# Developing Operational Excellence Strategy that Suits Your Business

**CEO Institute WA Syndicate 81**

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Lifetime Reliability Solutions

February 2012

# Content

1. Reliability
2. Quality
3. Risk

# What is Reliability?

- *"Reliability is the **probability** that an item of plant will perform its **duty** without **failure** over a designated **time**."*

- *"Reliability is the **chance** of completing the mission."*

- *"Reliability is the **chance** of success."*

# All Work is a Series of Activities

The Job

Task 1 → Task 2 → Task 3 → Task 4 → Task 5

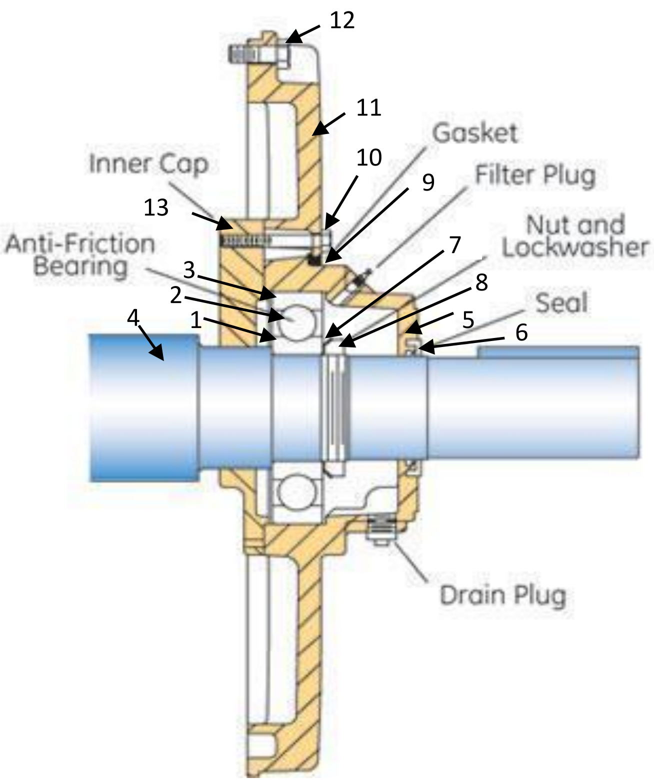
$$\underline{R}_{job} = \underline{R}_1 \times \underline{R}_2 \times \underline{R}_3 \times \underline{R}_4 \times \underline{R}_5$$

# All Your Machines are Parts in Series

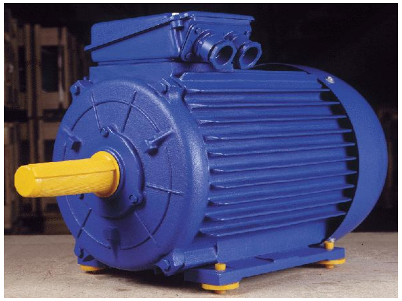
| 4 Shaft Journal | 6 Shaft Seal | 8 Lock Nut | 1 Inner Race | 14 Lube | 2 Roller Bearing | 14 Lube | 3 Outer race | 5 Housing Bore |
|---|---|---|---|---|---|---|---|---|
| $R_4$ | $R_6$ | $R_8$ | $R_1$ | $R_{14}$ | $R_2$ | $R_{14}$ | $R_3$ | $R_5$ |

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

NOTE: $\mathbf{R_n}$ = Component reliability

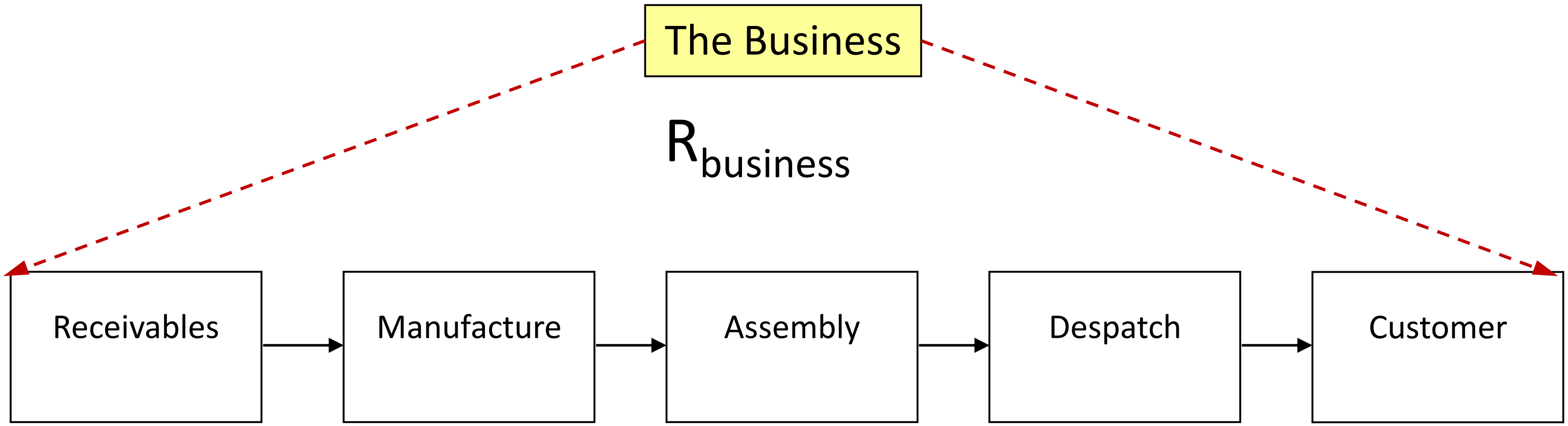



## **Reliability:** the chance of success



1. **For the motor to be highly reliable every bearing must be highly reliable.**
2. **For a bearing to be highly reliable each of its components must be even more reliable.**
3. **For every part to be reliable its design and operating health must be risk-free.**

# All Our Businesses are Processes in Series

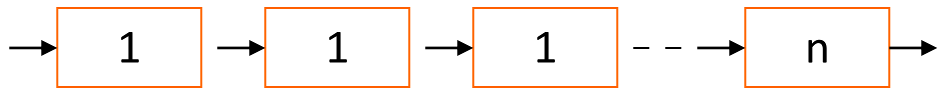



$$R_{business} = R_{process1} \times R_{process2} \times R_{process3} \times \ldots \times R_{process'n'}$$

# Reliability Properties for Series Systems

The mathematics can be difficult. You won't need to do the math, but you need to know that such mathematics exists and be able to use the principles to optimise maintenance.

- Series Systems



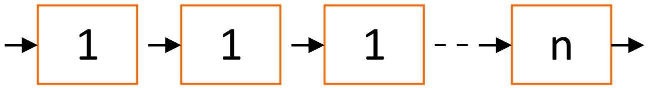

$$R_{system} = R_1 \times R_2 \times R_3 \ldots R_n$$

$R = 0.95 \times 0.95 = 0.9025$

| Number of Components | Series System Reliability | | | |
|---|---|---|---|---|
| 1 | **0.95** | **0.97** | **0.99** | **0.9999** |
| 2 | 0.9025 | 0.9409 | 0.9801 | 0.9998 |
| 4 | 0.8145 | 0.8853 | 0.9606 | 0.9996 |
| 6 | 0.7351 | 0.8330 | 0.9415 | 0.9994 |
| 8 | 0.6634 | 0.7837 | 0.9227 | 0.9992 |
| 10 | 0.5987 | 0.7374 | 0.9044 | 0.9990 |

# Reliability Properties 1, 2, 3 for Series Systems

$$R_{system} = R_1 \times R_2 \times \ldots R_n$$




**Properties of Series Systems**

1. ***The reliability of a series system can be no higher than the least reliable component.***

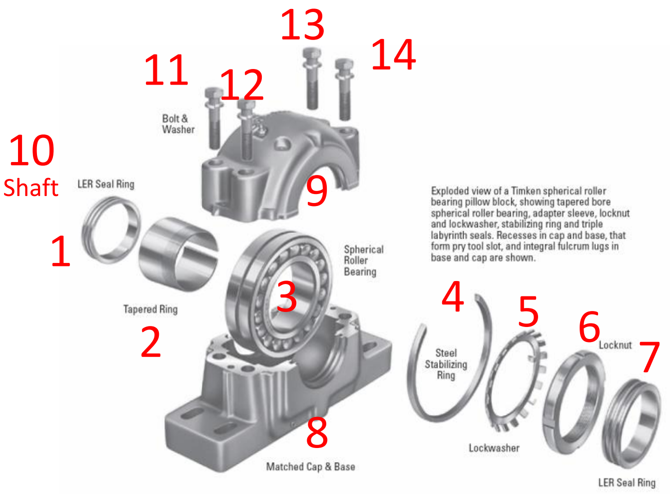
2. ***If 'k' more items are added into a series system of items (say 1 added to a system of 2, each with R = 0.9) the probability of failure of all items must fall an equal proportion (33%), to maintain the original system reliability.***
   ***(0.9 x 0.9 = 0.93 x 0.93 x 0.93 = 0.81)***

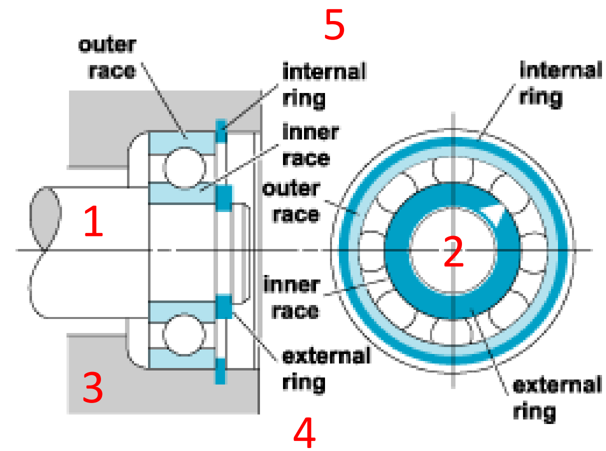
3. ***A small rise in reliability of all items (say R of the three items rises 0.93 to 0.95, 2.2% improvement) causes a larger rise in system reliability (from 0.81 to 0.86, 5%).***

- Implications for Equipment made of Series Systems

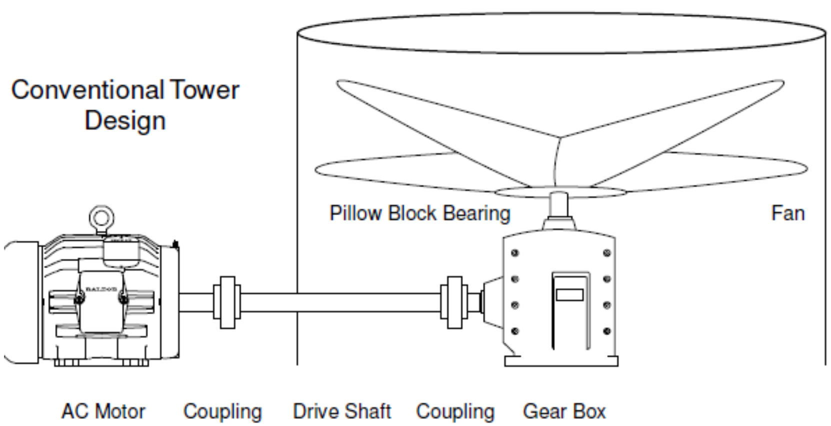
**1 System-wide improvements lift performance higher than local improvements. This is why Planning, SOP's, training and up-skilling pay-off.**
**2 Improve the least reliable parts of the least reliable equipment first.**
**3 Carry spares for series systems and keep the reliability of the spares high.**
**4 Standardise components so fewer spares are needed.**
**5 Removing failure modes lifts system reliability. This is why Root Cause Failure Analysis (RCFA) and Failure Mode and Effects Analysis (FMEA) pay off.**
**6 Provide pseudo-parallel equipment by providing tie-in locations for emergency equipment .**
**7 Simplify, simplify, simplify – fewer components means higher reliability.**

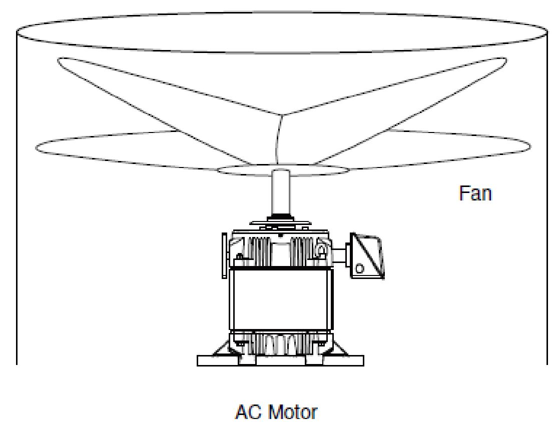
# Simplify, Simplify, Simplify



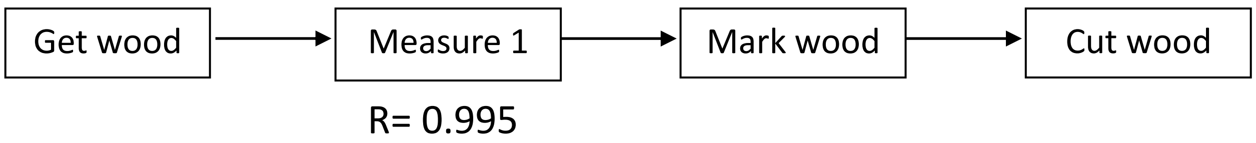




Direct Drive Tower Design

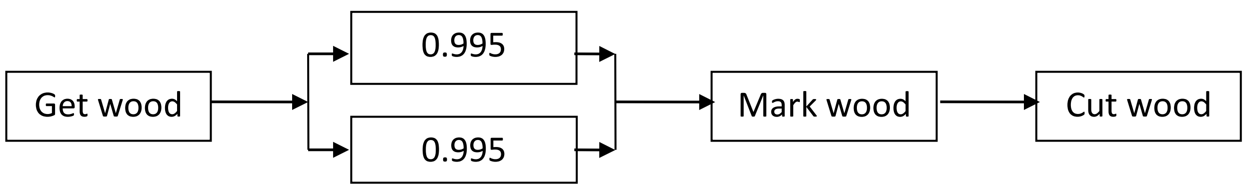


# Carpenter’s Creed: *measure twice, cut once*




1 error every 200 opportunities
~ 1 / wk




1 error every 4000 opportunities
~1 / 20 wk

**???** **???** **???**

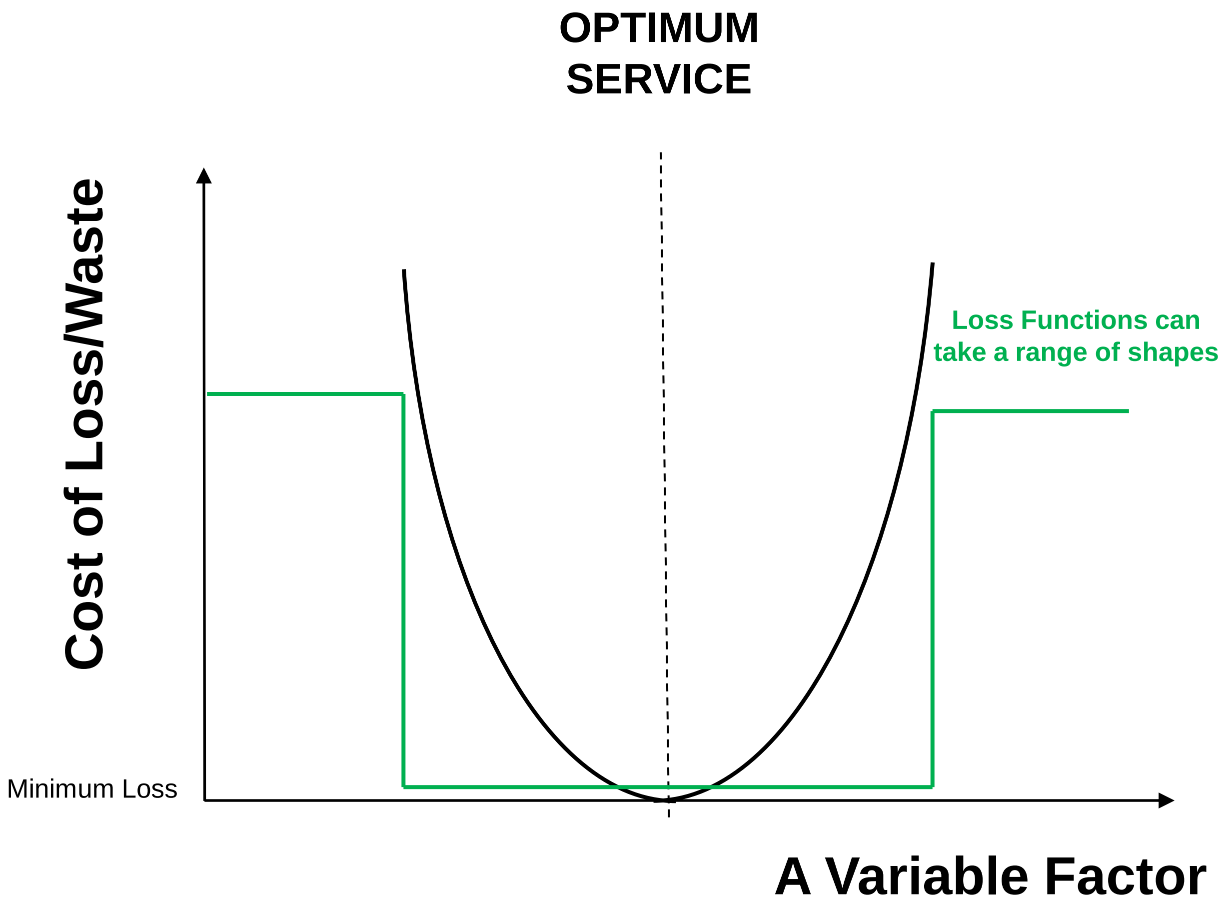
$$R_{parallel} = 1-[(1- R_1)x(1- R_2)]$$
$$= 1-[(1 – 0.995) \text{ x } [(1 – 0.995)]$$
$$= 0.999975$$

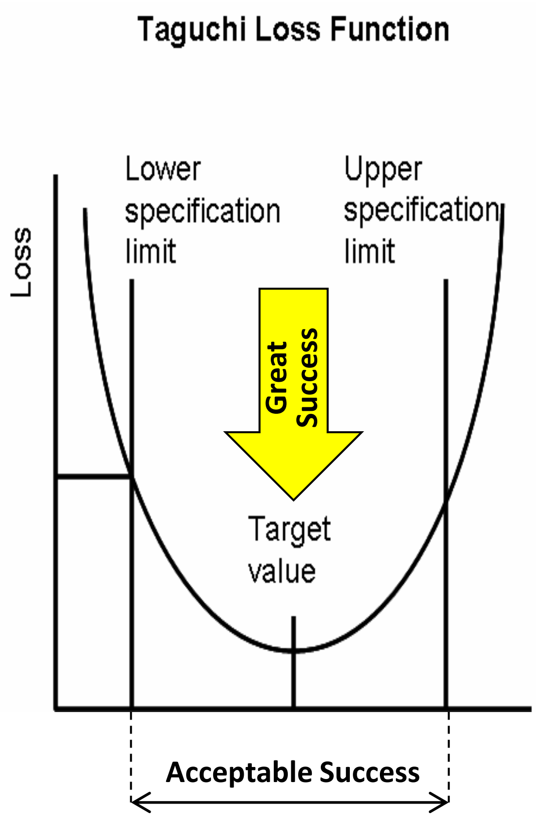
**This is a ‘mistake proofing’ method that greatly reduces the chance of an error being made and left behind in a job as a defect that will later cause failure.**

# Content

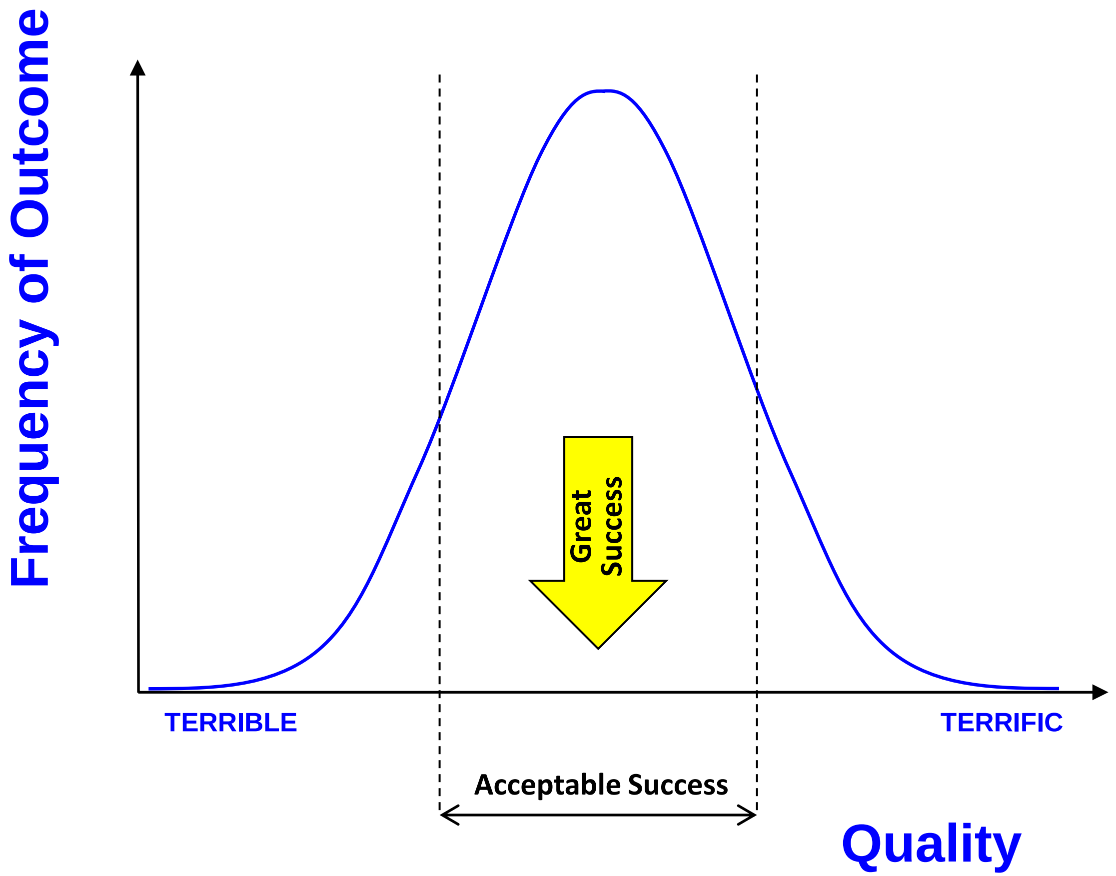
1. Reliability
2. Quality
3. Risk

# The Concept of a Quality Loss Function

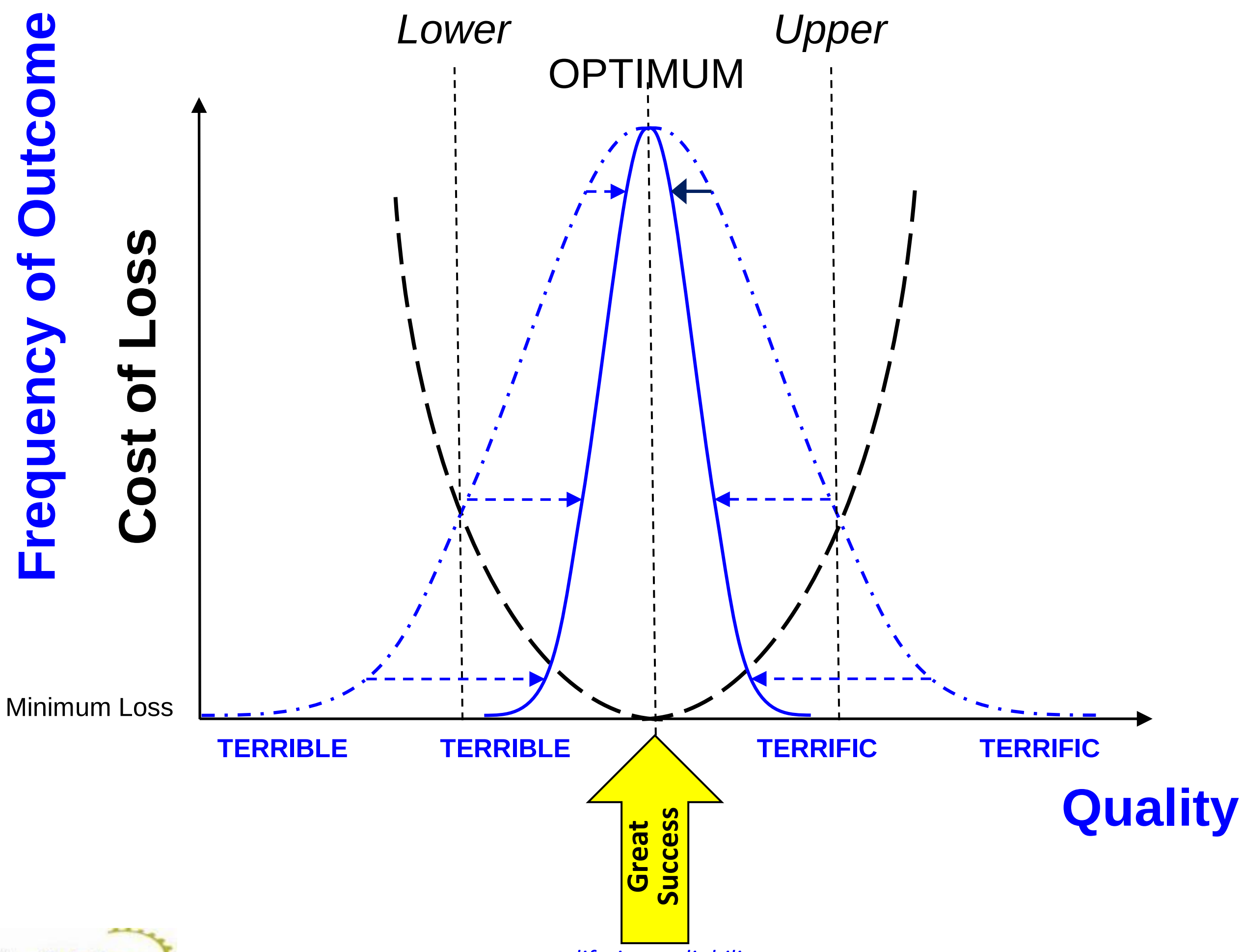


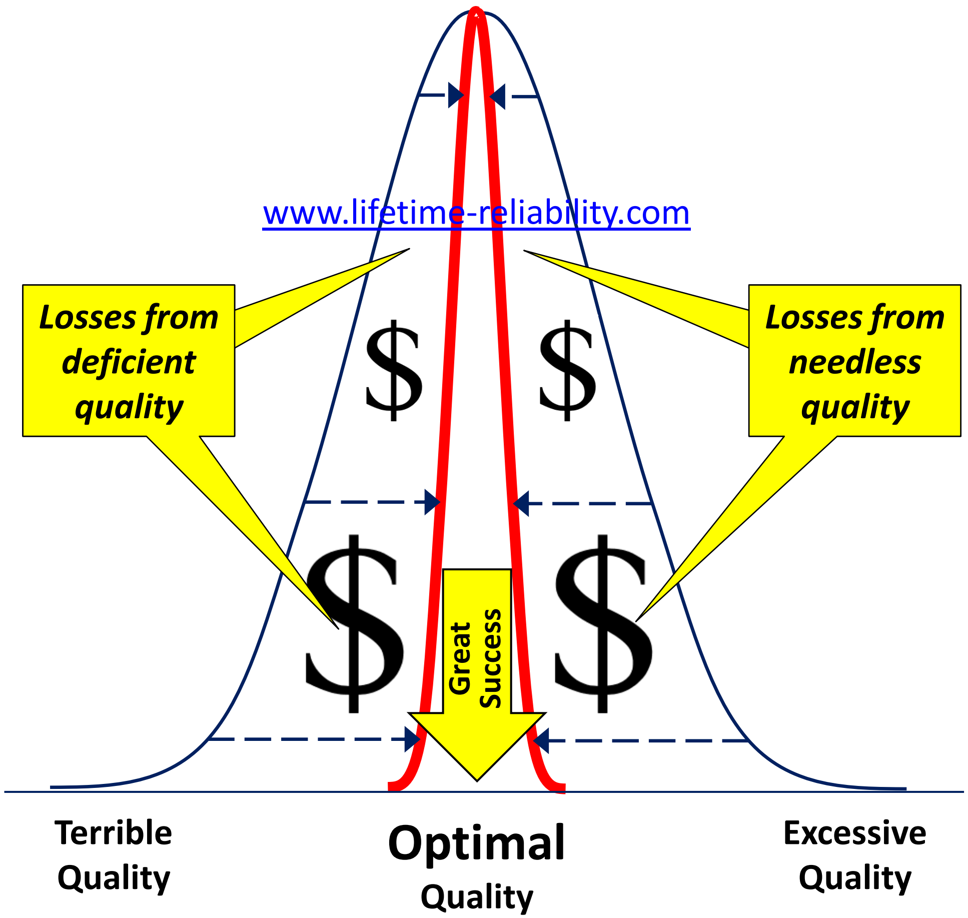
# Distribution of Work Quality Performance



# Work Quality that Makes Money



# Where the Money Comes from by doing Work to a 'Quality' Requirement



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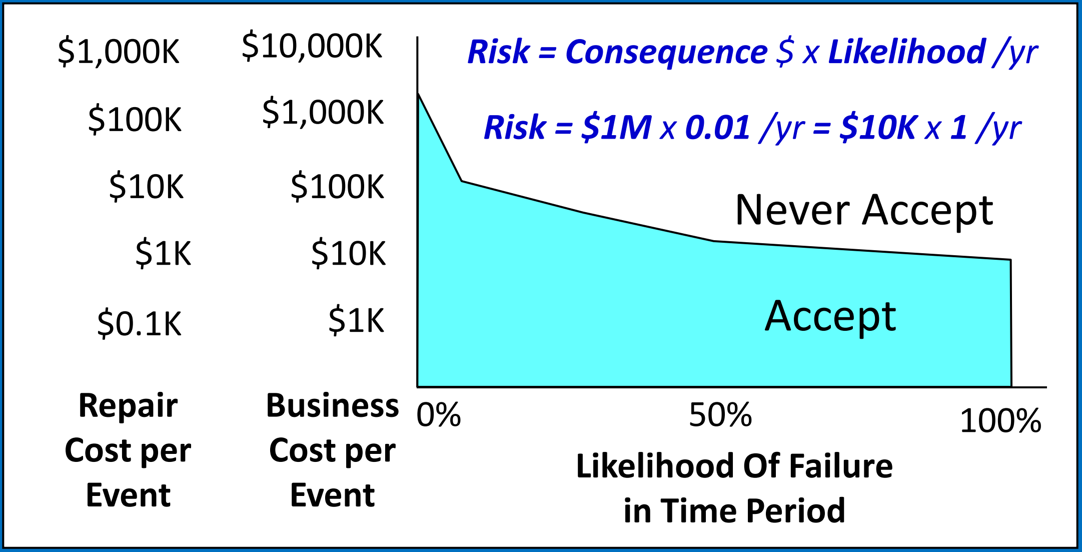
# The Risks You Live With and those You Prevent Show Your Risk Boundary

**If each failure costs your business $7,000 – $15,000 for every $1,000 of repair cost … what risk is the business willing to carry?**

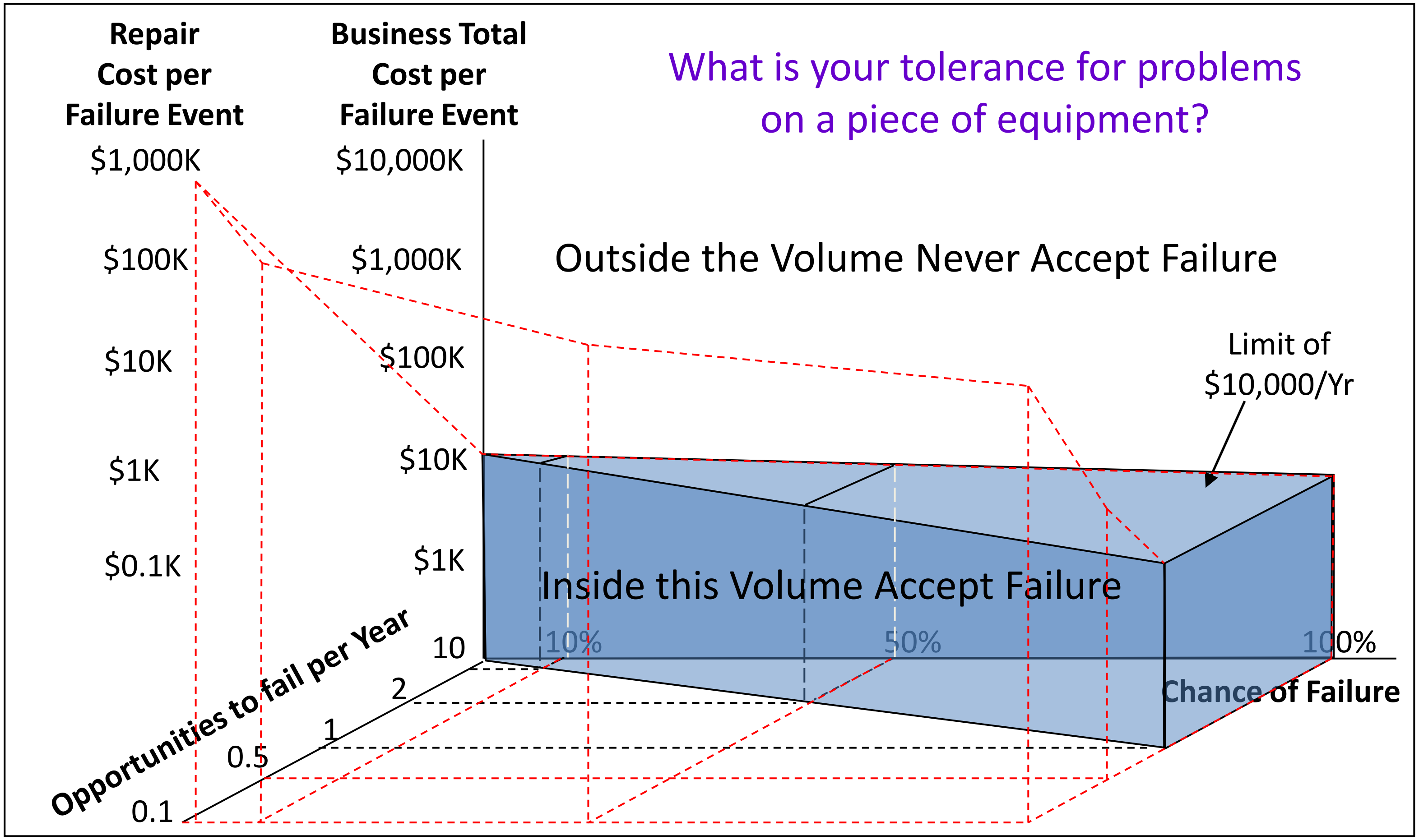
**How often will a failure event be accepted?**




- What failures don’t you bother repairing, but immediately replace with new? (The risks of using rebuilt equipment are too much.)
- Which production equipment will you let fail? (The cost of failure is insignificant.)
- Which production equipment will you never allow to fail? (The cost of failure is too expensive.)
- When will you be willing to replace equipment that you will not allow fail? (How much remaining life are you willing to give up to reduce the risk of failure?)
- What size safety and environmental failures will you allow? (Their cost is insignificant.)

# Acceptable Failure Domain

***Risk** = Consequence x [Frequency of Opportunity x Chance of Failure at Each Opportunity]*



# Example of Using a Risk Boundary

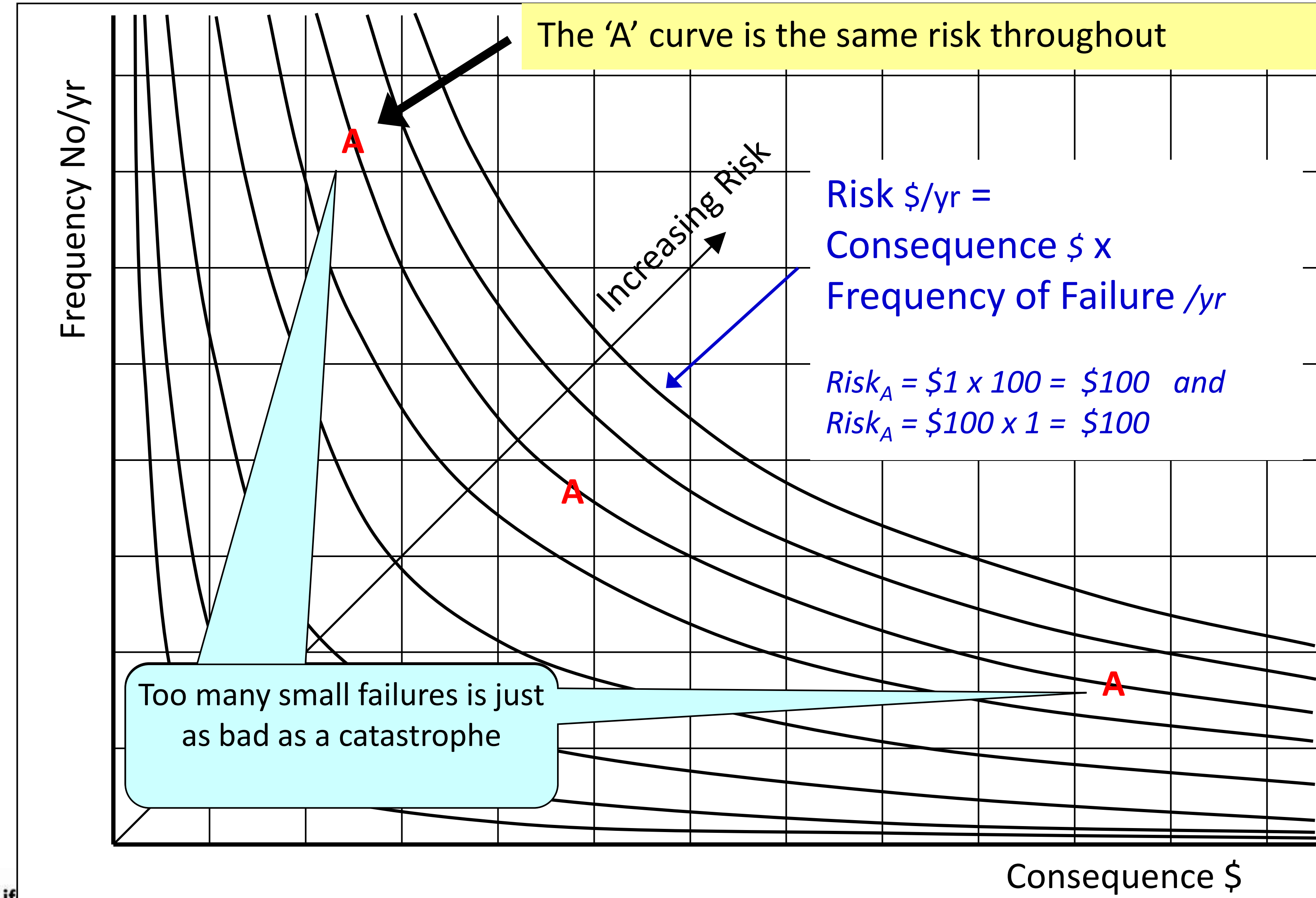
| E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Not Maintained | | | | | | | | | | | | | | | | | | | |
| kelihood of Failure Event per Year | | | DAFT Cost per Event | $30 | $100 | $300 | $1,000 | $3,000 | $10,000 | $30,000 | $100,000 | $300,000 | $1,000,000 | $3,000,000 | $10,000,000 | $30,000,000 | $100,000,000 | $300,000,000 | $1,000,000,000 |
| ne Scale | Descriptor Scale | Historic Description | | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 |
| eek | Certain-immediate | | L13 | | | | | | | | | | | | | | | | |
| rtnight | Certain-soon | | L12 | | | | | | | | | | | | | | | | |
| onth | Certain | | L11 | | | | | | 1 | | | | | | | | | | |
| uarter | | | L10 | | | | | | | | | 2 | | 3 | | | | | |
| ear | Almost Certain | Event will likely occur on an annual basis | L9 | | | | | | | | | | | | | | | | |
| 3 years | Likely | Even has occurred several times or more in a lifetime career | L8 | | | | | | | | | | | | | | | | |
| 0 years | Possible | Event might occur once in a lifetime career | L7 | | | | | 0 | | | | | | | | | | | |
| 0 years | Unlikely | Event does occur somewhere from time to time | L6 | | | | | | | | | | | | | | | | |
| 00 years | Rare | Heard of something like it occurring elsewhere | L5 | | | | | | | | | | | | | | | | |
| 300 years | | | L4 | | | | | | | | | | | | | | | | |
| 1,000 years | Very Rare | Never heard of this happening | L3 | | | | | | | | | | | | | | | | |
| 3,000 years | | | L2 | | | | | | | | | | | | | | | | |
| 10,000 years | Almost Incredible | Theoretically possible but not expected to occur | L1 | | | | | | | | | | | | | | | | |

| sk Level | |
|---|---|
| eme | 1) Risk Boundary is set at 'LOW' Level |
| gh | 2) Based on HB436:2004-Risk Management |
| edium | 3) Identify 'Black Swan' events as B-S (A 'Black Swan' event is one that people say 'will not happen' because it has not yet happened) |
| w | 4) DAFT Cost (Defect and Failure True Cost) is the total business-wide costs and lossses from the event |
| epted | |


**1 - Reliability**

**Risk = Consequence $ x [Frequency of Opportunity /yr x Chance of Opportunity becoming a Failure ]**

# Risk can be Measured and Graphed



# Reducing the Chance of Failure

*Chance of Failure = 1 – Chance of Success*

*Chance of Failure = 1 – Reliability*

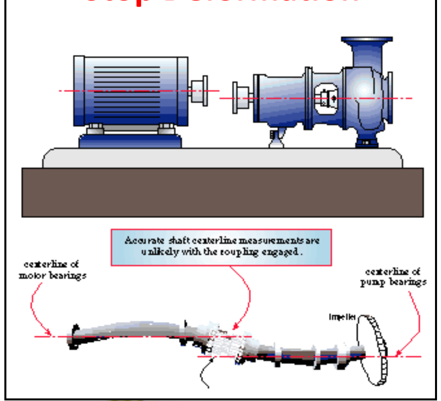
***Risk*** *= **Consequence** $ x **Chance** /yr*

***Risk*** *= **Consequence** $ x **[Freq of Opportunity** /yr x **Chance of Failure at Each Opportunity]***

***Risk*** *= **Consequence** $ x **[Freq of Opportunity** /yr x **{1 – Reliability}]***

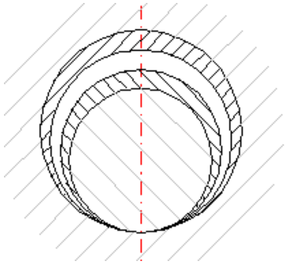
***Risk*** *= **Consequence** $ x **[Freq of Opportunity** /yr x **{Uncertainty}]***

**Excellent Lubricant Cleanliness**

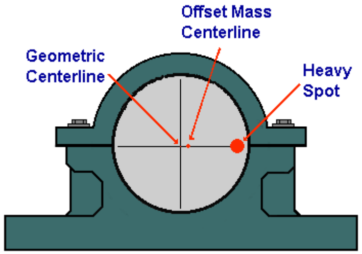



**Stop Deformation**

**Correct Fastener Torque**



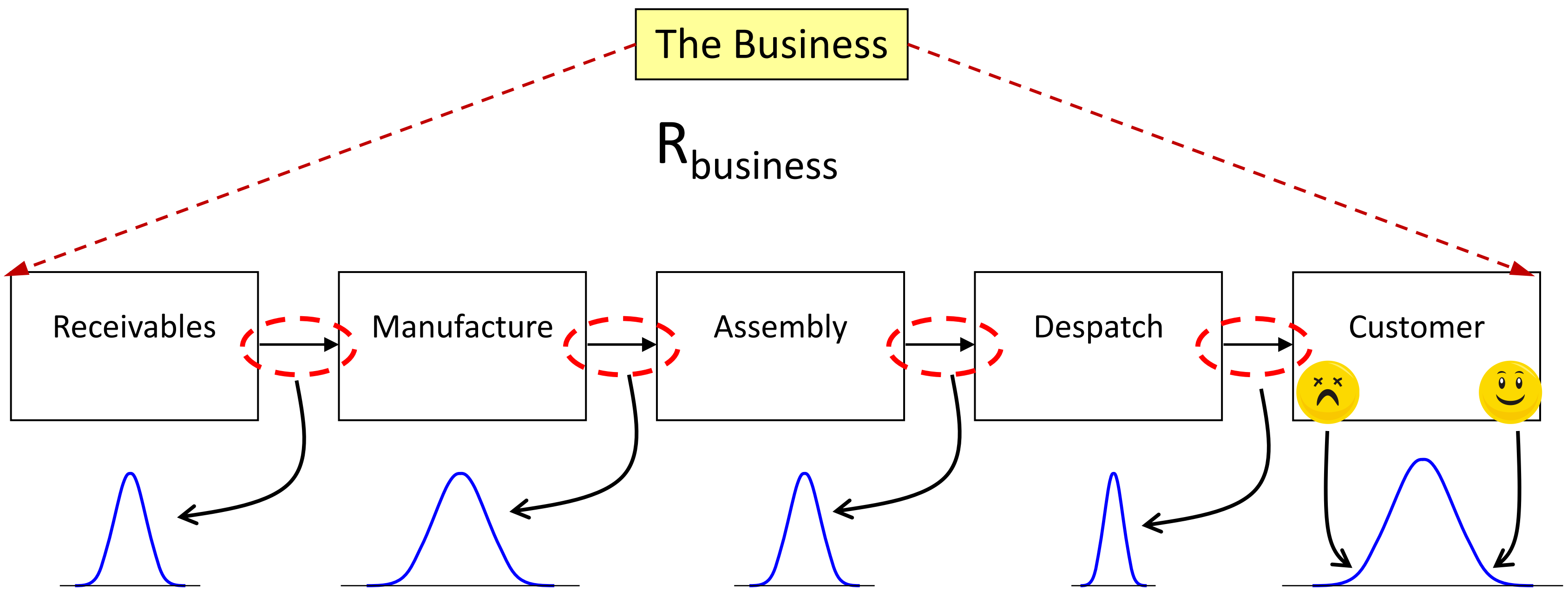
**Proper Fits and Tolerance**




**No Unbalance**

*Here are some opportunities…*

# All Our Businesses are Processes at Risk




$$Risk_{process1} + Risk_{process2} + \ldots + Risk_{process'n'} = Risk_{business}$$

# Measuring the Likely Risk Reduction from doing a Mitigation Activity

| Likelihood/Frequency of Equipment Failure Event per Year | | | | DAFT Cost per Event | $30 | $100 | $300 | $1,000 | $3,000 | $10,000 | $30,000 | $100,000 | $300,000 | $1,000,000 | $3,000,000 | $10,000,000 | $30,000,000 | $100,000,000 | $300,000,000 | $1,000,000,000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Count per Year** | **Time Scale** | **Descriptor Scale** | | | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 |
| 100 | Twice per week | | | L13 | H | H | H | E | E | E | E | E | E | E | E | E | E | E | E | E |
| 30 | Once per fortnight | | | L12 | M | M | M | M | H | E | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | E | E | E | E | E |
| 10 | Once per month | Certain | | L11 | L | L | L | L | M | H | E | E | E | E | [illegible] | E | E | E | E | E |
| 0.3 | Once per quarter | | | L10 | | | | | L | M | H | E | E | [illegible] | [illegible] | E | E | E | E | E |
| 1 | Once per year | Almost Certain | Event will occur on an annual basis | L9 | | | | | | L | M | H | E | [illegible] | E | E | E | E | E | E |
| 0.3 | Once every 3 years | Likely | Event has occurred several times or more in a lifetime career | L8 | | | | | | | L | M | [illegible] | E | E | E | E | E | E | E |
| 0.1 | Once per 10 years | Possible | Event might occur once in a lifetime career | L7 | | | | | | | | [illegible] | [illegible] | H | E | E | E | E | E | E |
| 0.03 | Once per 30 years | Unlikely | Event does occur somewhere from time to time | L6 | | | | | | | | [illegible] | L | M | H | E | E | E | E | E |
| 0.01 | Once per 100 years | Rare | Heard of something like it occurring elsewhere | L5 | | | | | | | | | | L | M | H | E | E | E | E |
| 0.003 | Once every 300 years | | | L4 | | | | | | | | | | | L | M | H | E | E | E |
| 0.001 | Once every 1,000 years | Very Rare | Never heard of this happening | L3 | | | | | | | | | | | | L | M | H | E | E |
| 0.0003 | Once every 3,000 years | | | L2 | | | | | | | | | | | | | L | M | H | E |
| 0.0001 | Once every 10,000 years | Almost Incredible | Theoretically possible but not expected to occur | L1 | | | | | | | | | | | | | | L | M | H |

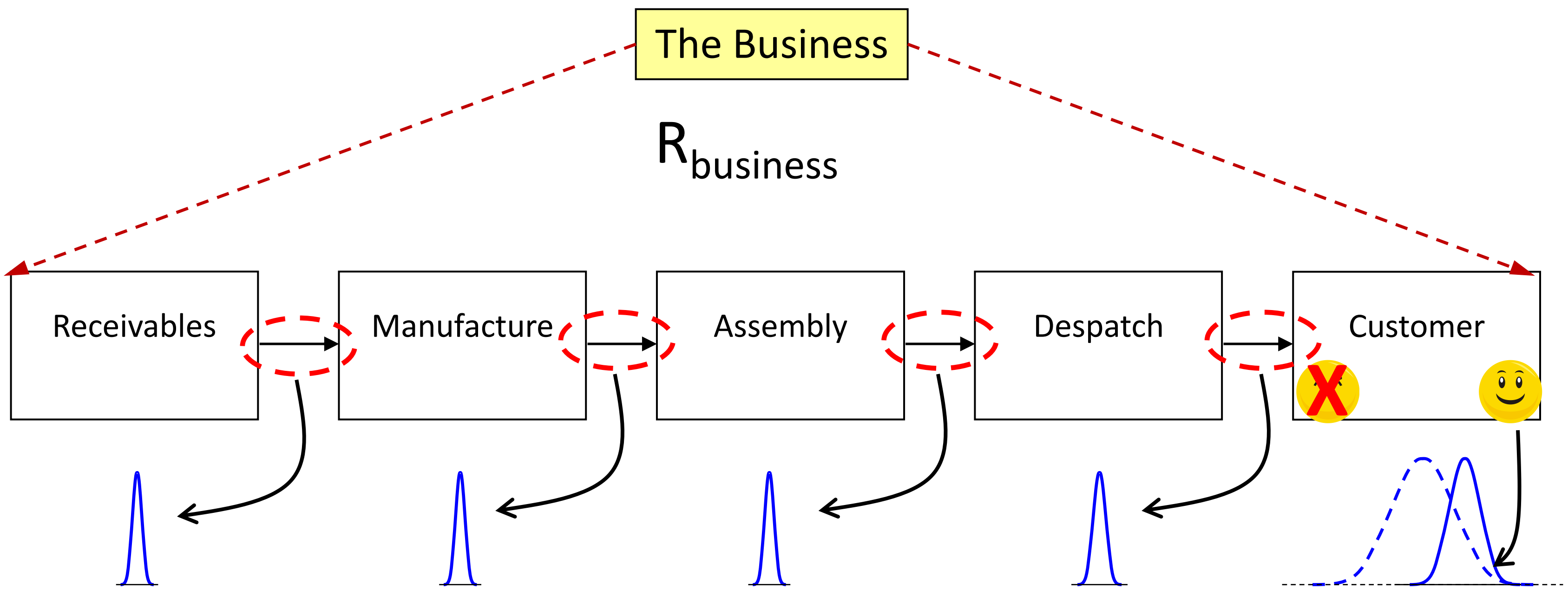
Consequence Reductio
Frequency Reduction
Money Saved by a Mitigation

**Note:** **Risk Level**

- Red = Extreme
- Amber = High
- Yellow = Medium
- Green = Low
- Blue = Accepted

1) Risk Boundary is adjustable and selected to be at 'LOW' Level. Recalibrate the risk matrix to a company's risk boundaries by re-colouring the cells to suit.
2) Based on HB436:2004-Risk Management
3) Identify 'Black Swan' events as B-S (A 'Black Swan' event is one that people say 'will not happen' because it has not yet happened)
4) Low level is calibrated at $10,000 per year per event

# Reducing Businesses Process Risk




$$Risk_{process1} + Risk_{process2} + \ldots + Risk_{process'n'} = Risk_{business}$$