NAVAIR Reliability Centered Maintenance
Compliance with SAE JA1011

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Abstract

Background.

The intent of this document is to demonstrate that the RCM process provided in NAVAIR 00-25-403 is compliant with SAE JA1011. It should be noted that several of the authors of SAE JA1011 were NAVAIRSYSCOM employees at the time and were also authors of NAVAIR 00-25-403. It was their intent to create a document that would allow the use of the NAVAIR 00-25-403 process in contract solicitations via the reference of commercial standard. It should therefore be evident that the authors would not have created a document that contradicted their own.

To illustrate the connection with NAVAIR 00-25-403, the following is quoted directly from SAE JA1011 (page 1): "The criteria in this SAE Standard are based upon the RCM processes and concepts in three RCM documents: (1) Nowlan and Heaps 1978 book, *Reliability-Centered Maintenance*, US Naval Aviation's MIL-STD-2173(AS) *Reliability-Centered Maintenance Requirements of Naval Aircraft, Weapons Systems and Support Equipment* and its successor, US Naval Air Systems Command Management Manual 00-25-403 *Guidelines for the Naval Aviation Reliability-Centered Maintenance Process*, and (3) *Reliability-Centered Maintenance (RCM II)* by John Moubray. These documents are widely-used RCM documents available."

While the above statements illustrate that a general assumption could be made that the NAVAIR 00-25-403 process is compliant with SAE JA1011 based on association and intent, the remainder of this document will demonstrate line by line and conclusively that this is the case. It is the authors' hope that this document may dispel all sources of doubt and rumor that have plagued the RCM community as this set of tools have undergone the transition from an aviation industry development to becoming a standard commercial practice.

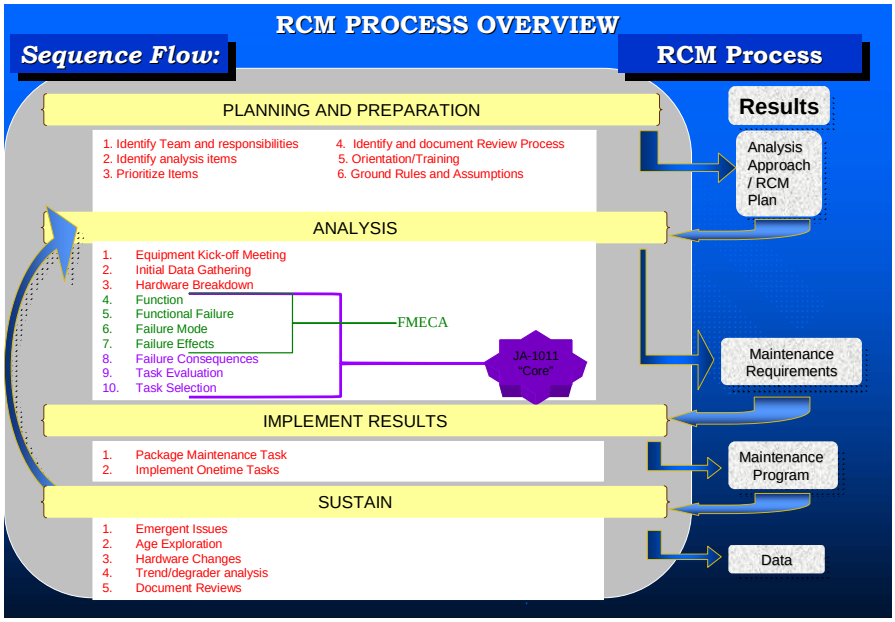
Discussion

I. SAE JA1011 General RCM Process Requirements:

The requirements for a process to be called RCM are provided in section 5 of SAE JA1011. The requirements are summarized at the beginning of the section as follows:

> "5**. Reliability-Centered Maintenance (RCM)** - Any RCM process shall ensure that all of the seven questions are answered satisfactorily and are answered in the sequence shown as follows:
> a. What are the functions and associated desired standards of performance of the asset in its present operating context (functions)?
> b. In what ways can it fail to fulfill its functions (functional failures)?
> c. What causes each functional failure (failure modes)?
> d. What happens when each failure occurs (failure effects)?
> e. In what way does each failure matter (failure consequences)?
> f. What should be done to predict or prevent each functional failure (proactive tasks and task intervals)?
> g. What should be done if a suitable proactive task cannot be found (default actions)?
>
> To answer each of the previous questions "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 of the asset." (SAE JA1011, page 6)

The following illustration, from the training material for NAVAIR 00-25-403 process, shows that the basic steps and sequence outlined above are included in the NAVAIR 00-25-403 RCM process:



(*Fundamentals of RCM Analysis*. page II.1.5.)

II. Specific RCM Process Step Requirements:

The remainder of section 5 of SAE JA1011 addresses specifics for each of these seven basic questions. The table in the following pages contains the remaining text of SAE JA1011 section 5, and provides, point by point, the NAVAIR 00-25-403 or training manual text of identical meaning.

5.1 Functions	
SAE JA1011	**NAVAIR 00-25-403 & Training Manual**
5.1.1 The operating context of the asset shall be defined.	"The FMECA is a process used to identify and document the functions, functional failures, failure modes and failure effects of an item. It is essential that the mission or usage phases and profiles be described in the RCM Plan so that the FMECA is developed based on a well-defined operational context. It may be that some functions, failures or effects only occur, or occur in a different manner, in certain operational scenarios. The FMECA should clearly indicate when functions, failure modes or effects are dependent on specific circumstances, environments, or mission phases." (NAVAIR 00-25-403, Section 3.2).
5.1.2 All the functions of the asset/system shall be identified (all primary and secondary functions, including the functions of all protective devices). 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 operating context.	"A function is the intended purpose of an item as described by a required standard of performance. It is not necessarily what the item is capable of doing, as shown in the example below. A complete function description should include any specific performance limits (upper and/or lower bounds). Although most equipment is designed to perform a specific or single function, many systems may perform multiple functions or have secondary functions. Some functions are "demand" driven, such as an ejection seat, while others operate continuously. Care must be taken to ensure functions are not overlooked, and that the function statement is clear, including any operating context notations." (NAVAIR 00-25-403, Section 3.2.1).

5.2 Functional failures	
SAE JA1011	**NAVAIR 00-25-403 & Training Manual**
5.2 Functional failures— All the failed states associated with each function shall be identified.	"A functional failure is defined as the inability of an item to perform a specific function within the specified limits. A functional failure may not necessarily be a complete loss of the function. Proper functional failure descriptions are based on the function description. Functional failures will likely result in either reduced performance or total loss of the system. Separate functional failures should be listed where the effects of less than total loss of the function are different from total loss." (NAVAIR 00-25-403, Section 3.2.2).

5.3 Failure modes	
SAE JA1011	**NAVAIR 00-25-403 & Training Manual**
5.3.1 All failure modes reasonably likely to cause each functional failure shall be identified.	"A failure mode is a specific physical condition that can result in a functional failure. The failure mode statement should include a description of the failure mechanism (e.g., fatigue) whenever possible. Many failure modes could be listed, but only failure modes that are "reasonable" should be identified." (NAVAIR 00-25-403, Section 3.2.4)
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.	"The RCM program plan's Ground Rules and Assumptions section will define 'reasonable'." (NAVAIR 00-25-403, Section 3.2.4)
5.3.3 Failure modes shall be identified at a level of causation that makes it possible to identify an appropriate failure management policy.	"Careful consideration is required to choose a level of analysis that will identify a manageable number of functions and failure modes. An analysis performed at too high a level will likely become overwhelming as the relationship between functions at the high level and the many failure modes become complicated. As the effort advances from a high level to progressively lower levels, the number of functions and related failure modes identified will multiply. This eventually will have a stifling effect on the analysis. The target level will normally be a level consistent with the likely level of "on-equipment" maintenance." (NAVAIR 00-25-403, Section 2.4.3) "Refinement of the failure modes and their descriptions may be required as the analysis proceeds. The analyst can choose to add more failure modes or expound on their descriptions, as necessary, to facilitate the identification of specific inspection and failure detection methods. This could be done, for example, when applying the analysis process to PHM. Care should be taken, however, that this is done only when required; otherwise, the analysis could experience unnecessary cost and delay." (NAVAIR 00-25-403, Section 3.2.4)

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 (credible) in the operating context.	"List all failure modes that are 'reasonable'". (Fundamentals of RCM Analysis. page II.4.24. Copyright 2002, Information Spectrum, Inc. All Rights Reserved)Failure mode sources:• Existing PM Tasks • Operating/Maintenance Manuals• Operator/Maintainer Input• Prior FMECA, RCM or other analyses• Failure Databases (Age Exploration)• Engineer/SME input• 3M/CMMS data***(Fundamentals of RCM Analysis. page II.4.25. Copyright 2002, Information Spectrum, Inc. All Rights Reserved)
	"The data available for identifying failure modes will vary depending on whether or not the item has an existing service history. Failure modes for items with an existing service history are determined mainly from operators and maintainers and failure data that have been collected. Descriptive failure data sources such as test reports, engineering investigation reports, hazardous material reports, and depot estimator and evaluator write-ups are useful for determining the failure modes of an item. A review of Maintenance and Material Management (3-M) data is useful to a lesser degree for identifying specific failure modes since, by design, the data is less descriptive. However, 3-M data may be used to identify the types of failure modes seen in-service such as cracks, wear, etc. It can be used as a check to support the notion that the failure modes, which were identified from other sources, are complete. Maintainers and operators who have first hand experience with the equipment serve as another very useful source of specific failure data.

	Failure mode identification on new designs is more difficult. Failure modes have to be inferred from knowledge of the hardware design, general knowledge of how things fail, and experience with similar equipment in similar applications. Data sources will include technical data (publications, drawings) and failure data sources mentioned above for similar equipment in similar usage. The context in which the equipment is operated should be carefully considered when determining the applicability of generic reliability data. Furthermore, data covering the results of fatigue, reliability, developmental, and qualification testing are useful for items with or without a service history." (NAVAIR 00-25-403, Section 3.2.4)
5.3.5 Lists of failure modes should include any event or process that is likely to cause a functional failure, including deterioration, design defects, and human error whether caused by operators or maintainers (unless human error is being actively addressed by analytical processes apart from RCM).	"A failure mode is a specific physical condition that can result in a functional failure. The failure mode statement should include a description of the failure mechanism (e.g., fatigue) whenever possible. Many failure modes could be listed, but only failure modes that are "reasonable" should be identified. The RCM program plan's Ground Rules and Assumptions section will define "reasonable." (NAVAIR 00-25-403, Section 3.2.4)

5.4 Failure Effects	
SAE JA1011	**NAVAIR 00-25-403 & Training Manual**
5.4.1 Failure effects shall describe what would happen if no specific task is done to anticipate, prevent, or detect the failure.	"Failure effects should be described as if no PM task is in place to prevent or find the failure." (NAVAIR 00-25-403, Section 3.2.5)
5.4.2 Failure effects shall include all the information needed to support the evaluation of the consequences of the failure, such as: a. What evidence (if any) that the failure has occurred (in the case of hidden functions, what would happen if a multiple failure occurred) b. What it does (if anything) to kill or injure someone, or to have an adverse effect on the environment c. What it does (if anything) to have an adverse effect on production or operations 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 the failure	"Failure effect is described as the impact that a functional failure has on the item under analysis, the surrounding items, and the functional capability of the end item. A failure effect should be described in terms of physical damage, including both primary and secondary damage that may occur. It should also address the action required to mitigate the loss of the function during operation." (NAVAIR 00-25-403, Section 3.2.5)

5.5 Failure Consequence Categories	
SAE JA1011	**NAVAIR 00-25-403 & Training Manual**
5.5.1 The consequences of every failure mode shall be formally categorized as follows:	See below:
5.5.1.1 The consequence categorization process shall separate hidden failure modes from evident failure modes.	"Failure consequence evaluation is a two-step process. First, functional failures are separated into two categories: those that are evident to the crew or operator and those that are not. For a functional failure to be classified as “evident,” it must be evident to the operator on its own. This means that no other failure or event needs to occur to make the functional failure evident." (NAVAIR 00-25-403, Section 3.4.1)
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 consequences (operational and non-operational consequences).	"The second step in evaluating failure consequences is to separate, within the hidden and evident categories, those failure modes that affect safety or environmental compliance from those that do not. Evident failures that have adverse impacts on safety or environmental compliance resulting from the loss of function (including any secondary damage that was caused by the occurrence of the failure mode) require action (on-condition task, hard time task, or other action) to avoid unacceptable consequences." (NAVAIR 00-25-403, Section 3.4.1)
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.	"Failure effects should be described as if no PM task is in place to prevent or find the failure." (NAVAIR 00-25-403, Section 3.2.5)

5.6 Failure Management Policy Selection	
SAE JA1011	**NAVAIR 00-25-403 & Training Manual**
5.6.1 The failure management selection process shall take account of the fact that the conditional probability of some failure modes 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.	"Facts about overhauls: - Many failure modes do not support overhaul philosophy- have no 'right' overhaul time. - Lose considerable component life. - Overhauls re-introduce infant mortality failures." (Fundamentals of RCM Analysis. page I.1.13. Copyright 2002, Information Spectrum, Inc. All Rights Reserved) "RCM applies the most appropriate maintenance philosophy to each failure mode." (Fundamentals of RCM Analysis. page I.1.16. Copyright 2002, Information Spectrum, Inc. All Rights Reserved)
5.6.2 All scheduled tasks shall be technically feasible and worth doing (applicable and effective), and the means by which this requirement will be satisfied are set out in 5.7. 5.6.3 If two or more proposed failure management policies are technically feasible and worth doing (applicable and effective), the policy that is most cost-effective shall be selected. 5.6.4 The selection of failure management policies shall be carried out as if no specific task is currently being done to anticipate, prevent or detect the failure.	"The cost of each possible solution plays a significant part in determining which one is ultimately selected. Remember that at this point in the analysis each option has already been shown to reduce the consequences of failure to an acceptable level. A solution that contains any of these options will meet the program's criteria. Since safety, environmental impact, and mission have already been dealt with at this point, considering cost is appropriate. The best solution at this point will be determined by the cost of executing that solution and the operational consequences that that solution will have on the program's maintenance operations." (NAVAIR 00-25-403, Section 3.6.1)

5.7 Failure Management Policies— Scheduled Tasks	
SAE JA1011	**NAVAIR 00-25-403 & Training Manual**
5.7.1 All scheduled tasks shall comply with the following criteria:	See below:
5.7.1.1 In the case of an evident failure mode that has safety or environmental consequences, the task shall reduce the probability of the failure mode to a level that is tolerable to the owner or user of the asset.	"Sometimes no single task can be found that adequately reduces the probability of failure to an acceptable level. In these cases, it is sometimes possible to combine tasks (usually of differing types) to achieve the desired level of reliability." (NAVAIR 00-25-403, Section 3.7.2)
5.7.1.2 In the case of a hidden failure mode where the associated multiple failure has safety or environmental consequences, the task shall reduce the probability of the hidden failure mode to an extent which reduces the probability of the associated multiple failure to a level that is tolerable to the owner or user of the asset.	"For a Failure Finding task to be acceptable for Hidden Safety/Environmental consequence failure modes, the probability of multiple failure (or failure on demand) with the Failure Finding task in place must be less than or equal to the acceptable probability of failure, Pacc established for functional failure of safety/environmental consequence failures. The probability of multiple failure (or failure on demand), Pmf, is the product of the probability of failure of the hidden function and the probability of failure of the function (or the probability of the occurrence of the event) that would make the hidden failure evident. As with the previously discussed tasks, there are various methods of ensuring that the Pmf £ Pacc. Appendix B provides some general methods for determining task intervals. The method(s) adopted for determining task intervals should be documented in the program's RCM plan." (NAVAIR 00-25-403, Section 3.5.7.1)
5.7.1.3 In the case of an evident failure mode that does not have safety or environmental consequences, the direct and indirect costs of doing the task shall be less than the direct and indirect costs of the failure mode when measured over comparable periods of time.	"3.5.8 No PM If safety/environmental compliance is not involved, not performing PM may be the most appropriate option of dealing with the functional failure. In this case, the item is allowed to remain in operation until it fails. When safety/environmental compliance is involved, however, the functional failure must be prevented. This is accomplished by either performing a PM task, or taking some other action that is warranted. 3.5.8.1 "No PM" Cost Analysis The cost of not doing PM must be calculated in order to compare this option to other methods of dealing with the failure mode." (NAVAIR 00-25-403, Section 3.5.8)

5.7.1.4 In the case of a hidden failure mode where the associated multiple failure does not have safety or environmental consequences, the direct and indirect costs of doing the task shall be less than the direct and indirect costs of the multiple failure plus the cost of repairing the hidden failure mode when measured over comparable periods of time.	"For Hidden Economic/Operational consequence failure modes, the method used must ensure that the Failure Finding task is cost-effective. Again, the task interval can be determined in a number of ways. The method(s) adopted should be documented in the program's RCM plan." (NAVAIR 00-25-403, Section 3.5.7.2)
5.7.2 ON-CONDITION TASKS— Any on-condition task (or predictive or condition-based or condition monitoring task) that is selected shall satisfy the following additional criteria:	See below:
5.7.2.1 There shall exist a clearly defined potential failure.	"A potential failure is a definable and detectable condition that indicates that a functional failure is in the process of occurring" (NAVAIR 00-25-403, Section 3.5.5)
5.7.2.2 There shall exist an identifiable P-F interval (or failure development period).	"To develop an On Condition task, the following questions must be addressed: * What will be defined as Functional Failure? * What will be defined as Potential Failure? * What is the Potential Failure to Functional Failure (PF) interval; how consistent is it? * Can a task interval be developed that reduces the probability of failure to an acceptable level?" (NAVAIR 00-25-403, Section 3.5.5.1)
5.7.2.3 The task interval shall be less than the shortest likely P-F interval.	"For failure modes that result in safety/environmental evident or hidden safety/environmental failure consequences, the shortest PF interval of the range should be selected." (NAVAIR 00-25-403, Section 3.5.5.4)
5.7.2.4 It shall be physically possible to do the task at intervals less than the P-F interval.	"If a lower limit for the PF interval cannot be determined, or if it is considered to be too short for one type of degradation indicator, the On Condition task might be salvaged by considering a different degradation indicator. If this approach fails, then another type of task should be considered. One method of conducting On-condition inspections at very short intervals is through on-board or imbedded PHM sensors and monitoring devices." (NAVAIR 00-25-403, Section 3.5.5.4)

5.7.2.5 The shortest time between the discovery of a potential failure and the occurrence of the functional failure (the P-F interval minus the task interval) shall be long enough for predetermined action to be taken to avoid, eliminate, or minimize the consequences of the failure mode.	"For failure modes with safety/environmental consequences, the goal is to develop a task interval that will reduce the probability of experiencing a functional failure to an acceptable level. For failure modes with hidden safety/environmental consequences, the goal is to develop a task interval that will reduce the probability of experiencing a multiple failure (or failure on demand for protective functions required upon the occurrence of a demand event) to an acceptable level." (NAVAIR 00-25-403, Section 3.5.5.5) "For failures that result in non-safety/environmental consequences, the goal is to pursue the most cost-effective option. Appendix B provides some methods for determining task intervals; other methods may be applicable. The method(s) adopted for determining task intervals should be documented in the program's RCM plan." (NAVAIR 00-25-403, Section 3.5.5.5)
5.7.3 SCHEDULED DISCARD TASKS— Any scheduled discard task that is selected shall satisfy the following additional criteria:	See below:
5.7.3.1 There shall be a clearly defined (preferably a demonstrable) age at which there is an increase in the conditional probability of the failure mode under consideration. 5.7.3.2 A sufficiently large proportion of the occurrences of this failure mode shall occur after this age to reduce the probability of premature failure to a level that is tolerable to the owner or user of the asset.	"To develop a Hard Time task that can prevent a failure mode from occurring, three questions must be addressed: * What is an identifiable wear out age? * What percentage of items survive to that wear out age? * Can a task interval be developed that reduces the probability of failure to an acceptable level?" (NAVAIR 00-25-403, Section 3.6.1) "Wear out is described as an increase in the conditional probability of failure with age." (NAVAIR 00-25-403, Section 3.6.2)
5.7.4 SCHEDULED RESTORATION TASKS— Any scheduled restoration task that is selected shall satisfy the following additional criteria:	See below:
5.7.4.1 There shall be a clearly defined (preferably a demonstrable) age at which there is an increase in the conditional probability of the failure mode under consideration. 5.7.4.2 A sufficiently large proportion of the occurrences of this failure mode shall occur after this age to reduce the probability of premature failure to a level that is tolerable to the owner or user of the asset.	"To develop a Hard Time task that can prevent a failure mode from occurring, three questions must be addressed: * What is an identifiable wear out age? * What percentage of items survive to that wear out age? * Can a task interval be developed that reduces the probability of failure to an acceptable level?" (NAVAIR 00-25-403, Section 3.6.1) "Wear out is described as an increase in the conditional probability of failure with age." (NAVAIR 00-25-403, Section 3.6.2)

5.7.4.3 The task shall restore the resistance to failure (condition) of the component to a level that is tolerable to the owner or user of the asset.	"After an item is removed by a Hard Time task, it is either reworked or discarded. If it is to be reworked, the item's acceptable level of failure resistance must be restored, and the item returned to service. If the item is discarded, it is replaced with a new item." (NAVAIR 00-25-403, Section 3.5.6)
5.7.5 FAILURE-FINDING TASKS— Any failure-finding task that is selected shall satisfy the following additional criteria (failure-finding does not apply to evident failure modes):	See below:
5.7.5.1 The basis upon which the task interval is selected shall take into account the need to reduce the probability of the multiple failure of the associated protected system to a level that is tolerable to the owner or user of the asset.	"For a Failure Finding task to be acceptable for Hidden Safety/Environmental consequence failure modes, the probability of multiple failure (or failure on demand) with the Failure Finding task in place must be less than or equal to the acceptable probability of failure, Pacc established for functional failure of safety/environmental consequence failures. The probability of multiple failure (or failure on demand), Pmf, is the product of the probability of failure of the hidden function and the probability of failure of the function (or the probability of the occurrence of the event) that would make the hidden failure evident. As with the previously discussed tasks, there are various methods of ensuring that the Pmf £ Pacc. Appendix B provides some general methods for determining task intervals. The method(s) adopted for determining task intervals should be documented in the program's RCM plan." (NAVAIR 00-25-403, Section 3.5.7.1)
5.7.5.2 The task shall confirm that all components covered by the failure mode description are functional.	"Since failure-finding tasks are directed at functional failures, it is often possible to determine one task that can protect multiple failure modes." (NAVAIR 00-25-403, Section 3.5.7)
5.7.5.3 The failure-finding task and associated interval selection process should take into account any probability that the task itself might leave the hidden function in a failed state.	"For a Failure Finding task to be acceptable for Hidden Safety/Environmental consequence failure modes, the probability of multiple failure (or failure on demand) with the Failure Finding task in place must be less than or equal to the acceptable probability of failure, Pacc established for functional failure of safety/environmental consequence failures. The probability of multiple failure (or failure on demand), Pmf, is the product of the probability of failure of the hidden function and the probability of failure of the function (or the probability of the occurrence of the event) that would make the hidden failure evident. As with the previously discussed tasks, there are various methods of ensuring that the Pmf & Pacc. Appendix B provides some general methods for determining task intervals. The method(s) adopted for determining task intervals should be documented in the program's RCM plan." (NAVAIR 00-25-403, Section 3.5.7.1)

5.7.5.4 It shall be physically possible to do the task at the specified intervals.	

5.8 Failure Management Policies— One-Time Changes and Run-to-Failure	
SAE JA1011	**NAVAIR 00-25-403 & Training Manual**
5.8.1 ONE-TIME CHANGES	See below:
5.8.1.1 The RCM process shall endeavor to extract the desired performance of the system as it is currently configured and operated by applying appropriate scheduled tasks. 5.8.1.2 In cases where such tasks cannot be found, one-time changes to the asset or system may be necessary, subject to the following criteria. 5.8.1.2.1 In cases where the failure is hidden, and the associated multiple failure has safety or environmental consequences, a one-time change that reduces the probability of the multiple failure to a level tolerable to the owner or user of the asset is compulsory. 5.8.1.2.2 In cases where the failure mode is evident and has safety or environmental consequences, a one-time change that reduces the probability of the failure mode to a level tolerable to the owner or user of the asset is compulsory. 5.8.1.2.3 In cases where the failure mode is hidden, and the associated multiple failure does not have safety or environmental consequences, any one-time change must be cost-effective in the opinion of the owner or user of the asset. 5.8.1.2.4 In cases where the failure mode is evident and does not have safety or environmental consequences, any one-time change must be cost-effective in the opinion of the owner or user of the asset.	"If it is determined that "No PM" is unacceptable and an appropriate PM task cannot be developed that will reduce the consequences of failure to an acceptable level, then some other action must be taken to deal with them. Several options, such as an item redesign (for example, improvements in reliability, introduction of PHM, or establishing redundant capability), the introduction of operational restrictions, or a change in maintenance procedures, can be applied to mitigate the problem. At times, some other action may be desirable even if a PM task is available. This course of action would be appropriate if a positive return on investment can be demonstrated in terms of, for example, increased equipment availability, reduced cost, or reduced exposure to a hazardous condition." (NAVAIR 00-25-403, Section 3.5.9)
5.8.2 RUN-TO-FAILURE— Any run-to-failure policy that is selected shall satisfy the appropriate criterion as follows:	See below:
5.8.2.1 In cases where the failure is hidden and there is no appropriate scheduled task, the associated multiple failure shall not have safety or environmental consequences. 5.8.2.2 In cases where the failure is evident and there is no appropriate scheduled task, the associated failure mode shall not have safety or environmental consequences.	"3.5.8 No PM If safety/environmental compliance is not involved, not performing PM may be the most appropriate option of dealing with the functional failure. In this case, the item is allowed to remain in operation until it fails. When safety/environmental compliance is involved, however, the functional failure must be prevented. This is accomplished by either performing a PM task, or taking some other action that is warranted. 3.5.8.1 "No PM" Cost Analysis The cost of not doing PM must be calculated in order to compare this option to other methods of dealing with the failure mode." (NAVAIR 00-25-403, Section 3.5.8)

5.9 A Living Program	
SAE JA1011	**NAVAIR 00-25-403 & Training Manual**
5.9.1 This document recognizes that (a) much of the data used in the initial analysis are inherently imprecise, and that more precise data will become available in time, (b) the way in which the asset is used, together with associated performance expectations, will also change with time, and (c) maintenance technology continues to evolve. Thus a periodic review is necessary if the RCM-derived asset management program is to ensure that the assets continue to fulfill the current functional expectations of their owners and users.	"A PM program that is based on the RCM philosophy must be dynamic. This is especially true during the early stages of a new program when it is based on limited information. Maintenance organizations must therefore be prepared to collect, analyze, review and respond to in-service data throughout the operating life of the equipment in order to continually refine the PM program. The procedures and processes used to monitor, analyze, update, and refine the PM program through RCM analyses will sustain the program. They should be identified in the RCM Program Plan." (NAVAIR 00-25-403, Section 5.1)
5.9.2 Therefore any RCM process shall provide for a periodic review of both the information used to support the decisions and the decisions themselves. The process used to conduct such a review shall ensure that all seven questions in Section 5 continue to be answered satisfactorily and in a manner consistent with the criteria set out in 5.1 through 5.8.	"The basis for the decisions made during an RCM analysis change continuously as the program experiences growth and maturity, which is brought about by time, use, modifications, updates, etc. Because of this, review and refinement of the PM program must be an ongoing process. It requires an organized information system that provides a means to conduct surveillance of items under actual operating conditions. The information is collected for two purposes. First, it is used to determine what refinements and modifications need to be made to the initial PM program (including task interval adjustments). Secondly, it is used for collecting data to determine the need for taking some other action, such as product improvement or making operational changes. These two purposes are met by monitoring and adjusting existing maintenance tasks, developing emergent requirements, and periodically assessing RCM-generated maintenance requirements. Analysts use this new information to revise RCM analyses, which subsequently may reflect a need for changes to the PM program." (NAVAIR 00-25-403, Section 5.1)

	"The objective of the sustainment process is to continually monitor and optimize the current PM program, delete unnecessary requirements, identify adverse failure trends, address new failure modes, and improve the overall efficiency and effectiveness of the RCM and PM programs. Sustainment efforts should be structured such that the results can be effectively used to support RCM analysis updates. The process of monitoring existing maintenance tasks entails reviewing the many sources of task effectiveness information and maintaining accurate and efficient analysis data. The types of efforts used in the RCM sustainment process include Top Degrader Analyses, Trend Analyses, PM Requirements Document Reviews, Task Packaging Reviews, Fleet Leader programs, Age Exploration (AE) tasks, and handling the day-to-day emergent issues." (NAVAIR 00-25-403, Section 5.2)

5.10 Mathematical and Statistical Formulae	
SAE JA1011	**NAVAIR 00-25-403 & Training Manual**
5.10.1 Any mathematical and statistical formulae that are used in the application of the process (especially those used to compute the intervals of any tasks) shall be logically robust, and shall be available to and approved by the owner or user of the asset.	NAVAIR, as a customer of the RCM analysis and owner of the assets, sets out in NAVAIR 00-25-403 & its training manuals the various definitions of acceptable formulas (probability, cost, MTBF, etc.) for calculations during an RCM analysis.

Specific concerns

Several specific concerns have been raised previously regarding the compliance of NAVAIR 00-25-403 with SAE JA1011. This section will attempt to address each of those known issues individually:

Concern:
Operating context was not adequately addressed.

Response:
NAVAIR 00-25-403 addresses operating context though-out. Prior versions of the training materials addressed operating context implicitly rather than directly. Training materials have since been updated to more thoroughly address the issue of operating context.

Concern:
NAVAIR 00-25-403 process excludes human error from RCM analysis.

Response:
NAVAIR 00-25-403 does not specifically exclude human error issues. It does not address human error directly because human error failures are addressed via other processes in NAVAIR such as quality assurance and human factors analysis. Reference SAE JA1011 Paragraph 5.3.5: “Lists of failure modes should include any event or process that is likely to cause a functional failure, including deterioration, design defects, and human error whether caused by operators or maintainers (unless human error is being actively addressed by analytical processes apart from RCM).”

Historically, some have improperly attempted to use PM to address human issues rather than attack them at the source. For example, inspecting for improperly installed components rather than enforcing quality assurance procedures. If a failure mode is caused by poor design, poor maintenance practices, etc. and can be predicted, there is nothing in the process that says not to include these failure modes. The Other Action category addresses maintenance process and design improvements as recommended failure management approaches. Additionally, NAVAIR RCM training materials have been updated to ensure human error failures are not overlooked.

Concern:
Significant function logic requires determination of failure consequences out of required order.

Response:
The significant function selection process is considered an “optional” step which does not in any way affect the remainder of the analysis steps. In most cases of properly performed analysis the logic does not preclude any functions from analysis; it is only used as a categorization tool. Additional response from NAVAIR is provided below:

The following is quoted directly from a NAVAIR response to the issue:
“We had much debate over this in developing the SAE JA1011. While John Moubray promotes analyzing all reasonable likely failure modes, he also understands there is diminishing return on many systems and equipment. The idea of "non-significant" functions was introduced to prevent wasting limited resources on systems/functions with little or no impact of failure. We concur that you must have an understanding of failure modes and effects when determining whether something is "non-significant" but we don't feel you must spend a lot of time analyzing the equipment or writing down those failure modes and effects to determine a system's "non-significance". If you read NA 00-25-403 regarding the specific logic questions you will see it clearly indicates an understanding of the function's failure modes and effects are required to determine something "non-significant". The idea of "non-significance" was introduced by Nowlan and Heap, and included in MIL-STD-2173. Even the JA1012 discusses subsystems "judged to be so insignificant that they will not be analyzed at all". Therefore, we believe the inclusion of the "significant function" process is important in causing the analyst to think through the functions identified for analysis, and usually causes additional functions to be added (for example because there is an existing PM), than for functions to be discarded. The criteria for eliminating a function from further analysis (no adverse effect or safety, environment, operations, or economics and no existing PM) usually result in eliminating functions that were somewhat nebulous to begin with. Recognizing that the RCM process is also "iterative", if a function were initially determined "non-significant" and later data showed revealed failure modes with impacts, it would be added to the analysis. Because (as you point out) we eliminate these functions from consideration before beginning the RCM analysis, we feel we are compliant with the intent of JA1011 in applying the process to the functions selected for analysis. We understand there may be some disagreement with that position.”

Concern:
NAVAIR 00-25-403 process does not require a description of the evidence (if any) that the failure has occurred and does not require information about what must be done to restore function to the system.

Response:
The description of evidence is included in the failure detection portion of the FMECA in NAVAIR 00-25-403. This meets the intent of the JA1011 for "description of evidence". As far as what is required to restore functionality, JA1011 was not meant to require a

complete description of the repair process or corrective maintenance steps. Something like "extensive depot repair required", or "removal and replacement required" is sufficient in most cases. Training has been updated to reflect this issue.

Conclusion

The guidelines set out in SAE JA1011 provided the RCM community with a consensus baseline by distilling the scope and thought process behind RCM as it was originally conceived and implemented. As one of the first implementers of RCM, NAVAIR has accumulated over 20 years of direct experience in deploying these tools and has condensed the body of knowledge generated by this experience in NAVAIR 00-25-403 and its related training materials. The NAVAIR RCM processes have remained true to the original RCM tenets as evidenced in this paper, and are thus fully compliant with SAE JA1011.

It has been the intent of the authors of NAVAIR 00-25-403 to comply with all requirements of SAE JA1011. Where questions of compliance do occur, it is usually a matter of interpretation of one document or the other. In any case, users of either document can make minor modifications or clarifications to achieve a desired interpretation. The NAVAIR 00-25-403 has always been intended to be used as a guide subject to adjustment by individual users.