Continuously Pushing the Limits of Innovation, Technology & Conventional Thinking

RCM Theory and Concepts Workshop
Module 3- Implementation and Outcomes

Agenda

- Implementation
- Sustainment
- Benefits
- Requirements for Success
- Pitfalls
- Software Overview
- Case Studies

Implementation Options

Scope of Analysis:

- **Full Analysis**
  - **All “reasonable likely” failure modes**
- **“Tailored” Analysis**
  - **Existing PM Tasks**
  - **Pilot or demonstration study**
  - **High cost/availability degrader failures**
  - **Hidden Failures**
  - **Combination of above**

Implementation Options

Scope of analysis: Which is best?

- Dependent mainly on goals and available resources
  - Funding/personnel resources/management commitment
  - Objectives of analysis
  - Fix current “headaches” vs. maintenance optimization
  - “Age/Remaining planned Life” of analysis items
  - Potential risk vs. return
  - Criticality analysis (Risk Indices) may be used to further prioritize or limit the analysis
- Some is usually better than none!

MUST ensure potential safety/environmental compliance issues are not overlooked in less than complete analysis!

Implementation Options

- Execution methods: Facilitated Group vs. Dedicated Analyst
  - Facilitated group approach
    - Analysis is performed during meetings of key personnel in presence of a facilitator
    - Maximizes buy-in from participants
    - Limited by amount of time key persons can attend meetings
    - Less emphasis on detailed/analytical solutions
    - Sustaining effort less likely to continue

Implementation Options

- Execution methods: Facilitated Group vs. Dedicated Analyst

  - Dedicated analyst
    - Analysis is performed by dedicated RCM expert(s) using information gathered from subject matter experts and other sources
    - Still must include participation of key SMEs (operators/maintainers) for analysis to be effective
    - Less daily impact on non-RCM analyst participants
    - Participants don't need extensive RCM training, just basic orientation
    - More conducive to outside analytical assistance (outsourcing)
    - Requires dedicated personnel

Implementation Options

- **Execution methods: Facilitated Group vs. Dedicated Analyst**

Which is best?

Again depends on goals and resources of each organization

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

Sustainment

- **The sustainment process must continually monitor and optimize the failure management strategy by:**
  - **Deleting unnecessary requirements or adjusting intervals**
  - **Identifying adverse failure trends**
  - **Addressing new Failure Modes**
  - **Pursuing opportunities for insertion of new maintenance procedures, techniques, design changes, and tools**
- **Sustainment methods include:**
  - **Emergent issue resolution**
  - **Root cause analysis**
  - **Degrader analysis**
  - **Trend analysis**
  - **Fleet reviews**

RCM Benefits

If performed properly, RCM will:

- Maximize safety and environmental health
- Depending on objective:
- Reduce overall maintenance cost
- Improve realized reliability/availability
- Provide a documentation trail for maintenance program changes
- Provide a vehicle for continuous improvement of the maintenance program and equipment performance

RCM Benefits

Who is using RCM now?

- Military – US, UK, Others
- NASA – spacecraft, facilities
- Commercial Airlines
- Power Generation – Fossil, Nuclear
- Oil – Production, refining, distribution
- Manufacturing
- Pulp & Paper
- Mining
- Facilities (buildings)
- Pharmaceuticals
- Steel
- Data Centers
- Many others…

RCM Benefits

- **Provide a basis for cost benefit analysis and identify needs for:**
  - Capital investment (equipment replacement)
  - Technology insertion (such as condition monitoring systems)
- **Provide input into spares forecasting**

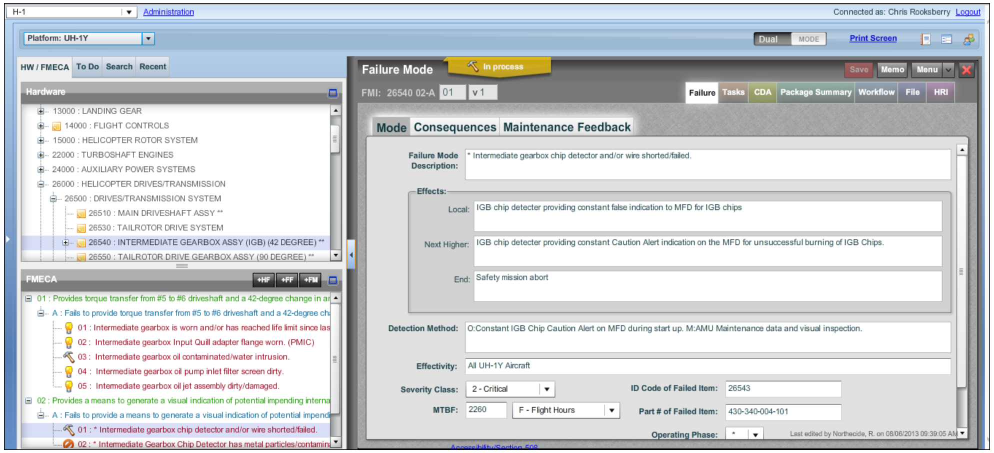
Requirements for Success

- A champion/internal leadership
- Management commitment
- Resources for execution AND IMPLEMENTATION
- Planning
- Communication
- Access to experts and data
- Get some “early wins”

Pitfalls

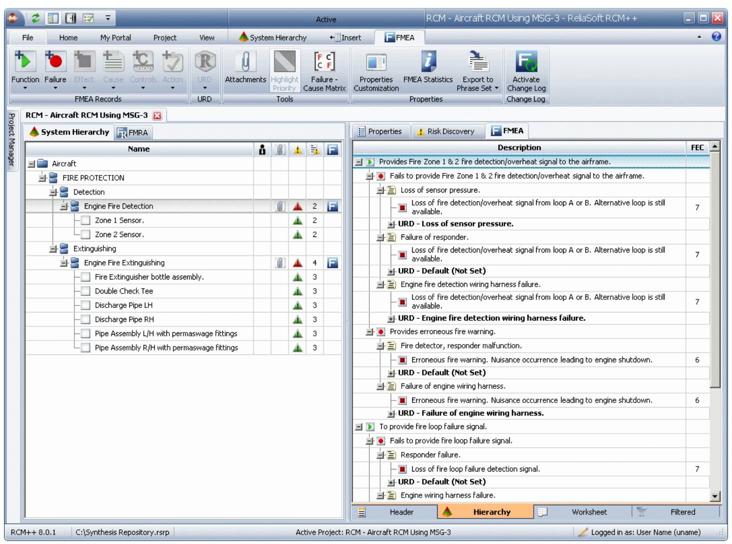
- **Not sustaining after initial analysis**
- **Wrong person in charge**
- **Starting too big**
- **Not planning ahead for implementing results**
- **Underestimating the effort**
  - Plan and get resources for help

Software Overview



Integrated Reliability-Centered Maintenance System (IRCMS) Software

- Government owned
- Developed by NAVAIR
- Used on wide array of equipment types



ReliaSoft's RCM++

- COTS
- Available thru AMRDEC

Next workshop will cover ReliaSoft's RCM ++

EA-6B Prowler

Case Studies

Description: EA-6B Prowler

The EA-6B Prowler is a carrier based twin-engine, mid-wing aircraft manufactured by Grumman Aerospace Corporation. It is a fully integrated electronic warfare system combining long-range, all weather capabilities and advanced electronic countermeasures.

Design Life: 12,500 Flight Hours

Number of Items in operation: 123 +/-

Case Studies

RCM Overview:

Perform a complete RCM analysis on the entire aircraft to develop a new depot maintenance concept. Goal was to significantly reduce maintenance cost and out of service time and provide more predictable costs by changing from a variable depot induction to a fixed induction schedule.

Case Studies

• RCM Case Study Issues:

- HWP from WUC manual (3M data follows)
- Subsystem level analysis
- Separate treatment of paint system 11Z (made up WUC)
- FMC 11Z 01A05
    - FM is for paint too thick -> cracks -> corrosion
    - HT task for strip and paint (interval dependent on lab work)
    - Main driver (but not only) for depot induction
- FMC 11300 04A01: Corrosion in “football” area of vertical fin.
    - Environment: Tail hangs over side of carrier.
    - Use of CPC in service/lube task. Re-application interval per mfg recommendations (1-2 yrs) and severe environment -> 1 yr.
    - Note failure mode source: depot artisans. No recorded data. (memo field)
    - Note use of email and P&E message for cost info in memo.
    - Cost calculation for tasks and No PM in memo.
    - Point out why tasks were selected over no PM (costs were close, but analysis considered task as stand-alone. When combined with other tasks it was assumed cost effective).

Case Studies

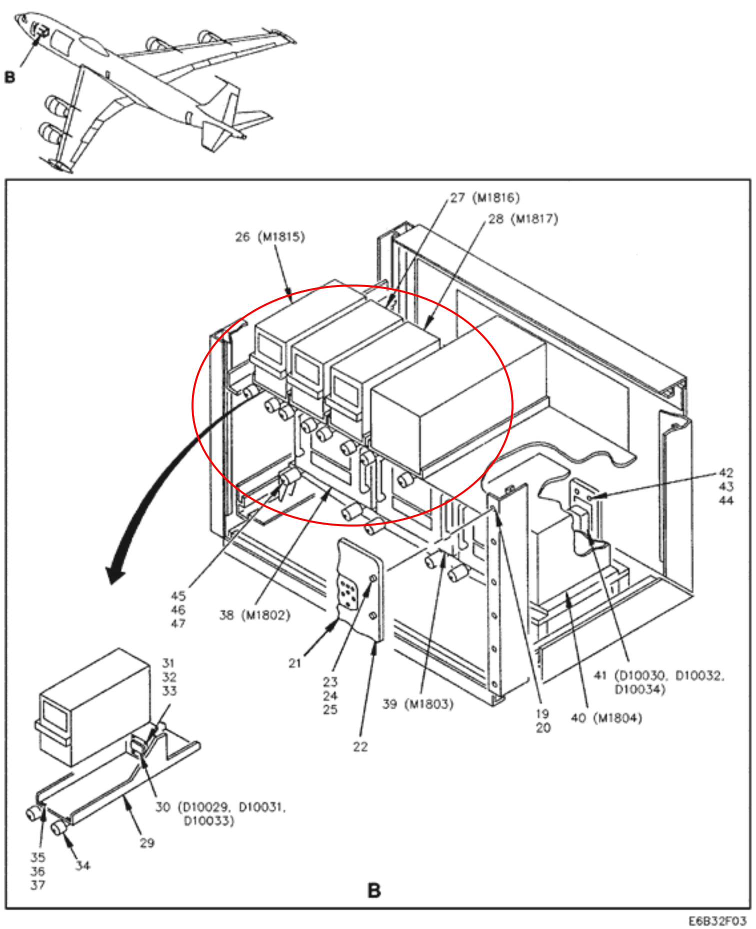
Post RCM Comparison- EA-6B EW Aircraft

4 A/C Squadron over 2 Years										
Pre RCM						After RCM				
Interval	Mhrs	Total Mhrs	TAT	Total TAT		Interval	Mhrs	Total Mhrs	TAT	Total TAT
14 Days	26	2704	0.5	52		14 Days	26	2704	0.5	52
28 Days	93	4836	3	156		28 Days	14	728	0.5	26
56 Days	126	6552	5	260		56 Days	11	572	0.5	26
224 Days	194	2328	5	60		364 Days	200	1600	5	40
ASPA	6	30	2	16		IMCF	109	436	14	56
Annual MHRS		16450		492		Annual MHRS		6040		148
Delta								-10410		-344
106 A/C over 2 Years										
Pre IMC						IMC				
Interval	Mhrs	Total Mhrs	TAT	Total TAT		Interval	Mhrs	Total Mhrs	TAT	Total TAT
14 Days	26	71656	0.5	1378		14 Days	26	71656	0.5	1378
28 Days	93	128154	3	4134		28 Days	14	19292	0.5	689
56 Days	126	173628	5	6890		56 Days	11	15158	0.5	689
224 Days	194	61692	5	1590		364 Days	200	42400	5	1060
ASPA	6	795	2	424		IMCF	109	11554	14	1484
Annual MHRS		435925		13038		Annual MHRS		160060		3922
Delta								-275865		-9116

Case Studies

Description: E-6B Mercury

Case Studies



IRU Battery/Charger Units:

-3 IRU units each one with its own BCU (battery charger unit) are present per aircraft

- The BCU provides backup power to the IRU in case of loss of 115 V aircraft power.

- Each sealed BCU contains a 20-cell battery, a constant-current charger, heaters, controls, and sensors.

- Current PM: scheduled removal for high time at 365 days for Depot routing.

-Batteries are managed as a rotating pool of repairable items.

Case Studies

Total Removals in Period:	**673**
Failures causing removals:	**372**
PM scheduled removals:	**281**
Non failure / PM removals:	**20**

Total Reported Failures in Period: 392

Percentage accounted on top 6 FM: 91.88%

Item MTBF: 1106 F/H

55 % of items are being removed prior to schedule

Is the scheduled PM relevant?

Case Studies

- **RCM – FMECA Conclusions on IRU Battery Charger Units:**

1. **Failure is evident to operator due to automatic self diagnostic upon mission start (reason why so many failures are being caught before high time).**

2. **The three system IRU's are double redundant.**

3. **IRU BCU's are a 2nd level backup to provide power to the IRU (powerplant, BCU).**

4. **Associated PM: 336-day corrosion inspection & every 2 years (2400 F/H) battery and cabinet cleanup.**

5. **No PM is recommended.**

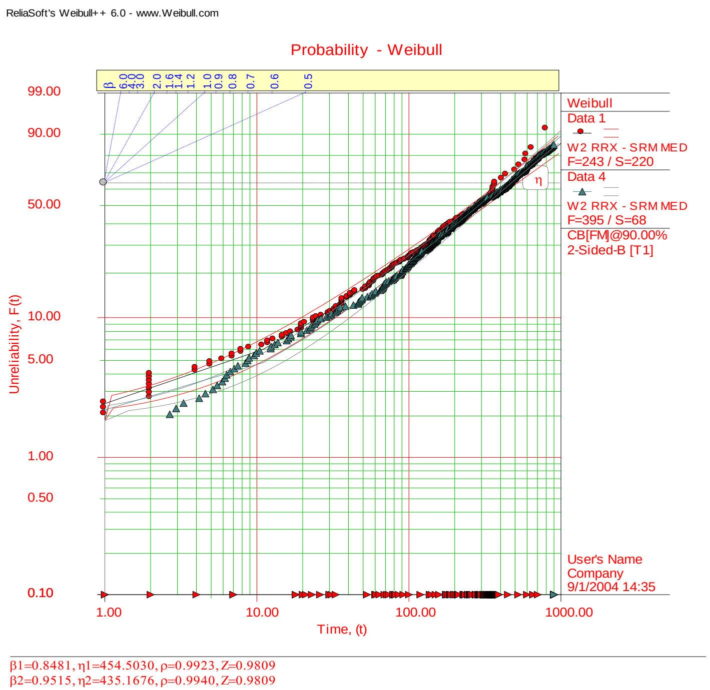
Quantifying the cost savings:

A Monte Carlo simulation of 354 observations was carried out assuming PM was modified to a proposed 900-day interval and its costs were compared to the actual data.

Cost Comparison 365 Day PMIC vs - 900 Day PMIC
Discarding bottom 25% of observations:

# of CHANGES	354
Dollar per change	$3,500.00

		365 PMIC	900 PMIC
TOTAL DAYS OF SERVICE		96681	172179
Cost per day		$12.82	$7.20
Savings per day	$5.62		
SAVINGS ESTIMATION			
Days left of fleet	127659.57		
Years left of fleet	21.86		
Dollar saved per year	**$32,816.96**		
Total saved	**$717,362.89**		



Estimated savings:
78% Increase in service time

Case Studies

Description: Air Turbine Starter (ATS) Test Facility

The ATS Test Facility is small turbine engine fixed mount test cell. It is used to test over 20 air turbine starter models over a wide range of simulated conditions in a controlled environment. Number of Items in operation: 1

Key Issues:

- One of a kind in the world
- Production critical asset

Case Studies

RCM Overview:

RCM analysis was performed to maximize equipment availability and ensure long term longevity of equipment by developing a comprehensive PM program.

RCM approach was to analyze all "significant" failure modes identified through operator and maintainer experience and work order data.

Case Studies

• RCM ATS Case Study Issues:

- **Development of PM program allowed for a one of kind asset to continue organic repair of aircraft engine starters. ATS Stand ran multiple types of Aircraft Starters.**

- **RCM drove the development of several Condition Based Maintenance (CBM)Strategy's**
  - **Vibration Analysis and Oil Analysis– ATS Gearbox**
  - **Infrared Inspections on electrical connections**

- **RCM developed an "Other Action" to address the mixing of different types of oil between F-18 Starters**

Case Studies

Description: F-18 Hornet

RCM Overview:

Issue:

Despite being fielded for several years, proper comprehensive RCM analysis was never completed to ensure cost effective PM policies

Solution:

RCM analysis was performed to implement and document a comprehensive PM program to ensure continued safe operation and minimize maintenance downtime.

RCM approach was to analyze all safety failure modes identified in Engineering Design FMEA.

Case Studies

F/A-18 Super Hornet Case Study Summary:

- Design FMEA previously completed by BOEING and Fleet Engineers contained 10,000+ design failure modes

- Several man-years of effort expended to combine failure modes, and translate into in-service Support failure modes before RCM analysis could be initiated.

- System by system clean up was performed, then all safety failure modes were analyzed to ensure safe operation of A/C

RCM analysis provided following benefits:

- Removed unnecessary maintenance procedures to minimize downtime and costs
- Allowed for proper documentation of maintenance decisions and strategies
- Provided a vehicle for long term sustainment and improvement initiatives (vice only having a design FMEA)
- Identified and corrected critical deficiencies in maintenance publications, tech manuals, and other documents

- Effort is currently on-going

Case Studies

Description: AH-1Z and UH-1Y

Continuously Pushing the Limits of Innovation, Technology & Conventional Thinking

Case Studies

Description:

The AH-1Z is a two seat assault type helicopter. Characteristics are a narrow fuselage, four-bladed main and tail rotors, twin turboshaft engines, weapons pylons, and provisions for a variety of armament.

The UH-1Y is a utility type helicopter. The wide cabin, with large cubic foot volume, permits these helicopters to be used for transportation of personnel, special equipment or supplies.

Design Life: 10,000 Flight Hours

Number of Items in operation: 78 Y's and 32 Z's

Number of Items to be Delivered: 160 Y's and 189 Z's

Case Studies

RCM Overview:

Perform a complete RCM analysis on the entire aircraft during the acquisition phase from BHTI. Highlight and identify and emergent issues while the aircraft is being introduced to the fleet. Goal was to reduce life-cycle costs of maintaining the AH-1Z / UH-1Y aircraft fleet, while concurrently ensuring safety and optimizing aircraft readiness, availability, and reliability.

Case Studies

• RCM Case Study Issues:

- Hardware breakdown used format from OOMA WUC Structure
- Analysis at "Subsystem" level of HWP

- RCM Analysis of H-1 Y and Z Main Rotor PCL Bearings
  - FMC 15100 04-A-01, 02, 03, and 04: Hard Time Task
  - Current 50 FH Inspection takes approximately 2.0 MMH's
  - Recommendation of Deletion of existing On-Condition Task (Originally set at 50 Flight Hour Interval)
  - PCL's found need replacement at 433 FH's
  - Recommend Interval change to existing Phase B Inspection every 400 FH's

Questions ?

Backup Slides