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Maintaining data center performance

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Reliability-Centered Maintenance Whitepaper

May 2012

Reliability centered maintenance: managing cost and risk

In this whitepaper we will answer the question, "How much maintenance is enough?"

Conventional data center maintenance programs have been based on a combination of recommendations from original equipment manufacturers (OEM) and best practices that have been adopted by industry groups and trade associations. Historically, there is very little empirical or statistical engineering science behind them. OEMs believe that more frequent maintenance means lower risk – at least for their equipment. But is this true? OEM recommendations have become the de-facto maintenance standard because they are required to support warranties, and are bundled into comprehensive service contracts that can easily be renewed for many years. Even after warranties expire, data center operators may be reluctant to risk a service disruption from failure to follow the OEM recommended maintenance.

Until now, operators have not had the benefit of a scientific method to make data backed decisions about alternatives to OEM recommendations. Studies indicate that a large percentage of data center failures occur while changing states during planned maintenance, leading data center operators to question whether following OEM prescribed tasks and frequencies may actually incur both higher cost and higher risk.

Long recognized as a best practice in the aerospace and telecommunication industries, Reliability Centered Maintenance (RCM) is a new concept being applied to data centers. Critical systems performance requirements and energy demands of data centers continue to increase at the same time economic and environmental pressures are forcing data center operators to reconsider how they meet cost and reliability goals.

A quantitative approach

The RCM approach consists of actions and procedures that result in greater reliability and lower life-cycle costs.

Minimizing unnecessary and potentially risky disruption while maximizing the durability and systems level health.

RCM is the only quantitative approach that provides a rational for maintenance to minimize unnecessary and potentially risky disruption while maximizing the durability and health. A failure, which is defined as the cessation of function or performance, can occur at the systems level, sub-system level, component level or even at the parts level. The core purpose of any maintenance program is to avoid failures at all levels, preserving function and performance continuity. RCM uses analytical processes to determine the proper balance of planned and unplanned maintenance, in addition to assessing other activities that comprise an integrated failure management strategy across the entire operation.

Preventive and corrective maintenance

RCM focuses on two types of maintenance: preventive and corrective. Preventive actions are taken to preserve functionality (to protect safety, or reduce the cost of repair), and to reduce unplanned downtime or impacts to mission-critical performance. Corrective maintenance responds to failures after they occur.

RCM incorporates Preventive Maintenance and Corrective Maintenance activities, along with Predictive Testing & Inspection (PT&I) and other actions (e.g., redesign, procedural changes or technology upgrades) to provide an optimal balance to achieve greater reliability and lower life-cycle costs. For a discussion of the history, philosophy, approach and outcomes of RCM, refer to the article, “Reliability Centered Maintenance: A New Approach to Reduce Data Center Risk & Cost,” Mission Critical magazine May/June 2012 issue.

The remainder of this white paper focuses on how organizations can approach implementing an RCM program.

Capability Maturity Model process

As the data center industry responds to ever increasing demands for availability, performance and cost-efficiency, sophisticated management models become more relevant. The Capability Maturity Model (CMM) provides a paradigm to assess operating performance. In systems engineering, the five CMM levels are defined as:

- Level 0 – not performed
- Level 1 – performed informally
- Level 2 – planned and tracked
- Level 3 – well-defined
- Level 4 – quantitatively controlled
- Level 5 – continuously improving

As shown in **Figure 1** below, applying the principles of RCM can help organizations advance CMM levels and deliver the reliability data center owners now demand. CMM is a pathway for growth in capabilities and organizational maturity – and there are no short cuts. Appropriate processes and procedures must be established to move an organization further up the model. RCM analysis helps to identify whether current systems are sufficient to support a comprehensive PT&I plan. Once the foundational elements are in place, implementing an RCM program will allow organizations to reap the benefits and attain what was once only an aspirational goal: guaranteed uptime.

Figure 1: Capability Maturity Model in data center operations

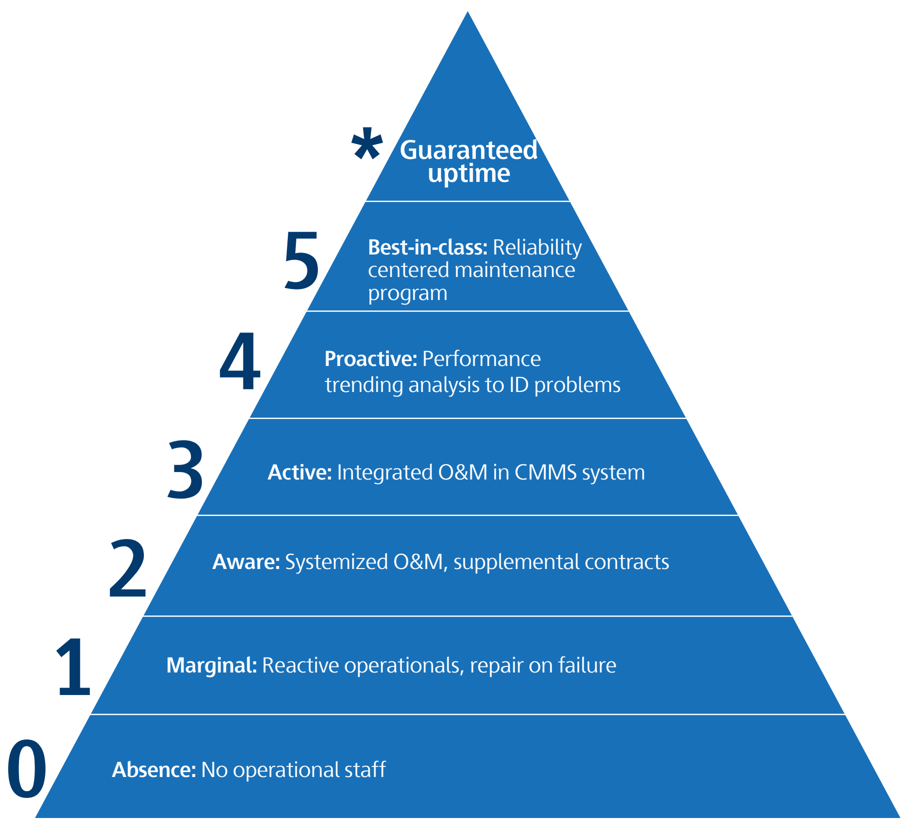


Figure 1
Processes and procedures that must be established to move an organization further up the model and allow them to reap the benefits and attain the goal of guaranteed uptime.

Transitioning to an RCM approach

How do you transition to RCM? Conventional maintenance programs are designed around preventing the failure of each of the individual components of the system. A key shift in thinking is letting go of preserving equipment function.

RCM is focused on preserving overall system function. It prioritizes operation of the system as a whole, even if that means allowing certain non-critical components to fail when they do not impact data center performance. RCM fosters a holistic view across the operation that leads to the optimal use of maintenance resources.

Implementation

There are many good reference guides that can help data center operators transition to the RCM process. One of the most commonly used is "SAE JA1012: A Guide to the Reliability-Centered Maintenance (RCM) Standard." The NASA RCM Guide also details a successful RCM approach for organizations to leverage as a roadmap.

Rolling out an effective RCM program is a multi-faceted initiative. It involves all functional areas of the organization, including maintenance, facilities, operations, risk management, human resources and purchasing. As with any significant initiative, executive sponsorship is critical.

The four elements of a successful RCM program implementation include:

1. Planning and preparation, including identifying the purpose or need for the effort, and development of the plan.
2. The core analysis process, including assessment of failure modes, effects and criticality analysis (FMECA), Significant Function Selection and RCM task evaluation and selection.
3. Analysis implementation and recommendations that result from the process.
4. Sustaining the recommendations and evaluating feedback.

Planning and preparation

Planning is vital to the success of broad-base initiatives such as RCM. In the planning stage, the RCM leadership team will need to:

- Establish acceptable levels for the various categories of failure consequences
- Develop ground rules and assumptions
- Establish team members' ongoing responsibilities

- Obtain training and certification as needed
- Identify the hardware breakdown or partition that will be used to facilitate technical analysis
- Identify and obtain resources and tools
- Pursue contract support if needed
- Ensure buy-in from management and key stakeholders.

Implementing RCM requires a systematic approach that extends from initial planning through many aspects of day-to-day operations within an organization. The next stage – and the cornerstone of everything that follows – is the analysis process.

RCM analysis

The seven-step process

The seven-step approach to RCM analysis provides a useful guideline to help organizations shift their thinking from the conventional maintenance mindset. RCM combined with a critical analysis allows organizations to:

- Design the system for redundancy as needed to maintain critical function
- Define a focused, cost-effective preventive maintenance program.

By following the steps illustrated in **Figure 2** on page 6, organizations can evaluate and balance financial, system risk, safety and reliability considerations.

RCM fosters a holistic view across the operation that leads to the optimal use of maintenance resources.

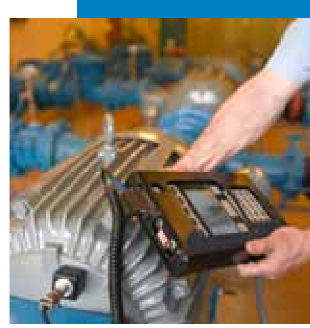


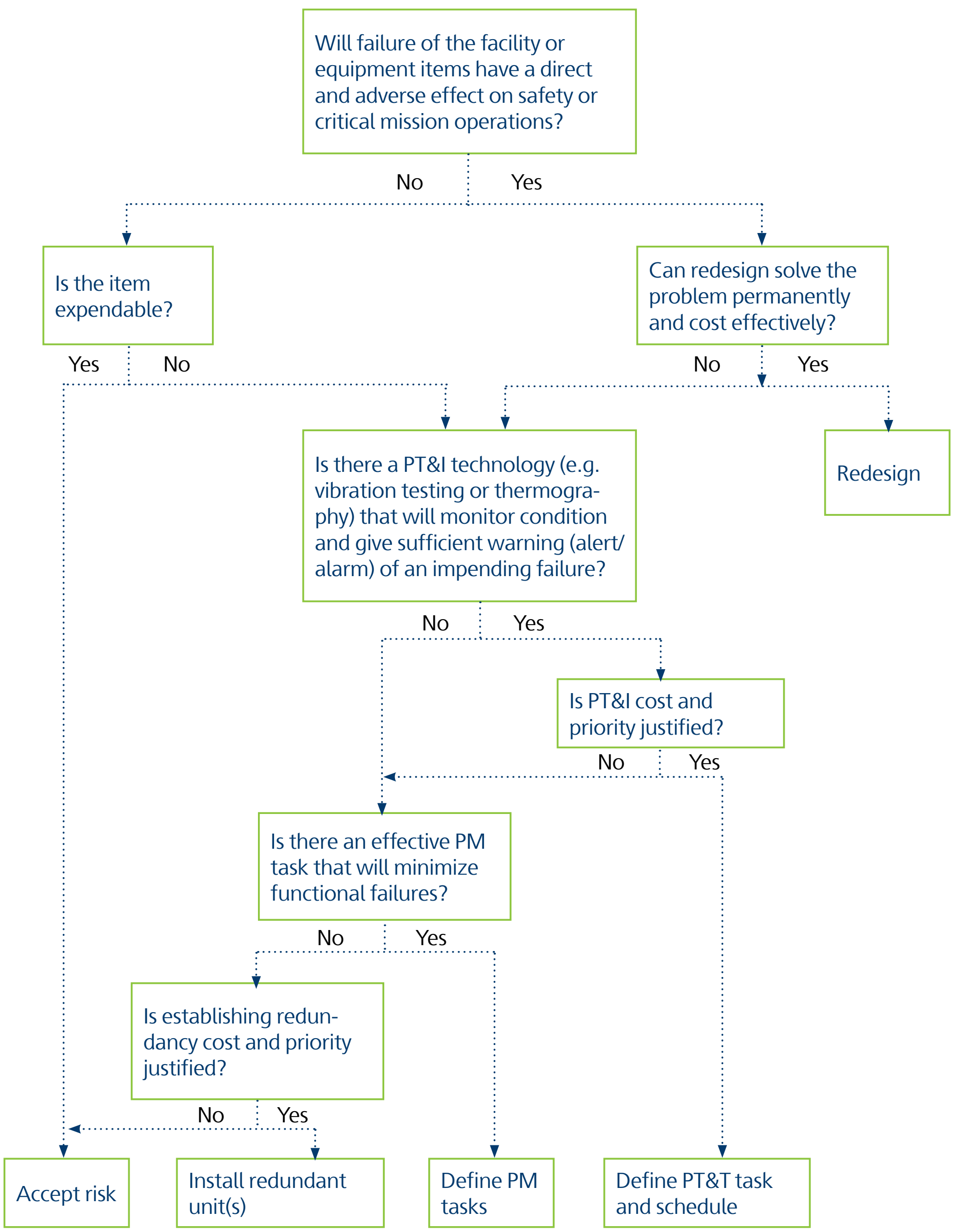
Figure 2. The seven-step RCM process

#	Steps	Reliability Centered Maintenance: Preserving overall system function	Conventional maintenance: Preserve equipment function
1	System selection focus: 80/20 rule	Data centers are no exception to the 80/20 principle: about 20 percent of the elements in the environment represent 80 percent of the risk of a significant or critical system failure. Organizations should identify those components with the greatest potential critical risk and take the time to drill down on the specifics of analyzing, monitoring, tracking and maintaining them. At the same time, identifying non-critical, low-risk and/or replicated components means that maintenance staff do not waste time on activities that yield little or no benefit from a risk- or cost-management perspective.	Minimal discrimination between the different component profiles and priorities.
2	System boundary definition	Identifying the mechanical and physical boundaries of the facility, system and sub-systems and where inputs/outputs cross those boundaries is one aspect of the RCM analysis process.	Not considered.
3	System description and functional block diagram	To assess system parameters, the RCM analysis also looks at a description of each component of the system (its function, performance specifications, tolerances, etc.). This helps establish a baseline status of the system against which ongoing performance or degradation can be measured. Functional diagrams are used to identify the critical path of the system: which components are included in the essential through-line functioning and which components are merely supporting elements (or non-critical components).	Not considered.
4	Functions and functional failures	Since the goal of RCM is to preserve system function, it is critical to assess and define the required functions of the system, what components and equipment provide or support that function, and what functional level is acceptable. Understanding the root causes of failure is also a key component, including consideration of factors such as wear, overload and fatigue.	Component functions are not considered.
5	Failure mode effects analysis	The next step in RCM analysis is defining the effect of failures: if X fails, then Y occurs. In some cases, the consequences of a failure are minimal (e.g., in the case of redundant components) until a certain threshold is reached. Identifying critical versus non-critical failures helps focus attention on those maintenance tasks that are essential.	Minimal correlation of failure modes to preventive maintenance tasks.
6	Logic tree analysis	A logic tree analysis leads data center managers through a very structured analysis of risk to establish the acceptable failure thresholds. There are some components that should be left in place after failure until the threshold is reached. The impact of hands-on maintenance intervention prior to reaching that threshold does not improve reliability; in fact, it can even have a negative impact on overall system performance due to maintenance downtime or the introduction of error into the system. An example of logic tree analysis is shown in Figure 3, below.	Does not assess or assign criticality.
7	Task selection focus: preventive maintenance	When critical versus non-critical failures are clearly identified, a preventive maintenance regimen can be designed that focuses efforts on preventing and managing critical failures and monitoring failure thresholds, while eliminating unnecessary maintenance tasks.	Preventive maintenance strategy is unfocused at best.

Logic tree analysis

An RCM decision logic tree helps data center managers to determine the type of maintenance appropriate for any given sub-system or equipment item. The result of this analysis indicates whether a particular piece of equipment should be maintained reactively (Accept risk and Install redundant units), through a preventive maintenance approach (Define PM task and schedule) or monitor and take maintenance action based on predictions of imminent failure (Define PT&I task and schedule).

Figure 3. RCM logic decision tree



The analysis process ultimately yields one of four possible courses of action for any sub-system or component:

1. Monitor and take action in response to specific conditions (condition-based maintenance)
2. Perform interval (time- or cycle-) based actions (preventive maintenance)
3. Determine that maintenance action will not reduce the probability of failure, so install redundant systems (if redesign is not a solution)
4. Take no action and implement a repair only following a failure (Run-to-Fail).

Implementation

Once the core analysis is completed, the result is a list of tasks and recommendations that must be effectively implemented into a comprehensive maintenance program. The next activity – packaging – includes grouping maintenance tasks to establish schedules and protocols for inspections and phase maintenance of equipment. Effective packaging allows an organization to efficiently maximize the value of the maintenance program, saving both time and cost. Implementing RCM requires the integration of operational and maintenance requirements and the dovetailing of activities to increase efficiency.

Sustaining and evaluating

To realize the full benefit from RCM, a regimen of monitoring and continuous process improvement must be employed. SAE JA1011 describes this as the living program aspect of a legitimate RCM process. Sustaining the benefits of RCM requires effective use of feedback as the vehicle for continuous improvement and fine tuning of an organization's chosen failure management strategy.

No RCM process can predict every future event, or predict changes to the operating environment. By continuing to gather information and accrue experience over time, initial (often conservative) assumptions can be refined. Successful RCM programs allow both maintenance and operations crews to improve execution, and enable them to respond rapidly to new or unpredicted issues and events.

Data and measurements

Another key determinant of RCM success is the use and availability of data. RCM can be accomplished with minimal hard data if personnel have thorough knowledge of the equipment and its maintenance and operational history. Better data yields better results. Organizations need to be wary of misused data, which can lead to unsubstantiated decisions. Care must be taken to balance data, knowledge and reasonable experienced judgment to yield the optimal decisions.

Relevant RCM data includes:

- What are the acceptable levels of performance? It is unreasonable to design a maintenance program that says equipment must be maintained like new. Equipment will degrade, and users must establish an acceptable level of degradation around which to build the failure management strategy.
- Are there compensating provisions? Compensating provisions should be documented in the FMECA and are critical to ensuring the correct failure management strategy is developed. If a function is protected, a greater degree of risk may be acceptable than if it is unprotected.
- What are the detection methods that will alert when a component has failed, or will help determine the underlying failure condition? This information is important both to separate hidden and evident functions, and to establish the options to pursue in terms of the failure management strategy.
- What are the characteristics of failure? Is there some condition that precedes failure in a predictable manner and that can be detected? If so, organizations can pursue various forms of on-condition tasks. The potential to use many proven detection technologies such infrared or vibration analysis are contingent upon understanding these precursors.
- Can the time between potential and functional failure be defined to a reasonable degree? Measures like crack and flaw growth rates are instrumental in establishing appropriate inspection intervals. Analyzing degradation curves and similar data that help establish patterns of failure progression will pay dividends in the form of a safe and effective strategy.
- Have engineers developed fatigue lives or wear out curves? Can the maintenance organization track individual items to establish a probability of failure pattern?
- Are individual items tracked? Organizations should collect data on maintenance actions from the pilot report of a problem to the ultimate identification of the failure mode and corrective action. Limited data on a sample of the population is often more reliable and usable than huge amounts of cursory information.
- Can analysis link costs, downtime and operational impacts to the associated failures and repairs? Reasonable estimates will often suffice, but good data will yield better results.

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Better data yields better results.

Summary

Once an organization has decided to undertake RCM, the following planning steps can be applied to any implementation:

- Establish the team and develop the RCM plan
- Gather maintenance engineer and operator input
- Obtain technical and maintenance data
- Perform the RCM analysis
- Identify the various options
- Package the PM tasks and age exploration requirements
- Take steps to implement other actions as applicable
- Develop and issue the necessary manuals and specifications
- Gather feedback to update and refine the implementation
- Update the analysis based on the new information or changes to the equipment or operating context
- Repeat the process periodically where potential for improvements are identified.

Early successes with RCM can help establish new patterns and a culture that will solicit the commitment needed to gain the maximum benefit organization-wide.

RCM success is best accomplished over the long haul. If RCM becomes nothing more than creating and documenting justification for decisions already made, it will quickly lose relevance and value. However, early successes with RCM can help establish new patterns and a culture that will solicit the commitment needed to gain the maximum benefit organization-wide.

About Skanska

Skanska's Mission Critical Center of Excellence (COE) offers a radically different delivery method. Our full complement of strategies and tools provides our clients with greater options to plan, design, construct and operate their facilities. Our approach integrates an in-depth focus on business needs and leverages a wide-range of technologies and tools. This approach has proven invaluable in advancing our clients' capacity planning efforts, improving asset utilization and dramatically reducing energy consumption portfolio-wide.

Skanska USA is one of the largest, most financially sound construction networks in the country serving a broad range of industries including healthcare, education, sports, data centers, government, aviation, transportation, and water/wastewater. Headquartered in New York with 36 offices across the country, Skanska USA employs approximately 9,400 people who are committed to sustainable construction and an injury-free workplace.

SKANSKA

Skanska USA Building Inc.
www.skanska.com

350 Fifth Avenue
32nd Floor
New York, NY 10018
P: 917.438.4500

Author

Lee Kirby
Vice President, Strategic Operations

For more information, please contact us at MissionCritical@Skanska.com or check our web site at **www.usa.skanska.com/missioncritical**