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Measurement Systems Analysis

MSA for Suppliers

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MSA Objective

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Qualification of a measurement system for use by quantifying its accuracy, precision, and stability

– Understand the quality characteristics of measurement
– Understand the method for establishing measurement capability
– Define the requirements of the measurement system

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The Importance of Good Measurement

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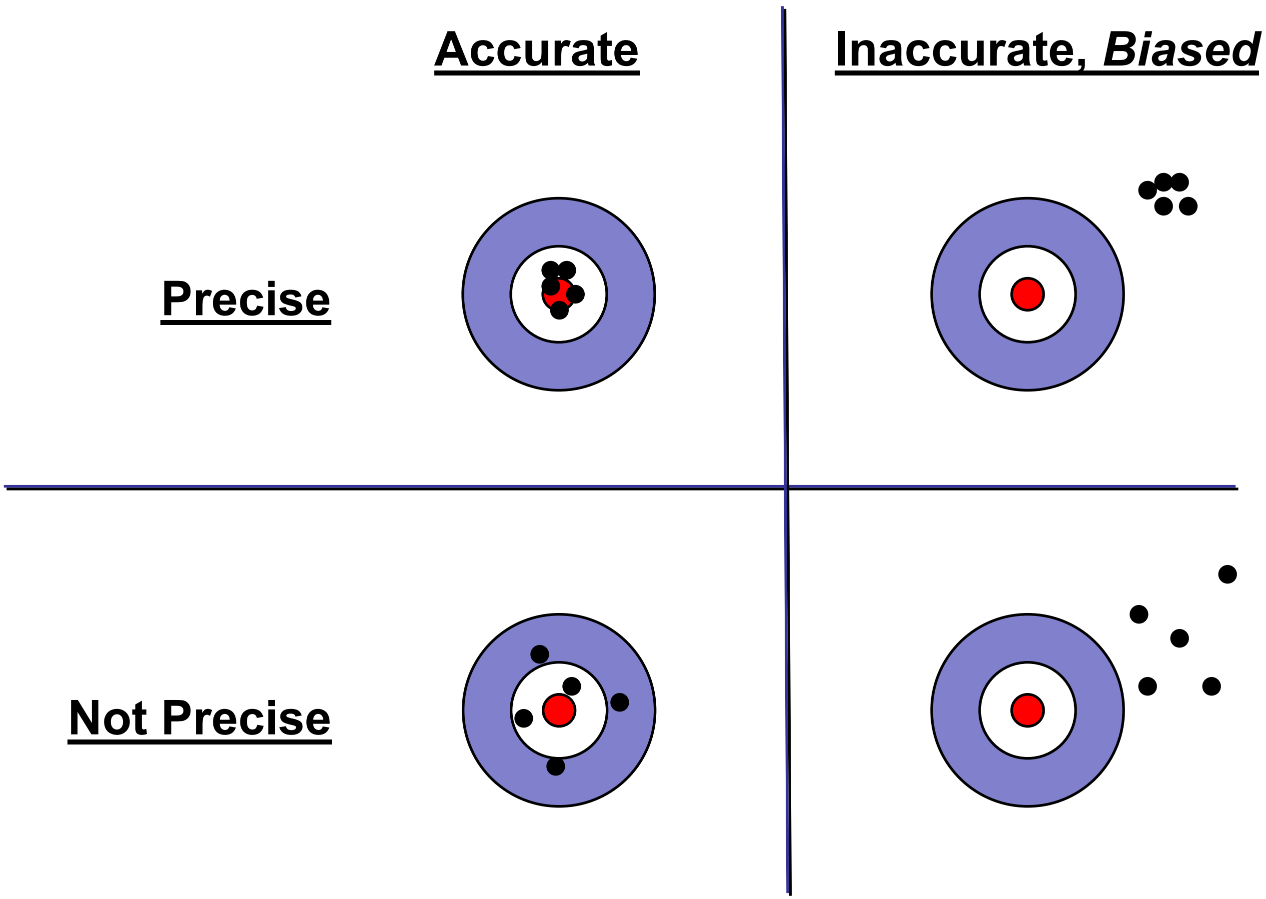

You cannot improve what you cannot measure

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The Qualities of Measurement

- Resolution
- Accuracy (Bias)
- Linearity
- Repeatability
- Reproducibility
- Stability

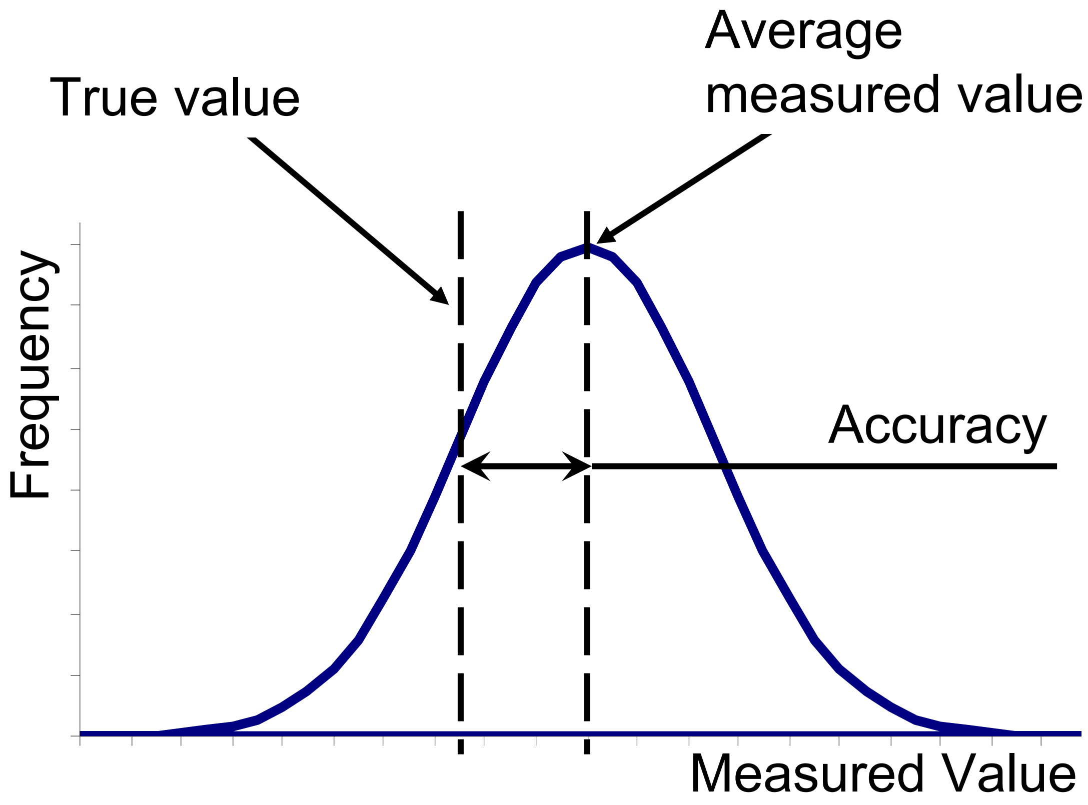
Resolution

Resolution is the incremental ability of a measurement system to discriminate between measurement values.

The measurement system should have a **minimum of 20 measurement increments** within the product tolerance (e.g, for a full tolerance of 1, minimum resolution is .05)

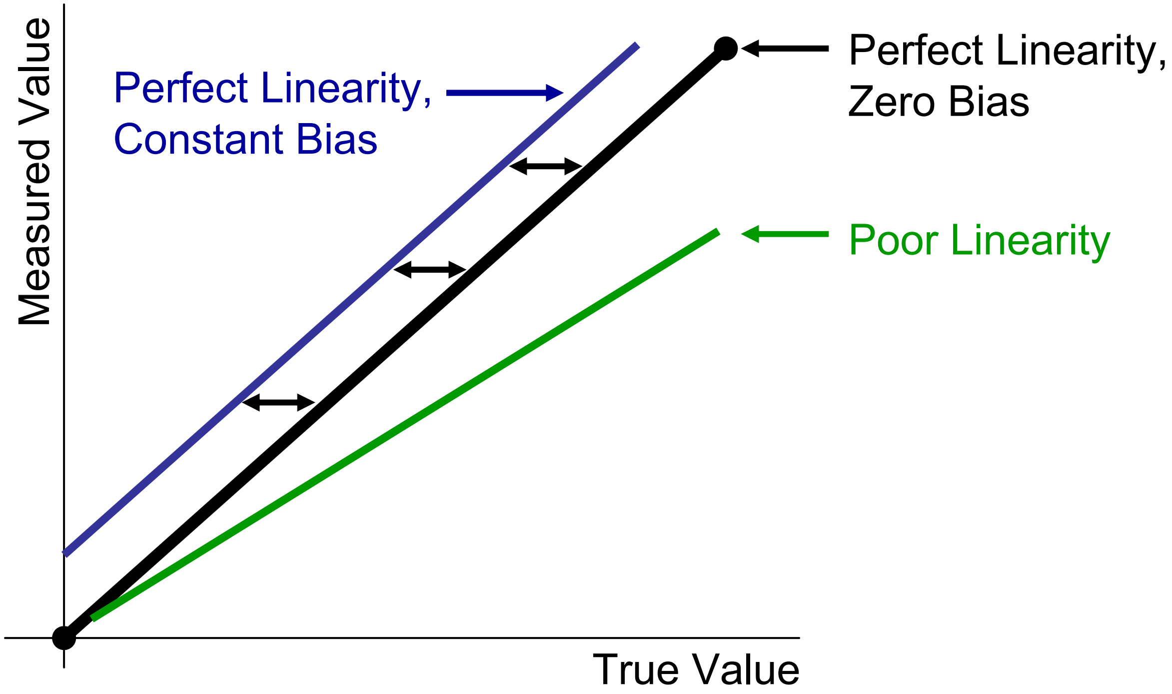
Accuracy

Accuracy—or **bias**—is a measure of the distance between the average value of the measurement of a part and the True, certified, or assigned value of a part



Linearity

Linearity is the consistency of **accuracy (bias)** over the range of measurement; a slope of one (unity) between measured and true value is perfect



Repeatability

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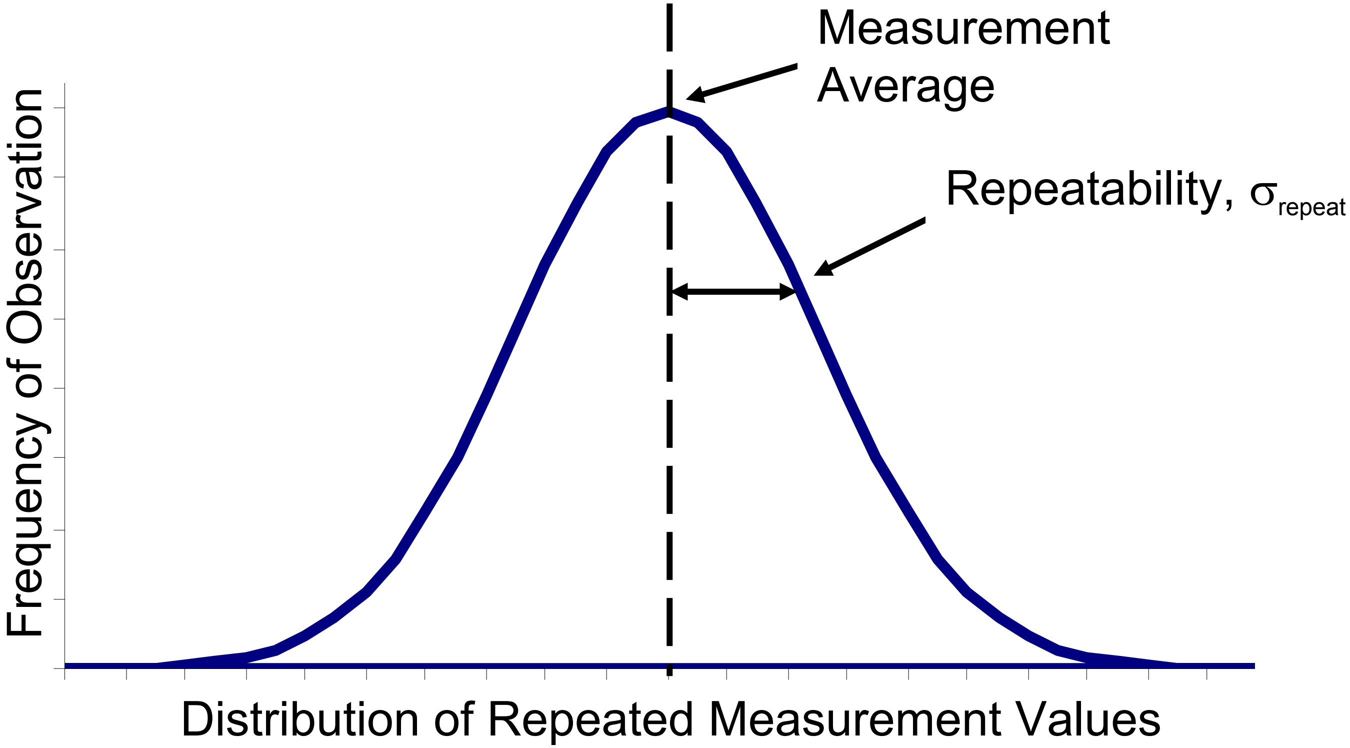
Repeatability is the consistency of a single appraiser to measure the same part multiple times with the same measurement system; it is related to the standard deviation of the measured values



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Reproducibility

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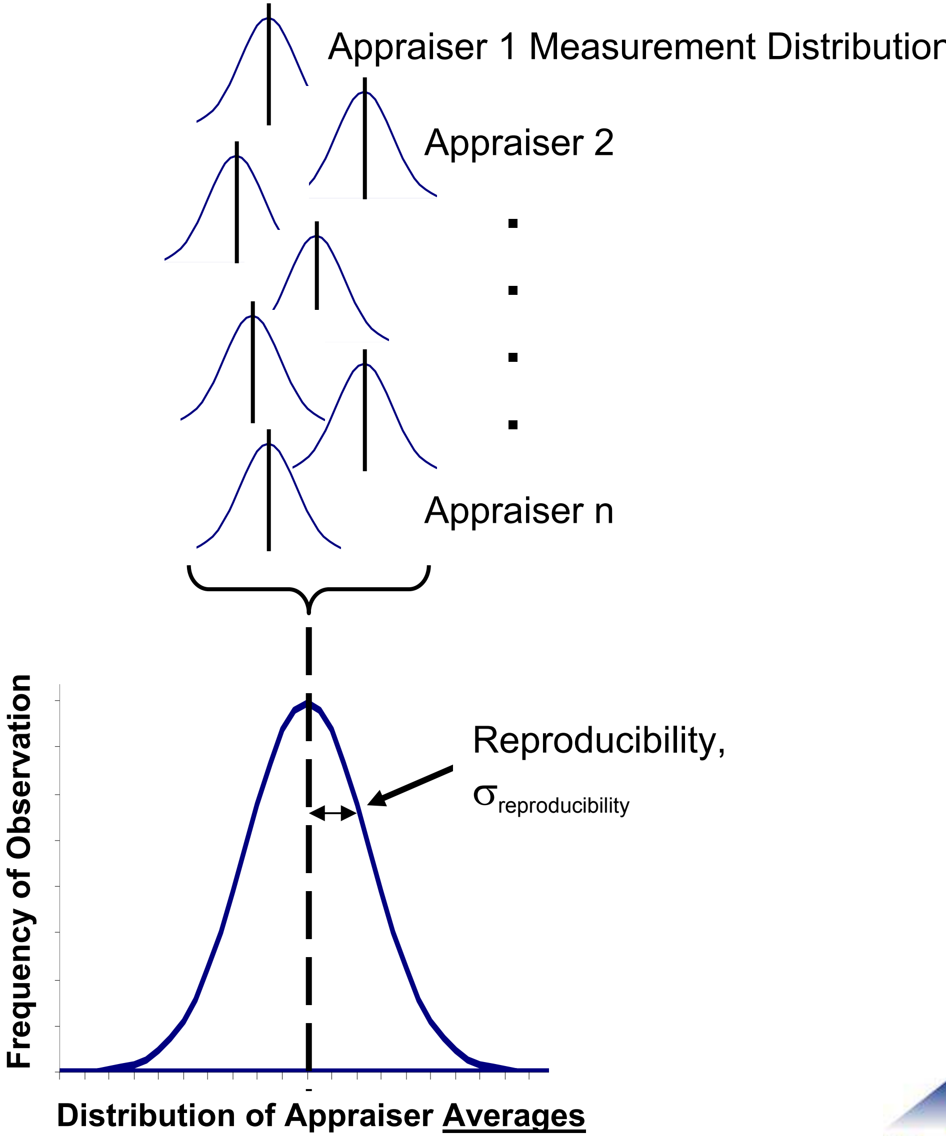
Reproducibility is the consistency of different appraisers in measuring the same part with the same measurement system; it is related to standard deviation of the distribution of appraiser averages



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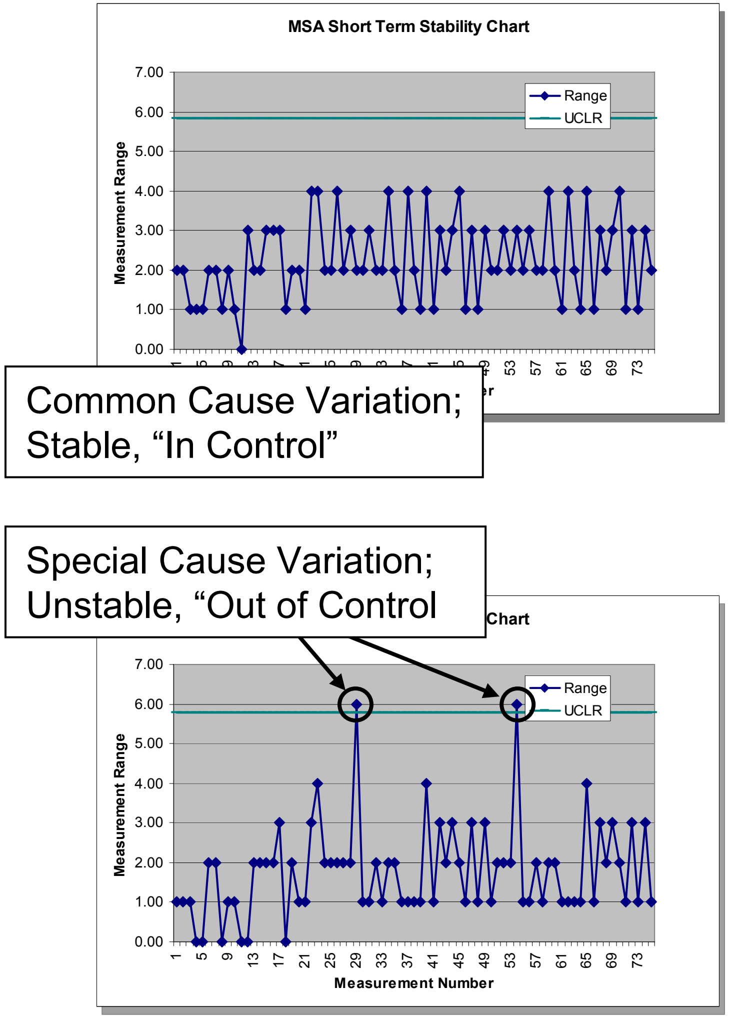
Stability

Stability is the ability of a measurement system to produce the same values over time when measuring the same sample



As with statistical process control charts, **stability means the absence of "Special Cause Variation"** which is indicated by an "in control" condition, leaving only "Common Cause" or random variation

Measurement Systems Metrics

- Generally, **precision is the principle concern**; inaccuracy due to linearity or constant bias can typically be corrected through calibration
- **Measurement Error** is the statistical summing of the error generated by Repeatibility (the variation within an appraiser) and Reproducibility (the variation between appraisers)
  - $\sigma_{error} = \sqrt{(\sigma_{repeability})^2 + (\sigma_{reproducibility})^2}$
- **Total Measurement Error** spans the interval that contains 99% of probable measurement values from a measurement system, using a single part
  - Total Measurement Error = 5.15 * σ_{error}
- Measurement system **precision** is defined by the **Precision/Tolerance Ratio**, the ratio between Total Measurement Error and the part tolerance
  - P/T Ratio = 5.15 * σ_{error} / (Upper Spec Limit – Lower Spec Limit)

Measurement Systems Metrics

- **Error Independence** is defined by the **lack of a relationship between measurement error and the measurement value**; error generated by the measurement process should be independent of the measured value
- **Stability** is defined by the **randomness of the measurement error**; purely random measurement error is evidence of good stability
- **Linearity** is defined by the slope of measured value vs. true value; a slope of 1 (a 1:1 relationship) is perfect
- **Bias Offset** is defined by the average difference between the measured value and the true value at the specification target; a value of zero is perfect
  - The combination Bias Offset and Linearity define the amount of systematic measurement error across the entire measurement range; they are typically corrected through calibration

Measurement System Requirements

MSA Parameter	Requirement
Precision/Tolerance Ratio	P/T<10% **Accept** 10%<P/T<30% **Marginal Accept** >30% **Fail**
Error Independence	**Pass** the hypothesis test that error is independent of measured value
Stability	Measurement error is **in control** when plotted on a control chart
Bias	**Pass** the hypothesis test that no offset exists between true and measured value at the spec target
Linearity	**Pass** the hypothesis test that slope between the true and measured values is equal to one (unity)

Conducting the MSA

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- Raytheon provides two template versions for the MSA
  - **Short Study,** which **requires 10 parts** to be measured a minimum of two repetitions by two different operators (or up to three times with three operators)
  - **Standard Study,** which **requires 25 parts** to be measured a minimum of two repetitions by two different operators (or up to three times with three operators)
- For the purposes of analysis, **a part is equivalent to a dimension**
  - 25 different (but similar) dimensions on a single part is equivalent to a single dimension on 25 parts
- Parts selected for use in the MSA should **span the full tolerance range**
- The **measurement system being assessed must be properly calibrated** using standard operating practice prior to the MSA
- The quality of the assessment is related to the number of parts, repetitions and operators, thus **we recommend the standard study**
- Randomizing the order of measurement during the MSA is a best practice

MSA Standard Study

MSA Short Study

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Using the MSA Study Template

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- Use the MSA Form worksheet in the MSA Excel file to capture measurement data on the parts
- **The "True Value" of a part is necessary to assess system linearity and accuracy**; parts with values that span the tolerance should be used; we recommend a minimum of six parts with true values for the linearity analysis
- **A minimum of two repeated measures of each part is required**; this is the minimum number needed to establish a measurement range for an individual part; three is recommended
- **A minimum of two appraisers is required**; this allows us to estimate reproducibility; three is recommended

MSA Data Acquisition Form — Raytheon, Customer Success Is Our Mission

Appraiser Name:	
Gage Name:	
Gage Type:	
Gage Number:	
Calibration Date	
Date:	

Part #	True Value	Trial 1	Trial 2	Trial 3
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				

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Using the MSA Study Template

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Data Input Sheet for Measurement Systems Analysis

Input data into green boxes

Gage Name:	AMS100
Gage Type:	Line Width Measurement
Gage Number:	23
Date:	24-Oct-07
Appraiser 1 Name:	Jim
Appraiser 2 Name:	Larry
Appraiser 3 Name:	Brian

Characteristic:	Gap
Upper Specification Limit:	50
Lower Specification Limit:	10
Number of Appraisers	3
Trials/Appraiser	3

Jim

Part #	True Value	Trial 1	Trial 2	Trial 3	Average	Range
1	2.5	2	3	1	2.00	2.00
2		3	2	4	3.00	2.00
3		2	3	3	2.67	1.00
4		3	4	3	3.33	1.00
5	4	4	4	3	3.67	1.00
6						
7						
8						
9						
10						
11						
12	5.2					
13						
14						
15		6	4	3	4.33	3.00
16	5	4	2	5	3.67	3.00
17		6	3	3	4.00	3.00
18		5	5	6	5.33	1.00
19		4	6	6	5.33	2.00
20		6	5	4	5.00	2.00
21	4	5	4	4	4.33	1.00
22		4	7	3	4.67	4.00
23		2	6	5	4.33	4.00
24	4.5	4	6	6	5.33	2.00
25		5	3	4	4.00	2.00

Linearity Assessment Performed

Larry

Part #	Trial 1	Trial 2	Trial 3	Average	Range
1	1	3	5	3.00	4.00
2	4	6	4	4.67	2.00
3	3	5	2	3.33	3.00
4	4	6	4	4.67	2.00
5	3	4	5	4.00	2.00
15	3	7	4	4.67	4.00
16	5	6	6	5.67	1.00
17	3	6	4	4.33	3.00
18	5	3	3	3.67	2.00
19	6	3	5	4.67	3.00
20	4	2	6	4.00	4.00
21	4	3	4	3.67	1.00
22	3	5	6	4.67	3.00
23	5	4	5	4.67	1.00
24	6	3	4	4.33	3.00
25	4	5	6	5.00	2.00

Brian

Part #	Trial 1	Trial 2	Trial 3	Average	Range
1	4	3	5	4.00	2.00
2	3	6	4	4.33	3.00
3	3	5	4	4.00	2.00
4	3	6	4	4.33	3.00
5	3	4	5	4.00	2.00
			2	3.67	3.00
			3	3.67	2.00
			2	3.00	2.00
			0	2.00	4.00
			4	4.00	2.00
			5	5.33	1.00
			3	5.33	4.00
			3	4.00	2.00
			5	4.67	1.00
15	3	7	4	4.67	4.00
16	5	6	6	5.67	1.00
17	3	6	4	4.33	3.00
18	5	3	3	3.67	2.00
19	6	3	5	4.67	3.00
20	4	2	6	4.00	4.00
21	4	3	4	3.67	1.00
22	3	4	6	4.33	3.00
23	5	4	5	4.67	1.00
24	6	3	4	4.33	3.00
25	4	5	6	5.00	2.00

Transcribe or import the measurement data into the green highlighted boxes on the MSA Input Sheet; the workbook calculates all of the MSA metrics from this data

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Interpreting the Results

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Measurement Systems Analysis Summary

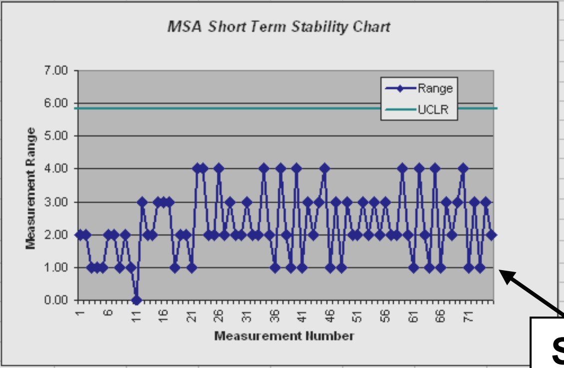
Gage Name:	AMS100
Gage Type:	Line Width Measurement
Gage Number:	23
Date:	10/24/2007
Appraiser 1 Name:	Jim
Appraiser 2 Name:	Larry
Appraiser 3 Name:	Brian

Characteristic:	Gap
Upper Specification Limit:	50
Lower Specification Limit:	10
Number of Appraisers	3
Trials/Appraiser	3

Precision and accuracy performance metrics for the gage

Gage Parametric Performance	
Sigma, repeatability (within Appraisers)	1.342
Sigma, reproducibility (between Appraisers)	0.155
Sigma, Total Measurement Error	1.351
Total Measurement Error (99% CI)	6.959
Tolerance	40.000
Precision/Tolerance (P/T) Ratio	17%

Gage Acceptance Tests	UCL_R	r-value	Decision
Stability	5.837		Pass
Error Independence		-0.1	Pass
Precision			Marginal

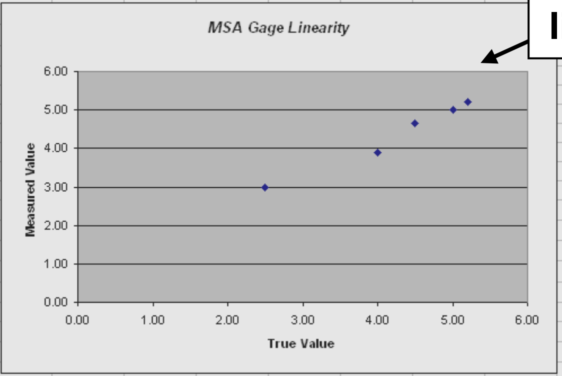


Supporting graphs for stability and linearity

Acceptability results; based on requirements from slide 13

Linearity Parametric Performance	
q	95.7%
	6
ope	0.8440
fset @ Zero Crossing	0.7331
edicted Value @Nominal Target	17.6125
curacy Error at Nominal	5.97%
curacy Threshold	2.21%
wer 95% of CI for Slope	0.8026
Upper 95% of CI for Slope	0.8854

Linearity Acceptance Tests	
Statistical Dependence	Pass
Unity Test	Requires calibration for slope
Nominal Error Test	Requires calibration for offset



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Call to Action

- MSA assures that the measurement equipment precision is aligned to the application requirement so that you don't pay for precision you don't need, or don't get the precision you do need
- Raytheon template is easy to use and requires no calculation or data manipulation from the user
- Utilizing MSA processes on production measurement equipment is an ISO requirement

References and Resources

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Textbooks:

- Quality Through Statistical Thinking: Robertson, Gordon
- Statistics for Management: Levin, Richard

On the Web:

- http://www.moresteam.com/toolbox/t403.cfm

Questions? Ask the expert!

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End