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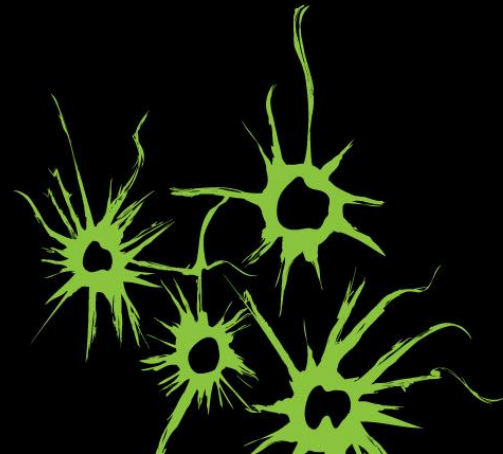


COLLOQUIUM PRIMAVERA

MAINTENANCE CONCEPT DESIGN AND IMPROVEMENT

“THE USE OF RCM/FMEA FOR MAINTENANCE”

DR. JAN BRAAKSMA, A.J.J.BRAAKSMA@UTWENTE.NL



ABOUT DR. JAN BRAAKSMA

[HTTPS://PEOPLE.UTWENTE.NL/A.J.J.BRAAKSMA](https://people.utwente.nl/a.j.j.braaksma)

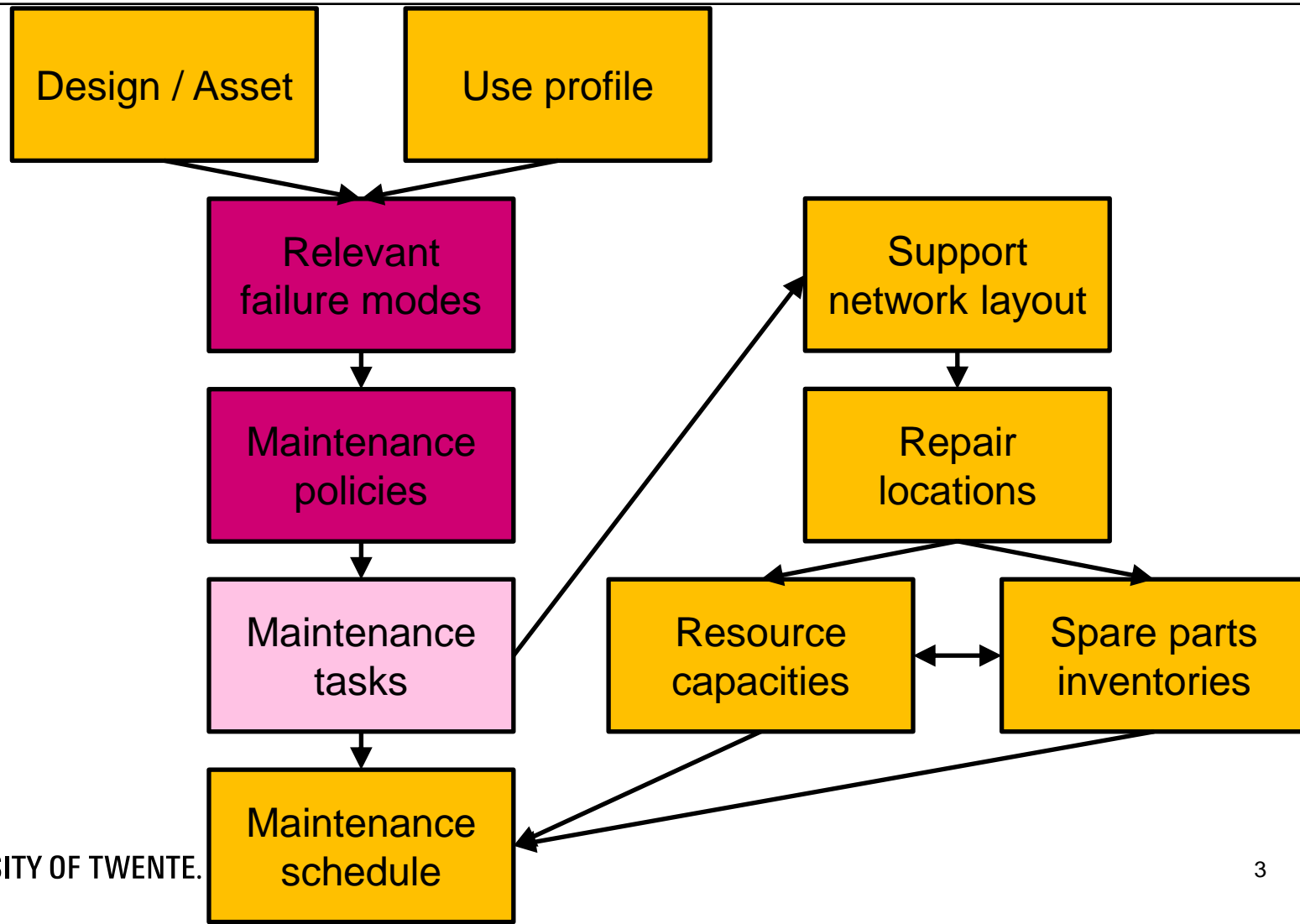
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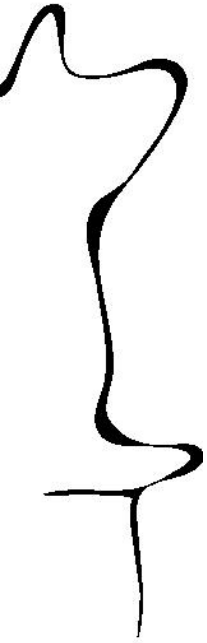
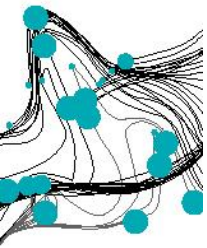
- Associate professor in leerstoel Maintenance Engineering & Management
- Docent Master Class Maintenance Engineering & Management
- Involved in PRIMAVERA, AMICO (IT/OT integration), SIRA (Systems Integration and Railway Advancement), Introduction next generations assets,

NEVENWERKZAAMHEDEN

- Director WCM Summer School
- Member NVDO kring Noord
- Lid Raad van Advies, opleiding Maintenance Management en Engineering Hogeschool Utrecht

DESIGN OF A MAINTENANCE PLAN AND SUPPORT NETWORK DURING THE DEVELOPMENT AND USE PHASES





DESIGNING MAINTENANCE CONCEPTS

MAINTENANCE CONCEPT DEVELOPMENT

MAINTENANCE CONCEPT

DEFINITION

Statement of broad concept, policy, or planned approach that governs the maintenance levels and type of maintenance actions to be performed for a equipment, machine, plant, or system.

Read more: <http://www.businessdictionary.com/definition/maintenance-concept.html>

DESIGNING MAINTENANCE CONCEPTS

FINDING THE OPTIMAL BALANCE

Preventive vs. corrective maintenance

CHOICE FOR OPTIMAL STRATEGY

E.g. after failure, time based, usage based or condition based maintenance

KNOWLEDGE OF BEHAVIOR

A maintenance concept is based on available knowledge of behavior of a technical system and the effects of failure/degradation



CORRECTIVE AND PREVENTIVE MAINTENANCE

CORRECTIVE MAINTENANCE (CM):

Corrective maintenance, sometimes called "repair," is conducted to get equipment working again.

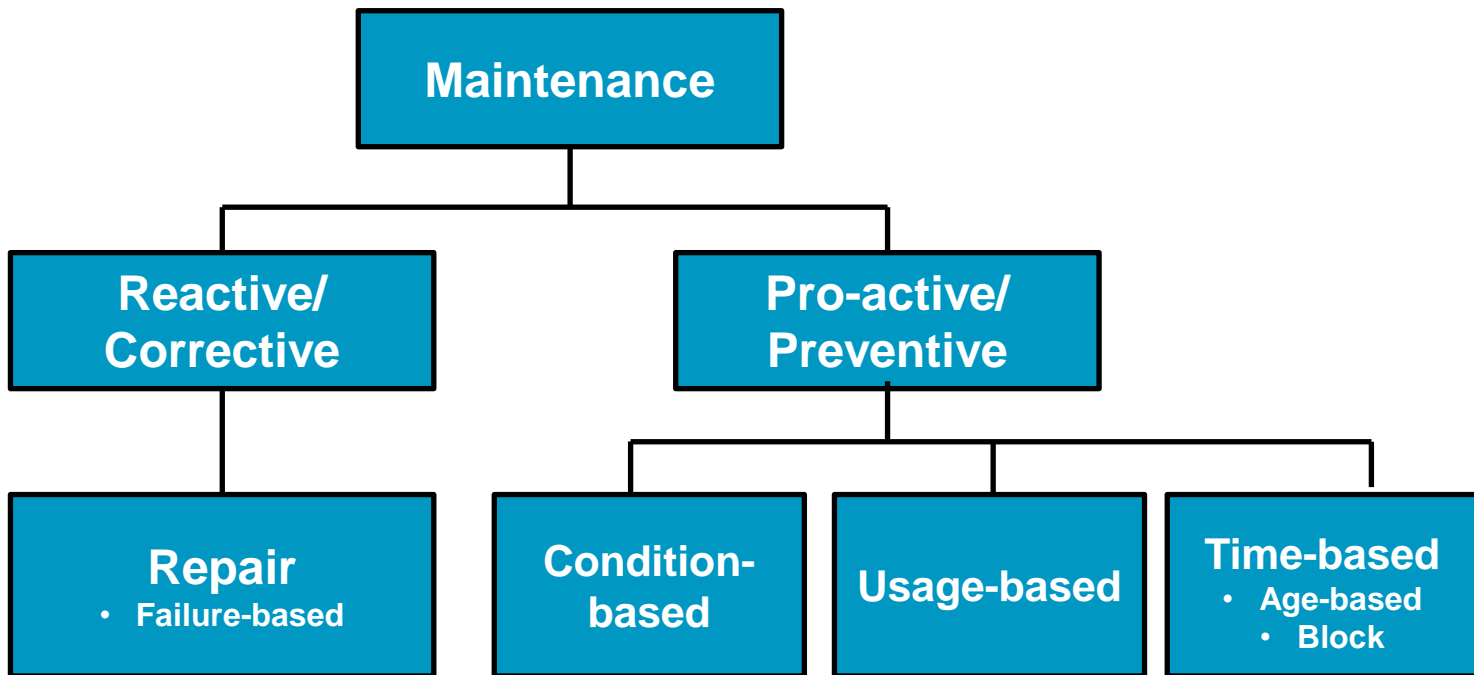
PREVENTIVE MAINTENANCE (PM):

The care and servicing by personnel for the purpose of maintaining equipment and facilities in satisfactory operating condition by providing for systematic inspection, detection, and correction of incipient failures either before they occur or before they develop into major defects.

THREE TYPES OF PREVENTIVE MAINTENANCE:

- Time base maintenance
- Usage based and
- Condition-based maintenance

MAINTENANCE STRATEGIES



QUESTION

COMPLEXITY OF RELIABILITY:

WHAT MAKES RELIABILITY SO COMPLEX TO ACHIEVE?

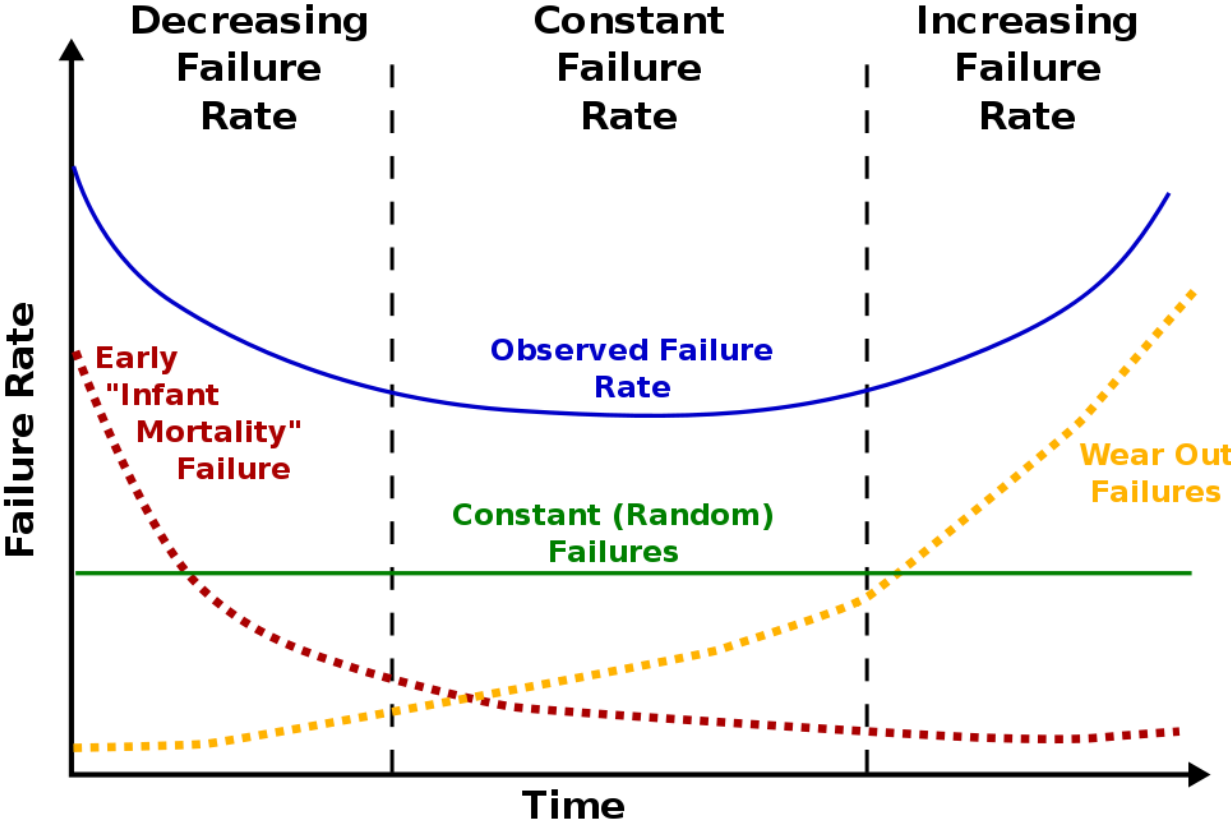


DESIGNING MAINTENANCE CONCEPTS

COMPLEXITY OF RELIABILITY

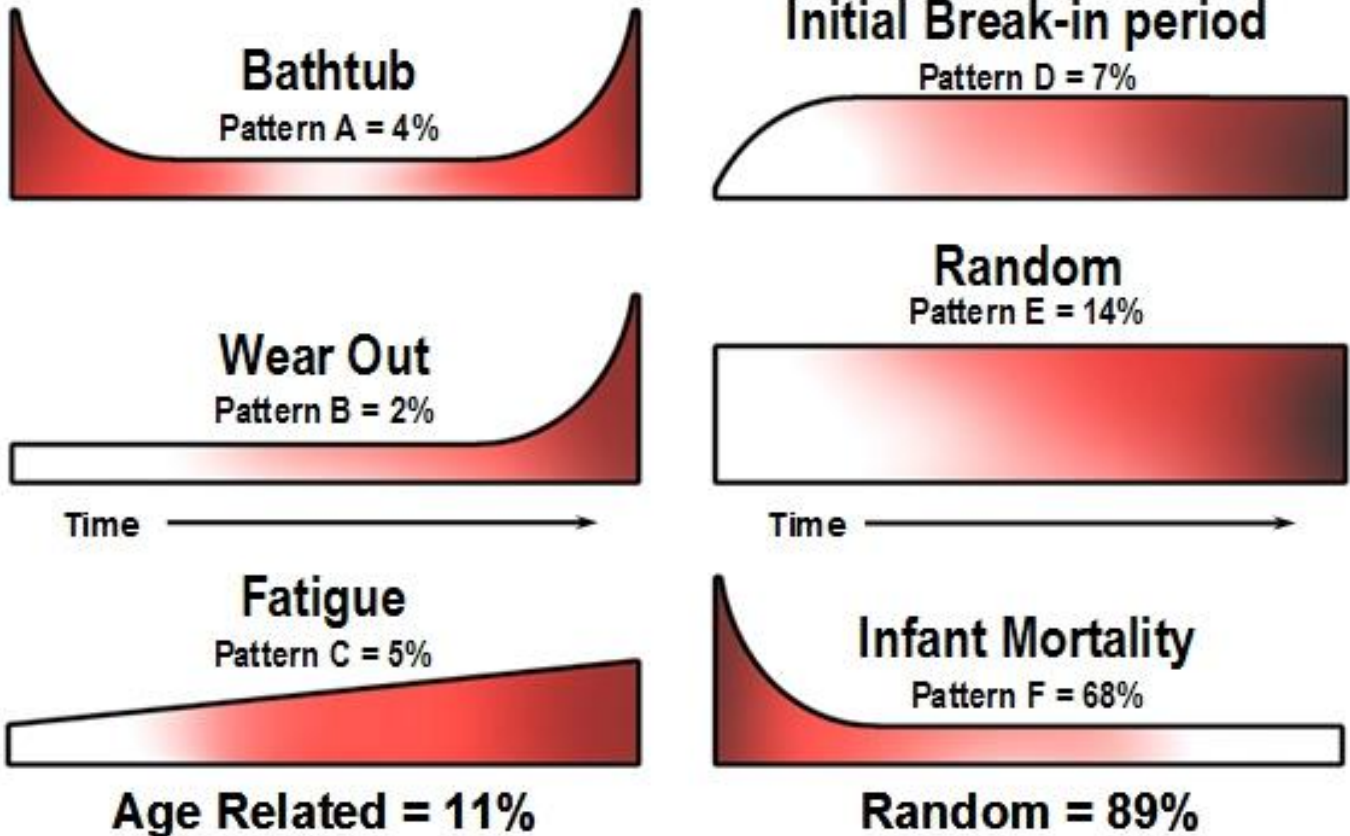
Reliability per part	Reliability Technical Systems		
	Number of parts		
	10	100	500
0,98	0,817	0,133	0,000
0,999	0,990	0,905	0,606
0,9999	0,999	0,991	0,952

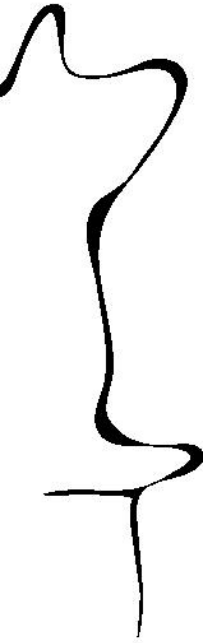
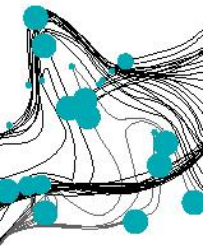
BATHTUB CURVE



DESIGNING MAINTENANCE CONCEPTS

RELIABILITY PATTERNS IN PRACTISE





FME(C)A AND RELIABILITY CENTRED MAINTENANCE

FMECA

What is a FMECA? –An Analysis technique which facilitates the identification of potential design problems by examining the effects of lower level failures on system operation.



RELIABILITY CENTRED MAINTENANCE

FMEA AS PART OF RELIABILITY CENTRED MAINTENANCE

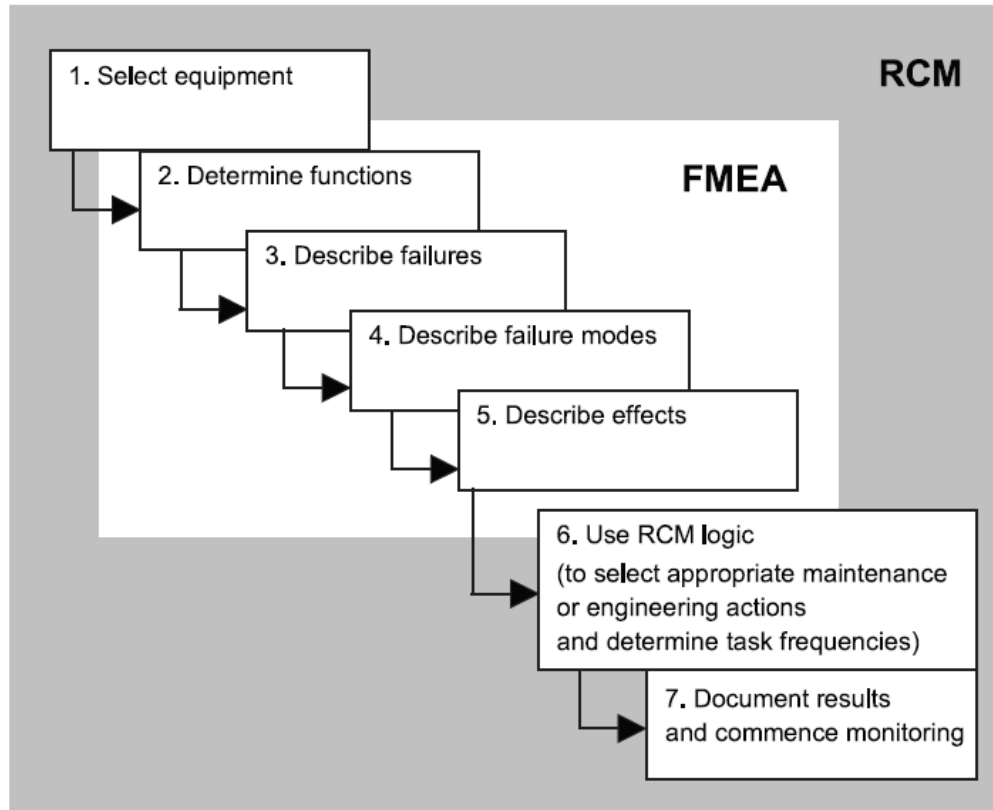


Figure: FMEA as part of RCM, amended from Picknell (1999)

RELIABILITY CENTRED MAINTENANCE

DRIVERS DEVELOPMENT RCM

- **RESEARCH REVISION INTERVALS (1965-1970)**
Periodic maintenance proven effective for only 6-23% of the components
- **JUSTIFICATION OF MAINTENANCE DECISIONS**
RCM requires maintenance decisions (maintenance concept) to be supported by sound technical and economic justification
- **ASSESSMENT CONSEQUENCE OF FAILURE**
The RCM approach considers the **consequence** (health, safety, environment, organisational) of a failure of a given component



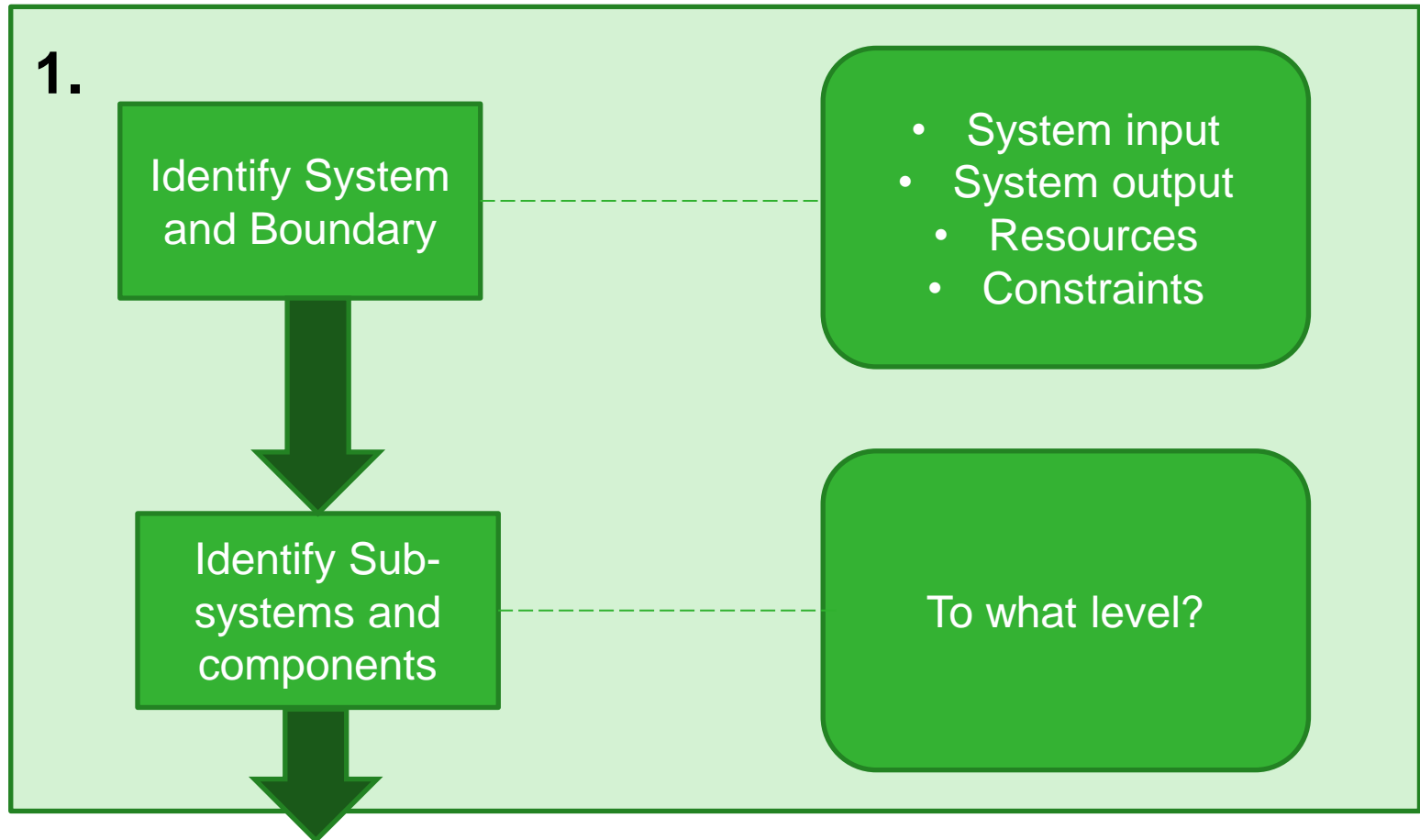
RELIABILITY CENTRED MAINTENANCE

GOALS OF RCM

- **REALIZE INHERENT SAFETY**
 - To ensure realization of the inherent safety and reliability levels of the equipment.
- **RESTORE EQUIPMENT**
 - To restore the equipment to these inherent levels when deterioration occurs.
- **OBTAIN INFORMATION FOR DESIGN IMPROVEMENT**
 - To obtain the information necessary for design improvement of those items where their inherent reliability proves to be inadequate.
- **ACCOMPLISH GOALS AT MINIMUM COST**
 - To accomplish these goals at a minimum total cost, including maintenance costs, support costs, and **economic consequences of operational failures**.

RELIABILITY CENTRED MAINTENANCE

STEP 1



RELIABILITY CENTRED MAINTENANCE

TWO APPROACHES

RIGOROUS RCM APPROACH (ALSO KNOWN AS CLASSICAL RCM)

- performed on new, unique, high-cost systems such as aircraft and spacecraft systems and structures

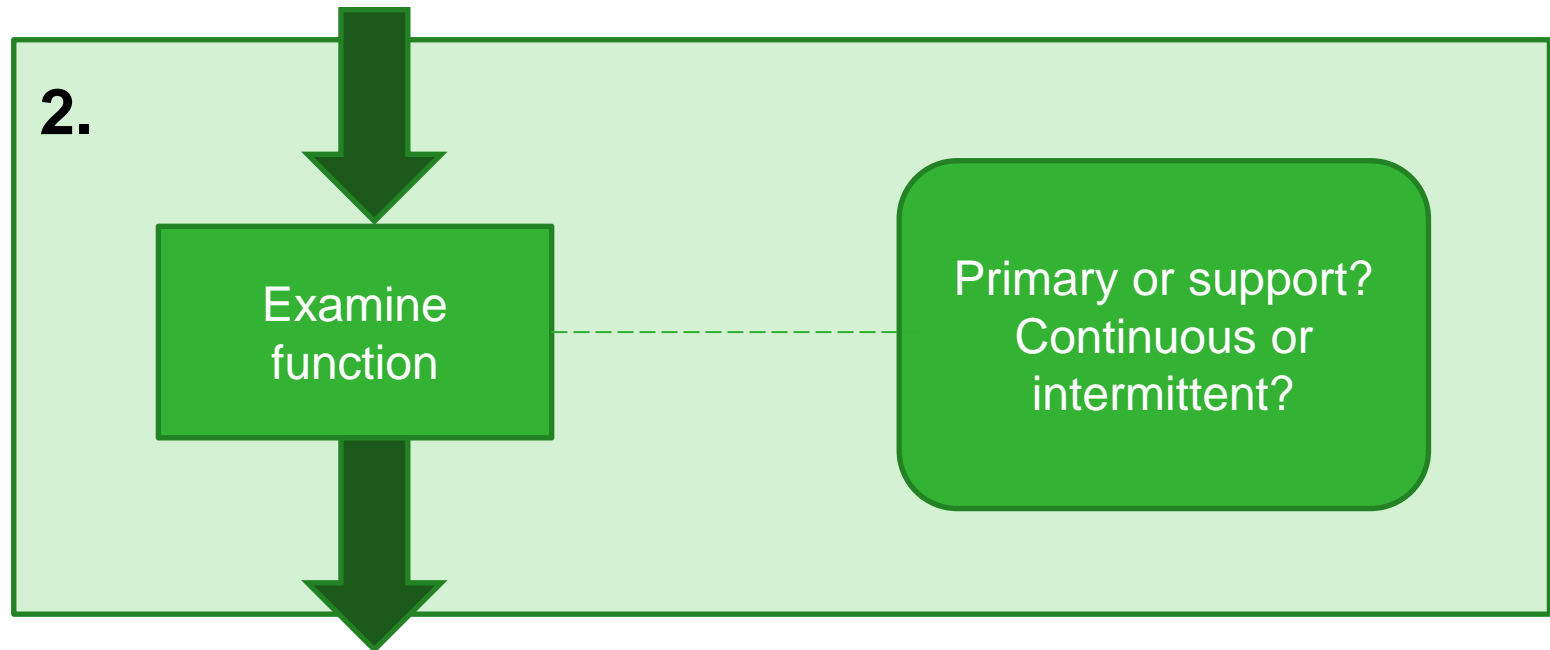
INTUITIVE RCM APPROACH (ALSO KNOWN AS STREAMLINED OR ABBREVIATED RCM)

- same principles as the Rigorous RCM approach, but recognizes that not all failure modes will be analyzed.



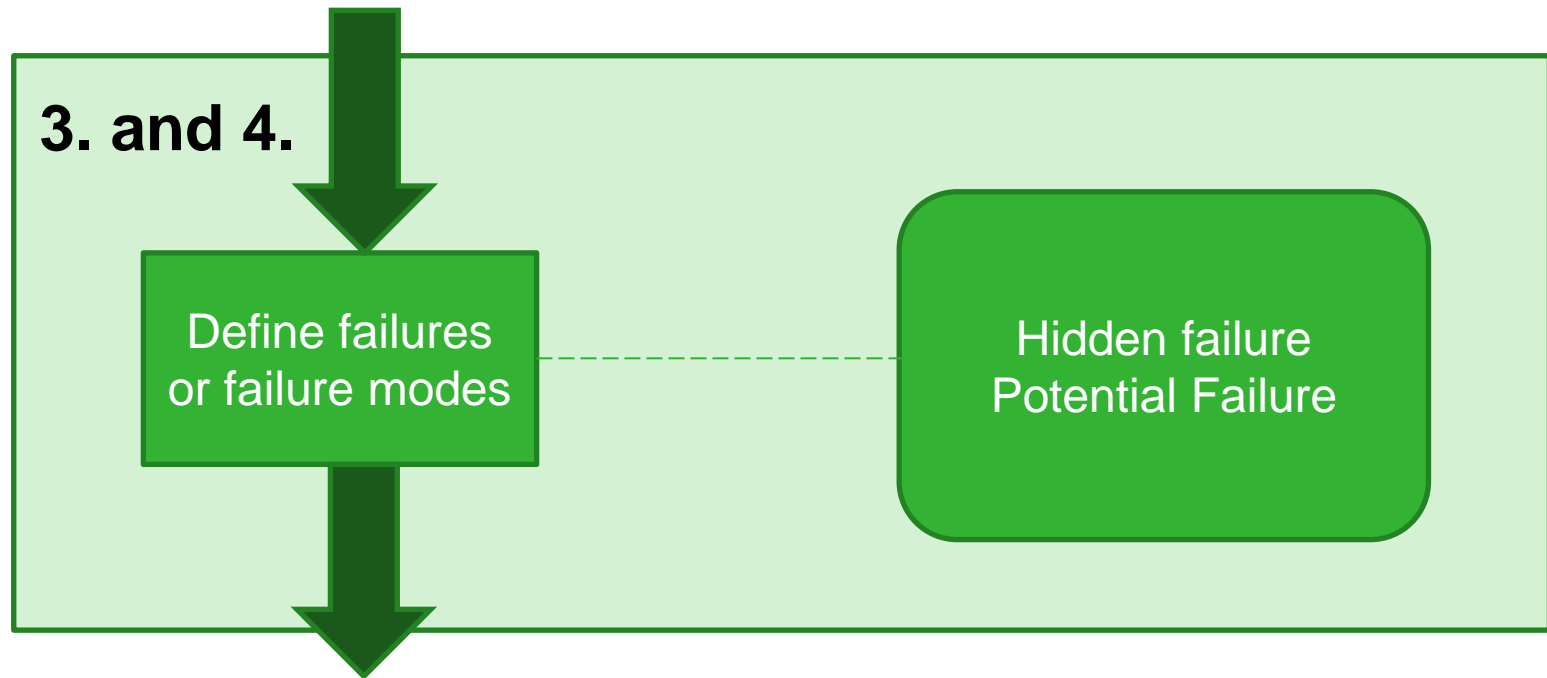
RELIABILITY CENTRED MAINTENANCE

RCM STEP 2 (FMEA)



RELIABILITY CENTRED MAINTENANCE

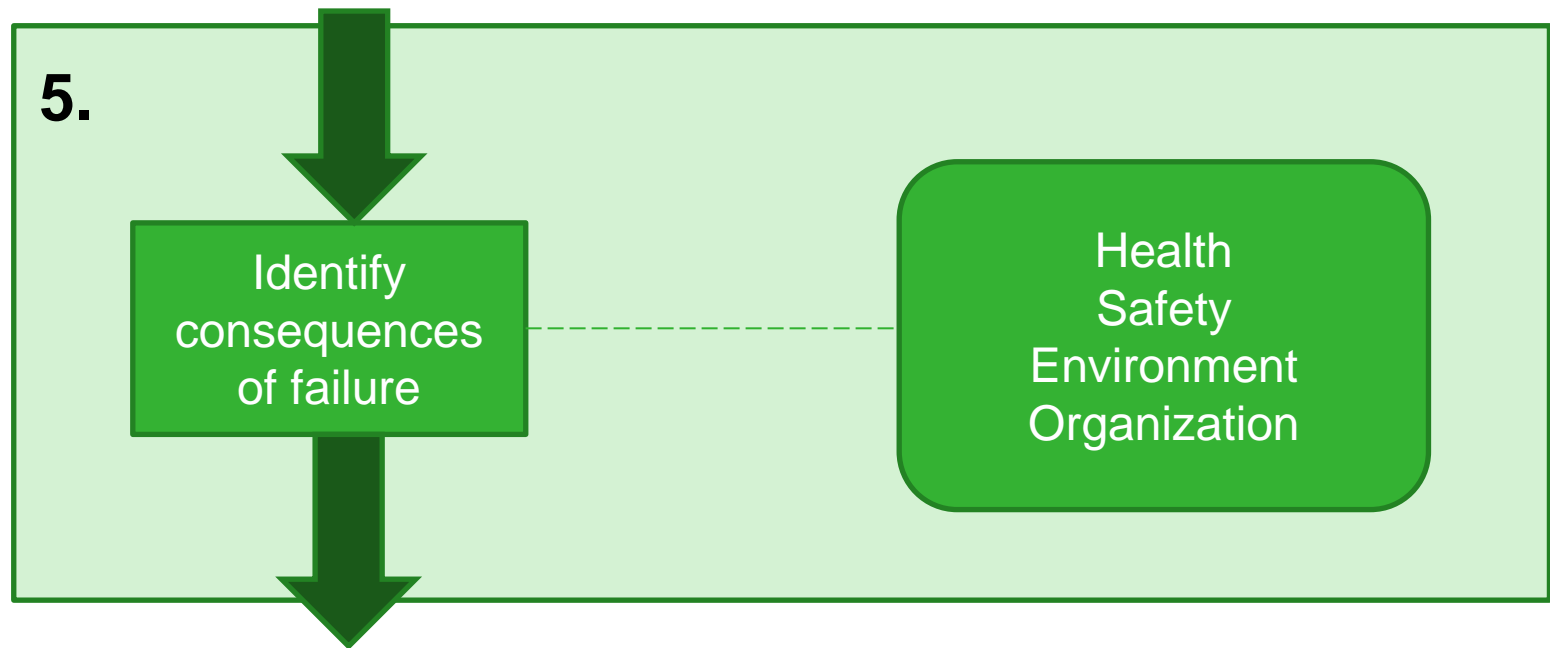
RCM STEP 3 AND 4 (FMEA)



Definition failure modes: Way or ways in which a piece or equipment can fail

RELIABILITY CENTRED MAINTENANCE

STEP 5



RELIABILITY CENTRED MAINTENANCE

RISK PRIORITY NUMBER (RPN)

To use the Risk Priority Number (RPN) method to assess risk, the analysis team must:

Rate the **Severity** of each effect of failure.

Rate the likelihood of **Occurrence** for each cause of failure.

Rate the likelihood of prior **Detection** for each cause of failure (*i.e.* the likelihood of detecting the problem) Calculate the RPN by obtaining the product of the three ratings:

$$\text{RPN} = \text{Severity} \times \text{Occurrence} \times \text{Detection}$$

The RPN can then be used to compare issues within the analysis and to prioritize problems

RELIABILITY CENTRED MAINTENANCE

MANY STANDARDS EXIST



Failure Modes & Effects Worksheet

Area: Center, Building
 System: Name
 FMEA Number: If Used
 Team Members: FMEA Preparers

Page: ___ of ___
 Printed: Date/Time

Date Started:
 Date Completed:

Control Number	Name & Function/ Performance Requirement	Potential Failure Mode	Potential Failure Effects	Criticality	Probability	Remarks/Continue
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Item	Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	RPN	Recommended Action(s)	Responsibility (for the Recommended Action)	Actions Taken	Sev	Occ	Det	RPN
Compressor	Transports the medium; Compresses the medium	Loosening of fastenings	Refrigerant pipe detaches, external leaks	9	B	Material faults, loosening of fastenings	1	Quality control	2	18	Oscillation tests			9	1	1	9
Gas cooler	Conducts heat to the external environment	Blockage in refrigerant flow	Low cooling capacity, increase in pressure	6	A	Bends, blockages	2	Deformation guard, layout; design of component	10	120	Parallel procedures, pressure sensor switched in front of the gas cooler, plausibility control via regulation control			6	2	6	72

RELIABILITY CENTRED MAINTENANCE

FMECA AS EXTENSION TO FMEA

Failure Mode and Effects Analysis (FMEA):

Analysis used to determine what parts fail, why they usually fail, and what effect their failure has on the systems in total.

Failure Mode and Criticality Analysis (FMECA)

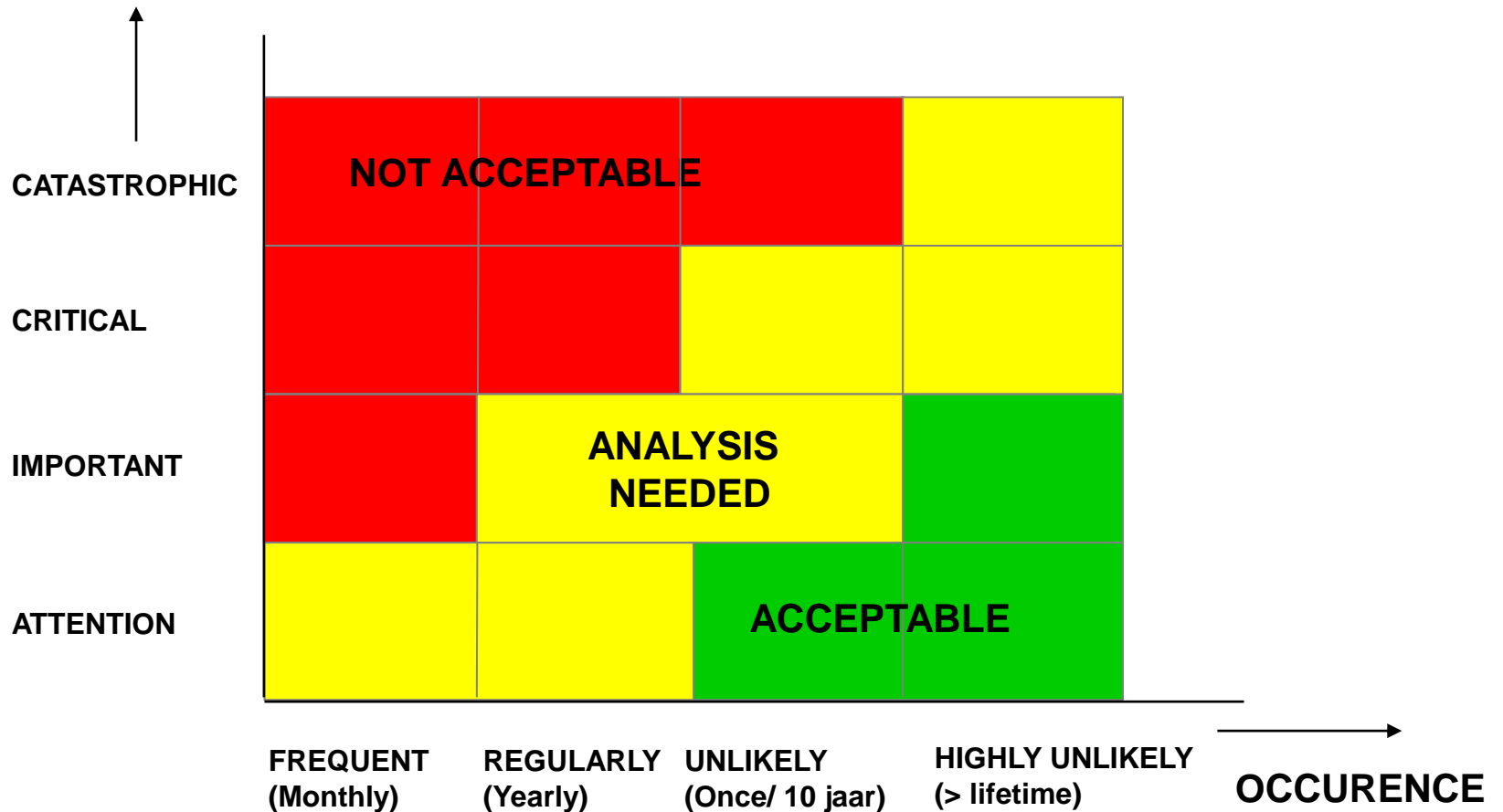
An extension of Failure Mode and Effects Analysis (FMEA). In addition to the basic FMEA, it includes a criticality analysis, which is used to chart the probability of failure modes against the severity of their consequences.

The result highlights failure modes with relatively high probability and severity of consequences, allowing remedial effort to be directed where it will produce the greatest value.

RELIABILITY CENTRED MAINTENANCE

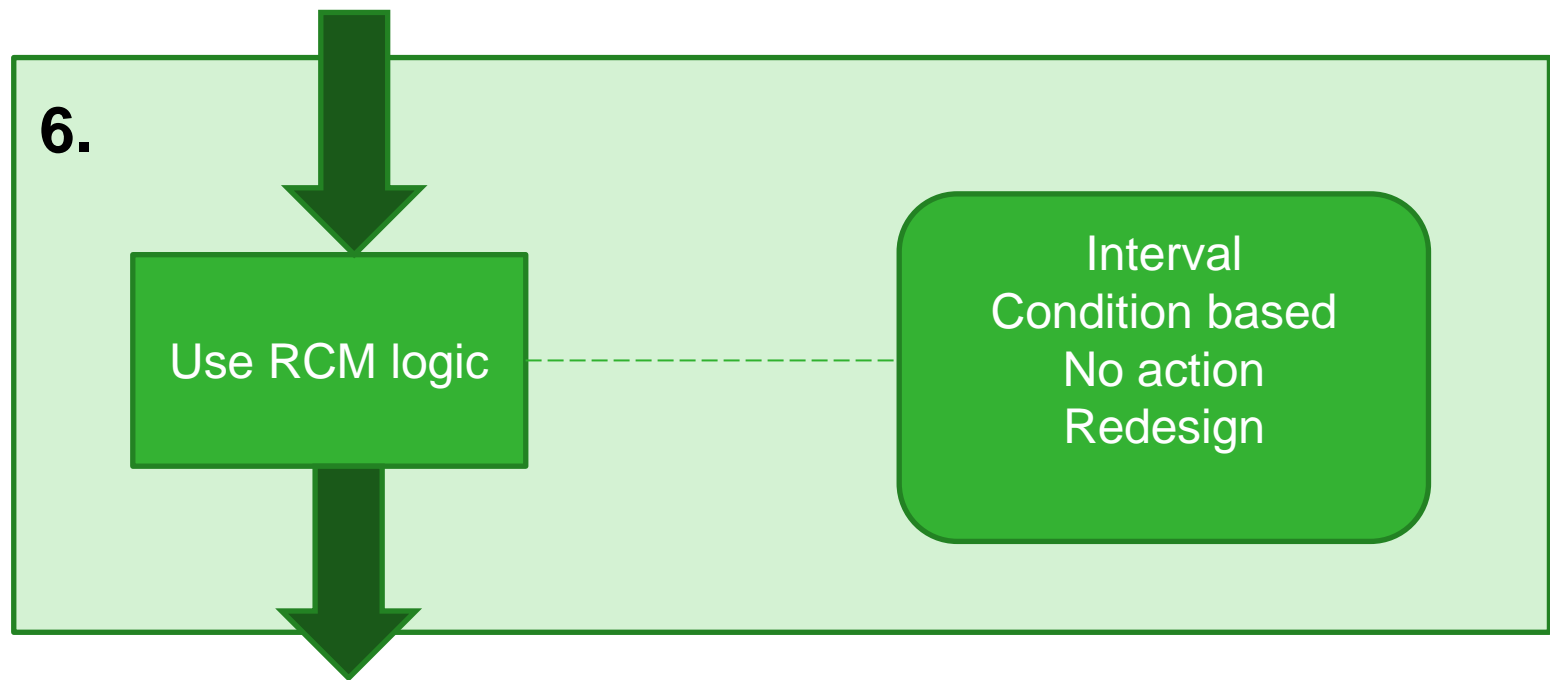
GENERIC FMECA CRITICALITY MATRIX (RISK = OCCURENCE X /SEVERITY)

SEVERITY CLASSIFICATION



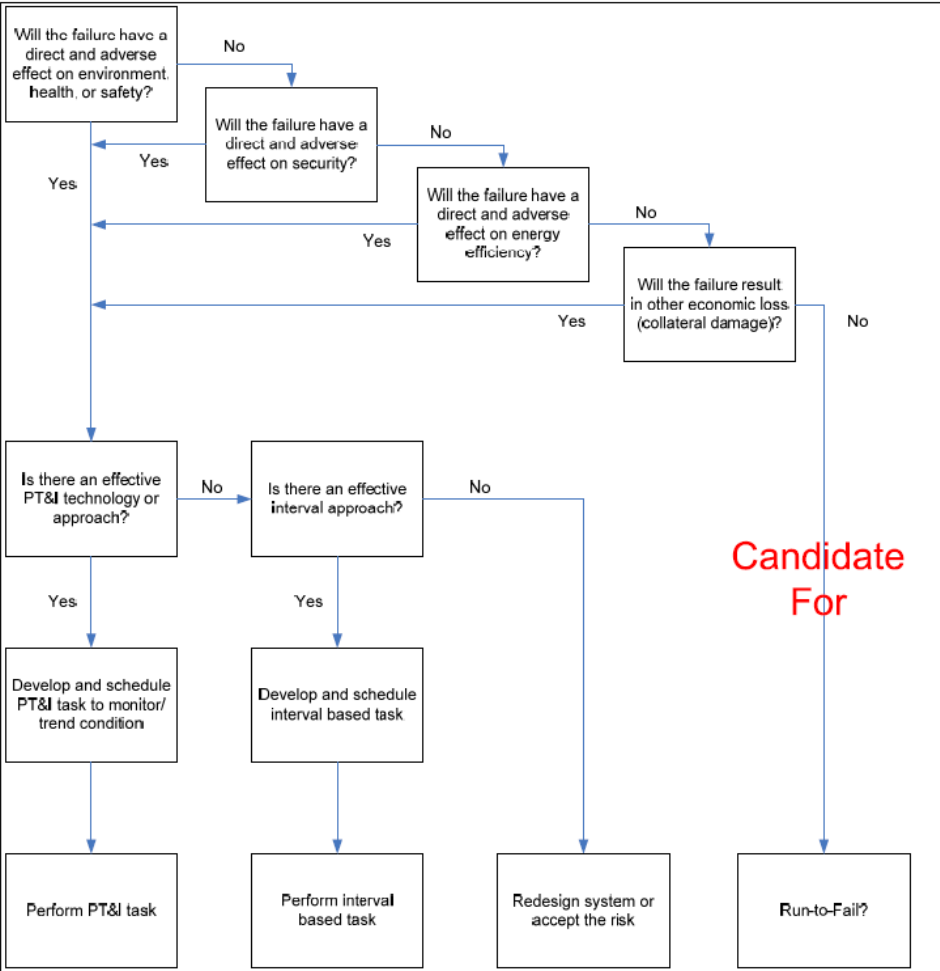
RELIABILITY CENTRED MAINTENANCE

STEP 6



RELIABILITY CENTRED MAINTENANCE

RCM LOGIC TREE (NASA, 2008)



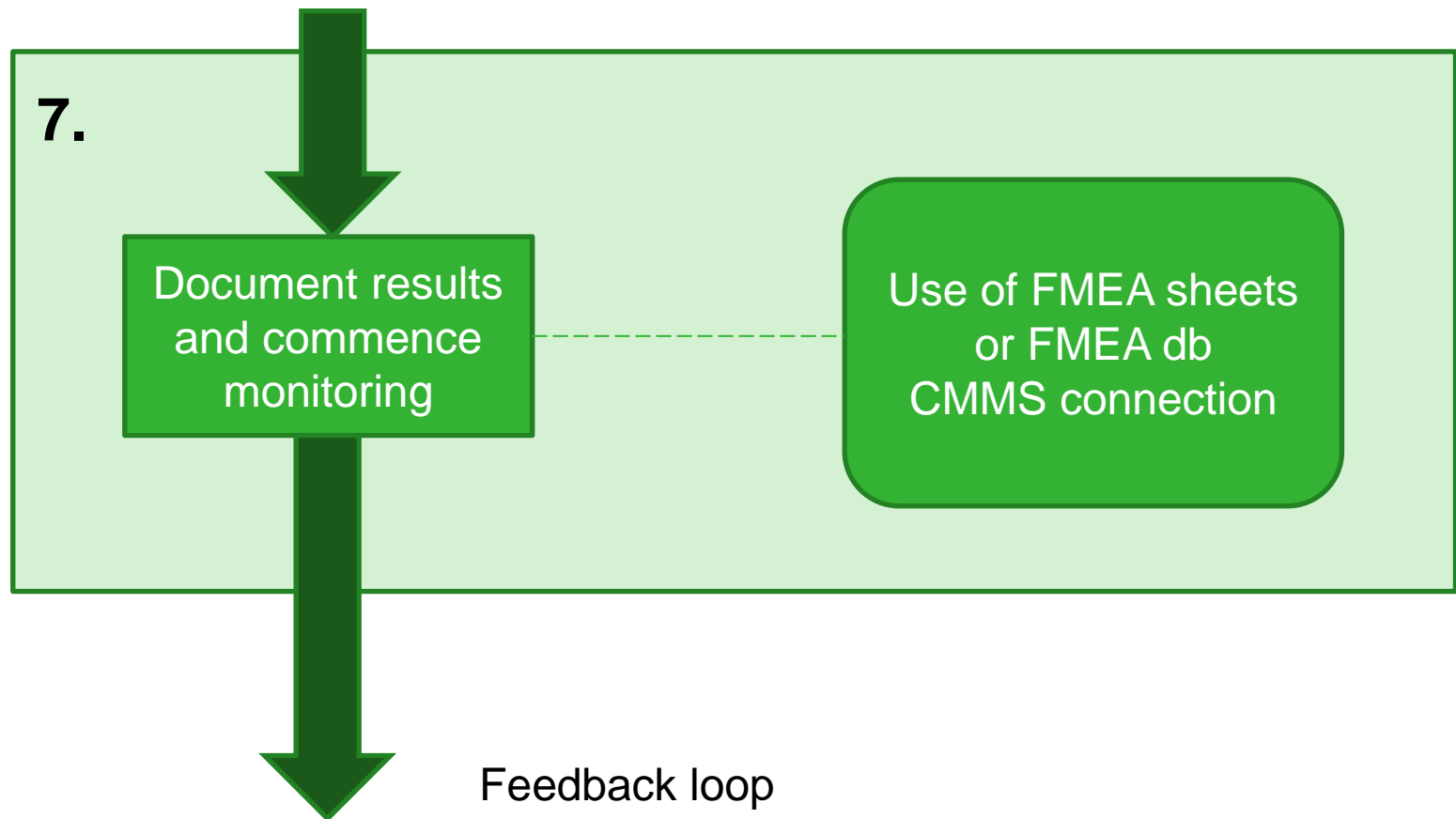
Candidate For

HYPOTHESIS:

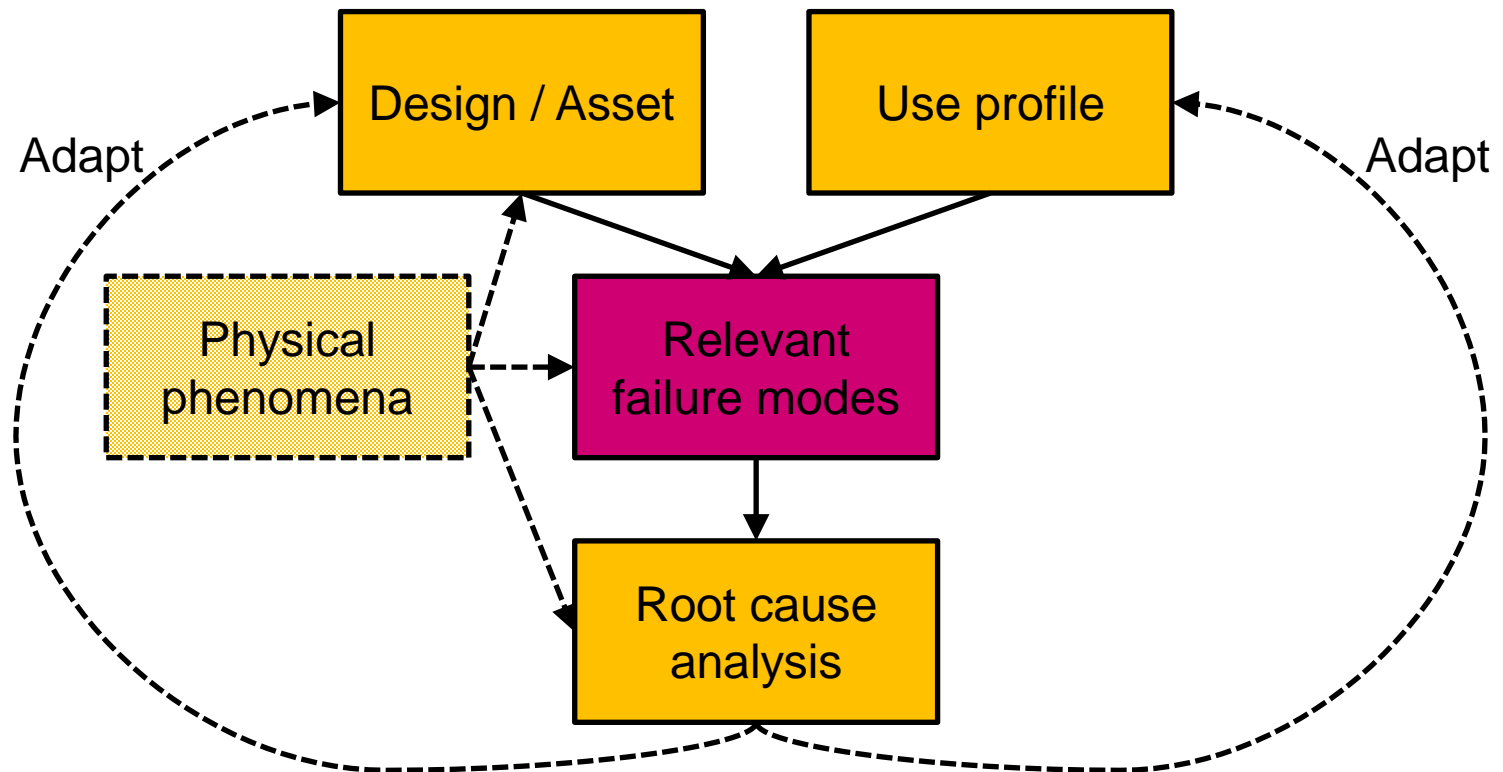
**WE NEED FMEA/RCM TO FILTER
CANDIDATES FOR PREDICTIVE
MAINTENANCE**

RELIABILITY CENTRED MAINTENANCE

STEP 7

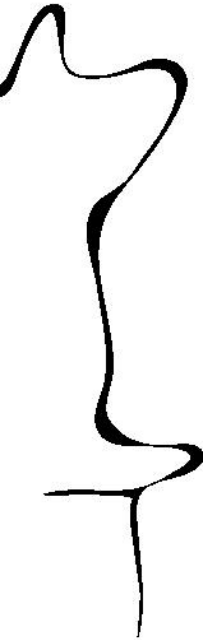
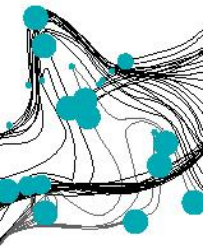


CONTINUOUS IMPROVEMENT DURING THE USE PHASE



HYPOTHESIS:

**WE NEED FMEA/RCM FOR
CONTINUOUS IMPROVEMENT OF
MAINTENANCE**



**ADDITIONAL
PROBLEMS WITH CONTINUOUS IMPROVEMENT OF
RCM/FMEA BASED MAINTENANCE CONCEPTS**

RESULTS CASE STUDY ON USE OF RCM/FMEA (BRAAKSMA, 2013)

- It is confirmed that capital goods are analysed based on the criticality of assets (not all assets are selected)
- Identification of capital goods and parts for analysis is possible, but selection process is not always transparent and objective
- FMEA regarded as a one-off exercise while in literature it is viewed as a continuous activity
 - FMEA/RCM logic is not used for changes in the maintenance plan → changes are made directly on the operational maintenance plan
 - No quality improvement cycle of the FMEA

RESULTS CASE STUDY ON USE OF RCM/FMEA (BRAAKSMA, 2013)

- FMEA is based on available expert knowledge, minimal use of quantitative data (such as failure and process data)
- Problematic registration of FMEA results hinders re-use
- Lack of procedures and consistency in application of FMEA

PROPOSED DESIGN PRINCIPLES FOR MAINTENANCE FEEDBACK (BRAAKSMA, 2012)

- Improved description rationale behind FMEA decision process
- Proactive registration of future needed data
- Criticality based information management
- Demand based and business case driven information analysis
- Implementation Maintenance feedback planning process and supporting information system



PROPOSED MAINTENANCE FEEDBACK ANALYSIS

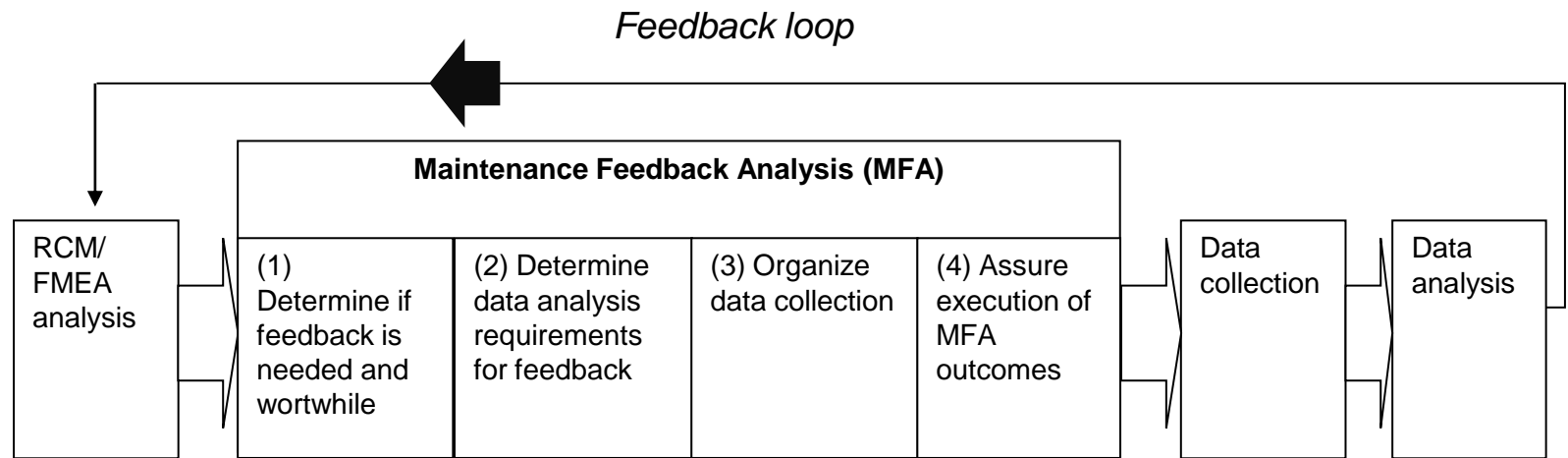


Figure: MFA steps as part of continuous improvement of maintenance

FMEA WITH MAINTENANCE FEEDBACK ANALYSIS

MFA STEP (1)	MFA STEP (2)	MFA STEP (3)
UNCERTAINTIES FAILURE MODES AND CAUSES / IMPROVEMENT POTENTIAL	PREFERRED DATA ANALYSIS/ DATA REQUIREMENTS	AVAILABLE DATA/ ADDITIONAL ACTIONS DATA COLLECTION

Note: MFA steps can be added as additional columns to a RCM/FMEA sheet

REFERENCES AND FURTHER READING

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