air academy ASSOCIATES

Measurement System Analysis (MSA)

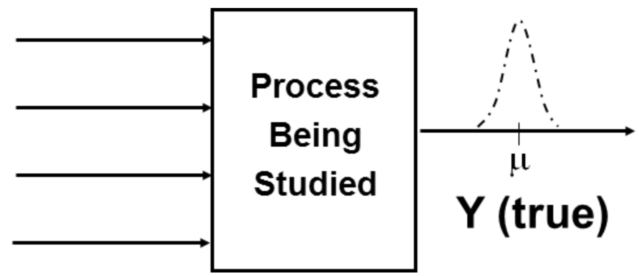
Measurement System Analysis (MSA)

- In this session, we will discuss:
  - The what and why of MSA
  - How to set up, conduct, and perform a measurement system analysis
    - Attribute Data
    - Variables Data
  - Interpreting MSA results and metrics
    - Effectiveness, Probability of False Accepts, Probability of False Rejects, Bias
    - Repeatability Reproducibility, Precision to Tolerance (P/Tol), Precision to Total (P/Tot), Discrimination (Resolution)

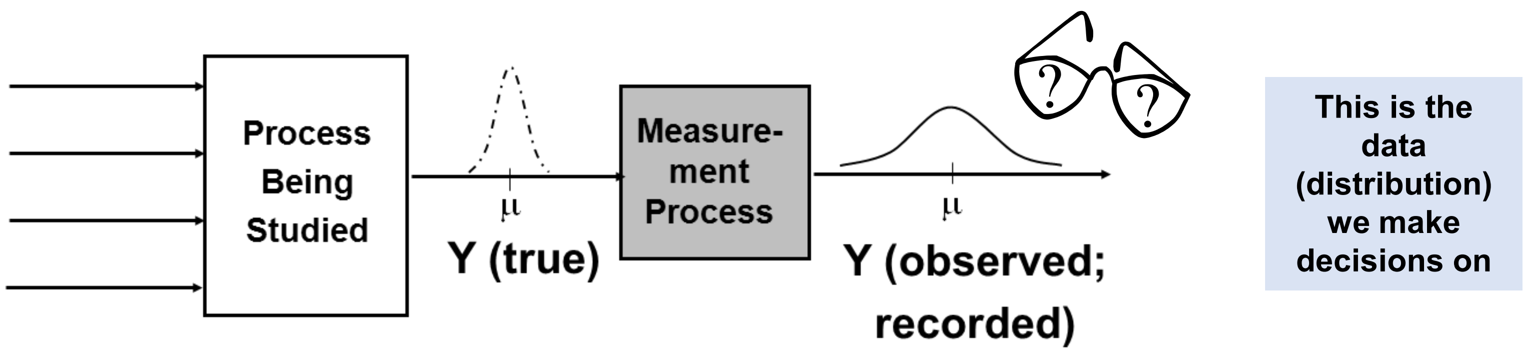
- A list of supplemental material and additional practice/review questions for this session are provided at the end of this presentation
- You can download the pdf of this presentation, along with any supporting data files, on the site where you are accessing this course

Understanding the Impact of Measurement Variation

- Processes behave in a certain (true) way

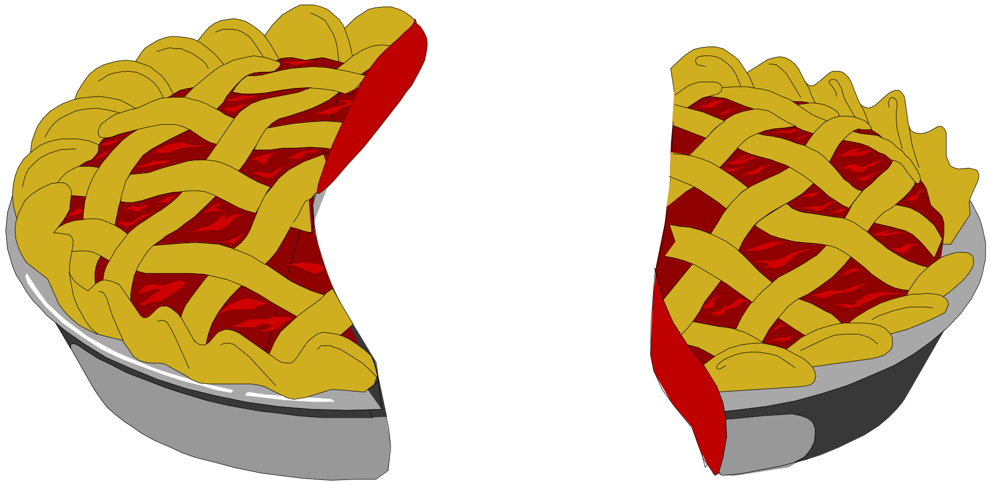


- However, we view the process through the "lens" (or filter) of a measurement system, which can often *distort* the results



- A measurement system analysis will help answer questions such as:
  - "How much variation (distortion) does the measurement system add?"
  - "How good (capable) is our measurement system?"

Measurement System Analysis (MSA)

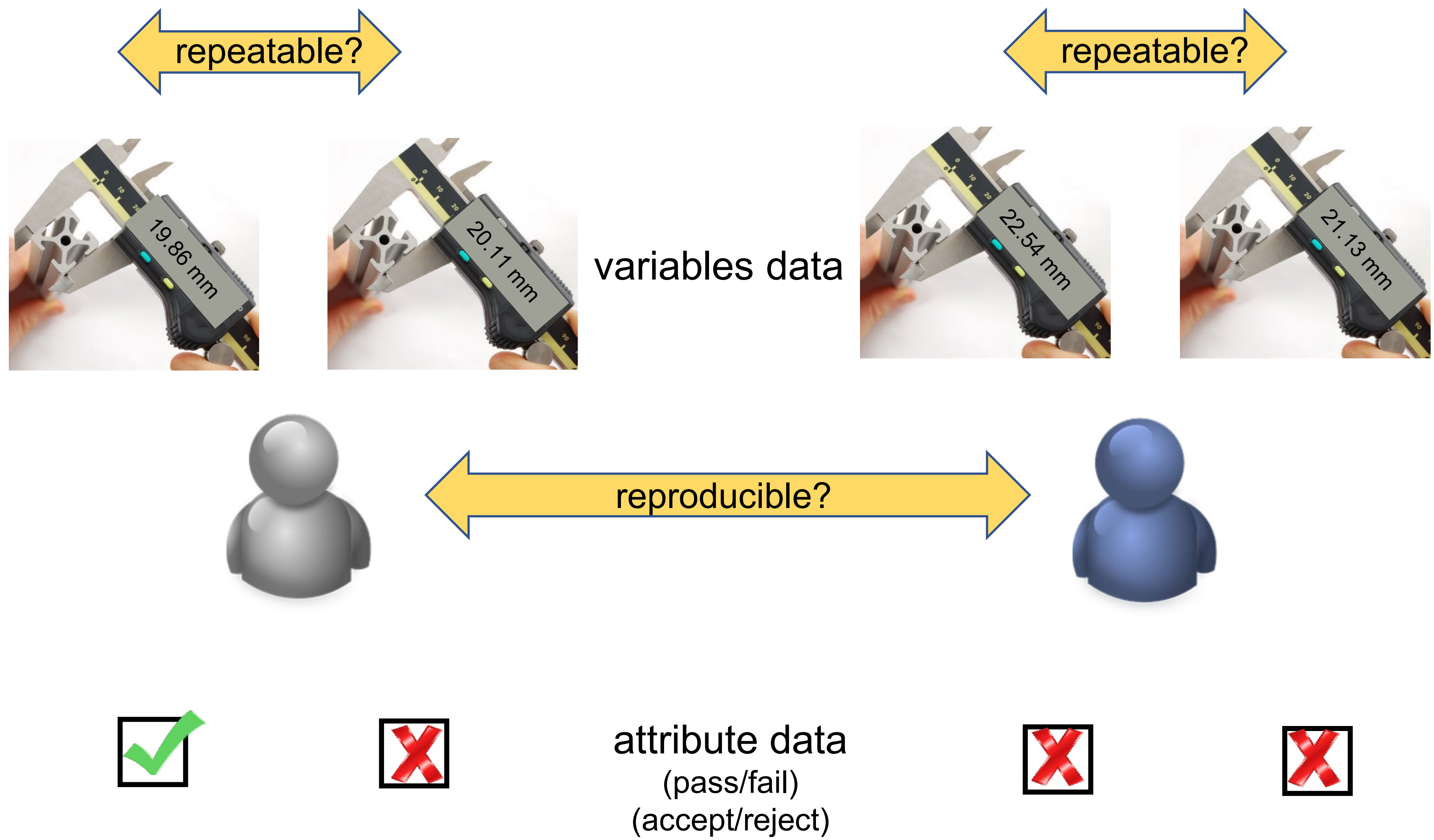


Product, Transaction Or Service Variability | **Measurement Variability**

- The objective of an MSA is to learn as much as possible about the measurement process in a short amount of time
- MSA identifies and quantifies the sources of variation that affect a measurement system
- Variation in measurements can be attribute to variation in the product, transaction, or service itself or to variation in the measurement system (measurement error)
- We would like the measurement error to be a small piece of the total variation or pie!

What is an MSA?

- An MSA is a test that we set up and conduct to assess a measurement system
- Different people will measure the same set of parts (items), ideally more than once



Guidelines for Setting Up and Conducting an MSA

- **Representative test**: The strategy is to include people, SOPs, data recording devices, etc., that are the usual elements of the measurement process
- **“Part” selection**: Determine how you will select the parts, transactions, or items that will be measured during the MSA
  - Attribute (binary) data: strive for an equal number of A’s and R’s (A = accept decision / “good” or correct item; R = reject decision / “bad” or unacceptable item)
  - Variables (continuous) data: want a random selection of parts, representing at least 80% of the total process variation
- **Avoid measurement bias**: The parts should be measured as independently as possible
- **Consider repeatability** (when possible): Each part should be measured multiple times (ideally, at least twice) by each person or operator using the same procedure
- **Sample size Rule of Thumb**:
  - Attribute (binary) data: (Number of People) x (Number of “parts”) $\geq$ 60
  - Variables (continuous) data: (Number of People) x (Number of “parts”) $\geq$ 20

Attribute Data MSA Case Study

- A Green Belt was tasked with investigating and improving an assembly process. One of the key measures of concern was the occurrence of visual defects (scratches) on a completed assembled unit

- The company had specific guidelines as to what counted as a scratch (based on size, severity, etc.). Inspectors completed visual assessments and recorded whether or not the part had scratches (pass/fail) according to the company standards, but there was some concern about the interpretation of the guidelines

- For the MSA study, 10 "good" and 10 "bad" parts were identified. "Good" meant that the part had no scratches per the company guidelines. "Bad" meant that the part did exhibit scratches based on the company guidelines.

- For the study, 3 inspectors ("operators") were selected, from those who make these determinations on a daily basis. Each inspector reviewed the 20 parts for scratches in a random order, and their decision was recorded. An "A" was used to designate the part was acceptable (no scratches), while "R" was used to designate the part was rejected (scratches were present).

Measurement System Analysis using Attribute (Binary) Data

R = Reject
A = Accept

1 = correct response
0 = incorrect response

Part #	True Standard	Op 1		Op 2		Op 3	
1	R	R	1	R	1	R	1
2	A	A	1	A	1	A	1
3	A	A	1	R	0	A	1
4	R	R	1	R	1	R	1
5	A	R	0	A	1	R	0
6	R	R	1	A	0	R	1
7	R	R	1	R	1	R	1
8	A	A	1	A	1	A	1
9	A	A	1	A	1	A	1
10	A	R	0	R	0	A	1
11	R	A	0	R	1	R	1
12	A	A	1	A	1	A	1
13	R	R	1	R	1	R	1
14	R	R	1	A	0	R	1
15	A	R	0	A	1	A	1
16	R	A	0	R	1	R	1
17	A	A	1	A	1	R	0
18	A	A	1	A	1	A	1
19	R	R	1	A	0	R	1
20	R	R	1	R	1	R	1
			15		15		18

Number of Occurrences and Type of Mistake by Operator

		Op 1	Op 2	Op 3
TRUTH	A	3	2	2
	R	2	3	0

Total Correct 48

Data file: MSA attribute data.xlsx

MSA Capability Measures (Attribute (Binary) Data)

- **Effectiveness (E)** is the ability of an individual to distinguish between good (accept) and bad (reject) parts or transactions.

$$E = \frac{\text{Number of items identified correctly}}{\text{Total number of opportunities to be correct}}$$

- **Probability of False Rejects (FR)** is the likelihood of rating a good part or transaction as bad.

$$P(FR) = \frac{\text{Number of times good items are rated as bad}}{\text{Total number of opportunities to rate good items}}$$

- **Probability of False Acceptance (FA)** is the likelihood of accepting a bad part or transaction as good.

$$P(FA) = \frac{\text{Number of times bad items are accepted as good}}{\text{Total number of opportunities to rate bad items}}$$

- **Bias (B)** is a measure of an individual's tendency to falsely classify a part or transaction as good or bad.

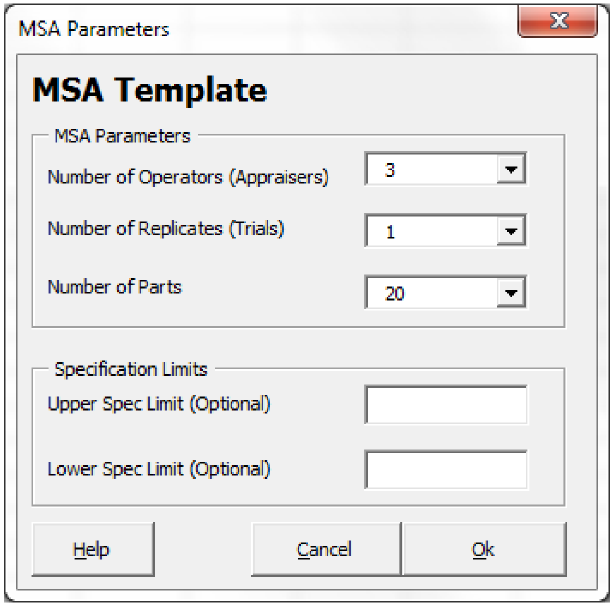
$$B = \frac{P(FR)}{P(FA)} \begin{cases} B = 1 & \Rightarrow \text{ no bias (i.e., both errors are equally likely)} \\ B > 1 & \Rightarrow \text{ bias toward rating good items as bad} \\ B < 1 & \Rightarrow \text{ bias toward rating bad items as good} \end{cases}$$

Parameter	Acceptable	Marginal	Unacceptable
E	≥ 0.90	0.8 - 0.9	< 0.8
P(FR)	≤ 0.05	0.05 - 0.10	> 0.10
P(FA)	≤ 0.02	0.02 - 0.05	> 0.05
B	0.8 - 1.20	0.5-0.8 or 1.2-1.5	< 0.5 or > 1.5

Evaluation Guidelines

SPC XL for Attribute MSA Analysis

- To analyze the data with SPC XL, first set up a template
- From the SigmaZone (SPC XL) ribbon, select **MSA (gage capability) / Create MSA Template**
- Specify the number of inspectors (operators) (3 in this example
- Specify the number of replicates (1 in this example)
- Specify the number of items (parts) being inspected (20 in this example)



Note

For video instruction on generating attribute MSA, go to: https://airacad.com/our-insights/training-videos/spc-xl/

Data Entry

- A blank template for recording data will appear. Enter the data from the MSA, using "A" for an accept and "R" for a reject decision

Data file: MSA attribute data.xlsx

MSA Data Template

Date: 4/10/2020
Part Type:

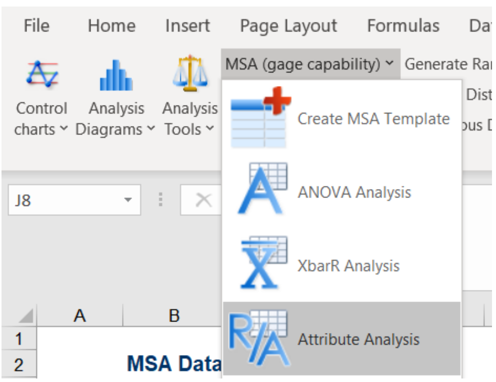
USL:
LSL:

Part #	Reference	Operator 1 Rep 1	Operator 2 Rep 1	Operator 3 Rep 1
1	R	R	R	R
2	A	A	A	A
3	A	A	R	A
4	R	R	R	R
5	A	R	A	R
6	R	R	A	R
7	R	R	R	R
8	A	A	A	A
9	A	A	A	A
10	A	R	R	A
11	R	A	R	R
12	A	A	A	A
13	R	R	R	R
14	R	R	A	R
15	A	R	A	A
16	R	A	R	R
17	A	A	A	R
18	A	A	A	A
19	R	R	A	R
20	R	R	R	R

SPC XL Analysis Results for Attribute Data

- Once the data is entered on the template, select **MSA (gage capability) / Attribute Analysis** from the SigmaZone (SPC XL) ribbon

- Output is shown below



Attribute MSA Analysis

Number and Type Mistake By Operator						
		OP 1	OP 2	OP 3	Total	
Truth	A	3	2	2	7	<-reject falsely
	R	2	3	0	5	<-accept falsely
Inspection Capability						
		OP 1	OP 2	OP 3	Total	
Effectiveness		0.75	0.75	0.9	0.8	
P(FR)		0.3	0.2	0.2	0.233333	
P(FA)		0.2	0.3	0	0.166667	
Bias		1.5	0.666667	NA	1.4	

Results by operator

Overall Results

Attribute Data MSA Case Study (Practice)

- A document audit process was being investigated a company. One of the key concerns was whether a document was being flagged correctly for review, because errors were turning up in a downstream process.

- The company had specific guidelines as to when a document should be flagged for review.

- For the MSA, 10 “good” documents and 10 “bad” documents were identified. “Good” meant the document had no issues and should not be flagged for review, while “bad” documents met the criteria and should be flagged per company guidelines.

- For the MSA, 3 auditors were selected and each reviewed the 20 documents in random order, twice. The documents were marked in such a way to prevent identification.

		Operator 1		Operator 2		Operator 3	
Part #	Reference	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2
1	A	A	A	A	A	A	A
2	A	R	A	A	A	R	A
3	A	A	A	A	A	A	A
4	A	A	A	A	A	A	A
5	A	A	A	A	A	A	A
6	R	R	A	R	R	R	R
7	R	A	A	A	A	A	A
8	R	R	R	A	R	R	R
9	R	A	R	R	R	A	A
10	R	R	R	R	R	R	R
11	A	A	A	A	A	A	A
12	A	A	A	A	A	A	A
13	A	A	A	A	A	A	A
14	A	A	A	A	A	A	A
15	A	A	A	R	A	A	A
16	R	R	R	R	R	R	R
17	R	A	R	R	A	A	R
18	R	A	R	R	R	A	R
19	R	R	R	R	A	R	R
20	R	R	R	R	R	R	R

Data file: MSA attribute data - practice.xlsx

Measurement System Study with Attribute Data (Practice)

Analyze the data and answer the questions below

1. Is there any concern about the overall effectiveness of the review process?

   ____

   ____

2. Does there are appear to be significant variability in the effectiveness from auditor to auditor?

   ____

   ____

3. Is there a bias toward either “good” (acceptable) documents being rejected (flagged), or “bad” (unacceptable) documents being approved (i.e., not flagged for review)?

   ____

   ____

4. Other observations, comments, or recommendations?

   ____

   ____

Data file: MSA attribute data - practice.xlsx

Considerations if the Measurement System is Poor

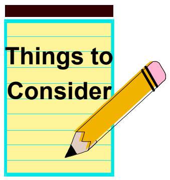
1. Review the training / SOPs for accuracy and completeness

2. Check for differences in interpretation between operators. Try to understand the root cause of the differences.

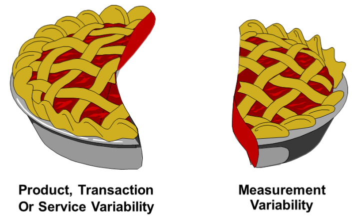
3. Identify items with the highest error rates. Is there anything different about these items? Can we use that information to help address improvements needed?

4. Revise training / SOPs.

5. Create or revise templates, guidelines, etc. Work to mistake-proof the measurement process.



MSA with Variables Data



PURPOSE:

To assess how much variation is associated with the measurement system and to compare it to the total process variation or tolerances.

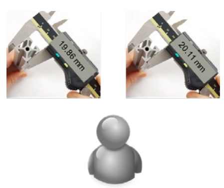
ANOVA
(analysis of
variance)

$$\sigma^2_{total} = \sigma^2_{product} + \sigma^2_{measurement}$$

$$\sigma^2_{measurement} \rightarrow \sigma^2_{repeatability} + \sigma^2_{reproducibility}$$

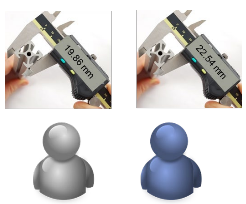
REPEATABILITY:

Variation obtained by the same person using the same procedure on the same product, transaction or service for repeated measurements (variability ***within*** operator).



REPRODUCIBILITY:

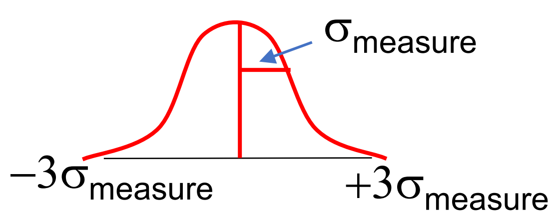
Variation obtained due to differences in people who are taking the measurements (variability ***between*** operators).



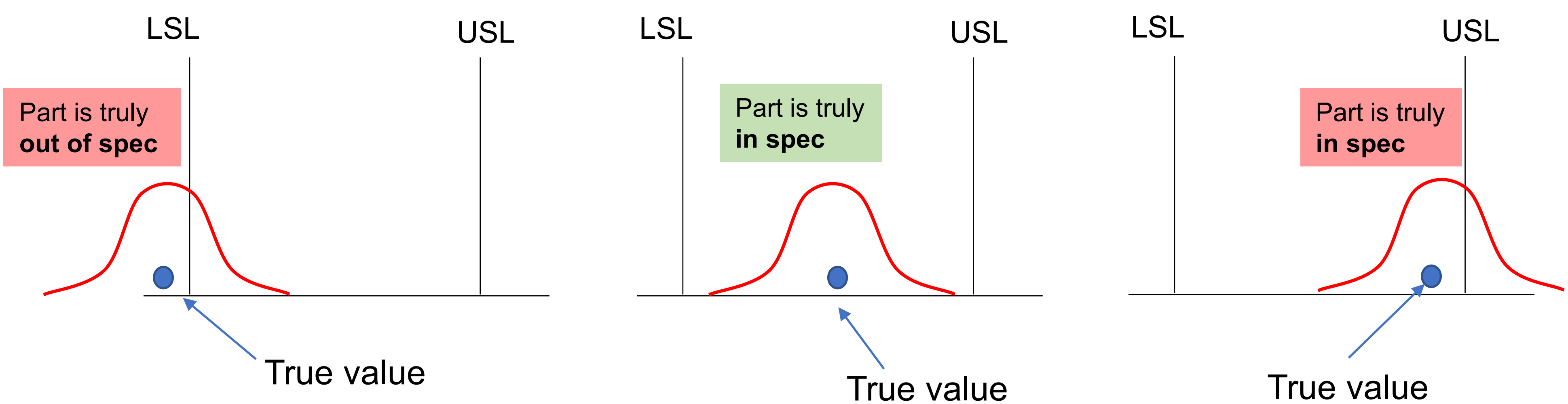
Why Reduce Measurement Error?

- Measurement error can cause us to make bad decisions (calling “good” parts “bad”, and “bad” parts “good”)

- Suppose our measurement standard deviation ($\sigma_{measure}$) is as shown:



- Consider the three scenarios below, and the impact of measurement error



Variables Data MSA - Example

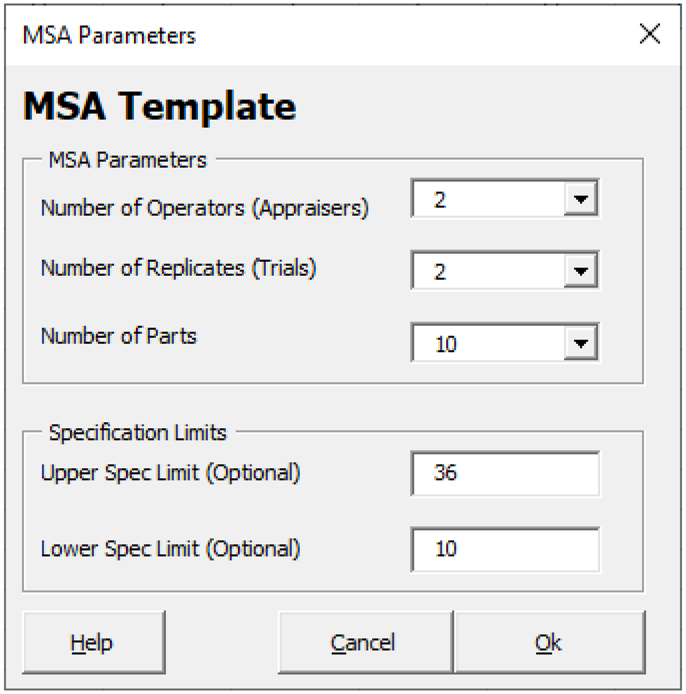
- Consider the MSA results shown below. Two operators were each given 10 parts, two times each, and they measured and recorded the part thickness in millimeters
- Parts were randomly selected from production, and the thickness spec is 23 +/- 13 mm
- Looking at the data, does there appear to be an issue with the measurement process? What do you think about repeatability vs. reproducibility?

	Operator 1		Operator 2	
	Rep 1	Rep 2	Rep 1	Rep 2
Part 1	21	23	26	28
Part 2	19	18	24	24
Part 3	20	23	27	24
Part 4	19	22	21	20
Part 5	28	25	31	33
Part 6	24	26	31	28
Part 7	30	31	32	34
Part 8	21	24	29	26
Part 9	26	24	29	33
Part 10	23	26	30	27

- Let's use SPC XL to analyze the results!

Creating an MSA Data Template in SPC XL

- To analyze the data with SPC XL, first set up a template
- From the SigmaZone (SPC XL) ribbon, select **MSA (gage capability) / Create MSA Template**
- Specify the number of inspectors (operators) (2 in this example
- Specify the number of replicates (2 in this example)
- Specify the number of items (parts) being inspected (10 in this example)
- Enter Specification Limits, if any (USL = 36 and LSL = 10 in this example)



Note For video instruction on generating variables MSA, go to: https://airacad.com/our-insights/training-videos/spc-xl/

Data Entry

- When conducting the MSA, be sure to randomize the parts, operators, and replicates
- Data in the template is shown below

MSA Data Template

Date:	4/11/2020
Part Type:	
USL:	36.0
LSL:	10.0

For Attribute data enter A for Accept and R for Reject

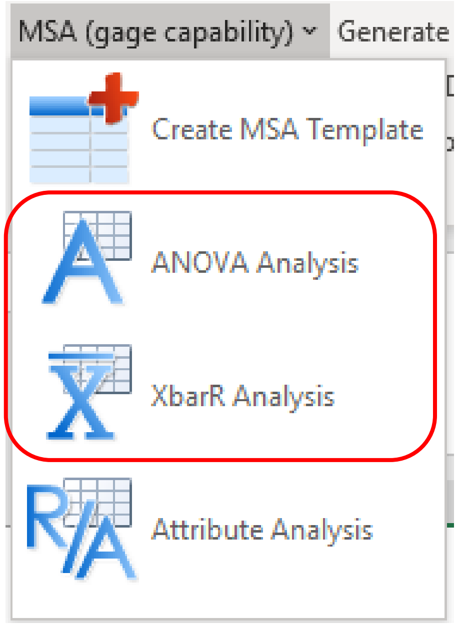
Description:

		Operator 1		Operator 2	
Part #	**Reference**	Rep 1	Rep 2	Rep 1	Rep 2
1		21	23	26	28
2		19	18	24	24
3		20	23	27	24
4		19	22	21	20
5		28	25	31	33
6		24	26	31	28
7		30	31	32	34
8		21	24	29	26
9		26	24	29	33
10		23	26	30	27

Data file: MSA variables data.xlsx

Variables (Continuous) Data Analysis Options in SPC XL

- XbarR Analysis
  - Simple, straightforward and can be done without software
  - More sensitive to outliers
  - Variance is estimated uses ranges (rather than standard deviation)



- ANOVA Analysis (Analysis of Variance)
  - Mathematically more complex, so software is necessary
  - Much less sensitive to outliers than the XbarR method
  - Can estimate (part x operator) interaction contribution to reproducibility (in other words, does the difference between operators depend on which part is being measured?)
  - More precise estimates of the variance components

- Recommended Approach: **ANOVA**

MSA Capability Measures for Variables (Continuous) Data

1. **Precision-to-Tolerance Ratio (P/TOL)** (% specs)

$$P/TOL = \frac{6\sigma_{meas}}{USL - LSL}$$

(Specification Limits are needed)

ROT: If P/TOL ≤ 0.10 : Very Good Measurement System

P/TOL ≥ 0.30 : Unacceptable Measurement System

2. **Precision-to-Total Ratio (P/TOT)** (sometimes called % GRR)

$$P/TOT = \frac{\sigma_{meas}}{\sigma_{total}}$$

ROT: If P/TOT ≤ 0.10 : Very Good Measurement System

P/TOT ≥ 0.30 : Unacceptable Measurement System

3. **Resolution** (sometimes called discrimination or # of distinct categories (ndc))

This is the number of truly distinct measurements that can be obtained by the measurement system

$$\text{Resolution} = \left(\frac{\sigma_{product}}{\sigma_{meas}}\right) \times 1.41$$

ROT: Resolution ≥ 5 represents an adequate measurement system

SPC XL Analysis – Interpreting the Results

- From the SigmaZone (SPC XL) ribbon: **MSA(gage capability) / ANOVA Analysis**

MSA ANOVA Method Results

Source	Variance	Standard Deviation	% Contribution	p Value
Total Measurement (Gage)	11.8	3.435112807	50.53%	
Repeatability	3.1	1.760681686	13.27%	
Reproducibility	8.7	2.949576241	37.25%	
Operator	8.66111111	2.942976573	37.09%	
Oper * Part Interaction	0.03888889	0.197202659	0.17%	0.4541
Product (Part-to-Part)	11.5527778	3.398937743	49.47%	
Total	23.3527778	4.832471187	100.00%	

USL	36
LSL	10
Precision to Tolerance Ratio	0.79271834
Precision to Total Ratio	0.71083979
Resolution	1.4

BIAS ANALYSIS	
Reference	Bias
Not Available	

sigma measure (the measurement process standard deviation)

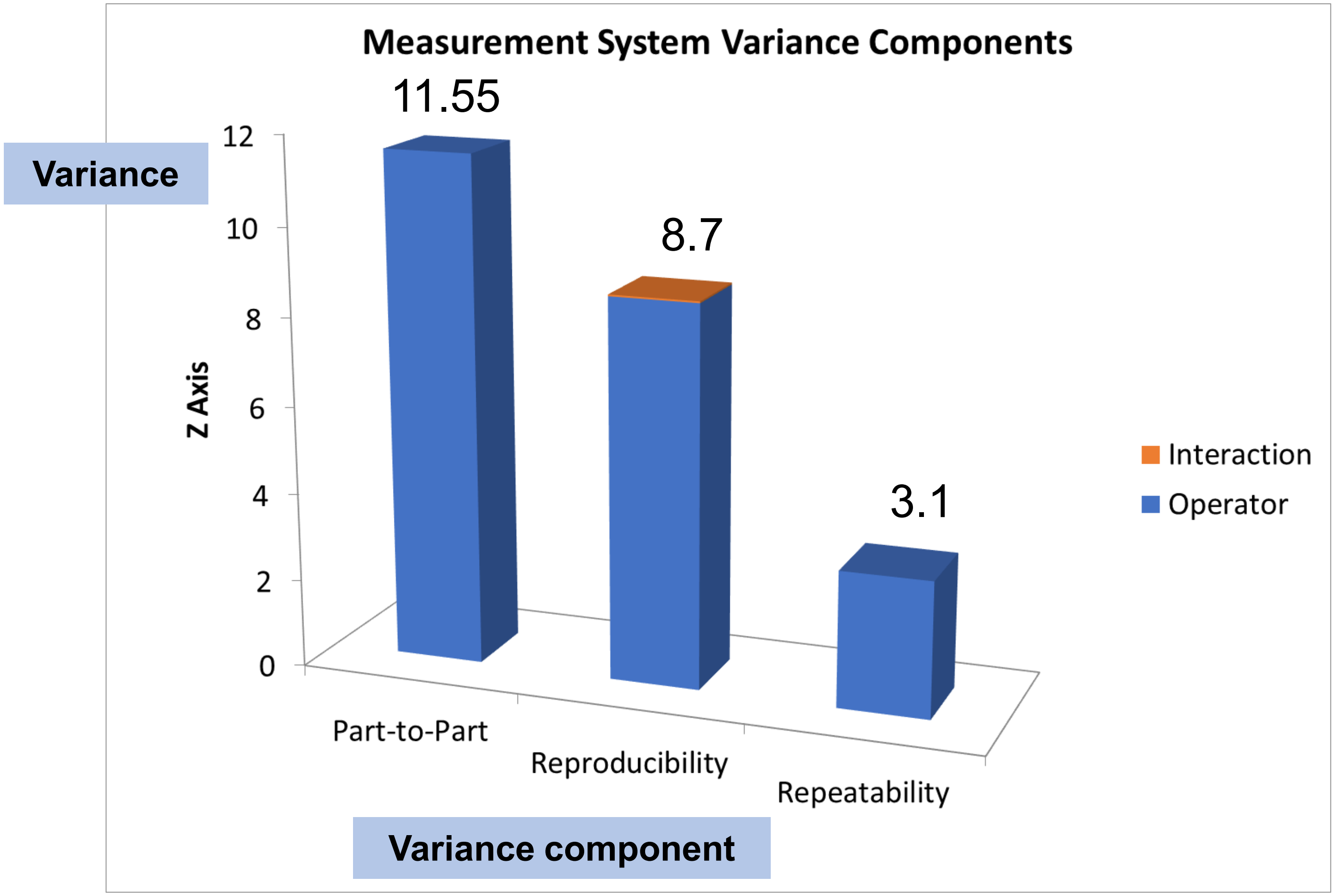
P/TOL is too high (0.79 > 0.3)

P/TOT is too high (0.71 > 0.3)

Resolution is unacceptable (1.4 < 5)

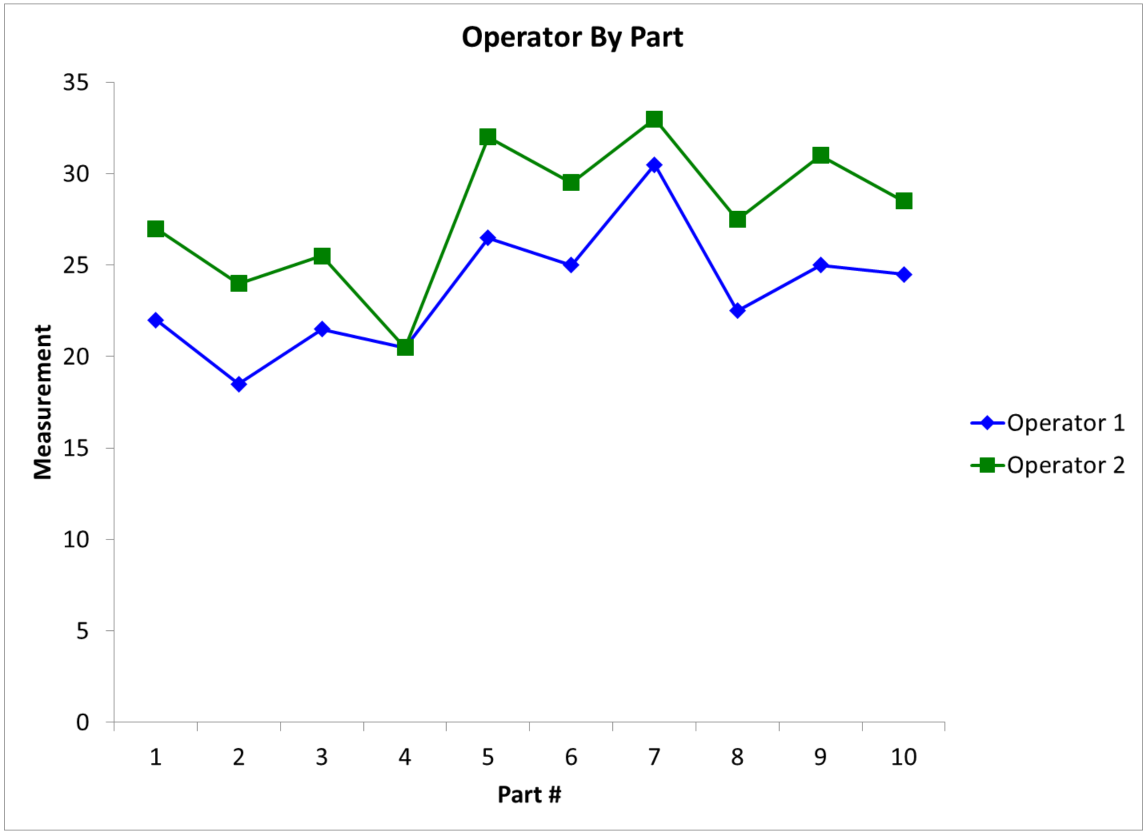
Reproducibility is much larger than **Repeatability**, and appears to be the biggest problem with this measurement process

Pareto (Variance Components)



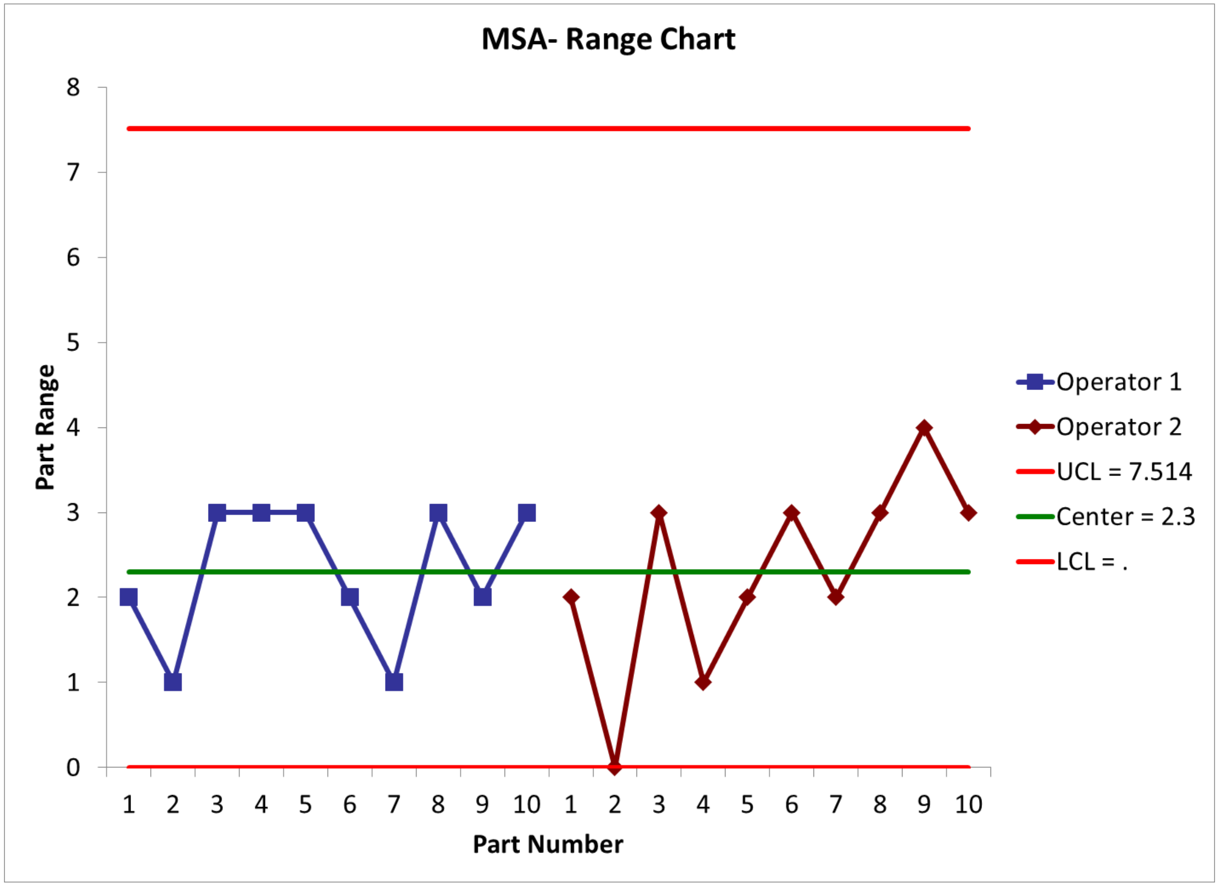
- Shows the variance components (here, part-to-part is largest contributor to the overall variation, which we would expect)
- Use this graph to compare reproducibility and repeatability to learn which is the biggest contributor to the measurement variation. In this example, reproducibility is the bigger contributor (in other words, there is more variation **between** operators compared to **within** operators)

Operator by Part Interaction Chart



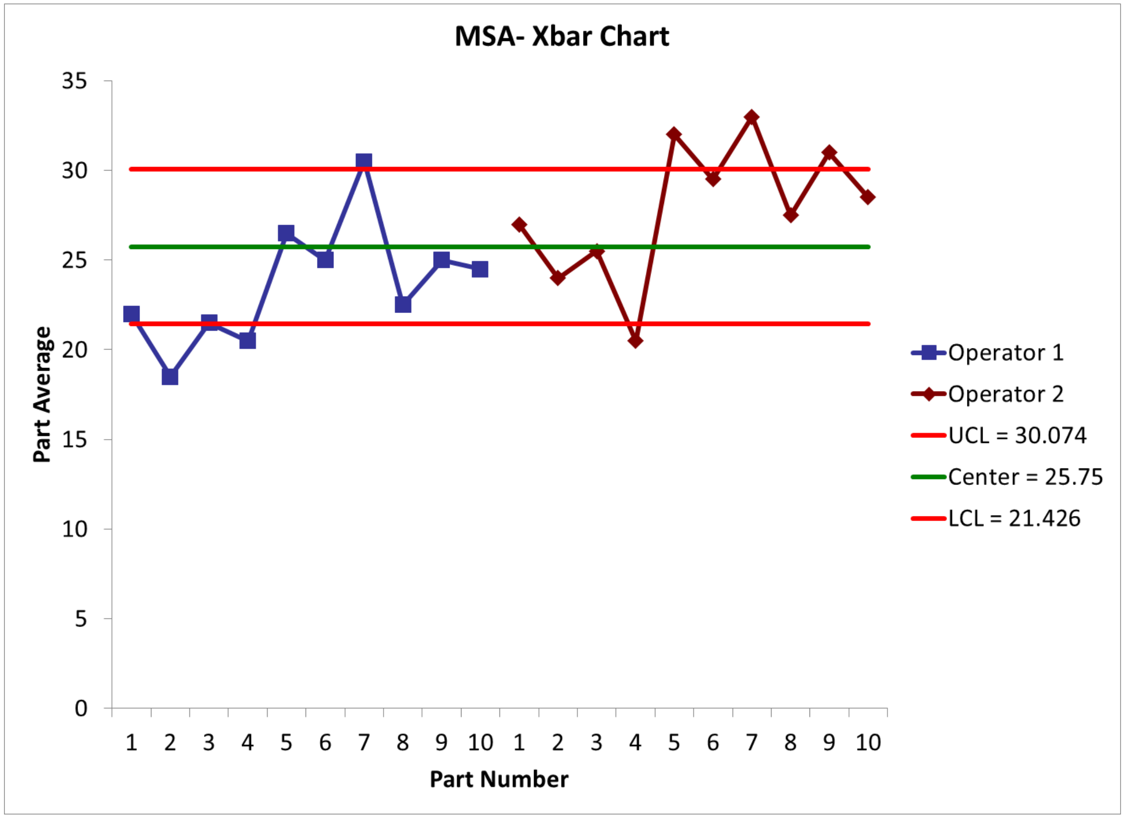
- Numbers plotted are the averages, by part, for each operators
- This chart helps show any **reproducibility** issues (in this example, operator 1s measurements tend to be lower than operator 2 . . . we should try to determine why)
- “No interaction” means that differences between operators are consistent for all parts (i.e., a constant delta). “Interaction” occurs when the differences between operators **depend on** which part is being measured. In this example, the average for part 4 is the same for both operators, but there is less agreement for the other parts. A slight “interaction”, but the ANOVA table shows that this interaction is not statistically significant

Range Chart



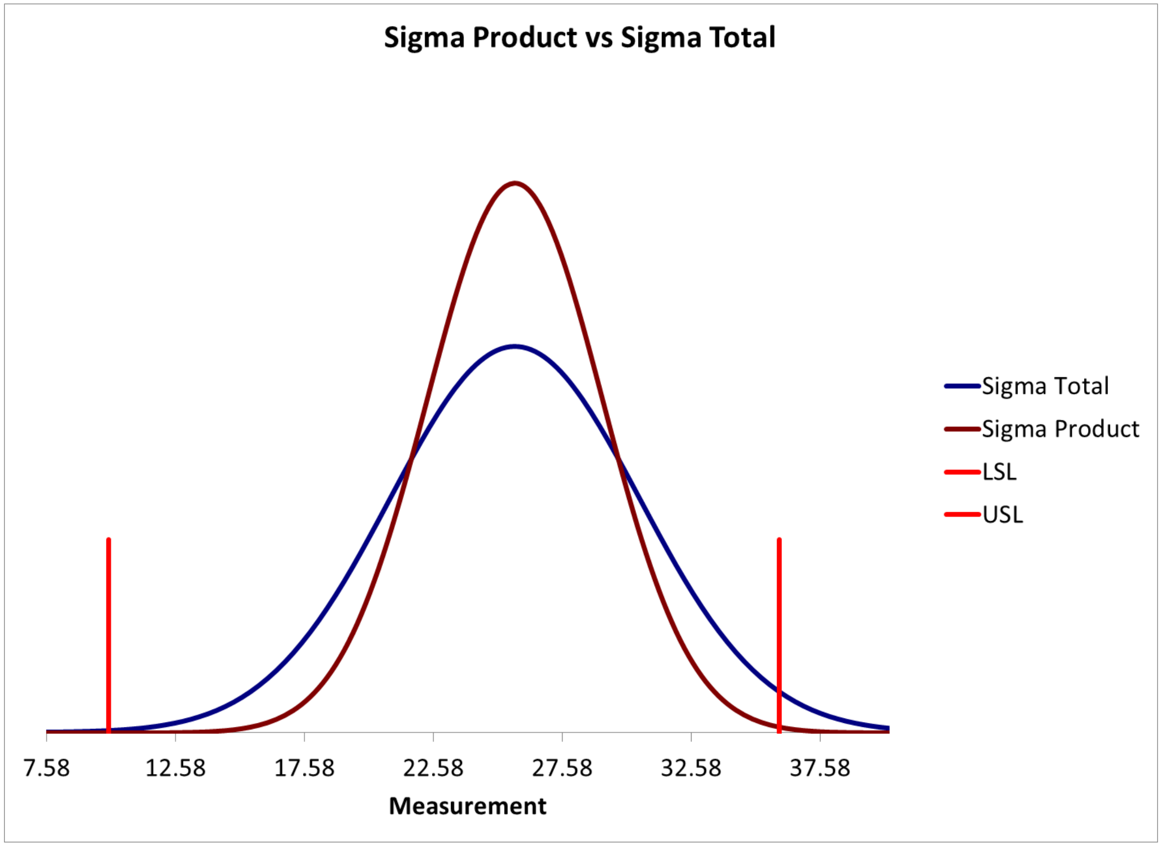
- Displays the differences in the repeated measurements made by each operator for each part
- In this example, operator 1 measured part 1 twice (results were 21 and 23, so the range equals 2)
- This chart helps to show any repeatability issues
- All points should fall below the red upper control limit
- Check to see whether repeatability seems consistent for all operators, or whether one or more operators is having a more difficult time with repeatability

Xbar Chart



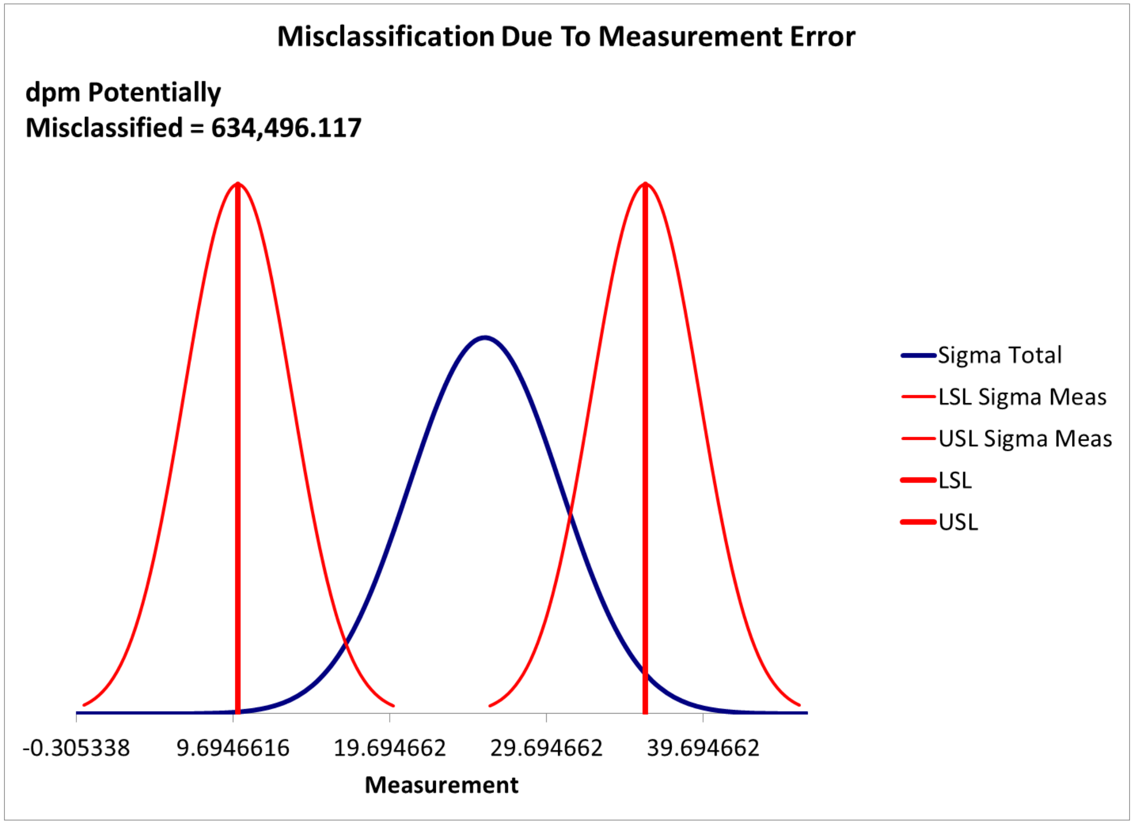
- Displays the average measurement made by each operator for each part
- In this example, operator 1 measured part 1 twice (results were 21 and 23, so the range equals 22)
- This chart helps to show any reproducibility issues
- **Rule of Thumb:** At least **half** of the plotted points should fall **outside** the control limits. If not, the measurement system lacks adequate resolution (can't distinguish parts from one another)

Sigma Product vs. Sigma Total



- Displays the effect of measurement error from a graphical perspective
- The “sigma product” graph represents the part variation, while the “sigma total” graph includes both the part variation AND the measurement variation
- The more different these graphs appear, the bigger the impact of measurement error

Potential Misclassification



- Displays measurement error (depicted by the red bell curves) at the worst-case scenario (when measuring a value right at the lower or upper spec limit)
- If the process starts producing actual values at/near the spec limits, then we have the biggest risk for mis-classifying parts (calling “good” parts “bad”, and “bad” parts “good”). That means we will have unnecessary rework or scrap, or worst yet, escapes to the customer)
- The dpm potentially misclassified, worst case, gives an idea of the potential impact on COPQ due to measurement error

Poor Measurement System Capability Actions

1. If repeatability is the dominant source of variability, it is an indication every person is having trouble measuring, indicating inadequate SOPs or equipment that needs to be repaired, replaced, or adjusted.

2. If reproducibility is the dominant source of variability, we should examine the differences between operators to determine whether it is a training, skill, or following an SOP type of problem. Inadequate SOPs or failing to follow SOPs could be an issue.

3. If P/TOL > 0.30, evaluate the specification limits. Are they reasonable?

4. If P/TOT > 0.30, check the items that were part of the measurement system study. Do they represent at least 80% of the total process variability? If they do and if the measurement system is already state-of-the-art and performing up to its specifications, we may have to live with it. One possible work-around is to take an average of 4 measurements, say, and use that value as the recorded entry for that item and that measurement. (note: This involves the property of the Sampling Distribution of the Mean, an advanced topic, which says that the standard deviation of sample averages is reduced by a factor of $\sqrt{n}$, where n is the sample size. If n = 4, $\sqrt{4} = 2$, and so we have cut the variability in half.) This technique should be used only as a short-term approach to a gage study and should not be used as a mask for an inherently poor measurement system.

5. If the measurement system is suspect (P/TOL or P/TOT close to 0.30) but the process is operating at high capability (Cpk > 2), then the measurement system is likely not a problem and we may be able to continue to use it.

Measurement System Study with Variables Data (Practice)

- A hospital laboratory has three technicians who perform a specific test. There was some concern about the repeatability and reproducibility of the test
- 10 samples were prepared and split into 6 for the purpose of testing (2 samples for each of the three technicians)
- The MSA results are shown below:

Data file: MSA variables data - Practice.xlsx

		Operator 1		Operator 2		Operator 3	
Part #	**Reference**	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2
1		34	36	24	30	30	27
2		29	27	27	35	32	34
3		23	20	25	19	28	25
4		34	37	27	32	34	32
5		33	30	30	37	34	36
6		50	54	51	44	50	48
7		16	12	14	9	13	16
8		40	39	35	40	40	43
9		37	39	32	38	35	38
10		46	49	42	48	47	50

- Spec limits for this are: LSL = 20 and USL = 60

Measurement System Study with Variables Data (Practice)

Analyze the data and answer the questions below

Data file: MSA variables data - Practice.xlsx

1. Is there any concern about the capability of the measurement process?

   ____

   ____

2. Is there more variation within a technician or between the technicians?

   ____

   ____

3. Which technician, if any, seems to have the biggest problem with repeatability?

   ____

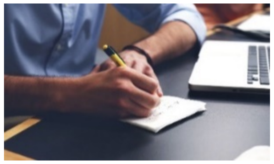
   ____

4. Other observations, comments, or recommendations?

   ____

   ____

Key Takeaways



- As a review, you may want to pause the video at this point and summarize the key learnings from this session, at least from a high-level view. When you are finished, resume the video.

Key Takeaways

- The purpose of MSA is to help answer the question: "How good (capable) is our measurement system?"

- Poor measurement system capability can lead to:
  - Wasted time and $ (reworking or correcting things that are acceptable to the customer)
  - Customer dissatisfaction (quality escapes from the process, by failing to detect things that don't meet the customer requirement)
  - Poor decision making based on untrustworthy data

- Some of the important considerations when setting up an MSA include:
  - Representative test (people, SOPs, equipment, etc.)
  - "Part" selection (how will select the parts or items to measure?)
  - "Operator" selection (who should participate in the MSA?; how do we define "operator" for the MSA? . . . different people? different test sets?)
  - Randomization (how will we conduct the data collection to avoid bias?)
  - Sample size (how do we ensure sufficient data?; use rules of thumb)
    - For attribute (binary) data: (Number of "Operators") x (Number of Parts) ≥ 60
    - For variables (continuous): (Number of "Operators") x (Number of Parts) ≥ 20

- If a measurement system is determined to be poor, improve it! Look at training, SOPs, repairing or calibrating equipment, etc. Use your fishbone to identify potential variables influencing the results.

Key Takeaways (cont.)

- MSA measures for attribute data
  - Effectiveness (% correct decisions)
  - Probability of False Rejects P(FR)
  - Probability of False Accepts P(FA)
  - Bias

- MSA measures for variables data
  - P/TOL (% of specs consumed by measurement system variation)
  - P/TOT (measurement standard deviation expressed as a % of the total standard deviation)
  - Resolution (number of distinct categories)
  - Sigma measure (the measurement system standard deviation)
  - Repeatability and Reproducibility

Supplemental Material

- Suggested Reading:
  - ***Lean Six Sigma: A Tools Guide*** by Adams, Kiemele, Pollock and Quan (pp. 29 - 39)
  - ***Basic Statistics – Tools for Continuous Improvement*** by Kiemele, Schmidt and Berdine, 4th edition (pp. 9-71 – 9-76)
  - ***Design for Six Sigma: The Tool Guide for Practitioners*** by Reagan and Kiemele (pp. 177 - 194)
  - Air Academy's app: ***Six Sigma Quick Tools***

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- SPC XL™ software training tutorials:
  - https://airacad.com/our-insights/training-videos/spc-xl/

- The data files for this session can be downloaded from the site where you are accessing this course

Additional Practice / Review Questions

1) What is the purpose of MSA?

2) In your organization, what are some measurement processes that could benefit from an MSA to determine if improvement is needed?

3) What is the difference between repeatability and reproducibility?

4) If a measurement system is poor, what are some consequences to the organization?

5) What are a few important considerations when conducting an MSA?

6) When analyzing variables data, which is the preferred analysis option for the MSA --- ANOVA or XbarR method?

Additional Practice / Review Questions (cont.)

7) A company was reviewing its credit approval process for a particular type of application. Given the standard guidelines, the company wanted to know whether the same decision (approve vs. reject) would be made consistently from analyst to analyst, in accordance with the company guidelines.

The data file: MSA Credit Approval Exercise.xlsx contains the results of the study, where 26 applications were shown to each of 4 analysts on 3 different occasions. Based on the results below, what do you conclude about the overall effectiveness of the credit approval process in terms of making the "correct" decision? Is the analyst-to-analyst variation? What are other comments or recommendations do you have?

Data file: MSA Credit Approval Exercise.xlsx

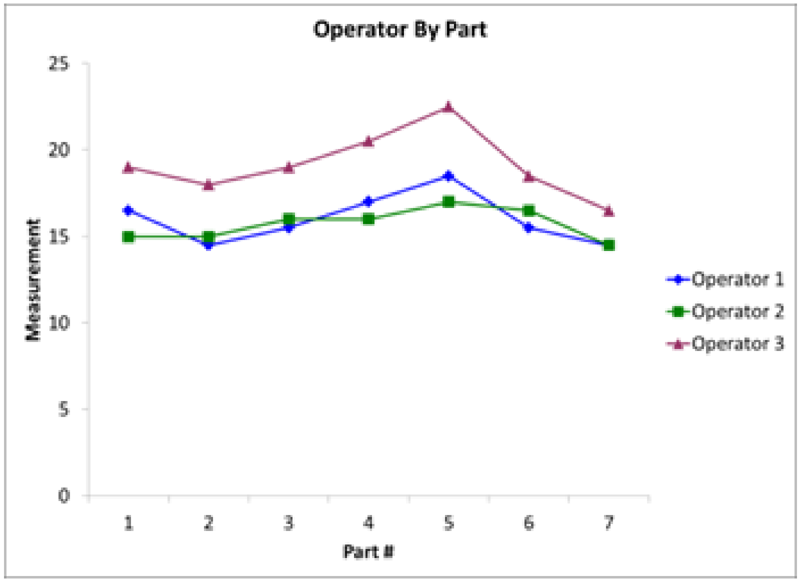
Attribute MSA Analysis

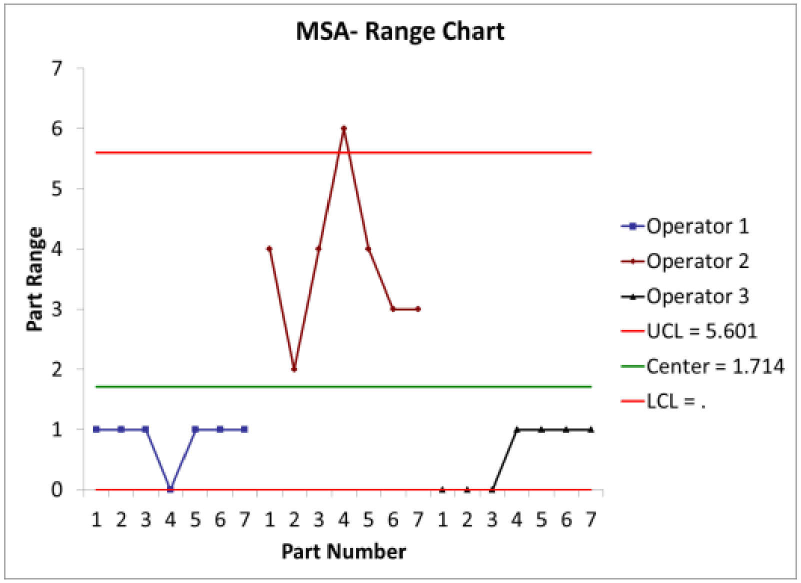
		Number and Type Mistake By Operator					
		OP 1	OP 2	OP 3	OP 4	Total	
Truth	A	7	4	8	0	19	<-reject falsely
	R	1	1	13	0	15	<-accept falsely

	Inspection Capability				
	OP 1	OP 2	OP 3	OP 4	Total
Effectiveness	0.8974359	0.9358974	0.7307692	1	0.8910256
P(FR)	0.17948718	0.1025641	0.2051282	0	0.1217949
P(FA)	0.02564103	0.025641	0.3333333	0	0.0961538
Bias	7	4	0.6153846	NA	1.2666667

Additional Practice / Review Questions (cont.)

8) Two graphical summaries from a variables data MSA are shown below. What does each indicate about the measurement system being studied?





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