Healthcare Facilities Management

Module 3: Operations & Maintenance
Student Workbook

Lesson 9 ~ O & M 1

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OPERATIONS &
MAINTENANCE
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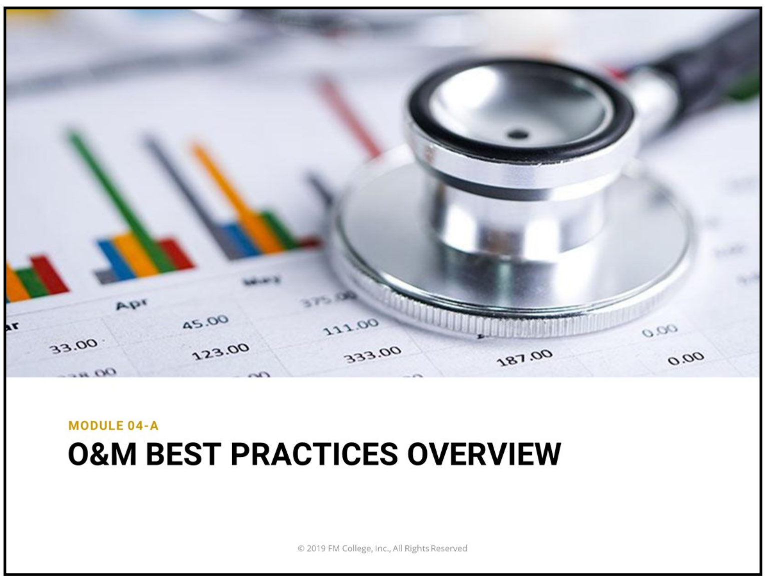
MODULE 04-A
O&M BEST PRACTICES OVERVIEW
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Initial Concepts

Definitions

Means	The instruments or equipment used to accomplish something. Includes calculations for our purposes.
Methods	The techniques or procedures used to accomplish specific result.
Concepts	An understanding retained in the mind, from experience, reason and/or imagination; a generalization, or abstraction, of a particular set of instances or occurrences
Strategies	A plan of action intended to accomplish a specific goal.

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Run to Failure

Run to Failure: Strategy?

Assets are deliberately allowed to operate until they break down, at which point reactive maintenance is performed.

Type of maintenance: Unplanned/Reactive

Used when:

- Cost of Preventative Maintenance would be nearly equal to replacement cost
- Failure is of low impact/risk
- Spare parts readily available

Run to Failure: Strategy sometimes

Common Examples
- Light bulb
- Bathroom exhaust fan

Advantages
- Minimal planning
- Easy to understand

Disadvantages
- Unpredictable
- Inconsistent
- Costly
- Inventory costs

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Time Based Maintenance

Time Based Maintenance (TbM)

A form of maintenance of an asset according to a strict timetable, with the following general attributes:

- Fixed Intervals
- Routine Tasks
- Contracted Services

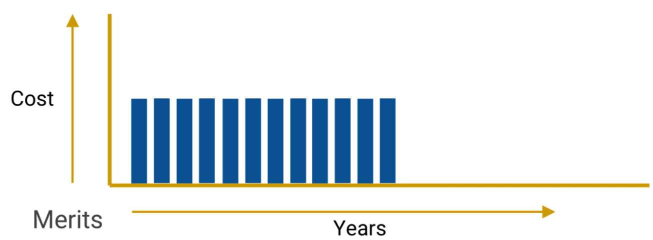
Example Tasks

- “Inspect exterior sealant every 3 years”.
- "Clean gutters every six months"
- 'Lubricate pumps every 6,000 run hours“

Assets that may be good candidates

- Bounded assets, such as fire safety equipment
- Critical assets (and critical components)

Time Based Maintenance (TbM)



Merits

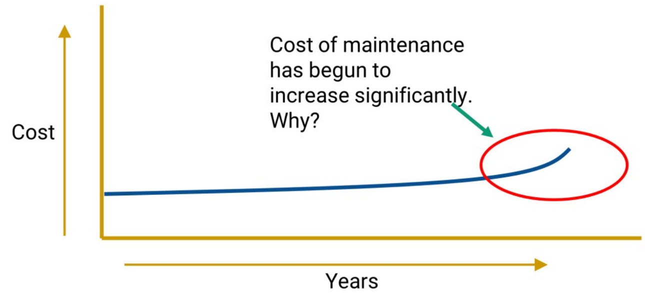
- Consistency and Predictability
- TbM may be quantitative (but not necessarily qualitative)

Limitations:

- TbM may result in over-maintenance
- It does not recognize the changing condition of assets over time

Maintenance Evaluation: Parameters

Cost



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Condition Based Maintenance

Condition Based Maintenance (CbM)

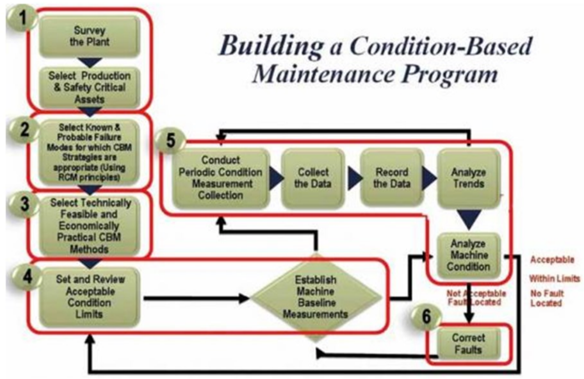
- A maintenance strategy that is based on measuring the condition of assets to assess whether they will fail during some future period, and then taking appropriate action to avoid the consequences of that failure.
- The terms condition-based maintenance, on-condition maintenance, and predictive maintenance are often used interchangeably.
- Three primary variants in addition to main strategy:
  - Exposure-Based Maintenance (EbM) (example, traffic or weather)
  - Use-Based Maintenance (UbM) (example conference area restroom in hotel)
  - Risk-Based Maintenance (RbM)

Condition Based Maintenance (CbM)

Types of CbM systems

- Periodic
  - acquire measurements from equipment at selected time intervals
  - analysis of the collected data is generally performed in the office or laboratory
- Continuous
  - on-line the measurement values at selected points continuously
  - compared with pre-established levels or criteria
  - "Set-points" are usually established for the purpose of providing automatic warnings and/or equipment shutdown

Condition Based Maintenance (CbM)



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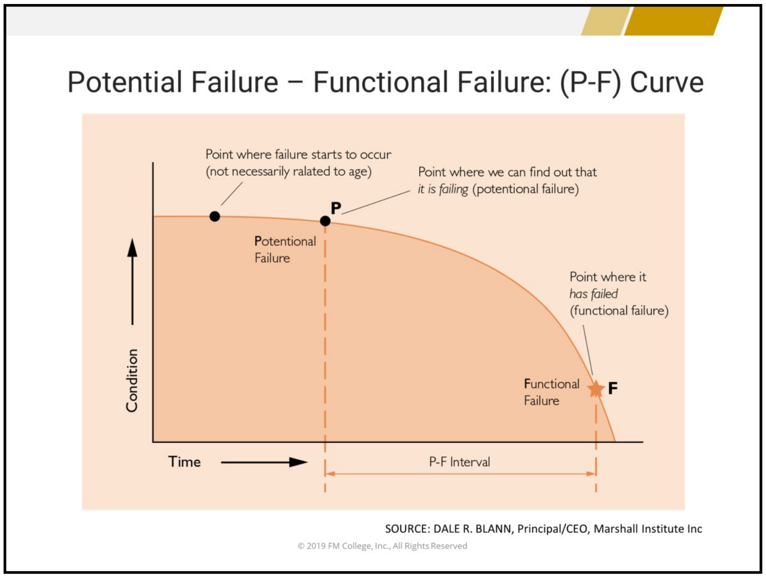
P-F Curve


Potential Failure – Functional Failure: (P-F) Curve
Point where failure starts to occur
(not necessarily ralated to age)
Point where we can find out that
it is failing (potentional failure)
P
Potentional
Failure
Point where it
has failed
(functional failure)
Functional
Failure
F
Condition
Time
P-F Interval
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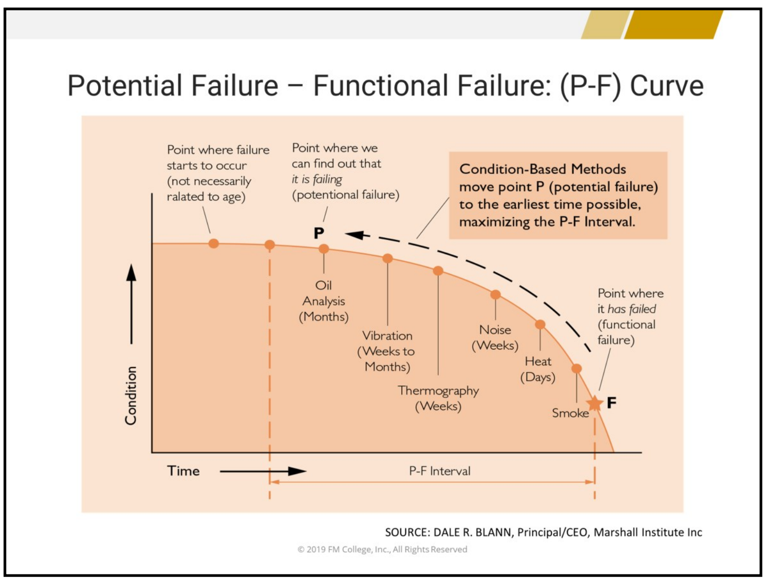
Potential Failure – Functional Failure: (P-F) Curve
Point where failure
starts to occur
(not necessarily
ralated to age)
Point where we
can find out that
it is failing
(potentional failure)
Condition-Based Methods
move point P (potential failure)
to the earliest time possible,
maximizing the P-F Interval.
P
Oil
Analysis
(Months)
Vibration
(Weeks to
Months)
Thermography
(Weeks)
Noise
(Weeks)
Heat
(Days)
Smoke
Point where
it has failed
(functional
failure)
F
Condition
Time
P-F Interval
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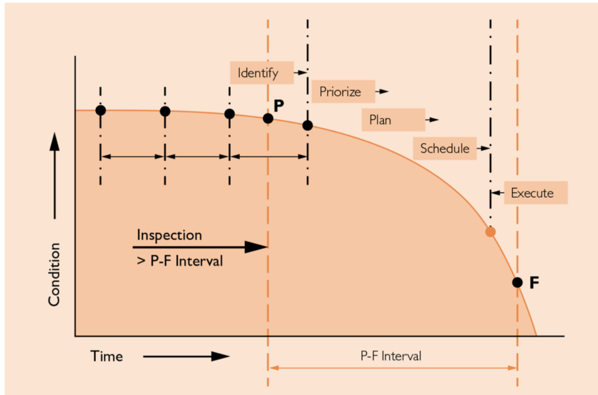
Potential Failure – Functional Failure: (P-F) Curve



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Equipment Maintenance Life Cycle

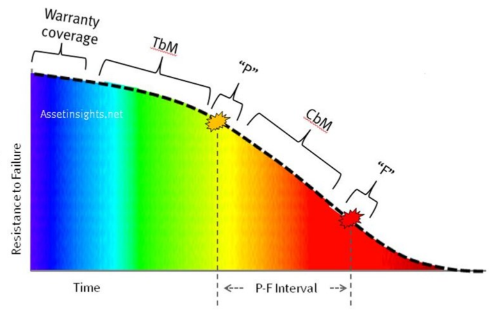
Equipment Maintenance Lifecycle

Age

- Early life time-based
- Condition exploration as life progresses

Condition

- Early testing can prevent premature failure
- Maintenance is based on test results



Equipment Maintenance Lifecycle

New/Start-up

- Initial Performance Documented (TAB Report?)
- Warranty Received/Recorded
- O&M Manual Received (Electronic Back-up)
- Sequence of Operation Documented
- Plan for OEM maintenance during warranty period
- Predictive Maintenance (PdM) initiated
- All data entered into CMMS
- Connect to Monitoring-based Cx system (if applicable)
- Job Task Analysis for all maintenance
- Staff/Contractor Training
- Compliance records and reviews (AHJ etc.)
- Initial Useful Life (UL) determination made

Equipment Maintenance Lifecycle

End of Warranty

- Validation of performance compared to initial start up
- Formal review of operation during warranty for any closeout issues
- Review for inclusion in AEM program
- Decision OEM/AEM maintenance plan
- Revision to CMMS tasking for AEM if selected
- "Hand over" of Maintenance from warranty maintenance provider
- CMMS tasking updated as needed
- Annual review of maintenance completed/recorded
- Compliance records and reviews (AHJ etc.)

Equipment Maintenance Lifecycle

Ongoing operation

- Validation of performance compared to initial start up
- Monitoring based Cx reporting (if applicable)
- Consideration for Retro-Cx (if applicable) based on performance and energy use
- Annual review of maintenance completed/recorded
- Based on maintenance review and PdM results consider adding Condition based Maintenance (CbM)
- Compliance records and reviews (AHJ etc.)
- Annual condition/performance audit performed and recorded for Strategic planning (Capital Replacement Plan etc.)
- Remaining Useful Life (RUL) updated based on audit annually
- UL/RUL recorded for planning purposes annually

Equipment Maintenance Lifecycle

Approaching Major Maintenance (MM) /Replacement

- Validation of performance compared to initial start up
- As equipment enters 3-5 year window for major maintenance initial budget estimate is developed and planned for
- RUL updated at least annually based on audit
- Consideration of upgrades versus repair/replace in kind
- At about 2 year mark for approaching MM, budget is formally planned and sent for approval
- When budgeted and approved, MM project developed (and bid spec, etc) and project management assigned.
- Sustainable approach to salvage/disposal of old equipment etc.
- When renewal project is complete, treat as in “New/Startup”

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Total Productive Maintenance

Total Productive Maintenance

Increase the productivity of a factory and its equipment with a modest investment in maintenance

Increase the Overall Equipment Effectiveness (OEE) of plant equipment

- Performance x Availability x Quality = OEE
- Losses:

Performance	Availability	Quality
Reduced Speed	Breakdowns	Startup Rejects
Minor Stops	Product Changeover	Running Rejects

Loss Causes: Identify -> Prioritize -> Eliminate

TPM: Principles

Eight Pillars of TPM

- Autonomous Maintenance
- Focused Improvement
- Planned Maintenance
- Quality management
- Early/equipment management
- Education and Training
- Safety Health Environment
- Administrative & office TPM

Utilizing these pillars, productivity can be increased

TPM: Implementation

Steps

- Initial evaluation of TPM level,
- Introductory Education and Propaganda (IEP) for TPM,
- Formation of TPM steering committee,
- Development of master plan for TPM implementation,
- Stage by stage training to the employees and stakeholders on all eight pillars of TPM,
- Implementation preparation process,
- Establishing the TPM policies and goals and development of a road map for TPM implementation

TPM committee should consist of production managers, maintenance managers, and engineering managers

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Autonomous Maintenance

Autonomous Maintenance: (Jishu-Hozen)

A maintenance strategy wherein machine adjustments and minor maintenance is performed by operators who are deemed to have unique knowledge about the equipment.

7 Steps

- Initial cleaning
- Countermeasures directed at source of troubles and difficult to access areas
- Tentative cleaning and oiling standard procedure
- General inspection
- Autonomous inspection
- Standardization
- Autonomous management

Autonomous Maintenance: Paradigm Shift

Old Philosophy	New Philosophy
I operate, you fix, he designs ...	We are all responsible for our equipment.
Quality is costly ...	Quality is free.
Supervisors & engineers are experts ...	Operators/Maintenance are experts too
Defects, speed losses & unplanned downtime are inevitable ...	Zero defects, zero speed losses, zero unplanned downtime
Inventory is useful	Inventory is costly

Autonomous & Routine Maintenance: Partnership

Operator is a partner with Maintenance
Operator is "eyes & ears" looking for performance issues
Maintenance staff still involved in Routine Maintenance

- Special tools
- Complex tasks
- Tasks requiring multiple machines down at same time
- Component replacements
- Etc.

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Condition Monitoring Techniques

Condition Monitoring Techniques

A variety of technologies are used to help diagnose the condition of assets using non-destructive techniques such as:

- Vibration Analysis
- Thermography
- Ferrography
- Ultrasonic Inspection
- Wear-Debris Analysis
- Tribology
- Motor Current Signature Analysis (MCSA)
- Impact Echo
- Camera scoping surveys
- Spectral Analysis of Surface Waves (SASW)
- And new technologies, etc.

Condition Monitoring Techniques

PdMA

Mechanical

Electrical

Applications	Eddy Current Thickness	Vibration Monitoring	Lubricant Analysis/Final Analysis	Wear Particle Analysis	Bearing Temperature Analysis	Leakage Detection	Performance Monitoring	Ultrasonic Monitoring (Bearings	Ultrasonic Flow	Infrared Thermography	Precise Timing & Trending	Proximity Position	Visual Inspection	RF Monitoring	Insulation Resistance	Motor Current Signature Analysis	Motor Circuit Analysis	Polarization Index/Dissipation Factor	Cable Condition Monitoring	Transformer Oil and Gas
Generators		●	●	●	●		●	●		●		●	●	●	●		●	●		
Turbines		●	●	●	●	●	●	●		●		●	●							
Pumps		●	●	●	●	●	●	●	●	●		●	●							
Electric Motors		●	●	●	●		●	●		●		●	●		●	●	●	●		
Diesel Generator Engines		●	●	●	●		●	●					●							
Condensers	●					●	●	●	●	●			●							
Conveyors		●	●	●	●								●							
Heavy Equipment/Cranes			●	●	●					●			●							
Circuit Breakers										●	●		●		●		●			
Valves						●		●	●	●	●		●							
Heat Exchangers	●					●	●	●	●	●			●							
Electrical Systems										●			●		●		●	●	●	●

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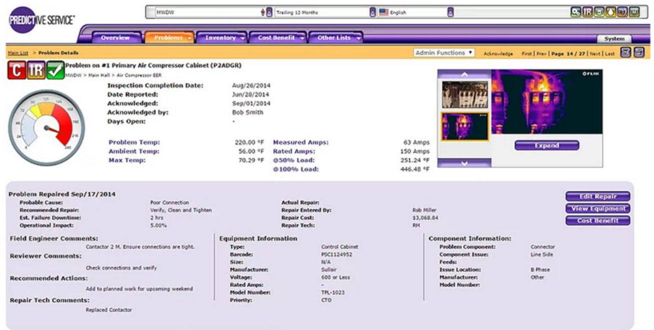
Condition Monitoring Techniques



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Condition Monitoring Techniques: Vibration

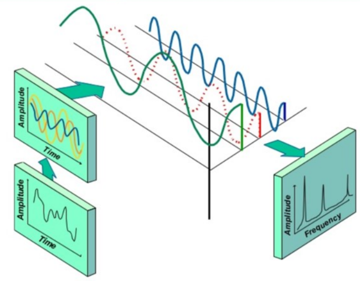
Measurements:

- Displacement
  - Actual physical movement of a vibrating object vibrating object
  - Emphasizes lower frequency components
  - Measured in mils or microns
- Velocity
  - Measure of the speed at which the mass is moving
  - Preferred unit of measurement as it is effective over a wide range, from low frequency to high frequency
  - Measured in inches / sec or mm / sec
- Acceleration
  - Rate of change of Velocity
  - Emphasizes high-frequency peaks in a spectrum
  - Measured in “g’s”

Vibration Basics & Asset Reliability

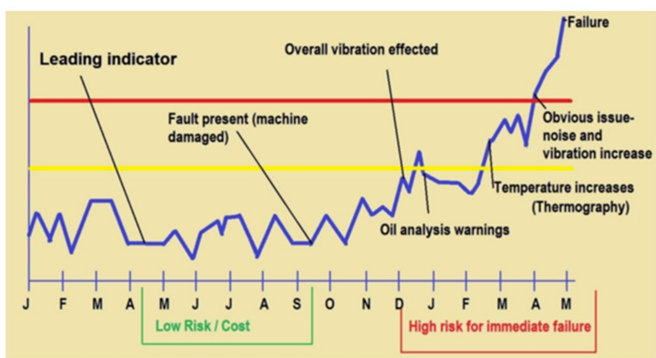
Condition Monitoring Techniques: Vibration

How the Vibration Spectrum is Created



Vibration Basics & Asset Reliability

Condition Monitoring Techniques: Vibration



Vibration Basics & Asset Reliability

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Risk Based Maintenance

Risk Based Maintenance (RbM)

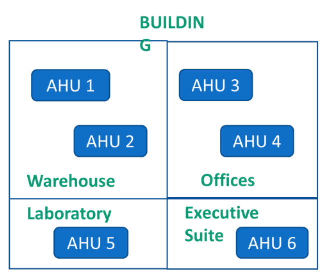
Risk-based maintenance (RBM) prioritizes maintenance resources toward assets that carry the most risk if they were to fail.

A methodology for determining the most economical use of maintenance resources

Two main phases:

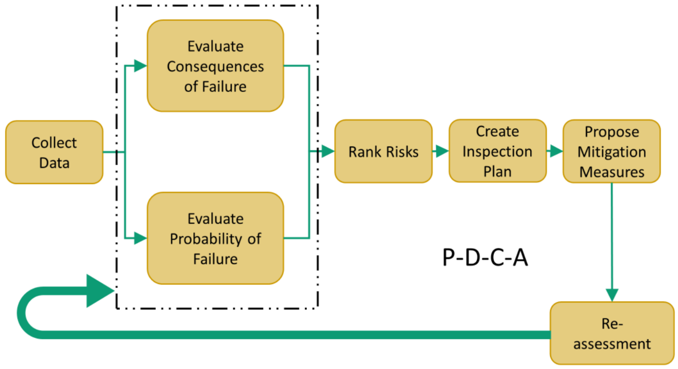
- Risk Assessment
- Maintenance Planning

Example:
Is risk the same for all 6 Air Handling Units (AHUs)?



Risk Based Maintenance (RbM)

Risk-based Maintenance Framework



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Proactive Maintenance

Proactive Maintenance

Changing the paradigm

Failure Reactive	Failure Proactive
Correct symptoms	Correct root causes
Make repairs even if nothing wrong	Extend the life of the machine
Failure is normal	Right lubricant
Detect impending failure	Misalignment
	Unbalance
	Operator error

Proactive maintenance depends on rigorous machine inspection and condition monitoring

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Failure Modes & Effects Analysis

Failure Modes & Effects Analysis (FMEA)

A design tool used to systematically analyze possible component failures and identify the resultant effects on system operations.

Successful development of an FMEA requires that all significant failure modes for each element or part in the system are included in the analysis.

Should be a living document during development of a hardware design

Typical “ground rules”:

- Only one failure mode exists at a time.
- All inputs (including software commands) to the item being analyzed are present and at nominal values.
- All consumables are present in sufficient quantities.
- Nominal power is available

Failure Modes & Effects Analysis (FMEA)

Basic Terms

- Failure
- Failure mode
- Failure cause and/or mechanism
- Failure effect
- Indenture levels (bill of material or functional breakdown)
- Local effect
- Next higher level effect
- End effect
- Detection
- Probability
- Risk Priority Number (RPN)
- Severity
- Remarks / mitigation / actions

Failure Modes & Effects Analysis (FMEA)

FMEA Ref.	Item	Potential failure mode	Potential cause(s) / mechanism	Mission Phase	Local effects of failure	Next higher level effect	System Level End Effect
1.1.1.1	Brake Manifold Ref. Designator 2b, channel A, O-ring	Internal Leakage from Channel A to B	a) O-ring Compression Set (Creep) failure b) surface damage during assembly	Landing	Decreased pressure to main brake hose	No Left Wheel Braking	Severely Reduced Aircraft deceleration on ground and side drift. Partial loss of runway position control. Risk of collision

(P) Probability (estimate)	(S) Severity	(D) Detection (Indications to Operator, Maintainer)	Detection Dormancy Period	Risk Level P*S (+D)	Actions for further Investigation / evidence	Mitigation / Requirements
(C) Occasional	(V) Catastrophic (this is the worst case)	(1) Flight Computer and Maintenance Computer will indicate "Left Main Brake, Pressure Low"	Built-In Test interval is 1 minute	Unacceptable	Check Dormancy Period and probability of failure	Require redundant independent brake hydraulic channels and/or Require redundant sealing and Classify O-ring as Critical Part Class 1

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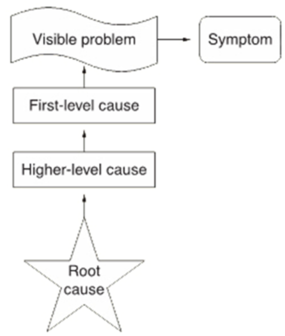
Root Cause Analysis

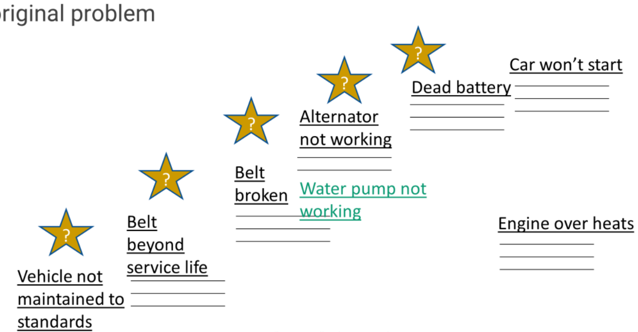
Root Cause Analysis (RCA)

- A root cause is a factor that caused a problem/breakdown and should be permanently eliminated through process improvement.
- RCA is a collective term that describes a wide range of approaches, tools, and techniques used to uncover causes of problems.



Root Cause Analysis (RCA)

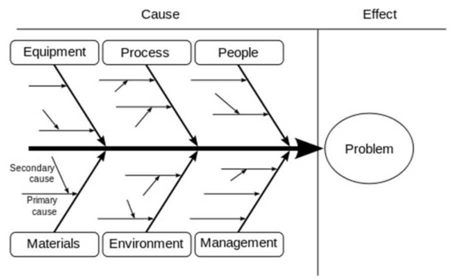
5 Whys – An iterative technique used to explore the cause-and-effect relationships underlying a particular problem. Often finds causes that solve additional problems to the original problem



Root Cause Analysis (RCA)

A fishbone diagram, also called a cause and effect diagram, is a visualization tool for categorizing the potential causes of a problem in order to identify its root causes.

- Create a head, (problem)
- Create a backbone for the fish
- Identify at least four "causes" (bones)
- Brainstorm (use 5 whys)
- Find root causes



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