ASQ Section 1302 Summer Series

Measurement System Analysis

Part 1 – Introduction to Measurement System Analysis

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What is Measurement System Analysis?

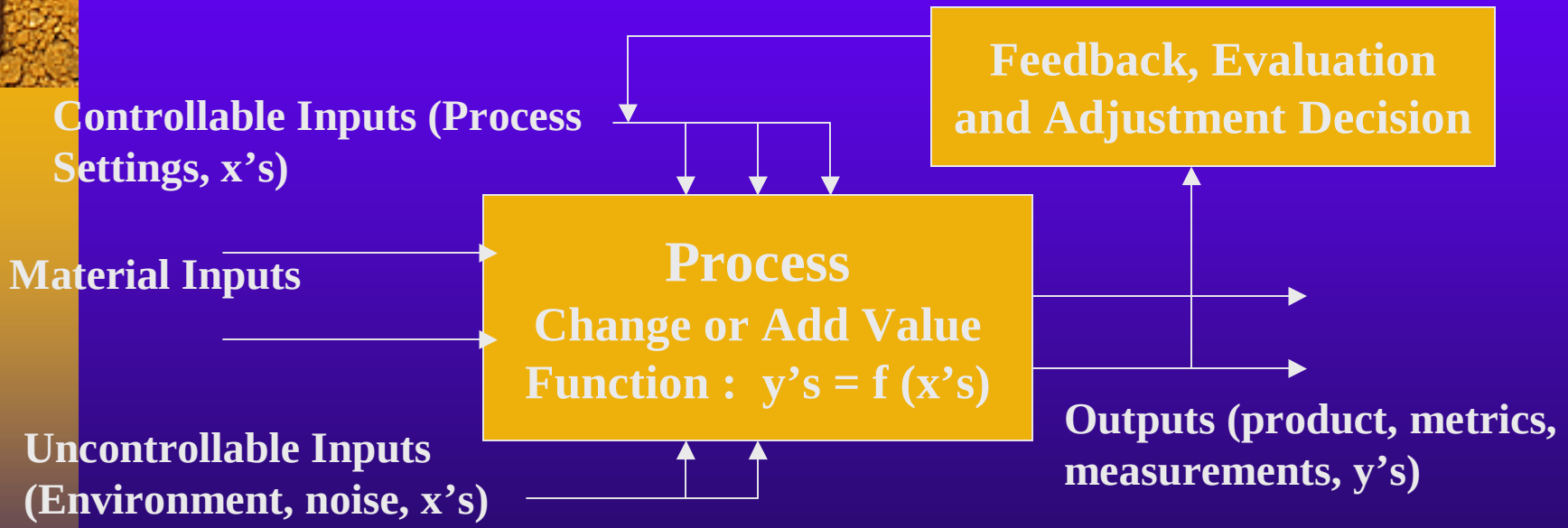
- A way to quantify the error or uncertainty in a measurement system
- A tool to help identify the sources of measurement variation in a measurement process

Definitions

- Measurement System – The collection of operations, procedures, gages, and other equipment, software, and personnel used to assign a number to the characteristic being measured; the complete process used to obtain measurements.
- Gage – Any Device used to obtain measurements, frequently used to refer specifically to the devices used on the shop floor. Includes go/no-go devices.
- Process – The act of changing an input to an output through the application of resources via a transformation activity.

Process Diagram

- Remember FEEDBACK. Somebody must take some action on the Process X's or the inputs.



Some Basic Concepts & More Definitions & Abbreviations

DUT – Device under test

MSA – Measurement System Analysis

Gage R&R – Gage Repeatability and Reproducibility. This is the bread and butter for most measurement system analysis

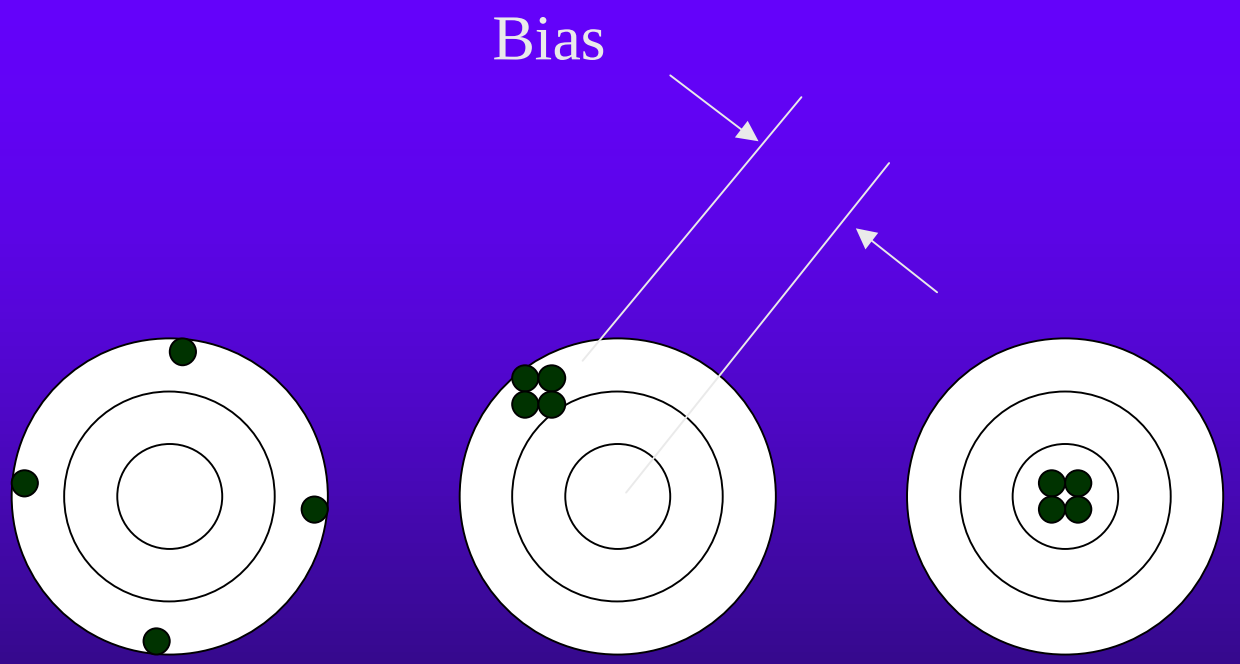
AIAG – Automotive Industry Action Group

Accuracy – A measure of location. How a group of measurements relates to the TRUE value of the DUT, or standard. Measures Error. Addressed with Calibration and Correlation.

Bias – A measure of the lack of accuracy.

Precision – A measure of spread or variation. How a group of measurements relate to each other. A measure of Uncertainty. Addressed with a Gage R&R Study

Illustration of Accuracy and Precision and Bias



Accurate (no Bias) but Uncertain

Precise and certain (tight group) but Inaccurate

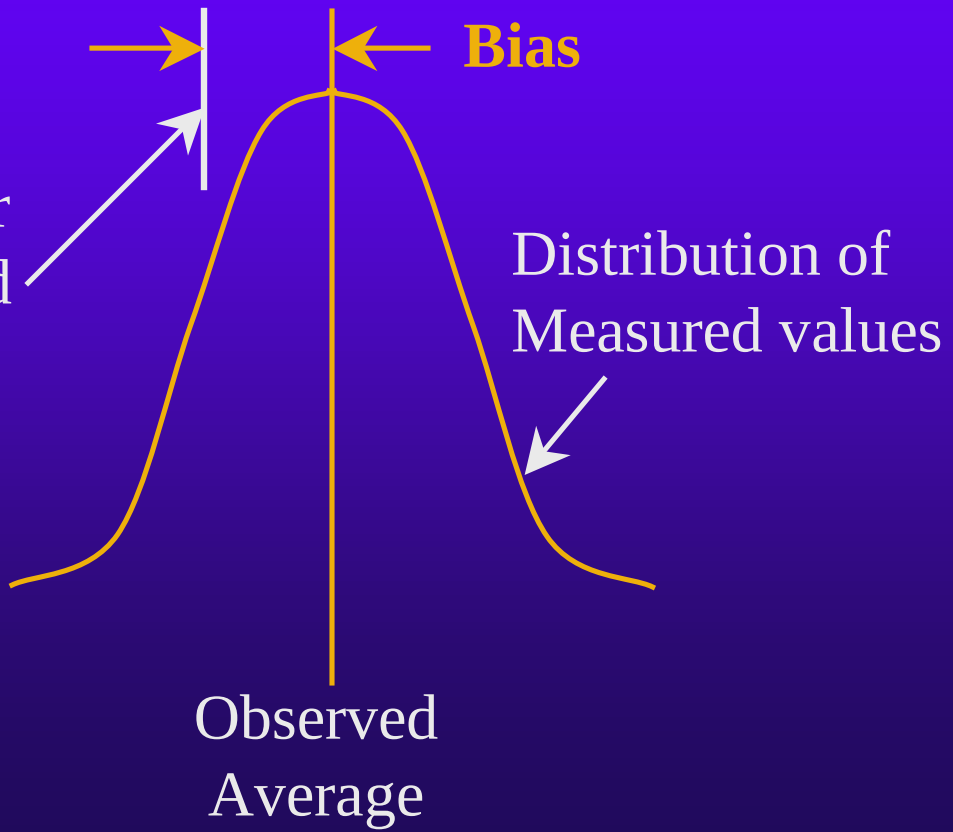
Both Accurate and Precise

Purposes of a Measurement System

- To be able to tell the difference between good and bad products.
  - Misclassification Rate. How often does the measurement system accept a bad part, or reject a good part?
- To be able to analyze the manufacturing process.
  - What is the smallest part difference my measurement system can detect?
  - Can I detect changes in the process?
- To be able to make the Customer Happy

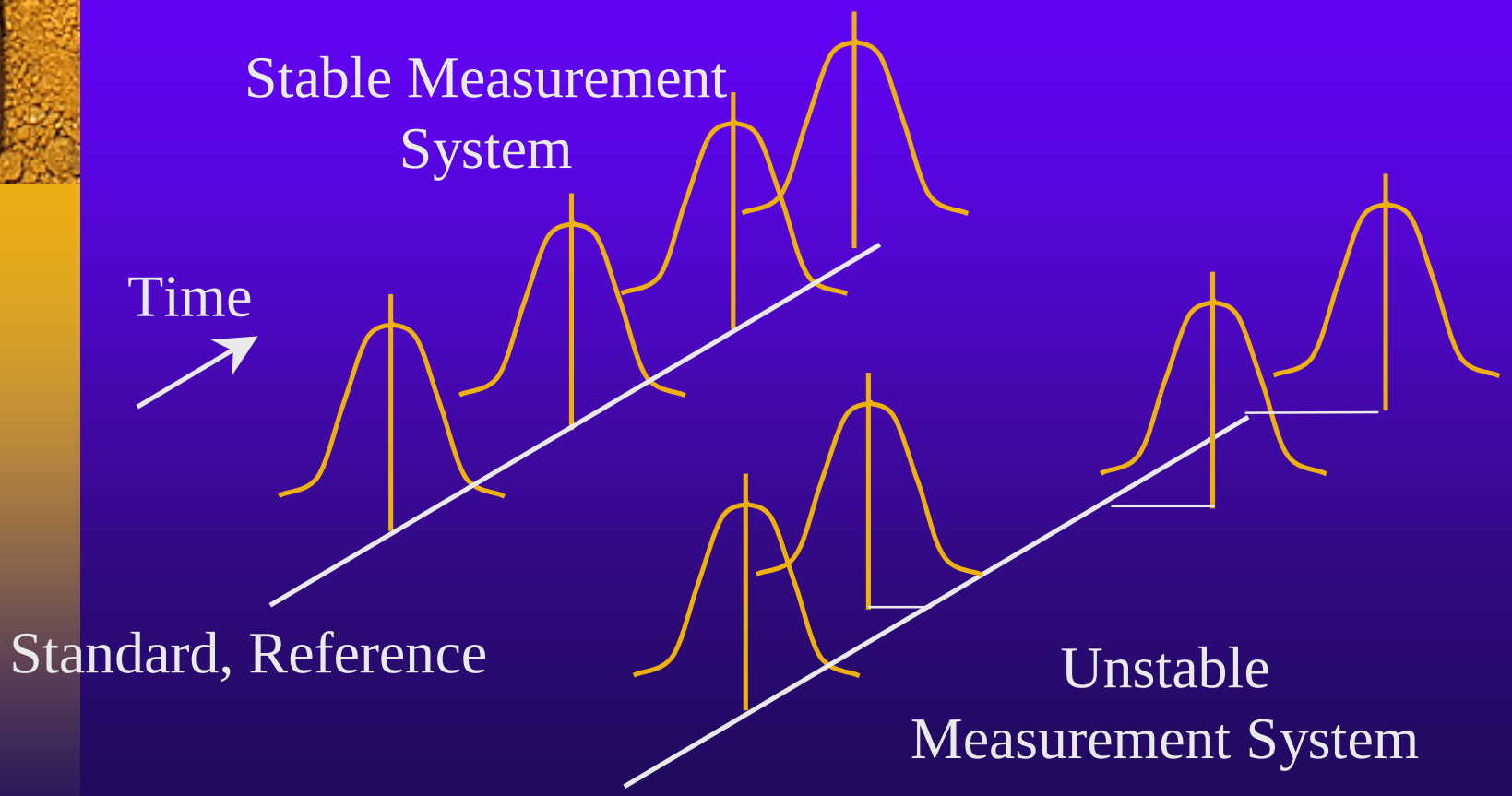
The 5 Basic features of a Measurement System.

Bias – Previously Defined as a measure of the lack of accuracy.



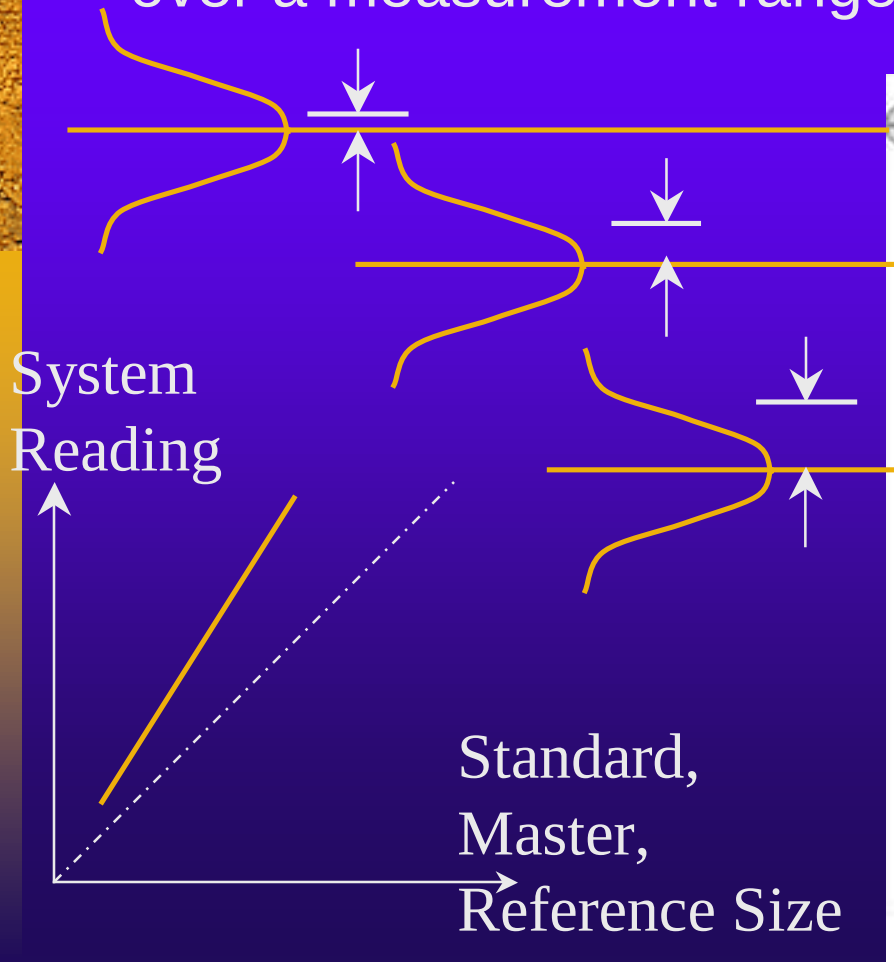
The 5 Basic features of a Measurement System.

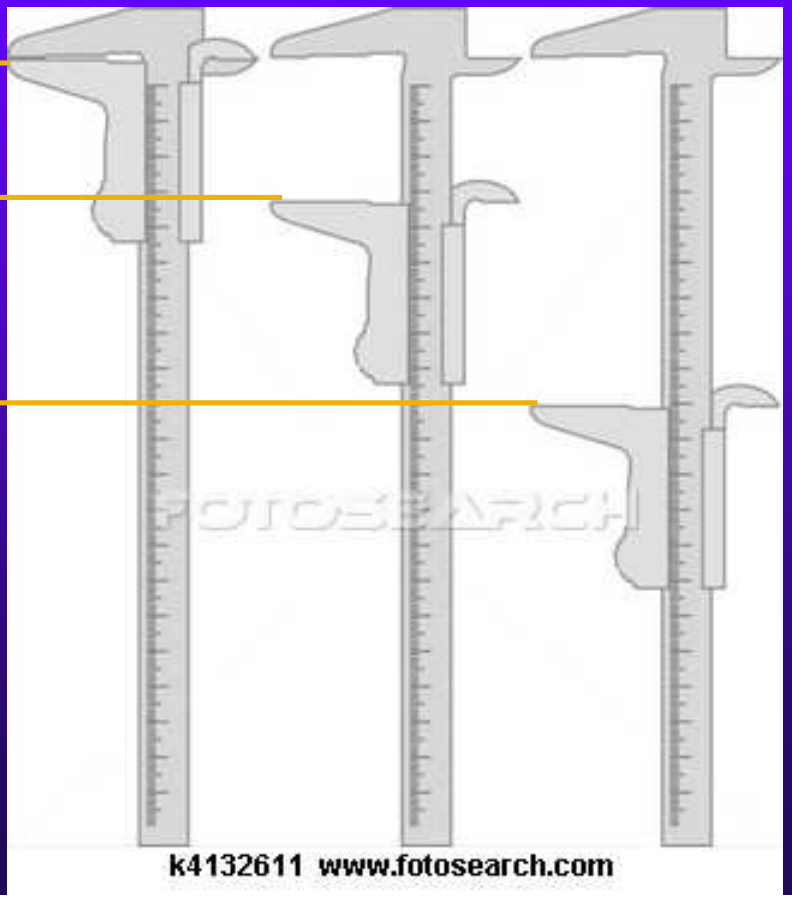
Stability – A measure of the change in bias, or accuracy, over time.



The 5 Basic features of a Measurement System.

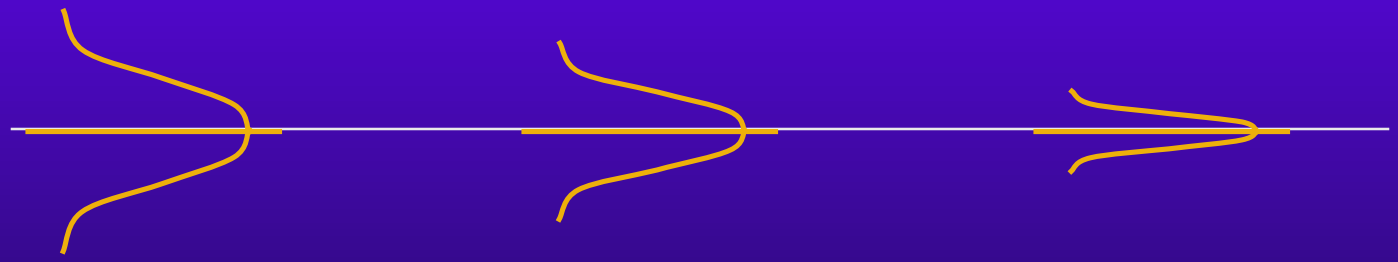
Linearity – A measure of the change in bias or accuracy over a measurement range, low values to high values





The 5 Basic features of a Measurement System.

Repeatability – The portion of the measurement system usually associated with the *Equipment* variation. (Same Operator, DUT, Set-up, etc.) This is an measurement of precision of the measurement system. How close are successive readings.



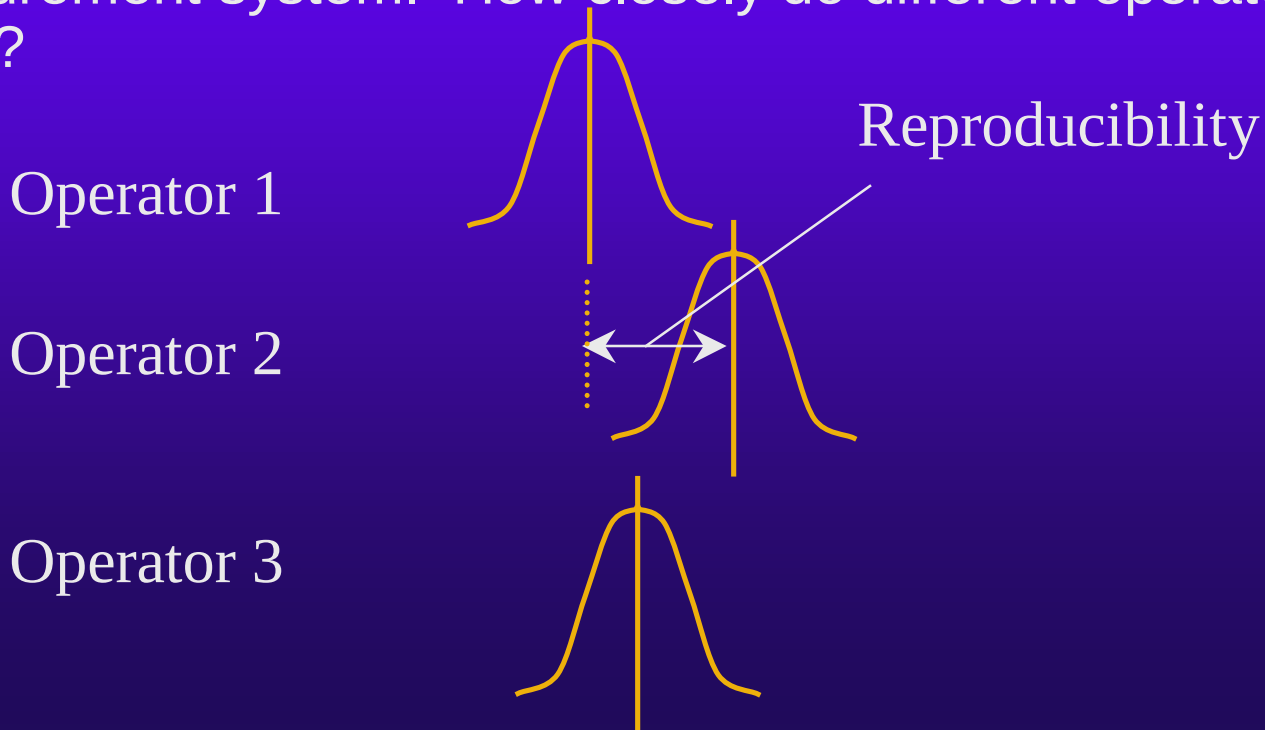
Calipers Micrometer Comparator

Side note about Resolution

- Resolution is the smallest increment that the gage is capable of reporting.
- Discrimination of a gage is the smallest incremental difference that can be consistently detected with the gage. It is the larger of Resolution or precision.
  - Differences smaller that the discrimination of a Measurement system can not be detected even statistically because the difference is masked by the gage uncertainty.
  - Discrimination should be about 1 tenth of the size of the variation you expect to see in the process you are measuring.

The 5 Basic features of a Measurement System.

Reproducibility – The portion of the measurement system usually associated with the *Operator* variation. (May include different set-ups, technique, training, etc.) (DIFFERENT Operator, SAME DUT, Set-up, etc.) Again, This measure addresses the precision of the measurement system. How closely do different operators agree?



Summary of the Basic Features of Measurement systems

- Features relating to Accuracy (Error determination)
  - Bias
  - Stability
  - Linearity
- Determined by calibration, or measuring a standard
- Features relating to Precision (Uncertainty determination)
  - Repeatability
  - Reproducibility
- Quantified by performing a Gage R&R Study

Stability Study

1. Obtain a Standard
   - May be a traceable calibration standard.
   - May be a production part from Mid and preferably High and Low parts of the characteristic's production range
     - Measure part 10 times on Layout Equipment
     - Average the readings

Stability Study

2. Periodically measure the master.
   - Determine sample size (measurement repeats) and frequency based on:
     - Calibration interval
     - Frequency of Measurement system use
     - Environmental stresses when used
   - Account for warm up or other factors that change during the day
3. Record data on an $\overline{X}$-S or $\overline{X}$-R chart

Stability Study

4. Calculate the control limits
   - Use standard Control Chart Equations and Methods
   - Evaluate the Control Chart for unstable conditions using standard Shewhart Rules
     - Or possibly modeling with a normal distribution
5. Calculate the Standard Deviation and compare with the Production Process
   - If unstable, Prime contributors of instabilities need to be identified and controlled or eliminated. (not usually an easy task)

Bias Study

1. Obtain a Standard as described in the Stability Study. The same one can be used
2. Have an appraiser(s) measure the sample 10 times
   - Use the measurement system being studied (Shop floor method, not with layout gages)
   - Calculate the appraiser's average

Bias Study

3. Compute Bias by subtracting the reference value from the Appraiser's average

Bias = Appraiser Average – Reference value

4. Compare the Bias to the Characteristic's production variation (6-sigma range)

$$\textit{Percent Bias} = \frac{\textit{Bias}}{\textit{Production Variation}}$$

Linearity Study

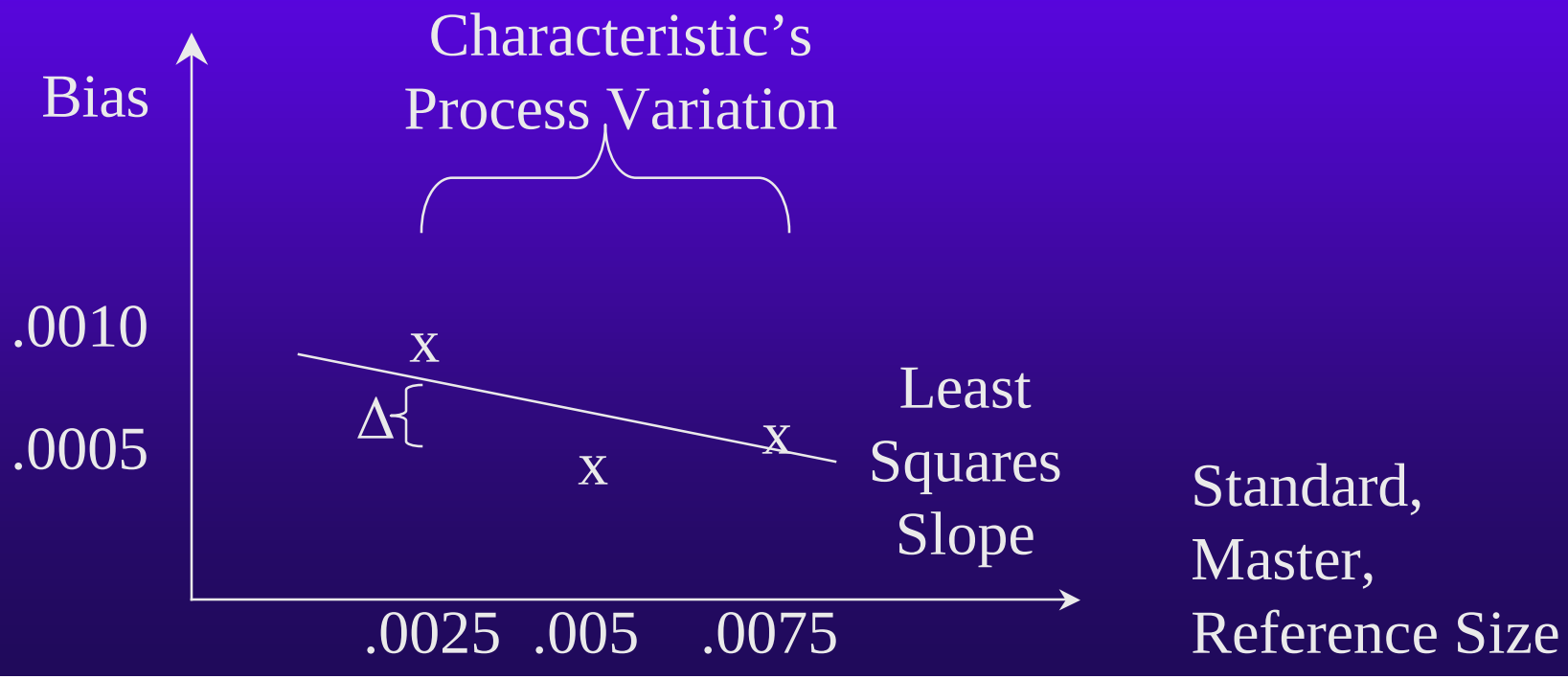
1. Repeat a Bias study for different points along the characteristic's production range (Low, Middle and High side), or the gage's range.
2. Use best fit to calculate the slope of a line going through the points.
   - X's are the Reference values
   - Y's are the associated biases
   - The Slope is the Linearity

$$\text{Slope} = \text{Linearity} = \frac{\Sigma x_i y_i - (\Sigma x_i * \Sigma y_i)/n}{\Sigma x_i^2 - (\Sigma x_i)^2/n}$$

Linearity Study

Δ = Change in Bias across the Process's spread (Or gage's Range)

Percent Linearity = Slope x 100%



Next Installments

- Gage R&R Studies – Variable Data
- Gage R&R Studies – Attribute Data
- Gage Performance Curves