

Continuously Pushing the Limits of Innovation, Technology & Conventional Thinking

RCM Theory and Concepts Workshop Module 2- RCM Process Overview

Agenda

- RCM Process Introduction
- Planning & Preparation
- RCM Analysis
 - Equipment Kick-off Meeting
 - Initial Data gathering
 - Hardware Partitioning
 - FMECA
 - Failure Consequences
 - Task Evaluation
 - Task Selection
- Review and Summary

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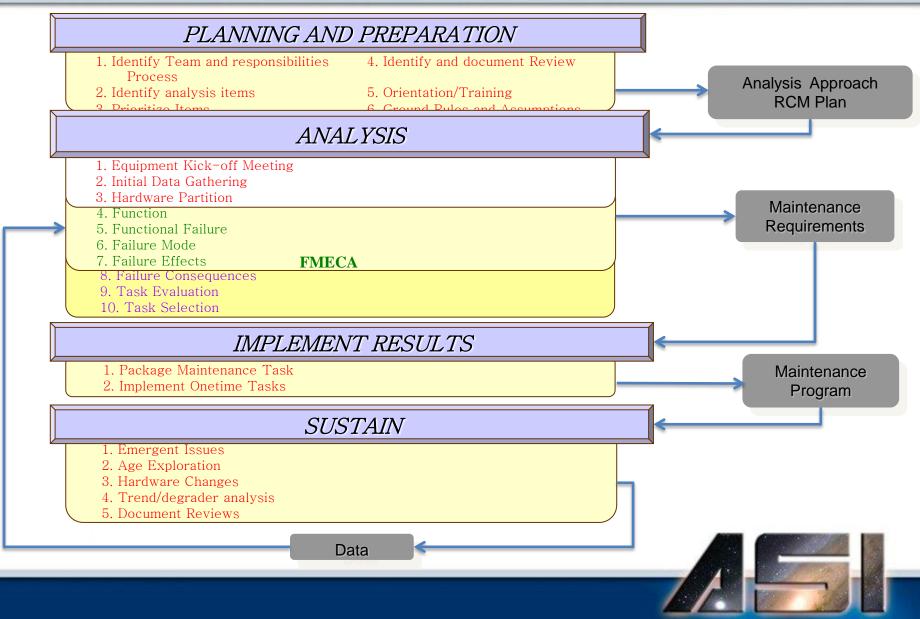
RCM Process Elements

There are 4 basic elements of an RCM Program:

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



RCM Process Overview





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

Planning and Preparation

- Team and Responsibilities
- Analysis scope (what and what order)
- Review and approval process
- Training Requirements
- Ground Rules and Assumptions
- RCM Sustaining procedures
- Hazard Risk Assessment Matrix
- Funding requirements
- Plan of action and milestones (schedule)
- Contractor/consulting support requirements
- Deliverables



Develop Organization & Review process

RCM Analysis Core Team

- Analysts
- Maintainers/Operators
- Cognizant engineer
- Review Process
 - Initial review: Analyst and SME
 - Final review/approval
 - Implementation



Prioritize Equipment

Factors used in the equipment selection process:

- Equipment utilization
- Equipment uniqueness
- Critical program
- Workload queue
- Safety
- Environmental





Ground Rules & Assumptions

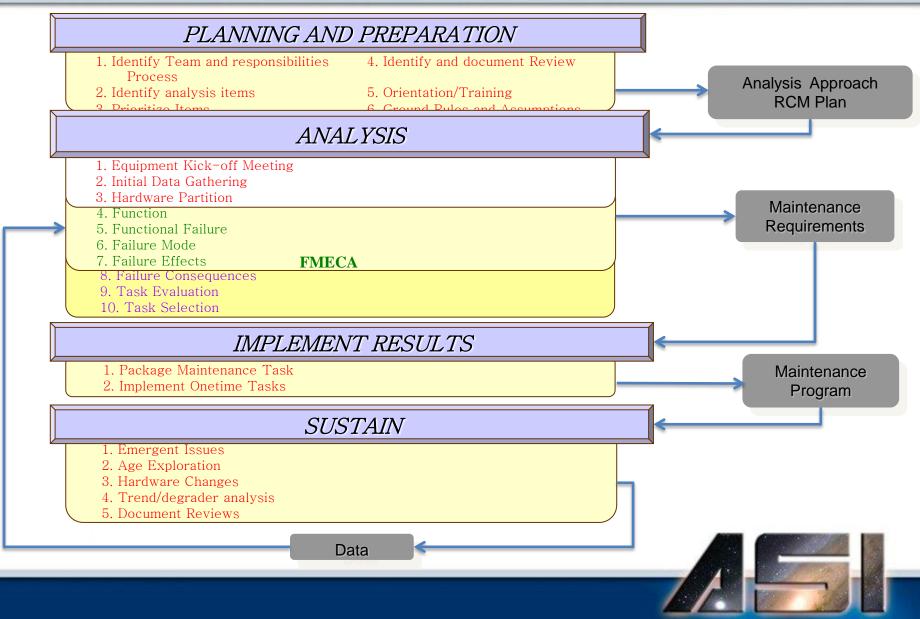
A document with a compilation of information needed by the RCM team to perform the analysis

Elements include:

- Guidelines for conducting the analysis
- Standard operating procedures
- Data sources
- Failure Mode sources
- Analytical methods
- Cost-benefit analysis methods
- Default Values



RCM Process Overview



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



Two "preliminary" steps in the Analysis Process:

• Equipment Kick-off meeting

- Critical for "buy-in"
- Should include key persons associated with item being analyzed
- Necessary to facilitate transfer of information from SME's
- Can be formal or informal
- Provides a detailed overview of the process: what is expected of participants and how it will benefit them (if not done in the initial "Orientation/Training" session)

Data Gathering

- Acquiring data such as pubs, logs, access to failure databases, etc. prior to beginning analytical work makes the analysis proceed faster and more efficiently
- ASAP after orientation to keep up "momentum"



Data Gathering

Possible Data sources:

- Operator/Maintainer Knowledge
- Current PM task lists/documentation
- Operator/Maintenance Manuals
- Equipment Logs
- Maintenance History Records (CMMS such as OOMA or ULLS etc.)
- Work orders
- Vendor information
- Spares purchase data
- Available PdM equipment
- Maintenance/Operating SOPs



Hardware Partitioning

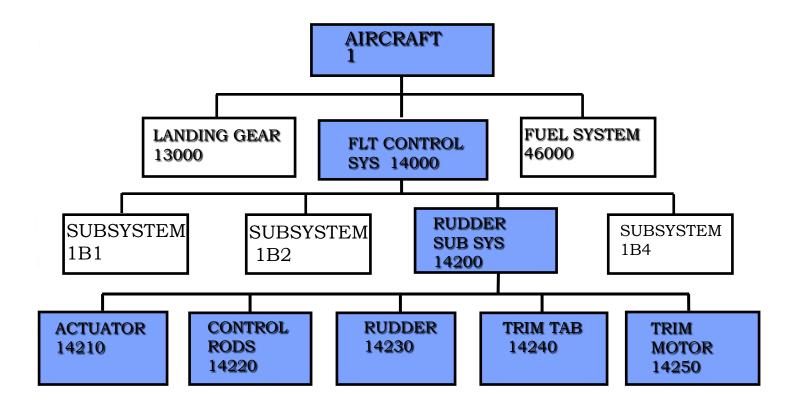
Setup the Hardware Partition

Hardware Partition is a logical, hierarchical division of an asset into progressively lower levels to show relationships among systems, subsystems, components, etc.

Also called EQUIPMENT HIERARCHY or HARDWARE BREAKDOWN

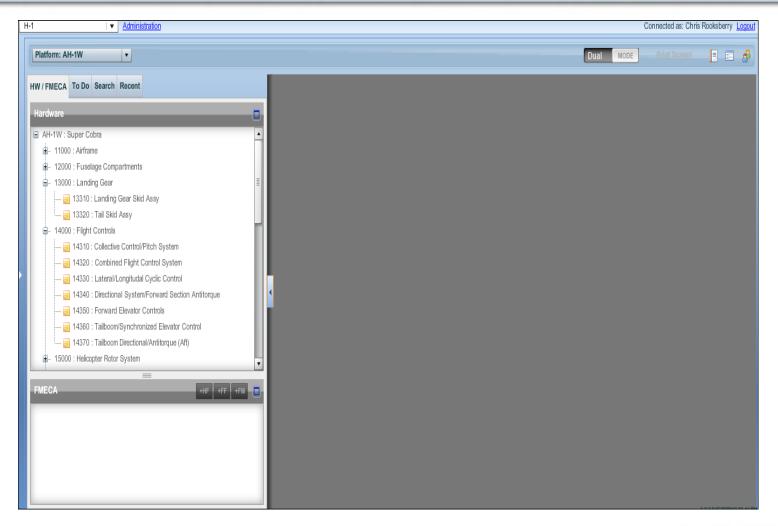


Initial RCM Analysis - Hardware partitioning





Hardware Partition Example





FMECA: Failure Mode, Effects, and Criticality Analysis

➢ Develop FMECA

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



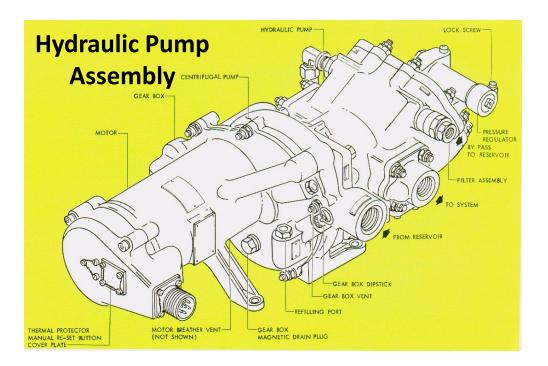


Functions/Functional Failures

- A function is what the user wants the item to do within a desired standard of performance.
- A functional failure is defined as the inability of an item to perform a specific function within the desired performance limits.



Functions



Provides hydraulic fluid at a pressure of 3000 psi +/-200 psi

FUNCTION

What the user expects the asset or system to do within a required standard of performance.



19

Functions

All equipment has primary and secondary functions

FMECA for RCM analysis should identify ALL primary AND secondary functions. Typical Secondary Functions:

- Control
- Warning or status indication
- Environmental protection
- Physical support or attachment
- Safety or protective functions
- Comfort and Aesthetics
- Fluid Containment

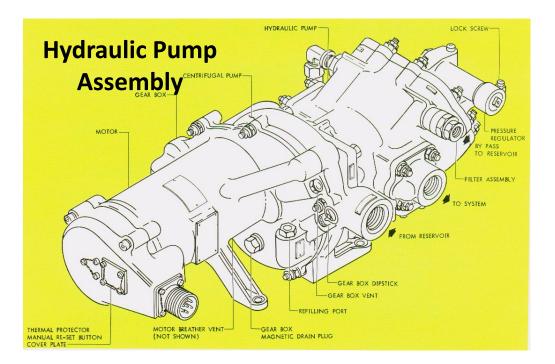


Function Example

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Hardware	Hardware Func	tion 02				
AH-1W : Super Cobra	Item ID:	13310				
🗐 11000 : Airframe	Function ID:	02 Read Only?	77			
tim 12000 : Fuselage Compartments						
i⊒ 13000 : Landing Gear	Function Description:	on Description: Provides support for the aircraft when sitting on ground and provides stability				
🥃 13310 : Landing Gear Skid Assy						
🔂 13320 : Tail Skid Assy		-Functional Significance Determination				
i⊟ 14000 : Flight Controls				Yes	No	
FMECA +HF +FM		 Does loss of the function have an ad- Does loss of the function have an ad- 	· · · · · · · · · · · · · · · · · · ·	r environment?		
01 : Provides environmental protection for the landing gear assembly and attach compone		3. Does loss of the function have an adv	verse economical impact?			
A : Fails to provide environmental protection for the landing gear assembly and attact	4. Is this function protected by an existing PM Task?					
2 PMI 1, 2 Pilots /Gunners step on crosstube is corroded. (S-3-4g)	Effectivity:	Effectivity: AH-1W				
20 04 : Landing gear crosstubes are corroded.	Linked Files:	Add Remove			01	inked file(s)
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Functional Failures



Fails to provide hydraulic fluid at a pressure of 3000 psi +/- 200 psi

FUNCTIONAL FAILURE

The inability of an item to perform a specific function within specified limits.



22

Functional Failures

- Note that functional failure may not be a complete loss of the function
- Separate functional failures should be listed where the effects of less than total loss of the function are different from total loss
- Ensure functional failure addresses the function as defined
- Common Errors:
 - Confusion with failure modes of hardware
 - Confusion with potential failures

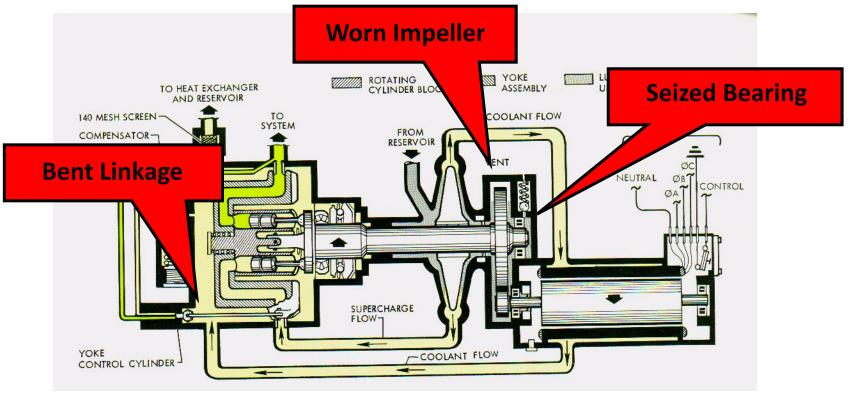


Function Failure Example

H-1 Connected as: Chris Rooksberry Logout				
Platform: AH-1W Print Screen Print Screen Platform: AH-1W Platform:				
HW/FMECA To Do Search Recent	Functional Failure			
Hardware	Functional Failure: A			
AH-1W : Super Cobra	Item ID: 13310			
🗟 11000 : Airframe	Function ID: 02			
B 12000 : Fuselage Compartments				
🖨 - 13000 : Landing Gear	Function Description: Provides support for the aircraft when sitting on ground and provides stability			
😡 13310 : Landing Gear Skid Assy	Functional Failure ID: A Read Only? OFF			
🦾 🔂 13320 : Tail Skid Assy	Functional Failure Failure Faile and the size of the s			
🖨 – 14000 : Flight Controls	Functional Failure Fails to provide support for the aircraft when sitting on ground and provides stability. Description:			
FMECA				
	Compensating			
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□ A : Fails to provide environmental protection for the landing gear assembly and attach components.	Effectivity: AH-1W			
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- 🥝 02 : PMI 1, 2 Pilots /Gunners step on crosstube is corroded. (S-3-4g)	Linked Files: Add Remove 0 linked file(s)			
- 🥝 03 : PMI 1 Landing gear skid tubes are corroded. (S-3-4b)				
- 🧭 04 : Landing gear crosstubes are corroded.	File Name Description Linked On Linked By			
02 : Provides support for the aircraft when sitting on ground and provides stability				
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- V 01. OPEN PMIT Landing gear skid assembly (tube and shoes) are distorted, (arrayed, 5/346) - V 02:** OPEN ** PMI1 Landing gear skid assembly (tube and shoes) are distorted, damaged or worn. (S-34b, S-34c)				
- 1 0 0 : Exhang you should assembly where crosstubes connect to skid tubes is cracked. (S-34d)				
	Last edited by Portal Admin, T.			



Failure Modes



FAILURE MODE

A specific physical condition that causes a particular functional failure.

25

Failure Modes

- When possible list failure cause or mechanism, ex. "cracked spar due to fatigue"
- List all failure modes that are "reasonable".
- Be as descriptive as possible
- Do not combine failure modes where failure effects, rates, or possible failure management solutions may be different
- Methods to identify "significant" failures vary by project.

- Possible Failure Mode sources:
 - Current PM tasks
 - Operator/Maintainer Knowledge
 - Logbooks
 - Work orders
 - Maintenance History Records
 - Spares purchase data



Failure Mode Example

H-1 I Administration		Connected as: Chris Rooksberry Logout
Platform: AH-1W		Dual MODE Print Screen 📃 📰 💰
HW / FMECA To Do Search Recent Failu	re Mode In process	Save Memo Menu 🗸 🗙
-Hardware FMI:	13310 02-A <mark>03 v1</mark>	Failure Tasks CDA Package Summary Workflow File HRI
AH-1W : Super Cobra		
	ode Consequences Maintenance Feedback	
B 12000 : Fuselage Compartments	Failure Mode Landing gear skid assembly has loose or missing hardware	
	Description:	
💷 13320 : Tail Skid Assy	- Effects:	
I4000 : Flight Controls	Local: Skid assembly is not secure	
FMECA HF +FF +FM		
	Next Higher: Diminished structural integrity of the skid assembly	
☐ 01 : Provides environmental protection for the landing gea ▲	Next righer.	
0 01 : PMI 1, 2 Saddle assembly where crosstul	End: Delay of mission, possible TFOA	
02 : PMI 1, 2 Pilots /Gunners step on crosstu	Eng: Doug of modern, poddolo in ork	
	Detection Method: O-None, M-Visually	
O2 : Provides support for the aircraft when sitting on group		
. A : Fails to provide support for the aircraft when sittin	Effectivity: All AH-1W	
	Severity Class: 3 - Major V ID Code of Failed Item: 13310-13	314
	MTBF: 599 FH - Flight Hours V Part # of Failed Item: 205-050-1	134-1, 205-050-134-3
	Operating Phase: All Phase	es Last edited by Northeoide, R. on 02/26/2013 03:07:27 PM
Cost PWI 1, 2 Saddle assembly where clossic		





Failure Effects/Detection

Determine the Failure Effects

> A failure effect is the result of a functional failure on surrounding items, the functional capability of the end item, and hazards to personnel and environment.

Determine the detection method

A description of the method or methods by which functional failures are detected and how their failure modes are identified. Both operator and maintainer methods should be addressed



Failure Mode Example

1 I	Administration	Connected as: Chris Rooksberry Logout
Platform: AH-1W	•	Duat MODE Print Screen 📮 🚍 🦂
FMI: 13310 02-A 03	V In process	Save Memo Menu V
Failure Mode Description:	Landing gear skid assembly has loose or missing hardware	
Effects:	alt Skid assembly is not secure	
Next Highe	pr. Diminished structural integrity of the skid assembly	
Er	nd: Delay of mission, possible TFOA	
Detection Method:	O-None, M-Visually	
Effectivity:	Al AH-1W	
Soverity Class: MTBF:		



Failure Frequency

Determine MTBF – How often does it fail?

MTBF is a basic measure of reliability

- Possible sources for MTBF
 - Use part failure data if possible
 - Operator/Maintainer interviews
 - Work Orders
 - Engineering judgment/default numbers





Severity Classifications

- Severity Classifications are qualitative measures used to categorize potential effects of each failure mode on the end item
- Severity Class, along with failure frequency, may be used to determine whether or not action has to be taken to address a failure mode



Hazard Risk Matrix Example:

FREQUENCY SEVERITY	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



Failure Consequences

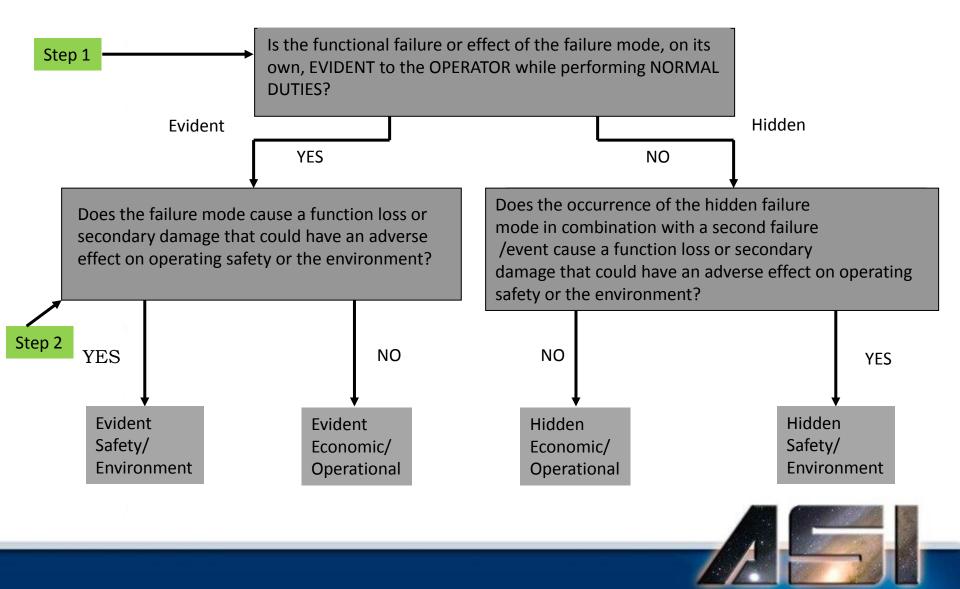
Determine the consequences

- Failure consequences describe the impact that a failure has on the equipment, the operators of the equipment and the environment around the equipment.
- Failure consequences are identified in terms of safety, the environment, operations, economics, and whether or not the failure is evident to the operator of the equipment.

Failure consequences are categorized in two steps:

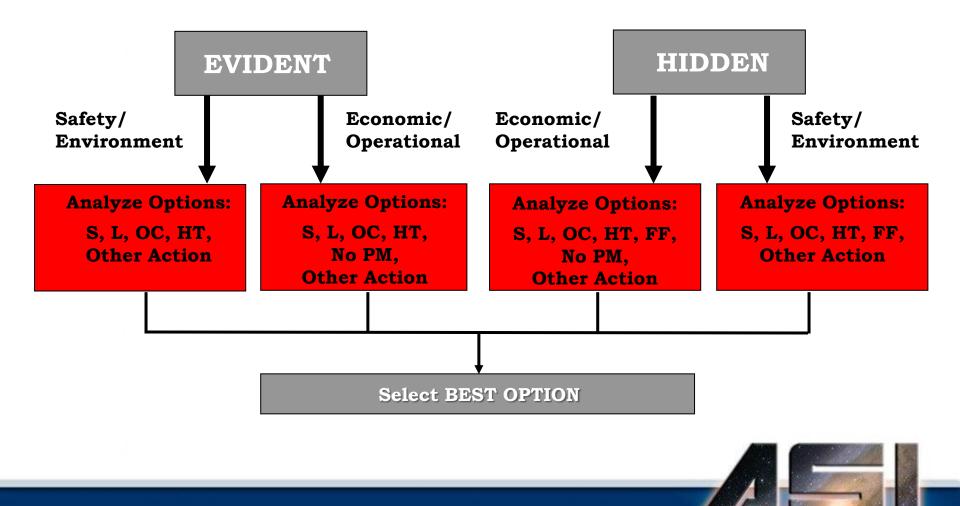
- Hidden or Evident
- Safety/Environment or Operational/Economic







Task Evaluation and Selection



Task Evaluation

- Servicing/Lubrication requirement
- On-Condition requirement (e.g. inspection-potential failure)
- Hard-Time requirement (e.g. overhaul, life-limit)
- Failure Finding (e.g. op check)
- Age Exploration (If more information needed)



Servicing:

The replenishment of consumable materials that are depleted during normal operations.



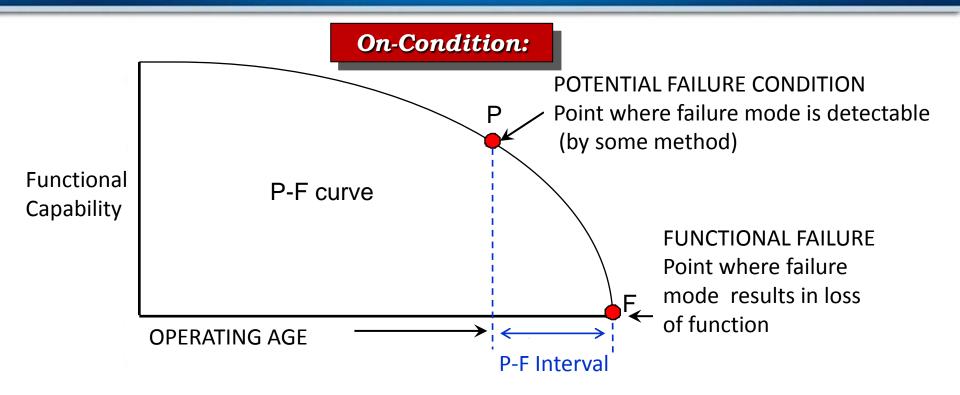
Lubrication:

The scheduled lubrication of a component (usually based on the manufacture's recommendations) where the item's design requires a non-permanent lubricant for proper operation









- If the inspection reveals a potential failure condition, corrective action is taken before functional failure. If potential failure condition is not detected, nothing is done, item continues in service
- Maximizes the useful life of each piece of equipment by allowing operation until potential failure is detected

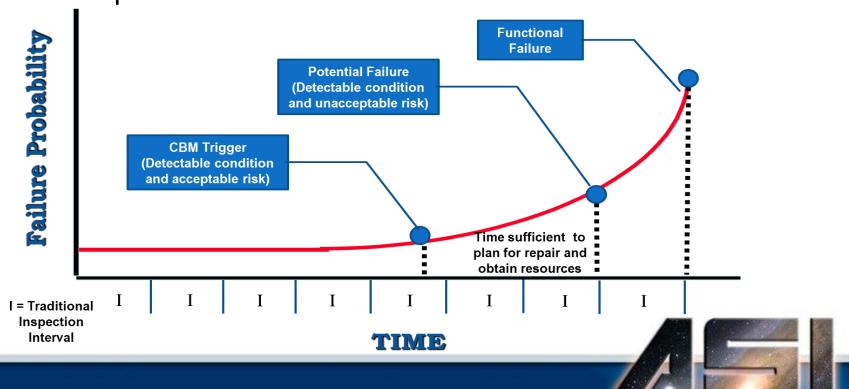


Condition Based Maintenance (CBM):

- A CBM course of action is a preventative or restorative action performed only upon evidence of need identified through direct or indirect monitoring.
- CBM requires specific knowledge of an asset's condition over time during its operating life. This knowledge allows a mitigating action to be planned with sufficient lead time to minimize the impact (safety, cost, and operational) of the occurrence of the failure mode.



 CBM differs from "on-condition" maintenance in that under CBM, knowledge of asset condition at any given time provides an understanding he of how much time is available to perform the required maintenance.



Hard Time:

Scheduled removal of an item or a restorative action at some specified age limit to prevent its functional failure

For example commonly referred to as:

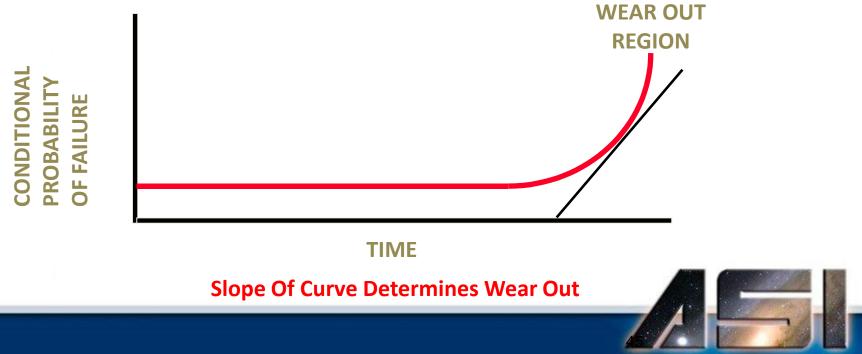
- Scheduled Removal
- Rework
- Overhaul





Hard Time:

- Some items show well defined wear out age where rapid increase in probability of failure occurs
- Described as increase in conditional probability of failure with age



Failure Finding:

A task performed at a specified interval to determine whether a hidden functional failure has occurred.



Prevalent in Back-up or Instrumentation Systems



Failure Management Strategy

Other Actions:

Usually a one time action, other than PM, that effectively reduces consequences of failure or resolves problems identified during the conduct of the analysis

Examples:

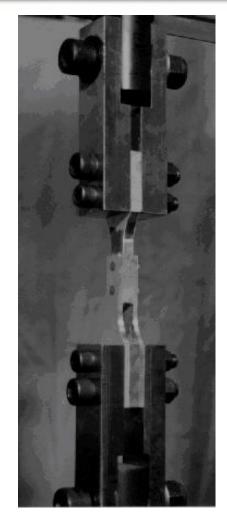
- Design changes
- Operational or maintenance procedure changes
- Operating restrictions
- Training updates
- Publications
- Technology insertion





Age Exploration

- Specific tasks to collect data to:
 - Refine RCM analysis assumptions and data
 - Optimize PM tasks
- Age Exploration tasks are targeted to specific failure modes and data shortfalls
- Age Exploration tasks may be:
 - In-service inspections or tests
 - Laboratory tests and studies
 - Data analysis
- For safety consequence failure modes, Age Exploration must not expose operators to unacceptable risk of failure





Task Evaluation

Determine task interval (in preferred order)

- Use hard data (previous studies) if available
- Use other analytical techniques when required
- Use engineering/analysts judgment

✓ Input from operators/maintainers✓ Engineering staff

• Consider existing PM task

✓ Effectiveness



Task Evaluation

Determine cost of each task option

- Cost to perform task
- Cost to repair failures
- Costs include:
 - Man hours
 - Material
- Costs obtained from experience, supply, and work order data





Task Evaluation

Once a failure mode has been subjected to the Decision Logic, one of the following outcomes is possible:

- PM Required- SL, OC, HT, FF
- No PM- Run to failure
- Other Action



Task Selection

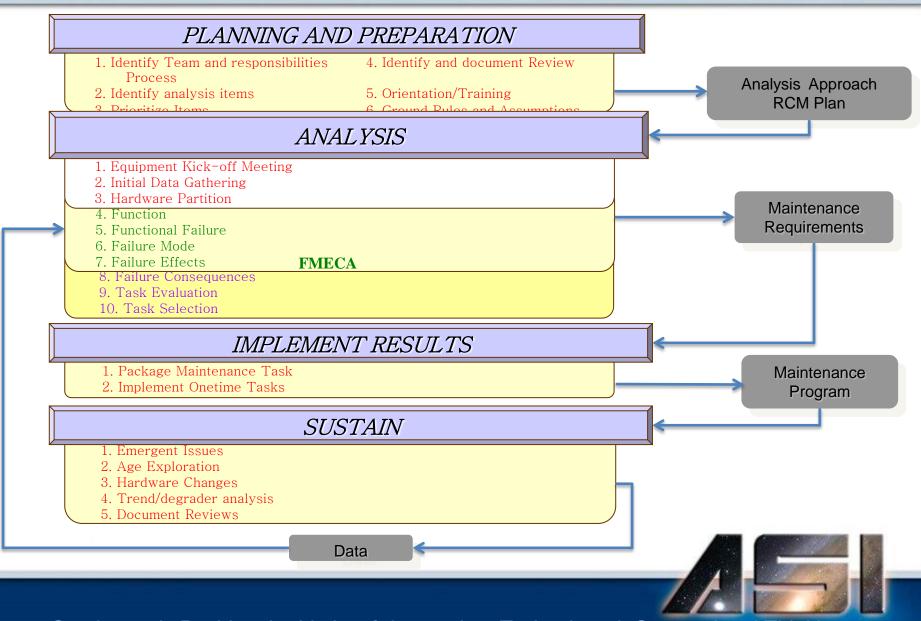
One or more PM tasks may prevent or reduce the probability of failure to an acceptable level. These tasks along with...

- a decision to allow the failure mode to occur (No PM)
- some "other action"...

... from a pool of options from which solutions can be generated.



RCM Process Overview



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Questions ?

