National Physical Laboratory

Evaluating the Measurement Process

3DMC Conference

Aachen

23rd November, 2016

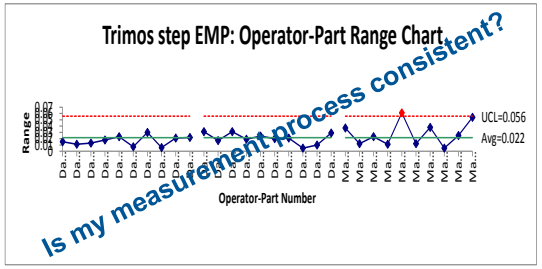
Geraint W Jones – Senior NPL Product Verification Specialist

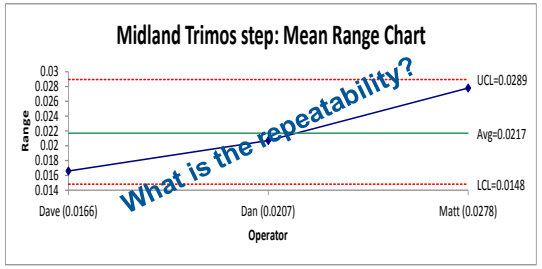
Evaluating the Measurement Process (EMP)

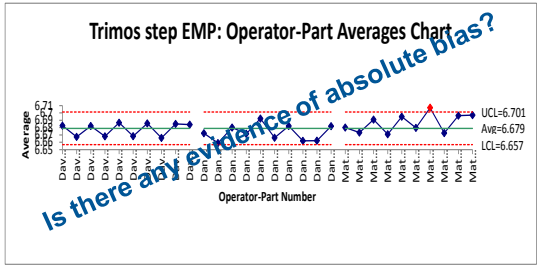
- The term describes data analysis tools which help to establish and optimise measurement processes
- The original tools emerged formally in the early 1960's and were sponsored and promoted by the Automotive Industry in the US
- The tools and approaches have evolved over the years and there are two distinct approaches in existence today, namely from the Automotive Industry Action Group (AIAG) and EMP (Evaluating the Measurement Process)
- EMP, which has some cross over to AIAG was developed by Donald J Wheeler and Richard Lyday in the early 1980's, whilst Measurement Systems Analysis (MSA) is the term which is used by the AIAG to described their approach

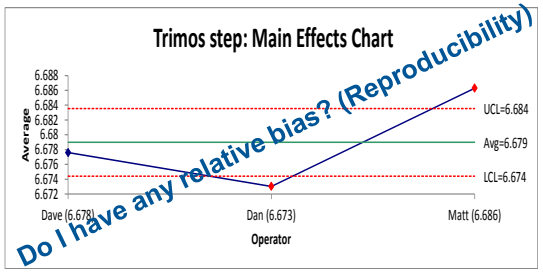
Many people are aware of the term MSA but for completeness and clarity of thought both EMP and MSA will be referenced in this presentation

EMP/MSA Techniques– Questions which can be answered









% Mfg. Specs	*Mfg. LSL*	*Mfg. USL*	*Consumed by Repeatability*	*Consumed by R&R*	*Diff.*
85.0%	-0.9918	0.0918	1.57%	1.75%	0.18%
96.0%	-0.9832	0.0832	3.14%	3.50%	0.36%
99.0%	-0.9745	0.0745	4.71%	5.26%	0.54%
99.9%	-0.9659	0.0659	6.29%	7.01%	0.72%

How much of the manufacturing specification is my measurement process consuming?

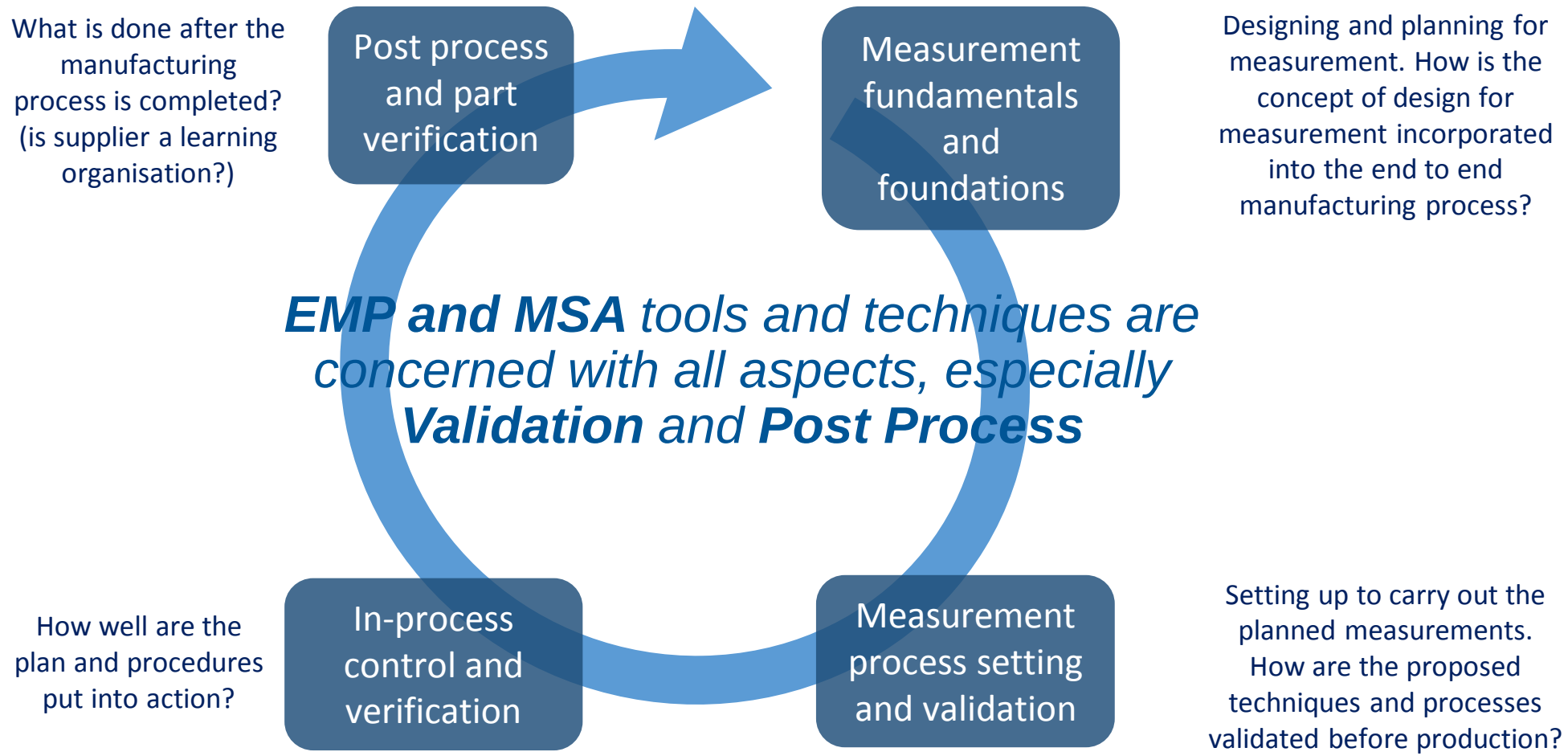
Intraclass Correlation	Type of Monitor	Reduction of Process Signal	Chance of Detecting ± 3 Std. Error Shifts	Ability to Track Process Improvements
0.8 to 1.0	First Class Monitor	Less than 10%	>99% with Rule 1	
0.5 to 0.8	Second Class Monitor	From 10% to 30%	>88% with Rule 1	
0.2 to 0.5	Third Class Monitor	From 30% to 55%	>91% with Rules 1, 2, 3, & 4	Up to Cp20 = 12.79
0.0 to 0.2	Fourth Class Monitor	Greater than 55%	Rapidly Vanishes	Unable to Track

Can I detect any variation in my manufacturing process using this measurement system?

Where do EMP/MSA Processes sit?

A Product Verification process defines all the processes which collectively combine to ensure that a manufactured product conforms to design intent

A diagnostic model for assessing the effectiveness of measurement systems and processes can be described via 4 main activities and constituent processes;



NPL work on EMP/MSA

Current

- Knowledge transfer to 40 + aerospace companies
- 10% classroom 90% applied informal training
- Assistance with data analysis
- Full range of EMP/MSA Tools used
- Studies range from simple to relatively complex

Future

- Workshops to promote best practice with experts
- Validate mathematical principles and assumptions
- Best Practice Documentation
- Apply to other sectors of manufacturing
- Influence and participate in standards

Continue to transfer the appropriate knowledge including the tools and techniques as a viable and essential means with which to establish, maintain and improve manufacturing processes

Status of EMP/MSA at Aerospace Suppliers

- Little or no formal training in this subject is apparent
- The spreadsheet or software is the process. Poor inputs = Poor Outputs
- Most companies perform the minimum required and concentrate on just the consumption of tolerance as an output
- The imparted knowledge has been instrumental in enabling suppliers to engage more completely with their customers
- Perceived as a subject which requires specialist knowledge…bring in Six Sigma Black Belts, difficult to get senior sponsorship

EMP/MSA is data analysis and there are some fundamental rules which need respecting in order to make sense of a data set

Underlying Fundamentals of EMP/MSA

National Physical Laboratory

The Homogeneity Question

Given a collection of observations, is it reasonable to assume that they come from one universe, or do they show evidence of having come from multiple universes?

Descriptive statistics, probability theory and statistical inference largely a single universe but in the real world we cannot make this assumption

Homogeneity – The Data Analysis Approach

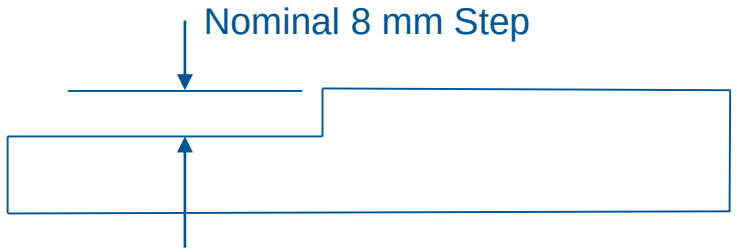
- ***Homogeneity in a measurement data stream is demonstrated when rationally sub grouped measurements plotted on an appropriate control chart are in control i.e. only random variation is present***
- ***When the data displays homogeneity the process can be characterised and decisions made with confidence about the current and future status***
- ***The notion of homogeneity as demonstrated by a control chart has synergies with SPC and it is the foundation of sound data analysis and EMP***

One of the consequences of ignoring homogeneity (which is common) is shown in the example study

Example Basic EMP/Gauge R&R Study – Method & Approach

National Physical Laboratory

Part feature to be measured



Measurement Equipment studied

- **Digital Depth Gauge**

Process detail

Depth mic had been used for this feature

No standard operating procedure for use in place

EMP/MSA study carried out on 10 parts with 3 operators. Each part feature measured 3 times.

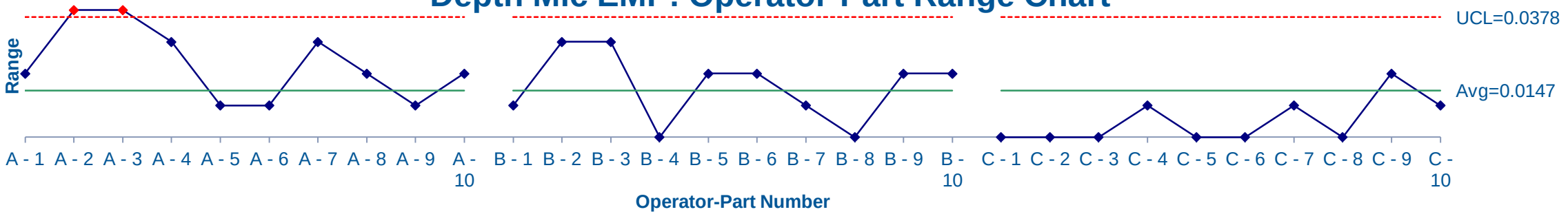
Example 1 data (to follow) depicts the ability of the measurement process to repeat. In the absence of any formal instructions the operators were each asked to measure and declare their measurements within a marked area (diameter 20 mm) on the part.

Example 2 data (to follow) is the same process except that each operator agreed to hold the gauge the same way against the part, to also approach the extending the scale and to mark the part where the measurement base was to be positioned as well as the position where the point was taken.

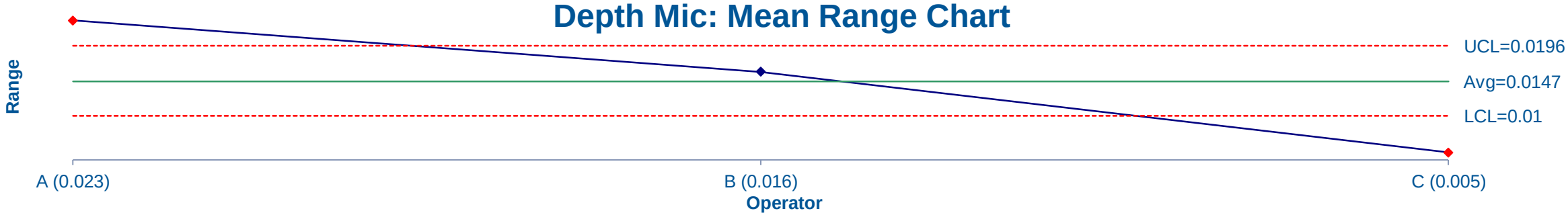
Basic EMP/Gauge R & R Study – Example 1

Specification = +/- 0.1 mm

Depth Mic EMP: Operator-Part Range Chart



Depth Mic: Mean Range Chart



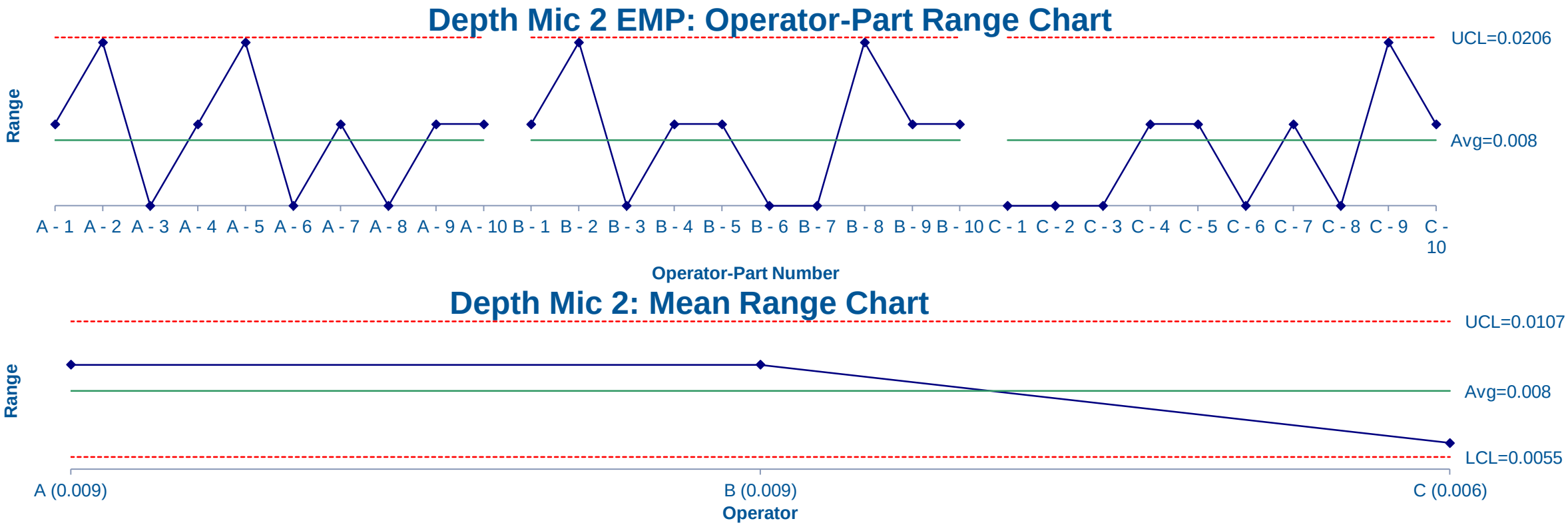
Repeatability estimate - 0.0147/1.693 = **0.008 mm**

Hypothetical Tolerance consumption due to Repeatability – (0.008 x 6) / 0.2) x 100 = **24%**

Does this process display homogeneity?

Basic EMP/Gauge R & R Study – Example 2

Specification = +/- 0.1 mm



Repeatability estimate - 0.008/1.693 = **0.004 mm**

Actual tolerance consumption due to Repeatability – (0.004 x 6) / 0.2) x 100 = **12%**

Does this process display homogeneity?

Summary of process performance for examples 1 and 2

National Physical Laboratory

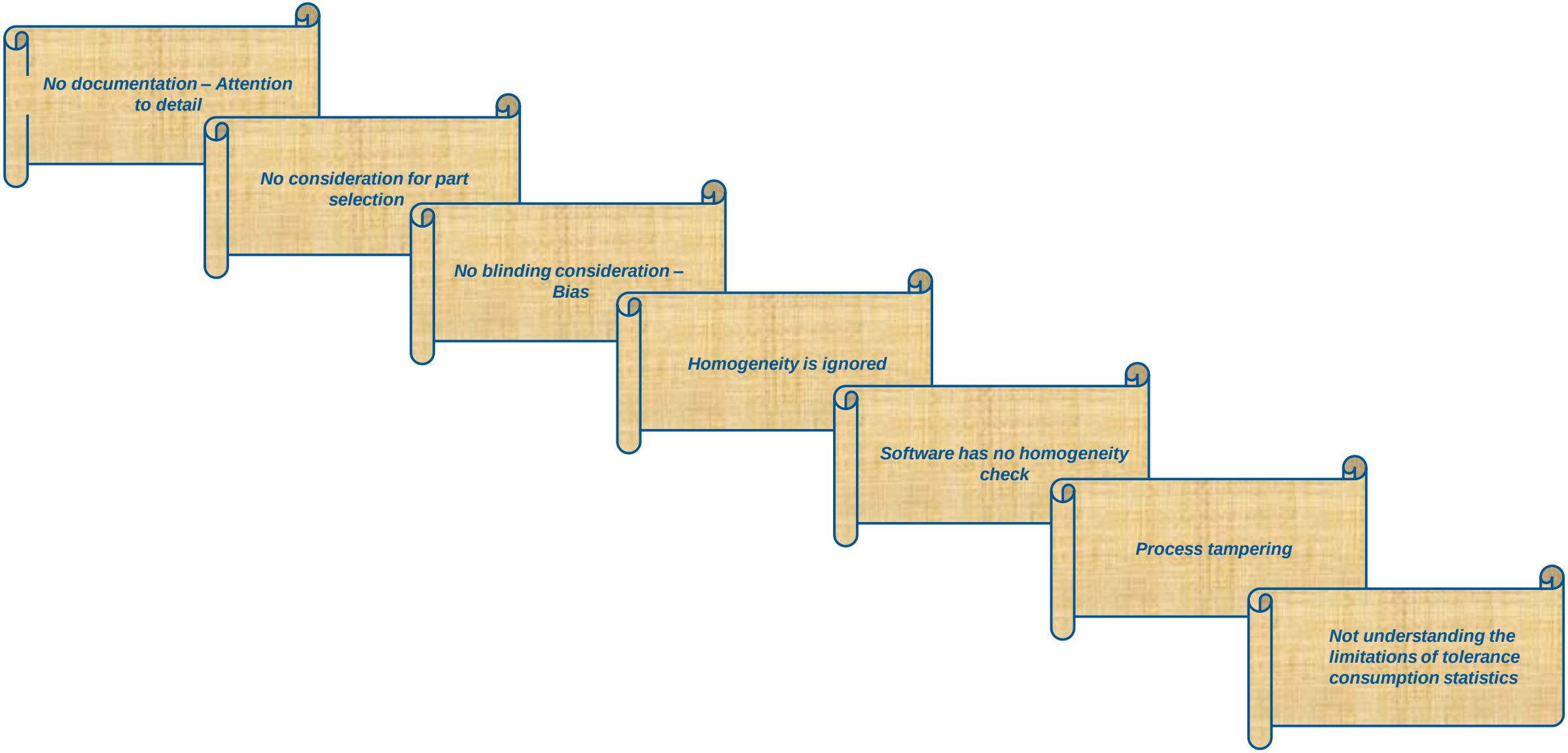
Example 1

- Homogeneity is not demonstrated
- Measurement process is not consistent therefore past performance is not indicative of future, unstable!
- Measurement process is not optimised, we are not reaching full normal potential
- Any summary statistics extracted from here are hypothetical and represent the minimum that could be achieved if the process reached full potential

Example 2

- Homogeneity is demonstrated and the process is consistently operating the best it can in terms of repeatability
- Process has been “debugged” and we can begin to characterise the process more completely with confidence
- The potential gains we see are typical.

Common Mistakes



Concluding Remarks

- Formal validation of measurement processes is clearly important and EMP/MSA tools help to answer many questions
- In the absence of such validation;

  - How can we get the best from our measurement processes?

  - How would we know when and how to improve our measurement process?

  - How do we know if we can track improvements to the manufacturing process and thus know when we are improving?

  - Where do we focus our attention, time and money? On the measurement or manufacturing process?

A debt of gratitude for his tireless and extensive work in the area of EMP and for applied data analysis is due to Dr Donald J Wheeler. The clarity of thought and applying process behaviour techniques to measurement processes has and continues to be an inspiration for process optimisation.

NPL
National Physical Laboratory

Department for
Business, Energy
& Industrial Strategy

FUNDED BY BEIS

The National Physical Laboratory is operated by NPL Management Ltd, a wholly-owned company of the Department for Business, Energy and Industrial Strategy BEIS).