

1-00

1-01

Definition of RCM

A process for determining which types of scheduled maintenance tasks should be applied to an item and how frequently the assigned tasks should be accomplished.


F. Stanley Nowlan
Howard F. Heap
Dec 29, 1978
Report of work performed by United Airlines
under the sponsorship of the Office of
Assistant Secretary of Defense (Manpower,
Reserve Affairs and Logistics)

3


RCM is a *data model*



4



**GUIDELINES FOR THE NAVAL AVIATION
RELIABILITY-CENTERED MAINTENANCE
PROCESS**

NAV  AIR

Facilitated RCM Review Group

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I-04

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2.1.1 QUIZ | INITIAL RCM INTRO

<https://forms.gle/PMjHz32FLhGLshLs8>

1. We may think of RCM as a knowledge model in which to structure what we know about the failure behavior of an physical asset. True or False?

☐ True

☐ False

2. There is only one way to perform RCM analysis, That is in group sessions of SME's led by a facilitator. True or False?

☐ True


☐ False

3. RCM analysis usually proceeds by recording the answers given by subject matter experts to a series of questions about the asset. True or False?

☐ True

☐ False

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In order to understand RCM we need to appreciate the historical context from which it emerged.

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I-05-01

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Profound changes occurred in the world of maintenance.



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Some were so **gradual** that they were imperceptible to those engaged day-to-day in maintenance activities.

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I-05-01

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Sweeping changes in maintenance.

1. Scope and **expectations** of maintenance expanded
2. **Theory** of maintenance and failure behavior changed.
3. **New** maintenance technology

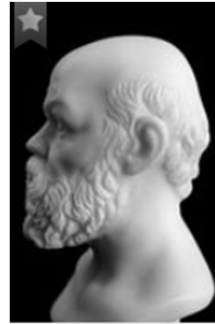
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I-05-02

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THE SOCRATIC METHOD OF TEACHING BY ASKING QUESTIONS

EDUCATION IS THE
KINDLING OF A FLAME
NOT THE FILLING OF A
VESSEL



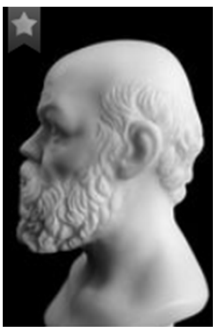
SOCRATES

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I-06-01

11

Moubray emphasized that RCM is a learning experience.



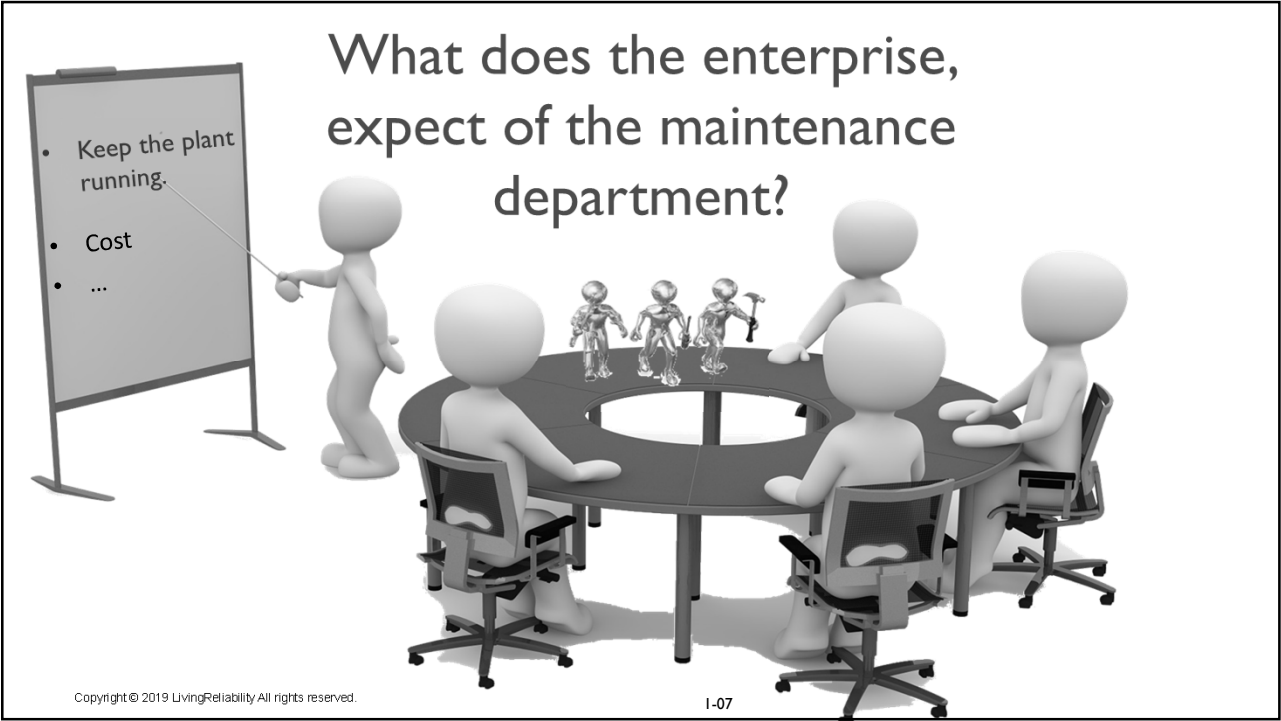
RCM, only asks questions.
RCM never answers them.

Socrates, taught the world that
questions provoke discovery.

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I-06-01

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MECHANIZATION AND AUTOMATION ← Reason I

Why is keeping the plant running more important today than in previous times? We explore a case from the automotive industry

Engine assembly plant

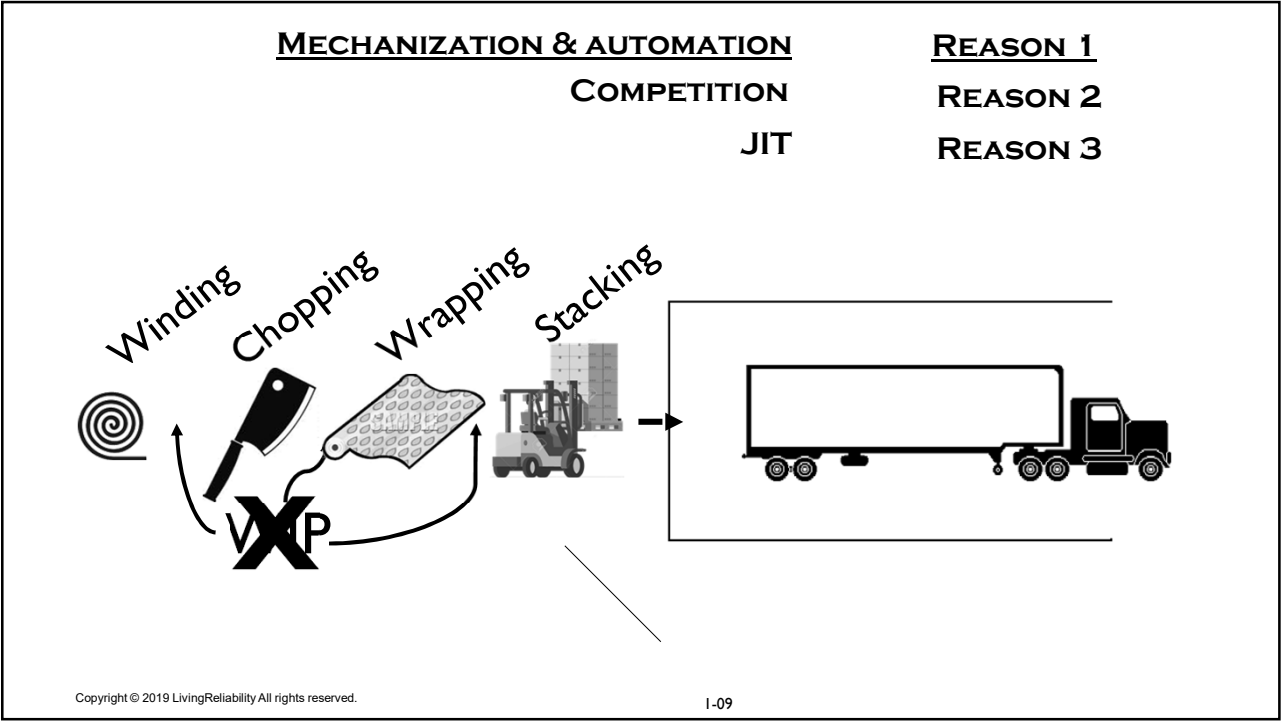
1986 2.5D		1991 2.0DOHC
		
70 operators		7 operators



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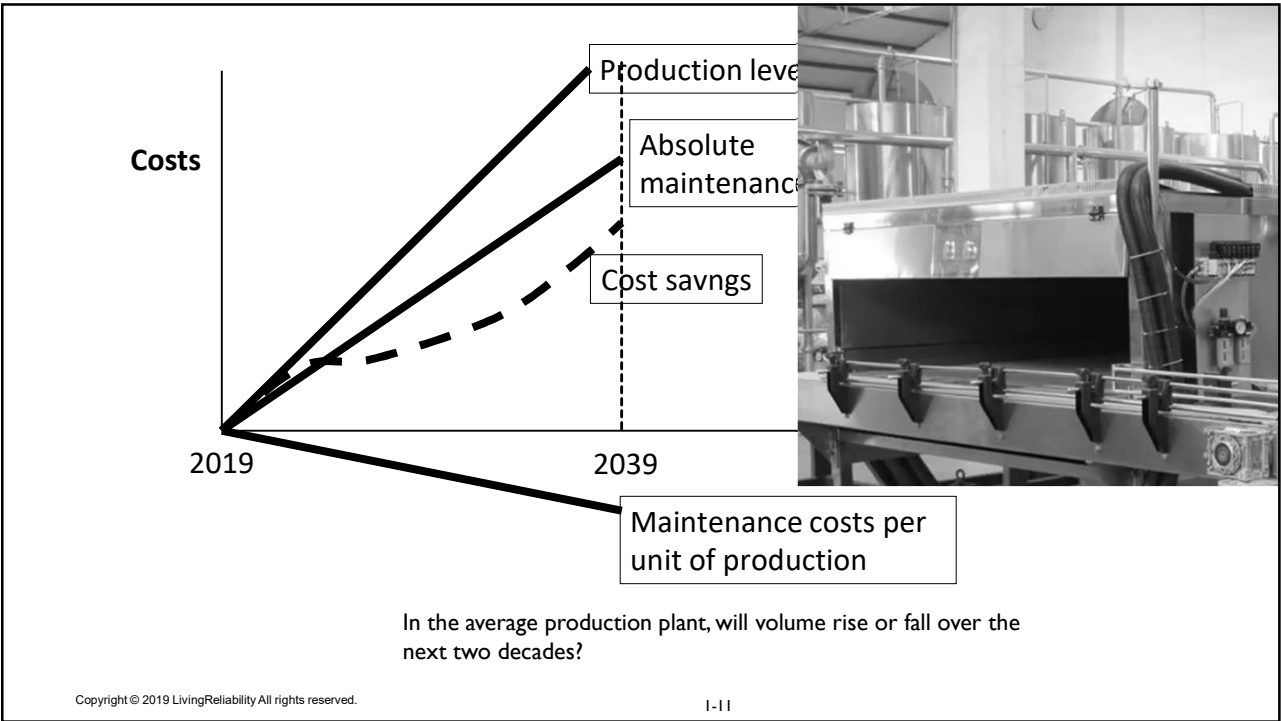
I-08

14



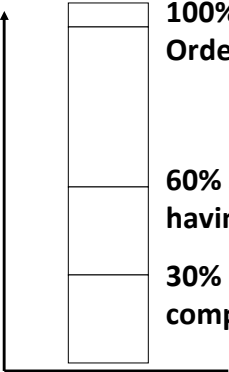


17



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BUT COST IN MAINTENANCE IS FRAUGHT WITH CONTRADICTION.



100% or Work Orders issued

60% signed off as having been completed

30% really completed

Claim: “If RCM is correctly applied to any existing fully developed PM program, it will reduce routine (cyclic) workloads by 40-70%”.

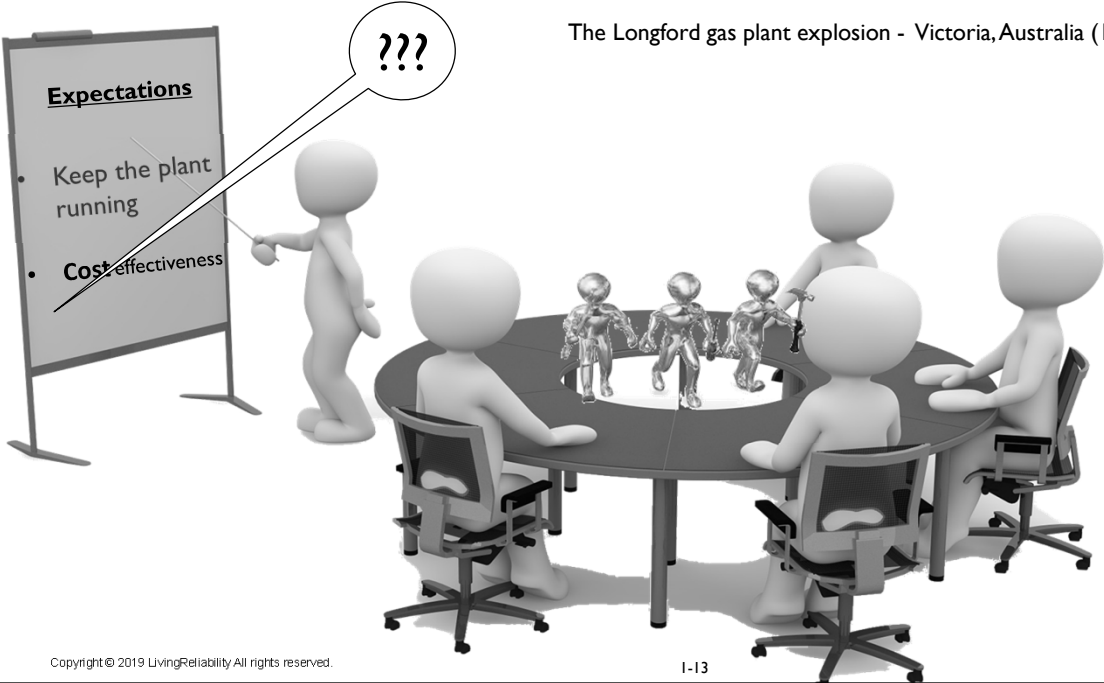
- RCM has been applied in 1200 plants, in 41 countries and 14 languages.
- Based on experience, RCM usually pays for itself within 7 weeks to 7 months after implementation.

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The Longford gas plant explosion - Victoria, Australia (1998)



Expectations

- Keep the plant running
- Cost effectiveness

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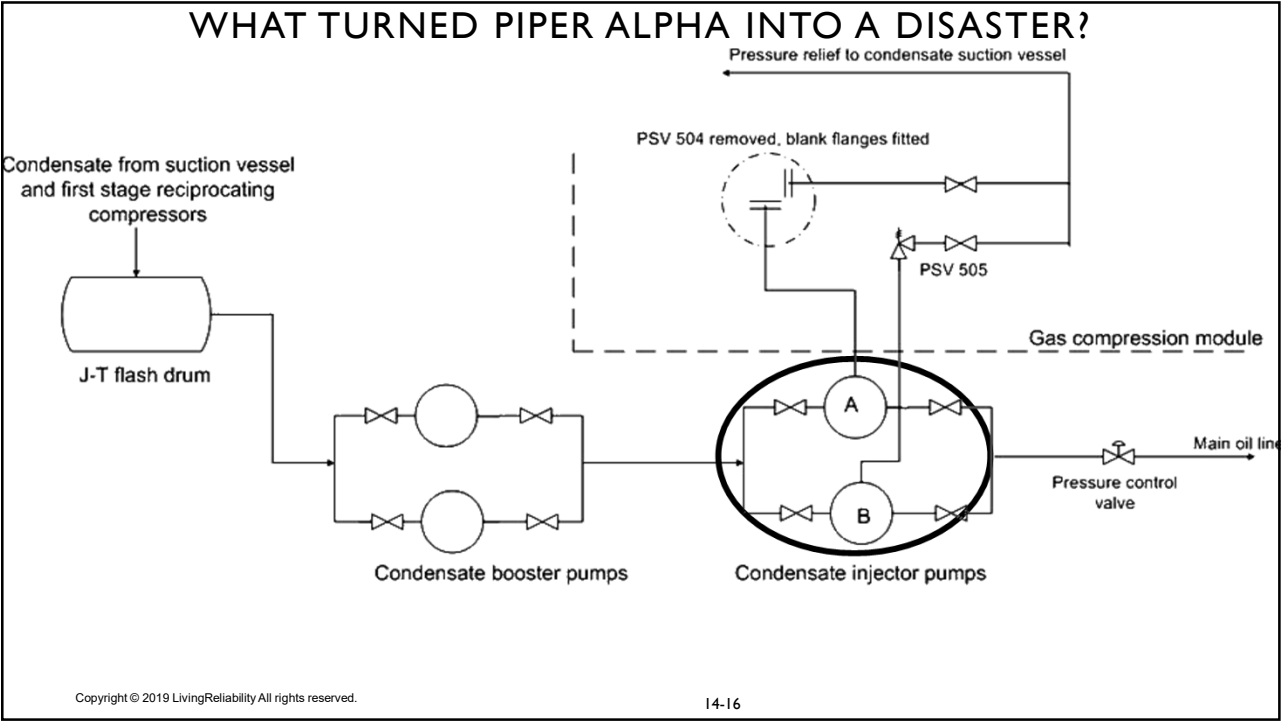
I-13

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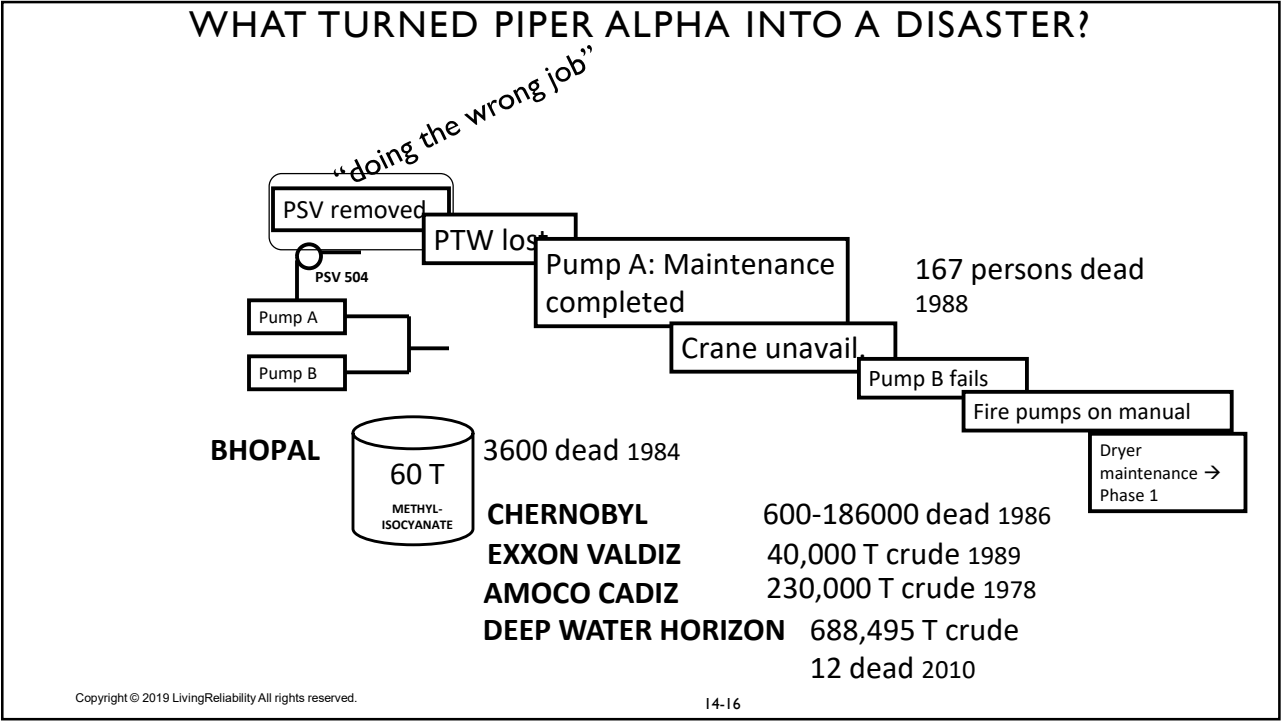
The 3 biggest accidents in industrial history (outside of mass transport and mining), in terms of the number of fatalities, were **not** the result of “cutting back” maintenance. In fact it was the contrary.

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22



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THUS WE HAVE MOVED INTO A NEW ERA OF CRIMINAL LIABILITY.

Australian Broadcasting Corporation
LATELINE
Late night news & current affairs

TV PROGRAM TRANSCRIPT
LOCATION: abc.net.au > lateline > broadcast
URL: http://www.abc.net.au/lateline/320793.htm
Broadcast: 28/06/01

Esso guilty
Esso now faces years of litigation and hundreds of millions of dollars in damages flowing from today's convictions over the Longford gas explosion. The company was found guilty on 11 charges in one of the longest and most complex prosecutions of its kind. The explosion killed two men and injured eight others at the Esso gas distribution complex in 1998. Today's verdict in Melbourne clears the way for civil action and victim compensation claims. Tomorrow, penalties possibly totalling millions of dollars will be imposed.

TRAIN ACCIDENT AT LADBROKE GROVE JUNCTION, 5 OCTOBER 1999
Third HSE Interim Report

1. INTRODUCTION
1.1 This is the third interim report in response to HSC's request for an investigation and report under section 14(2)(a) of the Health and Safety at Work etc. Act 1974. It consolidates the information in the first two interim reports and provides a statement of the current status of the investigation. **The investigation is still progressing, and there is still significant work to be completed.**
1.2 The accident, occurred at 8.09am on 5 October, when a Thames Train 3-car turbo class 165 diesel unit (the "165" for the purposes of this report) travelling from Paddington to Bedwyn, in Wiltshire collided with a Great Western High Speed Train (the "HST") travelling from Cheltenham Spa to Paddington. The accident took place 2 miles outside Paddington station, at Ladbroke Grove Junction. 31 people died (24 from the 165 and 7 from the HST), with a further 227 taken to hospital. 296 people were treated for minor injuries on site.

RCM processes that meet the SAE Standard provide a basis for prudent, responsible custodianship of physical assets.

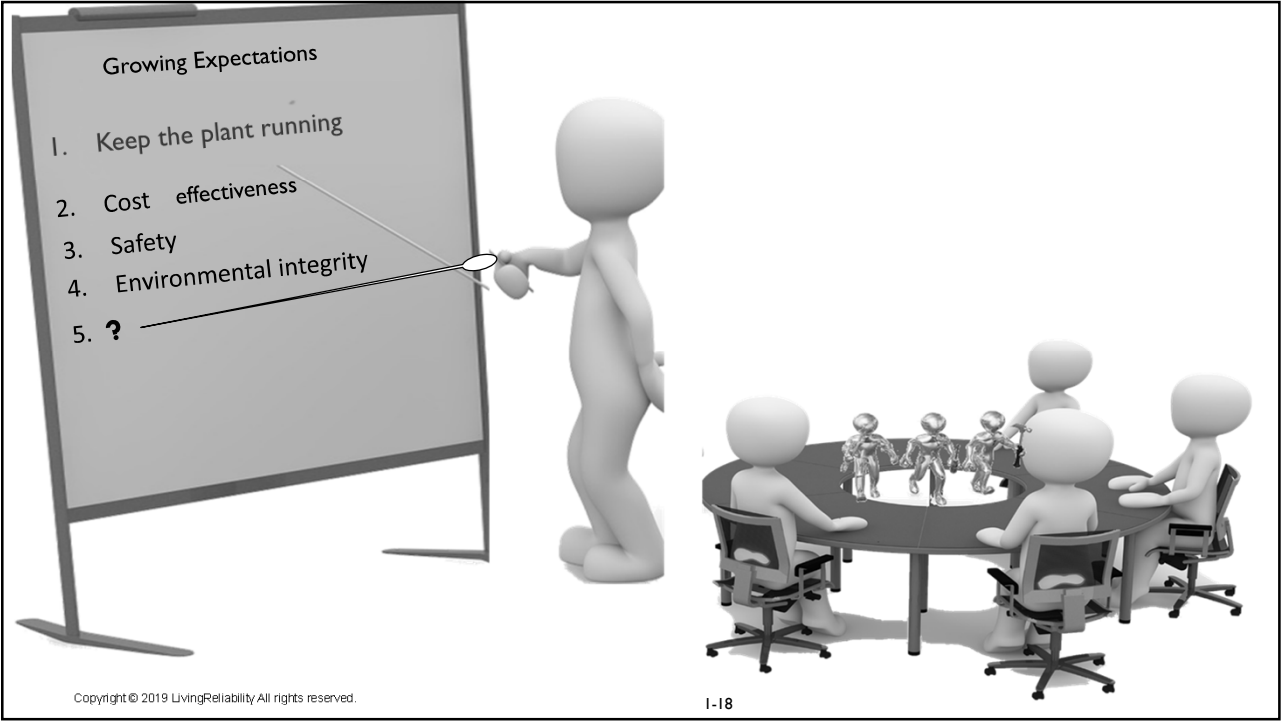
Bosses charged over Hatfield crash
Six senior managers and two companies have been charged over the Hatfield rail crash, which killed four people and injured dozens more in October 2000.

Network Rail, Balfour Beatty and the managers have been charged with gross negligence, manslaughter and an offence...

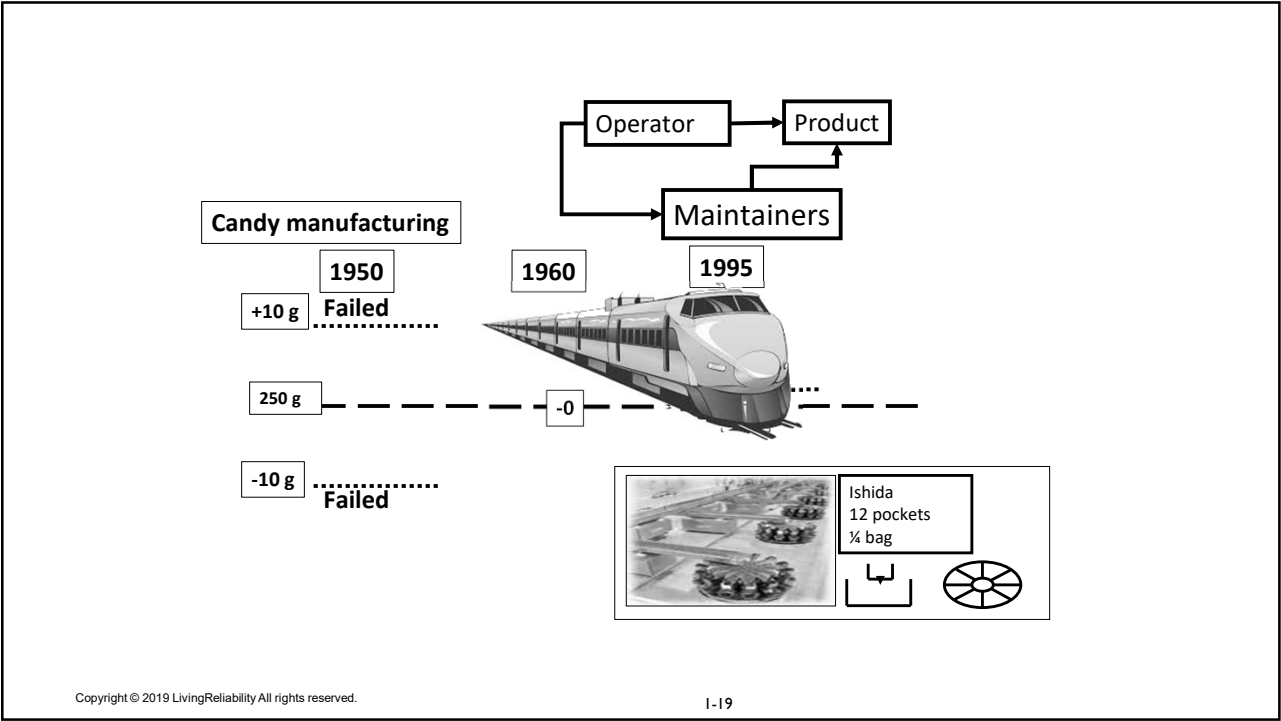
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1-17

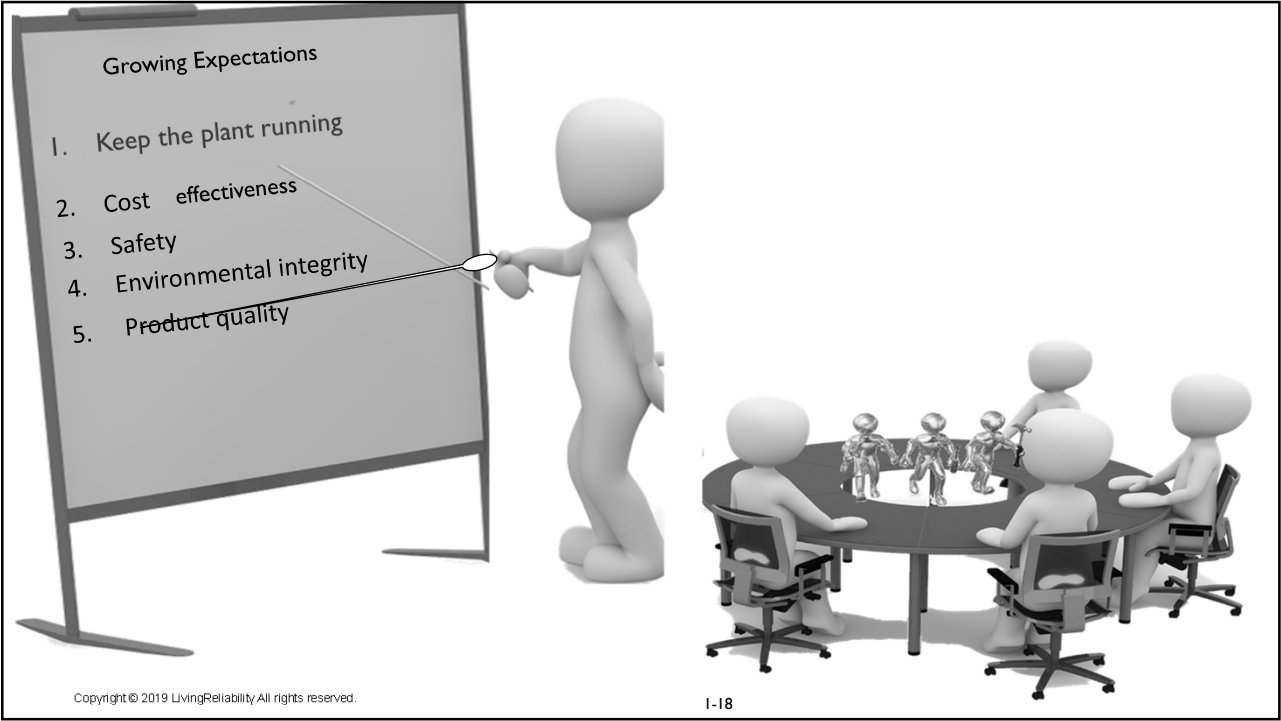
24



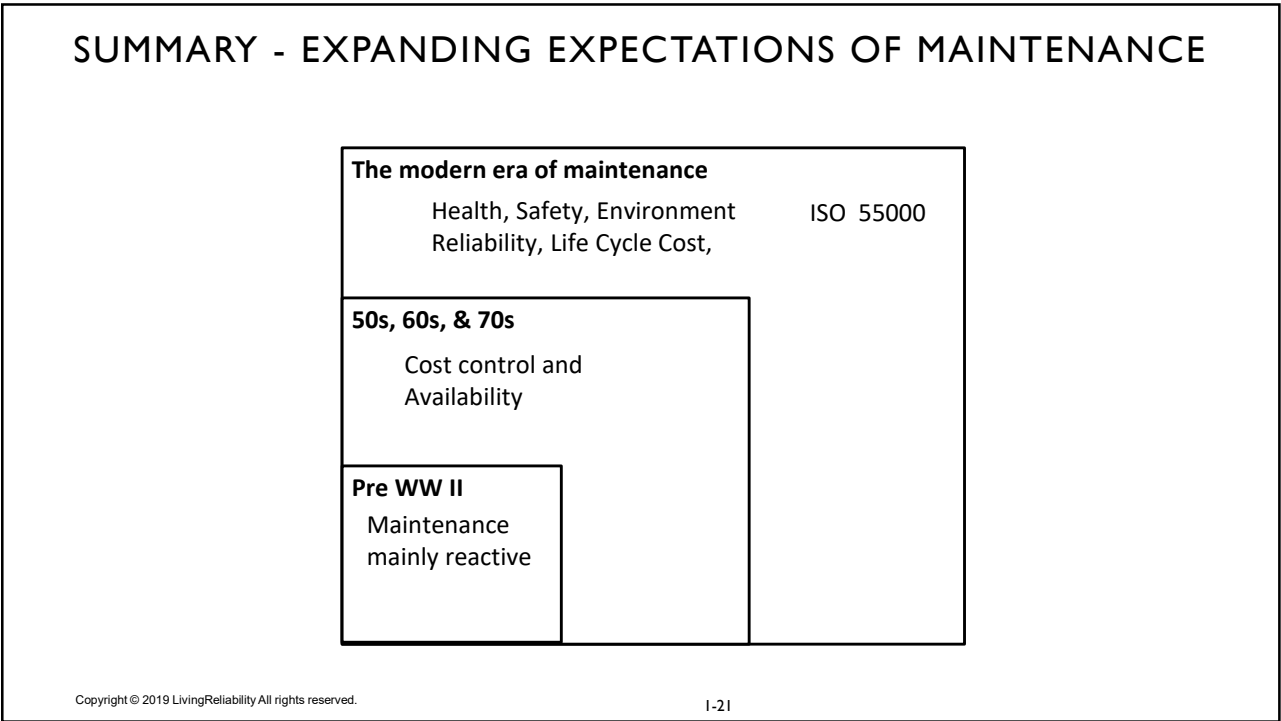
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26



27



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2.1.1 QUIZ 3 INITIAL RCM INTRO

<https://forms.gle/L3de9WANE5FHsHta9>

1. By the the mid 70s and 80s physical asset maintainers around the world found themselves increasingly responsible for:

☐ 1. Production throughput

☐ 2. Product quality

☐ 3. Compliance with environmental norms

☐ 4. Safety

☐ 5. Cost

☐ 6.. All of the above


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History: Three Sweeping Changes in Maintenance

1. Expanding expectations.

2.

3.



Ideas we have challenged so far:

Maintenance costs go up not down

More mtce ≠ Safer

Product quality depends on maintenance

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RCM – Introduction

Part 2

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Sweeping changes in maintenance

Ideas challenged so far:

- 1. Maintenance costs go up not down
- 2. More maintenance != safer
- 3. Product quality depends on maintenance

- 1. Expanding expectations
- 2. New understanding of physical asset failure behavior
- 3.


*As equipment gets older,
the more likely it is to fail,
T or F?*

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2-01

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Say you're the airline's chief maintenance engineer...



Gas turbine jet propulsion

Hydraulics , electronics

Pressurized cabin

...

You're expected to develop a maintenance program for this aircraft.

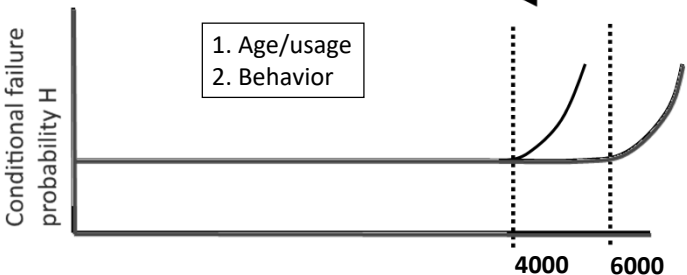
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2-02a

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COMMERCIAL AVIATION
Traditional view of failure

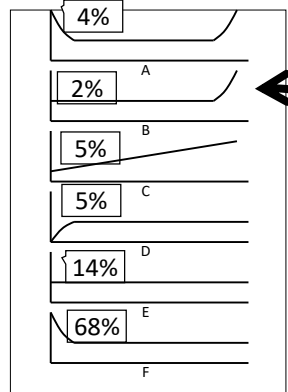
1. Age/usage
2. Behavior



60 CRASHES PER MILLION TAKE-OFFS
40 DUE TO EQUIPMENT FAILURE

"DO THE JOB RIGHT" → "DO THE RIGHT JOB "

85% components subject to fixed interval overhauls



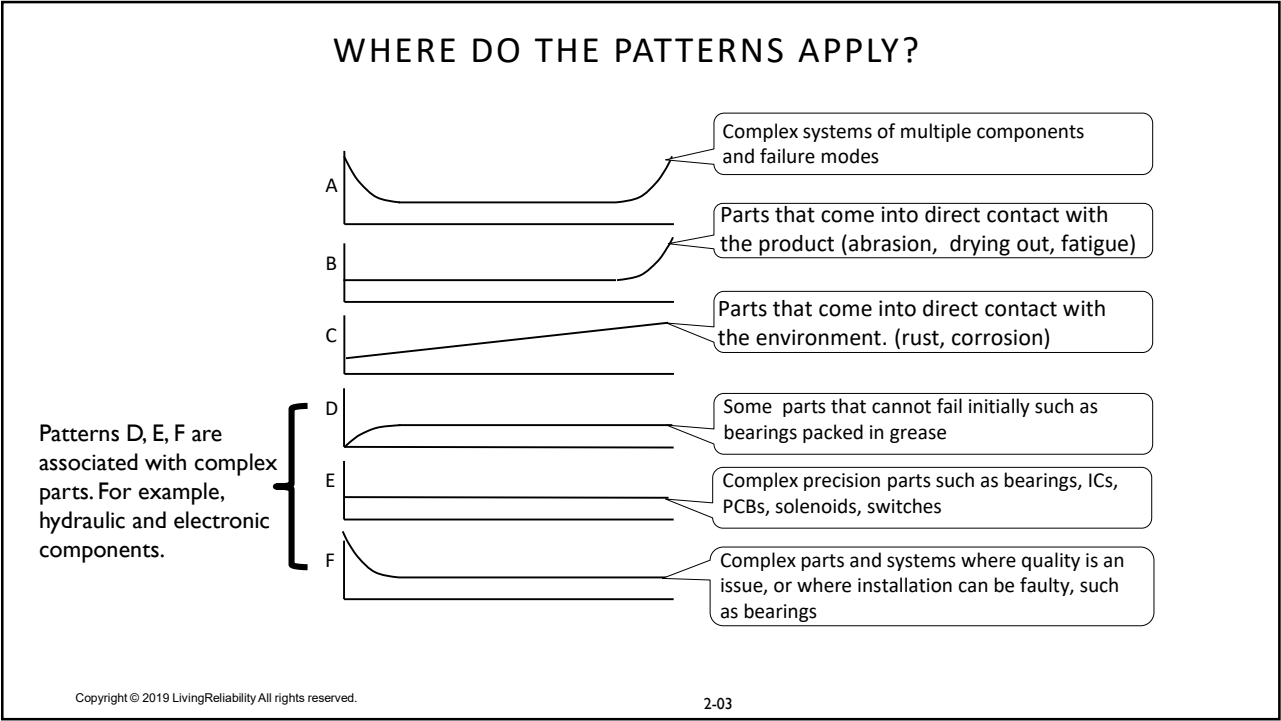
Component	Failure Percentage
A	2%
B	5%
C	5%
D	14%
E	68%
F	4%

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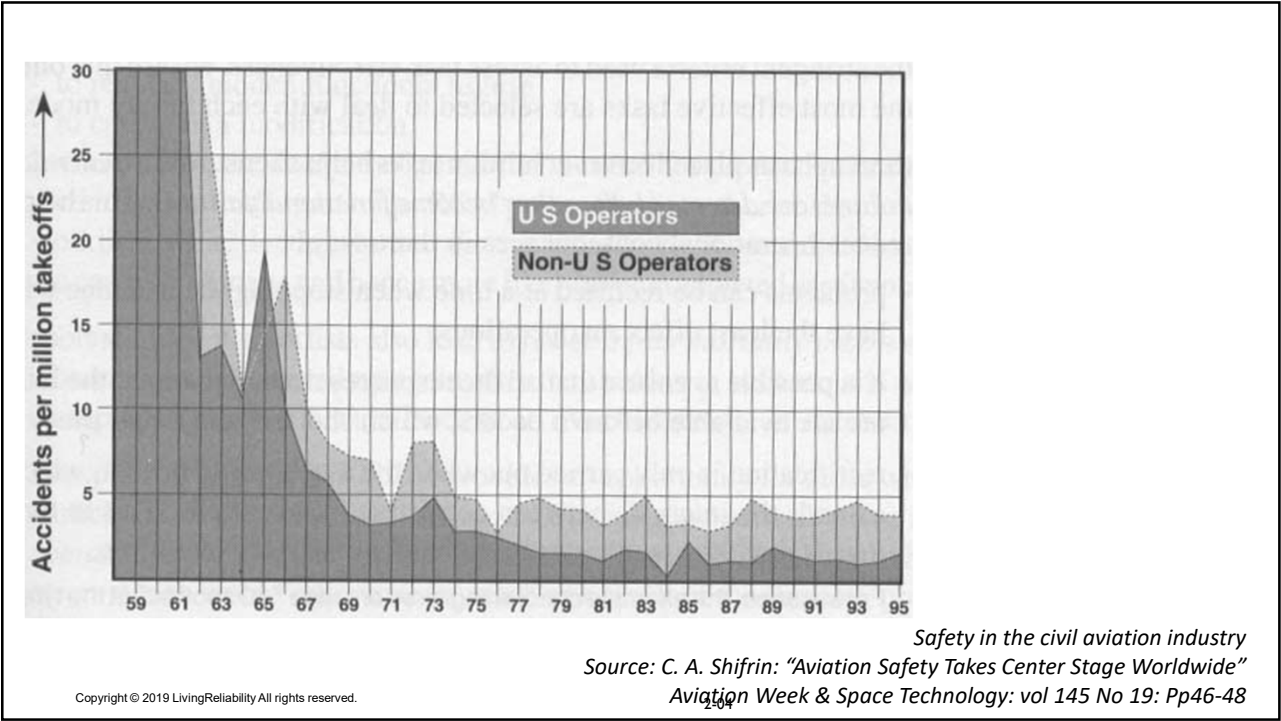
2-02b

Based on: J. Moubray, RCM Practitioner course

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Some people say that RCM, while justified in aviation, is not so in general industry.

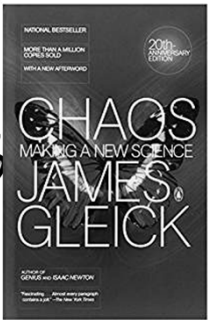

- 1. Government oversight
- 2. Cost-price squeeze
- 3. OEM – Operator relationship
- 4. Achieving reliability from data

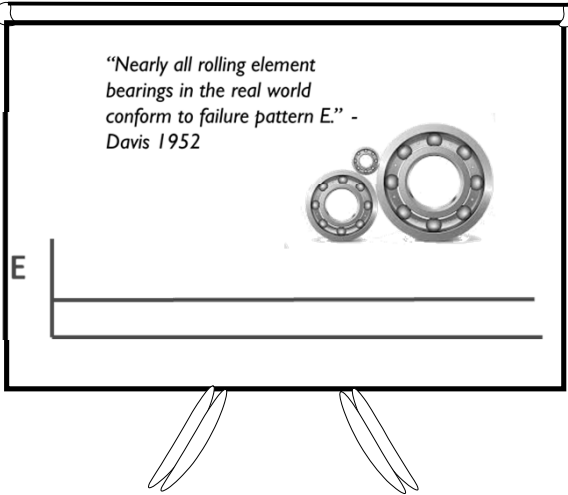


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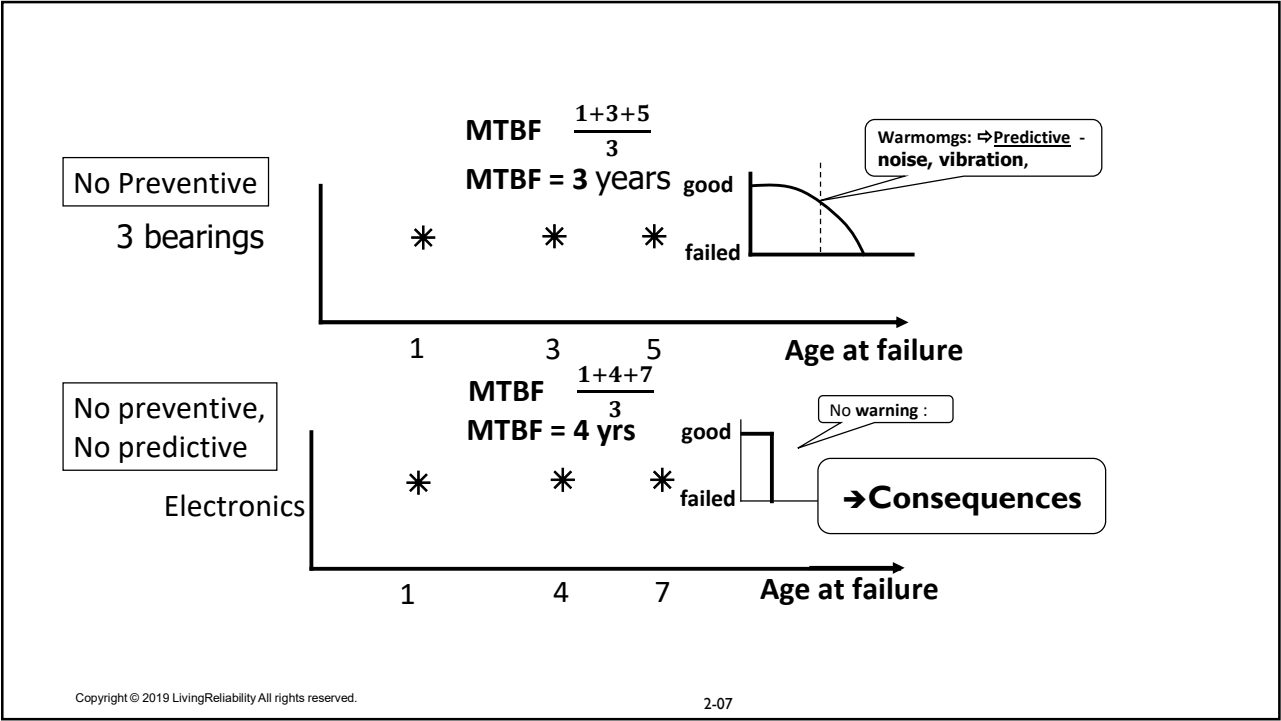
“Nearly all rolling element bearings in the real world conform to failure pattern E.” - Davis 1952



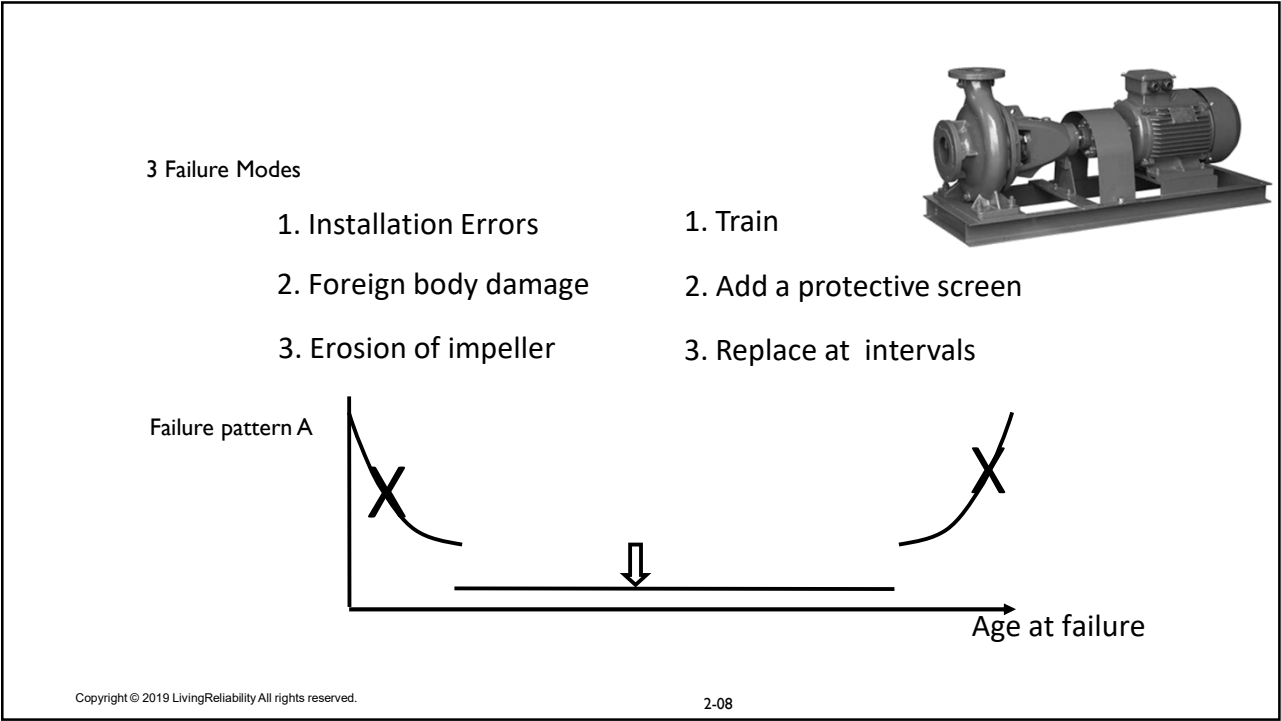
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2-06

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3 Failure Modes

1. Installation Errors


2. Foreign body damage

3. Erosion of impeller

1. Train

2. Add a protective screen

3. Replace at intervals



Failure pattern A

E

Therefore a well maintained complex system can change from pattern A to C

Age at failure

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2-08

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EXPANDING UNDERSTANDING OF MAINTENANCE BEHAVIOR

The modern era of maintenance

A

B

50s, 60s, & 70s

A

B

C

D

Pre WW II

B

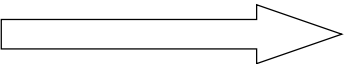
E

F

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Life cycle cost  Cost of the function

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2-10

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2.1.2 QUIZ I INITIAL RCM INTRO

<https://forms.gle/awsPzGebXrzg8iKSA>

2.1.6 As maintenance evolved post World War II new realities emerged. These realities changed the views of maintainers regarding probabilistic failure behavior patterns. They eventually understood that:

1 point

- ☐ 1. An older item is not necessarily more prone to failing than a newer item of the same type and service.
- ☐ 2. The failure behavior of complex items reflect the combined behaviors of each of their failure modes.
- ☐ 3. Scheduled overhauls of a production line or equipment could be counterproductive..
- ☐ 4 Maintenance personel should concern themselves primarily with the average cost of a unit of production moreso than the life cycle cost.
- ☐ 5. All of the above.

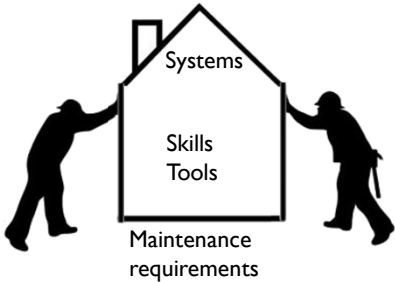
44

History: Three Sweeping Changes in Maintenance

- 1. Expanding expectations
- 2. New understanding of physical asset failure behavior
- 3. New maintenance technology

ISO 55000, sensor monitoring, Life Cycle Costing, HAZOPS, decision models, simulation, EAM , FMEA, employee motivation and participation, flexibility, multi-skilling, teamwork, LEAN,TBM, RCM, etc.

45



A logically structured approach to maintenance can be thought of, metaphorically, as building a house.

46

As new technology and standards proliferate, people tend to lose sight of the true meaning of the word “*maintenance*”.

"maintenance"

To cause to continue

Conservation

Oxford

To keep in an existing state

Maintain

Webster

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2-13

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THE GOAL OF MAINTENANCE IS

... to cause a physical asset to continue
to do what its users require it to do

Definition of RCM



A process to determine what must be done to keep the asset performing
to the level required by its user(s) in its operating context.

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2-14

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What does the user want?

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2-15

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What does the user want?

15 kw = "CAN"

20 kw = "WANT"

DESIGN CAPABILITY

REQUIRED PERFORMANCE

Limit of maintenance capability

400 l/m

300 l/m

350 lpm

RCM

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2-15

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Freeze dryer

The diagram illustrates a freeze dryer system. On the left, a box with three upward arrows is labeled "Temperature?". Below it are two thermometers and a beaker of water. A line connects this box to a horizontal line that branches into three boxes labeled L1, L2, and L3. A large question mark is placed below L2. An arrow points from L3 to a "Simplified psychrometric chart." The chart plots "DRY-BULB TEMPERATURE" (20° to 110°) against "GRAINS OF MOISTURE PER POUND OF DRY AIR" (20 to 240). It includes lines for "WET BULB AND DEW-POINT TEMPERATURES", "DEW POINT", and "RELATIVE HUMIDITY LINES".

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2.1.2 QUIZ 2 INITIAL RCM INTRO

<https://forms.gle/NTqxMYmWvBuRXHG27>

Maintenance policies should address all of the functions that the physical asset is expected to perform. True or false. *

☐ True

☐ False

52

1. What do its users require it do (Functions)?

2. What specific performance losses can occur (Failures)?

3, What event causes the failure (Failure mode)?

4. What happens when it fails (Effects)?

5. Why does it matter (Consequences)?

6. Can we predict, prevent/mitigate the failure consequences?
(Maintenance task)?

7.What if no mitigating task can be found (Default action)?
(Default action)

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Hydraulic shovel Hitachi EX3600 v23.0

1. Accessories

2. Engine system

3. Lubrication system

4. Air intake and exhaust system

5. Cooling system

6. Electronic control system

7. Fuel system

1. To contain the fuel

1. Does not contain

1. Fuel hose Fails caused by Friction or rubbing

2. Sellos de la bomba de combustible dañados caused by Cristalización

3. Mangueras del sistema de combustible Dañado caused by Cristalización

Questions 1 - 3

Failure Mode

Fuel hose Fails caused by Friction or rubbing

(From RCMCost):

Effects

Question 4

When the fuel hose fails functionally the engine stops. A red light flashes on the control panel signaling fuel tank empty. Takes four hours to troubleshoot at replace the hose.

Summary:

Corrective Task: Replace fuel hose.

Skills: Mech/Tech

Est. Downtime(h): 4

Consequence

Question 5

Operational

Mitigation Tasks


Questions 6-7

Type	Description	Interval	Skills	Time(h)
Condition based	Check the correct positioning and the condition of the clamps and fittings of the fuel system hoses	300 h	Técnico	0.0

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Daily meeting between operating and maintenance supervisors at shift change.

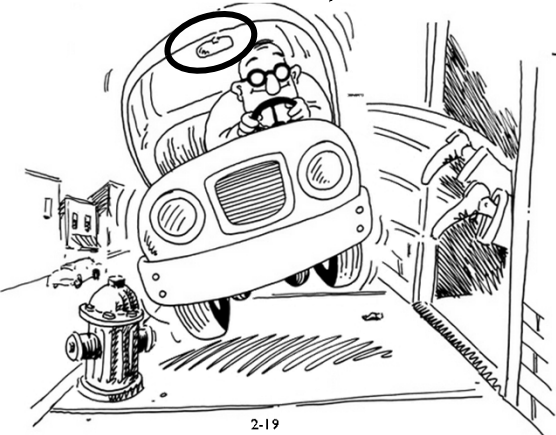
Failure Modes



Reactive

→


Proactive



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2-19

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A Duty Pump


24/7

Possible PM Tasks

1. Replace impellor

2. Check seals and pipe joints


3. Vibration analysis of bearings



B Operates in the presence of ...

Possible PM Tasks

1. Little or no maintenance (assuming no HSE or operational consequences other than switching to C and repairing B).



C Standby for **B**

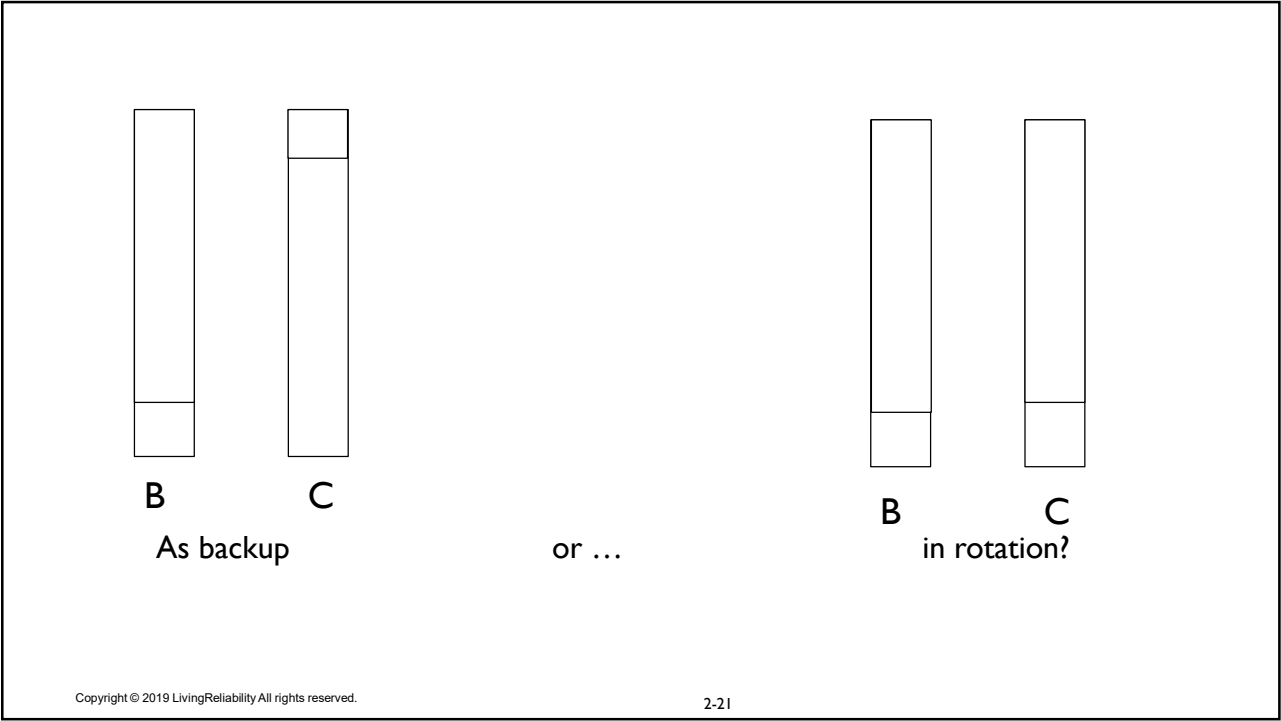
Possible PM Tasks

1. Test whether it works.

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2-20

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Consequences

We can think of Pump C as protecting the function of Pump B. Consider also a secondary containment function...

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Consequences

I. “Hidden failures, Hidden consequences and Hidden functions”



59

Consequences

I. “Hidden failures, Hidden consequences and Hidden functions”

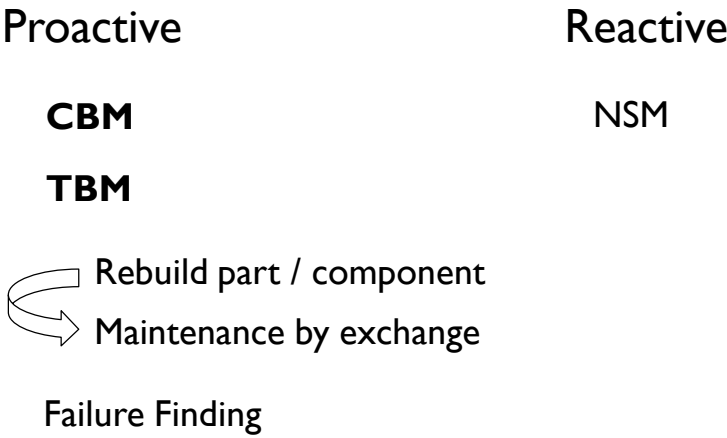


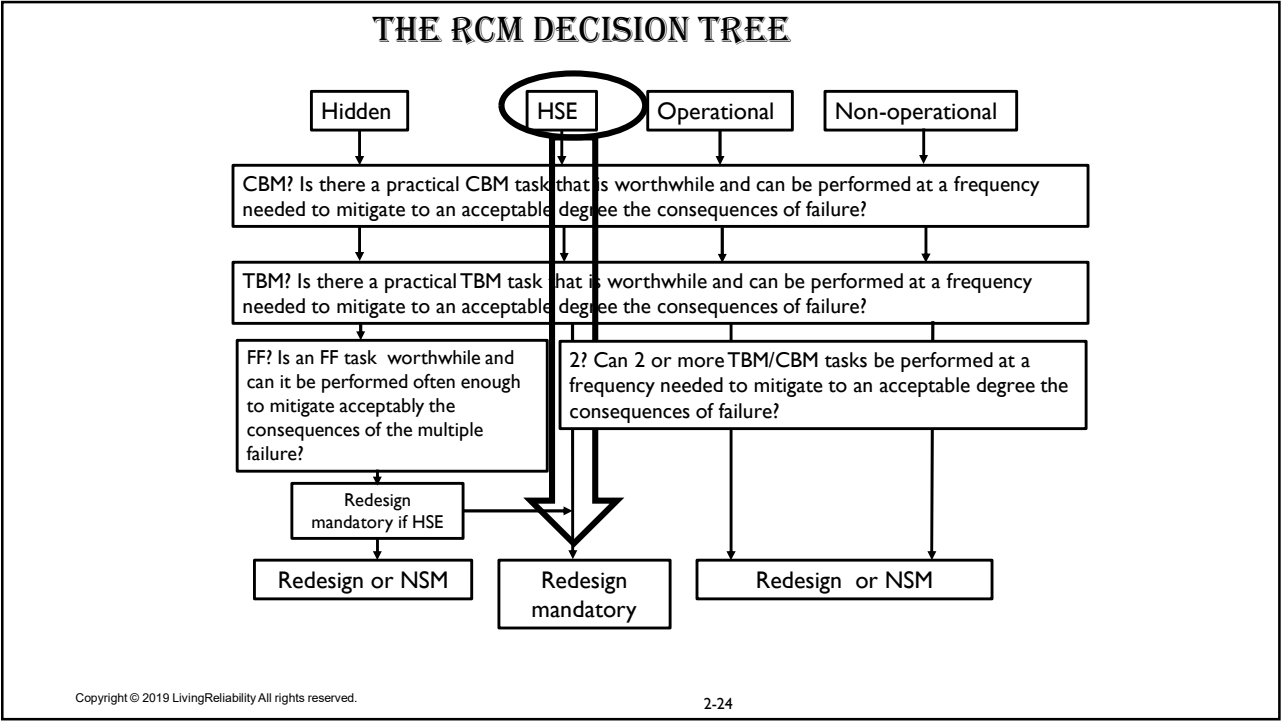
60

Consequences

- 1. “Hidden failures, Hidden consequences and Hidden functions”
- 2. Health, Safety, and Environmental consequences (HSE)
- 3. Operational consequences affect customer service or product costs
- 4. Non-operational – affecting only the maintenance budget.

Maintenance Policies





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Knowledge Base - RCM Hierarchy Builder

Start Edit Save Keywords Search Clear

- 3. Lubrication system
- 4. Air intake and exhaust system
- 5. Cooling system
- 6. Electronic control system
- 7. Fuel system
 - 1. To contain the fuel
 - 1. Does not contain
 - 1. Fuel pump Seals fail caused by n/a
 - 2. Fuel hose Fails caused by n/a
 - 3. Fuel hose Fails caused by Friction or rubbing
 - 4. Fuel Filter Seal fails caused by n/a
 - 5. Injector Seal fails caused by n/a
 - 6. Fuel pressure sensor Seal fails caused by n/a
 - 7. Valve actuator Seal fails caused by n/a
 - 8. Fuel manifold Seal fails caused by n/a

Failure Mode

Fuel hose Fails caused by Friction or rubbing

(From RCMCost):

Effects

Summary: When the fuel hose fails the engine stops. A red light flashes on the control panel signaling fuel empty.

Corrective Task: Replace fuel hose.

Skills: Mech/Tech

Est. Downtime(h): 4

Consequence

Operational

Mitigation Task

Type	Description	Interval	Skills	Time(h)
Condition based	Check the correct positioning and the condition of the clamps and fittings of the fuel system hoses	300 h	Técnico	0.1

"Line of Sight" ISO 55000

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Item Number:		Built-in test equipment:	
Item Description:		Can equipment / system / plant be operated with item inoperative? Describe limitations:	
Redundancies and Protective Features:		Operating phases:	
Reliability Data (if available):		Operating context:	

RCMREF	Function Statements (Quantitative Performance Requirements)	Failed States (Vags Performance is Lost)	Failure Causes	Local and Global Effects	Consequences - Decisions - Tasks	Maintenance Tasks (materials, tools, procedures, other requirements)	Initial Interval	By
	<p>The decision algorithm. Upon determination of the consequences (H, S, O, or N), proceed from left to right by answering the questions:</p> <p>C: Can CBM reliably detect the 'failing' state early enough to reduce the failure's probability and/or its consequences to a tolerable level? Does it make economic sense to perform this task at the frequency required?</p> <p>T: Is there an age (useful life) at which the probability of failure due to this failure mode increases rapidly, and do most items survive to this age? Can a routine (TBM) task reduce the failure's probability and/or its consequences to a tolerable level?</p> <p>D: Is a detection task applicable? Will it reduce the multiple failure's probability to a tolerable level. Is it effective? Is it practical to do the task at the required interval?</p> <p>2: Can a combination of 2 or more TBM and CBM tasks be effective to avoid or reduce the safety consequences to a tolerable level? Are they applicable (practical)?</p> <p>N: No time nor condition based activities need be scheduled.</p> <p>R: Redesign compulsory (H or S), optional (O or N)</p>			<p>Consequences:</p> <p>H = Hidden</p> <p>S = Safety/Environment</p> <p>O = Operational</p> <p>N = Non-operational</p>	<p>Record the consequence</p> <p>Record the most robust task that is applicable and effective.</p>			
				<p>What sequence of events (component level to organization) could be touched off by the failure mode?</p> <ul style="list-style-type: none">• how does the failure make itself known? What observable events lead up to the failure?• how is safety or the environment impacted? (without mentioning the words "safety" or "environment")• how is production impacted? (quality, cost, customer service)• is there any additional damage caused? Are there currently any mitigating circumstances or tasks?• how long will it take and what actions must be accomplished to correct the failure?• How does the likelihood of this failure depend on deeper causes? Has it happened before? How often?• Under what circumstances? How likely or unlikely is this failure mode considered to be? <p>usually written as noun followed by a verb and a due-to clause - deterioration (fatigue, abrasion, erosion, corrosion, etc.), lubrication, dirt, incorrect process, etc. - incorrect assembly / setup / operation, etc.</p> <p>it is the event that causes the loss in functionality (i.e. the failed state)</p> <p>decide how many reasonably likely failure modes (per failed state) to include (balance likelihood and consequences)</p> <p>decide how low on the causality chain to go (to the level that can be addressed by a suitable task).</p>				
	<p>1</p> <p>2</p> <p>3</p> <ul style="list-style-type: none">• how does the physical asset fulfill all the requirements of the user? (in its current operating context)• usually starts with the word "to" and contains at least one (preferably more) quantitative performance standards• list the actual user/owner/society requirements, <u>not</u> the asset's design or initial capability.• use code phrases to imply a hidden function (e.g. to be capable of, to be able to, ...to heat to 140C in the presence of a standby heater.)• secondary: Protection-Environment-Appearance-Control/contain/comfort-Health&safety-Efficiency-Structure/superfluous• specify the mission phase (during startup, during operation, during shutdown, during specified operating context)• decide whether the function is more simply represented as a failure mode of some more "primary" function							
						<p>Provide as much detail and clarity as possible so as to make subsequent transcription to SOPs and CMMS PM work orders quick and easy but ...</p> <p>do not spend valuable analysis time on redesign at this time! (Mainly specify the redesign requirements.)</p>		

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2.1.2 QUIZ 3 INITIAL RCM INTRO

<https://forms.gle/x9zVnVa58ZH7jZLW8>

1. To gain confidence that our maintenance plan is optimal we should ensure that every scheduled maintenance task clearly addresses the preservation of a required asset function. Which of the following are correct? *

☐ 1.RCM starts by identifying the components and their failure modes.


☐ 2. The RCM derived maintenance plan is concerned primarily with the prevention of failure.

☐ 3. The ultimate goal of physical asset management should be to design out all failures.

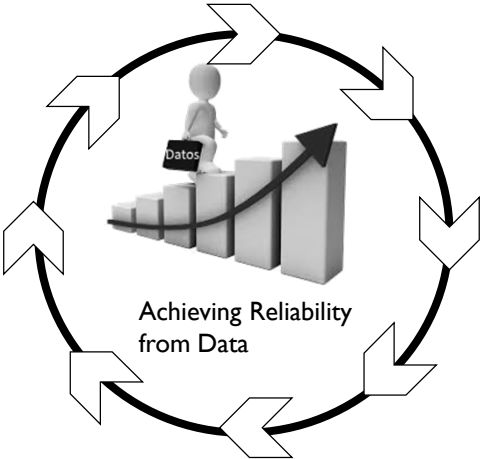
☐ 4, The failure effects describe the events that cause a failure mode.

☐ 5. None of the above.

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Initial RCM



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