and maintenance units.

(3) Updates to the maintenance planning section of the Integrated Logistic Support Plan.

b. Identification of maintenance resources. For example:

(1) Manpower and personnel.

(2) Procedural documentation.

(3) Spare and repair parts.

(4) Facilities.

(5) Support equipment.

c. Source data for the development of related documentation. For example:

(1) Provisioning.

(2) Training documentation.

(3) Technical manuals and orders.

(4) Spare parts and special tools lists.

d. Source data for input into related analysis. For example:

(1) Design improvement recommendation.

(2) Life cycle cost studies.

14. Responsibility for the Maintenance Concept and Maintenance Planning.

a. The maintenance concept is initially stated by the user or user's representative prior to the start of a new system development program during the Concept and Technology Development Phase of the materiel acquisition process and provides guidance for early design and support planning effort. Within the U.S. military services, the maintenance engineering function in the materiel developer community has overall responsibility for developing the maintenance concept.

b. As an engineering function, maintenance engineering is responsible for the application of techniques, engineering skills, and efforts which:

(1) During the Concept Technology Development phase, develop the maintenance concept, maintenance criteria, technical requirements for maintainability and equipment support, and initiate the maintenance planning process.

(2) During the System Development and Demonstration Phase, perform detailed analyses of equipment design on an iterative basis to verify attainment of maintainability characteristics and finalize the maintenance planning effort to include the complete identification of required maintenance resources such as manpower, personnel, procedures, repair parts, facilities, and support equipment requirements necessary to perform these tasks.

(3) During the Production and Deployment Phase, obtain support items necessary to ensure timely, adequate, and economical maintenance support of weapons and equipment and evaluate engineering change proposals and the impact on support system elements.

15. Role of the Acquisition Logistician with Respect to Maintenance Planning. The Acquisition Logistician must -

a. Coordinate with the maintenance engineering and supportability analysis to ensure maintenance planning is accomplished in a timely and efficient manner.

b. Coordinate with all other logistic element managers and system engineering disciplines to ensure proper inputs are provided for the maintenance planning effort and maintenance planning outputs are properly used.

16. Summary.

a. To effectively plan, control, and develop the logistic support system of a new materiel system, it is essential to understand some of the documents and devices available to the acquisition logistician and the logistic engineer.

b. The maintenance concept is a device for both planning and controlling early efforts to establish a cost and operationally effective maintenance plan for a new materiel system.

c. As the maintenance concept becomes more refined, it provides the basis for the maintenance plan which, in turn, guides the development of maintenance capability through the remaining developmental phases and deployment.

d. The maintenance plan for a new materiel system is a description of the required maintenance tasks and associated resources needed to achieve, restore, or sustain the operational capability of the new materiel system.