Getting High Equipment Reliability

SIRFRt CM & Lube Forum 2008 Conference

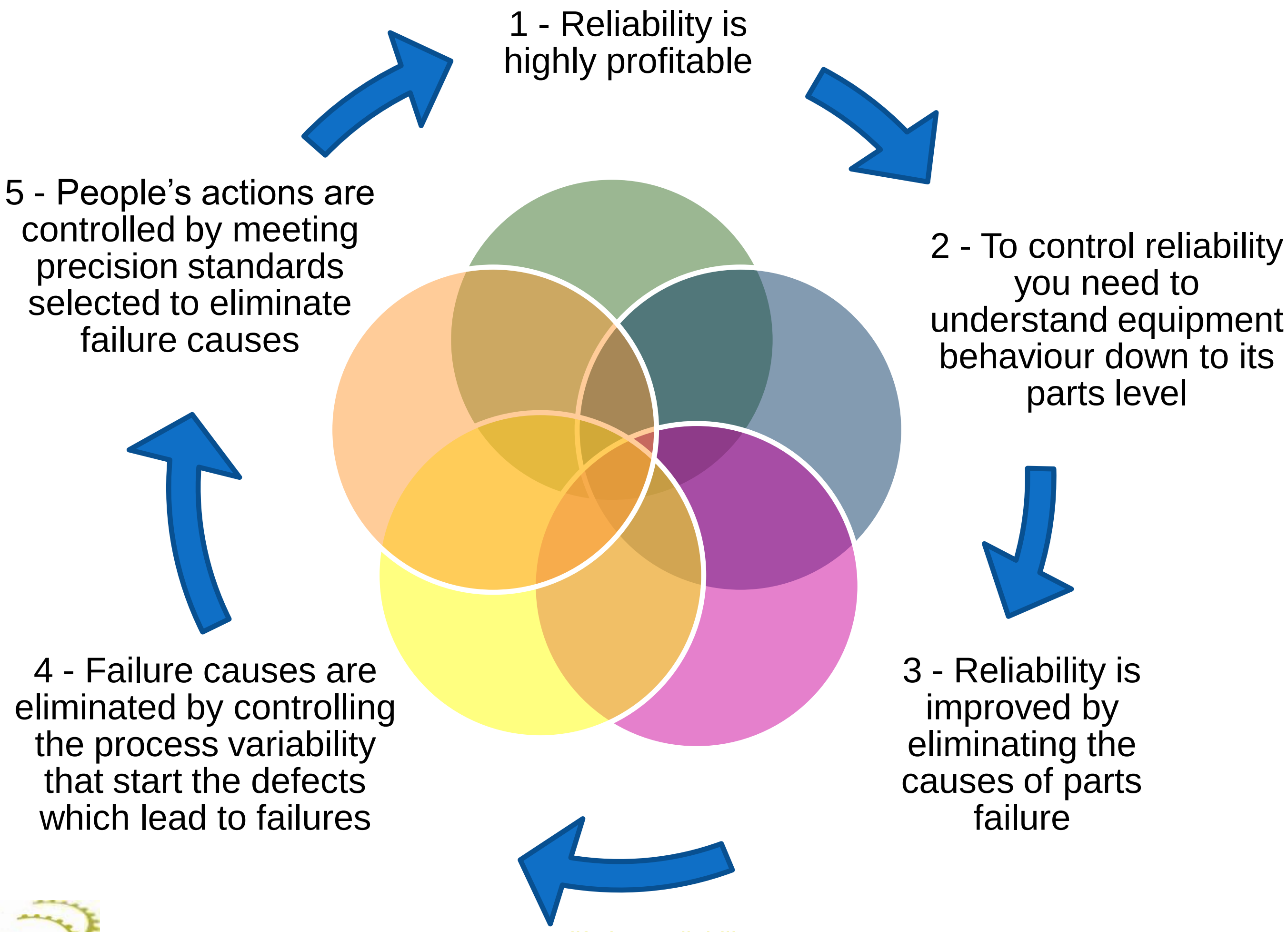
Mike Sondalini

Lifetime Reliability Solutions

www.lifetime-reliability.com

High Reliability is a choice

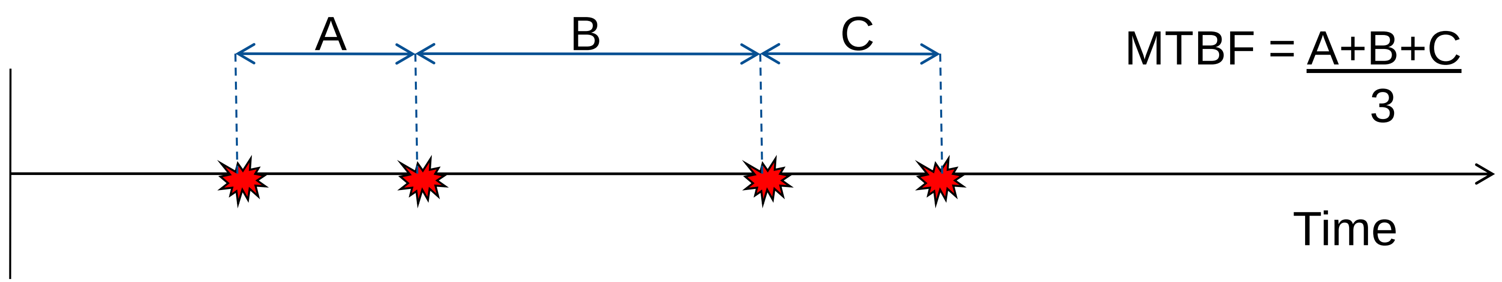
Reliability is the chance that an item will last long enough to do its duty



Valuing Reliability

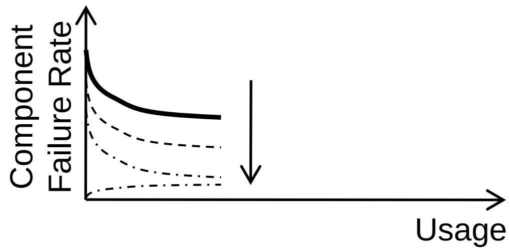
"Time is Money" – *Benjamin Franklin*

MTBF - average time between failures



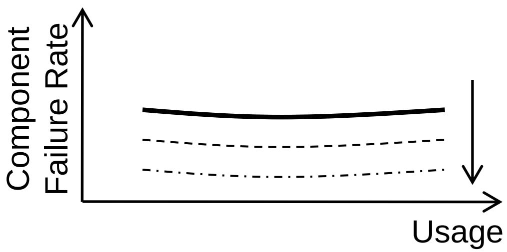
$$MTBF = \frac{A+B+C}{3}$$

Infant Mortality



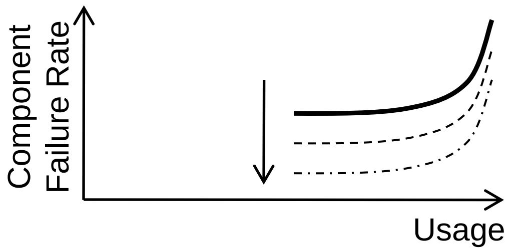
Cause: Human Error

Random



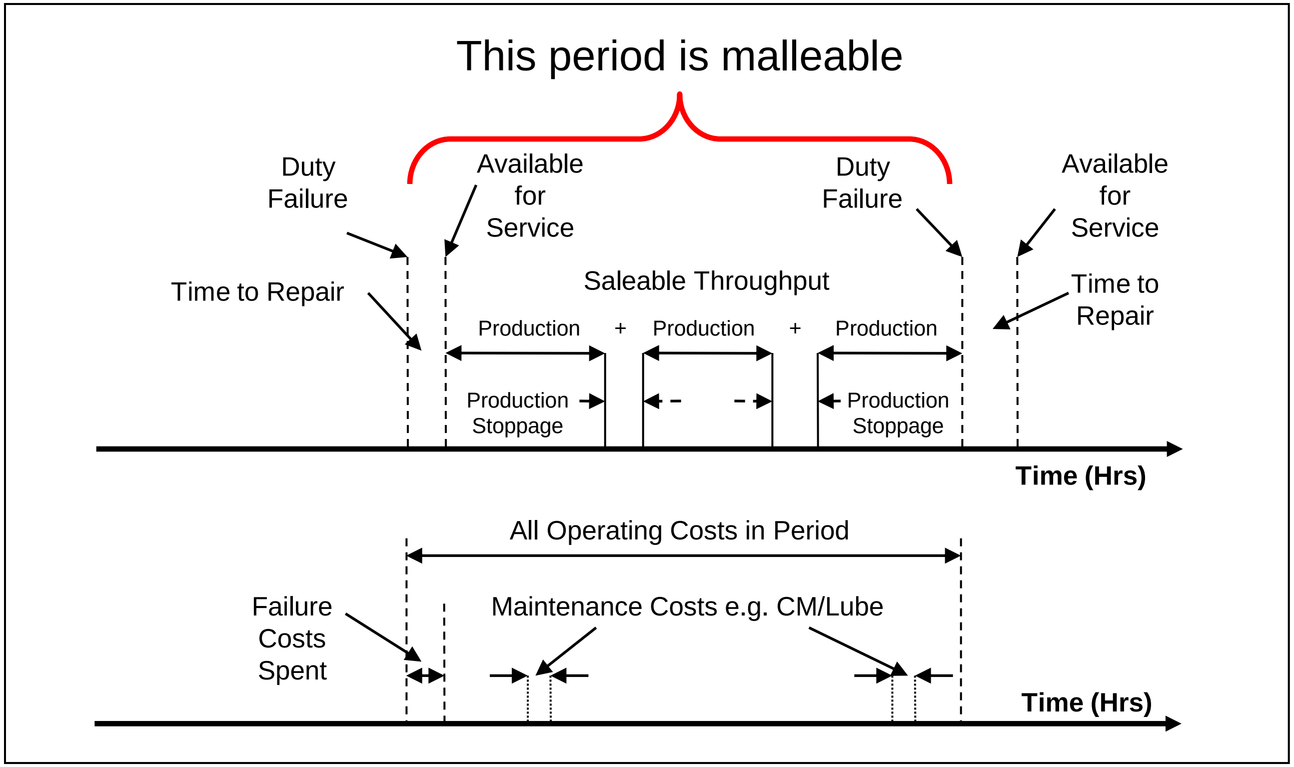
Cause: Stress Induced (by humans)

Wear-out



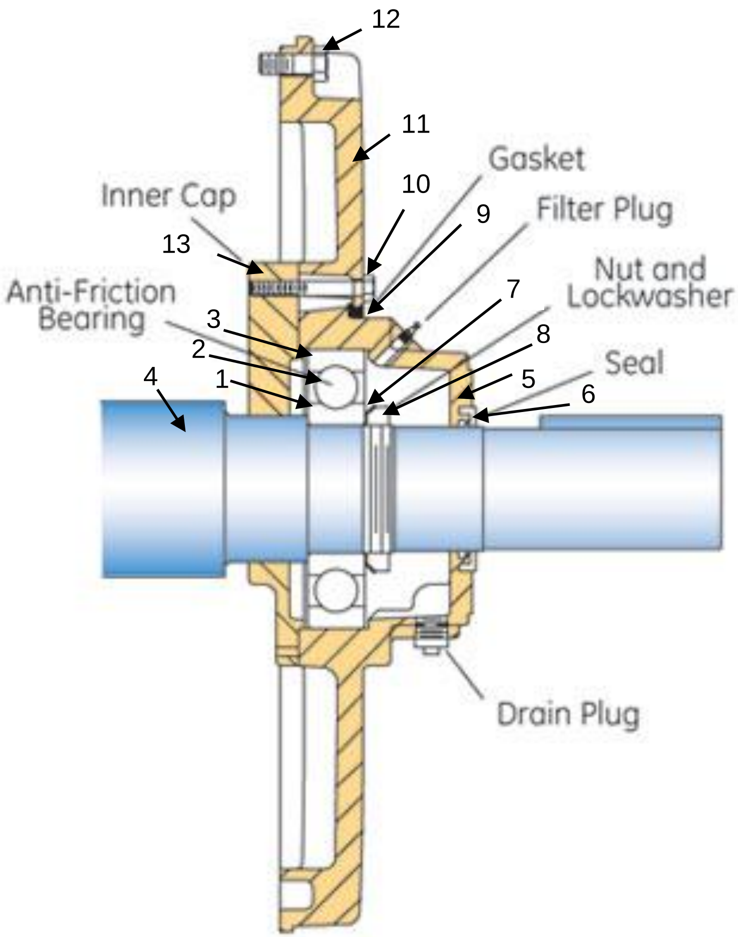
Cause: Accumulated Fatigue (controlled by humans)

Unit Cost of Production



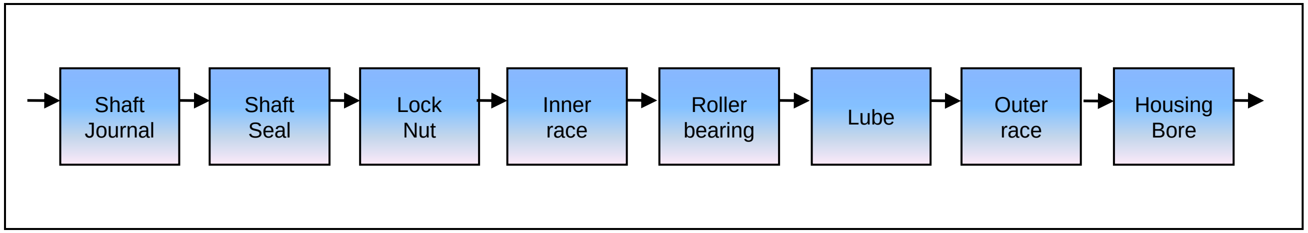
Unit Cost of Production ($/T) = Operating Costs in the Period ($) / Total Saleable Throughput (Tonne)

Equipment is components in series

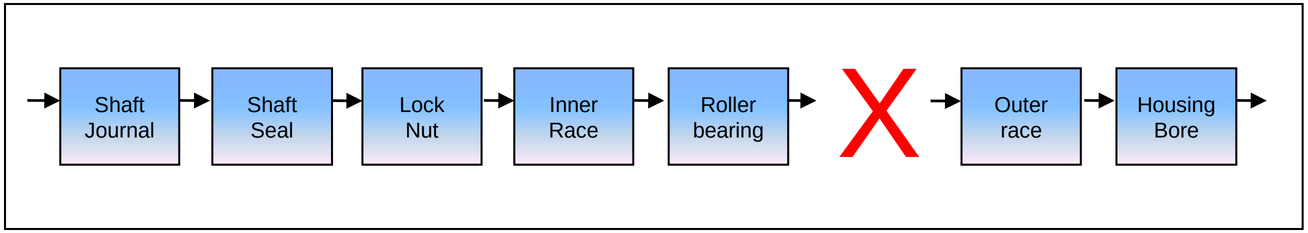


Electric motor drive end bearing

High risk in a series arrangement

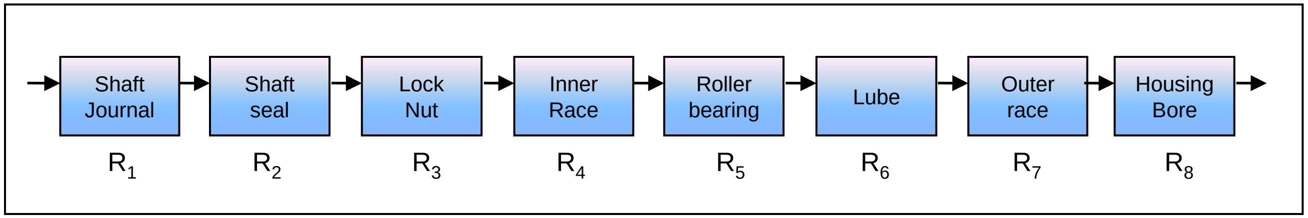


Parts shown as a series



"One fails, all fails"

Calculating series reliability



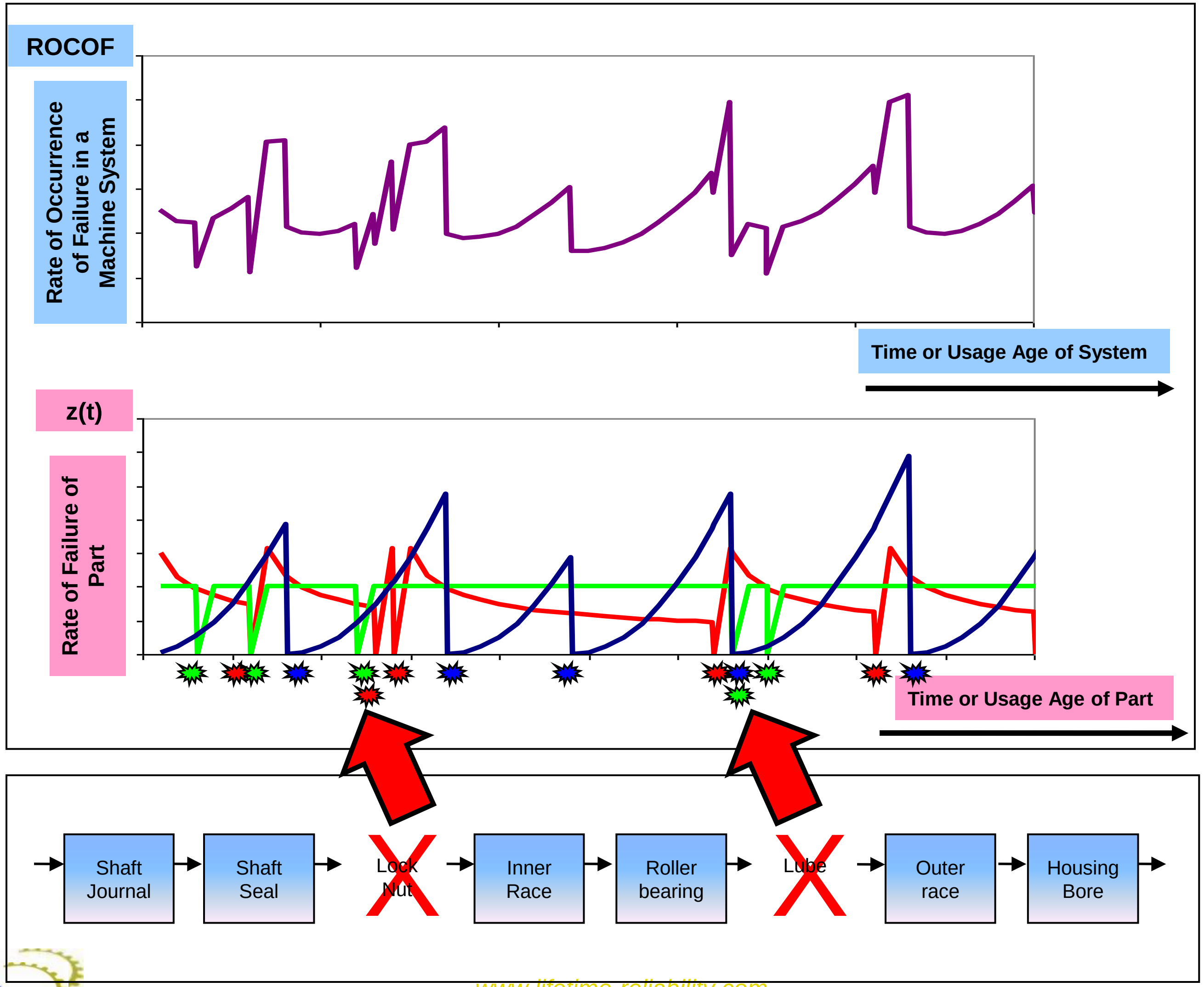
$$R_{series} = R_1 \text{ x } R_2 \text{ x } R_3 \text{ x} \ldots R_n$$

$$R_{series} = 0.99 \text{ x } 0.99 \text{ x } 0.99 \text{ x } 0.99 \text{ x } 0.99 \text{ x } 0.99 \text{ x } 0.99 \text{ x } 0.99 = (0.99)^8 = 0.92 \text{ (or 92\%)}$$

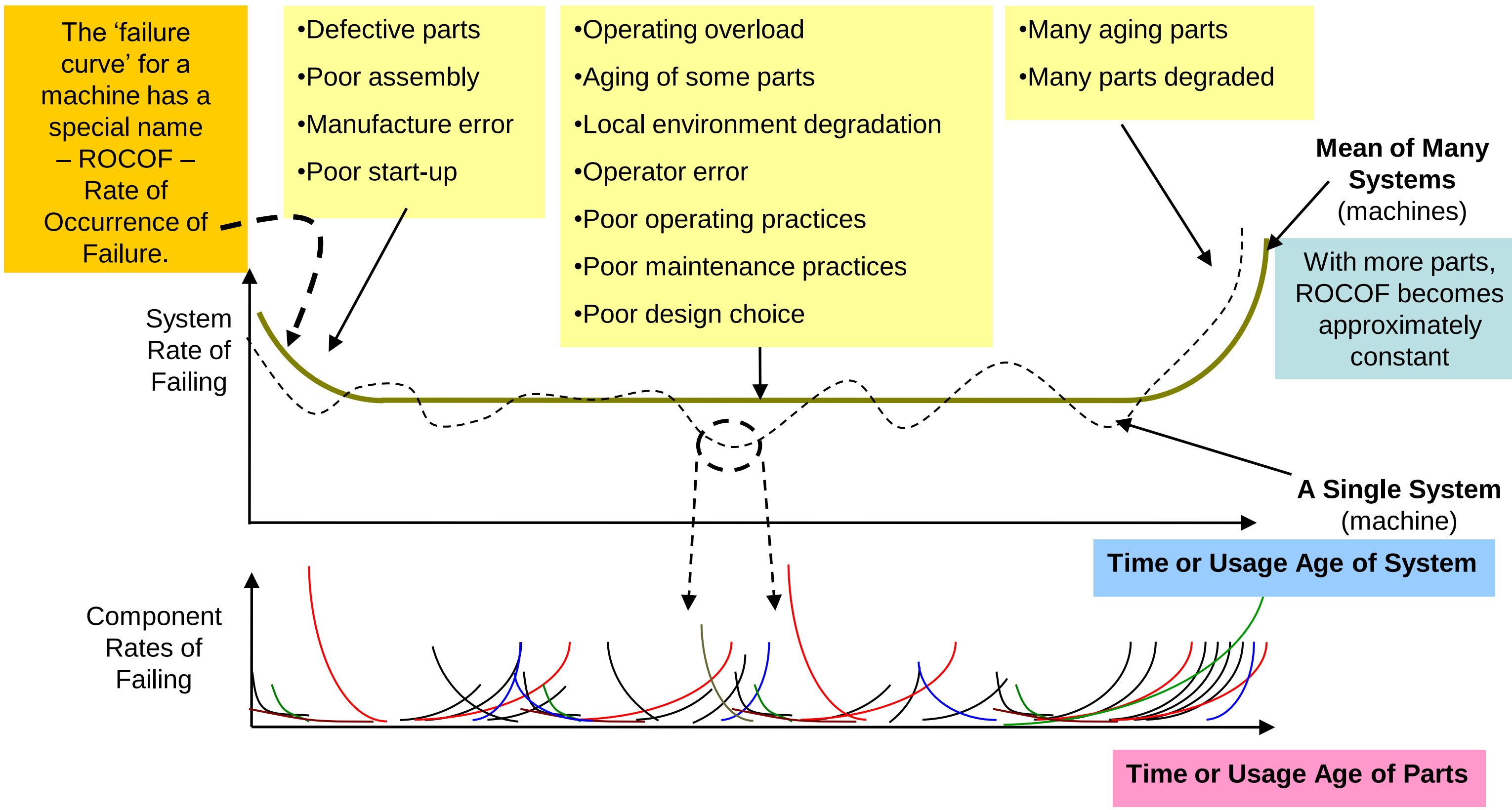
$$R_{series} = 0.99 \text{ x } 0.99 \text{ x } 0.99 \text{ x } 0.99 \text{ x } 0.99 \text{ x } 0.5 \text{ x } 0.99 \text{ x } 0.99 = 0.47 \text{ (or 47\%)}$$

"One poor, all poor"

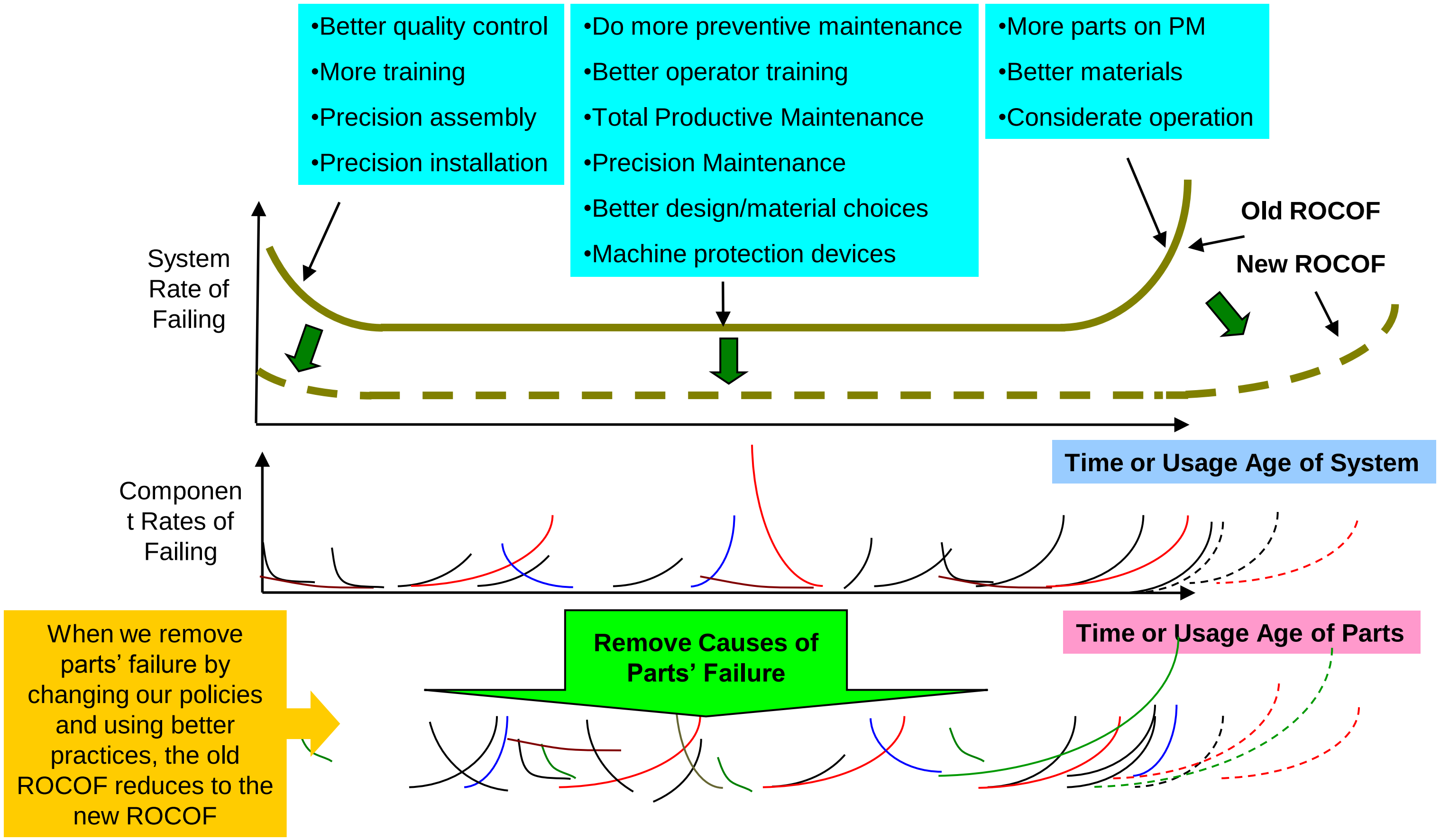
When the parts fail, our machines fail



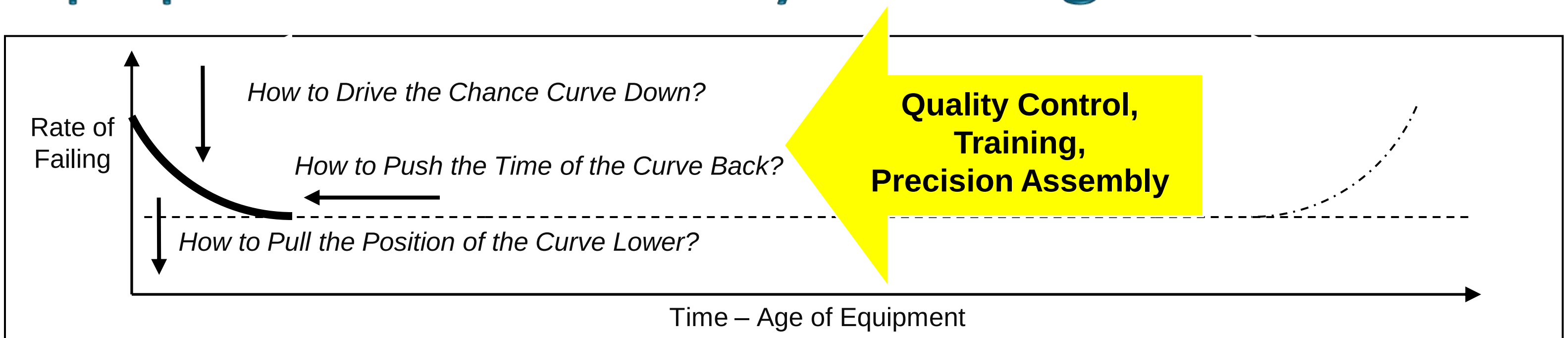
Cause and effect of our equipment failures



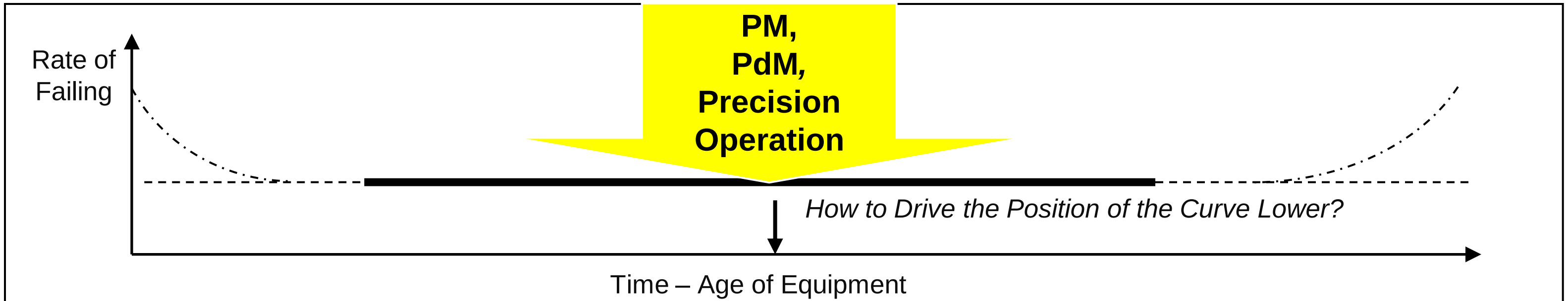
Equipment reliability is malleable by choice of policy and practice



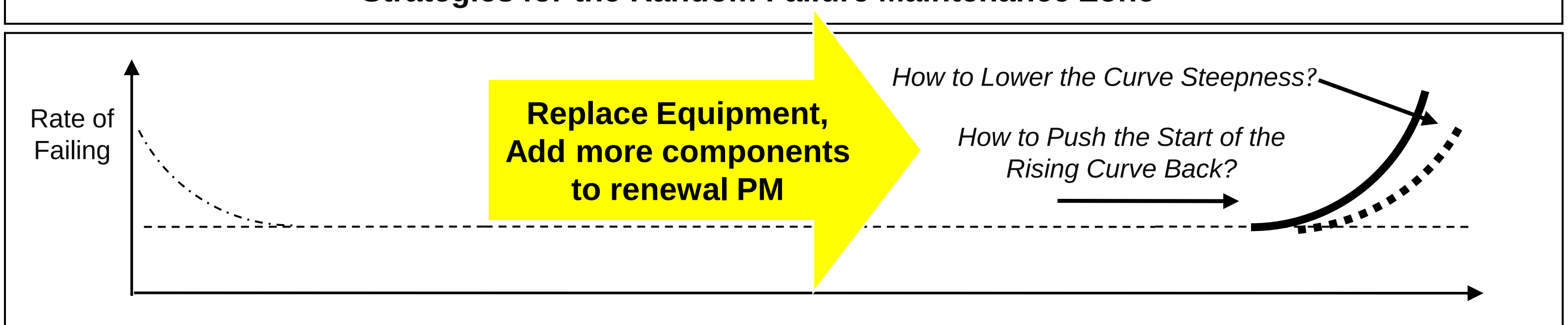
Equipment Reliability Strategies



Strategies for the Infant Mortality Maintenance Zone

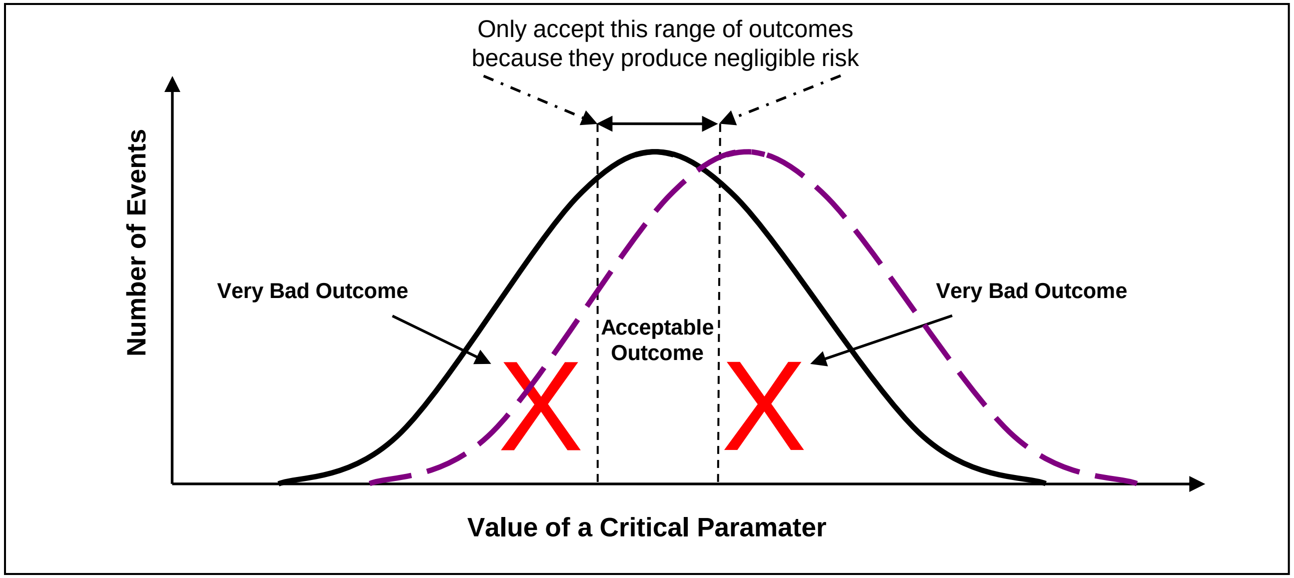


Strategies for the Random Failure Maintenance Zone



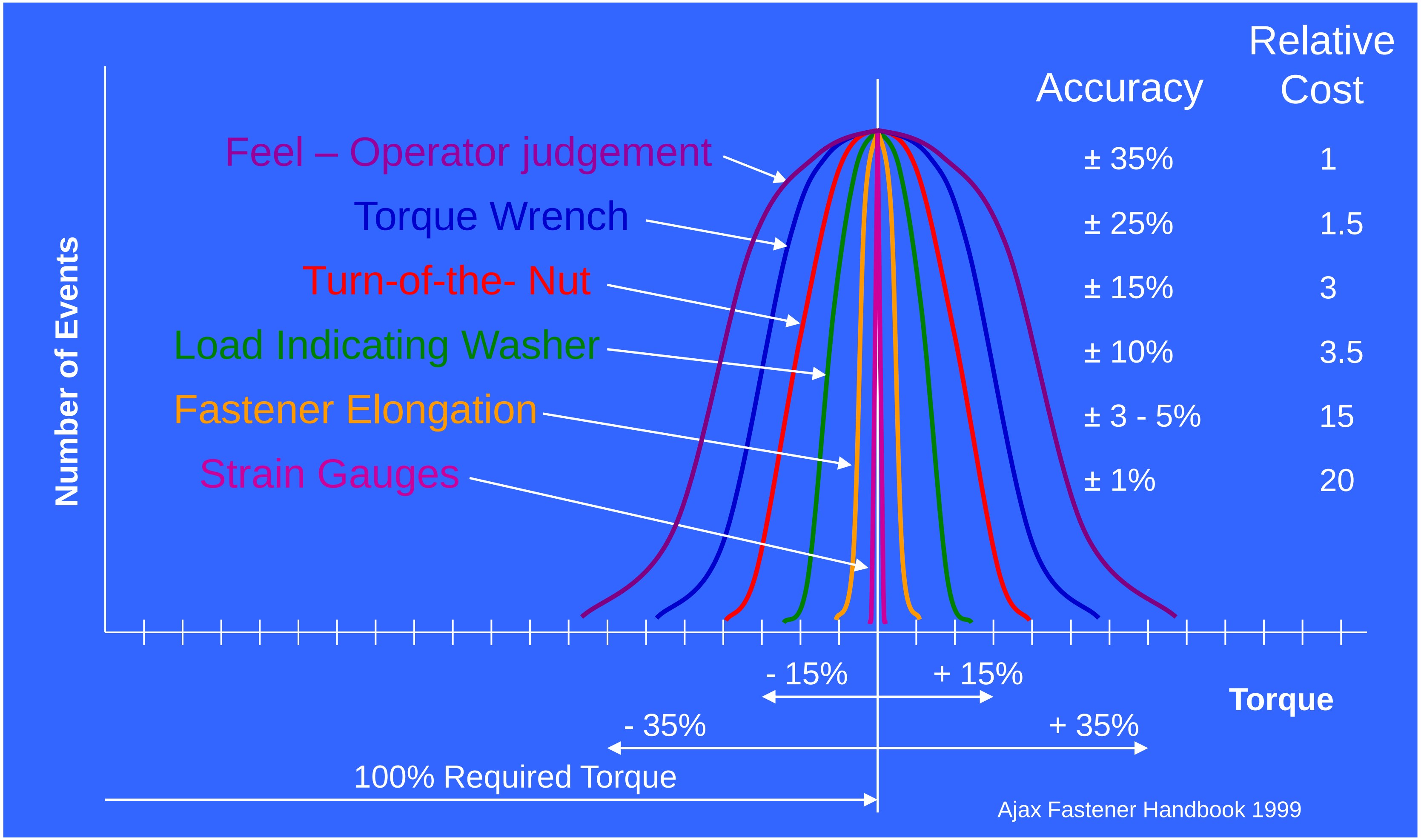
Strategies for the Wear-Out Failure Maintenance Zone

But where do the failures start?



Variability leads to defects

The Problems start with chance variation



Understanding what it means to be 'in control and capable'

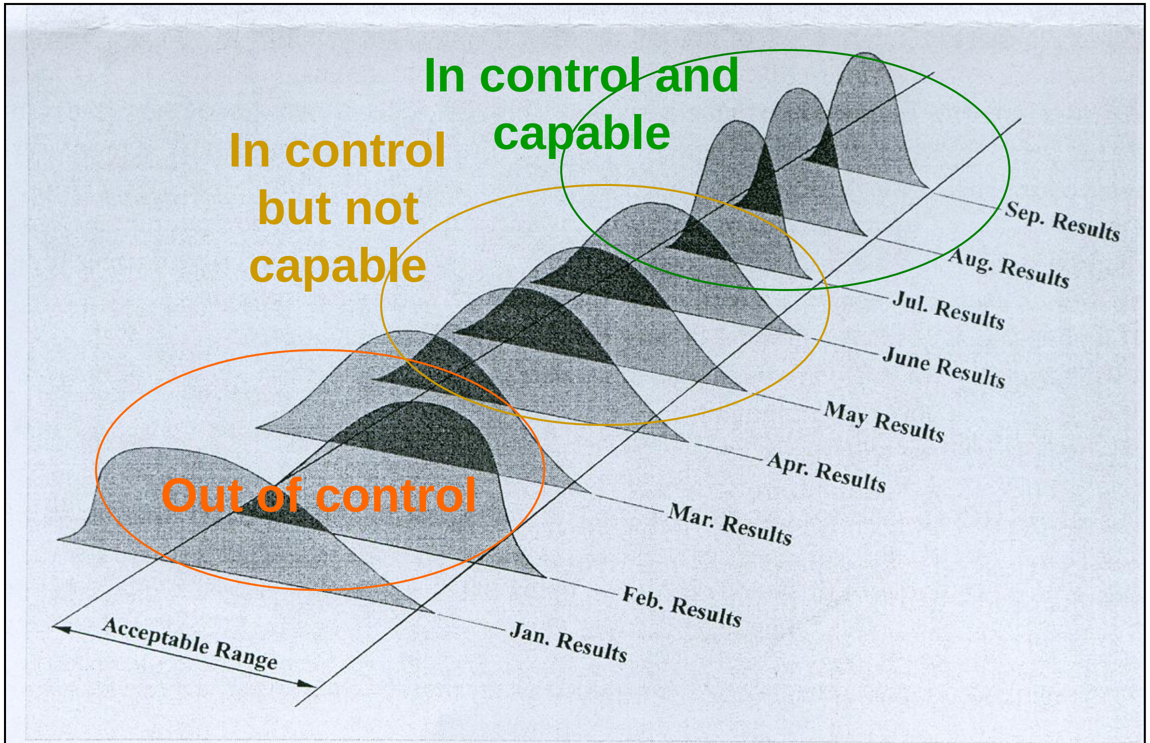
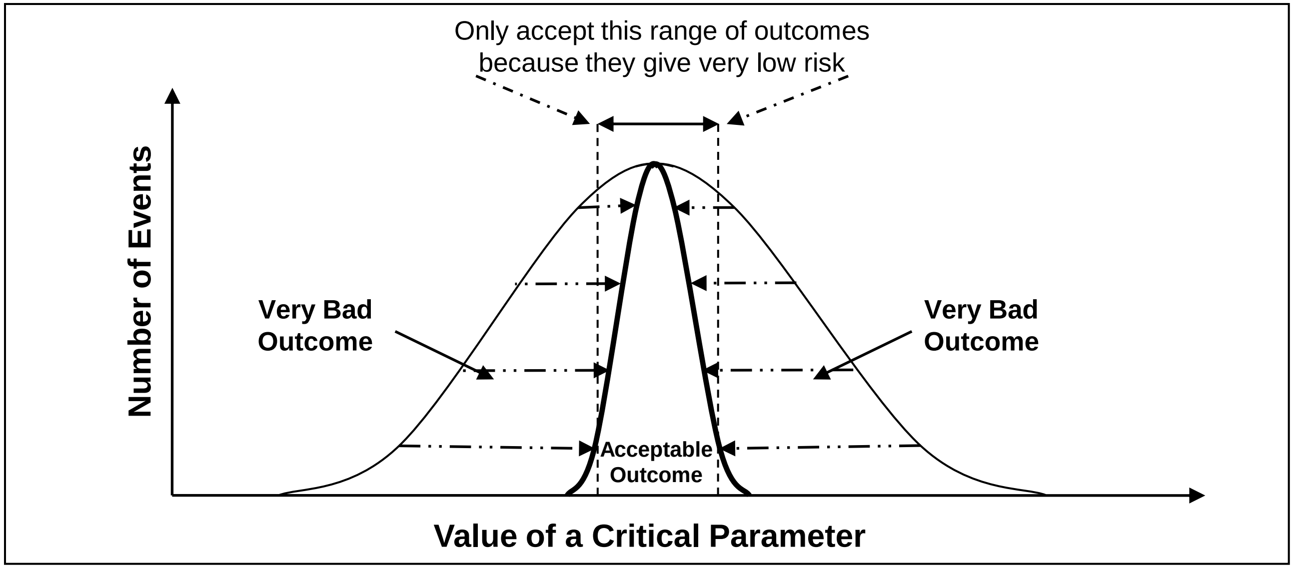


Figure 83: Progression of a Process to Capability

Control variability to beneficial limits



The best strategy is to reduce the chance of failure in every stage of the life-cycle

Risk = Chance x Consequence

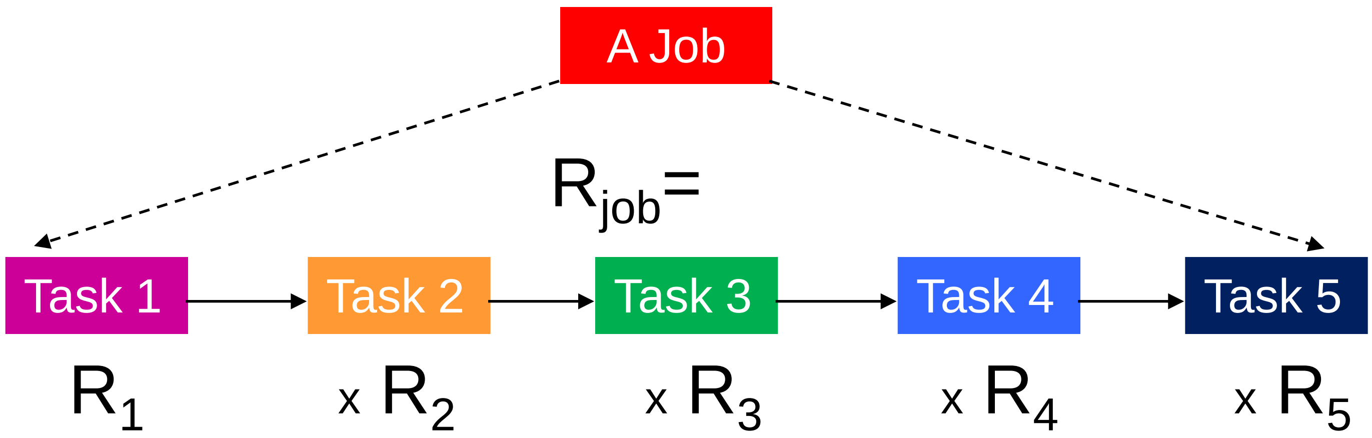
Chance Reduction Strategies
remove opportunity for failure to start

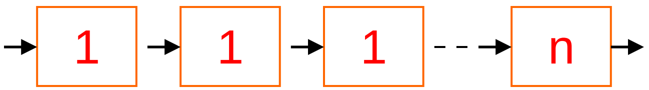
- Engineering and Maintenance Standards
- Standard Operating Procedures
- Failure Mode Effects Criticality Analysis (FMECA)
- Hazard and Operability Study (HAZOP)
- Hazard Identification (HAZID)
- Root Cause Failure Analysis (RCFA)
- Precision Maintenance (shaft alignment, oil particle filtration, deformation prevention, etc)
- Training and Up-skilling
- Quality Management Systems
- Planning and Scheduling
- Continuous Improvement
- Supply Chain Management
- Accuracy Controlled Enterprise (ACE 3T SOPs)
- Design and Operations Cost Totally Optimised Risk (DOCTOR)
- Defect and Failure True Cost (DAFTC)
- De-rate/Oversize Equipment
- Reliability Engineering

Consequence Reduction Strategies
reduce the loss after a failure has started

- Preventive Maintenance
- Corrective Maintenance
- Total Productive Maintenance (TPM)
- Non-Destructive Testing
- Vibration Analysis
- Oil Analysis
- Thermography
- Motor Current Analysis
- Prognostic Analysis
- Emergency Management
- Computerised Maintenance Management System (CMMS)
- Key Performance Indicators (KPI)
- Risk Based Inspection (RBI)
- Operator Watch-keeping
- Value Contribution Mapping (Process step activity based costing)
- Logistics, stores and warehouses
- Maintenance Engineering

Work is a series process of tasks





$$R_{series} = R_1 \times R_2 \times R_3 \ldots$$

We can say ‘Task Reliability’ is the chance that a task will be performed to its required duty

Playing with task reliability

Task Reliability is the chance that a task will be performed to its required duty.

This leads to two realisations...

- *You must clearly know the required duty*
- *Control chance and you control reliability*

1 → 2 → 3 → 4 → 5   A five task job.

$$R_{job} = R_1 \times R_2 \times R_3 \times R_4 \times R_5$$

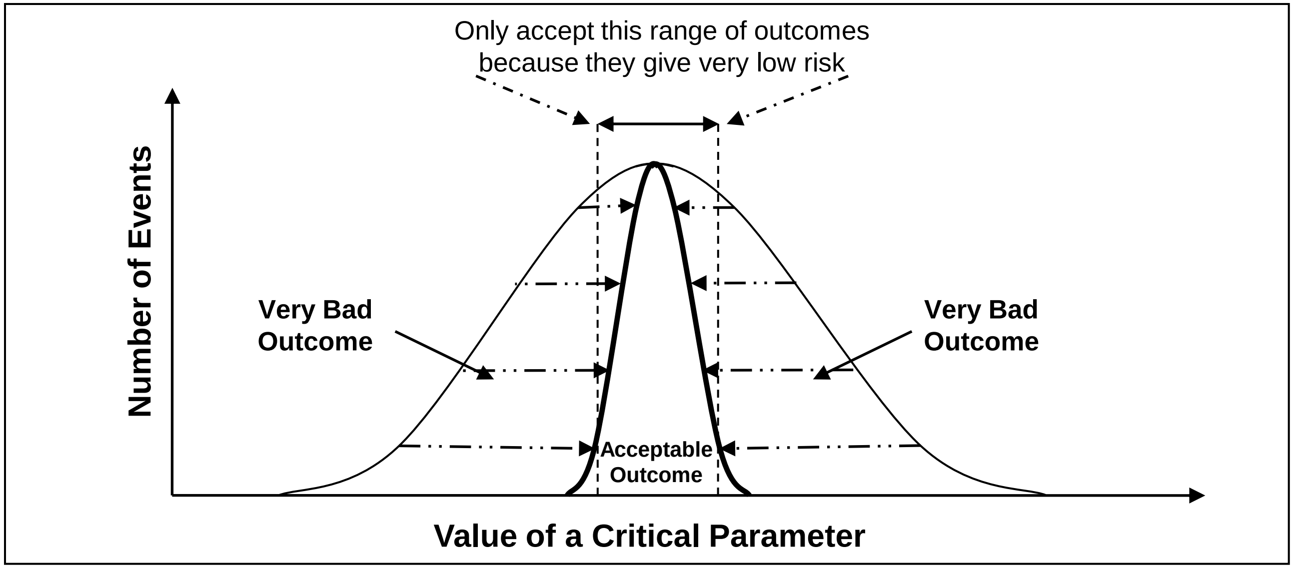
Task 1	Task 2	Task 3	Task 4	Task 5	Job
0.9	0.9	0.9	0.9	0.9	**0.59**
0.9	0.9	0.9	0	0.9	**0**
0.95	0.95	0.95	0.95	0.95	**0.77**
0.99	0.99	0.99	0.99	0.99	**0.95**
0.999	0.999	0.999	0.999	0.999	**0.995**

Controlling human error is the greatest challenge to reliability

One fails… all fails!
One poor… all poor!

In a series arrangement we must be exact because there is no redundancy (back-up). In a series work process, the only way to do a 100% reliable job is to make sure every task in it is done 100% reliably.

Getting high task reliability



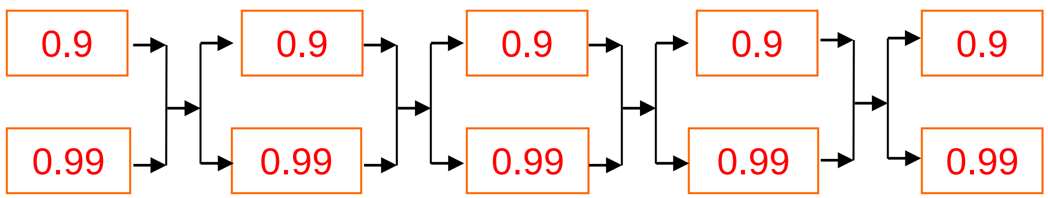
In the end... reliability is a quality control issue.

Because all our machines are a series of parts, and all our work are a series of activities, there are endless opportunities for variation – many of which will cause failures. Hence, we must set the correct standards of performance for every step in a series so that we deliver only those results that give us the right outcomes. This is quality. The more precisely we approach the standards; the better the quality; the more certain and reliable the series outcome.

The power of parallel proof-tests

Original task reliability

Proof-test reliability



0.59

0.95

$$R_{system} = 1 - [(1 - R_1) x (1 - R_2) x (1 - R_3) \ldots.]$$

$$1 - [(1 - 0.9) x (1 - 0.99)]$$

$$1 - [0.1 \text{ x } 0.01]$$

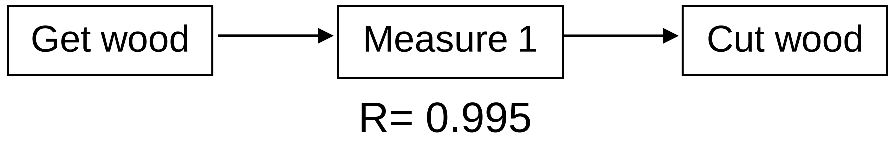
$$1 - [0.001] = 0.999$$

Equivalent series reliability

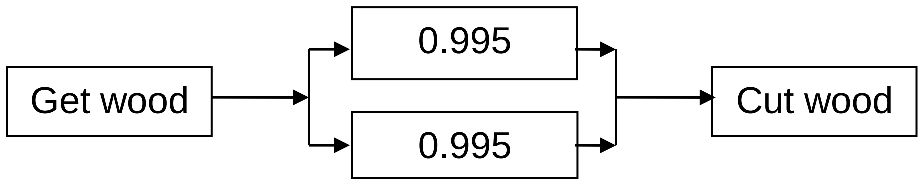
0.995

We can use a parallel arrangement to improve the chance of producing precise results. By adding a proof test into each series task you vastly improve the reliability of the process outcome.

Carpenter's creed: *'measure twice, cut once'*



1 error every 200 opportunities.



1 error every 5000 opportunities.

$$R_{system} = 1- [(1- R_1)x(1- R_2)x(1-R_3) \dots]$$

$$1- [(1- 0.995)x(1- 0.995)]$$

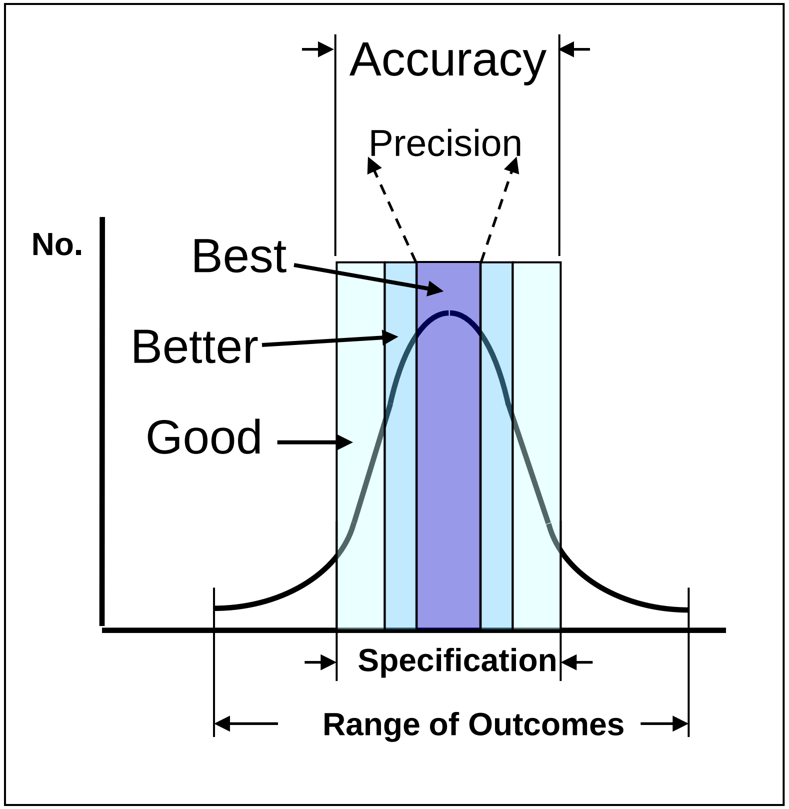
$$1- [0.005 \times 0.005]$$

$$1- [0.000025] = 0.999975$$

The typical error rate in reading a tape measure is five times in every thousand you will misread it, or 995 times out of 1000, it will be right. Without the parallel task, the carpenter will cut the wood in the wrong spot about once every 200 times. It is not hard to imagine a carpenter doing 50 cuts a day. So about once a working week, they would cut the wood wrong and have to throw it away.

With the second test 'measure' added, the chance of getting the cut right rises to 99.998% and the error rate falls to twice in every 10,000 times. With 50 cuts a day, they will make an error once every 100 working days, or about once every 20 working weeks. Can you now see the power of paralleling test activities to every task, and ensuring that they are right? For our carpenter the simple addition of a check test produced twenty times fewer mistakes.

Continual learning and mastery of your discipline



Now we all know what 'good enough is'!

Convert your SOPs to 3T Accuracy Controlled Procedures

Task Step No.	Task Step Owner	Task Step Name	Full Description of Task	Test for Correctness	Tolerance Range			Record Actual Result	Action if Out of Tolerance	Sign-off After Complete
		(Max 3 – 4 words)	(Include all tables, diagrams and pictures here)		Good	Better	**Best**			

Test

Tolerance

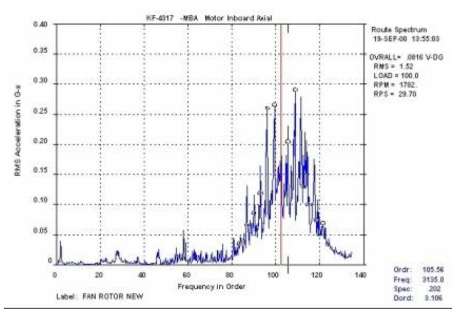
Target

Continual improvement

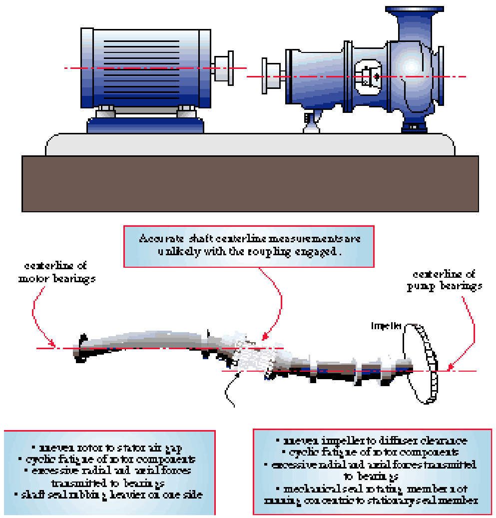
- Specify the 3Ts (Target, Tolerance, Test) for precision and accuracy
- Describe in a measurable fashion what ‘good’, ‘better’ and ‘best’ are.
- Make the SOP into a table of successive tasks in a column
- Range tolerance ‘good, better, best’ to challenge people to strive for excellence
- Provide columns for 3Ts and ranges
- Advise what to do when out of tolerance – i.e. when not ‘it’s good enough’
- Get a signature when 3T done to tolerance so people are committed to precision
- Drive continual improvement by regularly introducing an even more precise ‘best’

6 Standards to Set, Use and Keep

Vibration:



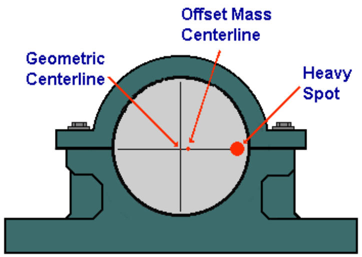
Deformation:



Alignment:

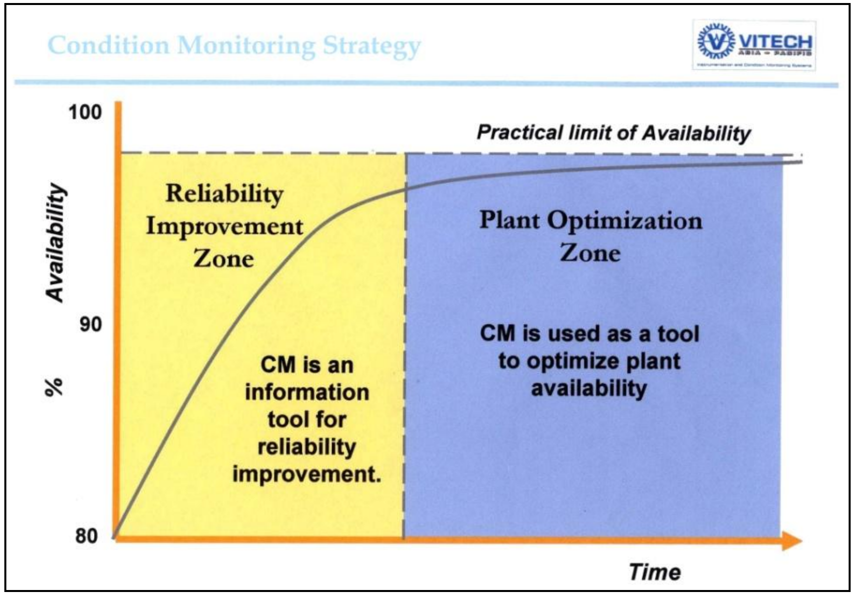
Fastener Torque:

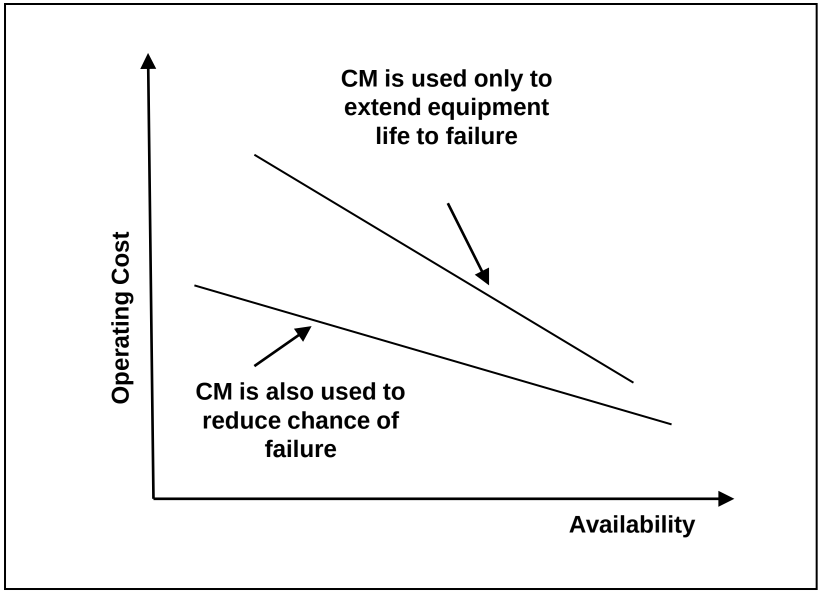
Balancing:



Lubricant Cleanliness:

Condition monitoring can be used to help you prevent failure

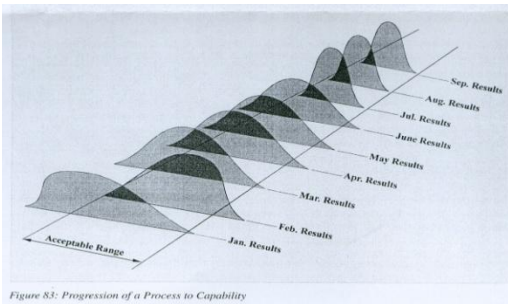


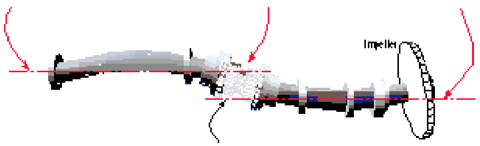


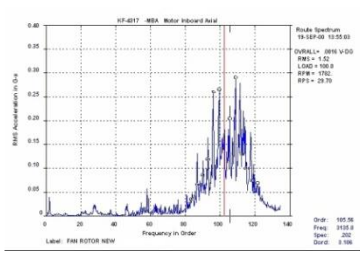
Life Extension Zone

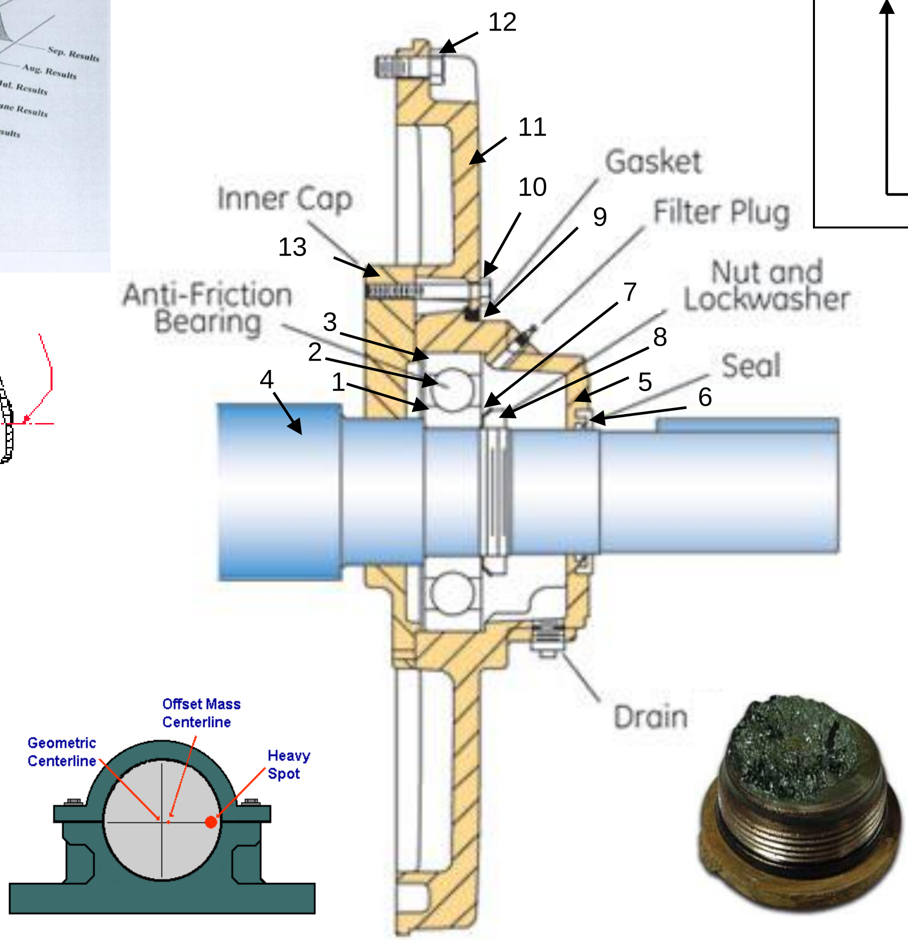
Failure Elimination Zone

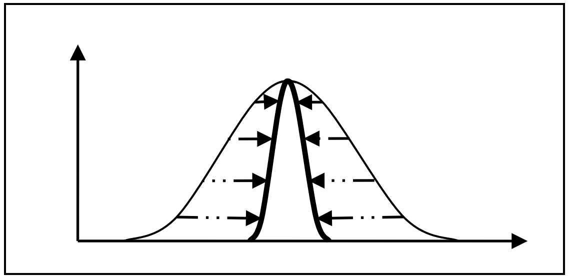
How do we apply it to our machines?

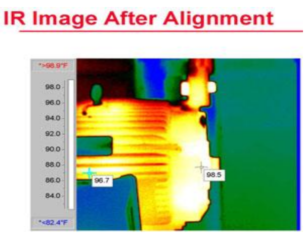












Electric motor drive end bearing

Getting high equipment reliability…