



**TOOLBOX**  
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**16**  
EDICIÓN

September 6, 2023

# Reliability Centered Maintenance (RCM)

A Case Study for FMEA,  
Criticality, and Task Selection

**Workbook**



**Nancy Regan, Workshop Instructor**



<https://RCMTrainingOnline.com>

## What you will learn in this Workshop

**Reliability Centered Maintenance (RCM)** is a powerful Reliability improvement process. RCM isn't a new process. The application of its principles spans five decades. It has been - *and is being* - applied in nearly every industry throughout the world. When it is **applied correctly**, with the **right people**, overwhelming positive results can be reaped that can transform an organization. *I've seen it first-hand.*

RCM embodies many Reliability fundamentals. Learning, understanding, and applying these fundamentals at a basic level can help you achieve Reliability goals. But here's the catch. ***You have to actually apply them!***

RCM is the technical love of my life and I often apply RCM principles in my own life. But, just as it often happens in the Reliability "real world," I got busy and didn't take the time to "walk my own talk." And I suffered the **Consequences** for it.

On a recent 400-mile journey in my 2014 Subaru Forrester (coming home from speaking at a Reliability conference!), I experienced an **unanticipated failure** with my boxer engine's lubrication system that interrupted my trip. While driving on the highway, my **Low Engine Oil Light** illuminated on the dashboard so I had to pull over at the nearest gas station to troubleshoot.

I could have completely avoided the situation if I had **proactively managed** one **Failure Mode**. But I didn't. Instead, I was thrown into full-blown **Reactive Mode** 150 miles from my home.

Given what I do for a living, I asked myself, *how did I let this happen?* I felt embarrassed until I realized that many organizations experience the same thing. "*Running from to fire*" and living in Reactive Mode is (unfortunately) a common circumstance in our industry. But it is largely avoidable. So I decided to make lemonade out of my lemons, and that's how this Workshop was born.

## What you will learn in this Workshop, continued

I deconstructed my (unfortunate) event and created this real-life **RCM Case Study**. Together, we will **learn and demonstrate** some of RCM's most important principles at a very basic level including:

- Building a Failure Modes and Effects Analysis (FMEA)
- Assessing Criticality
- Assigning safe and cost-effective maintenance tasks by applying the the **P-F Interval** versus the **useful life**
- Discovering what **Protective Devices** are, why they are so important, and how RCM can help you to properly take care of them

This workshop is not a comprehensive introduction to RCM. But you will leave understanding what RCM is and you will have a working knowledge of some very important Reliability fundamentals because we are going to apply them - *together!*



My mentor John Moubray taught me that **time is our most valuable asset**. I know you had a choice of workshops today, and you chose to spend your time with me. For that, I am sincerely grateful ❤️!

Nancy Regan  
Monterrey, Mexico  
September 6, 2023

# Case Study

## 2014 Subaru Forester Low Engine Oil Light



### Operating Context Excerpt

- 2014 Subaru Forester – personal use vehicle. (I drive it almost exclusively.)
- Drive approximately 12,000 miles per year in the Southeastern United States (almost entirely in Alabama). Longest journey ~ 4 hours from home.
- I do have a “backup” car – 2004 Toyota Corolla.
- Scope of analysis is limited to Failure Modes that result in illumination of the Low Engine Oil Light and the “Low Engine Oil Light system” itself.
- 2.5-liter horizontally opposed four-cylinder (boxer) engine, 170 horsepower.
- Low Engine Oil Light illuminates in the event that the engine oil decreases to the lower limit (2 quarts low).

# Reliability Centered Maintenance

## Definition

RCM is a zero-based process used to identify the **Failure Management Strategies** that are required to ensure an asset meets its **mission requirements** in its **operational environment** in the most **safe and cost effective** manner.

### RCM Process

1. Functions
2. Functional Failures
3. Failure Modes
4. Failure Effects
5. Failure Consequences
6. Proactive Maintenance and Intervals
7. Default Strategies

## Notes

# Reliability Centered Maintenance

## Step 1: Functions

When we write Functions properly, we **define the Reliability** we need from our assets. Then we use the rest of the RCM process to determine how to achieve that Reliability.

Record what you *need* the asset to *do*, not what it is designed to do.

### How to write Evident Functions



### Evident Function

Failure of the Function becomes evident to the operating crew under normal conditions.

### Hidden Function

Failure of the Function is not evident to the operating crew under normal conditions. Hidden Functions are almost always **Protective Devices**. A Protective Device is a device or system that is intended to protect *in the event that* another failure occurs.

### Multiple Failure

Includes the failure of a Protective Device and another failure (e.g., low pressure switch fails and system pressure falls below the normal level).

### **Notes**

# Reliability Centered Maintenance

## Step 1: Functions



**Primary Function: My 2014 Subaru Forester**

To + **Verb** + **Object** + **Performance Standard(s)** + **Operating Context**

<b>Verb</b>	
<b>Object</b>	
<b>Performance Standards</b>	<ul style="list-style-type: none"> <li>•</li> <li>•</li> <li>•</li> <li>•</li> </ul>
<b>Operating Context</b>	

## Notes

# Reliability Centered Maintenance

## Step 2: Functional Failures

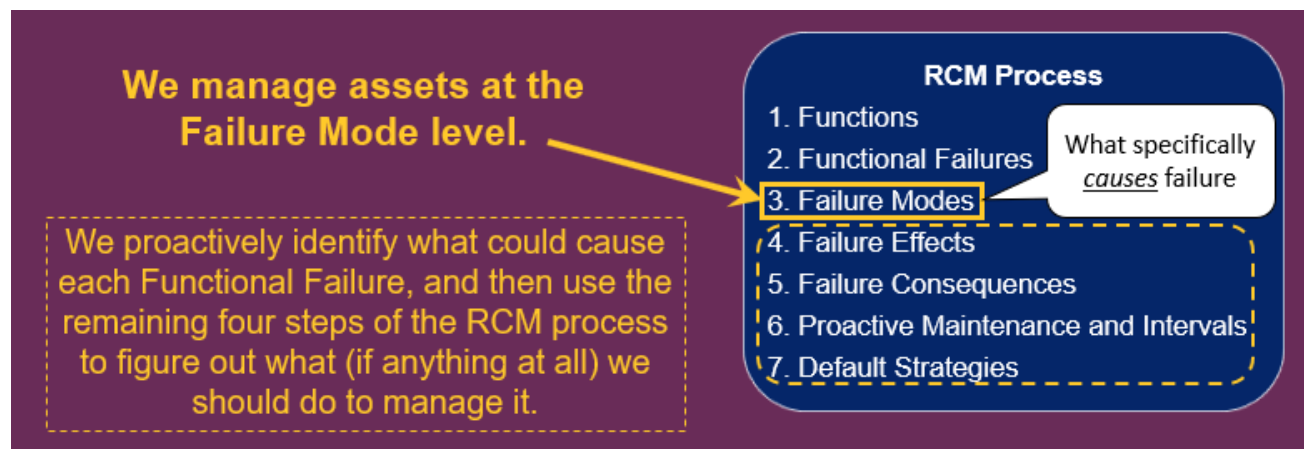
### Total Failure

Complete loss of Function

### Partial Failure

The inability to function at the level of performance specified as satisfactory.

## Step 3: Failure Modes

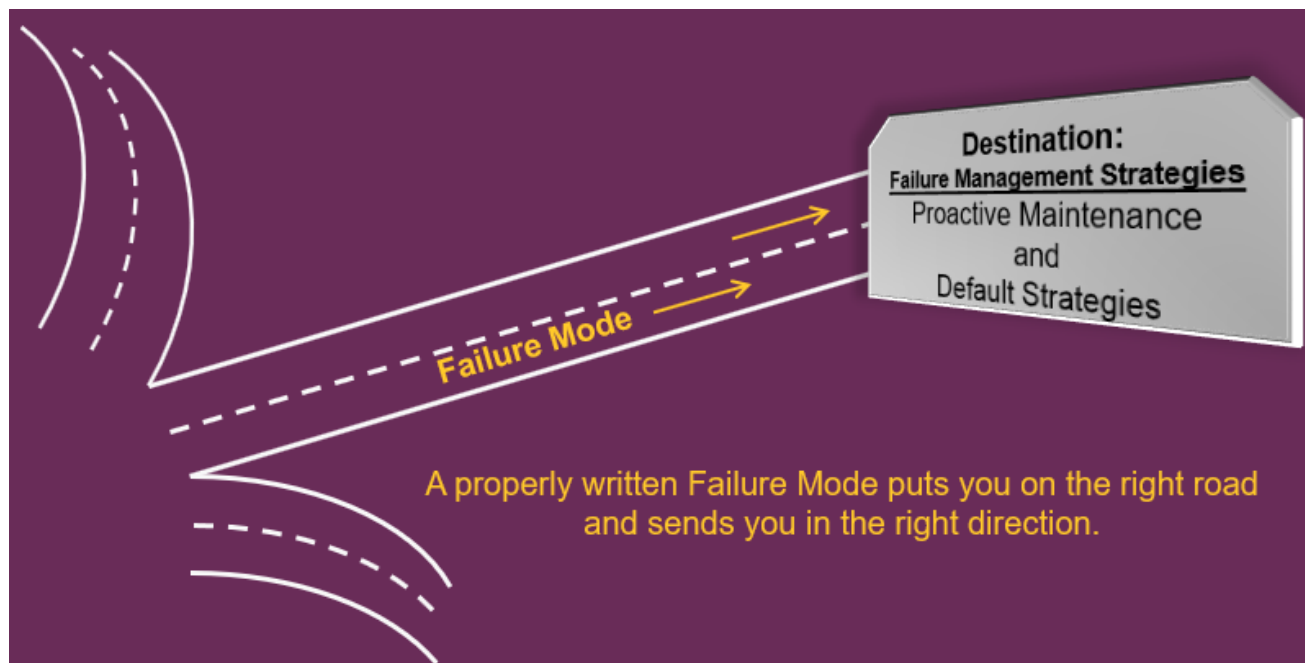


## Notes



# Reliability Centered Maintenance

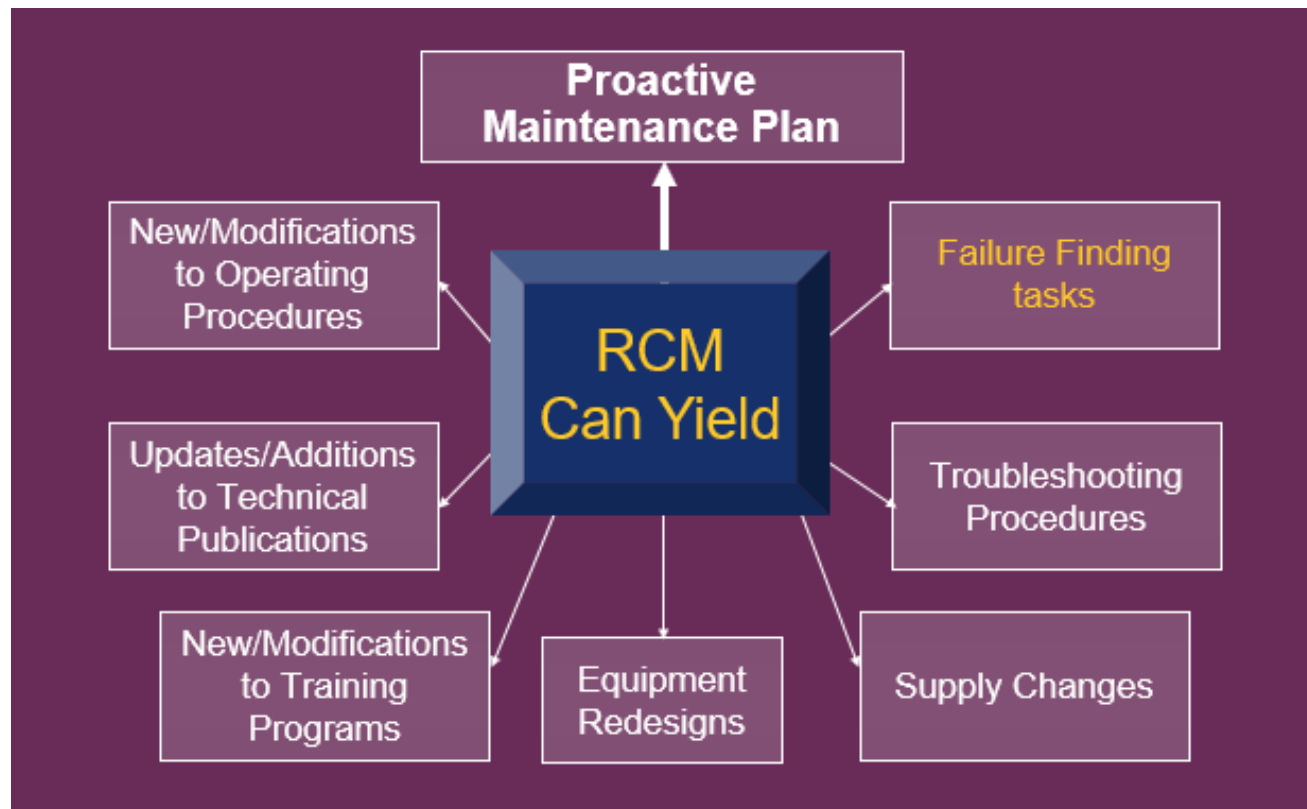
## Step 3: Failure Modes



## Notes

# Reliability Centered Maintenance

## Potential Products of an RCM Analysis



and many others...

## Notes

# Reliability Centered Maintenance

## Step 3: Failure Modes

### How to Compose Failure Modes

**Noun** + **Verb** + *(as necessary)* Operating Context

Hydraulic line chafes due to normal equipment vibration

Hydraulic line chafes due to improper routing

Oil filter clogs due to normal use

Oil filter clogs due to gearbox break-in

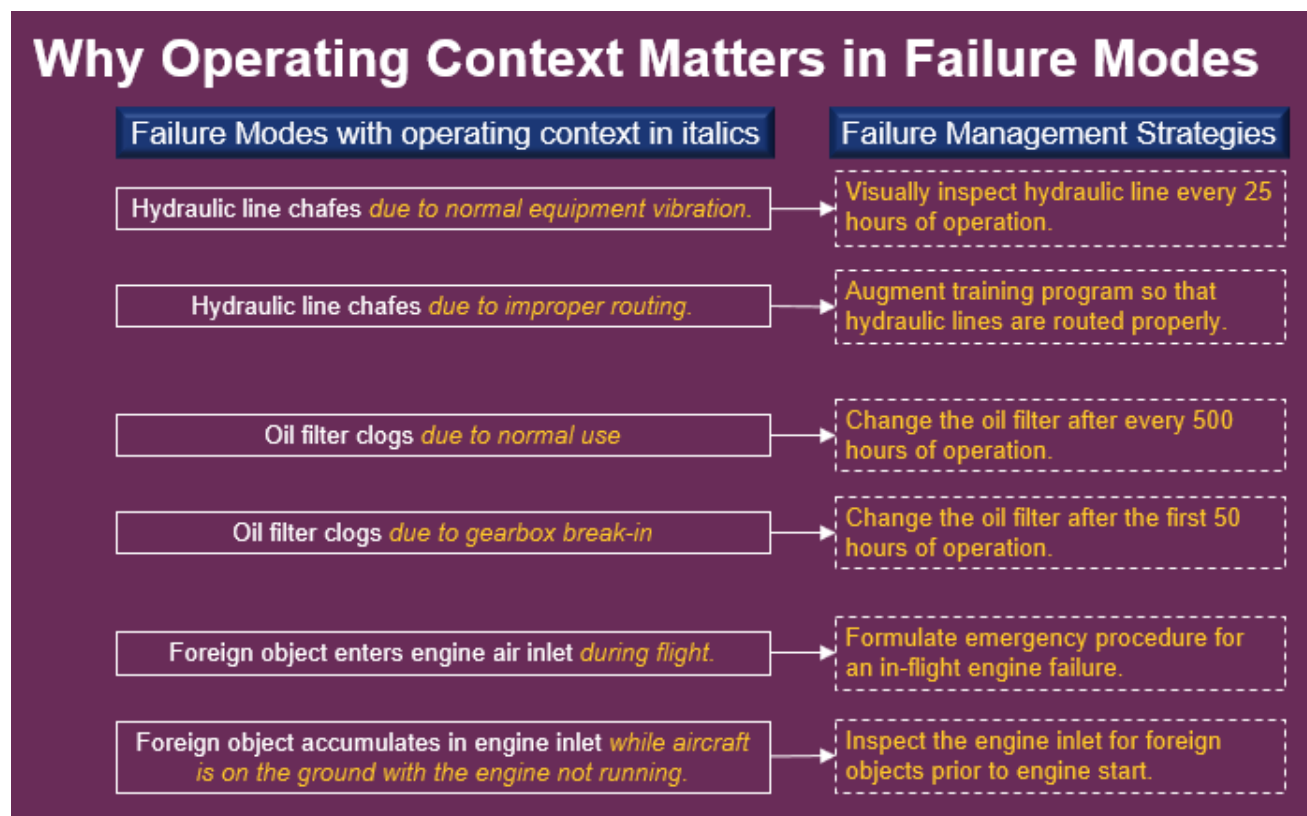
Foreign object enters aircraft engine air inlet during flight

Foreign objects accumulate in aircraft engine inlet while on the ground, with engine off

## Notes

# Reliability Centered Maintenance

## Step 3: Failure Modes



## Notes

# Reliability Centered Maintenance

## Step 3: Failure Modes

What specifically could cause the engine oil to drop to the low level limit and illuminate the LOW OIL LEVEL LIGHT?



1

2

3

## Notes

# Reliability Centered Maintenance

## **Step 4: Failure Effects**

### **Failure Effect**

A story of what would happen if nothing were done to predict, prevent, or manage its associated Failure Mode.

### **Important Points**

- Document worst-case-scenario
- Write in enough detail to assess consequences

### **Failure Effects Include**

- A description of the failure process from the occurrence of the Failure Mode to the Functional Failure
- Physical evidence that the failure has occurred
- How it adversely affects safety and/or the environment
- How it affects operational capability/mission
- Specific operating restrictions as a result of the failure
- Secondary damage
- What must be done and how long it takes to repair the failure

### **Notes**

# Reliability Centered Maintenance

## Step 5: Failure Consequences

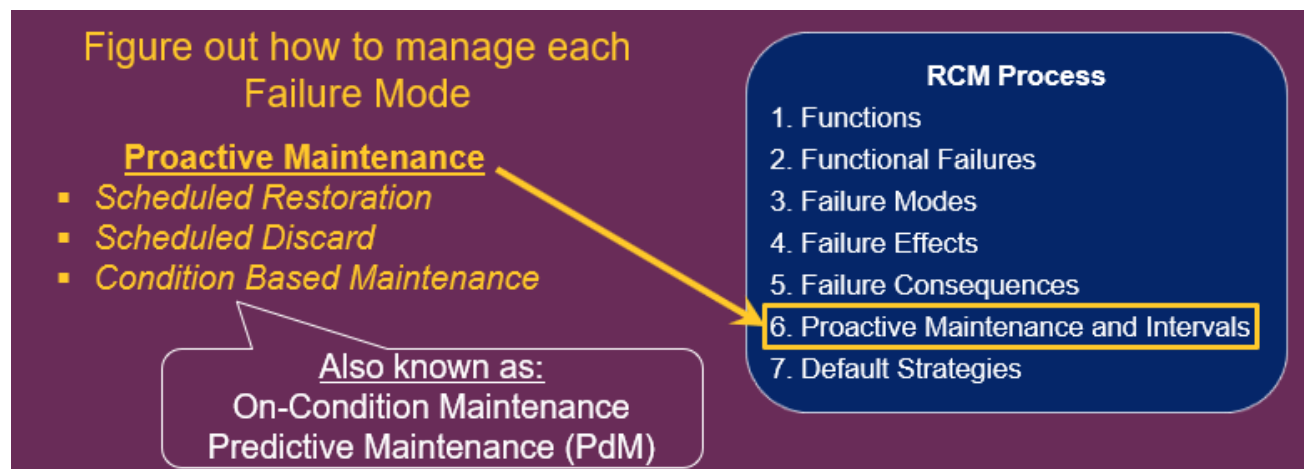
### **How a Failure Mode or a Multiple Failure *matters***

- Safety
- Environmental
- Operational
- Non-Operational

### **Notes**

# Reliability Centered Maintenance

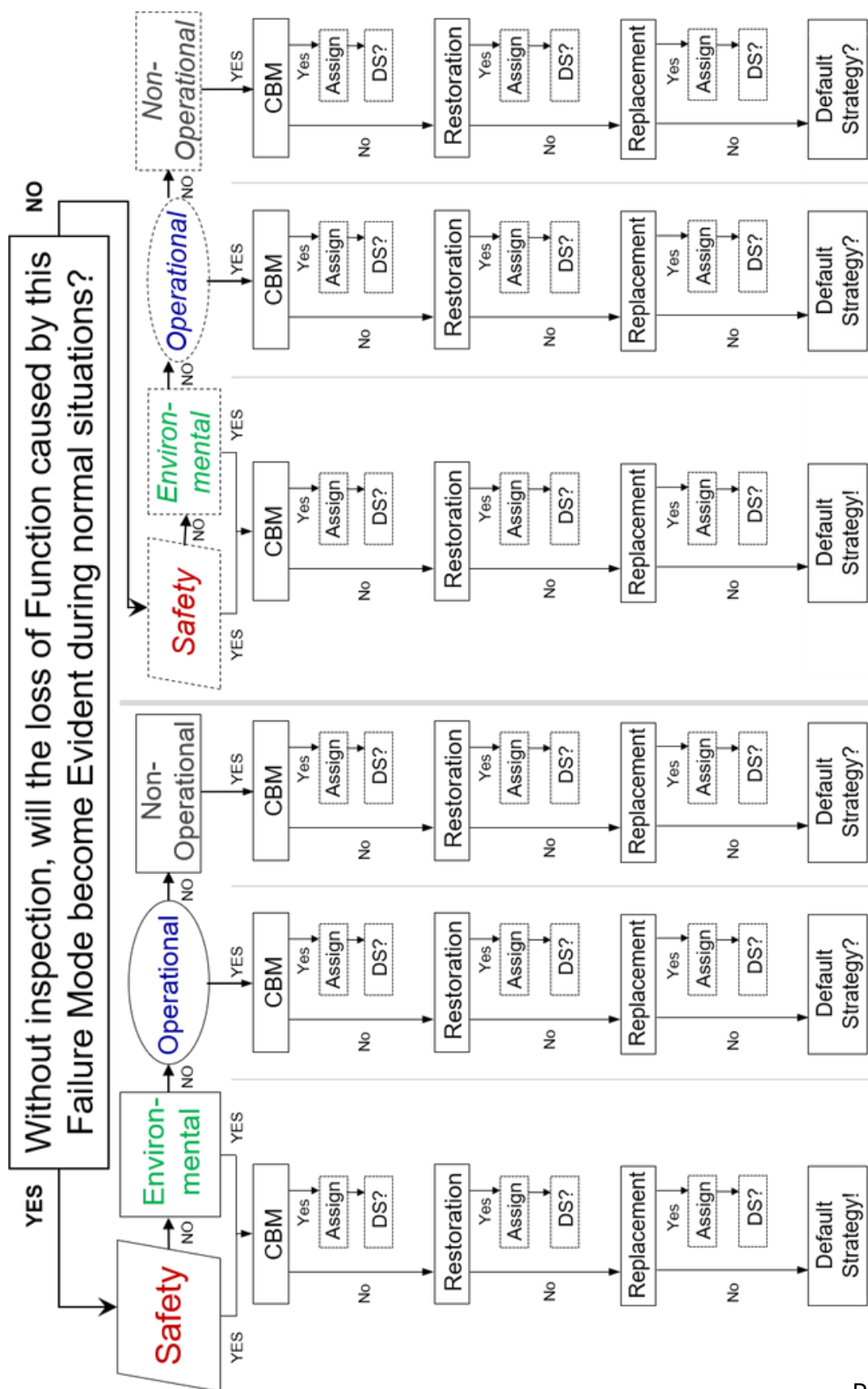
## Step 6: Proactive Maintenance and Associated Intervals



## Notes



## RCM Decision Diagram Outline



# Reliability Centered Maintenance

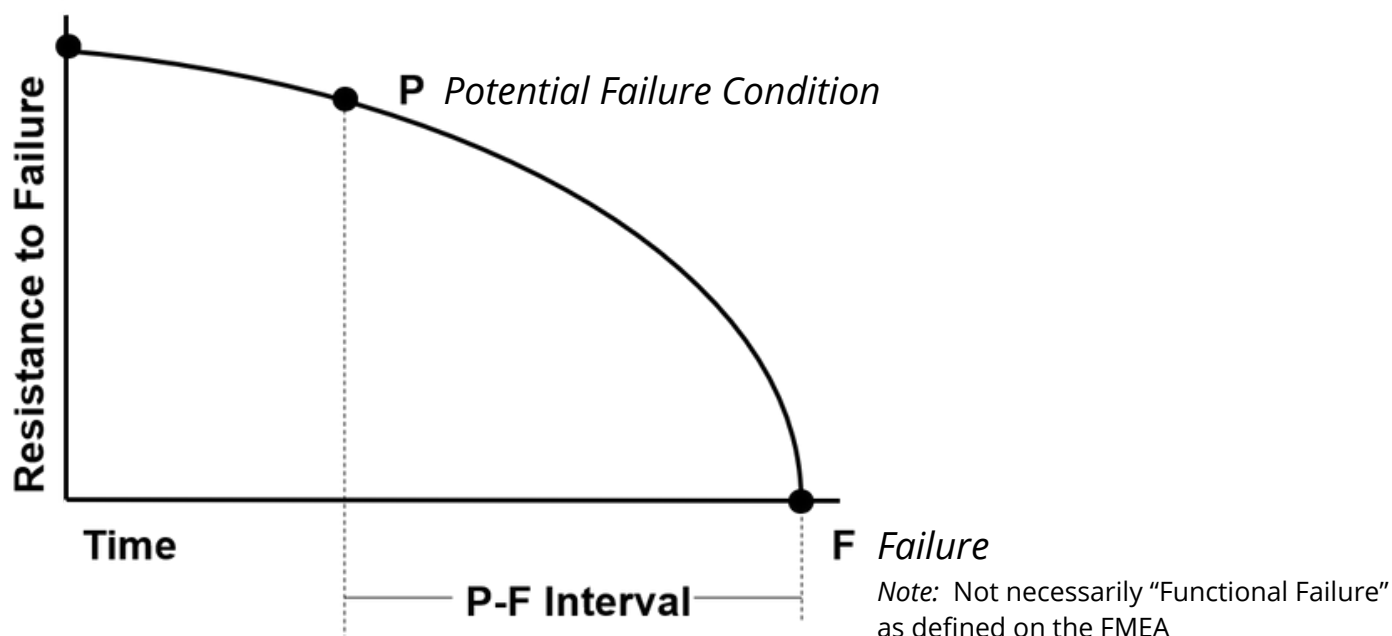
## Step 6: Proactive Maintenance and Associated Intervals

In the context of RCM, in order to assign a proactive maintenance task, it must be **Technically Feasible** AND **Worth Doing**. Let's look specifically at On-Condition Tasks.

### On-Condition Task

Performed at a defined interval to detect a *Potential Failure Condition* so that maintenance can be performed *before* the failure occurs.

### P-F Curve



### Notes

# Reliability Centered Maintenance

## Step 6: Proactive Maintenance and Associated Intervals

### P-F Curve: Four Key Points

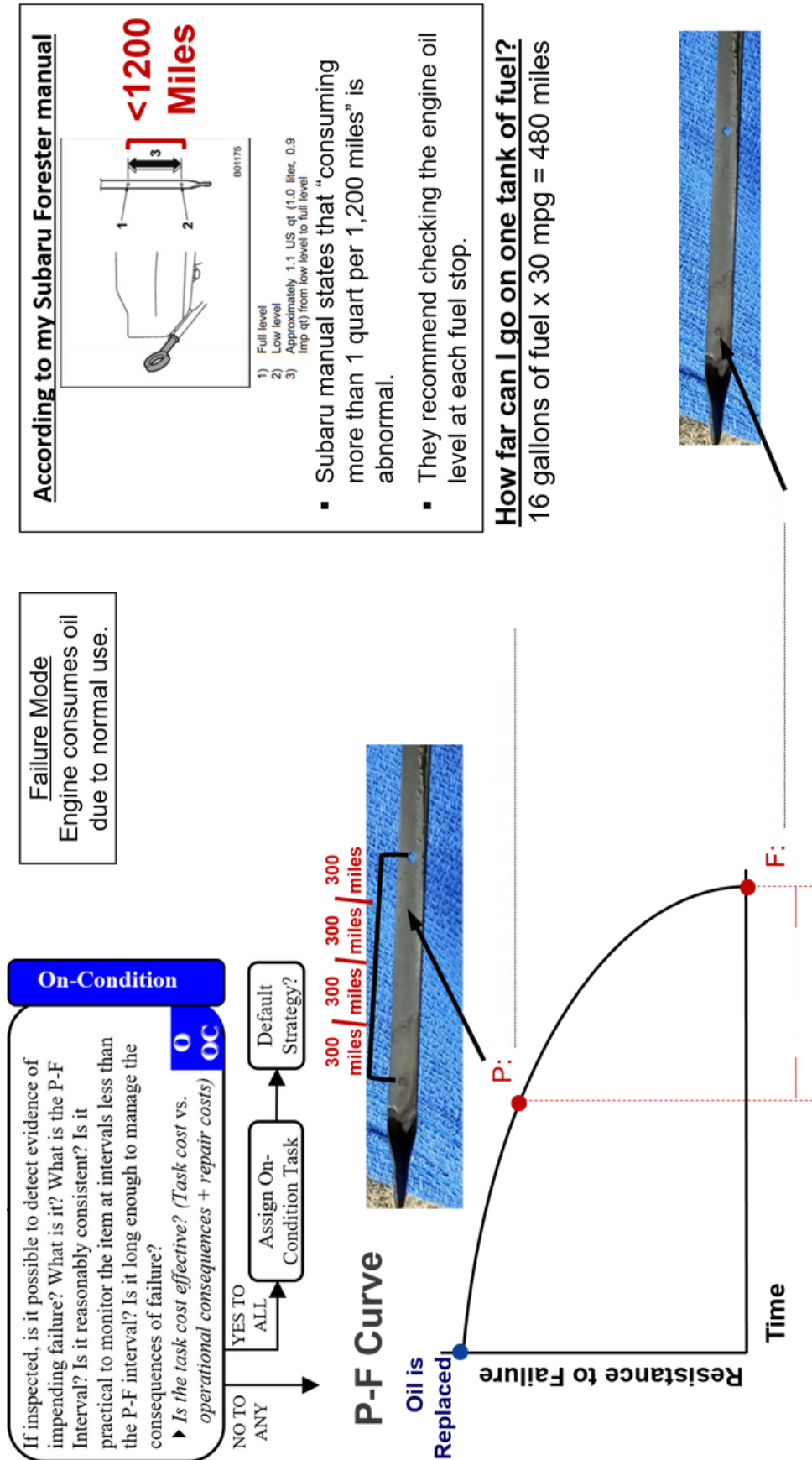
- On-Condition maintenance task intervals are NOT based upon *MTBF*.
- On-Condition maintenance task intervals are NOT based upon the *useful life* of a component.
- On-Condition maintenance task intervals are NOT based upon the *criticality of the failure*.
- On-Condition maintenance task intervals are based upon the P-F Interval.

In other words, On-Condition maintenance task intervals are based upon how ..... failure occurs once a ..... is *detectable*.

**Question:** Let's assume a P-F interval of 6 months has been established. Therefore, an inspection is performed every 3 months. Now, let's assume a technician has done the inspection every 3 months for two years and has never found the Potential Failure Condition. Does this justify extending the P-F interval (and thus the inspection interval)? **Yes or No?**

### Notes

## Subaru Forester P-F Curve Example



## Task:

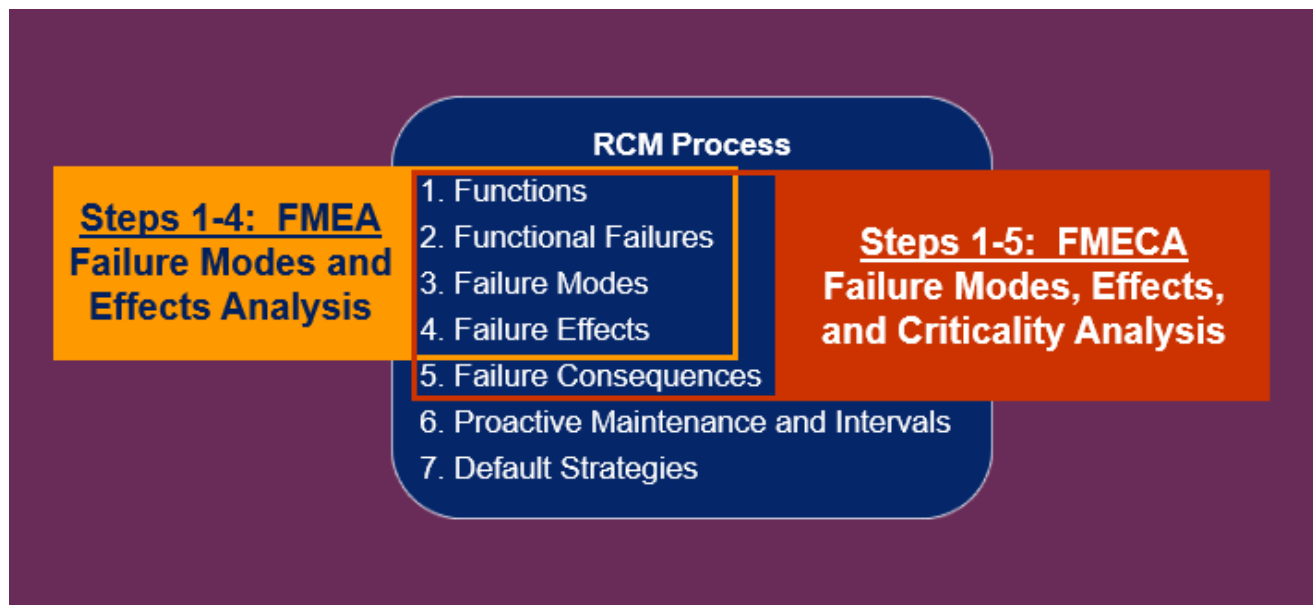
# Reliability Centered Maintenance

## Step 7: Default Strategies

### Default Strategy

A failure management strategy, other than Proactive Maintenance, implemented to manage the consequences of failure (e.g. engineering redesign, Failure Finding task, no scheduled maintenance)

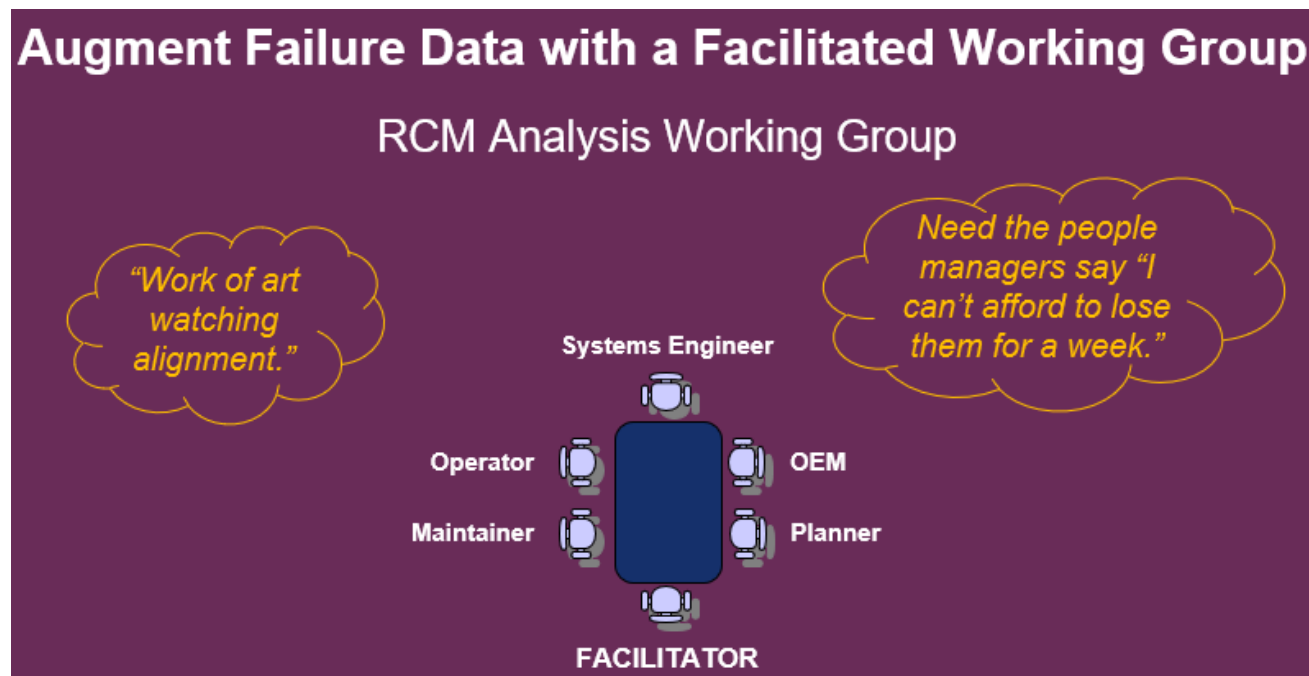
When you do RCM, the requirement for a FMEA/FMECA is largely satisfied.



### Notes

# Reliability Centered Maintenance

## Facilitated Working Group Approach to RCM



## Notes

## Nancy Regan, RCM Practitioner Workshop Instructor

Nancy Regan is a leading authority on Reliability Centered Maintenance (RCM) and has over 25 years' experience of hands-on practice facilitating RCM analyses, conducting RCM training, and assisting her clients in implementing RCM programs.

Amongst her largest projects are the CH-47 Chinook helicopter and her work with the National Security Complex in Oakridge, Tennessee. Both projects spanned years and yielded outstanding benefits for both organizations.



Nancy was mentored by the late John Moubray. She is a graduate of Embry-Riddle Aeronautical University with a B.S. degree in Aerospace Engineering. She is the author of *The RCM Solution, A Practical Guide to Starting and Maintaining a Successful RCM Program*.



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RCM Training with Nancy Regan



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