

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

#### 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



#### 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!

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



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

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**

| H-1 Administration  | Connected as: Chris Rocksberry Logaut  |
|---|--|
| Platform: UH-1Y •   | Dual MODE Print Screen 📮 🚍 🍰   |
| HW / FMECA To Do Search Recent  | Failure Mode Sove Memo Menu 🗸 🗙  |
| Hardware  | FMI: 26540 02-A 01 v1 Failure Tasks CDA Package Summary Workflow File HRI  |
| . 13000 : LANDING GEAR  |  |
| B- J14000 : FLIGHT CONTROLS   | Mode Consequences Maintenance Feedback   |
| 15000 : HELICOPTER ROTOR SYSTEM   |  |
|   | Failure Mode * Intermediate gearbox chip detector and/or wire shorted/failed.  |
| B- 24000 : ADXILIARY POWER STSTEMS  |  |
| - 26500 : DRIVES/TRANSMISSION SYSTEM  | Effects:   |
| 3 26510 : MAIN DRIVESHAFT ASSY **   | Locat IGB chip detecter providing constant false indication to MFD for IGB chips   |
| 🥃 26530 : TAILROTOR DRIVE SYSTEM  |  |
| 🖶 - 🛃 26540 : INTERMEDIATE GEARBOX ASSY (IGB) (42 DEGREE) **  | Next Higher: IGB chip detecter providing constant Caution Alert indication on the MFD for unsuccessful burning of IGB Chips. |
| 🥃 26550 : TAILROTOR DRIVE GEARBOX ASSY (90 DEGREE) **   |  |
| FMECA +FF +FM   | End: Safety mission abort  |
| 01 : Provides torque transfer from #5 to #6 driveshaft and a 42-degree change in at   |  |
| - A : Fails to provide torque transfer from #5 to #6 driveshaft and a 42-degree ch  |  |
|   | Detection Method: O:Constant IGB Chip Caution Alert on MFD during start up. M:AMU Maintenance data and visual inspection.    |
| 💡 02: Intermediate gearbox Input Quil adapter flange worn. (PMIC)   |  |
|   | Effectivity: All UH-1Y Aircraft  |
| 💡 04 : Intermediate gearbox oil pump inlet filter screen dirty.   | Enectivity: All On-Tr Alician  |
| 💡 05 : Intermediate gearbox oil jet assembly dirty/damaged.   | Severity Class: 2 - Critical V ID Code of Failed Item: 26543   |
| <ul> <li>02: Provides a means to generate a visual indication of potential impending interna</li></ul>  | MTBF: 2260 F - Flight Hours V Part # of Failed Item: 430-340-004-101   |
| A : Pais to provide a means to generate a visual indication of potential impend<br>01: * Intermediate gearbox chip detector and/or wire shorted/failed. |  |
| O 1: Internediate geabox chip detector analytic wire and technical.   | Operating Phase: * V Last edited by Northeode, R. on 08/06/2013 09:39:05 AM  |

Integrated Reliability-Centered Maintenance System (IRCMS) Software

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

| Palure Effect Cause Controls Action URD Attachment<br>FMEA Records URD URD | S Highl<br>Prior<br>Too | by ( |    | ure -<br>Matrix |     | pertie<br>omizat |  |     |     |
|--|-------------------------|------|----|-----------------|-----|------------------|--|-----|-----|
| M - Aircraft REM Using MSG-3 🛛   |                         |      |    |                 |     | Proper           | ties 🔥 Risk Discovery 📑 FMEA   |     |     |
|  | 10                      | 4    | 14 |                 | Ē   |                  | Description  | FEC |     |
| Aircraft   |                         | -    | -  |                 | 10  | Pro              | vides Fire Zone 1 & 2 fire detection/overheat signal to the airframe.  |     | 1   |
| FIRE PROTECTION  |                         |      |    |                 |     | •                | Fails to provide Fire Zone 1 & 2 fire detection/overheat signal to the airframe.   |     | -   |
| E Detection  |                         |      |    |                 |     | -                | Doss of sensor pressure.   |     |     |
| Engine Fire Detection  | D                       |      | 2  | F               |     |                  | <ul> <li>Loss of fire detection/overheat signal from loop A or B. Alternative loop is still<br/>available.</li> </ul>            | 7   |     |
| Zone 1 Sensor.   |                         | 4    | 2  |                 |     |                  | avaiable.     URD - Loss of sensor pressure.   |     | -11 |
| Zone 2 Sensor.   |                         | 4    | 2  |                 |     |                  | Falure of responder.   |     | -11 |
| Extinguishing  |                         |      |    |                 |     | T,               | - Loss of fire detertion/overheat signal from Joon & or B. Alternative Joon is still   | 7   | -11 |
| Engine Fire Extinguishing  | 0                       |      | 4  | F               |     |                  | avalable.  |     |     |
| <ul> <li>— Fire Extinguisher bottle assembly.</li> </ul>                   |                         | ۰    | 3  |                 |     |                  | uRD - Default (Not Set)  |     | -8  |
| - Double Check Tee   |                         | ۰    | 3  |                 |     | 2                | Engine fire detection wiring harness failure. Loss of fire detection/overheat signal from loop A or B. Alternative loop is still |     | -8  |
| - Discharge Pipe LH  |                         | ۰    | 3  |                 |     |                  | Loss of the detection(overheat signal from loop w or b. Alternative loop is still<br>available.                                  | 7   |     |
| - Discharge Pipe RH  |                         | 4    | 3  |                 |     | 1                | URD - Engine fire detection wiring harness failure.  |     |     |
| — Pipe Assembly L/H with permaswage fittings                               |                         | 4    | 3  |                 | i é | 1                | Provides erroneous fire warning.   |     |     |
| Pipe Assembly R/H with permaswage fittings                                 |                         | 4    | 3  |                 |     | - <b>1</b>       | E) Fire detector, responder malfunction.   |     |     |
|  |                         |      |    |                 |     |                  | Erroneous fire warning. Nuisance occurrence leading to engine shutdown.  | 6   |     |
|  |                         |      |    |                 |     |                  | H URD - Default (Not Set)  |     | -   |
|  |                         |      |    |                 |     | 봐                | Falure of engine wiring harness.   |     |     |
|  |                         |      |    |                 |     |                  | <ul> <li>Erroneous fire warning. Nuisance occurrence leading to engine shutdown.</li> </ul>                                      | 6   |     |
|  |                         |      |    |                 |     |                  | URD - Failure of engine wiring harness.  |     |     |
|  |                         |      |    |                 |     |                  | provide fire loop failure signal.  |     |     |
|  |                         |      |    |                 | ЬŤ  |                  | Falls to provide fire loop failure signal.   |     |     |
|  |                         |      |    |                 |     | 20               | Responder failure.   | -   |     |
|  |                         |      |    |                 |     |                  | <ul> <li></li></ul>  | 7   |     |
|  |                         |      |    |                 |     |                  | URD - Default (Not Set)  Engine wiring harness falure.   |     |     |

ReliaSoft's RCM++

- COTS
- Available thru AMRDEC

#### Next workshop will cover ReliaSoft's RCM ++



# **EA-6B** Prowler





# **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 +/-



#### **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.



### • 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).



#### Post RCM Comparison- EA-6B EW Aircraft

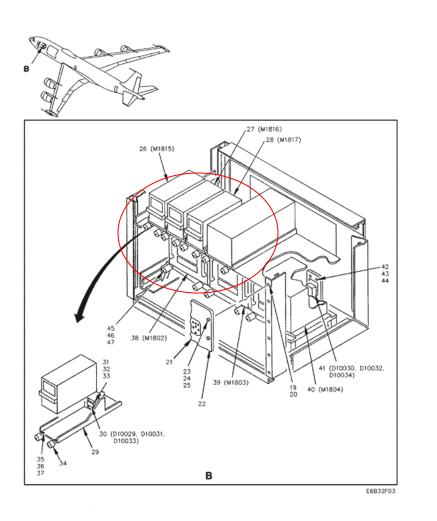
| 4 A/C Squadron over 2 Years |                           |                   |       |                             |       |           |         |                   |        |                  |  |  |  |
|-----------------------------|---------------------------|-------------------|-------|-----------------------------|-------|-----------|---------|-------------------|--------|------------------|--|--|--|
| Pre RCM                     |                           |                   |       |                             |       | After RCM |         |                   |        |                  |  |  |  |
| Interval                    | Mhrs                      | <b>Total Mhrs</b> | TAT   | <b>Total TAT</b>            |       | Interval  | Mhrs    | <b>Total Mhrs</b> | TAT    | <b>Total TAT</b> |  |  |  |
| 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                       | Contraction of the second |                   | -     | A REAL PROPERTY AND INCOME. | diate |           |         | -10410            |        | -344             |  |  |  |
|                             | 106 A/C over 2 Years      |                   |       |                             |       |           |         |                   |        |                  |  |  |  |
| Pre IMC                     |                           |                   |       |                             |       | IMC       |         |                   |        |                  |  |  |  |
| Interval                    | Mhrs                      | <b>Total Mhrs</b> | TAT   | <b>Total TAT</b>            |       | Interval  | Mhrs    | <b>Total Mhrs</b> | TAT    | <b>Total TAT</b> |  |  |  |
| 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            | 1     | 13038                       |       | Annual    | MHRS    | 160060            | JAP.   | 3922             |  |  |  |
| Delta                       | 100                       | A Real Providence | 2. 2. | and and a                   |       | 3164      | Ser Con | -275865           | Sec. 1 | -9116            |  |  |  |



## **Description: E-6B Mercury**







**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.

- 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?



- **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.

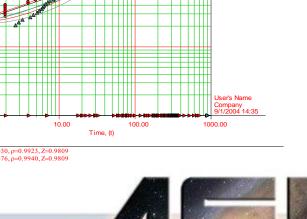


#### Quantifying the cost savings:

# 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.

2:0 1:6 1:2 0:9 0:7 0.7 Cost Comparison 365 Day PMIC vs - 900 Day PMIC 99.00 90.00 Discarding bottom 25% of observations: 50.00 # of CHANGES 354 \$3,500.00 Dollar per change Unreliability, F(t) 00'5 **365 PMIC 900 PMIC** 10.00 TOTAL DAYS OF SERVICE 96681 172179 Cost per day \$12.82 \$7.20 Savings per day \$5.62 1.00 SAVINGS ESTIMATION 0.50 127659.57 Days left of fleet Years left of fleet 21.86 0.10 \$32,816.96 Dollar saved per year 1.00 Total saved \$717,362.89 β1=0.8481, η1=454.5030, ρ=0.9923, Z=0.9809 **Estimated savings:** β2=0.9515, η2=435.1676, ρ=0.9940, Z=0.9809

78% Increase in service time



Probability - Weibull

Weibul Data 1

W2 RRX - SRM MED F=243 / S=220 Data 4

W2 RRX - SRM MED

F=395 / S=68 CB[FM]@90.00% 2-Sided-B [T1]

# **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 worldProduction critical asset



## **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.



- 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



## **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.



## 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 inservice 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



## **Description:** AH-1Z and UH-1Y





# **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

### **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.



# 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**

