Department of Defense

MANUAL

NUMBER 4151.22-M
June 30, 2011

USD(AT&L)

SUBJECT: Reliability Centered Maintenance (RCM)

References:
(a) DoD Directive 5134.01, "Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L))," December 9, 2005
(b) DoD Directive 4151.18, "Maintenance of Military Materiel," March 31, 2004
(c) DoD Instruction 4151.22, "Condition Based Maintenance Plus (CBM^+) for Materiel Maintenance," December 2, 2007
(d) Assistant Secretary of Defense for Logistics and Materiel Readiness, "Condition Based Maintenance Plus DoD Guidebook," May 2008
(e) Defense Acquisition University, "Defense Acquisition Guidebook," February 19, 2010

1. PURPOSE. In accordance with the authority in References (a) and (b), this Manual implements policy established in Reference (c), assigns responsibilities, and provides guidance for the RCM process to achieve inherent reliability and restore deteriorated reliability for DoD materiel as well as ensure safety and other performance characteristics are maintained.

2. APPLICABILITY. This Manual applies to OSD, the Military Departments, the Office of the Chairman of the Joint Chiefs of Staff and the Joint Staff, the Combatant Commands, the Office of the Inspector General of the DoD, the Defense Agencies, the DoD Field Activities, and all other organizational entities within the DoD.

3. DEFINITIONS. See Glossary.

4. POLICY. In accordance with Reference (c), it is DoD policy that, as one of the key enablers of Condition Based Maintenance Plus (CBM^+) and the life-cycle sustainment of DoD weapon systems, RCM shall be used to ensure effective maintenance processes are implemented. RCM shall also be used as a logical decision process for determining optimum failure management strategies, including maintenance approaches, and establishing the evidence of need for both reactive and proactive maintenance tasks.

5. RESPONSIBILITIES. See Enclosure 1.

6. PROCEDURES. See Enclosure 2.

7. RELEASABILITY. UNLIMITED. This Manual is approved for public release and is available on the Internet from the DoD Issuances Website at http://www.dtic.mil/whs/directives.

8. EFFECTIVE DATE. This Manual is effective upon its publication to the DoD Issuances Website.

Ashton B. Carter
Under Secretary of Defense for
Acquisition, Technology, and Logistics

Enclosures
1. Responsibilities
2. RCM

Glossary

TABLE OF CONTENTS

FIGURES

ENCLOSURE 1

RESPONSIBILITIES

1. ASSISTANT SECRETARY OF DEFENSE FOR LOGISTICS AND MATERIEL READINESS (ASD(L&MR)). The ASD(L&MR), under the authority, direction, and control of the Under Secretary of Defense for Acquisition, Technology, and Logistics, shall develop policy and provide guidance for RCM in accordance with Reference (c), and monitor and review implementation of these policies to ensure effectiveness throughout the DoD.

2. SECRETARIES OF THE MILITARY DEPARTMENTS AND DIRECTORS OF THE DEFENSE AGENCIES AND DoD FIELD ACTIVITIES. The Secretaries of the Military Departments and Directors of the Defense Agencies and DoD Field Activities shall:

a. Establish and coordinate policy and guidance for implementing RCM.

b. Direct incorporation of RCM throughout the total system life cycle, from requirements development through disposal.

c. Establish and maintain reporting systems for RCM data collection and feedback to address failure management, engineering, and logistics considerations and readiness issues.

d. Ensure that acquisition, operational, and support activities comply with RCM requirements.

e. Designate RCM leads, who will be responsible for implementation of the procedures contained in this Manual.

f. Establish RCM training.

g. Integrate RCM activity among the Military Departments, Defense Agencies, and DoD Field Activities.

ENCLOSURE 2

RCM

1. INTRODUCTION TO RCM

a. Purpose of RCM

(1) RCM is used to determine what failure management strategies should be applied to ensure a system achieves the desired levels of safety, reliability, environmental soundness, and operational readiness in the most cost-effective manner. In the context of RCM, this can mean identifying various maintenance actions. For example, one of the most useful products of an RCM analysis is the identification of technically defensible proactive maintenance tasks such as on-condition, scheduled restoration, and scheduled discard tasks. RCM can yield other results that also contribute significantly to the safe and reliable operation of assets. These can include design modifications, changes to a training program, identification of new operating and emergency procedures, or modifications to technical manuals.

(2) In some cases an existing maintenance program may have been developed outside the RCM methodology. Maintenance tasks within that program may have been added for a variety of reasons. They may have been developed based on original equipment manufacturer (OEM) guidance, been borrowed from other similar equipment, or were the result of a "this is the way it has always been done" approach. Often, the objective of such maintenance is to prevent all possible failures, and results in a maintenance program overloaded with ineffective maintenance. The application of RCM to such a maintenance program will often eliminate unnecessary maintenance tasks, resulting in a program of truly applicable and effective maintenance.

b. Precepts of RCM. RCM is based on the following precepts:

(1) The objective of maintenance is to preserve an item's function. RCM seeks to preserve a desired level of system or equipment functionality.

(2) RCM is a life-cycle management tool and should be applied from design through disposal.

(3) RCM seeks to manage the consequences of failure, not prevent all failures.

(4) RCM identifies the most applicable and effective maintenance task or other logical action.

(5) RCM is driven by (listed in order of importance) safety or a similarly critical consideration such as environmental law, the ability to complete the mission, and economics.

(6) RCM acknowledges design limitations and the operating context. At best, maintenance can sustain the inherent level of reliability within the operating context over the life of an item.

(7) RCM is a continuous process that requires sustainment throughout the life cycle. RCM uses design, operations, maintenance, engineering, logistics, and cost data to improve operating capability, design, and maintenance.

c. Benefits of RCM. RCM is a time-honored, proven process. When applied correctly and with qualified personnel, RCM produces overwhelmingly positive results. The goals of RCM can vary, but RCM has been used to enhance safety, reduce costs, improve availability, increase maintenance efficiency, improve environmental integrity, and achieve longer useful life for weapon system components.

d. Relationship of RCM to CBM^+

(1) CBM^+ encompasses the application of RCM and other technologies and processes. CBM^+ is a comprehensive strategy to select, integrate, and focus a number of process improvement strategies and diagnostic or machine health-sensing capabilities, thereby enabling maintenance managers and their customers to attain the desired levels of system and equipment readiness in the most cost-effective manner.

(2) There is a close relationship between RCM and CBM^+. RCM provides the evidence of need for other CBM^+ processes and technologies, such as health monitoring or prognostics. RCM provides an understanding of the applicability and effectiveness of proposed CBM^+ technologies as well as an analysis of alternatives. Guidance for CBM^+ and RCM has been established in Reference (c). Additional CBM^+ information is located in Reference (d).

e. Relationship of RCM to Systems Engineering. RCM utilizes a systems engineering approach to ensure optimal failure management strategies. Systems engineering is an interdisciplinary approach that encompasses all technical effort needed to evolve and verify an integrated and total life cycle-balanced set of system, people, and process solutions that satisfy customer needs. Systems engineering is the integrating mechanism across the technical efforts related to the development, manufacturing, verification, deployment, operations, support, disposal of, and user training for systems and their life cycle processes. An integration of systems engineering and RCM methodology is crucial early in the acquisition process in order to maximize the efficiency of both.

f. Relationship to Performance Based Product Support. See Appendix 1 to Enclosure 2.

2. ESSENTIAL ELEMENTS OF RCM

a. Program Management

(1) RCM program management entails the establishment and sustainment of the optimal mix of personnel for the RCM team, budgetary requirements, scheduling, and implementation of results. The elements of RCM program management are discussed in detail in section 3 of this enclosure.

(2) An integral part of any RCM program is to effectively manage the stakeholder's expectations along with forecasting realistic requirements and benefits. Additionally, keeping

management informed of resource expenditures and benefits gained will help mitigate loss of funding due to lack of information. Likewise, periodically meeting with the customer should help keep expectations in line with reality.

b. RCM Analysis

(1) RCM Process. The DoD-approved RCM process includes the identification of the following items in sequence: functions, functional failures, failure modes, failure effects, failure consequences, maintenance tasks and intervals, and other logical actions. The hardware partitioning and identification of the failure modes and failure effects during the RCM process, including severity classification, make up the failure modes and effects analysis (FMEA). These FMEA elements, plus criticality analysis, make up the failure modes, effects, and criticality analysis (FMECA). When RCM is performed, the requirement for a FMEA or FMECA is largely satisfied. FMECA differs from FMEA in that it includes the criticality of the failure mode.

(2) Functions. The intent of RCM is to formulate failure management strategies that allow assets to continue operating at the users' desired level of performance and not necessarily what the asset was designed to do. One very important point is to ensure that assets have the capability of meeting the users' needs. In a dynamic operating context, requirements must be understood and assets must provide the necessary capability to serve the user. For these reasons, functions are always recorded from the users' perspective and needs and not necessarily what the equipment was designed to do. The primary functions (the main reasons the item exists) and secondary functions (other functions of the item) are recorded.

(3) Functional Failures. Functional failure identification will classify and record the possible failed state(s) of a system. A total failure describes when the item no longer performs any part of the function at all. A partial failure describes how the item still performs the function, but performs it at an inadequate level.

(4) Failure Mode. The specific cause of the functional failure needs to be sufficiently detailed by failure mode so that an appropriate failure management strategy can be established. Only those failure modes that are reasonably likely to occur in the operating context should be recorded in the RCM analysis. Specifically, if a failure mode meets one or more of the criteria in 2.b.(4) (a) through (d), then the failure mode should be included in the analysis:

(a) Those that have happened before.

(b) Those that have not happened but are real possibilities.

(c) Those that have not happened and are unlikely to occur but have severe consequences.

(d) Those currently managed by a failure management strategy.

(5) Failure Effects. Failure effects describe what happens if a failure mode is allowed to occur. The description must be detailed enough to correctly evaluate the consequences of the

failure. The failure effect should describe the local, next higher-assembly, and the end-item effects. Any impacts to related subsystems should be described as well.

(6) Failure Consequences. Assessing how the loss of function caused by the failure mode matters will determine the failure consequences; that is, how it affects safety (causes injury or death), the environment (causes a breach of an environmental law, regulation, or standard), mission (adversely affects capability or drives an abort), or economics (does not adversely affect the mission and only involves economic considerations).

(7) Maintenance Tasks and Intervals. After consequences are assessed, the next step is to determine any proactive tasks that could be performed to predict, detect potential, prevent, or find failures. List a maintenance task or applicable action when it detects a potential failure, prevents a functional failure, or discovers a hidden functional failure. A maintenance task is considered effective when it reduces the risk of failure to an acceptable level. The consequences of failure must be used to determine task effectiveness.

c. Predicting Failure: On-Condition Tasks

(1) On-condition tasks are performed to identify signs of impending failure. They can be performed using numerous inspection techniques, human senses, sophisticated monitoring equipment, or continuous monitoring by sensors applied directly to the equipment. Examples of on-condition tasks are:

(a) Visual or Non-Destructive Inspection. Detects a potential failure condition (e.g., crack, corrosion).

(b) Performing Vibration Monitoring and Analysis. Detects increased vibration signatures.

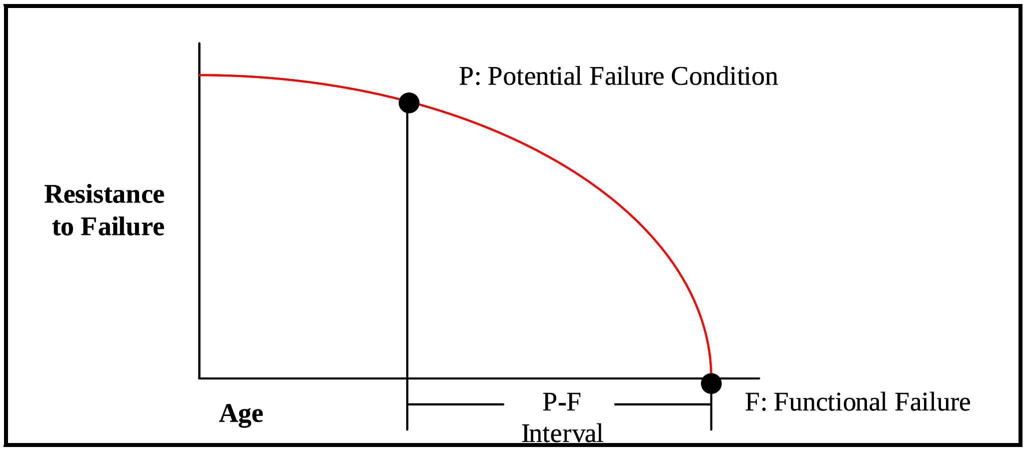
(c) Taking Oil Samples. Sample results indicate wear and/or contaminants.

(d) Measuring Brake Pads. Identifies how much of the pad is remaining.

(2) The purpose of an on-condition task is to identify when action is required based on the evidence of need. How often an on-condition task is performed depends on the potential to functional failure (P-F) interval (see Figure 1).

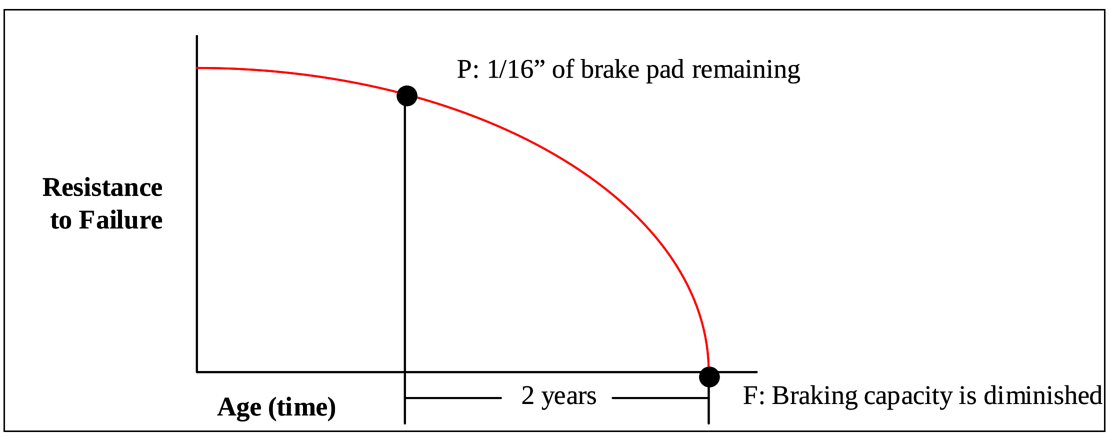
(3) Figure 1 depicts the P-F curve. The x-axis indicates age, which can be measured in any unit, such as calendar time, miles, operating hours, cycles, etc. The y-axis indicates the resistance to failure. P is the potential failure condition, which is defined as the evidence of an impending failure. F is the functional failure, as defined by the user.

Figure 1. P-F Curve



(4) Consider the failure mode, brake pads worn beyond acceptable limits, for the example illustrated in Figure 2.

Figure 2. P-F Curve Example



(5) One of the keys to on-condition maintenance tasks is that the inspection interval must be the same as or shorter than the P-F interval. Assume the potential failure condition in Figure 2 is 1/16" of the brake pad remaining, the functional failure is braking capacity is diminished, and the P-F interval is 2 years. In this example, an inspection of the brakes would need to be accomplished at intervals less than the P-F interval (every year, for example) to detect the potential failure condition before it turns into a functional failure.

(6) In the context of RCM, in order to assign an on-condition task it must be both applicable and effective.

(7) To be considered applicable, an on-condition task must fulfill the following criteria:

(a) It must be possible to detect the potential failure condition.

(b) The P-F interval must be relatively consistent.

(c) It must be practical to monitor the potential failure condition at intervals at or less than the P-F interval.

(d) The P-F interval must be long enough to take action to manage the consequences of failure.

(8) To be considered effective, an on-condition task must fulfill the following criteria:

(a) The task reduces the risk of failure to a tolerable level (for safety, environmental, or operational consequences).

(b) The task is cost effective (for operational or economic consequences).

d. Scheduled Restoration and Discard Tasks

(1) Scheduled restorations and discards are performed when a failure mode becomes more likely to occur as operating age increases.

(a) A scheduled restoration task restores an acceptable resistance to failure and is performed regardless of the item's condition at the time.

(b) A scheduled discard task replaces an item at a specified interval and is performed regardless of the item's condition at the time.

(2) In the context of RCM, to assign a scheduled restoration or discard task it must be applicable and effective. The following criteria must be satisfied for a restoration or discard task to be considered applicable:

(a) It must be possible to identify a useful life.

(b) The items can survive to this useful life.

(c) The task restores the failure resistance to an acceptable level (for restoration tasks only).

(3) The following criteria must be satisfied for a restoration or discard task to be considered effective:

(a) It reduces the risk of failure to a tolerable level (for safety, environmental, or operational consequences).

(b) It is cost effective (for operational or economic consequences).

e. Failure Finding Tasks. RCM also helps to develop failure finding tasks. Failure finding tasks are performed to identify if protective devices are in a failed state. A protective device is an item or system that is intended to mitigate the consequences of another failure; that is, it is only needed if something else happens. A smoke detector is an example of a protective device.

It is only needed to sound an alarm in the event of a fire. Other examples of protective devices include low pressure cutoff systems, circuit breakers, and relief valves. RCM provides a means to determine whether and how often failure finding tasks (e.g., testing a smoke detector) should be performed.

f. Other Logical Actions. Other logical actions are sometimes required to manage the consequences of a failure mode. These are one-time actions that are recommended to reduce the consequences of a failure or resolve problems that are identified during the RCM analysis. Some examples of other logical actions are design changes; changes to a training program, operating procedures, emergency procedures, or technical manuals; the collection of additional data; or no scheduled maintenance.

g. Data Management

(1) RCM is a formally structured and highly documented process. Consequently, a great deal of supporting information and data is generated during the analysis. The functions, failure modes, failure effects, and maintenance tasks are examples of the data generated. As the RCM analysis proceeds from start to finish, the amount of data grows in volume and complexity. When performing RCM analysis, assumptions, decisions, and associated rationale should be preserved for future reference and for the purpose of a well documented audit trail.

(2) After an analysis is completed, data collection does not stop. A successful RCM program is a continuous improvement process. Failure data is collected and evaluated. After the initial maintenance package has been deployed and used, the Service should continue to collect relevant data. Ideally, that data is recorded and stored in a database for analysis. During an RCM analysis, operators, and maintainers may provide useful information on how well the maintenance is working and how to improve it.

(3) To operate effectively, the Service must plan for a robust way to collect, store, organize, and access all of this data in phases (prior to initial RCM, during initial RCM analysis, and throughout RCM sustainment). The data should be organized to create an effective audit trail and support life-cycle maintenance decision making. Care must be taken to use a robust, expandable, and reliable database.

(4) Data needed to make informed decisions is often not available when performing an RCM analysis. When this is the case, it becomes necessary to make assumptions using subject matter expert judgment. When proactive tasks are developed using these assumptions, they are developed conservatively. This may cause the tasks to be less than optimally effective, and in most cases, schedules them to be performed more often than necessary. Age exploration tasks collect specific data from actual operational and test environments to replace the assumptions made during the initial RCM analysis and proactive task development efforts. Age exploration data may reveal the need to extend, shorten, establish, or eliminate proactive tasks.

(5) Completed RCM analyses are still valuable after the disposal of equipment. The RCM analysis and the source data used to generate it should be organized and archived to aid in RCM efforts of future equipment.

h. Implementation of RCM Results

(1) After the RCM analysis has been accomplished, the resulting outputs must be implemented before the end user can receive any benefit. The actions required for the implementation of RCM recommendations may take several forms, including developing maintenance tasks, redesigning hardware, modifying operating and maintenance processes and procedures, and incorporating results into maintenance plans.

(2) Once all items within the scope of an effort have been analyzed, it is necessary to package the tasks into discrete work packages and plans. The packaging process involves the grouping of task frequencies and maintenance levels. A maintenance program that is packaged properly is more cost effective than one that is not.

(3) An RCM analysis may yield other logical actions in addition to proactive maintenance tasks, but often there is not enough funding and other resources to implement all other logical actions. In that case, the recommendations, such as hardware redesigns and technical publication updates, are prioritized according to importance. This allows a Program Manager (PM) to allocate funding to the other logical actions that would provide the most benefit.

3. <u>ESTABLISHING AN RCM PROGRAM</u>. Before beginning analysis, an RCM program should be established. Elements to consider include the scope of analysis, ground rules and assumptions, manpower considerations, training and certification, funding requirements, and data sources. Often, an RCM program is begun by completing a series of pilot projects. This allows an organization to see first-hand what RCM has to offer and what it takes to see an analysis through to implementation, therefore promoting management commitment. The following define the RCM program management elements.

a. <u>Scope of Analysis</u>

(1) The analysis scope is the extent of the RCM analysis effort to be applied to meet program objectives. It includes the selection of items or systems for analysis, the indenture level at which analysis of the hardware will be performed, and the extent to which each item will be analyzed. The scope of analysis depends on several factors. These include, but are not limited to, the life-cycle phase, the quantity, quality, and validity of any prior analyses, the effectiveness of the current maintenance program, and available resources.

(2) The scope of the analysis drives the level of effort. The scope can range from analyzing one or two functions and selected failure modes of an in-service item during the sustaining phase to performing a complete analysis of all functions and failure modes of a new item during its acquisition. There are many intermediate levels of analysis between these two extremes. These include analyzing high cost or high man-hour drivers, readiness degraders, items with current maintenance tasks, or any combination of these.

b. <u>Ground Rules and Assumptions</u>

(1) The ground rules and assumptions are a compilation of specific data and information developed during RCM program planning. They are necessary for conducting RCM analyses. Ground rules may include:

(a) Description of operating context.

(b) Standard operating procedures.

(c) Data sources.

(d) Analytical methods.

(e) Cost-benefit analysis methods.

(f) Approaches to specific types of problems.

(g) Default values (e.g., labor rates, equipment usage rates, common material costs).

(h) Acceptable probabilities of failure for certain failure modes based on severity.

(i) Any other information that may be required to produce consistent and efficient analyses.

(2) With specific ground rules and assumptions all RCM analyses for a particular program are based on the same information. This also allows for consistent updates to the original RCM analyses.

c. Manpower Considerations. The number of personnel and associated skills required to sustain an RCM program depends on the extent of the program, but obtaining the proper mix is paramount for achieving a successful RCM program. Depending on the size and stage of an RCM program, several roles will likely be required. Likewise, how much time each person is required to spend on each responsibility depends on the extent of the RCM program. RCM roles include:

(1) RCM Lead. Oversees the RCM program, offers solutions to issues that arise, works with the analyst or facilitator to prioritize systems to analyze, and defines the various resources required to perform an RCM analysis.

(2) RCM Analyst or Facilitator. Performs and facilitates RCM analyses.

(3) Subject Matter Experts. Provide expert technical information regarding the asset during the RCM analysis. Subject matter experts may include operators, maintainers, engineers, logisticians, and the OEM.

(4) Ancillary Support Personnel. Assistance from the following may be required but is not necessarily included in the RCM team composition:

(a) RCM trainer.

(b) Information technology personnel.

(c) Budgeting personnel.

(d) Contracts personnel.

d. Training and Certification. RCM team members must be properly trained according to their level of responsibility within the RCM program. All RCM team members should have at least a basic knowledge of RCM principles. Analysts and facilitators should complete a training course that provides instruction on how to conduct RCM analyses. In addition to classroom training, all analysts and facilitators must complete a period of mentoring to transform their theoretical knowledge to the practical skills required to produce safe and technically defensible RCM analyses. RCM trainers should be certified analysts or facilitators with adequate experience conducting RCM analysis, and they should receive additional classroom instruction and mentoring. Service-specific guidance on RCM training and certification is located in Appendix 2 of this enclosure.

e. Funding Requirements. Funding requirements for implementing an RCM program are two-fold: initial implementation and sustainment. The PM is responsible for submitting and defending the RCM requirement and potential benefits during the budget process. It is essential that all RCM funding justifications identify any potential benefit (improved safety, greater intervals between maintenance, etc.) or return on investment (ROI). The PM should also develop an incremental RCM rollout strategy that will allow the program office to take advantage of partial funding as well as funding that may become available at the end of the fiscal year.

f. Data Sources

(1) A good deal of information is required to perform RCM analysis. Varying bodies of information that may be utilized include maintenance data systems, engineering data, vendor information, design reports, test result reports, and engineering investigations. However, this data often does not provide all the information that is required and, quite frequently, RCM analysis is performed with input from subject matter experts intimate with the equipment and the operating context. Input from these experts allows gaps in historical data to be filled with information based on actual experience.

(2) Data that is not available from existing sources may be required. In such cases, the establishment of activities, such as age exploration tasks, fleet leader programs, or other dedicated monitoring programs, may be required. The duration and scope of these activities should be limited to what is needed to collect the specific information required.

g. Modeling and Simulation (M&S). During the design stage, M&S can be an effective way to analyze maintenance strategies and begin an RCM program. M&S can fill in the gaps in system operations knowledge. In the implementation of RCM at fielding, M&S can be used extensively to trigger on-condition tasks. During the sustainment phase, M&S can continue to aid in the analyses of systems in new operating scenarios. The models used during the design phase of the system need to be kept current. This means models should be updated regularly to reflect engineering changes to the system (through the engineering change proposal process), and models should be updated to reflect advances in modeling technology and software compatibility.

4. SUSTAINING AN RCM PROGRAM. To fully realize the benefits of RCM, the analysis must be periodically reviewed and updated as the equipment, and how and where the equipment is used, changes over time. Maintain and update RCM analysis after initial analysis is completed using RCM sustainment.

a. Identifying the Need to Change. Many factors can force changes to the initial RCM analyses. For example, modifications to the equipment or changes to the operating context may result in updates, such as changes to the maintenance program. In addition, assumptions or decisions made during the initial analysis may need to be revised as more data is collected. These factors should drive a periodic review and update of the RCM analysis and resulting failure management strategies.

b. Measuring RCM Program Success

(1) Another important part of sustaining an RCM program is the ability to measure and provide visibility into the effectiveness of the RCM program. The RCM program should provide a means to evaluate and document its effectiveness.

(2) RCM sustainment is achieved by establishing a program that provides for continuous or frequent periodic monitoring of the performance of the maintenance program and, when needed, review and update of the RCM analysis. Processes, procedures, and resources required to execute RCM sustainment should be documented within the RCM program and integrated into equipment's program planning, budgeting, and execution documentation. The monitoring efforts should include mechanisms to:

(a) Identify and monitor appropriate performance metrics.

(b) Identify adverse failure trends.

(c) Update existing failure modes.

(d) Identify emergent failure modes.

(e) Identify top degraders and cost drivers.

(f) Identify opportunities for process improvements and technology insertion.

(g) Monitor changes to the equipment operating profile and environment.

(3) Appropriate metrics are needed to accurately track progress, reliably show results, and validate course adjustments when necessary. For illustrative purposes, RCM metrics are segregated into three very broad areas: business metrics, program management metrics, and technical metrics. These are the same metrics inherent in any program's metric set to show the benefits of investments like RCM in terms of a program's values.

(a) Business metrics are the measures of direct and indirect costs associated with implementing and sustaining an RCM program. ROI in terms of cost benefit is the ultimate goal in calculating business metrics. Business metrics for implementing an RCM program may be divided into two parts: the initial analysis effort and the sustaining effort. Business metrics reflect the cost and benefits of the program to the resource provider, user, and customer.

(b) Program management metrics are geared toward reporting the progress and health of the program. These metrics use data elements, such as number of personnel, number of work years, training received and provided, schedules, number of systems or subsystems analyzed, and the number of systems and subsystems still to be analyzed.

(c) Technical metrics measure specific behavior associated with equipment. These may include failure rates, mean time between failures, readiness or availability, servicing actions, maintenance man-hours, elapsed maintenance time, and proactive maintenance tasks or maintenance time.

(d) Regardless of the type of metrics to be used (business, program management, or technical), it is important that a baseline data set be established. This baseline will be used to measure results and support trend analysis.

c. Accessing Data. Sustaining an RCM program requires access to timely and accurate failure, maintenance, and performance data. Ideally, these data elements can be obtained from existing systems and personnel. The systems range from maintenance information systems to engineering investigation reports and item repair histories. OEMs, vendors, production inspection records, test reports, engineering studies, drawings, and computer modeling are also appropriate sources of data.

d. Reporting Requirements. Reference (b) requires that an effective RCM implementation establishes and maintains reporting systems for RCM data collection and feedback to address failure management engineering and logistics considerations and readiness issues. Reporting requirements should be documented and should include report format and content requirements, frequencies, and distribution.

APPENDIX 1 TO ENCLOSURE 2

RCM IN A PERFORMANCE BASED PRODUCT SUPPORT ENVIRONMENT

1. Performance based product support, explained in Chapter 5 of Reference (e), can be summarized as an environment where performance is measured and appropriate, fact-based corrective actions are taken to address the root causes of encountered problems. It is applicable to new and legacy programs. In this new environment outcomes are examined across the enterprise, that is, both the horizontal component across the supply chain and the vertical component within the program. In addition, performance is measured using a balanced set of metrics based on a meaningful user outcome (e.g., materiel availability) and supported, at a minimum, by:

a. Materiel quality measure (e.g., materiel reliability).

b. Sustainment quality or responsiveness measure (e.g., mean down time).

c. Cost measure (e.g., ownership cost).

2. The continuous application of RCM is a critical element of performance based product support because it aligns maintenance processes to optimize the same key performance measures. RCM should be applied regardless of the support provider including, in cases where the eventual provider is a contractor, under a performance-based logistics (PBL) contract. RCM principles also can have positive impact when applied early in a program's life cycle to help determine the optimum product support strategy and potentially influence system engineering decisions.

3. In PBL, the Government buys a guaranteed level of performance rather than specific goods and services. It is common for the provider to perform proactive maintenance and continuous improvement of maintenance processes to achieve operational readiness goals. RCM is the method recommended by the DoD for the development of failure management strategies. The RCM process ensures proactive and reactive maintenance are optimized; delivering the safest and most cost-effective maintenance program over the system's life. An RCM-based maintenance program directly affects the performance and maintenance cost of the system, and RCM analysis results should be integrated into any PBL business case. To encourage RCM creativity in a PBL environment, metrics should be established along with an incentive structure that rewards the attainment of high mission reliability. Metrics should be developed and tracked such that they tie directly to the general objectives of the PBL effort. RCM analyses and related data should be considered as key data in the Government's Data Management Strategy, as executed in requests for proposals and contracts. The Government should ensure that the proactive maintenance proposed by the contractor meets the minimum requirements established to ensure the Government has access to or ownership of key data, such as drawings, maintenance procedures, RCM analyses, performance data, and facilities. In fact, macro level RCM analysis and other supportability analysis elements (see section 5.2.1 of Reference (e)) should be used as

a factor in determining the extent to which PBL contracts should be used and the cost-effective outcome to be placed on contract.

4. The Government should ensure the PBL business case analysis includes a specific delineation of the proactive maintenance proposed by the contractor, and that it meets the minimum requirements established by an RCM analysis in accordance with Reference (c). The existence of a PBL contract does not preclude the requirement to apply RCM in accordance with Reference (c).

APPENDIX 2 TO ENCLOSURE 2

RCM RESOURCES

1. ARMY

a. Army Materiel Maintenance Policy, September 20, 2007

b. Army RCM Facilitator Training (2 weeks) (U.S. Army Aviation & Missile Command)

c. Army RCM for the Warfighter (2 days) (U.S. Army Aviation & Missile Command)

d. Army RCM Overview for Management (1.5 hours) (U.S. Army Aviation & Missile Command)

2. AIR FORCE

a. Logistics 032: RCM for In-Service Engines (4 day course, Air Force Institute of Technology)

b. Air Force Instruction 21-101, "Aircraft and Equipment Maintenance Management," April 12, 2010

c. Air Force Instruction 63-101, "Acquisition and Sustainment Life Cycle Management", April 17, 2009

d. Air Force Materiel Command Instruction 21-103, "Reliability-Centered Maintenance (RCM) Programs," August 8, 1994

e. Prognostics Center of Excellence (PCOE BP) 99-4, Best Practices for Application of RCM for USAF Gas Turbine Engines

3. NAVY

a. Chief of Naval Operations Instruction (OPNAVINST 4790.16A), "Condition-Based Maintenance (CBM) Policy," December 17, 2007

b. Naval Sea Systems Command (NAVSEA)

(1) Classic RCM for Maintenance Requirements Developers—Level II (5-day certification course)

(2) NAVSEAINST 4790.27 RCM and CBM Policy for Ships, Ship Equipment, September 2007

(3) Backfit RCM—Level I (2-day certification course)

(4) NAVSEA RCM Overview (2 hours)

(5) Military Specification MIL-P-24534A, Planned Maintenance System Development

(6) ePMS Gateway, https://algol.seajax.navy.mil/ePMSGateway/index.aspx

(7) eRCM (web-enabled RCM via ePMS Gateway)

(8) eWaiver (web-enabled via ePMS Gateway)

(9) NAVSEA RCM Handbook (downloadable from ePMS Gateway)

c. Naval Air Systems Command (NAVAIR)

(1) Fundamentals of RCM Analysis (3-day certification course)

(2) RCM Management Overview

(3) NAVAIR Instruction 4790.20, RCM Program Instruction, July 20, 2007

(4) NAVAIR 00-25-403, Naval Aviation RCM Process, July 1, 2005

(5) Integrated Reliability-Centered Maintenance System (client server)

(6) IRCMS, https://ircms.navair.navy.mil

(7) NAVAIR RCM homepage, http://www.navair.navy.mil/logistics/rcm/index.cfm

4. <u>MARINE CORPS</u>

a. Marine Corps Order 4000.57A, “Marine Corps Total Life Cycle Management (TLCM) of Ground Weapons Systems, Equipment and Material”, December 23, 2009

b. Society of Automotive Engineers Standard JA1011, Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes

c. Society of Automotive Engineers Standard JA1012, A Guide to the Reliability-Centered Maintenance (RCM) Standard

d. Training:

(1) Introduction to RCM (3-day certification course).

(2) RCM Facilitator Course (10-day certification course).

(3) Classic RCM for Maintenance Requirements Developers-Level II (5-day certification course).

(4) Backfit RCM-Level I (2-day certification course).

GLOSSARY

PART I. ABBREVIATIONS AND ACRONYMS

ASD(L&MR)	Assistant Secretary of Defense for Logistics and Materiel Readiness
CBM^+	Condition-Based Maintenance Plus
FMEA	failure modes and effects analysis
FMECA	failure modes, effects, and criticality analysis
M&S	modeling and simulation
OEM	original equipment manufacturer
P-F	potential to functional failure
PBL	performance-based logistics
PM	program manager
RCM	reliability centered maintenance
ROI	return on investment

PART II. DEFINITIONS

Unless otherwise noted, these terms and their definitions are for the purpose of this Manual.

age exploration. A process used to collect specific data to replace estimated or assumed values that were used during a previous RCM analysis.

CBM^+. The application and integration of appropriate processes, technologies, and knowledge based capabilities to improve the reliability and maintenance effectiveness of DoD systems and components. At its core, CBM^+ is maintenance performed on evidence of need provided by RCM analysis and other enabling processes. CBM^+ uses a systems engineering approach to collect data, enable analysis, and support the decision-making processes for system acquisition, sustainment, and operations.

conditional probability of failure. The probability that a failure will occur in a specific period provided that the item concerned has survived to the beginning of that period.

failure consequence. The description of how the loss of function caused by the failure mode matters (e.g., safety, environmental, mission, or economics).

failure effect. The description of what happens when each failure mode occurs. The description must be detailed enough to correctly evaluate the consequences of the failure.

failure finding task. A task performed to find functional failures of protective devices for which functional failure of these devices are otherwise not evident to the operating crew.

failure management strategies. Proactive maintenance or other logical actions (such as design changes and implementation of new operating procedures or run to failure) that are warranted to ensure safe and cost-effective operations.

failure mode. The specific condition that causes a functional failure. The failure mode describes what specifically causes the item to fail or to perform below an acceptable level.

function. The desired capability of the system, how well it must perform, and under what circumstances

functional failure. The failed state of the system (e.g., the system falls outside the desired performance parameters).

maintenance tasks and intervals. The description of the applicable and effective tasks, if any, performed to predict, prevent, or find failures.

on-condition task. A proactive maintenance task performed to identify signs of impending failure so that maintenance is performed only on the evidence of need.

operating age. The measure of how long a system, asset, or component has been in service. Operating age can be measured in many units, such as calendar time, operating hours, miles, or cycles.

operating context. The environment and conditions in which a system is intended to operate. Operating context is a combination of factors that affect the equipment while it is in operation. These include but are not limited to the external physical environment, duty-cycle, operational tempo, and stress factors.

other logical action. Any action other than proactive maintenance that is required to manage the consequences of a failure mode including, but not limited to, run-to-failure, engineering redesigns, and changes/additions to operating procedures or technical manuals.

performance based logistics. A strategy for system support. Instead of goods and services a supplier is paid for a guaranteed level of performance and system capability.

PBL contract. The purchase of support as an integrated, affordable, performance package designed to optimize system readiness and meet performance goals for a weapon system through long-term support arrangements with clear lines of authority and responsibility.

potential failure condition. Evidence of an impending failure (e.g., vibration, fatigue cracks, increased vibration levels).

potential to functional failure (P-F) interval. The time between when a potential failure condition can be detected and functional failure occurs.

proactive maintenance tasks. Condition based maintenance and scheduled restoration and discard tasks are proactive maintenance tasks. These tasks are accomplished on a scheduled interval and are intended to manage the consequences of failure.

protective device. An item or system that is intended to mitigate the consequences of another failure and is only needed if something else happens (e.g., a smoke detector or a relief valve).

RCM. A logical, structured process used to determine the optimal failure management strategies for any system, based on system reliability characteristics and the intended operating context.

reactive maintenance. Performed for items that are selected to run to failure or those items that fail in an unplanned or unscheduled manner. Run to failure is often the planned maintenance strategy for items that have little readiness or safety impact.

scheduled discard task. A proactive maintenance task that replaces an item at a specified interval regardless of its condition.

scheduled restoration task. A proactive maintenance task that restores the original resistance to failure at a specified interval, regardless of its condition.

systems engineering. The overarching process that a program team applies to transition from a stated capability to an operationally effective and suitable system.