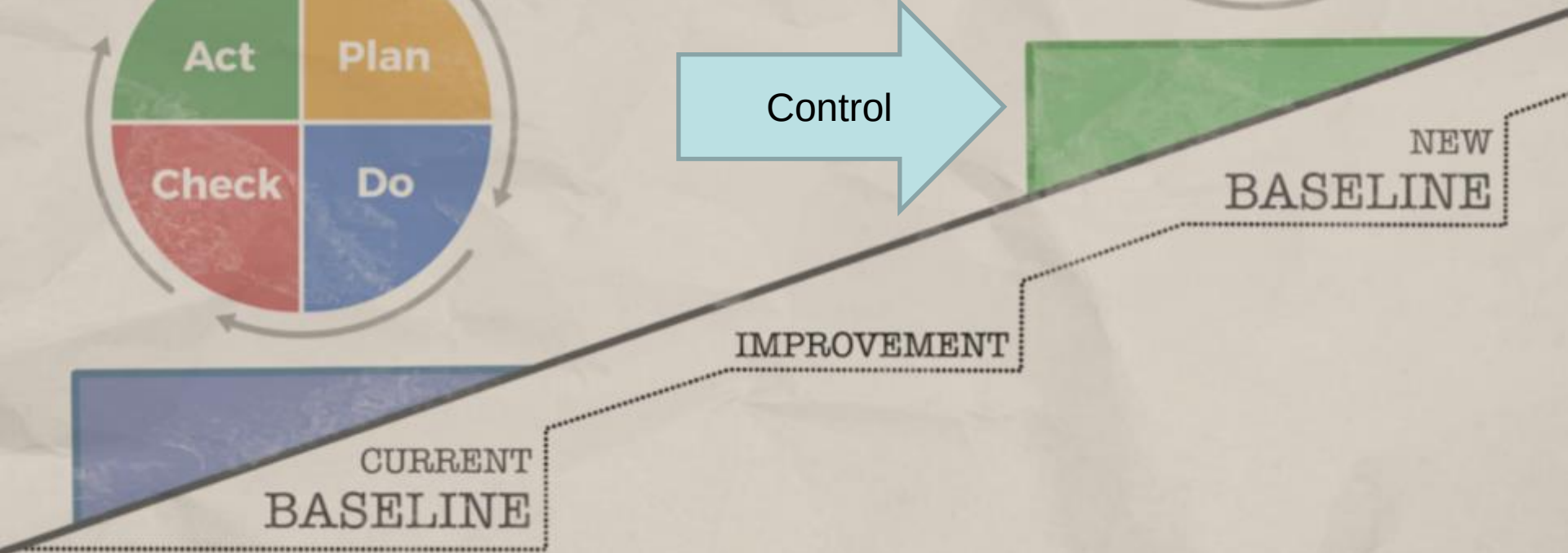
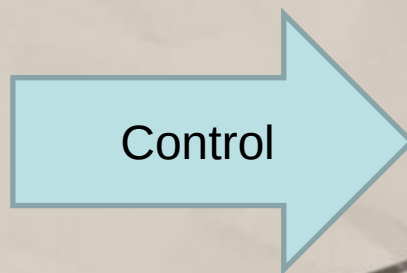




Level 5 – Continuous Improvement with Industry 4.0

Control 2 – Control Charts





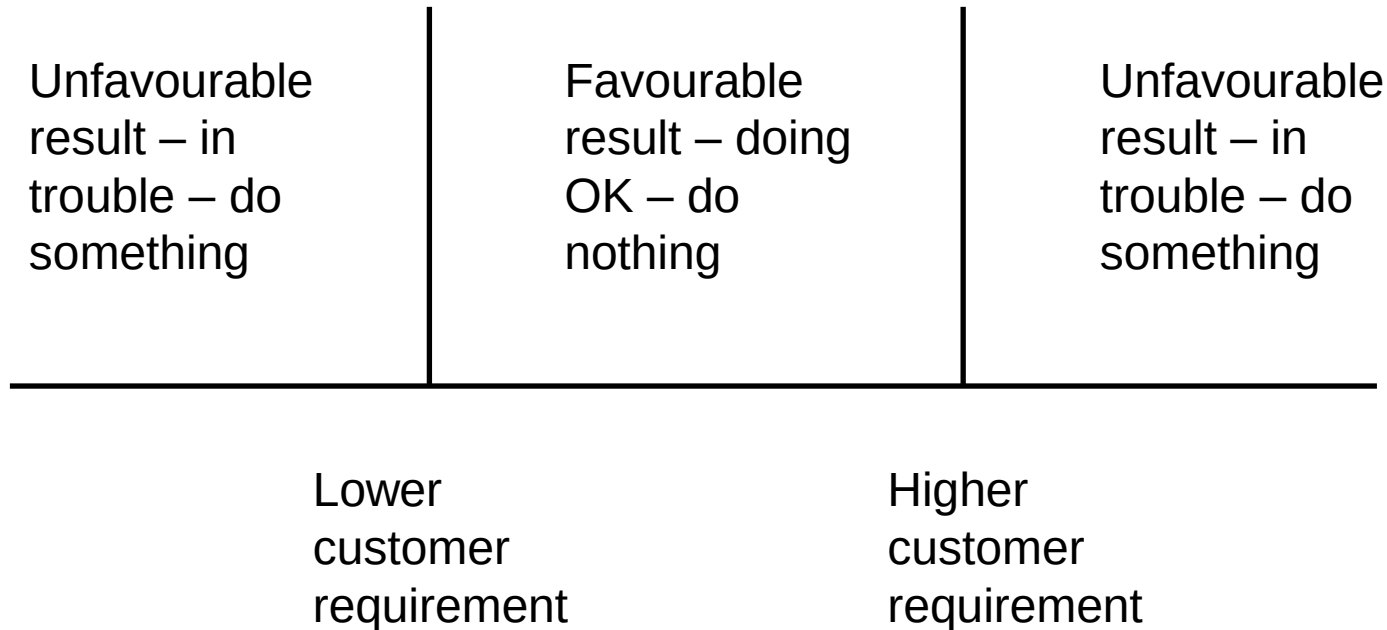
There are two methods for interpreting data within a manufacturing environment:-

The Specification Value approach (VoC)

Shewharts Control Chart approach (Voice of the Process)



The Specification Value approach (VoC)



Measure - Standard Deviation

Consider a sample of 5 data points; 6.5, 7.5, 8.0, 7.2, 6.8

The **Range** is the highest minus the lowest; $8.0 - 6.5 = 1.5$

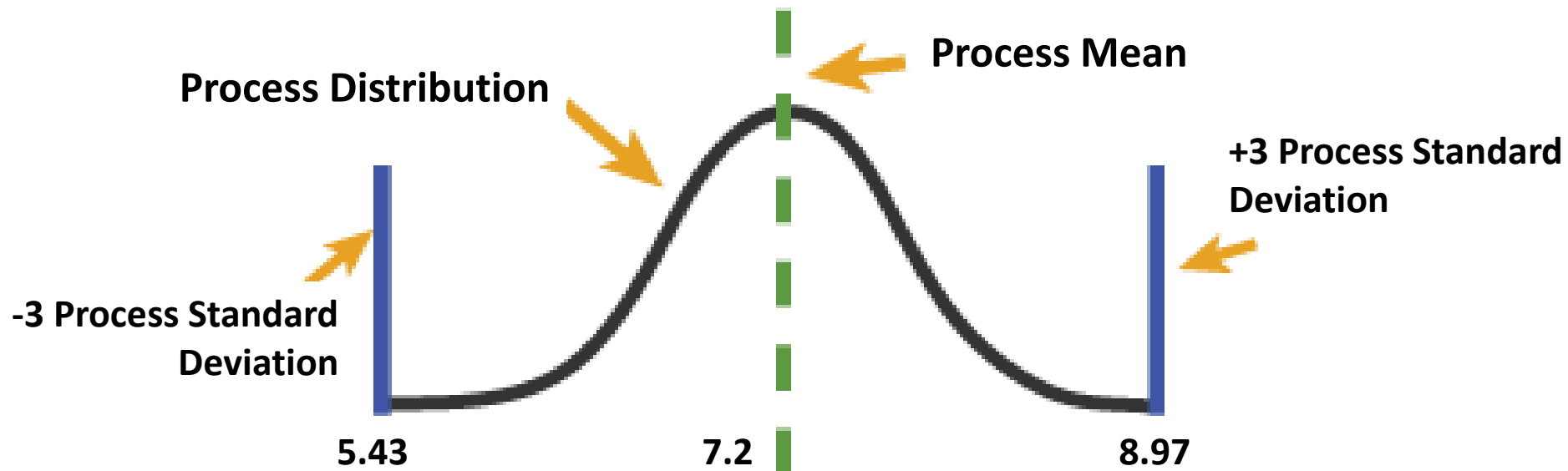
The **Mean** (X-bar) is 7.2

The Standard Deviation is

$$stdev = \sqrt{\frac{(6.5 - 7.2)^2 + (7.5 - 7.2)^2 + (8.0 - 7.2)^2 + (7.2 - 7.2)^2 + (6.8 - 7.2)^2}{5 - 1}}$$

$$stdev = 0.59$$

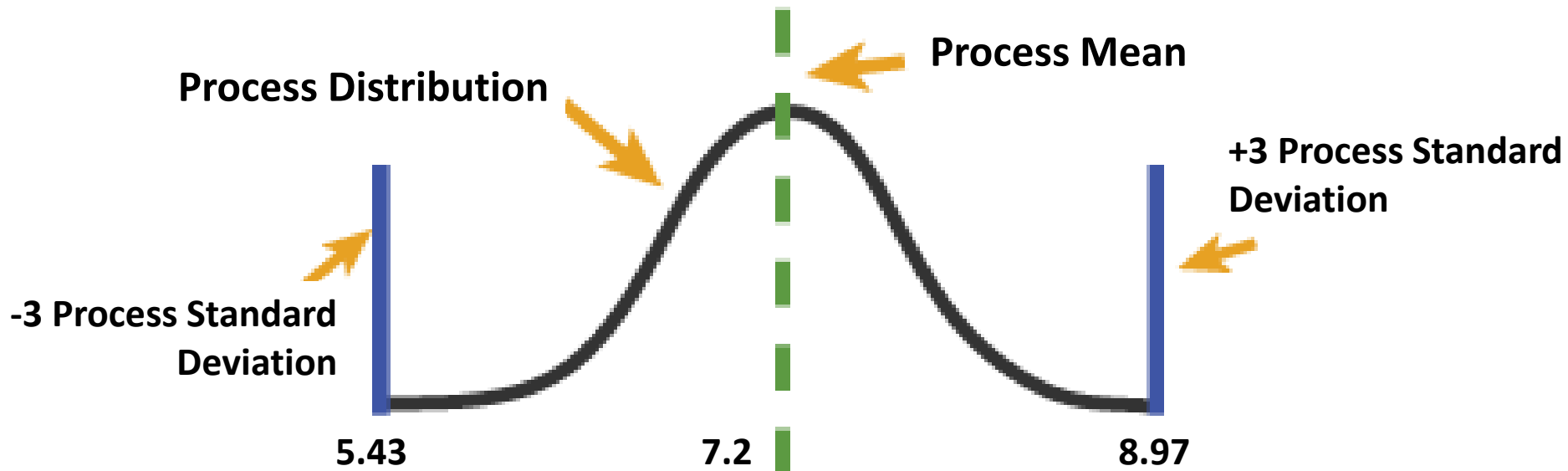
- Statistical tables have been developed for various types of distributions that quantify the area under the curve for a given number of standard deviations from the mean.
- Shewhart found that control limits placed at three standard deviations from the mean in either direction provide an economical trade-off between the risk of reacting to a false signal and the risk of not reacting to a true signal.



Measure - 3 Standard Deviations

- We want to calculate three-sigma, which is three standard deviations above the mean.
- $3 \times \text{STDEV} + \text{Mean}$
- ***stdev* = 0.59**
→ $(3 \times 0.59) + 7.2 = 8.97$

- The illustration below shows a normal curve for a distribution with a mean of 7.2, a mean less 3 standard deviations value of 5.43, and a mean plus 3 standard deviations value of 8.97. Values, or measurements, less than 5.43 or greater than 8.97 are extremely unlikely.
- These laws of probability are the foundation of the control chart.

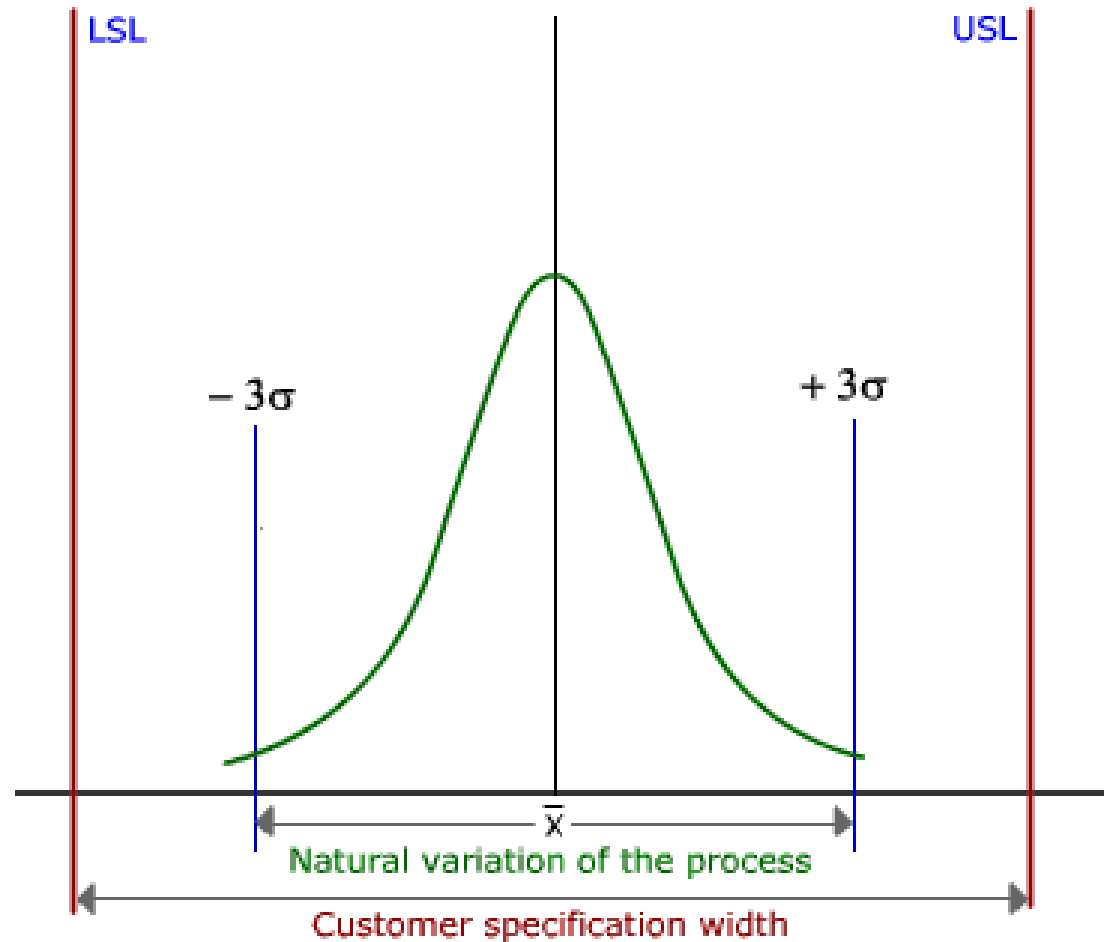


Control limits, are the 'Voice of the Process' Identified as;

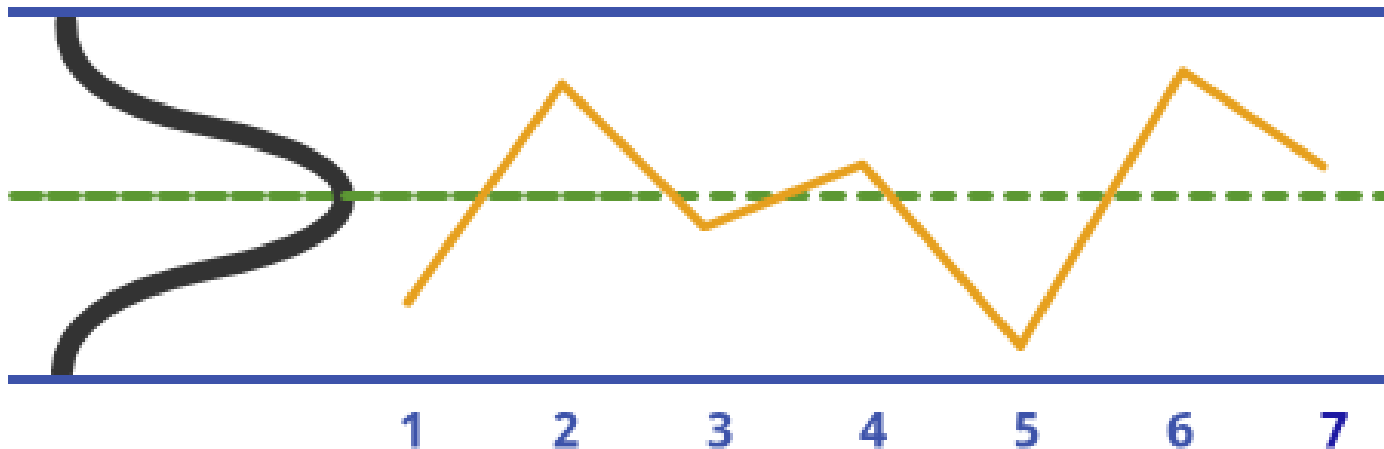
- Upper and Lower Control Limits

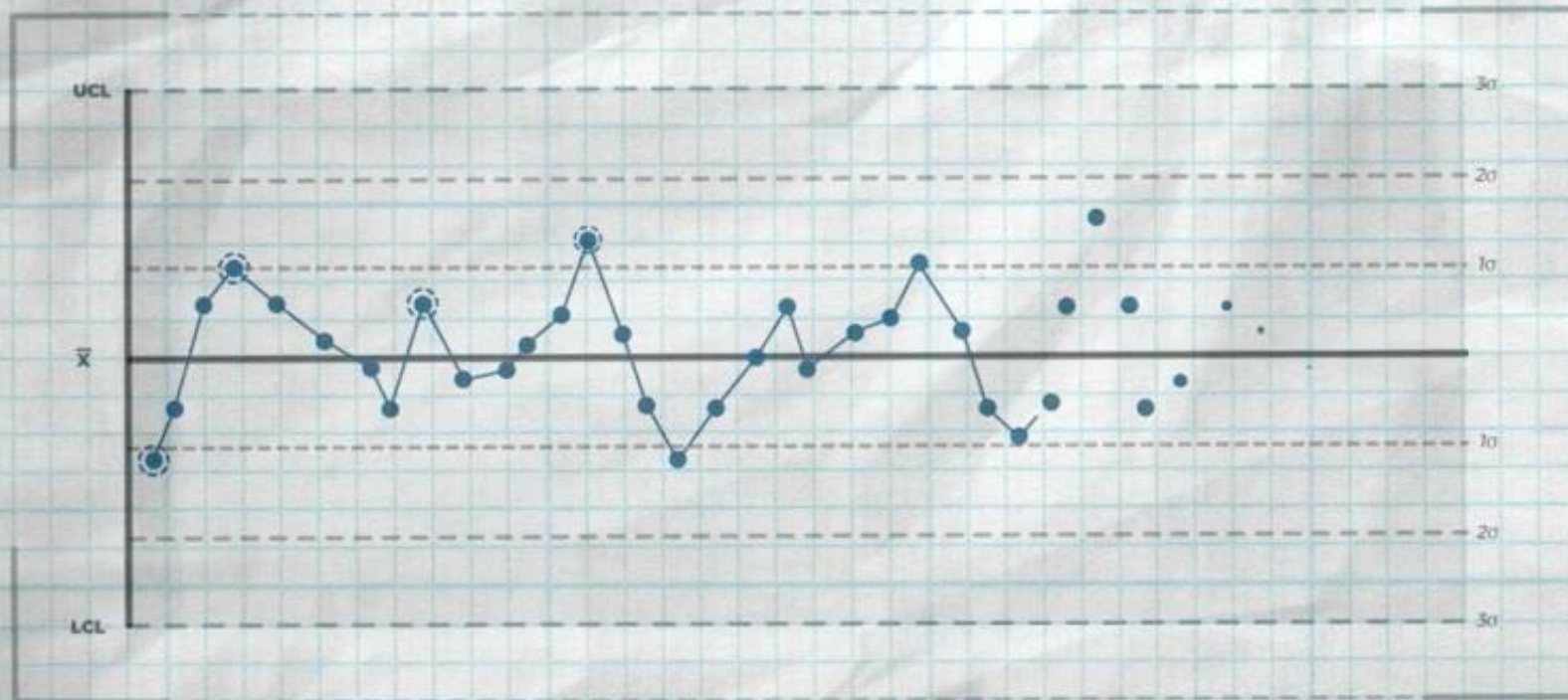
Tolerances are part of the Customer specification, and therefore the 'Voice of the Customer' Identified as;

- Upper and Lower Specification Limits (LSL & USL)



- Consider that the distribution is turned sideways, and the lines denoting the mean and ± 3 standard deviations are extended.
- This construction forms the basis of the Control chart.
- Time series data plotted on this chart can be compared to the lines, which now become control limits for the process.
- Comparing the plot points to the control limits allows a simple probability assessment.



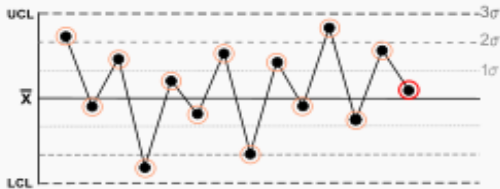
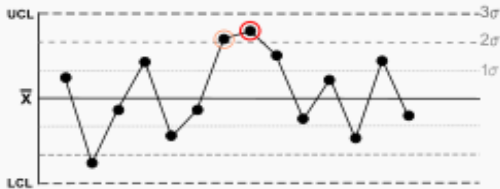
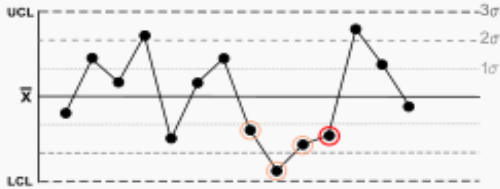


NELSON'S RULES

Nelson's Rules 1 to 3

Rule	Description	Chart Example	Problem Indicated
Rule 1	One point is more than 3 standard deviations from the mean.	Rule 1: One point is more than 3 standard deviations from the mean	One sample (two shown in this case) is grossly out of control.
Rule 2	Nine (or more) points in a row are on the same side of the mean.	Rule 2: Nine (or more) points in a row are on the same side of the mean	Some prolonged bias exists.
Rule 3	Six (or more) points in a row are continually increasing (or decreasing).	Rule 3: Six (or more) points in a row are continually increasing (or decreasing)	A trend exists.

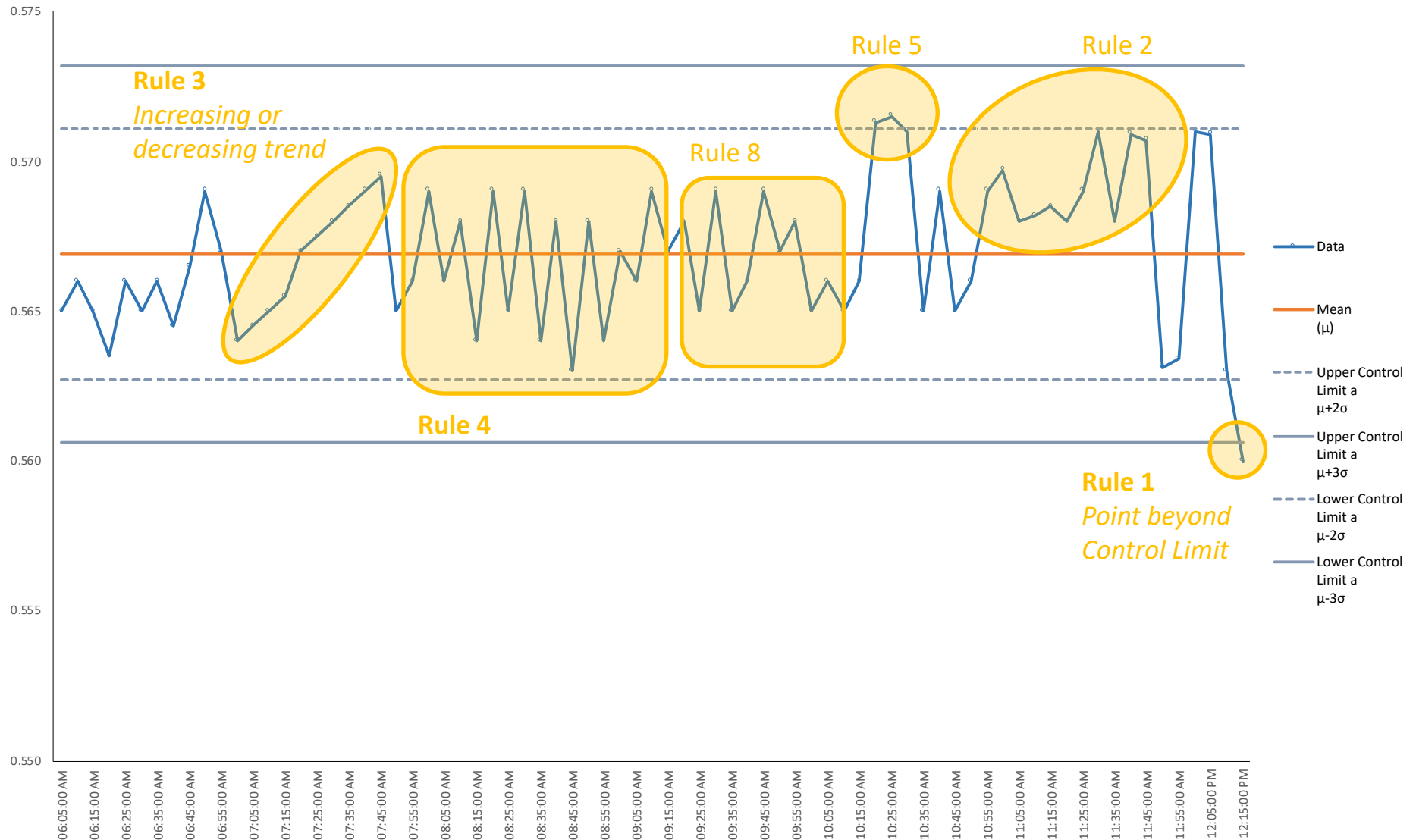
Nelson's Rules 4 to 6

Rule 4	Fourteen (or more) points in a row alternate in direction, increasing then decreasing.	Rule 4: Fourteen (or more) points in a row alternate in direction, increasing then decreasing 	This much oscillation is beyond noise. This is directional and the position of the mean and size of the standard deviation do not affect this rule.
Rule 5	Two (or three) out of three points in a row are more than 2 standard deviations from the mean in the same direction.	Rule 5: Two (or three) out of three points in a row are more than 2 standard deviations from the mean in the same direction 	There is a medium tendency for samples to be mediumly out of control. The side of the mean for the third point is unspecified.
Rule 6	Four (or five) out of five points in a row are more than 1 standard deviation from the mean in the same direction.	Rule 6: Four (or five) out of five points in a row are more than 1 standard deviation from the mean in the same direction 	There is a strong tendency for samples to be slightly out of control. The side of the mean for the fifth point is unspecified.

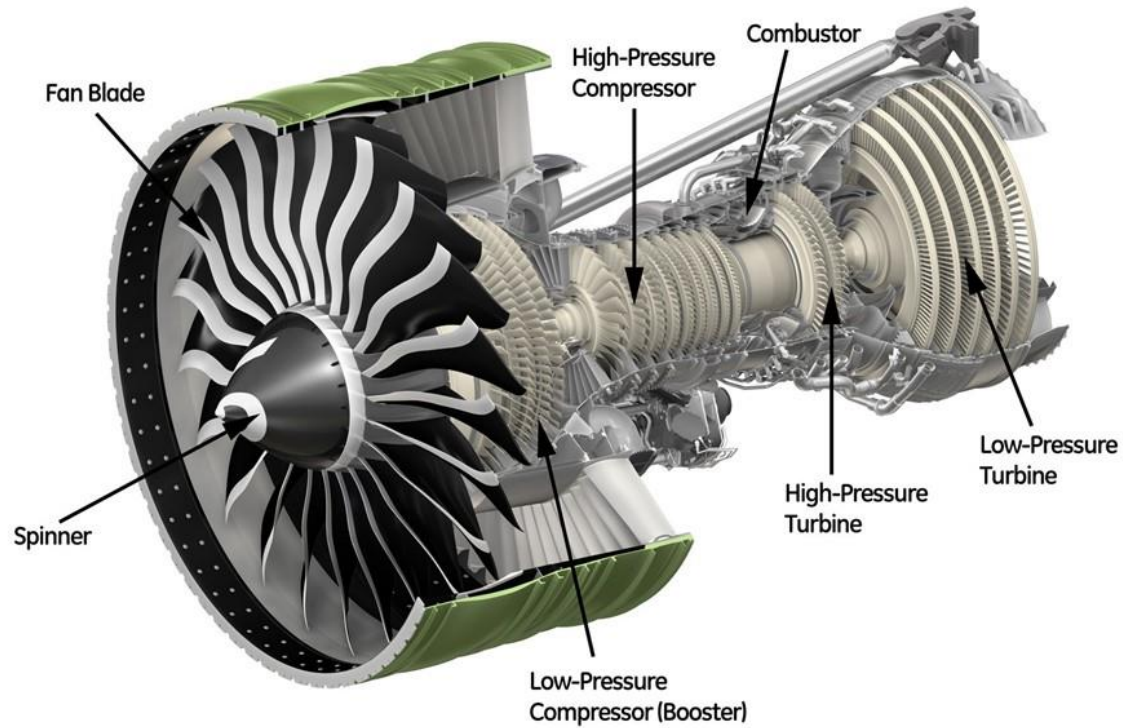
Nelson's Rules 7 and 8

Rule 7	Fifteen points in a row are all within 1 standard deviation of the mean on either side of the mean.	Rule 7: Fifteen points in a row are all within 1 standard deviation of the mean on either side of the mean	With 1 standard deviation, greater variation would be expected.
Rule 8	Eight points in a row exist with none within 1 standard deviation of the mean and the points are in both directions from the mean.	Rule 8: Eight points in a row exist with none within 1 standard deviation of the mean and the points are in both directions from the mean	Jumping from above to below whilst missing the first standard deviation band is rarely random.

Control Chart



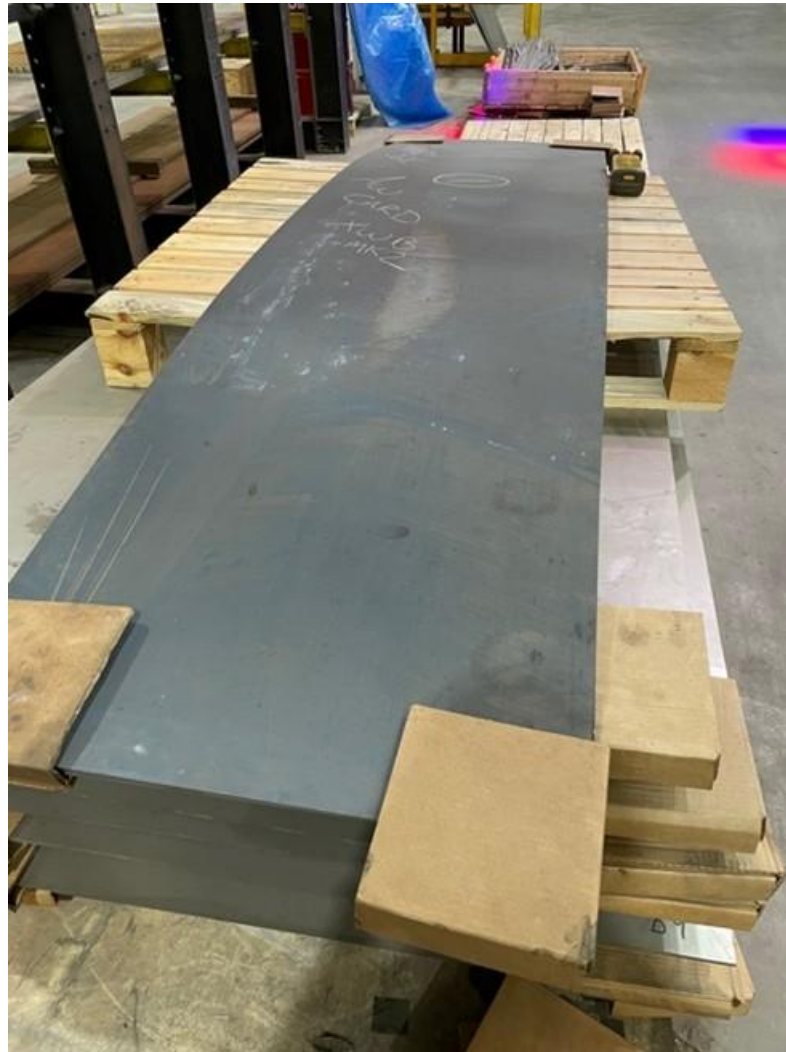
Control Chart – Case Study



[This Photo](#) by Unknown Author is licensed under [CC BY-SA](#)

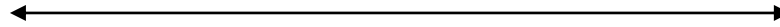
- Component sheared to length/width from mother-sheet
- 4 more value added processes undertaken until final inspection
- Approximately 10% of products rejected at FI for under- length/width (over-length/width may be re-sheared to size)

Control Chart – Case Study

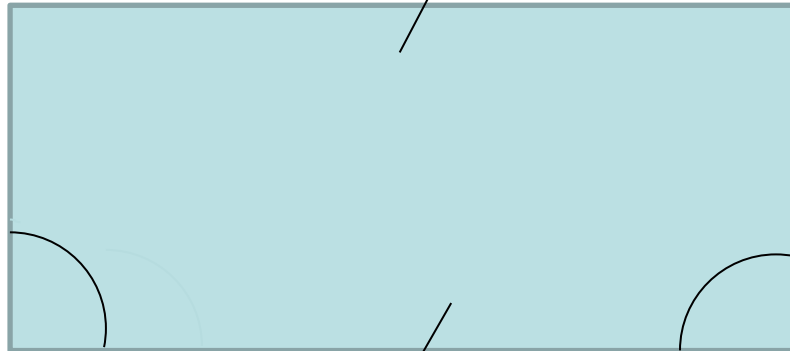


Control Chart – Case Study

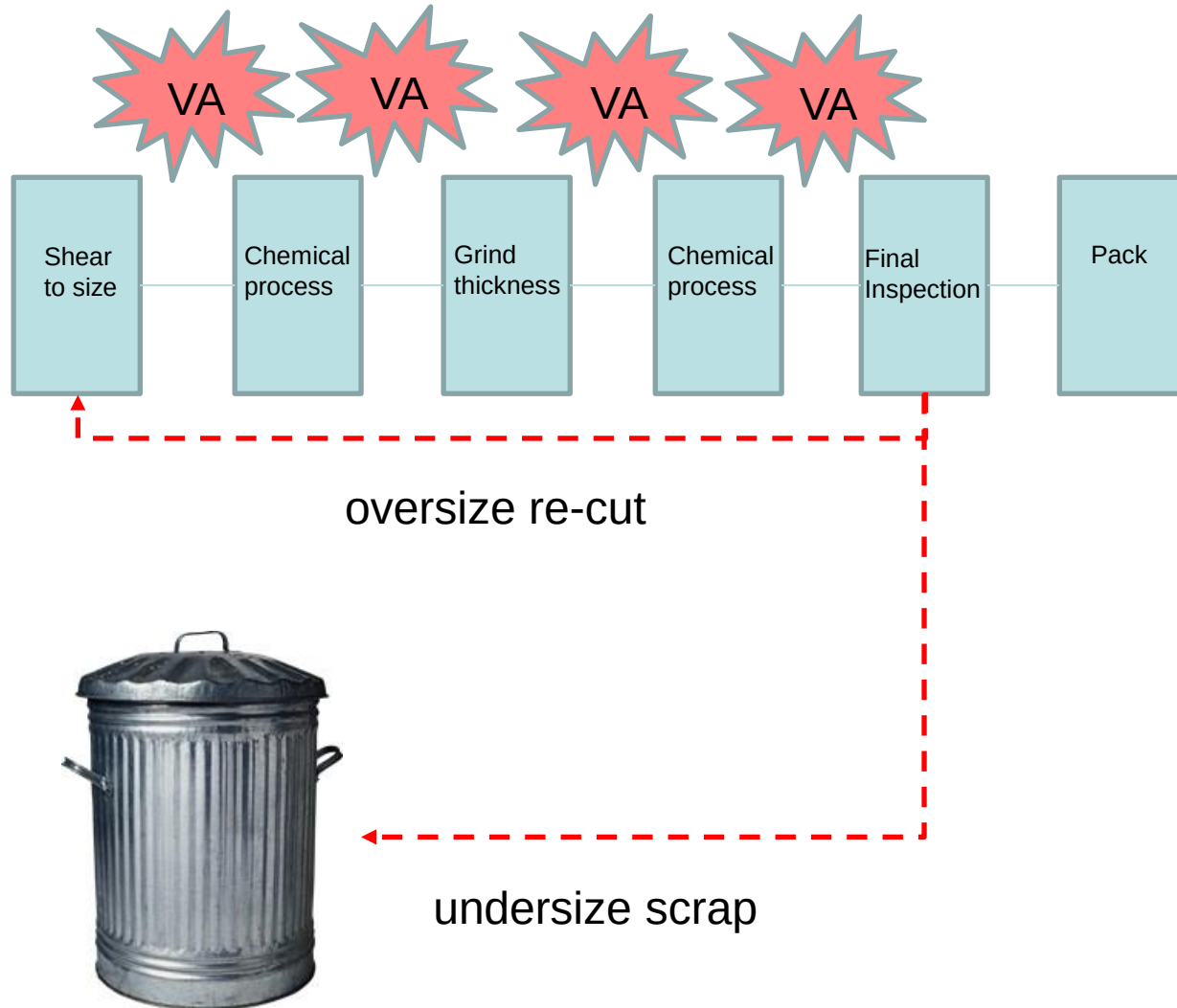
Length typically 850 -1200mm +/- 1.0



Width typically
500 - 600 mm +/-
1.0

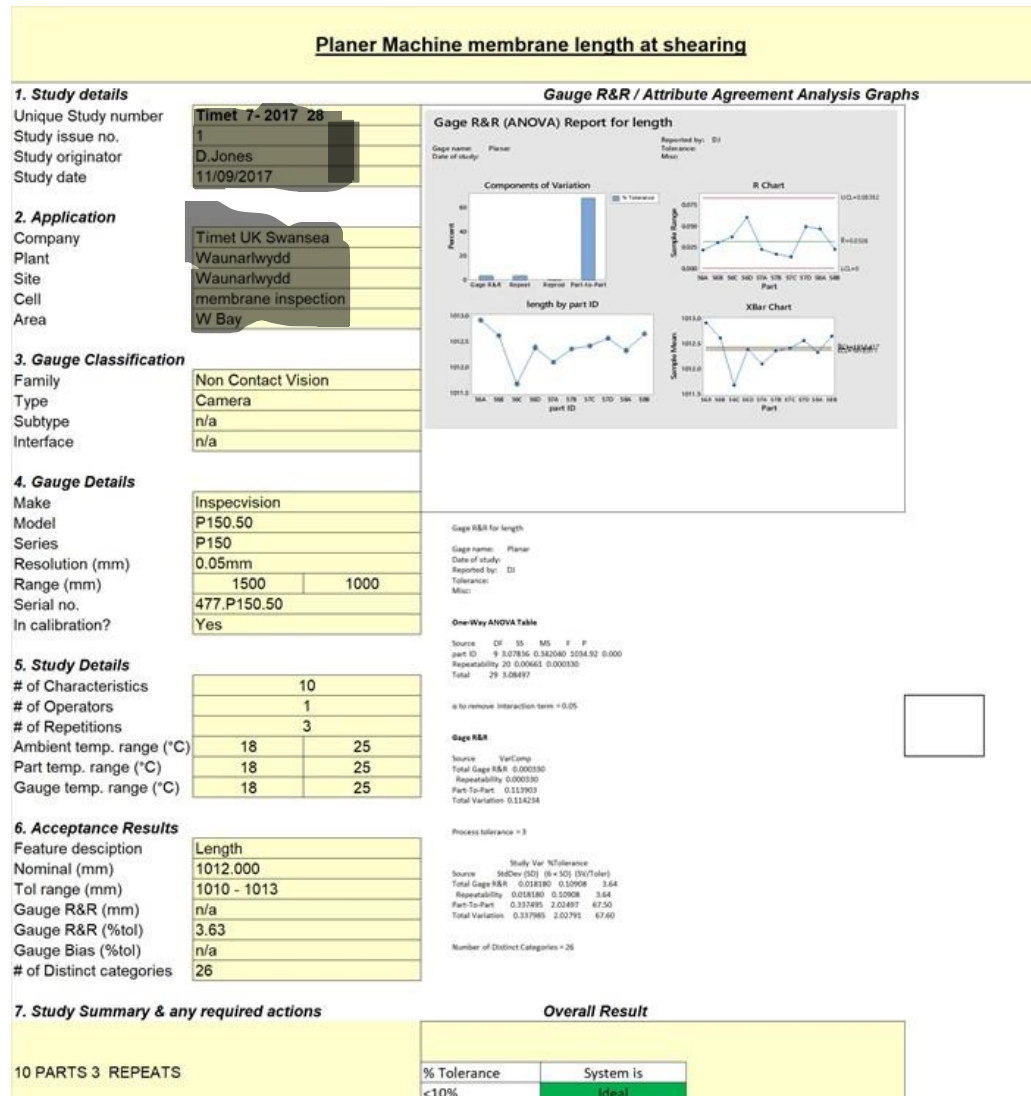


Control Chart – Case Study



- Capital case approved for new shears and visual inspection system to confirm conforming dimensions
- System commissioned and MSA undertaken on all key process characteristics
- Final Inspection of these characteristics removed

Control Chart – Case Study

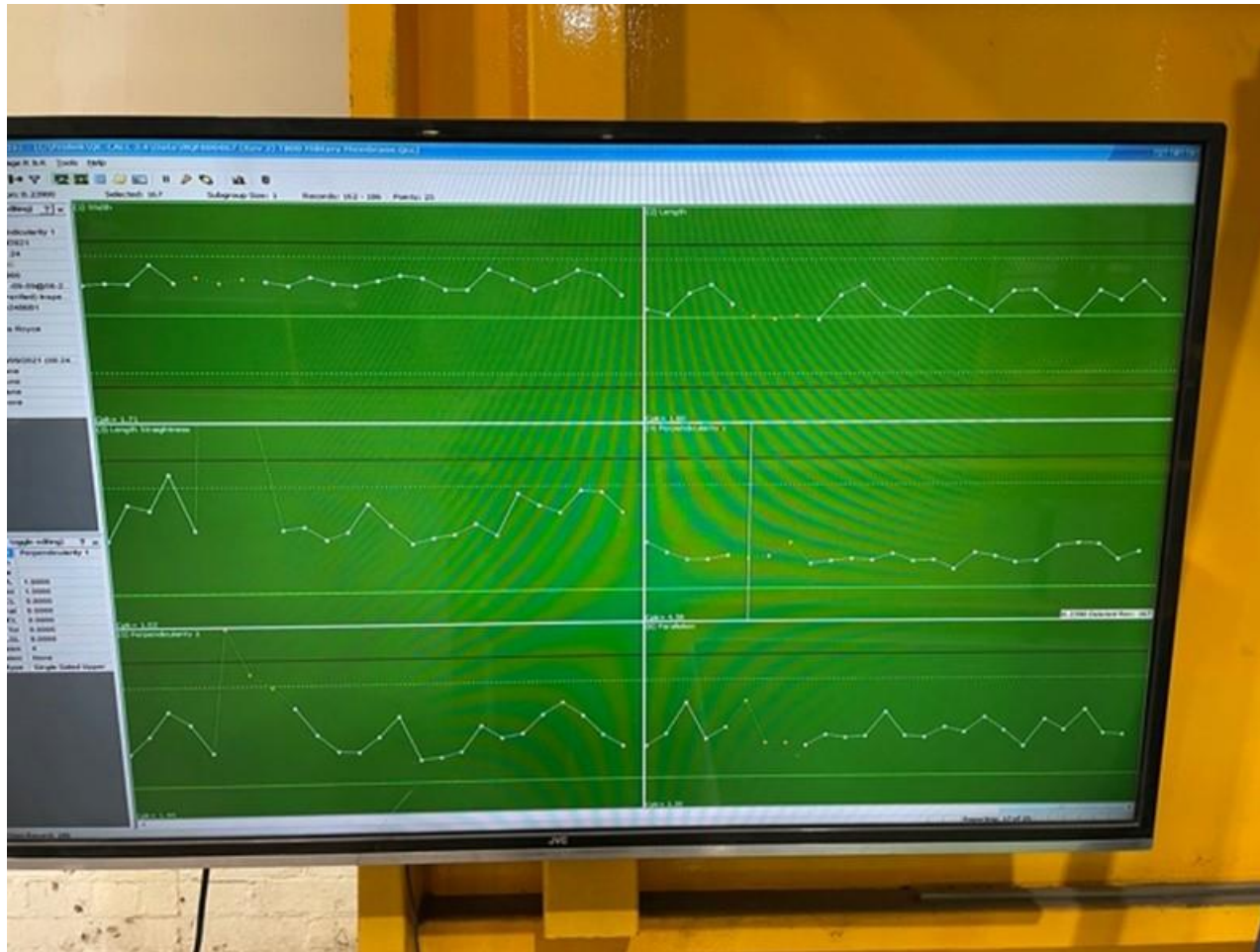


Control Chart – Case Study



- Only one mother-sheet sheared before measuring the two child panels
- Final inspection of the characteristics removed from final inspection – now only gauge and surface finish checked
- Automatic report generated for each panel
- Process control visible to all walking through the bay

Control Chart – Case Study





Level 5 – Continuous Improvement with Industry 4.0

Control 2 – Lessons Learnt/Recognition

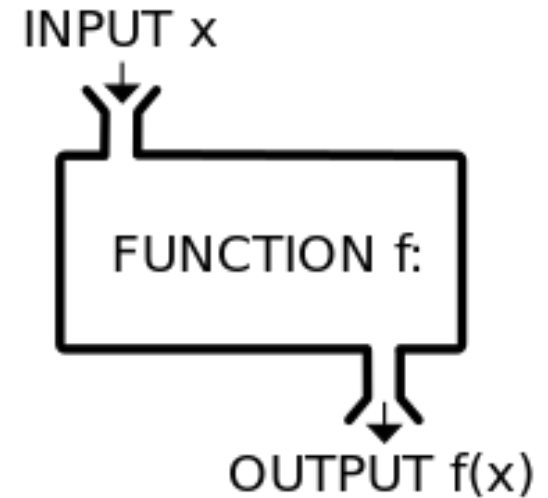
- Review the project
- Did the results meet the aims/targets of the project charter?
- If not, what were the issues around this
(i.e. scope, timings, resource allocation,
buy-in, application of tools, skills gap,)
- What will we do differently next time?

- Sometimes a simple verbal thank you will do
- An E-mail to the recipient will can be a more formal way of communicating – cc their boss too!
- Larger projects may require a more appropriate event
- Communicate success to the larger work environment – fly sheets, newsletter etc
- Don't forget it is always about people and how we interact and treat each other

$$Y = (f) X$$

$$Y = (f) X$$

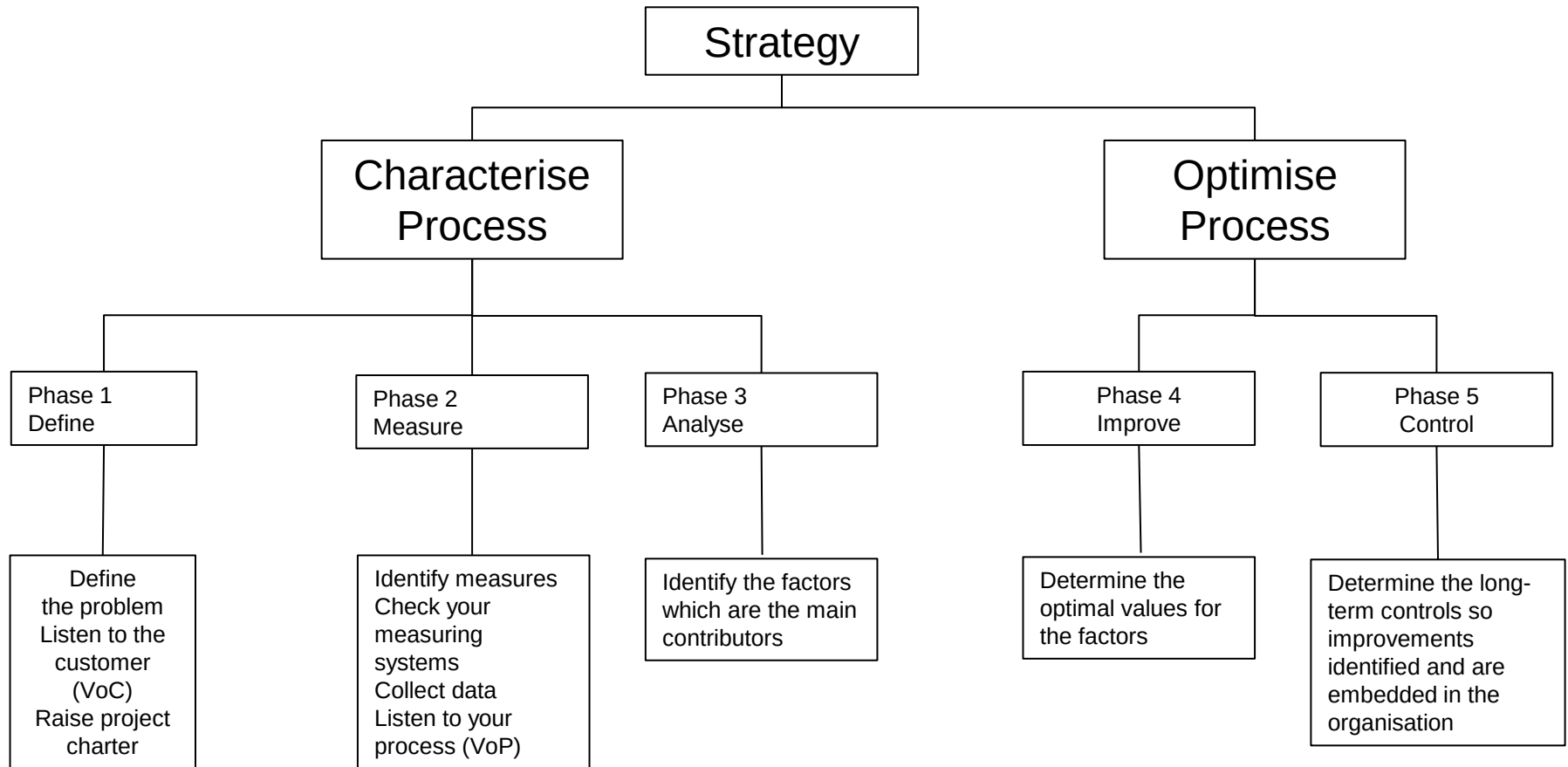
Outcome **Y** = (Function **f**) Output **X**



Level 5 – Inputs/Outputs

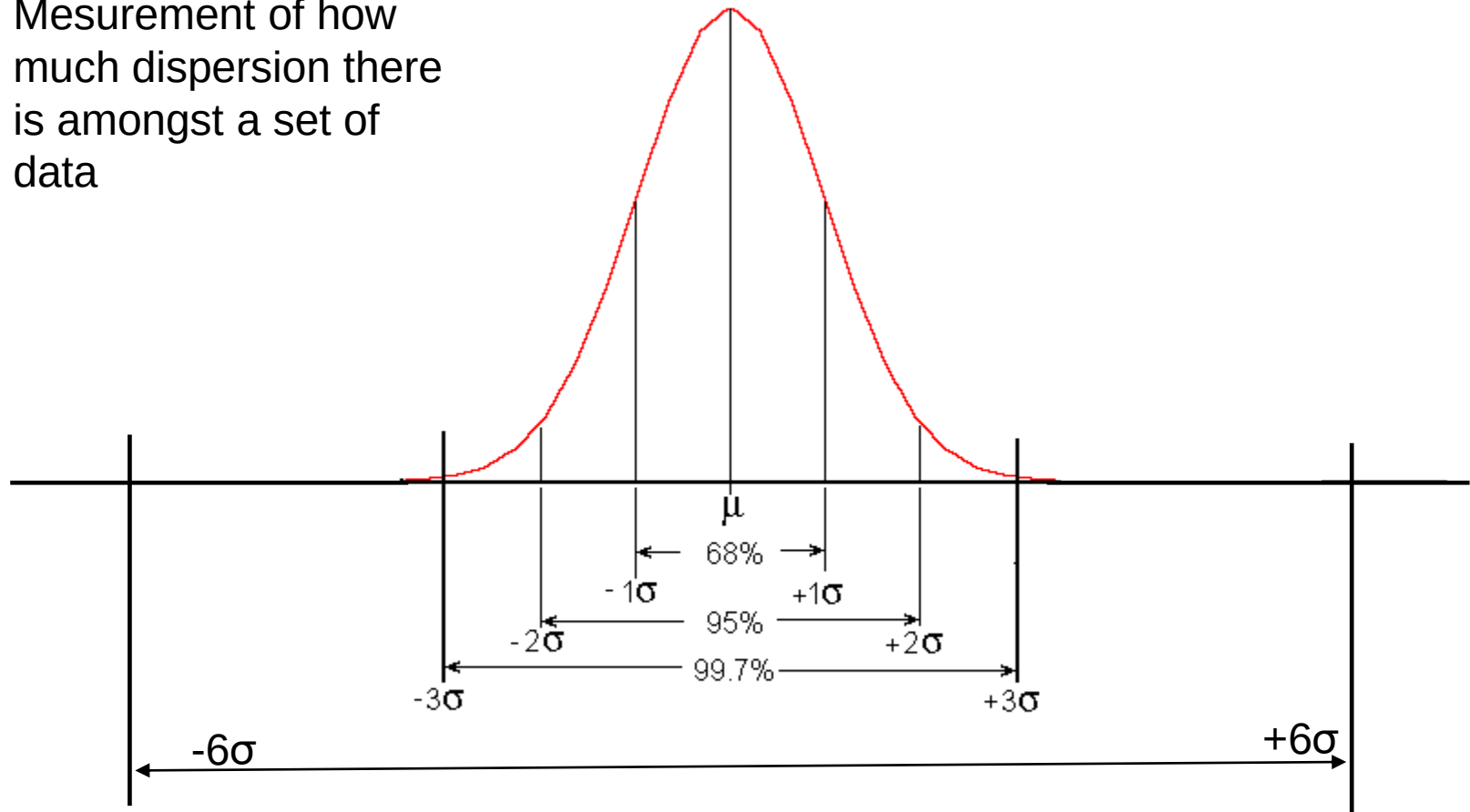
MADE





Level 5 – Capability

σ = standard deviation
Measurement of how
much dispersion there
is amongst a set of
data



99.99966% (3.4 defects / 1,000,000 opportunities)

- Mean, Mode, Median, Range, Variance and Standard Deviation
- Testing for Normality
- 2 Sample T Tests
- Analysis of Variance (ANOVA)
- Correlation
- Regression

Where do we think we are?

- No data or experience – all we can offer is an opinion
- No data – we use our experience to get through
- Some data - data collected we just look at the numbers
- Grouped data - basic charts and diagrams
- Descriptive statistics - mean, median, mode, Std Dev etc
- Characterising statistics - Cp, Cpk,
- Control statistics - SPC charts
- Inferential statistics - normality, regression, DOE etc

Go to www.menti.com and use the code 5499 3084



Improve /Control Quiz

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University of Wales
Trinity Saint David



Define

Measure

Analyse

Improve

Control

Team Project

Project Definition

Oct 22

Nov –
Dec 22

Jan 23

Feb 22

Mar 23

End Apr
Final
Review



Forthcoming Events

For your diaries:-

Test #2

Friday 31st March (covering complete course materials)

Open from 1pm on the Friday – close midnight following Monday

1 hour duration, multi-choice (approx. 40 questions)

Project Reviews

21/4/23 - 08:30 – 12:00

28/4/23 - 08:30 – 12:00

30 mins – 5 mins each phase, 5 mins Q&A

I Keep Six Honest Serving-Men

by Rudyard Kipling

I Keep six honest serving-men:
(They taught me all I knew)
Their names are What and Where and When
And How and Why and Who.