The Processes and People of Reliability Improvement

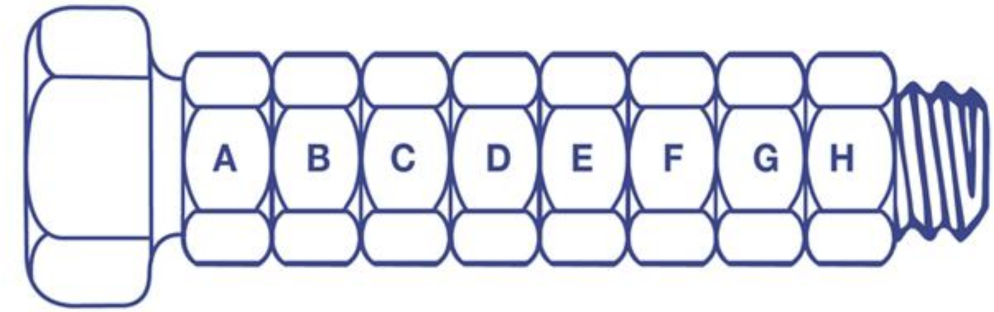
BHP Billiton Reliability Forum 2010 Presentation

By

Mike Sondalini

www.lifetime-reliability.com

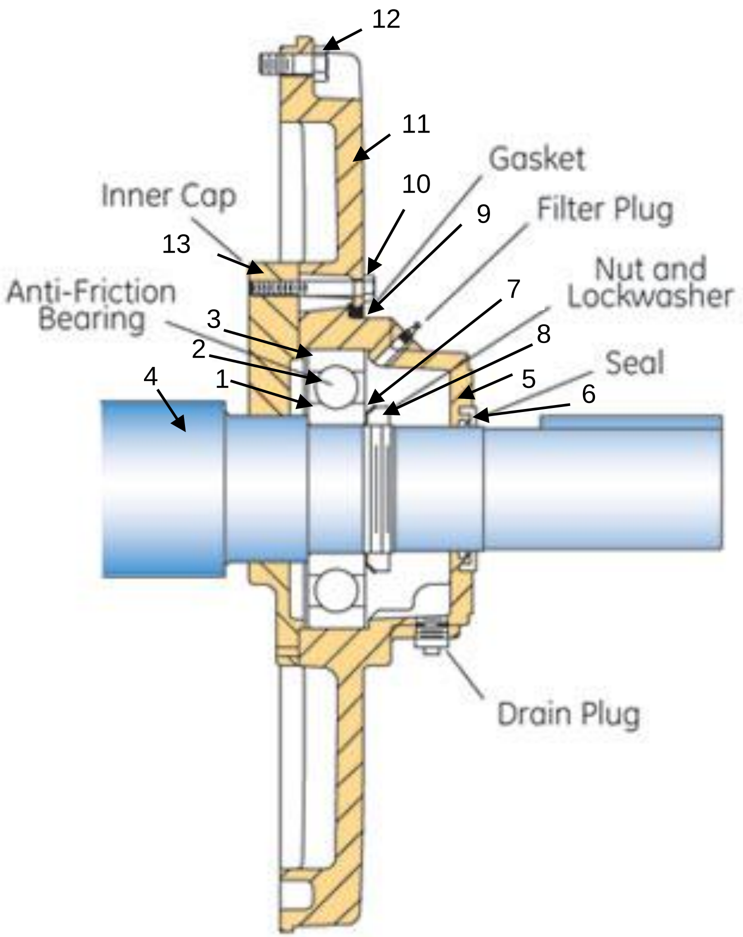
The Odds are Against Doing it Right!



Only one way to disassemble

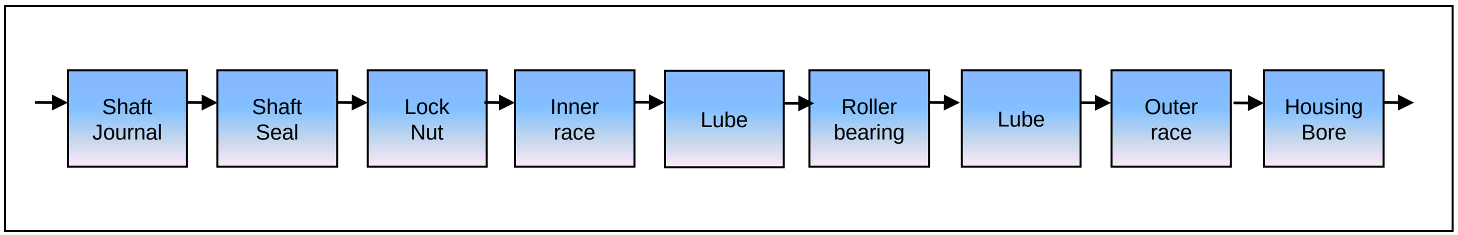
40,000+ ways to incorrectly reassemble!

Your machines are components in series

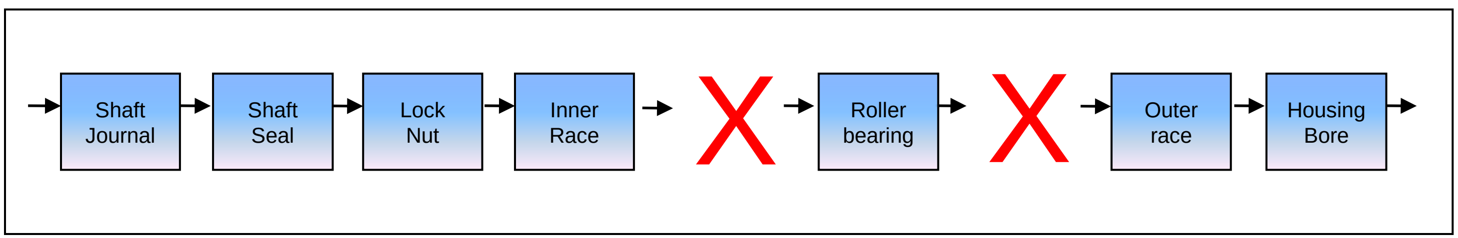


Electric motor drive end bearing

Series arrangements are at high risk



Motor parts shown as a series



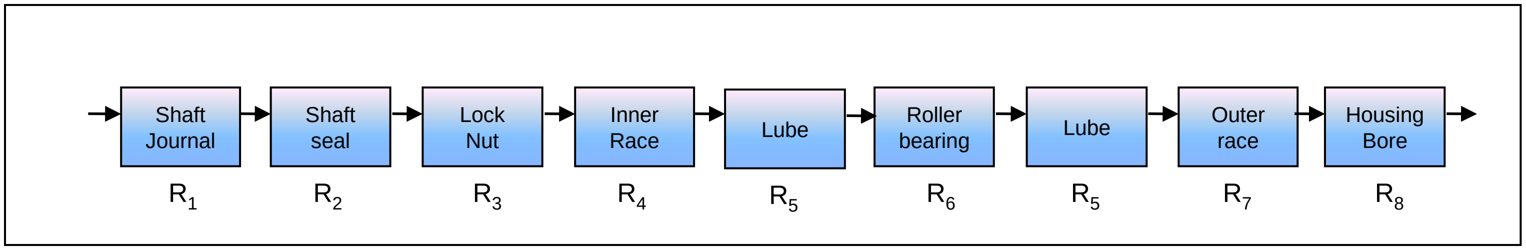
"Any one part fails; all fails"

This is why clean lubricant is so important:

It gets between all the parts and becomes a series component many time over!

Calculating series reliability

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



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

$$R_{series} = 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0.99 = (0.99)^9 = 0.91 \text{ (or 91\%)}$$

$$R_{series} = 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0.5 \times 0.99 \times 0.5 \times 0.99 \times 0.99 = 0.23$$

"Any poor, all poor"

$$R_{series} = 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0 \times 0.99 \times 0 \times 0.99 \times 0.99 = 0$$

"Any fails, all fails"

The Story in Human Error Rate Tables

	Error rate (per task) Read/ reason	Physical operation	Everyday yardstick
Simplest possible task			
Fail to respond to annunciator	0.0001		
Overfill bath			0.00001
Fail to isolate supply (electrical work)		0.0001	
Read single alphanumeric wrongly	0.0002		
Read 5-letter word with good resolution wrongly	0.0003		
Select wrong switch (with mimic diagram)		0.0005	
Fail to notice major cross-roads			0.0005
Routine simple task			
Read a checklist or digital display wrongly	0.001		
Set switch (multiposition) wrongly		0.001	
Calibrate dial by potentiometer wrongly		0.002	
Check for wrong indicator in an array	0.003		
Wrongly carry out visual inspection for a defined criterion (e.g. leak)	0.003		
Fail to correctly replace PCB		0.004	
Select wrong switch among similar		0.005	

~5 sigma

~4.5 sigma

	Error rate (per task) Read/ reason	Physical operation	Everyday yardstick
Read analogue indicator wrongly	0.005		
Read 10-digit number wrongly	0.006		
Leave light on			0.003
Routine task with care needed			
Mate a connector wrongly		0.01	
Fail to reset valve after some related task		0.01	
Record information or read graph wrongly	0.01		
Let milk boil over			0.01
Type or punch character wrongly		0.01	
Do simple arithmetic wrongly	0.01–0.03		
Wrong selection – vending machine			0.02
Wrongly replace a detailed part		0.02	
Do simple algebra wrongly	0.02		
Read 5-letter word with poor resolution wrongly	0.03		
Put 10 digits into calculator wrongly	0.05		
Dial 10 digits wrongly	0.06		
Complicated non-routine task			
Fail to notice adverse indicator when reaching for wrong switch or item	0.1		
Fail to recognize incorrect status in roving inspection	0.1		
New workshift – fail to check hardware, unless specified	0.1		
General (high stress)	0.25		
Fail to notice wrong position of valves	0.5		
Fail to act correctly after 1 min in emergency situation	0.9		

~4 sigma

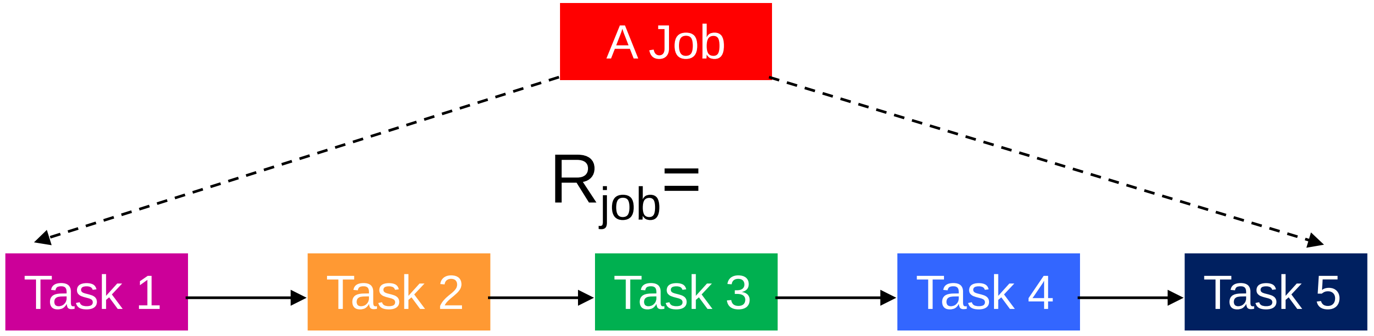
~2 - 3 sigma

In failure rate terms the incident rate in a plant is likely to be in the range of 20×10^{-6} per h (general human error) to 1×10^{-6} per h (safety-related incident).

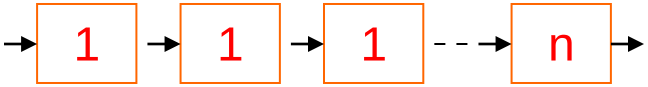
Source: Smith, David J., 'Reliability, Maintainability and Risk', Appendix 6, Seventh Edition, Elsevier – Butterworth Heinemann

The Table confirms that 'human element' error is real and <u>unavoidable</u>. We do not perform well when tasks are structured in ways that require care and we perform especially badly under complicated non-routine conditions. Add stress into that that mix and you get disaster.

Your work processes are a series of tasks



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



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

What is the chance that the whole job will done right?

Risks to work quality and machine reliability

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

1 → 2 → 3 → 4 → 5 A five task job.

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

						10 tasks	20 tasks	50 tasks
0.9	0.9	0.9	0.9	0.9	**0.59**	**0.35**	**0.12**	**0.05**

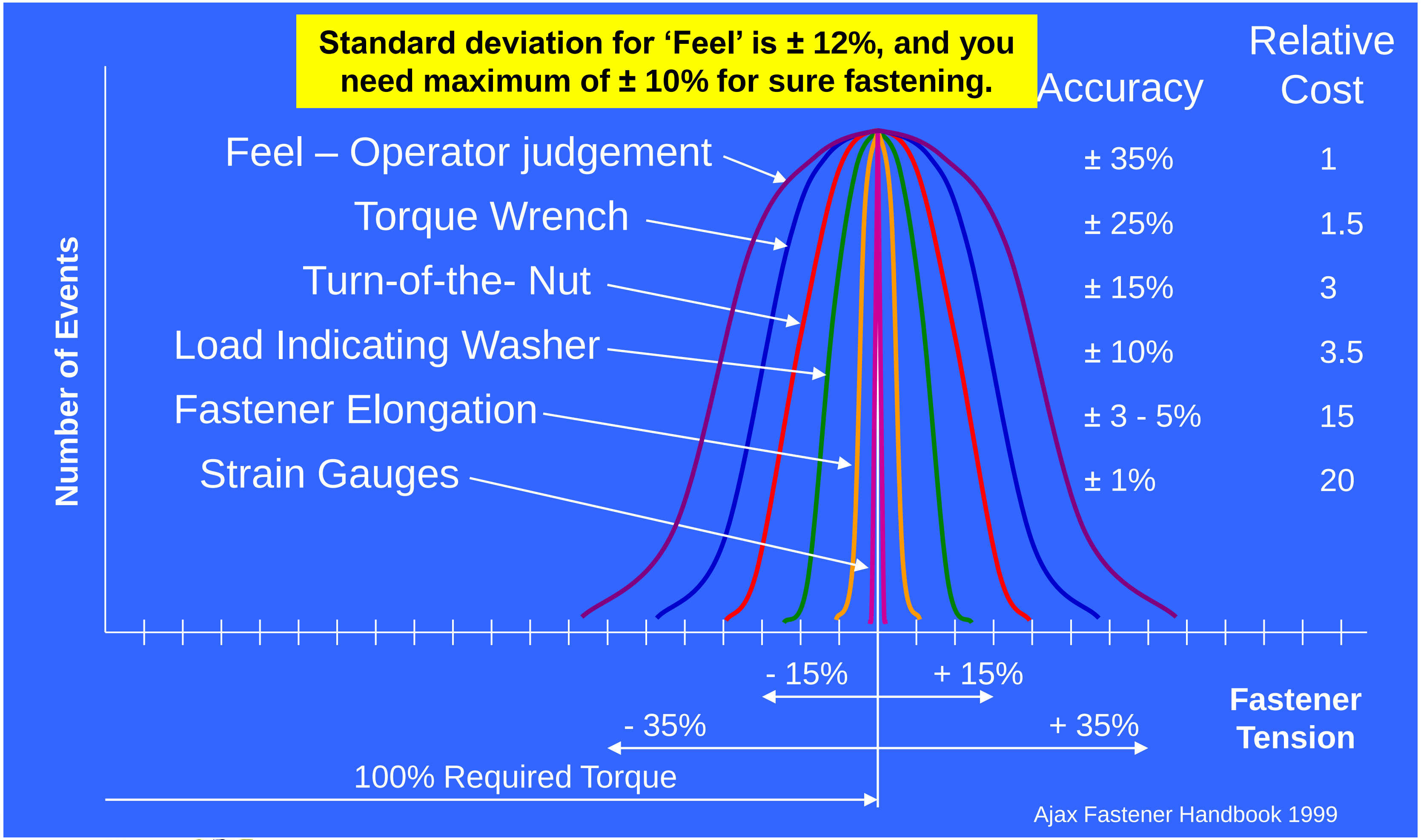
Complicated non-routine tasks

						10 tasks	20 tasks	50 tasks
0.95	0.95	0.95	0.95	0.95	**0.77**			
0.99	0.99	0.99	0.99	0.99	**0.95**	**0.90**	**0.82**	**0.61**

Controlling human error is the greatest challenge to reliability

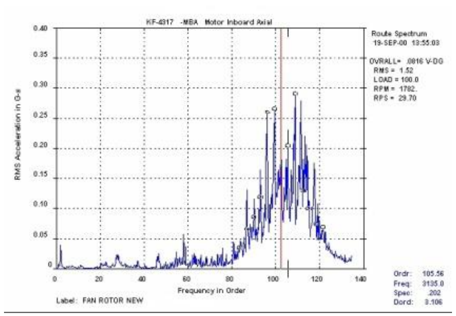
But where do your failures start?

Your problems start with chance variation…

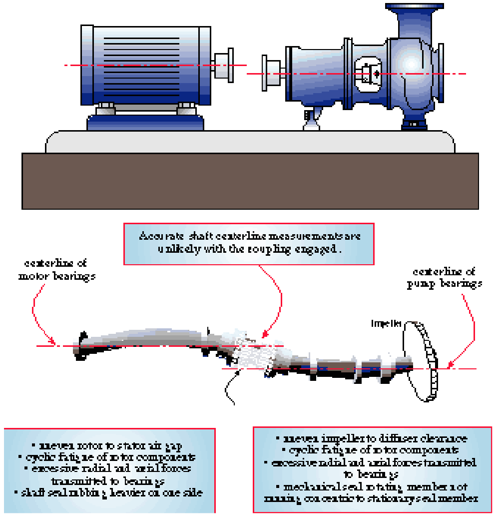


What chance variation does to machines

High Vibration:

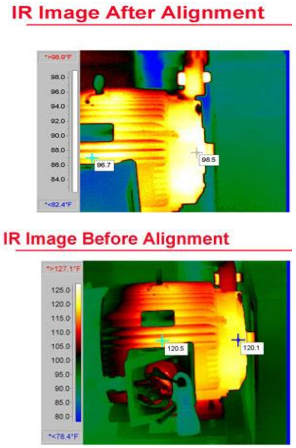


Deformation:



Extract from ‘Shaft Alignment Handbook ‘,Piotrowski

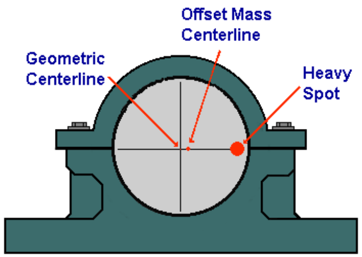
Misalignment:



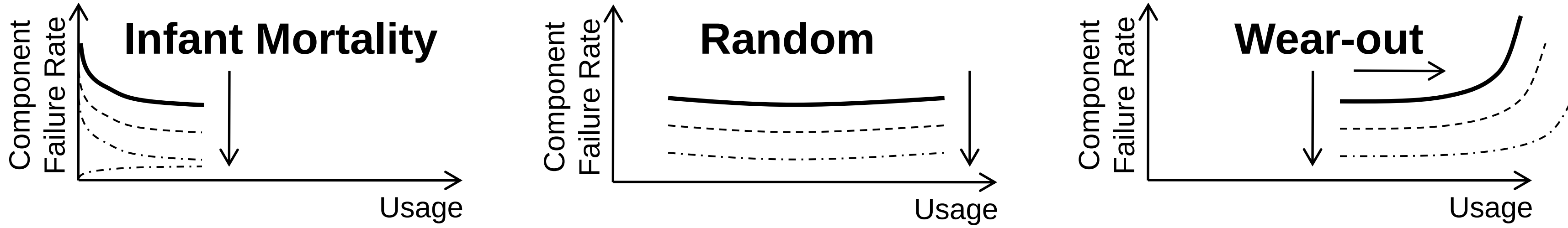
Fastener Torque Error:

Unclean Lubricant:

Unbalance:



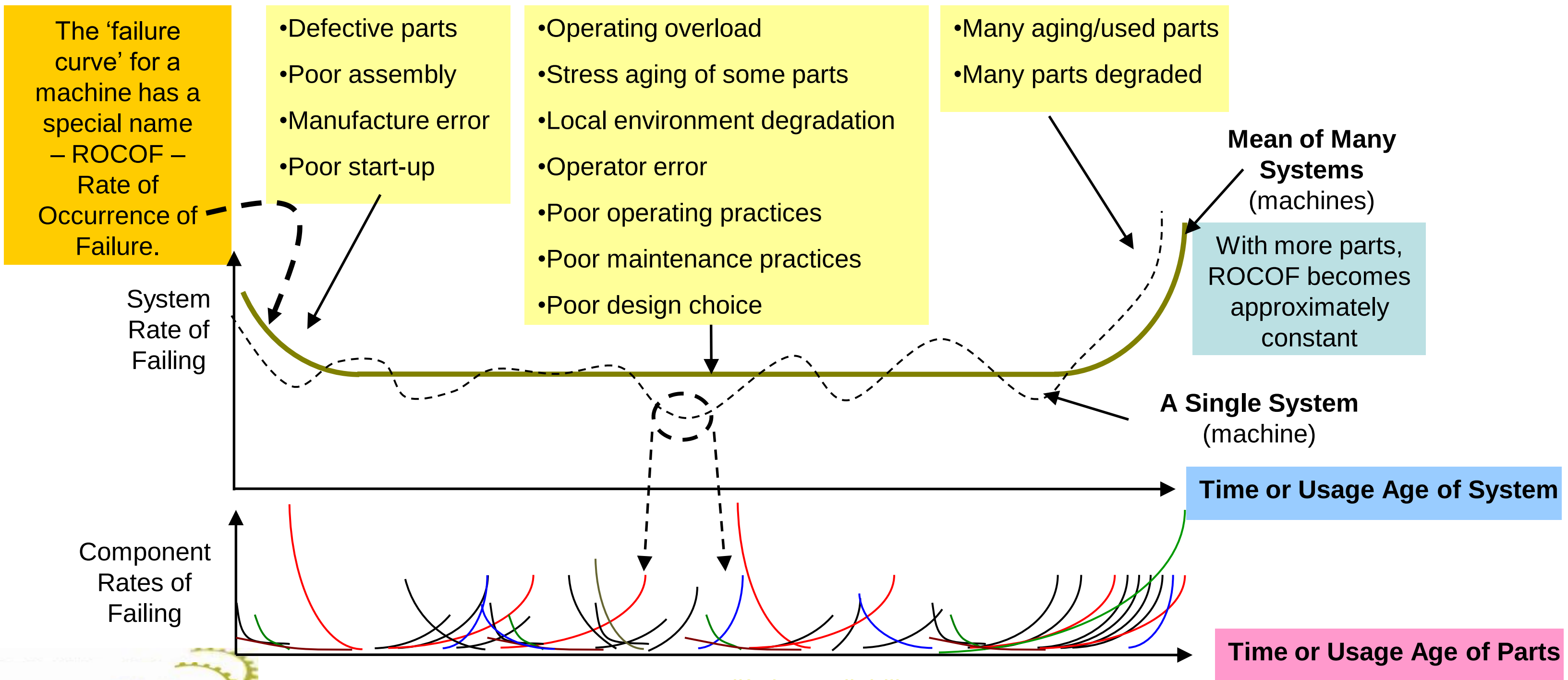
Cause and effect of your equipment failures



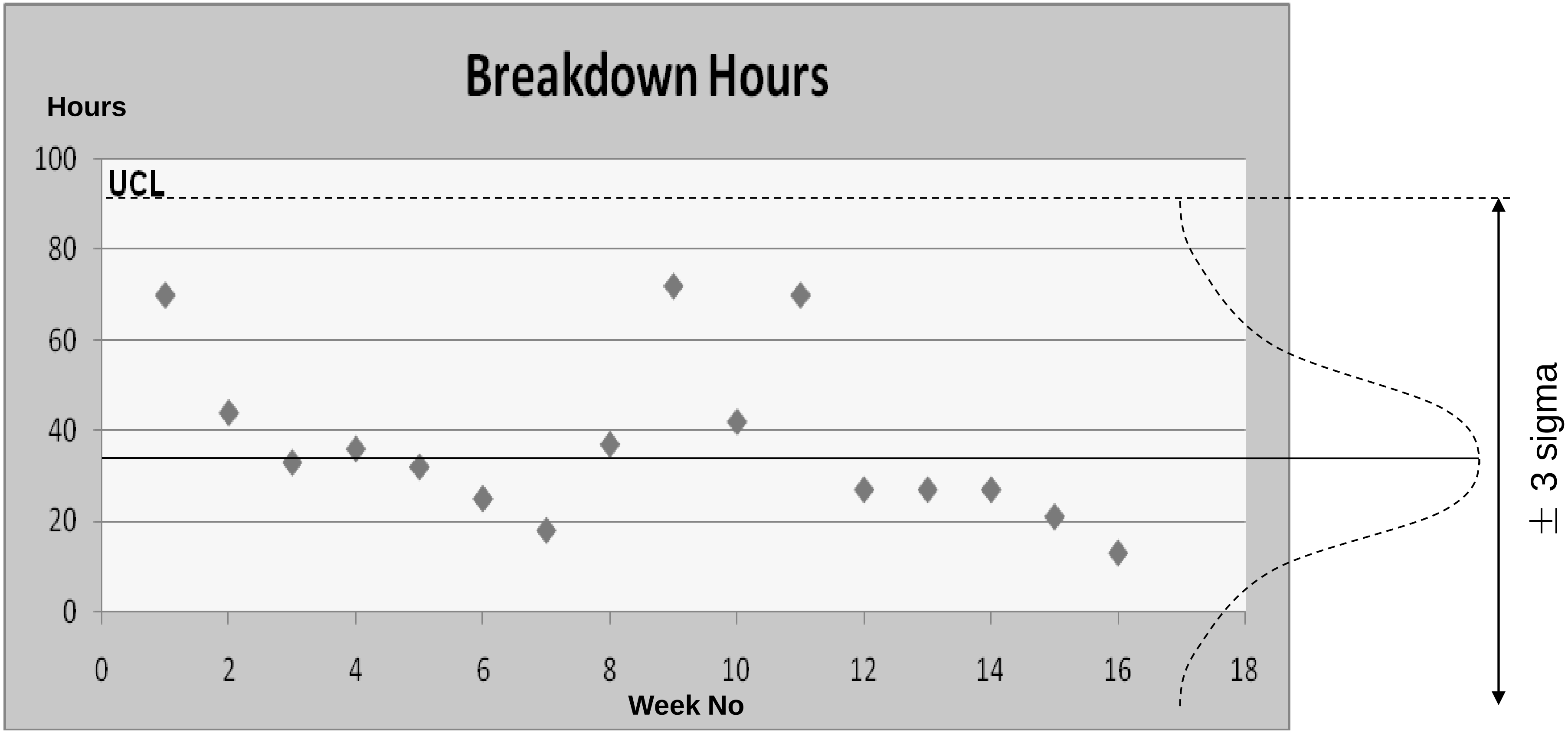
Cause: Incorrect Processes (controlled by management)

Cause: Induced Stress (controlled by people)

Cause: Accumulated Fatigue (controlled by people)



Most Business make their Machines Break



This is a statistically stable process of breakdown creation – this business makes breakdowns as one of its 'products'.

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

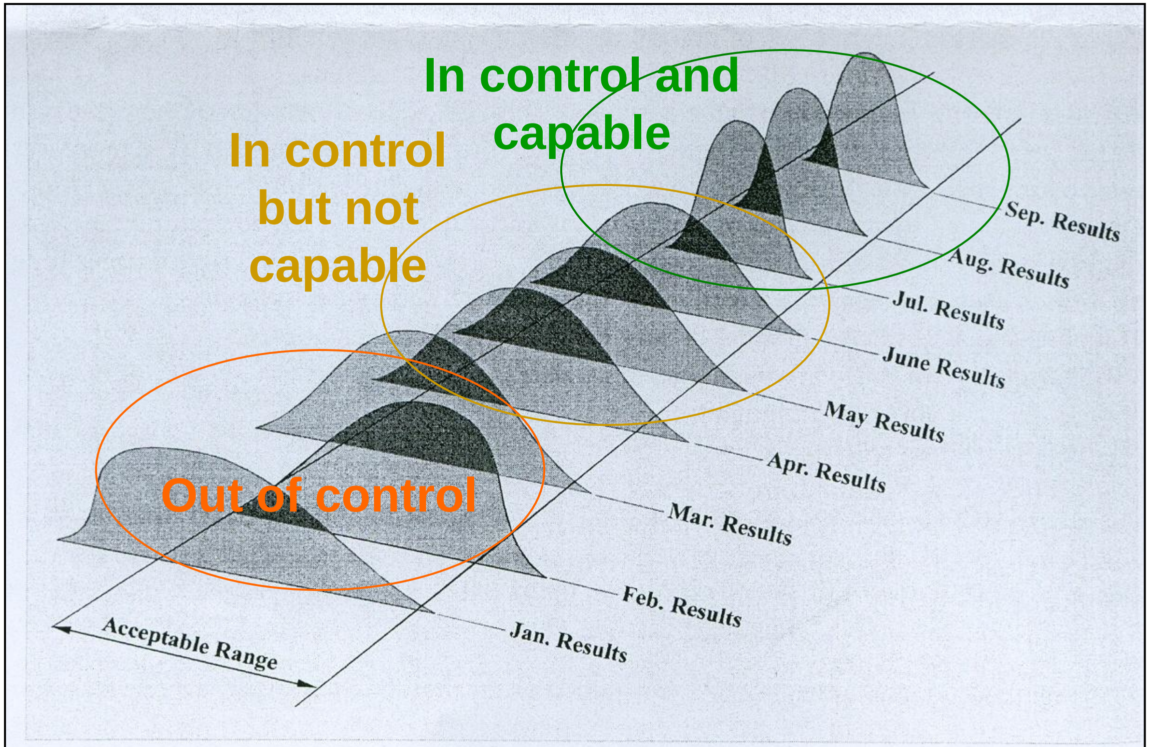
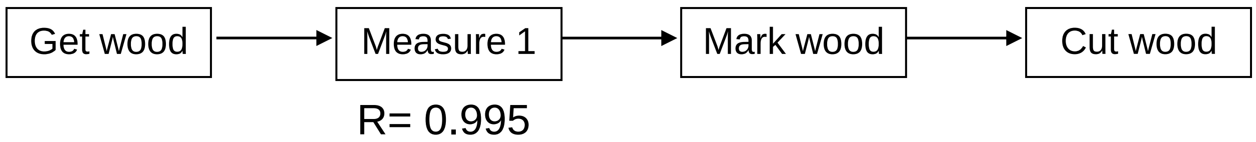
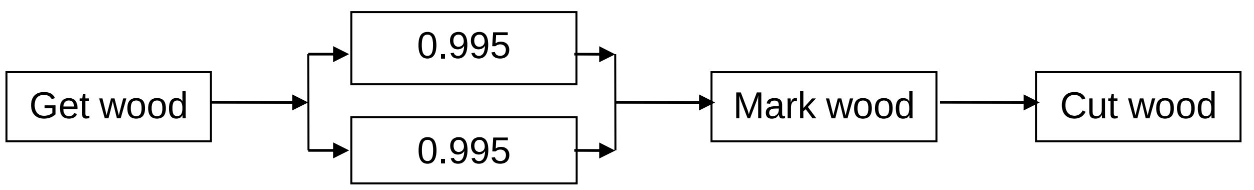


Figure 83: Progression of a Process to Capability

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



1 error every 200 opportunities
~ 1 / wk

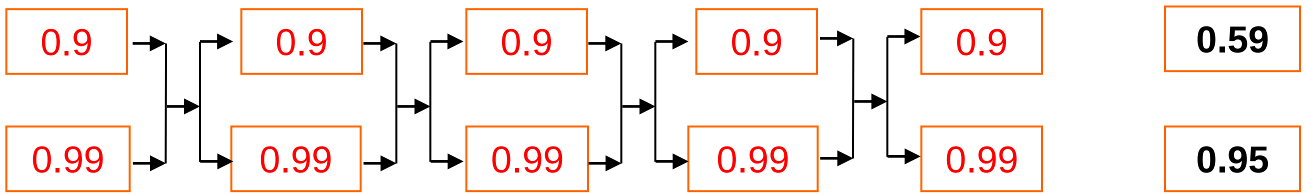


1 error every 5000 opportunities
~1 / 20 wk

The power of parallel proof-tests

Original task reliability

Proof-test reliability



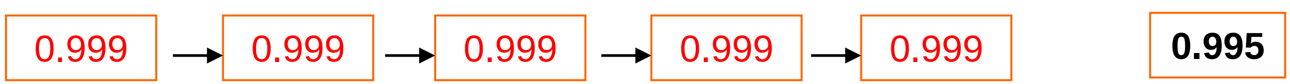
$$R_{system} = 1- [(1- R_1)x(1- R_2)x(1-R_3) \ldots]$$

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

$$1- [0.1 \times 0.01]$$

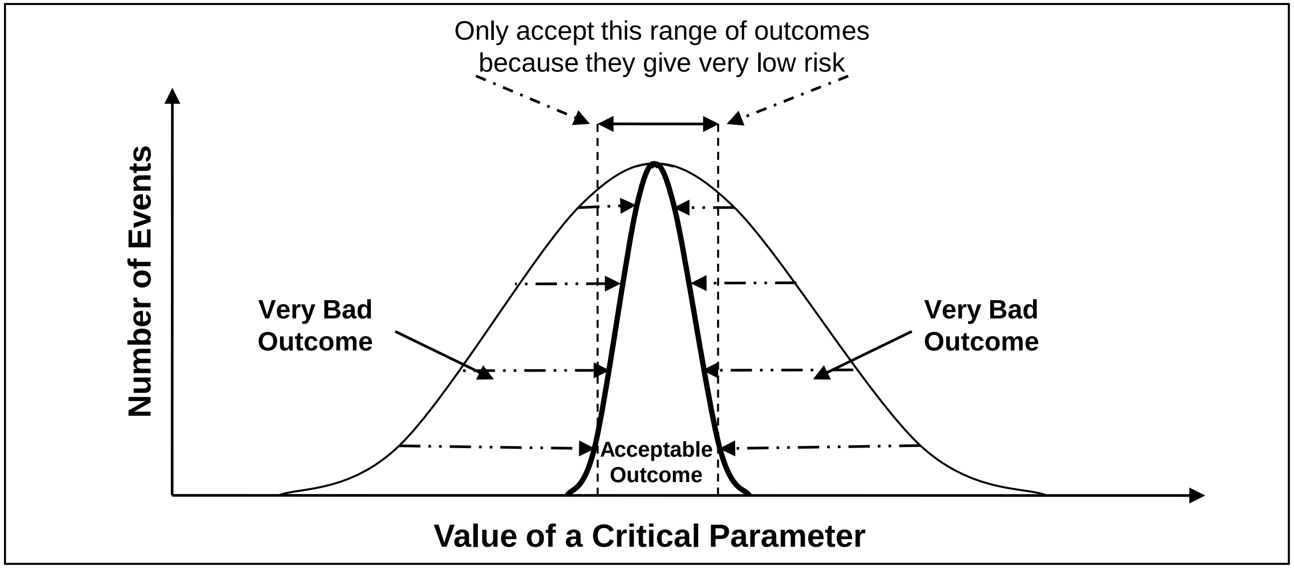
$$1- [0.001] = 0.999$$

Equivalent series reliability



Remove the variability from your business processes

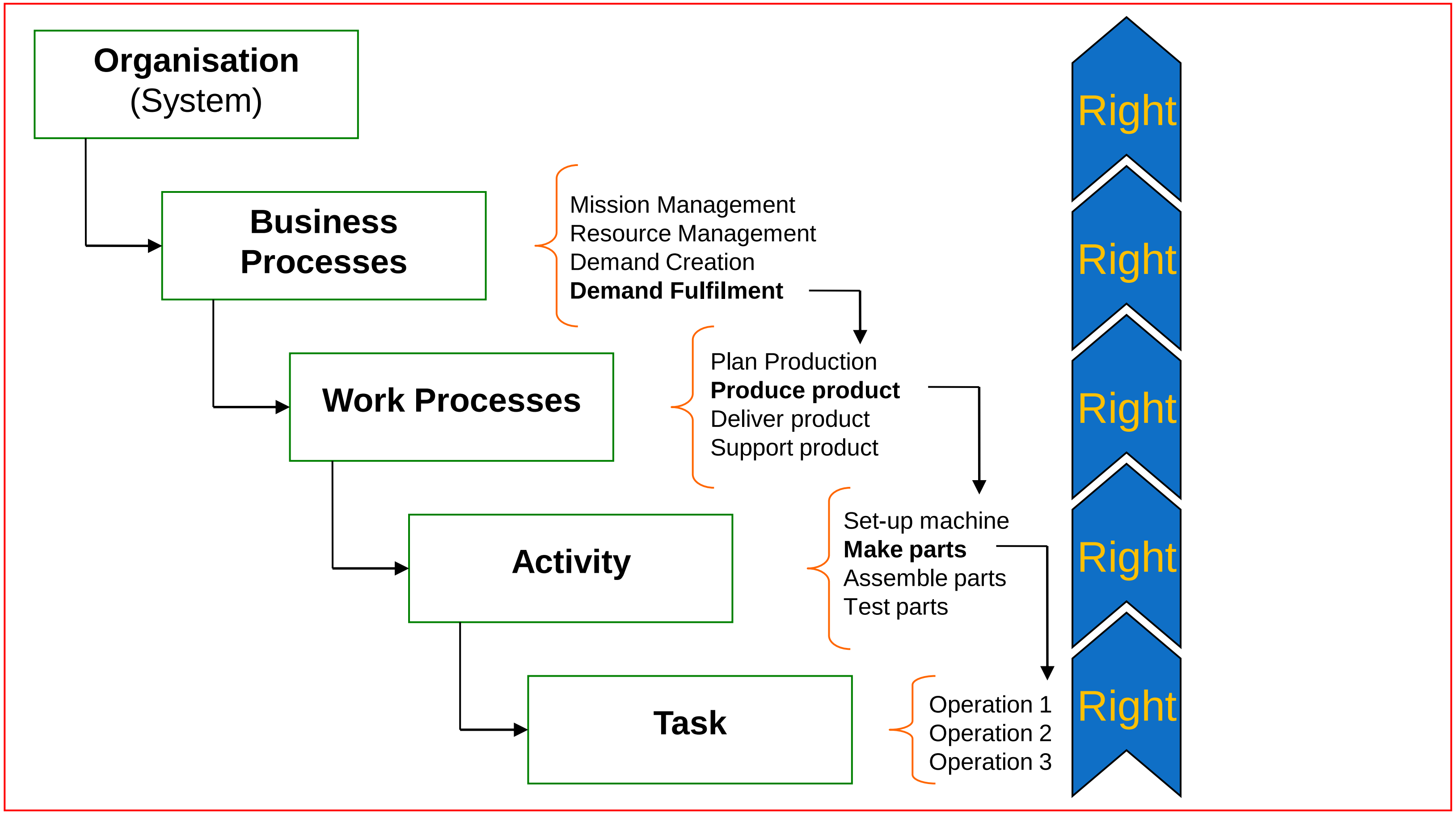
– unless you want to run your business by luck!



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

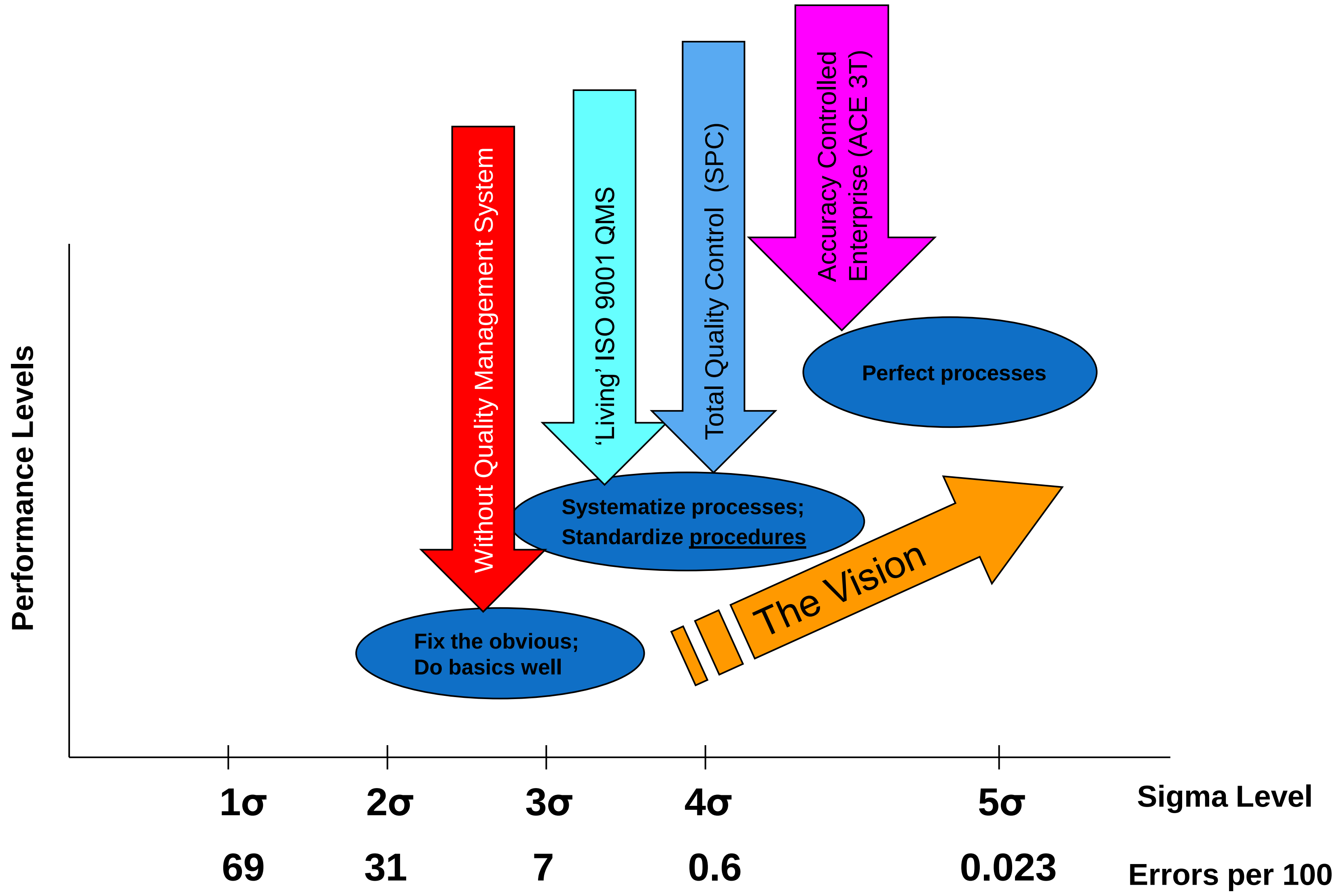
The secret is to control variability to within the limits that bring benefits

Right Work = Right Results



Procedures and Training control accuracy of Task Performance.
Focus on the content and quality of procedures and training.

Journey to 6 Sigma: Minimize Variability

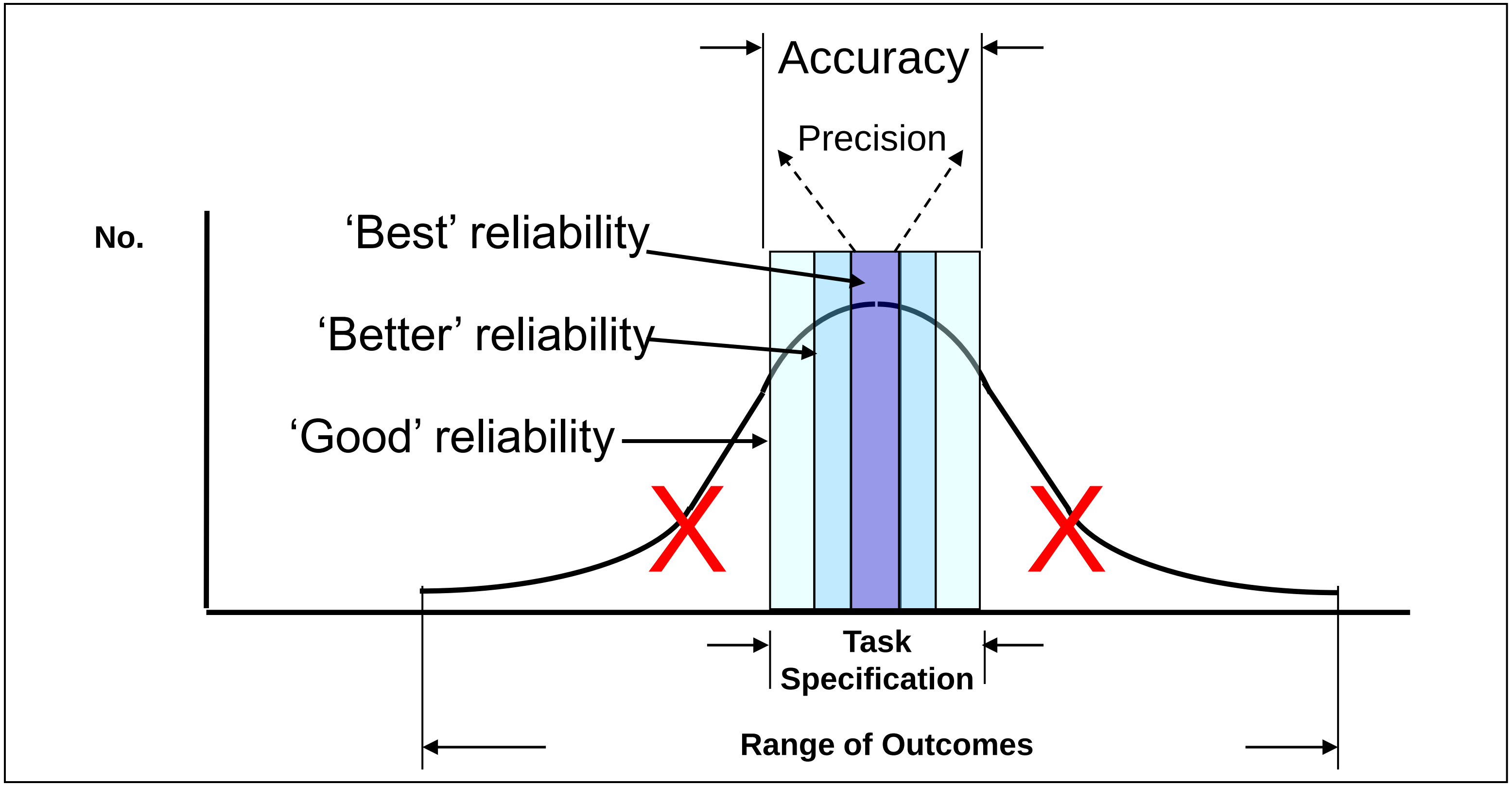


Sources: David Burns, SIRF Roundtables Ltd, Melbourne, Australia
George, Mike et al, 'What is Lean Six Sigma', McGraw-Hill, 2004

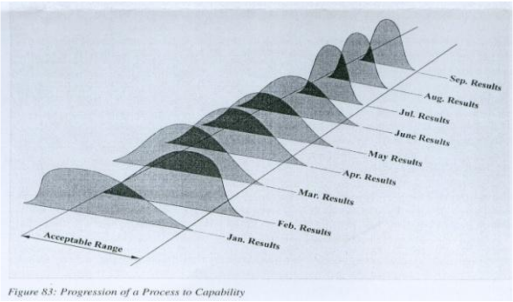
The Processes and World-Class Skills of Precision

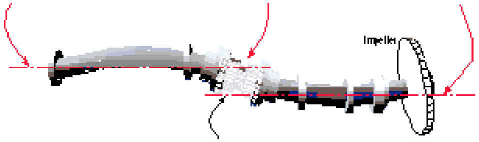
1. *Accurate Fits and Tolerance* – ISO/ANSI Shaft/Hole Tolerance Tables
2. *Clean, Contaminant-Free Lubricant* – ISO 4406
3. *Distortion-Free Equipment* – Shaft Alignment Handbook - Piotrowski
4. *Forces and Loads into Supports* – Shaft Alignment Handbook
5. *Accurate Alignment of Shafts* – Shaft Alignment Handbook
6. *High Quality Balancing of Rotating Parts* – ISO 1940
7. *Machine Vibration* – ISO 10816
8. *Correct Torques and Tensions* – ISO/ASME Bolt, Stud and Nut Standards
9. *Correct Tools in Condition* – 'As-New Specification'
10. *Only In-specification Parts* – OEM specifications, Machinery Handbook
11. *Failure Cause Removal* – '5 Why'; RCFA; Reliability Growth Cause Analysis
12. *Proof of Precision* – Measurements, Condition Monitoring at Start-up
13. *A **system** to use the standards successfully* – ACE 3T Procedures, ISO9001

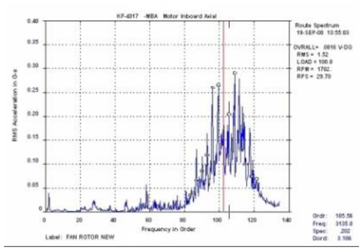
Set work task standards to deliver the quality that produces the reliability you want

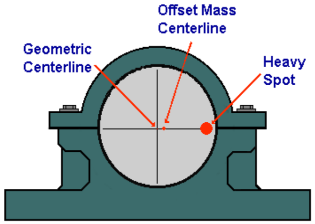


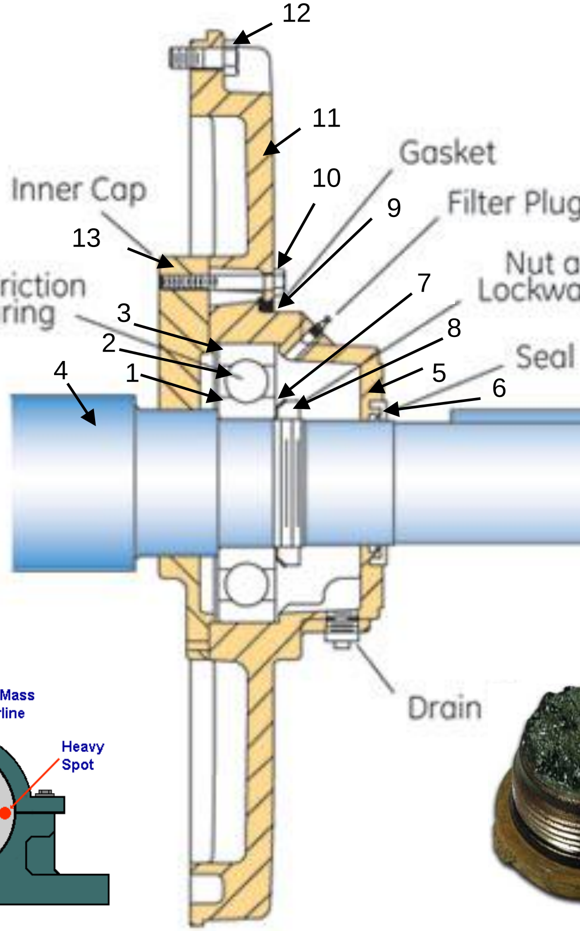
How do we apply it to our machines?

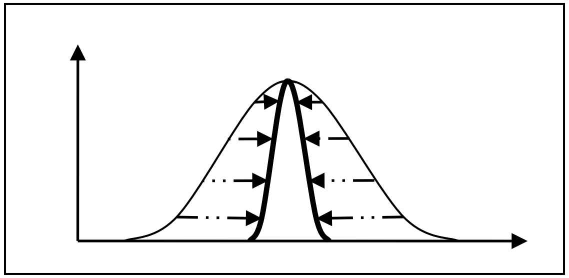




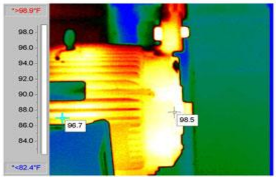








IR Image After Alignment



Electric motor drive end bearing

USS Nimitz - Some keys to their success

Preoccupation with Failure

- Highlight, Analyse & Learn from failures and problems
- There is healthy challenge to constantly improve
- Turnover of people helps stop operations becoming stale

Reluctance to Simplify Problems

- Seeks deeper understanding of problem causes
- Sensitive to the smallest whisper of things going wrong

Deference to Expertise

- Expertise overrides rank. Decision-making pushed down
- When things go wrong, turn to experts to help resolve
- Team communication is far in excess of the norm

Control Your Processes by Converting your SOPs to 3T Accuracy Controlled Procedures

Test

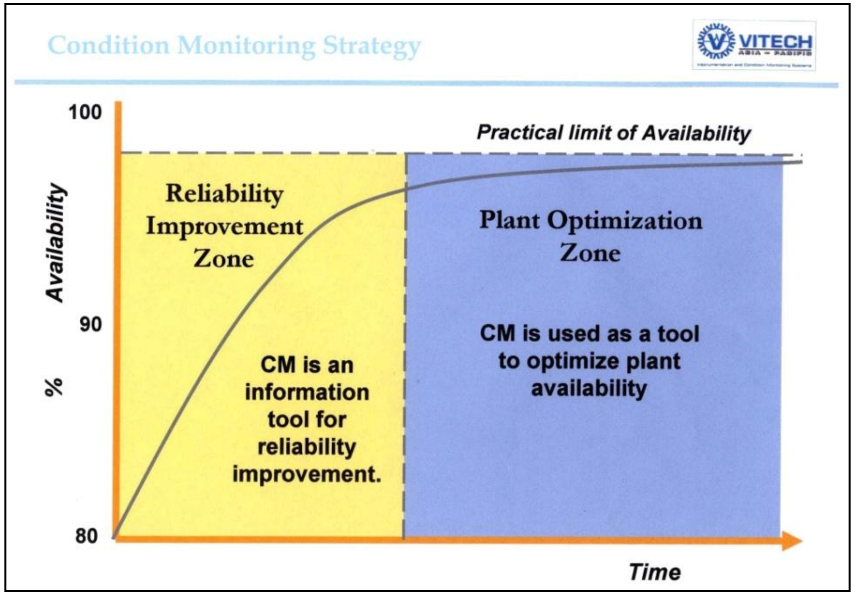
Tolerance

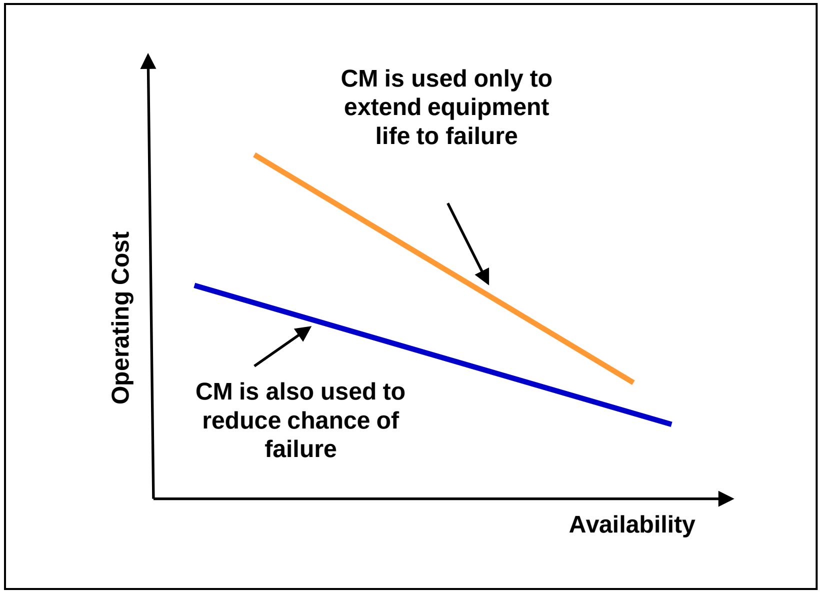
Target

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**			
			Continual improvement							

- Specify the 3Ts (Target, Tolerance, Test) for task precision and accuracy
- Describe in a measurable fashion what ‘good’, ‘better’ and ‘best’ are to challenge people to strive for excellence
- 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’

Use condition monitoring as the proof test for task quality

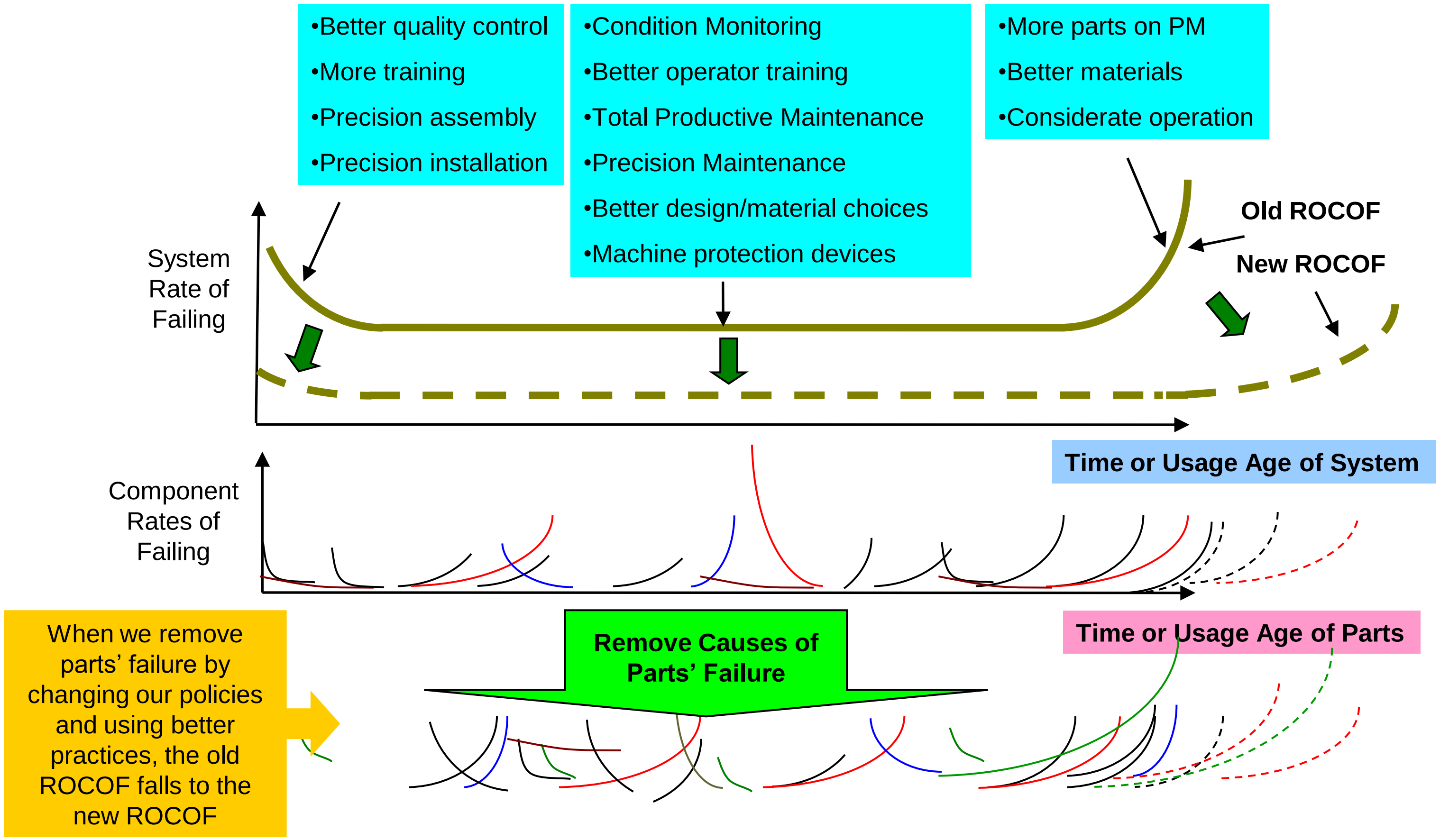




Life Extension Zone

Failure Elimination Zone

Equipment reliability is malleable by choice of policy and quality of practice



High equipment reliability is...