Progression from RCM2™ to RCM3™ including Highlights

RCM Element	RCM2 (SAE JA 1011)	RCM3 Highlights	Reason for additions / changes	Improvements and advantages
Operating Context	Mentions and considers the Operating Context (OC) throughout the process. Operating Context is considered when failure modes are identified and when failure management strategies are developed (Failure consequences are different when OC varies). SAE JA1011[1] mentions the OC as important but not necessary a requirement.	The Operating Context is the **FIRST** step and question that must be answered in RCM3: *What are the conditions under which the equipment is expected to operate?* The OC is not just important, but essential for developing a sensible and defensible risk management program.	The Operating Context *must* be defined prior to the FMEA, listing functions and performance standards, failed states, failure modes and failure effects is all based on the OC. The inherent risk posed by each failure and everything impacting the performance of an asset, are influenced by and derived from the OC.	Defining the Operating Context is undeniable the first step of the RCM process and all assumptions and decisions are based on the OC, making RCM3 compliant and exceeding requirements of SAE standard. Risk assessment and risk management must be performed within the context – according to ISO 31000[2] (ISO Standard for Risk Management). True optimization is only possible when the OC is defined.
Functions	Requires the definition of Primary and Secondary Functions with associated standards of performance • Performance standards should be defined (where possible) • Specific about the definition of functions for protective devices	Requires the definition of Primary and Secondary Functions with associated standards of performance • Performance standards should be defined (where possible) • Specific about the definition of functions for protective & detective devices • Expands Secondary Functions to include cleanliness, regulations, regulatory requirements, recycle / repurpose / reuse	The expectations of modern equipment have changed with the changing expectations of the people who own and operate the equipment. Expectation further changed with new advanced technologies and innovation, through interconnectivity, mobility and predictive technology. Rising pressure from governments and societies with regards to sustainability and environmental integrity, places higher demands on reusable energy and focus on sustainable operations.	Requirements for asset performance now includes elevated consideration for sustainability and environmental integrity. The focus is now more on what the equipment's role is in society as a whole rather than a siloed view of the organization who owns and operates the equipment. The performance standard for initial capability (inherent reliability) is now drawing the attention to defect elimination and longer asset life while meeting regulations and regulatory requirements.
Functional Failures	Functional failures are acknowledged as "failed states": • General failed state • Total failure • Partial failure	Now defined as "Failed State" and acknowledges the differences between: • General failed state • Failing state • Failed state • End state (as part of the failure process)	The general failed state, the failing state (process of failing), partial failure (failed state where equipment no longer meets performance criteria) are now clearly defined and distinguished from the end state (total failure). The RCM3 process deals with all possible failures at the appropriate level.	Agreement between different disciplines (e.g. engineering, operations and maintenance) can be reached much faster and therefore the process of identifying appropriate risk management strategies, is much quicker (saving time and money). The new definition encourages the use of new maintenance techniques and technology.

[1] SAE JA1011 - Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes, August 1999
[2] ISO 31000 - Risk management - Principles and guidelines, 2009

RCM Element	RCM2 (SAE JA 1011)	RCM3 Highlights	Reason for additions / changes	Improvements and advantages
Failure Modes	Defines a Failure Mode as the event that causes the Functional Failure / Failed State. The facilitator / review group must constantly be reminded of the correct level of detail (not to describe failure effects / symptom of the failure).	Defines a Failure Mode as a 'cause' and 'mechanism' that causes the Failed State. This allows the facilitator / review group to identify *root causes* consistently and with the correct level of detail. The failure mechanism also ties in with the degradation mechanisms (terminology used in RBI).	RCM review groups (and facilitators) are forced to define at least one or more failure mechanisms for each failure mode ensuring the level of detail is sufficient and appropriate for developing risk management strategies that are both technically feasible and worth doing. Failure causes are events causing the failed states while failure mechanisms are the conditions leading to the failures (e.g. corrosion, normal wear and tear, etc.).	Consistent and improved root cause failure identification is now possible, even for inexperienced facilitators. Templating of like type equipment is easier to perform, more information is carried over. Integration with other risk-based approaches (e.g. RBI) are now easy to achieve. Root causes are identified and treated and no longer the symptoms associated with failures.
Failure Effects	Failure Effect is defined as one statement (one paragraph that describes what will happen if the failure mode occurs and nothing was done to prevent it). It requires the facilitator to record the physical effects of each failure by asking the following questions: • What evidence (if any) that the failure has occurred? • In what ways (if any) it poses a threat to safety or the environment? • In what ways (if any) it affects production or operations? • What physical damage (if any) is caused by the failure? • What must be done to repair it?	Like RCM2, Failure Effects are described if no maintenance is being performed and no attempt is made to prevent them, but the effects are now separated in three levels: Local Effect, Next Higher-Level Effect and End Effect. RCM3 also describes Potential Worst-Case Effect (where protection is also in a failed state – allowing for true *zero-base* analysis). It does so by asking the following questions: • When is the failure most likely to occur? • How often the failure would occur if no attempt is made to prevent it? • What evidence (if any) that the failure has occurred? • In what ways (if any) it poses a threat to safety or the environment? • In what ways (if any) it affects production or operations? • What physical damage (if any) is caused by the failure? • What must be done to repair it? • Does it cause any secondary damage? • What is the revenue loss (if any)?	Separating the effect description makes it possible to distinguish more easily between the specifics of complex failure effects. Reporting on failure effects (assessing the consequence severity) to different levels in the organization is more granular and less time is spent during the analysis and the subsequent analysis audit meetings. Describing failure effects are far easier and the separation allows the different disciplines in the review group (engineering, operations and maintenance) to focus on their areas of expertise and knowledge. The first question now truly considers the Operating Context and when failures are more likely to occur. (e.g. storm events, start-up, take-off or landing, following maintenance intervention, etc.)	Easier and more comprehensive *templating* at equipment type level (Local Effect descriptions included in the analysis template). Indicators easier to define (clear difference between what operator / maintenance personnel sees vs. what management wants to see). Potential worst case describes multiple failure conditions separate and with appropriate level of detail. The focus is on increasing the reliability of the protected function/system as a first priority. True *zero-base* analysis now possible without considering protective systems to mitigate inherent risk. Using consequence definitions as defined in the organizations risk framework, allows everyone to relate and understand the effects of failure and the risk it poses. It is now possible to quantify inherent risk and develop risk mitigation strategies for intolerable risks.

Progression from RCM2™ to RCM3™ including Highlights

RCM Element	RCM2 (SAE JA 1011)	RCM3 Highlights	Reason for additions / changes	Improvements and advantages
Consequences vs. Risk	Considers the consequences of failure and categorizes them in four categories: Safety/Environmental, Operational, Non-Operational and a single category of hidden failure consequences. All failures are treated and consequences are evaluated based on the four categories.	Considers evident *Physical* and *Economic* Risks and separates the Hidden Risks in two categories, *Hidden Physical* and *Hidden Economic Risks.* Physical Risks are risks impacting health, safety or the environment while Economic Risks impact operational capability and financial well-being.	Assessing and managing risks allow the review team to distinguish between *tolerable* and *intolerable* risks as defined by the organizations risk framework. Not all risks are intolerable and therefore not all failures need to be analyzed – saving time and valuable resources.	This is valuable in high risk environments. Improved integrity and improved planning for testing protective devices are possible. The focus is on the devices that could impact safety vs. operations and improves the understanding of the economic impact (of functional tests) and risk of the same.
Inherent Risk	Follows a subjective approach to risk management and addresses risk only when failures (or multiple failures) impact safety or the environment. RCM2 is a process to determine what must be done to an asset system to preserve its functions (while minimizing or avoiding failure consequences).	RCM3 addresses risk directly and the risk management approach is based on ISO 31000 Standards for Risk Management. RCM3 is the process used to determine what must be done to an asset system to preserve its functions while minimizing the risks associated with failures to a tolerable level. RCM3 further considers a probabilistic risk assessment at component level when compulsory redesigns or one-time changes are required. Every reasonably likely failure mode is assessed and quantified in terms of its inherent risk. Less likely failure modes are considered based on inherent risk.	Inherent risk is *quantified in relative terms* as if no maintenance is being performed and if protection associated with failure is unavailable *(zero-base).* RCM3 is aligned with ISO Standards for Asset Management and Risk (ISO 55000[3] and ISO 31000). RCM3 considers risk mitigation through addressing the probability and the consequence severity both as proactive risk management strategies. This provides more ways to proactively deal with intolerable risk and more decisions are made (fewer compulsory redesigns). For tolerable risks, the default risk mitigation strategies (no scheduled maintenance, spare part policies, etc.) are true default actions. Further risk reduction (for tolerable risk) may be considered provided it can be achieved in a cost-effective manner. This truly makes risk management strategies feasible and worth doing.	The revised risk achieved through the new RCM3 decision process, demonstrates the impact of risk mitigation - both on cost and risk exposure. It allows for proper and formal assessment to determine requirement for one-time changes (redesigns) based on the relative risk. Risk is *quantified* in relative terms and less compulsory redesign decisions are made – this allows the review group to make more decisions (less open-ended results) and it leads to a more defensible failure management program. Once risk management strategies have been defined, especially for failure modes posing intolerable risks, it is possible to determine the risk and financial impact of the recommendations. Less likely failure modes are evaluated based on the real risk they pose, leading to realistic asset management strategies.

[3] ISO 55000 – ISO 55000 - Asset management - Overview, principles and terminology, 2014

Progression from RCM2™ to RCM3™ including Highlights

RCM Element	RCM2 (SAE JA 1011)	RCM3 Highlights	Reason for additions / changes	Improvements and advantages
Decision Diagram	The RCM2 Decision Diagram treats all Hidden Functions the same (single approach). The decision logic considers predictive and preventive maintenance tasks as proactive failure management strategies and failure finding, redesigns and no scheduled maintenance as default actions. A combination of tasks is also seen as a default action and consequence mitigation is achieved primarily through optimizing protective devices (protected functions). For any proactive maintenance task (PM) to be considered, the PM must be both technically feasible (according to the failure characteristics) and worth doing (reduces the consequences to an acceptable level).	RCM3 incorporates additional criteria to identify *Hidden Physical* and *Economic Risks*. A true *zero-base* analysis is only possible if protection related to the failure under consideration is ignored. Focus is placed on reliability of the protected function first. Failure-finding intervals are optimized through increasing reliability of the protected function (when applicable) as the primary concern. Dependency on protective devices are reduced. The *worth doing* criteria for different risk criteria is significantly different from the RCM2 decision logic. Any *Physical Risk* must be reduced to a tolerable level. *Economic Risks* are considered (first) and not cost only. The mitigation strategy must reduce intolerable operational risk (now quantified) in order to be considered. The RCM3 process leads to more defensible risk mitigation.	For hidden failures having an intolerable *physical risk*, risk thresholds are used to determine the failure-finding intervals. For hidden failures having an intolerable *economic risk*, the cost of doing failure- finding is compared to the cost of the multiple failure and intervals are optimized based on cost. *Functional checks* designed for protective devices that fail (not fail-safe devices) are now included (where applicable). The focus in RCM2 could be (and has been) misinterpreted as being biased towards protective devices present in the system (especially standby and redundant equipment), which resulted in "No Scheduled Maintenance" decision for the protected function. This meant that the risk to the organization is drastically increased during repair time when the protected function failed (risk of multiple failures).	The criteria for *Hidden Economic Risks* determine the optimum interval for failure finding (providing highest availability) at the lowest cost. The cost of the failure-finding task must still be acceptable to the user, otherwise a one-time change may be considered to reduce the overall cost of multiple failures (where applicable). Improved integrity through functional testing for protective systems that fail (based on risk tolerance). The RCM3 decision diagram focus on the protected function as a priority. The need for a protective device and failure-finding intervals are only considered AFTER the integrity of the protected function has been addressed. These decisions are all risk based.
SAE JA 1011/1012 International RCM Standard	RCM2 complies fully with the minimum requirements of the SAE JA 1011 and SAE JA 1012 RCM standards.	RCM3 complies fully with the minimum requirements of the SAE JA 1011 and SAE JA 1012 Standards and goes beyond these requirements. RCM3 aligns with ISO 55000 and ISO 31000 Management Systems.	To align and integrate RCM with recognized and adopted International Management Systems. To mainstream RCM with International Asset Management Systems.	RCM3 now aligns with new and emerging standards making the results easier to defend. International standards and management systems are rarely challenged. RCM3 will become the new standard.