Continuously Pushing the Limits of Innovation, Technology & Conventional Thinking

RCM Theory and Concepts Workshop

Module 1 – Introduction

Agenda

- RCM Introduction and Definition
- History
- Policy
- RCM Process Overview

RCM Introduction

Reliability-Centered Maintenance (RCM)

An analytical process used to determine appropriate failure management strategies to ensure safe and cost-effective operations of a physical asset in a specific operating environment.

Failure Management strategies

- Preventive Maintenance (PM) requirements
- Other actions
- Run to failure (No PM)

Helps the maintainer do the right maintenance at the right time.

RCM Introduction

Goal of RCM

- Avoid or reduce failure CONSEQUENCES
- Not necessarily to avoid failures

Failure Consequences are the effects of failure on:

- Personal and Equipment Safety
- Environmental Health/Compliance
- Operations
- Economics

RCM Defined

RCM develops logical failure management strategies based on the following precepts:

- The objective of maintenance is to preserve an item's function(s).
- RCM seeks to manage the consequences of failure – not to prevent all failures.
- RCM is driven first by safety. When safety is not an issue, maintenance must be justified on the ability to complete the mission and finally, on economic grounds.
- RCM acknowledges that at best, maintenance can only sustain the system to its inherent level of reliability within the operating context.
- RCM uses design, operations, maintenance, logistics, and cost data, to improve operating capability, design and maintenance.
- RCM is a continuous process that requires sustainment throughout the life cycle.

RCM Defined

- Currently there are many processes that call themselves RCM
- SAE JA1011 provides criteria to distinguish processes that follow the original tenets of RCM
- This workshop is based on the RCM methodology defined in SAE JA1011. Today the US Army performs RCM in accordance with SAE JA1011.

RCM Defined

SAE JA1011 “Evaluation Criteria for RCM Processes” defines seven questions for RCM:

- What are the functions…of the asset…(functions)?
- In what ways can it fail…(functional failures)?
- What causes each functional failure (failure modes)?
- What happens when each failure occurs (failure effects)?
- In what way does each failure matter (failure consequences)?
- What should be done…(proactive tasks and intervals)?
- What should be done if a suitable proactive task cannot be found?

  Also requires a “Living Program”

History of RCM

HOW DID RCM COME ABOUT?

- Early PM Programs were based on the concept that periodic overhauls ensured reliability and, therefore, safety.

- Aircraft overhauls were often massive teardown and rebuild efforts with the expectation that failures would be prevented due to these events.

History of RCM

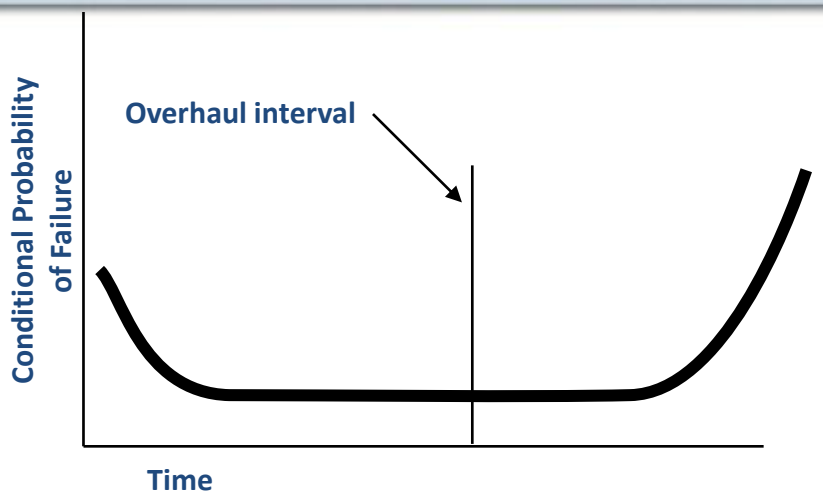
HOW DID RCM COME ABOUT?

- In 1960's, Commercial airlines questioned value of overhauls
  - Rising costs, without more reliability
  - 747 would have required millions of man-hours under previous maintenance philosophy

- FAA and airlines established "Maintenance Steering Group (MSG)" to investigate new approaches
- MSG logic developed and first applied to Boeing 747
- 1978 DoD commissioned United Airlines to develop maintenance analysis process
- Stan Nowlan and Howard Heep Report coined RCM term

History of RCM

OVERHAUL PHILOSOPHY
ASSUMES THIS
IS TRUE……



What the airlines discovered

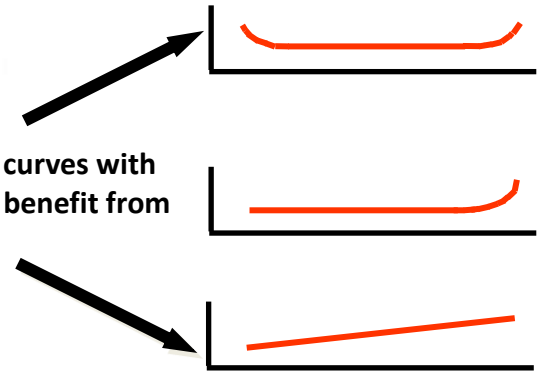
- Statistical analysis showed, in most cases, no change in safety or reliability when overhaul limits changed.
- Initial overhaul limits were not analytically based.
- High repair costs for little or no benefits.

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.

History of RCM

WEAR OUT CURVES



	UAL 1968	Broberg 1973	MSP 1982
Wear Out curves with potential benefit from overhaul	4%	3%	3%
	2%	1%	17%
	5%	4%	3%
Wear Out curves without potential benefit from overhaul	7%	11%	6%
	14%	15%	42%
	68%	66%	29%

Ranges from 8% to 23%

Ranges from 77% to 92%

RCM History

Alternatives to Overhaul based maintenance

- Inspections
  - Look for “potential failure” condition
  - Leaves item in-service for more of its useful life
- “Fly to failure”
  - When consequences are severe - not an option
  - When consequences are acceptable - “fly to failure” may be best approach for cost/mission
- RCM applies the most appropriate maintenance philosophy to each failure mode based on available data

History of RCM

1965: Studies show scheduled overhaul of complex equipment has little or no effect on in-service reliability

1967-68: Airline and manufactures form Maintenance Steering Group (MSG) and produce MSG 1, " Handbook: Maintenance Evaluation and Program Development." First applied to Boeing 747

1970: MSG handbook updated to MSG-2, "Airline/ Manufactures Maintenance Program Planning Document". Applied to L-1011 and DC-10

1972: MSG-2 techniques applied to NAVAIR systems (P-3A, S-3A, and F-4J)

1975: NAVAIR applied Analytical Maintenance Program to Naval aircraft and engine programs, using MSG-2 type logic (NAVAIR 00-25-400)

1978: Department of Defense (DOD) sponsored DOD report AD-A066579, "Reliability Centered Maintenance" by Nowlan and Heap - Updates MSG-2 approach with better guidance on process and interval determination

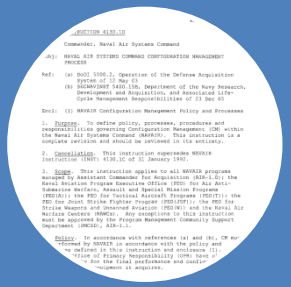
Foundation of Modern Day RCM Processes

History of RCM

1980: Army issued Army Pamphlet 750–40, “Guide to RCM for Fielded Equipment ”

1981: DOD issued MIL-HDBK-266, “Application of RCM to Naval Aircraft, Weapon Systems and Support Equipment” to implement RCM concepts from N&H Report

1983: MSG-3 issued. Used in design of Boeing 757 and 767 aircraft. Added emphasis on structural inspection programs. Similar to RCM, but lacked guidance on interval determination



1985: US Air Force (USAF) issued MIL-STD-1843, " RCM Requirements for Aircraft, Engines and Equipment“ - Similar to MSG-3 (Cancelled without replacement in 1995, USAF Instructions contain current policy/guidance)

1986: NAVAIR issued MIL-STD-2173, "RCM Requirements for Naval Aircraft, Weapons Systems and Support Equipment". Superseded MIL-HDBK-266 & NAVAIR 00-25-400

Also in **1986** NAVAIR 00-25-403 issued to provide Age Exploration guidance

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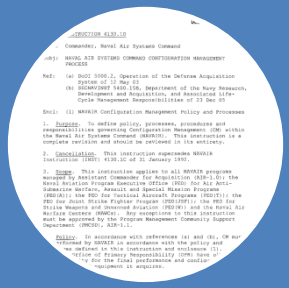
History of RCM



1992: Coast Guard issued CGTO PG–85–00–30, “Aeronautical Engineering Process Guide for RCM Process”

Mid 1990’s DOD directs replacement of Military Standards with commercial standards. DOD asks SAE to develop “commercial” RCM standard

1996: NAVAIR updated NAVAIR 00-25-403 to contain complete RCM process due to cancellation of MIL-STDs

Also in the 1990’s: Nuclear Power industry adopts approach due to focus on avoiding “safety consequences” while reducing costs

1999: SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) issued SAE JA1011, “Evaluation Criteria for RCM Processes”

History of RCM

Also in the 1990's:

- "RCM II" by John Moubray published in UK in 1990
- "Reliability-Centered Maintenance" by Mac Smith published in US in 1993
- As interest in RCM increased, Others introduced a variety of processes that they called "RCM"

In the 2000's:

- 2001: NAVAIR 00-25-403 updated to capture improvements developed during SAE JA1011 work
- 2002: SAE issued SAE JA1012, "A Guide to the RCM Standard" - amplifies and clarifies key concepts and terms from SAE JA1011
- 200X:DOD Instructions- CBM Standards
- 200X - Current: DOD RCM WIPT effort to collaborate on RCM practices between services

RCM Policy

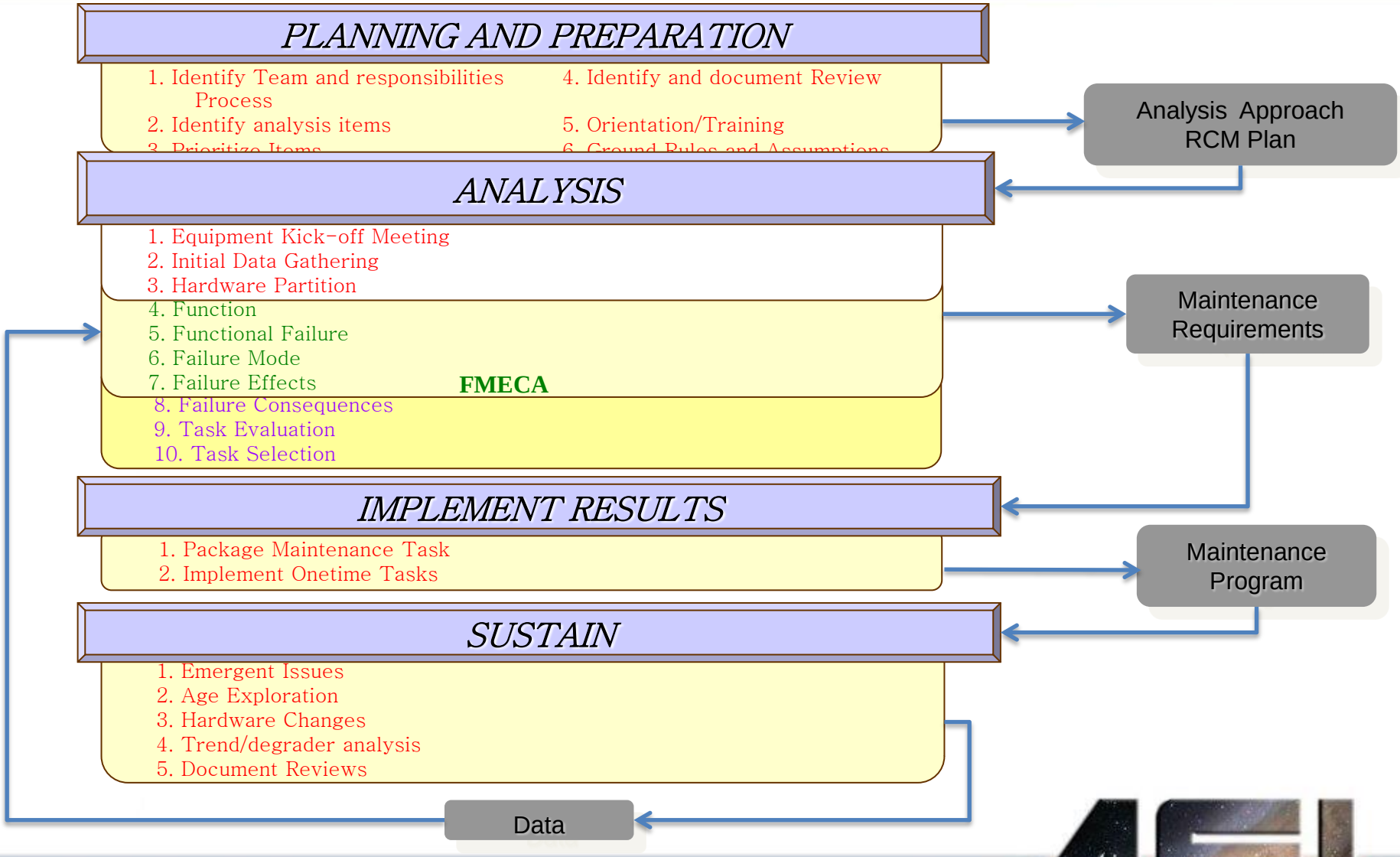
- DoDM 4151.22-M- DOD Reliability Centered Maintenance (RCM) Maunal
  - RCM shall be used to ensure effective maintenance processes are implemented. RCM shall also be used as a logical decision process for determining optimum failure management strategies, including maintenance approaches, and establishing the evidence of need for both reactive and proactive maintenance tasks.
- DoDI 4151.22 Condition Based Maintenance Plus (CBM+) for Materiel Maintenance Instruction
  - It is DoD policy that:
    a. CBM+ be included in the selection of maintenance concepts, technologies, and processes for all new weapon systems, equipment, and materiel programs based on readiness requirements, life-cycle cost goals, and RCM-based functional analysis.
    b. CBM+ be implemented into current weapon systems, equipment, and materiel sustainment programs where technically feasible and beneficial. This decision shall be based on any or all of the following:
       1) Results of reliability analyses, including RCM in accordance with Enclosure 3.
       2) Findings from CPI initiatives.
       3) Technology assessments.
       4) Business case analyses.
- DoD 5000 Operation of the Defense Acquisition System Instruction
  - Emphasizes RCM as a critical life-cycle process

RCM Process Overview

There are 4 basic elements of an RCM Program:

1. Planning and Preparation
2. RCM Analysis
3. Implementation of Results
4. Sustaining the Analysis

RCM Process Overview



RCM Process

Planning and Preparation

- Identifies and resolves issues that must be addressed prior to beginning an analysis.

- Answers the following:
  - Who
  - What
  - In what order
  - How
  - With what resources
  - When

RCM Analysis

Once an asset has been selected for analysis and the proper groundwork has been accomplished, the analysis phase begins.

Analysis Steps:

- Equipment Kick-off Meeting
- Initial Data gathering
- Hardware Partitioning
- FMECA
- Failure Consequences
- Task Evaluation
- Task Selection

RCM Process

Implementation

When complete, the RCM analysis provides a list of maintenance tasks and recommendations.

In order to realize the benefits of these recommendations, they need to be incorporated into a coherent and efficient maintenance program.

"Packaging" is the process of combining discrete maintenance recommendations into a maintenance program.

RCM Process

Sustainment

As with many other processes, a large part of the benefit of RCM may be realized over time through a process of formal monitoring and continuous improvement…

Initial analysis may need update over time:

- Incorrect assumptions on initial analysis
- Hardware changes
- Unexpected failures
- Operating environment changes
- Other emergent issues

Module Summary

- RCM Introduction and Definition
- History
- Policy
- RCM Process Overview

Questions ?

Backup Slides

Hazard Risk Matrix Example:

SEVERITY \ FREQUENCY	FREQUENT ≥ 1 per 1,000 Hours	PROBABLE ≥ 1 per 10,000 Hours	OCCASIONAL ≥ 1 per 100,000 Hours	REMOTE ≥ 1 per 1,000,000 Hours	IMPROBABLE < 1 per 1,000,000 Hours
CATASTROPHIC (I) • Death or Severe Injury • Significant Environmental Impact • Damage > $1M • Loss of availability > 1 week	1 HIGH	2 HIGH	4 HIGH	8 MED	12 ACCEPT
CRITICAL (II) • Minor Injury • Damage >$100K and < $1M • Loss of availability > 24 hrs and < 7 days	3 HIGH	5 HIGH	6 MED	10 LOW	15 ACCEPT
MARGINAL (III) • Damage >$10K and < $100K • Loss of availability > 4 hrs and < 24 hrs	7 MED	9 MED	11 LOW	14 ACCEPT	17 ACCEPT
MINOR (IV) • Damage <$10K • Loss of availability < 4 hrs	13 ACCEPT	16 ACCEPT	18 ACCEPT	19 ACCEPT	20 ACCEPT

FMECA

FMECA: Failure Mode, Effects, and Criticality Analysis

- Process used to identify, document, and rank the importance of potential failure modes for a system or piece of equipment:

Steps involve identifying...

- **Functions – what it does for you**
- **Functional Failures – how it fails to do it**
- **Failure Modes – why it fails to do it**
- **Failure Effects – what happens**
- **Severity of Failure – How bad it is**
- **Failure Frequency – How often it happens**
- **Failure Detection – How failures are identified**