ASQ Automotive Division
The Global Voice of Quality™

Automotive core tool: MSA

Everyone is muted.
We will start at 7pm EST.

Kush Shah, Chairman
ASQ Automotive Division

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Agenda

- Housekeeping Items
- About ASQ Automotive Division
- Our Vision
- Webinar Series
- Automotive core tool: MSA
- Questions & Answers

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Housekeeping Items

Everyone is muted

Session is being recorded

Session will last about 90 minutes

ASQ Automotive members can download the slides and video at www.asq-auto.org

Participate thru chat and questions

Will answer questions at the end:

- Q&A at the end of the presentation
- Please type your questions in the panel box

ASQ Automotive Chair

Kush Shah

- Manager, Global Electrification, General Motors, Michigan, U.S.
- Leadership positions in Engineering, R&D, Manufacturing, Quality
- 20+ years of quality experience
- Six Sigma Master Black Belt, Shainin Red X Master, ASQ CQA, CMQ/OE,CQE, CSSBB
- Speaker at International Quality Symposiums / Conferences
- Trainer for Six Sigma and Quality Management

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Global Automobile Outlook – 2020

>1 billion vehicles - Circle the earth **125 times**

15% ownership

~3% annual growth worldwide

American Society for Quality (ASQ):
ASQ is the world's leading professional association and authority on quality

ASQ Automotive Division Mission:
To be the recognized global network of automotive quality professionals that is helping individuals and organizations to achieve personal and organizational excellence

Key Objectives of ASQ Automotive Division:

Increase Member Value – Webinars, symposium and Automotive Excellence magazine

Develop Core Tools Competency –On-site training - PPAP, APQP, FMEA, SPC and MSA

Global Outreach – Participate in conferences and deliver training globally

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Key Objectives of ASQ Automotive Division:

U.S. Outreach - Engage all automotive OEMs and Tier 1 & 2 suppliers

Student Outreach – Collaborate with universities

Collaborate With Other Professional Societies – Engage with other societies and professional organizations

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Core Quality Tools for Automotive Industry:

Advanced Product Quality Planning (APQP)
Failure Mode and Effects Analysis (FMEA)
Production Part Approval Process (PPAP)
Measurement Systems Analysis (MSA)
Statistical Process Control (SPC)

ASQ Automotive Division provides on-site training by certified instructors.

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The ASQ Automotive Division is pleased to present a regular series of free webinars featuring leading international experts, practitioners, academics, and consultants. The goal is to provide a forum for the continuing education of automotive professionals.

ASQ Automotive members can download the presentation slides on our website www.asq-auto.org. Recorded webinars are also available for viewing after the events for members.

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Resources / Contacts:

Contact: Kush Shah, Chair - ASQ Automotive Division

E-mail : asq.automotive@gmail.com

Website: www.asq-auto.org

Group: ASQ Automotive Division Group

twitter.com/ASQautomotive

Mark A. Morris

Mark A. Morris has more than 30 years experience in tooling and manufacturing as a skilled machinist, toolmaker, college instructor, technical writer, and quality professional in roles from Quality Engineer to Director of Continuous Improvement. His expertise lies in dimensional issues, reliability, maintainability, and quality systems. Mr. Morris' credentials include undergraduate degrees focused on manufacturing engineering, industrial education, and metalworking; Master of Education degree from the College of Technology at Bowling Green State University; CQE, CRE, and CQA certifications from the American Society for Quality; and Senior Level Geometric Dimensioning and Tolerancing Professional (GDTP) certification from the American Society of Mechanical Engineers. Mr. Morris is also the Immediate Past Chair for the Ann Arbor section of ASQ, and for the past five years, has trained candidates to become ASQ Certified Quality Engineers. He presently serves as Education Chair on the Leadership Team of the Ann Arbor section of ASQ..

Automotive Division

ASQ The Global Voice of Quality™

Measurement Systems Analysis based on *MSA 4th Edition*

Mark A. Morris
ASQ Automotive Division Webinar

January 25, 2012

M and M Consulting

mark@MandMconsulting.com
www.MandMconsulting.com

Agenda

1. Quality Statistics Review
2. Fundamental MSA Concepts
3. Preparation for MSA Studies
4. Mathematics of MSA Studies
5. Evaluation of MSA Studies
6. Summary and Closure

Course Goals

1. To provide a fundamental understanding of the language that guides MSA studies.

2. To use MSA studies to determine where measurement processes require improvement to assess special characteristics.

3. To achieve robust capable measurement processes for special characteristics.

Quality Statistics Review

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We Need Operational Definitions

"Without an operational definition, investigations of a problem will be costly and ineffective, almost certain to lead to endless bickering and controversy."

W. Edwards Deming, Ph.D.

Operational definitions provide three components:

1. Specify Test to determine Compliance
2. Set Criteria for Judgment
3. Make Decisions based on the Criteria

Feature Control Frames

- **Feature Control Frame** is a rectangular symbol that consists of two to five compartments, used to specify geometric tolerances:
  - First compartment specifies the geometric characteristic.
  - Second compartment specifies the tolerance value.
  - Third compartment, if it exists, specifies the primary datum.
  - Fourth compartment, if it exists, specifies the second datum.
  - Fifth compartment, if it exists, specifies the third datum.

Use of Basic Dimensions

- Basic dimensions define the perfect location of features and surfaces relative to the datum reference frame.

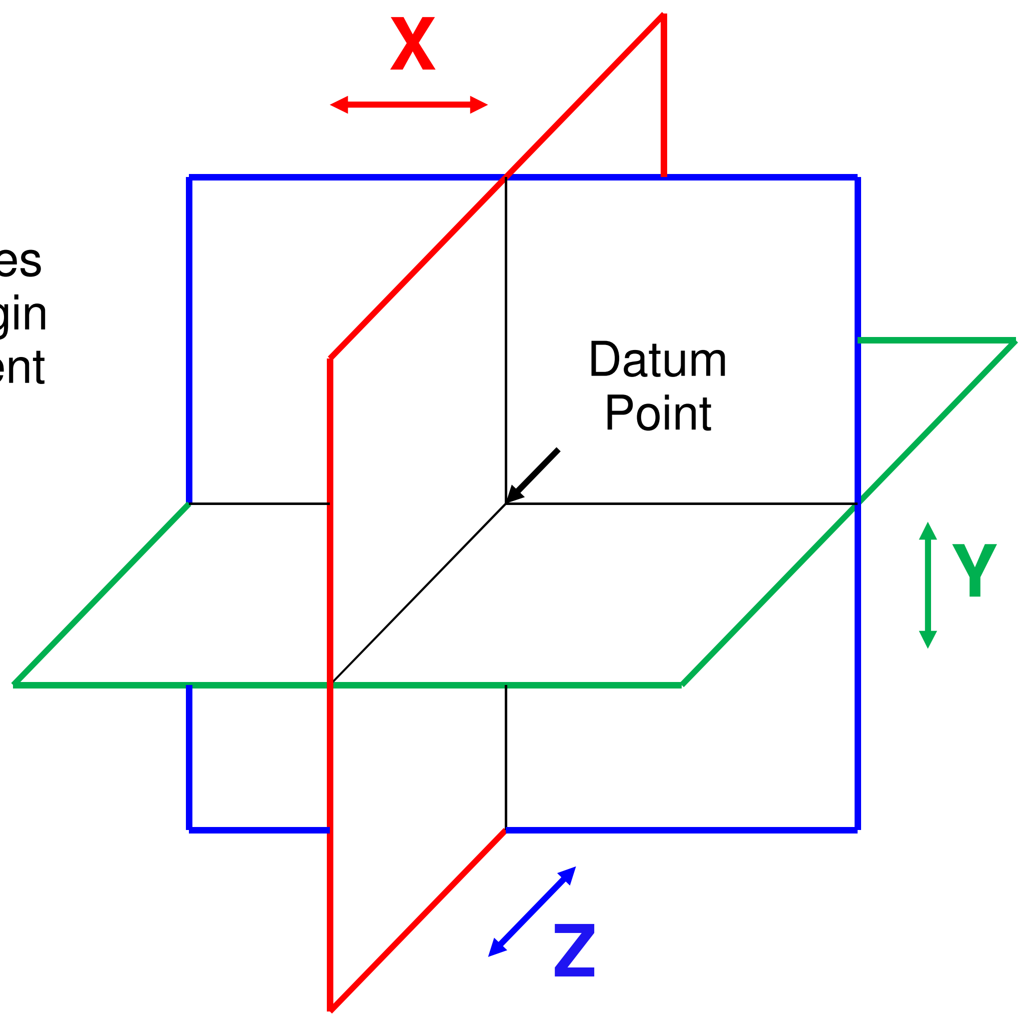
- Basic dimensions are used to define the theoretical exact size and location for features.

- Feature control frames define the intended tolerance for features.

A Datum Reference Frame

- Three mutually perpendicular planes.

3 Datum Planes define the Origin of Measurement



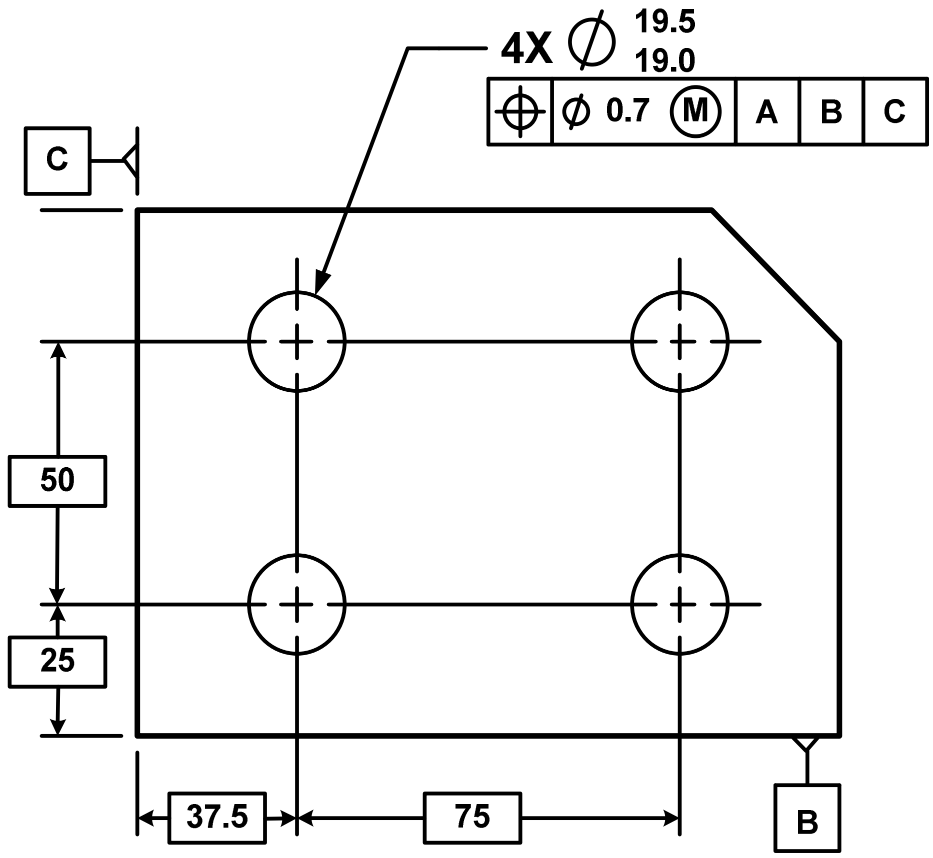
Datum Feature Simulators

- In the real world, we use physical datum feature simulators to establish datums:
  - Machine Tool Elements
  - Surface Plates
  - Angle Plates

2009

- Manufactured parts have irregularities.
- High points on parts make contact with datum feature simulators to establish datums.

Datum Schemes



Note: The back surface is datum A.

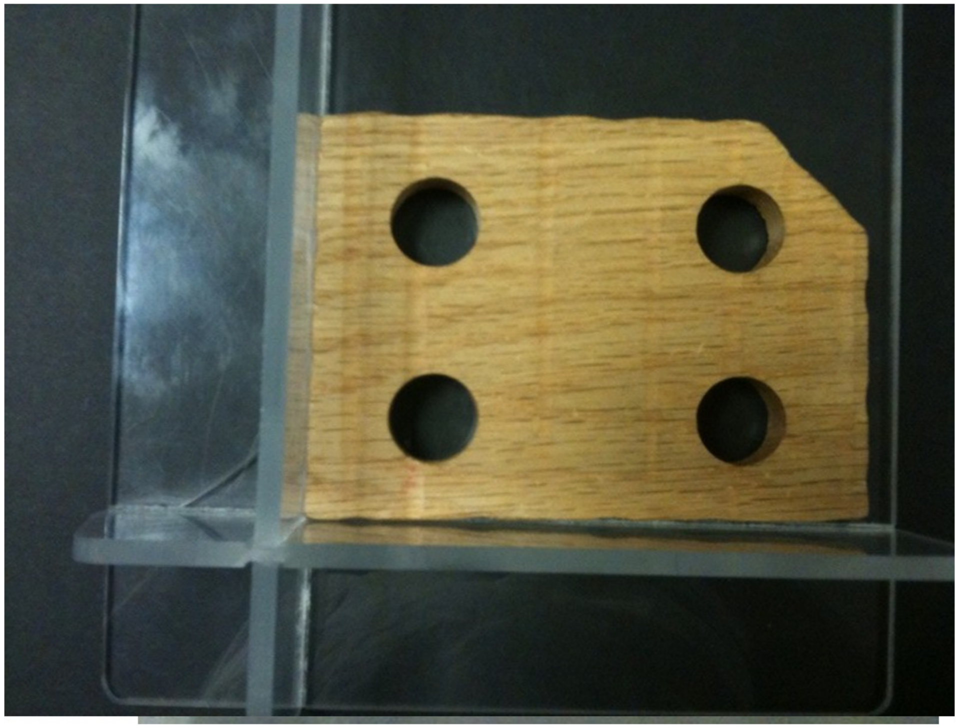
Datum Schemes

⌀ 19.5
19.0

⌖	⌀ 0.7 Ⓜ	A	B	C

⌀ 19.5
19.0

⌖	⌀ 0.7 Ⓜ	A	C	B

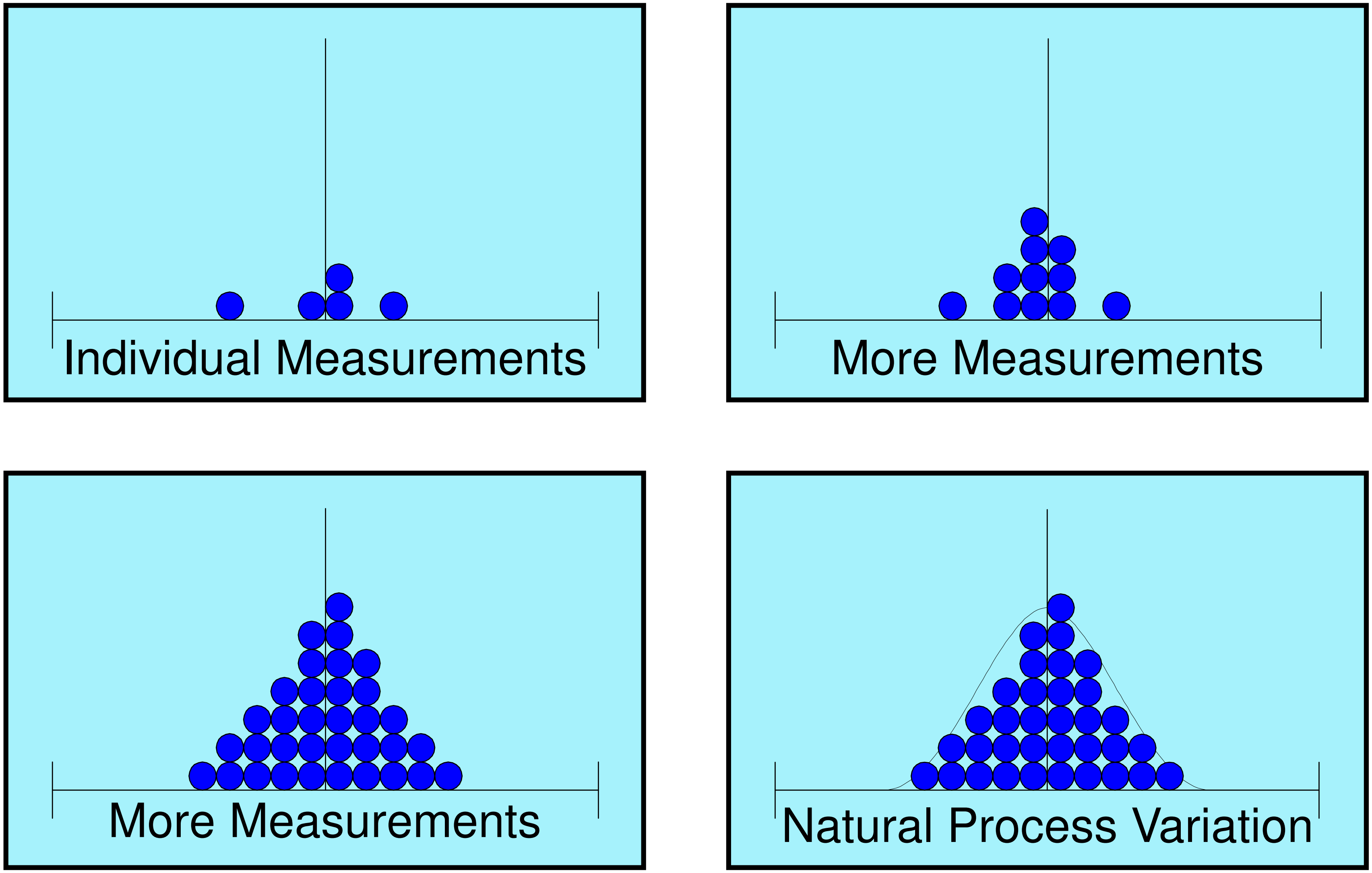


A Fundamental Concept

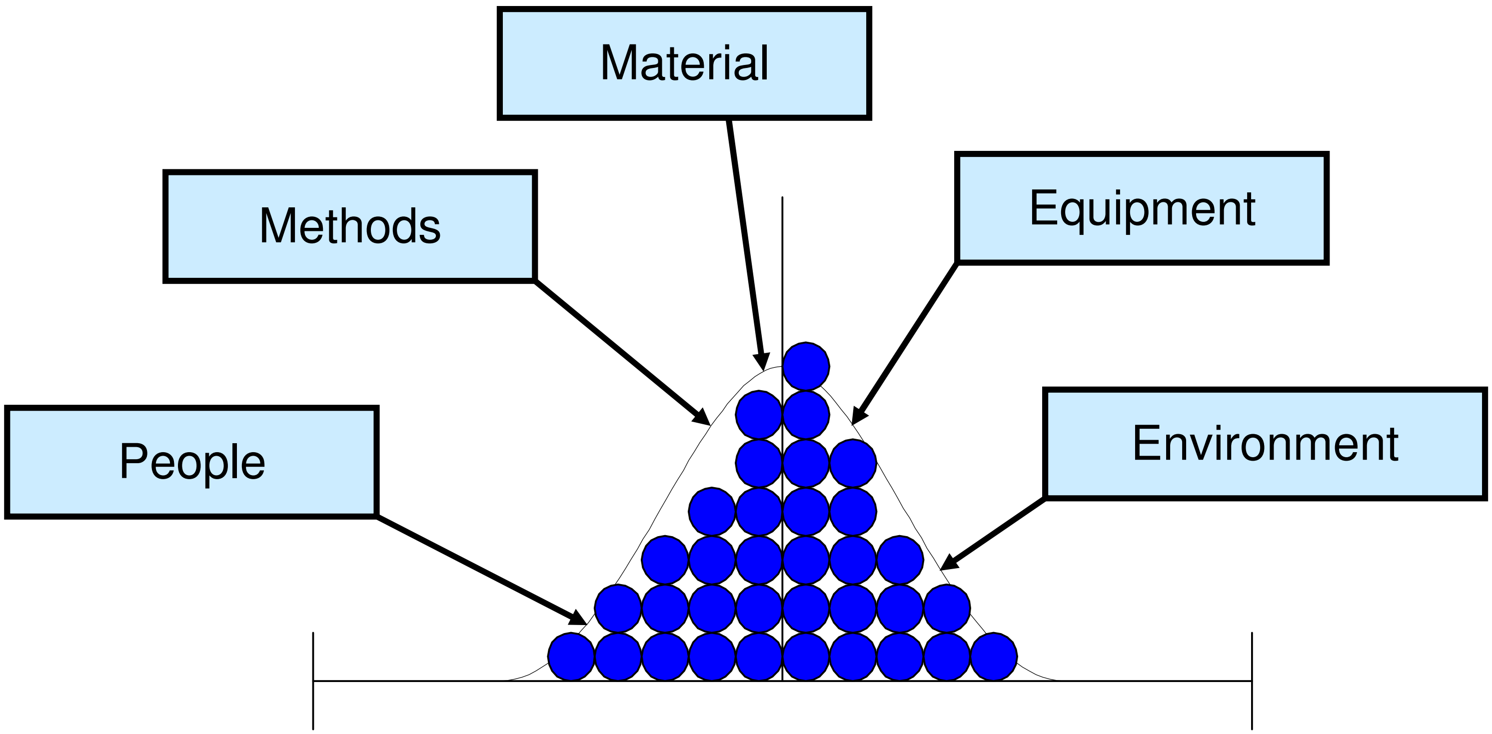
"No two things are alike, but even if they were, we would still get different values when we measured them."

Donald J Wheeler, Ph.D.

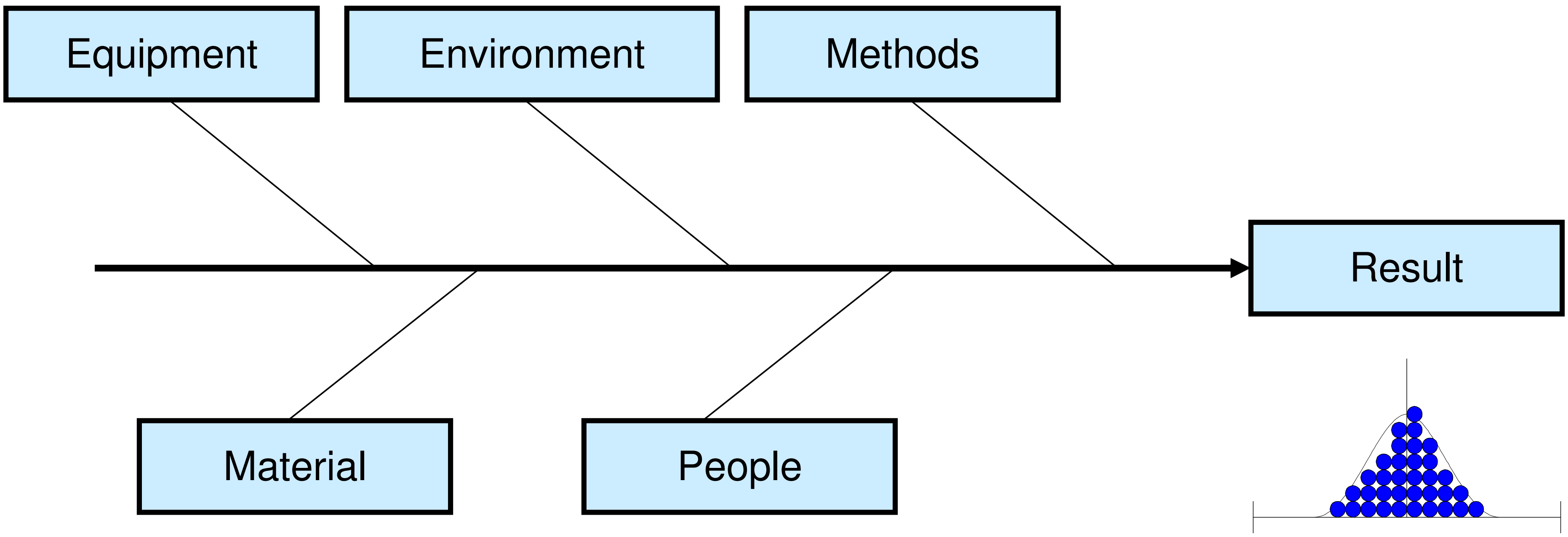
Variation in All Things



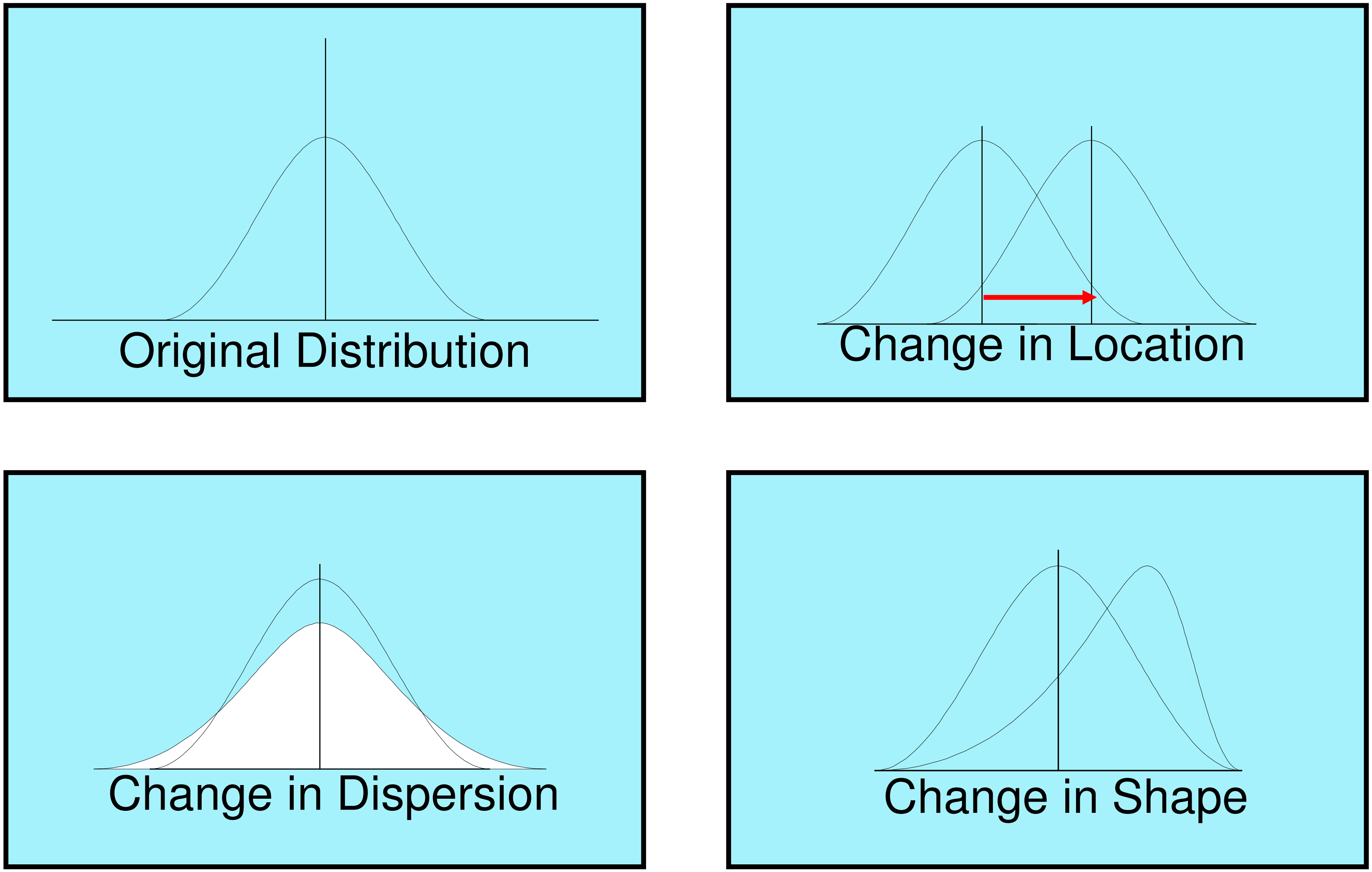
Natural Variation Inherent in the Process



Causes and Effects



Changes in Behavior



Purpose of SPC

- The purpose of SPC is to understand the behavior of a process.
- The goal of that understanding is to predict how the process may perform in the future.
- All, so we may take appropriate action.

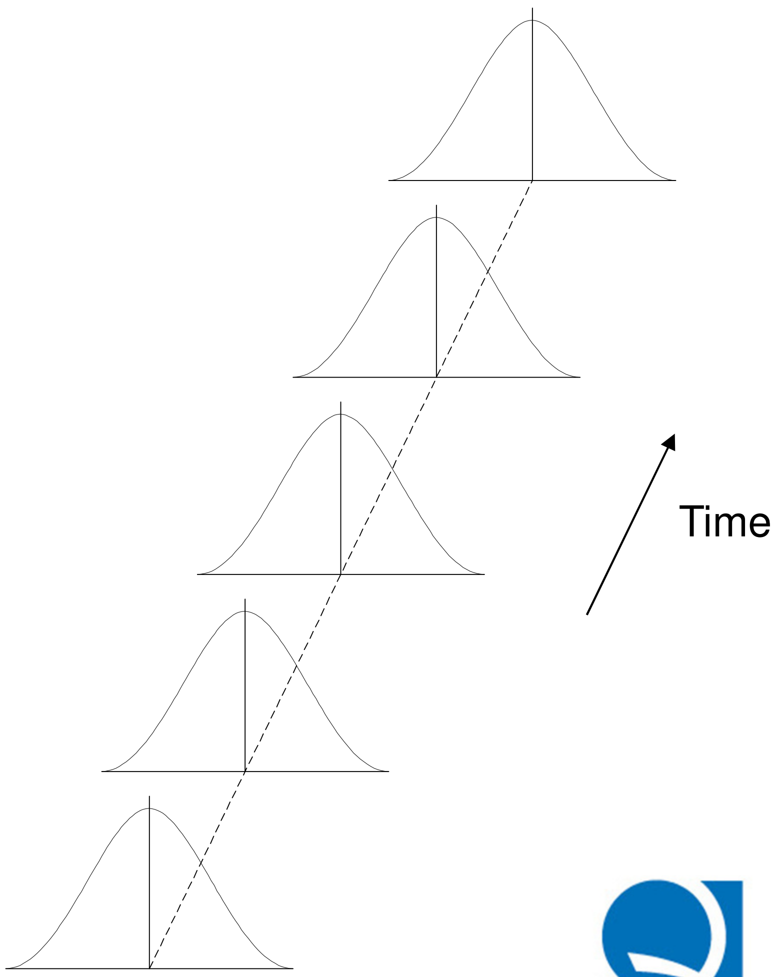
A Philosophy of Actionable Data

- No Inspection without Recording
- No Recording without Analysis
- No Analysis without Action

W. Edwards Deming, Ph.D.

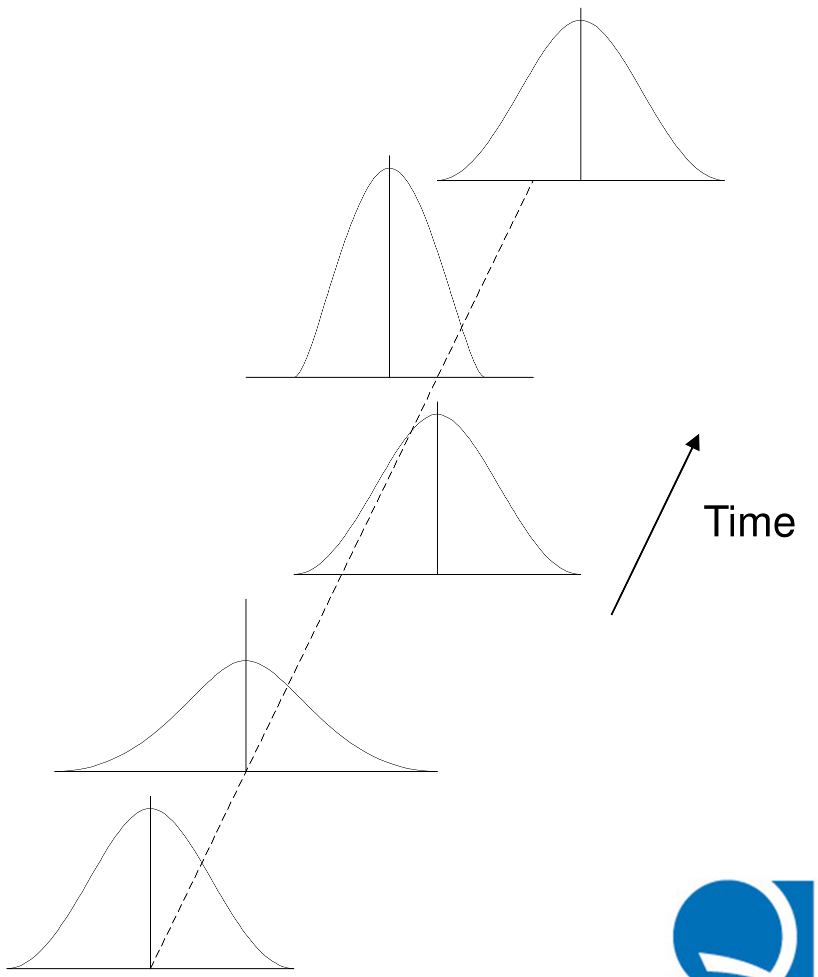
Some Processes are Predictable

- Absence of Unexpected Changes
- Common Cause Variation
- In Statistical Control
- Process is Stable

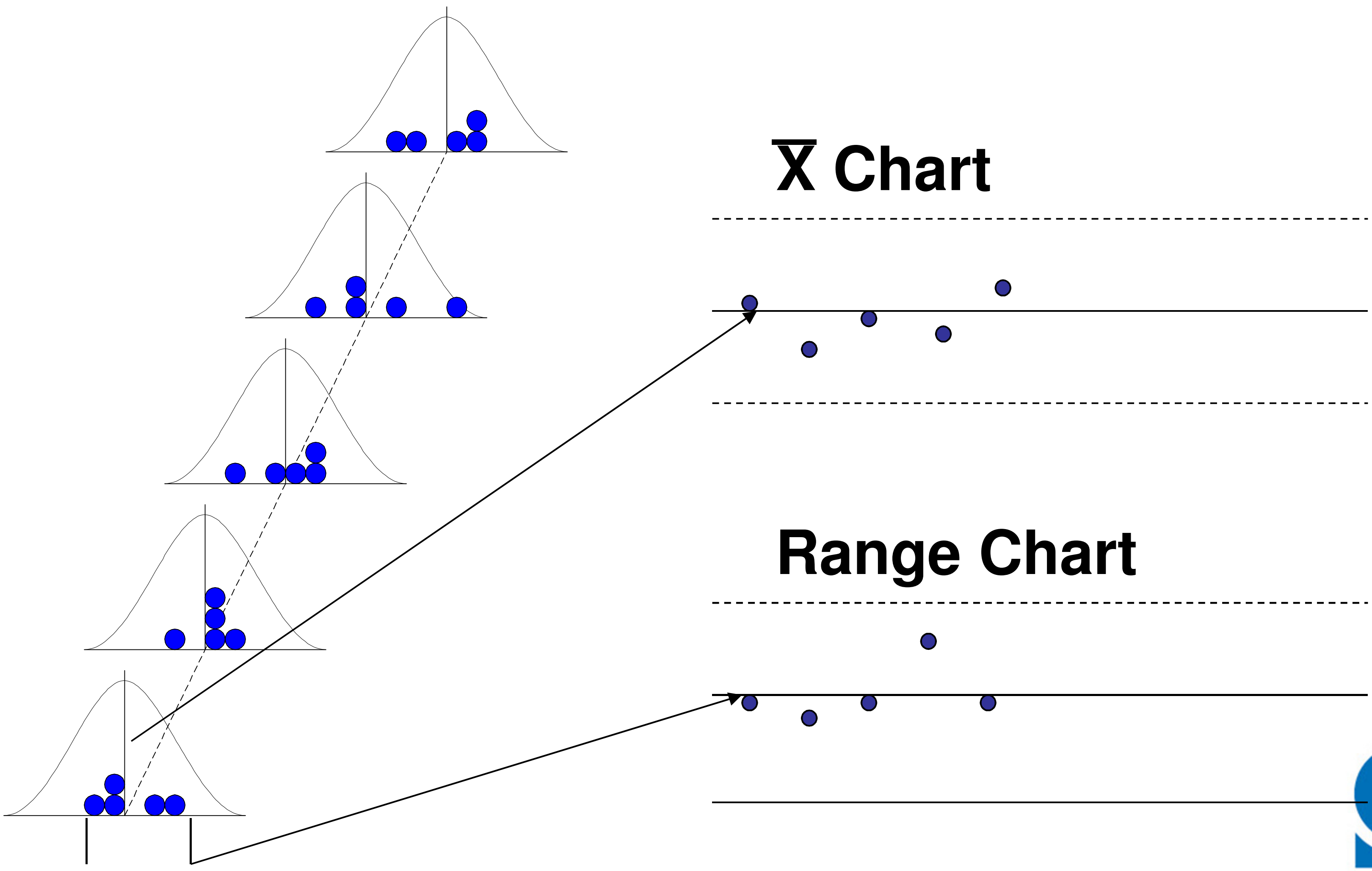


Other Processes Lack Stability

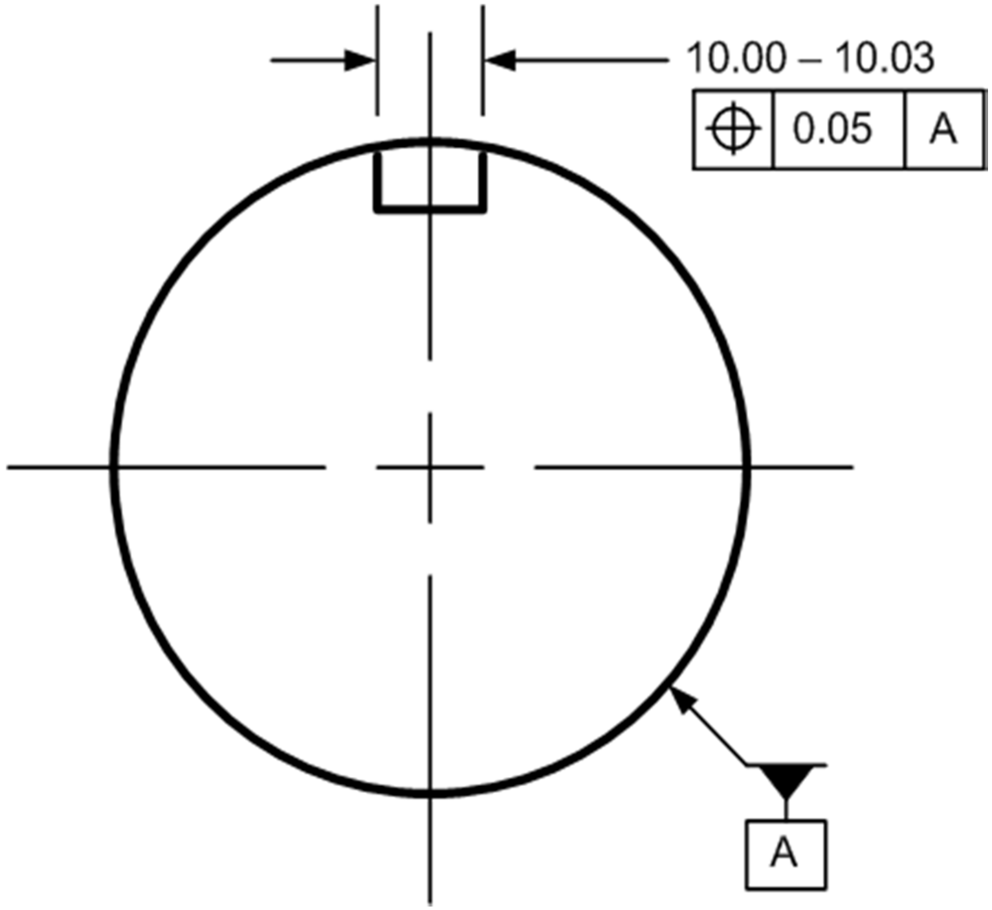
- Presence of Unexpected Changes
- Special Causes are Present
- Significant Changes Occur
- Process Out of Control
- Unstable



Control Chart Shows Stability

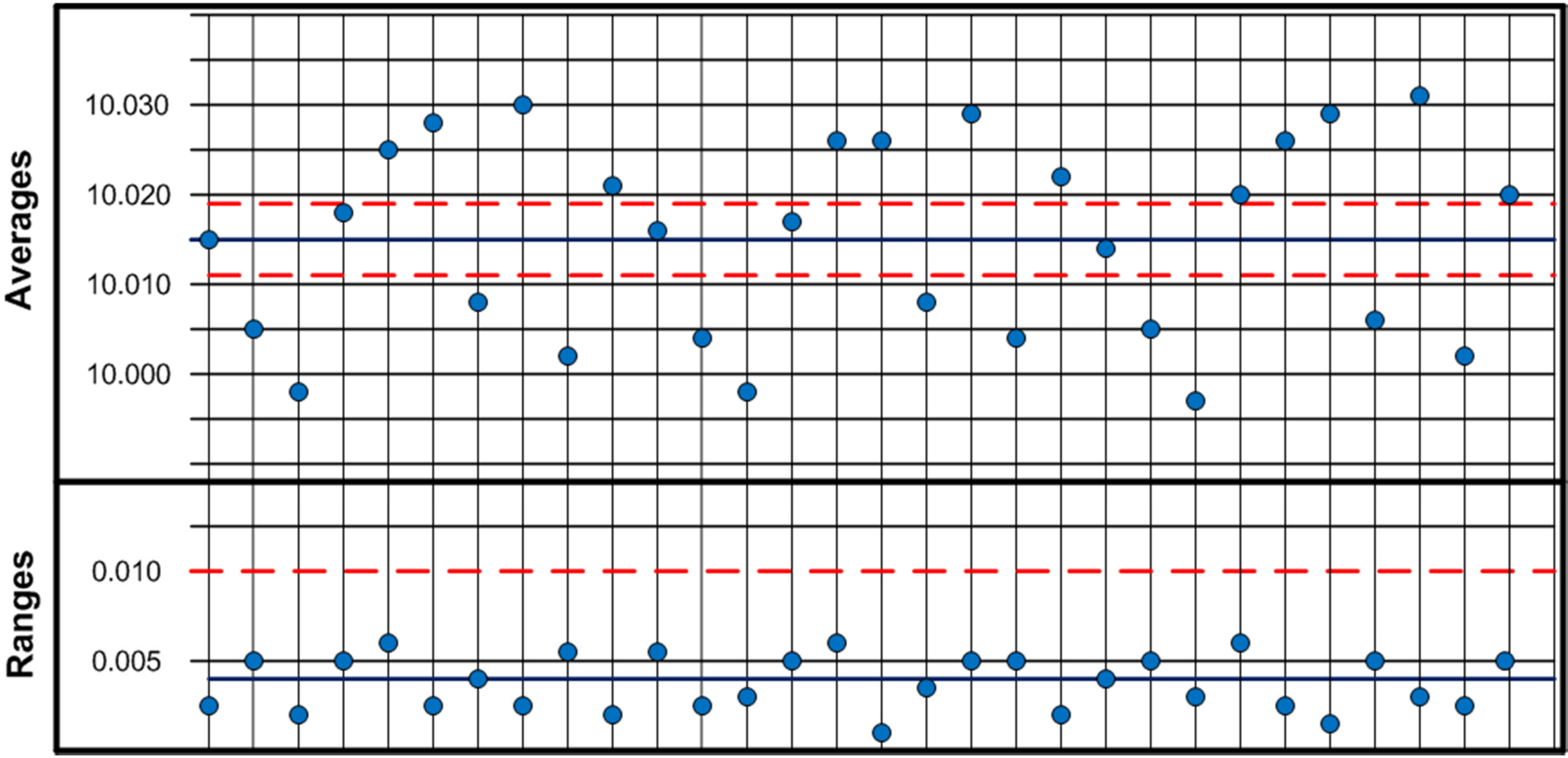


Partial Drawing of a Shaft



In this example we are going to look at the width of the keyway in the view above.

X-bar and R with Gage R&R Data



And Another Thing…

"If you are responsible for a measurement process, and you are not monitoring that process on a control chart, then you are not doing your job!!!"

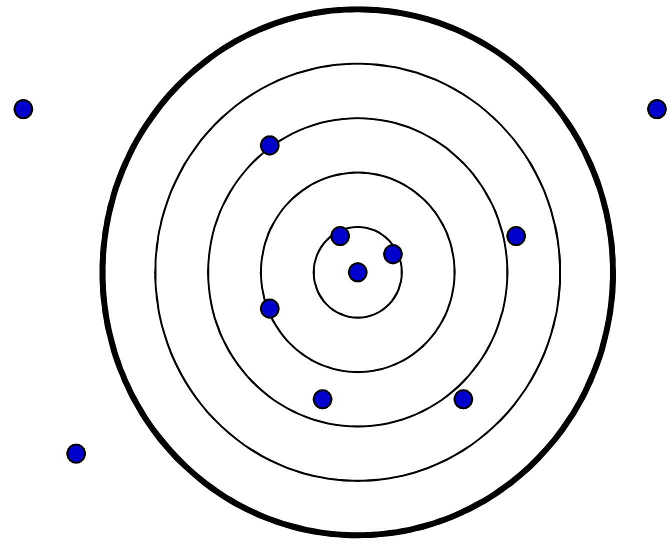
Emil Jebe, Ph.D.

Purpose of Control Charts

	Action Taken	No Action Taken
Action Required	**Good**	**Sin of Omission**
No Action Required	**Sin of Commission**	**Good**

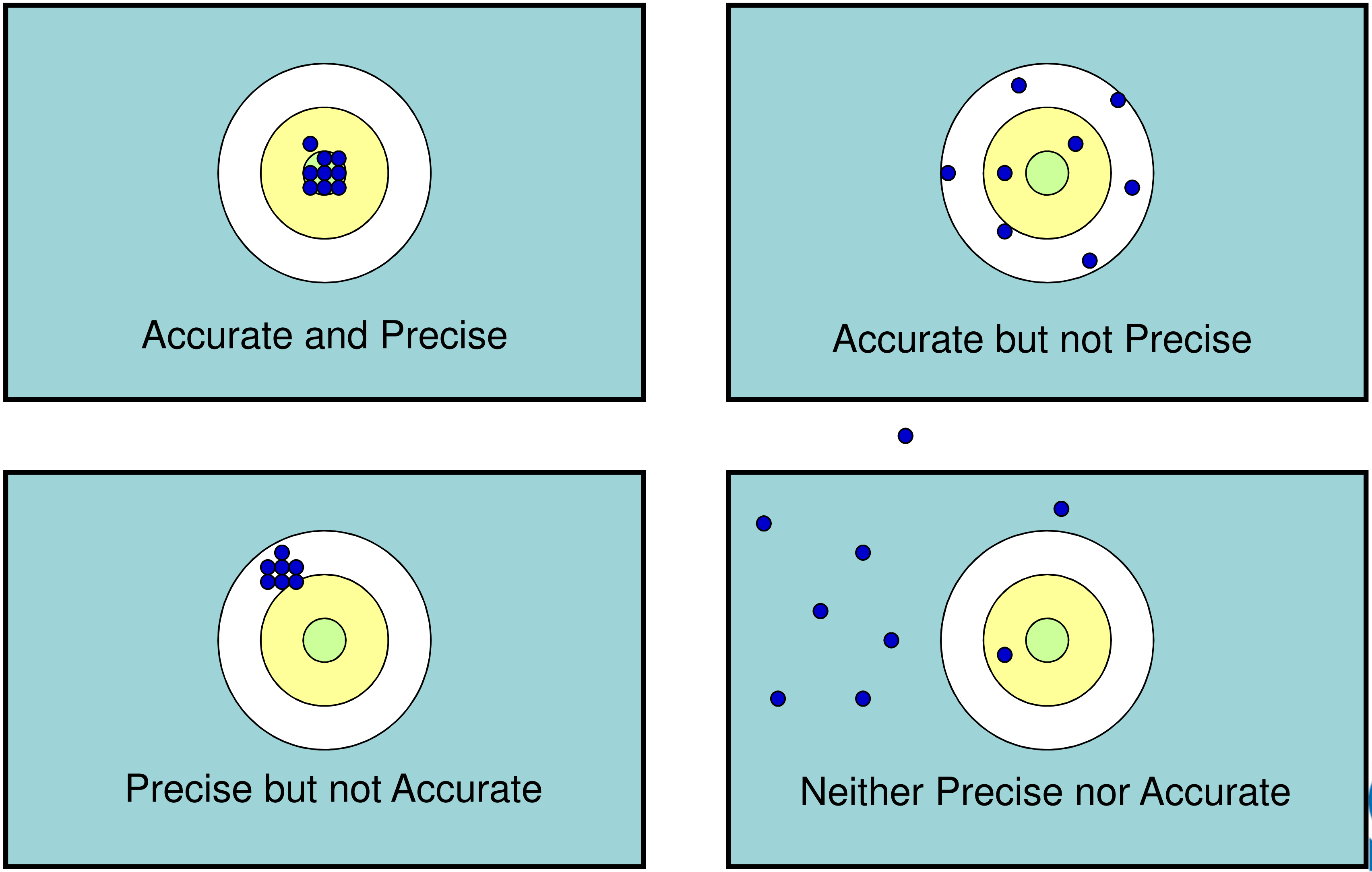
Measurement Systems Analysis

- Bias
- Linearity
- Stability
- Repeatability
- Reproducibility

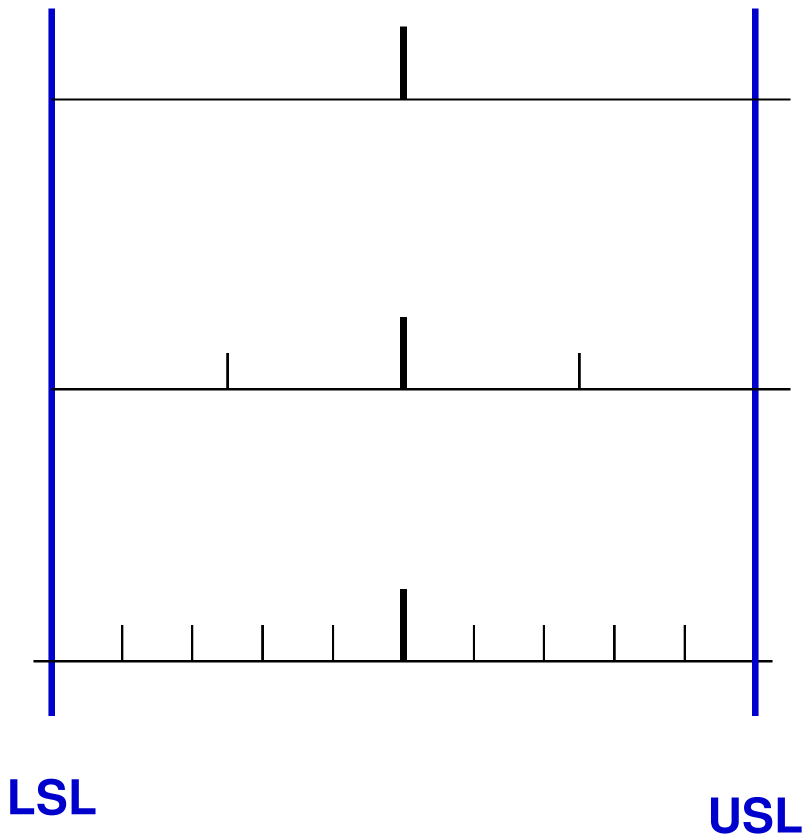


Target Practice

Accuracy and Precision



Resolution



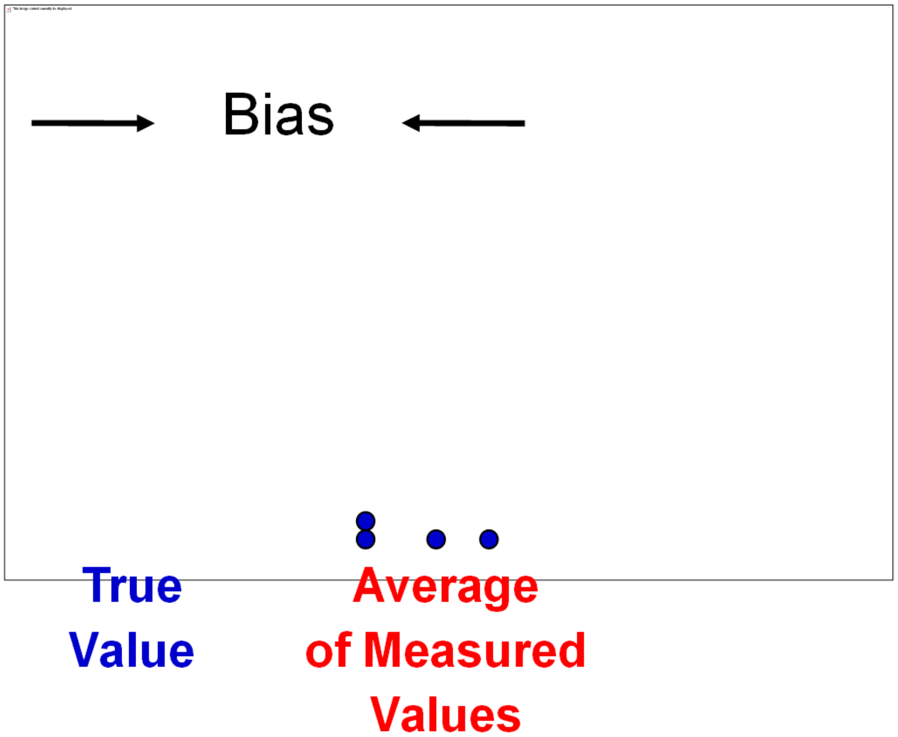
2 Increments or less → Inadequate

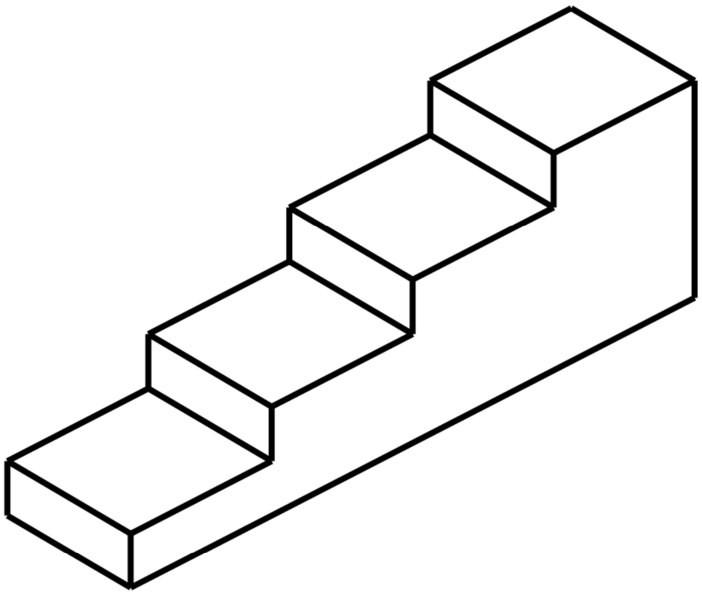
4 Increments → Minimum for Pre-Control

10 Increments → Minimum Recommended

Note: The MSA Guideline recommends a minimum of five distinct categories compared to the process distribution for control and analysis activities.

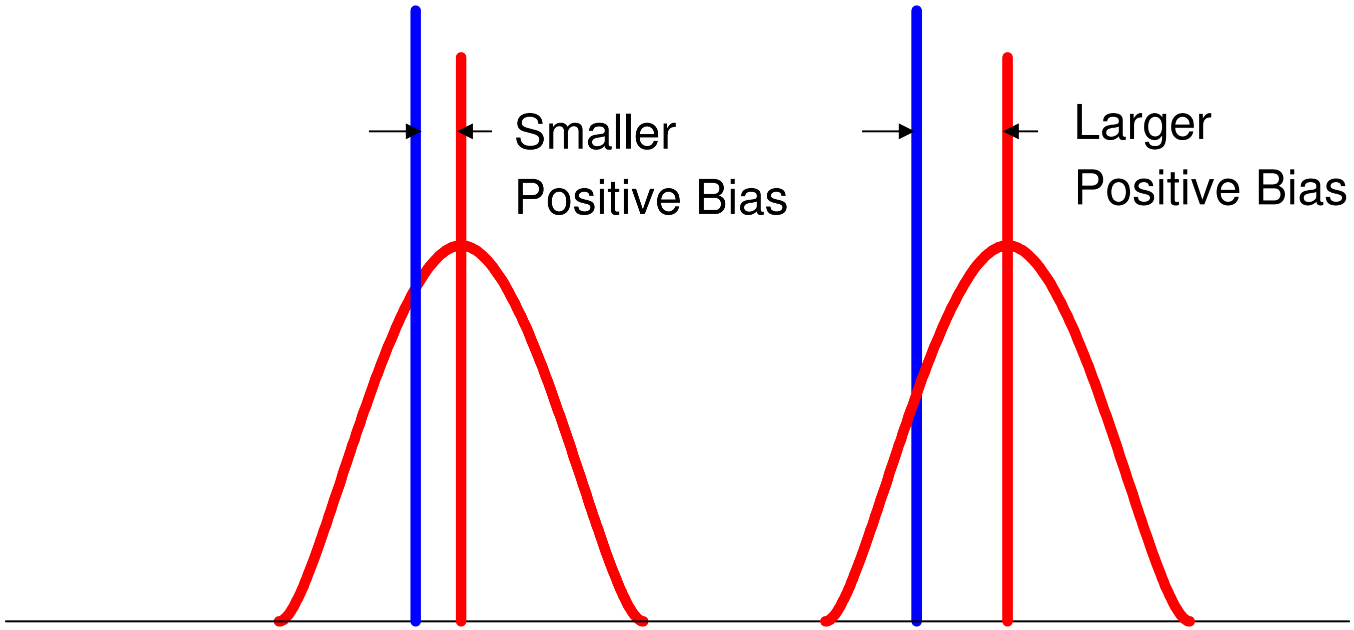
Bias





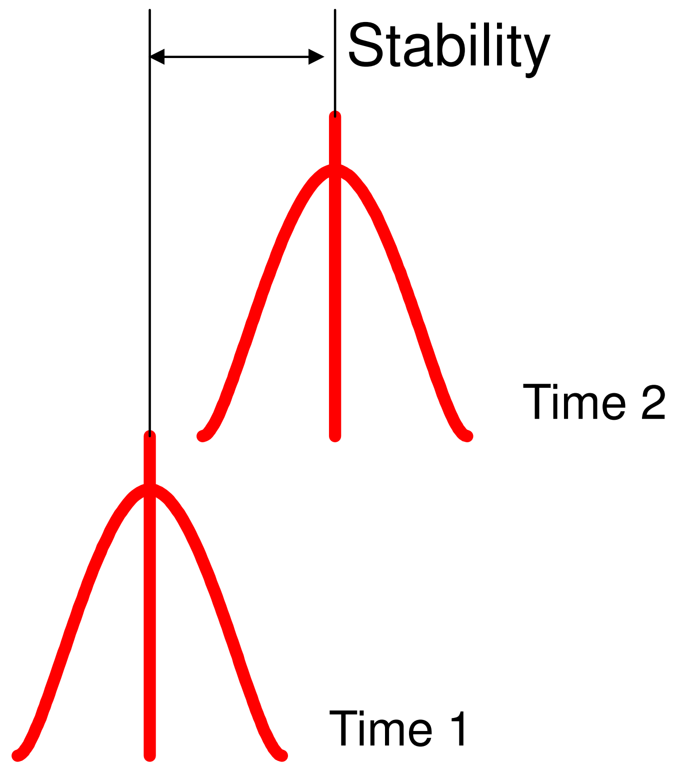
- Bias is the difference between the average of observed values and an assumed true value.

Linearity



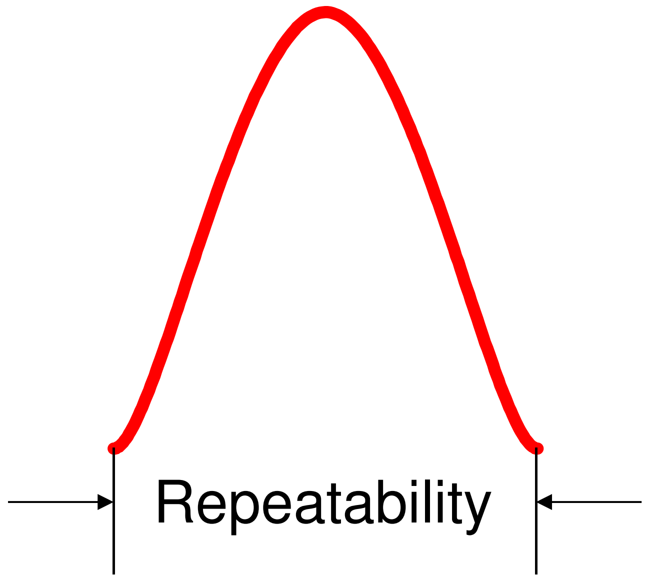
- Linearity is the difference in the bias values through the expected operating range of the gage.

Stability



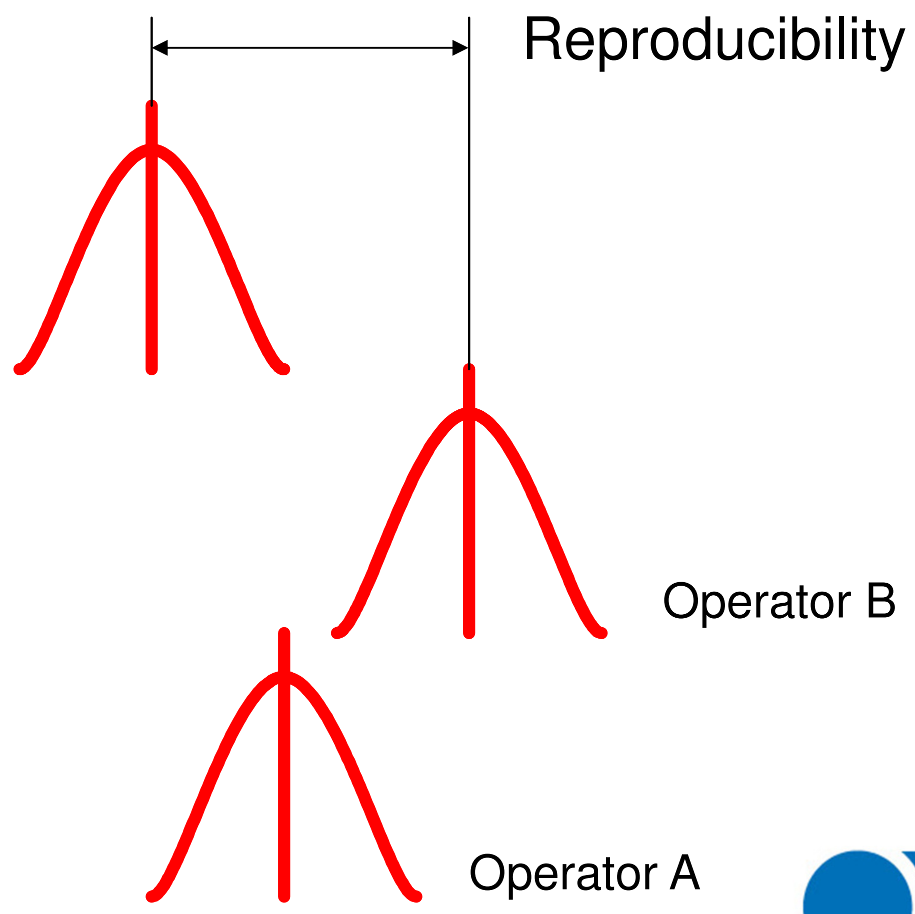
- Stability is the range between the largest and smallest bias from two or more sets of measurements taken over time.

Repeatability



- Repeatability is the variation from the **same operator** measuring the same part with the same gage.

Reproducibility



- Reproducibility is the variation from **different operators** measuring the same part with the same gage.

Purpose of Inspection

	Accept Parts	Reject Parts
Good Parts	**Good**	**Excess Cost**
Bad Parts	**Upset Customers and Higher Cost**	**Good**

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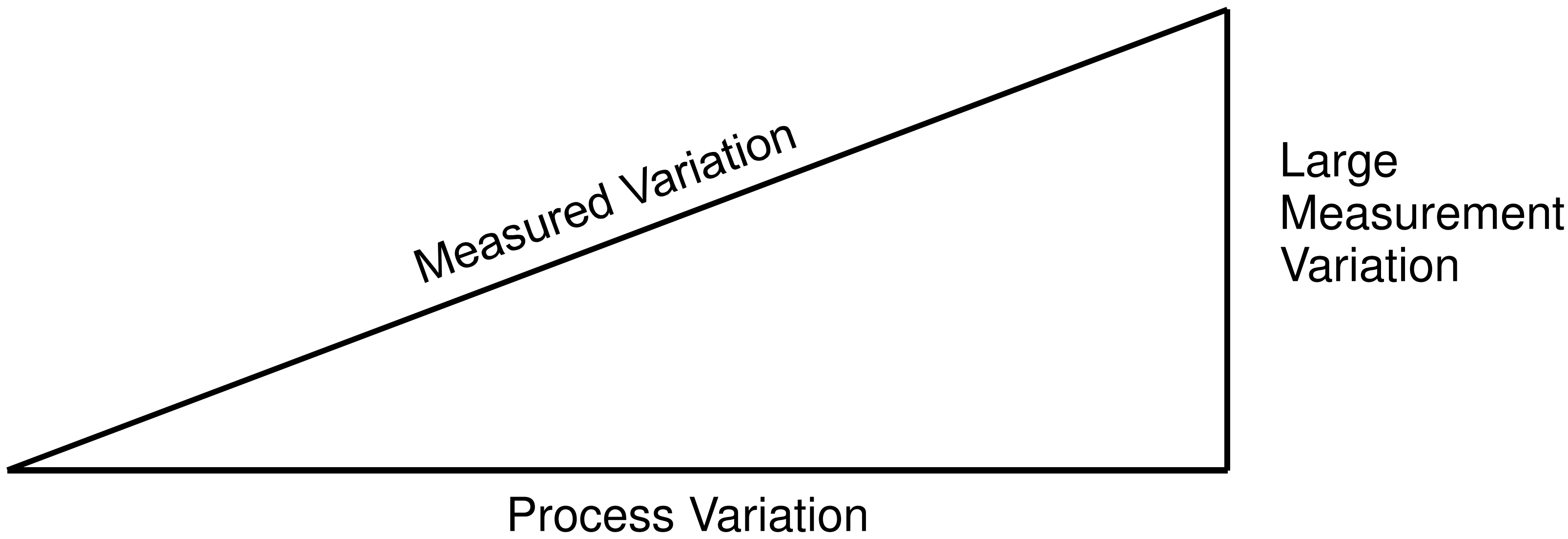
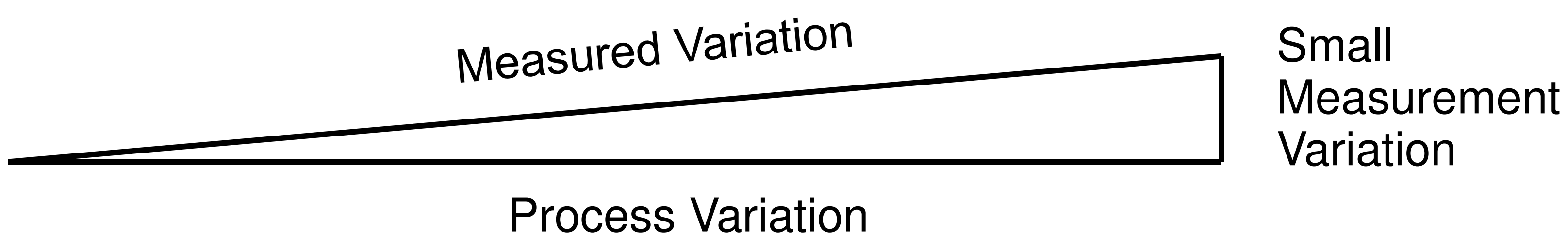
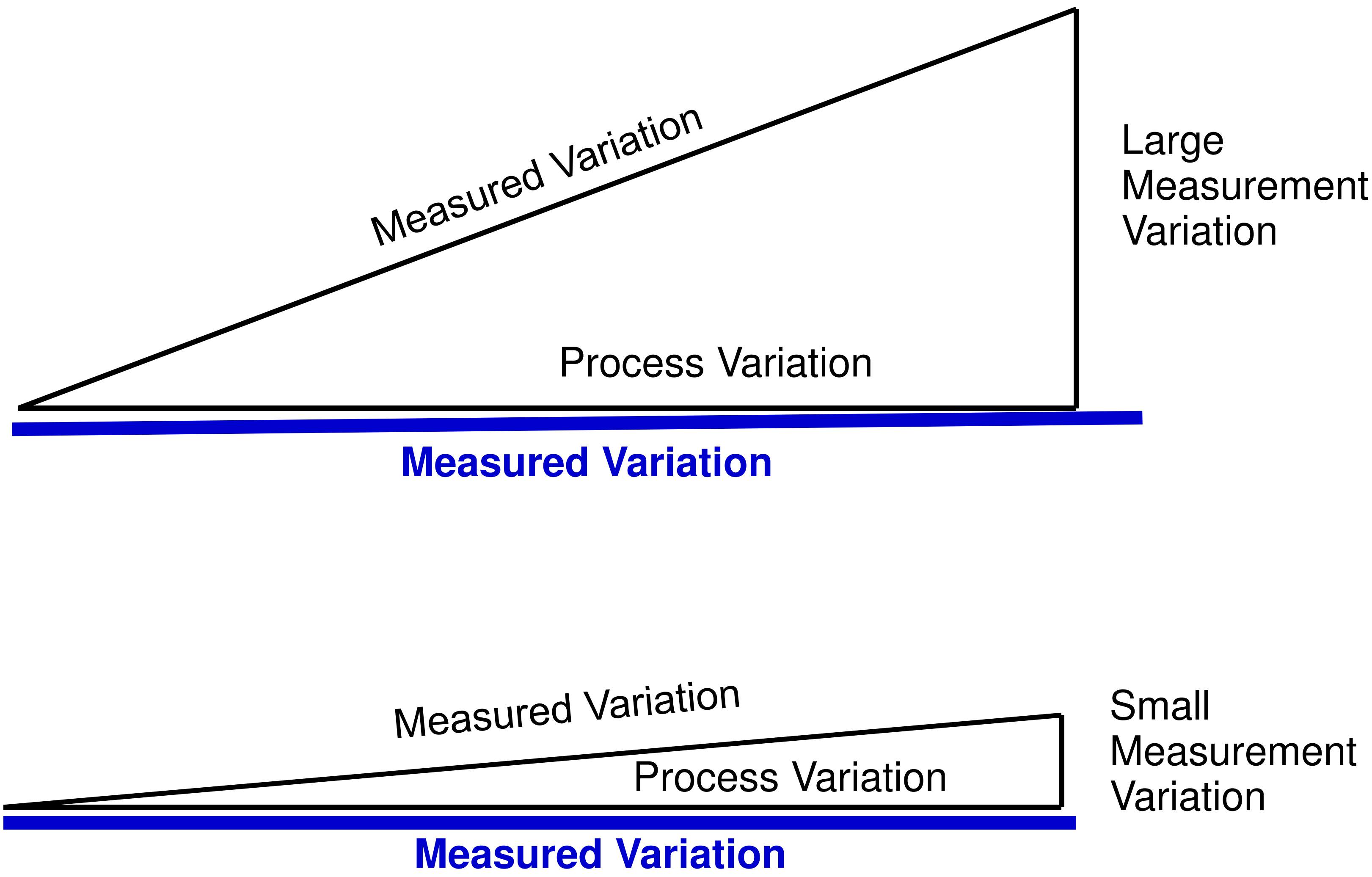
Measurement Error in Measurements

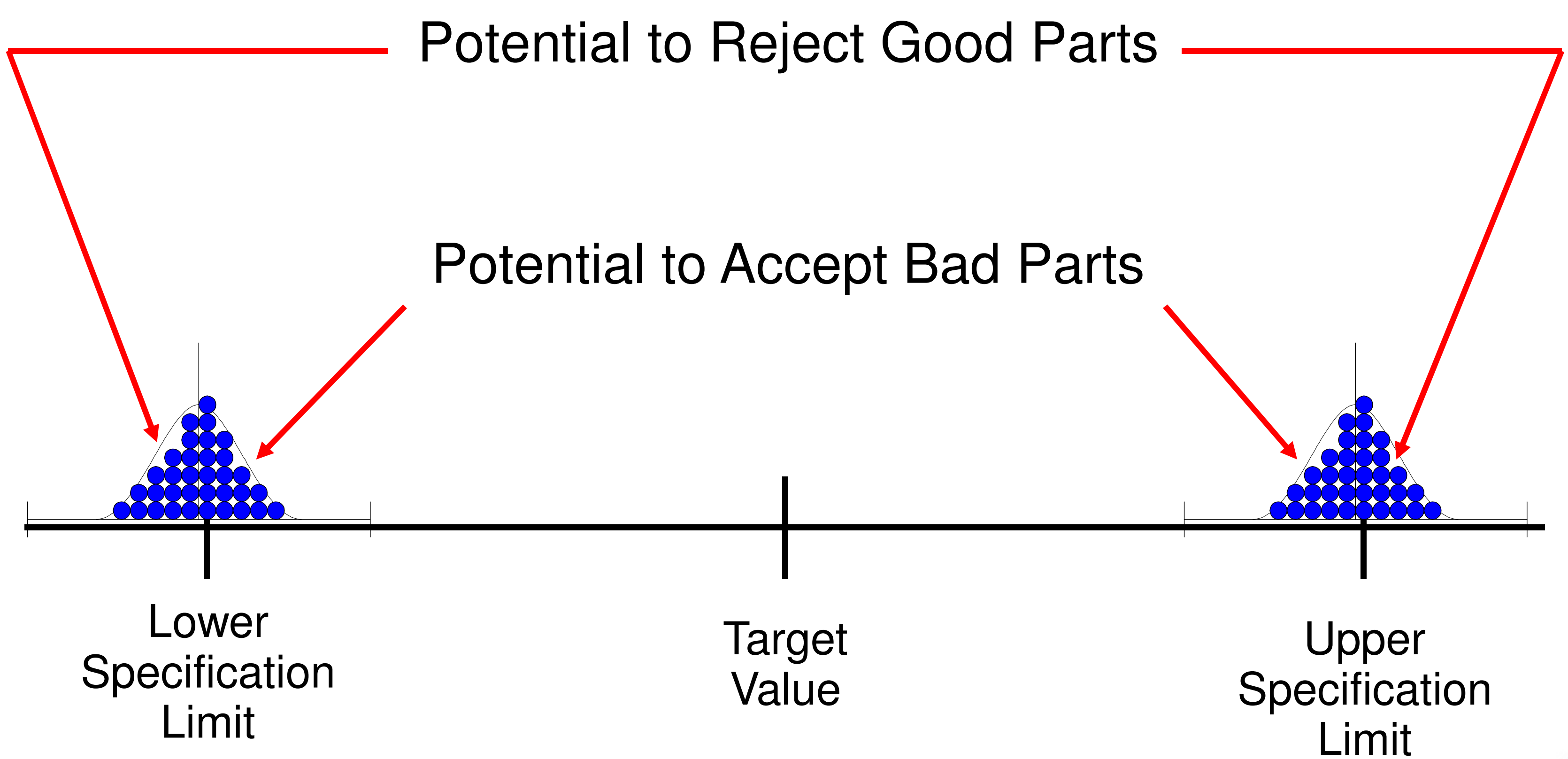




Small Measurement Error Provides Better Information on the Process



Impact of Measurement Uncertainty



Statistical Problem Solving

A three-step process for problem solving:

1. Identify and remove causes of instability.
2. Identify and correct causes of too much variation.
3. Identify and correct causes of off-target conditions.

Hans Bajaria, Ph.D.

Fundamental MSA Concepts

Fundamental MSA Concepts

Order of Presentation

Purpose of MSA Studies

Common Use of Terms

Requirements for Inspection

Measurement as a Process

Measurement System Planning

Measurement System Development

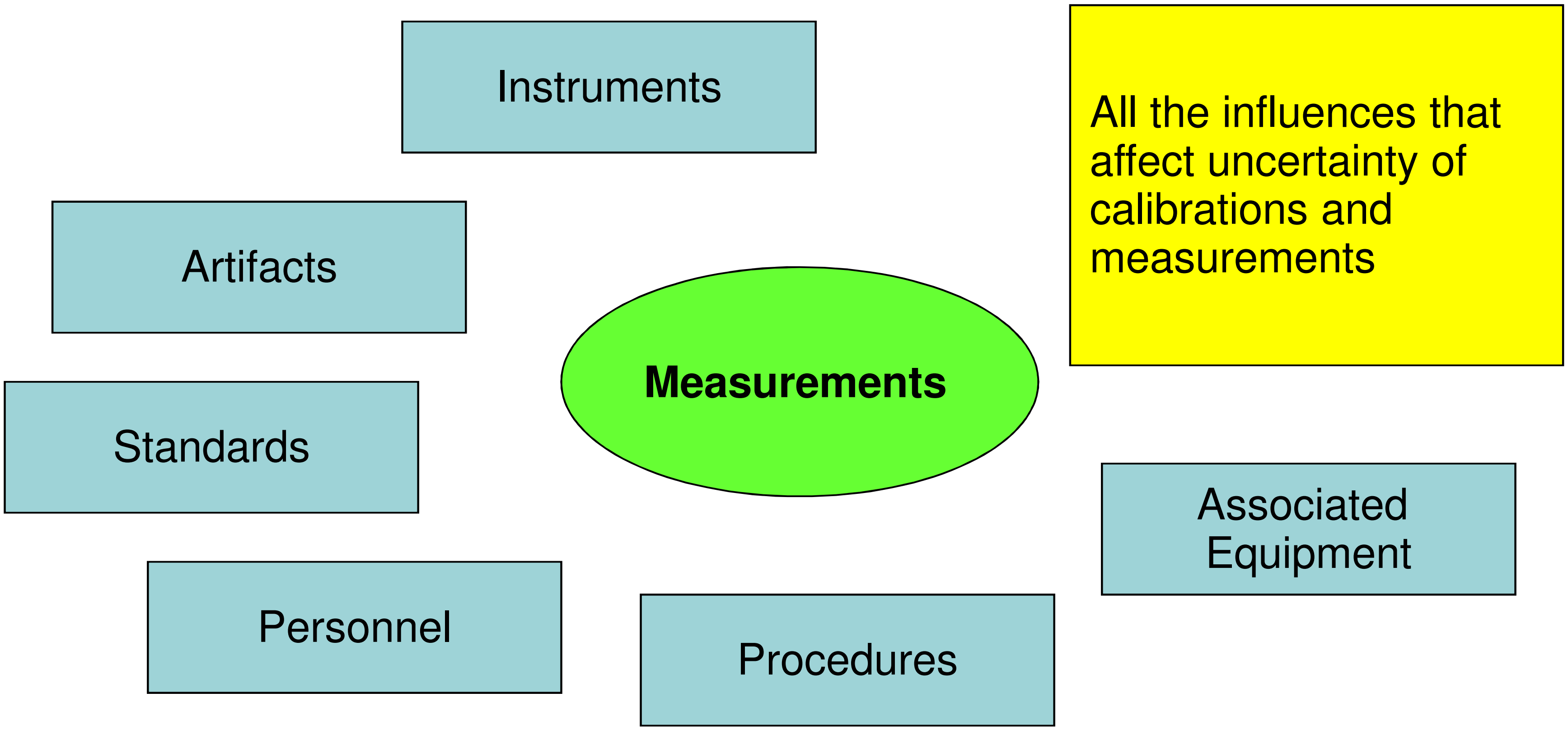
Quantification of Measurement Error

Measurement System Uncertainty

Common Use of MSA Terms

- **Measurement** allows us to assign numbers to material things to describe specific properties.
  - Measurement Process
  - Measured Value
- A **Gage** is any device used to obtain measurements, including attribute devices.
- **Measurement System** is the collection of instruments, gages, standards, methods, fixtures, software, personnel, environment, and assumptions used to quantify measurements.

A Measurement Ensemble



Note: The item being measured is outside the scope of the measurement ensemble.

Standard

- Accepted as the Basis for Comparison
- Provides the Criteria for Acceptance
- A Known Value (within limits of uncertainty)

A standard should be used within the context of an operational definition, to yield the same results with the same meaning yesterday, today, and tomorrow.

Basic Equipment

- Discrimination, Readability, Resolution
  - Smallest unit of measure for an instrument.
- Effective Resolution
  - Sensitivity of a gage for a particular application.
- Reference Value
  - The accepted value for an artifact.
- True Value
  - The actual value for an artifact. (unknown and unknowable)

Location Variation

- Accuracy
  - Closeness to the true value.
- Bias
  - Systematic error in the measurement process.
- Stability
  - Change in bias over time.
- Linearity
  - Change in bias in the normal operating range.

Width Variation

- Precision
- Repeatability
- Reproducibility
- GRR or Gage R&R
- Measurement System Capability
- Measurement System Performance

System Variation

- Capability
  - Variability in the short-term.
- Performance
  - Variability in the long-term. (estimate of total variability)
- Uncertainty
  - The MSA Guideline uses this term to describe a tolerance interval for measured values.

Note: The measurement system must be both stable and consistent.

Standards and Traceability

- It is appropriate to differentiate between the National Reference Standards and the National Institute of Standards and Technology where they are maintained.

- The key concept of traceability requires calibration of measurement devices through an unbroken chain of comparisons, all having known uncertainties.

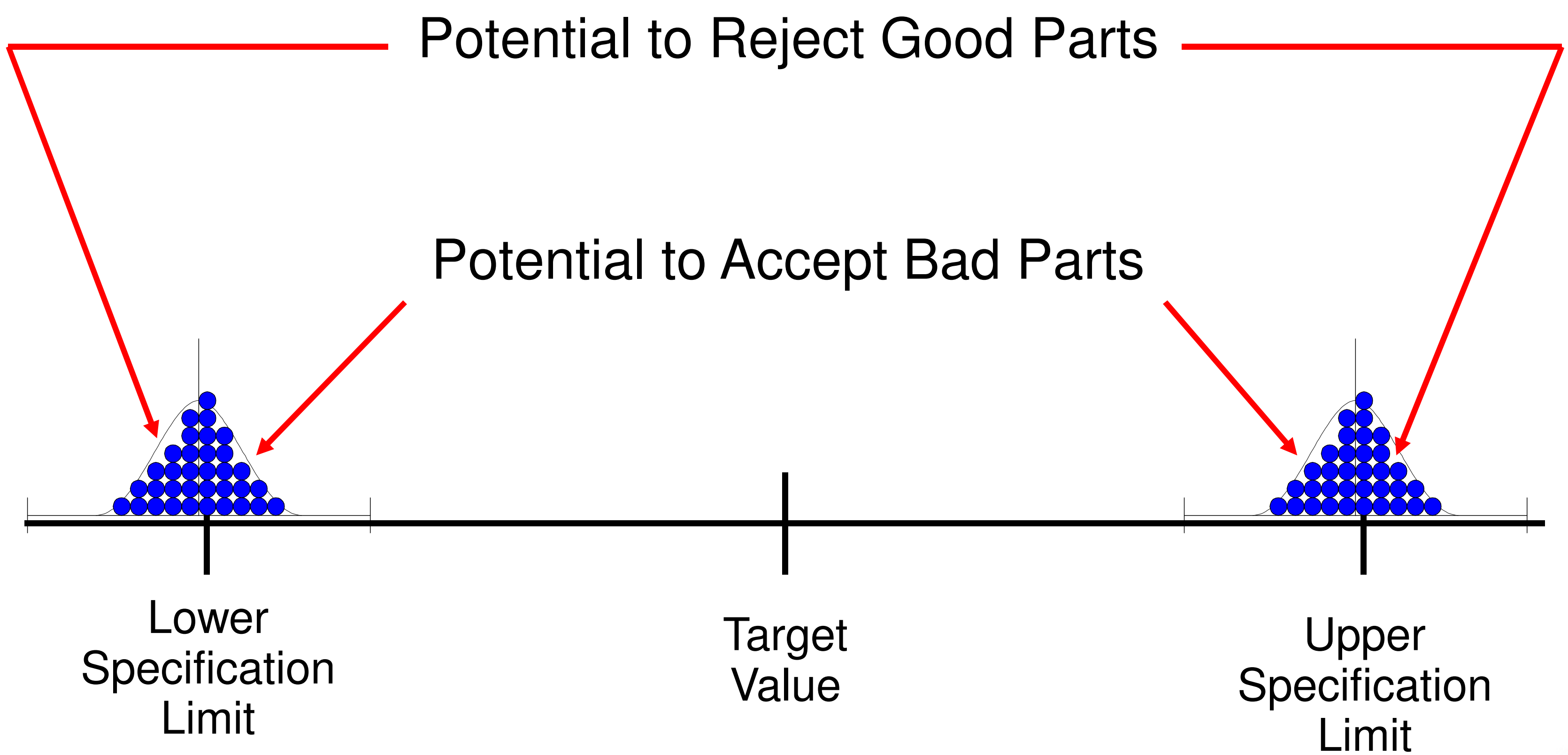
Purpose of Inspection

	Accept Parts	Reject Parts
Good Parts	**Good**	**Excess Cost**
Bad Parts	**Upset Customers and Higher Cost**	**Good**

Properties of Measurement Systems

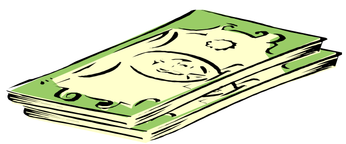
- Adequate Discrimination and Sensitivity
  - Increments of measure should be small compared to the specification limits for *Product Control*.
  - Increments of measure should be small compared to the process variation for *Process Control*.
- Measurement System in Statistical Control
  - The *Random Effects* model is essential.
  - Otherwise, a measurement process does not exist, according to Dr. Deming. (Out of the Crisis, 1986, p. 280)

Impact of Variability on Product Control



Impact of Variability on Process Control

- Measurement variability can lead us to act when we should not, or to not act when we should.



	Action Taken	No Action Taken
Action Required	**Good**	**Sin of Omission**
No Action Required	**Sin of Commission**	**Good**

A Tale of Two Technicians

Based on the thoughts of Wheeler and Lyday

Technician 1

- Careful his instrument was always calibrated.
- Every hour he checked his gage against the standard.
- If it did not read zero, he reset the gage to zero.
- Because of this hourly recalibration, Technician 1 was considered to be a very careful and conscientious worker.

A Tale of Two Technicians

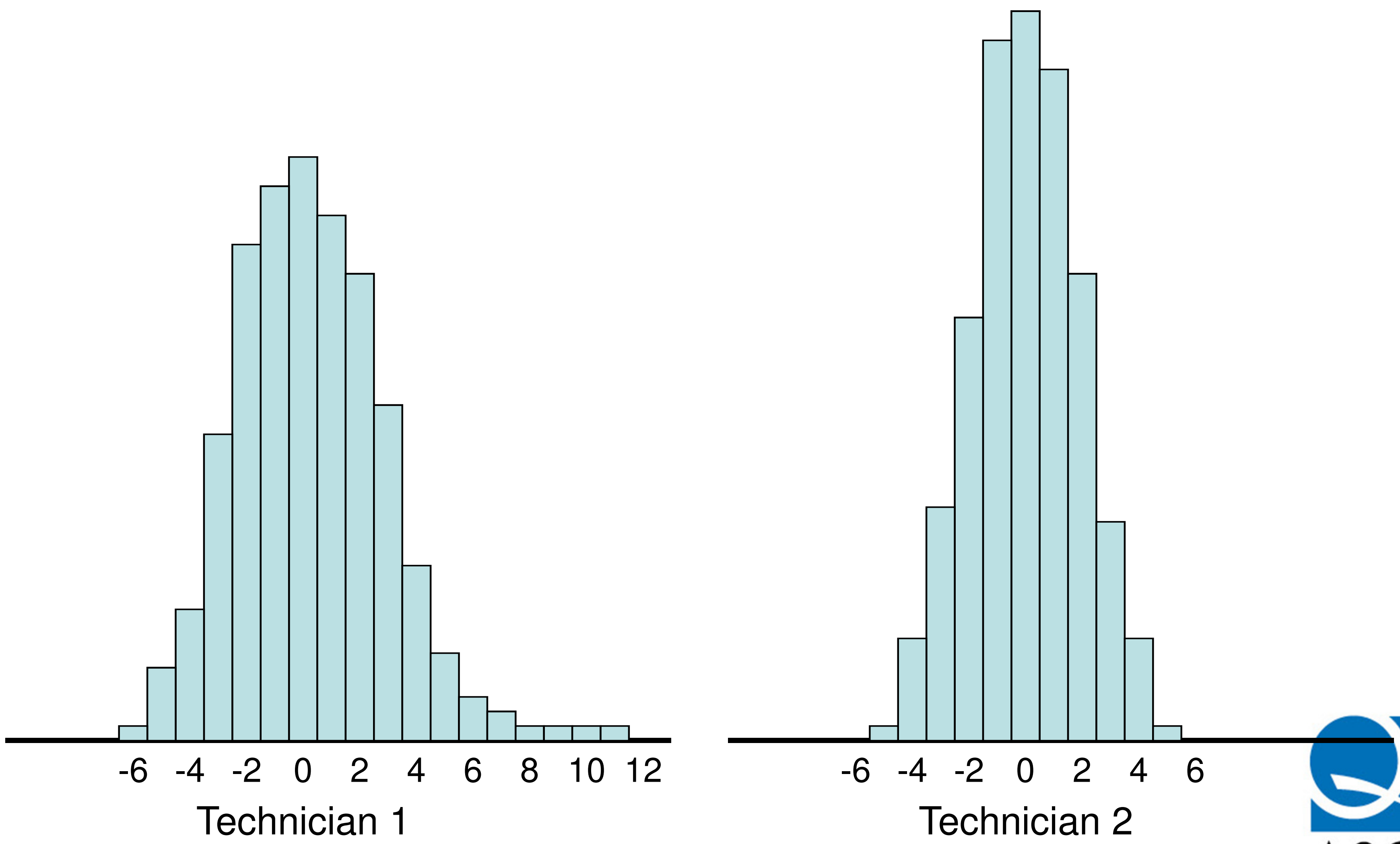
Technician 2

- Technician 2 used the same instrument.
- Every hour he checked his gage against the standard, but recorded the reading on a control chart.
- Instead of making hourly adjustments to the gage, he only adjusted the instrument when the value showed a lack of control.
- Otherwise, he continued to use the gage without adjustment.

A Tale of Two Technicians

- The two technicians continued to operate in this manner for several months.
- Finally, when their supervisor became aware of the different methods being used, she decided to study the results of the two methods.
- She created histograms that showed the amount of variation that the two technicians had recorded during their hourly calibrations.
- The scale shows variation from zero.

A Tale of Two Technicians



A Tale of Two Technicians

- Hourly adjustments by Technician 1 made the histogram wider.
- The variation of his adjustments was added to the natural variation of the measurements themselves.
- Many of the adjustments made by Technician 1 were unnecessary, and every one of them added to the variation seen in the wider histogram.

A Tale of Two Technicians

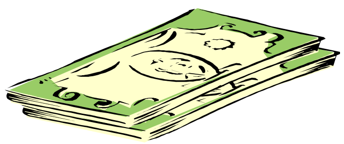
- Technician 2, on the other hand, had a narrower histogram because he only adjusted the gage when the control chart gave a clear signal of the need to adjust.
- In fact, Technician 2 rarely made any adjustments to the gage except at the beginning of his shift.
- The histogram suggests that these adjustments were necessary to undo the needless adjustments of Technician 1.

A Tale of Two Technicians

- Based on this study, a new calibration procedure was adopted.
- Control charts were made a routine part of every calibration scheme, and the standard operating procedure was changed so that adjustments would only be made in response to lack of control.
- Several of the company's test methods showed an immediate and dramatic improvement due to the elimination of over-calibration.

A Tale of Two Technicians

- Use of a control chart to check the consistency of a measurement process provides a scientific signal when recalibration is necessary.

	Action Taken	No Action Taken
Action Required	**Good**	**Sin of Omission**
No Action Required	**Sin of Commission**	**Good**

Preparation for MSA Studies

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Statement of the Problem

"A problem well defined is half solved."

John Dewey, Ph.D.

"The formulation of a problem is far more often essential than its solution, which may be merely a matter of mathematical or experimental skill."

Albert Einstein, Ph.D.

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Two Important Questions

- Are we measuring the correct variable at the correct location?
  - If the wrong variable is measured, then regardless of the accuracy and precision, we will simply spend money with no benefit.
- What statistical properties does the measurement process need to demonstrate to demonstrate that it is adequate?
  - These properties will guide the MSA study.

Preparing for the MSA Study

1. Plan the approach for the MSA study.
2. Select number of parts, appraisers, and trials.
3. Select appraisers from real operators.
4. Select parts that represent the process.
   - Select parts to represent the operating range.
   - If parts do not represent the total operating range, then you must ignore *TV* in the study.
5. Verify the gage has adequate discrimination.
6. Assure that the methods are clearly defined.

Mathematics of MSA Studies

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One Method to Assess Stability

1. Obtain a sample and establish its reference value relative to a traceable standard.

2. On a periodic basis, measure the master sample three to five times.

3. Record the data and plot the data on an X-bar & R chart or an X-bar & s chart.

Assessing Bias – Independent Sample

1. Obtain a sample and establish its reference value relative to a traceable standard.

2. Have a single appraiser measure the sample a predetermined number of times ($n \geq 10$).

3. Plot a histogram and review the graphical results.

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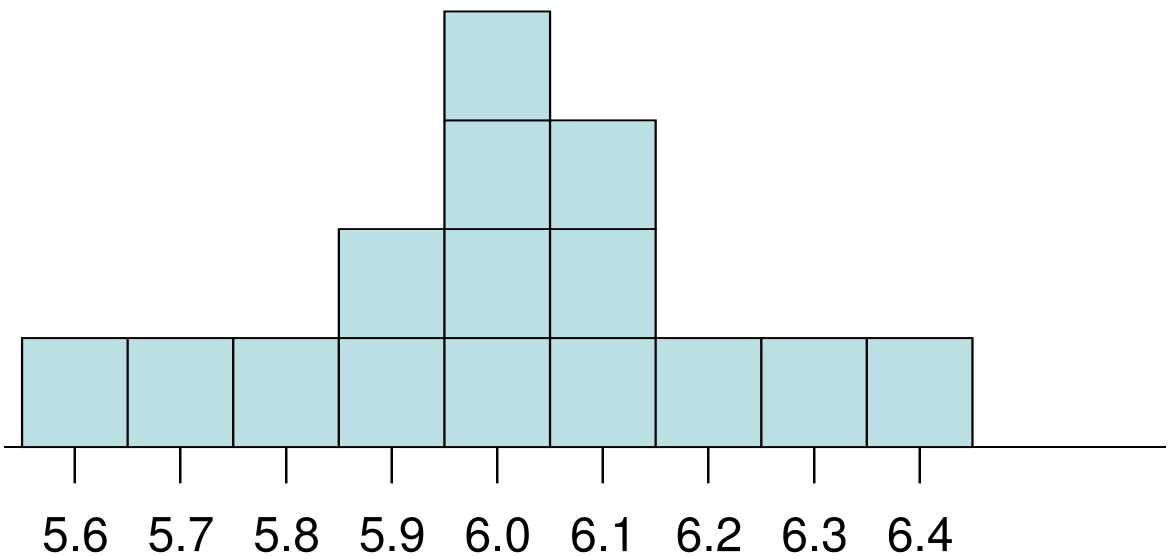
Assessing Bias – Independent Samples



Assessing Bias – Independent Sample

4. Compute the average of the *n* measurements.

5. Compute the repeatability standard deviation.

6. Determine the t statistic for the bias.

7. Bias is acceptable if the α level if zero is contained within the 1-α confidence bounds.

Assessing Bias – Control Chart Method

If a control chart is used to monitor stability of the measurement process, this data can also be used to evaluate bias.

1. Obtain a sample and establish its reference value relative to a traceable standard.

2. Plot a histogram and review the graphical results.

Methods to Assess Linearity

1. Select at least 5 parts with measured values that cover the operating range of the gage.
2. Have each of the parts measured to determine reference a value for each.
3. Measure each part at least 10 times to assess linearity of the gage in question.

Range Method for Gage R&R

Repeatability and Reproducibility
Range Method
MSA 4th Edition, Chapter 3, Section B, Pages 102 – 103
User Setup

Number of Parts	5
Number of Appraisers	2
Processs Standard Deviation (from previous study)	0.0777
Acceptable GRR Less Than	10%
Unacceptable GRR Greater than	30%

Range Method for Gage R&R

Repeatability and Reproducibility
Range Method
MSA 4th Edition, Chapter 3, Section B, Pages 102 – 103
Data Input

Parts		Appraiser A		Appraiser B		Appraiser C
1		0.85		0.80		
2		0.75		0.70		
3		1.00		0.95		
4		0.45		0.55		
5		0.50		0.60		
6						
7						
8						
9						
10						

Range Method for Gage R&R

Parts	Appraiser A	Appraiser B	Appraiser C	Range
1	0.85	0.80		0.05
2	0.75	0.70		0.05
3	1.00	0.95		0.05
4	0.45	0.55		0.10
5	0.50	0.60		0.10
6				-
7				-
8				-
9				-
10				-

Average Range (R-bar)	0.070
d*2	1.19
GRR	0.0588
Process Standard Deviation (from previous study)	0.0777
%GRR	75.64%
Acceptable GRR Less Than	10%
Unacceptable GRR Greater than	30%

Range Method for Gage R&R

Constant Tables

d*2	Appraisers (m)	
Parts (g)	**2**	**3**
1	1.41421	1.91155
2	1.27931	1.80538
3	1.23105	1.76858
4	1.20621	1.74989
5	1.19105	1.73857
6	1.18083	1.73099
7	1.17348	1.72555
8	1.16794	1.72147
9	1.16361	1.71828
10	1.16014	1.71573

Source: Appendix C, Page 203

Constants				d*2	1.19105

Average & Range Method – Gage R&R

Repeatability and Reproducibility
Average and Range Method
MSA 4th Edition, Chapter 3, Section B, Pages 103 – 119
User Setup

Number of Parts	10
Number of Appraisers	3
Number of Trials	3
Acceptable GRR Less Than	10%
Unacceptable GRR Greater than	30%
Acceptable Number of Distinct Categories	5

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Average & Range Method – Gage R&R

PART DESCRIPTION	Item #45
CHARACTERISTIC	Surface Friction
SPECIFICATION - NOMINAL	0.96
SPECIFICATION - LOWER LIMIT (LSL)	0.46
SPECIFICATION - UPPER LIMIT (USL)	1.46
GAUGE NAME:	Instron
GAUGE #:	1645
GAUGE TYPE:	SF Gage
DATE	21-Feb-03
ANALYSIS PERFORMED BY	Bev

User: Enter Data only in Yellow Boxes **Example:**

Average & Range Method – Gage R&R

PART DESCRIPTION:		Item #45		GAUGE NAME:	Instron	DATE:	21-Feb-03
CHARACTERISTIC:		Surface Friction		GAUGE #:	1645	PERFORMED BY:	
SPECIFICATION:	0.96	+ 0.5	- 0.5	GAUGE TYPE:	SF Gage	Bev	

DATA

Appraiser a:(NAME)=	Bill									
	PART									
TRIAL #	1	2	3	4	5	6	7	8	9	10
1	0.2900	-0.5600	1.3400	0.4700	-0.8000	0.0200	0.5900	-0.3100	2.2600	-1.3600
2	0.4100	-0.6800	1.1700	0.5000	-0.9200	-0.1100	0.7500	-0.2000	1.9900	-1.2500
3	0.6400	-0.5800	1.2700	0.6400	-0.8400	-0.2100	0.6600	-0.1700	2.0100	-1.3100

Appraiser b:(NAME)=	Rob									
	PART									
TRIAL #	1	2	3	4	5	6	7	8	9	10
1	0.0800	-0.4700	1.1900	0.0100	-0.5600	-0.2000	0.4700	-0.6300	1.8000	-1.6800
2	0.2500	-1.2200	0.9400	1.0300	-1.2000	0.2200	0.5500	0.0800	2.1200	-1.6200
3	0.0700	-0.6800	1.3400	0.2000	-1.2800	0.0600	0.8300	-0.3400	2.1900	-1.5000

Appraiser c:(NAME)=	Greg									
	PART									
TRIAL #	1	2	3	4	5	6	7	8	9	10
1	0.0400	-1.3800	0.8800	0.1400	-1.4600	-0.2900	0.0200	-0.4600	1.7700	-1.4900
2	-0.1100	-1.1300	1.0900	0.2000	-1.0700	-0.6700	0.0100	-0.5600	1.4500	-1.7700
3	-0.1500	-0.9600	0.6700	0.1100	-1.4500	-0.4900	0.2100	-0.4900	1.8700	-2.1600
Reference Value	1.0800	1.1000	1.0600	1.1000	1.0000	1.3340	1.3320	1.0800	0.9960	1.0020

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Average & Range Method – Gage R&R

Repeatability and Reproducibility Average and Range Method MSA 4th Edition, Chapter 3, Section B, Pages 103 – 119 Results	
Number of averages falling outside control limits	22
Percent of averages falling outside control limits	73%
Number of Ranges falling outside control limits	1
There are differences between the variability of the appraisers.	

Evaluation of MSA Studies

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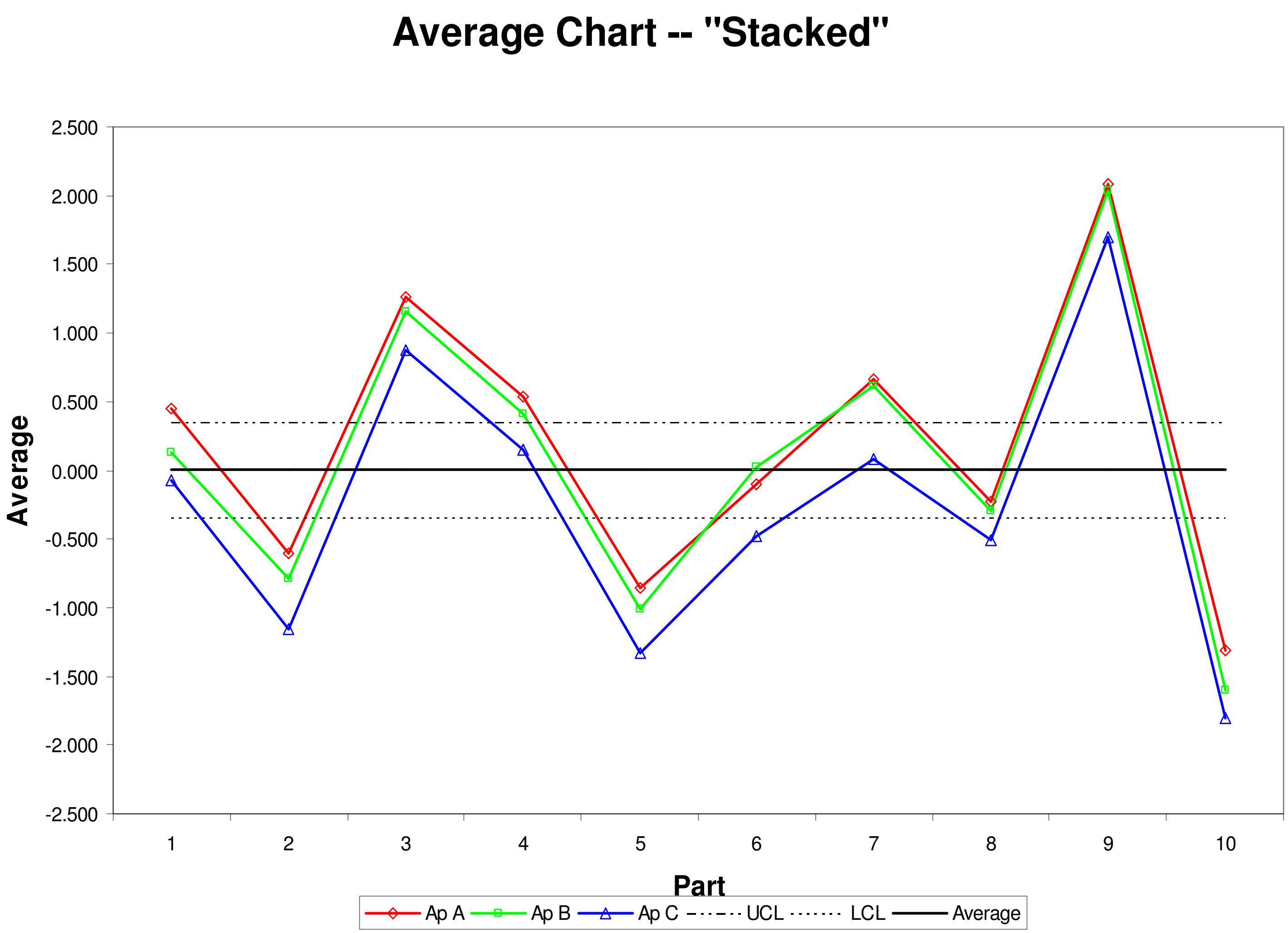
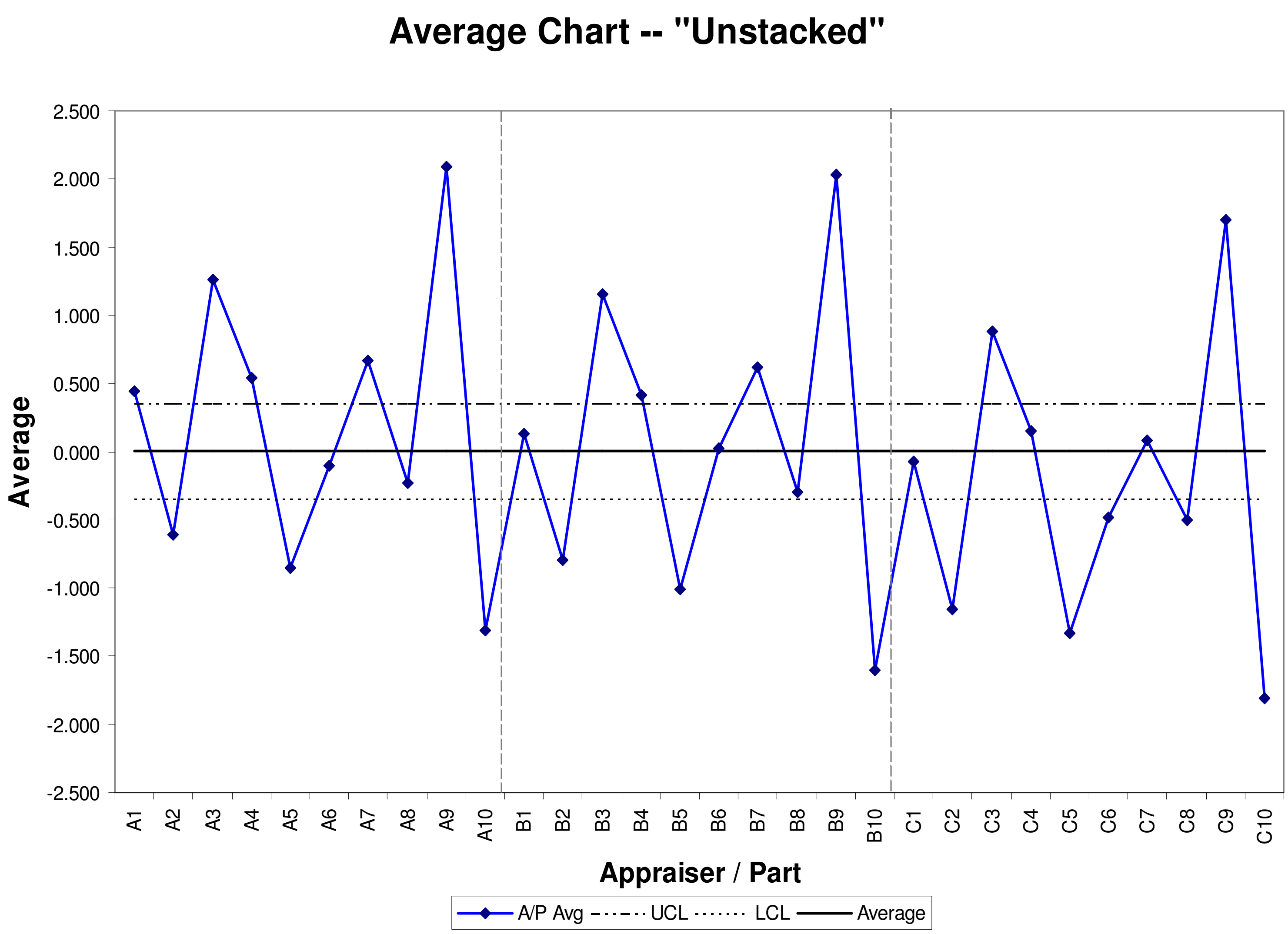
Analysis of Results for Stability

- Review range chart for adequate discrimination.
- Establish control limits and review range control chart for out-of-control signals.
- Take appropriate action when the range chart goes out-of-control.

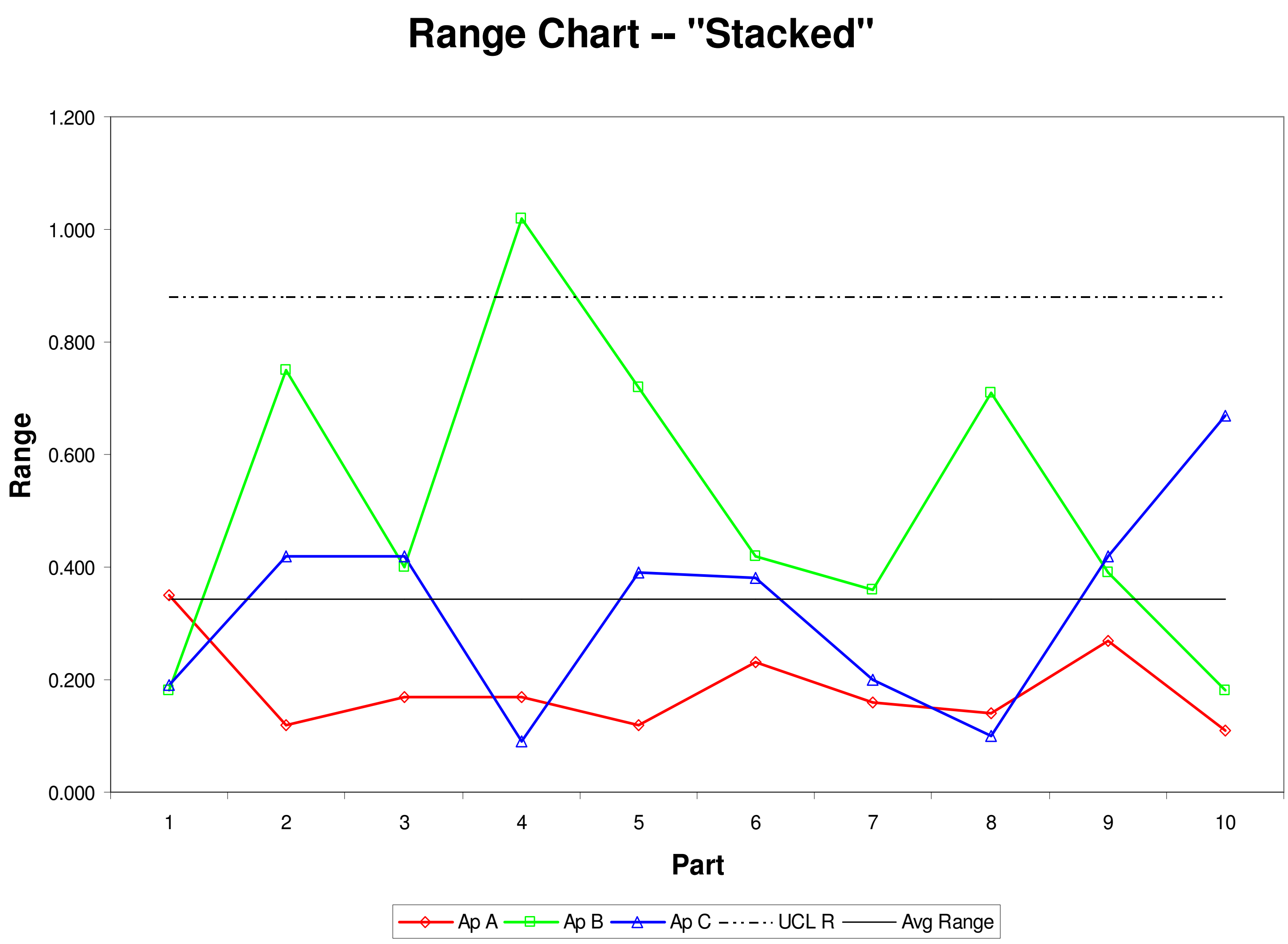
Analysis of Gage R&R Results



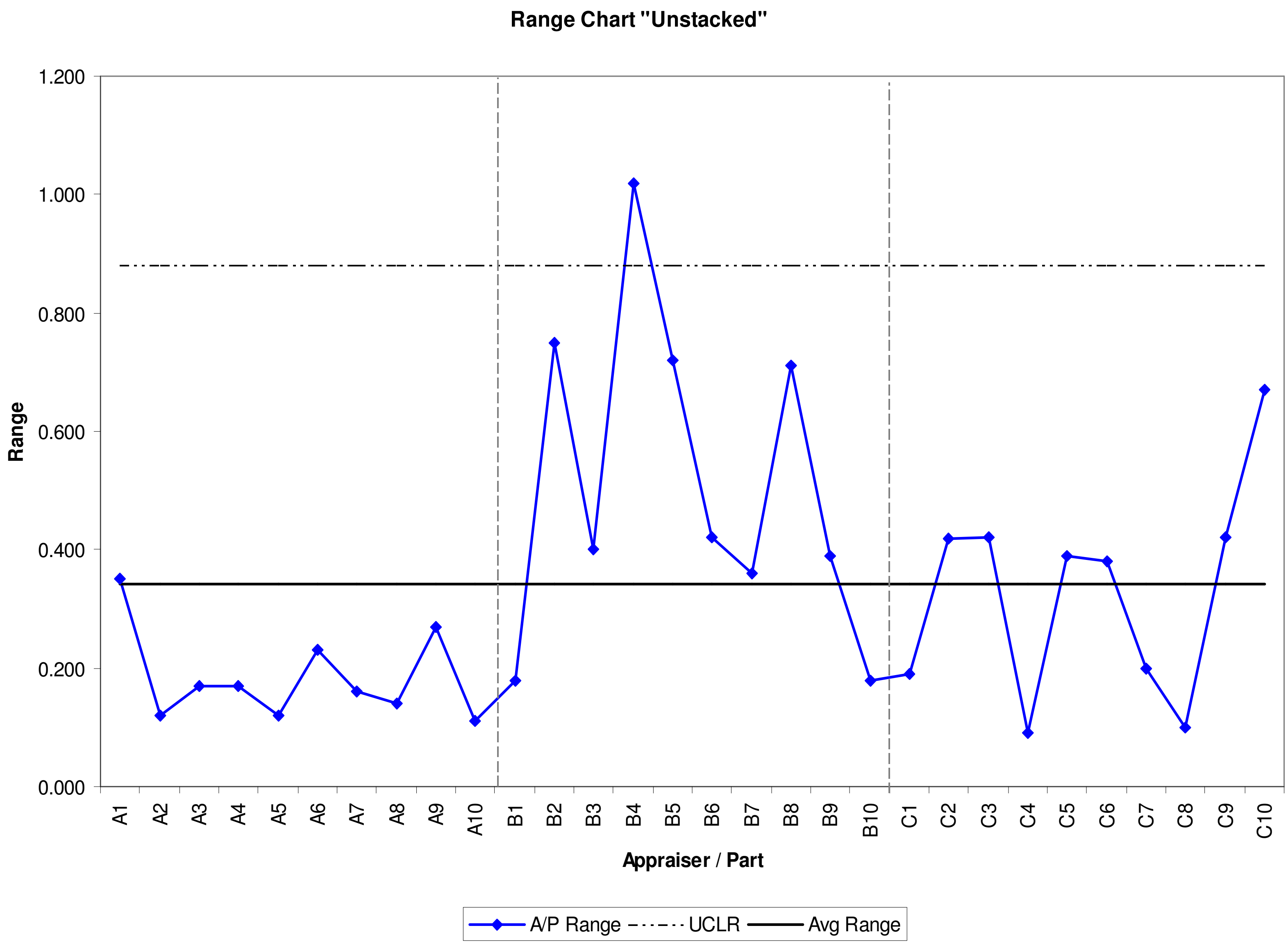
Analysis of Gage R&R Results



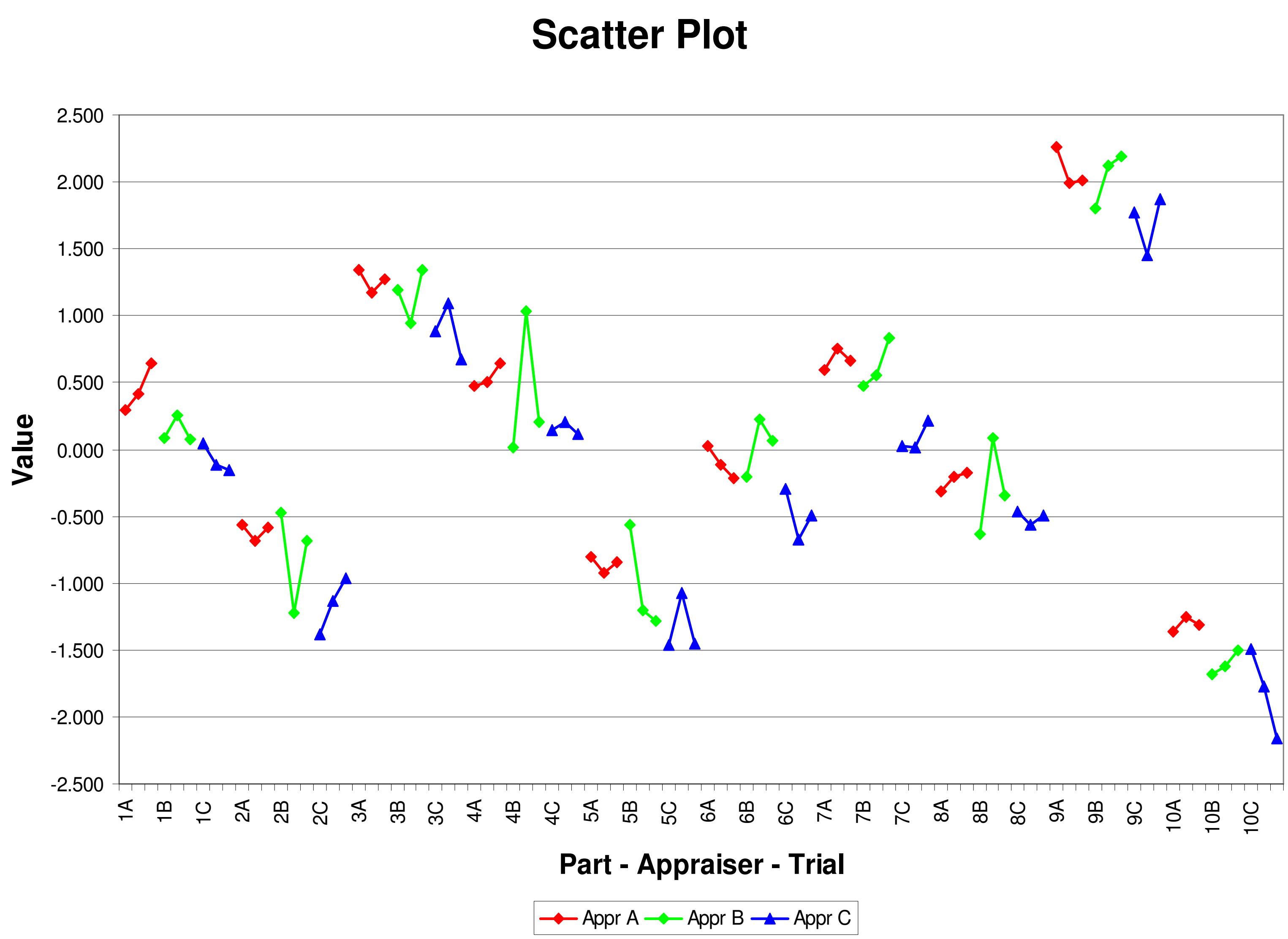
Analysis of Gage R&R Results



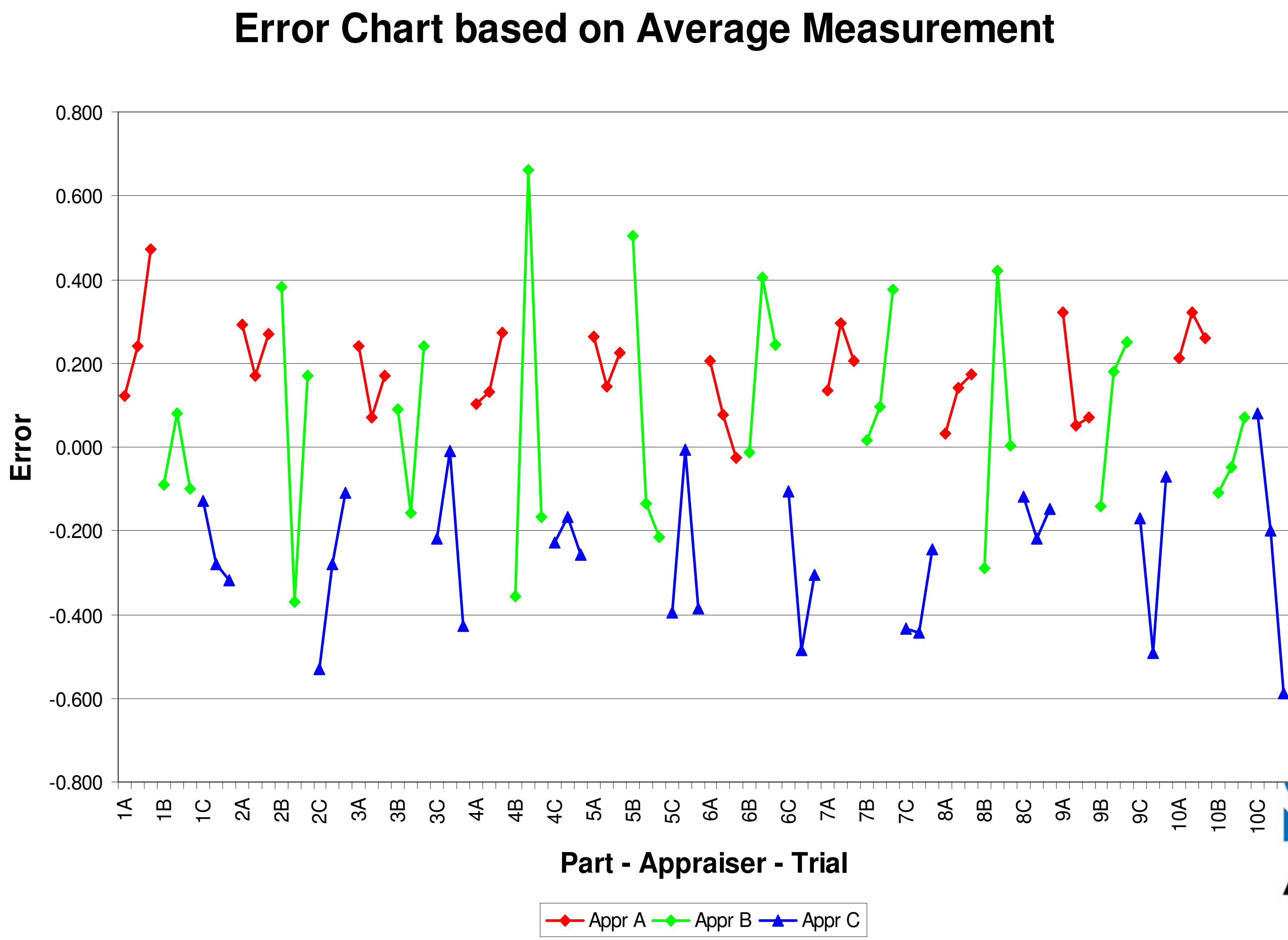
Analysis of Gage R&R Results



Analysis of Gage R&R Results



Analysis of Gage R&R Results



Measurement Problem Analysis

A three-step process for problem solving:

1. Identify and remove causes of instability.
2. Identify and correct causes of too much variation.
3. Identify and correct causes of off-target conditions.

Hans Bajaria, Ph.D.

Summary and Closure

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Course Goals

1. To provide a fundamental understanding of the language that guides MSA studies.

2. To use MSA studies to determine where measurement processes require improvement to assess special characteristics.

3. To achieve robust capable measurement processes for special characteristics.

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Questions and Answers

Please type your questions in the panel box

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Thank You For Attending

Please visit our website www.asq-auto.org for future webinar dates and topics.