Introduction to Gage R&R Studies

The Key to Understanding Measurement Systems

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Speakers

❑ Hank Scutoski

– VP Quality
– 30 Years Experience
– TI, Motorola, Cerprobe
– Motorola University's
  Six Sigma Research Institute
– Certified Quality Engineer
– Certified Quality Auditor

❑ Chander Sekar, Ph.D.

– Corporate Statistician
– 23 Years Experience
– Professor of Statistics at
  the University of
  Madras, India
– 3 Degrees in Statistics
– Certified Quality Engineer

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Cerprobe's Philosophy

We must determine the uncertainty of our measurement systems before we can compare, control or optimize our manufacturing processes.

Studies Completed

85 Studies to Date Including:

- – Tip Diameter
- – Tip Length
- – Contact Force
- – Probe Tip Alignment
- – Planarity
- – Contact Resistance
- – Leakage

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Benefits

- Validates consistent results between:
    - Cerprobe's many manufacturing facilities
    - Cerprobe & customer sites

- Provides for "Dock to Stock" certification

- Provides feedback to Cerprobe's suppliers.

- Able to provide customer with quality products with statistical consulting support.
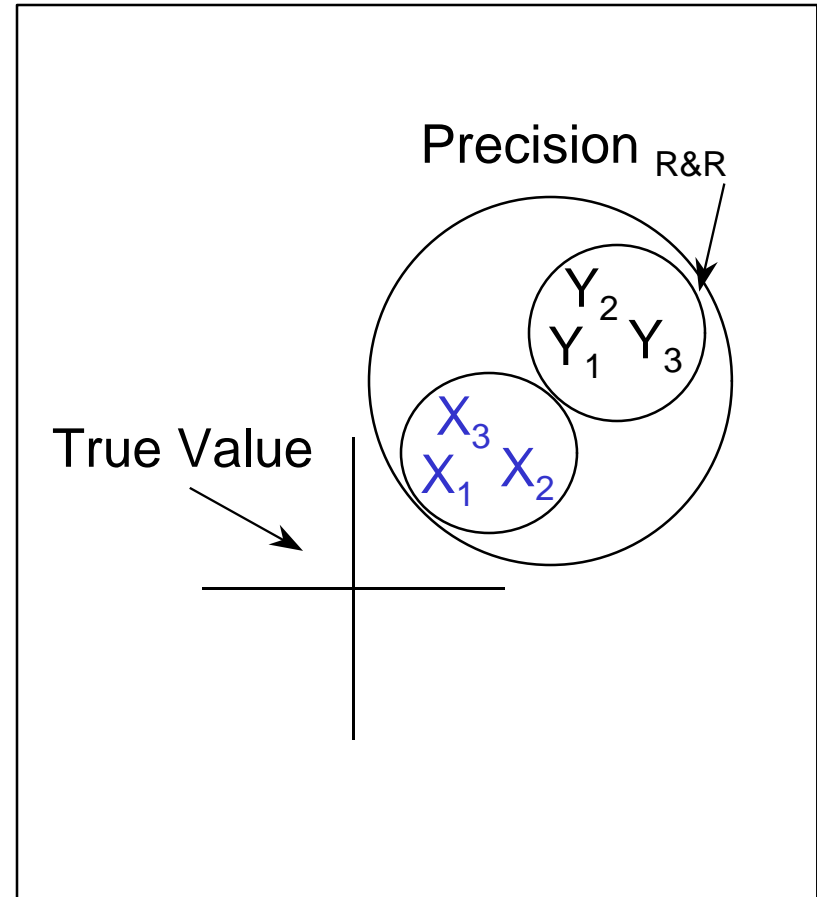
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Statistical Applications
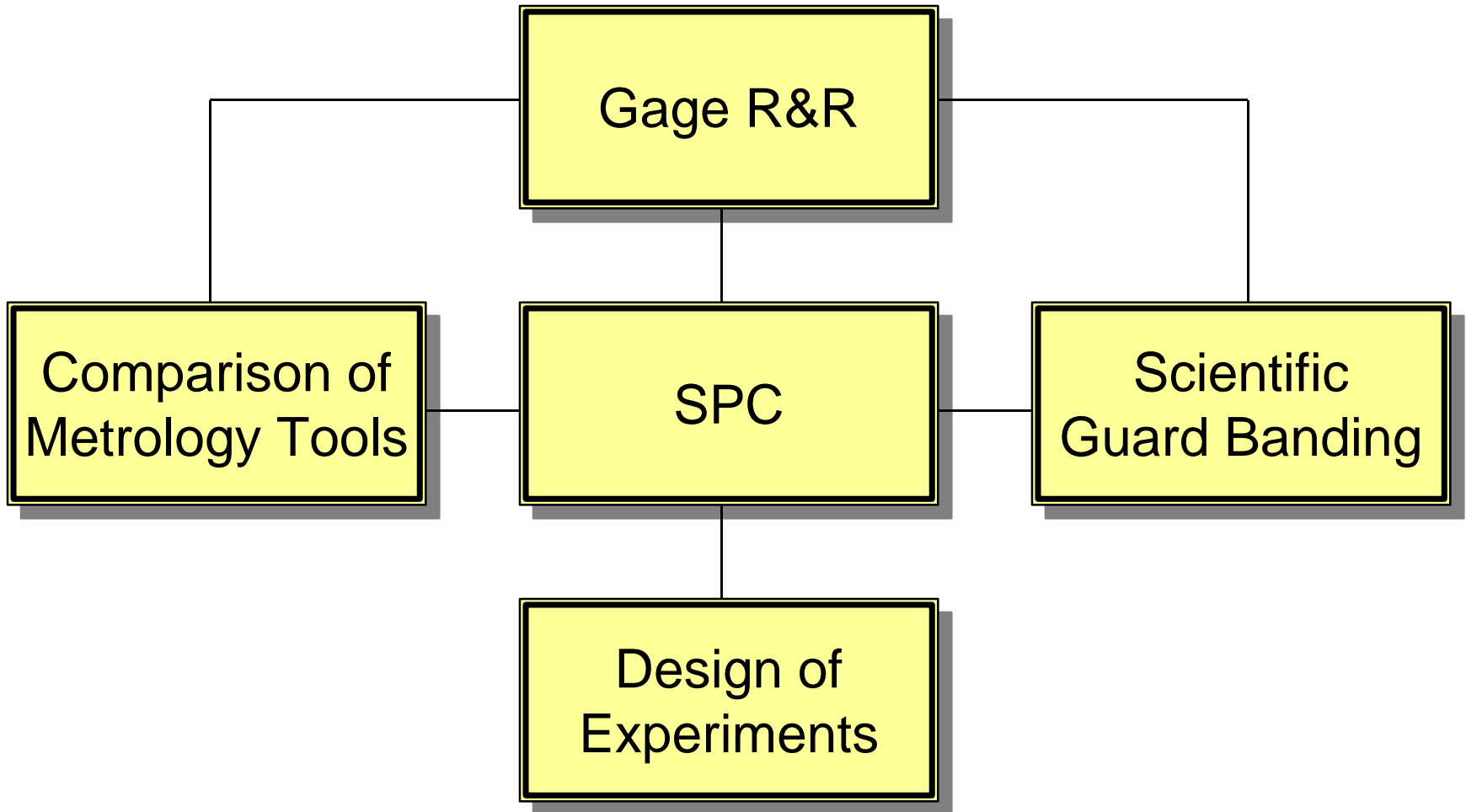
Gage Repeatability

- The variation obtained from **one gage** and **one operator** when measuring the **same part** several times.

- Machine Variation

- Only Applies to ATE

$Precision_R$ = Diameter = 6 Std Dev

True Value

X_3
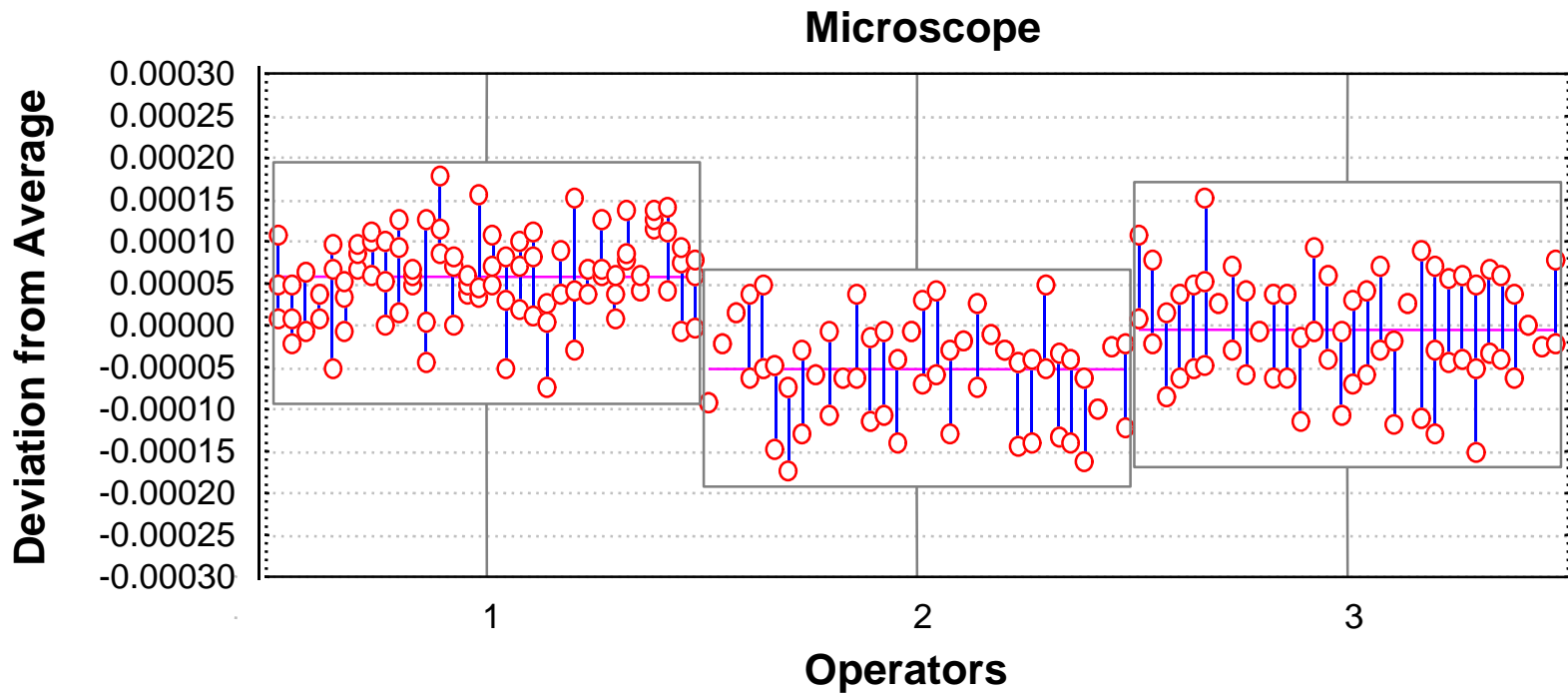X_1 X_2

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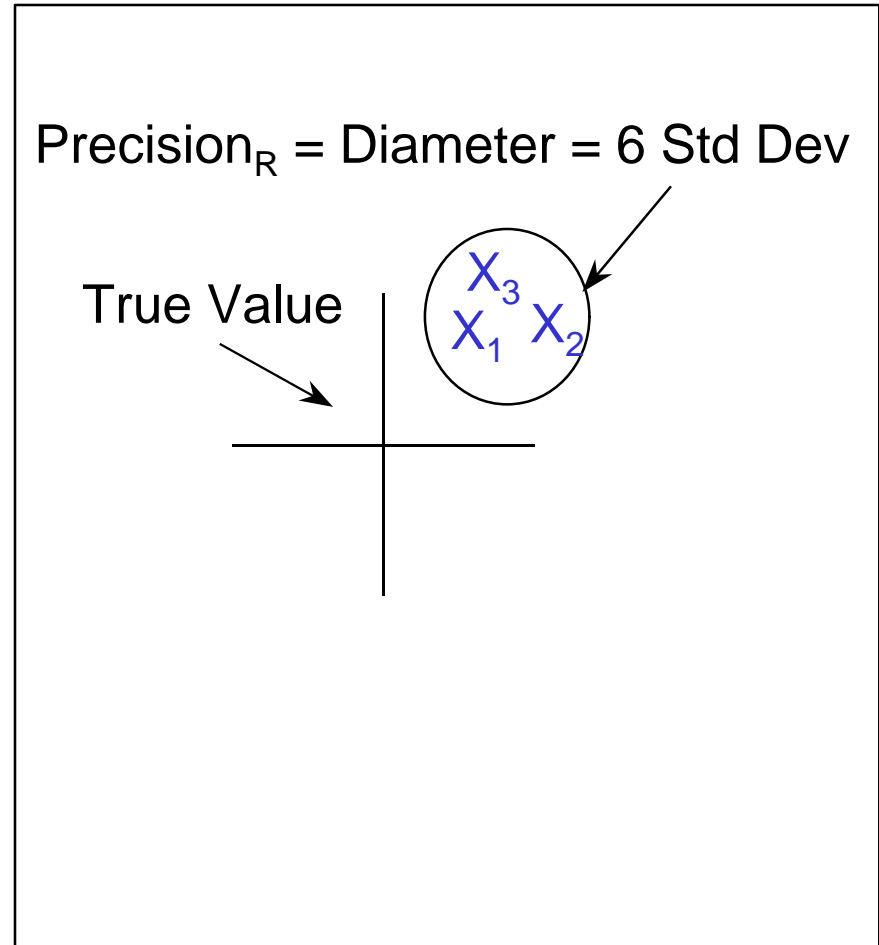
Gage Reproducibility

- The difference in the average of the measurements made by **different** operators using the **same** gage when measuring the **same part**.

- Operator-to-Operator Variation

Precision $_{R\&R}$

Y_2
Y_1 Y_3

X_3
X_1 X_2

True Value

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R&R Summary Plot

No. of Operators: 3
No. of Parts: 32
No. of Trials: 3

Microscope — Deviation from Average vs. Operators

R&R Summary Plot

No. of Operators: 3
No. of Parts: 32
No. of Trials: 3
Study #3

Video System
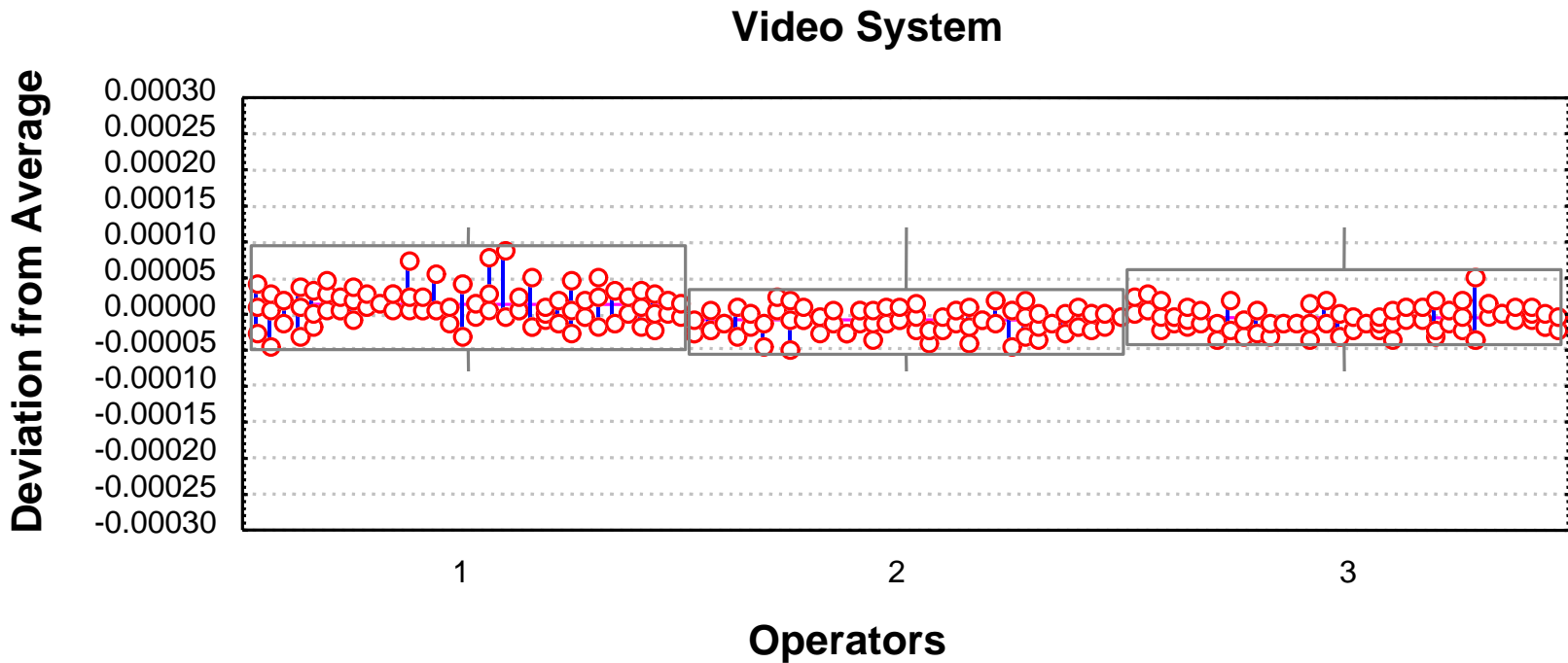
Total Variation

❑ *Process Variation*

❑ *Gage Variation*

- Repeatability

- Reproducibility

Repeatability

99.73%

-3σ $+3\sigma$

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                    o
   o   oooo ooo  o ooo     o
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Nominal
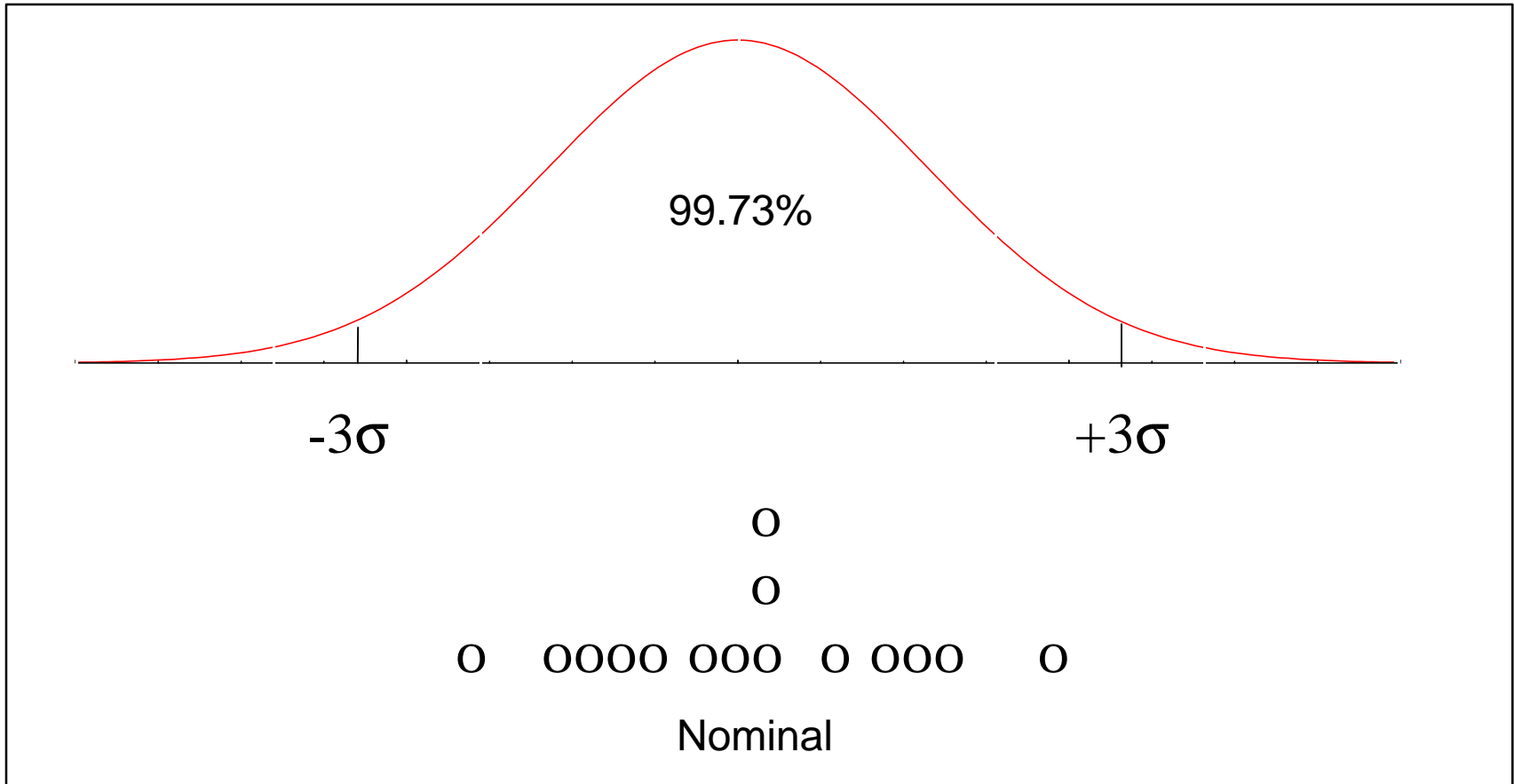
Note: ❑ One Gage
        ❑ 1 Operator
        ❑ Repeated Measurements

Reproducibility

Operator # 1
Distribution

Operator # 2
Distribution
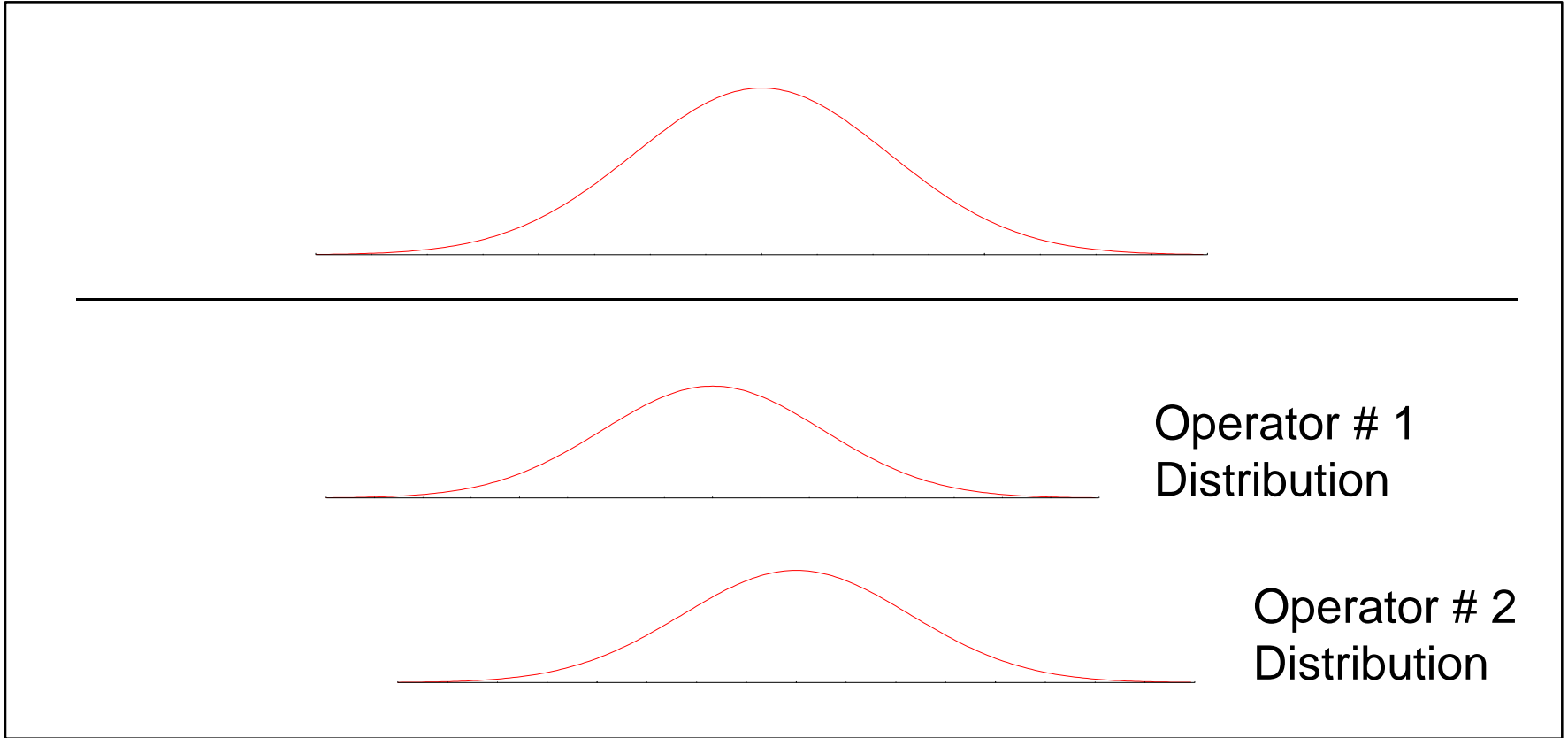
Note: ❑ One Gage
         ❑ 2 Operators
         ❑ Repeated Measurements
         ❑ One Part

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Measurement System Capability

■ Precision-to-Tolerance Ratio (P/T)

P/T < 0.1   Acceptable System

0.1 < P/T < 0.3 Marginally Acceptable System

P/T   > 0.3   Unacceptable System

Ref.: SEMATECH: Introduction to Measurement Capability Analysis
#91090709A-ENG

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Interpretation of P/T Ratios

P/T = 0.1

* Measurement system consumes 10% of tolerance

* Effect of T on P/T

P = 1.2   P = 1.2
T = 4.0   T = 3.0
P/T = 0.3   P/T = 0.4

Repeatability Study

- ■ Single operator performs multiple trials

- ■ No change in the setup between trials

- ■ Provides a quick estimate of measurement capability

- ■ P_R/T

Repeatability Study - Data

Trial #1	Trial #2	Trial #3	Trial #4	Trial #5	S	R
0.0170	0.0180	0.0190	0.0070	0.0930	0.0351	0.0860
0.2090	0.1400	0.1630	0.1540	0.1340	0.0297	0.0750
0.0790	0.1170	0.0600	0.0880	0.0970	0.0211	0.0570
0.0770	0.0750	0.1350	0.0820	0.1380	0.0322	0.0630
0.0840	0.0300	0.0730	0.0780	0.0240	0.0285	0.0600
0.0500	0.0420	-0.0030	0.0380	0.0520	0.0224	0.0550
-0.0480	-0.0510	0.0020	-0.0420	-0.0370	0.0215	0.0530
0.0690	0.0830	0.1360	0.1150	0.0690	0.0299	0.0670

S:Standard Deviation   R: Range

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Repeatability Study

P/T Calculations

$$P_R/T = 6 * (\bar{R} / d_2) / (USL - LSL)$$

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Gage R&R Study

- ■ Involves multiple operators and trials

- ■ Total tear down of the setup between trials

- ■ Provides separate estimates of repeatability and reproducibility

- ■ $P_{R\&R}/T$

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Gage R&R Study - Data

O1-T1	O1-T2	O1-T3	O2-T1	O2-T2	O2-T3
-0.0050	0.0360	0.0330	0.0040	-0.0070	-0.0420
-0.0100	-0.0460	-0.0600	-0.0170	-0.0680	-0.0700
0.0070	0.0110	0.0090	0.0230	-0.0190	-0.0040
-0.0170	-0.0820	-0.1060	-0.0890	-0.0540	-0.0580
-0.0620	-0.1000	-0.1010	-0.0270	-0.1090	-0.1000
-0.0830	-0.1480	-0.1210	-0.1200	-0.1280	-0.1870
-0.1100	-0.1460	-0.1520	-0.1200	-0.1890	-0.1900
-0.0560	-0.1490	-0.1290	-0.0900	-0.1650	-0.1780

O1, O2 - Operators 1 and 2
T1, T2, T3 - Trials 1, 2 and 3

Gage R&R Study

- ■ Repeatability

- ■ Reproducibility

- ■ Operator-Part Interaction

- ■ Part-to-Part Variation

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Operator-to-Part Interaction

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                    ┌─────────────────────┐
                    │     Significant     │
                    │  Operator-to-Part   │
                    │     Interaction     │
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| Bad Gage | Poor Operator Training | Improper Measurement Study Procedure |

Data Analysis Methods

- ■ Average Range Method
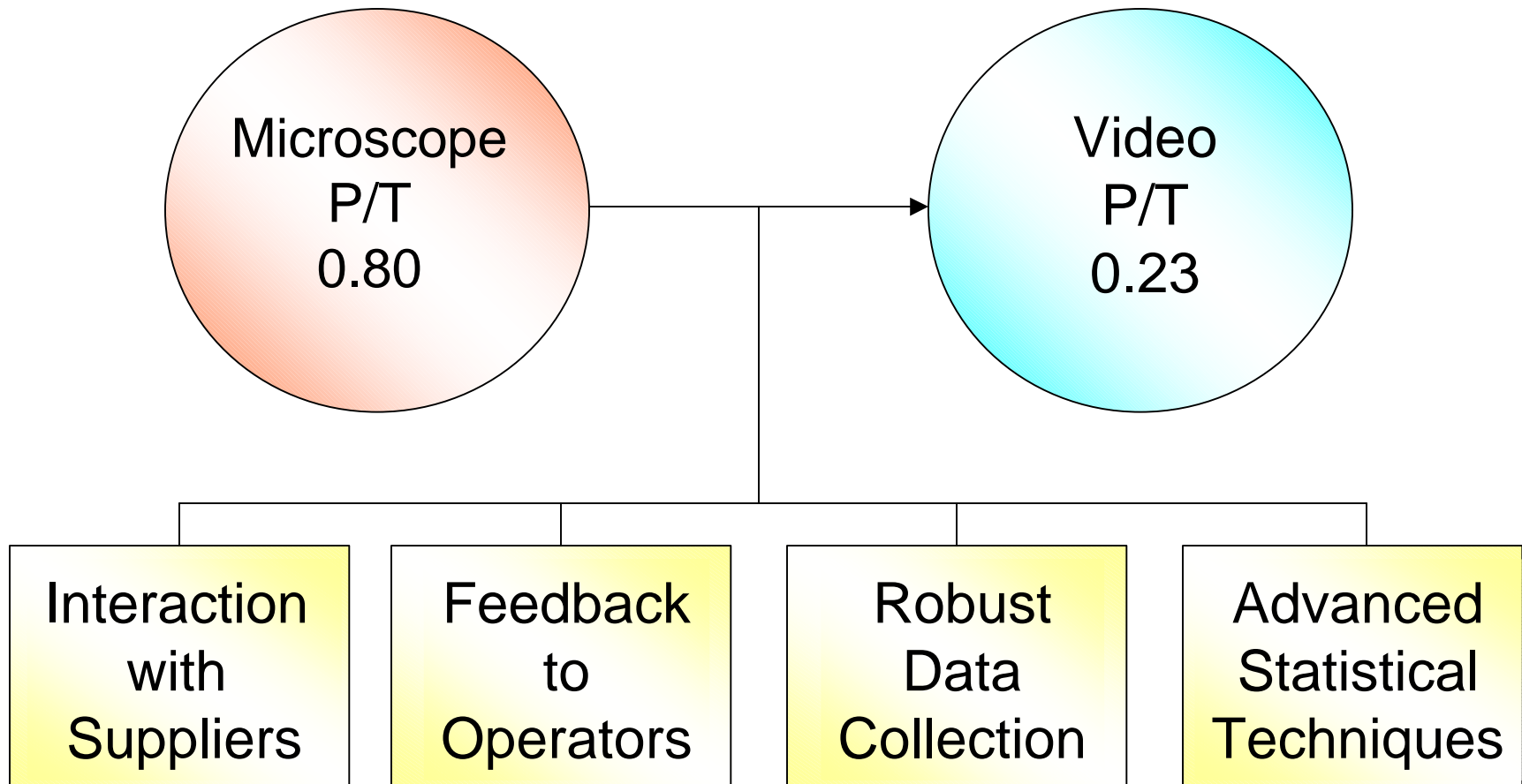
- ■ Analysis of Variance (ANOVA) Method

Gage R&R Study

P/T Calculations

$$P_{R\&R}/T = 6 * (R\&R\ Sigma) / (USL - LSL)$$

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Road Map to Success

Microscope P/T 0.80 → Video P/T 0.23

- Interaction with Suppliers
- Feedback to Operators
- Robust Data Collection
- Advanced Statistical Techniques

Consistent Product Quality

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