
AddQ
CONSULTING
Test and Measurement System

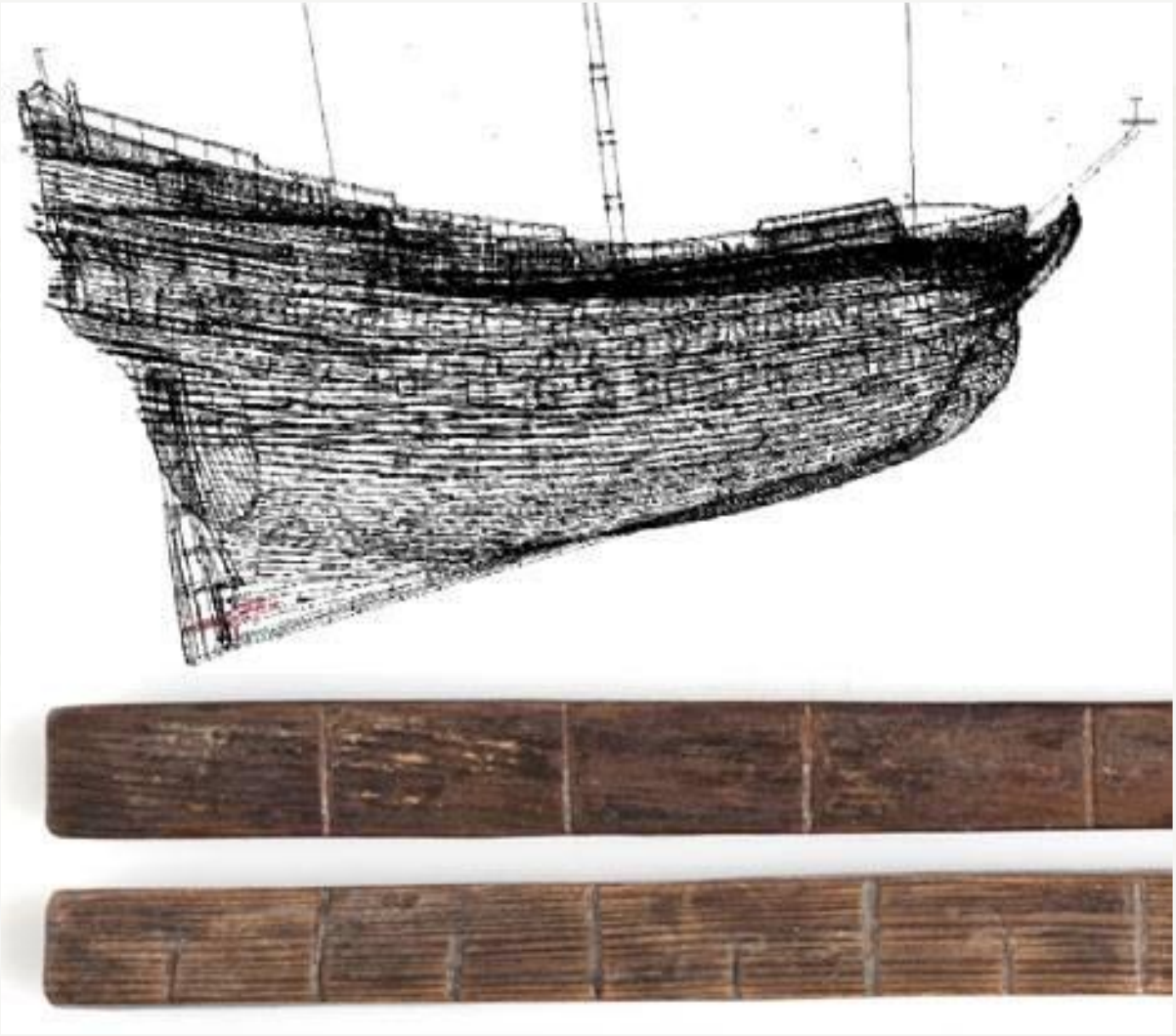
Presentation

- **Mattias Ericsson**
  - LabVIEW developer >10 years
  - CLA
  - LabVIEW Partner Program
    - G# Framework
    - G# StarUML
    - Free, open source tool
    - LabVIEW Add-On of the Year for Community 2011
    - *www.ni.com/labviewtools*
    - *www.addq.se/gsharp*

NATIONAL INSTRUMENTS LabVIEW CERTIFIED ARCHITECT

COMPATIBLE WITH NATIONAL INSTRUMENTS LabVIEW GOLD PRODUCT

AddQ CONSULTING



AddQ CONSULTING

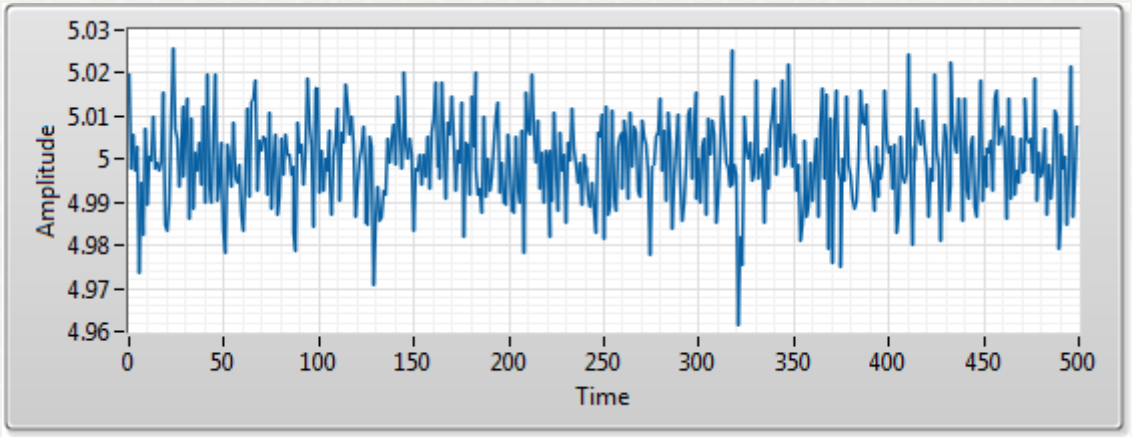
Agenda

- What is a Measurement System Analysis?
- Definition of variation
- Gage R&R study

AddQ CONSULTING

Measurement System Analysis

- Quality of measurement data

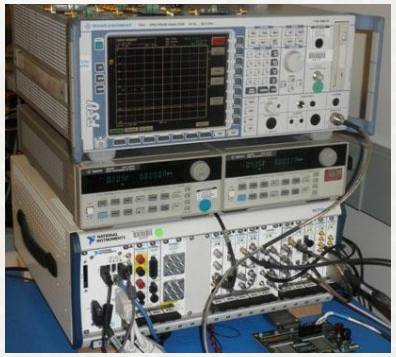


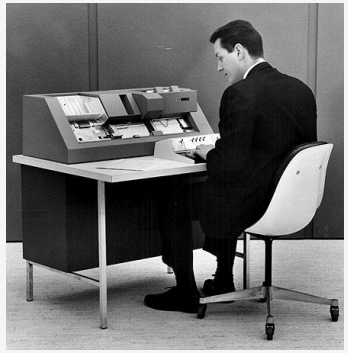
- Source of variations
- Statistical properties
  - Multiple measurements
  - Stable conditions

AddQ CONSULTING

Measurement System

- Instruments
- Methods
- Fixtures
- Software
- Personell
- Environment





AddQ CONSULTING

Statistical Properties

- Arithmetic mean, μ or $\overline{x}$
  - Same unit as data

$$\overline{x} = \frac{\sum x}{N}$$

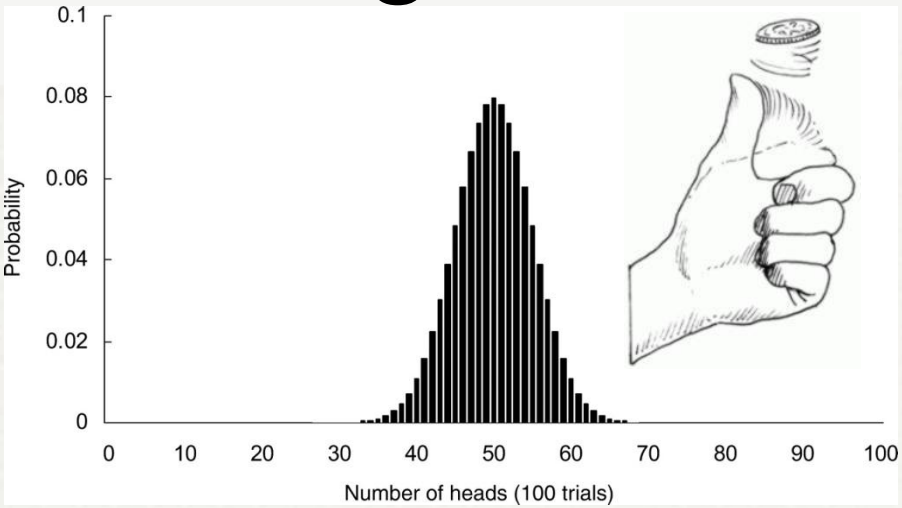
- Standard deviation
  - Shows how data is scatted around the mean
  - Same unit as data

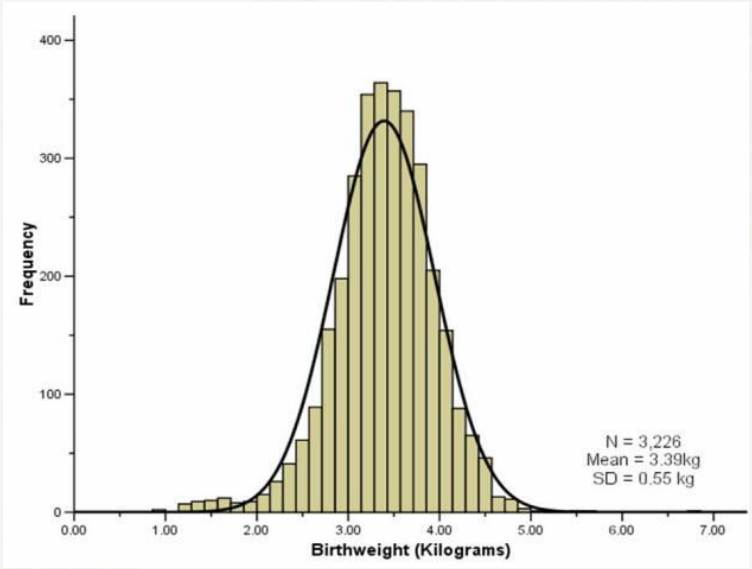
$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \overline{x})^2}{n-1}}$$

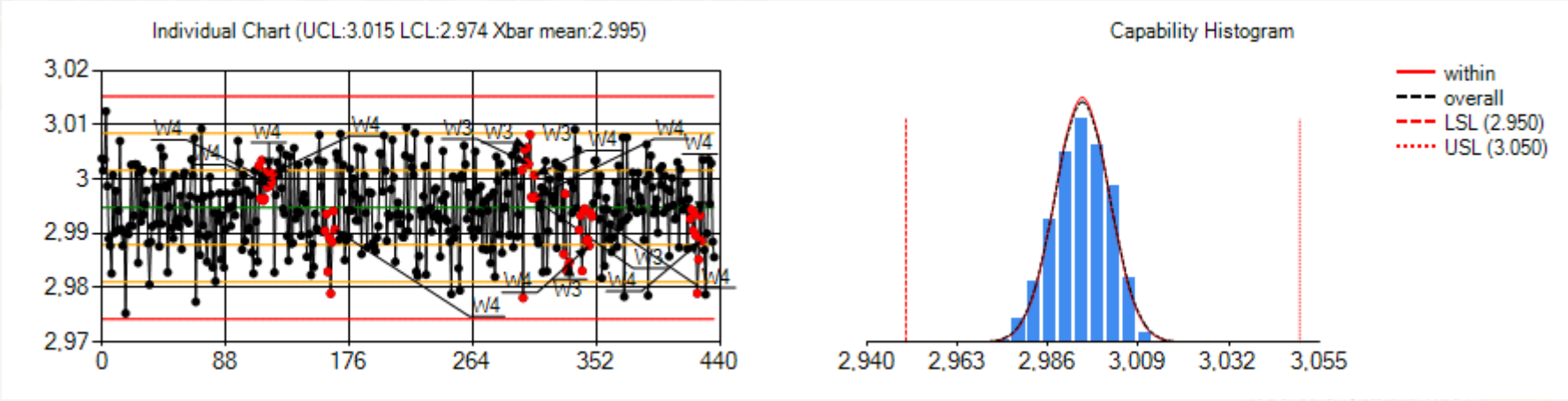
$$\sigma = \sqrt{\frac{\sum (x-\mu)^2}{N}}$$

AddQ CONSULTING

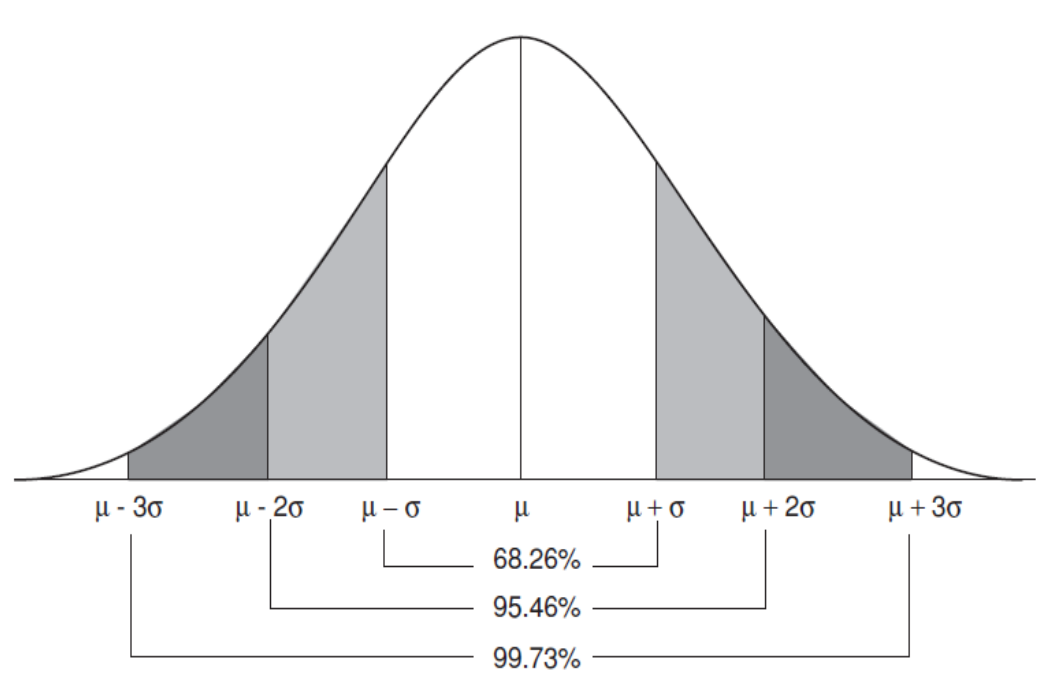
Histograms


0.1
0.08
0.06
0.04
0.02
0
Probability
0
10
20
30
40
50
60
70
80
90
100
Number of heads (100 trials)


400
300
200
100
0
Frequency
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Birthweight (Kilograms)
N = 3,226
Mean = 3.39kg
SD = 0.55 kg


Individual Chart (UCL:3.015 LCL:2.974 Xbar mean:2.995)
3,02
3,01
3
2,99
2,98
2,97
0
88
176
264
352
440
Capability Histogram
within
overall
LSL (2.950)
USL (3.050)
2,940
2,963
2,986
3,009
3,032
3,055

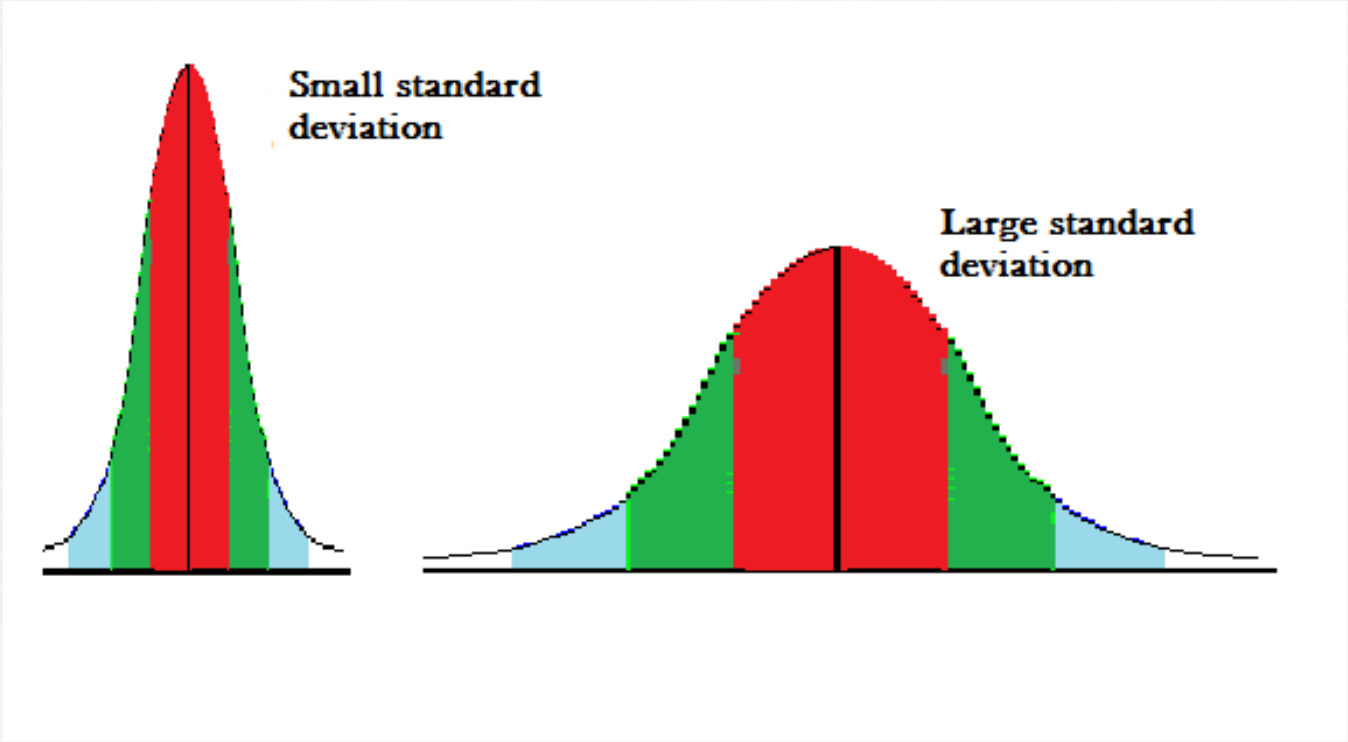
Normal Distribution



$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2}$$

AddQ CONSULTING

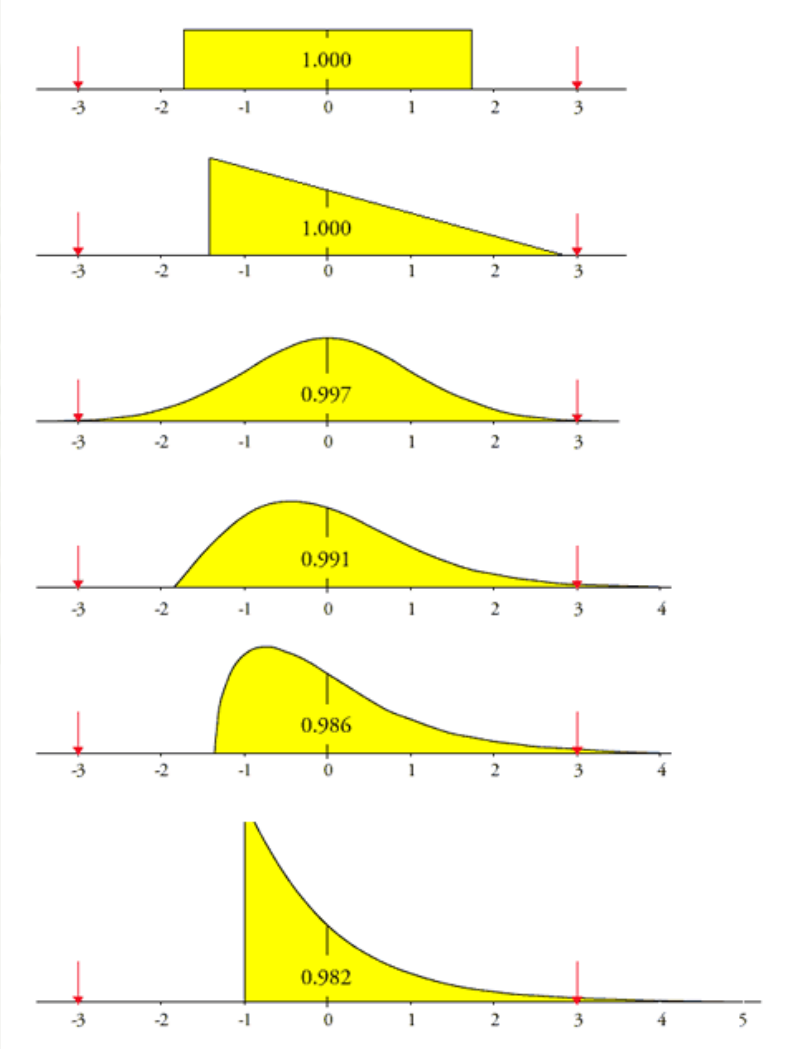
Normal Distribution



$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2}$$

AddQ CONSULTING

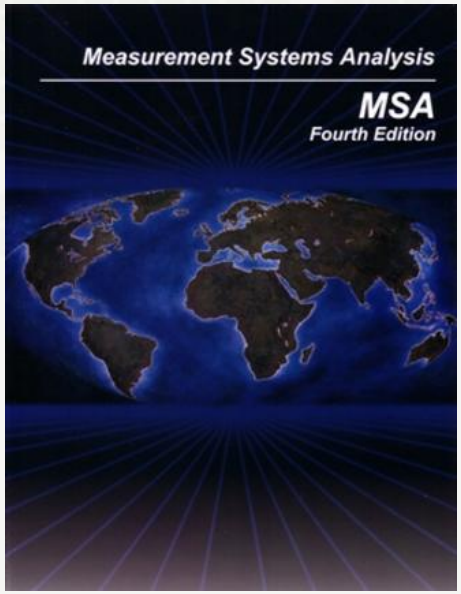
Other Distribution

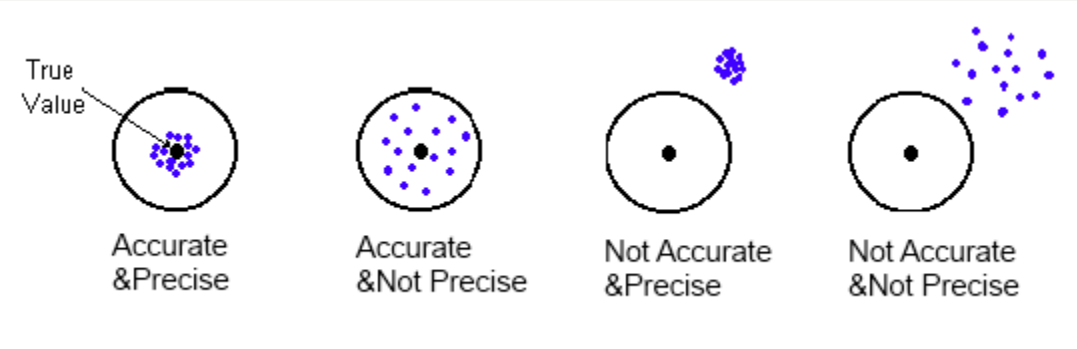


AddQ CONSULTING

MSA – Measurement System Analysis

- Qualify a measurement system for use
  - AIAG / ISO 16049
- Accuracy (Gage Study Type I)
  - Bias and Stability
- Precision (Gage R&R)
  - Repeatability
  - Reproducibility





AddQ CONSULTING

Gage R&R

- **Precision**
- Example: 10 UUTs are tested 3 times each by 3 operators.

- **Repeatability** – An operator repeats the same measurement the same?
- **Reproducibility** – Is there a difference between operators?

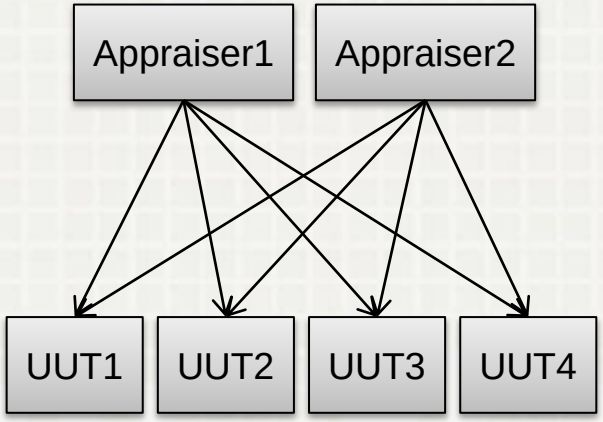
AddQ CONSULTING

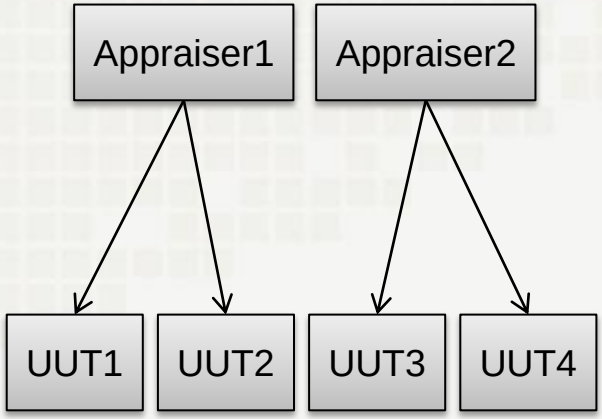
Appraiser

- Not always manual testing
- **Appraiser** used instead
  - Operator
  - Test Socket
  - Station
- Example: 10 UUTs are tested 3 times each by 3 appraisers

AddQ CONSULTING

Crossed or Nested





Variance

- Squared standard deviation

$$s^2 = \frac{\sum_{i=1}^{n} (x_i - \overline{x})^2}{n-1}$$

$$\sigma^2 = \frac{\sum_{i=1}^{N} (X_i - \mu)^2}{N}$$

- Difficult to use and interpret!
- But...

$$\sigma_{Total}{}^2 = \sigma_1{}^2 + \sigma_2{}^2 + \ldots + \sigma_n{}^2 \; (5^2 = 4^2 + 3^2)$$

$$\sigma_{Total} \neq \sigma_1 + \sigma_2 + \cdots \sigma_n \; (5 \neq 4 + 3)$$

AddQ CONSULTING

Gage R&R Variance

$$\sigma_{Total}^2 = \sigma_{part}^2 + \sigma_{meas}^2$$

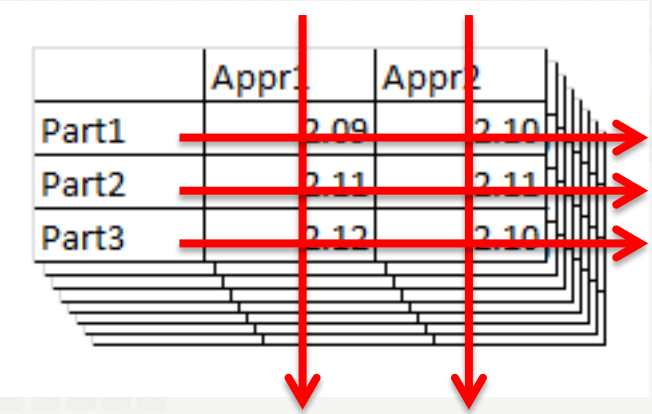
$$\sigma_{meas}^2 = \sigma_{repeat}^2 + \sigma_{reproducability}^2$$

$$\sigma_{Total}^2 = \sigma_{part}^2 + \sigma_{repeat}^2 + \sigma_{reproducability}^2$$

AddQ CONSULTING

ANOVA – Analysis of Variance

- **One-Way**
  - Only one appraiser
  - No Reproducibility



- **Two-Way**
  - More than one appraiser
  - Crossed
  - Nested

μ_{total}

μ_{Appr} and $\sigma^2{}_{Appr}$

μ_{Part} and $\sigma^2{}_{Part}$

AddQ CONSULTING

Gage R&R Output

Gage R&R (Nested) for RSSI Dongle

Source	DF	SS	MS	F	P
TestSocketIn	7	13482.8	1926.11	287.346	0.000
SerialNumber (TestSocketIn)	56	375.4	6.70	55.000	0.000
Repeatability	256	31.2	0.12		
Total	319	13889.4			

Gage R&R

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	48.1071	97.34
Repeatability	0.1219	0.25
Reproducibility	47.9853	97.09
Part-To-Part	1.3162	2.66
Total Variation	49.4234	100.00

Process tolerance = 50

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	6.93593	41.6156	98.66	83.23
Repeatability	0.34911	2.0946	4.97	4.19
Reproducibility	6.92714	41.5628	98.53	83.13
Part-To-Part	1.14728	6.8837	16.32	13.77
Total Variation	7.03018	42.1811	100.00	84.36

Number of Distinct Categories = 1

Precision-to-Tolerance (P/T)

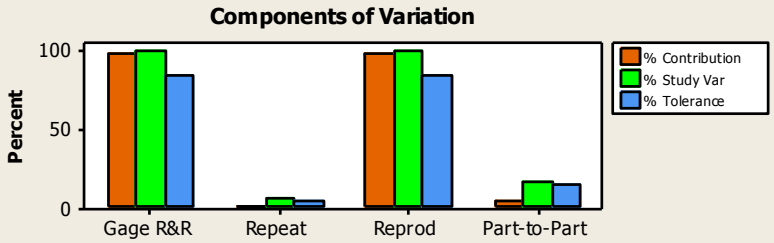
AddQ CONSULTING

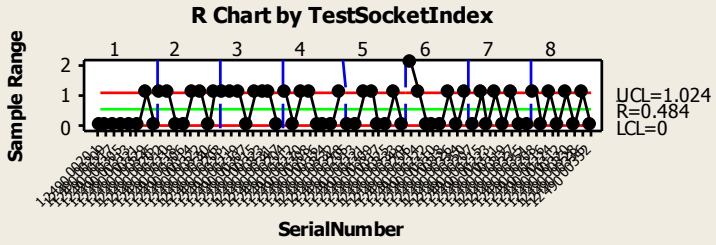
Gage R&R Output

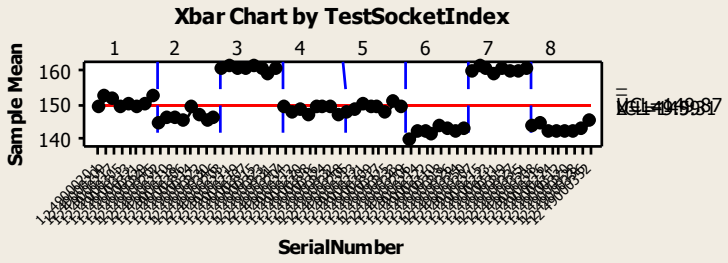
Gage R&R (Nested) for RSSI Dongle

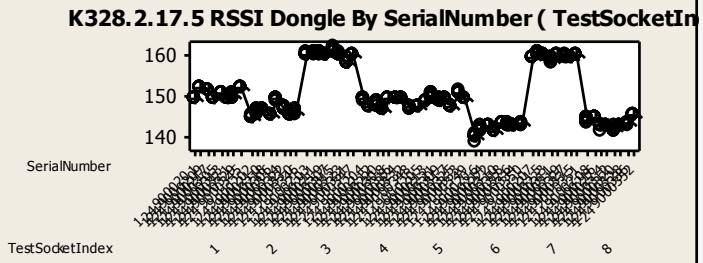
Gage name:
Date of study :

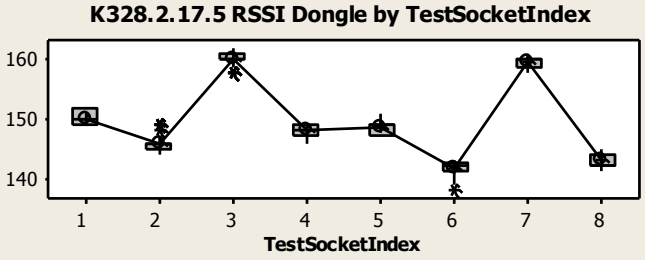
Reported by :
Tolerance:
Misc:





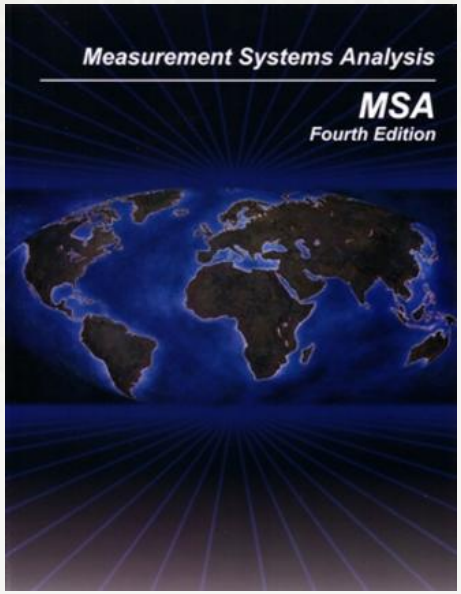






Gage R&R Criteria

- AIAG / ISO 16049
- Rule of thumb: **10 x 3 x 3**
  - 10 UUTs, 3 times each, 3 appraisers
- Gage R&R Variance Contribution
  - < 1% OK
  - < 9 % Acceptable
- P/T (Precision-to-tolerance)
  - < 10% OK
  - < 30% Acceptable



AddQ CONSULTING

Gage R&R Pitfalls

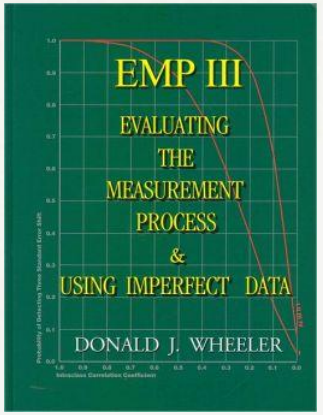
- AIAG Rules are hard to fulfil!

- Source of measurement
  - UUT reading
  - Calibrated measurements
    - Hard to see part-to-part

- Averaging

AddQ CONSULTING

Wheelers Honest Gage R&R



- 1st, 2nd, 3rd and 4th class systems

- Probable Error (PE)

  One PE = $\sigma_{meas} \times 0.6745$

  (50% interval of normal distribution)

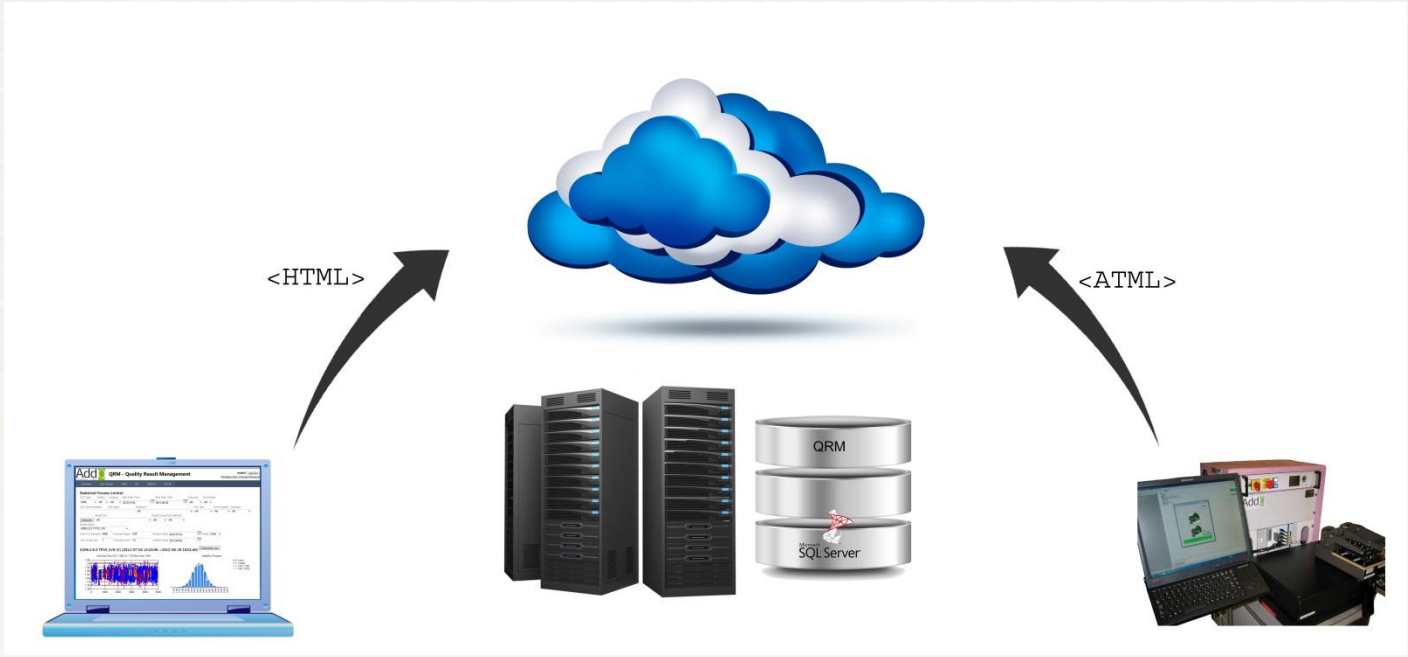
  True resolution of your system!

  Example RSSI: 6.9 x 0.6745 = 4.65

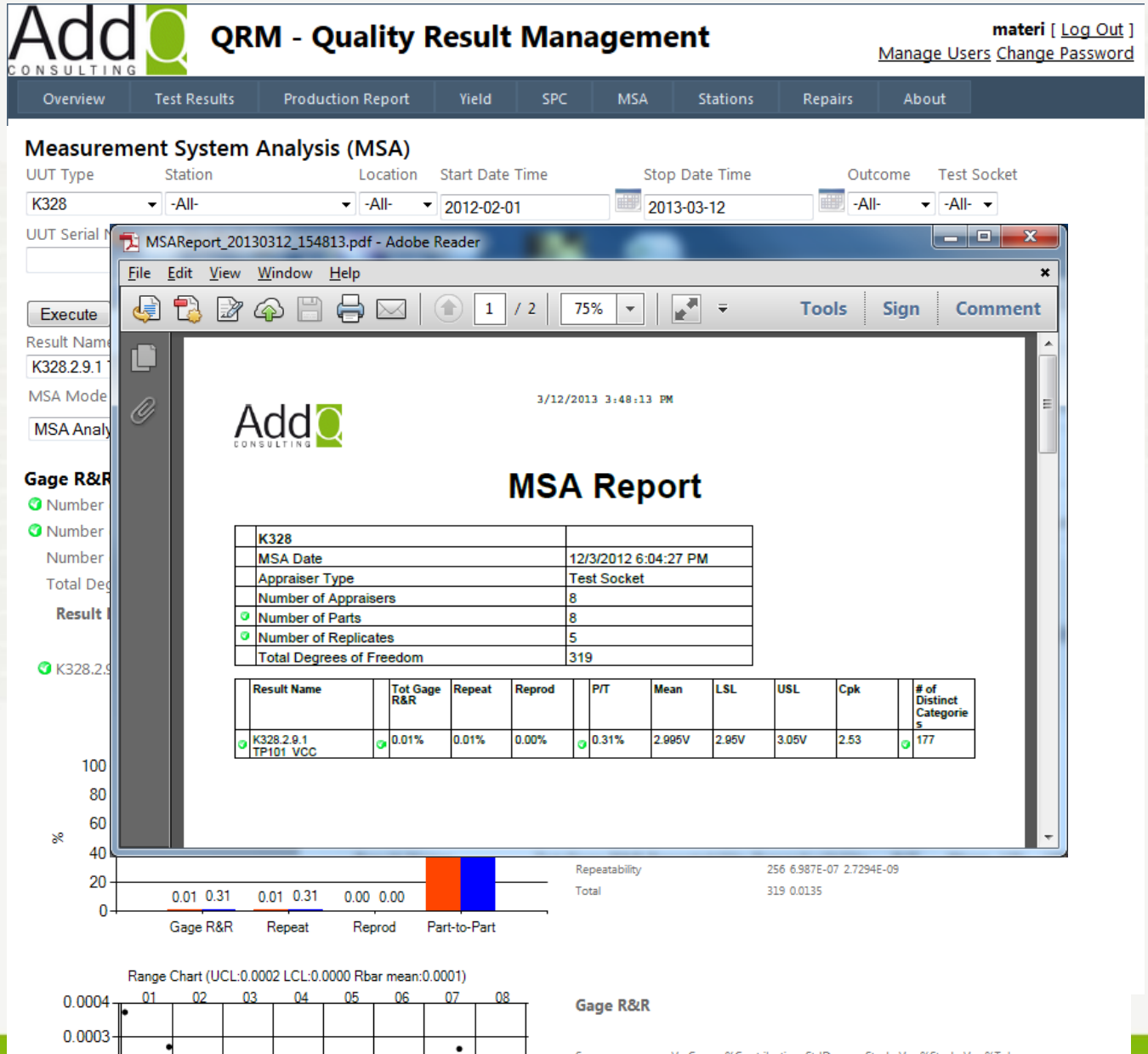
AddQ CONSULTING

QRM – Quality Result Management

Improved yield, quality and better decision making!



QRM Web Application



Conclusion

- Use MSA to ensure measurement system quility
- Use an automated tool for analysis
- Build in support to run MSA in your system
- Be careful when analysing results!
  - Variance contribution
  - P/T
  - Probable Error (PE)

AddQ CONSULTING

References

Books

AIAG Manual Measurement System Analysis

Bass, Issa: Six Sigma Statistics with Excel and Minitab.

Wheeler, Donald J: Evaluating the Measurement Process EMP III

Articles

Wheeler, Donald J: An Honest Gauge R&R Study
(http://spcpress.com/pdf/DJW189.pdf)

Other

Minitab Knowledge base

Course

Mätsystemanalys Gage R&R, Sandholm

(http://sandholm.se/Utbildning/Matsystemanalys_gage.asp)

Add Q CONSULTING