GEOTHERMAL POWER PLANT MAINTENANCE & RELIABILITY

Yogyakarta, 09-13 OCTOBER 2017

Course: "Training of Trainers of Geothermal Power Plant : Engineer"

Hosting by: PPSDM EBTKE

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Overview

- Maintenance
- Engineering & Maintenance
- Reliability
- Maintenance Management System : Planning and Scheduling
- Overview of Geothermal Powerplant Maintenance Activities

MAINTENANCE Definition

Maintenance (Moubray, 1997): The series of activities to ensure that physical assets could continuously do what their users want them to do properly

Source: Moubray, 1997

Maintenance Objectives

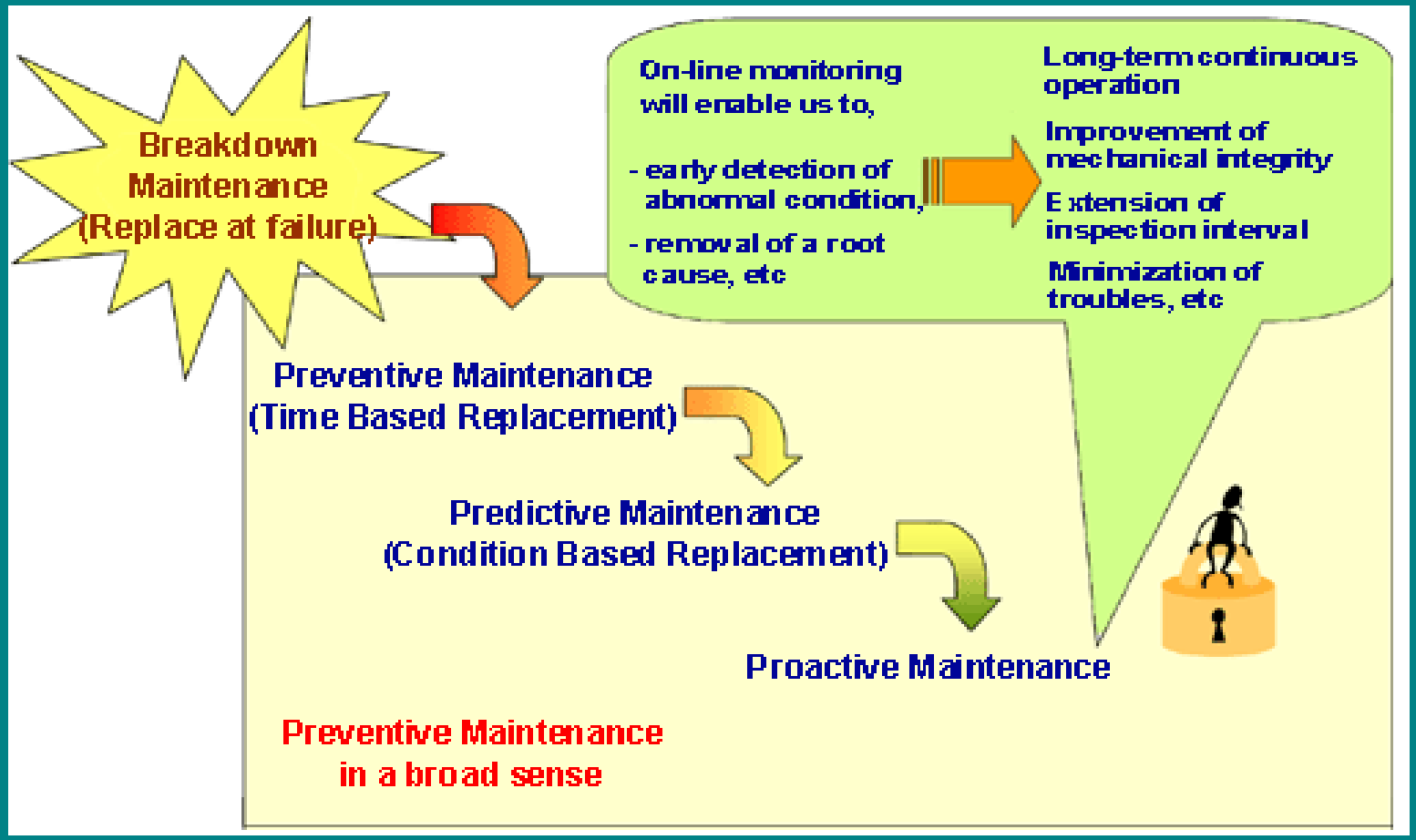
Direct :

- Minimize loss of productive time
- Minimize repair time & cost
- Keep expensive productive assets in working condition
- Minimize accidents
- Minimize total maintenance cost
- Improve quality of products

Indirect :

- Keep good reputation to maintain customer loyalty
- Easy to get investor
- Comply with goverment regulation

Maintenance Evolution



TYPE OF MAINTENANCE

PROACTIVE

Proactive Maintenance

- **Preventive Maintenance** → • Repair it at certain interval, despite the actual condition
- **Predictive Maintenance** → - Equipment condition monitoring
- Repair it only when needed
- **Improvement** → - Redesign
- Modification

REACTIVE

Reactive

- **Corrective Maintenance** → - Repair it after it breaks
- **Failure Finding** → - Functional Check/Test

Corrective Maintenance

- Early stage of Maintenance for all equipment in industry
- A lot of catastrophic failure
- A lot of downtime
- Huge loss of production
- Expensive recovery cost

Is it that bad ???

- Fit for small factory, where downtime is still acceptable, quick recovery for repair/replacement with cost less than preventive & predictive maintenance
- Fit for equipments (event in the big factory) : non critical (no impact to production loss), easy to replace, redundant i.e : light bulb, small sump pump for drainage, instrument indicator, exhaust fan

Preventive Maintenance (Time based)

- Second stage of Maintenance type evolution

Advantages

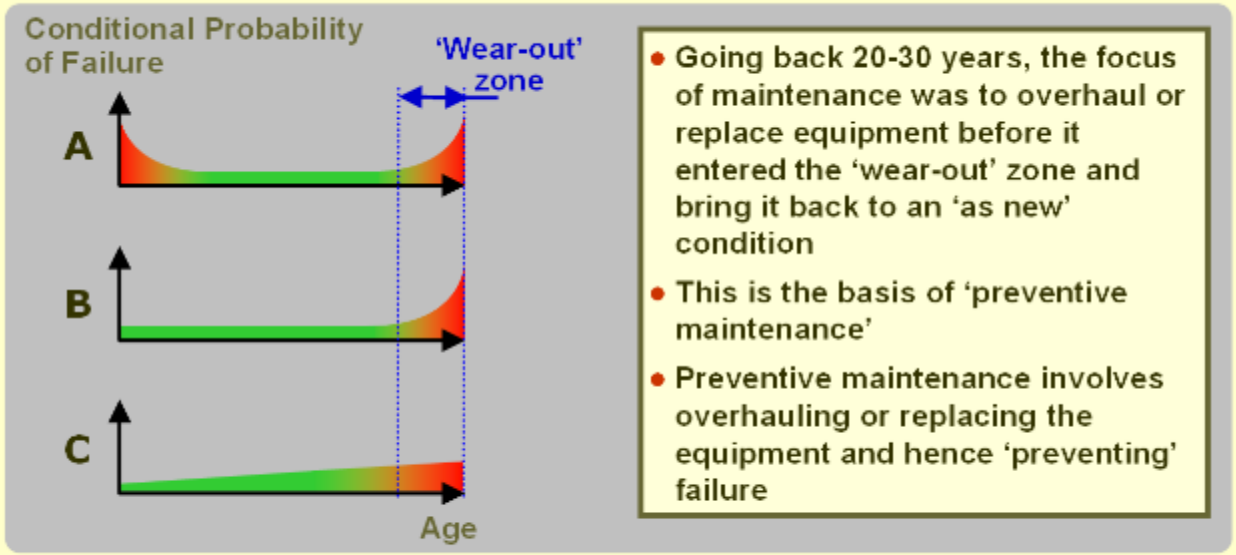
- Number of failure reduced
- Increase safety
- Easy maintenance budget expense forecast
- Fit for equipment that can not monitored or not cost effective if monitored by condition monitoring technology

Disadvantages

- Prone to initial failure/run in failure
- Wasting something that may be last longer
- High manpower and material cost compared to predictive maintenance

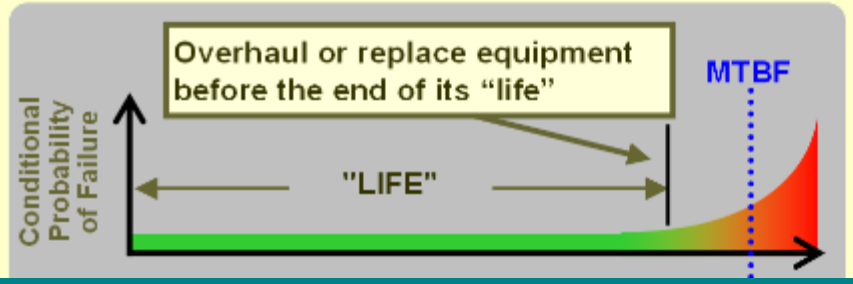
How to determine the preventive maintenance interval ?

Age-related Failures...



*Failure patterns A, B and C generally apply to simple items of equipment or complex items that have a **dominant** failure mode. The failures are usually characterised by erosion, corrosion, wear or fatigue etc.*

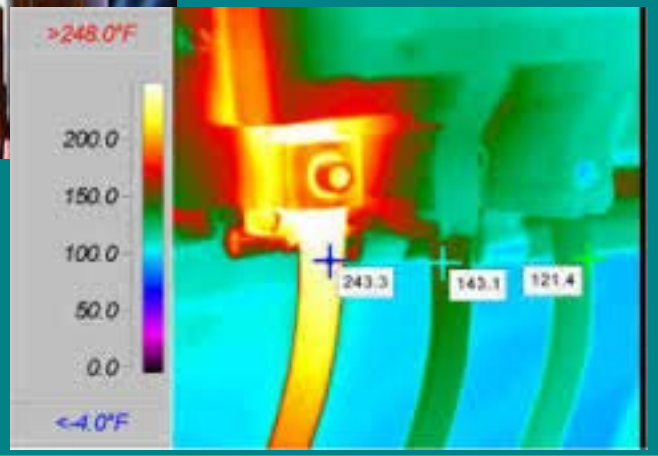
Condition-based Maintenance versus Overhaul/Replacement...



For a periodic overhaul or replacement, the assumption is that the equipment will not fail before the end of its "life".

- Usually start from "Operation and Maintenance Manual" from manufacturer that always "play safe". Manufacturer already tested their product and set the replacement interval in the "safe zone" based on the failure statistic.
- Improved by several trial to extent the maintenance interval or adopt international best practices to guess the more precise and longer "Useful Life"
- Only effective to prevent age related failure
- Can not fight random failure, and event more prone for equipment that have "infant mortality" failure characteristic. That is where condition monitoring rules the game

Predictive Maintenance



- "Process of monitoring a parameter of conditions in machinery (vibration, temperature, etc.), in order to identify a significant change which is indicative of a developing fault"

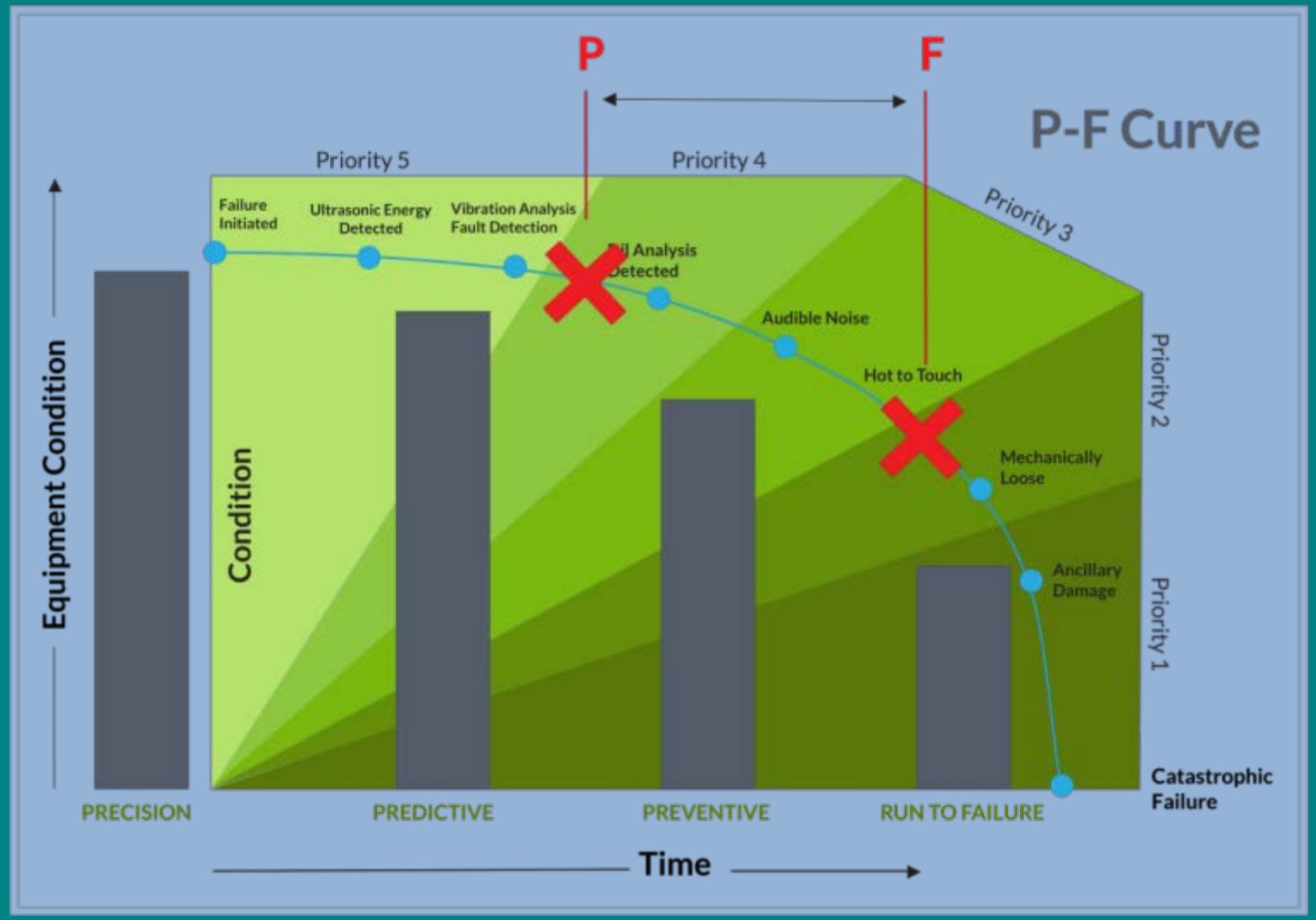
Advantages

- Number of failure reduced greatly
- Increase safety
- Give prediction when the equipment will fail from *trending* thus give time for planning *"preventing failure action"*
- Very helpfull for manpower planning & inventory strategy
- Reduce maintenance cost by reducing maintenance task, material usage, and manpower usage
- Fit for battling failure type as follow : random, run in

Disadvantages

- Can not implemented for equipment that does not generate symptom to be detected by con mon technology, i.e : instrument transmitter, normally open valve damage
- Expensive tools & need skilled manpower/engineer
- Not fit for small industries with low capital

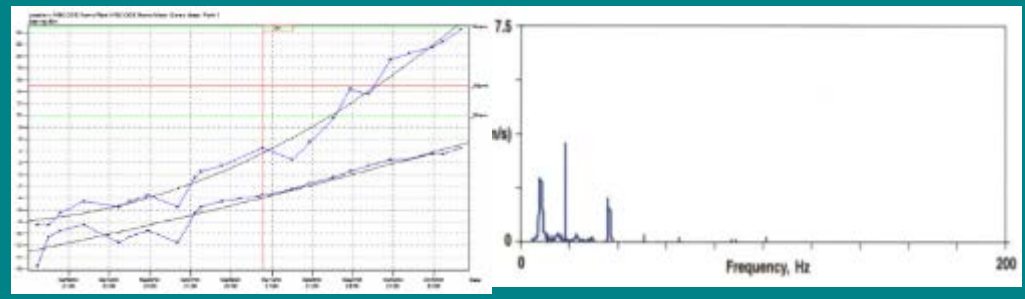
How to determine the predictive maintenance interval ?



- ***The PdM interval shall less than P – F interval in the P – F curve, not the actual failure frequency, also not related to criticality ranking***
- ***P = potential failure***, It is the condition where ***the fault or defect in the equipment component already detected*** and has the potential to fail in the near future
- New definition of Failure, ***F = Functionally Failure***, it is not the equipment break down, but whre the equipment ***"not performing intended function anymore"***
- *The function check/test is **not** PdM task, it is failure finding task. It is mean to determine it is still ok or already fail, not to predict when it will fail*

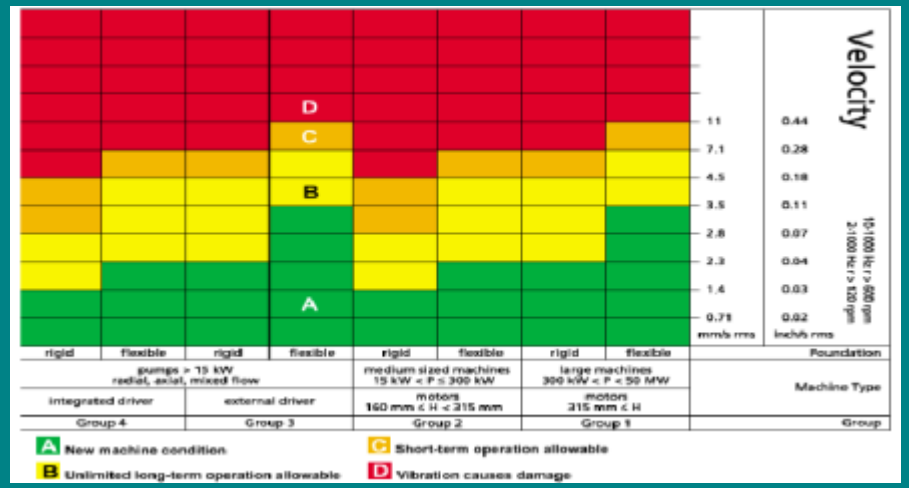
VIBRATION MONITORING

Purpose : for diagnosing mechanical & electrical faults in rotating machinery



Equipment

Turbine
Generator
Gearbox
Pump
Motor



Detected Defect

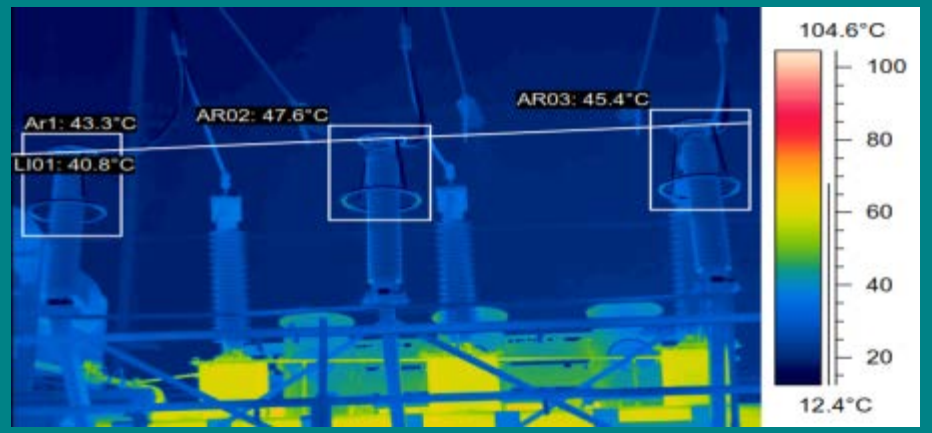
Unbalance
Bent shaft
Eccentricity
Misalignment
Looseness
Gear Defect
Bearing defect
Electrical fault
Cavitation
Hydraulic & Aerodynamic force

IR THERMOGRAPHY

Purpose : for finding electrical hot spot in swicthgear and motor controller. Also used to find - mechanical and process hot spot.

Equipment

Electrical connection
Transformer
Pump – motor bearing
.etc



Detected Defect

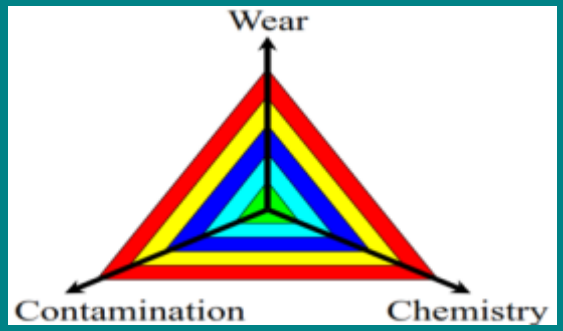
Hot bearing
Finding hot spot
Loose connectors
Blocked steam trap
Valve passing

GRADE LEVEL	ADVICE
0	NORMAL CONDITION. Request plan to reinvestigate within 6 to 12 months
1	MONITOR. Monitoring continually this condition, this matter can cause the temperature will progressively go up. Coordinate with the schedule operation it must, to conduct repair
2	SIGNIFICANT DEVIATION. Request arrange schedule of shutdown for an investigation and As Soon As Possible repair. Clean and Tighten all electrical connection was heated damage. Re inspect after repair completed.
3	UNACCEPTABLE DEVIATION. Request shut down and INVESTIGATES IMMEDIATELY, conduct repair or replace if required. Clean and Tighten all electrical connection was heated damage. Re inspect after repair completed.

OIL ANALYSIS

Purpose : for finding problem with lubricant, gearbox and recriprocating machine

Equipment
Turbine CT Gearbox LRVP Gearbox



Detected Defect
Impending failures of bearing (roller/journal) Oil contamination Abnormal gear wear Particle contamination in oil Oil oxidation Wrong oil in use Degraded lubricant Fatigue

TRANSFORMER OIL ANALYSIS

Purpose : for determining the condition of the insulating oil as well as the diagnosis of anly problem condition that may exist

Equipment
Transformer

Insulating Oil Quality Analysis
- Breakdown voltage
- Water content
- Neutralisation value
- Interfacial tension

Dissolve Gas Analysis
- Hydrogen
- Oxygen
- Methane
- CO, CO2
- Ethylene
- Ethane
- Acythelene
- Combustible gases

Furan Analysis

UT THICKNESS

The inspection, which measure the wall thickness of pipe, are performed to prevent failure due to corrosion, and to guide decisions regarding component life span / replacement.

Equipment
Steel pipeline Vessel

RBI / PIMS / CUI

- CORROSION RATE / YEAR
- REMAINING LIFE

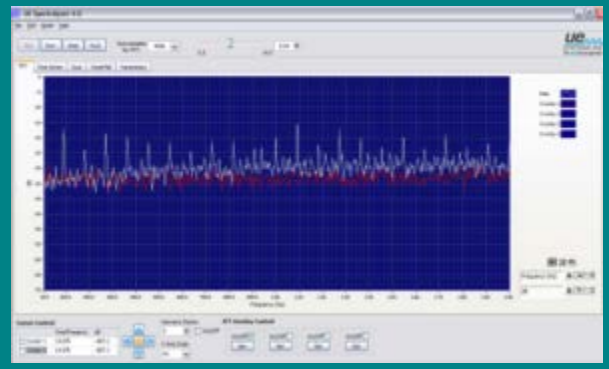
THICKNESS OF PIPE / VESSEL

ULTRASOUND ANALYSIS

Ultrasound analysis is very useful for detecting leaks and monitor or assisting bearing lubrication. Other than that, these analysis can also be integrated into IR and vibration to detect mechanical and electrical defect.

Equipment

Turbine
CT Gearbox
LRVP Gearbox
Valves
Electrical equipment

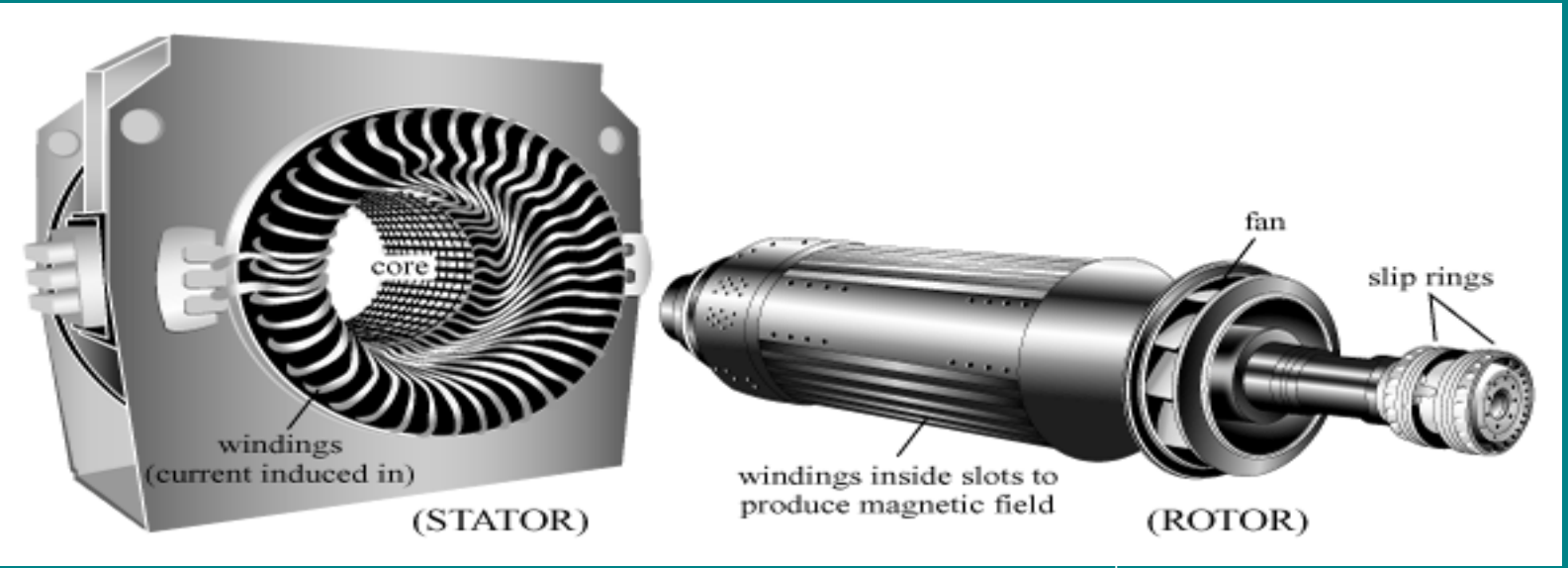


<u>Leak detection</u>
Valve leak
Steam trap leak

<u>Mechanical Inspection</u>
Bearing damage
Lubrication

<u>Electrical Inspection</u>
Tracking
Arching
Corona

MCSA – PARTIAL DISCHARGE - ROTOR FLUX – END WINDING VIB – SHAFT CURRENT ANALYSIS



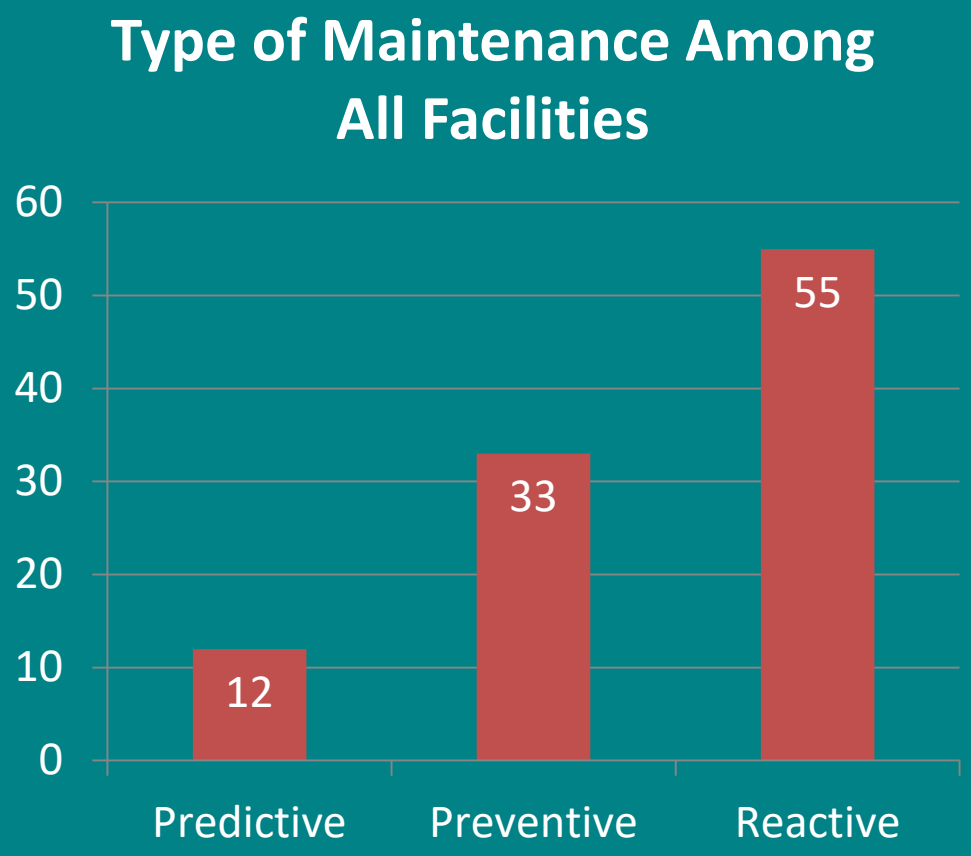
Detected Defect

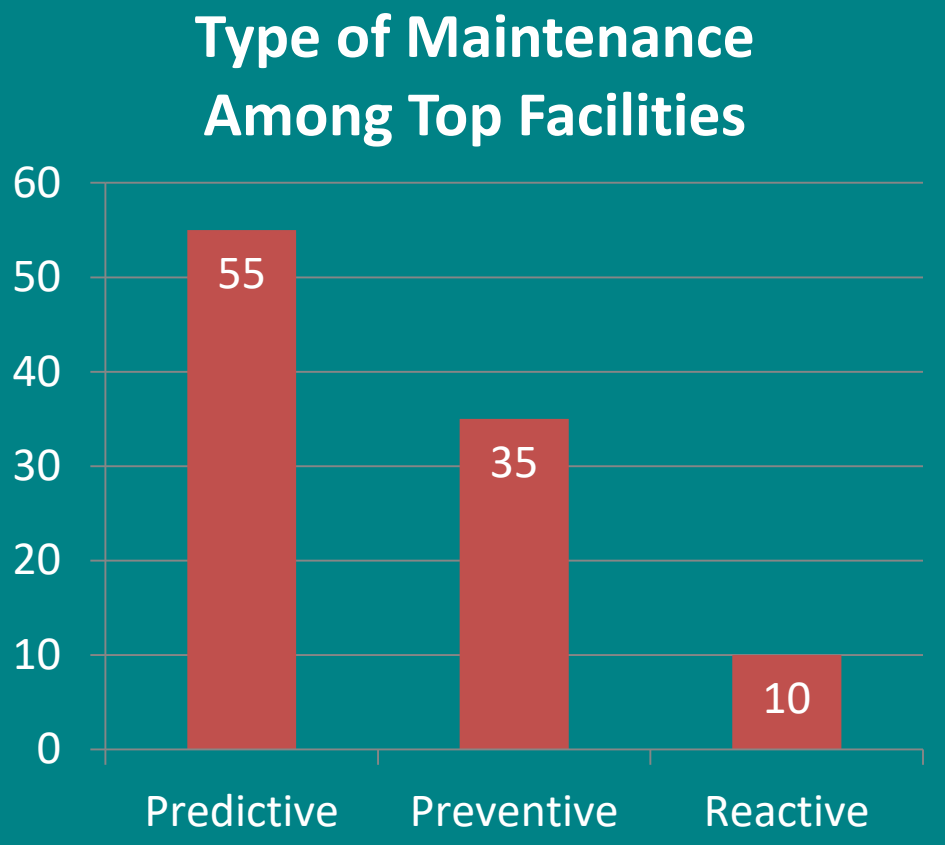
- ❑ Insulation condition of rotor & stator winding
- ❑ Rotor eccentricity
- ❑ Looseness

STATOR :
Partial Discharge (PD), End Winding Vibration, MCSA

ROTOR :
Rotor flux analysis, MCSA, shaft voltage

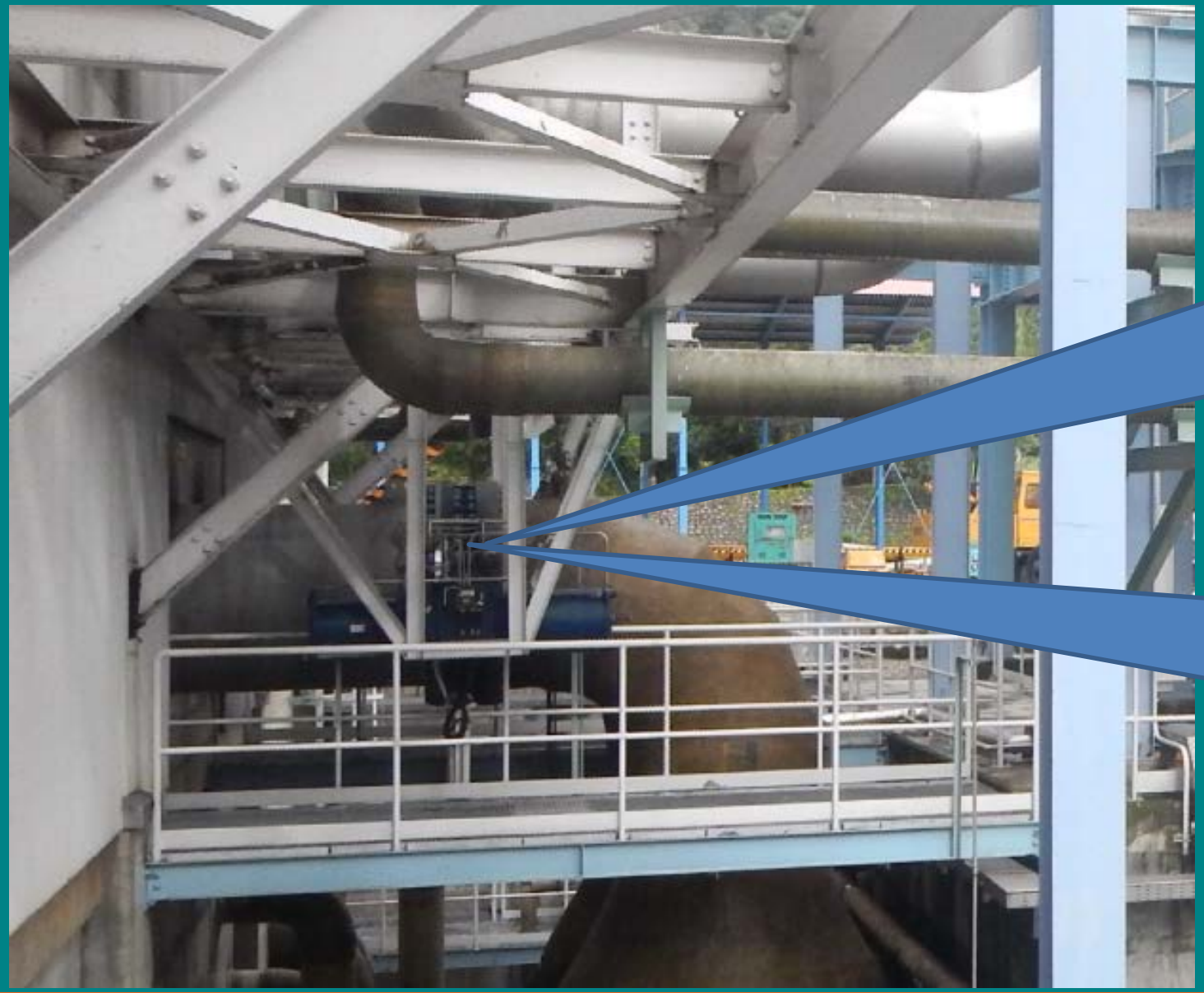
Maintenance Type Mixing in Industry





Sumber : http://blog.schneider-electric.com/building-management/2015/07/09/realize-predictive-maintenance-best-interest-building-budget/

Engineering & Maintenance



This is condenser inlet valve, size 48”, weight 5T, rubber seat damaged.
How to remove this valve for rubber seat replacement ?

Engineering & Maintenance

"Good Engineering design that considering maintainability is the first factor for a reliable, easy to operate, and easy to maintain geothermal powerplant."

Vs

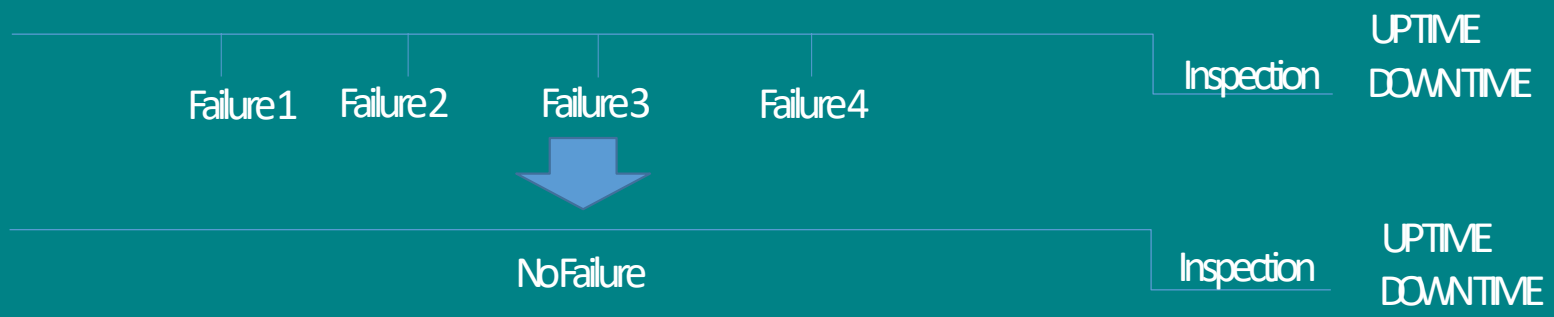
RELIABILITY

Availability: Probability that the system is operating properly when it is requested for use.

Reliability : Probability of the equipment could continuously operate without any failures

$$R_{(t)} = e^{-\lambda t} = e^{-(t/m)}$$

m or MTBF = *total running hour/number of fail*

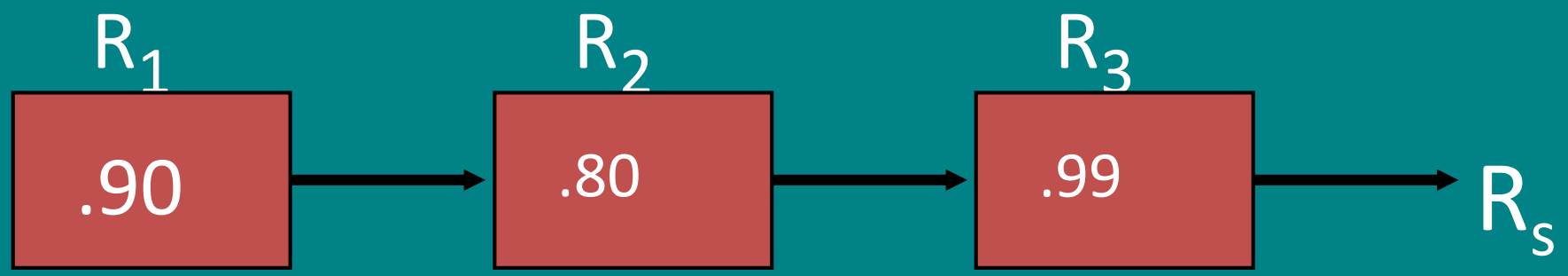


Reliability of systems consist of several components

$$R_s = R_1 \times R_2 \times R_3 \times \ldots \times R_n$$

where

R_1 = reliability of component 1
R_2 = reliability of component 2
and so on



Reliability of the process is

$R_s = R_1 \times R_2 \times R_3 = .90 \times .80 \times .99 = .713$ or 71.3%

Approaches to Improving Machine Reliability

Overdesign - enhancing the machine design to avoid a particular type of failure

Design simplification - reducing the number of interacting parts in a machine

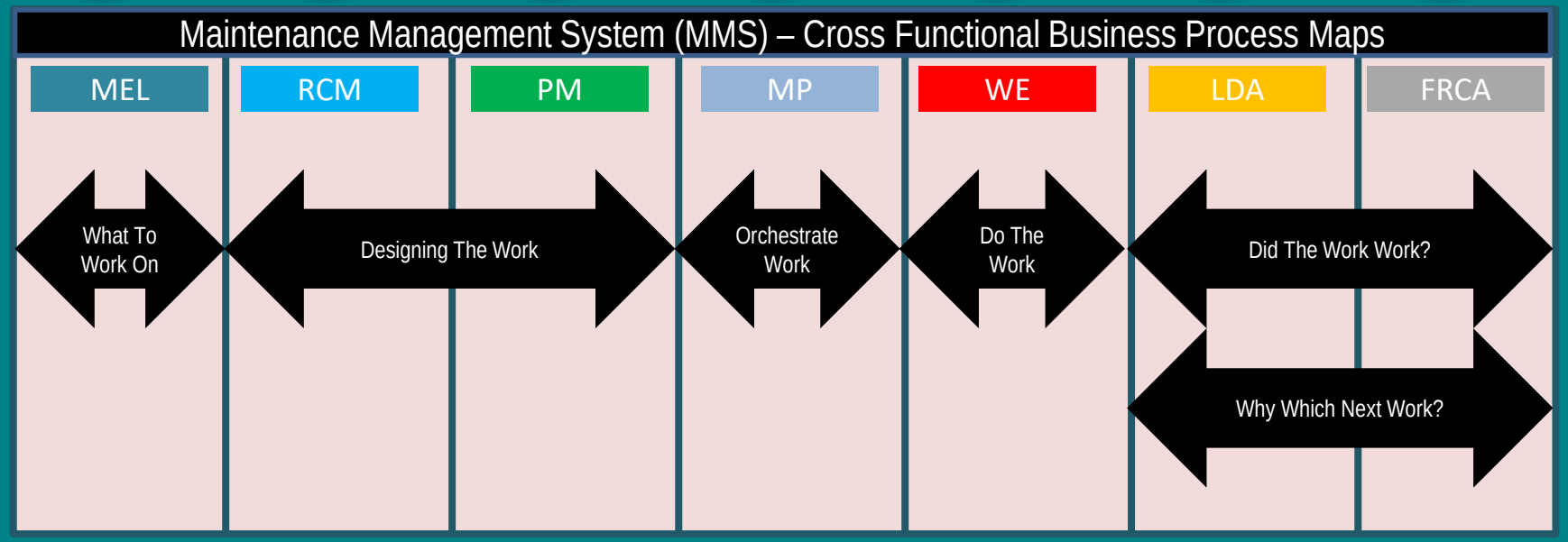
Redundant components - building backup components right into the machine so that if one part fails, it's automatically substituted

Calculation of Availability and Reliability

$$A = \frac{ST + IT}{T} \times 100 \qquad R = \frac{ST}{ST + FT} \times 100$$

A: availability
R: reliability
ST: total time in service mode during a defined period
FT: total time in failure mode during a defined period
MT: total time in maintenance mode during a defined period
IT: total time in idle mode during a defined period
T: defined period

Maintenance Management System

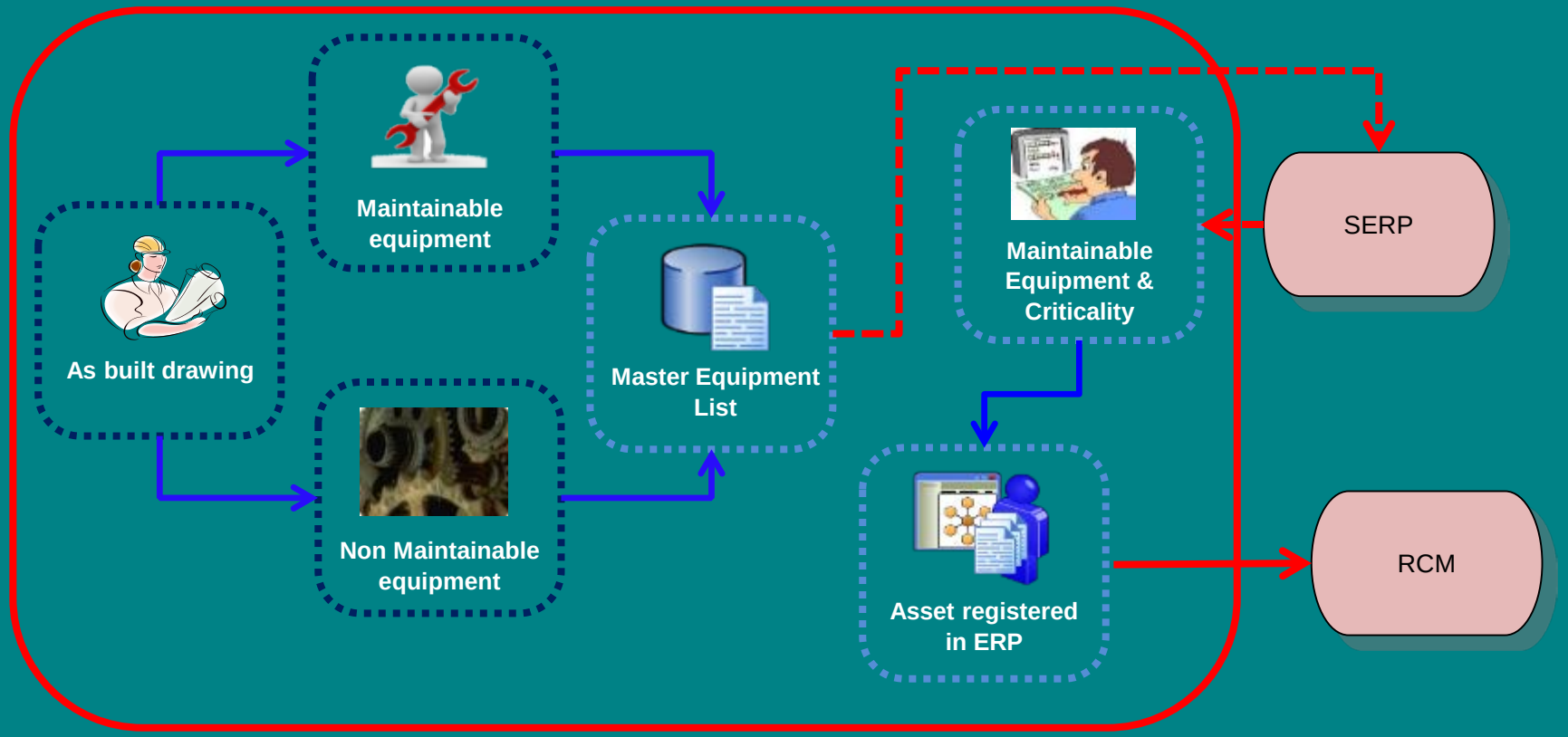


Main Equipment List (Asset Register)

Master Equipment List

- ✓Proper identification of plant equipment (usually using KKS code)
- ✓All equipment registered in CMMS or ERP
- ✓Criticality ranking (System/Equipment Ranking and Prioritization)
- ✓Bill of Material (for material management)

What To Work On ?



Reliability Centered Maintenance

Reliability Centered Maintenance (RCM)

What type to work on and when ?

- ✓ Assemble RCM assessment team (internal and consultant if needed)
- ✓ Conduct assessment using FMEA : Assess potential failure, failure mode, severity of failure, probability of failure for equipment that critical to plant reliability and or needed for legal compliance (SHE, government, insurance, etc). Then determine the maintenance task to prevent the failure happen (daily, weekly, monthly, semi annually, annually, include minor overhaul and major overhaul).
- ✓ The result of Assessment : Maintenance tasks package for each equipment. ***This is primary work identification.***
- ✓ The maintenance tasks package then uploaded to CMMS to generate ***Routine Work order*** (Time based work order and predictive work order)

Reliability Centered Maintenance

2nd : RCM

What type to work on and when ?

Master Equipment List (MEL)

Planning & Preparation

Initial Analysis

FMEA

Maintenance Strategy

Implement & Monitoring

Maintenance Planning & Work Execution

Example 1
Maintenance Package
Mechanic

What type to work on and when ?

MAINTENANCE PACKAGE
MECHANIC

N	Equipment	Function	Functional Failure	Effect	Sever	Failure Mode	Likelihood	Risk Ranking	Task Description	Type	Status	Assigned Interval	Labor (Crew	Procedure No
13	A1-Rotor	Converting thermal energy to kinetic energy	Unable to convert totally or partially	Production Loss, Process affected	1	Rotor; corrossion, crack, loss of seal fin, fatique	4	3 - Accepted with control	Dimensional Inspection and NDT, during overhaul	FF	Current	3Year	MTC-Rotating	TA Job
14	1MSV101A Main Steam Stop Valve 'A' Left	Isolate steam from main steam line to turbine casing	Failed to closed	High pressure in turbine casing	2	Actuator: malfunction Valve pin: scaling Valve spring: inelastic, valve seat: damage	2	2 - Undesireble	Valve maintenance: Stroking,lubrication,cleaning (during overhaul); penetrant test & visual	S	Current	3Year	MTC-Static	TA Job
	1MSV101A Main Steam Stop Valve 'A' Left	Isolate steam from main steam line to turbine casing	Failed to closed	High pressure in turbine casing	2	Actuator: malfunction Valve pin: scaling Valve spring: inelastic, valve seat: damage	2	2 - Undesireble	Valve lubrication	S	Proposed	6 Month	MTC-Static	EAI-MP-SMP-WI-61411
	1MSV101A Main Steam Stop Valve 'A' Left	Isolate steam from main steam line to turbine casing	Failed to open	Loss generation (turbine cannot be start)	2	Actuator: malfunction Valve pin: scaling Valve spring: inelastic, valve seat: damage	2	2 - Undesireble	Valve maintenance: Stroking,lubrication,cleaning (during overhaul); penetrant test & visual	S	Current	3Year	MTC-Static	TA Job
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2nd : RCM

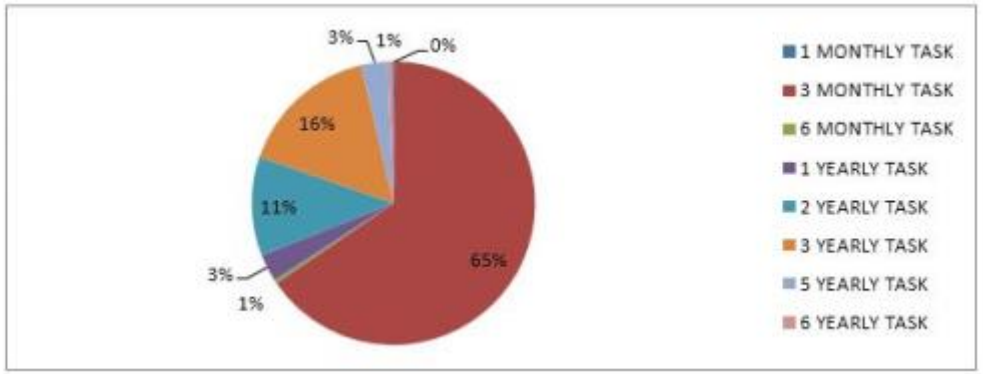
What type to work on and when ?

SUMMARY REPORT
MAINTENANCE PACKAGE - INSTRUMENT

TOTAL EQUIPMENT SHOULD BE MAINTAINED	311	EQUIPMENT	MAINTENANCE PACKAGE COMPLETENESS	91.1%
TOTAL MAINTENANCE TASK	929	TASK		
COMPLETED MAINTENANCE TASK	846	TASK		
TOTAL MAINTENANCE TASK TYPE	34	TASK TYPE		
TOTAL WORK INSTRUCTION TYPE	26	WI		
TOTAL EQUIPMENT TYPE	xx	EQUIPMEN TYPE		

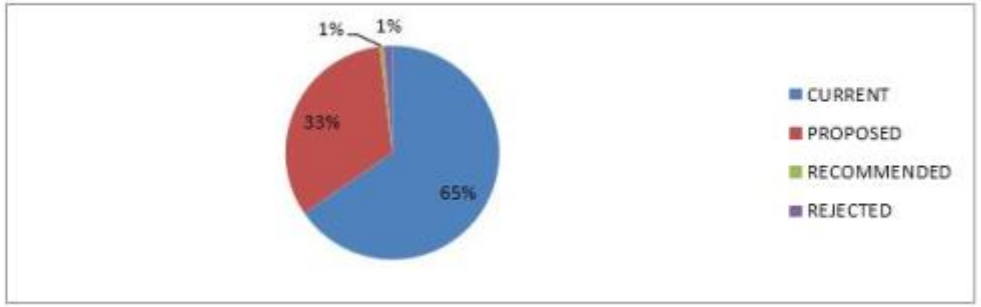
MAINTENANCE TASK INTERVAL

1 MONTHLY TASK	*2*	*TASK*
3 MONTHLY TASK	*606*	*TASK*
6 MONTHLY TASK	*4*	*TASK*
1 YEARLY TASK	*29*	*TASK*
2 YEARLY TASK	*105*	*TASK*
3 YEARLY TASK	*149*	*TASK*
5 YEARLY TASK	*28*	*TASK*
6 YEARLY TASK	*6*	*TASK*
TOTAL	*929*	*TASK*



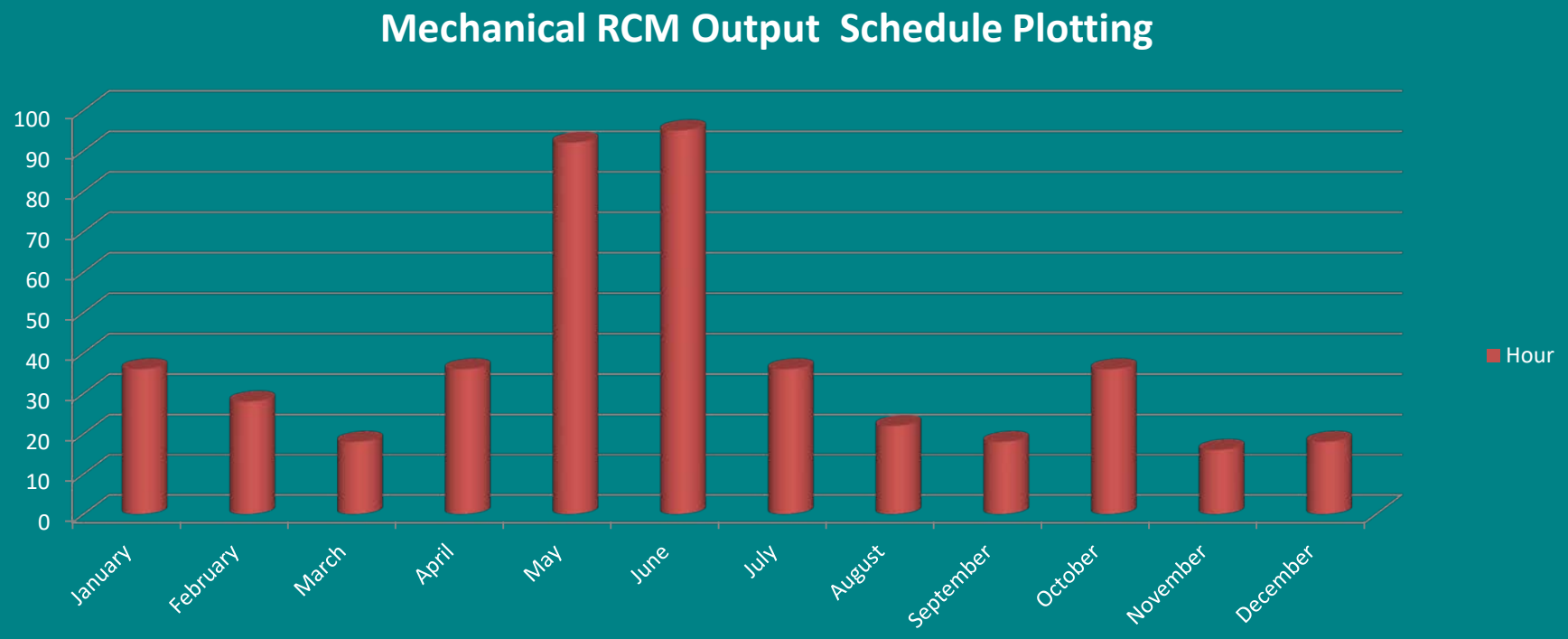
MAINTENANCE TASK STATUS

CURRENT	*608*	*TASK*
PROPOSED	*303*	*TASK*
RECOMMENDED	*6*	*TASK*
REJECTED	*12*	*TASK*
TOTAL	*929*	*TASK*



Reliability Centered Maintenance

What type to work on and when ?



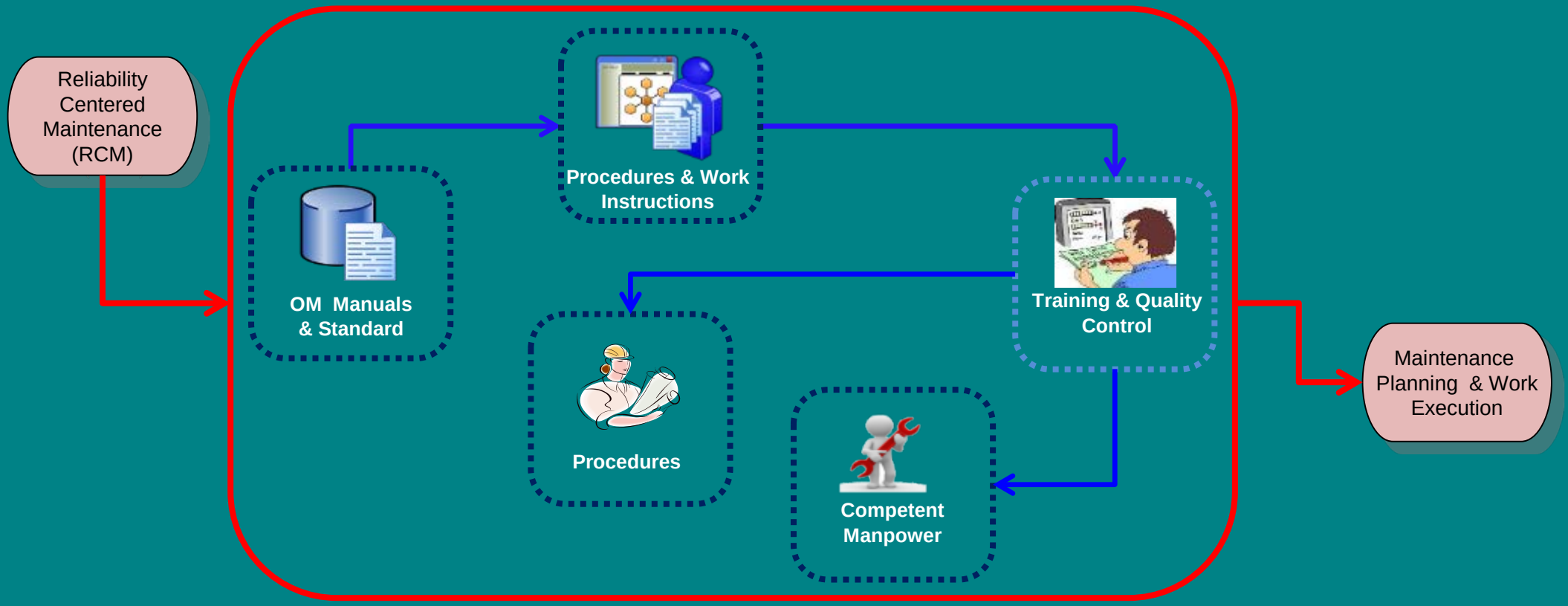
By predicting the duration of each task and plotting in the schedule, we know the work load in a year and next optimize and balancing the working hour each month.

Precision Maintenance

Precision Maintenance

- ✓ "Remove uncontrolled variable to minimize result deviation against the target"
- ✓ "Same standard of work execution, Consistent result (repeatable) and independent from ***who*** do the jobs"
- ✓ Include requirement from other sections : Job Safety Analysis, work permit, etc

How to do the work?



Maintenance Planning

4th : MP

Orchestrate The Work

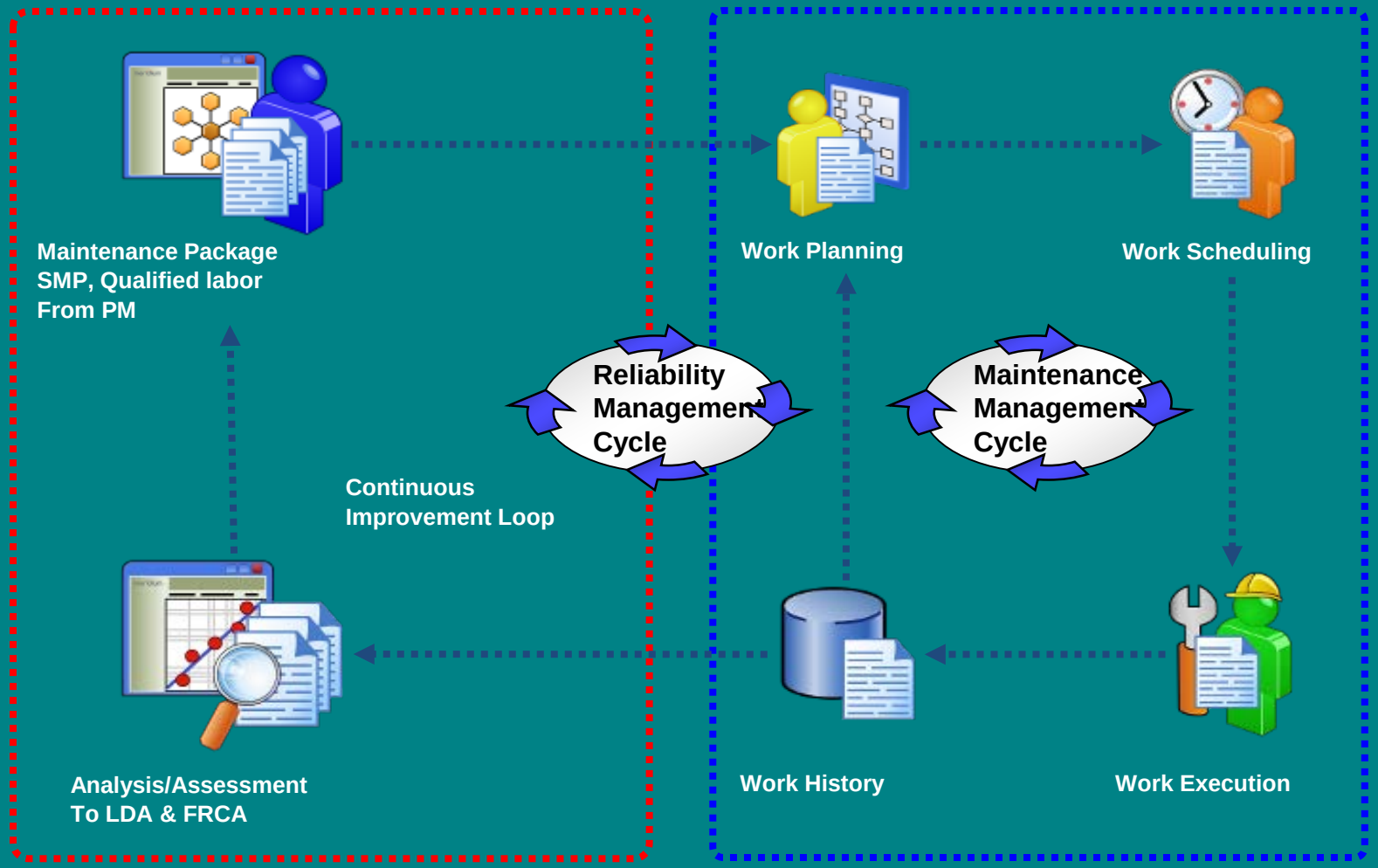
Maintenance Planning (This is the ***brain*** of maintenance, who control all other section. ***A MUST HAVE***)

- ✓ Manage CSMS for scheduling the work :
  - Primary works : Routine work order from maintenance tasks package from RCM
  - Secondary works : process notification from routine patrol, plant inspection report, audit finding, and predictive maintenance report (good corrective work), and other notification such as trip/failure report, broken equipment report, substandard condition (reactive work). ***This is secondary work identification.***
  - Schedule optimization (knitting work order from various section) for short term and long term planning (daily, weekly, monthly, semi annually, annually, include minor overhaul and major overhaul).
- ✓ Manage the resources : spare parts, tools, special tools, heavy equipment, labor
- ✓ Manage the historical records
- ✓ Manage the maintenance KPI
- ✓ Contract management : develop specification and close coordination with SCM for spare parts and service procurement process

Maintenance Planning

MMS - Maintenance Planning Process

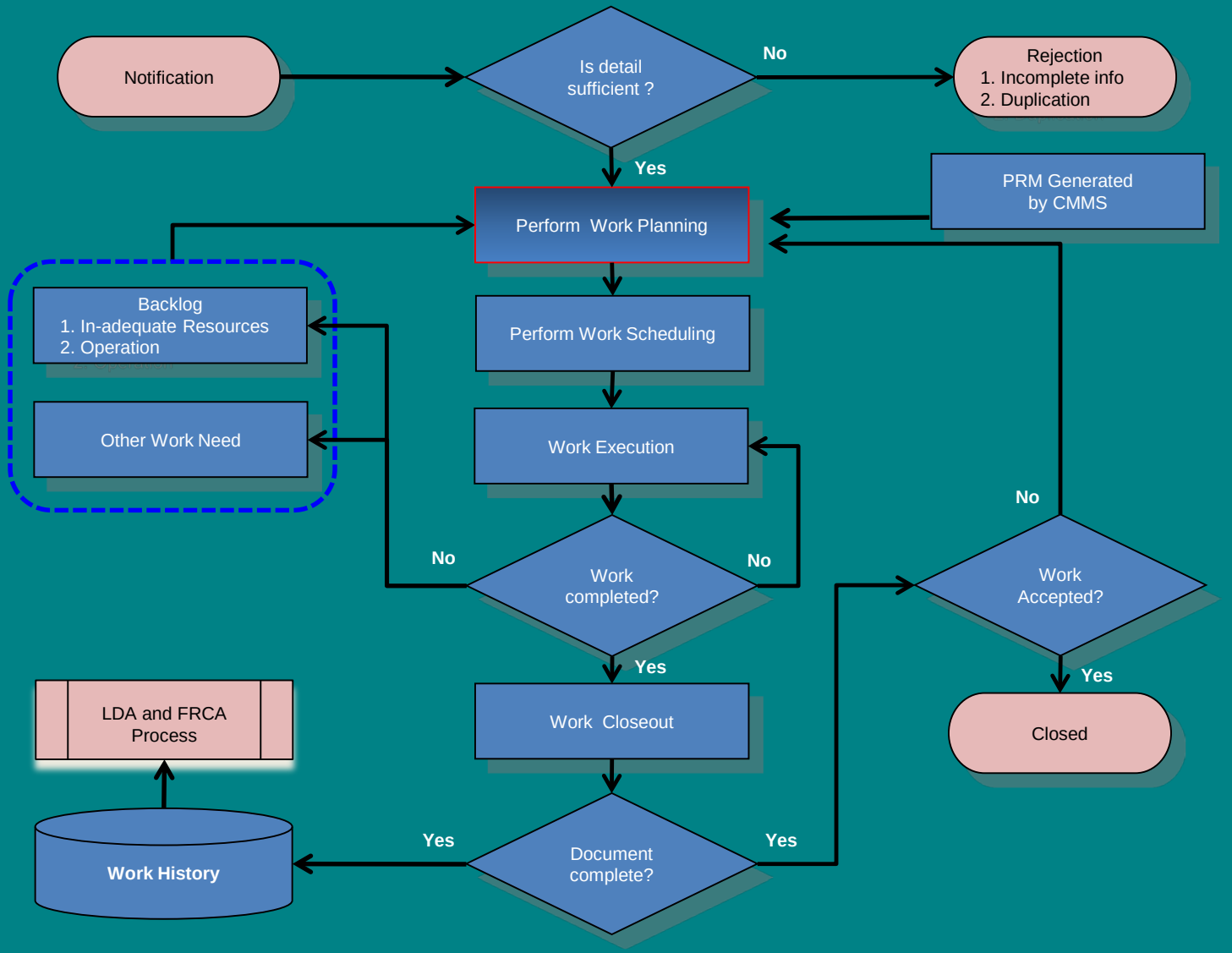
Orchestrate The Work



Work Request Flowchart

Orchestrate The Work

Planning & Scheduling Process

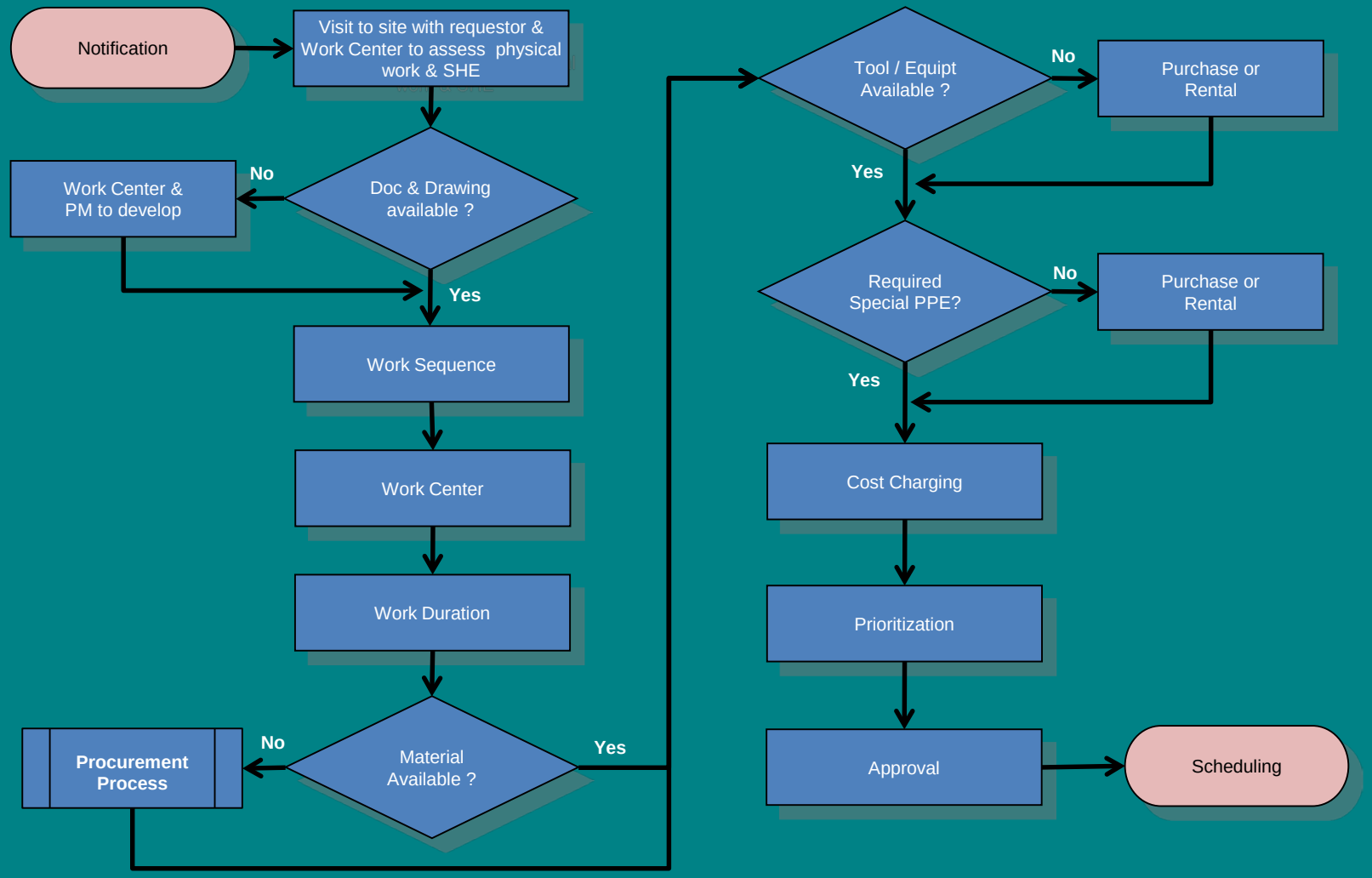


Work Planning

4th : MP

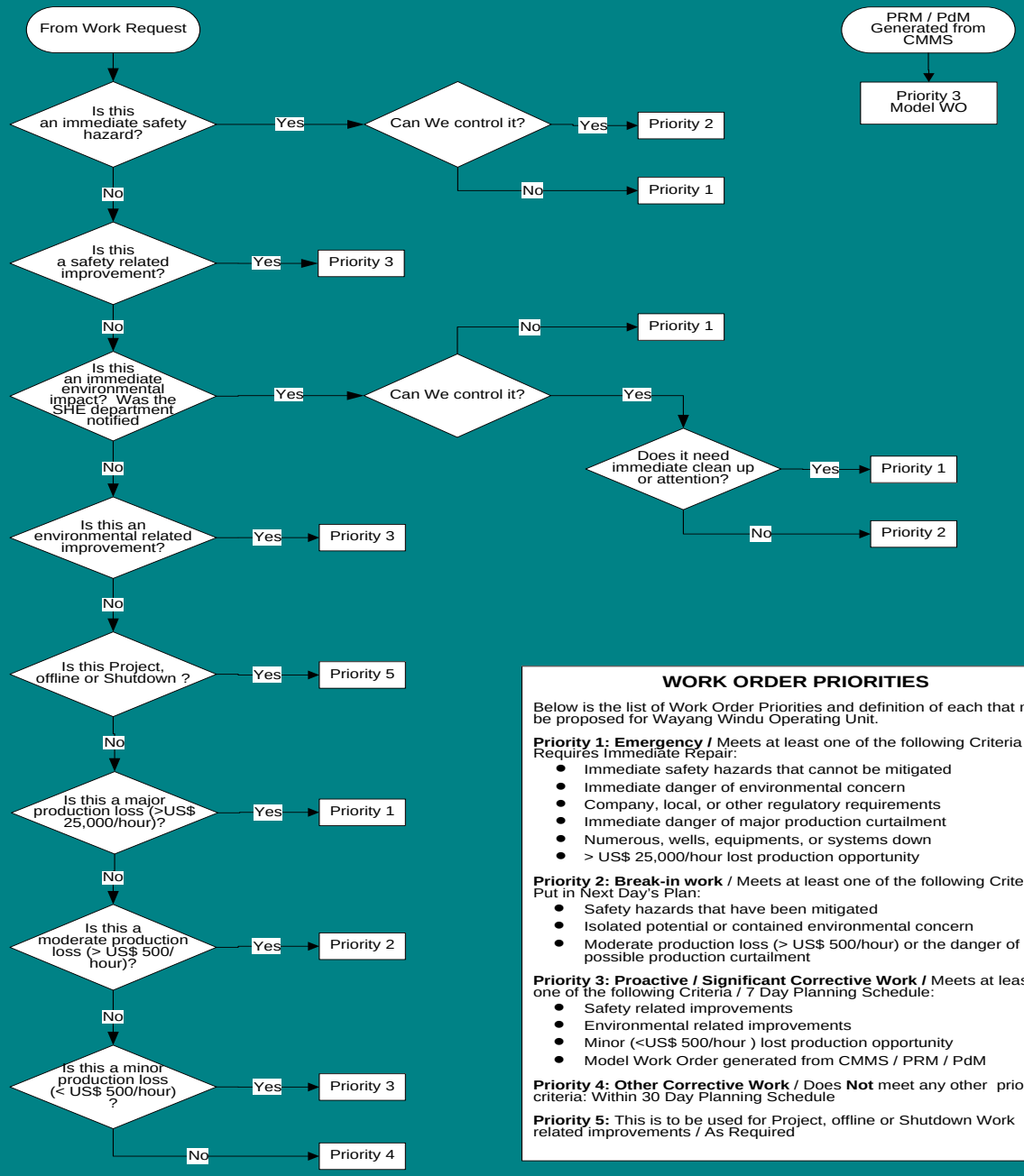
Orchestrate The Work

Planning & Job Assessment



Orchestrate The Work

Work Order Prioritization



WORK ORDER PRIORITIES

Below is the list of Work Order Priorities and definition of each that may be proposed for Wayang Windu Operating Unit.

Priority 1: Emergency / Meets at least one of the following Criteria / Requires Immediate Repair:

- Immediate safety hazards that cannot be mitigated
- Immediate danger of environmental concern
- Company, local, or other regulatory requirements
- Immediate danger of major production curtailment
- Numerous, wells, equipments, or systems down
- > US$ 25,000/hour lost production opportunity

Priority 2: Break-in work / Meets at least one of the following Criteria / Put in Next Day's Plan:

- Safety hazards that have been mitigated
- Isolated potential or contained environmental concern
- Moderate production loss (> US$ 500/hour) or the danger of possible production curtailment

Priority 3: Proactive / Significant Corrective Work / Meets at least one of the following Criteria / 7 Day Planning Schedule:

- Safety related improvements
- Environmental related improvements
- Minor (<US$ 500/hour) lost production opportunity
- Model Work Order generated from CMMS / PRM / PdM

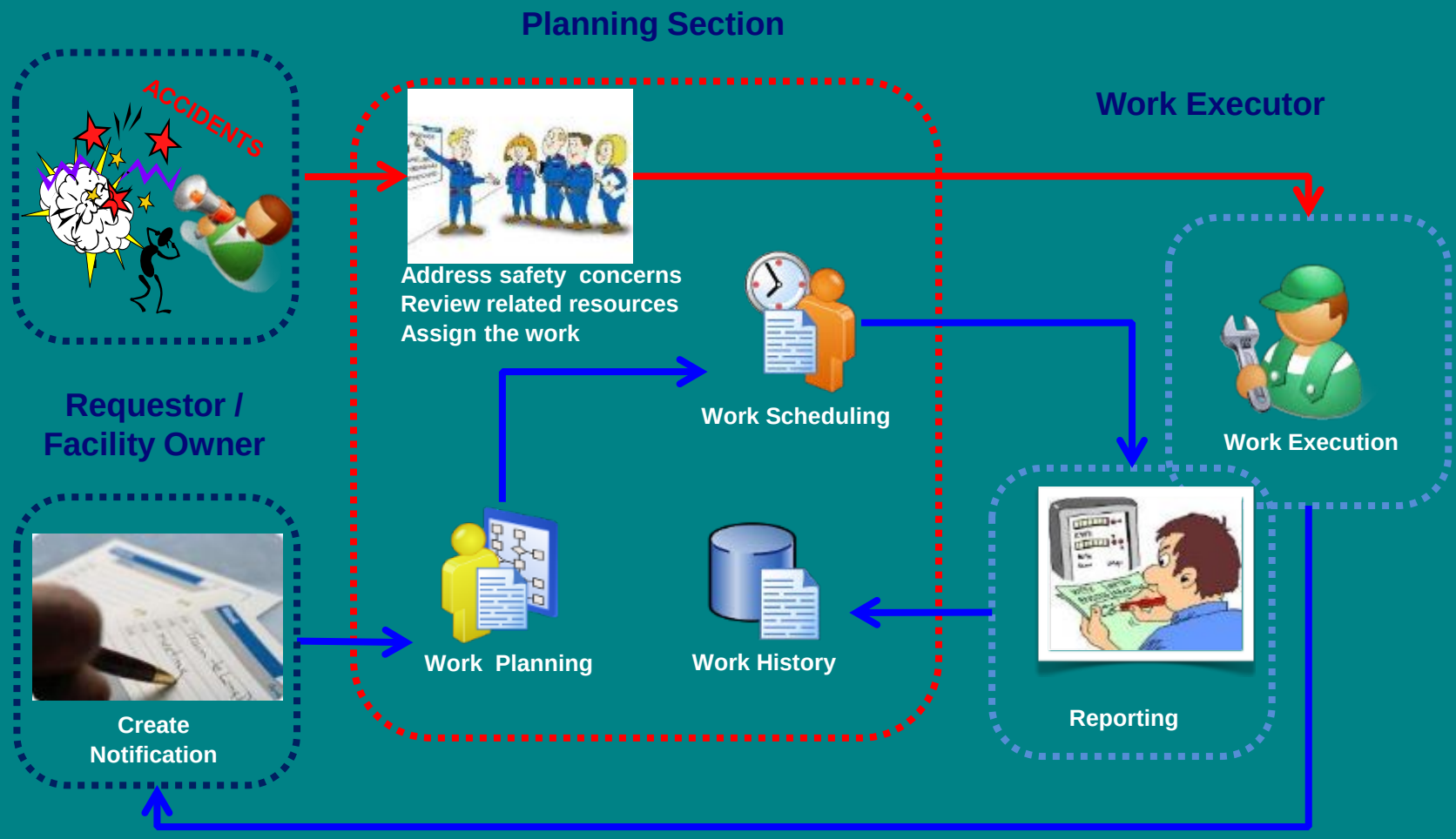
Priority 4: Other Corrective Work / Does **Not** meet any other priority criteria: Within 30 Day Planning Schedule

Priority 5: This is to be used for Project, offline or Shutdown Work related improvements / As Required

Emergency Work Process

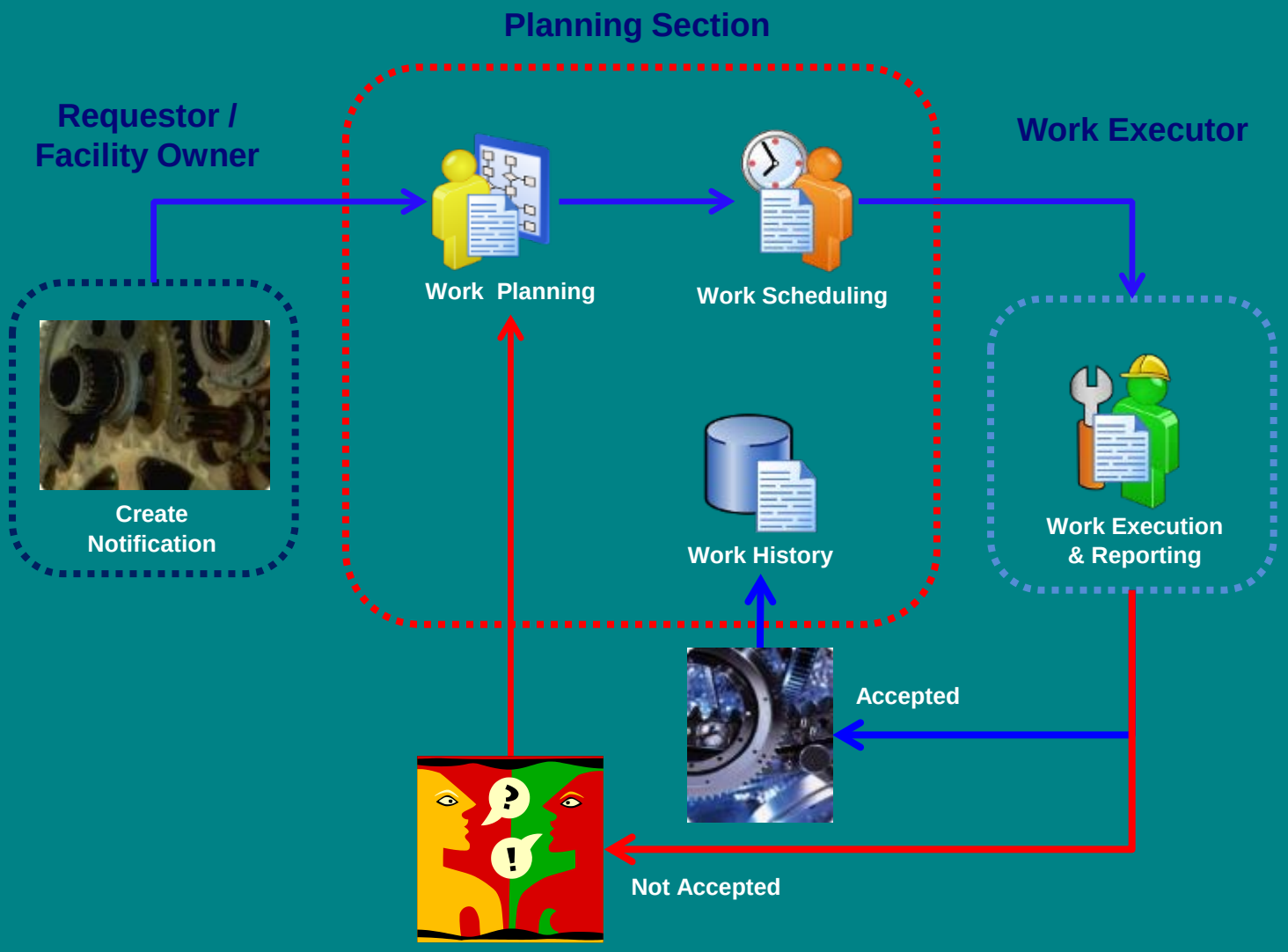
4th : MP

Orchestrate The Work



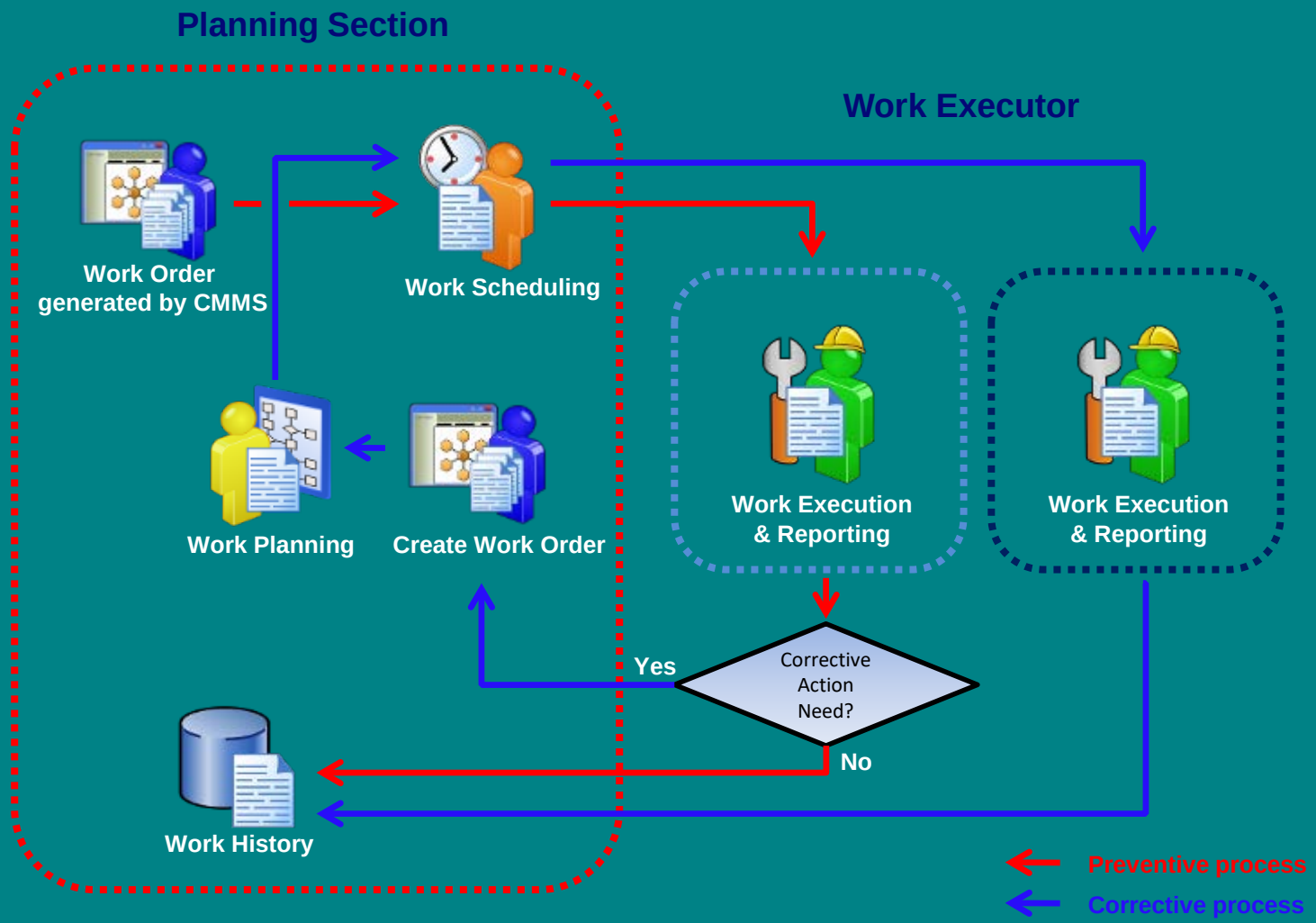
Non Emergency Work Process

Orchestrate The Work



Preventive & Predictive Maintenance Work Process

Orchestrate The Work



Work Execution

Do The Work

Work Execution

- ✓ Do the maintenance work orders as per planning schedule with SOP from Precision Maintenance process
- ✓ Always comply with other dept. regulation : Work permit from Powerplant operation, hazard control from SHE, etc
- ✓ Fill the maintenance records
- ✓ Report the records
- ✓ Analyze and make suggestion based on actual work execution result :
  - to precision maintenance for SOP improvement,
  - to planning section for improvement on schedule, work duration and resources

Life Data Analysis

5th : LDA

Did The Work Work ?

Maintenance Planning And Work Execution

Define Plant and/or equipment target RAM model

Collecting Data

Data Analysis

Plant and/or equipment reliability report

Plant and/or equipment reliable

Plant and/or equipment un-reliable

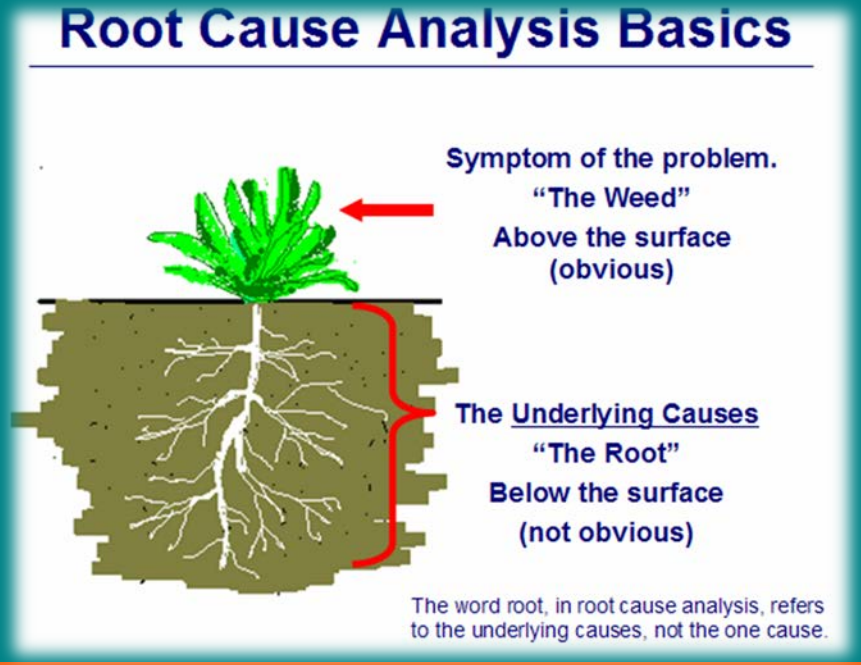
Failure Root Cause Analysis (FRCA)

Root Cause Failure Analysis (FRCA)

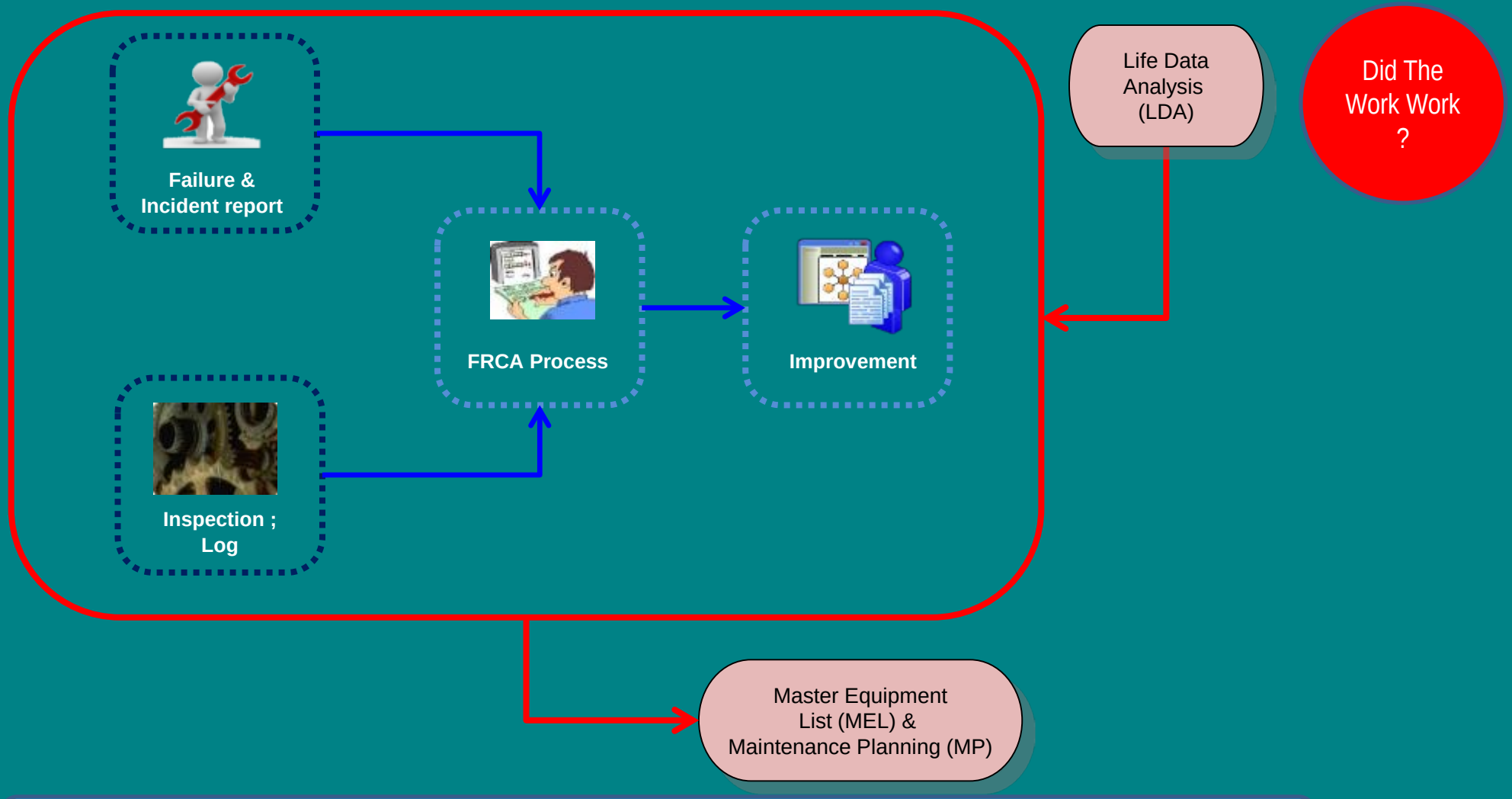
Did The Work Work ?

Root Cause Failure Analysis (RCFA)

- Further investigation to determine the root cause of significant failure (frequent failure or severe failure)
- Recommendation for improvement to prevent the same failure recurring (can be design change, additional maintenance task, change the maintenance interv(al shorter, material change, etc)
- FRCA is not to find WHO to blame !!! But to seek system improvement
- May need assistance from subject matter expert



Root Cause Failure Analysis (FRCA)



FRCA is not to find WHO (person) to blame !!!
But to seek system improvement to prevent same failure recurring