Deploying Advanced Quality and Lean Tools to Achieve Zero Defects

Measurement Systems Analysis (MSA)

Part 1 - Introduction

Advanced Quality Team

LOCKHEED MARTIN

GROUND RULES

Silence cell phones

Mute your microphone

No Multitasking

All Questions are welcome

LOCKHEED MARTIN

Deploying Advanced Quality and Lean Tools to Achieve Zero Defects

Measurement Systems Analysis (MSA)

Part 1 - Introduction

LOCKHEED MARTIN

Advanced Quality Team

Agenda

Part 1

- Training Objectives
- MSA Background
- Benefits and Fundamentals
- Terminology
- Gage Selection

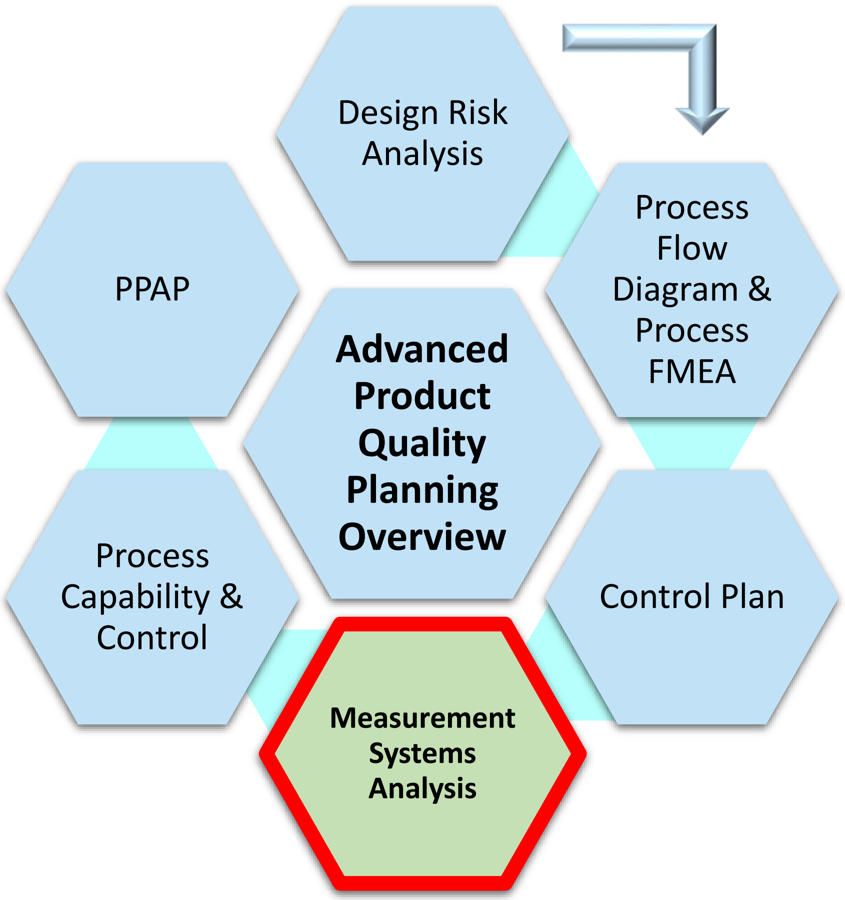
Part 2

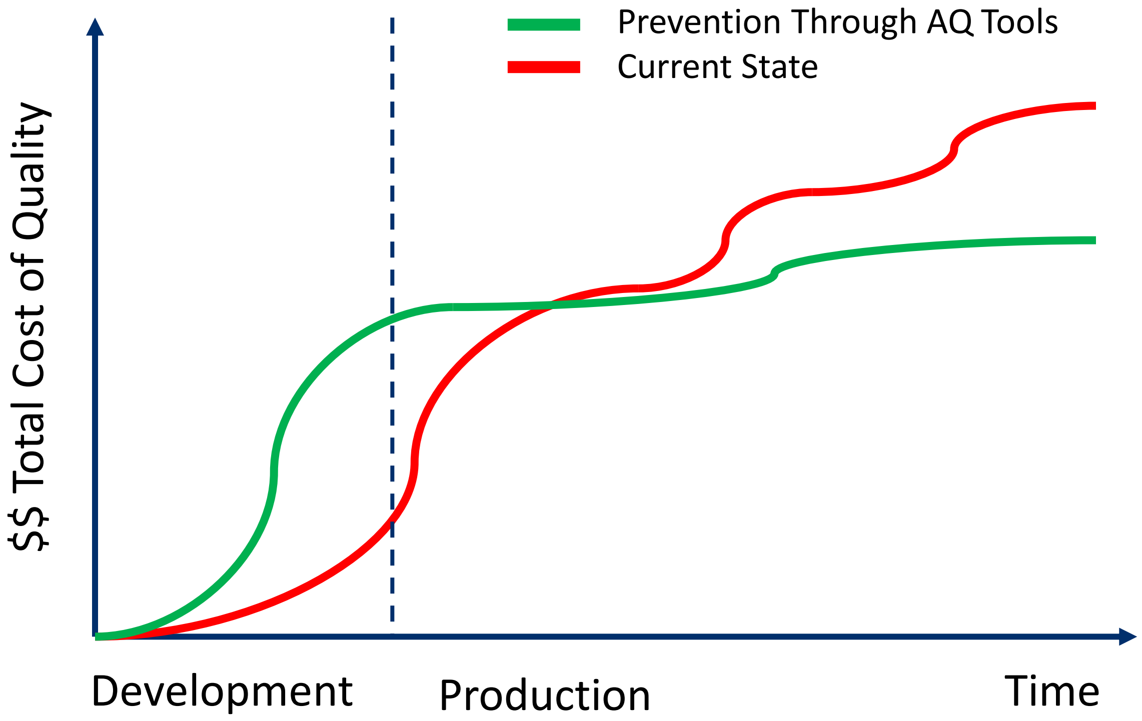
- Common MSA Assessment
- Stability Assessment
- Bias Assessment
- Gage R&R Example (Excel & Minitab)
- Further Analysis
- Resources

Training Objectives

- Introduce the MSA as part of the AQ Tool System and its linkage to other AQ Tools
- Outline the process for MSA including:
  - Terminology
  - Benefits
- Understand when and how to conduct MSA
- Communicate availability of guidance material and training

Background



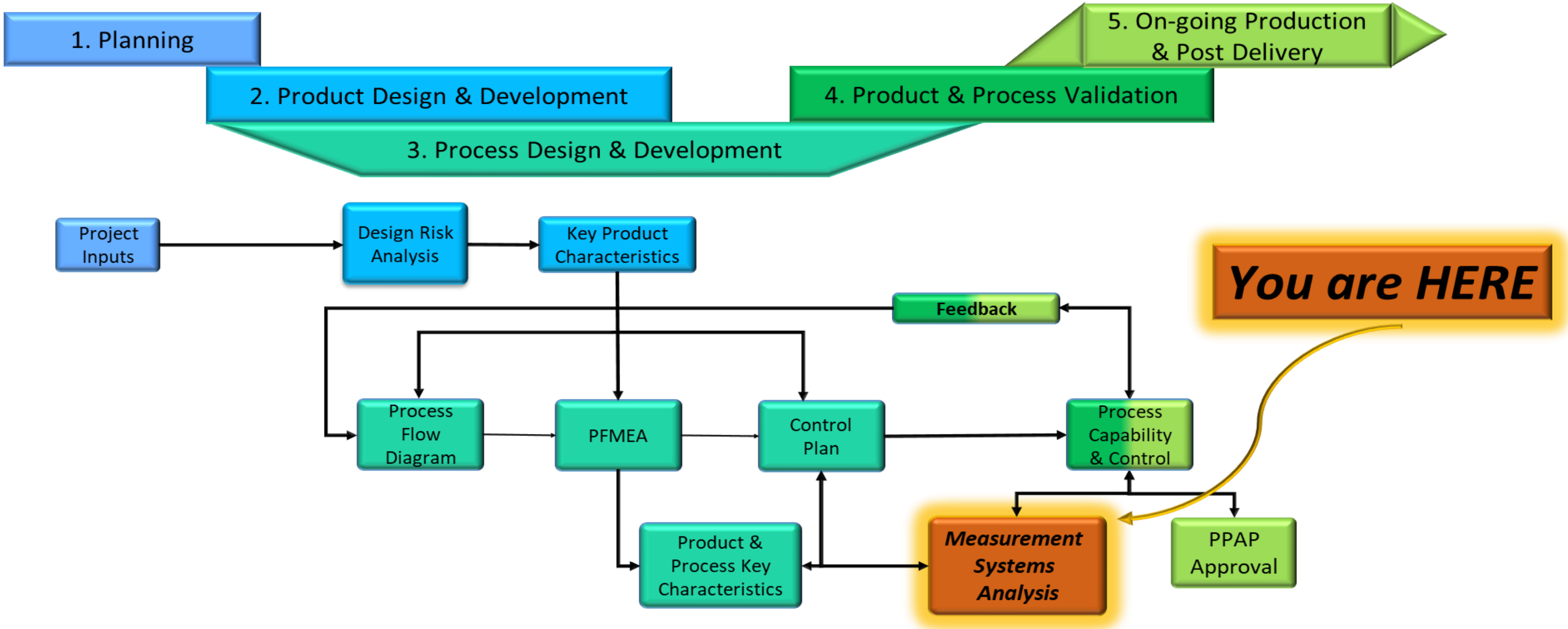


Value Proposition

Invest more in upfront planning to significantly reduce cost later in the product lifecycle!

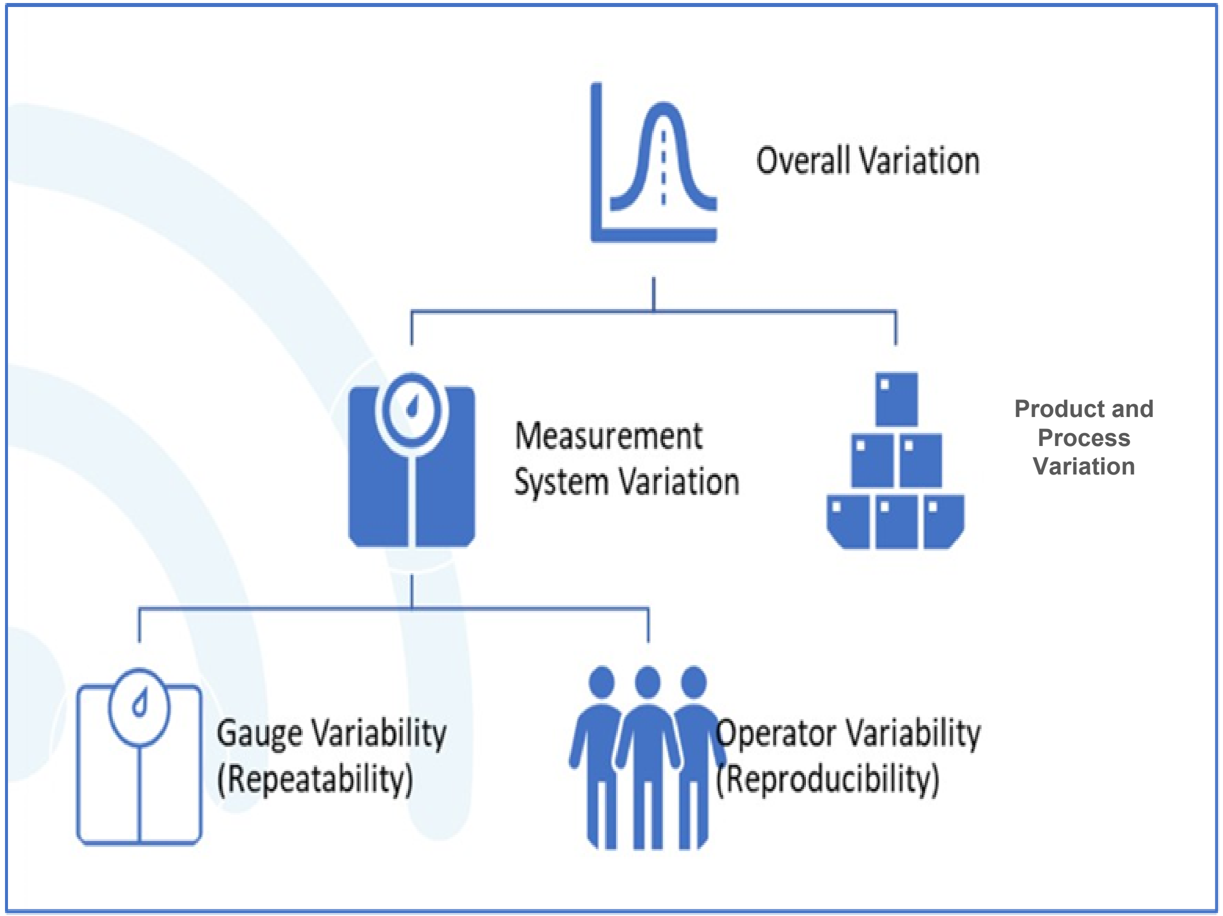
LOCKHEED MARTIN

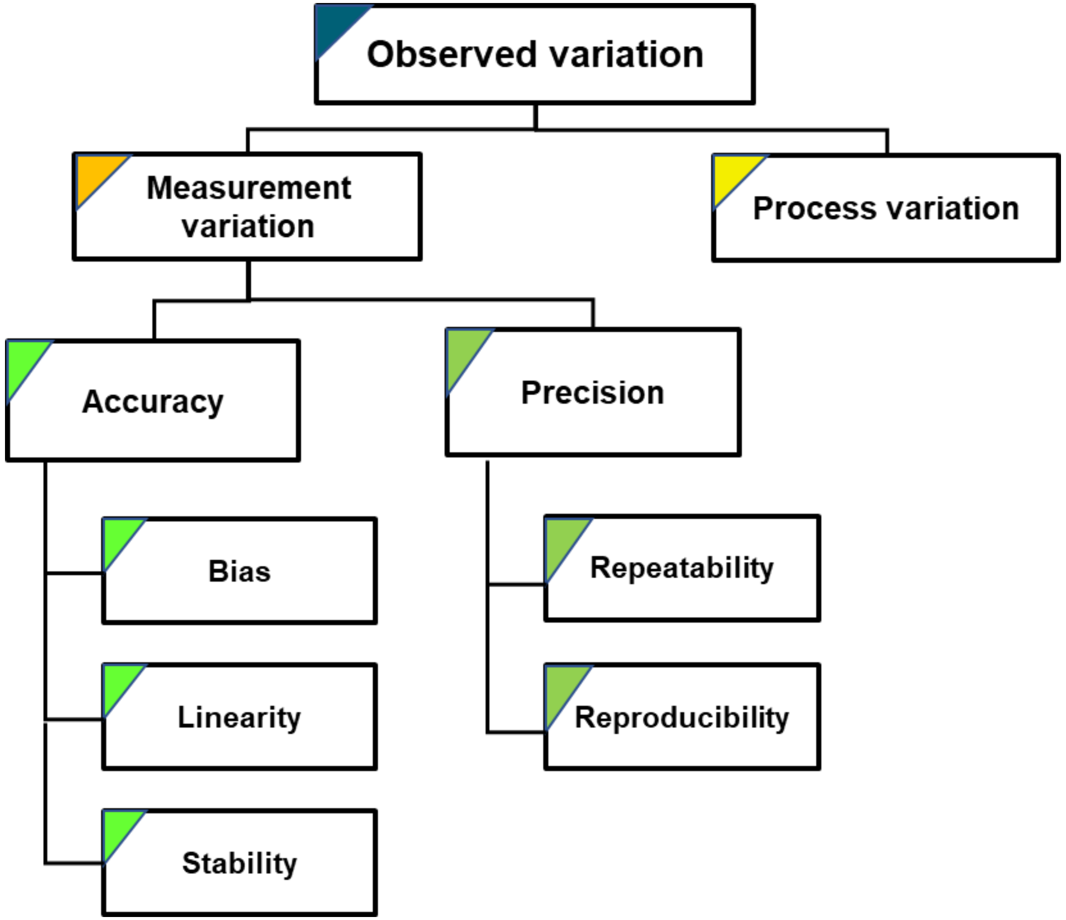
APQP Relationship



* Reference AS9145 Table 2 – Production part approval process

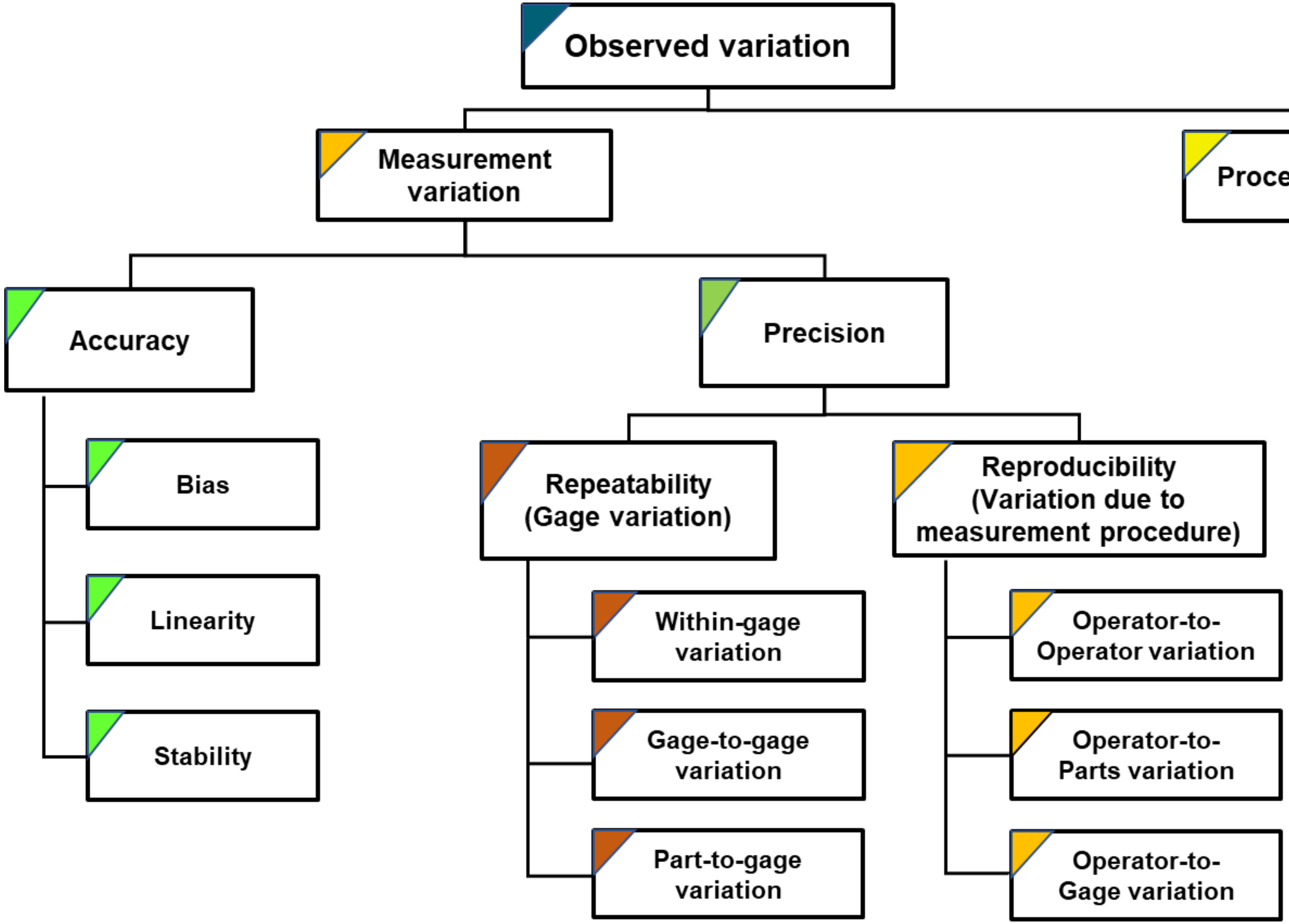
Where does Variation come from?





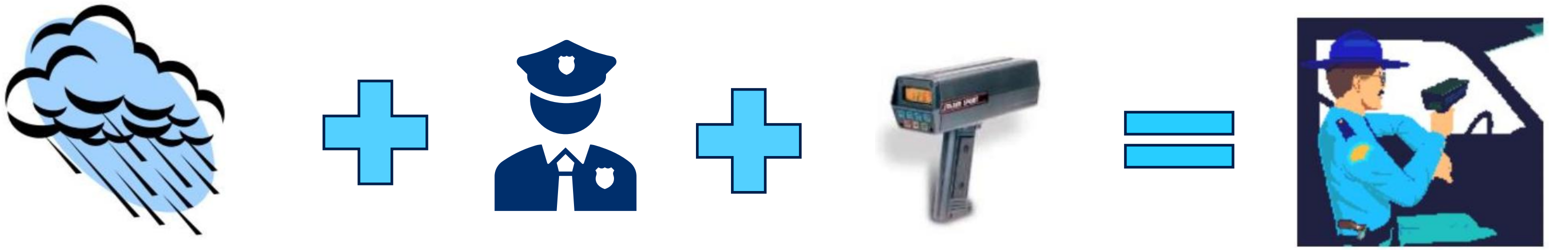
LOCKHEED MARTIN

Where does Variation come from?



What is a Measurement System?

A Measurement System is a set of elements used in combination to take a measurement.

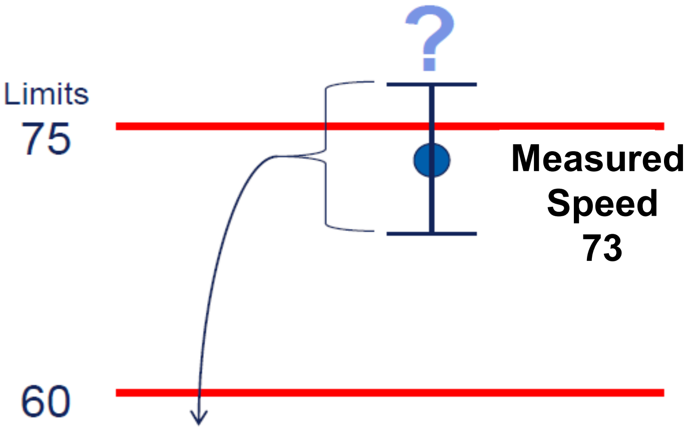


Environment + **Operator** + **Gage** = **Measurement System**

A Measurement System Analysis is a statistical tool used to determine if a measurement system is capable of accurate/precise measurements

Measurement System

Limits



Represents Variation in Measurement System

Objectives or Purpose of an MSA

- To identify and potentially eliminate sources of variation
- Ensure correct measurement system is being used
- Warrant the quality of the measurement data
- Reduce false pass / false fail
- Decision about whether a measurement process is adequate for a specific engineering/manufacturing application

When to Use It

- When trying to understand the effectiveness of your measurement system
- Any new or modified process to ensure the quality of the data
- Product escapes are occurring
- New verification device or method
- New product introduction

Why is an MSA important?

- How do you know if your measurement system has correctly approved your product?

  Because you have determined the variation in the measurement system!

- How was the variation in your measurement system determined?

  I performed a Measurement System Analysis!

If you don’t think an MSA is important, then why should you measure / test your Product at all?

MSA Benefits

- Improve Product Quality
- Reduces false fails (Producer risk)
- Reduces false accepts (Consumer risk)
- Risk Mitigation
- Helps reduce productions costs
- Improve yield / reduce scrap (through improved inspection capability)
- Supports statistical process control

LOCKHEED MARTIN

Measurement Data Types

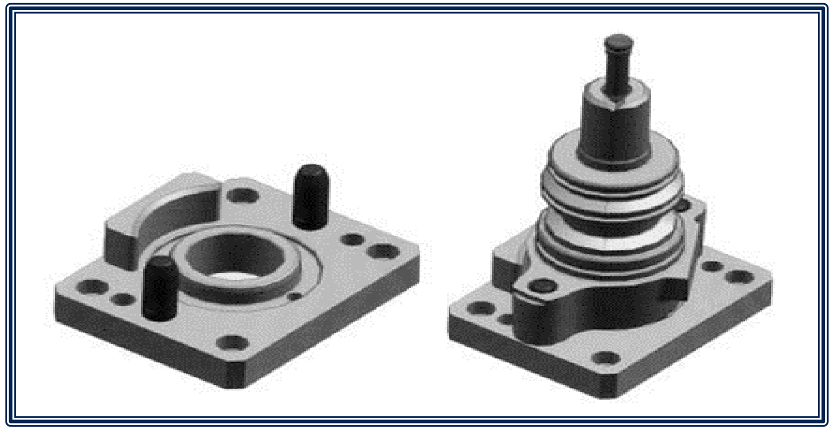
<u>Variable</u>

- Anything that can be measured on a continuous basis and can always be divided into smaller increments
- Examples: time, temperature, weight, length, torque
- Gages:

Measurement Data Types

<u>Attribute</u>

- Anything that can be classified as either/or, typically
- binary, including counts and rank orders
- Examples:
- Gages: Visual inspections, Go/No-Go Gages, etc.



PASS / FAIL

GOOD / BAD

Measurement Data Types (Quiz)

Data Description	Continuous	Attribute
Main landing gear bushing inside diameter measured undersize: 0.0005, 0.001, 0.0015, and 0.0020 on aircraft	✓	
During final pressure test, 3 of 10 flex hose assembly failed test (fuel leak) due to damaged tubes		✓
Fuel primer/coating peeling off during installation of wing straps on both LH and RH upper and lower wing skins		✓
At receiving inspection, assembly inspectors found average 36 defects in center fuselage received in last two years		✓
6 Tube assemblies received from supplier were out of round and bent per model and drawing requirements		✓

LOCKHEED MARTIN

Measurement Data Types (Quiz)

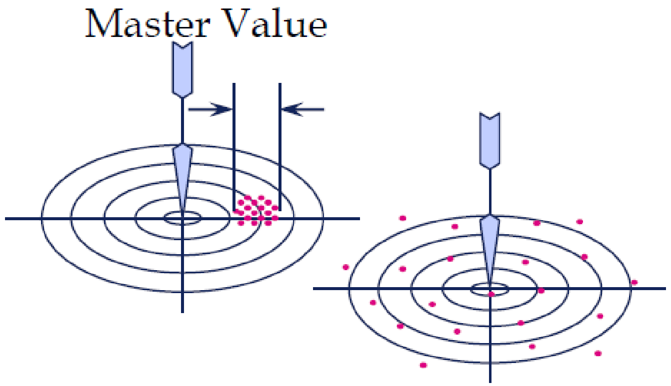
Data Description	Continuous	Attribute
Supplier measured 100 data points on profile of surface (KC) in range from 0.001 to 0.008 with some out of spec	✓	
SQE calculated average weight of bulkhead 300 lbs. of total 30 samples from the entire population of bulkheads	✓	
Workforce and training manager noticed that 15% of the team members did not complete their project on-time		✓
Several parts at final assembly failed the electrical bonding test requirements and paint adhesion/tape test requirements		✓
During nose and main landing gear cycle test (at flight line) hydraulic fluid was leaking from one of the strut/actuator		✓

LOCKHEED MARTIN

MSA Terminology

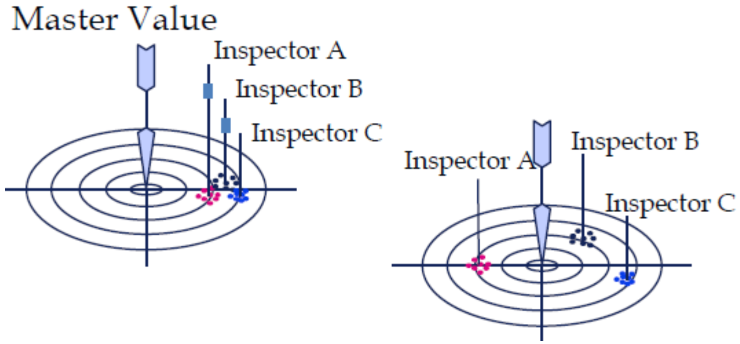
Precision

How close the repeated measurement results are to each other.



Repeatability (Precision) – The variation between successive measurements of the same part, by the same person, using the same instrument

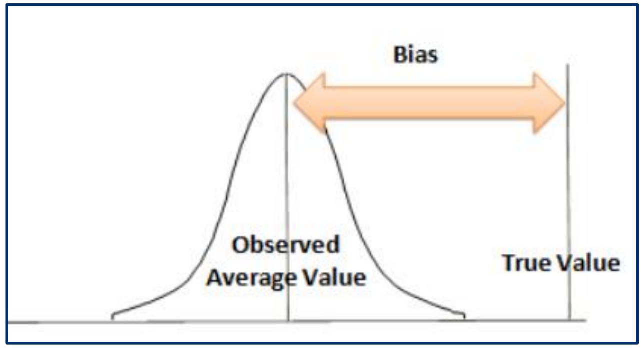
Reproducibility – The difference in measurements made by different people using the same or different instrument

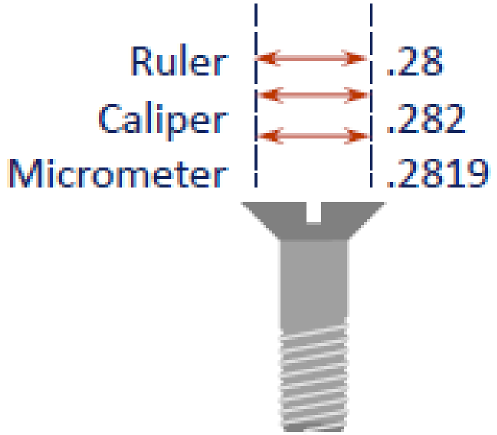


MSA Terminology

Bias (Or Accuracy)

The difference between average value of measurements and a master value





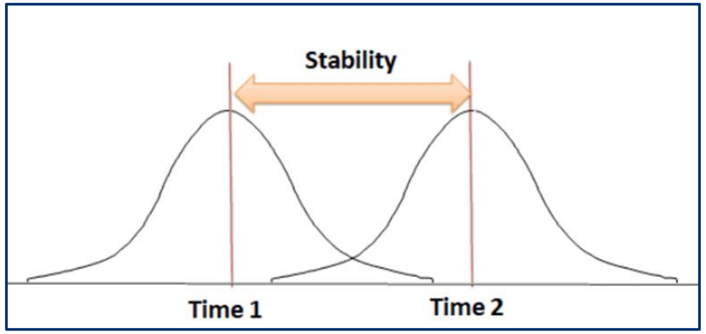
Resolution

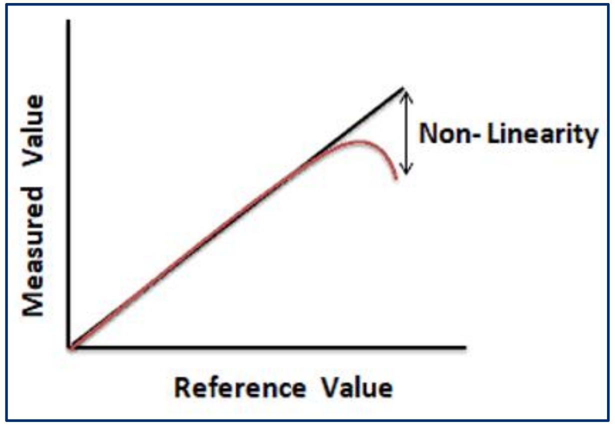
The number of discernable digits on an instrument

MSA Terminology

Stability (Drift)

A measure of how variation in accuracy (bias) changes over time

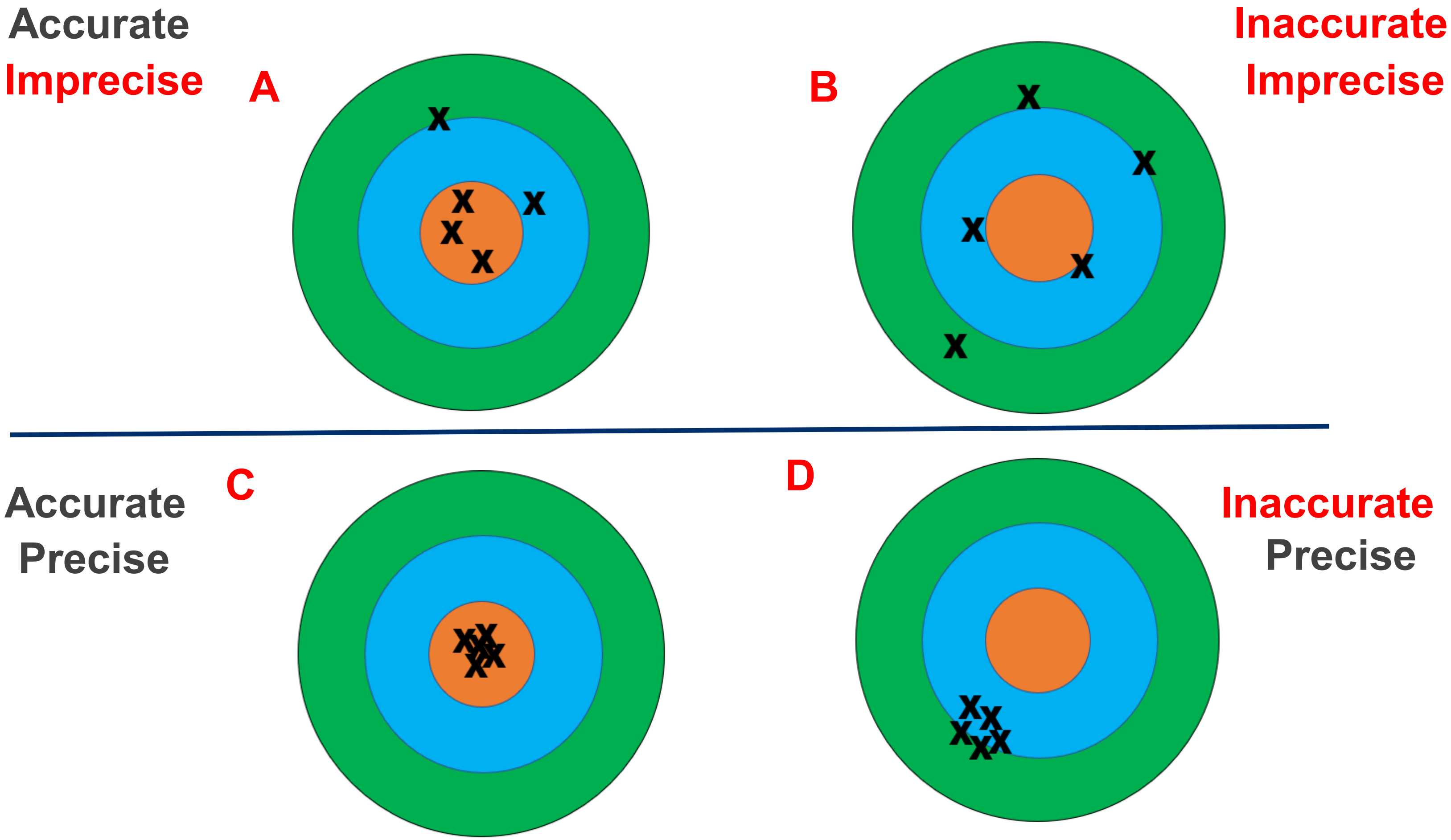


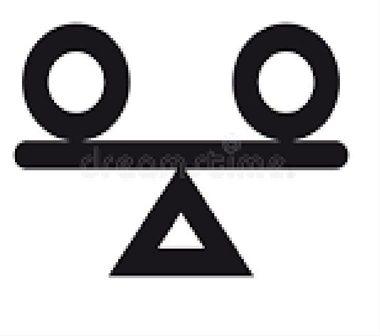


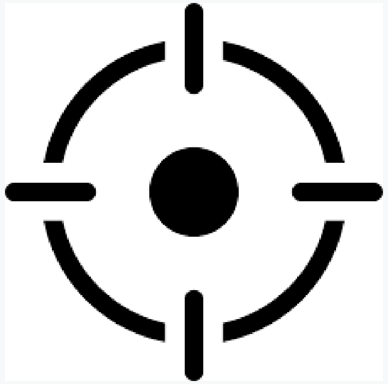
Linearity

The difference of accuracy (bias) over the expected operating (measurement) range of the gage/system

Quiz (Accuracy vs Precision)







LOCKHEED MARTIN

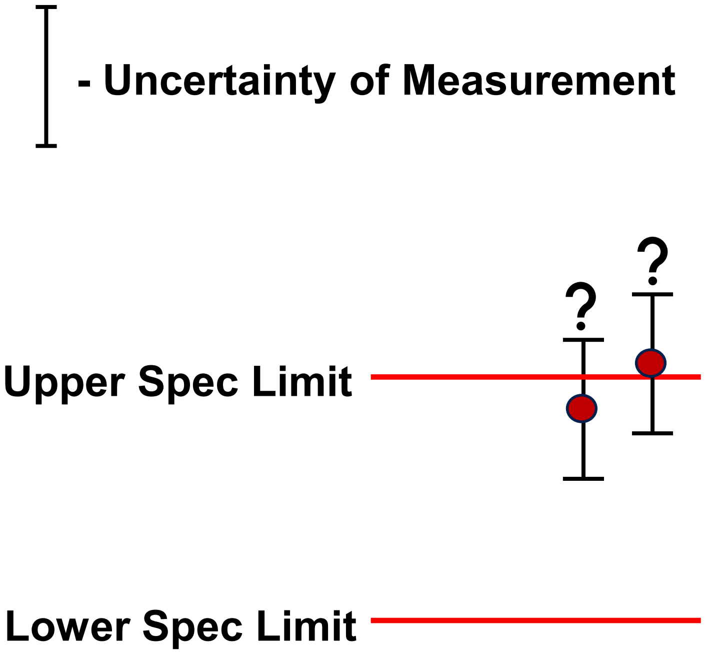
Gage Selection

Accuracy and Uncertainty

Measurement Accuracy – How close the measured value is to the ‘accepted reference value’

- Measurement Uncertainty – Provides a range where the true value of the measurement is assured to lie within

- Accuracy is part of the uncertainty; to determine an instruments uncertainty, the accuracy of the instrument is typically part of the calculation along with other contributing factors



The uncertainty of these measurements adds risk to the acceptance decision!

When performing an MSA consider the following:

1. The measurement equipment must be calibrated and traceable to a relevant national or international standard
2. Individuals involved in the study must be suitably trained and competent in the measurement task. They must be representative of the measurement system users.
3. Operators use the same measurement technique
4. Select Sample Parts (shall represent the entire production operating range and ideally the entire allowed tolerance range)
5. Recommended: Mark location of measurement, minimizing variation
6. Ensure Gage (Device) has adequate resolution (1/10 smaller than spec)
7. An environment representative of the production operation must be used for the MSA study
8. Record any observations during measurement

Gage R&R (Repeatability and Reproducibility)

1. Determine
Operators, # Parts,
Repeating readings

Recommended:
2-3 operators (Appraisers)
2-3 Trials
5-10 Parts (10 Recommended)

Study uses:
3 Appraisers
3 trials
10 parts

2. Identify Appraisers:
A
B
C

MEASUREMENT SYSTEMS ANALYSIS

REPEATABILITY & REPRODUCIBILITY DATE Sept. 2000

GAGE NAME	Dial Caliper	CHARACTERISTIC	Door Margin
GAGE TYPE	0.0 - 20.0 mm	SPECIFICATION	4.0 mm +/- 0.75 mm
GAGE NUMBER	C-100	TEST NUMBER	5
APPRAISER A NAME	Joe D.	APPRAISER B NAME	Tim K.
SAMPLE SIZE 10	APPRAISERS 3, TRIALS 3	APPRAISER C NAME	Barry S.

Appraiser/ Trail #	1	2	3	4	5	6	7	8	9	10		AVG
A												
1	4	4.1	3.8	3.5	4.5	3.9	3.7	4.1	3.6	4.2		3.940
2	4.1	4.1	3.7	3.5	4.5	4	3.8	4.1	3.7	4.1		3.960
3	4	4.2	3.7	3.4	4.4	3.9	3.8	4.1	3.6	4.1		[illegible]
AVG'S	[illegible]	4.133	3.733	3.467	4.467	3.933	3.767	4.100	3.633	4.133	Xa	3.940
Range	0.100	[illegible]	0.100	0.100	0.100	0.100	0.100	0.000	0.100	0.100	Ra	0.090
B												
1	4.1	3.9	3.6	3.4	4.4	4	3.8	4.2	3.5	4.2		3.910
2	4.1	4	3.8	3.4	4.5	3.8	3.9	4.3	3.6	4.2		3.940
3	3.9	4.1	3.9	3.5	4.5	3.8	3.7	4.2	3.7	4.3		3.960
AVG'S	4.033	4.000	3.767	3.433	4.400	3.867	3.800	4.233	3.600	4.233	Xb	3.937
Range	0.200	0.200	0.300	0.100	0.200	0.200	0.200	0.100	0.200	0.100	Rb	0.180
C												
1	4	4.1	3.7	3.4	4.4	3.8	3.6	4	3.6	4.1		3.870
2	3.9	3.9	3.7	3.5	4.4	3.9	3.7	3.9	3.5	4.2		3.860
3	4.1	4	3.8	3.5	4.5	3.9	3.8	4.1	3.5	4.3		3.950
AVG'S	4.000	4.000	3.733	3.467	4.433	3.867	3.700	4.000	3.533	4.200	Xc	3.893
Range	0.200	0.200	0.100	0.100	0.100	0.100	0.200	0.200	0.100	0.200	Rc	0.150
Part Average	4.0222	4.0444	3.7444	3.4556	4.4333	3.8889	3.7556	4.1111	3.5889	4.1889	X	3.923
											R_p	0.978

RANGE VARIATION

Ra	0.090
Rb	0.180
Rc	0.150
SUM	0.420
$R_{doublebar}$	0.1400

# Trials	D_4
2	3.267
3	2.575

Rdoublebar	x	(D_4)	=	UCL_R
0.1400		2.575	=	0.3605

Note: LCL is zero with < 8 trials

Tolerence = 1.5

Trials n = 10

Appr. r = 3

Max. X	3.940
Min. X	3.893
X Diff	0.047

3. Required background information:
Gage
Type
Date
Etc.

5. Collect 10 parts

6. Identify parts 1-10 but in a way the appraiser does not identify the number

7. Repeat measurement
(3 independent trials)

4. Fill total tolerance

The MSA study must be lead or facilitated by a person trained and competent in the methodology

LOCKHEED MARTIN

Resources

AS13003 – Measurement System Analysis Requirements for the Aero Engine Supply Chain

RM13003 – MSA Reference Manual

Measurement System Analysis (MSA), IAQG – Supply Chain Management Handbook (SCMH), https://scmh.iaqg.org/

Measurement System Analysis blue book, AIAG (Fourth Edition)

More Steam (MSA) https://www.moresteam.com/toolbox/measurement-system-analysis.cfm

SEMATECH and NIST statistics handbook:
http://www.itl.nist.gov/div898/handbook/mpc/section4/mpc4.htm

LOCKHEED MARTIN

LOCKHEED MARTIN

Deploying Advanced Quality and Lean Tools to Achieve Zero Defects

Measurement Systems Analysis (MSA)

Part 2 - Application

Advanced Quality Team

LOCKHEED MARTIN

GROUND RULES

Silence cell phones

Mute your microphone

No Multitasking

All Questions are welcome

Deploying Advanced Quality and Lean Tools to Achieve Zero Defects

Measurement Systems Analysis (MSA)

Part 2 - Application

Advanced Quality Team

LOCKHEED MARTIN

Agenda

- Training Objectives
- Gage Selection
    - Stability Assessment
    - Bias Assessment
- Gage R&R
    - Part Selection
    - Operators (Data Collection)
- Gage R&R Method of Analysis (Excel & Minitab)
- Gage R&R Practical Application & Interpretation of Results (Excel & Minitab)
- Resources

LOCKHEED MARTIN

Training Objectives

- How to complete a practical Gage R&R Example
- How to interpret Gage R&R results (Excel & Minitab)
- Communicate availability of guidance resource and supporting material

LOCKHEED MARTIN

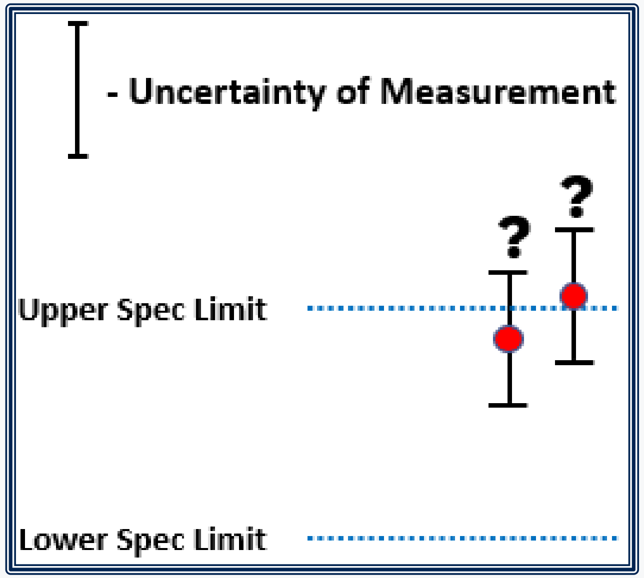
Gage Selection

Accuracy and Uncertainty

Measurement Accuracy – How close the measured value is to the ‘accepted reference value’

• Measurement Uncertainty – Provides a range where the true value of the measurement is assured to lie within e.g. as defined in such standards as ANSIZ540.3 and/or ISO-17025

• Accuracy is part of the uncertainty; to determine an instruments uncertainty, the accuracy of the instrument is typically part of the calculation along with other contributing factors



The uncertainty of these measurements adds risk to the acceptance decision!

Stability Assessment

1

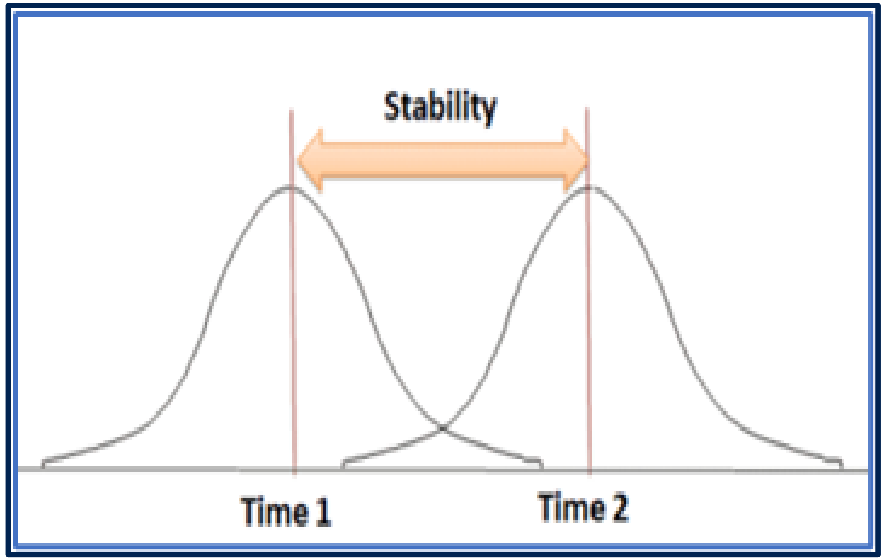
Select a random part form the middle process
- Determine its reference value relative to spec
- (If reference not available) Measure 10 times in controlled environment
    - Average the values for Reference Value

2

Over at least 20 periods (days/weeks) Measure:
- 3 to 5 times
- Capture the natural environmental variation

3

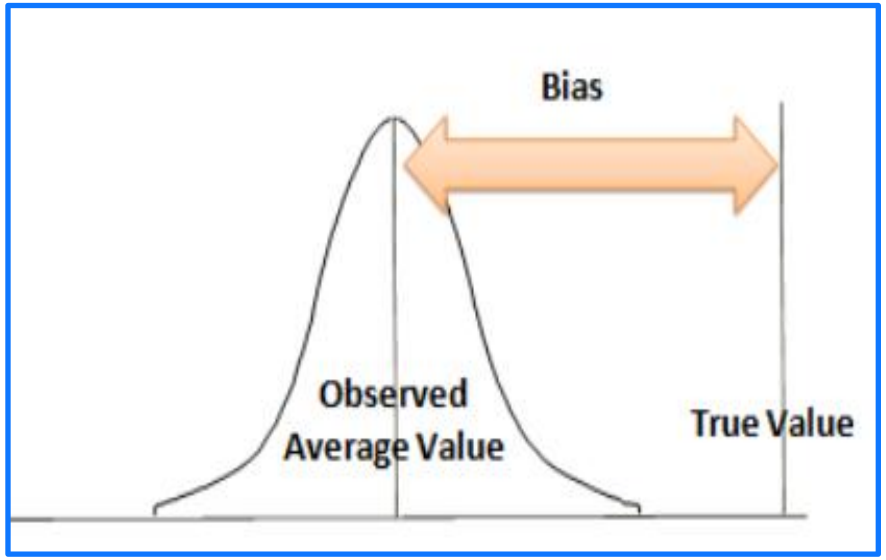
Plot the data Xbar & R chart, determine control limits



Bias Assessment

Subtract the reference value from $\bar{x}$ to yield the Bias:

Bias = Xbar- Reference Value



Process Variation = 6 Standard Deviations (Sigma)
Calculate the Bias percentage:

Bias Percentage = Bias / Process Variation

Analyze the results. If there is a relatively high value, examine the following potential root causes:

- Appraisers not following the measurement procedure
- An error in measuring the Reference Value
- Instability in the measurement. If the SPC chart shows a trend, the measurement device could be wearing or calibration could be drifting

Part Selection

So, how should parts be selected?
Samples must be selected in such a way to cover the entire range of variation.

- This does not necessarily mean that we use the entire tolerance band

Make sure that the samples are not collected in a row.
The samples must be collected over time.
This means **DO NOT** select consecutive parts.
Select parts from:

- Different shifts
- Different lots
- Different days

LOCKHEED MARTIN

Operators

Where possible, a representative sample of operators (2 or more) who normally use the measurement equipment should be included in the study.

Important factors to consider include:

- The most and the least experienced people
- People who work in different locations
- People who work on different shifts
- Any physiological factors that may affect the measurement process

LOCKHEED MARTIN

When performing an MSA consider the following

1. The measurement equipment must be calibrated and traceable to a relevant national or international standard

2. Individuals involved in the study must be suitably trained and competent in the measurement task. They must be representative of the measurement system users.

3. Operators use the same measurement technique

4. Select Sample Parts (shall represent the entire production operating range and ideally the entire allowed tolerance range)

5. Recommended: Mark location of measurement, minimizing variation

6. Ensure Gage (Device) has adequate resolution (1/10 smaller than spec)

7. An environment representative of the production operation must be used for the MSA study

Record any observations during measurement

Gage R&R (Repeatability and Reproducibility)

1. Determine
Operators, # Parts,
Repeating readings

Recommended:
2-3 operators
(Appraisers)
2-3 Trials
5-10 Parts
(10 Recommended)

Study uses:
3 Appraisers
3 trials
10 parts

2. Identify
Appraisers:
A
B
C

MEASUREMENT SYSTEMS ANALYSIS

REPEATABILITY & REPRODUCIBILITY

DATE Sept. 2000

GAGE NAME Dial Caliper — CHARACTERISTIC Door Margin
GAGE TYPE 0.0 - 20.0 mm — SPECIFICATION 4.0 mm +/- 0.75 mm
GAGE NUMBER C-100 — TEST NUMBER 5
APPRAISER A NAME Joe D. — APPRAISER B NAME Tim K.
SAMPLE SIZE 10 — APPRAISERS 3 — TRIALS 3 — APPRAISER C NAME Barry S.

Appraiser/ Trail #	1	2	3	4	5	6	7	8	9	10		AVG
A												
1	4	4.1	3.8	3.5	4.5	3.9	3.7	4.1	3.6	4.2		3.940
2	4.1	4.1	3.7	3.5	4.5	4	3.8	4.1	3.7	4.1		3.960
3	4	4.2	3.7	3.4	4.4	3.9	3.8	4.1	3.6	4.1		3.920
AVG'S	4.033	4.133	3.733	3.467	4.467	3.933	3.767	4.100	3.633	4.133	Xa	3.940
Range	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.000	0.100	0.100	Ra	0.090
B												
1	4.1	3.9	3.6	3.4	4.4	4	3.8	4.2	3.5	4.2		3.910
2	4.1	4	3.8	3.4	4.3	3.8	3.9	4.3	3.6	4.2		3.940
3	3.9	4.1	3.9	3.5	4.5	3.8	3.7	4.2	3.7	4.3		3.960
AVG'S	4.033	4.000	3.767	3.433	4.400	3.867	3.800	4.233	3.600	4.233	Xb	3.937
Range	0.200	0.200	0.300	0.100	0.200	0.200	0.200	0.100	0.200	0.100	Rb	0.180
C												
1	4	4.1	3.7	3.4	4.4	3.8	3.6	4	3.6	4.1		3.870
2	3.9	3.9	3.7	3.5	4.4	3.9	3.7	3.9	3.5	4.2		3.860
3	4.1	4	3.8	3.5	4.5	3.9	3.8	4.1	3.5	4.3		3.950
AVG'S	4.000	4.000	3.733	3.467	4.433	3.867	3.700	4.000	3.533	4.200	Xc	3.893
Range	0.200	0.200	0.100	0.100	0.100	0.100	0.200	0.200	0.100	0.200	Rc	0.150
Part Average	4.0222	4.0444	3.7444	3.4556	4.4333	3.8889	3.7556	4.1111	3.5889	4.1889	X	3.923
											R_p	0.978

RANGE VARIATION

Ra	0.090
Rb	0.180
Rc	0.150
SUM	0.420
$R_{doublebar}$	0.1400

# Trials	D_4
2	3.267
3	2.575

Rdoublebar x (D_4) = UCL_R
0.1400 2.575 = 0.3605
Note: LCL is zero with < 8 trials

Tolerence = 1.5

Trials n = 10

Appr. r = 3

Max. X	3.940
Min. X	3.893
X Diff	0.047

3. Required background information:
Gage
Type
Date
Etc.

5. Collect 10 parts

6. Identify parts 1-10 but in a way the appraiser does not identify the number

7. Repeat measurement
(3 independent trials)

4. Fill total tolerance

The MSA study must be lead or facilitated by a person trained and competent in the methodology

LOCKHEED MARTIN

Gage R&R (Excel Example)

VARIABLE MSA - GAUGE R & R - SETUP

Instructions:

1) Enter information in Setup worksheet
2) Enter information in Data worksheet
3) Remove any data in cells highlighted yellow
4) Review Results worksheet
5) Review Bias & Consistency charts
6) Review Averages & Ranges charts

Information Entry Key

> setup information (optional)
> required information
> excess information - clear contents
> results information
> intermediate calculations/results

SETUP

Date	May 25, 2022	Units	mm	Prepared by	Luis H Gomez
Gage Name	Caliper	Characteristic	width	Appraiser A Name	Peter
Gage Type	Digital 0-6"	Specification	4.05 +/- 0.75	Appraiser B Name	John
Gage Number	XR-2022	Test Number	2	Appraiser C Name	Mike

Sample Size (p) 10 | Appraisers (o) 3 | Trials (n) 3 | Upper Specification Limit 4.8 mm

Lower Specification Limit 3.3 mm

Tolerance (Upper Spec Limit - Lower Spec Limit) 1.50 mm

Next step: Enter Data

VARIABLE MSA - GAUGE R & R - DATA ENTRY

Appraiser (A): Peter

Trial\Sample	1	2	3	4	5	6	7	8	9	10	Average	
1	4	4.1	3.8	3.5	4.5	3.9	3.7	4.1	3.6	4.2	3.94	
2	4.1	4.1	3.7	3.5	4.5	4	3.8	4.1	3.7	4.1	3.96	
3	4	4.2	3.7	3.4	4.4	3.9	3.8	4.1	3.6	4.1	3.92	
Average	4.03	4.13	3.73	3.47	4.47	3.93	3.77	4.10	3.63	4.13	Xbar(A)	3.94
Range	0.10	0.10	0.10	0.10	0.10	0.10	0.10	-	0.10	0.10	Rbar(A)	0.09

Appraiser (B): John

Trial\Sample	1	2	3	4	5	6	7	8	9	10	Average	
1	4.1	3.9	3.6	3.4	4.4	4	3.8	4.2	3.5	4.2	3.91	
2	4.1	4	3.8	3.4	4.3	3.8	3.9	4.3	3.6	4.2	3.94	
3	3.9	4.1	3.9	3.5	4.5	3.8	3.7	4.2	3.7	4.3	3.96	
Average	4.03	4.00	3.77	3.43	4.40	3.87	3.80	4.23	3.60	4.23	Xbar(B)	3.94
Range	0.20	0.20	0.30	0.10	0.20	0.20	0.20	0.10	0.20	0.10	Rbar(B)	0.18

Appraiser (C): Mike

Trial\Sample	1	2	3	4	5	6	7	8	9	10	Average	
1	4	4.1	3.7	3.4	4.4	3.8	3.6	4	3.6	4.1	3.87	
2	3.9	3.9	3.7	3.5	4.4	3.9	3.7	3.9	3.5	4.2	3.86	
3	4.1	4	3.8	3.5	4.5	3.9	3.8	4.1	3.5	4.3	3.95	
Average	4.00	4.00	3.73	3.47	4.43	3.87	3.70	4.00	3.53	4.20	Xbar(C)	3.89
Range	0.20	0.20	0.10	0.10	0.10	0.10	0.20	0.20	0.10	0.20	Rbar(C)	0.15

	1	2	3	4	5	6	7	8	9	10		
Part Average	4.02	4.04	3.74	3.46	4.43	3.89	3.76	4.11	3.59	4.19	$X_{doublebar}$	3.92
											$R_{doublebar}$	0.14
Range of Part Averages											R_p	0.98
Range of Appraiser Averages											R_o	0.05

Previous step: Setup

Next step: View Results

VARIABLE MSA - GAUGE R & R - RESULTS

Click here for results interpretation | Click here for a key to terms used in the equations | Previous step: Enter Data

MoreSteam Recommended Alternative → Component Variance Method | AIAG Method

		Component Variance Method: % of Total Variation	AIAG Method: % of Total Variation	AIAG Method: % of Tolerance
REPEATABILITY - EQUIPMENT VARIATION (EV)	$EV = R_{doublebar} / d_2^*{}_{EV}$	$\%EV = EV^2/TV^2$	$\%EV = EV/TV$	$\%EV = EV/Tol$
	EV = 0.0826934 mm	%EV = 6.7%	%EV = 25.9%	%EV = 33.1%
REPRODUCIBILITY - APPRAISER VARIATION (AV)	$AV = \{[R_o / d_2^*{}_{AV}]^2 - [EV^2 / (n \times p)]\}^{0.5}$	$\%AV = AV^2/TV^2$	$\%AV = AV/TV$	$\%AV = AV/Tol$
	AV = 0.0192099 mm	%AV = 0.4%	%AV = 6.0%	%AV = 7.7%
REPEATABILITY & REPRODUCIBILITY (GRR)	$GRR = (EV^2 + AV^2)^{0.5}$	$\%GRR = GRR^2/TV^2$	$\%GRR = GRR/TV$	$\%GRR = GRR/Tol$
	GRR = 0.0848954 mm	%GRR = 7.1%	%GRR = 26.6%	%GRR = 34.0%
PRODUCT VARIATION (PV)	$PV = Rp / d_2^*{}_{PV}$	$\%PV = PV^2/TV^2$	$\%PV = PV/TV$	$\%PV = PV/Tol$
	PV = 0.3074773 mm	%PV = 92.9%	%PV = 96.4%	%PV = 123.0%
		Σ = 100%	Σ <=> 100%	
TOTAL VARIATION (TV)	$TV = (EV^2 + AV^2 + PV^2)^{0.5}$			
	TV = 0.318982 mm			

Review Bias & Consistency Charts — *Component Variance Method*

Review Averages & Range Charts — *AIAG Method*

Interpretation of Results for the Component Variance Method

Relative Utility: Goal - at least 80% of measurement is error attributable to the product

Range of % PV	Actual %PV
>= 80%	92.9%
50% <= %PV < 80%	
20% <= %PV < 50%	
< 20%	

This Means: The measurement system is acceptable for measurement and will be an excellent quantifier of process improvement.

Bias: Goal - all appraiser averages within Bias Chart control limits

Value	Result:	This Means:	Refer To:
0 1 or 2* # appraisers	1 appraiser has at least one average value outside the Bias Chart control limits	There may be appraiser bias present	Appraiser Bias Chart

Consistency: Goal - all appraisers ranges within Consistency Chart control limits

Value	Result:	This Means:	Refer To:
0 1 or 2* # appraisers	1 appraiser has at least one range value outside the Consistency Chart control limits	The results may be inconsistent across appraisers	Appraiser Consistency Chart

* 1 if there are 2 appraisers, 2 if there are 3 appraisers

Back to top

Interpretation of Results for the AIAG Method

Relative Utility: Goal - gauge R&R% is less than 10%

Range of % GRR	Actual GRR%
<= 10%	
10% < %GRR <= 30%	26.6%
> 30%	

This Means: The measurement system may be acceptable based on importance of application, cost of gage, cost of repairs, etc.

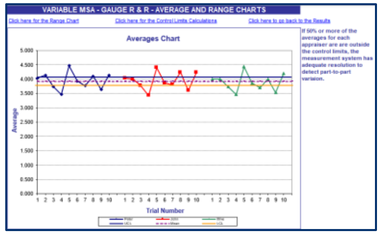
System Resolution: Goal - all appraisers have at least 50% of average values outside the Averages Chart control limits

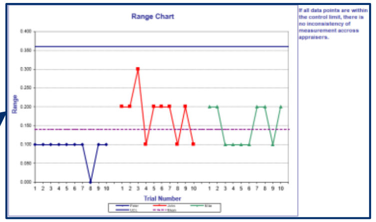
Value	Result:	This Means:	Refer To:
# Appraisers < # Appraisers	All appraisers have at least 50% of averages outside the Averages Chart control limits	The measurement system has adequate resolution to detect part-to-part variation	Averages Chart

Consistency: Goal - all appraisers have all range values below the Range Chart upper control limit

Value	Result:	This Means:	Refer To:
0 # appraisers	All appraisers ranges are within the Range Chart control limits	The results are consistent across appraisers	Range Chart

* 1 if there are 2 appraisers, 2 if there are 3 appraisers





LOCKHEED MARTIN

Table 2. Minimum Requirements for MSA (AS13003)

Method	Feature Category			Comments
	Critical	Major	Minor	
Resolution	≤ 10% of tolerance***			Based on Tolerance
Accuracy Ratio **	Requirement = 10:1		Requirement = 4:1	Values up to 4:1 may ne acceptable when approved by the purchaser
Accuracy Error / Bias	≤ 10% of total tolerance***			Purchaser requirements may override this
Repeatability	≤ 10% of total tolerance	≤ 20% of total tolerance	≤ 30% of total tolerance	Purchaser requirements may override this
Gauge R&R	≤ 10% of total tolerance	≤ 20% of total tolerance	≤ 30% of total tolerance	Purchaser requirements may override this
Computer driven measurement systems correlation	≤ 10% of total tolerance		≤ 20% of total tolerance	Purchaser requirements may override this
Linearity **	≤ 1% of total tolerance		-	
Attribute Study: pass/fail	Kappa ≥ 0.8		-	Only required on operator dependent interpretation
Attribute Study: ordinal	ICC ≥ 0.75		-	Only required on operator dependent interpretation

LOCKHEED MARTIN

Gage R&R (Minitab Example) using same data

LOCKHEED MARTIN

Gage R&R Minitab Example Results

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.085801	0.51481	28.06	34.32
Repeatability	0.083154	0.49892	27.19	33.26
Reproducibility	0.021149	0.12690	6.92	8.46
Operators	0.021149	0.12690	6.92	8.46
Part-To-Part	0.293526	1.76116	95.98	117.41
Total Variation	0.305810	1.83486	100.00	122.32

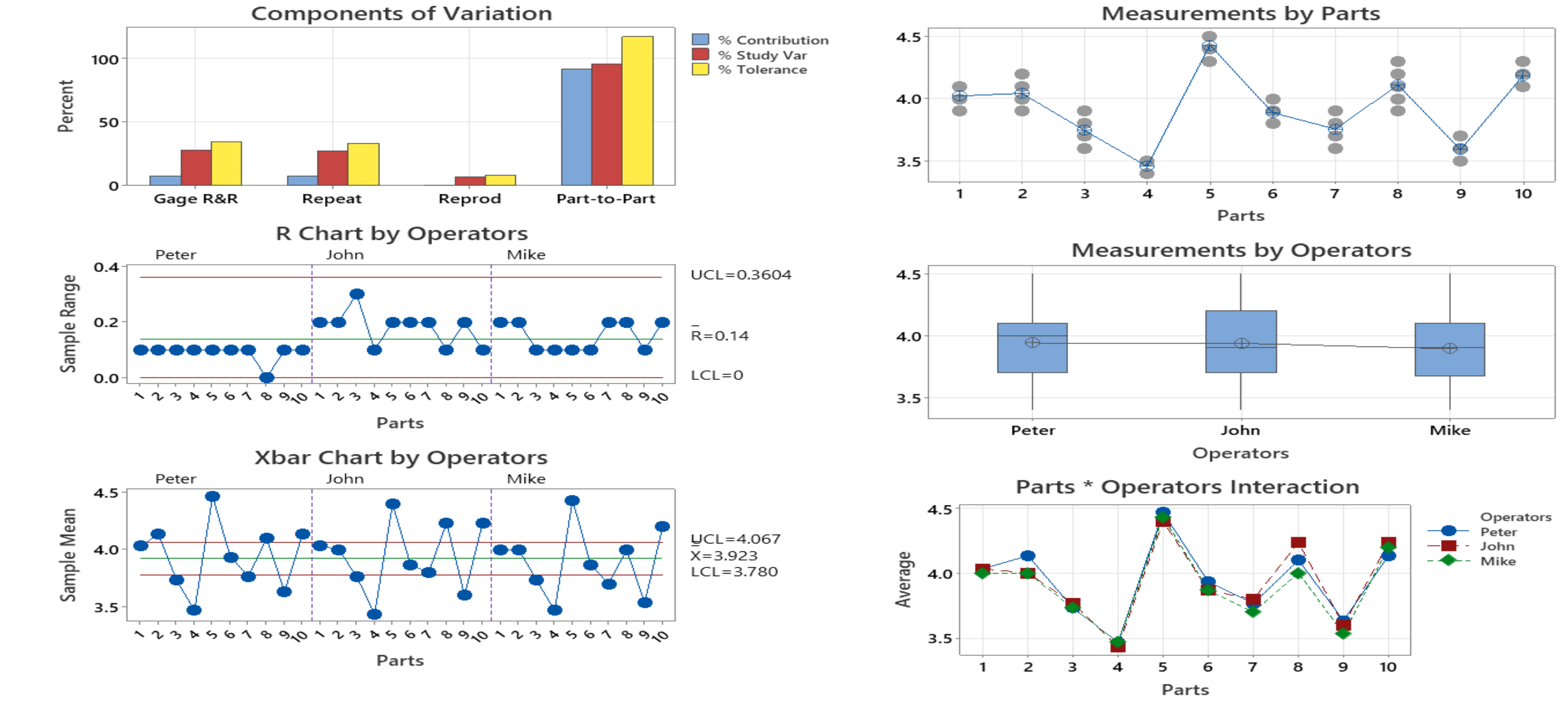
Number of Distinct Categories = 4

LOCKHEED MARTIN

Gage R&R Study - ANOVA Method

Gage name: Dial Caliper: XR-2022, Type: 0.0 - 20.0mm
Date of study: Aug 23, 2023

Reported by: Jesus Ortiz / Luis Gomez
Tolerance: 1.50 mm
Misc:



LOCKHEED MARTIN

Taking Action - MSA Results Unacceptable

Common Reasons:

- Excessive part variation
- Measurement technique not followed
- Training to Appraisers
- Recording of Measurements (rounding numbers)
- Appraiser physical / mental state
- Measurement dependably

LOCKHEED MARTIN

Taking Action - MSA Results Unacceptable

Common Reasons:

- Ergonomics
- Appraiser eyesight
- Lighting conditions
- Complexity of fixture use
- Environmental conditions
- Gage conditions

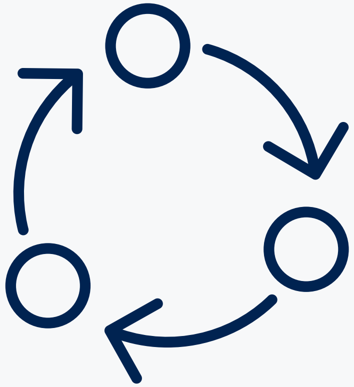
Repeating the MSA

The MSA should be repeated at regular intervals; such as every 6 months or annually. The MSA should also be repeated in any of the following circumstances (where relevant):

- Before implementing SPC for the first time in a process
- If a large process variation is seen and it is suspected to be caused by the measurement system
- After any significant changes or improvements to the process
- After any significant changes in the people making the measurement

Repeating the MSA (cont.)

- After a significant change in the measurement location
- After any major maintenance of measurement equipment
- After measurement equipment has been moved.
- As part of the acceptance for a new machine
- As part of the training for new people



LOCKHEED MARTIN

Resources

AS13003 – Measurement System Analysis Requirements for the Aero Engine Supply Chain

RM13003 – MSA Reference Manual https://aesq.sae-itc.com/supplemental-material

Measurement System Analysis (MSA), IAQG – Supply Chain Management Handbook (SCMH), https://scmh.iaqg.org/

Measurement System Analysis blue book, AIAG (Fourth Edition)

More Steam (MSA) https://www.moresteam.com/toolbox/measurement-system-analysis.cfm

SEMATECH and NIST statistics handbook:
http://www.itl.nist.gov/div898/handbook/mpc/section4/mpc4.htm

LOCKHEED MARTIN

LOCKHEED MARTIN