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“MEASUREMENT SYSTEMS ANALYSIS”
MSA

Measurement Systems Analysis

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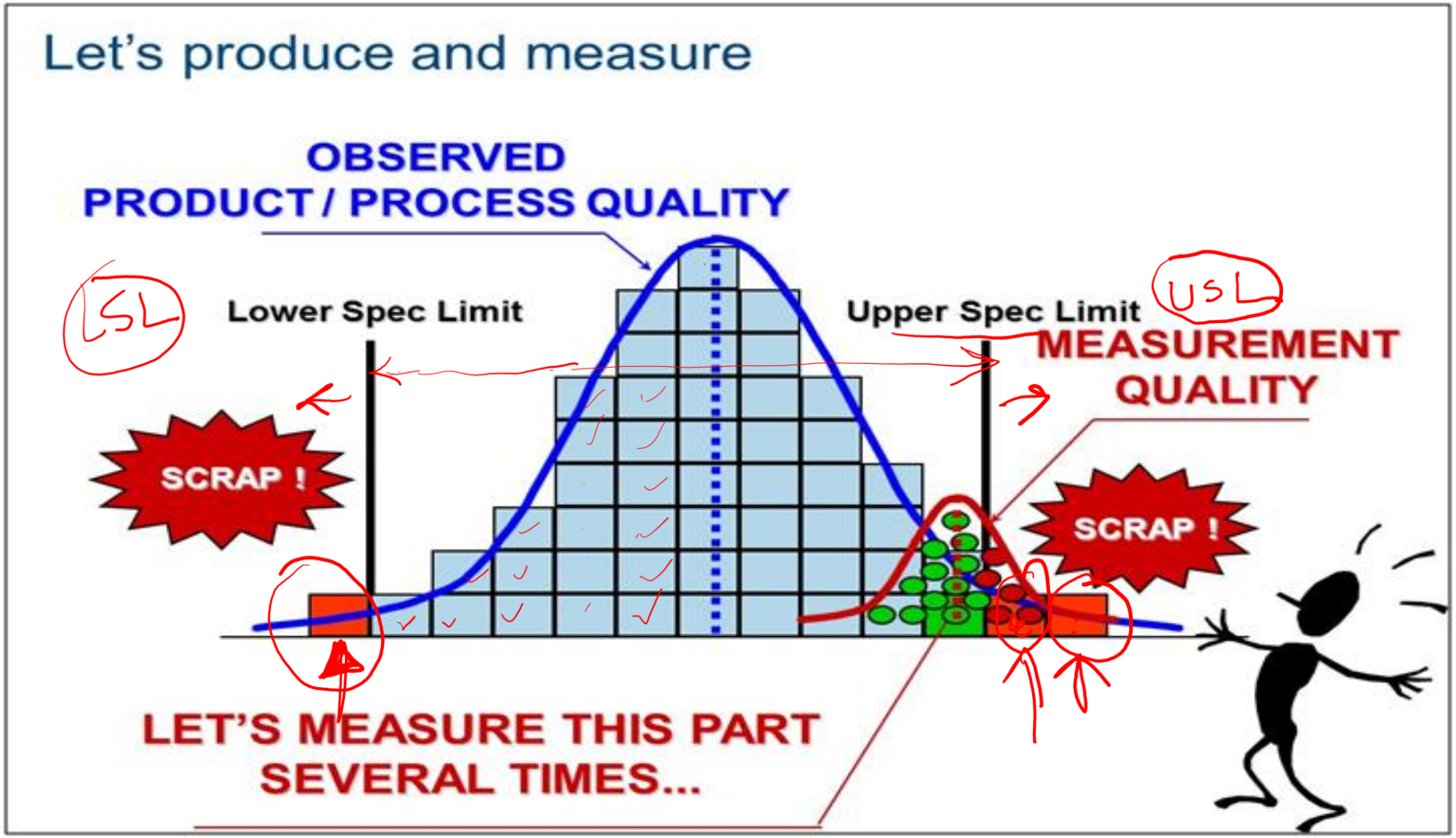

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Objectives

- Importance of data
- What is MSA?
- Types of MSA
- Key terms and definition
- Measurement Error Sources of Variation
- Precision (Resolution, Repeatability, Reproducibility)
- Accuracy (Bias, Stability, Linearity)
- What is Gage R&R?
- Explain MSA Sheet
- Attribute MSA and its Importance
- Steps to perform Attribute MSA
- Calculation of Kappa Value
- Calculation of Miss Rate and False Rate

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Dealing with Data

- Making decisions based on data is critical in business, and in life

- "Garbage in, garbage out" Need to ensure quality of data collected before analyzing or drawing conclusions

- How do you know if your data is "good"?

Type of MSA

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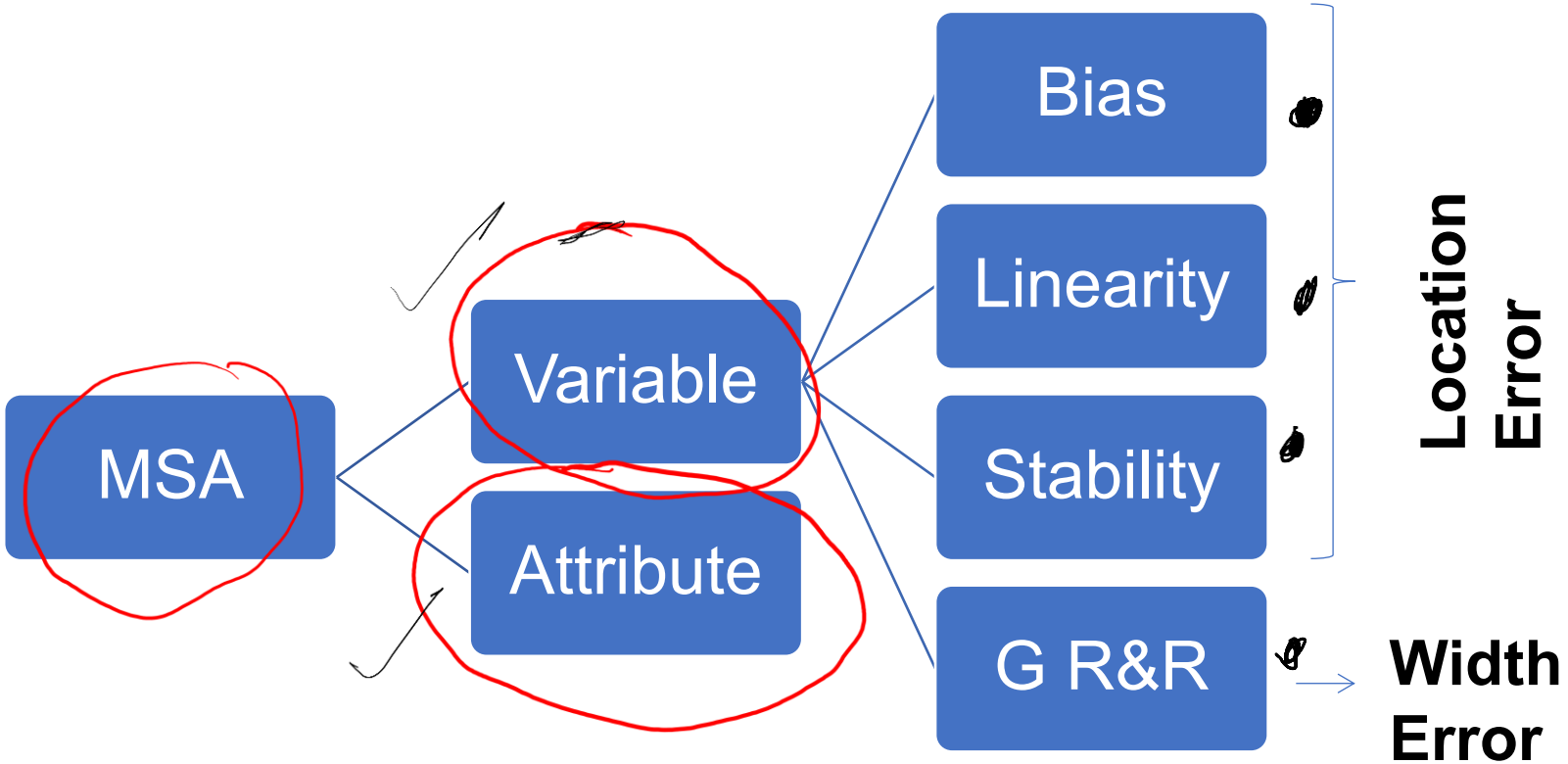

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What is MSA

- A controlled experiment where a sample of items are measured multiple times by different devices or people to separate the variation into specific sources
- Gage Repeatability and Reproducibility (R&R) is a subset of MSA
- Provides estimate of “measurement error” to determine if variation is excessive or acceptable

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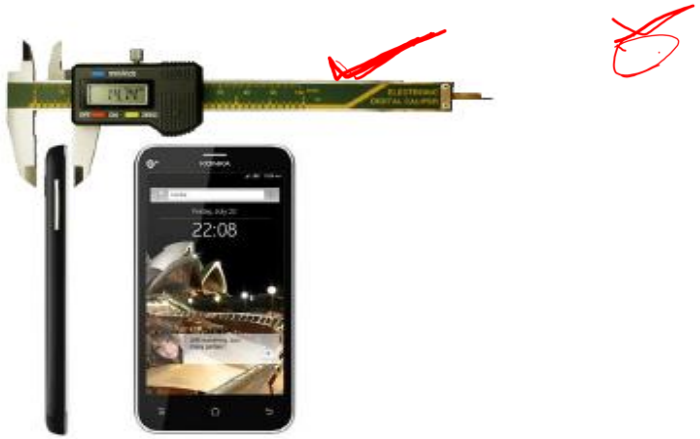
Example of Gage R&R

Measuring thickness of a phone using calipers



If the thickness measuring process has no variation, then all measurements of each phone would be identical, regardless of who took the measurement, or which measurement device they used.

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What does MSA evaluate?

•MSA can evaluate:
–The process to setup and calibrate the measurement device
–The technique used to setup the item prior to being measured
–Whether different measurement devices (equipment and tools) or different versions of the same device influence the variation
–The people who take the measurements
–How the data is collected and recorded
–The method for making a decision based on the data

MSA evaluates before, during and after the measurement is taken

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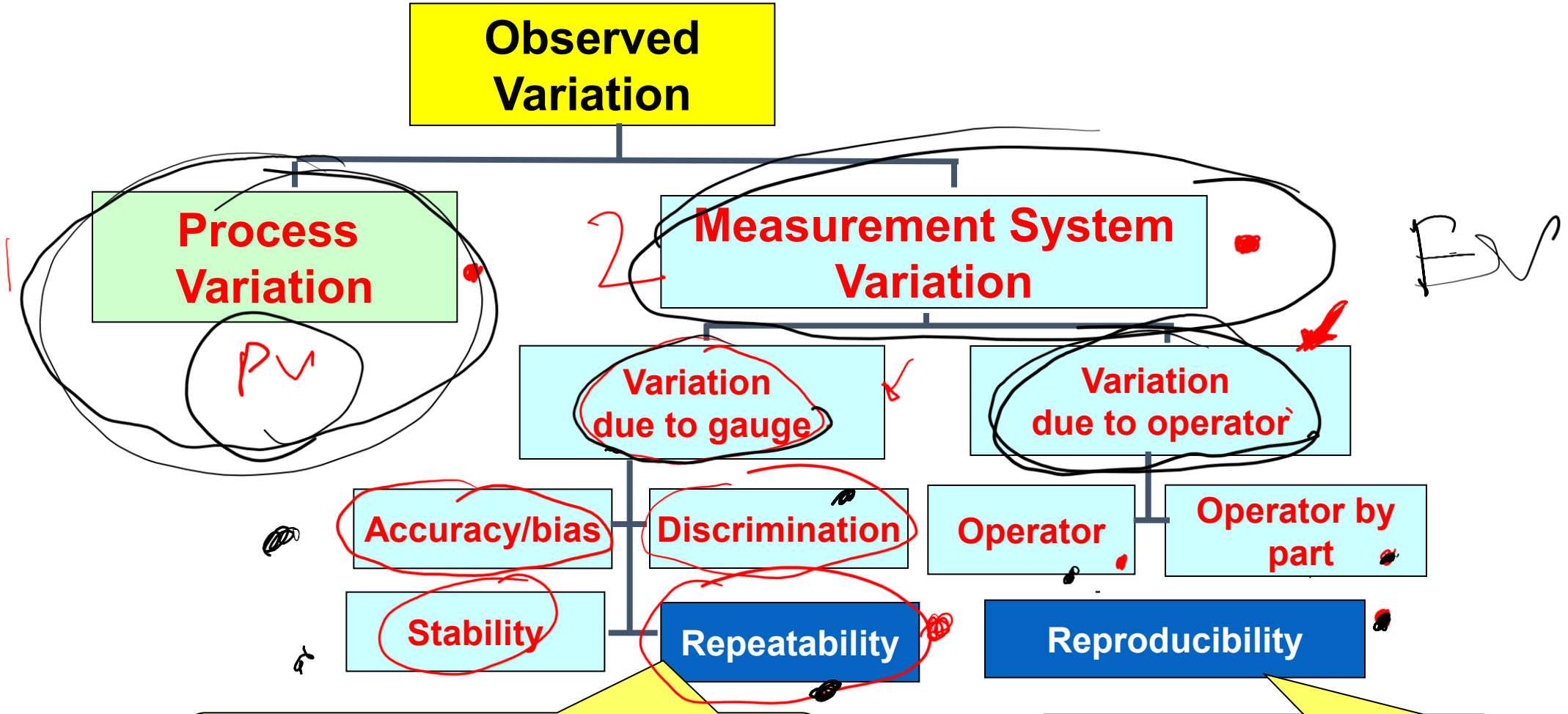
Why do we need a MSA?

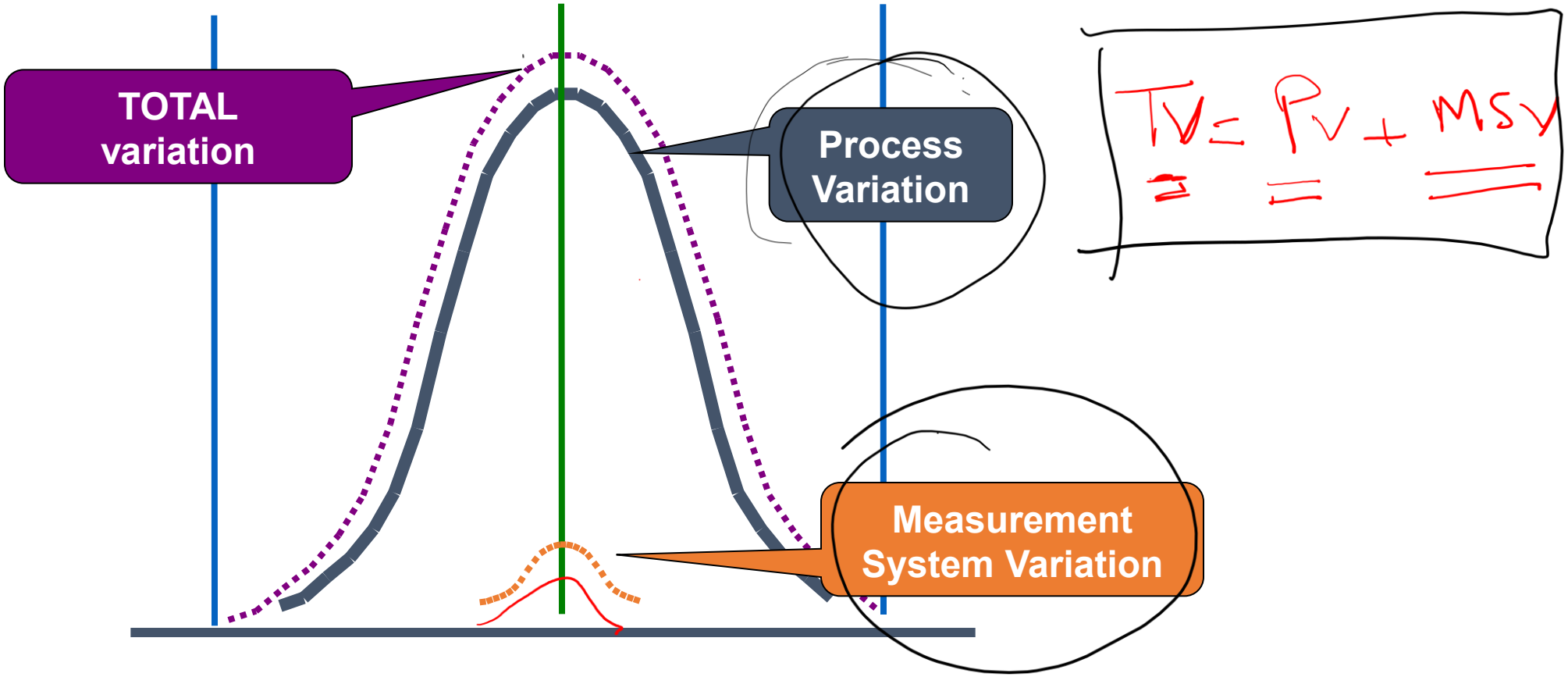
- In order to make good decisions in business, we need good data
- Without performing a MSA, we falsely assume the data is good
- If we are wrong and the data is not good, we might make an incorrect decision

- **MSA helps us determine if the data is good, so we can make the best decision possible**

Sources of Variation



Measurement System Analysis (Evaluation)



Variation in measurement system – can reject good or accept bad products/services

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Sources of Measurement

•These measurement sources can increase the measurement error

– Repeatability
– Reproducibility
– Accuracy
– Bias
– Stability
– Linearity
– Resolution

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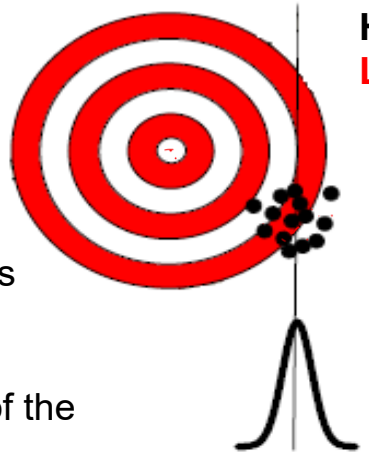
Accuracy vs. Precision

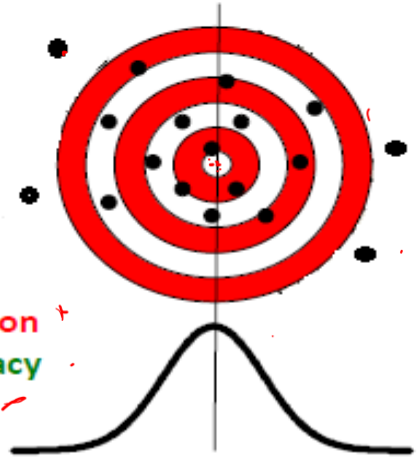
High Precision
High Accuracy

High Precision
Low Accuracy

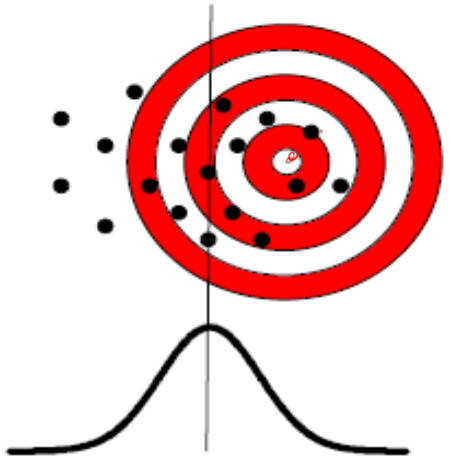


Precision: how spread out the shots are compared to each other

Accuracy: how close the average of the shots are to the bull's-eye



Low Precision
High Accuracy



Low Precision
Low Accuracy

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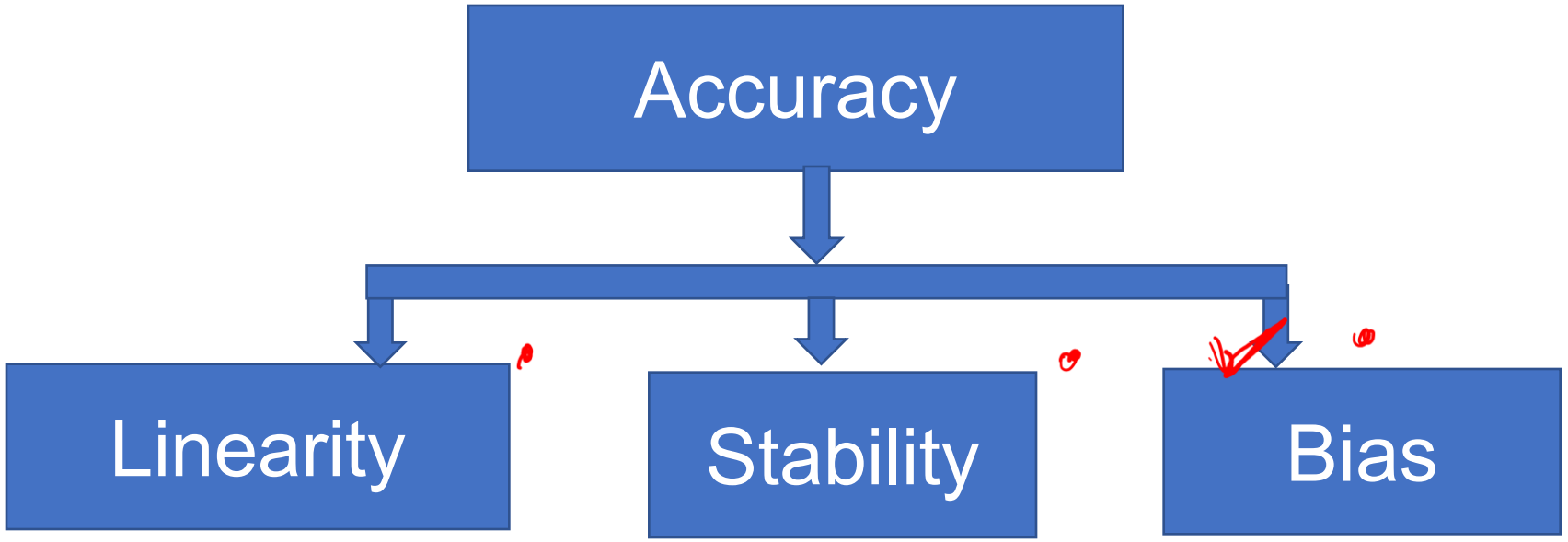
Accuracy

•Accuracy –how spread out the measurements are to each other, closeness to a reference value



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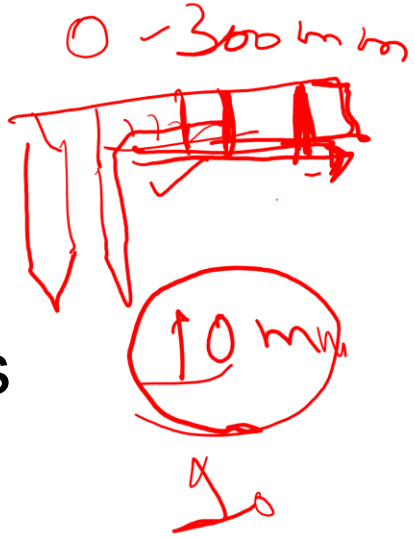
Linearity

- How accurate your measurements are through the expected range of measurements in which the device or instrument is intended to be used



– Ideally, the measurement error will be the same across the range of likely values

– Linearity often shows up as an increase in measurement error when measuring larger values

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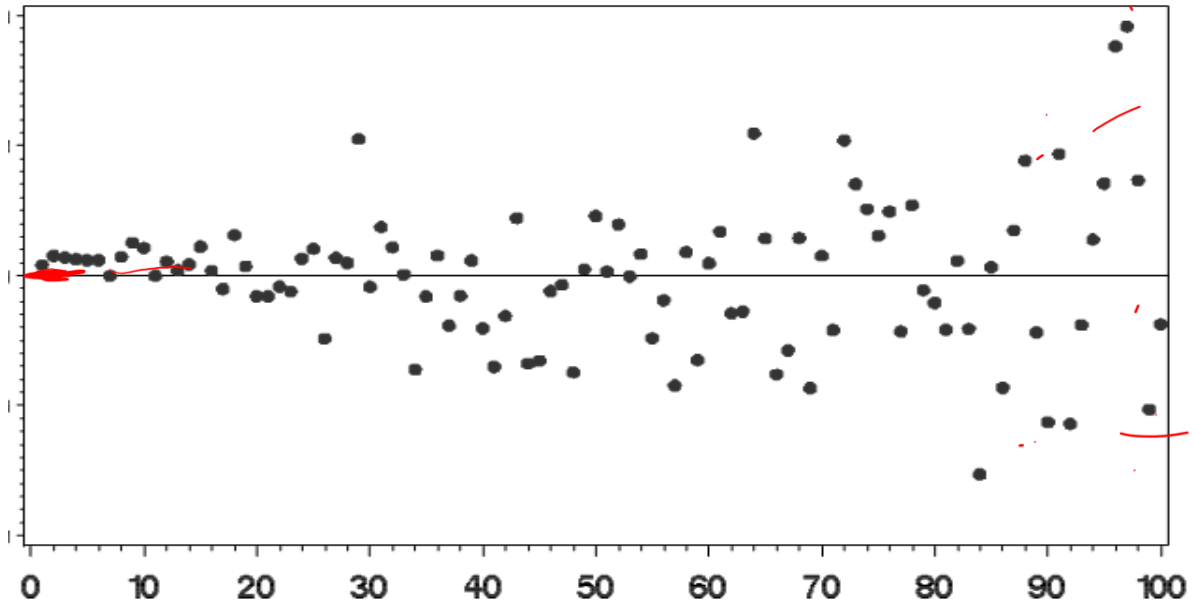
Linearity

- **Example: Thermometer is very good at low temperatures (around zero degrees C), but not as good near 100 degrees C or higher**



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Stability

- The change in bias over time (drift)

– Ideally, there should be no change in bias over time

– Stability issues may increase or decrease the values over time

- Control charts are commonly used to track the stability of a measurement system over time

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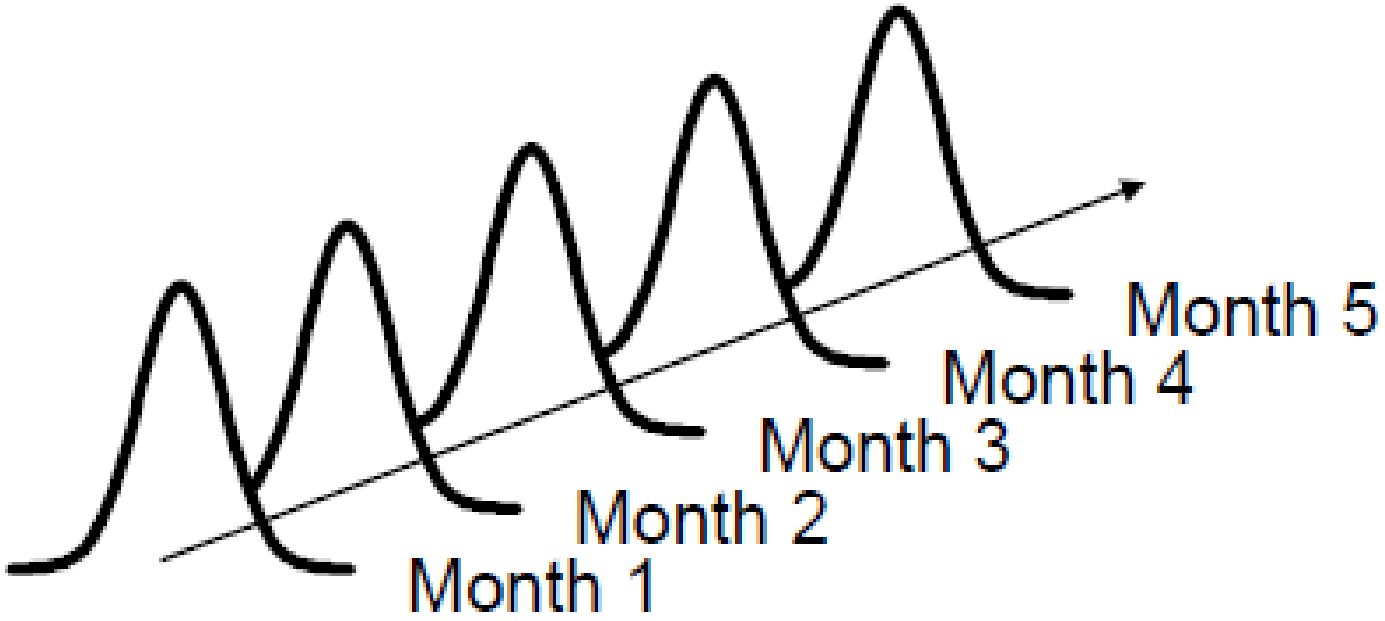
Stability

- **Example: Thermometer performs well today, but gets progressively worse each month**



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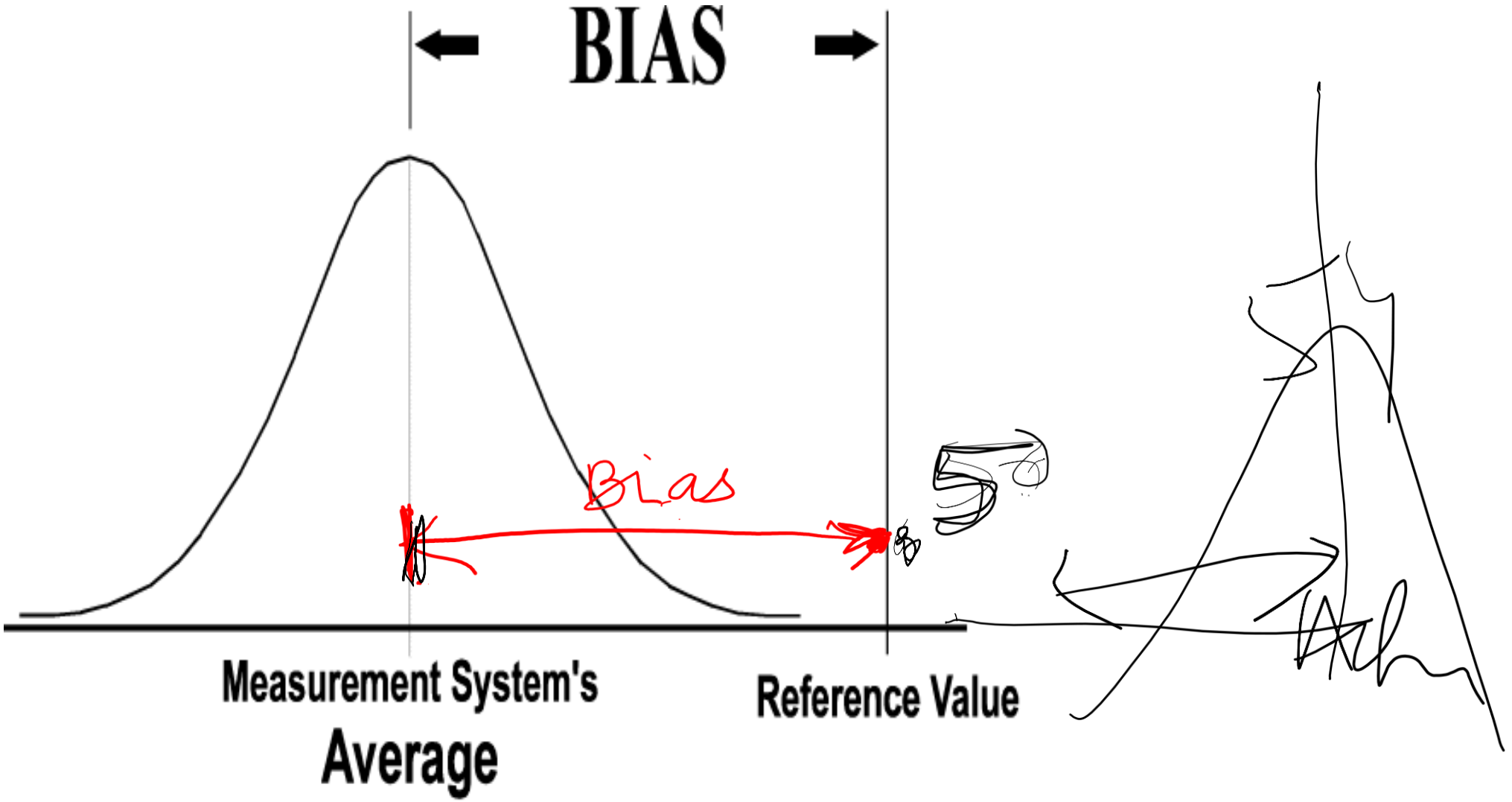
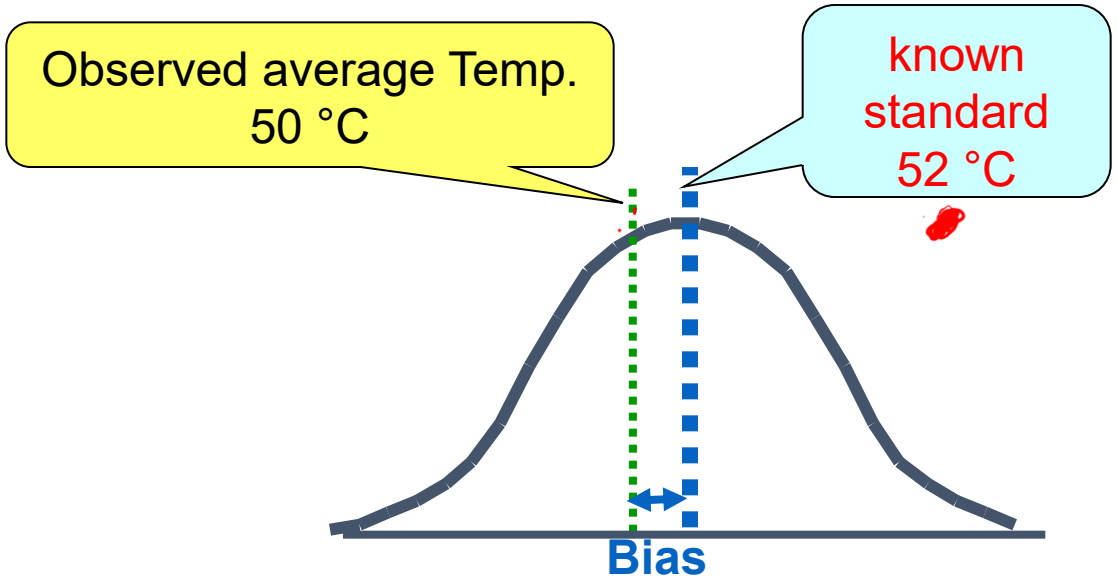
Bias

- How well your measurements compare to a reference, standard or known value
- Ideally, no difference between the measurement and the reference value
- Calibration is often performed to remove bias on a measuring device or equipment
- Only addresses one source of variation!
- **Example: Thermometer is consistently 2 degrees higher than actual temperature**



Bias



1. Identify a known standard/true value
2. 1 operator with 1 gauge measure 10 times, find average
3. Compare average to known standard
4. Gauge must then be offset positively by 2 °C due to bias

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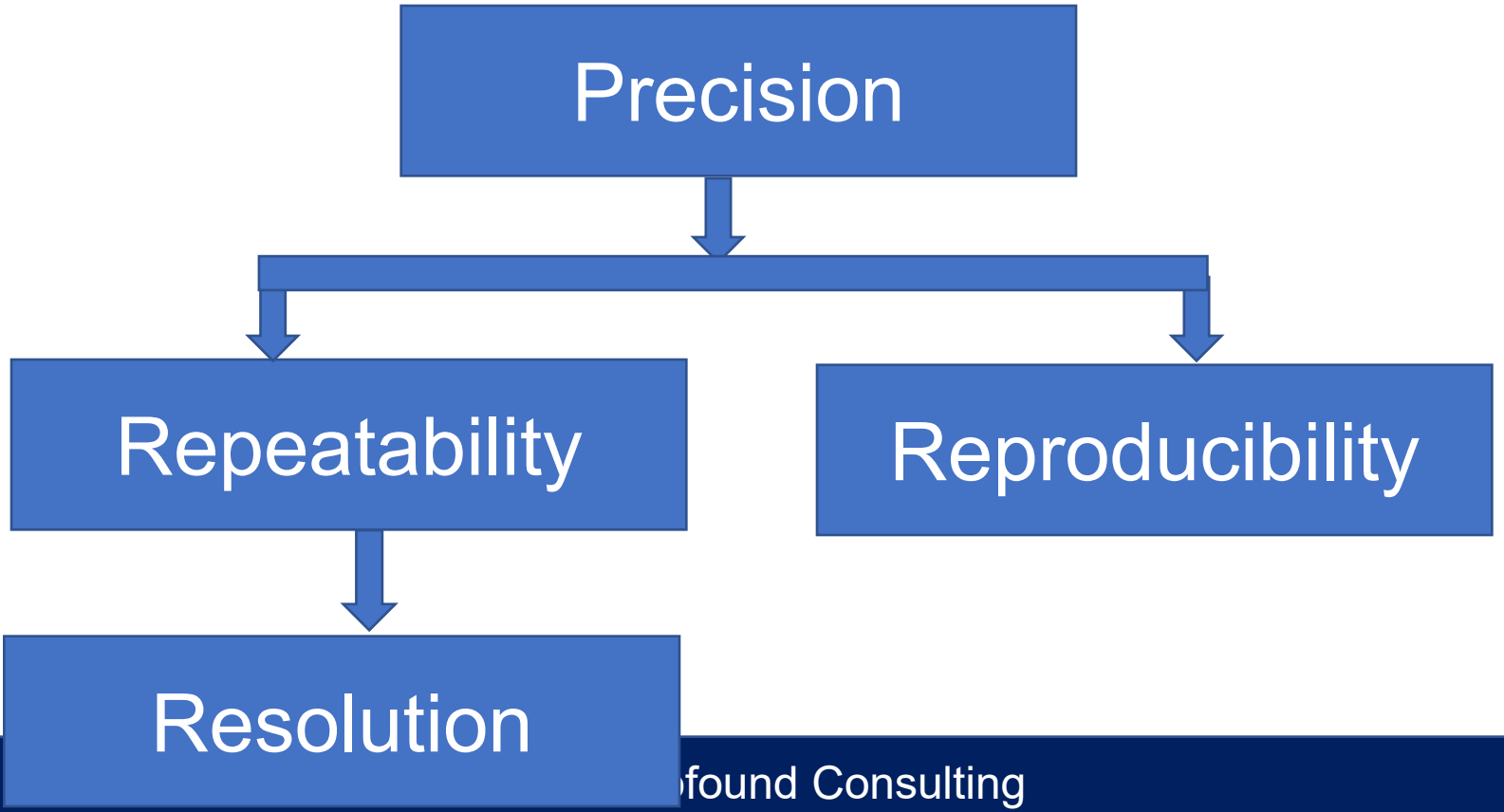
Precision

- Precision – how spread out are the measurements to each other



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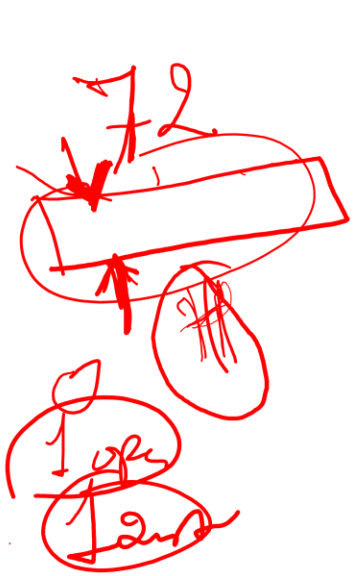
Repeatability

Repeatability is the variation in measurements obtained with **one measurement instrument** used several times by one appraiser while measuring the identical characteristic on the **same part.**

- Ideally, the results should be identical

- **Example**: Thermometer fluctuates from 72 to 78 degrees every minute (not repeatable), but actual temperature is not changing



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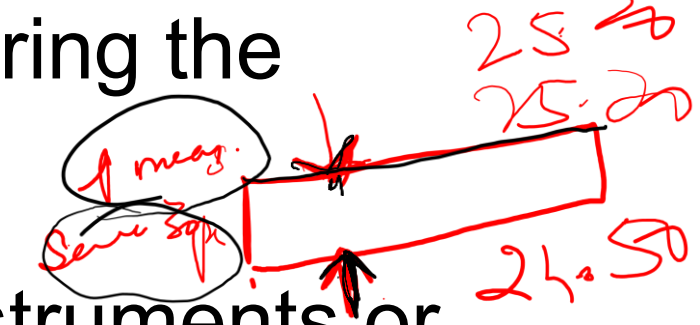
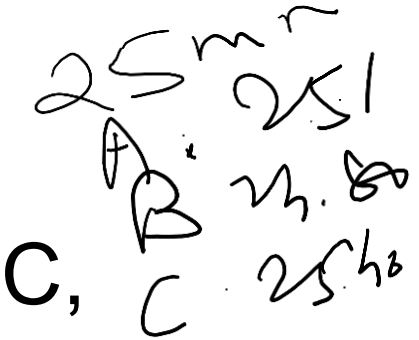
Reproducibility

• Reproducibility is the variation in the average of the measurements made by different appraisers using the same measuring instrument when measuring the identical characteristic on the same part.



• Ideally, the average results between instruments or people should be identical



• **Example**: You think the thermometer shows 56°C, but another observer thinks it shows 58°C

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Resolution

- Ability of the measurement system to detect and indicate small changes

– Ideally, the measurement can detect 10 or more values within likely range

- Each increment should be 10% or less of the range of values to be able to detect a change

- **Example: Thermometer only displays in increments of 5 degrees (35, 40, 45, etc), unable to get readings between 35 and 40. Prefer to have readings like 35.4 degrees.**

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Summary of Variation Sources

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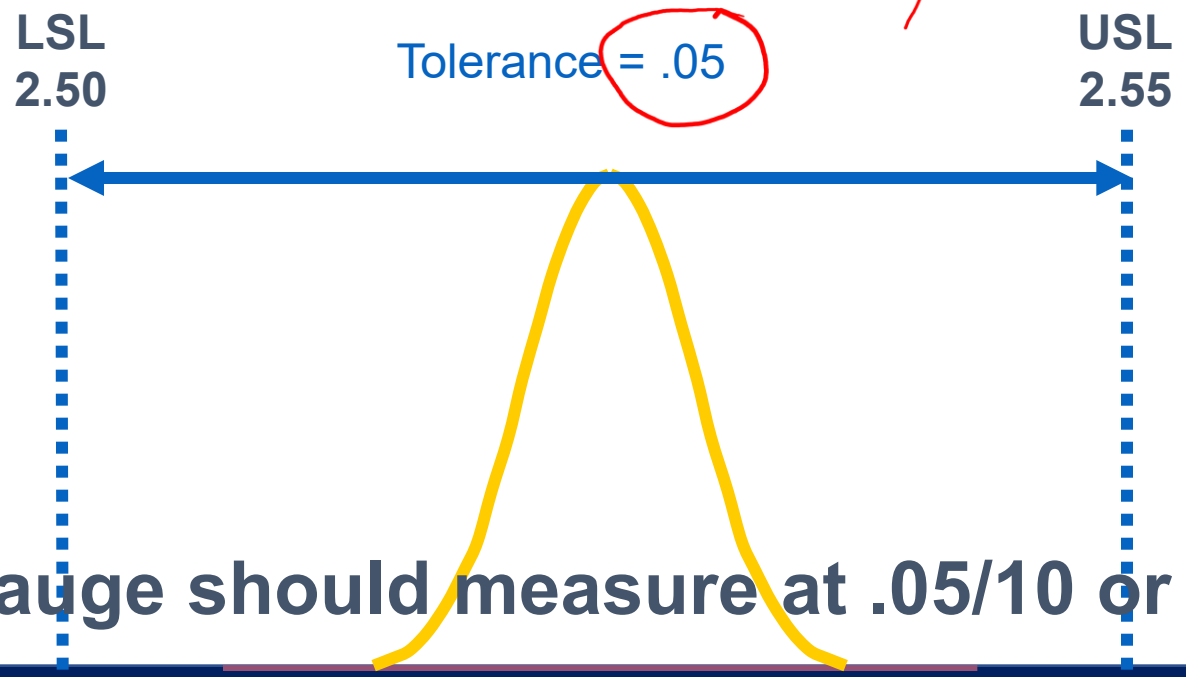
Rule of thumb – The measurement system should have resolution of at least 1/10th the smaller of either the specification tolerance or the process spread. If the resolution is not fine enough, process variability will not be recognized by the measurement system, thus blunting its effectiveness.

Tolerance = (USL – LSL)

: - **Rule of thumb =** (USL – LSL) / 10



Gauge should measure at .05/10 or .005

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- A GR & R Study must be a highly thought out and planned activity to ensure that the data obtained truly represents the measurement system.
- GR & R studies consist of five steps:
  1. Define the objective of the study.
  2. Define the components of the study.
  3. Make the measurements.
  4. Calculate the %GRR.
  5. Take action to improve the measurement system.

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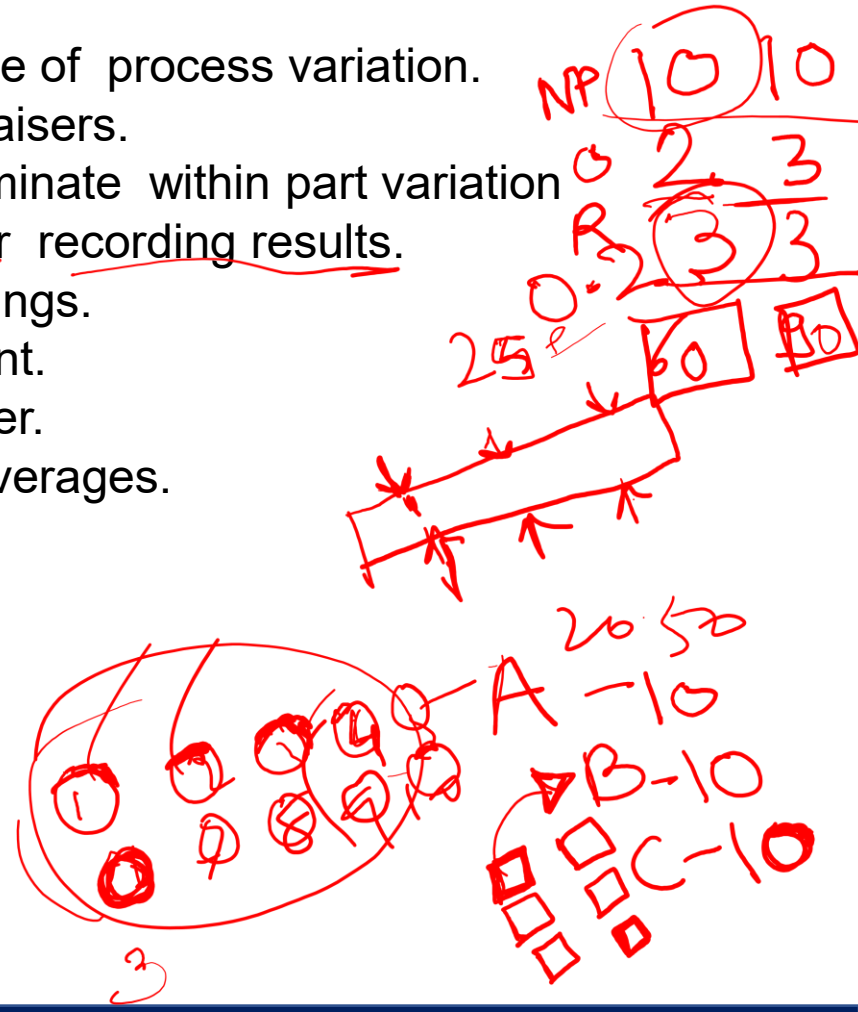
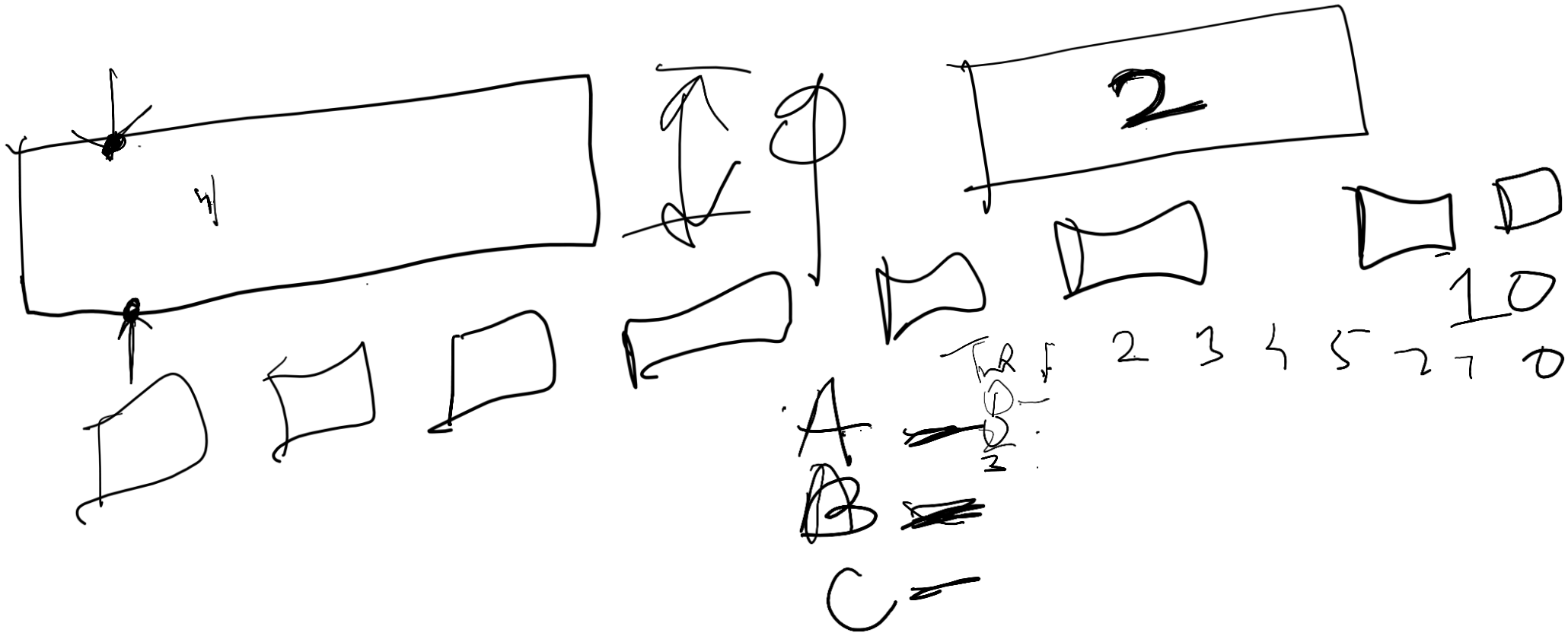
Gauge R&R Study Steps:

1. Select two or three appraisers who use the measurement system.
2. Obtain a sample of 10 parts that represent actual or expected range of process variation.
3. Number parts 1 through 10 so that numbers are not visible to appraisers.
4. Identify and Mark the place where measurement to be taken to eliminate within part variation
5. Measure 10 parts in random order by appraiser A, with an observer recording results.
6. Repeat step 5 with other appraisers conceal other appraisers readings.
7. Repeat step 5 and 6 using a different random order of measurement.
8. Calculate the average and ranges for all readings for each appraiser.
9. 9 Using attached GR&R report, enter part averages and range averages.
10. Calculate repeatability - equipment variation.
11. Calculate reproducibility - appraiser variation.
12. Calculate GR&R and convert to percentage.
13. Calculate part variation and convert to percentage.
14. Calculate total variation.





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SFL	GAGE REPEATABILITY AND REPRODUCIBILITY DATA SHEET									FORMAT NO.F/MSA/761/01	
TRIALS ↓	PARTS →										Average
	1	2	3	4	5	6	7	8	9	10	
1. A 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
2. 2	37.1	36.8	37.3	37.2	36.8	36.9	37.4	36.4	36.7	37.2	
3. 3	37.2	36.9	37.2	37.2	36.9	36.9	37.3	36.5	36.9	37.3	
4. Average	37.133	36.867	37.233	37.200	36.833	36.900	37.367	36.467	36.833	37.267	$\bar{X}a$ = 37.0100
5. Range	0.10	0.10	0.10	0.00	0.10	0.00	0.10	0.10	0.20	0.10	$\bar{R}a$ = 0.09
6. B 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
7. 2	37.1	36.9	37.2	37.2	36.8	36.8	37.5	36.5	36.8	37.2	
8. 3	37.1	36.9	37.2	37.3	36.9	36.9	37.4	36.5	36.9	37.3	
9. Average	37.100	36.900	37.200	37.233	36.833	36.867	37.433	36.500	36.867	37.267	$\bar{X}b$ = 37.02
10. Range	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.10	0.10	$\bar{R}b$ = 0.06
11. C 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
12. 2	37.1	36.9	37.2	37.2	36.9	36.9	37.5	36.5	36.9	37.3	
13. 3	37.1	36.9	37.2	37.2	36.8	36.8	37.4	36.6	36.9	37.3	
14. Average	37.100	36.900	37.200	37.200	36.833	36.867	37.433	36.533	36.900	37.300	$\bar{X}c$ = 37.0267
15. Range	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.00	$\bar{R}c$ = 0.04
16. Part Average (Xp)	37.111	36.889	37.211	37.211	36.833	36.878	37.411	36.500	36.867	37.278	$\bar{\bar{X}}$ = 37.019 Rp = 0.9111
17	[Ra + Rb + Rc] / No. of Appraisers =										$\bar{\bar{R}}$ = 0.06333
18	$\bar{X}_{Diff}$ = Max $\bar{X}$ - Min $\bar{X}$										0.0167
19	UCL_R= $\bar{\bar{R}}$ x D_4										0.207
20	LCL_R= $\bar{\bar{R}}$ x D_3										0

*D_4 = 3.27 for 2 Trials & 2.58 for 3 Trials; D_3 = 0 for upto 7 Trials. UCL_R represents the limit of Individual R's. Circle those that are beyond this limit. Identify the Cause & correct. Repeat these readings using the same appraiser & unit as originally used or discard values & re-average & recompute R & the Limiting value from the remaining observations.

MSA DATA SHEET WITH FORMULAS

GAGE R&R or Repeatability &Reproducibility

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- Xa,Xb,Xc : is a operator Average. Add up all ten values of Individual Appraiser and divided by 10

  : Total of all 10 Average value /10

		1	2	3	4	5	6	7	8	9	10	
1.	A 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
2.	2	37.1	36.8	37.3	37.2	36.8	36.9	37.4	36.4	36.7	37.2	
3.	3	37.2	36.9	37.2	37.2	36.9	36.9	37.3	36.5	36.9	37.3	
4.	Average	37.133	36.867	37.233	37.200	36.833	36.900	37.367	36.467	36.833	37.267	$\bar{X}a$ = 37.0100
5.	Range	0.10	0.10	0.10	0.00	0.10	0.00	0.10	0.10	0.20	0.10	$\bar{R}a$ = 0.09
6.	B 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
7.	2	37.1	36.9	37.2	37.2	36.8	36.8	37.5	36.5	36.8	37.2	
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9.	Average	37.100	36.900	37.200	37.233	36.833	36.867	37.433	36.500	36.867	37.267	$\bar{X}b$ = 37.02
10.	Range	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.10	0.10	$\bar{R}b$ = 0.06
11.	C 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
12.	2	37.1	36.9	37.2	37.2	36.9	36.9	37.5	36.5	36.9	37.3	
13.	3	37.1	36.9	37.2	37.2	36.8	36.8	37.4	36.6	36.9	37.3	
14.	Average	37.100	36.900	37.200	37.200	36.833	36.867	37.433	36.533	36.900	37.300	$\bar{X}c$ = 37.0267
15.	Range	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.00	$\bar{R}c$ = 0.04

GAGE R&R or Repeatability &Reproducibility

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- Ra,Rb,Rc : is a operator range Average. Add up all ten Range of Individual Appraiser and divided by 10

  : Total of all 10 Range /10

		1	2	3	4	5	6	7	8	9	10	
1.	A 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
2.	2	37.1	36.8	37.3	37.2	36.8	36.9	37.4	36.4	36.7	37.2	
3.	3	37.2	36.9	37.2	37.2	36.9	36.9	37.3	36.5	36.9	37.3	
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5.	Range	0.10	0.10	0.10	0.00	0.10	0.00	0.10	0.10	0.20	0.10	$\bar{R}a$ = 0.09
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9.	Average	37.100	36.900	37.200	37.233	36.833	36.867	37.433	36.500	36.867	37.267	$\bar{X}b$ = 37.02
10.	Range	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.10	0.10	$\bar{R}b$ = 0.06
11.	C 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
12.	2	37.1	36.9	37.2	37.2	36.9	36.9	37.5	36.5	36.9	37.3	
13.	3	37.1	36.9	37.2	37.2	36.8	36.8	37.4	36.6	36.9	37.3	
14.	Average	37.100	36.900	37.200	37.200	36.833	36.867	37.433	36.533	36.900	37.300	$\bar{X}c$ = 37.0267
15.	Range	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.00	$\bar{R}c$ = 0.04

GAGE R&R or Repeatability &Reproducibility

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- Xbar : is a average of all operator .Taken An average of $\bar{X}a, \bar{X}b, \bar{X}c$
  : $\bar{X}a + \bar{X}b + \bar{X}c /3$

	1	2	3	4	5	6	7	8	9	10	
1. A 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
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3. 3	37.2	36.9	37.2	37.2	36.9	36.9	37.3	36.5	36.9	37.3	
4. Average	37.133	36.867	37.233	37.200	36.833	36.900	37.367	36.467	36.833	37.267	$\bar{X}a$ = 37.0100
5. Range	0.10	0.10	0.10	0.00	0.10	0.00	0.10	0.10	0.20	0.10	$\bar{R}a$ = 0.09
6. B 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
7. 2	37.1	36.9	37.2	37.2	36.8	36.8	37.5	36.5	36.8	37.2	
8. 3	37.1	36.9	37.2	37.3	36.9	36.9	37.4	36.5	36.9	37.3	
9. Average	37.100	36.900	37.200	37.233	36.833	36.867	37.433	36.500	36.867	37.267	$\bar{X}b$ = 37.02
10. Range	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.10	0.10	$\bar{R}b$ = 0.06
11. C 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
12. 2	37.1	36.9	37.2	37.2	36.9	36.9	37.5	36.5	36.9	37.3	
13. 3	37.1	36.9	37.2	37.2	36.8	36.8	37.4	36.6	36.9	37.3	
14. Average	37.100	36.900	37.200	37.200	36.833	36.867	37.433	36.533	36.900	37.300	$\bar{X}c$ = 37.0267
15. Range	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.00	$\bar{R}c$ = 0.04
16. Part Average (Xp)	37.111	36.889	37.211	37.211	36.833	36.878	37.411	36.500	36.867	37.278	$\bar{\bar{X}}$ = 37.019 $\bar{R}p$ = 0.9111

Xbar

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- Rbar : it is the Average of Average range value .

  calculating : $\bar{R}a+\bar{R}b+\bar{R}c$ / 3

		1	2	3	4	5	6	7	8	9	10	
1.	A 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
2.	2	37.1	36.8	37.3	37.2	36.8	36.9	37.4	36.4	36.7	37.2	
3.	3	37.2	36.9	37.2	37.2	36.9	36.9	37.3	36.5	36.9	37.3	
4.	Average	37.133	36.867	37.233	37.200	36.833	36.900	37.367	36.467	36.833	37.267	$\bar{X}a$ = 37.0100
5.	Range	0.10	0.10	0.10	0.00	0.10	0.00	0.10	0.10	0.20	0.10	$\bar{R}a$ = 0.09
6.	B 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
7.	2	37.1	36.9	37.2	37.2	36.8	36.8	37.5	36.5	36.8	37.2	
8.	3	37.1	36.9	37.2	37.3	36.9	36.9	37.4	36.5	36.9	37.3	
9.	Average	37.100	36.900	37.200	37.233	36.833	36.867	37.433	36.500	36.867	37.267	$\bar{X}b$ = 37.02
10.	Range	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.10	0.10	$\bar{R}b$ = 0.06
11.	C 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
12.	2	37.1	36.9	37.2	37.2	36.9	36.9	37.5	36.5	36.9	37.3	
13.	3	37.1	36.9	37.2	37.2	36.8	36.8	37.4	36.6	36.9	37.3	
14.	Average	37.100	36.900	37.200	37.200	36.833	36.867	37.433	36.533	36.900	37.300	$\bar{X}c$ = 37.0267
15.	Range	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.00	$\bar{R}c$ = 0.04
16.	Part Average (Xp)	37.111	36.889	37.211	37.211	36.833	36.878	37.411	36.500	36.867	37.278	$\bar{X}$ = 37.019 Rp = 0.9111
17		[Ra + Rb + Rc] / No. of Appraisers =										$\bar{\bar{R}}$ = 0.06333

Rbar

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- Rp : average of each part

  : Max. operator Average Part value – Min. Average operator Part value

12.	2	37.1	36.9	37.2	37.2	36.9	36.9	37.5	36.5	36.9	37.3	
13.	3	37.1	36.9	37.2	37.2	36.8	36.8	37.4	36.6	36.9	37.3	
14.	Average	37.100	36.900	37.200	37.200	36.833	36.867	37.433	36.533	36.900	37.300	$\bar{X}c$ = 37.0267
15.	Range	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.00	$\bar{R}c$ = 0.04
16.	Part Average (Xp)	37.111	36.889	37.211	37.211	36.833	36.878	37.411	36.500	36.867	37.278	$\bar{\bar{X}}$ = 37.019
												Rp = 0.9111

Max. opr. Average Part value − Min. opr. Average Part value = Rp

GAGE R&R or Repeatability &Reproducibility

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Xbar diff : it is the difference of Max. and Min Average Value ($\bar{X}a, \bar{X}b, \bar{X}c$)

TRIALS	PARTS →										Average
↓	1	2	3	4	5	6	7	8	9	10	
1. A 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
2. 2	37.1	36.8	37.3	37.2	36.8	36.9	37.4	36.4	36.7	37.2	
3. 3	37.2	36.9	37.2	37.2	36.9	36.9	37.3	36.5	36.9	37.3	
4. Average	37.133	36.867	37.233	37.200	36.833	36.900	37.367	36.467	36.833	37.267	$\bar{X}a$ = 37.0100
5. Range	0.10	0.10	0.10	0.00	0.10	0.00	0.10	0.10	0.20	0.10	$\bar{R}a$ = 0.09
6. B 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
7. 2	37.1	36.9	37.2	37.2	36.8	36.8	37.5	36.5	36.8	37.2	
8. 3	37.1	36.9	37.2	37.3	36.9	36.9	37.4	36.5	36.9	37.3	
9. Average	37.100	36.900	37.200	37.233	36.833	36.867	37.433	36.500	36.867	37.267	$\bar{X}b$ = 37.02
10. Range	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.10	0.10	$\bar{R}b$ = 0.06
11. C 1	37.1	36.9	37.2	37.2	36.8	36.9	37.4	36.5	36.9	37.3	
12. 2	37.1	36.9	37.2	37.2	36.9	36.9	37.5	36.5	36.9	37.3	
13. 3	37.1	36.9	37.2	37.2	36.8	36.8	37.4	36.6	36.9	37.3	
14. Average	37.100	36.900	37.200	37.200	36.833	36.867	37.433	36.533	36.900	37.300	$\bar{X}c$ = 37.0267
15. Range	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.00	0.00	$\bar{R}c$ = 0.04
16. Part Average (Xp)	37.111	36.889	37.211	37.211	36.833	36.878	37.411	36.500	36.867	37.278	$\bar{X}$ = 37.019 Rp = 0.9111
17	[Ra + Rb + Rc] / No. of Appraisers =										$\bar{R}$ = 0.06333
18	X_{Diff} = Max $\bar{X}$ - Min $\bar{X}$										0.0167
19	UCL_R= $\bar{R}$ x D_4										0.207
20	LCL_R= $\bar{R}$ x D_3										0

Xdiff

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- Upper control Limit (UCL) : Average of average range **(Rbar)** x D4

:- (D4 Value is a constant value but Depends **on No of Trails**

D4 = 3.27 for 2 Trails & 2.58 for 3 Trails)

:- In this case we take 3 trails

17	[Ra + Rb + Rc] / No. of Appraisers =	$\bar{\bar{R}}$ = 0.06333
18	$\bar{X}_{Diff}$ = Max $\bar{X}$ - Min $\bar{X}$	0.0167
19	UCL_R= $\bar{\bar{R}}$ x D_4	0.207
20	LCL_R= $\bar{\bar{R}}$ x D_3	0

*D_4 = 3.27 for 2 Trials & 2.58 for 3 Trials; D_3 = 0 for upto 7 Trials. UCL_R represents the limit of Individual R's. Circle those that are beyond this limit. Identify the Cause & correct. Repeat these readings using the same appraiser & unit as originally used or discard values & re-average & recompute R & the Limiting value from the remaining observations.

GAGE R&R or Repeatability &Reproducibility

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- Lower control Limit (LCL) : Average of average range **(Rbar)** x D3

  :- (D3 Value is a constant value but Depends on No of Trail D3 = 0 for Up to 7 Trails)

  :- In this case we take 3 trails

17	[Ra + Rb + Rc] / No. of Appraisers =	$\bar{\bar{R}}$ = 0.06333
18	$\bar{X}_{Diff}$ = Max $\bar{X}$ - Min $\bar{X}$	0.0167
19	UCL_R= $\bar{\bar{R}}$ x D_4	0.207
20	LCL_R= $\bar{\bar{R}}$ x D_3	0

*D_4 = 3.27 for 2 Trials & 2.58 for 3 Trials; D_3 = 0 for upto 7 Trials. UCL_R represents the limit of Individual R's. Circle those that are beyond this limit. Identify the Cause & correct. Repeat these readings using the same appraiser & unit as originally used or discard values & re-average & recompute R & the Limiting value from the remaining observations.

Rbar

LCL

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Table of Control Chart Constants

Sample Size = m	D_3	D_4
2	0	3.267
3	0	2.574
4	0	2.282
5	0	2.114
6	0	2.004
7	0.076	1.924
8	0.136	1.864
9	0.184	1.816
10	0.223	1.777

Similarly, the UCL and LCL for the MR chart will be:

UCL = D4(Rbar) & LCL = D3(Rbar) but,

since D3 = 0 when n = 0 (or, more accurately, is "not applicable")

there will be no LCL for the MR chart

GAGE R&R or Repeatability &Reproducibility

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- Equipment Variation i.e., Repeatability (EV) :

This is with in “With in Appraiser” Verification. It measures the verification one appraiser has been measuring the same part (and the same characteristics) use the same gage more than one time K1 is constant depends on the number of Trail. For 2 trails K1 Value is 0.8862 & For 3 trails K1 Value is 0.5908

The calculation is given below :

$$EV = Rbar \times K1$$

& $\%EV = 100(EV/TV)$

Ex. :- if Rbar is 0.06333 & with in 3 trail then

$EV = 0.06333 \times 0.5908 = 0.0374$

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➢ Appraiser Variation i.e., Reproducibility (AV) :

This is the "between Appraiser Variation". It is the variation in the average of measurement made by the different appraisers when measuring the same characteristic on the same parts.

The calculation is given below :

$$AV = (Xdiff \times K2)^2 - EV^2/nr) = 0.0069$$

$$\%AV = 100\{EV/TV\}$$

Ex. :- Let us assume $(Xdiff \times K2)^2$ as X1 & $EV^2/n \times r$ as X2

n= no of parts

r = no of trial

AV= SQRT(X1 –X2)

Xdiff = 0.0167 (max. X bar- min. X bar) and k2 is constant depend on appraiser for 2 appraise k2= 0.7071 & for 3 appraise k2= 0.5231

Gage Capability (R&R)

Gage Capability is defined as:

$$\sqrt{(repeatability)^2 + (reproducibility)^2}$$

or symbolically as:

$$\sqrt{EV^2 + AV^2}$$

➢:- $\sqrt{(0.0374)^2 + (0.0069)^2} = 0.0380$

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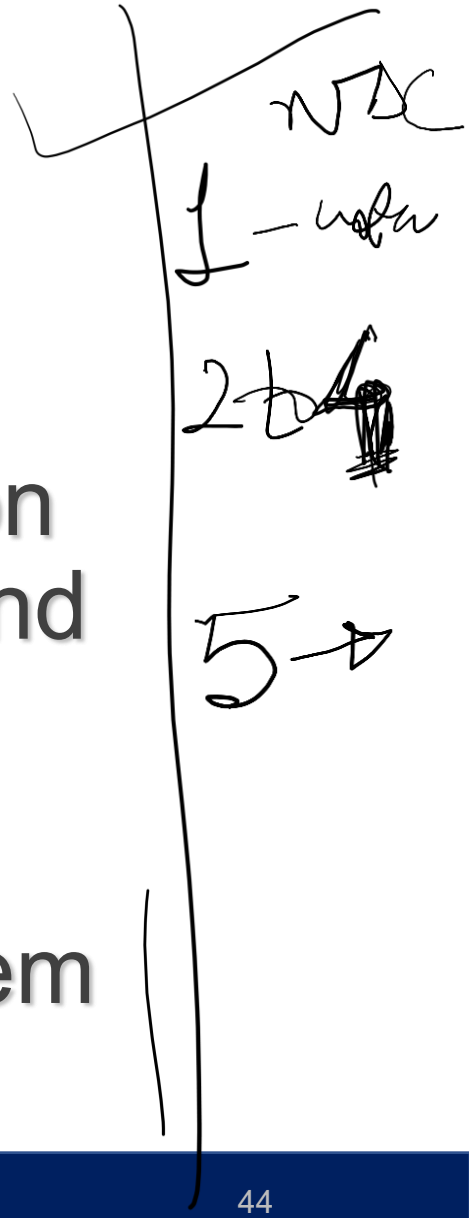
GRR acceptance Criteria of GR&R

1. <10% :Readily Acceptable

2. 10 to 30% : May be acceptable based on application Cost of measuring Device and cost of repair etc.

3. >30%: Not Acceptable. Measuring system needs improvement.



GAGE R&R or Repeatability &Reproducibility

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➢ Part Variation (PV) :

The PART Variation is determined by multiplying the range of part average (Rp) by a constant K3. K3 depends on the number of parts:

:- K3 Value is 0.3146 For 10 Parts

PV = Rp x K3

PV = 0.9111 X 0.3146

PV = 0.287

% PV = 100 [PV / TV]

Parts	K3
2	0.7071
3	0.5231
4	0.4467
5	0.403
6	0.3742
7	0.3534
8	0.3375
9	0.3249
10	0.3146

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- Total Variation (TV) :

This is total variation from the study it is determine by the following equation :

$$TV = SQRT(GRr \times GRr + PV \times PV)$$

Ex. :- if GRr is 0.0380 & PV is 0.287 then

TV= Square root (0.0380x0.0380+ 0.287x0.287)

TV= Square root (0.00145 +0.0823) =0.290

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- Once we get all the valve then we ready to calculate the % values of Followings :-

1. % EV = 100(EV/TV) = 12.88 %

2. % AV = 100(AV/TV) = 2.38 %

3. % GRR = 100(GRR/TV) = 13.10 %

4. % PV = 100(PV/TV) = 99.14 %

Measurement Systems Analysis

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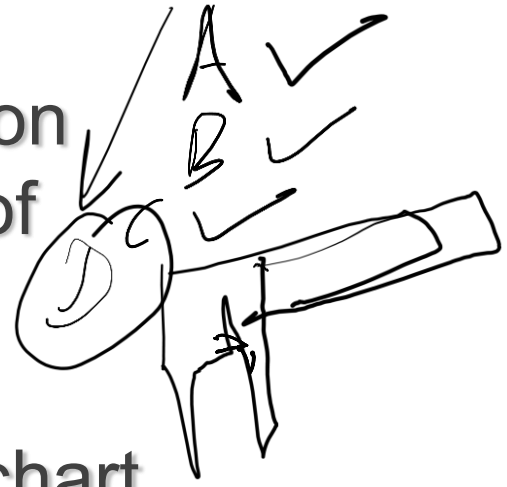
Number of distinct Categories(ndc) : Resolution in any measurement system needs to be taken into account in MSA ,we have ndc indicating this precision statement. Hence ndc is a measure of the number of distinct categories that can be distinguished by the measurement system. It is similar to looking at how many possible values there are on a range control chart .



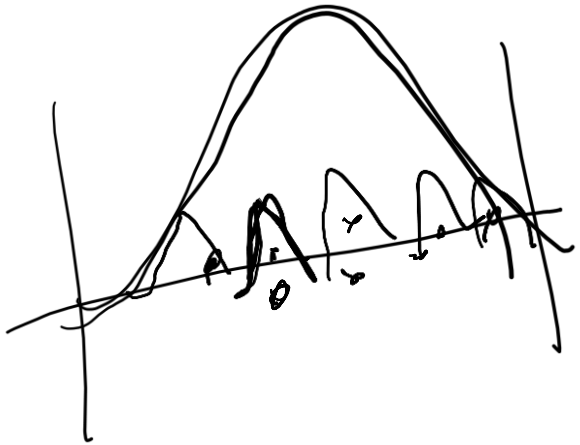
The calculation is :

$$ndc = 1.41\ (PV/\ GRR)$$

Ex. :- if GRr is 0.0380 & PV is 0.287 then

$$ndc = 1.41\ (\ 0.287/0.0380)$$

$$ndc = 10.65$$



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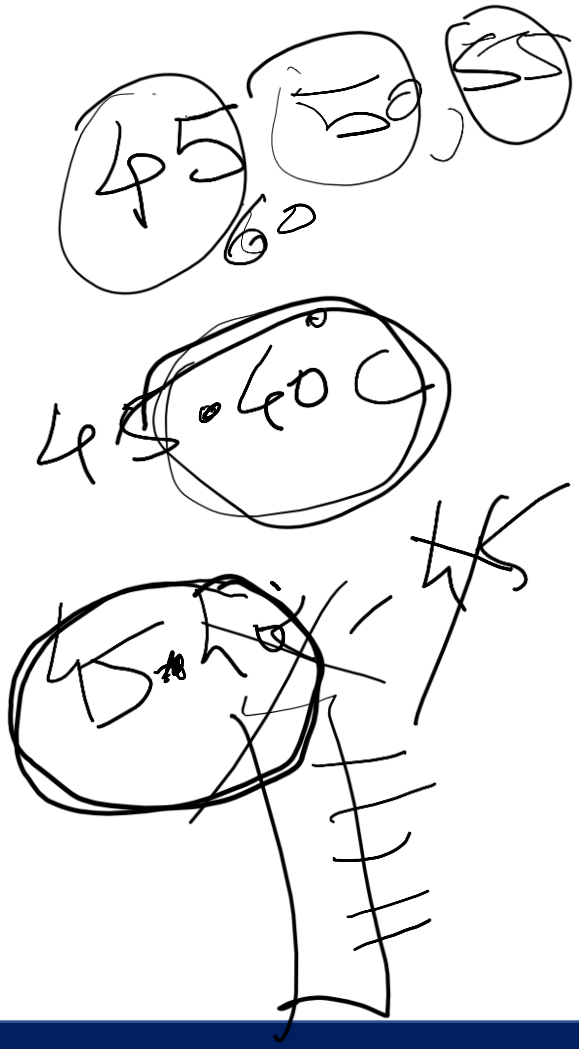
GRR acceptance Criteria of ndc

1. 1 : Not Acceptable: Difficult to distinguish one part from Another
2. 2 to 4 : Generally not acceptable
3. 5 and above : Acceptable



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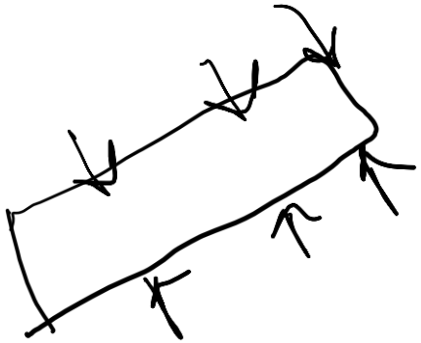
How to Improve Repeatability

- Look at the maintenance status of the instruments and its calibration status.

- Review and Reconsider the tolerance band of the gauge



- Verify the clamping or location for gauging. It should be more precise;
- There may be Excessive part variation .

GAGE R&R or Repeatability &Reproducibility

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How to Improve Reproducibility

- Appraiser is not skilled in MSA. Retrain him.
- Instrument not pre-calibrated before performing MSA. Recalibrate it.
- Appraiser not consistent in gauging . Need fixture as support.

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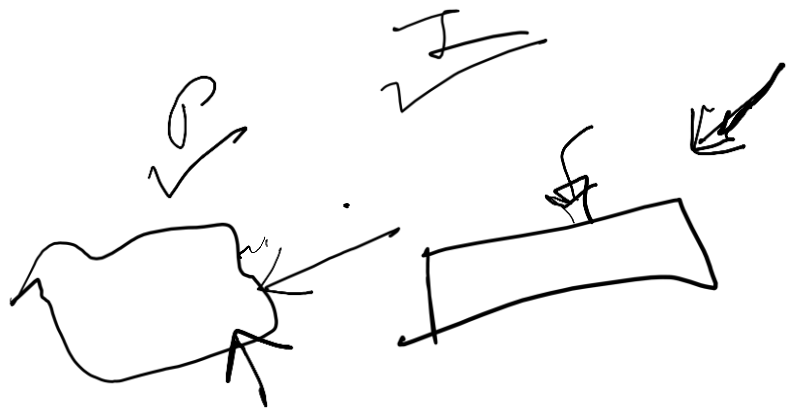
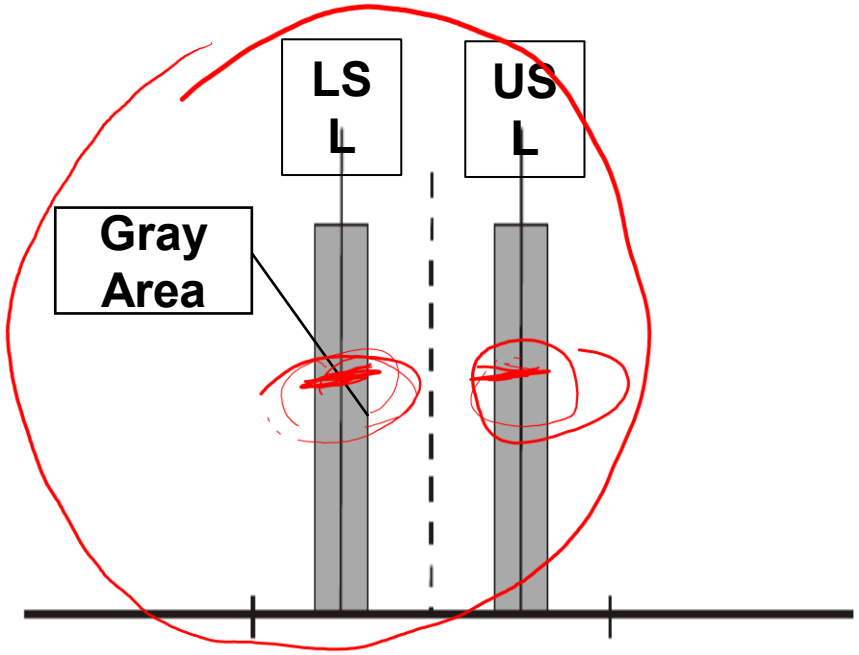


Attribute MSA

- Used when measurement value is one of the finite number of categories.
- Commonly use of these is Go/ No- Go gauge.



- The attribute MSA study is used to improve measurement capability for parts which are falling in gray area.

Steps to perform Attribute MSA

- The roadmap to planning, implementing , collecting data for a MSA attribute data follows.

Step 1: Select the gauge to be studied.

Step 2: 30 parts are to be selected in such a way that some parts are at border line from the regular production (i.e. complete process variation), the status of acceptance of samples shall be known to engineer who is conducting MSA studies.

Step 3: Select 3 different operators/Inspector who are performing the particular inspection activity actually.

Step 4: Ask operator to check and give decision for each sample 3 times in random manner and result is to be recorded by engineer.

Step 5: Enter the values in Attribute MSA format.

Step 6: Analyze the results 1) Kappa Values 2) Miss & False rate

Step 7: Take decision on acceptability of measurement system.

Microsoft Office
Excel Worksheet

Calculation of Expected Count

A*B Cross Tabulation				
		B		Total
		0.00	1.00	
A	0.00 Count	22	23	45
	Exp Count	13.5	31.5	45
	1.00 Count	5	40	45
	Exp Count	13.5	31.5	45
Total	Count	27	63	90
	Exp Count	27	63	90

Pae= {(A+B)*(A+C)} / Total Count
= {(22+23)*(22+5)}/90
= 1215/90 = **13.5**

Pbe= {(B+A)*(B+D)} / Total Count
= {(23+22)*(23+40)}/90
= 2835/90 = **31.5**

Pce= {(C+D)*(C+A)} / Total Count
= {(5+40)*(5+22)}/90
= 1215/90 = **13.5**

Pde= {(D+C)*(D+B)} / Total Count
= {(40+5)*(40+23)}/90
= 2835/90 = **31.5**

Calculation of Kappa Value

- **Kappa** :Kappa is an inter- rater agreement i.e. the ratio of the proportion of agreement divided by the maximum number of times they could agree.

$$Kappa = \frac{po - pe}{1 - pe}$$

Po = the sum of the observed proportions in the diagonal cells

Pe = the sum of the expected proportion in the diagonal cells

Calculation of Kappa Value

A*B Cross Tabulation				
		B		Total
		0.00	1.00	
A	0.00 Count	22	23	45
	Exp Count	13.5	31.5	45
	1.00 Count	5	40	45
	Exp Count	13.5	31.5	45
Total	Count	27	63	90
	Exp Count	27	63	90

P_O = The sum of the observed proportions in the diagonal cells.

= 22/90 + 40/90

= 0.24 + 0.44

= **0.68**

P_e = the sum of the expected proportion in the diagonal cells

= 13.5/90 + 31.5/90

= 0.15 + 0.35

= **0.5**

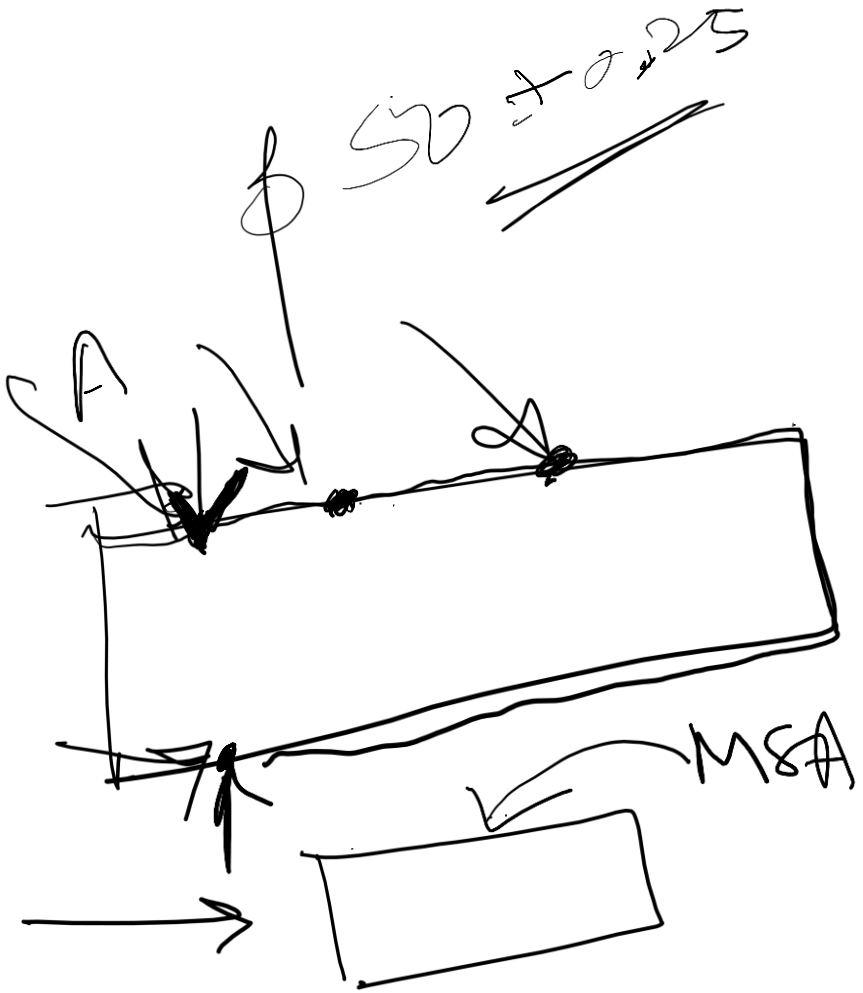
Kappa(K)= Po - Pe / 1- Pe

= 0.68-0.5/1-0.5

=0.18/0.5

= 0.36

Calibration
MSA



Acceptance Criteria

Kappa(k) = 1	Excellent (100% Agreement between appraisers and reference both)
Kappa (k)>0.75	Measurement System is Accepted
0.40> Kappa(k)< 0.75	Measurement system is conditionally accepted
Kappa(k) <0.40	Measurement System is not accepted

Note : The ultimate aim to achieve kappa value 1 so action plan should be made to achieve kappa value 1.

	Stability	Bias	Linearity	R&R	Absolute MSA
G1	April/May/Jun	April	A	once in 6 months	~~[illegible]~~ NA
G2	June/Dec.	June/Dec		NA	once [illegible]
G3	↕	30k 10k	G — 1 yr.	/ 2 yrs. →	10 Type — [illegible] Gauge — 300

Miss Rate & False Rate for Appraiser A

A*Reference Cross tabulation					
			Reference		Total
			0.00	1.00	
A	0.00	Count	24	6	30
		Exp Count	15.0	15.0	30
	1.00	Count	21	39	60
		Exp Count	30.0	30.0	60
Total		Count	45	45	90
		Exp Count	45	45	90

Miss Rate: Calling " BAD" part "GOOD".

i.e. Customer Risk =21/90 = 23.3%

False Rate: Calling a " GOOD" part "BAD".

i.e. Manufacturer's Risk =6/90= 6.66%

$$\text{Effectiveness} = \frac{\text{Number of correct Decisions}}{\text{Total opportunities for a decision}} = \frac{63}{90} = 70\%$$

Effectiveness Criteria Guideline

Decision Measurement system	Effectiveness	Miss Rate	False Alarm Rate
Acceptable for the appraiser	≥ 90%	≤ 2%	≤ 5%
Marginally acceptable for the appraiser – may need improvement	≥80%	≤ 5%	≤ 10%
Unacceptable for the appraiser – needs improvement	< 80%	> 5%	> 10%

Why Attribute MSA Fails?

- **Failure due to appraiser**
  - Improper clarification on reject/accept
    - Eyesight of appraiser

- **Failure due to inspection process**
  - Poor illumination of the work area.
  - Poor objectivity and clarity of conformance standards and test instructions.
  - Not enough time allowed for inspection.