CHAPTER 2

ESSENTIAL ELEMENTS OF A SUCCESSFUL RCM PROGRAM

2-1. RCM implementation plan

An overview of steps of the RCM process is shown in figure 2-1.

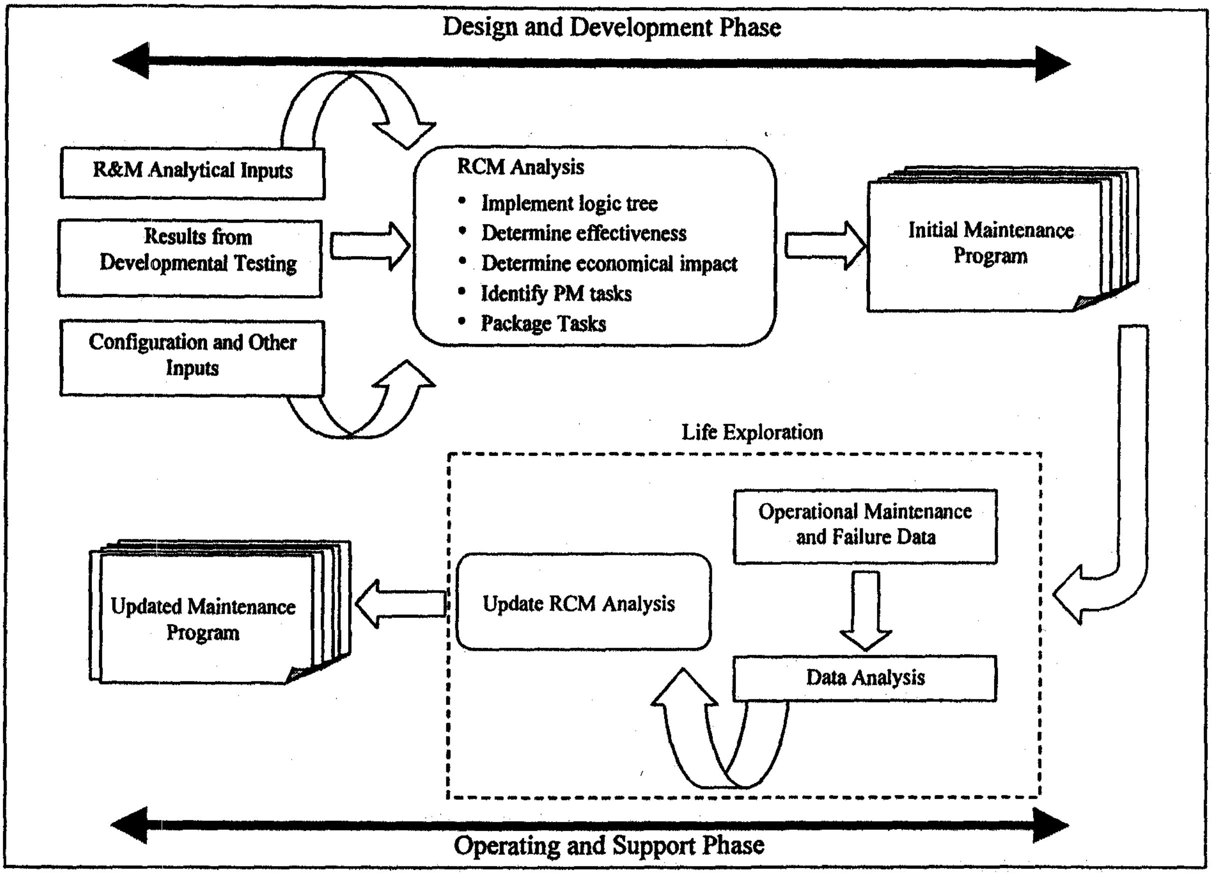

Figure 2-1. The RCM process starts in the design phase and continues for the life of the system.

a. *Major tasks.* As shown in figure 2-1, several major tasks are required to implement the RCM concept.

(1) *Conduct supporting analyses.* RCM is a relatively information-intensive process. To provide the information needed to conduct the RCM analysis, several supporting analyses are either required, often as prerequisites to beginning the RCM analysis, or desirable. These supporting analyses include the Failure Modes and Effects Analysis, Fault Tree Analysis, functional analysis, and others.

(2) *Conduct the RCM analysis.* The RCM analysis consists of using a logic tree to identify effective, economical, and, when safety is concerned, required PM. (As will be seen, PM is required when safety is involved; if no PM is effective, then redesign is mandatory).

b. *The implementation plan.* Planning to implement an RCM approach to defining the PM for a system or product must address each of the tasks noted in the preceding paragraph. The plan must address the supporting design phase analyses needed to conduct an RCM analysis. Based on the analysis, an initial maintenance plan, consisting of the identified PM with all other maintenance being corrective, by default, is developed. This initial plan should be updated through Life Exploration during which initial analytical results concerning frequency of failure occurrence, effects of failure, costs of repair, etc. are modified based on actual operating and maintenance experience. Thus, the RCM process is iterative, with field experience being used to improve upon analytical projections.

2-2. Data collection requirements

a. *Required data.* Since conducting an RCM analysis requires an extensive amount of information, and much of this information is not available early in the design phase, RCM analysis for a new product cannot be completed until just prior to production. The data falls into four categories: failure characteristics, failure effects, costs, and maintenance capabilities and procedures.

(1) *Failure characteristics.* Studies conducted by the MSGs and confirmed by later studies showed that PM was effective only for certain underlying probability distributions. Components and items, for example, for which a constant failure rate applies (e.g., the underlying probability distribution is the exponential) do not benefit from PM. Only when there is an increasing probability of failure should PM be considered.

(2) *Failure effects.* The effects of failure of some items are minor or even insignificant. The decision whether or not to use PM for such items is based purely on costs. If it is less expensive to allow the item to fail (and then perform CM) to perform PM, the item is allowed to fail. As stated earlier, allowing an item to fail is called run to failure.

(3) *Costs.* The costs that must be considered are the costs of performing a PM task(s) for a given item, the cost of performing CM for that item, and the economic penalties, if any, when an operational failure occurs.

(4) *Maintenance capabilities and procedures.* Before selecting certain maintenance tasks, the analyst needs to understand what the capabilities are, or are planned, for the system. In other words, what is or will be the available skill levels, what maintenance tools are available or are planned, and what are the diagnostics being designed into or for the system.

b. *Sources of data.* Table 2-1 lists some of the sources of data for the RCM analysis. The data elements from the Failure Modes and Effects Analysis (FMEA) that are applicable to RCM analysis are highlighted in paragraph 5-5b. Note that when RCM is being applied to a product already in use (or when a maintenance program is updated during Life Exploration – see paragraph 5-5e), historical maintenance and failure data will be inputs for the analysis. An effective Failure Reporting and Corrective Action System (FRACAS) is an invaluable source of data.

Table 2-1. Data sources for the RCM analysis

Data Source	Comment
Lubrication requirements	Determined by designer. For off-the-shelf items being integrated into the product, lubrication requirements and instructions may be available.
Repair manuals	For off-the-shelf items being integrated into the product.
Engineering drawings	For new and off-the-shelf items being integrated into the product.
Repair parts lists	
Quality deficiency reports	For off-the-shelf items being integrated into the product.
Other technical documentation	For new and off-the-shelf items being integrated into the product.
Recorded observations	From test of new items and field use of off-the-shelf items being integrated into the product.
Hardware block diagrams	For new and off-the-shelf items being integrated into the product.
Bill of Materials	For new and off-the-shelf items being integrated into the product.
Functional block diagrams	For new and off-the-shelf items being integrated into the product.
Existing maintenance plans	For off-the-shelf items being integrated into the product. Also may be useful if the new product is a small evolutionary improvement of a previous product.

Table 2-1. Data sources for the RCM analysis (Cont'd)

Data Source	Comment
Maintenance technical orders/manuals	For off-the-shelf items being integrated into the product.
Discussions with maintenance personnel and field operators	For off-the-shelf items being integrated into the product. Also may be useful if the new product is a small evolutionary improvement of a previous product.
Results of FMEA, FTA, and other reliability analyses	For new and off-the-shelf items being integrated into the product. Results may not be readily available for the latter.
Results of Maintenance task analysis	For new and off-the-shelf items being integrated into the product. Results may not be readily available for the latter.

2-3. Data analysis

Data can be considered the lifeblood of RCM. The data from the sources listed in table 2-1 is used in several ways. Data provides the basis for determining the failure characteristics of items. It is also used to evaluate the effectiveness of specific PM tasks used on past systems. Economic data provides the basis for determining whether PM is more economical than running an item to failure (only done when safety is not affected).

2-4. Commitment to life cycle support of the program

a. The Process Perspective. As will be shown in this section, RCM must be viewed as a continuing process, rather than an event that occurs once. Although a maintenance program based on RCM should be developed during design, it should be refined throughout the operational life of the system. In addition, RCM can be used to develop a maintenance program for an existing system for which the initial maintenance program was not based on RCM

b. Learning from Experience. Much of the information used to develop an RCM program, either during design for a new system or after fielding for an existing system will be based on estimates, may change over time, or be subject to some combination of these two factors. Consequently, it is essential to use experiential data to update the maintenance program.

2-5. RCM as a part of design

It is ideal to implement an RCM approach during the design and development of a new system to develop a maintenance program. The reasons will be briefly discussed here but will become clearer as the reader proceeds through the remaining sections of this TM.

a. *Effective use of analyses.* During design and development, numerous analyses are performed. Many of these analyses directly support an RCM analysis. In turn, the results of going through the RCM process of developing a maintenance program can affect and contribute to these analyses. Obviously, implementing RCM during design and development makes very effective use of analyses that are usually performed.

b. *Impact on design.* As will be seen when the RCM logic diagrams are discussed, redesign is either mandatory or desirable in many cases. The cost and level of effort of design changes made during the design and development phase of a system are much less than if they were made after the system was fielded. Additionally, the effectiveness of design changes is higher when made during the design and development phase. Of course, RCM can and is used to develop maintenance programs for fielded systems, for which RCM was not applied during design and development. However, it is always best to implement RCM during design and development.

2-6. Focus on the four Ws

Discussion of the four Ws: what can fail, why does it fail, when will it fail, and what are the consequences of failures.

a. *What can fail?* In determining required maintenance, the first and most fundamental question that must be answered is what can fail. A variety of methods can be used to answer this question.

(1) *Analytical methods*. Failure Modes and Effects Analysis, Fault Tree Analysis, and relayed analyses address, among other issues, what can fail that will prevent a system, subsystem, or component from performing its function(s).

(2) *Test*. Analytical methods are not infallible and a particular failure may be overlooked or cannot be anticipated by analysis. Testing often reveals these failures. Testing can, of course, also be used to confirm or validate the results of analytical methods.

(3) *Field experience*. Often, the same type of component, assembly, or even subsystem that is already used in one system may be used in a new system. If data is collected on field performance of these components, assemblies, and subsystems, it can be used to help answer the question, what can fail. Obviously, field experience is equally applicable to RCM when applied to an already fielded system.

b. *Why does an item fail*? To determine which, if any preventive maintenance tasks are appropriate, the reason for failure must be known. Insights into the modes and mechanisms of failure can be gained through analysis, test, and past experience. Some of the analytical methods are the same as those used to determine What Can Fail. The methods include the FMEA and FTA. Others include root cause analysis, destructive physical analysis, and non-destructive inspection techniques. Table 2-2 lists some non-destructive inspection (NDI) techniques (see table 5-3 for a more complete listing) and table 2-3 lists some of the modes and mechanisms of failure.

Table 2-2. Non-destructive inspection (NDI) techniques, briefly

Acoustic emission	Magnetic particle examination
Dye penetrant	Radiography
Eddy current	Spectrometric oil analysis
Emission spectroscopy	Stroboscopy
Ferrography	Thermography
Leak testing	Ultrasonics

Table 2-3. Examples of failure mechanisms and modes

	Modes	
Stuck open (valve)	Fractured (shaft)	Wear (bearing)
Shorted (connector)	Leakage (seal)	Slippage (belt drive)
Low torque (motor)	Excessive friction (shaft journal)	Short (resistor)
	Mechanisms	
Brinelling (bearing ring)	Spalling (concrete)	Elongation/yielding (structure)
Fretting (pump shaft)	Condensation (circuit board)	Freezing (battery)
Ionization (microcircuit)	Glazing (clutch plate)	Fatigue (springs)
Plastic deformation (springs)	Wear (clutch plate)	Galvanic corrosion (structure)

c. *When will an item fail*? If the underlying time to failure distribution is known for a part or assembly, then the probability of failure at any point in time can be predicted. For some items, the underlying distribution is exponential and the item exhibits a constant failure rate. In such cases, a new item used to replace an old item has exactly the same probability of failing in the next instant of time as did the old item. Consequently, changing such an item at some prescribed interval has no effect on the probability of failure. It makes more sense to run the item to failure. If that is not possible, if safety is involved for example, then redesign is necessary. As shown in figure 2-2, only a small percentage of items can benefit from PM. Knowing the underlying distribution of times to failure is essential in determining if PM is applicable.

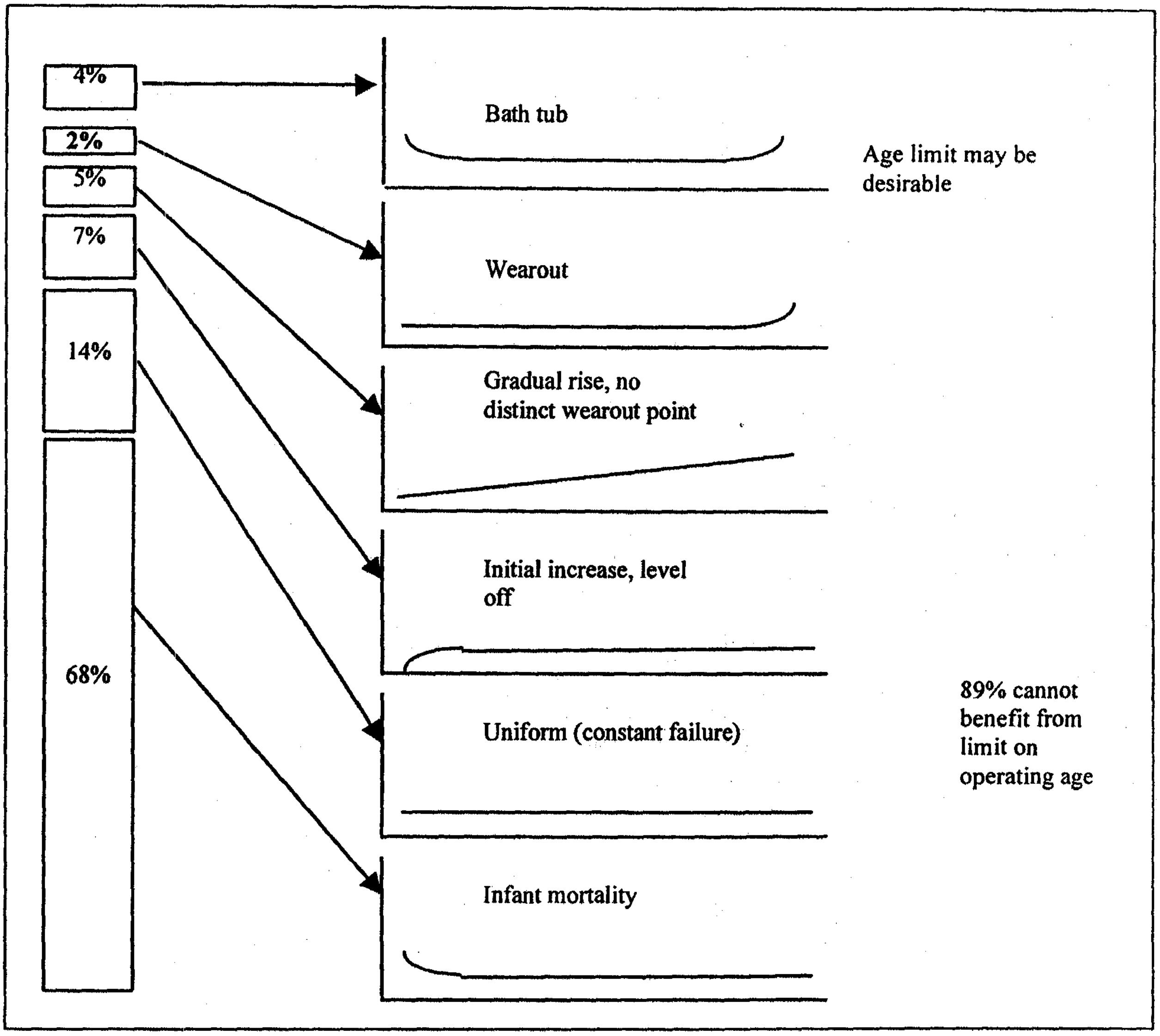

Figure 2-2. Applicability of age limit depending on failure pattern

d. *What are the consequences of the item failing?* Not all failures are equal in their effect on the system. Obviously, any failures that can cause death or injury to system operators or maintainers, or others who may be served by the system (e.g., airline passengers) or are nearby are the most serious. Very close in seriousness are failures that can result in pollution to the environment or a violation of government statutes. At the bottom of the list are failures such as cosmetic damage and other problems that have no effect on system operation. Knowing the effect of a failure helps prioritize decisions. Serious failures usually demand some form of PM or redesign is necessary. Minor failures usually do not lead to redesign and PM is performed only if it is less expensive than running the item to failure. Table 2-4, on the following page, lists some examples of failure effect categorization used in FMEAs and in the RCM process. The manner in which failure effects are categorized for C4ISR facilities should be based on the functions of the facility. Obviously, any failure that could kill or injure personnel or cause loss of the C4ISR mission would have to be categorized as the most serious. The criteria shown in table 2-4 or some combination could be the basis for a C4ISR facility-specific categorization approach. Note that in using the RCM approach to developing a PM program, all failure must be put into one of three categories. These categories are used in the logic trees.

Table 2-4. Examples of failure effect categorization

AIAG Standard (Automobile Industry Standard)		
Effect	**Severity of Effect**	**Ranking**
Hazardous without warning	Very high severity ranking when a potential failure mode affects safe system operation and/or involves non compliance with federal safety regulation without warning	10
Hazardous with warning	Very high severity ranking when a potential failure mode affects safe system operation and/or involves non compliance with federal safety regulation warning	9
Very High	System/item inoperable with loss of primary function	8
High	System/item operable, but at reduced performance level. User dissatisfied	7
Moderate	System/item operable, but comfort/convenience item inoperable	6
Low	System/item operable, but comfort/convenience item operable at reduced level	5
Very Low	Defect noticed by most customers	4
Minor	Defect noticed by average customer	3
Very Minor	Defect notice by discriminating customer	2
None	No effect	1
Example of a Simplified Categorization		
Critical	Death, loss of system, violation of governmental statute	
High	Injury, loss of some system functions, very high economic loss	
Moderate	Damage to system requiring maintenance at first opportunity, economic loss	
Low	Minor damage to system, low economic loss	
Negligible	Cosmetic damage, no economic loss	
RCM Analysis		
Safety	Directly and adversely affects on operating safety	
Operational	Prevents the end system from completing a mission	
Economic	Does not adversely affect safety and does not adversely affect operations - the only effect is the cost to repair the failure	