Automotive Core Tools

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Automotive Core Tools

Advanced Product Quality Planning (APQP)

Failure Mode and Effects Analysis (FMEA)

Control Plan

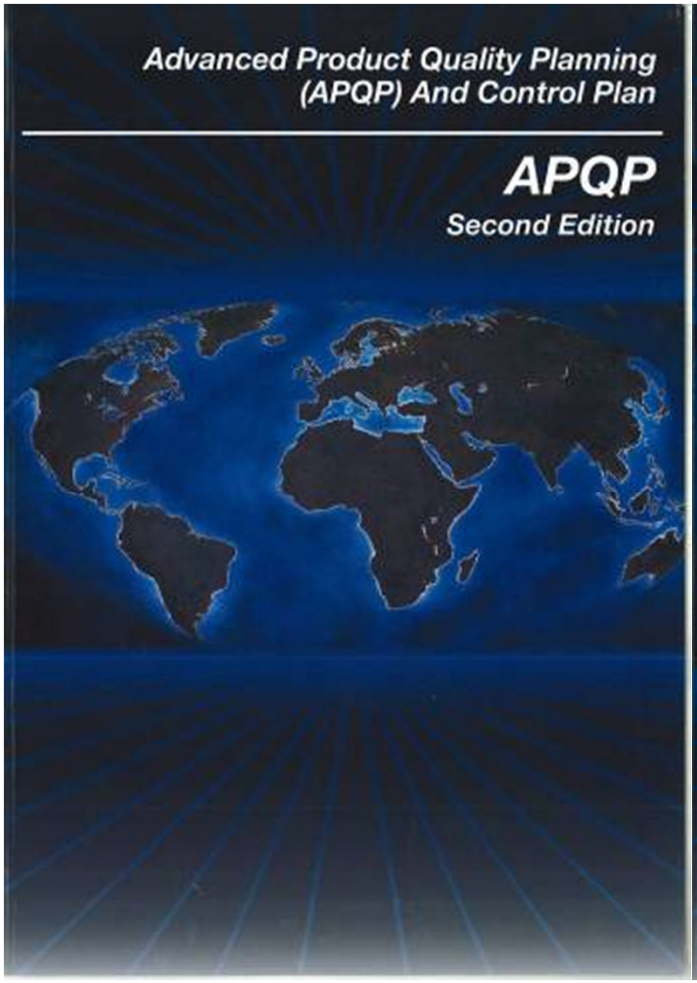
Production Part Approval Process (PPAP)

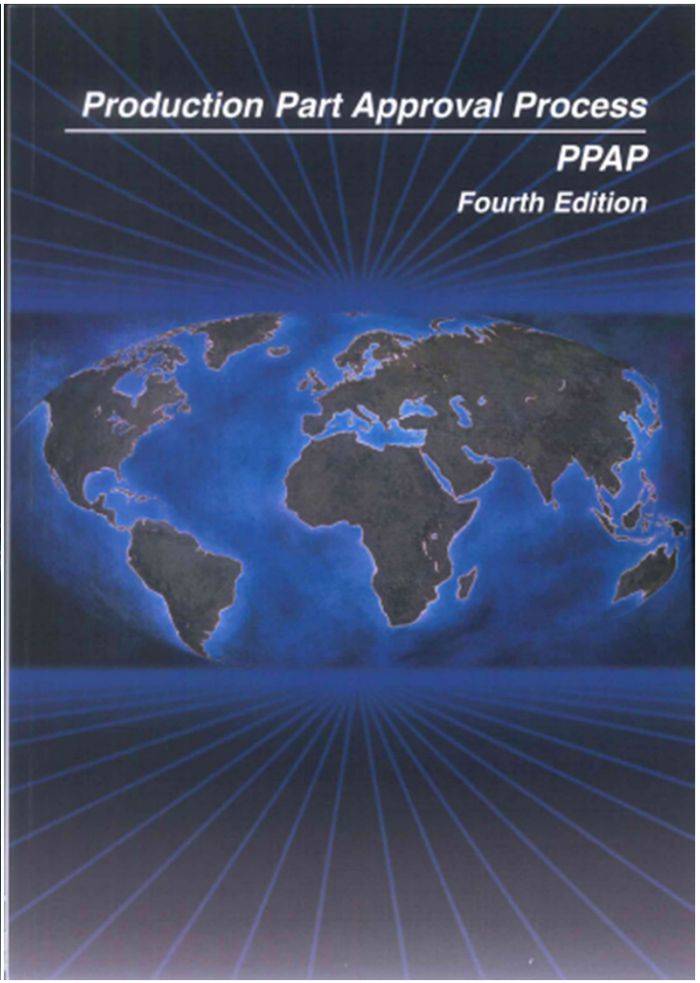
Statistical Process Control (SPC)

Measurement System Analysis (MSA)

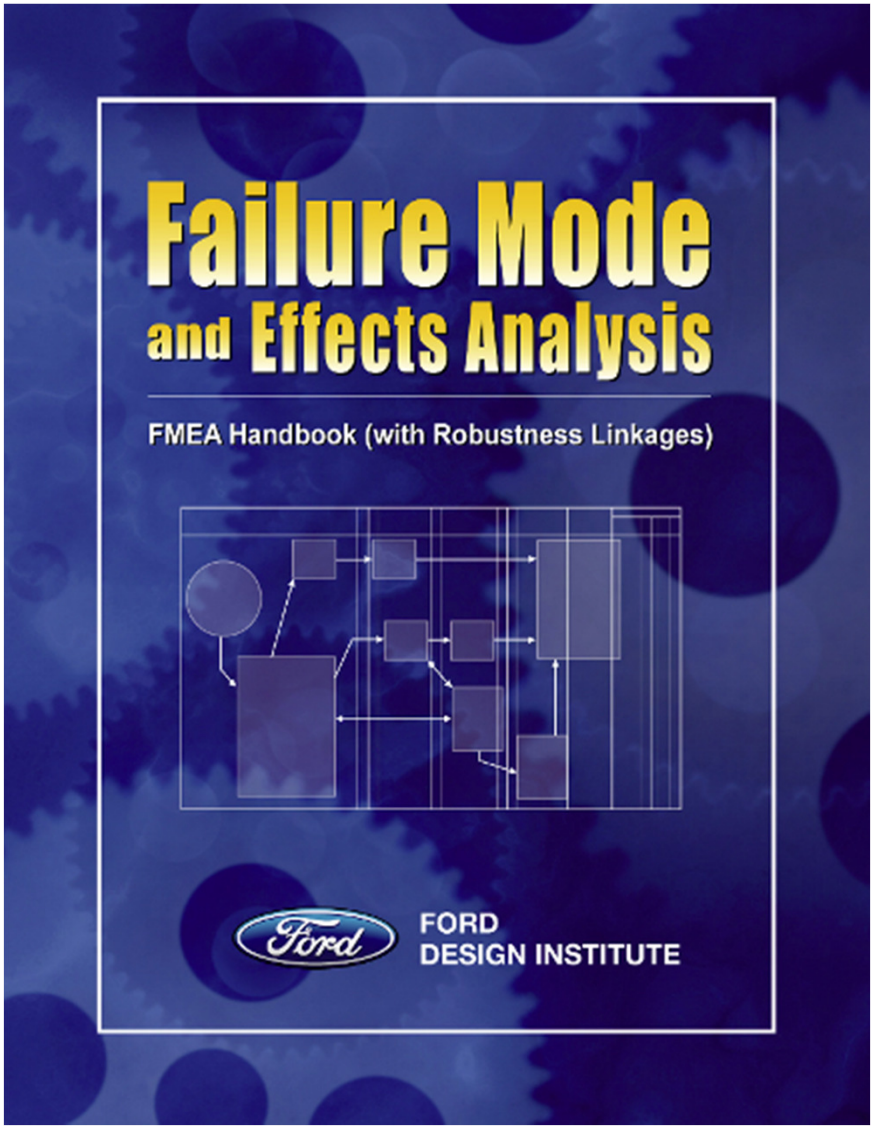
Automotive Core Tools

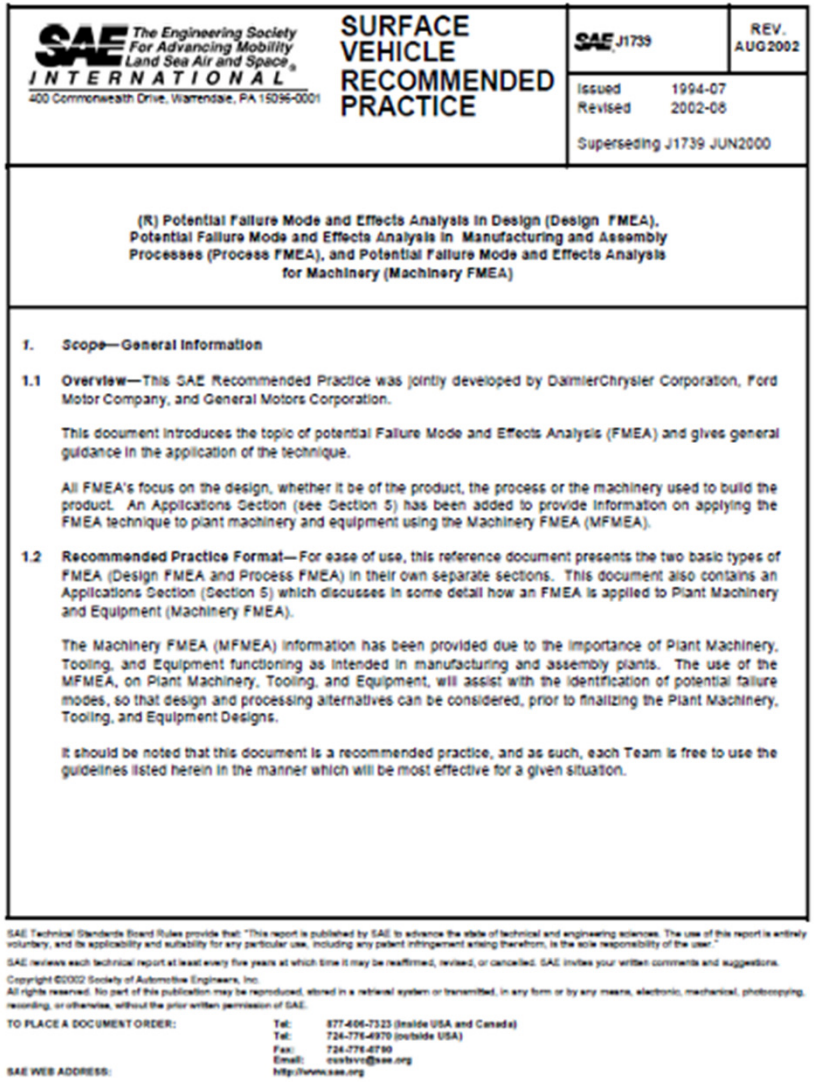
Examples: AIAG “Blue Book” Manuals





Examples: Other Manuals





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SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA), and Potential Failure Mode and Effects Analysis for Machinery (Machinery FMEA)

1. **Scope—General Information**

1.1 **Overview**—This SAE Recommended Practice was jointly developed by DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation.

This document introduces the topic of potential Failure Mode and Effects Analysis (FMEA) and gives general guidance in the application of the technique.

All FMEA's focus on the design, whether it be of the product, the process or the machinery used to build the product. An Applications Section (see Section 5) has been added to provide information on applying the FMEA technique to plant machinery and equipment using the Machinery FMEA (MFMEA).

1.2 **Recommended Practice Format**—For ease of use, this reference document presents the two basic types of FMEA (Design FMEA and Process FMEA) in their own separate sections. This document also contains an Applications Section (Section 5) which discusses in some detail how an FMEA is applied to Plant Machinery and Equipment (Machinery FMEA).

The Machinery FMEA (MFMEA) information has been provided due to the importance of Plant Machinery, Tooling, and Equipment functioning as intended in manufacturing and assembly plants. The use of the MFMEA, on Plant Machinery, Tooling, and Equipment, will assist with the identification of potential failure modes, so that design and processing alternatives can be considered, prior to finalizing the Plant Machinery, Tooling, and Equipment Designs.

It should be noted that this document is a recommended practice, and as such, each Team is free to use the guidelines listed herein in the manner which will be most effective for a given situation.

Core Tools in ISO/TS 16949:2009

APQP: 7.1 (Note)

FMEA: 7.3.3.1, 7.3.3.2

Control Plan: 7.5.1.1, Annex A

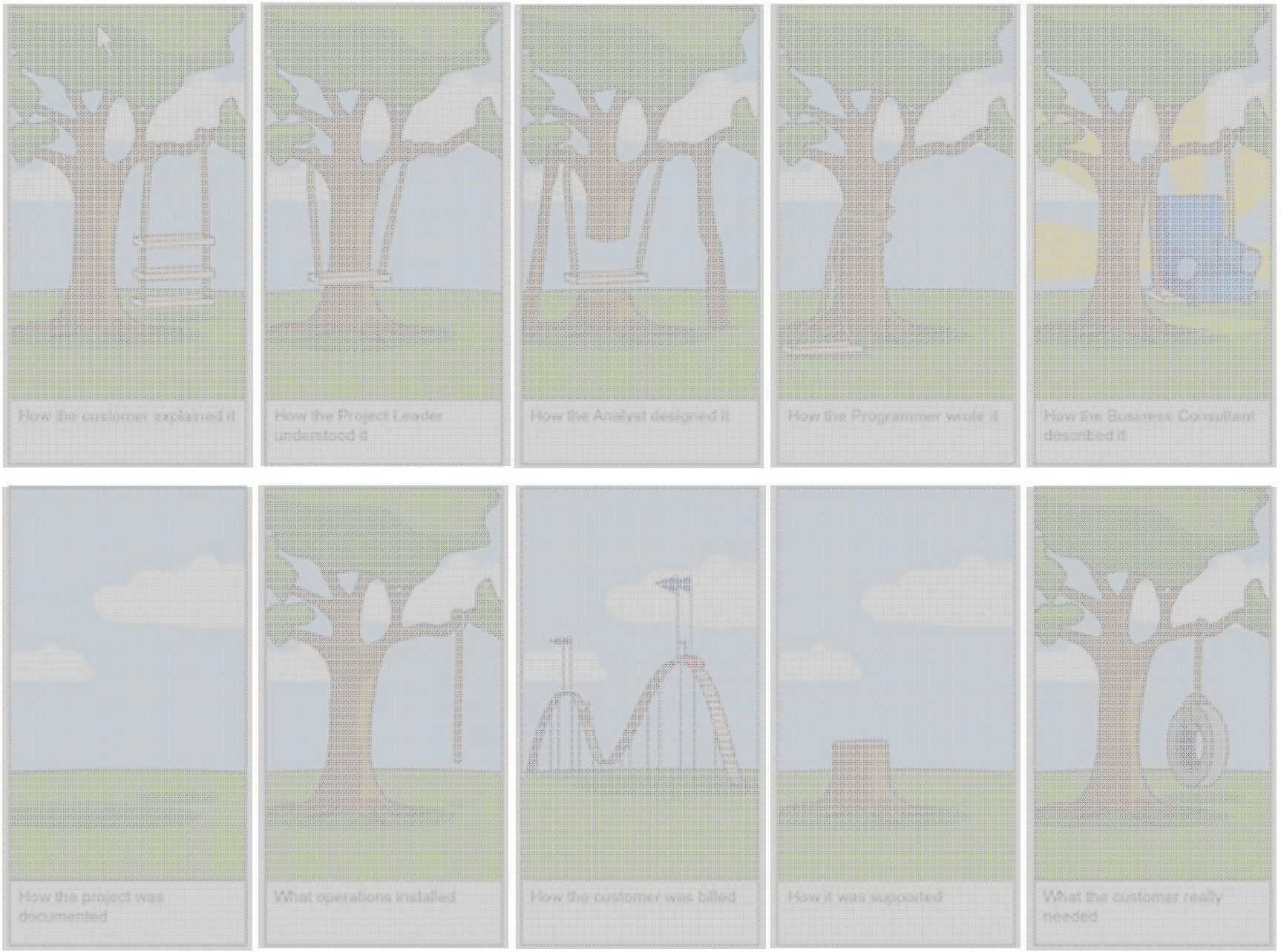
Product Approval Process (PPAP): 7.3.6.3

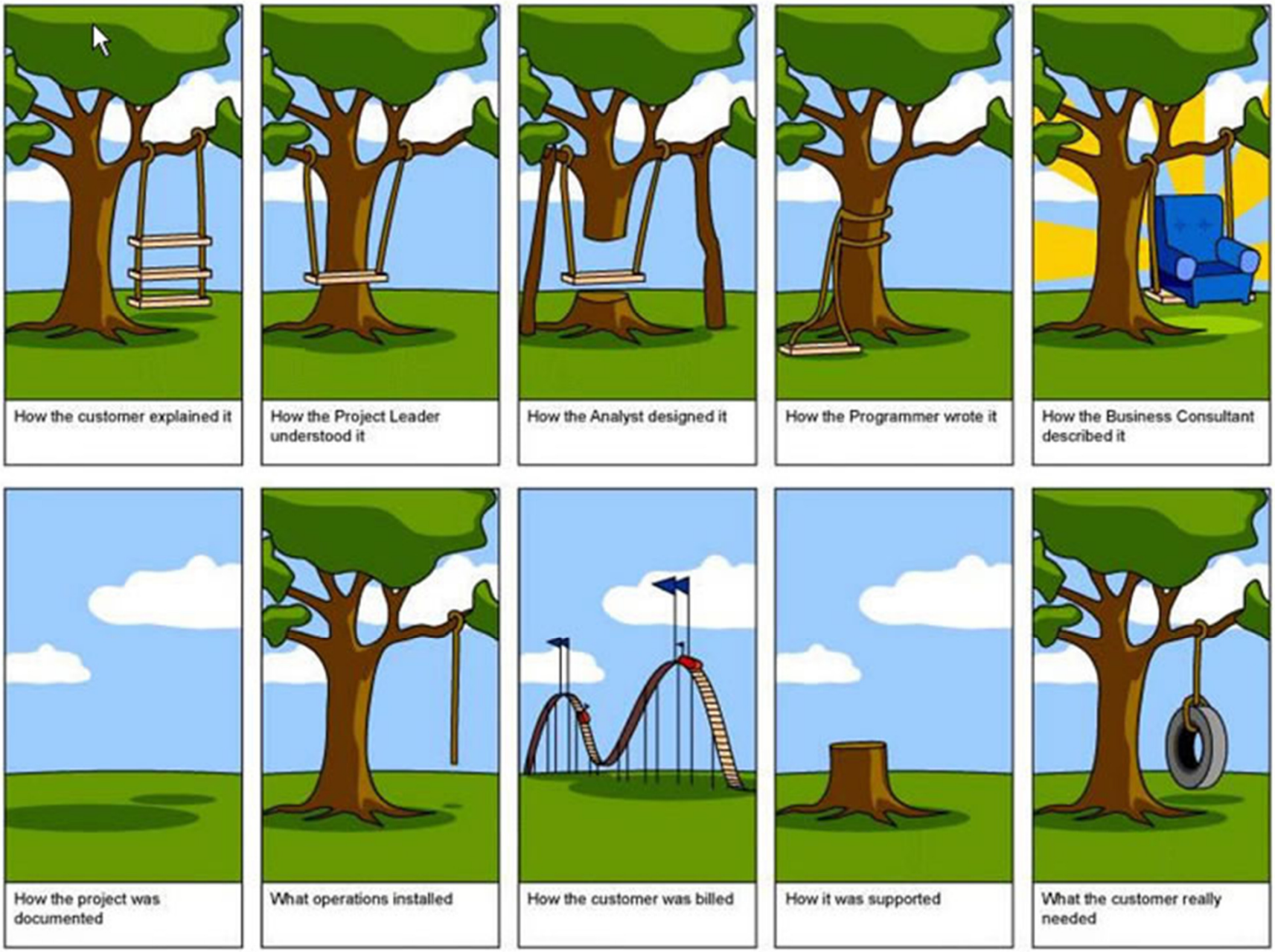
SPC: 8.1.2, 8.5.1.2

MSA: 7.6.1

APQP

Advanced Product Quality Planning


How the customer explained it
How the Project Leader understood it
How the Analyst designed it
How the Programmer wrote it
How the Business Consultant described it
How the project was documented
What operations installed
How the customer was billed
How it was supported
What the customer really needed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How the project was documented
What operations installed
How the customer was billed
How it was supported
What the customer really needed

APQP

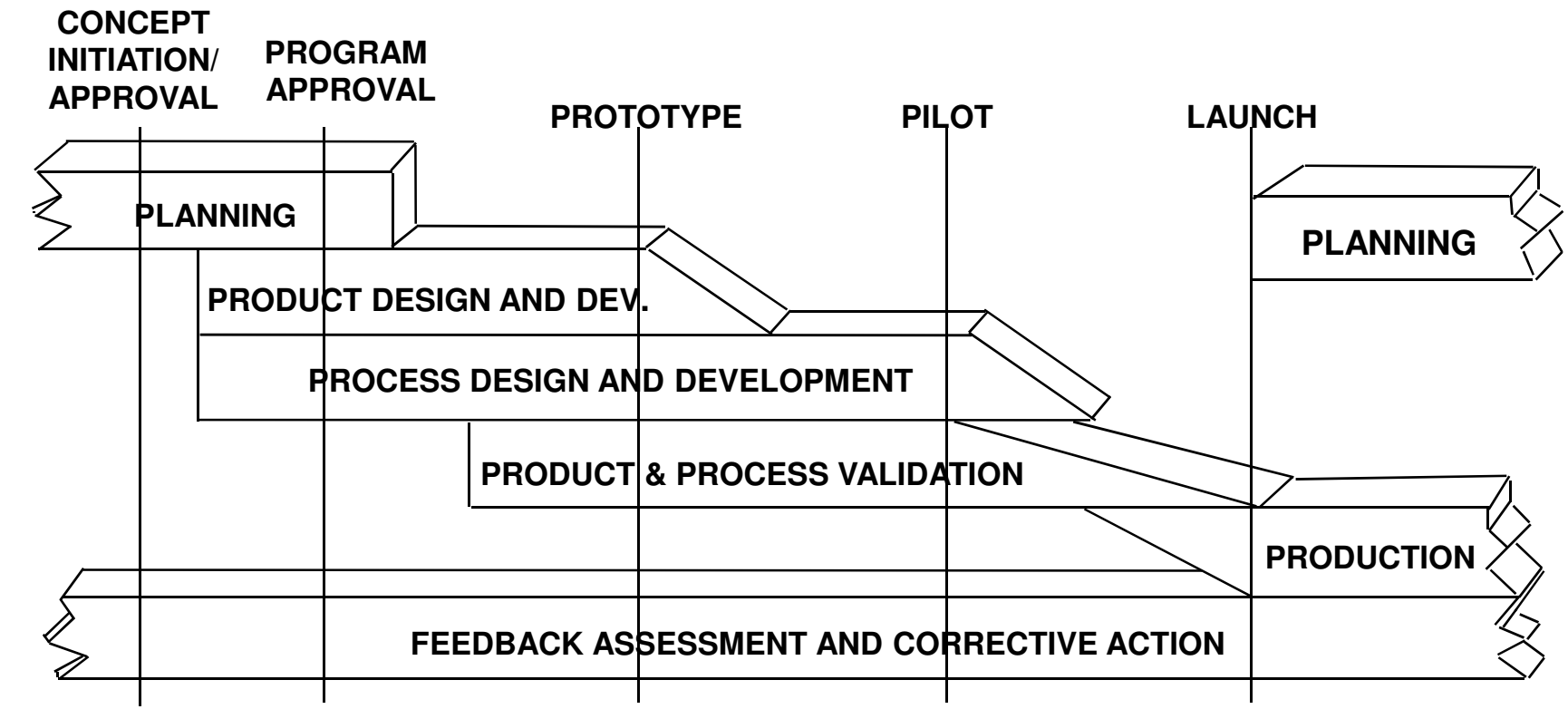
What is it?

Management of product development

Why do we use it?

To understand what our customer wants and fulfill those wants

Advanced Product Quality Planning



Planning INPUTS

Planning OUTPUTS

Product Design & Dev. INPUTS

Product Design & Dev. OUTPUTS

Process Design & Dev. INPUTS

Process Design & Dev. OUTPUTS

Product & Process Validation INPUTS

Product & Process Validation OUTPUTS

Feedback, Assessment & Corrective Action INPUTS

Feedback, Assessment & Corrective Action OUTPUTS

Concept Initiation/Approval

Inputs:

- Voice of the Customer
  - Market Research (Including OEM Vehicle Timing and Volume Expectations
  - Historical Warranty and Quality Information
  - Team Experience
- Business Plan/Marketing Strategy
- Product/Process Benchmark Data
- Product/Process Assumptions
- Product Reliability Studies
- Customer Inputs

Concept Initiation/Approval

Outputs:

- **Design Goals**
- **Reliability and Quality Goals**
- **Preliminary Bill of Materials**
- **Preliminary Process Flow Chart**
- **Preliminary Listing of Special Product and Process Characteristics**
- **Product Assurance Plan**
- **Management Support**

Program Approval

Design Outputs:

- Design Failure Mode and Effects Analysis (DFMEA)
- Design for Manufacturability and Assembly
- Design Verification
- Design Reviews
- Prototype Build -- Control Plan
- Engineering Drawings (Including Math Data)
- Engineering Specifications
- Material Specifications
- Drawing and Specification Changes

APQP Outputs:

- New Equipment, Tooling and Facilities Requirements
- Special Product and Process Characteristics
- Gages / Testing Equipment Requirements
- Team Feasibility Commitment & Management Support

Prototype

Outputs:

- Packaging Standards and Specifications
- Product/Process Quality System Review
- Process Flow Chart
- Floor Plan Layout
- Process Failure Mode and Effects Analysis (PFMEA)
- Characteristics Matrix
- Pre-Launch Control Plan
- Process Instructions
- Measurement System Analysis Plan
- Management Support
- Preliminary Process Capability Study Plan

Pilot

Outputs:

- Significant Production Run
- Measurement Systems Evaluation
- Preliminary Process Capability Study
- Production Part Approval
- Production Validation Testing
- Packaging Evaluation
- Production Control Plan
- Quality Planning Sign-Off and Management Support

Launch

Outputs:

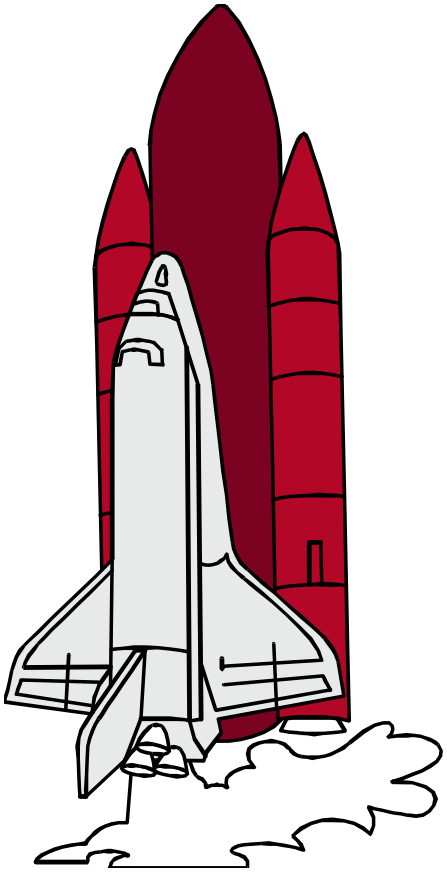
- Reduced Variation
- Improved Customer Satisfaction
- Improved Delivery and Service
- Effective Use of Lessons Learned/Best Practice

Pitfalls

- APQP treated as a "Quality Department Responsibility"
- APQP a separate process, not integrated into product development
- Key stakeholders brought in late (quality, production, suppliers)
- Milestones and deliverables ignored
- No top management involvement/support

FMEA

Failure Mode and Effects Analysis



FMEA

What is it?

A risk analysis of a part or process

Why do we use it?

To find and fix a problem before something breaks or someone gets hurt

Types of FMEAs

Design FMEA

Process FMEA

Types of FMEAs

Others:

System FMEA

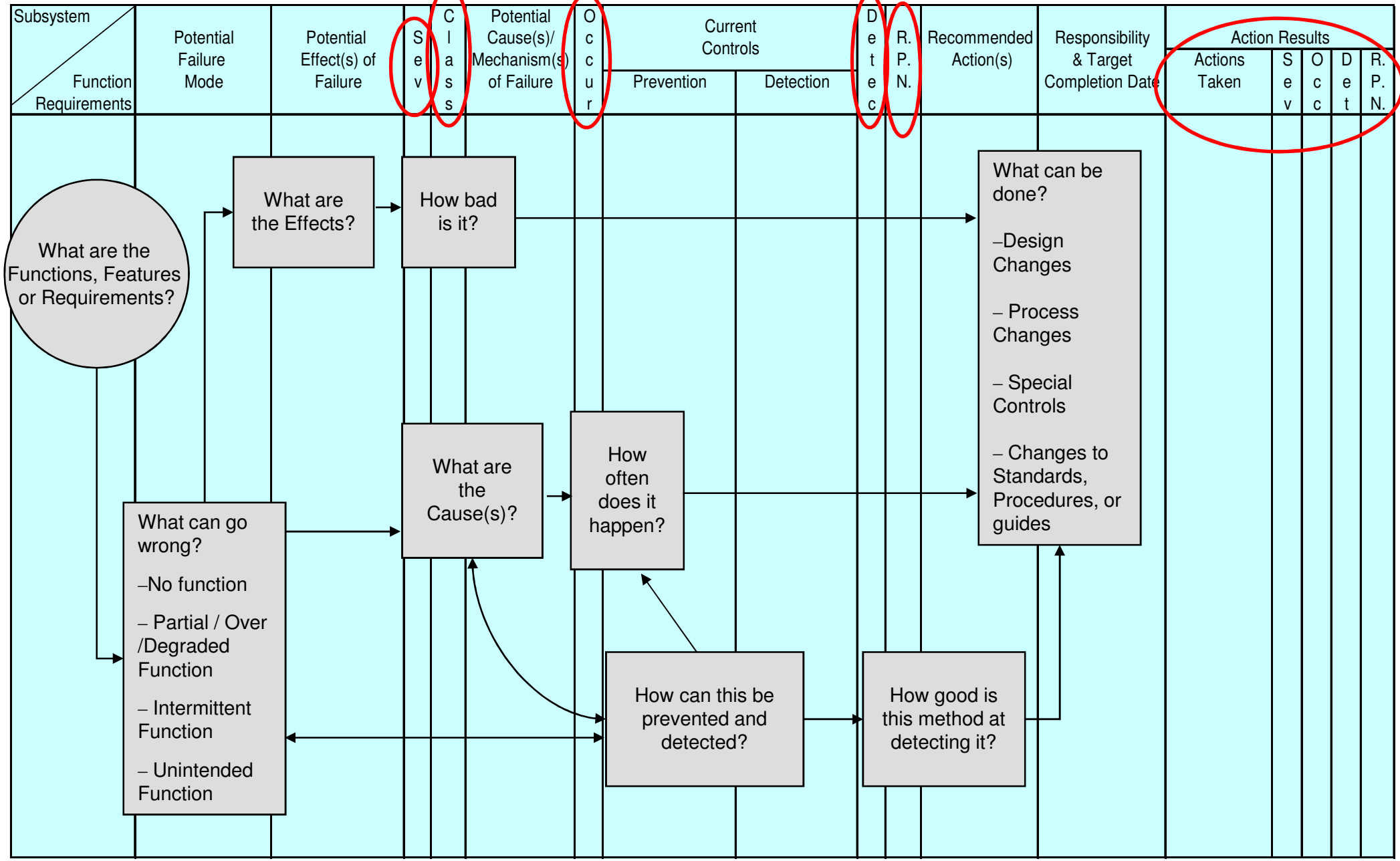
Concept FMEA

Environmental FMEA

Machinery FMEA

Software FMEA

FMEA Process



Risk Action Strategies

1st Priority is Severity. Severity has a direct impact on the customer.

2nd Priority is Criticality (Severity times Occurrence: S x O). Criticality evaluates the risk that an event with a high impact on the customer will occur.

3rd Priority is RPN. RPN evaluates the ability to detect and contain poor quality.

Pitfalls

- FMEA started late in the development process (just in time for PPAP!)
- FMEA never updated after release
- FMEA not updated from nonconformity corrective actions
- Right side (action area) is blank
- RPN thresholds
- FMEA written by one person
- FMEA treated as a “Quality Department Responsibility”


Control Plan

Control Plan

What is it?

A summary of controls used to make sure my customer gets good product

Why do we use it?

To make sure controls are used and stay in place

Control Plan

CONTROL PLAN

☐ Prototype ☐ Pre-Launch ☐ Production

Control Plan Number	Key Contact/Phone	Date (Orig.)	Date (Rev.)
Part Number/Latest Change Level	Core Team	Customer Engineering Approval/Date (If Req'd.)	
Part Name/Description	Supplier/Plant Approval/Date	Customer Quality Approval/Date (If Req'd.)	
Supplier/Plant / Supplier Code	Other Approval/Date (If Req'd.)	Other Approval/Date (If Req'd.)	

PART/ PROCESS NUMBER	PROCESS NAME/ OPERATION DESCRIPTION	MACHINE, DEVICE, JIG,TOOLS, FOR MFG.	CHARACTERISTICS			SPECIAL CHAR. CLASS	METHODS				REACTION PLAN
			NO.	PRODUCT	PROCESS		PRODUCT/PROCESS SPECIFICATION/ TOLERANCE	EVALUATION/ MEASUREMENT TECHNIQUE	SAMPLE SIZE	SAMPLE FREQ.	CONTROL METHOD	

Control Plan Elements

TS 16949 Annex A

A.2 Elements of the control plan

The organization shall develop a control plan that includes, as a minimum, the following contents.

a) General data

– control plan number,
– issue date and revision date, if any,
– customer information (see customer requirements),
– organization's name/site designation,
– part number(s),
– part name/description,
– engineering change level,
– phase covered (prototype, pre-launch, production),
– key contact,
– part/process step number,
– process name/operation description.

b) Product control

– product-related special characteristics,
– other characteristics for control (number, product or process),
– specification/tolerance.

c) Process control

– process parameters,
– process-related special characteristics,
– machines, jigs, fixtures, tools for manufacturing.

d) Methods

– evaluation measurement technique,
– **error-proofing,**
– sample size and frequency,
– control method.

e) Reaction plan and corrective actions

– reaction plan (include or reference),
– **corrective action**.

Pitfalls

- Control plan and PFMEA not aligned
- Control plan and operator instructions not aligned
- Control plan out of date
- Control plan not updated from nonconformity corrective actions

PPAP

Production Part Approval Process

PPAP

What is it?

Requirements for approval of production parts.

Why do we use it?

To make sure that I understand all my customer requirements, and that I can meet them under actual production conditions.

PPAP

1 Design Records
2 Authorized Engineering Change Documents
3 Customer Engineering Approval
4 Design FMEA
5 Process Flow Diagrams
6 Process FMEA
7 Control Plan
8 Measurement System Analysis Studies
9 Dimensional Results
10 Material / Performance Test Results
11 Initial Process Study
12 Qualified Laboratory Documentation
13 Appearance Approval Report
14 Sample Production Parts
15 Master Samples
16 Checking Aids
17 Customer-Specific Requirements (Records)
18 Part Submission Warrant
Bulk Material Requirements Checklist

Retention/Submission Requirements Table 4.2

(Normative)

*[NOTE: Table 4.2 lists submission and retention requirements. Mandatory and applicable requirements for a **PPAP** record are defined in the **PPAP** manual and by the customer.]*

		Submission Level				
Requirement		*Level 1*	*Level 2*	*Level 3*	*Level 4*	*Level 5*
1.	Design Record	R	S	S	*	R
	- for proprietary components/details	R	R	R	*	R
	- for all other components/details	R	S	S	*	R
2.	Engineering Change Documents, if any	R	S	S	*	R
3.	Customer Engineering approval, if required	R	R	S	*	R
4.	Design FMEA	R	R	S	*	R
5.	Process Flow Diagrams	R	R	S	*	R
6.	Process FMEA	R	R	S	*	R
7.	Control Plan	R	R	S	*	R
8.	Measurement System Analysis Studies	R	R	S	*	R
9.	Dimensional Results	R	S	S	*	R
10.	Material, Performance Test Results	R	S	S	*	R
11.	Initial Process Studies	R	R	S	*	R
12.	Qualified Laboratory Documentation	R	S	S	*	R
13.	Appearance Approval Report (AAR), if applicable	S	S	S	*	R
14.	Sample Product	R	S	S	*	R
15.	Master Sample	R	R	R	*	R
16.	Checking Aids	R	R	R	*	R
17.	Records of Compliance With Customer-Specific Requirements	R	R	S	*	R
18.	Part Submission Warrant (PSW)	S	S	S	S	R
	Bulk Material Checklist (see 4.1 above)	S	S	S	S	R

S = The organization shall submit to the customer and retain a copy of records or documentation items at appropriate locations.

R = The organization shall retain at appropriate locations and make available to the customer upon request.

* = The organization shall retain at appropriate locations and submit to the customer upon request.

DaimlerChrysler Ford GM

PART SUBMISSION WARRANT

Part Name _____ Cust. Part Number _____

Shown on Drawing No. _____ Org. Part Number _____

Engineering Drawing Change Level _____ Dated _____

Additional Engineering Changes _____ Dated _____

Safety and/or Government Regulation ☐ Yes ☐ No Purchase Order No. _____ Weight (kg) _____

Checking Aid No. _____ Checking Aid Engineering Change Level _____ Dated _____

SUBMISSION RESULTS

The results for ☐ dimensional measurements ☐ material and functional tests ☐ appearance criteria ☐ statistical process package

These results meet all design record requirements: ☐ Yes ☐ NO (If "NO" - Explanation Required)

Mold / Cavity / Production Process _____

DECLARATION

I affirm that the samples represented by this warrant are representative of our parts which were made by a process that meets all Production Part Approval Process Manual 4th Edition Requirements. I further affirm that these samples were produced at the production rate of _____ / _____ hours. I also certify that documented evidence of such compliance is on file and available for review. I have noted any deviations from this declaration below.

EXPLANATION/COMMENTS: _____

_____

Is each Customer Tool properly tagged and numbered? ☐ Yes ☐ No ☐ n/a

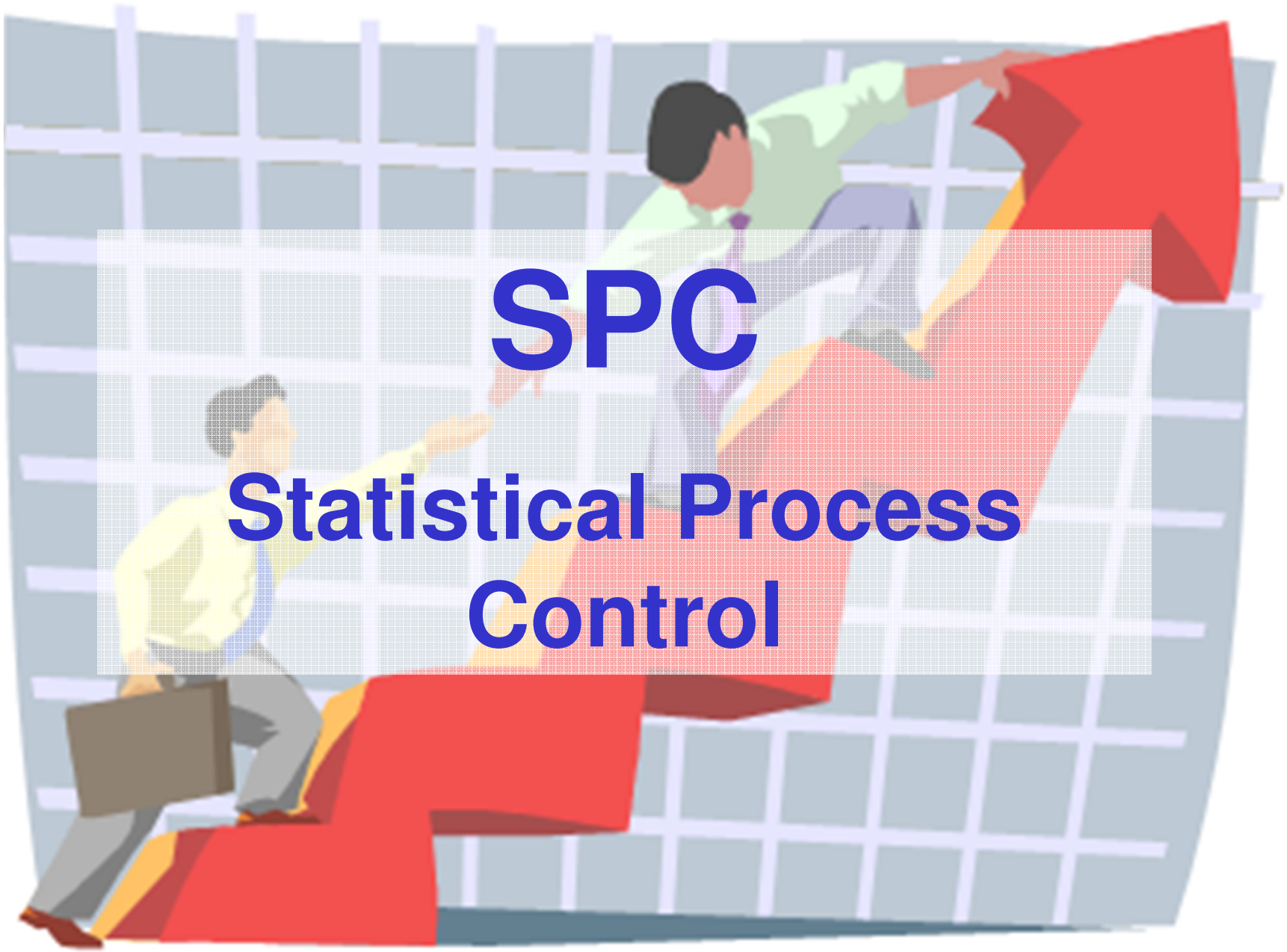
Organization Authorized Signature _____ Date _____

Print Name _____ Phone No. _____ FAX No. _____

Title _____ E-mail _____

Pitfalls

- PPAP is treated as a separate process, rather than integrated into product development
- Incomplete PPAP
- Assuming that submission levels are what's required, rather than what's submitted


SPC
Statistical Process Control

SPC

What is it?

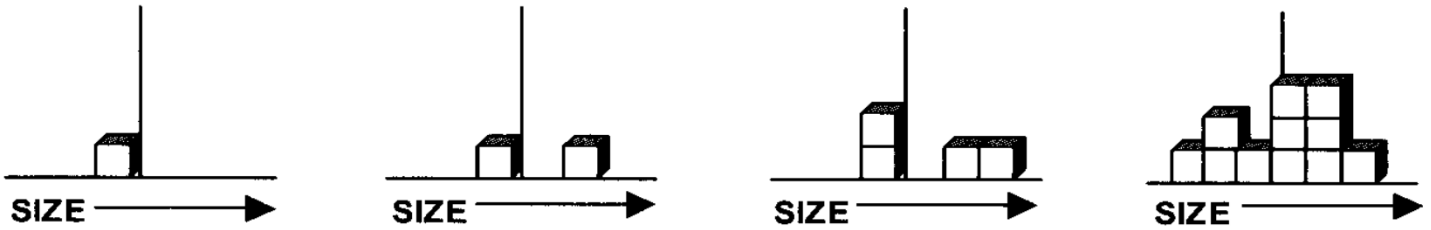
A collection of statistical methods, especially control charts, used to analyze and control a process

Why do we use it?

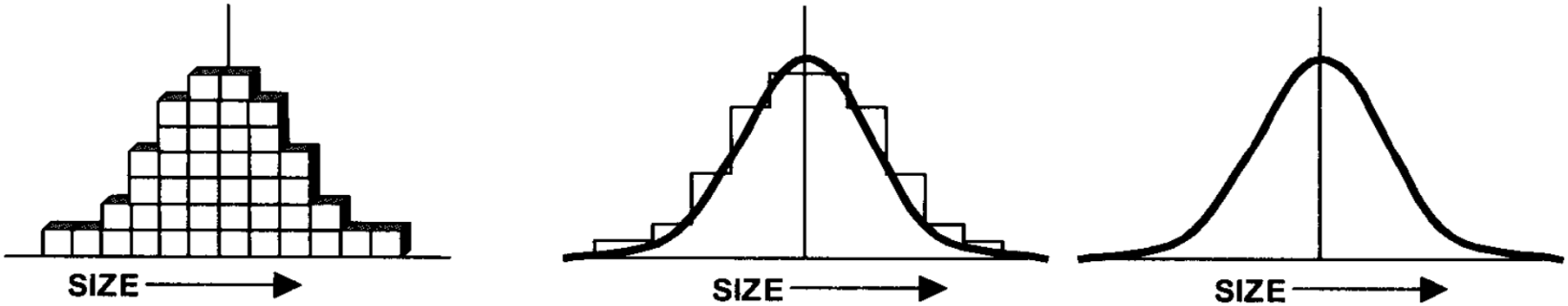
To know when processes change and respond accordingly

Variation

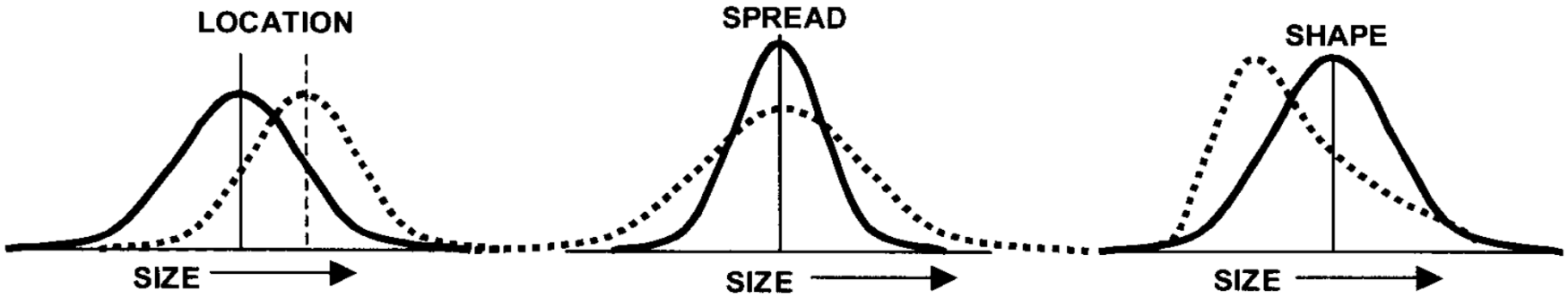
PIECES VARY FROM EACH OTHER



BUT THEY FORM A PATTERN THAT, IF STABLE, CAN BE DESCRIBED AS A DISTRIBUTION



DISTRIBUTION CAN DIFFER IN:



Distributions can vary in Location

Location (Center): 3 key measures

Mean = Average or $\overline{X}$

Median = Middle (by count)

Mode = Most often

Distributions can vary in Spread

Spread: 3 key measures

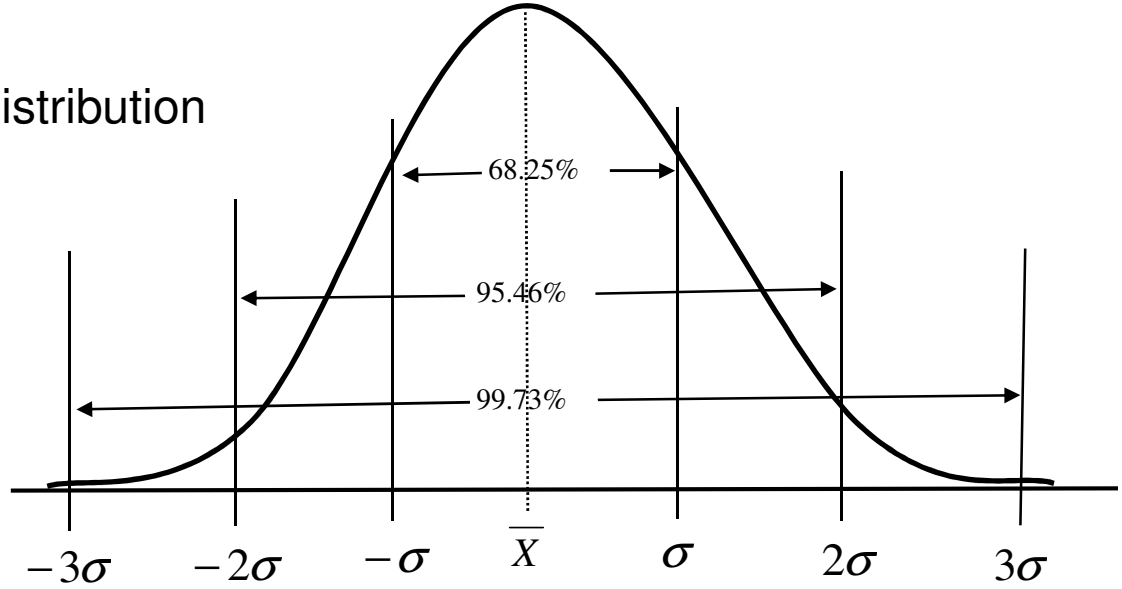
Range = R

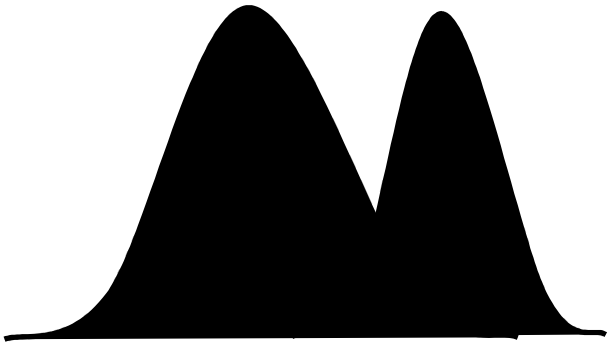
Standard Deviation = σ or S

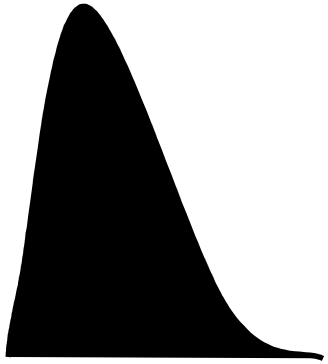
Variance = σ^2

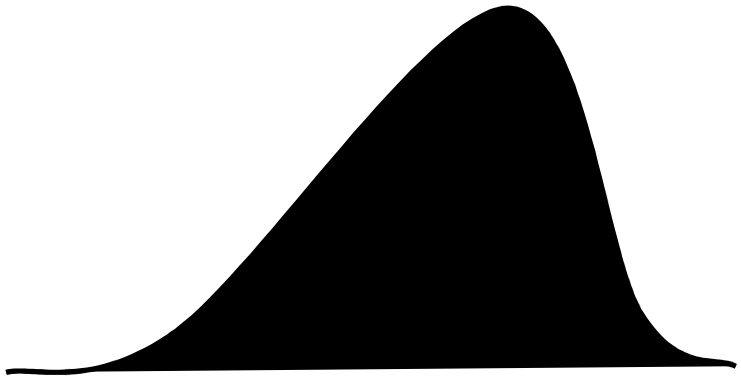
Distributions can vary in Shape

Normal Distribution







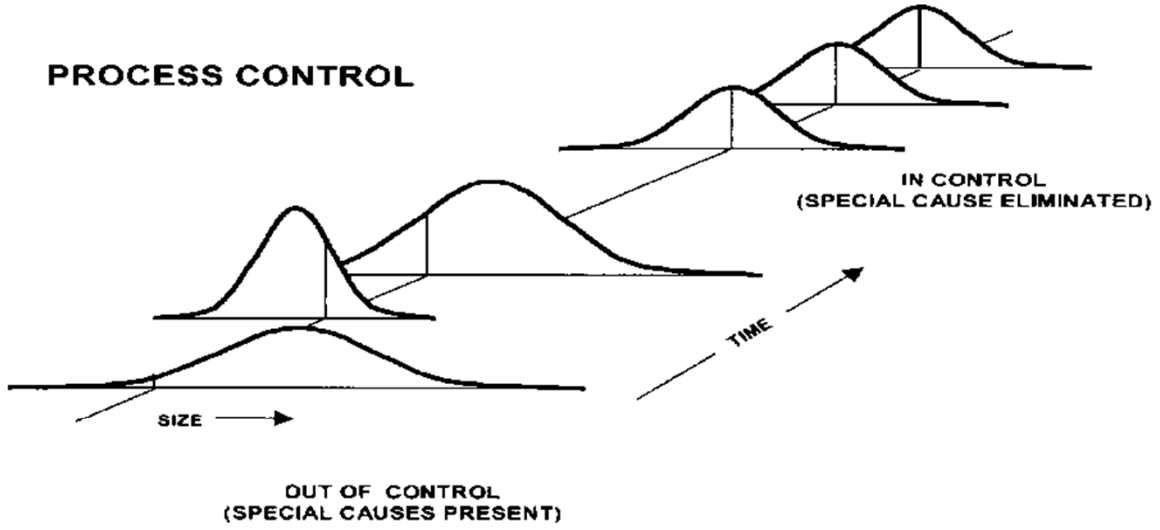


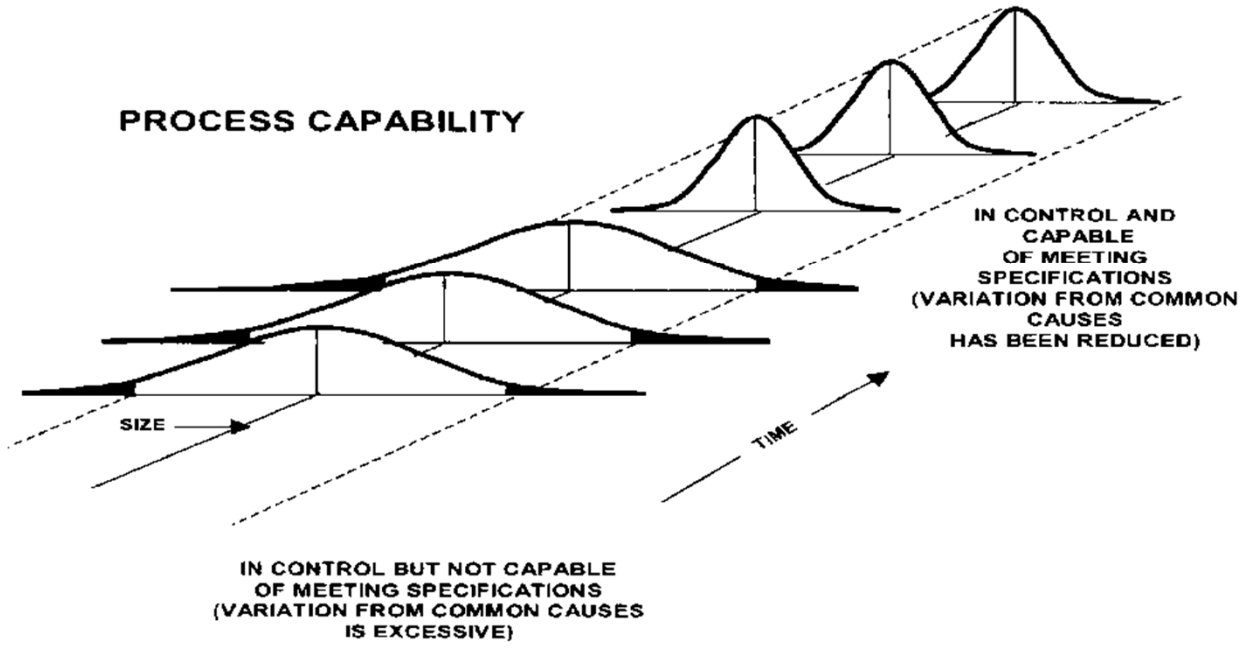
Control vs. Capability

Common and Special Causes

If only common causes of variation are present, the output of a process forms a distribution that is stable over time and is predictable

If special causes of variation are present, the process output is not stable over time



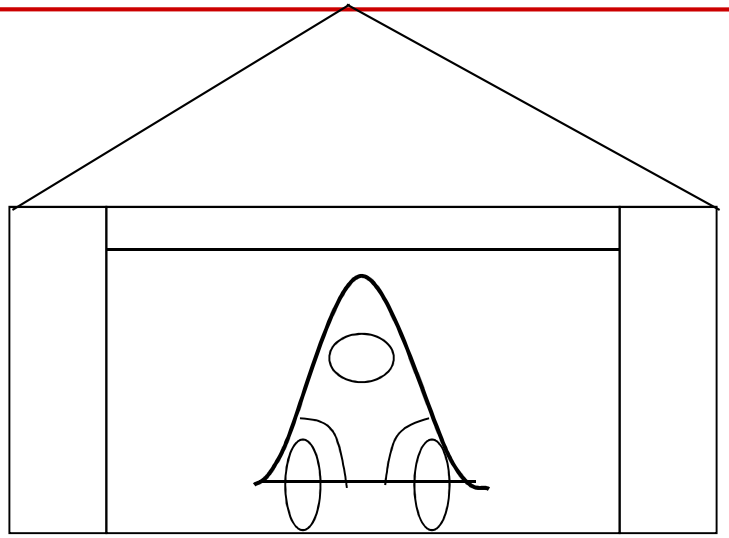


Control vs. Capability

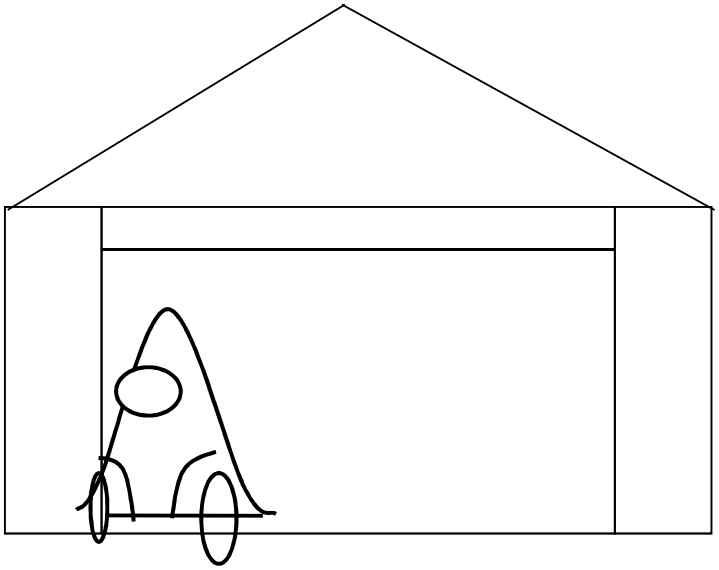
Variation (Capability)	Statistical Control: In- Control (Common Cause)	Statistical Control: Out-of-Control (Special Cause)
Acceptable	Case 1	Case 3
Unacceptable	Case 2	Case 4

Cp, Cpk, Pp & Ppk

Cp / Pp: can the car fit into the garage?



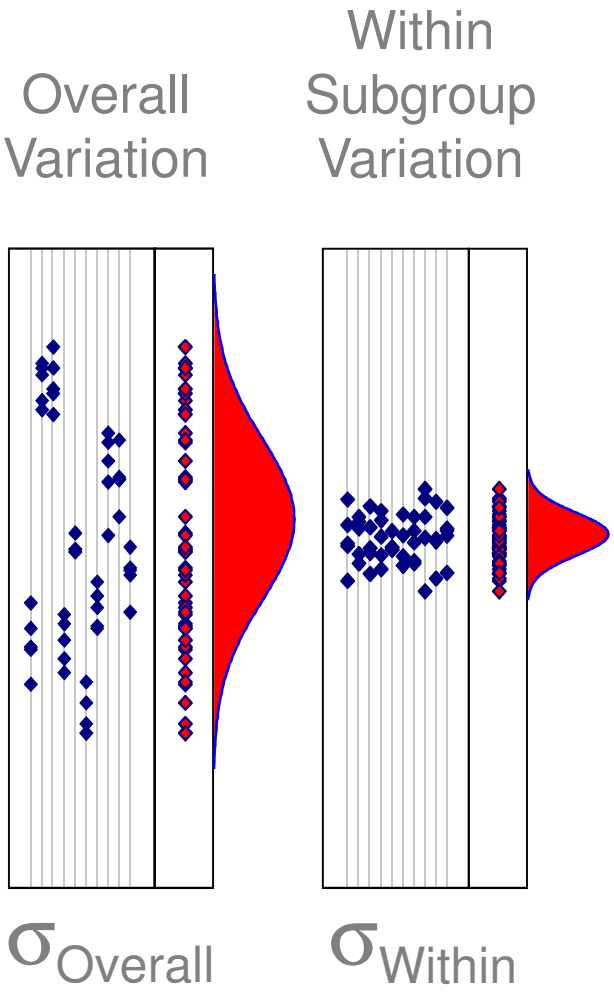
Cpk / Ppk: does the car fit into the garage?



Measures of Process Capability

(Capability Index)

	Overall Variation	**Within Subgroup Variation** if stable
Performance	Ppk	Cpk
Capability If centered	Pp	Cp



Kenneth J Kortge

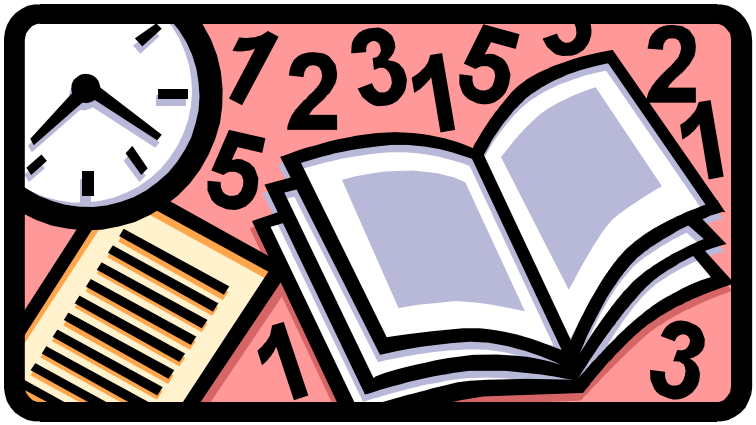
Capability Metrics – Acceptance Criteria

Typical:

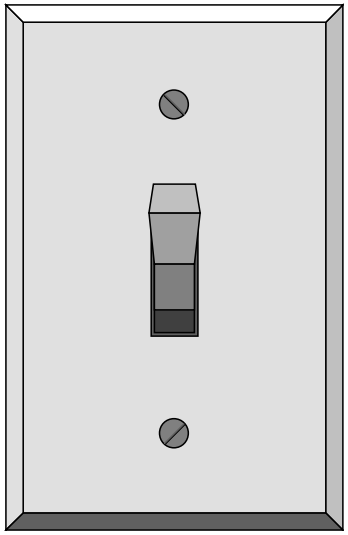
Index > 1.67	**Acceptable**
1.33 ≤ Index ≤ 1.67	**May Be Acceptable** May require an improvement plan
Index < 1.33	**Not Acceptable**

2 Types of Data

Variable



Attribute



Variables Charts

Typical:

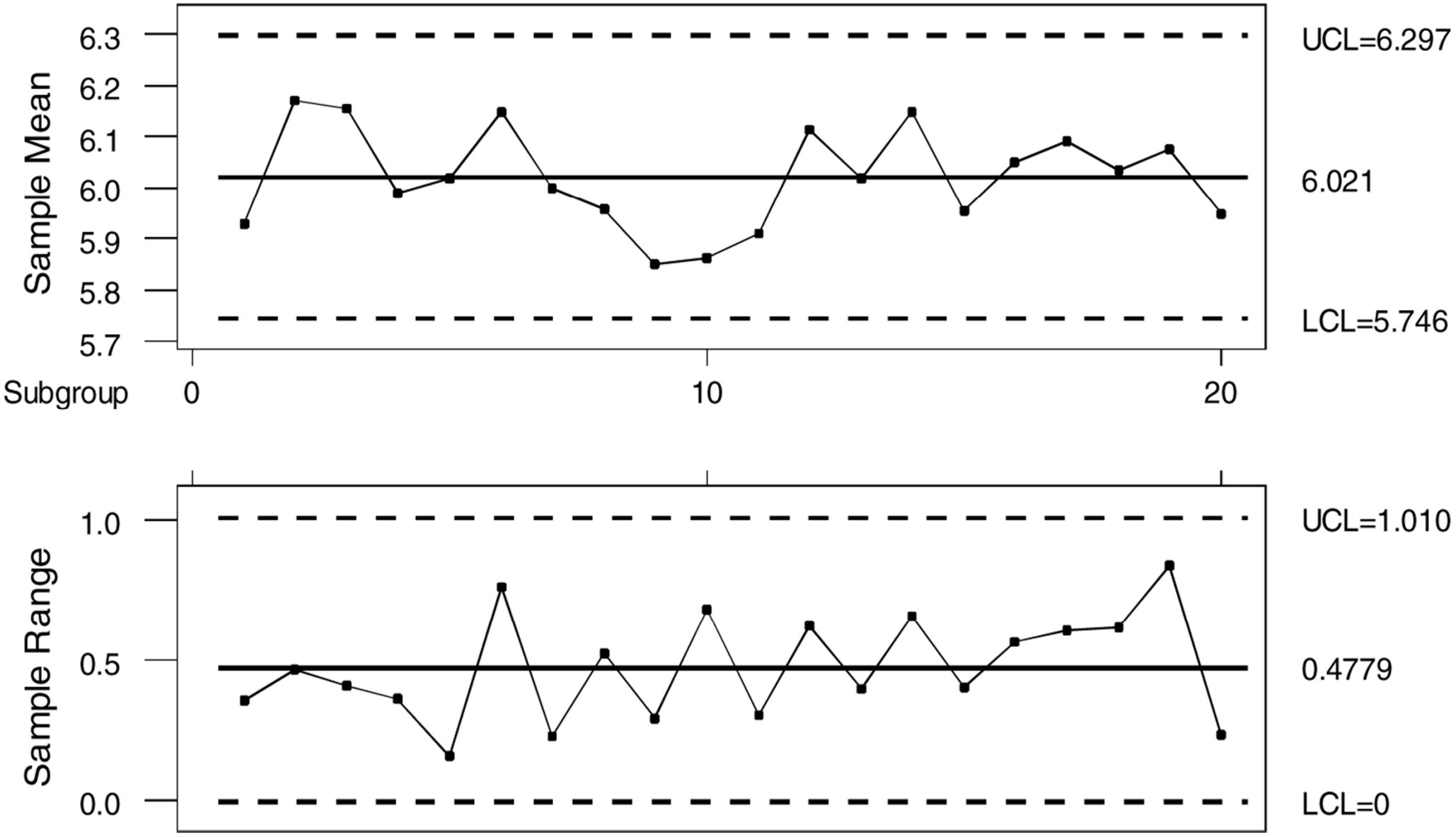
Chart Type	X-Bar & R	Median	Individual & Moving Range (MR)
Primary Usage	Routine monitoring of manufacturing processes	Usually used as a monitoring tool for product or processes	Used when only one sample is possible
What Is Charted	Plots the average size and the range of the part sizes	Plots the individual sizes of the parts and the median of the part sizes	Plots the sample size and the moving range of the sample size
Sample Subgroup Size	Usually 3 to 6	Should be an odd number: 3, 5, 7, etc.	One

Attribute Charts

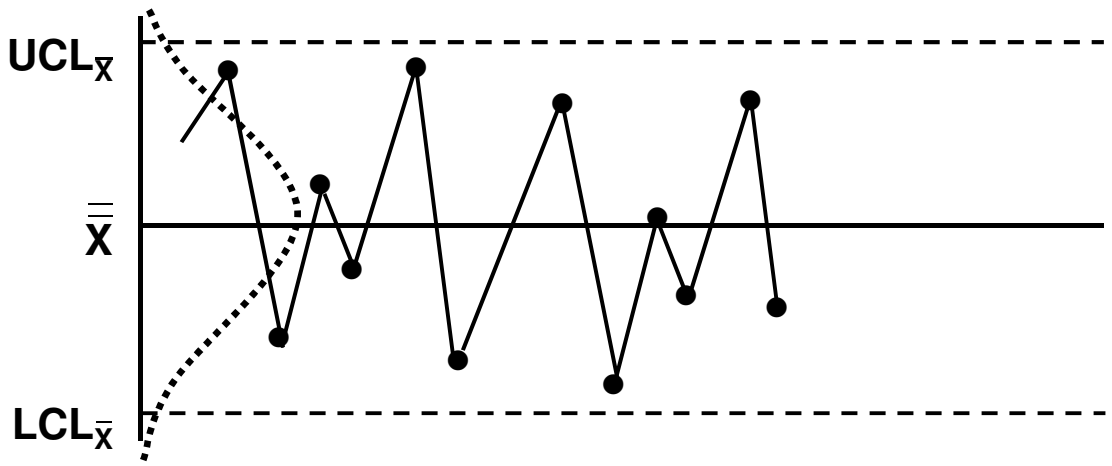
Typical:

Chart Type	P Chart	nP Chart	C Chart	U Chart
Primary Usage	Used for analyzing proportion or percent nonconforming or defective parts	Used for analyzing the number nonconforming or defective parts	Used for analyzing nonconformities or defects	Used for analyzing nonconformities per unit
What is Charted	Plots the proportion or percent of the nonconforming units	Plots the number of nonconforming items	Plots the count of all nonconformities found in the sample	Plots the average number of nonconformities in each sample
Sample Subgroup Size	Variable	Fixed	Fixed	Variable

$\overline{X}$ & R Chart



How Control Charts Work



Special Cause Criteria

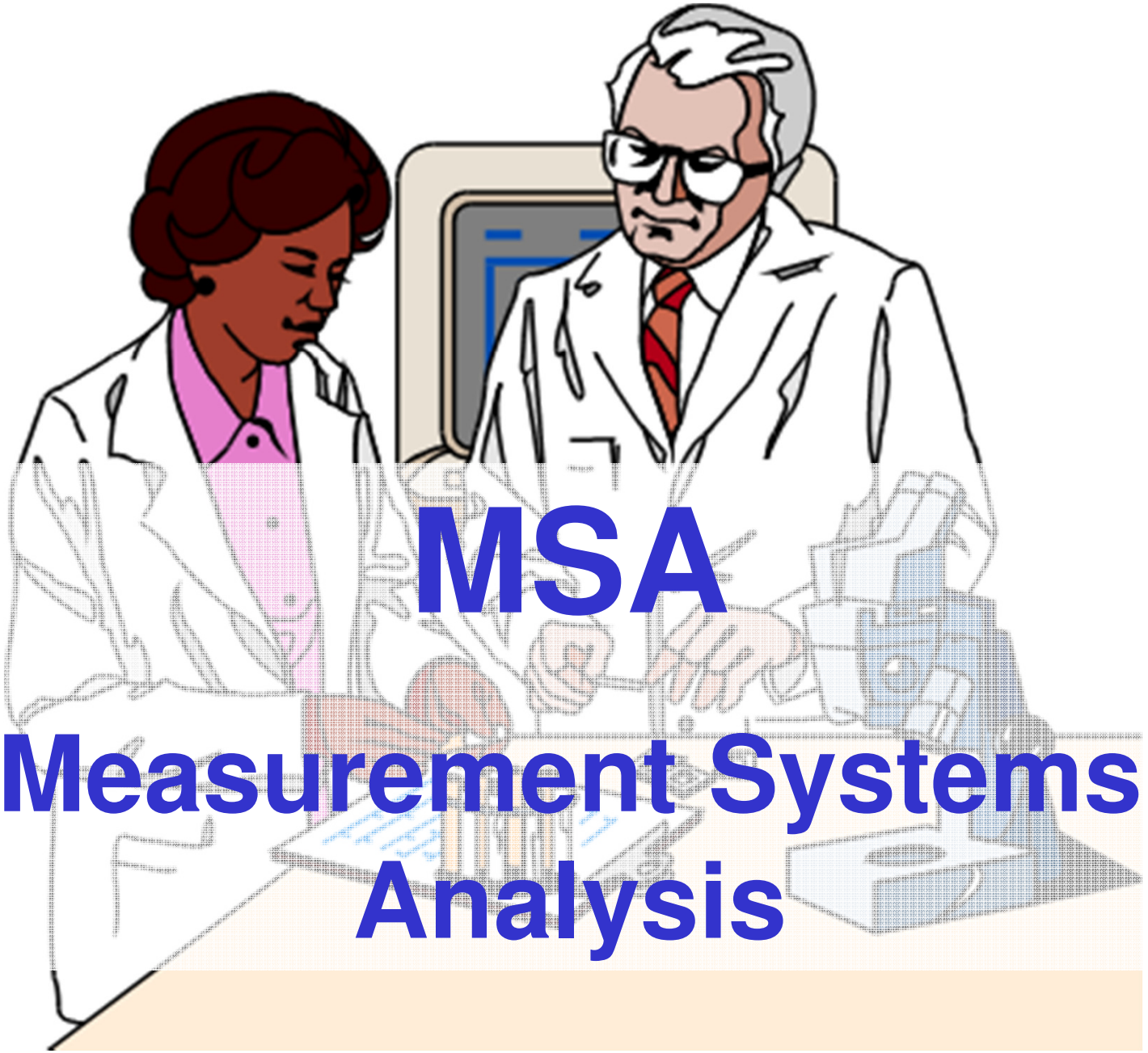
	Summary of Typical Special Cause Criteria
1	1 point more than 3 standard deviations[21] from centerline
2	7 points in a row on same side of centerline
3	6 points in a row, all increasing or all decreasing
4	14 points in a row, alternating up and down
5	2 out of 3 points > 2 standard deviations from centerline (same side)
6	4 out of 5 points > 1 standard deviation from centerline (same side)
7	15 points in a row within 1 standard deviation of centerline (either side)
8	8 points in a row > 1 standard deviation from centerline (either side)

Special Cause Criteria

1. Most measurements cluster around the center (average) line
2. A few measurements approach the edges (control limits)
3. No measurements outside the control limits
4. Same number of measurements on both sides of the center (mirror image)
5. Random (no patterns)

Pitfalls

- Ignoring out of control conditions
- Comparing control limits to spec limits
- Making process adjustments without understanding the source of the special cause variation
- Putting SPC charts on everything



MSA
Measurement Systems Analysis

MSA

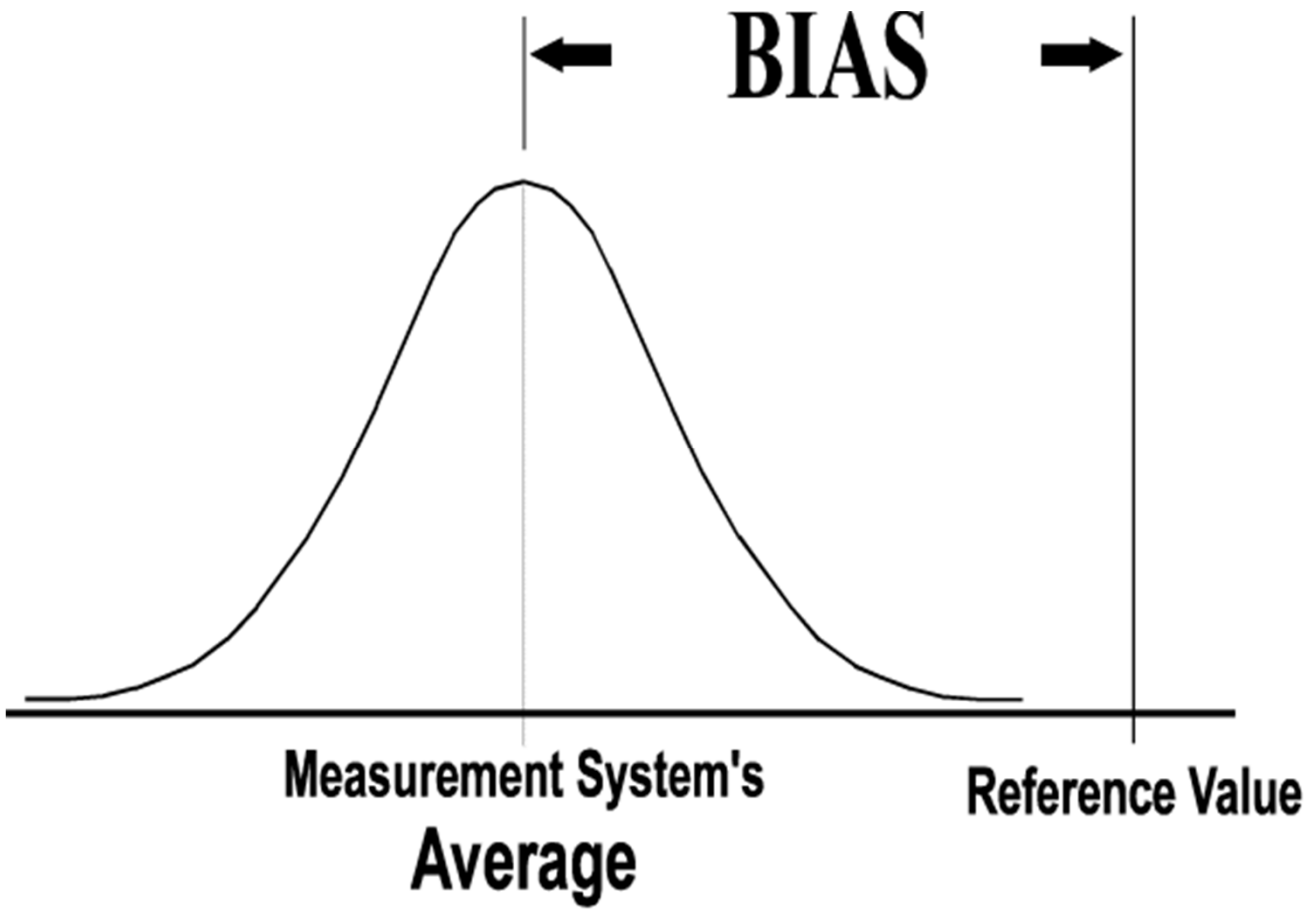
What is it?

A collection of statistical methods used to assess how much I can trust the information from a gauge

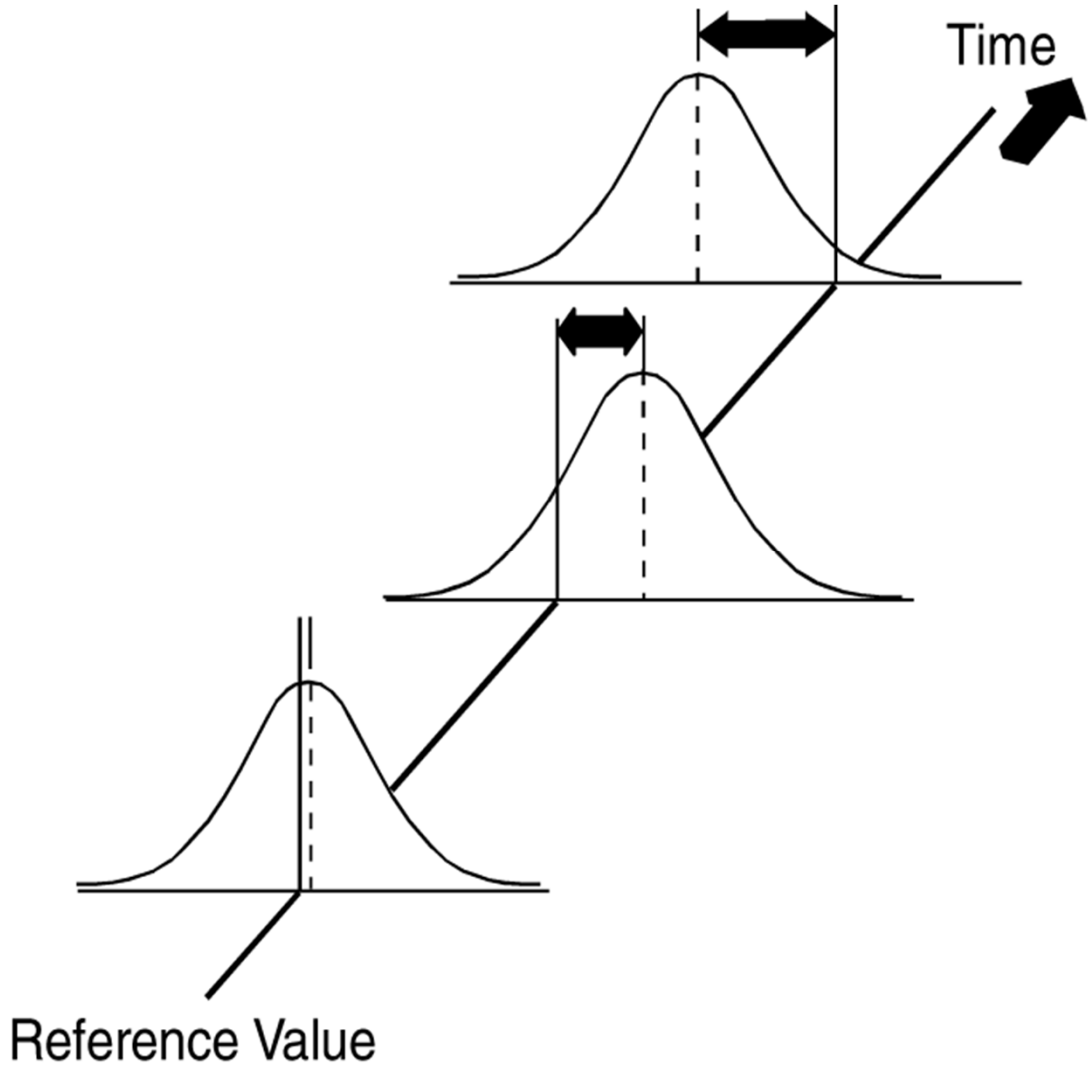
Why do we use it?

Since all my information about a part/process comes from gauges, I need to know when the gauge information is dependable, and do something when it's not

Bias: difference between the measurement and the "true" value

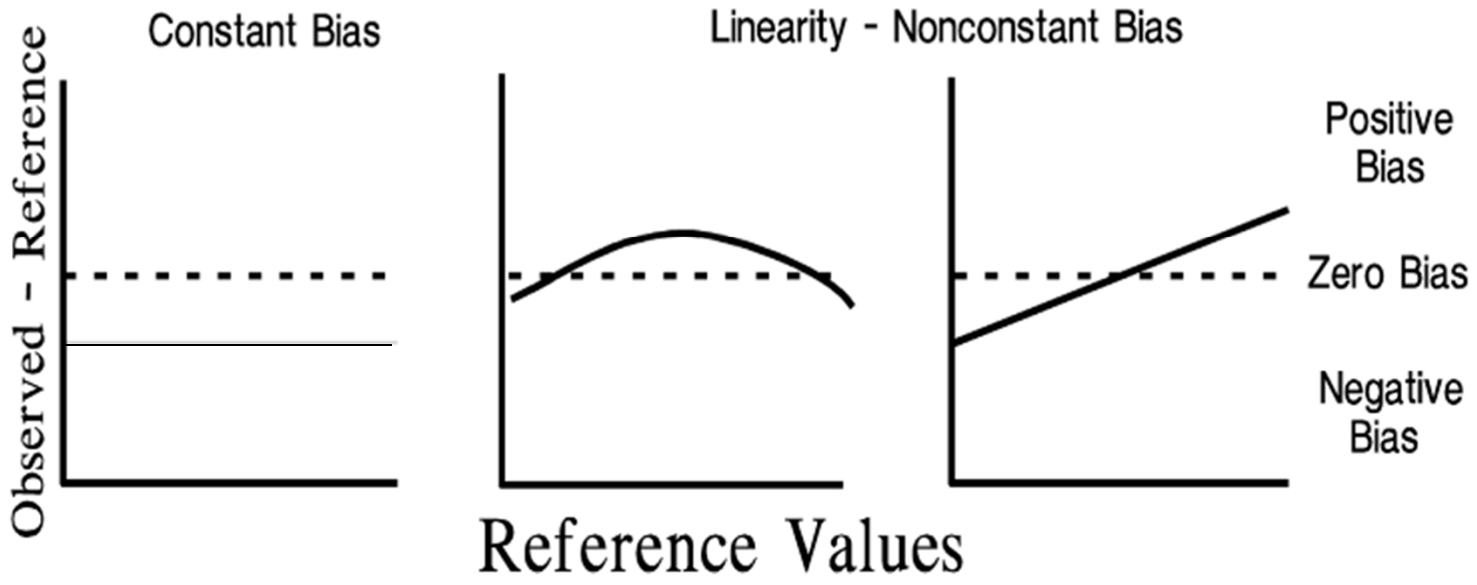


Stability: change in bias over time



Linearity: change in bias across expected range of measurements

Note that unacceptable linearity can happen in a variety of ways.
Do not assume a constant bias.



Gage Repeatability and Reproducibility = GRR = R&R

Variable, replicable measurements

Typical:

10 Parts

3 Appraisers

3 Trials

$$\sigma^2_{GRR} =$$

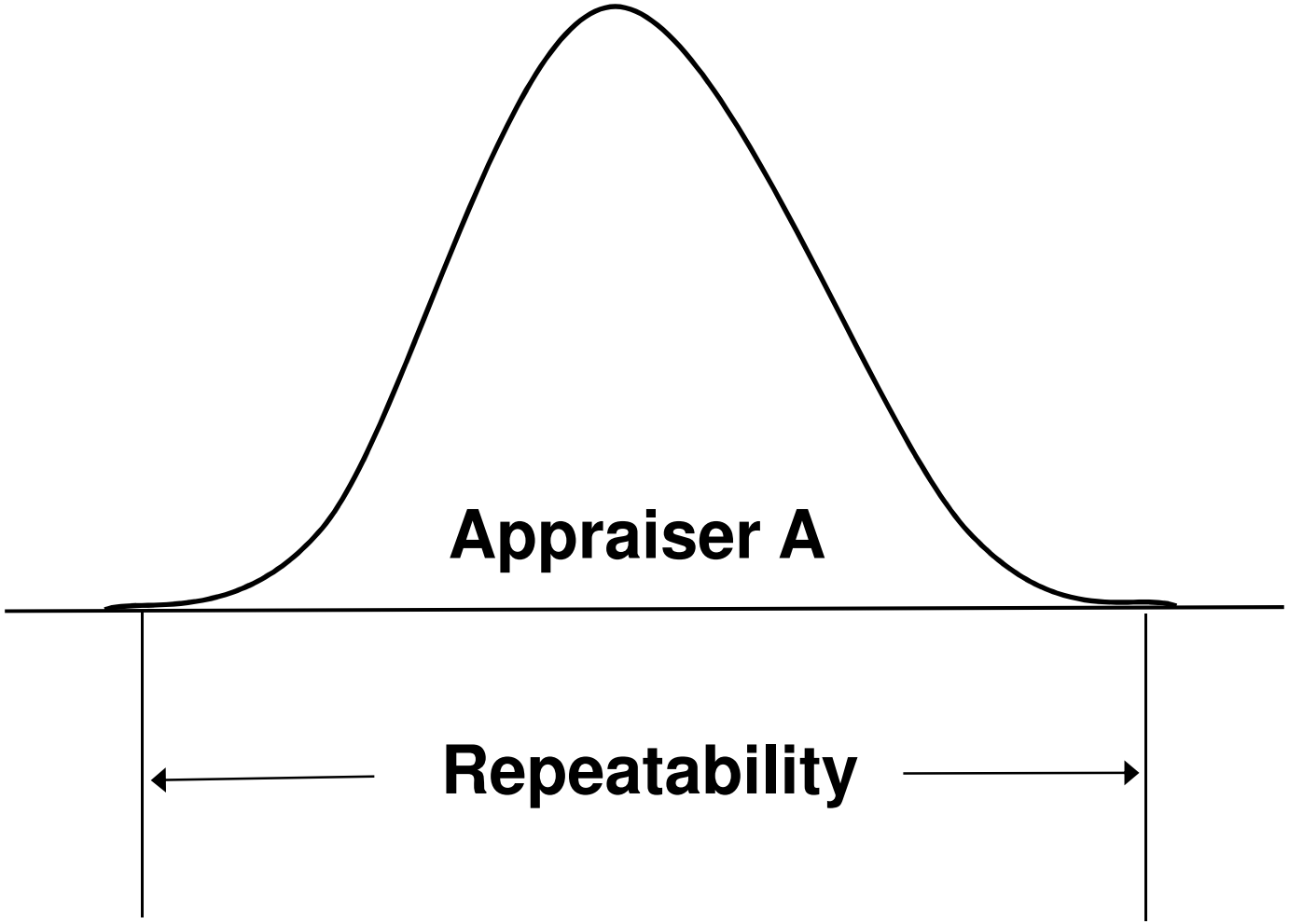
$$\sigma^2_{Reproducibility}$$

$$+ \sigma^2_{Repeatability}$$

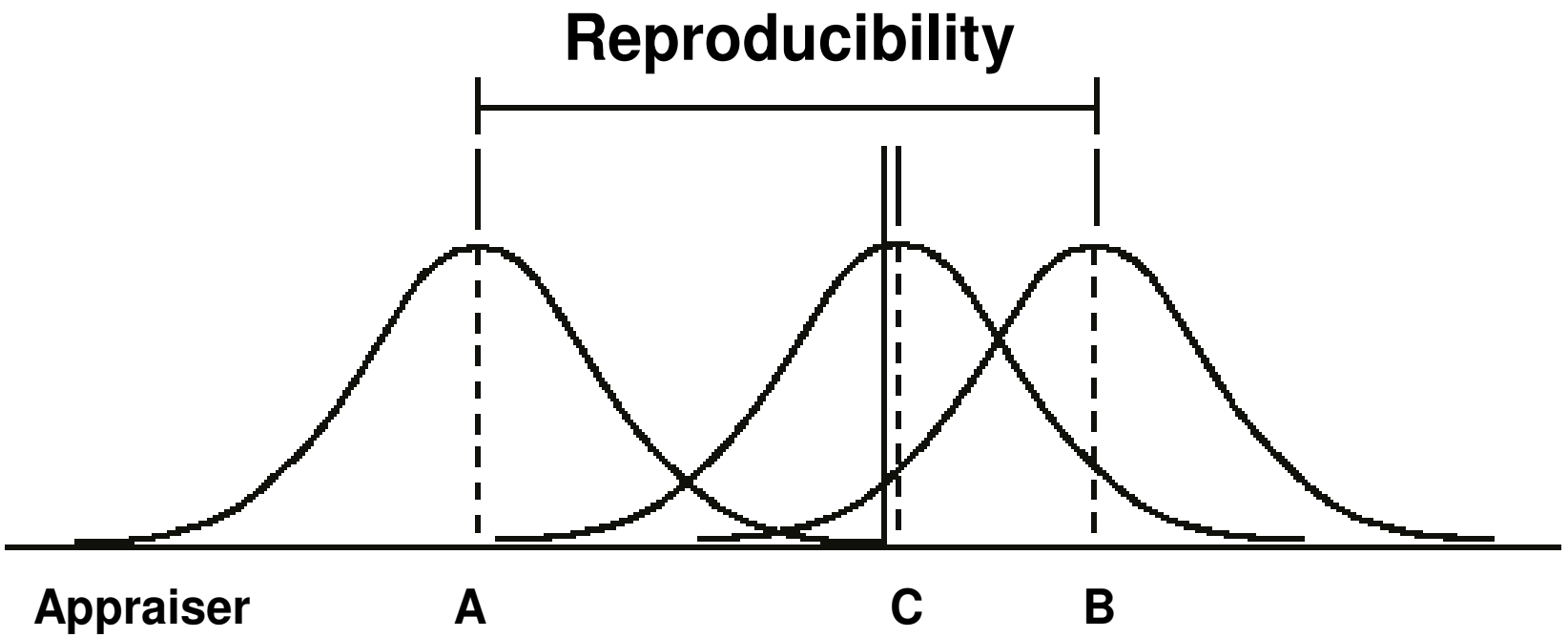
% Total Variation vs. % Tolerance

Number of Distinct Categories (NDC)

Repeatability: gage-induced variation



Reproducibility: operator-induced variation

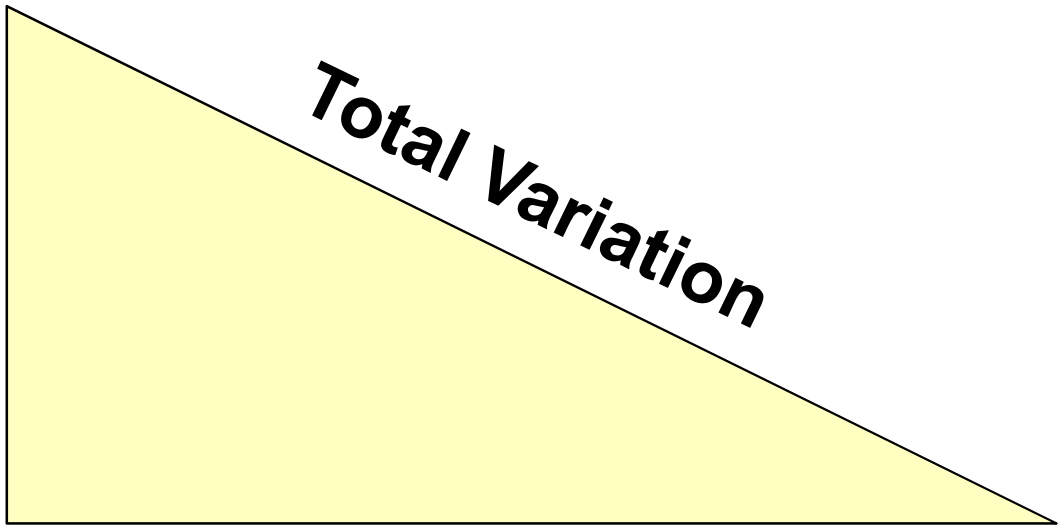


The Effect of Measurement Error

"Observed" "Actual"
Total Variation = Process Variation + Measurement Variation

$$\sigma^2_{Total} = \sigma^2_{Process} + \sigma^2_{Measurement}$$

Think of a right triangle

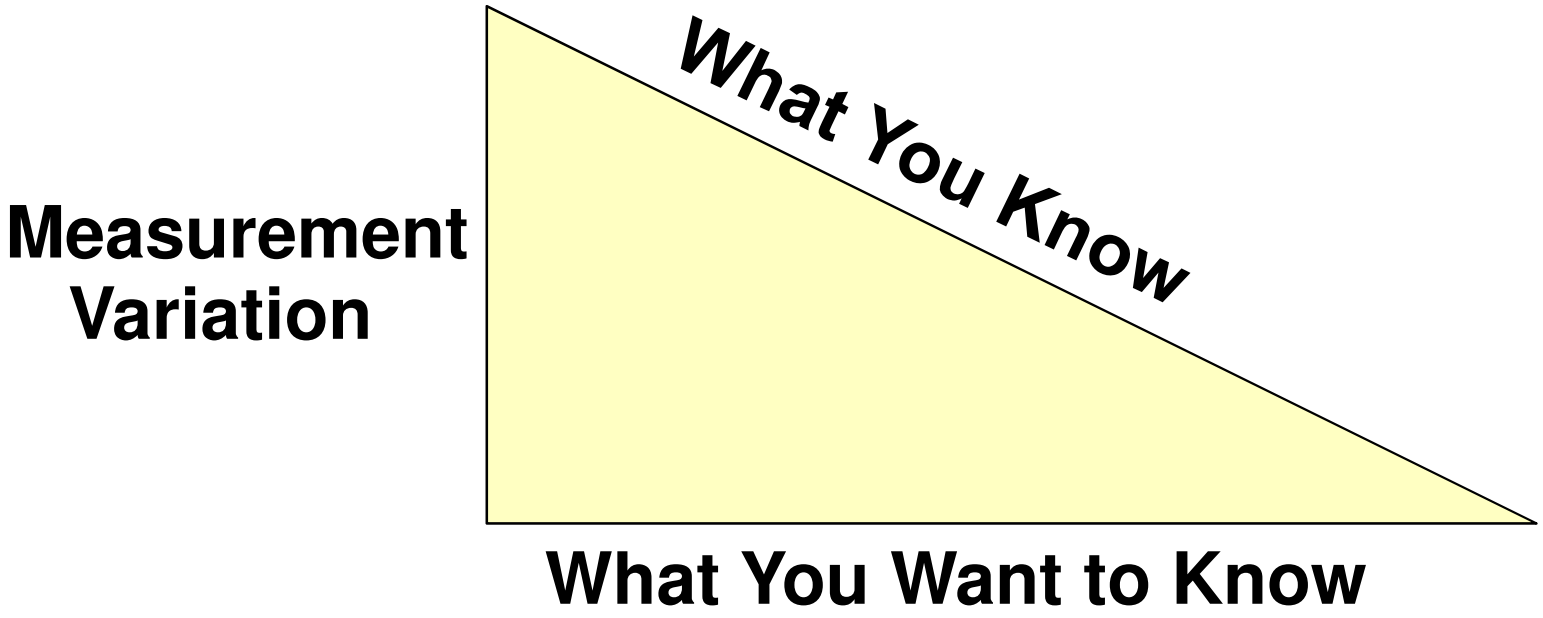


Kenneth J Kortge

The Effect of Measurement Error

Total Variation = Process Variation + Measurement Variation

$$\sigma^2_{Total} = \sigma^2_{Process} + \sigma^2_{Measurement}$$



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Gage R&R Acceptance Criteria (Typical)

% R&R

Under 10% error – Acceptable

10% - 30% error – May be acceptable based upon importance of application, cost of measurement device, cost of repair, etc.

Over 30% error – Not Acceptable. Every effort should be made to improve the measurement system

Number of Distinct Categories (NDC):

Greater than or equal to 5 – Acceptable

Less than 5 – Generally Not Acceptable

Pitfalls

- Using MSA to obtain a number, rather than to understand gage variation
- Not documenting a conclusion and any actions needed, as part of the study
- Not conducting MSA for all gages on the control plan (TS 16949 requirement)
- Not validating Software (TS 16949 requirement)
- Using wrong analysis method (non-replicable, attribute, etc.)

Automotive Core Tools

Advanced Product Quality Planning (APQP)

Failure Mode and Effects Analysis (FMEA)

Control Plan

Production Part Approval Process (PPAP)

Statistical Process Control (SPC)

Measurement System Analysis (MSA)

QUESTIONS