SURFACE VEHICLE/AEROSPACE STANDARD	JA1011™	NOV2024
	Issued 1999-08 Revised 2024-11 Superseding JA1011 AUG2009	

(R) Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes

RATIONALE

When complex systems are initially fielded, operators need to know what maintenance strategy will best address each potential failure. Because of the significant safety and cost implications of using a poor maintenance strategy, the aerospace industry developed a systematic analysis methodology called reliability-centered maintenance (RCM). The RCM analysis process guides the process user through the review and categorization of all failures and directs them to the appropriate maintenance actions to best address each of those failures based on the nature and characteristics of the failure. However, as more industries began to implement RCM, many elements of what users were calling RCM started to deviate from the original process described in the original RCM report by Nowlan and Heap. This divergence in how RCM was being defined and performed led to disagreements and confusion regarding what constitutes an RCM analysis.

This Joint Standard describes the minimum criteria that any process must comply with to be called RCM. Since this standard does not define a specific RCM process, SAE Surface Vehicle/Aerospace Recommended Practice JA1012 was published as a companion to this standard as an implementation guide for the user.

This revision incorporates minor corrections and clarifications for issues that have been identified over the last few years in the use of this document. It also corrects several inconsistencies with SAE JA1012.

FOREWORD

RCM was initially developed by the commercial aviation industry to improve the safety and reliability of its equipment. It was first documented in a report written by Nowlan and Heap (1978). Since then, RCM has been used to help formulate physical asset management strategies in almost every area of organized human endeavor, and in almost every industrialized country in the world. The process defined by Nowlan and Heap (1978) served as the basis of various application documents in which the RCM process has been developed and refined over the ensuing years. Most of these documents retain the key elements of the original process. However, the widespread use of the term “RCM” has led to the emergence of a number of processes that differ significantly from the original process. As a result, there has been a growing international demand for a standard that sets out the criteria that any process must comply with in order to be called “RCM.” This SAE Standard meets that need.

The criteria in this SAE Standard are based primarily upon the RCM process and concepts established in Nowlan and Heap (1978). Additionally, three other documents that closely followed the original tenets of Nowlan and Heap (1978), (1) MIL-STD-2173, (2) NES 45, and (3) Moubray (1997), were used extensively as sources for this SAE Standard.

This SAE Standard describes the minimum criteria that any process must possess to be deemed a compliant RCM process. It does not attempt to define a specific RCM process.

This SAE Standard is intended to provide a means for evaluating whether a given process remains true to the tenets of RCM as it was originally conceived. It is especially useful to people who wish to purchase RCM services (training, analysis, facilitation, consulting, or any combination thereof).

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1. SCOPE

This SAE Standard for reliability-centered maintenance (RCM) is intended for use by any organization that has or makes use of physical assets or systems that it wishes to manage responsibly.

1.1 Purpose

RCM is a specific process used to identify the policies which must be implemented to manage the failure modes which could cause the functional failure of any physical asset or system in a given operational context. This SAE Standard is intended to be used to evaluate any process that purports to be an RCM process, in order to determine whether it follows the original tenets of RCM as defined by Nowlan and Heap (1978). This SAE Standard supports such an evaluation by specifying the minimum criteria that a process must have in order to be an RCM process.

2. REFERENCES

2.1 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE JA1012 A Guide to the Reliability-Centered Maintenance (RCM) Standard

2.1.2 NAVAIR Publications

Available from Naval Air Warfare Center - Aircraft Division (Code AB43300), 48298 Shaw Rd., Building 1461, Patuxent River, MD 20670-1900.

NAVAIR 00-25-403 Guidelines for the Naval Aviation Reliability-Centered Maintenance Process

2.1.3 U.S. Government Publications

Copies of these documents are available online at https://quicksearch.dla.mil.

MIL-HDBK-2173 Reliability-Centered Maintenance Requirements for Naval Aircraft, Weapons Systems and Support Equipment

MIL-P-24534 Planned Maintenance System: Development of Maintenance Requirement Cards, Maintenance Index Pages, and Associated Documentation

MIL-STD-1629 Procedures for Performing a Failure Mode, Effects and Criticality Analysis

MIL-STD-1843 Reliability Centered Maintenance for Aircraft, Engines, and Equipment

2.1.4 UK Ministry of Defence Publications

Available from Reliability-Centred Maintenance Implementation Team, Ships Support Agency, Ministry of Defence (Navy), Room 22, Block K, Foxhill, Bath, BA1 5AB, United Kingdom.

NES 45 Naval Engineering Standard 45, Requirements for the Application of Reliability-Centred Maintenance Techniques to HM Ships, Royal Fleet Auxiliaries and other Naval Auxiliary Vessels

2.1.5 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 60300-3-11:2009 Dependability management - Part 3-11: Application guide - Reliability centered maintenance

2.1.6 A4A Publications

Available from Airlines for America, 1301 Pennsylvania Avenue, NW, Suite 1100, Washington, DC 20004, Tel: 202-626-4000, www.airlines.org.

MSG-3 Operator/Manufacturer Scheduled Maintenance Development, Volume 1 - Fixed Wing Aircraft

2.1.7 Other Publications

Anderson, R.T. and Neri, L. (1990). *Reliability-centered maintenance: Management and engineering methods*. Elsevier Science Publishers, Ltd.

Blanchard, B.S., Verma, D.C., and Peterson, E.L. (1995). *Maintainability: A key to effective serviceability and maintenance management*. John Wiley & Sons, Inc.

Jones, R.B. (1995). *Risk-based management: A reliability-centered approach.* Gulf Publishing Company.

Moubray, J. (1997). *Reliability-centered maintenance.* Industrial Press.

NAVSEA. (1983). *Reliability-centered maintenance handbook* (Report no. S9081-AB-GIB-101/Maint). Naval Sea Systems Command.

Nowlan, F.S. and Heap, H.F. (1978). *Reliability-centered maintenance* (Report no. AD-A066-579). U.S. Department of Commerce. Available from DEFENSE TECHNICAL INFORMATION CENTER, 8725 John J. Kingman Road, Fort Belvoir, Virginia 22060-6218, (800) 225-3842, https://apps.dtic.mil/sti/citations/ADA066579.

Smith, A.M. (1993). *Reliability-centered maintenance*. McGraw-Hill.

Zwingelstein, G. (1996). *Reliability-centered maintenance: A practical guide for implementation*. Hermès.

3. DEFINITIONS

3.1 AGE

A measure of exposure to stress computed from the moment an item enters service or first begins to degrade, either from new or reentering service after a task designed to restore its initial capability. Age can be measured in terms of calendar time, but also by appropriate usage measures such as operating time, distance traveled, duty cycles, or units of output or throughput.

3.2 APPLICABLE TASK

A task that is capable of preventing or mitigating the consequences of failure based on the technical characteristics of that failure.

3.3 ASSET

Equipment, inventory, or properties owned by an organization that provides value to that organization and requires maintenance to retain its value.

3.4 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.

3.5 DESIRED PERFORMANCE

The level of performance desired by the owner or user of a physical asset or system.

3.6 EFFECTIVE TASK

A task that reduces the probability or consequences of failure to an acceptable level and is feasible to perform.

3.7 ECONOMIC CONSEQUENCES

A classification assigned to failure modes, or multiple failures in the case of hidden failure modes, that do not adversely affect safety, the environment, or operations, but increase cost from repair or from lost or degraded operations or both.

3.8 ENVIRONMENTAL CONSEQUENCES

A classification assigned to failure modes, or multiple failures in the case of hidden failure modes, that could result in a breach of any industry or government environmental standard or regulation.

3.9 EVIDENT FAILURE

A failure mode whose effects become apparent to the operator(s) under normal circumstances if the failure mode occurs on its own.

3.10 EVIDENT FUNCTION

A function whose failure on its own becomes apparent to the operator(s) under normal circumstances.

3.11 FAILURE CONSEQUENCES

A classification of the failure effects of failure modes into categories based on evidence of failure, impact on safety, the environment, operational capability, and cost.

3.12 FAILURE EFFECT

What happens when a failure mode occurs.

3.13 FAILURE MANAGEMENT POLICY

A generic term that encompasses on-condition tasks, scheduled restoration, scheduled discard, failure-finding, run-to-failure, and one-time changes.

3.14 FAILURE MODE

A single event, which causes a functional failure.

3.15 FUNCTION

What the owner or user of a physical asset or system wants it to do.

3.16 FUNCTIONAL FAILURE

A state in which a physical asset or system is unable to perform a specific function to a desired level of performance.

3.17 HIDDEN FAILURE

A failure mode whose effects do not become evident to the operator(s) under normal circumstances if the failure mode occurs on its own.

3.18 HIDDEN FUNCTION

A function whose failure on its own does not become evident to the operator(s) under normal circumstances.

3.19 INITIAL CAPABILITY

The level of performance that a physical asset or system is capable of achieving at the moment it enters service.

3.20 MAINTAINER

A person or organization that may either suffer or be held accountable for the consequences of a functional failure or multiple failure by virtue of performing maintenance functions on behalf of the user and/or owner of the asset or system.

3.21 MULTIPLE FAILURE

An event that occurs if a protected function fails while its protective device or protective system is in a failed state.

3.22 NON-OPERATIONAL CONSEQUENCES

A classification assigned to failure modes that do not adversely affect safety, the environment, or operations, but only require repair or replacement of any item(s) that may be affected by the failure.

3.23 ONE-TIME CHANGE

Any action taken to change the physical configuration of an asset or system (redesign or modification), to change the method used by an operator or maintainer to perform a specific task, to change the operational context of the system, or to change the capability of an operator or maintainer (training).

3.24 OPERATING CONTEXT

The circumstances in which a physical asset or system is expected to operate, including how, where, and when it is to be used, and overall performance criteria governing issues such as output, throughput, safety, environmental integrity, etc.

3.25 OPERATIONAL CONSEQUENCES

A classification assigned to failure modes that adversely affect the operational capability of a physical asset or system (output, product quality, customer service, military capability, or operating costs, in addition to the cost of repair).

3.26 OWNER

A person or organization that may either suffer or be held accountable for the consequences of a functional failure or multiple failure of an asset or system by virtue of ownership of that asset or system.

3.27 P-F INTERVAL

The period between the point at which a potential failure becomes detectable and the point at which it degrades into a functional failure.

3.28 POTENTIAL FAILURE

An identifiable condition that indicates that a functional failure is either about to occur or is in the process of occurring.

3.29 PROTECTIVE DEVICE OR PROTECTIVE SYSTEM

A device or system which is intended to avoid, eliminate, or minimize the consequences of failure of some other system.

3.30 PRIMARY FUNCTION(S)

The function(s) which constitute the main reason(s) why a physical asset or system is acquired by its owner or user.

3.31 RUN-TO-FAILURE

A failure management policy that permits a specific failure mode to occur without any attempt to anticipate, mitigate, or prevent it.

3.32 SAFETY CONSEQUENCES

A classification of failure modes that could injure or kill a human being.

3.33 SECONDARY FUNCTIONS

Functions which a physical asset or system has to fulfill in addition to its primary function(s), such as those needed to fulfill regulatory requirements and those which concern issues such as protection, control, containment, comfort, appearance, energy efficiency, and structural integrity.

3.34 SYSTEM

A collection or group of one or more physical assets (see asset).

3.35 TASK

A specific set of actions performed to prevent, mitigate, or correct the occurrence of failure or other unacceptable condition.

3.35.1 FAILURE-FINDING TASK

A scheduled task used to determine whether a specific hidden failure has occurred.

3.35.2 ON-CONDITION TASK

A periodic or continuous task used to detect a potential failure.

3.35.3 SCHEDULED TASK

Maintenance tasks performed at fixed, predetermined intervals, or through the use of “continuous monitoring” (where the interval is effectively zero) to prevent or mitigate the consequences of failure or multiple failure.

3.35.3.1 SCHEDULED DISCARD

A scheduled task that entails replacing an item at or before a specified age limit regardless of its condition at the time.

3.35.3.2 SCHEDULED RESTORATION

A scheduled task that restores the capability of an item at or before a specified interval (age limit), regardless of its condition at the time, to a level that provides an acceptable probability of survival to the end of another specified interval.

3.36 USER

A person or organization that operates and/or maintains an asset or system or may either suffer from or be held accountable for the consequences of a failure of that asset or system.

4. ABBREVIATIONS

RCM reliability-centered maintenance

5. RELIABILITY-CENTERED MAINTENANCE (RCM)

Any RCM process shall ensure that all of the following steps are performed in the sequence shown:

a. Determine the operational context and the functions and associated desired standards of performance of the asset (operational context and functions).

b. Determine how an asset can fail to fulfill its functions (functional failures).

c. Determine the causes of each functional failure (failure modes).

d. Determine what happens when each failure occurs (failure effects).

e. Classify the consequences of failure (failure consequences).

f. Determine what should be performed to predict or prevent each failure (tasks and task intervals).

g. Determine if other failure management strategies may be more effective (one-time changes).

To perform these steps “satisfactorily,” the following information shall be gathered, and the following decisions shall be made. All information and decisions shall be documented in a way which makes the information and the decisions fully available to and acceptable to the owner or user of the asset.

5.1 Operational Context and Functions

5.1.1 The operational context of the asset shall be defined, recorded, and available.

5.1.2 All the primary and secondary functions of the asset/system shall be identified.

5.1.3 All function statements shall contain a verb, an object, and a performance standard (quantified in every case where this can be done).

5.1.4 Performance standards incorporated in function statements shall be the level of performance desired by the owner or user of the asset/system in its operational context (as opposed to the design capability).

5.2 Functional Failures

5.2.1 All the failed states associated with each function shall be identified.

5.3 Failure Modes

5.3.1 All failure modes reasonably likely to cause each functional failure shall be identified.

5.3.2 The method used to decide what constitutes a “reasonably likely” failure mode shall be acceptable to the owner or user of the asset.

5.3.3 Failure modes shall be identified at a level of causation that makes it possible to identify an appropriate failure management policy. Failure modes should be addressed at the same level of detail that the asset or system will be maintained. Failure modes that can occur within a component of the asset or system that cannot or will not be addressed individually (because the component is the lowest level at which the system will be repaired and maintained) do not need to be enumerated. However, if the component will be disassembled to address specific internal failure modes, then those failure modes do need to be itemized.

5.3.4 Lists of failure modes shall include failure modes that have happened before, failure modes that are currently being prevented by existing maintenance programs, and failure modes that have not yet happened but that are thought to be reasonably likely in the operational context.

5.3.5 Lists of failure modes should include any event or process that is likely to cause a functional failure (including design defects and human error whether caused by operators or maintainers) unless these events are being sufficiently addressed by processes apart from RCM.

5.4 Failure Effects

5.4.1 Failure effects shall describe what would happen assuming the failure mode and corresponding functional failure actually occurs.

5.4.2 Failure effects shall include all the information needed to support the evaluation of the consequences of the failure, such as:

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

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

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

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

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

5.4.2.6 What (if any) compensating provisions are available.

5.5 Failure Consequence Categories

5.5.1 The consequences of every failure mode shall be formally categorized as follows:

5.5.1.1 The consequence categorization process shall separate hidden failure modes from evident failure modes.

5.5.1.2 The consequence categorization process shall clearly distinguish events (failure modes and multiple failures) that have safety and/or environmental consequences from those that only have economic and/or operational consequences.

5.5.2 The assessment of failure consequences shall be carried out as if no specific task is currently being done to anticipate, prevent, or detect the failure.

5.6 Failure Management Strategy Selection

5.6.1 The failure management strategy selection process shall take account of the fact that the conditional probability of some failure modes occurring will increase with age (or exposure to stress), that the conditional probability of others will not change with age, and the conditional probability of yet others will decrease with age.