Determining Hard Time Task Periods

Risk Based Decision Making

Introduction

Jim Kennedy *CPEng, CFAM, CAMA*
Former Sensei, AM Council of Australia
Member of IEC TC 56 Dependability
Director Interlogis Consulting

Determining Optimum Hard Time Task Periods

Sessions Coverage

1. Maintenance taxonomy;
2. Overview of methods for determining a preventive maintenance program;
3. Approach to identifying optimum task periods for wear out items;
4. Hands on use of a simple spreadsheet model;
5. Discussion on how the described approach achieves a defensible budget

Session 1

Maintenance Taxonomy

What is Maintenance?

All activities necessary to retain an item in or return it to a serviceable condition.

Blanchard 1974
Nowlan and Heap 1978
*IEC International Electrotechnical Vocabulary**

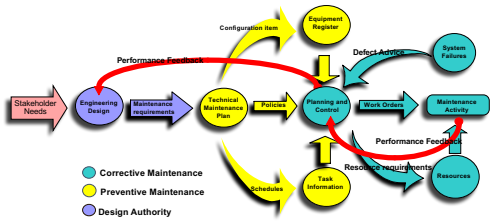
Maintenance Objectives - *Aerospace Industry*

- Preserve inherent levels of safety and reliability designed into equipment
- Restore safety and reliability to their inherent level when deterioration has occurred
- Obtain the information to improve all processes associated with the system lifecycle
- Do the above at lowest cost of ownership

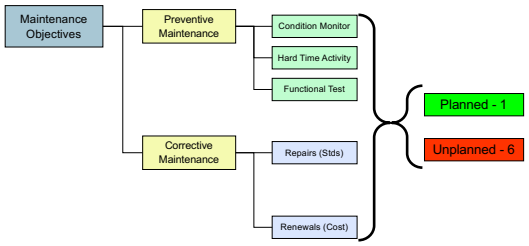
Adapted from
Nowlan and Heap page xvi
December 1978

Discussion 

Maintenance Management Model



Maintenance terminology



Reliability and maintenance facts

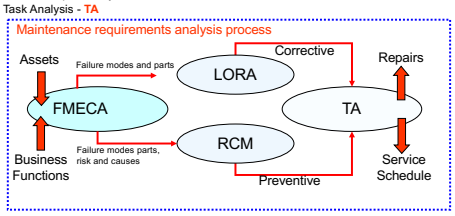
- Reliability characteristics are inherent in design solutions
- Equipment possess one of six reliability characteristics
- Maintenance action addresses the consequence of failures (all) rather than the frequency
- Valid maintenance actions must be:
  - applicable to the failure mode cause
  - effective in managing the consequences of failure mode

Session 2

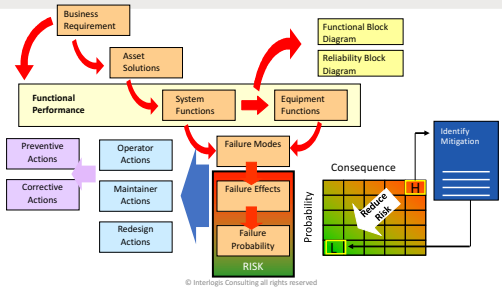
Determining Preventive Maintenance Plans

Maintenance Requirements Analysis

Failure Mode Effects and Criticality Analysis – FMECA
Reliability Centered Maintenance – RCM
Level of Repair Analysis - LORA
Task Analysis - TA



FMECA – a risk process

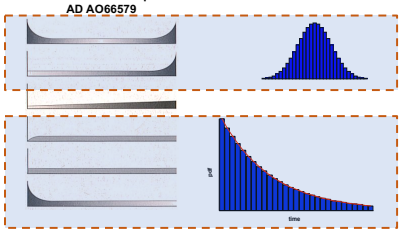


Relating characteristic to task type

% 2001
2
10
17
9
56
6

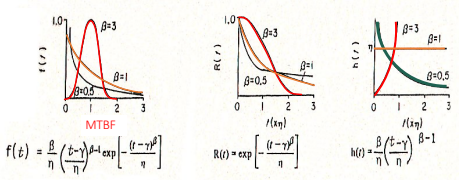
12%

Nowlan and Heap
AD AO66579



Source NASA

Weibull family of curves



$$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1}\exp\left[-\frac{(t-\gamma)^{\beta}}{\eta}\right]$$

$$R(t) = \exp\left[-\frac{(t-\gamma)^{\beta}}{\eta}\right]$$

$$h(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1}$$

Probability Density Function

Raw failure data set

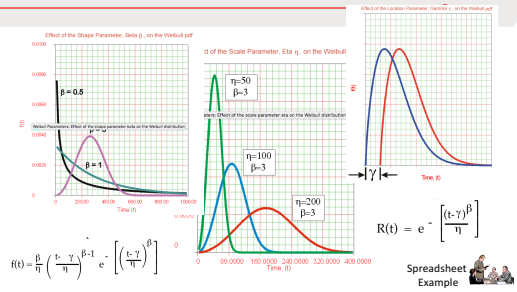
Reliability Function

Likelihood of surviving to time 't'

Hazard Function

Likelihood of failure having survived to time 't'

Effect of beta β (shape), eta η (scale) and gamma γ (position) parameter

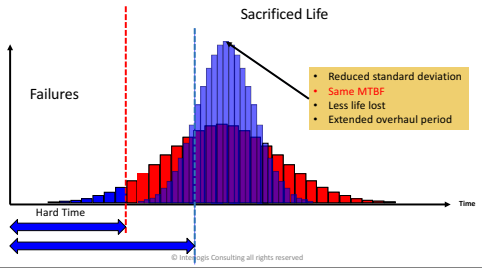


$$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} e^{-\left[\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right]}$$

$$R(t) = e^{-\left[\frac{(t-\gamma)^{\beta}}{\eta}\right]}$$

Spreadsheet Example

Hard time replacement, quality and lost life

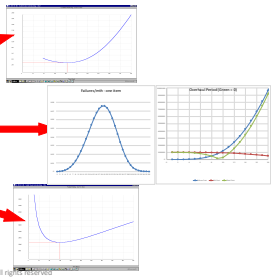


RCM – 7 Questions and 4 Answers

1. Which assets are important to the business?
2. What are its functions?
3. How does it fail to perform that function?
4. What causes it to fail?
5. What happens when it fails?
6. How can that failure be managed?
7. What can be done if the failure cannot be managed?

RCM - The four risk based solutions

- **Examine** condition to detect potential failures (Condition Monitor)
- **Restore** or discard before a maximum age (Hard Time)
- **Check** to find failures that are not evident (Failure Finding)
- **Apply default tasks** of "run to failure" or "redesign"



Session 3

Determining optimum “hard time” task period

Identifying failure modes

failure mode

- manner in which failure occurs
- *Note 1 to entry: A failure mode may be defined by the **function lost** or **state transition** that occurred.*

Valve, Hydraulic	Leaking Stuck Closed Stuck Open	.77 .12 .11
Valve, Pneumatic	Leaking Stuck Open Stuck Closed Spurious Opening Spurious Closing	.28 .20 .20 .16 .16
Valve, Relief	Premature Open Leaking	.77 .23

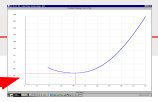
- *Examples – MIL-HDBK-338B*

Failure Mode Examples – MIL-HDBK-338B

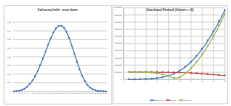
TABLE 7.8-1: FAILURE MODE DISTRIBUTION OF PARTS[6]

DEVICE TYPE	FAILURE MODE	MODE PROBABILITY (α)
Accumulator	Leaking Seized Worn Contaminated	.47 .23 .20 .10
Actuator	Spurious Position Change Binding Leaking Seized	.36 .27 .22 .15
Alarm	False Indication Failure to Operate Spurious Operation Degraded Alarm	.48 .29 .18 .05

RCM - The four risk based solutions

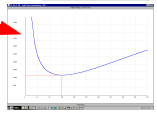


Examine condition to detect potential failures (Condition Monitor)



Restore or discard before a maximum age (Hard Time)

Check to find failures that are not evident (Failure Finding)



Apply default tasks of "run to failure" or "redesign"

Hard time task assessments – 3 methods

Weibull analysis

- Weibull analysis is a statistical technique that uses failure data to provide accurate failure predictions. It selects the time at which the number of occurrences of the failure mode reaches an unacceptable level. (i.e. where the overhaul of survivors is equal to the cost of failures to that point)

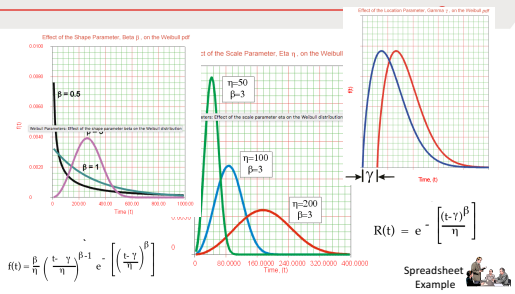
Testing

- Many components require certification tests that ensure that the component will operate for a certain period without failure. Aircraft structure, for example, is usually tested to failure under a full-scale fatigue test to ensure that it will remain crack-free for the life of the aircraft.

Fatigue analyses

- Fatigue analysis can be used to determine an item's life to crack initiation, which, in turn, can be used as a basis to establish a Hard Time task interval.

Effect of beta β (shape), eta η (scale) and gamma γ (position) parameter



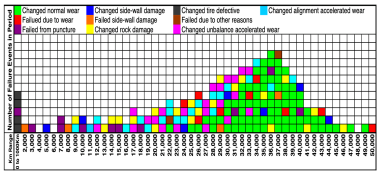
$$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} e^{-\left[\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right]}$$

$$R(t) = e^{-\left[\frac{(t-\gamma)^{\beta}}{\eta}\right]}$$

Spreadsheet Example

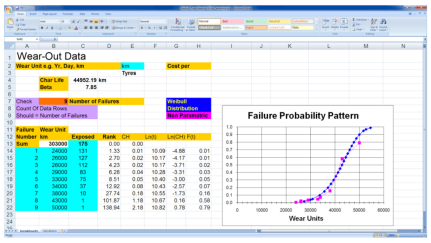
Calculating Beta (shaping factor) and Eta (characteristic life)

- Shaping factor ***Beta*** determines probability density function
- Characteristic life ***Eta*** is that time when 63.2% of items have failed.
- A practical lower limit of samples is considered to be **6 failures of the same failure mode** to assure some accuracy



Determining maintenance and sparing strategies

- We can expect tyre blowouts from 25,000 km (life units)
- This may occur even with a monitoring program that attempts to gain full life from each tyre.
- Question: How might this understanding inform our maintenance program?



Calculating Beta (shape factor) and Eta (expected life - MTBF)

All Data Are Failures

You've got 6 data points (**N=6**) representing age-to-failure which is [(death date) – (birth date)]:

140		**37**
37		**63**
69	--Step 1, Sort→	**69**
73		**73**
108		**108**
63		**140**

X-data

Calculate the Y-plot position using Benard's median rank = (i-0.3)/(N+0.4) for N=6:

i=1		**10.9%**
i=2		**26.6%**
i=3	--Step 2→	**42.2%**
i=4		**57.8%**
i=5		**73.4%**
i=6=N		**89.1%**

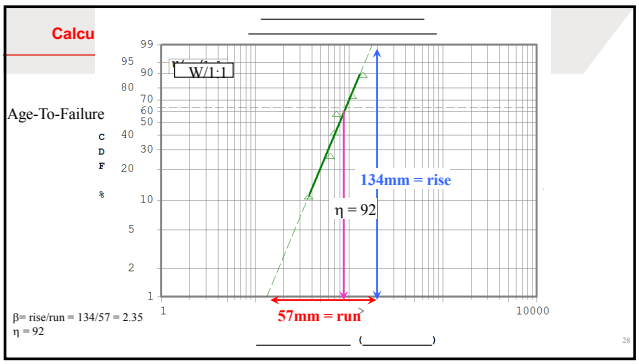
Y-Data

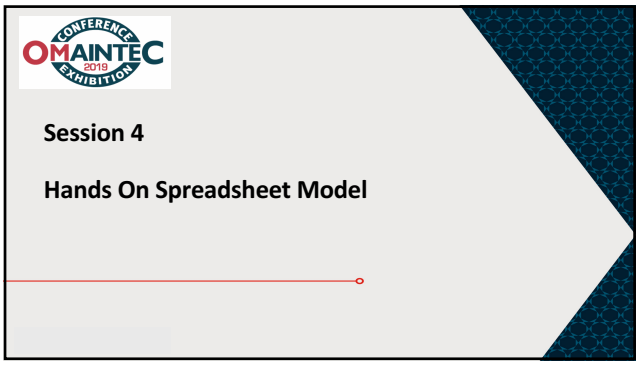
Step 3→ Plot the data on 1:1 Weibull paper (see attached Weibull paper)

Step 4→ Draw a trend line through the data

Step 5→ Where the trend line crosses 63.2%, drop down and read ***eta*** which is the characteristic life

Step 6→ On the 1:1 paper literally measure the rise over run of the trend line to calculate ***beta*** which is the Weibull slope or shape factor


Calcu
Age-To-Failure
W/1-1
134mm = rise
η = 92
57mm = run
β= rise/run = 134/57 = 2.35
η = 92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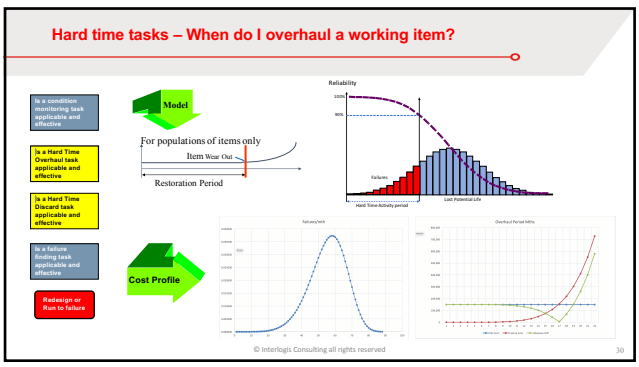
Hands On Spreadsheet Model


Hard time tasks – When do I overhaul a working item?
Is a condition monitoring task applicable and effective
Is a Hard Time Overhaul task applicable and effective
Is a Hard Time Discard task applicable and effective
Is a failure finding task applicable and effective
Redesign or Run to failure
Model
For populations of items only
Item Wear Out
Restoration Period
Reliability
Cost Profile
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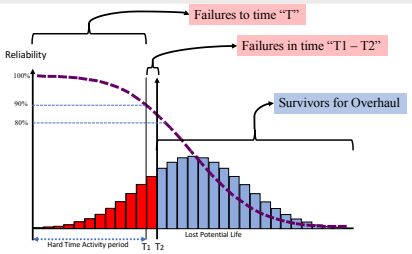
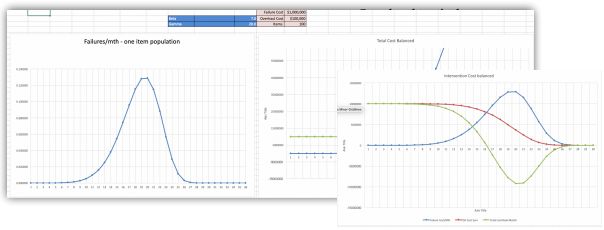
Setting a cost benefit ratio for possible hard time periods



Two approaches to financial optimisation – Case study spreadsheet



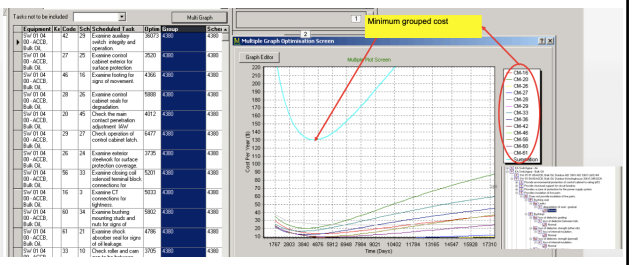
Activity 1.0

Activity 1.0 - Hard time task period case study

- Failure Characteristics for Weibull statistical measure
- Beta shaping factor = 4
- Gamma = MTBF of 20 (months)
- Functional Failure Cost = $200,000
- Overhaul Cost = $10,000
- Optimum Overhaul Period _____

- **OPTION 1**
- If I can achieve a Beta shaping factor of 7 what would be the reduction in overhaul costs?
- Overhaul costs reduced by _____%
-
- **OPTION 2**
- If I can extend my reliability by 20% (MTBF 60 mths to 72 mths)
- Overhaul costs would be reduced by _____

Packaging tasks into groups



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Session 5

Creating the "defensible budget"

Australian Defence Industry – Rizzo report

	Title	Description
Strategic Actions		
1	Formalise Asset and Sustainment Methodologies	Navy and DMO should jointly establish practical methodologies for integrated through-life Asset and Sustainment Management.
2	Take Whole-of-Life Decisions	Defence and DMO should ensure that decisions made during acquisition fully consider whole-of-life costs and capability, through a rigorous and formalised Asset Management process.

Value Proposition

Defining a **defensible** budget to achieve **agreed platform outputs**

The defensible budget revisited

- **Assures agreed and verifiable objectives of:**
  - Safety and environmental risks managed
  - Required performance achieved at known level of assurance
  - All done at a desired balance between the *performance, the cost and the residual risk*

- **Defensible is defined as comprising solutions that are:**
  1. **Fact and risk based**
  2. **Fully traceable to system/asset output requirements**
  3. Demonstrably good practice (*international and national standards*)
  4. Compliant with statutory and regulatory imperatives
  5. Implemented by competent (*certified*) staff
  6. Supported by verified technology (*information and decision systems*)
  7. Transparently and verifiably costed
  8. Deliverable in the agreed time frame

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Thanks and Questions