DoD MANUAL 4151.25

RELIABILITY-CENTERED MAINTENANCE

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Purpose: In accordance with the authority in DoD Directive (DoDD) 5135.02, this manual implements the policy in DoD Instruction (DoDI) 4151.22, assigns responsibilities, and provides information necessary for establishing, executing, and sustaining a reliability-centered maintenance (RCM) program.

- The procedures and processes contained in this manual:
  - Enable the development of failure management strategies, maintenance requirements, and maintenance plans.
  - Prescribe the need for continually updating maintenance requirements and plans across the life cycle of weapon systems, equipment, and materiel programs.
- This manual is renumbered in accordance with records keeping requirements for DoD issuances.

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SECTION 1: GENERAL ISSUANCE INFORMATION

1.1. APPLICABILITY.

This manual:

a. 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 Inspector General of the Department of Defense, the Defense Agencies, the DoD Field Activities, and all other organizational entities within the DoD.

b. Does **not** apply to medical equipment and medical materiel.

1.2. POLICY.

In accordance with DoDI 4151.22, the DoD will:

a. Use RCM as the foundation of condition-based maintenance plus (CBM+) and life-cycle sustainment of weapon systems, equipment, and material to ensure effective implementation of maintenance processes. RCM will be used as a logical decision process for determining the optimum failure-management strategies, including maintenance approaches, and determining when and if proactive and predictive maintenance tasks are necessary.

b. Require that new materiel acquisitions, when supported by RCM analyses, integrate CBM+ maintenance concepts, enabling technologies, and processes into the Joint Capabilities Integration and Development System.

SECTION 2: RESPONSIBILITIES

2.1. ASSISTANT SECRETARY OF DEFENSE FOR ACQUISITION.

Under the authority, direction, and control of the Under Secretary of Defense for Acquisition and Sustainment, the Assistant Secretary of Defense for Acquisition:

a. As part of program oversight responsibilities, considers integrating RCM processes into the Joint Capabilities Integration and Development System process during program acquisition and technical planning.

b. Considers integrating RCM during program support reviews and other oversight reviews.

c. Ensures that the Defense Acquisition University (DAU) considers integrating RCM into training and education.

2.2. ASSISTANT SECRETARY OF DEFENSE FOR SUSTAINMENT.

Under the authority, direction, and control of the Under Secretary of Defense for Acquisition and Sustainment, the Assistant Secretary of Defense for Sustainment:

a. Develops policy and provides guidance for RCM pursuant to DoDD 4151.18, DoDI 4151.22, and DoDI 5000.02.

b. Monitors and reviews the implementation of RCM and oversees RCM effectiveness across maintenance, acquisition, engineering, logistics, and industrial communities.

c. Ensures that serialized item management and item unique identification processes are integrated into RCM implementations.

2.3. SECRETARIES OF THE MILITARY DEPARTMENTS AND DIRECTORS OF THE DEFENSE AGENCIES.

The Secretaries of the Military Departments and Directors of the Defense Agencies:

a. Establish policy and guidance for implementing RCM.

b. Direct incorporation of RCM in the development of maintenance requirements, maintenance plans, and the continuous update of maintenance requirements and plans across the life cycle of materiel equipment.

c. Consider the inclusion of CBM+ requirements in solicitations and contracts, as appropriate, during the acquisition process.

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

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

f. Designate a focal point who will be responsible for implementing the procedures contained in this manual.

g. Require, as appropriate, accomplishment of DAU RCM training and any service or component specific RCM training.

SECTION 3: RCM

3.1. INTRODUCTION TO RCM.

a. Purpose of RCM.

(1) RCM is a principal component of the DoD's integrated product support maintenance planning and management element. RCM is used to determine the optimal failure management strategies for DoD materiel. RCM ensures that a system achieves the desired levels of safety, reliability, environmental soundness, and operational readiness in the most cost-effective manner.

(a) In the context of RCM, this can mean identifying the optimum mix of 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.

(b) RCM can also yield other results that contribute significantly to the safe and reliable operation of assets. These can include system design modifications, changes to training programs, identification of new operating and emergency procedures, or revisions to technical manuals.

(2) In some cases, an existing maintenance program may have been developed outside of 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 or commercial applications, adopted from other similar equipment, or were the result of a traditional approach. Often, the objective of such maintenance is to prevent all possible failures and results in a maintenance program overloaded with ineffective maintenance.

(3) The application of RCM practices, enhanced by CBM+ enablers, into a maintenance program should eliminate, enhance, and optimize maintenance tasks, resulting in a program of truly applicable and effective maintenance.

b. Precepts of RCM.

RCM:

(1) Seeks to preserve a desired level of system or equipment functionality.

(2) Is a life-cycle management process, applied from initial design through disposal.

(3) Seeks to manage the consequences of failure, and prevent failures if possible and cost-effective, by using condition monitoring and predictive maintenance strategies.

(4) Identifies the most applicable and effective maintenance tasks or other logical actions.

(5) Is driven by (in order of importance):

(a) Safety or a similarly critical consideration such as environmental law.

(b) The ability to complete the mission.

(c) Economics.

(6) 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 a system.

(7) Is a continuous process that requires life-cycle managers to reevaluate past analyses and validate that the basis for those analyses are still accurate. RCM routinely analyzes 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. RCM benefits can vary, but it has been used to:

(1) Enhance safety;

(2) Reduce costs;

(3) Improve availability;

(4) Increase maintenance efficiency;

(5) Improve environmental integrity; or

(6) Achieve longer useful life for weapon system components.

d. Relationship of RCM to CBM+.

(1) The effectiveness of an RCM program is enhanced by incorporating CBM+ enablers. CBM+ provides methods and technologies to enable predictive maintenance by selecting, integrating, and focusing process improvement strategies, diagnostic or machine health-sensing capabilities, artificial intelligence techniques, machine learning, and digital twins. This enables maintenance managers and their customers to attain the desired levels of system and equipment readiness in the most cost-effective manner.

(2) RCM and CBM+ are inherently connected; one cannot fully embrace CBM+ if the RCM principals are not implemented. RCM provides the evidence of need for condition-based maintenance (CBM) and CBM+ activities. RCM provides an understanding of the applicability and effectiveness of proposed CBM+ technologies as well as analyses of alternatives.

(a) DoDI 4151.22 establishes guidance for RCM and CBM+.

(b) The Condition-Based Maintenance Plus DoD Guidebook provides additional guidance on CBM+ implementation and execution.

e. Relationship of RCM to Systems Engineering.

(1) RCM uses a systems-engineering approach to ensure optimal failure maintenance strategies. Systems engineering is:

(a) An interdisciplinary approach that encompasses all the technical efforts needed to evolve and verify an integrated and total life cycle balanced set of systems, people, and process solutions that satisfy customer needs.

(b) The integrating mechanism across the technical efforts related to the development, manufacturing, verification, deployment, operations, support, disposal, and user training for systems and their life-cycle processes.

(2) CBM+ enablers needed to realize the benefits of RCM must not be an add-on feature after development but should be an integral part of the systems engineering process and included as a contract requirement in the acquisition process.

(3) Both systems engineering and RCM use functions and failure modes in the analysis process. Therefore, it is crucial that these elements are integrated early in the acquisition.

f. Relationship of RCM to Performance-Based Product Support.

(1) RCM principles will have the greatest positive impact when applied early in a program's life cycle to help determine the optimum product support strategy and influence system and support design decisions.

(a) It is not uncommon for the product support provider to perform proactive maintenance and continuously improve the maintenance processes to achieve operational readiness goals. RCM is the method recommended by the DoD for developing failure management strategies.

(b) The RCM process ensures proactive and reactive maintenance are optimized, delivering the safest and most cost-effective maintenance program over the system's life. RCM should be applied regardless of the support provider, including in cases where the eventual provider is a contractor, and the product support arrangement is a performance-based logistics (PBL) contract.

(2) In PBL, the government buys a guaranteed level of performance rather than specific goods and services. It is crucial to clearly articulate product support requirements in the contract documents. In fact, the government should ensure that the proactive maintenance proposed by the contractor meets the minimum requirements established and that the government has access to (with appropriate license rights) key data such as models, drawings, maintenance procedures, RCM analyses, performance data, and facilities.

(a) Two essential documents are the contract data requirements list (CDRL) and the data item description (DID). These documents ensure the program office is buying what is expected, valid, and useful in terms of supportability.

(b) Without these basics, the product support community will be disadvantaged with respect to product support data and be severely limited in their ability to participate in proactive supportability planning and execution activities.

(3) CDRLs and DIDs may be required in early stages of a program when constructing the appropriate sustainment approach, in mid-stages when developing detailed engineering estimates, or in the operating and support phase after an item has been successfully deployed.

(a) However, a best practice is to include CDRLs and DIDs early in the life cycle (e.g., engineering and manufacturing development phase of the major capability acquisition pathway) to drive down costs through competition and secure access to data, with appropriate license rights, even if the delivery of such data is deferred. An example of how these can be helpful is related to the level of repair analysis report.

(b) The level of repair analysis DID contains the format and content preparation instructions. Without the specifics contained in the existing DID, there may be a lack of understanding regarding the report requirements, including the format, content, and delivery method, which are extremely important in today's world of digital information. Without the DID, and without clearly understanding what the contractor is responsible for, there is a risk that the program would receive the report in an unexpected format or, in a worst-case scenario, in a format that the government could not access.

(4) 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 case. 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. The existence of a PBL contract does not preclude the requirement to apply RCM principles and processes.

(5) As described in DoDI 5000.91, performance-based product support solutions, which apply to new and legacy programs, include an appropriate mix of product and process metrics to monitor performance. Outcomes are examined across both the horizontal component across the supply chain and the vertical component within the program.

(a) To support RCM implementation in a PBL environment, metrics should be established along with an incentive structure that rewards the attainment of high mission reliability.

(b) Metrics should be developed and tracked such that they tie directly to the general objectives of the PBL effort.

(c) Metrics are adjusted as needed to satisfy warfighter requirements.

(d) Performance is often measured using a balanced set of metrics based on a meaningful user outcome (e.g., materiel availability) and supported at a minimum by:

1. Maintainability (e.g., materiel reliability and operational availability).

2. Reliability (e.g., mean down time).

3. Operating and support cost (e.g., ownership cost)

3.2. ESSENTIAL ELEMENTS OF RCM.

a. RCM Analysis.

(1) RCM Process.

(a) The DoD-approved RCM process includes the identification of these items in sequence:

1. Functions.

2. Functional failures.

3. Failure modes.

4. Failure effects.

5. Failure consequences.

6. Maintenance tasks and intervals.

7. Other logical actions.

(b) 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. These failure modes and effects analysis elements, plus criticality analysis, make up the failure mode, effects, and criticality analysis.

(2) Functions.

The intent of RCM is to formulate failure management strategies that allow assets to continue operating at the user's desired level of performance within a given context. 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 user's 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 states(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.

Failure mode describes what specifically causes the item to fail or perform below an acceptable level. The specific condition that causes the functional failure needs to be described in enough detail for it to be possible to select an appropriate failure management policy, but not in so much detail that excessive amounts of time are wasted on the analysis process itself. Only those failure modes that are reasonably likely to occur in the operating context should be recorded in the RCM analysis. Specifically, the failure mode should be included in the analysis if a failure mode meets one or more of the following criteria:

(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; or

(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 effects should describe the local, next higher-assembly, and end-item effects and must include:

(a) What evidence (if any) that the failure has occurred (in the case of hidden functions, what happens if multiple fails occurred).

(b) What it does (if anything) to kill or injure someone or have an adverse effect on the environment.

(c) What it does (if anything) to have an adverse effect on operations or mission.

(d) What physical damage (if any) is caused by the failure.

(e) What (if anything) must be done to restore the function of the system after failure.

(6) Failure Consequences.

(a) Assessing how the loss of function caused by the failure mode matters will determine the failure consequences; that is, how it affects:

1. Safety (causes injury or death).

2. The environment (causes a breach of an environmental law, regulation, or standard).

3. Mission (adversely affects capability or drives an abort).

4. Economics (does not adversely affect the mission and only involves economic considerations).

(b) Hidden failures are categorized separately from those that are evident to the equipment operators.

(7) Maintenance Tasks and Intervals.

After assessing consequences, the next step is to determine any proactive tasks that if performed would predict, detect potential, prevent, or find failures. A maintenance task is considered applicable 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.

(8) Other Logical Actions.

Other logical actions are sometimes required to manage the consequences of a failure mode. Recommending these one-time actions reduces the consequences of a failure or resolves problems identified during the RCM analysis. Some examples of other logical actions are design changes; changes to training programs, operating procedures, emergency procedures or technical manuals; the collection of additional data; or no scheduled maintenance.

b. Predicting Failure: On-Condition Tasks.

(1) On-condition tasks detect when there are signs of an impending failure and a need for further maintenance. They can be scheduled and performed using numerous inspection techniques, human senses, or sophisticated monitoring equipment. Tasks may also be identified through continuous monitoring by examining data from sensors applied directly to the equipment. In this case, sensor-based data that is processed by a health monitor system (on platform, off platform, or both) may report the current and predicted remaining useful life of a component and be used to initiate the necessary tasks. Examples of on-condition tasks are:

(a) Visual or non-destructive inspection, which detects a potential failure condition (e.g., crack, corrosion).

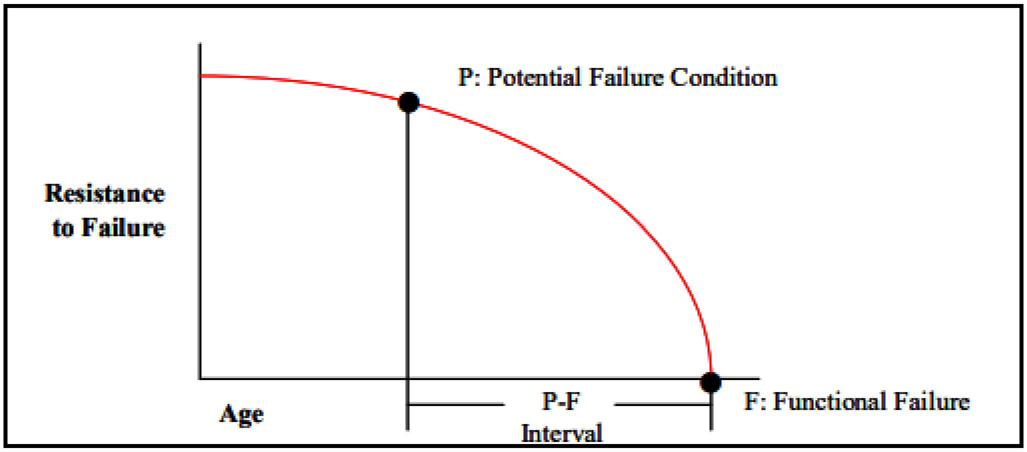
(b) Vibration monitoring and analysis, which detects increased vibration signatures.

(c) Fluid sampling where results indicate wear and contaminants.

(d) Measuring to identify the remaining life of an item (e.g., brake pad thickness).

(2) The purpose of an on-condition task is to identify when a maintenance action is required based on the evidence of need. How often one performs an on-condition task depends on either the potential to functional failure (P-F) interval (see Figure 1) or the predicted remaining useful life calculated by the health management systems.

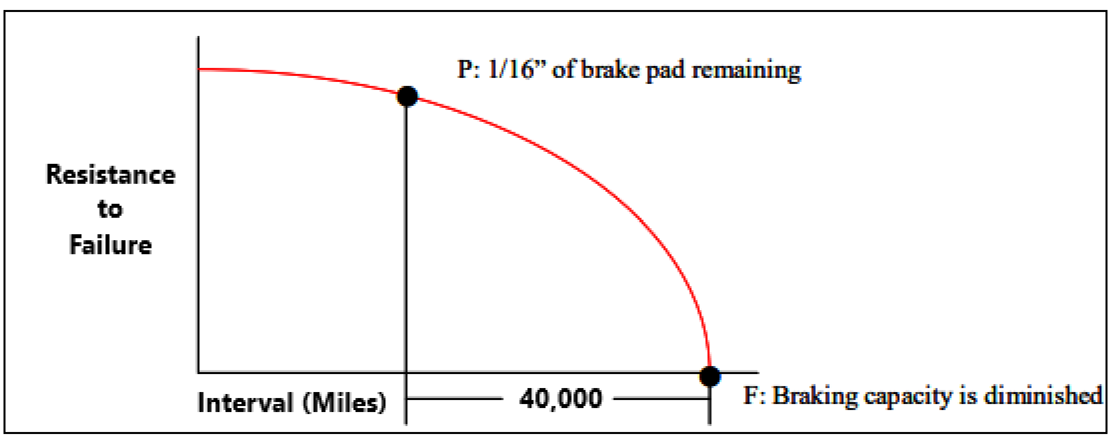
Figure 1. P-F Curve



(3) Figure 1 depicts the P-F Curve. The x-axis indicates the independent variable, measured in any unit (e.g., calendar time, miles, operating hours, or cycles). The y-axis indicates the dependent variable, in this example, resistance to failure. The "P" is the potential failure condition, defined as the evidence of an impending failure. The "F" is the functional failure, as defined by the user.

(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 tasks is that the inspection interval must be 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

depicted as 40,000 miles. In this example, an inspection of the brakes would need to be accomplished at intervals less than the P-F interval (e.g., every 10,000 miles) to detect the potential failure condition before it turns into a functional failure.

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

(7) To be considered applicable, an on-condition task must meet these 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 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:

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

(b) Be cost-effective (for operational or economic consequences).

c. 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 level of 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. Data analytics may further refine scheduled restoration or discard tasks by providing a more comprehensive and accurate estimate of the remaining useful life of a component. For a restoration or discard task to be considered applicable:

(a) It must be possible to identify a useful life. Useful life may reflect the general population of specific components based on calculated use factors.

(b) A sufficiently large proportion of items can survive to this useful life, or the prediction of useful life is sufficiently accurate to reduce the probability of premature failure to a level that is acceptable to the user of the item.

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

(3) For a restoration task to be considered effective, it must:

(a) Reduce the risk of failure to a tolerable level (for safety, environmental, or operation consequences).

(b) Be cost-effective (for operational or economic consequences).

d. Failure Finding Tasks.

A failure-finding task is a scheduled task used to determine whether a specific hidden failure has occurred. For a failure-finding task to be applicable, it must disclose a functional failure that is hidden from the operator during performance of their routine duties. To be effective, it must provide reasonable assurance that the affected function will be available until the next task accomplishment. RCM provides a means to determine whether and how often failure finding tasks (e.g., testing a smoke detector) should be performed.

e. 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, scheduled maintenance tasks, and methodologies for calculating predicted remaining useful life are examples of the data generated.

(a) As the RCM analysis proceeds from start to finish, the data grows in volume and complexity.

(b) When performing RCM analysis, assumptions, decisions, and associated rationale data should be preserved for future reference and the purpose of a well-documented audit trail.

(c) Artificial intelligence techniques, machine learning, modern data analytics, and digital twins should be used as applicable throughout the RCM process.

(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.

(a) After the initial maintenance package has been deployed and used, the Military Services and Defense Agencies should continue to collect relevant data. Ideally, that data is recorded and stored in a database for analysis.

(b) A feedback system from the operators and maintainers provides useful information on how well the strategies are working and provides valuable inputs for sustaining the RCM program.

(c) When feasible, data analytics methods should be used to examine RCM effectiveness.

(3) To operate effectively, the Military Services and Defense Agencies must plan for a robust way to collect, store, organize, and access all this data in phases (before initial RCM, during initial RCM analysis, and throughout RCM sustainment); organize the data to create an effective audit trail and support life-cycle maintenance decision making; and take care to use a robust, expandable, and reliable database.

(a) SAE TA-STD-0017A provides information on specifying the performance of RCM analysis activities.

(b) SAE GEIA-STD-0007C provides information on specifying the organizational structure and neutral exchange of the RCM data requirements resulting from the RCM analysis. This facilitates interoperability between the acquirer and the supplier and mitigates the risk of database vendor lock in.

(c) SAE JA1011 provides evaluation criteria for the RCM process. The standard sets the criteria that any process must comply with in order to be called "RCM."

(d) SAE JA1012 provides a guide to the RCM standard, SAE JA1011. The guide amplifies, and where necessary clarifies, the key concepts and terms, especially those that are unique to RCM.

(e) MIL-STD-3034A provides information on using the RCM process to develop a maintenance program.

(f) MIL-HDBK-502A provides additional information on the relationship between product support analysis, logistics product data, and tailoring RCM analysis and data requirements.

(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 judgement.

(a) 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.

(b) 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.

f. Implementing RCM Results.

(1) After accomplishing the RCM analysis, the resulting outputs must be implemented before the end user can receive any benefit. The actions required for implementing RCM recommendations may take several forms, including:

(a) Developing maintenance tasks.

(b) Redesigning hardware or updating software.

(c) Modifying operating and maintenance processes and procedures.

(d) 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 grouping 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, 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.

3.3. ESTABLISHING AN RCM PROGRAM.

a. Program Management.

An RCM program should be established before beginning any analysis. Often, an RCM program begins by completing a series of pilot projects. These pilot projects allow an organization to see first-hand what RCM offers and what it takes to see an analysis through to implementation, therefore promoting management commitment.

(1) At the simplest level, RCM program management entails establishing and sustaining an RCM program.

(2) Establishing an RCM program requires actions such as:

(a) Defining the scope of analysis.

(b) Establishing the ground rules and assumptions.

(c) Acquiring the work force.

(d) Providing the training.

(e) Securing the funding.

(f) Establishing or defining the data sources.

(g) Implementing the modeling and simulation (M&S) tools.

(3) Sustaining an RCM program requires many of the same actions in Paragraph 3.4., but also includes:

(a) Identifying the need to change.

(b) Measuring success.

(c) Maintaining continual access to necessary data sources.

(d) Reporting on program results.

(4) Effectively managing the stakeholder's expectations, along with forecasting realistic requirements and benefits, is an integral part of any RCM program. Additionally, keeping management informed of resource expenditures and benefits gained will help mitigate losing funding due to lack of information. Likewise, periodically meeting with the customer should help keep expectations in line with reality.

b. Program Management Elements.

(1) Scope of Analysis.

(a) The analysis scope is the extent of the RCM analysis effort to apply to meet program objectives. It includes selecting items or systems for analysis; the indenture level at which analysis of the hardware is to be performed; and the extent to which each item is to be analyzed. The scope of analysis depends on several factors. These include, but are not limited to:

1. The life-cycle phase.

2. The quantity, quality, and validity of any prior analyses.

3. The effectiveness of the current maintenance program.

4. Available resources.

(b) 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, including analyzing high cost or high person-hour drivers, readiness degraders, items with current maintenance tasks, or any combination of these.

(2) Ground Rules and Assumptions.

(a) 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:

1. Description of operating context.

2. Standard operating procedures.

3. Data sources.

4. Analytical methods.

5. Cost-benefit analysis methods.

6. Approaches to specific types of problems.

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

8. Acceptable probabilities of failure, for certain failure modes, based on severity.

9. Any other information that may be required to produce consistent and efficient analyses.

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

(3) Workforce 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 important 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:

(a) RCM Lead.

The 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.

(b) RCM Analyst or Facilitator.

The RCM analyst or facilitator performs and facilitates RCM analyses. A properly trained, unbiased RCM facilitator is critical in guiding the team of subject matter experts, without groupthink, to a consensus in developing the failure mode, effects, and criticality analysis, proactive tasks, and default tasks.

(c) Subject Matter Experts.

Subject matter experts provide expert technical information regarding the asset during the RCM analysis. They may include operators, maintainers, engineers, logisticians, data engineers, data scientists, and the OEM.

(d) Ancillary Support Personnel.

Ancillary support personnel may provide assistance but are not necessarily included in the RCM team composition. They may include:

1. RCM trainers.

2. Information technology personnel.

3. Budgeting personnel.

4. Contracts personnel.

(4) Training and Certification.

RCM team members must be properly trained according to their level of responsibility within the RCM program and should have at least a basic knowledge of RCM principles.

(a) The basic knowledge can be acquired by completion of the DAU LOG 0300 RCM online course (see Appendix 3A for RCM training resources). Analysts and facilitators should complete additional training courses that provide instructions on how to conduct RCM analyses.

(b) In addition to classroom training, all analysts and facilitators must complete a period of mentoring to demonstrate the transformation of their theoretical knowledge to the practical skills required to produce safe and technically defensible RCM analyses.

(c) RCM trainers should be certified analysts or facilitators with adequate experience conducting RCM analysis. They should receive additional classroom instruction and mentoring.

(5) Funding Requirements.

RCM is a requirement for DoD materiel maintenance, so the PM must plan to include RCM within the program budget. Funding requirements for implementing an RCM program include initial implementation and sustainment. The PM:

(a) Is responsible for submitting and defending the RCM requirements and potential benefits during the budget process. It is essential that all RCM funding justifications identify any potential benefit (e.g., improved safety, reduce maintenance burden, increase availability) or return on investment.

(b) Should develop an incremental RCM rollout strategy that allows the program office to take advantage of partial funding, as well as funding that may become available at the end of the fiscal year.

(6) Data Sources.

(a) A good deal of data and information is required to perform RCM analyses.

1. Varying bodies of information that may be used include maintenance data systems, health monitoring 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.

2. Quite frequently, RCM analysis occurs with input from subject matter experts intimate with the equipment and the operating context. Input from these experts populates gaps in historical data with information based on actual experience.

(b) Data that is not available from existing sources may be required. In such cases, establishing 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 necessary to collect the specific information required.

(7) M&S.

(a) 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 systems operations knowledge. In implementing RCM at fielding, M&S can be used extensively to trigger analysis of failure modes. During the sustainment phase, M&S can continue to aid in analyzing systems in new operating scenarios.

(b) The models used during the design phase of the system need to be kept current. This means models should:

1. Be updated regularly to reflect engineering changes to the system through the engineering change proposal process.

2. Be updated to reflect advances in modeling technology and software compatibility.

3.4. SUSTAINING AN RCM PROGRAM.

For full realization of RCM benefits, the analysis must be periodically reviewed and updated to capture changes in the operating contexts and conditions. RCM sustainment is achieved by establishing a program that provides for frequently or continuously monitoring the performance of the maintenance program and, when needed, a 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 the equipment's program planning, budgeting, and execution documentation.

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 revision 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. The monitoring efforts should include mechanisms to:

(a) Identify and monitor appropriate performance metrics.

(b) Monitor scheduled maintenance compliance.

(c) Monitor the effectiveness of maintenance tasks.

(d) Identify adverse failure trends.

(e) Update existing failure modes.

(f) Identify emergent failure modes.

(g) Identify top degraders and cost drivers.

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

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

(2) 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 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. Regardless of the type of metrics used, it is important that a baseline data set be established. This baseline is used to measure results and support trend analysis.

(a) Business metrics measure direct and indirect cost associated with implementing and sustaining an RCM program and reflect the cost and benefits of the program to the resource provider, user, and customer. The goal in calculating business metrics is return on investment in terms of cost benefit.

1. Business metrics for implementing an RCM program may be divided into the initial analysis effort and the sustaining effort.

2. RCM sustainment, which provides for continuously or frequently monitoring maintenance program performance, will often yield cost benefits in terms of eliminating unnecessary maintenance tasks and reducing maintenance person-hours, repair parts, and logistics support.

(b) Program management metrics are geared toward reporting the program's progress and health. These metrics use data elements such as:

1. Compliance and effectiveness of the maintenance tasks.

2. Number of personnel.

3. Number of work years.

4. Training received and provided.

5. Schedules.

6. Number of systems or subsystems analyzed, and the number of systems and subsystems still requiring analysis.

(c) Technical metrics measure specific behavior associated with equipment. These may include failure rates, mean time between failures, readiness or availability, servicing actions, maintenance person-hours, elapsed maintenance time, and proactive maintenance tasks or maintenance time. Validation of algorithms and processes used in developing predictive maintenance tasks must also be accomplished.

c. Accessing Data.

RCM program sustainment 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 models are also appropriate sources of data.

d. Reporting Requirements.

DoDD 4151.18 requires that maintenance programs:

(1) Facilitate, collect, and analyze maintenance-related reliability data.

(2) Include sufficient analytic capability for identifying needed adjustments based on operating experience; materiel condition; requirements for reliability, maintainability, and supportability modifications; and changes to training curricula or delivery methods.

(3) Provide maintenance activities with the means for assessing information generated by diagnostic and prognostic capabilities and for taking appropriate maintenance actions.

(4) Establish and evaluate performance metrics that promote continuous improvement in maintenance, ensuring responsiveness and best value to operating forces.

3.5. CONSIDERATIONS.

a. The most effective maintenance programs are changing and improving regularly to make ever better use of resources the longer they are in operation. They regularly test and explore the boundaries of maintenance, obtaining increasing knowledge of the maintained items as they proceed, while accepting unexpected failures as the price of progress.

b. Not all improvement initiatives have the same potential payoff leverage. Maintenance managers should:

(1) Seek opportunities to obtain the greatest advantage.

(2) Know that not all data have the same value, structures data collection, analysis, and display capabilities to give the most necessary information for continuing to make improvement while operating safely and reliably.

c. Regardless of the merit of specific improvement actions taken by individual maintenance managers, the message for all maintenance managers is to ensure continuous maintenance improvement. The ongoing process of developing, implementing, and following up on the results of an improvement is essential.

APPENDIX 3A: RCM TRAINING RESOURCES

3A.1. DAU.

LOG 300 RCM (2 hours; DAU online training course)

3A.2. ARMY.

a. Army RCM Facilitator Training (2 weeks; U.S. Army Aviation and Missile Command)

b. Army RCM for the Warfighter (2 days; U.S. Army Aviation and Missile Command)

c. Army RCM Overview for Management (1.5 hours; U.S. Army Aviation and Missile Command)

3A.3. AIR FORCE.

Logistics 032: RCM for In-Service Engines (1 day; Air Force Institute of Technology)

3A.4. NAVY.

a. Reliability-Centered Maintenance Program and Process for Non-practitioners (3 hours; Naval Air Systems Command)

b. Reliability-Centered Maintenance – Basic for Practitioners (3 days; Naval Air Systems Command)

c. Reliability-Centered Maintenance – Intermediate for Practitioners (3 days; Naval Air Systems Command)

d. Reliability-Centered Maintenance – Advanced for Practitioners (2 days; Naval Air Systems Command)

e. Classic RCM for Maintenance Requirements Developers certification course (5 days; Naval Sea Systems Command)

f. Backfit RCM certification course (2 days; Naval Sea Systems Command)

3A.5. MARINE CORPS.

Maintenance Planning and Management 202: Relationship Between CBM+ and RCM familiarization course (4 hours; Marine Corps Systems Command, Acquisition Logistics and Product Support)

GLOSSARY

G.1. ACRONYMS.

ACRONYM	MEANING
CBM+	condition-based maintenance plus
CDRL	contract data requirements list
DAU	Defense Acquisition University
DID	data item description
DoDD	DoD directive
DoDI	DoD instruction
M&S	modeling and simulation
OEM	original equipment manufacturer
PBL	performance-based logistics
P-F	potential to functional failure
PM	program manager
RCM	reliability-centered maintenance

G.2. DEFINITIONS.

These terms and their definitions are for the purpose of this issuance.

TERM	DEFINITION
age exploration	A process used to collect specific data to replace estimated or assumed values that were used during a previous RCM analysis.
applicable task	A maintenance or action task that detects a potential failure, prevents a functional failure, or discovers a hidden functional failure.

TERM	**DEFINITION**
CBM+	A collaborative DoD readiness initiative focused on the development and implementation of data analysis and sustainment technology capabilities to improve weapon system availability and achieve optimum costs across the enterprise. CBM+ is 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 based on evidence of need. CBM+ is built upon RCM and condition-based maintenance to enhance safety, increase maintenance efficiency, improve availability, and ensure environmental integrity. CBM+ diminishes life-cycle costs by reducing unscheduled maintenance and enabling predictive maintenance. CBM+ turns rich data into information about component, weapon system, and fleet conditions to more accurately forecast maintenance requirements and future weapon system readiness to drive process cost efficiencies and enterprise activity outcomes.
digital twin	An integrated multi-physics, multiscale, probabilistic simulation of an as-built system, enabled by digital thread, that uses the best available models, sensor information, and input data to mirror and predict activities and performance over the life of its corresponding physical twin.
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 failure.
failure finding task	A test or inspection to identify a functional failure that is not evident to the operating crew during the performance of normal duties.
failure management strategies	Proactive maintenance or other logical actions (e.g., 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 failure mode describes what specifically causes the item to fail or perform below an acceptable level.

TERM	DEFINITION
function	The desired capability of the system, how well it must perform, and under what circumstances.
functional failure	A state in which a physical asset or system is unable to perform a specific function to a desired level of performance.
maintenance task and intervals	The description of the applicable and effective tasks, if any, performed to predict, prevent, or find failures. Interval is the measured frequency the maintenance task must be performed (e.g., miles, hours, rounds, cycles).
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 equipment while it is 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 to operating procedures or technical manuals.
P-F interval	The time or period between when a potential failure condition can be detected, and functional failure occurs.
PBL	Synonymous with performance-based product support, where outcomes are acquired through performance-based arrangements that deliver warfighter requirements and incentivize product support providers to reduce costs through innovation. These arrangements are contracts with industry or inter-governmental agreements. Sources of support may be organic, commercial, or a combination, with primary focus optimizing customer support, weapon system availability, and reduced ownership costs.

TERM	DEFINITION
potential failure condition	Evidence of an impending failure (e.g., vibration, fatigue cracks, increased vibration levels).
predictive maintenance task	A maintenance task triggered by a capability or process using data to predict the remaining useful life of a line replaceable unit or component.
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.
product support arrangement	A contract, task order, or any other type of contractual arrangement, or any type of agreement or non-contractual arrangement with or within the Federal Government, for the performance of sustainment or logistics support required for major weapon systems, subsystems, or components. The term includes arrangements for PBL, sustainment support, contractor logistics support, life cycle product support, or weapon systems product support.
RCM	A logical structured process for determining maintenance requirements based on the analysis of the likely functional failures of components, equipment, subsystems, or systems having a significant impact on safety, operations, and life-cycle cost. RCM supports the failure-management strategy for any component, equipment, subsystem, or system based on its inherent reliability and operating context.
reactive maintenance	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.

TERM	**DEFINITION**
systems engineering	An interdisciplinary approach and process encompassing the entire technical effort to evolve, verify, and sustain an integrated and total life cycle balanced set of system, people, and process solutions that satisfy customer needs. Systems engineering is the integrating mechanism for the technical and technical management efforts related to the concept analysis, materiel solution analysis, engineering and manufacturing development, production and deployment, operations and support, disposal of, and user training for systems and their life cycle processes.

REFERENCES

Deputy Under Secretary of Defense for Acquisition and Sustainment, "Condition-Based Maintenance Plus DoD Guidebook," May 2008

DoD Directive 4151.18, "Maintenance of Military Materiel," March 31, 2004, as amended

DoD Directive 5135.02, "Under Secretary of Defense for Acquisition and Sustainment," July 15, 2020

DoD Instruction 4151.22, "Condition-Based Maintenance Plus for Materiel Maintenance," August 14, 2020

DoD Instruction 5000.02, "Operation of the Adaptive Acquisition Framework," January 23, 2020, as amended

DoD Instruction 5000.91, "Product Support Management for the Adaptive Acquisition Framework," November 4, 2021

Military Handbook MIL-HDBK-502A, "Product Support Analysis Handbook," March 18, 2013

Military Standard MIL-STD- 3034A, "Reliability-Centered Maintenance (RCM) Process," April 29, 2014

Society of Automotive Engineers GEIA-STD-0007C, "Logistics Product Data," November 6, 2019

Society of Automotive Engineers JA1011, "Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes," August 1, 2009

Society of Automotive Engineers JA1020, "A Guide to the Reliability-Centered Maintenance (RCM) Standard," August 1, 2011

Society of Automotive Engineers TA-STD-0017A, "Product Support Analysis," March 1, 2022