ACHIEVING RELIABILITY FROM DATA

Module 2.1

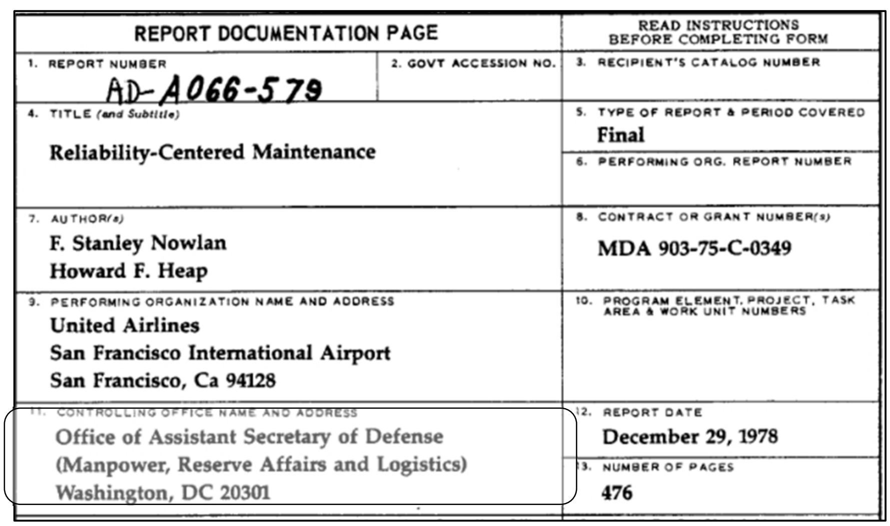
RCM – Introduction

Living RCM Certified®

Dynamic RCM

I-00

1



REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
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4. TITLE (and Subtitle) Reliability-Centered Maintenance		5. TYPE OF REPORT & PERIOD COVERED Final
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7. AUTHOR(s) F. Stanley Nowlan, Howard F. Heap		8. CONTRACT OR GRANT NUMBER(s) MDA 903-75-C-0349
9. PERFORMING ORGANIZATION NAME AND ADDRESS United Airlines, San Francisco International Airport, San Francisco, Ca 94128		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics) Washington, DC 20301		12. REPORT DATE December 29, 1978
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2

Definition of RCM

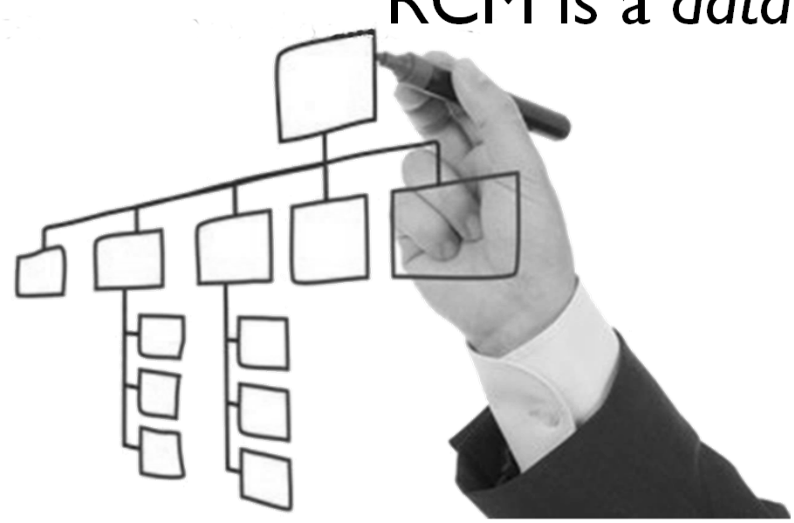
"A process for determining which types of scheduled maintenance tasks should be applied to an item and how frequently the assigned tasks should be accomplished.

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)

I-02

3

RCM is a *data model*



I-03

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GUIDELINES FOR THE NAVAL AVIATION RELIABILITY-CENTERED MAINTENANCE PROCESS

NAVAIR

Facilitated RCM Review Group

I-04

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2.1.1 QUIZ 1 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

6

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

 1-05-01

7

Profound changes occurred in the
world of maintenance.

 1-05-01

8

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

1-05-01

9

Sweeping changes in maintenance.

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

1-05-02

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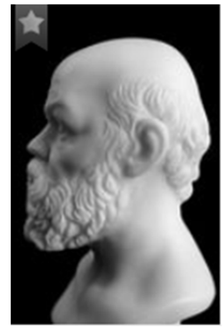
THE SOCRATIC METHOD OF TEACHING BY ASKING QUESTIONS

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



SOCRATES

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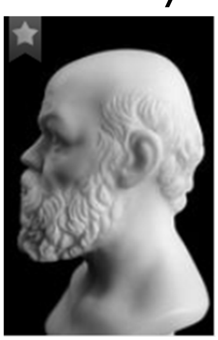
Moubray emphasized that RCM is a learning experience.



RCM, only asks questions.
RCM never answers them.

Socrates, taught the world that questions provoke discovery.

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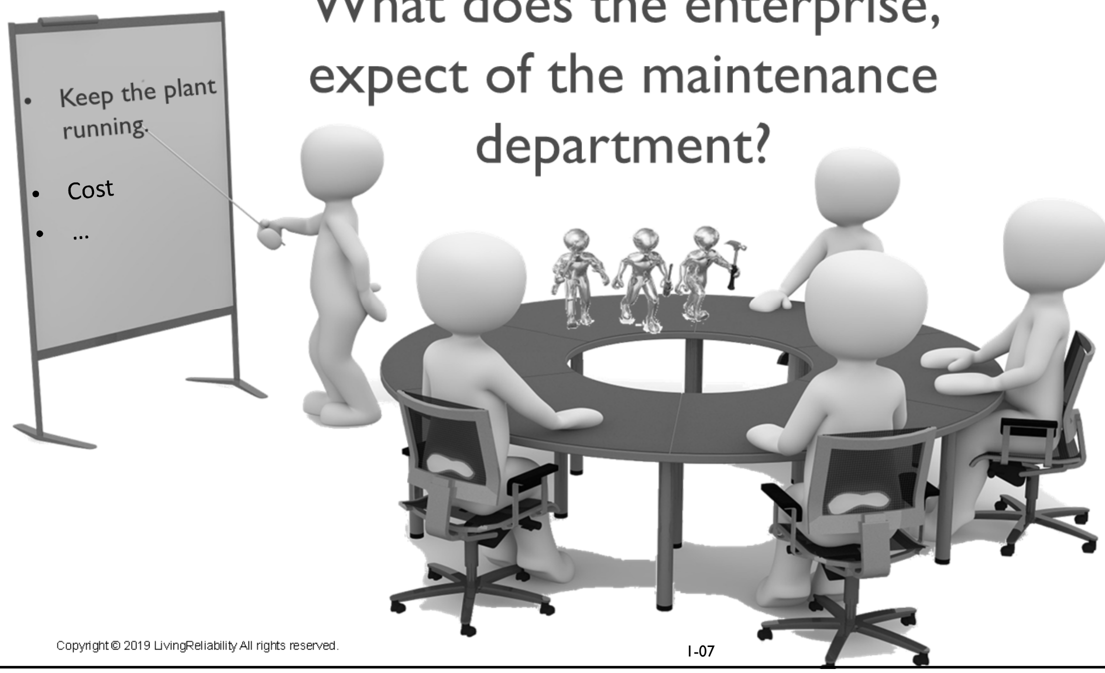
What does the enterprise, expect of the maintenance department?



I-07

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MECHANIZATION AND AUTOMATION ⟸ Reason 1

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**

I-08

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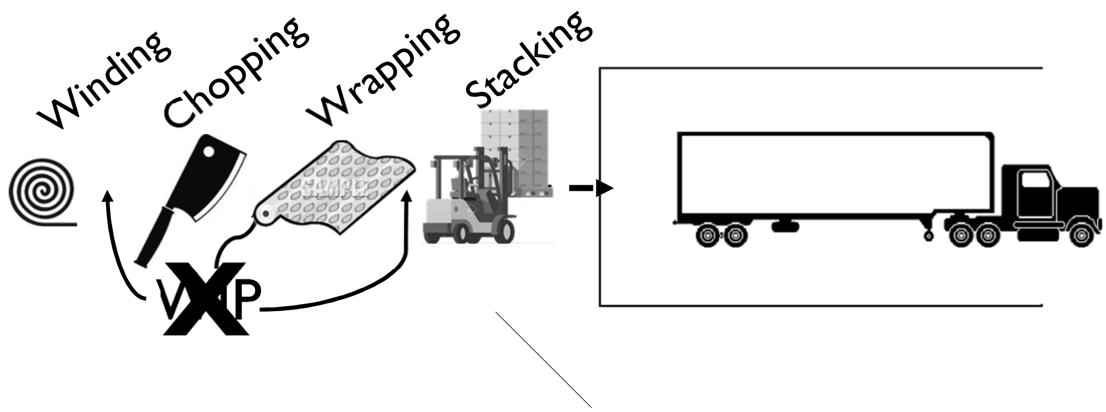
MECHANIZATION & AUTOMATION **REASON 1**

COMPETITION REASON 2

JIT REASON 3



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2.1.1 QUIZ 2 INITIAL RCM INTRO

https://forms.gle/zAQxC4YVp6FsXsZ57

1. Keeping the plant running became much more critical to the enterprise's viability beginning in the 1970s and 1980s because: *

- 1. Increased mechanization had to be financed. Continuous revenue was required to pay off the interest an...
- 2. Increased globalization caused acute international competition.
- 3. Minimal inventories caused interruptions to production to be more likely to impact customer service and...
- 4. All of the above.
- 5. None of the above.

16


What does the organization expect of its maintenance department?
Expectations
Keep the plant running
Cost
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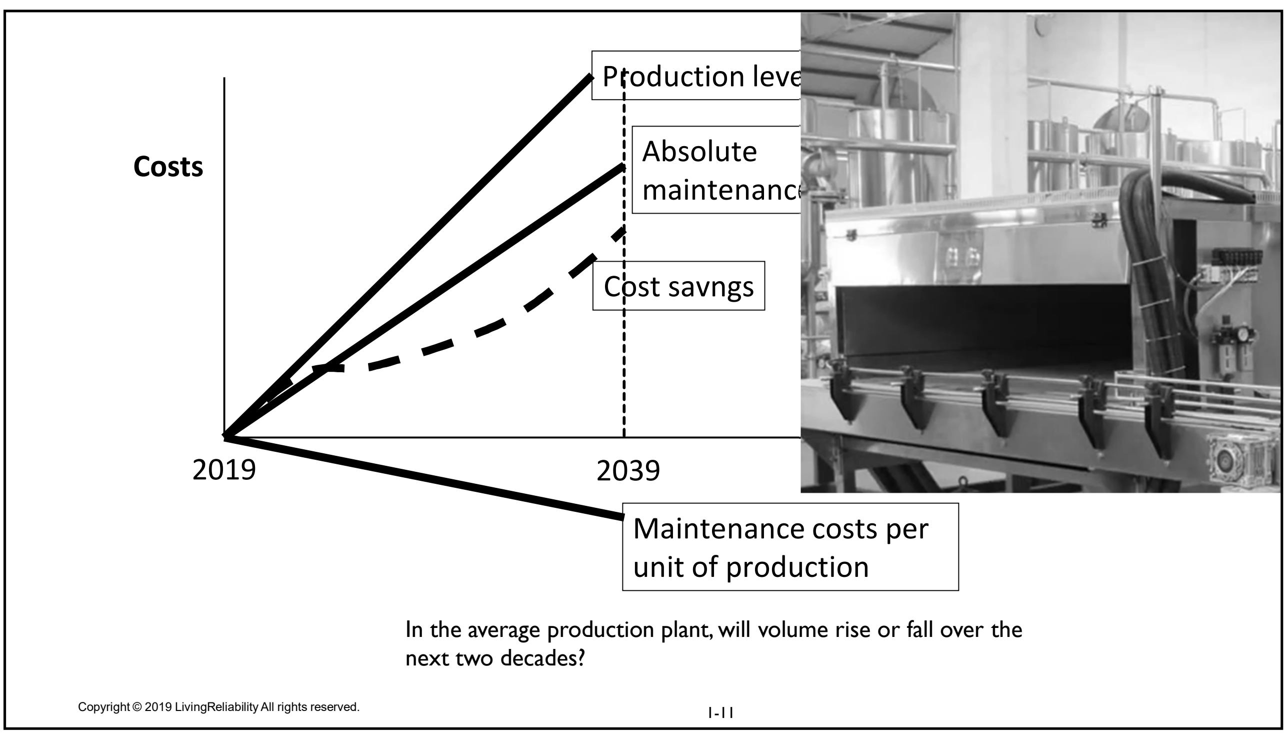
Production leve
Absolute maintenanc
Cost savngs
Costs
2019
2039
Maintenance costs per unit of production
In the average production plant, will volume rise or fall over the next two decades?
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I-11

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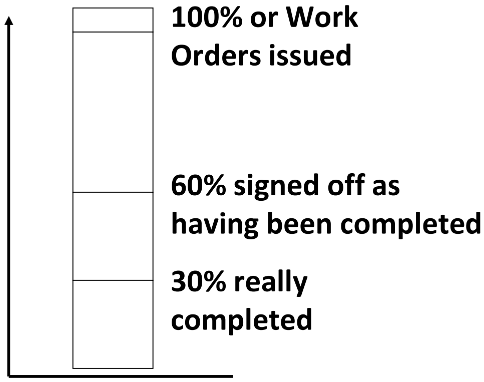
BUT COST IN MAINTENANCE IS FRAUGHT WITH CONTRADICTION.



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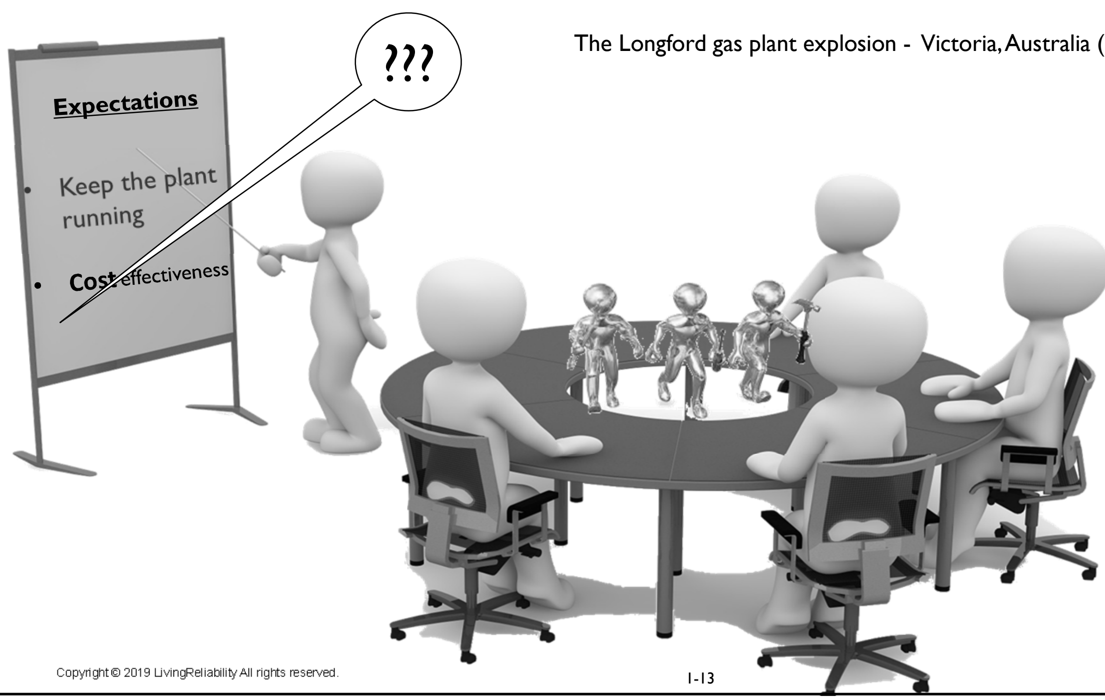
The Longford gas plant explosion - Victoria, Australia (1998)



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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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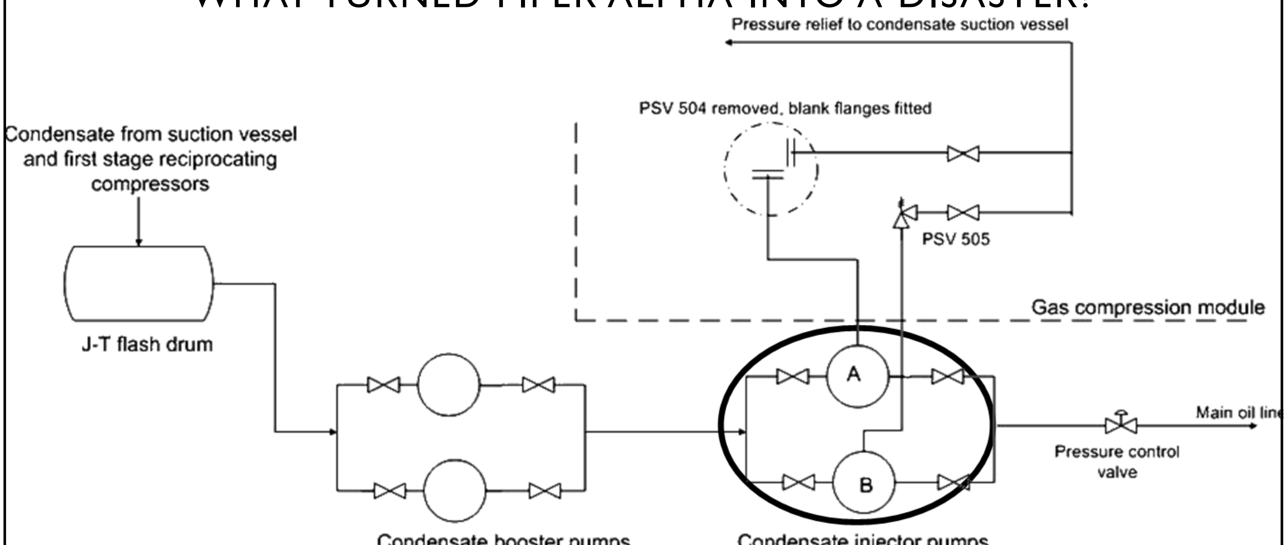
WHAT TURNED PIPER ALPHA INTO A DISASTER?



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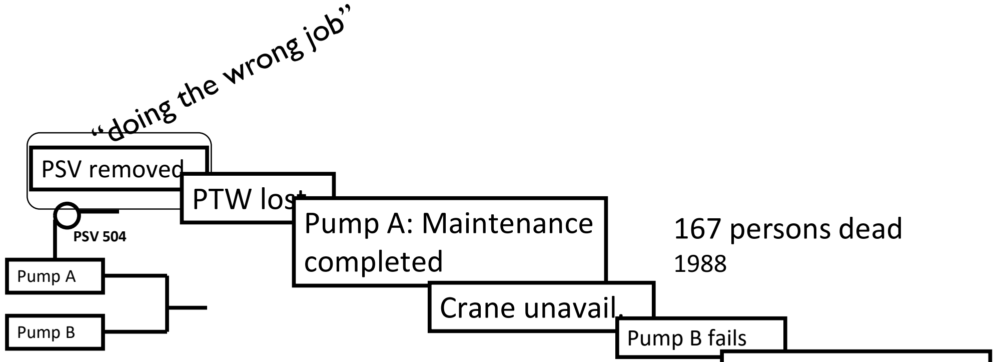
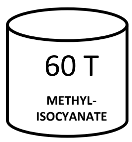
WHAT TURNED PIPER ALPHA INTO A DISASTER?



167 persons dead 1988

Dryer maintenance → Phase 1

BHOPAL



3600 dead 1984

CHERNOBYL 600-186000 dead 1986

EXXON VALDIZ 40,000 T crude 1989

AMOCO CADIZ 230,000 T crude 1978

DEEP WATER HORIZON 688,495 T crude 12 dead 2010

14-16

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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 > Archives
URL: http://www.abc.net.au/lateline/s320793.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

ur people died in the crash

1-17

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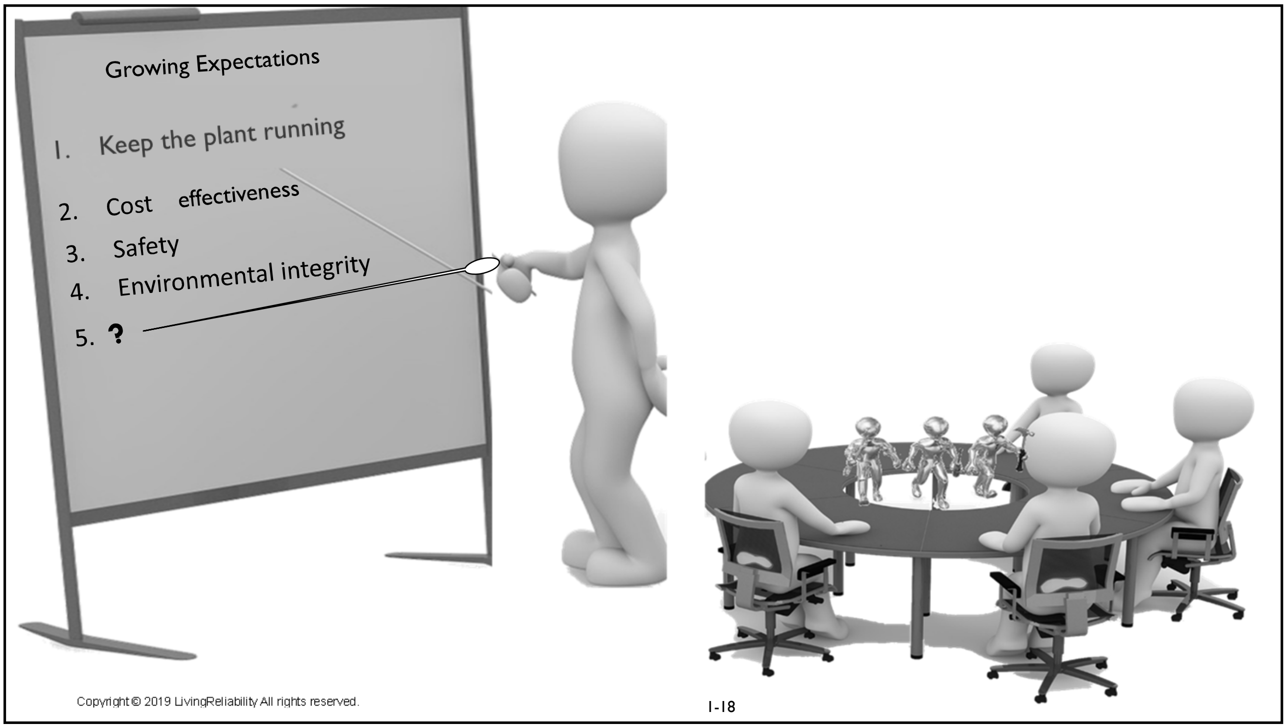
Growing Expectations
1. Keep the plant running
2. Cost effectiveness
3. Safety
4. Environmental integrity
5. ?
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I-18

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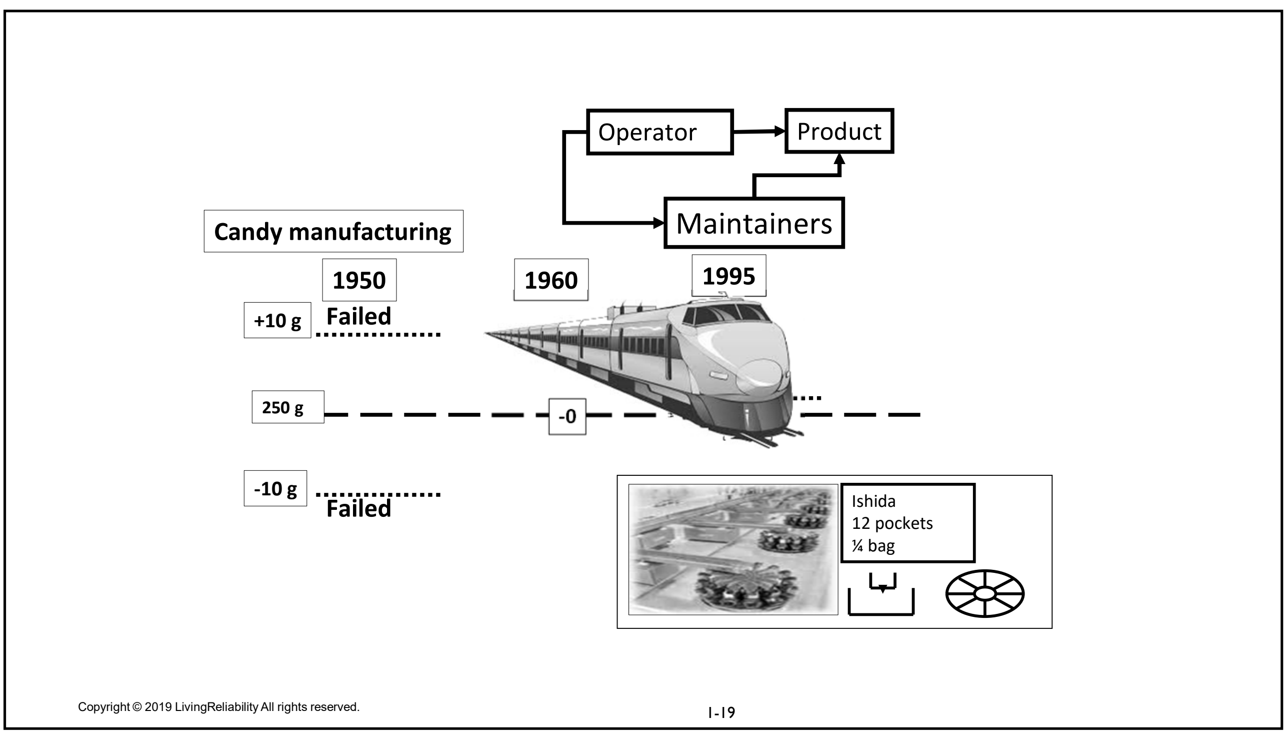
Operator
Product
Maintainers
Candy manufacturing
1950
1960
1995
+10 g
Failed
250 g
-0
-10 g
Failed
Ishida
12 pockets
¼ bag
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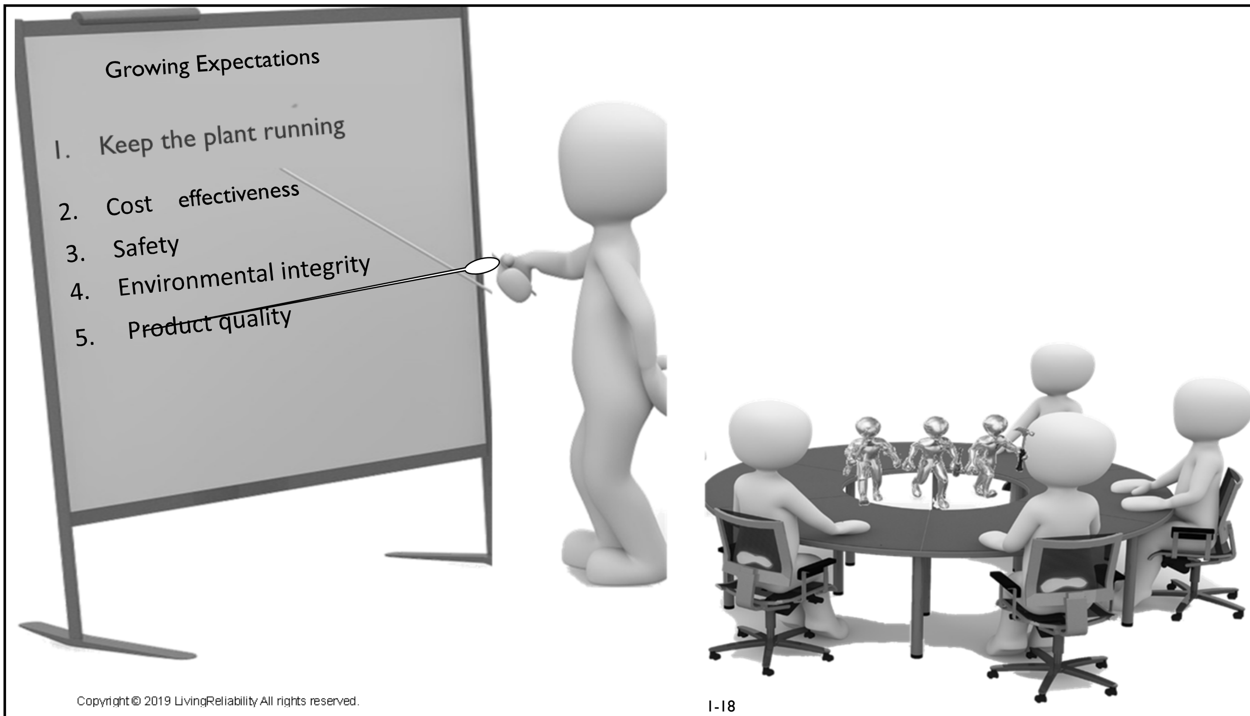

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SUMMARY - EXPANDING EXPECTATIONS OF MAINTENANCE

The modern era of maintenance

Health, Safety, Environment
Reliability, Life Cycle Cost,

ISO 55000

50s, 60s, & 70s

Cost control and
Availability

Pre WW II

Maintenance
mainly reactive

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2.1.1QUIZ 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.

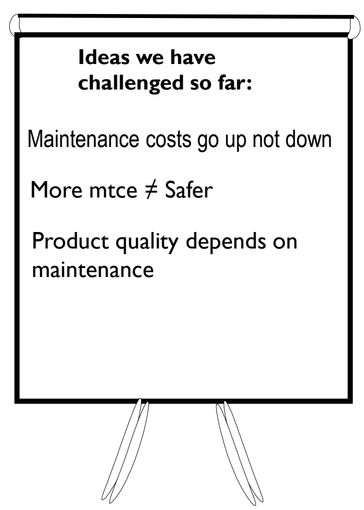
3.

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?

2-01

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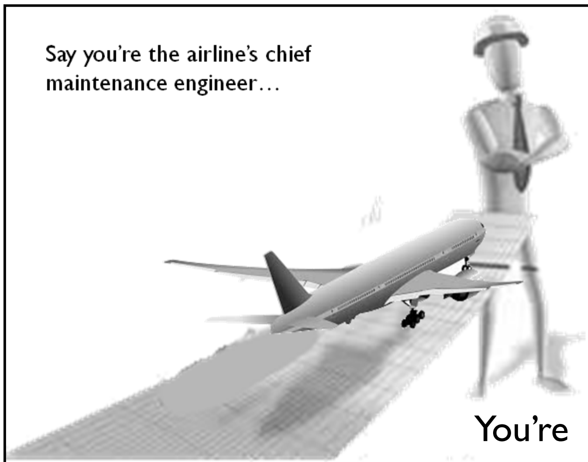
Say you're the airline's chief maintenance engineer…



Gas turbine jet propulsion

Hydraulics , electronics

Pressurized cabin

…

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

2-02a

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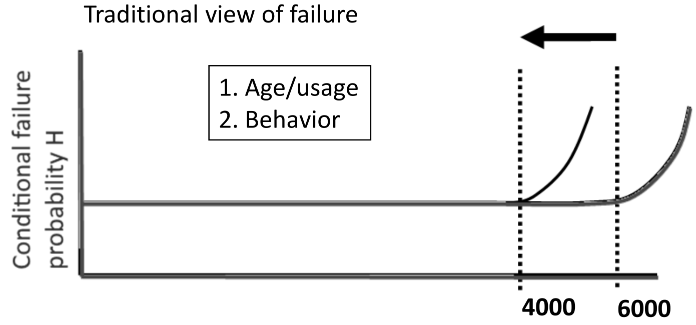
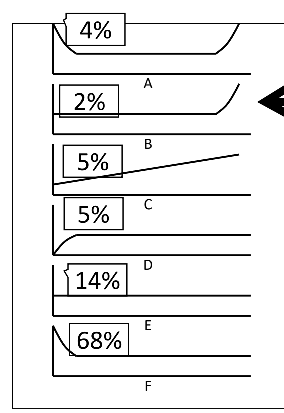
COMMERCIAL AVIATION
Traditional view of failure





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

Based on: J. Moubray, RCM Practitioner course

2-02b

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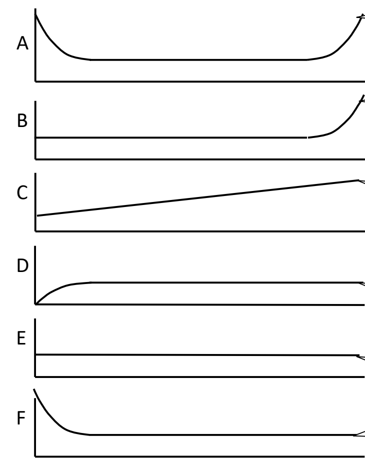
WHERE DO THE PATTERNS APPLY?



- A: Complex systems of multiple components and failure modes
- B: Parts that come into direct contact with the product (abrasion, drying out, fatigue)
- C: Parts that come into direct contact with the environment. (rust, corrosion)
- D: Some parts that cannot fail initially such as bearings packed in grease
- E: Complex precision parts such as bearings, ICs, PCBs, solenoids, switches
- F: Complex parts and systems where quality is an issue, or where installation can be faulty, such as bearings

Patterns D, E, F are associated with complex parts. For example, hydraulic and electronic components.

2-03

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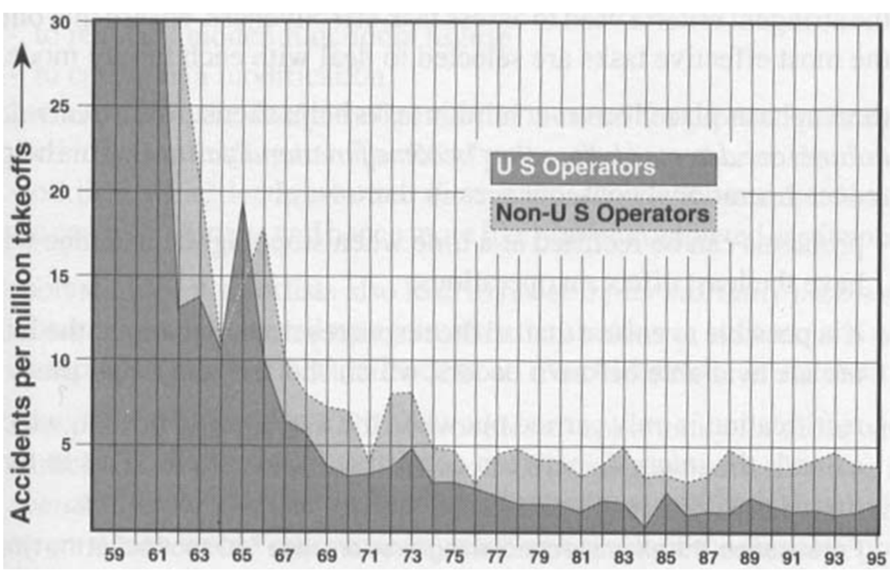

Safety in the civil aviation industry
Source: C. A. Shifrin: "Aviation Safety Takes Center Stage Worldwide"
Aviation Week & Space Technology: vol 145 No 19: Pp46-48

2-04

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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

2-05

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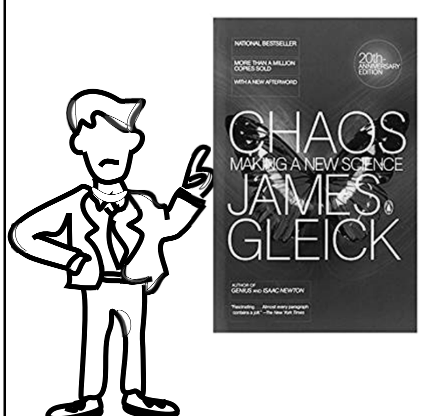

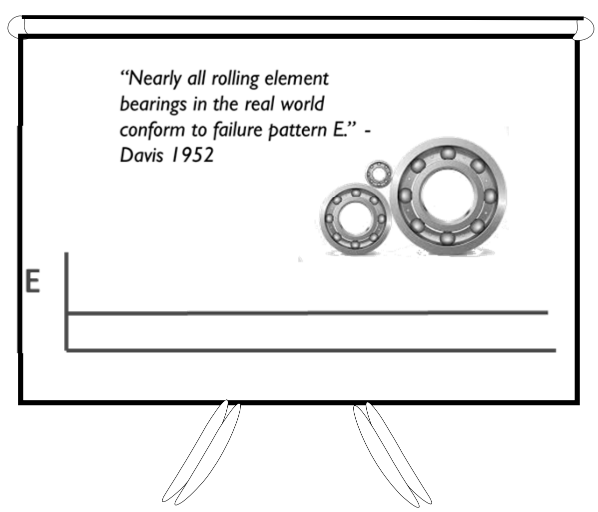

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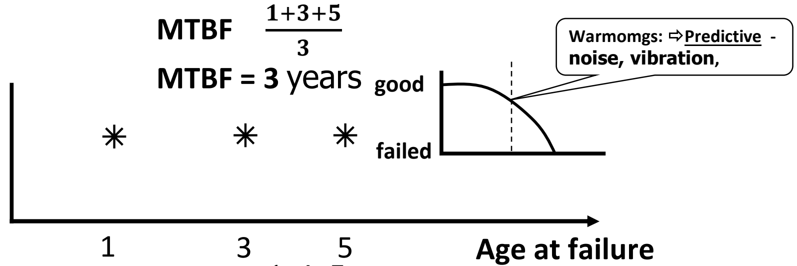
No Preventive

3 bearings

$$MTBF \quad \frac{1+3+5}{3}$$

MTBF = 3 years

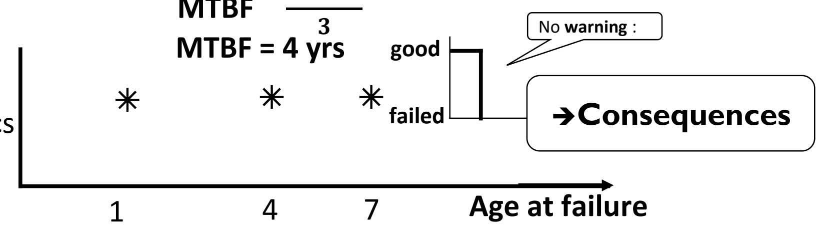


No preventive, No predictive

Electronics

$$MTBF \quad \frac{1+4+7}{3}$$

MTBF = 4 yrs



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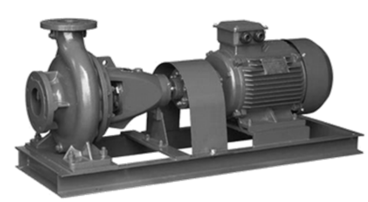
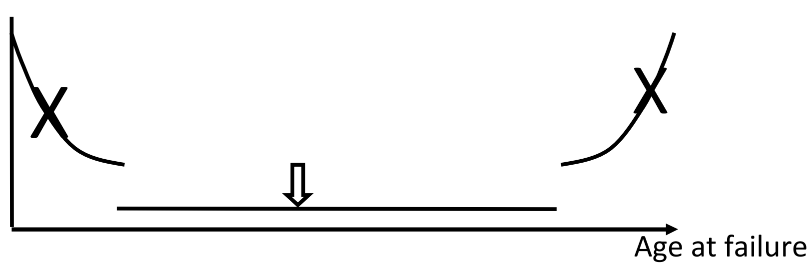


3 Failure Modes

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



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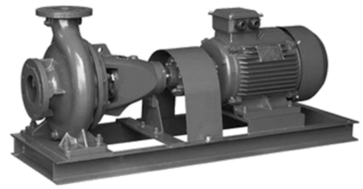
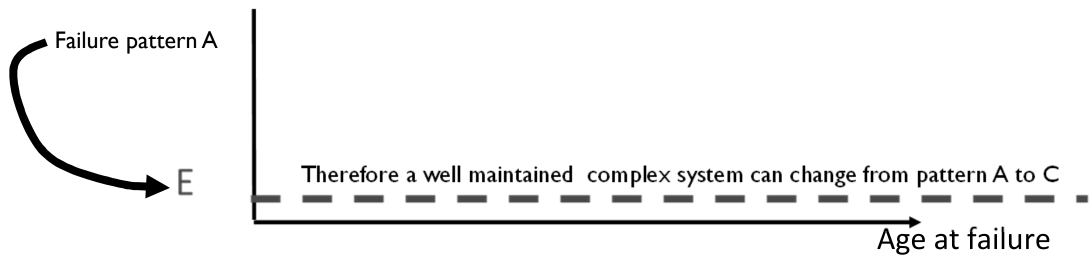


3 Failure Modes

1. Installation Errors
2. Foreign body damage
3. Erosion of impeller

1. Train
2. Add a protective screen
3. Replace at intervals



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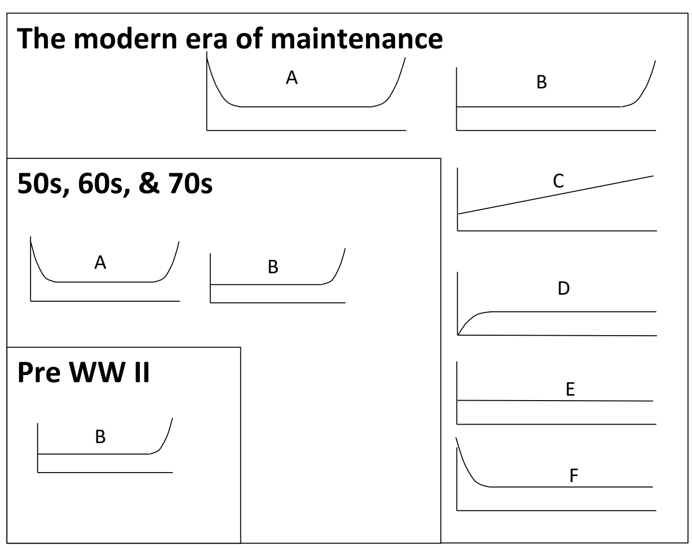
EXPANDING UNDERSTANDING OF MAINTENANCE BEHAVIOR



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Life cycle cost → Cost of the function

2-10

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2.1.2 QUIZ 1 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.

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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.

2-11

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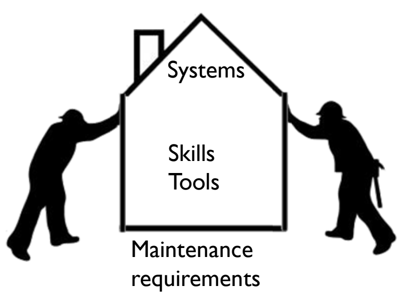

A logically structured approach to maintenance can be thought of, metaphorically, as building a house.

2-12

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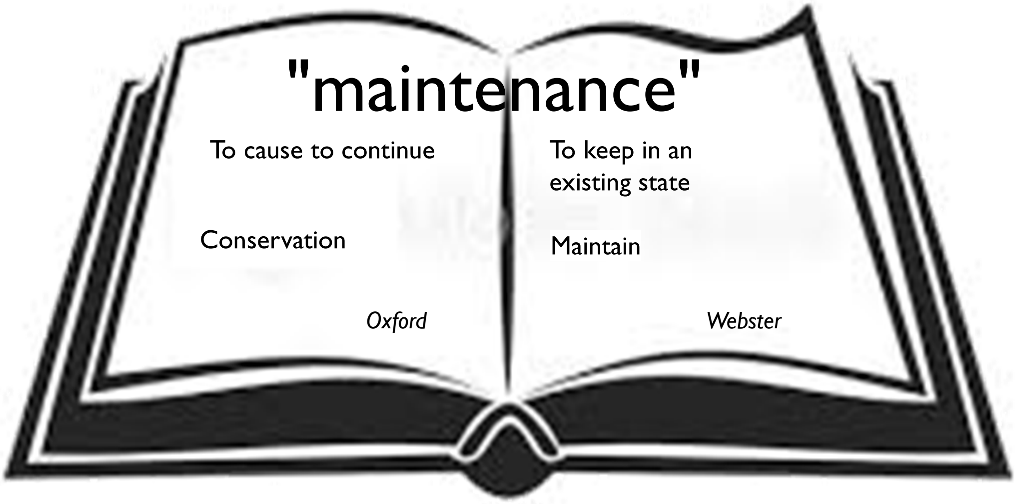
As new technology and standards proliferate, people tend to lose sight of the true meaning of the word "*maintenance*".



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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.

2-14

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What does the user want?

2-15

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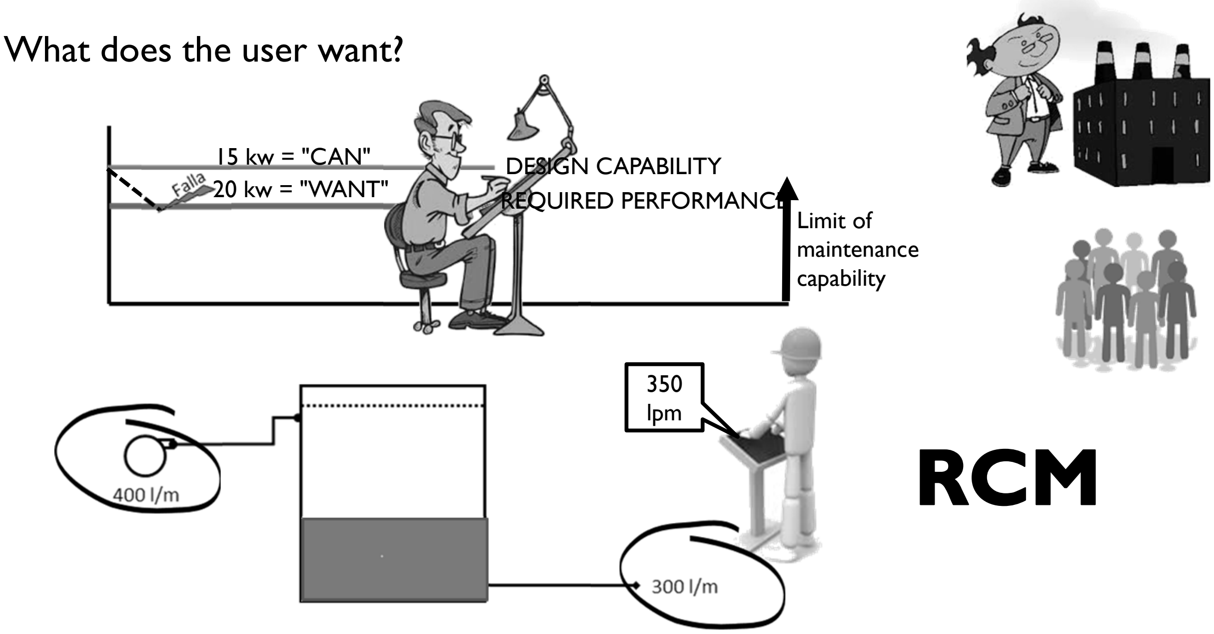
What does the user want?



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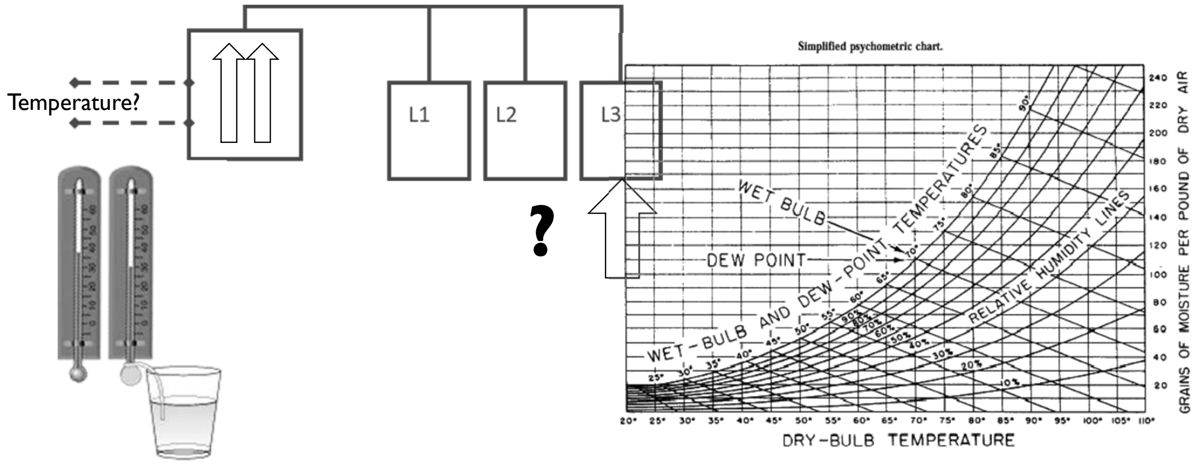
Freeze dryer



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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

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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)

2-17

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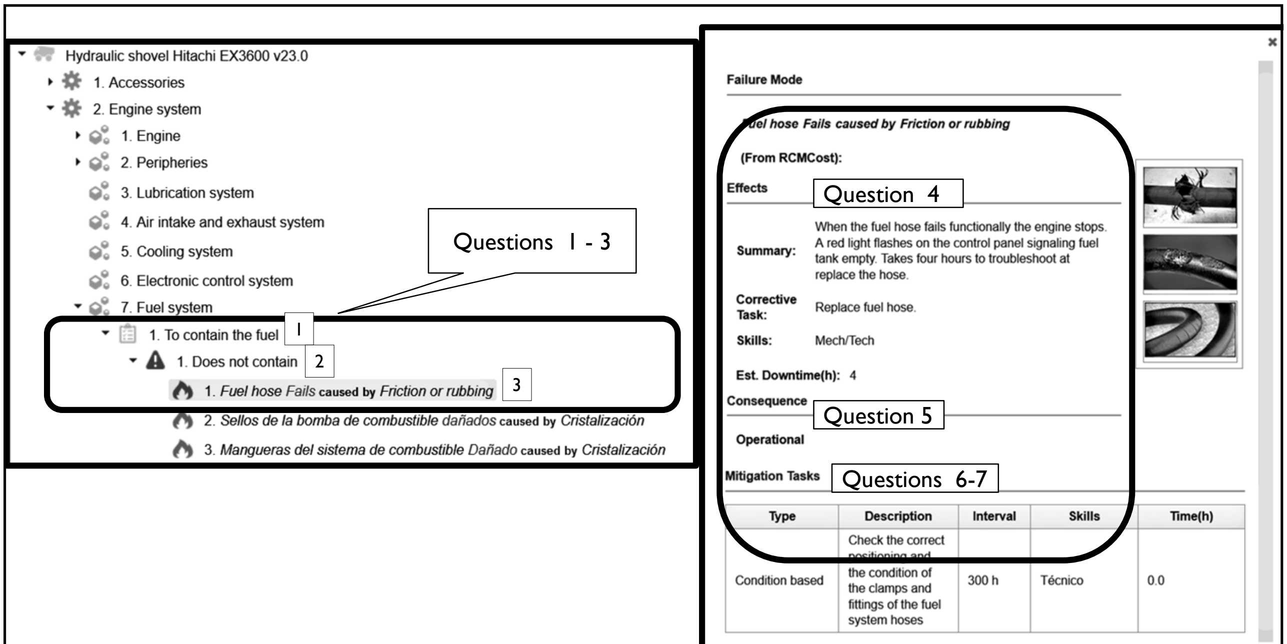

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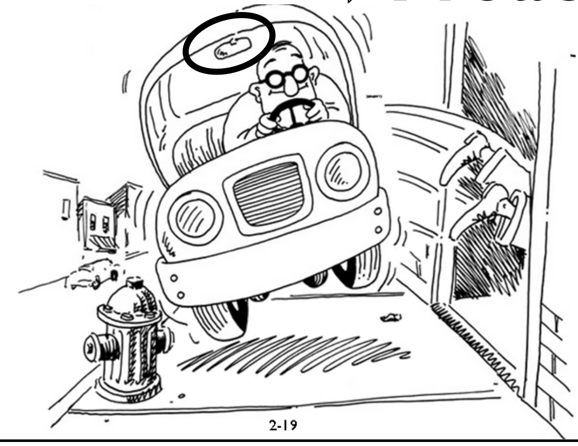
Daily meeting between operating and maintenance supervisors at shift change.

Reactive → Proactive



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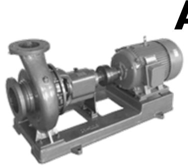

A Duty Pump
24/7

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.

2-20

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As backup or … in rotation?

 2-21

57

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

Consequences

 2-22

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Consequences

1. "Hidden failures, Hidden consequences and Hidden functions"

2-22

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Consequences

1. "Hidden failures, Hidden consequences and Hidden functions"

2-22

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.

2-22

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Maintenance Policies

Proactive

CBM

TBM

Rebuild part / component

Maintenance by exchange

Failure Finding

Reactive

NSM

2-23

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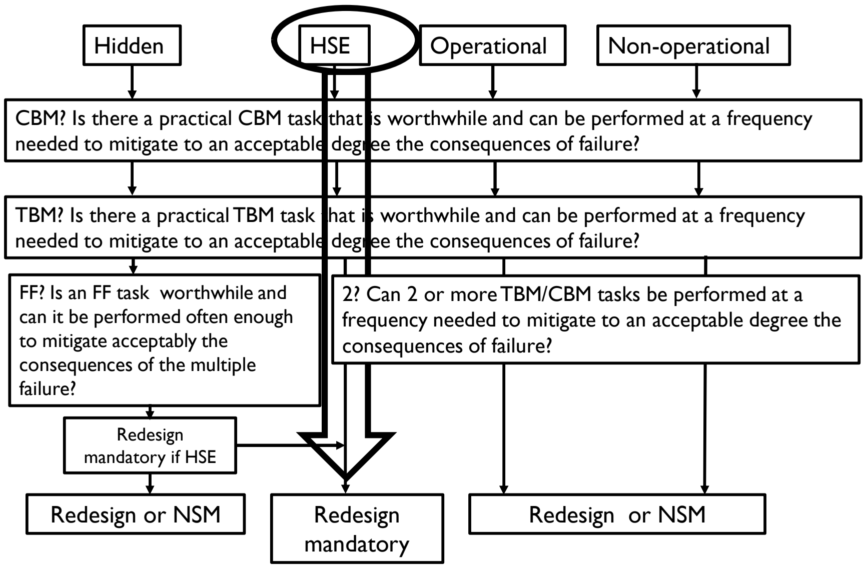
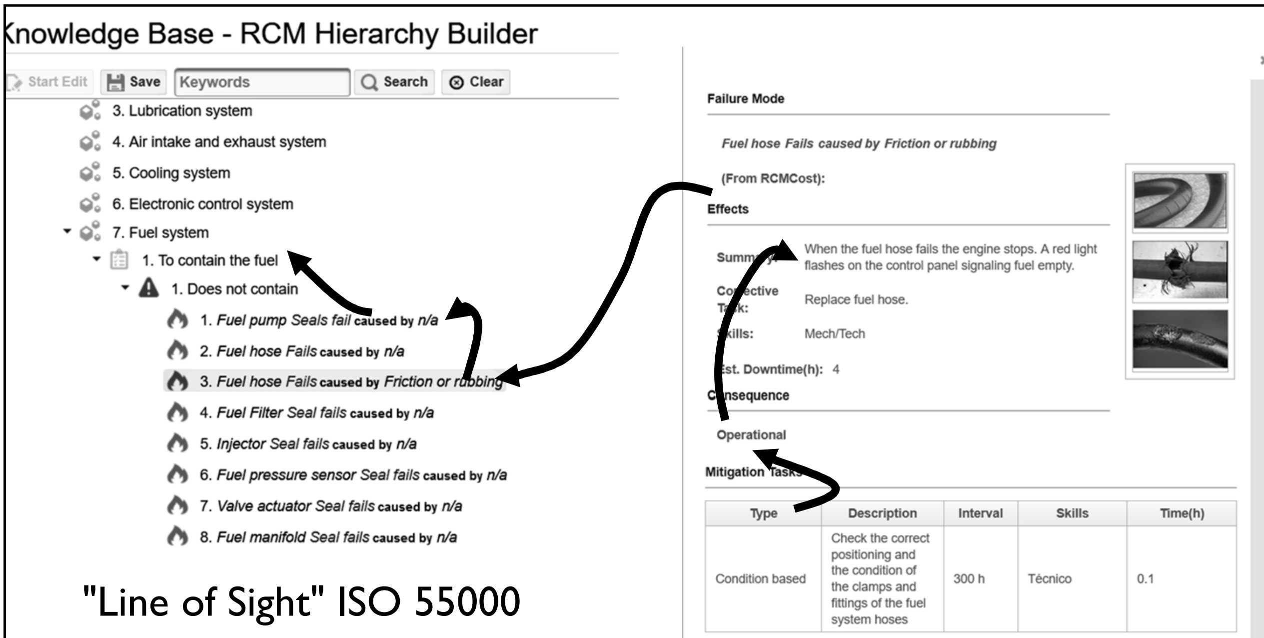
THE RCM DECISION TREE



2-24

63



2-25

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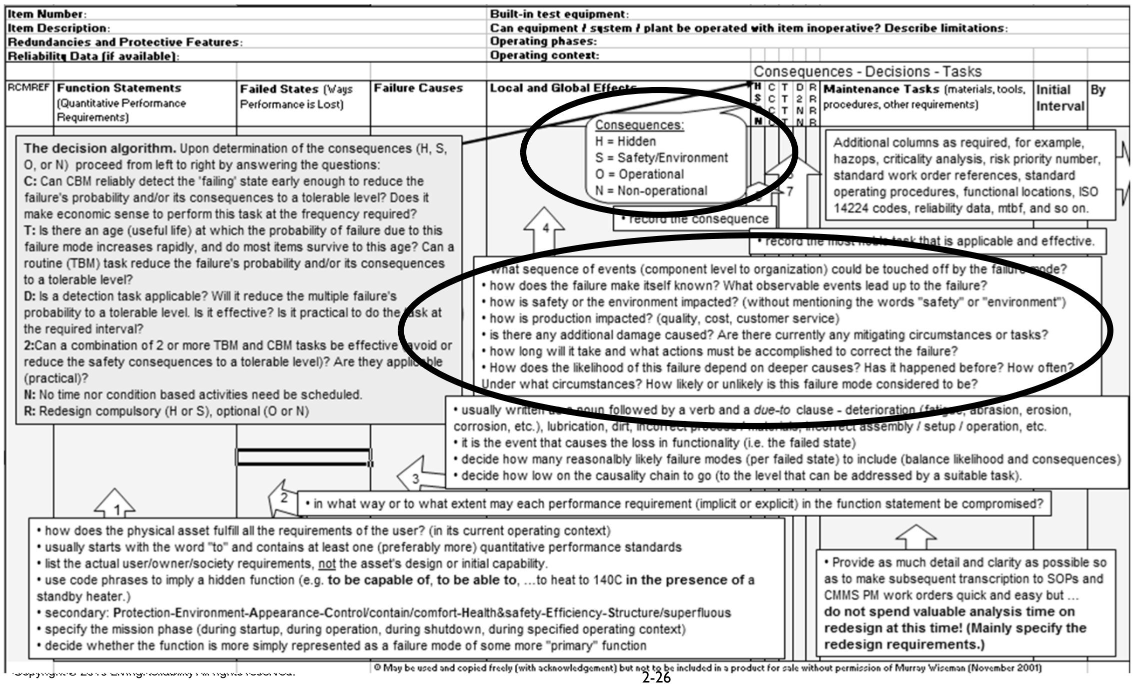

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2.1.2 QUIZ 3 INITIAL RCM INTRO

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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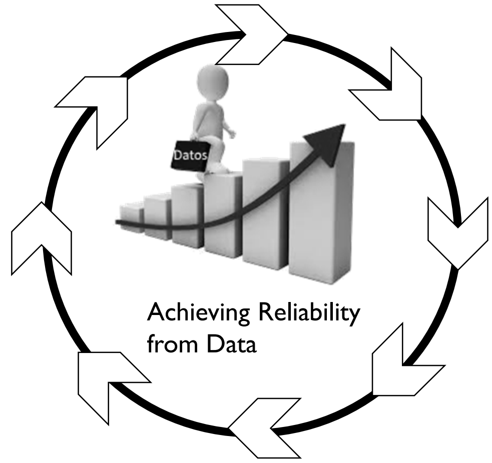

Initial RCM

Living RCM Certified®